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Climate change and interdisciplinarity: a co-citation analysis of IPCC Third Assessment Report

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Abstract This study addresses whether interdisciplinarity is a prominent feature of climate research by means of a co-citation analysis of the IPCC Third Assessment Report. The debate on interdisciplinarity and bibliometric measures is reviewed to operationalize the contested notion of interdisciplinarity. The results, based on 6417 references of the 96 most frequently used journals, demonstrate that the IPCC assessment of climate change is best characterized by its multidisciplinarity where the physical, biological, bodily and societal dimensions are clearly separated. Although a few fields and journals integrate a wide variety of disciplines, integration occurs mainly between related disciplines (narrow interdisciplinarity) which indicate an overall disciplinary basis of climate research. It is concluded that interdisciplinarity is not a prominent feature of climate research. The significance of this finding is explored, given that the problem scope of climate change necessitates interdisciplinarity. Ways to promote interdisciplinarity are suggested by way of conclusion.

Keywords Climate research · IPCC · Interdisciplinary · Multidisciplinary · Bibliometrics

Introduction

Climate change has a long time frame and a global scale. It transgresses natural systems as well as societal sectors, and has potentially far-reaching effects on nature and society (IPCC 2001a, b, c, 2007a, b, c). The resulting complexity is an intertwined political and scientific challenge where negotiations on national and international levels are necessary for effective societal responses (Bolin 2007). Since contemporary societies are highly specialised, this involves intricate collaborations with disparate interests (Giddens 2009; Newell 2006; Roberts and Parks 2006; Sarewitz 2004). The complexity of climate change makes policymaking dependent on science for informed responses (Miller 2001). Given that the problem scope of climate change is broader than any single discipline,

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the scientific community must draw on extensive knowledge from various scientific disciplines (Lenhard et al. 2006). The Intergovernmental Panel on Climate Change (IPCC), assigned to assess this comprehensive body of research, must therefore structure and integrate knowledge which to different degrees is heterogeneous and disconnected (Carolan 2008; Cohen et al. 1998; Jasanoff and Wynne 1998; Malone and Rayner 2001). This raises important questions regarding how disciplinary and interdisciplinary research can be combined.

Due to such external demands posed on science, it has been argued that science is becoming more and more interdisciplinary (Bordons et al. 2004; Gibbons et al. 1994; Klein 1996; Nowotny et al. 2001; Weingart and Stehr 2000). Climate research is often taken as a prime example of this type of development (Lenhard et al. 2006; Saloranta 2001). However, there are few studies which clearly show a substantial reshaping of science, within the climate change field or elsewhere. The debate on interdisciplinarity has also been criticized as being conceptually confused and muddled with normative agendas (Godin 1998; Hessels and Lente 2008; Shinn 2002; Weingart 1997). Interdisciplinarity is therefore in great need of clarification and empirical demonstration. This study addresses this need by a quantitative analysis of the IPCC's Third Assessment Report (TAR).

The overall question is: Is interdisciplinarity a prominent feature of climate research? This is further specified with two subquestions:

(a) How are the disciplines and groups of disciplines (here referred to as scientific fields) integrated and separated in TAR?
(b) What is the degree of interdisciplinarity in each of the identified scientific fields?

Conceptual approaches and measures

The research approach that will be developed in the following sections and applied in this paper will draw from three main areas including the scientific discussion on interdisciplinarity, interdisciplinarity in climate research, as well as the methodology of bibliometrics. Since interdisciplinarity is most often addressed either theoretically or empirically, this section aims to bridge these approaches by starting with a more in-depth conceptual discussion of interdisciplinarity and ending with an overview of how it has been measured in bibliometric research.

Disciplines and interdisciplinarity

Knowledge integration has occurred in one form or another throughout the history of science. While the unity of knowledge as a goal has been argued for since Plato's time, interdisciplinarity itself is a modern concept (Klein 1990). Its use increased greatly in the second half of the twentieth century as a reaction to the strong trend of scientific specialization throughout the previous century (Braun and Schubert 2003; Jacobs and Frickel 2009; Klein 1990). Some advocates of interdisciplinarity want to reform the disciplinary basis of research and education, a system that is perceived as constrained in various ways (Fuller 1993). Others argue that a strong disciplinary basis is needed for scientific progress (Abbott 2001). Such claims and counterclaims by situated academic stakeholders are manifold, yet seldom empirically demonstrated, despite being crucial for whether and how interdisciplinarity should be promoted (Bruce et al. 2004; Jacobs and Frickel 2009).

Despite the great deal of attention that interdisciplinarity has received, its meaning and implications are still vague and contested. One reason for this is that interdisciplinarity is an umbrella concept that is used to refer to a variety of different activities, components and degrees of integration (Hessels and Lente 2008). Regarding activities, interdisciplinarity is applied and used to refer to different types of collaboration within a variety of academic contexts which include diverse activities, such as knowledge production, knowledge application and education. Interdisciplinarity also refers to the integration of specific knowledge components, such as theories, methods and data. Another problem with formulating a concrete working definition of interdisciplinarity is the confusion regarding terminology (Jacobs and Frickel 2009; Klein 1990). There are a number of terms that are used inconsistently and often conflated with one another. The most common are multi-, cross-, inter- and transdisciplinarity. These prefixes may represent inherently different activities or a continuum of increasing knowledge integration (Klein 1990; Mobjörk 2009).

In this paper, interdisciplinarity will be used in an overarching sense as all activities where disciplinary boundaries are crossed (Bruun 2000). Practically this refers to the integration of different knowledge components (methods, theories and data) in such border crossings. This integration may occur throughout the knowledge production process (early integration) or consist of the integration of knowledge produced in disciplinary contexts (late integration). Interdisciplinarity can be *broad*, crossing boundaries between disciplines with dissimilar epistemologies such as physics and sociology, or *narrow*, crossing the boundaries between disciplines with similar epistemologies such as physics and geology. *Multidisciplinarity* will refer to collaboration between disciplines with superficial integration, for example in anthologies which include separate chapters of authors writing on the same topic from different disciplinary approaches (Mobjörk 2009). *Transdisciplinarity* refers to interdisciplinary as well as academic and non-academic collaboration, but is outside the scope of this study (Gibbons et al. 1994; Nowotny et al. 2001).

Another problem regarding why interdisciplinarity is contested stems from the notion of a ‘discipline’. All of the above definitions share a focus on *disciplines* and *integration* which are common to most notions of interdisciplinarity. The importance of boundary crossings in interdisciplinary activities thus begs the question: What constitutes disciplines and their boundaries? Disciplines are most often defined in terms of knowledge content. However, disciplines are also institutions (enduring structures of social order), the most obvious being university departments and professional associations (Buanes and Jentoft 2009; Klein 1990; Turner 2000). Disciplines exist and have developed within historical contexts where knowledge and institutional dimensions are interacting with one another (Becher and Trowler 2001; Gibbons et al. 1994; Klein 1990). Disciplinary borders and knowledge borders are therefore not necessarily tightly connected. For example, the difference between two frameworks within a discipline can be greater than the difference between two disciplines that, with respect to substantive knowledge content, are similar (Bruun 2000). Abbott (2001) argues that the institutional borders of disciplines stay remarkably stable despite knowledge drifts that blur knowledge boundaries (Geertz 1980). Others argue that the disciplinary basis of research is increasingly being eroded, where parts of science are approaching a post-disciplinary stage (Camic and Joas 2003; Case 2001; Gibbons et al. 1994; Nowotny et al. 2001).

