The Role of Europe in World-Wide Science and Technology: Monitoring and Evaluation in a Context of Global Competition

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Report for the European Commission, Brussels, Belgium

Universiteit Leiden

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Executive summary

Monitoring and evaluation of research (R&D) activities, particularly in relation to socio-economic needs is high on the agenda of European policy-makers. At the same time, assessment of what is called ‘European Added Value’ is demanded. In fact, all these desiderata focus to a few crucial questions: How are specific R&D activities ‘embedded’ in their scientific, technological and societal ‘environment’? How do the R&D fields in which the research activities take place, look like in terms of their cognitive and organizational structure? How are they related to other fields, particularly to fields of applied research and technology? Who and where are the important actors? Are networking activities between actors in the EU member states really reinforcing the quality of R&D and its application potentials, especially in relation to socioeconomic needs?

The work presented in this report aims at the development of a consistent, ‘standardized’ and generally applicable methodology to answer the above questions. We discuss a ‘mapping of science’ approach, based on advanced bibliometric methods. We claim that our approach yields concrete and objective information of high strategic value. For instance, maps over a range of years reveal changes in the structure of R&D fields and their ‘environment’. These changes can then be used as an evidence of the impact of R&D programs. In good approximation, we may apply the following model: solving a problem means removing a problem, and as a consequence the problem also disappears largely from the *scientific agenda*. In other words, the contribution of scientific research to solve human needs and societal problems can be monitored reasonably well by observing the scientific agenda. This implies that a powerful tool for assessing the socioeconomic impact of RTD would be the visualizing the cognitive landscape of an R&D field.

According to the above ‘scientific agenda model’, the observation of the disappearance of a specific socioeconomic as a ‘target’ of scientific research *might* be a strong indication that earlier R&D has been successful in contributing to solve, or at least to deal with this problem. Moreover, changes observed in the time-series of maps can also be extrapolated to act as a *foresight system* for near-future R&D developments.

The identification of the main, most prominent actors, particularly in relation to significant changes, is another crucial element. Excellent scientific work is the origin of breakthroughs, and therefore it is crucial to identify *centers of excellence* and to promote them. Moderate scientific work will not lead to important breakthroughs. Only excellent work really counts.

Policy makers are regularly informed by experts. Such qualitative opinions are and will remain central in R&D monitoring and evaluation. But opinions of experts may be influenced by subjective elements, narrow-mindedness, ‘old boys’ ideas, existing power-structures, and limited ‘cognitive horizons’. We need more objective ways to monitor and to evaluate scientific performance, and to assess technological and socioeconomic impact. This is the aim of our project, and we are convinced that the work presented in this report will contribute significantly to reach this goal. We stress however that our work is still in a typical research stage: methodology development. But the outcomes of our work already clearly indicate further steps in order to arrive at applicable tools.

What are the main conclusions resulting from our research work? First of all, the two bibliometric mapping methods investigated in this project (co-citation analysis and co-word analysis) disclose *different* structures of the same research field. We were not able to find enough evidence for the hypothesis that both methods eventually will ‘converge’, i.e., yield a similar structure of a field. This is an important finding. We think that both approaches will never converge and that they yield different ‘images’ of the same world. This is not a complete surprise. Particularly, the fact that we are dealing with such different elements (cited references –representing entire documents- versus keywords –representing concepts, topics) is supposed to cause these different results. For instance, in co-word analysis often keywords with an ambiguous meaning are found. In most cases, such words have to be excluded in the further steps of the analysis as they will cause artifacts in the clustering of topics. Linking cited references to words (i.e., linking keywords to a certain document context) would enable to cope with this problem and, at the same time, enhance the value of the map. Thus a sophisticated combination of both methods could substantially improve science mapping methodology.

But first it is necessary to study thoroughly the potentials of both methods separately and to compare the findings. That is the main methodological task addressed in this project.

We developed our methodology on the basis of four concrete fields of research, different in size, and different in ‘direct societal importance’: climate research, telecommunication research, neuroscience, and complex systems research.

On the basis of co-citation analysis, we were able to develop maps at 'any' level of aggregation, and to provide in a very compact form: main structure, its direct cognitive environment, and useful information about actors and about individual documents, particularly ‘front’ and core publications. In terms of activity (publication output) we are able to provide useful information at any required level (i.e., from individual scientists to entire countries) which allows identification of top-institutes and comparison of the performance of countries. With a time-series of maps we are also able to describe in detail the changes over time. Thus, these maps and additional facilities provide very specific information of any area of interest.

Using co-word analysis, we succeeded to create in a reliable way comprehensive overview maps of very large fields (such as neurosciences) as well as of smaller fields (such as complex systems). Moreover, we were able to provide useful information 'behind' the map, important for both general ‘exploration’ of R&D fields as well as for specific evaluation purposes. For instance, in the case of neuroscience we were able to characterize the activity of the EU as compared to the US over time. The results show a remarkable trend for the EU with respect to its activity in the clinical parts of the field.

Although methodology development was the central task in this project, our work also resulted in a concrete ‘information product’. First of all, we constructed a web-based facility, a user-internet interface. With this facility a user can easily extract further information from the map, to address a particular policy-related question. This development appeared to be successful and already within the context of this project we succeeded to go a step further. Major progress is now made in developing a more flexible interface, with a higher degree of functionality. The *iBex* interface enables a user to access the map in a bottom-up approach. The existing interface is only able to access the information top-down. This makes the map even suitable for many more applications than presented in this report.

We conclude that an important 'way forward' in monitoring and evaluation of R&D activities is the application of objective, high-quality analytical tools based on advanced bibliometric mapping methods. These methods include the identification of the best groups. We claim that our methodology can be applied to most socioeconomic problems. The scientific work 'around' these problems can be mapped and particularly a time series of maps may reveal important changes in R&D in relation to the seriousness of these problems.

THE ROLE OF EUROPE IN WORLD-WIDE SCIENCE AND TECHNOLOGY: MONITORING AND EVALUATION IN A CONTEXT OF GLOBAL COMPETITION

EXECUTIVE SUMMARY

1. INTRODUCTION 1

2. CO CITATION METHODOLOGY 3

2.1. The Co-citation Cluster analysis – Essentials 4

2.2. Delineation 8

2.3. Data organizing 10

2.4. Cluster analysis 10

2.5. Mapping the co-citation structure 12

3. CO WORD METHODOLOGY 15

3.1. Field keyword selection 15

3.2. Keyword clustering and subdomain identification 17

3.3. Mapping subdomains by MDS 18

4. GENERAL RESULTS 21

4.1. General results based on co-citation analysis 21

4.1.1. Climate research 21
4.1.1.1. Delineation 21
4.1.1.2. Overview 24
4.1.1.2.1. Climate research 1996 25
4.1.1.2.2. Climate research 1997 32
4.1.1.2.3. Climate research 1998 40
4.1.1.2.4. Changes from 1996 to 1998 47
4.1.1.3. Selected subfields of climate research 1998 49
4.1.2. Neuroscience 59
4.1.2.1. General overview 59
4.1.2.1.1. Neuroscience 1996 61
4.1.2.1.2. Neuroscience 1997 74
4.1.2.1.3. Neuroscience 1998 88
4.1.2.1.4. Changes from 1996 to 1998 104
4.1.2.2. Selected subfields of neuroscience 1998 105
4.1.3. Complex systems 115
4.1.3.1. General overview 115
4.1.3.1.1. Complex Systems 1996 116
4.1.3.1.2. Complex Systems 1997 121
4.1.3.1.3. Complex systems 1998 126
4.1.3.1.4. Changes from 1996 to 1998 131

4.2. General results based on co-word analysis 132
4.2.1. Telecommunication 132
4.2.2. Neuroscience 136
4.2.2.1. Data and Method 136
4.2.2.2. Results 138
4.2.3. Complex systems 143
4.2.3.1. Field database 143
4.2.3.2. Method 143
4.2.3.3. Clusters 144
4.2.3.4. MDS 144
4.2.3.5. Size 145
4.2.3.6. Actors in the database. 145
4.2.3.6.1. Top 15 nations - Activity 145
4.2.3.6.2. Top 15 nations – Citations 147

4.3. *iBEX* – The Interactive Bibliometric Explorer 149

Appendix A. 155

Appendix B. 156

5. COMPARISON OF METHODS 157

5.1. Neuroscience: epilepsy research 157
5.1.1. The co-citation analysis for the neurosciences 1998 157
5.1.1.1. The Epilepsy regions 158
5.1.1.2. The main epilepsy regions in detail 161
5.1.1.2.1. C2-796: MR in Temporal-Lobe Epilepsy 161
5.1.1.2.2. C2-497 Epilepsies in Childhood 165
5.1.1.2.3. C2-903 Antiepileptic and Antipsychotic Drugs 168
5.1.1.2.4. C2-686 Anxiety/Limbic Epilepsy/Immunoreactivity 172
5.1.1.2.5. C2-417: Epileptiform Activity 176
5.1.1.2.6. C2-1060 Absence Epilepsy 178
5.1.1.2.7. C2-313 Status Epilepticus 182
5.1.1.3. The external relations of the epilepsy regions 185
5.1.1.3.1. C2-796 MR in Temporal-Lobe Epilepsy 185
5.1.1.3.2. C2-497 Epilepsies in Childhood 186
5.1.1.3.3. C2-903 Antiepileptic and Antipsychotic Drugs 188
5.1.1.3.4. C2-686 Anxiety/Limbic Epilepsy/Immunoreactivity 189
5.1.1.3.5. C2-417 Epileptiform Activity 192
5.1.1.3.6. C2-1060 Absence Epilepsy 193
5.1.1.3.7. C2-313 Status Epilepticus 194
5.1.2. Neuroscience as depicted by co-word analysis 195
5.1.2.1. Seizure/Epilepsy/EEG research within neuroscience 195
5.1.2.2. Internal structure of Seizure/Epilepsy/EEG research 195
5.1.2.3. Publication characteristics of Seizure/Epilepsy/EEG research 196
5.1.2.4. Actors in Seizure/Epilepsy/EEG research 197
5.1.2.5. Citation characteristics of Seizure/Epilepsy/EEG 202
5.1.3. Comparing Epilepsy results 204

5.2. Complex systems 206

6. CONCLUSIONS AND PERSPECTIVES 209

1. Introduction

In this report we present the results of three years research work on an empirical approach to delineate, analyze, monitor and evaluate scientific developments for strategic, socio-economically relevant policies. A major goal of the project is to make a substantial improvement of the existing state-of-the-art of both the conceptual as well as the methodological basis of *monitoring and evaluation* techniques.

The *central problem* can be described as follows. Although a number of methods to analyze and monitor the dynamics of scientific development, particularly in relation to applications and technology does exist, these methods mostly concern only parts of the spectrum necessary to visualize the development of research and technology in a sufficiently broad and, most importantly, coherent way. For instance, often monitor and foresight techniques (such as 'Delphi' and 'scenario' models) are applied to fields or programs that are defined in a specific context, in an environment given beforehand, or focused on aspects that are considered to be politically important at this moment.

The first step in all monitoring, evaluation and foresight analyses is a very crucial one. It concerns the question: *what is the field* of science we are talking about? If we would like to monitor 'environmental research', 'energy research', 'information science and technology', 'nano-technology', how can we *delineate* such a field -with its actors- in a sufficiently comprehensive way, so that both the well-known mainstream of today as well as the more remote and exotic outer provinces -which might become extremely important in the near future- are covered? Clearly this problem presents itself even stronger in multidisciplinary fields. And these are precisely the fields where many important socioeconomic developments take place.

In order to tackle this problem and to put it in a broader context of monitoring and evaluation, we take a quantitative-empirical approach based on *self-organizing principles* applied to scientific documents, i.e., research publications. This approach will give us the opportunity to explore in a consistent, policy-oriented framework, the vast amount of data embedded in the scientific and technological literature.

We believe that the research work presented in this report offers a unique and powerful way to 'map' as good as possible any field of science with substantial added-values to what a more qualitative approach could offer:

- The most important value is that nobody prescribes how the field looks like or should look like. The data themselves organize the structure of the field: we make use of specific data-similarities (co-occurrences of specific entities such as words and references) that inevitably lead to characteristic patterns, the *landscape* of the field.
- The next added-value of this structure-discovery method is that, by definition, we can apply this approach in a *time-series*. Thus, a non-expert biased, objective representation of the dynamics in the research landscape is one of the results.
- A third important added value is the identification of *actors* (e.g., universities, institutes, organizations, firms, countries) and the positioning of these actors in the map of a field.

- A fourth important added value is the integration of our standard bibliometric *research performance* assessment indicators in the maps, in order to identify strengths and weaknesses of actors in the field.

The design of the project is such that the role of Europe in science and technology can be compared with relevant developments in, at the first place, Europe's main competitors: US, Japan, and the Asian Tigers. Furthermore, our methodology allows a focus on the dynamics of world-wide science and technology, and in particular the role of European players in *new, promising developments.* In this way the project contributes to the investigation of the relationship between scientific and technological innovation, and the market.

This report is organized as follows. In Chapters 2 and 3 the two central methodological approaches, co-citation analysis and co-word analysis are extensively discussed. We here focus on delineation of research fields and the basics of the construction of science maps. Chapter 4 presents the results of both mapping approaches. We apply these approaches to four fields of research. Two fields are analyzed by just one approach: climate research by co-citation analysis, and telecommunication research by co-word analysis. The two other fields, neuroscience and complex systems research, are analyzed with both approaches. The period covered is 1996-1998. We conclude Chapter 4 with the presentation of a new 'product' emerging from our work, the 'Interactive Bibliometric Explorer', a web-based user-facility to consult our (co-word) maps in an interactive way via internet.

Chapter 5 is devoted to a careful comparison of the results found with the two approaches for the two fields that are analyzed with both methods, neuroscience and complex systems. Chapter 6 summarizes the conclusions of our research work. The most important results of this project, the maps of the different fields, including systematic information (indicators) on actors, are presented in the web-sites of our institutes.

2. Co citation Methodology

In this chapter we will describe the method of co-citation cluster analysis in detail - including the essential features and basic assumptions (2.1) and the most important technical aspects (2.2 – 2.5). The main steps of the process are shown in figure 2.1, starting from the data in the scientific literature database ending at the maps of science.

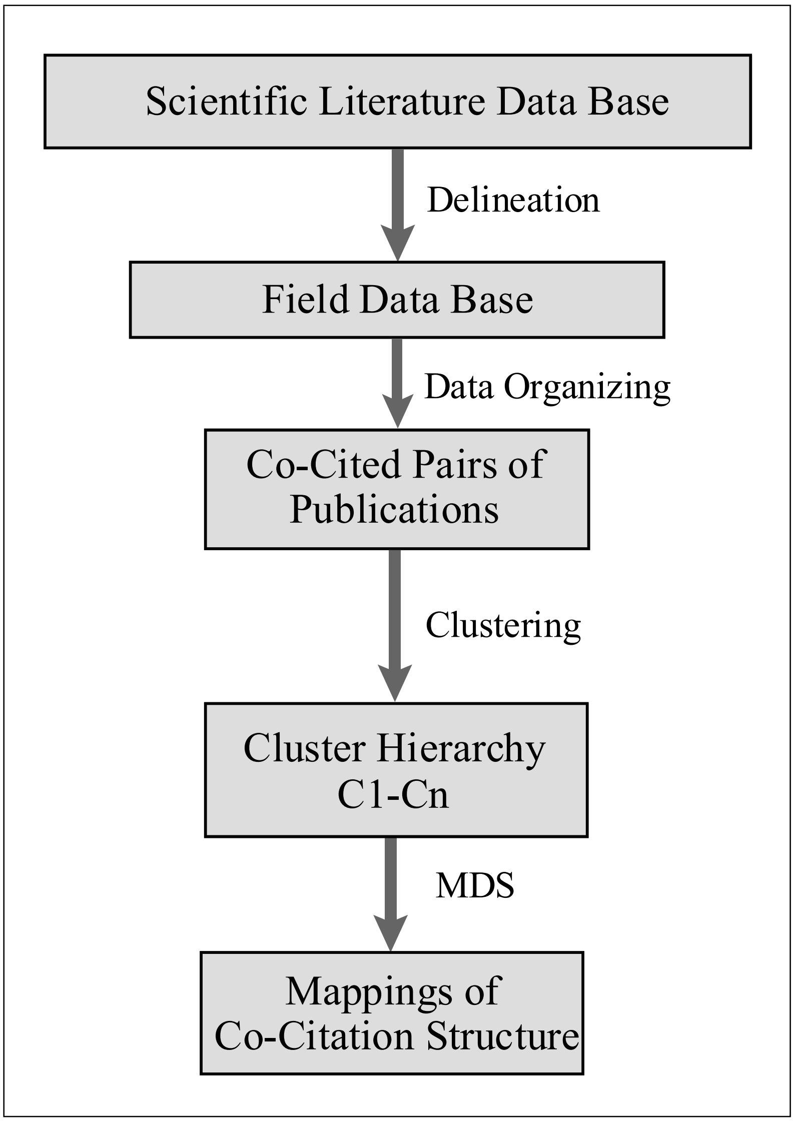

Figure 2-1
Basic steps of co-citation cluster analysis

Starting point of the analysis is the scientific literature database containing source documents as well as their references to other (older) publications. This can be a multidisciplinary database like the Science Citation Index or the Social Sciences Citation Index on the one hand - or a disciplinary database like the Neuroscience Citation Index on the other hand.

The first step is the **delineation** (See chapter2.2) of the research field and the download of the selected records containing all relevant information elements. For the two smaller research fields climate research and complex systems a delineation based on keywords and/or journals (For the details see chapter 2.1.1, 2.3) and in the case of climate research an additional special extension were carried out.

In the next step, the downloaded records have to be reorganized. From a technical perspective this **data organizing** (See chapter 2.3) means some simple but extensive formatting and computing in preparation of the cluster-analysis. But from the methodically perspective a very central procedure is done: the basic elements of the analysis, the co-occurrences of pairs of highly cited publications for each reference list are isolated and counted through the whole set of source publications. At the end of this procedure the co-cited pairs are ranked by their relative co-citation strength (See chapter 2.3).

On the basis of this ranked list the **cluster analysis** (see 2.4) is performed. The cited publications are clustered with a refined single linkage method. The result is a list of clusters each containing groups of heavily *co-cited* publications. The last two steps, data organizing and cluster analysis, can be repeated by taking the clusters as elements for the next clustering procedure. The iteration results in a sequence of aggregation levels from cited references up to the highest cluster level with only a few large clusters.
The last step is a visualization of the found structure in 2-dimensional maps using multidimensional scaling ("**MDS**"). In these maps the clustered elements of a selected cluster (detailed map) or the clusters of the highest cluster level (overview map) can be shown. (see 2.5)

2.1. The Co-citation Cluster analysis – Essentials

The co-citation cluster analysis[1] is a bibliometric method which uses the relations between publications indicated by the act of citing which is a fundamental element of the formal scientific communication. The analyzed co-citation network therefore reveals the inherent structure - independently from external preconfigured classifications like thesauri or disciplinary categories. Research fronts and larger connected areas of the scientific landscape can be explored by structuring the highly cited and co-cited publications. Based on the citations from the recent literature the highly cited publications are grouped to clusters, each building a core of cited literature shared by a number of recent co-citing publications - the research front.

The co-citation analysis uses the indirect linkages between jointly cited publications as indicators of their similarity. The most basic assumption is therefore that the **citation** marks a relation between the cited work and the citing article which is given in the context of the article.[2] The references to older publications given by the author and documented in the reference lists of the scientific articles can be seen as the cognitive resources which are of relevance for the reported work. They are all related to the cognitive contents of the citing article and therefore indirectly linked among themselves.

---

[1] The method has been developed by Small and Griffith (1974)

[2] The special types of relation and the different functions of citations have been critically discussed by several authors. See for example Cozzens (1989), Edge (1979), or MacRoberts and MacRoberts (1986).

From the direct relations between citing and cited articles the indirect links between the jointly cited pairs of publications are deduced: the **co-citations**.[3] In figure 2.2 this basic principle of the co-citation analysis is shown.

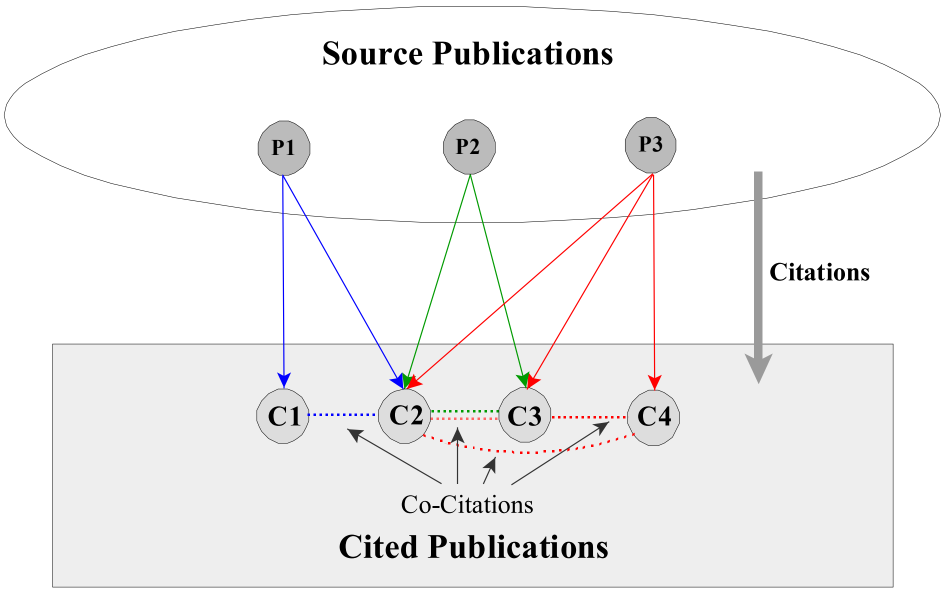

Figure 2.2

Basic principle of co-citation analysis

The references from the source publications P1 – P3 to the cited publications C1 – C4 are shown as arrows. They establish co-citation links between the cited publications marked by dotted lines. In this schematic depiction C2 is the most frequently cited Publication, co-cited with all others (and two times with C2), whereas C1 is co-cited only with C2. Through the citations each of the recent source publications P1-P3 leaves an individual trace into the huge amount of older publications which can be theoretically cited. The co-citation as a relationship between older publications is recognized and maintained by the analyzed recent publications.

Another more implicit but important principle of the co-citation analysis is the assumption of a correlation between citation frequency and. The frequency of citations

[3] The co-citation as an indirect link between cited publications was independently introduced by Small (1973) and Marshakova (1973).

is seen as an indicator of the importance of the cited publication. Therefore the analysis is limited to the most highly cited publications.[4]

Another assumption is related to the co-citations: The frequency of co-citations is proportional to the similarity of two cited publications and can be used - after **normalizing**[5] by the single citation counts - as a measure for their proximity in a spatial model. The actual significance of a single co-citation link can be very weak in some cases, but a relatively large number of co-citations of a pair of cited publications can be seen as a meaningful indicator for a link between the co-cited publications and there cognitive contents. Co-citations which are rather contingent, at least as related to the cognitive dimension, will probably not be frequently repeated by other authors.

The more citing publications are analyzed the more differentiated and extended the co-citation network becomes. Because of their relative coherent citation pattern larger areas of thematically connected publications will add their co-citations forming relatively dense regions of the co-citation network which are representing the shared intellectual resources of the coherently citing publications.

These networks can be identified by **clustering** the highly cited and heavily co-cited publications. With the clustering procedure the most dense parts of the complex co-citation network are grouped into clusters representing the included frequently cited and co-cited publications. A group of co-citing source publications – the research front - corresponds to each cluster

The cluster cores represent the broad range of cognitive aspects regarding research problems, methods, phenomena or artefacts referenced through the cited publications in the analyzed source articles. The research fronts on the other side are the set of source publications in which these aspects are one of the important points. They mark the recent research areas with a relatively coherent referencing pattern.

Research fronts vary in size and degree of reference coherence. They are therefore representing different types of entities. An extremely small cluster core formed by two very highly cited and co-cited methodological or technical papers for example can be surrounded by a large front of publications from many different research areas or fields. On the other side a large cluster core may be cited by many publications which reference lists show a great proportion of cited publications affiliated to the same corresponding cluster core. These research fronts are more coherent areas with a shared interest in the highly cited publications in the cluster core. They can be seen as specialties of the analyzed field whereas the smaller cores are more diverse as they are related to very special aspects or rather general methods or techniques.

The found cluster structure can be aggregated through an iteration of the clustering procedure using the degree of the research fronts overlap as similarity measure.[6] The overlap of a pair of research fronts is defined as the number of source publications citing articles from both corresponding clusters. The measure is analogous to the co-citations of documents.

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[4] We used integer citation counts to select the highly cited publications. Fractional citation counts proposed by Small (1985a) were not necessary, because in the analysed fields the difference between the referencing behaviours of the involved research areas are small compared to the whole SCI.

[5] Normalising the absolute numbers of co-citation was proposed by Small (1976)

[6] The clustering of co-citation clusters was introduced by Small (1985b)

But in difference to the cited publications the clusters as elements of the co-citation are not cited directly but represented by the clustered publication(s) in the reference lists.

The co-citation of clusters actually is a co-citation of publications which are (afterwards) assigned to different clusters.

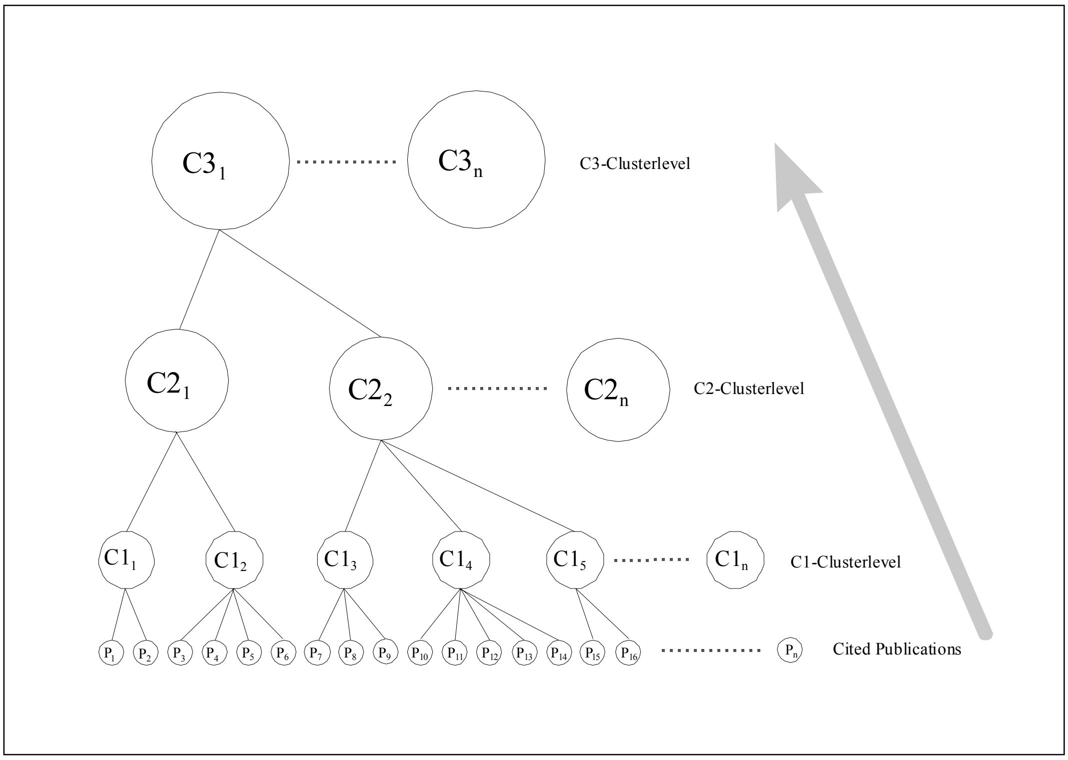

Figure 2.3:
Cluster levels

The iteration of the clustering procedure results in a nested hierarchy of cluster levels.(figure 2.3) The entities which are represented by the clusters in the cognitive dimension become more and more general. On the lowest level the clusters can be seen as rather small specialties and on the more aggregated higher levels as subfields or much broader areas. However the levels do not form a strict size hierarchy. The average of the cluster size increases but also its variance so that on each higher level small clusters can be found which are exceeded in size by some large clusters of the lower level. Therefore the cluster levels are not strictly corresponding to a certain level of generality of the represented entities.

The structure obtained by the co-citation cluster analysis as it has been described can be visualized in **maps** which show the relations between the entities of a selected level or inside a selected cluster in a 2-dimensional representation. The complex relations between the clusters of a selected region are represented in the spatial relationships of the objects shown in the map, which reveals the important aspects of the co-citation structure in an easy to read form.

2.2. Delineation

The method of co-citation clustering can be applied to an multidisciplinary database or to a defined research field. If the aim of the analysis is to visualize the internal structure of interdisciplinary fields of limited size like climate research, a delineation of the field can have some advantages. An interdisciplinary field will not always show up as a coherent region of the science landscape. Important specialties of the interdisciplinary field can be spread over different areas of the co-citation structure. A co-citation analysis with a broad perspective - based for example on the whole SCI database – could possibly show some of the climate related specialties embedded in different regions but on the other hand the selectivity for internal relations between some of the small interdisciplinary climate research specialties could be lost.

An alternative to the broad perspective therefore is the delineation of the research field beforehand. But the basic step of a field delineation is a very crucial one. The frontiers of a scientific field, discipline, sub-discipline or specialty are naturally far from clear cut. Experts have a biased view on the structure of their specialty. In the case of an interdisciplinary field like climate research a broad definition will reach far into classical disciplines and sub-disciplines like meteorology, atmospheric chemistry, geophysics or oceanography.

Such a definition is difficult to realize with a database search strategy based only on a list of relevant title word phrases and journals. Areas inside the classical disciplines which are important for climate research could be faded out, if their publications appear outside the few “climate journals” and do not have “climate phrases” in their title. To combine a good resolution of the co-citation analysis with a perspective as broad as possible and to overcome the difficulties with the selection we developed a special two stepped field delineation procedure (fig.2.4).

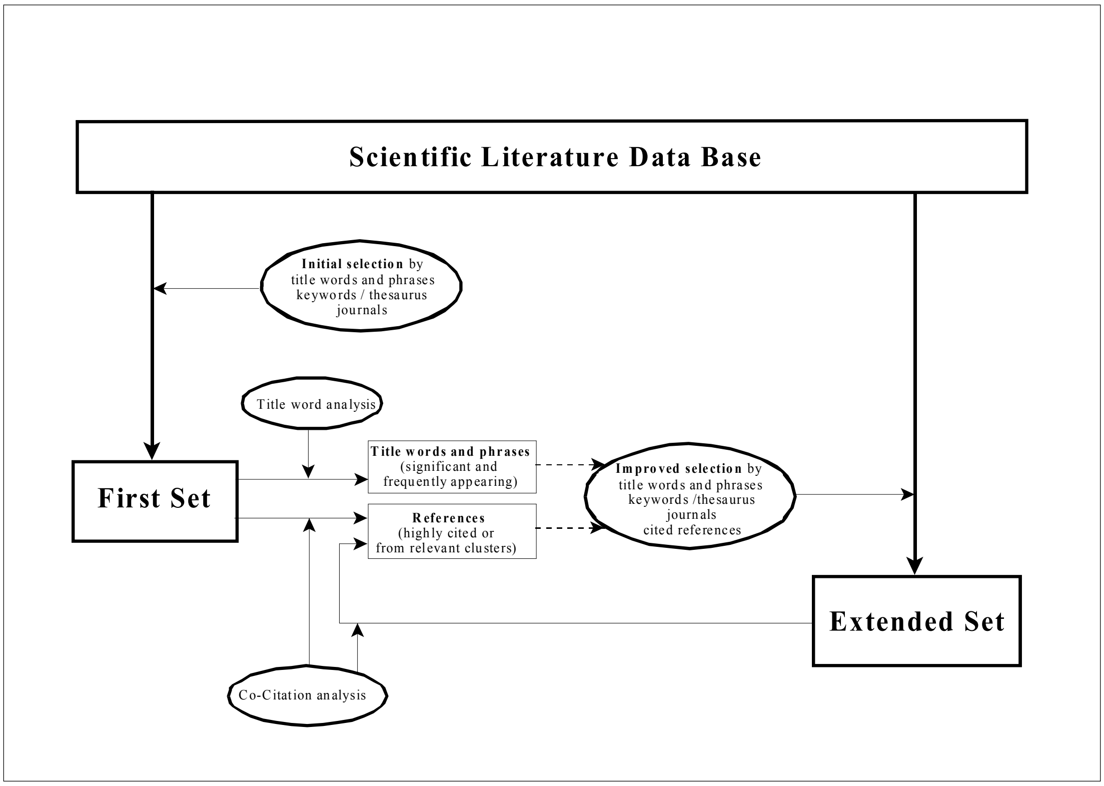

Figure 2.4:
Steps of Delineation

We start with an initial selection by title keywords derived from review articles, funding programmes etc. and a small set of definitely relevant journals. The first set of documents is then analyzed to improve the selection. A title word analysis is carried out to enrich the list of word phrases. Frequently appearing words or phrases are added to the initial selection if they are not too general. Another important path of the improvement procedure leads through the references from the documents of the first set. Assuming that the highly cited references are important pieces of the shared intellectual basis of the analyzed field we take them to find publications referring to them, which could be important for climate research but would not be retrieved using title keywords. Further we can use co-citation analysis to get a view of the area already covered, to monitor the process of improvement and in order to add references from relevant clusters to the selection. The extended set of documents can be analyzed once again in the same way. How many times the loop must be passed to get a comprehensive but not too broad field delineation cannot be determined by a general rule, but rather marginal or outstanding areas can be detected in the maps indicating that the definition might be too broad.

On the set of documents defined by the improved selection we perform the main co-citation analysis.

2.3. Data organizing

In this chapter the main transformation steps leading from the downloaded data to the input file for the cluster analysis are described. The downloaded data is organized by records containing all information about a publication, each in a block of the download file. At first the publications are serially numbered and the different information elements per publication like bibliographic information (authors, title, source etc.), addresses and the reference list are split into different files. These files are formatted for the load into tables of a working database.

Based on the file with the references of all publications the co-citation analysis is carried out. The cited publications are counted and the documents with a citation count below a defined threshold[7] are excluded. For all analyzed fields about 5-10% of the most frequently cited publications reached this threshold.

Then for each source publication all the possible pairwise combinations of the remaining references are built and added to the list of co-citations. This huge amount of single co-citations which have been collected from all citing publications can be grouped by counting their occurrences. The result is a list of distinct pairs of cited publications with their number of co-citations. The last step is the weighting of co-citations by the single citation counts. Because high single citation counts increase the statistical probability of co-occurrences, a similarity measure for co-cited publications has to weight the absolute number of co-citations by the single citation counts. This normalizing of co-citations is done with the Salton-Index and provides a similarity measure that takes the citation frequencies into account.[8]

The Salton-Index of a pair of cited publications i, j:

$$SI_{ij} = \frac{coc_{ij}}{\sqrt{cit_i \cdot cit_j}}$$

coc_{ij} - Number of Co-Citations of i and j
cit_i - Number of Citations of cited publication i
cit_j - Number of Citations of cited publication j

The more frequently two publications are cited, the more frequently they have to be co-cited to reach the threshold which is defined for the Salton-Index. Another threshold is set for the absolute number of co-citations. For all analyzed fields at least two co-citations are required to establish a significant link between two highly cited publications. After the pairs below the thresholds have been eliminated the list of co-cited pairs ranked by their Salton-Index is ready to be used as input for a special co-citation cluster analysis.

2.4. Cluster analysis

A cluster analysis is performed to group the highly cited and co-cited publications. The applied cluster analysis is an implementation of an algorithm developed by Henry Small (1985a,b), called variable-level-clustering. It is based on a single linkage clustering

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[7] The citation threshold was set to four citations in case of the smaller fields climate research and complex systems and increased to five citations for neuroscience.

[8] The Salton-Index was preferred by Small (1985a), because the links between high and low cited papers are not levelled out too much

which is multiply performed with an increasing threshold, combined with a maximum cluster size. Single linkage clustering connects all elements with a minimum similarity index and all clustered units if only two of their elements are connected. Only those elements without a link above the threshold remain unconnected.

This algorithm is suitable to structure the co-citation data, because the overall similarity matrix and even the more dense regions of it show a relatively sparse distribution of linkages. Only about one to two percent of all possible pairs are connected (after applying the thresholds). Alternative cluster algorithms which take multiple linkages into account would not be able to cover single branches of the co-citation network which are connected by single links and would therefore result in a more fragmented cluster structure.

On the other hand a single linkage clustering often results in very long chains which are connecting huge clusters if the threshold for the similarity measure is not set to a high level. A high clustering threshold to avoid this effect of chaining would enable research areas with weaker connections to become clustered. Such a high cut-off would fade great parts of the network. Therefore the variable level clustering uses a combination of a maximum cluster size and a variable threshold for the similarity index. The clustering procedure is repeated with increasing thresholds but in each run only those clusters are accepted, which keep below the defined maximum cluster size. The clusters exceeding the size limits at lower threshold will be broken into smaller ones at higher threshold levels. The result is a more differentiated structure with clusters formed at very different levels.

The limiting of the cluster size has a general rational in the assumption of limiting factors (social, technical) for the growth of coherent communication networks on special research themes as suggested by Derek Price (1965). A size limit for these so called invisible colleges seems reasonable but can not be determined, because it will certainly vary between research fields and depends for example on the organizational structure.

In practice a size limit has to be defined which avoids the agglomeration of too much amorphous big clusters. The internal structure of clusters as shown on the detailed maps can function as an indicator. If a cluster shows different areas which are connected only by relatively few weak links this could be a hint that the defined maximum cluster size is to high for that cluster. The other case, a relatively coherent subject area broken up into several fragments is less critically because an iteration of the clustering will offset the fragmentation if the connection between the clusters is strong enough. The clusters of one subject area then will be affiliated to the same cluster on the next level.

For the analyzed fields we worked with a maximum cluster size between 40 (climate research, complex systems) and 45 (neurosciences).

The result of the first cluster run is a great number of clusters of cited publications. Even for a smaller field like climate research we found about 350 clusters (and up to 10.000 for the neuroscience). So there is a need for further structuring. Analogously to the highly cited publications a similarity measure for pairs of clusters is computed, which is based on their overlap of citing literature. These source publications which are citing publications from different clusters are regarded as co-citing these clusters (represented by the clustered references). In the same way as in the first step we can now compute the Salton-Index for each pair of co-cited clusters using the citation count of the single clusters to normalize the integer co-citation count. On the basis of the list of co-cited clusters and their Salton-Indices the same cluster algorithm as in the first step but with suited parameters is done.

The start threshold for the clustering was decreased for the higher cluster levels because the distribution of Salton-Indices of the linked pairs changes with the level of aggregation. From this distribution the thresholds for the linkage strength at the different levels were derived: The thresholds for the higher levels were chosen in a way that about the same percentage of all connected pairs as for the first level could be included in the cluster analysis. So the signal to noise ratio is the same for all levels. The minimum number of co-citations of the analyzed pairs and the maximum cluster size was kept up for all cluster runs of a research field.

The iterative clustering of clusters results in a hierarchy of cluster levels from the smallest subject areas up to large subfields of the analyzed research field which are represented by the clusters on the highest level. We stopped the iterative process if the number of clusters of the highest level could be visualized in one overview map for the research field or the next clustering results in only very few and/or amorphous clusters.

For selected clusters the internal relations of the elements (clusters or cited publications) can be visualized and statistical information regarding bibliographic elements can be produced.

2.5. Mapping the co-citation structure

In the last step the results of the co-citation analysis are visualized in the form of maps using multidimensional scaling ("MDS"). In these maps the whole field or a selected cluster is shown as a kind of cognitive landscape. The maps can visualize selected parts of the co-citation structure of selected cluster levels up to the whole field in case of overview maps, which show the clusters of the highest level.

In figure 2.5 a nested co-citation structure is depicted schematically. The elements from different levels are shown with their linkages in form of a network graph. The different types of maps on the right side elucidate the principle of zooming in the complex structure of the complete graph (up to 90.000 highly cited documents in case of the Neurosciences). The overview map shows the whole landscape, but restricted to the elements of the highest cluster level, which in this example is the C2-level. The C2-clusters are depicted by simple circles positioned in the overview map, each representing the clustered elements on the lower levels.

The 2-dimensional spatial structure of the elements represents the internal relations of the mapped unit.

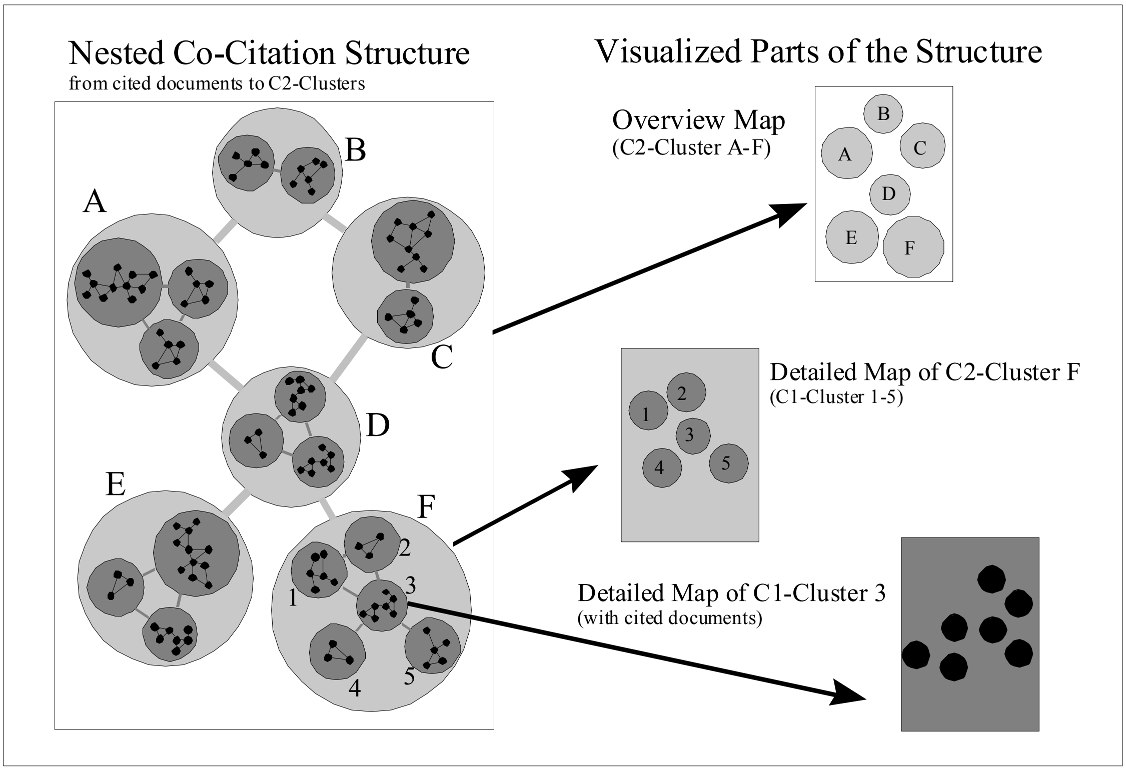


Figure 2.5:
Mapping of selected parts of the co-citation structure

The co-citation map of cited documents is generated by multidimensional scaling (MDS[9]) techniques, based on the matrix of the relative co-citation strength as a measure of similarity between the documents or clusters. Using the pairwise similarities of the clustered elements given by their Salton-Index, the MDS computes a solution with a minimized difference between these similarity measures and the distances in the map. So the maps visualize the multidimensional relations given by the co-citations inside the analyzed unit – a selected cluster or the clusters of the highest cluster level.

As the MDS transforms the originally n-dimensional space of co-citation links into an easy-to-read two-dimensional figure (“map“), there may be a loss of information, especially in cases of very complex co-citation structures. Therefore in certain cases additional lines are introduced into the final map to show strong co-citation links between specific documents or clusters, which otherwise would not become visible because they were leveled out by the MDS algorithm.

The depicted elements, clusters or cited publications, are represented by circles of different size and color, which are annotated with labels giving the numbers and descriptions of the represented elements.

---

[9] The MDS is computed with the ALSCAL procedure of SPSS

The size of the circle areas is proportional to the size of the clusters research front in terms of publication number or, in case of co-cited publications as the mapped elements proportional to the number of citations. The shading of the circles indicates the proportion of young publications (published not more than three years before the source year) included in the cores of the represented clusters. The descriptions given in the labels are composed of author name and publication year in case of cited publications. A title is given for the clusters as a description, generated in a semi-automatic procedure of selecting title word phrases from the most frequently co-citing publications of each cluster. The cluster titles are names which have to be concise and unambiguous and therefore can not function as complete descriptions of the cognitive content of the clusters.

The maps can be enriched and combined with additional bibliographic information about important aspects of the elements or the whole mapped unit, like main actors, the most frequent co-operations, journals or highly cited and co-cited documents.

References

Price, D.J.D. (1965). Networks of scientific papers. *Science* 149, 510-515.

Small, H. (1985). Clustering the Science Citation Index using co-citations. 1 A comparison of methods. *Scientometrics* 7, 391-409.

Small, H. (1985). Clustering the Science Citation Index using co-citations. 2 Mapping science. *Scientometrics* 8, 321-340.

3. Co word Methodology

Science maps based on co-word analysis have been developed since the seventies/eighties for policy supportive use. A detailed discussion of the whole procedure from publications to maps and additional information is available in Noyons (1999). The method discerns clusters of topics, identified as themes (Callon, 1986) or sub-domains (Noyons, 1999) as central entities. The method in this study uses word co-occurrence profiles to determine similarities between topics. This means that topics with a weak direct relation (small number of co-occurrences) but with strong indirect relations (similar high numbers of co-occurrences with other topics) can be identified as being closely related. Note that this method is able to identify synonyms (two different words with the same meaning) as being related. For instance, if A and B mean exactly the same thing, and part X of the community uses A, whereas part Y of the community uses B, the direct relation between A and B will be weak, or maybe even non-existent. The indirect relation between A and B will be, however very strong. A map aiming at disclosing the cognitive structure of a research field should be able to identify A and B as being closely related.

3.1. Field keyword selection

The selection of keywords to structure the bibliographic database, representing the field under study, is a procedure based on four word characteristics:

- lexical features;
- linguistic characteristics;
- bibliometric distribution;
- semantic scope.

First of all, only noun phrases (NPs) can become field keywords. In order to identify noun phrases in English texts, we use a 'noun phrase extractor' developed by Lingsoft Inc. in Finland (NPtool). The process from text to NPs is described in the scheme below.

The identified NPs are divided into two groups: the single word NPs (SWNP) and the multiword NPs (MWNP). At first, only a MWNP becomes a field keyword. From the list of MWNPs a list of phrases is withdrawn because they are used in text primarily for other reasons than to describe contents of research. Their semantic scope is outside scientific research. In the near future, we will be able to rule out such phrases on the basis of their bibliometric distribution within science.

Furthermore, some minor unification is conducted to words and phrases for efficiency and esthetical reasons. It concerns unification of plural to singular form not identified by NPtool, and unification of full terms to acronyms and abbreviations. In each project this list is adjusted, because word unification in one field can have unwanted effects in another.

Preprocessing

⇓

Morphological analysis

⇓

Constraint Grammar parsing

⇓ ⇓

NP-hostile finite state parsing	NP-friendly finite state parsing
⇓	⇓
NP extraction	NP extraction
⇓	⇓

Intersection of noun phrase sets

Source: Voutilainen (1993)

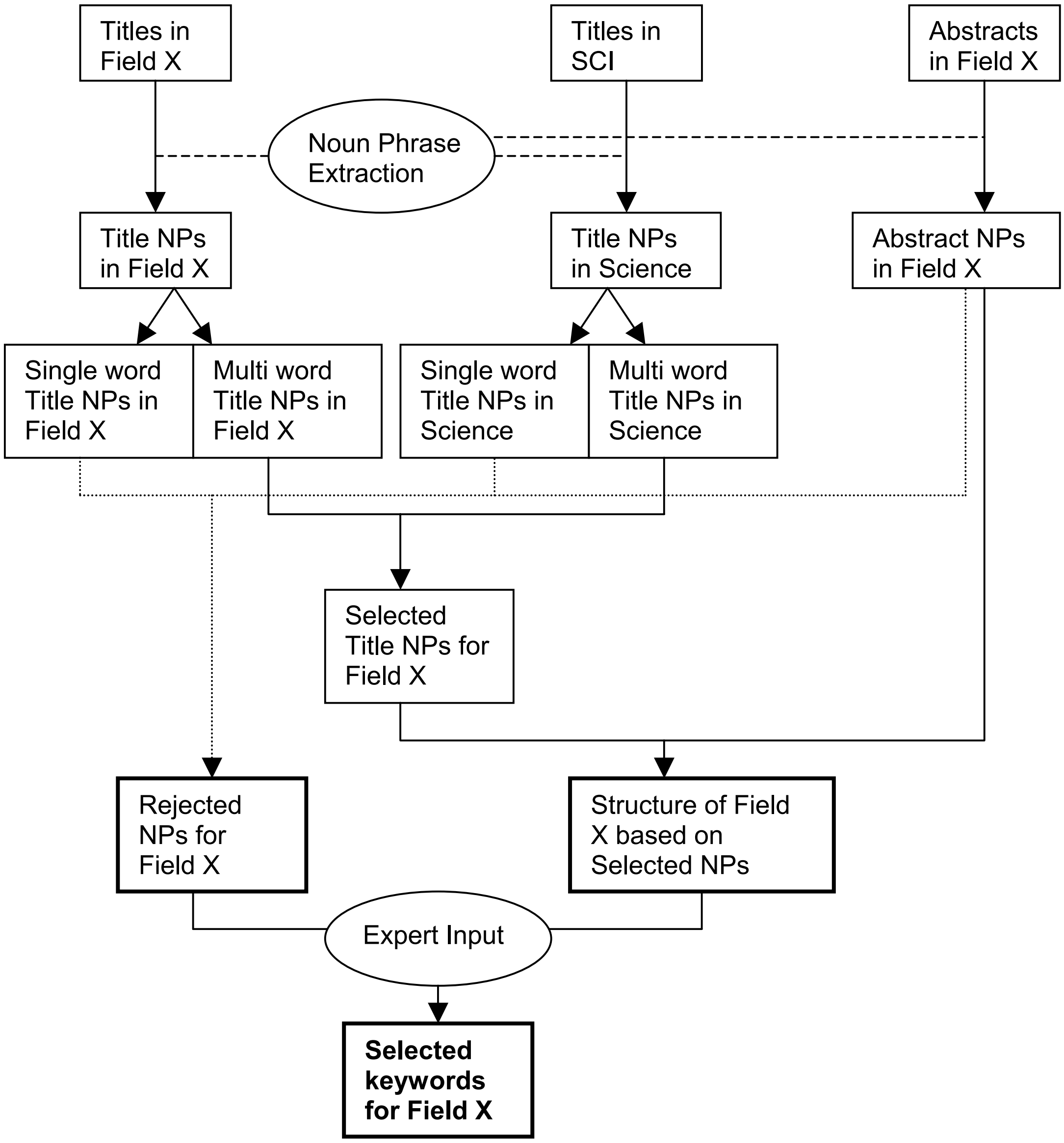
NPtool system flowchart

The selection of field keywords from the list of candidates is presently established on the basis of their bibliometric distribution, and (if possible) the input of a field expert. For each MWNP, we count the number of appearances in titles on the one hand, and in abstracts on the other within the field under study, as well as the number of appearances in titles in science as a whole. A combination of these three figures, indicates both the specificity of the NP within the field and its 'centrality' within the field.

The expert input is prompted with two sources of information:

- a list of excluded single word noun phrases (SWNPs);
- a preliminary list of selected field keywords within its cognitive context (see next section).

By using an 'on-line' feedback form, the field expert is able to remove preliminary selected keywords or to add preliminary excluded NPs from the two lists. A flowchart of the selection procedure is depicted below.



Field keyword selection flowchart

3.2. Keyword clustering and subdomain identification

In order to identify subdomains within a field, the selected keywords are clustered into groups on the basis of their similar cognitive orientation. At first, this cluster structure is used to provide a cognitive context for each preliminary selected keyword. In the final stage, this cluster structure is used to delineate subdomains within the field.

The clusters are identified by a cluster analysis on a normalized co-occurrence matrix. The matrix is composed by the keyword co-occurrences in the set of publications defining the field in a certain period of time. It will depend on the aims of a project, which period of time this is. The co-occurrence matrix looks like the example below, where each cell contains the number of times that the row and the column item appear together in a publication.

	keyword #1	keyword #2	keyword #3	...
Keyword #1	100	30	80	...
Keyword #2	30	50	0	...
Keyword #3	80	0	100	...
...	...	...	...	...

Keyword co-occurrence matrix sample

In the above sample, keyword #1 appears in 100 publications. In 30 publications it co-occurs with keyword #2, which appears in 50 publications.

The 'raw data' matrix is normalized in such a way that the similarity of keywords is no longer based on the pairwise co-occurrences, but rather on the cognitive orientation of two keywords in relation to all other keywords. The similarity is thus calculated on the co-occurrence profiles of keyword #1 and keyword #2 with all other keywords. In other words the vectors of #1 and #2, as defined by the co-occurrences with other keywords, is compared. The similarity is calculated on the based of the cosine index (the cosine of vectors):

$$sim(x,y) = \frac{\sum_i (x_i y_i)}{\sqrt{((\sum_i x_i^2)(\sum_i y_i^2))}}$$

The cosine of co-occurrence vectors

The recalculated matrix is input for a cluster analysis. In most cases, we use a hierarchical cluster algorithm with complete linkage.

The number of clusters to be formed is determined by combining three criteria provided by SAS ® (local peak of the cubic clustering criterion (CCC) and the Pseudo F statistic, together with a low Pseudo T2 and a much higher Pseudo T2 at the next cluster fusion). Of course, the determination of the number of clusters is related to the issue addressed in the mapping study. If a very coarse structuring of a field is required, a high number of clusters seems not appropriate. It should be noted that any number of clusters represents *a* structure of the field. In other words: both a structure based on 5 clusters as well as a structure based on 50 clusters is able to represent a field. In the former case, however, certain details provided by the latter may are not revealed.

The identified clusters of keywords represent field subdomains. These subdomains are labeled with a name by the four most frequent keywords in a cluster.

3.3. Mapping subdomains by MDS

In order to build a map of the field, the subdomains are positioned in a two-dimensional space. Each subdomain represents publications on the basis of keyword occurrence. If any of the keywords is in a publication, it will be attached to the subdomain to which the keywords belong. Thus, publications may be attached to more than one subdomain. The overlap between subdomains can be used to create a co-occurrence matrix (c.f., keyword co-occurrence matrix in the previous section). A normalization of the subdomain co-occurrences is performed is established by a cosine similarity matrix (c.f., previous section). The subdomains are positioned in two dimensions by multidimensional scaling (MDS: ordinal). The resulting field map renders the cognitive similarity of subdomains as measured by the distance between them. The distance is determined by the cognitive orientation of subdomains in relation to all other, in such a way, that subdomains with a similar cognitive profile are in each other's vicinity, and subdomains with different orientation are distant from each other.

The map provides information about the number of publications represented by a subdomain as well. The size of a subdomain (the surface of a circle) indicates the share of publications represented in relation to the full number in the whole field.

Finally, the pairwise cognitive relation between two individual subdomains is indicated by a connecting line. As the whole map is a representation of similarity between subdomains (taking into account all co-occurrence relations), connecting lines enhance the structure by emphasizing pairwise relations. A pairwise relation is measured by a normalized similarity of the Salton index.

$$sim(x,y) = \frac{C_{xy}}{\sqrt{C_x C_y}}$$

Where:
C_{xy} is the number of co-occurrences of x and y;
C_x is the number of occurrences of x; and
C_y is the number of occurrences of y.

Salton index

The maps are put in a digital form on the WWW server of CWTS[10]. Thus they are accessible for users to explore the field or to validate the results. We provide information 'behind' the map (actors, sources, impact figures) by an interface that can be used via standard graphical internet browsers (MS Internet Explorer and Netscape Communicator).

References

Callon, M. (1986), *Mapping of Science*. .

Noyons, E.C.M. (1999), *Bibliometric mapping as a science policy and research management tool*. DSWO Press, Leiden.

Voutilainen, A. (1993), 'NPtool, a Detector of English Noun Phrases'. In: *Proceedings of the Workshop on Very Large Corpera* 1993. Ohio State University, Columbus Ohio.

[10] CWTS WWW projects at http://www.cwts.leidenunv.nl

4. General results

4.1. General results based on co-citation analysis

In this chapter general results for the three analyzed research fields are presented: climate research, complex systems and neuroscience. Basic statistics, tables with main actors and an overview of the co-citation cluster structure for 1996 – 1998 are given. An overview is presented by co-citation maps, for neuroscience supplemented by a co-citation map of the largest C4-cluster and tables showing the largest isolated C3-clusters.

For all clusters included in the overview maps (and for the listed isolated neuroscience C3-clusters) in additional tables the proportion of publications from the three regions USA, EU and Japan (alternatively Canada for climate research) can be compared, as well as for the most active countries of the European Union (EU15). Values differ significantly from the country's field average are marked by special symbols in the tables.

Detailed maps for the clusters shown in the overview maps are presented for selected cases.

4.1.1. Climate research

4.1.1.1. Delineation

A thematic selection of publications from the multidisciplinary SCI was made to delineate the interdisciplinary field of climate research. A multistage delineation procedure was designed to get a comprehensive set of climate research publications. (Described in chapter 2.2)

In the first step publications were selected all

a) which contain explicitly climate relevant title words or phrases (listing 1)
b) which were published in explicitly climate relevant journals (listing 2)
c) which were published in an broader set of journals from geo science or meteorology (listing 3) and coincidentally show the stem "climat" in their title.

Listing 1: Climate relevant words and phrases

- ALBEDO and CLIMAT*
- ANTHROPO* and CLIMAT*
- ATMOSPHER* GENERAL CIRCULATION
- ATMOSPHERE OCEAN MODEL*
- CARBON DIOXIDE and CLIMAT*
- CCM1
- CCM2
- CHANG* CLIMAT*
- CIRCULATION ANOMALIES
- CLIMAT* ANOMALIES
- CLIMAT* CHANGE*
- CLIMAT* CYCLE*
- CLIMAT* DRIFT
- CLIMAT* EQUILIBRIUM
- CLIMAT* FORCING
- CLIMAT* FORECAST*
- CLIMAT* IMPACT*
- CLIMAT* IMPLICATION*
- CLIMAT* MODEL
- CLIMAT* MONITORING
- CLIMAT* OBSERV*
- CLIMAT* OSCILLATION
- CLIMAT* PREDICTION*
- CLIMAT* RESPONSE*
- CLIMAT* SIMULATION*
- CLIMAT* SYSTEM*
- CLIMAT* TREND*
- CLIMAT* VARIA*
- CLIMAT* WARMING
- CLIMATOLO*
- COUPLED ICE OCEAN MODEL*
- EL NINO
- ENHANCED GREENHOUSE
- ENSO
- GCM
- GCMS and CLIMAT*
- GENERAL CIRCULATION MODEL*
- GLOBAL CLIMAT*
- GLOBAL MEAN TEMPERATURE
- GLOBAL TEMPERATURE
- GLOBAL WARMING
- GREENHOUSE EFFECT
- GREENHOUSE GAS*
- GREENHOUSE WARMING
- LA NINA
- OCEAN ATMOSPHERE MODEL*
- OCEAN GENERAL CIRCULATION
- PALEOCLIMATIC
- RAINFALL ANOMALIES
- SOUTHERN OSCILLATION
- THERMOHALINE CIRCULATION*
-

Listing 2: Set of climate journals (completely covered)

- CLIMATE DYNAMICS
- CLIMATIC CHANGE
- INTERNATIONAL JOURNAL OF CLIMATOLOGY
- JOURNAL OF CLIMATE
- THEORETICAL AND APPLIED CLIMATOLOGY

Listing 3: Extended journal set (publications covered if containing "climat" in the title)

- ANNALES GEOPHYSICAE ATMOSPHERES HYDROSPHERES AND SPACE SCIENCES
- ATMOSPHERIC ENVIRONMENT
- AUSTRALIAN METEOROLOGICAL MAGAZINE
- BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY
- COMPTES RENDUS DE L ACADEMIE DES SCIENCES SERIE II-FASCICULE A SCIENCES DE LA TERRE ET DES PLANETES
- EARTH OBSERVATION AND REMOTE SENSING
- EARTH AND PLANETARY SCIENCE LETTERS
- ECOLOGICAL MODELLING
- ENVIRONMENTAL CONSERVATION
- GEOCHIMICA ET COSMOCHIMICA ACTA
- GEOLOGISCHE RUNDSCHAU
- GEOLOGY
- GEOMORPHOLOGY
- GEOPHYSICAL RESEARCH LETTERS
- GLOBAL AND PLANETARY CHANGE
- GLOBAL ENVIRONMENTAL CHANGE- HUMAN AND POLICY DIMENSIONS
- INTERNATIONAL JOURNAL OF REMOTE SENSING
- IZVESTIYA AKADEMII NAUK FIZIKA ATMOSFERY I OKEANA
- JOURNAL OF APPLIED METEOROLOGY
- JOURNAL OF ARID ENVIRONMENTS
- JOURNAL OF BIOGEOGRAPHY
- JOURNAL OF GEOLOGY
- JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES
- JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS
- JOURNAL OF HYDROLOGY
- JOURNAL OF MARINE SYSTEMS
- JOURNAL OF PHYSICAL OCEANOGRAPHY
- JOURNAL OF SEDIMENTARY RESEARCH
- JOURNAL OF THE ATMOSPHERIC SCIENCES
- LIMNOLOGY AND OCEANOGRAPHY
- MONTHLY WEATHER REVIEW
- NATURE
- OKEANOLOGIYA
- PALAEOGEOGRAPHY PALAEOCLIMATOLOGY PALAEOECOLOGY
- PALEOCEANOGRAPHY
- PROCEEDINGS OF THE INDIAN ACADEMY OF SCIENCES- EARTH AND PLANETARY
- SCIENCES
- PROGRESS IN PHYSICAL GEOGRAPHY
- QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
- QUARTERNARY SCIENCE REVIEWS
- QUATERNARY RESEARCH
- SCIENCE
- SEDIMENTOLOGY
- SURVEYS IN GEOPHYSICS
- TELLUS SERIES A-DYNAMIC METEOROLOGY AND OCEANOGRAPHY
- TELLUS SERIES B-CHEMICAL AND PHYSICAL METEOROLOGY
- WATER AIR AND SOIL POLLUTION
- WATER RESOURCES RESEARCH

This first step of the delineation procedure provides a basic set about 1500 of publications each year in the SCI. This was extended in the next steps of the delineation procedure by using the highly cited references of the first set as seeds to collect further thematic relevant literature. Those publications were added, which are citing three or more of the core set of highly cited documents and had not been included already.

This extension procedure was carried out iteratively two times, providing together about 1000 additional publications for each analyzed year, which were not covered by the initial delineation.

4.1.1.2. Overview

The size of the research field given by the set of selected source publications was rather stable over the three analyzed years. (Table 2.1)

Table 2.1:
Co-Citation analysis of climate research 1996-98: Basic statistics

	1996	1997	1998
First Set	1409	1454	1460
Source Publications (Extended Set)	2458	2465	2414
Cited Publications	56731	59055	59866
Highly Cited Publications	3736	4019	3839
Clustered Publications	2466	2580	2359
C1-Cluster	341	365	367
C2-Cluster	32	31	39

The changes in the number of climate research publications were less than one percent. For every year about 2450 publications were included in the analysis. Also the overall citation pattern did not change. The numbers of cited and of highly cited publications (four citations or more) increased from 1996 to 1997 slightly and from 1997 to 1998 the highly cited decreased, but the percentage of highly cited publications remained between 6.4% and 6.8%. The same stability can be observed in case of the clustered publications and the number of clusters. The cluster analysis was performed with a Salton Index threshold of 0.3 for the cited documents and down to a Salton Index of 0.15for the C1-clusters. A maximum cluster size of 40 was defined.

In the following chapters a general overview for the three years including the co-citation maps and basic actor statistics are given.

4.1.1.2.1. Climate research 1996

For the source year 1996 the cluster analysis was based on the (co-)citations provided by 2458 source publications of the extended set of climate research. The 2466 highly cited and co-cited publications are grouped into 32 C2-clusters shown in the following overview map.

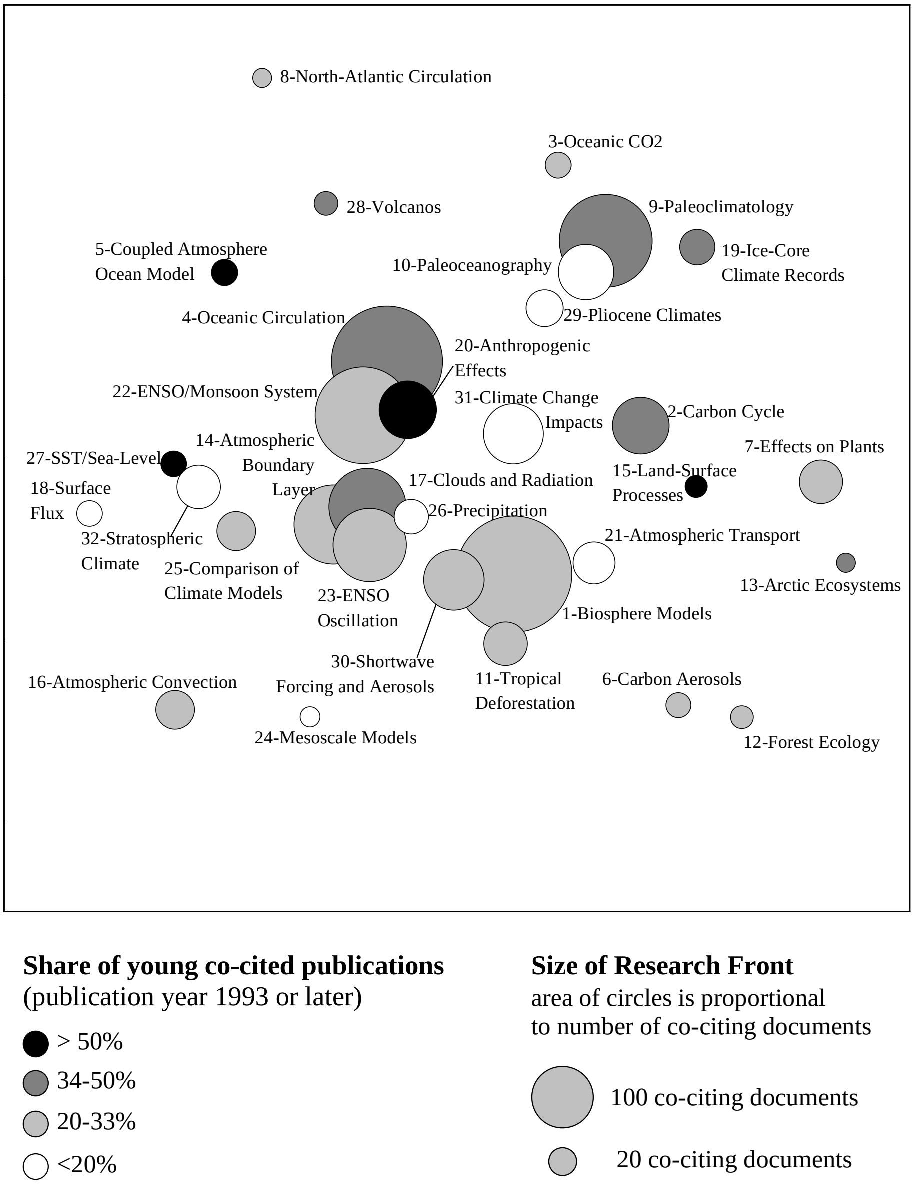


Figure 2.1:
Overview map for climate research 1996

Table 2.2:
C2-clusters of Climate Research 1996

Cluster	Title	C1	Core	Front	Imm
1	Biosphere Models	38	319	356	27
2	Carbon Cycle	9	68	86	35
3	Oceanic CO2	3	7	18	28
4	Oceanic Circulation	38	344	328	34
5	Coupled Atmosphere Ocean Model	3	8	19	62
6	Carbon Aerosols	2	13	17	23
7	Effects on Plants	3	39	50	23
8	North-Atlantic Circulation	2	5	10	20
9	Paleoclimatology	21	229	229	37
10	Paleoceanography	2	66	82	18
11	Tropical Deforestation	2	33	51	21
12	Forest Ecology	2	9	14	33
13	Arctic Ecosystems	2	8	10	37
14	Atmospheric Boundary Layer	16	114	168	25
15	Land-Surface Processes	2	6	13	83
16	Atmospheric Convection	4	47	40	23
17	Clouds and Radiation	17	135	157	37
18	Surface Flux Parameterization	3	6	18	0
19	Ice-Core Records	2	24	34	37
20	Anthropogenic Effects	8	67	88	52
21	Atmospheric Transport	3	44	47	13
22	ENSO/Monsoon System	16	175	247	30
23	ENSO Oscillation	18	123	143	32
24	Mesoscale Models	2	6	11	0
25	Comparison of Climate Models	5	23	41	21
26	Precipitation	3	14	32	14
27	SST/Sea-Level	2	5	18	80
28	Volcanos	4	13	15	38
29	Pliocene Climates	2	42	37	19
30	Shortwave Forcing and Aerosols	8	59	98	32
31	Climate Change Impacts	6	23	96	17
32	Stratospheric Climate	3	50	51	12

The overview map in figure 2.1 shows the 32 C2-clusters of climate research 1996 Table 2.2 lists basic information for each cluster: the number of C1-clusters included (c1), the number of cited publications in the involved c2-cluster cores (core), the size of the research front (front) and the immediacy (imm) as indicated by the percentage of younger cited publications (published 1993 or later) inside the cluster core.

The overall structure is dominated by a few large clusters. The largest cluster *Biosphere Models* (1) can be found in the lower right part of the center and has a moderate immediacy value. Its clustered publications are co-cited by 356 source publications. Another large cluster, *Oceanic Circulation* (4) with 328 publications at the research front, is positioned in the upper center of the map and is neighbored to *ENSO/Monsoon System* (22), which is a little smaller, but still has 247 co-citing front publications. A bit separated from the center on the upper right side of the map the Paleoclimatology can be found represented by a large cluster (9) and three smaller subfields: *Paleoceanography* (10), *Ice-Core Climate Records* (19) and *Pliocene Climates* (29). The latter (19 and 29) have rather small research fronts. In both of the last mentioned larger clusters (*Oceanic Circulation* and *Paleoclimatology*) more than one third of the cited publications are published after 1992. Apart from these clusters such a high immediacy value is attained only by one cluster with more than 100 front publications: the cluster *Clouds and Radiation* (17) in a group together with two other clusters of medium size, *Atmospheric Boundary Layer* (14) and *ENSO Oscillation* (23).

Many of the smaller clusters are building kind of satellites of the larger ones and are located more in the periphery of the map. This pattern can be observed on the lower right side of the map. Surrounding the cluster *Biosphere Models* smaller clusters dealing with related subjects can be found, like *Tropical Deforestation* (11), *Forest Ecology* (12), *Arctic Ecosystems* (13), *Effects on Plants* (7) or somewhat larger *Carbon Cycle* (2) with 86 front publications. On the outer regions of the opposite direction clusters dealing with oceanic phenomena can be found, like *North-Atlantic Circulation* (8) on the top of the map, *Coupled Atmosphere Ocean Model* (5), *Oceanic* CO_2 (3) and on the left side *SST/Sea Level* (27). Atmospheric phenomena are represented by the clusters on the lower part of the left side. For example *Stratospheric Climate* (32), *Atmospheric Convection* (16), *Shortwave Forcing* (30) and of course the medium sized clusters *Clouds and Radiation* (17) and *Atmospheric Boundary Layer* (14).

In the center of the map two clusters can be found dealing explicitly with causes and effects of climate change. The clusters *Anthropogenic Effects* (20) and *Climate Change Impacts* (31), both with about 90 co-citing publications. The cluster number 20 shows besides some very small clusters the highest dynamic. More than 50% of the clustered publications were published after 1992.

