CSQ-29 Summary

Question	Knowledge Advancement Objectives	Geophysical Observables	Measurement Requirements	Tools & Models	Policies / Benefits
Can we better quantify the temperature thresholds, time scales, and impacts of identified tipping points?	A) Characterization of temperature thresholds for currently established tipping points	• For the already identified tipping points, determination of a more precise range for the temperature thresholds depends on models. Model inputs require geophysical observable depending on the articular tipping element being addressed: **Cryosphere:** ✓ Greenland ice sheet ✓ Arctic winter sea ice ✓ West Antarctic ice sheet ✓ East Antarctic ice sheet and subglacial basins ✓ Mountain glaciers ✓ Boreal permafrost ✓ Barents Sea ice **Ocean-Atmosphere circulation:** ✓ Atlantic Meridional Overturning Circulation ✓ North Atlantic subpolar gyre / Labrador-Irminger Sea Convection collapse **Biosphere:** ✓ Low-latitude Coral Reefs ✓ Sahel & the West African Monsoon	• Given the wide range of typing elements and the many geophysical variables involved in the modelling of each one of the tipping elements, and the different sensitivity of the climate models to geophysical variables used as input (current observations versus future model predictions), a precise specification for the required measurements is not possible in this case.	Climate Models, both regional and global, in particular those models that include explicit behaviour of tipping points	A more precise determination of the temperature thresholds, time scales, and associated geographical impacts, would be extremely beneficial to establish more adequate adaptations and mitigation strategies at the proper spatial and temporal scales.

		✓ Boreal forest (southern dieback and northern expansión) ✓ Amazon rainforest			
	B) Characterization of time scales for currently established tipping points	• Time scales for each tipping point depends even more on models, and observations used as inputs to the models are in this case critical when long time series are available	• Same as above, but focused on time series of observables	Climate models can be used, although they are known to have some limitations and results may depend on model assumption	
	C) Characterization of geographical extend of the impacts for currently established tipping points	• Spatial maps (global and regional) are essential tools, for multiple variables depending on the tipping point considered in each case • Earth Observation data can play a key role in this particular aspect	• Key role of EO data in this particular aspect, but EO data represents current status and can only serve to validate models with current observations to make them more accurate in future predictions	Climate models can be used, although they are known to have limitations when coming to regional effects and coupling between tipping points having a global-scale effects and those tipping points that have regional impacts.	
	D) Identification of potential cascade effects in the coupling of multiple tipping points	• Coupling of models for multiple tipping points and general climate models, supported by available observations depending on the sets of tipping points considered in each cascade/teleconnection analysis	• All the variables needed to describe each tipping element separately, plus those variables that can serve to inter-connect the multiple tipping elements. Time	Models are not yet very accurate when handling multiple tipping point effects and the connections among them. Running ensembles of several models under multiple scenarios is the only possible approach, but	

			series are needed in all cases.	it is subject to potentially controversial interpretation of the results.	

CSQ-29 Narrative

Tipping points are characterized by three key aspects:

- Temperature threshold (the increase in temperature where the activation takes place)
- Time scale for such activation after the temperature threshold is reached
- Spatial impact scale (global or regional scale)

Assuming all the (main) tipping points in the climate system are already identified, the question would be to determine the temperature thresholds and associated time scales and impacts for each one of such tipping elements. Identification of the most critical tipping elements where more focused efforts are necessary is also important, but the impacts of reaching the corresponding tipping point for each tipping element are difficult to be quantified up to the level of establishing specific mitigation actions given the uncertainties in the time scales involved in each case.

As illustrated in Fig. 2-1, for some elements we have already reached (or are about to reach) the corresponding tipping point. This argument often used to justify the need for urgent climate actions.

