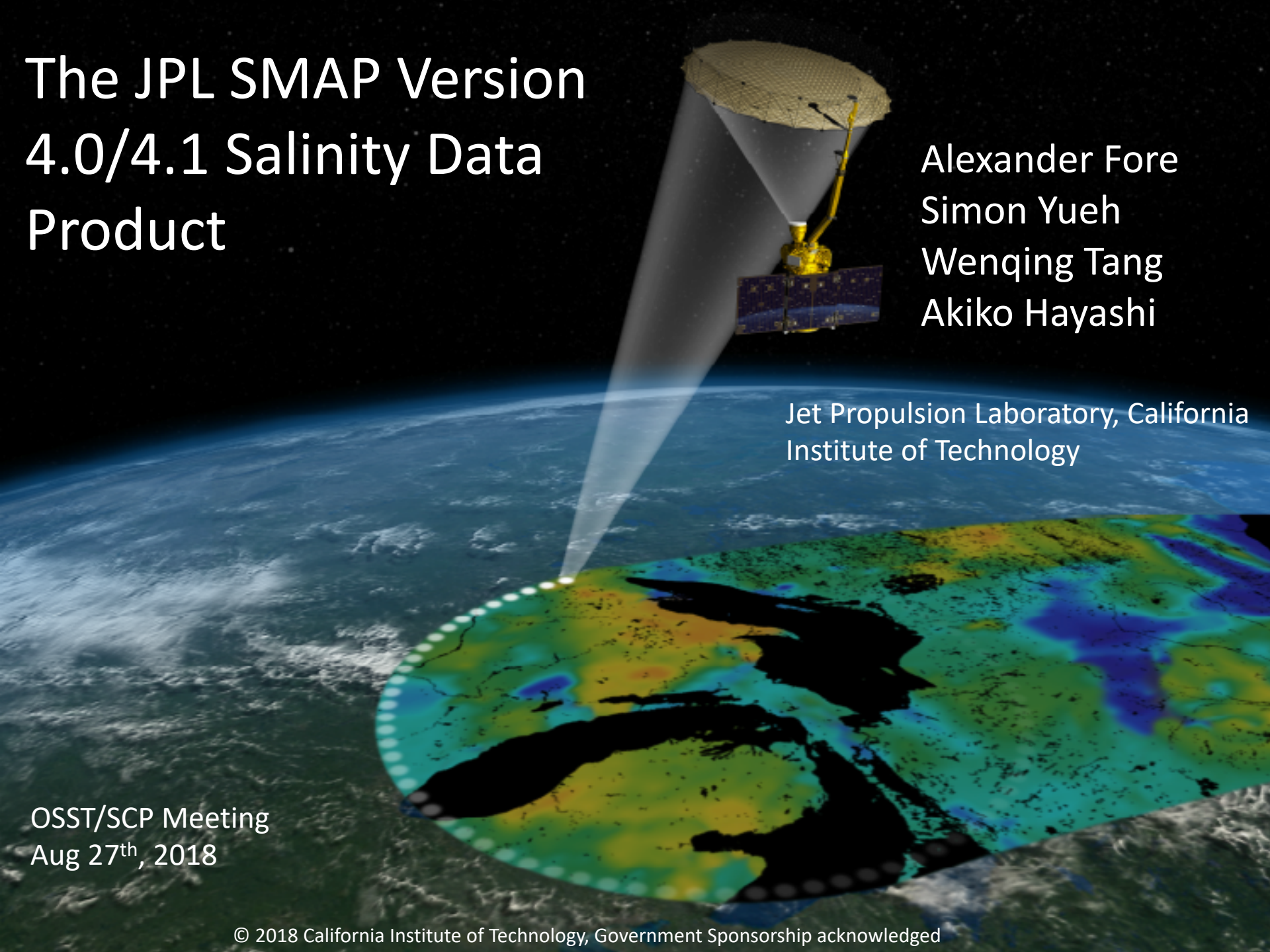
The JPL SMAP Version 4.0/4.1 Salinity Data Product



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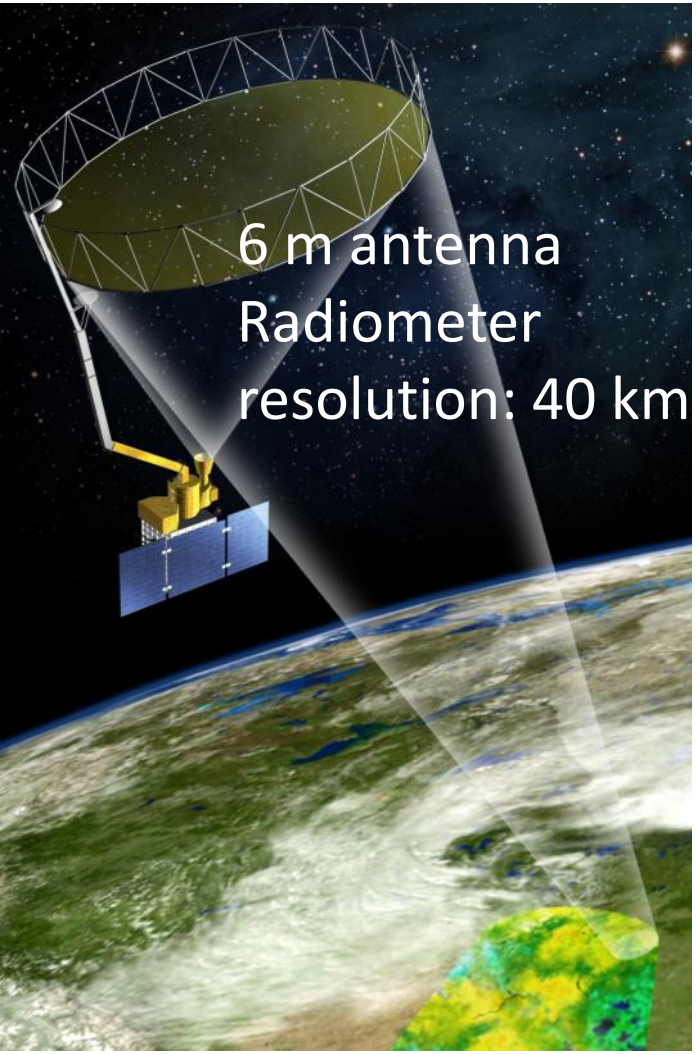
OSST/SCP Meeting
Aug 27th, 2018

SMAP Overview



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

Primary Science Objectives

- Global, high-resolution mapping of soil moisture and its freeze/thaw state to
  - Link terrestrial water, energy, and carbon-cycle processes
  - Estimate global water and energy fluxes at the land surface
  - Quantify net carbon flux in boreal landscapes
  - Extend weather and climate forecast skill
  - Develop improved flood and drought prediction capability

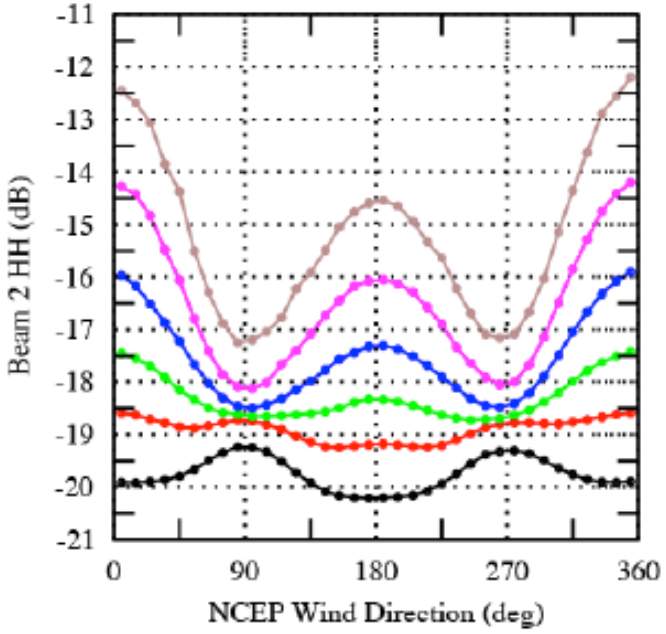
Mission Implementation

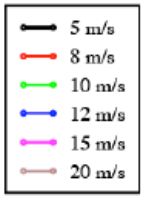
Partners	• JPL (project & payload management, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Launch	• January 31, 2015 on Delta 7320-10C Launch System
Orbit	• Polar Sun-synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band (non-imaging) synthetic aperture radar (JPL) • L-band radiometer (GSFC) • Shared 6-m rotating (13 to 14.6 rpm) antenna (JPL)