Interdisciplinarity also takes place at multiple levels (for example individual researchers or research teams). Interdisciplinarity has most often focused on the crossing or merging of disciplinary boundaries. However, as the discussion above suggests, disciplinary boundaries are arbitrary constructions due to the interaction of knowledge and institutional dimensions. Moreover, disciplines can also be defined at different levels. For example, the Earth sciences may be seen as either a discipline with subfields, or as a family of closely related disciplines (Good 2000). It is therefore reasonable to downplay a literal understanding of interdisciplinarity, in favor of a multi-level notion of both disciplines and interdisciplinarity. Another reason for this focus is that emerging subfields are increasingly important localities for interdisciplinarity due to specialization. Biochemistry is a prime example of strong border crossings with adjacent disciplines. The establishment of new boundaries distinguishes such fields as highly institutionalised interdisciplines (or disciplinary hybrids) that may eventually become a discipline in their own right. The design of the empirical analysis will mirror this multilevel notion of interdisciplinarity, with a focus on macro level analysis. But, before this is done, academic organization will be addressed as a decisive cause as to how disciplines are integrated and separated in climate research.

Interdisciplinarity in climate research

There is currently no consensus regarding the prominence of interdisciplinarity within climate research. Whether this notion is defended or contested seems to be due to whether the author stresses the characteristics of climate change or emphasizes academic organization. On the one hand, statements that climate research has post-normal characteristics (Saloranta 2001) and that "the disciplinary mix has continued to evolve to meet the challenge" (Munasinghe 2001, p. 14) assume that research adapts to the interdisciplinary nature of the problem. On the other, several studies acknowledge the problems involved in attempting to integrate diverse approaches. For example, Malone and Rayner (2001) distinguish between descriptive and interpretative social science, and argue for their complementarity and the unfeasibility of their successful integration. Bjurström and Polk (2011) show that there is a physical and economic bias in the IPCC Third Assessment Report. Other studies discuss how the social sciences are marginalized and weakly integrated with the natural sciences due to knowledge hierarchies and the framing of climate change originating in the latter (Cohen et al. 1998; O'Neill et al. 2010). Lenhard et al. (2006) argue, with coupled climate models as example, that the disciplinary basis of climate research is far from dissolved despite interdisciplinary trends within the natural sciences. Previous research has also shown that the integration of resilience, vulnerability and adaptation is weak in the human dimension of climate change (Janssen et al. 2006).

The IPCC organization is important for the integration and separation of disciplines in the assessment of climate research. The IPCC assessment process is divided between three working groups (WG). WG1 deals with the physical scientific basis (causes), WG2 deals with impact and adaptation (consequences) and WG3 deals with mitigation (responses). This basic division of topics between working groups has been rather stable over time, although the mandate of WG2 and WG3 was altered in the 1990's and cross cutting themes such as sustainable development were introduced with the 2001 report. While the development of the IPCC substantive structure can be understood as a learning process, it is strongly path dependent, where the past also constrains the near future (Agrawala 1998a, b; Bolin 2007; Siebenhüner 2002).

Measuring interdisciplinarity in bibliometrics research

Bibliometrics (also referred to as scientometrics) is one main approach for empirical studies of interdisciplinarity and will also be applied in this study. Bibliometrics encompasses the most extensive quantitative analysis of science (Moed et al. 2004). Its main objective is to measure scientific activities using statistics based on citation index databases. Many quantitative characteristics of science are therefore known, e.g., the evolution of disciplines and the impact factor of journals. There are a number of bibliometric studies that measure different aspects of interdisciplinarity on multiple levels as well as map out relations between disciplines. Bibliometric analyses focus on scientific dissemination through journals using metadata such as publications, journals and authors (Börner et al. 2005). The results are so far divergent regarding the extent of interdisciplinarity due to a lack of standards (Bordons et al. 2004; Morillo et al. 2003). The environmental field is rarely studied and there are only a few bibliometric studies of climate research (Bjurström and Polk 2011; Engels et al. 2005; Engels and Ruschenburg 2008; Janssen et al. 2006; Jappe 2007; Stanhill 2001).

Interdisciplinarity is most often operationalized within bibliometrics by focusing on collaboration or integration (Porter et al. 2007). Co-authored publications are widely used for measuring collaboration as well as to map social networks (Bordons et al. 2004; Porter et al. 2007). It is well established that all types of collaboration increase over time, including collaboration between researchers, departments, countries and disciplines (Engels et al. 2005; Engels and Ruschenburg 2008; Glänzel and Schubert 2004; Leydesdorff and Wagner 2008; Porter and Rafols 2009; Price 1963; Qin 1994). The measure of integration is less straightforward, and the results less conclusive. Three main approaches can be distinguished. The first is based on citations, for example, the number of disciplines cited in a paper, or the ratio of references from outside of the authors home discipline (Morillo et al. 2003; Porter and Rafols 2009). In the second, the variety of journals where an author publishes are used as a measure of interdisciplinarity (Bordons and Zulueta 1997; Van Raan 2000). Porter et al. (2007) show that these two approaches measure different theoretical constructs, namely integration (citation diversity) and specialisation (publication diversity). The diversity of impact (where a paper is cited) is a third option for measuring interdisciplinarity (Van Raan 2000). The first option is the soundest measure as the practice of citing other scholarly works is directly connected to the authors' practice of knowledge integration. The inflow (who do you cite) and outflow (who cites you) of knowledge across disciplines can be studied by combining one and three above. The measures for integration varies from simple measures (e.g., the number of disciplines cited) to index measures that take into account among others the strength of links, their degree of diversity, difference and coherence (Morillo et al. 2003; Porter and Rafols 2009; Rafols and Meyer 2010). The unit of analysis can also be aggregated, e.g., from papers to journals, from author to the departmental level or from subfields to disciplines. In this way, interdisciplinarity is often measured on the micro and meso level, i.e., from individual researchers to a single discipline (Bordons et al. 2004; Börner et al. 2005).

Materials and methods

This paper is based upon a co-citation analysis of journals from the IPCC Third Assessment Report (TAR). The material is rare as bibliometrics most often retrieve their material from databases but seldom collect empirical material from other sources. This statistical analysis is complemented by a quantitative content analysis of a strategic selection of journals to confirm the validity of the chosen unit of analysis and enable more nuanced interpretations of the results.

Sample and classification

Journals have been chosen as the main unit of analysis as this is suitable to capture interdisciplinarity at the macro level (Boyack et al. 2005; Börner et al. 2005). Due to journal classification standards, subjective categorizations can also be avoided which increase the reliability of the study. Journals are also favourable since they are familiar to the readers of this paper. Since disciplines and journals are linked, journals function well as an operational indicator for capturing interdisciplinarity as a theoretical construct. This operationalization captures a blend of knowledge related and institutional dimensions of interdisciplinarity, whereas words as the unit of analysis capture knowledge dimensions (especially semantics), and authorship captures cooperation, as discussed above (Börner et al. 2005).

TAR consists of 43 chapters divided in 3 parts, each part produced by a working group. It has 14,000 references of which two thirds are journal references, dispersed over 1,100 journals. A sample of the 96 most frequently used journals is chosen for the analysis, i.e., all journals cited 12 times or more. The sample includes 6,417 journal references (Table 2). The number of references to each journal is counted on the chapter level. This results in a frequency distribution for each journal, compiled in a 96 by 43 matrix, i.e., the number of times that each journal appears in the reference list of each chapter.

There are two potential sources of bias in the present analysis: the sample size and the classification of journals in subject categories (for the latter, see Sect. "Journal content analysis"). The choice of sample size is a trade-off between the goal to include as many journals as possible and the need to restrict the number of journals to make the analysis manageable, i.e., the interpretability of the visualization tools. The 96 journals were chosen because they represent the most important journals which are used in the IPCC. This sample covers 73% of the total number of journal references. Including a larger number of journals would only marginally impact the results because there is a strong exponential decline in how frequently journals are used. For example, 50% of the journals are referred to only one time. Journals with more interdisciplinary content could be among the journals that have been excluded from the analysis, but because of the exponential decline in frequency of journal mentioned above, these journals are judged as only having a marginal impact. The macro level analysis that has been chosen in this study thus aims to capture overall patterns in the entire IPCC data set, as opposed to micro level analysis which is limited to a selection of individual research fields or journals. Micro level analysis is equally needed but outside the scope of the present study.

