Land Prediction in NCEP Modeling Systems: 
Current Status and Future Plans 
(NGGPS Land Team)

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...and a large number of collaborators!
Outline

• Update on Improvement of Land Surface Modeling in NGGPS:
  
  • Land data sets, e.g. land use/land cover (vegetation type), soil type, surface albedo, snow cover, surface roughness, etc.
  
  • Land Data Assimilation Systems (LDAS): provide initial land states for NCEP modeling systems.
    
    • GLDAS
    
    • NLDAS
  
  • Physics: appropriate to represent land-surface processes (for relevant time/spatial scales) and assoc. LSM model parameters.
    
    • Rapid temperature dropoff during sunset
    
    • Cold biases over cold region

• Summary/Future
Land Data Sets Used in NCEP Modeling Systems

- **Vegetation Type**
  (1-km, IGBP-MODIS)

- **Soil Type**
  (1-km, STATSGO-FAO)

- **Max.-Snow Albedo**
  (1-deg, Robinson)

- **Green Vegetation Fraction (GVF)**
  (monthly, 1/8-deg, NESDIS/AVHRR)

- **Snow-Free Albedo**
  (seasonal, 1-deg, Matthews)

- **Climatologies:** fixed/annual, monthly, weekly.
- **Near real-time observations,** e.g. GVF “becoming” a land state.
Land Data Sets Used in NCEP Modeling Systems

Tiling or blockiness readily apparent

From Corey Guastini  NCEP/EMC MEG Jul 23, 2015
Land Data Sets Used in NCEP Modeling Systems

1: broadleaf-evergreen trees
2: broadleaf-deciduous trees
3: broadleaf and needleleaf trees
4: needleleaf-evergreen trees
5: needleleaf-deciduous trees (larch)
6: broadleaf trees with groundcover
7: groundcover only (perennial)
8: broadleaf shrubs with perennial groundcover
9: broadleaf shrubs with bare soil
10: dwarf trees and shrubs with groundcover (tundra)
11: bare soil
12: cultivations (the same parameters as for type 7)
13: glacial ice

GFS SIB VTYPE T1534

GFS IGBP VTYPE T1534
Land Data Sets Used in NCEP Modeling Systems

1: loamy sand
2: silty clay loam
3: light clay
4: sandy loam
5: sandy clay
6: clay loam
7: sandy clay loam
8: loam
9: glacial ice

1: sand
2: loamy sand
3: sandy loam
4: silt loam
5: silt
6: loam
7: sandy clay loam
8: silty clay loam
9: clay loam
10: sandy clay
11: silty clay
12: clay
13: organic material
14: water
15: bedrock
16: other (land-ice)
17: playa
18: lava
19: white sand
The issue of tiling or blockiness due to the coarse LSC data was solved. First soil layer moisture 18h fcst 2015122200
NGGPS Project: Incorporate near-realtime Green Vegetation Fraction (GVF), validation with LST

• Climatology vs. near real-time GVF.

AVHRR 5-year “Climatology”

• Ingest into NCEP models where near real-time GVF leads to better partition between surface heating & evaporation --> impacts surface energy budget, PBL evolution, clouds & convection.
• Initial summertime GFS tests in 2013, 2014, 2015 show improvements in low-level temperature and dew point, land-surface temperature.
• Part of a broader effort for land product data set ingest with focus on internal consistency among various products (i.e. albedo, burned area, soil moisture, etc).

Weizhong Zheng, Yihua Wu (NCEP/EMC), Bob Yu, Ivan Csiszar, Marco Vargas et al (NESDIS/STAR)
NGGPS Project: Satellite-based Land Data Assimilation in NCEP Modeling Systems

- Use NASA Land Information System (LIS) to serve as a global Land Data Assimilation System (LDAS) for testing both GLDAS, NLDAS.
- LIS EnKF-based Land Data Assimilation tool used to assimilate:
  - Soil moisture from the NESDIS global Soil Moisture Operational Product System (SMOPS).
  - Snow cover area (SCA) from operational NESDIS Interactive Multisensor Snow and Ice Mapping System (IMS), and AFWA snow depth (SNODEPTH) products.

**Verification of SNOW DA**

Jiarui Dong, NCEP/EMC

Jiarui.Dong@noaa.gov
• **Noah surface model** runs in semi-coupled mode with Climate Data Assimilation System version (CDASv2); daily update provides initial land states to operational Climate Forecast System version 2 (CFSv2).

• **Forcing**: CDASv2 atmospheric output, & “blended” precipitation, snow.

• **Blended Precipitation**: CPC satellite (heaviest weight in tropics); CPC gauge (heaviest mid-latitudes); model CDASv2 (high latitude).

• **Snow**: IMS cover & AFWA depth, cycled if within 0.5-2.0x “envelope”.

• **30+ year global land-surface climatology**.

• Research/partners supported by the NOAA Climate Program Office, Modeling, Analysis, Predictions, and Projections (MAPP) program.

