A global daily record of land parameter retrievals from AMSR2
Version 2.0

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I. Introduction of Version 2 AMSR-E/2 Algorithm

The version 2 AMSR-E/2 global geophysical land surface parameters were generated from RSS version 7 brightness temperature (T_b) observations from Advanced Microwave Scanning Radiometer for EOS (AMSR-E) and JAXA L1R swath T_b from Advanced Microwave Scanning Radiometer 2 (AMSR2). The daily retrievals spanning from Jun. 4, 2002 to Dec. 31, 2015 include 60-day smoothed fraction of water *(fw)* and non-smoothed fraction of water *(fwns)* ,daily air temperature minima and maxima (*ta*, ~2 m height), X-band vegetation canopy microwave transmittance (*tc*),volumetric soil moisture (*vsm*), and atmosphere total precipitable water vapor (*V*). The global retrievals were affected by land coverage of the footprints used for generating 25 km gridded T_b and were only carried out over land for non-precipitating, non-snow-covered, and non-ice covered conditions. Accordingly, ancillary quality flags files were also generated recording the average footprint land coverage of each 25 km grid and indicating the un-retrieved situations including missing Tb, snow cover, rain, and radio frequency interference (RFI) in the 6.9, 10.7, and 18.7 GHz channels.

The Version 2 algorithm was derived based on the general framework of Version 1 algorithm [Jones et al., 2010] and later algorithm revisions [Du et al., 2015a, 2015b]. For producing a consistent land surface parameter record spanning from AMSR-E to AMSR2 observation periods, AMSR2 brightness temperatures (T_b) were empirically inter-calibrated against AMSR-E based on overlapping MWRI observations [Du et al., 2014]. The gridded AMSR T_b data were calculated from footprints that lie within the boundary of the grids using Inverse Distance Weighting method. Unlike the previous gridding process, all the footprints were considered without being screened out based on their land coverage information. In addition, to account for the differences of RSS V7 and V6 AMSR-E T_b retrievals which were separately used in Version 2 and Version 1 algorithms, values of the following empirical parameters including reference dry soil emissivities, reference pure water emissivities, and delta parameter for descending orbits were adjusted from the original values in [Jones et al., 2010]. Accordingly, regressions were re-made for estimating water vapor and air temperature based on pre-defined procedures in [Du et al., 2015a].

References:

[1] Du, J.; Kimball, J.S.; Jones, L. A . Passive Microwave Remote Sensing of Soil Moisture Based on Dynamic Vegetation Scattering Properties for AMSR-E. *IEEE Transactions on Geoscience and Remote Sensing.* 2016, 54 (1), 597-608.

[2] Du, J., J.S. Kimball, and L.A. Jones. Satellite microwave retrieval of total precipitable water vapor and surface air temperature over land from AMSR2. *IEEE Transactions on Geoscience and Remote Sensing,* 2015, 53 (5), 2520-2531 (DOI 10.1109/TGRS.2014.2361344).

[3] Du, J.; Kimball, J.S.; Shi, J.; Jones, L.A.; Wu, S.; Sun, R.; Yang, H. Inter-Calibration of Satellite Passive Microwave Land Observations from AMSR-E and AMSR2 Using Overlapping FY3B-MWRI Sensor Measurements. *Remote Sens.* 2014, *6*, 8594-8616.

[4] Jones, L.A.; Ferguson, C.R.; Kimball, J.S.; Zhang, K.; Chan, S.T.K.; McDonald, K.C.; Njoku, E.;Wood, E. Satellite microwave remote sensing of daily land surface air temperature minima and maxima from AMSR-E. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens*. 2010, 3, 111–123.