Table 2.3:

Top national actors of climate research 1996

Publications	Percent	Country
1308	53.2	USA
697	28.4	EU 15
237	9.6	UK
184	7.5	CANADA
171	7.0	GERMANY
154	6.3	AUSTRALIA
152	6.2	FRANCE
74	3.0	JAPAN
64	2.6	NETHERLANDS
54	2.2	SWEDEN
47	1.9	SWITZERLAND
42	1.7	RUSSIA
39	1.6	PEOPLES-R-CHINA
36	1.5	INDIA
27	1.1	NEW-ZEALAND
26	1.1	DENMARK

In table 2.3 the 15 top national actors (and the EU15 group) are listed by numbers of publications for the field climate research. The ranking is clearly leaded by the USA, which are participating in more than half of the 1996 climate research publications, whereas none of the other reaches 10 % of the field's publications. European countries contributing more than 150 publications are the United Kingdom, Germany and France. Other countries above this threshold are Canada (which ranks on the third place) and Australia.

Table 2.4:

Top institutional actors of climate research 1996

Publications	Institution
152	NASA, USA
124	NOAA, USA
81	NATL-CTR-ATMOSPHER-RES, USA
69	UNIV-COLORADO, USA
59	CSIRO, AUSTRALIA
55	UNIV-WASHINGTON, USA
51	UNIV-CALIF-SAN-DIEGO, USA
50	COLORADO-STATE-UNIV, USA
47	COLUMBIA-UNIV, USA
46	PRINCETON-UNIV, USA
38	UNIV-WISCONSIN, USA
37	MAX-PLANCK-INST-METEOROL, GERMANY
36	UNIV-MARYLAND, USA
35	WOODS-HOLE-OCEANOG-INST, USA
34	OREGON-STATE-UNIV, USA
34	TEXAS-A&M-UNIV,USA
34	UNIV-E-ANGLIA, UK

The top institutions with more than 33 climate research publications are shown in table 2.4. Nearly all of them are US institutions, leaded by the NASA and the NOAA, which contribute by far the most publications. The first non US institution is the Australian CSIRO with 59 publications. The EU is represented only by the German Max Planck Institute (MPI) of Meteorology and the British University of East Anglia, which are leading the ranking of the EU15 actors in table 2.5.

Table 2.5:

Top European institutional actors of climate research 1996

Publications	Institution
37	MAX-PLANCK-INST-METEOROL, GERMANY
34	UNIV-E-ANGLIA, UK
26	LUND-UNIV, SWEDEN
21	CHRISTIAN-ALBRECHTS-UNIV-KIEL, GERMANY
21	CNRS, FRANCE
21	UNIV-PARIS-06, FRANCE
18	CEA, FRANCE
17	UNIV-READING, UK
14	UNIV-COPENHAGEN, DENMARK
14	UNIV-EDINBURGH, UK
13	UNIV-BAYREUTH, GERMANY
13	UNIV-UTRECHT, NETHERLANDS

Publications	Institution
12	ALFRED-WEGENER-INST-POLAR-&-MARINE-RES, GERMANY
12	ROYAL-NETHERLANDS-METEOROL-INST, NETHERLANDS
12	METEOROL-OFF, UK
12	UNIV-OXFORD, UK

Besides further British and German institutions table 2.5 shows the Swedish Lund University on the third place and several French institutions. Further on the Netherlands and Denmark are represented in the ranking of European institutions with more than 10 publications.

In the following tables (2.6 and 2.7) the comparative figure is the countries' proportion of publications at the research fronts of the C2-Clusters as a whole. This set of publications includes only those of the selected source publications which are co-citing at least one of the C2-clusters and is therefore differing from the distribution for the complete set of source publications. The proportion of the countries' publications for the subset are shown in the column headings for each selected country or region.

The significantly differing country shares are marked with symbols: a triangle pointing upwards for a value above and a triangle pointing downwards for a value significantly below the countries' proportion in the compared set of C2-front publications[11].

Table 2.6:

Share of EU15, USA and Canada in the C2-clusters' research fronts of climate research 1996, ranked by the share of EU15 publications on the research front

Rank	Title (CL.-No.)	Front	EU15 (29.1)	USA (59.7)	CAN (8.2)
1	Paleoclimatology (9)	229	52.0 ▲	40.6 ▼	9.6
2	Forest Ecology (12)	14	50.0	42.9	0
3	Coupled Atmosphere Ocean Model (5)	19	47.4	47.4	5.3
4	Ice-Core Records (19)	34	47.1 ▲	61.8	0
5	Paleoceanography (10)	82	42.7 ▲	50.0	2.4
6	Oceanic CO2 (3)	18	38.9	66.7	0
7	Atmospheric Transport (21)	47	38.3	72.3	8.5
8	Effects on Plants (7)	50	36.0	56.0	6.0
9	Shortwave Forcing and Aerosols (30)	98	35.7	58.2	8.2
10	Precipitation (26)	32	34.4	56.3	6.3
11	Volcanos (28)	15	33.3	80.0	0
12	Atmospheric Boundary Layer (14)	168	32.1	61.3	8.3
13	Clouds and Radiation (17)	157	31.8	65.6	8.9
14	Land-Surface Processes (15)	13	30.8	84.6	0
15	Pliocene Climates (29)	37	29.7	59.5	5.4
16	Anthropogenic Effects (20)	88	29.5	67.0	5.7
17	Carbon Aerosols (6)	17	29.4	70.6	11.8
18	Stratospheric Climate (32)	51	29.4	56.9	7.8
19	Carbon Cycle (2)	86	27.9	61.6	10.5
20	Biosphere Models (1)	356	27.2	61.2	10.7
21	Tropical Deforestation (11)	51	25.5	76.5 ▲	0

[11] The computation of the confidence interval for the differences between the subset of all C2-cluster front publications and single C2-cluster fronts is based on the assumption of a binomial distribution and an error probability of 0.05%.

Rank Title (CL.-No.)	Front	EU15 (29.1)	USA (59.7)	CAN (8.2)
22 Oceanic Circulation (4)	328	25.3	62.2	8.8
23 Climate Change Impacts (31)	96	25.0	46.9 ▼	12.5
24 North-Atlantic Circulation (8)	10	20.0	80.0	0
25 ENSO/Monsoon System (22)	247	18.2 ▼	63.6	7.3
26 SST/Sea-Level (27)	18	16.7	77.8	0
27 Comparison of Climate Models (25)	41	14.6 ▼	87.8 ▲	2.4
28 ENSO Oscillation (23)	143	12.6 ▼	72.7 ▲	3.5 ▼
29 Arctic Ecosystems (13)	10	10.0	90.0	0
30 Atmospheric Convection (16)	40	7.5	90.0 ▲	2.5
31 Surface Flux Parameterization (18)	18	5.6	61.1	5.6
32 Mesoscale Models (24)	11	0	90.9 ▲	0

The relative activity of the three largest regions for climate research (USA, EU15 and Canada) at the research fronts of the C2-clusters is given in table 2.6. For each C2-cluster the countries' contributions as percentage of the front publications are listed. The symbols in the cells indicate a significant difference from the countries' performance at all research fronts combined (given in the column headings). Clusters are ranked by share of EU15 publications.

On top of the list one of the largest subfield, *Paleoclimatology* (9), can be found. With 52% the EU15 share is significantly higher than the overall value, whereas the US share is quite low, although there are still more than 40% publications from US institutions at the front. The other two clusters with a significantly high EU15 share at the research front are smaller ones: *Ice-Core Records* (19) and *Paleoceanography* (10), both in direct vicinity of the large paleoclimatology cluster (See figure 2.1). The US share for these clusters reaches an average value.

The subfields with a significant low EU15 share at the end of the list are *ENSO/Monsoon System* (22) on rank 25, *Comparison of Climate Models* (25) and *ENSO Oscillation* (23). The two last mentioned subfields are neighbors in the lower center of the overview map and are both dominated by the USA, which participates in more than 70% of the front literature.

The C2-cluster *ENSO Oscillation* (23) is the only larger subfield (with more than 100 publications) which shows a significant low activity of Canada, but there are some clusters with smaller research fronts without Canadian publications. The subfield with the highest proportion of Canadian institutes at the research front is *Climate Change Impacts* (31).

Table 2.7:

Share of the top European countries in the C2-clusters' research fronts of climate research 1996, ranked by the share of EU15 publications on the research front

Rank Title (No.)	Front	EU15 (29.1)	UK (9.2)	GER (7.8)	F (7.0)
1 Paleoclimatology (9)	229	52.0 ▲	13.1 ▲	10.9	17.5 ▲
2 Forest Ecology (12)	14	50.0	7.1	21.4	0
3 Coupled Atmosphere Ocean Model (5)	19	47.4	21.1	36.8 ▲	0
4 Ice-Core Records (19)	34	47.1 ▲	5.9	17.6 ▲	11.8
5 Paleoceanography (10)	82	42.7 ▲	12.2	12.2	14.6 ▲

Rank Title (No.)	Front	EU15 (29.1)	UK (9.2)	GER (7.8)	F (7.0)
6 Oceanic CO2 (3)	18	38.9	0	33.3 ▲	11.1
7 Atmospheric Transport (21)	47	38.3	6.4	21.3 ▲	17.0 ▲
8 Effects on Plants (7)	50	36.0	18.0 ▲	8.0	0
9 Shortwave Forcing and Aerosols (30)	98	35.7	12.2	9.2	4.1
10 Precipitation (26)	32	34.4	15.6	12.5	6.3
11 Volcanos (28)	15	33.3	33.3	0	0
12 Atmospheric Boundary Layer (14)	168	32.1	7.7	11.3	8.3
13 Clouds and Radiation (17)	157	31.8	10.2	10.8	7.6
14 Land-Surface Processes (15)	13	30.8	0	0	15.4
15 Pliocene Climates (29)	37	29.7	10.8	10.8	2.7
16 Anthropogenic Effects (20)	88	29.5	19.3 ▲	8.0	1.1
17 Carbon Aerosols (6)	17	29.4	5.9	5.9	11.8
18 Stratospheric Climate (32)	51	29.4	17.6 ▲	11.8	0
19 Carbon Cycle (2)	86	27.9	5.8	11.6	9.3
20 Biosphere Models (1)	356	27.2	6.7	7.0	7.0
21 Tropical Deforestation (11)	51	25.5	11.8	3.9	3.9
22 Oceanic Circulation (4)	328	25.3	7.0	10.7 ▲	6.1
23 Climate Change Impacts (31)	96	25.0	14.6	4.2	0 ▼
24 North-Atlantic Circulation (8)	10	20.0	10.0	0	10.0
25 ENSO/Monsoon System (22)	247	18.2 ▼	6.9	4.0 ▼	6.5
26 SST/Sea-Level (27)	18	16.7	16.7	0	0
27 Comparison of Climate Models (25)	41	14.6 ▼	12.2	0	0
28 ENSO Oscillation (23)	143	12.6 ▼	6.3	4.9	1.4
29 Arctic Ecosystems (13)	10	10.0	10.0	0	0
30 Atmospheric Convection (16)	40	7.5	0	0	7.5
31 Surface Flux Parameterization (18)	18	5.6	0	0	5.6
32 Mesoscale Models (24)	11	0	0	0	0

The activity of the EU15 (as a unit shown in table 2.6 for a comparison with the USA and Canada) is shown in table 2.7 with a differentiated view on the proportions reached by the three most active EU15 countries in the field climate research (the United Kingdom, Germany and France). In case of the C2-clusters at the top, which show a strong EU15 contribution, the publication shares of the three single countries show some differences. At the research front of the subfield *Paleoclimatology* (9) the institutions from the UK and France participate in a significantly large part of the publications whereas Germany performs better than it's average, but not significantly. For the cluster *Paleoceanography* (10) the French contribution is remarkably strong too, whereas the third paleoclimatology cluster *Ice-Core Records* (19) shows a rather high proportion of German contribution. Another medium sized cluster positioned in the first third of the ranking and with a large part of publications from both countries, Germany and/or France, is *Atmospheric Transport* (21). The UK reaches a significantly high proportion of publications only in one other C2-cluster: *Effects on Plants* (7) has a share of UK publications nearly twice as high than the UK average, whereas France shows no participation at all.

In the second third of the table among the clusters with an EU15 contribution around the mean value only for the United Kingdom two C2-clusters with a clearly higher publication share can be found: *Anthropogenic Effects* (20) and *Stratospheric Climate* (32).

Among the C2-clusters with a smaller EU15 share at the lower ranked places the large subfield *Oceanic Circulation* (4) shows a significantly high share of German contribution to the research front, whereas the EU15 share is below the average.

A significantly low contribution of one of the three larger EU15 countries can be observed only in two cases: *Climate Change Impacts* (31) with a medium sized research front has no front publication with a French participation at all and for *ENSO/Monsoon System* (22) with 247 front publications a larger subfield Germany reaches only a publication share of 4%.

4.1.1.2.2. Climate research 1997

For the source year 1997 of the SCI we collected 1454 climate research publications in the first step of the delineation, slightly more (3%) than 1996. This basic set was extended to 2465 publications in the following steps of the delineation procedure. The co-citation cluster analysis was performed for the 4019 documents which were highly cited by the publications of the extended set. The results are presented on the following pages.

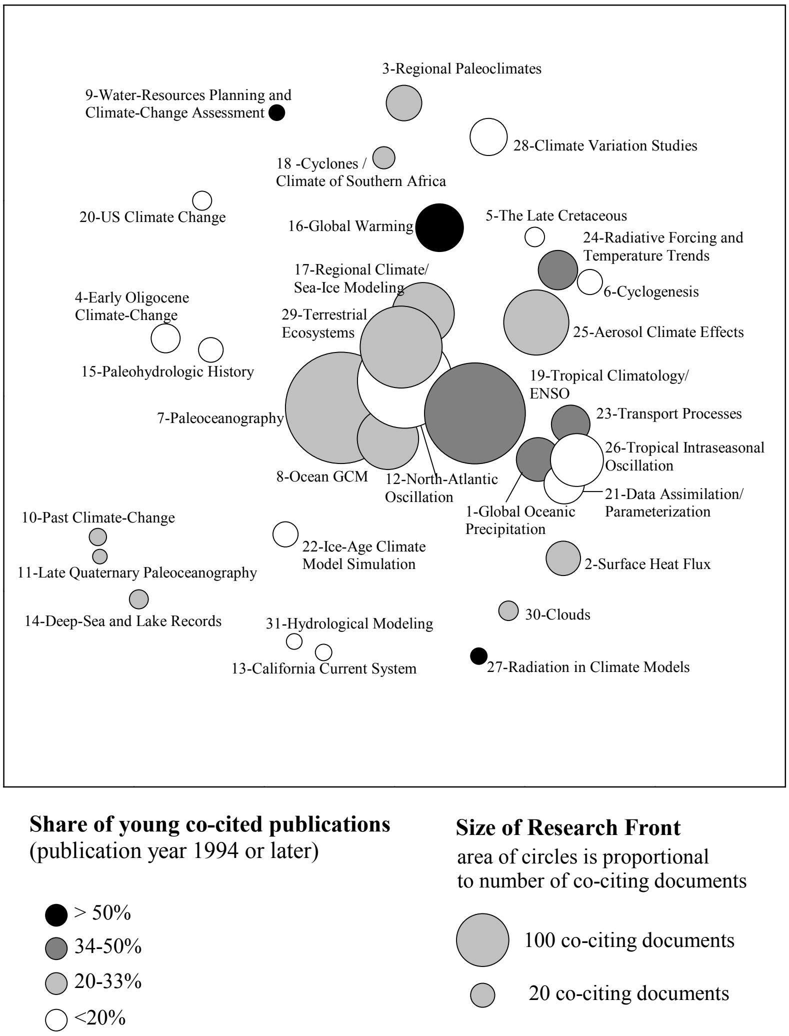


Figure 2.2:
Overview map of climate research 1997

Table 2.8:
C2-clusters of climate research 1997

Cluster	Title	C1	Core	Front	Imm
1	Global Oceanic Precipitation	4	44	69	45
2	Surface Heat-Flux	2	38	43	23
3	Regional Paleoclimates	4	38	46	21
4	Early Oligocene Climate-Change	7	28	31	14
5	The Late Cretaceous	3	6	14	0
6	Cyclogenesis	2	19	23	10
7	Paleooceanography	34	404	447	32
8	Ocean GCM	7	97	135	31

Cluster	Title	C1	Core	Front	Imm
9	Water-Resources Planning and Climate-Change Assessment	2	7	9	71
10	Past Climate-Change	2	6	11	33
11	Late Quaternary Paleoceanography	2	4	8	25
12	North-Atlantic Oscillation	28	251	323	16
13	California Current System	2	8	10	12
14	Deep-Sea and Lake Records	2	14	13	28
15	Paleohydrologic History	4	17	22	11
16	Global Warming	2	31	83	61
17	Regional Climate/Sea Ice Modeling	15	112	141	29
18	Cyclones/Climate of Southern Africa	2	15	18	33
19	Tropical Climatology/ENSO	35	301	367	35
20	US Climate Change	4	13	13	0
21	Data Assimilation/Parameterization	8	27	59	14
22	Ice-Age Climate Model Simulation	4	12	23	0
23	Transport Processes	5	56	54	35
24	Radiative Forcing and Temperature Trends	7	45	56	42
25	Aerosol Climate Effects	30	169	154	33
26	Tropical Intraseasonal Oscillation	11	106	101	18
27	Radiation in Climate Models	2	5	10	60
28	Climate Variation Studies	5	24	50	16
29	Terrestrial Ecosystems	30	270	242	16
30	Clouds	3	10	14	20
31	Hydrological Modeling	2	7	9	0

In the 1997 overview map (Figure 2.2) a very dense central region can be observed containing the four largest C2-clusters and two medium sized subfields. The largest cluster *Paleoceanography* (7) on the left side of the center is a successor of the 1996 paleoclimatology and paleoceanography clusters, which were more separated in the earlier overview map. The more central position in 1997 is due to the inclusion of a part of the cited documents, which were clustered in the 1996 subfield *Oceanic Circulation*. As in 1996 the paleoclimatology cluster is neighbored to some smaller thematically related satellites in the left periphery of the map like *Early Oligocene Climate-Change* (4) in the middle of the left margin or *Past Climate-Change* (10), *Late Quarternary Paleoceanography* (11) and *Ice-Age Climate Model Simulation* (22) in the lower half of the map.

The second largest subfield in the center is *Tropical Climatology/ENSO* (19) which has incorporated parts of the clustered publications of different central region clusters of 1996. It includes a proportion of young documents which is slightly higher than in most of the other central clusters and much higher than in the cluster core of *North-Atlantic Oscillation* (12). A close neighbor of the subfield *Tropical Climatology/ENSO* is a group of medium sized clusters on the right side of the map, two of them, *Transport Processes* (23) and *Global Oceanic Precipitation* (1), with a relative high immediacy value.

The large cluster *North-Atlantic Oscillation* (12) inside the central group shows the lowest immediacy by far, as indicate by the white colored circle. The predecessor of important parts of this subfield was in 1996 the C2-cluster *ENSO/Monsoon System*.

The last large central subfield is *Terrestrial Ecosystems* (29) which connects to the 1996 C2-cluster *Biosphere Models* (1) and has incorporated all the smaller 1996 clusters thematically related to the biosphere.

Besides the clusters in the central group another larger subfield can be observed a bit separated on the right side of the center: *Aerosol Climate Effects* (25). This thematic area was found in 1996 in three smaller clusters (*Carbon Aerosols*, *Atmospheric Transport* and *Shortwave Forcing*).

The C2-cluster with the largest dynamic in the whole field is *Global Warming* (16) positioned above the central group. It includes a part of the highly cited publications which were already highly cited and clustered in the 1996 subfield *Anthropogenic Effects*. A large part of the other core publications of this 1996 cluster have been included in the 1997 cluster *Climate Variation Studies* (28) and *Radiative Forcing and Temperature Trends* (24).

Table 2.9:

Top national actors of climate research 1997

Publications	Percent	Country
1223	49.6	USA
757	30.7	EU 15
249	10.1	UK
211	8.6	FRANCE
187	7.6	GERMANY
163	6.6	CANADA
138	5.6	AUSTRALIA
87	3.5	JAPAN
78	3.2	NETHERLANDS
71	2.9	PEOPLES-R-CHINA
59	2.4	RUSSIA
58	2.4	SWITZERLAND
41	1.7	INDIA
36	1.5	SWEDEN
35	1.4	DENMARK
29	1.2	SPAIN

The top 15 national actors as shown in table 2.9 are nearly the same as in 1996. Only Spain as another European country joined the top group and New-Zealand left it (because of a small lost in publication share). The relation of US and EU15 share of climate research publications has did not change considerably. the EU15 countries together however did reach a few points more, whereas the USA keeps below 50% of the fields' source publications in 1997. The countries which lost ground in the ranking are Canada, Australia and above all Sweden, which contributes to less source publications in 1997. The most significant winners are France (+39%) and the Peoples Republic of China (+82%).

Table 2.10:

Top institutional actors of climate research 1997

Publications	Institution
146	NASA, USA
104	NOAA, USA
80	UNIV-COLORADO, USA
63	UNIV-WASHINGTON, USA

Publications	Institution
62	NATL-CTR-ATMOSPHER-RES, USA
61	PRINCETON-UNIV, USA
57	COLUMBIA-UNIV, USA
45	UNIV-CALIF-SAN-DIEGO, USA
41	CSIRO, AUSTRALIA
41	MAX-PLANCK-INST-METEOROL, GERMANY
39	PENN-STATE-UNIV, USA
35	UNIV-WISCONSIN, USA
34	UNIV-MARYLAND, USA
33	MIT, USA
33	UNIV-ARIZONA, USA

The largest institutional actors in 1997 are again the NASA and the NOAA but the gap to the following institutions is now smaller. Third and fourth rank the universities of Colorado and Washington which improved their performance with an increase of publication output in climate research by about 15%. Princeton University could reach the sixth rank through a quite stronger increase in activity (33%). The only European institution among the top 15 is the German MPI of Meteorology, which contributes to slightly more publications than in 1996. The institutions which decreased their publication output in the field considerably and therefore lost places in the ranking are the Australian CSIRO and the US institutions National Center of Atmosphere Research and the Colorado State University, which ranks not among the top 15 in 1997, as well as Woods Hole Oceanographic Institute and the Oregon State University (See table 2.4).

Table 2.11:

Top European institutional actors of climate research 1997

Publications	Institution
41	MAX-PLANCK-INST-METEOROL, GERMANY
31	METEOROL-OFF, UK
31	UNIV-READING, UK
28	UNIV-E-ANGLIA, UK
24	CNRS, FRANCE
24	UNIV-COPENHAGEN, DENMARK
23	CHRISTIAN-ALBRECHTS-UNIV-KIEL, GERMANY
22	CEA,FRANCE
19	UNIV-PARIS-06, FRANCE
18	ROYAL-NETHERLANDS-METEOROL-INST, NETHERLANDS
18	UNIV-UTRECHT, NETHERLANDS
17	ORSTOM, FRANCE
17	UNIV-STOCKHOLM, SWEDEN
15	UNIV-OXFORD, UK
14	ALFRED-WEGENER-INST-POLAR-&-MARINE-RES, GERMANY
14	EUROPEAN-CTR-MEDIUM-RANGE-WEATHER-FORECASTS, UK
14	METEO-FRANCE, FRANCE
14	UNIV-CAMBRIDGE, UK
14	UNIV-HAMBURG, GERMANY

The list of the top European actors (Table 2.11) is leaded by the German MPI of Meteorology and three British institutions, the Meteorology Office and the universities of Reading and East-Anglia. The Meteorology Office and the University of East-Anglia could improve their rank because of a strong increase in publication whereas the University of East-Anglia dropped back from the second place because of a moderate decrease in publication count.

A clear increase in their publication count can be noticed for the University of Copenhagen, which comes up on the sixth place, and both of the Dutch institutions: the University of Utrecht and the Royal Netherlands Meteorology Institute.

Table 2.12:

Share of EU15, USA and Canada in the C2-clusters' research fronts of climate research 1997, ranked by the share of EU15 publications on the research fronts

Rank	Title (CL.-No.)	Front	EU15 (33.2)	USA (56.3)	CAN (6.7)
1	Past Climate-Change (10)	11	72.7 ▲	18.2	18.2
2	Ice-Age Climate Model Simulation (22)	23	60.9 ▲	30.4 ▼	4.3
3	Hydrological Modeling (31)	9	55.6	0	0
4	Global Warming (16)	83	51.8 ▲	41.0 ▼	6.0
5	Transport Processes (23)	54	48.1 ▲	53.7	9.3
6	Paleoceanography (7)	447	45.6 ▲	48.5 ▼	8.5
7	Paleohydrologic History (15)	22	45.5	40.9	4.5
8	Aerosol Climate Effects (25)	154	39.6	62.3	10.4
9	Deep-Sea and Lake Records (14)	13	38.5	46.2	0
10	Regional Climate/Sea Ice Modeling (17)	141	37.6	32.6 ▼	5.7
11	Radiative Forcing and Temperature Trends (24)	56	37.5	60.7	1.8
12	Terrestrial Ecosystems (29)	242	36.4	59.9	6.2
13	Ocean GCM (8)	135	35.6	47.4	5.2
14	Cyclogenesis (6)	23	34.8	69.6	13.0
15	Radiation in Climate Models (27)	10	30.0	60.0	0
16	Data Assimilation/Parameterization (21)	59	28.8	59.3	8.5
17	Regional Paleoclimates (3)	46	28.3	58.7	8.7
18	Global Oceanic Precipitation (1)	69	27.5	71.0 ▲	7.2
19	Climate Variation Studies (28)	50	26.0	38.0 ▼	18.0 ▲
20	Tropical Climatology/ENSO (19)	367	24.8 ▼	73.0 ▲	3.3 ▼
21	Early Oligocene Climate-Change (4)	31	22.6	74.2 ▲	3.2
22	Water-Resources Planning and Climate-Change Assessment (9)	9	22.2	66.7	11.1
23	Clouds (30)	14	21.4	85.7 ▲	7.1
24	North-Atlantic Oscillation (12)	323	20.4 ▼	52.6	6.2
25	Tropical Intraseasonal Oscillation (26)	101	18.8 ▼	71.3 ▲	3.0
26	Cyclones/Climate of Southern Africa (18)	18	16.7	22.2	0
27	Surface Heat-Flux (2)	43	14.0 ▼	67.4	7.0
28	Late Quaternary Paleoceanography (11)	8	12.5	50.0	0
29	The Late Cretaceous (5)	14	7.1	71.4	0
30	US Climate Change (20)	13	0	92.3 ▲	7.7
31	California Current System (13)	10	0	90.0 ▲	10.0

For the large regions, USA, EU15 and Canada the proportions of publications at the C2-clusters' research fronts can be compared in table 2.12. The C2-clusters are ranked by share of EU15 publications. On top several paleoclimatology clusters are ranked, including the large subfield *Paleoceanography* (7). The high activity of the EU15 in this thematic area could already be observed in 1996. In the large subfield *Paleoceanography* (7) and at the research front of *Ice-Age Climate Simulation* (22) the USA simultaneously show a significantly low activity. Other EU15 dominated subfields are *Global Warming* (16) and *Transport Processes* (23). The first one is partly a successor of the small 1996 subfield *Coupled Atmosphere Ocean Model*, which has had a relatively large proportion of EU15 publications at the research front, and (together with others) of the medium sized C2-cluster *Anthropogenic Effects*. The second one is a "new" cluster which includes parts of the clustered documents of the 1996 C2-clusters *ENSO Oscillation* (23), *Clouds and Radiation* (17) and *Stratospheric Climate* (32), with medium to low shares of the EU15 in their front publications.

On the other side the EU15 performance in terms of publication output is significantly low in case of two large subfields (*Tropical Climatology* (19) and *North-Atlantic Oscillation* (12)) as well as for the medium sized C2-cluster *Tropical Intraseasonal Oscillation* (26). In the subfields related to the tropical climate the USA participate in a very large part of the publications, as well as in case of the subfields *Global Oceanic Precipitation* (1) and *Early Oligocene Climate-Change* (4), a successor of *Pliocene Climates* (29) in 1996 with an average US contribution.

The second country in table 2.12, Canada, diverges significantly from its average contribution to the C2 research fronts only in two cases: *Climate Variation Studies* (28) and *Tropical Climatology* (19). In each of the cases the divergence shows the opposite direction as for the USA. Canada is well represented at the medium sized research front of the C2-cluster *Climate Variation Studies* (28), whereas in case of the large subfield *Tropical Climatology* (19) with 367 co-citing publications the Canadian activity is significantly low.

Table 2.13:

Share of the top European countries in the C2-clusters' research fronts of climate research 1997, ranked by the share of EU15 publications on the research front

Rank	Title (No.)	Front	EU15 (33.2)	UK (10.4)	GER (8.7)	F (9.8)
1	Past Climate-Change (10)	11	72.7 ▲	36.4	0	18.2
2	Ice-Age Climate Model Simulation (22)	23	60.9 ▲	17.4	0	30.4 ▲
3	Hydrological Modeling (31)	9	55.6	22.2	0	0
4	Global Warming (16)	83	51.8 ▲	20.5 ▲	20.5 ▲	8.4
5	Transport Processes (23)	54	48.1 ▲	9.3	14.8	18.5 ▲
6	Paleoceanography (7)	447	45.6 ▲	9.8	13.4 ▲	16.1 ▲
7	Paleohydrologic History (15)	22	45.5	22.7	0	9.1
8	Aerosol Climate Effects (25)	154	39.6	13.6	12.3	9.7
9	Deep-Sea and Lake Records (14)	13	38.5	23.1	0	15.4
10	Regional Climate/Sea Ice Modeling (17)	141	37.6	21.3 ▲	7.1	6.4
11	Radiative Forcing and Temperature Trends (24)	56	37.5	16.1	10.7	1.8
12	Terrestrial Ecosystems (29)	242	36.4	10.3	7.0	13.2
13	Ocean GCM (8)	135	35.6	11.9	12.6	7.4
14	Cyclogenesis (6)	23	34.8	4.3	4.3	21.7
15	Radiation in Climate Models (27)	10	30.0	20.0	0	10.0
16	Data Assimilation/Parameterization (21)	59	28.8	13.6	3.4	16.9
17	Regional Paleoclimates (3)	46	28.3	8.7	6.5	2.2
18	Global Oceanic Precipitation (1)	69	27.5	10.1	8.7	5.8
19	Climate Variation Studies (28)	50	26.0	14.0	2.0	4.0
20	Tropical Climatology/ENSO (19)	367	24.8 ▼	9.3	5.4 ▼	8.7
21	Early Oligocene Climate-Change (4)	31	22.6	12.9	0	3.2
22	Water-Resources Planning and Climate-Change Assessment (9)	9	22.2	11.1	11.1	0

Rank Title (No.)	Front	EU15 (33.2)	UK (10.4)	GER (8.7)	F (9.8)
23 Clouds (30)	14	21.4	7.1	0	7.1
24 North-Atlantic Oscillation (12)	323	20.4 ▼	8.0	4.0 ▼	5.3 ▼
25 Tropical Intraseasonal Oscillation (26)	101	18.8 ▼	7.9	4.0	6.9
26 Cyclones/Climate of Southern Africa (18)	18	16.7	5.6	0	5.6
27 Surface Heat-Flux (2)	43	14.0 ▼	4.7	9.3	2.3
28 Late Quaternary Paleoceanography (11)	8	12.5	0	0	12.5
29 The Late Cretaceous (5)	14	7.1	0	0	7.1
30 US Climate Change (20)	13	0	0	0	0
31 California Current System (13)	10	0	0	0	0

Table 2.13 shows the detailed view on the activity profiles of the three most active European countries United Kingdom, Germany and France. The significant differences between the countries' proportion at the single research fronts and their average publication activity are in almost all cases simultaneous with a significantly difference of the EU15. For Germany a relatively high activity can be observed in case of the large cluster *Paleoceanography* (7), whereas the research fronts of the smaller paleoclimatology related clusters on rank 1,2 and 7 do not include any publication with a German co-operation. Another subfield with a significantly high German contribution is *Global Warming* (16), whereas the subfields *Tropical Climatology/ENSO* (19) and *North-Atlantic Oscillation* (12) have significantly small proportions of German publications at their research fronts.

The United Kingdom is strongly represented at the research front of *Global Warming* (16), as well as Germany, and also at a subfield with only a slightly increased contribution of the EU15: *Regional Climate/Sea-Ice Modeling* (17) which is a medium sized C2-cluster with 141 co-citing publications.

France is significantly active at the research fronts of three clusters, the paleoclimatology clusters *Paleoceanography* (7) and *Ice-Age Climate Simulation* (22) and the cluster *Transport Processes* (23). The only subfield with a significantly low proportion of French publications is *North-Atlantic Oscillation* (12), the same as for Germany.

4.1.1.2.3. Climate research 1998

In the last year of our time series the delineation through title word phrases and journals provides a set of 1460 publications, nearly the same as in 1997 (1454 publ.). This basic set was extended to 2414 source publications, which means a decrease against 1997 by 2%.

Although the number of cited publications is slightly higher than in 1997 (about 1%) a decrease of the highly cited publications can be observed. The co-citation cluster analysis in 1998 was performed with 3839 highly cited documents and resulted in 367 C1-clusters, nearly the same number as in 1997, but some more C2-clusters. The 39 C2-clusters can be found in the overview map (Figure 2.3) and in the table 2.14.

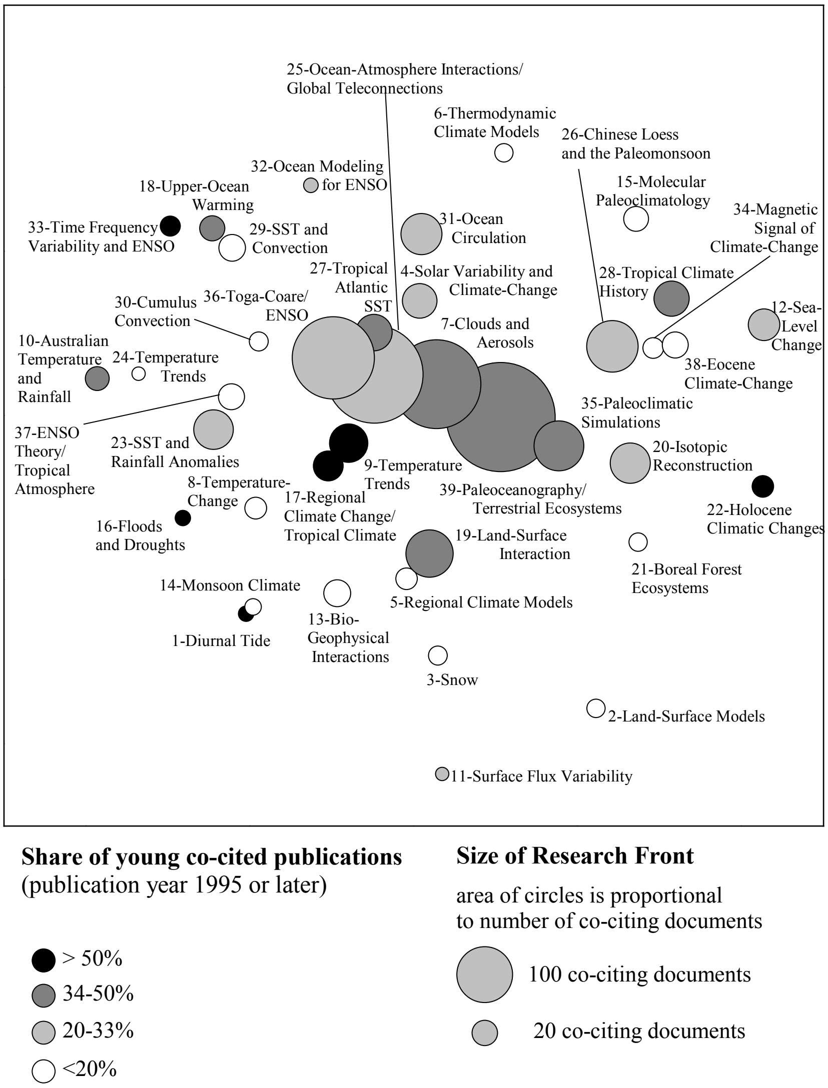


Figure 2.3:

Overview map of climate research 1998

Table 2.14:
C2-clusters of climate research 1998

Cl-No.	Title	C1	Core	Front	Imm
1	Diurnal Tide	2	5	8	60
2	Land-Surface Models	2	6	11	16
3	Snow	2	8	12	0
4	Solar Variability and Climate-Change	2	22	39	27
5	Regional Climate Models	2	5	15	0
6	Thermodynamic Climate Models	2	6	11	16
7	Clouds and Aerosols	24	256	254	37
8	Temperature-Change	2	5	16	0
9	Temperature Trends	2	40	48	52
10	Australian Temperature and Rainfall	3	15	19	46
11	Surface Flux Variability	2	4	6	25
12	Sea-Level Change	2	23	33	21
13	Bio-Geophysical Interactions	3	18	24	16
14	Monsoon Climate	2	4	9	0
15	Molecular Paleoclimatology	4	15	20	13
16	Floods and Droughts	2	7	8	57
17	Regional Climate Change/Tropical Climate	7	17	29	82
18	Upper-Ocean Warming	3	10	21	40
19	Land-Surface Interaction	5	61	73	40
20	Isotopic Reconstruction	5	40	52	27
21	Boreal Forest Ecosystems	2	6	11	0
22	Holocene Climatic Changes	2	8	15	50
23	SST and Rainfall Anomalies	2	11	51	27
24	Global Teleconnections /SST	2	4	6	0
25	Ocean-Atmosphere Interactions/Global Teleconnections	30	230	308	23
26	Chinese Loess and the Paleomonsoon	3	76	86	21
27	Tropical Atlantic SST	8	28	43	39
28	Tropical Climate History	3	16	40	43
29	SST and Convection	3	8	23	12
30	Cumulus Convection	2	8	12	0
31	Ocean Circulation	4	49	55	20
32	Ocean Modeling for ENSO	2	9	7	33
33	Time Frequency Variability and ENSO	2	6	13	66
34	Magnetic Signal of Climate-Change	2	8	14	12
35	Paleoclimatic Simulations	13	70	81	37
36	Toga-Coare/ENSO	39	248	219	30
37	ENSO Theory/Tropical Atmosphere	3	9	22	0
38	Eocene Climate-Change	2	16	22	18
39	Paleoceanography/Terrestrial Ecosystems	40	374	384	39

The co-citation structure in 1998 shown in the overview map (Figure 2.3) reveals some changes compared to the 1997 map. The configuration of the climate research subfields in the overview map is again dominated by four large clusters, but there is a shifting in the contents among these large areas since 1997. The largest cluster is the paleoclimatology cluster *Paleoceanography/Terrestrial Ecosystems* (39) which now includes a large part of the publications clustered in the 1997 cluster *Terrestrial Ecosystems* (29), which has another smaller successor in the 1997 cluster *Land-Surface Interactions* (19). In the same way the 1997 cluster *Ocean GCM* (8) was divided in the 1997 cluster *Ocean Circulation* (31) and some specialties are now included in *Paleoceanography/Terrestrial Ecosystems* (39). As in the previous years some other paleoclimatology-related clusters can be found in direct vicinity, in the 1998 overview map located at the right side of the map, for example the medium sized clusters *Chinese Loess and the Paleomonsoon* (26), *Paleoclimatic Simulations* (35) and smaller clusters like *Tropical Climate History* (28) or *Holocene Climatic Changes* (22). In the lower part of the surrounding area of cluster 39 the satellites related to the terrestrial ecosystem are placed, like *Boreal Forest Ecosystems* (21) or *Land-Surface Interaction* (19). Another subfield in 1998 whose in 1997 already clustered publications were affiliated to different clusters is *Clouds and Aerosols* (7), a neighbor of C2-cluster 39 and the most central one in the overview map. This subfield emerged from the 1997 cluster *Aerosol Climate Effects* (25) and some regions inside the large 1997 cluster *Tropical Climatology/ENSO* (19).

Apart from some smaller migrations the other part of the clustered publications of this large 1997 subfield is now clustered in *Toga-Coare/ENSO* (36), the most left of the four large subfields in the 1998 overview map which includes also large parts of the 1997 clusters *Tropical Intraseasonal Oscillation* (26) and *Surface Heat Flux* (2), the former satellites of the 1997 subfield *Tropical Climatology/ENSO* (19). Most of the smaller clusters on the left side in direct vicinity to cluster 36 or in the outer region of the map are thematically related, dealing with ENSO like *ENSO Theory/Tropical Atmosphere* (37), *Ocean Modeling for ENSO* (32) and *Time Frequency Variability and ENSO* (33), or dealing with the tropical convection system, for example *SST and Convection* (29), *Cumulus Convection* (30) and *Tropical Atlantic SST* (27).

The fourth large cluster in 1998 is *Ocean-Atmosphere Interactions/Global Teleconnections* (25), which is mainly a successor of the 1997 cluster *North-Atlantic Oscillation* (12), but includes also a small part of the 1997 paleoceanography cluster (7).

The highly dynamic C2-clusters *Temperature Trends* (9) *and Regional Climate Change/Tropical Climate* (17), which are neighbors in the overview map below the central large clusters are in parts successors of the 1997 cluster *Global Warming* (16). The cited documents clustered in *Temperature Trends* (9) stem to the same proportion from the 1997 cluster *Radiative Forcing and Temperature Trends* (24), and *Regional Climate Change/Tropical Climate* (17) emerges as well from the 1997 cluster *Regional Climate/Sea-Ice Modeling* (17).

Table 2.15:

Top national actors of climate research 1998

Publications	Percent	Country
1127	46.7	USA
816	33.8	EU15
263	10.9	UK
196	8.1	GERMANY
192	8.0	FRANCE
172	7.1	CANADA
132	5.5	AUSTRALIA
81	3.4	JAPAN
79	3.3	NETHERLANDS
68	2.8	SWEDEN
64	2.7	SWITZERLAND

Publications	Percent	Country
63	2.6	RUSSIA
47	1.9	NORWAY
46	1.9	DENMARK
45	1.9	SPAIN
40	1.7	PEOPLES-R-CHINA

The top national actors in table 2.15 are again leaded by the USA, although the proportion of US participated publications decreased a bit, whereas the European countries together improved their share in climate research publications to more than one third. The countries on the following places are nearly the same as in 1997. Only Norway as a new country reached a place among the top 15, whereas India fall out of the top group.

Only for Norway and Sweden a considerably high increase in publications (more than 80%) can be notified. The Peoples Republic of China on the opposite drops off to the last position, because of a decrease of its publications by nearly 50%.

Table 2.16:

Top institutional actors of climate research 1998

Publications	Institution
118	NASA, USA
110	NOAA, USA
102	NATL-CTR-ATMOSPHER-RES, USA
79	UNIV-COLORADO, USA
59	UNIV-WASHINGTON, USA
57	UNIV-CALIF-SAN-DIEGO, USA
54	COLUMBIA-UNIV, USA
42	CSIRO, AUSTRALIA
41	MAX-PLANCK-INST-METEOROL, GERMANY
38	MIT, USA
35	PRINCETON-UNIV, USA
35	UNIV-E-ANGLIA, UK
30	COLORADO-STATE-UNIV, USA
30	UNIV-MARYLAND, USA
30	WOODS-HOLE-OCEANOG-INST, USA

The ranking of the top institutions in climate research shows only marginal changes in the relations among the top institutions from 1997 to 1998. Only a few institutions are differing considerably in the number of publications compared to the previous year. The NASA could keep the first place in the ranking, although there was a decrease in publications by nearly 20%, whereas the US National Center for Atmosphere Research increases its publication output by 64%. The institution which has clearly lost ground in the field is the Princeton University with 43% less publications than in 1997.

Table 2.17:
Top European institutional actors of climate research 1998

Publications	Institution
42	MAX-PLANCK-INST-METEOROL, GERMANY
35	UNIV-E-ANGLIA, UK
31	METEOROL-OFF, UK
28	LUND-UNIV, SWEDEN
25	UNIV-COPENHAGEN, DENMARK
23	CHRISTIAN-ALBRECHTS-UNIV-KIEL, GERMANY
23	UNIV-PARIS-06, FRANCE
21	CNRS, FRANCE
20	UNIV-READING, UK
18	UNIV-CAMBRIDGE, UK
17	ORSTOM, FRANCE
16	ALFRED-WEGENER-INST-POLAR-&-MARINE-RES, GERMANY
16	UNIV-BREMEN, GERMANY
15	CEA, FRANCE
15	METEO-FRANCE, FRANCE
15	UNIV-UTRECHT, NETHERLANDS

The top European institutions as shown in table 2.17 show some marginal changes in the ranking but most of them they are due to small changes in the number of publications. However, two institutions show a more distinguished difference in their activity in comparison with 1997. The Swedish Lund University comes up to the third place because of a publication output more than twice as high as in 1997 and the British University of Reading shows a decrease of 36%.

Table 2.18:

Share of EU15, USA and Canada in the C2-clusters' research fronts of climate research 1998, ranked by the share of EU15 publications on the research fronts

Rank	Title (CL.-No.)	Front	EU15 (36.6)	USA (52.8)	CAN (7.5)
1	Magnetic Signal of Climate-Change (34)	14	92.9 ▲	21.4	0
2	Molecular Paleoclimatology (15)	20	65.0 ▲	25.0	15.0
3	Tropical Atlantic SST (27)	43	60.5 ▲	62.8	2.3
4	Holocene Climatic Changes (22)	15	60.0	33.3	13.3
5	Paleoclimatic Simulations (35)	81	54.3 ▲	39.5 ▼	12.3
6	Temperature Trends (9)	48	54.2 ▲	50.0	6.3
7	Chinese Loess and the Paleomonsoon (26)	86	53.5 ▲	33.7 ▼	4.7
8	Solar Variability and Climate-Change (4)	39	48.7	48.7	0
9	Paleoceanography/Terrestrial Ecosystems (39)	384	46.4 ▲	48.2 ▼	9.4
10	Bio-Geophysical Interactions (13)	24	45.8	58.3	0
11	Isotopic Reconstruction (20)	52	44.2	51.9	11.5
12	Temperature-Change (8)	16	43.8	62.5	18.8
13	Ocean Modeling for ENSO (32)	7	42.9	85.7	0
14	Regional Climate Change/Tropical Climate (17)	29	41.4	20.7 ▼	6.9
15	Land-Surface Interaction (19)	73	41.1	52.1	8.2
16	Regional Climate Models (5)	15	40.0	46.7	0
17	Sea-Level Change (12)	33	39.4	36.4	18.2 ▲
18	Clouds and Aerosols (7)	254	38.6	64.2 ▲	8.7
19	Thermodynamic Climate Models (6)	11	36.4	54.5	0
20	Land-Surface Models (2)	11	36.4	27.3	9.1
21	SST and Convection (29)	23	34.8	78.3 ▲	0
22	Ocean Circulation (31)	55	34.5	47.3	1.8
23	Surface Flux Variability (11)	6	33.3	66.7	0
24	Global Teleconnections /SST (24)	6	33.3	83.3	0
25	Eocene Climate-Change (38)	22	31.8	68.2	0
26	Time Frequency Variability and ENSO (33)	13	30.8	69.2	7.7
27	Ocean-Atmosphere Interactions/Global Teleconnections (25)	308	30.8 ▼	55.5	8.8
28	Tropical Climate History (28)	40	30.0	40.0	7.5
29	Cumulus Convection (30)	12	25.0	83.3 ▲	0
30	Monsoon Climate (14)	9	22.2	44.4	0
31	Toga-Coare/ENSO (36)	219	20.5 ▼	68.9 ▲	2.3 ▼
32	SST and Rainfall Anomalies (23)	51	19.6 ▼	62.7	7.8
33	Upper-Ocean Warming (18)	21	19.0	95.2 ▲	0
34	Boreal Forest Ecosystems (21)	11	18.2	72.7	18.2
35	Snow (3)	12	16.7	66.7	25.0
36	Australian Temperature and Rainfall (10)	19	15.8	31.6	5.3
37	ENSO Theory/Tropical Atmosphere (37)	22	13.6	72.7	0
38	Diurnal Tide (1)	8	12.5	87.5	25.0
39	Floods and Droughts (16)	8	0	87.5	0

Almost all paleoclimatology related subfields are positioned in the top third of the ranking in table 2.18, which presents the 39 C2-clusters of climate research 1998 in a sequence of decreasing share of EU15 participation in the research front publications. With one exception the high share of European countries differs significantly from the average contribution to the C2-cluster fronts of 36.6%. On three of these research fronts, including the large subfield *Paleoceanography/Terrestrial Ecosystems* (39) the USA are represented at a significantly low level. The subfields with a significant low EU15 activity are the large clusters *Ocean-Atmosphere Interactions/Global Teleconnections*

(25) and *Toga Coare/ENSO* (36), which shows by far the lowest share (20.5%) of the EU15 countries among the larger clusters. Only one medium sized cluster, *SST and Rainfall Anomalies* (23) has a lower share of the EU15.

Canada, the largest non European country apart from the USA, shows only two significantly differing subfields, because of the much smaller numbers and therefore broader confidence intervals. A clear domain of the Canadian research is the medium sized *subfield Sea-Level Change* (12) with a Canadian contribution of 18.2%. On the other hand a very low share of Canada can be observed for the *Toga-Coare/ENSO* (36) subfield.

Table 2.19:

Share of the top European countries in the C2-clusters' research fronts of climate research 1998, ranked by the share of EU15 publications on the research front

Rank	Title (No.)	Front	EU15 (36.6)	UK (11.6)	GER (9.8)	F (10.2)
1	Magnetic Signal of Climate-Change (34)	14	92.9 ▲	28.6	14.3	64.3 ▲
2	Molecular Paleoclimatology (15)	20	65.0 ▲	5.0	40.0 ▲	15.0
3	Tropical Atlantic SST (27)	43	60.5 ▲	14.0	20.9 ▲	18.6
4	Holocene Climatic Changes (22)	15	60.0	26.7	13.3	33.3
5	Paleoclimatic Simulations (35)	81	54.3 ▲	8.6	11.1	23.5 ▲
6	Temperature Trends (9)	48	54.2 ▲	37.5 ▲	12.5	0
7	Chinese Loess and the Paleomonsoon (26)	86	53.5 ▲	14.0	19.8 ▲	17.4 ▲
8	Solar Variability and Climate-Change (4)	39	48.7	12.8	7.7	12.8
9	Paleoceanography/Terrestrial Ecosystems (39)	384	46.4 ▲	16.1 ▲	15.4 ▲	9.1
10	Bio-Geophysical Interactions (13)	24	45.8	12.5	12.5	20.8
11	Isotopic Reconstruction (20)	52	44.2	5.8	11.5	17.3
12	Temperature-Change (8)	16	43.8	6.3	0	18.8
13	Ocean Modeling for ENSO (32)	7	42.9	14.3	0	28.6
14	Regional Climate Change/Tropical Climate (17)	29	41.4	24.1 ▲	10.3	6.9
15	Land-Surface Interaction (19)	73	41.1	12.3	9.6	21.9 ▲
16	Regional Climate Models (5)	15	40.0	6.7	0	26.7
17	Sea-Level Change (12)	33	39.4	6.1	6.1	21.2 ▲
18	Clouds and Aerosols (7)	254	38.6	11.8	10.6	13.4
19	Thermodynamic Climate Models (6)	11	36.4	0	9.1	0
20	Land-Surface Models (2)	11	36.4	9.1	0	0
21	SST and Convection (29)	23	34.8	8.7	13.0	21.7
22	Ocean Circulation (31)	55	34.5	12.7	12.7	9.1
23	Surface Flux Variability (11)	6	33.3	16.7	0	16.7
24	Global Teleconnections /SST (24)	6	33.3	16.7	0	16.7
25	Eocene Climate-Change (38)	22	31.8	9.1	4.5	4.5
26	Time Frequency Variability and ENSO (33)	13	30.8	15.4	0	15.4
27	Ocean-Atmosphere Interactions/Global Teleconnections (25)	308	30.8 ▼	11.0	9.7	4.5 ▼
28	Tropical Climate History (28)	40	30.0	7.5	5.0	7.5
29	Cumulus Convection (30)	12	25.0	8.3	0	8.3
30	Monsoon Climate (14)	9	22.2	0	11.1	11.1
31	Toga-Coare/ENSO (36)	219	20.5 ▼	7.3 ▼	4.6 ▼	8.7
32	SST and Rainfall Anomalies (23)	51	19.6 ▼	7.8	3.9	5.9
33	Upper-Ocean Warming (18)	21	19.0	4.8	9.5	4.8
34	Boreal Forest Ecosystems (21)	11	18.2	9.1	9.1	0
35	Snow (3)	12	16.7	0	16.7	0
36	Australian Temperature and Rainfall (10)	19	15.8	10.5	5.3	0
37	ENSO Theory/Tropical Atmosphere (37)	22	13.6	4.5	4.5	4.5

Rank Title (No.)	Front	EU15 (36.6)	UK (11.6)	GER (9.8)	F (10.2)
38 Diurnal Tide (1)	8	12.5	12.5	0	0
39 Floods and Droughts (16)	8	0	0	0	0

The subfields with a significant high activity of one of the large European countries United Kingdom Germany and France are top ranked subfields with a high EU15 share, as could be expected, but with some differences between the three countries. The United Kingdom is well represented in the large paleoceanography cluster (39), but not in the smaller paleoclimatology related subfields. The United Kingdom is strongly engaged in the highly dynamic subfields *Temperature Trends* (9) and *Regional Climate Change/Tropical Climate* (17), which are direct neighbors in the lower center of the map (See figure 2.3). That is in contrast to the other two countries, which are on average participating, or as France in case of the cluster *Temperature Trends* (9) even absent on the research front.

Besides the large subfield *Paleoceanography/Terrestrial Ecosystems* (39) Germany shows a significantly high activity at the research fronts of *Molecular Paleoclimatology* (15) and *Tropical Atlantic SST* (27) as well as *Chinese Loess and the Paleomonsoon* (26), where France is strong represented too.

The other clusters with a significantly high French contribution are the smaller ones *Magnetic Signal of Climate Change* (34) and *Sea Level Change* (12) as well as the medium sized subfields *Paleoclimatic Simulations* (35) and *Land-Surface Interaction* (19).

The research fronts with a significantly small activity of one or more of the three large European countries are those of *Ocean-Atmosphere Interactions/Global Teleconnections* (25), with only 4.5% co-citing publications published with at least one French address, and *Toga-Coare/ENSO* (36), a subfield with a low participation of Germany and the United Kingdom.

4.1.1.2.4. Changes from 1996 to 1998

The most prominent characteristics and the changes of the co-citation structure and actor profile as visible at the C2-cluster level are summarized here. They are possible clues about changes of the cognitive or social structure but have to be interpreted with cautious and in most of the cases need further and deeper insights into the underlying structure and the organizational framework of the involved research areas. Additional information from experts is required to validate the bibliometric results.

- In the center of the field climate research the large subjects Oceanic Circulation, Tropical Climatology and Ocean-Atmosphere Interactions can be found in a few large closely related C2-clusters.
- Two other prominent areas, the paleoclimatology and the biosphere related themes, both become more central and even included in one large C2-cluster in 1998.
- A third area dealing with atmospheric subjects like Clouds, Radiation, Aerosols, does not turn up in one homogenous cluster. The subjects are covered by some medium sized or small C2-clusters in 1996, included in the large central subfields (above all *in Tropical Climatology/ENSO*). Many of them can be found in the subfield *Aerosol Climate Effects* in 1997, which merges with parts of the large 1997

C2-cluster *Tropical Climatology/ENSO* to the 1998 subfield *Clouds and Aerosols* (7).

- The most dynamic region is *Anthropogenic Effects* (1996) and its successors, *Global Warming* (in 1997, besides *Climate Variation Studies* and *Radiative Forcing and Temperature Trends*) and *Temperature Trends* (1998) which come up to a share of more than 50% young clustered publications in all three years. The share of the United Kingdom in this region is significantly high and shows an increasing trend
- The USA show a very high activity for the field of climate research. The dominant role of the USA is particularly pronounced in the subfields related to ENSO and Tropical Climate.
- The EU15 countries reach a share on the climate research publications which his only about half as high as the USA, but the gap decreased from 1996 to 1998.

4.1.1.3. Selected subfields of climate research 1998

For the last analyzed year we will have a closer look into two of the larger subfields, both with a large divergence of the EU15 share from the value for the whole research fronts. We selected Toga-Coare/ENSO (36) with 20.5% EU15 publications at the front and Paleoceanography/Terrestrial Ecosystems (39) with 46.4% of the co-citing publications addressed by at least one country of the European Union.

C2-39 Paleoceanography/Terrestrial Ecosystems

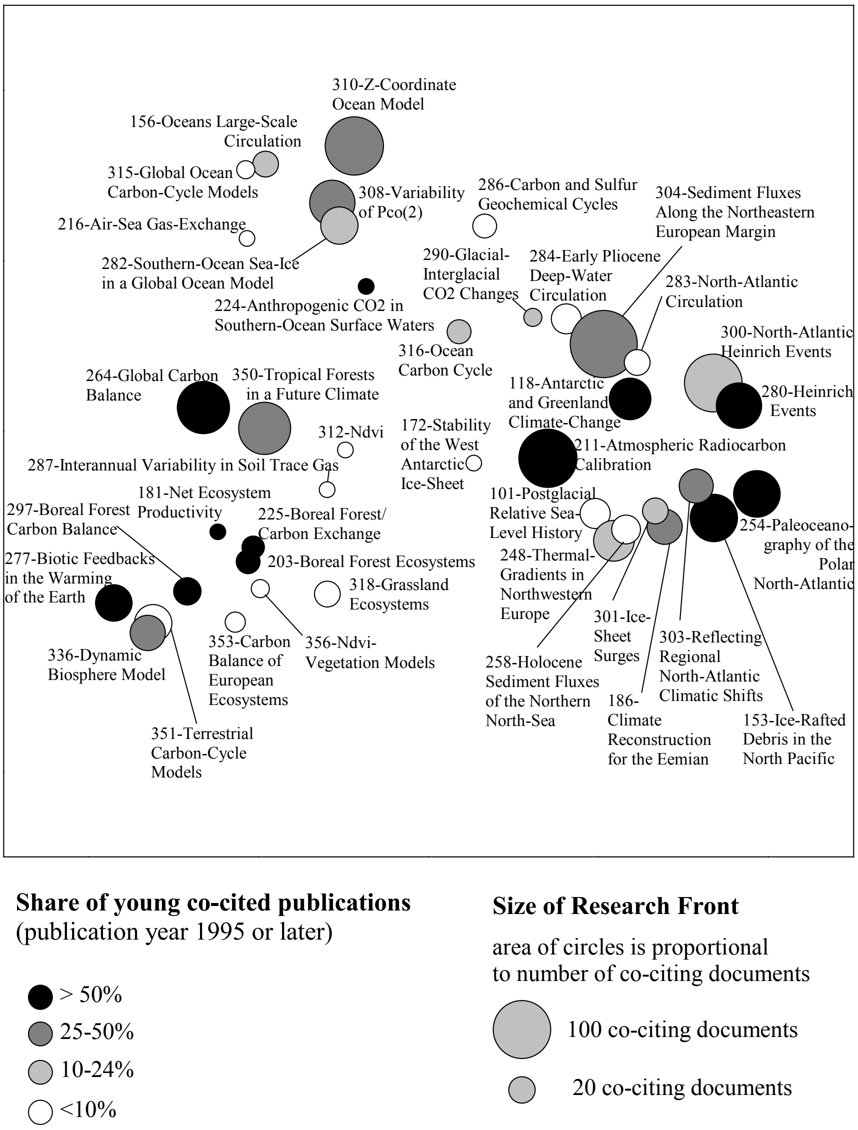


Figure 2.4:

Co-citation cluster map of C2-39 Paleoceanography/Terrestrial Ecosystems

Table 2.20:
C1-clusters of C2-39 Paleoceanography/Terrestrial Ecosystems

Cl-nr.	Titel	Core	Front	Imm
101	Postglacial Relative Sea-Level History	2	11	0
118	Antarctic and Greenland Climate-Change	12	21	58
153	Ice-Rafted Debris in the North Pacific	11	27	63
156	Oceans Large-Scale Circulation	4	8	25
172	Stability of the West Antarctic Ice-Sheet	2	3	0
181	Net Ecosystem Productivity	2	3	100
186	Climate Reconstruction for the Eemian	13	15	38
203	Boreal Forest Ecosystems	4	7	100
211	Atmospheric Radiocarbon Calibration	25	41	60
216	Air-Sea Gas-Exchange	2	3	0
224	Anthropogenic CO2 in Southern-Ocean Surface Waters	2	3	50
225	Boreal Forest/Carbon Exchange	4	6	75
248	Thermal-Gradients in Northwestern Europe	18	20	27
254	Paleoceanography of the Polar North-Atlantic	32	26	53
258	Holocene Sediment Fluxes of the Northern North-Sea	5	10	0
264	Global Carbon Balance	6	33	66
277	Biotic Feedbacks in the Warming of the Earth	4	16	50
280	Heinrich Events	2	25	50
282	Southern-Ocean Sea-Ice in a Global Ocean Model	13	17	23
283	North-Atlantic Circulation	2	8	0
284	Early Pliocene Deep-Water Circulation	3	11	0
286	Carbon and Sulfur Geochemical Cycles	6	7	0
287	Interannual Variability in Soil Trace Gas	2	3	0
290	Glacial-Interglacial CO2 Changes	4	4	25
297	Boreal Forest Carbon Balance	2	9	100
300	North-Atlantic Heinrich Events	16	40	31
301	Ice-Sheet Surges	3	8	33
303	Reflecting Regional North-Atlantic Climatic Shifts	12	14	41
304	Sediment Fluxes Along the Northeastern European Margin	39	54	41
308	Variability of Pco(2)	22	25	40
310	Z-Coordinate Ocean Model	27	41	40
312	Ndvi	2	3	0
315	Global Ocean Carbon-Cycle Models	2	4	0
316	Ocean Carbon Cycle	3	7	33
318	Grassland Ecosystems	6	8	0
336	Dynamic Biosphere Model	12	15	41
350	Tropical Forests in a Future Climate	38	33	34
351	Terrestrial Carbon-Cycle Models	5	17	0
353	Carbon Balance of European Ecosystems	3	5	0
356	Ndvi-Vegetation Models	2	4	0

The subfield Paleoceanography/Terrestrial Ecosystems (39) is a large C2-cluster including 40 C1-clusters (Table 2.20) with 374 cited publications in the cluster cores. The overview map in figure 2.4 reveals three groups of clusters, which can be identified as the research areas which were building single clusters in 1997: The region on the lower left side of the map consists of C1-clusters dealing with biosphere models and ecosystems, especially the Carbon Cycle. The second large group of clusters, the cyclic formation on the right side, can be seen as the paleoceanography region inside the C2-cluster including many clusters with a high immediacy value. Research themes represented in this region are climate reconstruction, Heinrich events, sea-level change, sediment fluxes and radiocarbon calibration. This area is responsible for the high share of EU15 publications at the C2-clusters research front. Almost all of the C1-clusters inside the "paleoceanography group" are reaching a very high share of EU15 publications. The third region inside the subfield is placed in the upper part of the map and includes the larger C1-cluster Z-Coordinate Ocean Model (310) and some smaller clusters dealing with ocean modelling. The C1-clusters of this region include parts of the 1997 C2-cluster Ocean GCM (8).

The biosphere region and the upper group are directly "bridged" between the large clusters Global Carbon Balance (264) and Tropical Effects in a Future Climate (350) on the one side and Variability of Pco(2) (308) on the other side, whereas the paleoceanography region and the ocean modelling clusters are connected through the smaller clusters Anthropogenic CO2 in Southern-Ocean Surface Waters (224) and Ocean Carbon Cycle (316), which also can be seen as the bridging cluster between the large groups on the left and on the right side.

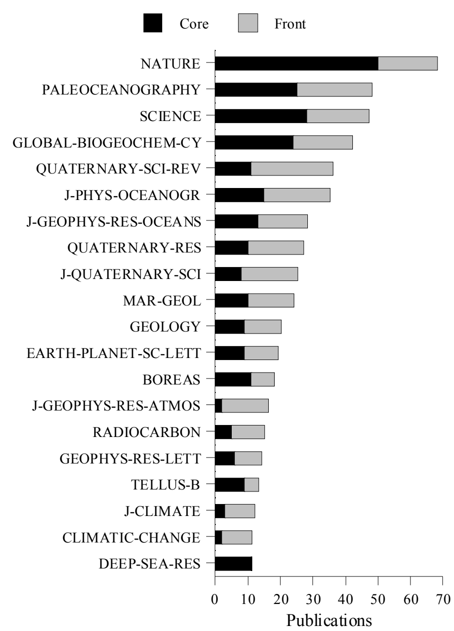


Figure 2.5:
Journal profile of Paleoceanography/Terrestrial Ecosystems

In the journal profile in figure 2.5 the main journals of the subfield are presented in a bar chart showing the relations of core and front publications. The bars indicate the absolute number of publications for each journal, the black filled part for the core and the Grey filled part symbolizing the number of front publications.

The top journals in the profile are *Nature* (which is particularly well represented at the cluster core) and *Paleoceanography*, both with more than 90 publications on the front or the core of cluster C2-39. They are followed by the *Journal of Geophysical Research Oceans*, almost exclusively represented at the front, and *Science* as another multidisciplinary journal.

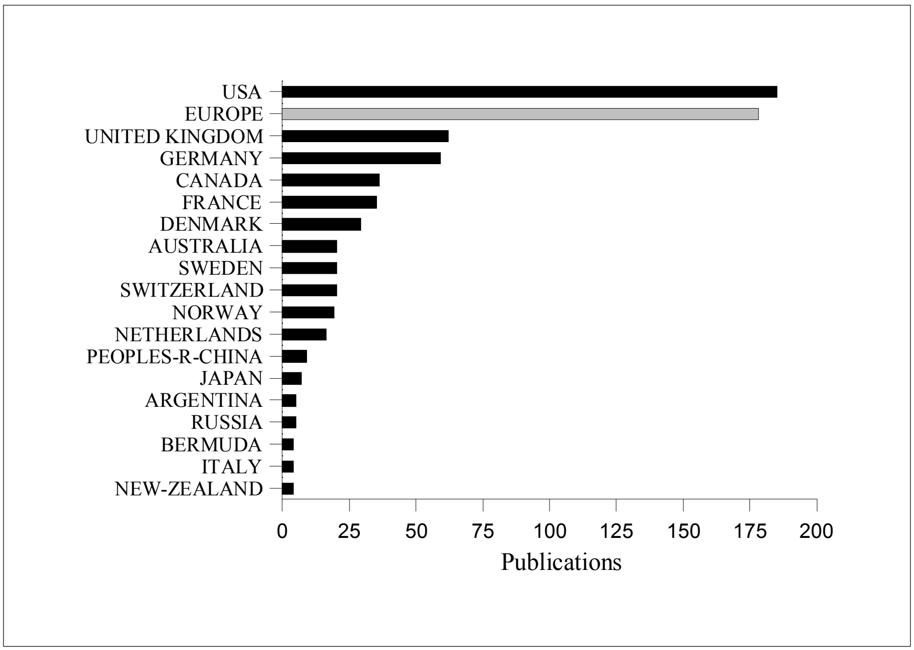


Figure 2.6:
Top countries of publication for the subfield Paleoceanography/Terrestrial Ecosystems

The ranking of the national actors in figure 2.6 is leaded by the USA, but closely followed by the EU15 aggregation. The most active countries besides the USA are the United Kingdom and Germany. Other European countries with more than 10 publications at the research front of C2-39 are France, Denmark, Sweden and the Netherlands.

Table 2.21:
Top institutional actors of the research front of C2-39 Paleoceanography/Terrestrial Ecosytems

Publications	Institutions
22	UNIV-COPENHAGEN, DENMARK
21	COLUMBIA-UNIV, USA
18	NOAA, USA
17	NATL-CTR-ATMOSPHER-RES, USA
14	NASA, USA
14	UNIV-BERGEN, NORWAY
14	UNIV-COLORADO, USA
13	UNIV-BERN, SWITZERLAND
13	US-GEOL-SURVEY, USA
12	CHRISTIAN-ALBRECHTS-UNIV-KIEL, GERMANY
12	UNIV-BREMEN, GERMANY

Publications	Institutions
11	LUND-UNIV, SWEDEN
10	ALFRED-WEGENER-INST-POLAR-&-MARINE-RES, GERMANY
10	WOODS-HOLE-OCEANOG-INST, USA

The top institutional actors ranked by their co-citing publications at the research front are listed in table 2.21. Worth mentioning is the leading role of Scandinavia at the institutional level. The Danish University of Copenhagen, even before the top US institutions, and the Norwegian University of Bergen rank on top places and another Scandinavian institution, the Swedish Lund University appears among the most active research institutes. A much higher position in the ranking as expectable from the countries overall activity can be noticed for the University of Bern, Switzerland. Three institutions on the list are from Germany, whereas the United Kingdom as the other very active European country on the research front is not represented by an institution publishing more than ten articles.

Table 2.22:

Most active co-operations at the research front of C2-39 Paleoceanography/Terrestrial Ecosystems

Publ.	Institutions	
8	UNIV-COPENHAGEN, DENMARK	LUND-UNIV, SWEDEN
6	NOAA, USA	COLUMBIA-UNIV, USA
5	UNIV-COLORADO, USA	NOAA, USA
5	UNIV-COPENHAGEN, DENMARK	UNIV-BERGEN, NORWAY
4	NOAA, USA	NATL-CTR-ATMOSPHER-RES, USA
3	UNIV-CALIF-SAN-DIEGO, USA	MAX-PLANCK-INST-METEOROL, GERMANY
3	UNIV-WASHINGTON, USA	UNIV-BRITISH-COLUMBIA, CANADA
3	UNIV-MIAMI, USA	NOAA, USA
3	UNIV-COPENHAGEN, DENMARK	UNIV-BERN, SWITZERLAND
3	UNIV-WALES, UNITED KINGDOM	UNIV-OSLO, NORWAY
3	UNIV-MONTPELLIER-2, FRANCE	COLUMBIA-UNIV, USA

The co-operations contributing more than two publications to the front of C2-39 are mainly North American or European co-operations. The exceptions are the German Max-Planck Institute for Meteorology and the University of California in San Diego, USA and the French University of Montpellier 2 co-operating three times with the US Columbia University.

C2-36 Toga Coare/ENSO

The subfield Toga Coare/ENSO is an US dominated research area dealing with the Tropical Ocean Global Atmosphere Observing System (Toga) and the Coupled Ocean-Atmosphere Response Experiment (Coare), both initiated and carried out mainly by US researchers. An important subject or aim of the Toga Coare research is the modelling and prediction of the El Niño Southern Oscillation.

