Application of NARR-Based NLDAS Ensemble Simulations to Continental-Scale Drought Monitoring

Brian Cosgrove and Charles Alonge
SAIC / NASA GSFC
CPPA Funded Proposal
LIS Science Meeting April, 12 2006
Introduction

- Droughts cause billions of dollars in damage each year.
- More effective identification of droughts would directly benefit resource managers, and reduce drought impacts.
- The multifaceted nature of droughts (meteorological, hydrological, and agricultural) coupled with the largely varying population densities, topography, and land use across North America causes considerable difficulty in creating a single universal drought index.
Introduction

- Numerous drought indices currently exist, each with its own inherent strengths and weaknesses:
  - Palmer Indices – PDSI, PHDI, Z-Index (Palmer 1965)
  - SPI - Standardized Precipitation Index (McKee et al. 1993)
  - Total Water Deficit – Hydrological drought (Dracup et al. 1980)
  - VHI – Vegetation Health Index (Kogan 1997)
- Difficult to calibrate and improve upon certain indices due to a lack of long term soil moisture observations on large scale
- Land surface models driven by modeled/observed atmospheric boundary conditions have become a useful commodity in depicting land surface states (Huang et al. 1996)
- 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 (Sheffield et al. 2004)
- Combine modeling infrastructure of North American LDAS (NLDAS) with long term (27 years+) forcing fields of North American Regional Reanalysis (NARR) to form drought monitor
Project Goals

- Construct and validate 1/8th degree forcing dataset based on NARR and observed precipitation and radiation
- Investigate optimal NLDAS forcing methodology using Noah and CLM3 LSMS
- Using optimal forcing methodology, execute two separate 1/8th degree 27 year-long ensemble runs using Noah, CLM3, Mosaic, HySSiB, and Catchment LSMS; one set forced with NARR-only data, and another forced with NARR and observed data
- Intercompare model output and validate against land surface observations
- Construct and execute drought monitor processing system using ensemble output
- Analyze drought monitor output to determine effect of model selection and NARR climatology length on drought characterization, and to determine performance versus existing drought monitoring systems
- Transition system to real-time operations, disseminate data
Project Flowchart

- NARR Obs. SW Obs. Precip.
- 27 Year forcing data set on 1/8th degree NLDAS grid
- NARR Only
- NARR and observations
- 27 Year ensemble runs Noah, CLM3, Catchment, HYSiB, Mosaic
- Hydrological Indexes
- Agricultural Indexes
- Meteorological Indexes
- Drought Monitor Post-processor
- Intercomparison, validation, and data dissemination
NLDAS Forcing Dataset

- Compatible with current NLDAS systems
  - Standard NLDAS 1/8\textsuperscript{th} degree North American domain
  - 1979-Present, Hourly temporal resolution
  - Consists of model data base and observation overlay

- NARR (and R-CDAS) model data base
  - 3 hourly, 32km, 1979 – Present over North America
  - Used as the backbone of new NLDAS forcing data set

- NESDIS/UMD Observed Short Wave Radiation
  - ½ degree hourly GOES-based 2000-Present
  - 1/8\textsuperscript{th} degree hourly GOES-based from 1996-2000
  - ½ degree, 3-hourly ISSCP DX-based 1994-1996

- CPC Observed Rain Gauge Data
  - 1/8\textsuperscript{th} degree daily 1948-Present (Schaake IDW/LSR and PRISM correction applied)
  - Hourly Precipitation Data Set (HPD) 2 x 2.5 degree, 1948 - Present
Forcing Methodology Study

- Ongoing NLDASE project highlighted need for LDAS forcing methodology investigation
- Use of 2m/10m fields versus lowest model level fields (with variable forcing height) can greatly impact simulation of surface fluxes
- Multi-model investigation
  - Noah and CLM3 LSMs
  - 1996-2005 with 5 year recursive spin-up
- Validation against OK Mesonet and SCAN
- Result will impact subsequent drought monitoring simulations
Multi-Model Ensemble Simulations

- Multi-model output will form base of drought monitor, and aid in LSM improvement as current NLDAS runs have done.
- Two sets of simulations: NARR-only forcing and NARR + observation forcing, both using optimal forcing methodology.
- Noah, CLM3, HySSiB, Catchment, Mosaic LSMs.
- 27 Years (1979-Present) with 5 year recursive spin-up (using mean climatological forcing).
- 3-hourly output on 1/8th degree NLDAS grid.
- Runoff routing scheme applied to each LSMs output to calculate stream flow (Lohmann 1998b).
- Ensemble mean and individual LSM output intercompared and validated against observations and CPC 50 year LDAS simulation (Noah LSM).
Drought Monitor Processing System

- Drought monitor will compute several drought indices from NLDAS LSM output, NARR land surface states, and forcing data.
- To aid in verification both standard and new NLDAS-based drought indices will be computed.

