1. Trends, nonlinearities and extreme events (Pirani).

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2. General elaboration and primary concerns

Understanding the past, predicting the near-term, and projecting the future weather and climate extremes is very important as it is these extreme events that cause major impacts, mostly negative, on both natural and human systems. On seasonal, inter-annual and interdecadal time scales, natural modes of ocean-atmospheric variability such as Atlantic Multidecadal Oscialltion, El-Nino Southern Oscillation, and North Atlantic Oscillation have strong influence on these extremes. On a much longer time scale, anthropogenic climate change is already influencing the frequency and magnitude of some extremes and will have greater influences in extremes in the future. Additionally, it is unclear if and how the large-scale modes of variability may respond to anthropogenic climate change. The response of weather and climate extremes to anthropogenic influence and to the modes of natural variability, as well as possible interactions between the natural and human induced variability can all be quite complex. These present significant challenges for the prediction and projection of weather and climate extremes in the future.

There are many types of weather and climate extremes such as heat waves, droughts cold winters, heavy precipitation, flooding, wind and wind wave storms over land ond ocean, extreme sea levels driven by different physical.. Climate and weather extremes span a very wide range of temporal scales, from minutes to years, and spatial scales, from a local to continental scales. As a result, it is difficult to obtain sufficient observational data to characterize extremes, it is also difficult for models to adequately simulate extremes.

Thus, the **major challenges** are as follows:

- *How to detect and quantify changes in the probability of past and current weather and climate extremes? What are the observational requirements for improved understanding the mechanisms and quantification of extremes in the present and the future?*
- *In what way do the key modes of ocean/atmosphere variability impact weather and climate extreme? How can we improve the ability of climate models to better predict and simulate these ocean variability that are the most relevant to weather and climate extremes? How can we improve model representation of the physical mechanisms by which ocean variability impacts on weather and climate extremes?*
- *If and how these teleconnections and their impact on climate extremes change in the future?*
- *Can we accurately discriminate between the effects of anthropogenic forcing and internal climate variability on extremes, and which modelling and observational activities are needed for this?*

3. The major themes

Improved observational data. Key initiatives are needed to improve the quality and availability of both historical and real-time in-situ observations for better characterization and quantification of weather and climate extremes. These include development of new and improvement of ongoing reanalyses, and continued homogenization and data rescue for in situ data, as well as development of new blended observational high resolution data sets synergising in-situ and remotely sensed data and spurring the advances of both.

Quantitative determination of trends in the key-climate variables over the globe. This includes quantification of trends in all parameters of probability distributions with a particular emphasis on the regions of the strongest changes in temperature and precipitation, including extremes, sea level, cyclone activity, marine storminess, sea ice. It is important that all estimates are associated with uncertainty measures based on the end-to-end consideration of data completeness, metadata and methods of data analysis.

Better understanding of the mechanisms and quantification of influence of the modes of ocean/atmosphere variability on the frequency and magnitudes of different temperatrure and hydroclimate extremes in different continental regions. Of a special importance is the analysis of mechanisms leading to the compound extremes, resulting from several extreme events.

Extending operational seasonal prediction capabilities. The literature suggests that the modes of ocean/atmosphere variability exert influences on extremes. There exists usable skill in predicting these modes at seasonal or longer time scale, some of which is harnessed in decadal prediction experiments. It is important to explore and harness potential predictability of extremes, and understand if decadal predictions allow prediction of the probability of extremes on timescales of decades.

Improved longer-term predictions/projections. Projections of weather and climate extremes due to anthropogenic climate change have been based on the coupled model inter-comparison projects. Future improvements in longer-term predictions of changes in weather and climate extremes requires better representation of key processes in climate models, and from a CLIVAR perspective, processes that lead to better prediction and simulation of ocean – related natural climate variability that influence weather and climate extremes.

4. The way forward

Implementation of CLIVAR strategy on weather and climate extremes should include facilitation of activities targeting the major themes and addressing the concerns. Of these activities the following should have a priority:

- Comprehensive consolidation and update of near-surface atmosphere, surface- and deep-ocean time series and cross-sections for the pre-WOCE, WOCE-phase and post-WOCE periods and obtaining observational evidence of the major modes of ocean and atmospheric climate variability at time scales from several years to decades.

- Contribute to building a reference data base of observational time series based on in-situ and remotely sensed data with highly accurate records and dense sampling to be used for testing capabilities of global/regional climate models to accurately replicate probability distributions of key climate variables.

- Consolidated effort on highly accurate long-term time series of air-sea interaction characteristics available from in-situ, remotely sensed and blended products with a special emphasis on poorly sampled regions, such as high-latitudinal areas and the subtropics and tropics.

- Continuous dialogue between the modelling community (both global and regional) and observational/diagnostic teams on quantitative estimation of scaling in climate extremes through the wide range of space-time scales (together with GEWEX).

- Modelling effort (including models of different complexity) on detection and estimation of predictability of natural modes in the epoch of climate change.

5. Knowledge exchange

Considerable effort is needed to co-operate with GEWEX on estimation of extremes and with WGNE on the analysis of model capabilities to replicate extremes.

There should be a synergy with paleoclimate community on building long-term climate time series extending to time scales of several centuries. These time series should be engaged in model experimentation on estimation of non-linear interactions between natural modes and climate change signals.

6. Capacity building

Studentships and more senior (postdoctoral) fellowships should be established for scientists from developing countries on the major themes. Leading research centers in co-operation with recognized foundations and industry are invited to use their capabilities to place calls for these fellowships.

Use capabilities of the leading climate-oriented master programmes to engage young scientists in high profile climate research.

Continue training workshops on climate data rescue and data management as well as methods of data analysis estimation of extremes in regions of economic transition.

7. Communication challenges

Communications should include a wider dissemination of results through publishing on-line bulletins and maintenance of the web-sites oriented on end-users and public.

8. Summary

Weather and climate extremes and changes in their frequency and magnitude critically affect the society activities and human well being. CLIVAR, being focused on the ocean’s role in climate will consider the role of anthropogenic forcing and natural variability modes, largely associated with sea –air interaction processes in variability of climate extremes across all scales from seasonal to centennial. For this purpose, consolidated efforts on improvement of existing and development of new data sets along with the improvement of predicting capabilities of modelling tools will be taken. This will result in both tangible and intangible deliverables, comprising understanding the mechanisms of long-term changes in climate extremes, including the role of ocean-related natural variability, better near-term prediction and long-term projection of climate variability, new human resources and societal benefits.

9. References –

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