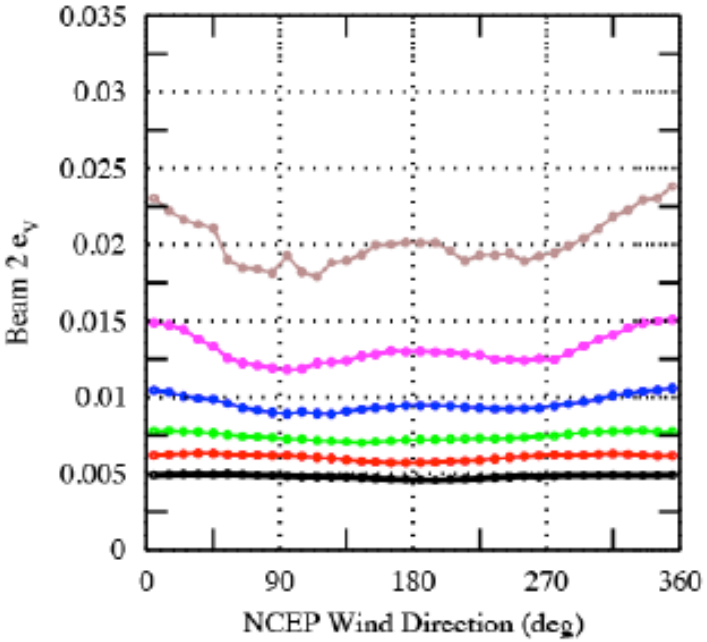
NRC Earth Science Decadal Survey (2007) recommended SMAP as a Tier 1 mission

Effects of Wind/Wave on Radar and Radiometer Signals Observed by Aquarius

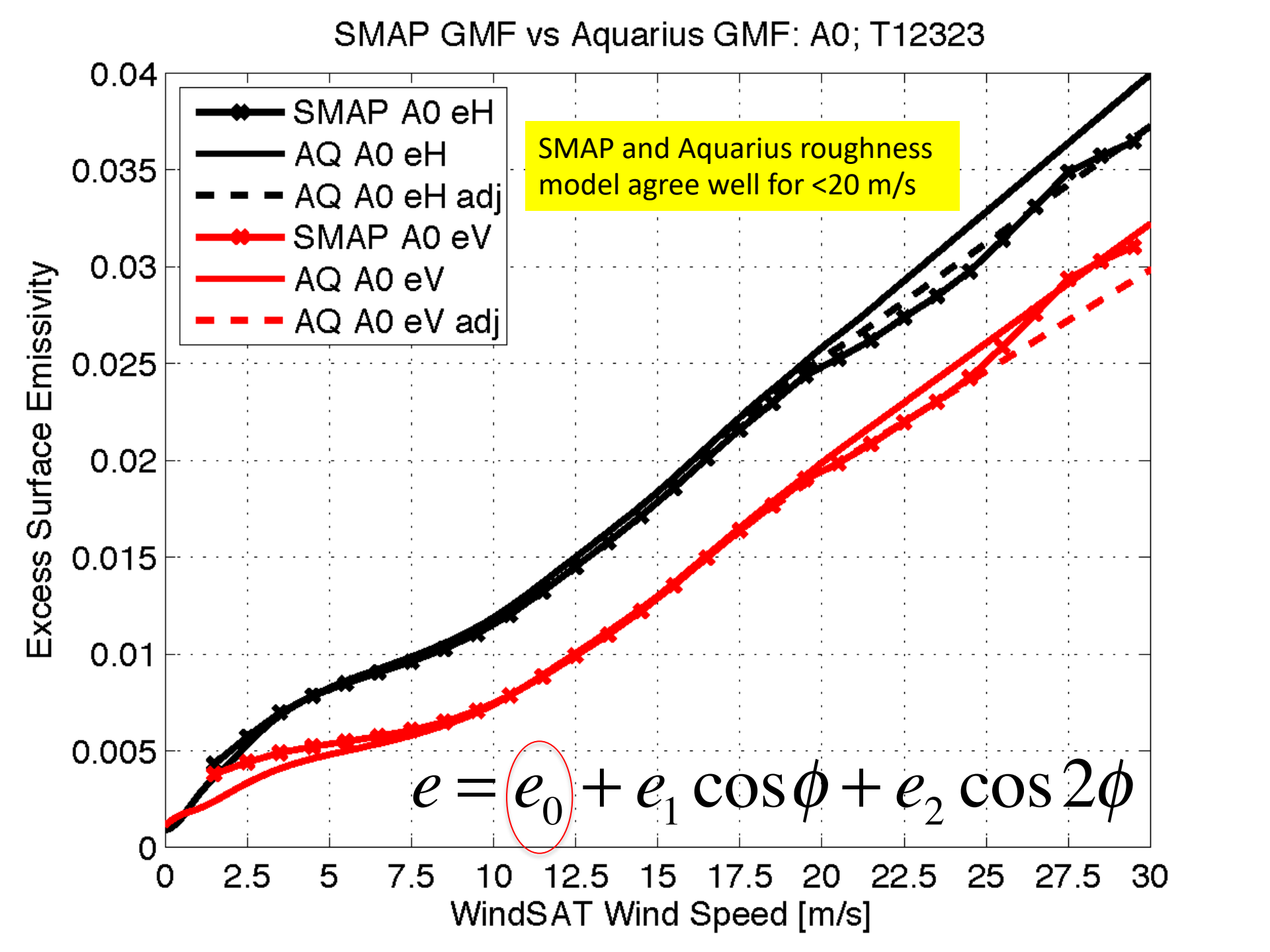
- The matchup of Aquarius data with NCEP wind direction, SSMIS wind speed indicates impact of ocean wind on radar and radiometer signals.
  - The charts below indicate the signal sensitivity for the data from Aquarius beam# 2 (~39 deg incidence angle)







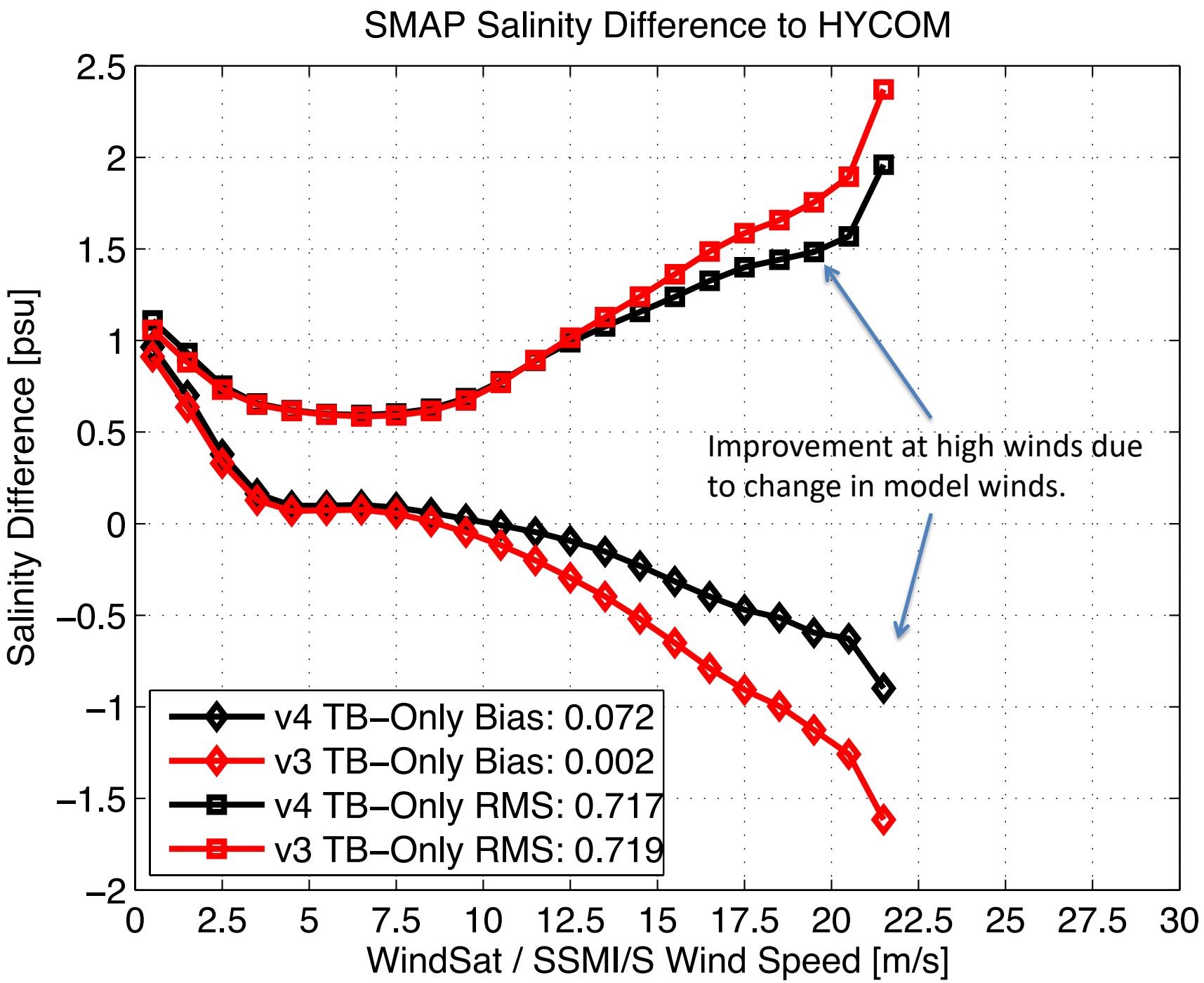
- Radar signals vary with wind speed and wind direction
  - Cosine signal changes sign at about 8 m/s
- Radio emissivity (TB/Ts) varies with wind speed and wind direction


