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Salinity Remote Sensing from SMAP

NASA/RSS SMAP Salinity Product

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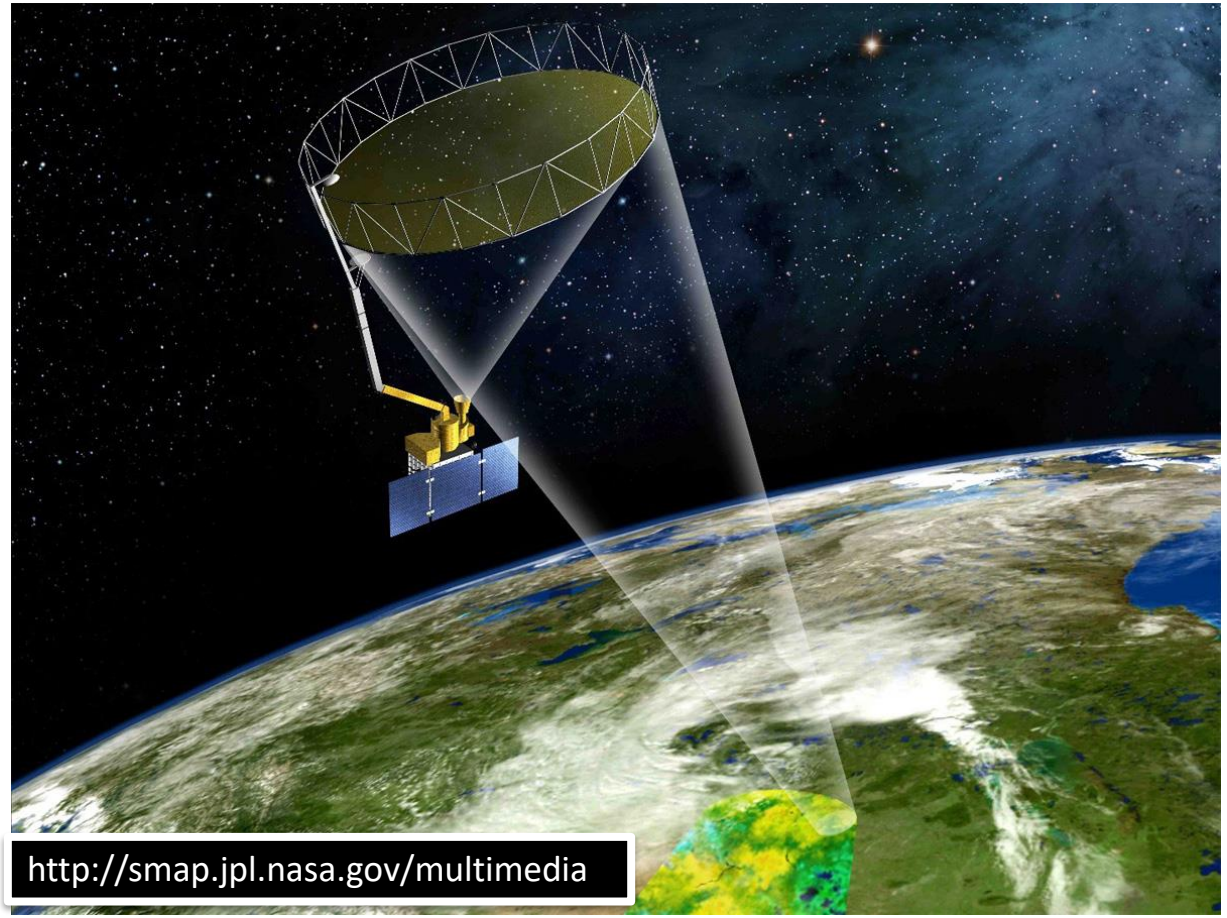
Global Ocean Salinity and the Water Cycle Workshop
WHOI, May 22 - 26, 2017

Outline

- Overview of SMAP Instrument
- RSS SMAP Salinity Retrieval Algorithm
- SMAP versus Aquarius
- Validation
- Data Distribution
- Future Plans

SMAP

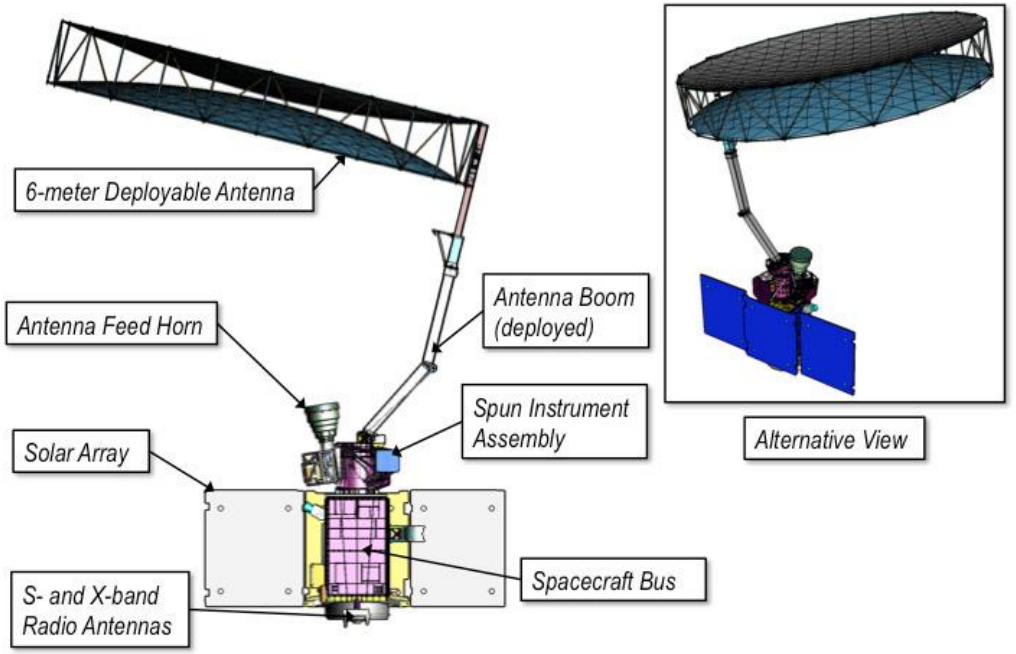
Soil **M**oisture **A**ctive **P**assive



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

SMAP

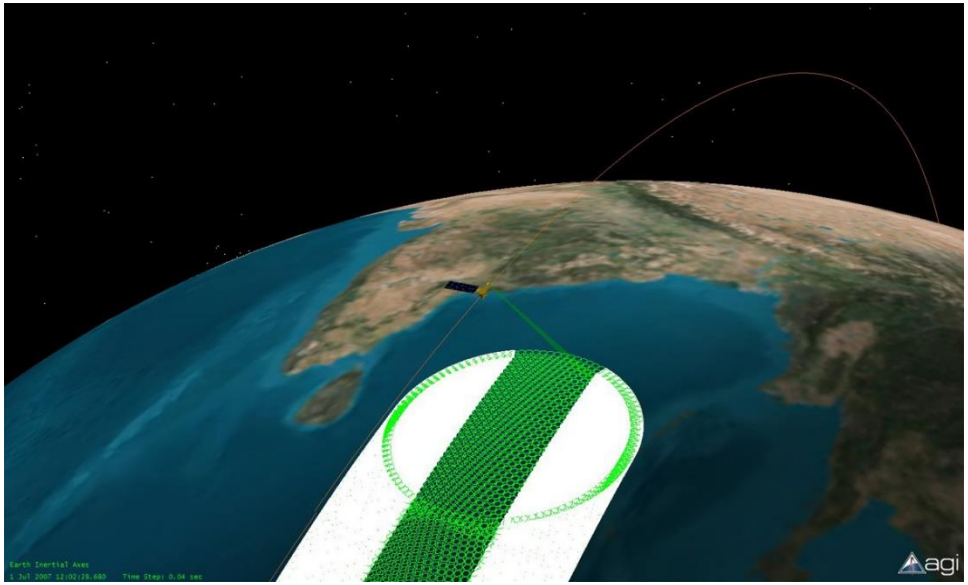
Instrument



- 6-meter mesh antenna.
- Conical scanning @ 14.6 rpm. Scan time: 4.1 sec
- Earth Incidence Angle: 40°.
- Radiometer: Center frequency: 1.41 GHz ~~+ Radar.~~
- Taking observations since April 2015.

