SMAP Sea Surface Salinity Retrieval Algorithm

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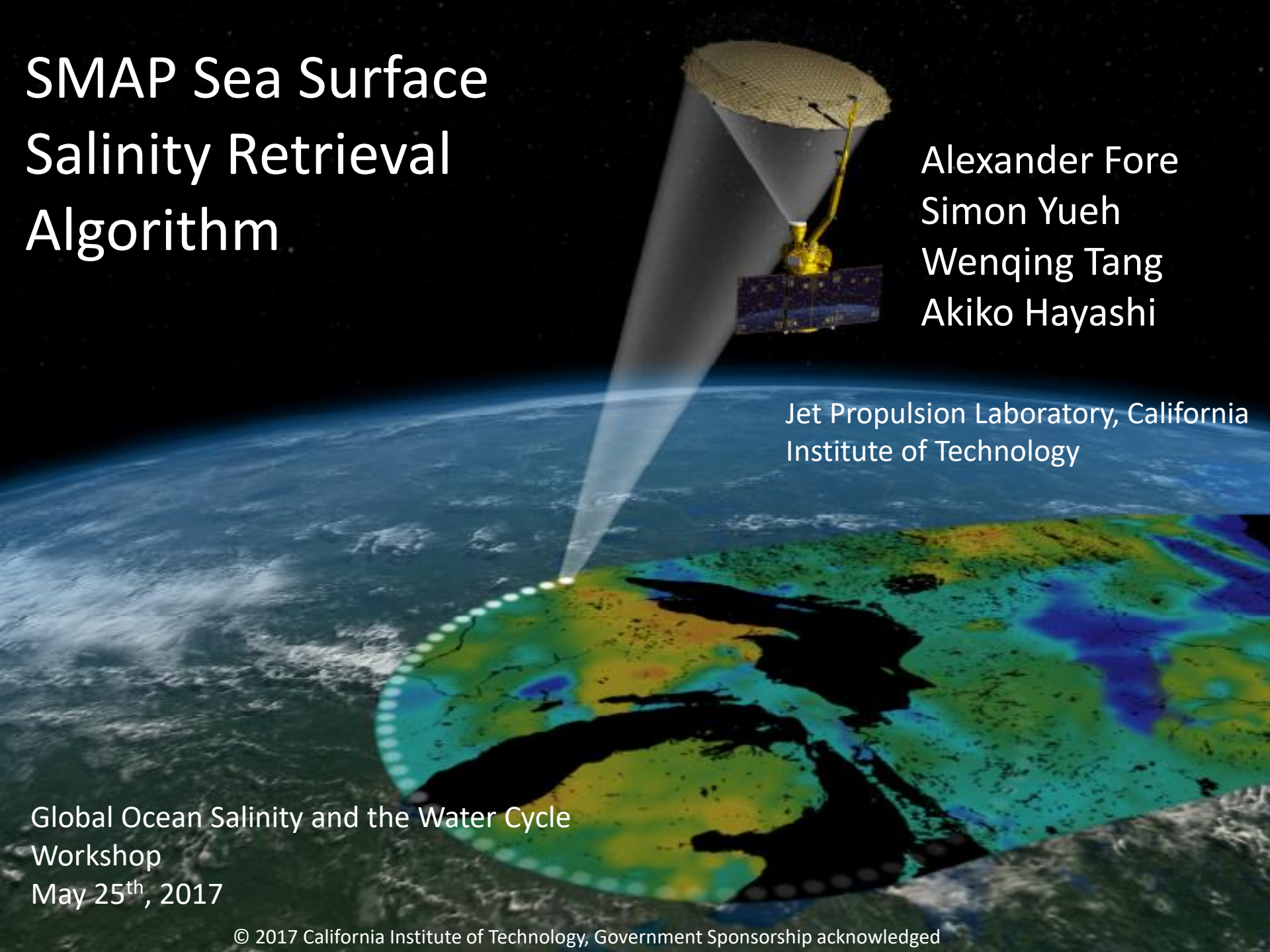

Global Ocean Salinity and the Water Cycle Workshop
May 25th, 2017

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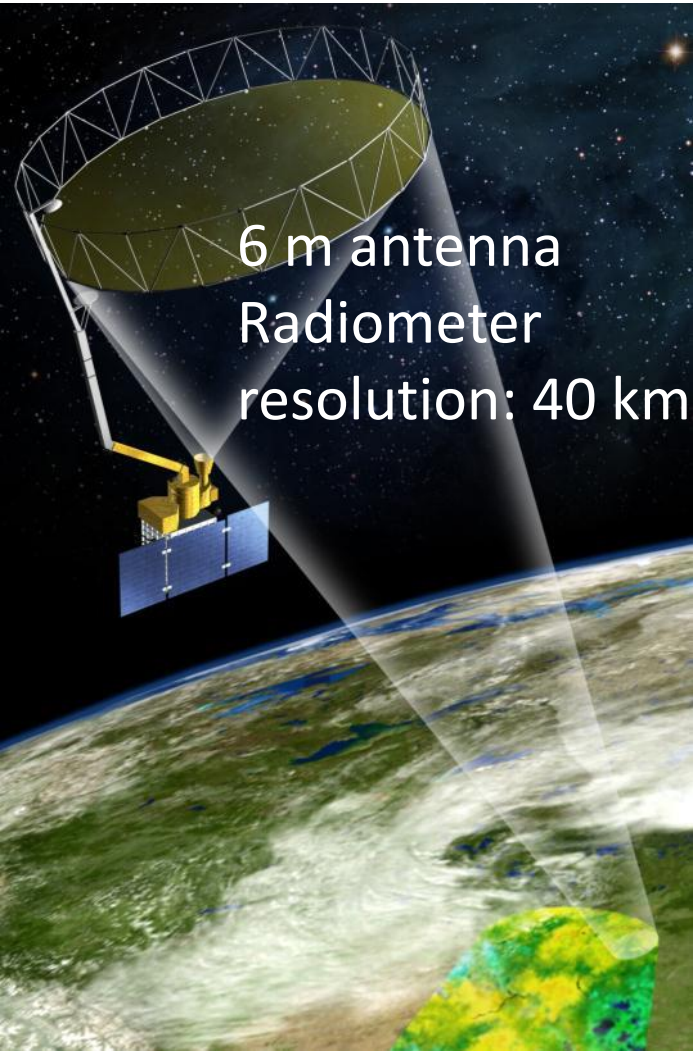
SMAP Overview



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

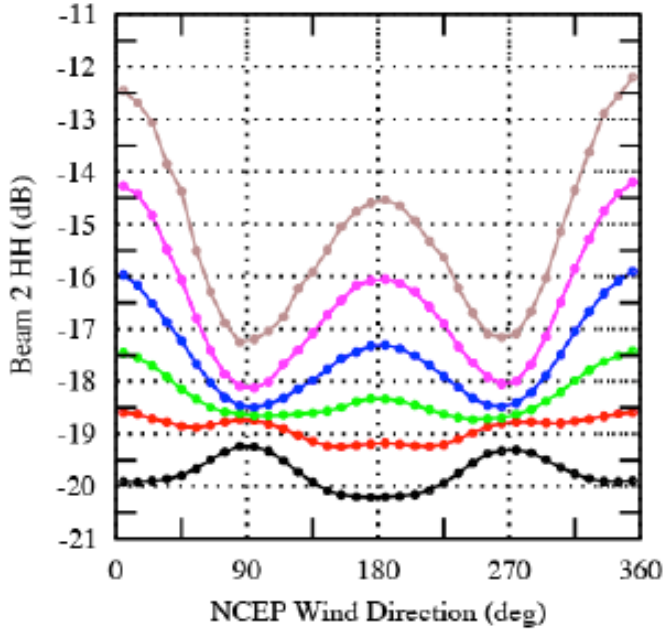
Mission Implementation

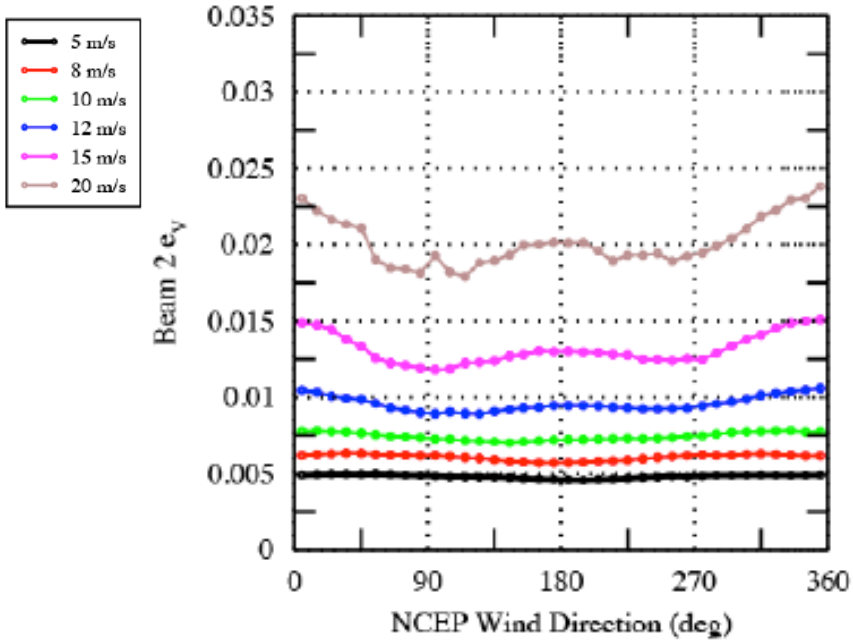
Partners	• JPL (project & payload management, science, spacecraft, radar, mission operations, science processing) • GSFC (science, radiometer, science processing)
Launch	• January 31, 2015 on Delta 7320-10C Launch System
Orbit	• Polar Sun-synchronous; 685 km altitude
Duration	• 3 years
Payload	• L-band (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