II. Data Format

Each retrieval file contains a 209091 element 1D binary array representing the global land area defined as containing <50% open water and <50% permanent ice according to the MODIS MOD12Q1 v4 IGBP 1-km land cover classification which was binned to the 25-km global EASE grid. The purpose of the 1D array format is to avoid allocating memory to placeholder values over the oceans. The full 586×1383 global EASE grid can be created from the 1D data arrays using ancillary row and column files (Please also find a sample matlab code for reading vegetation optical thickness originally written by Lucas A Jones at folder ***"./sample_reading_code"***). Each year's directory contains all the retrieved parameters in 8-byte double data type except for flag data files whose data type is BYTE. The offset of all the data is ZERO and scale factor is ONE.

III. File naming convention

AMSRU_Mland_{year}{day of year}{overpass (A or D)}.{parameter}

AMSRU represents a combination of AMSR-E, AMSR2 and MWRI observations.

The parameter strings are listed below:

fw (8-bytes): 60-day smoothed open water fraction (dimensionless). Valid range: 0-1.

fwns (8-bytes): non-smoothed open water fraction (dimensionless). Valid range: 0-1.

ta (8-bytes): surface air temperature in Kelvin. Daily temperature minima (maxima) generally occurs during the morning descending pass, 'D' (afternoon ascending pass, 'A'). Valid range: 240- 340 K.

V (8-bytes): vertically integrated atmospheric water vapor in mm. Valid range: 0-80 mm.

vsm (8-bytes): volumetric soil moisture in cm^3/cm^3 .Valid range: 0-1.0 .

tc10 (8-bytes) vegetation opacity (dimensionless) for 10.7GHz. Vegetation optical depth is calculated as -log(tc). The data were smoothed using a 30-day moving median filter. Valid range: 0-1.

IV. Results and Accuracy

Fractional Water

Version 2 fractional water retrievals were compared with the Version 1 results. As seen in Fig.1, the two products are highly consistent with each other with R^2 0.97 and 0.99 for respective ascending and descending retrievals over Northern Hemisphere from year 2003 to 2010. For post AMSR-E period, *fw* was possibly overestimated for the first half year of 2012 due to the use of MWRI *Tb*, whose original spatial resolutions are generally lower than AMSR-E or AMSR2. Besides the differences in spatial resolutions, the available *Tb* inter-calibration process is based on limited overlapping period of MWRI and AMSR observations. As a result, MWRI and AMSR2 *Tb* biases were not able to be completely removed by calibrating against AMSR-E and these biases can affect the consequent land surface parameter retrievals. A sample of global distribution of *fw* for the AMSR-E and post AMSR-E periods was presented as Fig.2.

