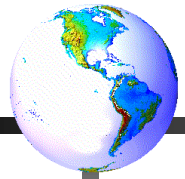
Planetary Boundaries

https://chrisriedy.me/planetary-boundaries-for-a-sustainable-future-2145584c998f

Planetary Boundaries



Non-linear transitions in the functioning of coupled human-environmental systems (Schellnhuber 2002, Lenton)

Thresholds are intrinsic features of those systems and are often defined by a position along one or more control variables.

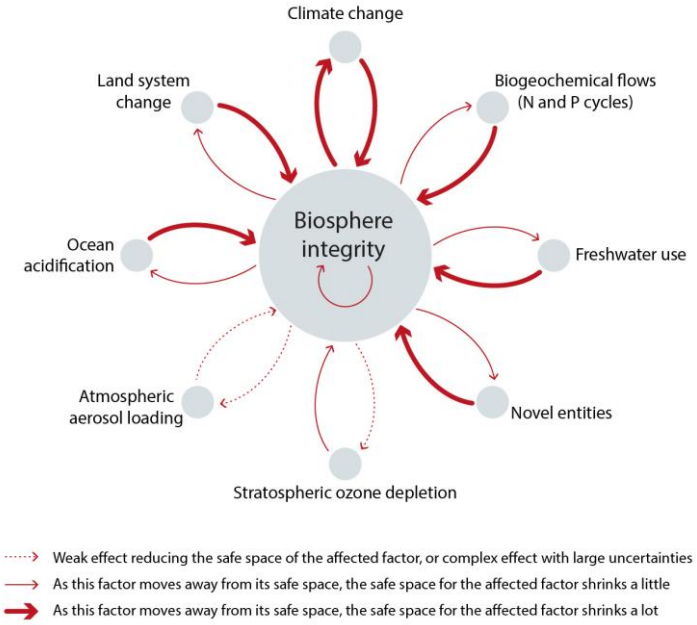
The choice of control variable for each planetary boundary (PB) was based on our assessment of the variable that on balance may provide the most comprehensive, aggregated, and measurable parameter for individual boundaries

Boundaries, on the other hand, are human determined values of the control variable set at a "safe" distance from a dangerous level.

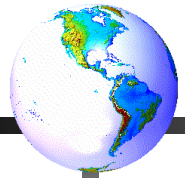
Planetary Boundaries

Much of the uncertainty in quantifying planetary boundaries is due to:

- Our lack of scientific knowledge about the nature of the biophysical thresholds themselves,
- The intrinsic uncertainty of how complex systems behave,
- The ways in which other biophysical processes such as feedback mechanisms interact with the primary control variable,
- And uncertainty regarding the allowed time of overshoot of a critical control variable in the Earth System before a threshold is crossed.



http://www.futureearth.org/blog/2015-feb-6/planetary-boundary-biodiversity



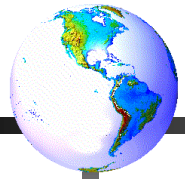
Planetary Boundaries

The PB approach rests on three branches of scientific inquiry.