SMAP

Swath – Footprint - Noise

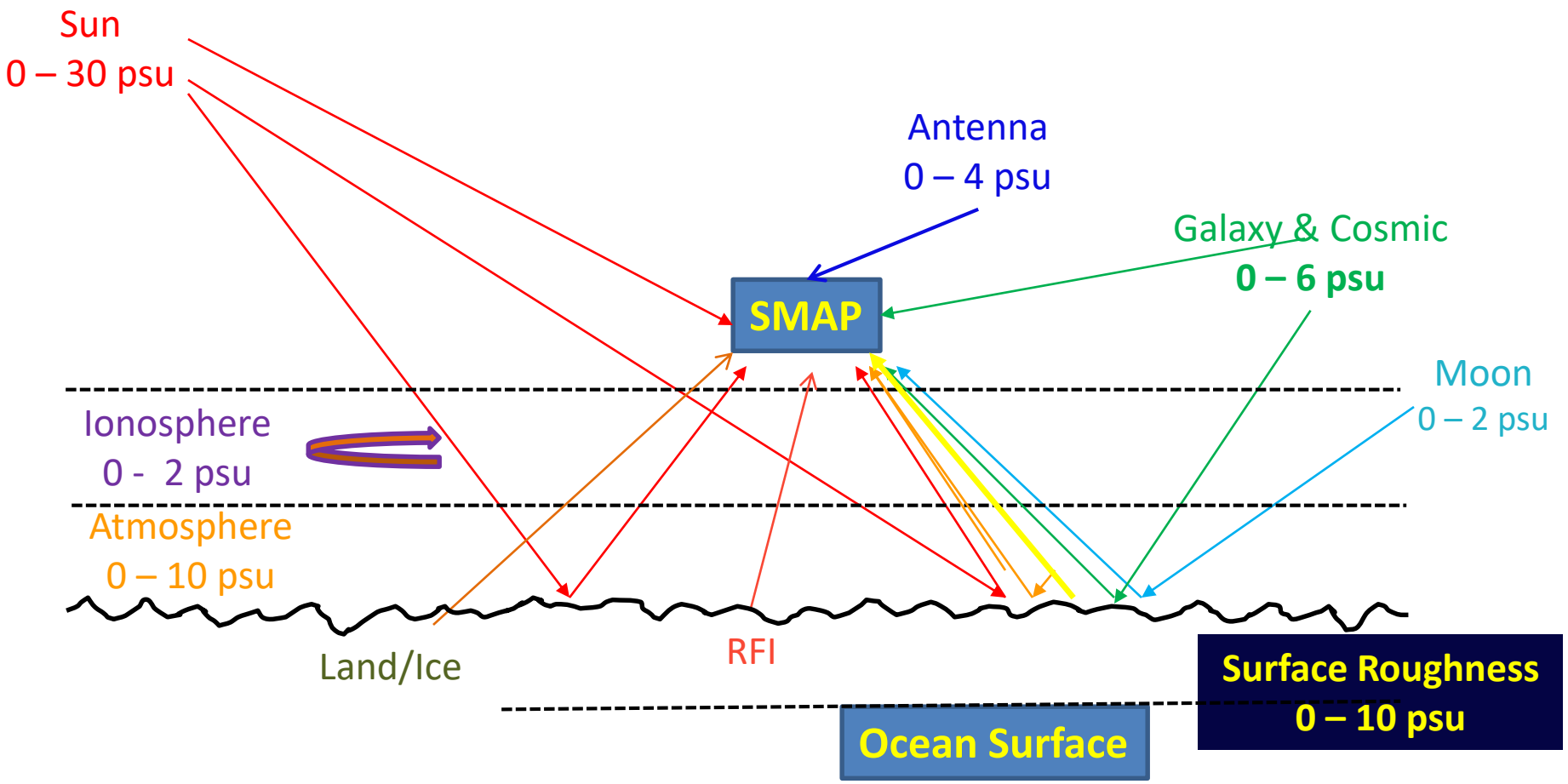


- Full 360° scan views the Earth.
- 1000 km wide swath.
- 3-dB (half power) footprint size: 40 km.
- Time for sampling 1 footprint: 17 msec.

Aquarius and SMAP have both about **the same instrument noise**.
The Aquarius data are pre-averaged during L1/L2 processing. The SMAP data do not.
Noise figures @ L2: **Aquarius ≈ 0.4 psu**. **SMAP ≈ 1.0 psu**.

SMAP Salinity Retrieval Algorithm Challenge

Removal of Many Large Spurious Signals



Needs to be done to 0.2 psu = 0.1 Kelvin accuracy

SMAP Salinity Retrieval Algorithm

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Basic Steps

adapted from Aquarius

SMAP Antenna Temperatures
calibrated + RFI filtered

↓

Remove antenna effects

↓

Remove space contributions:
galaxy, sun, moon, cold space

↓

Top of the Ionosphere
Brightness Temperatures

↓

Correct for Faraday Rotation
In Earth Ionosphere (3rd Stokes)

↓

Top of the Atmosphere
Brightness Temperature

↓

Remove atmospheric attenuation
(O_2, cloud and H_20 Absorption)

→

Sea-Surface Brightness
Temperature

↑

Remove Surface
Roughness Effects (Wind)

↑

Specular Brightness
Temperature

↑

Find Salinity for which
emissivity of Meissner-Wentz
2012 dielectric model matches
specular TB

↑

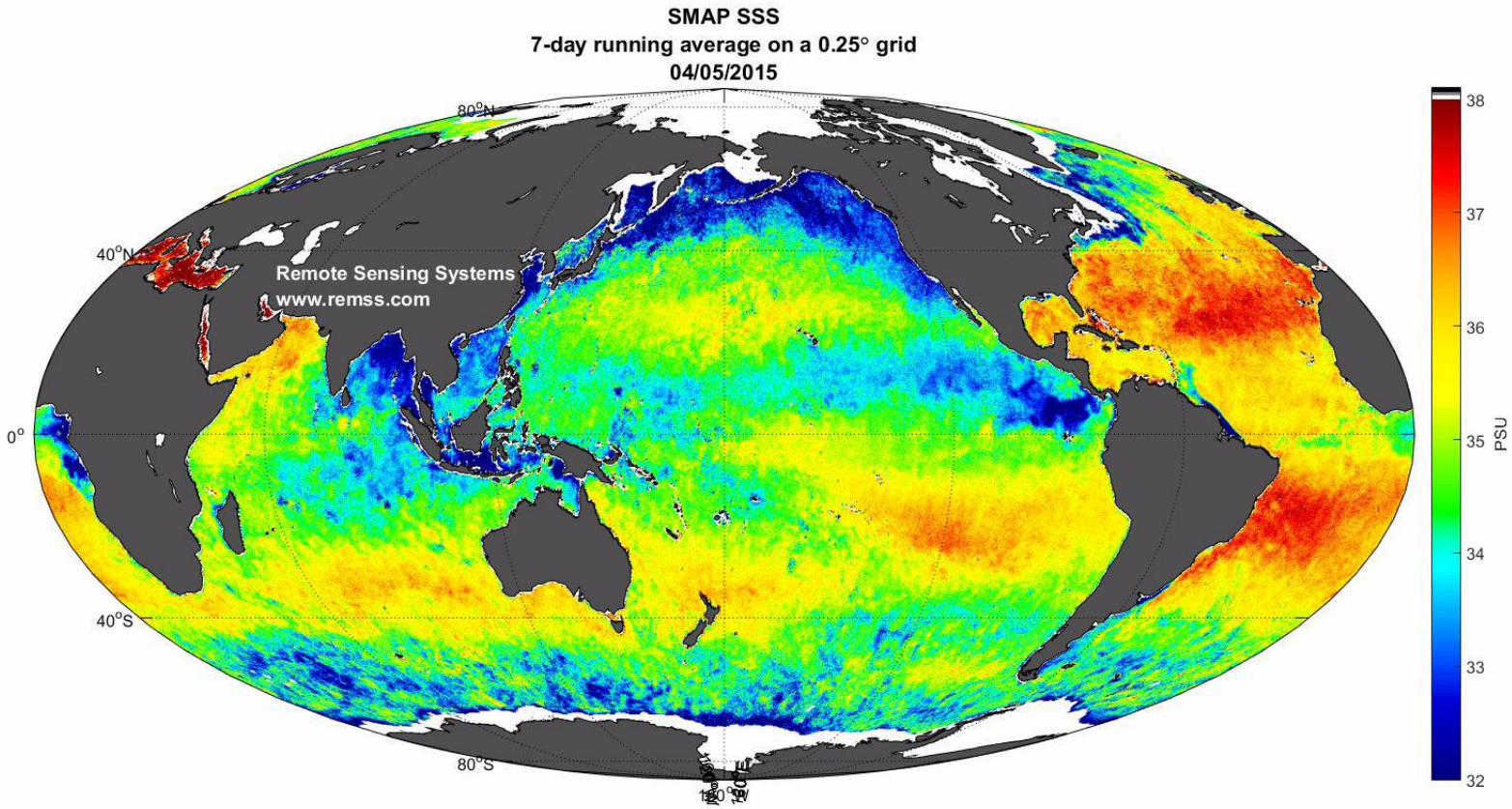
SMAP
Salinity

As it was the case with Aquarius, **the SMAP salinity retrievals are constrained by the global average,** which is matched to a **reference field (currently HYCOM).**

Other than the global average, the **HYCOM reference field is NOT an input** in the SMAP salinity retrieval.

SMAP Salinity

May 2015: First light NASA/RSS SMAP SSS image



Running 8-day average (April – August 2015)

Forward – Backward Look

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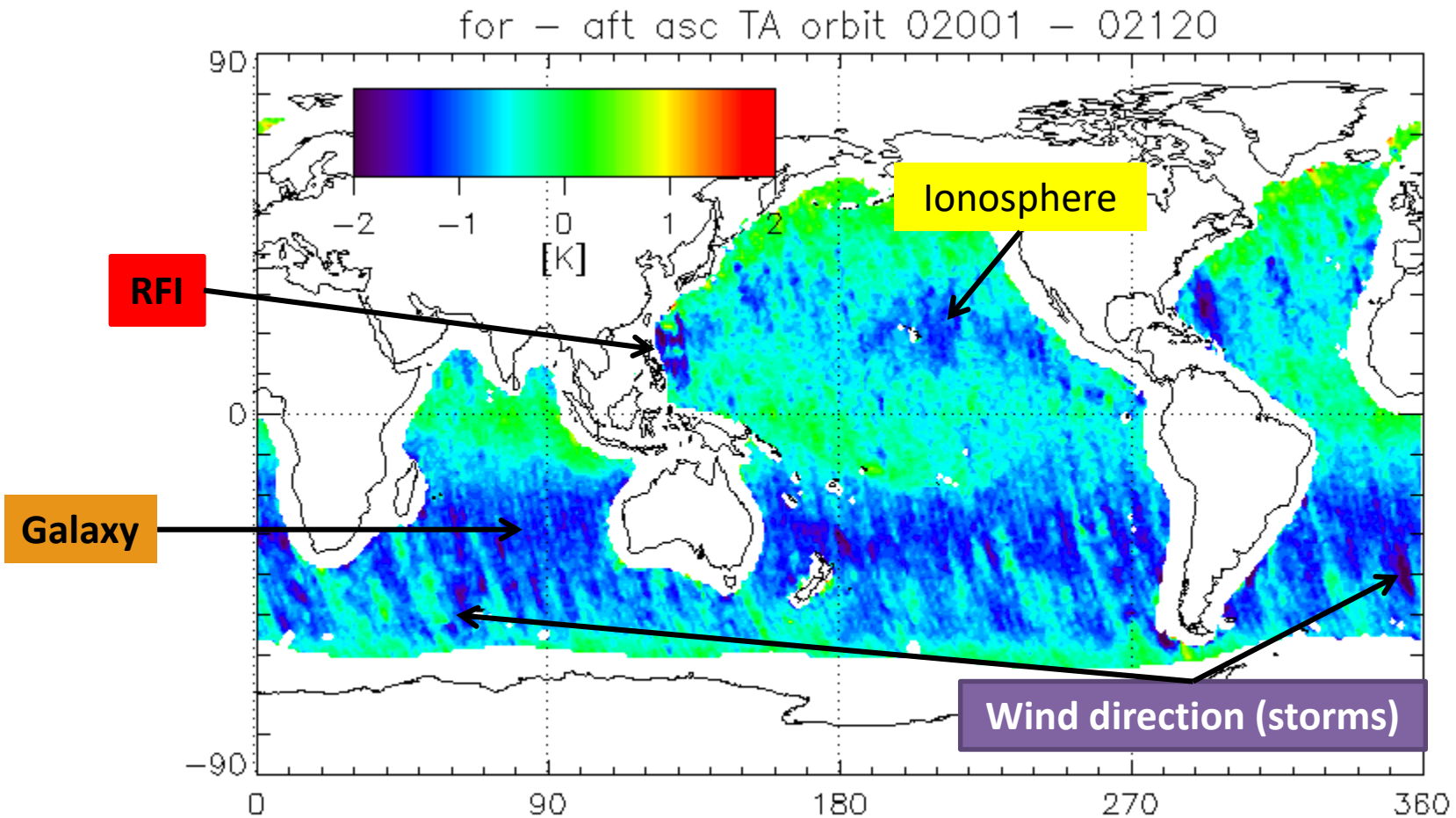
allows assessment of removal of spurious signals if they depend on looking direction without any external reference salinity field

