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The RSS/NASA SMAP Salinity Version 3 Release: Resampling and Correction for Land Contamination

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Resampling

Backus-Gilbert Optimum Interpolation

See Paper by Poe 1990

- Reduce the noise in the observations (averaging with positive weights)
- Increase spatial resolution (averaging with negative and positive weights)
- Modify the shape of the footprint (i.e., ellipses to circles)

Method requires specifying a 'Target Footprint' and then finds a set of weights for observations in the neighbor of the Target

$$T_{A,rsp} = \sum_i A_i T_{A_i}$$

$$Q = \iint dxdy \left[G_T(x,y) - \sum_{i=1}^{n} A_i G_i(x,y) \right]^2$$

$$\mathbf{A} = \mathbf{g}^{-1} \left[\mathbf{v} + \frac{\left(1 - \mathbf{u}^{\mathrm{T}} \mathbf{G}^{-1} \mathbf{v}\right)}{\mathbf{u}^{\mathrm{T}} \mathbf{G}^{-1} \mathbf{u}} \mathbf{u} \right]$$

$$u_i = \iint dxdy G_i(x,y)$$

$$v_i = \iint dxdy G_T(x,y) G_i(x,y)$$

$$g_{ij} = \iint dxdy G_i(x,y) G_j(x,y)$$

$$\mathbf{G} = \mathbf{g} + \beta \mathbf{I}$$

Backus-Gilbert Applied to SMAP

SMAP Observations are over-sampled along the scan

Reporting interval is every 11 km along the scan

The instantaneous width of the cell is 31 km

Radiometer noise for individual observation is high

SMAP was designed as a land sensor

Many applications (not necessarily all) benefit from noise reduction

In principle, averaging can be applied at various places in the processing

To antenna temperatures via Backus-Gilbert

Averaging brightness temperatures into 1-deg cells

Averaging salinities into 1-deg cells

We selected Backus-Gilbert because:

It provides quantitative metrics on true spatial resolution and noise reduction.

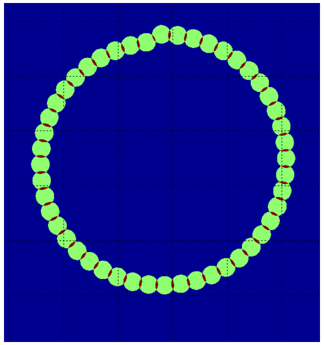
Better to do the averaging first because non-linearities can amplify noise (I think)

Consistent with our approach to other satellite sensors

Can be used to resample to fixed Earth grid

Two-Step Resampling

Step 1: Resampling in the along-scan direction



SMAP Level 1 data is typically 240 observation per scan,
with a variable starting azimuth angle.
This corresponds to an observation every 1.5^o.

The first step in the resampling is to take a single scan and adjustment
the position of the observations to corresponds to integer azimuth angles (i.e. 0 to 359^o).

The sampling in the along-scan direction well exceeds Nyquist sampling,
and the fit accuracy of the resampled data is very high: 0.002

Step 2: Resampling onto Fixed ¼^o Latitude/Longitude Earth Grid

Collocation of fore and aft observations requires an earth grid.
Use all observations having centers within a radius of 125 km of the ¼^o cell

$$T_{A,rsp} = \sum_i A_i T_{A_i}$$

Three Spatial Resolutions

Standard: SMAP footprint for one integration
Nominally called 40-km product (actually is 45 km)

Enlarged: Standard footprint enlarged by 1.5
Not used

Circle: Enlarged footprints average for 5 integrations to obtain circles
Nominally called 70-km product (actually is 75 km)

