Extending The Scatterometer Climate Record

David G. Long

Microwave Earth Remote Sensing Laboratory, Center for Remote Sensing
Brigham Young University

www.scp.byu.edu

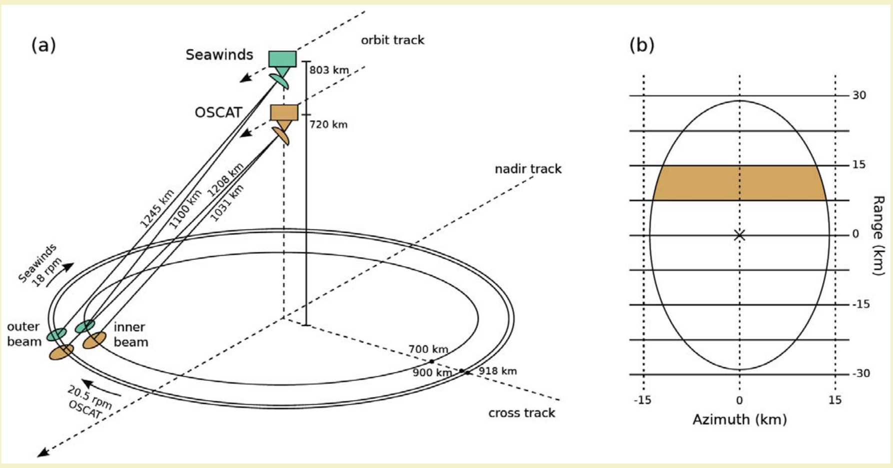
Summary

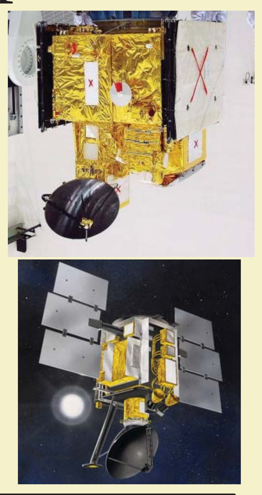
By compiling and processing previous scatterometer data, the Scatterometer Pathfinder Project (SCP) has generated a comprehensive Climate Data Record (CDR) of backscatter images to facilitate use of this unique dataset in climate studies of land and ice. This data is widely distributed to the climate research community. The SCP uses an innovative image formation technique to generate backscatter images from the various sensors on consistent and compatible grids at both conventional and enhanced resolution. Optimum spatial and temporal grid sizes have developed that facilitate fusion with microwave radiometer (AMSRE and SSM/I) image data sets also produced by the SCP.

Spanning nearly 35 years, the SCP dataset includes multiple Ku-band and C-band scatterometers: Seasat (Ku-band 1978), ERS-1/2 (C-band 1992-2001), NSCAT (Ku-band 1996-1997), QuikSCAT (Ku-band 1999-present), and SeaWinds (Ku-band 2003). We are now processing ASCAT (C-band 2007-present) and have started using Ku-band Oceansat-2 scatterometer (OSCAT) (2009-present) data.

We have developed a new method for inferring the spatial response function of the scatterometer measurements, which we use on QuikSCAT and OSCAT data to validate the predicted backscatter response functions. The method is based on island observations. We also evaluate azimuthal responses of backscatter from QuikSCAT, ASCAT, and OSCAT over the Amazon rainforest and regions of Antarctica.

