CLIMATE CHANGE

From science to service

Climate services are crucial for successful adaptation to current and future climate conditions

By **Lisa Goddard**

People rely on daily weather services to decide what to wear, make transport choices, prepare for rain, and more. Many societal decisions, however, need information not on time scales of days, but on climate time scales of months, years, or decades. New initiatives such as that of Copernicus in Europe provide a wealth of climate data, which are integral to climate services. However, data are only one aspect of climate services, which also involve translation and use of relevant information with the aim to help society manage the risks and opportunities of climate variability and change (*1*–*5*). To be successful, any climate service must have a clear problem focus, build on good-quality observations, and consider climate across different time scales.

WHAT'S YOUR PROBLEM?

Climate is rarely the only factor guiding decisions and actions. Even for sectors where climate is clearly a factor, such as in agriculture, climate considerations on their own may not be important enough to shape a particular decision. For example, in southeastern South America, rainfed soybean farming has expanded into less climatically suitable areas. This decision may be justified by rising global prices for soybeans in recent decades that make the industry less susceptible to drought occurrence. In other situations, climate information may not be certain enough to motivate its use. For example, the risk of extreme events is inherently uncertain even if the predicted odds of their occurrence may have doubled or tripled in next season's forecast. Projections for rainfall under climate change are also highly uncertain in regions where observed trends have been relatively weak and climate models disagree or have little skill.

Mounting evidence shows, however, that climate information can improve behaviors and outcomes when appropriately incorporated within the decision context. Rahman *et al.* recently conducted an independent evaluation of a newly developed seasonal drought information service in Jamaica. The service included drought monitoring, forecasting, agricultural extension, farmer forums, and regular SMS messaging and was developed cooperatively across several disciplines, ministries, international donors, and nongovernmental organizations. On average, those farmers who recognized climate as an important factor in their yields (and were thus more likely to use the drought outlooks in planning and practice) experienced 50% lower losses in the recent 2014 drought than did other farmers (*6*).

In another application of climate services, this time to the health sector, a comprehensive surveillance and early warning system for dengue was set up in Ecuador over several years. Climate scientists working with health experts, including the Ministry of Health, found that periods of high rainfall and high temperatures were associated with dengue outbreaks in many parts of the tropics, in addition to nonclimate triggers. As Borbor-Cordova *et al.* describe, the early warning system in Ecuador led to more targeted seasonal vector control interventions, risk maps, knowledge-translation through climate-health forums, as well as social media and bulletins for the health sector (*7*).

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Thus, to develop effective climate services, it is important to clearly define the role of climate within the broader decision-making context.

KNOW YOUR DATA

Good observational data are critical to climate services. Climate observations allow us to understand the past, monitor the present, and judge how well climate models perform for a particular region or application. Observations are thus necessary to help predict the future through model validation and calibration. However, not all observational data sets are created equal.

Many global data sets appear to provide amazingly high-resolution observations over a country or region. But peek under the hood and you start to see potential problems or limitations. For example, compared to Germany, the entire continent of Africa has less than 10% the number of rain gauges reporting to global data centers. And the number of these gauges worldwide is decreasing, especially in African countries. Such gaps in observational records severely limit their value.

Observational data sets with greater integrity are being created, however. For example, historical data may be available from written logs of temperature, rainfall, humidity, and other observations. Data rescue projects, such as the International Environmental Data Rescue Organization, rely on volunteers to recover and digitize these data and bring it online. These efforts contribute directly to a country's data wealth and facilitate a more informed use of models and forecasts. Other efforts merge station data with satellite data to increase the coverage of in situ observations (*8*) worldwide while helping to validate satellite-derived products. Even higher resolution and improved data quality can be achieved by working at the national level, because many countries hold more data than they make available to the global data community (*9*).

TIME SCALES MATTER

The climate varies continuously on time scales from months to centuries, with and without humanity's influence. Rarely is a region, sector, or company impacted by only a single time scale. For example, managers of municipal water systems consider a time horizon of 5 to 30 years when deciding on how much to expand. However, they must also address weekly, seasonal, and annual targets for water supply, hydropower production, and flood control. Dynamic risk assessment requires climate information that addresses time scales from weeks to decades (*10*).

