Using Land Data Assimilation Systems for Drought Monitoring, Water Resources, and Hydrologic Indicators

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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. PIs and Co-Is: Christa D. Peters-Lidard (NASA), David M. Mocko (SAIC at NASA), Sujay V. Kumar (NASA) Youlong Xia and Michael B. Ek (NOAA)

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A Land Data Assimilation System – or LDAS – is a dataset from land-surface models (LSMs) forced with the best-available observations to support water resources applications.

Remotely-sensed land satellite observations are assimilated into the LSMs to improve the depiction of water/energy cycles.

**INTERCOMPARISON and OPTIMAL MERGING** of land-surface data fields

Reanalysis and/or radar/satellite-observed surface meteorological data combined and used as land-surface model FORCING

**ASSIMILATION** of satellite-based land surface state fields (snow, soil moisture, terrestrial water storage, irrigation, etc.)

Ground-based observations used to VALIDATE model output

Examples from NASA’s GLDAS

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

Slide by Matt Rodell
Four LDAS systems are available from NASA/GSFC/HSL

**GLDAS** – Global LDAS

**NLDAS** – North American LDAS

**NCA-LDAS** – National Climate Assessment LDAS

**FLDAS** – Famine Early Warning System Network (FEWS NET LDAS)

http://ldas.gsfc.nasa.gov/
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.
- **Land surface Verification Toolkit (LVT)**: Model evaluation and benchmarking, Hydrological products (drought indices, flood indicators).

For more information, visit [http://lis.gsfc.nasa.gov/](http://lis.gsfc.nasa.gov/) @NASA_LIS
LIS software uses parameters, meteorological forcings, and remotely-sensed environmental data records

Using the Land Information System (LIS) is a flexible land-surface modeling and data assimilation framework developed with the goal of integrating satellite- and ground-based observed data products with land-surface models.

Satellite EDRs*: SM, SCA, SWE, TWS, and II

Best-available input datasets depending on the region of interest and application

Data Assimilation, multi-variate (EnKF, EnKS)

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

Land-surface models: (e.g., Noah, CLSM, VIC, Noah-MP, etc.)

Meteorological Boundary Conditions (Forcings)

Observations (Soil Moisture, Snow, Skin Temperature)

Parameters (Topography, Soil properties, vegetation properties)

* Satellite-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), & irrigation intensity (II)
NLDAS combines a high-quality surface forcing dataset and land-surface modeling to produce consistent products

- Jan 1979 to present (operationally w/ ~3.5-day latency); hourly/monthly
- 1/8\textsuperscript{th}-degree (~12.5km) over CONUS-centered domain (25-53°N; 125-67°W)

- NARR near-surface meteorology
- CPC Daily Precipitation Analysis
- Bias-corrected SW radiation (SRB)

- Stage II radar, CMORPH, other precipitation datasets, or NARR used to temporally disaggregate the CPC Daily Analysis into hourly precipitation
The NLDAS Drought Monitor is updated daily, and is one of the datasets used for the weekly U.S. Drought Monitor.

Percentiles and anomalies of: precipitation, soil moisture, snow, evaporation, runoff, and streamflow (from river routing)

http://www.emc.ncep.noaa.gov/mmb/nldas/drought/
Collaboration between NOAA/NCEP/EMC and NASA/GSFC w/ other groups; it runs 4 LSMs (Noah, Mosaic, VIC, & SAC)

http://ldas.gsfc.nasa.gov/nldas/
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.l, SAC-HTET-3.5.6, and Noah-3.6** 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.
Oct 23, 2007 – Southeast Drought

NLDAS-2 operational LSMs

LIS LSMs for next phase

Top 1-meter soil moisture
California winter drought reduction 2016-2017

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.
Create an enabling tool for development, evaluation, and dissemination of hydrological indicators to support the National Climate Assessment (NCA).

Generate indicators through multivariate assimilation of satellite-era data products (1979-present) using the NASA Land Information System (LIS) software framework.
Model domain: Same as NLDAS (1/8th-degree centered over CONUS)
Forcing data: NLDAS Phase 2 (w/ daily CPC gauge-based precipitation)
Models: Noah LSM ver 3.3, and CLSM Fortuna-2.5: a 60-year spin-up, followed by 36-year simulation; streamflow simulations using HyMAP (Getirana et al. 2012)
Data assimilation method: 1-d Ensemble Kalman Filter (EnKF) and 3-d Ensemble Kalman Smoother (EnKS)
Time period: Jan 1, 1979 to Dec 31, 2015
Univariate data assimilation experiments demonstrated that:

- Assimilation of satellite soil moisture, snow, and terrestrial water storage observations improved water cycle components of soil moisture, snow, terrestrial water storage, and evapotranspiration.
- Joint use of snow cover and passive microwave based snow depth data reduced RMSEs.
- Use of gridded GRACE TWS anomalies for DA are beneficial.
- These improvements also translated to short-term improvements for applications such as drought monitoring.

**Impact of soil moisture DA on drought estimates (May 10-17, 2011)**

- **No DA**
- **With DA**
LDAS Data Availability at NASA/GSFC

https://disc.gsfc.nasa.gov/hydrology

**NLDAS**: (Phase 1 and Phase 2)
0.125°, 1979-present (~3.5-day latency): Noah, Mosaic, VIC

**NCA-LDAS**: 0.125°, 1979-2015 (annual updates expected): Noah (CLSM to come)

**GLDAS**: (v1.0, v2.0, v2.1)
1.0° or 0.25°, 1979-present (1-2 month latency) or 1948-2010: Noah, Mosaic, VIC, CLM-2

**FLDAS**: 0.25° or 0.1°, 1982 or 2001-present (~1-day latency): Noah, VIC

- Access via HTTP, GDS, or quick-look visualization in Giovanni (right)
- GRIB-1 and NetCDF formats
- On-the-fly subsetting
- Full documentation, including README files and a FAQ
- LDAS projects support a growing number of national/international hydrometeorological investigations and water resources applications
Next steps

• Next phase of NLDAS will include new/updated LSMs with data assimilation of operational remotely-sensed products – and close the 3.5-day latency gap

• NLDAS will also expand the domain and to go finer resolution (details in a forthcoming white paper written in coordination with NOAA/NCEP)

• NCA-LDAS is expected to have annual updates to extend the record as well as include the assimilation of additional remotely-sensed products

• Studies with all LDAS systems are updated on the websites, including a LIS blog

• Datasets and documentation are being updated and a mailing list is available

@NASA_LIS

https://disc.gsfc.nasa.gov/hydrology
Take-away Messages

• A Land Data Assimilation System – or LDAS – is a dataset from land-surface models (LSMs) forced with the best-available observations to support water resources applications, including drought monitoring

• Remotely-sensed land satellite observations are assimilated into the LSMs to improve the depiction of water/energy cycles

• The NASA Land Information System (LIS) software framework is used for several different LDASs and datasets/documentation are available from NASA/GSFC

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

@NASA_LIS

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