

Seeing and Knowing the Earth as a System

An Effective History of Global Environmental Change Research as Scientific and Political Practice

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Abstract

This thesis traces the history of the Earth System as an object of concern in global environmental change research. In focus are the ways of seeing and knowing the global environment that the Earth System perspective rests upon, and the fields of possible action it may produce in science and policy. The study is primarily based on archival analyses of program and project documentation produced by the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme of Global Environmental Change (IHDP). Together these two programmes represent a wide network of global change research that over the course of 30 years has engaged with the Earth System as object of analysis, and global change as problem of government. The studied period spans from the planning of the IGBP in 1983 until 2013 when Future Earth was established as the new scientific hub for global change research. The thesis studies the effects of the IGBP's strategy to use predictive Earth system models as a tool for global change research coordination and integration. The results demonstrate the historicity of the present Earth system outlook. In particular it examines how the introduction of ecological and social complexity into Earth System modelling has altered the understanding of human-environment relations and the problem of global change. The thesis concludes that the Earth system outlook is the result of a productive and unsolved tension between the top-down gaze of global modelling, and bottom-up understandings of socio-ecological dynamics.

Keywords: Earth system, Global change, Governmentality, History of the present, history of environmental science, international research programmes, environmental governance

Sammanfattning

Genom att studera diskussioner inom internationella miljöforskningsprogram spårar den här avhandlingen framväxten av dagens syn på planeten jorden som ett sammanlänkat system – Jordsystemet. Detta holistiska synsätt spelar en viktig roll i pågående politiska och vetenskapliga diskussioner om hur en hållbar global miljö kan och bör formas. Kopplingen mellan makt och kunskap, styrning och mentaliteter, ligger till grund för studiens tolkande ansats. Den knyter samman sätt att betrakta och beräkna den globala miljön, grunden för jordsystemperspektivet, och de handlingsalternativ det synliggör inom politik och vetenskap. Studien baseras primärt på analyser av arkivmaterial från International Geosphere-Biosphere Programme (IGBP) och International Human Dimensions Programme of Global Environmental Change (IHDP). Tillsammans representerar dessa två program ett brett nätverk för forskning om globala miljöförändringar som under 30 år studerat Jordsystemet som ett objekt kopplat till globala miljöförändringar som ett problem i behov politisk styrning. Den undersökta perioden startar i och med planeringen av IGBP 1983 och avslutas 2013 med att Future Earth etableras som ett nytt internationellt program för forskning om globala miljöförändringar. Avhandlingen undersöker effekter av IGBPs strategi att använda prediktiva Jordsystemmodeller som ett redskap för att integrera och koordinera forskningen om globala miljöförändringar. Studiens resultat visar på historiciteten i nuvarande sätt att betrakta Jordsystemet. Framförallt studeras hur introducerandet av ekologisk och social komplexitet i förståelsen och modelleringen av Jordsystemet hänger samman med en förändrad bild av relationen människa-miljö och därmed också bilden av globala miljöförändringar som vetenskapligt och politiskt problem. Avhandlingen visar att förståelsen av Jordsystemet vuxit fram i en produktiv spänning mellan ovanifrånperspektivet i globala modeller och lokalt förankrad socio-ekologisk interaktion.

Nyckelord: Jordsystemet, Globala miljöförändringar, Governmentality, nuets historia, miljövetenskapernas historia, internationella forskningsprogram, miljöpolitik

Acknowledgments

As I write these last parts of the thesis my youngest son is stubbornly struggling to take his first steps with his two parents and older brother following his moves, part encouraging and part anxious. Over the last years my struggling steps has been followed by two supervisors at a distance that has given me space to find my own path but at the same time close enough to made sure that I have not fallen on any too sharp objects. I'm very impressed and grateful for their balancing act. Therefore the first person I want to thank for getting this far is my main supervisor Eva Lövbrand. With her analytical acuity, whole-hearted engagement in the project as well as patiently supporting attitude she has set an example that I will always bear in mind. Eva's invaluable guidance has been complemented by the warm-hearted, intellectual duellist Björn-Ola Linnér. Based on his broad knowledge in the history of environmental science and politics he has kept my attention to the important 'so what' question and thus helped me to remain with at least one foot in the soil.

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The work with the thesis has also benefited from a broad range of people generously giving of their time, the 16 interviewees, the staff at the IGBP secretariat, as well as opponents and commenters on previous versions of this manuscript. Your help has been indispensable. Also, thanks to all other friends and relatives that have made these years so much easier providing practical support and a world beyond analysis and methods.

Despite a wonderful environment of supervisors, colleagues, PhD students, and friends at work and elsewhere the best thing is still to come home to my wife Kristina, since while all the other persons are stars you are the Northern lights, to Nils our new long wished-for family member and to Emil, the most exciting and lovable person I have ever known. You will probably never fully understand what you have meant through these years.

I guess it goes for most dissertations but I know that it is true in this case; if I could add *et all* to Uhrqvist I definitely would. But, I'm afraid I can't, so instead I just say

Thanks!!

List of papers

- I) Uhrqvist, O. and Lövbrand, E., (2014). 'Rendering global change problematic: The Constitutive effects of Earth system research in the IGBP and IHDP', *Environmental Politics*, 23 (2), 339-56

- II) Uhrqvist, O., (in press, April 2015) One Model to Fit all?: The Pursuit of Integrated Earth System Models in GAIM and AIMES, *Historical Social Research*

- III) Uhrqvist, O., (2013). Governing through knowledge – START and the expansion of global environmental research, In C. Methmann, D. Rothe and B. Stephan eds., *Interpretive Approaches to Global Climate Governance: (De)constructing the greenhouse*, London: Routledge, pp. 152-165.

- IV) Uhrqvist, O. and Linnér, B-O., (Submitted manuscript) Narratives of the Past for Future Earth: The Historiography of Global Environmental Change Research.

Author's contributions

In paper I, co-written with Eva Lövbrand, the author has conducted most empirical work and preliminary analysis. Eva strengthened the theoretical foundations. Finalizing the manuscript was a collaborative effort.

In paper IV, co-written with Björn-Ola Linnér, the author has the lead role with the empirical work analytic efforts and writing are shared.

The author of this thesis is solely responsible for papers II and III.

Acronyms

BAHC	- Biospheric Aspects of the Hydrological Cycle (Core Project in the IGBP (1991-2003)
ESG	- Earth system governance (Core project in the IHDP 2009-)
ESSP	- Earth System Science Partnership Cooperation platform for Global Environmental change research (2001-2013)
GAIM	- Global Analysis Interpretation and Modelling (1993-2004)
GARP	- Global Atmospheric Research Programme
GCTE	- Global Change and Terrestrial Ecosystems (Core Project in the IGBP 1992-2003)
GEC	- Global Environmental Change
GEG	- Global Environmental Governance
GLP	- Global Land Project (Core Project in the IGBP and IHDP 2004-)
HDP	- Human Dimensions on Global environmental change Program
ICSU	- International Council of Science (formerly International Council of Scientific Unions)
IBP	- International Biological Program (1964-74)
IGBP	- International Geosphere-Biosphere Programme (1986-2014)
IGY	- International Geophysical Year (1957-58)
IHDP	- International Human Dimensions Programme on global environmental change
(I)HDP	- (International) Human Dimensions Programme (to show the continuity)
IIASA	- International Institute for Applied Systems Analysis
IPCC	- Intergovernmental Panel on Climate Change
ISSC	- International Social Science Council
LUCC	- Land Use and Land Cover Change (Core Project in the IGBP and IHDP 1994-2005)
MAB	- Man and Biosphere (UNESCO 1971-)
MTPE	- Mission To Planet Earth (NASA programme on global change (ca 1990-)
NASA	- National Aeronautic and Space Administration
QUEST	- Quantifying and Understanding the Earth System (UK programme on Global Change)
SCAR	- Scientific Committee on Antarctic Research
START	- SysTem for Analysis, Research and Training (1992-)
UNEP	- United Nations Environment Programme
UNESCO	- United Nations Education, Science and Cultural Organisation
UNU	- United Nations University
USGCRP	- United States Global Change Research Program
WCRP	- World Climate Research Programme
WMO	- World Meteorological Organisation

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1 Introduction

"What is the nature of Earth?"

(Steffen, 1998: 7)

The slogan 'Think globally, act locally' has been a rallying cry and the inspiration behind environmentally-friendly actions for over 40 years. It was, for instance, the first slogan of Friends of the Earth in 1969, and also informed the UN conference on the Human Environment where "a global state of mind" was expected to "generate a rational loyalty to the planet as a whole" (Ward and Dubos, 1972: xviii). Although more recent discussions on the limits of survival in the global environment rather support the phrase 'think globally, act locally' (e.g. Rockström et al., 2009b), it has been argued that the solving of problems caused by a changing environment is best left in the hands of global institutions guided by scientific experts (Dryzek, 2013: 48). This thesis engages with how attempts to produce predictive, scientific knowledge about a changing global environment have enabled particular ways of thinking and acting globally. In this thesis, it is argued that concepts such as 'the global environment' and 'global environmental change' are far from neutral; rather, they have particular effects on the actions and the organisation of environmental governance structures, as well as the design and governance of international research programmes. These concepts produce particular ways of seeing and knowing the Earth as a system, the place of humankind in this system, and how it can be governed/managed.

The current Earth System outlook in global environmental research is the result of the coordinated efforts of a number of scientists concerned with climate and global change to develop a predictive understanding of the Earth as an interconnected system, in which all physical, biogeochemical, and social processes are deeply intertwined. The meaning which those in the academic quarter take from the outcomes of this coordinated research effort is that human activities, such as agriculture, forestry, energy production, and chemical usage, are affecting the global environment to the point where once-natural processes cannot be considered to be natural anymore (Steffen et al., 2004, Galaz, 2014). In a time when the human imprint is ubiquitous, humans have become a major geological force that rivals some of the greatest forces of nature (Brito and Stafford Smith, 2012).

Since the turn of the millennium, global change scientists have developed a new concept, 'the Anthropocene', to describe this unprecedented period of environmental concern (Crutzen and Stoermer, 2000, Crutzen, 2002). The Anthropocene is in this thesis understood to be a label which simultaneously describes an intertwined Earth System, the problems arising from global change, and a need for a new ethics of planetary stewardship (Crutzen and Stoermer, 2000, Steffen et al., 2011a).

Coordinated efforts for the attainment of knowledge related to the Earth System, as well as how to make predictions regarding it, have engaged thousands of researchers globally and across disciplines over the past few decades. The of seeing and knowing of the global environment that result from these efforts have, in recent years, made their way into authoritative scientific assessments, such as that of the Intergovernmental Panel on Climate Change (IPCC, 2013). The Earth System outlook has also gained ground in social science circles and sparked debates regarding ways to reform global environmental institutions and democratic processes (Biermann et al., 2010, Dryzek and Stevenson, 2011).

This thesis studies the historical formation of the concept of the 'Earth System' as a knowable and governable object and, furthermore, an object of concern; moreover, it sets out to interpret the political implications of an Earth System outlook. Since its introduction by the American National Aeronautic and Space Agency (NASA) in 1986, the concept of the Earth System has been closely associated with urgent calls for management of the global environment as a whole (NASA-ESSC 1986). An explicit goal of Earth System science is to provide policy-relevant knowledge for rational management of the planetary life support system (Malone and Roederer, 1985, Schellnhuber and Tóth, 1999, Rockström et al., 2009b). As such, the Earth System concept carries with it a set of political implications.

Earth System science produces 'global environmental change' and the 'coupled human-environment system' as knowable objects which are possible to govern in a rational manner; integrated, discipline-transcending research efforts in this field have paved the way for concepts such as *planetary boundaries* (Rockström et al., 2009b), *global change syndromes* (Schellnhuber et al., 1997, Reenberg, 2011), and *Earth System tipping points* (Lenton and Williams, 2013), and given them a central role in the politics of *Earth System stewardship* (Brasseur, 2003, Folke et al., 2011, Steffen et al., 2011b). In the article 'Navigating the Anthropocene', Biermann et al. (2010) argue that Earth System interactions can be governed, and call for significant changes in the architecture of global environmental governance. Their article is just one example of a growing discussion about how to manage or govern changes in the global environment based on Earth System science (see also, Nilsson and Persson, 2012, Biermann, 2012, Galaz et al., 2012, Wijkman and Rockström, 2012).

However, efforts to reform governance arrangements to fit the Earth System perspective are far from uncontested. In preparation for the UN Conference on Sustainable Development in Rio de Janeiro in June 2012 (Rio+20), one of many critical voices was offered by Blomqvist et al. (2012) of the Breakthrough Institute. In a paper circulated prior to the conference, both the global implications of the planetary boundaries concept and the figures given for the Earth's environmental limits were questioned. The

Rio de Janeiro conference in 2012 became an arena for struggles over the feasibility of a planetary boundaries declaration (ICSU, 2011, Planetary Boundaries, 2012) and, while the debate initiated by Blomqvist et al. was deeply intertwined with the political dynamics of this intergovernmental meeting, it came to form part of a broader critical discussion on the intrinsically global gaze on Earth System science. In recent years, a growing number of scholars have questioned the Earth System outlook on the grounds that the categories 'human well-being' and 'humanity' pay insufficient attention to the aspects of culture, identity, power, and inequalities, and thus fail to take into account the key social dynamics of environmental change (O'Brien and Barnett, 2013, Malm and Hornborg, 2014). A growing number of social scientists and humanists have also begun to ask critical questions regarding what it means to be human in the Anthropocene (Pálsson et al., 2013, Clark, 2013, 2014). Rather than approaching humankind as a homogenous and collective force within the Earth System, a growing scholarship is calling for more nuanced and differentiated representations of the heterogeneous human and non-human populations of the planet.

Central to this thesis is the assumption that the Earth System is becoming an object of governance. While Earth System scientists work to define and quantify this object, the aim of this thesis is to interpret how the Earth System concept came into being in the first place and, to that end, I set out to trace the history of the present understanding of the concept. Tracing the history of the present was proposed by Foucault (1990: 10) as a way to study problematisations of who we are, what we do, and the world in which we live, and Foucault's mode of studying history informs this thesis in two important and related ways.

Firstly, this thesis adheres to Foucault's (1983) understanding of knowledge as a set of interpretations of our encounters with the material world, which in turn are based on earlier interpretations. As any search for the origin or essence of things will thus yield nothing but endless layers of interpretations, the focus in this thesis is instead turned to how knowledge is productive, in the sense that it enables certain kinds of actions to be performed while simultaneously restricting others (Dreyfus and Rabinow, 1983). Secondly, this thesis is inspired by Foucault's 'effective historicism', which is closely connected to the above in that it implies a history which challenges what is taken for granted in the present, from the vantage point that the existence of constant objects or pre-ordained directions on the path through time are a fallacy (Foucault, 1977). Thus, to trace the history of the present entails a critical study of how current problems and solutions come into being and gain effect (Dean, 1994).

As argued by Brown (1998), political rationality, with its norms and tactics, always flow from descriptions of reality and assumptions about the problems that need to be solved. Thus, the ways in which objects such as the Earth System and problems such as

global change, are formulated have profound effect on the politics that seek to deal with them (Miller and Rose, 2008). From this analytical horizon, the Earth System is far from necessary, but rather *the contingent effect* of an ongoing and historically entrenched interplay between scientific practices and systems of ideas. However, since becoming established as a proper unit of analysis, the Earth System has become an important reference point in environmental politics and, thus, has effects on how problems and solutions are discussed and devised.

In 1999, the efforts of scientists to understand the Earth as a system were described by Schellnhuber (1999) as a second Copernican revolution. The argument, published in *Nature*, was illustrated by an image of a surgeon in space, opening the atmospheric skin of planet Earth and observing the interlinked biogeochemical processes going on beneath the surface (the image is reproduced on the cover of this thesis). As suggested by scientists studying the social aspects of science, ways seeing and knowing the Earth from space appear to be closely intertwined with the birth of a global environmental consciousness in the 1960s, and the rise of international environmental cooperation in the 1970s (Jasanoff, 2001, Höhler, 2008). While a perspective from space is central to the understanding of the global environment as an Earth System, the ability to place a ‘surgeon’ in space draws on a scientific apparatus extending far beyond remote sensing. The ability to speak of the Earth System with scientific authority refers to the growing international cooperation of scientists, which traces its history back to the International Geophysical Year in the late 1950s. Furthermore, Earth System scientists occasionally make reference to an even older intellectual heritage, which claims that physical dynamics and life co-produce the environment. In the 1920s, the Russian scientist Vladimir Vernadsky (1998) refined the contemporary understanding of the Biosphere, the living envelope of the Earth, which was inaugurated as a concept by Austrian geologist Eduard Suess (1904) in the 1870s. The American diplomat George Perkins Marsh (1869) was a contemporary of Suess, and was the first to quantify human-induced environmental change on an international scale. At that point, a discussion related to the argument made by the Scot James Hutton (1788), who asserted that the Earth is in a state of constant change due to interacting geophysical and biological factors, had lasted for almost a hundred years.

More recently, the production of scientific knowledge regarding these interactions has been considered to be a key task of the global change research fostered within the International Geosphere-Biosphere Programme (IGBP). Since 1986, this international programme has invoked ‘the Earth System’ as a framework with which to unite the physical, biogeochemical, and, later, human sciences into an integrated and predictive framework (Dahan, 2010, Cornell et al., 2012). This thesis is an answer to the call to critically examine the underlying assumptions that facilitate the appearance of the Earth

System as a knowable entity (Lövbrand et al., 2009). As such, this study engages with the history of environmental science in ways that raise questions regarding its relation to current environmental politics.

1.1 Aim and research questions

The aim of this thesis is to critically examine how the Earth System has been constituted as an object of concern in global change research. Hence, rather than approaching the Earth System as a pre-given object to be discovered by scientific methods, this study will consider it to be the contingent effect of tensions in a landscape of problems, technologies, and practices which has developed and advanced within the broad and diverse field of global change research. Following Michel Foucault's nominalist approach to history, this study questions the naturalness of contemporary ways of seeing and knowing the global environment; rather than searching for the essential properties of the Earth System itself, the process by which these properties are conceived of and gain effect will be explored.

By encountering the Earth System as an 'object of concern', this thesis draws attention to the interface between engaged research communities, funders, and policymakers. A closer study of the internal discussions and politics within the Earth System science community may have offered a more detailed historical account of the many disciplinary negotiations and conflicts that have paved the way for the contemporary Earth System outlook. However, while this is important in other contexts, this thesis does not concern itself with the internal power politics of global change research; instead, it focuses on the constitutive effects of the knowledge claims, problem formulations, and sets of ideas produced at the intersection between scientific disciplines, funders, and policymakers involved in global change research. In essence, this thesis traces the history of ontological claims regarding what the Earth System constitutes, what kinds of environmental challenges the concept produces, and how these are best governed.

In order to grasp the Earth System sciences' intellectual and practical qualities, the research presented in this thesis is guided by the following three questions:

What is the effective history of the Earth System metaphor and scholarship?

Which scientific problematisations underpin how the Earth System is understood and represented in global change research?

How does Earth System science construe and portray contemporary environmental challenges, and with what political implications?

In this thesis, I trace the history of the present scientific articulations of the Earth System, which grant humans and ecosystems decisive roles in planetary dynamics. This

history is primarily approached via the scientific discussions fostered by the IGBP, which was the first international research programme to utilise the concept of the 'Earth System' to understand and predict the interlinkages and feedback loops existing between the biological, chemical, and physical systems of the Earth. In order to understand how 'the human component' of this Earth System has been depicted over time, this thesis also draws upon the Earth System discussions developed under the auspices of the IHDP. The inception of the IGBP in 1986 and the Human Dimensions Programme in 1987 provide the starting point for this empirical study. The articles included in this thesis trace the history of the Earth System outlook up until the global change conference entitled 'Planet under Pressure', held in London in March 2012, and the planning of the new global change research programme 'Future Earth' in 2013. Particularly the IGBP, but also the IHDP, have collaborated closely with the World Climate Research Programme (WCRP). This programme was established in 1980 to study the physical climate system. Although many previous studies have traced the roots of the Earth System outlook to the expansion of climate models (see, Edwards, 2010, Gramelsberger and Feichter, 2011), the WCRP did not begin to develop an Earth System vocabulary before 2000 (WCRP, 2005). For that reason, this thesis focuses on the research developed within the IGBP and the IHDP, although important developments within the WCRP are also taken into account.

Moreover, the global environmental change research carried out through the IGBP and the IHDP represent a research landscape which is far too vast to explore in a single research project. Therefore, this thesis pays particular attention to the efforts to develop integrated Earth System models within these two programmes. As expressed in the planning process of the IGBP, the "evolution of models of the various components of the Earth System, and of the system as a whole, is envisaged as the central unifying activity of the IGBP" (IGBP, 1986: 8). In this thesis, the numerical models themselves are not the primary focus; rather, it is the ways of seeing and knowing the Earth System that they have fostered which are considered at length. By seeking to harmonise different research traditions, these models have promoted the development of integrated knowledge of the 'system as a whole'.

In the hope of avoiding unnecessary misunderstandings, and due to the fact that attempts on the part of the author to present this work as a critical study of scientific knowledge production about global change occasionally generate responses along the lines of 'So... you're a climate sceptic?', I will add a very short personal note. My point of departure for this thesis project was that the only reasonable sources of knowledge on climate change, particularly regarding its future trajectories, are global simulation models and, furthermore, that this particular problem must be understood and governed at the global level. This personal conviction motivated a research design that set out to trace not *why* it was rational to think in this way, but rather *how* it became rational to do so. The

focus of this project therefore turned to the history of the international research underpinning global images, scenarios of possible futures, and particularly the history of the IGBP, the organisation where the term 'Earth System' first gained resonance (IGBP, 1986) and where the concept of the Anthropocene was coined in 2000 (Crutzen and Stoermer, 2000). After having studied the discussions among Earth System scientists for almost five years, I still believe that global simulation models are indispensable tools for producing knowledge regarding global environmental change. However, I am equally convinced that such technologies produce ways of understanding problems which are neither self-evident, nor separable from the practices producing them.

Hence, approaching the present Earth System ontology as the result of an effective history enhances reflections on the role of science in society, to the benefit of both political debates and dialogues between the scientific establishment and citizens. In the end, efforts to see and know the Earth as a system are in this thesis approached as inherently social practices which are deeply embedded in cultural understandings of nature and society's relationship to it; as a consequence, all interpretations of the production of knowledge about the Earth System (or any other phenomenon, for that matter) will unavoidably say more about the society asking for, producing, and using a particular kind of knowledge than about the Earth System as such. The latter is for Earth System scientists to answer.

1.2 Outline of the thesis

This thesis is organised as follows: Chapter Two provides a brief introduction to the scientific and institutional context in which the IGBP and IHDP research programmes coordinate their research. Chapter Three, the analytical point of departure, develops an 'effective historicism' along Foucauldian lines, emphasising the study of problematisations and governmentality. Chapter Four discusses the empirical material and research methods used in this thesis. Chapter Five connects the research presented in this thesis to existing literature related to the history and politics of global environmental science. Finally, Chapter Six discusses and synthesises the results of the individual papers in relation to the overarching aim and research questions.

2 Background to Earth System Science – basic ideas and institutions

The empirical investigation presented in this thesis takes its starting point in 1983, when plans for the IGBP began to take shape in the discussions of both the International Council of Scientific Unions (ICSU) and the National Research Council of the United States (USNRC). It was in the IGBP (1986) that the concept of the 'Earth System' was first put into action in a research programme. The use of the Earth System also exemplifies the close cooperation between knowledge-producing organisations; in 1986, NASA's Earth System Science Committee presented the Earth System as a conceptual framework for studying the combined physical, chemical, and biological aspects of the planet (NASA-ESSC, 1986). Among others, committee chairman Francis Bretherton was active in the planning of the IGBP during this period. The personnel overlap between this committee, the ICSU, the Ad Hoc Planning Group of the IGBP, and the National Research Council shows how integrated these organisations are and, hence, how difficult it is to attribute new ideas to only one of them.

However, efforts to understand the planet as a whole have a much longer history. This chapter therefore offers a short and descriptive background to the 'Earth System' as an object that can be known, measured, and understood in order to contribute to the management of global environmental change. This short outline takes the emergence of an international regime on environmental problems after the Second World War as its beginning. Along the way, it considers the institutions and organisations that are commonly related to the discussion on Earth System science, and proceeds to say a few words regarding the intellectual history of the Earth System in order to provide a backdrop for a presentation of two more recent declarations which consider the Earth System to be a problem: The Amsterdam Declaration on Global Change from 2001, and the State of the Planet Declaration from London, 2012.

2.1 An institutional context

As argued by the historian and sociologist of science Steven Shapin (1998: 5), objective knowledge, or 'Truth', has long been treated as the 'view from nowhere'. He suggests that science is a deeply social activity which is full of local scientific cultures and styles of science. Shapin argues that Truth and science rest on the question of 'whom we trust' and, since the late twentieth century, this trust has shifted away from the moral qualities of 'gentlemen', to be placed instead in 'expertise', methods and the institutions that guarantee it. Until a Foucauldian version of this practical understanding of scientific knowledge can be introduced and explicated in the next chapter, an acknowledgement of the fact that

scientific knowledge and expertise always emerge in a material and cultural context will suffice as motivation for presenting an outline of the institutional framework from which Earth System science emerged.

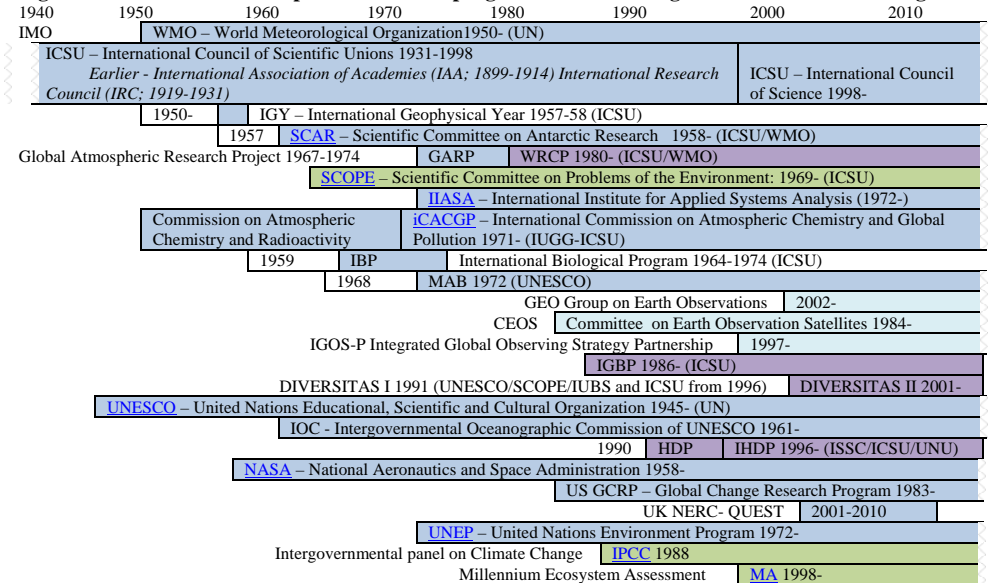
Since at least 1904, science has played an important part in collaborative attempts to bring about the conservation of nature; in that year, German botanist Hugo Conwentz argued for the preservation of natural monuments based on their scientific value (Lekan, 2004). Since then globalisation has radically amplified the international interdependences. Increased flows of resources and information, has brought people and organisations closer together and thus also paved way for a mental globalisation increasing the attention to world spanning issues (Beck, 2000, Selin and Linnér, 2005). The number of international agreements concerning the preservation of nature, as well as the management of the environment, has grown steadily since the late nineteenth century (Meyer et al., 1997). The focus in these international agreements has shifted over time, from a concern regarding species and aesthetic places, to resource management in relation to a growing world population (Worster, 1994, Linnér, 2003). Connected to these agreements are institutions and organisations providing scientific expertise on the global environment, and examples of the importance of scientific knowledge in policy formulations have been shown in relation to the problem of the Ozone hole and 'The Montreal Protocol on Substances that Deplete the Ozone Layer' (Haas, 1992a, Litfin, 1994), and regarding climate change and the IPCC (Miller, 2004, Bolin, 2007).

