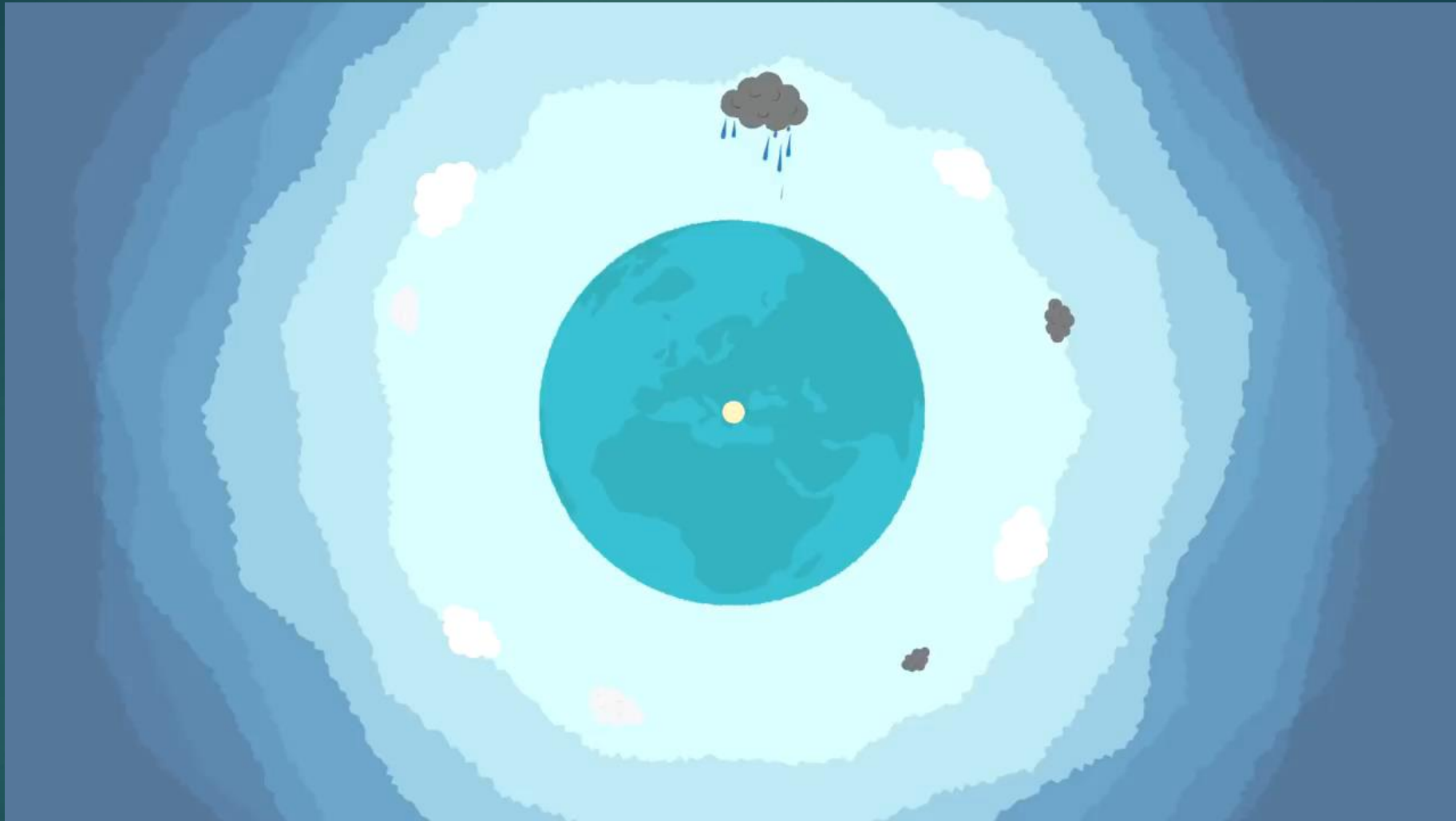


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Planetary Boundaries: A safe operating space for humankind

2



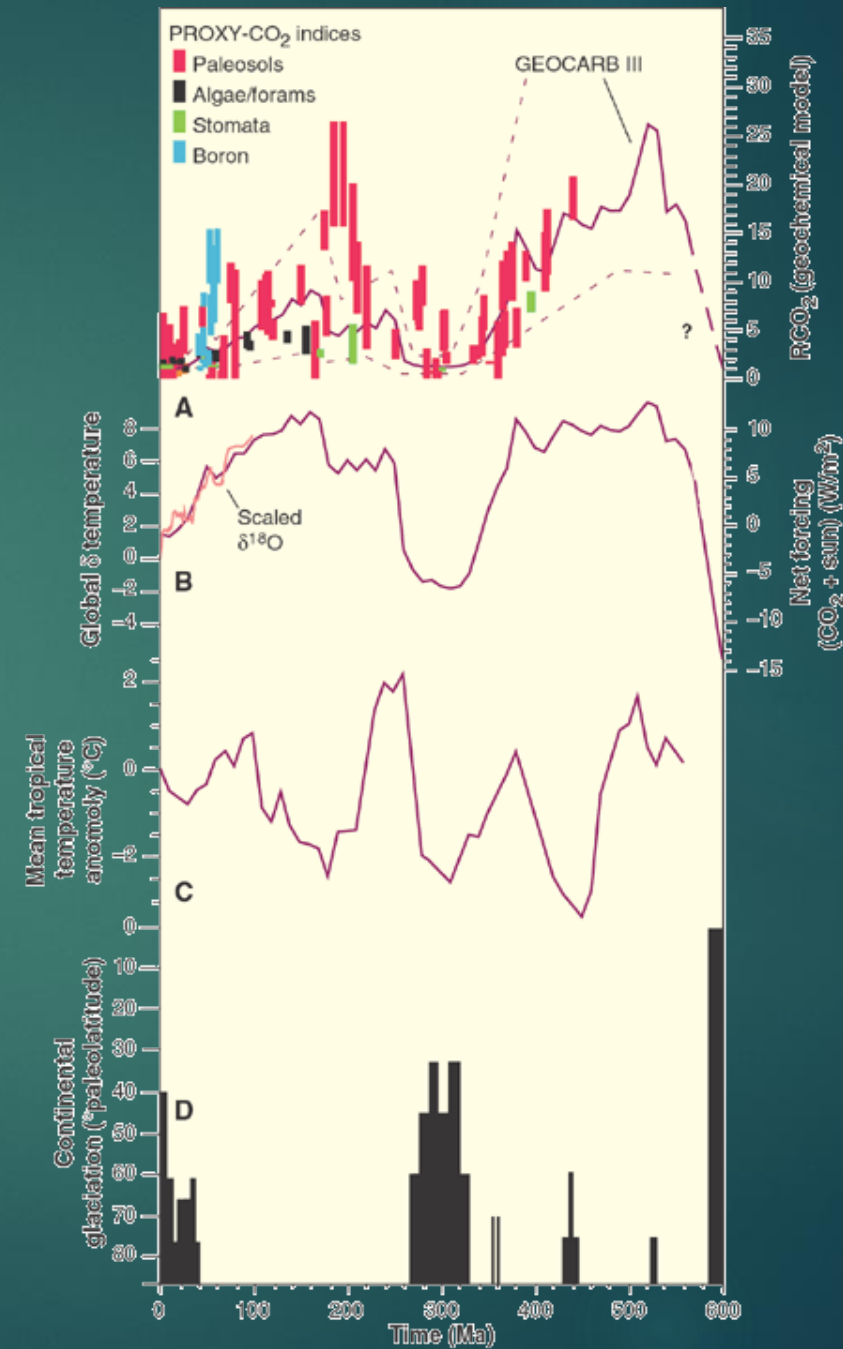
<http://www.ellenmacarthurfoundation.org>
<https://www.c2ccertified.org/>

The Anthropocene & The Rise of the Human Enterprize

STUDENT ACTIVITY: A-B MONOLOGUE

FROM LAST CLASS

The greenhouse levels in the planet today are amongst the lowest in the history of the Earth



The Planetary Boundaries: A safe operating space

THE NEW APPROACH TO GLOBAL SUSTAINABILITY

Skills you gain:

- 1- Understand the concept of PB
- 2- Get familiar with the levels of human perturbation of the Earth System
- 3- Obtain knowledge on the boundaries that we should not cross
- 4- Critically evaluate the current PBs

References:

RESEARCH

RESEARCH ARTICLE SUMMARY

SUSTAINABILITY

Planetary boundaries: Guiding human development on a changing planet

Will Steffen,* Katherine Richardson, Johan Rockström, Sarah E. Cornell, Ingo Fetzer, Elena M. Bennett, Reinette Biggs, Stephen R. Carpenter, Wim de Vries, Cynthia A. de Wit, Carl Folke, Dieter Gerten, Jens Heinke, Georgina M. Mace, Linn M. Persson, Veerabhadran Ramanathan, Belinda Reyers, Sverker Sörlin

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Johan Rockström | TEDGlobal 2010

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TEDEdited 2010 | July 2010

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Global Footprint Network
Advancing the Science of Sustainability

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Ecological Footprint

The Ecological Footprint is the only metric that measures how much nature we have and how much nature we use. The Footprint helps:

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Rockström, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society* 14(2): 32. [online] URL: <http://www.ecologyandsociety.org/vol14/iss2/art32/>

Research

Planetary Boundaries: Exploring the Safe Operating Space for Humanity

Johan Rockström^{1,2}, *Will Steffen*^{1,3}, *Kevin Noone*^{1,4}, *Asa Persson*^{1,2}, *F. Stuart III Chapin*⁵, *Eric Lambin*⁶, *Timothy M. Lenton*⁷, *Marten Scheffer*⁸, *Carl Folke*^{1,9}, *Hans Joachim Schellnhuber*^{10,11}, *Björn Nykvist*^{1,2}, *Cynthia A. de Wit*⁴, *Terry Hughes*¹², *Sander van der Leeuw*¹³, *Henning Rodhe*¹⁴, *Sverker Sörlin*^{1,15}, *Peter K. Snyder*¹⁶, *Robert Costanza*^{1,17}, *Uno Svedin*¹, *Malin Falkenmark*^{1,18}, *Louise Karlberg*^{1,2}, *Robert W. Corell*¹⁹, *Victoria J. Fabry*²⁰, *James Hansen*²¹, *Brian Walker*^{1,22}, *Diana Liverman*^{23,24}, *Katherine Richardson*²⁵, *Paul Crutzen*²⁶, and *Jonathan Foley*²⁷

