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Report on the conference
“Geoengineering the Climate:
An Issue for Peace and Security Studies?”

University of Hamburg
Research Group Climate Change and Security

Working Paper
CLISEC-20

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There is a growing interest in the intentional manipulation and control of the climate system – known as "geoengineering" or "climate engineering". Related concepts are moving into the mainstream debate. This is in part due to some scientists and political authorities considering geoengineering as a "Plan B" option for a "global last resort" to counter catastrophic climate change. In addition to the growing research in climate engineering options the ethical and political discourse is picking up speed as well.

While research on climate engineering is attracting resources and interest, there is a lack of understanding of the potential consequences, in particular for peace and security. Actions that intentionally modify global temperature can induce difficult issues concerning national, international and regional security that could lead to new security dilemmas. As far as human and environmental securities are concerned, the risks of geoengineering could provoke local responses of people who are concerned about the potential impacts and risks. This link between the global and local levels may have profound geostrategic implications and could provoke complex conflict constellations across geographic scales.

An international workshop at the University of Hamburg, Germany, on November 10 and 11, 2011 addressed these issues by aiming to improve the understanding of the potential impacts of climate engineering. The event was organized in cooperation by the Research Group Climate Change and Security (*CLISEC*), the Institute for Peace Research and Security Policy (*IFSH*) at the University of Hamburg, the Carl Friedrich von Weizsäcker Centre for Science and Peace Research (*ZNF*), and adelphi Research, Berlin. Detailed information about this workshop are available at the conference website of *CLISEC* *(http://clisec.zmaw.de/Geoengineering-the-Climate-An-Issue-for-Peace-and.1877.0.html)*.

The conference provided a first mapping of the problem landscape and identified knowledge gaps and emerging research questions, which was the subject of the public sessions on the first day. One particular focus of the workshop was the possible implications of geoengineering for peace and security affairs, based on a systematic analysis of geoengineering options and a taxonomy of possible consequences. These issues were addressed in three sessions on the second day of the event. The potential risks were discussed in an open discourse that involved researchers from various interdisciplinary backgrounds.

Opening Panel: Introduction to climate engineering

In the opening keynote, **Peter Liss** of the University of East Anglia (United Kingdom) gave an overview of the different possibilities for climate engineering that can be generally divided into two fundamental categories. Measures to remove carbon dioxide from the atmosphere (Carbon Dioxide Removal, CDR) attempt to regulate the earth's surface temperature by manipulating the amount of greenhouse gases in the atmosphere. This can be done e.g. by fertilizing the oceans to enhance the uptake of carbon dioxide by algae, massive afforestation or the removal of carbon dioxide from the atmosphere with scrubbers to store it under ground using "artificial trees" etc. In contrast, other measures aim to limit the amount of energy hitting the earth's surface to start with (Solar Radiation Management, SRM), e.g. by the injection of aerosols into the atmosphere, the whitening of the earth's surface and of clouds, or the positioning of large mirrors in space to block part of the incoming solar radiation. The overarching goal of all measures of climate engineering is to attempt to offset climate change and the potentially catastrophic consequences of changing environmental conditions for peace and security. If successful, climate engineering could therefore possibly even become an instrument of conflict prevention.

Nobel Laureate **Paul Crutzen** from the Max-Planck-Institute for Chemistry in Mainz, Germany, added some facets to the discussion. Crutzen has worked extensively on the human intervention with the environment, coining the term "anthropocene" as the geological era, in which humankind appears as fundamental factor in influencing the appearance of our planet. Here he commented on the fea-sibi-lity of cer-tain measures to intentionally manipulate climatic conditions.

Gernot Klepper from the Kiel Institute for the World Economy, Germany, provided some insights about a recently completed study on geoengineering that had been conducted by his research institute for the German Federal Ministry for Education and Research. The results indicate that geoengineering cannot replace mitigation and adaptation measures when it comes to dealing with climate change. Regardless of the possibilities hidden in geoengineering, the reduction of carbon dioxide emissions remains of utmost importance.

