Applying SMAP Data Products in Numerical Weather and Seasonal Climate Predictions at NOAA-NCEP

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OUTLINE

1. NOAA & NCEP need for SMAP products

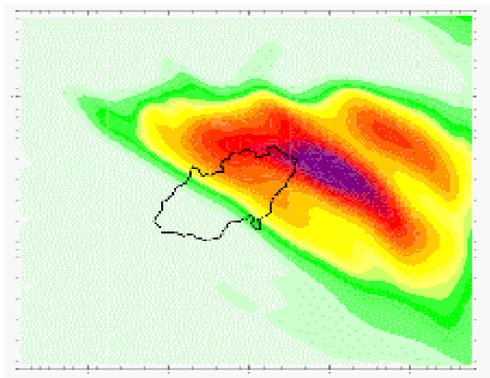
2. NESDIS soil moisture product system

3. Use of NASA Land Information System (LIS) for NCEP land data assimilation:
   - Coupling NEMS-LIS for SM DA
   - Coupling CRTM-LIS for T_B DA

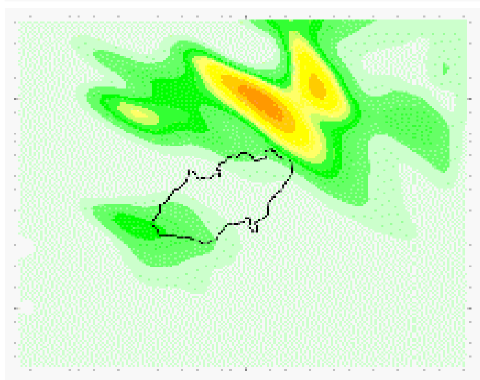
More Realistic Soil Moisture Data Lead to Better Rainfall Forecast

24 Hour forecast of rainfall over Buffalo Creek Basin, Colorado

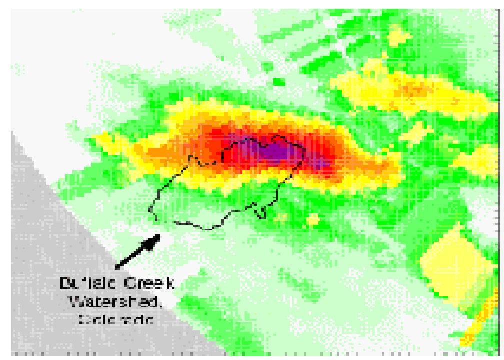
<u>With</u> Realistic Soil Moisture



<u>Without</u> Realistic Soil Moisture



24 Hour Observed Rainfall over Buffalo Creek Basin, Colorado



Observation

Buffalo Creek Basin

Observed Rainfall
0000Z to 0400Z 13/7/96
(Chen et al., NCAR)

Using realistic soil moisture in numerical weather prediction model improves the rainfall forecast significantly

Soil Moisture Impacts Seasonal Climate Forecast of Precipitation

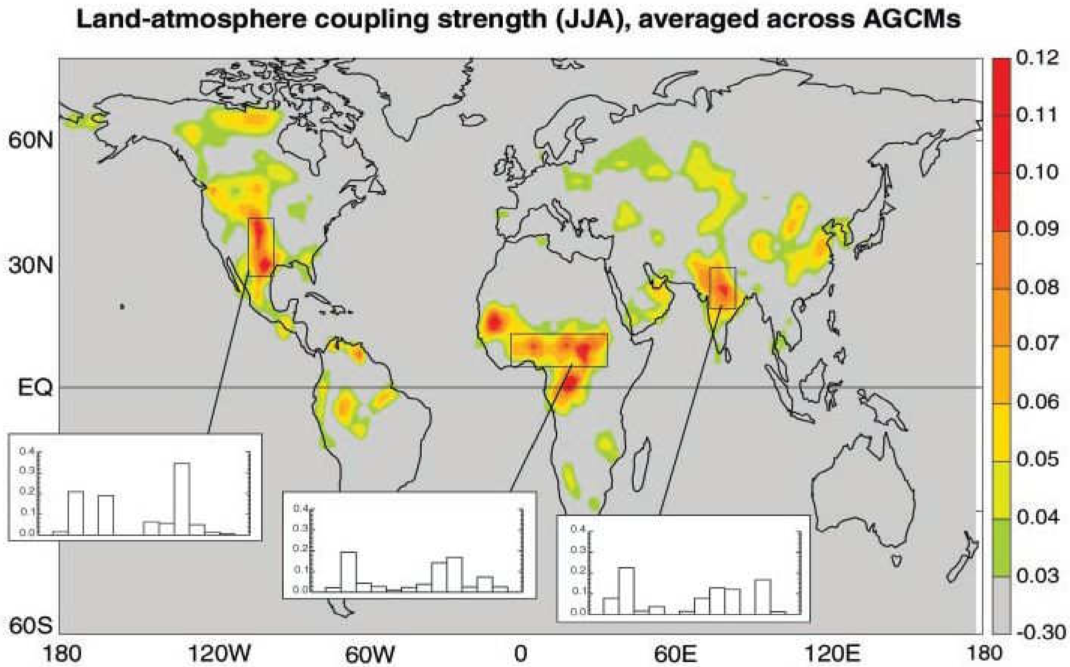
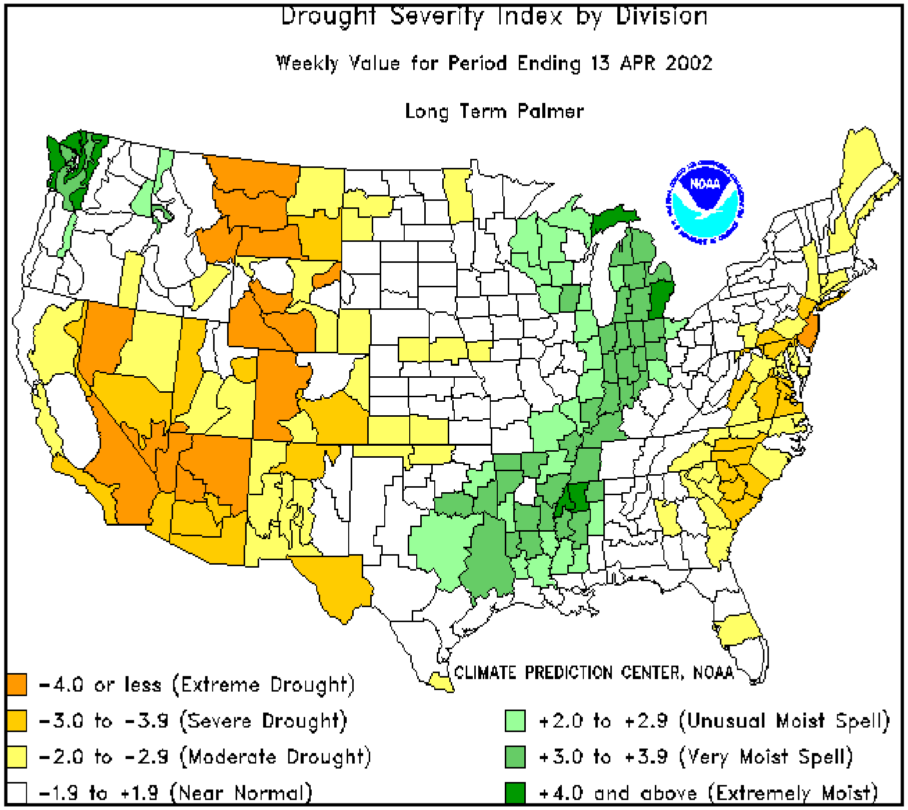


Fig. 1. The land-atmosphere coupling strength diagnostic for boreal summer (the Ω difference, dimensionless, describing the impact of soil moisture on precipitation), averaged across the 12 models participating in GLACE. (**Insets**) Areally averaged coupling strengths for the 12 individual models over the outlined, representative hotspot regions. No signal appears in southern South America or at the southern tip of Africa.

