Fundamentals of digital and ecological transitions

Applied ecology and climate change

Lesson 5

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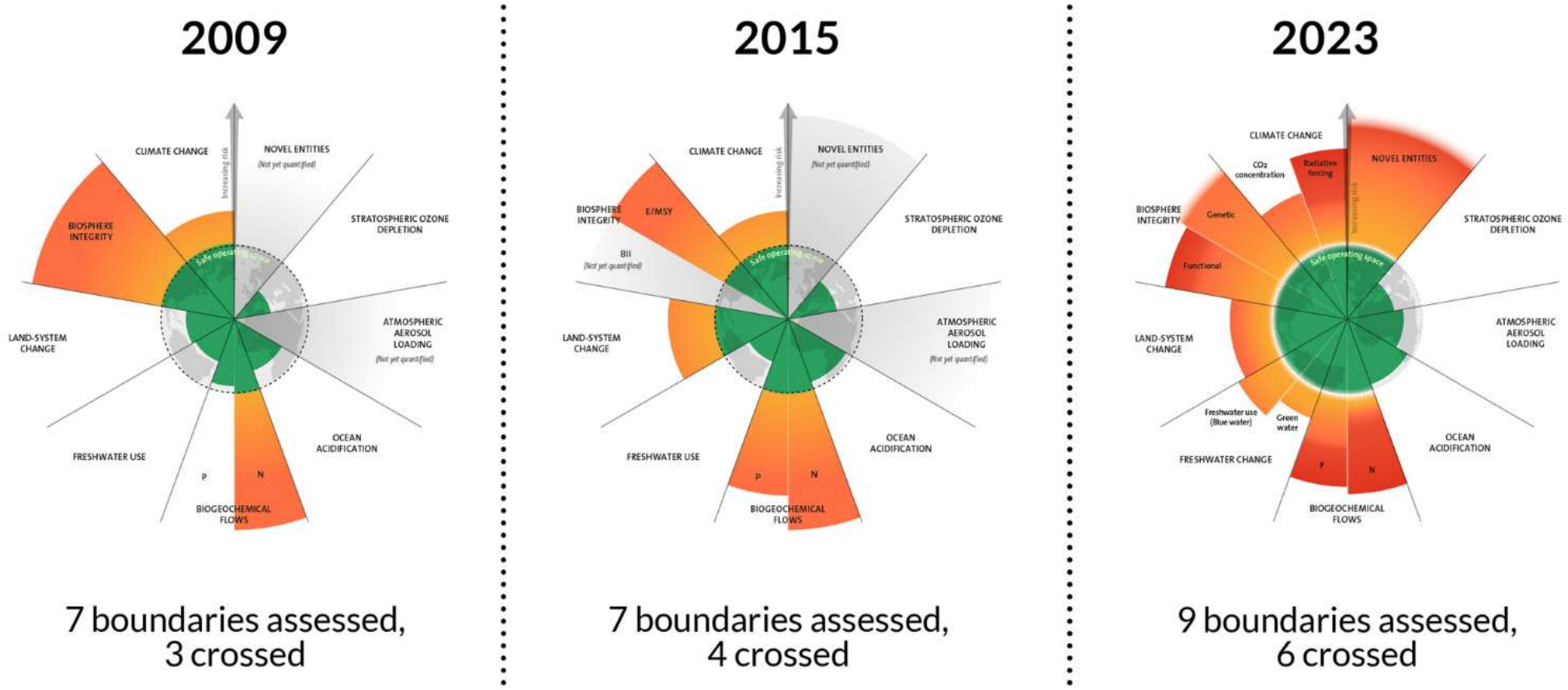
Planetary boundaries

- In September 2023, a team of scientists quantified, for the first time, all nine processes that regulate the stability and resilience of the Earth system.

- Planetary boundaries are a framework to describe limits to the impacts of human activities on the Earth system. Beyond these limits, the environment may not be able to self-regulate anymore.

These nine Planetary Boundaries were first proposed by former centre director Johan Rockström and a group of 28 internationally renowned scientists in 2009.



The evolution of the planetary boundaries framework. Licenced under CC BY-NC-ND 3.0 (Credit: Azote for Stockholm Resilience Centre, Stockholm University. Based on Richardson et al. 2023, Steffen et al. 2015, and Rockström et al. 2009) Click on the image to download.

Boundaries are the safe limits for human pressure on the nine critical processes which together maintain a stable and resilient Earth.

The 2023 update not only quantified all boundaries, it also concluded that six of the nine boundaries have been transgressed.

Planetary Boundaries are interdependent, meaning that if we cross one Boundary, we will affect others, or even cause them to cross out of the safe operating space.

Over the years, the planetary boundaries framework has generated enormous interest within science, policy, and practice.

Has the diversity an influence on the stability of an ecosystem?

- Charles Elton who first proposed (in the 1950s) that a **more complex and rich ecosystem** should also be **more stable**, meaning that it was **less prone to violent fluctuations** such as those caused by epidemic disease or pest outbreaks

- a **species** in a diverse ecosystem is **no less subject to fluctuations** caused by unfortunate events, such as drought or disease, than is a species in a simple ecosystem.

- On the conservation side, the loss of global biodiversity that we are currently experiencing may well be affecting the **functioning of the entire biosphere**: i.e. In the field of agriculture, the use of multi-cropping systems rather than single-species stands can provide advantages in terms of both productivity and stability of the system, which is a particular concern in marginal areas, such as arid regions.

- Some confusion can arise because of the different ways in which the term **diversity** is used.
- often, it is simply used as an alternative to the number of species present within an ecosystem: **species richness**

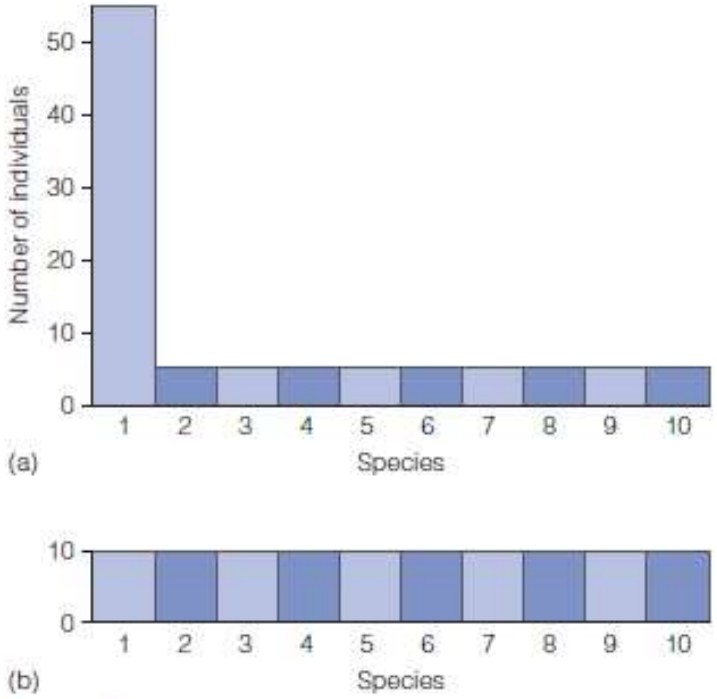


Figure 3.5 Hypothetical community of 10 species and 100 individuals. In (a), one species dominates; and in (b), all species have equal representation. It can be argued that (b) represents the more diverse of the two communities despite their having identical species richness.

What precisely do we mean by **stability**?