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**Precipitation**

- CMAP
- Surface gauge
- GDAS

**Snow**

- IMS cover
- AFWA depth

Jesse Meng, NCEP/EMC
Global Land Data Assimilation System (GLDAS) version 2

- **Motivation:** NCEP CFS Reanalysis ran 6 simultaneous “streams”; soil moisture time series may have trends and discontinuity due to insufficient land surface spin up (~1 year, where ~10-years+ required).

- **Solution:** Retrospective single-stream GLDAS2 with 10-year spin-up procedure to resolve the issues of spin-up and stream discontinuity.

- Significantly improved soil moisture time series in the semi-arid regions and cold regions where longer spin-up period required.

- Reasonable soil moisture climatology, energy/water budget closure.

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![Map of July 2012 Soil Moisture Anomaly from NCEP GLDASv2](image)

- **Russian drought**
- **US drought**
- **Uganda flooding**

**Jesse Meng, NCEP/EMC**
**LDAS Upgrade: Implementation of GLDAS in GFS**

- CDASv2/GLDAS paradigm: adapt for Global Forecast System:
  - Noah land model physics upgrades; accommodate higher-res. GFS.
  - Land surface forcing/downscaling, e.g. precipitation.
  - Land data sets, e.g. land-use, soils, green vegetation fraction (GVF).
  - Land data assimilation, e.g. snow, soil moisture.
  - Replace soil moist. nudging which uses CDASv2/GLDAS climatology.
  - Hydrology/river routing for ocean coupling. *(National Water Center)*
  - Eventually one global high-resolution LDAS for all NCEP systems.

- Continue to work with partners: Noah LSM model development group; NWS NGGPS land/other teams; supported by NOAA/CPO/MAPP; part of CPO/MAPP Task forces on reanalyses, model development, drought.

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**NCEP Realtime Operational GLDAS**

Vegetation Type Data

Soil Type Data

Jesse Meng and Helin Wei, NCEP/EMC
**Precipitation Data:**
- Gauge-satellite blended analysis of daily global precipitation.
- 0.25° lat/lon over the global land.
- Global daily analysis, 0.25-deg, 1979-present.
- Blending information from different sources:
  - CPC daily gauge analysis.
  - GPCC monthly gauge data.
  - OLR-based precipitation estimates.
  - CMORPH-based precipitation estimates.

**Preliminary Results:**
- Improved soil moisture spin-up & anomalies.
Supported by NOAA/CPO/MAPP.

**LDAS Upgrade: GLDASv2.2 with New Precipitation Forcing**

**Southwest US**

![Southwest US Graph](image)

**Northern Plains**

![Northern Plains Graph](image)

**Southeast US**

![Southeast US Graph](image)
North American Land Data Assimilation System (NLDAS) Operational at NCEP 05 August 2014

- **Land models**: Noah, SAC, VIC, Mosaic run in “uncoupled” mode.
- **Forcing**: NCEP Climate Prediction Center obs precip (gauge-based, radar/satellite disaggregated), and atmospheric forcing from NCEP North American Regional Climate Data Assimilation System.
- **Output**: 1/8-deg. land & soil states, surface fluxes, runoff/streamflow.
- **Climatology** from land model assimilation runs for 30+ years provide anomalies used for drought monitoring; supports USDM, NIDIS etc.
- **Comprehensive evaluation** of energy fluxes, water budget and state variables using in situ and remotely-sensed data sets.
- **Evaluate** land-atmosphere coupling metrics for NLDAS climatology.
- NOAA/CPO/MAPP-supported partners: NCEP, NASA, Princeton, UW, NWC.

www.emc.ncep.noaa.gov/mmb/nldas ldas.gsfc.nasa.gov/nldas/NLDAS2valid.php

NLDAS four-model ensemble monthly soil moisture anomaly

|--------------------|---------------------|-------------------|-------------------|
Next Generation NLDAS within Land Information System (LIS) and Actual Data Assimilation (Snowpack, Soil Moisture, GRACE)

**LIS-based next phase of NLDAS**

- Parameters (Topography, Soil properties, vegetation properties)
- Meteorological Boundary Conditions (Forcings)
- Observations (Soil Moisture, Snow, Skin Temperature)
- Data Assimilation, multi-variate (EnKF, EnKS)

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-based Environmental Data Records (EDRs): soil moisture (SM), snow-covered area (SCA), snow water equivalent (SWE), terrestrial water storage (TWS), & irrigation intensity (II)

1979 – Present
Updated w/ Larger Domain Forcings and Parameters at 4-km

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

Goddard Space Flight Center

* 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 Connection: Hydrology, River-Routing

Atmospheric Forcing

Ensemble mean daily streamflow anomaly (NLDAS)

Hurricane Irene and Tropical Storm Lee, 20 August – 17 September 2011

Superstorm Sandy, 29 October – 04 November 2012

Colorado Front Range Flooding, September 2013

Close Coordination with Office of Water Prediction (OWP) on National Water Model (NWM)
Model Physics Improvement: Decoupling

GFS T2m Rapid drop after sunset (from Manikin, NCEP/EMC MEG)
Approach to fix excessive cooling of T2m in GFS

“Excessive cooling and decoupling”: surface roughness, soil thermal diffusivity, vegetation layer, turbulence, etc.