The land-atmosphere coupling strength in atmospheric general circulation models (AGCMs) shows strong impact of soil moisture on seasonal precipitation in many regions around the world.

Koster et al. (2004), Science, 305, 1138-1140.

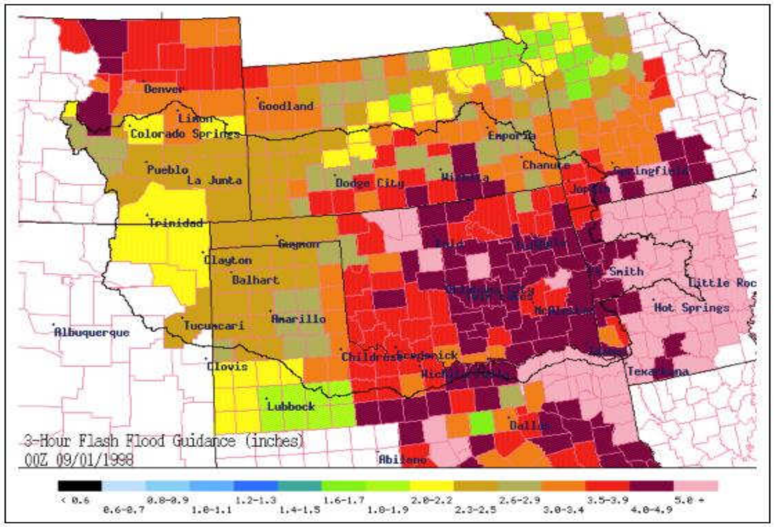
Soil Moisture Data Required for NOAA Operational Drought Monitoring



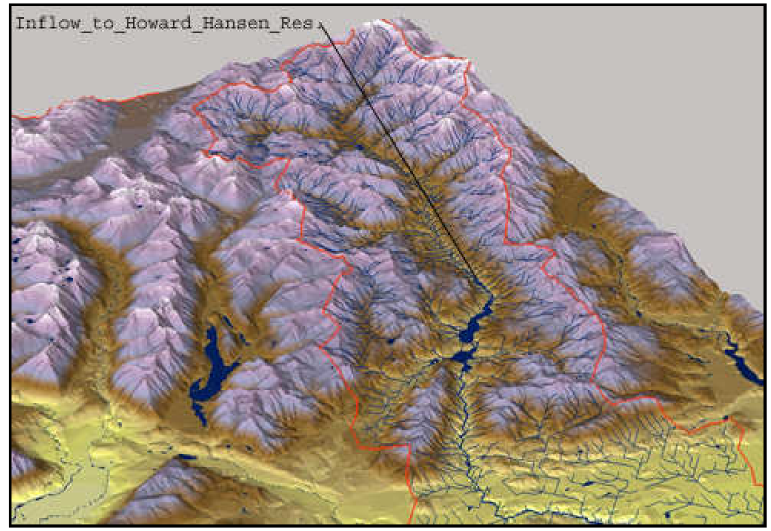
Current NOAA and National Drought Mitigation Center (NDMC) Operational Drought Index is based on Modeled Soil Moisture Data.

SMAP will provide soil moisture data of high quality, replacing the modeled soil moisture data, for NOAA's Operational Drought monitoring.

Soil Moisture Data Used for NOAA's Flash Flood Forecasting and River Forecast Models



Current NWS operational 30 km Flash Flood Guidance (FFG) is also based on modeled surface soil moisture data.



River Forecast Models used at NOAA River Forecast Centers also need surface soil moisture data for model initialization.

Soil moisture data from SMAP, more reliable than the modeled data, will enhance the Flash Flood Guidance of NOAA-NWS and improve the accuracy of these river forecast models of NOAA.

SMAP Baseline Science Data Products

Data Product	Description	Spatial Resolution	Latency*
L1B_S0_LoRes	Low Resolution Radar σ^o in Time Order	30 km	12 hours
L1C_S0_HiRes	High Resolution Radar σ^o on 1-3 km Earth Grid	1 – 3 km	12 hours
L1B_TB	Radiometer T_B in Time Order	40 km	12 hours
L1C_TB	Radiometer T_B on 36 km Earth Grid	40 km	12 hours
L3_F/T_HiRes	Freeze/Thaw State on 3 km Earth Grid	3 km	24 hours
L3_SM_HiRes	Radar Soil Moisture on 3 km Earth Grid (internal product)	-------	-------
L3_SM_40km	Radiometer Soil Moisture on 36 km Earth Grid	40 km	24 hours
L3_SM_A/P	Radar/Radiometer Soil Moisture on 9 km Earth Grid	10 km	24 hours
L4_C	Carbon Net Ecosystem Exchange on 9 km Earth Grid	10 km	14 days
L4_SM	Surface & Root Zone Soil Moisture on 9 km Earth Grid	10 km	7 days

*The SMAP Project will make a Best Effort to reduce the data latencies beyond those shown in this table.

