Comparison of Different Methods to Merge Satellite Soil Moisture Products from Different Sensors

Jicheng Liu[1,2], Xiwu Zhan[2] , Christopher Hain[1,2], Li Fang[1,2], Jifu Yin[1,2] and Zhengpeng Li[1,2]

1. Earth System Science Interdisciplinary Center (ESSIC) / Cooperative Institute for Climate & Satellite-Maryland (CICS-MD), University of Maryland, College Park, Maryland
2. Center for Satellite Application and Research (STAR), NOAA/NESDIS, College Park, Maryland

Introduction

Global soil moisture is one of the critical land surface initial conditions for numerical weather, climate, and hydrological predictions. Since it is not practical to provide global maps using ground measurements, land surface soil moisture remote sensing has been a hot research topic in the last several decades. As a result, a number of soil moisture products have been produced from different satellite sensors with different spatial and temporal coverage and quality. To make good use of all available soil moisture products, a Soil Moisture Operational Product System (SMOPS) has been developed at National Oceanic and Atmospheric Administration (NOAA) to produce a one-stop shop for all operational soil moisture products from different satellite sensors. To increase the spatial and temporal coverage of soil moisture product, SMOPS also provides a data layer that merges soil moisture retrievals from multiple satellites in addition to the individual soil moisture retrievals from each of the available satellites.

SMOPS has been operationally running at NOAA NESDIS since 2012. In the first version of SMOPS, soil moisture products from Soil Moisture and Ocean Salinity (SMOS), the Advanced Scatterometer (ASCAT) on EUMETSAT's MetOp-A satellite and WindSat on Coriolis satellite are used to produce the blended product. All soil moisture layers from individual sensors are also gridded and saved in SMOPS final product. SMOPS has a 6-hour product and a daily product both in GRIB2 format. An archive product is also produced in NetCDF-4 format with a 2-day time latency to catch all available swath data from individual sensors. SMOPS will be upgraded to Version 2 in 2015 that will improve the SMOPS product in following ways: 1) A new SMOS soil moisture product will be produced using NOAA's own retrieval algorithm to reduce the time latency in using SMOS data; 2) Soil moisture product from ASCAT on MetOp-B satellite will be ingested in the system; 3) Soil moisture product from the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the GCOM-W satellite will be ingested in the system, 4) WindSat soil moisture layer will no longer be included, and 5) The updated CDF with longer time range will be used to produce the blended product.

As we generating the new version of CDFs for SMOPS system, we compared approaches to blend soil moisture products from different satellite sensors. The major tested methods include mean-standard deviation method and CDF matching method. Both seasonal and annual time windows are tested. For testing purpose, only data from two sensors are used: SMOS and ASCAT-A.

Instruments

SMOS: Soil Moisture Ocean Salinity (SMOS) mission of European Space Agency (ESA) is the first ever satellite mission designated for soil moisture observation. SMOS was launched on November 2, 2009 and carries the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS). The MIRAS senses L-band microwave emission (1.400-1.427 GHz) that could penetrate soil depth to about 5cm and vegetation cover with vegetation water content up to 5 kg/m^2. The SMOS radiometer exploits the interferometry principle, which by way of 69 small receivers will measure the phase difference of incident radiation. The technique is based on cross-correlation of observations from all possible combinations of receiver pairs. A two-dimensional 'measurement image' is taken every 1.2 seconds. As the satellite moves along its orbital path each observed area is seen under various viewing angles. From an altitude of around 758 km, the antenna will view an area of almost 3000 km in diameter.

ASCAT: ASCAT is onboard both MetOp-A and MetOp-B satellites. It is an advanced version of the Scatterometer (called ESCAT) on board of the European Remote Sensing Satellites (ERS). These scatterometers are originally designed for indirectly determining wind stress over oceans by measuring the radar backscattering coefficient (σ_0) from the wind induced water ripples and waves. ASCAT has three radar antenna beams that illuminate a continuous ground swath at three different azimuth angles (45, 90, and 135 degrees sideward from the direction of the satellite motion) on both sides of the track. The result is a triplet of spatially averaged σ_0 values for each location along the swath. The ASCAT measurements have a 50-km spatial resolution along and across the swath, with an additional 25-km resolution product with experimental status. ASCAT also features a symmetrical second swath, which practically increases its temporal sampling capabilities to double that of the. Because of the significant width of the swath, the σ_0 measurements come not only at six different azimuth angles but also at various incidence angles ranging from 25 to 64 degrees. The C-band radar frequency is 5.255 GHz.