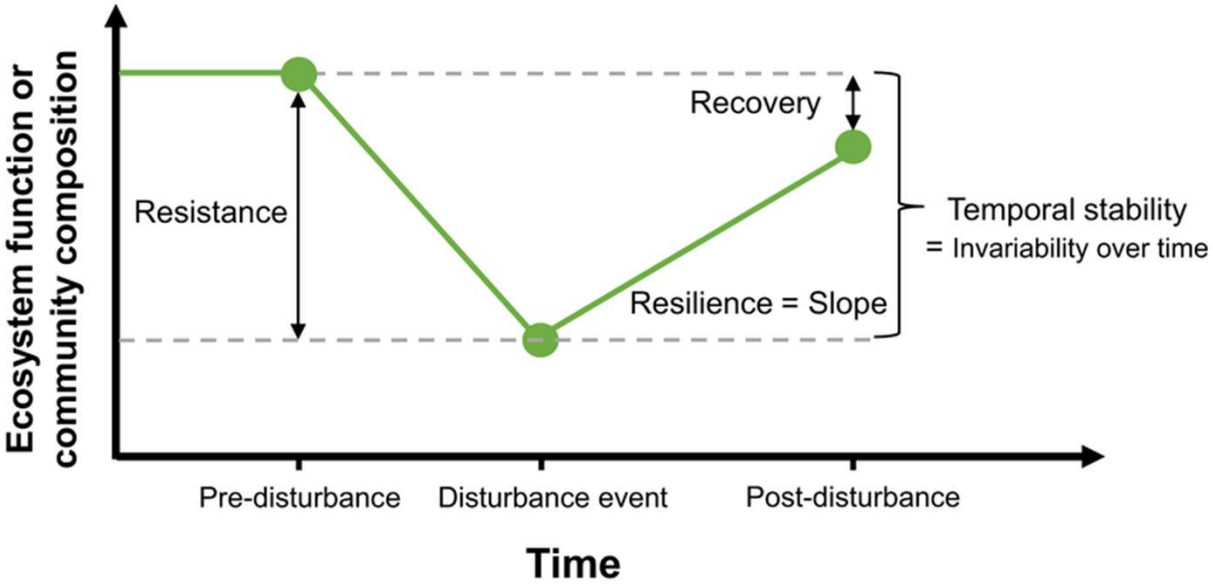
- Is a stable ecosystem one which is difficult to deflect from its current composition or function?

- Stability can be explained in terms of **inertia**, or **resistance** to change

- Alternatively, a stable ecosystem could be defined as one which rapidly returns to its original state following disturbance → this uses the concept of **resilience** as a basis for defining stability.

- A **stable ecosystem** should behave in a **predictable manner** no matter what fate may cast in its path, and biodiversity does appear to render an ecosystem predictable by providing a kind of '**biological insurance**' against the failure of certain sensitive species when exposed to particular stresses.

Responses of an ecosystem to disturbance



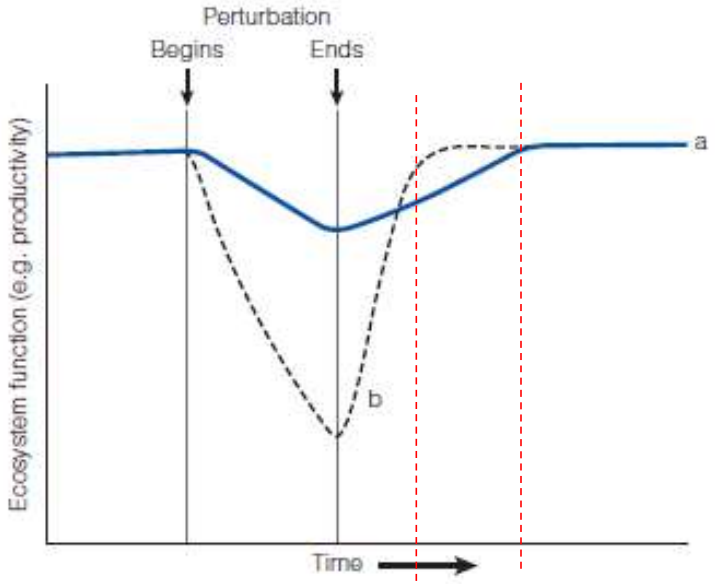
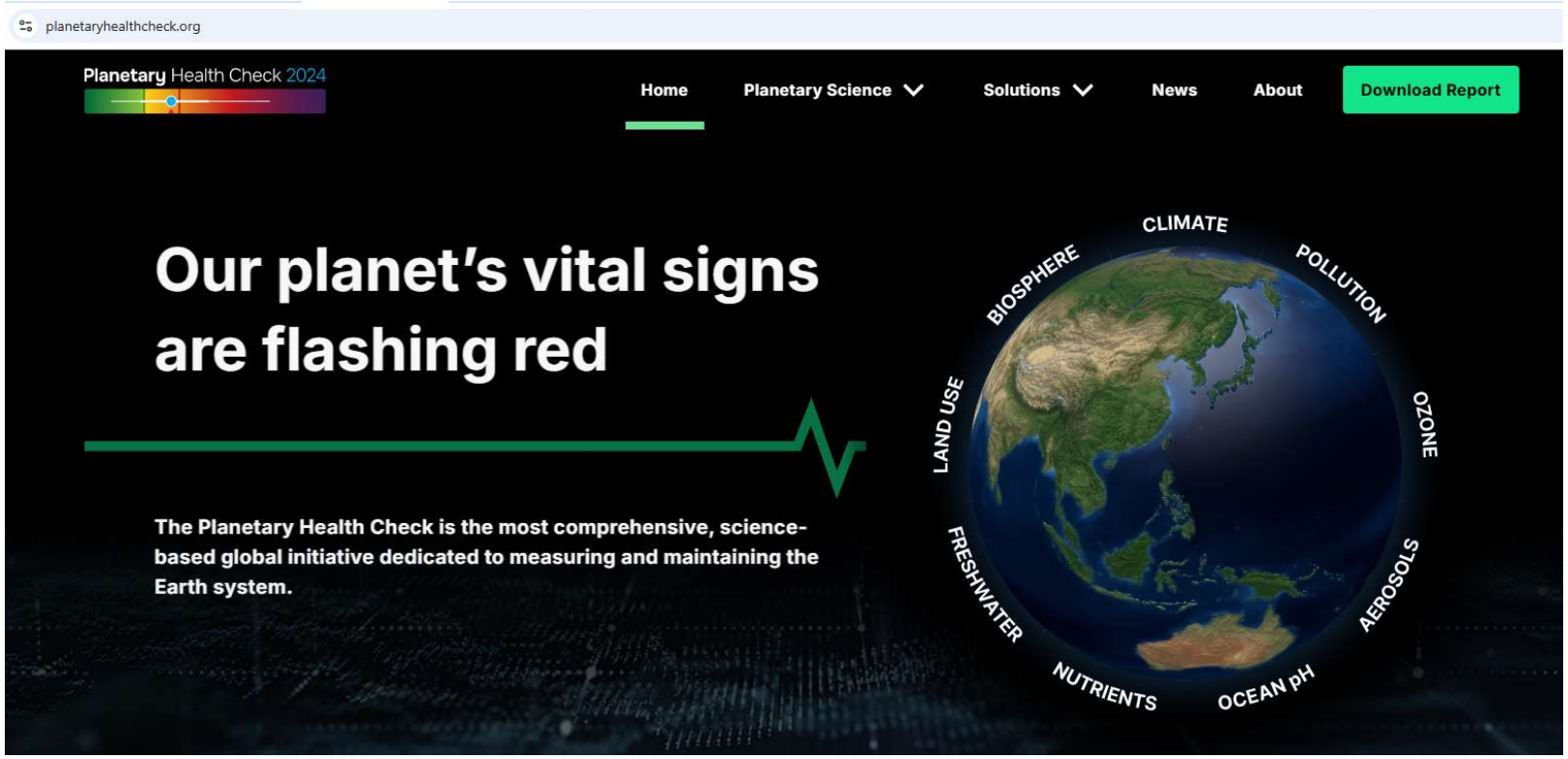


Figure 3.6 Two possible responses of an ecosystem to disturbance. Line a (solid) represents an ecosystem that is resistant to perturbation. Its response to disturbance is slower and less severe, but its return to its original state is slow. Line b (dashed) shows a resilient ecosystem that is more severely affected by the disturbance, but rapidly returns to its original state. Either could be regarded as an illustration of ecosystem stability. Adapted from Leps [16].