SMAP GMF vs Aquarius GMF: A0; T12323
SMAP A0 eH
AQ A0 eH
AQ A0 eH adj
SMAP A0 eV
AQ A0 eV
AQ A0 eV adj
SMAP and Aquarius roughness model agree well for <20 m/s
$e = e_0 + e_1 \cos\phi + e_2 \cos 2\phi$
Excess Surface Emissivity
WindSAT Wind Speed [m/s]
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30

Radiometer TB SSS and Wind Processing

- Compute delta TB using ancillary data and model
  - Average over each day; use 8 day median filtered value
  - Decimated by fore/aft x asc/dec
- Grid into a 25 km L2A swath grid just like JPL scatterometer products.
  - Gridding method oversamples observations onto the grid.
  - Effective L2 resolution is somewhat larger than 40 km, closer to 50-60 km.
- Estimate wind speed and salinity using constrained objective function minimization.
- New for Version 4: Use NCEP GDAS forecasts for wind speed constraint; yields a significant improvement in high-winds.

$$F(spd, sss) = \sum_i \left[\frac{T_{B,i} - T^m_{B,i}\left(spd, sss, anc\_dir, anc\_swh, anc\_sst\right)}{NEDT_i} \right]^2 + \left(\frac{spd - spd\_anc}{1.5 m/s} \right)^2 ,$$

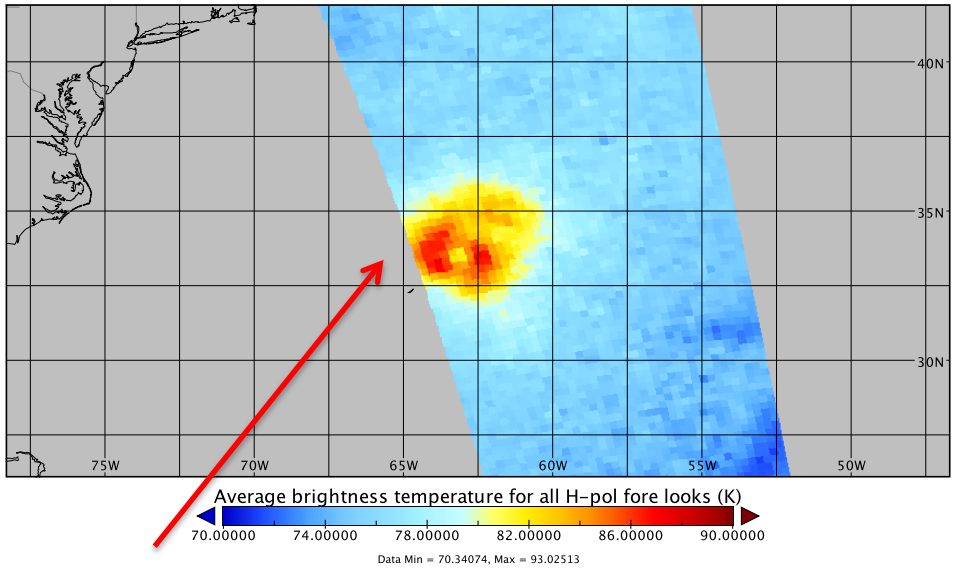

SMAP Salinity Difference to HYCOM
Salinity Difference [psu]
WindSat / SSMI/S Wind Speed [m/s]
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
Improvement at high winds due to change in model winds.
v4 TB–Only Bias: 0.072
v3 TB–Only Bias: 0.002
v4 TB–Only RMS: 0.717
v3 TB–Only RMS: 0.719

Shape of storm is better represented using forecast data instead of interpolation of 6 hour now casts.

Leads to improve SSS retrievals near storms.
Particular improvement at high latitudes.

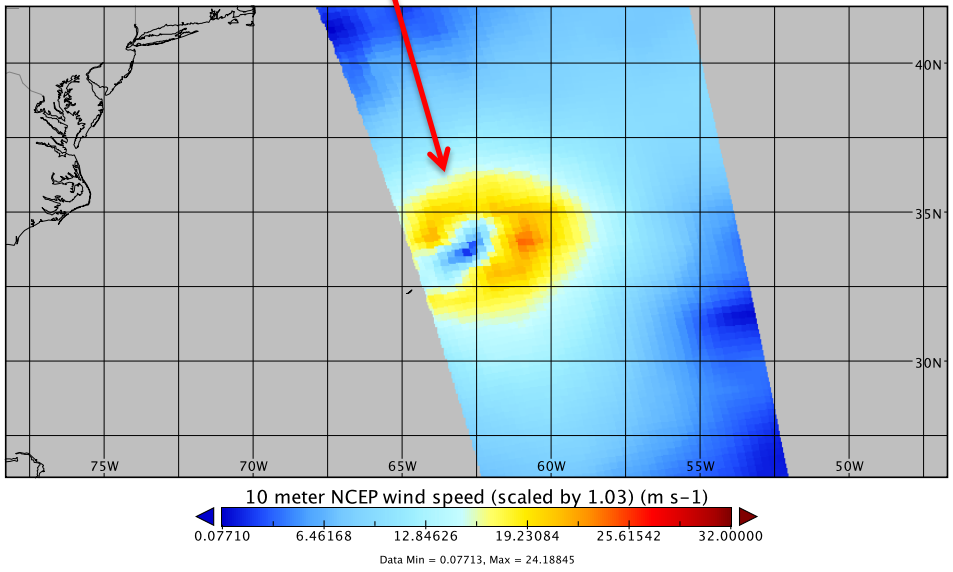
Smearing of eye in v3 ancillary winds.

TBH

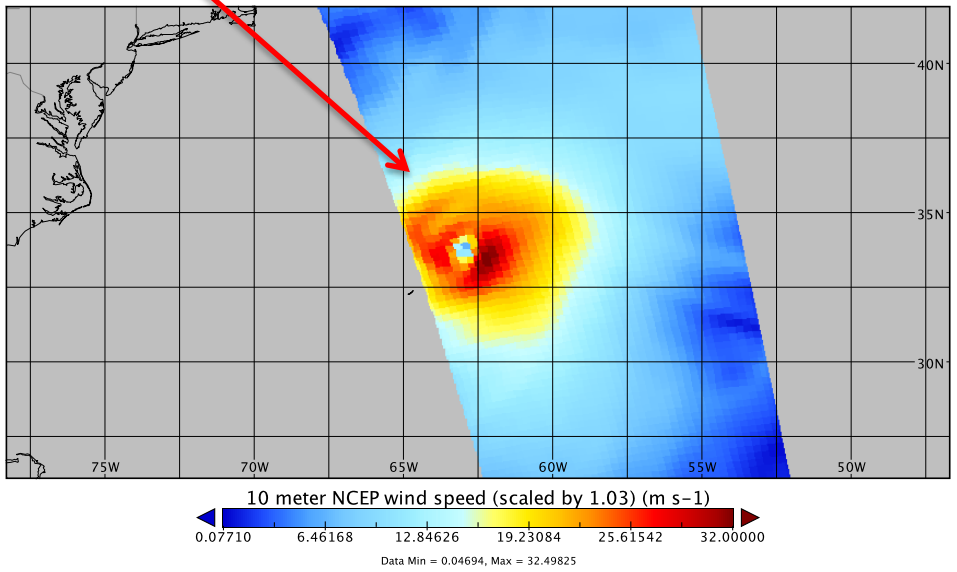


V4 ancillary winds preserve shape

10 meter NCEP wind speed (scaled by 1.03)



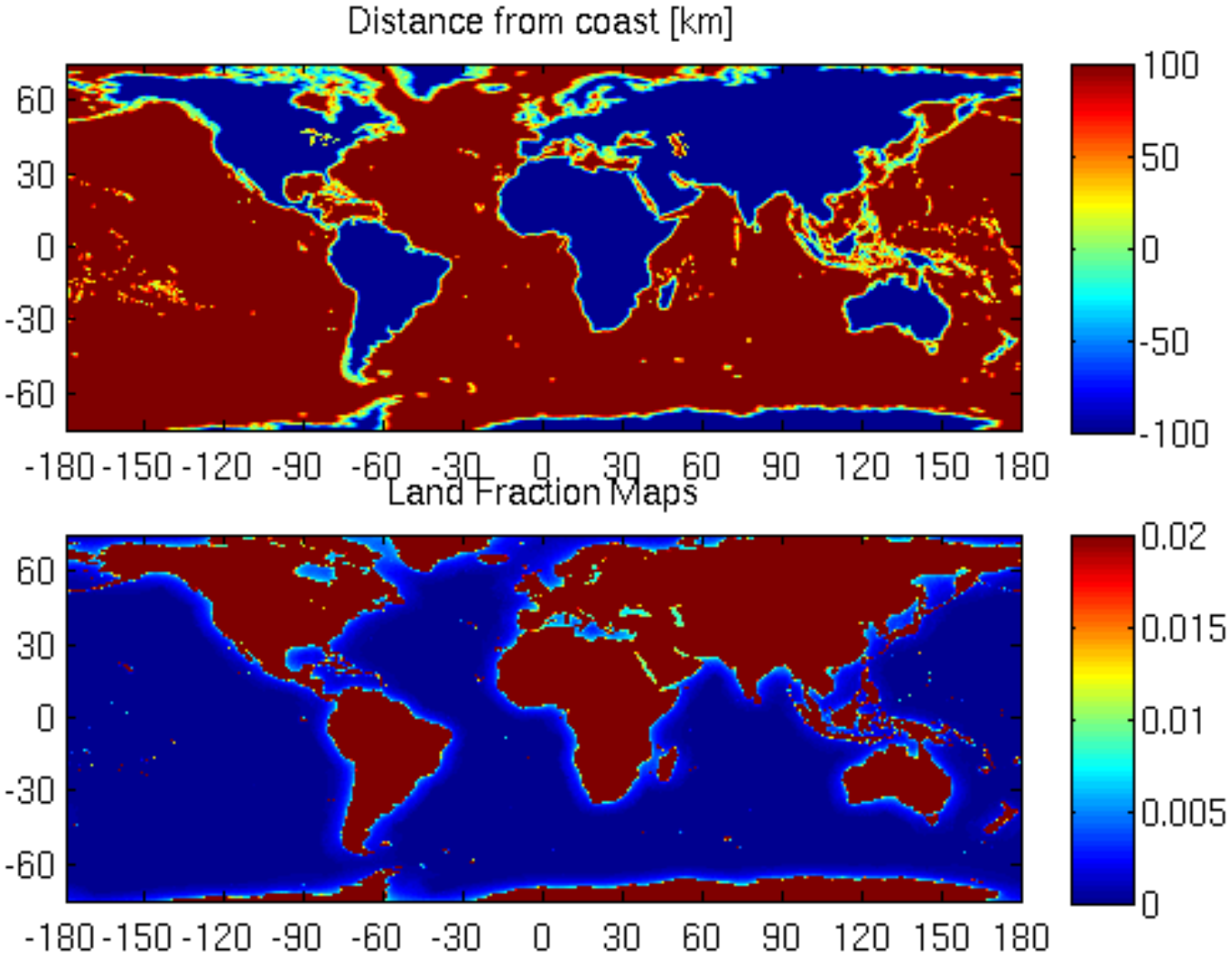
10 meter NCEP wind speed (scaled by 1.03)



