NCA-LDAS: An Integrated Terrestrial Water Analysis System for the National Climate Assessment

“Sustained Assessment”

NCA-LDAS TEAM

**PI:** Michael Jasinski, GSFC Hydrological Sciences Lab/617

**Co-Is:** Kristi Arsenault, Hiroko Beaudoin, John Bolten, Jordan Borak, Steven Kempler, Sujay Kumar, Bailing Li, Yuqiong Liu, David Mocko, Christa Peters-Lidard, Matthew Rodell, Hualan Rui, Bruce Vollmer

**Collaborators:** James Foster, Dorothy Hall, George Riggs

NCA-LDAS Vision for Sustained Assessment

A unique modeling system that assimilates multiple remote sensing measurements for assessment of terrestrial water states and fluxes for the satellite era.
Specific NCA-LDAS Objectives in 2015-17

“Multivariate Assimilation of New & Future Satellite EDRs, Dissemination of Indicators and Tools”

1. Develop multivariate data assimilation capability within NCA-LDAS
2. Compute & evaluate indicators for the terrestrial water budget
3. Public access to NCA-LDAS data and data products
Accomplishments

1. Development of Multivariate NCA-LDAS and Model Evaluation
**Model domain:** Continental United States (CONUS) at 1/8th degree spatial resolution, including parts of Canada/Mexico (25-53° N; 125-67° W)

**Forcing data:** NLDAS-phase II meteorological forcing data.

**Models:** Noah LSM version 3.3, and CLSM Fortuna 2.5: a 60-year spin-up, followed by 34 years of simulation;

**Data assimilation method:** 1-d Ensemble Kalman Filter (EnKF) and 3-d Ensemble Kalman Smoother (EnKS)

**Time period:** Jan 1, 1979 to 1 Jan 2013.

**Solid boxes** - products currently assimilated. **Dashed boxes** - products under development or planned.
Data – Methods - Experiment Details

**Soil moisture DA:**

Data flagged for light and moderate vegetation, no precipitation, no snow cover, no frozen ground, no RFI are used in data assimilation.

The observations are scaled to the LSM’s climatology using CDF matching

**Snow DA:**

Passive microwave snow depth retrievals are bias-corrected using the Cressman method using the in-situ observations from Global Historical Climate Network (GHCN).

\[
x^+ = x^- + \frac{\sum_{i=1}^{N} w_i(y_i - x_i^-)}{\sum_{i=1}^{N} w_i}
\]

\[
w = H(r)v(h)
\]

\[
H(r) = \max\left(\frac{r_{\text{max}}^2 - r^2}{r_{\text{max}}^2 + r^2}, 0\right)
\]

\[
v(h) = \begin{cases} 
1 & \text{if } 0 < h \\
\frac{h_{\text{max}}^2 - h^2}{h_{\text{max}}^2 + h^2} & \text{if } -h_{\text{max}} < h < 0 \\
0 & \text{if } h < -h_{\text{max}}
\end{cases}
\]

**Irrigation:**

Employs a demand-driver (“sprinkler”) irrigation scheme based on Ozdogan et al. JHM (2010).

Irrigation is triggered when the root zone soil moisture falls below a specified threshold (during the season, determined by green vegetation fraction/LAI)

Compute irrigation requirement as an equivalent height of water and add to the precipitation forcing
Evaluation of NCA-LDAS outputs

<table>
<thead>
<tr>
<th>Soil moisture:</th>
<th>USDA Soil Climate Analysis Network (SCAN); 123 stations chosen after careful quality control (used for evaluations between 2000-2011)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Four USDA ARS experimental watersheds (&quot;CalVal&quot; sites) (used for evaluations between 2001-2011)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Snow depth:</th>
<th>Canadian Meteorological Center (CMC) daily snow depth analysis – used for evaluations between 1998-2012.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Snow Data Assimilation System (SNODAS) products from the National Operational Hydrologic Remote Sensing Center (NOHRSC) – used for evaluations between 2003/10 – 2012</td>
</tr>
</tbody>
</table>

|---------------|-------------------------------------------------------------------------------------------------|

|---------------|-------------------------------------------------------------------------------------------------|

| Fluxes:       | Gridded FLUXNET (Jung et al. 2009), ALEXI (Anderson et al. 2007), UW (Tang et al. 2009) and MOD16(Mu et al. 2011) |