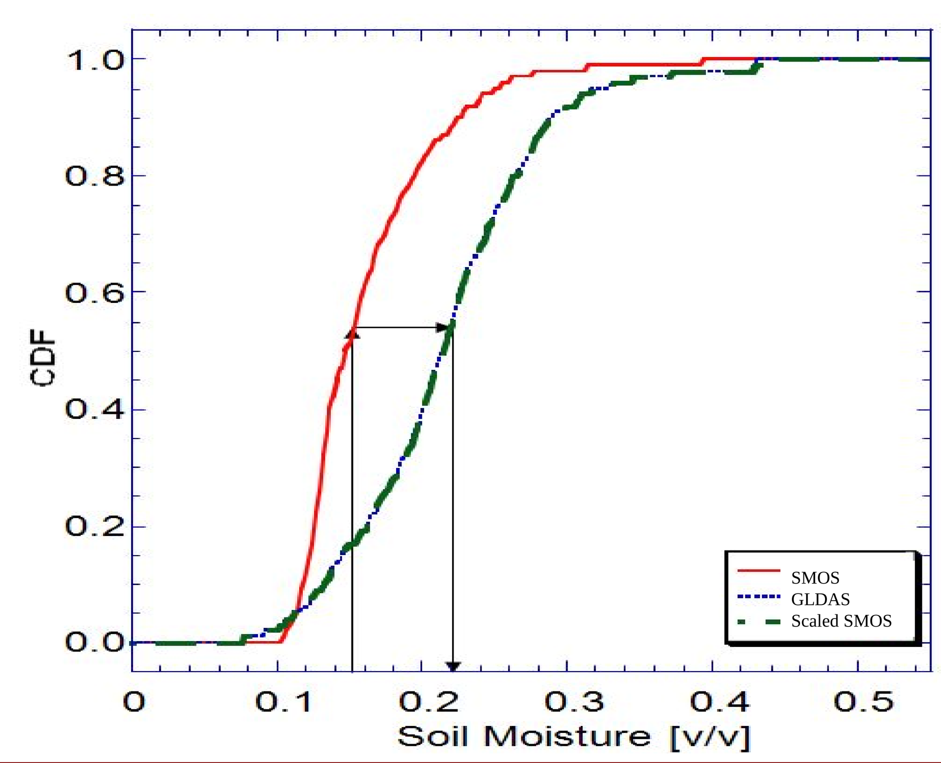
Gridding and Merging

SMOS Soil Moisture: SMOS soil moisture retrievals are available at 40km global grids with a 4% accuracy expectation. SMOS revisit time is 2-3 days for each grid.