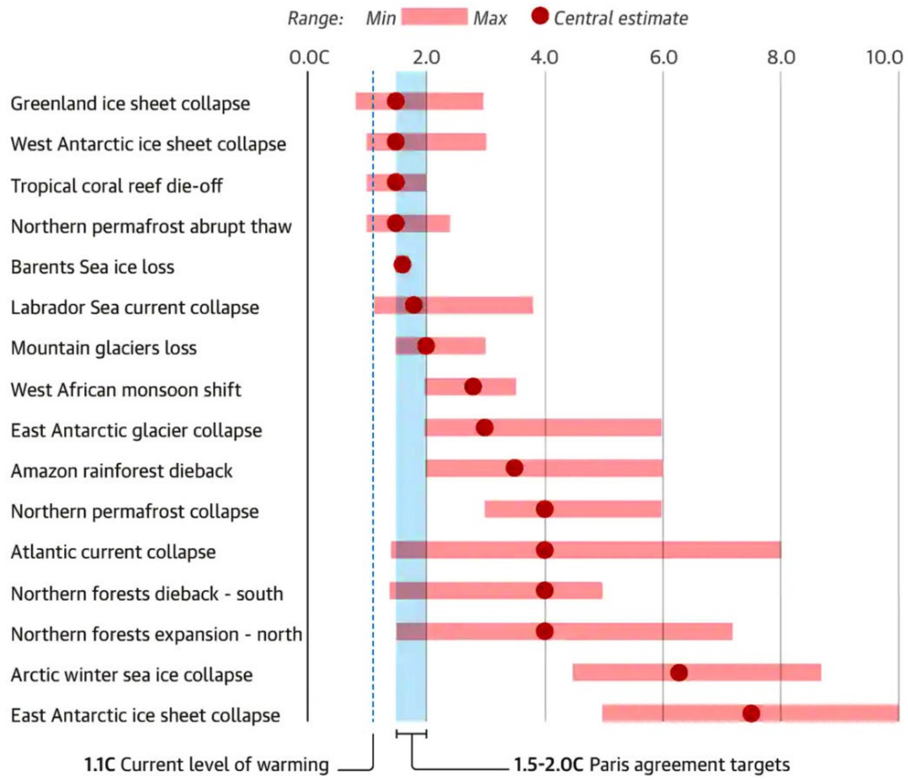

Fig. 2-1: Temperature thresholds (central estimate and min/max range) for identified tipping points in the climate system, indicating the current warming level and the targets for warming levels of the Paris agreements.

In order to identify specific mitigation actions, all tipping elements in the climate system must be identified and the tipping points well characterized. This is also important because of the interactions among tipping points (cascade effects) introduce enhancements in the effects associated to the coupling of multiple tipping points, related to the fact that triggering a tipping point may induce other cascade effects in the climate system. Particularly important is the potential coupling of multiple tipping points, the so called cascade effects, and teleconnections.

One element which makes the analysis of tipping points more complicated is the coupling of multiple tipping points, particularly through the so called “cascade effects”. That means activating a single tipping point may imply the activation of multiple tipping points just a kind of domino effect. There are multiple possibilities, with different probabilities and different effects depending on which is the tipping point that initiate the cascade, and again this is subject of research and a consensus on what are the dominant tipping points and the associated cascade effects is still somehow controversial.

Apart from cascade effects, there is another aspect that can connect multiple tipping points and that have deserved attention in the last years, the so called teleconnections (Zhou D. et al., 2015; Liu T. et al., 2023). While there are connections among different tipping points through feedback loops and cascade effects, teleconnections have a special effect and they imply some kind of pathways that connect tipping elements that are located even at large distance and are in principle independent. Climate teleconnections have been also proposed to modulate global burned area (Cardil et al., 2023). Whether or not such teleconnection really exist through some physical mechanism or they are just spurious statistical effects, the teleconnection effects illustrates the complexity of tipping points research.

Figure 2-2 illustrates how multiple tipping can be triggered together through cascade effects, and some of the identified teleconnections (indicated in red in the map) according to the current scientific understanding.

