Activities proposed by the Safe Landing Climates Lighthouse Activity

In March 2023 an in-person meeting was held in London by the Safe Landing Climates (SLC) Lighthouse Activity. One outcome was that seven new activities were proposed across SLC, some corresponding to activities already partly underway in some of the Working groups and others that are more cross-cutting. The next step will be to establish teams around each activity to work on how to take them forward. An outline of each activity is provided below.

1. CMIP for climate risks

Objective: To promote highly-coupled model runs in CMIP7; include new scenarios to represent different pathways than previous Representative Concentration Pathways (RCPs) (in particular overshoot scenarios with strong but late mitigation and CDR; and evaluate selected tipping impacts.
Lead WG: Understanding High-Risk Events
Leads: Bette Otto-Bliesner, Pierre Friedlingstein, Gabi Hegerl
External partners: TIPMIP, Ice Sheet Model Intercomparison Project (ISMIP), ESMO and possibly the Zero Emissions Commitment Model Intercomparison Project (ZECMIP)
Activities:

- Proposals to ScenarioMIP (Pierre Friedlingstein)
- Work with other MIPs or propose a new HighRiskMIP (Bette Otto-Bliesner)

Global climate change is often thought of as a steady and approximately predictable physical response to increasing forcings, which then requires commensurate adaptation. But adaptation has practical, cultural, and biological limits, and climate change may pose unanticipated global hazards, sudden changes or other surprises, as may societal adaptation and mitigation responses. Climate science must attempt to identify and quantify physical risks even–or especially–when they are highly uncertain. This improves the chances of identifying and communicating “safe landing” pathways that avoid the worst consequences of climate change.

The goal of the HighRisk Project is to coordinate simulations across the Coupled Model Intercomparison Project Phase 7 (CMIP7) suite of coupled models to identify and assess risks associated with tipping points, cascading impacts, and interacting feedbacks in the Earth system on multi-decadal to centennial time scales and beyond. Special attention will be paid to identifying the model output required for a broad range of stakeholders (e.g., the Intergovernmental Panel on Climate Change (IPCC), food supply, vulnerable and indigenous populations, the energy and financial sectors, etc.). As such, the HighRisk Project will provide key input to all three working groups of the IPCC. In addition, to make the HighRisk Project output useful to stakeholders, we will partner with the WCRP Regional Information for Society (RIfS) Core Project and COordinated Regional climate Downscaling EXperiment (CORDEX) as well as the Extremes Platform (under RIfS).

We are currently discussing two sets of coupled climate model experiments that could potentially contribute to CMIP7, IPCC, and other international and national assessments. These sets of experiments have the potential to identify and assess risks associated with tipping points, cascading impacts, and interacting feedbacks in the Earth system on multi-decadal to centennial time scales and beyond.

(1) A set of experiments taking advantage of the CMIP DECK 1% yr-1 CO_2 concentration increase (1pctCO_2) experiment and its companion experiment with CO_2 concentrations maintained at 4x pre-industrial concentrations until the end of the simulation (Eyring et al., 2016). To this, could be added the proposed TIPMIP protocols for complementary experiments to assess commitment and reversibility, and to include the additional contributions of predictive ice sheets and vegetation, working with the ISMIP and the Land Use Model Intercomparison Project (LUMIP).

a) ISMIP6 included such an experiment for CMIP6, their Tier 1 1pctCO_2to4x-withism [Nowicki et al., GMD, 2016]: a simulation with interactive ice sheet forced by 1% per year CO_2 increase to 4 x CO_2 (subsequently held constant to quadruple levels). We would also encourage this simulation in CMIP7.

b) We would also like to propose a simulation with vegetation feedbacks switched on for groups who have the capability to do so but have chosen not to for their DECK experiments as a Tier1 experiment, in order to allow rapid vegetation transitions triggered by extreme events for example, highlighted as a possibility in the LUMIP protocol (Lawrence et al., 2016), with the hope of better sampling and evaluating such possible transitions. It will also be important for groups to clarify which feedbacks are switched on in models to allow diagnostics.

(2) A set of 'whatif' experiments. The DECK 1%CO_2 to 4x coupled simulations may not cross a tipping point. Yet these tipping points, if they would have been crossed, could have local and remote impacts and interacting risks. The magnitudes and locations of these impacts across multiple CMIP7 models are critical to inform adaptation and uncertainties for taking action.

