The WindSat Global Surface Soil Moisture Data Set

Version 1.1

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Introduction

The WindSat instrument is a spaceborne polarimetric microwave radiometer launched by Naval Research Laboratory (NRL) under the sponsorship of the U.S. Navy and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) in 2003 (Gaiser et al., 2004). The second release of WindSat land data products includes the daily global data of the surface soil moisture, vegetation water content, land classification and the observation time. The land surface temperature data will be included in the next release following completion of the preliminary validation. Preview images of daily global soil moisture are also included in the data set. The goal of this data release is to explore the utility of passive microwave land data products, encourage collaborations among data developers and data users, expand the ongoing WindSat data evaluation and improvements, and seek user feedback for the risk reduction of the future NPOESS MIS (Microwave Imager/Sounder) mission. Therefore your communications with us on data assessment and research and applications using this data set will be greatly appreciated.

WindSat Land Algorithm and Data Validation/Performance

The WindSat soil moisture retrievals are based on a multi-channel maximum-likelihood algorithm using 10 to 37 GHz channels (Li et al., in press). The surface parameters considered by the algorithm include soil moisture, vegetation water content, land surface temperature, surface types, precipitation and snow cover. The algorithm outputs are validated against multi-scale data including soil moisture climatology, ground in-situ network data, precipitation patterns, and vegetation data from MODIS and AVHRR sensors. Some of the validation results are summarized below.

Figure 1 shows composite WindSat global surface soil moisture retrievals for the period of 20-29 September 2003. Overall, the soil moisture retrievals are very consistent with global dry/wet patterns of climate regimes. All the deserts and arid regions were captured well by the retrievals. High soil moisture was found in the typically wet regions in high latitude, stretching from Europe to Asia. In the United States, there are two distinct patterns of continental climate: the humid East and the arid West. The climate transition zone is around 100^o west longitude line extending through the Great Plains from North Dakota to Texas. Such a pattern of dry in the west and wet in the east is clearly depicted by soil moisture retrievals. The retrievals exhibit is a distinct and sharp boundary, which agrees with the strong west-to-east soil moisture gradient near this boundary that is predicted by the NASA Catchment Land Surface Model (CLSM) (Koster et al., 2000a, b).