Public Roundtable: Perspectives on Geoengineering

The speakers of the introductory session all were very cautions with regard to geoengineering. This is due to the enormous complexity of the subject. Sound decisions about geoengineering are only possible if all the facets involved are adequately considered. The second session of the opening day, the Public Roundtable, was designed to shed light on the different aspects of geoengineering (GE) such as historical, economic, ethical, and governance factors of geoengineering. The panel was open to scientific public.

The first speaker, **Jim Fleming** from the Colby College, Maine/USA argued that historical experiences are an important factor for interdisciplinary communication, innovation and citizen involvement. He quoted John von Neumann, having said in 1955: “After global climate control becomes possible, perhaps all our present involvements will seem simple. We should not deceive ourselves: once such possibilities become actual, they will be exploited”. Scientists such as Nobel Laureate I. Langmuir proposed dry ice to induce precipitation. In the 1950s and 1960s, weather modification projects were conducted and financed by the US-military, which applied cloud seeding or nuclear explosions to study and control local weather conditions. The early days of computer development were also justified by weather prediction modeling. The Monsoonal cloud seeding (“Operation Popeye”) during the Vietnam War led to the UN 1978 ENMOD-Convention and both superpowers stopped to invest in weather control research and development. Fleming concluded by promoting further research in the historical, legal, and social implications of GE to integrate the international, interdisciplinary and inter-generational issues and perspectives of this subject.

The second presentation by **Timo Goeschl** from the Marsillius College of the University of Heidelberg dealt with the economic perspectives of GE. Costs of different measures are difficult to compare. Indirect costs and risk premiums are orders of magnitude higher than actual direct costs. Cheap CDR technologies ($8 per ton of CO_2 for ocean fertilization) are as slow as mitigation but have limited potentials and considerable uncertainties. The not yet demonstrated SRM-technologies might be quick fixes and direct costs are conceivably low (€ 0.1-1 per ton of CO_2 equivalent), but indirect costs and risk premiums are also orders of magnitude higher. He concluded that climate engineering is still poorly understood and that early research in the field is of utmost importance. Whether CDR or SRM technologies are globally and economically meaningful is still an open question.

The next speaker, **Jason Blackstock**, from the Centre of International Governance Innovation in Waterloo, Canada, focused on GE and governance. He emphasized from the beginning that there are many unanswered questions: What ought we to do with GE? Furthermore, politics is not necessarily based on rational decision making. Given the critical juncture of the current debate, one also needs to include perception, public reaction and policy positions when dealing with the policy implications of GE. He stressed that climate change is not the only central problem but also other interrelated issues such as biodiversity, economics, innovation, population growth, global health, development, agriculture, renewable energy, and education. All these need to be included in societal considerations. Many projects, interest groups, and organizations with different views are included in the debate about GE, making the debate highly complex. GE technologies are today mostly imaginaries and will evolve significantly with further research in the foreseeable future.

The last speaker, **Konrad Ott**, from the Institute of Botany and Landscape Ecology, University of Greifswald, addressed the ethical dilemmas involved in the combating of climate change, in particular with SRM. Stratospheric Sulfate injection is quick, cheap and risky and constitutes a complex set of options for future actions. He discussed three major arguments. First, sulfate-based SRM can influence the “Political Economy of green interests” by blocking Climate Convention negotiations or discourage mitigation strategies. Large field tests and sulfate-based deployment may entail a slippery slope of serious and not yet completely identified risks that might bring future generations into a dilemma situation (risk transfer argument). The third argument is that SRM will veil the day- and night-sky, which could be considered a loss for the human livelihood. He concluded that “if there might be a slippery slope toward dilemmatic worst case and if there are better alternatives such as strong mitigation, we should not take steps on the SRM route.” However, modeling of the consequences SRM certainly remains permissible.

Session 1: Geoengineering: a taxonomy

After the general overview of the many aspects involved with geoengineering, the sessions on the second day provided in-depth insights into key issues related to climate engineering (CE). Session 1 focused on various technical approaches to CE, which according to the 2009 Royal Society report is the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change. In this session, several CE technologies were addressed in greater detail. While each of the technologies has specific risks, costs and efficiency, the consequences may be similar, in particular within the groups of CDR and SRM technologies.