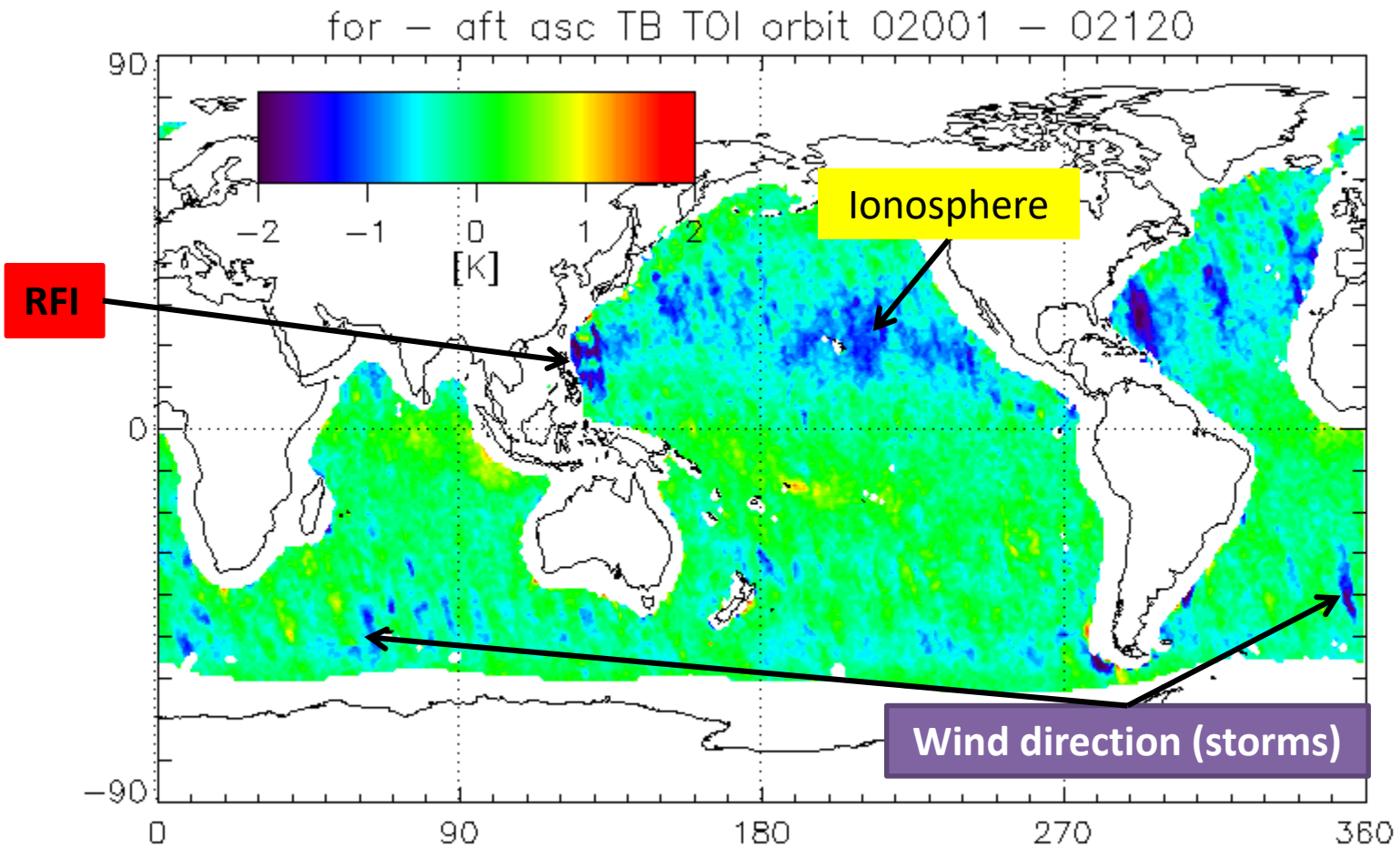


SMAP T_B (radiance)

1 Kelvin ΔT_B = 2 psu ΔSSS

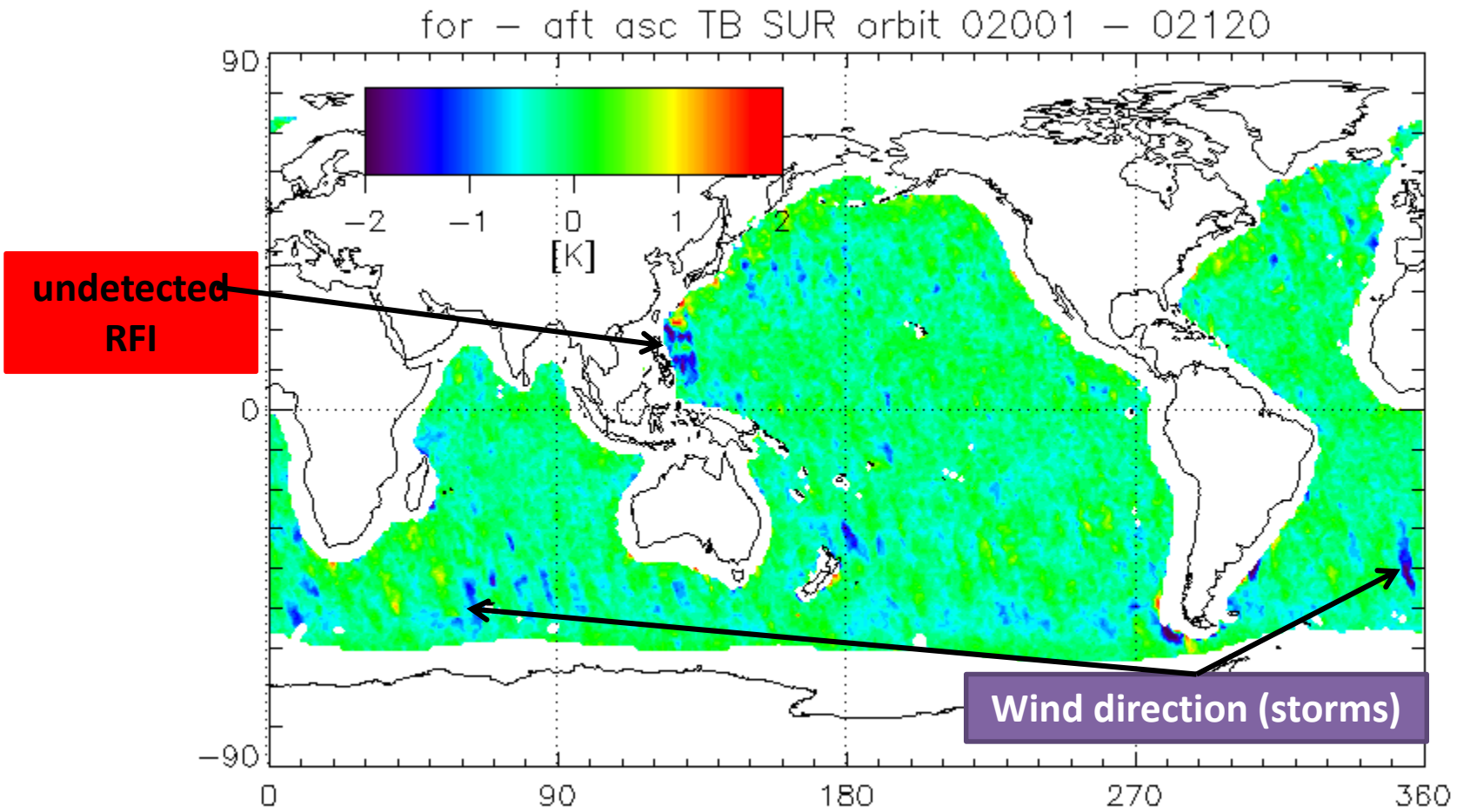
Forward – Backward Look

after removing galactic reflection



Forward – Backward Look

after removing Faraday Rotation in Earth Ionosphere



Forward – Backward Look

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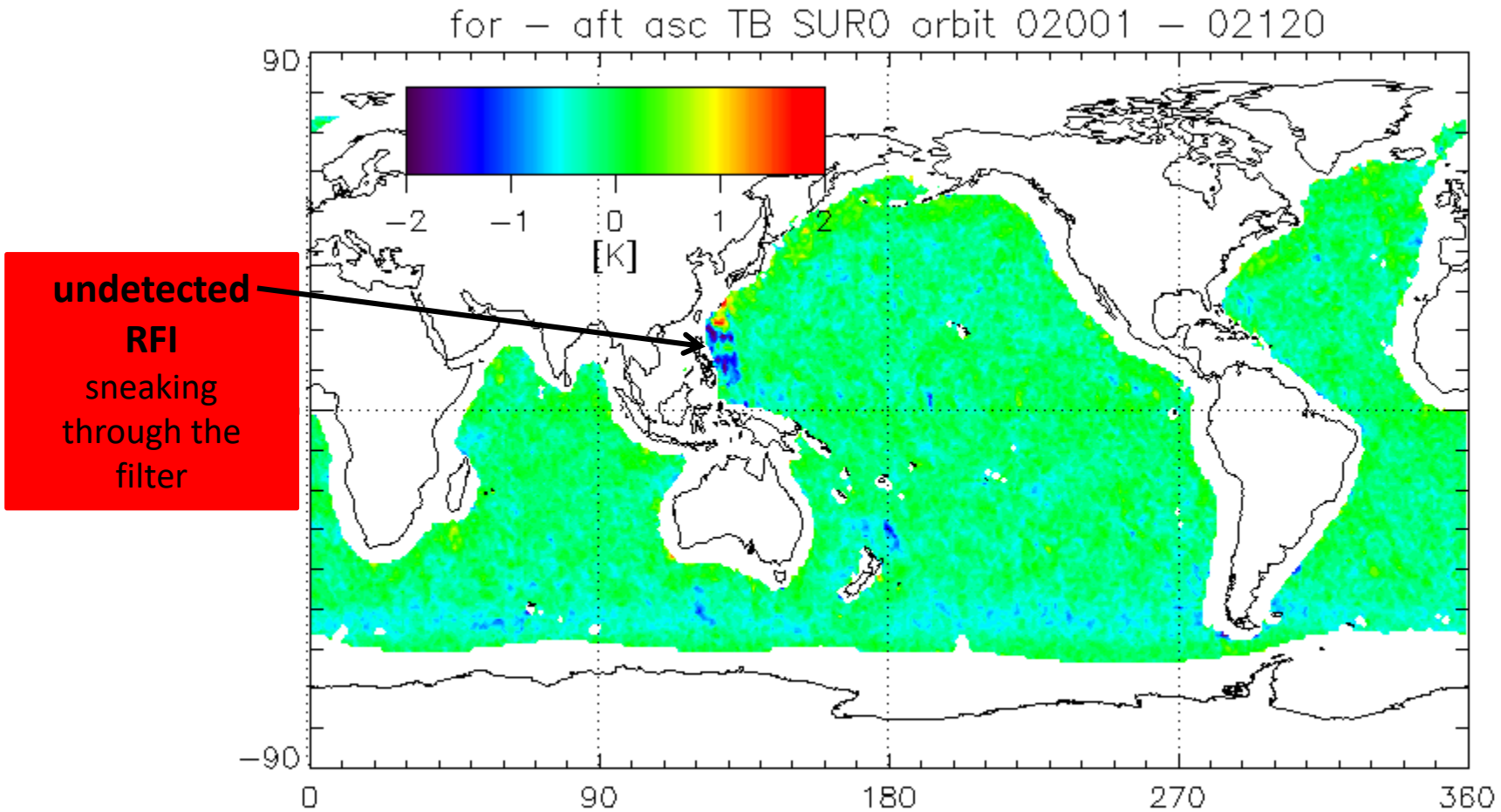
after removing wind direction component of surface emissivity



