VAMOS and Extremes

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Objective:

Extremes are an important issue in the VAMOS regions as they can induce dramatic socio-economic impacts in the countries of these regions, especially in countries of Central and South America where vulnerability to such events is major. Over the United States, the National Climate Data Center (NCDC) documented the billion dollar weather disasters for the recent years (Lott and Ross 2006). From 1980 to 2005, the 10 severe drought and flood events over the United States cost 144 billion dollars damage. The study of extremes – documenting, understanding, modeling and predicting – therefore constitutes an important cross-cutting theme between the VAMOS Programs (NAME, MESA, VOCALS and IASCLIP). Our work on extremes also allows VAMOS to assess impacts of changes in extremes in the VAMOS region, and to bridge research and society through the development of prediction and early-warning systems on one hand and of adaptation strategies aimed at reducing the vulnerability on the other hand.

VAMOS is in a unique position to utilize its continental perspective in linking extremes in warm season climate behavior to the circulation structures defined as the monsoon systems. Previous studies have analyzed seasonal climate anomalies from a perspective of a large-scale flow pattern modification (e.g. the 1993 U.S. flooding, the drought of Southeastern-Central Brazil in 2001 or the Amazon drought of 2005); however, few have linked similar climate anomalies to perturbations in the monsoon circulation and/or the impact of warm season transients in monsoon regions that may modify the onset of the rainy season. Such a perspective would constitute a multi-scale approach to understanding the subtle interplay of processes occurring at different space and time scales within monsoon systems, such as terrain heating, vegetation-atmosphere coupling, land-sea breezes, regional moisture flux patterns, synoptic disturbances and teleconnections.

This short paper presents plans or guidelines for how the VAMOS community will approach the study of extreme events. The first thing to establish is what VAMOS means by extreme events, which ones we should prioritize and why.

Defining extremes for the VAMOS regions:

Many definitions have been proposed for extremes. The IPCC computes specific Climate Model Extreme Indices (see Frich et al., 2002), and Burford (2006; http://www.drinetwork.ca/extremes/gdocs.php?pageid=definitions) proposed a list of extreme definitions for precipitation for CEOP/GEWEX. Broadly, we summarize two classes of definitions for extremes. One class of definition refers to a specific index (or variable), or a statistical property of the distribution of the variable used to describe the extreme events. The other class of definition refers to the impact of the event, usually quantified in terms of economic loss or ecological disturbance. Within the latter class of definition, extreme events are relative to the sector of study (e.g. reservoir management or agriculture) and its vulnerability (e.g. infrastructures, early-warning systems, emergency plans).

While the definition of extremes based on societal impact is of major interest for stakeholders and should be investigated further in the coming years, its sectoral and societal specificity makes it difficult to provide a general guideline for the VAMOS regions. In the following, we

do not define extreme events based on impacts, but we do acknowledge the need to address those impacts in the context of our definitions. We also acknowledge the need to assess where our more meteorologically-based definitions may be missing important societal impacts. There are many ways to define extreme events, but all definitions should allow the identification of strong events. Specific regional VAMOS Programs are encouraged to work on sectorally- and locally-specific definitions, where appropriate, as they will be of major importance to bridge research and society.

VAMOS's strengths exist in process-oriented, dynamical understanding of the warm season climate over the Americas. This understanding should inform and constitute the basis of our choices of extremes. Much of the existing work on extremes has relied on globally aggregated standardized indices, and often they do not get at the local climate peculiarities, or the implied vulnerabilities to extreme events. Such standard indices are also usually annual summaries, whereas the seasonality in VAMOS regions is very important.

It therefore appears that a common framework for the VAMOS community would be to work on statistical definitions of extreme events relevant to the warm season climate of the Americas for the analysis of interannual variability, decadal variability and climate change. We suggest using definitions of extremes targeted to capture specific historical events, perhaps based on historical events. We also advocate application of extreme value theory to variables of interest (e.g. total daily precipitation, total multi-day precipitation, average maximum temperature over a stretch of days), which may make better sense than using standard extreme indices. We should, for example, consider particular years or periods in which the seasonal expression of extreme events were outstanding, whether in the mean or the characteristics, to further the understanding of mechanisms, predictability and potential early warning.

