Making Sense of "Tipping Points"

Tipping Points: Part 1 - What are They, and are any Imminent?

Just this month, on Dec 6, 2023, the journal *Nature* published a major study on Tipping Points by more than 200 climate scientists . The announcement is at: https://www.nature.com/articles/d41586-023-03849-y. The 500 page report, and its constituent sections and summaries, can be accessed at: https://global-tipping-points.org/. The Punchlines are readily accessed at that site

https://www.pnc.com/en/personal-banking.html?lnksrc=topnav

Brown sediment marks rapidly melting ice on the Greenland ice sheet (and, being darker, the sediment absorbs even more sunlight, further **accelerating thawing - towards a Tipping Point?**).

While the report is comprehensive and definitely worth additional time, **let's take this opportunity to get a basic understanding of the topic itself** - we will not be hearing less about it as time hurries on…

[Unless I point out a different source, all material and graphics here will be from the above report.]

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First, here is a useful graphic of major components of our marvelous **"Earth System"**. "Tipping Points" have been identified in each of these "Spheres" (they are defined just below the graphic), but this graphic is simply setting the stage at this point. It's kind of a neat way to think of our Planet.

Figure 1.1.1: Illustration of the Earth system, showing the different 'spheres'.

The **Earth system** describes the interconnected complex system at the surface of the planet that sustains life (Figure 1.1.1). It is comprised of multiple subsystems (or spheres), including the

- **cryosphere (ice-related systems** , including ice sheets, sea ice, glaciers and permafrost) (from Greek *krios* 'cold' + *sphaira* 'ball, globe'),
- **biosphere (global ecosystems)** (*bio* 'of living things') ,
- **Atmosphere**, (*atmos* 'vapor')
- **hydrosphere (water-based systems**, including oceans, rivers and lakes) (*hydro* 'water'), and
- **lithosphere (the Earth's solid surface)** (*lithos* 'stone').

Together **these subsystems and their interactions determine the climate** (the average long-term weather conditions at a place or across the Earth, usually measured over 30 years).

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So, what are "Tipping Points"?

Environmental stresses could become so severe that large parts of the natural world are unable to maintain their current state, leading to **abrupt and/or irreversible changes. <u>These moments are called Earth system 'tipping points'.</u>**

My discussions will intentionally be focused on understanding what can cause and physically happen as a tipping point is reached, and then what might result. This report goes much deeper and farther, however. Larger perspectives and societal directions which are relevant are also studied in detail in this resource.

My experience is that appreciation of the magnitude of changes which might be in front of us first requires that we understand the mechanisms of the postulated events, so that is where we will spend our time. However, I will note the conclusions expressed by the authors:

> **"THESE TIPPING POINTS POSE THREATS OF A MAGNITUDE NEVER BEFORE FACED BY HUMANITY. These threats could materialize in the coming decades, and at lower levels of global warming than previously thought. They could be catastrophic, including global-scale loss of capacity to grow major staple crops. Triggering one Earth system tipping point could trigger another, causing a domino effect of accelerating and unmanageable damage. Tipping points show that the overall threat posed by the climate and ecological crisis is far more severe than is commonly understood."**

On the other hand, the report asserts that <u>Positive</u> Tipping Points are possible:

> ## "ONE <u>POSITIVE</u> TIPPING POINT CAN TRIGGER OTHERS, CREATING A DOMINO EFFECT OF CHANGE
>
> **For example, as electric vehicles pass a positive tipping point towards becoming a dominant form of transport, this reduces the costs of battery technology. Lower-cost batteries in turn provide essential storage capacity to reinforce the positive tipping point to renewable power, which can trigger another tipping point in producing green ammonia for fertilizers, shipping, and so on."**

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26 Earth system tipping points have been identified from evidence of past changes, observational records and computer models.

