SOIL MOISTURE PRODUCT USING AQUARIUS/SAC-D OBSERVATIONS

Version 2.0

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Contact information:

USDA Hydrology and Remote Sensing Lab,
BARC-West, B007, 10300 Baltimore Ave.
Beltsville, MD 20705, USA

Rajat Bindlish: Rajat.Bindlish@ars.usda.gov
Thomas J. Jackson: Thomas.Jackson@ars.usda.gov

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I. PURPOSE

This document provides an overview of the Aquarius/SAC-D soil moisture product. The Single Channel Algorithm (SCA) is used to estimate soil moisture using Aquarius brightness temperature observations. The results from the SCA algorithm are output to files in HDF5 format. This document describes the datasets in the files and their format.

II. SHORT ATBD: AQUARIUS SINGLE CHANNEL ALGORITHM (SCA)

SCA approach uses horizontally polarized (h-pol) brightness temperature observations from the lowest frequency channel due to its highest sensitivity to soil moisture observations. The Aquarius SCA algorithm uses h-pol L-band observations. The Aquarius SCA approach is based on the simplified radiative transfer model developed under the assumption of equal canopy and soil temperature (Jackson 1993). The SCA is applied to the individual Aquarius footprint brightness temperature observations (L2) to produce a swath based time-order product.

In the SCA approach, brightness temperatures are converted to emissivity using a surrogate for the effective physical temperature (T) of the emitting layer. The derived emissivity (e_{obs}) is corrected for vegetation and surface roughness to obtain the smooth soil emissivity (e_{smooth}). The Fresnel equation is then used to determine the dielectric constant of the soil-water mixture (k). Finally, a dielectric mixing model is used to obtain the soil moisture (SM). Additional details on these steps follow.

At the L-band frequency used by Aquarius, the brightness temperature of the land surface is proportional to its emissivity (e_{obs}, where $e_{obs} = 1 - r$) multiplied by its physical temperature (T). It is typically assumed that the temperatures of the soil and the vegetation are the same.

Based upon the above, the complete radiative transfer model can be simplified yielding the following expression for the observed TB:

$$TB = Te_{obs} \quad (1)$$

Ancillary surface temperature data from the Numerical Weather Prediction model (NCEP GFS) is used to correct for the effective physical temperature of the emitting medium.

The emissivity retrieved above is that of the soil as modified by any overlying vegetation and surface roughness. In the presence of vegetation, the observed emissivity is a composite of the soil and vegetation. To retrieve soil water content, it is necessary to isolate the soil surface emissivity (e_{surf}). The correction for the presence of vegetation is done based on Jackson and Schmugge (1991)

$$e_{obs} = [1 - \omega][1 - \gamma]\big[1 + (1 - e_{surf})\gamma\big] + e_{surf}\gamma \qquad (2)$$

Both the single scattering albedo (ω) and the one-way transmissivity of the canopy (γ) are dependent upon the vegetation structure, polarization and frequency. The transmissivity is a function of the optical depth (τ) of the vegetation canopy:

$$\gamma = \exp[-\tau \sec \theta] \qquad (3)$$

where θ is the system incidence angle.

A constant value of the single scattering albedo is used in the Aquarius formulation ($\omega = 0.05$). Re-arranging equation 2 yields

$$e_{surf} = \frac{e_{obs} - 1 + \gamma^2 + \omega - \omega\gamma^2}{\gamma^2 + \omega\gamma - \omega\gamma^2} \qquad (4)$$

The vegetation optical depth is also dependent upon the vegetation water content (VWC). In studies reported in Jackson and Schmugge (1991), it was found that the following functional relationship between the optical depth and vegetation water content could be applied:

$$\tau = (b \times VWC)/\cos\theta \qquad (5)$$

where b is a proportionality value which depends on both the vegetation structure and the microwave frequency. The baseline algorithm uses a default global constant value of b=0.8 for all vegetation classes. We are currently evaluating the use of different values based on the IGBP vegetation classes. The vegetation water content can be estimated using several ancillary data sources. The baseline approach utilizes a set of land cover-based equations to estimate VWC from values of the MODIS derived Normalized Difference Vegetation Index ($NDVI$), an index derived from visible-near infrared reflectance data. The baseline approach uses a MODIS NDVI climatology that was derived based on observations from 2001-2010.

The emissivity that results from the vegetation correction is that of the soil surface, including any effects of surface roughness. These effects must be removed in order to determine the smooth surface soil emissivity (e_{soil}), which is required for the Fresnel equation inversion. One approach to removing this effect is a model described in Choudhury et al. (1979) that yields the bare smooth soil emissivity:

$$e_{soil} = 1 - \left[1 - e_{surf}\right] \exp\left[h \cos^2 \theta\right] \quad (6)$$

The $\cos^2 \theta$ term is often dropped to avoid overcorrecting for roughness. The parameter h is dependent on the polarization, frequency, and geometric properties of the soil surface. A constant roughness parameter of h=0.1 is used in the formulation.