<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>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>VIC</td>
<td>Agricultural</td>
<td>LSM Soil Moisture Output</td>
<td>U. Washington</td>
</tr>
<tr>
<td>LDAS PDSI</td>
<td>Meteorological</td>
<td>LSM Output and Forcing</td>
<td>NCDC PDSI</td>
</tr>
<tr>
<td>LDAS PHDI</td>
<td>Hydrological</td>
<td>LSM Output and Forcing</td>
<td>NCDC PHDI</td>
</tr>
<tr>
<td>LDAS Palmer Z</td>
<td>Agricultural</td>
<td>LSM Output and Forcing</td>
<td>NCDC Palmer Z</td>
</tr>
<tr>
<td>CLM3 VHI</td>
<td>Agricultural</td>
<td>CLM3 LAI/NDVI Output</td>
<td>NOAA VCI</td>
</tr>
</tbody>
</table>
Analyze Drought Monitor Index Output

- How does the characterization of drought vary by LSM?
- What impact does use of the ensemble mean have on drought detection?
- How do drought indices produced by the ensemble LSMs compare to drought index values produced directly from NARR land surface fields?
- Can an NARR/NLDAS system produce standard and experimental-LDAS drought index fields which capture the same droughts detected by established measures such as PSDI and US Drought Monitor?
- How does climatology-length affect drought characterization, and does the NARR offer a suitably accurate and lengthy record of forcing data to serve as the base of a drought monitor?

- SPI and soil moisture percentiles will be calculated from full 50+ year CPC simulation as well as 27 year subset to gauge impact of climatology length on indices, and results will be used to guide interpretation of NARR/NLDAS-based values.
Real-time Operations and Data Dissemination

- Real-time drought monitor will mirror retrospective efforts
  - 1/8th Degree forcing creation
  - Multi-model ensemble runs
  - Computation of drought indices
  - Data display on web
NLDAS Experimental Drought Monitor

URL: http://ldas.gsfc.nasa.gov/monitor/

NOTE: This page is best viewed with a screen resolution of at least 1024x768

<table>
<thead>
<tr>
<th>MOSAIC LSM OUTPUT</th>
<th>NOAH LSM OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Root Zone (0 - 40 cm) Soil Moisture</td>
<td>Root Zone (0 - 40 cm) Soil Moisture</td>
</tr>
<tr>
<td>Current Conditions (Soil Wetness %)</td>
<td>Current Conditions (Soil Wetness %)</td>
</tr>
<tr>
<td>Past Week Soil Moisture Anomaly</td>
<td>Past Week Soil Moisture Anomaly</td>
</tr>
<tr>
<td>Past Month Soil Moisture Anomaly</td>
<td>Past Month Soil Moisture Anomaly</td>
</tr>
<tr>
<td>Past Week Soil Moisture Percentile</td>
<td>Past Week Soil Moisture Percentile</td>
</tr>
<tr>
<td>Past Month Soil Moisture Percentile</td>
<td>Past Month Soil Moisture Percentile</td>
</tr>
</tbody>
</table>

Mosaic Total Column Soil Wetness (%)  
Valid: APR 09, 2006

Noah Total Column Soil Wetness (%)  
Valid: APR 09, 2006

CLICK ONE OF THE LINKS TO BEGIN
NLDAS Experimental Drought Monitor Methodology

- Mean root zone and total column soil wetness values were computed for each day of the year from the 1997-2005 NLDAS Mosaic and Noah output (1996 discarded due to spin-up) and stored in mean daily climatology files.
- Anomalies are computed by comparing the near real-time data (past week/month) to the same time of the year in the mean climatology files.
- 365 daily data distributions were also developed from the historic data using an 11-day data window (11 daily mean values).
- Percentiles are extracted by comparing (# greater/less than) the current soil wetness values (past week/month) with the empirical distributions.
- A series of shell/GrADS scripts creates visual output and copies images to the LDAS website.
- Modeled after existing websites (U. Washington, Princeton, and CPC)
  - http://hydrology.princeton.edu/forecast/
  - http://www.cpc.ncep.noaa.gov/soilmst/