A second motive for this international scientific cooperation stems from weather predictions for regional use, which are seen as being driven largely by scientific needs and interests. Cooperation regarding the sharing of data, particularly relating to the field of meteorology, also grew from the late nineteenth century onwards, and escalated with improvements in information technology during the twentieth century (Edwards, 2010). A third motive relates to the Cold War; on the one hand, knowledge about the functioning of the global environment enabled analysis of the possible effects of an atomic war and detection of nuclear test sites through the circulation of isotopes and naval vessels (Doel, 2003, Dennis, 2003). On the other hand, as the UN conference on the human environment in 1972 demonstrated, cooperation on environmental problems provided a forum for the superpowers to interact in a more peaceful manner (Linnér, 2003). At a more fundamental level, scientific cooperation was a strategy to increase trust between the superpowers of the Cold War, as well as to generate public support for expensive defence projects (Miller, 2001).

Figure 2.1 summarises organisations commonly referred to in the literature on the Earth System and global environmental change. The timeline shows that international cooperation in the fields of meteorology and atmospheric physics began early (WMO, IGY, SCAR, GARP), closely followed by the chemistry of the atmosphere, with the non-

state ICSU acting as primary sponsor. The organisations concerned with biology and the productivity of the ecosystems appeared only a decade later (IBP, MAB). The closer relation to resource management problems is shown by the increased role of UNESCO; in 1969, as the planning for the UN Conference on the Human Environment commenced, the ICSU launched an assessment committee to provide a unified scientific voice on problems of the environment (SCOPE). For many years, this committee was a scientific forum for a broad range of natural and social researchers (Greenaway, 1996), and many of the influential scientists involved in the International Global Environmental Change Research Programmes have worked together within SCOPE; cooperation usually continued into the more recent and well-known assessment bodies of the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment (MA).

Figure 2.1 Institutions and important research programmes related to global environmental change



In the figure, **light blue** indicates organisations for planetary observation, **green** is used for assessment organisations, **purple** represents the international global environmental change programmes, and **blue** is used for other institutions and programmes. **White** boxes indicate planning processes, where such information was available. Acronyms in parenthesis represent programme or project sponsors. Missing in this overview are sub-national research institutions.

Despite its three decades of existence, the global environmental change research programmes (marked by purple boxes in Figure 2.1) are among the more recent of the large, collaborative, knowledge-producing cooperations; the World Climate Research Programme (WCRP), sponsored by the ICSU and the WMO, is the oldest among them, and draws most directly on the heritage of the International Geophysical Year. The International Geosphere-Biosphere Programme (IGBP) commonly traces its history back

to both the International Geophysical Year and the International Biological Program. As the social sciences would be left out of the IGBP, a Human Dimensions Programme (HDP), sponsored by the ISSC and the UNU, was launched in 1990. In 1996, the ICSU joined as a co-sponsor to the HDP, which was also reorganised under a new name; the International Human Dimensions Programme on global environmental change (IHDP). In 2001, DIVERSITAS, which focuses on biodiversity, was the last programme to join the global environmental change programmes.

Cooperation in the wider global change community with regard to research, assessment, and policy-making is as interconnected as the four global environmental change programmes are. Over time, researchers move between programmes, and are frequently involved in more than one of them during the same time period.

As this institutional landscape took shape, it was primarily organised around particular problems (e.g. weather prediction, nuclear radiation, population/food, or pollution). With access to satellite data, simulation models, and accelerating computer power, the 1970s brought with it a growing interest in the interaction between various parts of the environment, and, in the early years of the decade, research groups began to develop dynamic models of the relations between different systems. One early example is Jay W. Forrester's (1973) pioneering work on world dynamics in the World II model, which also underpinned simulations of global dynamics in the Club of Rome's famous report, 'Limits to Growth' (Meadows et al., 1972). Systems analysis was fostered at the International Institute for Applied Systems Analysis (IIASA) in Vienna which, from 1972, provided a forum for discussions between the East and the West, based on simulations of possible futures. Together with SCOPE, the IIASA is one of the places of great significance where many important global change researchers have worked during their careers. During the year in which the IGBP was launched, researchers at the IIASA launched their 'Sustainable Development of the Biosphere' programme (Clark and Munn, 1986).

The Earth System concept can be traced back through the inauguration of the Earth System Science Committee, which was convened by NASA in 1983. In fact, NASA had been thinking along these lines earlier, under the auspices of 'global habitability' (Goody 1982, see also, Lambright 1997); however, as their 'Global Habitability' Programme failed to gain sufficient international and domestic policy support, it had to be abandoned (McElroy and Williamson, 2004) - another reminder as to the importance of the institutional context regarding the funding of research. Thus, physicist and historian of science, Spencer R. Weart (2003: 150), traces the origins of Earth System science to the shrinking budgets for research in the United States; moreover, Weart asserts that the Earth System Science Committee emerged as a NASA-coordinated response, with the aim of creating a coordinated framework with which to study the planet as a whole and, perhaps more pragmatically, in order to secure funding in a time when Cold War research could

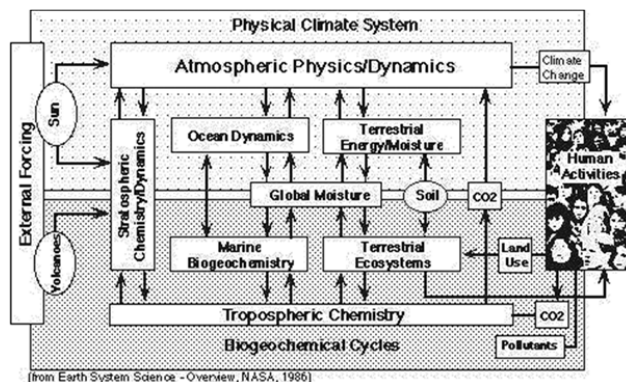
no longer be depended upon to do so. During these same years, the ICSU set out to organise an international research programme directed at global change, in order to move from solving "the 'crisis of the month' ... to establish a comprehensive scientific framework for dealing with these crises" of global change (Malone 1985, p. xviii); here, again, the issue of economic considerations as a driving force is invoked. Kwa (2006) argues that the interdisciplinary design of the IGBP was strategic work on the part of science policymakers and funders to steer research towards policy relevance and make more out of steadily diminishing budgets. Furthermore, the IGBP has been argued to be a way for the ICSU to direct available research funding, as both the US and the UK withdrew from UNESCO in 1984 and 85 (Dickson 1986).

2.2 Some basic ideas in Earth System science

This thesis will show that there is no clear definition of the Earth System, but rather that definitions change over time and, more crucially, differ between research communities. In order to highlight central questions, this section utilises tensions and contrasts between the scientific fields dealing with the concept.

The concept of the Earth System is sometimes used to refer to the global system that emerged during studies of the interaction between global biogeochemical cycles, such as those of carbon or nitrogen (Jacobson et al., 2000b). More physically-oriented definitions consider the Earth System to represent an expanded knowledge about the climate that now also include hydrology, biology, etc. (Paillard, 2008). It is also common to refer to the conceptual model of the Earth System developed by a research team at NASA between 1983 and 1988; in this wiring diagram, both the physical climate and the biogeochemical cycles are organised on equal terms.

Figure 2.2 The Bretherton diagram of the fluid Earth System



(NASA-ESSC, 1986)

In line with the two approaches to the Earth System mentioned above, there are two main auto-historiographical narratives which attempt to locate the origins of the research approach. One takes its point of departure with the more recent interest in the Earth System within climate change research (WCRP, 2005) and assessment (IPCC, 2013). Here, historians of science trace the concept via the gradual inclusion of an increasing number of processes into global climate models by the atmospheric sciences (Edwards, 2010, Gramelsberger and Feichter, 2011). From this perspective, the increased computing power placed at the disposal of meteorologists has gradually allowed for the inclusion of hydrology, biogeochemistry, and, eventually, ecology into their models.

A second narrative regarding the origins of the concept follows the study of biogeochemical cycles via global change and into Earth System science (Jacobson et al., 2000a). Following this strand backwards brings in the work on the biosphere initiated by Eduard Suess (1904) in the late-nineteenth century, which was developed by Vernadsky (1998) in the early decades of the twentieth century. Going even further back brings in the contributions of Scottish Enlightenment geologist James Hutton who, in the late-eighteenth century, argued that the Earth was not a stable, divine creation, but under constant change due to interacting geological and biological phenomena; pioneering the scientification of geology, he argued that observation had primacy over religious texts and theological speculation (Boardman, 2010). Vernadsky's suggestion that the biosphere could, and had to be, analysed as a thermodynamic system sparked a theoretical discussion from which an early visionary example of the expectations of a future understanding of the Earth System derived.

"If we assume certain physical conditions, mass, temperature, etc., of the original earth-filament, it should (with greater knowledge than we now possess, of course) be possible to construct a system of equations that would represent all phases of the earth-system from its initial one to that ultimate phase which we envisage in the remote future ..."

(Professor Johnstone in 'Entropy and Evolution', , 1932: 291)

As visible in the Bretherton diagram (Fig. 2.2), both of these narratives of the origins of Earth System science place the human dimension at the margins, on an equal standing with other 'external forces'. As was explicitly stated in the report from the NASA Earth System Science Committee (NASA-ESSC, 1988), a key part of the new approach to global change studies of Earth System science was the expanded timeframe, which proposed that the Earth's dynamic system should be understood on all timescales. This contrasted with earlier attempts to study global change, both at NASA and elsewhere; Goody and the global habitability programme had primarily focused on timescales from

a human perspective, since this was thought to be most relevant for policymakers (Goody, 1982, Conway, 2008).

Already, the 'Global change – impacts on habitability' programme suggested by NASA in 1982 had brought a new approach to the study of global change, due to its connecting the field to the natural sciences. In the 1970s, the concept of global change began to be used in social and economic studies on the causes and effects of globalisation, which "refer[ed] to changes in international social, economic, and political systems" (Price, 1989: 18, Cox and Sinclair, 1996). The history of social studies on global change, along with the impact of human activity upon the physical environment, is usually traced back to the work of American diplomat George Perkins Marsh, who produced an early account of the impact of industrialisation. This integrated study of humans and the environment was taken up by geographers (Kates, 1987) and these studies later played a key role in bringing the human dimensions into global change research via the IHDP (Liverman et al. 2003).

2.3 Two declarations on global change - Amsterdam 2001 and London 2012

Certain events in the diverse intellectual and institutional landscape described above enable the production of condensed statements which articulate what the Earth System is and the problems connected to it. Such scientific descriptions are not neutral, but rather problematise human behaviour and point to more rational ways of interacting with the object of concern; i.e. better ways to act as subjects (Dean, 2010). The major problem described by Earth System science is human-induced global environmental change. The Anthropocene narrative places humanity on an equal footing with major geological forces, which in turn implies new ethics, modes of science, and policies in order to manage the global environment in a rational manner. Hence, how to understand problematisations will be an important part in the discussion of the analytical approach in the next chapter, and the question of how to interpret them will be central to the Materials and Methods chapter. The Amsterdam Declaration on Global Change from 2001, and the State of the Planet Declaration, formulated in London 2012, are two prominent problematisations in the history of Earth System science. These provide good introductions to the recent history of the Earth System concept.

The Amsterdam Declaration on Global Change was produced during the first open science conference on global change hosted by the four international global change research programmes developed under the auspices of the International Council of Science (ICSU); the IGBP, the IHDP, the World Climate Research Programme (WCRP), and DIVERSITAS. The conference provided an opportunity to synthesise results from the first decade of integrated Earth System research. The resulting declaration is an

important reference point for contemporary ways of seeing and knowing the state of the global environment. It is one of several specific events in the history of Earth System science when the environmental implications of human activity were called into question and new ways of thinking about and acting upon the global environment were enacted.

The declaration states that "the Earth System behaves as a single, self-regulating system comprised of physical, chemical, biological and human components" (Moore et al. 2002, p. 207). The detrimental effects of human activity on the natural processes and dynamics of the Earth System are thus presented as the central problem. Confidence in the scientific knowledge of the Earth System promoted it as "a sound basis for evaluating the effects and consequences of human-driven change". The declaration articulates the problematic description of the emerging Anthropocene discourse.

"Anthropogenic changes to Earth's land surface, oceans, coasts and atmosphere and to biological diversity, the water cycle and biogeochemical cycles are clearly identifiable beyond natural variability. They are equal to some of the great forces of nature in their extent and impact." (Moore et al. 2002, p. 207).

The declaration also stresses that global change is not something which will happen in the distant future, but that it "is real and is happening now" (Ibid.). The urgency is further underpinned by statements such as the following;

"the Earth System has moved well outside the range of the natural variability exhibited over the last half million years at least", and "The Earth is currently operating in a non-analogue state". (Moore et al. 2002, p. 207).

As such, the declaration argues for the notion of the planet as a complex system, by emphasising the position that "[g]lobal change cannot be understood in terms of a simple cause-effect paradigm". Instead, multiple effects of human activity interact and "cascade through the Earth System in complex ways". Understanding the present dynamic behaviour of the Earth System is based on a longer history which shows "abrupt transitions (a decade or less) sometimes occurring between" different states. Lurking beyond the reach of state-of-the-art scientific knowledge lie critical thresholds, over which human activity may inadvertently push the mode of planetary operation. The planetary boundaries suggested by Rockström et al. (2009) provide a more recent effort to show how these limits can be understood and quantified.

Based on the scientific description of a complex Earth System, the Amsterdam declaration also suggests "an ethical framework for global stewardship and strategies for Earth system management" (Moore et al., 2002: 207). Rooted in both the scientific requirements of understanding a global complex system and the urgency of changing ethics and governance, "a new system of global environmental science" was seen to be required. This new system calls for integration at all levels, and "the common goal must

be to develop the essential knowledge base needed to respond effectively and quickly to the great challenge of global change." By acknowledging the Earth System as the central object of knowledge and global governance, the declaration manifests the scientific framing of global change in 1984 (Malone and Roederer 1985).

Organised by the same four programmes as in Amsterdam, and gathering together 3000 scientific decision-makers, a second joint Open Science Conference on Global Change was held in London in March 2012; 'Planet Under Pressure: New Knowledge Towards Solutions'. This conference produced a declaration, now designated the State of the Planet Declaration (Brito and Stafford Smith 2012); this confirms the position taken in 2001, by stating that the "Earth system is a complex, interconnected system that includes the global economy and society". It also strengthens the image of the functioning of the Earth System as endangered by human activity, on a scale comparable to that of geological forces. In contrast to the Amsterdam declaration, the urge for action is much stronger, and examples are given for what needs to be done.

The Earth System articulated in the State of the Planet Declaration is more or less the same as in the Amsterdam declaration; "The Earth system is a complex, interconnected system that includes the global economy and society" - the functioning of which is at risk (Ibid.: 1). The Earth System has, furthermore, "experienced large-scale, abrupt changes in the past [which] indicates that it could experience similar changes in the future." The Anthropocene discourse is also articulated: "humanity's impact on the Earth system has become comparable to planetary-scale geological processes such as ice ages." Compared with the Amsterdam Declaration on Global Change of 2001, the relative importance given to defining what the Earth System is has decreased; on the other hand, the 2012 declaration is more confident, and communicates a greater need for action.

As in the Amsterdam declaration, the problem description of its London counterpart is connected to the need to change behaviours in order to meet the "the defining challenge of our age[, which] is to safeguard Earth's natural processes". More articulated in the State of the Planet Declaration is an emphasis on going from an understanding of global change to finding and, as quickly as possible, implementing solutions to the broad spectrum of interacting problems (e.g. poverty, overconsumption, values, ineffective institutions, etc.). Present governance is problematised, since "a new perception of responsibilities and accountabilities of nation states" is considered essential in the challenge of planetary stewardship. This argument is supported by "insights from recent research [which] demand" new modes of governance. In the declaration, the international global change research community "proposes a new contract between science and society in recognition that science must inform policy to make more wise and timely decisions". This contract includes sustainability goals, based on scientific assessments of how natural and social

processes interact. The focus on governance structures also problematises centralised government.

"There is growing evidence that diverse partnerships amongst local, national and regional governments as well as business and civil society provide essential safety nets should singular global policies fail – a polycentric approach for planetary stewardship." (Brito and Stafford Smith, 2012: 2)

In this study, the Amsterdam and London declarations are interpreted as key problematisations of a troubled relationship between humans and nature, which connect an ontology of the Earth System with ethics, problems, and solutions. However, as the declarations represent dense summaries of more nuanced discussions, attention must be given to how they were able to emerge with scientific authority. These scientific discussions are thus the focus of the papers and conclusions presented in this thesis.

3 Tracing the history of the present

"...knowledge is not made for understanding; it is made for cutting."

(Foucault, 1977: 154)

How we might understand the knowledge upon which we act has been analysed along two broad lines for over two hundred years, following Immanuel Kant's philosophical reflections on reason in the late eighteenth century. One of these strands of reasoning seeks to learn the conditions that enable true knowledge, and draws upon notions of a possible universal rationality, providing an "analytics of truth". The other represents a mode of critical questioning that asks for "the contemporary field of possible experience" or, as will be discussed below, "an ontology of the present" (Foucault, 1993: 18). Hacking (2002) strengthens Foucault's formulation in emphasising the historical character by calling it a "historical ontology".

The analytical vantage point taken in this thesis draws on the latter line of inquiry, understanding knowledge as being the product of the dynamic interaction between practices and ideas. Here, a web of historical relations produce seemingly independently existing objects (Daston, 2000). These objects and their effects are far from self-evident, and can be said to "not exist in any recognizable form until they are objects of scientific study" (Hacking, 2002: 11). Connecting scientific objects and problems with political effects, Brown (1998) argues that political tactics and norms flow from perceived needs to respond to problematisations offered in ontologies of the present. What follows is my analytical perspective, related to how to interpret the interaction between problem descriptions and the production of scientific knowledge, as well as political and scientific rationalities.

To provide a rational critique of rationality, Foucault suggested a need to empirically show the historicity of the "ontology of the present". At the core of Foucault's (1977: 142) genealogical approach is "the secret that [things] have no essence". Thus, the challenge for a genealogy is to provide an account of how a web of relations is turned into things, about which it becomes possible to make meaningful statements of true or false nature. By historicising things previously seen as eternal, this kind of study draws attention to natural and social facts (Saar, 2002, Shiner, 1982).

Historicising rationality does not, however, imply that rationality is arbitrary and, perhaps more crucially, does not accept the black and white question: 'Are you for or against reason?' Rather, a genealogical tracing of the history of the present is based on the argument that reason is historical in a non-deterministic way (Hoy, 1998). As a first, blunt positioning, the genealogical approach implies that there are no extra-historical universals to rely on in an analytics of Truth. Moreover, genealogy differs from what

Brown (1998: 37) calls progressive history, since it does not seek "lines of determination laid by laws of history"; more nuanced, this implies that a genealogical interpretation cannot presuppose any direction in the history it engages with, due to the fact that present accounts of such directions are an important part of the study. The genealogical approach argues that the interpreter inevitably becomes a part of the present ontology, and that interpretations of the historicity of knowledge provide a means for a rational critique of rationality.

The mode of interpretation suggested here differs from early hermeneutic interpretations, which sought to uncover buried universal meaning and coherence. Instead, genealogical studies suppose that our reality will always consist of interpretations based on other interpretations (Dreyfus and Rabinow 1983, p. 108), and that the role of the genealogist is to record the history of these interpretations. Hence, genealogy engages with "moving objects", assuming that words are used in different ways. This should be contrasted with "universals", which are assumed to have a stable ontological existence but probably shifting interpretations (Foucault 2007). As expressed by Walters (2012, p. 39), these moving objects in a genealogical work imply that it will always be "incomplete – *by design*".

As a Foucauldian reading of history, the analytical framework will be organised by the concepts of *governmentality*, *problematizations*, and *history of the present*. Three themes structure the discussion. The first concerns different versions of governmentality, where their applicability to studies of scientific discourses is argued for. The empirical focus on research programmes positions this thesis somewhat on the margins of governmentality studies, which usually interpret scientific knowledge more directly embedded in practices of government. Secondly, attention is turned to the ethos of Foucauldian studies, and how it effects and motivates the study of problematizations. The understanding of power and knowledge plays a key role here. In the third theme, the implications of a study of governmentality for the understanding of the production of ways of seeing and knowing will be discussed; i.e. fields of visibility and truth in scientific research programmes.

3.1 Governmentality

The concept of governmentality belongs to the later phases of Foucault's intellectual work. In his earlier works, *Discipline and Punish* and *The History of Sexuality*, Foucault (1995, 1998) took an interest in the micro-cosmos of power, engaging with how subjects are made in everyday practices. In the later stages of his career, he translated this micro-cosmos for an analysis of the operations and functions of the modern European state (Jessop, 2007), setting out to expand the analysis of power and the discipline of the individual body relative to the governing of populations (Foucault, 2007). The understanding of power and knowledge are the same, but Foucault redirects his

discussions about the state towards an understanding of power from below, i.e. from local practices (Rose and Miller 1992). This puts governmentality studies in contrast to those which approach the state as a single actor; a Leviathan, to use the words of Hobbes (Whitehead, 2009). Hence, governmentality functions as a grid with which to analyse relations of power, making it possible to conduct the conduct of people, from an individual up to the level of entire populations (Foucault, 2008: 186). Emphasising the notion that governing ventures beyond States, Rose and Miller (1992: 181) posited "conduct of conduct" as governing "at a distance". 'Governing' in this sense is to be interpreted broadly as meaning "to structure the possible field of action of others" (Foucault, 1983: 221). To the mind of Foucault, there was nothing universal about states; on the contrary, they are understood to be the aggregation of dispersed processes of governing. As argued by Walters (2012: 40), "governmentality does not exist in pure form anywhere". Instead, 'governmentality' refers to a particular configuration of power/knowledge relations.

As a research ethos, it therefore becomes reasonable to ask *how* objects of governance take shape; *how* certain sets of relations become problems which are subject to government action and correction. Here, scientific knowledge plays a vital role, by enabling and restricting the field of vision of governments and others engaged in governing (Dean, 2010: 41). Keeping in mind the ethos and historicity of *problems* and *truth*, the following section positions this thesis in relation to three different modes of *governmentality* studies. More particularly, it argues for the value of application of these concepts to the production of scientific knowledge in general, and to global change research in particular.

Simply stating that a thesis draws on governmentality studies is not precise enough, however, as the concept is used in various ways across different fields. Following Walters (2012), three major approaches to governmentality are identified in the literature. The first is primarily descriptive in character, due to the fact that governmentality is the label of the period in which the modern European State and its related art of government took shape (Foucault, 2007). In contrast to earlier modes of power which idealised a sovereign monarch, the process of governmentalisation gave rise to a new, more bureaucratic mode of governing and strengthened the position of scientific knowledge (Foucault, 1991).

Secondly, and related to modern modes of governing, Walters (2012) notes that the governmentality concept is currently employed in discussions related to the particular rationality of governing in liberal societies. In this Anglo-American tradition of governmentality studies, the concept lends itself to the study of government through freedom, a mode which is attentive to the boundaries between individual freedom and optimisation of the population as a whole (Dean, 2010: 29). Authoritarian governmentality as an art of government, which administers by fostering obedience to

authority, has been outlined by Dean (2002, Dean, 2010), as have the hybrid character of most states where liberal and illiberal modes of governing co-exist (Valverde, 1996, Walters, 2012, see also, Stoler, 1995, Sigley, 1996, 2006). Hence, it is far from self-evident that one may restrict the concept of governmentality to liberal and/or neo-liberal modes of governing. Further illustrating the broad usage of 'governmentality'. Foucault (1991: 102) suggested that a range of governing techniques are present at all times. However, at least in Western Europe, the relative balance between them has shifted from sovereign rulers, via the detailed discipline of individuals, to the government of society (or the population) as a whole.

The analysis in this thesis primarily draws on a third, broader understanding of governmentality. Experimenting at the interface between governmentality studies and actor-network theory, Rose and Miller (1992: 187) argued for analysing "political power beyond the state". Due to its neutral status, expert knowledge is seen as a part of liberal government, in that it provides authority to intervene in private spaces. As outlined by Walters (2012: 12), this analytical approach engages with the relation between problem descriptions and the related rationalities for governing oneself and others. Dressed in more theoretical terms, Foucault (1997: 299) called this relation the zone between "strategic relations" and "states of domination". This broad understanding of governmentality should not lead to the assumption that all interaction is a manifestation of governmental rationalities; rather, techniques of government have to be informed by some degree of rational calculation. Such reflection has to be grounded in knowledge about the objects to be governed. Foucault (2007: 496) exemplified this relation by stating that "governing less, out of concern for maximum effectiveness, in accordance with the naturalness of the phenomena one is dealing with". Considering the important role of scientists in the coalescing of the Earth System as an object of government, the analysis in this thesis focuses on how systems of ideas have modified the way global change is understood.

3.2 Problematisations

The relations between knowledge and politics have been an important topic in the historical analysis of ideas and science. Among other things, these studies display a history consisting of periods of relative stability, interrupted by gradual or sudden shifts (e.g. Lovejoy, 1940, Worster, 1994, Jamison, 2001). Foucauldian inspired studies of problematisations adds to this this long scholarly tradition by emphasising the interplay between ideas and materiality in the production of our ways of seeing and knowing. The Foucauldian history of the present is characterised not so much by a unified theory or method as by a scientific ethos that seeks to open spaces for reflection and multiple views concerning our present situation (Walters, 2012). Historical analysis inspired by Foucault

takes as its point of departure a particular problem in the present, and turns to the past to ascertain how it came to be seen and treated as such. Hence, this thesis is an analysis of *problematizations*, i.e. how particular social relations are organised as problems (Bacchi, 2012). Within the broad field of governmentality studies, this thesis focuses on the problematisation of the global environment as the Earth System. As argued by Dean (2010: 32), a good starting point in the analysis of the *how* of government is the specific places and times where behaviour is called into question.