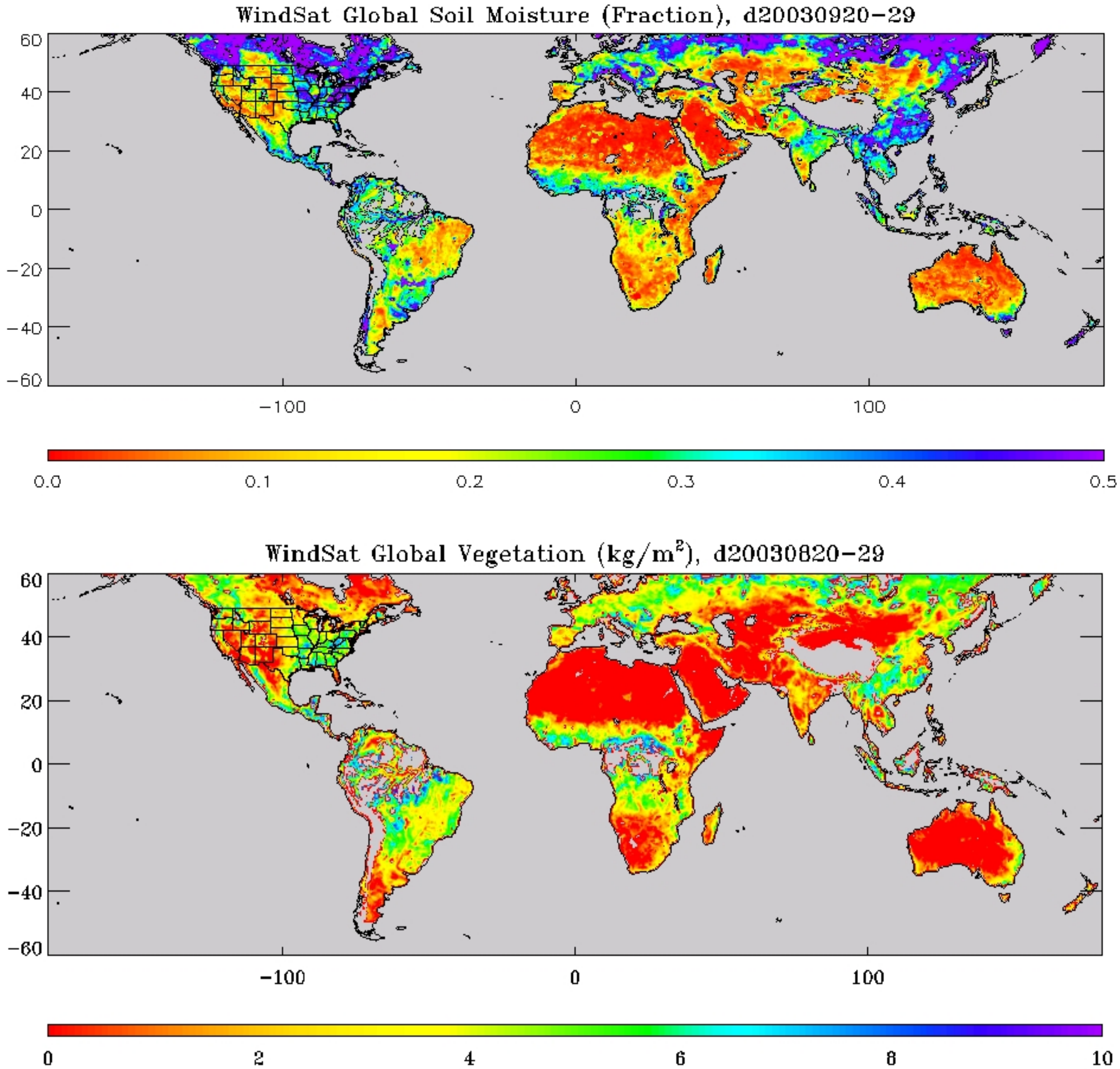

Figure 1. Global soil moisture and vegetation water content retrievals for 20 – 29 September 2003.

The quantitative algorithm validation is based on soil moisture data of top 5 cm soil layer acquired using dense in-situ network during the Soil Moisture Experiment (SMEX) over the United States by USDA (Jackson et al., 2005) The SMEX data available to us cover the summer months in three years: 2003 in Oklahoma, 2004 in Arizona, and 2005 in Iowa. Despite the relatively short temporal coverage in the summer, these three experiment sites provided diverse vegetation covers (rangeland, winter wheat, sparse shrubland, agricultural domain with corn and soybean) and extreme wet and dry soil conditions. Figure 2 plots the area-averaged in-situ soil moisture data against the WindSat retrievals for all three SMEX field experiments. Data from different experiments are separated using different plotting symbols. In general, the WindSat retrieved soil moisture retrievals agree very well with the in-situ data from all the SMEX sites with an uncertainty of about 4% and bias of 0.4%. The retrieved soil moisture is also highly correlated with in-situ data with a correlation coefficient of 0.89.

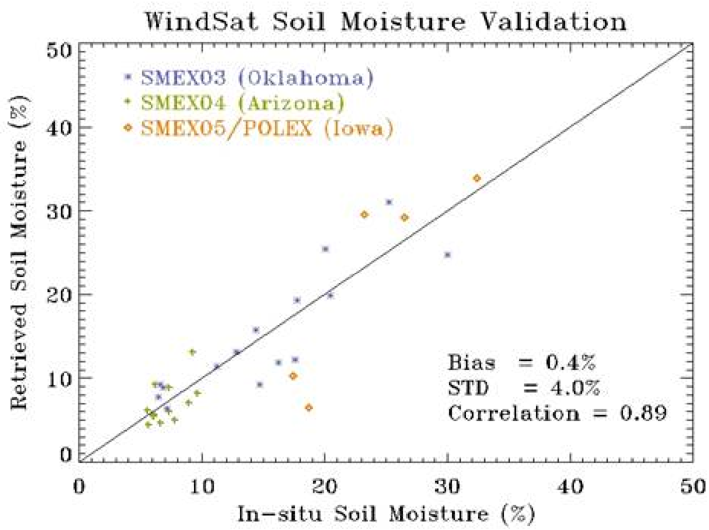

Figure 2. WindSat soil moisture validation against SMEX data.

