Planetary boundaries and tipping points

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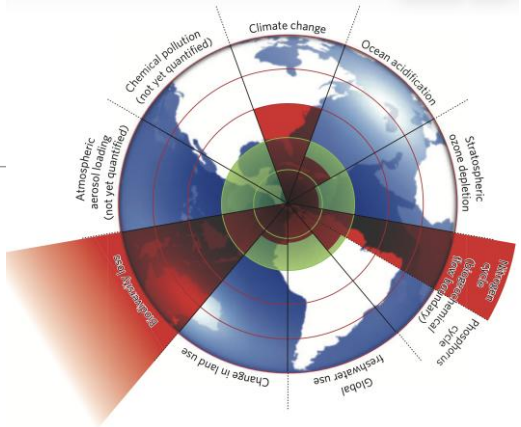
FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue Johan Rockström and colleagues.



Authors
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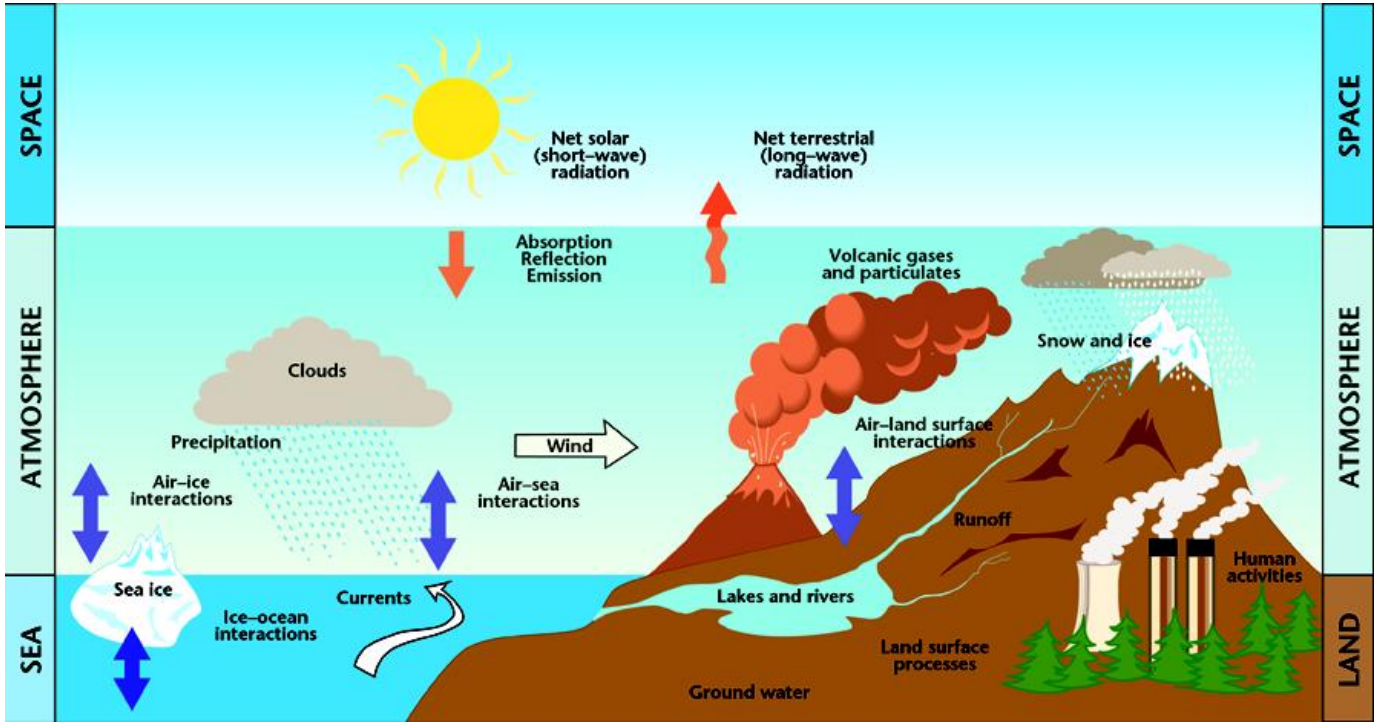
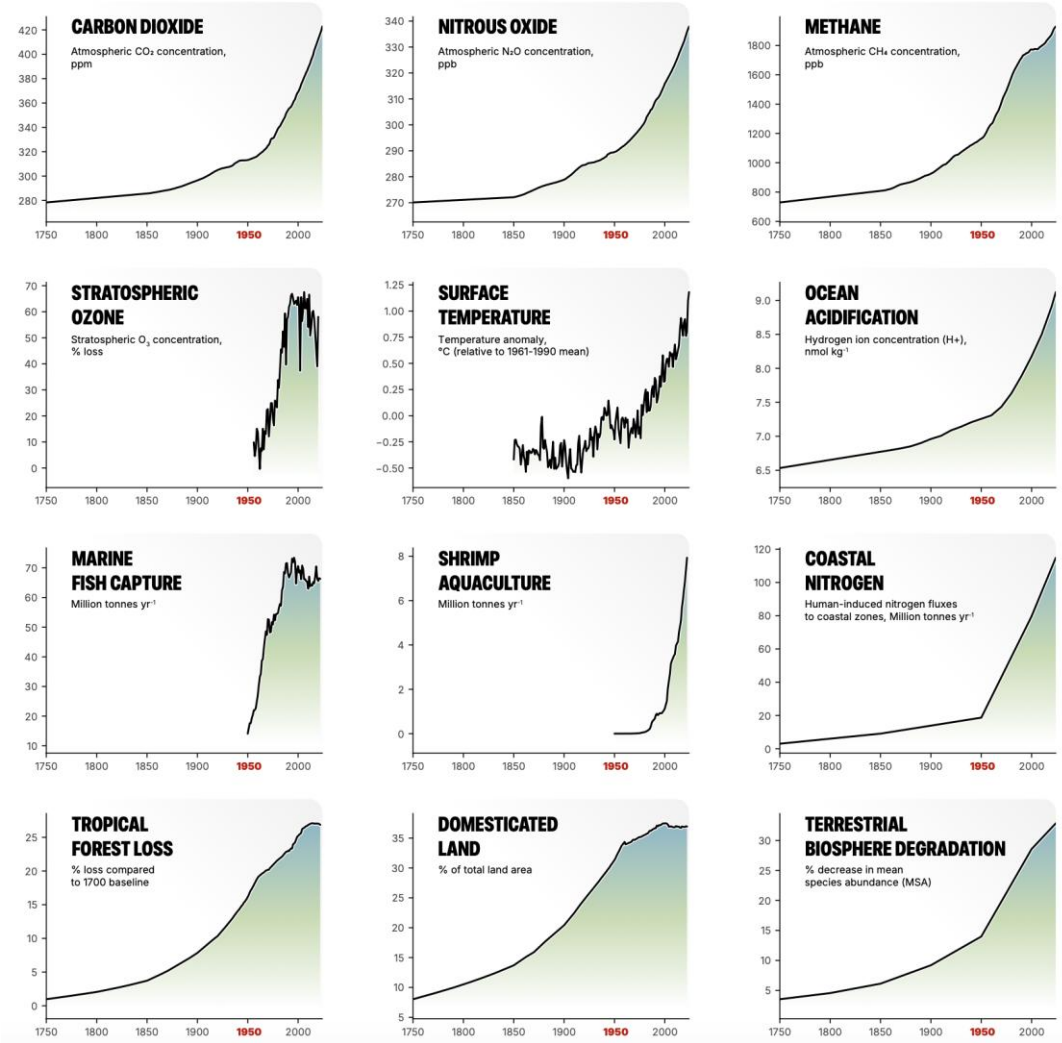
Earth system: a complex, dynamic system



« The great acceleration »



