– Marsilius Project Proposal –
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The Global Governance of Climate Engineering

Introduction and motivation

"Climate engineering" is the emerging concept of a deliberate alteration of the global climatic system by technological means. Over the last few years, climate engineering has received increasing attention among scientists, policy-makers, and the public as an additional strategy for combating climate change.

Climate engineering is a global undertaking of the highest complexity. Climate engineering experiments of the German research vessel „Polarstern" in the Southern Atlantic have been discussed controversially. The United Nations have called for expert fora and conferences on the topic. Scientists have been convening workshops. Despite these efforts, the public discourse as well as the scientific discussion are still at a very early stage. Climate Engineering is a typical example of a technology of an ambivalent nature: Both opportunities and risks are present to a significant extent. In this, climate engineering is characteristic for the global risk societies of the 21st century that face complex choices between technological capabilities and problems of political and social acceptance. Opportunities and risks of deliberate large-scale climate modification will be perceived, judged, and exercised differently by different individuals, societies and countries.

The fact that the technology is at an early stage compounds the uncertainty about its possible consequences. These consequences will also manifest themselves with a high degree of spatial heterogeneity. Geo-engineering at the global level – while reducing greenhouse effects overall - is likely to lead to some locations experiencing higher temperatures. This will require national and international negotiations about benefit and risk sharing. What complicates these deliberations from a geographical perspective is that the world is economically and politically fragmented. Rather than resolving this fragmentation, climate engineering will conceivably aggravate these divisions and exacerbate North-South conflicts. Like climate change, "climate engineering" will give rise to winners and losers with the broad ambit of resolving humanity's global problems. New instruments of effective global governance to accompany these technological options are therefore indispensable.

While the contours of the future challenges implicit in climate engineering are taking shape, no clear scenarios are as yet available from an academic perspective. Clear scenarios, however, form the basis of a non-academic discourse about the challenges of climate engineering technologies that has been taking place in the media and entertainment industries for some time. Science fiction novels and natural catastrophe dramas in movies and books provide simplified, but telling reflections of human society on the future potentials and consequences of climate engineering.[1] Earlier treatments of „geoforming" or „geo-engineering" (Houghton, 1957) show how such reflections are embedded within the geopolitical situation of the times (such as the Cold War) and how they are subject – as a result – to shifting discourses over time.

Exercising this technological option will conceivably lead to far-reaching economic, political, and cultural consequences at different spatial scales. Observers have painted stark images of what

[1]Examples are episodes of Star Trek, Raumpatrouille, and movies such as The Day after Tomorrow and A Quantum of Solace.

climate engineering might entail. One scenario that has been considered as an illustration is a large country, think of Brazil, unilaterally deciding to remedy the adverse effects of climate change on its population by releasing large amounts of aerosols into the stratosphere. By doing so, Brazil decreases the absorption of energy from the sun and causes a cooling of surface temperatures. However, in the following year, global climate dynamics conspire with Brazil's measure to cause Russia to experience an abnormally cold winter and unusually high levels of precipitation. As a result, several hundred casualties, unprecedented harvest losses, and significant property damage hit Russia. What should the global governance response to climate engineering options be that will conceivably lead to scenarios such as the one illustrated above?

The discussion of scenarios like the one above make clear that climate engineering is not simply a question of natural sciences and the physical and chemical processes they describe and seek to utilize. At least of equal importance are the social consequences, political interests and – ultimately – a global governance of climate engineering. Policy-makers and the public will turn to the academic disciplines to provide key inputs in order to formulate an answer to the question of global governance. Generating these inputs will be an inherently interdisciplinary undertaking and will involve three challenges. The first is mobilizing what we currently know about how to think about climate systems and their modification, understanding spatial and intertemporal impacts of climate modifications, managing the global risks of such interventions and their public perception, handling their deep technological uncertainty, and assessing the role of institutions in coordinating national policies. The second is enabling these disciplines to build on their present knowledge in order to meet the specific research needs of assessing climate engineering options, on which the literature is currently scarce. The result of meeting this challenge will be further developments within each discipline that speak to the specific topic of climate engineering and – for doing so – depend on complementary knowledge of other disciplines. The third challenge is bringing together these developments to provide a joint and comprehensive perspective on the desirable and likely shape of a global governance structure for climate engineering.

A team of researchers at the University of Heidelberg with different disciplinary backgrounds ranging from the humanities and social sciences to the natural sciences has come together to undertake this interdisciplinary venture, united by a common research interest in climate engineering. What is envisaged is an assessment of the currently available climate engineering options and their limitations and risks. This comprehensive assessment will be carried out against the background of a globalized economy and politically fragmented societies at the start of the 21st century. The researchers hail from different disciplines – physics, economics, law, philosophy, geography, political sciences, and psychology – and will both draw on each others' expertise to advance their own thinking and pull these advances together into unified transdisciplinary answers.

Within project activities of the following three years, particularly female scientists working on related questions will be associated with the project. In the research group of Prof. Gebhardt, Dr. Annika Mattissek, who is funded by a Margarete von Wrangell habilitation scholarship and studies issues of global climate politics, will accompany the project. In the environmental economics and in psychology, collegues and young researchers concerned with behavioral economics, psychology of perception and cognition will be associated, as well a female researcher in environmental physics.

1. Research questions and transdisciplinary methodology

The research project examines the chances and risks of a man-controlled global climate from a variety of perspectives. Engineering the global climate is inherently technical but at the same time political and social in its consequences, an interdisciplinary perspective is necessary to develop a more comprehensive understanding of the topic. In the fragmented world of the 21st century, regulating human-environment interactions involves a variety of institutions, actors and discourses on different scales. To cope with the complexity of regulating practices, particularly in the absence of a clearly structured institutional framework, a concept of Global Governance[2] offers the opportunity to extent the analytical focus to formal as well as informal modes of governing and non-state actors.

Informal institutions comprise norms and values that influence the way in which political decisions on climate engineering are made. These norms and values evolve from debates on the ethical and moral fundamentals of engineering the climate. Such discourses will be analysed for different scales (e.g. national, european, global) and actors (e.g. political decision makers, private companies, NGOs, the public, the media). Furthermore, political decisions are not only bound to public perceptions of risks and benefits but ground on *individual* perceptions of decision makers. Formal institutions address modes of regulation as they appear in international law, contracts and economical institutions. Concerning climate engineering it has to be asked which existing institutions may apply to different schemes (e.g. legal frameworks on the protection of marine ecosystems and the atmosphere, CO_2 trading schemes, the Clean Development Mechanism) and how new institutions evolve (and can be shaped) to mediate risks and benefits and regulate political action. The latter question is directly linked to the informal institutions as it can be seen as a stabilization of informal regulating practices. The adequacy of current and potential governance regimes needs to be addressed based on a comprehensive understanding of the natural processes and potential side effects involved. Finally, scenarios of climate engineering and its governance will have impacts on the global economic and political organisation which have to be assessed.

Accordingly, the project will adress two interrelated questions: first, how do the risk-benefit perception of climate engineering technologies differ and evolve across time, disciplines and political actors. Secondly, how may these risk perceptions inform individual, societal and international capacities to foster a global governance of climate engineering?

We begin our collaborative endeavour by fostering the understanding of disciplinary risk and benefit perceptions in the first year. Against this background, we then consider the effects of specific climate engineering techniques on various actors and how these relate to disciplinary perceptions of risk and fairness. As we seek to harness the existing research excellence in environmental physics, environmental economics, geography, political science, philosophy, psychology and international law through transdisciplinarity dialogue, we do strive to produce a common set of specific scenarios in the third year. These scenarios specifically adress the cultural, technical, political and legal challenges of employing climate engineering technologies. Our main

[2]The concept of Global Governance adresses the question of how climate engineering is regulated on a global scale. In addition to states and formal institutions it extends the analysis to informal institutions and non-state acotors [Nohlen 1998; The Commission on Global Governance 1995].

focus lies upon the risks and benefits of climate engineering in contrast to CO_2 mitigation, but we do integrate a risk management scenario that portrays potential intended and unintended consequences and possible alleys for political action.

We consider our transdisciplinary and collaborative research on climate engineering essential to enter the public debate with both decision-makers, interest groups and the broader public. The envisaged project enters the debate on the global governance of climate engineering cautiously, but we intend to write a book and organize various workshops and a major conference that adress technical, ethical, legal and political challenges involved.

2. Climate Engineering – The Technology

Basic Principles of the Climate System

The most important driver for the climate of the Earth is the radiation balance: The Earth is heated by absorption of solar radiation, mostly in the visible and near infrared spectral range. This power input must be balanced by emission in the mid-infrared spectral range. The Earth albedo (surface albedo, cloud cover, and aerosol contents of the atmosphere) modulates the power input. Greenhouse gases reduce the re-emission of power to space thus forcing the Earth-system into a state with higher surface temperature. Clouds have an ambivalent effect on the surface temperature: they enhance the Earth albedo, thus cooling the Earth, however they also impede infrared emission, thus heating the Earth.

The options of mankind in the present situation can be summarized as:

– Quickly (within the next 2-3 decades) reduce greenhouse gas emissions to about 1/10 of the present levels and thus largely avoid critical climate change
– Adopt some kind of geoengineering measures to counteract climatic change while continuing to emit greenhouse gases
– Do nothing and adapt to climate change while hoping that adaption will be possible (i.e. there are no unmanageable changes)

Of course, combinations of the above, extreme options are possible [see e.g. Wigley 2006].

