Providing Climate Information Across a Range of Time Scales

Arthur M. Greene, Lisa Goddard, Walter Baethgen, Upmanu Lall

The International Research Institute for Climate and Society

Introduction

Climate-related planning may involve time horizons ranging from weeks to decades, and decision- makers require predictive information on a correspondingly wide range of time scales. In the seasonal-to-interannual (SI) domain, ENSO drives climate variability in many parts of the world, providing a basis for prediction. On centennial time scales, the response of coupled atmosphere-ocean general circulation models (AOGCMs) to imposed boundary-value forcing may also provide useful guidance. Presently, neither ENSO-based predictions nor long-range climate projections provide direct guidance for the intermediate, decadal time horizon.

The various climate time scales are not experienced separately, but as a whole: interannual variability is superimposed on decadal fluctuations, which themselves are departures from a slowly changing base state. Decision-makers must therefore assimilate the full spectrum of climate variability at once. Providers of climate information must also consider variability across the range of time scales, which may then inform a range of forecast products. These products may derive from different kinds of predictions or prediction tools.

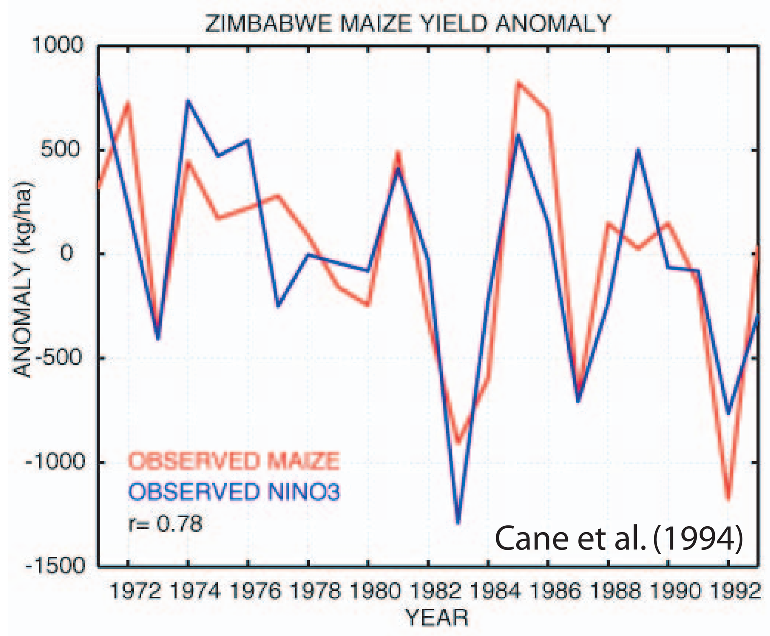
The International Research Institute seeks to provide such a range of climate information, with a focus on developing countries. In terms of the three scales of variability discussed herein, multimodel climate change projections and probabilistic decadal information serve as background against which response to SI forecasts may be considered, in the context of long-term planning.

Impacts

Seasonal-to-interannual (SI) scale: A role for ENSO

The El Niño-Southern Oscillation (ENSO) has a profound effect on climate in many regions; these effects are felt in many economically important sectors, among them agriculture.

Somewhat paradoxically, strong ENSO events are potentially beneficial, since they are associated with enhanced predictability (Goddard and Dilley, 2005).

