An Integrated Terrestrial Water Analysis System for the NCA (NCA-LDAS)

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NCA-LDAS Science

The hypothesis to be tested in this project is that assimilating NASA’s satellite soil moisture, SWE, SCA, TWS and irrigation products into an NCA-LDAS will produce improved characterization of the continental scale water budget, which will directly improve the monitoring and prediction of climate-relevant water availability indicators, including droughts and floods.

Specific science questions to be addressed include:

• How have North American water storages and fluxes evolved in the satellite era?
• How have the relationships among hydrologic fluxes and states changed?
  – Snowpack-streamflow-flood anomalies?
  – Groundwater-soil moisture-evapotranspiration-drought anomalies?
  – Irrigation impacts?
• Which global indicators help us understand North American impacts?
• What are key hydrologic indicators that encapsulate these impacts?
NCA-LDAS Schematic

LDAS (Land Data Assimilation System), SCA (Snow Covered Area), SWE (Snow Water Equivalent), TWS (Terrestrial Water Storage), SM (Soil Moisture), II (Irrigation Intensity)
Figure 1: March 2011 Snow Water Equivalent (SWE) Mean Percentile from NASA Aqua/AMSR-E EDR (2003-2011).

Figure 2: Irrigation Intensity (% Area) from MODIS circa 2001 (Ozdogan and Gutman 2008).

Figure 3: March 2011 Surface Soil Moisture Percentile from LPRM v5 – NASA Aqua/AMSR-E Aqua EDR (2003-2011).

Figure 4: March 2011 GRACE-based Groundwater Percentile from GRACE TWS EDR (2002-present).
Mean Annual SWE, NLDAS-2 Soil Moisture, and GW EDR percentiles for Colorado River Basin
NCA-LDAS Soil Moisture Data Assimilation

Experimental Setup:
- Domain: CONUS, NLDAS
- Resolution: 0.125 deg.
- Period: 1979-01 to 2012-01
- Forcing: NLDASII
- LSM: Noah 3.3

Data Assimilation:
- AMSR-E LPRM (Owe et al., 2008; Peters-Lidard et al., 2011) 2002-2011
- ESA ECV (Liu et al., 2012; Wagner et al., 2012) 1978-2011
- Flags: light and moderate vegetation, precipitation, snow cover, frozen ground, RFI
- The observations are scaled to the LSM’s climatology using CDF matching
- 12-member ensemble
- A spatially distributed observation error standard deviation (between 0.02-0.12 m3/m3)

Figure 3: March 2011 Surface Soil Moisture Percentile from LPRM v5 – NASA Aqua/AMSR-E Aqua EDR (2003-2011)
Soil moisture DA (LPRM): Evaluation of streamflow

<table>
<thead>
<tr>
<th>Streamflow (USGS)</th>
<th>Open loop (no DA)</th>
<th>LPRM DA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE (m³/s)</td>
<td>51.0 +/- 4.0</td>
<td>36.5 +/- 4.0</td>
</tr>
<tr>
<td>Bias (m³/s)</td>
<td>41.6 +/- 4.0</td>
<td>29.9 +/- 4.0</td>
</tr>
</tbody>
</table>

Significant improvements to the streamflow simulations are observed in most basins.
Soil moisture DA (LPRM): Drought indices (NLDAS domain average)

SRI, SSWI, and Soil Moisture Percentiles indicate that DA causes an increased drought in early 2000s and reduced drought 2008-2011. DA also simulates an increased onset of the 2011-2012 drought.

Note: The fitted distributions for SRI/SSWI/Percentiles in this analysis are computed by using 2002-2011 period.
Soil moisture DA (ECV) : Drought indices (NLDAS domain average)

Exceptional drought where the percentiles are below 2%

SRI, SSWI, and Soil Moisture Percentiles indicate that DA indicates an increased drought in early 2000s and reduced drought 2008-2011. DA also simulates an increased onset of the 2011-2012 drought.
NCA-LDAS Snow Data Assimilation

Data Assimilation:
• SMMR (spans 1978-1987), SSM/I (spans 1987-2002) and AMSR-E (spans 2002-2011); SMMR and SSM/I retrievals are based on the Chang et al. (1987) and AMSR-E retrievals are based on the improved retrieval algorithm from Kelly et al. (2009).
• AMSR-E retrievals are further improved by combining the information from MODIS snow cover retrievals – a product known as ANSA (AFWA NASA snow algorithm; Foster et al. 2010).

Figure 1: March 2011 Snow Water Equivalent (SWE) Mean Percentile from LPRM v5 – NASA Aqua/AMSR-E EDR (2003-2011).
Significant improvements to the streamflow simulations are observed in Ohio, Upper Mississippi, Significant degradations in Northwest and California.
Over both basins, DA estimates increased drought in early 2000s and reduced drought 2009-2011.

Note: The fitted distributions for SRI in this analysis are computed by using 2002-2011 period.
Next Steps

Open Loop (no DA)
• Complete open loop run with Catchment Fortuna 2.5

Data Assimilation Tasks
• Finalize station-based bias correction for SWE
• Finalize EnKF assimilation of SCA using depletion curves for Noah and Catchment
• Complete ensemble smoother for GRACE terrestrial water storage
• Complete irrigation module

NCA-LDAS
• Complete Noah assimilation runs with SM, SWE, SCA, and II
• Complete Catchment assimilation runs with SM, SWE, SCA, II and GRACE DA
• Assess indicators and trends
NCA Regions

- Northeast
- Southeast and Caribbean
- Midwest
- Great Plains
- Northwest
- Southwest
- Alaska and Arctic
- Hawaii and Pacific Islands

+ Guam, Northern Mariana Islands, American Samoa and other minor outlying islands

+ Puerto Rico and US Virgin Islands
NCA Biogeographical Cross-Cuts

• Oceans and marine resources
• Coastal zone, development, and ecosystems, e.g.,
  – SF Bay Delta
  – Chesapeake Bay
  – Gulf Coast
• Watersheds, e.g.
  – Great Lakes
  – Colorado River
  – Columbia River
  – Mississippi River
References

• Hydrology DISC (HDISC)
  http://disc.gsfc.nasa.gov/hydrology/

• NASA/GSFC NLDAS website:
  http://ldas.gsfc.nasa.gov/nldas/

• NASA/GSFC LIS website:
  http://lis.gsfc.nasa.gov/