One way is to run existing models and impose ice sheet collapse; savannah in Amazon; boreal forest northward expansion in North America and Siberia; complete thaw of permafrost; or freshwater input to the North Atlantic and see the model response. For example, in CMIP6, LUMIP included a Tier 1 experiment an idealized transient global deforestation experiment (idealized-global-deforest) and Tier 3 paired idealized time slice control and deforestation experiments for specific regions (e.g. tropical, boreal, temperate) [Lawrence et al., 2016]. The North Atlantic Hosing Model Intercomparison Project (NAHosMIP) organized a set of idealized experiments with CMIP6 unflux-adjusted, coupled climate models to investigate the sensitivity of the AMOC to freshwater forcing [https://www.tipes.dk/na-hosing-mip/].

References:
Eyring, V. and Bony, S. and Meehl, G. A. and Senior, C. A. and Stevens, B. and Stouffer, R. J. and Taylor, K. E., 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization. Geoscientific Model Development, 9(5), pp. 1937-1958.

Lawrence, D. M. and Hurtt, G. C. and Arneth, A. and Brovkin, V. and Calvin, K. V. and Jones, A. D. and Jones, C. D. and Lawrence, P. J. and de Noblet-Ducoudr\'e, N. and Pongratz, J. and Seneviratne, S. I. and Shevliakova, E., 2016. The Land Use Model Intercomparison Project (LUMIP) contribution to CMIP6: rationale and experimental design. Geoscientific Model Development 9(9), pp. 2973-2998.

2. Gaming and decisions/scenario exploration

Objective: To develop future scenarios that are more relevant outside the climate sphere.
Lead WG: Safe Landing Pathways
Leads: Kevin Reed, Neil Harris
External partners: Future Earth Pathways, Aspen Global Change Institute (AGCI)

Activities:

- Workshop #1: Liaise with industries/governments (maybe in the first half of 2024). The outcome may be to form a task force to continue working beyond the workshop.
- Workshop #2: A framework for gaming. The objective would be to provide science input into games (not to produce the game itself)

Analytical gaming exercises can often illuminate the intricacies and feedbacks of complex scenario planning and decision (or tipping) points that lead to unexpected outcomes. Moreover, communicating climate change is often fraught with challenges, which the use of gaming can help overcome. This activity will explore the potential for the use of “climate pathways” gaming exercises to inform various scenarios relevant for climate science, planning and modeling. The development and implementation of an initial series of "climate pathways” gaming workshops could allow for an assessment of ever-evolving scenario pathways to safe (or unsafe) climates on decadal and century timescales.

The success of such a venture would require inclusive groups of scientists, stakeholders, industry partners, community groups and policymakers to include input on recent geopolitical, societal, technological, and sustainable advances and ideas. Building on ongoing international initiatives in the future, the output of these activities could help to inform more nimble scenarios for climate modeling, international and local policies, and behavioral change, and could provide an understanding of the range of plausible and timely pathways to safe landing climates. Finally, such an approach to scenario planning would benefit from the inclusion of early career professionals in educational settings. A first workshop will discuss and debate the useful needs of “climate pathways” gaming and the practical aspects of implementing this technique more widely in climate science. With this workshop we seek to (1) understand relevant gaming approaches (including those already in use by the sustainability research community), (2) gain perspectives of applications of gaming of relevant industries and disciplines, and (3) assess the potential to design possible games to inform climate scenarios.

3. Water variability impacts

Objective: Activity addressing resilience of water-use sectors, valuation, and optimal allocation of water, and ‘green finance’ in various future scenarios of (greater) water variability.
Lead WG: Water Resources
Leads: Hyungjun Kim, Paulo Nobre
External partners: WCRP Global Energy and Water Exchanges (GEWEX) Core Project, the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), World Resources Institute (WRI), etc.
Activities: Workshop in May 2024 in the Amazon, TBD. A possible meet-up at the WCRP Open Science Conference (OSC) in Kigali in October 2023. Poster Session at WCRP OSC, October 2023

In this activity we will investigate climate and social processes that lead to global and regional water variability and its socioeconomic impacts. We will achieve this by categorizing the water availability question into three main areas: (i) multi-scale temporal and spatial water availability; (ii) natural processes determining water availability; and (iii) water management and quality. All three subject areas will be considered in terms of cross-cutting aspects of the Lighthouse Activity, such as "whatif" scenarios and tipping elements.

