The RSS/NASA SMAP Salinity Version 3 Release: Algorithm and Geophysical Model Function

T. Meissner, F. Wentz and A. Manaster

Remote Sensing Systems

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Santa Rosa, CA
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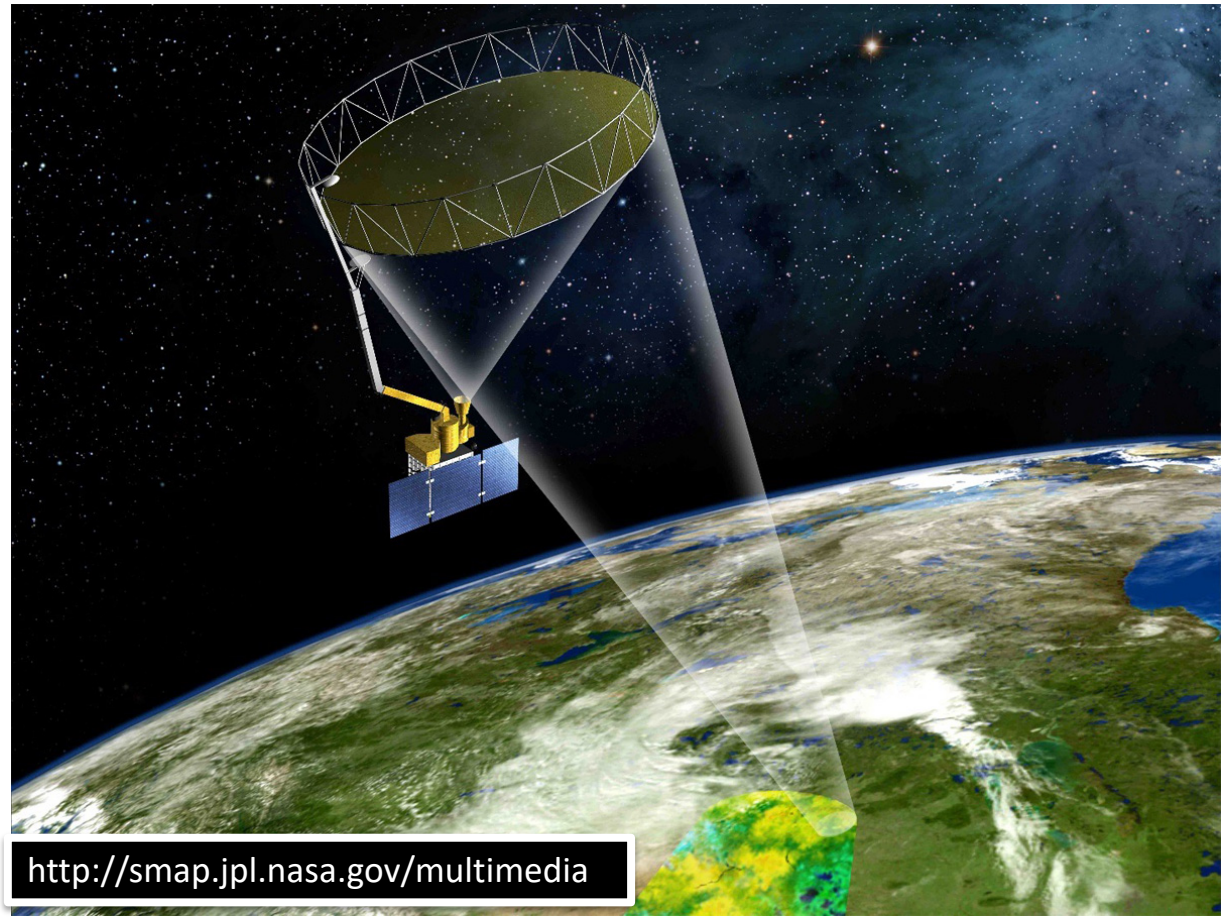
Outline

- Overview of SMAP Instrument
  - Footprint, Sampling and Noise Figures
- RSS/NASA V3 SMAP Salinity Retrieval Algorithm
  - Changes/Improvements over V2
  - GMF
  - Ancillary Input
- Data Distribution for SMAP V3
- SMAP V3 versus Aquarius V5: Continuity
- Future Plans for SCPS

SMAP

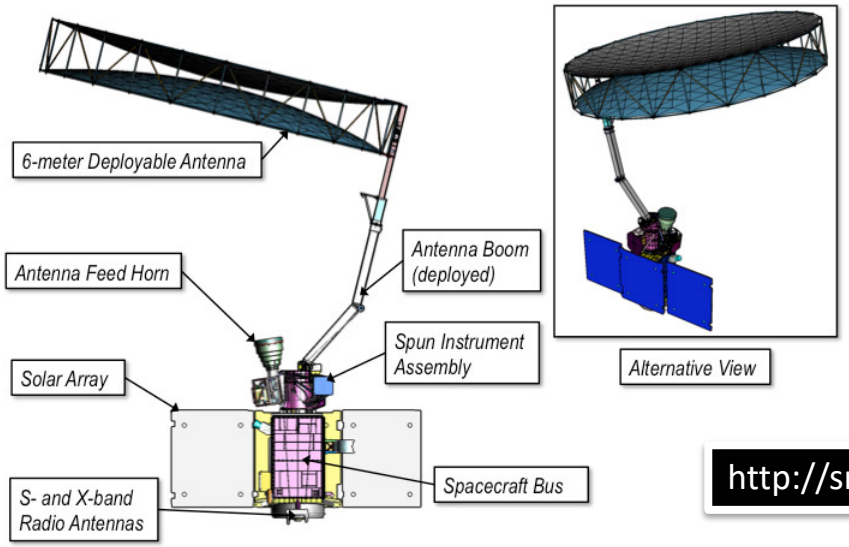
Soil **M**oisture **A**ctive **P**assive



Orbit Altitude: 685 km. Inclination: 98 deg.
Local ascending/descending time: 6 PM/AM.
8-day repeat orbit.

SMAP

Instrument



http://smap.jpl.nasa.gov/multimedia

- 6-meter mesh antenna.
- Conical scanning @ 14.6 rpm. Scan time: 4.1 sec
- Earth Incidence Angle: 40^{o}.
- Radiometer: Center frequency: 1.41 GHz ~~+ Radar.~~
- Taking observations since April 2015.
- Radiometer/Radar switch on/off multiple times April – July 2015.
  - Degraded Calibration.