In this thesis, the 'problem' is global environmental change, the evidence of which can be found in many different places. The mode in which environmental problems have been discussed has also varied over time. Deforestation, the ozone hole, growing populations in relation to global resource scarcity, and climate change are just a few examples of contemporary global environmental problems. From a Foucauldian perspective, these are never given, natural, or necessary, but the contingent effects of historical processes, and the organisation of all of these problems is based on scientific knowledge production, which render a complex materiality, visible as things or events. If climate change is taken as an example of an object of governance, one could, very simplistically, state that governance has thus far relied on an approach to climate change which measures changing concentrations of carbon dioxide in relation to effects on thermodynamics and, from there, the impacts on bio-productivity in different places (Jacobson et al., 2000b). Regarding the human dimension, feedback from climate-related land use and land cover change also has to be quantified due to its effects on the carbon cycle.

Effective problematisations require the production of knowledge which visualises the nature of the governed object. Moreover, enabling strategic governance of the climate requires that the effects of different emission-reducing policies are made visible. The 'object of concern' must be digested into the included components and how they interact in order for strategic decisions to be made. Rose and Miller (1992) argue that these (usually scientific but also ethical) accounts connected to problematisations produce a "political rationality" which defines what can and should be done; thus pointing to a close relationship between the diagnosis of a problem and its suggested solution (Miller and Rose, 2008: 15). At least from the perspective of governance, there is little point in identifying problems if one does not simultaneously seek to rectify them. Furthermore, it has been stated that "to become governmental, thought had to become technical"; a position which proposes "techniques to intervene" (Miller and Rose, 2008: 15, see similar argument in Dean, 2010: 27), which is contrasted with the observing role of the critic and philosopher. The research strategy of this thesis follows that of Dean as well as Rose and Miller, as it begins with problematisation and the 'political rationality' also produced by accounts of how the global environment should be understood.

As argued by Rose and Miller (1992), governing involves acting from a distance. Hence, direct governing of the material is a lesser concern than the problem of how to work upon the action of others, which Foucault referred to as the "conduct of conduct"; he further argued that the implementation of self-discipline techniques was an important component of governing. As pointed out in Foucauldian governmentality studies, this depends on whether or not others subject themselves to particular ways of knowing their field of possible action (Walters, 2012). The position that knowledge is itself far from self-evident adds two additional questions: What does it take to provide legitimate knowledge about global change, and who can provide this?

Foucault (1990: 10) argues that the task of the history of thought, and in effect that of the history of the present, is "to define the conditions in which human beings 'problematize' what they are, what they do, and the world in which they live". This implies an analysis of "the *problematizations* through which being offers itself to be, necessarily, thought—and the *practices* on the basis of which these problematizations are formed". The result is a project, the goal of which "is a history of truth" (Foucault, 1990: 11). Problematization is found to be useful as a marker indicating the importance of the process of becoming. In so doing, it highlights the analytical vantage point that problems are always a mix of ideas and materiality. Over time, a threefold interaction between practices, reflections on their shortcomings, and attempts to rectify these in relation to desired ends, which also exist in a state of flux, provides a mode for engaging with historical processes. Hence, as further developed in the chapter on methods below, the use of research plans and reflections on these as empirical focus provide a fruitful entry into the history of the present problem of global change.

Problematizations, i.e. the coming into existence of problems, have a double function, in that they also indicate that the issues under discussion are in need of rectification. As has been developed further by Rose and Miller (1992: 181), governing is a problematizing activity, where the "ideals of government are intrinsically linked to the problems around which it circulates". Their descriptive analytics of government from below can be contrasted with normative approaches which start with the ideals of government, such as efficiency or legitimacy (e.g. Biermann, 2007). In this thesis, problematization provides an argument for studying how global change was rendered problematic, and particularly how the Earth System provides a way of making the global environment visible, thus opening it for strategic calculation and particular forms of management. Turning normative analysis of government on its head opens up a space for studying the coalescing of problems in a more open-ended fashion.

3.2.1 *Power(/Knowledge)*

Motivating the analytical ethos for studies of governmentality and problematizations requires a closer engagement with Foucault's understanding of how power is related to

knowledge. In Foucault's view, power is primarily considered to be productive rather than repressive. Triantafyllou (2012: 8) exemplifies this in discussing the disciplinary techniques employed in order to conduct the conduct of skilled workers and citizens with rights and responsibilities in modern societies; the very same processes have also created new ways of thinking about and debating how to organise most parts of public and private life. The core of this argumentation is that the shaping of subjects in modern society must work on the abilities and desire of the subjects, rather than through repressive force. Programmes for the conduct of conduct have to connect knowledge about the subjects with desired ends and means in order to be effective. Here, it becomes apparent that the close relationship between power and knowledge is mutually dependent, and that the two are not reducible to one another. Working through the relations between free subjects, power requires truthful knowledge in order to function. As Dean (2010):44 puts it governing is only effective to the extent that subjects experience themselves through the categories and abilities produced by knowledge. Thus, while knowledge is not a veil used to conceal real power, neither does authoritative knowledge determine power (Triantafyllou, 2012: 11). The interpretation of power as a productive relation differs from how the concept is often used in social and political science. In order to illustrate the manner in which 'power' and 'knowledge' are used in this thesis, they are first explained separately, although they are to be seen as two sides of the same coin.

The first component, power, has been nicely systematised as four faces by Hay (2002). First, in the process of decision-making, power is a resource that enables an actor to produce an effect upon others; as classically formulated by Dahl (1957: 202), "A has power over B to the extent that he can get B to do something that B would not otherwise do". Dahl's words describe power as repressive, and represent a very direct form of power, as a resource which is controlled and used deliberately. In contrast, Foucauldian studies introduce a productive mode of power into social science research, and so Dahl's view of power is radically opposite to that of Foucault. However, the range of approaches to power extends far beyond those of Dahl and Foucault. The second face of power relates to setting an agenda, in that it functions to delimit which issues are open for decision-making and which are not. The repressive and agenda-setting approaches to power have, however, been criticised for failing to analyse situations in which no explicit conflict of interests can be identified. With regard to preference-shaping, Hay's third face, power is considered to be a largely invisible or structural force which shapes interests; in this vein, ideological critique provides a methodology with which to unravel the interests enhanced by social structures. The fourth face of power, which is championed by Foucault, argues that power is always present and, in contrast to the previous three faces of power, is here understood as both limiting and productive, due to the fact that it does not simply restrict action, but also enables it (see also, Hindess, 1996, Lukes, 2005).

Hay's four faces are well illustrated by Barnett and Duvall's (2005: 12) categorisation of power along two axes. The horizontal axis distinguishes between direct and diffuse relations of power, and the vertical between power as actions by specific actors and power constituted as relations. The four-field matrix illustrates compulsory power (actor to actor), institutional power (actor to context/institutions), structural power (social positions to relations of domination), and productive power (multi-dimensional relations to subject positions).

Figure 3.1 Types of power as presented by Barnett and Duvall (Hay's four faces of power added)

		<i>Relational specificity</i>	
		<i>Direct</i>	<i>Diffuse</i>
<i>Power works through</i>	<i>Interactions of specific actors</i>	Compulsory (Decision making)	Institutional (Agenda setting)
	<i>Social relations of constitution</i>	Structural (Preference-shaping)	Productive (Power/knowledge)

Source Barnett and Duvall 2005, p.12

In clear contrast to Dahl's search for an exact definition of power, Foucault explicitly resisted developing a 'theory of power'. Based on a nominalist viewpoint, power is not seen as something that exists and can be defined, and Foucault opposes any perspectives which are founded on such definitions (Walters, 2012, Lemke, 2011), his argument being that this leads to a commodification of power as something which is possible to possess and therefore resides in the hands of actors. Instead, Foucault (1978) accounts for power as dispersed and relational; it is thus not understood as a thing or resource which can be owned, but as a web of relations beyond the control of any individual actor or group. Power is "non-subjective" (p. 94).

Hence, the analytical approach involves the interpretation of the web of relations which makes it possible to speak as an expert, rather than attributing power and interest to particular actors; thus, a Foucauldian analysis suggests a more open-ended approach to power, based on the effects produced by particular power-knowledge nexuses. As power, along with knowledge, is considered to be productive, it furthermore is constituted by conceptions of what is right, true, and necessary, and thereby shapes the ways people think and act. This thesis encounter the rendering of global environmental problems and the Earth System as problematic objects, about which scientific knowledge is possible as productive power.

3.2.2 (Power/)Knowledge

Knowledge makes 'things' visible and simultaneously produces relations of power which can be submitted to strategic calculation (Dean, 2010). Accepting that 'things' become visible at the intersection between ideas and materiality implies that objects are never to

be considered as neutral entities. Foucault (1977) states that the will to cause effect is one of the drivers behind the production of knowledge due to the fact that it increases the chances of achieving the desired effect. Later, Foucault (1983) articulated the will to knowledge as a strategy, as it was seen to be connected to the achievement of desired effects. As it is the result of problematisations and strategies adopted to cause a certain effect, knowledge about an 'object' such as the Earth System is always intentional in character. However, knowledge is also ambivalent and non-subjective, in the sense that it is not controlled by any single actor. Also, since knowledge alone cannot change materiality, nor disposition it, it instead connects things with ideas of how to deal with them; hence, knowledge of what an object is must be interpreted in the context of the problems it helps to diagnose, as well as the remedies; i.e. the proposed actions, which are drawn from the ontological properties of the object (Dean, 2010). Thus, ontological statements are essential to those fields of power/knowledge that are involved in the conduct of conduct. This thesis primarily studies this relation in the conducting of scientific practices; the global change research programmes studied herein function as a means of fostering scientific practices, which in turn produce authoritative knowledge.

Understanding knowledge as practical and intentional has important implications for this thesis, as it places the focus not only on problematisation of the interactions within the Earth System, but also on how these emerge from apparatuses connecting the organisation of research by institutions, the material aspects of various technical devices (e.g. computers and satellites), the practices related to scientific knowledge production, and historical ontologies. Hence, knowledge production is here understood as an intentional but non-subjective strategy, adopted in order to cause a desired effect (i.e. the production of policy-relevant scientific results) and emerging in a heterogeneous setting of technologies, culture, and institutions.

In research inspired by the Foucauldian perspective, this has been termed 'dispositif', translated into English as 'apparatus' or 'assemblage' (Triantafillou, 2012). Foucault explained that his intention with the concept was to show how multiple components, such as institutions, regulations, ethics, and scientific statements, together form an ensemble of materiality and ideas wherein power can operate; more precisely, the *apparatus* is the system of relations between these components (Foucault, 1980a: 194). In other words, the apparatus seeks to provide a space for analysing the mute materiality and practices, as well as more vocal systems, of ideas or discourses. The analytical aim is to capture the heterogeneity of the possible connections that are assembled during a specific period in history in response to 'urgent needs' (p.195)

Since each apparatus is unique, analyses of them have to remain open to include all interactions that facilitate problematisations, production of ontologies, and interventions to rectify diagnosed problems. As argued by Triantafillou (2012), a study of productive

power does not trace the power of individual agents in these apparatuses, but rather the total effect of it, along with the manner in which it enables certain forms of governing. In this thesis, the apparatus concept is used to support interpretations of how the Earth System was able to emerge as an object of concern, and does so by tracing the arrangement of organisations, technologies, and practices, along with the resulting effects.

The result of placing the production of knowledge at the intersection of ideas and materiality is that the study of 'practices' has been given a central position in many studies on governmentality (Miller and Rose, 2008, Dean, 2010). Since the empirical material studied in this thesis consists of documents and interviews, a few words should be said with regard to the analytical approach of the thesis in relation to this. As will be further developed in the chapter on method below, the documents studied are interpreted as remnants of the practices of problematising recent developments in Earth System science and global change research; related to this, the documents are also understood as remnants of the practices of aligning international research networks with the production of policy-relevant knowledge about global change. Followed over time, these practices of problematisation display the intricate connections between the problems that need to be solved and the solutions suggested in relation to the ends that motivate research. After presenting governmentality as an important analytical concept for this thesis, I will return to the connections between knowledge production and the governing of societies.

3.3 The production of scientific truth as a part of the governmental apparatus

One of the effects of the dynamics of positivistic science is that it produces a view from nowhere (Shapin, 1998). Here, I follow the advice of the geographer of science David Livingstone (2003: 184), who argues that this objective view should be replaced by a "view from somewhere". In line with the Foucauldian perspective on power/knowledge, Miller and Rose (1990) argue that political discourse is more than just rhetoric; political rationalities are, rather, to be seen as parts of an "intellectual apparatus for rendering reality thinkable in such a way that it is amenable to political deliberations" (Rose and Miller, 1992: 179, Dean, 2010). As such, political rationalities are "articulated in relation to some conceptions of the nature of the objects governed" (p. 179). This thesis engages with the Earth System as an object to be governed, i.e. as an 'object of governance'. The historical and spatial character of knowledge described in this chapter motivates a study of the formation of the present understandings of the Earth System as an object of governance and, furthermore, to make an attempt to record the history of interpretations as argued by Dreyfus and Rabinow (1983); the latter in particular directs attention to the organisation of scientific knowledge production.

As this thesis focuses on scientific knowledge production regarding the Earth System, it diverges slightly from the mainstream of governmentality studies, which generally focus on the everyday practices of governing (e.g. forms of calculation, methods for categorisation, standard-setting practices). This is particularly true for studies belonging to what Jessop (2011) refers to as the Anglo-Foucauldian approach to governmentality studies, with Rose, Miller, and Valverde as its key figures. However, the workings of science are far from outside of the realm of governmental practices, and this is exemplified by the work of the Intergovernmental Panel on Climate Change (IPCC), which shows how important science is for the rationalities of environmental governance (Stripple and Bulkeley, 2014).

Studies of the relation between science and policy tend to treat scientific knowledge as a sidekick to power, a resource to bring in or ignore at the convenience of policymakers. In line with Whitehead's (2009: 25) concept of "government with science", this thesis argues that, even if political ambitions act as important influences on knowledge production, an analysis of the latter has to allow for a science that is often a driving force behind change in its own right. An important contribution of Whitehead's study of the interaction between scientific knowledge and governing is that it shows that aligning governmental legitimacy to decisions based upon scientific knowledge sometimes causes problems for the original political agenda; the outcomes of scientific practices are neither predictable nor fully controllable, as the dynamics of scientific knowledge production make a commitment not to rely on "fixed techniques of truth telling, but on the basis of an open commitment to ever-changing forms of practice, technique and technology that can, at any point, falsify governmental truth" (p. 25). In other words, the results of scientific methods can support, as well as problematise, political agendas, and so scientific practices have to be approached with the understanding that they have agency. As shown in the papers and discussion presented in this thesis, research on the Earth System exemplifies this ever-changing form of scientific knowledge production. Connecting Whitehead's argument with the importance of scientific knowledge in the governmentalisation of States motivates a historical study of how scientific practices have rendered the problem of global change calculable, by making the Earth System visible as a particular object of government.

In contrast to theories starting from the definition of what a State is (or should be), an analysis of governmentality starts with the practices of governing that may or may not become a part of a State. A State should not be seen as a single, sovereign source of power, but rather as "the mobile effect of a regime of multiple governmentalities" (Foucault 2008, p. 77). Moreover, a government should not be understood as "expressions of a particular principle, reducible to a particular set of relations, or as referring to a single set of problems and functions" (Dean, 2010: 41); instead, regimes of government should

be considered as being constituted by multiple elements, which do not necessarily fit well together. An essential part of a regime of government is the production of knowledge, usually including scientific practices. This apparatus plays an important part in the rationalities for the production of Truth (Dean, 2010). This thesis traces the production of governable reality in research programmes which, in spite of their formal independence of States, are nevertheless reliant on the financial support of these governments. Studying governing bottom-up, these international research programmes are found to be central to the field of power/knowledge which stabilises the problem of global change. As argued by Dean (2010: 33), governing is characterised by specific forms of visibility or ways of seeing, specific ways of thinking, and "procedures for the production of truth", all of which are highly dependent on scientific practices. In the case of the Earth System, this can be exemplified with the issuing of authoritative accounts of the future state of the planet.

The application of governmentality opens a particular analytical space in which to study scientific knowledge production as one aspect of governing. Here, the Foucauldian understanding of how objects are made visible through historical practices allows for an interpretation that does not presuppose theories of how science and scientific knowledge connect with government (Jessop, 2007). Hence, the analysis is open for the heterogeneous components that have shaped what is seen as a governable reality (Rose et al., 2006). From the vantage point of governmentality, the Earth System as an 'object of governance' becomes the manifestation of a history of a web of interactions between desired ends, ideas, materiality, technological devices, and the practices wherein all of these are realised.

3.4 The research ethos – history of the present as a critique

So, with problematisations, power, and knowledge as a backdrop, it is now possible for this narrative to return to the ethos of the Foucault-inspired 'history of the present' and 'effective history' developed for this thesis. The study of power/knowledge is commonly framed as a mode of analysis, rather than an effort to establish new theories (Triantafillou, 2012, Walters, 2012). Dean (1994: 4) eloquently formulates the different kinds of critique provided in relation to critical theory by contrasting critical theory with critical history. This thesis is less informed by a distinct Foucauldian 'theory' than it is by the research ethos which follows his analytical legacy, which seeks to foster reflection about how to engage with expert knowledge, identities, and power by making their history and dynamics visible (Taylor, 2011). As an effective history, it seeks to provide a view where our present is not the result of a history determined by laws or extra-historical reason; rather, it questions the potential implications of making decisions of a serious nature in an era which is increasingly referred to as 'the Anthropocene'. At best, the results of the

research presented in this thesis will make opaque the relations that produced our ontology of the present.

Analytical efforts to make the historical character of knowledge visible do not reduce knowledge to a subjective opinion. On the contrary, the analytical approach developed in this thesis attempts to understand how particular ways of seeing and knowing the Earth and global change have become accepted as scientific knowledge. Using the ontology of the present as a yardstick for visualising the paths leading from the past up to the present, however, offers a weak basis for such a historical cartography; as has been argued in Foucauldian inspired governmentality studies (Miller and Rose, 2008, Whitehead, 2009), as well as by other researchers in the field of social studies of science (Fleck, 1979, Kuhn, 1970), knowledge gradually erases its social and cultural genesis and masquerades as pure fact. In order to excavate the *becoming* of present configurations of knowledge and practices, a Foucauldian analysis has to turn to the past. Here, the comparison of different pasts and the present makes the varying configurations of knowledge visible, and opens up these areas for reflection.

The rationale behind approaching present knowledge as a history of the present is eloquently put forward by Dreyfus and Rabinow (1983: 204): "We have no recourse to objective laws, no recourse to pure subjectivity, no recourse to totalizations of theory. We have only the cultural practices which have made us what we are. To know what that is, we have to grapple with the history of the present". Instead of searching for origins or following universals through the past, the model of history employed here seeks to understand a problem in the present. This is achieved through a study of how a field of knowledge and practice came to coalesce around it, potentially altering the understanding of the problem itself. Highlighting the ambition to broaden the understanding of present problems through the use of history, this approach has been labelled 'history of the present'.

Tracing the history of the present leads to employing genealogy as an analytical strategy (further discussed in the chapter on methods below). At the core of Foucault's (1977: 142) genealogical approach is "the secret that [things] have no essence" and, thus, the challenge for a genealogical method is to provide an account of how a web of relations is turned into things, about which it becomes possible to make meaningful statements that are true or false. By giving a history to things previously seen as eternal, Foucault turned his eyes to natural and social facts (Saar, 2002, Shiner, 1982) and, as such, "history becomes effective to the degree that it introduces discontinuity in our very being" (Foucault, 1977: 154). What this position does is to raise questions about how we come to experience things in certain ways, and the effects thereof.

4 Material and Methods

My encounter with Earth System science primarily draws on Dean's (2010: 31) analysis of government. This implies considerations of the "conditions under which regimes of practices come into being, are maintained and are transformed". The research efforts presented in this thesis were broken down into four overlapping sub-projects, which were designed to trace different aspects of how, where, and when the Earth System was constituted as a coherent object of analysis and thereby rendered as governable. The primary empirical material comprises the programme and project documentation produced by the two global change programmes, the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), all of which were published between 1982 and 2013. The document analysis is supported by 14 interviews with project managers who were engaged in these two programmes during the time period 1986-2012.

4.1 Problematisations in the IGBP and the IHDP as empirical foci

The empirical analysis is limited to the problematisations of how to know the Earth in the IGBP and the IHDP, starting in 2013 and working backwards to 1983. This delimitation was the result of a snowball strategy (Noy 2008), starting with the Amsterdam Declaration on Global Change, which was formulated in 2001 (see Ch. 2). The declaration was chosen since it represents an articulation of the central problem description and ontology in Earth System science. As the results of the first decade of Earth System studies were synthesised, biological processes and human activity were included as important drivers in the emerging conception of the planet as functioning as a single system (Moore et al., 2002).

There are clear differences in the way the Earth System is described in the Amsterdam Declaration, the planning process of the IGBP in 1983, and the Human Dimensions Programme in 1987 (US NRC, 1983, Jacobson, 1987). Hence, my focus came to be placed on the study of how this new role of biology/ecology and human activity came about, which in turn directed attention towards research on land use and land cover change; two fields where ecology interact with the social sciences (Paper I). The second empirical focus draws on the work of bringing together all of the components in the Bretherton diagram to form predictive models of the Earth System. This directed attention to problematisations of how the Earth System could be known as a single system via global integrated modelling (Paper II).

It would not be unreasonable to expect that the discussions within the World Climate Research Programme (WRCP) would be one of the empirical foci of this thesis; however,

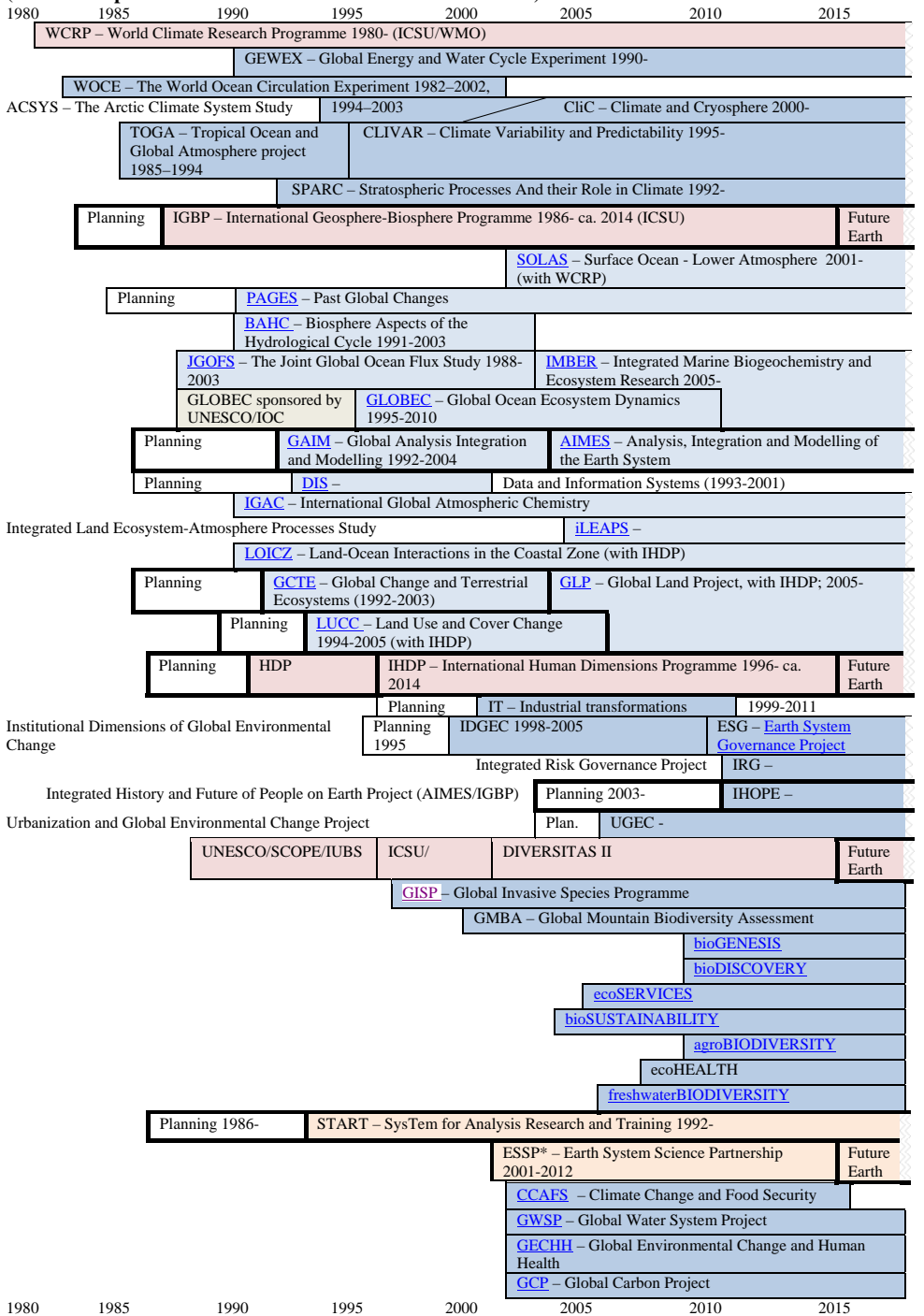
for a long period of time, discussions in the WCRP remained focused on refining the understanding of physical aspects, rather than the Earth System as a whole. Thus, the motivation for Paper III is found in the need for and establishment of a global technological zone, to enable the circulation of harmonised data, research practices, and results. The last paper (IV) contributes to the thesis by providing a broader perspective of how the global environmental change programmes, projects, and participants have positioned and motivated global environmental change research by writing auto-histories. Table 4.1 presents the empirical coverage of the thesis in relation to the full range of core-projects related to the IGBP, the WCRP, the IHDP, and DIVERSITAS.

It is important to note that the above-mentioned delimitations exclude the discussions of most parts of the four global environmental change programmes. Figure 4.1 accounts for these four programmes and their major research projects; bold frames indicate projects which have been studied in this thesis. However, as argued above, this thesis should neither be seen as an institutional study, nor as an attempt to provide a comprehensive history of Earth System science. Rather, it traces the problematisations that have enabled the generation of scientific knowledge regarding the Earth System as a governable object, and the political rationalities connected to its ontology.

As argued by Walters (2012, p. 39), a genealogical study will always be incomplete, and tracing a greater number of scientific discussions would, of course, be valuable. However, rather than proceeding to further broaden the scope and volume of the empirical material by including other research projects, the last sub-project engage more broadly with Earth System science through a study of how Earth System scientists position themselves in their capacity as experts in their own accounts of the history of the field (Paper IV). This study positions global change and the Earth System as problems in relation to earlier scientific activities and other approaches in environmental science.

