NESDIS Satellite Land Data Products for NCEP NWP and Drought Monitoring

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OUTLINE

- Satellite Soil Moisture Data Products
- SM Data Assimilation for Drought Monitoring
- SM Data Assimilation for NCEP NWPs
- Future Data Assimilation Plan
<table>
<thead>
<tr>
<th>Name</th>
<th>Satellite/Sensor/System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albedo</td>
<td>NOAA, MetOp, NPP/JPSS, GOES/GOES-R</td>
</tr>
<tr>
<td>Fire</td>
<td>NOAA, MetOp, NPP/JPSS, GOES/GOES-R</td>
</tr>
<tr>
<td>LST</td>
<td>NOAA, MetOp, NPP/JPSS, GOES/GOES-R</td>
</tr>
<tr>
<td>NDVI/GVF</td>
<td>NOAA, MetOp, NPP/JPSS, GOES/GOES-R</td>
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<tr>
<td>Sfc Emissivity</td>
<td>MSPPS/MiRS</td>
</tr>
<tr>
<td>SM</td>
<td>GOES/GOES-R, GCOM-W1, SMOPS</td>
</tr>
<tr>
<td>Snow</td>
<td>AutoSnow, MSPPS/MiRS</td>
</tr>
<tr>
<td>SWE</td>
<td>AutoSnow, MSPPS/MiRS</td>
</tr>
</tbody>
</table>
Two ways to retrieve soil moisture from satellites:

- **Microwave (MW):** Observed MW brightness temperature depends on soil dielectric constant that is related to soil moisture:
  - **Strength:** higher reliability based on direct physical relationships
  - **Weakness:** antenna technology limits spatial resolution

- **Thermal Infrared (TIR):** Observed surface temperature changes result from surface energy balance that is dependent on soil moisture:
  - **Strength:** TIR sensor could have higher spatial resolution
  - **Weakness:** relies on land surface energy balance model that is prone to input data errors.

Two-Source Model (ALEXI)

Satellite Soil Moisture Remote Sensing Science
Soil Moisture Operational Product System (SMOPS)

1. Start
2. Read PCF file
3. Check if TB or SM data available
   - Yes: Read ancillary data
   - No: Check if new input file run
     - Yes: Read footprint TBs
     - No: Check if 6 hour/daily or Archive
       - Yes: Merge gridded SM files
       - No: Check if 6 hour/daily
         - Yes: Repeat branch 1, 2, 3 for all data after 2 days
         - No: Check if End of input file
           - Yes: End
           - No: Grid ASCAT/SMOS SM

End

*All data acquired within the 6 hour or whole day time period arrived in the past 48 hours*
Microwave Soil Moisture Products from SMOPS

- Increased spatial coverage
- Multi retrieval variance could be used as error estimate
Microwave Soil Moisture Products from SMOPS

WindSat

SMOS

ASCAT

Blended
Soil Moisture Daily Maps

To display maps, please select a data type, region, year, month, and date, and then click 'Refresh'.

Use the '<=' and '>' buttons to step ahead or backward through the images. Soil moisture is expressed in Volumetric Soil Moisture Content [m$^3$ water/m$^3$ soil] (see Documents for details).

Data Types:
- NOAA-AMSR-E
  NOAA Soil Moisture from AMSR-E: Land surface soil moisture retrieved from AMSR-E X-band brightness temperature (TB10H) observations using the Single-Channel-Retrieval (SCR) algorithm.
- NOAA-WindSat
  NOAA Soil Moisture from WindSat: Land surface soil moisture retrieved from Naval Research Lab's (NRL) WindSat X-band brightness temperature (TB10H) observations using the Single-Channel-Retrieval (SCR) algorithm.
- NOAA-TMI
  NOAA Soil Moisture from TMI: Land surface soil moisture retrieved from the X-band brightness temperature
Land surface temperature (LST) and solar insolation (Rs) from NOAA Geostationary Operational Environmental Satellite (GOES) imager and future GOES-R Advance Baseline Imager (ABI) are used in an Atmosphere-Land Exchange Inversion (ALEXI) model to generate ET and an Evaporative Stress Index (ESI) for drought monitoring.

ALEXI model output using GOES data have good agreement with field observations and full-scale land surface model simulations of ET.

ALEXI ET and ESI data products are being used at US operational drought monitoring.
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Current US Drought Monitoring

![Palmer Drought Index](image1)

Palmer Drought Index

![Vegetation Health Index](image2)

Vegetation Health Index

![U.S. Drought Monitor](image3)

U.S. Drought Monitor

May 25, 2004

![LSM SM Output](image4)

LSM SM Output
Enhanced Drought Monitoring

Palmer Drought Index

Vegetation Health Index

U.S. Drought Monitor

GOES/GOES-R ESI

Satellite ST, Alb, GVF/VI

LSM SM Output

Satellite SM
Current Noah LSM Runs

- 1990s/2000s AVHRR/MODIS ST, VI/GVF, albedo
- No Satellite LST, SM assimilation
- Noah
- LIS (NLDAS)
Enhanced Noah LSM Runs

NRT
NPP/JPSS
ST,
VI/GVF,
albedo

LIS (NLDAS,
GLDAS)