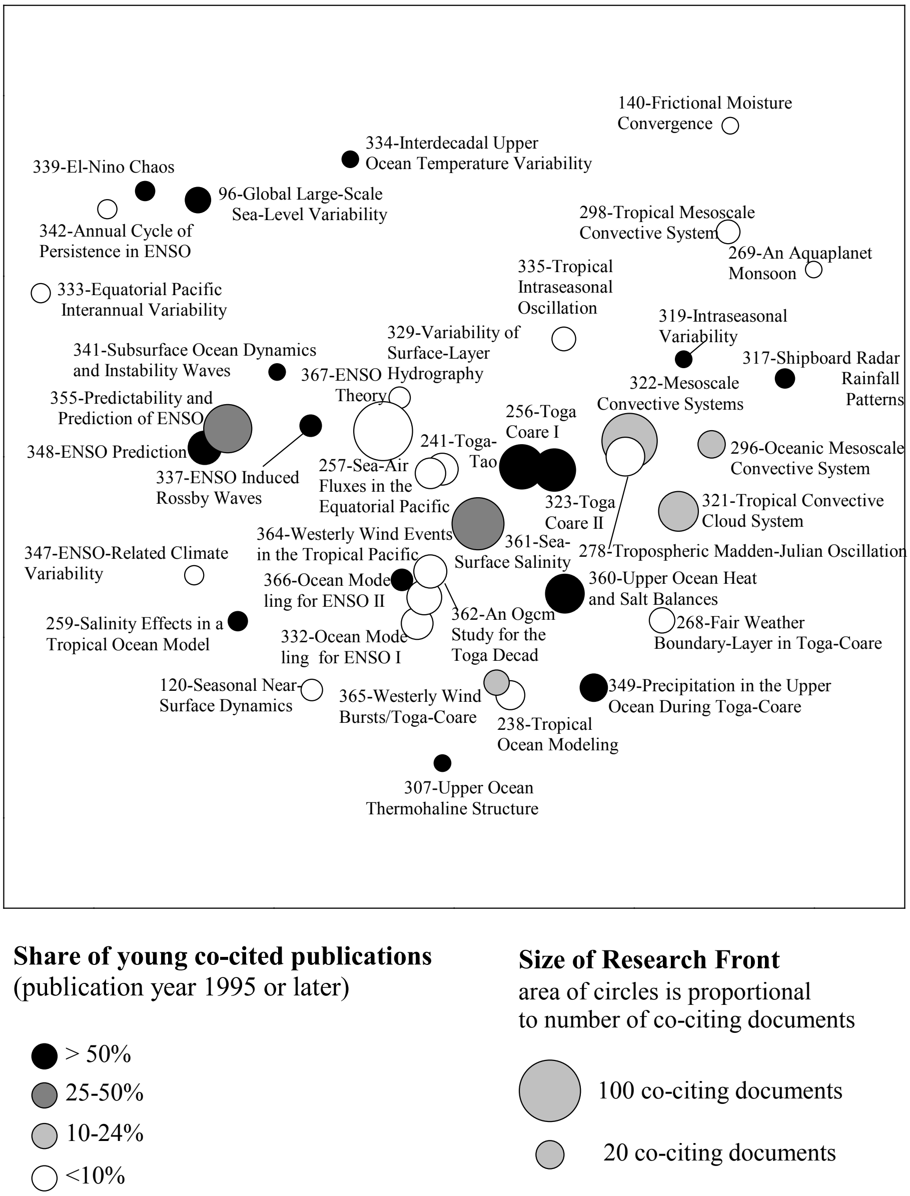


Figure 2.7:

Co-citation cluster map of C2-36 Toga Coare/ENSO

Table 2.23:
C1-clusters of C2-36 Toga Coare/ENSO

Cl-no.	Title	Core	Front	Imm
96	Global Large-Scale Sea-Level Variability	6	7	66
120	Seasonal Near-Surface Dynamics	2	5	0
140	Frictional Moisture Convergence	2	3	0
238	Tropical Ocean Modeling	2	9	0
241	Toga-Tao	2	11	0
256	Toga Coare I	6	21	66
257	Sea-Air Fluxes in the Equatorial Pacific	14	10	14
259	Salinity Effects in a Tropical Ocean Model	3	4	66
268	Fair Weather Boundary-Layer in Toga-Coare	6	7	0
269	An Aquaplanet Monsoon	2	3	0
278	Tropospheric Madden-Julian Oscillation	2	16	0
296	Oceanic Mesoscale Convective System	3	8	33
298	Tropical Mesoscale Convective System	3	6	0
307	Upper Ocean Thermohaline Structure	2	3	50
317	Shipboard Radar Rainfall Patterns	3	4	66
319	Intraseasonal Variability	2	3	100
321	Tropical Convective Cloud System	15	17	33
322	Mesoscale Convective Systems	35	33	22
323	Toga Coare II	2	19	50
329	Variability of Surface-Layer Hydrography	2	5	0
332	Ocean Modeling for ENSO I	4	11	0
333	Equatorial Pacific Interannual Variability	2	4	0
334	Interdecadal Upper Ocean Temperature Variability	2	3	50
335	Tropical Intraseasonal Oscillation	2	6	0
337	ENSO Induced Rossby Waves	4	5	50
339	El-Niño Chaos	2	4	50
341	Subsurface Ocean Dynamics and Instability Waves	2	3	50
342	Annual Cycle of Persistence in ENSO	2	4	0
347	ENSO-Related Climate Variability	2	4	0
348	ENSO Prediction	8	12	50
349	Precipitation in the Upper Ocean During Toga-Coare	6	8	50
355	Predictability and Prediction of ENSO	15	25	46
360	Upper Ocean Heat and Salt Balances	11	16	81
361	Sea-Surface Salinity	13	29	46
362	An Ogcm Study for the Toga Decade	3	13	0
364	Westerly Wind Events in the Tropical Pacific	8	12	12
365	Westerly Wind Bursts/Toga-Coare	5	7	20
366	Ocean Modeling for ENSO II	3	5	66
367	ENSO Theory	40	37	15

The overview map shows a region with many small clusters and some larger ones in a middle belt, which reaches thematically from the phenomenon “El Niño Southern Oscillation”, represented by the clusters on the left side, *Predictability and Prediction of ENSO* (355) and *ENSO Prediction* (348) and the large and more central C1-cluster *ENSO Theory* (367) to the tropical convection system on the right side. In the center of the map the main Toga Coare clusters (256, 323) can be found. They are clusters with small cores, which contain a high proportion of young and highly cited documents.

The share of the USA is very high on all of the C1-clusters’ research fronts. At 33 of the 39 clusters the USA contribute to more than two third of the co-citing publications.

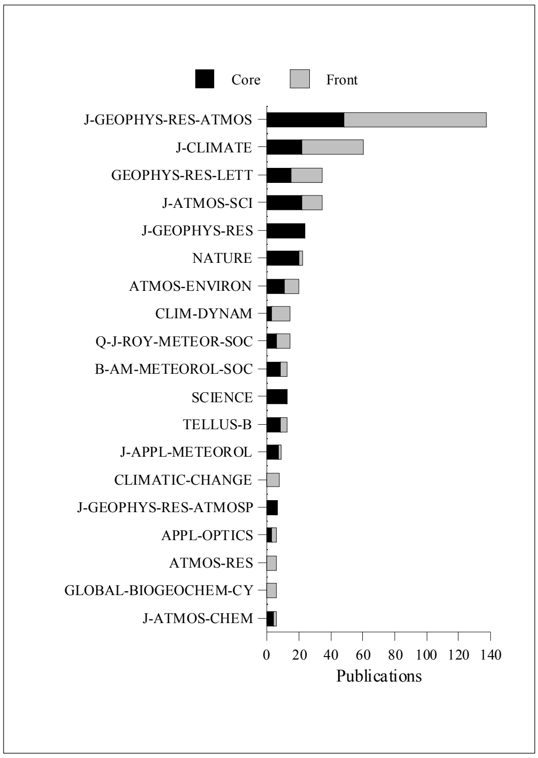


Figure 2.8:
Journal profile of C2-36 Toga Coare/ENSO

By far most of the publications at the front and in the core of the subfield Toga Coare/ENSO are published in the *Journal of Geophysical Research - Atmosphere*. The *Journal of Climate*, *Geophysical Research - Letters* and the *Journal of Atmospheric Science* contribute each more than 30 publications to front and core. Further 8 journals count more than 10 publications, among them the multidisciplinary journals *Nature* and *Science*, which are almost exclusively represented at the research front.

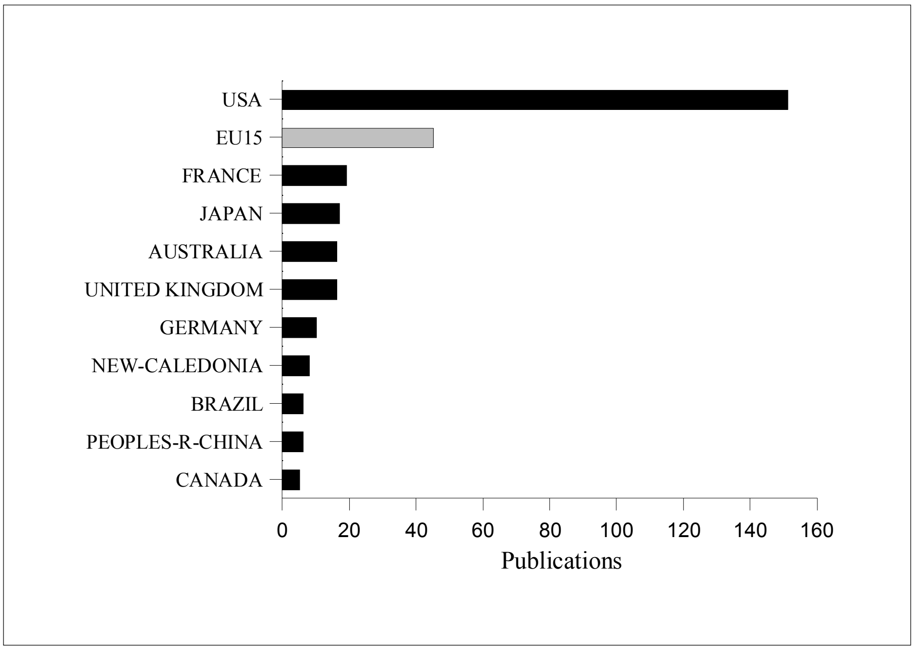


Figure 2.9:
Top countries of publication for the subfield C2-36 Toga Coare/ENSO

The country profile in figure 2.9 illustrates the predominant role of the USA in the subfield. The second strongest country, France, is participating in less than 10% of the front publications.

Table 2.24:
Top institutional actors of the research front of C2-36 Toga Coare/ENSO

Publications	Institutions
26	NOAA, USA
20	NASA, USA
17	UNIV-COLORADO, USA
14	UNIV-CALIF-SAN-DIEGO, USA
12	UNIV-WASHINGTON, USA
12	WOODS-HOLE-OCEANOG-INST, USA
10	NATL-CTR-ATMOSPHER-RES, USA
9	COLUMBIA-UNIV, USA
9	CSIRO, AUSTRALIA
8	UNIV-CALIF-LOS-ANGELES, USA
8	UNIV-HAWAII, USA
7	CALTECH, USA
7	COLORADO-STATE-UNIV, USA
7	FLORIDA-STATE-UNIV, USA
7	UNIV-S-FLORIDA, USA

Table 2.24 shows the top institutions of the subfield, which are from the USA, almost without an exception. Only the Australian CSIRO appears among the top institutions.

Table 2.25:
Most active co-operations at the research front of C2-36 Toga Coare/ENSO

Publ.	Institutions	
6	NOAA, USA	NASA, USA
5	UNIV-CALIF-SAN-DIEGO, USA	CALTECH, USA
5	WOODS-HOLE-OCEANOG-INST, USA	NOAA, USA
4	NOAA, USA	CALTECH, USA
4	UNIV-CALIF-SAN-DIEGO, USA	NOAA, USA
4	UNIV-COLORADO, USA	NOAA, USA
4	WOODS-HOLE-OCEANOG-INST, USA	UNIV-CALIF-SAN-DIEGO, USA
3	NASA, USA	CALTECH, USA
3	NOAA, USA	COLUMBIA-UNIV, USA
3	UNIV-MARYLAND, USA	NASA, USA
3	UNIV-WASHINGTON, USA	CSIRO, AUSTRALIA
3	UNIV-TOKYO, JAPAN	CSIRO, AUSTRALIA
3	WOODS-HOLE-OCEANOG-INST, USA	UNIV-WASHINGTON, USA
3	WOODS-HOLE-OCEANOG-INST, USA	UNIV-CALIF-IRVINE, USA
3	WOODS-HOLE-OCEANOG-INST, USA	CALTECH, USA
3	UNIV-WASHINGTON, USA	NOAA, USA
3	UNIV-CALIF-SAN-DIEGO, USA	UNIV-CALIF-IRVINE, USA
3	UNIV-CALIF-SAN-DIEGO, USA	NASA, USA
3	UNIV-CALIF-IRVINE, USA	CALTECH, USA
3	SPACE-APPLICAT-CORP, USA	NASA, USA

Also the co-operations reflect the predominance of the USA in this subfield (Table 2.25). The most active US institutions are mainly co-operating among themselves. Only the CSIRO is publishing together with an US institution, the University of Washington, and the University of Tokyo, Japan.

4.1.2. Neuroscience

4.1.2.1. General overview

For the field neuroscience the Neuroscience Citation Index (NSCI) was analyzed in total. The NSCI is one of ISI's specialty indexes, covering 3100 important journals related to the interdisciplinary field of neuroscience. After a limitation to selected document types (article, review, note, letter, meeting-abstract) about 75.000 to 85.000 source publications per year provide the citations which have been the basis of our co-citation cluster analysis. The numbers for the basic units and the resulting cluster levels are listed in table 2.26 for the three analyzed years.

Table 2.26:
Co-citation analysis neuroscience 1996-98: Basic statistics

	1996	**1997**	**1998**
Source Publications	77183	80277	86539
Cited Publications	965006	1039618	1100467
Highly Cited Publications	85991	93984	99526
Clustered Publications	53019	64314	67721
C1-Clusters	7821	9543	10341
C2-Clusters	894	1053	1130
C3-Clusters	109	133	151
C4-Clusters	7	10	18

The highly cited and co-cited publications of each year, which have been cited 5 or more times, were clustered into 7821 C1-clusters in 1996 up to 10341 C1-clusters in 1998. After further clustering of the clusters we got 109 – 151 C3-clusters and 7 to 18 C4-clusters each year at the highest level.

The clustering of the C3-clusters with the variable level algorithm for each year results in one large cluster, a few very small C4-subfields and many isolated C3-clusters. Although the large cluster represents the core of the field containing the C3-clusters with the strongest connections to the most central subfields, the restriction/boundary of this central region is somewhat due to the defined cluster size threshold. Other cluster solutions with increased size thresholds always lead to a large core cluster including the maximum allowed number of elements. With increasing cluster size the large clusters contain more and more of the previously isolated C3-clusters. A MDS solution for the largest central cluster containing 100 C3-clusters revealed a relative homogenous structure inside with only one more dense region in the center. Therefore an overview based on a map of such a large cluster would be less informative regarding its center region, because the inclusion of the outer regions would be due to a loss of precision regarding the relations between the central C3-clusters of the field.

To give an overall view of the large field neuroscience, we present the overview map based on the clustering with a maximum cluster size of 45 elements and a zoom into the large central C4-cluster. The largest C3-clusters which remained isolated after the last step of clustering are listed in special tables with core size, front size and immediacy value and with the activity profile regarding the triad and the most active European countries. So they can be used as entry points for more detailed analysis, as well as the clustered C3-clusters.

4.1.2.1.1. Neuroscience 1996

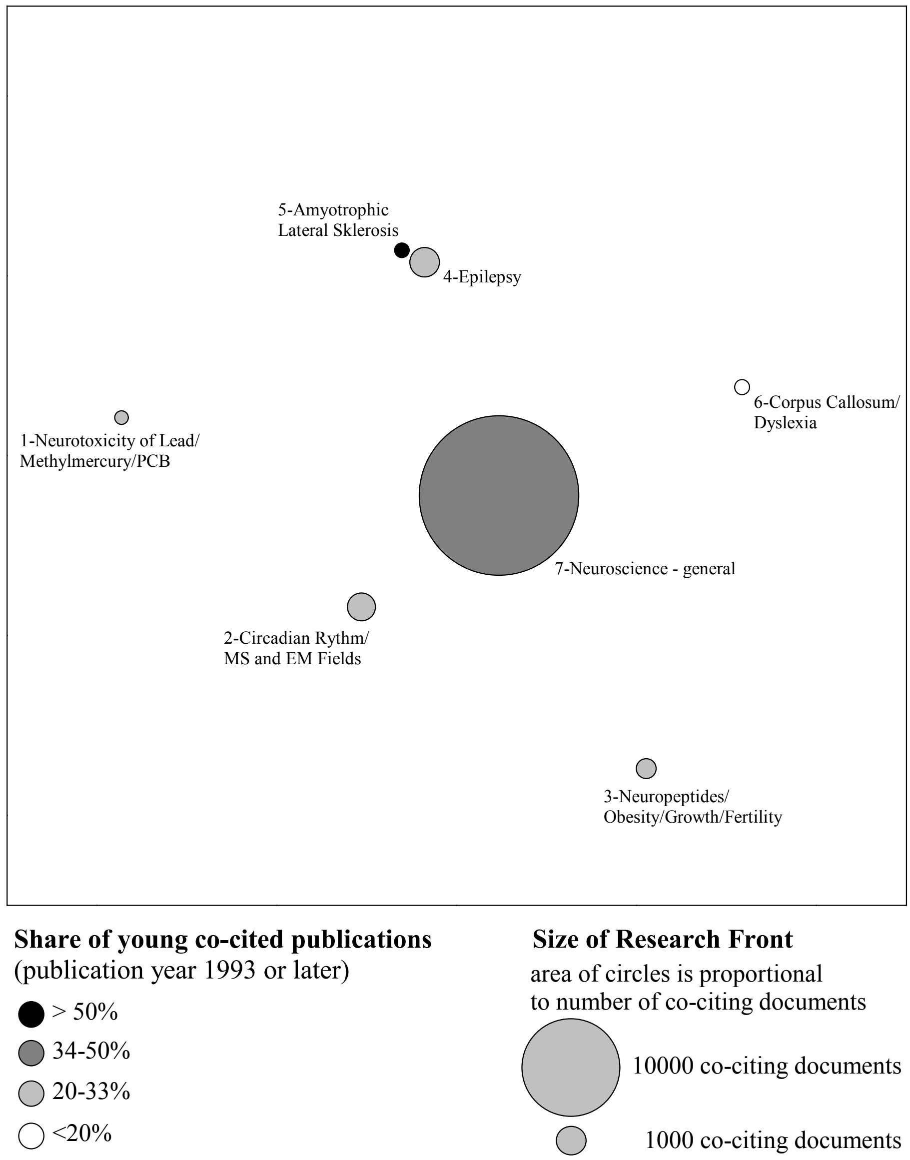


Figure 2.10:
Overview map of neuroscience 1996

Table 2.27:
C4-clusters of neuroscience 1996

Cl.-no.	Title	C3	Core	Front	Imm
1	Neurotoxicity of Lead/Methylmercury/PCB	2	169	204	23
2	Circadian Rythm/MS and EM Fields	2	791	853	32
3	Neuropeptides/Obesity/Growth/Fertility	2	341	421	26
4	Epilepsy	3	747	950	33
5	Amyotrophic Lateral Sklerosis	2	118	232	50
6	Corpus Callosum/Dyslexia	2	162	253	18
7	Neuroscience - general	45	24125	27229	34

At the fourth aggregation level the highly cited publications (which were co-cited by the source publications of the 1996 neuroscience research) are forming seven C4-clusters, shown in the overview map in figure 2.10. By far the most of the clustered publications are included in one large cluster, which was named “Neuroscience - general” (7) containing 24125 cited publications, which are co-cited by 27229 source publications. (table 2.27) The 45 C3-clusters included in this large C4-cluster represent the central region of the neuroscience landscape which is relative densely connected by co-citations. The surrounding satellites are smaller regions each including two or three C3-clusters with stronger connections between each other than to the center. The cluster *Amyotrophic Lateral Sclerosis* (5) contains the highest percentage of younger cited publications (50%), indicated in the map by the darkest shaded circle. It is closely neighbored by the epilepsy cluster (4), the largest of the satellites with nearly 1000 front source publications co-citing the 747 core documents.

Table 2.28:
Top national actors of neuroscience 1996

Publications	Percent	Countries
31627	41.0	USA
26756	34.7	EU15
7408	9.6	UK
6793	8.8	JAPAN
5896	7.6	GERMANY
4127	5.3	FRANCE
3937	5.1	CANADA
3267	4.2	ITALY
1678	2.2	NETHERLANDS
1676	2.2	SWEDEN
1613	2.1	AUSTRALIA
1513	2.0	SPAIN
1235	1.6	SWITZERLAND
889	1.2	RUSSIA
848	1.1	ISRAEL
745	1.0	BELGIUM

Table 2.28 shows the 15 most active national actors and the EU15 with their publications in the field in absolute numbers and percentage of the total amount of

neuroscience publications in 1996. The ranking is leaded by the USA which is contributing to more than 40% of the neuroscience publications. The following nations, the United Kingdom, Japan, Germany and France, come up to about 5% - 10%. Besides the three large European countries further five member states of the European Union can be found in the ranking. The EU15 countries together, listed for a comparison with the USA, reach a share of 34.7% in the neuroscience literature of 1996.

Table 2.29:
Top institutional actors of neuroscience1996

Publications	Institution
1315	HARVARD-UNIV, USA
1110	UNIV-TEXAS, USA
835	UNIV-CALIF-LOS-ANGELES, USA
696	UNIV-PENN, USA
687	JOHNS-HOPKINS-UNIV, USA
644	UNIV-PITTSBURGH, USA
641	UNIV-CALIF-SAN-FRANCISCO, USA
634	UNIV-CALIF-SAN-DIEGO, USA
634	UNIV-MICHIGAN, USA
625	YALE-UNIV, USA
608	UNIV-TORONTO, CANADA
602	UNIV-WASHINGTON, USA
581	VET-ADM-MED-CTR, USA
571	MCGILL-UNIV, CANADA
494	DUKE-UNIV, USA

The 15 top institutional actors each with more than 400 publications are nearly completely US universities. Only two Canadian institutions, the University of Toronto and the McGill University are visible among the top group listed in table 2.29.

Table 2.30:
Top institutional actors of the EU15 for neuroscience 1996

Publications	Institution
484	KAROLINSKA-INST, SWEDEN
412	UNIV-OXFORD, UNITED KINGDOM
388	UNIV-MILAN, ITALY
384	UNIV-MUNICH, GERMANY
355	UNIV-CAMBRIDGE, UNITED KINGDOM
354	UNIV-TUBINGEN, GERMANY
312	UNIV-HEIDELBERG, GERMANY
279	UNIV-ROMA-LA-SAPIENZA, ITALY
277	INST-PSYCHIAT, UNITED KINGDOM
262	HOP-LA-PITIE-SALPETRIERE, FRANCE
256	UNIV-WURZBURG, GERMANY
251	UNIV-LONDON, UNITED KINGDOM
251	UNIV-VIENNA, AUSTRIA
250	CNRS, FRANCE
244	UNIV-COLL-LONDON, UNITED KINGDOM
228	GOTHENBURG-UNIV, SWEDEN

The ranking of the top European actors (EU15 members) is leaded by a Swedish institution. The Karolinska Institute is ranking above the British University of Oxford and the Italian University of Milan which are followed by the German universities of Munich, Tübingen and Heidelberg and the British University of Cambridge.

In the next tables the activity profiles of the triad countries and the three most active European nations for the C4-clusters of neuroscience research in 1996 can be compared. The national proportions of publications for the large central cluster *Neuroscience - general* are not much differing from the national shares in all the C4-research front publications.

Table 2.31:

Share of the triad in C4-research fronts for neuroscience1996, ranked by share of EU15

Rank Title (CL,-No,)	Front	EU15 (37.5)	USA (47.1)	Japan (9.0)
1 Epilepsy (4)	950	44,0 ▲	41,2 ▼	6,4 ▼
2 Amyotrophic Lateral Sklerosis (5)	232	40,5	48,7	7,8
3 Circadian Rythm/MS and EM Fields (2)	853	38,7	40,4 ▼	7,9
4 Neuroscience - general (7)	27229	37,1	47,2	9,0
5 Neurotoxicity of Lead/Methylmercury/PCB (1)	204	32,4	58,8 ▲	4,9 ▼
6 Corpus Callosum/Dyslexia (6)	253	31,6	55,7 ▲	3,2 ▼
7 Neuropeptides/Obesity/Growth/Fertility (3)	421	31,4 ▼	51,5	10,2

The publication activity of the EU15 differs only in two C4-subfields significantly from its average on the C4-level. The highest share of front publications was computed for the EU15 at the research front of C4-4 *Epilepsy*, which shows on the other hand a rather low activity of the USA and Japan. (table 2.31)

A significant low contribution of the EU15 countries shows the C4-cluster *Neuropeptides/Obesity/Growth/Fertility* (3).

Table 2.32:

Share of most active European countries in C4-research fronts for neuroscience1996, ranked by share of EU15

Rank Title (Cl.-No.)	Front	EU15 (37.5)	UK (10.5)	GER (8.5)	F (6.2)
1 Epilepsy (4)	950	44.0 ▲	15.8 ▲	8.0	6.7
2 Amyotrophic Lateral Sklerosis (5)	232	40.5	12.5	6.5	8.6
3 Circadian Rythm/MS and EM Fields (2)	853	38.7	8.7	7.6	8.0 ▲
4 Neuroscience. general (7)	27229	37.1	10.3	8.5	6.1
5 Neurotoxicity of Lead/Methylmercury/PCB (1)	204	32.4	8.3	6.9	0 ▼
6 Corpus Callosum/Dyslexia (6)	253	31.6	12.3	6.3	7.5
7 Neuropeptides/Obesity/Growth/Fertility (3)	421	31.4 ▼	10.0	4.0 ▼	4.3

In table 2.32 the publication shares of the most active European countries for the C4-clusters are given. The differences to the countries average are significant only in a few cases. The activity of the United Kingdom, which contributes a relative large part of the front publications, corresponds to the whole EU15 in Epilepsy and Germany has a very low activity in C3-3. France shows a relative strong activity in the subfield Circadian Rythm/MS and EM Fields (2) and to the contrast, has no publication at the research front of Neurotoxicity of Lead/Methylmercury/PCB (1).

After this general overview of the field of neuroscience a view on the internal structure of the large central C4-cluster *Neuroscience – general* will be provided in the next figure and tables, showing which large subfields are included in the central region of the neuroscience and how they are related.

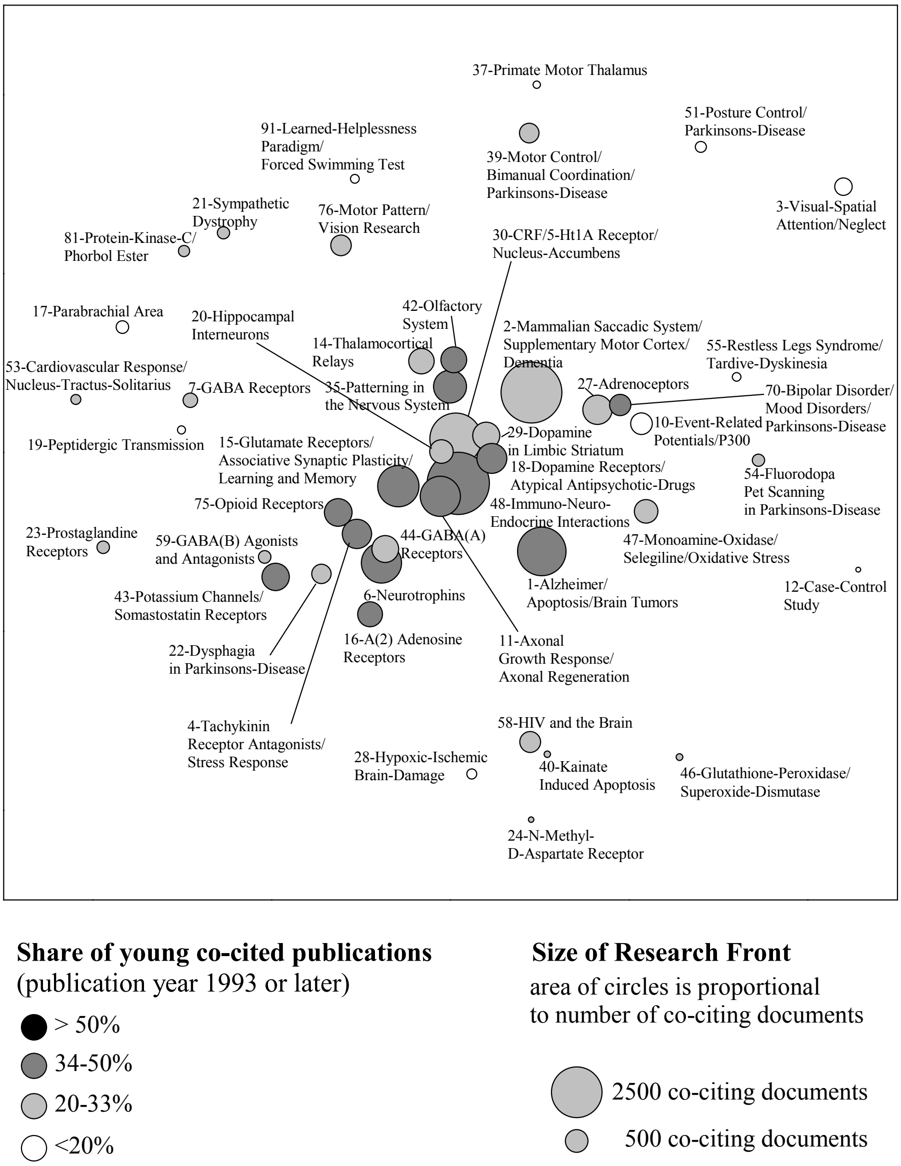


Figure 2.11:

Detailed map of C4-7 Neuroscience - general

Table 2.33:
C3-clusters of C4-7 Neuroscience – general

Cl.-no.	Title	C2	Core	Front	Imm
1	Alzheimer/Apoptosis/Brain Tumors	21	1744	2594	49
2	Mammalian Saccadic System/Supplementary Motor Cortex/Dementia	37	2761	4039	23
3	Visual-Spatial Attention/Neglect	2	259	335	21
4	Tachykinin Receptor Antagonists/Stress Response	6	528	958	35
6	Neurotrophins	16	1109	1794	44
7	GABA Receptors	4	166	243	21
10	Event-Related Potentials/P300	2	344	507	15
11	Axonal Growth Response/Axonal Regeneration	27	1443	1786	38
12	Case-Control Study	2	9	29	11
14	Thalamocortical Relays	5	431	727	32
15	Glutamate Receptors/Associative Synaptic Plasticity/Learning and Memory	15	1025	1869	47
16	A(2) Adenosine Receptors	8	340	683	37
17	Parabrachial Area	2	113	178	17
18	Dopamine Receptors/Atypical Antipsychotic-Drugs	6	535	995	38
19	Peptidergic Transmission	2	44	74	13
20	Hippocampal Interneurons	5	403	614	27
21	Sympathetic Dystrophy	2	95	170	29
22	Dysphagia in Parkinsons-Disease	2	240	411	29
23	Prostaglandine Receptors	3	132	186	32
27	Adrenoceptors	6	586	963	31
28	Hypoxic-Ischemic Brain-Damage	2	78	112	19
29	Dopamine in Limbic Striatum	9	476	805	26
30	CRF/5-Ht1A Receptor/Nucleus-Accumbens	35	2235	2941	29
31	Respiratory Network/-Rhythm	2	110	147	24
35	Patterning in the Nervous System	16	1042	1170	42
39	Motor Control/Bimanual Coordination/Parkinsons-Disease	8	302	426	20
40	Kainate Induced Apoptosis	2	17	50	29
42	Olfactory System	7	722	746	38
43	Potassium Channels/Somastostatin Receptors	11	615	830	45
44	GABA(A) Receptors	4	574	788	33
46	Glutathione-Peroxidase/Superoxide-Dismutase	2	20	51	30
47	Monoamine-Oxidase/Selegiline/Oxidative Stress	2	409	607	28
48	Immuno-Neuro-Endocrine Interactions	41	2813	4219	35
51	Posture Control/Parkinsons-Disease	2	99	132	8
53	Cardiovascular Response/Nucleus-Tractus-Solitarius	3	84	112	25
54	Fluorodopa Pet Scanning in Parkinsons-Disease	3	102	168	29
55	Restless Legs Syndrome/Tardive-Dyskinesia	2	83	88	16
59	GABA(B) Agonists and Antagonists	2	93	186	29
70	Bipolar Disorder/Mood Disorders/Parkinsons-Disease	2	354	494	37

The figure 2.11 allows a detailed view into the co-citation clusters of the largest C4-cluster, which contains the most central research fronts of the neurosciences in 1996. In the co-citation map of C4-7 *Neuroscience – general* the larger clusters are forming a region in the center of the map. Two of the largest clusters with more than 2500 co-citing publications can be found in direct neighborhood in the middle of this region: *CRF/5-Ht1A Receptor/Nucleus-Accumbens* (30) and *Immuno-Neuro-Endocrine Interactions* (48), which is the largest C3-cluster, containing more than 2800 highly cited publications, 35% of them published after 1992 and co-cited by more than 4000 source publications. Further two very large C3-subfields are *Mammalian Saccadic System/Supplementary Motor Cortex/Dementia* (2) in the upper right of the center region and *Alzheimer/Apoptosis/brain Tumors* (1) in the lower right, a rather dynamic subfield with nearly 50% younger cited documents in the cluster cores. In the lower left area of the center region many medium sized C3-cluster dealing with different kinds of receptors can be found, for example *Glutamate Receptors/Associative Synaptic Plasticity/Learning and Memory* (15) *Opioid Receptors* (75), *Tachykinin Receptor Antagonists/Stress Response* (4). Another clearly discernible area is build by the upper clusters, which are more separated from the center. They are dealing with motor control especially regarding Parkinsons-disease and vision research. The subject Parkinsons-disease is represented in some more clusters which are not concentrated in a special area: Connected with bipolar disorders or Pet at the right (clusters 70 and 54) and dealing with dysphagia in Parkinsons disease (cluster 22) at the lower left.

Table 2.34:

Share of the triad in C3-research fronts of C4-7, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (39.3)	USA (48.4)	Japan (9.6)
1	N-Methyl-D-Aspartate Receptor (24)	33	57.6 ▲	45.5	3.0
2	Case-Control Study (12)	29	55.2	51.7	0
3	Prostaglandine Receptors (23)	186	46.8 ▲	39.8 ▼	9.1
4	Monoamine-Oxidase/Selegiline/Oxidative Stress (47)	607	43.8 ▲	37.2 ▼	11.4
5	Posture Control/Parkinsons-Disease (51)	132	43.2	40.9	6.1
6	Learned-Helplessness Paradigm/Forced Swimming Test (91)	84	42.9	29.8 ▼	15.5
7	Motor Pattern/Vision Research (76)	476	42.9	40.1 ▼	5.9 ▼
8	Neurotrophins (6)	1794	41.6 ▲	46.0 ▼	9.8
9	Visual-Spatial Attention/Neglect (3)	335	40.9	41.5 ▼	6.9
10	Dopamine in Limbic Striatum (29)	805	40.5	45.6	6.8 ▼
11	Motor Control/Bimanual Coordination/Parkinsons-Disease (39)	426	40.4	50.0	3.3 ▼
12	Respiratory Network/-Rhythm (31)	147	40.1	39.5 ▼	15.6 ▲
13	Mammalian Saccadic System/Supplementary Motor Cortex/Dementia (2)	4039	40.1	48.2	6.0 ▼
14	HIV and the Brain (58)	482	38.6	51.7	7.9
15	Sympathetic Dystrophy (21)	170	38.2	40.0 ▼	6.5
16	Dysphagia in Parkinsons-Disease (22)	411	38.2	48.9	6.3 ▼
17	Immuno-Neuro-Endocrine Interactions (48)	4219	37.6 ▼	44.9 ▼	10.7 ▲
18	Hypoxic-Ischemic Brain-Damage (28)	112	37.5	47.3	1.8
19	Tachykinin Receptor Antagonists/Stress Response (4)	958	36.7	42.4 ▼	12.6 ▲
20	Event-Related Potentials/P300 (10)	507	36.7	46.7	7.5
21	GABA(A) Receptors (44)	788	36.2	54.1 ▲	5.7 ▼
22	Adrenoceptors (27)	963	35.7 ▼	53.1 ▲	5.7 ▼
23	Hippocampal Interneurons (20)	614	35.7	42.7 ▼	8.5
24	A(2) Adenosine Receptors (16)	683	35.7	40.3 ▼	14.5 ▲
25	Fluorodopa Pet Scanning in Parkinsons-Disease (54)	168	35.1	50.6	6.5
26	Potassium Channels/Somastostatin Receptors (43)	830	34.6 ▼	52.8 ▲	6.7 ▼
27	Axonal Growth Response/Axonal Regeneration (11)	1786	34.5 ▼	55.1 ▲	9.1
28	CRF/5-Ht1A Receptor/Nucleus-Accumbens (30)	2941	34.4 ▼	52.5 ▲	5.7 ▼
29	Dopamine Receptors/Atypical Antipsychotic-Drugs (18)	995	34.2 ▼	51.0	9.7
30	Patterning in the Nervous System (35)	1170	33.9 ▼	58.1 ▲	8.2
31	Bipolar Disorder/Mood Disorders/Parkinsons-Disease (70)	494	33.8 ▼	50.4	5.3 ▼
32	Olfactory System (42)	746	33.4 ▼	55.0 ▲	8.3
33	Alzheimer/Apoptosis/Brain Tumors (1)	2594	32.6 ▼	54.0 ▲	12.3 ▲
34	Glutamate Receptors/Associative Synaptic Plasticity/Learning and Memory (15)	1869	32.5 ▼	52.1 ▲	8.9
35	GABA Receptors (7)	243	31.7 ▼	45.3	9.5
36	Thalamocortical Relays (14)	727	31.5 ▼	45.4	6.9 ▼
37	Restless Legs Syndrome/Tardive-Dyskinesia (55)	88	30.7	54.5	1.1
38	Peptidergic Transmission (19)	74	28.4	48.6	4.1
39	Opioid Receptors (75)	850	28.4 ▼	55.5 ▲	10.8
40	GABA(B) Agonists and Antagonists (59)	186	28.0 ▼	51.1	10.2
41	Primate Motor Thalamus (37)	67	26.9 ▼	47.8	13.4
42	Cardiovascular Response/Nucleus-Tractus-Solitarius (53)	112	26.8 ▼	44.6	12.5
43	Kainate Induced Apoptosis (40)	50	26.0	72.0 ▲	8.0
44	Parabrachial Area (17)	178	22.5 ▼	53.9	10.7
45	Glutathione-Peroxidase/Superoxide-Dismutase (46)	51	21.6 ▼	60.8	7.8

Table 2.35:

Share of the most active European countries in C3-research fronts of C4-7, ranked by share of EU15

Rank	Title (Cl.-No.)	Front	EU15 (39.3)	UK (10.8)	GER (8.8)	F (6.4)
1	N-Methyl-D-Aspartate Receptor (24)	33	57.6 ▲	24.2 ▲	6.1	6.1
2	Case-Control Study (12)	29	55.2	13.8	17.2	10.3
3	Prostaglandine Receptors (23)	186	46.8 ▲	17.2 ▲	14.5 ▲	1.1
4	Monoamine-Oxidase/Selegiline/Oxidative Stress (47)	607	43.8 ▲	9.4	10.5	5.4
5	Posture Control/Parkinsons-Disease (51)	132	43.2	9.1	6.8	18.2 ▲
6	Learned-Helplessness Paradigm/Forced Swimming Test (91)	84	42.9	3.6	1.2	11.9 ▲
7	Motor Pattern/Vision Research (76)	476	42.9	14.5 ▲	10.1	7.4
8	Neurotrophins (6)	1794	41.6 ▲	11.0	8.9	6.6
9	Visual-Spatial Attention/Neglect (3)	335	40.9	14.6 ▲	7.8	4.8
10	Dopamine in Limbic Striatum (29)	805	40.5	11.4	8.0	7.7
11	Motor Control/Bimanual Coordination/Parkinsons-Disease (39)	426	40.4	9.4	7.0	9.6 ▲
12	Respiratory Network/-Rhythm (31)	147	40.1	4.8 ▼	8.8	15.6 ▲
13	Mammalian Saccadic System/Supplementary Motor Cortex/Dementia (2)	4039	40.1	13.7 ▲	8.8	6.1
14	HIV and the Brain (58)	482	38.6	7.1 ▼	10.6	9.3 ▲
15	Sympathetic Dystrophy (21)	170	38.2	10.6	9.4	2.4
16	Dysphagia in Parkinsons-Disease (22)	411	38.2	9.2	8.8	3.9 ▼
17	Immuno-Neuro-Endocrine Interactions (48)	4219	37.6 ▼	9.6 ▼	10.2 ▲	4.6 ▼
18	Hypoxic-Ischemic Brain-Damage (28)	112	37.5	15.2	5.4	4.5
19	Tachykinin Receptor Antagonists/Stress Response (4)	958	36.7	10.0	6.3 ▼	6.1
20	Event-Related Potentials/P300 (10)	507	36.7	8.1	12.6 ▲	4.3 ▼
21	GABA(A) Receptors (44)	788	36.2	8.6 ▼	9.1	5.8
22	Adrenoceptors (27)	963	35.7 ▼	14.4 ▲	7.3	5.3
23	Hippocampal Interneurons (20)	614	35.7	8.3 ▼	8.8	5.9
24	A(2) Adenosine Receptors (16)	683	35.7	8.5	7.9	3.8 ▼
25	Fluorodopa Pet Scanning in Parkinsons-Disease (54)	168	35.1	6.0 ▼	8.3	5.4
26	Potassium Channels/Somastostatin Receptors (43)	830	34.6 ▼	10.6	8.4	5.8
27	Axonal Growth Response/Axonal Regeneration (11)	1786	34.5 ▼	9.5	9.5	6.9
28	CRF/5-Ht1A Receptor/Nucleus-Accumbens (30)	2941	34.4 ▼	9.6 ▼	5.5 ▼	6.1
29	Dopamine Receptors/Atypical Antipsychotic-Drugs (18)	995	34.2 ▼	9.3	5.0 ▼	7.6
30	Patterning in the Nervous System (35)	1170	33.9 ▼	11.5	9.0	6.8
31	Bipolar Disorder/Mood Disorders/Parkinsons-Disease (70)	494	33.8 ▼	13.2	6.9	4.9
32	Olfactory System (42)	746	33.4 ▼	7.9 ▼	10.7	7.8
33	Alzheimer/Apoptosis/Brain Tumors (1)	2594	32.6 ▼	8.2 ▼	7.6 ▼	5.8
34	Glutamate Receptors/Associative Synaptic Plasticity/Learning and Memory (15)	1869	32.5 ▼	10.8	8.5	5.1 ▼
35	GABA Receptors (7)	243	31.7 ▼	11.9	2.9 ▼	6.2
36	Thalamocortical Relays (14)	727	31.5 ▼	8.5 ▼	9.5	5.6
37	Restless Legs Syndrome/Tardive-Dyskinesia (55)	88	30.7	6.8	11.4	3.4
38	Peptidergic Transmission (19)	74	28.4	5.4	4.1	2.7
39	Opioid Receptors (75)	850	28.4 ▼	7.4 ▼	6.0 ▼	5.8
40	GABA(B) Agonists and Antagonists (59)	186	28.0 ▼	7.0	5.9	7.0
41	Primate Motor Thalamus (37)	67	26.9 ▼	4.5	4.5	10.4
42	Cardiovascular Response/Nucleus-Tractus-Solitarius (53)	112	26.8 ▼	5.4	5.4	7.1
43	Kainate Induced Apoptosis (40)	50	26.0	4.0	6.0	2.0
44	Parabrachial Area (17)	178	22.5 ▼	6.7	3.4 ▼	5.6
45	Glutathione-Peroxidase/Superoxide-Dismutase (46)	51	21.6 ▼	5.9	3.9	3.9

The EU15 participates at the research fronts of four C3-clusters in C4-7 significantly above the C3-level average. Among them two larger clusters with more than 500 front publications can be found: *Monoamine-Oxidase/Selegiline/Oxidative Stress* (47) and *Neurotrophins* (6).

At the research fronts of several C3-clusters only relatively few EU15 publications have been counted, among these subfields shown in the lower part of the tables 2.34, 2.35 all very large C3-clusters can be found.

Table 2.35 reveals differences between the activity profiles of the three most active European countries. Whereas France and more clearly the United Kingdom show a significantly stronger activity mainly in those clusters with an average EU15 contribution, Germany shows a more individual profile. More clusters with a German contribution above the average can be found on the places with a lower EU15 share.

The larger C3-clusters (front size > 100) which were not clustered at the last level are listed in the next three tables. They are more isolated in terms of their co-citations to other C3-regions. In the following tables their general cluster characteristics (table 2.36) and national shares in the research front publications (table 2.37) are presented.

Table 2.36:
C3-Isolates of neuroscience 1996 with more than 100 front publications

Cl-no.	Title	C2	Core	Front	Imm
85	Otoacoustic Emissions/Cochlear Nucleus/Nicotinic Receptors	7	858	879	28
62	Neuromuscular Diseases	10	561	750	57
90	Diabetic Neuropathy	5	490	686	19
36	Radial Basis Function Networks	7	190	476	10
79	Opioid Analgesic Therapy	5	279	370	16
93	Autism/Obsessive Compulsive Disorder	2	285	349	28
26	Brain Injuries	2	189	290	13
45	Blood-Brain-Barrier	3	184	259	21
94	Mitochondrial Encephalomyopathies/Optic Neuropathy	2	167	206	42
65	Natural-Killer-Cell/Immunomodulation by Opioid-Peptides	3	148	190	31
64	Intracranial Aneurysms/Internal Carotid-Artery	3	119	178	16
63	Vasoactive Intestinal Polypeptide/Pacap	4	154	165	34
84	Motor Units/Medial Gastrocnemius-Muscles	3	109	149	15
49	Aromatase-Immunoreactive Cells/Food-Storing Memory	2	168	146	29
38	Vasopressin/Supraoptic Nucleus	2	108	142	32
13	Mast-Cell/Substance P	3	99	138	20
66	Sleep in Psychiatric-Disorders	3	85	136	17
99	Polyunsaturated Fatty-Acids	2	77	136	16
67	Tyrosine-Hydroxylase Messenger-RNA	3	102	134	30
68	Somatosensory-Evoked Potentials	3	99	130	19
81	Protein-Kinase-C/Phorbol Ester	2	53	118	28
60	Primary CNS Lymphomas	2	107	117	14
71	Endothelin Peptides/-Receptors	2	80	113	43
82	Taste Transduction	2	115	109	18
105	Cervical Spondylosis	3	78	105	3

Table 2.37:
Share of the triad in research fronts of C3-isolates for neuroscience1996, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (39.3)	USA (48.4)	Japan (9.6)
1	Somatosensory-Evoked Potentials (68)	130	52.3 ▲	19.2 ▼	19.2 ▲
2	Mast-Cell/Substance P (13)	138	48.6 ▲	35.5 ▼	5.1
3	Mitochondrial Encephalomyopathies/Optic Neuropathy (94)	206	47.6 ▲	33.0 ▼	9.7
4	Neuromuscular Diseases (62)	750	44.8 ▲	41.7 ▼	12.5 ▲
5	Diabetic Neuropathy (90)	686	41.4	33.8 ▼	13.8 ▲
6	Primary CNS Lymphomas (60)	117	41.0	43.6	2.6
7	Aromatase-Immunoreactive Cells/Food-Storing Memory (49)	146	40.4	50.7	12.3
8	Vasoactive Intestinal Polypeptide/Pacap (63)	165	40.0	41.2	9.7
9	Motor Units/Medial Gastrocnemius-Muscles (84)	149	37.6	34.2 ▼	6.0
10	Polyunsaturated Fatty-Acids (99)	136	37.5	44.1	15.4 ▲
11	Endothelin Peptides/-Receptors (71)	113	35.4	43.4	16.8 ▲
12	Vasopressin/Supraoptic Nucleus (38)	142	34.5	45.8	9.2
13	Protein-Kinase-C/Phorbol Ester (81)	118	33.9	47.5	10.2
14	Opioid Analgesic Therapy (79)	370	33.2 ▼	48.9	.5
15	Blood-Brain-Barrier (45)	259	32.8 ▼	46.3	15.1 ▲
16	Cervical Spondylosis (105)	105	32.4	39.0	16.2 ▲
17	Otoacoustic Emissions/Cochlear Nucleus/Nicotinic Receptors (85)	879	32.3 ▼	57.9 ▲	5.0 ▼
18	Autism/Obsessive Compulsive Disorder (93)	349	31.5 ▼	58.2 ▲	1.1
19	Intracranial Aneurysms/Internal Carotid-Artery (64)	178	30.3 ▼	42.1	21.3 ▲
20	Radial Basis Function Networks (36)	476	30.0 ▼	35.5 ▼	13.0 ▲
21	Natural-Killer-Cell/Immunomodulation by Opioid-Peptides (65)	190	30.0 ▼	55.8 ▲	5.3 ▼
22	Sleep in Psychiatric-Disorders (66)	136	28.7 ▼	52.2	2.9
23	Brain Injuries (26)	290	25.2 ▼	60.3 ▲	2.4 ▼
24	Tyrosine-Hydroxylase Messenger-RNA (67)	134	20.9 ▼	64.2 ▲	8.2
25	Taste Transduction (82)	109	13.8 ▼	63.3 ▲	26.6 ▲

Four larger isolated C3-clusters are visible at the top of the table 2.36 showing more than 400 front publications. Among them the large and extraordinarily dynamic subfield *Neuromuscular Diseases* (62) can be found. It contains 57% younger cited documents in the cluster core, an immediacy value which is not exceeded by any other cluster on the C3-level. The EU15 countries are very well represented in this dynamic clusters, contributing nearly 45% of the research front publications. Japan shows a significantly high share of front publications as well, whereas the portion of US publications is rather low. (see table 2.36, 2.37)

A different picture is presented by another large isolated C3-cluster 36, *Radial Basis Networks* (rank 20 in table 2.37), which has a very low immediacy value of 10% and a significantly low contribution to its research front of both, the EU15 and the USA, whereas Japan is well represented in this subfield too.

The other two larger subfields *Diabetic Neuropathy* (90) and *Otoacoustic Emissions/Cochlear Nucleus/Nicotinic Receptors* (85) show as well significant differences from the C3-average regarding their publication shares of the EU15 and the USA in their research fronts. The first one with a high EU15 proportion and a significantly low US proportion, the second one (85) vice versa.

4.1.2.1.2. Neuroscience 1997

In 1997 the number of source publications increased by about 4% to 86197. The source publications in 1997 are citing 7% more publications, of which even about 20% more than in 1996 are highly cited (more than four times). Correspondingly the numbers of clusters on the aggregation levels one to four are growing.

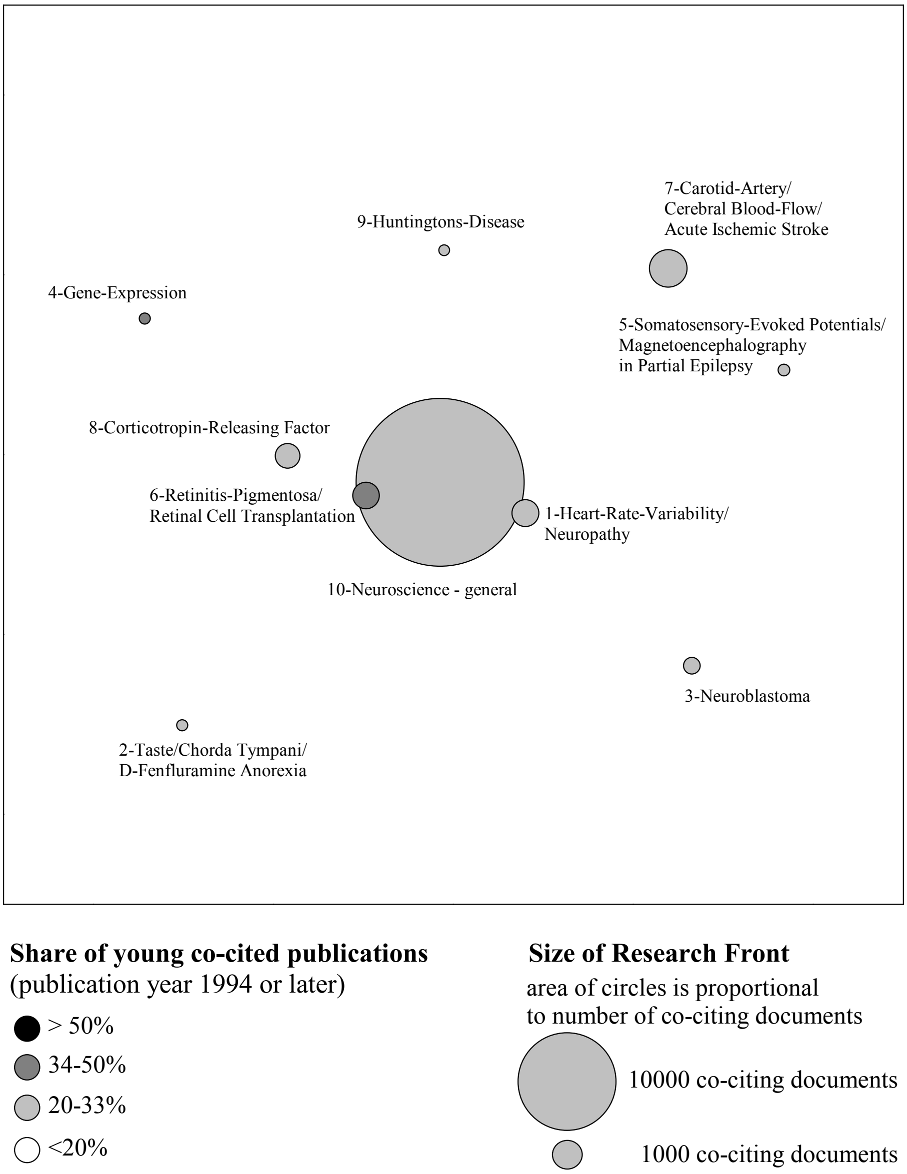


Figure 2.12:
Overview map of neuroscience 1997

Table 2.38:
C4-clusters of neuroscience 1997

Cl.-no.	Title	C3	Core	Front	Imm
1	Heart-Rate-Variability/Neuropathy	3	621	794	22
2	Taste/Chorda Tympani/D-Fenfluramine Anorexia	2	130	143	21
3	Neuroblastoma	3	254	294	22
4	Gene-Expression	2	93	134	37
5	Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy	2	104	151	22
6	Retinitis-Pigmentosa/Retinal Cell Transplantation	2	629	771	41
7	Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke	3	1181	1540	31
8	Corticotropin-Releasing Factor	2	476	659	23
9	Huntingtons-Disease	2	54	126	33
10	Neuroscience - general	45	29068	30197	33

In the overview map of 1997 a large C4-cluster containing the central subfields of neuroscience is positioned in the center of the map, surrounded by smaller satellites like in 1996. These smaller C4-clusters are build of only two or three C3-clusters each. Four larger ones are counting more than 400 source publications at the research fronts, whereas the other five C4-clusters keep just below 300 front publications down to the smallest one, *Huntingtons Disease* (9), with only 126 front publications.

The immediacy values on the C4-cluster level are rather moderate. Only the cluster core of *Retinitis-Pigmentosa/Retinal Cell Transplantation* (6) is build of more than 40% young cited publications. (see table 2.38)

This rather dynamic C4-cluster is positioned in direct vicinity of the large central C4-cluster *Neuroscience – general* (10), as well as *Heart-Rate Variability/Neuropathy* (1) on the other side. The cluster C4-1 with its three included C3-clusters is in many parts a successor of the 1996 isolated C3-cluster *Diabetic Neuropathy* (see table 2.36).

Besides the subfield *Corticotropin-Releasing Factor* (8) on the left side all other clusters are positioned at the periphery of the map. (see figure 2.12)

Table 2.39:
Top national actors of neuroscience1997

Publications	Percent	Countries
31833	39.7	USA
28882	36.0	EU15
7256	9.0	UK
7147	8.9	JAPAN
6701	8.3	GERMANY
4371	5.4	FRANCE
3989	5.0	CANADA
3728	4.6	ITALY
1871	2.3	NETHERLANDS
1833	2.3	SPAIN
1808	2.3	SWEDEN
1808	2.3	AUSTRALIA

Publications	Percent	Countries
1306	1.6	SWITZERLAND
927	1.2	ISRAEL
879	1.1	BELGIUM
850	1.1	FINLAND

The top places of the ranking in table 2.39 do not show any significant changes in comparison with the previous year. Only in the lower half some marginal differences to 1996 can be noticed. Russia leaves the top 15, and Finland participates in 850 publications, 28% more than in 1996 and therefore turns up in the ranking. Another country with a very clearly increasing publication output is Spain with 21% more publications. Though the changes in percent of the total neuroscience publications are rather small, two European countries can be found at the top places, Germany and Italy, which contribute to 14% more neuroscience source publications than in 1996. The same is true for the EU15 countries counted as a whole, whereas the US researchers are participating in a smaller portion of the 1997 neuroscience publications.

Table 2.40:

Top institutional actors of neuroscience1997

Publications	Institution
1378	HARVARD-UNIV, USA
1129	UNIV-TEXAS, USA
772	UNIV-CALIF-LOS-ANGELES, USA
713	YALE-UNIV, USA
712	JOHNS-HOPKINS-UNIV, USA
695	UNIV-CALIF-SAN-DIEGO, USA
678	UNIV-CALIF-SAN-FRANCISCO, USA
668	UNIV-PENN, USA
643	UNIV-WASHINGTON, USA
634	UNIV-PITTSBURGH, USA
627	UNIV-TORONTO, CANADA
623	UNIV-MICHIGAN, USA
613	MCGILL-UNIV, CANADA
527	WASHINGTON-UNIV, USA
513	VET-ADM-MED-CTR, USA

The top institutional actors (table 2.40) are exclusively US institutions (besides the two Canadian institutions University of Toronto and McGill University) and nearly the same as in 1996.

Table 2.41:

Top institutional actors of the EU15 for neuroscience 1997

Publications	Institution
510	KAROLINSKA-INST, SWEDEN
418	UNIV-OXFORD, UNITED KINGDOM
412	UNIV-MILAN, ITALY
377	UNIV-MUNICH, GERMANY

Publications	Institution
363	UNIV-HEIDELBERG, GERMANY
355	UNIV-CAMBRIDGE, UNITED KINGDOM
352	UNIV-TUBINGEN, GERMANY
345	UNIV-HELSINKI, FINLAND
320	UNIV-COLL-LONDON, UNITED KINGDOM
305	UNIV-ROMA-LA-SAPIENZA, ITALY
294	CNRS, FRANCE
282	UNIV-VIENNA, AUSTRIA
272	UNIV-DUSSELDORF, GERMANY
268	INST-PSYCHIAT, UNITED KINGDOM
265	HOP-LA-PITIE-SALPETRIERE, FRANCE
254	UNIV-BRISTOL, UNITED KINGDOM

The ranking of the European actors as shown in table 2.41 has undergone some more changes, although nearly the same institutions can be found in the ranking. The top four ranks are occupied by the same institutions as in 1996 but on the following places some institutions can be found, which increased their publication activity clearly. Most remarkably is the case of the University of Helsinki, in 1996 not among the top 15 it comes up to the ninth rank because of a doubling of their publications in 1997. A considerably growth of publications and therefore a higher rank among the top 15 can be noticed for the British University College London with 76% more neuroscience publications than in 1997.

The German universities of Heidelberg, Düsseldorf, the Austrian University of Vienna and the French CNRS could improve their relative positions due to an increase of their publication output by about 10% and more, whereas the publication counts of the British universities of Oxford and Cambridge as well as those of the University of Tübingen, Germany stagnates or increases by a lesser portion than the whole field.

Table 2.42:

Share of the triad in C4-research fronts for neuroscience1997, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (38.6)	USA (45.1)	Japan (9.5)
1	Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy (5)	151	56.3 ▲	25.8 ▼	15.9 ▲
2	Heart-Rate-Variability/Neuropathy (1)	794	44.8 ▲	30.4 ▼	11.3
3	Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke (7)	1540	41.9 ▲	36.8 ▼	11.6 ▲
4	Neuroscience. general (10)	30197	38.1	45.4	9.1 ▼
5	Neuroblastoma (3)	294	38.1	48.0	10.5
6	Huntingtons-Disease (9)	126	37.3	50.0	6.3
7	Corticotropin-Releasing Factor (8)	659	36.0	48.3	5.0 ▼
8	Retinitis-Pigmentosa/Retinal Cell Transplantation (6)	771	30.7 ▼	55.6 ▲	13.1 ▲
9	Gene-Expression (4)	134	29.9 ▼	56.7 ▲	8.2
10	Taste/Chorda Tympani/D-Fenfluramine Anorexia (2)	143	15.4 ▼	67.8 ▲	21.7 ▲

Table 2.43:

Share of the most active European countries in C4-research fronts for neuroscience1997, ranked by share of EU15

Rank	Title (Cl.-No.)	Front	EU15 (38.6)	UK (10.0)	GER (8.9)	France (6.0)
1	Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy (5)	151	56.3 ▲	2.6	19.9 ▲	9.3
2	Heart-Rate-Variability/Neuropathy (1)	794	44.8 ▲	10.6	8.6	4.2 ▼
3	Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke (7)	1540	41.9 ▲	7.5 ▼	12.5 ▲	4.5 ▼
4	Neuroscience. general (10)	30197	38.1	10.1	8.7	6.1
5	Neuroblastoma (3)	294	38.1	8.5	8.2	5.8
6	Huntingtons-Disease (9)	126	37.3	10.3	7.9	9.5
7	Corticotropin-Releasing Factor (8)	659	36.0	8.0	7.1	6.7
8	Retinitis-Pigmentosa/Retinal Cell Transplantation (6)	771	30.7 ▼	7.3 ▼	9.9	4.4
9	Gene-Expression (4)	134	29.9 ▼	11.2	6.7	6.0
10	Taste/Chorda Tympani/D-Fenfluramine Anorexia (2)	143	15.4 ▼	1.4	1.4	2.8

In case of the EU15 and Japan the publishing activity in the core region of neuroscience as represented by the large C4-cluster *Neuroscience – general* (10) drops back slightly behind their average publication share, whereas the USA are a bit more active compared with their share in the whole C4-research fronts (see table 2.42). In contrast the EU15 shows a significantly strong activity in the subfields *Heart-Rate-Variability/Neuropathy* (1), *Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy* (5) and *Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke* (7), which can be found on the right side of the overview-map.(figure 2.12). In table 2.43 this strong activity is reflected in the German share in the front publications.

The C4-clusters with a US share above the average, for example *Retinitis-Pigmentosa/Retinal Cell Transplantation* (6) or *Corticotropin-Releasing Factor* (8) are positioned on the left side of the overview map.

Among the three most active European countries only Germany reaches significantly high publication shares on C4 research fronts *(Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy* (5), *Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke* (7))

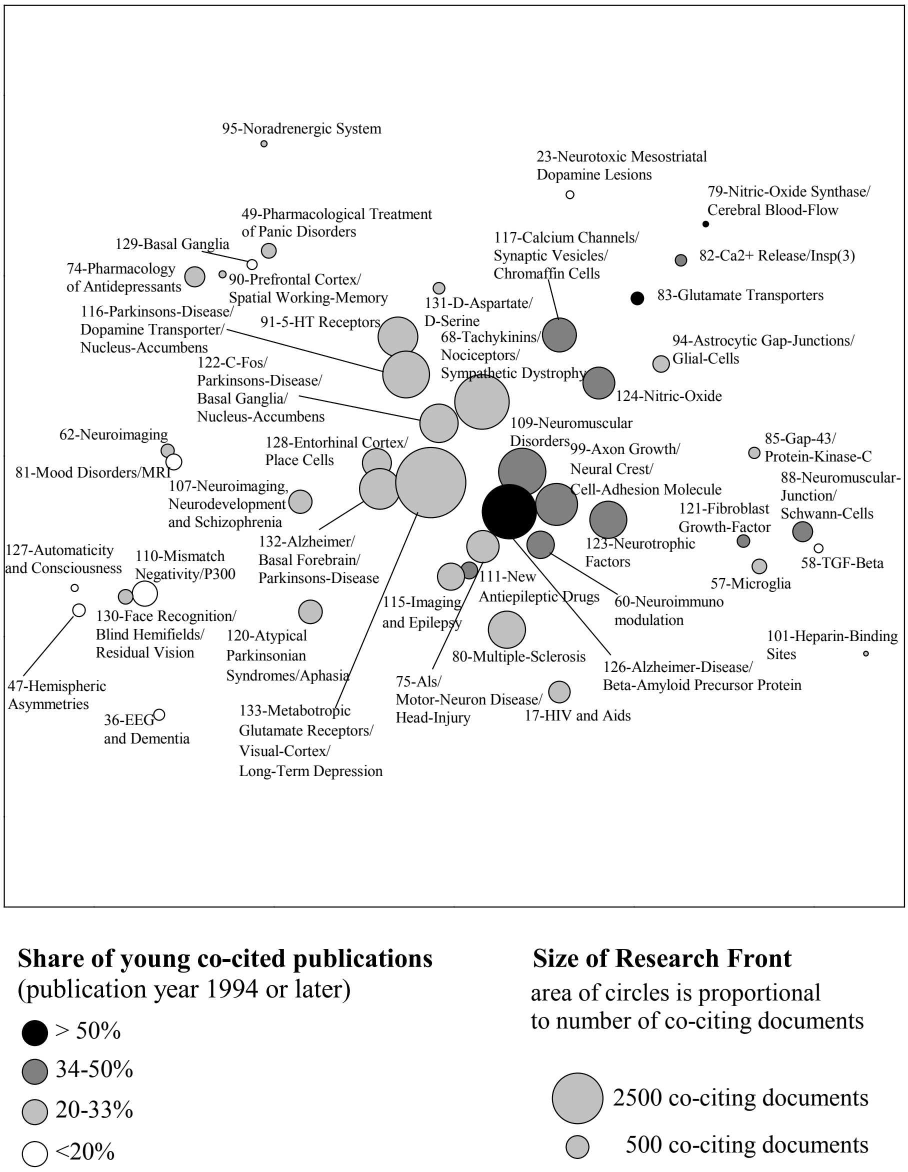


Figure 2.13:

Detailed map of C4-10 Neuroscience – general

Table 2.44:
C3-clusters of C4-10 Neuroscience – general

Cl-no	Title	C2	Core	Front	Imm
133	Metabotropic Glutamate Receptors/Visual-Cortex/Long-Term Depression	45	3623	5393	29
68	Tachykinins/Nociceptors/Sympathetic Dystrophy	41	2839	3220	29
126	Alzheimer-Disease/Beta-Amyloid Precursor Protein	28	1979	3184	51
109	Neuromuscular Disorders	45	1959	2446	39
116	Parkinsons-Disease/Dopamine Transporter/Nucleus-Accumbens	21	1835	2387	28
99	Axon Growth/Neural Crest/Cell-Adhesion Molecule	27	2040	1927	40
132	Alzheimer/Basal Forebrain/Parkinsons-Disease	10	825	1809	23
91	5-HT Receptors	23	1402	1707	32
122	C-Fos/Parkinsons-Disease/Basal Ganglia/Nucleus-Accumbens	6	1060	1622	26
123	Neurotrophic Factors	9	939	1515	44
80	Multiple-Sclerosis	12	1341	1508	32
117	Calcium Channels/Synaptic Vesicles/Chromaffin Cells	14	907	1256	44
75	Als/Motor-Neuron Disease/Head-Injury	13	770	1145	28
124	Nitric-Oxide	12	618	1118	47
128	Entorhinal Cortex/Place Cells	4	618	924	25
60	Neuroimmunomodulation	9	638	819	36
115	Imaging and Epilepsy	12	580	797	26
110	Mismatch Negativity/P300	8	589	689	17
120	Atypical Parkinsonian Syndromes/Aphasia	3	499	601	27
107	Neuroimaging, Neurodevelopment and Schizophrenia	8	436	596	27
17	HIV and Aids	4	455	516	30
74	Pharmacology of Antidepressants	9	425	442	33
88	Neuromuscular-Junction/Schwann-Cells	17	386	435	37
111	New Antiepileptic Drugs	5	231	317	39
94	Astrocytic Gap-Junctions/Glial-Cells	5	209	296	33
81	Mood Disorders/MRI	2	223	279	13
49	Pharmacological Treatment of Panic Disorders	2	221	250	21
57	Microglia	11	155	240	25
130	Face Recognition/Blind Hemifields/Residual Vision	3	145	231	26
62	Neuroimaging	2	126	201	24
83	Glutamate Transporters	2	78	185	61
47	Hemispheric Asymmetries	4	122	183	6
121	Fibroblast Growth-Factor	2	99	175	39
131	D-Aspartate/D-Serine	2	107	156	30
85	Gap-43/Protein-Kinase-C	2	107	148	28
82	Ca2+ Release/Insp(3)	3	98	145	46
36	EEG and Dementia	3	111	136	17
129	Basal Ganglia	3	72	115	18
58	TGF-Beta	3	52	88	15
23	Neurotoxic Mesostriatal Dopamine Lesions	3	41	72	14
90	Prefrontal Cortex/Spatial Working-Memory	2	28	57	21
127	Automaticity and Consciousness	2	14	55	0
95	Noradrenergic System	2	22	43	22
79	Nitric-Oxide Synthase/Cerebral Blood-Flow	2	25	39	60
101	Heparin-Binding Sites	2	19	25	31

The co-citation map in figure 2.13 shows the 45 C3-clusters (see also table 2.44) affiliated to the large central C4-cluster *Neuroscience – general* (10) and their co-citation relations in a 2-dimensional space. A very large C3-cluster, *Metabotropic*

Glutamate Receptors/Visual-Cortex/Long-Term Depression (133) with more than 5000 source publications at its research front forms the center of the map. From the 1996 perspective its core is build mainly by parts of the 1996 C3-clusters *Glutamate Receptors/Associative Synaptic Plasticity* (15) and *Mammalian Saccadic System/Supplementary Motor Cortex/Dementia* (2) and parts of further medium sized subfields of the center region. Further four rather large C3-clusters with more than 2000 front publications can be found in the 1997 map, for example *Tachykinins/Nociceptors/Sympathetic Dystrophy* (68) and *Alzheimer/Beta-Amyloid Precursor Protein* (126).

The C3-subfield 126, containing more than 50% young cited documents (published after 1993), is by far the most dynamic large subfield in 1997, as symbolized by the dark shade of the corresponding circle. It is a successor of the 1996 C3-*cluster Alzheimer/Apoptosis/Brain Tumors* (1). In the direct vicinity of the "Alzheimer" subfield and also on the right hand periphery of the map further relative dynamic subfields can be found, whereas on the left side subfields with lower or medium immediacy values are predominant.

Other subjects, which turned up already in the 1996 map of the "Neuroscience – general" cluster, as neurotrophic factors or HIV, can be found in the 1997 map again, but some are appearing in the central C4-cluster the first time – for example epilepsy. The epilepsy relevant C3-clusters *Imaging and Epilepsy* (115) and *New Antiepileptic Drugs* (111) are successors of the 1996 C4-cluster *Epilepsy* (4) (see overview map for 1996, figure 2.10).

Other new subjects are visible as autonomous C3-clusters in the center C4-subfield, like *Multiple Sclerosis* (80) or *Nitric-Oxide* (124). The core documents of these clusters were integrated in the largest 1996 C3-cluster *Immuno-Neuro-Endocrine Interactions* (48).