1. The scale of human action in relation to the capacity of the Earth to sustain it.

2. The work on understanding essential Earth System processes.

3. The framework of resilience and its links to complex dynamics

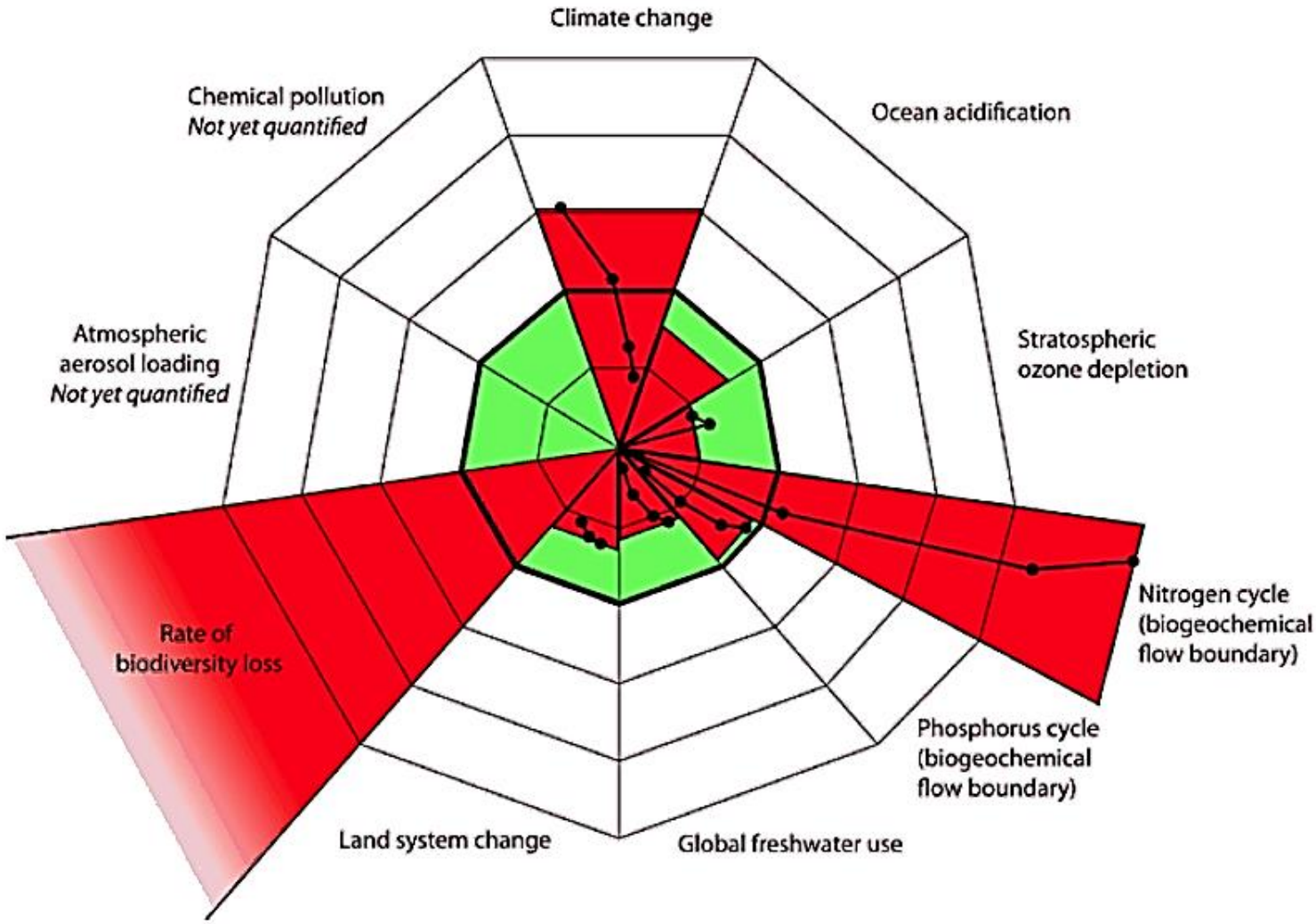


Planetary Boundaries

Normative judgment influence the definition and position of PB.

