# CE assessment metrics – Comparative, Integrative, Comprehensive

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# Climate Engineering Conference 2017

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## Parallel Session 3.4: CE assessment metrics – Comparative, Integrative, Comprehensive

Thursday, 09:00 - 10:30
01 I Großer Saal
To enable fair, comprehensive and comparative decision-making on Climate Engineering, we need to foster a multidisciplinary and integrative selection process for assessment metrics. In this session we want to learn to what extent established climate-change assessment metrics are applicable for Climate Engineering assessment and what kind of extensions are needed.

This session aims to foster discussions about approaches to comparatively assess different climate engineering (CE) ideas, both among each other and in the context of mitigation. We encourage contributions that address the following questions:

- How can effects of SRM and CDR methods be compared with each other and with classical mitigation approaches?
- Which indicators are useful for a comprehensive assessment of SRM and CDR methods?
- To what extent are structurally new metrics compared to global warming mitigation assessment metrics needed for CE?
- How can uncertainty be treated explicitly in metrics design?
- What new challenges arise for the assessment process when different CE methods are combined?
- How to select indicators for a fair and comprehensive comparison of different CE methods?
- How to ensure societal relevance of the assessment criteria?
- How should stakeholders co-shape the design of metrics?

The session will start with an introductory talk by Elnaz Roshan and Nadine Mengis and continue with talks by Peter Irvine, Yann Chavaillaz, Mohammad Khabbazan and Nils Matzner. The session is convened by Nadine Mengis, Elnaz Roshan, Sebastian Sonntag, Andreas Oschlies, Wilfried Rickels and Hermann Held.
Elnaz Roshan, Sebastian Sonntag and Nadine Mengis will also be giving a poster presentation during the poster session on Wednesday.

Note: Hermann Held and Wilfried Rickels, while playing a lead role in co-convening this session, are unfortunately not able to attend in person.

## Talks:

- Peter Irvine
  - Solar geoengineering could offset some of the effects of climate change on key drivers of climate risks but it would not do so perfectly and could exacerbate some of the effects of climate change in some regions. Using the GFDL's high-resolution tropical-cyclone permitting model HiFLOR and for the Geoengineering Model Intercomparison Project ensemble we quantify whether solar geoengineering reduces or increases the magnitude of climate trends at the gridcell level. We focus on 5 key variables: temperature, maximum annual daily max temperature, precipitation, precipitation minus evaporation, and 5-day maximum precipitation. We find that if solar geoengineering is deployed to offset all global mean temperature change from an increase in $CO_2$ concentrations (100%Geo) the majority of regions see a reduction in hydrological changes but a significant fraction of the land area see greater hydrological change. However, we show that for 50%Geo many fewer areas are made worse off for these hydrological variables. Furthermore, we find limited consistency between those regions made worse off in terms of precipitation and precipitation minus evaporation. These results suggest that most regions would benefit from a moderate deployment of solar geoengineering and highlights the importance of a detailed hydrological impacts assessment of solar geoengineering.

- Yann Chavaillaz
  - Stratospheric aerosol injection (SAI) is discussed as an option for counteracting anthropogenic global warming. But most rather consider it as a portfolio measure holding the potential to avoid an overshoot of mean temperatures, and minimizing our vulnerability to climate change. But climate extremes might pose a higher threat on our societies, ecosystems and infrastructures. Therefore, we investigate if the implementation of SAI can

efficiently mitigate extremes in daily temperature, precipitation and heat stress or if it only forces extremes to shift to new spatial or temporal regimes. We used simulations from the MPI-ESM-LR model based on the socio-economic assumptions of the RCP8.5 scenario, with an SAI scenario until 2100 targeting the radiative forcing of RCP4.5 values. These simulations are compared to the three existing members of both RCP4.5 and RCP8.5 scenarios. We show that, despite a significant decrease of the occurrence of current daily extremes due to SAI, the total number of extremes remains higher over the century than with RCP4.5 mitigation measures. The probability of their occurrence does also not evolve at a similar pace throughout the century. Overall, our results challenge the concept of implementing SAI as a 'shaving-the-cap' measure to avoid dangerous climate change.