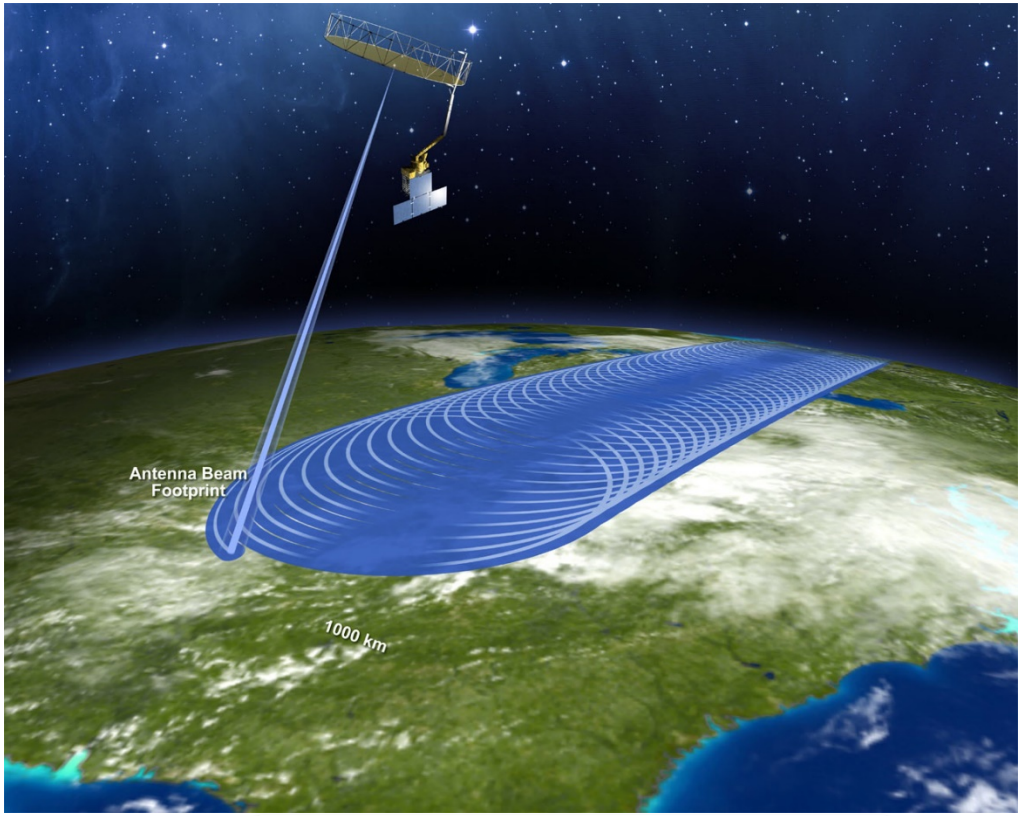
SMAP

Swath – Scanning

http://smap.jpl.nasa.gov/multimedia

SMAP

Swath – Scanning

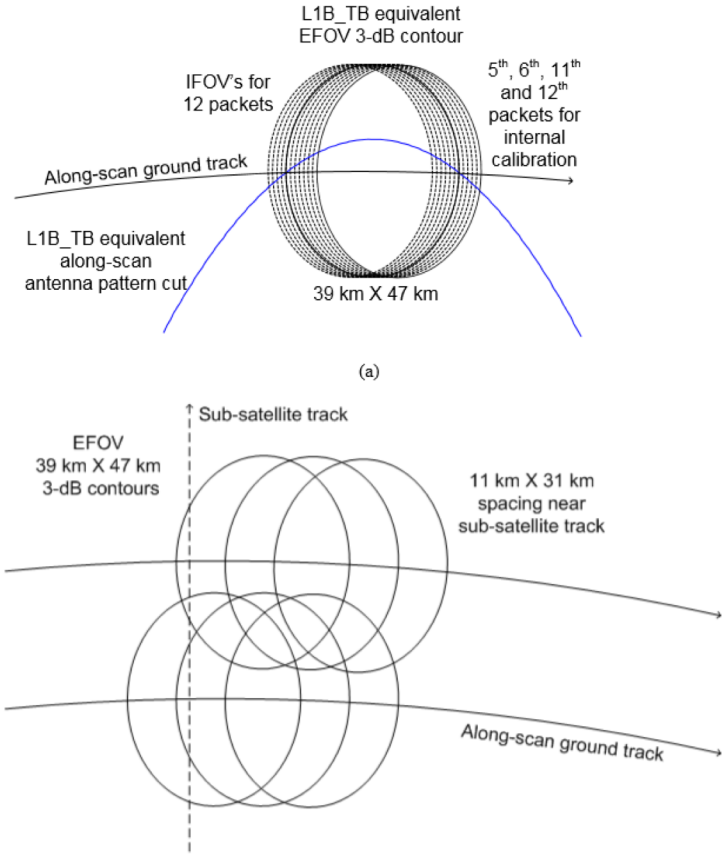


http://smap.jpl.nasa.gov/multimedia

- Full 360° scan views the Earth.
- 1000 km wide swath.
- 3-dB (half power) footprint size: 40 km.

SMAP

Footprint – Sampling – Noise



from SMAP L1B ATBD (J. Piepmeier et al.)

L1B sampling time:
Aquarius: 1.44 sec (pre-averaged)
SMAP: ~ 14 msec (EFOV)
results in 10 times larger noise in SMAP L1B

Noise figure for SMAP L1B EFOV is ~ 2 psu.
All random noise.
Useless for most oceanic applications and validation.

RSS/NASA SMAP L2 processing resamples SMAP L1B using Backus-Gilbert type Optimum Interpolation (OI) onto fixed ¼ deg Earth grid. Utilize over-sampling in along-scan direction.

- 40 km elliptical (keep original resolution)
- **70 km circular: standard product in Version 3. Should be used for ocean science applications.**

See presentation by F. Wentz

SMAP

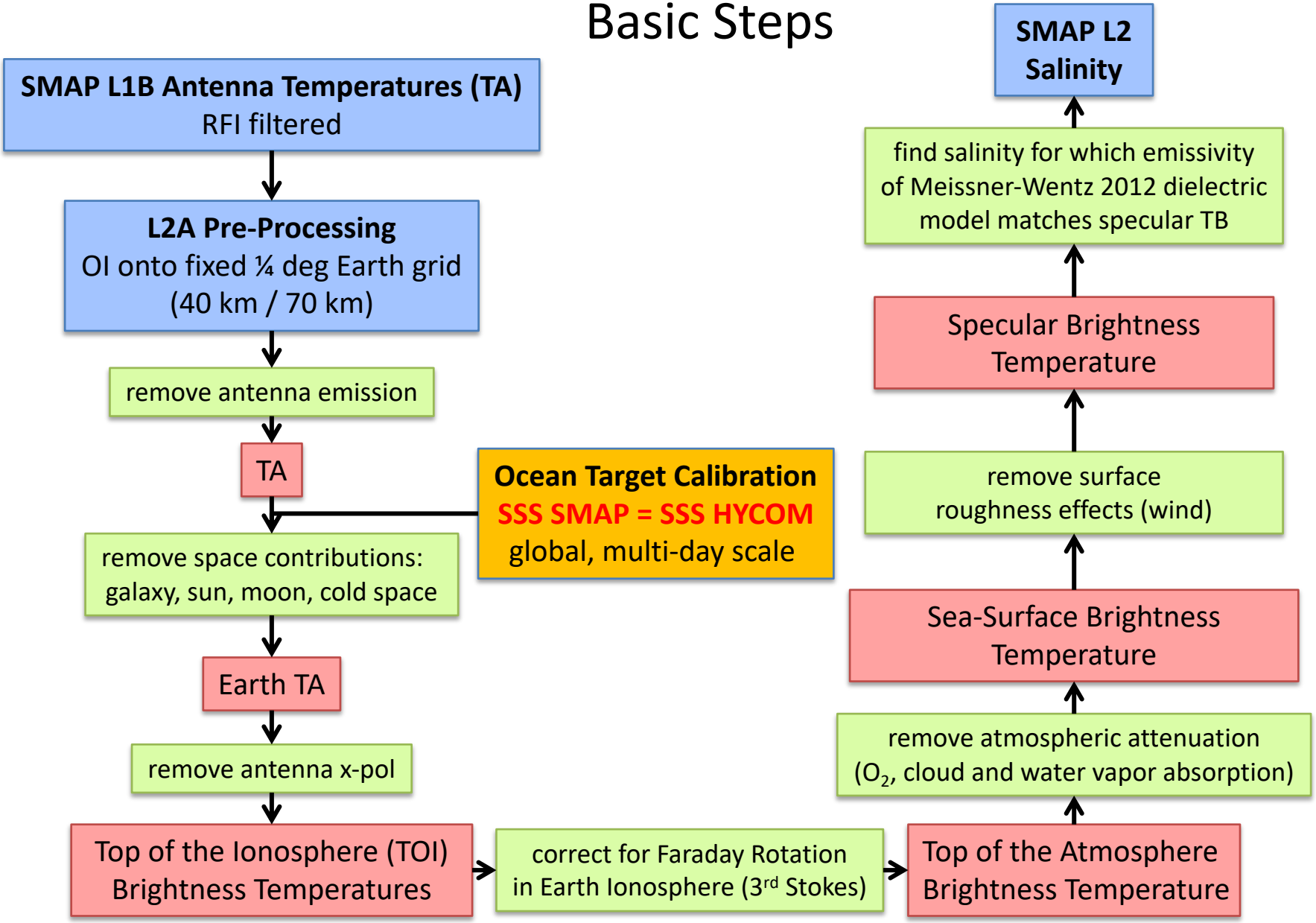
Approximate Noise Figures + Spatial Resolution for Salinity Product

