Max-Planck-Institut
für Meteorologie

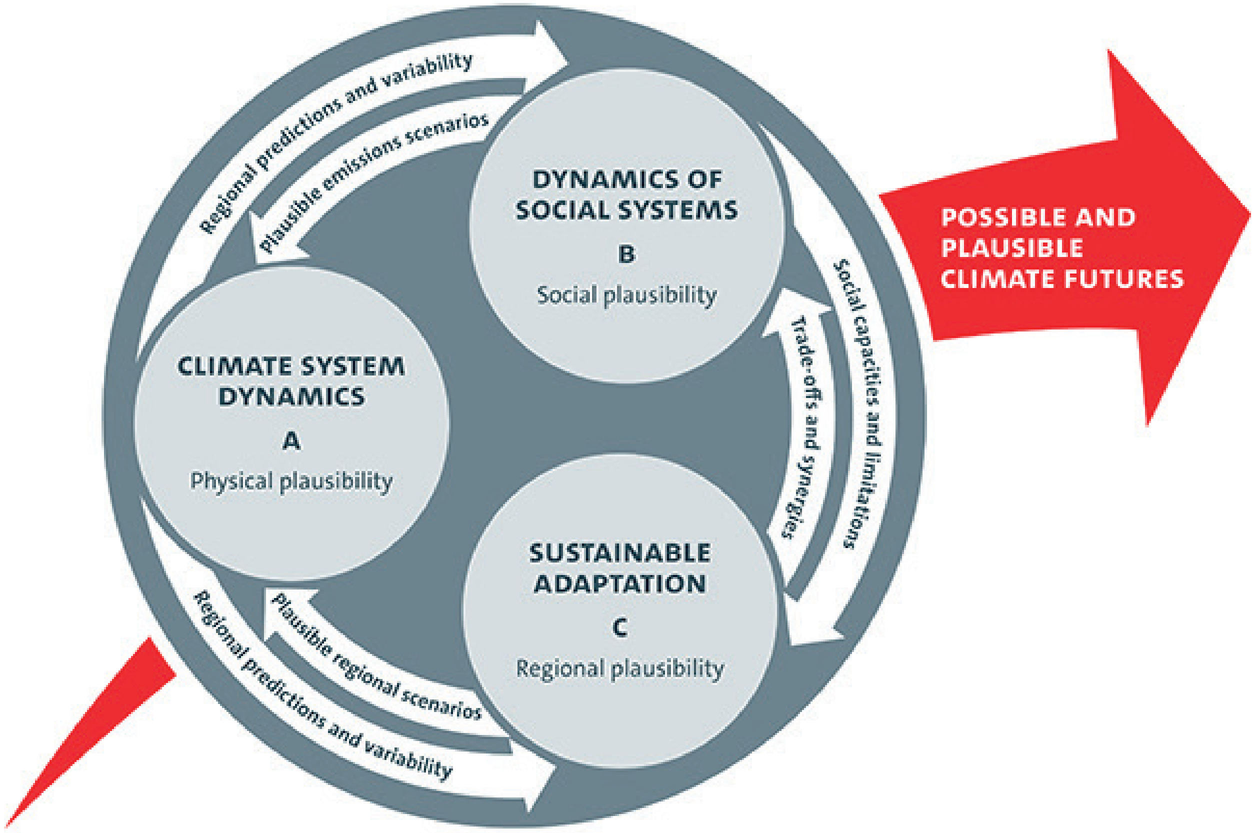
CLICCS – A cluster of excellence for climate research – Which climate futures are possible and which are plausible?

The Paris climate agreement from December 2015 recognized that the world is warming and that humans are primarily responsible for it. This provided a powerful impetus not only for climate policy but also for climate research. To address the resulting new challenges, the Cluster of Excellence "Climate, Climatic Change, and Society" (CLICCS) at Universität Hamburg established a long-term program in 2019, spanning the range from basic research on climate dynamics and climate-related social dynamics to the transdisciplinary exploration of human–environment interactions.