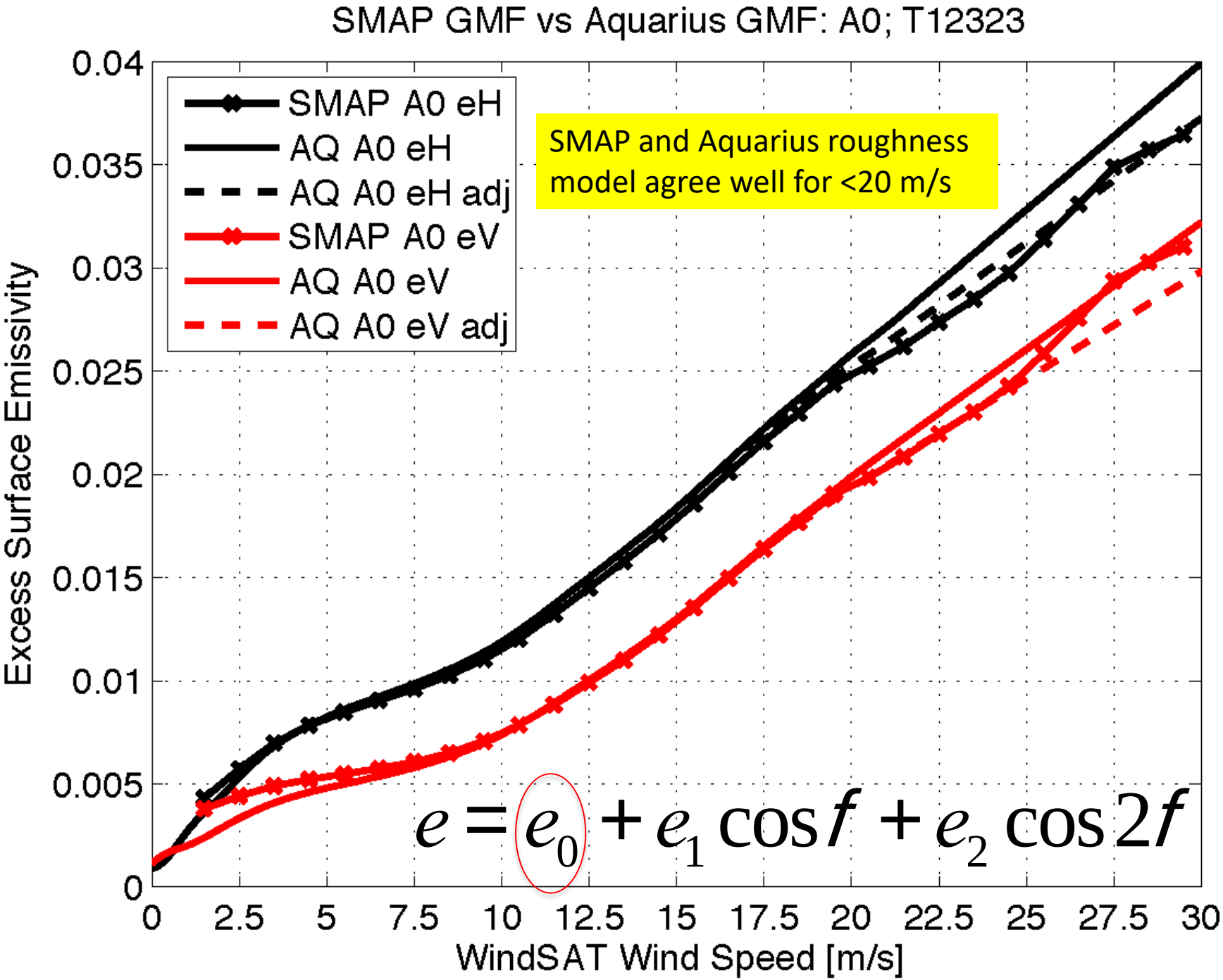
- The matchup of Aquarius data with NCEP wind direction, SSMIS wind speed indicates impact of ocean wind on radar and radiometer signals.
  - The charts below indicate the signal sensitivity for the data from Aquarius beam# 2 (~39 deg incidence angle)





- 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
$e = e_0 + e_1 \cos f + e_2 \cos 2f$
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

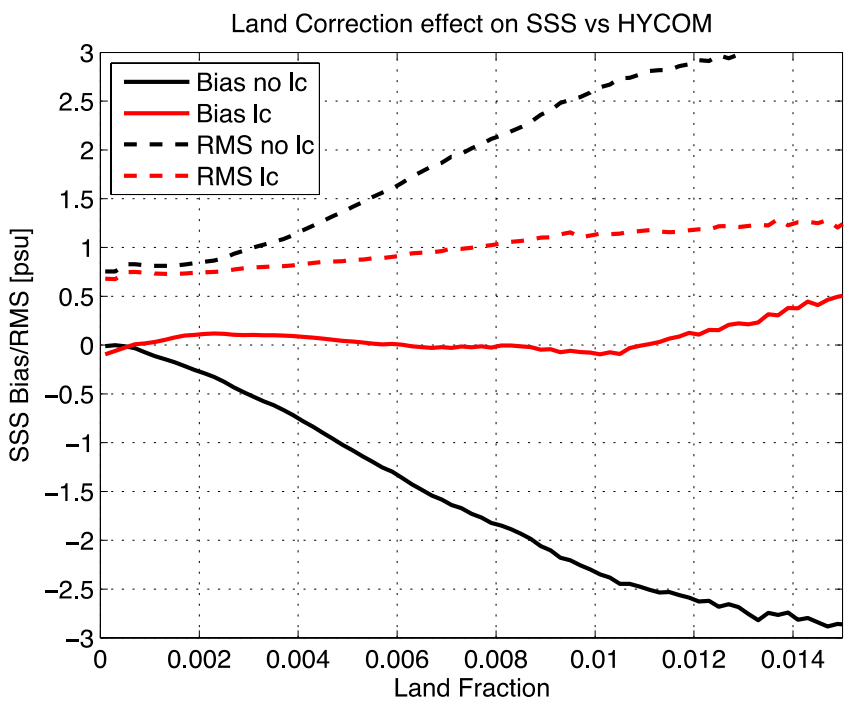
Radiometer TB SSS and Wind Processing

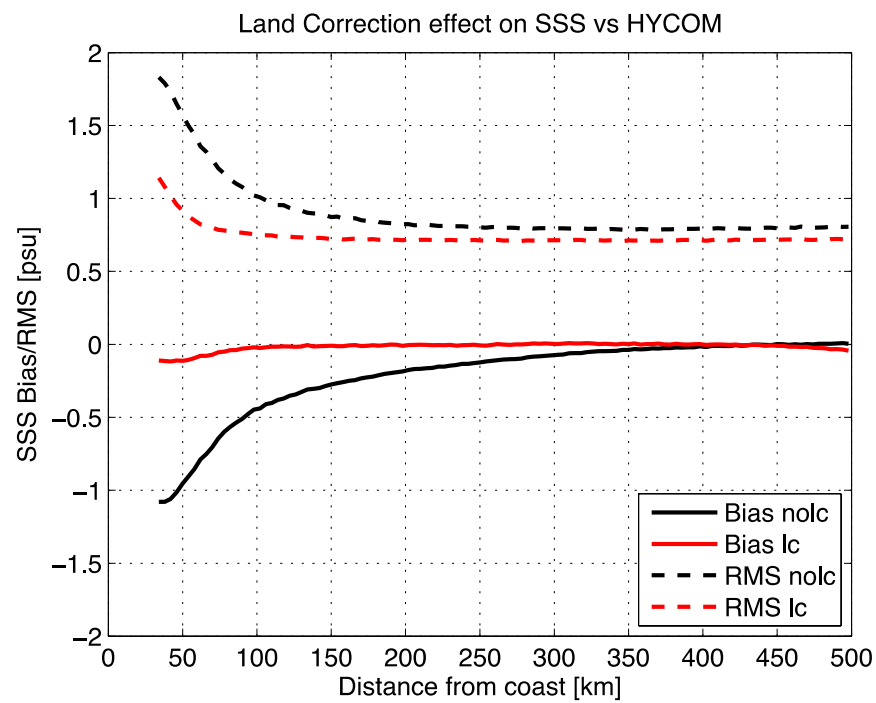
- Compute delta TB using ancillary data and model
  - Average over each day; use 8 day median filtered value
  - Decimated by fore/aft x asc/dec
- Grid into a 25 km L2A swath grid just like JPL scatterometer products.
  - Gridding method oversamples observations onto the grid.
  - Effective L2 resolution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

$$F(spd, sss) = \sum_i \left[\frac{T_{B,i} - T_{B,i}^m \left(spd, sss, anc_dir, anc_swh, anc_sst \right)}{NEDT_i} \right]^2 + \left(\frac{spd - spd_anc}{1.5 m/s} \right)^2,$$

