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RSS SMAP Salinity:
Version 2 Validated Release

Release Notes
Algorithm Theoretical Basis Document (ATBD)
Validation
Data Format Specification

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1. Release Date 5
2. Data Access 5
3. Citation and DOI 5
4. Summary of Updates from V1.0 5
5. Processing Schedule and Distribution 6
6. Spatial Resolution 6
7. Level 2 Processing 6
7.1 Input Data 6
7.2 Optimum Interpolation (OI) onto Fixed Earth Grid (L2A) 6
7.3 Ancillary Fields (L2B) 7
7.4 Salinity Retrieval (L2C) 7
8. SMAP Salinity Retrieval Algorithm 7
8.1 Surface Roughness Correction 8
8.2 Correction for Emissive SMAP Antenna 9
8.3 Correction for Reflected Galaxy 10
8.4 Tuning of Land Correction 12
8.5 Quality Control (Q/C) Flag 12
9. Antenna Pattern Correction and Absolute Calibration 13
9.1 Spillover Adjustment 14
9.2 Reflector Emissivity 14
9.3 Dynamic Calibration Drift Correction for V/H 14
9.4 3rd and 4th Stokes Calibration Offset 15
10. Level 3 Processing 15
11. Validation 16
11.1 Level 2C 16
11.2 Level 3 8-day Running Average Maps 18
11.3 Level 3 Monthly Average Maps 19
11.4 Known Issues 21
12. References 21
13. Data Format Specification 22
13.1 Level 2C 22
13.2 Level 3 26

Figure 1: Flow diagram of the SMAP salinity retrieval algorithm. 8

Figure 2: Physical temperature $T_{phys.ant}$ of the SMAP mesh antenna: JPL thermal model. 9

Figure 3: Physical temperature of the SMAP mesh antenna with empirical adjustment: $T_{phys,ant} + \Delta T_{phys.ant}$ 10

Figure 4: Reflected galaxy for the SMAP aft look. Left: using the geometric optics (GO) model. Right: based on the SMAP for – aft look. 11

Figure 5: TA measured – expected for the SMAP look. Left: using the geometric optics (GO) model for the reflected galaxy. Right: using the updated galaxy model based on the SMAP for – aft look analysis. The residual biases in the right figure are mainly caused by the emissive reflector. The adjustment for the physical reflector temperature (section 8.2) has not been included in this figure. Figure 5 only shows the effect of the changed reflected galaxy. 11

Figure 6: Left: Land correction for V1.0 (full lines) and V2.0 (dashed lines). Right: TA measured minus expected using the land correction in V1.0 (full lines), using no land correction (dashed lines) and using the mitigated land correction in V2.0 (dotted lines). 12

Figure 7: Running 3-day averages of TA measured – expected v-pol and h-pol over the open ocean. 15

Figure 8: Latitudinal mean SMAP SSS – FOAM SSS. Left: V1.0 (BETA). Right: V2.0. Provided by J. Martínez, BEC.....18

Figure 9: SMAP SSS – FOAM SSS as function of time and distance from the coast. Upper: V1.0 (BETA). Lower: V2.0. Provided by J. Martínez, BEC. 18

Figure 10: Global [60S; 60N] standard deviation of SMAP SSS – FOAM SSS for the 0.25°x0.25° L3 8-day running averages maps. Red: V1.0 (BETA). Blue: V2.0. Provided by J. Martínez, BEC. 19

Figure 11: Comparison of zonally averaged statistics: time-mean difference, RMS, Standard Deviation of SMAP – ARGO SSS. Left: for V1.0 (BETA). Right: V2.0. Provided by T. Lee, JPL. 19

Figure 12: Seasonal distribution of zonally averaged biases between SMAP and ARGO SSS. Left: V1.0 (BETA). Right: V2.0. Provided by T. Lee, JPL. 20

Figure 13: Seasonal distribution of zonally averaged biases between SMAP and HYCOM SSS. Left: V1.0 (BETA). Right: V2.0. 21

Table 1: Ancillary data sources. 7

Table 2: 32- bit Level 2 Q/C flag in the SMAP V2.0 release. 12

Table 3: Absolute calibration of SMAP radiometer. Shown are the TA biases for the average of v-pol and h-pol. 13

Table 4: Global statistics: SSS SMAP – SSS ARGO monthly 1°x1° maps. Provided by T. Lee, JPL. 20

1. RELEASE DATE

09/13/2016

2. DATA ACCESS

ftp://ftp.remss.com/smap/

www.remss.com/missions/smap/

Contact: Thomas Meissner, meissner@remss.com.

3. CITATION AND DOI

As a condition of using these data, we require you to use the following citation:

Meissner, T. and F. J. Wentz, 2016: Remote Sensing Systems SMAP Ocean Surface Salinities [Level 2C, Level 3 Running 8-day, Level 3 Monthly], Version 2.0 validated release. Remote Sensing Systems, Santa Rosa, CA, USA. Available online at www.remss.com/missions/smap, doi: 10.5067/SMP20-xxxxx.

In the doi, the string *xxxxx* is:

1. *2SOC*S for the L2C files.
2. *3SPCS* for the L3 8-day running maps.
3. *3SMCS* for the L3 monthly maps.

Continued production of this data set requires support from NASA. We need you to be sure to cite these data when used in your publications so that we can demonstrate the value of this data set to the scientific community. Please include the following statement in the acknowledgement section of your paper:

"SMAP salinity data are produced by Remote Sensing Systems and sponsored by the NASA Ocean Salinity Science Team. They are available at www.remss.com."

4. SUMMARY OF UPDATES FROM V1.0

1. Antenna Pattern Correction (APC): The spillover, or equivalently the matrix element A_{II} in the APC matrix, was increased from 1.0929 (V1.0) to 1.1080 (V2.0).
2. The along-scan bias correction in V1.0 has been removed.
3. The emissivity of the mesh antenna was set to 0.01 for both V-pol and H-pol polarizations.
4. JPL has updated their thermal model for the physical temperature of the reflector.
5. In addition, an empirical adjustment to the thermal model has been introduced in order to mitigate observed zonal and seasonal biases in V1.0.
6. The correction for the reflected galaxy has been updated based on the SMAP for – aft look analysis.

7. The land correction has been tuned to mitigate salty biases around the continents in the S hemisphere (E coast of S America, Australia) that were prevalent in V1.0.
8. The ancillary SST for V2.0 is taken from the Canadian Meteorological Center CMC. V1.0 had used Reynolds OI SST as ancillary SST input.
9. Level 2C (L2C) data files including all intermediate steps from TA to SSS are released including a L2 Q/C (quality control) flag.
10. The Level 3 data include averages for land fraction, sea ice fraction and SST.

5. PROCESSING SCHEDULE AND DISTRIBUTION

RSS plans to batch process the V2.0 Level 3 SMAP salinities retroactively about once every month. Newly processed files (L2C files, L3 8-day running and monthly files) will be placed into the corresponding directories on the RSS FTP server once every month. All files will also be made available through PO.DAAC.

6. SPATIAL RESOLUTION

The **spatial resolution** of the SMAP salinity observations is the same as the SMAP L1A antenna temperature data [Piepmeier et al., 2015], which is **approximately 40 km**. New products, smoothed to a coarser spatial resolution of **approximately 70km,** are available as of March 2018. They are produced concurrently with the 40km products and also include L2C, L3 8-day running mean, and monthly files.

7. LEVEL 2 PROCESSING

7.1 Input Data

The RSS SMAP salinity retrieval algorithm ingests RFI filtered antenna temperatures (TA) from the SMAP L1B data files (Version 3, CRID13080) [Piepmeier et al., 2016a] and the physical temperature of the SMAP antenna from the JPL thermal model together with basic spacecraft ephemeris information (S/C location, velocity, and attitude) and time of observation.

7.2 Optimum Interpolation (OI) onto Fixed Earth Grid (L2A)

As a first step we perform an optimum interpolation (OI) and resample the L1B TA onto a fixed 0.25^{o} Earth grid, which are called Level 2A files. The resampling is done separately for the forward (for) and the backward (aft) look.

The 40-km product keeps approximately the noise and the spatial resolution and shape (47 km x 36 km) of the original SMAP L1B swath observations (Piepmeier et al., 2016ab). The target of the 70-km product is a circle whose diameter is 70 km. The noise in the 70-km product is greatly reduced.

7.3 Ancillary Fields (L2B)

The auxiliary fields that are needed in the salinity retrieval algorithm get resampled onto the same grid (Level 2B files).

The ancillary sources for the V2.0 Level 2 processing are listed in Table 1 .

Table 1: Ancillary data sources.