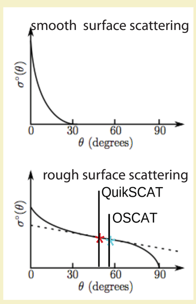
OSCAT & QuikSCAT Comparison



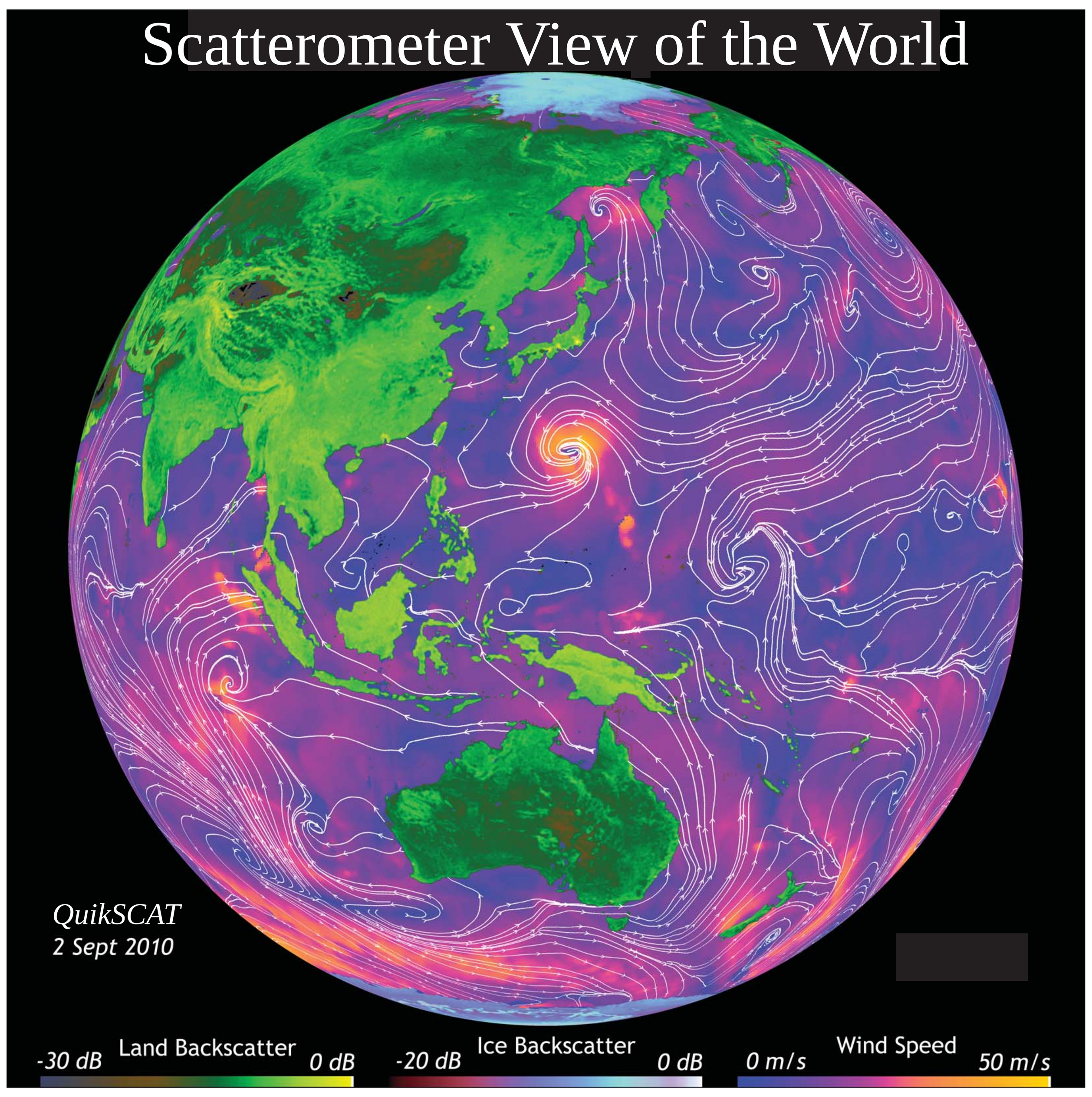


Beam	Parameters	QuikSCAT (Ku-band)	OSCAT (Ku-band)
Both	Ascending Node Time	6:00 a.m. +/- 30 min	12:00 midnight +/- 30 min
H-pol (Inner)	Incidence Angle	46˚	49˚
	Footprint (Az x El) km	24.0 x 31.0	26.8 x 45.1
	Reported Slices	8	7
V-pol (Outer)	Incidence Angle	54˚	57˚ (~58˚ observed)
	Footprint (Az x El) km	26.0 x 36.0	29.7 x 68.5
	Reported Slices	8	12

Otherwise very similar, a key difference between QuikSCAT and OSCAT is the incidence angle. To use OSCAT to extend the QuikSCAT climate record for land/ice imaging we must compensate for the difference in incidence angle using NSCAT measurements. The different orbit ascending times means that the local-time-of-day for the observations also differ, which can be important for vegetation and snow/ice monitoring.