The journals are classified according to the subject categories of the Journal Citation Reports. The 96 journals in the sample embrace 39 subject categories (many journals are classified with more than one subject category). These are aggregated into 10 larger categories, here labelled *scientific fields*, based on qualitative readings of the Journal Citation Reports subject category descriptions (see Table 1). The journals are also classified into the natural and the social sciences according to the Journal Citation Reports. Thus, three levels of classifications are used: subject categories, scientific fields and the natural and social sciences.

Table 1 Subject categories and scientific fields

Subject category		Scientific fields	
1	Geochemistry & geophysics	1	Geosciences
2	Geography, physical		
3	Geology		
4	Paleontology		
5	Geosciences, multidisciplinary		
6	Oceanography	2	Oceanography
7	Meteorology & Atmospheric sciences	3	Meteorology
8	Multidisciplinary sciences	4	Multidisciplinary sciences
9	Infectious diseases	5	Medicine
10	Immunology		
11	Medicine, general & internal		
12	Public, environmental & occupational health		
13	Tropical medicine		
14	Veterinary sciences		
15	Limnology	6	Biology
16	Marine & freshwater biology		
17	Plant sciences		
18	Biodiversity conservation		
19	Ecology		
20	Biology		
21	Biotechnology & applied microbiology		
22	Genetics & heredity		
23	Evolutionary biology		
24	Entomology		
25	Thermodynamics	7	Energy & resources
26	Energy & fuels		
27	Engineering, civic		
28	Water resources		
29	Forestry		
30	Fisheries		
31	Agricultural engineering	8	Agriculture
32	Agronomy		
33	Agriculture, soil science		
34	Engineering, environmental	9	Environmental science
35	Environmental sciences		
36	Business	10	Social sciences
37	Economics		
38	Geography		
39	Environmental studies		

Source Subject categories according to the Journal Citation Reports

Journal content analysis

The second potential source of bias in this study regards the choice of journals as the unit of analysis. The classification of journals in subject categories cannot perfectly reflect the variety of content in the journals, since they are classified in subject categories according to their overall main content (Gomez et al. 1996). An additional analysis of the content of strategically selected journals was therefore carried out. This selection includes both a stratified sample of journals from all of the scientific fields and a sample of potentially interdisciplinary journals, which were all systematically checked in a previous article using a similar data set (see Bjurström and Polk 2011). The present journal content analysis follows the procedure of Bjurström and Polk (2011) to establish whether knowledge dissemination in journals is interdisciplinary. This is achieved by analyzing each discipline's variety of journals, to what degree these journals also contain content from other disciplines, and to what degree each discipline publishes in journals with other disciplinary labels.

Co-citation analysis

Measuring the number of disciplines cited in each chapter can be seen as the most straightforward way to measure interdisciplinarity (see Section "Measuring interdisciplinarity in bibliometrics research"), since the authors of each TAR chapter govern the selection of which disciplines are consulted. However, the many contributing authors and lack of classification standards for the chapters precludes direct citations from being an effective way to measure the degree of interdisciplinarity in each scientific field. Although co-authorship is suitable to measure collaboration, our interest is to measure knowledge integration and map the integration and separation of disciplines. We therefore prefer bibliometric mapping based on co-citation analysis.

Bibliometric mapping gives an overview of the structural relations of disciplines that enable a situated analysis of interdisciplinarity (Boyack et al. 2005; Leyedesdorff 2007a, b; Liu 2005). Bibliometric mapping, based on a co-citation analysis with journals as the unit of analysis, will be used in this study and developed in the following. Co-citation analysis was introduced as a method to measure similarities of documents, assuming that two documents are similar if they are cited together (Small 1973). Degree of similarity can accordingly be measured as the number of times two documents are cited together (their co-citation frequency). Co-citations are often used as a similarity measure in bibliometric mapping. Bibliometric mapping originates from the insight that publications are linked through their citations into networks of scientific papers (Price 1965). In this paper, the structural relations of journals are mapped out, using multivariate statistics with co-citations to establish similarity. Correspondence analysis, carried out with the software UC-INET, is used for the statistical analysis and visualisations (Borgatti et al. 2002). Any two journals included in this study will be close or distant to each other in the resulting visualisation depending on how often they appear in the same TAR chapters. The distance is interpreted as a degree of integration.

There are three different units of analysis used in the co-citation analysis, namely journals (based on the 96 by 43 matrix), subject categories (based on an 39 by 43 matrix) and scientific fields (based on an 10 by 43 matrix). Additionally, three levels of classifications are used when visualising and analysing the journals (see Sect. "Sample and classification"). This research design enables a multi-level analysis of interdisciplinarity, to avoid the risk of overestimating interdisciplinarity which can occur when fields are defined narrowly and to capture *narrow* as well as *broad* interdisciplinarity (Porter and Rafols 2009; Song 2003). The result section begins with the most aggregated level (the co-citation analysis of scientific fields) and ends with the least aggregated level (the co-citation analysis of journals).

Results

The object of study is to what extent the dissemination of climate research through journal articles and the IPCC subsequent assessment of these articles is interdisciplinary. One of the main hypotheses is that TAR is structured in conformity with the organization of climate research, since the same research communities are involved in both stages of the process. However, the assessment may include late integration despite the prevalence of a disciplinary mode of knowledge dissemination. We expect to find stronger emphasis on integration in TAR since it is often argued that interdisciplinarity is driven by external demands posed on science, including the context of application and societal demands for policy relevance (Gibbons et al. 1994; Nowotny et al. 2001).This results in three likely combinations: disciplinary knowledge dissemination and assessment, disciplinary dissemination with interdisciplinary assessment, and interdisciplinary dissemination and assessment. The fourth option is not considered, because it is not likely that an assessment systematically filters out disciplinary components from interdisciplinary dissemination.

The formal journal classifications and the content analysis are used to establish whether knowledge dissemination is interdisciplinary. The co-citation analysis is used to establish whether the subsequent knowledge assessment is interdisciplinary. The following scheme for interpretation is used. First, a disciplinary assessment approach is identified where the core research questions of each discipline are addressed in separate chapters of TAR. In this case, each chapter consequently and mainly contains the core journals of one discipline. Disciplinary knowledge dissemination and assessment will therefore cause the journals from each scientific field to form clusters. The stronger the disciplinary approach, the more dense the clusters. Second, disciplinary dissemination with interdisciplinary assessment will form less dense clusters or even a more dispersed structure if the assessment is strongly interdisciplinary. Third, interdisciplinary dissemination and assessment will be seen to lack a disciplinary structure when there are dispersed and overlapping clusters, since broad questions transgressing disciplinary borders are addressed and several disciplines assembled in each chapter.

Relations and distances between scientific fields

On the most aggregated level, the results from the co-citation analysis of *scientific fields* in Fig. 1 show one extended cluster and three outliers. The extended cluster in turn consists of two parts with three scientific fields each and one intermediator. ‘Geosciences’, ‘Oceanography’ and ‘Meteorology’ form a dense cluster, while the cluster of ‘Biology’, ‘Agriculture’ and ‘Environmental science’ is less dense. ‘Multidisciplinary sciences’ bridge these two clusters. Two of the three outliers, ‘Social sciences’ and ‘Energy and resources’ are related to each other, but distant from all other scientific fields. The final outlier, ‘Medicine’ is also distant from all other scientific fields. The results from the separate co-citation analysis of each working group follow the same overall pattern as seen in Fig. 1. This confirms that the overall structure of scientific fields also permeates the different parts of TAR.