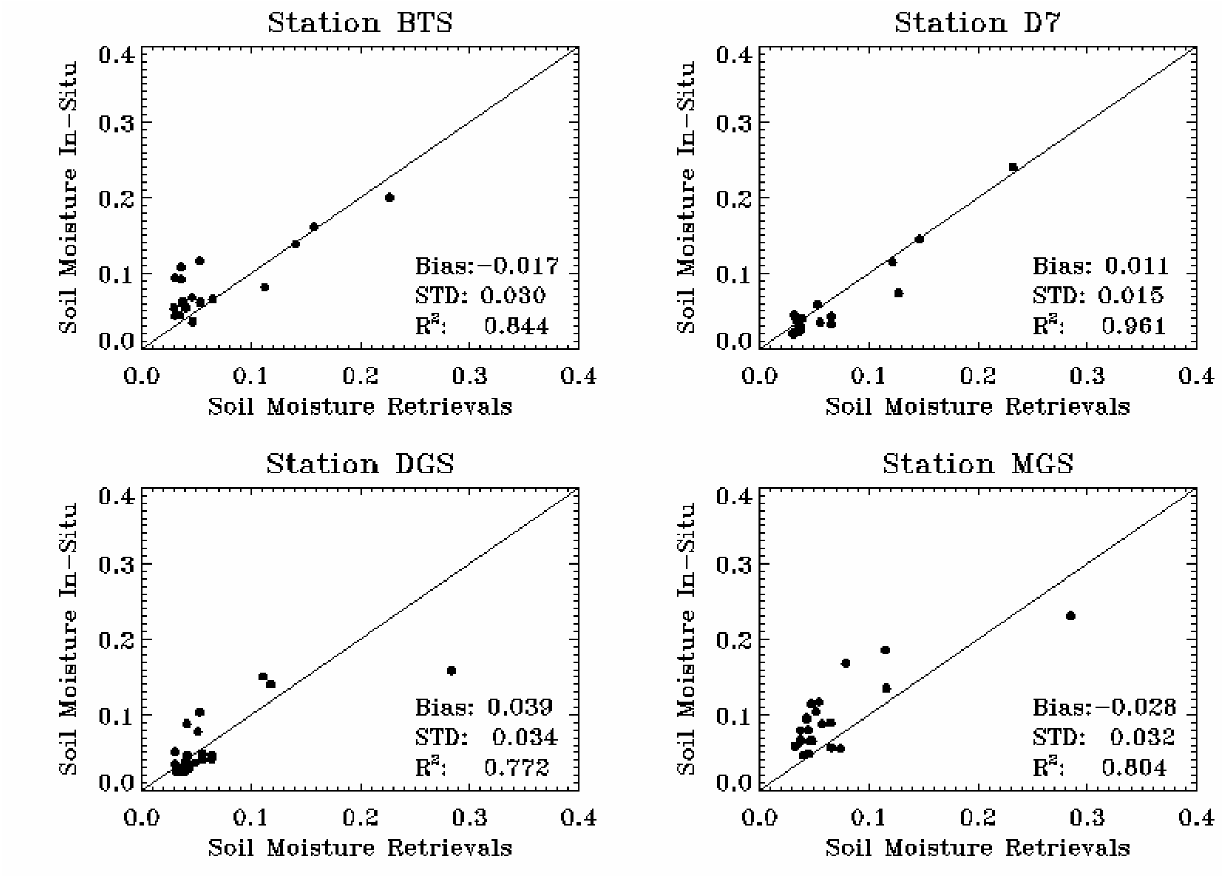

Figure 3. WindSat soil moisture validation against CEOP Mongolia data.