The relative importance of the climate on different time scales varies with variable, location, and even time of year (see the figure). Understanding the magnitudes of climate variations and trends can help guide what information is most needed for planning and resilience. Such analyses also provide a focus to the study of historical social and economic impacts from past climate variations, which may guide future adaptation efforts.

Warming trends have dominated the annual mean temperatures records for some parts of the world over the past 100 years; in other areas, the long-term trends are

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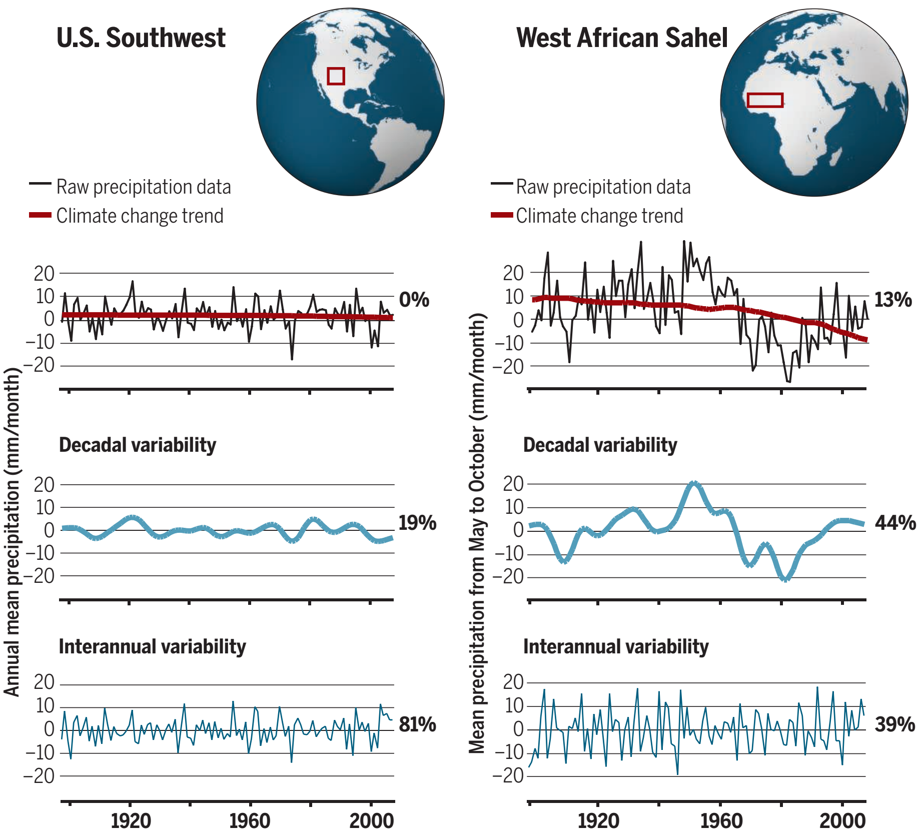
Two regions, two climate stories

In the outlined area of the U.S., year-to-year variability has been the primary driver of rainfall, accounting for 75% of the variance we see in the historical record. The long-term climate trend accounts for only 1% of the variance. The story is different in the Sahel, where fluctuations on a decadal scale were more dominant, accounting for about 40% of the variance (*11*).



secondary to interannual or decadal variability. For precipitation, the story is totally different. Most observations indicate that long-term trends accounted for only a few percent of the variance over the 20th century. The relative importance of decadal-scale variability on precipitation is typically 20 to 30%. Year-to-year variations account for most of the rainfall variations that communities experience locally.

For example, over much of the western United States, decadal rainfall variability accounts for only about 20% of what people living there experienced (see the figure). Yet such variability can have significant social impacts, such as the Dust Bowl of the 1930s, the Great Basin Drought of the 1950s, and recent dry conditions. Most of the variability by far is at the interannual time scale, causing either severe drought years or years of extreme flooding. Much of the interannual-to-decadal variability derives from slow changes in ocean temperatures and may be potentially predicted for preparedness measures, or at least characterized to help build resilience. Any predictive capacity adds to the value of climate services beyond the mere characterization for resilience.