A suggested list of major extreme events for VAMOS is given by the following:

* Droughts: *Drought is broadly defined by persistent precipitation deficits. Monthly mean data should be sufficient to analyze drought. For meteorological drought, we propose use of standardized precipitation indices. In other contexts, drought may be defined using different variables, such as soil moisture deficit for agricultural drought or streamflow deficits for hydrological droughts. Where data are available to conduct complimentary analyses for these sectoral contexts, such work could increase greatly the local relevance of the work. Characterization or prediction should consider timescales from seasonal to multi-year periods based on monthly mean data.*

* Fluvial or inundation periods: *Wet extremes are envisioned to encompass a wider range of timescales. Daily data would be required to identify events of extreme precipitation intensity or wet spells. One example, taken from the GEWEX/CEOP definition, could be "substantial precipitation for 24h to several days that affects basins or regions on scales of at least* 10^5 km^2*". In the context of climate variability and change, VAMOS should study periods of anomalous frequency of heavy precipitation events, based on daily to weekly characteristics.*

* Heat waves: *Temperature-based extremes would also require daily data. The specific definition will be regionally dependent. Since heatwaves would be of greatest interest in the context of drought, the temperature extremes should probably be considered mainly in terms of their covariance with precipitation extremes.*

VAMOS plans for the 2009-2013 period:

In drafting a plan for work on extremes within VAMOS, we considered issues that were coherent across VAMOS program areas, aspects of extremes that could be somewhat unique to VAMOS, and how we might capitalize on existing and on-going efforts within the climate community. Based on this we believe that our definitions of extremes should be cast in terms of seasonal to intra-seasonal departures from climate normals, even if the dynamical understanding of specific types of extreme events requires examination at shorter timescales, such as analyzing the underlying synoptic meteorology. We would like to be creative in advancing new metrics for anomalous 'high impact' or 'extreme' behavior such as changes in the seasonal frequency of threshold events (heavy rainfall, hail, high winds), integration of daily departures over a season (e.g. integrated evaporative demand over a season, similar to degree days), etc. We hope that such metrics develop from the investigation into the societal impacts side of extremes. The unique perspective that VAMOS brings to the study of extremes, is the emphasis on extremes in warm season 'monsoon' hydroclimate.

1) The initial activity that should be coordinated is refinement of the proposed list of extreme events, including more specificity in how extremes events and indices should be defined, and a listing of season(s) of focus for the various VAMOS program areas. This list could be modified as research progresses, particularly that on the social impacts, but an initial list will be an important first step.
2) The next activity necessary to lay the foundation for guiding observation, modeling and prediction studies on extremes, will be to document extremes over the historical record. What are the regional characteristics of the defined extremes? What climate variability or change can be deduced in those extremes? Are there particular years that would be important to study more closely?

Outcomes from these first two activities should help to focus further efforts on extremes within VAMOS.

Numerous on-going efforts could benefit our ability to analyze, characterize and/or diagnose extremes within VAMOS:

a) One of the most important efforts within the climate community that is absolutely essential to any study of extremes is provision of sufficient length of quality controlled observational data. For indices of extremes, 20 years of data can provide a good signal through averaging. Extreme value theory, which addresses concepts like 50/100 year return levels, needs more decades. If we can access a good inventory for data (both observations and model data), then this will be a good step forward

- <u>Precipitation and surface temperature data</u>:
  - For the United States: Both are available as gridded data at 0.5 (or less) degrees from 1950-present, and as station data back to 1900. These are available from the NCDC.
  - For Mexico: Precipitation and surface temperature station data from 1950 to 2007 are also available. (contact: Art Douglas). A gridded data set covering Mexico and part of the United States at 0.5 degrees was constructed at UNAM and is available through the IRI Data Library. It would be nice to have an inventory of P and T for the IAS and South America.
  - For La Plata Basin & tropical South America: Daily data for temperature and precipitation are being gathered, quality controlled, homogenized and gridded from meteorological stations through CLARIS European Projects.