History

Scientifically founded schemes for changing the climate of Earth were proposed since the 1950s, some examples (Geoforming, Geoengineering) are given in the following:

1) Weather modification (mostly for military purposes):

This is exemplified in a note by Henry Houghton, MIT, 1957: „As our civilization steadily becomes more mechanized and as our population density grows the impact of weather will become ever more serious. ...The solution lies in ... intelligent use of more precise weather forecasts and, ideally, by taking the offensive through control of weather... I shudder to think of the consequences of a prior Russian discovery of a feasible method for weather control.“

2) Avoidance of possible future ice ages [Teller et al. 1997]

3) Large infrastructure measures (construction of large dams to modify regional water systems). A dam across the Bering strait plus diversion of large Siberian rivers to irrigate central Asia would result in (possibly complete) loss of sea ice in the north polar sea [Borisov 1969, Lamb 1971].

Modern Climate Engineering

In recent years many climate engineering schemes were proposed, which are all aimed at either avoiding climate change altogether or at avoiding or mitigating the consequences of climate change. In fact our present habits to emit large amounts of greenhouse gases to the atmosphere could be called an inadvertent climate engineering project. However, here we will exclude both greenhouse gas emissions (or land use change for purposes other than changing the climate) and measures to reduce greenhouse gas emissions from our discussion of geoengineering. Under the headline geoengineering (or climate engineering) we will discuss technical measures to avoid or mitigate climate change without tackling its primary causes. Geoengineering measures can be categorized:

1) **Change of IR absorption of the atmosphere by reducing greenhouse gas concentrations**
   Up to now mostly measures to reduce CO_2 levels were proposed:

– **Direct capture** of (already emitted) CO_2 from ambient air by a suitable chemical absorbent, so that it can subsequently be released and put to final storage [Lackner 2003, Broecker 2007]. Proposed schemes have advocated using towers to carry out ‚wind scrubbing', or using the wind fields around turbines [Broecker 2007]. The so captured CO_2 must be removed from the atmosphere for millennia by e.g. ‚Carbon burial' i.e. long-term physical storage of atmospheric CO_2 under pressure, confined below the Earth's surface within geological structures such as disused aquifers [Keith and Dowlatabadi 1992, Stephens and Keith 2008]. Alternatively, deep-ocean carbon sequestration could be employed.

– **Ocean fertilization** by continuous fertilization (e.g. by adding iron), over decades, of ocean waters that have a perennial excess of plant nutrients, in order to boost phytoplankton productivity and consequently increase the uptake and eventual sequestration of atmospheric CO_2 into deep water [Boyd 2008a]. Other suggested approaches include nitrogen fertilization of coastal waters [Keith and Dowlatabadi 1992], or purposeful mixing of deep nutrient-rich waters into the surface ocean [Lovelock and Rapley 2007] in the low-latitude ocean [Boyd et al. 2007, Boyd 2008b].

– Electrochemical **Acceleration of Chemical Weathering** [e.g. House et al. 2007] relies on electrochemical removal of HCl from ocean water and neutralizing it by reaction with suitable rocks thus enhancing the alkalinity of the ocean and therefore its ability to take up atmospheric CO_2.

2) **Reduction of the solar constant**

This can be accomplished by placing reflectors in space between sun and Earth (either in Earth orbit or at Lagrange point L1) and has become known as "Sunshades in space". It requires launch of a very large number of shading elements (e.g. thin disks), reflecting incoming sunlight back into space, [Keith 2001, Keith and Dowlatabadi 1992, Boyd 2008b].

3) Increase of Earth albedo

– Scatterers (aerosol) in the stratosphere: Injection of sulphur into the upper stratosphere (by balloons, aircraft or rocket), sulphur would form aerosols there [Caldeira 2008, Crutzen 2006] and thus enhance the Earth's albedo and reflect a proportion of incoming sunlight back into space, mimicking the effect of a volcanic eruption.

– Absorbers in the stratosphere

– Scatterers (aerosol, clouds) in the troposphere, 'Cloud-whitening'**:** Spraying of small seawater droplets from many wind-driven vessels into the turbulent boundary layer underlying marine clouds. The scheme is based on observations of the cumulative impact of ship exhausts in busy shipping lanes [Latham et al. 2008, Boyd 2008b]. The droplets are thought to increase the reflectance or albedo in existing clouds.

– Change of land- or sea surface albedo [Boyd 2008b]. Earth's albedo could be enhanced by e.g. painting surfaces white, deploying white, floating objects on the oceans, or by adding aerosol to the lower atmosphere. The latter could be accomplished by fertilising oceans to enhance production of the chemical dimethyl sulphide, which in turn is a precursor to aerosol [Wingenter et al. 2007].

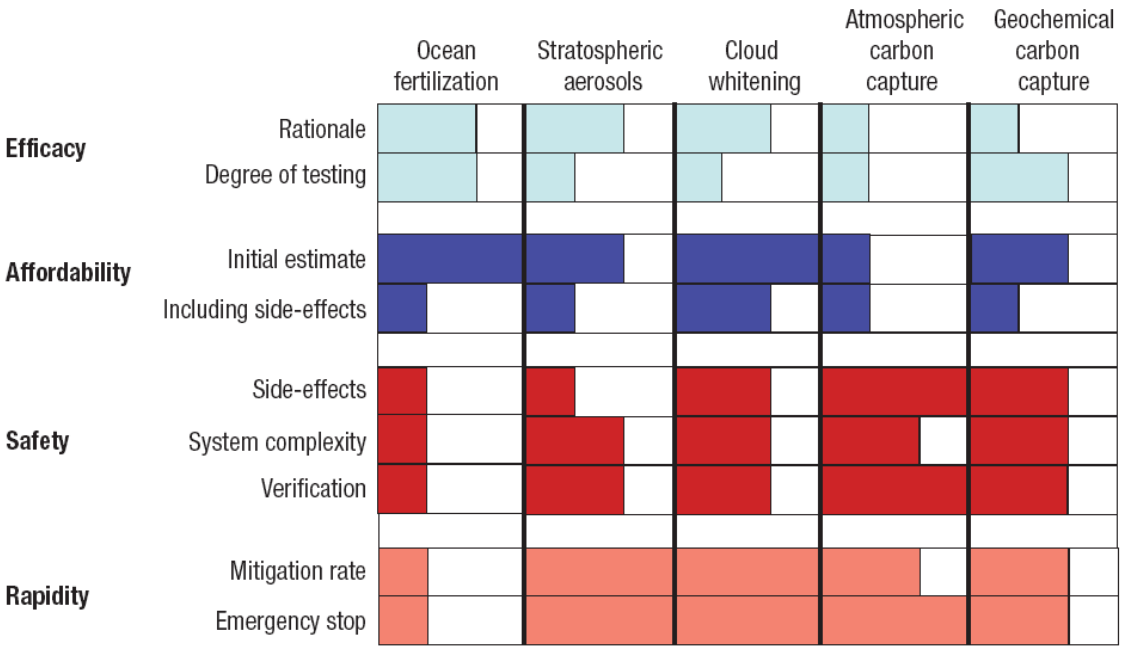

Fig. 1; Comparison of aspects of five geo-engineering proposals. The figure highlights schematically some facets of the four criteria: efficacy, cost, risk and time. The assessment gives scores relative to other schemes. For each facet, more colour denotes a higher ranking. From Boyd [2008b].

Clearly, efficiency, affordability, safety and rate of mitigation are very different and also quite unknown for most techniques summarised above. In Fig. 1 an attempt is made to assess these characteristics for the different techniques.

Criticism

Geoengineering measures as described under 1) (see above) will only reduce CO_2, but not other greenhouse gases, thus a proportionally larger reduction of CO_2 levels will be required, which may have side effects on the environment. Geoengineering measures 2), 3) aim at compensating reduced thermal IR emission by reducing solar input to Earth. Climate modeling studies show that, while mean Earth temperatures can be maintained at present levels, significant changes in other climate parameters are likely to occur, e.g. in precipitation patterns [Matthews and Caldeira 2007] or global temperature distribution [Lunt et al. 2008].

Also, these measures will not avoid other effects of enhanced CO_2, most prominently ocean acidification [e.g. Bengtsson 2006] or effects on the biosphere [e.g. Keith and Dowlatabadi 1992]. Moreover, unexpected side effects e.g. of stratospheric aerosol [Beig 2008] are likely.

3. Work packages (WPs)

Work package A: Environmental Physics – The Physical Basis of Climate Engineering

The WP is aimed at understanding the basic physics of climate engineering and its intended and unintended consequences. The focus will be on the physics of climate engineering and Earth's radiation budget as well as the hydrological impacts of climate engineering schemes.

We will study the physical principles behind the proposed climate engineering schemes (see section 3) and some of their consequences. Here our long standing experience from studies of the physics of our environment will come to bear.

Presently there is a growing body of literature describing various climate engineering schemes in greatly varying degree of detail. This literature provides a starting point for all work packages, but also needs to be critically reviewed, as in some cases even a superficial physical assessment of the proposed schemes reveals serious questions about their effectiveness and efficiency. The main task of this WP will be an analysis of the physics behind the proposed schemes in order to assess effectivity, side effects, cost, time scale, and other aspects of the schemes proposed in the literature.

This information will enable the participants from the societal sciences to start and proceed from more accurate descriptions of the proposed climate engineering schemes than presently given in the available literature and will thus help to focus the research done in WP's B-F on the relevant scenarios. Our main methodology will be scrutinisation of the physical principles employed and assumptions made in the various proposals of climate engineering schemes. This will sometimes require the development and use of simple models (e.g. of seed-aerosol coagulation in the case of "Cloud Whitening", see section 3). Large scale climate modelling is not the key point of this WP, but if the need should arise it will be done using the existing connections of the proposers to modelling groups (e.g in the KIT Karlsruhe).