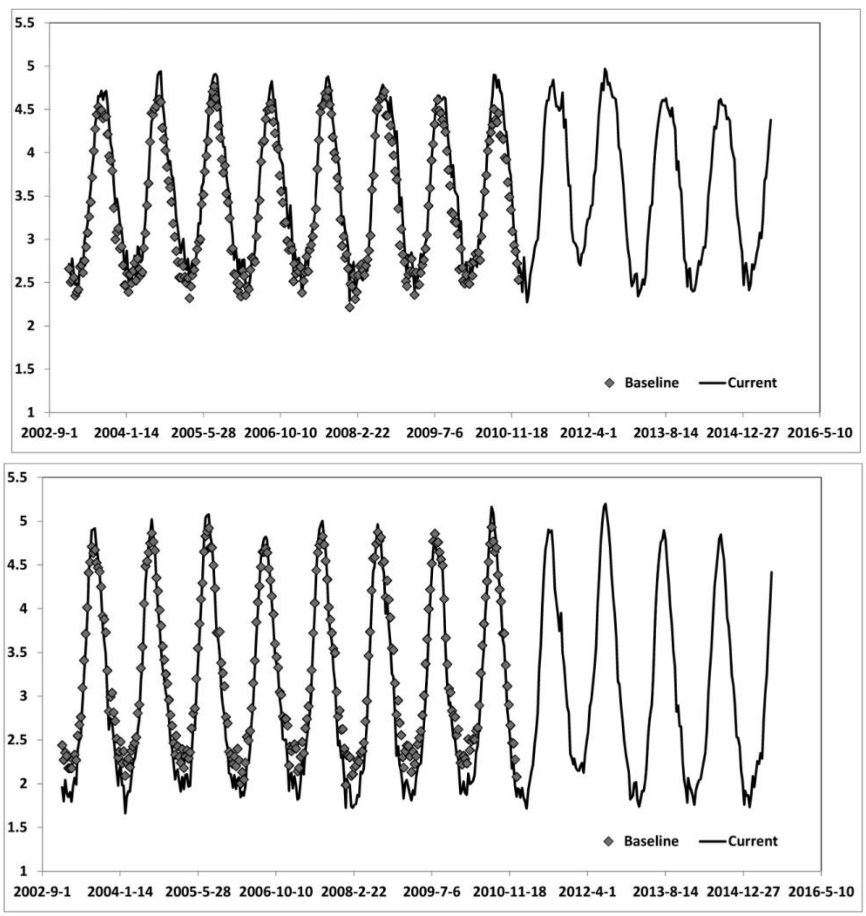

Fig.1 Inundation area (unit MKM^2)dynamics estimated from 10-day average of *fw* retrievals from baseline and current algorithms over Northern Hemisphere from year

Jan. 2003 to Jun. 2015. (upper: ascending pass; lower: descending pass).

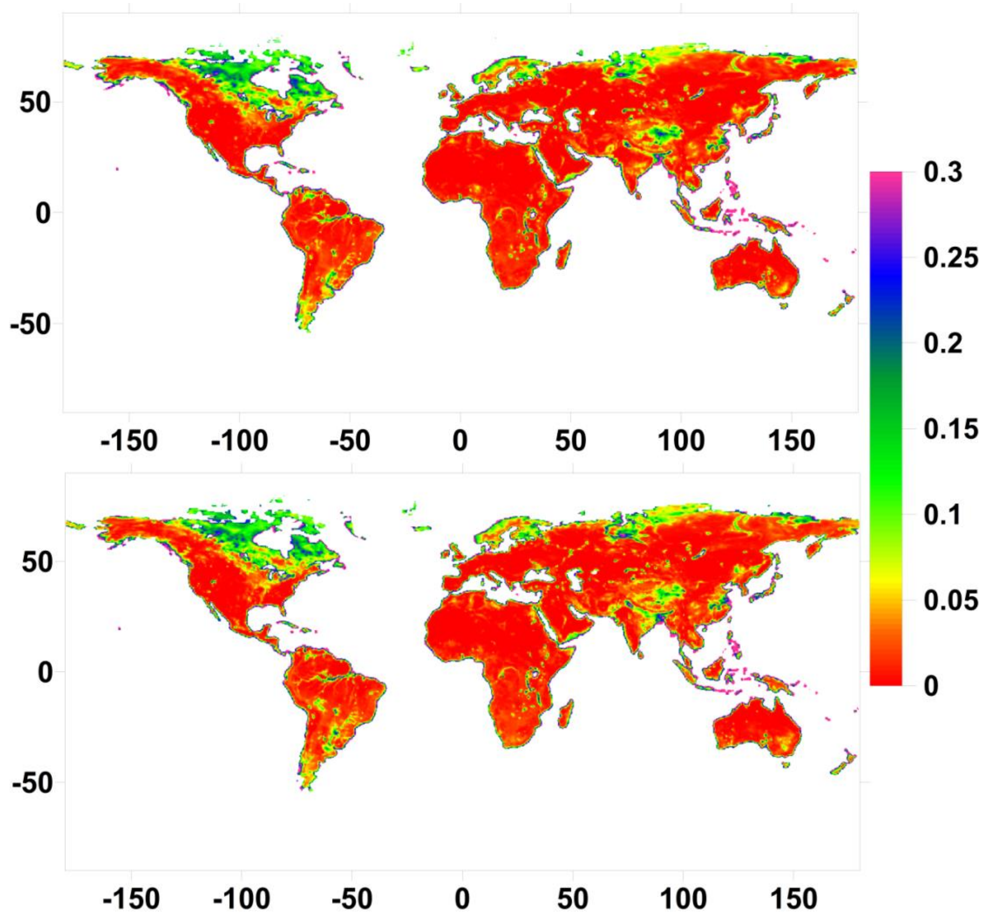

Fig.2 Five-day composite (DOY 180-184) of Global Fractional Water over land (upper: year 2010; lower: year 2015)