- **In the cryosphere,** six Earth system tipping points are identified, including large-scale tipping points for the Greenland and Antarctic ice sheets. Localized tipping points likely exist for glaciers and permafrost thaw. Evidence for large-scale tipping dynamics in sea ice and permafrost is limited.
- **In the biosphere,** 16 Earth system tipping points are identified, including forest dieback (e.g. in the Amazon), savanna and dryland degradation, lake eutrophication (relates to human activities where the artificial introduction of plant nutrients has led to community changes and a deterioration of water quality in many freshwater systems), die-off of coral reefs, mangroves, and seagrass meadows, and fishery collapse.
- **In ocean and atmosphere circulations,** four Earth system tipping points are identified, in the Atlantic Meridional Overturning Circulation (AMOC), the North Atlantic Subpolar Gyre (SPG), the Southern Ocean Overturning Circulation and the West African monsoon.

Some Earth system tipping points are no longer high-impact, low-likelihood events, they are **rapidly becoming high-impact, high-likelihood events**.

Already, at today's 1.2°C global warming, tipping of warm-water coral reefs is likely and we cannot rule out that four other systems may pass tipping points: the ice sheets of Greenland [7m sea level rise potential over centuries to millennia] and West Antarctica [3m], the North Atlantic Subpolar Gyre circulation, and parts of the permafrost subject to abrupt thaw. **We will investigate these in detail in later studies.**

Passing 1.5°C global warming, widespread mortality in warm-water coral reefs becomes very likely, and another three potential tipping systems start to become vulnerable: boreal (northern) forest, mangroves and seagrass meadows.

At 2°C global warming and beyond, several more systems could tip, including the Amazon rainforest and subglacial basins in East Antarctica [19m], and irreversible collapse of the Greenland and West Antarctic ice sheets is likely to become locked in. Some systems can cross tipping points due to other drivers, or have their warming thresholds reduced by other human pressures, with for example Amazon dieback possible at lower warming if deforestation continues.

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5 major Earth systems are already at risk of crossing tipping points at the present level of global warming**: warm-water coral reefs (A), the Greenland (B) and West Antarctic (C) ice sheets, permafrost regions (D), and North Atlantic Subpolar Gyre circulation (E).** These are pointed out below in the context of the 26 potential Tipping Points mentioned above (again, we will look at these in more detail in later studies):