Product	Spatial Resolution	Noise	Noise Type
SMAP L1B	40 km	2 psu	random (NEDT)
RSS SMAP L2	40 km OI	1 psu	random (NEDT)
RSS SMAP L2	**70 km OI**	**0.5 psu**	**random (NEDT) + systematic (GMF)**
RSS SMAP L3 monthly	**70 km**	**0.2 psu**	**systematic (GMF)**

The OI results in a significant noise reduction of an otherwise extremely noisy product.

SMAP V3 Salinity Retrieval Algorithm

Basic Steps



SMAP V3 Salinity Retrieval Algorithm

Major Changes from V2 Release

1. Use **same geophysical model function (GMF) as for Aquarius V5 release**.
   - i. Meissner Wentz dielectric model.
   - ii. Liebe oxygen absorption (important to mitigate biases in Aquarius V5).
   - iii. Wind emissivity.
     - different ancillary wind speeds
   - iv. Galaxy (based on SMAP fore – aft, already implemented in V2).
   - **v. Use ARGO as reference SSS to derive GMF. Biases between ARGO/HYCOM. Ocean target calibration uses HYCOM.**
2. CCMP ancillary wind speed + direction.

Version 2.1 evaluation version

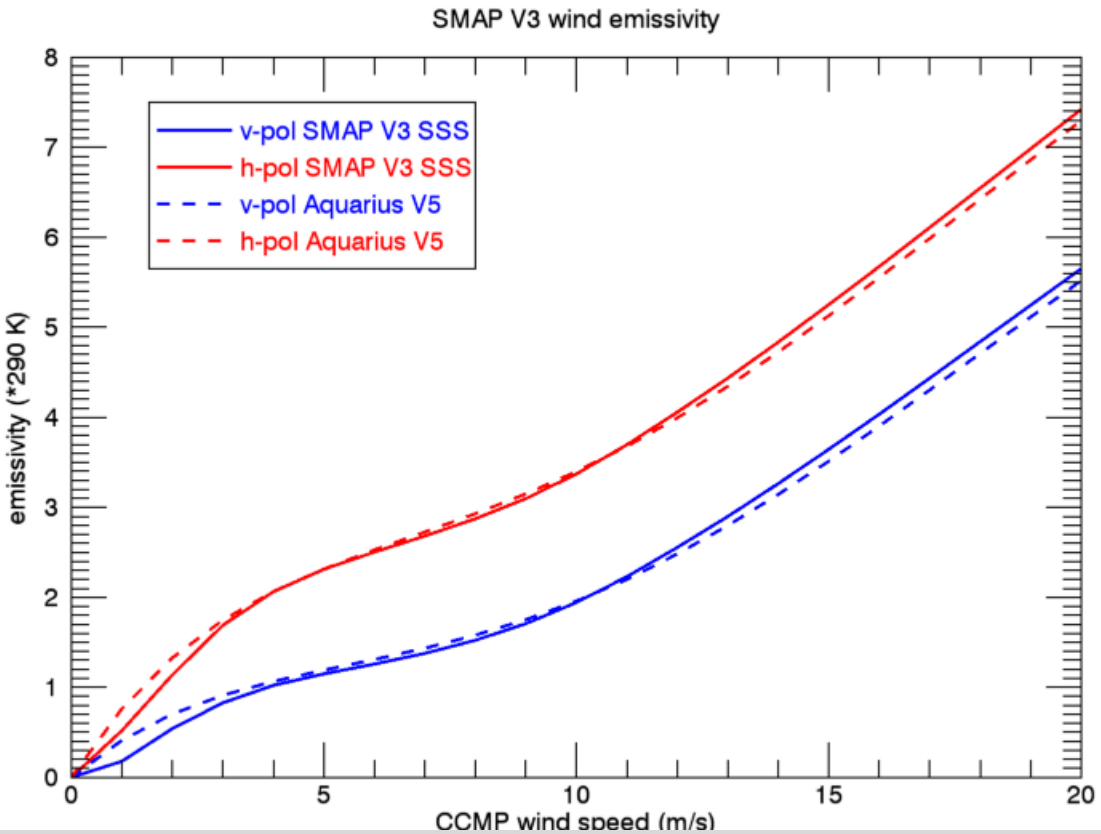
3. Improved land correction (see talk by F. Wentz).
4. Input SMAP Version 4 L1B TA (latest calibration).
5. Include IMERG rain rate.
   - Level 4 merged rain product.
   - by G. Huffman (GFSC) et al. Largely based on GPM rain rate measurements.
   - Global, 30 min. coverage.
   - Resampled to SMAP resolution: 40 km/70 km.
   - Similar to RIM product in Aquarius V5.
   - Used for rain flagging (comparison with ARGO).
   - Used for atmospheric cloud water correction (instead of NCEP cloud water).

Surface Roughness Correction

CCMP (Cross Calibrated Multi-Platform) Winds

- **Surface roughness is the largest error source**
  - **0.3 m/s error in wind speed makes 0.2 psu error in SSS**
- SMAP lost its scatterometer.
  - Information in radiometer channels is not sufficient to retrieve salinity and wind speed simultaneously.
  - SMAP V/H response to increase in wind is similar to decrease in salinity.
  - **Need external wind speed in surface roughness correction.**
- SMAP V2: used WindSat, F17 SSMIS, NCEP in order of availability
- CCMP for SMAP V3:
  - Blended Level 4 wind vector product.
  - Variational Assimilation Method (VAM): RSS satellite wind fields + NWP background field.
  - V1: R. Atlas et al. 1996 + 2012, BAMS.
  - V2: produced by C. Mears at RSS.
- **SMAP salinity retrievals use near-real time CCMP V2.0**
  - All RSS radiometers (WindSat, AMSR2, SSMIS, GMI).
  - NCEP GDAS as background field. 6 hourly. 0.25°. Space-time interpolated to SMAP.

