Towards society-relevant metrics for climate extremes and their impacts

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Context and Motivation

As the impacts of climate extremes are becoming increasingly harmful, we need to improve our understanding of extreme events, and produce predictive products that can help society to manage associated risks. In the climate science community, "extremes indices" have found widespread application to illustrate and quantify changes in the occurrence of weather and climate extremes on regional to global scales (SREX 2012, Sillmann et al. 2013, Zhang et al. 2014). However, their definition is commonly based on a univariate and purely climatological framework, which hinders application in a more impact-oriented setting, especially when different types of impacts shall be considered[1]. There is a need to develop new indices calibrated or based on impact data, building on or complementing the currently available climate extremes indices to increase their relevance to stakeholders. Novel and interdisciplinary approaches based on mutual learning between social and natural scientists as well as stakeholders are required, and must include efforts to share data and knowledge in order to derive meaningful and actionable extremes indicators. The design and carrying-out of co-production processes that accommodate for these diverse considerations remains a mostly underexplored topic.

Key research questions

1. How can we design mutual learning processes that accommodate for different decision makers' information needs in the context of climate extremes?
2. What are the valuable assets in socio-ecological systems exposed to severe impacts? Which factors determine their susceptibility to impact (vulnerability)?
3. To what extent have decisions in response to direct and indirect impacts of climate extremes, across different governance levels, sectors and by different actors, affected the resilience of societies? Can these past decisions be explored to design a cross-community multi-level framework for improved decision-making?
4. Can we develop a generic continuously updated probabilistic framework and toolbox for society-relevant extremes metrics across various sectors and what are the desirable requirements of such a framework? Specifically,
    - What data is available and needed and what spatio-temporal scales are required in the probabilistic impact functions?
    - How to set up data gathering and sharing for quantifying climate-impact relationships?
    - How can we design a toolbox that enables stakeholders to derive from the probabilistic framework the extremes indicators that are relevant to their concerns?
    - How can we set up procedures for updating the network when new information on climate-impact links becomes available, or when the needs of stakeholders change?
5. How can we improve the identification, understanding and quantification of the climate-impact relationships represented by such a probabilistic framework?

Expected Methodologies and Disciplines

[1] *The term "Impact" refers to the effects of physical events, of disasters, and of climate change on natural and human systems; following the definition outlined in the IPCC AR5 WGII (IPCC 2014).*

The development of a generic and actionable framework, from which society-relevant indicators can be derived, crucially requires a research approach that combines methodologies from various disciplines as specified below.

First, an improved understanding of the requirements of an actionable framework for impact-based extremes indicators, including information on relevant sectors, requires an in-depth dialogue and *mutual learning process* in a focussed cross-disciplinary approach between social and natural sciences, specialists and generalists, including relevant stakeholders and non-academic expertise to be involved. The involvement of stakeholders and relevant sectors is context-dependent and will be evaluated on a case-by-case basis.

Second, *mutual learning* is crucial and must be conducted in an iterative manner. This iterative process includes the development and implementation of an impact-based probabilistic and generic framework that is continuously tested, evaluated and updated.

Third, an improved quantification and understanding of the link between climate extremes and their impacts across various sectors requires in-depth cross-sectoral and cross-disciplinary data analysis, dialogue and process-based modelling activities.

Preliminary requirements for deriving extremes metrics based on or calibrated from impact data in a generic and actionable framework:

- Uncertainty quantification
- Communicable indicators across different specific contexts
- Accounting for situations of very little information/data scarcity
- Disentangling of risk into different components (hazard, exposure, vulnerability), including drivers of change
- Continuously updated for key system variables
- Indicators require to be generically derivable on various temporal and spatial scales; spanning the local domain up to decadal and continental scales
- "Sustainability of data" and transparency: long-term availability, accessibility, affordability, exportability

Stakeholder involvement

Identification of the relevant stakeholders ultimately depends on the context, including the various sectors and levels (local, regional, national, etc.) of decision-making, and must consequently be considered on a case-by-case basis. A general guideline is that the process should be open to anyone who claims to have a stake in it. Importantly, the process must be multidirectional between stakeholders and scientists, implying that also the knowledge of stakeholders is considered. The process should follow the Future Earth principles of co-design and co-production and ideally be guided by process facilitators (e.g. social scientists and communication specialists). Possible stakeholders may include (but are limited to) policy-makers at all administrative levels, the public (both rural and urban communities), and the private sector. An inclusive process secures ownership of results, and legitimacy and relevance of the knowledge produced.

Societal Impact

The framework for deriving relevant extremes metrics will benefit from and contribute to the World Climate Research Programme (e.g., Grand Challenges on Climate Extremes), Copernicus Sectoral Information System (C3S) and similar national and international organisations.

Furthermore, a co-produced unified cross-sectoral framework that may allow deriving society-relevant extremes metrics based on impacts would address urgent societal needs, and could thus be relevant for better informed decision-making at various levels both in the public and private sector. These societal needs include emergency prevention, preparedness, response and recovery (risk management), more risk-aware decision-making and education, improved cross-disciplinary cooperation, and a better coordination between long- and short-term policy objectives.

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