The Princeton African Drought Monitor

1. Rationale

Droughts are one of the most devastating of natural hazards, affecting millions of people and inflicting widespread economic impacts (Wilhite et al., 2007). These impacts can be mitigated through the provision of real-time drought information, which in turn can be used to respond to the needs of the population and maintain the health of ecosystems (Sheffield and Wood, 2011). The potential for mitigation is highly desirable in drought-vulnerable areas such as the Sahel in Africa, where droughts in the 1970's and 1980's caused devastating human loss and economic repercussions (Sheffield and Wood, 2011).

Monitoring drought globally is challenging because of the lack of dense in-situ hydrologic data in many regions. This is particularly problematic for developing regions such as Africa where water information is arguably most needed, but virtually non-existent on the ground in many regions. A potential way forward is to use a modeling framework that couples available satellite remote sensing and in-situ information. This results in physically consistent and spatially and temporally continuous estimates of the water cycle and drought.

A drought monitor based on this framework and an accompanying web-based user interface have been developed, in collaboration with UNESCO, for operational and research use over Africa. Based on macro scale hydrologic modeling, the system ingests available data to provide a real-time assessment of the water cycle and drought conditions, and puts this in the context of the long-term record back to 1950. The data is made available online for drought research and operational use to augment on-the-ground assessments of drought.

2. Methods: The Drought Monitoring System

The monitoring system comprises two parts:

i) First, a historic reconstruction (1950 – 2008) of the water cycle forced by a merged reanalysis/observational meteorological data set; this forms the climatology against which current conditions are compared.

ii) Second, a real-time monitoring system (2009 – present) driven by remote sensing precipitation and atmospheric analysis data that tracks drought conditions in near real-time.

The historic and real-time data are calculated using the Variable Infiltration Capacity (VIC) land surface hydrological model (Liang et al., 1994), which is run at a daily time step and ¼ degree spatial resolution for the whole of Africa. For the historic reconstruction, the model is forced by meteorological data derived from a blending of reanalysis (NCEP/NCAR) and gridded observation-based datasets including: the Climate Research Unit TS3.1 monthly precipitation and temperature data set, the NASA Tropical Rainfall Measurement Mission (TRMM), the monthly gridded precipitation and temperature data set of Willmott and Matsura, and the Global Precipitation Climatology Project (GPCP) monthly data set (Sheffield et al., 2006).

For the real-time monitor, the VIC model is forced by a mixture of observations and modeled/remotely sensed meteorology to produce updates of water cycle variables (e.g., soil moisture, runoff, and evapotranspiration). Daily mean wind speed and daily maximum and minimum temperatures are taken from NOAA's Global Forecast System (GFS) analysis fields, which ingest data from multiple sources including remote sensing and in-situ observations in real-time (Parrish and Derber, 1992); this is a reliable source for real-time data over large-scales. Daily precipitation comes from the NASA TRMM Multi-satellite Precipitation Analysis (TMPA) data set (Huffman et al., 2007) when available, otherwise from GFS. Both TMPA and GFS are bias-corrected to ensure consistency with the historical meteorological data set.

Drought is estimated primarily in terms of low soil moisture, which is given as a drought index based on soil moisture percentiles. The index is calculated by determining the percentile of the daily average of relative soil moisture at each grid cell with respect to its empirical cumulative probability distribution function provided by the historical simulations (1950 – 2008). The drought index (and all hydrological variables and meteorological forcings) is available for the entire record between 1950 and real-time. Using the daily land surface model output, multiple hydrologic variables and derived drought products are estimated for more than 800 catchments over Africa that correspond to the Global Runoff Data Center (GRDC) network and Food and Agriculture Organization (FAO) reservoir database. The variables include: simulated discharge and basin averaged water cycle variables including precipitation, evaporation, surface runoff, baseflow, and the soil moisture drought index.

3. Data Dissemination: Web-based User Interface

A challenge for monitoring efforts is the rapid and efficient dissemination of the drought monitor's products. To this end, a simple and intuitive web-based interface has been developed to display the data of the African Drought Monitor. The interface allows users to access the entire daily record from 1950 to three days before real-time through a basic and interactive interface. The data that are available through the user interface include: maps of evaporation, surface runoff, soil moisture, drought index, precipitation, temperature, and mean wind speed. The data also includes catchment specific information such as simulated discharge and basin averaged hydrologic variables.

Basic Interface: This interface provides quick and easy access to current hydrological and drought conditions in the form of maps. The user is also able to choose to display maps from a different date back to 1950 and download the preprocessed images.