Land Correction: Land Fraction

- We forward compute the land fraction for 1 year of SMAP L1B data (used supercomputer).
  - Use full earth disk beam integration.
  - Use SMAP antenna patterns.
  - 1 year enough to sample the orbit variations of 20 km from exact repeat.
- Take all this data, and bin into a map as a function of: (lat, lon, cell azimuth).
- Creates a look up table of land fraction that is used in processing -> *extremely fast.*

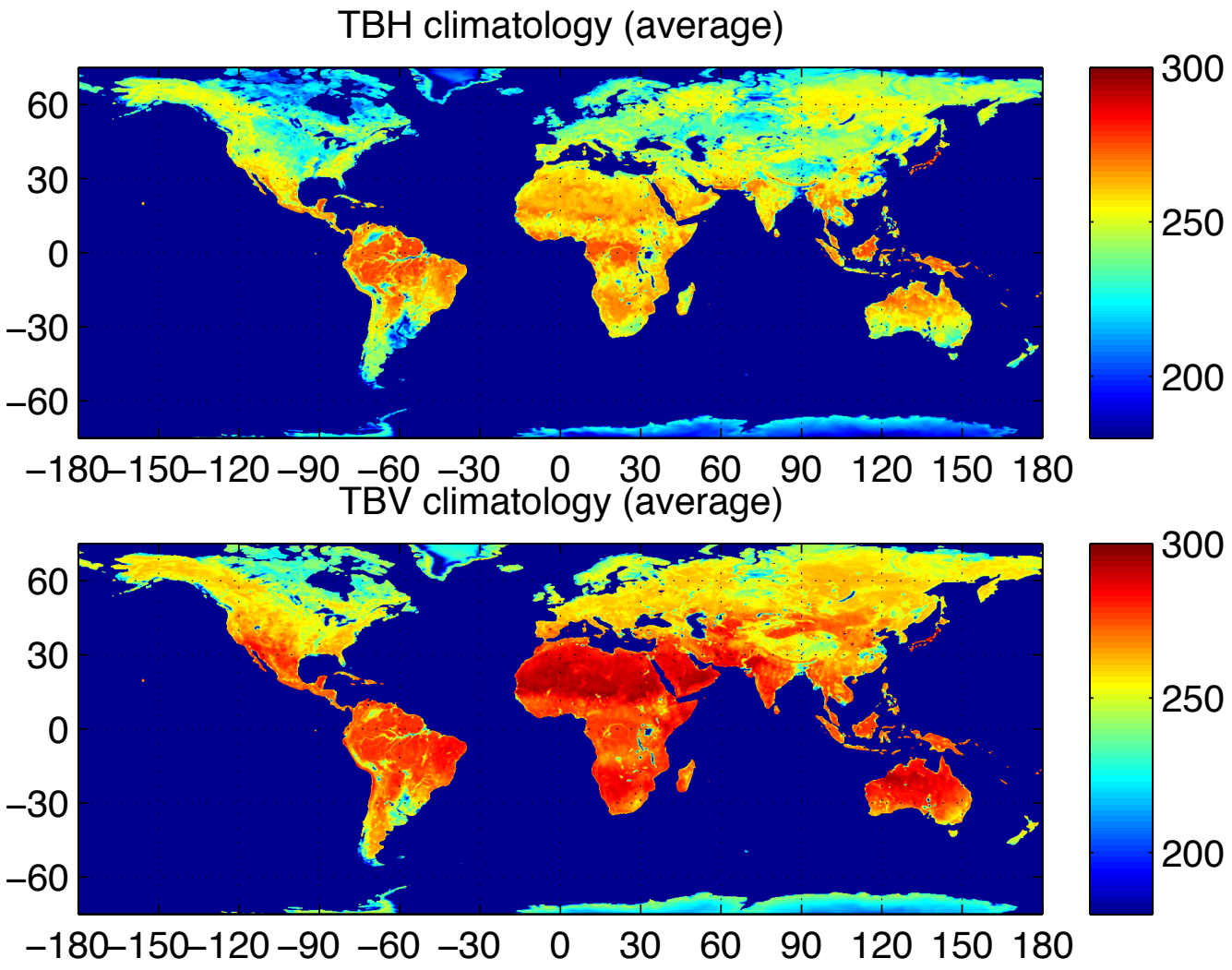
Coast Distance and Land Fraction



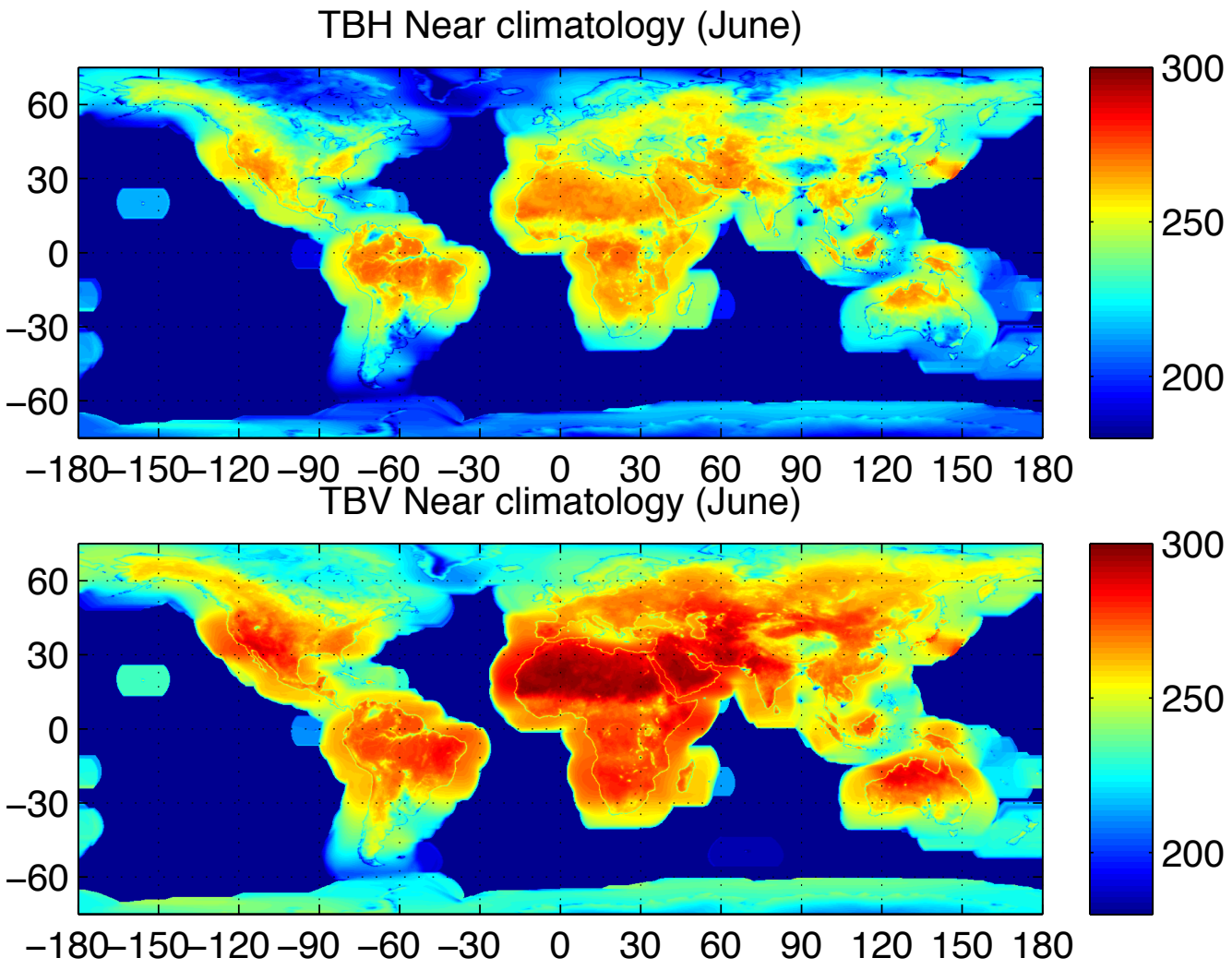
Land Correction: Near Land TB

- First: compute a climatology of land TBs.
  - Perform a water correction to the land TBs near water *(note: easier than land correction of water TBs!).*
  - Bin into a monthly climatology.
- Second: for all water pixels, compute a TB from the land values near to that water pixel.
  - This is the TBnear climatology.
  - Supposed to represent off-mean beam contributions of land to a TB at that particular water pixel.