Total Precipitable Water Vapor and Air Temperature

Total precipitable water vapor and surface air temperature minima and maxima have been separately validated against AIRS water vapor product and in-situ temperature measurements over 245 WMO meteorological stations for year 2010 (Table 1). For evaluating the algorithm performance over post AMSR-E period, air temperature retrievals were also compared against in-situ measurements using another 142 WMO stations for year 2010 to 2013 (Table 2). The retrieval accuracy is generally highest using the AMSR-E observations and lowest for MWRI. The global distributions of V and Ta were also shown in Fig. 3 and 4.

Table 1. Summary of the accuracy of the satellite based daily minimum and maximum air temperature (T_{mn} , T_{mx}) and precipitable water (PWV) estimates in relation to respective in-situ temperature measurements and AIRS PWV products over 245 global WMO sites for year 2010.

	Ascending Orbits		*Descending Orbits*	
	R^2 T_{mx}	*RMSE* T_{mx} (Celsius)	R^2 T_{mn}	*RMSE* T_{mn} (Celsius)
Air Temperature	0.90	3.26	0.80	3.43
	R^2	*RMSE*(mm)	R^2	*RMSE* (mm)
PWV	0.86	4.39	0.83	5.00

Table 2. Summary of the accuracy of the satellite based daily minimum and maximum air temperature (T_{mn} , T_{mx}) estimates in relation to independent temperature measurements from 142 global WMO weather stations for AMSR-E (year 2010), AMSR2 (year 2013) and MWRI (DOY 274,2011 – DOY 205,2012).

	R^2 T_{mx}	*RMSE* T_{mx} (Kelvin)	R^2 T_{mn}	*RMSE* T_{mn} (Kelvin)
AMSRE	0.88	3.46	0.79	3.29
AMSR2	0.87	3.53	0.77	3.21
MWRI	0.85	3.86	0.76	3.33

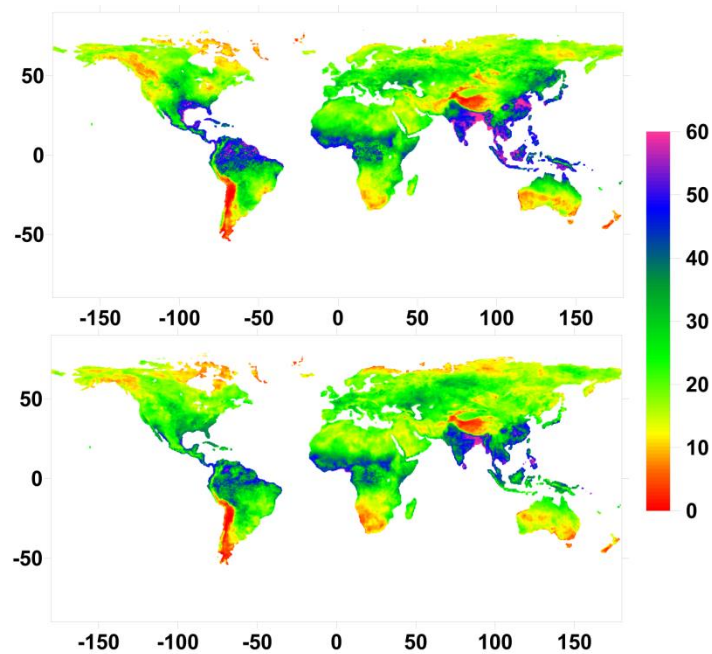

Fig.3 Five-day composite (DOY 180-184) of Global Precipitable Water Vapor over land in unit mm (upper: year 2010; lower: year 2015)