Ancillary Input	Data Source
sea surface temperature	Canadian Meteorological Center. GHRSST Level 4 CMC0.2deg Global Foundation Sea Surface Temperature Analysis (GDS version 2). doi: 10.5067/GHCMC-4FM02. https://podaac.jpl.nasa.gov/dataset/CMC0.2deg-CMC-L4-GLOB-v2.0.
sea surface wind speed and surface rain rate WindSat	Wentz F. et al., 2013, Remote Sensing Systems Coriolis WindSat Daily Environmental Suite on 0.25 deg grid, Version 7.0.1.: All-weather 10-meter wind speed and rain rate, Remote Sensing Systems, Santa Rosa, CA. Available online at www.remss.com/missions/windsat.
sea surface wind Speed and surface rain rate F17 SSMIS	Wentz F. et al., 2012, Remote Sensing Systems DMSP SSSMIS Environmental Suite on 0.25 deg grid, Version 7.: WSPD_MF and rain rate, Remote Sensing Systems, Santa Rosa, CA. Available online at www.remss.com/missions/ssmi.
sea surface wind speed and direction NCEP (10m above surface)	NCEP GFS 0.25-deg 6-hour. UGRD, VGRD. Available from http://nomads.ncep.noaa.gov/.
atmospheric profiles for pressure, height, temperature, relative humidity, cloud water mixing ratio	NCEP GDAS 1-deg 6-hour. HGT, PRS, TMP, TMP, RH, CLWMR. Available from http://nomads.ncep.noaa.gov/.
solar flux	Noon flux values from US Air Force Radio Solar Telescope sites 1415 MHz values. Available from NOAA Space Weather Prediction Center, www.swpc.noaa.gov.
total electron content (TEC)	IGS IONEX TEC files. Available from ftp://cddis.gsfc.nasa.gov/pub/gps/products/ionex/.
sea ice fraction	NCEP sea ice fraction. Available from http://nomads.ncep.noaa.gov/pub/data/nccf/com/omb/prod/.
land mask	1 km land/water mask from OCEAN DISCIPLINE PROCESSING SYSTEM (ODPS). Based on World Vector Shoreline (WVS) database and World Data Bank. Courtesy of Fred Patt, Goddard Space Flight Center, frederick.s.patt@nasa.gov.
reference salinity	Hybrid Coordinate Ocean Model, GLBa0.08/expt_90.9, Top layer salinity. Available at www.hycom.org.

7.4 Salinity Retrieval (L2C)

The SMAP salinity retrieval algorithm is then run on these Level 2B files and produces calibrated SMAP Level 2C surface ocean brightness temperatures (TB) and sea surface salinity (SSS) values.

8. SMAP SALINITY RETRIEVAL ALGORITHM

The SMAP Level 2C salinity retrieval algorithm (Figure 1) follows the basic steps of the Aquarius Level 2 V4.0 salinity retrieval algorithm [Wentz and LeVine, 2012; Meissner et al., 2014; Meissner et al., 2015] after adapting it to the SMAP configuration. The most important differences between the Aquarius and the SMAP salinity retrieval algorithms are discussed in the following.

We use equal channel weights of 1.0 for v-pol and h-pol in the MLE for the salinity retrieval.

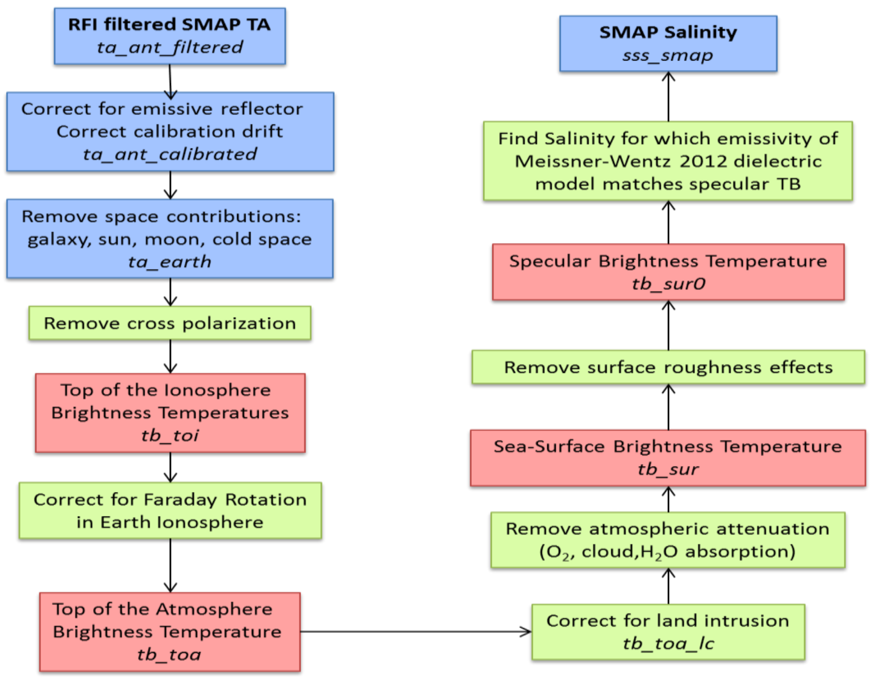

Figure 1: Flow diagram of the SMAP salinity retrieval algorithm.

8.1 Surface Roughness Correction

Due to the loss of the SMAP radar in early July 2015, there are no scatterometer wind speeds available for performing the surface roughness correction.

The surface roughness correction of the SMAP salinity retrievals is based on ancillary wind speeds from the RSS WindSat [Wentz et al., 2013] and the SSMIS F17 [Wentz et al., 2012] Version 7 environmental data suites. If a rain-free match-up WindSat wind speed is available within 1-hour of the SMAP observation it is used. If not, then a rain-fee match-up SSMIS F17 observation is used if available within 1-hour of the SMAP observation. If neither a rain-free WindSat nor a rain-free SSMIS F17 wind speed match-up observation is available within 1-hour of the SMAP observation, then the NCEP GDAS wind speed is used in the surface roughness correction. The NCEP GDAS wind speeds leads to a degradation of the surface roughness correction and the SSS retrievals compared to using the microwave imager wind speeds. A missing imager wind speed is indicated by setting bit 13 of the Q/C flag in the L2C files.

The geophysical model function (GMF) that is used in the SMAP salinity retrieval is obtained from the one that is used in the retrieval algorithm of the Aquarius V4.0 release [Meissner et al., 2014b; 2015] after interpolating to the SMAP Earth Incidence Angle. It also includes the empirical adjustment that depends on SST and wind speed that is discussed in [Meissner et al., 2015].

8.2 Correction for Emissive SMAP Antenna

The SMAP mesh antenna is slightly emissive, which was not the case with Aquarius. If T_A is the antenna temperature that is received at the antenna, which is at a physical temperature $T_{phys,ant}$, then an emissivity ε_{ant} acts as a radiometric loss and T_A changes into:

$$T_{A1} = (1-\varepsilon_{ant}) \cdot T_A + \varepsilon_{ant} \cdot T_{phys,ant} \qquad (1)$$

Before processing the SMAP TA into surface TB and SSS a correction for the antenna emissivity needs to performed, which needs both ε_{ant} and $T_{phys,ant}$ as input. This done by inverting (1).

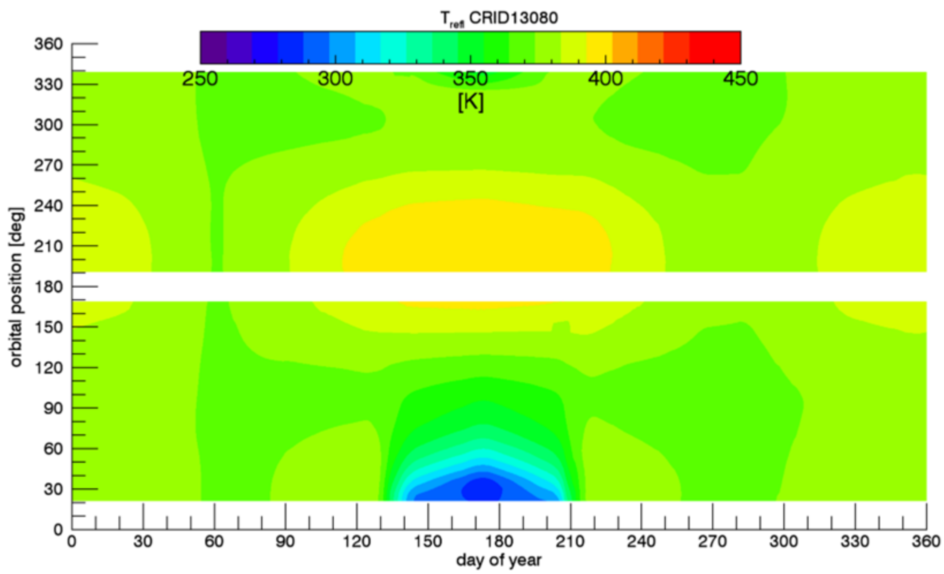

Figure 2: Physical temperature $T_{phys.ant}$ of the SMAP mesh antenna: JPL thermal model.

The value for ε_{ant} given in the SMAP L1B files approximately 0.0025, which is based on pre-launch measurements. Analysis of the SMAP TA shows that this value is much too small. For V2.0 we use a value of 0.010 for both v-pol and h-pol. This is very close to the value that we had used in V1.0 (BETA), which was 0.011.

There are no direct measurements of the physical reflector temperature available but thermal model data provided by the JPL thermal team have to be used. The values are included in the L1B files. Despite improvements in the JPL thermal model for the physical temperature of the SMAP mesh antenna in CRID13080 over earlier versions, there remain significant zonal and temporal biases in the SMAP TA (Figure 1) and consequently also in the SMAP SSS retrievals. These biases can be clearly traced back to the reflector temperature. The biases peak when the spacecraft goes into eclipse or when there is a large change in the incident solar power over the course of one orbit. For the V2.0 validated SSS release we want to mitigate these zonal and temporal biases. The physical temperature of the SMAP antenna is driven by solar heating and therefore the biases are expected to repeat them-selves on an annual cycle. We have decided to derive an empirical adjustment $\Delta T_{phys,ant}$ for the physical temperature of the mesh antenna so that the biases are minimized. In deriving this adjustment, we have assumed that the emissivity ε_{ant} and the physical temperature of the reflector $T_{phys,ant}$ are the same for v-pol and h-pol. The correction depends on orbital angle (z-angle) and day of year and we assume that it repeats every year. Figure 2 shows $T_{phys,ant}$ from the JPL thermal model and Figure 3 shows the total physical temperature after adding the empirical adjustment.