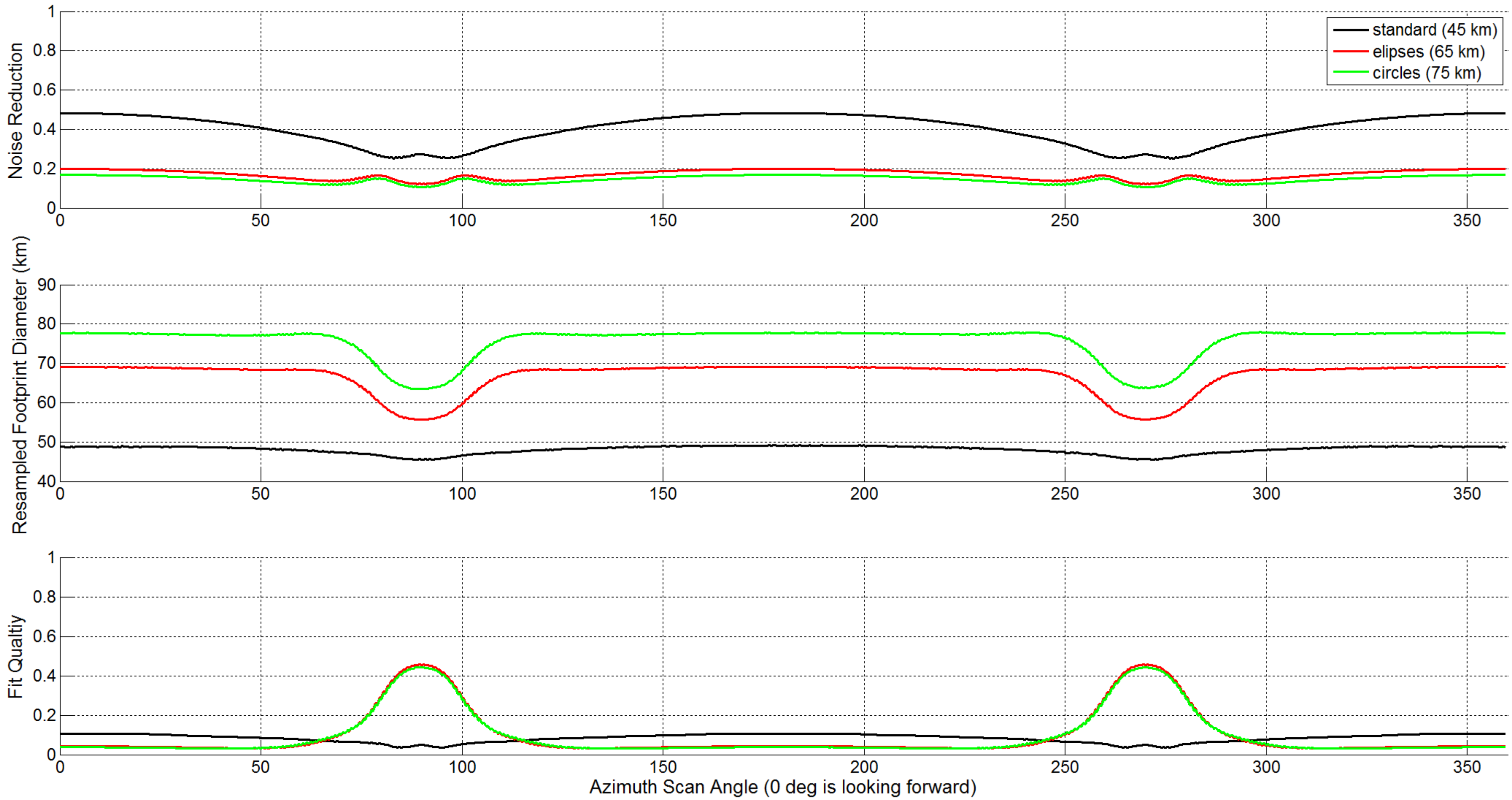
Definition of Resampling Metrics

$$\textbf{noise reduction factor} = \sqrt{\sum_i A_i^2}$$

$$\textbf{Cell Size} = \sqrt{\frac{4A_{3dB}}{\pi}}$$

$$\textbf{fit quality} = \frac{\iint dxdy \left| G_{rsp}(x,y) - G_T(x,y) \right|}{\iint dxdy G_T(x,y)}$$

Resampling Metrics Vs. Scan Azimuth Angle



Land Correction

Land (Sidelobe) Correction: Formulation

Desired Quantity
Footprint-Averaged T_B

$$\mathbf{T}_{\mathbf{B},3dB} = \frac{\int_{3dB\ footprt} \mathbf{T}_{\mathbf{BE},toa}\left(\bar{\theta}_i\right) dA}{\int_{3dB\ footprt} dA}$$

Measured Quantity
T_B averaged over 4π steradians

$$\mathbf{T}_{\mathbf{A}} = \frac{1}{4\pi}\int_{4\pi} \mathbf{G}(\mathbf{b})\boldsymbol{\Psi}(\phi)\mathbf{T}_{\mathbf{B}}\frac{\partial\Omega}{\partial A}dA \qquad \mathbf{T}_{\mathbf{B},mea} = \mathbf{A}\cdot\mathbf{T}_{\mathbf{A}}$$

Sidelobe Correction

$$\Delta\mathbf{T}_{\mathbf{B}} = \mathbf{T}_{\mathbf{B},3dB} - \mathbf{T}_{\mathbf{B},mea}$$

The 3 dB brightness temperature $\mathbf{T}_{\mathbf{B,3dB}}$ and the measured brightness temperatures $\mathbf{T}_{\mathbf{B,mea}}$ are found by the on-orbit simulator.