The next level, the co-citation analysis of *subject categories,* analyzes the degree of separation and integration within and between the scientific fields in more detail

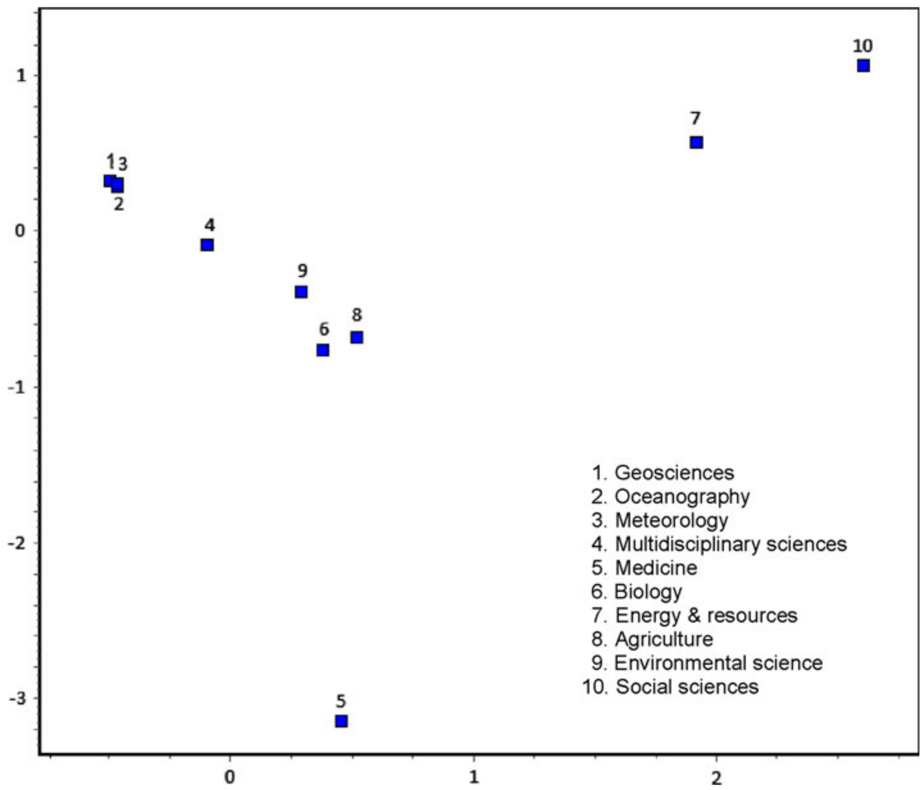

Fig. 1 Scientific field relations in the IPCC third assessment report

(see Table 1 for a list of all subject categories and their respective scientific fields). The subject categories in Fig. 2 follow the same pattern as their respective scientific fields in Fig. 1, with a few exceptions. One of the most interesting exceptions is Geography which is located among 'Biology' and 'Energy and resources'. Another exception is 'Energy and resources' which contains two distinct subgroups, namely *resource* related subject categories (located among 'Biology') and *energy* related subject categories (located much closer to the 'Social sciences'). 'Energy and resources' will henceforth be treated as two scientific fields, namely 'Energy' and 'Resources'. Agricultural engineering and Biotechnology and applied microbiology are located closer to 'Energy' compared with all other subject categories included in 'Agriculture' and 'Biology' respectively. Entomology (included in 'Biology') is located among subject categories that belong to 'Medicine'.

The journal content analysis identified four main categories: the Earth, Biological, Interdisciplinary and Social sciences. The Earth sciences include 'Geology', 'Oceanography' and 'Meteorology'. The content analysis shows the expected content in these areas, where other scientific fields are sparsely represented. The Earth sciences also publishes sparsely in journals from other scientific fields. The Biological sciences include 'Biology', 'Agriculture' and 'Medicine'. The content analysis shows that 'Biology' and 'Agriculture' are similar, and that they also overlap with the Interdisciplinary sciences. 'Biology' overlaps to a lesser extent with 'Medicine'. The Interdisciplinary sciences include

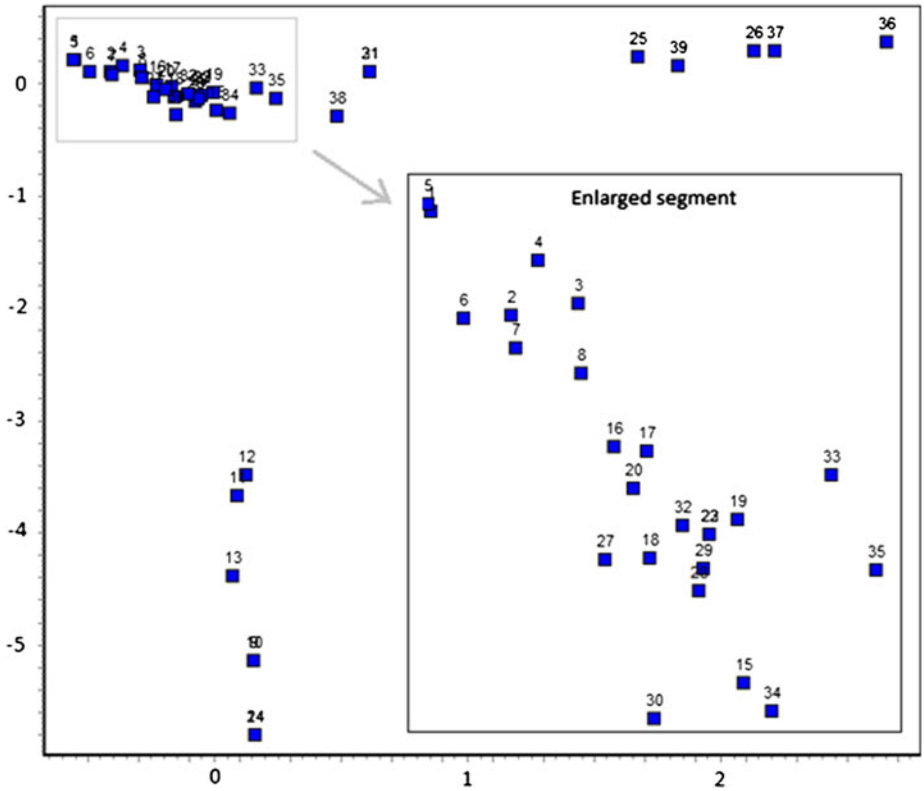

Fig. 2 Subject category relations in the IPCC third assessment report (see Table 1 for subject categories and their corresponding numbers) (Enlargement of the upper left cluster)

'Multidisciplinary sciences', 'Energy', 'Resources' and 'Environmental science'. 'Multidisciplinary sciences' consist mainly of the two journals *Nature* and *Science*, with their well known multidisciplinary content. 'Energy' and 'Resources' are composite categories which includes a number of subject categories representing applied fields without distinct disciplinary labels. The content analysis shows that both overlap with 'Environmental Science', 'Biology' and 'Agriculture'. They differ in that 'Resources' overlap more strongly with 'Biology' and 'Agriculture' whereas 'Energy' overlaps also with 'Social sciences'. Overall 'Environmental science' is a unique subject category since it is a field in its own right, yet has multiple bases in a variety of different disciplines. The content analysis shows that 'Environmental Science' has indistinct borders and heterogeneous content which substantively overlap with all of the scientific fields. The journal content of the Social sciences overlaps to some extent with the Interdisciplinary sciences and to a lesser extent with the Biological sciences.