Specifics of NCEP Data Need for SMAP Products

- ***SM impact intra-seasonal, inter-seasonal, to inter-annual climate varibilities.***
- ***SM data are important for LSM validation as well as other land remote sensing data, e.g.: soil temperature, snow, albedo, green vegetation fraction.***
- ***Different SMAP data product will have different usage for verifying modeled temporal and spatial variability of soil moisture, and freeze/thaw states.***

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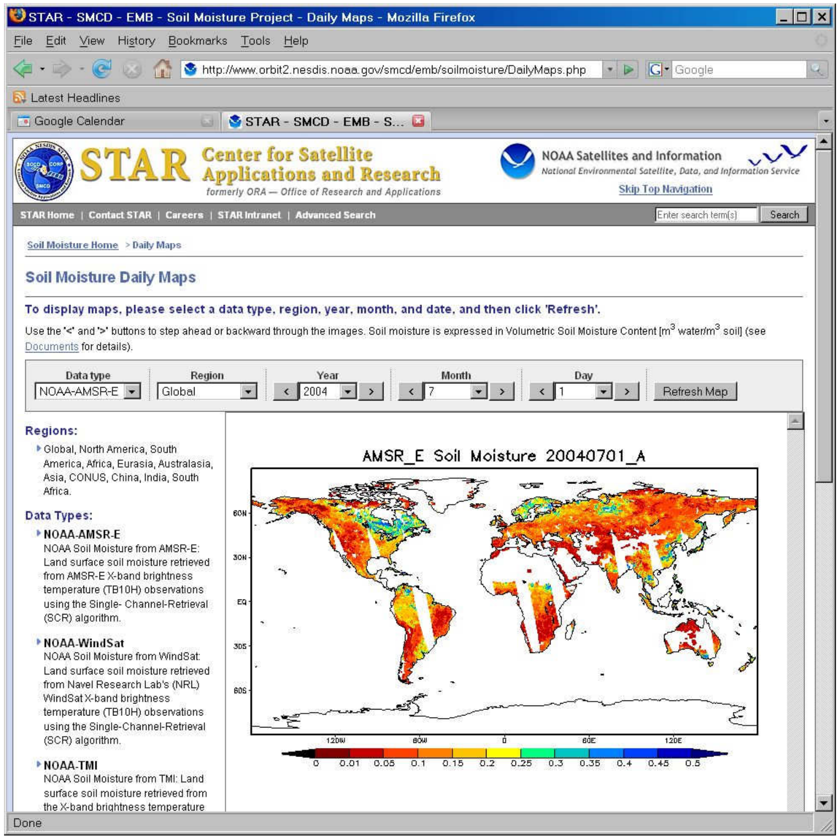
NESDIS Soil Moisture Product System (SMOPS)

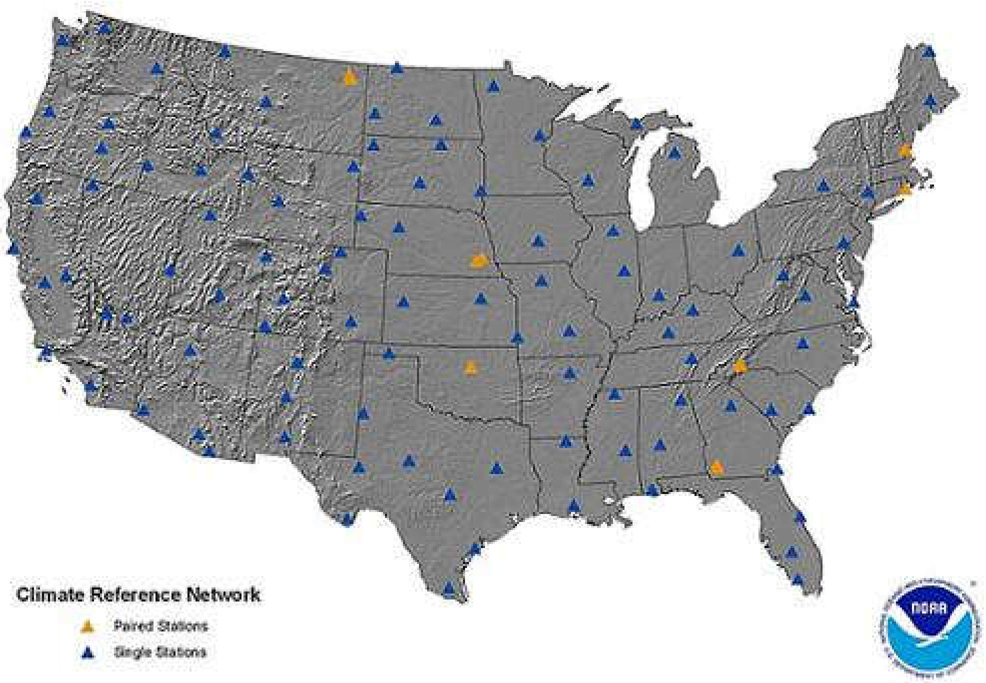
- ***NOAA-NESDIS is developing a “Soil Moisture Product System (SMOPS)” that collects and merges various satellite soil moisture retrievals for a consistent global soil moisture data product.***
- ***SMOPS can be used to quickly distribute SMAP TB data to users.***
- ***Several available global soil moisture data products in user-friendly formats will be made available to the public through NOAA-NESDIS Soil Moisture Data Portal.***



NOAA-NESDIS expertise on operational satellite data product validation, distribution and archive may help save SMAP costs.

NCDC Climate Reference Network (CRN) SM Ground Observations for Validation

- *NOAA-NCDC has built a US Climate Reference Network (USCRN) that measures climate variables continuously for more than 100 stations around US. Soil moisture sensors are being installed for these stations too. The ground soil moisture measurements will be used for validating SMAP data products and output from assimilating SMAP products at NCEP.*



NOAA's US Climate Reference Network soil moisture observations will help validate SMAP soil moisture data products.

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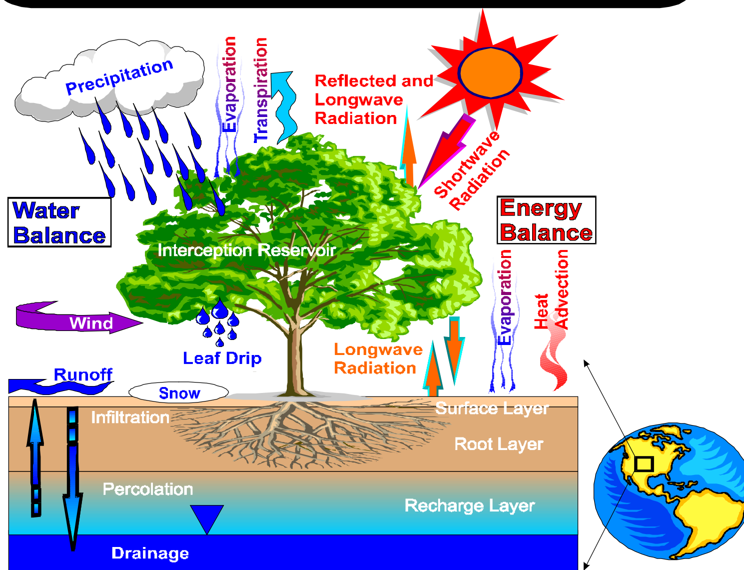
NASA Land Information System (LIS)

Inputs

- Topography, Soils
- Land Cover, Vegetation Properties
- Meteorology
- Snow Soil Moisture Temperature