Our approach to achieving this is twofold: (1) to use state of the art Earth system models and available supercomputing infrastructure and IT tools (e.g., artificial intelligence, machine learning, data assimilation) to fill the gaps between the several orders of magnitude processes related to drinkable water availability; from raindrop formation to planetary scale oceanic-atmospheric-forests coupled processes; and (2) to put together a concept paper encompassing the role of water stressors, such as water use for agriculture, industry, and the energy sector, domestic water supply, and ecosystem needs, that impact water demand and socio-economic impacts.

In order to do this, we will call for the contributions of experts across several fields, including Earth system modeling and climatology, and ecological, agricultural, economic impacts assessment and health. This will include contributions from both the physical and social sciences to identify and quantify potential stressors and the coupled processes that modulate water availability in a warmer and more populous world. We will identify case studies that exemplify these coupled interactions between climate phenomena and water demand to anticipate the impacts on society and the environment.

4. Signposts for sea level rise

Objective: Identify indicators of sea level change and their implications for the future, and integrate these indicators with communication strategies
Lead WG: Sea Level Rise
Leads: Beth Holland, Molly Mitchell

- Communication sub-theme - leads Marco Cabrizio, Mike Evans
- MIPS signposts sub-theme - leads Heiko Goelzer, Swapna Panickal
- Local community signpost - leads Molly Mitchell, Beth Holland

External partners: TBD
Activities:

- Webinar in SLC Discussion Series — May/June 2023
- Signposts Workshop
- A white paper describing the approach taken (Nature Sustainability)
- Participate in MIPs
- Participation in WCRP OSC in Kigali in October 2023

In this activity, we will investigate geographically specific signposts of accelerating sea level rise in locations around the globe and translate this information for practitioner use. We will achieve this by combining expertise regarding changes in drivers of sea level rise, their impacts to sea level rise trajectories, and modifying factors (storm surge and resource loss) with practitioner-identified decision points. Our goal is to provide guidance that will allow practitioners to accurately assess current and future risk from sea level rise in their decision-making.

5. High-risk cascading shocks

(Including impacts on the carbon cycle and quantification of costs)

Objective: Interesting examples are multiyear drought and heat waves
Lead WG: Understanding High Risk Events, Perturbed Carbon
Leads: Laura Suarez-Gutierrez, Gabi Hegerl, Ana Bastos
External partners: Explaining and Predicting Earth System Change (EPESC), Climate and Ocean Variability, Predictability and Change (CLIVAR), Risk KAN (Future Earth)
Activities:

- Webinars 2023 - topics including cascading impacts, emulators
- AGU 2023 session proposal
- Workshop (2024) with EPESC, ensuring interdisciplinary participation and marking the start of a continuing activity or taskforce.

In this activity we will investigate high-risk events where climate hazards lead to cascading climatic, ecological, and socioeconomic impacts. We will achieve this by combining expertise and methodologies across varied multidisciplinary fields including climate science, ecological and agricultural impact assessment, financial risk assessment, and social sciences. Furthermore, we will utilize innovative state-of-the-art applications made possible by advances in high-performance computing, machine learning and state of the art modelling techniques. Our goal is not only to bridge along the chain from climate hazards to their cascading impacts, but also to identify and quantify potential links and coupled effects that ultimately make this not a chain, but an interlinked system.

We will identify several cascading shocks study cases that best exemplify these coupled interactions between climate hazards and their cascading ecological and socioeconomic impacts (e.g., forest mortality events triggered by compound heat and drought leading to economic and ecological loss, but also leaving the region more vulnerable to climate hazards in the following years due to land-cover changes). Then, we will assess whether this cascading or coupled linkages, commonly ignored in traditional climate-risk assessments, lead to systematically underestimated risks, and, ultimately, we will quantify these risks using relevant metrics for socio-economic and ecological loss.

6. Connecting across the IAM-GCM-impact hierarchy

Objective: To discover the unexpected climate hazards possible in a fully coupled system, and enable a two-way flow of information across hierarchies, with error framing. A possible joint project with ESMO.
Lead WG: Understand High Risk Events
Leads: Hannah Liddy, Steve Sherwood
External partners: ESMO, the Analysis, Integration and Modeling of the Earth System (AIMES) Project
Activities:

- Workshop with ESMO and AIMES- TBC
- Textbook / educational foundation (with the WCRP Academy)

In this activity, we will investigate if the societal response to the impacts of a changing climate are significant enough to include in a coupled modeling system and whether new risks emerge in a coupled behaviour. The global trajectory of anthropogenic greenhouse gas emissions is the main determinant of global temperature, but this key driver, dependent on human activity, is treated as an exogenous forcing in nearly all climate models. This is largely due to the fact that emissions pathways are a product of a complex system involving interactions between social, political, economic, and technological systems and are often analyzed separately. This activity will explore the interactions between these systems.