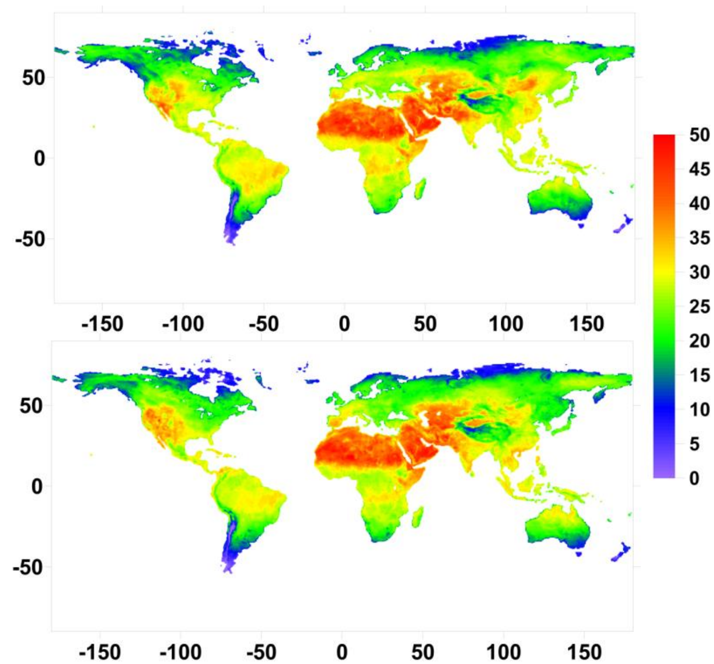

Fig.4 Five-day composite (DOY 180-184) of Global Surface Maximum Air Temperature in unit Celsius (upper: year 2010; lower: year 2015)

X-band Vegetation Optical Thickness

Global distribution of X-band vegetation optical thickness (VOD) was mapped as Fig. 5. It can be seen that both AMSR-E and AMSR2 VOD retrievals have a similar spatial distribution pattern. However, cautions are needed when analyzing long term VOD changes since detectable VOD biases are found for the AMSR2 retrievals especially for the high biomass regions where AMSR *Tb* observations tend to get saturated and more sensitive to the accuracy of sensor inter-calibrations.

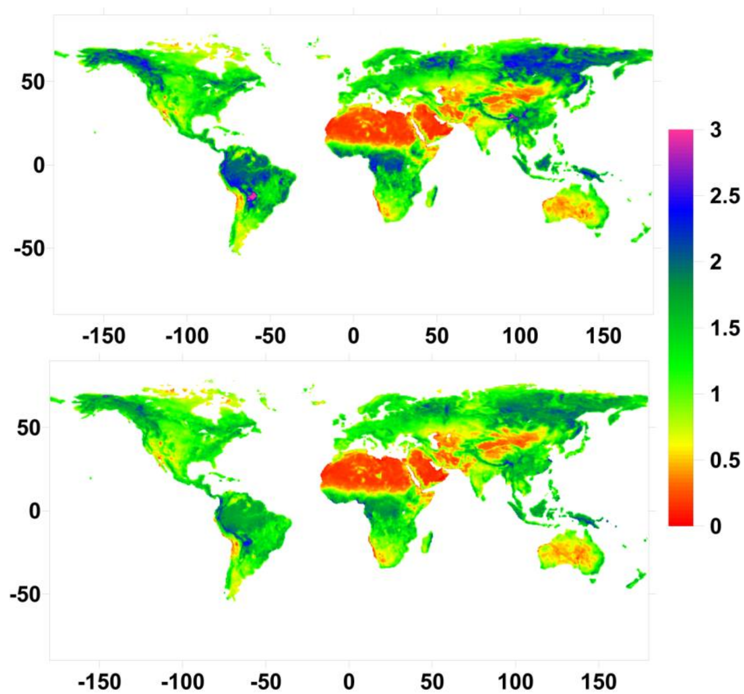

Fig.5 Five-day composite (DOY 180-184) of Global Vegetation Optical Thickness at X-band (upper: year 2010; lower: year 2015)