Physics

Land Surface Models



Data Assimilation Modules

Outputs

- Soil Moisture & Temperature
- Evaporation
- Runoff
- Snowpack Properties

Applications

- GFS Initialization
- Tactical Decision Aids
- USDA FAS
- NCEP
- Other Users

** Courtesy of NASA LIS group (Peters-Lidard, Kumar, Geiger, et. Al.)*

LIS Running Modes

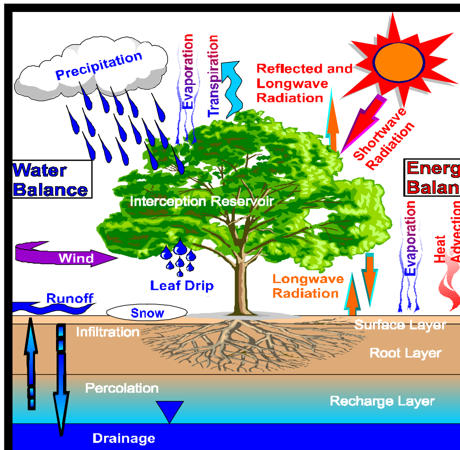
Uncoupled or Analysis Mode

Coupled or Forecast Mode

Station Data

Global, Regional Forecasts and (Re-)Analyses

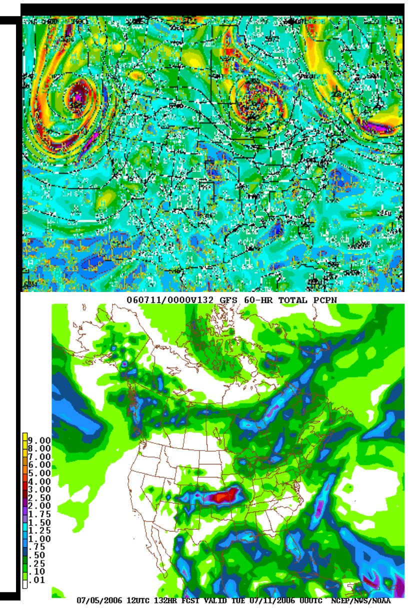
Satellite Products (e.g. SMAP SM)



LSM Physics (Noah and EnKF DA)

ESMF

NEMS



LSM Initial Conditions

These efforts supported by JCSDA.

** Courtesy of NASA LIS group (Peters-Lidard, Kumar, Geiger, et. al.)*

Preliminary SM Data Assimilation Using LIS at NCEP

- Noah Land Surface Model simulated SM are compared with AMSR-E soil moisture retrievals
- AMSR-E soil moisture retrieval climatology compared with Noah LSM simulations
- Ensemble Kalman Filter data assimilation algorithm are tested to assimilate AMSR-E soil moisture retrievals into Noah LSM in LIS.

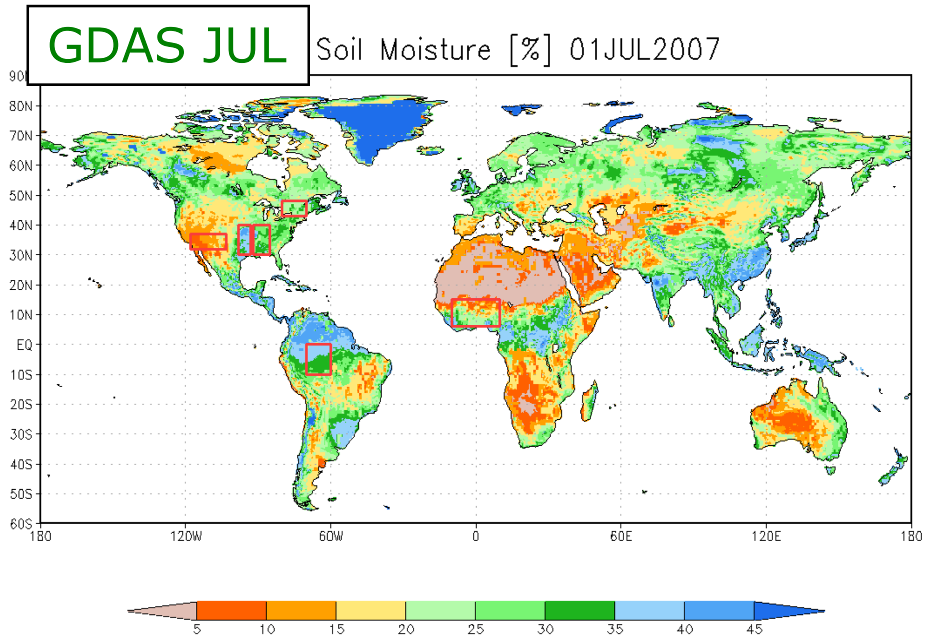
Comparison of NOAA soil moisture products

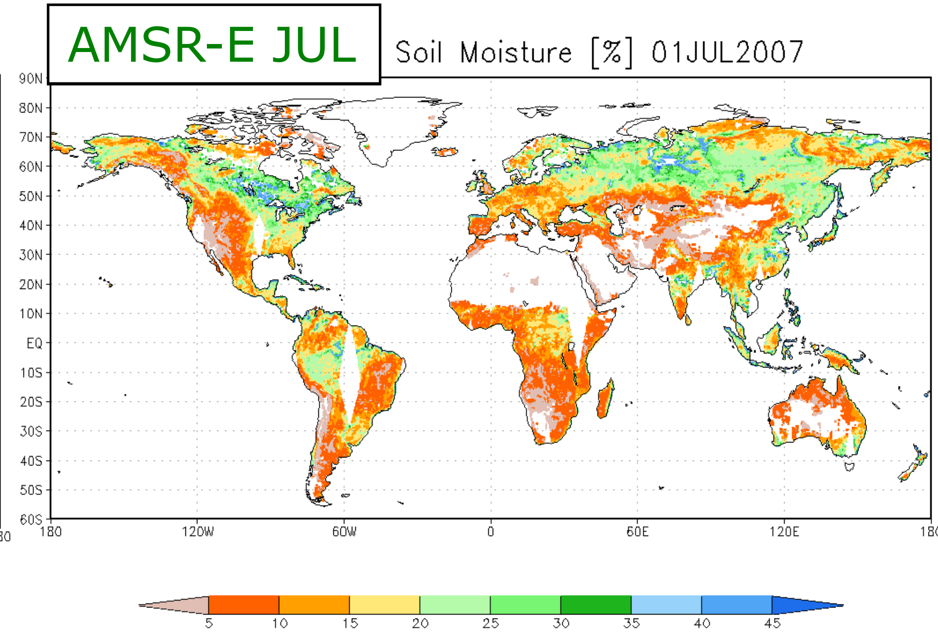
GDAS (global model)

- 0.3 degree product on global domain
- Soil moisture is simulated by the Noah land surface model (Ek et. al., 2003)
- 4 soil layers at 0-10cm, 10-40cm, 40-100cm, and 100-200cm
- 9 soil types (Zobler, 1986)
- 13 vegetation types (Dorman and Sellers, 1989)

AMSR-E

- 0.25 degree product on global domain
- Single-channel retrieval (Zhan et. al., 2008)
- Primary input :
  AMSR-E 10GHz H-pol TB
- Ancillary input :
  AMSR-E 37GHz V-pol TB
  MODIS NDVI


