CSQ-30 Summary

Question	Knowledge Advancement Objectives	Geophysical Observables	Measurement Requirements	Tools & Models	Policies / Benefits
Are the limitations in predicting climate tipping points driven by lack of process understanding or limited data availability?	A) Identify those tipping points where predictive capabilities are limited by lack of process understanding	• Focus on specific tipping elements where deficient model understanding has been identified, such as ✓ Boreal permafrost: collapse, versus abrupt thaw or gradual thaw ✓ Boreal forest: southern dieback and northern expansion ✓ Land carbon sink: Amazon rainforest, temperate forests ✓ Ocean biological pump and ocean carbon sink ✓ Cloud feedbacks: equatorial stratocumulus clouds	• Running ensemble of models under prescribed conditions to set the statistical dispersion in model predictions	Current climate models available, but with identified limitations.	With the final goal of establishing mitigation and adaptation approaches, early enough to avoid major consequences, any advance in the characterization of tipping points and the evolution of processes that may lead to tipping points, is clearly important. The fact that the current limitations come from the understanding and modelling of the processes or by the availability of adequate data is important to establish appropriate actions to solve the predictive capability
	B) Determination of experiments and activities needed to advance the understanding for such tipping points limited by lack/incomplete process understanding	• Dedicated field experiments where all relevant data are collected simultaneously over a period of time long enough to see trends in observations • Focus on tipping elements identified above	• Accuracy equal or better than current model predictive performances • Long time series is a key step to identify trends	Existing climate models would have to be improved according to such new observations, with emphasis on the pieces of the models related to the tipping points where deficiencies were previously identified	

	C) Identify those tipping points where predictive capabilities are limited by lack of appropriate data	• Focus on specific tipping elements where data availability is the limitation, such as ✓ Greenland ice sheet ✓ Arctic winter sea ice ✓ West Antarctic ice sheet ✓ East Antarctic: ice sheet and subglacial basins ✓ Mountain glaciers	• Since in this case the models are well understood, uncertainty in each observation can be set to make an improvement in model performances	Current climate models are available and known to be already with a good description of key processes and adequate model parameterization	of the models to allow establishing more precise corrective actions.
	D) Determination of datasets and observations needed to advance the understanding of such tipping points	• Identification of current archived datasets, covering long time series with relevant information ready to be used • Identification of new observations not yet available but necessary for the future	• Accuracy requirements depend on each particular tipping elements and geophysical variables involved in each tipping element model	Methods to ingest the datasets into climate models already exist, particularly for existing or new datasets with information already represented in the models	

CSQ-30 Narrative

Our ability to quantify the tipping points in the climate system, and to better predict future trends and effects, is limited by two different factors. On the one hand, for some tipping points there is a lack of detailed physical understanding of the mechanisms underlying the different effects, and their interactions (feedback loops), or at least a lack of capability to transform such knowledge into numerical equations and process mechanisms that can be incorporated in climate models. This is even more obvious when not just physical processes are involved, but also chemical cycles and biological processes, like plant adaptations to environmental stresses or the role of biodiversity that improves resilience, which are even more difficult to model than the pure physical phenomena. On the other side, the limitations can come from the lack of proper data, covering the adequate spatial and temporal scales, and providing direct information about the processes and not just indirect proxies with limited correlation to the true physical observables.

Identification if the limitations come from inadequate understanding of the processes or lack of adequate data is critical to better focus the actions. In the case of lack of process understanding, dedicated experiments can be planned to focus on the unresolved processes, and to incorporate such understanding into the models. In the case limitation comes from the lack of input data to such models, dedicated observations by means of in-situ networks or global satellite systems can be put in place. In some cases, like when tipping elements involve ocean or ice, the tipping point can be reached while the behaviour is not seen yet in the observations. Developing indicator tools for tipping points where there is not enough knowledge or confidence in the predictions can also be addressed.

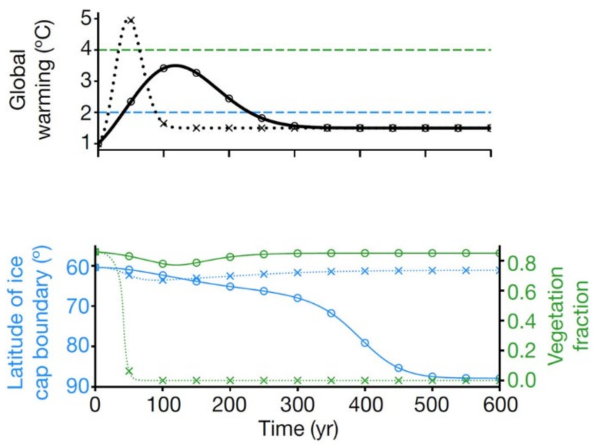

Fig. 3-1: (top) Time series of sample overshoot trajectories in global warming, and thresholds for the ice cap (blue) and forest dieback (green). (bottom) Time series of ice cap boundary (blue) and Amazon vegetation fraction (green) in response to the two overshoot trajectories presented above (Ritchie P. D. L., et al., 2021)

To illustrate these two situations, Fig. 3-1 shows an interesting example. In the top plot we have time series of sample overshoot trajectories in global warming, and thresholds for the ice cap (blue) and forest dieback (green). In the bottom plot we have the corresponding time series of ice cap boundary (blue) and Amazon vegetation fraction (green) in response to the two overshoot trajectories presented above. The tipping point behaviour is very different for both cases, and occur for different overshoot trajectories.

It looks like the behaviour of ice caps is well understood and then it would be a question of data availability to better model the process (based on physics at the end). However, for the case of Amazon forest dieback, the behaviour seems quite extreme (in one scenario they will disappear quickly) and probably there is a lack of understanding on the underlying processes and feedback looks (biology also plays a role in vegetation dynamics).

Specific actions can be established to help improving the models as needed. Moreover, the examples indicated also show the large potential and relevant possibilities to use time series of spatial maps derived from EO data as inputs to such models. Many of the inputs needed by the models are readily observable at the global scale by means of dedicated satellites, representing a unique source of data for such global climate models.

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