Reflected Galaxy (1)

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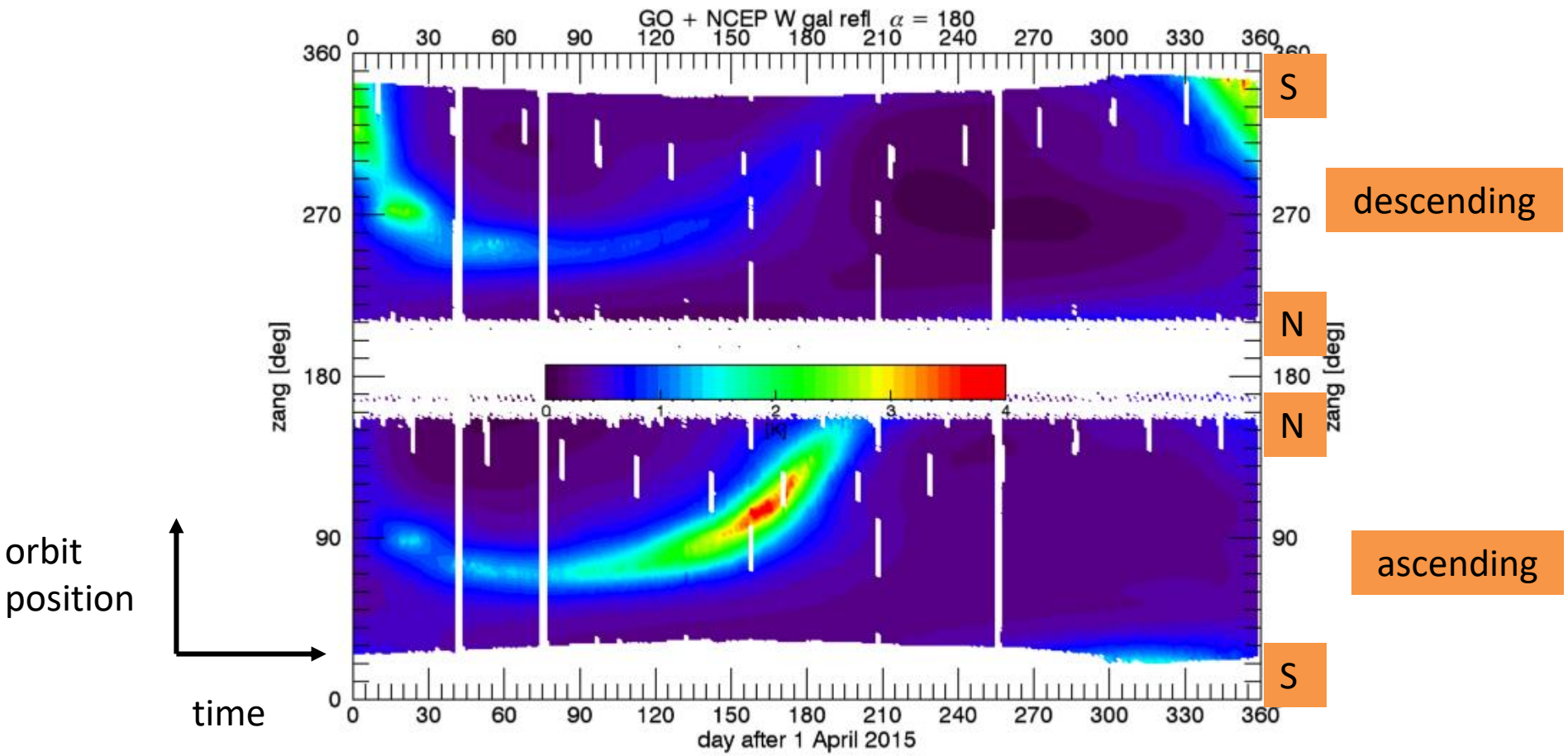
One of the major error sources

SMAP For-Aft allows improvement of galaxy model

Tilted facet model of reflected galaxy from rough ocean surface



Reflected Galaxy (2)

Remote Sensing Systems
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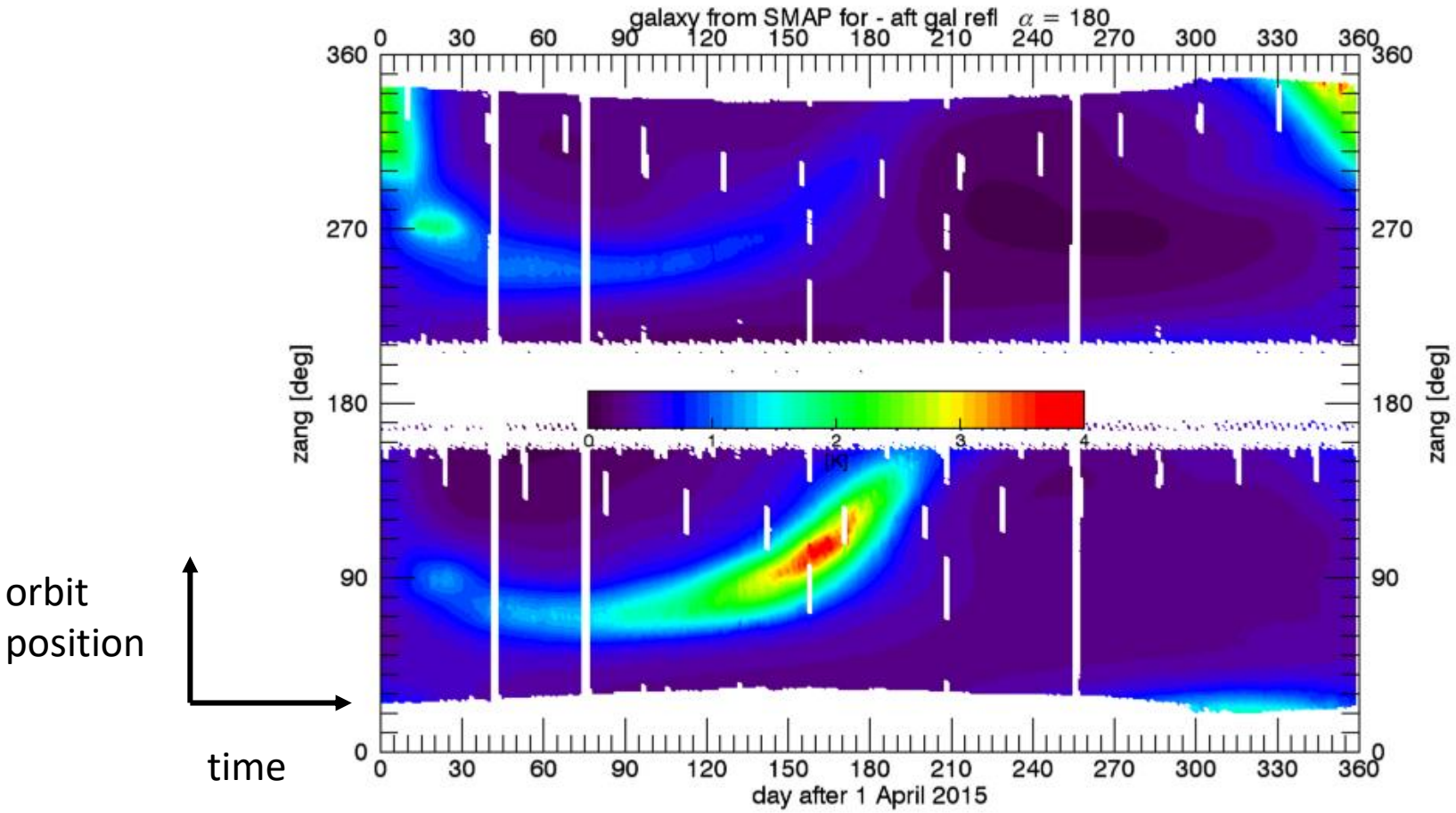
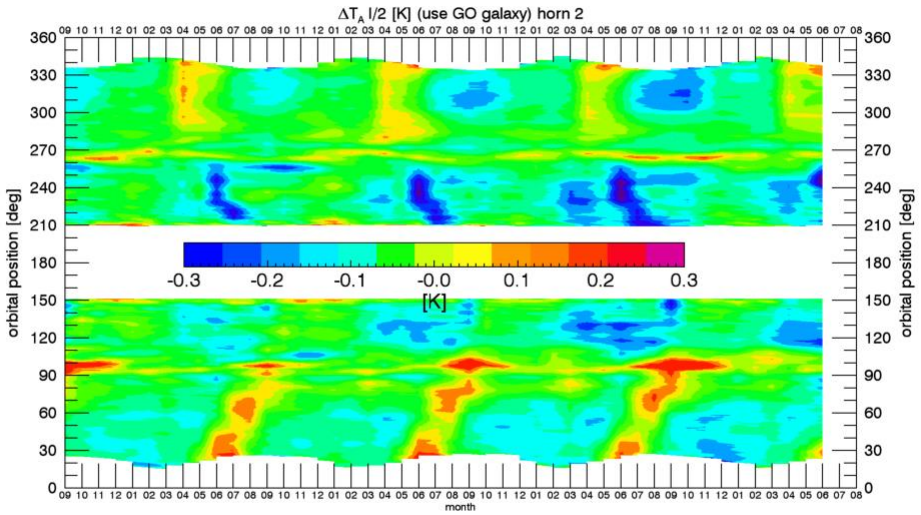
One of the major error sources

