Application of NLDAS Ensemble LSM Simulations to Continental-Scale Drought Monitoring

Brian Cosgrove and Charles Alonge
SAIC / NASA GSFC

Collaborators: Kenneth Mitchell\textsuperscript{1}, Youlong Xia\textsuperscript{1},
Kingtse Mo\textsuperscript{2}, Wanru Wu\textsuperscript{2}, Eric Wood\textsuperscript{3}
\textsuperscript{1}NOAA/NCEP/EMC, \textsuperscript{2}NOAA/NCEP/CPC, \textsuperscript{3}Princeton University

Funded by NOAA CPPA and NASA WMP
Introduction

- Accurate drought characterization is vital to drought impact assessment and amelioration.
- Wide range of drought indices currently exist, each with its own strengths and weaknesses.
- Difficult to calibrate and improve upon certain indices due to a lack of long term and spatially continuous soil moisture observations on large scale.
- Land Data Assimilation Systems (LDAS) offer high quality soil moisture fields with good spatial and vertical resolution and are a potentially useful tool in monitoring droughts.
- Combine NASA’s Land Information System (LIS) modeling infrastructure and North American LDAS (NLDAS) resources with long term (28 years+) forcing fields of NOAA’s North American Regional Reanalysis (NARR) to form a NARR-based NLDAS drought monitor.

Heatwave/Droughts: 10 Events
144 Billion dollars damage
36.8% of damage
NASA GSFC Drought Project Overview

- Analyze drought monitor output to determine effect of **model selection**, forcing data, **NARR climatology length**, and **ensemble construction** on drought characterization.

- Transition system to real-time operations, providing objective data to existing drought monitoring efforts such as the U.S. Drought Monitor.
Project Forcing and Drought Indices

- Forcing is hourly, 1/8\textsuperscript{th} degree, compatible with original NLDAS data
  - NARR model data base (3 hourly, 32km, 1979 – Present)
  - Hourly NARR SW bias correction developed from GOES data for each month
  - Hourly observed precipitation based on daily PRISM-corrected gauge data, and hourly Stage II Doppler radar, CMORPH, and HPD data
  - Elevation correction for temperature, pressure, humidity, and long wave
  - Includes 22 standard sfc/2m/10m and lowest model layer forcing fields

- Drought monitor will compute several drought indices from NLDAS LSM output, NARR land surface states, and forcing

<table>
<thead>
<tr>
<th>Drought Index</th>
<th>Drought Type</th>
<th>Required NARR/NLDAS Monitor Data</th>
<th>Comparison Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wtd/UnWtd PDSI</td>
<td>Meteorological</td>
<td>Forcing</td>
<td>NCDC PDSI</td>
</tr>
<tr>
<td>SPI</td>
<td>Meteorological</td>
<td>Forcing</td>
<td>U. Nebraska SPI</td>
</tr>
<tr>
<td>PHDI</td>
<td>Hydrological</td>
<td>Forcing</td>
<td>NCDC PHDI</td>
</tr>
<tr>
<td>TWD</td>
<td>Hydrological</td>
<td>Streamflow Output</td>
<td>USGS Streamflow</td>
</tr>
<tr>
<td>Palmer Z</td>
<td>Agricultural</td>
<td>Forcing</td>
<td>NCDC Palmer Z</td>
</tr>
<tr>
<td>LSM Percentile</td>
<td>Agricultural</td>
<td>LSM Soil Moisture Output</td>
<td>U. Washington</td>
</tr>
</tbody>
</table>

- Experimental LDAS indices

| LDAS PDSI | Meteorological | LSM Output and Forcing | NCDC PDSI |
| LDAS PHDI | Hydrological | LSM Output and Forcing | NCDC PHDI |
| LDAS Palmer Z | Agricultural | LSM Output and Forcing | NCDC Palmer Z |
| CLM3 VHI | Agricultural | CLM3 LAI/NDVI Output | NOAA VHI |

- Selection of indices is a key area for drought community input
Project Status

- Second year of three year project
- Ongoing collaborations with US Drought Monitor and NLDAS, links to NASA Water Management Program drought project
- Real-time beta drought monitor on NLDAS website
- Follows in footsteps of existing websites (U. Washington, Princeton, and CPC)
  - [http://hydrology.princeton.edu/forecast/](http://hydrology.princeton.edu/forecast/)
  - [http://www.cpc.ncep.noaa.gov/soilmst/](http://www.cpc.ncep.noaa.gov/soilmst/)
- Mosaic, Noah, and SAC runs performed, highlighting several key issues for further investigation
  - Climatology length
  - Meteorological forcing data
  - Model selection
Impact of Climatology Length

Noah LSM Total Column Soil Moisture (mm), Southern Indiana, 1980-2007

Average Climatology Based on 10 Year Simulation
Average Climatology Based on 28 Year Simulation

Noah LSM Total Column Moisture Climatology (mm), Southern Indiana

Average Climatology Based on 28 Year Simulation
Average Climatology Based on 10 Year Simulation

January 1st
December 31st
Impact of Climatological Length

- Use of longer climatology acts to decrease severity of current events by putting them into better historical context.