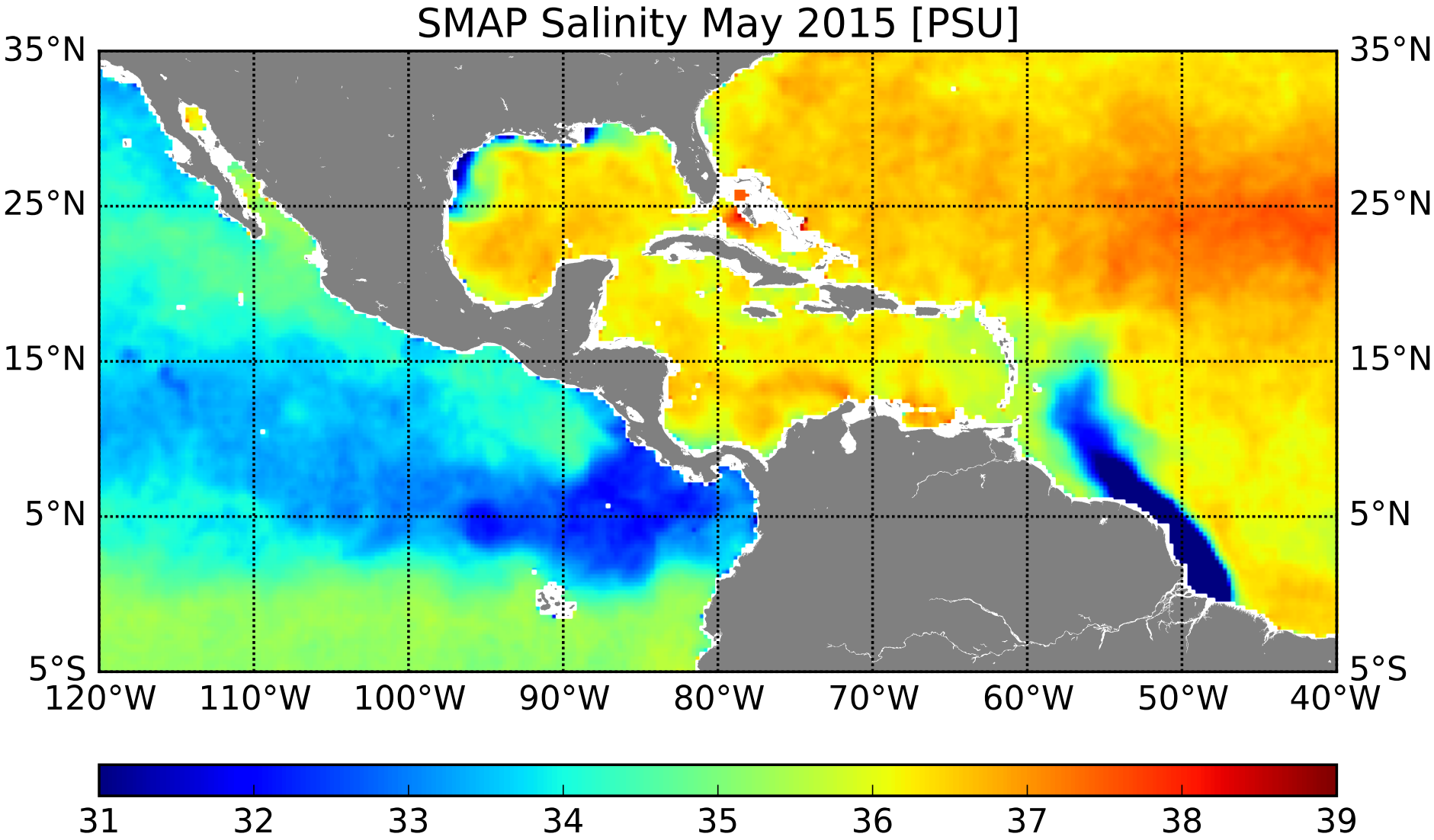
SMAP Land Correction

- Compute land fraction (f_{land}) for every T_B footprint.
  - Use look-up table to make problem feasible.
  - Function of lon, lat, cell azimuth angle.
- Climatology of land T_B values near to footprint.
  - Represents average T_B of land not in main beam.
- Only for land fractions ~ 1% or less; about 40 km from coast.
  - Effects of land extend out to 300 km via side-lobes of antenna.
  - TB bias high => SSS bias low.