Scatterometer View of the World



OSCAT Spatial Response Estimate Results

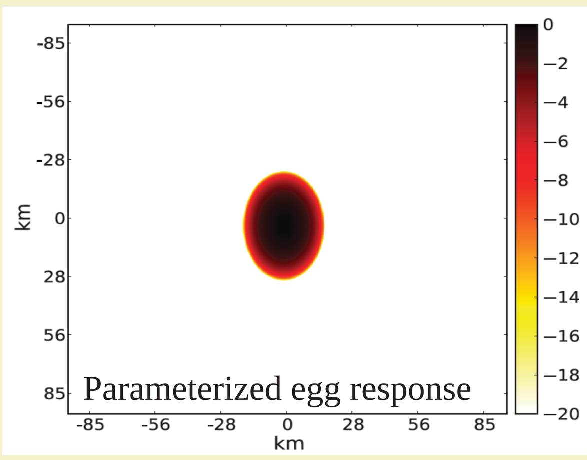
Estimated responses compare well to reported sizes. Reported footprint sizes:

H-pol: 26.6 km x 45.1 km

V-pol: 29.7 km x 68.5 km

Estimated footprints about 10 % smaller (see tables)

Elevation/azimuth ratio of estimated footprint agrees with reported to within 3% for H-pol



Estimated 6 dB footprint sizes

H-pol

Type	6 dB Beamwidth (Az x El) (km)
Egg	24.9 x 40.8
Slice 0	22.6 x 14.6
Slice 1	23.7 x 15.4
Slice 2	24.9 x 13.4
Slice 3	27.2 x 14.2
Slice 4	26.1 x 15.4
Slice 5	24.9 x 15.6
Slice 6	24.9 x 17.5

V-pol

Type	6 dB Beamwidth (Az x El) (km)
Egg	29.0 x 49.8
Slice 0	29.4 x 16.6
Slice 1	30.8 x 16.6
Slice 2	34.0 x 17.5
Slice 3	29.4 x 17.5
Slice 4	28.5 x 15.6
Slice 5	31.2 x 17.8
Slice 6	34.0 x 18.1
Slice 7	29.4 x 18.1
Slice 8	36.2 x 15.6
Slice 9	40.8 x 17.8
Slice 10	37.9 x 23.3
Slice 11	32.0 x 20.6

OSCAT Spatial Response

For applying land and ice contamination ratio processing, as well as generating enhanced resolution backscatter and winds, an estimate of the spatial response function of OSCAT measurements is needed. Isolated islands in the polar region are used to estimate the egg and slice responses through a forward measurement model, whose integral is discretized. The island is modelled with a constant, uniform sigma-0. For each pass the ocean sigma-0 is estimated and subtracted from sigma-0 measurements near the island. A least-square approach is then used to estimate the matrix that describes the spatial response function of the measurements.

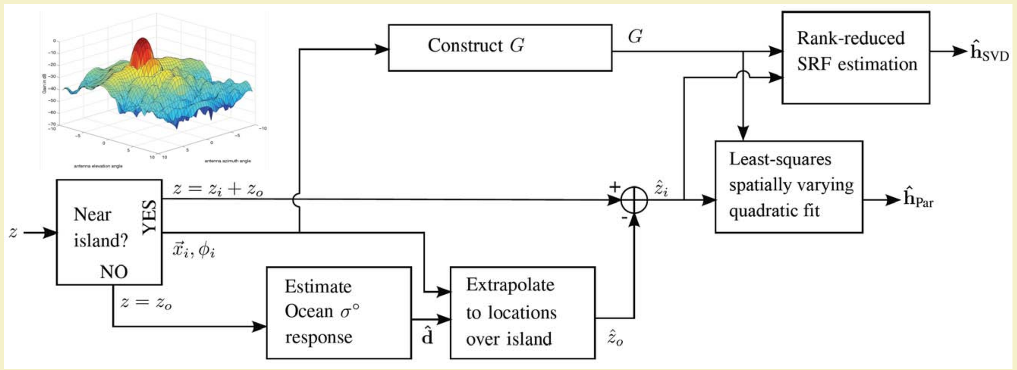
The forward measurement model:

$$z = \int_{area} h(x,y)S(x,y)\,dx\,dy + noise$$

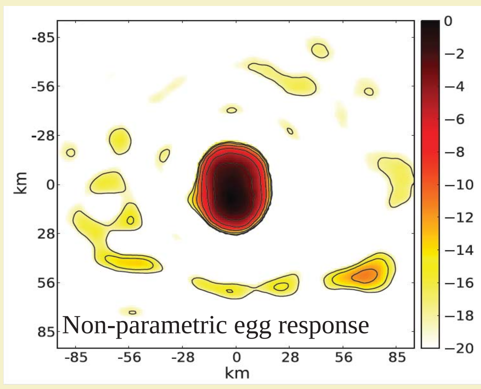
where z is the sigma-0 measurement, $h(x,y)$ is the spatial response function, and $S(x,y)$ is the assumed known island sigma-0 function. Discretizing this equation, $S(x,y)$ becomes the elements of G, and the vectors **h** and **z** have elements $h(x,y)$ and z

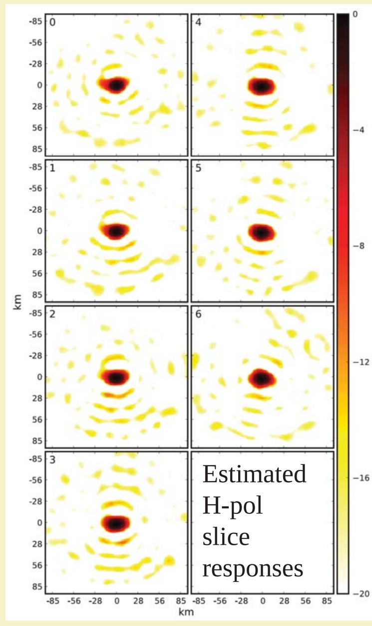
$$\mathbf{z} = \mathbf{G}\mathbf{h} + noise$$

SVD regularization improves the noise rejection performance or the pattern shape can be parameterized with a low-order 2-D polynominal. Island size affects the SNR of the estimate. Simulation was used to select the optimum island size, which is approximately equatl to the slice or egg dimensions. The Spatial response is assumed to be time constant.



(above) Estimation algorithm flow diagram. (right) Estimated H-pol egg and slice spatial response functions. Estimated V-pol responses tend to be noisier and have artifacts which we are investigating.





Sigma-0 Calibration over the Amazon

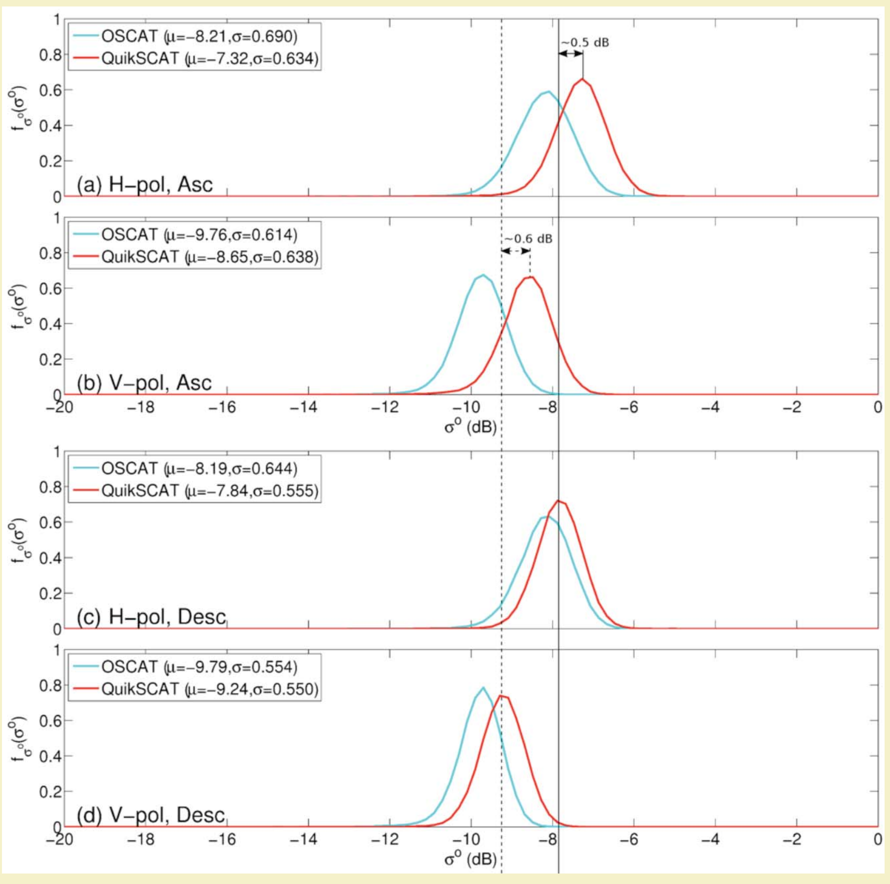
For image-based calibration we create sigma-0 images from both sensors during overlap period, select homogenous areas, and compute the calibration offset. We must account for incidence and azimuth angle differences, and possibly local time-of-day differences in computing the calibration offset β for images.