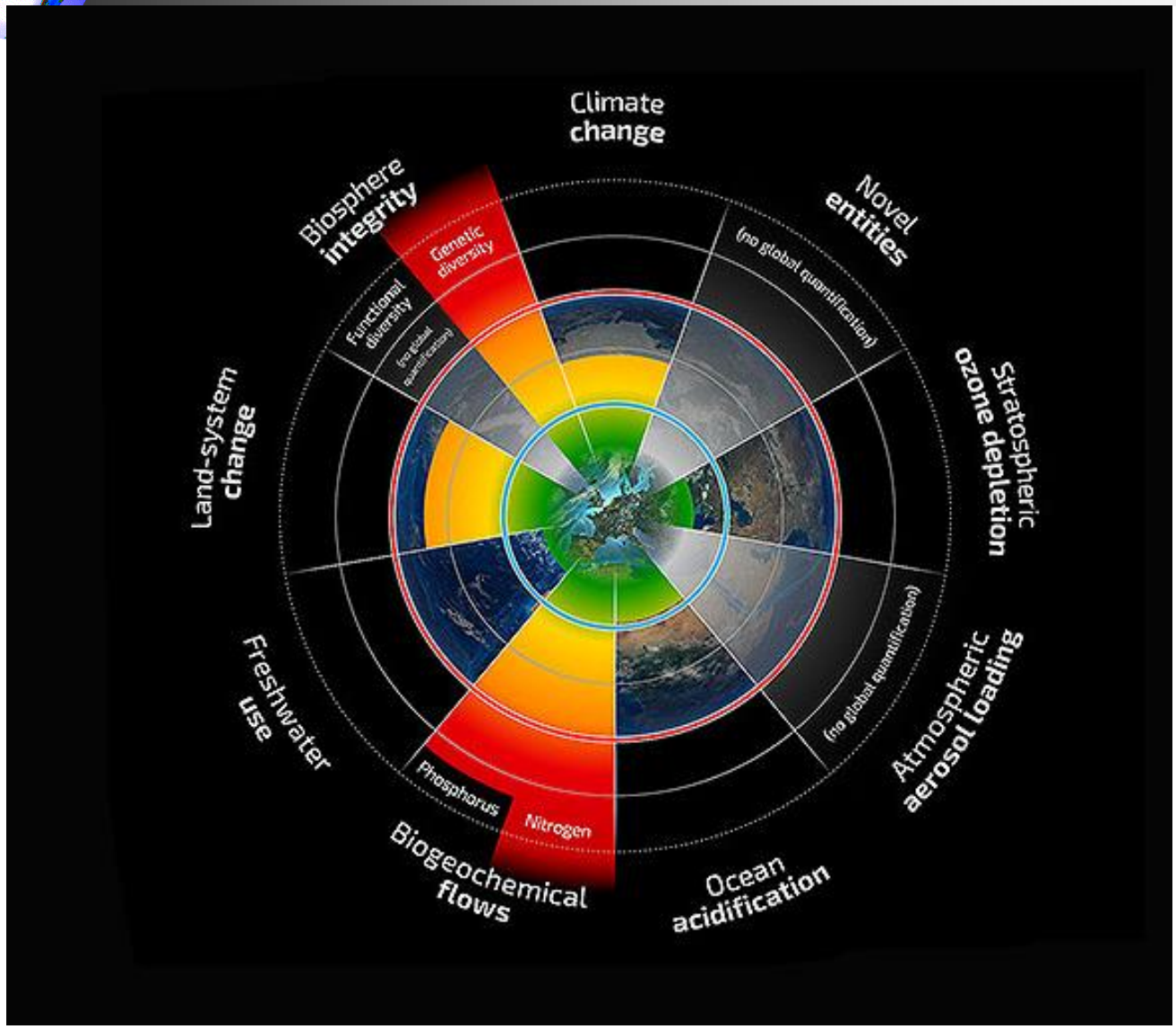
- Selection ➡ What constitutes unacceptable human-induced global environmental change.
- Position ➡ Function of the degree of risk the global community is willing to take.
- Position ➡ Is furthermore a function of the social and ecological resilience of the impacted societies.
- Identified ➡ For processes where the time needed to trigger an abrupt or irreversible change is within an "ethical time horizon".

Boundaries we must NOT CROSS



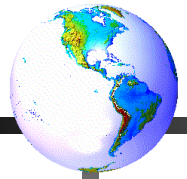
http://energyskeptic.com/2011/9-planetary-boundaries/

Boundaries we must NOT CROSS, update



- Climate change
- Loss of biodiversity
- Biogeochemical cycles of N & P

https://www.stockholmresilience.org/research/research-news/2015-01-15-planetary-boundaries---an-update.html



Boundary character / Scale of process	Processes with global scale thresholds	Slow processes without known global scale thresholds
Systemic processes at planetary scale	Climate Change	
	Ocean Acidification	
		Stratospheric Ozone
Aggregated processes from local/regional scale	Global P and N Cycles	
	Atmospheric Aerosol Loading	
	Freshwater Use	
	Land Use Change	
		Biodiversity Loss
		Chemical Pollution