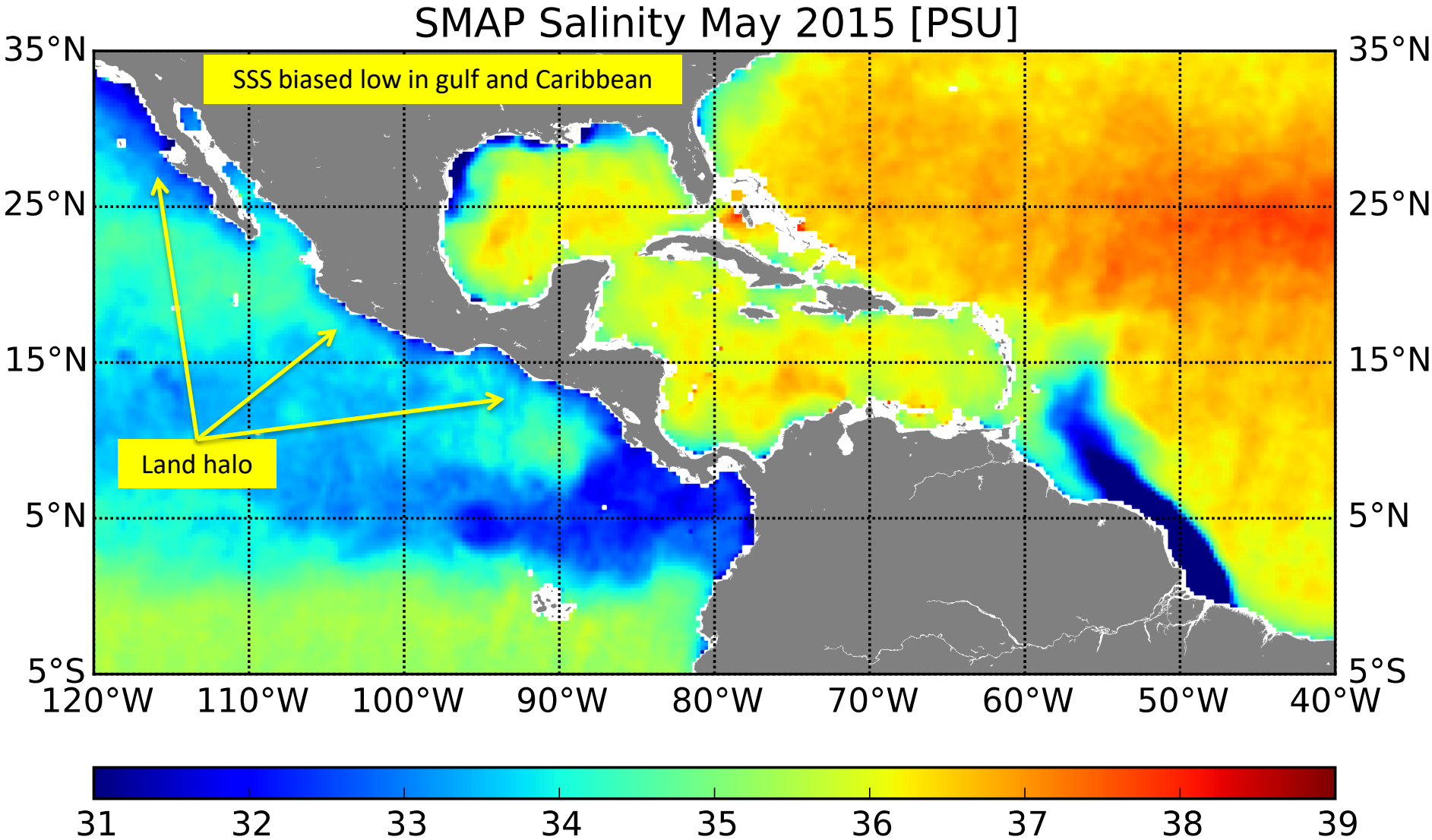




With Land Correction

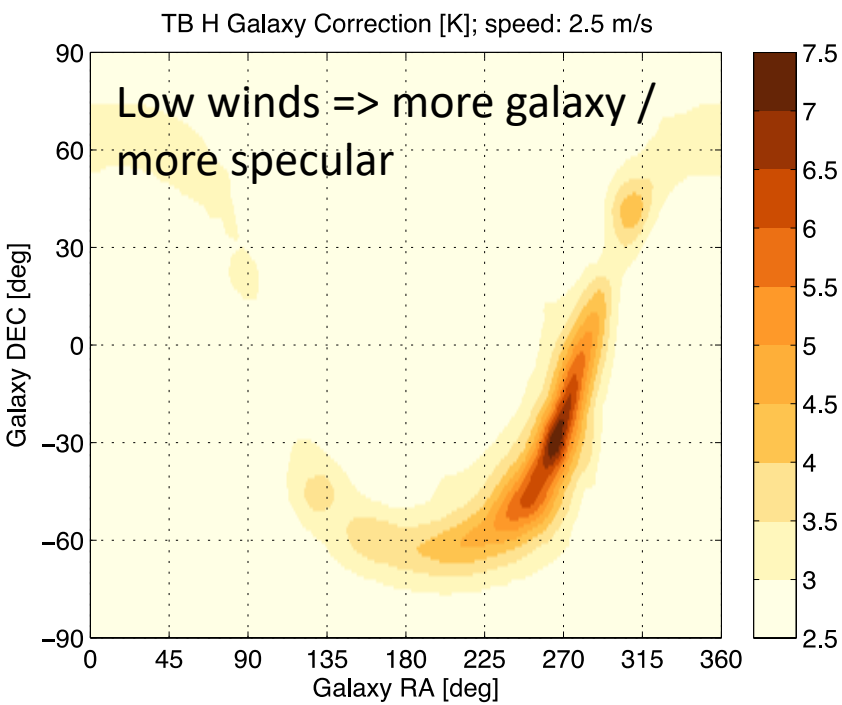


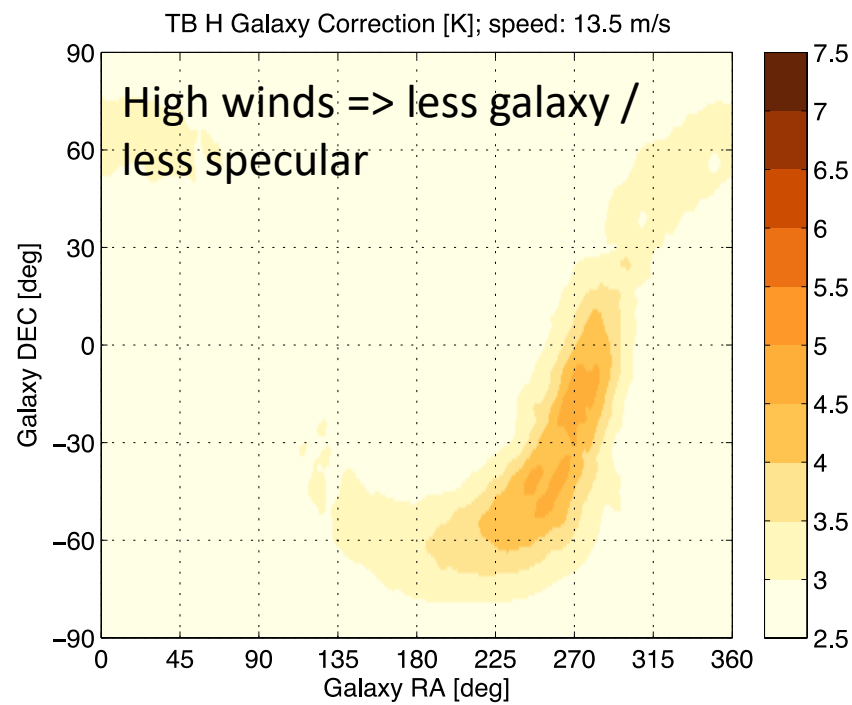
No Land Correction



SMAP Galaxy Correction

- Operational SMAP galaxy correction is not sufficient for salinity processing.
  - Operational correction is not a function of wind speed.
  - 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.