In detail we propose the following course of action:

Since changes of Earth's radiation budget are the main reason for the man-made climate change, many climate engineering proposals seek to influence Earth's radiation budget. Therefore we will study the radiation transport in the atmosphere and at the surface, and its modification by aerosols and clouds. Changes due to elevated levels of greenhouse gases will be contrasted to reduced short-wave incoming radiation (e.g. due to shading measures). A particular topic are the effects of clouds and the feedback of temperature change on cloud cover and cloud properties [e.g. Wagner et al. 2007] and the absorption of radiation by clouds [e.g. Pfeilsticker et al. 1997, 1998].

In this work package, we will also address feasibility issues of various climate engineering proposals, as far as they are subject to physical limitations. As an example, we will assess the size distribution of aerosols produced by different deployment schemes in the troposphere and stratosphere.

We will also study the relationship between the global radiation budget and the hydrological cycle. In all current climate engineering proposals, temperature is the primary control variable. However, any climate engineering effort will not only affect temperature, but in particular the precipitation, with potentially drastic consequences for human activities. Climate simulations show that climate engineering may lead to significantly reduced precipitation [Matthews and Caldeira, 2007; Rasch et al., 2008]. However, the effects of rising CO_2 and changing radiation regimes on the water cycle are complex and not fully understood. E.g., CO_2 fertilization enables plants to use water more efficiently, and thereby increases surface runoff [Gedney et al., 2006] but decreases evapotranspiration and precipitation over continents [Matthews and Caldeira, 2007]. Reduced short-wave radiation or changes in cloud cover as a result of climate engineering measures will also affect the water cycle.

The results of the studies in WP A will form the background of the other WPs of the proposal, while at the same time questions arising from the other WPs will stimulate further research in WP A, particularly close connections are foreseen with Economics (WP D), Geography (WP C), and International Law (WP F).

Work package B: Analysis of medial representation of climate engineering in movies

Given the global scope and the long-term effects of geoengeneering, it is clear that a discussion of its feasibility must be embedded in the broader horizon of economical, political, juridical and cultural issues concerning the different terms of its acceptance. While the features of the economical, the political, and the juridical questions are more or less clear-cut, philosophy and psychology must hold their specific questions against the largest possible background of human understanding. Psychology, as indicated in the work package E, does so by assessing the relevant individual factors for risk assessment and risk perception, philosophy, on the other hand, will have to take into account the community aspects of a (in the best case world-wide) acceptance of large scale technological measures, an acceptance that depends on the most general worldviews held in different cultural backgrounds. Moral backgrounds and religious influences have to be considered. One fine instrument to get hold of these general perceptions of chances and risks

appears to be the investigation of the representation of climate engeneering in movies and novels.

The philosophical work unit has therefore its goal in a clarification of the content, the status and the strategy behind the representation of geo-engineering in movies. The leading questions are the following: 1.) what technical choice is made concerning the representation of geo-engineering, i.e. which particular technology among many others is chosen; 2.) what are the possible reasons for those choices and how is the technology appreciated; 3.) what are the general interests behind the choice of a specific technology. While the first question require empirical research, the second and the third questions open up the horizon of philosophical investigations. The analysis of medial representation of climate engineering in movies is done in three ways: on a philosophical level, geoengineering will be considered as a technology that actually functions either as a relief and compensation of damages caused by climate change, or appears on the contrary as a possible threat to Humanity, when it is used as a power tool in the hands of criminals. Of course there is a tendency in many movies to put the the actors and their (more or less personal) motives in the foreground of the tale, and not the technology in itself; but there is a neat tendency as well (and not only in the latest movies) to stage the technology and its globalized implications as the driving force behind the events. The latest James-Bond for instance showed clearly how powerless all the involved personal must appear in comparison with the anonymous strength of a purely self-centered and profit-orientated administration of ecological development. And there is another reason why technologies like geoengeneering won't work only as exchangeable instruments in the hands of their inventors: once the use of a technology has consequences that are global and in the worst case lethal for life on earth, the stakes are high enough to put the technology in itself into the prime focus of the social and philosophical debates. The Atomic bomb and the nuclear energy were the first technologies that produced this shift of interest, and geoengeneering can be seen along these lines.

On an aesthetic level it has to be investigated how the threat scenario and the discharge scenario are staged. Particular attention is required regarding the ambivalence in the representation of a technique, that appears either politically correct or at least in appearance neutral, but has in truth the potential for abuse, i.e. for local or global destruction (most recently in James Bond: A Quantum of Solace); or vice versa, just when scientists, with their bold ideas for rescuing the climate, are not at all or hardly or too late appreciated by the public opinion (The Day after Tomorrow). In these questions the philosophical project will work together with the discourse analysis of the human geography project. At a third level there is the political and social impact of geoengineering to be investigated, as far as it depends on the particular portrayal of the climate technique. The question is whether the 'mise en scene' is able to educate or to manipulate public opinion, i.e how well the staging matches with the state of science and technology and how emotionally tinted the respective representation appears ('Hollywood horrors'). Last is to ask how the presentation of geoengineering deals with the need to always prefer a specific technical option before others. To investigate is how the question about the aesthetic possibilities of staging has in turn an impact on the cinematic choice of technical options, and later on, on the political choice of a specific geoengineering technique. Finally, the normative question comes into play when the (fictional) description of viable means may suggest that the chosen strategy in the movies should also represent the right means in reality. This normative question includes the far reaching aspect of a fair solution between the different interests from different countries and different sectors in the pursuit of climate engineering.

The philosophical project examines the cultural implications and perceptions of geoengineering from a comparative perspective. It will thus generate empirical and theoretical findings that centre on the overall research questions, but also relate to the specific questions raised in the work packages by our colleagues from the disciplines of environmental economics, philosophy, human geography, and international law by informing about the central cultural issues at stake.

Work package C: Human Geography

The WP covered by Human Geography deals with the expected geographical effects of climate engineering (CE) in an economically and politically fragmented world. CE techniques are discussed very often on a global scale, but have various spatial implications as they affect zonal climates differently and will have consequences for the regional political and economic organization of the global society.

Despite an increasing interest in CE processes, the techniques as well as scientific research are at a rather early stage. There are some expectations on the political side effects of different techniques [Keith 2000, Robock 2008] and there is an emerging branch of public discourse about the chances and risks of influencing climate parameters within the broader debate on Global Change. Climate Engineering as a topic shares the ambivalence between new opportunities (technology) and risks (uncertain regional and global ramifications), that has been characteristic for the risk society of the 21st century.

Under which circumstances global scale intervention into the climate system is rendered acceptable is the result of competing perspectives on how to deal with environmental and technological risks. Central task for the project is therefore an analysis of the discourses about expected consequences of CE techniques and their political and social evaluation in different cultural and political regions of the world. The Discourse Analysis[3] will cover:

- Discourses about technological possibilities and natural risks: which regional impacts of CE processes can be expected and how are they evaluated within different cultural contexts?
- Discourses about the North-South divide and CE as a postcolonial project: How are obligations and risks of CE regionally distributed? Is CE presented as a mean to ease problems of a global fragmentation by mitigating global warming or does it raise fears of exacerbating spatial disparities and North-South conflicts?
- Discourses about spatial governance: which rationalities in handling the CE problem shape the debate? How do perceptions over "fair solutions" differ and how could they be brought together? In which way does the discussion on CE reflect the power structure of global organizations, their main actors and their political interests?

The Discourse Analysis will be based on selected print media, scientific publications in the field of geosciences and publications of international organizations. The research questions suggest a close cooperation of the human geography project with the other disciplines. This applies

[3] See Glasze, G., Mattissek, A. (eds.): Handbuch Diskurs und Raum. Theorien und Methoden für die Humangeographie sowie die sozial- und kulturwissenschaftliche Raumforschung. 2009. Bielefeld: transcript. (forthcoming).

especially to the staging of CE in movies and the reasons for particular modes of presentation as well as to the psychological project and its research on "fair solutions" and risk perceptions in our (western) societies. As questions of regional effects in an economically and politically fragmented world are concerned, close linkages exist to the projects of environmental economics and political science, the latter assessing the role of the EU as a potential model case for environmental governance. Eventually, the dissertation is expected to benefit from the findings of the environmental physics project as it identifies technological possibilities and associated risks.

Work package D: Environmental Economics

The WP covering environmental economics consists of three distinct research tasks:

The first task consists of summary cost-benefit analyses of the main geoengineering options, drawing on the natural science research completed by WP A of the present proposal. A prerequisite for this work is the development of a conceptual valuation model for geoengineering solutions, with the work of Moreno-Cruz and Smulders (2008) as a starting point.

The second task focuses on willingness to pay studies by the global public for funding a geoengineering response to climate change. Willingness to pay will be tested for robustness with respect to information supplied, international distribution of cost, and other external factors. This task will be complemented by research undertaken by researchers in cognitive psychology in WP E.

The third task examines how the presence of geoengineering options interacts with international agreements on greenhouse gas emissions abatement. As a technology for resolving a global public goods problem, geoengineering has very different economic properties compared to conventional climate change mitigation and adaptation (Barrett 2008), giving rise to a different set of incentives for countries engaged in international negotiations and requiring a different set of institutions for coordinating national activities. The task will interact directly with the international legal research carried out in WP F of the proposal.

Work package E: Psychology

Climate as a system influenced and controlled by men opens the broad field of questions related to the human understanding of complex systems, especially their abilities to identify and control these systems. Based on our understanding of complex systems, we evaluate risks and chances of specific interventions in light of our central values and the values of our culture.