Planetary Boundaries

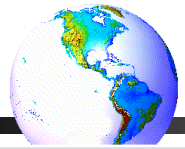
Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Climate change	Atmospheric CO_2 concentration, ppm; Energy imbalance at Earth's surface, W m^{-2}	Loss of polar ice sheets. Regional climate disruptions. Loss of glacial freshwater supplies. Weakening of carbon sinks.	Atmospheric CO_2 concentration: 350 ppm (350–550 ppm) Energy imbalance:+1 W m^{-2} (+1.0–+1.5 W m^{-2})	1. Ample scientific evidence. 2. Multiple sub-system thresholds. 3. Debate on position of boundary.
Ocean acidification	Carbonate ion concentration, average global surface ocean saturation state with respect to aragonite (Ω_{arag})	Conversion of coral reefs to algal-dominated systems. Regional elimination of some aragonite- and high-magnesium calcite-forming marine biota Slow variable affecting marine carbon sink.	Sustain ≥80% of the pre-industrial aragonite saturation state of mean surface ocean, including natural diel and seasonal variability (≥80%–≥70%)	1. Geophysical processes well known. 2. Threshold likely. 3. Boundary position uncertain due to unclear ecosystem response.
Stratospheric ozone depletion	Stratospheric O_3 concentration, DU	Severe and irreversible UV-B radiation effects on human health and ecosystems.	<5% reduction from pre-industrial level of 290 DU (5%–10%)	1. Ample scientific evidence. 2. Threshold well established. 3. Boundary position implicitly agreed and respected.
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis	Disruption of monsoon systems. Human-health effects. Interacts with climate change and freshwater boundaries.	To be determined	1. Ample scientific evidence. 2. Global threshold behavior unknown. 3. Unable to suggest boundary yet.

Planetary Boundaries

Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Biogeo-chemical flows: interference with P and N cycles	P: inflow of phosphorus to ocean, increase compared with natural background weathering N: amount of N_2 removed from atmosphere for human use, Mt N yr^{-1}	P: avoid a major oceanic anoxic event (including regional), with impacts on marine ecosystems. N: slow variable affecting overall resilience of ecosystems via acidification of terrestrial ecosystems and eutrophication of coastal and freshwater systems.	P: < 10× (10× - 100×) N: Limit industrial and agricultural fixation of N_2 to 35 Mt N yr^{-1}, which is ~ 25% of the total amount of N_2 fixed per annum naturally by terrestrial ecosystems (25%–35%)	P: (1) Limited knowledge on ecosystem responses; (2) High probability of threshold but timing is very uncertain; (3) Boundary position highly uncertain. N: (1) Some ecosystem responses known; (2) Acts as a slow variable, existence of global thresholds unknown; (3) Boundary position highly uncertain.
Global freshwater use	Consumptive blue water use, km^3 yr^{-1}	Could affect regional climate patterns (e.g., monsoon behavior). Primarily slow variable affecting moisture feedback, biomass production, carbon uptake by terrestrial systems and reducing biodiversity	<4000 km^3 yr^{-1} (4000–6000 km^3 yr^{-1})	1. Scientific evidence of ecosystem response but incomplete and fragmented. 2. Slow variable, regional or subsystem thresholds exist. 3. Proposed boundary value is a global aggregate, spatial distribution determines regional thresholds