Noah LSM Total Column Soil Moisture Percentile
July 1st, 2007, Based on 10 Year Climatology

Noah LSM Total Column Soil Moisture Percentile
July 1st, 2007, Based on 28 Year Climatology
Impact of Meteorological Forcing Data

- Use of new forcing data set over same 10 year time period leads to large changes in drought depiction.
Impact of Model Choice

- Choice of land surface model can greatly influence depiction of drought severity due to differences in model physics and parameterizations.
Drought Monitoring Comparison

Ens. Mean - Total Column Soil Moisture Percentile
Valid: 20070901

Ens. Spread - Total Column Soil Moisture Percentile
Valid: 20070901

Probability of Severe Drought (D2)
Valid: 20070901

U.S. Drought Monitor
September 4, 2007
Valid 8 a.m. EDT

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm
Mosaic LSM
Time and Depth Cross Section of Drought Severity

Mosaic Layer 1 Soil Moisture Percentile, 6/9/07

Mosaic Soil Moisture Percentile (%, 34.6N, 84W)

Mosaic Soil Moisture Percentile (%, 31N, 82W)
Conclusions

- NLDAS LSM-based drought project underway at NASA GSFC in collaboration with NOAA/NCEP/EMC, NOAA/NCEP/CPC and Princeton University

- Project seeks to leverage ensemble, high quality, multi-layer, spatially continuous soil moisture simulations in NLDAS framework to form a robust real-time drought monitor

- Goals are to investigate climatology, forcing data, model, and ensemble-related issues as well as offer an effective suite of objective drought indices to drought assessment organizations such as NIDIS and the U.S. Drought Monitor

- End user input will be key to the success of this project, and all input is welcome
Additional Material Follows
Soil moisture percentiles from each LSM combined to form ensemble mean percentile map.

Project will eventually use Mosaic, Noah, VIC, Sacramento, CLM3, HySSiB, and Catchment models with a variety of lineages (climate modeling, weather forecasting, hydrological).

Ensembles often offer more accurate depictions of drought.

Even poor depictions are informative--Large model spread indicates lack of confidence.
Noah LSM
Time and Depth Cross
Section of Drought Severity
Mosaic LSM
Time and Depth Cross Section of Drought Severity

Mosaic Layer 1 Soil Moisture Percentile, 12/24/07

Mosaic Soil Moisture Percentile (%, 34.6N, 84W)

Mosaic Soil Moisture Percentile (%, 31N, 82W)
Time and Depth (cm) Cross Section of Drought Severity (Soil Moisture Percentile)

- Noah LSM -

January to December 2007

- Mosaic LSM -

May 31 to June 9, 2007
NASA GSFC Drought Project Outline

**Forcing Data**
- Construct and validate 1/8th degree forcing dataset based on NARR, supplemented with observed precipitation, and bias corrected with observed radiation

**LSM Runs**
- Execute and validate 1/8th degree 28 year-long ensemble runs using Noah, CLM3, and NASA’s Mosaic, HySSiB, and Catchment LSMs within NASA’s Land Information System (LIS) modeling framework

**Drought Monitor**
- Construct and execute drought monitor processing system using individual as well as 7 member ensemble output (includes VIC and Sacramento output from NCEP)
- Analyze drought monitor output to determine effect of model selection, forcing data, NARR climatology length, and ensemble construction on drought characterization, and to benchmark performance versus existing drought monitoring systems
- Transition system to real-time operations, providing objective data to existing drought monitoring efforts such as the U.S. Drought Monitor DST where possible
Impact of Model Choice

LSM Total Column Soil Moisture (mm), Northern New York, 1997-2007

- Total Column Soil Moisture (Noah LSM)
- Total Column Soil Moisture (Mosaic LSM)

LSM Total Column Moisture Climatology (mm), Northern New York

- Average Soil Moisture Climatology (Noah LSM)
- Average Soil Moisture Climatology (Mosaic LSM)