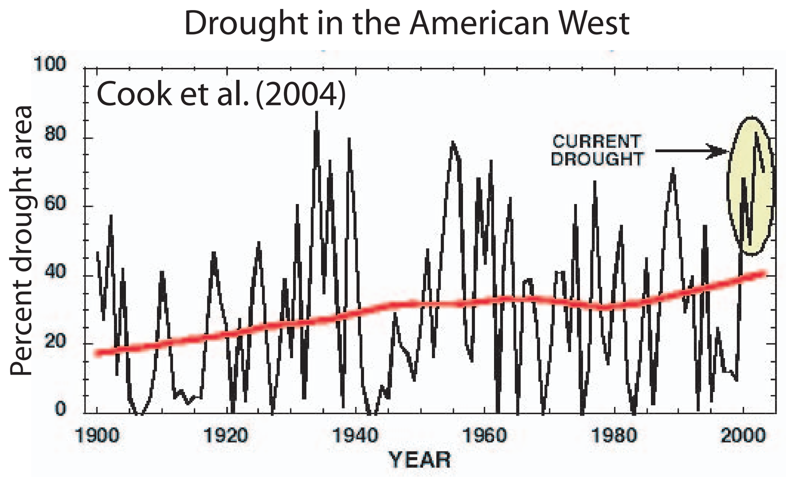


Decadal / multidecadal

Drought can occur on many time scales, from seasonal to multidecadal. Positive land-atmosphere feedback, or decadal persistence in large-scale SST patterns may account for the long time scales associated with some droughts.

Variability in the decadal band, including the Dust Bowl period, is quite evident in the accompanying figure.

Drought in the American West

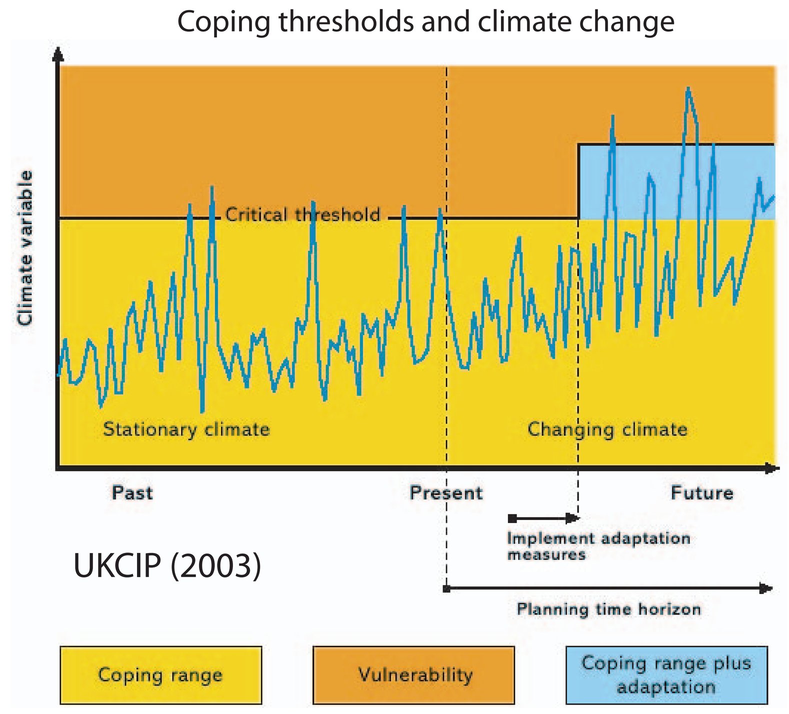


Climate Change

Hundred-year time horizons may seem irrelevant for the purposes of planning today. Yet, it may be well to keep in mind the potential consequences of a slow but steady drift in the basic state we think of as "climatology."

One can think of the time series shown at right as a drought index, for example. With a slow, but persistent, upward drift in the mean state, the critical threshold in drought severity is crossed more and more often, and for longer periods, as time advances. Adaptation raises the critical threshold.