The integration over the Earth's surface is at a spatial resolution of 1 km over the mainlobe of the antenna and a coarser resolution is used outside the mainlobe.

Land (Sidelobe) Correction: Numerics

Aquarius Sidelobe Correction Table

polarization	(v-pol, h-pol)
spacecraft nadir longitude	(1440 elements in 0.25° increment)
spacecraft position in orbit	(1440 elements in 0.25° incremen t)
horn	(Inner, middle, and outer)
month	(12 elements)

Tb_land_correction(2,1440,1440,3,12), total elements = 149,299,200

SMAP Sidelobe Correction Table

polarization	(v-pol, h-pol)
cell longitude	(720 elements in 0.5° increment)
cell latitude	(361 elements in 0.5° increment)
Ascending/descending	(2 elements)
Scan angle	(30 elements in 12° increments)
month	(12 elements)

Tb_land_correction(2,720,361,2,30,12), total elemetns = 374,284,800

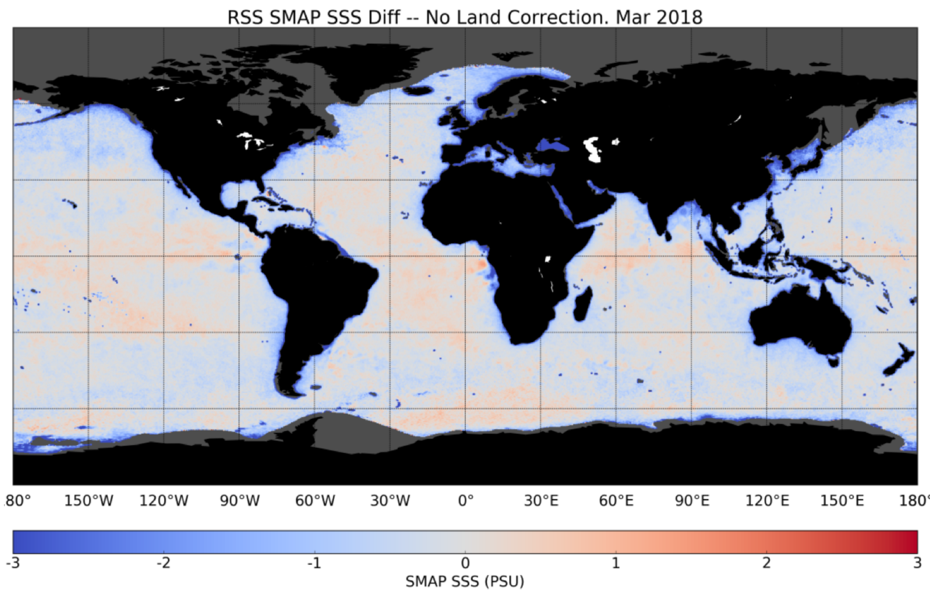
Using 60 processors, it takes about one week of processing to produce the T_B correction table for one month.