- Mohammad Khabbazan
  - While solar radiation management (SRM) offers an option to ameliorate anthropogenic temperature rise, it is not simultaneously expected to perfectly compensate for anthropogenic changes in further climate variables. Here, considering different regional weights in precipitation disparities, we ask to what extent a proponent of the 2°C-temperature target would apply SRM in conjunction with mitigation. We utilize cost-risk analysis in 'Giorgi'-regional-scale to evaluate the optimal mixture of SRM and mitigation under probabilistic information about climate sensitivity for global temperature-risk-only, regional precipitation-risk-only, and equally-weighted both-risks scenarios. We find that although SRM can almost perfectly substitute for mitigation in temperature-risk-only scenarios, it matters how Giorgi regions are weighed in regional precipitation-risk-only and both-risks scenarios. Giving the whole weight to one region, only six critical regions get welfare-loss under joint-mitigation-SRM portfolio with perfect substitution of SRM for mitigation in all cases except Amazonia and Central America. Considering all specific trade-off parameters from previous evaluation divided by the number of regions, SRM saves about 1/3 of welfare loss under joint-mitigation-SRM portfolio. Under equal weights, SRM can save 1/3 to 2/3 of welfare-loss. However, considering only critical regions' precipitation risks, SRM can save only about 1/10 to 1/5 of welfare loss in precipitation-risk-only and both-risks scenarios.

- Nils Matzner
  - Policy advisors and research institutions increasingly emphasize the "need to understand the possibilities, limitations, and potential side effects" of so-called climate interventions. Understanding the impacts of climate engineering (CE) depends to a large extent on choosing the right indicators and metrics for assessing CE simulations. Although it is clear that they often differ from conventional climate change research metrics due to changes in

prevailing correlations (e.g. the breakdown of a correlation between global mean temperature and other indicators with a solar CE deployment), only a few studies have attempted to identify the metrics required for a fair and comprehensive CE assessment. This study utilizes the available CE literature and aims to identify and map currently used indicators and metrics to highlight research gaps. Applying quantitative text analysis to a comprehensive corpus of scientific CE literature allows us to efficiently map scientific applications of metrics. Furthermore, we aim to track how the metrics have changed over time, and if there are predominant metrics that appear in certain types of studies. By pointing to research gaps our results will foster research on insufficiently studied metrics and help to select the most appropriate ones, which have both scientific and societal relevance.

## Poster presentations:

- Nadine Mengis
    - Climate engineering (CE) alters prevailing correlations between Earth system variables, hence an appropriate assessment of CE must include a reevaluation of the chosen assessment indicators. A fair comparison of CE methods presents an additional challenge, since they aim at manipulating different components of the Earth system.
      This study systematically identifies changes in correlation patterns introduced by three idealized Climate Engineering (CE) scenarios: Large-scale Afforestation (LAF), Ocean Alkalinity Enhancement (OAE) and Solar Radiation Management (SRM). Firstly, we investigate changes in prevailing correlations between Earths system variables of the single CE scenarios compared to two future emission scenarios, and the implications of such changes on chosen assessment indicators. Secondly, we evaluate a common correlation matrix and identify a set of 14 indicators for a comprehensive comparison of the three CE scenarios. The evaluation of the CE scenarios relative to a defined reference climate state shows, that each CE method can be found to show a good performance, depending on the given indicator. It is beyond the scope of this study to give a value judgement on which of these variables is of higher importance for society, but here we aim to provide the natural science knowledge to enable such a discussion.