From a psychological point of view, complex systems are characterized by (a) their complexity which requires information reduction in light of bounded human rationality, (b) their connectivity between the system variables which requires systems analysis and the identification of major and minor effects, (c) their intransparency which requires collection of missing information, (d) their dynamics which requires assumptions about temporal developments, and (e) polytely (=many goals) which requires the balance between possibly heterogenous goals. These factors are all relevant for risk assessment and risk perception on the individual level. As we now know, humans often ignore or underestimate side effects of their interventions. At the same time, they overestimate small probabilities due to biases from different heuristics for risk evaluation.

Central for the project will be the two questions: (1) what are the risks and the chances of climate engineering in the eyes of naive subjects; (2) what constitutes a fair solution between the different interests from different countries and different sectors in the pursuit of climate engineering. The first question addresses the broad issue of risk perception, especially with respect to global risks which are assessed differently to local or individual risks. It is intended to evaluate the risks of climate engineering in the context of other global risks within society. The second question addresses primarily the factor of polytely in research on complex problem solving, namely, how to come to a problem solution, which seems fair to all participants. It is intended to compare fairness judgements from novices versus experts from the area. Information will be presented by means of scenario techniques, that is, presenting a problem together with different solution proposals.

Work package F: International Law

Governing climate engineering raises questions about the legal framework that may apply to different technologies and about how to account for such under international law. Traditionally, international parameters, standards and procedures for the management of the climate are developed through international negotiations and they crystallize in international agreements. Such agreements are mostly static in the sense that they reflect the assessment of the situation (e.g. of the climate etc.) at the time of the deliberations. They adopt solutions considered appropriate at that moment (more often than not, not even that) but it is extremely difficult, if not impossible, to adjust existing legal regimes to new scientific findings. The review clauses common to most international environmental agreements cannot accommodate the needs for a flexible adaption of international environmental agreements to the needs as described.

Some environmental regimes, in particular the one on the protection of the ozone layer provide for amendments or rather modifications as far as the emission of certain gases are concerned. This paved the way to strengthen this regime (Vienna Convention on the Protection of the Ozone Layer/Montreal Protocol) considerably and could be considered as a starting point for a legal framework of climate engineering. The objectives of the legal project are the following:

1. To assess the possibilities under international treaty law in general to modify international obligations so as to accommodate new scientific findings or results, particularly with regards to climate engineering schemes.
2. To establish as to whether the system of the Montreal Protocol can be applied more generally on interferences with the climate system.
3. Assess the role of scientists in formulating such modifications.
4. Asses the possibilities of harmonizing a global legal framework with national law.

Work Package G: Political Science

Long-term policy challenges, i.e. public policy issues that occupy at least one human generation, which include substantial uncertainty over time and causal effects and which engender public goods problems, raise serious committment problems, both for national and global governance institutions. Climate change as well as the proposed climate engineering schemes pose such long-term policy challenges. First, their long-term adverse effects continue at least for 25 years, because they imply deep uncertainty about the effects of input parameters on a yet unknown

class of values by stakeholders. Secondly, climate engineering schemes contain public goods aspects, because questions of contemporaneous and intertemporaneous liability as well as fairness are raised.

Against this background it is noticeable, that the European Union has displayed considerable global leadership with respect to global carbon emission goals in recent years: through „tactical cohesion“ the Union has provided international leadership in the process of creating an internal burden – sharing scheme for CO_2 mitigation (Bubble concept). Recently, the EU has endorsed a 2 degrees celsius target for an increase in global average surface temperature and has committed itself to an unconditional goal for reducing Global Greenhouse Gas (GHG) emission by 20% by 2020.

Therefore, the proposed research cluster starts from the assumption that recent EU leadership in climate change policy point to governance qualities that may potentially help to overcome the protracted long-term challenges involving climate engineering. The first task of the proposed cluster is to pinpoint the specific leadership qualities that may be applied in establishing regional, plurilateral or multilateral governance structures for a climate engineering scheme. Secondly, the cluster will have to establish viable hypotheses deducted from theories of International Relations that can explain EU leadership behavior to solve collective action problems. Recent research on overcoming collective action problems in international politics suggests that there are both rationalist (e.g. club goods theory) and social constructivist approaches (e.g. role theory and solidarity approaches) that can explain leadership. Thirdly, the cluster will examine if and how far rationalist and/or social constructivist antecedent conditions are given for EU leadership in the different techniques of climate engineering. Based on scenario techniques the cluster will finally evaluate the different policy options for EU leadership in the climate engineering field.

4. Meeting the ‘Marsilius’ objectives

The MK’s objectives are both (i) to foster the interaction between the different scientific cultures and (ii) to initiate and implement research that bridges the boundaries between the disciplines. The proposed project meets both of these objectives comprehensively. The proposal itself is the product of the interaction between economists, physicists, psychologists, and geographers that share a common interest in addressing environmental challenges of global importance. The project will both broaden and deepen this interaction between the different disciplines as the young and senior researchers draw on the expertise of their colleagues in other disciplines in order to answer research questions in their own domain. The project also bridges the boundaries between the disciplines involved by establishing a common set of problem-oriented research objectives that unite the different scholarly traditions under one aegis. The PIs on this project have already successfully collaborated together in research proposals and are therefore able to provide guidance on discipline-bridging research to the junior researchers involved.

The Marsilius project will provide a structure of interdisciplinary workshops, an annual conference, and an ongoing lecture series that will offer an infrastructure and forum for researchers involved in the Marsilius Project to share research ideas and results, communicate challenges and obstacles, and to exploit the research capabilities of the collaborators.

5. The Consortium

Composition

The project consortium consists of the following eight senior researchers and co-principal investigators.

– *Prof. Dr. Werner Aeschbach-Hertig (Environmental Physics)*
Remit: Consequences of global climate engineering, in particular impacts on the water cycle, based on physical climate models

– *Prof. Dr. Joachim Funke (Psychology)*
Remit: Psychological foundations of individual and social responses vis-a-vis climate engineering

– *Prof. Dr. Hans Gebhardt (Geography)*
Remit: Spatial consequences of climate engineering; relationship between international discourses of regulation and regional climate engineering impacts

– *Prof. Dr. Martin Gessmann (Philosophy)*
Remit: Analysis of medial representation of geoengineering in movies

– *Prof. Timo Goeschl, Ph.D. (Economics)*
Remit: Cost-benefit analysis of geoengineering; economics of international agreements on geoengineering

– *Prof. Dr. Sebastian Harnisch (Political Science)*
Remit: Analysis of the international Politics of global governance of geoengineering.

– *Prof. Dr. Ulrich Platt and Prof. Dr. Thomas Leisner (Environmental Physics):*
Remit: Assessment of climate engineering technologies with regard to feasibility, side effects, and consequences

– *Prof. Dr. Rüdiger Wolfrum (Max Planck Institute for International Public Law)*
Remit: Perspectives of international law and international institutions required for global geoengineering and managing its consequences

Interaction

Members of the project consortium are all co-directors of the project. The members elect an executive director and his substitute who will provide internal guidance and external representation of the project. The co-directors meet at least on a termly basis.

6. Young researchers

PhD students and supervision structure

The project will involve both PhD students and promising undergraduate students as young researchers. Six PhD students will complete research theses. The following research questions will be covered in the PhD theses (co-advisors, see Table 1):

– Human Geography: "International discourses of climate regulation and their regional geographical implications in the fragmented world of the 21th century"

– Environmental Economics: “Geo-engineering: Cost-benefits analysis, determinants of willingness-to-pay, and its interaction with international climate change agreements”

– International Law: "International law and international institutions for the global governance of geo-engineering"
– Environmental Physics: "The physics of aerosol and cloud modification for 'climate engineering' and its consequences on the hydrological cycle"
– Psychology: "Individual and social responses to climate engineering from a complex problem solving point of view"
– Philosophy: "Ficton and forecast: an analysis of medial representation of geoengineering in movies"
– Politics: "The Politics of Geoengineering: Global Governance, Leadership and the European Union"

Supervision arrangements are maintained by a supervision team. This consists of a supervisor from the student's original discipline and typically two advisors from the other disciplines with which the dissertation topic intersects. In addition to ongoing interaction, supervision team and student meet at least once every term on a formal basis to discuss and assess progress. The supervision matrix below sets out the supervision structure.

Table 1: Supervision structure "Global Governance of Geoengineering"

Dissertation topic in	**Supervision by researchers from**						
	Environmental Physics	Philosophy	Human Geography	Political Science	Environmental Economics	Psychology	International Law
Environmental Physics	**S**		**A**		**A**		
Philosophy		**S**	**A**			**A**	
Human Geography			**S**	**A**		**A**	
Political Science	**A**			**S**			**A**
Environmental Economics	**A**				**S**	**A**	
Psychology		**A**			**A**	**S**	
International Law			**A**	**A**			**S**

S: Supervisor, **A:** Advisor

Seminars and workshops

To develop a fundamental understanding of the different disciplinary perspectives and methods on climate engineering, students will complete a first term that includes taught elements of eight hours each in three areas:

– Natural sciences and technological foundations of climate engineering: Participants will study the technical and scientific mechanisms involved in different climate engineering proposals. This will comprise the global energy balance and greenhouse effect, the global carbon cycle, the role of aerosols and the interaction of the atmospheric and hydrological system.
– Social science research on global environmental problems: Participants will study the underlying social, economical and political questions related to climate engineering proposals. It will be discussed, how the different approaches can be subsumed under the larger frame of global governance.
– Methods of natural and social science research on global environmental problems: to enable mutual understanding, the different methods of social and natural sciences are discussed in terms of their possibilities, presumptions and limitations (e.g. basics of qualitative and quantitative methods in the social sciences, experimental research in the natural sciences, modelling of atmospheric processes).