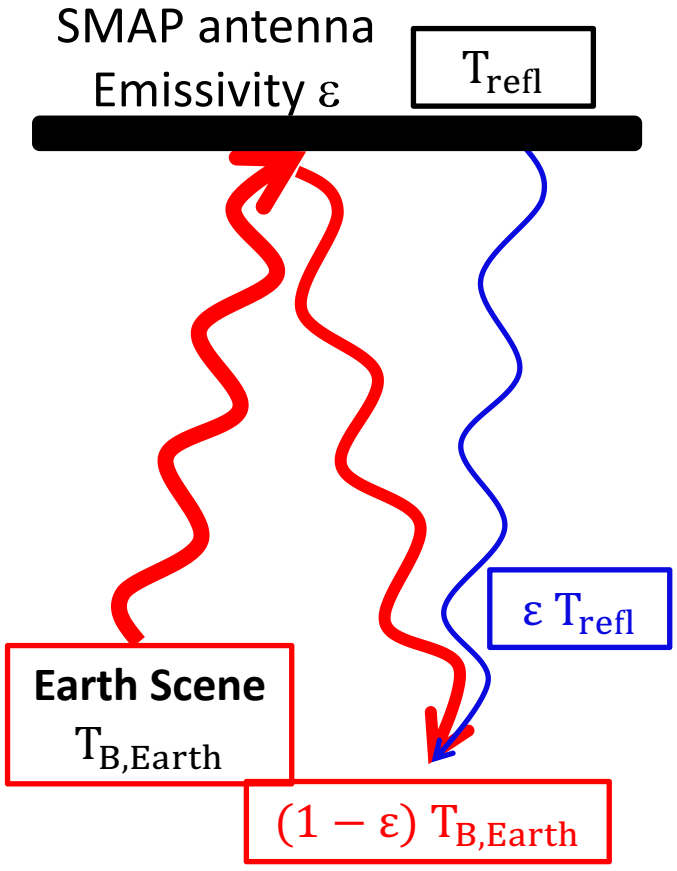
Wind Emissivity



Aquarius V5 uses HHH wind speed (Aquarius scatterometer).
SMAP V3 uses CCMP NRT wind speed.
There are small systematic differences between these ancillary wind speeds.
Rederiving GMF with different wind speed gives slightly different results at very low/very high winds.
See Aquarius versions (NCEP, SSMI, WindSat, Aquarius scatterometer, …).

Emissive Antenna

requires additional calibration effort



- The Aquarius antenna was not emissive.
- The SMAP reflector mesh and component of the feedhorn are **lossy (emissive).**
- $T_B = T_{B,Earth} + \varepsilon\,(T_{refl} - T_{B,Earth})$
- **No measurement of physical temperature of SMAP antenna.**
  - Driven by solar heating.
  - Only JPL thermal model data are available.
  - OK for soil moisture.
  - **JPL Thermal model is inaccurate when S/C goes into eclipse (50 K temperature change) resulting in large (1 – 2 psu) biases.**
- **Emissivity** about 1%. This is **4 times larger than pre-launch value.**
- **SMAP RSS SSS algorithm makes static empirical adjustment to thermal model.**
- Additional degree of freedom / knob to turn in GMF.

