**CSQ-9 Summary**

| Question | Knowledge Advancement Objectives | Geophysical Observables | Measurement Requirements | Tools & Models | Policies / Benefits |
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| What are the characteristics of the processes related to climate extremes and the hazards related to them? | A) Quantify how climate change is affecting large scale circulation patterns and extreme events linked to them, including changes in their magnitude, frequency and spatial distribution. | • High spatial resolution and temporally continuous observations of many basic weather and climate related atmospheric and surface parameters<br>• Oceans, currents, ocean-atmosphere processes<br>• Vertical profiles of temperature, humidity, and wind.<br>• Cloud observations | High frequency measurements of key geophysical parameters, ideally co-located in space and time | ESMs, RCMs | Improved understanding of various types of extremes and their changes in a changing climate |
| | B) Improve understanding of feedback mechanisms of extreme events at local and regional scales, including aerosol effects, albedo effects, land-atmosphere and land-ocean feedbacks. | • High horizontal and vertical resolution and temporally continuous observations of many basic weather and climate related atmospheric and surface parameters<br>• Aerosols, clouds, atmospheric chemistry (aerosol formation), radiation, albedo<br>• Land-ocean feedbacks, land-atmosphere feedbacks (soil moisture). | Earth system models need to be refined in resolution. Measurements commensurate with time and scale length with local downscaled models needed. | ESMs, RCMs | |
| | C) Quantify the effects of extreme climate events on agriculture and food | • Temperature, soil moisture, precipitation, wind<br>• SIF? | VHR optical/NIR, soil moisture (passive/active microwave, 50m- | DGVMs, agricrop models, | |

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| | production in the short and long term. | • Land use, vegetation parameters | 25km), biospheric measures (LAI, SIF, …) | | |
| | D) Quantify the effects of extreme marine heat waves on marine ecosystems. | • Ocean parameters, currents, temperature, marine ecosystems | Hi resolution (<= 1km) SST, Ocean Colour, | Ocean bio-models | |

**CSQ-9 Narrative**

Climate change has already increased the frequency and intensity of several extreme weather phenomena as documented in the latest IPCC AR6 cycle reports. To minimize risks of potential disasters related to extreme events we need to understand the processes causing the events and their effects. Managing risks and hazards related to climate extremes has become an increasingly important part of climate change adaptation planning.

Large-scale atmospheric circulation patterns and modes of internal climate system variability (such as. the El Niño–Southern Oscillation (ENSO), the North Atlantic Oscillation (NAO), the Atlantic Multi-decadal Variability (AMV), and the Pacific Decadal Variability (PDV)) are important to understand the changes in timing, duration, extent, and intensity of extreme events such as droughts, heavy rains, flooding, and snow cover (Chen et al, 2018). Some changes to circulation patterns are clearly linked to human-induced climate change, like the poleward shift of extratropical jets and cyclone tracks. But there are critical gaps in understanding how climate change affects other key circulation patterns such as changes in monsoonal circulations which may cause extreme precipitation (IPCC 2021). This uncertainty in how some large-scale circulation patters are affected by climate change, means there is also uncertainty in how altered circulation patterns may affect related climate extremes, and the sectoral impacts of those extreme events (e.g. on agriculture).

While understanding large-scale patterns is a key factor, climate extremes are often further modulated by local and regional forcings and feedback processes, including aerosols, albedo, and land-atmosphere and ocean-atmosphere feedbacks. Understanding hazards related to climate extremes requires an improved understanding of these regional feedback mechanisms. This understanding needs to be underpinned by observations of these phenomena at the scale at which they are to be modelled.

Finally, quantifying the social and economic impacts of the climate extremes is crucial for developing effective adaptation strategies. A significant consequence of climate change is extreme weather events that affect food security, both on land and in the ocean. Changes in rainfall patterns, droughts, and flooding are expected to hamper agriculture through reduced crop productivity. Whilst in the oceans, marine heat waves cause dramatic effects on marine ecosystems, including mass mortality of species and habitats, caused by heat stress.

**References**

AR6, IPCC 2021 (WG-I: Climate Change 2021, The Physical Science Basis)

Chen, Y., et al., Recent Progress and Emerging Topics on Weather and Climate Extremes Since the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, *Annu. Rev. Environ. Resour.* 2018. 43:35–59, doi:10.1146/annurev-environ-102017-030052