Project Workshops and Conferences

Four times per year, students will attend joint Project Workshops in which all PhD students present their approach and preliminary findings. The workshops provide the frame for discussing the respective research results and how they contribute to the overall questions raised by the project. To keep in touch with the broader debate, climate engineering experts working at other universities will be invited to hold seminars along the workshop series. Young researchers will attend at least one international scientific conference per year in order to participate in the international academic community and to share their research results.

The project will also draw in highly promising undergraduate students into cutting edge interdisciplinary science by involving them in various aspects of the research work.

7. The Budget

The following gives a breakdown of the budget for 3 years.

7 PhD students, 50% TVL-E13, for 3 years at approx. EUR 27.000 p.a.	€ 567,000
9 undergraduate project assistants, requiring funds for 4.320 hours or research assistance (12 months per PI at 40 hours, HiWi ungeprüft)	€ 43,200
Research travel, Conference travel, PIs and PhD students, EUR 1500 per year per person	€ 87,000
Lecture series, incidentals	€ 5,000
TOTAL	**€ 702,200**

Annual workshops can be financed within the Marsilius Fellowship funding (app. 3 x €15,000).

8. Follow-on research work

We envisage a DFG "Research Unit" (Forschergruppe); also this project will significantly contribute to our efforts in preparing a proposal for the forthcoming second phase of the "Excellenziniative".

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Appendix: Researchers involved

Prof. Dr. Joachim Funke – CV and selected publications

Short Biography

Born 1953 in Düsseldorf

1972-1980	Studies in philosophy, psychology, German language at Düsseldorf University (Germany), Basel University (Switzerland), Trier University (Germany)
1980	Diploma in Psychology
1984	Doctoral degree (Dr. rer.nat.) at Trier University
1984-1997	Assistant Professor at Bonn University
1990	Habilitation at Philosophische Fakultät Universität Bonn
since 1997	Full Professor (C4) for Cognitive, Theoretical and Experimental Psychology at the Department for Psychology, Heidelberg University.

Research Interests: Thinking and Problem solving, decision making in complex environments, dynamic systems.

Research Grants for different projects on Dynamic Systems, Script Monitoring, Sequence Learning, Complex Problem Solving, sponsored by German Science Foundation (DFG), 1992-2009; project on Complex Problem Solving in Clinical Contexts, sponsored by Bundesministerium für Bildung (BMBF), 2007-2009; project on Problem Solving, sponsored by European Council (EC), 1997-2002. From 2008-2009 appointed as Fellow at the Marsilius-Kolleg, Univ. of Heidelberg.

20 Selected Publications (Journal Articles – Chapters – Books)

Blech, C., & Funke, J. (2006). Zur Reaktivität von Kausaldiagramm-Analysen beim komplexen Problemlösen. Zeitschrift für Psychologie, 117, 185-195.

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Hans Gebhardt – CV and selected publications

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Office Address:	Department of Geography Ruprecht-Karls-University Heidelberg Berliner Str. 49 D-69120 Heidelberg, Germany
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Education and positions

2008	Fellow at the Marsilius Kolleg 2008/2009, University of Heidelberg
2005-2007	Dean of Studies, Faculty of Chemistry and Geosciences, Heidelberg
1996-present	Professor (C4) of Human Geography, Department of Geography, University of Heidelberg
1990-1996	Professor (C 3) of Human Geography and Regional Geography of South-West Germany, University of Tübingen
1988	Habilitation at the University of Cologne (Industry in the Alpine Regions)
1979-1990	Postdoctoral Fellow and Assistant Professor, Department of Geography, University of Cologne
	PhD in Human Geography, University of Tübingen; Thesis on the urban region of Ulm/Neu-Ulm as an industrial location
1973-1979	Studies in geography, german language and literature and geology at the University of Tübingen

Selected publications

Gebhardt, H. (2007): Entwicklung und Kultur aus geographischer Sicht. Perspektiven nach dem „cultural turn“ in der Geographie. In: Boeckh, A./Sevilla R. (Hrsg.): Kultur und Entwicklung. Vier Weltregionen im Vergleich. Baden-Baden, S. 15-38

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Martin Gessmann – CV and selected publications

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Education and positions

1982-1989	Studies in philosophy, French literature and German studies at the University of Tübingen
1989-1992	PhD (summa cum laude) at the University of Tübingen
1992	Visiting Scholar at the Dept. of Philosophy at Georgetown University, Washington D.C.
1993-1995	Assistant Professor, University of Halle/Wittenberg
1993-1996	Television journalist at public tv-stations SWR, WDR and ZDF
1997	Assistant Professor, University of Heidelberg
2002	Second dissertation (Habilitation) at the University of Heidelberg

Fellow at the Marsilius Kolleg 2008/2009, University of Heidelberg

Scientific distinctions, awards, memberships

Member of the jury concerning the Raymond-Aron-Award of the dva-foundation; Research Associate of the *International Center for Cultural and Technological Studies* at Stuttgart

Selected Publications

Wittgenstein als Moralist (forthcoming - transcript)

Philosophisches Wörterbuch (forthcoming – Kröner-Verlag)

Was der Mensch wirklich braucht (forthcoming – Fink-Verlag)

„Jaspers' Menschenbild an der Grenze von Trieb und Transzendenz", evangelische aspekte, Heft 2, 2009 (forthcoming)

„Foucaults Theorie der Macht", in: F. Heidenreich (ed.), Das Staatsverständnis von Michel Foucault, Nomos, Baden-Baden, 2009 (forthcoming)

„Dialektik als Topik. Zur Aktualität eines hermeneutischen Konzepts" in: M. Giusti (ed.), "La cuestión de la dialéctica", Lima 2009 (forthcoming)

„Was der Mensch wirklich braucht. Für eine anthropologische Hermeneutik". Publication of the proceedings of XXI. Deutscher Kongress für Philosophie - Sektion 19.1 Technikphilosophie

„Was ist Kulturphilosophie", in: Philosophische Rundschau, Band 55, Heft 1, 2008, S. 1-23.

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Article: „Pathos“, in: F. Wolfzettel, K. Barck, M. Fontius, D. Schlenstedt, B. Steinwachs, Stuttgart (ed.) Historisches Wörterbuch ästhetischer Grundbegriffe, 2003, Bd. 4, S. 724-734.

Article: „moralisch-amoralisch“ (vom Mittelalter bis zum 18. Jahrhundert), in: F. Wolfzettel, K. Barck, M. Fontius,

D. Schlenstedt, B. Steinwachs (ed.): Historisches Wörterbuch ästhetischer Grundbegriffe, hrsg. v., Stuttgart 2004, Bd. 4, S. 190-198

Logik und Leben. Zur praktischen Grundlegung der Hegelschen Dialektik,

Dissertation (summa cum laude), Tübingen 1992.

Timo Goeschl – CV and selected publications

Short CV:

Born 1970.

1994	Master of Arts in Economics, Univ. of Notre Dame, Indiana, USA.
1995	Magister rer.soc.oec. Univ. of Innsbruck, Austria.
1996	M.Phil. in Economics, Univ. of Cambridge.
2000	Ph.D. in Economics, Univ. of Cambridge. 1997-1999 Marie Curie Fellow, Faculty of Economics, Cambridge.
1998-1999	Research Fellow, Centre for Social and Economic Research on the Global Environment, Department of Economics, University College London.
2000-2003	University Lecturer and Director, Cambridge Research for the Environment, Univ. of Cambridge.
2003-2005	Assistant Professor, University of Wisconsin-Madison.
Since 2005	Full Professor (C4) of Environmental Economics, Department of Economics, University of Heidelberg.
Research Interests	Environmental and Resource Economics; Economics of Innovation; Law and Economics. Numerous research grants by ESRC (UK), European Commission, NSF (USA), BMBF (Germany).
Prizes and awards	Fulbright Scholar; Austrian Academy of Sciences Scholarship; Würdigungspreis des Bundesministers (Austria); Marie-Curie Fellowship. From 2008-2009 appointed as Fellow at the Marsilius-Kolleg, Univ. of Heidelberg.

Representative Publications

Distributive Issues in Conservation Policy (with P. Bagnoli and E. Kovacs). Paris: OECD 2008

Optimal Conservation, Extinction Debt, and the Augmented Quasi-Option Value (with A. Leroux and V. Martin). *Journal of Environmental Economics and Management*. Forthcoming 2009

The Value of Conserving Genetic Resources for R&D (with M. Sarr and T. Swanson). *Ecological Economics* 67(2), September 2008, 184-193.

Innovation Without Magic Bullets: Stock Pollution and R&D Sequences (with G. Perino). *Journal of Environmental Economics and Management*, 54(2), Sept. 2007, 146-161.

Property Rights for Biodiversity Conservation and Development: An Analysis of Extractive Reserves in the Brazilian Amazon (with D. Igliori). *Development and Change* 37(2), March 2006, 427-451.

Non-Binding Linked-Issues Referenda: Analysis and an Application. *Public Choice* 124 (3-4), September 2005, 249-266.

Incentivizing Ecological Destruction: The Joint International Regulation of the Conservation and Use of Biodiversity (with R. Gatti, B. Groom and T. Swanson), *Indiana Law Review* 38(3), May 2005, 619-635.

Reconciling Conservation and Development: A Dynamic Hotelling Model of Extractive Reserves (with D. Igliori). *Land Economics* 80(3), Aug. 2004, 340-54.

Plagues, Pests, and Patents (with T. Swanson). Journal of the European Economic Association, Vol. 1(2-3), May-June 2003, 561-575.