Reflector Temperature

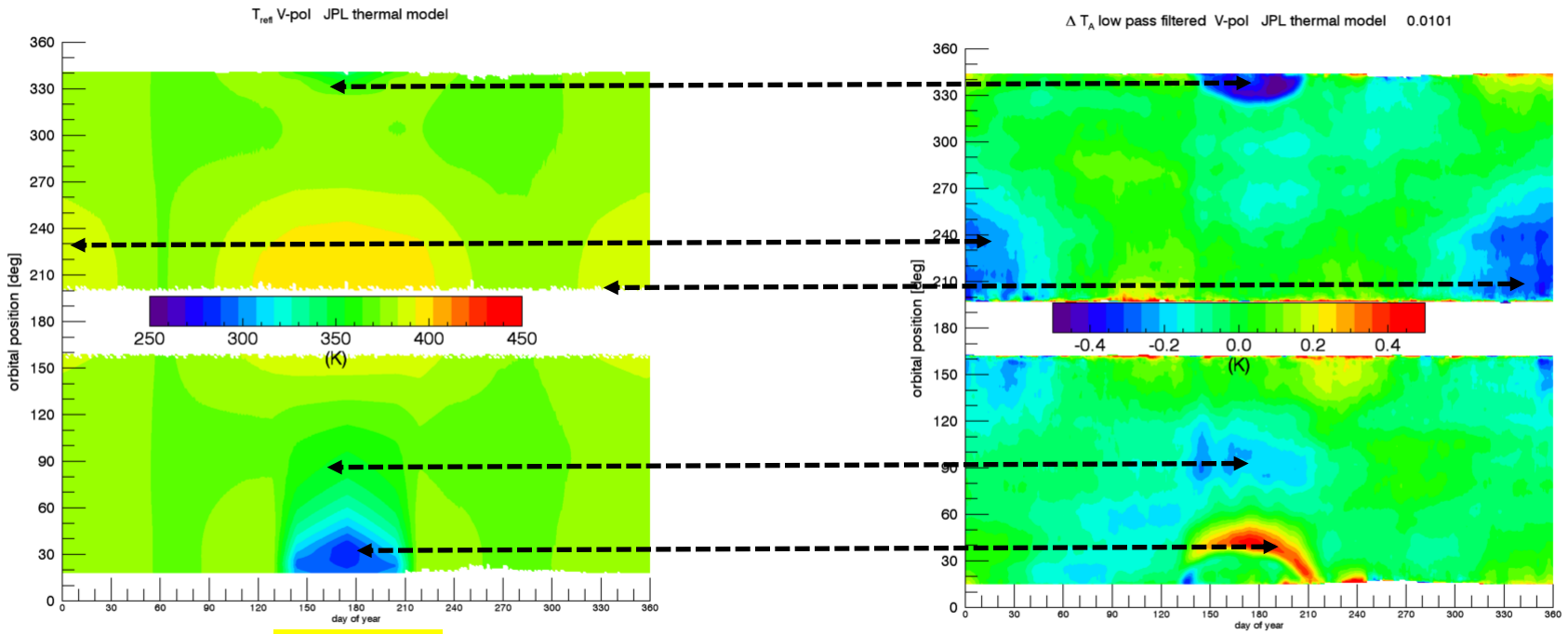
JPL Thermal Model

orbit position

DOY

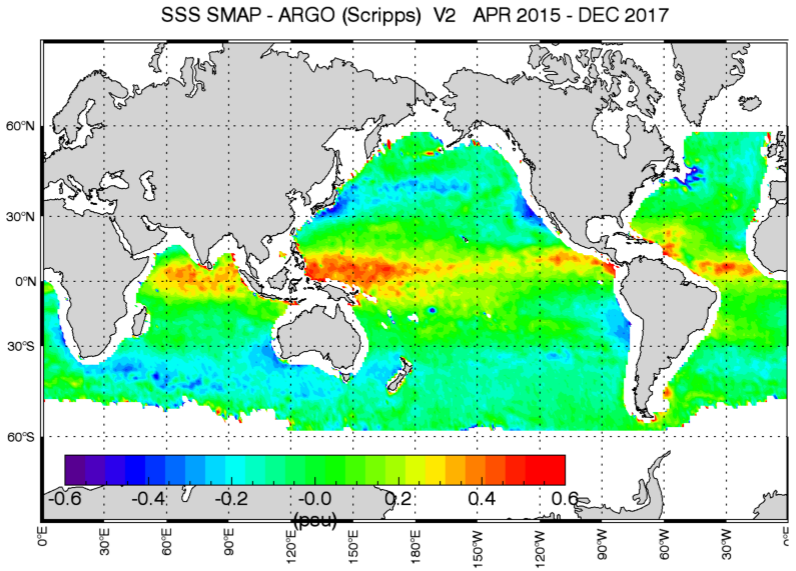
T_{refl}: JPL thermal model

TA Bias

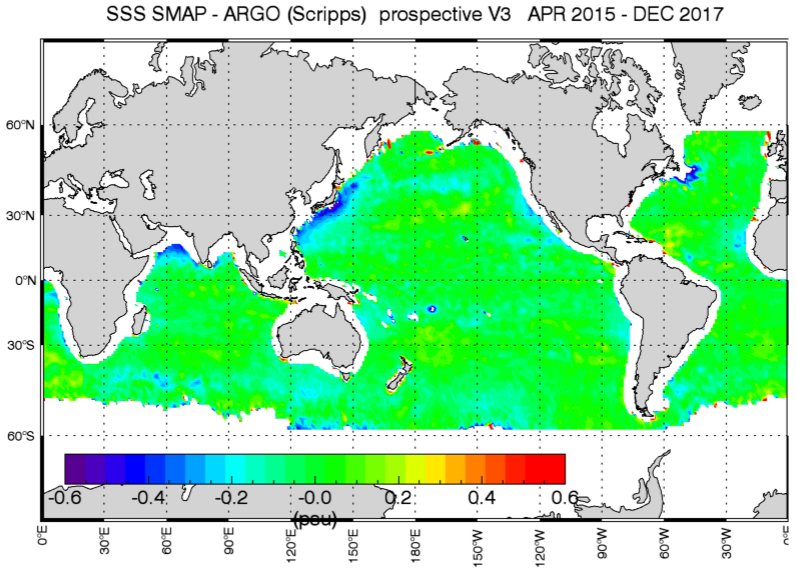


Eclipse Season

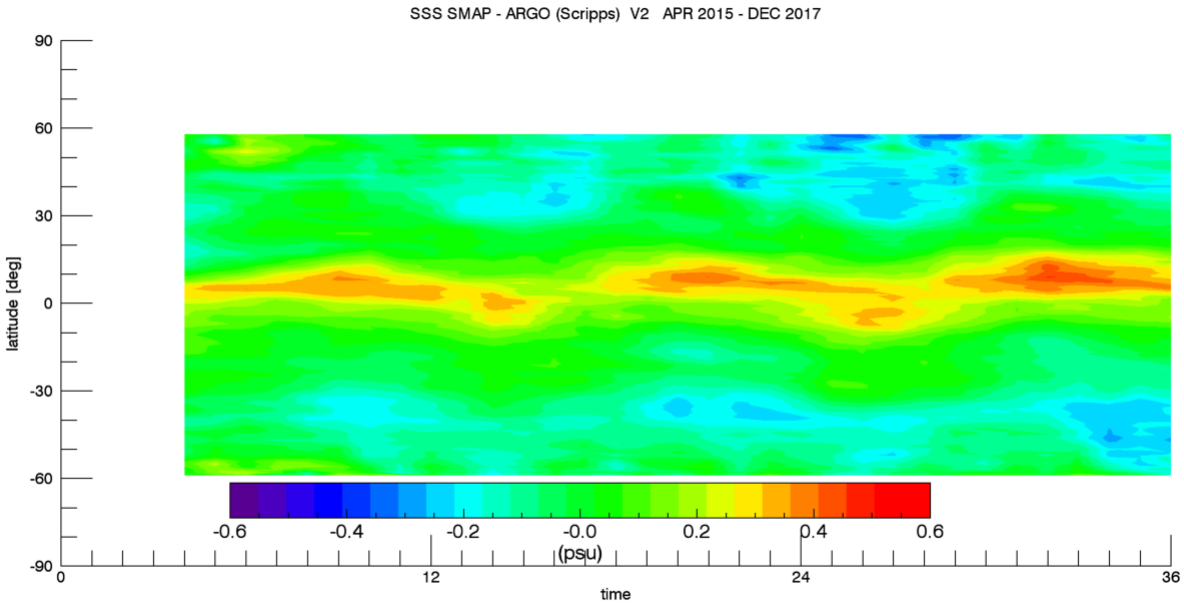
V2.0



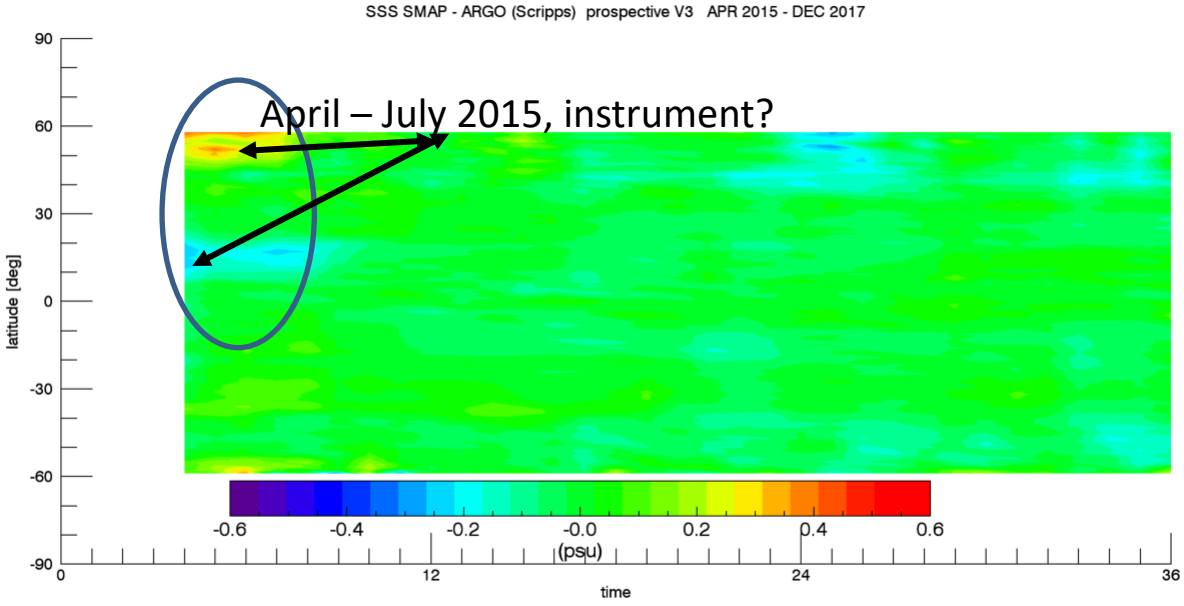
V2.1/V3.0



V3 removes spurious salty biases in the tropics that were prevalent in V2.