- Since September 2024, the Potsdam Institute for Climate Impact Research produces a yearly update to the framework, called the Planetary Health Check.

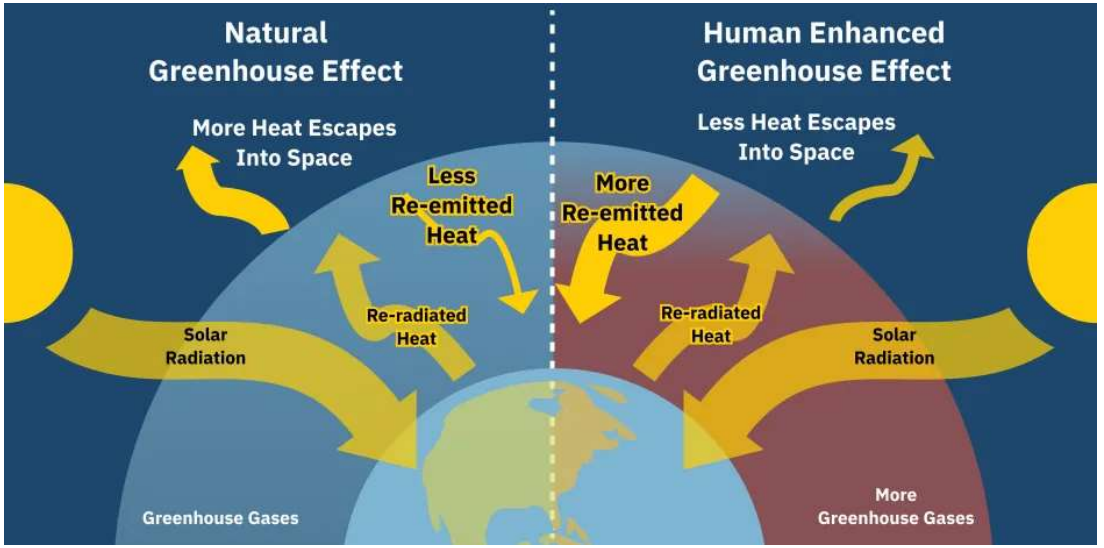


The nine planetary boundaries and their status

Climate change

The change in the ratio of incoming and outgoing energy of the Earth, caused by increased greenhouse gasses and aerosols. More trapped radiation causes an increase in global temperatures and alters climate patterns.

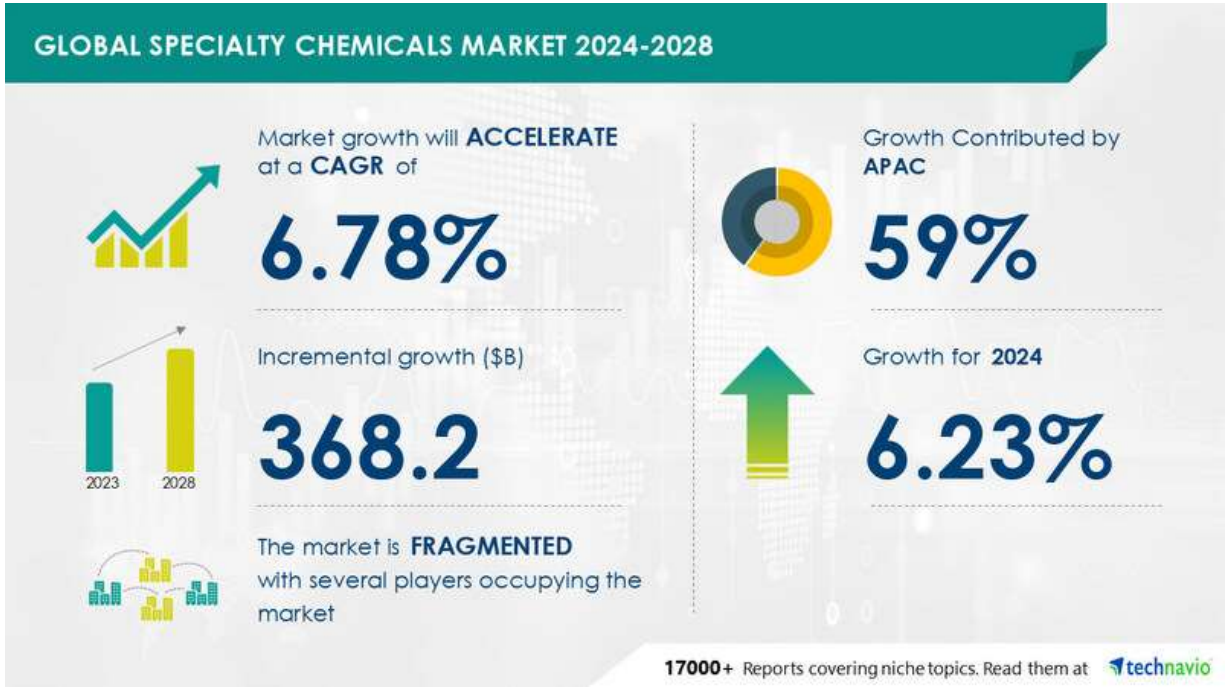
This boundary is transgressed.



Novel entities

The introduction of novel entities includes synthetic chemicals and substances (e.g. microplastics, endocrine disruptors, organic pollutants), anthropogenically mobilized radioactive materials (e.g. nuclear waste, nuclear weapons), and human interventions in evolutionary processes, such as genetically modified organisms (GMOs) and other direct modifications of evolution.

Currently, the amount of synthetic substances released into the environment without adequate testing is above the safe level.



Endocrine-disrupting chemicals (EDCs)

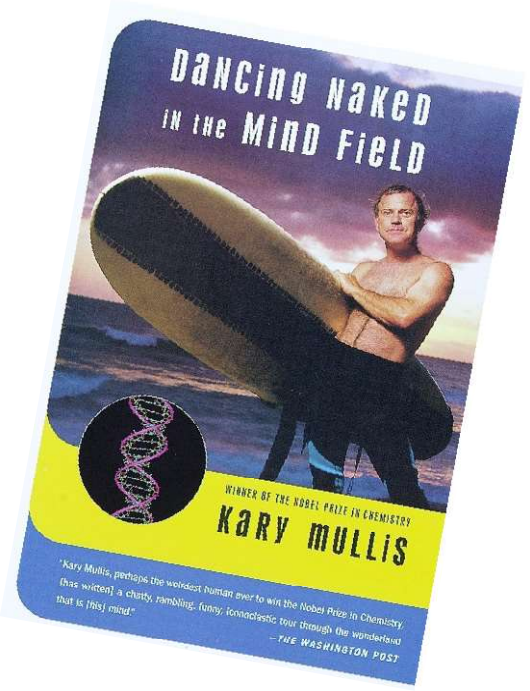
There are more than 16,000 chemicals used in plastics manufacturing, and over 1,000 industrial chemicals used today are suspected EDCs. But aside from a small percentage of substances that are regulated, plastic producers aren't required to disclose the chemical ingredients they use.