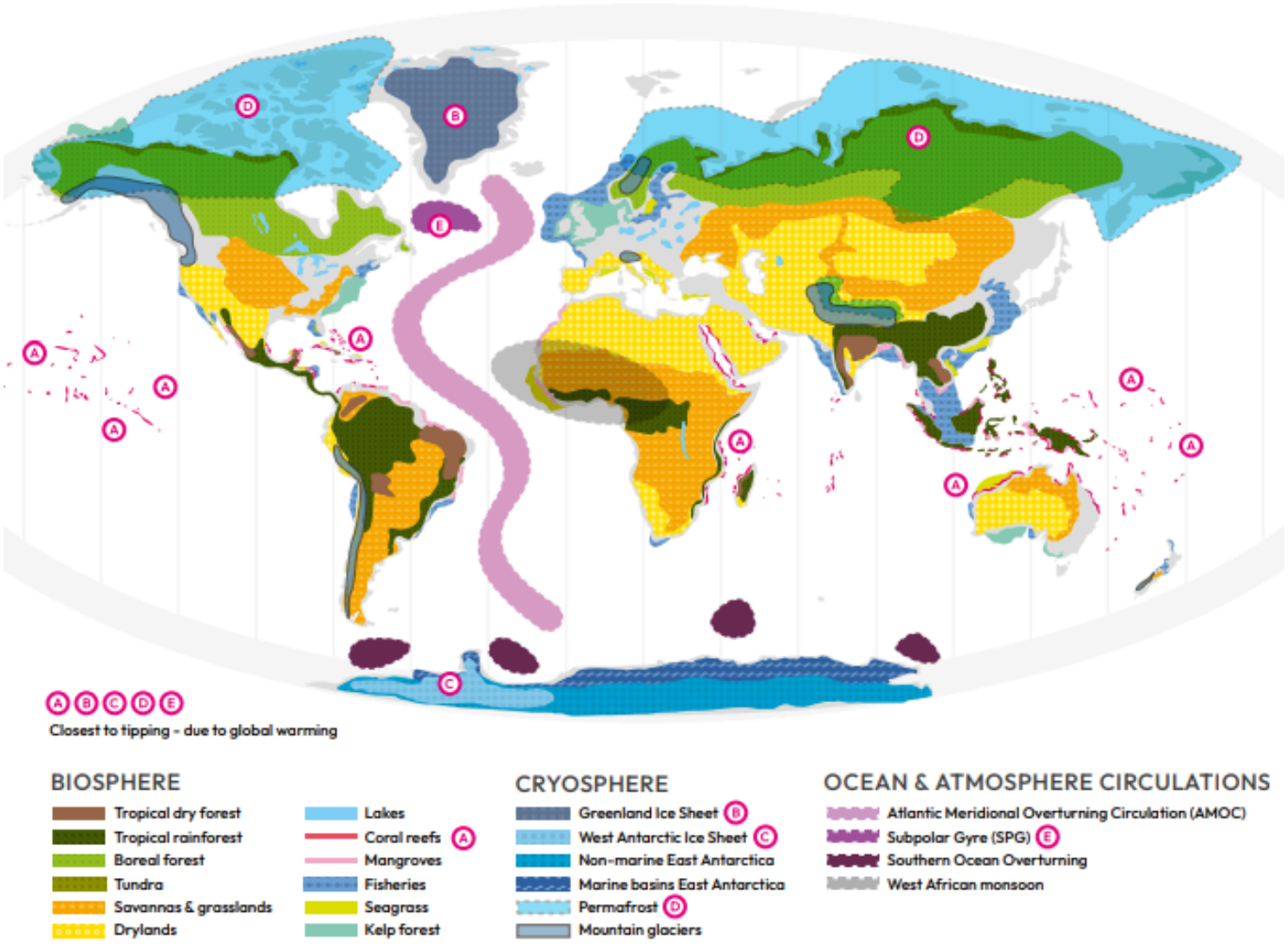

Figure 1: Parts of the Earth system identified in this report as featuring 26 tipping points.