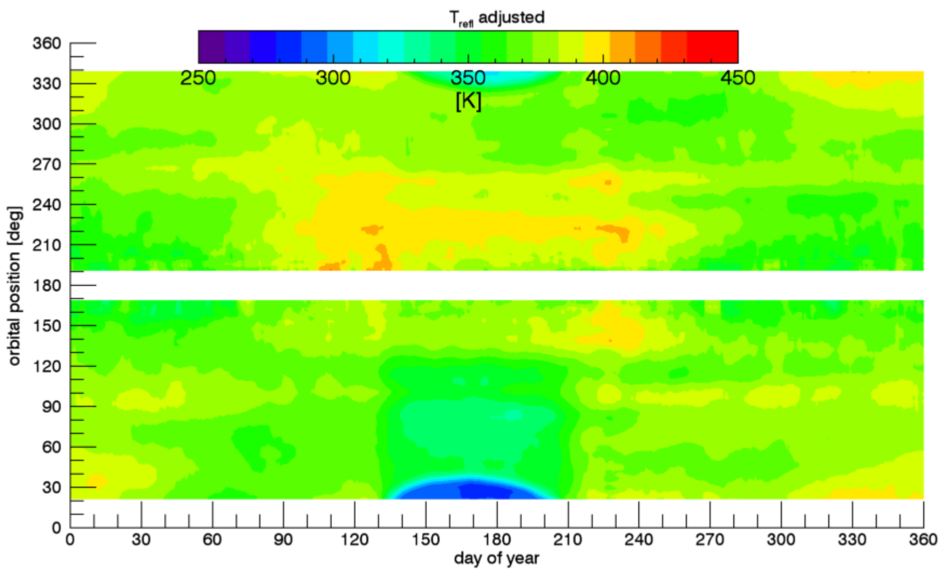

Figure 3: Physical temperature of the SMAP mesh antenna with empirical adjustment: $T_{phys,ant} + \Delta T_{phys.ant}$.

8.3 Correction for Reflected Galaxy

The correction for the reflected galaxy has been updated based on the SMAP for – aft look analysis.

The for-aft look analysis uses the fact that the reflected galaxy has significant contributions only in either the for or the aft look but not in both at the same time. After correcting all other signals for which for and aft look differ (Faraday rotation, wind direction signal), taking the difference between the SMAP for and aft look observations from the same orbit allows an empirical determination of the reflected galaxy signal. In V1.0, as in the Aquarius salinity retrieval algorithm, the reflected galaxy has been calculated using the geometric optics (GO) model, which models the ocean surface as an ensemble of tilted facets [Wentz and LeVine, 2012]. The slope variance ΔS^2 for L-band frequencies that has been used in Aquarius and SMAP V1.0 algorithms is about 25% of the Cox-Munk value. For the derivation of the reflected galaxy in V2.0 we have used one full year of SMAP observations. Comparing the empirically determined for-aft galaxy signal with the GO calculation from V1.0 shows:

1. The slope variance ΔS^2 needs to be increased bringing it back closer to the original Cox-Munk value. This can be effectively done by adding 2.0 m/s to the wind speed that is used as input for the calculation of the reflected galaxy.
2. The strengths of some of the sources in the galactic map [LeVine and Abraham, 2004] that is used as input to the calculation of the reflected galaxy need to be increased or decreasedby 5-10%.

Figure 5 verifies the improvement in TA measured – expected using the for-aft reflected galaxy in V2.0 when compared with the GO calculation in V1.0.

Neither SMAP V1.0 nor SMAP V2.0 use an empirical symmetrization procedure as it has been introduced for the Aquarius salinity retrievals starting with Version 3.0.

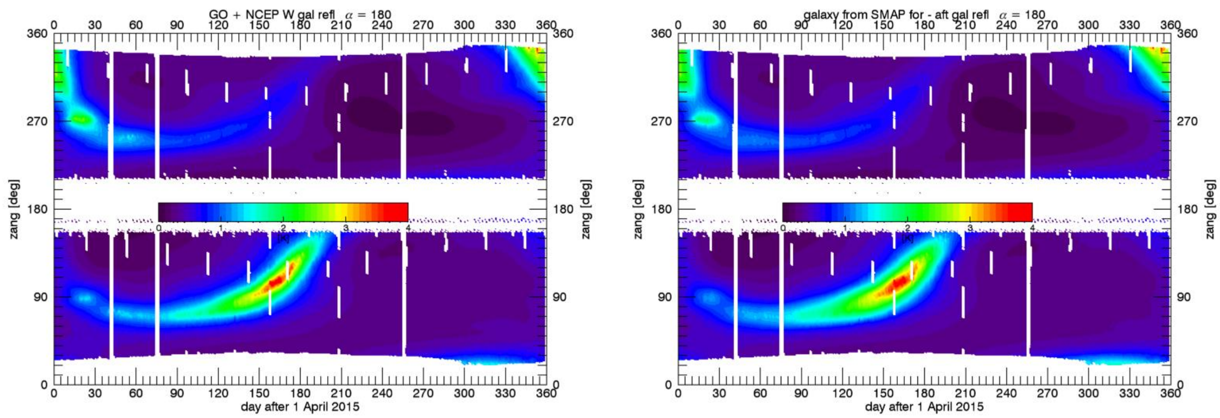

Figure 4: Reflected galaxy for the SMAP aft look. Left: using the geometric optics (GO) model. Right: based on the SMAP for – aft look.

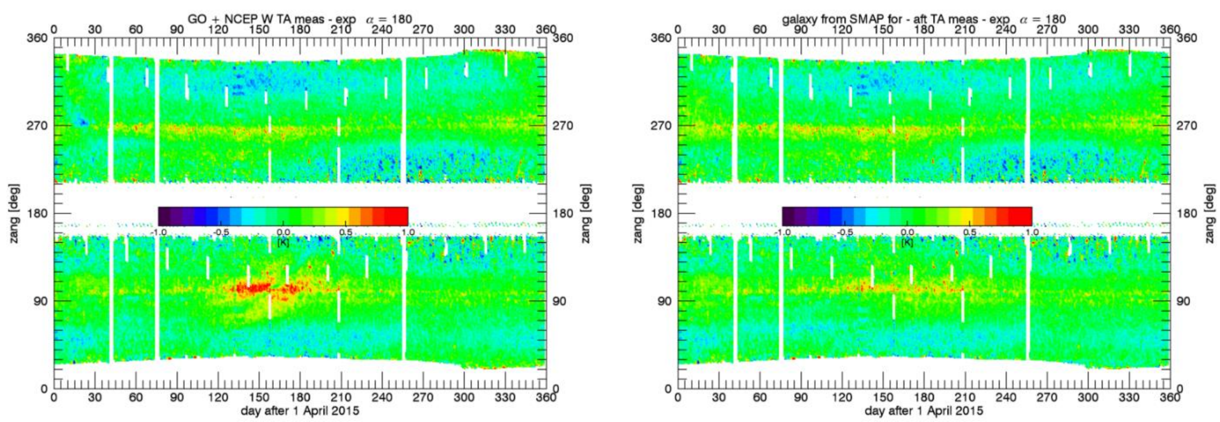

Figure 5: TA measured – expected for the SMAP look. Left: using the geometric optics (GO) model for the reflected galaxy. Right: using the updated galaxy model based on the SMAP for – aft look analysis. The residual biases in the

right figure are mainly caused by the emissive reflector. The adjustment for the physical reflector temperature (section 8.2) has not been included in this figure. Figure 5 only shows the effect of the changed reflected galaxy.

8.4 Tuning of Land Correction

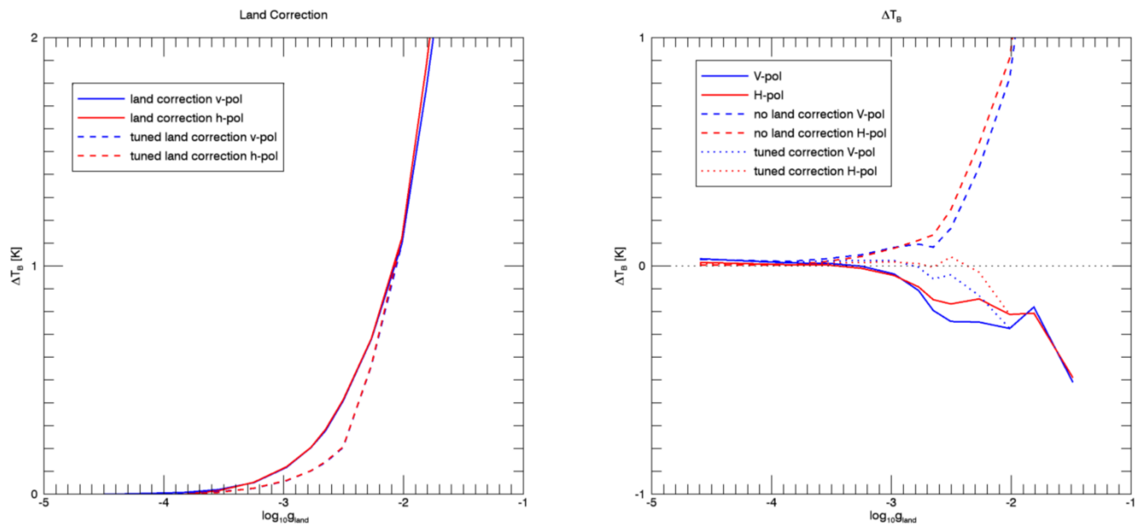

Figure 6: Left: Land correction for V1.0 (full lines) and V2.0 (dashed lines). Right: TA measured minus expected using the land correction in V1.0 (full lines), using no land correction (dashed lines) and using the mitigated land correction in V2.0 (dotted lines).