Continuing the contextualisation of the empirical focus, Figure 2.1 illustrates how much of the available empirical material falls outside of the scope of this study. Firstly, the study deals with problematisations as they play out in research projects; therefore, the impact of Earth System science on policies is only visible as it appears in the scientific discussions. The focus on the IGBP and the IHDP also does not give due attention to other large research organisations, and it is well-known that the United States National Aeronautic and Space Administration (NASA) and the International Institute for Applied Systems Analysis (IIASA) have played important roles in global change research. Moreover, the WCRP, the largest of the global change programmes, is only visible in this study via its interactions with the IGBP and the IHDP.

Figure 4.1 The four international global change research programmes and their main projects (with the empirical focus of this thesis marked in bold frames)



* The history of the ESSP has been studied in relation to this thesis project; see Uhrqvist and Lövbrand (2009).

Although it would have been very interesting to include the above-mentioned organisations in the study, there are two main reasons for excluding them: Firstly, the Earth System concept was primarily fostered within the IGBP. Secondly, the aim of this thesis is not to provide an institutional history of rivaling interests, but rather to construct a map of changes in how it has been meaningful to speak seriously about the Earth System. It is also important to remember that these organisations experience significant personal mobility, which makes institutional boundaries a poor delimitation in regard to studies of discourses on global change and the Earth System.

Due to these overlaps, the programmes and projects studied are better viewed as a mix of centrally organised and funded 'big science', and 'invisible collages', which are temporary networks of researchers united by an interest in a set of problems (Mulkay et al., 1975, Zuccala, 2006). As Kwa (2005b) adeptly demonstrates, detailed analysis of ecological research networks, their interests, funding, and the conflicts that arise when engaging with Earth System science provide important insights into the dynamics of knowledge production. Engaging with the IGBP and the IHDP as complete entities would, however, quite probably have proven to be an overly-ambitious step, considering the time-frame of a PhD project such as this.

4.1.1 Assembling archives of the IGBP and the IHDP

How to approach the archives of research organisations is far from self-evident. In contrast to governmental institutions, which produce archives to record their activities, those of the IGBP and the IHDP are of an ad hoc character; moreover, the remnants of time-limited research projects are stored in an unstructured way, with the exception of any material that is considered to be of importance with regard to financial accounting. Regarding the IHDP, most of its collection of papers from the period 1988-1995 was dispersed during the dismantling of the initial secretariat, located in Barcelona and Geneva. The work of bringing the remaining documents together requires some reflection regarding the potential gaps and blind spots in the material studied.

Galbraith (1934, p. 12) colourfully depicted governmental archives as “secretions of an organism”; usually dusty, and located in specific places. These kinds of archives enable studies of the information stored in repositories, but the organisation of the archive itself also greatly informs the historian regarding the interests of the institution, through its selection of material for inclusion (Zeitlyn 2012). In that sense, the nature of archives is political, as they function as a memory for governing bodies and thus privilege certain views on behalf of others (Osborne 1999). This thesis, however, does not draw upon such a repository of global change research, but has instead had to rely on material assembled from a number of different repositories; such an undertaking is, however, fortunately not an uncommon exercise for historians.

Table 4.2 Assembled sources used as archival material

IGBP	Period	Character of content
Global change reports	1986-2010	1-59, Science plans, reports from major meetings
Global change newsletters	1986-2012	1-79, Programme-wide discussions, reports from projects and conferences/workshops
IGBP Annual Reports	2002-2010	
Drafts from programme and project planning	1984-2006	
Project and programme synthesis	1996-2012	
IHDP		
IHDP reports	1996-2012	Science plans, reports from major meetings
IHDP Update	1997-2011	The IHDP newsletter, project-wide discussions, and reports from events and projects
IHDP Annual Reports	2000-2012	
HDP Reports	1990-1995	1-7
HDP occasional papers	1990-1992	
HDP planning reports and working papers	1987-1990	
START		
Network News 1-8	1996-2003	START's newsletter, project-wide discussions, and reports from events and projects
Annual Reports	1998-2003	The earlier period of START is also covered by the Global change reports and newsletters.
Reports and newsletters from regional networks	1996-2010	Primarily from the Asian-Pacific Network, and South East Asia network.
GAIM/AIMES		
GAIM News	1997-2003	The earlier period of GAIM is also covered by the Global change reports and newsletters.
GAIM Reports 1-9	1996-2000	
AIMES	2003-2012	
QUEST	2001-2012	QUEST is an independent research project, but very closely related to AIMES
GCTE/LUCC/GLP		
GCTE synthesis	1996	
LUCC Reports 3-7	1997-2005	
GLP Reports 1-6	2010-2012	
GLP Newsletter 1-8	2006-2012	
FUTURE EARTH		
ICSU-IGFA reviews	2006-2009	IHDP, ESSP, IGBP, WCRP
Planning documents and drafts	2010-2013	Including communication between the transition team and the various ongoing research projects.
INTERVIEWS		
Executive directors and project developers		14 recorded interviews of about one hour each. Covering the years 1986-2012 (Appendix Table A.1)
OTHER		
A broad set of unorganised material	1984-2013	Letters, meeting reports, etc., found via later references or by coincidence. This includes work of US Global change programme and NASA.

As early as 1971, a group of historians, including Thomas Kuhn and Emmanuel Le Roy Ladurie, discussed the new situation in which the historians of the twentieth century found themselves. Summarising the outcome of the discussion, Gilbert (1971) argued that technologies for multiplying sources open for a new kind of historical archive; originally, such collections of records had been the result of governmental and other institutional activities, but the new kind could be made up of assembled photocopies, gathered in order to support the solving of scientific problems. Following the latter strategy, this thesis has utilised lists of key publications, report series, and newsletters, in order to construct what can be considered to be an archive of global change research (see Table 4.2). Among these documents, extra attention has been given to publications that have been referred to frequently in later discussions.

4.2 Kinds of material

Before moving on to the discussion of the method utilised to perform the interpretive analysis, it may prove valuable to briefly reflect on the character of the empirical foundation of this thesis. Shankar (2007), who primarily studies practices in laboratories, reflects on the practices of storage that are applicable to communication in reports and newsletters and, drawing on an overview of earlier research, argues for the value of performing studies at the micro-level of scientific practice. She finds that researchers' notebooks are valuable, as they represent the raw scientific process of creation, while at the same time acknowledging the difficulty of gaining access to such notebooks, and ascribes the fact that they are seldom explanatory or structurally clear to the personal character of the researchers. Moreover, it has been suggested that scientific publications and reports should not to be considered to be archival material; as argued by Holmes (1987), the process of fitting them for a certain genre or style of writing leaves them too stylised to represent the actual work of scientific discovery.

Tracing such a 'discovery' of the Earth System back to individual notebooks would be too ambitious a project, considering the thousands of scientists who have been involved over the decades. Instead, the strategy employed was to gather empirical material which represents discussions in the research communities and, although the empirical level chosen here does not capture the instant of the 'discovery' of the Earth System in Holmes' terms, it does capture the conclusions drawn in laboratories and other research settings, along with the process of negotiating these within a broader community - a pre-requisite for the production of credible accounts of the Earth System. Table 4.2 (above) presents the main empirical sources used in the thesis; in addition to these, documents have been gathered, albeit in a more unsystematic manner, from NASA and the majority of the other projects connected with the IGBP, the IHDP, and the WCRP. The study also included the

International Group of Funding Agencies (IGFA), which worked to review and coordinate funding between national funders and global change research projects.

4.2.1 Reports, newsletters, and synthesis documents

The primary sources of empirical material for the thesis are published reports, newsletters, and synthesis documents. Since the authors of these texts generally belonged to the research projects, evidence of conflicts within projects and between its participating scientists are not to be expected. The documents studied are understood to be remnants of the practices of governing researchers and their heterogeneous networks, which was partly accomplished through the issuing of stabilising accounts of what the Earth System is; as such, the documents were created and published in order to bring about particular effects in the known environment of scientific peers.

Programme reports, and particularly the more regular newsletters, functioned to present and connect the different projects carried out by the globally distributed network of researchers and institutions. Also, the production of these documents, as well as larger syntheses reports, also functioned to advertise the image of an important and productive research community; all with the purpose of raising interest, both external and internal, from scientists, funders, and policy-makers. Furthermore, synthesising activities in programmes and projects were assumed to take the research results one step further in relation to the project's work packages. As these documents can be said to have functioned at the boundaries between different research communities, they are understood to represent a programme-wide discourse, which it was necessary to foster in order to unite the scientific knowledge of the Earth System.

4.2.2 Interviews

Working under the assumption that the primary aim of the published material was to bring the research community together, I did not anticipate that tensions and conflicts would be openly visible in the documents. Therefore, the documents were complemented by interviews with 14 persons who took part in the design and/or development of the research programmes and projects; two of these were interviewed twice, resulting in a total of 16 semi-structured interviews of 45-60 minutes each (see Appendix A2). Five were conducted in person, two via telephone, and nine via Skype, all of which were recorded, with the exception of the two telephone interviews. This reflects a pragmatic approach, in which face-to-face interviews were preferred when possible, while tools such as the telephone and Skype were used only to facilitate interviews with those participants with whom it was not possible to meet in person due to their geographical location. In a paper on interviewing members of the scientific elite, Stephens (2007) reports that the anticipated problem of interviews conducted face-to-face and via telephone, i.e. a lack of rapport caused by distance, failed to appear; it may be argued, however, that this effect

was possibly somewhat eased by the video link used in this study. Regardless, the experience of the 16 interviews conducted in this thesis follows that of Stephens, as no significant differences were noticed between the interviews.

Since the aim of the interviews was to broaden the initial interpretation of the published material by opening for participants' perspectives, the decision was made to utilise a semi-structured interview method, based on Berg's (2001: 70) distinction between structured and unstructured interviews. The basic assumption of the former is that the interviewer is familiar with the concepts used in the studied culture/community, whereas the point of departure of the latter is that it is impossible for the interviewer to know all of the necessary questions beforehand. Positioned in-between these two methods, the semi-structured interview allows for a certain degree of steering of the interview while, at the same time, providing the interviewee with space in which to give their own account in relation to the questions they are asked.

The interviews were structured around questions which aimed to direct the interviews towards the respondent's personal experiences as active participants in the global change research programmes (see Appendix A1). One of the challenges in the design of the interviews was to stay as close as possible to the direct interests of the research, while at the same time providing space for the respondents to relate their personal accounts (Bryman, 2008). The resulting interview design initially sought to set the scene by explaining the interviewer's research interest and the purpose of the interview, after which the strategy was to interfere as little as possible with the personal accounts of the interviewee.

A further intended function of the interviews was for them to assist in the triangulation of the preliminary interpretations of the documents. In order to avoid steering the conversation in a particular direction, this topic was only put forward at the end of the interview. The general theme of all of the interviews was an interest in the researchers' personal accounts but, as the design had to be adjusted to fit the individual interviewees, any attempt at systematic comparison of the interviews will meet with serious difficulties; this does not, however, complicate the main purpose, which was to gather as many perspectives as possible on the empirical material studied.

In contrast to the documents, which were produced at the time and by the participants of the research processes, it must be remembered that the majority of the interview material consists of 10-20-year-old memories. Although the recollection of events usually adequately reflects the content of the documents, they are, for the purposes of this study, understood to have been affected by later experiences in the lives of the informants (Hoddeson, 2006). In that sense, the interviews are considered to be remnants of an exercise of sense-making and, as such, they provide valuable material for individual histories of Earth System research by enriching the reading of documents through the

addition of participants' perspectives. In relation to the main body of the empirical material, i.e. the documents, the interviews contributed new angles, which did not change the fact that the texts were given priority when it came to the matter of details.

All interviewees were informed about the purpose of the interview and were offered the chance to comment, in the event that their utterances were cited in a paper. No other issues concerning research ethics have been found to exist in relation to the interviews.

4.3 Making the documents speak – a genealogical encounter

With the empirical material as a backdrop, it is now time to present the methods used to interpret the selected texts. The literature on the 'history of the present' and genealogy provides few methodological templates; rather, Michel Foucault is renowned for his analytical playfulness and unwillingness to adhere to any distinct theoretical or methodological tradition. Some scholars have used this Foucauldian heritage as an excuse for not engaging seriously with questions of method (Milliken, 1999), while others have undertaken excavations into Foucault's texts with the aim of distilling systematised methods (Kendall and Wickham, 1999, Flynn, 2005); and at some instances found an explanatory logic that enables both criticism and explanation of social phenomena (Glynos and Howarth, 2007).

This thesis draws on a third strand of scholarly work, which engages with the study of governmentality as an experimental approach and an analytical toolbox (Walters, 2012). As suggested by the heading 'making the documents speak', this thesis engages with the empirical material from the vantage point that the results inevitably emerge at the intersection between the material studied, the methods used, and the researcher himself. In this thesis, the ontology of the present Earth System and the related political rationalities are encountered by way of a genealogical document analysis. The term 'encounter' is important here; during a reflection on the use of governmentality today, Walters (2012: 5) explored two meanings of the word. One suggests an 'unexpected meeting', thus pointing to the value of approaching the empirical material so as to be open to unexpected outcomes. As such, the approach needs to be reflexive, in the sense that the analytical tools, as well as the studied object, are questioned, and the researcher made visible (Alvesson and Sköldböck, 2009); neither of these should be taken-as-given, i.e. unquestioningly used as a secure foundation of knowledge.

A second meaning of 'encounter' highlights that this unexpected meeting is not devoid of tensions and is, as such, related to politics. Being reflexive is a way to avoid what Walters (2012) terms "applicationalism", a process through which a theoretical toolbox comes to be taken for granted in the same sense as the object it seeks to destabilise. Critical encounters, as proposed by Walters (2012), are here understood as a mode of research that engages with problems by posing questions regarding their underpinning

assumptions, and which is open to modifications to both analytical standpoints and methods, as well as the understanding of the empirical material. In this sense, 'encounter' implies the construction of an experimental connection between empirics and analytical tools, simply in order to see what happens.

Governmentality studies have to be combined with methods that are more explicit with regard to how the studied material is to be engaged with, and normally involve the implementation of different kinds of discourse analysis to supplement the analytical perspective. The study presented in this thesis is, however, not detailed enough to be a discourse analysis and, while such approaches have the advantage of a high level of detail, they are also very time-consuming, which limits the amount of material that can be analysed. My encounter with the Earth System as a governmentality was initially considered to be performed as a discourse analysis. However I soon adopted document analysis, as a more time-efficient method (Bowen, 2009), in order to be able to trace the discussions through a broader body of empirical material over a longer period of time. Still, I consider that which I analyse to be a discourse, i.e. a field where ideas, practices, and materiality are combined so as to enable 'true' statements to be made.

The method usually connected to the study of governmentalities is genealogy (Flynn, 2005). While the philosophy underpinning genealogy has been described in Chapter 3, little has yet been said here about how to carry out a genealogical analysis in an encounter with the empirical material. As argued by Diaz-Bone (2006), a connection between the theoretical understanding of discourse and how it can be assessed empirically is required in order to enable an analysis that penetrates the surface of the texts. Although the analysis method employed in this thesis draws on document analysis, its structure is, however, based on an understanding of the connection between knowledge and power presented earlier; this is accomplished by employing both *interpretative analytics* as a method of reading, which was first suggested by Dreyfus and Rabinow (1983), and Dean's (2010) analytical grid, which suggests four dimensions that are to be identified in the regimes of practice that enable governing and the production of authoritative knowledge.

Interpretive analytics, as described by Dreyfus and Rabinow (1983: 202, see also, Flynn, 2005, May and Powell, 2007) trace the historical formation of problematisations and, as pointed out by Martilla (2013), require an epistemological break that must make the familiar seem strange in order to function properly. This thesis creates such a break by tracing the present understanding of the Earth System back to the time when it was engaged with in other ways; i.e. when its existence was far from being taken for granted. Discussing the project of writing histories of 'Truth', Burchell (1996: 33) states that "the historian's starting point is the non-necessity of what passes for necessary in our present".

As further described in Chapter 3, ideas are understood as the effects of practices, rather than the reverse; they perform the double function of providing a rationality for the

practices, while also serving as problematisations of inefficient ways of reaching particular desired ends. The primacy given to practices by interpretative analytics must be allowed to inform the reading of the material (Dreyfus and Rabinow, 1983). In this thesis, practices cannot be observed directly, but they are still of significant importance to the interpretation of the empirical material. The documents provide detailed accounts of how participating researchers argue for and against different practices in relation to the production of policy-relevant scientific knowledge. As this thesis studies how practices are problematised, paying attention to the 'conditions of existence' provides an important entry into the texts, while still drawing on the theoretical understanding of the primacy of practice in the transformation of knowledge production.

Dreyfus and Rabinow (1983: 202) compare their use of history to the three steps of a medical diagnosis; this is a good analogy, and will thus be used to structure the remainder of the description of the method for engaging with the empirical material: Firstly, the patient is asked to relate their own account of the problem, and so the analysis is primarily concerned with the question of 'what?'; what is the problem, what objects and practices are touched upon in the patient's key narrative? All four sub-projects presented in this thesis have begun with a reading of flagship documents, such as the Amsterdam and London declarations, and synthesis reports from the IGBP and the IHDP. In this material, I tried to elucidate the central themes in the scientific problematisations of the global environment and the related knowledge production. This initial strategy to map central themes included both early and more recent documents, so that significant shifts over time became visible. In the vast documentation from the research programmes, these themes functioned to direct the empirical focus. A key concern in this first step of the process was to keep the coding open for unexpected outcomes in the empirical material (Strauss and Corbin, 1990, Coffey and Atkinson, 1996) and, thus, this first reading sought to avoid encounters with previous knowledge from the history of research concerning the global environment, instead staying close to the way problems and prospects was presented. Hence, this became a descriptive, rather than analytical, step.

Secondly, making a professional and scientific diagnosis requires meticulous attention to empirical observations. Developed around the themes and major issues which had been elucidated during the first step of the reading, the second focused on details and how connections between the themes were articulated. Here, the analysis turns from 'what?' to focus on 'how?' with regard to the nature of the Earth System and related motivations for how scientific practices can produce relevant knowledge. As argued before, practices were not studied directly in this thesis; rather, it was the participant's problematisations of these practices that were in focus. Hence, the statements found in the documents were encountered as remnants of the practices of developing and stabilising research programmes, and thus the study of statements as practices opens for a history of the

present, by mapping the conditions that enable meaningful statements about truth and tracing how these shift over time (Dreyfus and Rabinow 1983, p. 103).

In this second step, the empirical material was drastically expanded to include less conspicuous documents such as newsletters, project reports, and interviews. The detailed encounter with the broader set of documents also enabled an element of critical self-reflection, which involved determining whether the main themes from the first step were important in the context of the broader discussions. Particular attention was given to ascertaining which parts of the knowledge-producing apparatus that were most frequently discussed. In this step, it was useful to perform a parallel analysis that was structured according to Dean's analytical scheme (described below), as his four dimensions offered a more detached interpretation of the discussions, in comparison to the closer, more detailed reading of the text performed during the interpretative analysis.

The third and final step returns to the problem description derived from the main themes elucidated during the first step and, based on the detailed and structured second step, it can ideally provide an account of how the present problematisation took shape. As a critical history, this account will probably show that the ontology of the present and the political rationalities flowing from it are not the result of a progressive history moving in a certain direction, be it rationalisation or class struggle. Neither can it be expected to support claims to a universal rationality, or metaphysics, with which an ahistorical account of true knowledge can be supported.

Equipped with a detailed empirical account of the scientific discussions which resulted from the second step, the move back to an improved understanding of the initial problematisation can now contextualise this with regard to the historical processes of a particular time and place. Without seeking to provide a theory or general trend, the final step seeks to bring the present ontology back, through its process of coming into being. Hence, the third step also includes a return to the key documents which were in focus during the first step, in order to compare the interpretations with the empirical point of departure. Taking Foucault's (1978) view that knowledge is always intentional (but also non-subjective) opens for questions regarding which, and whose, strategies are being supported or obscured by the actual problematisations.

4.3.1 An analytical grid to structure interpretations of the documents

Dean has made one of the most structured efforts to suggest methods of connecting the historical emergence of knowledge (i.e. genealogy) and the art of governing. He argues that analysing “mentalities of government is to analyse thought made practical and technical” (Dean, 2010: 27); this means that an Earth System discourse should be analytically encountered through its most visible expressions. The interpretive analysis performed in this thesis, and particularly in its second step, is supported by an analytical

grid proposed by Dean (2010: 40), in order to facilitate an analysis of what he terms "dimensions of regimes of practice [of government]".

Dean's four dimensions - *fields of visibility*, *technologies and practices*, *knowledge and rationality*, and *formation of identities*, are all understood as necessary, but also irreducible into one another and, to some degree, autonomous. Given the interest in knowledge and rationality of this thesis, the grid has been modified to be better attuned to the focus on knowledge production herein. However, the four dimensions are still used, as important parts of the apparatus for governing and knowledge production, which Dean refer to as the "regime of practice", are historical assemblages through which governance is possible.

Seeing problematisations as rare events, Dean suggests that analyses should take problematisations as their point of departure; in relation to this thesis, Dean's problematisations are comparable to step one of the interpretative analysis. However, the 'rare event' strategy proved to be an unproductive approach to encountering the ways in which research has developed the Earth System as a means of understanding the global environment, as this thesis takes 'problematisation' to be a long series of problematising events which affect ways of knowing and governing (see Miller and Rose, 2008). This position sits better with the empirical material, due to the fact that the history of Earth System research comprises a long chain of problematisations which are better viewed as engines for analysis than used as points of departure.

The tracing of this series of problematisations through the documents was done according to Dean's four dimensions, using them as meta-categories within which themes emerged, shifted, and disappeared. As such, the four dimensions helped to structure the discussions and turn attention to such dimensions (usually formation of identity) that were less pronounced. They also assisted in raising questions about how the dimensions were connected to one another in the formation of a whole regime of practice.

The first dimension, *fields of visibility*, was applied in terms of how the problem to be governed was presented in images, graphs, maps, etc., and thus produced an ontology that highlighted some aspects of the problem while obscuring others. Examples related to the Earth System and global change research carried out by the IGBP and the IHDP include images with a global perspective, maps, and graphs from simulations of probable futures or long-term effects of global change, geological timescales, concentrations of greenhouse gases extracted from ice-cores; although the list could be made much longer, one final addition worthy of notice is the inclusion of conceptual models of the connections within the Earth System.

The second dimension covers the material aspects of the regime. As argued by Dean (2010: 42), governing has to be practical so as to cause effect. Hence, the *technologies and practices* available are important, since they represent what is actually done; how is

science performed or, in relation to this study, proposed to be performed? After all, the research design employed can be expected to propose strategies which are likely to bring about the desired changes, in effect taking action rather than contentedly but abstractedly considering an ideal end-point. As the analysis in this thesis is based on interpretation of documents, it does not study practices per se, but takes them to be important nexuses where tensions emerge between ideas and materiality. Instead of observing these directly, the strategy in this thesis is to study the discussions between participants of the IGBP and IHDP projects in relation to expected, as well as unexpected, problems and possibilities which emerged during the pursuit of a predictive understanding of the Earth System. In order to be effective, research designers have to propose ways of achieving these objectives while simultaneously considering the practical limitations (e.g. computer power, availability of skilled personnel, quality and accessibility of data).

The third dimension is the forms of *knowledge and rationality* of governing, along with the expertise which informs them. Dean (2010) approaches these as emerging from the practices of governing, and it is important to remember that the broad definition of 'governing' includes all strategic attempts to direct the action of others. The choice to focus on the history of international research programmes, rather than on government agencies, has led me to approach this dimension as primarily intra-scientific; thus, the practices discussed and rationalised are practices of knowledge production, and the knowledge and rationality produced is twofold. On the one hand, research practices are problematised and subject to suggestions for change; on the other, these practices are responsible for the ontology of the present, which makes it possible to speak scientifically about the Earth System. Still, the effect of the 'fields of visibility', as well as the practices and technologies involved in governing, rely on accepted conventions for knowledge production. As a large part of the empirical material used in this thesis consists of plans or arguments for new research designs, old ways of visualising and practising Earth System science is constantly problematised in relation to rationalities for the production of scientific knowledge.

The fourth dimension is the *formation of identities*. If reality is supposed to function in a certain way, rational subjects have to adjust their strategies accordingly. Hence, scientific knowledge becomes an important technology to "govern at a distance" (Rose and Miller, 1992: 181). This connection, between the practicalities of governing and thought/knowledge, is at the heart of governmentality (Dean, 2010: 42) and, thus, statements need to be accepted as authoritative knowledge in order to be effective. When studying governmental programmes that seek to effect a change of conduct on a wider scale, the fourth dimension is very important, due to the fact that implementing ideas of 'the good subject' is one way of governing from a distance via the instilling of self-discipline in citizens. In the literature on governmentality, there are many examples of

this; in order to make subjects become, for example, carbon-aware, they must be informed about and attentive to the effects of their lifestyle, as well as motivated to choose less harmful alternatives (Paterson and Stripple, 2010, Lövbrand and Stripple, 2013, McGuirk et al., 2014).

In this thesis, the identities, or subjects, discussed are more internal to the research programmes. Due to the scientific character of the texts, clear accounts of desired identities are seldom available, although one exception is the interdisciplinary scientist ready to engage in large research networks. If not for Papers III and IV, which study the introduction of research agendas in new settings and where desired identities become more visible, this dimension could have passed by unnoticed in this thesis. However, inspired by Dean and based on a jigsaw puzzle of suggested practices and historical narratives, this dimension of the regime of practice was included among the others in the analysis. However not as substantial as the others. Figure 4.3 provides an overview of Dean's categories; this analytical scheme will be substantiated with results from the four papers in Chapter 6.

Figure 4.3 Dean's analytics of government

Field of visibility	Technologies and practices	Knowledge and rationalities	Formation of identities
What is illuminated, what is obscured?	By what instruments, procedures, and technologies is rule accomplished?	Which forms of thought arise from and inform the activity of governing?	What forms of self are presupposed by practices of government?
What problems are to be solved?			Which transformations are sought?

Source: Dean (1999: 30-33)

4.3.2 Interpretative analysis and analytics of government in the four sub-projects

In pursuit of the aims of the thesis, the empirical work was divided into four sub-projects, based on the analytical perspective and an initial overview of the history of the Earth System science partnership (see, Uhrqvist and Lövbrand, 2009). As will be further discussed in connection with the presentation of the four papers, this delimitation sought to trace the increased role of the human dimension and dynamics of the ecosystem in relation to the functioning of the Earth System, as well as the efforts to produce predictive models of the integrated Earth System. Furthermore, it sought to encounter changes in the ways in which the Earth System was engaged with, based on the problematisations included in the establishment and coordination of the global research network, which were argued to be necessary in order to understand and make predictions regarding the Earth System. These three sub-projects were then positioned in relation to a larger context, which was provided by the fourth paper's analysis of how auto-history produced

by the participants of the global change research programmes made sense of the role and prospects of Earth System science.