The Max Planck Institute for Meteorology (MPI-M) is the most important non-university partner alongside the Helmholtz-Zentrum Geesthacht, Centre for Materials and Coastal Research (HZG) and the German Climate Computing Center (DKRZ).

Objectives and research in CLICCS

CLICCS will explore climate change in unparalleled breadth. CLICCS will investigate how the climate changes and how society changes with it, thereby feeding back on climate. Understanding these changes, including how societies adapt, will enable us to assess with far greater confidence than before the range of imaginable climate futures. In taking on this challenge, CLICCS is guided by the overarching question: "Which climate futures are possible and which are plausible?"



CLICCS themes and exchange of gained knowledge between them. (Fig.: Universität Hamburg)

The aim is to develop assessments of this overarching question by understanding climate change and social dynamics in relation to each other. Another aim is to identify the social prerequisites for the deep decarbonization, i.e. society´s turning away from the use of carbon-based energy sources, required to reach the Paris climate targets. CLICCS wants to construct self-consistent scenarios of future climate that incorporate the latest process-based knowledge of natural climate variability and social dynamics, and to construct case studies of sustainable adaptation scenarios. The Cluster of Excellence will account for how the irreducible (aleatoric) uncertainty arising from internal climate variability, including extreme events, affects climate–socio-economic interactions and decision-making processes. A central synthesis project will summarize the research results on possible and plausible climate futures in an annual "Hamburg Climate Futures Outlook". The results of other institutions will also be used for this purpose. These results will contribute to the assessment of what future co-developments of climate change and society are possible and plausible.

Examples of CLICCS research at MPI-M

Prof Jochem Marotzke, director at MPI-M, is a member of the board and deputy spokesperson of CLICCS. Together with Prof Inga Hense from Universität Hamburg, he heads research theme A "Sensitivity and Variability in the Climate System". The group leaders Prof Victor Brovkin, Dr Peter Korn, and Dr Tatiana Ilyina as well as the directors Prof Bjorn Stevens and Prof Martin Claussen are chairing projects in CLICCS. The MPI-M is involved in theme A and B (Climate-Related Dynamics of Social Systems). Theme A provides the natural-science basis for understanding climate system dynamics, including climate variability and extremes, and the climate change expected for the future. Theme B investigates the climate-related dynamics of social systems. This theme will provide the social science foundation for the construction of plausible climate scenarios.

Examples of the work of Dr Ann Kristin Naumann (department "The Atmosphere in the Earth System"), Dr Chao Li, and Dr Dian Putrasahan (department "The Ocean in the Earth System") are described in more detail below.

CLICCS joint working group „Drivers of Tropical Circulation“ (Ann Kristin Naumann) – project A2 (Clouds and Tropical Circulation)

The CLICCS joint working group on "Drivers of Tropical Circulation", led by Dr Ann Kristin Naumann, aims to better understand the tropical heat budget, its link to the circulation system, and how these respond to warming. The group focuses on process understanding and the interplay between the tropical circulation and its different diabatic drivers such as radiation, microphysics, and surface fluxes. It studies the climate system with kilometer-scale models and the challenging question to what extent microphysical processes influence the energy budget of the tropics, and its sensitivity to perturbations. Even at hectometer scales these processes will be crudely represented, raising the question as to whether the crude representation of the processes in the model plays a decisive role, and if so, to what extent the representation can be improved by means of observations.

Global storm-resolving models come along with methodological challenges: because of the large cost of the simulations, new methods to explore sensitivities using only very short runs are needed. To bring models and data together, the group refined a method based on a statistical representation of moisture distribution to fairly compare kilometer-scale simulations and airborne observations (Naumann and Kiemle, 2020). In an ongoing project, this method is applied to compare the distribution of upper-tropospheric moisture and how it affects the energy budget in different global storm-resolving models based on only month-long simulations.

In addition to trying to link models to observations, the group members also have a history of developing conceptual models to interpret more complex behavior. They developed a conceptual framework for the shallow convective boundary layer. By developing and applying a conceptual model for a flat, convective boundary layer, they were able to show that heterogeneities in low-level heating rates drive shallow circulations that help organize shallow convection on the mesoscale (Naumann et al., 2019). Building on the combination of storm-resolving models with observations and conceptual approaches, the group tries to better understand how much of the heat budget of the tropics is controlled by circulations and dynamics as compared to by microphysical processes.