The translucent exterior of a plastic soda bottle hides a secret in plain sight: hundreds of synthetic chemicals embedded in its seemingly innocuous material. These chemicals give the plastic its structure, flexibility and durability, among other qualities—the same traits that also make plastic last for centuries, causing it to accumulate and endure in nature.

Stratospheric ozone depletion

The stratospheric ozone layer protects life on Earth from harmful ultraviolet radiation. The thinning of the ozone layer in the upper atmosphere, primarily due to human-made chemicals, allows more harmful UV radiation to reach Earth's surface.

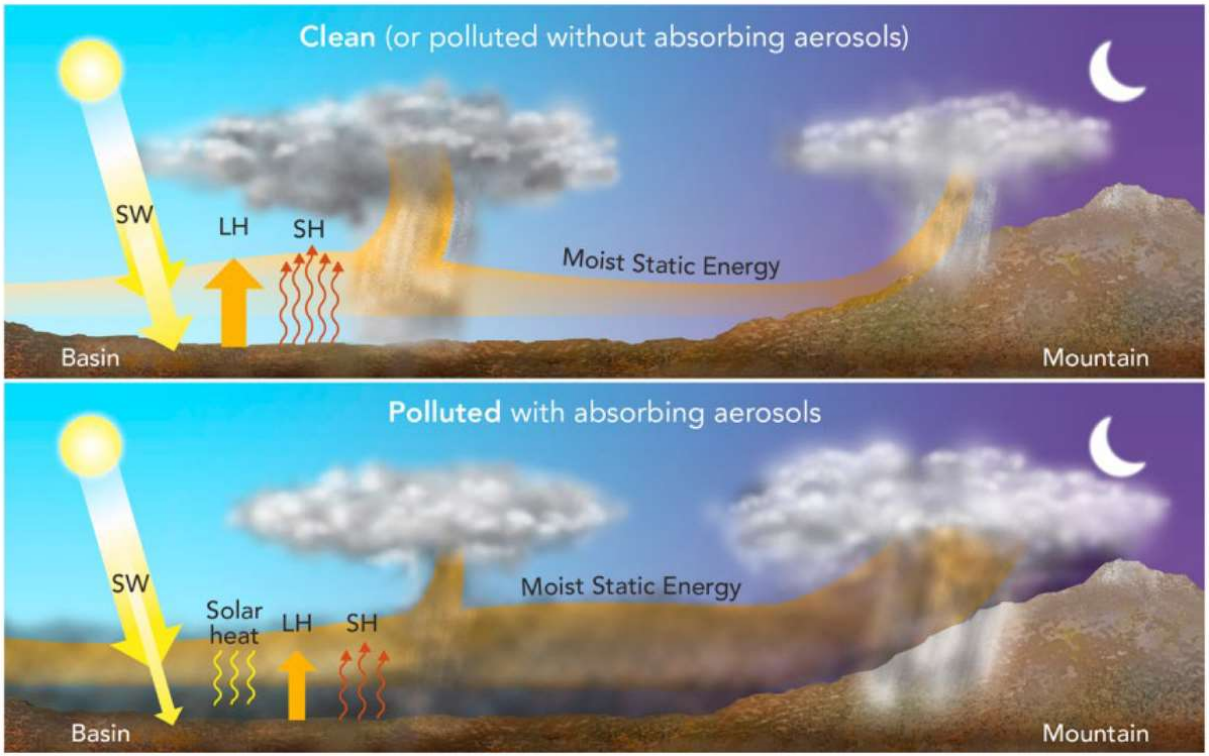
The current total amount of stratospheric ozone is within safe levels, and recovery is ongoing, with values still below mid-20th century levels.



Atmospheric aerosol loading

The rise in airborne particles from human activities or natural sources influences the climate by altering temperature and precipitation patterns.

Currently, the interhemispheric difference in atmospheric aerosol loading is within the Safe Operating Space.

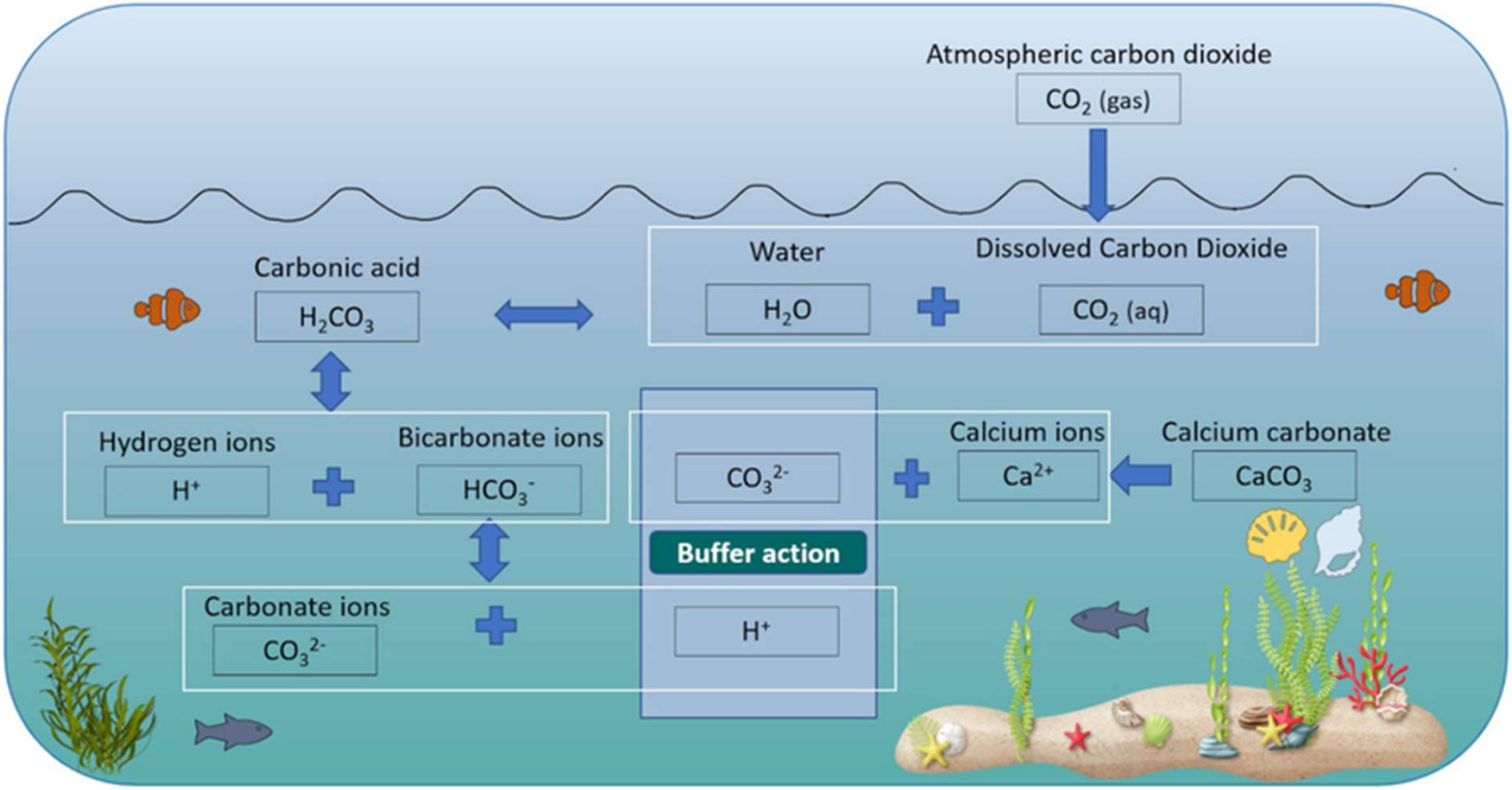


Ocean acidification

Ocean acidification is the phenomenon of increasing acidity (decreasing pH) in ocean water due to the absorption of atmospheric CO_2. This process harms calcifying organisms, impacting marine ecosystems, and reduces the ocean's efficiency in acting as a carbon sink.