Tracing the shifting importance of human activity and the dynamics of the ecosystem, Paper I directs attention to the ideas which were fostered in three projects; Global Change and Terrestrial Ecosystems (GCTE, 1990-2003), Land Use and Land Cover Change (LUCC, 1994-2005), and Global Land Project (GLP, 2005-). In the original Bretherton diagram of the Earth System, humans were represented as an external stressor (NASA 1986), and Paper I traces the new roles given to ecosystems and humans in the Amsterdam declaration of 2001, in which humans were included as a part of the Earth System. Over the same period of time, ecosystems had been elevated from the status of a green slime in the Soil-Vegetation-Atmosphere Transfer (SVAT) models to driving forces in their own right (Chapin and Shaver, 1996, Peng, 2000), thus the empirical focus in Paper I is also placed on following the development of conceptions of the Earth, from green slime to a fully integrated human-environment in the Land system. This sub-project thus provides input to the research questions on shifting representations of the Earth System (Q1) and their connections to rationalities of government (Q3).

In Paper II, the focus is directed to the shifting problematisations found in the two modelling units; Global Analysis, Interpretation and Modelling¹ (GAIM) and Analysis Integration and Modelling of the Earth System (AIMES). From its outset, the IGBP had identified predictive computer models of the Earth System as an important synthesising technology that would generate "a common lexicon" for the various programme activities and its participating scientists (IGBP, 1986: 9). Considering this emphasis on computer modelling, large-scale modelling activities were found to be a good means of studying the arena in which the different disciplines were assumed to meet and negotiate their role in the overall Earth System. GAIM and AIMES were structured quite differently; GAIM (1992-2003) was organised as a task force for the scientific committee comprised of a handful of modellers, active at key modelling institutions, whereas AIMES (2004-) was, and still is, a Core Project, located at the very centre of the organisational structure of the IGBP and explicitly mandated to provide a bridge to the IHDP so as to include human dynamics in Earth System modelling. Paper II provides input to all three research questions as it deals with shifting representations of the Earth System (Q1), shifting problematisations of practices (Q2), and political implications related to the global environment (Q3).

Paper III provides a more spatial perspective by interpreting the tensions produced in relation to the establishment of a global apparatus for enabling research and, as it transpired, policy impact. The concept of the Earth System emerged as a way to better utilise NASA's satellite systems by providing a scientific framework (Moore, 2011).

¹ From 2000 Global Analysis, Integration and Modelling

However, the planning process of the IGBP acknowledged that a study of global change had to be "truly international, in planning, in execution, and in final analyses," (IGBP, 1986: 4), and thus had to be ubiquitous. Technological zones (Barry, 2001) and knowledge infrastructure (Edwards, 2010) highlight the challenges of gathering, processing, and circulating scientific knowledge, and this turned the empirical focus of Paper III to activities within the SysTem for Analysis, Research and Training (START), the joint initiative which is co-sponsored by the WCRP, the IGBP and the (I)HDP. START provided a means of studying the effects of the Earth System research agenda as it encountered the challenges of organising a global research network, which was designed to produce harmonised input to Earth System models as well as political support and funding. This sub-project provides input to the research questions on the assignment of roles (Q2) and strategies for enhancing political effect (Q3).

In order to trace the sense-making developed in relation to the needs and prospects of Earth System science, Paper IV encounters the auto-historiographies produced in connection to the programmes from 1983 to 2013. This sub-project draws on material from all four global change programmes, as well as the personal accounts of their history which can be found in scientific journals. As the past efforts to know the planet as the Earth System are historicised, these auto-historiographies become sources which provide empirical material for interpretations of how the programmes are positioned as rational continuations of past events. By including key events and leverages, these historical narratives also provide accounts of how participants understand the driving forces behind successful research programmes, and how these understandings change over time. Paper IV contribute to the aim of the thesis by engaging with the rationalities for how to organise research programmes based on problematisations of the needs for such research, as well as arguments for the most promising way to conduct it (Q2).

Table 4.4 Summary of the objectives, methods, and materials of Papers I-IV

Paper	Objective	Method	Material
I	To trace the changes in the ways of seeing and knowing the Earth System as humans and ecology were added.	Document analysis and interviews	IGBP, IHDP, GCTE, LUCC, GLP, and Future Earth
II	To trace shifts in the problematisations related to how to produce predictive models of the Earth System.	Document analysis and interviews	GAIM and AIMES
III	To trace changes in the organisation of global change research in the efforts to establish a global research network.	Document analysis and interviews	IGBP and START
IV	To locate the position of Earth System science in a wider research landscape, including the rationales for the organisation of research.	Document analysis	IGBP, WCRP, IHDP, DIVERSITAS, Future Earth, and personal accounts in research articles

The overlaps between the papers are better shown in Figure 4.5, where the results are organised by their contribution to separate research questions; these overlaps are intentional, and serve to support different accounts of the constitution of the Earth System as a knowable and governable object, which is the reason Papers I and II cover the entire period between 1983 and 2012. Paper III traces the establishment of START up until 2002, when its networks became stable. The empirical material of Paper IV also covers the period from 1983 to 2013, as it organises and discusses a much longer history.

Table 4.5 The content of Papers I-IV, organised after their contribution to the research questions

Question	What the papers does	Paper
How the Earth System is represented (Q1)	Traces the changes in GCTE, LUCC and GLP	I,
	Studies the approaches to Earth System modelling in GAIM and AIMES	II
How the understanding of the Earth System has changed (Q1)	Traces how the understanding of the Earth System has changed as humans and ecosystems were integrated into the system.	I, II
	Traces the longer history of the assembling of Earth System as a scientific field.	IV
Scientific problematisations underpinning the Earth System (Q2)	Who does what, and why? How do roles change in the research networks?	II, III,
Rationalities of government based on the Earth System governmentality (Q3)	Follows the long history of scientific efforts to legitimise the need and ability to govern the planet as a whole.	IV
	Connects the shifting ontologies to implications for government.	I, II
	Traces the understanding of possibilities to connect the results of different disciplines to one another.	III

5 Previous research on the history and politics of global environmental science

At the heart of this thesis lies an effort to historicise the present ontology of the global environment as the Earth System, and thus to contribute to discussions reflecting on the power and politics embedded in scientific knowledge about the environment. Encountering the Earth System as an object of concern from a historical perspective draws attention to the large support structure which makes it possible to speak with scientific authority about global change; this structure, moreover, includes discourses, practices, technical devices, and research organisation/design. My encounter resonates with three partly overlapping bodies of literature which discuss the political implications of environmental science. These are: The science-policy interplay with epistemic communities (Haas, 1992b) and the idiom of co-production (Jasanoff, 2004b); literature on green governmentality, drawing on Foucault's account of power/knowledge (Luke, 1999); "histories of nature's production" (Braun, 2000), i.e. studying scientific natures as social constructions with a focus on political geography and the history of environmental science.

5.1 The science-policy interplay

The literature on science-policy interplay is grounded in constructivist traditions of international relations research, and features important contributions from science and technology studies. Central to the constructivist understanding of international relations is the assertion that States' interests are shaped through social interactions, and thus that interests should not be analysed as prior or external to political processes (Wendt, 1999). This has led to an interest in how scientific expertise informs and affects international environmental politics and interstate treaty-making by shaping interests and identity.

Epistemic community theory (Haas, 1992b, Adler and Bernstein, 2005) focuses on how scientific information can shape the preferences and cost-benefit calculations of States; an example which is often brought to the fore are global environmental assessments, such as those of the IPCC. One important theme here is how they should be designed to influence state behaviour (Mitchell et al., 2006). While it adopts a constructivist ontology, this body of research draws on a rationalist epistemology, testing hypotheses against a general theory; here, then, the key question is why some assessments and expert advice have more effect than others. There is also a more post-structuralist understanding of the science-policy interface, which points to the role of unique contexts and discourses in the shaping of scientific knowledge, hence shifting causality from actors to discourse (Litfin, 1994).

Researchers in science and technology studies have taken this interest in the constitutive role of ideas further. Based on case studies, attention is drawn to the micro-processes of meaning-making and expert legitimation in global environmental assessments such as the IPCC (Miller, 2007, Beck, 2012). In 2004, Jasanoff introduced the conception of co-production to denote the close intertwining of scientific representations of the world and how we live in that world. This concept bridges the boundaries within science and technology studies, and provides a conceptual framework with which to discuss the messy interactions between science, technology, social norms, and power. Shortly summarised, co-production implies that the "ways in which we know and represent the world, both nature and society, are inseparable from the ways in which we choose to live in it" (Jasanoff, 2004b: 2). In relation to climate change, co-production studies have shown how the requirements of policy-relevant or usable knowledge have fostered interaction between researchers, funders, and decision-makers (Lemos and Morehouse, 2005, Dilling and Lemos, 2011). As pointed out by Lövbrand (2011), co-production is used in a dual sense; to provide a critical perspective, but also normatively, to enhance the efficiency of science-policy interactions.

5.2 Global environmental research as green governmentality

While research performed on the science-policy interplay takes as its main concern the institutions of global environmental governance, studies inspired by Foucault's conception of governmentality have set out to interpret how a broader set of practices produce understandings of a governable nature. This literature draws on an account of power as productive in the sense that it enables, as well as limits, a field of possible actions (see Ch. 3.). Here, studies of how scientific processes render the global environment visible as a problematic but also governable object directs the attention to times and places beyond the direct policy negotiations (Lövbrand et al., 2009, Luke, 2009). As argued by Whitehead (2008: 416), the value of this approach is that it takes "neither the state nor the environment as pre-given objects of analysis", and instead focuses on how political rationalities emerge in complex webs of institutions, scientific practice, and environmental events.

Governmentality was introduced by Foucault in 1978-79, and took the historical emergence and governing of 'the Population' as its main object (Foucault, 2007, Gordon, 1991). Perhaps as a result of Foucault's disinterest in the environment, almost two decades were to pass before scholars began to use governmentality in the analysis of environmental knowledge, politics, and power. Here, Darier's (1999) edited anthology, *Discourses of the Environment*, provided the first collection texts in this direction, although early attempts to connect governmentality to environmental studies had been made by Timothy W. Luke (1995, 1999), who argued that green governmentality

represented a form of resource management which renders the environment as goods, organised to support a capitalist industrial economy.

In Darier's anthology, Paul Rutherford (1999) espoused the concept of "ecological governmentality", broadening Foucault's conception of 'population' to include the environment as a part of the population-resource problem. As compared to Luke, Rutherford attributed a more active role to science, and global ecology in particular, in shaping assumptions about a nature governable with the aid of ecology (Rutherford, 1999: 37, see also, Worster, 1994). The overlaps between green and ecological governmentality are considerable, as both deal with the intellectual machinery of government, and discussions about eco-governmentality sometimes refer to them as interchangeable (Goldman, 2001, Bridge and Perreault, 2009).

The concept of green governmentality has inspired a growing body of scientific literature, which now encompasses questions of both a local and global nature (Bäckstrand, 2004, van der Heijden, 2008). However, Rutherford's argument, that science plays a more active role in the production of environmental 'problems', has survived. A recent example is Whitehead's (2009) concept of "government with science", which depicts scientific knowledge as a powerful but not entirely loyal ally to those who seek to build legitimacy for governing. Hence, this thesis follows Whitehead's assertion that the close connection between science and politics should not lead to the conclusion that either are reducible to an effect of changes in the other.

From the related perspective of political science, Bäckstrand and Lövbrand (2006) offer green governmentality as one of three discourses that inform the global governance of climate change, together with ecological modernisation and civic environmentalism. Here, green governmentality represents a state-administered (in contrast to market-oriented) approach to environmental problems connected to 'mega-science' and big business. Two versions of green governmentality are described; on the one hand, as a technocratic and elitist approach to environmental problems, and on the other as a more humble version, which includes a broader range of voices representing both expertise and laity (p. 55). The former conception is also found in Luke (1999), and the latter in Jasanoff's (2004a) history of the politics of environmental images.

Studying shifts in the rationalities for governing climate change, Oels (2005) shows how different governmentalities produce effects on modes of governing. The core message is a transition, from a state-controlled biopolitics to advanced (or neo-) liberal, market-oriented, modes of governing, where experts have a privileged position (see also Liverman, 2009, Methmann, 2013).

While Earth System science and global environmental change research is clearly concerned with the environment, it also involves a global gaze on problems and their solutions. 'The global', or the planet, is ultimately, what needs to be governed or managed.

The discussion regarding 'planetary boundaries' in relation to 'safe operating space for humanity', initiated by Rockström et al. (2009), provides an illustrative example of this. The vantage point of governmentality suggests an engagement with the history, which has made it possible to conceptualise a global or planetary entity that can be known in ways that enables strategic calculation of optimal pathways towards sustainability. Considering that the interest of governmentality studies lies in the regime of practices that produce the 'truths' needed for governing, very little research has been performed on the global environmental change research programmes.

5.3 Histories of nature's production

While the previous section connects scientific approaches to global environment and climate change with governmentality, this section turns to what Braun (2000: 14) terms the "histories of nature's production", connecting my interest in the Earth System with the work of political geographers, ecologists, and historians of science (Braun, 2000, Hannah, 2000, Rutherford, 2007). The explicitly local interactions between power/knowledge and the organisation of space have inspired critical geographers to take up the concept, positing governmentality as a useful concept for studying how territory, or space, becomes organised in ways that make governing possible. The body of literature presented in this section has many analytical overlaps with the previous, and many relate to Foucault and governmentality. As such, this section draws attention to the work related to how culturally and socially embedded scientific practices have produced governable objects related to the environment, at different times and in different places. These geographical and historical inquiries suggest that 'nature' and 'natural' are politically loaded terms, although in slightly differing ways (Latour, 2004, Castree, 2013).

Engaging with political space, geographers and political scientists have problematised the ways in which geopolitics has been organised around maps that made modes of governing rational (Tuathail, 1994, Luke, 1996). The construction of maps as scientific practice has been shown to play an important role in the production of certain natures, as well as its inhabitants. Hannah (2000) has shown how the late-nineteenth century censuses in the United States reinforced cultural categories, such as race and gender, and hence changed the ways in which national territory was considered and regulated. Braun (2000) showed a similar effect when mapping in western Canada produced specific geological ways of seeing the landscape, and hence fostered a particular and mostly economic rationality for behaving in relation to it.

Tracing the efforts to govern the skies over Britain, Whitehead's (2009) analysis of knowledge production exemplifies the fertile crossbreeding of history, power analysis, and geography. He does so by showing how a contingent patchwork of technologies, regulation, scientific and profane knowledge, and unexpected events, when taken

together, produced problem descriptions and governmental rationalities for how to solve them. The same can be said about the boreal (Baldwin, 2003) and colonial forests (Agrawal, 2005), where shifts in how to regulate the relation between forest and humans produced different subjects. Both cases show how colonial governmental apparatuses enabled governing from a distance, as well as how colonial rule was not simply based on repression, but on new ways of rendering the environment and people visible in certain ways (Scott, 1995, Agrawal, 2005). Although colonial governmentality studies the ordering of distant territories, it still operates within sovereign imperial states. In contrast, global governmentality engages with the challenge of governing spaces that lie beyond the reach of any single authority (Larner and Walters 2004).

One history of nature's production, more in line with global governmentality, is found in relation to the Cold War. In this global struggle, particular scientific natures were produced to manage the globe as a battlefield, surveilled and controlled by advanced computers. Working generally outside of the analytical framework of governmentality, scholars interested in the history of science tend to contextualise early science on the global environment within the grand narrative of Cold War geopolitics; for example, Doel (2003) discusses the contributions of various branches of military intelligence in mapping ocean seafloors and global water circulation as preparation for submarine warfare. In addition, the arctic atmosphere was studied for military purposes, such as the use of and defence against intercontinental missiles (Heymann et al., 2010).

Doel (2003) also traces current interdisciplinary modes of conducting research in environmental science to the problem orientation found in military institutions, such as the geophysics programmes at Lamont, Scripps, and Woods Hole, which were considered to be novel modes of research at the time. Global observation systems have also been interpreted in the context of global conflict, and an extensive body of literature on the formation of the satellite systems of NASA and others shows how environmental concerns have been used to promote expensive technological systems since the end of the Cold War (Lambright, 1994, Litfin, 1994). It has also been argued that the expensive nature of these systems has fostered interdisciplinary cooperation, thus producing global data (Kwa, 2005a). The involvement of climate science with the military complex is an important context for this thesis, since persons such as Thomas Malone and Bert Bolin were involved in research programmes such as the Global Atmospheric Research Program (GARP) and in the organisation of the IGBP.

So, what effects did this daunting context have on how the environment was rendered visible? The ordinary two-dimensional maps, which had an important function in earlier geopolitics, were here complemented by computer powered simulations. Placing post-war environmental sciences in an early Cold War context brings in the culture of surveillance and control that characterised the discourse of US military organisation

(Kwa, 1994, Fleming, 2010). Paul N. Edwards (1997) uses the phrase "the closed world" to describe the Cold War discourse on the global, as something which was manageable thanks to surveillance and computer models.

Other historical studies have attempted to problematise the control paradigm, at least when studying recent decades. Aubin and Dalmedico (2002) describe a turn to chaos, non-linear systems, and unpredictability, beginning in the late 1970s and gaining momentum in the 1980s. The environmental historian Worster (1993) traces a similar move away from reductionism, control, and determinism in the history of ecological ideas. In the history of ecology, nature went from being on a generally predictable path towards optimisation, to an ever-shifting state of flux, lacking even a theoretical endpoint. Worster also points to the clear connections between social trends and the ideals of nature; here, it seems as if fashionable social ideas are applied to the functioning of ecosystems, and then recycled as ideal models of social organisation in accordance with the example of nature.

Other examples more closely related to the history of Earth System science also show how broad cultural frameworks are reproduced in knowledge production. Boardman (2010: 69) shows how the eighteenth-century enlightenment ideals of a benevolent creation were manifested in the understanding of an ordered and harmonious, but far from static, Earth. At that time, proposing ongoing geological processes challenged the dominant religious rendering of the planet as perfectly created once and for all. This can be contrasted with the more recent conceptions of an unstable Earth, as described by Dahan (2010). In her work, the Earth System of the 1990s is located in a cultural context which embraces chaos as a means of scientific understanding. The placing of chaos as a concept which is central to the understanding of the environment significantly undermines reductionist ideals of control and prediction. Hence, both Boardman and Dahan offer analyses of the social and scientific construction of nature with clear connections to the broader culture in which it was produced. Here, the development of knowledge is primarily explained as the effects of changing cultural and social contexts.

The Earth System, with its associated view of the planet as one interlinked system which it is possible to understand through usage of advanced technology, has many resemblances to the 'Spaceship Earth' concept of the 1960s. Combining the perspectives of culture, science, and technology, Höhler (2008) interprets the narratives connected to the spaceship metaphor; thus, 'the ship' is a symbol which combines the sense of unity offered by a fragile vessel with the possibilities of exploration and expansion. Making use of the ideas of Buckminster Fuller (1969) and Boulding (1966), Höhler shows how the metaphor also combined the global environment with a rationality of apolitical optimisation, led by an expertise in engineering, ecology, and economics. The spaceship should ideally be governed as a closed system, where a 'spaceman economy' would ensure

that essential resources were maintained. Again, as shown by Anker (2007), scientific arguments resonated current social values; at this time, space exploration and rationally governed colonies.

The interpretations of the spaceship metaphor also provide a good example of the relation between ontology and governing rationalities. As shown by Höhler (2008), the concept's life-support system suggests a reduction of life on Earth to those functions essential to the continuous operation of the planet as a machine. Thus, aesthetics, desires, as well as the intrinsic values of individuals, are obscured by the rational optimisation of the system. The biologist Garret Hardin drew an even more dystrophic conclusion from the spaceship metaphor as he connected 'carrying capacity' with 'life-boat ethics', arguing that, in the face of over-population and societal collapse, it was better to allow some to perish than to sacrifice the whole system (Linnér, 2003). There were, however, other voices; Ward (1966) used the metaphor to draw attention to the uneven allocation of resources and opportunities between the global North and South.

Even if the metaphor of 'Spaceship Earth' was conceived before the famous Apollo photographs of 1968 and 1972, these pictures served as a catalyst for the dissemination of a global perspective on environmental problems. Having examined the influence of the images on politics, Jasanoff (2001: 318) argues that "images become persuasive only when ways of looking at them have been carefully prepared in advance". Her study also shows that the images did not produce a sudden, paradigmatic, shift in ways of seeing the environment; rather, they took different paths through international negotiation, environmental movements, research, and commerce. However, images of the Earth from space have, in various ways, fostered a 'one-world' discourse.

Historical explanations of this globalisation of perspectives tend to be in line with interest-based interpretations, where the worldview of the elite is reinforced by scientific knowledge. When the charting of the global environment is interpreted in the context of global economy and politics, it fits well with studies on how the 'global' makes local issues invisible (Forsyth, 2003: 168, Stevis, 2005, Jasanoff and Martello, 2004). Particularly when combined with historical geography and science studies, environmental history engages with issues of 'science and empire' (Vetter, 2011: 18). Here, then, the ordering of nature is an inseparable aspect of governing faraway places.

Finally, considering the substantial literature on the history of geophysical research (Launius et al., 2010, Aronova et al., 2010) and the International Biological Program (1964-1974) (Kwa, 1987), the use of novel technology (Lambright, 1994, NOAA, 2007), and climate science (Demeritt, 2001, Gramelsberger and Feichter, 2011), surprisingly little research has been directed specifically towards the history of the global environmental change research programmes (WCRP, IGBP, IHDP, and DIVERSITAS), particularly when one considers that these organisations have coordinated thousands of

researchers, in international and interdisciplinary research networks, for more than 30 years. Most accounts of this history are provided by participants (e.g. Price, 1990, Fleagle, 1992, Mooney, 1999, Bolin, 2007, Steffen et al., 2011b, Mooney et al., 2013) and, while these accounts provide valuable pieces of the story, such narratives function as biographies, rather than historical analyses, and usually explain changes based on research rationales.

One exception is Kwa's historical research on the IGBP, which shows how ecology as a field, with its attention to local relations, navigated in a research structure dominated by the global perspectives which dominated geophysics (Kwa, 2005b). In one paper Kwa (2005a), uses the IGBP as a means of demonstrating how interdisciplinarity has many postmodern features, and that remedies for the resultant incommensurability of theories are sought in massive amounts of data. As such, the research of the IGBP connects to the interest of science-policymakers in applicable and useful knowledge, rather than coherent theories. In another paper, Kwa (Kwa, 2006) connects the interdisciplinary work done by the IGBP to the question of funding, showing that the ICSU organised the IGBP in a new way, in that the programme designed and promoted a bold research agenda while suggesting that funding should be applied for from the national funding agencies. Soon, science-policy officials reclaimed the initiative via the International Group of Funding Agencies for Global Change research (IGFA), which worked to assess the programmes and coordinate funding.

The landscape of scientific literature described in the three sections above deals with the production of environmental knowledge related to politics and power, predominantly from a critical and constructivist perspective. The encounters in this thesis with the production of the Earth System as an object of concern offer a connection between the literature on 'histories of nature's production' and governmentalities related to the global environment. Drawing on material from the problematisation and design of research in the global environmental change programmes, this thesis fills an empirical gap, since the IGBP and the IHDP have generally not been subjects of historical analysis. More important in my view, however, is the fact that the attention paid to the history of these programmes sheds light on a stage in the production of knowledge which precedes the more frequently studied global environmental assessments. Standing with one foot in each 'literature camp' provides a position that supports a discussion of the present political rationalities which flow from a historically produced Earth System. For example, the implications of natures produced by more traditional cartography, circulated as maps, provide a backdrop for interpretations of the natures produced by the scientific methods related to advanced simulation models. In the Anthropocene, this proves to be important due to a shift in the temporality of nature.

6 Results and discussion

"There is no way to secure a sustainable future for isolated places"
(Young et al., 2014: 2)

At the United Nations Conference on Sustainable Development, held in Rio de Janeiro in the summer of 2012 (Rio+20), various world leaders explored the possibility of adopting quantitative goals for global sustainability. In the Rio+20 outcome document, 'The Future We Want', it is stated that such global Sustainable Development Goals (SDGs) "should address and incorporate in a balanced way all three dimensions of sustainable development and their inter-linkages" and be "action-oriented" and "global in nature" (United Nations, 2012: § 246-7). The proposition to replace the Millennium Development Goals (MDGs), adopted by the UN in 2000, with new SDGs by 2015 continues on a path laid out in human-development focused debates (Linnér and Selin 2013). By drawing on 'planetary must-haves' and the importance to find productive balance between sometimes contradicting interests of human development Earth System researchers seeks to add planetary boundaries as a twin priority to global environmental governance (e.g. Griggs et al. 2013; Young et al. 2014). While disagreement remains regarding the specific nature of these new goals, most arguments rest upon a systemic representation of contemporary environmental problems and the invocation of biophysical limits for social and economic development. As highlighted at the conference, resolution, poverty, climate change, and other pressing environmental and developmental challenges of today are too interconnected and international in nature to be dealt with in isolation. As a consequence, 'The Future We Want' underscores "the importance of interlinkages among key issues and challenges and the need for a systematic approach to them" (United Nations, 2012: § 76).

In this thesis, I argue that there are close links between how problems such as global change are represented and 'known', and the political arrangements devised to address these problems. In order to understand how long-standing scientific discussions about the dynamics and trajectory of global environmental problems are linked to a global politics of the environment, I have traced how the ontology of the Earth System took shape, from a visionary hypothesis in the mid-1980s to a knowable and governable object in time for the Rio+20 conference in 2012. Tracing the history of contemporary ways of seeing and knowing the 'Earth System' offers a critical vantage point for reflecting upon the contingency of seemingly stable conceptions of nature and the necessity of particular forms of eco-politics. Writing a history of the present which is both critical and effective does not, however, leave me with any generalisable conclusions. As explained by Rose

et al. (2006), governmentality studies offer a way of asking questions which does not lay claims to totality; it does not seek to explain *why* things happen, but *how* they happen and how they differ from what has occurred before. Demonstrated in such a 'history of Truth' is that scientific knowledge, coherent as it might seem, rests on historically produced "localized and heterogeneous ontologies" (Dean, 1996: 210).

What follows brings together the findings of my study's four papers in order to outline how the Earth System was produced as an object of concern, and to discuss what political *implications* this particular way of seeing and knowing human-environment relations may generate. The scientific discussions studied in this thesis are interpreted as an important part of an Earth System governmentality, which implies that ways of seeing and rationalities for knowing are understood as intertwined with materiality through practices oriented towards the goal of producing scientific knowledge relevant for policy-making. Thus, the power/knowledge of Earth System ontologies are seen as intentional, but also non-subjective in the sense that they are beyond control of any actor. However these ontologies are important since they constitute "different ways of *thinking* about who we are, [and] how we should act" (Dean, 1996: 210). Hence, scientific knowledge both produce knowledge that enable strategic governing and a mentality which makes decisions accepted and thus enable 'governing at a distance' (Rose and Miller, 1992).