Table 2.45:

Share of the triad in C3-research fronts of C4-10, ranked by share of the EU15

Rank	Title (CL.-No.)	Front	EU15 (40.0)	USA (46.3)	Japan (9.9)
1	EEG and Dementia (36)	136	55.1 ▲	21.3 ▽	7.4
2	New Antiepileptic Drugs (111)	317	49.2 ▲	34.4 ▽	4.4 ▽
3	Face Recognition/Blind Hemifields/Residual Vision (130)	231	48.5 ▲	47.2	3.5 ▽
4	Automaticity and Consciousness (127)	55	47.3	41.8	0 ▽
5	Atypical Parkinsonian Syndromes/Aphasia (120)	601	46.4 ▲	38.9 ▽	10.6
6	Mismatch Negativity/P300 (110)	689	45.6 ▲	42.4 ▽	4.2 ▽
7	Pharmacological Treatment of Panic Disorders (49)	250	45.6	34.0 ▽	4.8 ▽
8	Multiple-Sclerosis (80)	1508	45.2 ▲	41.5 ▽	7.0 ▽
9	5-HT Receptors (91)	1707	44.9 ▲	41.4 ▽	5.8 ▽
10	Neurotoxic Mesostriatal Dopamine Lesions (23)	72	44.4	38.9	5.6
11	HIV and Aids (17)	516	42.1	44.8	7.6
12	D-Aspartate/D-Serine (131)	156	41.7	38.5	14.7 ▲
13	Astrocytic Gap-Junctions/Glial-Cells (94)	296	40.5	46.3	4.1 ▽
14	Gap-43/Protein-Kinase-C (85)	148	39.9	43.2	5.4
15	Pharmacology of Antidepressants (74)	442	39.8	39.8 ▽	7.0 ▽
16	Glutamate Transporters (83)	185	39.5	43.2	13.5
17	Neurotrophic Factors (123)	1515	39.2	47.3	11.0
18	Alzheimers-Disease/Basal Forebrain/Parkinsons-Disease (132)	1809	39.1	47.4	6.2 ▽
19	Microglia (57)	240	38.8	42.5	9.2
20	Calcium Channels/Synaptic Vesicles/Chromaffin Cells (117)	1256	38.6	43.5 ▽	9.6
21	Metabotropic Glutamate Receptors/Visual-Cortex/Long-Term Depression (133)	5393	38.4 ▽	48.0 ▲	7.3 ▽
22	TGF-Beta (58)	88	37.5	47.7	9.1
23	Axon Growth/Neural Crest/Cell-Adhesion Molecule (99)	1927	37.4 ▽	52.3 ▲	11.1
24	Noradrenergic System (95)	43	37.2	48.8	11.6
25	Entorhinal Cortex/Place Cells (128)	924	37.1	50.8 ▲	4.9 ▽
26	Neuroimmunomodulation (60)	819	37.0	46.9	10.3
27	Neuromuscular Disorders (109)	2446	36.4 ▽	52.0 ▲	9.2
28	Neuroimaging. Neurodevelopment and Schizophrenia (107)	596	35.9 ▽	55.7 ▲	2.3 ▽
29	Tachykinins/Nociceptors/Sympathetic Dystrophy (68)	3220	35.8 ▽	42.8 ▽	9.3
30	Neuromuscular-Junction/Schwann-Cells (88)	435	35.4 ▽	49.7	11.5
31	Nitric-Oxide (124)	1118	34.9 ▽	44.4	12.1 ▲
32	Als/Motor-Neuron Disease/Head-Injury (75)	1145	34.5 ▽	48.8	8.1 ▽
33	Alzheimer-Disease/Beta-Amyloid Precursor Protein (126)	3184	34.3 ▽	51.6 ▲	12.1 ▲
34	Mood Disorders/MRI (81)	279	34.1 ▽	51.6	4.3 ▽
35	Parkinsons-Disease/Dopamine Transporter/Nucleus-Accumbens (116)	2387	33.5 ▽	51.1 ▲	5.9 ▽
36	Imaging and Epilepsy (115)	797	33.0 ▽	45.7	7.7 ▽
37	Neuroimaging (62)	201	32.3 ▽	54.2 ▲	4.5 ▽
38	Fibroblast Growth-Factor (121)	175	32.0 ▽	46.9	13.1
39	C-Fos/Parkinsons-Disease/Basal Ganglia/Nucleus-Accumbens (122)	1622	31.9 ▽	50.6 ▲	8.8
40	Nitric-Oxide Synthase/Cerebral Blood-Flow (79)	39	28.2	64.1 ▲	5.1
41	Prefrontal Cortex/Spatial Working-Memory (90)	57	28.1	68.4 ▲	7.0
42	Heparin-Binding Sites (101)	25	28.0	56.0	24.0 ▲
43	Hemispheric Asymmetries (47)	183	27.9 ▽	47.0	1.6
44	Basal Ganglia (129)	115	23.5 ▽	54.8	9.6
45	Ca2+ Release/Insp(3) (82)	145	20.0 ▽	56.6 ▲	14.5

Table 2.46:
Share of the most active European countries in C3-research fronts of C4-10, ranked by share of EU15

Rank	Title (Cl.-No.)	Front	EU15 (40.0)	UK (10.1)	GER (9.2)	F (6.3)
1	EEG and Dementia (36)	136	55.1 ▲	2.2	22.1 ▲	8.1
2	New Antiepileptic Drugs (111)	317	49.2 ▲	15.5 ▲	8.2	6.3
3	Face Recognition/Blind Hemifields/Residual Vision (130)	231	48.5 ▲	25.1 ▲	13.0 ▲	5.6
4	Automaticity and Consciousness (127)	55	47.3	7.3	10.9	5.5
5	Atypical Parkinsonian Syndromes/Aphasia (120)	601	46.4 ▲	19.1 ▲	7.0	8.3 ▲
6	Mismatch Negativity/P300 (110)	689	45.6 ▲	8.1	15.7 ▲	4.2 ▼
7	Pharmacological Treatment of Panic Disorders (49)	250	45.6	8.8	6.4	8.8
8	Multiple-Sclerosis (80)	1508	45.2 ▲	12.3 ▲	9.0	5.2
9	5-HT Receptors (91)	1707	44.9 ▲	13.6 ▲	5.3 ▼	8.1 ▲
10	Neurotoxic Mesostriatal Dopamine Lesions (23)	72	44.4	11.1	11.1	12.5 ▲
11	HIV and Aids (17)	516	42.1	7.6	6.2 ▼	8.7 ▲
12	D-Aspartate/D-Serine (131)	156	41.7	13.5	8.3	3.2
13	Astrocytic Gap-Junctions/Glial-Cells (94)	296	40.5	5.4 ▼	15.9 ▲	7.1
14	Gap-43/Protein-Kinase-C (85)	148	39.9	8.8	9.5	5.4
15	Pharmacology of Antidepressants (74)	442	39.8	8.1	10.4	6.3
16	Glutamate Transporters (83)	185	39.5	9.2	10.3	6.5
17	Neurotrophic Factors (123)	1515	39.2	9.1	8.9	5.9
18	Alzheimers-Disease/Basal Forebrain/Parkinsons-Disease (132)	1809	39.1	10.7	6.6 ▼	4.5 ▼
19	Microglia (57)	240	38.8	7.5	13.8 ▲	3.8
20	Calcium Channels/Synaptic Vesicles/Chromaffin Cells (117)	1256	38.6	10.0	9.2	6.5
21	Metabotropic Glutamate Receptors/Visual-Cortex/Long-Term Depression (133)	5393	38.4 ▼	11.3 ▲	10.3 ▲	5.9
22	TGF-Beta (58)	88	37.5	4.5	11.4	4.5
23	Axon Growth/Neural Crest/Cell-Adhesion Molecule (99)	1927	37.4 ▼	11.7 ▲	11.9 ▲	8.1 ▲
24	Noradrenergic System (95)	43	37.2	14.0	7.0	4.7
25	Entorhinal Cortex/Place Cells (128)	924	37.1	13.7 ▲	8.1	6.8
26	Neuroimmunomodulation (60)	819	37.0	6.2 ▼	8.5	5.5
27	Neuromuscular Disorders (109)	2446	36.4 ▼	9.2	8.7	8.3 ▲
28	Neuroimaging. Neurodevelopment and Schizophrenia (107)	596	35.9 ▼	14.1 ▲	8.9	4.2 ▼
29	Tachykinins/Nociceptors/Sympathetic Dystrophy (68)	3220	35.8 ▼	9.2	7.4 ▼	5.6
30	Neuromuscular-Junction/Schwann-Cells (88)	435	35.4 ▼	12.2	7.6	4.8
31	Nitric-Oxide (124)	1118	34.9 ▼	8.3 ▼	7.8	4.4 ▼
32	Als/Motor-Neuron Disease/Head-Injury (75)	1145	34.5 ▼	10.2	10.9	4.1 ▼
33	Alzheimer-Disease/Beta-Amyloid Precursor Protein (126)	3184	34.3 ▼	8.2 ▼	9.5	5.1 ▼
34	Mood Disorders/MRI (81)	279	34.1 ▼	10.4	7.5	2.9 ▼
35	Parkinsons-Disease/Dopamine Transporter/Nucleus-Accumbens (116)	2387	33.5 ▼	7.5 ▼	5.8 ▼	5.6
36	Imaging and Epilepsy (115)	797	33.0 ▼	8.9	7.2 ▼	5.4
37	Neuroimaging (62)	201	32.3 ▼	11.4	5.5	2.5 ▼
38	Fibroblast Growth-Factor (121)	175	32.0 ▼	8.6	10.3	4.0
39	C-Fos/Parkinsons-Disease/Basal Ganglia/Nucleus-Accumbens (122)	1622	31.9 ▼	7.1 ▼	5.9 ▼	6.6
40	Nitric-Oxide Synthase/Cerebral Blood-Flow (79)	39	28.2	2.6	15.4	5.1
41	Prefrontal Cortex/Spatial Working-Memory (90)	57	28.1	8.8	10.5	1.8
42	Heparin-Binding Sites (101)	25	28.0	4.0	0	8.0
43	Hemispheric Asymmetries (47)	183	27.9 ▼	8.7	8.2	6.0

Rank	Title (Cl.-No.)	Front	EU15 (40.0)	UK (10.1)	GER (9.2)	F (6.3)
44	Basal Ganglia (129)	115	23.5 ▼	7.8	5.2	3.5
45	Ca2+ Release/Insp(3) (82)	145	20.0 ▼	7.6	4.8	1.4

In 1997 some more C3-clusters inside the large and central Neuroscience cluster show a significantly high share of publications with participation of EU15 countries. Among these seven C3-clusters two large subfields, *Multiple Sclerosis* (80) and *5-HT-T Receptors* (91), and two medium sized subfields, *Atypical Parkinsonian Syndromes/Aphasia* (120) and *Mismatch Negativity/P300* (110) can be found, each with more than 500 publications at their research fronts.

In almost all of the top EU15 clusters the activity of the USA and Japan is significantly low. But such a correlation between the activity profiles of the USA and Japan can be observed only for the top ranked subfields in the table with a high portion of EU15 publications.

In the table 2.46 each of the large European national actors reveals a somewhat special profile of publication activity. Significantly high publication shares of two or three of the listed countries at the same time are rare. In three cases the United Kingdom and Germany are represented on the same research front clearly above their C3-level average: *Face Recognition/Blind Hemifields/Residual Vision* (130), a subfield with a high EU15 share on rank 3 and two large clusters with a significant low EU15 share, *Metabotropic Glutamate Receptors/Visual-Cortex/Long-Term Depression* (133) on rank 21 *and Axon Growth/Neural Crest/Cell-Adhesion Molecule* (99) on rank 23. The last one, C3-cluster 99, shows a significant high participation of France too.

Table 2.47:

C3-Isolates of neuroscience 1997 with more than 100 front publications

Cl-nr.	Title	C2	Core	Front	Imm
106	Suprachiasmatic Nucleus/Circadian Clock/Melatonin	10	749	774	34
100	Cochlear Nucleus/Hair Cells	7	846	736	20
13	Neuropeptide-Y	2	443	530	40
87	Transcranial Magnetic Stimulation/Motor Cortex	9	440	519	18
30	Neural Networks	4	258	516	15
65	Nicotinic Acetylcholine-Receptors	11	426	476	35
51	Bipolar Cells in the Retina	2	345	346	24
26	Sleep Disorders	4	266	311	24
28	Blood-Brain-Barrier/Endothelial-Cells	3	231	309	19
64	Chronic Low-Back-Pain/Chronic-Fatigue-Syndrome	7	277	307	16
77	Sigma-Receptor Ligands/Neuroactive Steroids	4	202	296	26
73	Mitochondrial Encephalomyopathies/Mitochondrial-DNA	3	231	275	36
31	Tourettes-Syndrome/Obsessive-Compulsive Disorder	3	257	247	23
2	Dural Arteriovenous-Malformations	2	199	219	21
86	Antennal Lobe Neurons/Memory in Drosophila	3	175	211	23
84	Muscarinic Receptor in Smooth-Muscle	2	140	202	28
55	Somatostatin Receptor/Growth Hormone	5	192	197	29
18	Prenatal Cocaine/Fetal Alcohol Exposure	3	201	195	14

Cl-nr.	Title	C2	Core	Front	Imm
29	Sleep and Epilepsy/Genetics of Epilepsy	2	169	195	24
14	Botulinum Toxin/Cerebral-Palsy	2	129	186	33
89	RNA-Binding Proteins/Small-Cell Lung-Cancer	4	134	179	37
12	Critically Ill Polyneuropathy	2	128	173	28
39	Lysophosphatidic Acid/Plasminogen-Activator	3	109	156	50
43	Systemic Lupus-Erythematosus/Cerebral Venous Thrombosis	3	138	153	21
25	Meningiomas/Gamma-Knife Radiosurgery	2	112	137	16
46	G-Proteins	2	84	125	26
3	Acoustic Neuromas/Vestibular Schwannomas	2	101	119	19
108	Lazaroids/Cerebral-Ischemia/Spinal-Cord Injury	3	71	112	16
33	Ethanol-Metabolism in the Brain	2	71	101	25

Table 2.48:

Share of the triad in research fronts of C3-isolates for neuroscience1997, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (40.0)	USA (46.3)	Japan (9.9)
1	Somatostatin Receptor/Growth Hormone (55)	197	58.4 ▲	29.4 ▼	9.1
2	Sleep and Epilepsy/Genetics of Epilepsy (29)	195	50.3 ▲	24.6 ▼	5.1 ▼
3	Mitochondrial Encephalomyopathies/Mitochondrial-DNA (73)	275	46.9 ▲	30.2 ▼	14.2 ▲
4	Acoustic Neuromas/Vestibular Schwannomas (3)	119	46.2	33.6 ▼	10.1
5	Meningiomas/Gamma-Knife Radiosurgery (25)	137	43.1	32.1 ▼	19.7 ▲
6	Transcranial Magnetic Stimulation/Motor Cortex (87)	519	42.0	28.7 ▼	9.2
7	Botulinum Toxin/Cerebral-Palsy (14)	186	41.4	36.0 ▼	5.4 ▼
8	RNA-Binding Proteins/Small-Cell Lung-Cancer (89)	179	40.2	45.3	11.2
9	Systemic Lupus-Erythematosus/Cerebral Venous Thrombosis (43)	153	39.9	40.5	3.9 ▼
10	Muscarinic Receptor in Smooth-Muscle (84)	202	39.6	49.5	8.4
11	Neural Networks (30)	516	39.5	32.2 ▼	8.5
12	Antennal Lobe Neurons/Memory in Drosophila (86)	211	39.3	51.7	4.3 ▼
13	Sleep Disorders (26)	311	37.6	49.5	1.9 ▼
14	Blood-Brain-Barrier/Endothelial-Cells (28)	309	37.5	46.0	14.9 ▲
15	Suprachiasmatic Nucleus/Circadian Clock/Melatonin (106)	774	37.1	41.7 ▼	10.6
16	Neuropeptide-Y (13)	530	37.0	50.6 ▲	4.5 ▼
17	Critically Ill Polyneuropathy (12)	173	36.4	39.9	4.0 ▼
18	Dural Arteriovenous-Malformations (2)	219	36.1	35.6 ▼	15.5 ▲
19	Bipolar Cells in the Retina (51)	346	35.8	43.1	12.7
20	Ethanol-Metabolism in the Brain (33)	101	33.7	46.5	10.9
21	Chronic Low-Back-Pain/Chronic-Fatigue-Syndrome (64)	307	33.6 ▼	48.5	.7
22	Cochlear Nucleus/Hair Cells (100)	736	33.3 ▼	54.8 ▲	5.7 ▼
23	G-Proteins (46)	125	31.2 ▼	40.8	9.6
24	Nicotinic Acetylcholine-Receptors (65)	476	30.9 ▼	58.8 ▲	5.3 ▼
25	Sigma-Receptor Ligands/Neuroactive Steroids (77)	296	30.7 ▼	48.6	6.8
26	Lazaroids/Cerebral-Ischemia/Spinal-Cord Injury (108)	112	27.7 ▼	52.7	8.9
27	Lysophosphatidic Acid/Plasminogen-Activator (39)	156	27.6 ▼	52.6	20.5 ▲
28	Tourettes-Syndrome/Obsessive-Compulsive Disorder (31)	247	27.1 ▼	59.5 ▲	2.4 ▼
29	Prenatal Cocaine/Fetal Alcohol Exposure (18)	195	22.1 ▼	67.2 ▲	4.1 ▼

The largest isolated C3-clusters having a research front of more than 100 publications are listed in tables 2.47 with the number of included C2-clusters, core and front size as well as their immediacy value and in table 2.48, showing the publication shares of the triad countries at their research fronts.

As in 1996 some larger subfields with more than 400 publications can be found on top of table 2.47. The subfields *Suprachiasmatic Nucleus/Circadian Clock/Melatonin* (106) with 774 front publications (the largest isolated C3-cluster) and *Neuropeptide-Y* (13) have there 1996 equivalent in the C4-clusters *Circadian Rythm/MS and EM Fields* (2) and *Neuropeptides/Obesity/Growth/Fertility* (3), whereas the C3-clusters *Cochlear Nucleus/Hair Cells* (100) and *Nicotinic Acetylcholine-Receptors* (65) are both successors of the large 1996 isolated subfield *Otoacoustic Emissions/Cochlear Nucleus/Nicotinic Receptors* (85). All these above mentioned large C3-isolates show a relatively weak performance of the EU15, which could be observed in 1996 for their predecessors already. The subfield *Neural Network* (30) in contrast shows an average share of EU15 publications, whereas its predecessor in 1996, *Radial Basis Function*

Networks (36) was significantly below the average in terms of EU15 contribution. The sixth 1997 C3-isolate with more than 400 front publications, *Transcranial Magnetic Stimulation/Motor Cortex* (87), is a “new” cluster on the C3-level, with clustered core documents, which were in 1996 mainly clustered in different isolated clusters from lower cluster levels.

4.1.2.1.3. Neuroscience 1998

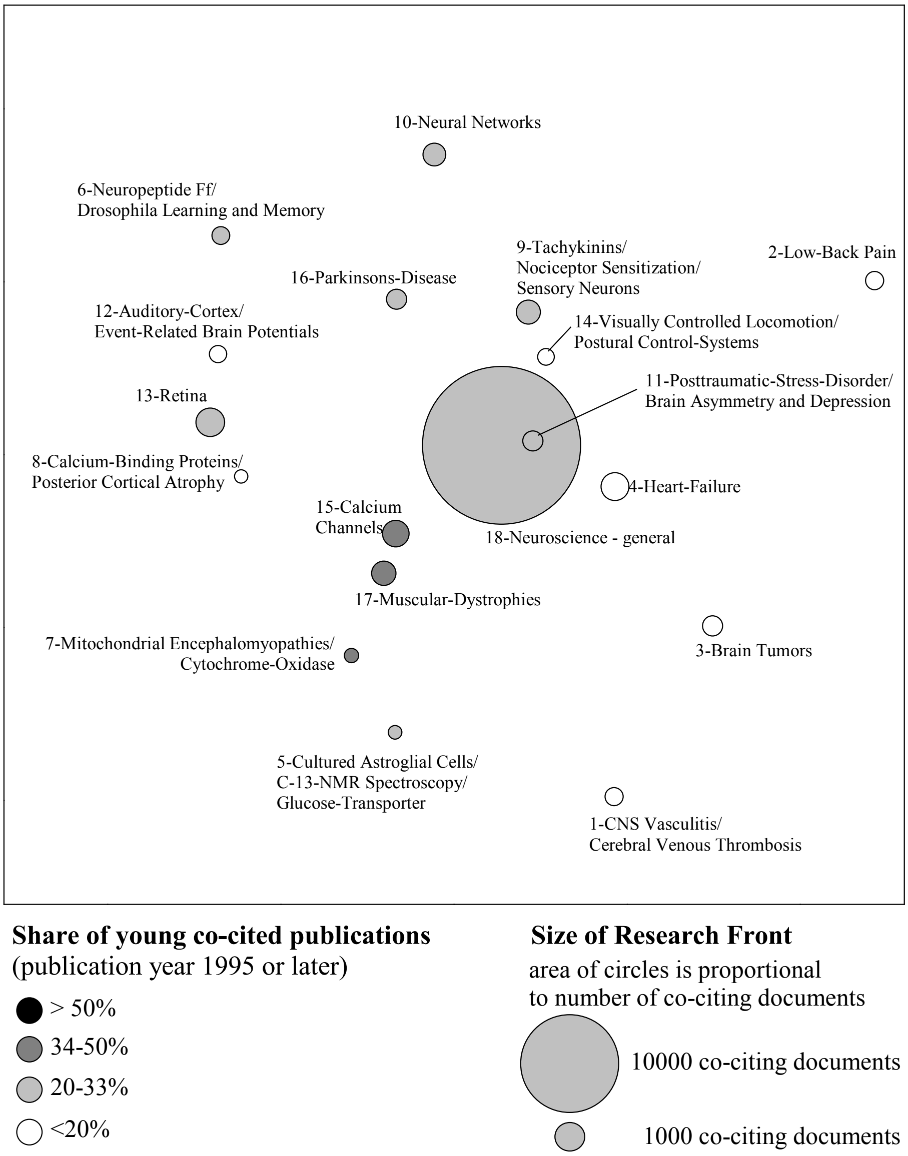


Figure 2.14:
Overview map of neuroscience 1998

Table 2.49:
C4-clusters of neuroscience 1998

Cl.-no	Title	C3	Core	Front	Imm
18	Neuroscience – general	45	24332	26741	32
13	Retina	2	782	882	27
4	Heart-Failure	3	591	857	18
15	Calcium Channels	3	620	770	38
17	Neuroscience – general	3	689	655	42
9	Tachykinins/Nociceptor Sensitization/Sensory Neurons	2	527	636	24
10	Neural Networks	2	275	561	20
11	Posttraumatic-Stress-Disorder/Brain Asymmetry and Depression	2	330	447	24
16	Parkinsons-Disease	3	290	438	27
3	Brain Tumors	2	377	437	14
1	CNS Vasculitis/Cerebral Venous Thrombosis	2	308	368	17
2	Low-Back Pain	3	292	367	17
6	Neuropeptide Ff/Drosophila Learning and Memory	2	367	349	28
12	Auditory-Cortex/Event-Related Brain Potentials	2	384	326	17
14	Visually Controlled Locomotion/Postural Control-Systems	3	259	304	19
7	Mitochondrial Encephalomyopathies/Cytochrome-Oxidase	2	165	220	39
5	Cultured Astroglial Cells/C-13-NMR Spectroscopy/Glucose-Transporter	2	150	206	28
8	Calcium-Binding Proteins/Posterior Cortical Atrophy	2	110	196	18

In 1998, the last year of the reporting period, the co-citation cluster analysis results again in one very large and central C4-cluster, *Neuroscience – general* (18) with 26741 front publications and 24332 highly cited publications in the cluster core, but in this year once more surrounded by an clearly increased number of smaller subfields with a front size from 196 (*Calcium-Binding Proteins/Posterior Cortical Atrophy* (8)) to 882 source publications (*Retina* (13))

Many of the smaller subfields in the neighborhood of *Neuroscience – general* (18) contain to a large part cited documents which are previously clustered in subfields included in the large central 1997 C4-cluster. The subfields *Muscular-Dystrophies* (17) and *Calcium Channels* (15) for example are both in parts successors of C2-clusters affiliated to the 1997 C3-cluster *Neuromuscular Disorders* (109). The last one (15) includes also parts of the 1997 C3-cluster *Calcium Channels/Synaptic Vesicles/Chromaffin Cells* (117). Another example is *Tachykinins/Nociceptor Sensitization/Sensory Neurons* (9), which can be seen as one of the successors of the 1997 C3-cluster *Tachykinins/Nociceptors/Sympathetic Dystrophy* (68). Other parts of this 1997 subfield are clustered in different subfields included in the 1998 *Neuroscience – general* cluster.

One of the neighbored C4-clusters of C4-18, the cluster *Heart-Rate Failure* is a direct successor of the 1997 C4-cluster *Heart-Rate Variability/Neuropathy* (1).

Another subject area, which is represented in 1998 by a C4-cluster is *Retina* (13) on the left side of the map. It includes a C3-cluster, whose clustered publications were in 1997 affiliated to an isolated C3-cluster (Bipolar Cells in the Retina) and therefore has moved more to the periphery.

Examples for C4-clusters which come mainly or exclusively from 1997 C3-isolates are *Neural Networks* (10) on the upper periphery and *Low-Back Pain* (2) positioned on the right margin of the map.

Table 2.50:

Top national actors of neuroscience1998

Publications	Percent	Countries
32679	37.8	EUROPE
32513	37.6	USA
8173	9.4	GERMANY
7997	9.2	UK
7602	8.8	JAPAN
4894	5.7	FRANCE
4105	4.7	ITALY
4005	4.6	CANADA
2295	2.7	SPAIN
2116	2.4	NETHERLANDS
2052	2.4	SWEDEN
1897	2.2	AUSTRALIA
1524	1.8	SWITZERLAND
1419	1.6	ISRAEL
1021	1.2	RUSSIA
919	1.1	BELGIUM

The top 15 countries of neuroscience in 1998 mainly did not change very much regarding their place in the ranking. Only Germany ranks clearly higher, appearing now as the most active European country. The publication activity of the EU15 just exceeds those of the USA because of an increase clearly above the growth of the total field.

The countries show a different increase in publications. Three countries, Germany, Spain, and Israel increased their activity by more than 20%, whereas the publication activity of the USA grows only by 2%, and Japan, Canada, Australia and Belgium show an increase below the total field average of about 8%,. Finland falls out of the top 15 group because of a decrease of publications about 5%.

Table 2.51

Top institutional actors of neuroscience1998

Publications	Institution
1315	HARVARD-UNIV, USA
1138	UNIV-TEXAS, USA
834	UNIV-CALIF-LOS-ANGELES, USA
727	UNIV-PENN, USA
714	UNIV-CALIF-SAN-DIEGO, USA
681	UNIV-CALIF-SAN-FRANCISCO, USA
674	UNIV-PITTSBURGH, USA
660	JOHNS-HOPKINS-UNIV, USA
652	UNIV-TORONTO, CANADA
651	UNIV-WASHINGTON, USA

Publications	Institution
629	YALE-UNIV, USA
595	KAROLINSKA-INST, SWEDEN
578	MCGILL-UNIV, CANADA
573	UNIV-MICHIGAN, USA
535	WASHINGTON-UNIV, USA
516	STANFORD-UNIV, USA
510	DUKE-UNIV, USA

The institutional actors of the neuroscience are in 1998 again dominated by US institutions. The ranking of the top 15 institutions has changed only marginal, but an European institution, the Swedish Karolinska Institute could join the top 15 group the first time.

Table 2.52:
Top institutional actors of the EU15 for neuroscience 1998

Publications	Institution
595	KAROLINSKA-INST, SWEDEN
490	UNIV-OXFORD, UNITED KINGDOM
452	UNIV-CAMBRIDGE, UNITED KINGDOM
451	UNIV-MILAN, ITALY
442	UNIV-COLL-LONDON, UNITED KINGDOM
405	UNIV-MUNICH, GERMANY
399	CNRS, FRANCE
391	UNIV-TUBINGEN, GERMANY
378	UNIV-HEIDELBERG, GERMANY
318	UNIV-ROMA-LA-SAPIENZA, ITALY
317	INSERM, FRANCE
308	UNIV-HELSINKI, FINLAND
303	INST-PSYCHIAT, UNITED KINGDOM
300	UNIV-VIENNA, AUSTRIA
297	HOP-LA-PITIE-SALPETRIERE, FRANCE

Table 2.52 shows the top 15 institutional actors of the EU15, leaded by the Swedish Karolinska Institute - as already in 1996 and 1997. Another Scandinavian institution, the University of Helsinki, which ranked eighth in 1997 drops back to the twelfth place due to a decrease of publication output by 9%. On the other hand the British university of Cambridge and the University College London, as well as the French institutions CNRS and INSERM increased in publication count by 25% or more.

Table 2.53:
Share of the triad in C4-research fronts for neuroscience1998, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (41.1)	USA (46.8)	Japan (9.8)
1	Tachykinins/Nociceptor Sensitization/Sensory Neurons (9)	636	51.7 ▲	34.9 ▼	10.2
2	Visually Controlled Locomotion/Postural Control-Systems (14)	304	48.4 ▲	41.8	7.2
3	Muscular-Dystrophies (17)	655	47.2 ▲	42.3 ▼	8.5
4	Mitochondrial Encephalomyopathies/Cytochrome-Oxidase (7)	220	45.5	34.1 ▼	15.5 ▲

Rank	Title (CL.-No.)	Front	EU15 (41.1)	USA (46.8)	Japan (9.8)
5	Neural Networks (10)	561	45.3 ▲	30.7 ▼	9.6
6	Cultured Astroglial Cells/C-13-NMR Spectroscopy/Glucose-Transporter (5)	206	45.1	39.8 ▼	8.3
7	Parkinsons-Disease (16)	438	42.5	41.3 ▼	4.1 ▼
8	Neuropeptide Ff/Drosophila Learning and Memory (6)	349	42.1	43.8	9.7
9	Heart-Failure (4)	857	41.8	37.5 ▼	13.8 ▲
10	Calcium-Binding Proteins/Posterior Cortical Atrophy (8)	196	41.3	42.9	10.2
11	CNS Vasculitis/Cerebral Venous Thrombosis (1)	368	41.3	34.0 ▼	7.9
12	Neuroscience - general(18)	26741	38.5 ▼	45.5 ▼	9.2 ▼
13	Retina (13)	882	38.5	49.9	10.0
14	Low-Back Pain (2)	367	38.4	43.9	3.5 ▼
15	Brain Tumors (3)	437	34.3 ▼	49.2	5.0 ▼
16	Calcium Channels (15)	770	33.6 ▼	56.2 ▲	9.9
17	Posttraumatic-Stress-Disorder/Brain Asymmetry and Depression (11)	447	32.0 ▼	55.5 ▲	2.7 ▼
18	Auditory-Cortex/Event-Related Brain Potentials (12)	326	27.6 ▼	57.1 ▲	4.6 ▼

Table 2.53 shows the activity profiles for the triad countries on the C4-cluster level in 1997 and reveals an activity of the EU15 clearly below the C4-level average, but the same can be observed for the USA and Japan, though their publication shares are only slightly below the average. Regarding the smaller C4-clusters the shaping of the activity profiles of the USA and the EU15 is rather different. The subfields on the top ranks of table 2.53 (mainly with a significant higher share of the EU15) are all showing a contribution of the USA clearly below its C4-level average. At the research fronts of the three C4-clusters at the end of the table the relation of the relative strength is exactly the opposite.

Japan is extraordinary active at the research fronts of *Heart Failure* (4) and *Mitochondrial Encephalomyopathies/Cytochrome-Oxidase* (7).

Table 2.54:

Share of the most active European countries in C4-research fronts for neuroscience1998, ranked by share of EU15

Rank	Title (Cl.-No.)	Front	EU15 (41.4)	UK (10.4)	GER (10.2)	F (6.5)
1	Tachykinins/Nociceptor Sensitization/Sensory Neurons (9)	636	51.7 ▲	9.7	11.3	7.1
2	Visually Controlled Locomotion/Postural Control-Systems (14)	304	48.4 ▲	6.9 ▼	11.8	17.1 ▲
3	Muscular-Dystrophies (17)	655	47.2 ▲	12.1	12.5 ▲	10.7 ▲
4	Mitochondrial Encephalomyopathies/Cytochrome-Oxidase (7)	220	45.5	13.6	8.6	3.6
5	Neural Networks (10)	561	45.3 ▲	12.7	9.6	4.8
6	Cultured Astroglial Cells/C-13-NMR Spectroscopy/Glucose-Transporter (5)	206	45.1	7.3	10.7	6.8
7	Parkinsons-Disease (16)	438	42.5	12.1	5.7 ▼	7.8
8	Neuropeptide Ff/Drosophila Learning and Memory (6)	349	42.1	12.3	13.2	8.6
9	Heart-Failure (4)	857	41.8	5.5 ▼	8.8	4.4 ▼
10	Calcium-Binding Proteins/Posterior Cortical Atrophy (8)	196	41.3	5.1 ▼	15.3 ▲	4.6
11	CNS Vasculitis/Cerebral Venous Thrombosis (1)	368	41.3	5.2 ▼	7.9	8.7
12	Neuroscience – general (18)	26741	38.5 ▼	10.1	9.5 ▼	6.2
13	Retina (13)	882	38.5	9.9	14.4 ▲	4.9
14	Low-Back Pain (2)	367	38.4	7.9	7.6	4.4
15	Brain Tumors (3)	437	34.3 ▼	7.1 ▼	11.9	4.1 ▼
16	Calcium Channels (15)	770	33.6 ▼	10.4	9.6	5.3
17	Posttraumatic-Stress-Disorder/Brain Asymmetry and Depression (11)	447	32.0 ▼	9.6	7.6	3.6 ▼
18	Auditory-Cortex/Event-Related Brain Potentials (12)	326	27.6 ▼	6.4 ▼	13.2	4.0

The large European countries (table 2.54) show differences in their main emphasis regarding the subfields with a high European participation. The activity profiles of Germany and France are rather similar in the top half of the table 2.54, whereas the research fronts with a relative strength of the United Kingdom are mainly differing. This difference is particularly pronounced in case of the *subfield Visually Controlled Locomotion/Postural Control-Systems* (14), but also visible on the ranks 4 and 5.

At the research fronts with a relative low activity of the whole EU15 Germany reaches publication shares clearly above the German average, especially in case of the C4-cluster *Retina* (13).

Figure 2.15:

Detailed map of C4-18 Neuroscience – general

Table 2.55:
C3-clusters of C4-18 Neuroscience – general

Cl.-no	Title	C3	Core	Front	Imm
150	Alzheimers-Disease/Dementia/Apoptosis	44	4256	6014	38
151	Visual Cortex/Event-Related Potentials/Working-Memory	38	3503	4222	26
126	Neuronal Growth/Neurotrophin/Patterning	41	3487	4109	40
134	Glutamate and Ampa Receptors	16	1004	1893	36
127	Opioids/Pain	16	1058	1266	36
125	Serotonin Reuptake/Depression	10	1056	1154	24
73	Stroke	10	855	1109	27
82	Dopamine-Receptors	4	641	1067	38
48	Circadian System/Melatonin	11	832	889	32
145	Cortical Motor System	11	555	858	24
141	Gap-43/Apoptosis	8	511	800	42
142	Nitric-Oxide	6	317	754	39
121	Migraine	8	552	729	33
131	GABA(A) Receptors	4	539	726	31
76	Circadian-Rhythms/Birdsong	8	621	686	23
147	Schizophrenia	4	424	604	24
103	Stress/Epilepsy/Anxiety	7	373	592	26
51	Angiotensin Receptors	6	440	508	24
49	Cortical Plasticity	2	344	489	24
78	Corticosteroids	4	394	465	27
144	Hypothermic Neuroprotection	4	242	426	33
97	Pain/Epilepsy	2	229	329	24
149	Mismatch Negativity/P300	4	195	268	16
102	Prenatal Alcohol Exposure/Effects of Alcohol-Consumption	3	198	237	23
107	Neuropsychological Assessment	2	18	227	11
50	Serotonin Transporter Expression	4	146	224	16
140	Head-Injury/Cerebral Pressure	2	153	204	18
116	Treatment of Alcoholism	6	149	203	26
70	Cocaine and Alcohol Abuse	5	125	200	16
139	Object Recognition	3	117	172	17
95	Coordination Dynamics/Bilateral Movement	2	123	170	21
133	Inflammation and Acute Stroke	4	83	156	42
148	Nitric-Oxide Synthase	3	50	146	56
105	Schizophrenia/Sensorimotor Gating/Antipsychotics	3	100	137	28
138	Axonal Injury	2	76	127	26
137	Heat-Shock Proteins	2	72	122	18
130	Ischemic Brain-Lesions	2	65	115	40
87	Projections of the Nucleus-Accumbens	2	63	114	19
109	Lipid Hydroperoxides	3	61	112	26
124	Infections of the Nervous-System	2	79	110	40
20	Regulation of Dopamine Release	3	49	86	12
117	Glycine Receptors	2	78	86	23
106	Neuronal Nitric-Oxide	2	44	81	13
46	Endogenous Oxytocin	2	35	46	20
118	Nucleus-Accumbens Dopamine Release	2	20	38	25

The detailed map of the largest 1998 C4-cluster *Neuroscience – general* (18) in figure 2.15 shows more concentration than in 1997. The three very large C3-*clusters Alzheimers-Disease/Dementia/Apoptosis* (150), with about 6000 front publications as well as *Visual Cortex/Event-Related Potentials/Working-Memory* (151) and *Neuronal*

Growth/Neurotrophin/Patterning (126) with more than 4000 co-citing source publications are larger than in 1997, whereas only 8 C3-clusters at all reach a front size of 1000 publications, compared to 14 included in the 1997 C4-cluster *Neuroscience – general*.

The largest cluster C3-150 is a successor of the 1997 large Alzheimers-disease cluster C3-126 and the smaller Alzheimer related cluster *Alzheimer/Basal Forebrain/Parkinsons-Disease* (132), as well as the C3-cluster *Multiple Sclerosis* (80) and Parkinsons related clusters (116,120). The emerged very large subfield still has a rather high immediacy value (see table 2.55), which is superseded among the larger clusters (frontsize > 1000) only by its direct neighbor *Neuronal Growth/Neurotrophin/Patterning* (126). This second large central and dynamic subfield comes from the three neighbored 1997 C3-*clusters Neuromuscular Disorders* (109), *Axon Growth/Neural Crest/Cell Adhesion Molecule* (99) *and Neurotrophic Factors* (123) (see the co-citation map of the 1997 C4-cluster *Neuroscience – general*, figure 2.13).

The third of the large C3-clusters in C4-18 with 4222 co-citing publications is *Visual Cortex/Event-Related Potentials/Working-Memory* (151), a successor of the 1997 subfields *Metabotropic Glutamate Receptors/Visual-Cortex/Long-Term Depression* (133) accumulated with cited publications from its neighbored C3-clusters in the lower left area of the 1997 map, like *Entorhinal Cortex/Place Cells* (128) or *Mismatch Negativity/P300* (110). Other parts of the last mentioned predecessor C3-110 are clustered in the 1998 cluster 149 with the same title.

Other subjects, which have 1998 an unambiguous successor in a subfield of the largest C4-cluster of the neurosciences, are nitric oxide (C3-124 in 1997 and C3-142 in 1998) and schizophrenia. The 1998 C3-cluster *Schizophrenia* (147) on the right side of the co-citation map has a predecessor in the 1997 cluster *Neuroimaging, Neurodevelopment and Schizophrenia* (107).

Subjects which appear the first time in C3-cluster titles of the largest C4-cluster are the circadian system represented by the clusters *Circadian System/Melatonin* (48) and *Circadian-Rhythms/Birdsong* (76) (their core documents were clustered in isolated C3-clusters in 1997) or stroke. The subfield *Stroke* (73), positioned above the central region in the map, contains cited publications which were, if clustered in 1997, mainly affiliated to the C4-cluster *Carotid Artery/Cerebral Blood Flow/Acute Ischemic Stroke* (4) (see overview map, figure 2.12).

Other “new” subfields like the neighbored clusters *Migraine* (121) and *Opioids/Pain* (127) in the lower margin of the central region are build of parts from different C3-clusters from the previous year. These two clusters are the C3-subfields from the upper area of the central region of the 1997 map of *Neuroscience – general* (figure 2.13): *5-HT-Receptors* (91), *Parkinsons-Disease/Dopamine-Transporter/Nucleus-Accumbens* (116) and *Tachykinins/Nociceptors/Sympathetic Dystrophy* (68).

On the right periphery of the map some clusters related to the effects of alcohol can be found, which consist mainly of previous parts of the 1997 cluster *5-HT-Receptors* (91).

Table 2.56:

Share of the triad in C3-research fronts of C4-18, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (41.6)	USA (46.0)	Japan (9.7)
1	Migraine (121)	729	50.5 ▲	35.7 ▼	5.8 ▼
2	Pain/Epilepsy (97)	329	48.3 ▲	35.0 ▼	16.7 ▲
3	Stroke (73)	1109	46.3 ▲	40.1 ▼	6.7 ▼
4	Ischemic Brain-Lesions (130)	115	46.1	34.8 ▼	13.0
5	Head-Injury/Cerebral Pressure (140)	204	45.6	36.3 ▼	6.9
6	Infections of the Nervous-System (124)	110	43.6	36.4 ▼	3.6
7	Schizophrenia (147)	604	43.5	46.9	3.6 ▼
8	Endogenous Oxytocin (46)	46	43.5	45.7	4.3
9	Cortical Motor System (145)	858	43.2	42.0 ▼	8.6
10	Coordination Dynamics/Bilateral Movement (95)	170	42.9	49.4	4.1 ▼
11	Axonal Injury (138)	127	42.5	39.4	13.4
12	Object Recognition (139)	172	42.4	54.7 ▲	3.5 ▼
13	Glycine Receptors (117)	86	41.9	48.8	4.7
14	Serotonin Reuptake/Depression (125)	1154	41.9	43.7	2.9 ▼
15	Schizophrenia/Sensorimotor Gating/Antipsychotics (105)	137	41.6	44.5	8.8
16	Stress/Epilepsy/Anxiety (103)	592	41.2	39.0 ▼	6.8 ▼
17	Mismatch Negativity/P300 (149)	268	41.0	41.0	9.3
18	Circadian System/Melatonin (48)	889	40.7	40.4 ▼	10.8
19	Visual Cortex/Event-Related Potentials/Working-Memory (151)	4222	39.5 ▼	47.6 ▲	5.6 ▼
20	Neuronal Nitric-Oxide (106)	81	39.5	24.7 ▼	23.5 ▲
21	Alzheimers-Disease/Dementia/Apoptosis (150)	6014	39.1 ▼	45.1	11.9 ▲
22	Neuronal Growth/Neurotrophin/Patterning (126)	4109	38.8 ▼	48.3 ▲	10.1
23	Inflammation and Acute Stroke (133)	156	38.5	50.6	9.6
24	GABA(A) Receptors (131)	726	38.4	45.6	8.4
25	Corticosteroids (78)	465	37.8	47.3	7.3
26	Nucleus-Accumbens Dopamine Release (118)	38	36.8	36.8	7.9
27	Nitric-Oxide Synthase (148)	146	35.6	41.8	15.1 ▲
28	Dopamine-Receptors (82)	1067	35.1 ▼	47.7	6.9 ▼
29	Regulation of Dopamine Release (20)	86	34.9	46.5	12.8
30	Nitric-Oxide (142)	754	33.4 ▼	41.1 ▼	15.8 ▲
31	Projections of the Nucleus-Accumbens (87)	114	33.3	57.0 ▲	1.8
32	Glutamate and Ampa Receptors (134)	1893	33.2 ▼	51.7 ▲	8.6
33	Opioids/Pain (127)	1266	33.2 ▼	57.0 ▲	7.0 ▼
34	Neuropsychological Assessment (107)	227	32.2 ▼	53.7 ▲	1.3
35	Cortical Plasticity (49)	489	31.9 ▼	56.4 ▲	2.0 ▼
36	Gap-43/Apoptosis (141)	800	31.5 ▼	52.1 ▲	11.9 ▲
37	Cocaine and Alcohol Abuse (70)	200	30.0 ▼	70.0 ▲	1.0
38	Circadian-Rhythms/Birdsong (76)	686	28.4 ▼	56.3 ▲	7.0 ▼
39	Heat-Shock Proteins (137)	122	27.0 ▼	39.3	23.8 ▲
40	Angiotensin Receptors (51)	508	26.2 ▼	42.3	11.0
41	Hypothermic Neuroprotection (144)	426	25.1 ▼	48.4	18.5 ▲
42	Lipid Hydroperoxides (109)	112	25.0 ▼	50.9	21.4 ▲
43	Prenatal Alcohol Exposure/Effects of Alcohol-Consumption (102)	237	24.5 ▼	65.4 ▲	1.7
44	Serotonin Transporter Expression (50)	224	24.1 ▼	56.7 ▲	4.9 ▼
45	Treatment of Alcoholism (116)	203	23.6 ▼	69.5 ▲	2.5 ▼

Only the three top clusters in table 2.56 stand out to a significant high percentage of EU15 publications at their research fronts. The subfield *Migraine* showing a participation of EU15 countries to more than half of the front publications includes mainly cited documents already clustered in the 1997 subfield *5-HT Receptors* (91), which was rather similar regarding the large countries' contribution to the research front. The other two subfields with a significant strong portion of European front publications, *Pain/Epilepsy* (97) and *Stroke* (73), are successors of parts of the 1997 C4-clusters, *Somatosensory-Evoked Potentials/Magnetoencephalography in Partial Epilepsy* (5) and *Carotid-Artery/Cerebral Blood-Flow/Acute Ischemic Stroke* (7), of which research fronts included a significantly high portion of EU15 publications as well.

The publication activity of the USA and Japan is significantly lower than their C3-level average in most cases of the three top ranked clusters. Only Japan shows a significant high strong activity in *Pain/Epilepsy* (97).

Other clusters where Japanese are particularly engaged at research fronts can be found in the lower half of table 2.56, partly concerned with nitric oxide and Apoptosis. In the co-citation map these clusters are located in the lower left periphery (figure 2.15).

Table 2.57:

Share of the most active European countries in C3-research fronts of C4-18, ranked by share of EU15

Rank	Title (Cl.-No.)	Front	EU15 (41.6)	UK (10.5)	GER (10.2)	F (6.6)
1	Migraine (121)	729	50.5 ▲	13.3 ▲	7.1 ▼	9.9 ▲
2	Pain/Epilepsy (97)	329	48.3 ▲	7.9	18.2 ▲	5.5
3	Stroke (73)	1109	46.3 ▲	8.3 ▼	14.9 ▲	4.3 ▼
4	Ischemic Brain-Lesions (130)	115	46.1	7.8	27.0 ▲	1.7
5	Head-Injury/Cerebral Pressure (140)	204	45.6	11.8	13.2	3.9
6	Infections of the Nervous-System (124)	110	43.6	10.0	14.5	8.2
7	Schizophrenia (147)	604	43.5	14.9 ▲	12.6 ▲	5.8
8	Endogenous Oxytocin (46)	46	43.5	2.2	17.4	10.9
9	Cortical Motor System (145)	858	43.2	12.9 ▲	7.8 ▼	12.4 ▲
10	Coordination Dynamics/Bilateral Movement (95)	170	42.9	12.9	5.3 ▼	8.2
11	Axonal Injury (138)	127	42.5	12.6	14.2	3.1
12	Object Recognition (139)	172	42.4	21.5 ▲	11.0	6.4
13	Glycine Receptors (117)	86	41.9	7.0	20.9 ▲	7.0
14	Serotonin Reuptake/Depression (125)	1154	41.9	11.2	7.4 ▼	6.3
15	Schizophrenia/Sensorimotor Gating/Antipsychotics (105)	137	41.6	8.0	10.2	2.9
16	Stress/Epilepsy/Anxiety (103)	592	41.2	9.1	11.0	9.0 ▲
17	Mismatch Negativity/P300 (149)	268	41.0	4.5 ▼	16.0 ▲	2.6 ▼
18	Circadian System/Melatonin (48)	889	40.7	10.6	7.5 ▼	10.3 ▲
19	Visual Cortex/Event-Related Potentials/Working-Memory (151)	4222	39.5 ▼	14.4 ▲	10.3	6.1
20	Neuronal Nitric-Oxide (106)	81	39.5	11.1	7.4	4.9
21	Alzheimers-Disease/Dementia/Apoptosis (150)	6014	39.1 ▼	9.3 ▼	10.1	5.2 ▼
22	Neuronal Growth/Neurotrophin/Patterning (126)	4109	38.8 ▼	10.0	10.6	6.3
23	Inflammation and Acute Stroke (133)	156	38.5	7.7	12.2	5.8
24	GABA(A) Receptors (131)	726	38.4	10.9	7.2 ▼	7.4
25	Corticosteroids (78)	465	37.8	6.0 ▼	9.5	6.9
26	Nucleus-Accumbens Dopamine Release (118)	38	36.8	7.9	2.6	10.5
27	Nitric-Oxide Synthase (148)	146	35.6	7.5	8.2	4.8
28	Dopamine-Receptors (82)	1067	35.1 ▼	7.8 ▼	6.7 ▼	7.1
29	Regulation of Dopamine Release (20)	86	34.9	9.3	1.2	4.7
30	Nitric-Oxide (142)	754	33.4 ▼	9.8	6.4 ▼	3.2 ▼
31	Projections of the Nucleus-Accumbens (87)	114	33.3	6.1	7.0	7.0
32	Glutamate and Ampa Receptors (134)	1893	33.2 ▼	9.5	9.8	5.5
33	Opioids/Pain (127)	1266	33.2 ▼	7.2 ▼	6.1 ▼	7.3
34	Neuropsychological Assessment (107)	227	32.2 ▼	16.7 ▲	3.1 ▼	5.7
35	Cortical Plasticity (49)	489	31.9 ▼	8.2	11.9	3.5 ▼
36	Gap-43/Apoptosis (141)	800	31.5 ▼	8.0 ▼	8.8	4.6 ▼
37	Cocaine and Alcohol Abuse (70)	200	30.0 ▼	8.5	7.0	3.0 ▼
38	Circadian-Rhythms/Birdsong (76)	686	28.4 ▼	5.0 ▼	5.1 ▼	5.8
39	Heat-Shock Proteins (137)	122	27.0 ▼	4.1 ▼	9.8	3.3
40	Angiotensin Receptors (51)	508	26.2 ▼	8.1	6.5 ▼	6.3
41	Hypothermic Neuroprotection (144)	426	25.1 ▼	6.3 ▼	7.3	3.5 ▼
42	Lipid Hydroperoxides (109)	112	25.0 ▼	1.8	12.5	2.7
43	Prenatal Alcohol Exposure/Effects of Alcohol-Consumption (102)	237	24.5 ▼	5.5 ▼	3.4 ▼	4.2
44	Serotonin Transporter Expression (50)	224	24.1 ▼	7.6	6.3	8.0
45	Treatment of Alcoholism (116)	203	23.6 ▼	4.4 ▼	5.9 ▼	2.5 ▼

Table 2.57 shows that the three large European countries, of which shares at the research fronts are listed, are particularly active each in different subfields of the top ranks. Whereas the C3-cluster Migraine (121) includes a relatively large portion of British and/or French publications at the research front, the following three subfields are areas with a strong German presence and a weak activity of the United Kingdom and France. This contrary tendency can be observed at other research fronts too, for example *Cortical Motor System* (145) and *Coordination Dynamics/Bilateral Movement* (95) at the ranks 9 and 10 or *Mismatch Negativity/P300* (149) and *Circadian System/Melatonin* (48) at ranks 17 and 18.

Many of the subfields with a strong British activity can be found in the upper right region of the co-citation map in figure 2.15.

Table 2.58:

C3-Isolates of neuroscience 1998 with more than 100 front publications

Cl-no.	Title	C2	Core	Front	Imm
21	Temporal Lobe Epilepsy	8	556	773	28
113	MR and Multiple-Sclerosis	7	486	745	40
23	Obesity/Neuropeptide Y	5	369	516	46
63	Brain Nicotinic Receptors	5	424	472	35
57	Hereditary Neurological Diseases	4	375	470	52
96	Antiepileptic Drugs	2	429	452	33
120	Exocytosis/Neurotransmitter Release/Synaptotagmins	4	359	426	54
30	Olfactory Neurons/Cyclic Nucleotide-Gated Channels	2	366	358	31
91	Dystonia/Botulinum Toxin	4	292	338	28
135	Prion Diseases	3	258	298	45
29	Nitric-Oxide/Guinea-Pig Small-Intestine	2	204	280	30
45	Cerebral-Palsy/Premature-Infants	5	216	264	18
43	Cerebral-Circulation/Cerebral Vasodilators	5	216	248	38
16	Cochlear Outer Hair-Cells/2 F1-F2 Distortion-Product Otoacoustic Emission	2	240	242	26
77	Neuroblastoma Screening	3	186	240	30
90	Glial Calcium/Gap Junction	4	131	210	37
55	Traumatic Brain Injury	2	172	192	20
13	Critical Illness Polyneuropathy	4	161	186	16
14	Cannabis	2	177	186	59
42	Sleep-Apnea	2	172	184	19
66	Pdz Domain Protein/Postsynaptic Density	2	90	165	65
52	Latent Inhibition	2	132	144	18
35	CCK in Anxiety and Cognitive Processes	3	93	129	13
38	Gangliosidoses/Sphingolipidoses	2	107	126	31
84	Planum Temporale/Developmental Language Disorder	2	78	126	11
67	Brain Excitability	2	84	122	21
111	Neuroendocrine Differentiation in Prostatic-Carcinoma	2	115	118	35
2	Lead Exposure/Brain Metallothionein	3	117	113	24
100	Pet/Striatal Dopamine Release	2	52	103	30
22	Autism/Fragile-X-Syndrome	2	96	101	31

Table 2.59:
Share of the triad in research fronts of C3-isolates for neuroscience1998, ranked by share of EU15

Rank	Title (CL.-No.)	Front	EU15 (41.6)	USA (46.0)	Japan (9.7)
1	CCK in Anxiety and Cognitive Processes (35)	129	62.8 ▲	25.6 ▼	4.7
2	Prion Diseases (135)	298	60.4 ▲	30.9 ▼	8.1
3	Neuroendocrine Differentiation in Prostatic-Carcinoma (111)	118	59.3 ▲	28.8 ▼	2.5
4	Pet/Striatal Dopamine Release (100)	103	55.3 ▲	35.9 ▼	6.8
5	Cannabis (14)	186	53.2 ▲	44.1	2.2
6	MR and Multiple-Sclerosis (113)	745	50.2 ▲	38.0 ▼	3.4 ▼
7	Latent Inhibition (52)	144	45.8	42.4	1.4
8	Hereditary Neurological Diseases (57)	470	45.7	37.0 ▼	15.5 ▲
9	Dystonia/Botulinum Toxin (91)	338	45.0	36.1 ▼	7.7
10	Nitric-Oxide/Guinea-Pig Small-Intestine (29)	280	44.6	33.2 ▼	9.6
11	Cerebral-Palsy/Premature-Infants (45)	264	44.3	36.7 ▼	3.8 ▼
12	Autism/Fragile-X-Syndrome (22)	101	42.6	42.6	4.0
13	Temporal Lobe Epilepsy (21)	773	41.4	42.0 ▼	8.4
14	Critical Illness Polyneuropathy (13)	186	40.9	30.1 ▼	3.8 ▼
15	Cochlear Outer Hair-Cells/2 F1-F2 Distortion-Product Otoacoustic Emission (16)	242	40.9	45.0	5.8 ▼
16	Obesity/Neuropeptide Y (23)	516	40.5	48.1	7.6
17	Sleep-Apnea (42)	184	40.2	44.0	9.8
18	Antiepileptic Drugs (96)	452	39.2	46.5	3.5 ▼
19	Glial Calcium/Gap Junction (90)	210	39.0	51.9	7.1
20	Planum Temporale/Developmental Language Disorder (84)	126	38.9	46.8	2.4
21	Exocytosis/Neurotransmitter Release/Synaptotagmins (120)	426	37.6	54.2 ▲	12.7 ▲
22	Neuroblastoma Screening (77)	240	37.5	43.8	22.1 ▲
23	Brain Excitability (67)	122	36.1	37.7	11.5
24	Olfactory Neurons/Cyclic Nucleotide-Gated Channels (30)	358	36.0 ▼	53.1 ▲	9.8
25	Gangliosidoses/Sphingolipidoses (38)	126	29.4 ▼	48.4	15.1 ▲
26	Brain Nicotinic Receptors (63)	472	28.8 ▼	60.0 ▲	7.2
27	Traumatic Brain Injury (55)	192	28.6 ▼	55.2 ▲	1.0
28	Lead Exposure/Brain Metallothionein (2)	113	23.9 ▼	49.6	9.7
29	Cerebral-Circulation/Cerebral Vasodilators (43)	248	23.4 ▼	51.2	19.4 ▲
30	Pdz Domain Protein/Postsynaptic Density (66)	165	21.8 ▼	66.7 ▲	17.6 ▲

In tables 2.58 and 2.59 the thirty largest isolated C3-subfields with more than 100 co-citing publications are shown. Among these subfields, which are not clustered in the last step of the iterative cluster procedure, are 7 medium sized clusters with research fronts of more than 400 source publications and a lot of smaller ones. (table 2.58)

Five of the larger clusters are successors of subfields, which have been affiliated to the large central C4-cluster *Neuroscience – general* in the previous year. For example the “epilepsy-clusters” *Temporal Lobe Epilepsy* (21) and *Antiepileptic Drugs* (96) *and MR and Multiple Sclerosis* (113) as well as *Hereditary Neurological Diseases* (57), one of the successors of the 1997 C3-cluster *Neuromuscular Disorders* (109). The research themes represented by the isolated clusters *Obesity/Neuropeptide Y* (23) and *Brain Nicotinic Receptors* (63) could be found at the research fronts of isolated C3-clusters already in 1997 (see table 2.58)

There is only one C3-cluster among the larger C3-isolates, which shows a significant higher participation of the EU15 at its research front: *MR and Multiple Sclerosis* (113) ranking sixth in table 2.59. A corresponding research front in 1997, *Multiple Sclerosis* (80), was included in the large C4-cluster *Neuroscience – general* and had a similar high share of EU15 publications at its research front. This 1997 multiple sclerosis cluster was split in 1998 mainly in two parts, the isolated C3-cluster *MR and Multiple Sclerosis* (113) and a part, which was included in the largest C3-cluster *Alzheimers-Disease/Dementia/Apoptosis* (150) (for a more detailed view of this C3-cluster see chapter 2.3.5)

The other five isolated C3-clusters with even higher EU15 shares at the research fronts shown at the top of table 2.59 are partly "new" C3-clusters, which appeared the first time on the C3-level as a large region with relative dense co-citation links. These "new" clusters are *Prion Diseases* (135), *Neuroendocrine Differentiation in Prostatic-Carcinoma* (111) and *Cannabis* (14).

The others are coming from the central C4-cluster Neuroscience – general. *CCK in Anxiety and Cognitive Processes* (35) is one of the two successors of the 1997 C3-cluster *Pharmacological Treatment of Panic Disorders* (49), which has been located in the co-citation map of C4-10 in the upper left corner (see figure 2.13) The second C3-cluster in 1998, which has a predecessor in the 1997 cluster C3-49 is *Serotonin Reuptake/Depression* (125). This part moved more to the center of the 1998 C4-18 co-citation map and can be found in the region just below the center (see figure 2.15). The different position of the two successors of the 1997 C3-cluster 49 coincides with changes of the US and EU15 publication shares in different directions. Compared to their jointly predecessor the more central cluster C3-125 includes a clearly decreased portion of EU15 participated front publications and an increased share of the USA, whereas the now isolated part C3-35 shows changes of the publication shares of the USA and the EU15 in the opposite directions. This is an example for an observation of which possible implications should be discussed with experts in the field.

4.1.2.1.4. Changes from 1996 to 1998

- The EU 15 and the USA show divergent trends regarding their neuroscience publication shares from 1996 to 1998. The US contribution decreased from 41% to 37.6% whereas the EU15 share in neuroscience publications increased from 34.7% to 37.8%.
- Among the large European nations Germany could increase its participation in neuroscience publications most strongly.
- The co-citation structure of neuroscience reveals no explicit disciplinary structure. The largest areas, which are constituting relative dense co-citations networks, are Alzheimer disease/dementia/Apoptosis, glutamate receptors, 5-ht-receptors and visual cortex.
- Other prominent themes in the overview maps like Parkinsons disease, epilepsy, multiple sclerosis, schizophrenia or nitric oxide are partly differentiated, forming special high level clusters or integrated in the large central areas.
- "Stroke" and "circadian rhythms" are subjects which become more central and differentiated in the analyzed period. The publications related to "stroke", which were not represented by an own C3-subfield in 1996, constituted a C4-cluster (7) in 1997 and emerged in a C3-cluster inside the large central C4-cluster *Neuroscience – general* in 1998. "Circadian rhythms" and related subjects turning up in a C4-cluster in 1996 were clustered in one large but isolated C3-cluster in 1997 and are integrated in *Neuroscience – general* C4-18 in 1998.
- Further more research fields, which mainly can be found in more peripheral areas of the neuroscience landscape are "neuropathy", "obesity/Neuropeptides Y", "neural networks" and "nicotinic receptors".
- Research themes which are represented by larger clusters with a continuously high EU15 contribution are "stroke" and "multiple sclerosis" and "antiepileptic drugs". In 1998 three C4- level subfields, *Tachykinins/Nociceptor Sensitization/Sensory Neurons* (9), *Neural Networks* (10) and *Muscular Dystrophies* (17), show a significantly high EU15 participation. In case of the first two a clearly increase of the EU15 share can be noticed compared with their predecessors, whereas the subject "muscular dystrophies" was represented in 1997 by a region inside C3-109 *Neuromuscular Disorders* (see figure 2.13) in which more than 50% of the front publications are participated by EU15 actors.
- Leading international actors are the Harvard University and the University of Texas. Among the large European actors the Swedish Karolinska Institute and the University of Oxford are on top places followed by the Universities of Cambridge, Milan and Munich.

4.1.2.2. Selected subfields of neuroscience 1998

Two different clusters were selected as examples for a more detailed view into C3-subfields. On one hand the very large C3-cluster *Alzheimers-Disease/Dementia/Apoptosis* (150), taking a central position in C4-18 *Neuroscience – general*, and on the other hand the smaller and isolated C3-113 *MR and Multiple Sclerosis*. For both clusters the co-citation maps, journal-profiles, rankings of top countries and institutions and their most active co-operations are presented in the following figures and tables.

C3-150 Alzheimers-Disease/Dementia/Apoptosis

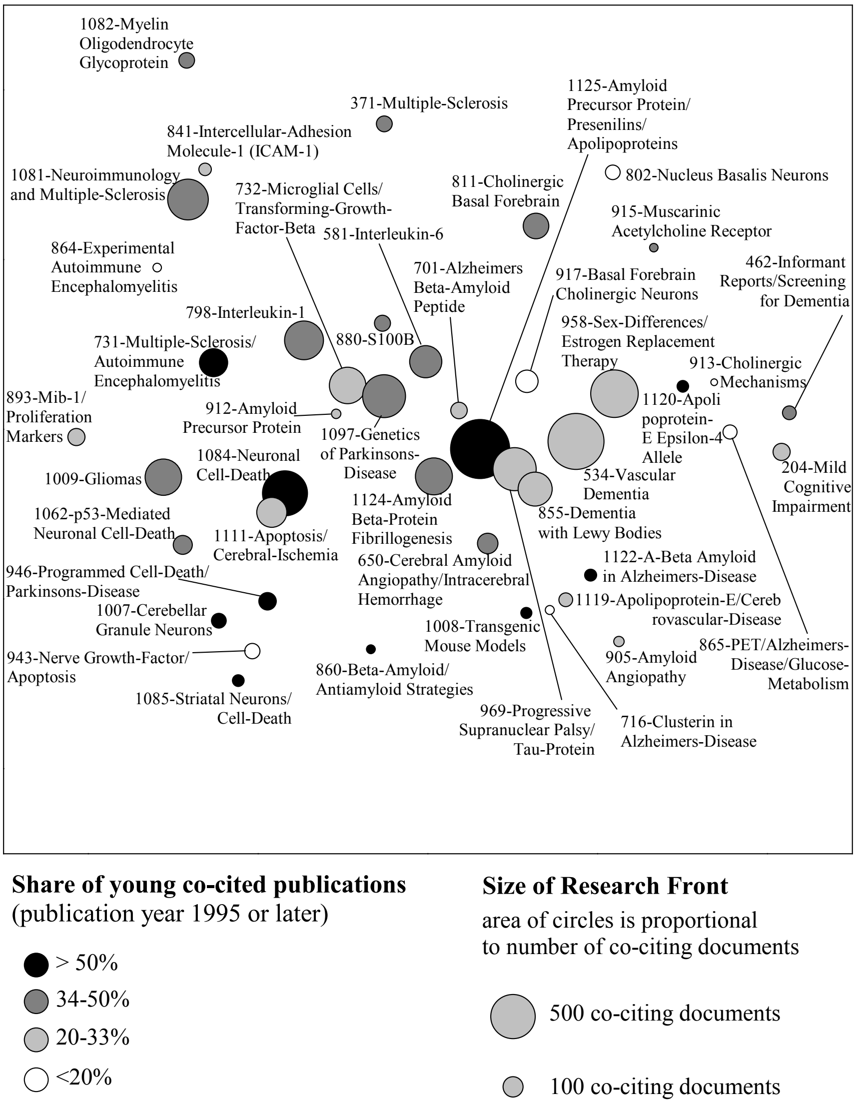


Figure 2.16:

Co-citation cluster map of C3-150 Alzheimers-Disease/Dementia/Apoptosis

Table 2.60:
C2-clusters of C3-150 Alzheimers-Disease/Dementia/Apoptosis

Cl.-No.	Title	C2	Core	Front	Imm
1125	Amyloid Precursor Protein/Presenilins/Apolipoproteins	45	413	844	53
534	Vascular Dementia	39	329	759	29
958	Sex-Differences/Estrogen Replacement Therapy	33	379	544	26
1084	Neuronal Cell-Death	36	235	488	71
969	Progressive Supranuclear Palsy/Tau-Protein	45	397	448	33
1097	Genetics of Parkinsons-Disease	43	346	446	39
1081	Neuroimmunology and Multiple-Sclerosis	24	291	404	36
798	Interleukin-1	38	217	366	38
1124	Amyloid Beta-Protein Fibrillogenesis	9	91	333	46
732	Microglial Cells/Transforming-Growth-Factor-Beta	28	181	322	33
1009	Gliomas	28	231	319	41
855	Dementia with Lewy Bodies	33	136	279	27
581	Interleukin-6	10	98	253	36
1111	Apoptosis/Cerebral-Ischemia	6	42	219	33
731	Multiple-Sclerosis/Autoimmune Encephalomyelitis	17	98	196	56
811	Cholinergic Basal Forebrain	10	128	161	36
917	Basal Forebrain Cholinergic Neurons	2	7	121	0
650	Cerebral Amyloid Angiopathy/Intracerebral Hemorrhage	12	76	103	34
1062	p53-Mediated Neuronal Cell-Death	10	38	88	42
946	Programmed Cell-Death and Parkinsons-Disease	2	40	76	50
893	Mib-1/Proliferation Markers	5	49	72	22
204	Mild Cognitive Impairment	4	36	71	25
701	Alzheimers Beta-Amyloid Peptide	10	42	68	23
371	Multiple-Sclerosis	2	39	64	46
880	S100B	5	38	63	36
1082	Myelin Oligodendrocyte Glycoprotein	7	34	62	35
943	Nerve Growth-Factor/Apoptosis	2	4	58	0
1007	Cerebellar Granule Neurons	3	9	54	66
802	Nucleus Basalis Neurons	10	32	53	6
865	PET/Alzheimers-Disease/Glucose-Metabolism	5	31	50	19
1119	Apolipoprotein-E/Cerebrovascular-Disease	5	23	47	30
462	Informant Reports/Screening for Dementia	5	19	46	42
841	Intercellular-Adhesion Molecule-1 (ICAM-1)	6	19	39	21
1122	A-Beta Amyloid in Alzheimers-Disease	3	14	37	64
1120	Apolipoprotein-E Epsilon-4 Allele	3	8	34	100
1085	Striatal Neurons/Cell-Death	3	17	33	58
1008	Transgenic Mouse Models	4	11	30	100
905	Amyloid Angiopathy	5	13	26	23
912	Amyloid Precursor Protein	3	7	23	28
716	Clusterin in Alzheimers-Disease	2	12	21	8
860	Beta-Amyloid/Antiamyloid Strategies	4	10	20	60
864	Experimental Autoimmune Encephalomyelitis	3	6	19	16
915	Muscarinic Acetylcholine Receptor	2	5	18	40
913	Cholinergic Mechanisms	2	5	11	0

In figure 2.16 the co-citation map of C3-150 allows a more detailed look at the largest C3-cluster in 1998. The 44 affiliated C2-clusters contain 4256 highly cited core documents, which are co-cited by 6014 recent source publications. The range of their cluster size reaches from a core of 4 clustered publications (*Nerve Growth-Factor/Apoptosis* (943)) or a front build by 11 co-citing publications (*Cholinergic*

Mechanisms (913)) to the very large C2-cluster *Amyloid Precursor Protein/Presenilins/Apolipoproteins* (1125) with 413 core documents and 844 publications at the research front (table 2.60), which is located in the center of the co-citation map in figure 2.16.

In the neighborhood on the right hand of this central C2-cluster other large C2-clusters related to Alzheimer and dementia can be found. On the left side of the center region a group of clusters related to Parkinsons disease and interleukin is positioned and at the upper left periphery the multiple sclerosis related clusters *Multiple-Sclerosis/Autoimmune Encephalomyelitis* (731) on the left, *Neuroimmunology and Multiple-Sclerosis* (1081) in the upper left corner and the smaller cluster *Multiple Sclerosis* (371) on the upper margin. These multiple sclerosis related C2-clusters are parts of the former C3-cluster *Multiple Sclerosis* (80) in 1997 included in *Neuroscience – general*, of which the other part, *MR and Multiple Sclerosis* remained isolated in 1998 and will be the second example for a detailed look at 1998 C3-clusters.

Another region in the lower left is related to neuronal cell death and apoptosis.

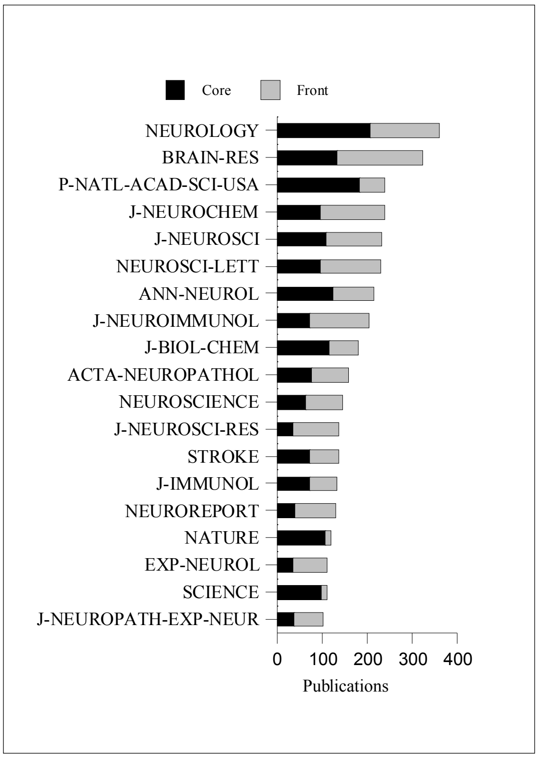


Figure 2.17:

Journal-profile of C3-150 Alzheimers-Disease/Dementia/Apoptosis

In the journal profile in figure 2.17 the main journals of the subfield are presented in a bar chart showing the relations of core and front publications. The bars indicate the absolute number of publications for each journal, the black filled part for the core and the Grey filled part symbolizing the number of front publications.

The most prominent journals in the journal profile of C3-150 are *Neurology* and *Brain Research* both with more than 300 publications at the core or the front of the cluster. *Neurology* is the leading journal at the cluster core, whereas *Brain Research* is the most active journal at the research front, with 188 source publications. Most of the listed top journals of C3-150 are quite equally represented at both sides, core and front. The interdisciplinary journals *Proceedings of the National Academy of Science* (ranked on the third place) and *Nature* and *Science*, listed at the end of the journal profile however are predominantly contributing core publications.

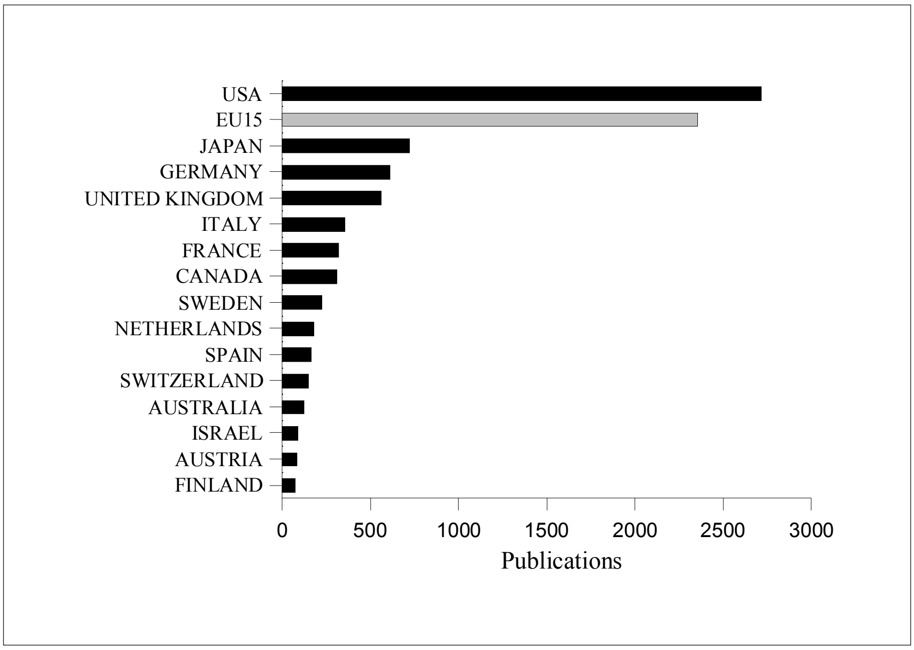


Figure 2.18:

Top countries of publication for the research front of C3-150 Alzheimers-Disease/Dementia/Apoptosis

The ranking of the most active countries for C3-150 shown in figure 2.18 reveals a predominance of the USA. The following countries are Japan, United Kingdom and Germany, each contributing more than 500 publications to the research front of C3-150. The EU15 countries together come up to more than 2300 source publications.