- Soil moisture data: required for agricultural definition of extremes, are not in a good shape. For drought monitoring, the CPC uses the North American Land Data Assimilation System (NLDAS), but of course, the NLDAS depends on model and input data.
- Streamflow data: required for hydrological definition of extremes, is available within the US is available from the USGS. For other regions, data may be available, from NMHSs. Similar data is available in Brazil from the ANA (Brazilian National Water Authority).
- For the land surface, satellite data is available for the global vegetation. Data is also available from land data assimilation, although model based.
- Various station and gridded datasets are available through the IRI data library (http://iridl.ldeo.columbia.edu), indexed through variable category or dataset source.
- Paleo-data would provide a valuable insight to the historical variability and change in extreme events, particularly in the context of climate change. Dave Gochis has talked with tree-ring folks about historical monsoon failures but there are big issues with diagnosing warm season precipitation from tree rings. Paleo data records (indicators) may be available for available for the last 10000 years in parts of South America.

b) An ongoing activity that will help contribute to extremes based on social impact is that seeking to quantify the cost of specific extreme events (human lifes, infrastructure damages, animal and vegetation damages, biodiversity, …). The NCDC routinely documents the Risk and cost for the United States. They call billion Dollar events: http://www.ncdc.noaa.gov/oa/reports/billionz.html. They list events for each year and give the dollar amounts for the damage. Similarly, severe disasters at the national level are catalogued and quantified in various ways by the Emergency Events Database (EM-DAT, http://www.emdat.be/).

c) The VAMOS work on extremes will also seek to evaluate the skill/value of current predictive systems in predicting specific extreme events. Contributing to those efforts, several activities are underway, some as part of other CLIVAR activities.
   i. The NAME Forecast Forum (and previous NAMAP effort) has been focusing on seasonal scale prediction, which was a critical focus of NAME. In future seasons the NAME forecast forum may expand its effort to analyze model forecasts in their ability to detect the aforementioned anomalies in a few key 'extreme' metrics. (Dave Gochis leads the NAME Forecast Forum).
   ii. The CLIVAR drought working group is running AGCM experiments that should be very useful for addressing monsoon variability on a wide range of time scales. In these runs, each AGCM (NASA/NSIPP, GFDL, NCEP, CAM3.5, CCM3) was forced with a set of idealized SST forcing patterns deemed to have an impact on drought in the Americas. These include control simulations with climatological SST, and for some models, runs with fixed soil moisture. In addition Ben Kirtman is doing some runs in which CFS (the NCEP coupled model) is relaxed to the SST anomaly fields. Together these runs represent a considerable investment of resources (thousands of years of simulation), and should be an important community resource for understanding linkages between SST anomalies and regional climate extremes. More info at: http://www.usclivar.org/Organization/drought-wg.html (Sigfried Schubert co-chairs the US CLIVAR Drought Working Group).

iii. A program has been outlined and endorsed by the CLIVAR AAMP panel for a coordinated project in which climate models are run at high resolution to address weather/climate issues to focus on tropical storm climate connections (e.g., impact of MJO, SST anomalies). A number of groups are already doing these type of runs and the idea is to try to coordinate these efforts. The focus is on tropical storms but the runs/project would clearly also be relevant to VAMOS. VAMOS might want to consider designing similar and/or complementary set of experiments relevant to the Americas (a couple of regionally relevant years - 2005, 1997 – already are included).

d) Finally, some efforts examining observed and projected extremes have already begun.
   i. To provide context to projected climate change impact on extreme event frequency and intensity, Tereza Cavazos has been examining extreme events of NW Mexico precipitation using historical records.
   ii. Anji Seth is involved in the Sustainable Agriculture and Natural Resource Management Collaborative Research Project (SANREM CRSP), which is a program working with SENAHMI Bolivia to perform analysis of observed and projected extremes for the Altiplano region.
   iii. Jose Marengo and Carlos Nobre are involved in studies of trends in extremes in Southeastern South America, Amazonia and Northeast Brazil, as part of UK funded projects, with the objective of assessing impacts and vulnerability and also to proposed adaptation measurements. Emphasis is on water resources, human health, agriculture, and energy generation.
   iv. The CLARIS LPB European project includes a specific WorkPackage dedicated to changes in extremes events under climate change in the La Plata Basin.

Frich P, Alexander LV, Della-Marta P, Gleason B, Haylock M, Klein Tank AMG, Peterson T (2002) Observed coherent changes in climatic extremes during the second half of the twentieth century. Clim Res 19:193–212.