Coping thresholds and climate change



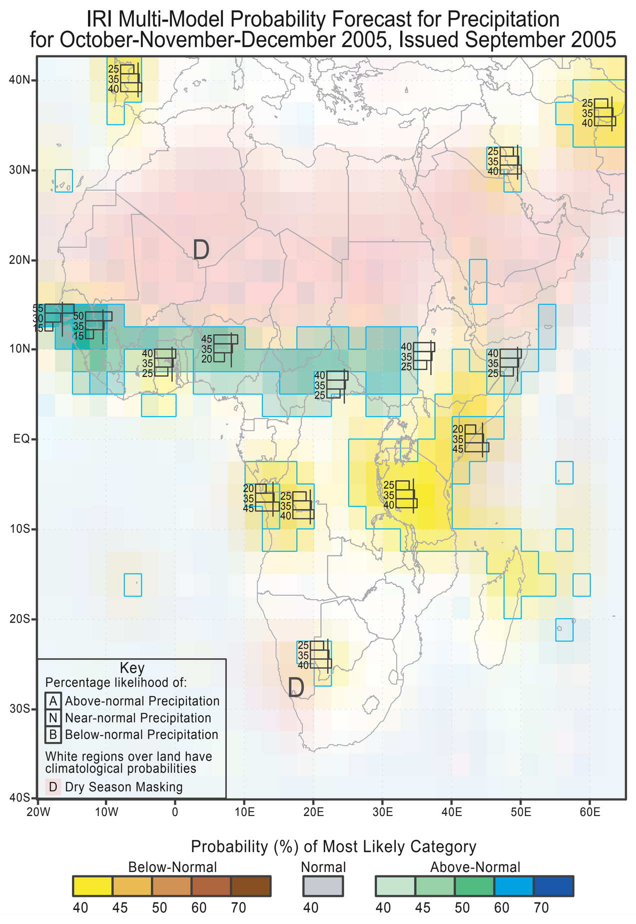
The International Research Institute for Climate and Society

http://iri.columbia.edu
amg@iri.columbia.edu
The Earth Institute, Columbia University, Lamont Campus
61 Route 9W, Palisades, NY 10964-8000, USA

The IRI was established as a cooperative agreement between U.S. NOAA Office of Global Programs and Columbia University.

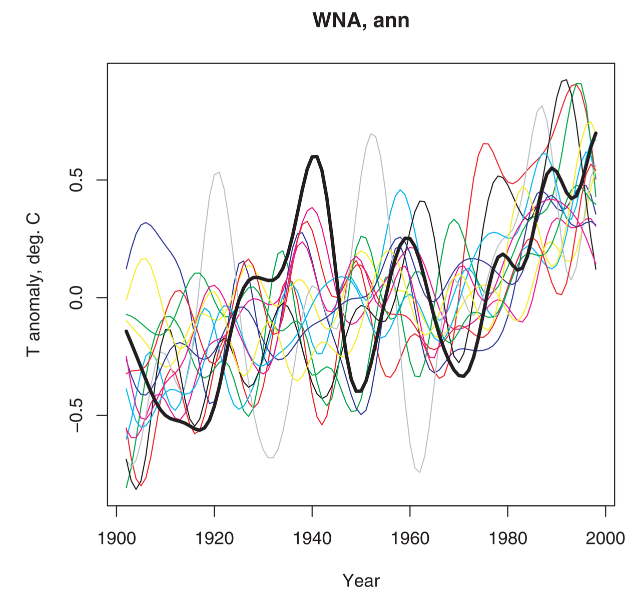
Forecasting

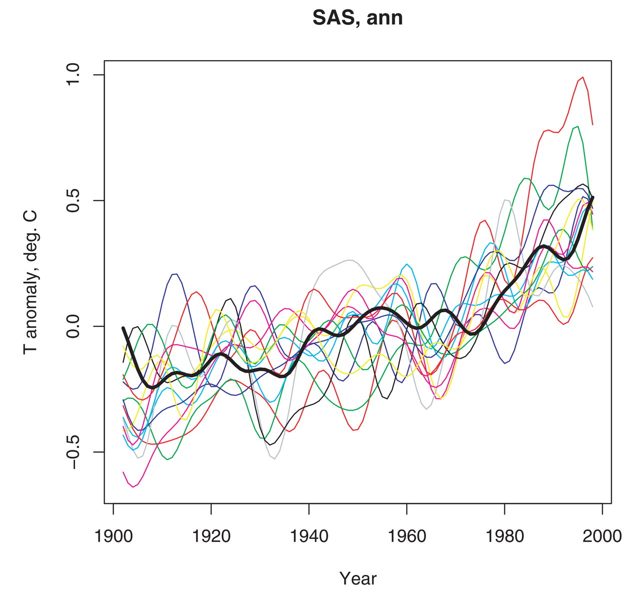
Seasonal-to-interannual (SI) predictions are provided for year-to-year changes in average temperature and total precipitation, typically for 3-month seasons. Predictability derives from changes in the ocean and land boundary conditions that evolve more slowly than day-to-day atmospheric variability. These boundary conditions do not dictate the specific evolution of the weather, but rather, influence weather characteristics, such as the intensity and/or frequency of rainfall, within a season. Dynamical seasonal prediction, which relies on the physical equations governing the climate system, constitutes the preferred method for producing seasonal forecasts. The resulting forecast products are probabilistic, indicating the relative likelihood of the range of possibilities suggested by the boundary forcing. Forecast uncertainty reflects imperfect knowledge of the initial atmospheric and oceanic states, as well as the chaotic internal dynamics of the atmosphere . Reliable forecasts require quantification of this uncertainty.