6.1 Elements of an Earth System governmentality

The papers included in this thesis offer different entry points to the historical constitution of the Earth System as a knowable and governable object in environmental science and policy. In Paper I, I offer a historical analysis of how planetary dynamics were rendered problematic through Earth System research, developed at the intersection of the IGBP's and the IHDP's ecosystem and land use research. Paper II offers a closer scrutiny of the integrative ambition of Earth System modelling and the difficulty inherent in coordinating and streamlining diverse, and sometimes competing, analytical traditions and agendas into a singular understanding of the planetary life support system as a whole. Paper III draws attention to the political geography of the IGBP's scientific networks, and explores how efforts to coordinate Earth System research on a global scale have been preoccupied with the geopolitical dynamics of global North-South relations. Finally, in Paper IV, I study how Earth System scientists themselves historicise their research endeavours.

In the following section I do not offer a detailed summary of each paper; instead the findings are synthesised into an analysis of the Earth System outlook with particular reference to governmentality (Lövbrand et al., 2009). To that end, I make use of the analytical variables proposed in Dean's (2010) analytics of government (discussed in Chapter 4). As outlined in Table 6.1 below, I bring together the *fields of visibility, technologies and practices, knowledge and rationality, and formation of identities, the*

latter being the agents and selves made possible by the Earth System outlook of global change research. The table does not account for the historicity of the Earth System concept, but presents important components of the current imaginary. In the following, I show how these components were assembled over time into an apparatus of technologies, practices, and ideas, representing an integrated Earth System science. My analysis suggests that the 'Earth System governmentality' outlined in Table 6.1 is the (contingent) effect of a long history of knowledges and rationalities that have produced the Earth System as a distinct object of concern. My analysis also raises questions about the kinds of identities and subject positions invoked by an Earth System outlook. Against the backdrop of the findings in Table 6.1, I discuss both the historicity of the present Earth System ontology and the political implications of this particular way of seeing and knowing the environmental problems of today.

Figure 6.1 Analytics of Earth System governmentality

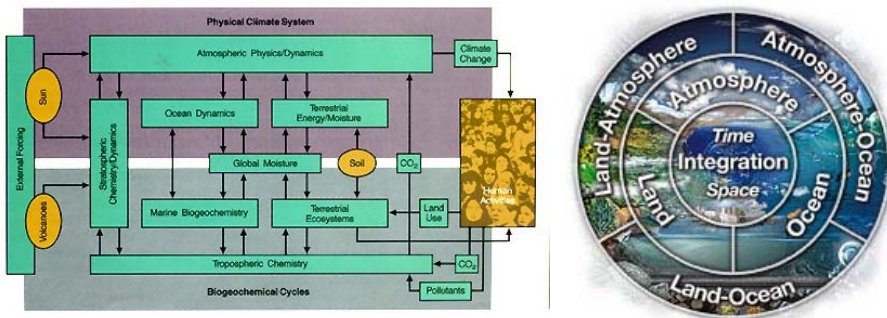
Field of visibility	Technologies and practices	Knowledge and rationalities	Formation of identities
<i>What is illuminated, what obscured?</i>	<i>By what instruments, procedures and technologies is rule accomplished? (here, primarily scientific)</i>	<i>Which forms of thought arise from and inform the activity of governing?</i>	<i>What forms of self are presupposed by practices of government?</i>
<i>What problems are to be solved?</i>			<i>Which transformations are sought?</i>
Planetary boundaries, thresholds, tipping points	Sustainable Development Goals	Planetary stewardship – global vs. polycentric policy coordination	Earth System stewards or managers
The Anthropocene - human domination of the planetary life support system	Computerised analytics and integrated Earth System models	State of exception, environmental urgency	Universal humanity as driver of global change but also heterogeneous, situated political subjects
Geological timescales, maps of possible futures	International and interdisciplinary research coordination	Integrated knowledge leads to better decisions	The interdisciplinary global change scientist
The Earth System as one interlinked 'human-environment system'	Human-environment and socio-ecological systems research	Interconnected problems require interconnected solutions	
The whole Earth as a living body to be diagnosed by rational scientific inquiry	Top-down/bottom-up approaches	Systems thinking and complexity science	
	Harmonised, world-wide data collection		

Source: The table structure draws upon Dean (1999) and Oels (2005).

6.1.1 Fields of visibility

According to the 2006 strategic plan of the International Geosphere-Biosphere Programme, its aim is "to provide scientific knowledge to improve the sustainability of the living Earth" (IGBP 2006:3). This formulation speaks to 'ways of seeing' the Earth and the problem of global change fostered within the international networks of global change research studied in this thesis. In Paper I, I contrast the mechanistic vision of the Earth System captured in the Bretherton Diagram from the mid-1980s with the more integrated and dynamic Earth System imaginary forged at the intersection of the IGBP's and IHDP's land use projects (see Fig. 6.2). When the IGBP was founded in 1986, the Earth System was represented as the aggregated sum of different subsystems, such as the atmosphere, the terrestrial biosphere, and the hydrosphere. These subsystems corresponded to the disciplinary interests of the participating IGBP research networks, which were each given a box in the Earth System diagram and subsequent research projects in the IGBP. By 2006, however, the Earth System imaginary had developed in a more integrated and dynamic direction. The increased interdisciplinary collaboration within and across the IGBP and the IHDP complicated the mechanics of the box-like Earth System, and pointed towards the many dynamic interactions across the various subsystems. Human activity had also moved away from a marginal position as an external force or stressor, to the centre stage of Earth System dynamics. The Earth System had become an interlinked 'human-environment system' (Paper I). As shown by the auto-history of global environmental change research at this time, the shift was supported by the new research agenda being contextualised by the long history of a co-evolving Earth System, instead of the logical next step in the history of science, as in 1986 (Paper IV).

Figure 6.2 The two Earth Systems; the Bretherton diagram of 1986, and the IGBP representation of 2006.



Sources (NASA-ESSC, 1986, IGBP, 2006)

In this thesis, I suggest that this fundamental shift in the ways of seeing the Earth and its environmental dynamics is the unanticipated effect of the growing analytical attention being paid to ecosystem and social dynamics in the study of global change, as well as increased computer power for Earth System simulations (Papers I and II). In the IGBP's early Earth System models from the late 1980s, vegetation was treated as the effect of conditions in soil, temperature, and moisture. Due to a lack of sensitivity for spatial relations and species composition, modellers sometimes called these uniform ecosystems "green slime or big-leaf" (Chapin and Shaver, 1996: 822). In response to this passive and static account of ecosystems, ecologists active within an IGBP initiative known as the 'Global Change and Terrestrial Ecosystem' project (GCTE) in the mid-1990s introduced ecosystem complexity and spatial relations to the Earth System equation. Through Dynamic Global Vegetation Models (DGVM), the GCTE project showed that ecosystems do not react linearly to changes in moisture and atmospheric conditions, but had to be included as dynamic components in Earth System models (Paper I). A necessary condition for this shift in approach was increased computer power, which made it possible to represent global vegetation simulations spatially. Through the introduction of DGVMs, ecosystem modellers were able to produce realistic maps that were comparable with images from space (Paper II). The intuitive qualities of these maps raised the acceptance of dynamic vegetation models in the global change research community, thereby paving the way for an Earth System vision that accounted for changes in vegetation type and spatial extension (Paper I).

As ecosystem dynamics became increasingly important in Earth System modelling, attention was also drawn to social dynamics. In order to predict changes in vegetation and climate, modellers had to incorporate assumptions about the drivers and impact of human land use change into their simulations. To that end, cooperation was established in 1991 between social scientists active within with the HDP/IHDP network, through the joint programme on Land-Use and Land Cover Change (LUCC). Working in close cooperation with the GCTE, the LUCC project struggled with the challenge of combining remotely sensed data on global and regional land cover change with qualitative case studies of the socio-economic drivers of land use change in particular places (Paper I). In 2000, the combined work of ecologists, social scientists, and the modellers of GCTE and LUCC had problematised the interconnections of the terrestrial component of the Earth System, to the point that the contributors began to merge them into a new project, focused on the land system.

As the Global Land Project (GLP) was presented in 2005, the various land systems were not simply represented as complex human-environment systems; rather, they were also seen to be non-continuous, in the sense that they affect, and are affected by, socio-economic processes and drivers in faraway places as a result of global trade and

information flows. Economic relations, power, and social memory influence land use dynamics in relation to natural as well as social change on different time and spatial scales (Paper I). By acknowledging the heterogeneity of places and regions across the land system, the Global Land Project began to challenge the possibility and utility of singular and uniform kinds of Earth System knowledge that, in the words of Hulme (2010: 558), "so easily erase difference and collapse meaning". Instead, the interdisciplinary collaboration within the GLP paved the way for more regionally-sensitive ways of seeing and knowing Earth System dynamics.

In this thesis, I argue that developments within the GCTE, LUCC, and GLP all feature a broad shift, away from machine-like ways of seeing planetary dynamics and towards notions of the Earth System as a living entity. In Paper II, I trace how, in the late 1990s, the IGBP task force, known as Global Analysis Integration and Modelling (GAIM), started to describe the planet with metaphors borrowed from medicine rather than mechanics. Led by the new chairman Hans-Joachim Schellnhuber, GAIM criticised the "boxed vision" of the Bretherton diagram and its model of "weakly coupled organs" (GAIM, 2002: 10). As an alternative, Schellnhuber (2000: 3) called for a new mode of Earth System analysis that would produce policy-relevant knowledge about the various 'syndromes' of the Earth System. The 'Sahel syndrome' is a commonly used example, in which overuse of marginal lands, climatic variations, and migrations co-evolve (Petschel-Held et al., 1999, Steffen et al., 2004). This way of seeing the Earth System is effectively illustrated by the image of 'Earth System diagnostics' (reproduced on the cover of this thesis), which portrays an Earth System scientist as a surgeon, opening the planetary skin from a position in space (originally published in Schellnhuber, 1999: C19). When seen as a living body replete with historically co-evolving organs, syndromes, and fever, it was no longer possible to analyse the components of the Earth System in isolation. As previously recognized by Dahan (2010), the new Earth System vision instead called for a more holistic form of knowledge production and analysis.

With the Amsterdam Declaration on Global Change from 2001, jointly signed by the chairs of the IGBP, the IHDP, the WCRP, and DIVERSITAS, the global change research community called for new forms of global environmental science that will move beyond the simple cause-effect paradigm of the past. In order to account for the multitudinous, complex, and non-linear dynamics of the Earth System, more integrated and collaborative forms of knowledge are required (Moore et al., 2002). Starting from the Amsterdam declaration's representation of the Earth System as "a single, self-regulating system, comprised of physical, chemical, biological and human components" (Ibid.: 207), the IGBP formulated a new research agenda, in which the integrated Earth System was to be the very foundation of the research design, rather than the result of syntheses (Paper II). As a consequence, the boundaries of the old projects were redrawn in 2003 to focus on

three subsystems and three zones of sub-system interaction (see Fig. 6.2). Notably, the two projects that most clearly engaged with models of the global cycles of carbon (GCTE) and water (BAHC) were dismantled and incorporated into the other projects. In order to understand the planetary life support system as a whole, the IGBP wanted to bring about "a single, coherent [analytical] framework built jointly by social and natural scientists" (Steffen et al., 2004: 284). To that end, programme developers in the IGBP envisioned a close cooperation between the four global environmental change programmes, with Earth System modelling as the bridge (Interview with Steffen 2009). However, that ambition proved difficult to realise, and instead a more loose partnership for integrated global change research was established; the Earth System Science Partnership (ESSP) (Uhrqvist and Lövbrand, 2009).

At the heart of this integrated research agenda is the problem of global change. In this thesis, I have approached *global change* as the key problematisation of human-environment relations that motivates and informs global environmental change research. It is a concept that has evolved in relation to the Earth System imaginary, and come to denote the ability of human civilization to undermine the planetary life support system upon which it depends (Zalasiewicz et al., 2010). In recent years 'the Anthropocene' has popularised the global change concept, and produced a daunting narrative of human resource exploitation, planetary limits, and environmental urgency. In the Anthropocene, we are told, nature is domesticated, technologised, and capitalised upon, to the extent that it cannot be considered to be natural any longer (Arias-Maldonado, 2013). As argued in Paper I of this thesis, this representation of humankind, as a geological agent on par with many of the great forces in nature, is hard to separate from the integrated research efforts developed across the IGBP and the IHDP. By studying the dynamics and effects of anthropogenic changes to the Earth's land surface, oceans, coasts, and atmosphere across spatial and temporal scales, the Earth System scientists have come to understand humankind as a global force that is pushing the Earth System into a non-analogue state.

However, in the Anthropocene, problem space, resulting from 30 years of global change scholarship on human-induced global change, remains highly complex and unpredictable (Paper IV). As outlined in the Amsterdam Declaration on Global Change, "[h]uman-driven changes cause multiple effects that cascade through the Earth System in complex ways. These effects interact with each other and with local- and regional-scale changes in multidimensional patterns that are difficult to understand and even more difficult to predict" (Moore et al., 2002: 207). The highly uncertain effects of these complex Anthropocene relations have, in recent years, generated discussions about the feasibility and desirability of planetary limits for social and economic development. In 2009, Rockström et al. published a famous commentary in *Nature*, in which they sought to specify "the safe operating space for humanity" by invoking nine planetary boundaries

for human resource use and development. In order to avoid "human activities push[ing] the Earth System outside the stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world", Rockström et al. (2009b: 472) suggested that abrupt global change must be regulated and contained.

The present field of visibility is dominated by complex and interconnected human-environment systems behaving non-linearly and thus prone to surprises. Hence the way the Earth System is made visible is connected to problems; both since such complex systems are difficult to manage in general but particularly since human activity has pushed CO₂-concentrations and other important environmental parameters of the Earth System outside of normal variability and thus threaten the functionality of this life-support system. The 'State of the Planet Declaration', published during the Planet under Pressure conference in London 2012, provides a good example where the Earth System ontology is tied to a political rationality which require integrated goals for global sustainability based on scientific evidence (Brito and Safford 2012). The implications for political rationalities will be further discussed in the section on rationalities and knowledges below. As far as the field of visibility is concerned I conclude by pointing to the shift from an Earth System seen as a predictable machine to an Earth System as a living organism that can both confer remarkable stability and innovativeness, but which is also susceptible to abrupt and rapid changes and crises. As will be argued below, due to the multiple interactions so important in the Earth System ontology, the management of this living body cannot rely on long term prediction.

6.1.2 *Technologies and practices*

Since 1986, when the Earth System was suggested as a conceptual framework for global environmental change research, the ambition of the IGBP has been to develop simulation models with predictive capacity (IGBP, 1986, 2006). The technologies and practices related to global modelling are the most distinguishing and novel feature of the global change research agenda studied in this thesis. As many critics have argued, global modelling practices foster a top-down perspective on planetary relations and, as a result, a highly generalised understanding of environmental dynamics (Hulme, 2010, Jasanoff, 2010). This global gaze is said to be reinforced by the Anthropocene narrative, which takes humankind to be a unified geological force (Malm and Hornborg, 2014). In this thesis, however, I suggest that Earth System modelling has also led to a more complex and dynamic way of seeing human-environment relations. Efforts to predict the behaviour and long-term trajectory of the Earth System have continuously been complicated by new disciplinary perspectives and qualitative indicators; as a consequence, non-linear dynamics and unexpected consequences have come to represent central features of this research endeavour. In what follows, I will reiterate the central role granted to Earth

System models in the IGBP research networks, and discuss the productive work they have performed over the course of 30 years of global change research.

When the IGBP was planned in the early 1980s, Earth System models were approached as a means of unifying the global change research community. According to the programme founders (IGBP 1986:9), predictive models would offer discrete disciplinary networks "a common lexicon", and thus allow the environmental sciences to study the Earth as one integrated system. The integrative logic of computer models has continued to inform the global change community during the 30 years covered in this thesis. In the Global Land Project, for instance, modelling remains the remedy to disciplinary fragmentation, allowing diverse research communities to stay focused "on the same relational and behavioural issues" (GLP 2005:7). In Paper II, I discuss how these integrative modelling efforts have been coordinated by the IGBP's task force, GAIM, and core project, AIMES. My study points to an intricate interplay between top-down and bottom-up approaches which has complicated global ways of seeing and knowing human-environment relations (Paper II).

The top-down approach to modelling fostered by GAIM and AIMES takes stock of what is measurable at the boundaries of the Earth System (and its sub-systems), in order to explore possible ways to simulate the behaviour of the Earth System as a whole. Since the IGBP was founded, this top-down approach has sought to identify gaps in various disciplinary representations of global environmental dynamics, and thereby steer global change research towards one integrated understanding of the planetary life-support system as a whole. Bottom-up approaches, by contrast, work from the specificities of local socio-ecological dynamics and towards increased generalisation. Informed by detailed case studies of land use change and vegetation dynamics, this is an approach to modelling that stresses the complexity of place-based process interaction. During the 30 years covered by this thesis, the balance has shifted between centralising approaches such as Earth System analysis (Schellnhuber, 2000) and more empirical studies of process interaction, as found in the GCTE, LUCC, and GLP projects (Paper I). The history of GAIM illustrates tensions in the apparatus of Earth System governmentality.

Partly due to limited computing power in the late 1980's, the early Earth System simulations of GAIM organised the planet in the "form of crude box-models" representing huge geographical areas (IGBP 1990: 8.1-10). The initial mandate of GAIM was to incorporate the study of these boxes into one full picture of the dynamics of the Earth System as a whole. However, the coordinating function of GAIM proved difficult to achieve and, as a consequence, the mandate of GAIM changed over time. Rather than steering the various research projects under the IGBP umbrella to the needs of effective global modelling, GAIM's task became to enhance cooperation between the research communities already engaged in the modelling of the global circulation of carbon, water,

and nutrients (Paper II). When the IGBP's research efforts were synthesised between 1998 and 2001, discussions intensified regarding how to produce policy-relevant and predictive models that would better reflect a full-system perspective. At this point, assigned with the task of putting the pieces together, GAIM became engaged with Earth System analysis (Schellnhuber, 2000: 4).

As outlined in Paper III in this thesis, Earth System analysis represents an effort to simulate the past and present behaviour of the Earth System as a coupled human-environment system. Whereas the Bretherton diagram had portrayed human activities as an external stressor to the natural dynamics of the Earth System, humankind was now approached as an integrated part of a complex system based on a "few dozen key processes" (GAIM, 2002: 10). Based on this integrated approach, GAIM formulated 23 strategic questions that would help to foster and guide a unified Earth System science. Categorised as analytical, operational, normative, or strategic, these raised questions regarding the ontology of the Earth System, proper methods to simulate its behaviour, desired ends, and ways to get there. The second phase of the IGBP (2006) was highly influenced by these questions and, as GAIM was replaced by AIMES in 2004, the mandate was to find ways to better integrate 'the human dimension' into Earth System modelling (Paper II). As such 'the human-environment system' became an organising concept for the IGBP, and efforts were thus made to bring together a much broader range of analytical perspectives from the humanities and social sciences.

The continuous interplay and tensions between the top-down and bottom-up approaches to Earth System modelling studied in this thesis have, over the course of 30 years, resulted in a highly complex Earth System imaginary. The global ways of seeing and knowing the Earth fostered by the IGBP have, time and again, been questioned by the programme's discipline-transcending research activities, and forced modellers to adapt to the socio-environmental dynamics of particular places. When directing analytical attention to the internal dynamics of global change research at the intersection of the IGBP and the IHDP, I have found more geographically-sensitive and -situated forms of environmental knowledge which challenge the detached global gaze that critics often associate with the Earth System sciences (Hulme, 2010, Litfin, 1998a, Lövbrand et al., 2014). As more disciplinary perspectives have been included in the integrated study of the Earth System, the "globalizing instinct" (Hulme 2010) that initially informed the set-up of the IGBP in the mid-1980s has been complemented by more humble and locally grounded ways of seeing and knowing socio-environmental relations. An interesting example of this trend is found in the joint IGBP and IHDP project, SysTem for Analysis, Research and Training (START).

Another important coupling of technology and practice in an Earth System governmentality is the world of global change research networks, along with the

programmes themselves. As pointed out by Edwards (2010), a vast infrastructure, enabling the gathering, processing, and circulation of data, is needed for global modelling. Paper III traces the discussions, which initially took place in the IGBP and later as part of the START project, regarding how to make sure that the needed information was produced and circulated. The founding principle of START was to complement the use of satellites with much-needed work on the ground. The history of the START project provides an entry into the changing rationalities for expanding the research network.

As outlined in Paper III, the START project was designed to turn the global change research agenda of the IGBP into a "truly global network of research activities" (IGBP, 1991: 13). The global knowledge infrastructure of START was initially designed around 15 Global Biosphere Observatories that would function as regional centres for data gathering and research coordination. In order to ensure the global harmonisation of project data based on uniform measuring standards, START also worked in close cooperation with GAIM. However, in response to critiques from developing countries, this top-down coordination of global change research was soon complemented by decentralising ambitions. As stated in an early report from a START meeting in South East Asia, without "significant involvement of their own scientists, developing countries could disregard research generated primarily in developed countries" (IGBP, 1992: 13). As the START project developed, regional policymakers were also invited to ensure that the research results would be of relevance to regional policy making. This decentralisation of the IGBP's global change research agenda caused tensions between the interests, concerns, and needs of local populations on the one hand, and the harmonisation of data gathering for the purpose of global comparison and modelling on the other. Hence, the START project deliberately worked to enable researchers in all parts of the world to fully engage with global environmental change research agendas. As such, it can be seen as an important post-colonial critique of the global gaze of the IGBP, and has helped to connect the Earth System outlook to the many diverse realities of people and places across the developing world. The history of START, however, is far more complex; since most parts of the initial research agenda, formulated in Europe and the United States, remained intact. Thus, the project could also be seen as a way of implementing western modes of knowledge production and scientific ideals in developing countries. In either case, it was deliberately deployed as a strategy to increase scientific and political acceptance of the problem description of global environmental change.

6.1.3 Knowledge and rationalities

Efforts to translate the global change and the Anthropocene problem descriptions to environmental policy prescription have, to date, given rise to multiple concepts; these include Earth System stewardship, planetary management, and planetary boundaries.

Amongst these, the planetary boundaries concept, outlining nine biophysical thresholds for human resource use and social development, has thus far gained the most widespread recognition. (Rockström et al., 2009b). These thresholds rest upon global descriptions of environmental problems, such as climate change, stratospheric ozone depletion, global freshwater use, and biodiversity loss, and together specify "the safe operating space" for human civilization as a whole. In order to avoid "human activities push[ing] the Earth System outside the stable environmental state of the Holocene, with consequences that are detrimental or even catastrophic for large parts of the world", Rockström et al. (2009b: 472) suggest that abrupt global change must be regulated and contained at the system level. Despite the planetary rhetoric Rockström et al. (2009a) also "distinguish between identifiable planetary thresholds driven by systemic global scale processes... and thresholds that may arise at the local and regional scales". With six out of nine boundaries seen as arising from aggregated local activity the relation between global and local becomes more complicated. What kind of political implications may result from this way of seeing and knowing human-environment relations?

Some critics have claimed that the invocation of planetary boundaries harbours a managerial impulse that paves the way for grand geo-engineering schemes (Pielke, 2010). Just as with political rationality, geoengineering draws heavily upon the expertise and technical advice of the Earth System sciences, and only those with knowledge of the intricate dynamics of the planetary life support system as a whole can aspire to devise and predict the consequences of large-scale management of the Earth's biogeophysical processes and systems (UK Royal Society, 2009). However, geoengineering is by no means an automatic political response to the Anthropocene problem description. As discussed in Paper I of this thesis, geoengineering remains a contentious topic within Earth System science circles, as its critics claim that it is politically unfeasible and an irrational use of important resources (Schellnhuber, 2011); moreover, detractors also point to the complexity of the Earth System, especially when ecosystems are included (Russell et al., 2012). According to Steffen et al. (2011b: 752) the deliberate manipulation of Earth System processes also represent a short-term "symptom treatment" rather than a long-term reversal of the anthropogenic pressures which lead to dangerous global change in the first place. Any efforts to adjust socio-economic development to the biophysical boundaries of the planet must, therefore, address human behaviour and values (Ibid.). To that end, global collective action through interstate treaty-making is one of the most commonly supplied responses.

In 2012, Frank Biermann and colleagues suggested that the environmental urgency of the Anthropocene represents a constitutional moment for international environmental cooperation which may prompt states to abandon established decision-making conventions and accept qualified majority voting as a way to forge more effective

environmental agreements on a global scale. In order to safely navigate the Anthropocene crisis, structural change in global governance is required (Biermann et al., 2012). As further discussed below, the active subjects in this global governance are primarily the Earth System experts who define the possible pathways by delineating limits and calculating priority trade-offs. The suggestion to reform international institutions for the purpose of Earth System stewardship resonates with recent efforts to establish integrated global goals for sustainable development. According to Griggs et al. (2013), the introduction of SDGs may help to strengthen the global environmental targets from existing international environmental agreements, and offer a unified social and environmental framework for global sustainability. The underlying political rationality of such targets is that the interconnected problems of the Earth System require interconnected solutions. The protection of the Earth's life support system as a whole is a prerequisite for a thriving global society (Griggs et al., 2013). As a consequence, "integrated goals for global sustainability based on scientific evidence are needed to provide essential targets for societies" (Brito and Stafford Smith, 2012: § B1).

Running parallel to these proposals to govern the environmental consequences of human behaviour through the establishment of global-scale and expert-informed limits to social development, this thesis has also identified a more down-scaled and modest political rationality. This alternative political imaginary is heavily informed by the urgency of the narrative of the Anthropocene, but questions the possibility and desirability of global-scale managerial schemes. In the face of Earth System complexity, and non-linearity, along with its capacity for the unexpected, new forms of governance are said to be required (Duit et al., 2010). As exemplified in Paper I, the integrated modelling of land use dynamics across the IGBP and the IDHP has paved the way for a more geographically-sensitive Anthropocene vocabulary which is attentive to the spatially variable interactions between people and their lands. A similar trend is found in the auto-histories contextualising global change research. The more solution-oriented the research agendas and narratives become the more attention is given to local and regional variation (Paper IV). By beginning the analysis of the Earth System in local or regional land use dynamics, a growing number of global change scholars have offered a forceful counter-narrative to the global and managerial impulse that informed the initial design of the IGBP. Rather than thinking of integrated Earth System models as powerful "time machines" that will allow humankind to trace its footsteps into the future and thus make "collective 'rational choices' on the system's level" (Schellnhuber, 1999: C22), this parallel narrative embeds Earth System dynamics in the non-linear realities of particular social groups and places.

This alternative way of seeing and knowing the Earth System suggests the adoption of a more humble attitude to what can be known about the system components, as well as

the location of their boundaries and possible tipping points. Given the fundamental complexity of Earth System dynamics, it suggests that universal global-scale management of the system as a whole is beyond reach. In its place, there is a selection of possible and desirable futures, towards which societies may decide to strive (See paper II and Schellnhuber, 2007, O'Brien, 2012). Efforts to identify and mediate transitions to such futures are often informed by the political vocabulary of adaptive and polycentric governance. As outlined in the 'State of the Planet Declaration', crafted by the global change research community prior to the Rio+20 meeting in the summer of 2012,

"there is growing evidence that diverse partnerships amongst local, national and regional governments as well as business and civil society provide essential safety nets should singular global policies fail – a polycentric approach for planetary stewardship" (Brito and Stafford Smith, 2012: § 7).