Contrast the western U.S. with the western Sahel (see the figure). Here, decadal variability, tied to both natural and aerosol-forced changes in Atlantic Ocean temperatures, has a relatively much larger influence on the historical climate record. Additionally, climate-change scale trends have been large compared to other parts of the world. The compounding effect of year-to-year variability is to worsen or ameliorate the dry and wet periods. This can result in shifts that are as large as the decadal ones, and larger than the century-long trend. The confluence of factors here points to the need for climate information across scales for national adaptation and resilience planning, and that decisions across time scales would benefit from information focused at that time scale, from monitoring to seasonal forecasts to climate change projections.

OUTLOOK

The field of climate services is relatively new. Despite the WMO's Global Framework for Climate Services (*1*) and the growing body of literature, considerable confusion remains about what climate services are or what they should provide. What is clear is that climate services require more than just climate science. To work, they depend on a solid understanding of how climate fits into the broader decision context, as well as the political will to foster multidisciplinary research and practice.

The humanitarian community—including the International Federation of Red Cross/Red Crescent and the World Food Programme—has recently embraced preparedness and resilience more actively. Climate information was used much more effectively to guide the response to the large El Niño event of 2015–2016 than to the comparable sized El Niño event in 1997–1998. Such applications of climate services are important steps toward helping vulnerable populations and sectors to adapt to the climate of today and of the future. The success of climate services will depend on their ability to address risks and opportunities at relevant time scales with appropriate solutions informed by high-quality data. ■

REFERENCES AND NOTES

1. C. Hewitt, S. Mason, D. Walland, *Nat. Clim. Change* **2**, 831 (2012).
2. P. Adams *et al.*, *WMO Bull.* **64**, 51 (2015).
3. J. Brugger, A. Meadow, A. Horangic, *Bull. Am. Meteorol. Soc.* **97**, 355 (2016).
4. C. Vaughan, S. Dessai, *Wiley Interdiscip. Rev.: Clim. Change* **5**, 587 (2014).
5. R. Moss, *Clim. Change* **135**, 143 (2015).
6. T. Rahman, J. Buizer, Z. Guido, *The Economic Impact of Seasonal Drought Forecast Information Service in Jamaica, 2014-2015.* Paper prepared for USAID (2016); see www.climatelinks.org/sites/default/files/asset/document/Economic-Impact-of-Drought_Information_Service_FINAL.pdf.
7. M. Borbor-Cordova *et al.*, in *WHO/WMO, Climate Services for Health: Improving Public Health Decision-Making in a New Climate*, J. Shumake-Guillemot, L. Fernandez-Montoya, Eds. (WHO/WMO, Geneva, 2016), pp. 108–109.
8. C. Funk *et al.*, *U. S. Geological Survey Data Series 832* (USGS, Washington, DC, 2014).
9. T. Dinku *et al.*, *The ENACTS Approach: Transforming Climate Services in Africa One Country at a Time*, New York: World Policy Institute, New York, 2016); www.worldpolicy.org/policy-paper/2016/03/16/enacts-approach.
10. G. Pizarro, U. Lall, M. Atallah, *Environ. Fin.* **10**, 26 (2009).
11. The figure shows a time series decomposition of annual rainfall (mm/month) from CRU-TS3.1 (*12*) over the 20th century for the demarked regions of the western United States (37°N to 42°N; 110°W to 102°W) and of the African Sahel (12.5°N to 17°N; 17.5°W to 10°E) [see (*13*) for details of the methodology]. The top graphs show the full time series with the time mean average removed. The red lines are an estimate of the climate change trend in the data. Once this trend signal is removed, the data are low-pass filtered at decadal and longer time scales (center graphs). The remaining variabilities represent the year-to-year variabilities (bottom graphs). The percentages to the right represent the total variance contained in each time scale. Covariance between decadal and interannual variability may reduce the total.
12. I. Harris, P. Jones, T. Osborn, D. Lister, *Int. J. Climatol.* **34**, 623 (2014).
13. A. Greene, L. Goddard, R. Cousin, *Eos Trans.* **92**, 397 (2011).

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