Decadal/multidecadal climate predictions are not currently issued, since forecasting on these scales is still in its infancy. However, for many decision purposes, such as estimating the historical risk of exceeding defined thresholds, knowledge of the *character* of climate fluctuations may be adequate. One approach for generating such information is the creation of *synthetic* time series that preserve the autoregressive and other statistical properties of the observations. With many such series in hand, risk assessment going forward may be carried out.

The IRI has recently begun exploratory research directed at statistical prediction of decadal-scale behavior, and is also in contact with several dynamical modelling centers, monitoring progress in the development of dynamically-based decadal forecast systems.



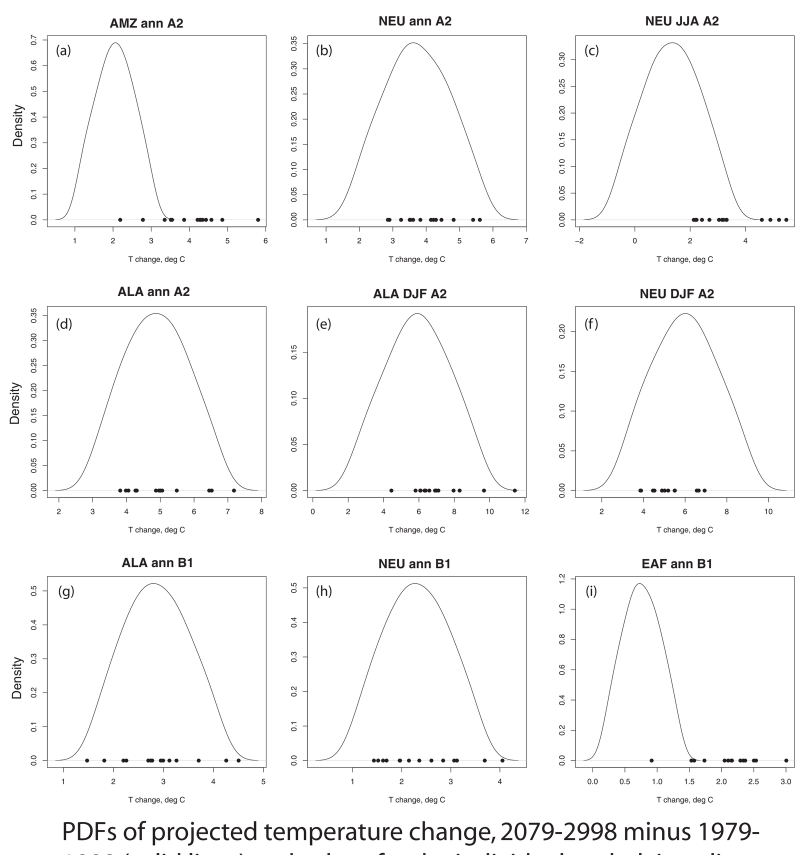


General lack of coherency between coupled models and observations on the decadal time scale. Regions: WNA, Western North America; SAS, Southern Asia (Indian subcontinent)

Climate change projections address the statistics, rather than the details, of secular variations driven by the slowly changing atmospheric concentrations of radiatively active trace gases such as CO_2. Here, much as climate model ensembles are combined in producing SI forecasts, coupled AOGCMs are combined, using a Bayesian linear model, in order to generate temperature projections for the coming century. The Bayesian model identifies the optimal combination of AOGCMs, given observations and simulations of 20th-century regional temperatures. That combination is projected forward in time using simulations of the 21st century.