Outlook: In global storm-resolving models that resolve convection explicitly instead of parameterizing it, microphysical processes are now fundamentally linked to their controlling factors, i.e., the circulation. While in conventional climate models the convective parameterization is one of the main sources of uncertainties (and a popular tuning parameter), this role might be passed on to the microphysical parameterization in global storm-resolving models. At the moment, Naumann´s group investigates how the representation of the microphysical processes affects the albedo, radiative fluxes, and the heat budget in more general. How much do we screw up the tropical heat budget with a (too crude) representation of microphysics? How much can we gain by using a more sophisticated (but hence also more expensive) representation of microphysics? Furthermore, the group confronts models with observational data, increasingly so from the EUREC4A field campaign that took place in January/February 2020 on and around Barbados. Here, the scientists focus on precipitation from shallow trade wind clouds and how rain fraction and intensity relate to the spatial distribution, size, and lifecycle of precipitating objects both in observations and in models.

Identification of plausible projections from state-of-the-art climate models (Dian Putrasahan) – project A6 (Earth System Variability and Predictability in a Changing Climate)

How climate variability and predictability will change in a changing climate is only rudimentarily known, and yet this knowledge is crucial for assessing the magnitude of aleatoric uncertainty that is always arising from variability. One critical challenge is the role of the interactions between small-scale and large-scale processes in variability, predictability, and the occurrence of extremes. These three aspects have strong impacts on social dynamics and human–environment systems.

Guided by the overarching question of “Which climate futures are possible and which are plausible”, Dr Dian Putrasahan works on identifying plausible projections from the available possible projections obtained from the state-of-the-art climate models. This will be done by resolving the relevant small-scale processes, namely ocean eddies and convection, which contribute to the model uncertainty of climate projections. The crux is to identify the plausible physical mechanisms, via which these small-scale processes influence climate projections. Small-scale processes can influence the climate response and variability in a transient climate through scale interactions. Examples are heat and carbon uptake through ocean eddies or the modification of diabatic heating profile through resolved convection. Current generation climate models do not resolve the aforementioned processes, they are rather parameterized. Hence, they may not adequately capture the climate response or variability changes that high-resolution models would. To identify the plausible physical mechanisms related to these small-scale processes, Putrasahan will employ climate change simulations by the Earth system models MPI-ESM and ICON-ESM with an eddy-resolving ocean, as well as time-sliced convection-resolving ICON-A runs.

In this early phase of CLICCS, new configurations of the ICON-ESM are currently being prepared, with the intention of conducting centuries-long runs to understand the response of the climate when processes are resolved on a smaller scale. To this end, the vertical resolution of the ocean will also be increased to study the role of vertical processes on climate variability. In parallel, simulations with the atmosphere model of ICON (ICON-A) with different resolutions are performed to investigate the role of dissolved convection on the diabatic heating profile of the atmosphere in a warming world. The main objective is to quantify and understand the influence of resolved versus parameterized processes on climate variability/reaction in a temporarily warming world.

Exploring plausible mitigation scenarios (Chao Li) – project B5 (Coping with Climate-Related Uncertainties and Variabilities)

Climate change occurs over longer periods of time. As a result, social actors, for example from politics and business, are often unable to directly access and react to actual experiences with climate events. They have to rely on scientific predictions as to which changes are likely under climate change. Not only does the global climate system vary greatly spatially and temporally, the social systems, which in turn are influenced by other policy fields, also differ. This allows for different social reactions to variabilities and uncertainties in climate and social systems. In order to create an empirically sound basis for determining which climate change impacts are plausible, these processes must be investigated. The task of MPI-M scientist Dr Chao Li and his colleagues is aiming at advancing understanding of how uncertainties and variabilities in natural and social processes interact by prototypically generating more plausible scenarios of climate futures.