- Sebastian Sonntag
    - We assess atmosphere-, ocean-, and land-based climate engineering (CE) measures with respect to their effects and unintended consequences consistently within one comprehensive model. We use the Max Planck Institute Earth System Model (MPI-ESM) with

prognostic carbon cycle to compare solar radiation management (SRM) by stratospheric sulfur injection with carbon dioxide removal methods: afforestation and ocean alkalinization. We show that the CE methods differ vastly in terms of their effects on different Earth system components. We find that mitigating feedbacks emerge: for example, as a response to SRM temperatures are reduced leading to a reduction of atmospheric CO2 due to enhanced land carbon uptake. We also identify challenges arising in a comparative assessment of CE methods: the quantitative results depend on details of the CE scenarios and on the underlying models, and an interpretation of relative efficiency depends on the choice of variables that are analyzed. Furthermore, we show that normalisations allow for a better comparability of different CE methods. For example, we find that despite different amounts of global surface cooling achieved, local amplification factors compared to the global mean temperature changes are generally similar in the CE scenarios, with the exception of Arctic amplification, which is strengthened in SRM.

- Elnaz Roshan
    - Following the Paris Agreement, the research question has been raised about the role of climate engineering in compliance with 1.5°C-temperature target. Comparing target-based decision frameworks for 1.5°C- and 2°C- temperature targets in both global- and 'Giorgi'-regional-scale analyses, here we ask for the optimal mix of SGE and mitigation while considering global and regional temperature and precipitation anomalies. Using a deterministic cost-effectiveness analysis (CEA) for climate sensitivity (CS) of 3°C, our simulations find no feasible solution to comply with 1.5°C-temperature target by only mitigation. By altering the target from 2°C to 1.5°C under CEA, SGE usage either does not change in the regional analysis or decreases in the global analysis. Applying cost-risk analysis (CRA) with probabilistic information on CS ranging between 1.01°C and 7.17°C, the cooling effect of SGE increases by 0.4°C for median CS of 3°C, when the temperature target is reduced. SGE can save approximately 2/3 to 3/4 of the welfare-loss in the mitigation-only portfolio in the regional setting of 1.5°C-temperature target analysis, respectively in precipitation-risk-only and both-risks scenarios. Moreover, regardless of the temperature target and decision framework, SGE usage is restricted by regionalizing the model.

**Convened by:**

Nadine Mengis (/person/nadine-mengis)
Concordia University

Canada

Dr. Nadine Mengis is a PostDoc in the department of Geography at the Concordia University, Montreal, Canada. While she worked on single Climate Engineering scenarios, and in particular the Climate Engineering assessment challenge during her PhD, her main research interest is uncertainty assessment within Earth system models. At her new position she is hence working on assessing the uncertainty within carbon budget estimates for ambitious climate target such as the 1.5 °C temperature target.

**Sebastian Sonntag** (/person/sebastian-sonntag-0)
Max Planck Institute for Meteorology
Germany

**Earth system effects, side-effects, and carbon cycle feedbacks of reforestation and ocean alkalinization**

For the assessment of CDR methods side-effects and carbon cycle feedbacks play an important role as they may alter the methods' mitigation potential. Here we comparatively assess a reforestation scenario and an ocean alkalinization scenario as examples for land- and ocean-based CDR methods with respect to their effects in the coupled Earth system. We perform model experiments using the Max Planck Institute Earth System Model (MPI-ESM) with prognostic carbon cycle, forced by fossil-fuel CO2 emissions according to the high-emission scenario RCP8.5. The two CDR scenarios are very different regarding their potential to reduce global warming. Yet, normalized to the same reduction in global warming, we find that more CDR is needed via reforestation than via ocean alkalinization. This lower cooling efficiency of reforestation is due to the biogeophysical effects of land cover change counteracting the cooling CDR signal and to the climate sensitivity possibly being state-dependent. Furthermore, we find a lower efficiency to remove carbon from the atmosphere for reforestation compared to ocean alkalinization, since the ocean releases more carbon in response to reforestation than the land in response to alkalinization. Overall our findings illustrate how side-effects and feedbacks in the Earth system alter the mitigation potential of CDR methods.

Sebastian Sonntag is a scientist at the Max Planck Institute for Meteorology, Hamburg, Germany. He has a background in physics, he holds a PhD in geoscience, and his research involves understanding interactions and feedbacks in the Earth system using models of different complexity. He is working on both SRM as well as land- and ocean-based CDR methods with a focus on the climate and carbon cycle response as simulated with an Earth system model.