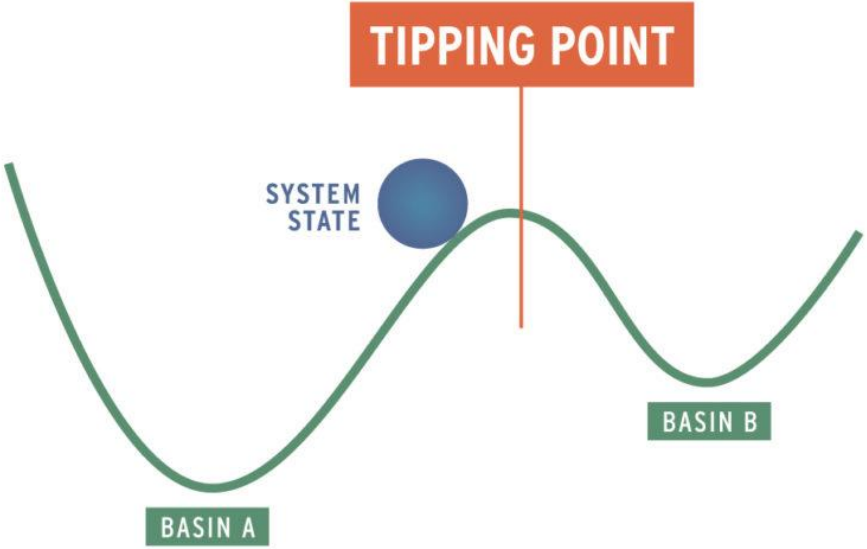
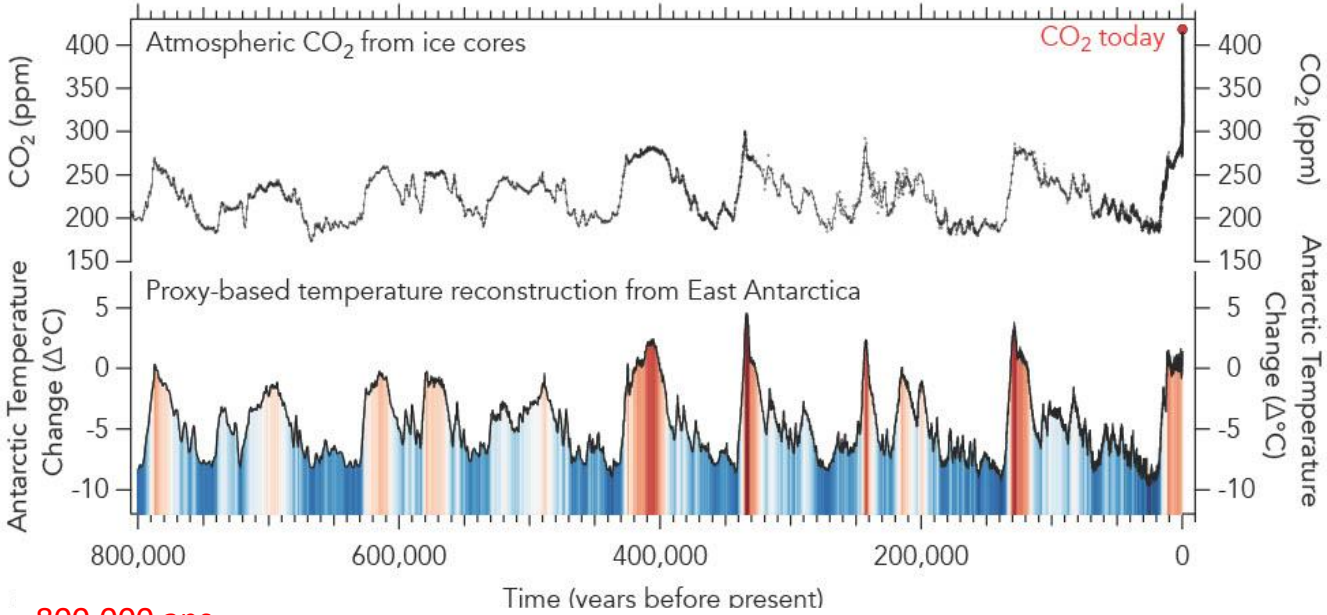