The decision-making in climate change has been fraught with large future climate projection uncertainties. The future climate projection uncertainties arise from reducible uncertainties of external forcing and climate sensitivity, and irreducible uncertainties of climate internal variability in the physical part and carbon uptake in the Earth system. The reducible uncertainties have been considered in integrated assessment models for suggesting mitigation scenarios, but the irreducible uncertainties have not. Spatial and temporal variability within the climate system is complemented by variability within the social system that arises from dynamics within other policy fields.

The scientists will investigate how climate-relevant variability and uncertainty manifest themselves at climate-relevant economic damages. The future carbon emission mitigation scenarios, such as Representative Concentration Pathways (RCPs), are usually developed within an integrated assessment model framework, searching for the most cost-effective way of reducing emissions. The climate-relevant economic damages have usually not been taken into account in the development processes of future mitigation scenarios. Li and his colleagues will further develop the integrated assessment framework by including climate-relevant economic damages. The new framework will enable them to investigate how climate-relevant policy decisions depend on the perceived and experienced variability and further uncertainties of the climate system. The scientists will construct and investigate prototypical climate scenarios that explicitly incorporate the social dynamics and are thus both informative to society and consistent with our understanding of social and natural processes.

Li and his colleagues review and assess the plausibility of the extremely low emission scenarios consistent with the 1.5°C climate target of the Paris Agreement and explore more plausible future mitigation scenarios to achieve this target. A majority of previous studies has found negative emissions technologies as an implied demand. However, the feasibility of these technologies is disputed because of their conflict with land use for food production and biodiversity protection. Moreover, mitigation costs double when raising the ambition from 2°C to a 1.5°C target. Given these previous findings, it is implausible that annual global temperature never exceeds 1.5°C of warming, and a temporary overshoot is usually implied as consistent with meeting the 1.5°C target. Li and his co-authors recently found an option of optimal temperature overshoot profile by limiting global sea-level rise, instead of global temperature change, as a lower-cost climate target (Li et al., 2020). They found that a global sea-level rise target will provide a more sustainable and more cost-effective solution to limit both short-term and long-term climate change. This should appeal particularly to stakeholders for whom sea-level rise is most important among all global warming impact categories, compared to a temperature target with the same sea-level rise by 2200. Li and co-authors also find that a sea-level rise target provides rational justification of a certain temperature overshoot through a physical constraint rather than arbitrarily defining an overshoot range of temperature as acceptable.

Publications:

Li, C., Held, H., Hokamp, S. & Marotzke, J. (2020) Optimal temperature overshoot profile found by limiting global sea level rise as a lower-cost climate target. *Science Advances*, 6: eaaw9490. **doi:10.1126/sciadv.aaw9490**.

Naumann, A. K., & Kiemle, C. (2020) The vertical structure and spatial variability of lower tropospheric water vapor and clouds in the trades. *Atmospheric Chemistry and Physics*, 20, 6129-6145. **doi:10.5194/acp-20-6129-2020**.

Naumann, A. K., Stevens, B., and Hohenegger, C. (2019) A moist conceptual model for the boundary layer structure and radiatively driven shallow circulations in the trades, J. *Atmos. Sci*., 76, 1289–1306, **doi.10.1175/JAS-D-18-0226.1**.

More information:

CLICCS website Universität Hamburg: **https://www.cliccs.uni-hamburg.de/about-cliccs.html**

CLICCS joint working group “Drivers of Tropical Circulation”: **https://www.mpimet.mpg.de/en/science/the-atmosphere-in-the-earth-system/working-groups/drivers-of-tropical-circulation/**

Contact:

Dr Chao Li
Max Planck Institute for Meteorology
Phone: +49 (0) 40 41173 458
Email: **chao.li@mpimet.mpg.de**

Dr Ann Kristin Naumann
Max Planck Institute for Meteorology and Universität Hamburg
Phone: +49 (0) 40 41173 239
Email: **ann-kristin.naumann@mpimet.mpg.de**

Dr Dian Putrasahan
Max Planck Institute for Meteorology
Phone: +49 (0) 40 41173 468
Email: **dian.putrasahan@mpimet.mpg.de**