Climatology of Land TB

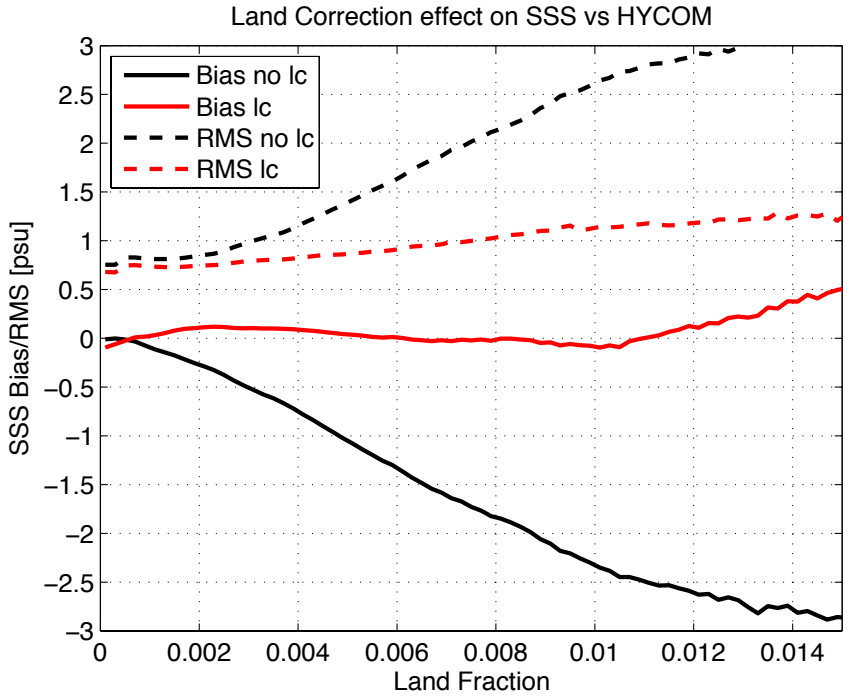


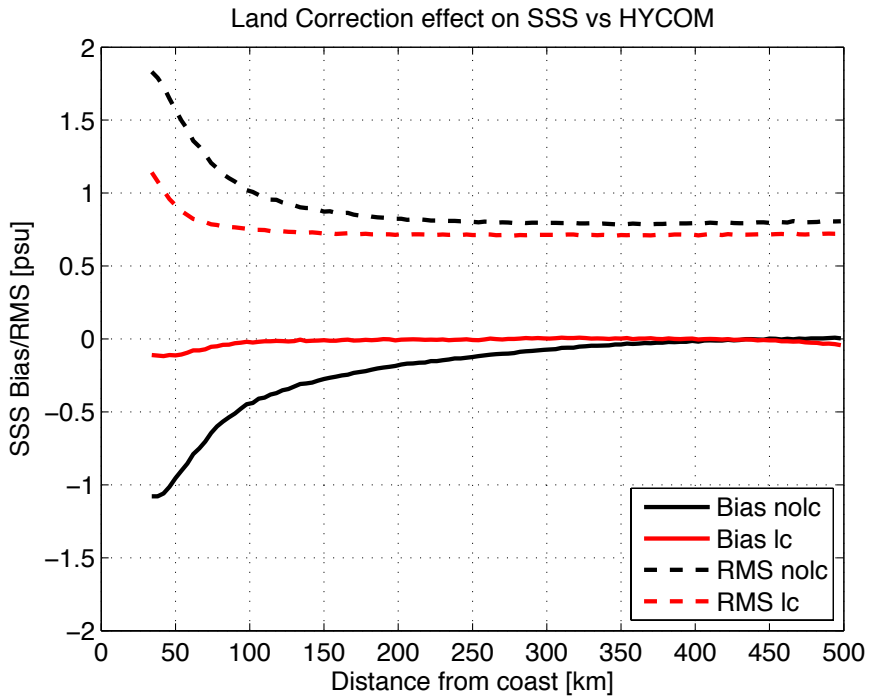
Climatology of Near Land TB



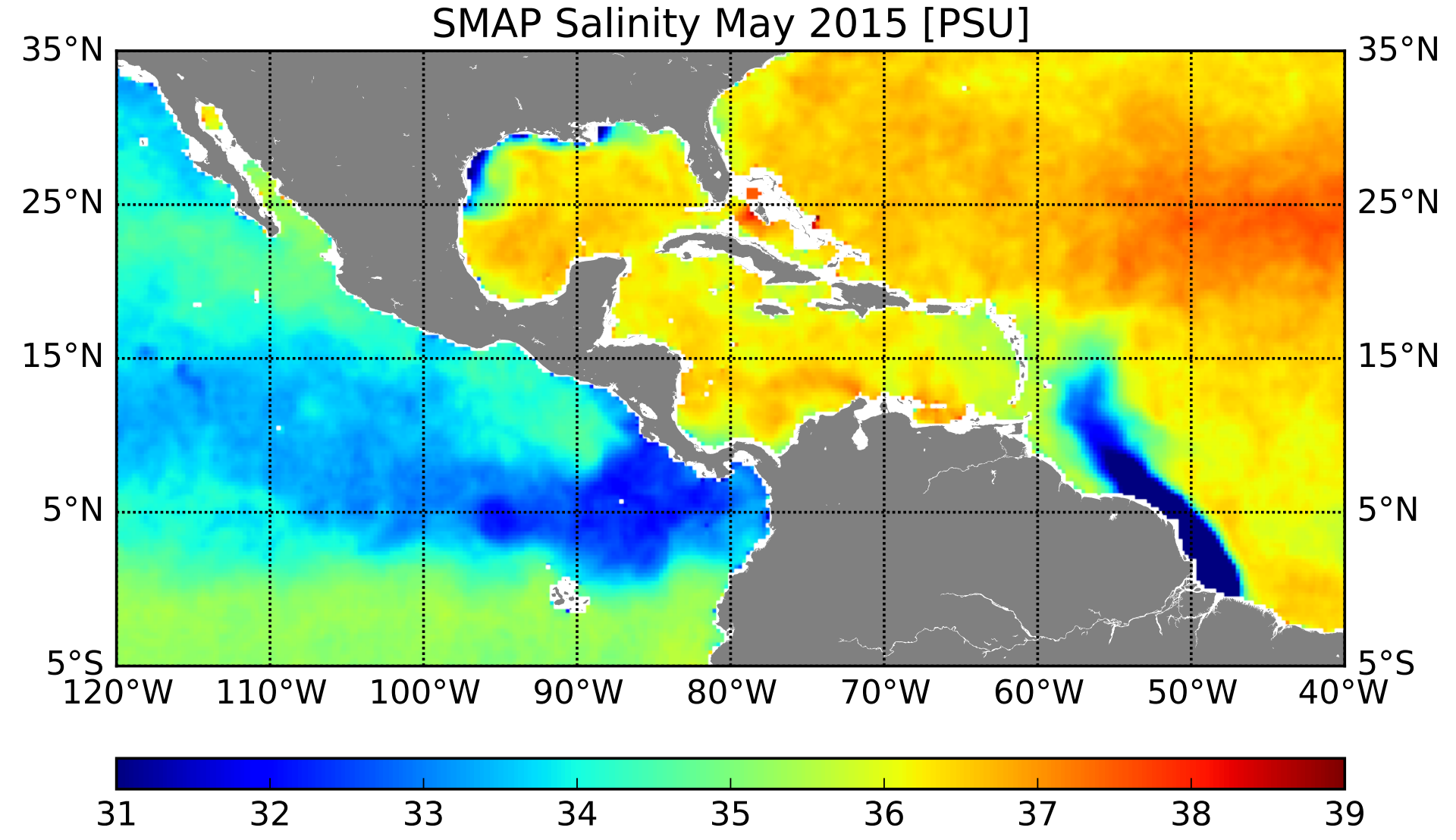
SMAP Land Correction

- We have look up tables for land fraction and land near TB.
  - Correction is to get values from the two LUTs, and use this equation (+ variance propagation on measurement error):
  - $T_B^{lc} = (T_B - F_{Land} * T_B^{near})/(1 - F_{Land})$
  - *Extremely fast since all done with LUTs.*
- Version 4 changes:
  - Retrievals allowed within 35 km from coast (v3 only > 45 km).
  - Land correction extended out to 1000 km from coast (v3 stopped at 500 km).
  - Land T_B tables updated with 2 years of data.
  - Land fraction available as L2B and L3 dataset for **user-configurable land rejection**.