During the Coordinated Enhanced Observing Period (CEOP), soil moisture data were collected over Mongolia using an in-situ network by JAXA (Kaihotsu, 2005). Since the network is located in the cold region and the WindSat snow cover data have yet to be validated, we only used summer 2003 data for this soil moisture validation. Since the network is relatively sparse, no spatial averaging was performed on the point measurements of each station. Therefore the WindSat data were compared against in-situ data from each individual station. Figure 3 compares WindSat retrievals against four in-situ stations. Of 16 total stations, four stations did not pass the quality control procedure, two did not pass consistency check, and similar results are obtained for rest of the stations. These validation results are also quite consistent with the SMEX validation results.

The comparisons of soil moisture retrievals and precipitation patterns offer an indirect, qualitative but multi-scale way to validate soil moisture retrievals (McCabe et al., 2005). As an example, at the synoptic scale, the hot and dry July and August 2003 resulted in extreme short-term drought conditions in 109-year record from western Great Lakes to northern Rockies and Great Plains, including Nebraska, Kansas, and Oklahoma (http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html). On 11 September 2003, a very heavy rain band was formed across northern and central plains (Minnesota, Nebraska, and Kansas), which lasted for many hours and created saturated conditions on the ground. Figure 4(a) shows the 24-hour rainfall total for 11 September. The rain band location is illustrated well on the image. By the morning of 12 September, the rain started to move to the east of Mississippi river and then diminished, as shown in Figure 4(b). The WindSat morning pass on 12 September has a swath lined up well with the rain band on the previous day and captures the wet event under rain-free conditions. Figure 4(c) and (d) depict the Windsat soil moisture retrievals over the similar region on September 6 and 12, respectively. Figure 4(c) shows mostly very dry conditions prior to the rain event and Figure 4(d) the very wet conditions after the rain. Not only are the WindSat soil moisture data able to capture these two extreme dry and wet conditions well, demonstrating sufficient retrieval sensitivity, but the spatial patterns of rainfall and soil moisture also show strong correlations. The location of the patterns almost overlaps with each other, despite of the qualitative nature of such comparison. The results suggest that WindSat soil moisture data can capture the hydrological processes at the synoptic scale.