By adopting this approach to planetary stewardship, actors across society may learn to adapt to catastrophic shifts and surprises in biophysical systems, and hence build more resilient social-ecological relations (Folke et al., 2011, Duit et al., 2010). A polycentric interpretation of Earth System stewardship is thus informed by the logic of social learning, which is also deemed to be necessary for the long-term transformation of "values, beliefs and aspirations towards sustainable prosperity" (Brito and Stafford Smith, 2012: § 9).

The tension between these two parallel political rationalities reoccurs in my material, but seldom in a neat, binary fashion. The scientific discussions about the Earth System, fostered at the intersection of the IGBP and the IHDP, are themselves complex and dynamic, and therefore do not lend themselves to any unequivocal political interpretation. Ways of seeing and knowing the Earth System have shifted over time; in its infancy, it was thought to be predictable, and many believed that observations of natural behaviour could be distilled via long-term observation and modelling of natural variability (IGBP, 1988). The increased importance attributed to ecosystems, human activity, and spatial relations contributed to an increasingly complex understanding of the Anthropocene Earth System as a co-evolving human-environment system (Steffen et al., 2004).

What remains clear from my analysis, however, is the close interplay between ways of seeing, knowing, and acting upon the Earth System, and the problem of global change. As argued by Miller and Rose (2008: 15), from the perspective of governing it makes little sense to identify "a problem unless one simultaneously set out some measures to rectify it". Hence, "if a particular diagnosis or tool appears to fit a particular 'problem', this is because they have been made so that they fit each other" (Ibid.). In this thesis the apparent 'fit', both in science and politics, is interpreted and as the result of an 'effective history' that has made processes stand out as durable and diagnosable objects (Dean, 1994).

In the case of the Earth System, the more complex the system is seen to be, the more support is to be found for co-production of knowledge, adaptive governance strategies and polycentrism. When understanding governing as relying on productive power that enable the 'conduct of conduct' of subjects free to do otherwise, shared knowledge, which produces a field of possible action and points to desired ends, becomes a requisite (Dean, 2010). In an Earth System governmentality, the subjects, be they scientists in global change research programmes or Mr. and Mrs. Smith, must embody an Earth System way of seeing if governing is, at its most basic, going to work. Particular ways of seeing and knowing are made possible through interpretation based upon interpretation and, as such, the effects of history shape our engagement with the world. Hence, ontologies, historically produced as they are, do matter.

6.1.4 Formation of identities

Governmentality studies draw an analytically important distinction between effects which result from 'force', which imply direct action upon bodies and things, and 'power' which is "acting upon others' actions" (Foucault, 1983: 220). This productive form of power thus requires that subjects both act and be acted upon. As part of a constructivist understanding of identities and interests, these subjects are not prior to knowledge production (Foucault, 1980b: 97). Instead, subjects are produced with interests and desires, through which governing becomes possible. Hence, ways of knowing the Earth System produce subjects with particular fields of visibility, including problems to be dealt with and strategies to reach desired ends.

In the following section I discuss three subjects to Earth System governmentality, the first of which are the interdisciplinary global change experts that embody the scientific ideals of Earth System research. What follows are some accounts of decision-makers and, finally, a discussion of 'global humanity', who need to adapt their lifestyles to secure human wellbeing and the functioning of global and local environments. However, as the empirical material of this thesis relate primarily to discussions about the problematic relation between research practices and studied objects, the other subjects only appear occasionally. This section will therefore be of a speculative nature, in that disparate comments about subjects are drawn together and interpreted. Thus, the section will primarily reflect upon the potential effects of different subjectivities produced in an Earth System governmentality.

The interdisciplinary global change researcher is the most present subject in the studied material. The existence of, and coordination work performed by, international research programmes suggests that this subject was not self-evident. As shown in Paper IV, the strategy in the early years was to position global change researchers as the natural continuation of a long and successful scientific history. Paraphrasing Isaac Newton, Malone (1985: xix) stated that Earth System scientists "now stand – on the shoulders of

our predecessors – on the threshold of a revolution of historic proportions on human understanding". This new step for science was also articulated as necessary due to the fact that the earlier success of disciplinary research had brought such fields to the point where interactions with other processes were needed. Attributing to subjects a capacity for and values of international cooperation, interdisciplinary study and the use of advanced technology placed future participants in the IGBP as a part of the creation of a better world for humankind (Paper IV).

The global change researcher as an active subject in the Earth System governmentality is also visible in the work of implementing the research agenda globally. The researcher subject is considered to be the agent who takes the integrated view of human-environment interaction to new places, and increases support for research and policymaking related to global change (Paper III). This role developed from that of an implementer of universally standardised templates for global change research to the facilitator of a more interactive process, where the relevance of research questions and implementation was negotiated in regional contexts. However, the researcher was still supposed to be the initiator and driver of these processes (Paper III). The active role of the researcher indirectly suggests the status of policymakers as passive subjects, possible to govern through their interest in local matters and locally produced knowledge. Beyond the subjects of scientists and policymakers, other subjects, as actors with interests or desires, rarely appear at all in the discussions.

From around the year 2000, the focus shifted towards the global change researcher as a part of Earth System stewardship. Here, researchers were increasingly described as actors in relation to the task of finding solutions to the problems posed by global change. This, in turn, fostered a subject able to develop closer cooperation with policymakers and stakeholders (Paper IV). From 2001, the projects of the Earth System Science Partnership (ESSP) provided the primary arena for this integrated problem-solving (Uhrqvist and Lövbrand, 2009, Ignaciuk et al., 2012). Again, agency was attributed to the researchers initiating science-policy interaction and providing integrated assessments of pathways through the human-environment system. This more socially active research subject was closely connected to the shift towards seeing the Earth System as increasingly complex.

The Earth System governmentality also produces subjects beyond the science-policy interaction. One problematisation which has emerged from the Earth System outlook is that "citizens" need to change their behaviour (e.g. Biermann et al., 2012, Griggs et al., 2013). This vaguely defined group of humans is usually connected to the Anthropocene narrative. From the perspective of governmentality, governing behaviour requires detailed knowledge of the interests and desires through which governing can operate (Miller and Rose, 2008). Dean (2010: 44) argues that regimes of government do not determine subjectivity, but attribute and foster capacities and qualities to agents, and "are

successful to the extent that these agents come to experience themselves through such capacities". Hence, a governmentality that does not foster active subjects will not have the desired effect.

In the Anthropocene narrative, humankind emerges as a universal and disembodied entity which acts as a collective and destructive entity, together with the major geological forces. Critics maintain that this contracting of social diversity and complexity into a single path for humanity has resulted in a de-politicised vocabulary, with little social content. As claimed by Lövbrand et al. (2014), there are no actors, interests, or social categories acknowledged within this humanity, and nor is there any evidence of social injustice or asymmetry. By erasing local diversity and difference, the "environmental big-talk" (Radcliffe et al. 2010) of the Anthropocene produces an empty view of humanity, amenable to grand managerial schemes (Hulme 2010).

This thesis argues that to understand the Earth System outlook one has to look beyond the global rhetoric and to also attend to internal, more nuanced discussions, where local dynamics problematise the accuracy of a global perspective. However, the material I have studied barely covers active subjects, beyond the scientists. One exception is Paper I, which shows how the modelling of land systems requires the inclusion of power relations, culture, and history in order to produce simulations that represent the differing responses to similar pressures observable in case studies of land use and land use change. This example shows that the discussions about the Earth System found in the global change research programmes is more nuanced than the present Anthropocene narrative, which seem to produce a 'humankind of geology'.

However, the Anthropocene narrative also argues that the old boundary between humanity and nature has lost its significance and that has been taken up beyond the scientific networks for global change research. For almost a decade, the Anthropocene was an internal concept in the global change research community. Since 2009, however, it has been taken up by a much broader range of scientific disciplines; these are often more closely connected to experience and local relations, and primarily interested in the effects of a post-nature or new human-nature relation (e.g. Weakland, 2012). This raises interesting questions about the potentiality of subjects in the Anthropocene and also exemplify the non-subjective dimension of power/knowledge.

Discussing the possible implications of the 'global gaze' enabled by remote sensing, Litfin (1998b: 214) points both to the potential of further commodification of nature and to possibilities for other subjects understanding and politicising their interests. It is quite probable that similar ambiguities, drawn from the relations between humans and nature, may become visible as the Anthropocene concept is taken up by fields beyond global change research. In the end, an Earth System governmentality, effective in securing a safe operating space for humanity, will have to embody subjects through which persons can

make sense of their everyday lives and make strategic choices. Remembering the differences within the humanity (e.g. Malm and Hornborg, 2014, O'Brien and Barnett, 2013), this will probably require a range of different subjects to match the current heterogeneity of the human species, as the 'empty subject' of the current Anthropocene narrative, as it stands at present, will not be enough.

6.2 So what? Knowledge, power, and the Anthropocene

My encounter with the Earth System as an object of concern draws attention to the intrinsic connections between ways of seeing global environmental problems, scientific knowledge about the Earth System, and strategies for securing global sustainability. The Earth System outlook connects generalised global syntheses and detailed studies of interactions in human-environment systems, down to the local levels of case studies. This dual perspective nuances earlier interpretations of the Earth System as an exclusively global kind of knowledge, removed from the local places that contain nuance, ambiguity, and meaning (e.g. Hulme, 2010, Malm and Hornborg, 2014). These social studies approach the Earth System outlook at the intersection between science and policy or through the global rhetoric of the Anthropocene narrative. Based on the results of this thesis, there seems to be a discrepancy between how the Earth System is discussed in the research programmes, and how it plays out in policy discussions and environmental assessments. While the political rationalities embedded in the Earth System ontology, as discussed in the programmes, point to local and global processes, surprises and adaptive management, the Earth System evoked in policy processes draw on global dynamics and universal subjects. A conclusion that can be drawn from this is the importance of broadening the analysis of science-policy interactions, to include more detailed accounts of the scientific processes at work before and beyond the science/policy interface.

In such a broadened analysis the history of science must be considered to have its own interests, motives, and rationalities. This supports Whitehead's (2009) argument that science can be an unreliable ally for governance, since the outcome of research cannot always be foreseen or desired. Moreover, if only the global perspective of the Earth System outlook is incorporated into international global environmental politics, the dual perspectives suggested in this thesis raise questions about how and why the important role of local dynamics were omitted. By pointing to the importance attributed to local interconnections in the human-environment systems, my interpretations add a dimension to the voices which seek to criticise the global and distanced gaze, represented by Earth System analysis and other global approaches.

The shift from a global, predictable Earth System towards an Earth System as a living body with important local interactions is connected with new ideals of governing. There has been a move away from the role of science and scientists as knowledge suppliers,

towards one which privileges co-productive relationships between policymakers, researchers, and other stakeholders. This ideal, of increased engagement in policymaking, resonates with an understanding of the Earth's human-environment as complex systems. The inherent difficulties in predicting and controlling such systems has placed adaptive government as the most rational mode for managing human well-being in the context of global environmental change. Again, the tension between local and global becomes visible, since the suggested, dispersed governing still has to align its goals to the safeguarding of planetary boundaries.

As part of the IGBP's ambition to understand the natural behaviour of the planet, the temporal perspective expanded, from the human viewpoint of centuries to interglacial periods, incorporating biological and geological cycles. The Anthropocene thus emerged from this geological perspective, and problematises our time as one where humanity has become one of the great geological forces. Crutzen (2002) termed this "the geology of mankind". Interpreting the problem description and implications of the Anthropocene narrative in relation to the history of the scientific context where it emerged shows that the story so far treats the effects of human activity as inputs in models of the natural environment. The as-yet untold second act of the Anthropocene story needs to include a well-developed account of the spatially distributed and long-term social processes which created central events such as the industrial revolution and the great acceleration. Such a narrative would avoid the present articulation of a mankind of geology. For those who look forward to this sequel, the good news is that many of the reflections required can already be found in research on more local human-environment systems.

Dreams of Earth System models able to predict the global environment and thus guide strategic decision-making still motivate research initiatives. In 2011, the key funders and users of Earth System science organised in the Belmont Forum (2011: 2) found it reasonable to ask for an "Earth System analysis and prediction system"; a "seamless, holistic environmental decision-support system". The history studied in this thesis shows that seamlessly integrating humans and the environment, as well as what to include in a holistic view has been far from self-evident issues in global environmental change research. My study argues that studies of the genealogy of the Earth System outlook has to journey further and more broadly than the production of global integrated models and their impact on environmental assessments such as the IPCC. The detailed studies of local interactions play an important role together with Earth System modelling in the formation of the Earth System governmentality. Hence, the final argument in this thesis is that participating scientists, policymakers, and citizens need to remain reflective about which processes are included, and how they are incorporated, when calculating or simulating the future of our planet. The Anthropocene could be the end of nature, but it is far from the end of history.

7 References

- Adler, E. & Bernstein, S., 2005. Knowledge in power: the epistemic construction of global governance. In: Barnett, M. & Duvall, R. (eds.) *Power in Global Governance*. Cambridge: Cambridge University Press, 294-318.
- Agrawal, A., 2005. *Environmentality : technologies of government and the making of subjects*, Durham, Duke University Press.
- Alvesson, M. & Sköldbberg, K., 2009. *Reflexive Methodology : New Vistas in Qualitative Research*, SAGE Pubns Ltd.
- Anker, P., 2007. Buckminster Fuller as captain of Spaceship Earth. *Minerva*, 45, 417-434.
- Arias-Maldonado, M., 2013. Rethinking Sustainability in the Anthropocene. *Environmental Politics*, 22, (3) 428-446.
- Aronova, E., Baker, K. S. & Oreskes, N., 2010. Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957–Present. *Historical Studies in the Natural Sciences*, 40, (2) 183-224.
- Aubin, D. & Dalmedico, A. D., 2002. Writing the History of Dynamical Systems and Chaos: Longue Durée and Revolution, Disciplines and Cultures. *Historia Mathematica*, 29, (3) 273-339.
- Bacchi, C., 2012. Why Study Problematizations? Making Politics Visible. *Open Journal of Political Science*, 2, (1) 1-8.
- Baldwin, A., 2003. The Nature of the Boreal Forest: Governmentality and Forest-Nature. *Space and Culture*, 6, (4) 415-428.
- Barnett, M. N. & Duvall, R. (eds.) 2005. *Power in global governance*, Cambridge, UK; New York: Cambridge University Press.
- Barry, A., 2001. *Political machines : governing a technological society*, London; New York, Athlone Press.
- Beck, S., 2012. Between Tribalism and Trust: The IPCC Under the "Public Microscope". *Nature and Culture*, 7, (2) 151-173.
- Beck, U., 2000. *What is globalization?*, Cambridge, En, Polity Press.
- Belmont, F., 2011. The Belmont Challenge: A Global, Environmental Research Mission for Sustainability, white paper.
- Berg, B. L., 2001. *Qualitative research methods for the social sciences*, Boston, Allyn and Bacon.
- Biermann, F., 2007. 'Earth system governance' as a crosscutting theme of global change research. *Global Environmental Change-Human and Policy Dimensions*, 17, (3-4) 326-337.
- 2012. Planetary boundaries and earth system governance: Exploring the links. *Ecological Economics*, 81, 4-9.
- Biermann, F., et al., 2010. Navigating the anthropocene: the Earth System Governance Project strategy paper. *Current Opinion in Environmental Sustainability*, 2, (3) 202-208.
- Biermann, F., et al., 2012. Navigating the anthropocene: Improving earth system governance. *Science*, 335, (6074) 1306-1307.
- Blomqvist, L., Nordhaus, T. & Shellenberger, M., 2012. Planetary Boundaries: A Review of the Evidence. Oakland: Breakthrough institute.
- Boardman, R., 2010. *Governance of Earth systems : science and its uses*, Basingstoke, Hampshire England ; New York, Palgrave Macmillan.

- Bolin, B., 2007. *A history of the science and politics of climate change : the role of the Intergovernmental Panel on Climate Change*, Cambridge, Cambridge University Press.
- Boulding, K. E., 1966. The economics of the coming spaceship earth. In: Boulding, K. E. & Jarrett, H. (eds.) *Environmental quality in a growing economy; essays from the Sixth RFF Forum*. Baltimore: Published for Resources for the Future by the Johns Hopkins Press, 3-14.
- Bowen, G. A., 2009. Document Analysis as a Qualitative Research Method. *Qualitative Research Journal*, 9, (2) 27-40.
- Brasseur, G., 2003. 3 rd IGBP Congress Overview. *IGBP Newsletter*, (55) 1-3.
- Braun, B., 2000. Producing vertical territory: Geology and governmentality in late Victorian Canada. *Ecumene*, 7, (1) 7-46.
- Bridge, G. & Perreault, T., 2009. Environmental Governance. In: Castree, N. (ed.) *A companion to environmental geography*. Chichester, U.K.; Malden, MA: Wiley-Blackwell, 475-497.
- Brito, L. & Stafford Smith, M., 2012. State of the planet declaration - from the conference Planet under pressure in London 2012. http://www.planetunderpressure2012.net/pdf/state_of_planet_declaration.pdf.
- Brown, W., 1998. Genealogical Politics. In: Moss, J. (ed.) *The later Foucault : politics and philosophy*. London; Thousand Oaks: SAGE Publications, 33-49.
- Bryman, A., 2008. *Social research methods*, Oxford; New York, Oxford University Press.
- Burchell, G., 1996. Liberal Government and techniques of the self. In: Barry, A., Osborne, T. & Rose, N. S. (eds.) *Foucault and political reason : liberalism, neo-liberalism, and rationalities of government*. Chicago: University of Chicago Press, 19-36.
- Bäckstrand, K., 2004. Scientisation vs. civic expertise in environmental governance: Eco-feminist, eco-modern and post-modern responses. *Environmental Politics*, 13, (4) 695-714.
- Bäckstrand, K. & Lövbrand, E., 2006. Planting trees to mitigate climate change: Contested discourses of ecological modernization, green governmentality and civic environmentalism. *Global Environmental Politics*, 6, (1) 50-75.
- Castree, N., 2013. *Making sense of nature*, Abingdon, Oxon, Routledge.
- Chapin, F. S., III & Shaver, G. R., 1996. Physiological and Growth Responses of Arctic Plants to a Field Experiment Simulating Climatic Change. *Ecology*, 77, (3) 822-840.
- Clark, N., 2013. Geoengineering and geologic politics. *Environment and Planning A*, 45, (12) 2825-2832.
- 2014. Geo-politics and the disaster of the Anthropocene. *Sociological Review*, 62, (SUPPL1) 19-37.
- Clark, W. C. & Munn, R. E. (eds.) 1986. *Sustainable development of the biosphere*, Cambridge Cambridgeshire ; New York: Cambridge University Press.
- Coffey, A. & Atkinson, P., 1996. *Making sense of qualitative data : complementary research strategies*, Thousand Oaks, SAGE Publications.
- Conway, E. M., 2008. *Atmospheric science at NASA : a history*, Baltimore, Johns Hopkins University Press.
- Cornell, S., et al., 2012. *Understanding the earth system : global change science for application*, Cambridge, Cambridge University Press.
- Cox, R. W. & Sinclair, T. J., 1996. *Approaches to world order*, Cambridge; New York, Cambridge University Press.
- Crutzen, P., 2002. Geology of mankind. *Nature*, 415, 23.

- Crutzen, P. J. & Stoermer, E. F., 2000. The “Anthropocene”. *Global Change Newsletter*, (41) 17-18.
- Dahan, A., 2010. Putting the Earth System in a numerical box? The evolution from climate modeling toward global change. *Studies In History and Philosophy of Science Part B: Studies In History and Philosophy of Modern Physics*, 41, (3) 282-292.
- Dahl, R. A., 1957. The concept of power. *Behavioral science*, 2, (3) 201-215.
- Darier, É. (ed.) 1999. *Discourses of the environment*, Oxford, UK; Malden, Mass.: Blackwell.
- Daston, L., 2000. The coming into being of scientific objects. In: Daston, L. (ed.) *Biographies of scientific objects*. Chicago: University of Chicago Press, 1-14.
- Dean, M., 1994. *Critical and effective histories: Foucault's methods and historical sociology*, London, Routledge.
- 1996. Foucault, government and the enfolding of authority. In: Barry, A., Osborne, T. & Rose, N. S. (eds.) *Foucault and political reason : liberalism, neo-liberalism, and rationalities of government*. Chicago: University of Chicago Press, 209-230.
 - 1999. *Governmentality : power and rule in modern society*, London; Thousand Oaks, Calif., SAGE Publications.
 - 2002. Liberal government and authoritarianism. *Economy and Society*, 31, (1) 37-61.
 - 2010. *Governmentality : power and rule in modern society*, London etc., SAGE.
- Demeritt, D., 2001. The Construction of Global Warming and the Politics of Science. *Annals of the Association of American Geographers*, 91, (2) 307-337.
- Dennis, M. A., 2003. Earthly Matters: On the Cold War and the Earth Sciences. *Social Studies of Science* 33, (5) 809-819
- Diaz-Bone, R., 2006. Zur Methodologisierung der Foucaultschen Diskursanalyse. *Historical social research*, 31, (2) 243-274.
- Dilling, L. & Lemos, M. C., 2011. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change*, 21, (2) 680-689.
- Doel, R. E., 2003. Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945. *Social Studies of Science*, 33, (5) 635-666.
- Dreyfus, H. L. & Rabinow, P., 1983. *Michel Foucault, beyond structuralism and hermeneutics*, Chicago, University of Chicago Press.
- Dryzek, J. S., 2013. *The politics of the Earth : environmental discourses*, Oxford, Oxford University Press.
- Dryzek, J. S. & Stevenson, H., 2011. Global democracy and earth system governance. *Ecological Economics*, 70, (11) 1865-1874.
- Duit, A., et al., 2010. Introduction: Governance, complexity, and resilience. *Global Environmental Change*, 20, 363-368.
- Edwards, P. N., 1997. *The closed world computers and the politics of discourse in Cold War America*, Cambridge, Mass., MIT Press.
- 2010. *A vast machine : computer models, climate data, and the politics of global warming*, Cambridge, Mass., MIT Press.
- Fleagle, R. G., 1992. From the international geophysical year to global change. *Reviews of Geophysics*, 30, (4) 305-313.
- Fleck, L., 1979. *Genesis and development of a scientific fact*, Chicago, University of Chicago press.
- Fleming, J. R., 2010. *Fixing the sky : the checkered history of weather and climate control*, New York, Columbia University Press.

- Flynn, T. R., 2005. Foucault's mapping of history. In: Gutting, G. (ed.) *The Cambridge companion to Foucault*. 2nd ed. Cambridge: Cambridge University Press, 29-48.
- Folke, C., et al., 2011. Reconnecting to the Biosphere. *Ambio*, 40, (7) 719-738.
- Forrester, J. W., 1973. *World Dynamics*, Cambridge, Massachusetts, Wright-Allen Press Inc.
- Forsyth, T., 2003. *Critical political ecology : The politics of environmental science*, New York; London, Routledge.
- Foucault, M., 1977. Nietzsche, Genealogy, History. In: Bouchard, D. F. (ed.) *Language, Counter-Memory, Practice: Selected Essays and Interviews*. Ithaca: Cornell University Press, 139-164.
- 1978. *The history of sexuality*, New York, Pantheon Books.
 - 1980a. The Confession of the Flesh. In: Gordon, C. (ed.) *Power/knowledge : selected interviews and other writings, 1972-1977*. New York: Pantheon Books, 194-228.
 - 1980b. Two lectures. In: Gordon, C. (ed.) *Power/knowledge : selected interviews and other writings, 1972-1977*. New York: Pantheon Books, 78-108.
 - 1983. The subject and power. In: Dreyfus, H. L. & Rabinow, P. (eds.) *Michel Foucault : beyond structuralism and hermeneutics*. Chicago: Chicago U.P., 208-228.
 - 1990. *The use of pleasure : volume 2 of The history of sexuality*, New York, Vintage Books.
 - 1991. Governmentality. In: Burchell, G. & Gordon, C. M. (eds.) *The Foucault effect : studies in governmentality*. London: Harvester Wheatsheaf, 87-104.
 - 1993. Kant on Enlightenment and revolution. In: Gane, M. & Johnson, T. (eds.) *Foucault's new domains*. London; New York: Routledge, 10-18.
 - 1995. *Discipline and punish : the birth of the prison*, New York, Vintage Books.
 - 1997. What is Critique? In: Lotringer, S. (ed.) *The politics of truth*. Los Angeles: Semiotext(e), 23-82.
 - 1998. *The history of sexuality. Vol. 1 : the will to knowledge*, London, Penguin Books Ltd.
 - 2007. *Security, territory, population : lectures at the Collège de France, 1977-78*, Basingstoke; New York, Palgrave Macmillan : République Française.
 - 2008. *The birth of biopolitics : lectures at the Collège de France, 1978-79*, Basingstoke; New York, Palgrave Macmillan.
- Fuller, R. B., 1969. *Operating manual for spaceship earth*, Carbondale, Southern Illinois University Press.
- GAIM, 2002. GAIM's Hilbertian questions. *Research GAIM*, 5, (1) 1-16.
- Galaz, V., 2014. *Global environmental governance, technology and politics : The Anthropocene gap*, Cheltenham, Edward Elgar Publishing.
- Galaz, V., et al., 2012. 'Planetary boundaries' — exploring the challenges for global environmental governance. *Current Opinion in Environmental Sustainability*, 4, 80-87.
- Glynn, J. & Howarth, D., 2007. *Logics of Critical Explanation in Social and Political Theory*, Abingdon, Routledge.
- Goldman, M., 2001. Constructing an environmental state: Eco-governmentality and other transnational practices, of a 'green' World Bank. *Social problems*, 48, (4) 499-523.
- Goody, R., 1982. *Global Change: Impacts on Habitability - A Scientific Basis for Assessment : A report by the Executive committee of a workshop at Woods Hole, Massachusetts, June 21-26 1982*. Pasadena: NASA.