The combined results from the content analysis and the co-citation analyses can be used to estimate the degree of interdisciplinarity in each of the scientific fields. The overall separation of scientific fields suggests that dissemination and assessment of climate research is weak in broad interdisciplinarity, especially in transgressing borders between the natural and social sciences. It can be preliminarily concluded that the Earth sciences represent disciplinary dissemination and assessment. This conclusion is based on the content analysis together with the co-citation analysis where all subject categories included in the Earth sciences form a distinct cluster, which is clearly separated from all other subject categories. The combined results suggest that 'Medicine', like the Earth sciences, represent disciplinary dissemination and assessment. The same combination of results suggests that 'Social sciences' are weak in broad interdisciplinarity, with one exception. Geography is the most distinct example of *broad* interdisciplinarity which bridges the natural and social sciences. 'Energy', like Geography, is an interdisciplinary field that bridges the natural and social sciences. 'Biology', 'Agriculture', 'Environmental Science' and 'Resources' are interrelated with each other. The combined results suggest that 'Biology' and 'Agriculture' are more interdisciplinary compared to the Earth sciences and 'Medicine'. 'Environmental Science' is the most interdisciplinary scientific field.

The results from the content analysis and the co-citation analyses closely resemble each other. This suggests that the research community imposes overall patterns of integration and separation of scientific fields that the IPCC reproduces. The four main categories identified by the content analysis are mirrored in the relationships between scientific fields in the co-citation analyses. Overall the Earth and Social sciences are separated whereas Biological and Interdisciplinary sciences are partly integrated with and partly separated from the former two. This resemblance holds also for the more detailed levels of analysis. For example, all analyses detect a close relation between 'Biology' and 'Agriculture'. The similarity of the results from the content analysis and the co-citation analyses establish that the dissemination of climate research through journal articles is reflected in the IPCC assessment. The results verify the hypothesis that TAR is structured in conformity with academic organization. However, the results do not confirm the expected emphasis on interdisciplinary assessment (late integration) despite the prevalence of a disciplinary mode of knowledge dissemination. Academic organization seems consequently to be more robust than external demands for interdisciplinarity posed on science, even though the IPCC works closely to a policymaking context.

The IPCC assessment seems to mirror overall academic organization. While the formal descriptions of subject categories suggest that the substantive differences between 'Medicine' and 'Biology' are no larger than the substantive differences within the earth sciences, in TAR, the former shows strong separation while the latter shows strong integration. The peculiar position of 'Medicine' can be due to the fact that it belongs to the faculty of medicine, related to 'Biology' in knowledge content, but institutionally separated. The Earth sciences, on the other hand, is institutionalised in academia as one discipline or a family of closely related disciplines. This indicates the importance of the institutional dimension in the integration and separation of scientific fields. Overall the results suggest that climate research mirror the faculty organization (the faculties of the natural, medical and social sciences).

Journal co-citation analysis

The co-citation analysis in this section uses journals as the unit of analysis to enable a substantiated description of interdisciplinarity at a level that is familiar to working scientists (See Table 2 for a list of all journals). The overall aim is to nuance the estimation of interdisciplinarity on a more concrete and detailed level by focusing the analysis on a selection of subfields and individual journals.

The distribution of the journals along three branches in Fig. 3 is the most distinct characteristic of the overall results from the co-citation analysis of journals. The same

Table 2 Journal names and frequencies in the IPCC third assessment report

Journal	Frequency
J. Geophysical Research	700
Nature	560
J. Climate	537
Climatic Change	425
Science	405
Geophysical Research Letters	399
Climate Dynamics	237
Bulletin of the American Meteorological Society	140
Tellus	135
Climate Research	134
International Journal of Climatology	128
Energy Policy	121
Global Biogeochemical Cycles	113
Global Environmental Change	100
J. Atmospheric Science	90
Global Change Biology	80
Annals of Glaciology	67
Quarterly Journal of the Royal Meteorological Society	66
Atmospheric Environment	64
Energy Journal	62
J. Physical Oceanography	58
Monthly Weather Review	50
J. Coastal Research	49
J. Glaciology	49
Water, Air and Soil Pollution	49
Ambio	48
Mitigation and Adaptation Strategies for Global Change	48
Lancet	47
Ecological Applications	46
Global Planetary Change	45
J. Hydrology	40
Agricultural and Forest Meteorology	39
Water Resources Research	38
Deep Sea Research	36
J. Environmental Economics and Management	35
Environmental and Resource Economics	34
Ecology	33
Oecologia	31
American Economic Review	30
Environmental Monitoring and Assessment	30
Limnology and Oceanography	30

Table 2 continued

Journal	Frequency
Ecological Economics	29
Holocene	29
Environmental Health Perspectives	27
American Journal of Tropical Medicine and Hygiene	26
Bioscience	26
Environmental Modeling and Assessment	26
Eos Transactions, American Geophysical Union	26
J. Meteorological Society of Japan	26
Hydrological processes	25
Theoretical and Applied Climatology	23
Atmospheric Research	22
Ecological Modelling	22
Quaternary Science Reviews	22
Paleoceanography	21
Plant and Soil	21
Quaternary Research	21
J. Applied Meteorology	20
Plant, cell, environment	20
Resource and Energy Economics	20
Arctic and Alpine Research	19
Biogeochemistry	19
Biomass and Bioenergy	19
Forest Ecology and Management	19
Global Ecology and Biogeography	19
Energy	18
Reviews of Geophysics	18
Annual Review of Energy and the Environment	17
Arctic	17
Fisheries Oceanography	17
Environmental Economics and Policy Studies	16
Meteorology and Hydrology	16
Philosophical Transactions of the Royal Society	16
Soil and Tillage Research	16
Coral Reefs	15
Geology	15
J. Ecology	15
Ocean and Coastal Management	15
Palaeogeography, Palaeoclimatology, Palaeoecology	15
Emerging Infectious Disease	14
J. Economic Perspectives	14
Australian Meteorological Magazine	13
Energy Economics	13

Table 2 continued

Journal	Frequency
Environmental Research	13
Environmental Science and Technology	13
J. Public Economics	13
Progress in Physical Geography	13
The Geographical Journal	13
Trends in Ecology and Evolution	13
British Medical Journal	12
Conservation Biology	12
Earth and Planetary Science Letters	12
Environmental Modelling and Software	12
International Journal of Global Energy Issues	12
J. Medical Entomology	12
Permafrost and Periglacial Processes	12

clusters of scientific fields are found here, as was also seen in the co-citation analysis of the scientific fields and subject categories. The left branch is dense with natural science journals, the lower branch contains predominantly journals from ‘Medicine’, while the right branch contains both natural and social science journals. The left branch contains a majority of the journals and the vast majority of the total number of references.

As can be seen in the enlarged segment in Fig. 3, the upper half contains journals from the Earth sciences (‘Geosciences’, ‘Oceanography’ and ‘Meteorology’). These journals are closely related to each other and separated from the journals of all other scientific fields except for ‘Environmental Science’ and ‘Multidisciplinary sciences’. There are no clear patterns of separation between ‘Geosciences’ and ‘Meteorology’. ‘Oceanography’, on the other hand, is related to both the Earth sciences and ‘Biology’ and ‘Resources’, for example, the journal *Ocean and Coastal Management* from ‘Oceanography’, is located among ‘Biology’ and ‘Resources’. The scattering of references over journals is also very low for the Earth sciences since they contain many journals that are frequently used in TAR. These characteristics are likely due to knowledge dissemination in discipline based journals and a most influential position within the IPCC, which facilitate the prioritization of the core questions of the Earth sciences in the assessment. The Earth sciences are a prime example of a disciplinary mode of dissemination and assessment. While there are some substantive differences in the content analysis between the journals, there are no clear clustering of subfields within TAR. Given that the Earth sciences is a family of closely related disciplines, it is strong in narrow interdisciplinarity.