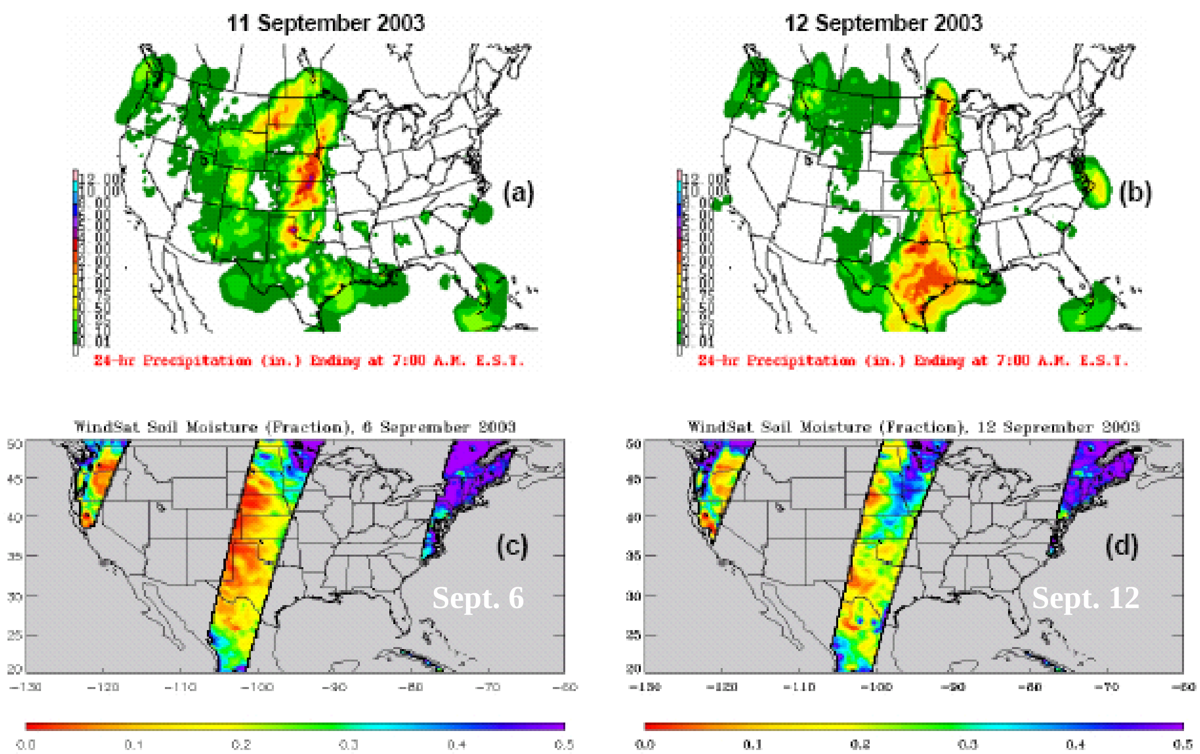

Figure 4. Comparisons of precipitation with soil moisture retrievals before and after the rain event. The precipitation images are provided by Dr. Andy Jones/CIRA, Colorado State University.

Caveat

The retrieval quality flag is not provided in this data release. Therefore, caution is recommended when dealing with the extreme dry/wet, vegetation, land surface temperature, and atmospheric conditions.

Data Format

The WindSat land data products use binary data format. The brightness temperatures of 50 km spatial resolution are first resampled to a global cylindrical EASE-Grid of 25 km resolution (true at 30^o latitude) with the grid size of 1383 columns by 586 rows. During the resampling to EASE-grid, the swath was trimmed to remove the edge effect due partial blockage of antenna beams by the calibration targets. Small but non-negligible biases for all the channels are removed based on the brightness temperature calibration over the ocean scene. Detailed information about EASE-Grid can be found at http://nsidc.org/data/ease/index.html. IDL tools are included in this data release, including programs for the conversions between geographic coordinates and EASE-grid coordinates. The data fields are summarized in the following table. A sample IDL program is also provided to read all the data fields.

Field Name	Data Type	Data Range	Description	Flag Value
Time	Float 64		The number of seconds since January 1, 2000 ***noon*** GMT	-999
Soil Moisture	Float 32	0.0 – 0.5 cm^3/cm^3	Volumetric soil moisture	-999
Land Surface Temperature	Float 32	1 – 60 ^oC		-999
Vegetation	Float32	0 – 15 kg/m^2	Vegetation water content	-999
Surface Type	Integer 16		Surface classification	-999

The surface type has integer value as follows,

Surface Type	value
Water body/ocean	0
Permanent ice sheet	10
Mountainous terrain	20
Snow Cover	30
Frozen Ground	40
Precipitation	50
10 GHz RFI	60
Dense vegetation	70

Moderate vegetation	80
Low vegetation	90

The daily composite data are organized according to observation date. Each data parameter is in a separate file with the following naming convention,

dyyyymmddGEZ25av_pass.pp#

Where d field is the date (yyyymmdd), GEZ25av indicate the data points are defined on global 25 km resolution EASE-grid, pass indicates ascending or descending pass ('a' or 'd', respectively), pp is the land parameter, and # is the version number. For the pp field, sm is soil moisture; ts is the land surface temperature; cls is the land type; tm is the observation time. Currently, only the data of descending orbit are processed. Descending orbits have early morning passes when the differences between effective land surface and vegetation temperatures are at the daily minimum. This simplifies the modeling and retrieval algorithms. We expect larger retrieval errors for the afternoon passes when the surface and vegetation temperatures differ significantly. We do plan to process the ascending orbit data and examine their retrieval performance in the near future.

Example file name: d20030808GEZ25av_d.sm1

The temporal coverage of this release contains data for three and a half years from 2003 to 2006. They are stored in appropriate year and month subdirectories. The daily global quick look soil moisture images are created as JPEG images during the archive process. They are also available in this data release.

Data Access and Tool

The WindSat land data products are available from February 2003 to May 2006 at the Center for Spatial Information Science and Systems (CSISS) at the George Mason University. This release includes the daily global data of the surface soil moisture, vegetation water content, land classification and the observation time. The WindSat brightness temperature data (Sensor Data Records, or SDR) and ocean data products are also available through CPI data center. The land surface temperature data will be included in the next release following completion of the preliminary validation.