GDAS JUL
Soil Moisture [%] 01JUL2007
90N 80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S
180 120W 60W 0 60E 120E 180
5 10 15 20 25 30 35 40 45


AMSR-E JUL
Soil Moisture [%] 01JUL2007
90N 80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S
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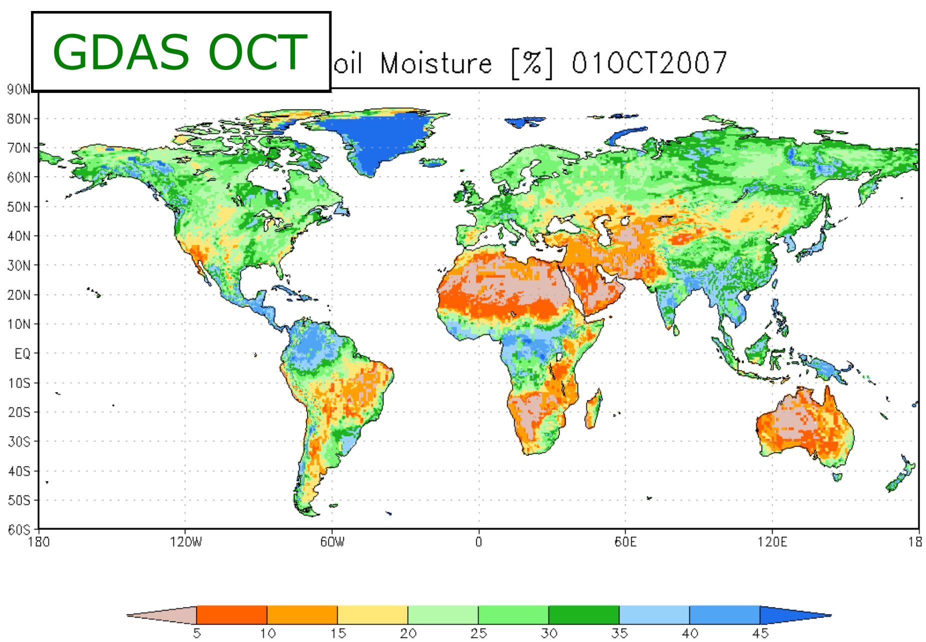
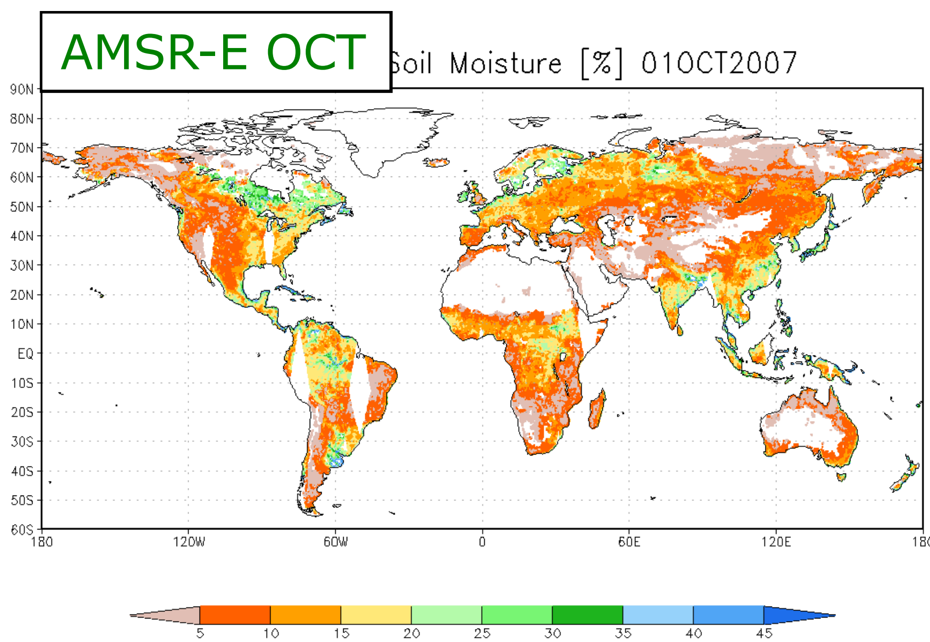
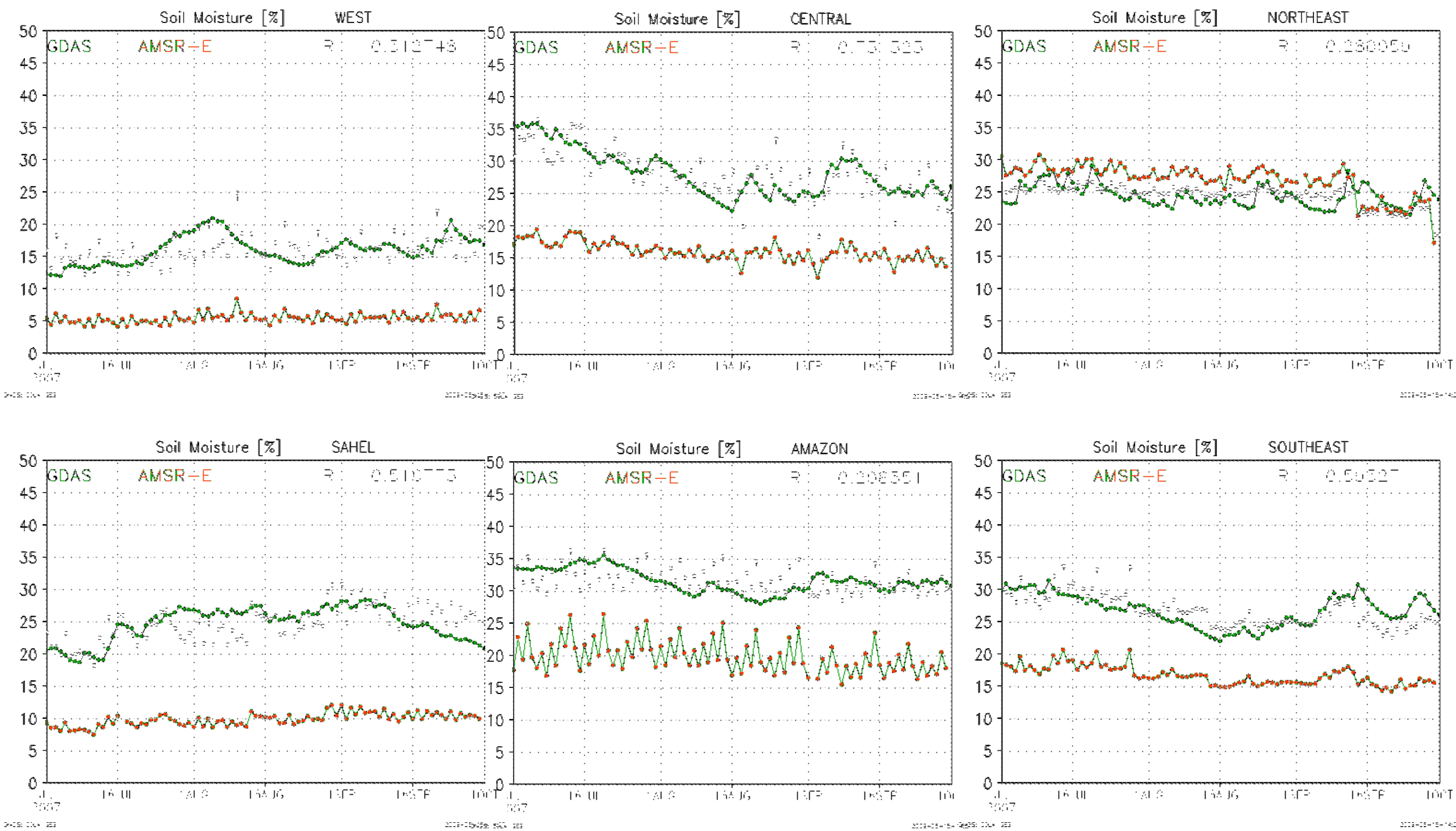
5 10 15 20 25 30 35 40 45