The journals from ‘Biology’ form a surprisingly dense cluster in the lower part of the left branch. This is due to the fact that most of these journals are concentrated to a single chapter in WG2. ‘Agriculture’, as an example of an applied field, shares a great deal of substantive overlap with both ‘Biology’, ‘Energy’ and ‘Environmental science’. For example, the positions of *Soil and Tillage Research* and *Biomass and Bioenergy* demonstrate a relationship to ‘Energy’. The position of *Plant and Soil* is also closely related to ‘Biology’. ‘Resources’ is also located within the lower part of the left branch. This includes journals such as *Hydrological processes* and *Fisheries Oceanography*. Such journals along

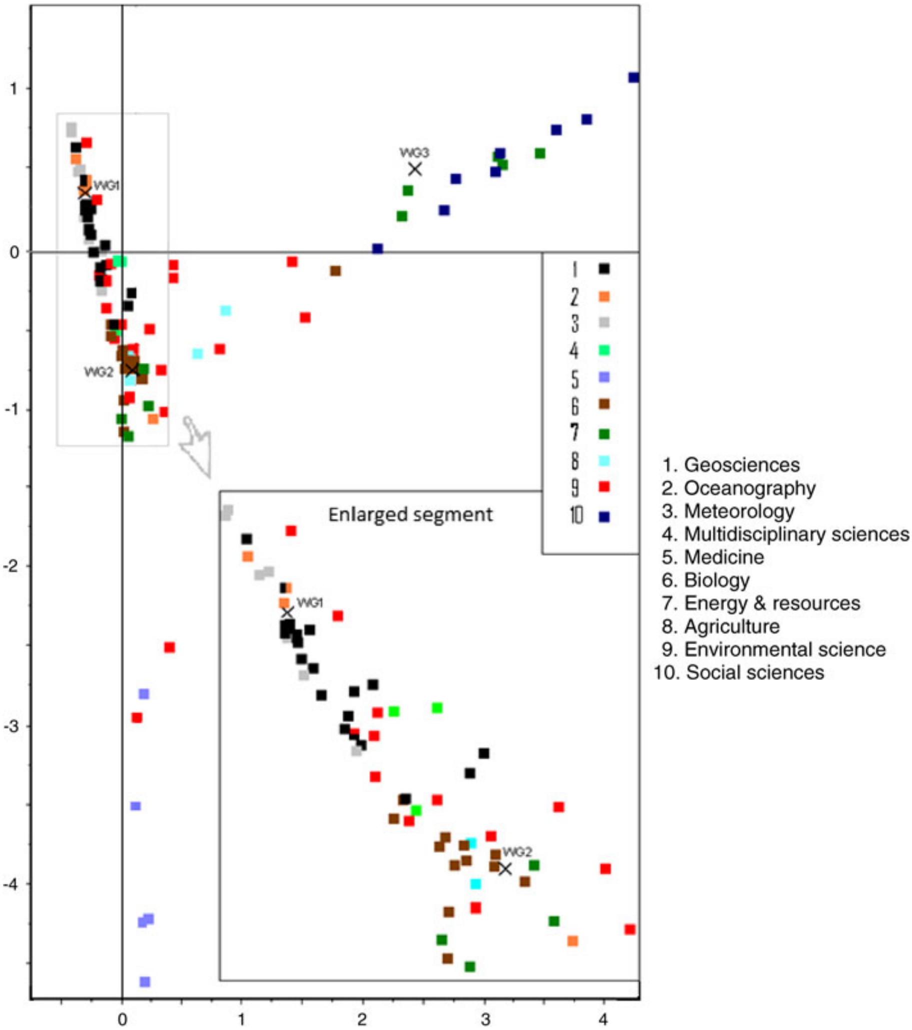

Fig. 3 Journal relations in the IPCC third assessment report (Enlargement of the upper left cluster)

with *Ocean and Coastal Management*, *Coral Reefs* and *Limnology and Oceanography* form a thematic subfield cluster across a variety of scientific fields which focus on water issues. The results suggest that 'Biology' represents a disciplinary assessment mode, while 'Agriculture' and 'Resources' are more interdisciplinary. One likely explanation for this is that the latter two are applied sciences.

In the lower branch, 'Medicine' is separated from 'Biology' as well as from the other scientific fields, with the exception of a few journals from 'Environmental science' consisting of environmental medicine, such as *Environmental Health Perspectives*. 'Medicine' is the only scientific field with a few journals categorised as both natural and social sciences, such as the *American Journal of Tropical Medicine and Hygiene*. While this suggests a broad interdisciplinarity, it is only to a limited degree and within related medical subfields. ‘Medicine’ is not at all related to ‘Social sciences’ in the right branch or to the natural sciences in the upper. One explanation for this can be that the medical subfields and different occupational categories are strongly institutionalized in medical faculties and facilities.

In the right branch, a gradual transition from the natural sciences towards ‘Social sciences’ is clearly visible. While the division of ‘Energy and resources’ into two groups was motivated on the subject category level, *Biomass and Bioenergy*, *Ecological Economics* and *Resources and Energy Economics* are journals that bridge these areas. These areas also bridge the natural and social sciences. Overall, ‘Social sciences’ are separated from the natural sciences and have a peripheral role in climate research. They are predominantly integrated with ‘Energy’. ‘Social sciences’ are represented mainly by economic journals, and include both environmental and traditional economic approaches. The latter are the least integrated with all other scientific fields. Examples include *Journal of Public Economics* and *Journal of Economic Perspectives*. Journals that integrate economics with energy or environmental issues are more interdisciplinary. Examples include *Environmental and Resource Economics* and *Journal of Environmental Economics and Management*. These examples show the differences that exist between the economic subfields which study environmental issues. The two most prominent are ecological and environmental economics. Ecological economics is much more interdisciplinary than environmental economics, which also is evident in its location in TAR. ‘Social sciences’ are weak in broad interdisciplinarity, especially when this refers specifically to the integration of the natural and social sciences. There is one exception, *The Geographical Journal*, is the only ‘Social sciences’ journal that is well integrated within the natural sciences.

As this analysis has shown, there are a number of clusters of scientific fields which to a greater and lesser degree exhibit different types of interdisciplinarity. Overall the IPCC assessment represents a clear multidisciplinary approach. However, there are also a number of journals that are located between the different clusters of scientific fields and hence are more interdisciplinary. A number of such examples have already been discussed such as ecological economics and environmental health. There is also one scientific field, ‘Environmental science’, which is strongly interdisciplinary. ‘Environmental science’ is related to all of the scientific fields and is prominently located in the areas which connect the right and left branches. Its journals are by far the most broadly distributed demonstrating the broadness and heterogeneity of the field. Examples of ‘Environmental science’ journals that are mainly related to one discipline include: *Atmospheric Environment* (Earth sciences), *Environmental Research* (‘Medicine’), and *Conservation Biology* (‘Biology’). Examples of more broadly interdisciplinary journals are: *Environmental Modelling and Assessment*, *Environmental Science and Technology* and *Ambio*. There are also a number of journals focusing explicitly on climate change that integrate a number of scientific fields. The most prominent are *Climatic Change*, *Global Environmental Change* and *Mitigation and Adaptation Strategies for Global Change*. These are all broadly interdisciplinary but with different emphasis. *Climatic change* is oriented towards the natural sciences while *Mitigation and Adaptation Strategies for Global Change* is oriented more towards the social sciences. The broad distribution and strong relation with most scientific fields implies that ‘Environmental science’ is a genuinely interdisciplinarity field, strong also in broad interdisciplinarity. However, this broad distribution is also due to the indistinctness of the label ‘environmental science’ and its association to a multitude of disciplinary subfields that are not well integrated with each other.