- Limit the system not beyond the turning point (MO stability parameter):

\[ \frac{z}{L} < \frac{z}{L} \bigg|_M = \frac{\ln(z_0/z)}{2 \alpha (1 - z_0/z)} \]

Here \( z_0 \) is the momentum roughness length, and \( \alpha = 5 \).

Van de Wiel et al.
Reduced cold bias afternoon and nighttime (~ 1.2 °C); Reduced RMSE afternoon and nighttime up to 1.0 °C (~ 25% RMSE).

Pr skills (CONUS) f36-f60
1/21-3/2, 2015
Improved scores for light and medium precipitation and reduced their bias.

T fits Obs:
8/15-9/22, 2014
Reduced temperature bias and RMSE near the surface.
Model Physics Improvement: Cold Biases

- Cold temperate bias over snow
- Stable boundary
- Decoupling
- Surface exchange coefficient (Ch)
- Snow albedo being too large

Alaska, NW, NE

NWC T2m, March of 2013

Southern Alaska, T2m, March of 2014
Revised ground heat flux under deep snow

\[ G = \left( T_1 - T_{\text{soil}}(1) \right) \cdot \frac{DF_1}{DTOT}, \]

\[ DTOT = \Delta Z_s + \Delta Z_{SI}, \]

\[ DF_1 = F_{sn} \frac{\Delta Z_s K_s + \Delta Z_{SI} K_{SI}}{\Delta Z_s + \Delta Z_{SI}} + (1 - F_{sn}) K_{SI}, \]

\[ G = \left( T_1 - T_{\text{soil}}(1) \right) \cdot \max(DD_{min}, DF_1/DTOT), \quad (8) \]

where \( DD_{min} = 7 \text{ W m}^{-2} \text{ K}^{-1} \), as motivated by the European Centre for Medium-Range Weather Forecasts (ECMWF) land model (see http://www.ecmwf.int/research/ifsdocs/CY28r1). Figure 2 shows that equation (8) (Exp. 4) improves the Noah simulation of SWE and snow depth.

MAX Snow Albedo
(upper bound over deep snow)

• Radiation driver

  Diffuse Albedo: 0.90(vis) 0.75(nir)

  Direct Albedo:
  -- low zenith angle same as diffuse
  -- high zenith angle: 0.98~1

  Usually substantially higher than that in Noah LSM (below)

• Noah LSM

  Based on global field of Maximum Snow albedo
Model Physics Improvement: Cold Biases

2m-T and Td over Alaska, January of 2016

reduced cold bias
Model Physics Improvement: Cold Biases

2m-T and Td over NW CONUS, January of 2016

reduced nighttime cold bias, but still have significant day/nighttime cold bias
Model Physics Improvement: Cold Biases

2m-T and Td over East CONUS, January of 2016

reduced daytime cold bias, nighttime warm bias likely due to more ground heat flux from new soil texture
Model Physics Improvement: Cold Biases

2m-T and Td over West CONUS, January of 2016

reduced cold bias
Proposed Changes for the Next NEMS Implementation

- IGBP 20-type land classifications and STASGO 19-type soil classifications
- The new MODIS-based snow free albedo from BostonU/Mark-Friedl (JCSDA funded)
- The new MODIS-based maximum snow albedo from UAZ/Xubin (JCSDA funded)
- Fanglin’s diurnal albedo treatment
- Unify two aspects between radiation driver and Noah LSM
  - Snow cover
  - Snow albedo
- Fix excessive cooling of T2m
- Increase ground heat flux under the deep snow
Land Prediction at NCEP: Summary/Future

• Improve & unify Noah land model and GLDAS/NLDAS at NCEP:
  – Forcing, e.g. precipitation, & land data sets, e.g. near-realtime GVF.
  – Run GLDAS, NLDAS under NASA Land Information System (LIS):
    parallel run environment, latest land model versions, land data
    sets, data assimilation/validation tools for e.g. snow, soil moisture.
  – Land model physics improvements, including next-generation
    “Noah-MP” with dynamic vegetation, etc; account for agriculture,
    irrigation, etc; lakes; hydrology/groundwater/river-routing.
  – Higher resolution and downscaled forcing and model output.
  – Enhance land model spin-up procedures.
  – Extend domain/resolution of NLDAS to North America, to then
    “merge” with GLDAS for global models (GFS, CFS), providing
    unified initial land conditions for all NCEP regional, global and
    climate models.
  – Comprehensive hierarchy of model development and evaluation.

• Land models role expanding for weather & climate in increasingly more
  fully-coupled Earth-System Models (atmosphere-ocean-land-ice-waves-
  aerosols) with connections between Weather & Climate and
  Hydrology, Ecosystems & Biogeochemical cycles (e.g. carbon),
  and Air Quality, models and communities, i.e. under community
  model development, e.g. NOAA Environ. Modeling System (NEMS).