SSS SMAP - ARGO (Scripps) V2 APR 2015 - DEC 2017
latitude [deg]
90
60
30
0
-30
-60
-90
-0.6
-0.4
-0.2
-0.0
0.2
0.4
0.6
(psu)
0
12
24
36
time

V2.0

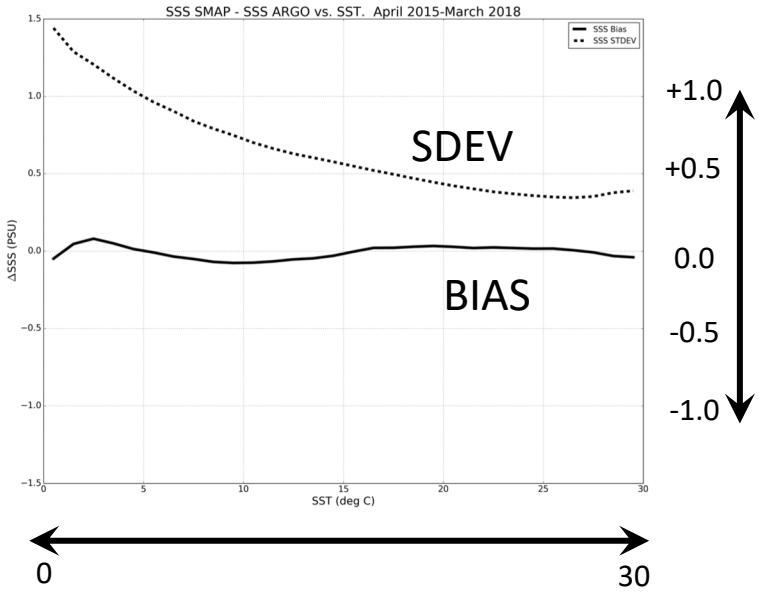

SSS SMAP - ARGO (Scripps) prospective V3 APR 2015 - DEC 2017
April – July 2015, instrument?
latitude [deg]
90
60
30
0
-30
-60
-90
-0.6
-0.4
-0.2
-0.0
0.2
0.4
0.6
(psu)
0
12
24
36
time

V2.1/V3.0

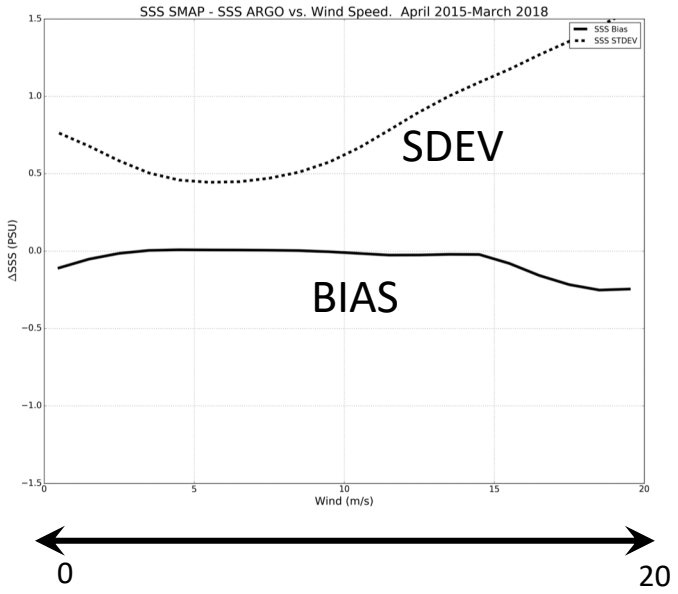
RSS SMAP v2.1 Level 2 – ARGO

Binned v SST and Wind Speed

VS. SST



VS. WIND SPEED



No biases over whole SST range and wind speed range (< 15 m/s).
Consistency of GMF (dielectric model, wind emissivity model).

NASA/RSS SMAP SSS Version 3 Release

Schedule

- netCDF4 (CF and ACDD compliant).
- Detailed release notes (ATBD, Data Format SPEC, Validation).
- Scheduled: September/October 2018.
- **Available at**
  - **RSS** www.remss.com/missions/smap/salinity
  - **PO.DAAC** ftp://podaac-ftp.jpl.nasa.gov/allData/smap/