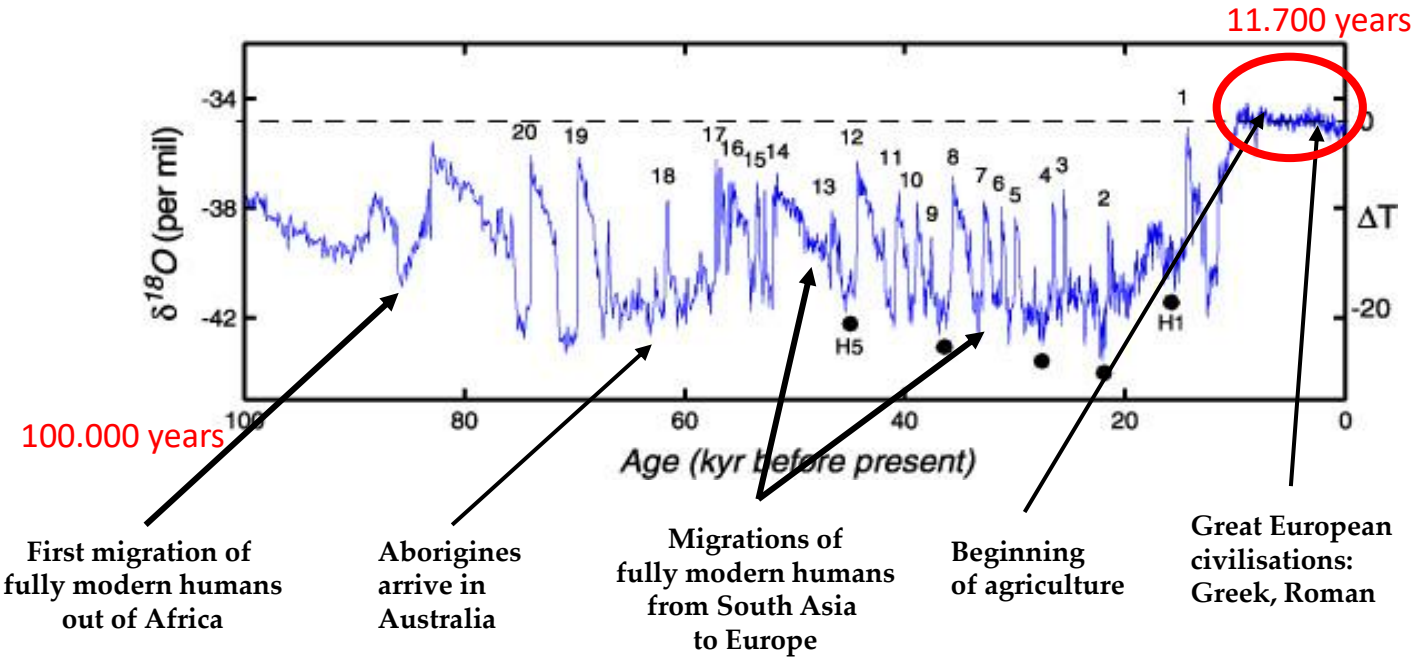
Illustration by Andrew Bernier, adapted from Walker, B. & Salt, D. (2006) Resilience Thinking: Sustaining Ecosystems and People in a Changing World. Island Press: Washington, DC.

Glacial and interglacial periods



800.000 ans

The grace period for humanity:
Holocene



Source: GRIP ice core data (Greenland) and S. Oppenheimer, "Out of Eden", 2004

To be preserved:

Stability

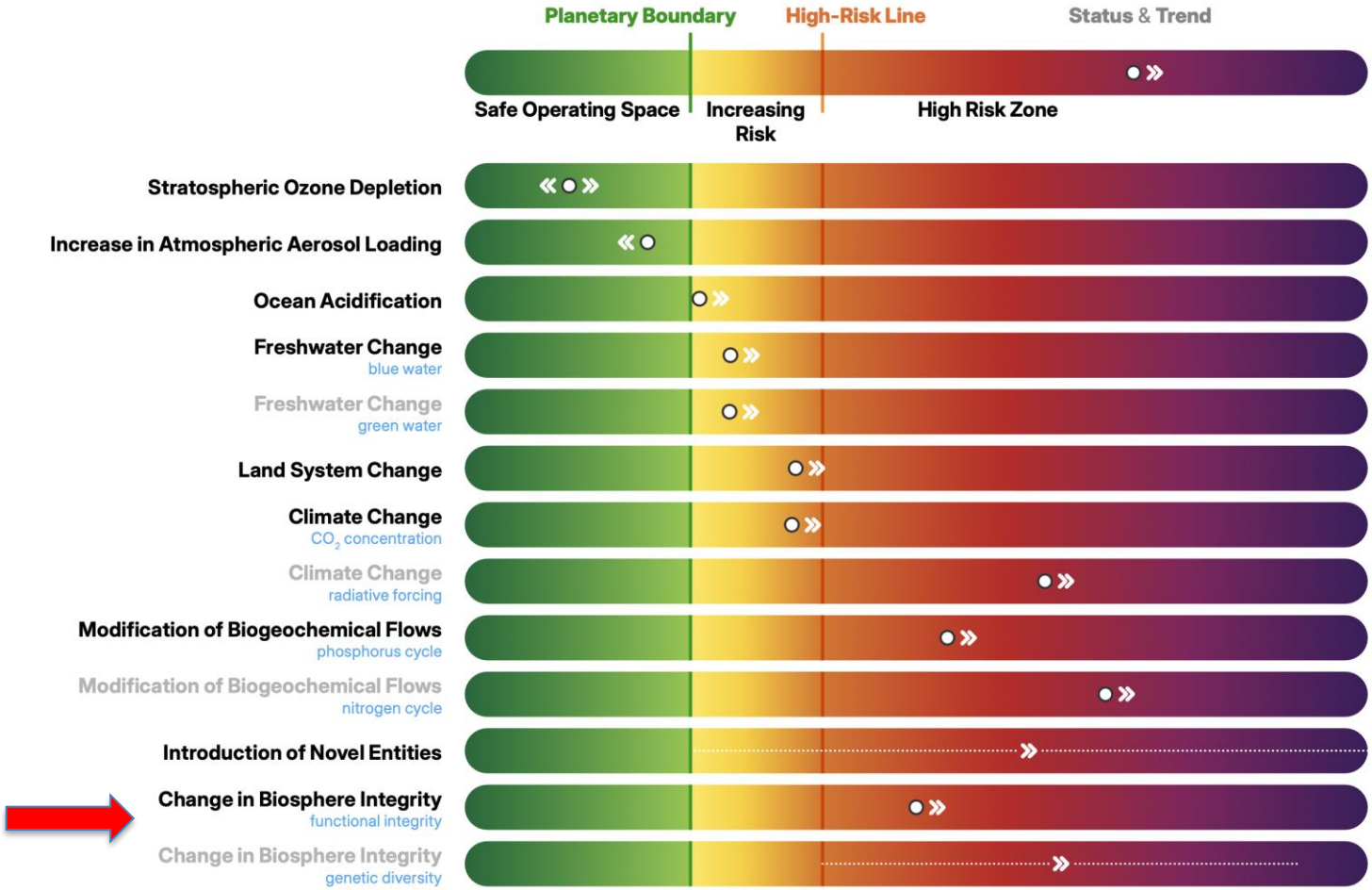
The Earth system's ability to not disrupt relatively constant conditions over long periods, as seen during the Holocene.