The far-sidelobe correction for intrusion from land surfaces [Wentz and LeVine, 2012] in SMAP V1.0 was based on assuming a fixed equatorial crossing time. However, the SMAP equatorial crossing time has slightly changed since launch, which leads to inaccuracies in the land correction. Salty biases around some of the continents in the S hemisphere (E coast of S America and Australia) that vary in time have been observed in V1.0 and are due to overcorrection by the land correction algorithm. For V2.0 we have tuned the land correction in order to mitigate this problem (Figure 6).

8.5 Quality Control (Q/C) Flag

The V2.0 salinity retrieval algorithm produces the following Q/C flag:

Table 2: 32- bit Level 2 Q/C flag in the SMAP V2.0 release.

bit	Q/C flag if bit is set	SSS value and expected level of degradation
0	**no valid radiometer observation in cell**	SSS value set to missing/invalid
1	**problem with OI:** parameter *wt_sum* not normalized to 1	SSS value set to missing/invalid
2	**strong land contamination:** gain weighted land fraction *gland* exceeds 0.1	SSS value set to missing/invalid
3	**strong sea ice contamination:** gain weighted land fraction *gice* exceeds 0.1	SSS value set to missing/invalid
4	**MLE in SSS retrieval algo has not converged:** *iflag_sss_conv* = 1	SSS value set to missing/invalid

5	**sunglint:** sunglint angle *sunglt* between 0° and 50° and scan angle *alpha* between 30° and 150°	SSS retrieved very strong degradation
6	**moonglint:** moonglint angle *mongl*t less than 15°	SSS retrieved moderate – strong degradation
7	**high reflected galaxy:** 1st component *ta_gal_ref(1, …)/2* [=(V+H)/2] exceeds 2.0K.	SSS retrieved moderate – strong degradation
8	**land contamination:** gain weighted land fraction *gland* exceeds 0.0005	SSS retrieved moderate – strong degradation
9	**sea ice contamination:** gain weighted sea ice fraction *gice* exceeds 0.0005	SSS retrieved moderate – strong degradation
10	**high residual of MLE in SSS retrieval algo:** Variable *tb_consistency* exceeds 1.0 K.	SSS retrieved moderate – strong degradation
11	**low SST:** *surtep - 273.15* below 5°C	SSS retrieved moderate – strong degradation
12	**high wind:** *winspd* exceeds 15 m/s	SSS retrieved moderate degradation
13	**no valid imager (WindSat, F17 SSMIS) wind speed available within 60 minutes of SMAP observation** NCEP wind speed is used in surface roughness correction	SSS retrieved light degradation
14	**rain flag:** valid rain rate from imager (WindSat, SSMIS F17) within 60 minutes of SMAP observation	SSS retrieved possibly light degradation due to degraded wind speed or poor atmospheric correction. validation of SMAP versus ARGO/HYCOM might result in error due to SSS stratification within the upper ocean layer
15 - 31	sparse	

9. ANTENNA PATTERN CORRECTION AND ABSOLUTE CALIBRATION

Table 3: Absolute calibration of SMAP radiometer. Shown are the TA biases for the average of v-pol and h-pol.

Calibration Scene	**TA Bias [K] (v+h)/2** E_{refl} **= 0.0025** **use APC from RSS BETA Release**	**Version 2.0** **TA Bias [K] (v+h)/2** ε_{ant} **= 0.01** **increase spillover or A(I,I) by 1.4%**
Land (Amazon Calibration Site) compared with Aquarius	≈ - 2.8	≈ 0.0
Global Ocean Meissner Wentz RTM	≈ + 0.9	≈ 0.0
Cold Space	≈ + 3.2 (according to Fig 6.1 from J. Piepmeier's April 2016 cal/val report [Piepmeier et al., 2016b].)	≈ + 0.4 estimated

For the SMAP V2.0 release we have attempted to achieve accurate absolute calibration for a wide range of physical scenes (Table 3):

1. Cold sky, which is observed about once every months during the cold space maneuvers CSM.
2. Open ocean.
3. The Amazon rain forest calibration site [1S,3N], [52W, 59W].

In order to achieve this, the following parameter tuning was performed:

9.1 Spillover Adjustment

The spillover, or equivalently the matrix element A_{II} in the APC matrix, is increased from currently 1.0929 to 1.1080. This increases the TB over warm targets, which is too low by about 3 K in the V3 SMAP L1B TB files [Piepmeier et al., 2016]. The APC matrix of V2.0 is:

A Earth Integration IQ basis (used in SMAP L2 algo Version 2.0)

1	1.1080	-0.0001	0.0036	-0.0006
2	0.0000	1.1349	+0.0066	-0.0001
3	0.0009	0.0042	1.1336	-0.0553
4	0.0003	0.0014	0.0117	1.1297

9.2 Reflector Emissivity

As explained in detail in section 8.2, the value for the emissivity of the SMAP mesh antenna was set to $\varepsilon_{ant} = 0.01$ for both polarizations. This value is very close to the one that we have been using in the Version 1.0 BETA salinity release but four times as large as the value from the V3 SMAP L1B TB files that are produced by the SMAP radiometer team and that is used in the current soil moisture retrievals. Together with the spillover adjustment (section 9.1) this brings the TB over Amazon, ocean and cold space in line.

9.3 Dynamic Calibration Drift Correction for V/H

Plotting TA measured – expected over the open ocean as function of rev# exhibits a small residual calibration drift (Figure 7). In order to remove this drift we calculate the 3-day running average of TA measured – expected $\langle \Delta T_A(i) \rangle = \langle T_{A,meas}(i) - T_{A,\exp}(i) \rangle$ as well as the average $\langle T_A(i) \rangle$ for each orbit i. These values are included in the metadata of the L2 files. We assume that the drift is mainly caused by a drift in the noise diodes, which corresponds to a pivot around the Dicke (reference) load temperature T_D. If T_{Ap} is the antenna temperature of a SMAP observation for polarization p=V/H after correcting for the emissive reflector, we calculate the *calibrated antenna temperature* $T_{A,cal}$ as:

$$T_{Ap,cal} = T_{Ap} - \frac{\langle \Delta T_{A,p}(i) \rangle}{\langle T_{Ap}(i) \rangle - \langle T_D \rangle} \cdot \left(T_{Ap} - \langle T_D \rangle \right) \qquad p = V, H \qquad (2)$$

We use a value of 293 K for the average Dicke load temperature $\langle T_D \rangle$. Per construction, according to (2) the running 3-day average of $T_{Ap,cal}$ is zero for each orbit: $\langle T_{Ap,cal}(i) \rangle = 0$.

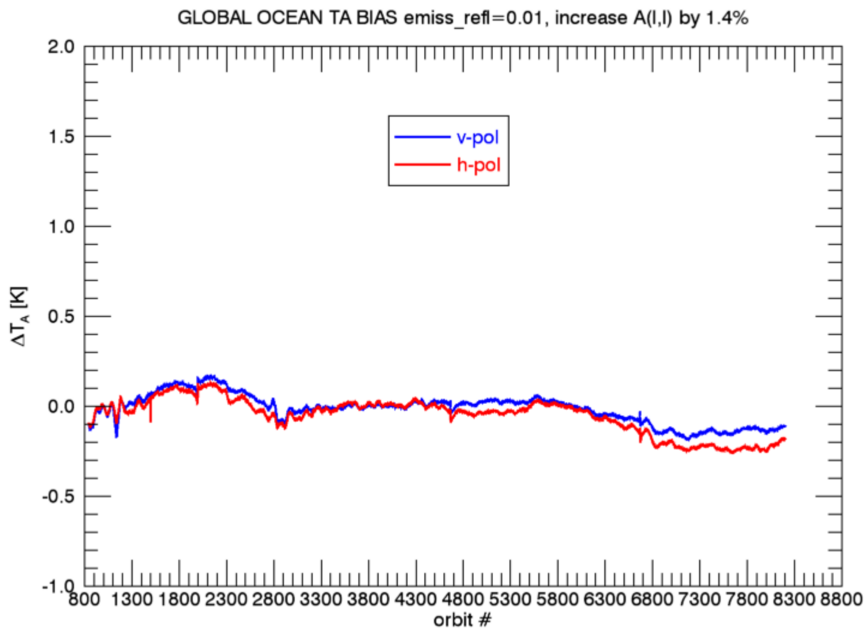

Figure 7: Running 3-day averages of TA measured – expected v-pol and h-pol over the open ocean.

9.4 3rd and 4th Stokes Calibration Offset

Analysis of the 3rd and 4th Stokes parameters over the open ocean and over the Amazon calibration site, warrant a small offset correction for the 3rd (S3) and 4th (S4) Stokes parameters:

$$T_{Ap,cal} = T_{Ap} - \omega_p \qquad p = S3, S4 \tag{3}$$

where $\omega_{S3} = +0.10K$, $\omega_{S4} = -0.42K$ after rev# 2812 and $\omega_{S4} = -0.21K$ before rev# 2812.

10. LEVEL 3 PROCESSING

Both the 40km and 70km L2C salinity values are gridded into the Level 3 data product. The L3 grids are regular 0.25° latitude/longitude Earth grids and a straight average of the valid L2C observations is performed. For and aft looks are averaged together. We produce a running 8-day average L3 and a monthly average L3 file. For the 8-day running average that is centered on day *DOY* we use observations within +/- 3.5 days of *DOY* . For example, for the L3 file of January 15, we are averaging L2 observations that fall between 12UTC January 11 and 12 UTC January 19. The reason for providing 8-day averages rather than weekly averages is that SMAP has an exact 8-day repeat cycle.