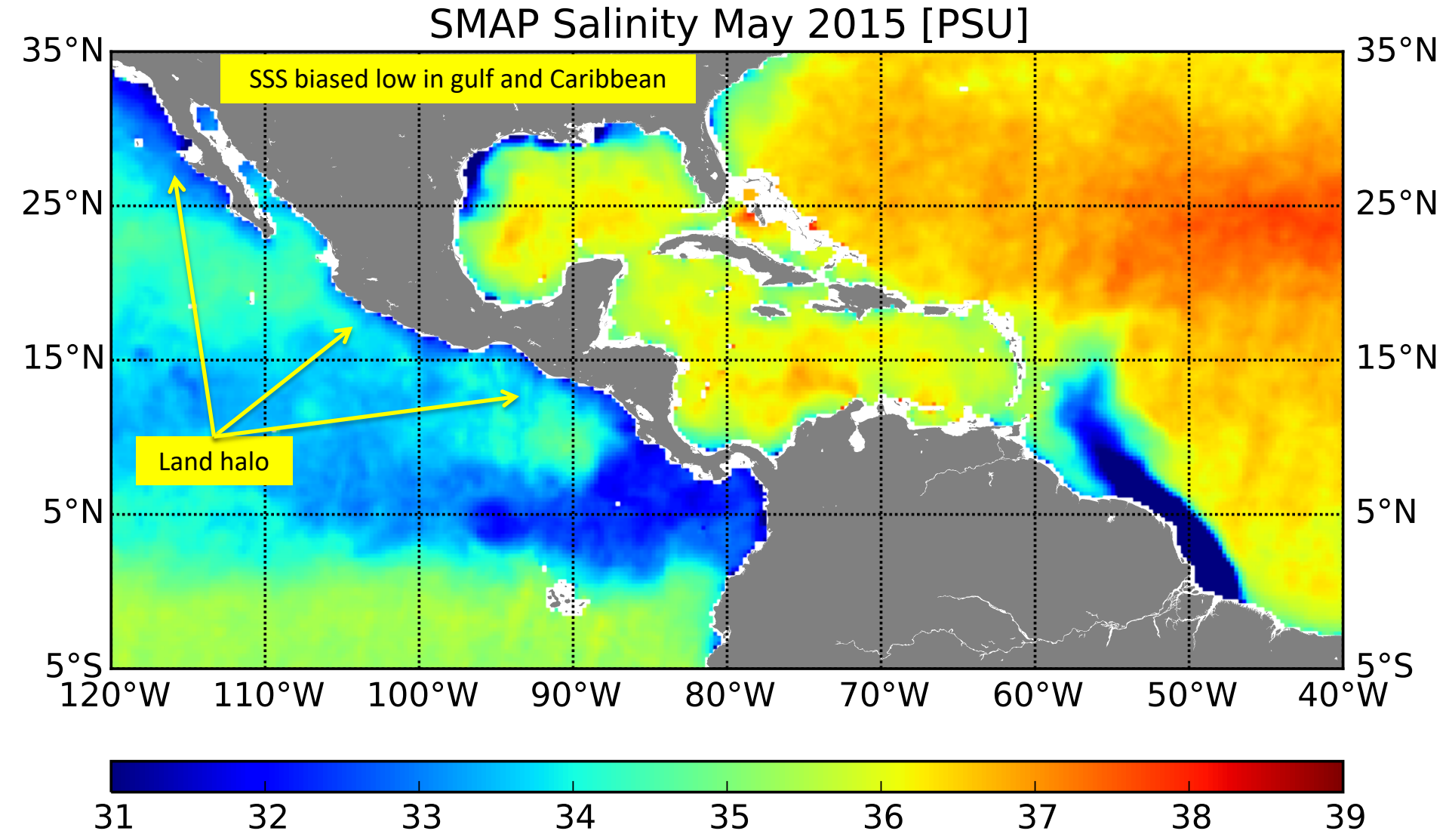




With Land Correction

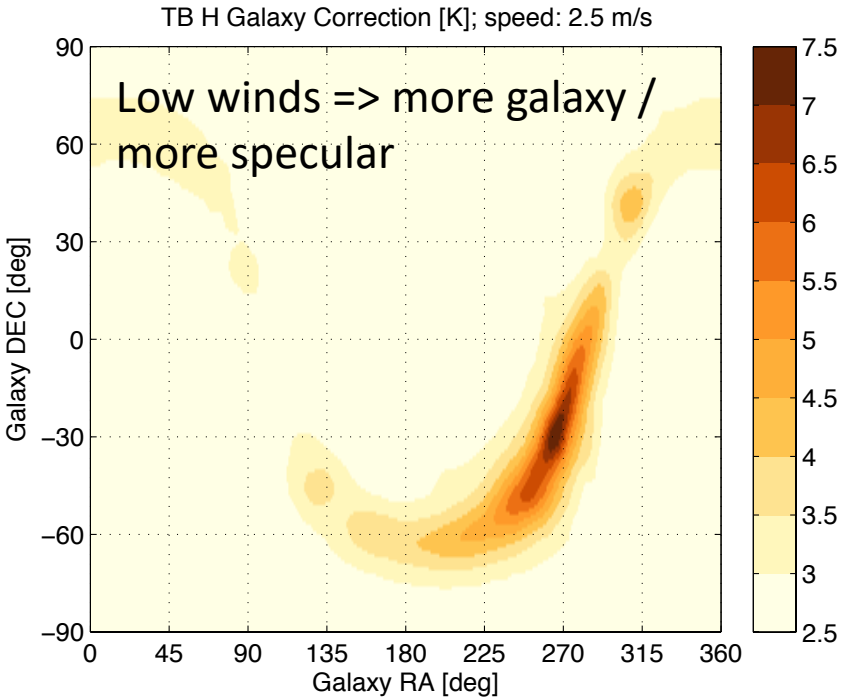


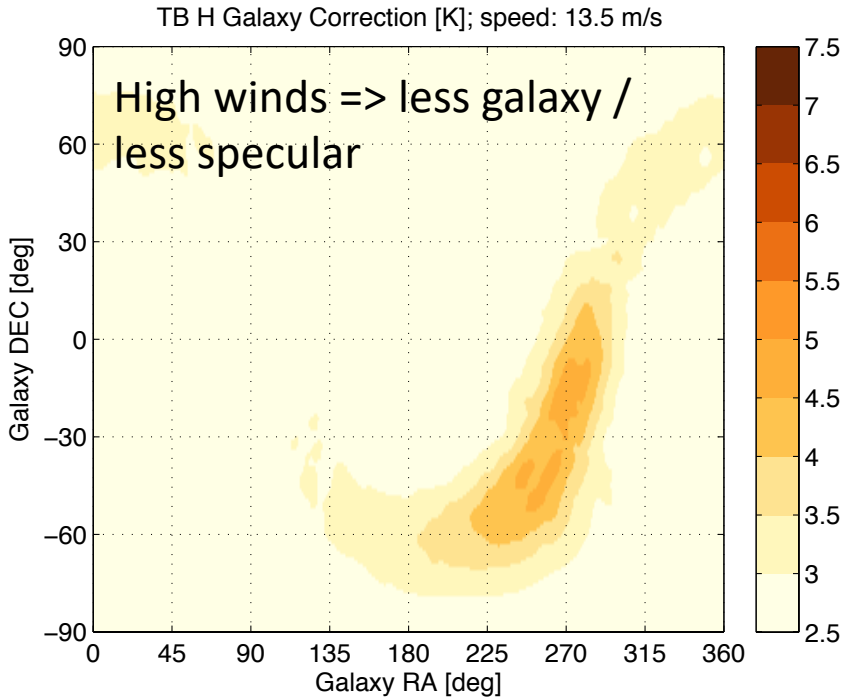
No Land Correction



SMAP Galaxy Correction

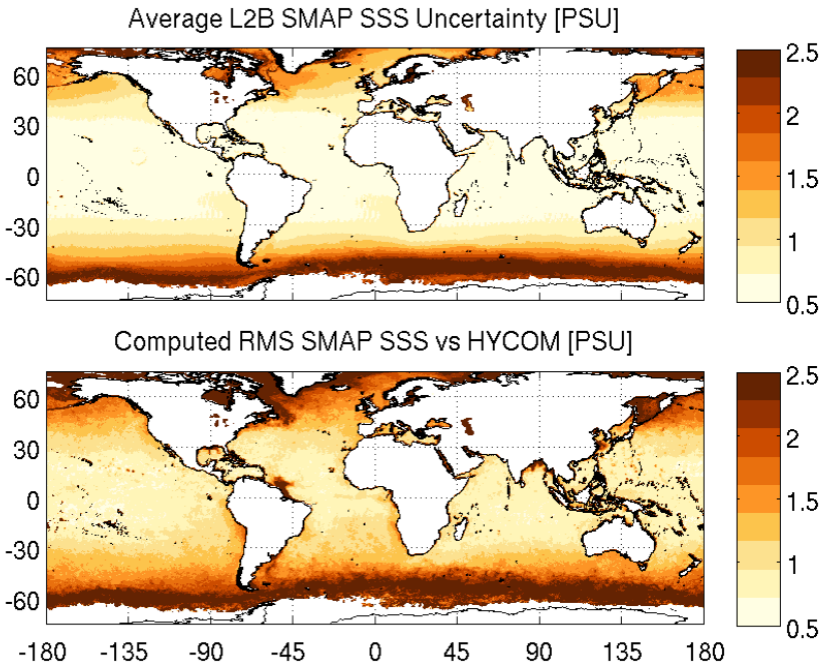
- Operational SMAP galaxy correction is not sufficient for salinity processing.
  - Operational correction is not a function of wind speed but rather a constant.
  - Direct estimation of galaxy is possible with SMAP unlike Aquarius (two look).
- With two years of SMAP; match fore look to aft look on ocean:
  - Use ancillary galaxy map to select “hot” look and “cold” look.
  - TB delta of hot-cold look nearly all due to galaxy* (after removal of sun, moon, wind direction).
  - Bin-average hot-cold delta as function of hot look galaxy RA, DEC, and surface wind speed.
- Galaxy table updated using 2 years of data for version 4.

