RapidScat Recalibration and Reprocessing Status

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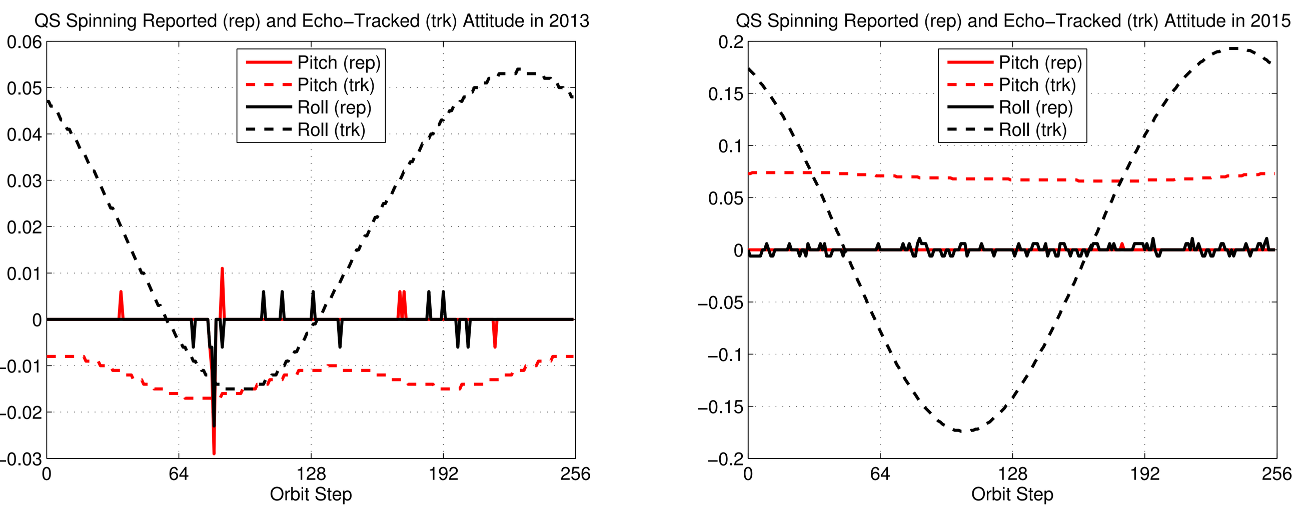
Introduction

First we consider the recent performance of non-spinning QuikSCAT, which is an essential calibrator for RapidScat as well as other Ku-band scatterometers. We have found evidence of an uncompensated frequency shift which has affected the QuikSCAT calibration for data starting in 2015. We show that when spinning in 2015 there is a significant difference between the predicted attitude of QuikSCAT and that determined using echo-tracking. During nominal operations this has no effect on calibration as the L1B processor can determine the actual echo mis-centering and compensate using the Xfactor tables. However, when not spinning we must use the reported attitude for Xfactor computation and thus an un-compensated echo mis-centering will cause an Xfactor error for non-spinning QuikSCAT. We develop an algorithm to determine the actual frequency shifts due to the attitude errors using the slice powers and show it gives the same estimated frequency shift as determined by the processor using echo-tracking for the spinning data. We re-estimate the echo mis-centering and then Xfactors for all of the non-spinning QuikSCAT and show that it improves consistency of the calibration of QuikSCAT. Finally we transfer this improved QuikSCAT calibration to RapidScat for the next major reprocessing of RapidScat. We conclude with some other significant changes planned for the next version of the RapidScat L2B data products.