SMAP For-Aft allows improvement of galaxy model

Reflected galaxy from SMAP for – aft
corresponds to effective increase in roughness



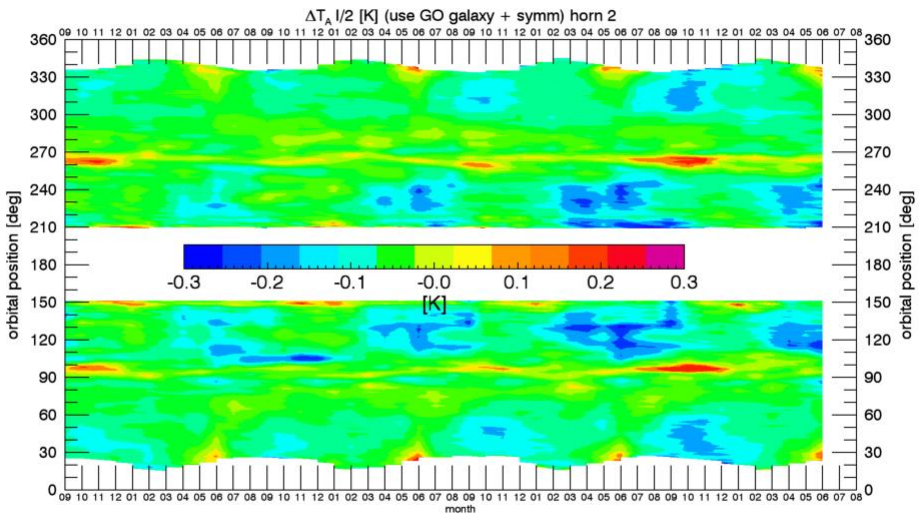
The SMAP for-aft galaxy model is used in the Aquarius V5 Salinity Retrievals



Aquarius TB (or salinity) biases using tilted facet model of reflected galaxy from rough ocean surface.

orbit position

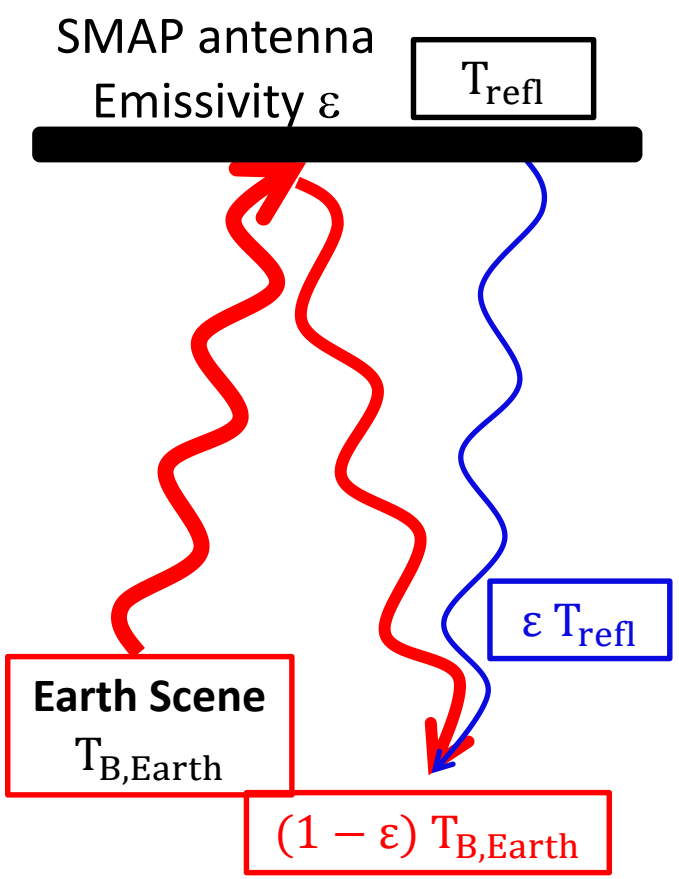
time



Aquarius TB (or salinity) biases using model of reflected galaxy based on SMAP for – aft.

Emissive Antenna

requires additional calibration effort



- The SMAP reflector mesh is **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.
  - Thermal model appears to be inaccurate when S/C goes into eclipse (50 K temperature change).
- **Emissivity** about 1%. This is **4 times larger than pre-launch value**, which is used in SMAP TB L1B.
- **Use of SMAP L1B TB (Version 3) would cause large biases (1 -2 psu) in the salinity retrieval.**
- The Aquarius antenna was not emissive.

Reflector Temperature

JPL Thermal Model

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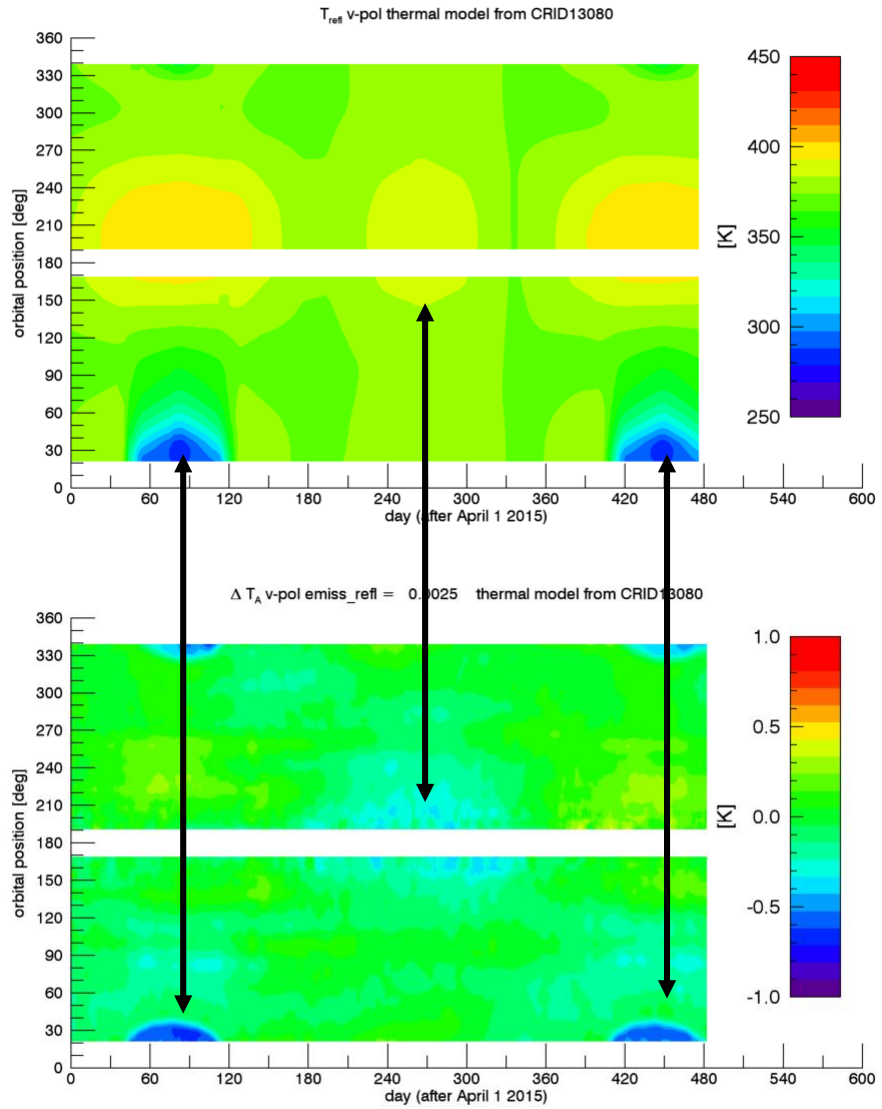
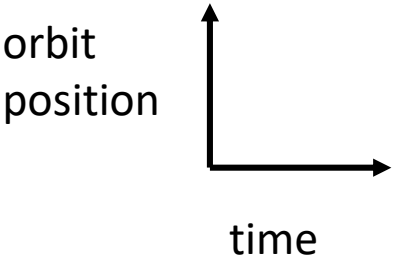
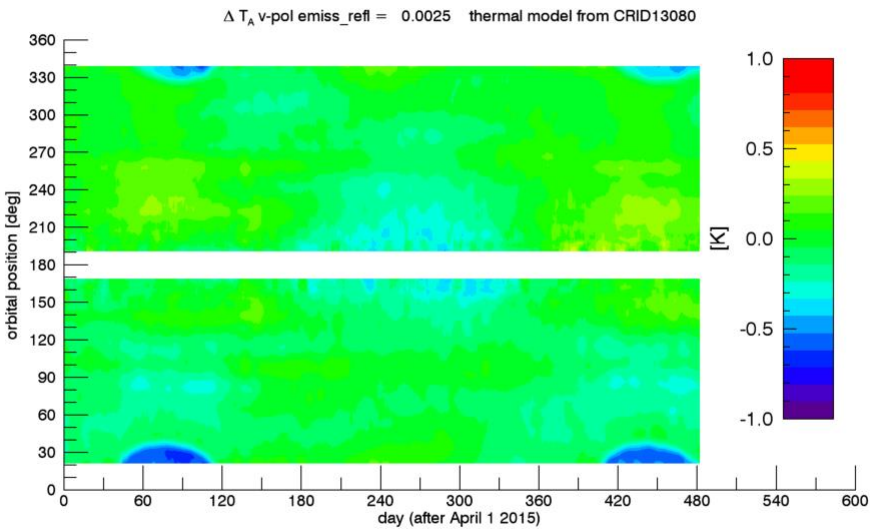
T_{refl}: JPL thermal model