The Development Impact of Genetic Use Restriction: A Forecast based on the Hybrid Crop Experience (with T. Swanson). *Environment and Development Economics* 8, 2003, 149-165.

The Social Value of Biodiversity for R&D (with T. Swanson). *Environmental and Resource Economics* 22(4) Aug. 2002, 477-504

Genetic use restriction technologies and the diffusion of yield gains to developing countries (with T. Swanson). *Journal of International Development* 12(8) Dec. 2000, 1159-1178.

Property Rights Issues Involving Plant Genetic Resources: Implications of Ownership for Economic Efficiency (with T. Swanson); *Ecological Economics* 32(1), Jan. 2000, 75-92.

An Analysis of the Impacts of Genetic Use Restriction Technologies (GURTs) on Developing Countries (with T. Swanson), *International Journal of Biotechnology Vol. 2,* Jan-Feb. 2000, 56-84.

Prof. Dr. Sebastian Harnisch – CV and selected publications

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Short CV:

2004	Habilitation (Political Science), University of Trier
1998	Dissertation PhD (Political Science), University of Trier
1993	M.A. (Political Science, History), University of Trier
1990-1991	Graduate Studies (Diplomacy), Georgetown University, Washington DC

Education and positions:

2007 to present	Professor for Political Science, Institute for Political Science, University of Heidelberg
2006-2007	Associate Professor, Chair for International Politics, Federal Armed Forces University Munich
2003-2007	Associate Professor in International Relations and Foreign Policy, University of Trier
1998-2003	Assistant Professor, Department of International Relations, University of Trier
1993-1998	Reader in International Relations and Foreign Policy, University of Trier
1997	Research Fellow in Korean Studies, Seoul National University, Seoul (Korea Foundation Scholarship)
1996	Research Fellow at the East Asian Institute, Columbia University, New York (funded by German Research Foundation, GSF)
1996	Research Fellow at Yonsei University, Seoul and the Japan Center for International Exchange, Tokyo (funded by GSF)

20 selected publications

Harnisch Sebastian (Ed.) (forthcoming): On World Stage: Role Theory in International Relations, Leiden: Brill Publ. (co-edited with /Frank, Cornelia/Maull, Hanns W.)

Harnisch, Sebastian (Ed.) 2009: Solidarity and Community Building in International Politics, Frankfurt/ Main: Campus 2009 (co-editors Hanns W. Maull/Siegfried Schieder, in German)

Harnisch, Sebastian 2009: Solidarity and Community Building: Interdisciplinary Dialogue and synthesis, in: Harnisch et al. (Eds.), pp. 361-374

Harnisch, Sebastian (Ed.) 2009: EU-Policy in Kosovo, Baden-Baden: Nomos 2009 (co-editor Bernhard Stahl, in German)

Harnisch, Sebastian 2009: 'The politics of domestication: A new paradigm in German foreign policy, in: German Politics (forthcoming)

Harnisch, Sebastian/Wolf, Raimund 2009: Germany's Changing Security Culture and Governance, in: Kirchner, Emil/Sperling, James (Hg.): National Security Cultures and Global Security Governance, New York: Routledge.

Harnisch, Sebastian (2009): Constructivist Approaches, in: Wilhelm, Andreas/Masala, Carlo (Ed.): Handbook of International Politics, Wiesbaden: Verlag für Sozialwissenschaften. (in German)

Harnisch, Sebastian 2008: Minilateralisms, Formal Institutions and Transatlantic Cooperation: The EU-3 Initiative vis-à-vis Iran's Nuclear Program, in: Schmidt, Peter (Hg.): Beyond NATO - Transatlantic Cooperation in a new Era, Baden-Baden

Harnisch, Sebastian 2008: High Demand Pressure from Asia: The External Energy Policies of the two Koreas, in: Die Internationale Politik. Yearbook of the DGAP: world compatible energy security, Bonn (in German)

Harnisch Sebastian 2007: Minilateral Cooperation and Transatlantic Coalition Building: The EU3-Iran Initiative, in: European Security 16: 1, pp. 1-27, 2007

Harnisch, Sebastian 2007: At the Limit. German Europe Policy and European Constitutional Treaty, in: Zeitschrift für Politikwissenschaft 17: 1, pp. 61-77 (in German)

Harnisch, Sebastian 2006: International Politics and the Constitution. The Domestication of German Security and European Policy, Baden-Baden 2006 (in German)

Harnisch, Sebastian (Ed.) 2004: German Security Policy. An Assessment of the Schröder government's track record, Baden-Baden (in German) (co-editors Christos Katsioulis/Marco Overhaus)

Harnisch, Sebastian (Ed.) 2003: Germany in the offside? Red-Green Foreign Policy 1998-2003, Baden-Baden: Nomos Verl. (in German) (co-editors Hanns W. Maull/Constantin Grund)

Harnisch, Sebastian 2003: Theories of Foreign Policy Analysis in an Era of Change, in: Hellmann, Gunther et al. (Ed.) 2003: New International Relations Scholarship. State of the Art and Perspectives in Germany, Baden-Baden: Nomos Verl., pp. 313-360 (in German)

Harnisch, Sebastian European Union, in: Baker, Richard (Ed.): Asia Pacific Security Outlook 2004, Tokyo: Japan Center for International Exchange 2004, pp. 89-98

Harnisch, Sebastian European Union, in: Morrison, Charles (Ed.): Asia Pacific Security Outlook 2003, Tokyo: Japan Center for International Exchange 2003, pp. 53-60

Harnisch, Sebastian 2003: Building Europe – preserving Germany: the European policy of the Red-Green coalition, in: Harnisch, Sebastian et al. (Ed.): Is Germany offside? Red-Green Foreign Policy 1998-2003, Baden-Baden: Nomos Verl., pp. 65-78 (co-author Siegfried Schieder) (in German)

Harnisch, Sebastian (Ed.) 2001: Germany as a Civilian Power. The Foreign Policy of the Berlin Republic, Manchester: Manchester University Press (co-editor Hanns W. Maull)

Harnisch, Sebastian 2001: Introduction, in: Harnisch, Sebastian/Hanns W. Maull (Ed.): Germany as a Civilian Power. The Foreign Policy of the Berlin Republic, Manchester: Manchester Univ. Pr. 2001, pp. 1-9 (co-author Hanns W. Maull)

Harnisch, Sebastian 2001: Conclusion: Learned its lesson well? Germany as a Civilian Power ten years after unification, in: Harnisch, Sebastian/Hanns W. Maull (Ed.): Germany as a Civilian Power. The Foreign Policy of the Berlin Republic, Manchester: Manchester University Press 2001, pp. 128-156 (co-author Hanns W. Maull)

Werner Aeschbach-Hertig – CV and selected publications

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Office Address:	Institute of Environmental Physics Ruprecht-Karls-University Heidelberg Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany
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Education and positions:

2008	Appointed as Fellow at the Marsilius Kolleg in 2009/10, Univ. of Heidelberg
2008-present	Dean of Studies, Faculty of Physics and Astronomy, Heidelberg
2003-present	Professor (C3), Institute of Environmental Physics, Heidelberg
2000-2002	Assistant Lecturer, ETH Zurich, Switzerland
1996-2002	Research Associate, Environmental Physics, ETH Zurich and Eawag
1994-1996	Postdoctoral Fellow, Geochemistry Division, Lamont-Doherty Earth Observatory of Columbia University, Palisades, NY, USA

PhD in environmental sciences at ETH Zurich; Thesis on helium and tritium as tracers for physical processes in lakes

1990-1994	Research Assistant, Environmental Physics, ETH Zurich and Eawag (Swiss Federal Institute of Aquatic Science and Technology, Dübendorf)

Diploma in physics at ETH Zurich; Thesis on trace analytics in air

Studies in experimental physics, ETH Zurich, Switzerland

20 selected publications

Aeschbach-Hertig, W., J. F. Clark, M. Stute, R. Reuter and P. Schlosser, 2002. A paleotemperature record derived from dissolved noble gases in groundwater of the Aquia Aquifer (Maryland,USA). *Geochim. Cosmochim. Acta*, 66: 797-817.

Aeschbach-Hertig, W., H. El-Gamal, M. Wieser, and L. Palcsu, 2008. Modeling excess air and degassing in groundwater by equilibrium partitioning with a gas phase. Water Resour. Res., 44, W08449, doi:10.1029/2007WR006454.

Aeschbach-Hertig, W., C. P. Holzner, M. Hofer, M. Simona, A. Barbieri, and R. Kipfer, 2007. A time series of environmental tracer data from deep meromictic Lake Lugano, Switzerland. Limnol. Oceanogr. 52: 257-273.

Aeschbach-Hertig, W., F. Peeters, U. Beyerle and R. Kipfer, 1999. Interpretation of dissolved atmospheric noble gases in natural waters. *Water Resour. Res.* 35: 2779-2792.

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Beyerle, U., W. Aeschbach-Hertig, D. M. Imboden, H. Baur, T. Graf and R. Kipfer, 2000. A mass spectrometric system for the analysis of noble gases and tritium from water samples. Environ. Sci. Technol. 34: 2042-2050.

Beyerle, U., R. Purtschert, W. Aeschbach-Hertig, D.M. Imboden, H.H. Loosli, R. Wieler and R. Kipfer, 1998. Climate and groundwater recharge during the last glaciation in an ice-covered region. *Science* 282: 731-734.

Beyerle, U., J. Rüedi, M. Leuenberger, W. Aeschbach-Hertig, F. Peeters, R. Kipfer and A. Dodo, 2003. Evidence for periods of wetter and cooler climate in the Sahel between 6 and 40 kyr BP derived from groundwater. *Geophys. Res. Lett.* 30, DOI 10.1029/2002GL016310.