Resilience

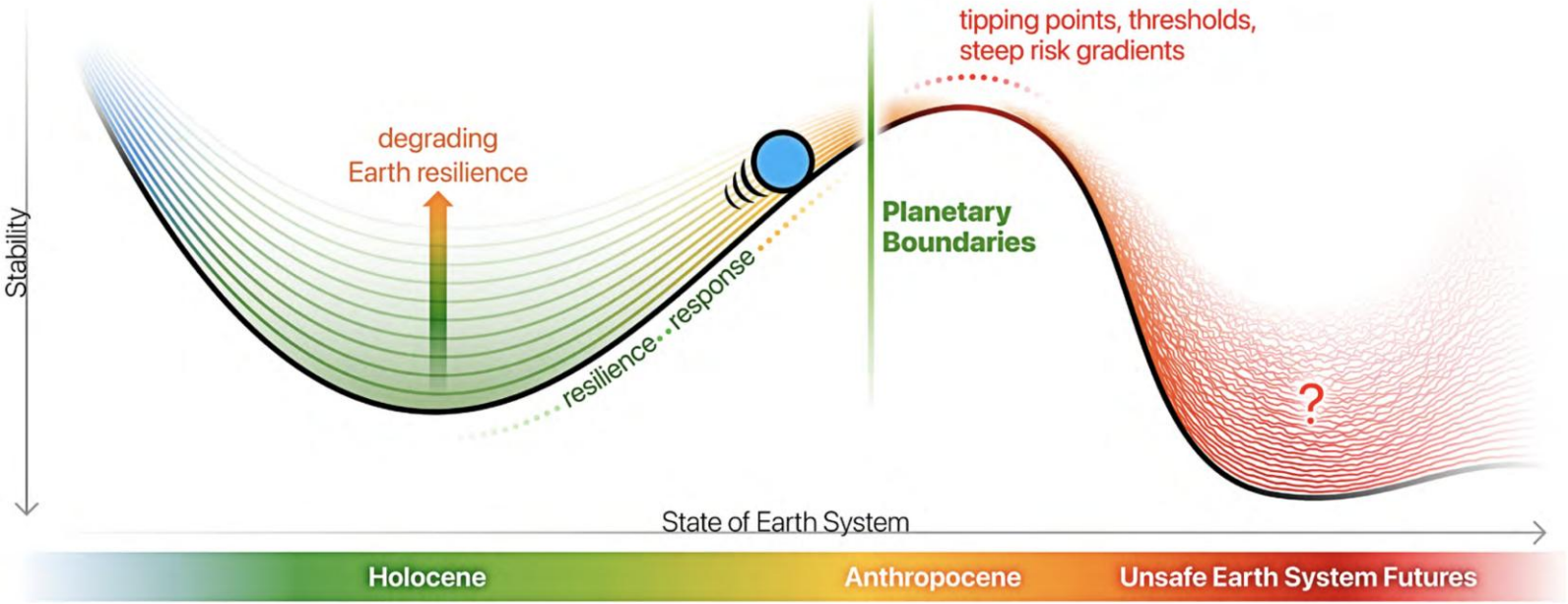
The Earth's capacity to withstand disturbances and recover from them, such as the ability of a forest to recover from a wildfire disturbance and return to a comparable pre-fire state.

Life-support functions

The essential processes provided by the Earth system that sustain life on our planet, for example by maintaining temperature ranges suitable for abundant life in many regions or sustaining the water cycles.


Planetary Boundary
High-Risk Line
Status & Trend
Safe Operating Space
Increasing Risk
High Risk Zone
Stratospheric Ozone Depletion
Increase in Atmospheric Aerosol Loading
Ocean Acidification
Freshwater Change
blue water
Freshwater Change
green water
Land System Change
Climate Change
CO_2 concentration
Climate Change
radiative forcing
Modification of Biogeochemical Flows
phosphorus cycle
Modification of Biogeochemical Flows
nitrogen cycle
Introduction of Novel Entities
Change in Biosphere Integrity
functional integrity
Change in Biosphere Integrity
genetic diversity