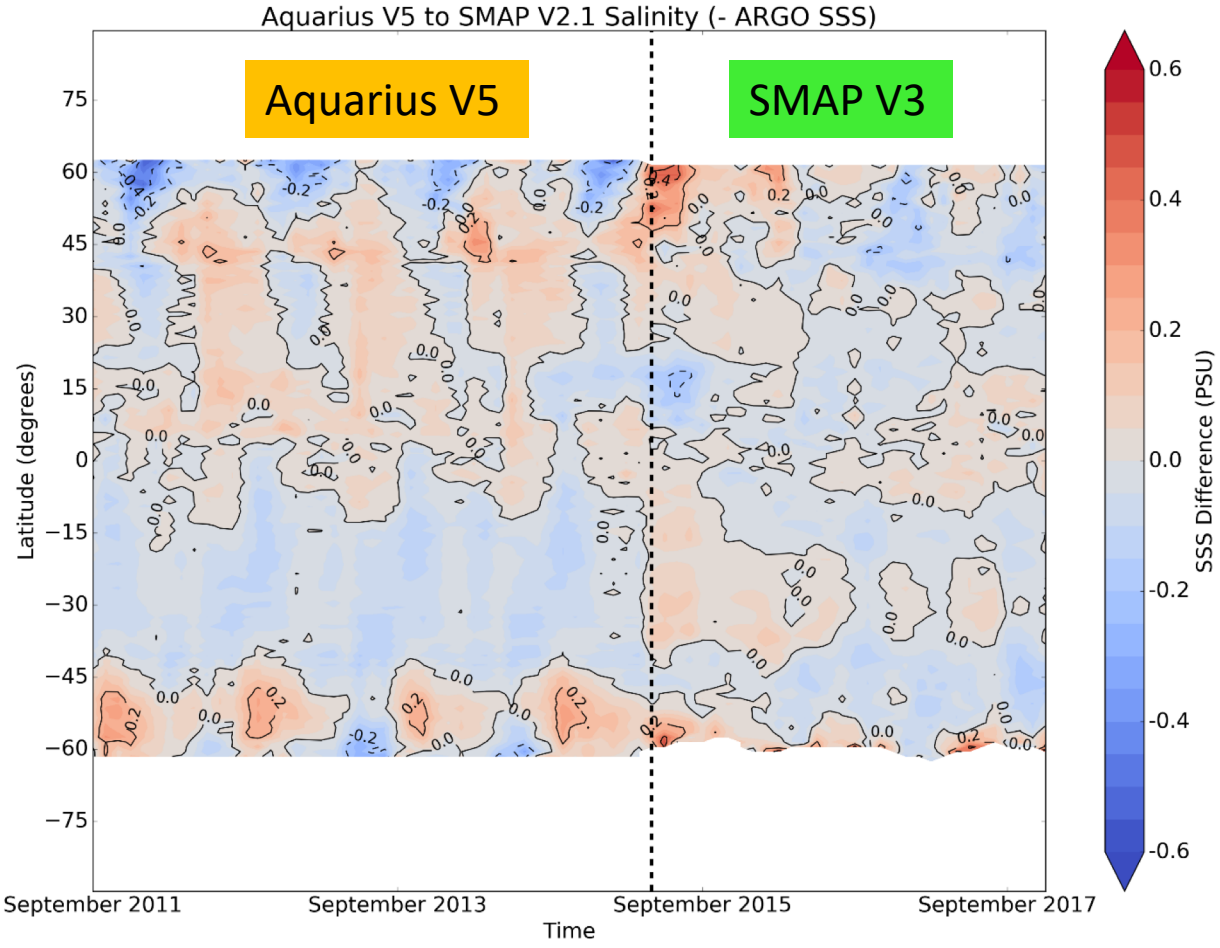
NASA/RSS SMAP SSS Version 3 Release

Data Products

40 km	70 km standard product	content	latency
L2C	L2C	¼ deg swath grid SSS + all essential orbital and pointing parameters, all TA, TB, ancillary fields, all corrections, forward model (TA expected)	~ 1 day
L3 8-day running	L3 8-day running	¼ deg map SSS + land fraction, sea-ice fraction, SST	~ 1 week after center day
L3 monthly	L3 monthly	¼ deg map SSS + land fraction, sea-ice fraction, SST	~ 1 week after end of the month
	L3 monthly rain filtered (RF) @ RSS only	¼ deg map SSS + land fraction, sea-ice fraction, SST	

Aquarius – SMAP Continuity

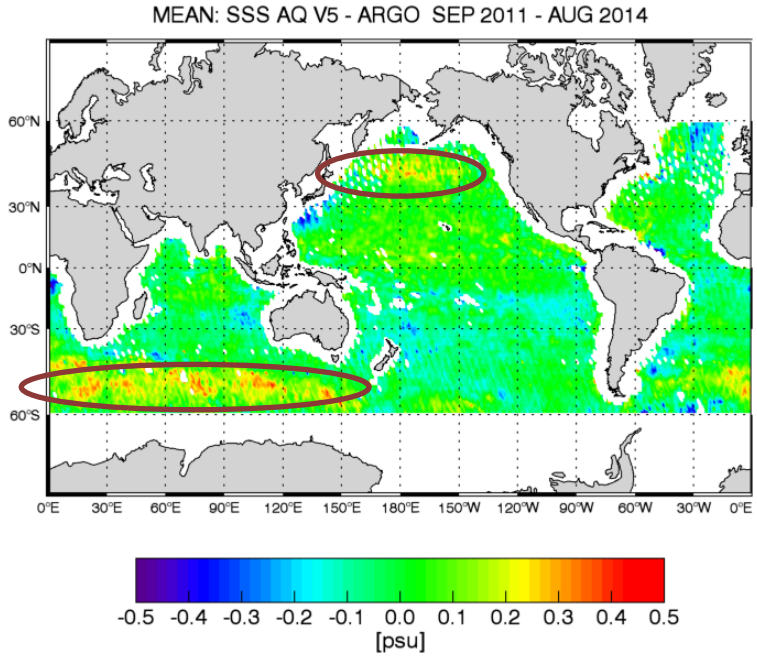
use ARGO as common reference



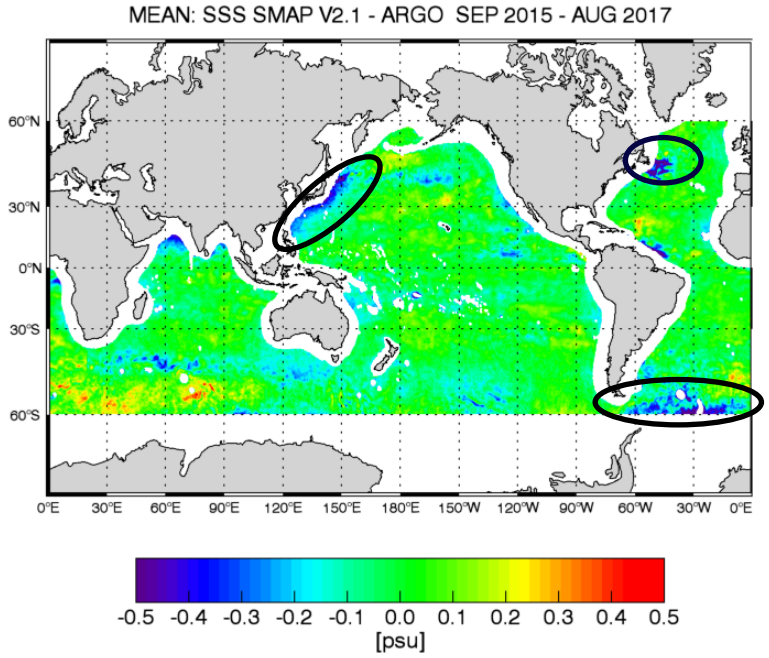
Aquarius – SMAP Continuity

use ARGO as common reference

Aquarius V5 (2012 – 2014) - ARGO



SMAP V3 (2016 – 2017) - ARGO



SCPS: Path forward

- **Aquarius – SMAP Consistency:**
  - **residual biases (mainly in Aquarius)**
  - **track down their cause:** roughness, ancillary wind speed, … ?
  - need to keep consistency in GMF for both products
- Reprocessing of Aquarius
  - increase time window in ocean target calibration
- **Formal uncertainties (error bars) in SMAP**
  - as we did in Aquarius V5.
- Quick-Look (near real time) product
  - ancillary fields with less latency = higher errors
  - demand?
- Cold SST, near sea-ice edge, closer to land, …
- Other special products, e.g. salinity on L1B grid (Hawaii group)

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Open Access

Article

The Salinity Retrieval Algorithms for the NASA Aquarius Version 5 and SMAP Version 3 Releases

Thomas Meissner [1,*], **Frank J. Wentz** [1] and **David M. Le Vine** [2]

[1] Remote Sensing Systems, 444 Tenth Street, Suite 200, Santa Rosa, CA 95401, USA

[2] NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

[*] Author to whom correspondence should be addressed.