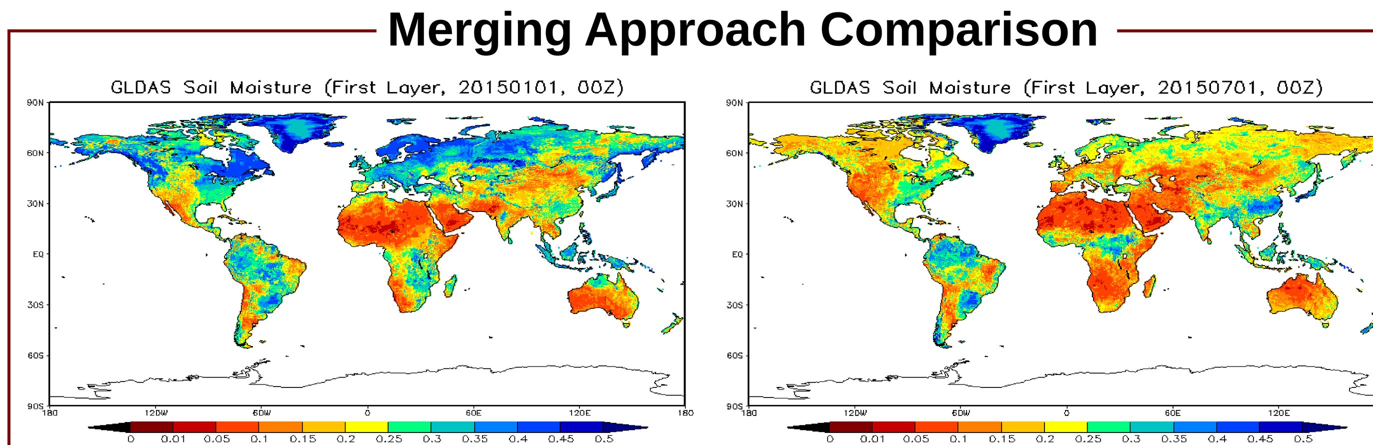
ASCAT Soil Moisture: The ASCAT Level 2 Soil Moisture product is generated and distributed in near real-time. The expected average RMS error of the ASCAT soil moisture index is about 25%, which corresponds to about 0.03-0.07 [vol/vol], depending on soil type. ASCAT soil moisture data is available at 25km global grids.

Gridding: Both of these two products are gridded to 0.25 degree lat/lon projection before merging.

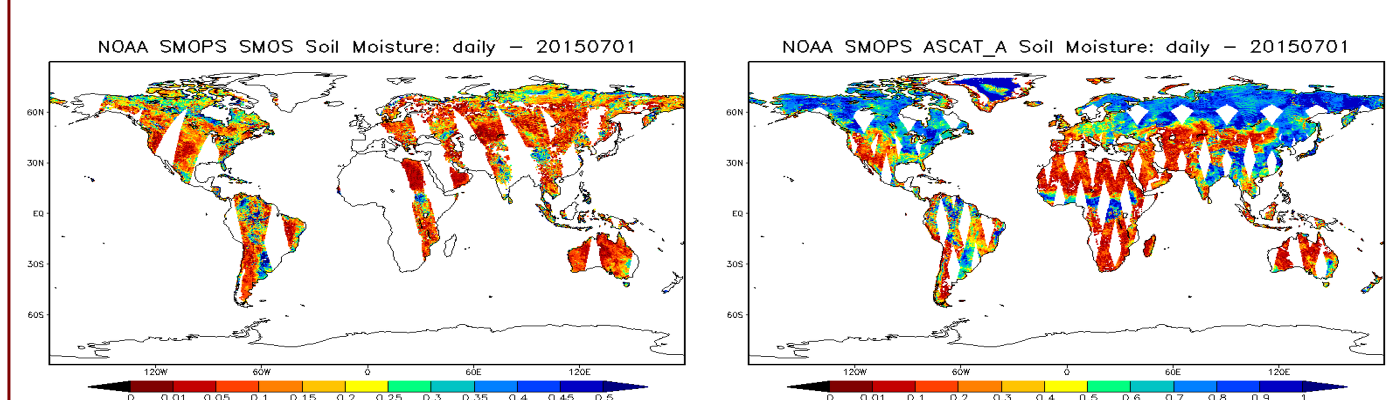
Merging Approaches: 1) Mean-Standard Deviation (MeanSD) approach. Satellite retrievals are first adjusted to the reference product mean, GLDAS mean in this case, and the bias from mean is then adjusted proportionally to the standard deviation ratio of reference product to the satellite product. 2) The CDF-matching method. This approach is to match the cumulative distribution functions of two soil moisture data sets as shown in following figure.



