Updated assessment of climate tipping elements suggests >1.5°C global warming could trigger multiple tipping points

David I. Armstrong McKay*[1,2,3], A. Staal[1,2,4], J.F. Abrams[3], R. Winkelmann[5], B. Sakschewski[5], S. Loriani[5], I. Fetzer[1,2], S.E. Cornell[1,2], J. Rockström[1,5], & T.M. Lenton*[3]

[1]Stockholm Resilience Centre, Stockholm University (*work started here*); [2]Bolin Centre, Stockholm University; [3]Global Systems Institute, University of Exeter; [4]Copernicus Institute of Sustainable Development, Utrecht University; [5]Potsdam Institute for Climate Impact Research; ***david.armstrongmckay@su.se / d.mckay@exeter.ac.uk, t.m.lenton@exeter.ac.uk**

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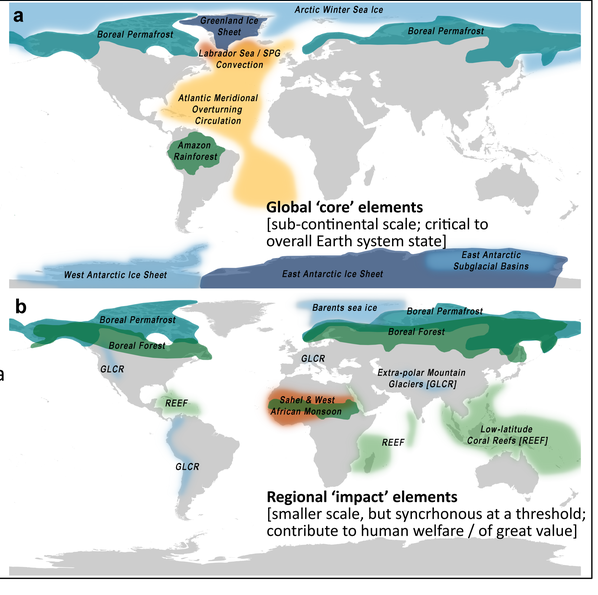
Summary

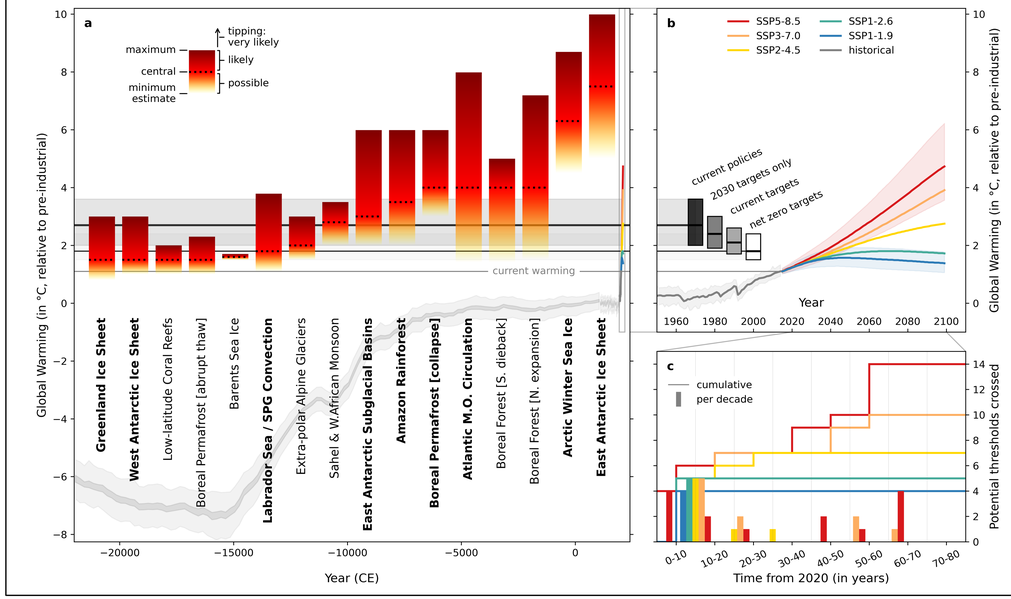
- Climate tipping points occur when change in a part of the climate system becomes **self-perpetuating beyond a forcing threshold**, leading to abrupt and/or irreversible impacts
- Synthesising palæoclimate, observational, and model-based studies, **we provide a revised shortlist** of global 'core' and regional 'impact' tipping elements and their **temperature thresholds, timescales, and impacts**
- **Current global warming** of ~1.1°C above pre-industrial already **lies within the lower end of some tipping threshold ranges**
- **Several more tipping points may be triggered in the Paris Agreement range** of 1.5-2°C global warming, with many **more possible at the 2-3°C of warming expected** on current policy trajectories
- **Implies global warming >1°C is not 'safe'**, but 1.5°C is safer than ≥2°C
- This provides **compelling scientific evidence for urgent action to limit warming to 1.5°C** and to develop improved tipping point estimates & risk assessment, early warning capability, and adaptation strategies