## Elnaz Roshan (/person/elnaz-roshan)

Universität Hamburg, International Max Planck Research School on Earth System Modeling
Germany

Elnaz Roshan is a doctoral candidate in economics at University of Hamburg and International

Max Planck Research School on Earth System Modeling. Her research focuses on integrated cost-risk trade-off of solar radiation management (SRM) and mitigation when regional climate disparities and probabilistic information on climate sensitivity are taken into account. She is interested in decision making under uncertainty and studying the most prominent pros and cons of SRM in the concept of cost and risk.

**Andreas Oschlies** (/person/andreas-oschlies-0)
GEOMAR Kiel
Germany
**Wilfried Rickels** (/person/wilfried-rickels)
Institut für Weltwirtschaft Kiel
Germany
**Hermann Held** (/person/hermann-held)
Universität Hamburg
Germany

Hermann Held is chair for Sustainability & Global Change at Universität Hamburg. His research focusses on decision-making under heterogeneous uncertainty within climate economics. For the special case of solar radiation management he develops schemes for risk-cost-risk intercomparison within the value system spanned by global mean temperature targets. He has served as Lead Author within IPCC-AR5-WGIII and is currently a member of the Scientific Steering Committee of Hamburg’s Cluster of Excellence on climate CliSAP.

**Speakers:**

**Peter Irvine** (/person/peter-irvine)
Harvard School of Engineering and Applied Sciences

USA

Pete Irvine is a Postdoctoral Research Fellow at the Harvard School of Engineering and Applied Sciences. Pete conducts research on the climate and broader impacts of solar geoengineering and works to put those findings into perspective with the risks posed by climate change. He works with researchers from a range of disciplines to explore the implications of solar geoengineering as a potential means of reducing the risks of climate change. Current work includes evaluating the potential effectiveness of different solar geoengineering proposals at reducing sea-level rise and on contextualizing the effects of solar geoengineering against the effects of climate change.

**Yann Chavaillaz** (/person/yann-chavaillaz)

Ouranos Inc and Concordia University
Canada

Yann Chavaillaz is currently a Postdoctoral Fellow at Ouranos Inc and Concordia University in Montreal, Canada. His main motivation in research is to develop new ways to communicate about climate change to be relevant for general audience and to deliver useful results for end-users. He currently focuses on creating a catalogue of changes in the characteristics of extreme events in the province of Quebec due to abrupt climate changes occurring in the climate system and link them with cumulative carbon emissions. He also involved in several projects regarding consequences of climate engineering implementation, working capacity under extreme heat, floods and restoration of mining rejections.

**Mohammad Khabbazan** (/person/mohammad-khabbazan)
Universität Hamburg
Germany

Mohammad Khabbazan is a Postdoctoral Researcher at Universität Hamburg, in his functional position as a member of the Integrated Modeling Activities team within the Cluster of Excellence "CliSAP". Having a background in theoretical economics, his current research focuses on interdisciplinary study of climate change, namely risk assessment, integrated assessment modeling (IAM), decision-making under uncertainty, and validation of climate emulators. Mohammad has applied IAMs to investigate the optimum use of joint-geoengineering-mitigation when global and regional climatic risks are taken into account. He is also working on the role of SRM and BECCS for ambitious climate targets in the case of delayed climate policy.

**Nils Matzner** (/person/nils-matzner)
Alpen-Adria-Universität Klagenfurt

Austria

Nils Matzner is a doctoral candidate in Science and Technology Studies (STS) at Alpen-Adria-Universität Klagenfurt (AAU, Austria). His research focuses on the constitution of an epistemic community of climate engineering research, taking into account the communities' political influence. He is also interested in sociology of science, research policy, and international relations. He gained a master's degree in Political Science from RWTH Aachen University. Further, he is web editor of www.climate-engineering.eu (http://www.climate-engineering.eu).

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