Boundaries *versus* tipping points



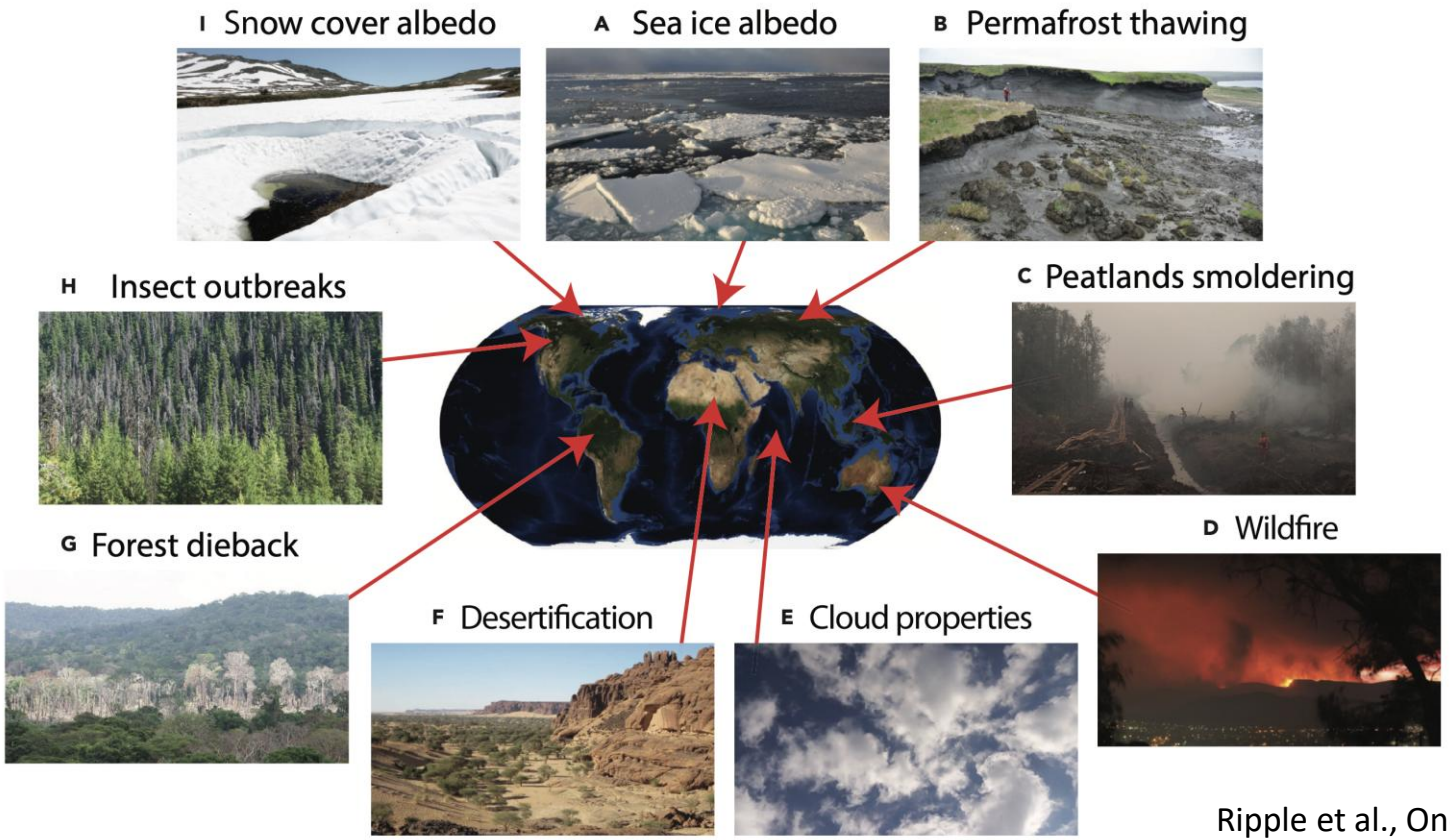
Tipping points

Critical thresholds at which small perturbations qualitatively alter the state or development of the system.

Shift from negative feedbacks (dampening) to positive feedbacks (amplifying).

Self-perpetuating/self-reinforcing evolution leading to state shifts in systems, thus difficult to reverse.