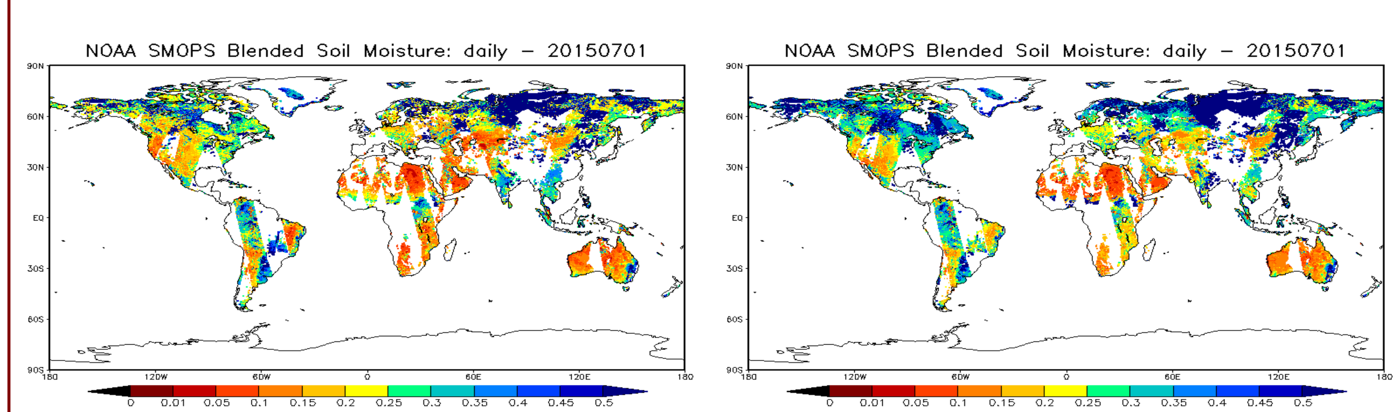
Merging Approach Comparison



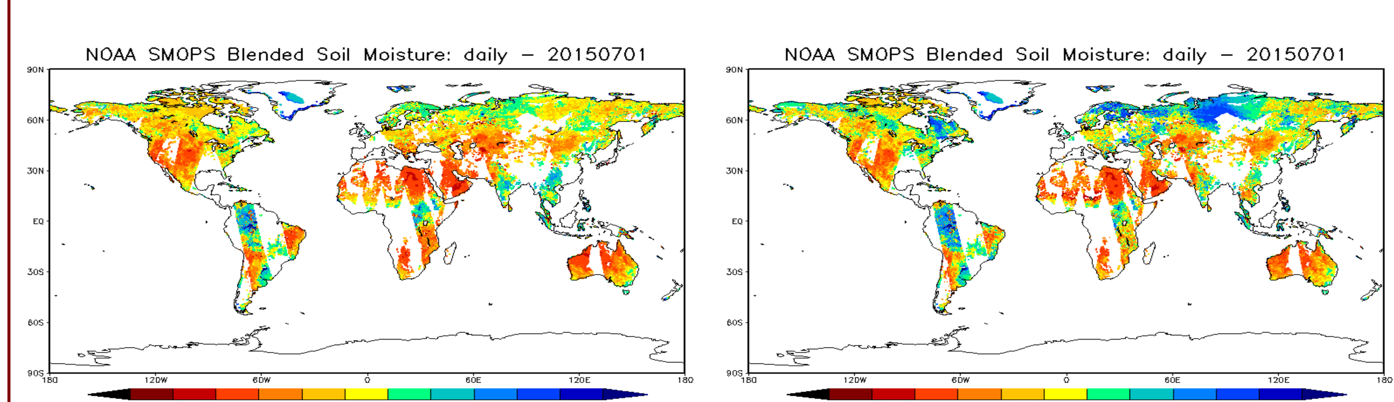
GLDAS soil moisture maps (top layer).



Gridded SMOS (left) and ASCAT-A (right) soil moisture maps.