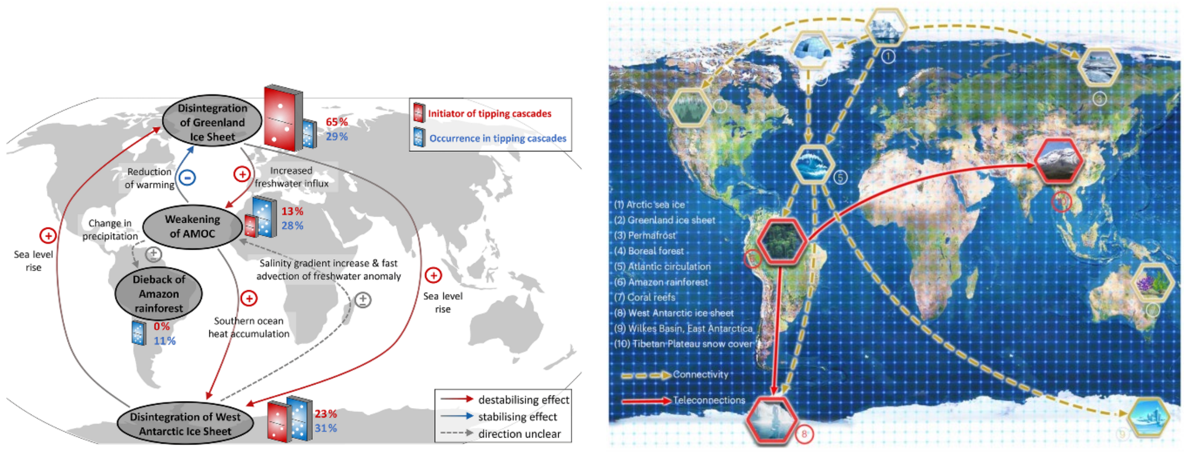

Fig. 2-2: (left) cascade effects activation of multiple tipping points, (right) teleconnections relating the potential activation of multiple tipping points

As illustrated in Fig. 2-3, while triggering a tipping point is a concern, triggering multiple tipping points at the same time, by reaching the corresponding temperature thresholds, can have unpredictable consequences. The figure illustrates how multiple tipping points can be sequentially reached over the next decades. A more quantitative characterization of the temperature thresholds and time scales is essential when multiple tipping points get activated in parallel. Up to 14 different tipping points may be activated in the next 80 years in this century, with significant couplings among them, as a function of different potential warming scenarios.

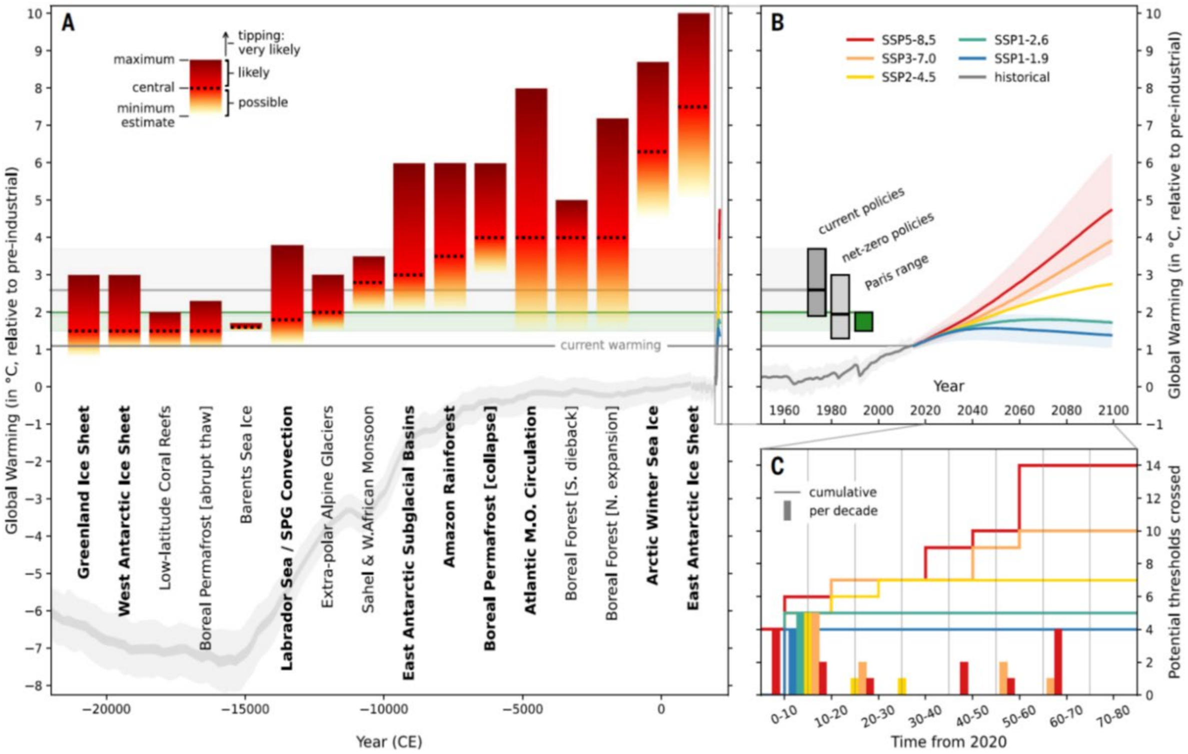

Fig. 2-3. Activation of multiple tipping points by reaching the corresponding temperature thresholds, over the next 80 years, for assumed warming scenarios (McKay, D. I. et al., 2022)

According to recent research, although tipping points are thresholds assumed to be a point of no return, they could be temporarily exceeded without prompting permanent changes, if global warming is reversed quickly enough. Clearly this is a controversial aspect that need more attention to better identify and characterize the different tipping points in the climate system.