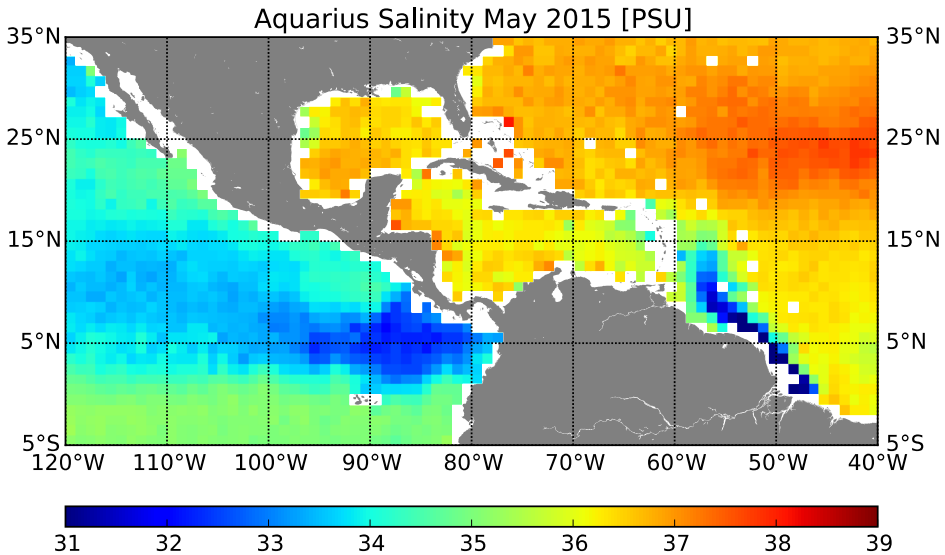


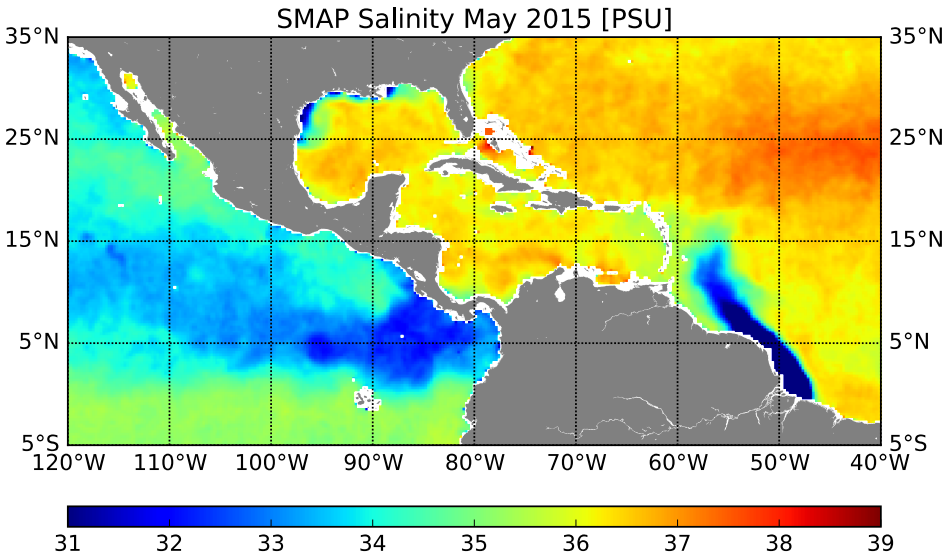


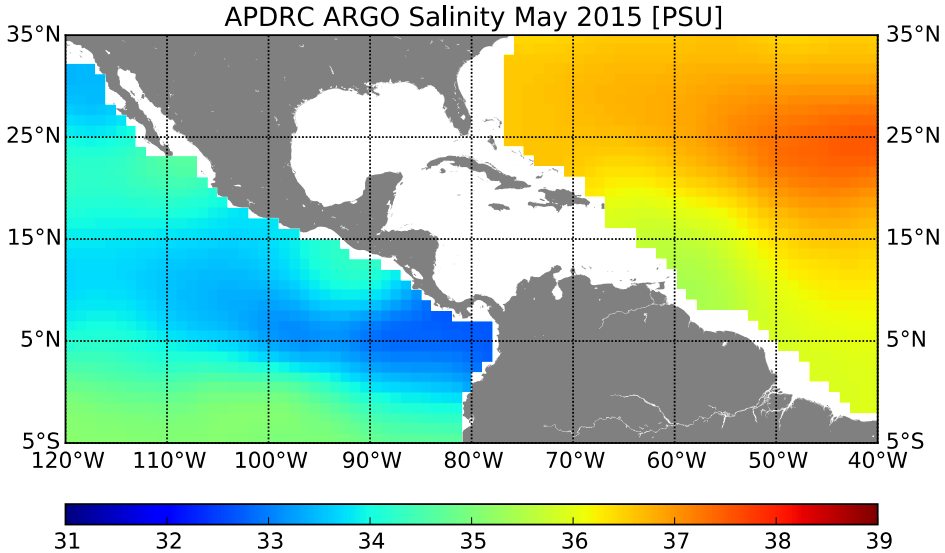
Level 3 Processing

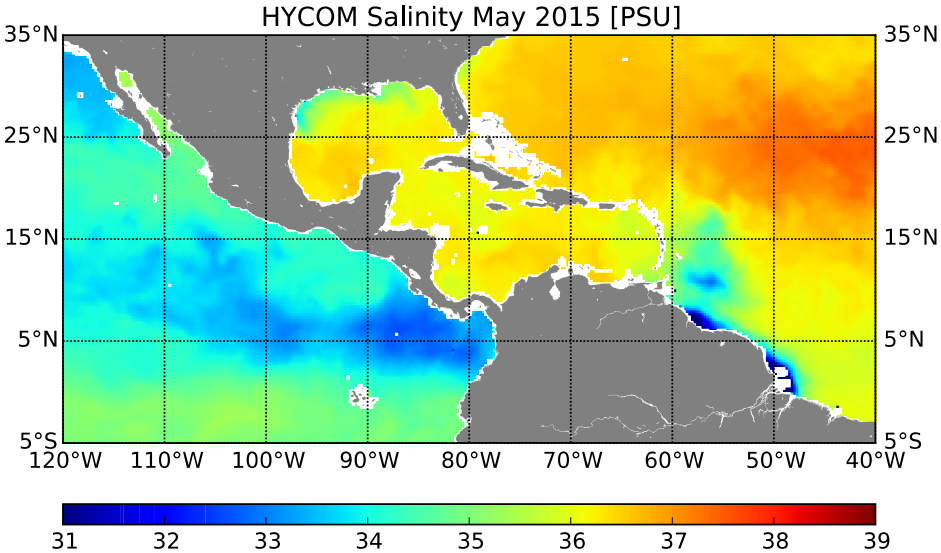
- L2B data are aggregated on a 0.25 x 0.25 geographic grid.
- Two flavors of L3 data:
  - Moving 8-day time average centered on 1200 UTC +/- 4 days.
  - Monthly time average: all orbits that start in that month.
- Use Gaussian weighting to aggregate L2B swath data onto fixed grid:
  - Half-power radius of 30 km
  - Cut-off radius of 45 km
- SMAP L3 resolution slightly larger than 60 km; Aquarius was ~ 100-150 km.