Emissivity is related to the dielectric properties (ε) of the soil and the viewing or incidence angle. For ease of computational inversion, it is assumed that the real component (ε_r) of the dielectric constant provides a good approximation of the complex dielectric constant; however, this assumption can be modified if additional evidence is found to support the use of this more complex formulation. The Fresnel equations link the dielectric constant to emissivity. For horizontal polarization:

$$e_{surf} = 1 - \left| \frac{\cos\theta - \sqrt{\varepsilon_r - \sin^2\theta}}{\cos\theta + \sqrt{\varepsilon_r - \sin^2\theta}} \right|^2 \quad (7)$$

The dielectric constant of soil is a composite of the values of its components – air, soil, and water, which have greatly different values. A dielectric mixing model is used to relate the estimated dielectric constant to the amount of soil moisture. The Aquarius SCA uses Wang and Schmugge (1980) dielectric mixing model to estimate soil moisture.

III. DATA FORMAT

Each swath is stored in a separate file. The files are in HDF5 format. Each file is divided into the following blocks of attributes: Aquarius Data, Aquarius Flags, Block Attributes, and Navigation. Each block contains parameters that are relevant to that block. Each parameter within the block contains 4083 x 3 (Aquarius beams) elements.

Aquarius Data

Name	Long Name	Valid Range	Units
anc_subsurf_temp	0-10 cm NCEP GFS sub-surface temperature (same as present in Aquarius L2 files)	0-500	Kelvin

anc_surface_temp	NCEP GFS surface temperature (same as present in Aquarius L2 files)	0-500	Kelvin
anc_sm	NCEP GFS soil moisture	0-1.0	Volumetric Fraction (m3/m3)
rad_land_frac	Gain weighted land fraction integrated over the antenna footprint (1=land, 0=water)	0-1.0	Area Fraction (m2/m2)
rad_ice_frac	Gain weighted ice fraction integrated over the antenna footprint (1=ice, 0=no ice)	0-1.0	Area Fraction (m2/m2)
anc_swe	NCEP GFS snow water equivalent		Kg/m2
rad_TbH	Aquarius L2 brightness temperature at the Earth surface after atmospheric correction (h-pol) (same as present in Aquarius L2 files)	0-500	Kelvin
rad_TbV	Aquarius L2 brightness temperature at the Earth surface after atmospheric correction (v-pol) (same as present in Aquarius L2 files)	0-500	Kelvin
scat_HH_toa	Aquarius L2 normalized radar cross-section at the		dB

	top of the atmosphere at HH polarization (same as present in Aquarius L2 files)		
scat_HV_toa	Aquarius L2 normalized radar cross-section at the top of the atmosphere at HV polarization (same as present in Aquarius L2 files)		dB
scat_VH_toa	Aquarius L2 normalized radar cross-section at the top of the atmosphere at VH polarization (same as present in Aquarius L2 files)		dB
scat_VV_toa	Aquarius L2 normalized radar cross-section at the top of the atmosphere at VV polarization (same as present in Aquarius L2 files)		dB
rad_sm	Aquarius Soil Moisture estimates	0-1.0	Volumetric Fraction (m3/m3)

Aquarius Flags

The Aquarius flag is in bit format with the following bit order

Bit order	Parameter	Description
1	Soil Moisture	No Soil Moisture retrieval performed
2	Brightness temperature	TB<0 or Tb > 320
3	Orbit Maneuver	ACS mode = 5

4	RFI	Tbh> Tbv; Tb>320
5	Tsurf	Tb > Tsurf
6	Frozen ground	NCEP surface or sub-surface temperature below 273.15
7	Snow	NCEP SWE > 10 kg/m2
8	Ice	NCEP ice fraction > 0.1
9	NDVI quality	MODIS NDVI climatology flag
10	Dense Vegetation	Vegetation Water Content > 5 kg/m2
11	Urban	IGBP Land Cover
12	Soil Texture	Invalid Soil Texture data
13	Water	Land Fraction < 0.99
14	No NCEP temperature data	

IV. FILE NAMING CONVENTION

The file names are similar to the Aquarius L2 version 2.0 files. The first part of the file name is the same as that in the Aquarius L2 files. The extension "SCI" was replaced by "SM" in the file name. For example, Q2012275001600.L2_SM_V2.0, is the file for the data pass started at 00:16:00 UT on day 275, 2012. "V2.0" indicates the version of Aquarius L2 files used for the soil moisture algorithm.

V. REFERENCES

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