Incidence correction model

$$z_i(\phi) = z_i(\theta,\phi) - \mathcal{B}(\theta_i - \Theta)$$

Azimuth correction model

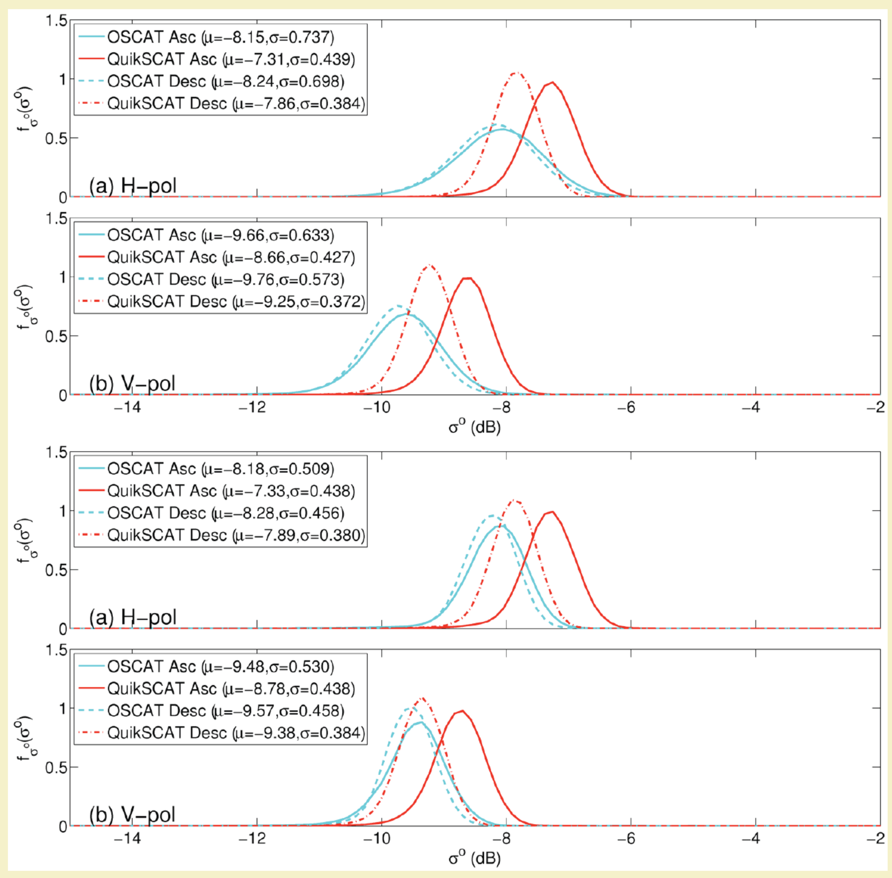
$$z_i = z_i(\phi) - \sum_{k=1}^{4}\left[D_k \cos(k\phi_i) + F_k \sin(k\phi_i)\right]$$



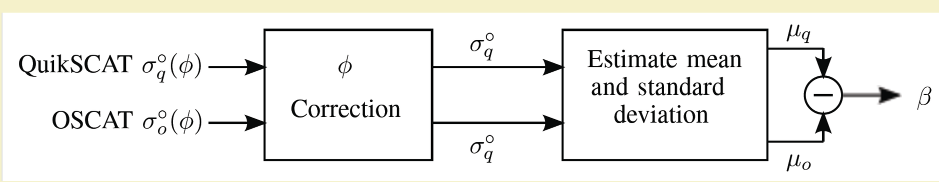
Key idea is to use QuikSCAT as a reference, and adjust OSCAT measurements to "look" like QuikSCAT, i.e. have same mean and similar azimuth response within the Amazon mask region. Repeat for other regions.