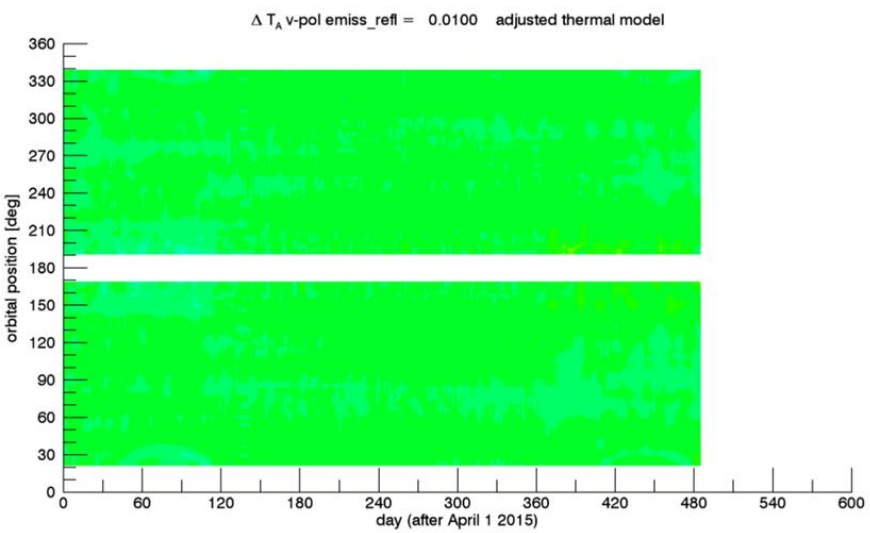
TB Bias

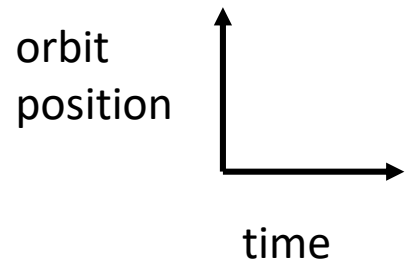




Adjusted Reflector Temperature







TB biases with JPL thermal model

static table based on zonal average of reference salinity

assume same reflector temperature for v/h-pol.

annual repeat cycle for reflector temperature

TB biases with adjusted reflector temperature in RSS V2 Release

Other Differences between SMAP and Aquarius

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- **Correction for surface roughness**
  - **SMAP lost its radar.**
  - Use **wind speeds from WindSat and SSMIS F17.**
  - Same ascending node time as SMAP (good overlap).
  - Unavailable in rain (use NCEP wind speeds).
- **Sun glint**
  - Aquarius was staring away from the sun. SMAP performs full scan.
  - SMAP sees sun reflection (glint) from the ocean surface
  - Can be large (exceeding 15 K = 30 psu).
  - Solar radiation at L-band is strong and variable (1 Mio Kelvin).
  - Signal enters through sidelobes of the antenna (uncertainties).
  - Signal depends on surface roughness (not well modelled).
  - Approach: Flag out areas of potential strong signal (<10% lost data).

Time Mean SMAP – ARGO

1-deg monthly average. Scripps ARGO fields

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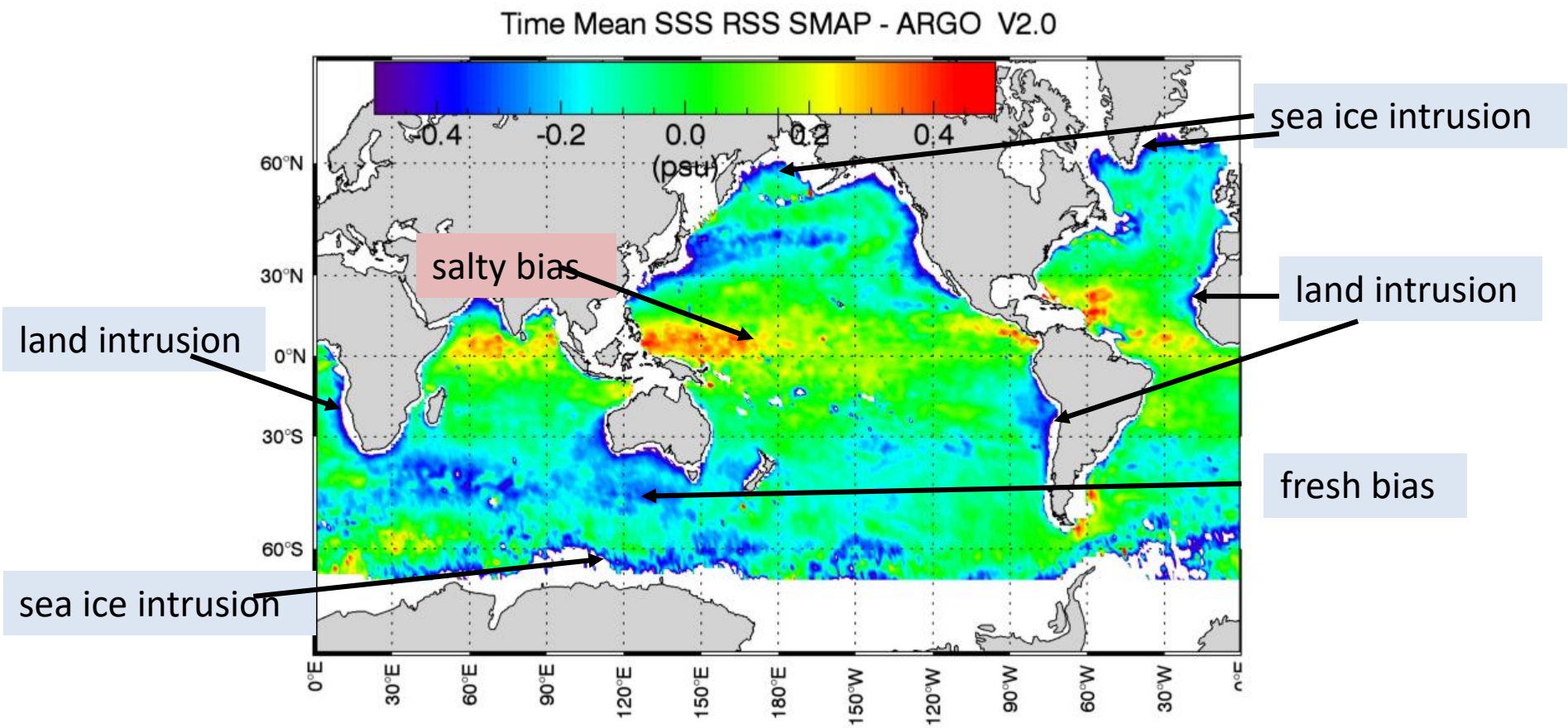
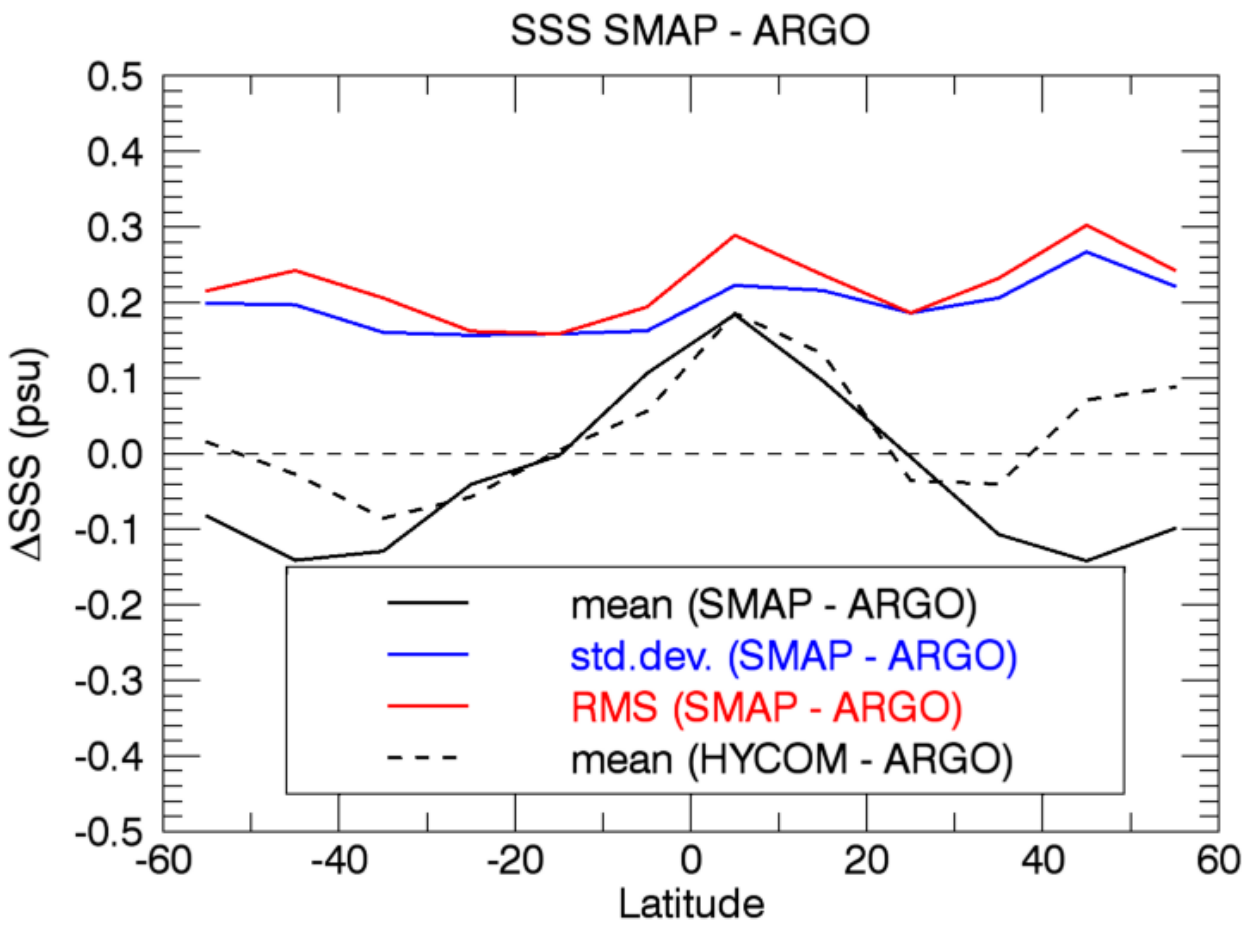