Of particular interest here are panels (a), (c) and (i), where projected temperatures are lower than the corresponding unweighted ensemble means. This is a reflection of relationships during the 20th-century, the "training period" used in fitting the statistical model.

Probabilistic multimodel regional temperature change projections

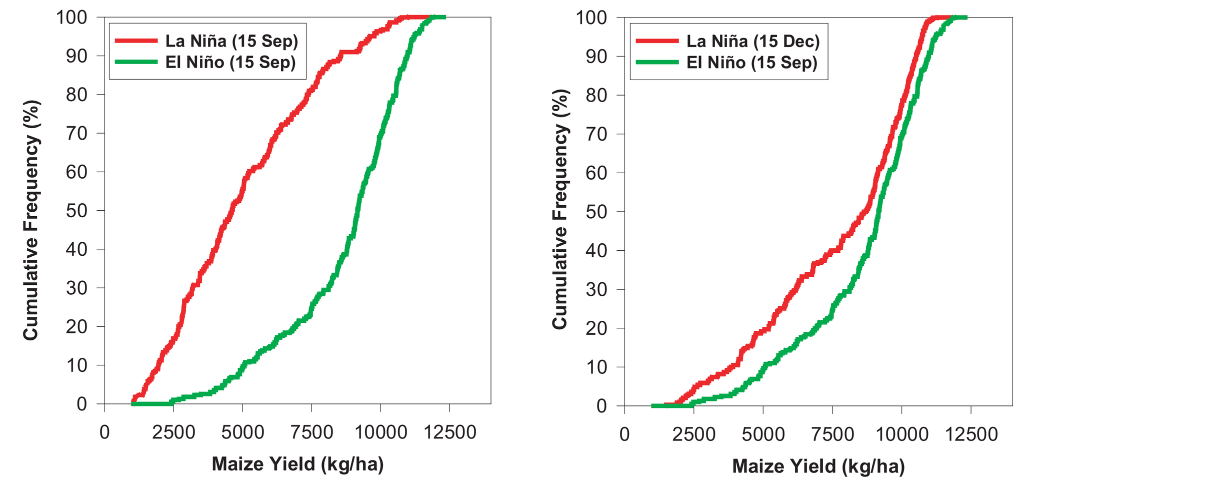


PDFs of projected temperature change, 2079-2998 minus 1979-1998 (solid lines) and values for the individual underlying climate models. Distributions are derived using a linear Bayesian probability model. Region codes: AMZ, Amazon; NEU, Northern Europe; ALA, Alaskan region; EAF, East Africa. Top two rows refer to SRES scenario A2, bottom row to B1.