Table 2.61:

Top institutional actors of the research front of C3-150 Alzheimers-Disease/Dementia/Apoptosis

Publications	Institutions
162	HARVARD-UNIV, USA
90	UNIV-TEXAS, USA
84	UNIV-PENN, USA
82	UNIV-CALIF-LOS-ANGELES, USA
81	UNIV-TOKYO, JAPAN
78	UNIV-CALIF-SAN-DIEGO, USA
73	DUKE-UNIV, USA
73	UNIV-WASHINGTON, USA
73	WASHINGTON-UNIV, USA
70	JOHNS-HOPKINS-UNIV, USA
70	KAROLINSKA-INST, SWEDEN
67	UNIV-PITTSBURGH, USA
66	MASSACHUSETTS-GEN-HOSP, USA
62	UNIV-CALIF-SAN-FRANCISCO, USA
59	UNIV-CAMBRIDGE, UNITED KINGDOM

The top institutional actors of C3-150 shown in table 2.61 are mainly US universities. Among the top 15 institutions are only three non-US institutions: the University of Tokyo, the Swedish Karolinska Institute and the British University of Cambridge

Table 2.62:

Most active co-operations at the research front of C3-150 Alzheimers-Disease/Dementia/Apoptosis

Publ.	Institutions	
34	MASSACHUSETTS-GEN-HOSP, USA	HARVARD-UNIV, USA
24	HARVARD-UNIV, USA	BRIGHAM-&-WOMENS-HOSP, USA
22	UNIV-CAMBRIDGE, UNITED KINGDOM	MRC, UNITED KINGDOM
15	UNIV-TORONTO, CANADA	TORONTO-HOSP, CANADA
14	UNIV-KUOPIO, FINLAND	KUOPIO-UNIV-HOSP, FINLAND
10	HARVARD-UNIV, USA	CHILDRENS-HOSP, USA
10	STOCKHOLM-GERONTOL-RES-CTR, SWEDEN	KAROLINSKA-INST, SWEDEN
9	KAROLINSKA-INST, SWEDEN	HUDDINGE-UNIV-HOSP, SWEDEN
9	UNIV-SO-CALIF, USA	UNIV-CALIF-LOS-ANGELES, USA
9	W-LOS-ANGELES-VET-AFFAIRS-MED-CTR, USA	UNIV-CALIF-LOS-ANGELES, USA
9	UNIV-N-CAROLINA, USA	UNIV-MINNESOTA, USA
8	UNIV-MELBOURNE, AUSTRALIA	UNIV-HEIDELBERG, GERMANY
8	VET-AFFAIRS-MED-CTR, USA	UNIV-CALIF-SAN-DIEGO, USA
7	HUDDINGE-UNIV-HOSP, SWEDEN	BIOMED-PRIMATE-RES-CTR, NETHERLANDS
7	UNIV-HOSP-CLEVELAND, USA	CASE-WESTERN-RESERVE-UNIV, USA
7	UNIV-CALIF-SAN-FRANCISCO, USA	STANFORD-UNIV, USA
7	JOHNS-HOPKINS-UNIV, USA	HARVARD-UNIV, USA
7	VET-AFFAIRS-PUGET-SOUND-HLTH-CARE-SYST, USA	UNIV-WASHINGTON, USA
7	UNIV-TOKYO, JAPAN	OSAKA-UNIV, JAPAN
7	MCLEAN-HOSP, USA	HARVARD-UNIV, USA
7	TEL-AVIV-UNIV, ISRAEL	RABIN-MED-CTR, ISRAEL

The most active pairs of institutions listed in table 2.62 are national co-operations, mainly between universities and large hospitals. Besides the large US institutions Canadian, Finnish and Swedish institutions can be found among the very active co-operating pairs at the top. The first placed international co-operations are those of the Australian University of Melbourne with the German University of Heidelberg and between the Huddinge University Hospital in Sweden and the Netherlands Biomedical Primate Research Centre.

C3-113 MR and Multiple Sclerosis

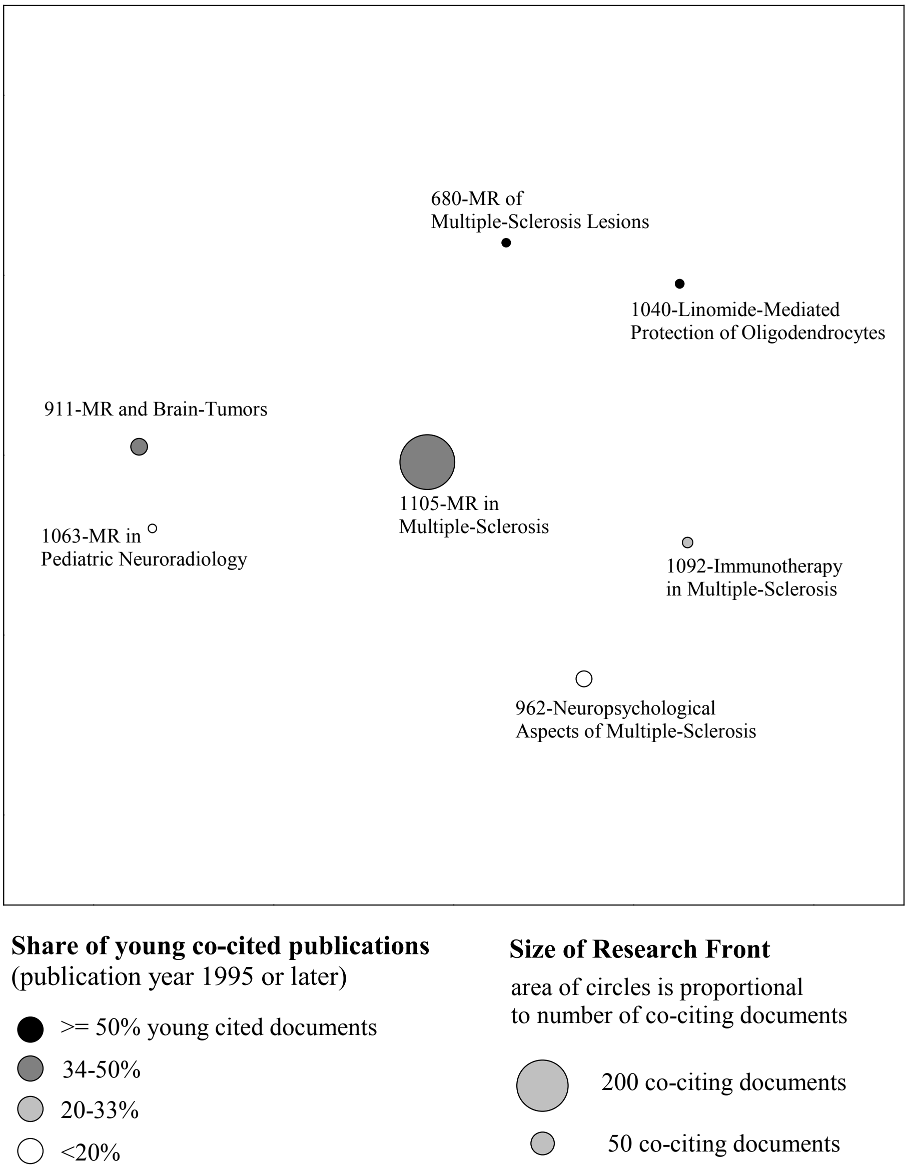


Figure 2.19:

Co-citation cluster map of C3-113 MR and Multiple Sclerosis

Table 2.63:
C2-clusters of C3-113 MR and Multiple Sclerosis

Cl-no.	Title	C2	Core	Front	Imm
680	MR of Multiple-Sclerosis Lesions	2	8	16	100
911	MR and Brain-Tumors	2	40	60	42
962	Neuropsychological Aspects of Multiple-Sclerosis	2	43	55	13
1040	Linomide-Mediated Protection of Oligodendrocytes	2	7	17	71
1063	MR in Pediatric Neuroradiology	2	4	16	0
1092	Immunotherapy in Multiple-Sclerosis	2	12	24	33
1105	MR in Multiple-Sclerosis	45	372	644	42

The subfield *MR and Multiple Sclerosis* (113) includes 7 C2-clusters, which are shown in the co-citation map in figure 2.19. By far the largest C2-cluster is *MR in Multiple Sclerosis* containing 372 of the 486 clustered publications in C3-113. (see table 2.63) The 644 co-citing publications are dealing with different aspects of magnetic resonance imaging in the diagnosis of multiple sclerosis.

The surrounding clusters are representing research fronts related to other subjects of the technique, like *MR and Brain Tumors* (911) and *MR in Pediatric Neuroradiology* (1063) or other subjects related to multiple sclerosis like *Neuropsychological Aspects of Multiple-Sclerosis* (962) or *Immunotherapy in Multiple-Sclerosis* (1092).

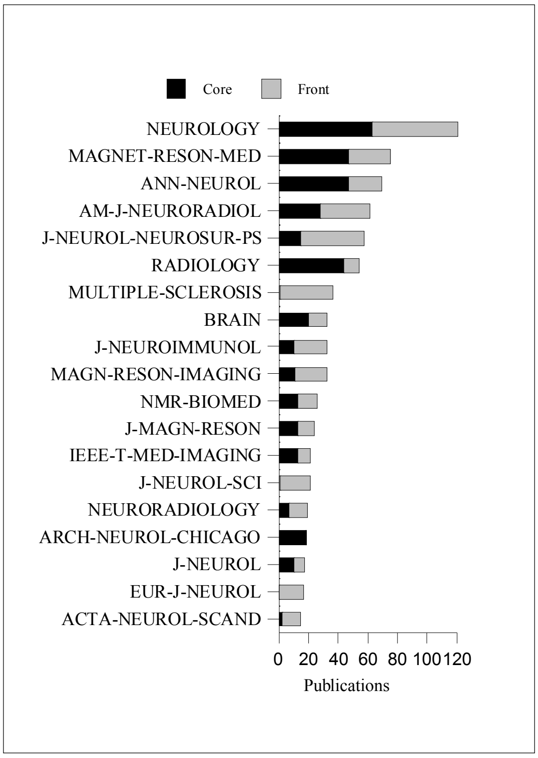


Figure 2.20:
Journal-profile of C3-113 MR and Multiple Sclerosis

By far the largest number of publications of C3-113 (core and front) are published in the journal *Neurology*, followed by *Magnetic Resonance in Medicine* and *Annals of Neurology* (figure 2.20). *Radiology* is more strongly represented at the core, whereas the *Journal of Neurology, Neurosurgery and Psychiatry* is relative strong at the research front, ranking with 42 source publications at the second place in terms of front publications, followed by *Multiple Sclerosis*, which is contributing almost exclusively to the front.

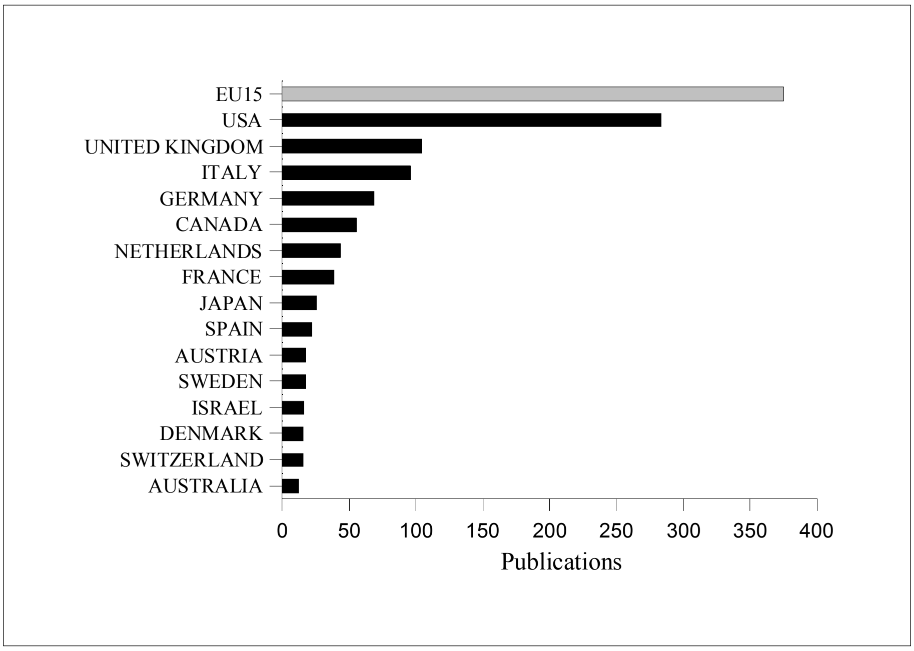


Figure 2.21:

Top countries of publication at the research front of C3-113 MR and Multiple Sclerosis

In figure 2.21 the relative strength of the EU15 at the research front of C3-113 is visible. The EU15 countries together are superseding the USA, leaded by the United Kingdom and Italy. Japan, the third part of the triad, is remarkably weak, participating in only 25 of the 745 front publications.

Table 2.64:

Top institutional actors at the research front of C3-113 MR and Multiple Sclerosis

Publications	Institutions
33	INST-NEUROL, UNITED KINGDOM
33	UNIV-MILAN, ITALY
18	MCGILL-UNIV, CANADA
18	NATL-HOSP-NEUROL-&-NEUROSURG, UNITED KINGDOM

Publications	Institutions
18	UNIV-CALIF-SAN-FRANCISCO, USA
17	HARVARD-UNIV, USA
17	UNIV-PENN, USA
14	FREE-UNIV-AMSTERDAM-HOSP, NETHERLANDS
13	UNIV-ROMA-LA-SAPIENZA, ITALY
13	UNIV-TEXAS, USA
12	UNIV-MINNESOTA, USA
11	HUDDINGE-UNIV-HOSP, SWEDEN
11	NIH, USA
11	NINCDS, USA
11	UNIV-MARYLAND, USA
11	UNIV-MUNICH, GERMANY

The leading European countries of publication at the research front of C3-113, United Kingdom and Italy, are represented at the first position of table 2.64. The Institute of Neurology, since 1997 a constituent of the University College of London Medical School, as well as the Italian University of Milan are both participating at the research front with 33 publications. They are followed by the Canadian McGill University, the British National Hospital for Neurology and Neurosurgery and three US universities.

Table 2.65:

Most active co-operations at the research front of C3-113 MR and Multiple Sclerosis

Publ.	Institutions	
10	NATL-HOSP-NEUROL-&-NEUROSURG, UNITED KINGDOM	INST-NEUROL, UNITED KINGDOM
8	UNIV-MILAN, ITALY	UNIV-LEICESTER, UNITED KINGDOM
7	HARVARD-UNIV, USA	BRIGHAM-&-WOMENS-HOSP, USA
7	UNIV-MUNICH, GERMANY	UNIV-MILAN, ITALY
6	UNIV-MILAN, ITALY	UNIV-BRESCIA, ITALY
6	UNIV-ROMA-LA-SAPIENZA, ITALY	UNIV-MILAN, ITALY
5	NINCDS, USA	NIH, USA
5	UNIV-MILAN, ITALY	NATL-INST-CANC-RES, ITALY
5	RADCLIFFE-INFIRM, UNITED KINGDOM	JOHN-RADCLIFFE-HOSP, UNITED KINGDOM
4	CHAIM-SHEBA-MED-CTR, ISRAEL	ABARBANEL-MENTAL-HLTH-CTR, ISRAEL
4	NINCDS, USA	NIMH, USA
4	MONTREAL-NEUROL-HOSP-&-INST, CANADA	MCGILL-UNIV, CANADA
4	UNIV-MUNICH, GERMANY	UNIV-LEICESTER, UNITED KINGDOM
4	VET-AFFAIRS-MED-CTR, USA	UNIV-MARYLAND, USA
4	UNIV-ROMA-LA-SAPIENZA, ITALY	UNIV-BRESCIA, ITALY
4	NIMH, USA	NIH,USA

The leading institutions at the research front, the University of Milan and the Institute of Neurology are showing the most active co-operations in table 2.65. The national co-operation between the Institute of Neurology and the National Hospital for Neurology and Neurosurgery is the most frequent one, but both institutions do not participate in another co-operation resulting in more than three publications at the research front of

C3-113, whereas the University of Milan appears five times in the list, two times with international co-operations with the British University of Leicester and the German University of Munich. The listed co-operations of US institutions are only national.

4.1.3. Complex systems

Research on complex systems is an interdisciplinary effort which finds its subjects in many areas of the real world, from the micro level up to large aggregates, in the inanimate nature as well as in living or even psychic or social systems. General principles or concepts underlying the different phenomena are non-linearity, chaotic behavior and self-organization. Therefore the disciplinary scope of complex systems research reaches from mathematics and the natural sciences to psychiatry and sociology and beyond.

To delineate the field a rather simple search profile including only a few title word phrases was applied. Based on the Web of Science version of the ISI databases Science Citation Index and Social Sciences Citation Index the delineation through keywords of the general concepts captured a broader set of publications without bias for any special areas. This would have been impossible through a more specialized search profile.

The following keywords and phrases have been applied to delineate the field:

- chaos
- chaotic * system*
- complex * system*
- non(-)linear * dynamic*
- non(-)linear * system*
- self(-)organi*

4.1.3.1. General overview

Based upon this delineation complex systems is the smallest one among the analyzed fields, counting about two thousand publications in the Science Citation Index, but with a steady increase of slightly above 5 percent source publications: from 1976 in 1996 to 2234 in 1998 (see Table 1).

Table 1

Co-citation analysis complex systems 1996-98: Basic statistics

	1996	**1997**	**1998**
Source Publications	1976	2122	2234
Cited Publications	31958	34904	36878
Highly Cited Publications	948	1156	970
Clustered Publications	604	778	631
C1-Cluster	76	116	91
C2-Cluster	6	9	7

The complex systems source publications from a single database year are citing all together more than 30000 publications. For all three years about 1000 of the cited publications got four or more citations from the selected source publications.

The co-citation cluster analysis results for the source year 1996 in about 350 Clusters on the first level (C1) each year. The clustering process ends with a few clusters at the second level.

These C2-clusters can provide a general overview of the field and are shown in the following chapters for each year in overview maps and corresponding tables with numbers of clustered publications, co-citing publications and immediacy value, which counts the cited documents published not more than three years before the source year. In the overview maps from 1996 to 1998 the C2-clusters based on their co-citation linkage strength are shown. Lines between the circles indicate the strongest co-citation links with a Salton-Index above 0.05 (see chapter 2.5).

In addition to the overview maps national and institutional actors are listed and their contribution to the C2-clusters as proportion of the research fronts is shown.

4.1.3.1.1. Complex Systems 1996

948 publications which are highly cited by the 1976 complex systems source publications in 1996 are clustered into 76 C1-clusters on the first level and 6 C2-clusters on the second level. These six C2-clusters are listed in table 2.67 and shown in the overview map in figure 2.22.

Table 2

C2-clusters of complex system 1996

Cl-nr.	Title	C1	Core	Front	Imm
1	Chaos in the Solar System	2	10	9	10
2	Quantum Chaos	11	81	84	28
3	H-Infinity-Control/Adaptive Control	4	45	70	13
4	Self-organized Criticality	3	54	62	38
5	Chaotic Advection/Chaotic Mixing	2	13	21	15
6	Chaotic Systems	40	314	426	33

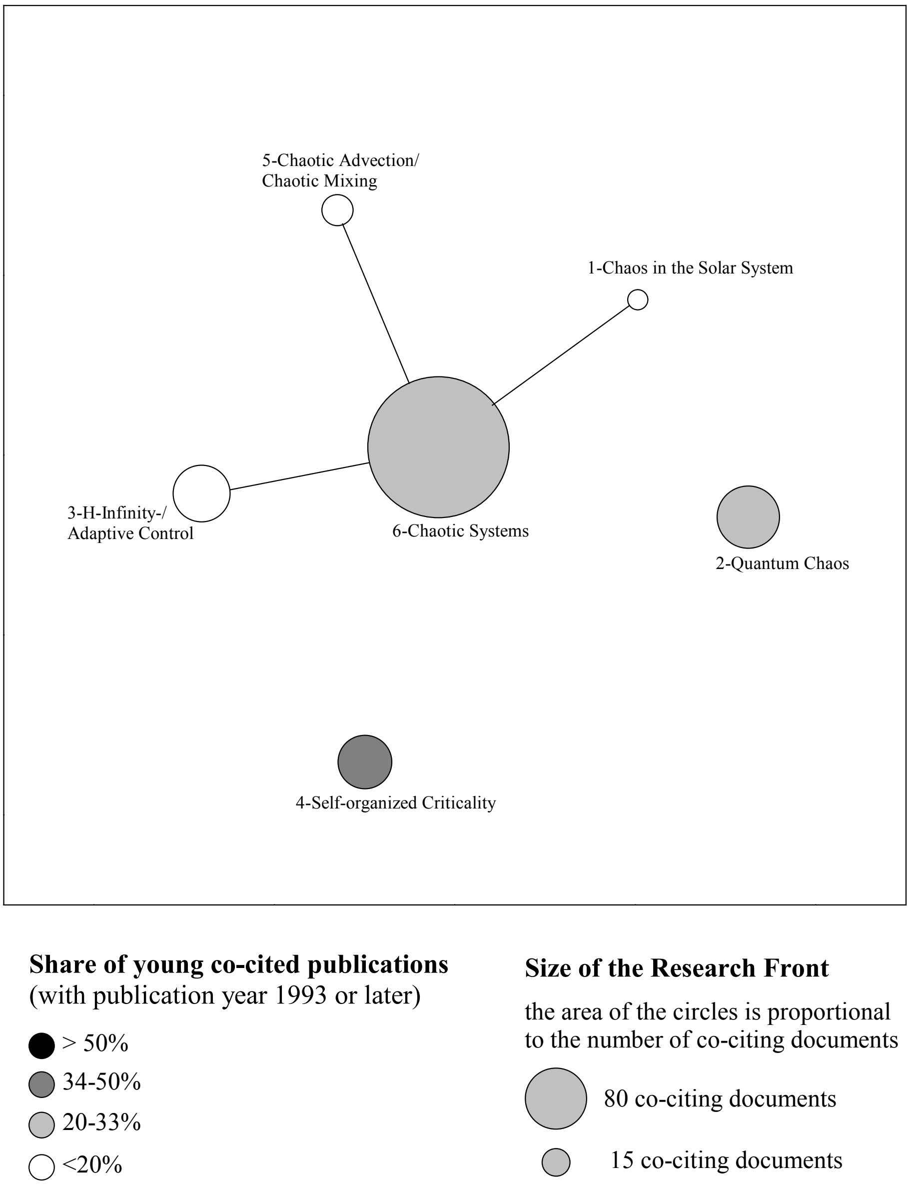


Figure 2.1
Overview map complex systems 1996

The structure of the field was dominated in 1996 by the large region *chaotic systems* represented by C2-cluster number 6 in the middle of the map (figure 2.22). More than half of the clustered cited publications are affiliated to this central cluster, containing 40 sub-clusters. The other clusters surrounding the central region are much smaller, including each less than 100 highly cited publications. The largest surrounding C2-cluster is *Quantum Chaos* (2), which together with *self-organized criticality* (4) is more isolated from the central region than the other three smaller clusters. The dynamic of the subfields visible in the overview map is rather low as indicated by the percentage of younger cited publications in the clusters. This share of younger documents called the immediacy value reaches only up to one third for the two largest clusters and only cluster 4 *self-organized criticality* comes to a slightly higher value (38%), as shown by the darker shade of the corresponding circle.

Table 3

Top national actors of complex systems 1996

Publications	Percent	Country
558	28.2	USA
541	27.4	EU
190	9.6	GERMANY
186	9.4	JAPAN
136	6.9	UK
125	6.3	RUSSIA
105	5.3	ITALY
101	5.1	FRANCE
71	3.6	PEOPLES R CHINA
61	3.1	SPAIN
61	3.1	CANADA
59	3.0	INDIA
41	2.1	TAIWAN
41	2.1	POLAND
39	2.0	AUSTRALIA
31	1.6	ISRAEL

The fifteen main national actors and in addition the European Union (EU15) are listed in table 2.68 according to their number of source publications. The country ranking is leaded by the USA (28.2%) followed by Germany (9.6%) and Japan (9.4%). The nations of the European Union together come to a proportion of publications clearly above the USA. The non-European countries following Japan are Russia, the Peoples Republic of China and Canada.

Table 4

Top institutional actors of complex systems 1996

Publications	Institutions
56	UNIV MARYLAND, USA
46	UNIV CALIF SAN DIEGO, USA
45	RUSSIAN ACAD SCI, RUSSIA
25	UNIV CALIF BERKELEY, USA
24	UNIV TOKYO, JAPAN
21	BOSTON UNIV, USA
21	IST NAZL FIS NUCL, ITALY
21	UNIV TEXAS, USA
19	FREE UNIV BRUSSELS, BELGIUM
17	UNIV KANSAS, USA
17	UNIV ROMA LA SAPIENZA, ITALY
16	INDIAN INST TECHNOL, INDIA
16	UNIV CALIF SANTA BARBARA, USA

Publications	Institutions
15	MIT, USA
15	MOSCOW MV LOMONOSOV STATE UNIV, RUSSIA

The list of the 15 top institutional actors, contributing 13 publications or more is leaded by the Russian Academy of the Sciences with 44 publications, followed by three US universities, the universities of Maryland (26 publ.) and of California, San Diego (25 publ.) and of California, Berkeley (20 publ.). The first European institute in the ranking is the Italian Istituto Nazionale di Fisica Nucleare (INFN) with 19 publications.

Table 5

Top European institutional actors of complex systems 1996

Publications	Institutions
21	IST NAZL FIS NUCL, ITALY
19	FREE UNIV BRUSSELS, BELGIUM
17	UNIV ROMA LA SAPIENZA, ITALY
14	CNRS, FRANCE
13	TECH UNIV BERLIN, GERMANY
13	UNIV MILAN, ITALY
12	UNIV CAMBRIDGE, ENGLAND
12	UNIV FRANKFURT, GERMANY
11	UNIV LEEDS, ENGLAND
10	UNIV FLORENCE, ITALY
10	UNIV LONDON IMPERIAL COLL SCI TECHNOL & MED, ENGLAND

In table 2.70 only the top European institutions are listed. Besides the leading INFN Italy is represented by three institutions. Germany as the leading European country in table 2.69 is represented by three universities (TU Berlin, Frankfurt and Potsdam). Remarkably is the second position of the Belgian Free University Brussels although Belgium does not appear between the top countries listed in table 2.69.

The last tables were focussed on the activity of the main actors for the whole field of complex systems. In the next tables the shares on the research front publications of the C2-Clusters are listed for the most important countries and regions providing an activity profile against the background of the co-citation structure.

Table 6

Share of the triad countries in the C2-clusters' research fronts of complex systems 1996, sorted by the share of EU15 publications on the research front

Rank	Title (CL.-No.)	Front	EU15 (36.6)	USA (33.3)	JAPAN (10.8)
1	Quantum Chaos (2)	84	48.8 ▲	28.6	10.7
2	Self-organized Criticality (4)	62	48.4	32.3	9.7
3	Chaotic Systems (6)	426	35.2	30.5	12.0
4	Chaos in the Solar System (1)	9	33.3	11.1	11.1
5	H-Infinity-/Adaptive Control (3)	70	27.1	48.6 ▲	8.6
6	Chaotic Advection/Chaotic Mixing (5)	21	19.0	66.7 ▲	0

Table 7

Share of the top European countries in the C2-clusters' research fronts of complex system 1996, sorted by the share of EU15 publications on the research front

Rank	Title (No.)	Front	EU15 (36.6)	GER (9.7)	UK (7.9)	F (4.4)	Italy (6.8)
1	Quantum Chaos (2)	84	48.8 ▲	16.7 ▲	15.5 ▲	6.0	6.0
2	Self-organized Criticality (4)	62	48.4	16.1	8.1	3.2	9.7
3	Chaotic Systems (6)	426	35.2	9.4	6.8	3.5	6.6
4	Chaos in the Solar System (1)	9	33.3	0	0	33.3	0
5	H-Infinity-/Adaptive Control (3)	70	27.1	2.9	5.7	4.3	8.6
6	Chaotic Advection/Chaotic Mixing (5)	21	19.0	0	9.5	4.8	0

In table 2.71 the activity profile for the triad, USA, EU15 and Japan is given. The C2-clusters are ranked by the percentage of EU15 publications at their research fronts. The cluster having the highest EU15 contribution is *Quantum Chaos.* Compared with the average EU15 contribution of 36.8% it is at the same time the only C2-cluster which is differing significantly. The cluster *self-organized criticality* shows nearly the same rather high share of EU15 publications, but the smaller number of publications on the research front results in a wider confidence interval.[12] For the large central cluster the compared units are represented with average shares of publications. Only in the smaller clusters *Adaptive Control* and *Chaotic Advection/Chaotic Mixing* the USA are represented clearly over the average. Japan as third part of the triad shows a rather balanced activity profile.

The contribution of Japan is differing hardly from the overall share of 10.7%, besides the cluster *Chaotic Advection/Chaotic Mixing*

Table 2.72 allows a detailed view on the activity profiles of the most active European countries for the field complex systems. It can be seen that the strong position of the EU15 is sustained to a great part by Germany and the United Kingdom, which show a significantly high proportion of front publications for the C2-cluster Quantum Chaos.

[12] The computation of the confidence interval for the differences between the national subsets of all C2-cluster front publications and single C2-cluster fronts is based on the assumption of a binomial distribution and an error probability of 0.05%.

Germany is also rather active in *Self-organized Criticality* and is only poorly represented in the smaller clusters *H-Infinity-/Adaptive Control* and *Chaotic Advection/Chaotic Mixing* which are USA dominated. The other countries show a more expectable distribution of publications against the C2-clusters.

4.1.3.1.2. Complex Systems 1997

In 1997 we found ca. 10% more source publications compared to the first year of the analysis, and about 20% more highly cited publications. Because the increase is even much higher than for all cited publications (10%), more coherent citation patterns in 1997 can be expected from these relations. Therefore also the co-citation density is higher and as a consequence different cluster structures will emerge.

After the cluster analysis (with the same parameters) the 1156 highly cited publications were affiliated to 116 C1-clusters including 778 of the cited publications. The increase of more than 50% in the number of C1-clusters is an indication for an effect of the higher co-citation density in this year. Also the next step of the clustering procedure results in more clusters compared with the year before.

The 9 C2-clusters are listed in table 2.73 with numbers of clustered C1-clusters (C1), clustered core publications (Core), publications on the C2 research fronts (Front) and the immediacy value (Imm).

Table 8

C2-clusters of complex systems 1997

Cl-nr.	Titel	C1	Core	Front	Imm
1	H-Infinity-/Adaptive Control	6	53	86	7
2	Chaotic Dynamics of Shallow Arch Structures	2	8	16	12
3	Self-organizing Maps	4	17	34	5
4	Chaos and Organization	2	9	13	0
5	Chaotic Dynamics of Populations	3	27	47	18
6	Chaotic Time-Series	6	65	105	12
7	Hamiltonian chaos	5	18	33	0
8	Quantum Chaos	13	104	88	38
9	Chaotic Systems	38	294	349	40

In 1997 the cluster list shows a more differentiated distribution regarding the core and front size and is more polarized regarding the dynamic of the represented areas. As in 1996 the larger clusters, *Chaotic Systems* (9) and *Quantum Chaos* (8), have been formed, but the first one is much smaller in 1997. That is due to the separation of a part of the large central cluster as a new cluster, *Chaotic Time Series* (6), which is strongly connected with the remaining cluster *Chaotic Systems*.

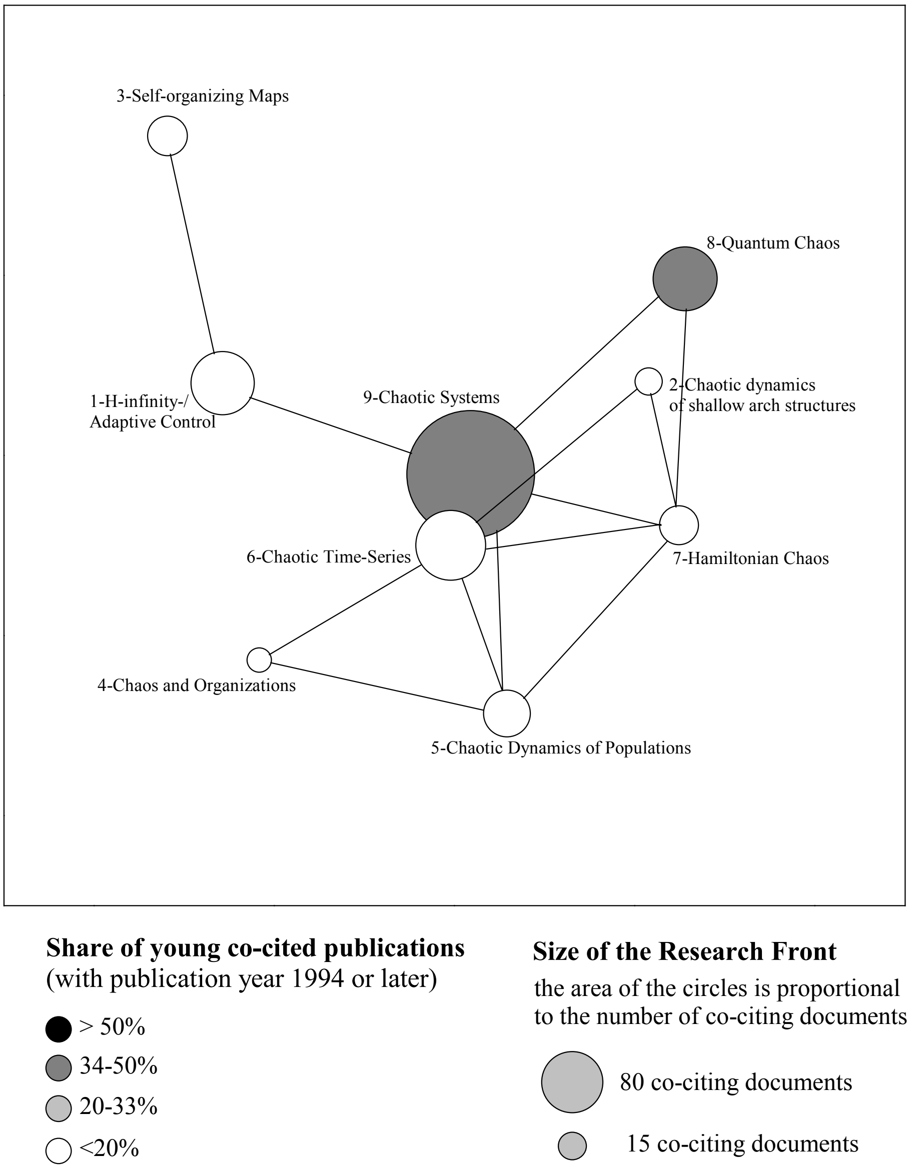


Figure 2.2

Overview map for complex systems 1997

On a first glance the overview map shows much difference to the corresponding map in 1996. But the relation of the larger clusters is relative stable. The clusters *Quantum Chaos* (8) and *H-Infinity-/Adaptive Control* (1) are positioned nearly diametrically opposed both with relative strong links to the central cluster *Chaotic Systems*. On the same side of the map a smaller cluster dealing with self-organization, *Self-organizing Maps* (3) is located. In the overview map of 1996 the cluster *Self-organized Criticality* could be found, which was (in opposite to the 1997 map) directly linked to the large central cluster. However, the cluster *Self-organizing Maps* in 1997 has its predecessor not in the cluster *Self-organized Criticality* but in a C1-cluster. In 1997 the core publications of the 1996' cluster *Self-organized Criticality* which were highly cited again are partly grouped in a C1-cluster outside the C2-regions.

The core publications of the new cluster *Chaotic Time Series* (6) which have been already highly cited and clustered in the analysis for 1996 were all clustered in the predecessor of the cluster *Chaotic Systems* (9). Remarkable is the small proportion of younger cited publications (published after 1993) in the core of the cluster *Chaotic Time Series* (6), which come to only 12% of the clustered publications. The thematic scope of the cluster regarding the phenomenon areas in which the analyzed chaotic time series are found, reach from medicine (EEG, cardiac interbeat intervals), physics (geophysical time series, chaos in geomagnetic fields, chaotic laser dynamics) to economics (foreign exchange rate return) and psychology (psychotherapy as a chaotic process).

Among the other smaller clusters is only one which can be traced back to an area visible in the 1996 co-citation structure. The cluster *Chaotic Dynamics of Populations* (5) positioned on the bottom of the overview map consists of a number of cited publications which were already clustered in C1-clusters positioned in an area of the central cluster in 1996.

The clusters *Chaos and Organizations* (4), *Hamiltonian Chaos* (7) and *Chaotic Dynamics of Shallow Arch Structures* (2) are "new" regarding the clustered elements. The cited publications of these 1997 cluster were in great parts not or not often enough cited from 1996 source publications or they remained isolated in the 1996 clustering procedure.

The turning up and disappearing of clusters from one year to another is a normal characteristic of co-citation structures not always indicating arising or vanishing specialties. It results partly from the fluctuation in terms of analyzed cited publications. In cases of small specialties represented by a few highly cited and co-cited publications it often depends on a few citations if it gets visible as a co-citation cluster.

Table 9

Top national actors of complex systems 1997

Publications	Percent	Country
604	28.5	USA
587	27.6	EU
203	9.6	GERMANY
179	8.4	JAPAN
152	7.2	RUSSIA
147	6.9	UK
116	5.5	FRANCE
106	5.0	ITALY
98	4.6	PEOPLES R CHINA
80	3.8	CANADA
73	3.4	INDIA
57	2.7	SPAIN
55	2.6	AUSTRALIA
38	1.8	ISRAEL
36	1.7	NETHERLANDS
35	1.6	BRAZIL

The lists of top actors of the field complex systems is presented in table 2.74. The ranking changed only slightly compared with the 1996 country list (table 2.68). At the first places Russia and the United Kingdom as well as France and Italy swapped their places and in the same way the places below has shifted only marginal.

Table 10

Top institutional actors of complex systems 1997

Publications	Institutions
60	UNIV MARYLAND, USA
55	RUSSIAN ACAD SCI, RUSSIA
31	UNIV CALIF SAN DIEGO, USA
30	UNIV TEXAS, USA
24	MIT, USA
23	UNIV CALIF BERKELEY, USA
22	ACAD SINICA, PEOPLES R CHINA
21	UNIV KANSAS, USA
21	UNIV TOKYO, JAPAN
20	FREE UNIV BRUSSELS, BELGIUM
19	UNIV TORONTO, CANADA
17	GEORGIA INST TECHNOL, USA
17	UNIV PARIS 06, FRANCE
16	MOSCOW MV LOMONOSOV STATE UNIV, RUSSIA
16	NATL UNIV SINGAPORE, SINGAPORE
16	UNIV CALIF LOS ANGELES, USA
16	UNIV ILLINOIS, USA
16	UNIV POTSDAM, GERMANY

The ranking of the top institutional actors of complex systems shown in table 2.75 indicates some changes. The two leading institutions are the same as in 1997 but three institutions have improved their positions. The MIT and the University of Texas as well as the Chinese Academy Sinica increased their number of publications in the field of complex systems by more than 35%. At the places below many institutions can be found which have not been listed in 1996 and from those some disappeared. However the changes at the lower places are due to very small changes in the numbers of publications and therefore can hardly be interpreted.

Table 11

Top European institutional actors of complex systems 1997

Publications	Institutions
20	FREE UNIV BRUSSELS, BELGIUM
17	UNIV PARIS 06, FRANCE
16	UNIV POTSDAM, GERMANY
14	IST NAZL FIS NUCL, ITALY
13	UNIV ROMA LA SAPIENZA, ITALY
12	UNIV CAMBRIDGE, ENGLAND
11	LEIDEN UNIV, NETHERLANDS
11	NATL UNIV IRELAND UNIV COLL DUBLIN, IRELAND

Publications	Institutions
10	CNR, ITALY
10	CNRS, FRANCE
10	MAX PLANCK INST PHYS KOMPLEXER SYST, GERMANY
10	TH DARMSTADT, GERMANY
10	UNIV ESSEN GESAMTHSCH, GERMANY
10	UNIV FLORENCE, ITALY
10	UNIV SHEFFIELD, ENGLAND

For the European institutions with 8 or more publications two of the top positions changed. The University of Paris 06 and the German University of Potsdam joined the top of the ranking because of an increase in publications of more than 100%. The changes on the lower places are due to only minor differences in absolute numbers of publications.

Table 12

Share of the triad countries in the C2-clusters' research fronts of complex systems 1997, sorted by the share of EU15 publications on the research front

Rank Title (CL.-No.)	Front	EU15 (39.1)	USA (32.2)	JAPAN (6.7)
1 Quantum Chaos (8)	88	54.5 ▲	21.6 ▼	10.2
2 Chaotic Dynamics of Populations (5)	47	46.8	31.9	2.1
3 Self-organizing Maps (3)	34	44.1	32.4	5.9
4 Hamiltonian Chaos (7)	33	39.4	45.5	3.0
5 Chaotic Time-Series (6)	105	39.0	39.0	6.7
6 Chaotic Systems (9)	349	39.0	31.8	7.2
7 H-Infinity-/Adaptive Control (1)	86	27.9 ▼	36.0	3.5
8 Chaotic Dynamics of Shallow Arch Structures (2)	16	25.0	56.3 ▲	0
9 Chaos and Organizations (4)	13	7.7	76.9 ▲	0

Table 13

Share of the top European countries in the C2-clusters' research fronts of complex system 1997, sorted by the share of EU15 publications on the research front

Rank Title (No.)	Front	EU15 (39.1)	GER (12.2)	UK (6.6)	F (6.1)	Italy (5.4)
1 Quantum Chaos (8)	88	54.5 ▲	15.9	10.2	9.1	2.3
2 Chaotic Dynamics of Populations (5)	47	46.8	12.8	21.3 ▲	4.3	6.4
3 Self-organizing Maps (3)	34	44.1	29.4 ▲	2.9	0	2.9
4 Hamiltonian Chaos (7)	33	39.4	12.1	0	9.1	15.2 ▲
5 Chaotic Time-Series (6)	105	39.0	16.2	3.8	6.7	6.7
6 Chaotic Systems (9)	349	39.0	12.6	5.4	6.6	4.9
7 H-Infinity-/Adaptive Control (1)	86	27.9 ▼	0 ▼	8.1	5.8	8.1
8 Chaotic Dynamics of Shallow Arch Structures (2)	16	25.0	0	0	0	12.5
9 Chaos and Organizations (4)	13	7.7	0	0	7.7	0

In tables 2.77 and 2.78 the activity profiles of the main national actors of the triad show a similar distribution regarding the large clusters as in the year before.

As well as in 1996 the EU15 is significantly strong represented in the cluster *Quantum Chaos* (8), contributes to a rather high proportion of publications to the cluster *Self-organizing-Maps* (3), shows an average share on the central clusters *Chaotic Systems* (9) and *Chaotic Time Series* (6) and its activity in the subfield represented by the cluster *H-Infinity-/Adaptive Control* (1) is significantly low. (table 2.77) In the remaining clusters without a predecessor on the C2-level in 1996 no significant divergence from the C2-average is visible, but the EU15 countries are participating very strongly in the cluster *Chaotic Dynamics of Populations* (5) at least partly due to the high proportion of UK addressed front publications. (C2-cluster 5 is the only one with very high activity of the United Kingdom.)

The USA show the highest proportional activity in the two very small clusters *Chaotic Dynamics of Shallow Arch Structures* (2) and *Chaos and Organizations* (4) in which more than a half of the front publications have at least one US address. Another cluster with an US contribution clearly above the expected average value is *Hamiltonian Chaos* (7). An aggravation of the proportional activity of the USA can be stated for the *cluster Quantum Chaos* (8) in which the USA are in 1997 significantly bad represented and the cluster *H-Infinity-/Adaptive Control* (1) in which the proportion of US publications decreased from a significantly high level to 36%, just a little above the C2-average.

The third country shown in the table 2.77, Japan, contributes only to 6.7% to the C2 research fronts at all and its shares in the cluster's research fronts are not diverging significantly. The highest Japanese research activities are to be noted in the cluster *Quantum Chaos* (8).

Besides France the main European national actors as listed in table 2.78 all have a main emphasis on a single cluster. Germany is very well represented in the *cluster Self-organizing maps* (3), the United Kingdom contributes to the cluster *Chaotic Dynamics of Populations* (5) more than three times stronger as expectable, and Italy is very active on the research front of *Hamiltonian Chaos* (7).

4.1.3.1.3. Complex systems 1998

In 1998 again a slightly increase of source publications can be noticed. The 2234 publications are citing 36878 older publications from which 970 (2%) got more than three citations. (see table 2.66) That is a decrease referring to the number of highly cited publications in 1997. Therefore the proportion of highly cited documents falls back to a level even beneath the 1996 value, whereas the number of cited publications increased again.

This development is reflected in the figures for both cluster levels which are comparable to 1996 more than to 1997. The cluster analysis revealed 91 C1-clusters including 631 highly cited publications and the C1-clusters form 7 C2-clusters which are shown in the overview map (figure 2.24) and in table 2.79.

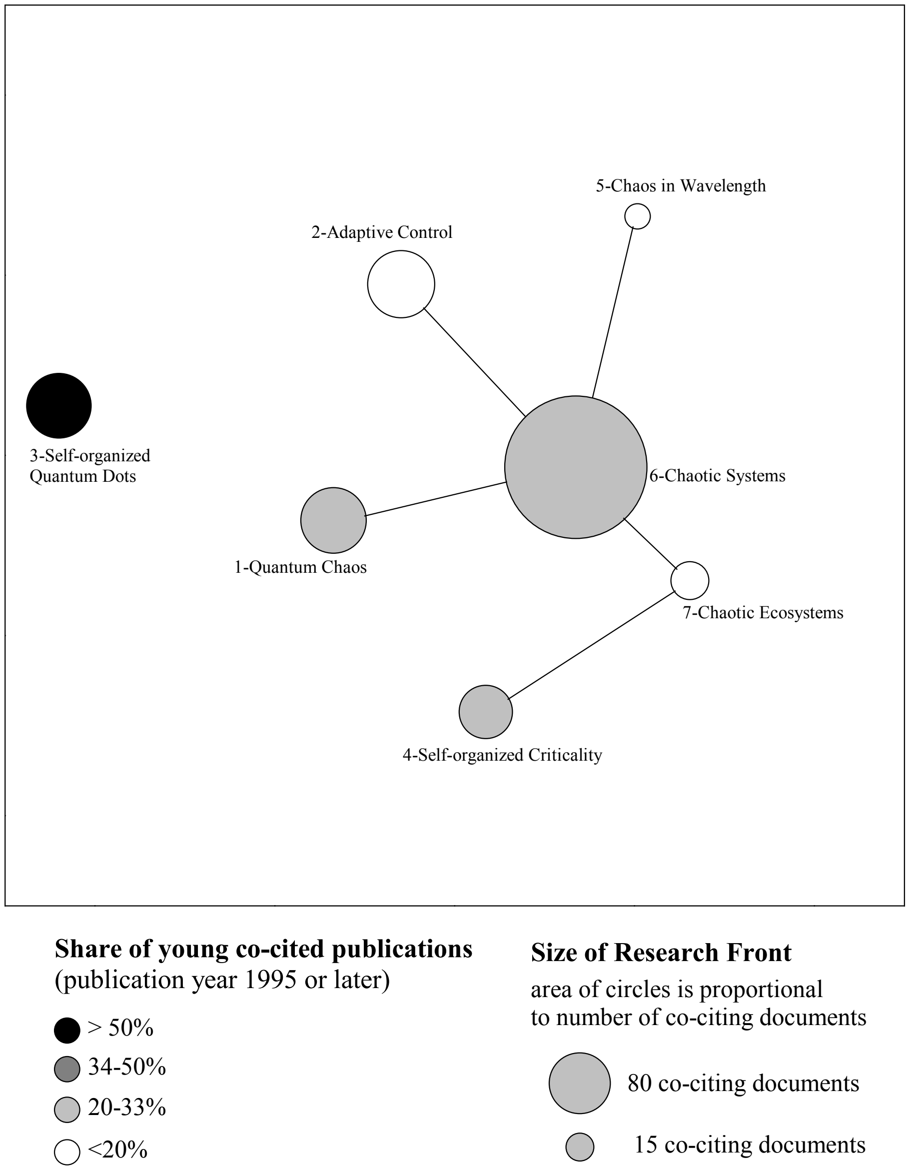


Figure 2.24:
Overview map for complex systems 1998

Table 2.79:
C2-clusters of complex systems 1998

Cl-nr.	Titel	C1	Core	Front	Imm
1	Quantum Chaos	9	72	92	33
2	Adaptive Control	7	52	97	13
3	Self-organized quantum dots	9	67	90	59
4	Self-organized Criticality	4	48	61	25
5	Chaos in wavelength	3	8	14	0
6	Chaotic systems	38	318	435	22
7	Chaotic Ecosystems	4	12	31	8

Compared with the co-citation structure in 1997 the appearance of a new subfield at the periphery of the map is the most striking development. The C2-cluster *Self-organized Quantum Dots* (3) consists of 67 cited publications. These publications were partly clustered in the 1997 C1-cluster *Self-organized Nanoscale Structures* which remained isolated and therefore invisible at the C2-level.

Most of the other clusters are known from both years analyzed before. The smaller cluster *Chaos in wavelength* (5) turns up as a new one and *Self-organized Criticality* (4) was amongst the C2-clusters in 1996 and followed by an isolated C1-cluster in 1997 (The Bak-Sneppen Model) which was the predecessor of the 1998 C2-cluster.

Table 2.80:
Top national actors of complex systems 1998

Publications	Percent	Country
763	34.2	EU15
642	28.7	USA
210	9.4	Germany
204	9.1	Japan
175	7.8	United Kingdom
161	7.2	Russia
142	6.4	France
140	6.3	Peoples R China
101	4.5	Italy
65	2.9	Spain
64	2.9	India
54	2.4	Canada
53	2.4	Taiwan
51	2.3	Australia
42	1.9	Brazil
38	1.7	South Korea
38	1.7	Netherlands

The list of the main national actors of the field (table 2.80) shows only marginal changes in the top positions. The countries loosing in proportion and in absolute numbers of publications are Italy, India and Canada which publications decreased about more than one third compared to 1997. The countries with particularly high rates of increase are the two Chinese countries, the Peoples Republic and Taiwan.

Table 2.81:
Top institutional actors of complex systems 1998

Publications	Institution
56	Russian Acad Sci, Russia
29	Univ Calif Berkeley, USA
29	Univ Maryland, USA
21	Chinese Acad Sci, Peoples R China
18	Boston Univ, USA
18	USN, USA
17	Georgia Inst Technol, USA
17	MIT, USA
17	Univ Texas, USA
17	Univ Tokyo, Japan
16	Indian Inst Technol, India
16	Moscow MV Lomonosov State Univ, Russia
16	Univ Illinois, USA
15	Texas A&M Univ, USA
13	Univ Calif Los Alamos Natl Lab, USA
13	Univ Houston, USA

The main changes in the ranking of the 15 top institutional actors of complex systems from 1997 to 1998 concerns the top positions. Whereas the Russian Academy of the Sciences and the University of Maryland kept their positions, the University of California, Berkeley got on the third position, because of an increase of their complex systems publications by more than 50%, whereas the University of Texas has lost its top position. A newcomer in the ranking appears on the fourth position, the Chinese Academy of the Sciences joins the list with 21 publications in 1998. And also on both of the following places are two US institutions which could not be found on the top 15 positions in the two years before, the Boston University and the US Navy research institutes (USN) both with a trebling of their complex systems publications.

Table 2.82:
Top European institutional actors of complex systems 1998

Publications	Institution
12	CNRS, France
12	Free Univ Brussels, Belgium
12	Univ Cambridge, United Kingdom
12	Univ Paris 06, France
11	Max Planck Inst Phys Komplexer Syst, Germany
11	Univ Rome La Sapienza, Italy
11	Univ Sheffield, United Kingdom
10	Tech Univ Berlin, Germany
10	Univ Bologna, Italy
9	Ist Nazl Fis Nucl, Italy
9	Univ London Imperial Coll Sci Technol & Med, United Kingdom
9	Univ Milan, Italy
9	Univ Padua, Italy
8	Helsinki Univ Technol, Finland

Publications	Institution
8	Univ Amsterdam, Netherlands
8	Univ Cantabria, Spain
8	Univ Oxford, United Kingdom
8	Univ Paris Sud, France
8	Univ Stuttgart, Germany

The ranking of the top European institutions again shows only a narrow range of publication counts and all changes are due to only small differences in absolute numbers. All of the institutions at the first places appeared among the top European institutions already in 1997.

Table 2.83:

Share of the triad countries in C2-clusters' research fronts of complex systems 1998, ranked by share of EU15 publications

Rank Title (CL.-No.)	Front	EU15 (33.7)	USA (32.1)	JAPAN (11.4)
1 Quantum Chaos (1)	92	47.8 ▲	31.5	7.6
2 Self-organized Criticality (4)	61	44.3	41.0	1.6
3 Chaotic Ecosystems (7)	31	41.9	25.8	6.5
4 Chaotic Systems (6)	435	33.3	32.2	12.0
5 Self-organized Quantum Dots (3)	90	28.9	26.7	24.4 ▲
6 Chaos in Wavelength (5)	14	28.6	7.1	14.3
7 Adaptive Control (2)	97	25.8	32.0	4.1

The three large national or regional units compared in table 2.83 changed their distribution of publication shares in the C2 research fronts only slightly. For the EU15 and the USA the C2 activity profile is more balanced, but the same pattern is visible. The EU15 countries are well represented in *Quantum Chaos* (1), the self-organization cluster (4) and in the small cluster *Chaotic Ecosystems* (7), but contribute to a less than expectable amount to the publications co-citing the *Adaptive Control* (2) cluster core. For the USA the relative activity changes to an average value: in the cluster *Quantum Chaos* (1) by a decrease and in *Adaptive Control* (2) by an increase of publication share. The C2-cluster with the highest US share in 1998 is *Self-organized Criticality* (4) but this share is not significantly higher than the C2 level average. Japan on the other hand shows a main emphasis on *Self-organized Quantum Dots* (3) which can not be compared to the years before because the cluster appeared on the C2-level in 1998 first.

Table 2.84:
Share of the top European countries in C2 research fronts of complex systems 1998, ranked by share of EU15 publications

Rank Title (No.)	Front	EU15 (33.7)	GER (10.1)	UK (6.9)	F (6.5)	Italy (5.6)
1 Quantum Chaos (1)	92	47.8 ▲	16.3	8.7	6.5	8.7
2 Self-organized Criticality (4)	61	44.3	9.8	11.5	11.5	19.7 ▲
3 Chaotic Ecosystems (7)	31	41.9	3.2	6.5	12.9	0
4 Chaotic Systems (6)	435	33.3	10.1	6.0	6.0	4.4
5 Self-organized Quantum Dots (3)	90	28.9	15.6	5.6	6.7	3.3
6 Chaos in Wavelength (5)	14	28.6	7.1	0	21.4	14.3
7 Adaptive Control (2)	97	25.8	1.0	8.2	7.2	6.2

Table 2.84 shows the distribution of the proportion on the front publications of C2-clusters for the large EU15 countries. For some clusters the relative weight of the countries is differing from the EU15 value. For the cluster *Self-organized Criticality* (4) relatively high values for the UK, France and especially Italy (which differs significantly) correspond to the relative activity of the whole EU15, but contrast to a German contribution below the average of Germany on the C2-level. At the research front of the "new" C2-cluster *Self-organized Quantum Dots* (3) on the opposite the contribution of Germany is relatively high.

4.1.3.1.4. Changes from 1996 to 1998

- In this chapter the most striking patterns and developments regarding the co-citation structure and the most active actors of the field are listed in summary. The developments have to be interpreted with cautious because of the short time span.
- The co-citation structure is dominated by the large central cluster *Chaotic Systems* over the whole period.
- Two smaller but stable areas are represented by C2-clusters: *Quantum Chaos* with a significantly high contribution of EU15 countries in all three years and *Adaptive Control* with a high US share in 1996, continuously decreasing to an average value in 1998 .
- The cluster *Adaptive Control* shows a rather low share of younger publications in the cluster-core, an indicator for a more established research specialty.
- The research areas self-organized criticality and self-organized maps constitute co-citation clusters, but do not appear in all subsequent years on the C2-level. They are more remote from the central themes.
- In 1998 a research area turned up on the overview map, *Self-organized Quantum Dots* which is formed by 67 clustered publications including a rather high proportion of younger publications. It has a predecessor in the C1-cluster *Self-organized Nanoscale Structures*

4.2. General results based on co-word analysis

In this chapter we discuss the main results of the three studied fields in this part of the project. These results are all available at the Internet pages dedicated to the co-word analyses (c.f., http://www.cwts.leidenuniv.nl/ed/projects.html). On these pages, we provide interfaces to explore and evaluate the maps with the information behind the maps. A full summary of all the information available there, would be impossible. Therefore, we confine ourselves to the highlights of results in each field.

4.2.1. Telecommunication

The field of telecommunication was delineated on the basis of publications covered by the INSPEC database with the classification code B62 (telecommunication). We discerned two periods of time (1996-1997 and 1998-1999). By the time the data was collected the complete data of 1999 was not available yet. Because of that, the latter period covers fewer publications than the former. The total number of publications in the entire period is around 45,000. These publications are distributed over years, document types and language in the table below.

Table 14

Distribution of Telecom publications over years, document types and languages

Years

6	1993
11	1994
761	1995
7492	1996
17129	1997
16881	1998
4801	1999

Document types

3	Book
39	Book-chapter
23439	Conference-Paper
2736	Conference-Paper; Journal-article
417	Conference-Proceedings
107	Conference-Proceedings; Journal-article
20302	Journal-article
36	Report
2	Report-Section

Languages

1	Bulgarian
840	Chinese
1	Chinese; English
38	Croatian
2	Danish
25	Dutch
42676	English
79	English; Italian
100	French
5	French; English
712	German
1	German; English
1	Hungarian
94	Italian
70	Italian; English
1632	Japanese
306	Korean
2	Lithuanian
345	Polish
1	Romanian
92	Russian
1	Serbian
12	Slovenian
44	Spanish
1	Ukrainian

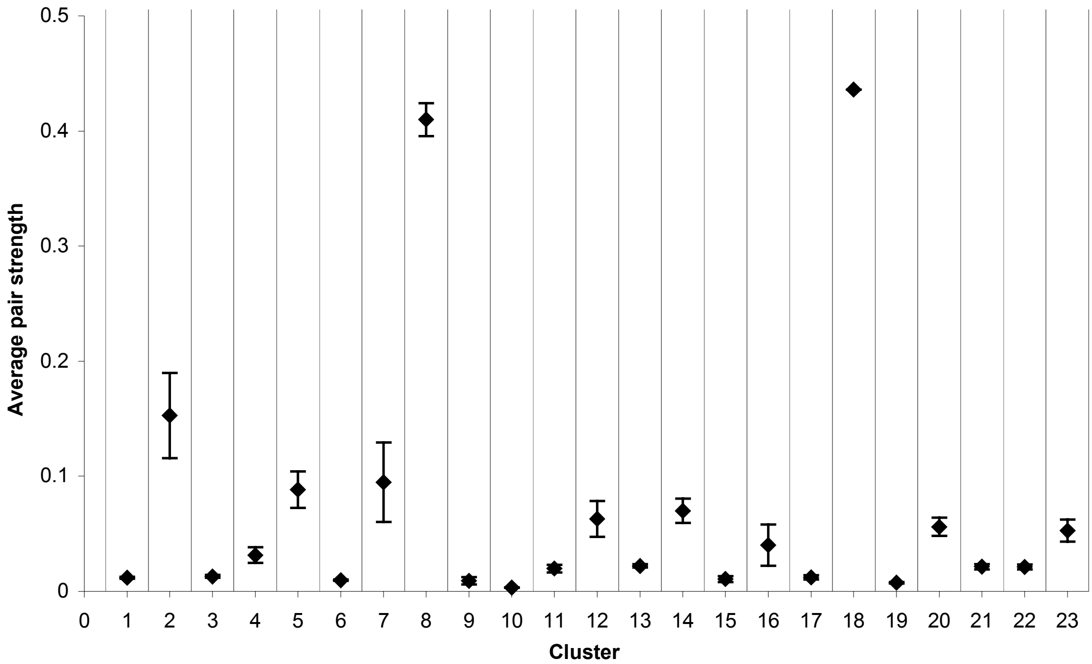
Using the selection procedure described in the method chapter, we selected 542 keywords for telecommunication. The clustering analysis distributed these 542 keywords over 23 subdomains of telecommunication. The list of identified subdomains and the numbers of publications covered in 1996-1997 and 1998-1999 are in the Table below.

Table 15

Identified subdomains in telecommunication (INSPEC, class. code B62)

Cluster	96/97	98/99	Label
1	1792	1666	optical communication / optical signal / EDFA / erbium doped fiber amplifier
2	373	292	direct sequence / spread spectrum / spread spectrum system / spread spectrum com
3	2359	2258	IP / multimedia application / multimedia service / TCP
4	1088	993	mu m / dynamic range / optical receiver / free space
5	535	529	optical amplifier / wavelength conversion / four wave / dispersion compensation
6	3121	2971	mobile communication / GSM / wireless communication / mobile communication syste
7	280	306	wireless atm / wireless atm network / wireless access / mobility management
8	1006	1007	multiple access / CDMA / code division
9	1130	1005	communication system / digital signal / system design / OFDM
10	5101	4315	GPS / low cost / computer network / satellite communication
11	810	809	optical network / transmission system / wdm system / wdm network
12	2051	1588	ATM / atm network / atm switch / traffic management
13	1824	1777	base station / cellular system / cdma system / TDMA
14	1158	976	Fiber / optical fiber / single mode fiber / chromatic dispersion
15	1096	832	high speed / access network / high performance / high bit rate
16	787	585	LAN / local area network / WAN / switching system
17	855	761	laser diode / low loss / optical fibre / optical link
18	1072	1086	WDM / wavelength division
19	2384	2197	real time / ISDN / data transmission / multimedia communication
20	666	813	QoS / multimedia traffic / bandwidth allocation / flow control
21	1624	1607	wireless network / performance analysis / performance evaluation / mobile user
22	1243	1246	bit error rate / system performance / fading channel / channel estimation
23	357	326	network management / network management system / service management / mobile age

The internal strength of subdomains is determined by the average direct linkage between keyword pairs. In the Figure below these subdomain strengths are depicted, together with their standard deviation.

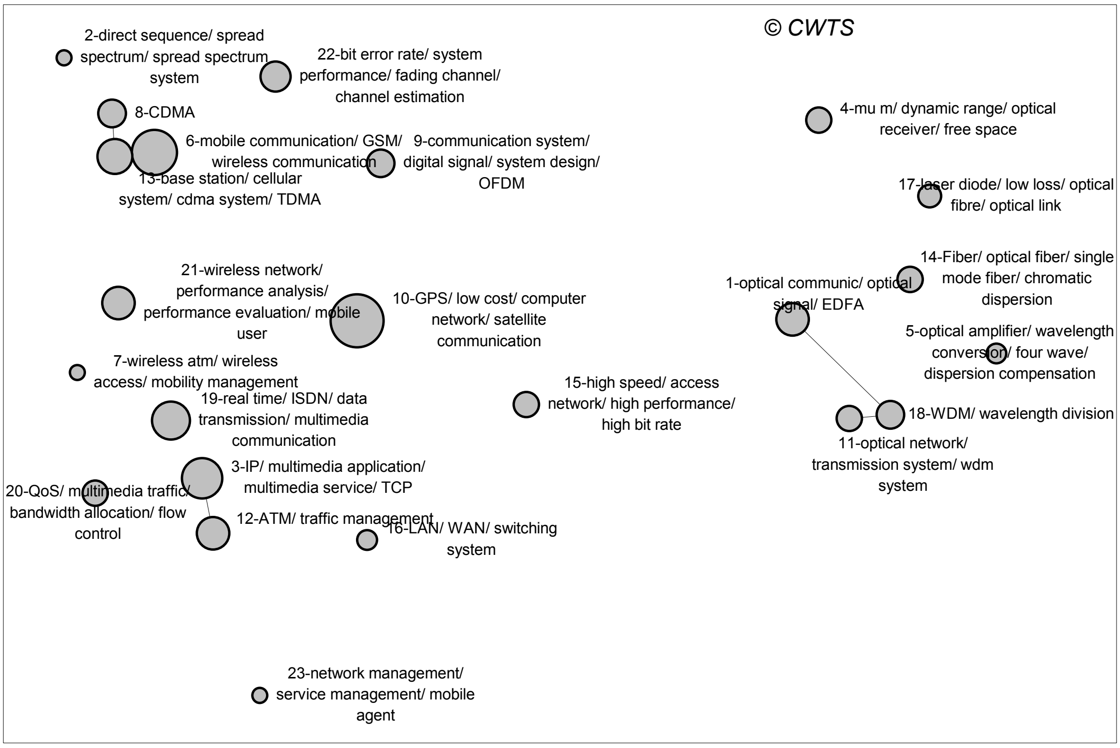


Subdomains	
1-optical communic/ optical signal/ EDFA	12-ATM/ traffic management
2-direct sequence/ spread spectrum/ spread spectrum system	13-base station/ cellular system/ cdma system/ TDMA
3-IP/ multimedia application/ multimedia service/ TCP	14-Fiber/ optical fiber/ single mode fiber/ chromatic dispersion
4-mu m/ dynamic range/ optical receiver/ free space	15-high speed/ access network/ high performance/ high bit rate
5-optical amplifier/ wavelength conversion/ four wave/ dispersion compensation	16-LAN/ WAN/ switching system
6-mobile communication/ GSM/ wireless communication	17-laser diode/ low loss/ optical fibre/ optical link
7-wireless atm/ wireless access/ mobility management	18-WDM/ wavelength division
8-CDMA	19-real time/ ISDN/ data transmission/ multimedia communication
9-communication system/ digital signal/ system design/ OFDM	20-QoS/ multimedia traffic/ bandwidth allocation/ flow control
10-GPS/ low cost/ computer network/ satellite communication	21-wireless network/ performance analysis/ performance evaluation/ mobile user
11-optical network/ transmission system/ wdm system	22-bit error rate/ system performance/ fading channel/ channel estimation
	23-network management/ service management/ mobile agent

Figure 4-1

Coherence of identified Telecommunication keyword clusters

The Figure shows a couple of areas with a very strong internal coherence (2,5,7,8 and 18). These are, on average, smaller subdomains. The bigger clusters (with relatively many keywords and many publications) show a relatively low internal coherence.



Two-dimensional representation of Telecom based on the similarities between identified clusters of keywords (subdomains). The circle size indicates the number of publications represented. The color of the circles indicates a significant increase/decrease of activity:

- Red: increase of activity
- Blue: decrease of activity

The badness-of-fit criterion is 0.09, the distance correlation is 0.98 (statistics provided by SAS).

Figure 4-2

Map of telecommunication (1998-1999)

4.2.2. *Neuroscience*

In this part of the project we map the field of Neurosciences. Within the field the activity profile of EC countries is characterized. We explore the potentials of mapping large fields (such as neuroscience) on the basis of co-word analysis, i.e. an analysis on the basis of co-occurrences of words and phrases in publications. In a parallel study the same field is mapped on the basis of co-citation analysis by IWT at the University Bielefeld in Germany. To map the field of neuroscience we both use a specialty database, the Neuroscience Citation Index (NCI 1991-1998).

4.2.2.1. Data and Method

The data we used to explore the field is retrieved from the specialty CDROM version of the Science Citation Index, the Neuroscience Citation Index (NCI). In this part of the study, the full database of NCI (1991-present) is loaded into the CWTS data system. The publication data from NCI (publication years 1997-1998) were processed for the bibliometric mapping procedures. The total number of publications is around 500,000. The bibliographic data base consists of

- Author names
- Author addresses
- Publication title
- Source (Journal, serial, book etc.)
- Cited References
- Abstract

A most important part of a bibliometric mapping study based on words/terms co-occurrence data, is the selection of keywords. The selection in this project was established on the basis of two keyword characteristics and on the basis of the input of a field expert. The keyword characteristics concern the bibliometric distribution (the number of time a term is found in a publication), and its syntactic structure. On the basis of identified Noun Phrases (NPs) in titles, we compiled two lists of candidates. One containing multiple word NPs, which are most likely to be selected because of their specific meaning. The other list consists of single word NPs which are most likely to be excluded because of their non-specific meaning. Both lists can be checked by visitors of this website. Visitors can give there comments to the selected list of candidates by filling out the NP selection forms on-line. There are two forms available: one lists the single word NPs, which have not been selected unless indicated otherwise, the other lists the multiple word NPs which have been selected.

On the basis of previous projects and expert input in an earlier stage of this project, two lists of NPs were compiled which should be removed from the list of selected (multiword) NPs (the field keywords). The list based on earlier projects is here, the list based on expert input is here.

The 810 selected keywords were subject to a cluster analysis in order to identify groups of keywords, representing subdomains of Neuroscience. The clustering procedure yielded 37 keyword clusters. As the clustering algorithm accounts for 37*37 relations, we calculated within each cluster the average linkage between pairs of keywords. Thus, we obtain an indication of the cluster-internal coherence.

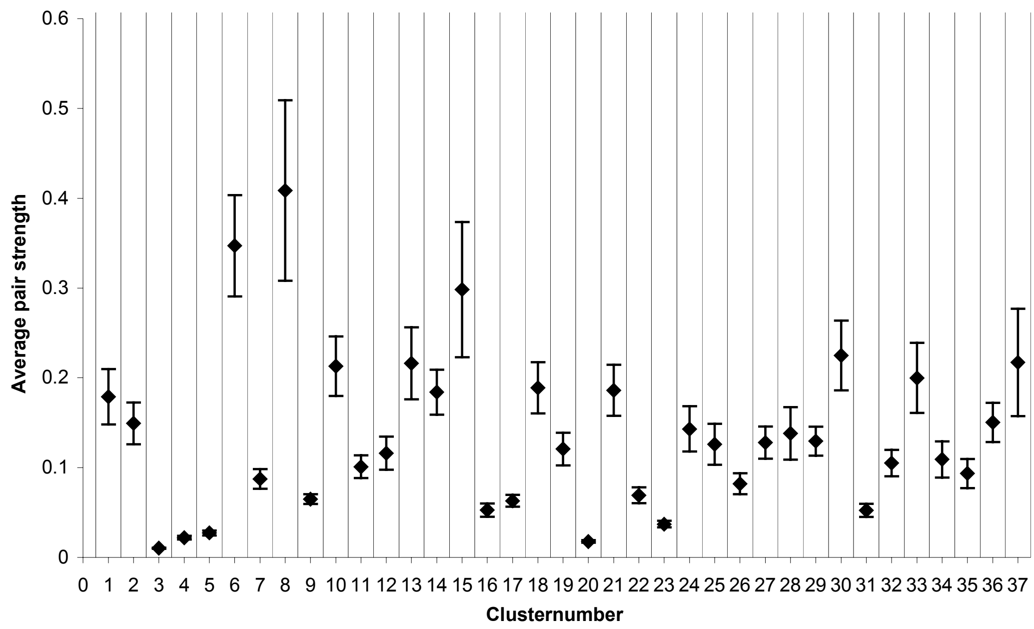


Figure 4-3

Cluster-internal coherence for the 37 identified subdomains in Neuroscience research (1997-98)

Average pair strength per cluster of keywords (plus/minus standard deviation).
Subdomains

1-multiple sclerosis/ myelin basic protein/ experimental autoimmune encephalomyelitis/ lewis rat
2-Astrocytes/ Glial cell/ TNF Alpha/ acidic protein
3-Etiology/ differential diagnosis/ neurological deficit/ spinal cord injury
4-Schizophrenia/ Ethanol/ Alcohol/ normal control
5-Retina/ skeletal muscle/ neuronal cell/ molecular mechanism
6-NGF/ nerve growth/ neurotrophic factor/ pc12 cell
7-Ca2+/ inhibitory effect/ protein kinase
8-amyotrophic lateral sclerosis/ motor neuron disease
9-h 3/ Dopamine/ Antagonist/ Agonist
10-Stroke/ ischemic stroke/ stroke patient/ cerebral infarction
11-subarachnoid hemorrhage/ middle cerebral artery/ internal carotid artery
12-Peptide/ Hormone/ Secretion/ Male Rat
13-CSF/ HIV/ AIDS/ human immunodeficiency virus
14-Glutamate/ NMDA/ NMDA Receptor/ glutamate receptor
15-MRI/ computed tomography/ Functional MRI
16-Acetylcholine/ Neurotransmitter/ Uptake/ Norepinephrine
17-Depression/ Placebo/ Anxiety
18-Alzheimers Disease/ a beta/ amyloid precursor protein/ beta amyloid
19-Apoptosis/ cell death/ neuronal death/ neurodegenerative disease
20-Animal model/ electrical stimulation/ Fiber/ Pathophysiology
21-Ischemia/ cerebral ischemia/ neuronal damage/ neuroprotective effect
22-Dementia/ Aging/ cognitive function/ cognitive impairment
23-Axon/ Immunoreactivity/ Immunohistochemistry/ Adult Rat
24-heart rate/ blood pressure/ sympathetic nervous system/ heart rate variability
25-Gaba/ synaptic transmission/ gamma aminobutyric acid/ synaptic plasticity
26-PET/ cerebral blood flow/ white matter
27-Hypothalamus/ c fos/ paraventricular nucleus/ locus coeruleus
28-Gene/ CDNA/ polymerase chain reaction/ expression pattern
29-Seizure/ EEG/ Epilepsy/ temporal lobe
30-nitric oxide synthase/ l arginine/ neuronal nitric oxide synthase
31-Stress/ substance p/ neuropeptide y/ tyrosine hydroxylase
32-spinal cord/ Peripheral nerve/ sensory neuron/ dorsal root ganglion
33-Memory/ Learning/ working memory/ memory impairment
34-Pathogenesis/ Parkinsons Disease/ basal ganglion/ oxidative stress
35-MRNA/ rat brain/ gene expression/ olfactory bulb
36-Hippocampus/ Cortex/ Cerebellum/ Striatum
37-Tumor/ Brain Tumor/ radiation therapy/ primitive neuroectodermal tumor

The co-occurrence of publications between subdomains was calculated and input for the mapping procedure (multidimensional scaling). This procedure yielded the map of Neuroscience 1997-98.