The entire archive of data and browse files can be accessed through the File Transfer Protocol (FTP) at the CSISS interface http://geobrain.laits.gmu.edu:8099/windsat/index.jsp. Registration is recommended so that we can inform you of the future data releases. Please email windsat_land@nrl.navy.mil to register.

The EASE-Grid Geolocation Tools can be found at http://nsidc.org/data/ease/tools.html. The computer programs and ancillary data can be extracted from the "Ml_geolocation" tar file.

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Appendix A: A sample IDL program to read land EDR.

```
FUNCTION read_wsat_opt_ledr1_gez25, file, mv, ts, tm, scls
;
;input:    file - file name of the soil moisture data
;outpour:  mv   - soil moisture
;          ts   - land surface temperature
;          tm   - WindSat time
;          scls - surface class
;
;


if(file eq '') then return, -1

files = findfile(file,COUNT=ct)
 if(ct le 0) then begin
;   print, 'WindSat data not found:', file
    return, -1
 endif


 nx=1383L
 ny=586L

 mv =fltarr(nx,ny) - 999.
 ts =fltarr(nx,ny) - 999.
 tm = dblarr(nx,ny) - 999.d
scls = intarr(nx,ny) - 999

 slen = strlen(file)
 file2 = strmid(file, 0, slen-3)+'ts1'
 file3 = strmid(file, 0, slen-3)+'tm1'
 file4 = strmid(file, 0, slen-3)+'cls1'

 lun = 10
 openr,lun,file
 readu, lun, mv
 close,lun
 free_lun,lun

 openr,lun,file2
 readu, lun,ts
 close,lun
 free_lun,lun
```

```
 openr,lun,file3
 readu, lun,tm
 close,lun
 free_lun,lun

 openr,lun,file4
 readu, lun, scls
 close,lun
 free_lun,lun

 return, 0

end
```

Appendix B: Sample IDL programs for the conversions between geographic coordinates and EASE-grid coordinates.

```
FUNCTION ease_convert, lat, lon, r, s
;
;
;       status = ease_convert (lat, lon, r, s)
;
;
;
;------------------------------------------------------------------------

;      if ((lat lt -86.72) or (lat gt 86.72)) then return, -1
       if ((lat lt -90.0) or (lat gt 90.0)) then return, -1
       if ((lon lt -180.0) or (lon gt 180.0)) then return, -1



       pi = 3.141592653589793
       re = 6371.228        ; Earth radius (km)
       cell = 25.067525     ; Nominal cell size (km)
       cols = 1383          ; Number of columns
       rows = 586           ; Number of rows

       r0 = (cols-1)/2.     ; Map origin (column)
       s0 = (rows-1)/2.     ; Map origin (row)

       ctrue = 0.866025403 ;! cos(TRUE*pi/180.)
       r = r0 + (re/cell)*(lon*pi/180.)*ctrue
       s = s0 - (re/cell)*sin(lat*pi/180.)/ctrue

       return, 0

       end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
```

```
;-------------------------------------------------------------------------
FUNCTION ease_inverse, r, s, lat, lon
;
;       status = ease_inverse (r, s, lat, lon)
;
;-------------------------------------------------------------------------


        if ((r lt -0.5) or (r gt 1382.5)) then return, -1
        if ((s lt -0.5) or (s gt 585.5))  then return, -1

        pi = 3.141592653589793 ;!!3.14159
        re = 6371.228       ; Earth radius (km)
        cell = 25.067525    ; Nominal cell size (km)
        cols = 1383         ; Number of columns
        rows = 586          ; Number of rows

        r0 = (cols-1)/2.    ; Map origin (column)
        s0 = (rows-1)/2.    ; Map origin (row)

        ctrue = 0.866025403 ;!!cos(TRUE*pi/180.)
        lon = ((r-r0)/((re/cell)*ctrue))*180./pi
        lat = asin(-(s-s0)*ctrue/(re/cell))*180./pi

        return, 0

        end


;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
```