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Technical Briefing Paper (1): Climate Variability and Change

Synopsis Climate variability is observed over a range of time and space scales: from apparently random, highly-localized extreme rainfall events lasting a few minutes to hours, through to long term shifts in ocean temperatures that affect continental climate over centuries to millennia. Assessing vulnerability of water infrastructure and operations to past extreme events is the first step towards formulating robust strategies to confront *future* climate risks. Advances in seasonal climate forecasting potentially offer valuable information for managing the effects of inter-annual climate variability on society, especially in the water and agricultural sectors.

Explanation Reconstructions from tree rings and ice cores tell us that the global climate varies between decades, centuries and millennia. According to the Intergovernmental Panel on Climate Change (IPCC) climate variability is defined as variations in the mean state and other statistics of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Internal variability results from continuous redistributions of heat and moisture between the ocean and the atmosphere, and between different states, such as vapor to liquid, or water to ice, and dynamic interactions among these processes. Globally, the two most important modes of internal climate variability are the El Niño-Southern Oscillation (ENSO) and the Arctic Oscillation (AO). Even though ENSO is the single most important driver of inter-annual variability in global patterns of precipitation, droughts and floods, the index explains just ~7% of the total variance in global precipitation in autumn (September to October). During a typical warm phase, it enhances global mean precipitation by just ~0.2%. However, regional effects may be much greater. For example, warm episodes are typically associated with higher temperatures, lower precipitation and less snowpack over the Pacific Northwest but cool, wet winters over the south and southeastern United States. Even so, these patterns are further modulated by interactions between ENSO and conditions in the north Pacific.

External variability may be due to either natural or human-induced changes to the atmosphere's energy balance. Ice core records of the Beryllium isotope ^{10}Be suggest generally increasing solar activity during the 20th Century. Conversely, records of sulphate aerosols injected into the stratosphere by the volcanism of the 17th Century show reductions in downward shortwave radiation, coinciding with widespread cooling of the Little Ice Age. Records of electrical conductivity and sulphate deposition in ice cores from Greenland and Antarctica reveal a cluster of volcanic eruptions in the early 20th Century and a quiet period between 1920 and 1960 (coinciding with a period of above average global temperatures). Since the Industrial Revolution, emissions of anthropogenic greenhouse gases (carbon dioxide, methane, nitrous oxides, and chlorofluorocarbons) have contributed to a net radiative forcing of the atmosphere, by reducing the amount of upward emission of infrared radiation at the tropopause, and by increasing downward emissions from the stratosphere.

Applications Adapting better to *present* climate variability is regarded by some as the first step towards addressing the greater development and scientific challenges posed by climate change. Seasonal (and even decadal) climate predictability is made possible because slowly varying ocean temperatures and land surface properties (such as the area covered by snow and ice) imprint themselves on overlying atmosphere circulation patterns for several months, even years to come. Knowledge of climate variability can be informative in several ways:

- ***Seasonal climate forecasts*** combined with real-time monitoring can help schedule agricultural activities (such as crop planting, fertilizer and pesticide application, irrigation scheduling, etc.), wildfire, rangeland, reservoir and hydro-power management, or improve preparedness for extreme events, disease control, and civil construction.

- ***Decadal outlooks*** suggest temporary *cooling* for Europe and North America due to an expected weakening of the Meridional Overturning Circulation (an index of the strength of conveyance of warm surface water from the Caribbean to the North Atlantic). Such a cool downturn could pose a reputational risk to organizations that communicate or plan only for a warming scenario over the next few decades.

- ***Baseline periods*** (such as 1961-1990) are routinely used to define present climatology, allocate resources, or to benchmark changes in climate risk. However, palaeoclimatic reconstructions show that trends and extreme weather statistics are highly dependent on the years chosen for the baseline. Placing recent floods and droughts in a longer context better characterizes the risks posed to society by climate variability.

Case Study Summer 2007 flash-floods in England and Wales

Public perceptions of climate are largely governed by the frequency and intensity of extreme weather events. Awareness has been heightened by the apparent volatility of weather patterns over recent decades, and by media assertions that such events could herald anthropogenic climate change. However, even in Europe and North America, where the density, quality and homogeneity of climate records are relatively high, it is not yet possible to statistically isolate human-induced trends from natural variations in regional rainfall.

Recent extremes such as the exceptionally wet summer 2007 in England and Wales appear to counter widely accepted projections of hotter and drier summers (Figure 1). Yet, widespread flash-flooding caused by the torrential rainfall in June and July exposed the vulnerability of energy, water and transportation infrastructure. The ensuing Pitt Review concluded that *...The summer 2007 floods cannot be attributed directly to climate change, but they do provide a clear indication of the scale and nature of the severe weather events we may experience as a result....*

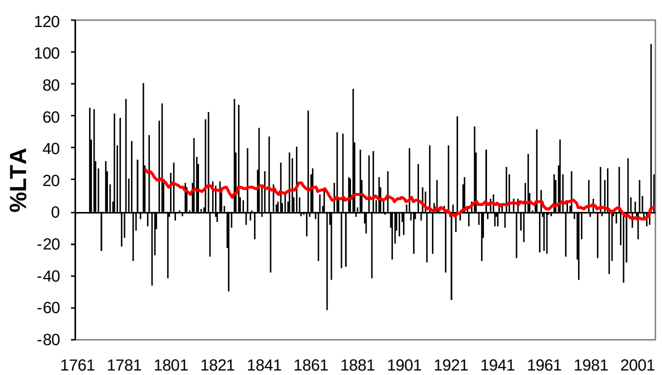

Figure 1 England and Wales summer (May to July) rainfall totals as a percentage of the long term1961-1990 average (%LTA). Note that the large year-to-year variability and the 2007 outlier are superimposed on a long-term trend towards drier summers, consistent with climate model projections.

Data source: British Atmospheric Data Centre

Supporting materials and links

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See Water Research Foundation Technical Briefing Papers 2 (*How Hydrological Change is Measured*) and 5 (*Climate Vulnerability Assessment*)

For palaeoclimatic records and proxy data see the National Climatic Data Center: http://www.ncdc.noaa.gov/paleo/data.html

For examples of seasonal forecasts see the International Research Institute: http://iri.columbia.edu/climate/forecast/net_asmt/