All model verifications and analysis generated using the Land surface Verification Toolkit (LVT; Kumar et al. 2012)
Multivariate assimilation (evaluation of soil moisture)

Noah (soil moisture, snow depth, snow cover, irrigation)

CLSM (soil moisture, snow depth, snow cover, irrigation, terrestrial water storage)

Surface soil moisture

Root zone soil moisture

Maps show Anomaly R differences – Anomaly R(DA) – Anomaly R (OL) (using SCAN data as reference) ; Warm colors indicate improvements and cool colors indicate degradations.


Noah - improvements in soil moisture fields are small, some degradation in the western locations observed

CLSM – more significant improvements in both surface and root zone fields

<table>
<thead>
<tr>
<th>Anomaly R</th>
<th>Surface soil moisture</th>
<th>Root zone soil moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noah OL</td>
<td>0.60</td>
<td>0.55</td>
</tr>
<tr>
<td>Noah DA</td>
<td>0.65</td>
<td>0.55</td>
</tr>
<tr>
<td>CLSM OL</td>
<td>0.43</td>
<td>0.48</td>
</tr>
<tr>
<td>CLSM DA</td>
<td>0.61</td>
<td>0.58</td>
</tr>
</tbody>
</table>
Multivariate assimilation (evaluation of snow depth)

Noah: Snow depth fields are generally improved, with biases significantly reduced during the peak snow season. However, during the melt periods DA simulation shows an increased negative bias.

CLSM: The improvements in snow depth fields are minor. DA leads to marginal improvements in bias during the late winter and melt periods.

Quantifying the added value of snow cover area observations in passive microwave snow depth data assimilation
Multivariate assimilation (evaluation of streamflow)

Noah: Generally improvements in streamflow simulation are observed in most parts of the domain. Notable degradations are in the Western U.S.

CLSM: Degradations observed in the eastern parts of the domain. Notable improvements over Missouri, Northwest, parts of Northeast.

NIC of NSE using USGS station measurements as reference.
Accomplishments

2. Development/Evaluation of NCA-LDAS Indicators
Evaluation of NCA groundwater estimates using in situ groundwater

- 10~30 years of monthly depth-to-water table measurements
- Unconfined and semi-confined aquifers
- Located in four Mississippi sub-basins and four NE regions
- Converted to groundwater storage anomalies at each well using specific yield

Comparison of region averaged groundwater storage anomalies from in situ and NCA multi-sensor assimilated CLSM estimates (r represents temporal correlation)