The status quo for modeling the climate, mitigation, adaptation, and impacts follows a linear exchange of model output beginning with emissions and land use trajectories quantified by integrated assessment models to meet a range of future socio-economic and political projections (Meinshausen et al., 2020). These emissions trajectories are used by climate models to explore the climate response to anthropogenic forcing. Climate models then produce globally gridded results of climate metrics such as near-surface temperature change that can be used as forcing data for impact models to estimate metrics such as crop yields, forestry stocks, and marine ecosystems and fishing potentials completing the chain of information exchange.

While this exchange of information is fit-for-purpose given the history of modeling and development of modeling centers, the potential dynamics of a coupled human-Earth system and the significant feedbacks, linkages, and thresholds between the systems are largely unknown. Due to assumptions of economic equilibrium in IAMs, the processes that may give rise or prevent rapid societal change are not considered. However, high impact-low likelihood climate risks and exposure to extreme events may have implications for the societal response to climate through changes in infrastructure, ecosystem services, demographics, and public perceptions of climate change. There is a small but growing body of literature that explores feedbacks between climate and society ranging from approaches ranging from more stylized models (Woodard et al., 2019) to hard coupling between integrated assessment models and Earth system models through the land component (Thornton et al., 2017).

This activity will explore the possible feedbacks and interactions between natural and social systems by working across modeling groups focused on climate, mitigation, adaptation, and impacts to discover the unexpected climate hazards possible in a fully coupled system, and enable a two-way flow of information across hierarchies, with error framing. This effort will be highly interdisciplinary and will forge new collaborations between colleagues working at the interface of climate, socio-economics, and impacts. We will also explore the role of novel methodologies such as emulators and machine learning to improve the representation of human activities on the Earth system in current modeling structures.

References:

Meinshausen, Malte, et al. "The shared socio-economic pathway (SSP) greenhouse gas concentrations and their extensions to 2500." Geoscientific Model Development 13.8 (2020): 3571-3605.

Thornton, Peter E., et al. "Biospheric feedback effects in a synchronously coupled model of human and Earth systems." Nature Climate Change 7.7 (2017): 496-500.

Woodard, et al., "Economic carbon cycle feedbacks may offset additional warming from natural feedbacks." Proceedings of the National Academy of Sciences 116.3 (2019): 759-764.

7. TCRE assessment

Objective: Assess the pdf of transient climate response to cumulative emissions of carbon dioxide (TCRE) using a similar approach to Sherwood et al. (2020) for Equilibrium Climate Sensitivity (ECS)
Lead WG: Perturbed Carbon
Lead: Chris Jones, Pierre Friedlingstein, Tatiana Ilyina, Roland Séférian
External partners: TBD
Activities:

- Poster Session at WCRP OSC, October 2023
- Webinars on the various strands of TCRE (TBC), including process understanding, sources of uncertainty, latest in manipulation experiments, emergent constraints
- Workshop in late 2023, possibly in Exeter

Following IPCC Sixth Assessment Report (AR6) release and update of carbon budgets, the transient climate response to cumulative emissions of carbon dioxide (TCRE) remains a key uncertainty in determining remaining carbon budgets to achieve climate goals. Recent advances in climate sensitivity and aerosol forcing make it timely for TCRE/carbon cycle response to be formally assessed. In this activity we will assess the latest knowledge on climate and carbon cycle feedbacks which determine the response of the climate system to CO_2 emissions, i.e., TCRE. We will achieve this by bringing together expertise on land and ocean carbon cycle, process models, ESMs and observational constraints.

Specifically, we will address process level understanding of what drives TCRE, with a focus on carbon cycle feedbacks which affect the airborne fraction of CO_2 emissions; sources of current TCRE uncertainty - what components and processes of the natural global carbon cycle and climate system are mostly responsible for TCRE uncertainty; multiple time periods - combining evidence from a range of time periods and targeting information from past climates and the historical record. We will also draw on understanding derived from observational data and site-level stations (FluxNET) and manipulation experiments (FACE, soil warming) and the latest understanding of the ocean heat/carbon nexus. We will draw on improved models, and also novel techniques to constrain their output such as emergent constraints or machine learning techniques.