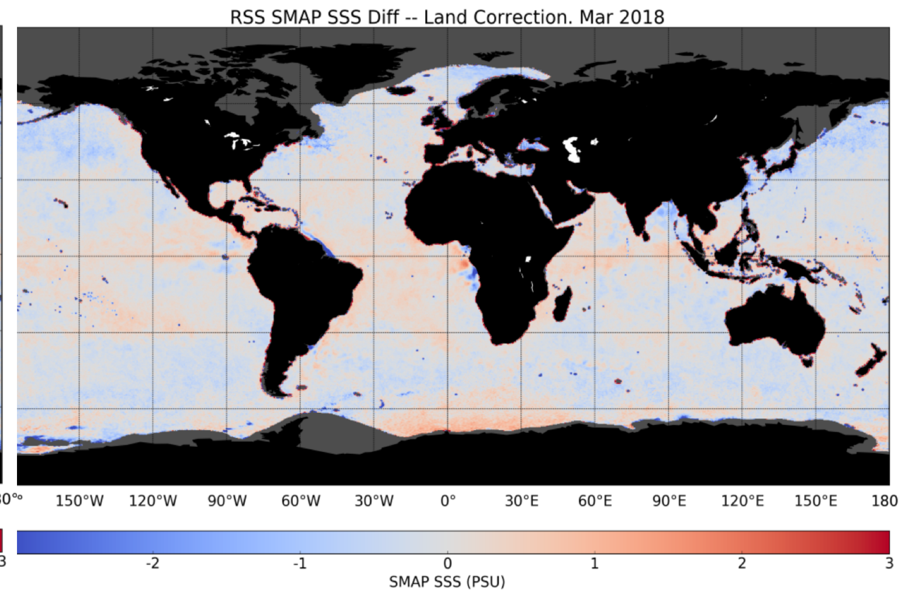
Land (Sidelobe) Correction: Example

March 2018, 40-km product

No Land Correction

With Land Correction





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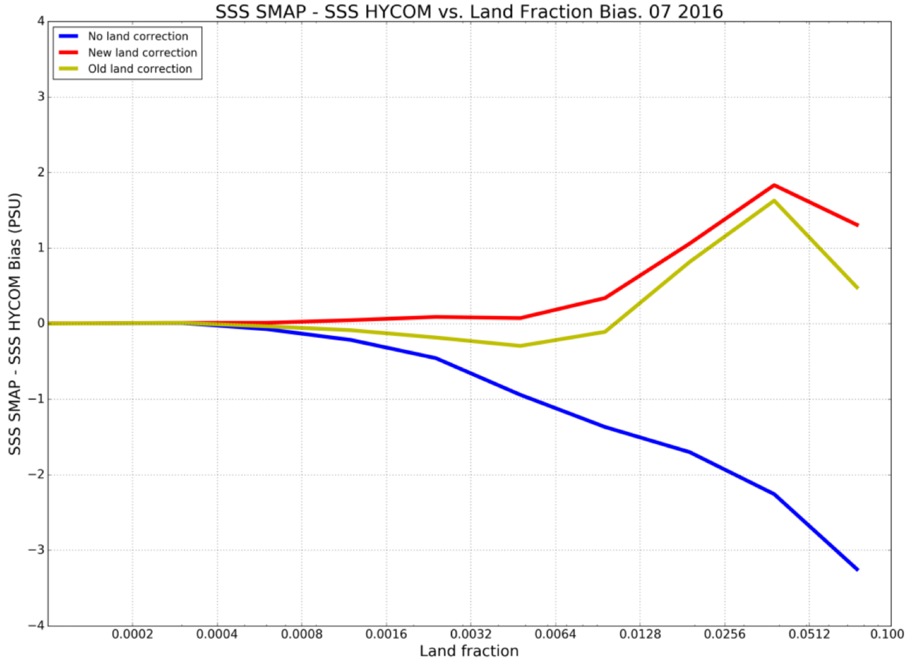
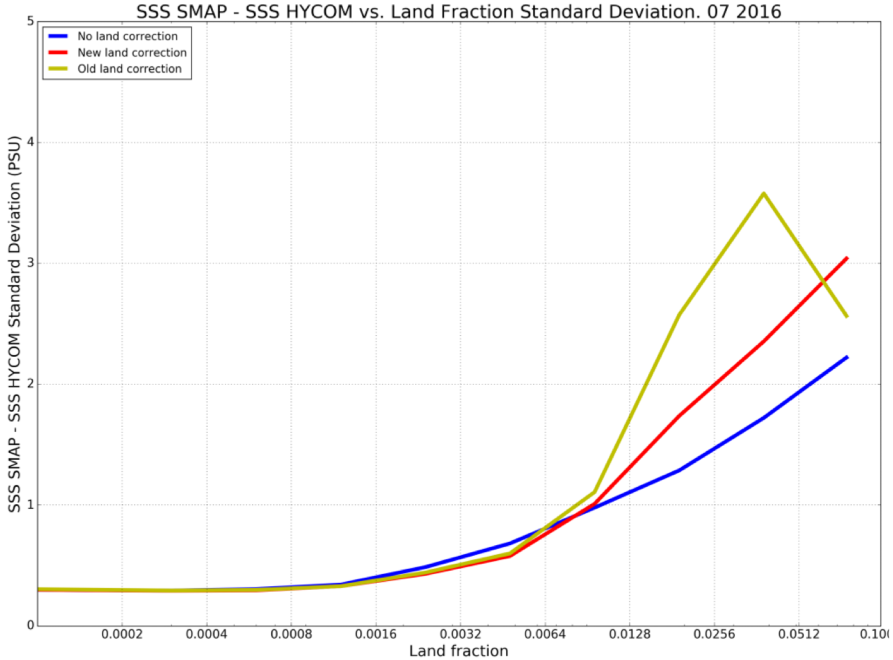
Performance of Land Correction

Bias



Standard Deviation



This is for July 2016.
For other months new correction (red) is stable and old correction (olive) varies.

Future Work

- Salinity Retrievals with just Step-1 Resampling are ‘just about’ ready.
- Simulated Land Correction needs evaluation for both 40 and 70 km products
- Empirical adjustments to simulated land correction should be made.