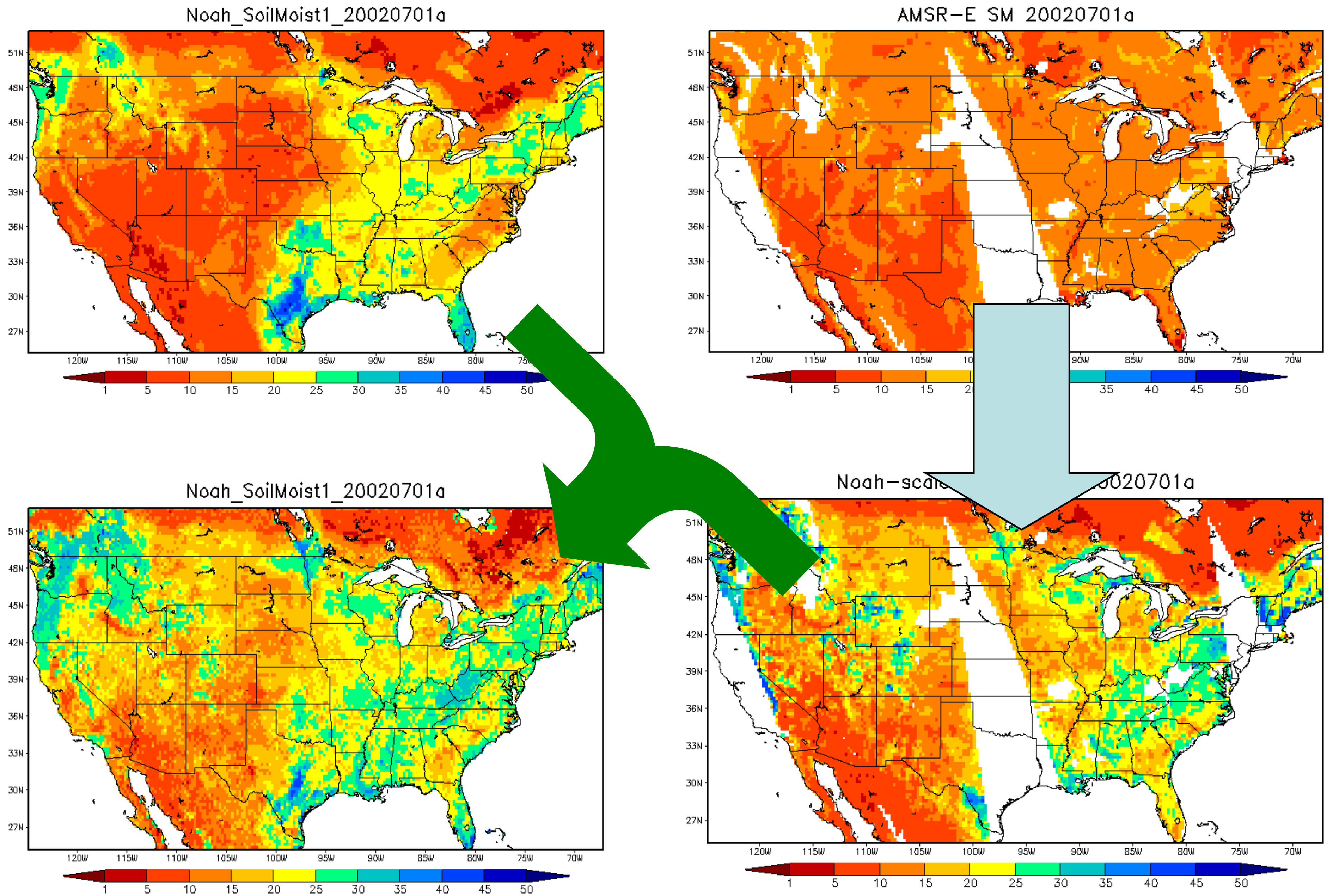

GDAS OCT
oil Moisture [%] 01OCT2007
90N 80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S
180 120W 60W 0 60E 120E 18
5 10 15 20 25 30 35 40 45


AMSR-E OCT
Soil Moisture [%] 01OCT2007
90N 80N 70N 60N 50N 40N 30N 20N 10N EQ 10S 20S 30S 40S 50S 60S
180 120W 60W 0 60E 120E 180
5 10 15 20 25 30 35 40 45

