ISciences Global Water Monitor & Forecast: Anticipating Change in the Human-Earth System

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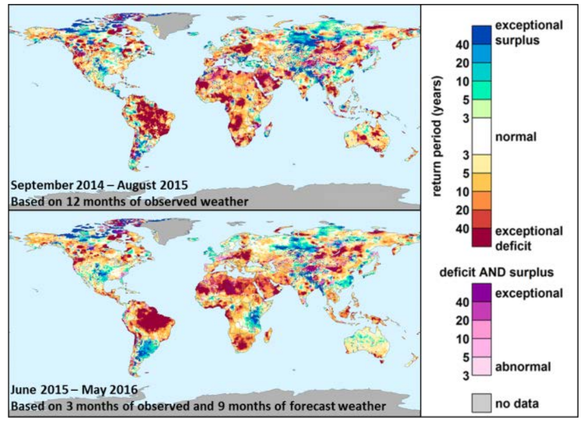
Water is an essential resource for civilization that is tightly coupled to climate and weather. We live in a world today that is significantly more water stressed than at the beginning of the last century, and we can expect it to get worse over time. Demand for fresh water increased approximately eight-fold last century due to population growth and economic development (Shiklomanov & Rodda 2003). At the same time, climate is changing (IPCC 2014). These climatic changes alter the distribution and timing of fresh water supply due to changes in temperature and precipitation regimes. Greater demand and changing supplies create environmental stresses such as droughts and floods that affect people, agriculture and commerce. When added to social, political, and economic stresses, they have the potential to trigger outcomes affecting human security. These outcomes may include agricultural shortfalls, infectious disease outbreaks, electricity shortages, transnational water disputes, or population displacements that may lead to economic disruptions or human insecurity.

While numerous studies have documented contemporary water stress (Smakhtin et al. 2004, Gassert et al. 2015) and long-term projections of change in water stress (Schewe et al. 2013, Luck et al. 2015). These studies focus on the important topic of chronic imbalances between water supply and demand and the projections typically have multi-decadal or longer time-horizons. However, they typically do not address episodic events such as droughts and floods. Hall et al. (2014) describe the complex relationships between freshwater variability, institutions, infrastructure, information, and economic development. Wealthy countries have invested in water storage schemes and associated institutions and information systems in an effort to reduce exposure to droughts and floods. In contrast, these investments are typically lacking in less affluent countries. It is not clear whether the existing capacity to manage freshwater variability in relatively wealthy countries is sufficient to cope with increased variability expected with climate change, or whether less affluent countries should follow the paths established by wealthy countries or innovate new approaches. It is clear that all countries need to renew efforts to evaluate exposure to freshwater variability and enhance management capacity.

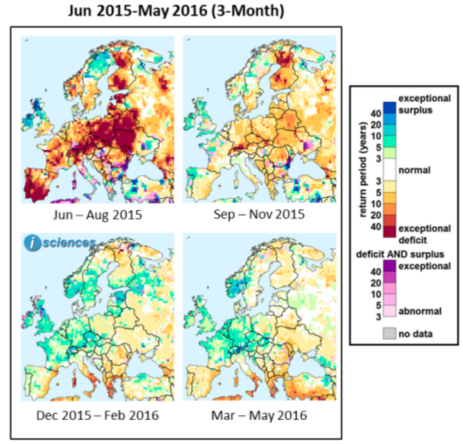
ISciences developed our *Global Water Monitor & Forecast* capability to address the need to provide early warning of regionally significant water anomalies on time-scales that would provide sufficient warning to anticipate and plan orderly responses as events unfold. This capability monitors and forecasts water deficits and surpluses on a global monthly basis. Each report documents current conditions and forecasts future conditions with lead times of 1-9 months at 0.5x0.5° resolution. It has been in continuous operation since April 2011 and has proven to provide reliable forecasts of emerging water security concerns in that timeframe. ISciences has also developed impact assessments for agricultural production and electricity generation that couple hydrological forecasts with demographics, land use, cultural practices and infrastructure to identify regions where anomalies will likely have significant socio-economic impacts. In addition to providing early warning for water deficits and surpluses and they unfold, tools such as these can help assess approaches to building adaptive capacity over the long-term.