Figures show probabilty densities of OSCAT and QuikSCAT over the Amazon mask region. (left) eggs. (right) slices.

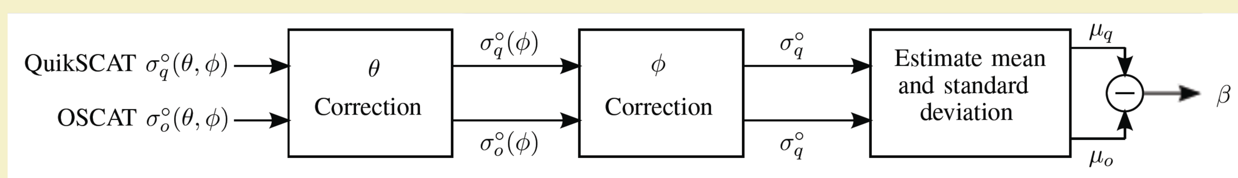
Note the mean offsets due to incidence angle differences and calibration offsets. Also note similarity of standard deviations of eggs. Slice standard deviations have more variability between sensors.



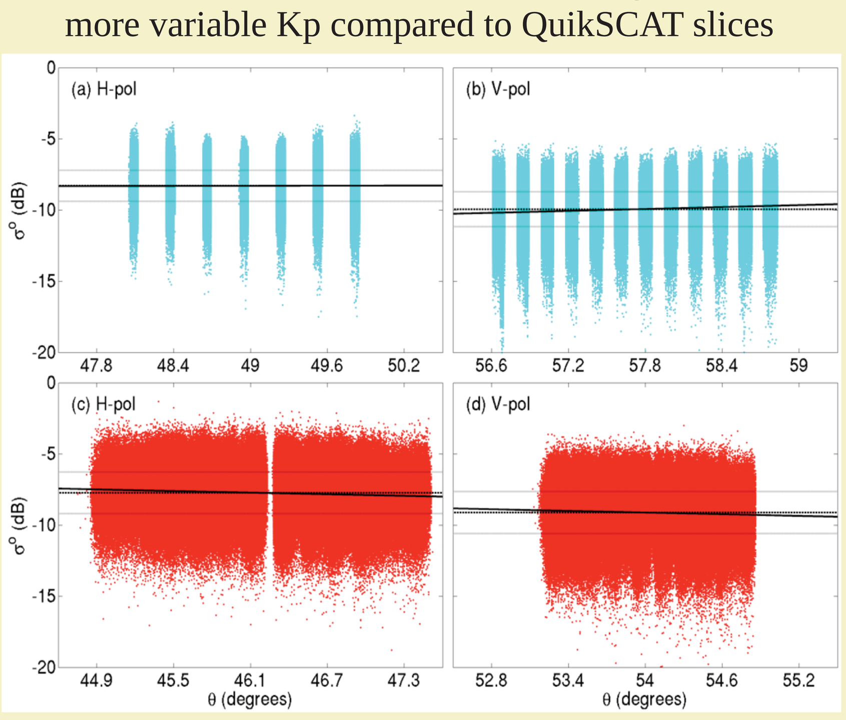
(w/o incidence angle correction)



(incidence & azimuth angle correction)



OSCAT slices have discrete incidence angles but also more variable Kp compared to QuikSCAT slices



Estimated sigma-0 offsets (dB/deg) for Amazon

Type	Satellite Pass	β_h	β_v
Egg	Ascending	0.89	1.11
	Descending	0.34	0.55
	Combined	0.64	0.85
Slice	Ascending	0.81	1.16
	Descending	0.27	0.47
	Combined	0.57	0.84

- OSCAT
- QuikSCAT

Since QuikSCAT azimuth variation over the Amazon is flat, OSCAT azimuth variation is corrected using azimuth model