1 Climate Tipping Elements

- **Climate tipping elements** are parts of the climate system vulnerable to tipping points being triggered
- First systematic assessment by ***Lenton et al. (2008)***, but many advances since then from observ. & models
- We define a tipping point as a **self-perpetuating state-change** after reaching a **critical threshold**
- This condition excludes some past candidates, e.g. Arctic summer sea ice, but allows slow change in e.g. ice sheets



2 Threshold Estimates and IPCC projections



- We assess ~175 papers since *Lenton et al. (2008)* and **collate a range of estimates** for thresholds, timescales, climate impacts (global & regional), and dynamics for each proposed element:

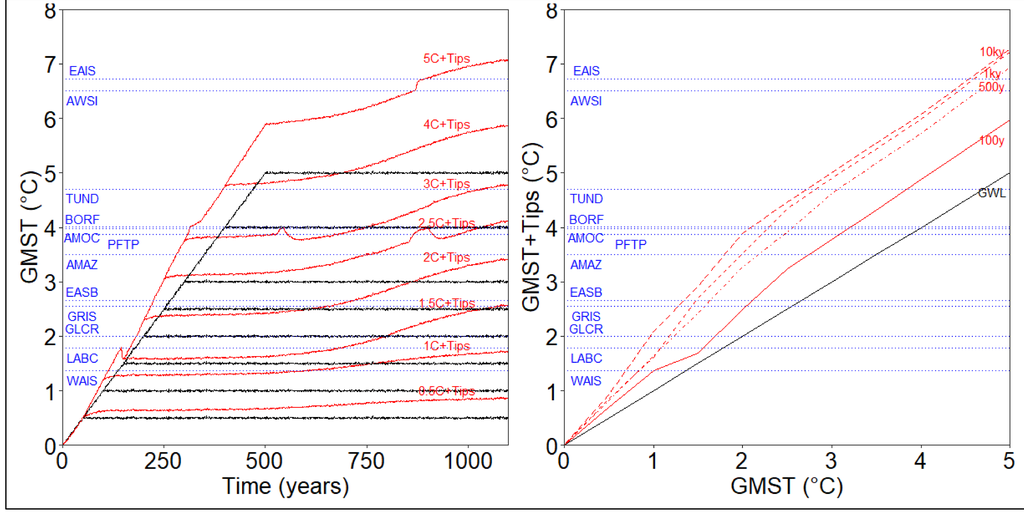
a) Bars show our **minimum, central, and maximum estimated temperature thresholds** for what we categorise as global 'core' or regional 'impact' tipping elements

b) IPCC AR6 **SSP projections to 2100**, with grey bars [*extending into a*] showing thresholds crossed under different targets

c) Bars/lines show **when the central threshold estimate for each element is reached on each SSP** (per decade and cumulatively)

- **Current warming (~1.1°C) within ranges** for Greenland / West Antarctic ice sheets, warm corals, and abrupt permafrost thaw
- These **become likely in Paris range** (1.5-2°C) **and others become possible/likely** (e.g. Labrador Sea convection, extra-polar glaciers)
- **Several become possible in current policy range** (e.g. AMOC, Amazon forest, boreal forest, East Antarctic subglacial basins)
- **Some thresholds are crossed even in low emission scenarios** [*c, blue/green*], but many more thresholds are avoided

3 Interactions & Global Warming Feedback



- A **simple system dynamics model** was developed to **explore element interactions and global warming feedbacks**
- Tipping element impacts are simulated as feedbacks on global mean surface temperature (GMST) following logistic equations, with max. impact dependent on GMST below the tipping threshold and independent of GMST above
- **Interactions** (modelled by adding estimated regional GMST impacts) **reduce the effective threshold of some elements**, e.g. WAIS (West Antarctica), **but others are increased**, e.g. Labrador Sea (LABC) causing cooling over Greenland (GrIS) [*left panel*]
- **Tipping elements amplify long-term global warming level** (GWL) by ~23% over 100y & ~68% over 10ky if GWL is maintained [*right panel*]
- **If GWL peaks and declines** [*not shown*] long-term warming reflects final rather than peak GWL unless GMST exceeds ~3.7°C (locking in an extra ~+0.5°C from permafrost collapse)