During the gridding for both the 8-day running averages and the monthly averages we apply Q/C checks and discard data if:

1. The sun glint angle is less than 50° and the azimuthal look angle lies between 30° and 50° (bit 5 in L2 Q/C flag is set).
2. The moon glint angle is less than 15° (bit 6 in L2 Q/C flag is set).
3. The v/h-pol average of the reflected galactic radiation exceeds 2.0 K (bit 7 in L2 Q/C flag is set).
4. The TB consistency, which is defined as the $\sqrt{\chi^2}$ of the MLE in the salinity retrieval algorithm, exceeds 1.0 K (bit 10 in L2 Q/C flag is set).
5. The gain weighted land fraction g_{land} exceeds 0.01.
6. The gain weighted sea ice fraction g_{ice} exceeds 0.001.
7. The wind speed exceeds 20 m/s.

The L3 files contain the number of observations in each grid cells, the averaged salinity values, as well as the averages for g_{land} , g_{ice} and the ancillary SST in each grid cell.

11. VALIDATION

11.1 Level 2C

From comparing with the HYCOM SSS field, we conclude that the **SMAP Level 2C SSS at 40km** resolution have an estimated accuracy of almost 1.0 psu due to the high noise figures of the L1B TA, which is input into the L2 processing. The V2.0 validated release includes the L2C data.

When comparing the **SMAP Level 2C SSS at a 70km** resolution to the HYCOM SSS field, we conclude that this product has an estimated accuracy of about 0.5 psu due to the reduction in noise caused by the spatial smoothing of the L1B TA. A comparison of the 40km and 70km Level 2C SSS products for June 2015 is shown below:

SMAP 40km

	Bias	Standard Deviation
Tb Measured – Tb Modeled (h-pol)	-0.000639	0.498
Tb Measured – Tb Modeled (v-pol)	-0.0130	0.440
SSS SMAP – SSS HYCOM	0.00884	0.920

SMAP 70km

	Bias	Standard Deviation
Tb Measured – Tb Modeled (h-pol)	-0.00674	0.268

Tb Measured – Tb Modeled (v-pol)	-0.0113	0.263
SSS SMAP – SSS HYCOM	0.00593	0.559

The noise in the Level 2C salinity is strongly reduced from 0.92 psu (40 km) to 0.56 psu (70 km) when compared to HYCOM. This noise reduction and smoothing is still visible in the 8-day and monthly averages:

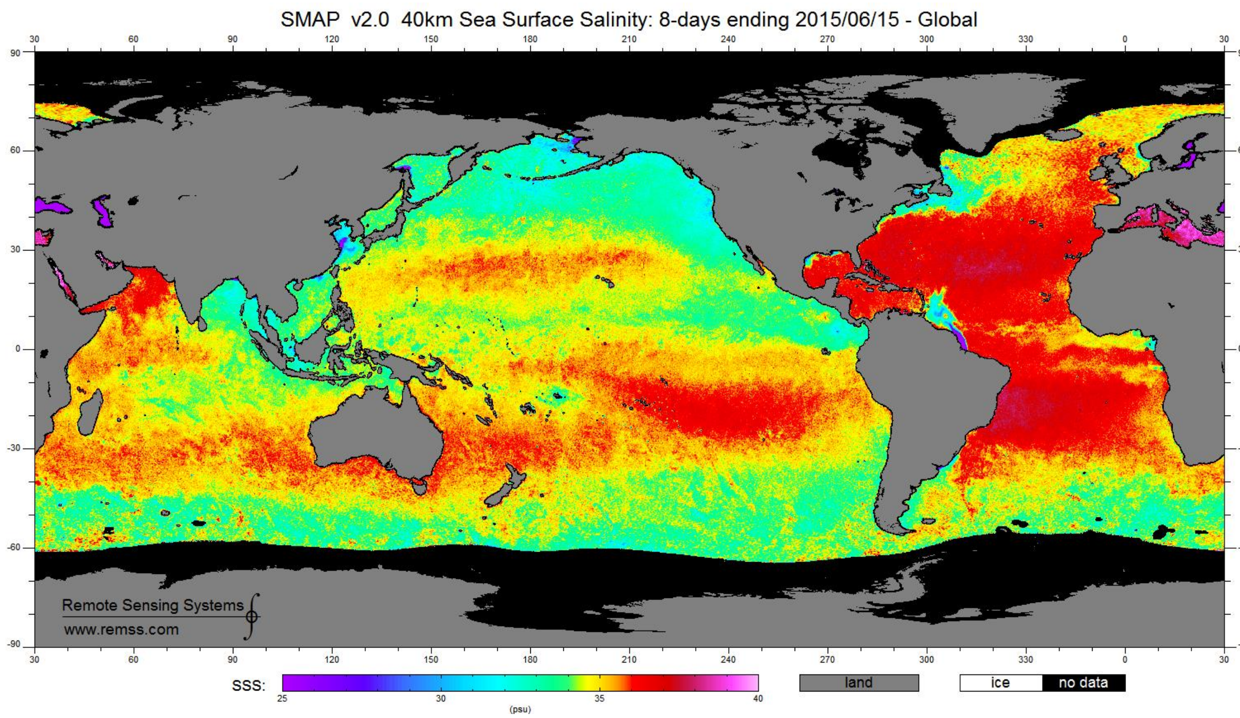

Figure 8: SMAP 40km L3 8-day running mean SSS ending June 15, 2015

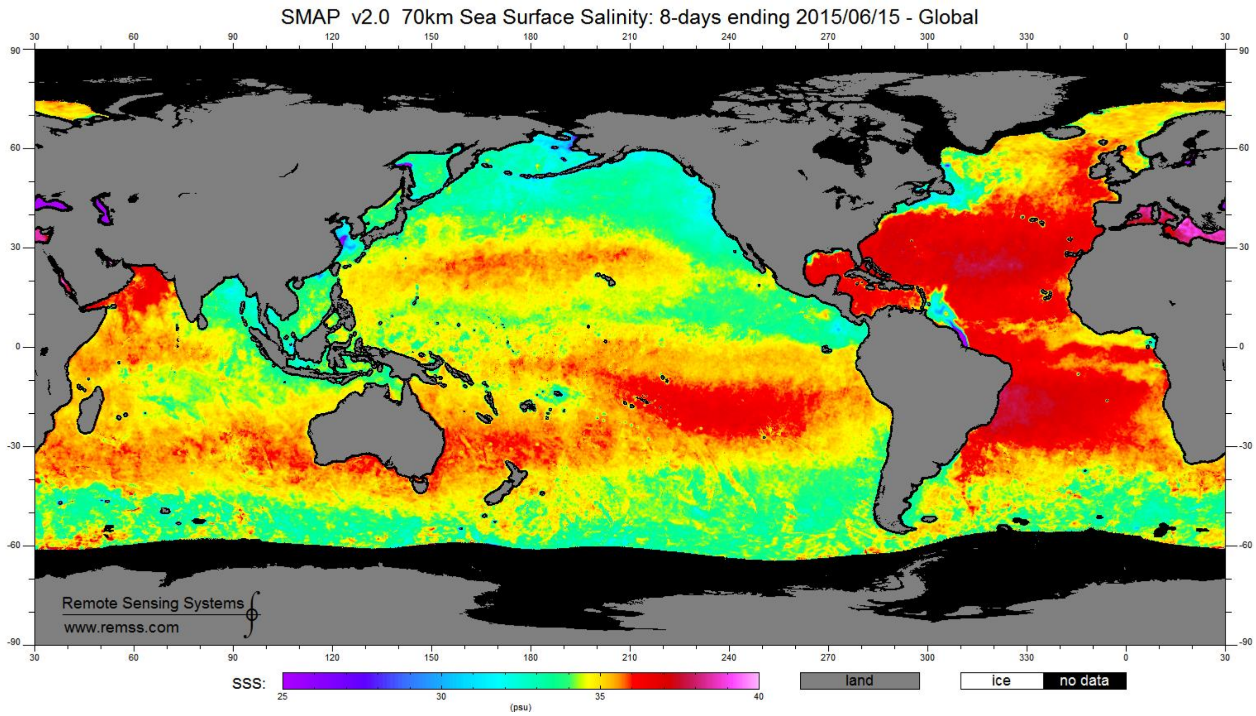

Figure 9: SMAP 70km L3 8-day running mean SSS ending June 15, 2015

11.2 Level 3 8-day Running Average Maps

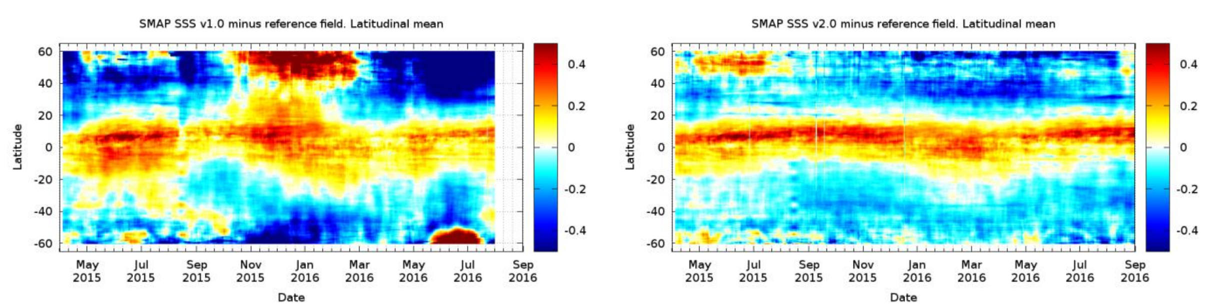

Figure 10: Latitudinal mean SMAP SSS – FOAM SSS. Left: V1.0 (BETA). Right: V2.0. Provided by J. Martínez, BEC.