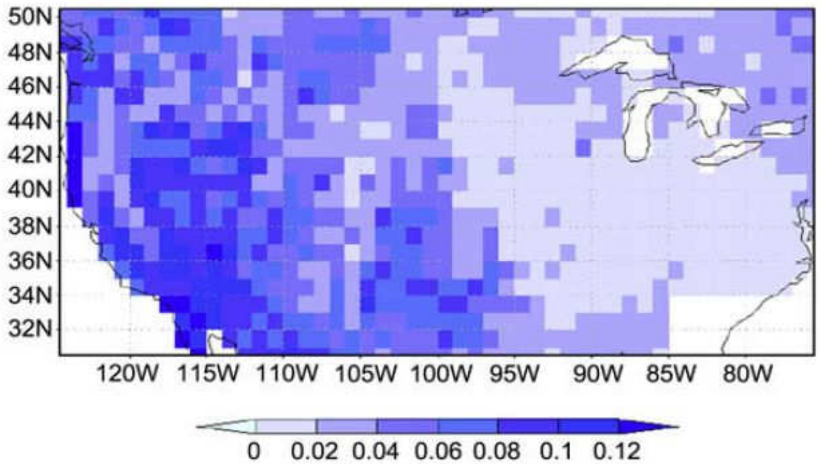
GDAS AMSR-E Rescaled AMSR-E



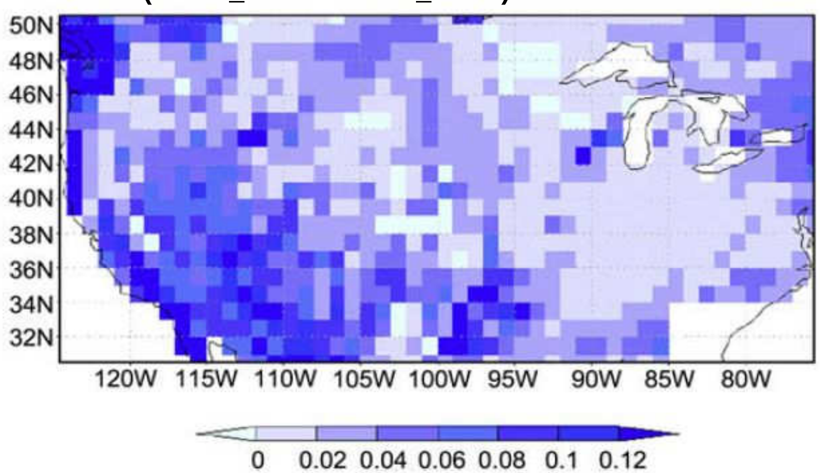
LIS/Noah AMSR-E soil moisture data assimilation



Soil Moisture Data Used in Data Assimilation



(RMSE_Noah – RMSE_EnKF) for Surface



(RMSE_Noah – RMSE_EnKF) for Root Zone

Assimilating AMSR-E soil moisture data significantly using the Ensemble Kalman Filter (EnKF) reduces the root-mean-square-errors (RMSEs) of the Noah land surface model simulations of surface layer and root-zone soil moisture.

Assimilating more reliable SMAP soil moisture data is expected to improve numerical weather prediction models.

Kumar et al. (2008), Adv. Water Resour., 31 (2008) 1419–1432.

Coupling LIS with CRTM of JCSDA for T_B Data Assimilation

- Coupled LIS-CRTM system is available for TOVS sensors such as AMSU-A and AMSU-B, and will be completed for AMSR-E sensor soon.
  - *Radiance-based data assimilation in LIS*

- No AMSR-E measurements are assimilated over **<u>land</u>** in current NCEP Ops GSI/CRTM.

- **Correction of RFI for observed AMSR-E Tb**
  - **With Ying Wu et al.'s Method**

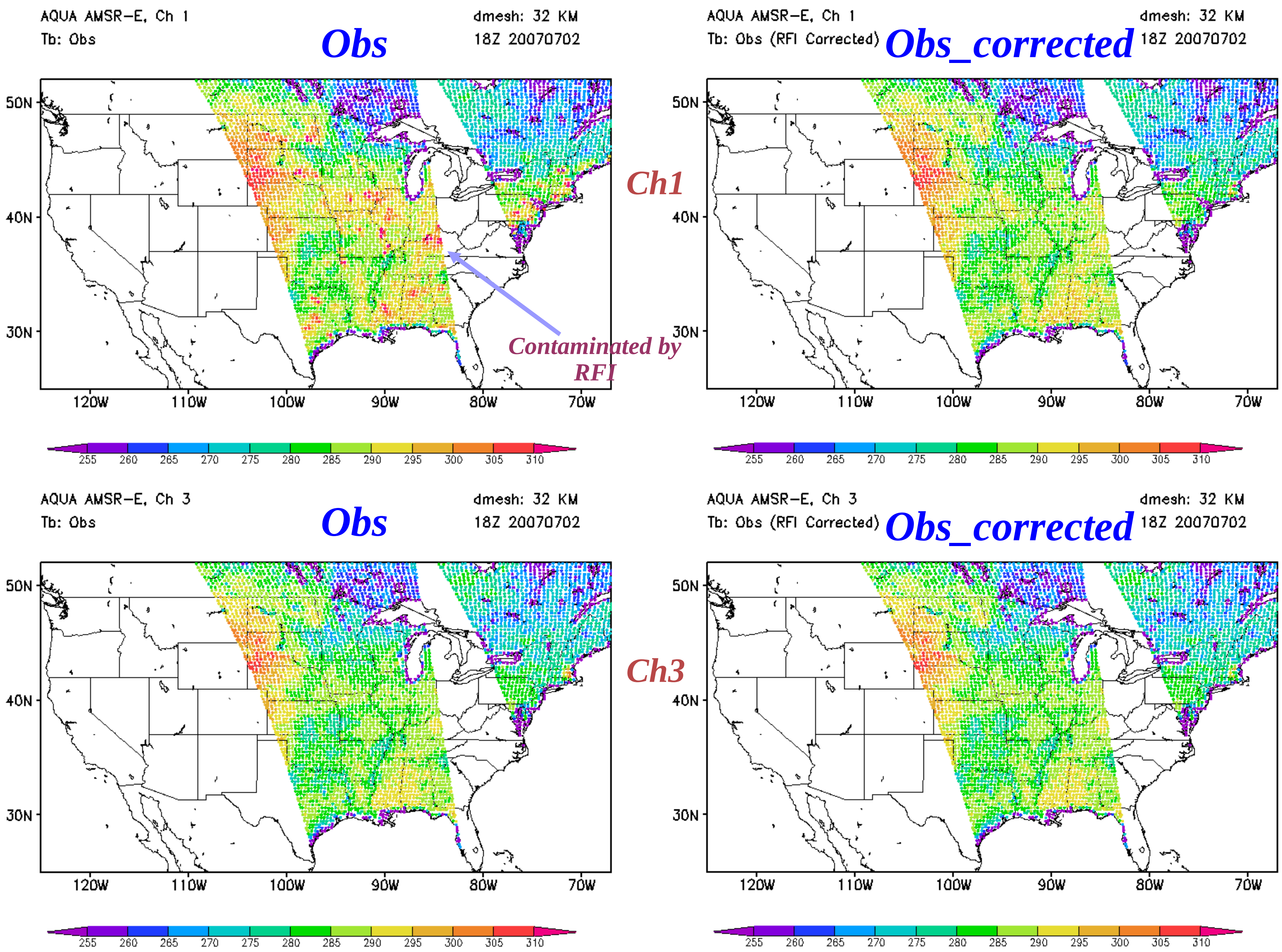
- **Improvement of land surface skin temperature (LST) over arid and semi-arid regions in GFS**
  - **New formula of thermal roughness length (Zot) (X. Zeng et al).**

- **Impact test of soil moisture on Tb calculation**
  - **Model soil moisture changed by +25% or -25%.**
  - **Assimilation of AMSR-E retrieved soil moisture beneficial ?**