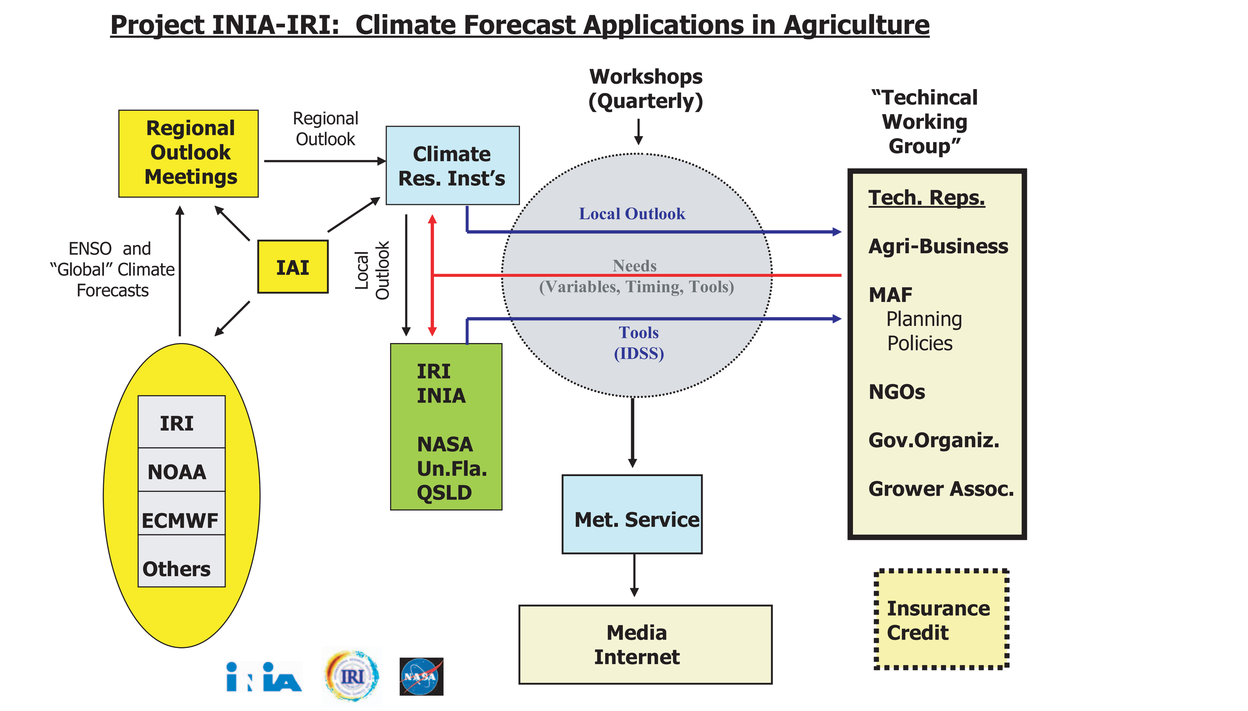
Applications

Agriculture

Below are two plots of simulated maize yields in southwestern Uruguay. The commonly planted hybrid flowers in December, when rainfall is strongly ENSO-dependent: La Niña years tend to be dry, with poor yields, compared with El Niño years (left). If La Niña can be *anticipated,* a late-flowering hybrid with a shorter cycle can be planted, in which case yields approach those of El Niño years. This and the following plot illustrate projects in which IRI is a partner organization.

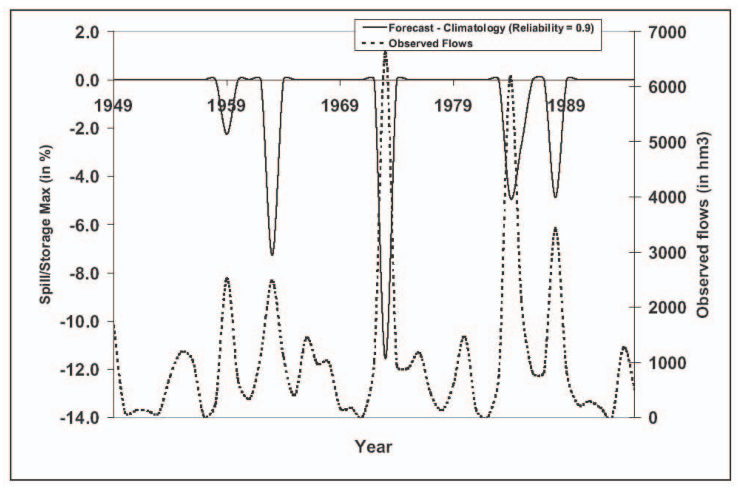


Following is a schematic for an information decision and support system (IDSS) created in partnership with the Instituto Nacional de Investigación Agropecuaria (INIA) of Uruguay and other organizations, that has been in operation since year 2000. An array of component agencies participates in the generation and assimilation of climate information. "Insurance credits," an economic "flywheel," represents a potential entry node for decadal-scale climate information.