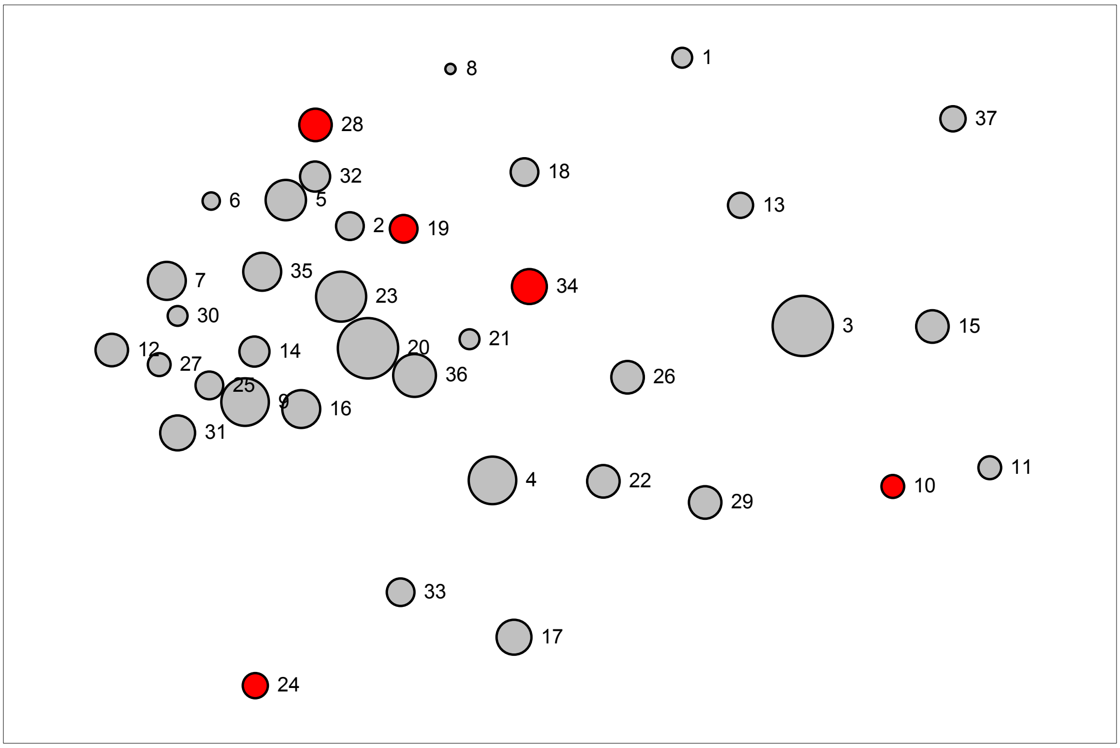


Figure 4-4

Map of Neuroscience Research (1997-1998)

Two dimensional representation of Neuroscience based on the similarities between identified clusters of keywords (subdomains). The circle size indicates the number of publications represented. The color of the circles indicates a significant increase/decrease of activity:

- Red : increase of activity
- Blue : decrease of activity

The badness-of-fit criterion is 0.19, the distance correlation is 0.91 (statistics provided by SAS).

As sets of publications represent subdomains of Neuroscience, we are able to give general characteristics of subdomains on the basis of several information items extracted from these publication sets. By subdomain, we compiled rankings of most active actors (e.g., countries, organizations), most frequently used journals, most highly cited publications, etc. etc. Thus, the activity (or impact) of scientific actors (countries, institutes, etc.) in neuroscience is compared to others within subdomains, rather than within the whole field of neuroscience.

4.2.2.2. Results

We identified 37 subdomains in neuroscience for the period 1997-1998. The map shows a clear structure with areas of interest. On the left-hand side, we find clusters of biochemical and neurophysiological research in the field. On the right-hand side of the map, research is more clinical (most neuroscience-related diseases are here). In the map we also indicated by colors the growth during the period 1995-1998 in terms of numbers of publications. Red subdomains have an increasing interest (a significant increase of publications), whereas blue subdomains show a decreasing interest (not found here).

With respect to the activity of the EU countries, we found that on average the EU share in Neuroscience is around 36%. Obviously, this share is not equally distributed over the identified 37 subdomains. Some subdomains enjoy an EU interest below, others above average. In the next Figure an overview of the EU share in 1995/96 and in 1997/98 is depicted.

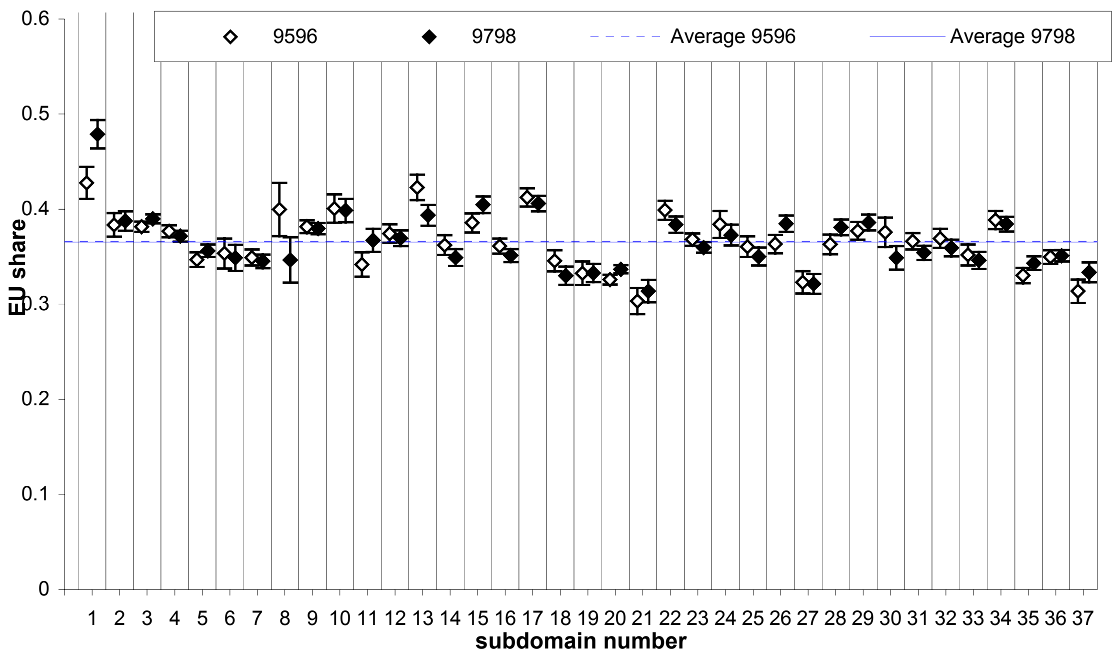


Figure 4-5

EU share in 37 identified subdomains in Neuroscience research (1995/96 and 1997-98)

Percentage of publications per subdomain with at least one EU address. Blue lines indicate EU average in neuroscience (1995/96 and 1997/98).

There are some clear foci of EU interest. In subdomain 1 (Multiple Sclerosis), it is significant above EU average and this interest is even increasing in 1997/1998. If we put this information about the EU focus in the cognitive map, we clearly see a preference for the right-hand side of the map, being the clinical area of neuroscience.

This outcome is in contrast with the results for the United States of America. The US clearly focuses on the more fundamental side of neuroscience. As the EU and US form the most important actor 'blocks' in science in general, it is not surprising that in none of the subdomains both EU and US have a share that is above their individual field average. It is, however, striking to notice that there seems to be such a strict division of focus between the fundamental area and the more clinical area of the field. In fact, the EU on the one side, and the US on the other seem to function as a kind of balance. If one of them focuses (in terms of activity share) on the one side, the other 'automatically' focuses on others. Therefore, the conclusion that the EU focuses more on the clinical side, is too simple. The matter, as such, is much more complicated. If the US appears to focus more on fundamental research (in relation to their own field average), this has consequences to the focus of the EU. The EU share will be automatically below their own average in the fundamental area (because of the increased US share), so that their share in the clinical area will be above their own average. The found situation can lead to at least four conclusions:

- The EU focuses on the clinical area;
- The US focuses on the fundamental area;
- The EU does not focus on the fundamental area;
- The US does not focus on the clinical area.

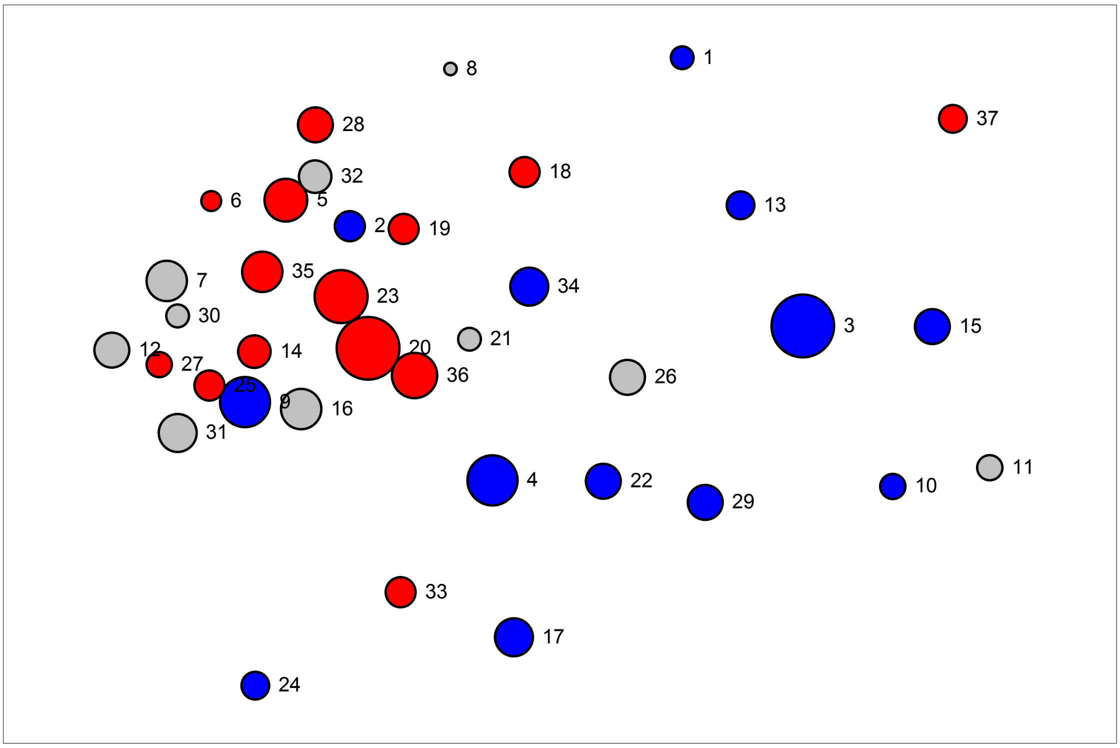


Figure 4-6

EU and US focus in neuroscience 1997-1998

Indication of EU and US focus in neuroscience, where subdomains with EU focus are Blue and subdomains with US focus are Red.

The map of the situation in 1992/93 should shed more light on this matter. In the next map, we used the same configuration (1997-98) and colored each subdomain circle, according to the focus of EU and US. It seems that in this earlier period, there wasn't such a strict division. Apparently, the focus of either of the two (or both) has been concentrated during the nineties to either the clinical or the fundamental areas.

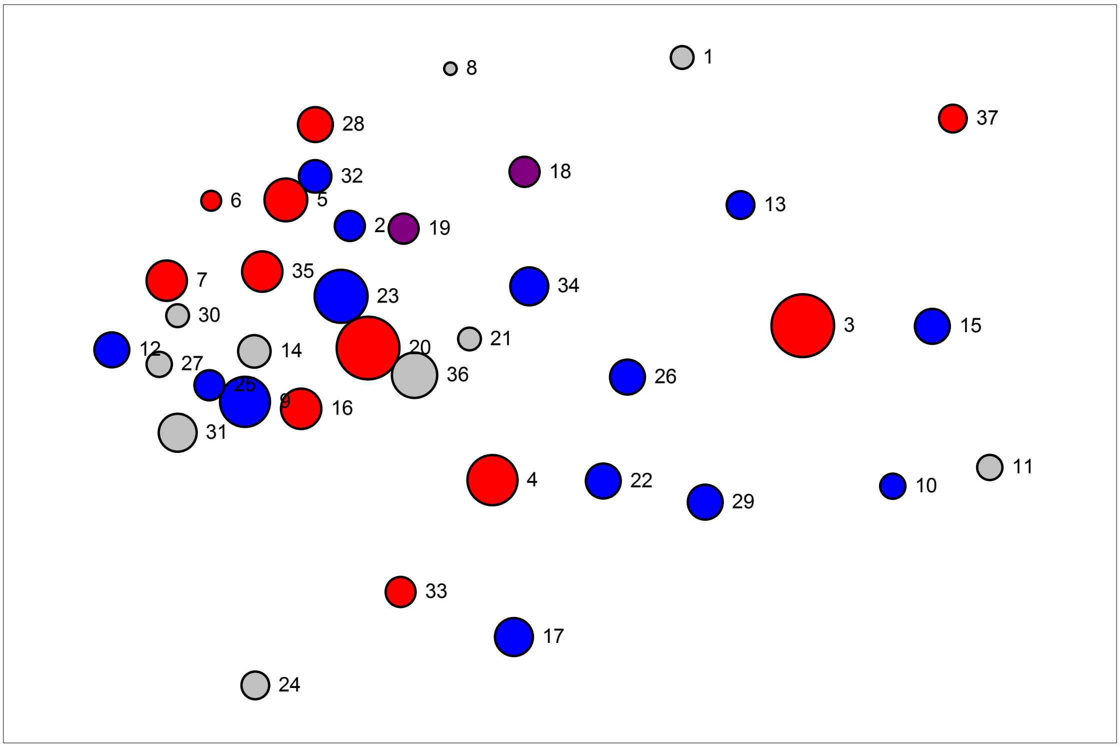


Figure 4-7

EU and US focus in neuroscience 1992-1993

Indication of EU and US focus in neuroscience, where subdomains with EU focus are Blue, subdomains with US focus are Red, and subdomains with both EU and US focus are purple.

In order to get a clearer view on the differences between 1992/1993 and 1997/1998, we divided the map into two areas: a clinical area and a fundamental area. As a very rough and simple indicator, we took the subdomains left from subdomain 4, as being *fundamental*, and those right from 4 (including 4) as *clinical*.

First of all, we found that the growth of the clinical area was much larger than the growth of the fundamental area. The average increase of the former was 1700 numbers of publications (37% of 1992/93), while the average increase in the latter was around 1000 publications.

Comparing the EU with the US, we find that they both increase their activity in each area. In absolute numbers of publications, the average increase of the US is 382 whereas the EU increases its activity on average with 542 publications. For both EU and US the increase in the clinical area is larger than the increase in the fundamental area. The ratio clinical increase vs. fundamental increase is slightly higher for the EU (1.75 vs. 1.5). Regarding their share in the whole field, we found that the average US share (percentage with a US address) decreased with 3%, whereas the EU share increased with 1.3%. The ratio clinical to fundamental was 1.9 to 1.1 for the EU and -3.6 vs. -2.6 for the US.

Table 16

Numbers of publications and share for EU and US by field area

		EU		*US*		*World*	
Indicator	*Area*	*92/93*	*97/98*	*92/93*	*97/98*	*92/93*	*97/98*
Av. Npubs	C	1462	2208	1631	2113	4033	5733
	F	1661	2087	2114	2434	4867	5903
Av. Share	C	36.8%	38.6%	40.3%	36.7%	100%	100%
	F	34.3%	35.2%	43.5%	41.0%	100%	100%

In absolute numbers of publications, we found an EU increase of activity during 1992-1998. As the overall share of the EU was and still is lower than the share of the US, we may note this as a remarkable trend. In the clinical area this has already lead to a share that is larger than the US. In 32 out of 37 subdomains the absolute EU activity *increase* was higher. In the remaining 5 subdomains, where the US increase was larger, we were dealing with 4 fundamental subdomains and one clinical.

The decreasing share of US publications in the whole of neuroscience is caused by the increasing share of EU publications and others. Particularly the increasing share of EU publications in 1997/98 confirms that the focus on clinical research in the EU is caused by an increased interest of the EU rather than a decreasing interest of the US.

Many more results are available at http://www.cwts.leidenuniv.nl/ed/projects.html.

4.2.3. Complex systems

4.2.3.1. Field database

The field database (FDB) used for the co-word analysis was composed from the CDROM version of the SCI (as opposed to the WOS version used by the co-citation analysis). The CDROM years were 1997, 1998 and 1999 up until October of that year. Using the in table17 (appendix A) shown *regular expression*, articles matching that expression in either abstract or title were added to the FDB. Thus, a collection of 9435 papers was composed. Table 1 shows the distribution over publication years.

Table 1.
Distribution of source papers over years

year	*papers*	*%*
1995	1	0,0%
1996	341	3,6%
1997	3297	34,9%
1998	3510	37,2%
1999	2284	24,2%
2000	2	0,0%
total	9435	100,0%

Based upon this distribution, the years 1997 and 1998 were made the focus of the analysis.

4.2.3.2. Method

The articles and titles in the FDB were analyzed by a fast linguistic tool[13], and their *Noun Phrases* (NPs) were extracted. The distinction between NPs extracted from titles and the ones extracted from abstracts was maintained.

The object of this extraction is to create a *small* (with one NP having as exact a meaning as possible) corpus of NPs which maintains a good *recall* (covers as much papers as possible). Experience from other projects learned that it is useful to make a distinction between *singular* (one word) and *compound* (multiple word) NPs when composing such a corpus: compound NPs are have a more strict meaning than singular NPs. Yet some singular NPs have, for the field at hand at least, such a distinct and specific meaning, they can be added also.

For this analysis the compound NPs that were found in at least 4 titles of papers published in 1997 were entered into the corpus. Added to that was a hand-picked set of singular NPs (also from titles of papers published in 1997), thought to be specific enough to enter the corpus also. Result is a set of 131 NPs on which the co-word analysis was based. This selection is listed in appendix B. The recall for a number of years is listed in table 2.

[13] This is NPtool, from Lingsoft inc., see `http://www.lingsoft.fi`

Table 2.
Recall or coverage of selected NPs over years.

year	*papers*	*papers covered by a selected NP*	*percentage of covered papers*
1996	341	233	68,33%
1997	3297	2389	72,46%
1998	3510	2547	72,56%
1999	2284	1653	72,37%

Overall this seems quite acceptable. Judging the trade-off between recall and precision (here to be interpreted as *semantic precision*) is still somewhat of a trade, since no generally accepted, objective criteria are available.

4.2.3.3. Clusters

The set of NPs was subsequently used to construct a co-occurrence matrix for the NPs. This (131x131) matrix was used as input to a *complete-linkage clustering* algorithm. A number of *cut-off* points were judged using both objective (statistical) and subjective (interpreting the statistics, reading the clusters of NPs) criteria. Finally, the hierarchy was cut at 10 clusters. The final clustering is listed in Table 3.

Table 3.
The names of the ten clusters in the final clustering

nr	*name*
1	(spectral) statistics, semiclassical theory
2	self organized quantum dot/growth
3	synchonization, communication
4	complex systems [general]
5	self organization, discrete time, optimization
6	class(ification), neural network
7	quantum
8	chaos, dynamics, bifurcation
9	chaotic system, energy, instability
10	nonlinear (dynamics), wave

The name of a cluster reflects the most prevalent NPs of this cluster. For example, among the most frequent NPs in cluster '6' are 'class', 'classification' and 'neural network'.

4.2.3.4. MDS

Using the 10 clusters, the papers per cluster (*ppc)* were counted for respectively 1997 and 1998 and used to build other co-occurrence matrices. These (10x10) matrices served as input to a *Multidimensional Scaling* (MDS) algorithm. The output of such an algorithm is a two-dimension projection of the distances in the matrix.

The projections which were created, are called *maps* in the discussion below. Thus, two of these maps were used in the analysis: one for 1997 and one for 1998.

4.2.3.5. Size

The size of the clusters is measured in the number of distinct source papers. Note that there is overlap between the clusters, since a paper may be associated with NPs in different clusters. The *ppc* for the years 1997 and 1998 is listed in table 18, together with the difference (*delta*) between the years. The *mean overlap* shown in the years, is the *chance* a single paper may appear in more than one cluster.

Table 4.
The number of papers per cluster.

	papers		***delta***	
cluster number	*1997*	*1998*	*absolute*	*relative to 1998*
1	42	46	4	8,7%
2	61	107	46	43,0%
3	106	115	9	7,8%
4	641	712	71	10,0%
5	338	382	44	11,5%
6	266	296	30	10,1%
7	145	155	10	6,5%
8	1013	944	-69	-7,3%
9	631	642	11	1,7%
10	269	304	35	11,5%
sum	3512	3703	191	5,2%
total	3297	3510	213	6,1%
mean overlap	6,5%	5,5%		

This table show the field as a whole grew approximately 5.5%. Note the stark growth of cluster ‘2’ (*self organized quantum dot/growth*) and the decline of cluster ‘8’ (*chaos, dynamics, bifurcation*). While this is the biggest field, and as the name suggests one of the more general ones, this may, together with the growth of every other field *and* the field as a whole, suggest the field is becoming more specialized.

4.2.3.6. Actors in the database.

To limit the size of this chapter, only tables showing countries and the EU. More specific analyses may be conducted using the interface which is presented at the end of this chapter.

4.2.3.6.1. Top 15 nations - Activity

The activity or output of a country is measured in the number of *distinct* papers a country produces for a given period. Below are listed the 15 most active countries[14] and

[14] Note that in this discussion, the UK is *not* listed – only England, Wales and Scotland. This is a database artifact.

added to that, the EU. The papers taken into account are the papers which were used to extract NPs from, i.e. the *source papers* with a publication year 1997 or 1998.

Table 5.
The 15 most active countries (and EU) in 1997.

Rank 1998	*name*	*activity*
1	USA	1417
2	**EU**	1081
3	*GERMANY*	485
4	JAPAN	346
5	*FRANCE*	295
6	RUSSIA	273
7	*ITALY*	262
8	*ENGLAND*	238
9	PEOPLES R CHINA	221
10	CANADA	162
11	*SPAIN*	144
12	INDIA	115
13	AUSTRALIA	111
14	BRAZIL	92
15	ISRAEL	84

Note again that the number of papers of the EU is not the sum of the papers of all individual countries, but the distinct number of papers which can be assigned to at least one member of the EU. The countries in *italics* are member of the EU.

Table 6.
The 15 most active countries (and EU) in 1998.

rank 1998	*rank 1997*	*name*	*activity*
1	1	USA	1402
2	2	**EU**	1108
3	3	*GERMANY*	465
4	4	JAPAN	423
5	7	*ITALY*	373
6	5	*FRANCE*	335
7	8	*ENGLAND*	293
8	6	RUSSIA	284
9	9	PEOPLES R CHINA	272
10	10	CANADA	157
11	11	*SPAIN*	133
12	14	BRAZIL	123
13	13	AUSTRALIA	112
14	12	INDIA	110
15	15	ISRAEL	99

In Table 6 we also listed the rank a country occupied the previous year. No important changes here, with compared to the previous year.

4.2.3.6.2. Top 15 nations – Citations

The number of citations a country receives is the sum of the individual citations per paper for a given country. The *referring* papers taken into account are the papers that were used to extract NPs from, i.e. the *source papers* with a publication year 1997 or 1998. The papers referred to may be published in any given year before (or sometimes even in) the publication year of the referring paper.

Table 7.
The most cited countries (and EU) for papers in 1997.

rank	*Country*	*citations*
1	USA	37821
2	EU	14661
3	GERMANY	5477
4	FRANCE	5321
5	ENGLAND	4630
6	JAPAN	4492
7	ITALY	3533
8	CANADA	2545
9	FED REP GER	2080
10	NETHERLANDS	1509
11	ISRAEL	1477
12	SWITZERLAND	1242
13	RUSSIA	1236
14	AUSTRALIA	1092
15	SPAIN	1047

Table 8.
The most cited countries (and EU) for papers in 1998.

rank 1997	*Rank 1998*	*Country*	*Citations*
1	1	USA	37930
2	2	EU	16019
3	3	GERMANY	6127
4	4	FRANCE	5616
5	5	ENGLAND	5108
6	6	JAPAN	4695
7	7	ITALY	3981
8	8	CANADA	2487
9	9	FED REP GER	1868
10	10	NETHERLANDS	1715
13	11	RUSSIA	1680
11	12	ISRAEL	1614
12	13	SWITZERLAND	1312

14	14	AUSTRALIA	1198
15	15	SPAIN	1163

Not surprisingly, the USA is by far the most highly cited nation.

As with the output, there are no important changes in the top 15, except for the slow disappearance of the ‘old country names’, like the FRD and USSR.

4.3. *iBEX* – The Interactive Bibliometric Explorer

One of the most important technological improvements funded by the TSER project, was the design and implementation of a next-generation interactive tool to analyze mapped science field. For the moment it has been baptized *iBEX*. Below is a short description of its functionality, but this is somewhat limited due to the status of the application. At the moment of writing, the application is still in its infancy, with only its most basic design having been implemented. It is expected to have a full version available at the end the fourth quarter of 2000.

Top-down versus bottom-up

Some of the design goals of *iBEX* were:

a) it must be accessible via the WWW;
b) it should be easy to use;
c) it should be responsive;
d) it must be possible not only to access the database *top-down*, but also *bottom-up*.

While the implementation tried to achieve all goals, especially the last goal was given a lot of attention, since in theory should bring the science map “closer” the user of the map.

With *top-down* access is meant the access ‘through the map into the database’. For example, when clicking on a specific cluster, the user can request the most cited organization within that cluster/field.

Yet it may be of interest for a user to allow him to first locate his or her internal fieldmarks on the map: by locating his organization, or even by locating his papers in the field, in an 'inverse' way. This is meant by the *bottom-up* approach of the interface.

A small tour

In the near future the application and the example database (*complex systems*, introduced in the previous chapter) will be available from the WWW pages of the CWTS. That is why, instead of describing the field more thoroughly in the previous chapter, or to describe the design of the application in all its details, we will just present *iBEX* with a mini-tour and invite the reader to drop by one time, to be able to actually experience it.

When starting the application, the user is shown the window in figure 1, which is the map for 1997. This map can be zoomed in or out, and may be rotated. Also, the clusters can be dragged away from their original position. When done so, a line as drawn which points to the original position, to maintain the important spatial information of the map. Usually the user is only interested in some parts of the may, so clusters can be selected or deselected. The application will show *selected* clusters by drawing them in a different color, and with a thicker border around it.

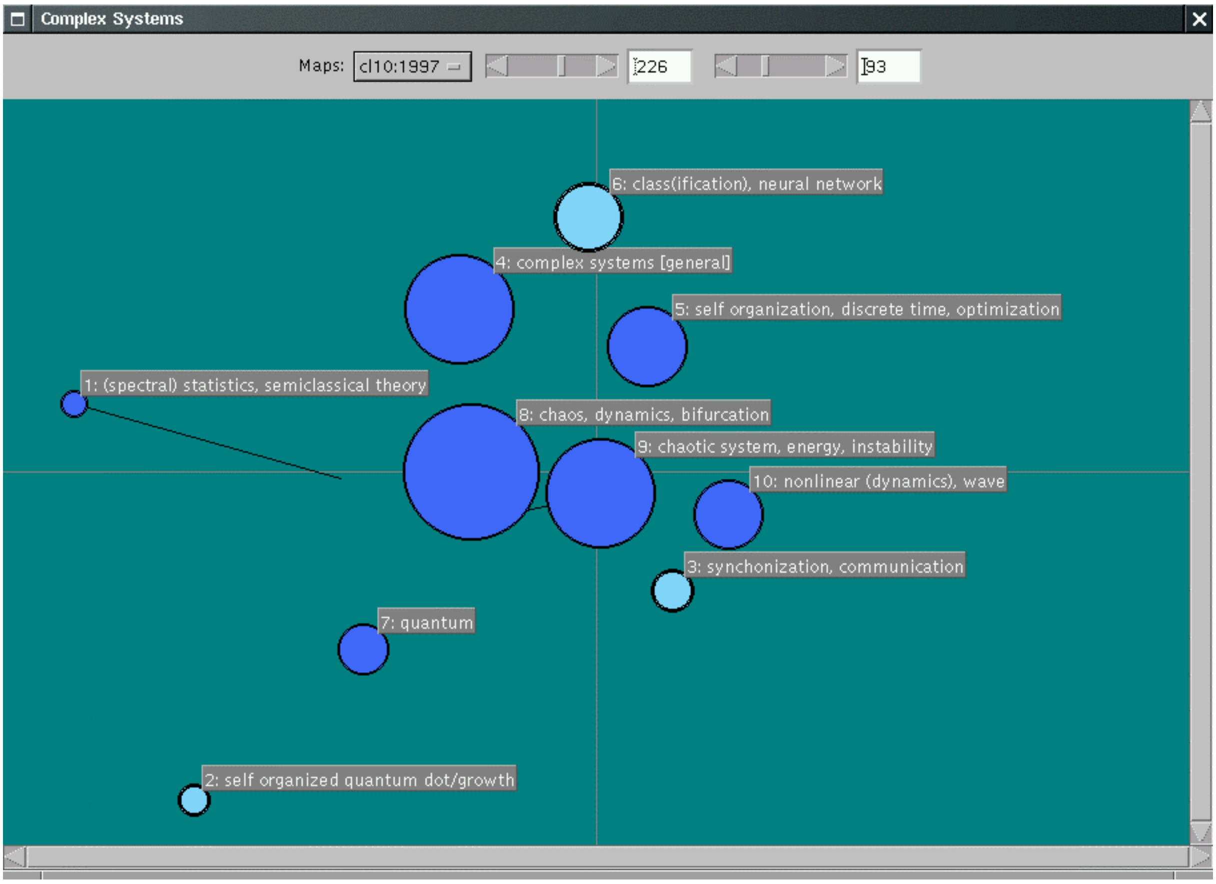


Figure 1.
The map of Complex Systems of 1997.

For example, in figure 2, the map is rotated 226 degrees and zoomed to 93% of its original size. Besides this, the clusters 1 and 9 have been dragged away to clear up the cluttering of clusters somewhat. The boundary clusters 2, 3 and 6 have been selected.

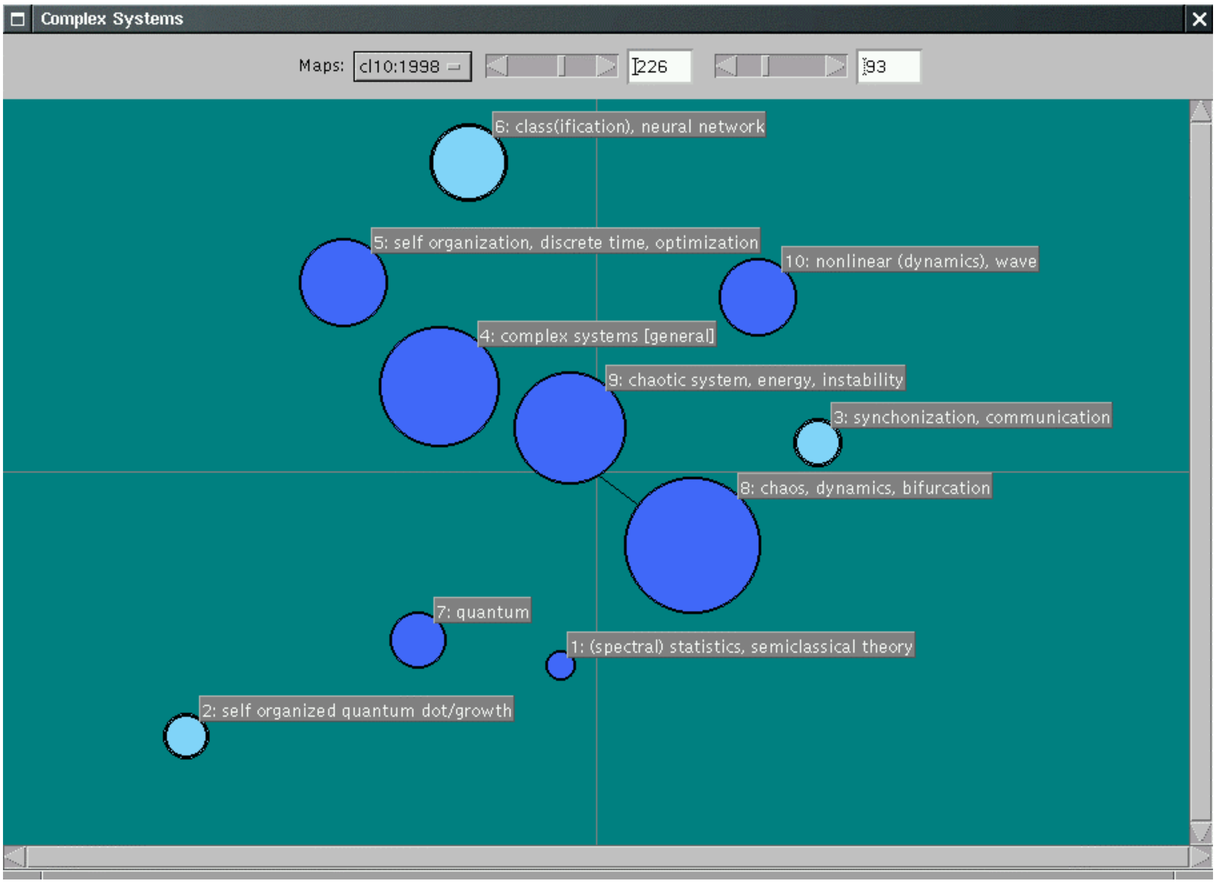


Figure 2.
The map of Complex Systems of 1998.

If the user is interested in another map, it may select another by the pulling down the list on the left of the upper bar above the map, which shows ‘`cl10: 1997`’ in figure 4-8. The next figure then shows the map of 1998.

After getting a bit familiar with the clusters and its names, and having glimpsed over a number of alternative maps, the user may be interested in the information within the database associated with the map. An example of the *bottom-up* access of that information is illustrated in figure 3. In this figure it is shown how the user has located an organization in the database which is well known to him. There may be more *entities* available in the database which can be searched; these options are provided through the ‘`Search`’ menu of the search window. When the user has located an instance he wants to use in the analysis, he may ‘`Save`’ that piece. After collecting a number of such instances, the user may than press the ‘`Use`’ button which will transfer the list to another window. The contents of this window can than be a basis for a more thorough analysis.

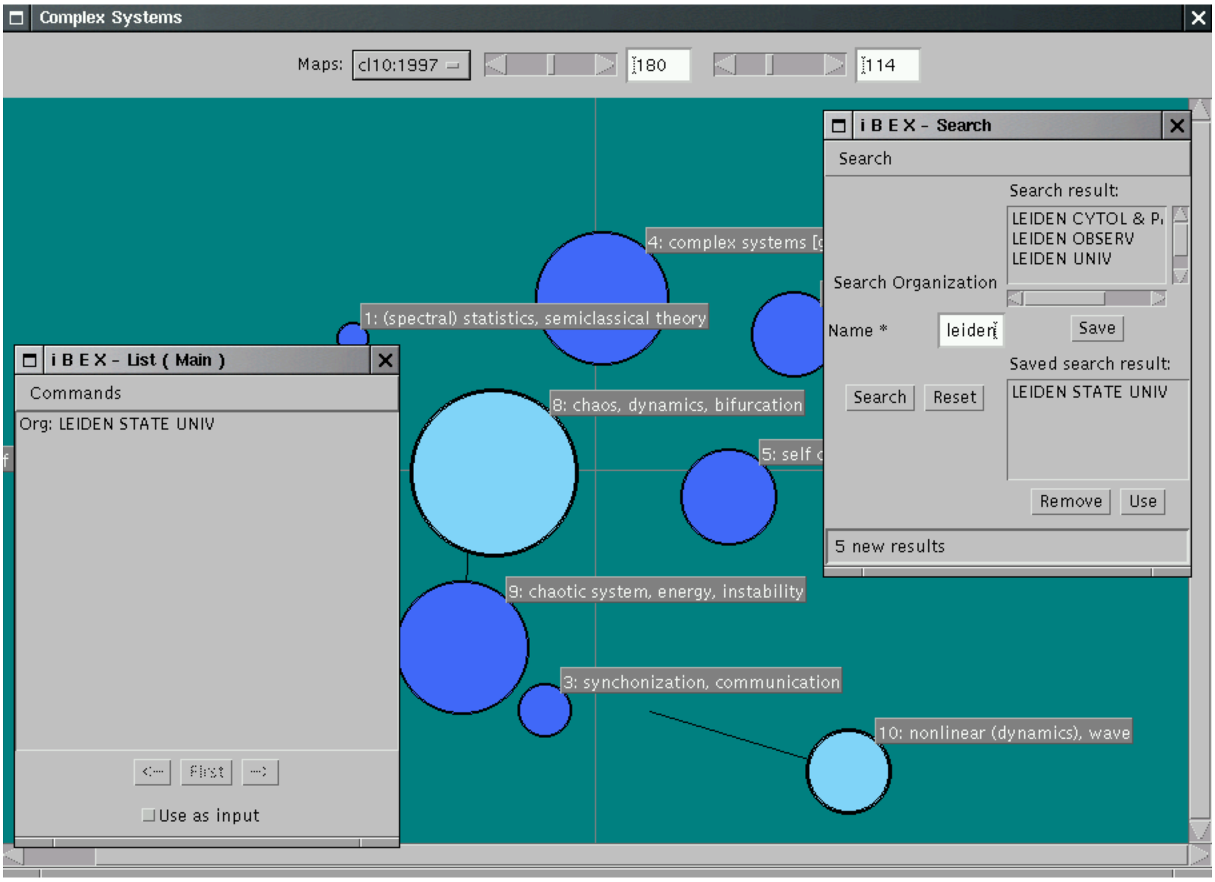


Figure 3.
An example of bottom-up *access to the information in the map.*

The rest of the analysis is done through the ‘`Commands`’ menu of the window containing the list of selected instances. Note again that only the selected clusters will be involved when retrieving information from the database.

The next figure shows an example of the graphical display information retrieved. The user has now collected a list of organizations, from which the he has selected seven. Using a command from the menu, he has retrieved the relative share of the *knowledge base* provided by this selection of organizations (for two selected clusters/fields in the map).

Since he was interested in a relative measure, he has selected to display the information as *pie-charts*. He could however, also have chosen to be shown a textual list, or to be displayed one or more bar charts. Note how the application has taken the selected list as input, and also displayed a legend, to enable the user to distinguish the organizations in the chart. The function of the third window call ‘*Names..*’ will become clear in the next figure.

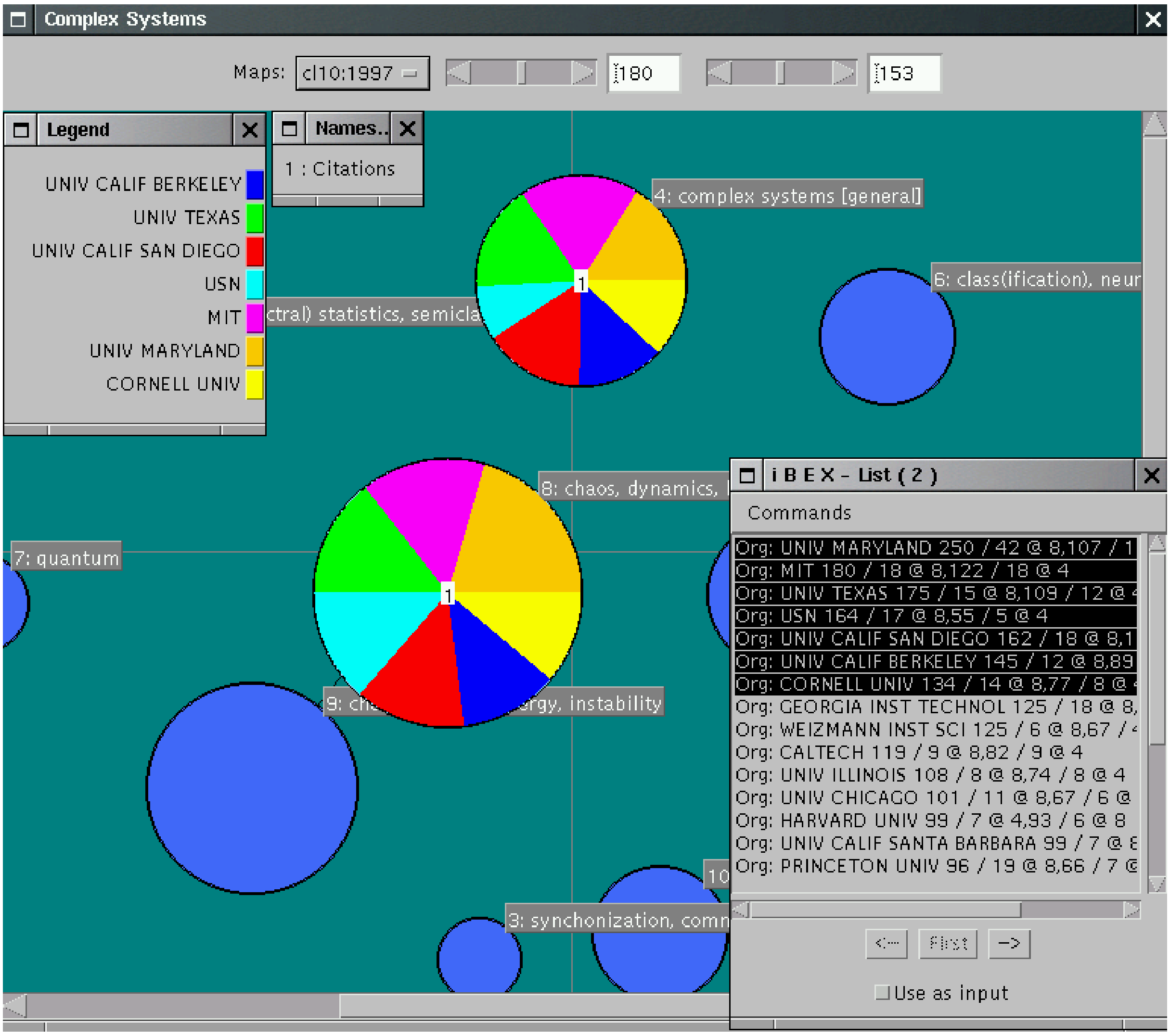


Figure 4.
An example of the graphical display of information on the chart.

The map in figure 4 is the same as the one in figure 5, and the list window contains the same list of organizations. Now however, the user also requested the relative *activity* or *output* to be shown in the map. The application then drew an additional *pie-charts* on the clusters. To distinguish between the charts, they have been given a number. The meaning of the numbers is explained in the window '*Names of charts*', immediately making clear the use of this mysterious little window.

Having interacted with a map, the user will have been armed with some familiarity with the information shown in the database. Hopefully he or she may now dig somewhat deeper and find more specific knowledge about the field at hand.

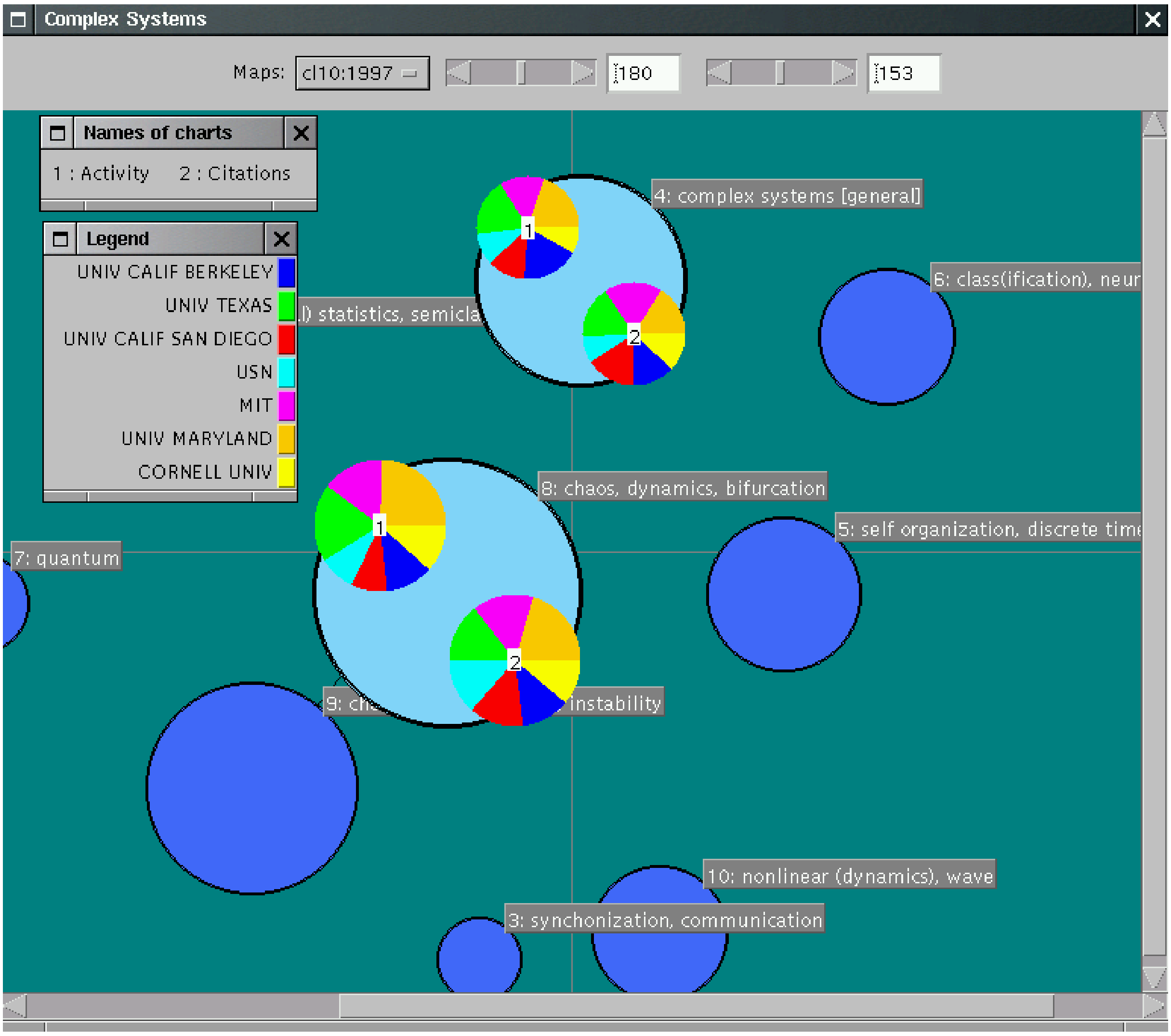


Figure 5.

An example of two related pieces of information for a single set of instances.

Appendix A.

The regular expression used to select the papers.

The regular expression uses the extensions introduced by the Perl language.

```
(
      \b(complex|non(?:\s|-?linear)\s+([^\s]+\s+)?system\w*
      |\bnon(?:\s|-)?linear\s+([^\s]+\s+)?dynam\w+
      |\bchaos\b
      |\bchaotic\w*
      |\bself(?:\s|-)?orga\w+
)
```

Appendix B.

The selected Noun Phrases for Complex Systems.

The table below lists the 131 selected NPs of the Complex Systems case. The three columns are:

- NP: the *noun phrase* itself;
- TF: the *title frequency*, i.e. the number of titles the NP was found in;
- PF: the *paper frequency*, i.e. the number of papers the NP was found in.
- CL: the *cluster number* the NP was assigned to, using the 10 cluster solution.

NP	CL	TF	PF
Periodic orbits	1	6	6
Statistical property	1	4	24
Semiclassical theory	1	4	13
Spectral statistic	1	4	6
Spectral statistics	1	4	6
Quantum dot	2	21	59
self organized quantum dot	2	17	24
Molecular beam epitaxy	2	10	41
self organized growth	2	10	11
self organized inas quantum dot	2	5	14
self organized inas/gaas quantum dot	2	5	7
inp substrate	2	4	6
Synchronization	3	39	78
chaos synchronization	3	7	14
Coupled system	3	6	17
secure communication	3	6	11
Coupled map	3	5	11
Generalized synchronization	3	5	10
Chaotic synchronization	3	5	8
Coupled chaotic oscillator	3	5	7
self organized criticality	4	26	51
Simulation	4	17	144
2 dimensional	4	13	13
Pattern	4	10	91
Transport	4	9	35
Mixing	4	9	27
Complex systems	4	9	9
Chaotic flow	4	8	14
Scaling	4	7	30
Pattern formation	4	7	13
Magnetic fields	4	7	7
Stabilization	4	6	33
Regulation	4	6	21
Chaotic scattering	4	6	14
Chaotic time series	4	6	14
Chaotic dynamical systems	4	6	6
Complex system	4	5	233
Interference	4	5	17
porous media	4	5	7
Dynamical model	4	4	12
Hydrogen atom	4	4	11
Statistical analysis	4	4	11
Anomalous diffusion	4	4	9
self similarity	4	4	8
Mathematical modeling	4	4	6
self organization	5	59	138
Spatiotemporal chaos	5	17	29
Dynamical systems	5	11	11
discrete time	5	9	31
optimization	5	7	20
self organizing map	5	7	12
nonlinear dynamic systems	5	7	7
self organizing	5	6	24
coupled map lattice	5	6	15
soil	5	6	15
art	5	6	14
nonlinear stochastic systems	5	6	6
fuzzy model	5	5	15
physicochemical property	5	5	6
self assembly	5	5	5
nonlinear model	5	4	23
stability analysis	5	4	19
genetic algorithm	5	4	12
extended kalman	5	4	7
nonlinear dynamic analysis	5	4	6
nonlinear systems	6	42	42
neural network	6	34	93
class	6	24	136
classification	6	12	30
robust stabilization	6	5	6
uncertain nonlinear systems	6	5	5
artificial neural network	6	4	25
self organizing neural network	6	4	11
approximate solution	6	4	6
recurrent neural network	6	4	6
quantum chaos	7	26	47
quantum	7	18	104
quantum dynamics	7	6	10
quantum mechanics	7	5	15
quantum classical correspondence	7	4	6
chaos	8	236	454
dynamics	8	69	315
bifurcation	8	27	108
chaotic dynamics	8	18	75
chaotic behavior	8	17	77
chaotic motion	8	9	53
chaotic attractors	8	9	34
hysteresis	8	6	21
chaos control	8	6	15
controlling chaos	8	6	14
chaotic vibration	8	6	10
lyapunov exponent	8	5	63
chaotic attractor	8	5	30
chaotic oscillator	8	5	16
feedback control	8	5	9
complex dynamics	8	4	16
period doubling	8	4	13
coupled oscillator	8	4	11
chaotic system	9	35	112
correlation dimension	9	11	36
energy	9	10	109
instability	9	10	83
turbulence	9	10	28
stochastic resonance	9	10	18
adaptive control	9	10	16
laser	9	9	53
chaotic oscillation	9	9	37
3 dimensional	9	9	9
one dimensional	9	9	9
nonlinear dynamical systems	9	8	8
deterministic chaos	9	7	38
chaotic map	9	7	17
locking	9	7	14
beam	9	6	23
eeg	9	6	17
chaos theory	9	6	16
time dependent	9	6	6
initial condition	9	5	52
bifurcation analysis	9	5	13
nonlinear oscillator	9	5	11
on off intermittency	9	5	9
exact solution	9	4	15
molecular dynamics simulation	9	4	10
nonlinear oscillation	9	4	9
self pulsing	9	4	5
nonlinear dynamics	10	81	183
wave	10	11	73
nonlinearity	10	7	57
nonlinear analysis	10	7	19
solitary wave	10	5	10
domain walls	10	5	5

5. Comparison of methods

The two bibliometric mapping methods used in this report are applied to different kinds of data. The co-citation analysis builds structures of science based on co-occurrences of citations (cited reference in publications). The co-word analysis builds structures on the basis of topics in publications (keywords). However tempting it may seem, a comparison of results of the methods is very difficult if not impossible, as they are based on such different concepts: publications and keywords. The maps they yield represent totally different structures. Still, it is a useful exercise to collect the results in both studies and to compare them, to see what each method returns.

For the field of neuroscience we chose one subfield ('epilepsy research'), for the field of complex systems, we give an overview of the differences between the overall structure.

5.1. Neuroscience: epilepsy research

5.1.1. The co-citation analysis for the neurosciences 1998

This work is based on a co-citation cluster analysis for the field of neuroscience. The co-citation cluster analysis is used to explore the „landscape“ of the scientific field which is represented by clusters of highly cited and co-cited publications – the intellectual basis of the field – and their relations to each other. The analyzed structure results only from the act of citing which is documented in the citation database Science Citation Index (SCI) and depends not on external classification schemes or the view of experts. The clustered highly cited and co-cited publications – the cluster cores – can be seen as the shared intellectual basis of a set of source publications which are co-citing (citing at least two publications of) the cluster core. This set of source publications is called the research front. The research fronts are overlapping because more or less of the front publications are citing also other cluster cores. The degree of overlap, the relative co-citation strength of different clusters, can be used for another clustering procedure. This iteration of the clustering results in clusters of clusters. At the end of the process a nested hierarchy of cluster levels is formed.

For the neurosciences we performed the iterative clustering process up to the third level. Starting with 99526 highly cited publications which are cited five or more times by the 86539 source publications[15] of the Neuroscience Citation Index (NSCI) we got 10341 clusters on the first level, therefore called C1-clusters. The following steps of the clustering process resulted in 1130 C2-Clusters and 151 C3-clusters. On each step several elements are not clustered because they show relatively weak relations to the other elements.

The research fronts of the clusters are areas with a shared interest in the highly cited publications in a cluster core. They can be seen as specialties of the analyzed field in case of the C1-clusters or in case of the larger clusters on the higher levels (C2,C3) as sub-domains of the neurosciences. For each specialty aside the basic characteristics like core-size and frontsize the proportion of younger publications in the cluster cores is computed. The proportion of cited documents published not more than three years before the source year - called the immediacy value - can be seen as an indicator for the dynamic of the research front.

To show the **internal structure** of a cluster the pairwise similarities of the clustered items are computed into distances using multidimensional scaling (MDS). The resulting map is the spatial representation of the internal relations of the objects which can be cited documents on the first cluster level (C1) or clusters themselves on the higher aggregation level (C2). In the co-citation map the clustered objects are symbolized by circles. The area of the circles is

[15] The analysis was limited to the document types article, review, note and letter.

proportional to the size of the research front, that means the number of co-citing source publications. The shading of the circles visualizes the dynamic of the research front which is indicated by the immediacy value. The darker the circles the higher the percentage of young cited publications in the cluster core.

The co-citation maps and some cluster characteristics will be used to describe the epilepsy regions in section 2.1.

To show the **external relations** of the epilepsy regions two different perspectives are possible. If the C2-“epilepsy-cluster“ is assigned to a cluster of the next higher level which includes more than four C2-clusters the co-citation map will be shown. In the other cases a graph with the nearest neighbors will be given which shows the eight C2-clusters with the highest relative co-citation strength. The external relations of the seven epilepsy regions are presented in section 2.2.

5.1.1.1. The Epilepsy regions

We will concentrate on the main regions of epilepsy research in the landscape of neuroscience which will be analyzed in detail. To find the regions in the co-citation structure where epilepsy related research is done we use the source publications with „epilep*“ (to cover epilepsy, epilepsies, epileptic, epileptical, epileptiform etc.) in their title as markers. The set of 1660 found publications covers not the whole amount of publications which are relevant to the selected topic. But these explicitly epilepsy relevant publications can guide us to the main epilepsy regions. To identify these main regions we concentrate on the large C1-clusters (having 5 or more cited documents) which show 30 percent or more „epilepsy“-publications on their research front. In this way we found 82 C1-clusters which belong half to a few C2-regions. These six main C2-„epilepsy-regions“, each with at least three or at least 25% C1-„epilepsy-clusters“ inside, are listed in table 1. In table 1 the C3- and C2-clusternumbers, the number of C1-„epilepsy-clusters“ (C1-ep) inside, the cluster title, the core-size (number of cited publications clustered) and the size of the research front (front) is shown. There are three larger C2-regions each having more than five of the selected C1-clusters inside and four smaller ones, all analyzed in detail in the following sections.

Table 1:
Main epilepsy regions (C2-cluster)

C3-No	C2-No	C1-ep	Title	core	front	imm
21	796	11	MR in Temporal-Lobe Epilepsy	279	399	29
21	497	3	Epilepsies in Childhood	57	79	15
96	903	7	Antiepileptic and Antipsychotic Drugs	411	437	31
103	686	6	Anxiety/Limbic Epilepsy/Immunoreactivity	240	457	30
67	417	5	Epileptiform Activity	80	116	21
0	1060	2	Absence Epilepsy	44	60	31
0	313	2	Status Epilepticus	57	69	19

There are further 46 C1-„epilepsy-clusters“ spread throughout the neuroscience landscape which are not included in the main epilepsy regions. In table 2 these C1-„epilepsy-clusters“ are listed sorted by the percentage of front publications with „epilep“ in their titles (%ep). Some small clusters dealing with special issues like C1-8865 *Unverricht-Lundborg Disease* or C1-5579 *Ion Channels in Epilepsy* but also larger clusters with more than 35 clustered publications in the core can be found, for example C1-7323 *Sudden Unexpected Death in*

Epilepsy, C1-2820 *Psychogenic Seizures* or C1-10178 *Pregnancy and Epilepsy* with a lower proportion of „epilep“-publications.

The relative large proportion of epilepsy relevant C1-clusters outside the few C2 epilepsy regions shows that epilepsy research is not a rather homogenous field which concentrates on a single area of the neuroscience landscape. Neither it is included in a certain general research field.

Table 2:

C1-Epilepsy-clusters outside the selected C2-regions

C1-No	Clustertitle	core	front	imm	% ep
6705	Juvenile Myoclonic Epilepsy	12	20	0	0.9
7323	Sudden Unexpected Death in Epilepsy	39	54	23	0.8
9043	Antiepileptic Drug-Induced Worsening of Seizures	11	15	9	0.7
8865	Unverricht-Lundborg-Disease	9	17	55	0.7
5579	Ion Channels in Epilepsy	8	7	25	0.7
2820	Psychogenic Seizures	41	52	9	0.6
9862	Catamenial Epilepsy	14	17	0	0.6
3426	Schizophrenia and Epilepsy	14	20	0	0.6
6872	Amygdala Modulation	11	18	27	0.6
1870	Iron-Induced Epileptic Discharges	8	9	0	0.6
10176	Women and Epilepsy	7	13	0	0.6
7483	EEC Findings in Extratemporal Seizures	7	8	0	0.6
1754	Antiepileptic Drug Hypersensitivity Syndrome	7	9	28	0.6
5798	Vagus Nerve-Stimulation	26	22	26	0.5
4315	Epilepsy in Elderly	20	21	10	0.5
8275	Clinical Seizure Lateralization	19	22	21	0.5
7036	Topiramate	16	25	75	0.5
3324	Localization of Epileptiform Activity	15	22	26	0.5
9382	First-Seizure Presentation	9	16	0	0.5
5617	C-11 Flumazenil Pet in Neocortical Epilepsy	9	11	33	0.5
5996	Corpus Callosotomy	7	10	0	0.5
3560	Cost of Parkinson and Epilepsy	6	10	33	0.5
808	Epileptic Focus Localization Using EEG	5	6	60	0.5
9321	Ecog and Temporal Lobectomy	29	27	20	0.4
8365	Proton MRI and Temporal-Lobe Epilepsy	13	40	46	0.4
1854	Fosphenytoin	10	14	10	0.4
1511	Hypothalamic Hamartomas and Gelastic Epileps	7	8	28	0.4
10178	Pregnancy and Epilepsy	42	44	14	0.3
9324	Ampa/Kainate Receptors and Antiepileptic Drugs	35	38	22	0.3
6692	Endogenous Serotonin/Epileptiform Activity	23	26	4	0.3
3672	Ketogenic Diet	15	20	26	0.3
5618	Interhemispheric Memory Transfer	14	19	35	0.3
6648	Kainic Acid-Induced Seizures	10	25	0	0.3
8277	Entorhinal Cortex/Epileptic Temporal-Lobe	9	17	22	0.3
2805	Epileptiform Discharges in Neocortex	8	20	25	0.3
3778	CNS Adenosine A(1) Receptors/Pentylenetetrazol-Induced Seizures	7	11	0	0.3
7549	Cortical Microdysplasia	6	23	16	0.3
5426	Celiac-Disease and Epilepsy	6	12	16	0.3
2980	Disorders of Neuron Migration	6	8	0	0.3
1951	Valproate Associated Liver-Failure	6	9	16	0.3
814	Epileptiform Spikes in the Electrocorticogram	6	9	0	0.3
9326	Functional Hemispherectomy	5	6	20	0.3

C1-No	Clustertitle	core	front	imm	% ep
4545	Somatosensory-Evoked Potentials(Begnin Rolandic Epilepsy)	5	8	0	0.3
4322	Brain GABA Levels	5	8	80	0.3
3242	Amygdala-Kindled Seizures	5	8	0	0.3
2241	Electrocorticography in the Surgery of Epilepsy	5	6	0	0.3

5.1.1.2. The main epilepsy regions in detail

In this section the six selected C2-regions will be analyzed in detail. For each C2-cluster a short description and the following information will be given:

- The **co-citation map** shows the C1-clusters in a spatial representation which is based on multidimensional scaling. The circle areas symbolizing the clustered elements are proportional to the number of co-citing publications.

- A **journal profile** gives an overall picture of the most important journals for both sides: the cluster core and the research front

- The ranking of the top **national actors** on the research front is shown.

- At last the main players - the **institutional actors** on the research front - are listed with their number of publications

5.1.1.2.1. C2-796: MR in Temporal-Lobe Epilepsy

The cluster C2-796 *MR in Temporal-Lobe Epilepsy* includes 41 C1-clusters (table 3) with 279 clustered publications which are co-cited by 399 source publications. The **co-citation map** (figure 1) shows the relative position of the C1-clusters computed by the MDS. The cluster titles give a rough impression of the thematic range in this sub-domain. The main themes are MRI partly in connection with Alzheimers Disease, Positron Emission Tomography (Pet) used on Epilepsy patients, Temporal Lobectomy and the genetics of Epilepsy.

In the **journal profile** of C2-796 (figure 2) the three journals *Neurology*, *Epilepsia and Annals of Neurology* are the most prominent journals. Most of the top journals are represented in the core and the front publications. Whereas two journals appear only at one side: *The Archives of Neurology – Chicago* is represented only at the cluster core and in the journal *Revista de Neurologia* only publications from the research front of this C2-cluster can be found.

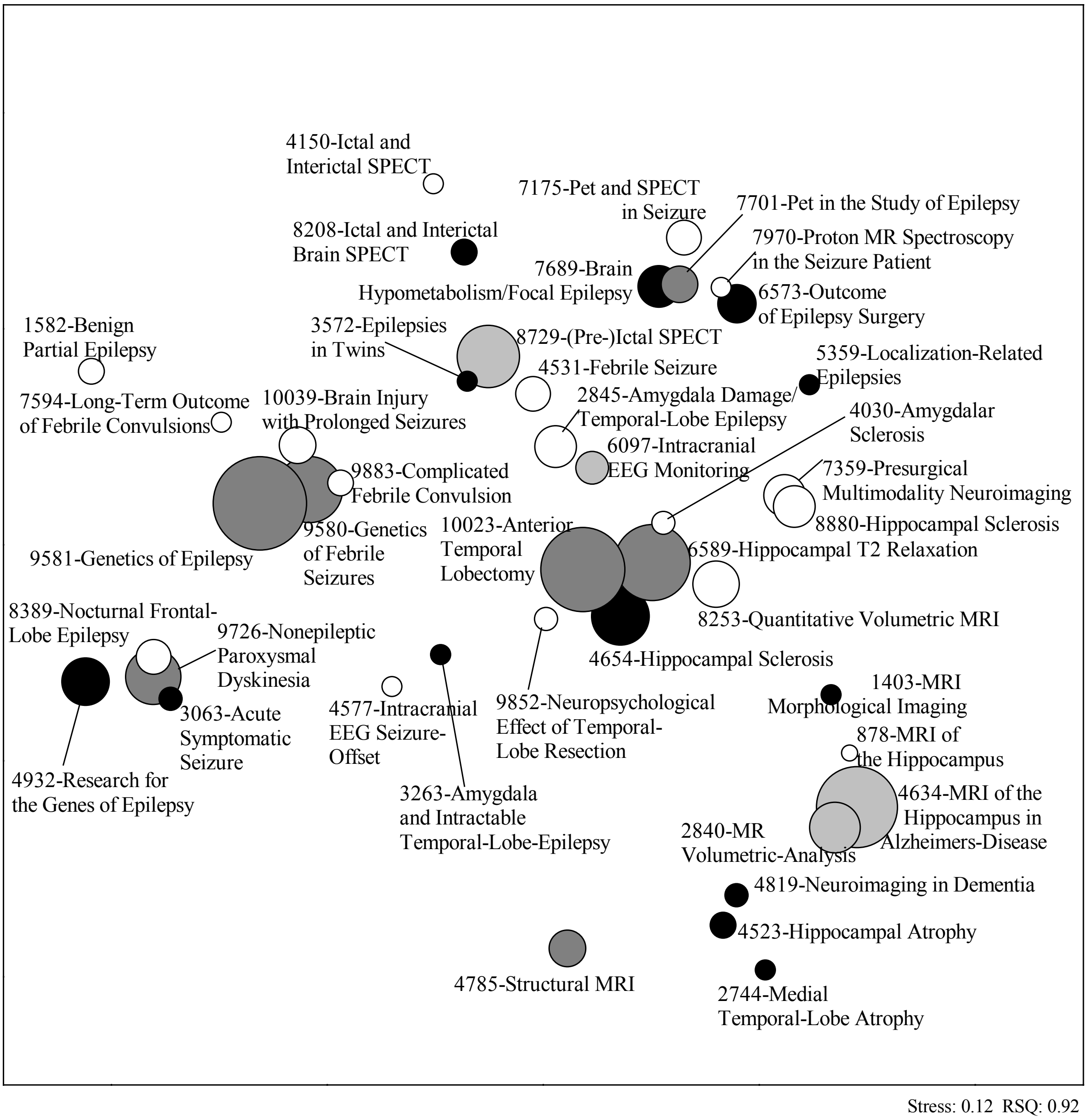
The **national actors** of C2-796 are given in figure 3. The European countries as a whole (EU15) are well represented on this research front (41,6%). Germany and Spain are the top European countries with a contribution to the research front which surpasses the value for the whole field clearly. UK and France drop back slightly against their overall value.

The list of top **institutional actors** (table 4) is leaded by two US institutions *the University of Los Angeles* and the *Mayo Clinic* followed by the universities of Bonn and Melbourne.