NRT
NPP/JPSS
LST,
GCOM-W/
ALEXI
SM
assimilation

Noah
Sat SM DA Improves LSM Runs

Time averaged improvement metric \((\text{RMSE(open loop)} - \text{RMSE (EnKF)})\) for (top) surface soil moisture and (bottom) root zone soil moisture from the (left) Catchment LSM and the (right) Noah LSM assimilation experiments. Units are volumetric soil moisture \((m^3/m^3)\) (Kumar et al 2008)
Synergy between TIR and MW Methods

**TIR methods provide:**
- Relatively higher spatial resolution (100 m to 10 km)
- Potential for SM retrievals over a wider range of vegetation cover
- Longer repeat cycles (2 to 7 days, depending on cloud climatology)

**MW methods provide:**
- Relatively low spatial resolution (25 to 60 km)
- High temporal resolution (1 to 2 days)
- No retrievals over dense vegetative canopies
Dual Assimilation of MW and TIR Sat SM

Averaged RMSD [m$^3$ m$^{-3}$] in (a) 0-5 cm SM and (b) 5-100 cm SM predictions
NLDAS is tested with or without ALEXI (TIR) and AMSR-E (MW) soil moisture assimilation.
Dual Assimilation of MW and TIR Sat SM

- NLDAS is tested with or without ALEXI (TIR) and AMSR-E (MW) soil moisture assimilation

<table>
<thead>
<tr>
<th>Method</th>
<th>CONUS-Average RZ Soil Moisture RMSD (m$^3$ m$^{-3}$)</th>
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<tbody>
<tr>
<td>OLP</td>
<td>0.055</td>
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<tr>
<td>LPRM</td>
<td>0.044</td>
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<tr>
<td>ALEXI</td>
<td>0.042</td>
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<tr>
<td>DUAL</td>
<td>0.042</td>
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</table>

![Graph showing soil moisture RMSD over time](image-url)
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Assimilation of MW SM into NCEP GFS

Pros:
- GFS can demonstrate SM impact on forecasts
- GFS may take advantage of satellite SM obs earlier than full scale implementation

Cons:
- Hardwiring limits more flexibility for assimilating other observational data
Assimilation of MW SM into NCEP GFS

- **Time:** DA at 00z from April 1 – May 5, 2012
- **Data:** SMOPS Blended Surface SM
- **Method:** EnKF DA within GFS/GSI
- **Experiments:**
  - **CTL:** Regular GFS run without SM DA
  - **EnKF:** Daily EnKF run
Comparison of soil moisture from SMOPS Blended 18Z, 1-30 April 2012

SMOPS BL: SOILM1 (Fraction)  Ave 1–30 April 2012

GFS_CTL: SOILM1 (Fraction)  Ave 1–30 April 2012

GFS EnKF: SOILM1 (Fraction)  Ave 1–30 April 2012

Diff of SOILM1  Ave 18Z, 1–30 April 2012

EnKF-CTL
Comparison of soil moisture from SMOPS Blended 18Z, 1-30 April 2012

SMOPS: SOILM: Fraction

GFS_CTL: SOILM: Fraction

GFS_EnKF: SOILM1 (Fraction)

Diff of SOILM1

EnKF-CTL
### GFS Top Layer SM Validation
With USDA-SCAN Measurements
1-30 of April, 2012

<table>
<thead>
<tr>
<th></th>
<th>East CONUS (26 sites)</th>
<th>West CONUS (25 sites)</th>
<th>Whole CONUS</th>
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<tr>
<td></td>
<td>RMSE</td>
<td>Bias</td>
<td>Corr-Coef</td>
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<tr>
<td><strong>CTL</strong></td>
<td>0.135</td>
<td>0.046</td>
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<tr>
<td><strong>EnKF</strong></td>
<td>0.130</td>
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<tr>
<td><strong>SMOPS</strong></td>
<td>0.133</td>
<td>-0.055</td>
<td>0.601</td>
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Bias

HGT: Bias
P500 G2 00Z, fh120

<table>
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<th>PREMKF01</th>
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<td>26 APR 2012</td>
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<tr>
<td>1 MAY 2012</td>
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RMSE

HGT: RMSE
P500 G2 00Z, fh120

<table>
<thead>
<tr>
<th>Verification Date</th>
<th>PREMKFCTL</th>
<th>PREMKF01</th>
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<td>6 APR 2012</td>
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<tr>
<td>1 MAY 2012</td>
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</table>

Bias: -0.36
RMSE: -0.43
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Assimilation of S-NPP/JPSS Land EDRs

- S-NPP/JPSS data processing tools ready for input files of albedo, GVF, ST and LST to LIS (NLDAS/GLDAS)

Gridded ST EDR for day 12/31/2012
GLDAS is tested using either old AVHRR ST map or newer VIIRS QST IP seed (MODIS C5). Impact of ST changes LSM runs is studied.
• NLDAS is being tested using either multi-year albedo average or NRT MODIS monthly values
Many satellite land data products are ready for NWP model assimilation

Drought monitoring could be significantly enhanced by dual assimilation of both MW and TIR soil moisture observations

GFS forecasts are improved by assimilating SMOPS daily soil moisture products

More land data could be tested if …..
Thanks ......