The indicator for Ocean Acidification, the current aragonite saturation state, is within the Safe Operating Space but is close to crossing the safe boundary.

Ocean acidification



Modification of biogeochemical flows

The disruption of the natural nutrient cycles of key elements like nitrogen, and phosphorus through the environment and organisms, which are crucial for supporting life and maintaining ecosystems.

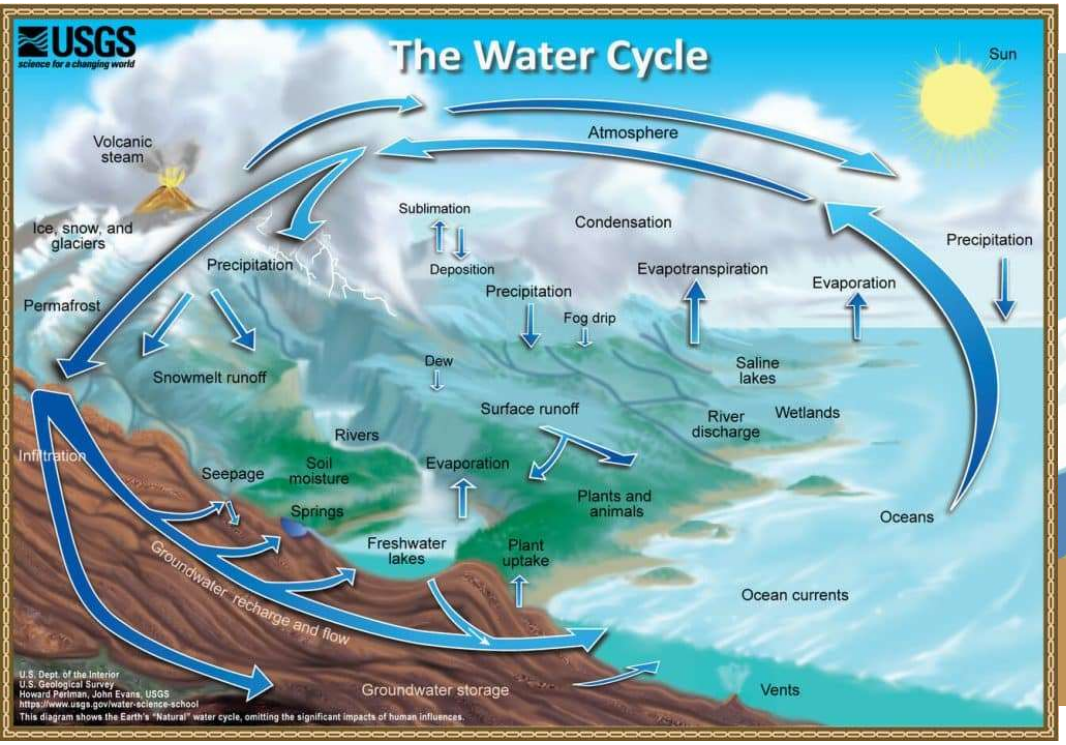
Both the global phosphorus flow into the ocean and the industrial fixation of nitrogen (extracting nitrogen from the atmosphere), are disrupting the corresponding nutrient cycles beyond the safe level.

Freshwater change

The alteration of freshwater cycles, including rivers and soil moisture, impacts natural functions such as carbon sequestration and biodiversity, and can lead to shifts in precipitation levels.

Human-induced disturbances of both blue water (e.g. rivers and lakes) and green water (i.e. soil moisture) have exceeded the safe level.

The consequences of climate change on terrestrial ecosystems and human societies are primarily experienced through changes to the global water cycle