The results of the journal co-citation analysis confirm that the methodological approach, bibliometric mapping, works well in estimating interdisciplinarity. It is both effective in capturing the structural relations of disciplines and precise in enabling a situated estimation of the degree of interdisciplinarity. The content of each journal can be remarkably well predicted by its location in the co-citation analysis. The results suggest that interdisciplinarity is not a prominent feature of climate research and that the IPCC assessment is notably weak in broad interdisciplinarity. Integration occurs mainly between related disciplines (narrow interdisciplinarity) which indicate a traditional disciplinary basis of climate research. A few fields and journals represent broad interdisciplinarity. Thus, the IPCC Third Assessment Report is best characterized by its multidisciplinarity.

The overall, macro structure of TAR can be summarized in the schematic illustration in Fig. 4. The two dimensions are interpreted as a physical/social dimension and a physical/bodily dimension. This is based on the fact the physical, social and medical sciences are most prominent in each of the corners. The diagonal forms a social/bodily dimension. There is a biological and environmental area in the middle of each dimension. The three clusters of journals represent the domains of Nature, Human society and Human body. This mirrors the division of academia in the faculties of the natural, social and medicinal sciences, although each meta-disciplinary field to some extent study all three domains. The physical dimension of climate change is separated from the human dimension. The human dimension of climate change is separated into a social dimension, dominated by economic

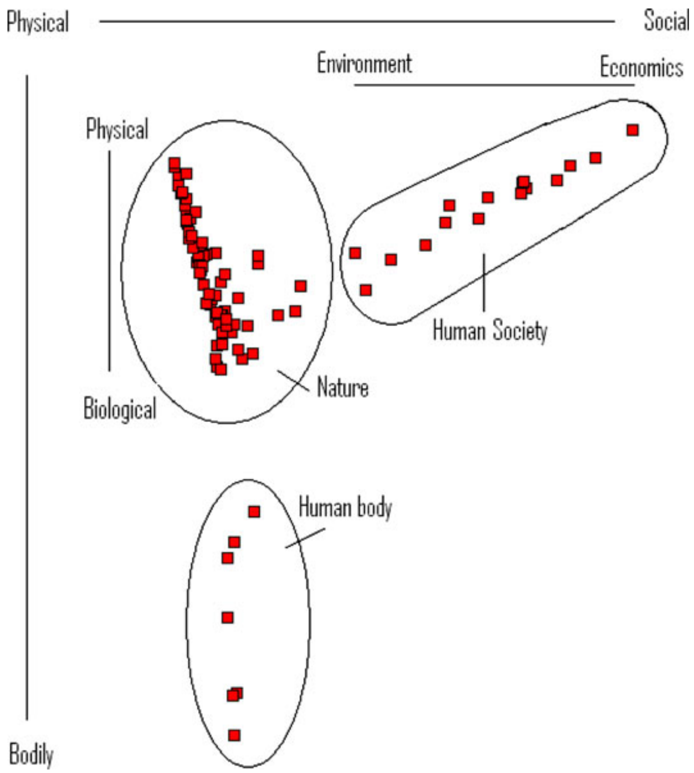

Fig. 4 Schematic illustration of the separation of natural and human dimensions in the IPCC third assessment report

sciences, and a bodily dimension, dominated by medicine. There is a much less distinct separation between the physical and the biological dimension of climate change.

Conclusions: is interdisciplinarity a prominent feature of climate research?

This study addresses whether interdisciplinarity is a prominent feature of climate research by means of a co-citation analysis of the IPCC Third Assessment Report. The results, which are based upon the 96 most frequently used journals in the Third Assessment Report, suggest that the IPCC assessment of climate change is best characterized by its multidisciplinarity where the physical, biological, bodily and societal dimensions are clearly separated. These results suggest that the IPCC assessment is weak in broad interdisciplinarity, which is defined as the transgressing of boundaries between disciplines with dissimilar epistemologies. The strong separation between the natural and social sciences is the most distinct example of this. Although a few fields and journals in the sample integrate a wide variety of disciplines, integration occurs mainly between related disciplines (narrow interdisciplinarity) which indicate an overall disciplinary basis of climate research.

The results suggest that Environmental science is the most important field where interdisciplinarity of all kinds thrives. The IPCC assessment is strong in narrow interdisciplinarity, defined as the transgressing of boundaries between disciplines with similar epistemologies. While climate change as a real world problem transgresses disciplinary borders, the scientific community addresses climate change predominantly from a multidisciplinary approach defined as loose cooperation between disciplines with limited integration. The IPCC assessment is similar to an anthology which includes separate chapters of authors writing on different aspects of the same topic from different disciplines. The IPCC assessment seems to mirror overall academic organization. While we expected to find stronger emphasis on integration in TAR compared with the research community, this was not evident in the results. This suggests that the research community imposes overall patterns of integration and separation of scientific fields that the IPCC reproduces. The results verify the hypothesis that TAR is structured in conformity with the academic organization of knowledge production. However, the results do not confirm the expected emphasis on late integration, namely a shift towards interdisciplinarity in the IPCC assessment process, despite the prevalence of a disciplinary mode of knowledge production and dissemination. Academic organization seems consequently to be more robust than external demands for interdisciplinarity posed on science in the policy-close context of the IPCC. Institutions (enduring structures of social order) are likely important causes to the robustness of academic organization and the integration and separation of knowledge in climate research.

Discussion

Climate change is often seen as a prime example of an interdisciplinary research area, yet as this study concludes, interdisciplinarity is not a prominent feature of climate research. These results strongly suggest that academic organization structures climate research and imposes overall patterns of integration and separation of disciplines that the IPCC reproduces. The results from this study together with previous bibliometric research also suggest that the overall structural relations of disciplines are similar irrespective of research area, although research areas differ in the variety of included and emphasized disciplines. For example, the relations of disciplines found in this study resemble Biotechnology, Engineering and Nanotechnology (Porter and Rafols 2009; Porter and Youtie 2009). 'Maps of science', an approach that visualizes science at large, also resemble this meso level. In such macro studies scientific fields are related as follows: Mathematical/Technical/Physical/Chemical/Earth/Environmental/Biological/Medical/Psychological/Social/Humanistic sciences (Boyack et al. 2005; Moya-Anegón et al. 2004). This ordering shows, for example, how the Biological sciences are related to Medical and Environmental sciences, but distant from Social sciences in ways that resemble the results presented here. Subfields are positioned within this macro structure, e.g., Biochemistry is located between Biology, Chemistry and Medicine (Boyack et al. 2005). Balaban and Klein (2006) argue that disciplines are hierarchically related and that the hierarchy is branching, especially at the Chemical and Biological sciences, which also agrees well with the present results from this study.

The crucial point when measuring the degree of interdisciplinarity is how disciplines are delimited, how interdisciplinarity is defined, and what criteria are used to judge whether it is prominent. As noted earlier, collaboration as well as integration across disciplines is increasing over time (Porter and Rafols 2009). Thus, on one level, it is easy to say that science is becoming more interdisciplinary. However, specialisation is also increasing which can be seen in the growing number of disciplines and subfields. Since the degree of interdisciplinarity is overestimated when fields are defined narrowly, the growth rate is accordingly overestimated as specialization increases and the number of disciplines multiplies with time. In a longitudinal study of six research areas, Porter and Rafols (2009) show a 50% increase in interdisciplinarity over the last three decades, when the number of cited disciplines are used to measure interdisciplinarity. However, when the degree of difference between disciplines is taken into account, in so-called index measures, this is reduced to a 5% increase, indicating the increase of narrow and broad interdisciplinarity, respectively (Porter and Rafols 2009). This suggests that this increase in interdisciplinarity is, in part, a superficial effect due to the establishment of new borders among related disciplines, in what we refer to as *narrow* interdisciplinarity. Given that interdisciplinarity is complementary to the disciplinary system, an increase in narrow interdisciplinarity is both expected and desired. However, defining interdisciplinarity in only its narrow sense is problematic because it discounts other significant types of knowledge integration. Overall, the different perceptions and assumptions surrounding interdisciplinarity help explain the contradictory results that are often seen. These underlying issues become especially relevant when attempts are made to estimate what is considered to be a sufficient degree of interdisciplinarity.