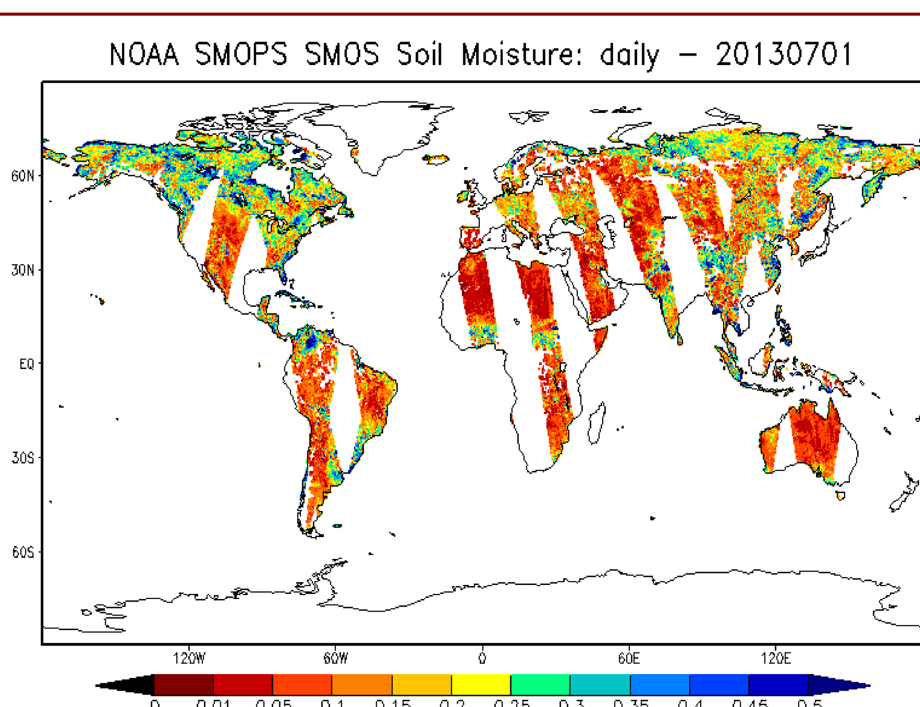


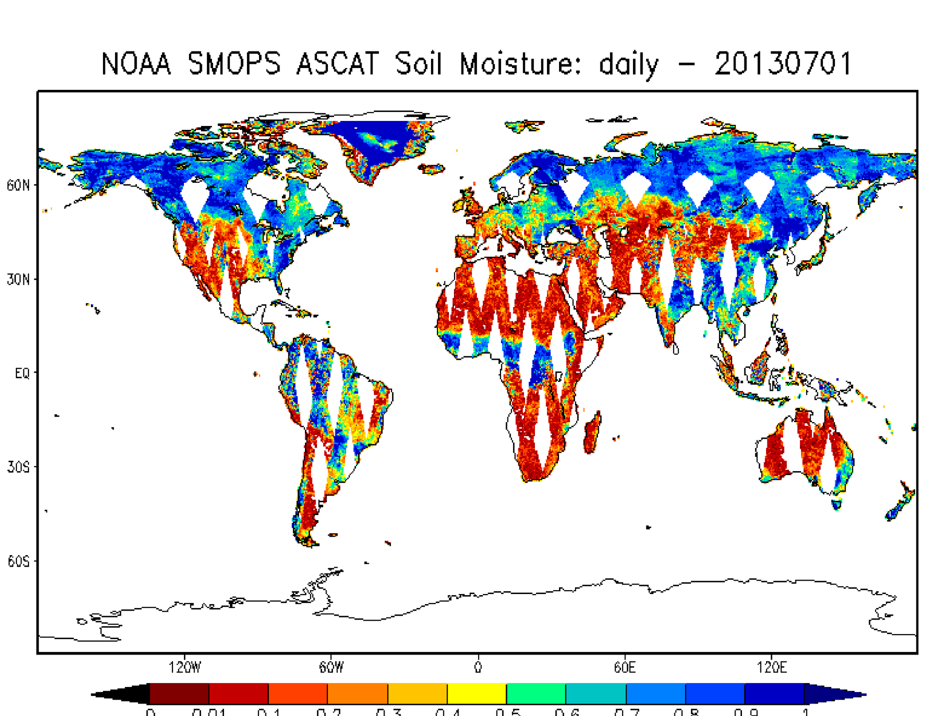
Merged SM maps using MeanSD seasonal (left) and annual (right) data.