Holocene: the environmental quality limits for our development

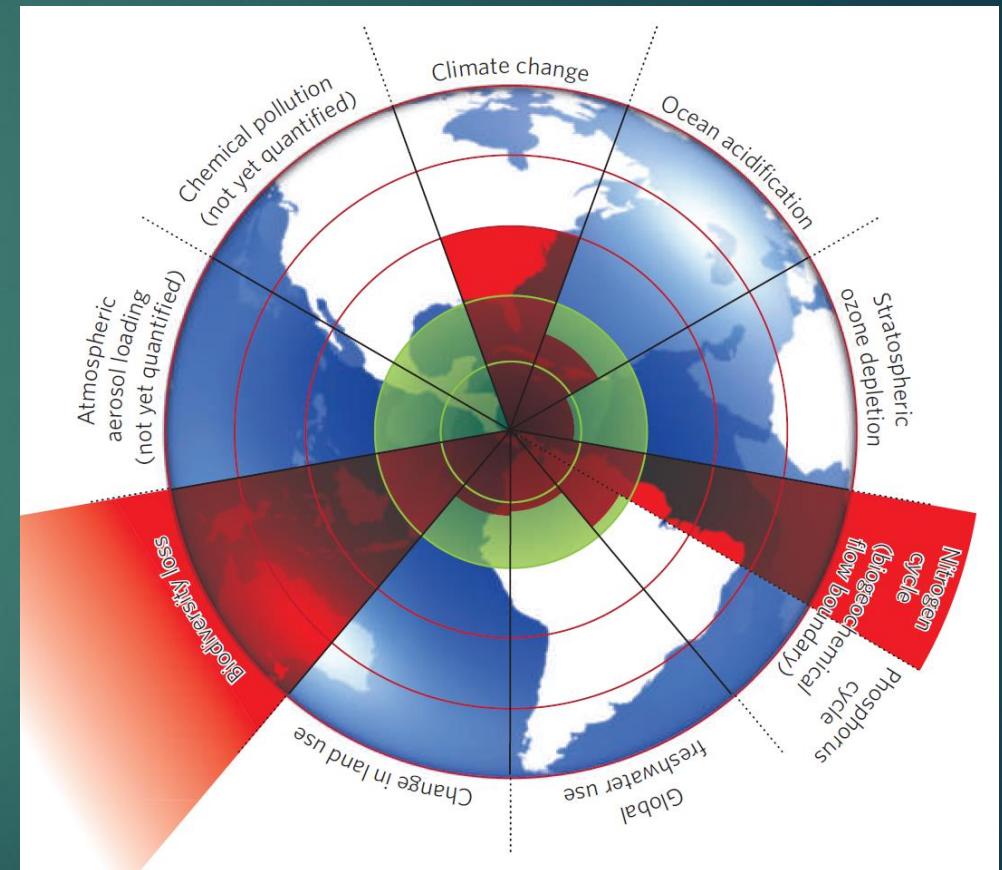
How did the Holocene look like?



Key ecosystem, biogeochemical and atmospheric parameters fluctuating within a relatively narrow range

Setting biophysical conditions for human development

- ▶ Main assumptions:
 - ▶ Scale of human action in relation to the capacity of Earth to sustain it (e.g. agenda 31).
 - ▶ Prioritizing Earth processes in the context of global change.
 - ▶ Resilience of the Earth System (i.e. shifts between states and early warning systems)



Nature:Vol 461 | 24 September 2009

Early warning signals: proxies for the state of a system



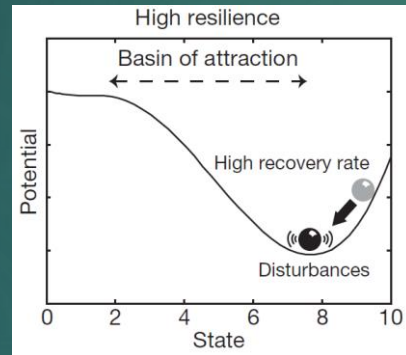
www.vskills.in

Complex dynamical systems can have sudden shift to a contrasting dynamical regime. Early-warning signals indicate for a wide class of systems if a critical threshold is approaching.

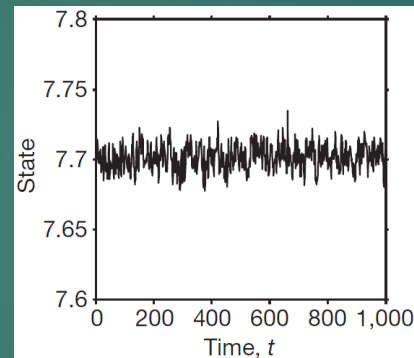
Early warning signals: Critical slowing down and its symptoms

System far from bifurcation point

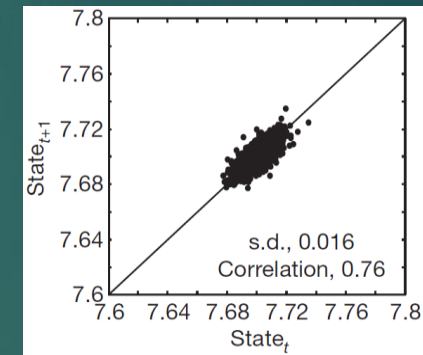
System resilience



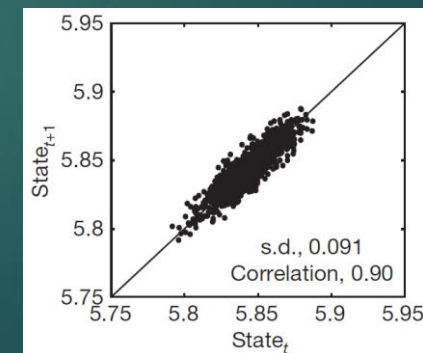
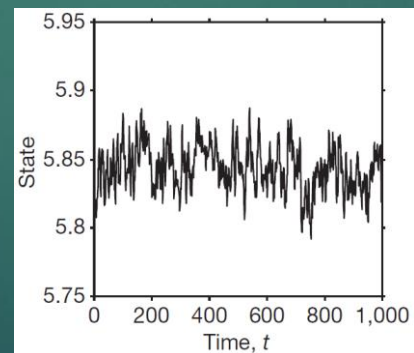
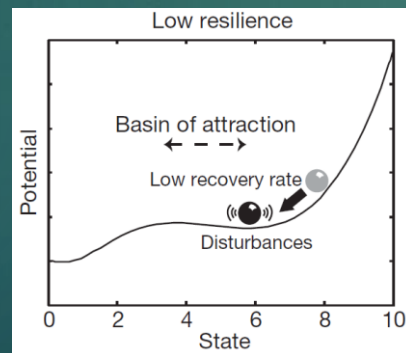
System variance