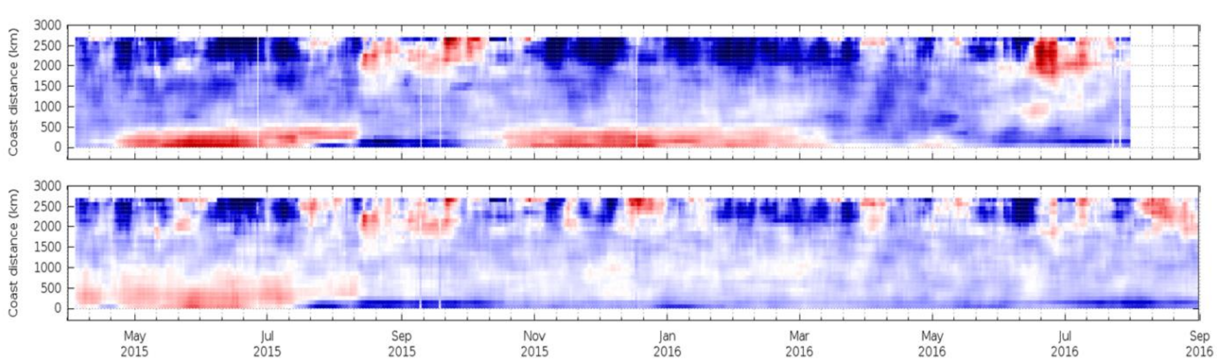

Figure 11: SMAP SSS – FOAM SSS as function of time and distance from the coast. Upper: V1.0 (BETA). Lower: V2.0. Provided by J. Martínez, BEC.

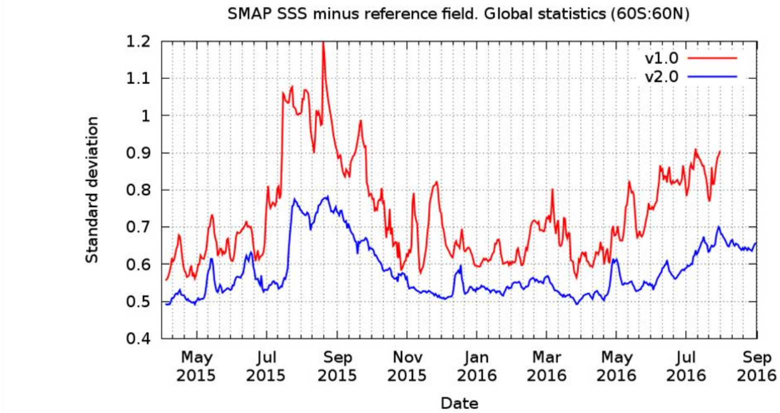

Figure 12: Global [60S; 60N] standard deviation of SMAP SSS – FOAM SSS for the 0.25°x0.25° L3 8-day running averages maps. Red: V1.0 (BETA). Blue: V2.0. Provided by J. Martínez, BEC.

A preliminary validation of the 0.25°x0.25° L3 8-day running average maps was performed by J. Martínez and the BEC team by comparing the SMAP SSS retrievals with the FOAM (Forecast Ocean Assimilation Model) reference field that is provided by the UKMET Office. See Figure 10 - Figure 12.

11.3 Level 3 Monthly Average Maps

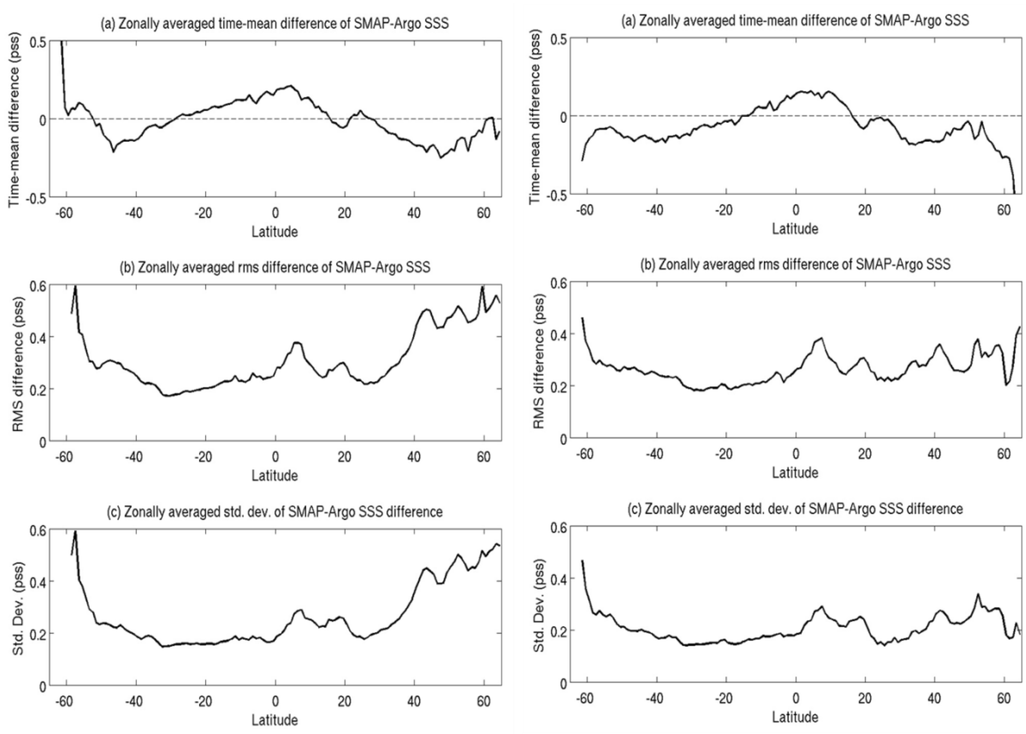

Figure 13: Comparison of zonally averaged statistics: time-mean difference, RMS, Standard Deviation of SMAP – ARGO SSS. Left: for V1.0 (BETA). Right: V2.0. Provided by T. Lee, JPL.

A validation of the L3 monthly average maps was performed by T. Lee, JPL, by comparing 1°x1° bin averaged monthly SMAP SSS with ARGO 1°x1° OI maps from Scripps Institutions of Oceanography.

See Figure 13, Figure 14 and Table 4.

Table 4: Global statistics: SSS SMAP – SSS ARGO monthly 1°x1° maps. Provided by T. Lee, JPL.

(unit: psu)	RMS difference (with time mean)	Standard deviation (no time mean)
V2.0	0.25	0.19
V1.0	0.26	0.21

The RMS difference between SMAP V2 and ARGO salinity is 0.25 psu for monthly 1° x 1° maps (Table 4). This value comprises not only the error in the SMAP salinity but also errors in the ARGO data as well as sampling mismatch between SMAP and ARGO. A triple point analysis for the Aquarius Version 4 release [Lagerloef et al., 2015] estimates the error in ARGO to about 0.13 psu. Subtracting this error in a root-sum square manner from the total RMS difference between SMAP and ARGO gives a **total uncertainty estimate for monthly 1° x 1° SMAP salinity maps of about 0.21 psu**.

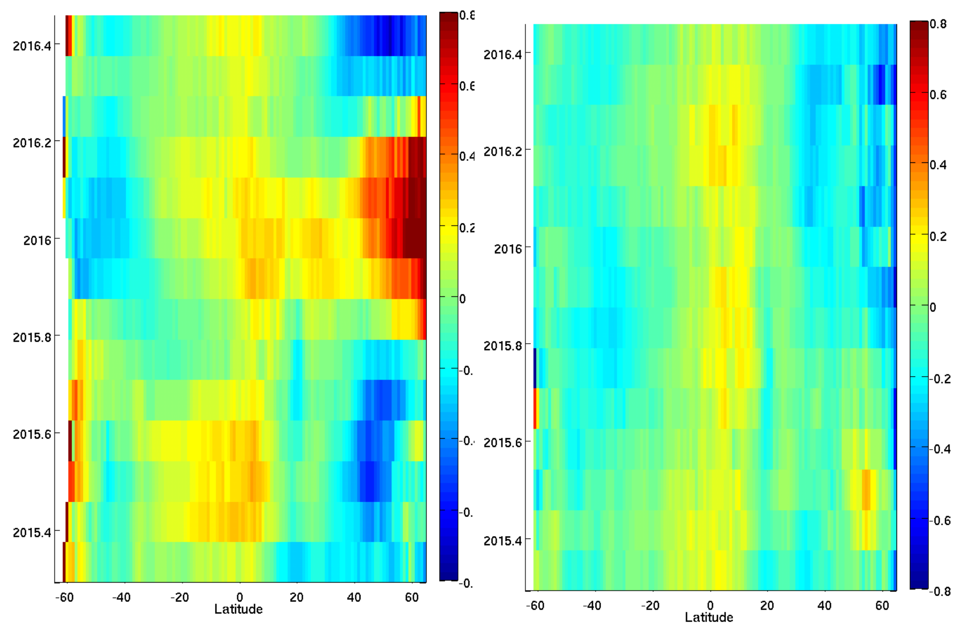

Figure 14: Seasonal distribution of zonally averaged biases between SMAP and ARGO SSS. Left: V1.0 (BETA). Right: V2.0. Provided by T. Lee, JPL.

Figure 15 shows the temporal and zonal biases between SMAP and HYCOM SSS.