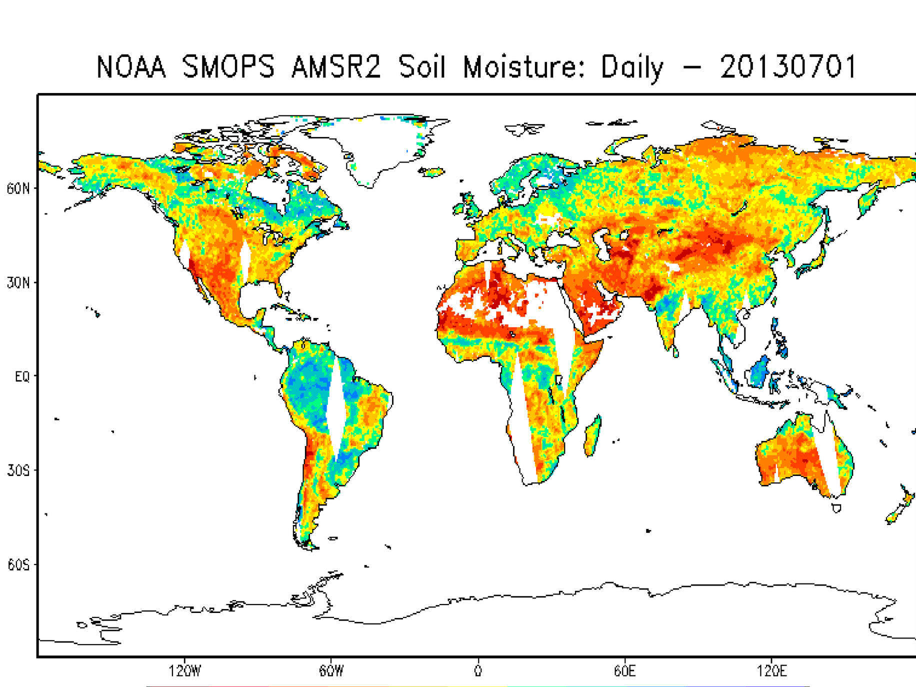


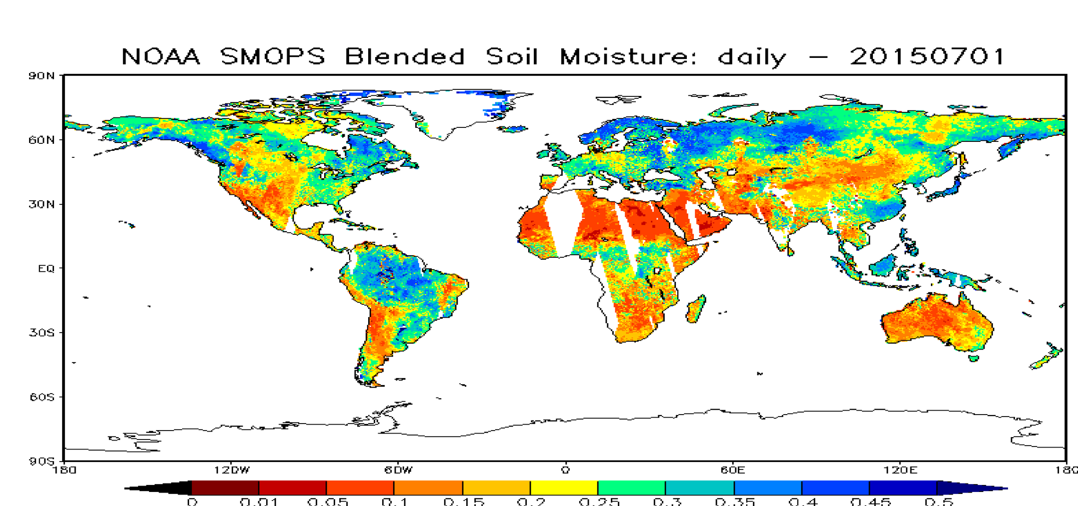
Merged SM maps using seasonal CDF (left) and annual CDF (right). Multi-year annual CDF is used in SMOPS operational product.