Temporal autocorrelation

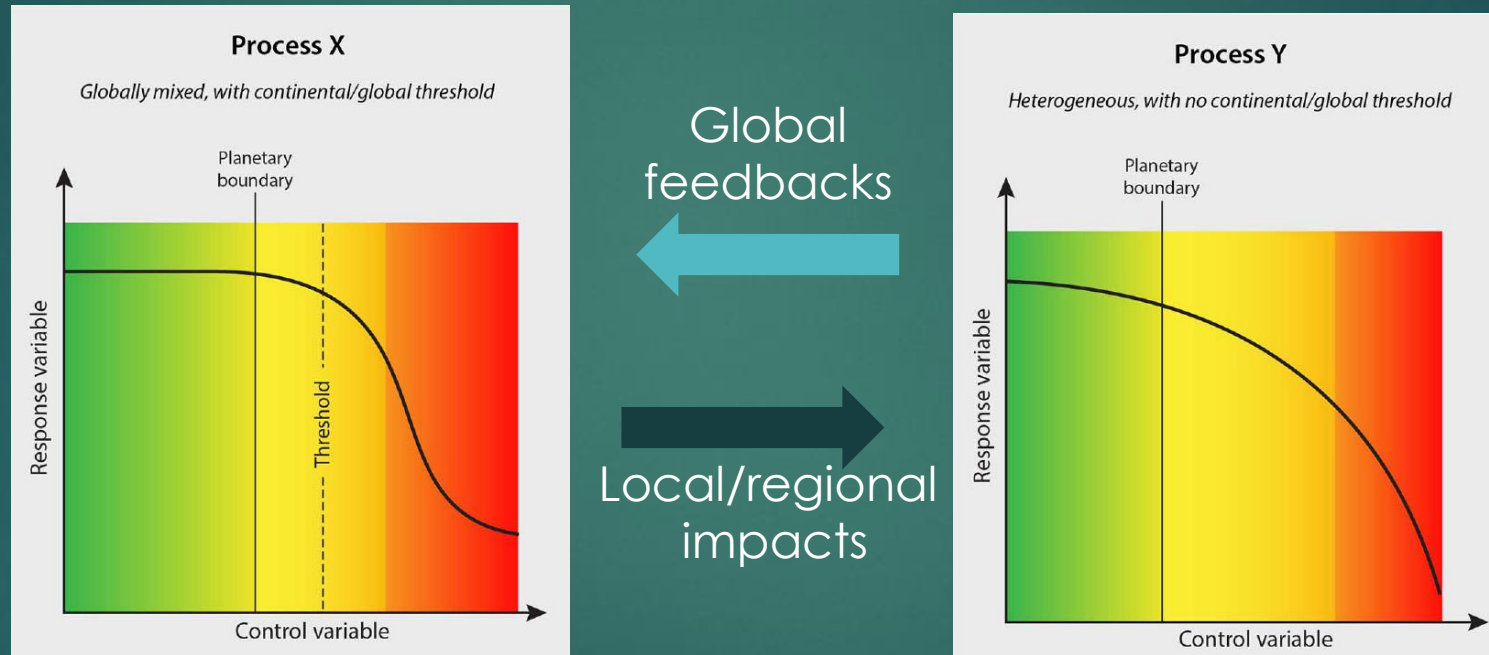


System close to bifurcation point



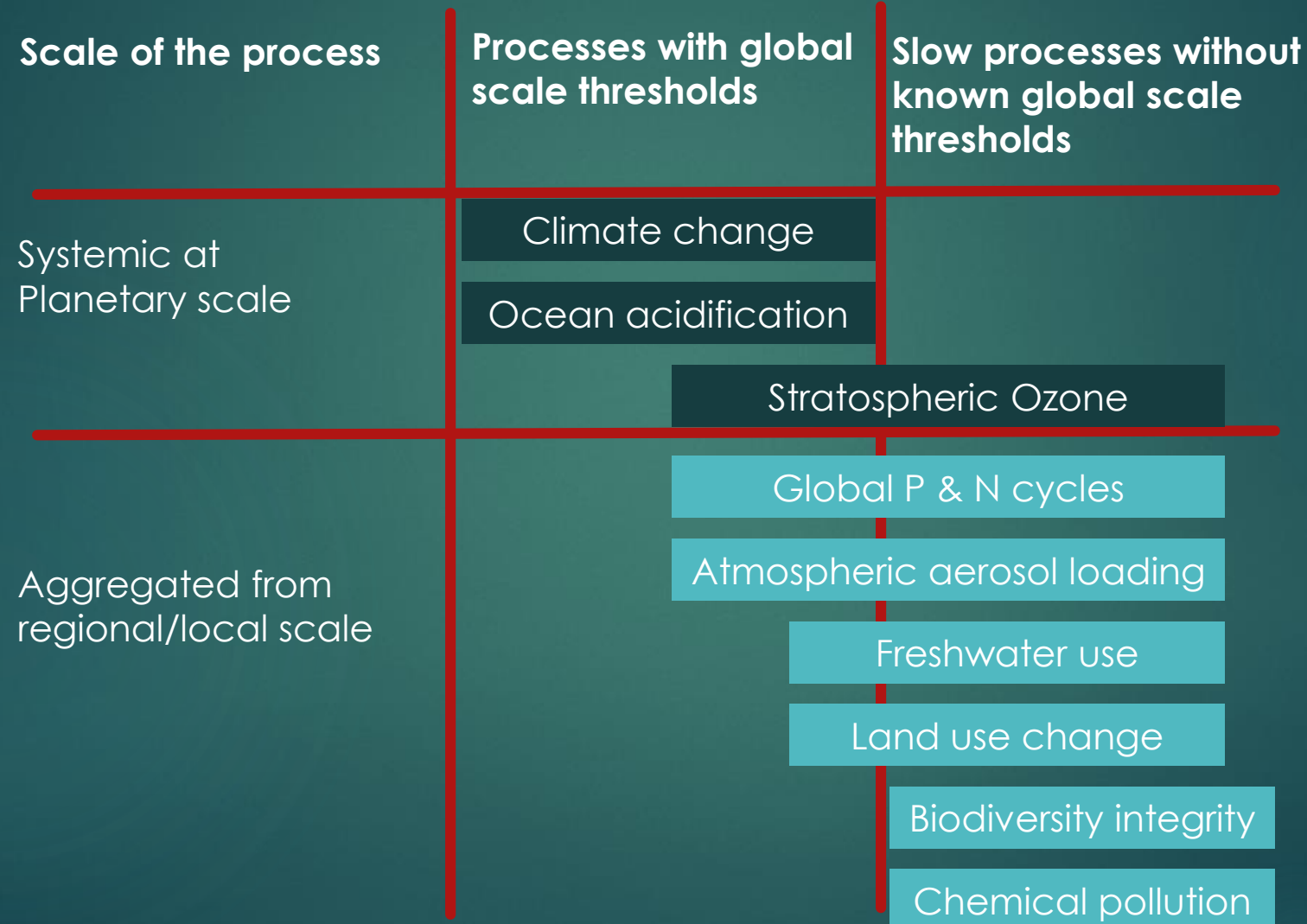
Non-equilibrium dynamics as a systems approaches catastrophic bifurcation

Thresholds, feedbacks, resilience & uncertainties

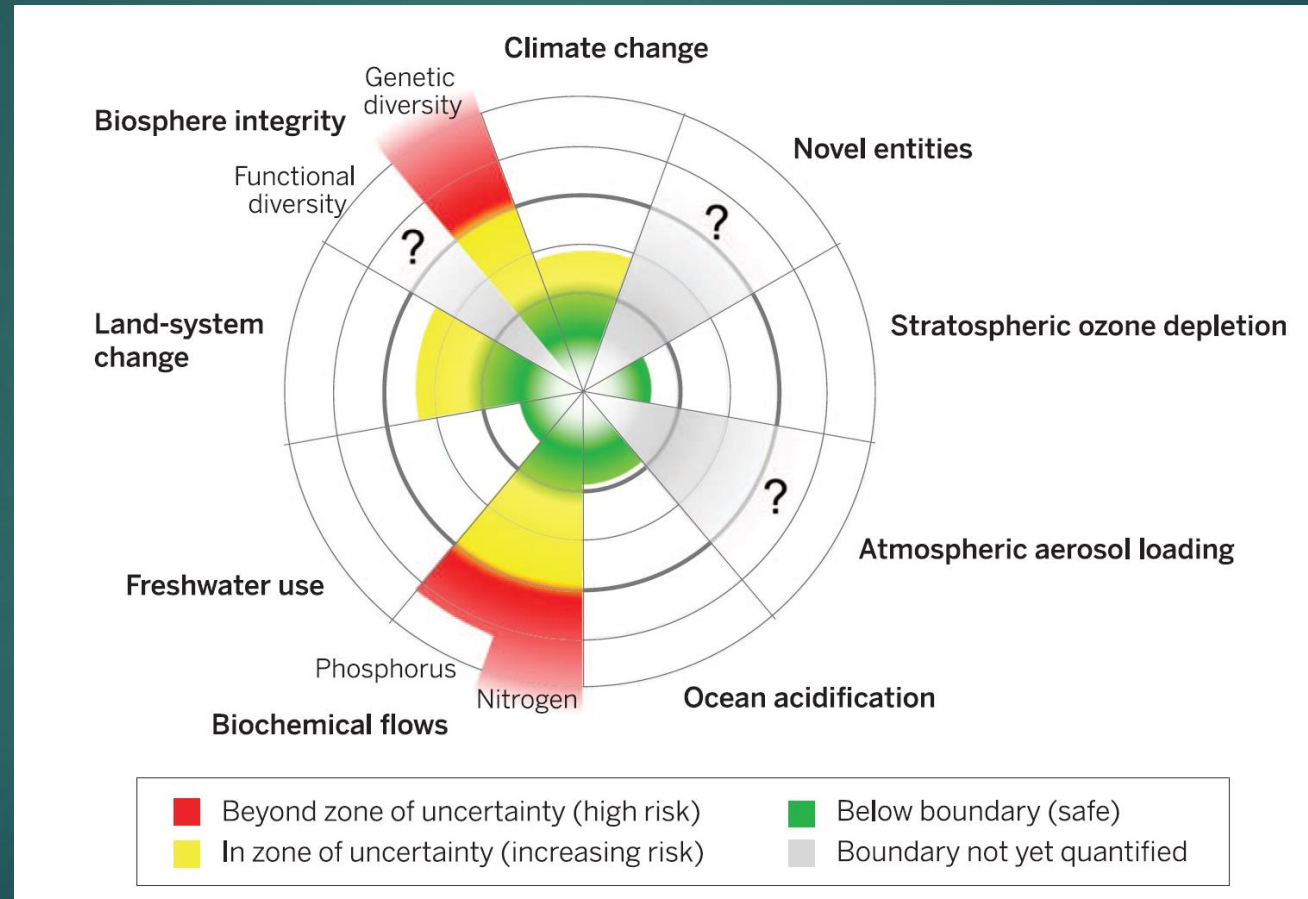


- Safe operating space
- Zone of uncertainty
- Dangerous level

Types of planetary boundaries



The planetary boundaries define a safe operating space for humanity



Activity in groups:

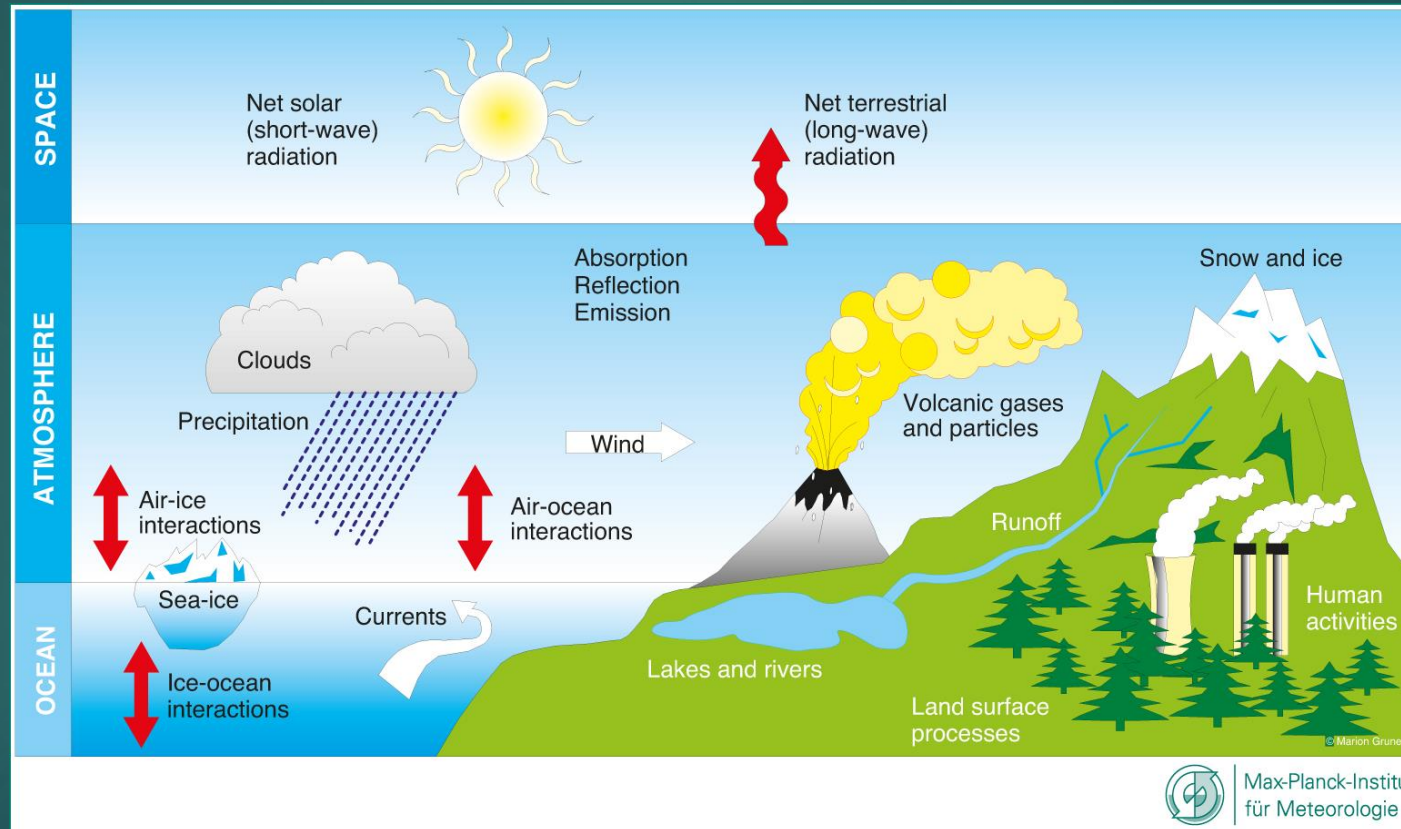
1- Discuss what & why are the boundaries proposed. How do they compare to the list you have done by the end of last section?

2- What is the control variable? Is it exceeded? By how much (% x-fold)?

What changed from the first to the second proposal?

Two of the planetary boundaries- climate change and biosphere integrity- are recognized as "core" based on their fundamental importance for the Earth system.

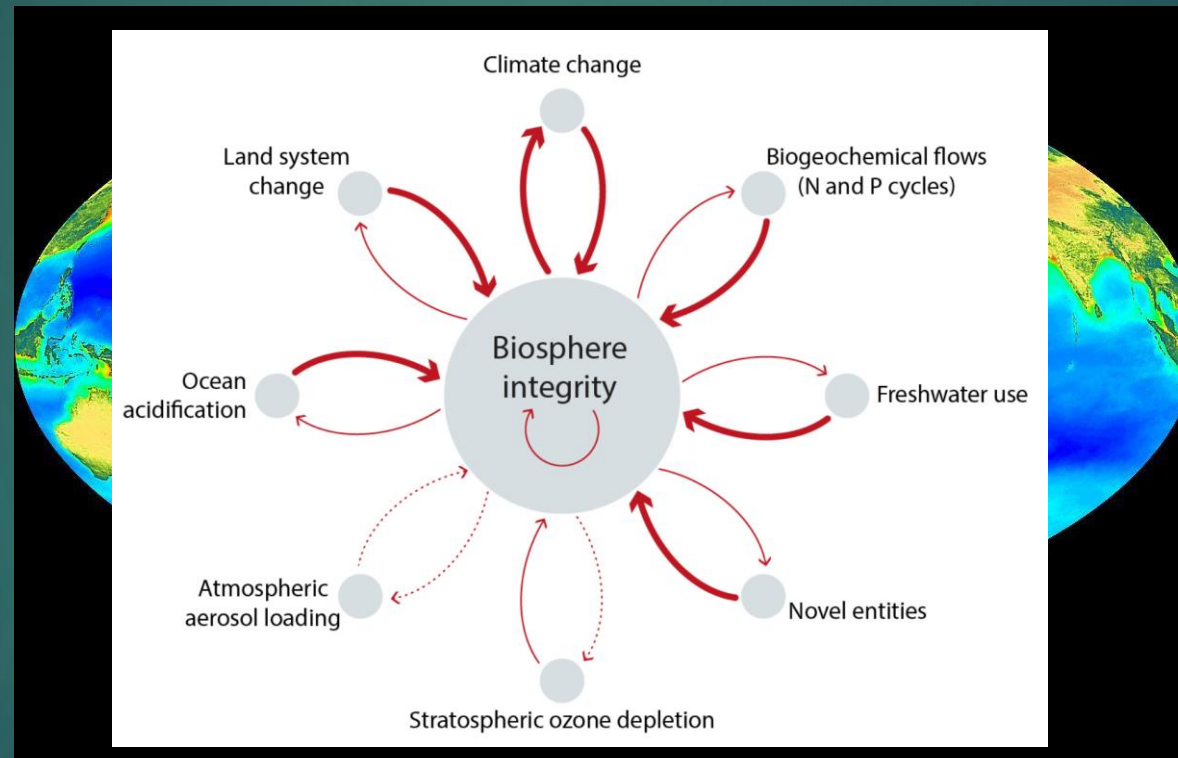
Core planetary boundary: Climate change



Activity: A group explains what & why are the boundaries proposed.

The climate system is a manifestation of the amount, distribution, and net balance of energy at Earth's surface. The total amount of energy sets the overall conditions for life.

Core planetary boundary: Biosphere integrity (Biodiversity loss)

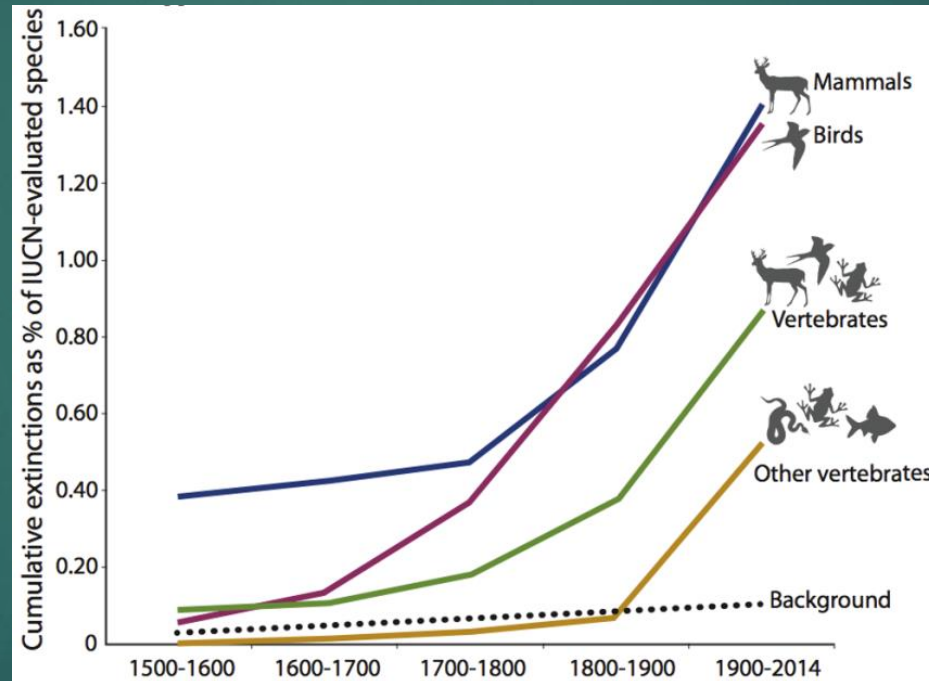


Activity: A group explains what & why are the boundaries proposed.

Biological diversity provides ecological functions that support biophysical sub-systems of the Earth, and thus the underlying resilience of other planetary boundaries.

DOI: <https://doi.org/10.1016/j.science.2019.06.005>

Changes in biosphere integrity: The extinction rate



Ceballos et al. Sci. Adv. 2015;1:e1400253

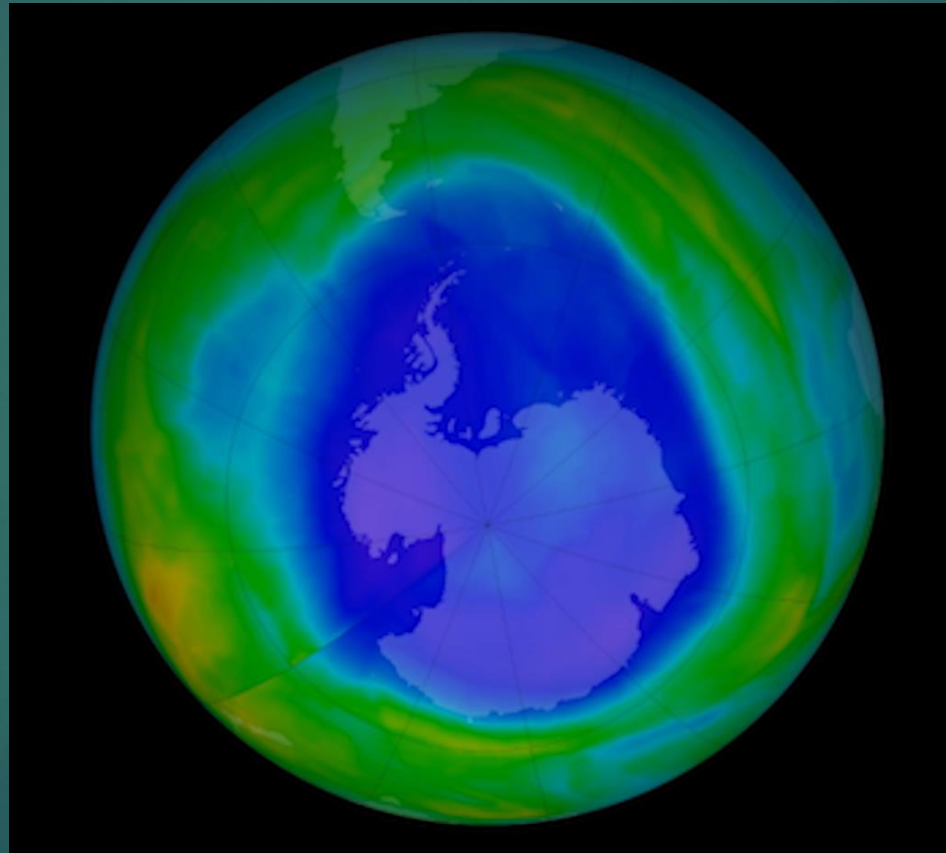
The current and projected rates of biodiversity loss constitute the sixth major extinction event in the history of life on Earth. This might have non-linear and largely irreversible consequences.