Ulrike Niemeier of the Max-Planck-Institute for Meteorology introduced aerosol dispersion techniques that occur naturally in volcanic eruptions. These eruptions transport aerosols into the stratosphere and increase the planetary albedo, inducing a cooling effect until removal processes take effect. Various physical phenomena are important, including rainout, nucleation and particle growth. Based on simulations in the project "Implications and Risks of Novel Options to Limit Climate Change" (IMPLICC) and the "Geoengineering Model Intercomparison Project" (GeoMIP), she presented results for sulfate emissions to maintain the climatic conditions of the year 2020 in the long run. Emission strategies depend on the lifetimes of different sulfur inputs, particle types and sizes, emission heights, and the distribution of sulfate concentration. Adequate design may allow more selective geoengineering approaches. Aerosol inputs in the order of the Pinatubo emissions are considered for the time period after 2050.

The presentation also discussed possible side effects of deliberate aerosol injections including impacts on sky whitening, surface cooling and vegetation, as well as impacts on the ozone layer, the ocean circulation and marine biogeochemistry. Future research could focus on impacts and emission strategies, comparing different models and the simulation of various aspects of the earth system (land, ocean, and biogeochemistry).

Andreas Oschlies (IFM-GEOMAR, Kiel) described CDR techniques based on ocean fertilization, compensating for lack of micro- and macro nutrients. To fix one ton of carbon requires about 140 kg of NH_4 macronutrients. The sequestration potential of all methods is limited to about 1 Gt C/yr over a period of a century. Inputs from land and artificial upwelling in the ocean are possible. These include ocean nourishment, which requires large amounts of energy and mass and is most useful in nitrogen-limited areas (low latitudes). Artificial upwelling has only a small direct CO_2 effect but has the potential for direct cooling of the sea surface. Iron fertilization needs 1000 – 100 000 times less mass than is required for macronutrient fertilization, which requires vast amounts of energy and mass. Possible adverse effects of such fertilization are enhanced oxygen consumption (with high vulnerability in low-latitude regions) and N_2O production. Warming and acidification will impact marine ecosystems as a result of CO_2 emissions. The extent of suboxic conditions and acidification in near-surface waters may be "less severe" in a fertilized ocean. However, artificial upwelling adversely affects the earth's radiation balance while iron fertilization messes up ecosystems. Whenever ocean upwelling is stopped, mean temperatures soon exceed those of a world without previous climate engineering. When assessing the effectiveness of such CE measures, the effects have to be compared to a world with CO_2 emissions but without ocean fertilization. In conclusion it is obvious that humankind cannot afford to do nothing. Difficult choices have to be made as there will be winners and losers.

Michael Köhl from the Center for Wood Science at the University of Hamburg gave an assessment of afforestation and reforestation, including sustainable forest management strategies. From a comparison of daily deforestation and afforestation rates he concludes that global deforestation of 13 million ha/yr and afforestation of 7.8 million ha/yr between 2000 and 2010 have led to a net reduction of forests. Therefore, the potential for future reforestation is huge. For instance, foresting the Australian outback and Saharan Desert could contribute to solving the problem of climate change. Although afforestation is carbon sequestration, it also affects the solar radiation balance because of the low albedo of forest cover. Köhl compared the sequestration potentials in different countries and presented some results of a life cycle assessment of wood products, in which recycling leads to reduced energy consumption. Future research should focus on the rehabilitation of degraded sites by forest plantations; mitigation strategies in forest management and timber utilization (energy, bio-refinery, material use).

Daniel Vallentin from the Wuppertal Institute for Climate, Environment and Energy critically considered the potentials and barriers of carbon capture and sequestration (CCS). While CCS is globally considered a highly relevant technology for climate protection, its CO_2 mitigation potential depends on technical, economic, geographic and temporal factors. In principle, CCS may achieve a net GHG reduction of 67% to 87% and is expected to capture more than 10 Gt of CO_2 in 2050. However, integrated, large-scale CCS projects are unlikely to be available before 2025. Within the next 10 years, 100 projects would be needed, and until 2050, 3400 CCS projects would have to be materialized. But implementation and deployment of CCS are highly complex, not only from a technical but also from economic, logistic, political and societal perspectives. Non-OECD countries, especially China and India, are key actors when it comes to long-term CCS deployment.