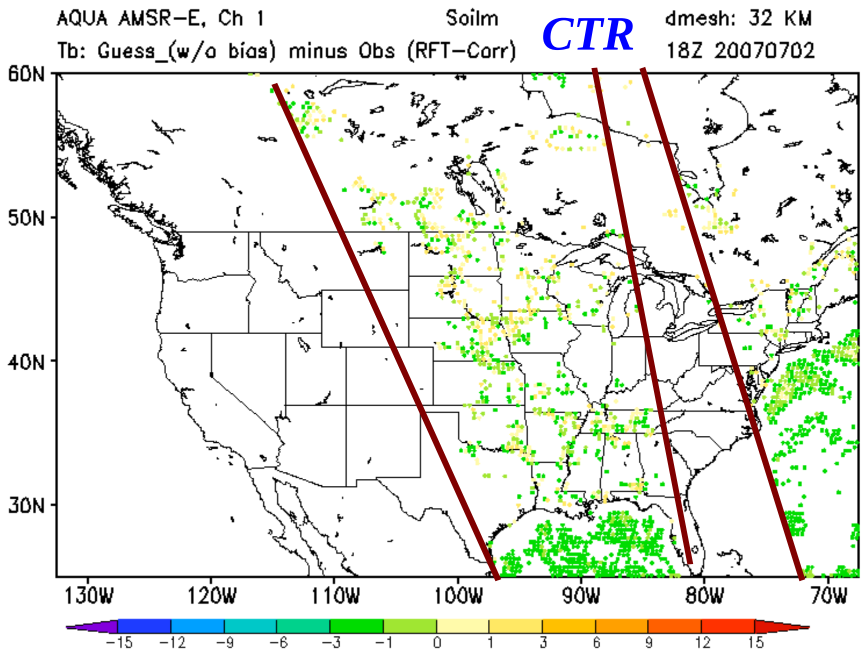
AMSR-E ***C-Band: 6.925 Ghz, V- & H-Polarization***

X-Band: 10.65 Ghz, V- & H-Polarization

Tb Observation for AMSR-E V-POL Ch1(6.925GHz); Ch3(10.65GHz)



Tb Bias for AMSR-E V-POL *Ch1(6.925GHz)* Pixels passed QC in GSI



Impact tests of soil moisture on Tb simulation

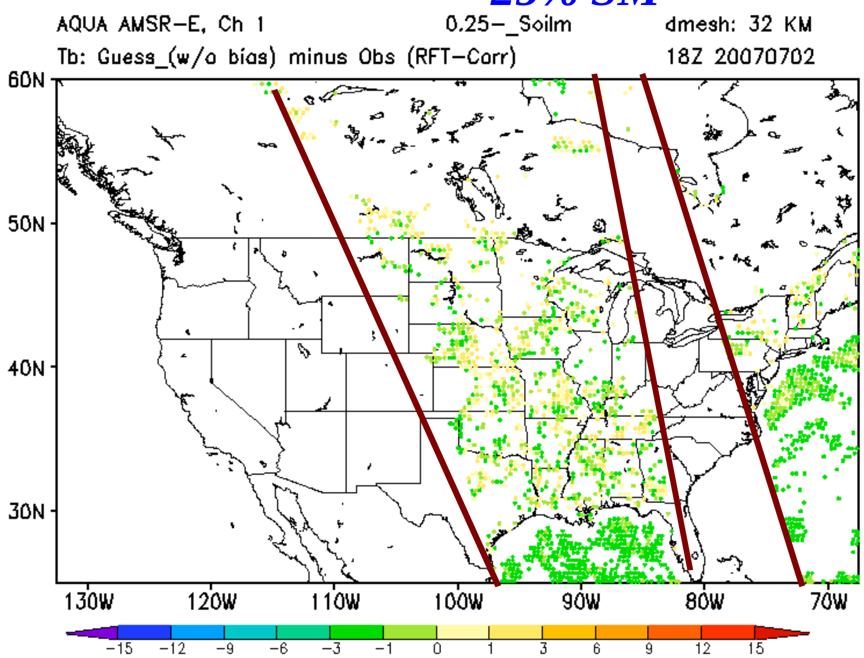
Test 1: Soil moisture reduced by 25%

Test 2: Soil moisture increased by 25%

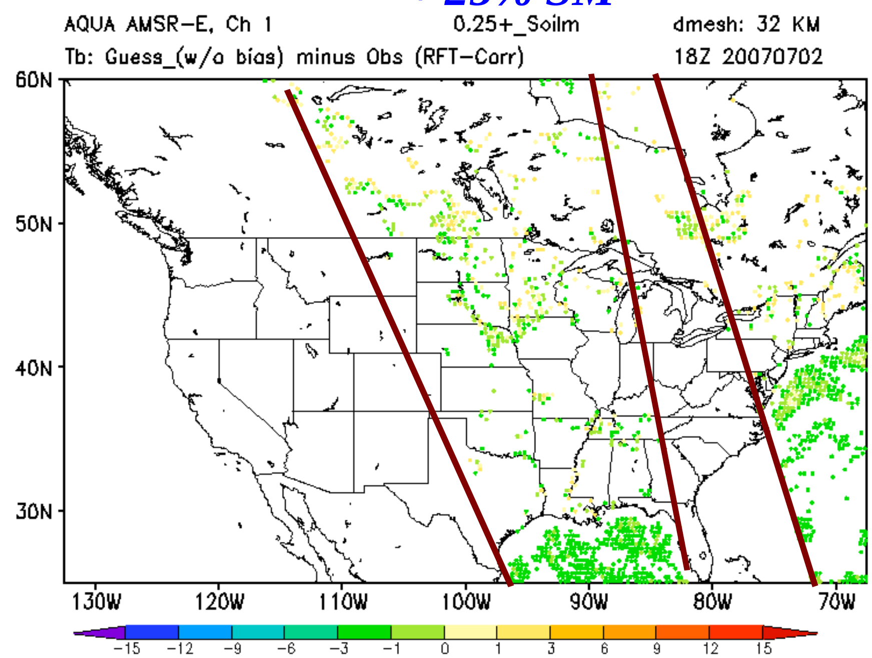
In this case, it shows that the model soil moisture is generally too high.

Tb: Very sensitive to soil moisture change !

- 25% SM



+ 25% SM



Conclusions and Future Plan

- Satellite remote sensing provides an opportunity to observe soil moisture on global scale.
- A single microwave channel retrieval from AMSR-E has been developed at NOAA/NESDIS.
- NASA LIS provides a framework for testing land data assimilation (soil moisture and TB).
- Compared to the AMSR-E retrieval, the simulated soil moisture from the NCEP GDAS assimilation system shows larger spatial and temporal variability.
- AMSR-E data (RFI-corrected) for C-band and X-band has been tested in GSI and substantial bias in brightness temperature calculation was found over land, i.e., inaccurate soil moisture predicted in the NCEP model can result in the large errors in brightness temperature calculation of AMSR-E low frequency channels, thus most of satellite data would be rejected at the first step of GSI data assimilation.
- ***Future Plan:***
- Improvement of soil moisture and skin temperature predicted from the Noah LSM.
- Improvement of soil moisture with the AMSR-E retrieval data. Further calibration and QC are ongoing to handle the challenges of AMSR-E retrieval in dry, cold, and dense vegetation conditions.
- Improvement of surface emissivity calculation for low frequency channels in CRTM.