Development of a global drought information system at the University of Washington

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APEC Climate Symposium

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University of Washington Surface Water Monitor (real-time drought monitoring)
Natural Climate Variability

- Precipitation deficiency (amount, intensity, timing)
- High temperature, high winds, low relative humidity, greater sunshine, less cloud cover
- Reduced infiltration, runoff, deep percolation, and ground water recharge
  - Increased evaporation and transpiration

Soil water deficiency

- Plant water stress, reduced biomass and yield
- Reduced streamflow, inflow to reservoirs, lakes, and ponds; reduced wetlands, wildlife habitat

Economic Impacts
Social Impacts
Environmental Impacts

(Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.)
Variable Infiltration Capacity (VIC) macroscale hydrologic model
Drought Monitoring at the UW CEE Land Surface Hydrology Group

Development of a Global Drought Information System
Soil moisture percentile (-)
# Drought severity classifications

<table>
<thead>
<tr>
<th>Standardized Precipitation Index (SPI)</th>
<th>Standardized Runoff Index (SRI)</th>
<th>Soil Moisture Percentile (SMP)</th>
<th>Drought Severity Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.50 to 1.0</td>
<td>0.50 to 1.0</td>
<td>0.50 to 1.0</td>
<td>1</td>
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<tr>
<td>0.35 to 0.50</td>
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<td>0.20 to 0.35</td>
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<td>0.10 to 0.20</td>
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<td>0.05 to 0.10</td>
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<td>5</td>
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<td>0 to 0.05</td>
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<td>0 to 0.05</td>
<td>6</td>
</tr>
</tbody>
</table>

**Intensity:**
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional
Simulations

- long-year spinup
  - model climatology

- recent
  - model spin-up

Monitoring
  - now
  - forecast

Long-term climatology

Real-time data

Forecast Products
- streamflow
- soil moisture
- runoff
- snowpack

Monitoring

A Long-term climatology
Soil Moisture Observations

Sparse and mostly not in real-time

Location of COSMOS Probes

Click on balloons for site descriptions and data access. Station List Diagnostics Utilities

Sparse and no climatology

Use meteorological observations and hydrological models to simulate soil moisture dynamics

http://cosmos.hwr.arizona.edu/Probes/probemap.php
Three requirements:
- long term data record (climatology)
- near real-time reporting
- consistency

http://www.ncdc.noaa.gov/; Global Summary of the Day
TRMM instruments:

- Precipitation Radar (PR)
- TRMM Microwave Imager (TMI)
- Visible and InfraRed Scanner (VIRS)
- Cloud and Earth Radiant Energy Sensor (CERES)
- Lightning Imaging Sensor (LIS)
GFS Global Forecast System

GFS4 Tmax Jan. 2009–2011

GFS4 Tmin Jan. 2009–2011

http://www.emc.ncep.noaa.gov/
Forcing data

Precipitation data sets used:
Sheffield et al: 1948-2008 (T and P) (SH)
TRMM V7:
  Real-time product RT: 3/1/2000-current
    available in near real-time

Temperature data sets used:
Sheffield et al: 1948-2008
NCEP/NCAR Reanalysis: 1979-2011
GFS 4: 2009-current
  available in near real-time

Station-based: climatology
Satellite + stations: spinup
Satellite only: real-time
Model + stations: spinup
Model + stations: real-time

For the purpose of this presentation, current is 10/01/2013. However, the RT and GFS4 datasets can be updated daily.
The challenge

• The climatological period, used to determine the soil moisture percentiles for each grid cell for a given date, is based on the period 1960-2008 (Sheffield data set)

• Because soil moisture conditions in the real-time simulations are compared with those from the climatological period, systematic differences between the forcing datasets must be avoided

• Correct the precipitation and temperature data sets used for the post-2008 period so that they match the Sheffield data set (in a statistical sense) for any overlapping period
Forcing data

• Wind speed values are climatological values based on a reanalysis

• All other meteorological forcings needed to drive the models are estimated from the daily temperature range and precipitation
  – downward shortwave radiation
  – downward longwave radiation
  – humidity
Selected droughts

Multimodel estimates

VIC / Noah / SAC

GDIS simulates historic droughts

VIC estimates (Sheffield and Wood 2007)
Global area in each drought category
Soil moisture state (percentile) at the end of the retrospective period – based on Sheffield et al. (2006)

From January 1, 2009 the inputs for the global drought monitor are based on TRMM-TMPA precipitation forcings and analysis temperature fields
July 1, 2012

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
September 1, 2012

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
November 1, 2012

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
January 1, 2013

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
March 1, 2013

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
May 1, 2013

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
July 1, 2013

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
September 1, 2013

US Surface water monitor (station-based)

Global drought monitor (satellite-based)
• Systems provide soil moisture progressions for the United States that are qualitatively similar.
• However, the systems differ in the drought intensity that they indicate (different reference periods are unlikely to be able to explain all of this difference).
• In certain regions (e.g. Sahel) there is a persistent wet bias:
  – In areas with small dynamic ranges of soil moisture, small, but systematic changes in the forcings between the reference and satellite period can lead to large differences in percentiles (see next slide).
Small changes in absolute soil moisture in areas/periods with a small dynamic range can lead to large changes in percentiles.
Conclusions

1) Global multimodel drought nowcasting is entirely feasible now

2) Consistent forcings are essential
   a. Droughts only make sense when expressed relative to a climatology – hence climatically consistent near real-time data are essential
   b. There is a need for improved methods that combine long-term historical records, which provide temporal continuity but have poor spatial coverage, with new observing and modeling platforms that provide great spatial detail, but lack a long-term climatology.

A prototype Global Drought Information System based on multiple land surface models

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