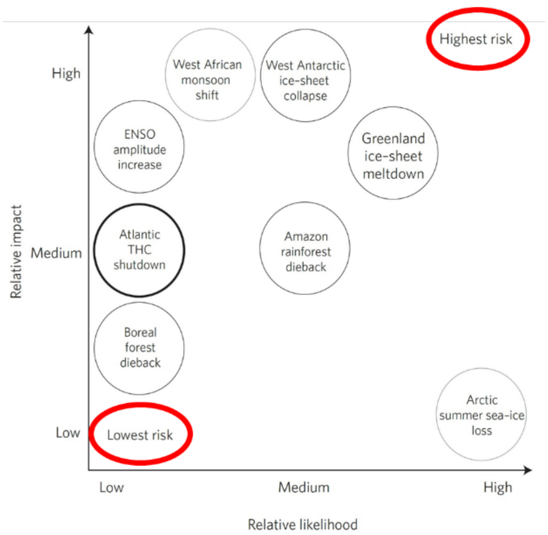

Fig. 2-4: Classification of tipping points in terms of relative likelihood and impact, and then associated risk (Risk (R) = probability (p) multiplied by damage (D)) (Lenton, 2011c.)

Tipping points also need to be modelled in terms of relative likelihood and impact, and then associated risk, defining Risk as the probability of occurrence multiplied by damage. There is another relevant concept for tipping points which is the Emergency, defined as the product of risk and urgency. Based on this we can classify the tipping points according to the risk, as illustrated in Figure 2-4. Then research can be focused on those tipping points with more risk, like melting ice-sheets or Amazon forest dieback.

But the quantification is somehow model-dependent, and different approaches may lead to classification of tipping elements into other categories.

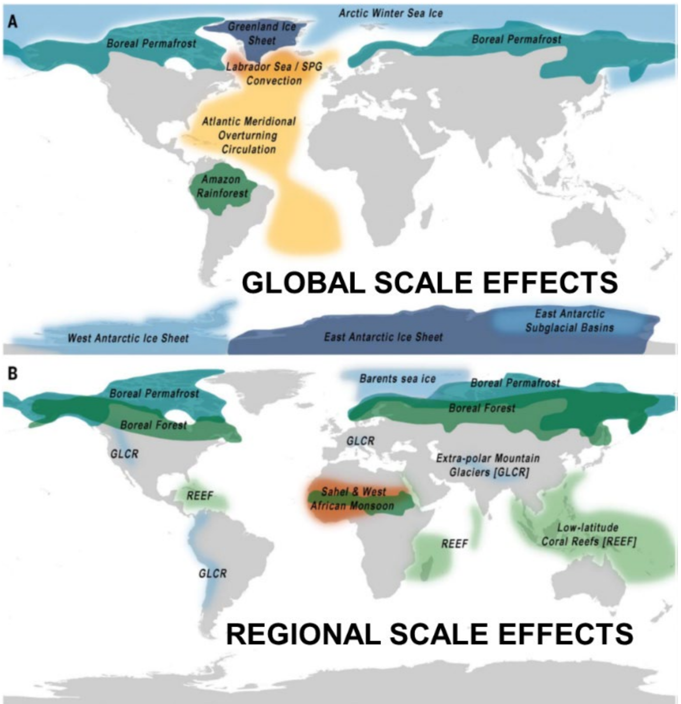

Fig. 2-5. Some tipping points have a global impact, or can be associated to a global tipping elements, while some other tipping points have regional scale affects associate to some specific tipping elements. The need to address such different geographical scenarios represents a unique opportunity for global Earth Observation, as a key source for geophysical variables in the form of spatial maps (McKay, D. I. et al., 2022)

Considering the implications in the context of the ESA Earth Observation Strategy, the spatial scales of impacts for climate tipping points deserve special attention. Some tipping points have a global impact, but many other have regional impacts that need spatial maps, with high spatial resolution to determine spatial internal variance of the phenomena under study, and accounting for spatial and temporal correlations. Time series of satellite data are essential tools for such type of characterization of tipping point effects.

References

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