Corcho Alvarado, J. A., R. Purtschert, F. Barbecot, C. Chabault, J. Rüedi, V. Schneider, W. Aeschbach-Hertig, R. Kipfer, and H.H. Loosli, 2007. Constraining the age distribution of highly mixed groundwater using ^{39}Ar: a multiple environmental tracer (^{3}H/^{3}He, ^{85}Kr, ^{39}Ar and ^{14}C) study in the semi-confined Fontainebleau Sands aquifer (France). Water Resour. Res. 43, W03427, doi:10.1029/2006WR005096.

Corcho Alvarado, J. A., R. Purtschert, K. Hinsby, L. Troldborg, M. Hofer, R. Kipfer, W. Aeschbach-Hertig, H.-A. Synal, 2005. ^{36}Cl in modern groundwater dated by a multi tracer approach (^{3}H/^{3}He, SF_6, CFC-12 and ^{85}Kr): A case study in quaternary sand aquifers in the Odense Pilot River Basin, Denmark. *Appl. Geochem.* 20: 599-609.

Edmunds, W. M., J. Z. Ma, W. Aeschbach-Hertig, R. Kipfer, and D. P. F. Darbyshire, 2006. Groundwater recharge history and hydrogeochemical evolution in the Minqin Basin, North West China. Appl. Geochem. 21: 2148-2170.

Holocher, J., F. Peeters, W. Aeschbach-Hertig, M. Hofer, M. Brennwald, W. Kinzelbach and R. Kipfer, 2002. Experimental investigations on the formation of excess air in quasi-saturated porous media. Geochim. Cosmochim. Acta 66: 4103-4117.

Holocher, J., F. Peeters, W. Aeschbach-Hertig, W. Kinzelbach and R. Kipfer, 2003. Kinetic model of gas bubble dissolution in groundwater and its implications for the dissolved gas composition. *Environ. Sci. Technol.* 37: 1337-1343.

Kipfer, R., W. Aeschbach-Hertig, F. Peeters and M. Stute, 2002. Noble gases in lakes and ground waters. In: Porcelli, D. et al. (eds.), Noble gases in geochemistry and cosmochemistry. *Rev. Mineral. Geochem.*, 47: 615-700.

Kluge, T., T. Marx, D. Scholz, S. Niggemann, A. Mangini, and W. Aeschbach-Hertig, 2008. A new tool for palaeoclimate reconstruction: Noble gas temperatures from fluid inclusions in speleothems. Earth Planet. Sci. Lett., 269: 407–414.

Kreuzer, A. M., C. von Rohden, R. Friedrich, Z. Chen, J. Shi, I. Hajdas, R. Kipfer, and W. Aeschbach-Hertig, 2008. A record of temperature and monsoon over the past 40 kyr from groundwater in the North China Plain. Chem. Geol., doi:10.1016/j.chemgeo.2008. 11.001.

Peeters, F., U. Beyerle, W. Aeschbach-Hertig, J. Holocher, M. S. Brennwald and R. Kipfer, 2003. Improving noble gas based paleoclimate reconstruction and groundwater dating using ^{20}Ne/^{22}Ne ratios. Geochim. Cosmochim. Acta 67: 587-600.

Weyhenmeyer, C. E., S. J. Burns, H. N. Waber, W. Aeschbach-Hertig, R. Kipfer, H. H. Loosli and A. Matter, 2000. Cool glacial temperatures and changes in moisture source recorded in Oman groundwaters. *Science* 287: 842-845.

Winckler, G., W. Aeschbach-Hertig, J. Holocher, R. Kipfer, I. Levin, C. Poss, G. Rehder, E. Suess and P. Schlosser, 2002. Noble gases and radiocarbon in natural gas hydrates. *Geophys. Res. Lett.* 29, DOI 10.1029/2001GL014013.

Thomas Leisner – CV and selected publications

Name:	Thomas Konrad Leisner
Office Address:	Institute of Environmental Physics, Ruprecht-Karls-University Heidelberg, Im Neuenheimer Feld 229, D-69120 Heidelberg, Germany
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Education and positions:

1986	Diploma in Physics at the University of Konstanz
1991	Promotion (Dr. rer. nat.) at the University of Konstanz
1991	Postdoc at the University of New Hampshire, Durham, NH, USA
1992 -2000	Research Assistant, Dpt. of Physics Free Universtity of Berlin, Berlin
1999	Habilitation in Experimental Physics, Free University of Berlin
2000 – 2006	Full Professor at Technische Universität Ilmenau; Chair in Environmental Physics
since 2006	Chair at the Univ. of Heidelberg in physics of the atmosphere.
since 2006	Head of the Atmospheric Aerosol Research Division at the Institute for Meteorology and Climate Research (IMK) at the Forschungszentrum Karlsruhe (FZK).
since 2008	Managing Direktor of the IMK at FZK

Visiting Professor at the University of Tokyo and Fellow of the Japanese Associaition for the Advancement of Sciences, Japan

Member of DPG (Deutsch Physikalische Gesellschaft), speaker of the section 'Physics of the Environment' (Fachverbandssprecher, 'Umweltphysik') (since 2008).

Member of the Senate and the “Coucil of Research and Young Scientists” of the Karlsruhe Institute of Technology (KIT)

Selected publications:

Kramer, B.; Schwell, M.; Hubner, O.; Vortisch, H.; Leisner, T.; Ruhl, E.; Baumgartel, H.; Woste, L., Homogeneous ice nucleation observed in single levitated micro droplets. Berichte Der Bunsen-Gesellschaft-Physical Chemistry Chemical Physics 1996, 100, (11), 1911-1914.

Leisner, T.; Rosche, C.; Wolf, S.; Granzer, F.; Woste, L., The catalytic role of small coinage-metal clusters in photography. Surface Review and Letters 1996, 3, (1), 1105-1108.

Berry, R. S.; BonacicKoutecky, V.; Gaus, J.; Leisner, T.; Manz, J.; ReischlLenz, B.; Ruppe, H.; Rutz, S.; Schreiber, E.; Vajda, S.; deVivieRiedle, R.; Wolf, S.; Woste, L.; Gerber, G.; Letokhov, V. S.; Rice, S. A.; Zewail, A. H.; Marcus, R. A.; Tannor, D. J.; Kobayashi, T., Size-dependent ultrafast relaxation phenomena in metal clusters. Chemical Reactions and Their Control on the Femtosecond Time Scale Xxth Solvay Conference on Chemistry 1997, 101, 101-139.

Kasparian, J.; Kramer, B.; Dewitz, J. P.; Vajda, S.; Rairoux, P.; Vezin, B.; Boutou, V.; Leisner, T.; Hubner, W.; Wolf, J. P.; Woste, L.; Bennemann, K. H., Angular dependences of third harmonic generation from microdroplets. Physical Review Letters 1997, 78, (15), 2952-2955.

Frejafon, E.; Kasparian, J.; Rambaldi, P.; Vezin, B.; Boutou, V.; Yu, J.; Ulbricht, M.; Weidauer, D.; Ottobrini, B.; de Saeger, E.; Kramer, B.; Leisner, T.; Rairoux, P.; Woste, L.; Wolf, J. P., Laser applications for atmospheric pollution monitoring. European Physical Journal D 1998, 4, (2), 231-238.

Kasparian, J.; Kramer, B.; Leisner, T.; Rairoux, P.; Boutou, V.; Vezin, B.; Wolf, J. P., Size dependence of nonlinear Mie scattering in microdroplets illuminated by ultrashort pulses. Journal of the Optical Society of America B-Optical Physics 1998, 15, (7), 1918-1922.

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Schwell, M.; Baumgartel, H.; Weidinger, I.; Kramer, B.; Vortisch, H.; Woste, L.; Leisner, T.; Ruhl, E., Uptake dynamics and diffusion of HCl in sulfuric acid solution measured in single levitated microdroplets. Journal of Physical Chemistry A 2000, 104, (29), 6726-6732.

Vortisch, H.; Kramer, B.; Weidinger, I.; Woste, L.; Leisner, T.; Schwell, M.; Baumgartel, H.; Ruhl, E., Homogeneous freezing nucleation rates and crystallization dynamics of single levitated sulfuric acid solution droplets. Physical Chemistry Chemical Physics 2000, 2, (7), 1407-1413.

Duft, D.; Lebius, H.; Huber, B. A.; Guet, C.; Leisner, T., Shape oscillations and stability of charged microdroplets. Physical Review Letters 2002, 89, (8), -.

Weritz, F.; Simon, A.; Leisner, T., Infrared microspectroscopy on single levitated droplets. Environmental Science and Pollution Research 2002, 92-99.

Duft, D.; Achtzehn, T.; Muller, R.; Huber, B. A.; Leisner, T., Coulomb fission - Rayleigh jets from levitated microdroplets. Nature 2003, 421, (6919), 128-128.

Manil, B.; Ntamack, G. E.; Lebius, H.; Huber, B. A.; Duft, D.; Leisner, T.; Chandezon, F.; Guet, C., Charge emission and decay dynamics of highly charged clusters and micro-droplets. Nuclear Instruments & Methods in Physics Research Section B-Beam Interactions with Materials and Atoms 2003, 205, 684-689.

Weidinger, I.; Klein, J.; Stockel, P.; Baumgartel, H.; Leisner, T., Nucleation behavior of n-alkane microdroplets in an electrodynamic balance. Journal of Physical Chemistry B 2003, 107, (15), 3636-3643.

