Drought monitoring and prediction using NOAH land surface model and GRACE satellite observation

Xiaodong Zhang, Jiexia Wu
Department of Earth System Science and Policy
University of North Dakota
Drought: #1 hazard in terms of its impact

Unlike floods, hurricanes, earthquakes, and tornadoes, a drought seldom results in structural damages.

Yet, In the U.S. the cost of drought is about $6-8 billion per year.

In January 2013, about 70% of the conterminous U.S. suffered from drought at different levels.

Lack of recognition of drought events because drought develops more slowly than other disasters and it is hard to recognize drought until it becomes severe.

Therefore it is important to develop the capability that can predict and monitor drought progression to inform drought mitigation plans and limit adverse effects.
Drought classification

- Meteorological, hydrological, agricultural and socio-economic droughts.
- Ground water drought

A. Parmer Drought Severity Index (PDSI)
B. Top layer soil moisture (Soil Moisture Deficit Index, SMDI)
C. Total Terrestrial water storage (Total Storage Deficit Index, TSDI)
GLDAS/Noah Model

Noah LSM provides a complete description of physical processes with limited number of Parameters includes:

- Runoff
- Soil water flow
- Soil heat flow
- Heat exchange with the atmosphere
- Different evaporation comp.
- Frozen soil
- Snow pack

Drought index (SMDI) input:

- Soil moisture (top 2 meters)
- Snow water equivalent
- Canopy water storage
- 1° × 1° grid cell, Monthly (1982 – 2012)
GRACE satellite observation

• Gravity Recovery and Climate Experiment (GRACE) Satellite Observation
  – Launched March 2002 to measure earth gravity change
  – Terrestrial water storage (groundwater, surface water, soil moisture)
  – 1° × 1° grid cell, Monthly (2003 – 2012)
Soil Moisture Deficit Index (SMDI, Narasimhan and Srinivasan 2005) 
Total Storage Deficit Index (TSDI, Yirdaw et al. 2008)

Historical range of moisture conc. ($\theta$) for May
- Max
- Median
- Min

Actual $\theta$ for May 05/2011

$$\text{Deficit}_{05/2011} = \frac{\Delta \theta}{\Delta \theta}$$

Historical range of moisture conc. ($\theta$) for Oct
- Max
- Median
- Min

$\theta$ for Oct 10/2011

$$\text{Deficit}_{10/2011} = \frac{\Delta \theta}{\Delta \theta}$$

Deficit Index $i = p \times \text{Deficit Index}_{i-1} + q \times \text{Deficit}_i$
An example of Drought Indices in the Red River Valley

Flood threshold
Drought threshold

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Drought monitoring

U.S. Drought Monitor

SMDI (NOAH simulation)

TSDI (GRACE)

March 2012

April 2012

May 2012
2010 – 2012 drought monitoring (SMDI)
2010 – 2012 drought monitoring (TSDI)

Jan – Jun 2010

Jul – Dec 2010

Jan – Jun 2011

Jul – Dec 2011

Jan – Jun 2012

Jul – Aug 2012
Drought Prediction: Probability

\[ \text{DeficitIndex}_i = p \times \text{DeficitIndex}_{i-1} + q \times \text{Deficit}_i \]

Deficit for next month

Estimated \( \theta \) for next month

Compare with the climatology of \( \theta \) of next month to determine the probability
Drought probability prediction

U.S. Drought Monitor Mar, 2012

CPC’s Monthly U.S. Soil Moisture (percentile)

CPC’s Monthly U.S. Soil Moisture Anomaly


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Soil moisture anomaly in March released by CPC

Monitored drought severity (SMDI)

Predicted drought severity (SMDI)
Comparison of drought prediction and monitoring for March 2012
Conclusions and future work

• The indices are able to identify the major drought and show good agreement with U.S. drought monitor

• Preliminary results showed that our method was able to predict the severe drought occurred earlier this year.
  – Prediction is in general consistent with Princeton’s results,
  – Disagreement was found in New Mexico and Texas region.

• Princeton’s forecasting uses VIC model and we use NOAH
  – Difference in methodology
  – Difference in models
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