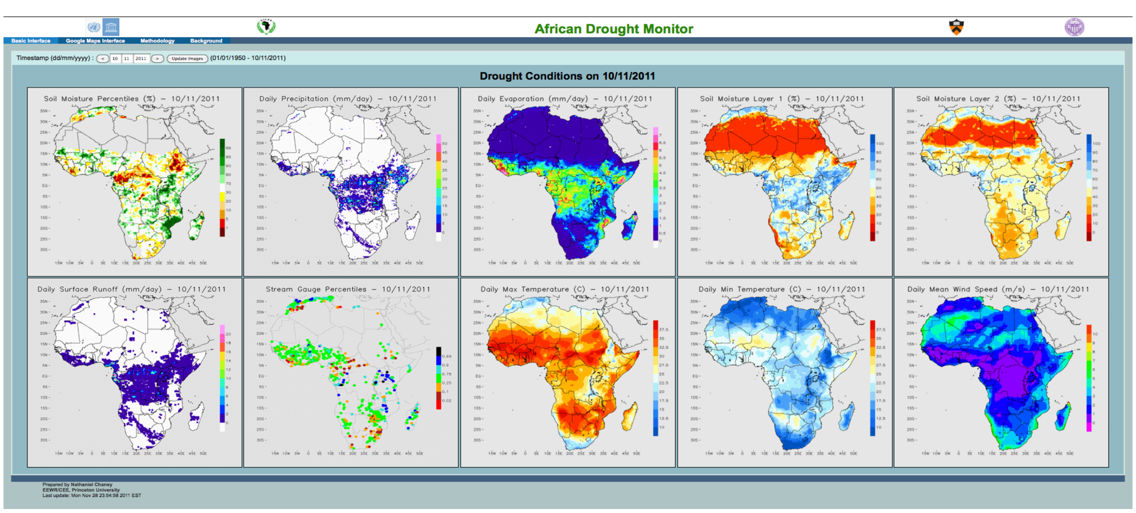

Figure 1- Example of the basic user interface showing soil moisture percentiles, precipitation, evaporation, soil moisture, surface runoff, stream gauge percentiles, temperature, and mean wind speed on November 10th, 2011.

Interactive Interface: This interface is based on Google Maps and allows the user to interact with the system, to zoom in on specific regions, display maps and time series, and download data. This functionality is provided by the standard Google Maps interactive controls and a menu for selecting variables and display methods. Among its functionalities is the ability to show maps of hydrologic variables on the entire African continent (Figure 2). The user can then choose a time interval to animate the images and show the evolution of drought and hydrologic variables. Furthermore, the user can zoom in to a region or basin of interest and inspect the animated maps in closer detail.

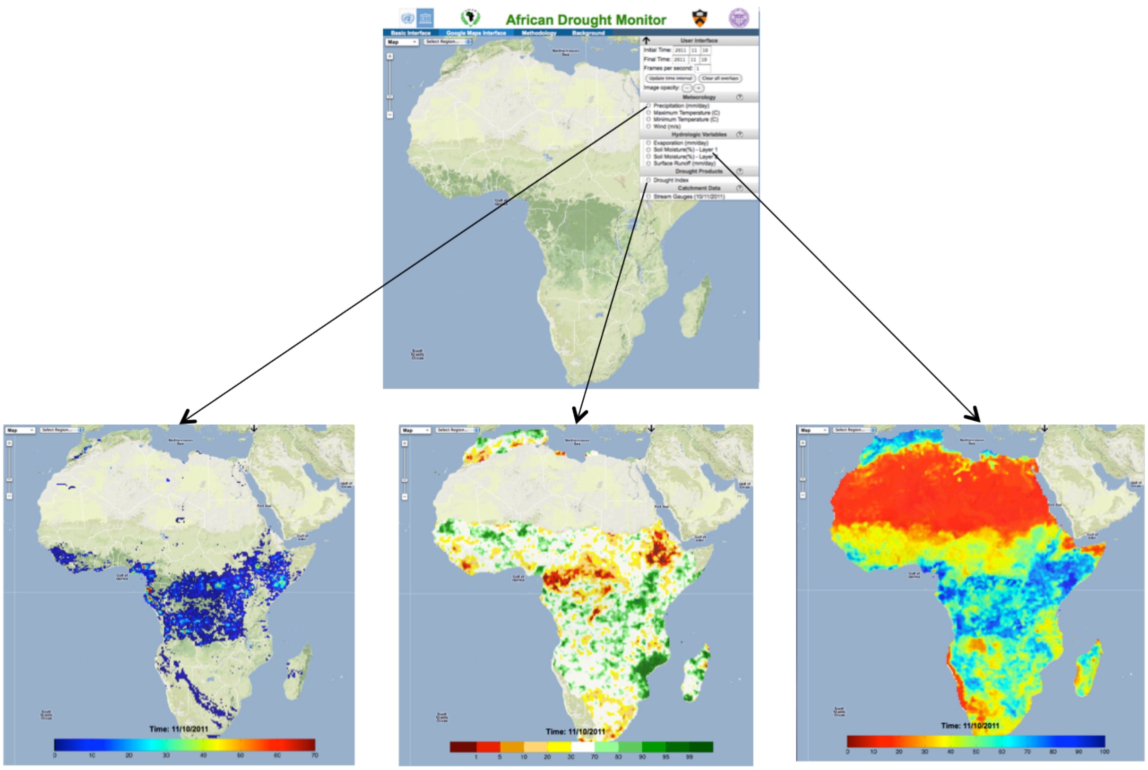

Figure 2 - Example of the interactive user interface showing the main interface (upper center), precipitation (lower left), drought index (lower center), and the relative soil moisture of the top layer (lower right) on November 10th, 2011.