Li, B., Rodell, M., 2015.
Sample Water Indicators Computed Using NCA-LDAS

K. Arsenault, H. Beaudoin, J. Borak, M. Jasinski, B. Li, Yuqiong Liu, D. Mocko, M. Rodell
Accomplishments

3. Dissemination to Public
NCA-LDAS Variables to be Distributed
Fluxes and States of Energy and Water Balance Variables*

<table>
<thead>
<tr>
<th>Forcing Variables</th>
<th>Principal Output Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind_f</td>
<td>Swnet Net shortwave radiation W/m²</td>
</tr>
<tr>
<td>Rainf_f</td>
<td>Lwnet Net longwave radiation W/m²</td>
</tr>
<tr>
<td>Tair_f</td>
<td>Qle Latent heat flux W/m²</td>
</tr>
<tr>
<td>Tair_f_max</td>
<td>Qh Sensible heat flux W/m²</td>
</tr>
<tr>
<td>Tair_f_min</td>
<td>Qg Ground heat flux W/m²</td>
</tr>
<tr>
<td>Qair_f</td>
<td>Snowf Snowfall rate kg/m²s</td>
</tr>
<tr>
<td>Psurf_f</td>
<td>Rainf Rainfall rate kg/m²s</td>
</tr>
<tr>
<td>SWdown_f</td>
<td>Evap Total evapotranspiration kg/m²</td>
</tr>
<tr>
<td>LWdown_f</td>
<td>Qs Surface runoff kg/m²</td>
</tr>
<tr>
<td>Irrigated water</td>
<td>Qsb Subsurface runoff kg/m²</td>
</tr>
<tr>
<td></td>
<td>Qsm Snowmelt kg/m²</td>
</tr>
<tr>
<td></td>
<td>RadT Surface radiative temperature K</td>
</tr>
<tr>
<td></td>
<td>SWE Snow Water Equivalent kg/m²</td>
</tr>
<tr>
<td></td>
<td>SoilMoist Average layer soil moisture m³/m³</td>
</tr>
<tr>
<td></td>
<td>SoilTemp Average layer soil temperature K</td>
</tr>
<tr>
<td></td>
<td>PotEvap** Potential evapotranspiration kg/m²</td>
</tr>
<tr>
<td></td>
<td>CanopInt Total canopy water storage kg/m²</td>
</tr>
<tr>
<td></td>
<td>TWS*** Terrestrial Water Storage mm</td>
</tr>
<tr>
<td></td>
<td>Snowcover Snow cover fraction</td>
</tr>
<tr>
<td></td>
<td>SnowDepth Snow depth m</td>
</tr>
<tr>
<td></td>
<td>Streamflow Streamflow m³/s</td>
</tr>
<tr>
<td></td>
<td>SnowT Snow surface temperature K</td>
</tr>
<tr>
<td></td>
<td>VegT Vegetation canopy temperature K</td>
</tr>
<tr>
<td></td>
<td>BareSoilT Temperature of bare soil K</td>
</tr>
<tr>
<td></td>
<td>AvgSurfT Average surface temperature K</td>
</tr>
<tr>
<td></td>
<td>ECanop Interception evaporation kg/m²</td>
</tr>
<tr>
<td></td>
<td>TVeg Vegetation transpiration kg/m²</td>
</tr>
<tr>
<td></td>
<td>ESoil Bare soil evaporation kg/m²</td>
</tr>
<tr>
<td></td>
<td>SubSnow Snow sublimation kg/m²</td>
</tr>
</tbody>
</table>

*Assistance for Land-surface Modelling Activities (ALMA)
GES DISC NCA-LDAS Summary Activities

- Planning for 3 data products to be supported through GES DISC
  - NCA-LDAS Noah-3.3 Land Surface Model L4 Daily 0.125 x 0.125 degree
  - NCA-LDAS CLSM-F2.5 Land Surface Model L4 Daily 0.125 x 0.125 degree
  - NCA-LDAS Terrestrial Water Indicators
- Sample data reviewed and tested
  - netCDF format specification, metadata
  - Ingest into data management system
  - GLDAS file spec available for consistency (GLDAS, NLDAS, FLDAS, NCA-LDAS)
  - Common tools available
- README file drafted (based on available information)
- Global Change Master Directory (GCMD) metadata records compiled
- Reserved DOIs for 3 products
  - 10.5067/ITMVTTVN18AD

The NCA-LDAS data will be archived at NASA GES DISC and accessed via:
- THREDDS: http://hydro1.sci.gsfc.nasa.gov/thredds/catalog.html
- Mirador search and download: http://mirador.gsfc.nasa.gov/
- Simple Subset Wizard: http://disc.gsfc.nasa.gov/SSW/
- Giovanni Visualization and Analysis: http://giovanni.gsfc.nasa.gov/giovanni/
NLDAS_NOAH0125_M Version 002: NLDAS Noah Land Surface Model L4 Monthly 0.125 x 0.125 degree