Barriers for CCS are CO_2 mitigation costs, limited geographic proximity of potential CO_2 sources and storages and the uncertain regulatory framework conditions. The EU Directive on CO_2 Storage requires member states to adopt national regulatory frameworks by June 2011. The example of Germany shows that the lack of a regulatory framework and societal acceptance may significantly hamper CCS deployment. The first draft CCS law was rejected by the German parliament in June 2009, and the Federal Council rejected new CCS draft law in September 2011. The lack of a regulatory framework therefore inhibits CCS investments such as for the Jänschwalde demonstration plant by Vattenfall.

Jens Hartmann from KlimaCampus Hamburg presented key research results on enhanced weathering techniques, the development of management concepts for enhanced weathering and the consequences of global scale measures which “consume” CO_2 and deliver dissolved inorganic carbon to the ocean (carbonate, olivine, albite). The natural land-ocean fluxes within the global carbon and silica cycle need to be considered. Due to land-ocean matter fluxes, an action on land has consequences for aquatic systems as well. One practiced approach is “liming”, the application of calcium- and magnesium-rich materials to soil. To avoid carbonate liming to become a source of CO_2, carbonate fertilization can be replaced by Ca-Mg silicates. When doing so, it is important to consider the role of soil types (histosols via peatlands; gleysols indicating wetlands) and how these are affected by shielding effects against natural chemical weathering of rocks.

Hartmann further developed scenarios to assess the potential of enhanced weathering with 1 and 5 Gt of carbon sequestered, identifying the respective effects on temperature, acidity (pH) and CO_2 concentration. One side effect is the increase of ocean water pH via the fluvial carbon/alkalinity, where the local pH increase in coastal zones is particularly significant. Land-ocean silica fluxes would increase from recent levels and impact the biological carbon pump in coastal zones; a large proportion is trapped in regional seas. In the scenarios, two cases are simulated with high (low) Si-land-ocean transport rates and a strong (weak) biological carbon pump. The applicability of ocean based enhanced weathering is unknown and needs more research. Not included in the assessment of the enhanced weathering potential are the effect of increased pH on soil carbon (e.g. respiration), the phosphorus-release by rock weathering as additional nutrient supply, and the increased biomass/crop yield of rice/wheat due to nutrient silica. There are estimates of increases of up to +25% in dry biomass of rice, an increased water use efficiency and resistance to biotic stress, as well as increased resilience against diseases and parasites.

Session 2: Geoengineering – Peace and Security

In contrast to the technical aspects of geoengineering, possible consequences for local, national and international peace and security have so far received rather little attention among the various issues related to geoengineering. Conference session 2 was designed to explore this topic by highlighting different angles from which to look at geoengineering from the perspective of peace and security.

The first presentation was a broad overview over the potential benefits and costs of geoengineering by **Alan Robock** from Rutgers University, USA. He distinguished 25 negative and 9 positive consequences of geoengineering. The prime justification for geoengineering is that it can prevent climate change. If it did this, it might indeed prevent future conflict and other negative consequences of climate change for peace and conflict. However, this potential benefit is very likely to be outbalanced by negative effects of geoengineering resulting from differences in its consequences for particular regions and groups of people. Such differences likely give rise to contention and conflict. Furthermore, geoengineering might be misused for military purposes. There are too many examples of recent history that new technologies were used by the military, even if they were introduced with only civilian intention, to ignore the potential military use of geoengineering.

Jürgen Scheffran from KlimaCampus of the University of Hamburg picked up on the issue of unequal distribution of the effects of geoengineering. If implemented, geoengineering would sharpen a number of fundamental problems of climate change which are potential sources of conflict: Who is losing, who is benefitting? Whose power is decreasing, whose is increasing? Who has created the problem in the first place? Geoengineering adds another layer of complexity to these problems by allowing intentional human manipulation of the extent of climate change. Conflict becomes more likely as a consequence.

Conflict can come about on many levels, because geoengineering will have multiple effects that can reach from the local to the global level. Some are intended – particular the cooling of the planet – but some are unintentional. The latter may only become noticeable after some time, making it difficult to establish their links to geoengineering.