There are numerous studies of interdisciplinarity which reach different conclusions based upon the definitions and operationalizations of interdisciplinarity that are applied. For example, from the maps of science approach mentioned earlier, Biochemistry is seen as one of the most interdisciplinary fields in all of science, due to its structural position with strong and diverse links to many disciplines (Boyack et al. 2005). In our terminology, Biochemistry is a discipline characterized by *narrow* interdisciplinarity. Nanotechnology is another area that has received a great deal of attention within bibliometric studies of interdisciplinarity and contradictory results. Some researchers (such as Porter and Youtie 2009) conclude that Nanotechnology is strongly interdisciplinary whereas others (such as Schummer 2004) conclude that it contains weakly integrated disciplines. Nanotechnology and climate research are often characterized as interdisciplinary fields. Given the definitions of interdisciplinarity applied in the present study, we contest such claims. Nanotechnology and climate research are best characterised by their multidisciplinarity and narrow interdisciplinarity, and their weakness in broad interdisciplinarity.

A number of conclusions can be extrapolated from the results and above discussion regarding the frequency of types of interdisciplinarity. The structural relations of disciplines are similar irrespective of research area and follow academic organization. This implies that interdisciplinarity is most common between similar fields. Narrow interdisciplinarity will consequently always be much more common than broad interdisciplinarity. Thus, research areas are most often characterised by either disciplinarity or multidisciplinarity, depending on the variety of disciplines included. The degree of interdisciplinarity, on the other hand, may differ between disciplines and subfields, as well as between different research contexts. For example, Geography is more interdisciplinary than Economics; Environmental Economics is more interdisciplinary than traditional Economics; and each may be more interdisciplinary when applied to climate change compared with their accustomed research contexts.

It is typically argued that interdisciplinarity enhances problem solving capacity, especially for complex and broad issues that transgress disciplinary borders and are addressed outside of academic contexts (Gibbons et al. 1994; Horlick-Jones and Sime 2004; Max-Neef 2005; Nowotny et al. 2001). For this reason, it is often argued that interdisciplinarity needs to be promoted in environmental research (Newell et al. 2005; Pohl 2005). Applied interdisciplinary objectives can also evolve into transdisciplinarity, i.e., academic and non-academic collaboration. Following this approach, the IPCC assessment could be characterized as transdisciplinary science since non-academics participate in the selection of experts, the review process as well as the approval of the final text. The climate issue can also be characterised as post-normal, defined as a situation of uncertain facts, disputed values, high stakes and urgent decision needs (Funtowicz and Ravetz 1991). Saloranta (2001), following Funtowicz and Ravetz, argues that the problem solving capacity of the IPCC is enhanced due to the post-normal characteristics of climate research surrounding the IPCC. However, the IPCC can also be interpreted as adhering strongly to a linear model of science and policymaking, where science is seen to be restricted to communicating scientific information. This is far from a transdisciplinary position which would argue instead that science needs to be more participatory and value-driven to be able to effectively handle the post-normality of the climate issue. It thus seems that there are both contradictory tendencies within the IPCC, as well as contradictory interpretations of these tendencies. This is to be expected since the IPCC is a boundary organization that derives authority from the status of the natural sciences as objective knowledge producer at the same time that it adapts to policymaking (Agrawala 1998b; Cohen et al. 1998; Demeritt 2001; Hulme 2009; Miller 2001). The results of the present study do not support Gibbons et al. (1994) and Nowotny et al. (2001) renowned claim that a far-reaching reshaping of science, driven by societal needs, is taking place. We agree instead with Hessels and Lente (2008) that the various claims by the former are conceptually problematic and that each claim needs to be studied separately. For example, the results of this study give empirical support to the theory driven argumentation by Lenhard et al. “that the demand for ‘socially robust knowledge’ that makes transdisciplinary science inevitable, as is claimed by Nowotny, does not imply a weakening of the disciplinary structure of science” (2006, 341).

The IPCC has become the most well-known climate change institution, with the formal role to assess policy-relevant scientific knowledge to inform but not guide rational action. In contrast to this traditional view of science as objective knowledge producer, science can instead be seen as actively framing the way we view climate change and how resulting problems should be solved (Hulme 2009). This can be contrasted with the realistic assumption of interdisciplinary advocates who argue that the disciplinary mix must fit the problem in question (Buanes and Jentoft 2009). What then, if disciplines to some extent instead are constructing the problem to fit the discipline (Weingart 2000). For example, as some researchers suggest, it is likely that climate change to some extent is constructed by the Earth sciences as a global, physical, environmental problem at the expense of its local and non-physical aspects, as a social problem (Cohen et al. 1998; Demeritt 2001; Kwa 2005).

That the disciplinary basis of research constrains understanding and adequate responses to real world problems is a common critique from interdisciplinary advocates. The main result of this study, and arguably also one of the most problematic, is the strong separation of society from the climate system within climate research (Charlesworth and Okereke 2010; Cohen et al. 1998; Hulme 2009; Pielke and Sarewitz 2005; Rayner and Malone 1998). The IPCC assessment structure mirrors this separation and clearly constrains the types of questions that can be addressed and answered. For example, WG1 explicitly and systematically addresses the physical scientific basis, but not the ultimate societal causes to climate change. This focus is especially important since the working groups and their respective scientific communities are hierarchically related (Cohen et al. 1998; O'Neill et al. 2010). The initial framing of climate change originates from the Earth sciences, represented by WG1, which includes most sub-systems of the earth except human societies, despite the fact that the problem addressed is human induced climate change, while WG2 and 3 focus on adaptation and mitigation, but not on causes. Given that climate change is a severe problem facing mankind, it is mandatory to see humans as a crucial, if not integral part, of the climate system (Crutzen 2002). Moreover, while the separation of focal areas in the three working groups has proven conducive to understanding the physical causes to climate change, this same structure has restricted how climate change can be understood and evaluated, weakened the addressing of synergies in adaptation and mitigation responses and excluded a number of significant research areas. The entire history of humankind has been dependent upon the ability to adapt to different local climates as well as to changes in global climate trends (Lamb 1982). This is a typical example of research area which is difficult to address within the current IPCC structure. The history of climate research, which also includes the social context of research and its application, is another example of an interdisciplinary approach which could potentially increase the applicability of the IPCC assessment (Fleming 1998; Kwa 2001; Storch and Stehr 2000). The interaction of physical and social subsystems relating to climate change is another research area that could and should be addressed systematically. For example, climate change and globalization have varied regional effects where the societal impact is the combined outcome of societal and natural processes in different spatial contexts (Leichenko and O'Brien 2008).

One way to promote interdisciplinarity, as argued, is to broaden each working group, especially WG1 which is the most narrowly delineated working group in terms of the variety of included disciplines (Bjurström and Polk 2011). However, this will most likely result in a multidisciplinary approach where the added disciplines will be concentrated to one or a few chapters and hence not well integrated. As this study shows, the division of the IPCC assessment into the three working groups is not the main cause of how the scientific fields are separated and integrated in the third assessment report. The outcome of broadening each working group will likely be the same multidisciplinary approach that the results from this study describe. To overcome the disciplinary structure of the IPCC, broad questions transgressing disciplinary borders must be jointly formulated within research and early in the IPCC assessment process (Malone and Rayner 2001). This will foster the inclusion of several disciplines in each *Chapter*. This is the most sound way, and perhaps the only way, to promote interdisciplinarity as the authors of each TAR chapter govern the selection of which disciplines are consulted and how their knowledge are integrated. To separate disciplines between chapters, and hope that integration will occur between the chapters, is by definition a multidisciplinary approach.

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