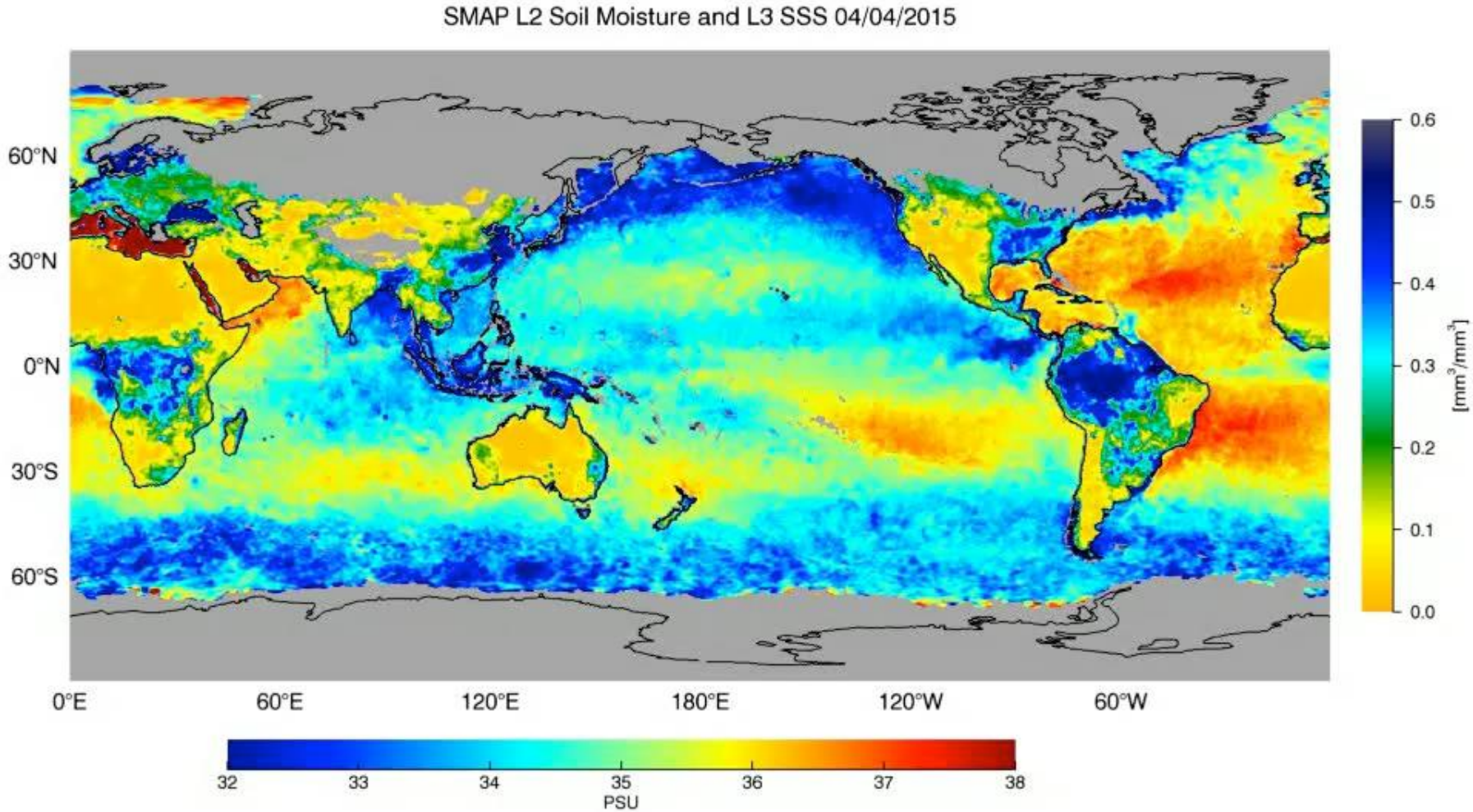
Sea Surface Salinity Maps May 2015



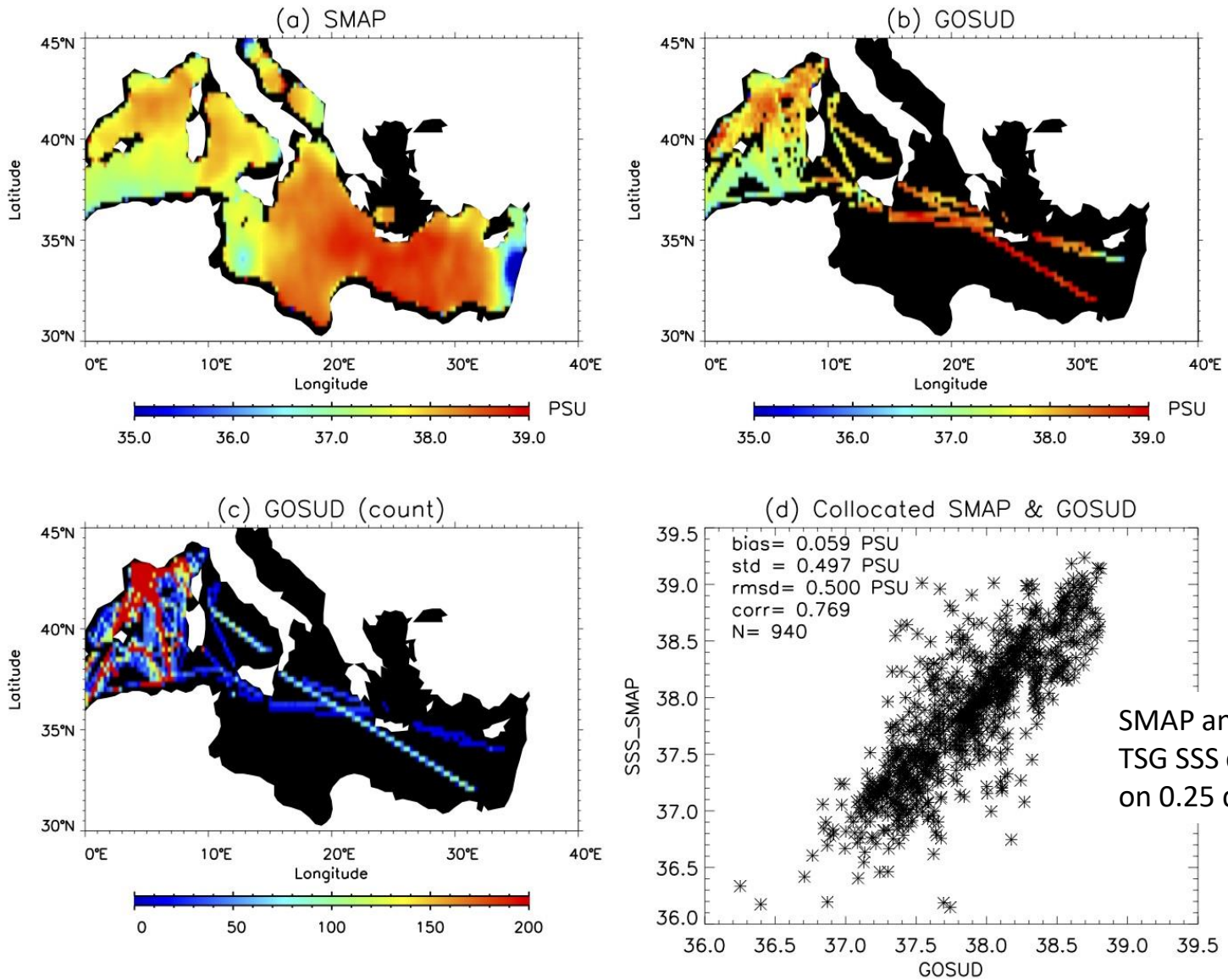






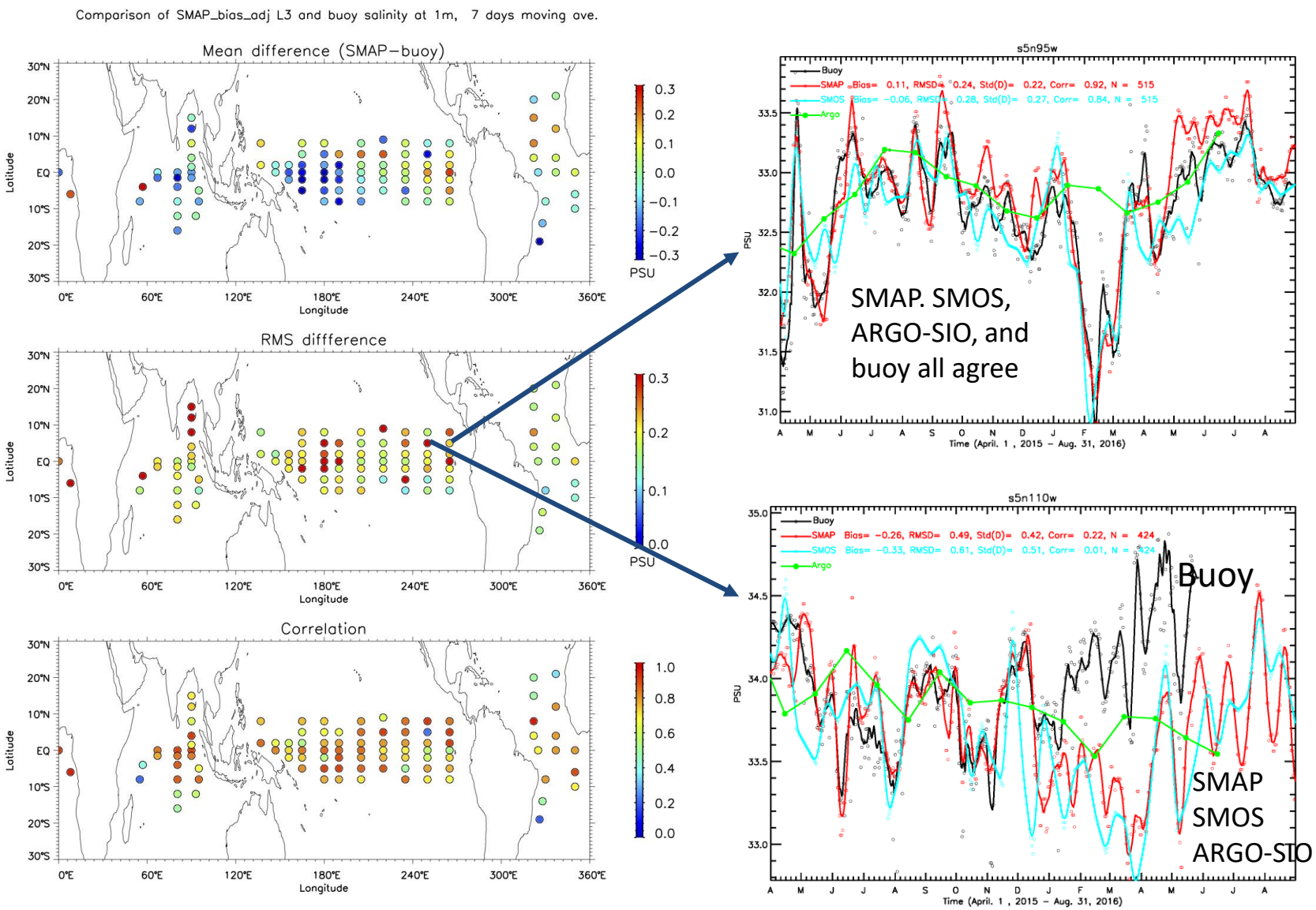

SMAP L2 Soil Moisture and L3 SSS 04/04/2015
60°N
30°N
0°N
30°S
60°S
0°E
60°E
120°E
180°E
120°W
60°W
0.6
0.5
0.4
0.3
0.2
0.1
0.0
[mm³/mm³]
32
33
34
35
36
37
38
PSU

JPL SMAP SSS and GOSUD Ship TSG Comparison in the Mediterranean (2015-2016)



SMAP and GOSUD ship TSG SSS data are binned on 0.25 deg grid

SMAP Salinity Comparison with Buoys



Comparison charts requested by and sent to PMEL

Summary of SMAP and SMOS vs. Buoy

- Excellent agreement between SMAP and mooring SSS in the tropical oceans based on the summary of statistical differences between them for 29 buoys with contiguous time series of SSS during April 2015 and August 2016.
- OI: 45 km search radius and 30 km half power

SMAP	Bias	Standard Deviation	Correlation
15 day average	0.07 psu	0.22 psu	0.73
30 day average	0.05 psu	0.17 psu	0.80

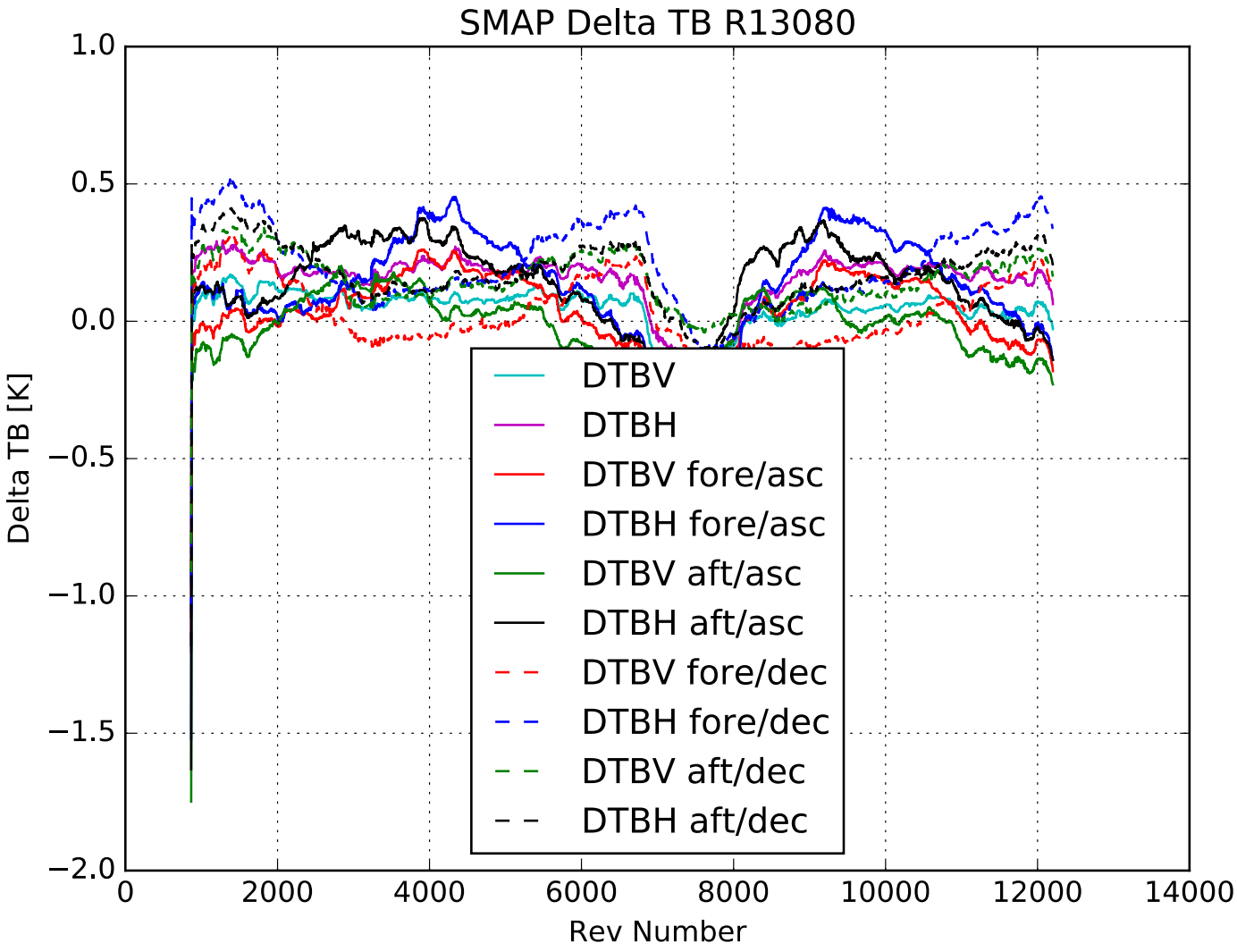
SMOS	Bias	Standard Deviation	Correlation
15 day average	-0.15 psu	0.26 psu	0.63
30 day average	-0.16 psu	0.22 psu	0.71