Examples of SMOPS Product





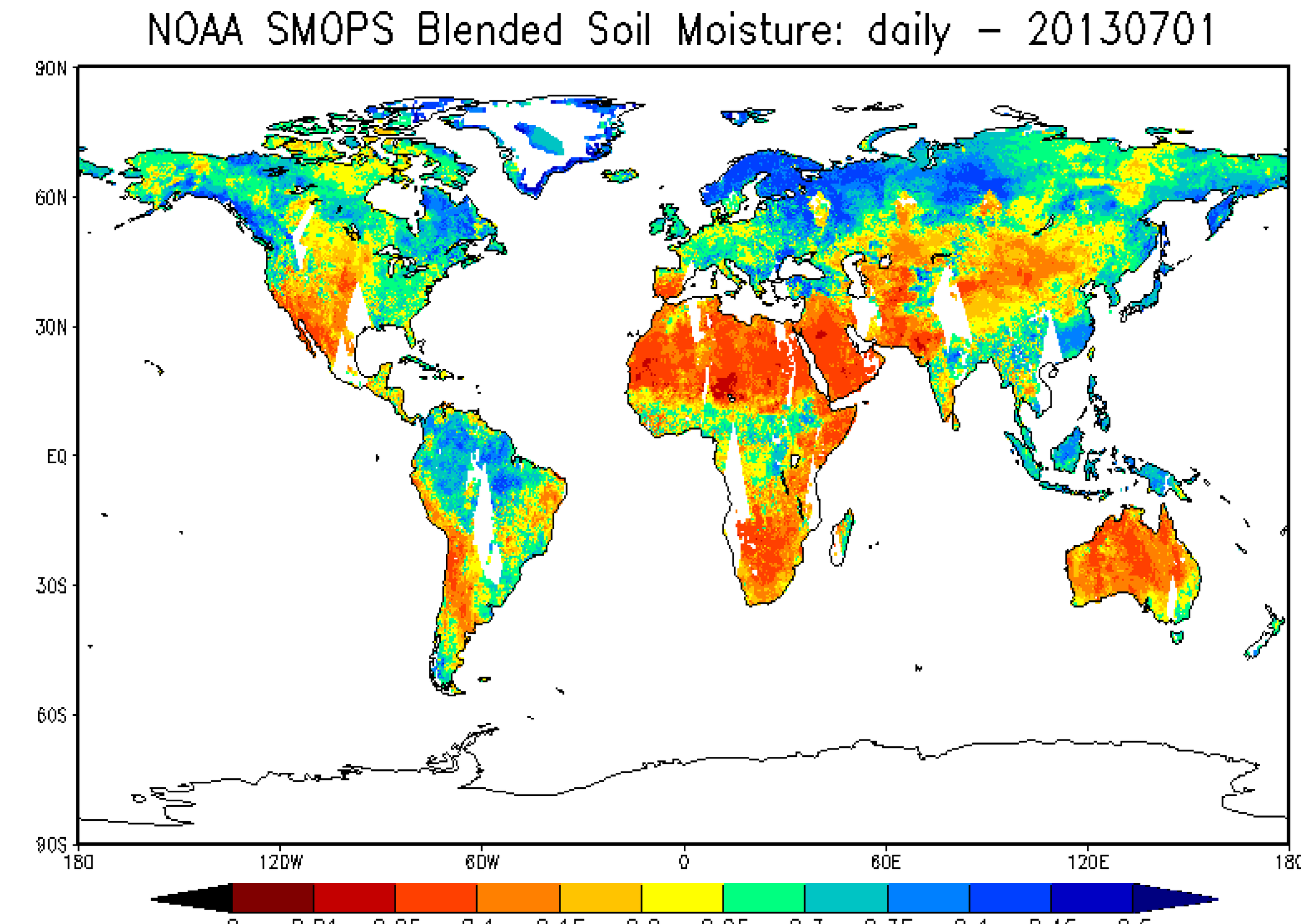




SMOPS Product Distribution: The near real time data distribution is through following ftp site at Office of Satellite and Product Operations (OSPO) of NOAA/NESDIS:

ftp://satepsanone.nesdis.noaa.gov/product/smops/TestData/

Data links for 6-hour product and daily product will be provided upon requests.



Contact Information:

Xiwu Zhan: Xiwu.Zhan@noaa.gov;
Limin Zhao: Limin.zhao@noaa.gov;
Jicheng.Liu: Jicheng.Liu@noaa.gov