- Gordon, C., 1991. Governmental rationality : an introduction. In: Burchell, G. & Gordon, C. M. (eds.) *The Foucault effect : studies in governmentality : with two lectures by and an interview with Michael Foucault*. London: Harvester Wheatsheaf, 1-52.
- Gramelsberger, G. & Feichter, J., 2011. Modelling the climate system: An overview. In: Gramelsberger, G. & Feichter, J. (eds.) *Climate change and policy the calculability of climate change and the challenge of uncertainty*. Heidelberg; New York: Springer, 9-90.
- Greenaway, F., 1996. *Science International - A history of the International Council of Scientific Unions*, Cambridge, Cambridge university press.
- Griggs, D., et al., 2013. Policy: Sustainable development goals for people and planet. *Nature*, 495, (7441) 305-307.
- Haas, P. M., 1992a. Banning Chlorofluorocarbons: Epistemic Community Efforts to Protect Stratospheric Ozone. *International Organization*, 46, (1) 187-224.
- 1992b. Introduction: Epistemic Communities and International Policy Coordination. *International Organization*, 46, (1) 1-35.
- Hacking, I., 2002. *Historical ontology*, Cambridge, Mass., Harvard University Press.
- Hannah, M. G., 2000. *Governmentality and the mastery of territory in nineteenth-century America*, Cambridge England ; New York, Cambridge University Press.
- Hay, C., 2002. *Political analysis*, Houndmills, Basingstoke, Hampshire; New York, Palgrave.
- Heymann, M., et al., 2010. Exploring Greenland: Science and Technology in Cold War Settings. *Scientia Canadensis: Canadian Journal of the History of Science, Technology and Medicine*, 33, (2) 11-42.
- Hindess, B., 1996. *Discourses of power : from Hobbes to Foucault*, Oxford, UK; Cambridge, Mass., Blackwell Publishers.
- Hoddeson, L., 2006. The conflict of memories and documents - Dilemmas and pragmatics of oral history. In: Doel, R. E. & Söderqvist, T. (eds.) *The Historiography of Contemporary Science, Technology, and Medicine - Writing recent science*. New York: Routledge, 187-200.
- Hoy, D. C., 1998. Foucault and Critical Theory. In: Moss, J. (ed.) *The later Foucault : politics and philosophy*. London; Thousand Oaks, 18-32.
- Hulme, M., 2010. Problems with making and governing global kinds of knowledge. *Global Environmental Change*, 20, (4) 558–564.
- Hutton, J., 1788. *Theory of the Earth*, Edinburgh, Royal Society of Edinburgh.
- Höhler, S., 2008. "Spaceship Earth": Envisioning human habitats in the Environmental Age. *GHI Bulletin*, (42) 65-85.
- ICSU, 2011. Input for Rio+20 Compilation Document.
- IGBP, 1986. Global Change Report 1 - The International Geosphere-Biosphere Programme: a Study of Global Change: final report of the Ad Hoc Planning Group; prepared for the ICSU 21st General Assembly, Berne, September 14-19, 1986. Stockholm: International Geosphere-Biosphere Programme.
- 1988. Global Change Report 4 - The International Geosphere-Biosphere Programme, a study of global change, IGBP: a plan for action. Stockholm, Sweden: International Geosphere-Biosphere Programme.
- 1991. Global Change Report 15 - Global change System for Analysis, Research and Training (START) : report of a meeting at Bellagio, December 3-7, 1990. Boulder Colo.: International Geosphere-Biosphere Programme.
- 1992. Global Change Report 22 - Report from the START Regional Meeting for Southeast Asia. Stockholm: The International Geosphere-Biosphere Programme: A Study of Global Change.

- 2006. Global Change Report 55 - Science Plan and Implementation Strategy. Stockholm: IGBP Secretariat.
- Ignaciuk, A., et al., 2012. Responding to complex societal challenges: A decade of Earth System Science Partnership (ESSP) interdisciplinary research. *Curr.Opin.EnvIRON.Sustainability Current Opinion in Environmental Sustainability*, 4, 147-158.
- IPCC, 2013. Working Group I Contribution to the IPCC Fifth Assessment Report Climate Change 2013: The Physical Science Basis. Summary for Policymakers.
- Jacobson, H. K., 1987. Report of the 9 and 10 September 1987 Ann Arbor Workshop on a Social Science research Program to Complement the International Geosphere-Biosphere Programme. UNESCO.
- Jacobson, M. C., Charlson, R. J. & Rodhe, H., 2000a. Introduction: Biogeochemical Cycles as Fundamental Constructs for Studying Earth System Science and Global Change. In: Jacobson, M. C., Charlson, R. J., Rodhe, H. & Orians, G. H. (eds.) *Earth system science : from biogeochemical cycles to global change*. San Diego, Calif.: Elsevier Academic Press, 3-13.
- Jacobson, M. C., et al., 2000b. *Earth system science : from biogeochemical cycles to global change*, San Diego, Calif., Elsevier Academic Press.
- Jamison, A., 2001. *The making of green knowledge environmental politics and cultural transformation*, Cambridge; New York, Cambridge University Press.
- Jasanoff, S., 2001. Image and Imagination: The formation of Global Environmental Consciousness. In: Miller, C. A. & Edwards, P. N. (eds.) *Changing the atmosphere : expert knowledge and environmental governance*. Cambridge, Mass.: MIT Press, 309-338.
- 2004a. Heaven and Earth: The Politics of Environmental Images. In: Jasanoff, S. & Martello, M. L. (eds.) *Earthly politics local and global in environmental governance*. Cambridge, Mass.: MIT Press, 31-52.
- 2004b. The idiom of Co-production. In: Jasanoff, S. (ed.) *States of Knowledge : The co-production of science and social order*. London and New York: Routledge, 1-12.
- 2010. A New Climate for Society. *Theory, Culture & Society*, 27, (2-3) 233–253.
- Jasanoff, S. & Martello, M. L. (eds.) 2004. *Earthly politics local and global in environmental governance*, Cambridge, Mass.: MIT Press.
- Jessop, B., 2007. From micro-powers to governmentality: Foucault's work on statehood, state formation, statecraft and state power. *Political Geography*, 26, (1) 34-40.
- 2011. Constituting another Foucault effect: Foucault on States and Statecraft. In: Bröckling, U., Krasmann, S. & Lemke, T. (eds.) *Governmentality - Current Issues and Future Challenges*. New York: Routledge, 56-74.
- Johnstone, J., 1932. Entropy and Evolution. *Philosophy*, 7, (27) 287-298.
- Kates, R. W., 1987. The Human Environment: The Road Not Taken, The Road Still Beckoning. *Annals of the Association of American Geographers*, 77, (4) 525-534.
- Kendall, G. & Wickham, G., 1999. *Using Foucault's methods*, London; Thousand Oaks, Calif., SAGE Publications.
- Kuhn, T. S., 1970. *The structure of scientific revolutions*, Chicago University of Chicago Press.
- Kwa, C., 1987. Representations of Nature Mediating between Ecology and Science Policy: The Case of the International Biological Programme. *Social Studies of Science*, 17, (3) 413-442.
- 1994. Modelling technologies of control. *Science as Culture*, 4, (3) 363-391.

- 2005a. Interdisciplinarity and Postmodernity in the Environmental Sciences. *History and Technology*, 21, (4) 331-344.
- 2005b. Local Ecologies and Global Science: Discourses and Strategies of the International Geosphere-Biosphere Programme. *Social Studies of Science*, 35, (6) 923–950.
- 2006. Speaking to science : The programming of interdisciplinary research through informal science-policy interactions. *Science and Public Policy*, 33, (6) 457–467.
- Lambright, W. H., 1994. The Political Construction of Space Satellite Technology. *Science, Technology, & Human Values*, 19, (1) 47-69.
- Latour, B., 2004. *Politics of nature : how to bring the sciences into democracy*, Cambridge, Mass., Harvard University Press.
- Launius, R. D., Fleming, J. R. & DeVorkin, D. H. (eds.) 2010. *Globalizing polar science : reconsidering the International Polar and Geophysical years*, New York: Palgrave Macmillan.
- Lekan, T. M., 2004. *Imagining the nation in nature landscape preservation and German identity, 1885-1945*, Cambridge, MA, Harvard University Press.
- Lemke, T., 2011. *Foucault, governmentality, and critique*, Boulder, Colo., Paradigm Publishers.
- Lemos, M. C. & Morehouse, B. J., 2005. The co-production of science and policy in integrated climate assessments. *Global Environmental Change*, 15, (1) 57–68.
- Lenton, T. M. & Williams, H. T. P., 2013. On the origin of planetary-scale tipping points. *Trends in Ecology & Evolution*, 28, (7) 380-382.
- Linnér, B.-O., 2003. *The return of Malthus. Environmentalism and post-war population-resource crisis*, Isle of Harries, White Horse Press.
- Litfin, K. (ed.) 1998a. *The greening of sovereignty in world politics*, Cambridge, Mass.: MIT Press.
- 1998b. Satellites and Sovereign Knowledge: Remote Sensing of the Global Environment. In: Litfin, K. (ed.) *The greening of sovereignty in world politics*. Cambridge, Mass.: MIT Press, 193-221.
- Litfin, K. T., 1994. *Ozone Discourses - Science and Politics in Global Environmental Cooperation*, New York, Columbia University Press.
- Liverman, D. M., 2009. Conventions of climate change: constructions of danger and the dispossession of the atmosphere. *Journal of Historical Geography*, 35, (2) 279-296.
- Livingstone, D. N., 2003. *Putting science in its place : geographies of scientific knowledge*, Chicago, University of Chicago Press.
- Lovejoy, A. O., 1940. Reflections on the History of Ideas. *Journal of the History of Ideas*, 1, (1) 3-23.
- Luke, T. W., 1995. On Environmentality: Geo-Power and Eco-Knowledge in the Discourses of Contemporary Environmentalism. *Cultural Critique*, 31, 57-81.
- 1996. Governmentality and contragovernmentality: rethinking sovereignty and territoriality after the Cold War. *Political Geography*, 15, (6-7) 491.
- 1999. Environmentality as Green Governmentality. In: Darier, É. (ed.) *Discourses of the environment*. Oxford, UK; Malden, Mass.: Blackwell, 121-151.
- 2009. Developing planetarian accountancy: fabricating nature as stock, service, and a system for green Governmentality. In: Dahms, H. (ed.) *Nature, Knowledge and Negation*. Bingley UK: Emerald Group Pub Ltd, 129–159.
- Lukes, S., 2005. *Power: A radical view*, New York, Palgrave Macmillan.

- Lövbrand, E., 2011. Co-producing European climate science and policy: a cautionary note on the making of useful knowledge. *Science & Public Policy*, 38, (3) 225–236.
- Lövbrand, E., et al., 2014. Taking the human (sciences) seriously: Realizing the critical potential of the Anthropocene. *ECPR General Conference*. Glasgow
- Lövbrand, E. & Stripple, J., 2013. Bringing Governmentality to the study of global climate governance. In: Stripple, J. & Bulkeley, H. (eds.) *Governing the climate : new approaches to rationality, power and politics*.
- Lövbrand, E., Stripple, J. & Wiman, B., 2009. Earth System governmentality Reflections on science in the Anthropocene. *Global Environmental Change-Human and Policy Dimensions*, 19, (1) 7-13.
- Malm, A. & Hornborg, A., 2014. The geology of mankind? A critique of the Anthropocene narrative. *The Anthropocene Review*, 1, (1) 62-69.
- Malone, T. F., 1985. Preface. In: Malone, T. F. & Roederer, J. G. (eds.) *Global Change: The proceedings of a Symposium sponsored by the International Council of Scientific Unions (ICSU) during its 20th General Assembly in Ottawa, Canada on September 25, 1984*. Cambridge: ICSU press, xi-xxi.
- Malone, T. F. & Roederer, J. G. (eds.) 1985. *Global Change: The proceedings of a Symposium sponsored by the International Council of Scientific Unions (ICSU) during its 20th General Assembly in Ottawa, Canada on September 25, 1984*, Cambridge: ICSU press.
- Marsh, G. P., 1869. *Man and nature, or Physical geography as modified by human action*, New York, Charles Scribner & Co.
- Marttila, T., 2013. *The Culture of Enterprise in Neoliberalism Specters of Entrepreneurship*, Hoboken, Taylor and Francis.
- May, T. & Powell, J., 2007. Foucault: Interpretive analytics and the constitution of the social. In: Edwards, T. (ed.) *Cultural theory: Classical and contemporary positions*. London: SAGE Publications Ltd, 123-140.
- McElroy, J. H. & Williamson, R. A., 2004. The Evolution of Earth Science Research from Space: NASA's Earth Observing System. In: Logsdon, J. M., Garber, S. J., Launius, R. D. & Williamson, R. A. (eds.) *Exploring the Unknown Volume VI Selected Documents in the History of the U.S. Civil Space Program*. Washington DC: NASA, 441-690.
- McGuirk, P., Bulkeley, H. & Dowling, R., 2014. Practices, programs and projects of urban carbon governance: Perspectives from the Australian city. *Geoforum*, 52, (0) 137-147.
- Meadows, D. H., et al., 1972. *The Limits to growth; a report for the Club of Rome's project on the predicament of mankind*, New York, Universe Books.
- Methmann, C., 2013. The sky is the limit: Global warming as global governmentality. *European Journal of International Relations*, 19, (1) 69-91.
- Meyer, J. W., et al., 1997. The structuring of a world environmental regime, 1870-1990. *International Organization*, 51, (4) 623-51.
- Miller, C. A., 2001. Scientific Internationalism in American Foreign Policy. In: Miller, C. A. & Edwards, P. N. (eds.) *Changing the atmosphere : expert knowledge and environmental governance*. Cambridge, Mass.: MIT Press, 167-217.
- 2004. Climate science and the making of a global political order. In: Jasanoff, S. (ed.) *States of Knowledge : The co-production of science and social order*. London and New York: Routledge, 46-66.
- 2007. Democratization, International Knowledge Institutions, and Global Governance. *Governance*, 20, (2) 325–357.

- Miller, P. & Rose, N., 1990. Governing economic life. *Economy and Society*, 19, (1) 30.
- Miller, P. & Rose, N. S., 2008. *Governing the present: administering economic, social and personal life*, Cambridge, Polity.
- Milliken, J., 1999. The Study of Discourse in International Relations: A Critique of Research and Methods. 5, (2) 225-254.
- Mitchell, R. B., et al. (eds.) 2006. *Global Environmental Assessments - Information and Influence*, Cambridge, Massachusetts and London, England: The MIT Press.
- Mooney, H. A., 1999. On the road to global ecology. *Annual Review of Energy and the Environment*, 24, 1-31.
- Mooney, H. A., Duraiappah, A. & Larigauderie, A., 2013. Evolution of natural and social science interactions in global change research programs. *Proceedings of the National Academy of Sciences*, 110, (Suppl 1) 3665-3672.
- Moore, B., III, 2011. Earth System Science at 20 Oral History Project. In: Wright, R. (ed.). http://www.jsc.nasa.gov/history/oral_histories/NASA_HQ/ESS/MooreB/MooreB_4-4-11.pdf; NASA.
- Moore, B., III, et al., 2002. The Amsterdam Declaration on Global Change. In: Steffen, W. L., Jäger, J., Carson, D. J. & Bradshaw, C. M. (eds.) *Challenges of a changing earth: proceedings of the Global Change Open Science Conference, Amsterdam, the Netherlands, 10-13 July 2001*. Amsterdam, Netherlands ed. New York: Springer-Verlag, 207-208.
- Mulkay, M. J., Gilbert, G. N. & Woolgar, S., 1975. Problems and areas and research networks in science. *Sociology*, 9, (2) 187-203.
- NASA-ESSC, 1986. Earth system science - Overview: a program for global change. Washington, D.C.: National Aeronautics and Space Administration - Earth System Sciences Committee.
- 1988. Earth system science : a closer view. Washington, D.C.: National Aeronautics and Space Administration.
- Nilsson, M. & Persson, Å., 2012. Can Earth system interactions be governed? Governance functions for linking climate change mitigation with land use, freshwater and biodiversity protection. 75, 61-71.
- NOAA. 2007. *Rockets, Radar, and Computers: The International Geophysical Year* [Online]. NOAA. Available: http://docs.lib.noaa.gov/noaa_documents/time_capsules/2007/disc_7/celebrating_200years.noaa.gov/magazine/igy/welcome.html [Accessed 11/16 2009].
- O'Brien, K. & Barnett, J., 2013. Global Environmental Change and Human Security. *Annual Review of Environment and Resources*, 38, (1) 373-391.
- O'Brien, K., 2012. Global environmental change II: From adaptation to deliberate transformation. *Progress in Human Geography*, 36, (5) 667-676.
- Oels, A., 2005. Rendering climate change governable. From biopower to advanced liberal government? *Journal of Environmental Policy and Planning*, 7, (3) 185-207.
- Paillard, D., 2008. From atmosphere, to climate, to Earth system science. *Interdisciplinary Science Reviews*, 33, (1) 25-35.
- Palsson, G., et al., 2013. Reconceptualizing the 'Anthropos' in the Anthropocene: Integrating the social sciences and humanities in global environmental change research. *Environmental Science & Policy*, 28, 3-13.
- Paterson, M. & Stripple, J., 2010. My Space: governing individuals' carbon emissions. *Environ.Plann.D Environment and Planning D: Society and Space*, 28, (2) 341-362.

- Peng, C., 2000. From static biogeographical model to dynamic global vegetation model: a global perspective on modelling vegetation dynamics. *Ecological Modelling*, 135, (1) 33-54.
- Petschel-Held, G., et al., 1999. Syndromes of Global Change: a qualitative modelling approach to assist global environmental management. *Environmental Modeling & Assessment*, 4, (4) 295-314.
- Pielke, R. A., 2010. *The climate fix : what scientists and politicians won't tell you about global warming*, New York, Basic Books.
- Planetary Boundaries, I., 2012. Input for Compilation Document Submission by the Planetary Boundaries Initiative, UN Conference on Sustainable Development, Rio de Janeiro, 4 – 6 June 2012.
- Price, M. F., 1989. Global change: Defining the ill-defined. *Environment*, 31, (8) 18-20,42-44.
- 1990. Humankind in the biosphere: The evolution of international interdisciplinary research. *Global Environmental Change*, 1, (1) 3-13.
- Reenberg, A., 2011. Toolbox options for conceptualizing change in human-environmental systems - Pathways, path dependency, legacies, syndromes and scenarios. Copenhagen: GLP Report No. 2. GLP-IPO.
- Rockström, J., et al., 2009a. Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, 14, (2) Article 32.
- Rockström, J., et al., 2009b. A safe operating space for humanity. *Nature*, (461) 472-475.
- Rose, N. & Miller, P., 1992. Political power beyond the state: problematics of government. *The British Journal of Sociology*, 43, (2) 173-205.
- Rose, N., O'Malley, P. & Velverde, M., 2006. Governmentality. *Ann. Rev. Law Soc. Sci.*, 2, 83–104.
- Russell, L. M., et al., 2012. Ecosystem Impacts of Geoengineering: A Review for Developing a Science Plan. *AMBIO*, 41, 350-369.
- Rutherford, P., 1999. The entry of life into history. In: Darier, É. (ed.) *Discourses of the environment*. Oxford, UK; Malden, Mass.: Blackwell, 37-62.
- Rutherford, S., 2007. Green governmentality: insights and opportunities in the study of nature's rule. *Progress in Human Geography*, 31, (3) 291–307.
- Saar, M., 2002. Genealogy and Subjectivity. *European Journal of Philosophy*, 10, (2) 231-245.
- Schellnhuber, H.-J., 1999. 'Earth system' analysis and the second Copernican revolution. *Nature*, 402, (6761 SUPPL. 1) C19-C23.
- 2000. The Waikiki principles: rules for a new GAIM. *IGBP Newsletter*, 41, 3-4.
- 2007. Foreword. In: Costanza, R., Graumlich, L. & Steffen, W. L. (eds.) *Sustainability or collapse? : an integrated history and future of people on earth*. Cambridge, Mass.: MIT Press in cooperation with Dahlem University Press, xvii-xxii.
- Schellnhuber, H.-J., et al., 1997. Syndromes of global change. *GAIA*, 6, (1) 19-34.
- Schellnhuber, H.-J. & Tóth, F. L., 1999. Earth system analysis and management. *Environmental Modeling and Assessment*, 4, (4) 201-207.
- Schellnhuber, H. J., 2011. Geoengineering: The good, the MAD, and the sensible. *Proceedings of the National Academy of Sciences*, 108, (51) 20277-20278.
- Scott, D., 1995. Colonial governmentality. *Social Text*, 43, (Autumn) 191-220.
- Selin, H. & Linnér, B.-O., 2005. The Quest for Global Sustainability: International Efforts on Linking Environment and Development. *CID Graduate Student and Postdoctoral Fellow Working Paper No. 5. Science, Environment and Development Group, Center for International Development*. Cambridge, MA.

- Shapin, S., 1998. Placing the view from nowhere: historical and sociological problems of the location of science. *Transactions of the Institute of British Geographers*, 23, (1) 5-12.
- Shiner, L., 1982. Reading Foucault: Anti-Method and the Genealogy of Power-Knowledge. *History and Theory*, 21, (3) 382-398.
- Sigley, G., 1996. 'Governing Chinese bodies': the significance of studies in the concept of governmentality for the analysis of government in China. *Economy and Society*, 25, (4) 457-482.
- 2006. Chinese Governmentalities: Government, Governance and the Socialist Market Economy. *Economy and Society*, 35, (4) 487-508.
- Steffen, W., 1998. How well do we understand the nature of Earth - The challenges to the IGBP Synthesis. *Global change Newsletter*, (34) 6-7.
- Steffen, W., et al., 2011a. The Anthropocene: conceptual and historical perspectives. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, (369) 842–867.
- Steffen, W., et al., 2011b. The Anthropocene: From Global Change to Planetary Stewardship. *Ambio*, 40, (7) 739–761.
- Steffen, W., et al. (eds.) 2004. *Global Change and the Earth System - A Planet Under Pressure*, Heidelberg: Springer Verlag.
- Stephens, N., 2007. Collecting data from elites and ultra elites: telephone and face-to-face interviews with macroeconomists. *Qualitative Research*, 7, (2) 203-216.
- Stavis, D., 2005. The globalizations of the environment. *Globalizations*, 2, (3) 323-333.
- Stoler, A. L., 1995. *Race and the education of desire : Foucault's History of sexuality and the colonial order of things*, Durham, Duke University Press.
- Strauss, A. L. & Corbin, J. M., 1990. *Basics of qualitative research : grounded theory procedures and techniques*, Newbury Park, Calif., SAGE Publications.
- Stripple, J. & Bulkeley, H. (eds.) 2014. *Governing the climate : new approaches to rationality, power and politics*, New York, NY: Cambridge University Press.
- Suess, E., 1904. *The face of the earth = Das Antlitz der Erde*, Oxford, Clarendon Press.
- Taylor, D., 2011. Practices of the self. In: Taylor, D. (ed.) *Michel Foucault : key concepts*. Durham: Acumen, 173-186.
- Triantafillou, P., 2012. *New forms of governing : a Foucauldian inspired analysis*, New York, NY, Palgrave Macmillan.
- Tuathail, G. Ó., 1994. Problematizing Geopolitics: Survey, Statesmanship and Strategy. *Transactions of the Institute of British Geographers*, 19, (3) 259-272.
- Uhrqvist, O. & Lövbrand, E., 2009. Seeing and knowing the earth as a system - tracing the history of Earth System Science Partnership. <http://www.earthsystemgovernance.org/ac2009/papers/AC2009-0107.pdf>.
- UK Royal Society, 2009. *Geoengineering the climate: science, governance and uncertainty*. London: The Royal Society.
- United Nations, 2012. *The future we want?* New York: United Nations.
- US NRC, 1983. *Toward an international geosphere biosphere programme - a study of global change*. Washington D.C.: National academy press.
- Walters, W., 2012. *Governmentality : critical encounters*, New York, Routledge.
- Valverde, M., 1996. "Despotism" and ethical governance. *Economy and Society*, 25, (3) 357-372.
- van der Heijden, H.-A., 2008. Green governmentality, ecological modernisation or civic environmentalism? Dealing with global environmental problems. *Environmental Politics*, 17, (5) 835-839.
- Ward, B., 1966. *Spaceship earth*, New York, Columbia University Press.

- Ward, B. & Dubos, R., 1972. *Only one earth : the care and maintenance of a small planet / an unofficial report commissioned by the secretary-general of the United Nations conference on the human environment*, New York Norton.
- WCRP, 2005. World Climate Research Programme: 25 years of science serving society. Geneva: WRCP and WMO.
- Weakland, J. P., 2012. Queering ecology: Interrogating 'seductions to organic wholeness' in popular environmental rhetoric. *Learning for Sustainability in Times of Accelerating Change*. 121-132.
- Weart, S. R., 2003. *The discovery of global warming*, Cambridge, Mass., Harvard University Press.
- Wendt, A., 1999. *Social theory of international politics*, Cambridge, U.K.; New York, Cambridge University Press.
- Vernadsky, V. I., 1998. *The biosphere*, New York, Copernicus.
- Vetter, J., 2011. Introduction. In: Vetter, J. (ed.) *Knowing global environments : new historical perspectives on the field sciences*. New Brunswick, N.J.: Rutgers University Press, 1-16.
- Whitehead, M., 2008. Cold Monsters and Ecological Leviathans: Reflections on the Relationships between States and the Environment. *Geography Compass*, 2, (2) 414-432.
- 2009. *State, science and the skies : governmentalities of the British atmosphere*, Chichester, U.K.; Malden, MA, Wiley-Blackwell.
- Wijkman, A. & Rockström, J., 2012. *Bankrupting nature : denying our planetary boundaries*, London, Routledge.
- Worster, D., 1993. *The wealth of nature : environmental history and the ecological imagination*, New York, Oxford University Press.
- 1994. *Nature's economy : a history of ecological ideas*, Cambridge; New York, NY, Cambridge University Press.
- Young, O. R., et al., 2014. Earth System Challenges and A Multi-layered Approach for the Sustainable Development Goals. *POST2015/UNU-IAS Policy Brief #1*.: Tokyo: United Nations University Institute for the Advanced Study of Sustainability.
- Zalasiewicz, J. A., et al., 2010. The new world of the Anthropocene. *Environmental Science & Policy*, 44, 2228-2231.
- Zuccala, A., 2006. Modeling the invisible college. *Journal of the American Society for Information Science and Technology*, 57, (2) 152-168.

8 Appendix

Table A.1 Interview guide

Questions
How did you become involved in Global Environmental change research?
Which were the most important shifts in Earth System science?
What are the most important contributions of Earth System science?
Which were the main problems you had to deal with?
Is there something you expected me to ask, but I didn't?
Eventual questions about how to understand particular issues...

Table A.2 Interviews

Who	Active	Roles (relevant to this thesis)
Ian Burton	1984-	Pre-HDP (not recorded)
Joseph Canadell	1995-	Executive Director of GCTE (1998-2003) and GCP (2001-)
Sarah Cornell	-2012	AIMES, QUEST
Martin Heimann	1992~2000	GAIM (1992-2000)
John Ingram	1984-2006	Executive Director of Global Change and Food Security, GCTE
Jill Jäger	1996-2002	Executive Director of IHDP (1996-2002)
Berrien III Moore	1986-2002	Chair of GAIM, Scientific Chair of IGBP (1998-2002)
Colin Prentice	1989-2012	(GCTE), Co-Chair of GAIM and AIMES, Chair of QUEST
Anette Reensberg	2006-2012	Executive Director of GLP (recording failed)
Thomas Rosswall (×2)	1984-1994	Executive Director of IGBP (1987-1994), START, also in ICSU
Dork Sahagian	1992-2004	Executive Director of GAIM (1994-2004)
Will Steffen (×2)	1986-2012	Executive Director of IGBP (1998- 2004), GCTE (1990-1998)
Uno Svedin	1986-2004	Planning of HDP, Chair of IGFA (-2004)
Bill Lee Turner	1990-2012	Executive Director of LUCC, GLP

The period during which a person is considered to be 'Active' is based on when they appear in the newsletters and reports.

Papers

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