Summary

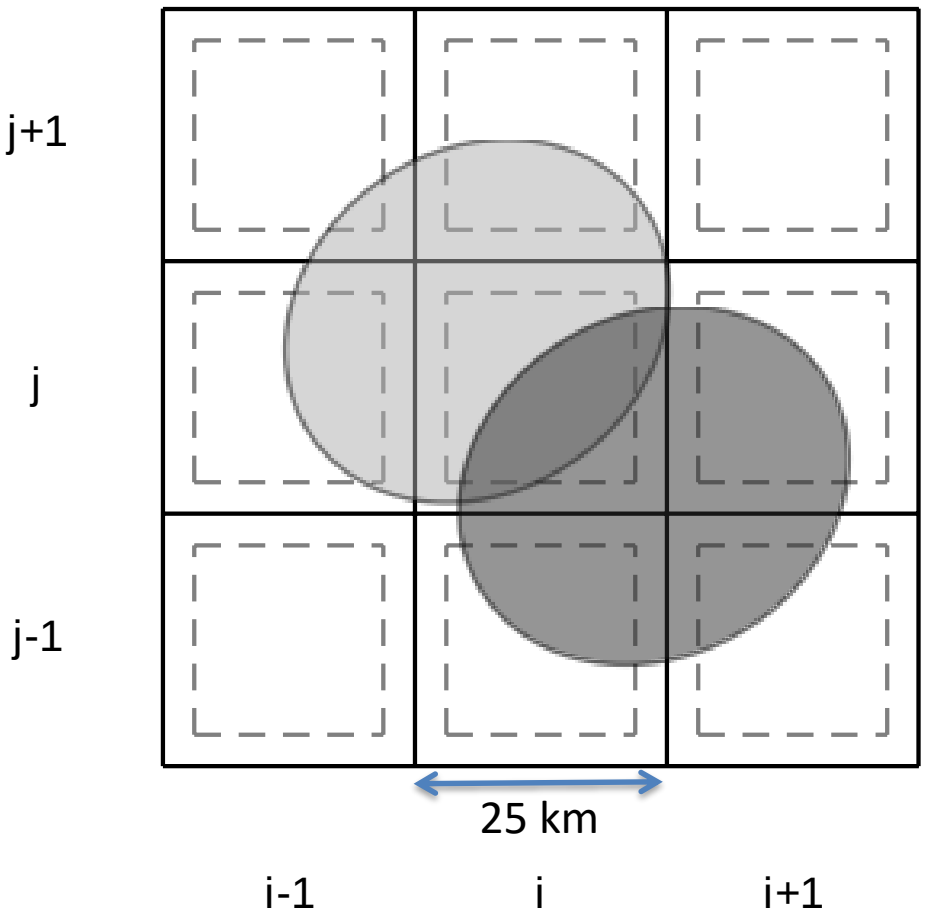
- SMAP radiometer-only is capable of providing an ocean salinity data product.
- SMAP SSS has ~ 0.18 psu accuracy for monthly gridded SSS products in the tropics and mid-latitude.
  - Can resolve TIW and large weekly SSS changes.
- Data are available at: http://podaac.jpl.nasa.gov/
  - L2B with a 3 day delay.
  - L3 8-day with a 7 day delay from center of 8-day window.
- Near-real-time data available at: ftp://sealion.jpl.nasa.gov/pub/outgoing/smap/
  - L2B NRT data with about 4.5 hour delay.
- Future Work:
  - Improve salinities in far northern / southern latitudes.
  - Ice correction based on NSIDC ice concentration maps.
  - Update land correction look up tables with 2nd year of SMAP data.

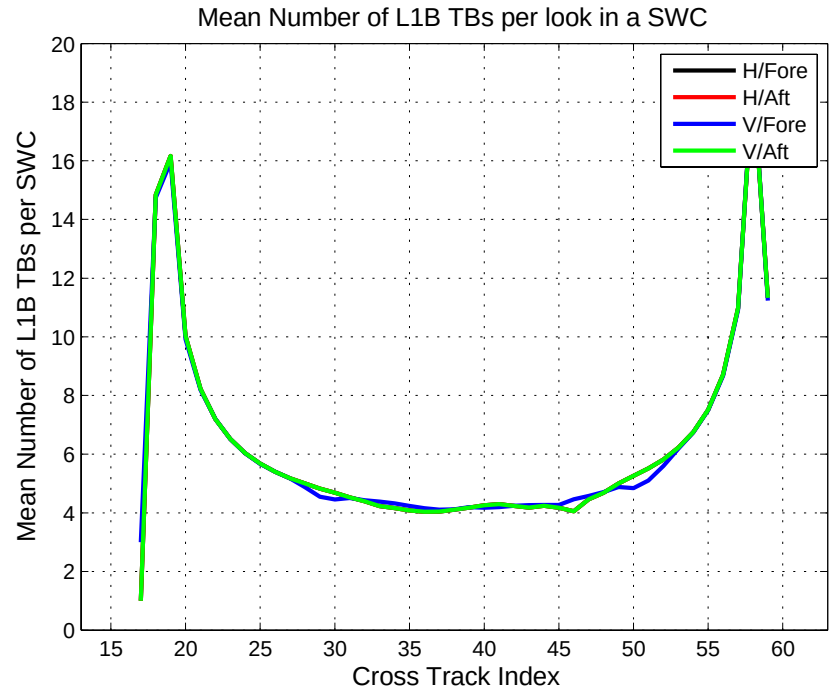
Publications

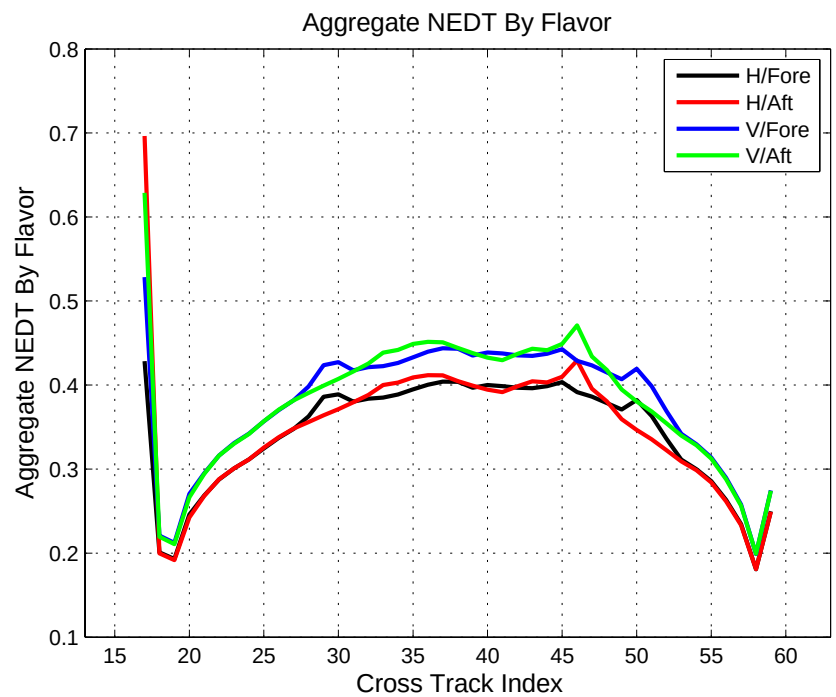
- Publications
  - Fore, A., S. Yueh, W. Tang, B. Stiles, and A. Hayashi (2016). Combined Active/Passive Retrievals of Ocean Vector Wind and Sea Surface Salinity with SMAP, IEEE Trans. Geoscience and Remote Sensing, doi: 10.1109/TGRS.2016.2601486.
  - Yueh, S., A. Fore, W. Tang, H. Akiko, B. Stiles, 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.
- Under revision
  - Wenqing Tang, Alexander Fore, Simon Yueh, Tong Lee, Akiko Hayashi, Alejandra Sanchez-Franks, Brian King, Dariusz Baranowski, and Justino Martinez, “Validating SMAP SSS with in situ measurements,” Remote Sensing of Environment


SMAP Delta TB R13080
Delta TB [K]
Rev Number
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
0
2000
4000
6000
8000
10000
12000
14000
DTBV
DTBH
DTBV fore/asc
DTBH fore/asc
DTBV aft/asc
DTBH aft/asc
DTBV fore/dec
DTBH fore/dec
DTBV aft/dec
DTBH aft/dec