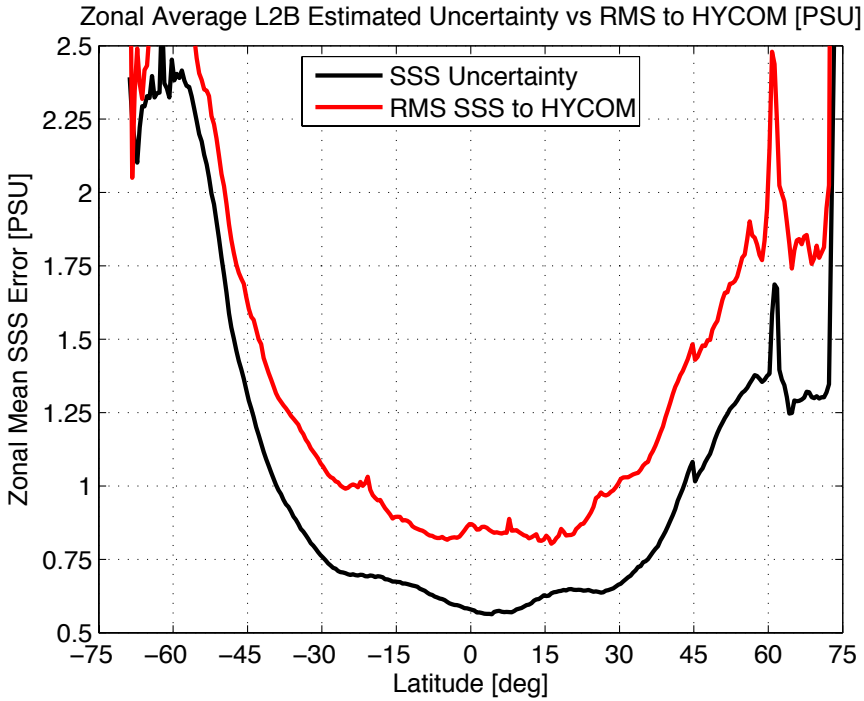




New in V4: Estimated SSS Uncertainty

- Use width of objective function minima for each SWC.
  - Captures all known information (predicted variance via NEDT).
  - Captures effects of all unknowns via residual mismatch of measurements to model function (can't model it if we don't know it).
- For L3 use propagation of variance and assumptions about correlation of adjacent SWCs and L3 binning.
- Allows for user-configurable quality control; new for version 4.0!





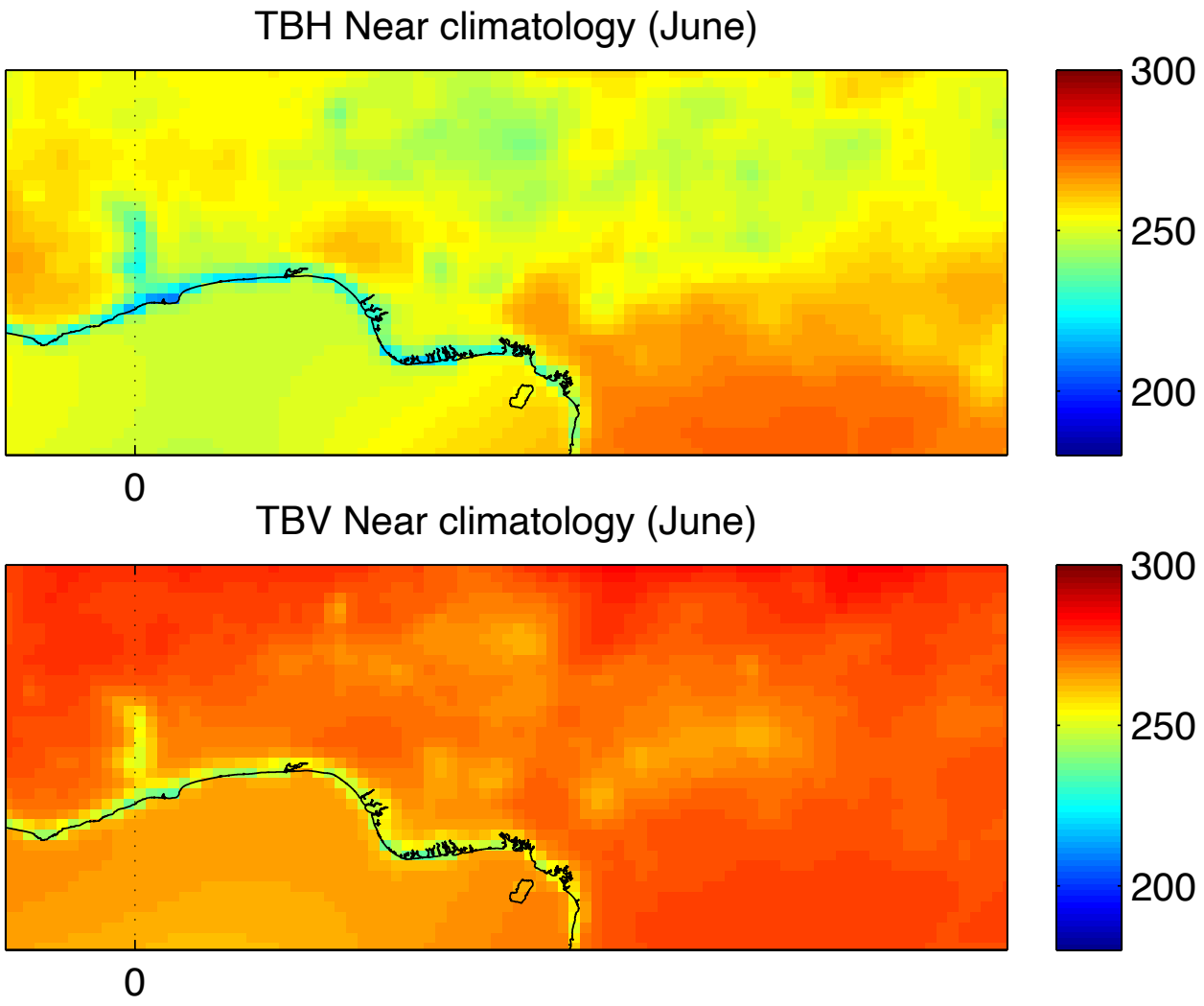
Summary

- SMAP radiometer-only data is capable of providing a ocean salinity data product that meets the Aquarius science requirement of 0.2 PSU:
  - 0.2 PSU STD as compared to SIO ARGO at 1x1 deg monthly scale.
  - 0.17 PSU STD as compared to tropical moored buoys at 1x1 deg monthly scale.
- Version 4 improves on previous algorithm:
  - Improved coastal correction + SSS in very large lakes.
  - Extended range of SSS retrievals to 45 PSU.
  - Improved roughness correction using forecast data.
  - Addition of **land fraction** and **SSS estimated uncertainty** at L2 and L3 for **user-configurable data rejection**.
- Data are available at http://podaac.jpl.nasa.gov
  - L2B with a 3 day delay.
  - L3 with a 7 day delay from center of 8-day window.
- NRT data available at ftp://sealion.jpl.nasa.gov/outgoing/smap
  - L2B NRT data have about 4.5 hour median latency.
- Version 4.1 coming soon, based on L1B_TB version 4.
  - Major difficulties with calibration of L1B_TB data due to incorrect reflector emissivity used in v4 TB data.