Jürgen Scheffran identified a number of scenarios how geoengineering might trigger conflict between states. One might be that geoengineering triggers the deterioration of the living conditions in one country but not in others. A second might be the creation of an unintentional effect such as a large weather event, which would be difficult to causally relate to geoengineering. Finally, he also saw the potential of military use of geoengineering. In preparing for geoengineering, states may get into something like an arms race, connected through the climate system. While he favored more research on the consequences of geoengineering, more attention should be on the improvement of anticipatory and adaptive policies and the improvement of governance structures to deal with climate change.

Achim Maas (adelphi Berlin) asked whether geoengineering "makes us free" in the sense of removing or at least lessening the threat to fundamental freedoms, which he identified as freedom from fear, freedom from want and freedom to live in dignity based on the report by former UN Secretary-General Kofi Annan "In Larger Freedom", which covers most dimensions of security discussed in the context of geoengineering. With respect to freedom from want, the likelihood to have an acceptable level of provision of goods and services, he was agnostic: Geoengineering might in principle prevent some of the negative effects of climate change. However, there was a danger that it does not and it may even have additional unintended side effects. Thus, the uncertainty about the effects of geoengineering on livelihoods makes climate mitigation a much more attractive strategy.

With respect to freedom from fear, the speaker focused on the link between climate change and conflict. He reiterated the concerns of earlier speakers about unequal costs and benefits among states and groups, which might lead to conflict.

Finally, Maas addressed the question of "a life in dignity", in which he introduced problems geoengineering might create for democracy, the rule of law, and societal institutions. Geoengineering might necessitate various restrictions of fundamental freedoms if it becomes a technical fix necessary to keep global temperature at a certain level, particularly when it needs to be enforced against popular opposition.

There already exists a treaty which prohibits the modification of the environment for non-peaceful purposes, the U.N. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) of 1977, which has been ratified by 85 states. As **Götz Neuneck** of the

Institute for Peace Research and Security Policy Hamburg showed, the ENMOD treaty was negotiated at the height of the Cold War, because the Vietnam war had demonstrated the dangers of destroying the environment through wars. The ENMOD Convention prohibits the “military or any other hostile use of environmental modification techniques“, but allows their peaceful use. Geoengineering does not neatly fit into these categories. Geoengineering may have harmful consequences for some states or regions, and therefore be considered hostile by them, even though its intentions were solely peaceful. The ENMOD convention can therefore be not directly applied to geoengineering. However, it points to the importance of preventive measures, developed in the framework of preventive arms control. It would be important to set such norms and standards, to establish criteria for instance for crisis stability and confidence building, and to build institutions for the monitoring and verification of lawful behavior and for the exchange of relevant information.

Henning Hetzer of the Bundeswehr Transformation Center presented three scenarios for geoengineering coming about in the future. These were developed within a larger effort to study potential environment-related threats in the year 2040 with the help of scenario techniques. The first scenario “UN Climate Security” is a truly multilateral effort, in which geoengineering occurs with widespread international cooperation and shared costs. Scenario two “Geoengineering by Climate Solutions Inc” is less cooperative but driven by states with the most advanced technology in relevant fields. In the final scenario, the geoengineering “Ghost escaped the bottle”. Geoengineering technology becomes available to many actors, including large companies, there is little control over who is doing what. Geoengineering occurs in a trial and error mode with many unintended consequences and thus becomes a source for widespread international conflict.

Session 3: Geoengineering – A Global Governance Issue?

Conference session 3 finally focused on possible governance arrangements for geoengineering. Particular risk management is necessary not only for deployment but already for research given the possible social, political, economic and environmental consequences.

In this context, a key issue is the question of public perception and framing. In several countries such as the UK and the USA, public awareness of geoengineering is growing. However, in most countries, including Germany, there is hardly any public knowledge or awareness. There are few analyses of public perceptions of geoengineering available, as **Ortwin Renn** from the University of Stuttgart pointed out. Also, few non-governmental organizations have addressed geoengineering but have generally rejected it.

Judging from research on other technologies, such as carbon capture and storage (CCS), communication early on and throughout the entire decision-making process is crucial for the acceptance of decisions. In particular, Professor Renn highlighted:

- Different framings and perspectives on geoengineering should be acknowledged, but also climate change at large.