This safe boundary of biodiversity loss (1 E/MSY) is clearly being exceeded by at least one to two orders of magnitude, indicating an urgent need to radically reduce biodiversity loss rates.

Planetary boundary: Stratospheric ozone depletion

Activity: A group explains what & why are the boundaries proposed.

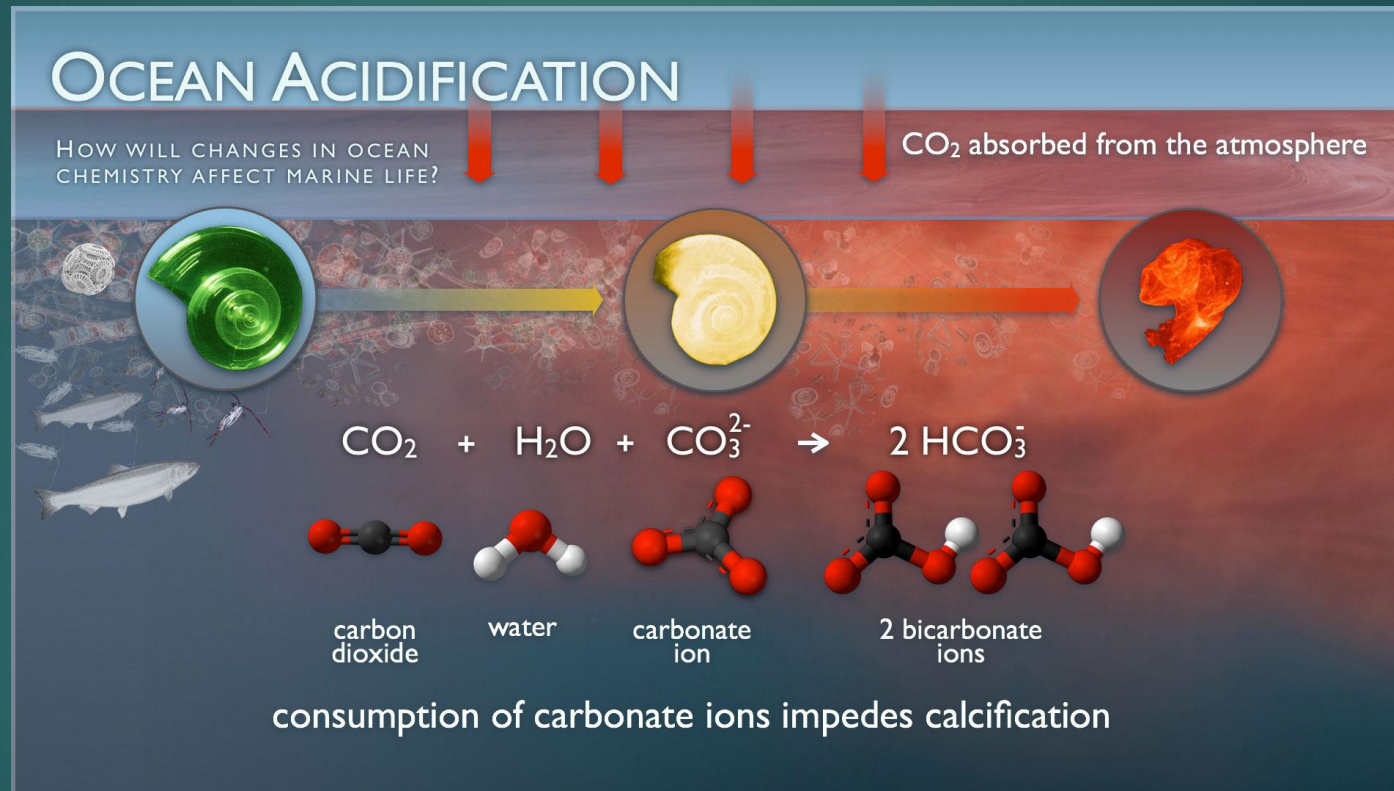
Fortunately, because of the actions taken as a result of the Montreal Protocol (and its subsequent amendments), we appear to be on a path that avoids transgression of this boundary.



<https://svs.gsfc.nasa.gov>

Stratospheric ozone filters ultraviolet radiation from the sun. The thinning of the Austral polar stratospheric ozone layer has negative impacts on marine and terrestrial life on Earth.

Planetary boundary: Ocean acidification



Activity: A group explains what & why are the boundaries proposed.

Ocean acidification poses a challenge to marine biodiversity and the ability of oceans to continue to function as a sink of CO₂ (~25% of human emissions).

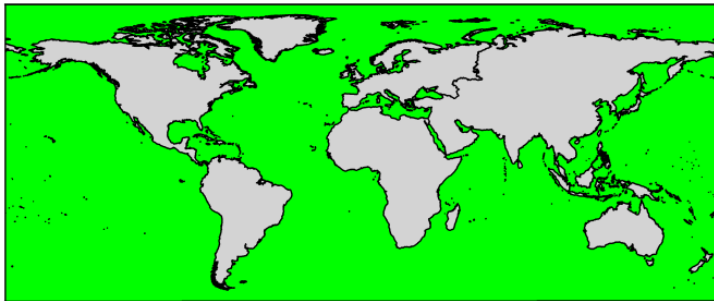
Addition of CO₂ to the oceans lowers pH of the surface seawater. Marine organisms are sensitive to changes in pH. Surface ocean pH has decreased by about 0.1 pH units (corresponding to a 30% increase in hydrogen ion concentration since pre-industrial times. This rate of acidification is at least 100 times faster than at any other time in the last 20 million years

www.pmel.noaa.gov

Ocean acidification: Past, present & future

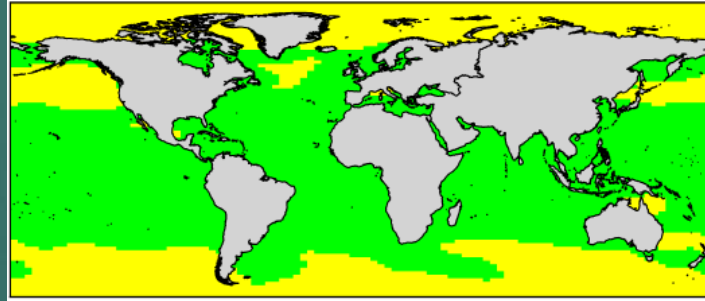
Pre-industrial state

(280 ppm CO₂ atm)



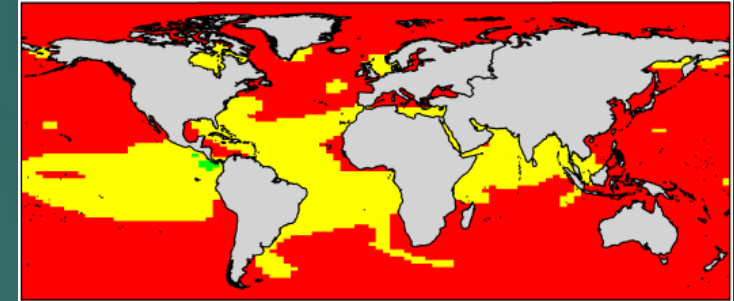
Current state

(~400 ppm CO₂ atm)



“Business as usual” state

(550 ppm CO₂ atm)

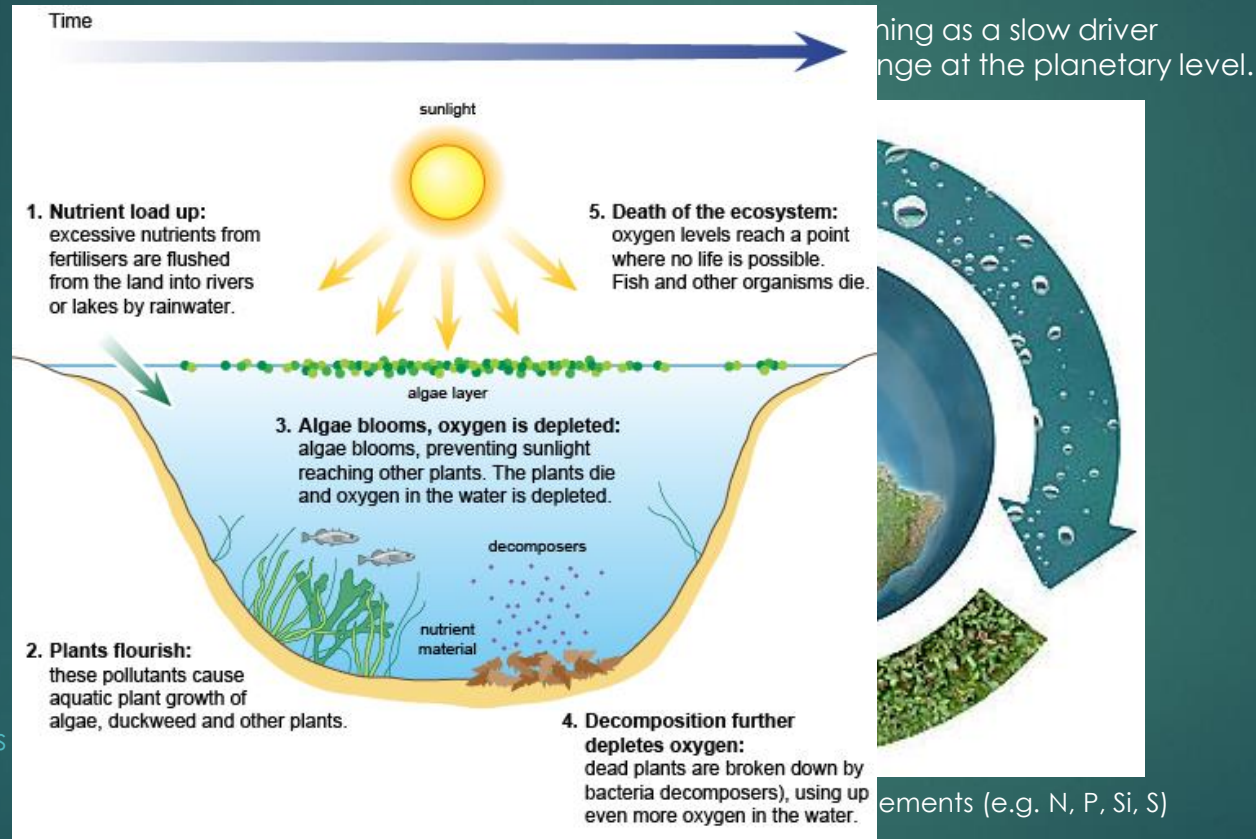


The ocean acidification boundary using as control variable aragonite saturation state

- Safe operating space Ω_{arag}
- Zone of uncertainty Ω_{arag}
- Dangerous level Ω_{arag}

DOI: [10.1126/science.1259855](https://doi.org/10.1126/science.1259855)

Planetary boundary: Biogeochemical flows



Activity: A group explains what & why are the boundaries proposed.