The figure to the right depicts global water anomalies relative to a 1950-2009 baseline period for the 12 month periods ending in August 2015 (top) and May 2016 (bottom). The anomalies are depicte d in terms of return period. This describes how rare the surpluses (increasing intensity of blue) or deficits (increasing intensity of red) are relative to expectations. For example an anomaly with a return period of 10 years would be expected to occur, on average, once every 10 years based on historical distributions. We calculate a composite deficit indicator based on the most extreme (largest return period) soil moisture, evapotranspiration deficit, and total blue water anomaly. Similarly, the composite surplus anomaly indicator is the most extreme of the runoff and total blue water (flow accumulated runoff) anomalies. Purple is used to depict regions that exhibit characteristics of both water deficits and surpluses. A good example is a river that runs through a region with below normal soil moisture, but where flow rates are relatively high due to a larger than normal spring snow melt in the headwaters.



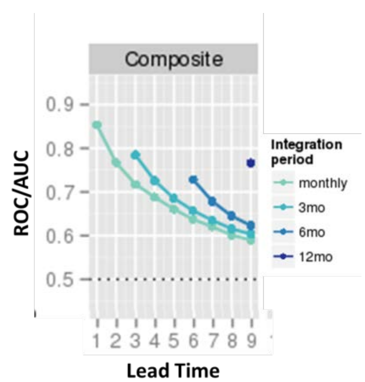
Our data are produced on a monthly time step. This enables us to anticipate the evolution of surpluses and deficits over the forecast period. The four maps to the right depict short term (three month) anomalies based on the current conditions (upper left) and the three subsequent three month periods (upper right, lower left, lower right). In this case, the forecast suggests a transition in portions of Europe from widespread exceptional deficits to surpluses in the December 2015 – February 2016 time frame.

WSIM Composite Water Anomaly Index
Jun 2015-May 2016 (3-Month)



Based on observed data through August
and forecasts issued the last week of August 2015

We have been able to compare our composite water anomaly forecasts with subsequent estimates based on observed weather data in order to evaluate skill. The plot below depicts a skill metric known as “receiver operating characteristic/area under the curve (roc/auc)” for forecasts of 10-year deficits as a function of lead time and integration period. A perfect roc/auc is 1 and a random forecast would have an roc/auc of 0.5. In this case, auc/roc> 0.6 at lead times up to 8 months. Monthly forecasts have auc/roc >0.7 with lead times up to 3 months, seasonal (3 month integration periods) forecasts have auc/roc>0.7 with lead times up to 4 months, and 6 month integration periods have auc/roc>0.7 with lead times of 6 months.[1] The 12-month integration periods include 3 months of indices based on observed data and 9 months based on forecast data. Even with 9 months of forecasts, the auc/roc is about 0.78. While these forecasts are not perfect, they do provide significant value added. In general, our skill is better for regionally significant persistent anomalies as opposed to localized singular events such as flash floods or tropical storms.



[1] Note that lead time is based on the last month of the forecast target period.

ISciences has also developed algorithms to assess the impact of water anomalies on agricultural production and electricity generation. The agricultural assessment evaluates the degree to which water anomalies restrict agricultural production. In addition to water anomaly data, it uses data about cultivation areas, relative yields, crop calendars, and reservoir capacity to provide geographically explicit loss risk maps. This capability has been validated against USDA yield and insurance data for the coterminous United States. The electricity assessment evaluates the degree to which water deficits restrict electricity production from hydropower and thermal plants (including nuclear). It considers upstream reservoir capacity and consumptive use, fuel stock and cooling technology, and downstream water stress.

We consider our *Global Water Monitor & Forecast* capability to be an effective tool for anticipating large scale regional water anomalies with sufficient lead time to plan orderly responses as events unfold. The skill of tools such as ours will improve as the skill of climate forecasting tools such as NOAA's Climate Forecast System (Saha et al. 2014) and its counterparts throughout the world improve. Toward that end, we have begun planning to incorporate multi-model ensemble forecasts such as the National Multi-Model Ensemble into subsequent versions of the *Global Water Monitor & Forecast*.

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