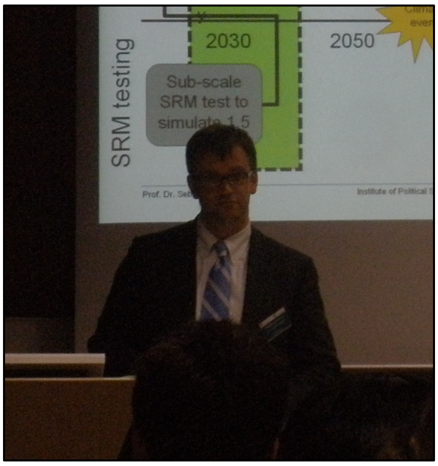
- Stakeholder involvement needs to start even before research commences, with broad dissemination of information to allow for an unemotional, sober debate of risks, benefits and impacts of equity.
- Governance needs to be inclusive by integrating a broad range of stakeholders.
- Credible regulation and excellent performance without incidents is necessary to sustain trust in decisions on research and potential deployment.

The question of regulation was further addressed and elaborated by **Alexander Proelß** from the University of Trier. Given the transboundary nature of virtually all geoengineering technologies, regulation needs to be international if not global. However, no treaty exists to deal with geoengineering in a comprehensive manner. Only some partial aspects are covered under existing international law. For example:

- The ENMOD Convention outlaws environmental modification for hostile purposes, yet clearly allows the use for peaceful purposes, whereby "peaceful" is not defined in the convention.
- The UN Framework Convention on Climate Change (UNFCCC) defines the concept of "sink", which may cover carbon dioxide removal technologies, but is not applicable to radiation management.
- The UN Convention on the Law of the Sea and the London Protocol may be applicable to ocean fertilization but not to any other method.

From the perspective of customary international law significant transboundary harm needs to be prohibited and states have to take due regard to territorial integrity of other states when researching or deploying geoengineering – such as informing and consulting potentially affected countries. Additionally, environmental impact assessments need to be carried out in advance. However, based on the existing treaty law as well as customary international law, it can be concluded that unilateral action – whether significant field tests or actual deployment – would be unlawful.

Beyond the legal realm, **Sebastian Harnisch** from the University Heidelberg generally challenged the notion of unilateral geoengineering, which was also discussed in session 2, for a number of reasons. Aside from the question whether a single country could really achieve creating a locally favorable climate, the mere risk of unintended side effects to the deploying country as well to other countries may create domestic and international opposition.



For instance, if solar radiation measures by the USA would result – as some researchers estimated during the conference – in significantly reduced rice production for example in China, the affected countries would not wait until this has occurred: Even "quick" options like solar radiation management would take years to prepare and implement, more then enough time to apply a variety of instruments to prevent such action. This makes unilateral deployment highly unlikely.

Professor Harnisch further criticized the polarization of the geoengineering debate: A more nuanced approach would be to consider a policy mix, including mitigation, adaptation and geoengineering, as it is neither likely nor prudent to focus purely on one of these areas. In particular, he outlined the concept of "window of responsibility", i.e. the remaining time frame to act: Especially the testing of solar radiation management measures needs to be conducted early. If it is postponed until its application becomes necessary due to failed mitigation, there may no longer be time for testing, requiring deployment with uncertain consequences. This window may close within the next few decades. A key dispute within the discussion was what and how a test or research may look like, and if it can be limited to computer modeling or whether it requires real world experiments.

Given the dangers involved in possible field tests, the precautionary principle may indeed prohibit research in this area, as environmental harm could not be ruled out – yet this would also prevent collecting the scientific evidence to determine the suitability of geoengineering. The principle needs to be further developed and it can serve as a starting point for balancing risks and benefits. Such balancing would also require taking into account the risks of un- or insufficiently mitigated climate change.

Against the background of these issues, **Hartmut Graßl** from the Max-Planck-Institute for Meteorology strengthened the need to focus on minimizing impacts on the climate using renewable energies, reforestation, changed agricultural practices and a strong reduction of deforestation. Geoengineering is not only risky but also difficult to govern. In view of the many major unresolved questions with respect to geoengineering, all countries having adopted the precautionary principle for environmental policy making (like the European Union) need to currently refrain from adopting any geoengineering measures.

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