Soil Moisture

Similar to [Du et al., 2015b], soil moisture retrievals were compared against watershed measurements as shown in Table 3. The overall retrieval accuracy is similar to that presented in [Du et al., 2015b] with a general better performance of descending retrievals than the ascending. A sample map (Fig.6) of the global soil moisture distribution was also presented.

Table 3. UMT Soil Moisture Algorithm Performance Summary

Statistics	**Little River (USA; year 2003-2005)**	**Little Washita (USA; year 2003-2005)**	**Naqu (China; year 2010-2011)**	**Yanco (Australia; year 2009-2011)**	**All Sites**
Ascending Orbits					
R^2	**0.398**	**0.595**	**0.669**	**0.571**	**0.671**
RMSD*	**0.035**	**0.036**	**0.057**	**0.059**	**0.044**
Bias	**0.042**	**0.055**	**-0.073**	**-0.038**	**0.018**
Descending Orbits					
R^2	**0.480**	**0.538**	**0.718**	**0.646**	**0.706**
RMSD*	**0.033**	**0.036**	**0.043**	**0.053**	**0.041**
Bias	**0.068**	**0.085**	**-0.036**	**-0.032**	**0.041**

R^2 is coefficient of determination; RMSD (Root Mean Square Difference) and Bias are in cm^3/cm^3. *RMSD is calculated with watershed bias corrected.

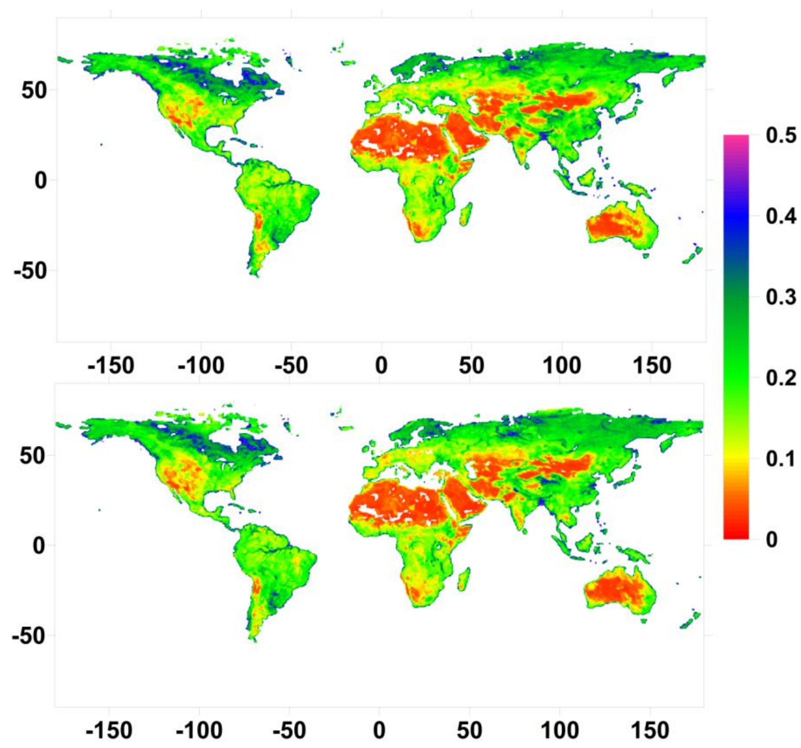

Fig.6. Five-day composite (DOY 180-184) of global surface Volumetric Soil Moisture in unit cm3/cm3(upper: year 2010; lower: year 2015)