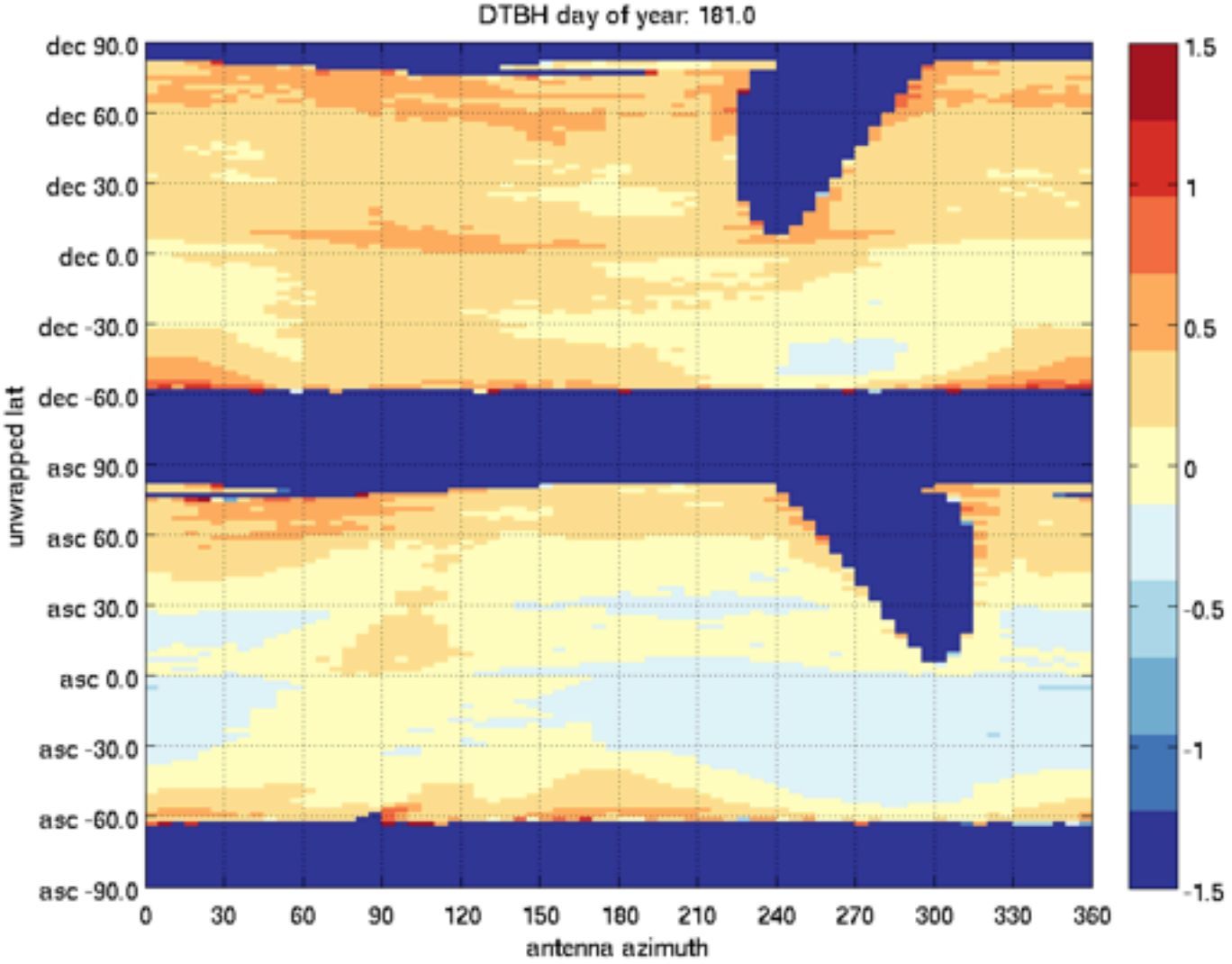
Publications

- Publications
  - Fore, A., S. Yueh, W. Tang, B. Stiles, and A. Hayashi (2016). Combined Active/Passive Retrievals of Ocean Vector Wind and Sea Surface Salinity with SMAP, IEEE Trans. Geoscience and Remote Sensing, doi: 10.1109/TGRS.2016.2601486.
  - Yueh, S., A. Fore, W. Tang, H. Akiko, B. Stiles, N. Reul, Y. Weng and F. Zhang, (2016): SMAP L-band passive microwave observations of ocean surface wind during severe storms, *IEEE Trans Geosci. Remote Sens.*, doi:10.1109/TGRS.2016.2600239.
  - Wenqing Tang, Alexander Fore, Simon Yueh, Tong Lee, Akiko Hayashi, Alejandra Sanchez-Franks, Brian King, Dariusz Baranowski, and Justino Martinez (2017): "Validating SMAP SSS with in situ measurements," Remote Sensing of Environment, doi:10.1016/j.rse.2017.08.021
  - A. G. Fore, et al., "SMAP Radiometer-Only Tropical Cyclone Intensity and Size Validation", in IEEE Geoscience and Remote Sensing Letters, Early Release 2018.

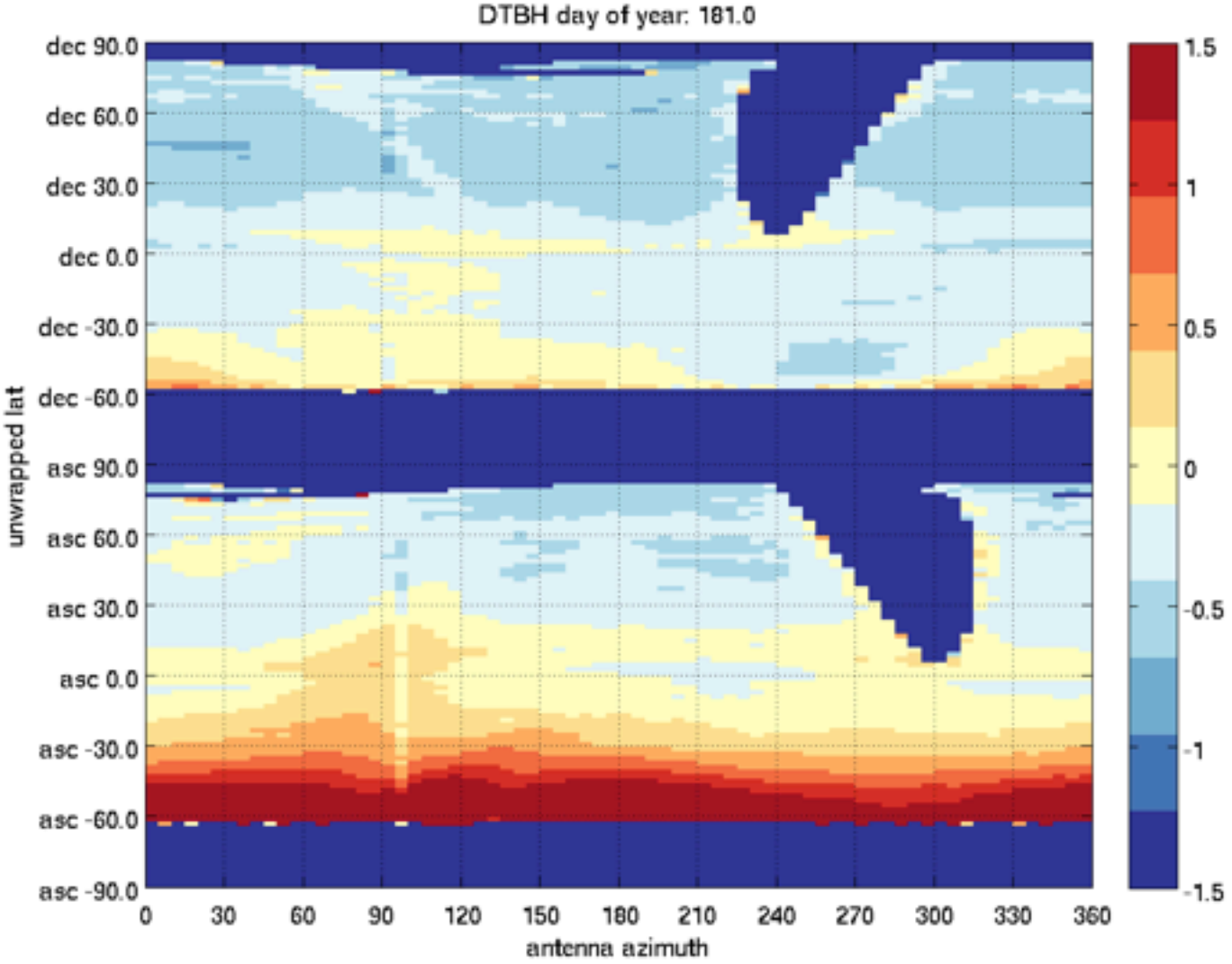
Climatology of Near Land TB (zoomed)



L1B_TB V3


DTBH day of year: 181.0
dec 90.0
dec 60.0
dec 30.0
dec 0.0
dec -30.0
dec -60.0
asc 90.0
asc 60.0
asc 30.0
asc 0.0
asc -30.0
asc -60.0
asc -90.0
unwrapped lat
0
30
60
90
120
150
180
210
240
270
300
330
360
antenna azimuth
1.5
1
0.5
0
-0.5
-1
-1.5

L1B_TB V4


DTBH day of year: 181.0
dec 90.0
dec 60.0
dec 30.0
dec 0.0
dec -30.0
dec -60.0
asc 90.0
asc 60.0
asc 30.0
asc 0.0
asc -30.0
asc -60.0
asc -90.0
unwrapped lat
0
30
60
90
120
150
180
210
240
270
300
330
360
antenna azimuth
1.5
1
0.5
0
-0.5
-1
-1.5

Version 4.1

- Version 4.1 is the version 4 algorithms applied to the newest L1B_TB SMAP data product.
- There is a major known issue with the version 4 L1B_TB data that requires significant changes to calibration.
  - Reflector emissivity is far too high in TB V4.
  - Causes a large error in TB (~1.5 K) for all data below -30 S, ascending, in eclipse season.