Assessment paper on high impact climate events, tipping points and irreversible regional impacts Gabriele Hegerl



# Why the assessment paper?

- Topic of climate risks and high impact outcomes is crucial and may need more emphasis (as you know)
- Evidence is a tricky combination of records of the past (in different climate states not well resolved), nonlinear dynamical models and Earth system models. Resolving processes involved needs scales and detail that may be tricky for ESMs (as you know)
- Research community is split on evidence for and concern about tipping (eg global tipping point report vs Kopp et al., 2025) = > consensus building needed ahead of AR7
- Scope: slightly broader definitions of tipping points
- Process: scoping group followed by nomination of section leads
- Builds on Armstrong McKay; Wang et al., 2023; Global tipping point report





Romanou, Hegerl, Seneviratne et al., Extreme Events Contributing to Tipping Elements and Tipping Points. Surveys in Geophysics, 2024

# High impact climate events, tipping points and irreversible regional impacts: how robust is our understanding?

Research questions (revised):

- What are the most severe impact events we are concerned about in the Earth system? Irreversibility, rapid or self accelerating change in system or impacts: Tipping points (Kopp et al . 2025 e.g.)
- Are processes that lead to such events, or stabilize, well enough represented in ESMs or can we otherwise anticipate them (eg food system models, impact models)? Does palaeoclimate evidence or other observations constrain models?
- What are the carbon cycle consequences of such events?
- What can WCRP science do to better enable early warning?
- How do we analyse upcoming CMIP and TipMIP runs to gain maximum value on climate risk for the IPCC report and beyond?
- Publication: may be reviews in Geophysics, building on Wang et al., 2023; timescale 1-2 yrs; presently assembling draft outline final stage of author additions



#### Section 1: definition and scope



Climate perturbation

- Lead: Hannah Liddy and Gabi Hegerl; Sebastian Bathiany; Bette Otto-Bliesner; Caroline Zimm; Tim Lenton; Thomas Stocker; Sonia Seneviratne; Narelle van der Wel; Jochem Marotzke; Peter Ashwin
- Irreversibility: on Human timescales (Solomon et al., 2009) or system timescales – reversible if system reverses?
- IPCC: Tipping point is Critical threshold[s] beyond which a system reorganizes, often abruptly and/or irreversibly; following a more specific definition Lenton et al 2008
- Kopp et al 2025 critique:
  - Traits of abruptness, or acceleration of change
  - irreversibility
  - feedback-driven self-amplification
  - Cascading effects/irreversible impacts of high impact events (in climate and impacts)

#### Section 2: Ocean

- Lead: Anastasia Romanou and Thomas Froelicher; Jochem Marotzke; Torben Koenigk; Ayako Abe Ouchi; Regina Rodrigues; William Cheung; Didier Swingedouw
- AMOC; SPG; Coral Reefs; high impact extreme events (the blob)





Example: left stochastic tipping in the ocean, Romanou et al.; above example compound

## Section 3: Cryosphere

- Lead: Tim Naish and Ricarda Winkelmann; Bette Otto-Bliesner; Ayako Abe Ouchi; Nick Golledge; Mathieu Morlighem; Helene L. Seroussi; Alessandro Silvano; Hilmar Gudmundsson; Rob DeConto; Ray Bradley; Lauren Vargo; Judy Lawrence; Marolijn Haasnoot; Roderick van de Wal; Heiko Goelzer; Sophie Nowicki; Martin Siegert; Petra Heil; Jonathan Wille; Tamsin Edwards; Florence Colleoni; Bill Lipscomb
- Antarctic and Greenland ice sheet
- Sea ice
- Glaciers
- Impacts, mitigation and adaptation options

#### Section 4: Tropical Land system



Leads: Lina Teckentrup and Laibao Liu; Sonia Seneviratne Sebastian Bathiany; Christiano Chiessi; David Lapola; Pascale Braconnot; Marina Hirota

Focus on all tropical ecosystems not just Amazon; link to extremes and cascading impacts Signals from the past to evaluating present state

Figure (from Sherwood et al. 2024 which reproduced Radarretrieved forest canopy moisture decline (since 1992) in tropical rainforestsfrom **Tao et al.** (2022);

Further threats: deforestation

#### Section 5: Boreal land system

- Lead: Victor Brovkin and Annette Bartsch; Bette Otto-Bliesner; Gustaf Hugelius; Jan Nitzbon; Christina Schädel; Pascale Braconnot; Lina Teckentrup; Lars Nieradzik
- High latitude Boreal system: vegetation and permafrost; feedbacks, how well represented in ESMs
- Global and regional significance. Evidence from past warm periods; data and models



Changes in boreal forest and permafrost (considered by Wang et al. (RG, 2023) as potential tipping elements)



Permafrost carbon storage https://global-tipping-points.org/resources-gtp/

## Section 6: Threshold breaching / tipping in impacts

- Lead: Alaa Al Khourdajie and Jonathan Moyer; Peter Alexander; Caroline Zimm; Minal Pathak; Steven Sherwood; Benjamin Gwinneth; Franziska Gaupp; Joyashree Roy; Kris Ebi; Harini Nagendra; Robin Lamboll; Jonathan Donges
- How do physical tipping points translate into high-impact consequences across human and ecological systems; and what climatic events lead to threshold breaching, self accelerating rapid or irreversible change in impacts (which extreme events)
- Mitigation/adaptation/early warning
- High impact unknown likelihood events; Cascading effects

Interlinkages (draft) and Dustbowl example: Feedback driven amplification for heat, dust and drought; Near term irreversibility Papers Cowan et al 2018; 2020a,b;





# Section 7: Outstanding uncertainties and model capabilities

- Lead: Bette Otto-Bliesner and Torben Koenigk; Colin Jones; Lina Teckentrup; David Lawrence; Pascale Braconnot; Shuting Yang; Sabina Abba Omar; Michio Kawamiya; Peter Alexander; Alaa Al Khourdajie; Bill Lipscomb
- TipESM and ClimTIP early results could be really useful here
- Examples of events across model hierarchies
- Land/atmosphere/vegetation processes realism and limitations; ocean/ice coupling; model limitations and progress; role of large-scale extreme events; missing responses; resolution and potential of hybrid (hybrid resolution and hybrid in ML and dynamic) ESMs
- Overlap with subject sections needs to be well managed
- Followed by a final section with recommendations/conclusions (all authors)

#### How to contribute

- Authors are already selected although we may identify gaps...
- Make us aware of relevant papers (email to me or Peter Michael Abbott <pabbott@wmo.int) for further distribution</li>
- Contribute to comunity review of paper draft later this year