Development of the next phase of NLDAS for improved drought monitoring and progress towards its operational transition

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The North American Land Data Assimilation System (NLDAS) is a collaborative project between NOAA/NCEP and NASA/GSFC, and is supported by the NOAA Climate Program Office’s Modeling Analysis, Predictions, and Projections (MAPP) Program.
Collaboration between NOAA/NCEP/EMC and NASA/GSFC w/ other groups; it runs 4 LSMs (Noah, Mosaic, VIC, & SAC)

https://ldas.gsfc.nasa.gov/nldas/
The next phase of NLDAS will use updated models and data assimilation using NASA’s Land Information System.

**LIS-based next phase of NLDAS**

- **1979 – Present** To be Updated w/ Larger Domain Forcings and Parameters at finer-scale
- **Satellite EDRs**
  - SM, SCA, SWE, TWS, and II

**Parameters** (Topography, Soil properties, vegetation properties)

**Meteorological Boundary Conditions** (Forcings)

**Observations** (Soil moisture, Snow, Skin Temperature)

Data Assimilation, multi-variate (EnKF, EnKS)

Noah-3.X, Noah-MP-3.X, CLSM-F2.5, VIC-4.1.2.1

Water and Energy Fluxes, Soil Moisture and Temperature profiles, Land surface states

* Satellite-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), & irrigation intensity (II)
NASA’s Catchment LSM as well as CLM are being added, with the other LSMs being upgraded to their latest versions.

**Catchment LSM (CLSM)** is developed by NASA/GMAO, and is the land-surface component of the NASA GEOS-5 GCM.

**Community Land Model (CLM-4.5)** is maintained by NCAR, and is the land-surface model for the Community Earth System Model (CESM).

**Noah-MP-3.6** is a LSM option within WRF, with Multiple Physics options, including dynamic vegetation & groundwater modules.

**VIC-4.1.2.1, Noah-3.6, RUC, & other LSMs** are also in LIS and contain numerous upgrades.
The new and upgraded LSMs for the next phase of NLDAS have been run using the LIS software framework, and the new results and the NLDAS-2 operational LSMs have been evaluated against observations using the LVT software.

Anomaly correlations are shown for the 4 NLDAS-2 LSMs (left of the dashed line) and various instances/options of the LIS LSMs (right of the dashed line). Against 117 quality-controlled SCAN soil moisture sites (left panel), the new versions of Noah and Noah-MP are improved over NLDAS-2's Noah. For routed streamflow (middle) against USGS observations at 572 small, unregulated basins, the LSMs do well, particularly the new version of VIC. Groundwater anomaly correlation is shown (right) against 136 USGS well observations. Groundwater is not available in any of the NLDAS-2 LSMs, while two of the new LSMs in LIS calculate groundwater. Fluxes, snow, TWS are also in evaluation.
Both the HyMAP router (Getirana et al., 2012) and the NLDAS router (Lohmann et al., 2004) are included within LIS. However, the NLDAS router is tied to the current NLDAS grid, while HyMAP supports finer-scale and global domains. Also, HyMAP provides river depth as well as discharge, considers floodplains among many other physics upgrades.

LEFT) Experiments with HyMAP router

RIGHT) Experiments with NLDAS router
Comparisons to the U.S. Drought Monitor on Jan 3 and Jan 24, 2017 are shown. The percentiles of groundwater from Noah-MP in LIS show dryness despite many winter storms. The USDM noted the dry groundwater well observations in many areas of Southern California in issuing the USDM maps for these dates. The root zone soil moisture percentiles do not tell the entire story.
Comparison of TWS against GRACE observations

Noah-MP-3.6 and CLSM-F2.5 within LIS were evaluated for various terrestrial water storage (TWS) components (including groundwater) against CLM-4.0 LSM. This figure compares GRACE TWS anomalies for various River Forecast Centers (RFCs) in the NLDAS domain.

The CLM-4.5 LSM has been integrated into LIS and work is underway to run and evaluate it for the NLDAS Science Testbed.

Xia, Mocko, Huang, Li, Rodell, Mitchell, Cai, and Ek, 2017: J. Hydrometeorology, doi:10.1175/jhm-d-16-0112.1
Data assimilation of GRACE terrestrial water storage anomalies can help with the depiction of drought

Comparison of the drought percentile maps from CLSM-F2.5 (center) without and (right) with assimilation of GRACE against (left) the corresponding U.S. Drought Monitor (USDM) estimate for four representative cases.