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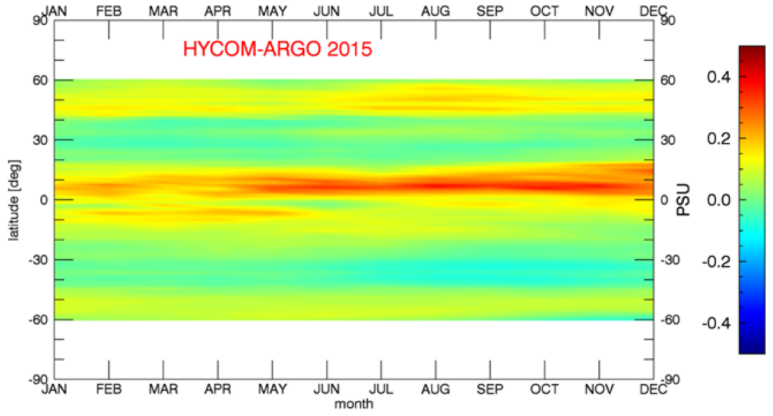
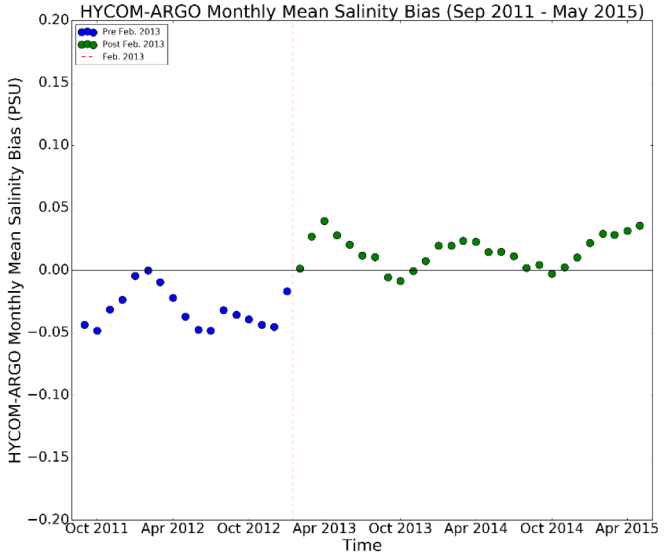
Abstract: The Aquarius end-of-mission (Version 5) salinity data set was released in December 2017. This article gives a comprehensive overview of the main steps of the Level 2 salinity retrieval algorithm. In particular, we will discuss the corrections for wind induced surface roughness, atmospheric oxygen absorption, reflected galactic radiation and side-lobe intrusion from land surfaces. Most of these corrections have undergone major updates from previous versions, which has helped mitigating temporal and zonal biases. Our article also discusses the ocean target calibration for Aquarius Version 5. We show how formal error estimates for the Aquarius retrievals can be obtained by perturbing the input to the algorithm. The performance of the Aquarius Version 5 salinity retrievals is evaluated against salinity measurements from the ARGO network and the HYCOM model. When stratified as function of sea surface temperature or sea surface wind speed, the difference between Aquarius Version 5 and ARGO is within ±0.1 psu. The estimated global RMS uncertainty for monthly 100 km averages is 0.128 psu for the Aquarius Version 5 retrievals. Finally, we show how the Aquarius Version 5 salinity retrieval algorithm is adapted to retrieve salinity from the Soil-Moisture Active Passion (SMAP) mission.

Backup Slides

Reference Salinity: HYCOM -> ARGO (Scripps)

Space-time interpolated to Aquarius observations

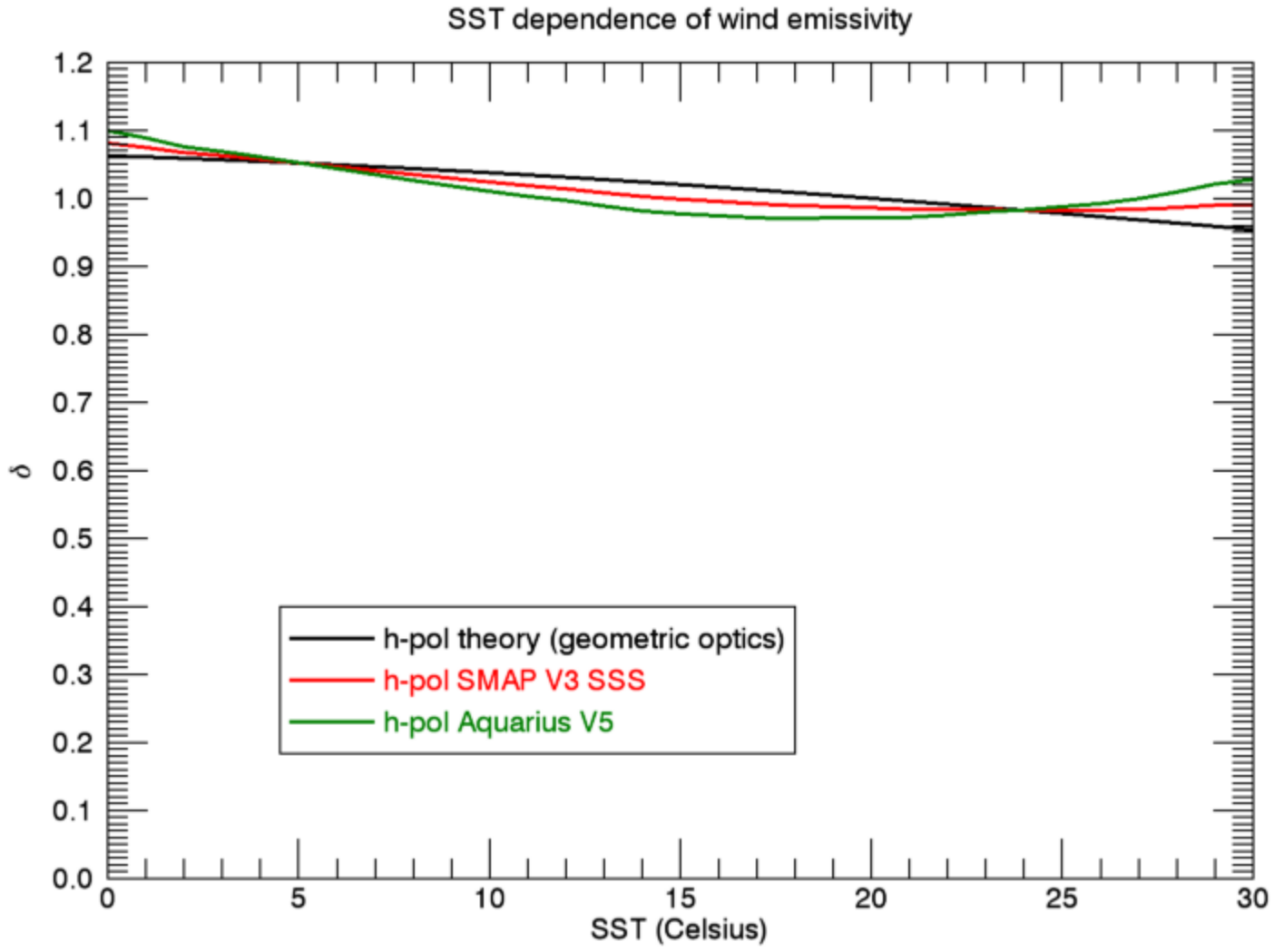




Reference salinity is used for

1. Deriving geophysical model function (offline).
2. Calibration: 7-day global average is fixed to reference SSS.

Important for SMAP (tomorrow's talk)


SST dependence of wind emissivity
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
δ
0
5
10
15
20
25
30
SST (Celsius)
h-pol theory (geometric optics)
h-pol SMAP V3 SSS
h-pol Aquarius V5