Zonal Averages: SMAP - ARGO

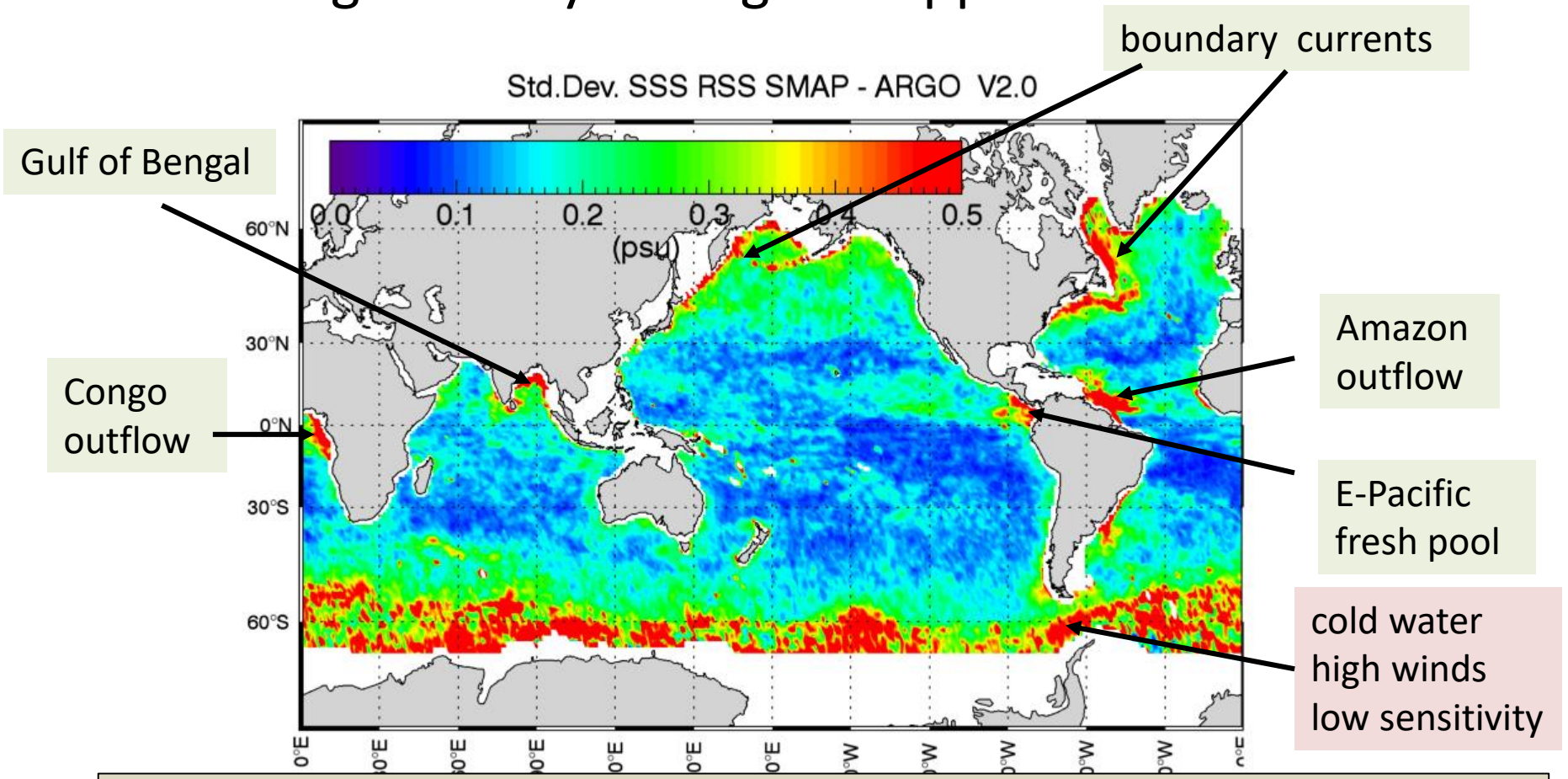


The **HYCOM field** was used as reference for **developing the geophysical model function and the adjusted reflector temperature.**

The **salty biases** (0.15 psu zinal average) **between SMAP and ARGO in the tropics** are mainly a reminiscent of the salty bias between **HYCOM and ARGO.**

Std.Dev. of Time Series SMAP – ARGO

1-deg monthly average. Scripps ARGO fields



In most cases the observed std.dev. between SMAP and OI ARGO field is not due to an error in SMAP. In many instances it is due to poor sampling of ARGO measurements. **As it was the case with Aquarius, it is the systematic errors (biases) we need to worry about.**

Global Performance Estimate

SMAP (RSS V2.0) – ARGO (Scripps) 1-deg monthly average [60S, 60N], SST>5°C open ocean (land and sea ice fractions < 10^{-3})	
BIAS	-0.03 psu
RMS Difference	**0.22 psu**
RMS Difference AQUARIUS – ARGO	0.19 psu

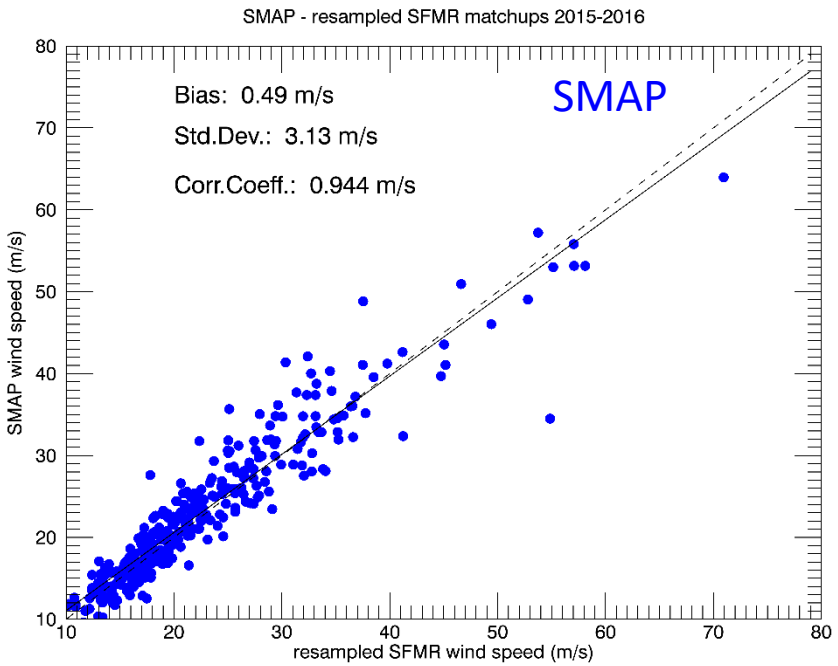
Triple Collocation Estimate: RMS differences SMAP – ARGO - HYCOM	
SMAP - ARGO	0.22 psu
SMAP - HYCOM	0.24 psu
HYCOM - ARGO	0.18 psu
Estimated RMS SMAP	**0.19 psu**
RMS AQUARIUS (triple point)	0.17 psu

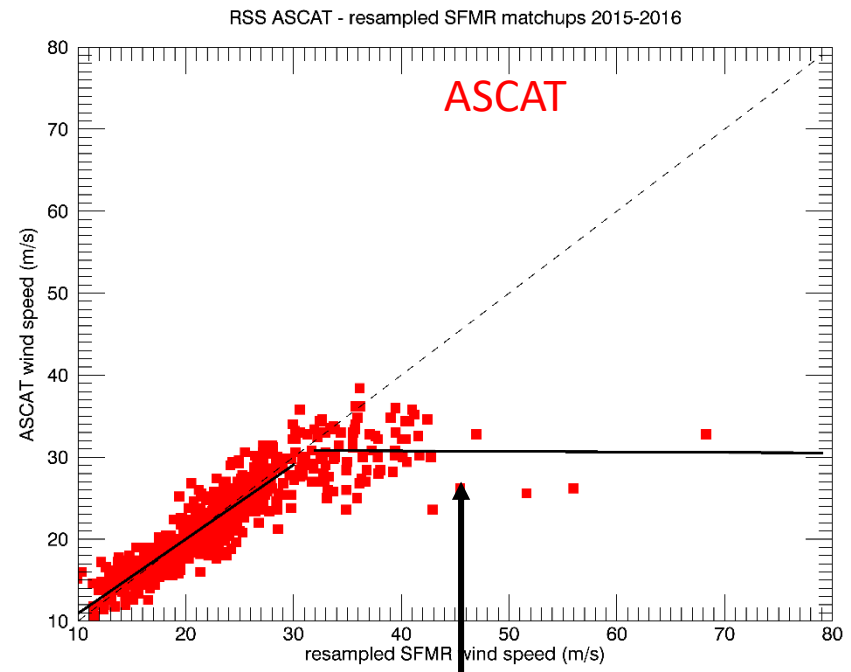
SMAP is an excellent high wind sensor

L-band radiometer (SMOS, SMAP) has good sensitivity up to 70 m/s.

Not affected by precipitation.

T. Meissner, L. Ricciardulli + F. Wentz: BAMS 2017 in print.
http://journals.ametsoc.org/doi/10.1175/BAMS-D-16-0052.1.





satellite wind speed

SFMR aircraft wind speed
re-sampled to satellite resolution

VV-pol scatterometer
signal saturates

Realistic Values of Intensity and Wind Radii in Tropical Cyclones

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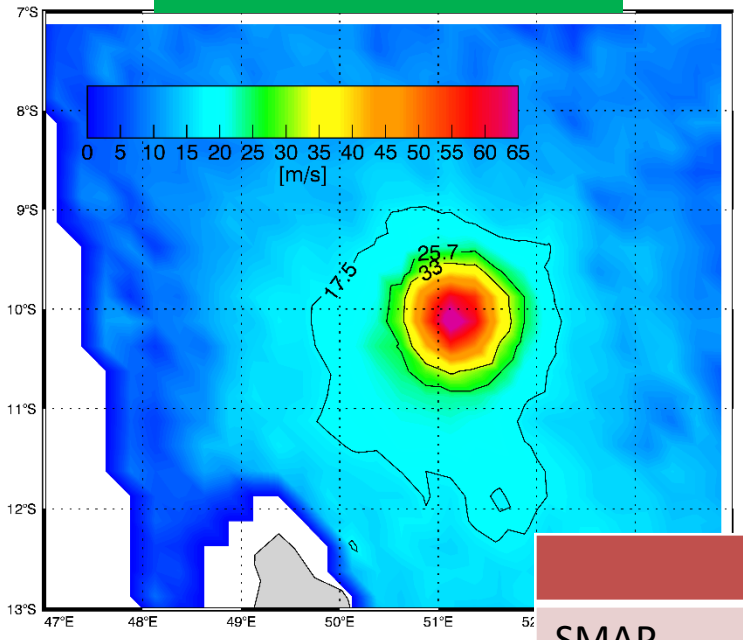
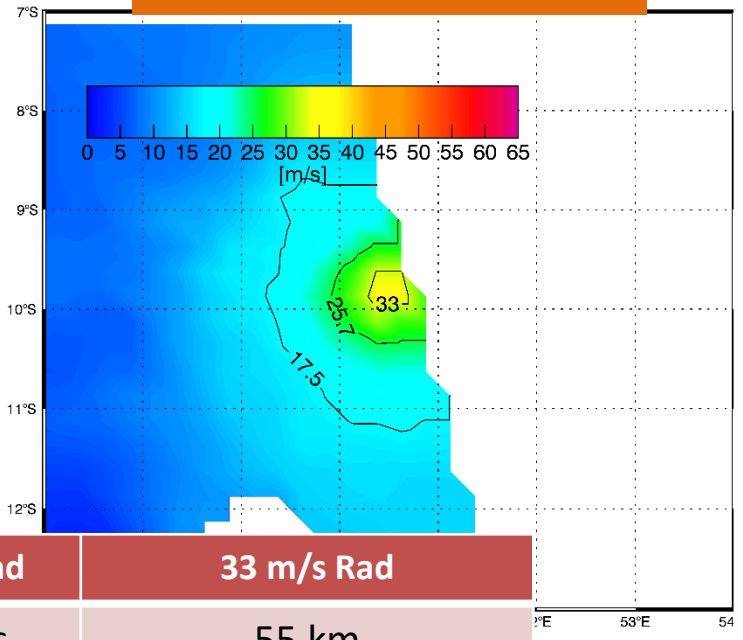
SMAP: cat.5 TC



ASCAT: cat 1 TC



	Max wind	33 m/s Rad
SMAP	70 m/s	55 km
ASCAT	35 m/s	10 km
Best Track 10-min sustained	69 m/s	63 km

TC Fantala (Seychelles) April 17, 2016.
Estimated max. 10-min sustained winds: 69 m/s.