Evaluations against in situ observations also showed improvements in simulated groundwater and soil moisture.

Kumar et al., 2016, JHM, Figure 12, doi:10.1175/jhm-d-15-0157.1
Multi-variate data assimilation of remotely-sensed snow and soil moisture improves modeled stats against obs.

- **Soil moisture** against USDA ARS, NRCS SCAN, and USCRN station network data (change in AC)

- **Snow depth** against CMC and SNODAS (change in [mm] of RMSE)

Warm = improvement
Cool = degradation

Kumar et al., 2017, submitted, Figure 3 (top) and Figure 4 (bottom)
Oct 23, 2007 – Southeast Drought

NLDAS-2 operational LSMs

LIS LSMs for next phase

Top 1-meter soil moisture
The 8 LSMs under evaluation (the 4 operational NLDAS-2 LSMs and 4 of the LIS LSMs) were included in a formal similarity assessment to assess their utility to the ensemble. The runoff estimates from the LSMs were shown to be most dissimilar, and the soil moisture shown to be the most similar. The figure on the right show which of the 8 LSM is the most similar (left column) and the most dissimilar (right column) to the ensemble, for the latent (Qle) and sensible (Qh) heat fluxes, runoff (Q), root zone soil moisture (RZMD), and snow-water equivalent (SWE).

Kumar, Wang, Mocko, Peters-Lidard, and Xia: WRR, revised version submitted
NOAA/NCEP/EMC and NASA/GSFC have written a white paper on the vision, requirements, and implementation of LDAS systems at NCEP. Here are some highlights w/r/t new NLDAS phases:

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<thead>
<tr>
<th>Phase</th>
<th>Highlights</th>
<th>Operational Date</th>
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<tbody>
<tr>
<td>NLDAS-2.5</td>
<td>• Close the 3.5-day latency gap to real-time</td>
<td>~Fall 2017 to Spring 2018</td>
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<td>• Same LSMs as NLDAS-2</td>
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<tr>
<td>NLDAS-3.0</td>
<td>• Running in NASA’s LIS software framework</td>
<td>~Fall 2018 to Spring 2019</td>
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<td>• Upgrade Noah and VIC LSMs</td>
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<td>• Noah-MP replaces SAC</td>
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<td>• CLSM-F2.5 replaces Mosaic</td>
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<td></td>
<td>• Snow, soil moisture, GRACE data assimilation</td>
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<td></td>
<td>• HyMAP streamflow router</td>
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<td>• Irrigation scheme in MODIS-derived areas</td>
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How NLDAS-2.5 closes the 3.5-day latency gap

Figure 1: Illustration of the NLDAS-2.5 operational timeline and data sources. The real-time update for 15 June 2017 is used as an example.
Take-away Messages

• NLDAS-2.5 will close the 3.5-day latency gap (using the same LSMs)

• NLDAS-3.0 will include new/updated LSMs running in NASA’s LIS software framework with data assimilation of operational remotely-sensed products, along with an irrigation scheme and the HyMAP streamflow router.

• Data assimilation has been shown to improve NLDAS depiction of soil moisture, snow, evaporation, and streamflow compared to in situ & gridded observations.

• Similarity assessment of the operational and future NLDAS LSMs underway.

• Many LSMs in NLDAS-3.0 consider groundwater; may help with drought depiction.

@NASA_LIS

http://www.emc.ncep.noaa.gov/mmb/nldas/
NASA’s Land Information System (LIS) software framework is used to drive the models and perform data assimilation.

Land surface Data Toolkit (LDT)

- Land surface parameter processing
- DA/OPTUE preprocessing
- Downscaling support
- Forcing adjustments (bias correction)
- Restart/ensemble generation

Land Information System (LIS)

- Models (Noah, VIC, CLSM, JULES, SAC-SNOW17, FLake, HyMAP)
- Meteorological data (NLDAS, MERRA, GPM, ECMWF, …)
- RTMs (CRTM, CMEM)
- High performance computing support
- DA (EnKF, EnKS)
- Remote sensing data (SMAP, MODIS, DIS, MODIS, …)
- Optimization/Uncertainty Estimation (LM, GA, MCMC)

Land surface Verification Toolkit (LVT)

- Model evaluation and benchmarking
- Hydrological products (drought indices, flood indicators)

https://lis.gsfc.nasa.gov/

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