<http://www.bbc.co.uk>

Eutrophication due to human induced influxes of nitrogen & phosphorus push aquatic and marine systems across thresholds, generating abrupt non-linear change from, e.g. a clear-water oligotrophic state to a turbid-water eutrophic state

Agriculture: A major source of biogeochemical impacts



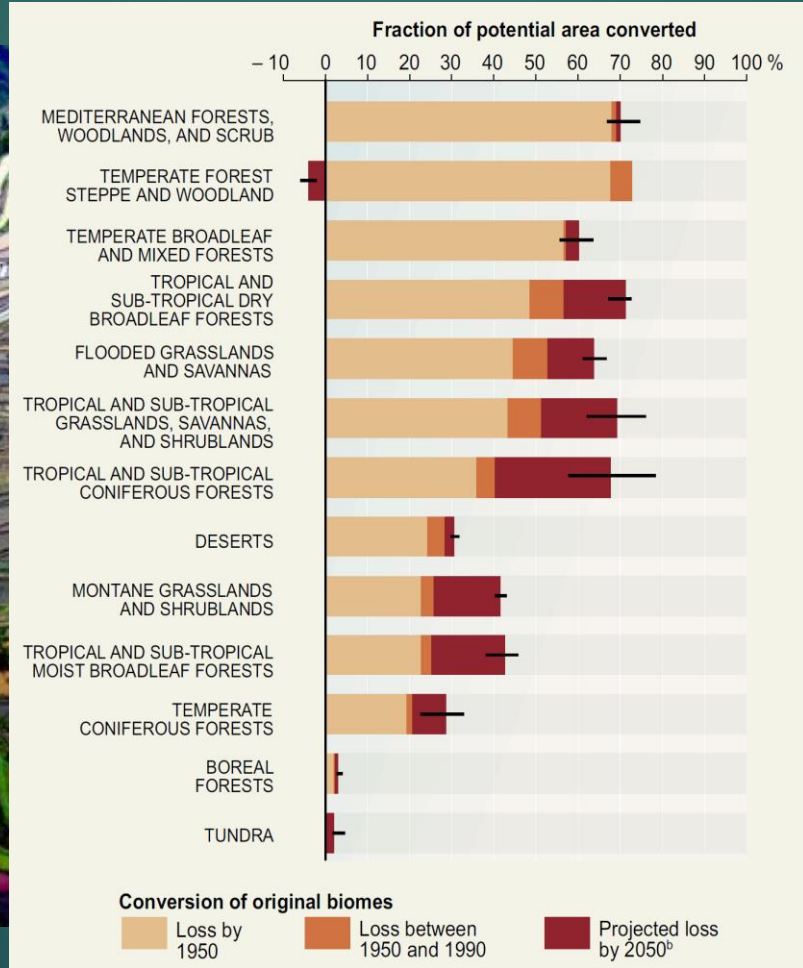
More information on N & P impacts on lecture about agriculture.

<https://gerenciaderiesgosyseguros.com>

Few agricultural regions of very high N & P application rates are the main contributors to the transgression of this boundary. A redistribution of fertilization from areas where it is currently in excess to areas where the soil is naturally poor may simultaneously boost global crop production and reduce the transgression of the N-P boundaries.

Planetary boundary: Land-system change

Another face of agriculture



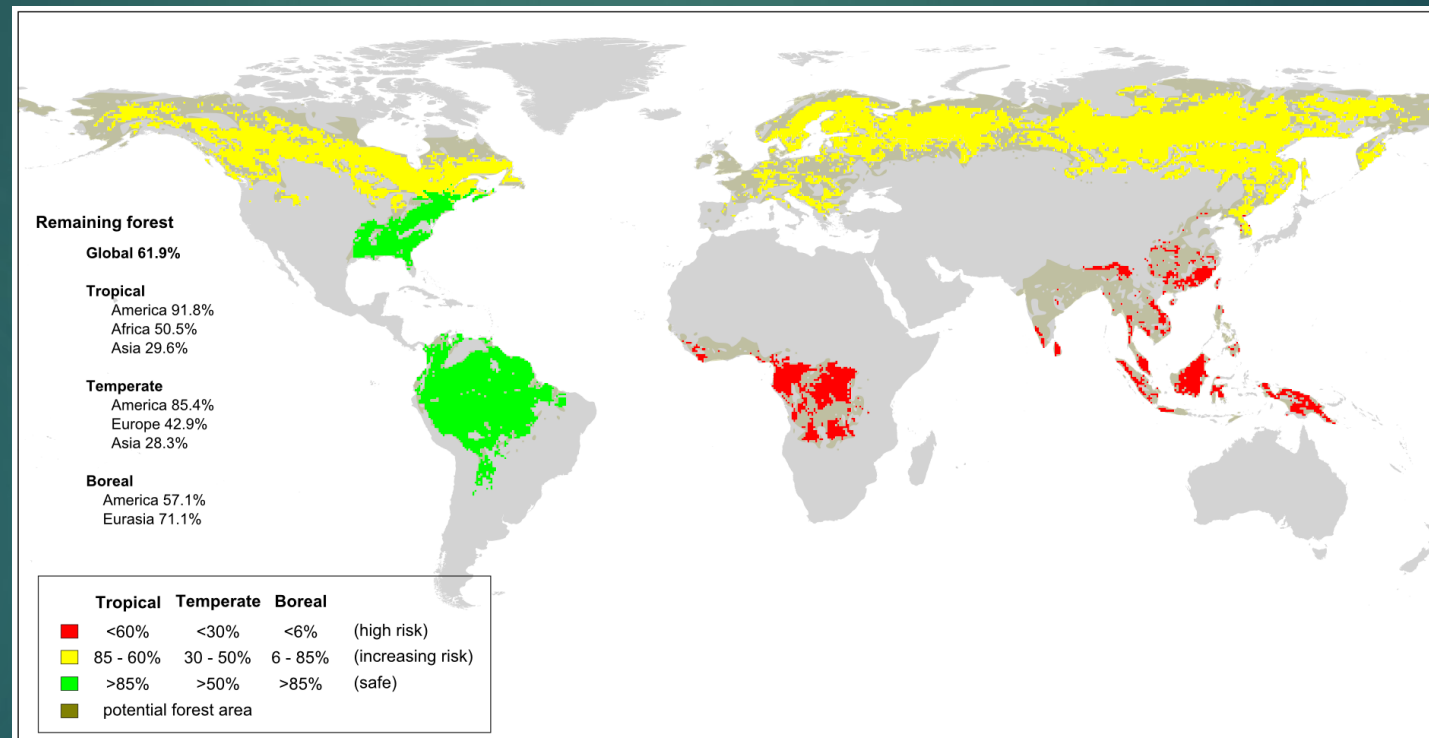
Activity: A group explains what & why are the boundaries proposed.

Cropland should be at the most productive areas, and processes that lead to the loss of productive land, such as land degradation, loss of irrigation water, and competition with land uses such as urban development or biofuel production, should be controlled.

Ecosystem conversion to agricultural land occurs at ~ 0.8 % yr⁻¹ over the past 40–50 years and is the major global driver behind loss of ecosystem functioning and services.

Land-system change

Forest cover remaining in the world's major continuous forest biomes



This boundary focuses on a specific constraint: the biogeophysical processes in land systems that directly regulate climate—exchange of energy, water, and momentum between the land surface and the Atmosphere.

DOI: 10.1126/science.1259855

The biosphere integrity boundary provides a considerable constraint on the amount and pattern of land-system change in all terrestrial biomes.

Planetary boundary: Freshwater use



Activity: A group explains what & why are the boundaries proposed.