Duft, D.; Leisner, T., Laboratory evidence for volume-dominated nucleation of ice in supercooled water microdroplets. Atmospheric Chemistry and Physics 2004, 4, 1997-2000.

Leisner, T., Mikro-Jets und Gewitterwolken: Stabilität und Zerfall hochgeladener Flüssigkeitströpfchen. Physik Journal 2006, 5, (6), 41-45.

Wagner, R.; Benz, S.; Möhler, O.; Saathoff, H.; Schnaiter, M.; Leisner, T., Influence of Particle Aspect Ratio on the Midinfrared Extinction Spectra of Wavelength-Sized Ice Crystals. J. Phys. Chem. A 2007, 111, (50), 13003-13022, 2007.10.1021/jp0741713.

Giglio, E.; Gervais, B.; Rangama, J.; Manil, B.; Huber, B. A.; Duft, D.; Muller, R.; Leisner, T.; Guet, C., Shape deformations of surface-charged microdroplets. Physical Review E 2008, 77, (3), 0363191-7.

Treuel, L.; Schulze, S.; Leisner, T.; Zellner, R., Deliquescence behaviour of single levitated ternary salt/carboxylic acid/water microdroplets. Faraday Discussions 2008, 137, 265-278.

Wagner, R.; Benz, S.; Bunz, H.; Möhler, O.; H., S.; Schnaiter, M.; Leisner, T.; Ebert, V., Infrared optical constants of highly diluted sulfuric acid solution droplets at cirrus temperatures. The Journal of Physical Chemistry A 2008, DOI: 10.1021/jp8066102.

Ulrich Platt – CV and selected publications

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Education and positions:

1974	Diploma in Physics at the University of Heidelberg
1977	Promotion (Dr. rer. nat.) at the University of Heidelberg
1977	Scientist at the Institute for Atmospheric Chemistry of the Nuclear Research Centre Jülich (today: Forschungszentrum Jülich, KFA).
1980	Visiting scientist at the "Statewide Air Pollution Research Center (SAPRC)", University of California/Riverside.
1981 - 1982	Visiting scientist at the SAPRC, University of California, Riverside.
1984	Habilitation in Geophysics at the University of Colone
since 1989	Chair (Ordinarius) at the Univ. of Heidelberg in experimental physics.
since 1990	Director at the Institute for Environmental Physics, Univ. of Heidelberg.
1995	Dean of the faculty of Physics of the University of Heidelberg.

Member of the IGAC (International Global Atmospheric Chemistry) Scientific Steering Committee (SSC) (2001-2006).

Member of the SOLAS (Surface Ocean and Lower Atmosphere Studies) Scientific Steering Committee. (2002-2007).

Member of the GOME (Global Ozone Monitoring Experiment on the ESA satellite ERS-2) and SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY on ESA satellite ENVISAT) Science Advisory Committees.

Visiting professor at the Gwangju Institute of Science and Technology (GIST), Gwangju, Korea.

Member of the OMI (Ozone Monitoring Instrument) for the NASA EOS AURA mission Science Team.

Member of DPG (Deutsch Physikalische Gesellschaft), speaker of the section 'Physics of the Environment' (Fachverbandssprecher, 'Umweltphysik') (2003-2008).

Chair of the Science Advisory Committee for the „High Altitude and Long Range Aircraft" (HALO), (since 2008).

External scientific member of the Max-Planck Society

Member of Academia Europaea, section EARTH & COSMIC SCIENCES.

Member of the German National Committee On Global Change Research (NKGCF) (since 2008)

Selected publications (from more than 200 in the reviewed literature):

Platt U., Perner D., and Pätz H.W. (1979), Simultaneous measurement of atmospheric CH_2O, O_3, and NO_2 by differential optical absorption, J. Geophys. Res. 84, 6329-6335.

Platt U.,. Perner H., Harris G.W., Winer A.M., and Pitts J.N. (1980), Observations of nitrous acid in an urban atmosphere by differential optical absorption, Nature 285, 312-314.

Platt. U., Perner D., Schröder J., Kessler C., and Toennissen A. (1981), The diurnal variation of NO_3, J. Geophys. Res. 86, 11965-11970.

Platt U., Rateike M., Junkermann W., Rudolph J., and Ehhalt D.H. (1988), New tropospheric OH measurements, J. Geophys. Res. 93, 5159-5166.

Platt U., LeBras G., Poulet G., Burrows J.P., and Moortgat G. (1990), Peroxy radicals from night-time reaction of NO_3 with organic compounds, Nature 348, 147-149.

Platt U. and Hausmann M. (1994), Spectroscopic measurement of the free radicals NO_3, BrO, IO, and OH in the troposphere, Res. Chem. Intermed., 20, 557-578.

Platt. U. and Janssen C., (1995), Observation and role of the free radicals NO_3, ClO, BrO and IO in the Troposphere, Faraday Discuss 100, 175-198.

Platt U. and Le Bras G. (1997), Influence of DMS on the NO_X - NO_Y Partitioning and the NO_X Distribution in the Marine Background Atmosphere, Geophys. Res. Lett., 24, 1935-1938.

Pfeilsticker K., Erle F. and Platt U. (1997), Absorption of solar radiation by atmospheric O_4, J. Atm. Sci., 54, 933-939.

Wagner T. and Platt U. (1998), Observation of Tropospheric BrO from the GOME Satellite, Nature 395, 486-490.

Alicke B., Hebestreit K., Stutz J., and Platt U. (1999), Detection of Iodine Oxide by DOAS in the Marine Boundary Layer, Nature 397, 572-573.

Platt U. (1999), Modern Methods of the Measurement of Atmospheric Trace Gases, J. Physical Chemistry Chemical Physics 'PCCP' 1, 5409-5415.

Hebestreit K., Stutz J., Rosen D., Matveev V, Peleg M., Luria M., and Platt U. (1999), First DOAS Measurements of Tropospheric BrO in Mid Latitudes, Science, 283, 55-57.

Platt U., Alicke B., Dubois R., Geyer A., Hofzumahaus A., Holland F., Mihelcic D., Klüpfel T., Lohrmann B., Pätz W., Perner D., Rohrer F., Schäfer J., and Stutz, J. (2002), Free Radicals and Fast Photochemistry during BERLIOZ, J. Atmos. Chem. 42, 359-394.

Hönninger G. and Platt U. (2002), The Role of BrO and its Vertical Distribution during Surface Ozone Depletion at Alert, Atmos. Environ. 36, 2481-2489.

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Rüdiger Wolfrum – CV and selected publications

Born 1941 in Berlin

1964-1969 Study of Law at Bonn University (Germany), Tübingen University (Germany)

1969	First State-Examination
1969-1973	Junior barrister
1973	Graduation, Dr. iur.
1973-1980	Assistant professorship, Institute of International Law, University of Bonn
1977-1978	Research fellow at the Center for Oceans Law and Policy of the University of Virginia, scholarship from the German Research Foundation
1980	Habilitation, venia legendi for national public and international public law
1982	Professor, Chair of national public and international public law, University of Mainz, Faculty of Law and Economics
1982-1993	Professor, Chair of national public and international public law, University of Kiel, Law Faculty, Director of the Institute of International Law
1986-1993	Judge at the Court of Appeals for Administrative Matters for the states of Niedersachsen and Schleswig-Holstein
1991-	judge at the Court of Appeals for Administrative Matters of the Land Schleswig Holstein
1990-1993	Vice-rector of the Christian-Albrechts-Universität at Kiel
1993-1998	Chairman of the Working Group of Legal Experts to the Antarctic Treaty Parties Meetings
1993-	Director of the Max Planck Institute for Comparative Public Law and International Law, Heidelberg, Professor at Heidelberg University
1994-1997	Chairman of the board of the United Nations German Association
1996-2002	Vice-President of the German Research Foundation, 1996- Judge at the International Tribunal for the Law of the Sea, re-elected in 1999 and 2008
1996-1999	Vice-President of the International Tribunal for the Law of the Sea
1999-	Doctor honoris causa of the Russian Academy of Sciences, Moscow
1999-	Doctor honoris causa of the "Shihutug" Law College", Ulan Bator/Mongolia
2002-2006	Vice-President of the Max Planck Society for the Advancement of Sciences
2005-	President of the German Society for International Law
2005-2008	President of the International Tribunal for the Law of the Sea

Publications (selection)

I. Books (author/editor)

Economic and Legal Aspects of International Environmental Agreements – The case of enforcing and stabilising an international CO_2 agreement, Kieler Arbeitspapiere (Kiel Working Papers), no. 711 (with J. Heister, E. Mohr, W. Plesmann, F. Stähler and T. Stoll), Kiel 1995

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II. Articles

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Die Individualisierung des internationalen Umweltrechts (The Individualization of International Environmental Law), in: Mensch und Umwelt (Mankind and the Environment). Laudationes und Vorträge gehalten aus Anlaß der Verabschiedung von Frau Ursula Far-Hollender (Laudatios and speeches hold on the occasion of Ms. Ursula Far-Hollender's retirement) (ed. E. Ehlers), Colloquium Geographicum, vol. 25, 2001, 26-35

Völkerrechtliche Beurteilung des Handels mit Emissionsrechten (Trade with Emission Rights from the Perspective of International Law), in: Klimaschutz durch Emissionshandel (Climate Protection by Emission Trade), Achte Osnabrücker Gespräche zum deutschen und europäischen Umweltrecht am 26./27. April 2001 (8th Osnabrück Talks on German and European Environmental Law on 26/27 April 2001) (ed. H.-W. Rengeling), Schriften zum deutschen und europäischen Umweltrecht, vol. 26, Carl-Heymanns Verlag KG, München, 2001, 189-203

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