Planetary Boundaries

Earth System process	Control variable	Threshold avoided or influenced by slow variable	Planetary Boundary (zone of uncertainty)	State of knowledge*
Land-system change	Percentage of global land cover converted to cropland	Trigger of irreversible and widespread conversion of biomes to undesired states. Primarily acts as a slow variable affecting carbon storage and resilience via changes in biodiversity and landscape heterogeneity	≤15% of global ice-free land surface converted to cropland (15%–20%)	1. Ample scientific evidence of impacts of land-cover change on ecosystems, largely local and regional. 2. Slow variable, global threshold unlikely but regional thresholds likely. 3. Boundary is a global aggregate with high uncertainty, regional distribution of land-system change is critical.
Rate of biodiversity loss	Extinction rate, extinctions per million species per year (E/MSY)	Slow variable affecting ecosystem functioning at continental and ocean basin scales. Impact on many other boundaries—C storage, freshwater, N and P cycles, land systems. Massive loss of biodiversity unacceptable for ethical reasons.	<10 E/MSY (10–100 E/MSY)	1. Incomplete knowledge on the role of biodiversity for ecosystem functioning across scales. 2. Thresholds likely at local and regional scales. 3. Boundary position highly uncertain.
Chemical pollution	For example, emissions, concentrations, or effects on ecosystem and Earth System functioning of persistent organic pollutants (POPs), plastics, endocrine disruptors, heavy metals, and nuclear wastes.	Thresholds leading to unacceptable impacts on human health and ecosystem functioning possible but largely unknown. May act as a slow variable undermining resilience and increase risk of crossing other thresholds.	To be determined	1. Ample scientific evidence on individual chemicals but lacks an aggregate, global-level analysis. 2. Slow variable, large-scale thresholds unknown. 3. Unable to suggest boundary yet.

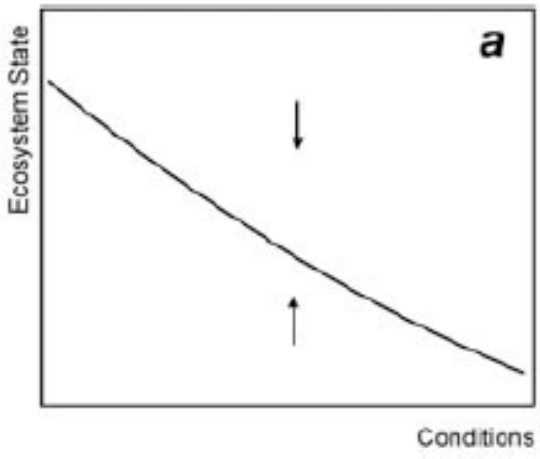


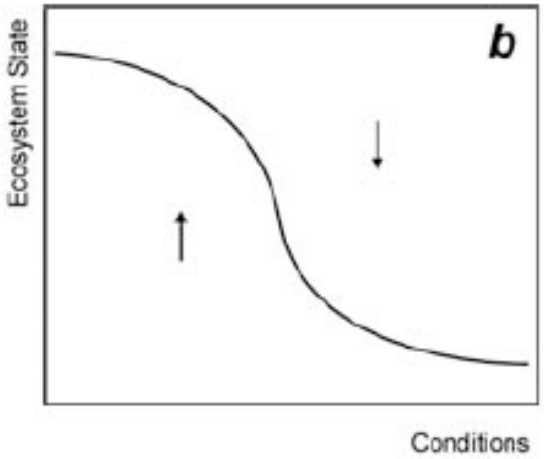
PB, A comparison of what we know

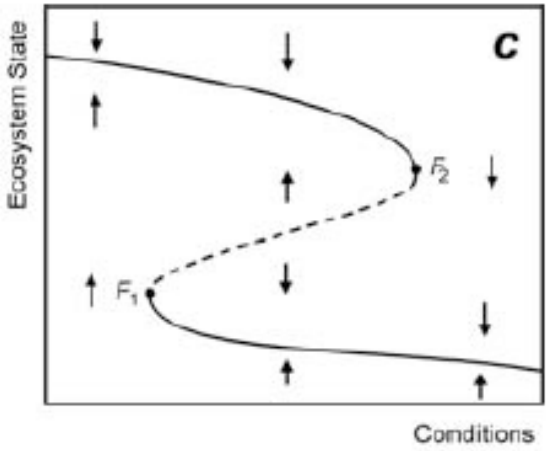
Earth System process	Control variable	Boundary	Pre-industrial	1950	1970	1990	Latest data
Climate change	Atmos-pheric CO2 (ppm)	350	280	311	326	354	387
Ocean acidification	Global aragonite saturation ratio	2.75	3.44	n.a.	n.a.	n.a.	2.90
Stratospheric Ozone	O3 concentration (DU)	276	290	n.a.	292	282	283
Nitrogen cycle	Amount of N2 re-moved (Mt/yr)	35	0	4	39	98	121
Phosphorus cycle	Quantity of P flowing (Mt/yr)	11	1.1	3.4	6.0	8.5	10.3
Freshawater	Consumptive use (km3/yr)	4,000	415	887	1,536	2,192	2,600
Land system change	% of natural cover to cropland (Mha)	15	5	n.a.	10.71	11.45	11.68
Biodiversity	Extintion rate (# of species per million per year	10	1	n.a.	n.a.	n.a.	>100

PB, Dynamics of system change

Ecosystems have different responses.