Table 3:

C1-clusters of C2-796: MR in Temporal-Lobe Epilepsy

C1-No	Title	core	front	imm
878	MRI of the Hippocampus	28	49	14
1403	MRI Morphological Imaging	2	3	100
1582	Benign Partial Epilepsy	3	5	0
2744	Medial Temporal-Lobe Atrophy	2	3	50
2840	MR Volumetric-Analysis	6	19	16
2845	Amygdala Damage/Temporal-Lobe Epilepsy	4	13	0
3063	Acute Symptomatic Seizure	2	4	50
3263	Amygdala and Intractable Temporal-Lobe-Epilepsy	2	3	50
3572	Epilepsies in Twins	2	3	50
4030	Amygdalar Sclerosis	2	4	0
4150	Ictal and Interictal SPECT	2	3	0
4523	Hippocampal Atrophy	2	5	50
4531	Febrile Seizure	2	9	0
4577	Intracranial EEG Seizure-Offset	2	3	0
4634	MRI of the Hippocampus in Alzheimers-Disease	16	49	18
4654	Hippocampal Sclerosis	9	25	66
4785	Structural MRI	4	10	25
4819	Neuroimaging in Dementia	2	4	50
4932	Research for the Genes of Epilepsy	3	17	100
5359	Localization-Related Epilepsies	2	3	100
6097	Intracranial EEG Monitoring	6	8	16
6537	Outcome of Epilepsy Surgery	6	11	66
6589	Hippocampal T2 Relaxation	21	43	38
7175	Pet and SPECT in Seizure	4	9	0
7359	Presurgical Multimodality Neuroimaging	3	13	0
7594	Long-Term Outcome of Febrile Convulsions	2	3	0
7689	Brain Hypometabolism/Focal Epilepsy	10	13	50
7701	Pet in the Study of Epilepsy	5	10	40
7970	Proton MR Spectroscopy in the Seizure Patient	2	3	0
8208	Ictal and Interictal Brain SPECT	2	5	50
8253	Quantitative Volumetric MRI	2	16	0
8389	Nocturnal Frontal-Lobe Epilepsy	5	9	0
8729	(Pre-)Ictal SPECT	18	29	11
8880	Hippocampal Sclerosis	2	13	0
9580	Genetics of Febrile Seizures	24	33	25
9581	Genetics of Epilepsy	29	65	48
9726	Nonepileptic Paroxysmal Dyskinesia	15	23	26
9852	Neuropsychological Effect of Temporal-Lobe Resection	4	4	0
9883	Complicated Febrile Convulsion	4	5	0
10023	Anterior Temporal Lobectomy	41	53	29
10039	Brain Injury with Prolonged Seizures	3	10	0



Share of young documents in cluster cores

- > 50% young cited documents
- 25-50%
- 10-24%
- < 10%

Size of the Research Front

the area of the circles is proportional to the number of co-citing documents

Figure 1:

Co-Citation map of C2-796: MR in Temporal-Lobe Epilepsy

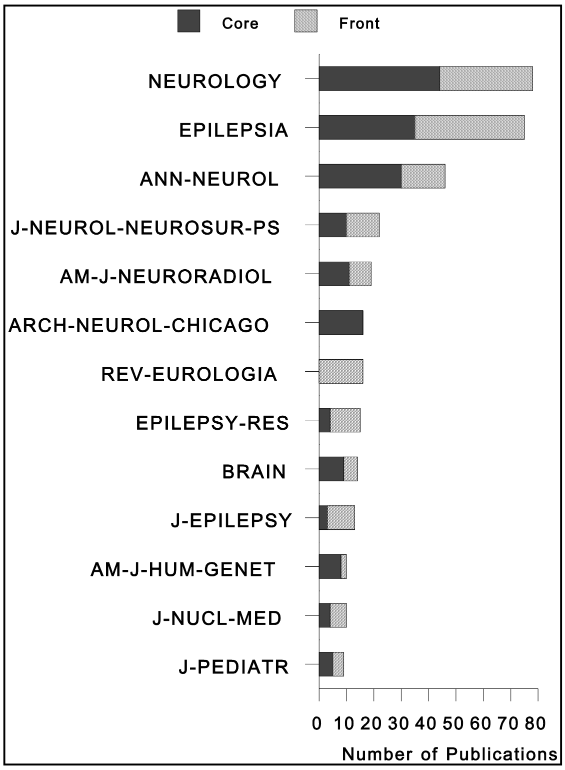


Figure 2:
Journal profile of C2-796

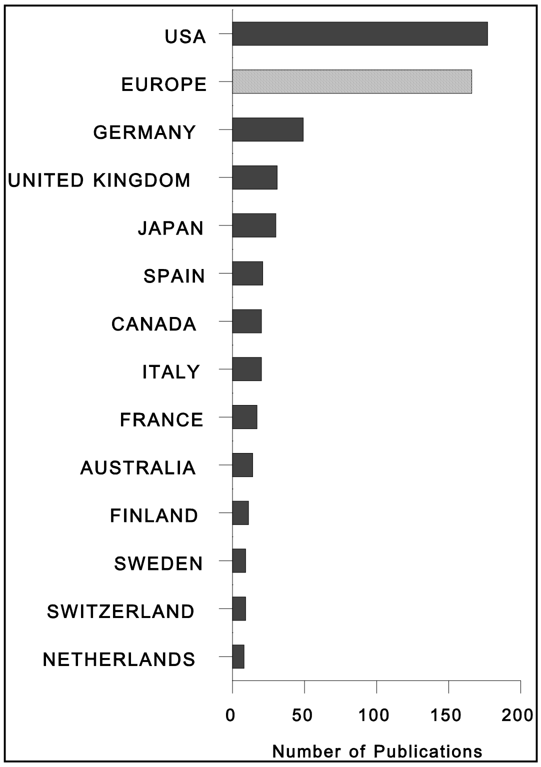


Figure 3:
National Actors C2-796

Table 4:
Top Institutions of C2-796

Pub.	Institution
14	UNIV-CALIF-LOS-ANGELES, USA
12	MAYO-CLIN-&-MAYO-FDN, USA
11	UNIV-BONN, GERMANY
10	UNIV-MELBOURNE, AUSTRALIA
9	MCGILL-UNIV, CANADA
9	UNIV-ALABAMA, USA
9	UNIV-TEXAS, USA
8	CLEVELAND-CLIN-FDN, USA
8	INST-NEUROL, UNITED KINGDOM
7	NATL-HOSP-NEUROL-&-NEUROSURG, UK
7	UNIV-DUSSELDORF, GERMANY
7	YALE-UNIV, USA
6	HARVARD-UNIV, USA
6	KUOPIO-UNIV-HOSP, FINLAND
6	SRI-INT, USA
6	STANFORD-UNIV, USA
6	UNIV-CALIF-SAN-FRANCISCO, USA
6	UNIV-TENNESSEE, USA
6	UNIV-WISCONSIN, USA

5.1.1.2.2. C2-497 Epilepsies in Childhood

Another small epilepsy region is *Epilepsies in Childhood* a C2-cluster with 9 C1-clusters including 57 cited publications which are co-cited by 79 source publications. Apart from one larger C1-cluster – *C1-8890 Landau-Kleffner Syndrome/Rolandic Epilepsy* - with 30 cited and 41 co-citing publications it consists only of very small clusters (table 5). This large cluster C1-8890 can be found in a central position in the **co-citation map** (figure 4). Apart from a small enclave dealing with Migraine the other clusters are epilepsy related: occipital epilepsies in the upper half and epilepsy surgery below the large cluster in the center are the main themes.

In the **journal profile** of this C2-cluster (figure 5) one single journal is dominating the core as well as the front. The journal *Epilepsia* comes up to 34 publications relatively equally distributed on the core and the front whereas none of the following journals contributes more than 8 publications.

The dominating **national actor** (figure 6) are the USA but the EU15 countries surpass them clearly with a contribution to nearly 40 of the 79 research front publications. The stronger European countries are Spain, Italy and France whereas Germany and the United Kingdom are rather under-represented. From the other nations Canada with ten publications ranking on the third position is very strong whereas the next not-European nations (Australia and Japan) remain under three publications.

The list of top **institutional actors** (table 6) shows the institutions with two or more publications. There is only one institution *Cleveland-Clinic-FDN* from the USA which has three publications on the research front. Nearly half of the institutions are hospitals.

Table 5:

C1-cluster of C2-497: Epilepsies in Childhood

Cl-No.	Title	core	front	imm
2985	Phonophobia in Migraine	2	3	0
3084	Hemispheric Epilepsy	2	4	0
3557	Neurotology of Migraine	2	2	0
4069	Basilar Migraine	3	4	0
5394	Occipital Lobe Epilepsy	4	8	0
7262	Epilepsy Surgery in Frontal-Lobe Epilepsy	2	6	50
8890	Landau-Kleffner Syndrome/Rolandic Epilepsy	30	41	13
9082	Occipital Epilepsies of Childhood	5	8	40
9312	Epilepsy Surgery in Children	7	9	28

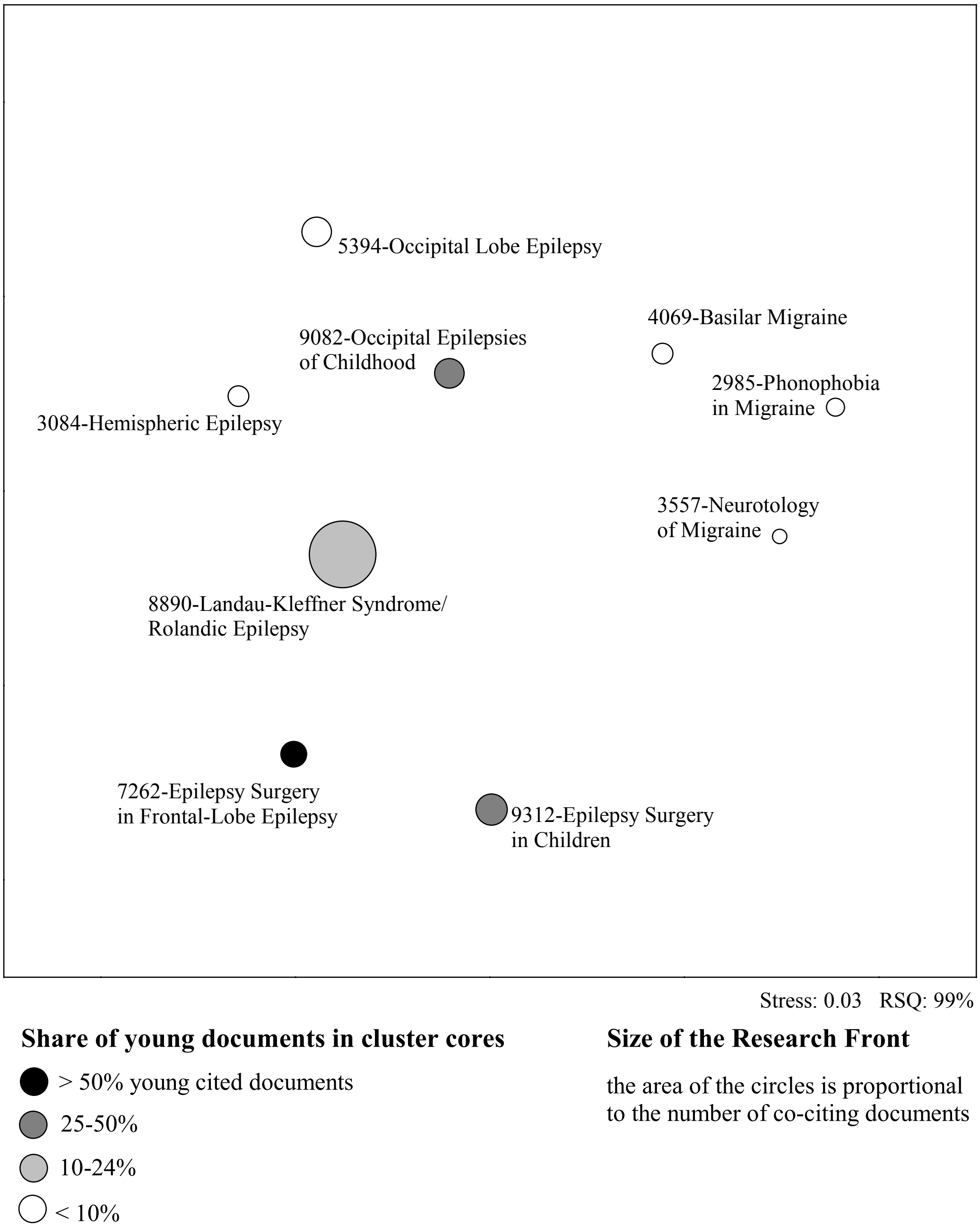


Figure 4:
Co-citation map of C2-497: Epilepsies in Childhood

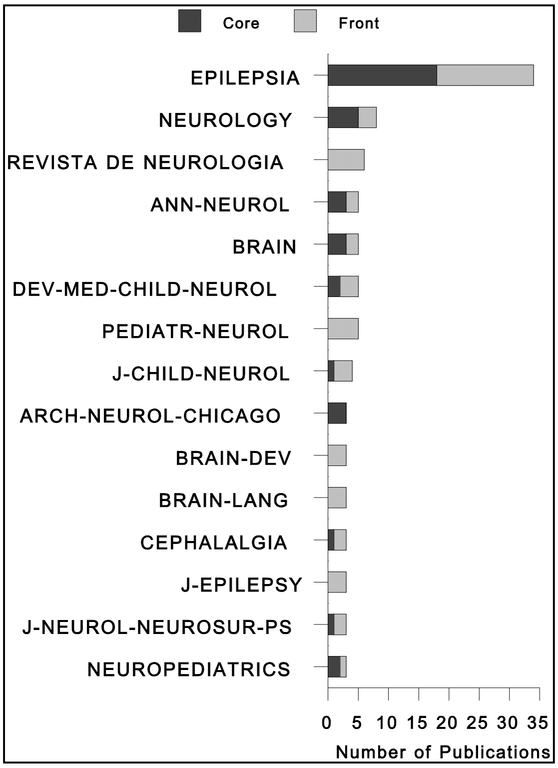


Figure 5:
Journal profile of C2-497

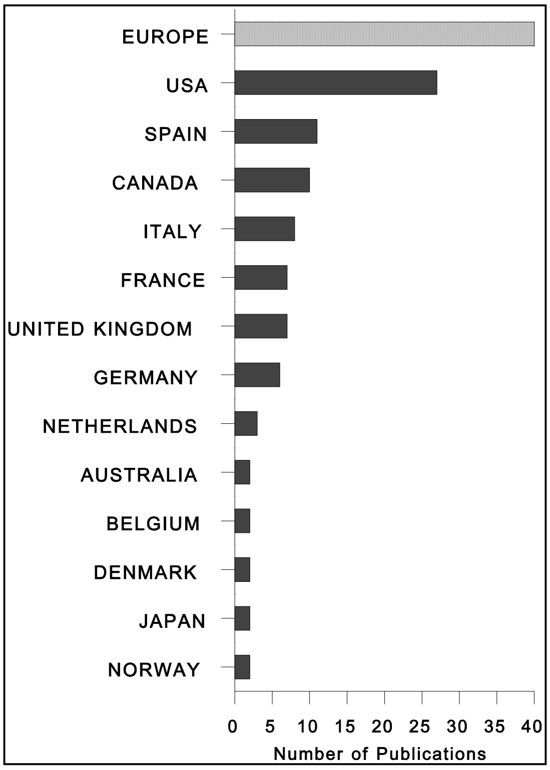


Figure 6:
Top national actors of C2-497

Table 6:
Top institutional actors C2-497

Pub.	Institutions
3	CLEVELAND-CLIN-FDN, USA
2	CHRISTIAN-ALBRECHTS-UNIV-KIEL, GERMANY
2	COLUMBIA-UNIV, USA
2	HOSP-CRUCES, SPAIN
2	HOSP-NTRA-SRA-SONSOLES, SPAIN
2	MCGILL-UNIV, CANADA
2	MIAMI-CHILDRENS-HOSP, USA
2	MONTREAL-CHILDRENS-HOSP, CANADA
2	MONTREAL-NEUROL-HOSP-&-INST, CANADA
2	NYU, USA
2	RA-NEUROL, USA
2	ROYAL-CHILDRENS-HOSP, AUSTRALIA
2	ST-THOMAS-HOSP, UNITED KINGDOM
2	UNIV-BONN, GERMANY
2	UNIV-HOSP, SPAIN
2	UNIV-NEBRASKA, USA
2	UNIV-TRONDHEIM-HOSP, NORWAY
2	UNIV-VERONA, ITALY

5.1.1.2.3. C2-903 Antiepileptic and Antipsychotic Drugs

The C2-cluster *Antiepileptic and Antipsychotic Drugs* is one of the largest C2-„epilepsy-regions" with 411 clustered cited publications and 467 publications on the research front. The 45 C1-clusters are listed in table 7. In the **co-citation map** two areas can be distinguished which represent the two classes of drugs mentioned in the title of the C2-cluster. (figure 7) On the right hand side a group of larger clusters are positioned all with a relatively high proportion of young core documents. They are dealing with the substances Gabapentin, Felbamate, Tigabine, Vigabatrin and Lamotrigine which are used as antiepileptic drugs but also with different concepts of pharmacotherapy and quality-of-life issues. All of the 7 clusters with more than 30% of explicitly epilepsy relevant publications on the research front fall into this area. The other group of clusters is more fragmented and deals with mood disorders especially bipolar depression, and their pharmacological treatment with lithium and other drugs. The two areas are bridged by the research fronts *Lamotrigine in Bipolar Disorders* (7497) and *Gabapentin Treatment of Mood Disorders* (8717) dealing with the antipsychotic use of anticonvulsants

In the **journal profile** of C2-903 (figure 8) the two top journals *Epilepsia* and *Journal of Clinical Psychiatry* are dominating the research front whereas in the group of top journals of the cluster core three more journals are included: *Epilepsy Research*, *American Journal of Psychiatry* and the *Archive of General Psychiatry* which is represented only on the cluster core.

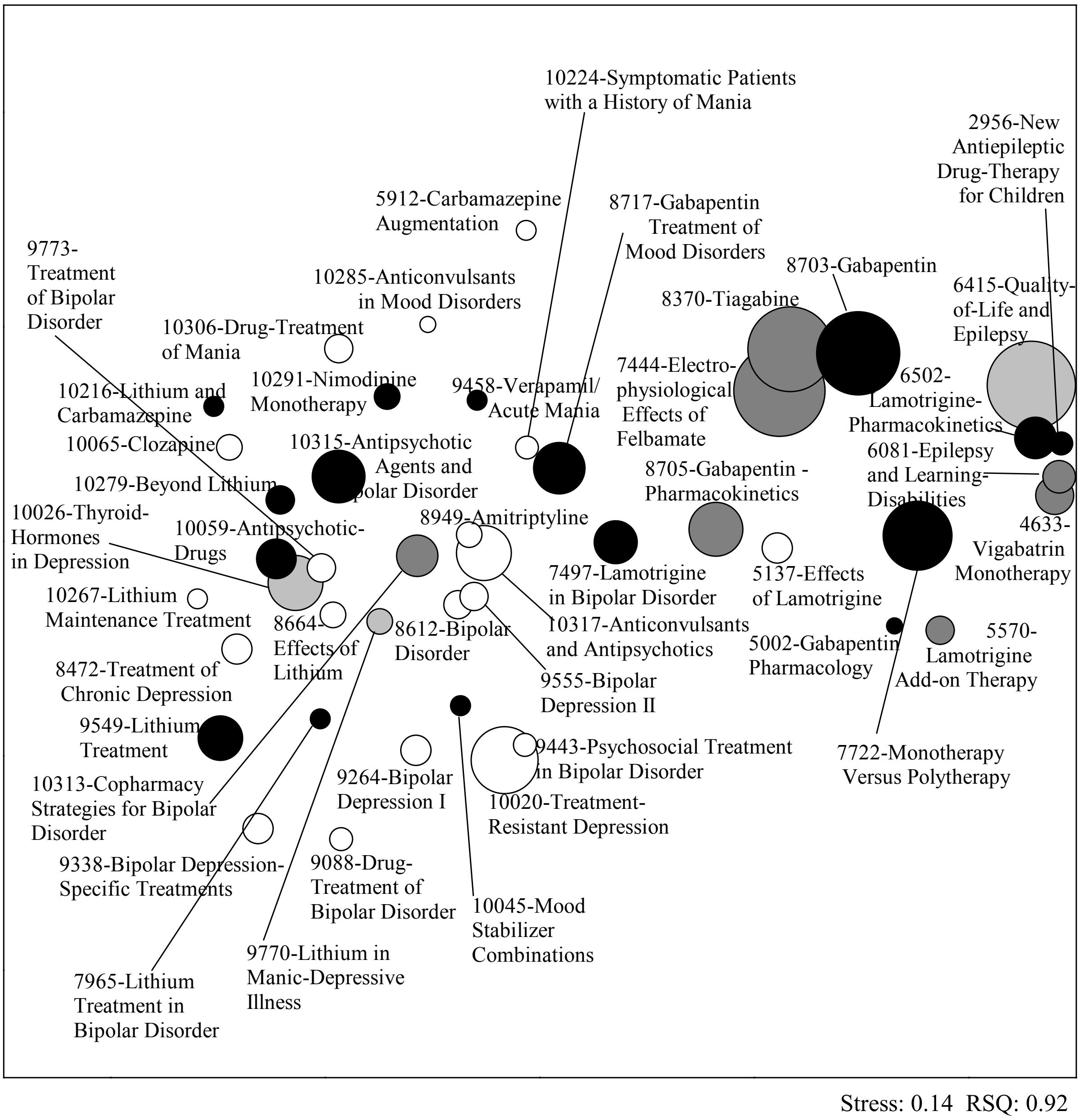
The main **national actors** are the USA, the United Kingdom and Germany followed by Italy which is well represented compared to its share of publications in the whole field (figure 9).

The three strongest institutions on the top of the ranking of **institutional actors** (table 8) are the US universities of Harvard and Texas and the *Yale University* followed by the *National Institute for Mental Health (NIMH)* and the *Virginia-Commonwealth University*. The top European actors are the *Freie Universität Berlin* and the *Universität München* each with 7 publications on the research front.

Table 7:

C1-clusters of C2-903: Antiepileptic and Antipsychotic Drugs

C1-No	Title	core	front	imm
2956	New Antiepileptic Drug-Therapy for Children	2	4	100
4633	Vigabatrin Monotherapy	7	11	28
5002	Gabapentin Pharmacology	2	2	100
5137	Effects of Lamotrigine	2	7	0
5570	Lamotrigine Add-on Therapy	3	6	33
5912	Carbamazepine Augmentation	2	3	0
6081	Epilepsy and Learning-Disabilities	4	8	25
6415	Quality-of-Life and Epilepsy	37	59	16
6502	Lamotrigine - Pharmacokinetics	9	13	55
7444	Electrophysiological Effects of Felbamate	42	63	38
7497	Lamotrigine in Bipolar Disorder	6	14	100
7722	Monotherapy Versus Polytherapy	13	36	61
7965	Lithium Treatment in Bipolar Disorder	2	3	100
8370	Tiagabine	44	54	40
8472	Treatment of Chronic Depression	2	7	0
8612	Bipolar Disorder	4	6	0
8664	Effects of Lithium	2	5	0
8703	Gabapentin	38	52	50
8705	Gabapentin - Pharmacokinetics	15	22	40
8717	Gabapentin Treatment of Mood Disorders	7	20	100
8949	Amitriptyline	3	5	0
9088	Drug-Treatment of Bipolar Disorder	2	4	0
9264	Bipolar Depression I	2	7	0
9338	Bipolar Depression-Specific Treatments	6	7	0
9443	Psychosocial Treatment in Bipolar Disorder	2	4	0
9458	Verapamil/Acute Mania	2	3	100
9549	Lithium Treatment	4	15	50
9555	Bipolar Depression II	2	6	0
9770	Lithium in Manic-Depressive Illness	6	5	16
9773	Treatment of Bipolar Disorder	2	6	0
10020	Treatment-Resistant Depression	35	34	8
10026	Thyroid-Hormones in Depression	20	23	15
10045	Mood Stabilizer Combinations	2	3	100
10059	Antipsychotic-Drugs	4	12	75
10065	Clozapine	3	5	0
10216	Lithium and Carbamazepine	2	3	100
10224	Symptomatic Patients with a History of Mania	2	4	0
10267	Lithium Maintenance Treatment	2	3	0
10279	Beyond Lithium	2	6	50
10285	Anticonvulsants in Mood Disorders	13	12	0
10291	Nimodipine Monotherapy	2	5	50
10306	Drug-Treatment of Mania	5	6	0
10313	Copharmacy Strategies for Bipolar Disorder	3	13	33
10315	Antipsychotic Agents and Bipolar Disorder	12	21	75
10317	Anticonvulsants and Antipsychotics	30	23	0



Share of young documents in cluster cores

- > 50% young cited documents
- 25-50%
- 10-24%
- < 10%

Size of the Research Front

the area of the circles is proportional to the number of co-citing documents

Figure 7:

Co-Citation map of C2-903: Antiepileptic and Antipsychotic Drugs

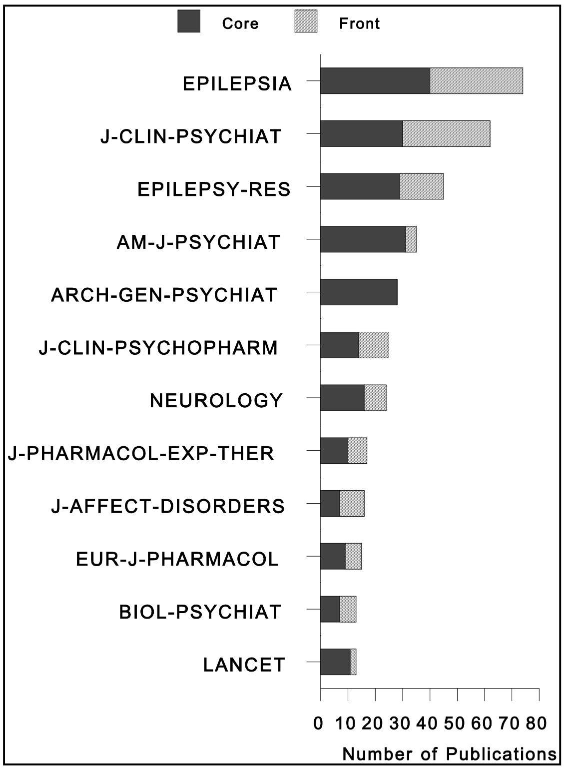


Figure 8:
Journal Profile of C2-903

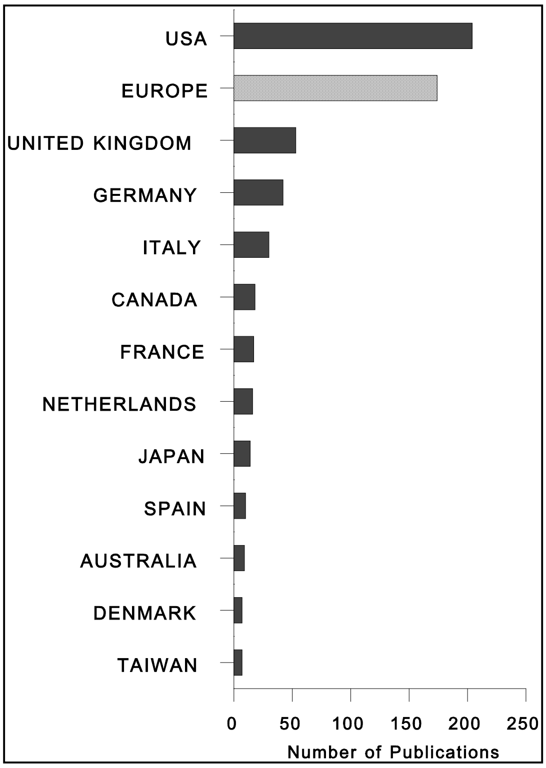


Figure 9:
Top national actor of C2-903

Table 8:
Top institutions of C2-903

Pub.	Institution
20	HARVARD-UNIV, USA
16	UNIV-TEXAS, USA
16	YALE-UNIV, USA
13	NIMH, USA
11	VIRGINIA-COMMONWEALTH-UNIV, USA
7	ABBOTT-LABS, USA
7	FREE-UNIV-BERLIN, GERMANY
7	UNIV-FLORIDA, USA
7	UNIV-MUNICH, GERMANY
7	UNIV-ROMA-TOR-VERGATA, ITALY
7	UNIV-WASHINGTON, USA
6	MASSACHUSETTS-GEN-HOSP, USA
6	STANFORD-UNIV, USA
6	UNIV-CALIF-LOS-ANGELES, USA
6	UNIV-CINCINNATI, USA
6	UNIV-GLASGOW, UNITED KINGDOM
6	VET-ADM-MED-CTR, USA
6	VET-AFFAIRS-MED-CTR, USA

5.1.1.2.4. C2-686 Anxiety/Limbic Epilepsy/Immunoreactivity

The cluster *Anxiety/Limbic Epilepsy/Immunoreactivity* is the third larger region with a lot of C1-“epilepsy-clusters“. (table 9) As in the case of C2-686 two areas can be distinguished in the **co-citation map** (figure 10): a group of C1-clusters on the right hand side dealing with anxiety and elevated plus-maze and on the left hand side a larger area with the epilepsy related clusters. The dominating themes in this epilepsy region are GABA-, Kainate- and other Receptors, mossy fiber sprouting and kindling. The 40 C1-clusters with core and front size and their immediacy value are shown in table 6.

In the **journal profile** (figure 11) the largest journal is *Brain Research* which is more strongly represented on the research front whereas the involved publications from the journal *Neuroscience* on the second position can be found mainly in the cluster core. Furthermore their are two journals with a contribution of more than 30 publications: *Epilepsy Research* and *Psychopharmacology* .

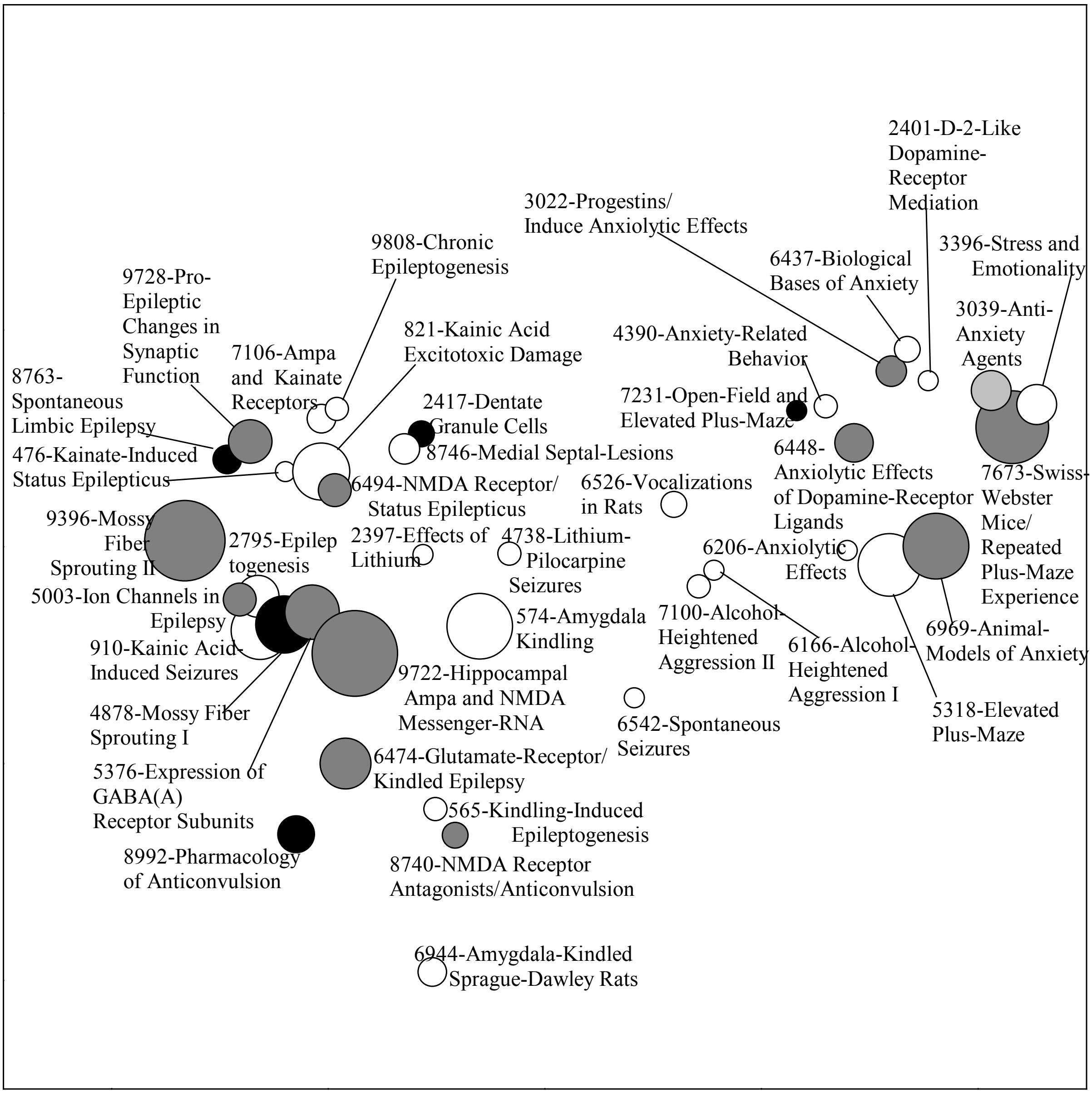
The strongest **national actors** are the USA, Germany and the United Kingdom (figure 12). The USA are surpassed by the EU15 countries which come up to nearly 200 of the 457 co-citing publications building the research front which corresponds with an percentage of 43%. Compared to a share of 31% for the whole field the member states of the European Union are well represented in this larger cluster. Especially Germany and France show a good performance in this region.

The list with the main **institutional actors** (table 10) is leaded by the *University of California* with 19 publications followed by the German *Hannover School of Veterinary Medicine* with 16 publications and further universities mainly from the USA apart from *Okayama University, Japan* and *University of Toronto, Canada* both with 8 publications and *University Leeds, United Kingdom* (7 pub.).

Table 9:

C1-clusters of C2-686: Anxiety/Limbic Epilepsy/Immunoreactivity

C1-No	Title	Core	front	imm
6526	Vocalizations in Rats	3	5	0
6448	Anxiolytic Effects of Dopamine-Receptor Ligands	6	11	33
7673	Swiss-Webster Mice/Repeated Plus-Maze Experience	27	39	37
6944	Amygdala-Kindled Sprague-Dawley Rats	3	6	0
6494	NMDA Receptor/Status Epilepticus	4	8	25
6206	Anxiolytic Effects	2	3	0
3039	Anti-Anxiety Agents	5	12	20
4390	Anxiety-Related Behavior	2	4	0
6542	Spontaneous Seizures	2	3	0
5318	Elevated Plus-Maze	2	29	0
4878	Mossy Fiber Sprouting I	6	24	50
2401	D-2-Like Dopamine-Receptor Mediation	3	3	0
565	Kindling-Induced Epileptogenesis	3	3	0
8740	NMDA Receptor Antagonists/Anticonvulsion	3	5	33
821	Kainic Acid Excitotoxic Damage	4	10	0
8746	Medial Septal-Lesions	2	7	0
9396	Mossy Fiber Sprouting II	13	48	23
3022	Progestins/Induce Anxiolytic Effects	4	7	25
6969	Animal-Models of Anxiety	21	32	42
6437	Biological Bases of Anxiety	2	5	0
3396	Stress and Emotionality	3	12	0
4738	Lithium-Pilocarpine Seizures	2	4	0
2795	Epileptogenesis	2	13	0
8763	Spontaneous Limbic Epilepsy	4	6	75
7100	Alcohol-Heightened Aggression II	3	4	0
6166	Alcohol-Heightened Aggression I	2	3	0
476	Kainate-Induced Status Epilepticus	4	5	0
2397	Effects of Lithium	2	3	0
7231	Open-Field and Elevated Plus-Maze	2	3	100
7106	Ampa and Kainate Receptors	2	6	0
8992	Pharmacology of Anticonvulsion	10	10	50
5003	Ion Channels in Epilepsy	4	8	25
574	Amygdala Kindling	12	27	50
9722	Hippocampal Ampa and NMDA Messenger-RNA	40	54	45
6474	Glutamate-Receptor/Kindled Epilepsy	12	19	25
5376	Expression of GABA(A) Receptor Subunits	12	22	41
910	Kainic Acid-Induced Seizures	3	25	0
2417	Dentate Granule Cells	3	5	66
9808	Chronic Epileptogenesis	2	4	0
9728	Pro-Epileptic Changes in Synaptic Function	12	14	25



Stress: 0.1 RSQ: 0.96

Share of young documents in cluster cores

- ● > 50% young cited documents
- ● 25-50%
- ● 10-24%
- ○ < 10%

Size of the Research Front

the area of the circles is proportional to the number of co-citing documents

Figure 10:

Co-Citation map of C2-686: Anxiety/Limbic Epilepsy/Immunoreactivity

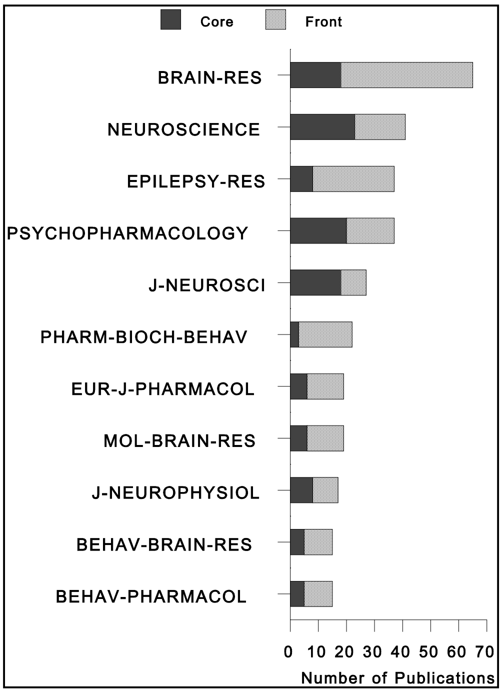


Figure 11:
Journal profile of C2-686

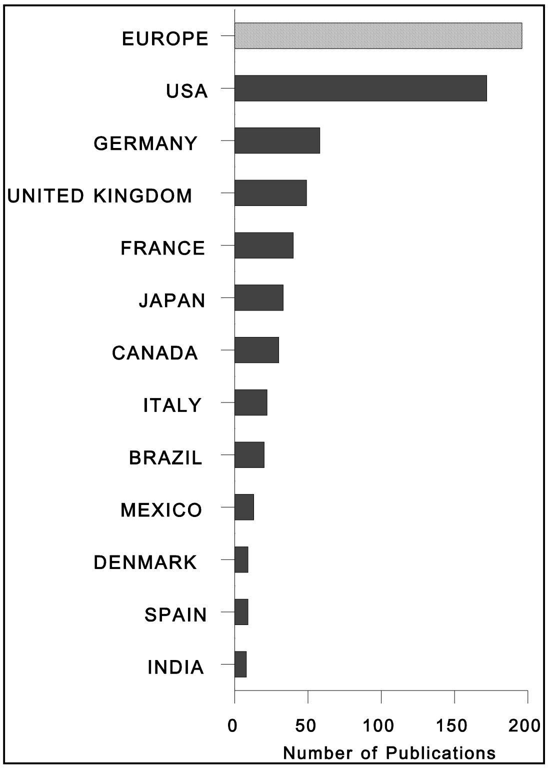


Figure 12:
Top national actors of C2-686

Table 10:
Top institutional actors C2-686

Pub.	Institutions
19	UNIV-CALIF-LOS-ANGELES, USA
12	SCH-VET-MED, GERMANY
10	UNIV-SO-CALIF, USA
8	CLEVELAND-CLIN-FDN, USA
8	OKAYAMA-UNIV, JAPAN
8	TUFTS-UNIV, USA
8	UNIV-TORONTO, CANADA
7	DUKE-UNIV, USA
7	NIMH, USA
7	UNIV-LEEDS, UNITED KINGDOM
7	VIRGINIA-COMMONWEALTH-UNIV, USA
6	HUMBOLDT-UNIV, GERMANY
6	INST-MEXICANO-PSIQUIATRIA, MEXICO
6	UNIV-DUSSELDORF, GERMANY
6	UNIV-SAO-PAULO, BRAZIL
6	UNIV-SOUTHAMPTON, UNITED KINGDOM
6	UNIV-VIRGINIA, USA

5.1.1.2.5. C2-417: Epileptiform Activity

The C2-cluster *Epileptiform Activity* is one of the small regions including 80 cited publications clustered in 12 C1-clusters (table 11). The size of the research fronts is rather small. Two of the largest fronts and *Aconitum Alkaloid Mesaconitine* and *Enhanced Propagation of Epileptiform Activity* are positioned in direct vicinity below the center of the **co-citation map** (figure 13) whereas *GABA-Induced Intrinsic Light-Scattering* – another larger cluster with 21 publications on the research front and a great proportion of young core documents is positioned on the right hand side.

The top journals of C2-417 shown in the **journal profile** (figure 14) are leaded by the *Journal of Neurophysiology*, *Brain Research* and the *Journal of Neuroscience* each with more than 10 publications equally distributed to the research front and the cluster core. The first explicitly epilepsy related journal *Epilepsy Research* ranks at the sixth position and is represented on the core only with one publication.

The main national actors (figure 15) are the USA and Germany which contributes to more than a quarter of the publications of the research front. They are followed by Canada and Japan each contributing more than 10 publications. The top group of national actors is completed by the United Kingdom, also with more than 10 publications.

The strong contribution of Germany is reflected in the list with top **institutional actors** (table 12). The ranking is leaded by two German institutions, the *Humboldt Universität* and the *Universität Ulm*. Another German university (*Universität Düsseldorf*) participate with four publications to the clusters research front.

Table 11:
C1-cluster of C2-417: Epileptiform Activity

C1-No	Title	Core	front	imm
3489	Applied Currents/Spontaneous Epileptiform Activity	3	3	0
5686	GABA(A)-Mediated Inhibition	7	11	28
4104	Ictal Epileptiform Activity	5	9	0
2695	Optical Imaging	3	3	33
5948	GABA-Induced Intrinsic Light-Scattering	12	21	50
5625	Osmolarity/Ionic Flux	5	8	40
4126	Modulation of Epileptiform Activity	2	3	0
5919	Lamotrigine/Valproate/Trimipramine	3	7	0
5937	Veratridine-Treated Brain-Slices	2	4	0
5661	Aconitum Alkaloid Mesaconitine	22	27	18
5390	Optical Mapping of Neural Responses	6	13	0
3851	Enhanced Propagation of Epileptiform Activity	10	19	20

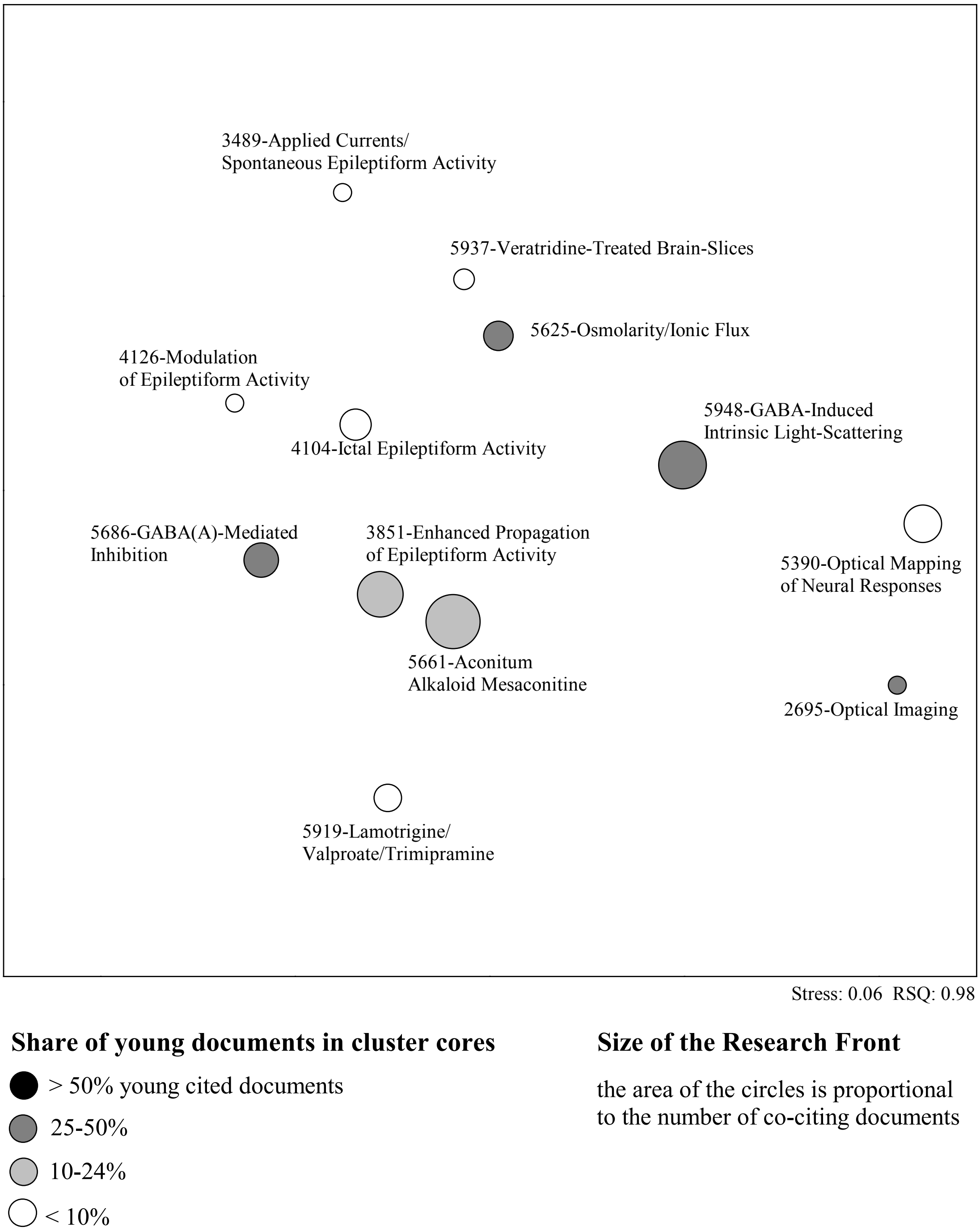


Figure 13:

Co-citation map of C2-417: Epileptiform Activity

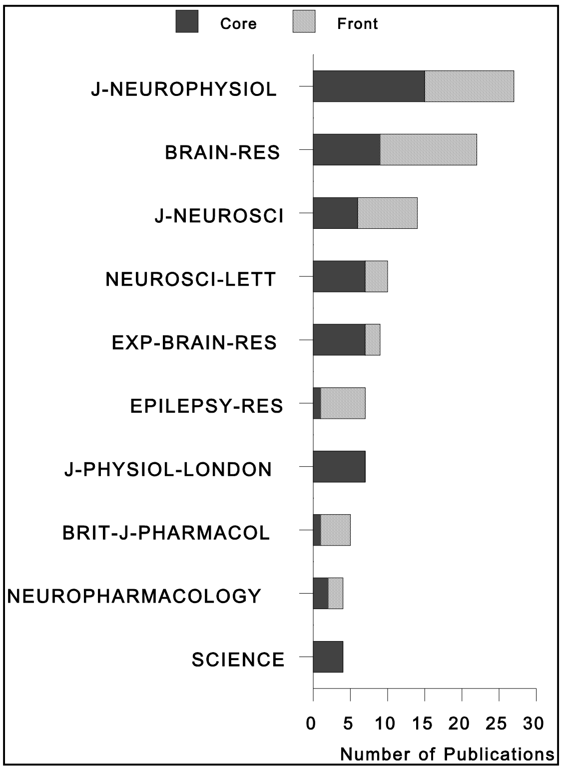


Figure 14:
Journal profile of C2-417

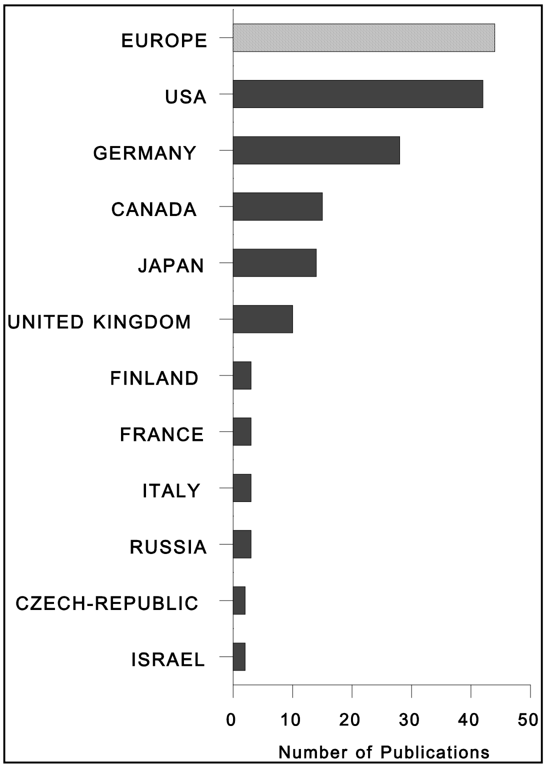


Figure 15:
Top national actors of C2-417

Table 12:
Top institutional actors of C2-417

Pub.	Institutions
7	HUMBOLDT-UNIV, GERMANY
6	UNIV-ULM, GERMANY
5	UNIV-CALIF-LOS-ANGELES, USA
4	MCGILL-UNIV, CANADA
4	TOKYO-MED-&-DENT-UNIV, JAPAN
4	UNIV-DUSSELDORF, GERMANY
4	UNIV-WASHINGTON, USA
3	DUKE-UNIV, USA
3	QUEENS-UNIV, CANADA
3	RUSSIAN-ACAD-SCI, RUSSIA
3	UNIV-BIRMINGHAM, UNITED KINGDOM
3	UNIV-FREIBURG, GERMANY
3	UNIV-KUOPIO, FINLAND
3	UNIV-WISCONSIN, USA

5.1.1.2.6. C2-1060 Absence Epilepsy

The smallest cluster in our list is C2-1060 *Absence Epilepsy* with only 44 clustered publications in 6 C1-clusters (table 13). The two larger clusters C1-7829 *Absence Seizures* and C1-*7506 Genetic Absence Epilepsy* and a smaller cluster on the upper left hand side of the

co-citation map (figure 16) are explicitly epilepsy related. The other clusters are dealing with themes related to the thalamus.

In the **journal profile** of C2-1060 (figure 17) the most contributing journals are *Brain Research*, *Epilepsia* and *Epilepsy Research* for the research front and *Neuroscience*, *Epilepsia* and *Experimental Neurology* for the cluster core.

In the figure 18 showing the top **national actors** the USA (14 publications) can be recognized as the leading nation but very closely followed by France and the United Kingdom both with 11 publications and Canada and Germany with 9 publications so that the Eu15 countries as a whole come up to 33 publications.

The list with **institutional actors** (table 14) shows a French institution on the top position. The *University Strasbourg* with 9 publications is followed by the *University Toronto, Canada* with 5 publications on the research front.

Table 13:
C1-clusters of C2-1060: Absence Epilepsy

C1-No	Title	core	front	imm
1123	GABA(A) Receptors in Convulsant-Induced Epileptiform Activity	3	5	66
5251	Intracellular-Recordings in Thalamic Neurons	2	2	0
5306	Metabotropic Glutamate-Receptor/Thalamus	3	5	100
7506	Genetic Absence Epilepsy	24	26	29
7829	Absence Seizures	9	18	0
8264	Corticothalamic Feedback	3	6	66

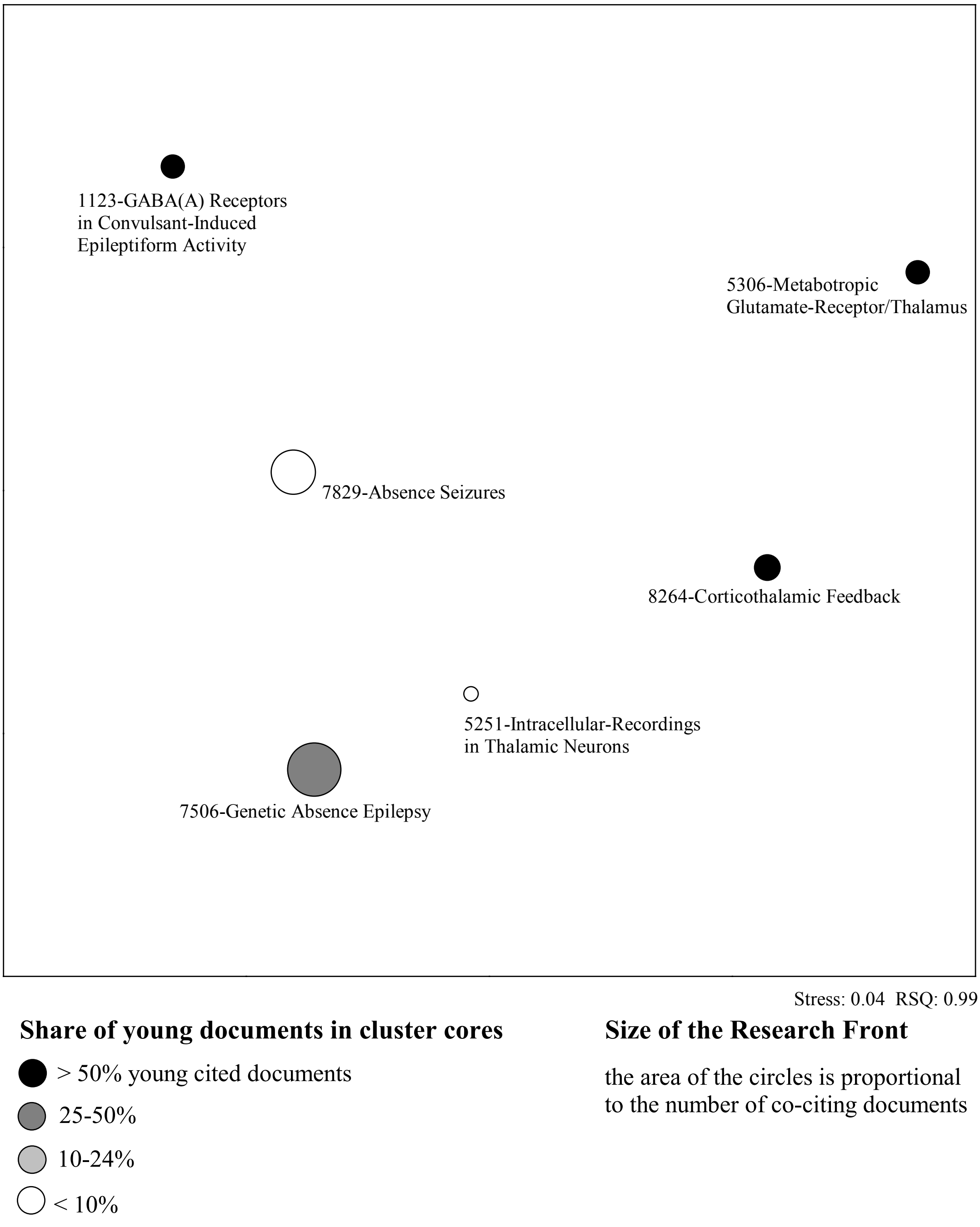


Figure 16:
Co-citation map of C2-1060: Absence Epilepsy

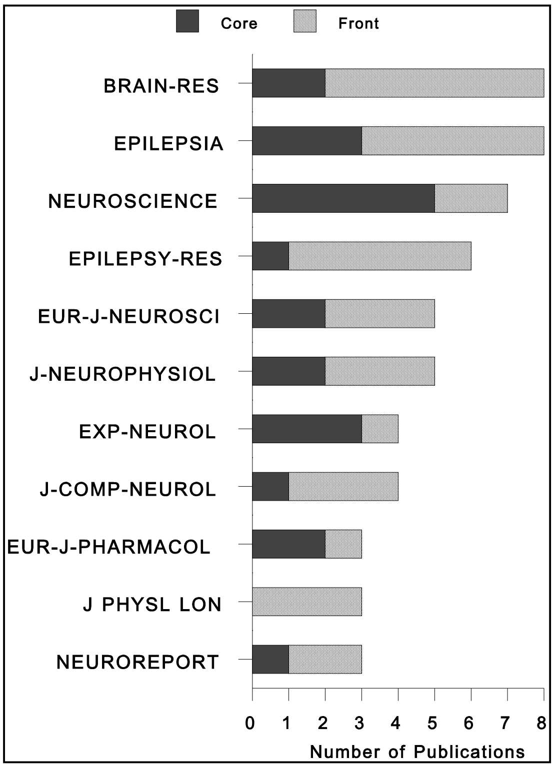


Figure 17:
Journal profile of C2-1060

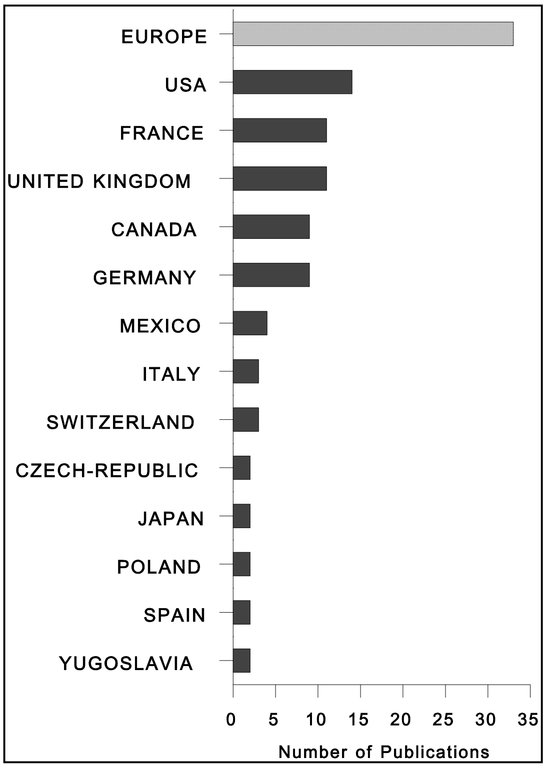


Figure 18:
Top national actors of C2-1060

Table 14:
Top institutional actors of C2-1060

Pub.	Institutions
9	UNIV-STRASBOURG, FRANCE
5	UNIV-TORONTO, CANADA
4	UNIV-CALIF-IRVINE, USA
3	UNIV-COLL-LONDON, UNITED KINGDOM
3	UNIV-LAVAL, CANADA
2	HARVARD-UNIV, USA
2	HUMBOLDT-UNIV, GERMANY
2	INST-POLITECN-NACL, MEXICO
2	MAX-PLANCK-INST-PSYCHIAT, GERMANY
2	NOVARTIS-PHARMA-AG, SWITZERLAND
2	UNIV-BELGRADE, YUGOSLAVIA
2	UNIV-BIRMINGHAM, UNITED KINGDOM
2	UNIV-CALIF-LOS-ANGELES, USA
2	UNIV-DUSSELDORF, GERMANY
2	UNIV-LONDON, UNITED KINGDOM
2	UNIV-NACL-AUTONOMA-MEXICO, MEXICO
2	UNIV-ROMA-TOR-VERGATA, ITALY
2	UNIV-WALES-COLL-CARDIFF, UNITED KINGDOM

5.1.1.2.7. C2-313 Status Epilepticus

The C2-cluster *Status Epilepticus* represents one of the smallest regions with only 69 publications on the research front. In table 15 the 8 C1-clusters are listed which are shown in **the co-citation map** in figure 19. The largest cluster is *Nonconvulsive Status Epilepticus* positioned in the center of the map. It is surrounded by some smaller clusters which are dealing in part also with status epilepticus (*C1-6011 Convulsive Status Epilepticus* and *C1-4470 Status Epilepticus in Childhood*). Other themes are related to the electroencephalography and the emergency treatment of head injury or status epilepticus *(Electroencephalographic and Histological Characteristics* and *Emergency EEG in Head-Injury* and *Rectal Use of Benzodiazepines*)

In the **journal profile** (figure 20) we can find two journals clearly dominating the region: *Epilepsia* and *Neurology*. The journal *Epilepsia* is stronger represented on the research front whereas the most cited articles are published in *Neurology*.

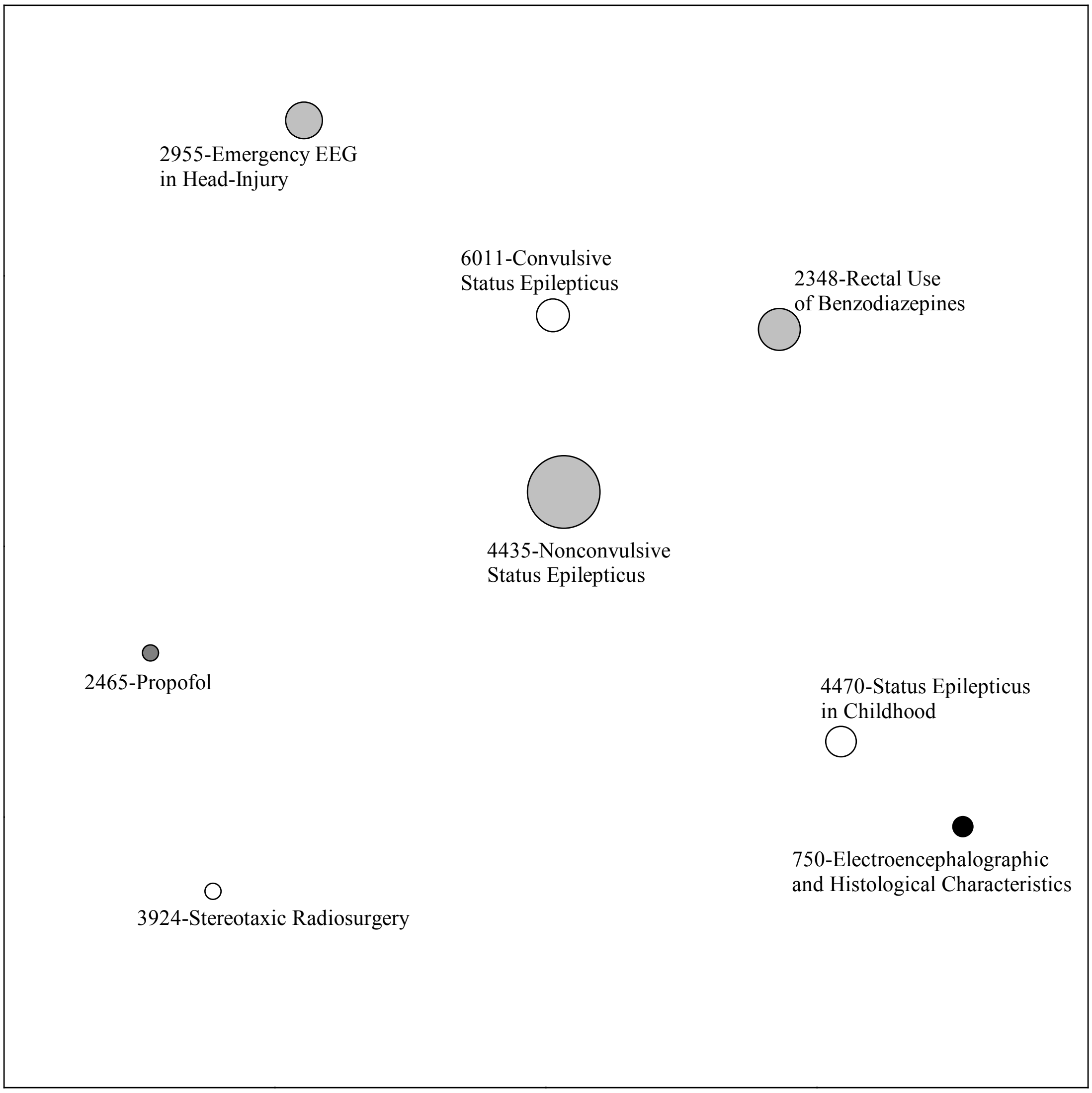
On the list with **national actors** the USA ranks first with 35 publications (figure 21). The EU15 nations contribute only with 21 publications of which more than a half with an UK (co) authorship. Another country with a grater share on the research front publications is Canada.

It is also represented twice on the list of stronger **institutional actors** (table 16). Aside the Canadian institutions – *McGill University* and *Montreal Childrens Hospital* – only US universities can be found on the top part of the ranking. The strongest institution with 7 publications is the *Virginia Commonwealth University*.

Table 15:

C1-clusters of C2-313: Status Epilepticus

C1-No	Title	core	front	imm
750	Electroencephalographic and Histological Characteristics	2	3	100
2348	Rectal Use of Benzodiazepines	12	13	16
2465	Propofol	2	2	50
2955	Emergency EEG in Head-Injury	5	10	20
3924	Stereotaxic Radiosurgery	2	2	0
4435	Nonconvulsive Status Epilepticus	26	39	19
4470	Status Epilepticus in Childhood	4	7	0
6011	Convulsive Status Epilepticus	4	8	0



Stress: 0.03 RSQ: 0.99

Share of young documents in cluster cores

- > 50% young cited documents
- 25-50%
- 10-24%
- < 10%

Size of the Research Front

the area of the circles is proportional to the number of co-citing documents

Figure 19:
Co-citation map of C2-313: Status Epilepticus

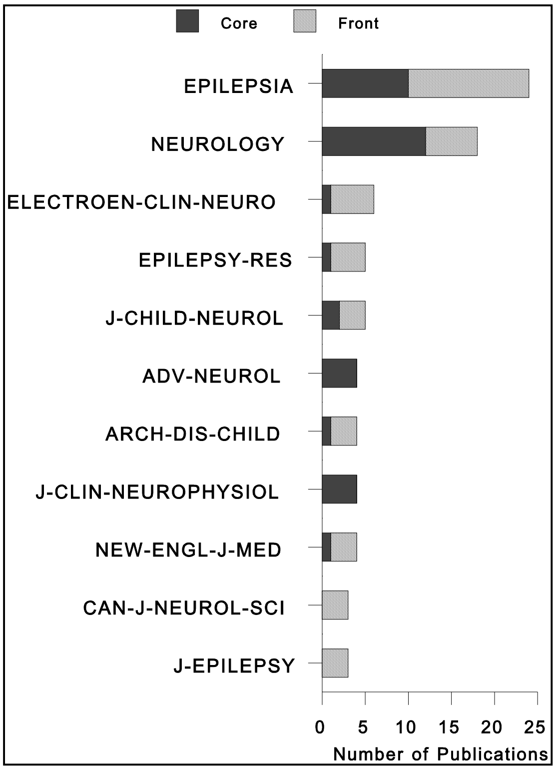


Figure 20:
Journal profile of C2-313

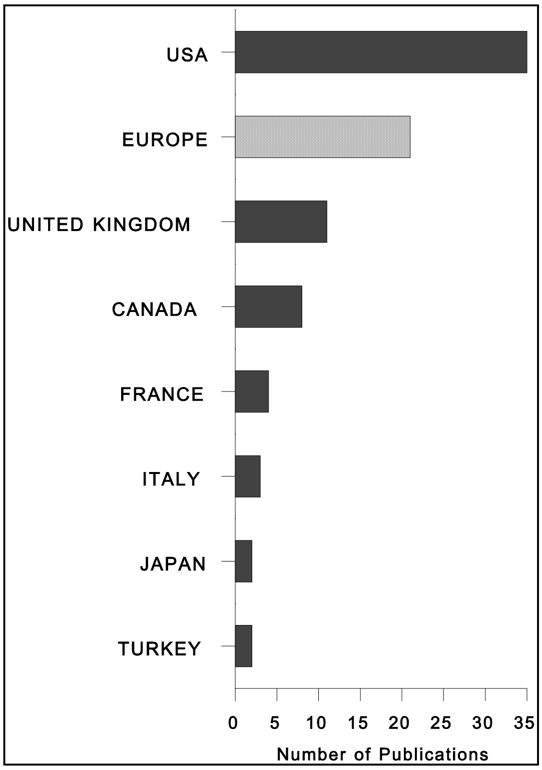


Figure 21:
Top national actors of C2-313

Table 16:
Top institutional actors C2-313

Pub.	Institutions
3	MONTREAL-CHILDRENS-HOSP, CANADA
3	UNIV-CALIF-LOS-ANGELES, USA
2	CORNELL-UNIV, USA
2	HOSP-UNIV-PENN, USA
2	MAYO-CLIN-&-MAYO-FDN, USA
2	NATL-HOSP-NEUROL-&-NEUROSURG, UK
2	OSPED-MIULLI-ACQUAVIVA, ITALY
2	ST-THOMAS-HOSP, UNITED KINGDOM
2	UNIV-ALABAMA, USA
2	UNIV-COLL-LONDON, UNITED KINGDOM
2	UNIV-MINNESOTA, USA
2	UNIV-TEXAS, USA
2	VET-AFFAIRS-MED-CTR, USA

5.1.1.3. The external relations of the epilepsy regions

The external relations of a cluster are given by the co-citation relations to the other clusters which are also the basic information for the clustering procedure. Therefore two different views are possible:

- We can look inside the higher level cluster. Its co-citation map shows the relations to the other clusters also assigned to this unit of the higher aggregation level.

- The other perspective is independent from the higher level cluster structure. It shows the nearest neighbors in terms of their relative co-citation strength. In a special graph which is not a spatial representation the **nearest neighbors** are presented. The nearest neighbors of the selected cluster – which is positioned in the center - are plotted in succession of their relative co-citation strength inversely represented by the distance to the center. (Note that the distances of the surrounding clusters to each other are not meaningful in this representation)

Which perspective is used to show the external relations for the epilepsy regions depends on their affiliation to the higher level (C3) clusters. In case of a C2-„epilepsy-cluster" which is clustered with more than three other C2-clusters a co-citation map is presented. Otherwise the graph with the nearest neighbors will be used. In this way we can look inside the higher level clusters or on the surrounding areas of the C2-co-citation „landscape".

5.1.1.3.1. C2-796 MR in Temporal-Lobe Epilepsy

The C2-region *MR in Temporal-Lobe Epilepsy* is assigned to the C3-*cluster Temporal-Lobe Epilepsy* (C3-21), a cluster with 8 C2-clusters (table 17) with 556 cited publications which are co-cited by 773 source publications. Around the largest cluster C2-796 in the co-citation map of C3-21 (figure 22) we find some smaller ones and a bit further away *C2-964 Cortical Dysplasia* with 120 cited publications in its cluster core another larger C2-region.

Other larger C2-clusters with relative strong links to C2-796 but not assigned to this cluster *are C2-534 Vascular Dementia* and *C2-105 Muscular Dystrophy/Neuromuscular Junction*.

Table 17:

C2-clusters of C3-21 Temporal-Lobe Epilepsy

C2-No	Title	#C1	core	Front	imm
16	Epilepsy Related to Onchocerciasis	2	5	8	0
234	Surgical-Treatment of Epilepsy	2	7	9	42
495	Tuberous Sclerosis Complex	7	61	71	39
497	Epilepsies in Childhood	9	57	79	15
615	Semiological Seizure Classification	2	5	52	20
763	EEG/Frontal-Lobe Epilepsies	6	22	37	9
796	MR in Temporal-Lobe Epilepsy	41	279	399	29
964	Cortical Dysplasia	19	120	176	31

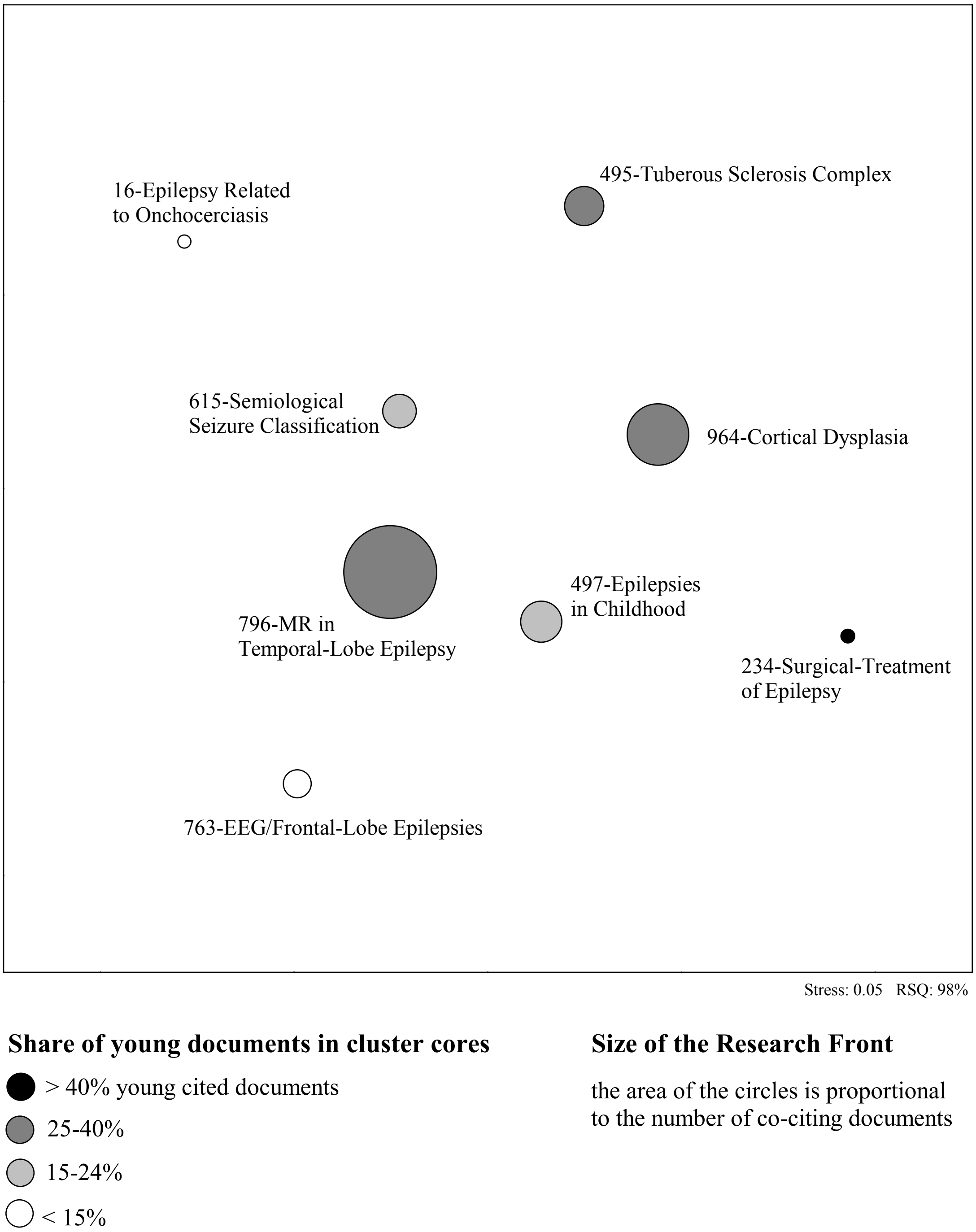


Figure 22:

Co-Citation map of C3-21: Temporal-Lobe Epilepsy

5.1.1.3.2. C2-497 Epilepsies in Childhood

The C2-cluster *Epilepsies in Childhood* can be found in the same C3-cluster as C2-796. It is one of the smaller clusters surrounding C2-796 in the co-citation map of C3-21 (figure 22). The clusters with the strongest co-citation links are the same as in the case of C2-796 apart from C2-234 *Surgical Treatment of Epilepsy* which is placed on the right side of the map.

5.1.1.3.3. C2-903 Antiepileptic and Antipsychotic Drugs

The C2-cluster *Antiepileptic and Antipsychotic Drugs* is assigned to a C3-cluster (C3-97 *Antiepileptic and Antipsychotic Drugs/Topiramate*) together with only one other C2-cluster (C2-835 *Topiramate*) so that a co-citation map of the cluster is not possible. Therefore the graph with the nearest neighbors of C2-903 is shown in figure 23.