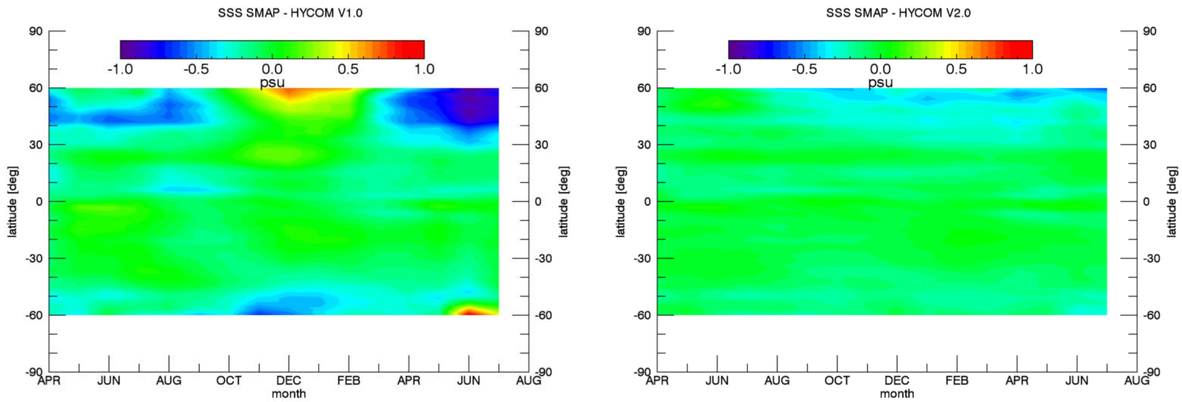

Figure 15: Seasonal distribution of zonally averaged biases between SMAP and HYCOM SSS. Left: V1.0 (BETA). Right: V2.0.

11.4 Known Issues

Likely intrusion of undetected RFI is observed in the Western Pacific near China, Korea and Japan and in the Gulf of Bengal, which manifests in fresh biases on the SMAP SSS in these regions.

12. REFERENCES

LeVine, D. and S. Abraham, 2004: Galactic noise and passive microwave remote sensing from space at L-band, IEEE Transactions on Geoscience and Remote Sensing, 42 (1), 119-129.

Piepmeier, J. R., P. Mohammed, J. Peng, E. J. Kim, G. De Amici, and C. Ruf. 2016a: SMAP L1B Radiometer Half-Orbit Time-Ordered Brightness Temperatures, Version 3. CRID 13080. [RFI filtered antenna temperatures]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. http://dx.doi.org/10.5067/YV5VOWY5V446.

Piepmeier, J. et al., 2016b: SMAP Radiometer Brightness Temperature Calibration for the L1B_TB and L1C_TB Version 3 Data Products, Soil Moisture Active Passive (SMAP) Project, https://pdms.jpl.nasa.gov/.

Lagerloef, G., H-Y Kao, T. Meissner, and J. Vasquez, 2015: Aquarius Salinity Validation Analysis, Data Version 4.0, 2 August 2015, http://podaac.jpl.nasa.gov/SeaSurfaceSalinity/Aquarius.

Meissner, T., F. Wentz, D. LeVine and J. Scott, Addendum III to ATBD, June 4, 2014a: RSS Report #060414, ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs.

Meissner, T., F. Wentz, and L. Ricciardulli, 2014b: The emission and scattering of L-band microwave radiation from rough ocean surfaces and wind speed measurements from Aquarius, J. Geophys. Res. Oceans, vol. 119, doi: 10.1002/2014JC009837.

Meissner, T. F. Wentz, D. Le Vine and P. de Matthaeis, Addendum IV to ATBD, July 15, 2015: RSS Report #071515, ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs.

Wentz, F.J., K.A. Hilburn, D.K. Smith, 2012: Remote Sensing Systems DMSP [SSM/I or SSMIS] [Daily] Environmental Suite on 0.25 deg grid, Version 7, [WSPD_MF]. Remote Sensing Systems, Santa Rosa, CA. Available online at www.remss.com/missions/ssmi.

Wentz, F., L. Ricciardulli, C. Gentemann, T. Meissner, K.A. Hilburn, J. Scott, 2013: Remote Sensing Systems Coriolis WindSat [Daily] Environmental Suite on 0.25 deg grid, Version 7.0.1, [WSPD_LF]. Remote Sensing Systems, Santa Rosa, CA. Available online at www.remss.com/missions/windsat.

Wentz, F. and D.M. LeVine: Aquarius Salinity Retrieval Algorithm, ATBD, August 29, 2012, RSS Technical Report 082912, ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs.

Wentz, F., and T. Meissner, 2016: Atmospheric absorption model for dry air and water vapor at microwave frequencies below 100GHz derived from spaceborne radiometer observations, Radio Science, vol. 51, doi:10.1002/2015RS005858.

13. DATA FORMAT SPECIFICATION

13.1 Level 2C

13.1.1 Paths and Filenames

- **pathname (40 km):** *\SMAP\SSS\V02.0\40km\L2C\r00001_05001*. The SMAP L2 files are ordered by rev# into folders containing 5000 revs each, 00001_05000, 05001_10000, ….
- **filename (40 km):** The SMAP L2 files are named by 5-digit rev#, e.g. *RSS_SMAP_sss_L2C_r00870.nc* for rev 870.
- **pathname (70 km):** *\SMAP\SSS\V02.0\70km\L2C\r00001_05001*. The SMAP L2 files are ordered by rev# into folders containing 5000 revs each, 00001_05000, 05001_10000, ….
- **filename (70 km):** The SMAP L2 files are named by 5-digit rev#, e.g. *RSS_SMAP_sss_L2C_r00870_v02.0_70km.nc* for rev 870.

13.1.2 Most Relevant Global Attributes

- **start_time_sec2000** (8-byte real): seconds of first valid record in this rev since 2000-01-01 00:00:00 UTC.
- **start_time_year, start_time_month, start_time_day_of_month, start_time_day_year** (4-byte integer): year, month, day of month, day of year of first valid record in this rev.
- **start_time_sec_of_day** (8-byte real): seconds of day of first valid record in this rev.
- **emissivity_reflector_vpol, emissivity_reflector_hpol** (4-byte real): ε_{ant} (section 8.2).
- **A_ij** (4-byte real): APC matrix element (i, j) where the indices i, j run over the Stokes vector I, Q, S3, S4 (section 9.1).
- **ta_ocean_ave_vpol, ta_ocean_ave_hpol** (4-byte real): average ta over open ocean for this rev (section 9.3).
- **ta_bias_ocean_vpol, ta_bias_ocean_hpol, ta_bias_ocean_S3, ta_bias_ocean_S4** (4-byte real): TA biases= TA measured – expected over the open ocean (section 9.3 and section 9.4). The computation of TA expected is based on the HYCOM reference SSS. The computation of TA expected for the 3rd Stokes parameter (S3) is based on ancillary TEC maps from IGS (Table 1).

13.1.3 Gridding and Dimensions

The L2C files contain SMAP observations that were optimum interpolated onto a fixed 0.25°x0.25° Earth grid.

The grid (x, y) dimensions are:

- **xdim_grid=1560**, which corresponds to 360° longitude plus 30° in order to accommodate the whole swath.
- **ydim_grid =720**, which corresponds to 180° latitude.

Though the grid cell indices are related to longitude and latitude, the variables cellon and cellat (section 13.1.4) should be used to identify the location.

- **look** = 2 (1 = for look, 2= aft look) defines the look direction of the variable. If the variable does not depend on look direction, then this dimension is omitted.
- **polarization_2** = 2, **polarization_3** = 3, **polarization_4** = 4 specifies the polarization of the variable fields. Note that for some variables the Stokes polarization basis (I, Q, S3, S4) is used, whereas for other variables the modified Stokes polarization basis (V, H, S3, S4) is used. See section 13.1.4.

Any grid cell for with one of the bits 0 – 1 set has invalid entries and none of the variable fields should be used. Any grid cells with one of the bits 2 – 3 set has no valid salinity retrieval.

The observations in the L2C grid cells are **not time ordered**.

13.1.4 Variables

All variable values refer to the average of the OI in the grid cell.

- **time** (8-byte float, array size = [look, xdim_grid, ydim_grid]): seconds of observation since 2000-01-01 00:00:00 UTC.
- **cellat** (4-byte float, array size = [look, xdim_grid, ydim_grid]): geodetic latitude. range: [90°S, 90°N].
- **cellon** (4-byte float, array size = [look, xdim_grid, ydim_grid]): longitude. range: [0°, 360°].
- **eia** (4-byte float, array size = [look, xdim_grid, ydim_grid]): boresight Earth incidence angle. range: [0°, 90°]
- **eaa** (4-byte float, array size = [look, xdim_grid, ydim_grid]): boresight Earth azimuth angle. range: [0°, 360°].
- **zang** (4-byte float, array size = [look, xdim_grid, ydim_grid]): orbital position angle of S/C. range: [0°, 360°]. It is defined as: $zang = \arctan\frac{\left(\hat{R}_{S/C}\cdot\hat{z}\right)}{\left(\hat{V}_{S/C}\cdot\hat{z}\right)} + 90^{\circ}$. $\hat{z}$ is the z-unit vector in the Earth centered inertial system (ECI).

  $\hat{R}_{S/C}$ is the S/C location unit vector in the ECI system. $\hat{V}_{S/C}$ is the S/C velocity unit vector in the ECI system. 0° is S, 90° is equator crossing in the ascending swath, 180° is N, 270° is equator crossing in the descending swath, 360° is S.
- **alpha** (4-byte float, array size = [look, xdim_grid, ydim_grid]): scan angle. range: [0°, 360°]. 0° is forward, 90° is left of forward, 180° is aft, 270° is right of forward, 360° is forward.
- **pra** (4-byte float, array size = [look, xdim_grid, ydim_grid]): polarization basis rotation angle (geometrical part), which is the angle between polarization basis of S/C and polarization basis on the Earth. range: [-90°, +90°].
- **sunglt** (4-byte float, array size = [look, xdim_grid, ydim_grid]): sun glint angle. range: [-180°, +180°]. It is the angle between specular reflection of boresight and the ray to the sun. A negative value means that the ray to the sun is piercing the Earth.
- **monglt** (4-byte float, array size = [look, xdim_grid, ydim_grid]): moon glint angle. range: [-180°, +180°]. It is the angle between specular reflection of boresight and the ray to the moon.
- **gallat** (4-byte float, array size = [look, xdim_grid, ydim_grid]): polar angle of specular reflection ray from boresight in ECI J2000 system (Earth centered inertial system of year 2000). range: [-90°, +90°].
- **gallon** (4-byte float, array size = [look, xdim_grid, ydim_grid]): azimuthal angle of specular reflection ray from boresight in ECI J2000 system (Earth centered inertial system of year 2000). range: [0°, +360°].
- **sun_beta** (4-byte float, array size = [look, xdim_grid, ydim_grid]): sun zenith angle in S/C coordinate system. [0°, +180°].
- **sun_alpha** (4-byte float, array size = [look, xdim_grid, ydim_grid]): sun azimuth angle in S/C coordinate system. [0°, +360°].