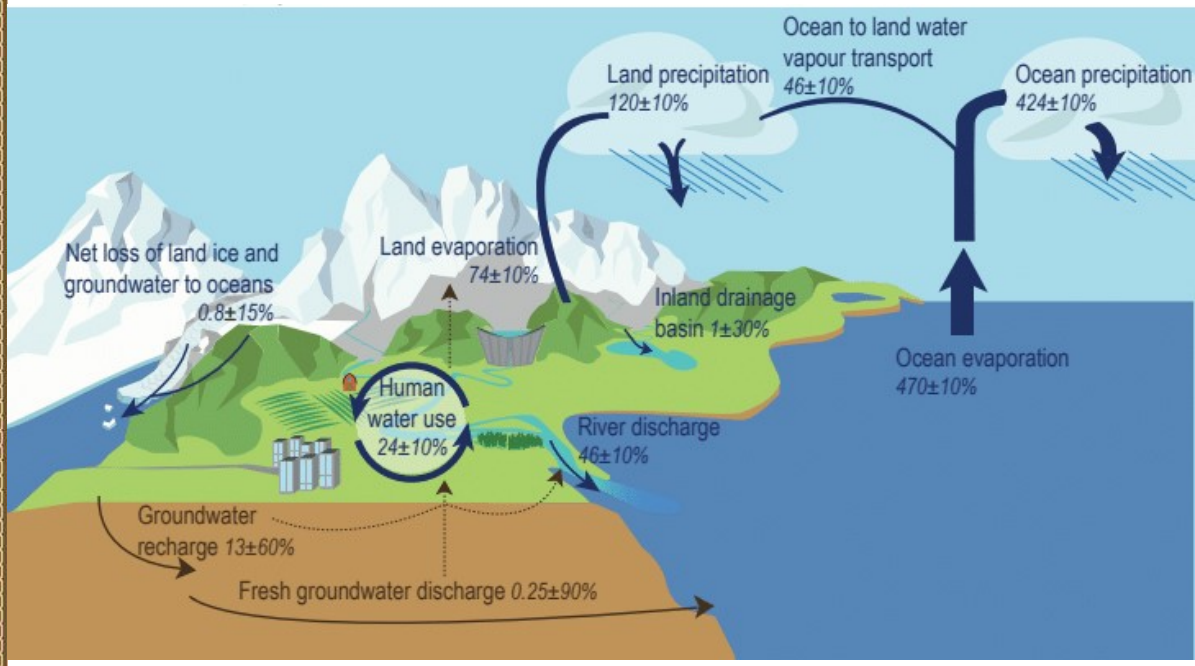
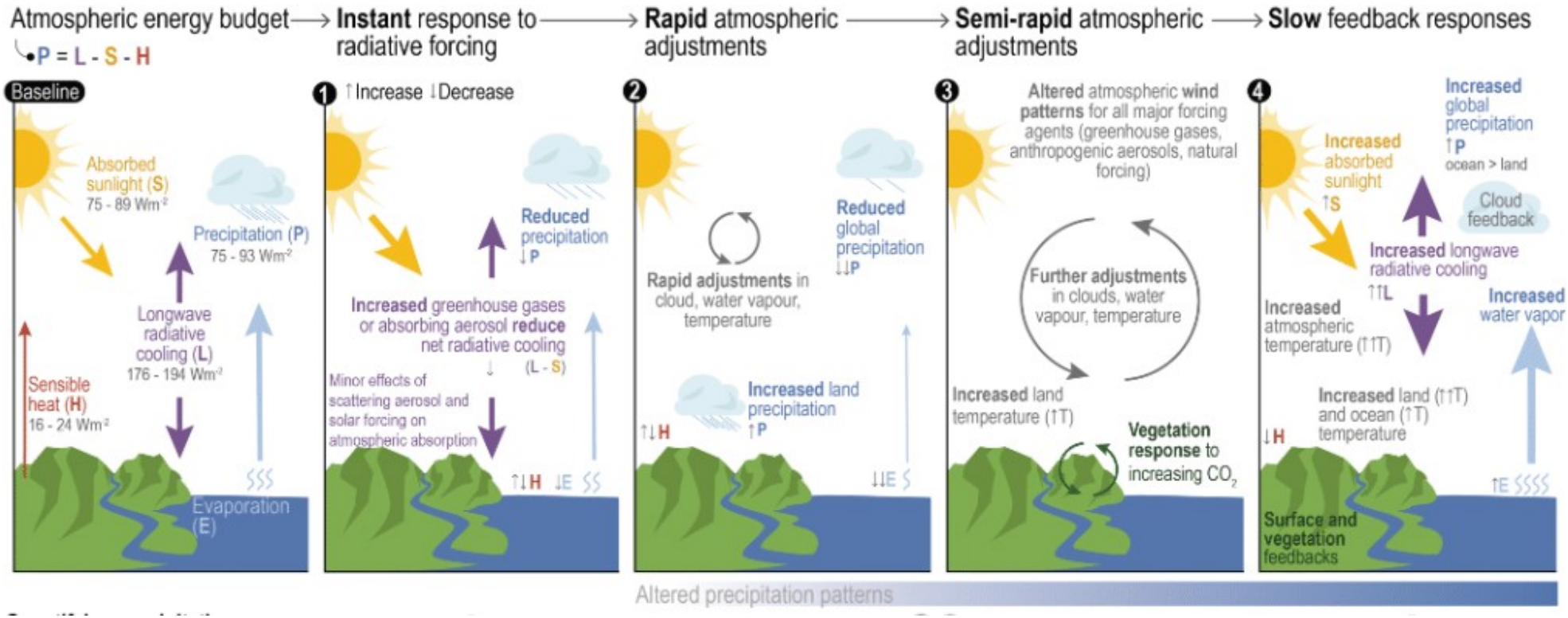
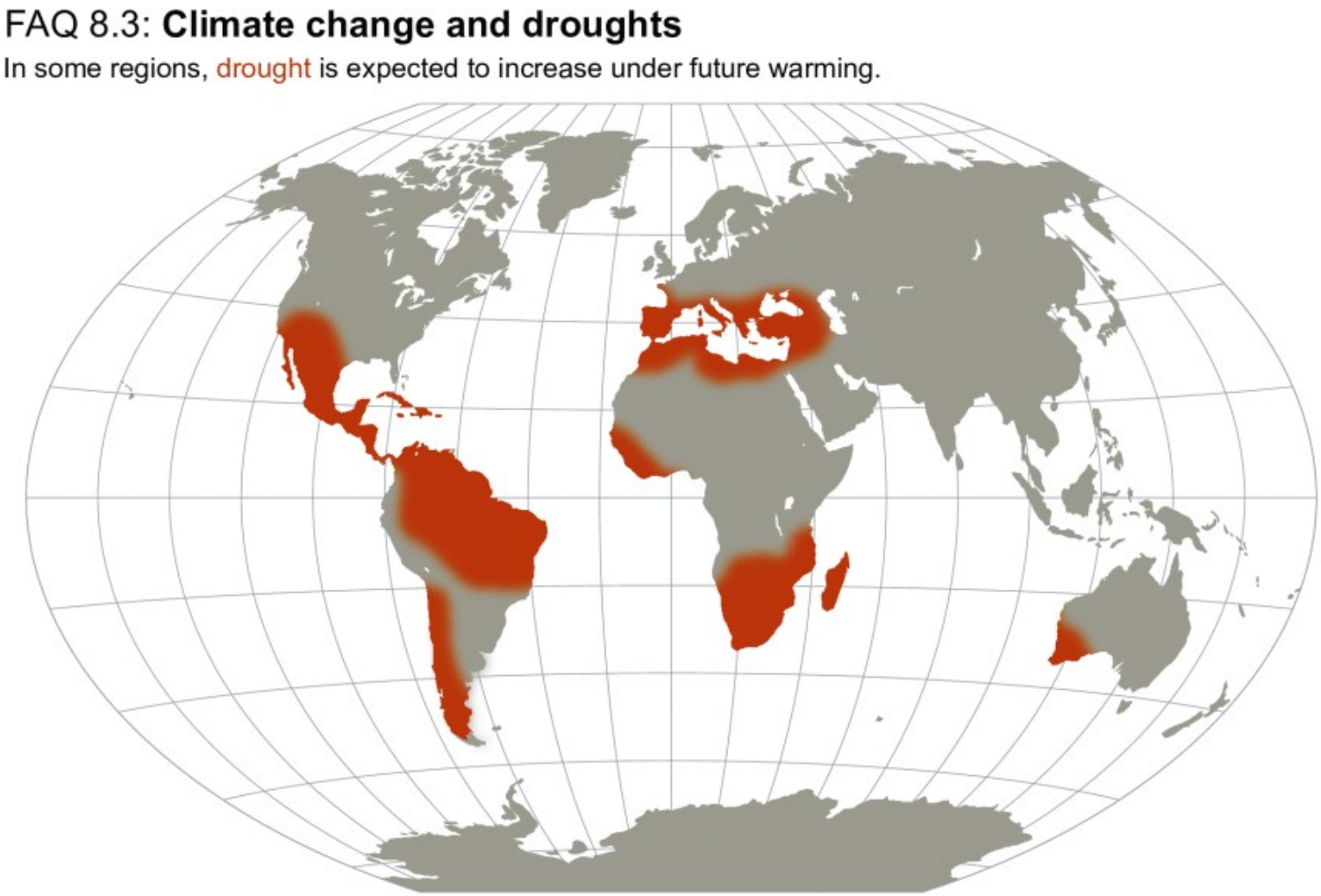


Diagram showing the flux (movement) of water through Earth's water cycle in cubic kilometers (km^3) per year.