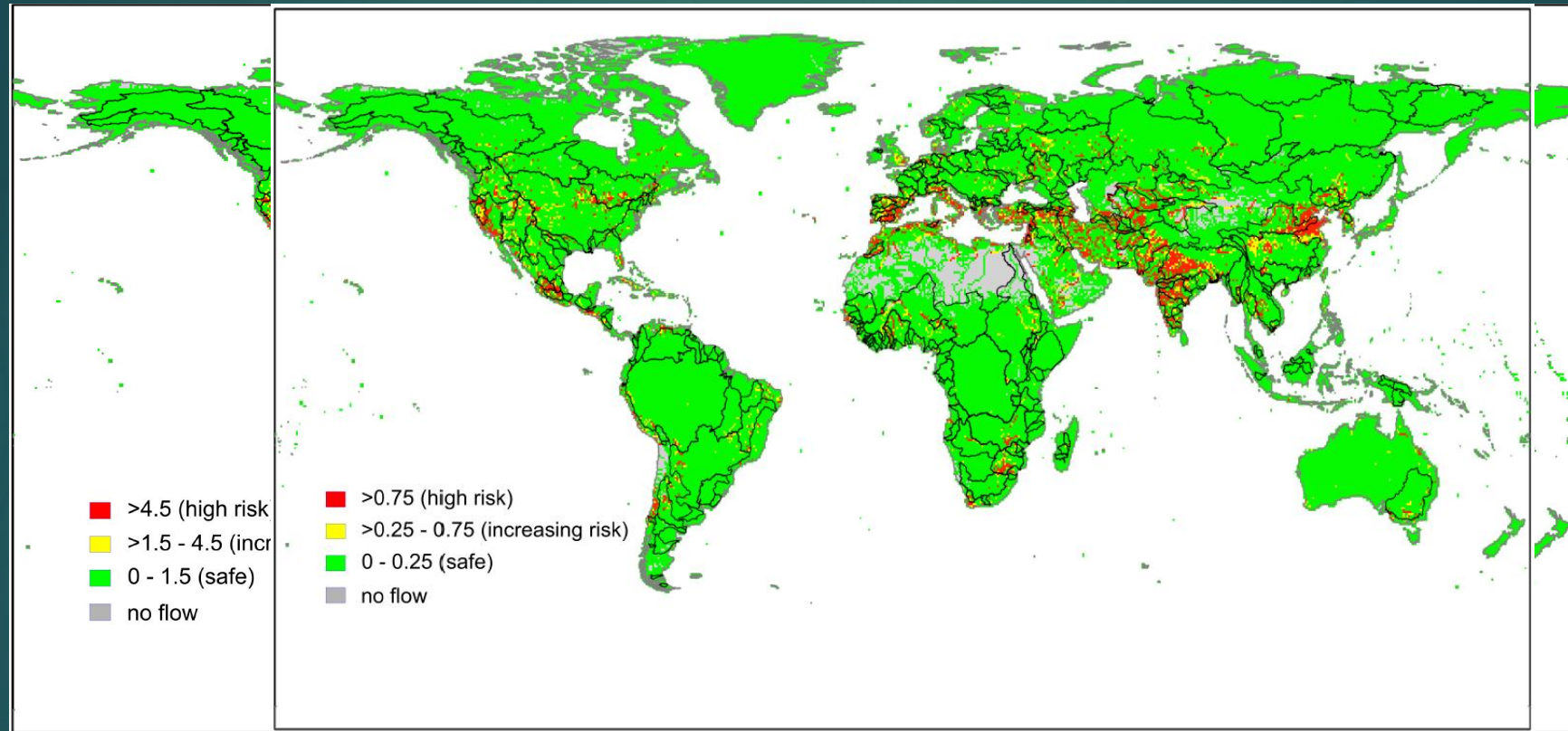
Risk: collapse of terrestrial and aquatic ecosystems, major shifts in moisture feedback, and freshwater/ocean mixing at regional to continental scales.

About 90% of global green water flows are required to sustain critical ecosystem services, whereas 20%– 50% of the mean annual blue water flows in river basins are required to sustain aquatic ecosystem functioning.

<http://riosvoadores.com.br/english/>

25% of the world's river basins run dry before reaching the oceans due to use of freshwater resources in the basins

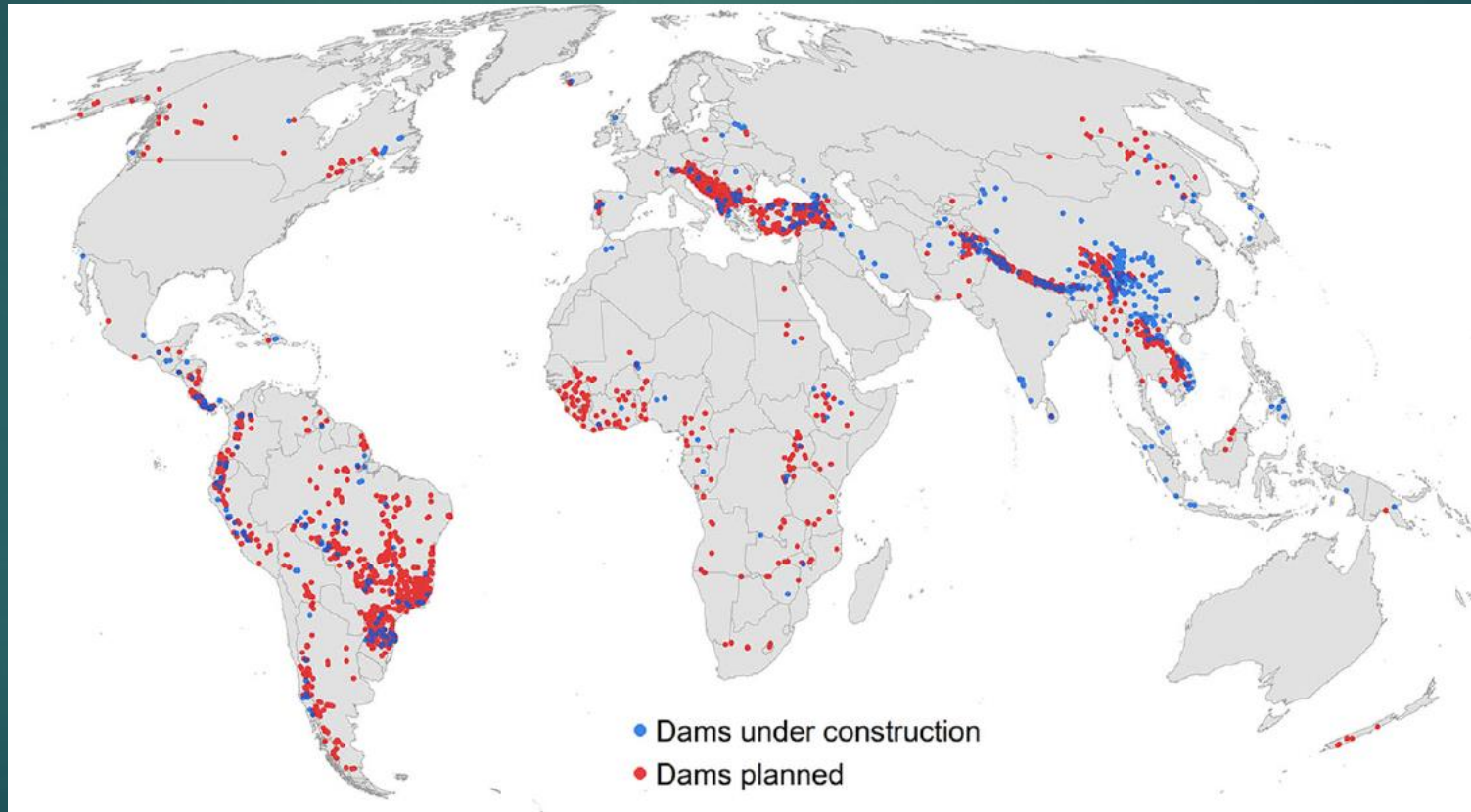
Where freshwater use boundary is transgressed



DOI: 10.1126/science.1259855

Green water use in rainfed agriculture, currently estimated at $\sim 5000 \text{ km}^3 \text{ yr}^{-1}$, may have to increase by 50 % by 2030 in order to ensure food security, whereas consumptive blue water use for irrigation may increase by 25%–50%, corresponding to $400\text{--}800 \text{ km}^3 \text{ yr}^{-1}$ by 2050

Fresh water environmental services: Are they really safe?



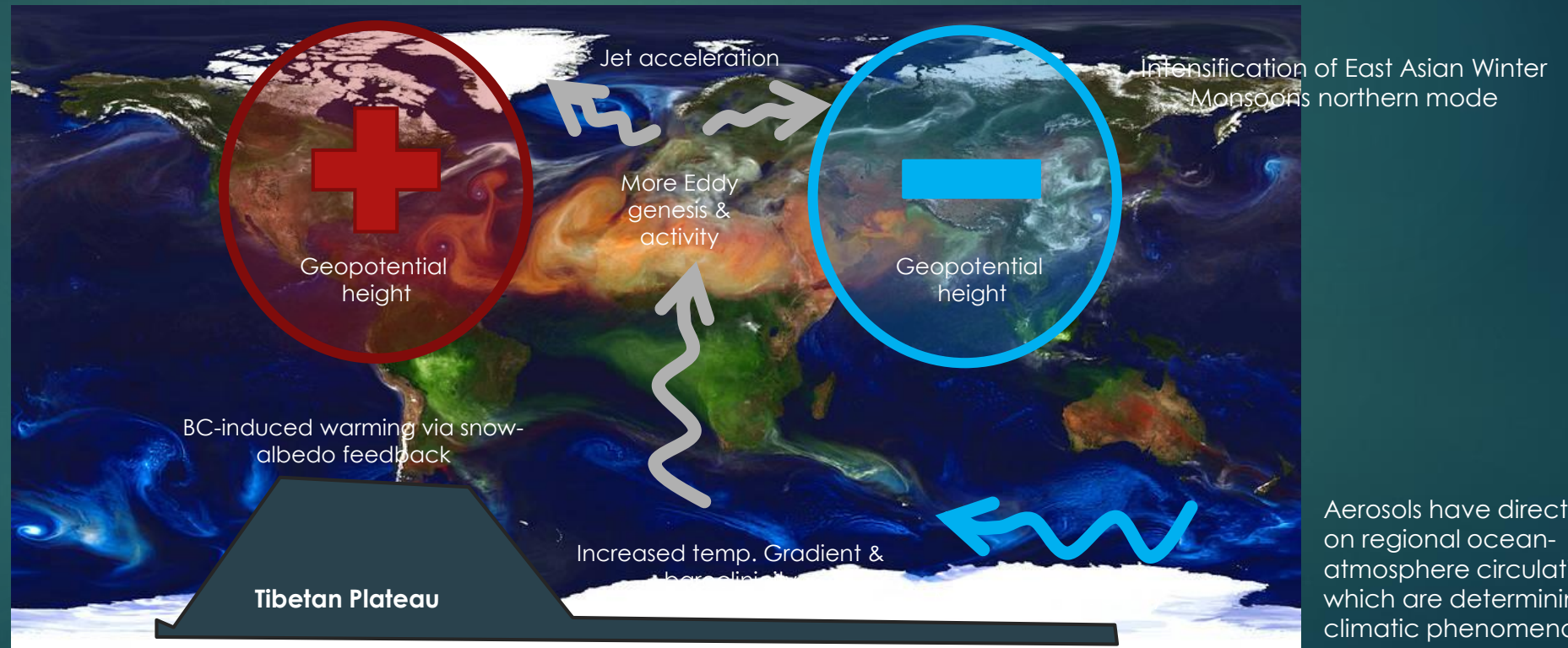
Dams change the regional climate, cause habitat fragmentation and sound pollution.