NASA/RSS SMAP SSS Version 2 Release

Data Distribution

- **Version numbering does NOT match other SMAP data versions** (including JPL product).
  - partly different calibration
  - different gridding
  - different algorithm
- **available at**
  - **RSS** www.remss.com/missions/smap/salinity
  - **PO.DAAC** ftp://podaac-ftp.jpl.nasa.gov/allData/smap/
- Currently batch processed once every month
  - we consider producing the data with less latency or near real time if there is demand
  - like Aquarius Quick-Look
- netCDF4 (CF and ACDD compliant)
- Detailed Release Notes (ATBD, Data Format SPEC, Validation)

NASA/RSS SMAP SSS Version 2 Release

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Data Products

- **Level 2C**
  - swath data resampled on fixed ¼ deg Earth grid (like WindSat L2)
  - keep original resolution
  - no noise reduction. noise ≈ 1.0 psu
  - contains all necessary swath information
  - brightness temperatures: antenna, TOI, TOA, surface
  - **Q/C flag (important!)**
- **Level 3**
  - **¼ deg maps**
    - real spatial resolution about 40 km.
  - **Monthly maps**
  - **Daily 8-day running average maps**
    - +/- 3 ½ days from center day
    - SMAP repeat cycle = 8 days
  - **contains sea surface temperature, land fraction, sea ice fraction**
    - allows user flexibility

Summary

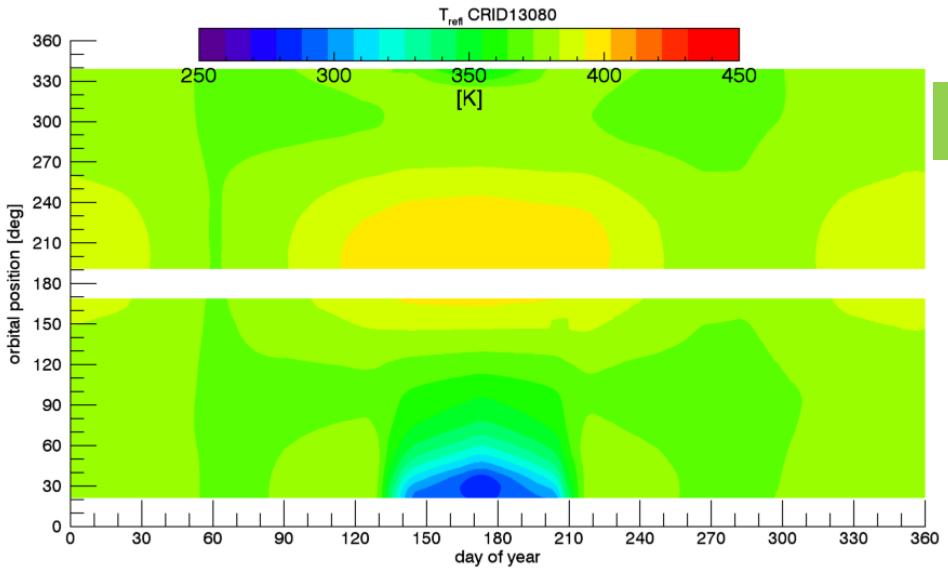
- **SMAP** is able to measure ocean surface salinity over the open ocean with **almost the same accuracy** as **Aquarius**.
- **SMAP** has **better resolution** (40 km) than **Aquarius** (100 – 150 km).
- **SMAP's emissive reflector** does require static, **zonal information** from an external **reference salinity field** (HYCOM, ARGO, …)
  - loss of predictive power for zonal averages
- **SMAP's 2-look capability** helps to improve the salinity retrievals for SMAP and Aquarius.
- **SMAP** is an **excellent high wind sensor**.
  - Future L-band missions.

Path forward

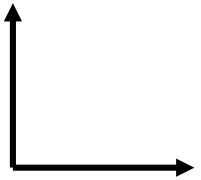
- Next NASA/RSS release (V3) planned for early 2018.
- Geophysical model function fully consistent with Aquarius V5, which will be released in late 2017.
- As with Aquarius V5 we will switch from HYCOM to ARGO as reference salinity.
  - Eliminate small positive bias between SMAP and ARGO in tropics.
- Include uncertainty estimates.
- Improved correction for intrusion from land surfaces thtough sidelobes.
  - Improve retrieval accuracy close to land.
  - Possibly also near sea ice edge (further out).

Backup Slides

Adjusted Reflector Temperature



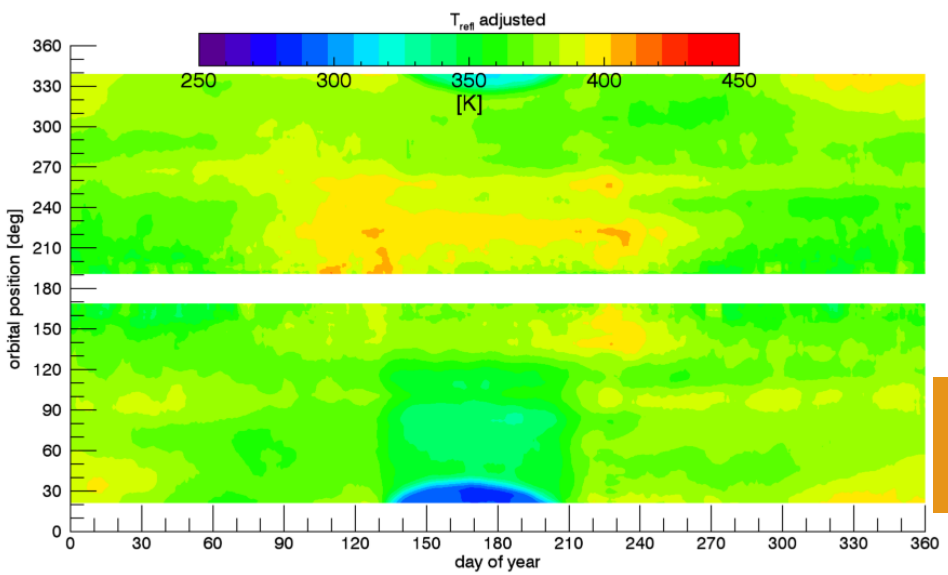
T_{refl}: JPL thermal model



static table based on zonal average of reference salinity

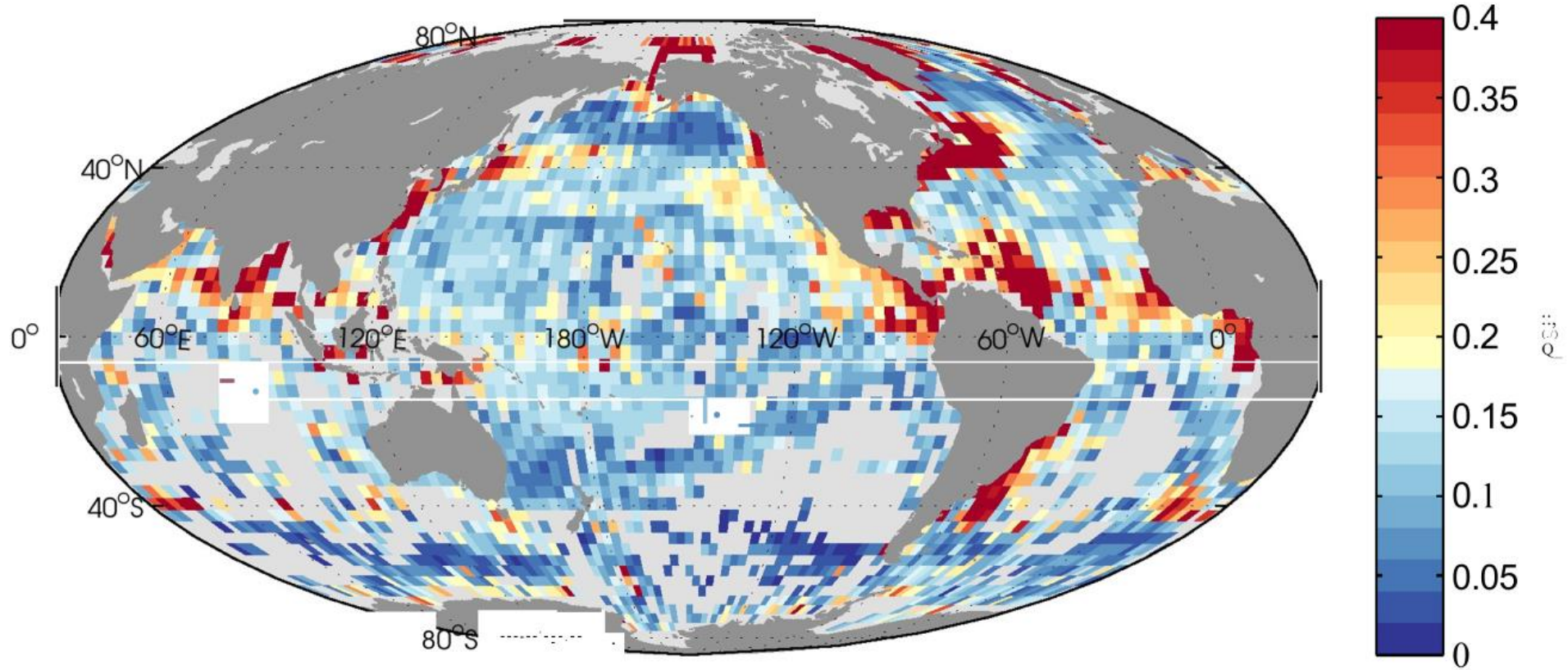
assume same reflector temperature for v/h-pol.

annual repeat cycle for reflector temperature



T_{refl}: adjusted reflector temperature in RSS V2 Release

TSG std.dev.



Courtesy of K. Drushka