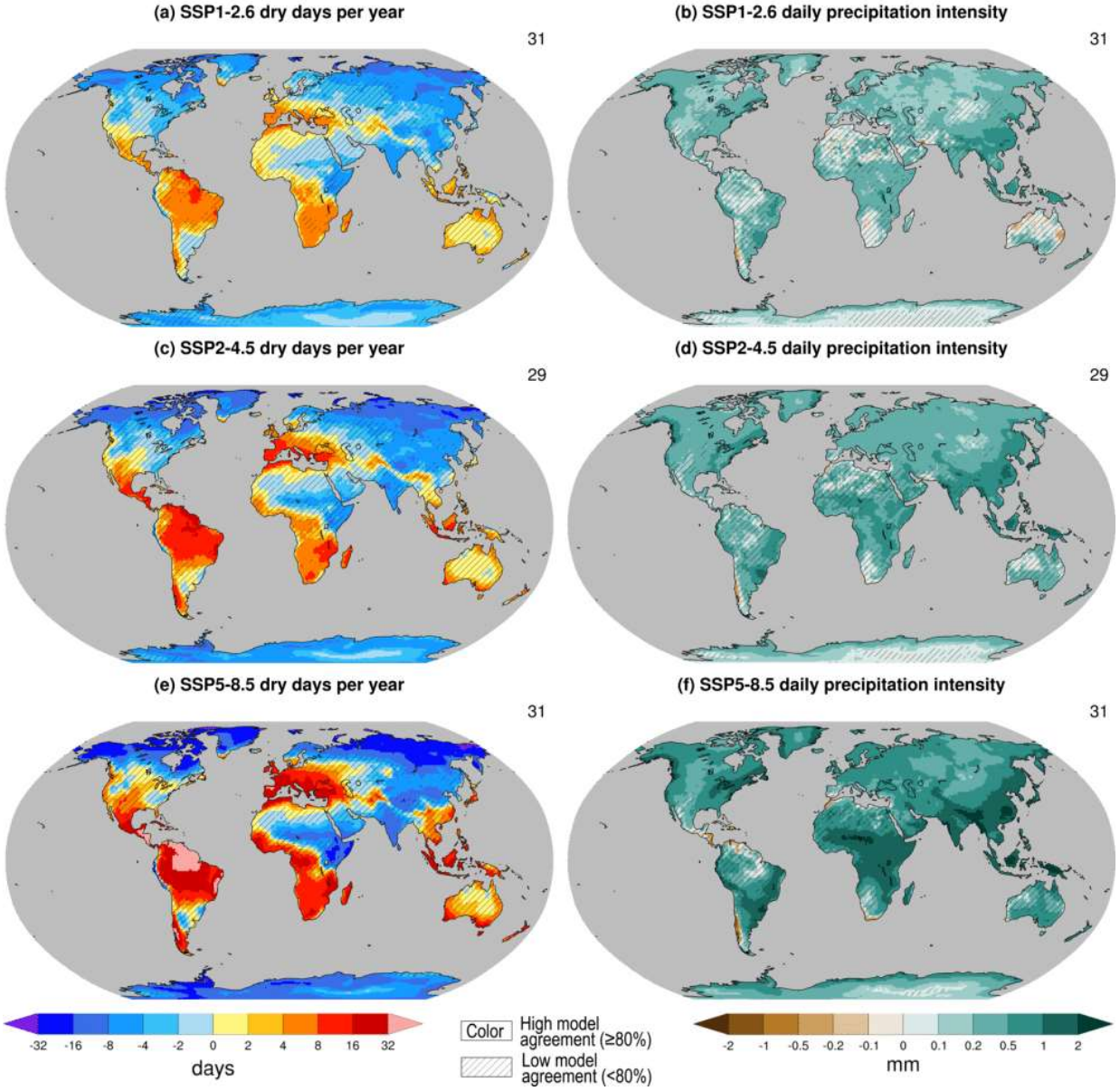


the ability of the near-surface atmosphere to hold water increases with temperature at a rate of roughly 7% per 1°C increase[



Regions (orange) where drought is expected to worsen under future global warming. The pattern is the same regardless of greenhouse gas emission scenarios, but the magnitude of drought worsens with increased emissions.
Source: IPCC (2021)

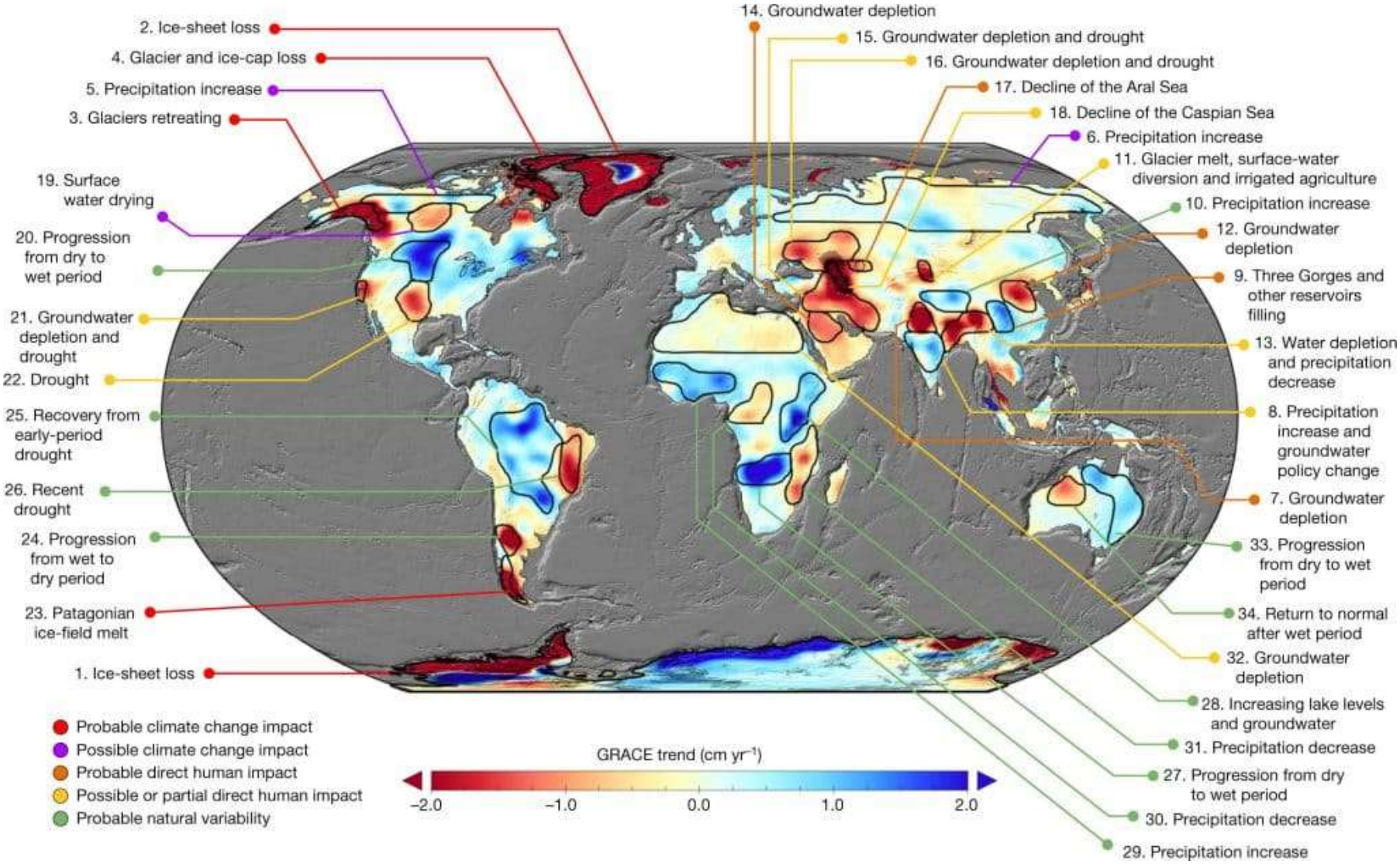
Multi-model annual mean long-term changes in daily precipitation statistics



Land system change

The transformation of natural landscapes, such as through deforestation and urbanization, diminishes ecological functions like carbon sequestration, moisture recycling, and habitats for wildlife, all crucial for Earth system health.

Globally, the remaining forest areas in all three biomes (tropical, boreal, and temperate) have fallen below the safe levels.