Global spatial distribution of future hydropower dams, either under construction (blue dots 17 %) or planned (red dots 83 %)

doi:10.1007/s00027-014-0377-0

Planetary boundary: Atmospheric aerosol loading

Aerosols affect the functioning of the Earth system in many ways.



Activity: A group explains what & why are the boundaries proposed.

Aerosols have direct effects on regional ocean-atmosphere circulation, which are determining many climatic phenomena.

20°N https://www.nasa.gov/multimedia/imagegallery/image_feature_23960.html 40°N 60°N

BC-deposition & snow darkening

Planetary boundary: Introduction of novel entities

Activity: A group explains what & why are the boundaries proposed.

Scientific challenges:

- Chemicals with unknown disruptive effect on vital Earth-system process
- Disruptive effect may not discovered until it is a problem at the global scale
- Effect may not be readily reversible
- Database for timely screening of chemicals
- Which boundary?



<http://medlarge.com>

The novel entities might display:

- Persistence
- Mobility across scales with consequent widespread distributions
- Potential impacts on vital Earth-system processes or subsystems

Originally as chemical pollution, the revised version of this planetary boundary is referring to new substances, new forms of existing substances, and modified life forms that have the potential for unwanted geophysical and/or biological effects.

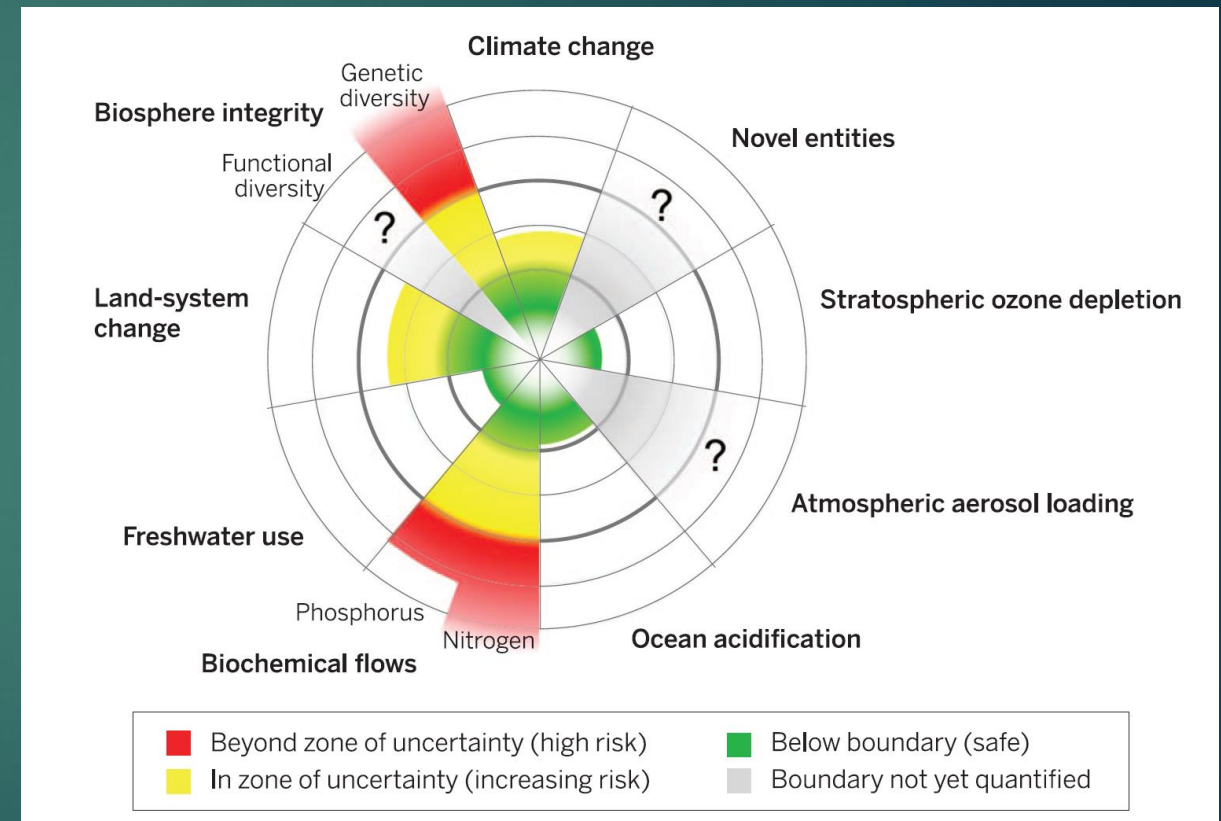
Planetary boundaries in a societal context

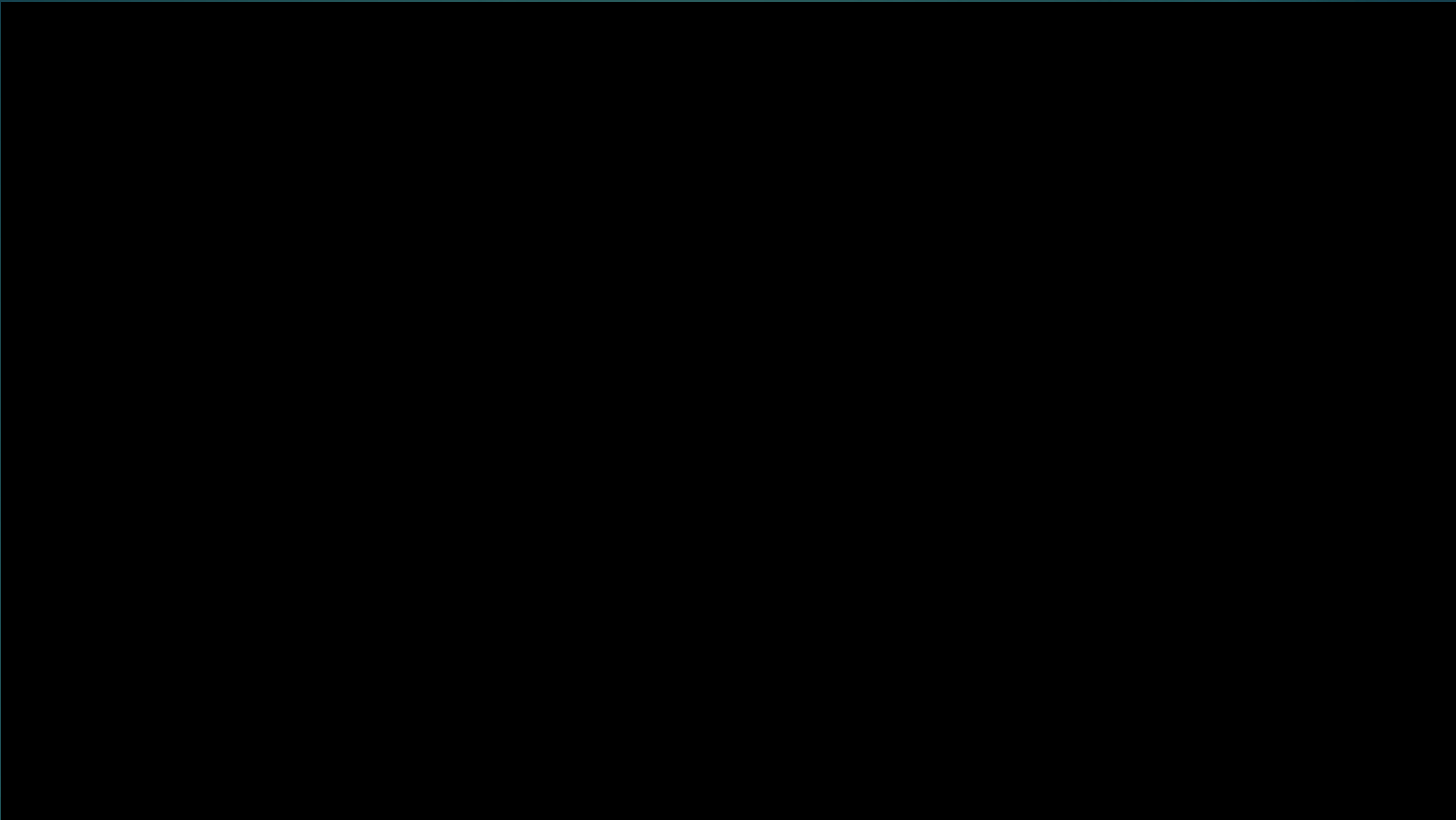
- ▶ The prospect of tighter resource constraints and rising environmental hazards is also unavoidably turning the focus onto global social equity and the planetary stewardship of Earth's life-support system.
- ▶ It is easy to foresee that uneven distribution of causation and benefits will continue, and these differentials must surely be addressed for a Holocene-like Earth-system state to be successfully legitimated and maintained.
- ▶ PB says what (but not how) to manage.
- ▶ PB framework (or something like it) will need to be implemented alongside the achievement of targets aimed at more immediate human needs, such as provision of clean, affordable, and accessible energy and the adequate supply of food.



Summary: Planetary boundaries

- ▶ PBs are scientifically based levels of human perturbation of the ES beyond which ES functioning may be substantially altered.
- ▶ Transgression of the PBs thus destabilizes the Holocene state.
- ▶ Nine boundaries are currently proposed by identifying a safe operating space for humanity on Earth.
- ▶ PB framework does not dictate how societies should develop.





Thanks

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