The system can also display the real-time simulated discharge percentiles at several hundred stream gauges across Africa, as shown in Figure 3. When the user clicks on a stream gauge of interest, a popup window appears showing multiple derived variables for the catchment at both daily and monthly time steps. These variables include simulated discharge, water deficit, and basin averaged variables (e.g. precipitation, evaporation, surface runoff, and the drought index). The user can control the time period and time step. The plotted images and corresponding data can be downloaded.

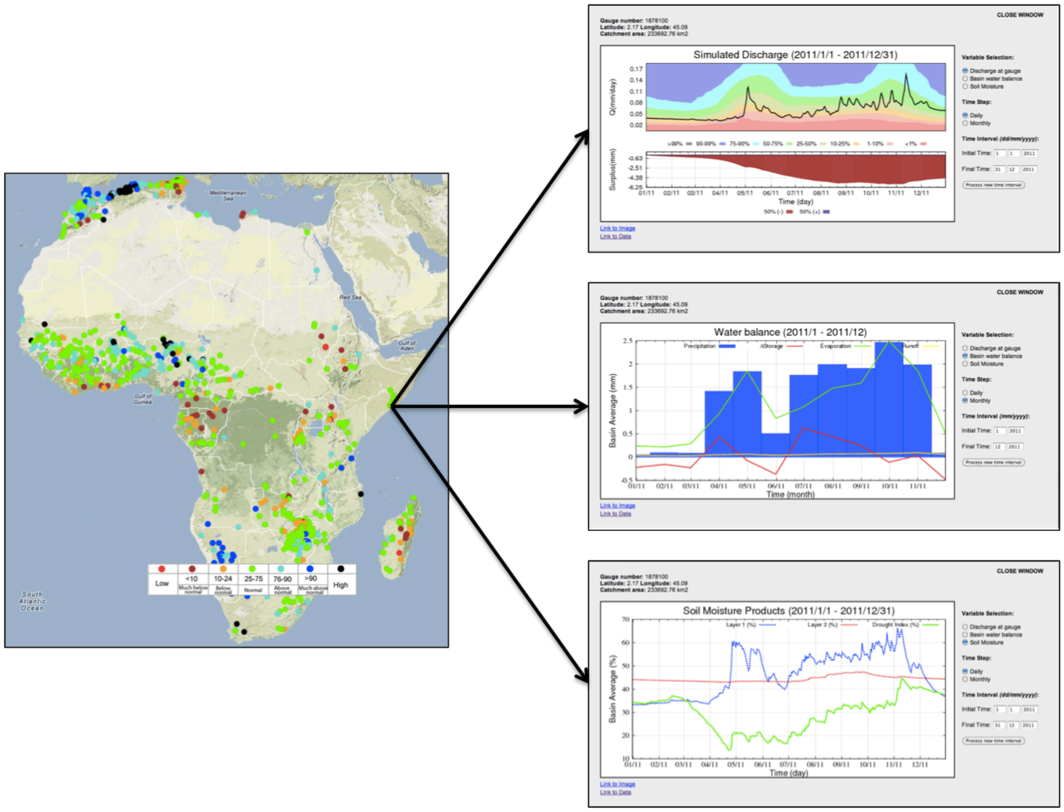

Figure 3–The user can click on a gauge location on the map (left), to bring up a popup window of data corresponding to the upstream basin including simulated discharge (upper right), water balance (center right), and soil moisture products (lower right).

4. Summary

The African Drought Monitor contains both data from a historic reconstruction (1950 – 2008) and real-time monitoring (2009 – Present) of the hydrologic cycle and drought events. The system is updated daily and provides multiple hydrologic variables at continental and basin scales.

The monitor data are made available to the public through the web-based interface. This interface enables quick access to the data and plots of current and past conditions for the whole of Africa and a set of river basins.

The Monitor is a stable and robust system, which provides consistent and continuous hydrologic data. The system has been calibrated to available streamflow data for several hundred gauges across Africa and so provides a reasonable estimate of the hydrological cycle and drought occurrence. However, more comprehensive evaluations are needed as well as feedback on the drought products and utility of the system. In terms of data sources, there is potential to assimilate real-time gauge precipitation data into the gridded data that would provide improvements to the modeling and the depiction of drought. Future work will improve the consistency between the satellite precipitation and historical data sets, and there will be updates to the land surface model.

References:

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