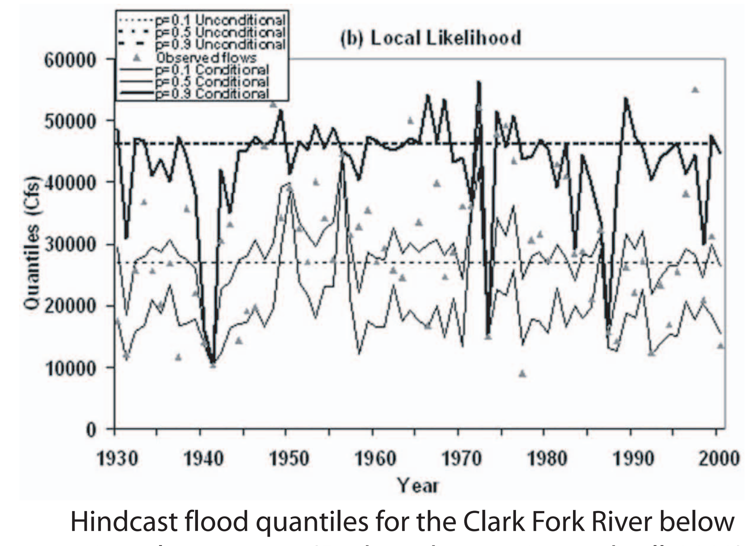
Water resource management

Plot at right illustrates the potential advantage of utilizing climate forecasts in reservoir management. Ability to anticipated high-inflow years reduces the necessity of spillage, and enables increased drawdowns without compromising reliability. Long-term information is not utilized in this analysis (see below).



Spill reduction (%) achieved using k-nearest neighbor streamflow forecasts (Filho and Lall, 2003) for the Oros reservoir, Ceara, Brazil.

At right is shown output of a flood prediction algorithm utilizing climate indices (Pacific Decadal Oscillation index, NINO3) that exhibit decadal and lower-frequency fluctuations. Such an algorithm may, at least in theory, be used to project flood risk forward on long time scales. One important proviso is that the underlying climate models must be able to simulate well the physics giving rise to the observed indices. Projections would take the form of distributions, rather than deterministic forecasts.



Hindcast flood quantiles for the Clark Fork River below Missoula, Montana, (Sankarsubramanian and Lall, 2003).

References

Baethgen, W.E., H. Meinke and A. Gimenez, Adaptation of agricultural production systems to climate variability and climate change: Lessons learned and proposed research approach, in: Insights and Tools for Adaptation: Learning from Climate Variability, NOAA-OGP, Washington, D.C., 2004.
Cane, M.A., G. Eschel and R.W. Buckland, Forecasting Zimbabwean maize yield using eastern equatorial Pacific sea surface temperature, Nature, 370, 204-205, 1994.
Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko and D.W. Stahle, Long-Term Aridity Changes in the Western United States, Science, 306, 1015-1018, 2004.
Goddard, L. and M. Dilley, El Niño: Catastrophe or opportunity, J. Climate, 18: 651-665, 2005.
Greene, A.M., L. Goddard and U. Lall, Probabilistic multimodel regional temperature change projections, J. Climate, in review, 2005.
Filho, F.A.S. and U. Lall, Seasonal to interannual ensemble streamflow forecasts for Ceara, Brazil: Applications of a multivariate, semiparametric algorithm, Water Resour. Res., 39(11), 1307, doi:10.1029/2002WR001373, 2003.
Sankarasubramanian, A. and U. Lall, Flood quantiles in a changing climate: Seasonal forecasts and causal relations, Water Resour. Res., 39(5), 1134, doi:10:1029/2002WR001593, 2003.
UKCIP (United Kingdom Climate Impact Programme), Climate adaptation: Risk, uncertainty and decision-making, Tech. Report, 2003.