with improved instrumentation will give more information on this potentially highly interesting, but also still highly uncertain, story.

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NOTA BENE: CLIMATE

Seasonal Climate Prediction

Weather prediction is generally restricted to a time scale of about 2 weeks, a limit imposed by the intrinsic variability of the atmosphere (*1*). However, because of the coupling between the atmosphere and the more slowly varying oceans, climate prediction over longer time scales of seasons, years or even decades may be possible (*2*). In recent years, climate researchers have made major advances in seasonal prediction, especially in the tropical Pacific. At a recent meeting of the World Climate Research Program (WCRP) (*3*) in Geneva, the successful prediction of the 1997–98 El Niño–Southern Oscillation (ENSO) event was hailed as a significant step in understanding and predicting climate. ENSO, a major interannual climate fluctuation in the tropical Pacific, is known to affect climate worldwide, with consequences for agriculture and energy-consumption planning.

A number of factors made the ENSO prediction possible. Because of their persistence, prediction of eastern tropical sea surface temperatures (SSTs) is possible a year or more in advance (*4*), allowing, in principle, the forecast of atmospheric conditions. However, such forecasts require high-quality observational data that are immediately available and equally high-quality prediction models based on state-of-the-art understanding of oceanic and atmospheric processes.

After the catastrophic 1982–83 ENSO event, which came as a surprise to researchers and the affected nations alike, the Tropical Oceans and Global Atmosphere (TOGA) program (*5*, *6*), which was already in the planning stages, got another boost. TOGA aimed to establish an observational and modeling infrastructure to allow seasonal prediction. At the time, observational coverage was inadequate, data were analyzed and transmitted too slowly and were not internally consistent, and the models were inappropriate. Within TOGA the existing observational network was expanded into an integrated observing system of moored buoys, drifting buoys, tide gauge systems, and volunteer observing ships. These data are delivered rapidly to prediction models and are used in conjunction with satellite data. The program aimed to improve understanding of the climate processes themselves and how they were represented in the models (*5*).

Coupled atmosphere-ocean general circulation models (CGCMs) were first applied to ENSO prediction in the mid-1980s (*7*). These early predictions were able to forecast a warming event in 1987 but predicted it to occur 3 months earlier than it did; moreover, spatial details of the event could not be forecast accurately. Today's models, such as the CGCM at COLA (Center for Ocean-Atmosphere Studies), have shown in "hindcast" simulations that not only could details of earlier ENSO events have been predicted for the tropical Pacific but so could their effect on extratropical atmospheric circulation, affecting, for example, the Indian Monsoon and North American climate (*8*). For 1997–98, the models predicted a warm ENSO event 6 months before the SSTs began to show the typical ENSO features (*9*). Such prediction allows affected countries such as Peru and Australia to take measures against floods and droughts and to adjust agricultural policy accordingly.

Since the TOGA program was officially brought to a close in 1994, the International Research Institute (IRI) (*10*) has been set up to continue and expand routine climate monitoring and accurate climate prediction in close collaboration between observation and modeling. Other programs such as CLIVAR (Study of Climate Predictability and Variability), another WCRP program (*11*), aim to take climate prediction further. Future projects aim to provide more detailed regional prediction and to assess decadal predictability of climate, as well as climate change and its attribution to natural variability versus human influences.

These are major challenges on the way to an operational worldwide climate observing and prediction system. Other regions of the world suffer from insufficient observation; for example, the Indian Ocean (and particularly the southern Indian Ocean) has a very sparse observational network, and major gaps exist in the understanding of its climate and variability and their influence on world climate. The North Atlantic Oscillation (*12*), which is less regular than ENSO but has a major influence on climate in mid-latitudes and as far south as Morocco, is also monitored much less intensively and is presently not understood or predicted nearly as well as ENSO. In addition, the interactions between these large-scale climate features are not well understood (*13*). Future developments depend crucially on an extended, sustained worldwide observation system that covers both terrestrial and oceanic areas.

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–Julia Uppenbrink