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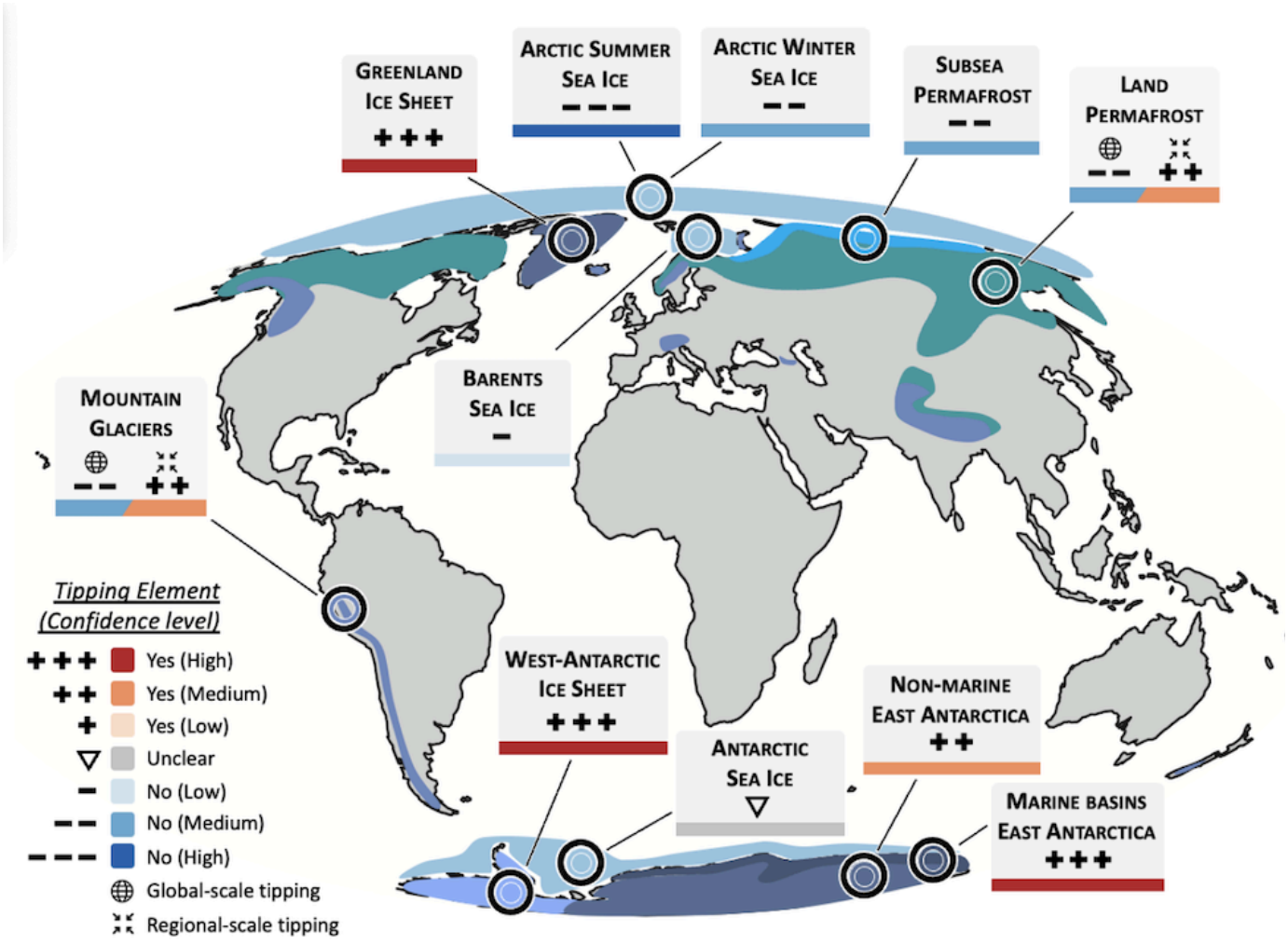
Confidence in Projections. The report identifies multiple tipping points in these Earth systems - the **cryosphere,** for example, as shown on the map below.

The colors and markers indicate how confident the authors are that each system has a tipping point. A red bar and "+++" marker indicates that the authors are very confident that the system is a tipping point. **A blue bar and "- – -" marker indicates that the authors are very confident that the system is not a tipping point**. The four arrows and globe symbols indicate regional and global systems, respectively.



Cryosphere tipping points. The ++ and – – markers indicate how confident the authors are that the system has a tipping point.

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A few extra notes on how Tipping Points can play out:

Earth's tipping systems can **interact in ways that destabilize one another**, making tipping 'cascades' possible. Tipping systems in the climate are closely coupled together. Hence a tipping point in one system can have significant implications for other systems. Most interactions between climate tipping systems are destabilizing, tending to destabilize the Earth system beyond the effects of climate change on individual systems.

Early warning signals have been detected that are consistent with the Greenland Ice Sheet, AMOC, and Amazon rainforest heading towards tipping points. Loss of resilience (the ability to recover from perturbations) is expected before reaching a tipping point, but does not directly reveal how close a tipping point is.

The central western Greenland ice sheet, AMOC (see CSSG-2.7 *The Great Conveyor: Part 3 - The Global Ocean Conveyor* - the "Atlantic Meridional Overturning Circulation (AMOC) is the Atlantic portion of the Great Conveyor) **, and Amazon rainforest all have independent evidence of being prone to tipping and show observational evidence of loss of resilience consistent with moving towards tipping points.**

The risks of crossing Earth system tipping points can be minimized through rapidly reducing anthropogenic drivers of global change. Urgently and ambitiously reducing greenhouse gas emissions can limit the risks of crossing tipping points in the cryosphere, biosphere, ocean and atmosphere circulation.

I realize the above material is a bit wordy, but it is the context for our looking in detail at the mechanics of the most near-term threats in later studies.