L2A Gridding

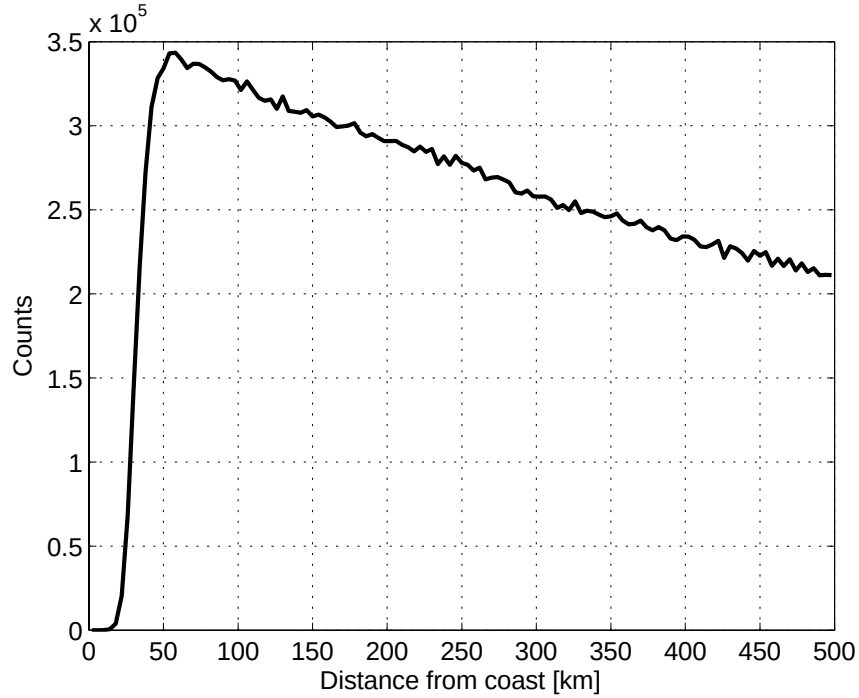


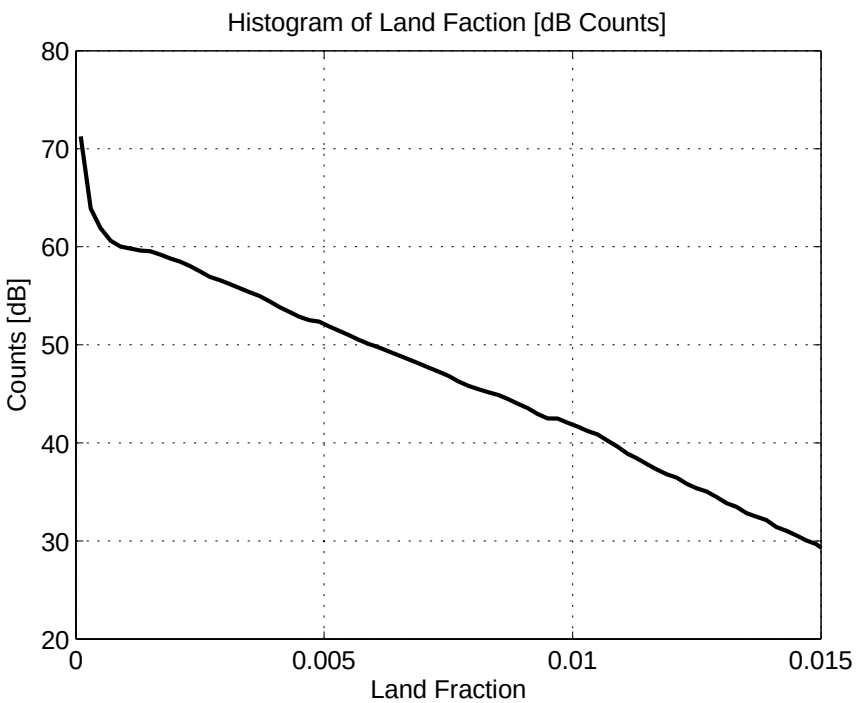


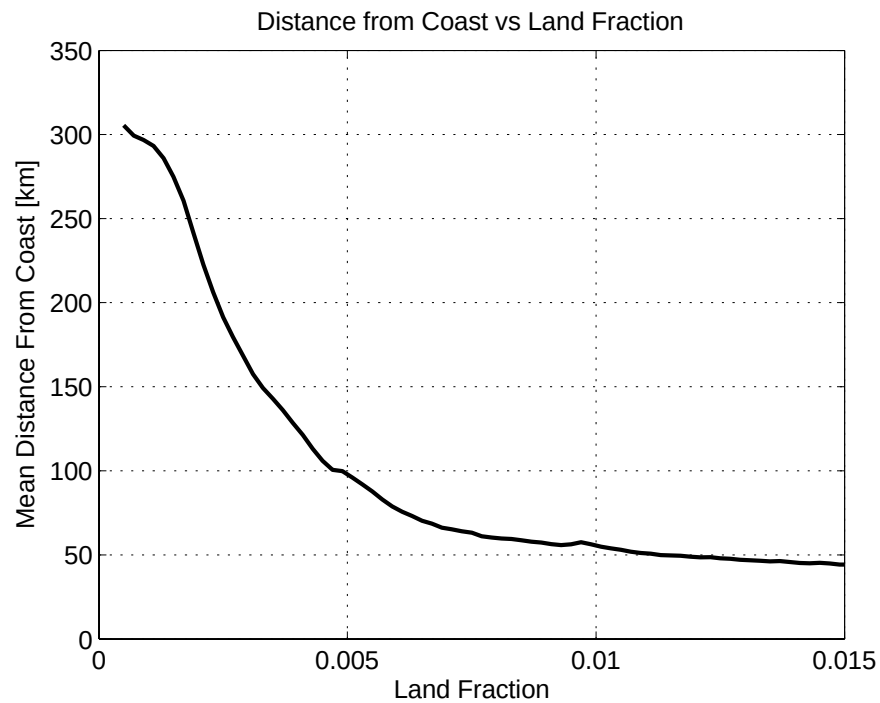
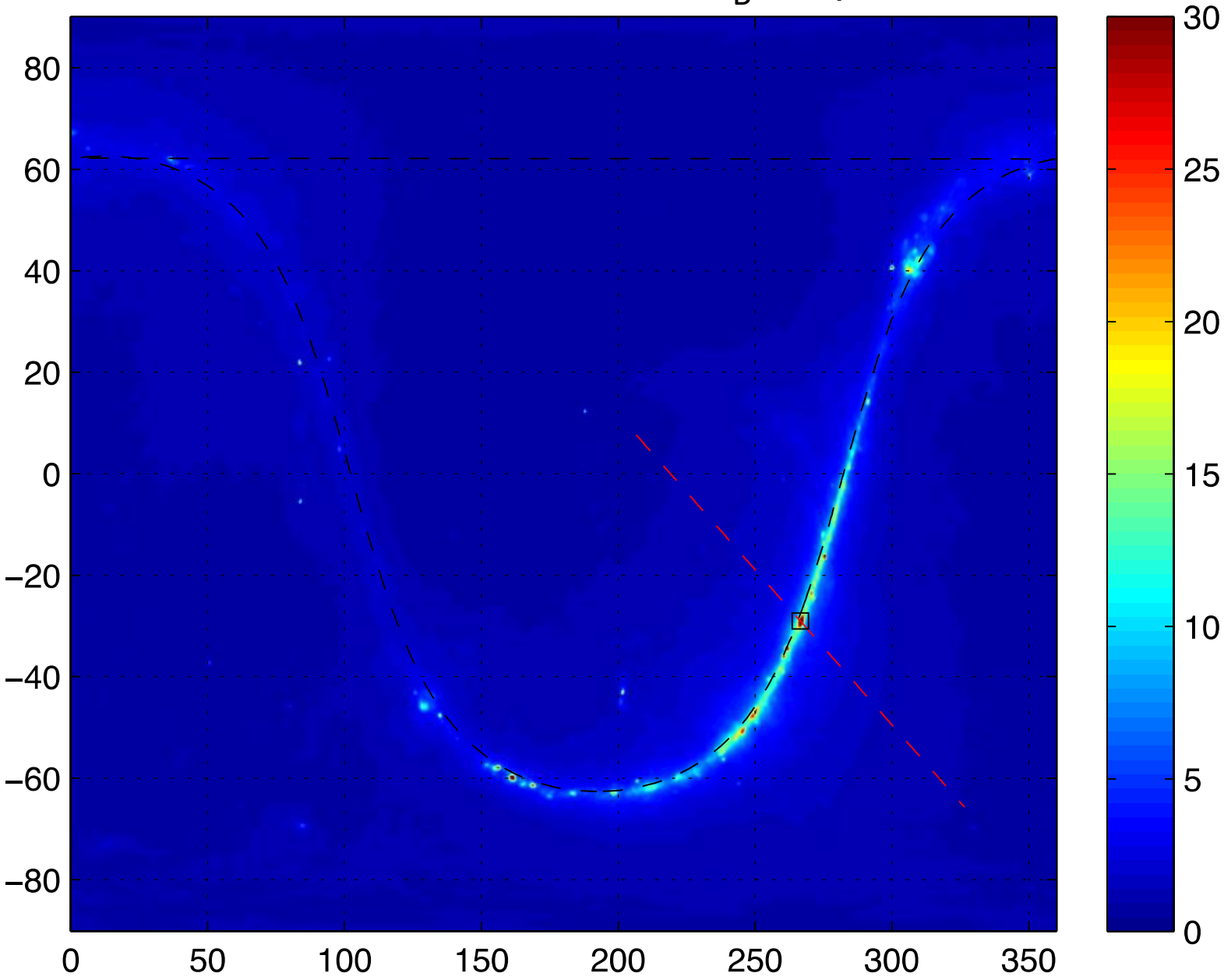


Land Correction Backup Figs

$$T_{corr} = \left(T_B - f_{land} T_{B,land}\right) / \left(1 - f_{land}\right)$$







L-band cosmic T_B map