Data Citation
To cite the data in publications:
David Madron, NASA/GSFC/MDA (10/01/2012). NLDAS Noah Land Surface Model L4 Monthly 0.125 x 0.125 degree, version 002, Greenbelt, Maryland, USA: Goddard Earth Sciences Data and Information Services Center (GES DISC).
Accessed Enter User Data Access Date at http://disc.sci.gsfc.nasa.gov/datacollection/NLDAS_NOAH0125_M_V002.html

Product Description
This data set contains a series of land surface parameters simulated from the Noah land-surface model (LSM) for Phase 2 of the North American Land Data Assimilation System (NLDAS-2). The data are in 18th degree grid spacing and range from Jan 1979 to the present. The temporal resolution is monthly. The file format is netCDF-4. The NLDAS-2 monthly Noah model data were generated from the NLDAS-2 hourly Noah model data, as monthly accumulation for rainfall, snowfall, subsurface runoff, surface runoff, and snowmelt, and monthly average for other variables. Monthly period of each month is from 002 at start of the month to 23,682 at the end of the month, except the first month (Jan 1979) that starts from 002 for Jan 1979. Also for the first month (Jan 1979), because the variables listed as Instantaneous in the README file (http://hydro1.sci.gsfc.nasa.gov/data/dep/nldas/README.NLDAS2.out) do not have valid data exactly on 002 for Jan 1979, and this one hour is not included in the average for this month only.

Brief description about the NLDAS-2 monthly Noah model can be found from the GCMD DIF for GES_DISC_NLDAS_NOAH0125_M_V002 at http://gcMD.gesdisc.nasa.gov/gmd/featureNLDAS_NOAH0125_M_V002.

Details about the NLDAS-2 configuration of the Noah LSM can be found in Xia et al. (2012).

The NLDAS-2 Noah monthly data contain fifty-two fields. The data set applies a user-defined parameter table to indicate the contents and parameter number. The CRISTAB file (http://disc.sci.gsfc.nasa.gov/EarthON/CRISTAB/ftp/NLDAS/NOAH0125) offers a list of parameters for this data set, along with their Product Definition Section (PDS) IDs and units.
NCA-LDAS webpage, with documentation of the project, and (soon) links to the datasets. The website address is not yet released to the public while the webpage information is populated, and the datasets are being added to the NASA GES DISC. The current target for a public release of the webpage and datasets is **July 2015**.

LDAS dataset mailing list: [https://lists.nasa.gov/mailman/listinfo/ldas-users](https://lists.nasa.gov/mailman/listinfo/ldas-users)
Participation at Interagency Level

Dr. Christa Peters-Lidard

- NCA Water Cycle and Management Indicators Team Lead (2014-2015)
- SITT Technical Task Team (NCA Indicators advisory group to USGCRP) (9/2014-present)
- USGCRP Indicators Interagency Working Group (3/2015-present)
Publications


Presentations


NCA-LDAS next steps

- Freeze current NCA-LDAS instance and migrate to GES-DISC (July 2015).
- Complete soil moisture data assimilation support for SMOS, AMSR2 and WindSat (June 2015)
- Snow depth data assimilation support for AMSR2 is in progress. The bias correction support with in-situ GHCN data must be extended to the AMSR2 time periods (July 2015)
- Updated DA runs will be conducted to include data from new sensors (AMSR-2 + SMOS) (Nov 2015)
- Build DA capability for VIIRS snow cover (Feb 2016).
- Continue evaluation of NCA-LDAS trends through comparison of other data sets.
- The project also focuses on assimilating radiance measurements (as opposed to assimilating retrieval products
  - Forward radiative transfer model implementation in LIS (done)
  - Develop plugins to read SMAP L2 Tb data (Jan 2016)
  - Calibrate the RTM parameters to SMOS data (Jan 2016)
Challenges

- We have identified some limitations of current bias correction strategies in representing unmodeled features. Alternatives to the current practices are being explored.
- Continue to improve multivariate DA calibration at seasonal and regional scales including use ancillary information.
Thank You!