The C2-cluster with the strongest link to C2-903 is C2-835 *Topiramate* followed by C2-854 *Selective Serotonin Reuptake* one of the larger clusters with a strong co-citation link to C2-903. Together with the other larger cluster C2-851 *Serotonin Syndrome* it is clustered in C3-125 *Serotonin Reuptake/Depression*.

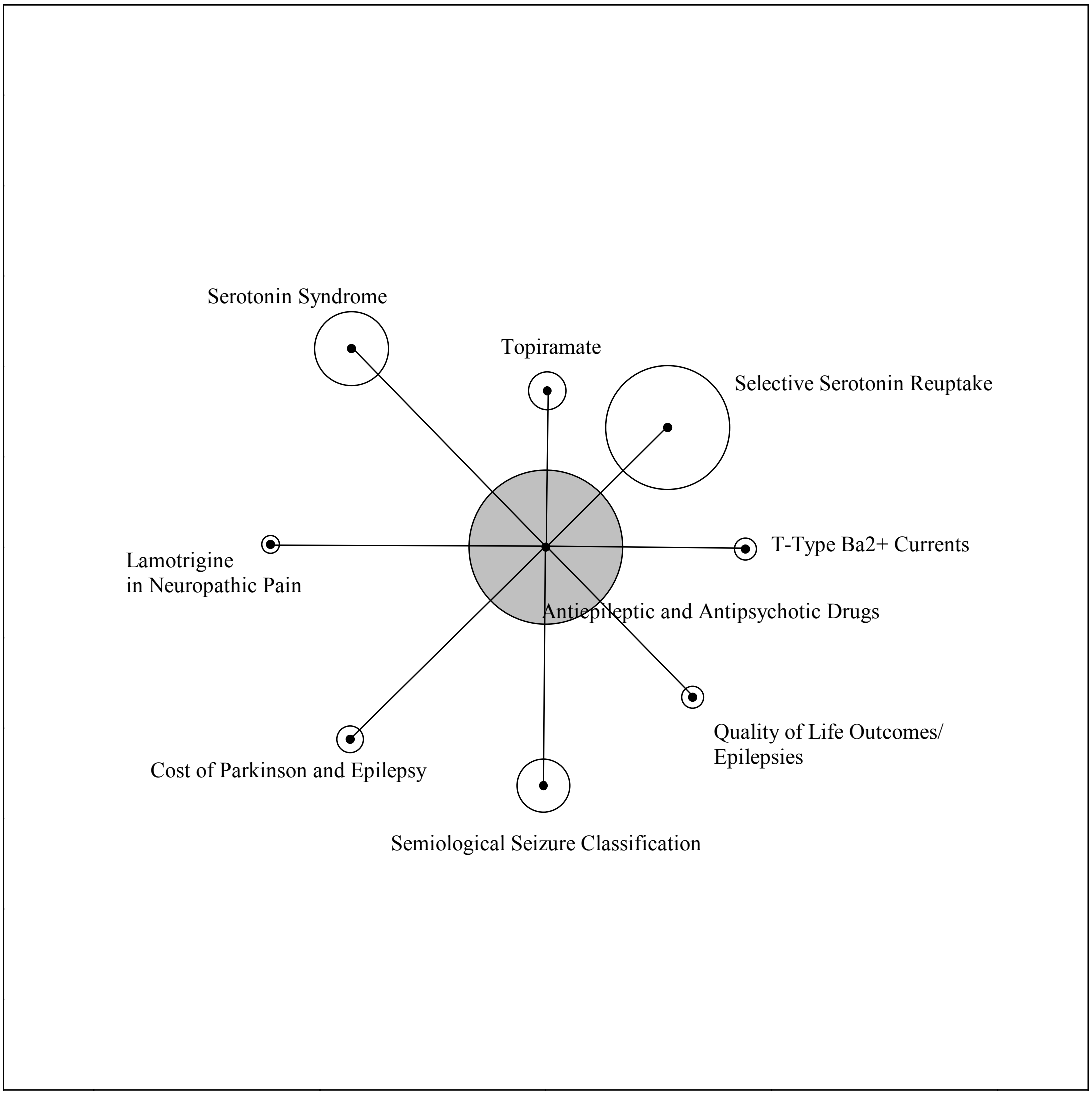


Figure 23:
Nearest Neighbors of C2-903

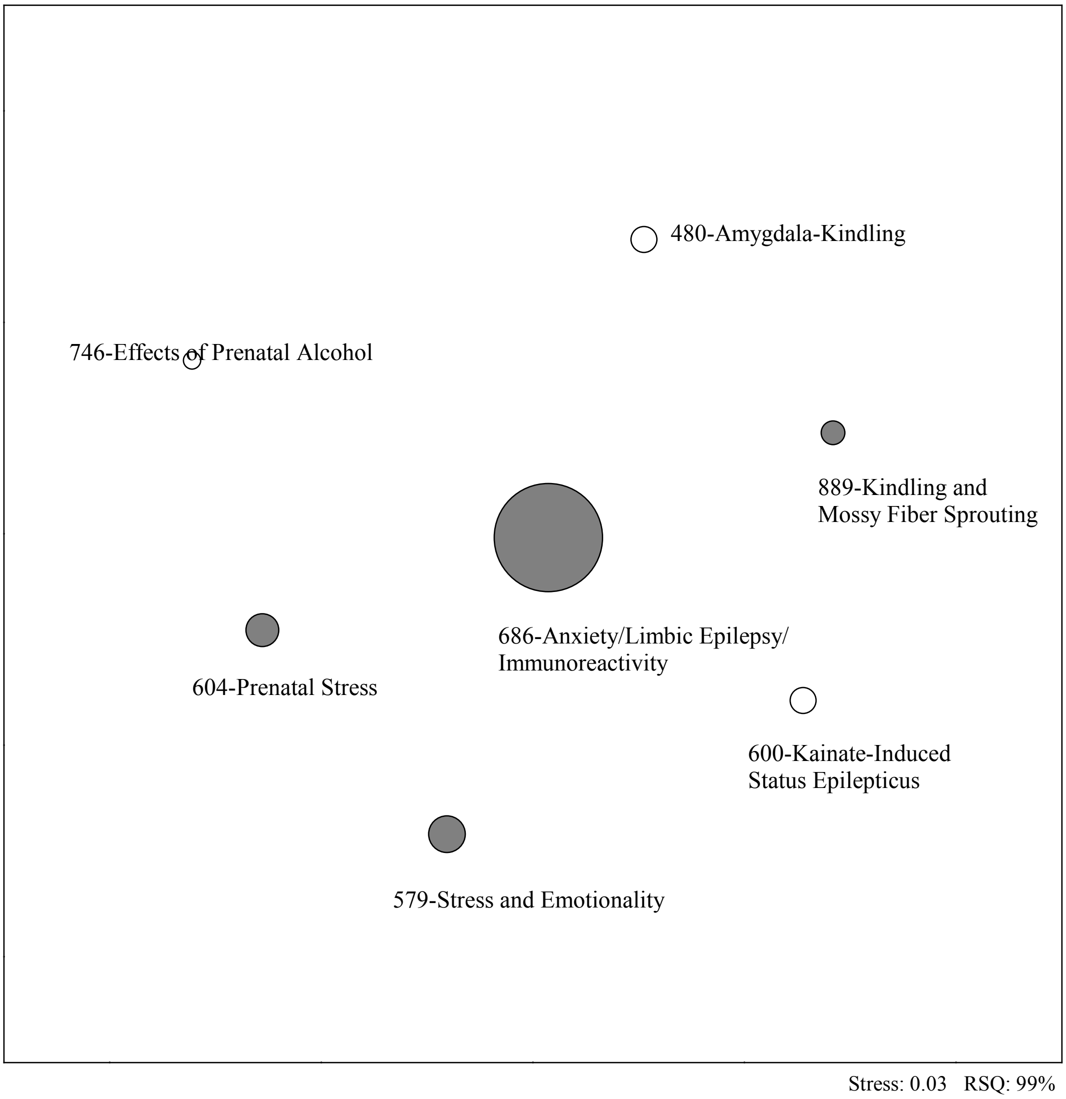
5.1.1.3.4. C2-686 Anxiety/Limbic Epilepsy/Immunoreactivity

C2-686 *Anxiety/Limbic Epilepsy/Immunoreactivity* is also clustered on the third level. It is by far the largest C2-cluster in C3-103 *Anxiety/Epilepsy* (table 18) where it is surrounded by six other very small C2-clusters as shown in the co-citation map (figure 24). To have a wider look on the larger areas linked to C2-686 in figure 25 the graph showing the nearest neighbors of C2-686 is presented. Aside some of the C2-clusters also assigned to C3-103 and other small clusters like C2-*369 Perirhinal Cortical Kindling*, C2-629 *Human Epileptogenic Hippocampal-Formation* and C2-*509 Anoxia/Kainate Status Epilepticus* we can see the large region C2-*134 Neuropharmacology of Ampa- and Kainate Receptors* as one of the strongest links of C2-686.

Table 18:

C2-clusters of C3-103 Anxiety/Epilepsy

C2-No	Title	C1	core	front	imm
480	Amygdala-Kindling	5	18	27	5
889	Kindling and Mossy Fiber Sprouting	3	12	22	25
746	Effects of Prenatal Alcohol	3	11	12	9
600	Kainate-Induced Status Epilepticus	2	12	27	0
686	Anxiety/Limbic Epilepsy/Immunoreactivity	40	240	457	30
604	Prenatal Stress	3	34	43	26
579	Stress and Emotionality	7	46	52	28



Share of young documents in cluster cores

- > 40% young cited documents
- 25-40%
- 15-24%
- < 15%

Size of the Research Front

the area of the circles is proportional to the number of co-citing documents

Figure 24:
Co-Citation map of C3-103 Anxiety/Epilepsy

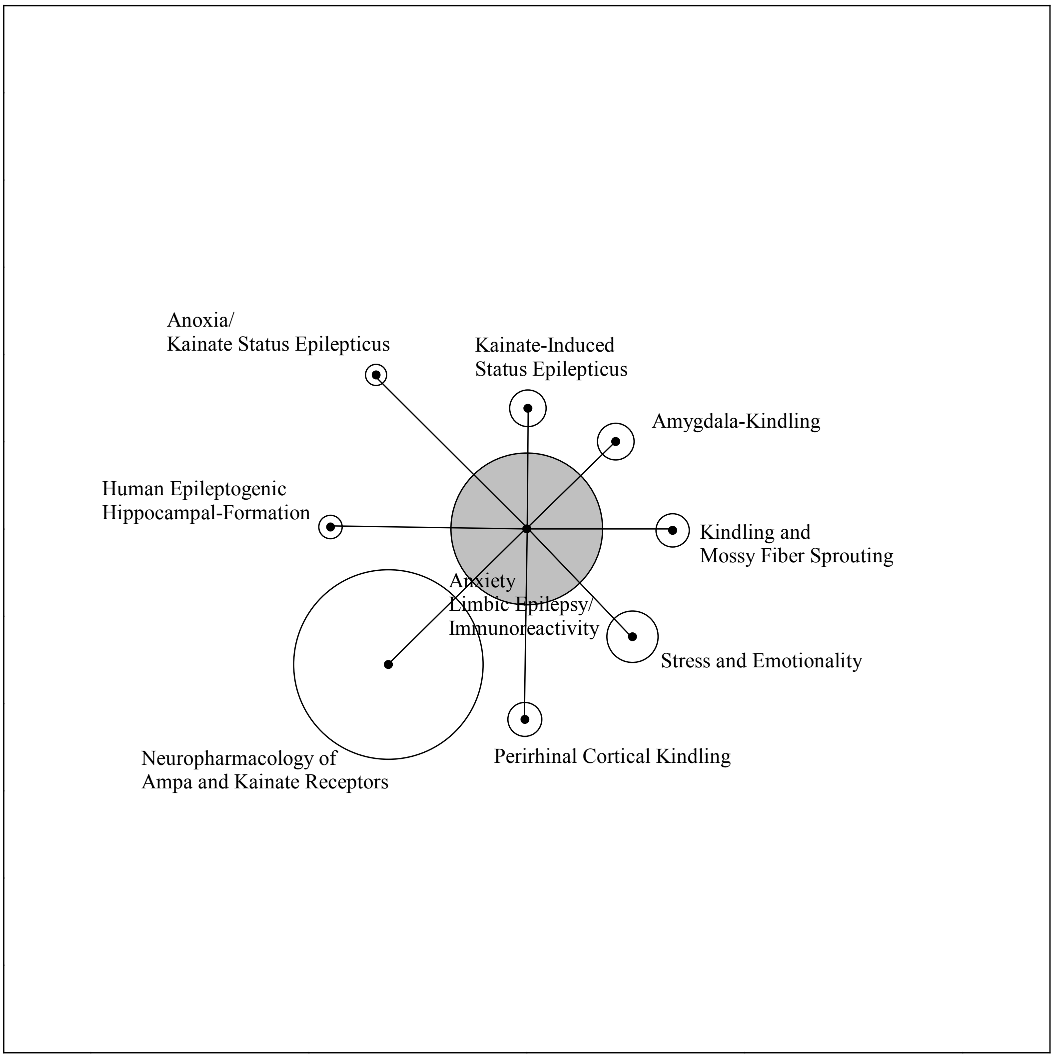


Figure 25:
Nearest Neighbors of C2-686

5.1.1.3.5. C2-417 Epileptiform Activity

The epilepsy region C2-417 *Epileptiform Activity* is clustered on the third level but also with only one other C2-cluster. In the graph with the nearest neighbors of C2-417 (figure 26) this cluster, C2-389 *Postanoxic Coma*, can be found on the top as the nearest neighbor of C2-417. Aside some very small C2-clusters there are three larger regions among the eight nearest neighbors: C2-910 *Theta- and Gamma-Rhythm*, C2-548 *GABA(A) Receptor-Mediated Inhibition* and C2-314 *ATP-Sensitive K+ Channels*.

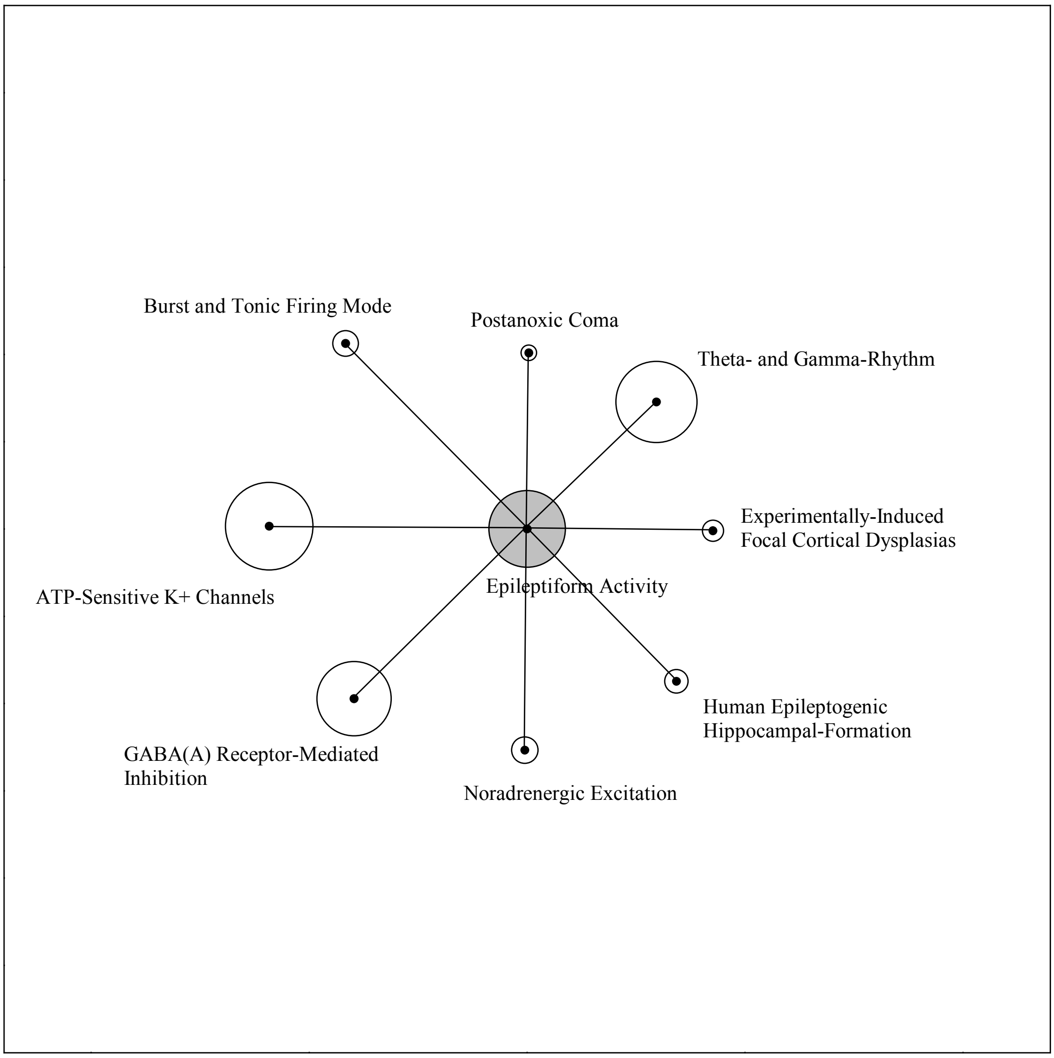


Figure 26:
Nearest Neighbors of C2-417

5.1.1.3.6. C2-1060 Absence Epilepsy

The last epilepsy region C2-1060 *Absence Epilepsy* shows a relatively strong connection to the larger cluster C2-1099 *Visual-Cortex/Thalamic Reticular Nucleus*. Among the eight nearest neighbors (shown in figure 27) no other epilepsy regions can be found, but two smaller clusters are also linked to one of the other C2“epilepsy-clusters“: C2-1024 *T-Type Ba2+ Currents* with C2-903 (see figure 23) and C2-369 *Perirhinal Cortical Kindling* with C2-686 (see figure 25). The cluster C2-615 *Semiological Seizure Classification* which is assigned to C3-21 *Temporal-Lobe Epilepsy* (see figure 22) is also connected with C2-313 (figure 28) and C2-903 (see figure 23)

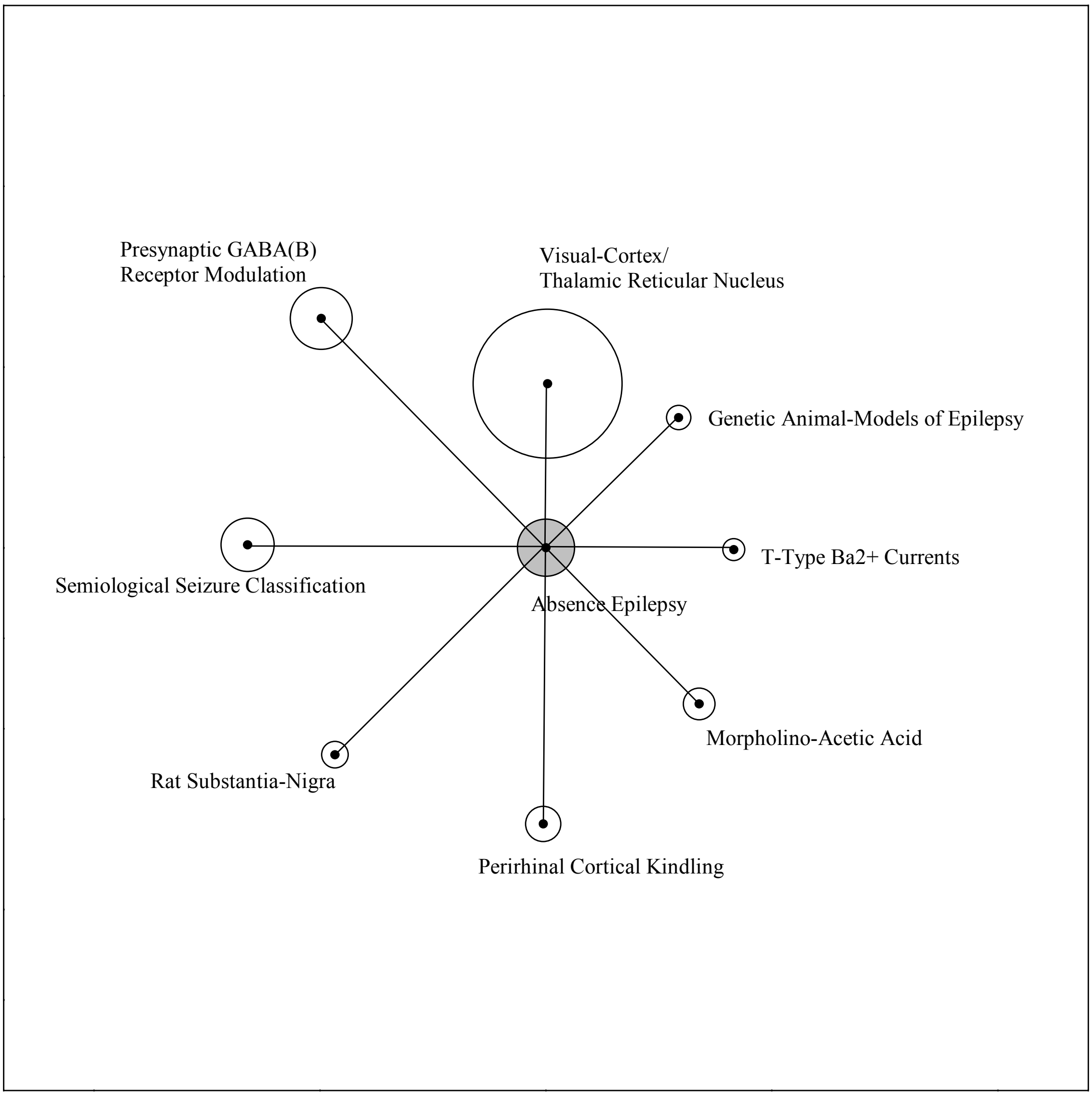


Figure 27:
Nearest Neighbors of C2-1060

5.1.1.3.7. C2-313 Status Epilepticus

The C2-region Status Epilepticus remains as an isolate after the third level clustering. But the plot with its nearest neighbors (figure 28) reveals some linkages to other epilepsy regions. The strongest links shows two small clusters dealing with Kainate Status Epilepticus. C2-600 *Kainate-Induced Status Epilepticus* is clustered in C3-103 *Anxiety/Epilepsy* (see figure 24). The next links go to three C2-clusters which are assigned to C3-*21 Temporal-Lobe Epilepsy* (see figure 22) including C2-796 *MR in Temporal-Lobe Epilepsy* – one of the C2"epilepsy-regions". The other large C2-cluster shown in the graph with the nearest neighbors is another epilepsy region C2-686 *Anxiety/Limbic Epilepsy/Immunoreactivity.*

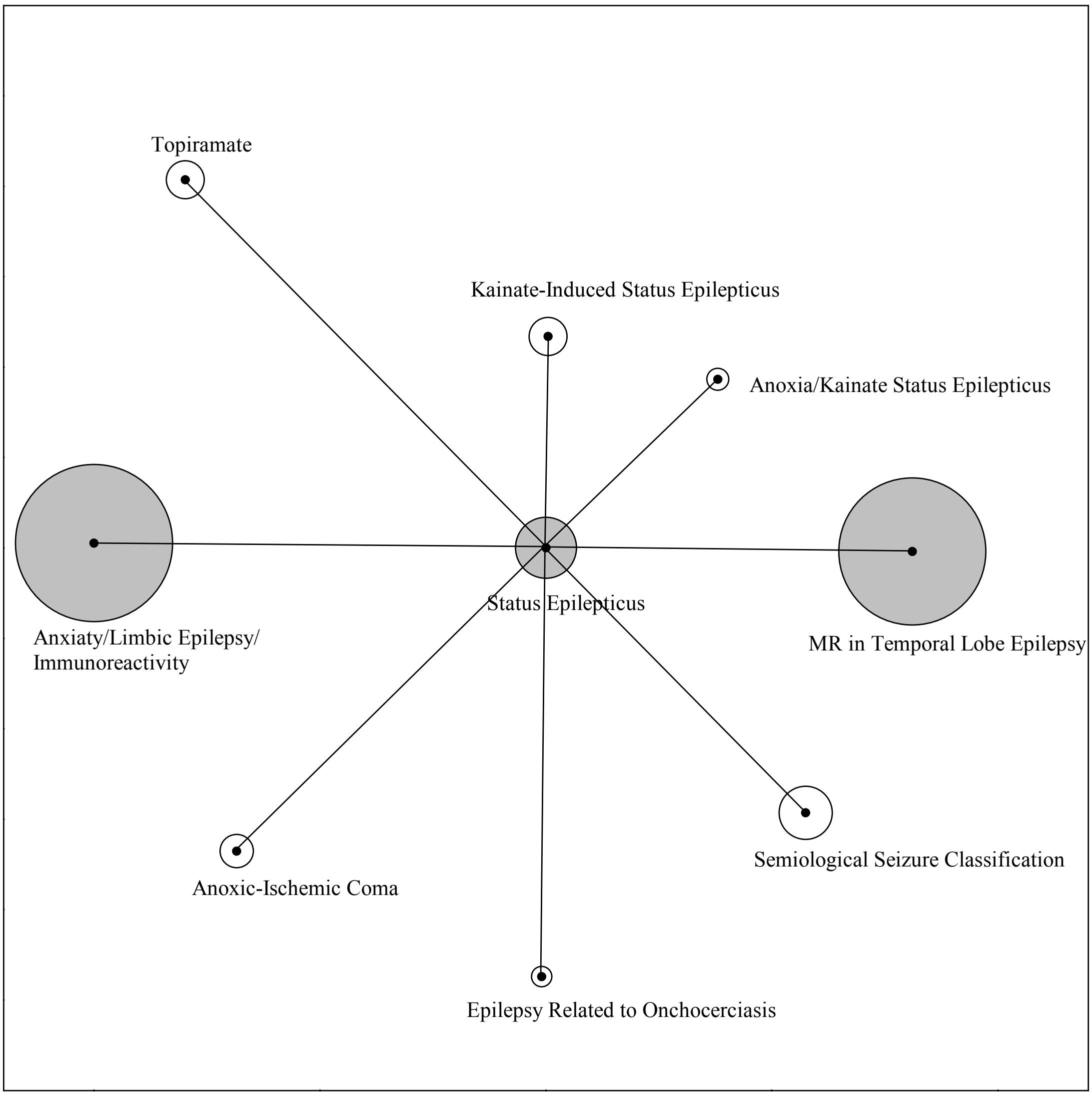


Figure 28:
Nearest Neighbors of C2-313

5.1.2. Neuroscience as depicted by co-word analysis

In neuroscience, epilepsy research clusters with the following keyterms: seizure, EEG, and temporal lobe, as determined by its co-word links. Its environment is rather clinical (right-hand side: neurology and neurosurgery), as opposed to the more fundamental area on the left-hand side ('hard' neuroscience: neurochemistry, neurophysiology and biochemistry).

5.1.2.1. Seizure/Epilepsy/EEG research within neuroscience

The most related subdomains in its environment are: 15 (*MRI/ computed tomography/ Functional MRI*), 36 (*Hippocampus/ Cortex/ Cerebellum/ Striatum*), 3 (*Etiology/ differential diagnosis/ neurological deficit/ spinal cord injury) and 26 (PET/ cerebral blood flow/ white matter*). And, on a lower level, 4 (*Schizophrenia/ Ethanol/ Alcohol/ normal control*), 20 (*Animal model/ electrical stimulation/ Fiber/ Pathophysiology*), 23 (*Axon/ Immunoreactivity/ Immunohistochemistry*) and 25 (*Gaba/ synaptic transmission/ gamma aminobutyric acid/ synaptic plasticity*). As compared to 1995/1996, the direct linkage with 25 has become more prominent. Moreover, 10 (*Stroke/ ischemic stroke/ stroke patient/ cerebral infarction*) and 22 (*Dementia/ Aging/ cognitive function/ cognitive impairment*) are in its environment but do not have such a strong direct relation to 29. It should be noted that this does not happen accidentally. The reason for their positioning is their indirect relation. For instance 29 and 10 share the strong relationships with other subdomains (in particular 3, 15 and 26), but do not have such strong connections directly.

5.1.2.2. Internal structure of Seizure/Epilepsy/EEG research

The internal structure of Seizure/Epilepsy/EEG research, shows a core of kinds of Seizure/Epilepsy/EEG or disorder in which epileptic seizures occur: partial epilepsy, childhood epilepsy, intractable epilepsy, refractory epilepsy, temporal lobe epilepsy, (complex) partial seizure, febrile seizure, and tuberous sclerosis. Around a particular kind (temporal lobe epilepsy), there is an area with related topics (hippocampal sclerosis, schizophrenia and Alzheimer). The structure shows an area around the neurophysiological and neurochemical aspects. Via hippocampus it is connected to the temporal lobe epilepsy area. Furthermore, there is an area around all kinds of scanning and imaging techniques (EEG, PET and MRI). Finally, there is an area around epileptic drugs and their use, including social aspects (quality of life).

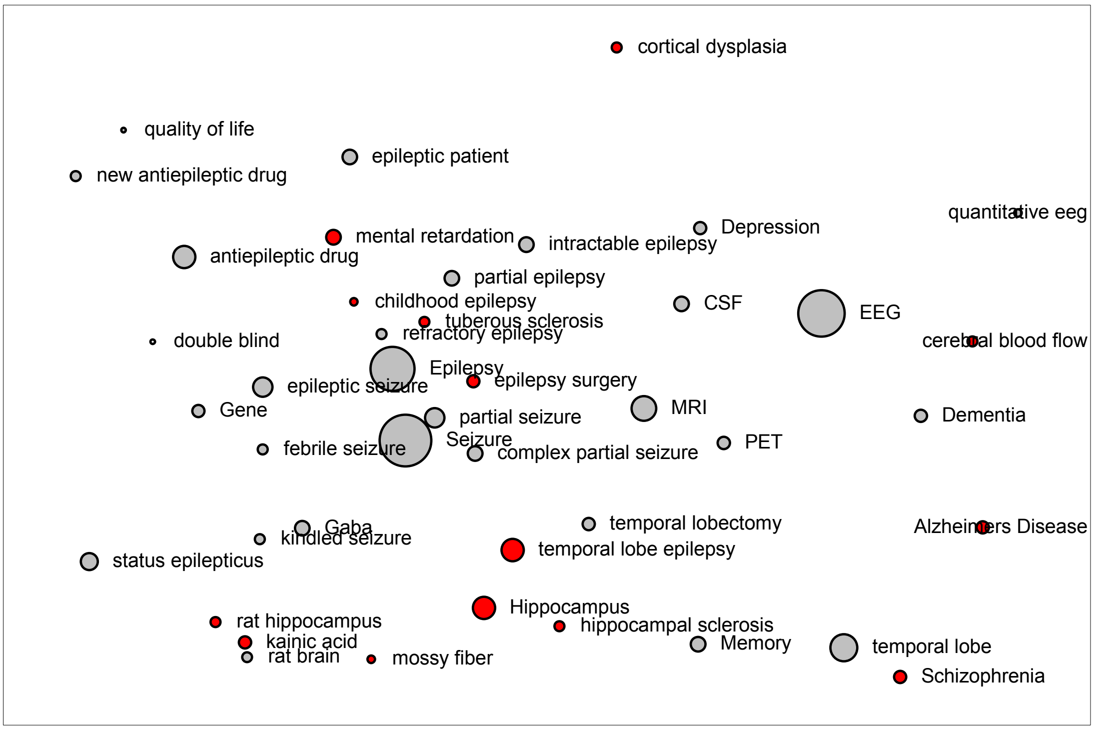


Figure 5-1:

Detail map of neuroscience subdomain 29: Seizure/Epilepsy/EEG research

Two dimensional representation of subdomain based on the similarities between identified keywords. The circle size indicates the number of publications represented. The color of the circles indicates a significant increase/decrease of activity: dark Grey: increase, white: decrease. The badness-of-fit criterion is 0.19, the distance correlation is 0.91 (statistics provided by SAS).

5.1.2.3. Publication characteristics of Seizure/Epilepsy/EEG research

The research is published in typical Epilepsy journals and in other neurology journals. In the Table below, we listed the most prominent ones in 1997/98 together with their frequency in 1995/96. Remarkable is the top position of 'Revista de Neurologia' and 'Seizure European Journal of Epilepsy', in the most recent year block. In the earlier period this journal either did not exists or was not covered by the NSCI.

Table 19:
Most frequently used journals

95/96	97/98	Journal
271	342	EPILEPSIA
147	184	NEUROLOGY
0	136	REVISTA DE NEUROLOGIA
106	131	EPILEPSY RESEARCH
80	128	ELECTROENCEPHALOGRAPHY AND CLINICAL NEUROPHYSIOLOGY
81	117	BRAIN RESEARCH
64	93	JOURNAL OF EPILEPSY
0	72	SEIZURE EUROPEAN JOURNAL OF EPILEPSY
47	70	NEUROSCIENCE LETTERS
40	69	JOURNAL OF NEUROLOGY NEUROSURGERY AND PSYCHIATRY
41	61	PEDIATRIC NEUROLOGY
34	58	ANNALS OF NEUROLOGY
70	54	SEIZURE
37	52	BRAIN & DEVELOPMENT
32	51	ARQUIVOS DE NEURO PSIQUIATRIA

5.1.2.4. Actors in Seizure/Epilepsy/EEG research

In this subdomain the share of publications with at least one EU address is about 38.6%, while the average EU share in neuroscience is about 36.5%. The EU share in this subdomain was slightly increased though not significantly, still in both periods of time significantly above the EU field average.

In absolute numbers, the EU is the most active actor. And within the EU, we found that Germany is the most active country followed by England, France and Italy. In the DAE, Japan is the main actor, followed by South Korea and Taiwan.

On organization level, the UCLA, Harvard, McGill, Univ Bonn, and Yale are on top. Furthermore, we found Univ Calif San Fransisco and Univ Toronto as newcomers in the top-ten, and at a lower rank, Univ Helsinki and Childrens Hosp Boston with a significant increase of activity.

With respect to the most active authors, we found Elgers, CE on top, followed by Duncan JS, with a significant increase of activity, and Andermann, F.

With regard to collaborations, we found that in most cases the partners are in the same geographical region. The most active international collaboration in 1997/98 has only 5 publications (Univ Padua, Italy and Univ Tubingen, Germany). Moreover, their collaboration in 1995/97 yielded more publications.

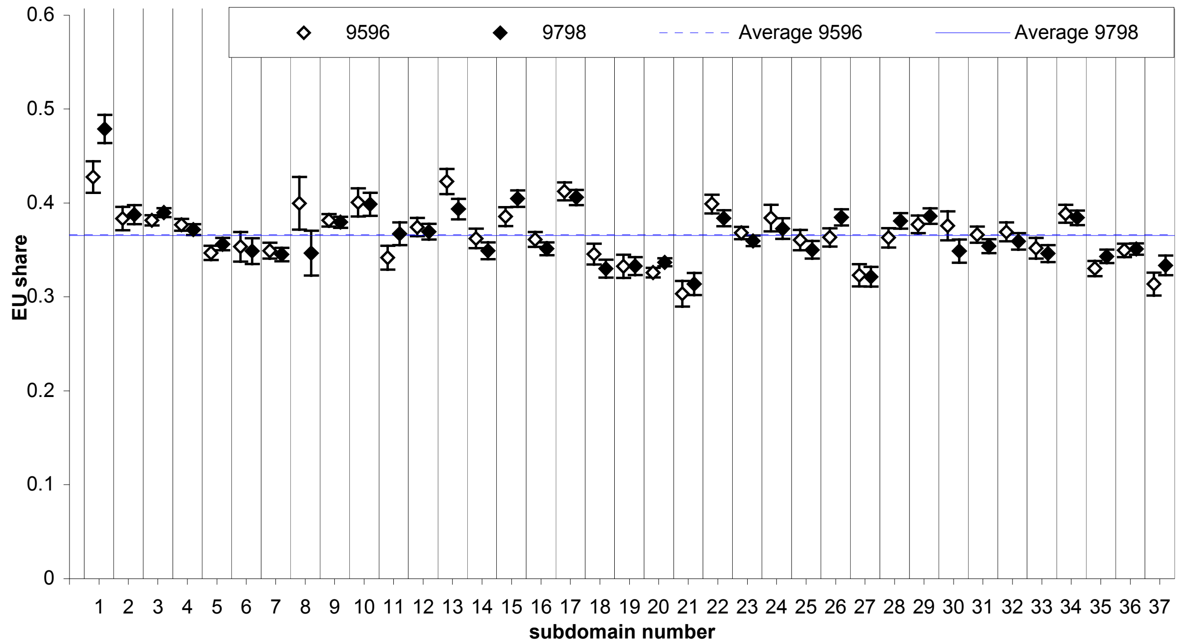


Figure 5-2:

Share of EU publications in neuroscience subdomains

The error lines are calculated under the assumption of a poison distribution (sqrt(N)/N)

Table 20:

Most active country aggregations (EU, US, Japan, and others)

95/96	97/98	Country aggregation
1598	2156	EU
1406	1829	US
827	1147	Other
347	506	DAE
113	148	EFTA 3

Table 21:

Most active countries

95/96	97/98	Country
1406	1829	USA
390	527	GERMANY
325	431	JAPAN
338	404	ENGLAND
220	311	FRANCE
227	296	CANADA
288	278	ITALY
57	177	SPAIN
98	161	NETHERLANDS
92	119	SWITZERLAND
84	115	SWEDEN
80	114	AUSTRALIA
66	99	FINLAND
95	96	RUSSIA
61	91	AUSTRIA
55	91	BRAZIL

95/96	97/98	Country
57	70	INDIA
32	56	BELGIUM
41	54	POLAND
42	52	TURKEY
27	48	CZECH REPUBLIC
44	44	DENMARK
35	43	ISRAEL
29	43	SCOTLAND
37	35	MEXICO
14	33	SOUTH KOREA
6	32	ARGENTINA
30	30	TAIWAN
22	29	NORWAY
14	25	SAUDI ARABIA
10	24	HUNGARY
19	21	NEW ZEALAND
10	21	GREECE
16	19	WALES
11	19	PEOPLES R CHINA
11	12	IRELAND
6	12	CUBA
4	12	YUGOSLAVIA
.	11	KUWAIT
1	10	SINGAPORE
7	9	PORTUGAL
7	9	SOUTH AFRICA
7	7	BULGARIA
1	7	ICELAND
1	7	URUGUAY
5	6	HONG KONG
2	6	NIGERIA
1	6	SLOVENIA
6	5	ECUADOR
4	5	NORTH IRELAND

Table 22:

Most active organizations

95/96	97/98	Institute
85	91	UNIV CALIF LOS ANGELES, LOS ANGELES, USA
57	84	HARVARD UNIV, BOSTON, USA
42	68	MCGILL UNIV, MONTREAL, CANADA
42	65	UNIV BONN, BONN, GERMANY
48	60	YALE UNIV, NEW HAVEN, USA
26	54	UNIV CALIF SAN FRANCISCO, SAN FRANCISCO, USA
36	48	UNIV PITTSBURGH, PITTSBURGH, USA
22	48	UNIV TORONTO, TORONTO, CANADA
26	45	UNIV WASHINGTON, SEATTLE, USA
30	39	DUKE UNIV, DURHAM, USA
22	39	NYU, NEW YORK, USA
22	39	UNIV ALABAMA, BIRMINGHAM, USA
33	38	UNIV PENN, PHILADELPHIA, USA
36	37	MAYO CLIN & MAYO FDN, ROCHESTER, USA
48	36	NATL HOSP NEUROL & NEUROSURG, LONDON, ENGLAND
42	36	INST NEUROL, LONDON, ENGLAND
37	36	CLEVELAND CLIN FDN, CLEVELAND, USA
22	35	JOHNS HOPKINS UNIV, BALTIMORE, USA
20	35	UNIV ZURICH, ZURICH, SWITZERLAND
32	34	STANFORD UNIV, STANFORD, USA

95/96	97/98	Institute
30	32	RUSSIAN ACAD SCI, MOSCOW, RUSSIA
24	31	UNIV WISCONSIN, MADISON, USA
21	31	UNIV VIRGINIA, CHARLOTTESVILLE, USA
31	30	COLUMBIA UNIV, NEW YORK, USA
29	30	UNIV VIENNA, VIENNA, AUSTRIA
22	30	UNIV MICHIGAN, ANN ARBOR, USA
19	30	UNIV TEXAS, HOUSTON, USA
11	30	UNIV HELSINKI, HELSINKI, FINLAND
8	30	CHILDRENS HOSP, BOSTON, USA
14	29	UNIV CALIF IRVINE, IRVINE, USA
25	28	UNIV TUBINGEN, TUBINGEN, GERMANY
22	28	UNIV ROMA LA SAPIENZA, ROME, ITALY
22	28	UNIV TEXAS, DALLAS, USA
20	28	UNIV FLORIDA, GAINESVILLE, USA
19	28	UNIV MUNICH, MUNICH, GERMANY
13	28	INST PSYCHIAT, LONDON, ENGLAND
12	27	EMORY UNIV, ATLANTA, USA
20	26	NIMH, BETHESDA, USA
17	26	KYOTO UNIV, KYOTO, JAPAN
13	25	UNIV ROCHESTER, ROCHESTER, USA
24	24	UNIV KUOPIO, KUOPIO, FINLAND
23	24	NINCDS, BETHESDA, USA
14	24	OKAYAMA UNIV, OKAYAMA, JAPAN
14	24	UNIV PISA, PISA, ITALY
13	24	UNIV CALIF SAN DIEGO, LA JOLLA, USA
13	24	UNIV ERLANGEN NURNBERG, ERLANGEN, GERMANY
6	24	HOP LA PITIE SALPETRIERE, PARIS, FRANCE
20	23	UNIV MINNESOTA, MINNEAPOLIS, USA
18	23	UNIV MUNSTER, MUNSTER, GERMANY
11	23	UNIV AMSTERDAM, AMSTERDAM, NETHERLANDS

Table 23:

Most active authors

95/96	97/98	Author
18	45	ELGER CE
9	32	DUNCAN JS
26	29	ANDERMANN F
14	24	LOSCHER W
13	23	DUBEAU F
14	21	BERKOVIC SF
13	21	DEVINSKY O
10	21	KLEINROK Z
5	19	FAUGHT E
12	18	HOLMES GL
10	18	CZUCZWAR SJ
6	18	KUZNIECKY R
5	18	GUERRINI R
11	17	CASCINO GD
8	17	MARESCAUX C
2	17	VANPAESSCHEN W
15	16	SPENCER DD
9	16	CENDES F
5	16	HELMSTAEDTER C
3	16	BROUWER OF
3	16	GILLIAM F
16	15	HAUSER WA
12	15	DULAC O
11	15	PFURTSCHELLER G

95/96	97/98	Author
15	14	SPENCER SS
8	14	WATANABE K
4	14	BAULAC M
36	13	SHORVON SD
9	13	BRODIE MJ
8	13	SCHRAMM J
5	13	GASIOR M
.	13	FEJERMAN N
12	12	OLIVIER A
8	12	KUZNIECKY RI
8	12	ROSCHKE J
7	12	STEINHOFF BJ
6	12	EBERT U
6	12	MARES P
6	12	NEVILLE BGR
6	12	PANAYIOTOPOULOS CP
5	12	CONNELLY A
3	12	BAUMGARTNER C
2	12	WIESER HG
.	12	BERTRAM EH

Table 24:

Most active collaborations

9596	9798	Actor1	Actor2
3	20	CHILDRENS HOSP, BOSTON, USA	HARVARD UNIV, BOSTON, USA
8	14	UNIV CALIF LOS ANGELES, LOS ANGELES, USA	W LOS ANGELES VET AFFAIRS MED CTR, LOS ANGELES, USA
10	12	MCGILL UNIV, MONTREAL, CANADA	MONTREAL NEUROL HOSP & INST, MONTREAL, CANADA
11	11	KUOPIO UNIV HOSP, KUOPIO, FINLAND	UNIV KUOPIO, KUOPIO, FINLAND
3	10	GREAT ORMOND ST HOSP CHILDREN, LONDON, ENGLAND	INST CHILD HLTH, LONDON, ENGLAND
3	10	HOSP SICK CHILDREN, TORONTO, CANADA	UNIV TORONTO, TORONTO, CANADA
12	9	INST NEUROL, LONDON, ENGLAND	NATL HOSP NEUROL & NEUROSURG, LONDON, ENGLAND
.	8	BETH ISRAEL DEACONESS MED CTR, BOSTON, USA	HARVARD UNIV, BOSTON, USA
2	8	HARVARD UNIV, BOSTON, USA	TUFTS UNIV, BOSTON, USA
3	8	MCGILL UNIV, MONTREAL, CANADA	MONTREAL CHILDRENS HOSP, MONTREAL, CANADA
6	7	ACAD SCI CZECH REPUBL, PRAGUE, CZECH REPUBLIC	CHARLES UNIV, PRAGUE, CZECH REPUBLIC
1	7	JULIANA CHILDRENS HOSP, THE HAGUE, NETHERLANDS	WESTEINDE ZIEKENHUIS, THE HAGUE, NETHERLANDS
1	7	NATL HOSP NEUROL & NEUROSURG, LONDON, ENGLAND	NATL SOC EPILEPSY, CHALFONT ST PETER, ENGLAND
.	7	NYU, NEW YORK, USA	SUNY STONY BROOK, STONY BROOK, USA
15	6	BAPTIST MEM HOSP, MEMPHIS, USA	UNIV TENNESSEE, MEMPHIS, USA
2	6	KYUSHU UNIV, FUKUOKA, JAPAN	KYUSHU UNIV, MAIDASHI, JAPAN
1	6	NATL YANG MING UNIV, TAIPEI, TAIWAN	VET GEN HOSP, TAIPEI, TAIWAN
5	6	UNIV CALIF IRVINE, IRVINE, USA	UNIV CALIF LOS ANGELES, LOS ANGELES, USA
1	5	ABO AKAD UNIV, TURKU, FINLAND	UNIV TURKU, TURKU, FINLAND
2	5	AMER MEM HOSP, REIMS, FRANCE	HOP ST VINCENT DE PAUL, PARIS, FRANCE
1	5	AUSTIN & REPATRIAT MED CTR, MELBOURNE, AUSTRALIA	UNIV MELBOURNE, MELBOURNE, AUSTRALIA
3	5	BRIGHAM & WOMENS HOSP, BOSTON, USA	HARVARD UNIV, BOSTON, USA
.	5	CEA, ORSAY, FRANCE	HOP LA PITIE SALPETRIERE, PARIS, FRANCE
2	5	COLUMBIA UNIV, NEW YORK, USA	UNIV TEXAS, HOUSTON, USA
4	5	DUKE UNIV, DURHAM, USA	VET AFFAIRS MED CTR, DURHAM, USA
1	5	EMORY UNIV, ATLANTA, USA	UNIV MICHIGAN, ANN ARBOR, USA
.	5	ERASMUS UNIV, ROTTERDAM, NETHERLANDS	JULIANA CHILDRENS HOSP, THE HAGUE, NETHERLANDS
.	5	ERASMUS UNIV, ROTTERDAM,	LEIDEN UNIV, LEIDEN, NETHERLANDS

9596	9798	Actor1	Actor2
		NETHERLANDS	
1	5	GREAT ORMOND ST HOSP CHILDREN, LONDON, ENGLAND	UNIV LONDON, LONDON, ENGLAND
.	5	HAMMERSMITH HOSP, LONDON, ENGLAND	INST NEUROL, LONDON, ENGLAND
4	5	HARVARD UNIV, BOSTON, USA	MASSACHUSETTS GEN HOSP, BOSTON, USA
1	5	INST CHILD HLTH, LONDON, ENGLAND	NATL HOSP NEUROL & NEUROSURG, LONDON, ENGLAND
1	5	IRCCS S LUCIA, ROME, ITALY	UNIV ROMA TOR VERGATA, ROME, ITALY
.	5	JULIANA CHILDRENS HOSP, THE HAGUE, NETHERLANDS	SOPHIA CHILDRENS UNIV HOSP, ROTTERDAM, NETHERLANDS
2	5	KANAZAWA UNIV HOSP, KANAZAWA, JAPAN	KANAZAWA UNIV, KANAZAWA, JAPAN
2	5	MCGILL UNIV, MONTREAL, CANADA	UNIV MONTREAL, MONTREAL, CANADA
2	5	ROYAL CHILDRENS HOSP, MELBOURNE, AUSTRALIA	UNIV MELBOURNE, MELBOURNE, AUSTRALIA
.	5	SRI INT, MENLO PK, USA	STANFORD UNIV, STANFORD, USA
3	5	ST LOUIS CHILDRENS HOSP, ST LOUIS, USA	WASHINGTON UNIV, ST LOUIS, USA
1	5	UNIV BREMEN, BREMEN, GERMANY	UNIV LUBECK, LUBECK, GERMANY
.	5	UNIV CALIF LOS ANGELES, LOS ANGELES, USA	UNIV CALIF SAN FRANCISCO, SAN FRANCISCO, USA
1	5	UNIV CALIF LOS ANGELES, LOS ANGELES, USA	UNIV WASHINGTON, SEATTLE, USA
9	5	UNIV PADUA, PADUA, ITALY	UNIV TUBINGEN, TUBINGEN, GERMANY
.	5	UNIV TENNESSEE, MEMPHIS, USA	UNIV WISCONSIN, MADISON, USA

5.1.2.5. Citation characteristics of Seizure/Epilepsy/EEG

The average Seizure/Epilepsy/EEG publication in 1995/96 had a short term (citations received from 1995-1998) impact 3.0, which is somewhat below world field average as measured by the ISI journal categories. About 30% of the publications found in the ISI source data was not cited.

Among the most highly cited organizations (Table 27) are mostly the most active ones (see Table 22). A remarkable position has Univ London, which is among the top-five of most highly cited organizations but not found among the most active organizations.

With respect to the most highly cited publications in 1997/98, we found Mattson, RH (1985), Daumasduport C (1988), and Mattson, RH (1992) as the top-three. The former two of these publications are already from some time ago, and at a stable level of around 10 citations. The latter is a more recent publication. A 'new' high impact publication is Scheffer IE (1995). Furthermore, we mention Gastaut H (1982). Although the publication is rather 'old', its impact increases significantly during 1995-1998.

A final conclusion about the most highly cited publications should be made about their scope. It appears that almost all publications receive more than 80% of their citations from within this very subdomain. From this top-50 there is only one publication that receives about 40% from outside this subdomain (Steriade M, 1993, a publication in *Science*).

Table 25:

General Citation statistics

Publication year: 1995 – 1996 Citation Window: 3 years	
Number of Publs:	3699
Number of Cits:	15068
Percentage Self-cits:	25.6
Cits per Publication (excl):	3.0
Percentage Uncited Publs:	28.8
Ratio C/P to Journal Average (excl):	1.0
Ratio C/P to Field Average (excl):	0.9

Table 26

Most highly cited country aggregate

95/96	97/98	Country aggregation
41343	64632	US
25351	39708	EU
12984	19476	Other
3561	5947	DAE
2095	3264	EFTA 3

Table 27:

Most highly cited organizations

95/96	97/98	Organization
53	69	YALE UNIV, NEW HAVEN, USA
43	54	UNIV CALIF LOS ANGELES, LOS ANGELES, USA
46	47	HARVARD UNIV, BOSTON, USA
30	47	UNIV LONDON, LONDON, ENGLAND
17	44	UNIV PENN, PHILADELPHIA, USA
30	42	NATL HOSP NEUROL & NEUROSURG, LONDON, ENGLAND
46	39	MAYO CLIN & MAYO FDN, ROCHESTER, USA
27	38	UNIV MINNESOTA, MINNEAPOLIS, USA
42	37	UNIV CALIF SAN FRANCISCO, SAN FRANCISCO, USA
28	35	UNIV ALABAMA, BIRMINGHAM, USA
41	34	MCGILL UNIV, MONTREAL, CANADA
34	34	DUKE UNIV, DURHAM, USA
20	31	COLUMBIA UNIV, NEW YORK, USA
35	30	MONTREAL NEUROL HOSP & INST, MONTREAL, CANADA
12	30	UNIV PITTSBURGH, PITTSBURGH, USA
19	29	UNIV WASHINGTON, SEATTLE, USA
23	28	NYU, NEW YORK, USA
36	27	INST NEUROL, LONDON, ENGLAND
27	27	UNIV MICHIGAN, ANN ARBOR, USA
20	26	JOHNS HOPKINS UNIV, BALTIMORE, USA
17	24	UNIV TEXAS, HOUSTON, USA
10	24	CLEVELAND CLIN FDN, CLEVELAND, USA
19	23	INST CHILD HLTH, LONDON, ENGLAND
17	23	MASSACHUSETTS GEN HOSP, BOSTON, USA
13	23	UNIV TEXAS, DALLAS, USA
11	23	UNIV MIAMI, MIAMI, USA
9	23	UNIV MELBOURNE, MELBOURNE, AUSTRALIA
12	22	STANFORD UNIV, STANFORD, USA
17	21	UNIV TORONTO, TORONTO, CANADA
19	20	AUSTIN HOSP, HEIDELBERG, AUSTRALIA
19	20	HOP ST VINCENT DE PAUL, PARIS, FRANCE
12	20	ERASMUS UNIV ROTTERDAM, ROTTERDAM, NETHERLANDS
18	19	WASHINGTON UNIV, ST LOUIS, USA
16	19	VIRGINIA COMMONWEALTH UNIV, RICHMOND, USA
27	18	NINCDS, BETHESDA, USA
17	18	UNIV BONN, BONN, GERMANY
16	18	BAYLOR COLL MED, HOUSTON, USA
11	18	VANDERBILT UNIV, NASHVILLE, USA
6	18	ALBERT EINSTEIN COLL MED, BRONX, USA
18	17	UNIV WALES COLL MED, CARDIFF, WALES
13	17	BETH ISRAEL HOSP, BOSTON, USA
6	17	MAUDSLEY HOSP & INST PSYCHIAT, LONDON, ENGLAND
6	17	MONTEFIORE MED CTR, BRONX, USA
4	17	UNIV HEIDELBERG, HEIDELBERG, GERMANY
16	16	VET ADM MED CTR, W HAVEN, USA
11	16	UNIV N CAROLINA, CHAPEL HILL, USA
7	16	EMORY UNIV, ATLANTA, USA
16	15	UNIV HELSINKI, HELSINKI, FINLAND
10	15	DALHOUSIE UNIV, HALIFAX, CANADA
9	15	CHILDRENS HOSP, BOSTON, USA
6	15	UNIV PISA, PISA, ITALY
6	15	UNIV ROCHESTER, ROCHESTER, USA
14	14	UNIV SO CALIF, LOS ANGELES, USA
10	14	HOSP SICK CHILDREN, TORONTO, CANADA
7	14	TUFTS UNIV NEW ENGLAND MED CTR, BOSTON, USA

95/96	97/98	Organization
7	14	UNIV COLORADO, DENVER, USA
6	14	UNIV CHICAGO, CHICAGO, USA
1	14	MAYO CLIN, ROCHESTER, USA
1	14	WALTON CTR NEUROL & NEUROSURG, LIVERPOOL, ENGLAND
13	13	UNIV KUOPIO, KUOPIO, FINLAND

Table 28:

Most highly cited publications

95/96	97/98	Cited reference
11	10	MATTSON RH (1985) NEW ENGLAND JOURNAL OF MEDICINE 313. 145-151 (tot=22)
9	10	DAUMASDUPORT C (1988) NEUROSURGERY 23. 545-556 (tot=24)
8	10	MATTSON RH (1992) NEW ENGLAND JOURNAL OF MEDICINE 327. 765-771 (tot=19)
7	9	AWAD IA (1991) EPILEPSIA 32. 179-186 (tot=18)
5	9	KIRKPATRICK PJ (1993) JOURNAL OF NEUROSURGERY 78. 19-25 (tot=15)
5	9	MORRELL F (1989) JOURNAL OF NEUROSURGERY 70. 231-239 (tot=14)
1	9	STEFAN H (1990) ANNALS OF NEUROLOGY 27. 162-166 (tot=12)
.	9	SCHEFFER IE (1995) BRAIN 118. 61-73 (tot=11)
13	8	CASCINO GD (1991) ANNALS OF NEUROLOGY 30. 31-36 (tot=24)
8	8	BERKOVIC SF (1991) ANNALS OF NEUROLOGY 29. 175-182 (tot=17)
6	8	HAUSER WA (1993) EPILEPSIA 34. 453-468 (tot=16)
6	8	KUZNIECKY R (1987) ANNALS OF NEUROLOGY 22. 341-347 (tot=17)
5	8	BOON PA (1991) EPILEPSIA 32. 467-476 (tot=13)
5	8	STERIADE M (1993) SCIENCE 262. 679-685 (tot=22)
3	8	OZKARA C (1993) EPILEPSIA 34. 294-298 (tot=11)
1	8	GASTAUT H (1982) CLINICAL ELECTROENCEPHALOGRAPHY 13. 13-22 (tot=9)
.	8	SAWHNEY IMS (1995) JOURNAL OF NEUROLOGY NEUROSURGERY AND PSYCHIATRY 58. 344-349 (tot=8)
9	7	ROWE CC (1989) ANNALS OF NEUROLOGY 26. 660-668 (tot=18)
6	7	JACKSON GD (1990) NEUROLOGY 40. 1869-1875 (tot=16)
5	7	DAUMASDUPORT C (1993) BRAIN PATHOLOGY 3. 283-295 (tot=15)
4	7	AMINOFF MJ (1980) AMERICAN JOURNAL OF MEDICINE 69. 657-666 (tot=11)
4	7	COCITO L (1982) STROKE 13. 189-195 (tot=11)
4	7	HAUSER WA (1990) NEUROLOGY 40. 1163-1170 (tot=12)
4	7	WILLIAMSON PD (1985) ANNALS OF NEUROLOGY 18. 497-504 (tot=14)
3	7	AICARDI J (1982) DEVELOPMENTAL MEDICINE AND CHILD NEUROLOGY 24. 281-292 (tot=10)
2	7	BARKOVICH AJ (1996) NEUROPEDIATRICS 27. 59-63 (tot=14)
2	7	DEONNA TW (1991) JOURNAL OF CLINICAL NEUROPHYSIOLOGY 8. 288-298 (tot=9)
2	7	SHINNAR S (1994) ANNALS OF NEUROLOGY 35. 534-545 (tot=10)
2	7	YEH HS (1993) JOURNAL OF NEUROSURGERY 78. 12-18 (tot=9)
.	7	VIGEVANO F (1992) EUROPEAN JOURNAL OF PEDIATRICS 151. 608-612 (tot=7)
36	6	EPILEPSIA (1989) EPILEPSIA 30. 389-399 (tot=45)
10	6	JACK CR (1990) RADIOLOGY 175. 423-429 (tot=23)
10	6	LENCZ T (1992) ANNALS OF NEUROLOGY 31. 629-637 (tot=18)
9	6	PALMINI A (1991) ANNALS OF NEUROLOGY 30. 741-749 (tot=17)
6	6	LESSER RP (1985) EPILEPSIA 26. 622-630 (tot=12)
6	6	SHORVON SD (1990) LANCET 336. 93-96 (tot=12)
5	6	OLSEN TS (1987) NEUROLOGY 37. 1209-1211 (tot=13)
5	6	RICHENS A (1994) JOURNAL OF NEUROLOGY NEUROSURGERY AND PSYCHIATRY 57. 682-687 (tot=11)
5	6	SCHLUMBERGER E (1994) EPILEPSIA 35. 359-367 (tot=11)
4	6	BARKOVICH AJ (1987) AMERICAN JOURNAL OF NEURORADIOLOGY 8. 1009-1017 (tot=12)
4	6	BERKOVIC SF (1995) NEUROLOGY 45. 1358-1363 (tot=10)
4	6	DOOSE H (1989) EUROPEAN JOURNAL OF PEDIATRICS 149. 152-158 (tot=10)
4	6	HAUSER WA (1991) EPILEPSIA 32. 429-445 (tot=11)
4	6	ROWE CC (1991) NEUROLOGY 41. 1096-1103 (tot=11)
3	6	RISINGER MW (1989) NEUROLOGY 39. 1288-1293 (tot=9)
3	6	SPENCER SS (1994) EPILEPSIA 35. S72-S89 (tot=10)
2	6	DELGADOESCUETA AV (1982) NEW ENGLAND JOURNAL OF MEDICINE 306. 1337-1340 (tot=8)
2	6	ENGEL J (1981) ANNALS OF NEUROLOGY 9. 215-224 (tot=9)
2	6	MCNAMARA JO (1994) JOURNAL OF NEUROSCIENCE 14. 3413-3425 (tot=11)
2	6	MORRELL F (1985) ARCHIVES OF NEUROLOGY 42. 318-335 (tot=8)

Between parentheses is the total number of citations received in neuroscience in 1995-1998

5.1.3. Comparing Epilepsy results

As mentioned before, it is difficult to compare the results of the two methods, as the structures are based on such different elements (cited references, i.e., publications, and keywords). Still, there is some overlap in the results.

Table 29

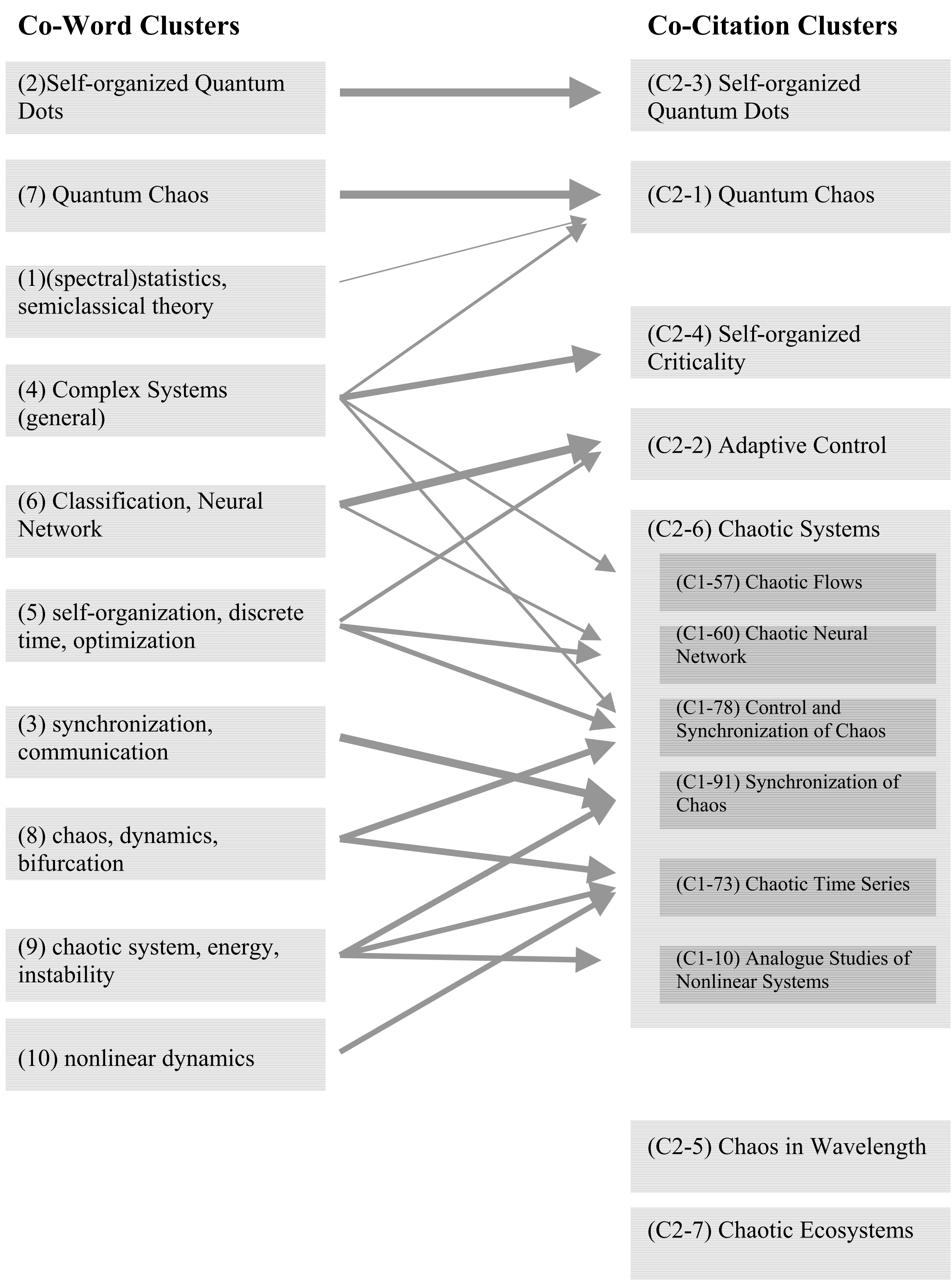
List of most active organizations (97/98) in 'Status epilepticus'

95/96	*97/98*	*Organisation*
17	30	VIRGINIA COMMONWEALTH UNIV, RICHMOND, USA
12	21	UNIV CALIF LOS ANGELES, LOS ANGELES, USA
3	7	UNIV CALIF SAN FRANCISCO, SAN FRANCISCO, USA
4	6	ALBERT EINSTEIN COLL MED, BRONX, USA
2	6	COLUMBIA UNIV, NEW YORK, USA
3	6	HARVARD UNIV, BOSTON, USA
3	6	MAYO CLIN & MAYO FDN, ROCHESTER, USA
4	6	UNIFESP, SAO PAULO, BRAZIL
1	6	UNIV PITTSBURGH, PITTSBURGH, USA
1	6	UNIV WISCONSIN, MADISON, USA
.	5	CLEVELAND CLIN FDN, CLEVELAND, USA
.	5	UNIV CALIF LOS ANGELES, SEPULVEDA, USA
8	5	UNIV KUOPIO, KUOPIO, FINLAND
.	5	USC, LOS ANGELES, USA
.	4	ALBERT EINSTEIN COLL MED, NEW YORK, USA
.	4	OSPED MIULLI ACQUAVIVA, BARI, ITALY
.	4	UNIV COPENHAGEN, COPENHAGEN, DENMARK
1	4	UNIV TEXAS, HOUSTON, USA
.	3	COPENHAGEN UNIV HOSP, COPENHAGEN, DENMARK
1	3	GOTHENBURG UNIV, GOTHENBURG, SWEDEN

The identified Epilepsy clusters identified in the co-citation analysis can partly be retraced in the co-word map: MRI and Temporal-Lobe Epilepsy, Anti-epileptic drugs, and Status epilepticus. These clusters can be found directly in the co-word map as clusters of topics. However, when it comes to the identification of most active institutes the results are different. For instance, the C2-co-citation cluster 313 'Status epilepticus', as well as the topic 'Status epilepticus' in the Epilepsy subdomain, identifies the *University of California*, *Mayo Clin & Mayo Fdn*, *Osped Miulli Aquaviva, Italy*, and *Univ Texas* as some of the most active organizations in this area. For the rest, the lists are completely different. One of the reasons is that in the co-citation analysis, we are dealing with a much smaller area than in the co-word case. In the former, 69 publications are involved, whereas in the latter, we are dealing with 191 publications. The co-citation analysis shows a much more detailed picture.

In general this is one of the main difficulties of comparing the two methods. As we are dealing with such different elements on the basis of which we create structures, it is very difficult to determine a level on which the comparison is useful. We can identify overlaps by looking for similar terms (like 'status epilepticus') but in order to get to this level in which we find this term, we followed a very complex procedure. This procedure is so different (not in the least because of the data used) from one method to the other, that it would be a coincidence if the results would be comparable.

5.2 Complex Systems



This comparison of the results of co-word and co-citation analysis has been carried out on the basis of the clusters cited literature. For the highly cited publications of the co-word clusters' publications their distribution on co-citation cluster cores was checked. The arrows in the figure are pointing from the co-word clusters on the left to the co-citation clusters on the right side which include a larger part of their top highly cited publications (about 20). Stronger arrows indicate the main emphasis where the highly cited publications of co-word clusters are distributed to more than one co-citation cluster.

Most of the clusters on both sides can be assigned to one or more areas of the other type. Two pairs of clusters can be unambiguously assigned:

The clusters *Self-organized Quantum Dots*, which are in both maps rather separated from the rest of the network.

A strong overlap could be detected for the Quantum Chaos clusters too - number 7 (quantum) in the co-word map and number 1 *Quantum Chaos* in the co-citation map).

Another co-word cluster, number 6 (classification, neural network) is with a large part of the highly cited publications represented in the cluster core of the C2-co-citation cluster *Adaptive Control* and with a smaller part in the cluster core of *Chaotic Neural Network*, a C1-cluster included in the largest co-citation cluster *Chaotic Systems* (6). Also related to these two co-citation clusters is the co-word subfield 5 (self-organization, discrete time, optimization), but with an emphasis on *Chaotic Systems*, actually to the C1-clusters *Chaotic Neural Networks* (60) and *Control and Synchronization of Chaos* (78).

The co-word subfield 3 (synchronization, communication) is also partially represented by a specialty inside the co-citation subfield *Chaotic Systems*. Most of the highly cited publications of subfield 3 which are co-cited fall into C1-91 *Synchronization of Chaos*, the others spread to other clusters inside the same co-citation subfield.

Two more co-word clusters are represented by the large central co-citation cluster number 6, but can not be assigned to one special regions. The publications which are highly cited by subfield 8 (chaos, dynamics, bifurcation) are clustered in the co-citation *clusters Control and Synchronization of Chaos* (78) and *Chaotic Time Series* (73), whereas the highly cited of the co-word subfield 9 (chaotic system, energy, instability) which are assigned to co-citation clusters spread to C1-cluster 73, 91 and 10 (*Analogue Studies of Nonlinear Systems*).

The co-word cluster 10 (nonlinear dynamics) is related to the C1-cluster Chaotic Time Series (73).

For the smallest co-citation clusters *Chaos in Wavelength* (5) and *Chaotic Ecosystems* (7) no correspondent region in the co-word map can be found. The co-cited publications did not turn up amongst the highly cited publications of the co-word clusters.

On the co-word side the cluster number 1 ((spectral) statistics, semiclassical theory...) can not be clearly assigned to a special region of the co-citation network. Only three of the fifteen most frequently cited publications of that subfield are clustered on the co-citation side. However these three fall into the subfield Quantum Chaos.

6. Conclusions and perspectives

The conclusions we reach in this report do not primarily concern the results of the mapping studies as such, but rather way in which we consider the proposed methods to be helpful to conduct certain analyses.

First of all, we may conclude that co-citation analysis on the one hand and co-word analysis on the other disclose *different* structures of the same research field. We were not able to find enough evidence for the hypothesis that both methods yield a similar structure of a field. Particularly, the fact that we are dealing with such different elements (cited references –representing entire documents- versus keywords –representing concepts, topics) is supposed to cause the different results. It would however, be interesting to investigate whether a combination of both methods could be used to improve the structuring procedure. In our opinion this could be investigated in at least two settings:

1. One of the methods provides the overall structure and the other provides a structure on more detailed level;
2. In the co-word analysis we always come across keywords that are ambiguous (synonyms). For this reason, such words are often excluded from the analysis because they artificially cause clustering of topics. Linking cited references to words (in fact: keywords within a certain context) maybe able to cope with this problem.

In the co-citation part, we were able to develop maps at 'any' level of aggregation, and to provide in very compact form: the structure, its environment, and useful information about actors and about individual documents, particularly ‘front’ and core publications. In terms of activity (publication output) we are able to provide useful information, at any required level, to identify top institutes and to compare the performance of countries. As a result, we are also able to describe in detail the changes over time. These maps and additional facilities provide very specific information of any area of interest.

In the co-word part, we managed to create in a trustworthy way, overview maps of huge fields as well as of smaller fields. Moreover, we were able to provide useful information 'behind' the map, either for exploring or for evaluating the structure. In the case of neuroscience we were able to characterize the activity of the EU as compared to the US over time. The results in this study show a remarkable trend for the EU with respect to its activity in the clinical parts of the field.

We also made a major step ahead with the map interface. First of all, we managed to set up the interface in such a way that information behind the maps is easily retrieved. Most of the information is available in one and the same computer environment. In such a way it is easier to extract the needed information from the map, to address a particular policy-related question. Secondly, we made a major progress in developing a more flexible interface, with a higher degree of functionality. The *iBex* interface enables a user to access the map in a bottom-up approach. The existing interface is only able to access the information top-down. This makes the map even suitable for many more applications than presented in this report.

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