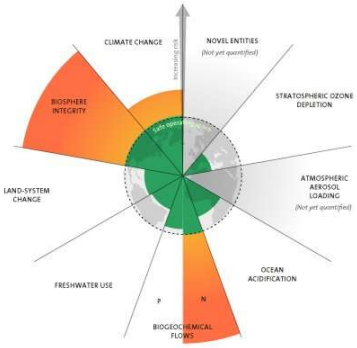

2. Ice-sheet loss
4. Glacier and ice-cap loss
5. Precipitation increase
3. Glaciers retreating
19. Surface water drying
20. Progression from dry to wet period
21. Groundwater depletion and drought
22. Drought
25. Recovery from early-period drought
26. Recent drought
24. Progression from wet to dry period
23. Patagonian ice-field melt
1. Ice-sheet loss
14. Groundwater depletion
15. Groundwater depletion and drought
16. Groundwater depletion and drought
17. Decline of the Aral Sea
18. Decline of the Caspian Sea
6. Precipitation increase
11. Glacier melt, surface-water diversion and irrigated agriculture
10. Precipitation increase
12. Groundwater depletion
9. Three Gorges and other reservoirs filling
13. Water depletion and precipitation decrease
8. Precipitation increase and groundwater policy change
7. Groundwater depletion
33. Progression from dry to wet period
34. Return to normal after wet period
32. Groundwater depletion
28. Increasing lake levels and groundwater
31. Precipitation decrease
27. Progression from dry to wet period
30. Precipitation decrease
29. Precipitation increase
Probable climate change impact
Possible climate change impact
Probable direct human impact
Possible or partial direct human impact
Probable natural variability
GRACE trend (cm yr⁻¹)
−2.0
−1.0
0.0
1.0
2.0

Biosphere integrity

The decline in the diversity, extent, and health of living organisms and ecosystems, threatens the biosphere's ability to co-regulate the state of the planet by impacting the energy balance and chemical cycles on Earth.

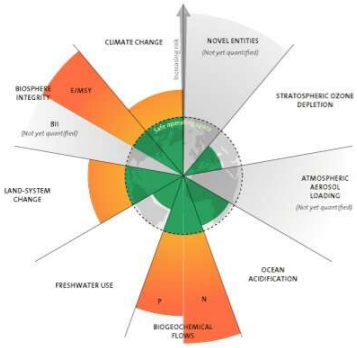
Both the loss of genetic diversity, and the decline in the functional integrity of the biosphere, have exceeded their safe levels.

2009



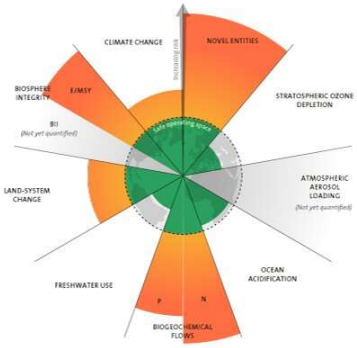
3 boundaries crossed

2015



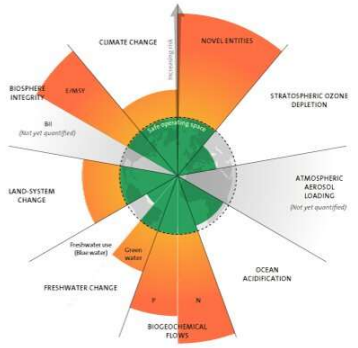
4 boundaries crossed

2022



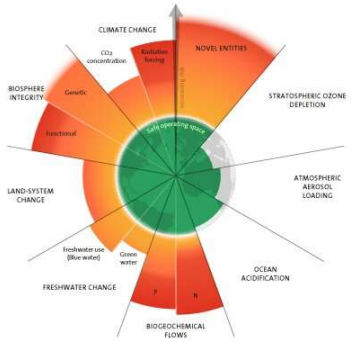
5 boundaries crossed

2022



6 boundaries crossed

2023



6 boundaries crossed

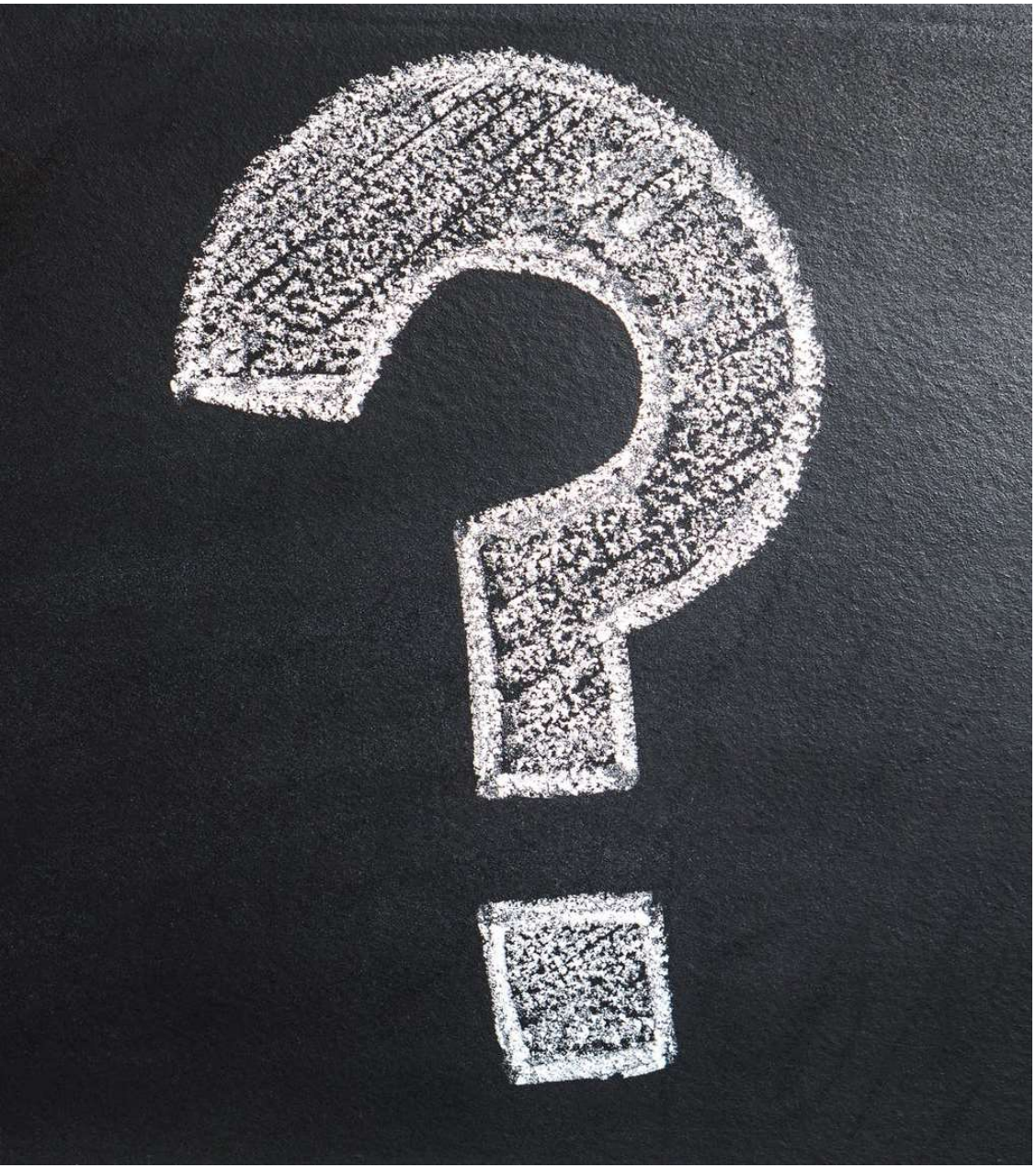
Video watched in class (until 22:42 min)

- https://youtu.be/7KfWGAjJAsM?si=Gev9N9J6GgEFZ7MW

More videos if you are interested

https://www.ted.com/talks/johan_rockstrom_10_years_to_transform_the_future_of_humanity_or_destabilize_the_planet?subtitle=en&lng=it&geo=it

https://www.ted.com/talks/johan_rockstrom_the_tipping_points_of_climate_change_and_where_we_stand?subtitle=en&lng=it&geo=it



Questions

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