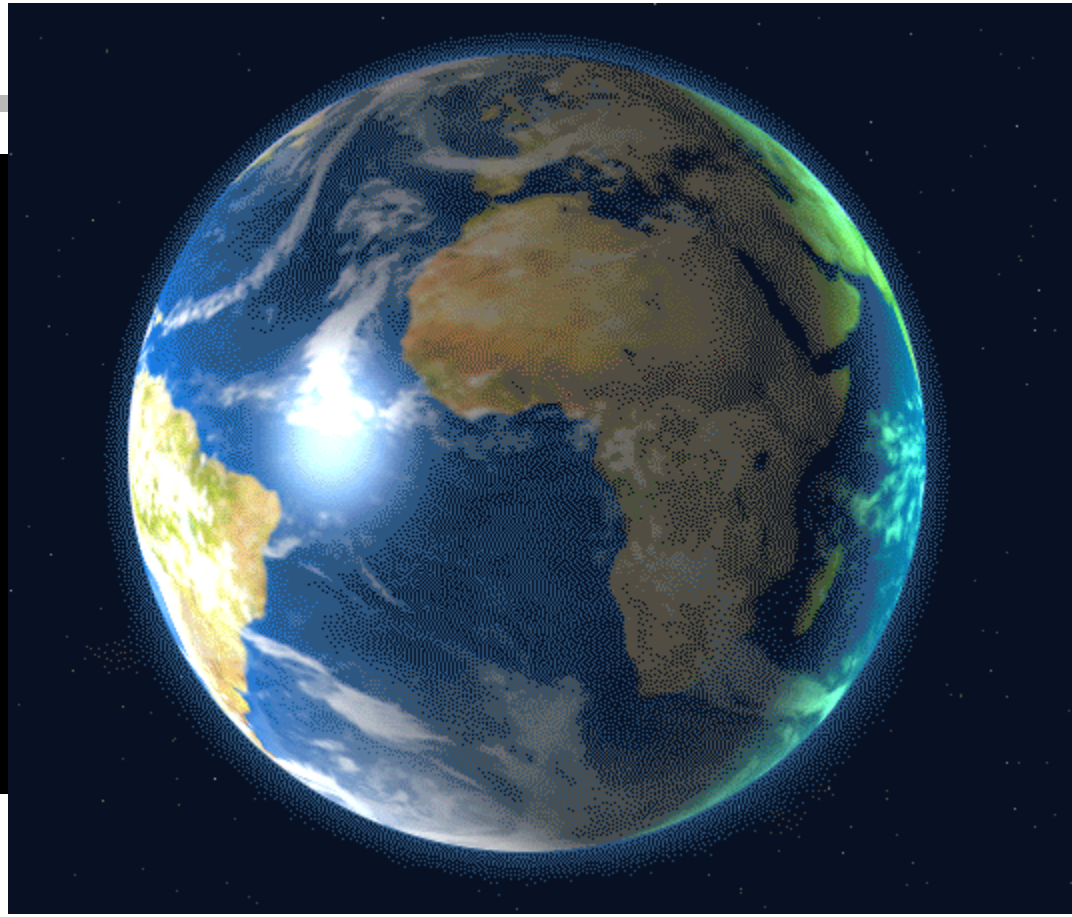




Beyond the Anthropocene, Johan Rockström

https://www.fotomuseum.ch/en/explore/still-searching/articles/27011_welcome_to_the_anthropocene

https://www.youtube.com/watch?v=V9ETiSaxyfk 21’14’’



We have our foot on the accelerator driving towards the Abyss…"

Ban Ki-moon Secretary General of the UN Sept 2009