- **gland** (4-byte float, array size = [look, xdim_grid, ydim_grid]): land fraction within footprint weighted by antenna gain pattern. range: [0.0, 1.0].
- **gice** (4-byte float, array size = [xdim_grid, ydim_grid]): sea ice fraction within footprint weighted by antenna gain pattern. range: [0.0, 1.0].
- **surtep** (4-byte float, array size = [xdim_grid, ydim_grid]): ancillary sea surface temperature from CMC. units: Kelvin.
- **winspd** (4-byte float, array size = [xdim_grid, ydim_grid]): ancillary sea surface wind speed. that is used in the surface roughness correction. order of availability: WindSat, F17 SSMIS, NCEP GDAS. see section 8.1. units: m/s.
- **windir** (4-byte float, array size = [xdim_grid, ydim_grid]): ancillary wind direction relative to N from NCEP GDAS. meteorological convention. 0^o: wind coming out of N, $+90^o$: wind coming out of E, etc. range: [0^o, $+360^o$].
- **tran** (4-byte float, array size = [xdim_grid, ydim_grid]): total atmospheric transmittance. computed from ancillary NCEP GDAS atmospheric profile fields for pressure, geopotential height, temperature, relative humidity, cloud water mixing ratio. range: [0.0, 1.0]. The computation uses the atmospheric absorption model by Wentz and Meissner [2016].
- **tbup** (4-byte float, array size = [xdim_grid, ydim_grid]): atmospheric upwelling brightness temperature. computed from ancillary NCEP GDAS atmospheric profile fields for pressure, geopotential height, temperature, relative humidity, cloud water mixing ratio. units: Kelvin. The computation uses the atmospheric absorption model by Wentz and Meissner [2016].
- **tbdw** (4-byte float, array size = [xdim_grid, ydim_grid]): atmospheric downwelling brightness temperature. computed from ancillary NCEP GDAS atmospheric profile fields for pressure, geopotential height, temperature, relative humidity, cloud water mixing ratio. units: Kelvin. The computation uses the atmospheric absorption model by Wentz and Meissner [2016].
- **rain** (4-byte float, array size = [xdim_grid, ydim_grid]): imager rain rate within 60 minutes of SMAP. order of availability: WindSat, F17 SSMIS. units: mm/h.
- **solar_flux** (4-byte float, array size = [xdim_grid, ydim_grid]): ancillary mean solar flux from NOAA SWPC. units: SFU.
- **ta_ant_filtered** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP RFI filtered antenna temperatures. This is the basic input from the SMAP L1B TB files. units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **ta_ant_calibrated** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP antenna temperatures after correcting for the emissive antenna (section 8.2) and calibration drift (sections 9.3, 9.4). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **ta_earth** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP antenna temperatures after correcting for celestial intrusions: cold space (spillover), galaxy (direct and reflected), sun (direct and reflected) , moon (reflected). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **tb_toi** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP top of the ionosphere brightness temperatures. units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **tb_toa** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP top of the atmosphere brightness temperatures (before applying land correction). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.

- **tb_toa_lc** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP top of the atmosphere brightness temperatures after applying land correction). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **tb_sur** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP brightness temperature at rough ocean surface (before applying surface roughness correction). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **tb_sur0** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): SMAP brightness temperature referenced to flat ocean surface (after applying surface roughness correction). units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **temp_ant** (4-byte float, array size = [polarization_2, look, xdim_grid, ydim_grid]): physical temperature of the SMAP mesh antenna from JPL thermal model $T_{phys,ant}$ (section 8.2). This value is included in SMAP L1B TB files. units: Kelvin. polarization basis: 1=V, 2=H.
- **dtemp_ant** (4-byte float, array size = [polarization_2, look, xdim_grid, ydim_grid]): empirical correction $\Delta T_{phys,ant}$ to the physical temperature of the SMAP mesh antenna (section 8.2). units: Kelvin. polarization basis: 1=V, 2=H.
- **ta_sun_dir** (4-byte float, array size = [polarization_3, look, xdim_grid, ydim_grid]): TA of direct sun intrusion. units: Kelvin. polarization basis: 1=I, 2=Q, 3=S3.
- **ta_sun_ref** (4-byte float, array size = [polarization_3, look, xdim_grid, ydim_grid]): TA of reflected sun intrusion. units: Kelvin. polarization basis: 1=I, 2=Q, 3=S3.
- **ta_gal_dir** (4-byte float, array size = [polarization_3, look, xdim_grid, ydim_grid]): TA of direct galaxy intrusion. units: Kelvin. polarization basis: 1=I, 2=Q, 3=S3.
- **ta_gal_ref** (4-byte float, array size = [polarization_3, look, xdim_grid, ydim_grid]): TA of reflected galaxy intrusion. units: Kelvin. polarization basis: 1=I, 2=Q, 3=S3.
- **sss_smap** (4-byte float, array size = [look, xdim_grid, ydim_grid]): retrieved SMAP sea surface salinity. units: PSU.
- **tb_consistency** (4-byte float, array size = [look, xdim_grid, ydim_grid]): $\sqrt{\chi^2} = \sqrt{\left[T_{B,sur0} - T_{B,RTM}\left(SSS_{SMAP}\right)\right]_{V-pol}^2 + \left[T_{B,sur0} - T_{B,RTM}\left(SSS_{SMAP}\right)\right]_{H-pol}^2}$ of MLE in salinity retrieval algorithm. units: Kelvin.
- **iqc_flag** (4-byte integer, array size = [look, xdim_grid, ydim_grid]): 32-bit quality control flag (section 8.5).
- **sss_ref** (4-byte float, array size = [xdim_grid, ydim_grid]): ancillary reference sea surface salinity from HYCOM. units: PSU.
- **ta_ant_exp** (4-byte float, array size = [polarization_4, look, xdim_grid, ydim_grid]): expected antenna temperature before any losses. This value is to be compared with **ta_ant_calibrated**. The RTM computation is performed at boresight and based on the HYCOM reference salinity. units: Kelvin. polarization basis: 1=V, 2=H, 3=S3, 4=S4.
- **pratot_exp** (4-byte float, array size = [look, xdim_grid, ydim_grid]): expected total polarization rotation angle = geometric part + Faraday rotation. The computation of the Faraday rotation part is based on the ancillary TEC fields from IGS. range: [-90°, +90°].

13.2 Level 3

13.2.1 Paths and Filenames

- **8-day running averages**:
  - 40 km*:*
  \SMAP\SSS\V02.0\40km\L3\8day_running*YYYY*\RSS_smap_SSS_8day_running_*YYYY_DOY*_v02.0.nc.
  - 70km*:*
  \SMAP\SSS\V02.0\70km\L3\8day_running*YYYY*\RSS_smap_SSS_8day_running_*YYYY_DOY*_v02.0_70km.nc.

- **Monthly averages**:
  - 40 km*:*
  \SMAP\SSS\V02.0\40km\L3\monthly *YYYY*\RSS_smap_SSS_monthly_*YYYY_DOY*_v02.0.nc.
  - 70 km*:*
  \SMAP\SSS\V02.0\70km\L3\monthly*YYYY*\RSS_smap_SSS_monthly_*YYYY_DOY*_v02.0_70km.nc.

YYYY is the 4-digit year, *DOY* is the Julian day of the year and *MM* is the months of the year.

13.2.2 Most Relevant Global Attributes

- **first_orbit** (4-byte integer): the 1st rev that is used in the L3 time averaging.
- **last_orbit** (4-byte integer): the last rev that is used in the L3 time averaging.
- **start_time_of_product_interval** (8-byte real): seconds of start time of product interval since 2000-01-01 00:00:00 UTC.
- **end_time_of_product_interval** (8-byte real): seconds of end time of product interval since 2000-01-01 00:00:00 UTC.

13.2.3 Grid and Dimensions

All L3 files are provided on a uniform 0.25^{o}x0.25^o rectangular Earth grid.

The **longitude** varies between 0^o and 360^o in **nxdim = 1440** uniform 0.25^o increments. The longitudinal interval midpoints are: 0.125^o, 0.375^o, …359.875.

The **latitude** varies between -90^o and +90^o in **nydim = 720** uniform 0.25^o increments. The latitudinal interval midpoints are: -89.875^o, -89.8625^o, …, +89.875^o.

The **time** corresponds to the center of the product time interval.

13.2.4 Variables

- **nobs** (4-byte integer, array size = [nxdim, nydim]): number of L2C observations that are averaged into L3 grid cell.
- **sss_smap** (4-byte float, array size = [nxdim, nydim]): SMAP sea surface salinity. units: PSU.
- **gland** (4-byte float, array size = [nxdim, nydim]): land fraction within footprint weighted by antenna gain pattern. range: [0.0, 1.0].
- **gice** (4-byte float, array size = [nxdim, nydim]): sea ice fraction within footprint weighted by antenna gain pattern. range: [0.0, 1.0].
- **surtep** (4-byte float, array size = [nxdim, nydim]): ancillary sea surface temperature from CMC. units: Kelvin.