Biophysical (regional) tipping points: *+20-30% of warming*



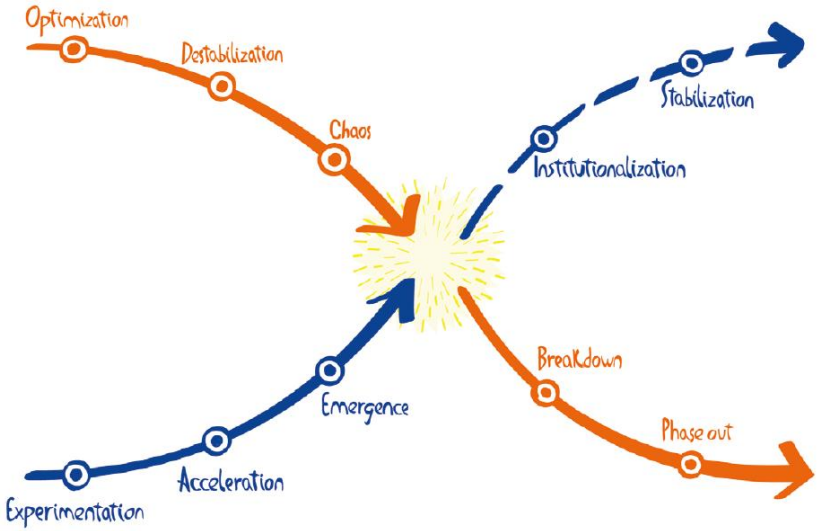
Ripple et al., One Earth, 2023

Social (positive) tipping points

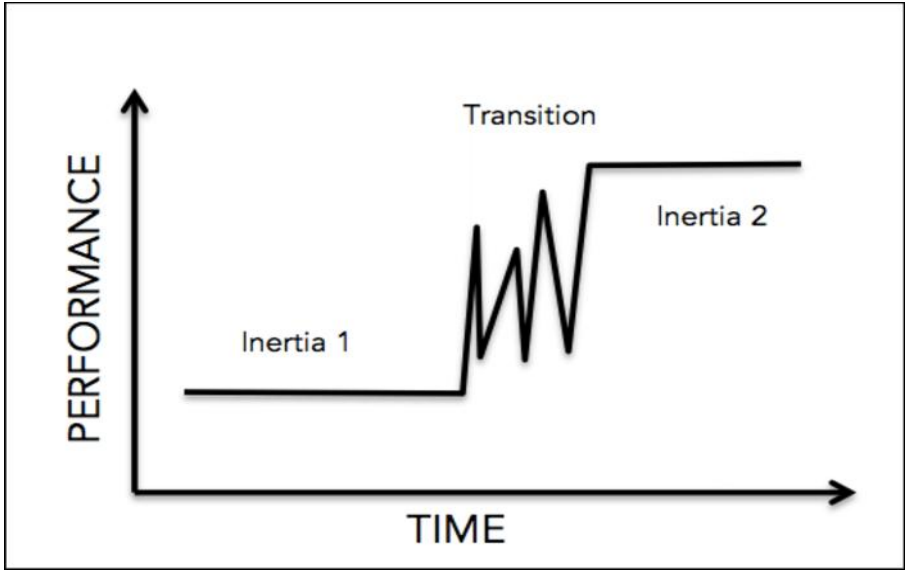
- Clean and cheap electricity (solar & wind): unlocks electric mobility, heat pumps, clean industry, clean air.
- Plant-based diets: health benefits, animal well-being, land sparing for nature, less CO_2 & CH4 emissions, water savings, …
- Effective marine protected areas: recovery of fish stocks, sustainable fishing, …
- Responsible commodity supply chains (soy, palm oil, timber, beef, cocoa, coffee): decrease tropical deforestation, less CO_2 emissions, biodiversity conservation, indigenous groups, …

Upscaling innovations +

phasing out incumbent system



Change as a nonlinear process:
punctuated equilibrium



Paleontology: Eldredge & Gould (1972)

Political science: Baumgartner and Jones (1993)

Policy mixes

Multiple complementary policies that reinforce each other

Pathways to transformation at scale

- Governments initiate sectoral transformations, which are implemented by private sector – e.g. EU's mandate on 90% tailpipe emissions reduction for cars by 2035.

- Large private firms voluntarily adopt sustainable practices and apply them throughout their supply chains – e.g. zero deforestation sourcing commitments.

- Innovations initiated by civil society and then integrated in public or private policies – e.g. voluntary sustainability standards: FSC, MSC, BCI, …

Lambin et al. (2019, 2020)