QuikSCAT Recalibration

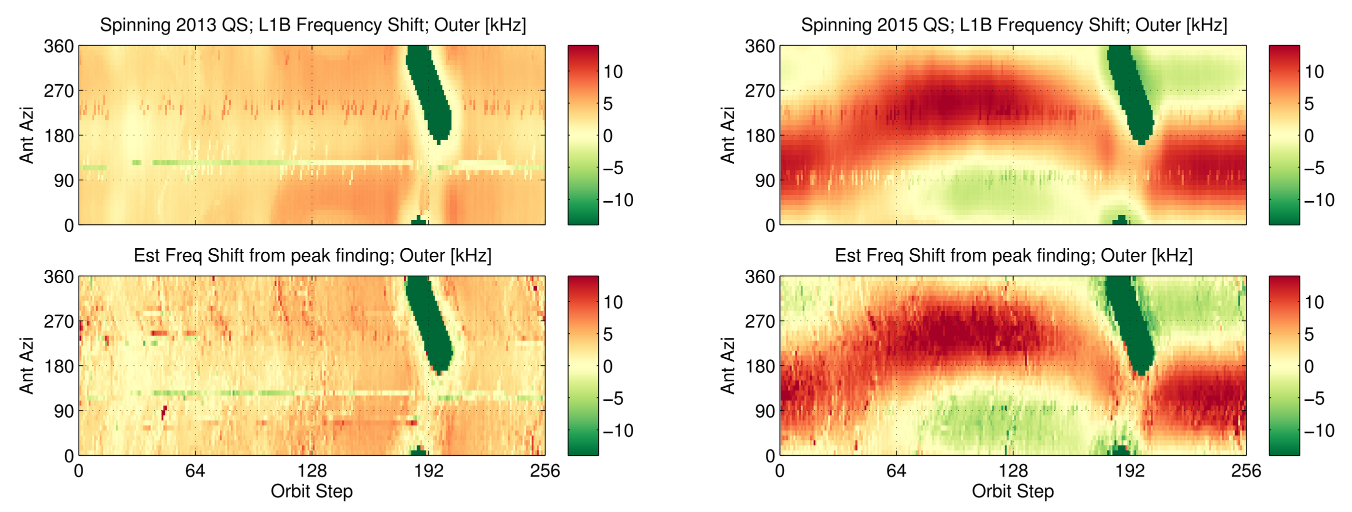
Spinning QuikSCAT

In 2013 and 2015 when we activated QuikSCAT after the eclipse season QuikSCAT operated in its nominal spinning mode for quite some time before the antenna stopped moving. During the time when QuikSCAT is spinning the echo-tracking algorithm is used to determine the actual pitch and roll from the slice powers as a function of antenna azimuth angle, while yaw is assumed to be zero. Here are some comparisons between the echo-tracked attitude and reported attitude in 2013 and 2015:



Reported pitch (red line) and echo-tracked pitch (red dashed), reported Roll (black line) and echo tracked (black dashed). (left) 2013 spinning QuikSCAT data (right) 2015 spinning QuikSCAT.

In 2015 we find a 0.3° peak to peak variation in echo tracked versus reported roll and a smaller difference for pitch – these differences were not present in the 2013 data on the left plot. If we consider the effect of this attitude on the echo centering for these spinning QuikSCAT data we see:

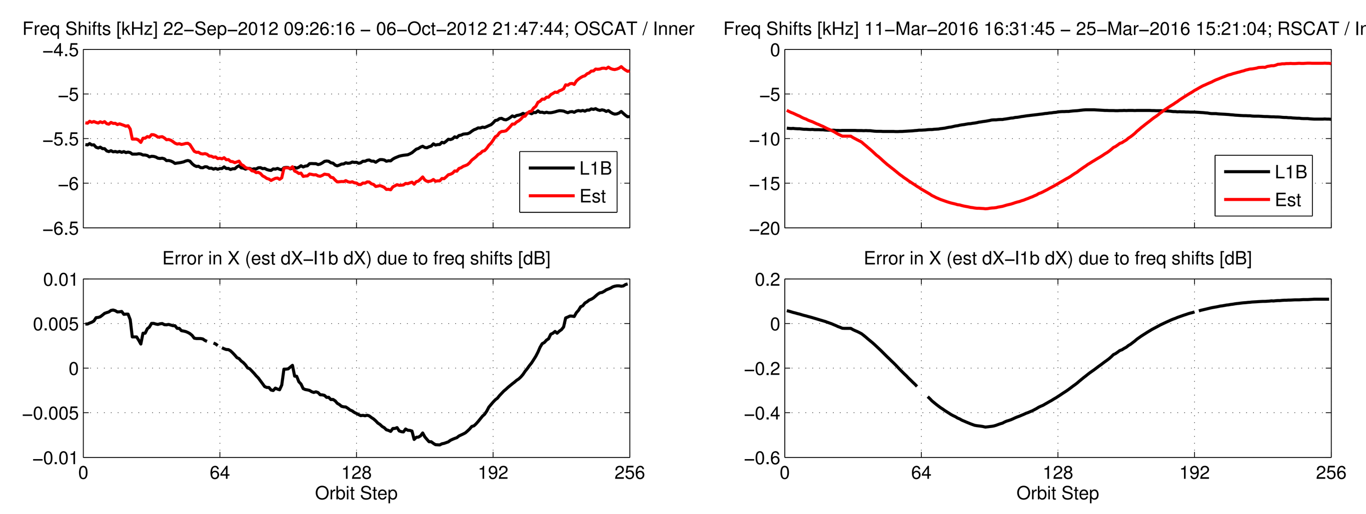


(left) 2013 spinning QuikSCAT (top) frequency shifts computed from echo-tracked attitude and (bottom) those computed using the slice powers using a peak-finding technique. (right) same for 2015 spinning QuikSCAT data.

Note the frequency shifts for 2013 data were quite small while those for 2015 were significant and would incur a significant change to the footprint Xfactors. The L1B processor computes this frequency shift as a part of its normal processing and adjusts the Xfactors as a function of that frequency shift. When QuikSCAT is spinning, this does not present a problem so long as the frequency shift is small enough.

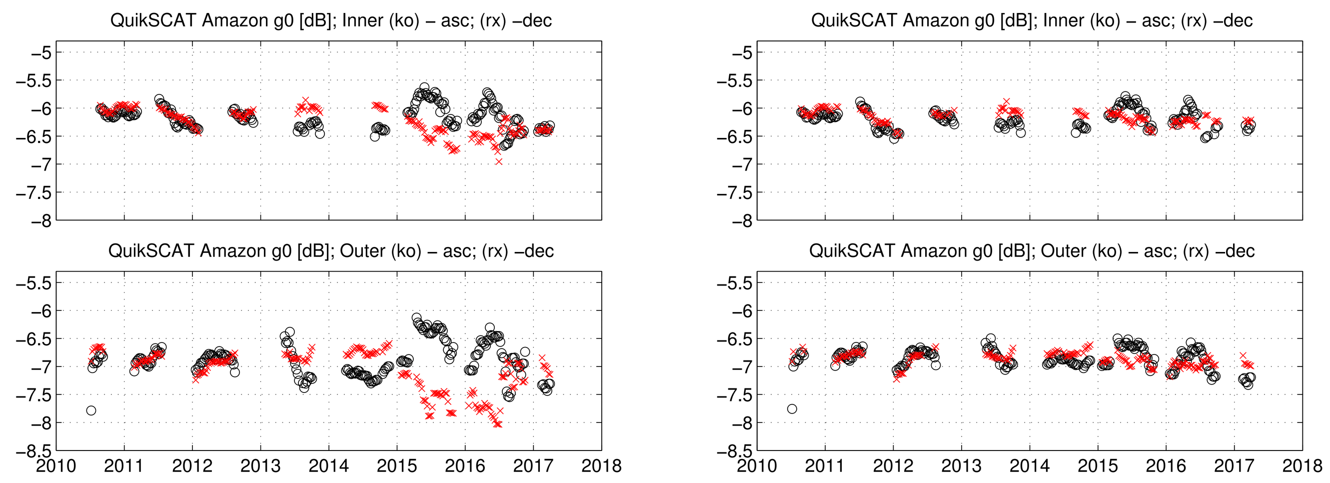
Non-spinning QuikSCAT

For non-spinning QuikSCAT we cannot use echo-tracking to determine the attitude and we must use the reported attitude for processing and determination of Xfactor. While we cannot determine the attitude, we can determine the frequency shift for computation of Xfactor adjustments as the Xfactor is a function of frequency shift for small perturbations about zero. We divide the non-spinning data up into intervals of at most two weeks of data. For each interval we compute the average power as a function of slice number and orbit step for that two week period. For each orbit step we then fit a polynomial to determine the location of the peak response in slice number. The frequency shift is then linearly related to the peak response in slice number. We have verified this method using the spinning 2013 and 2015 data as shown in the previous figure. We see that the frequency shifts determined using echo-tracking and those determined using our method agree very well for both the 2013 and 2015 data proving that we can use this method to determine the residual calibration error due to un-compensated mis-centering of the echo in the science slices. The effect was largest in 2015 and 2016, being fairly small before that and not as large in 2017 so far. Here we show two examples of the estimated frequency shifts and the resulting Xfactor error due to the differences between the L1B frequency shift value computed using reported attitude and the frequency shift determined from the echo itself.



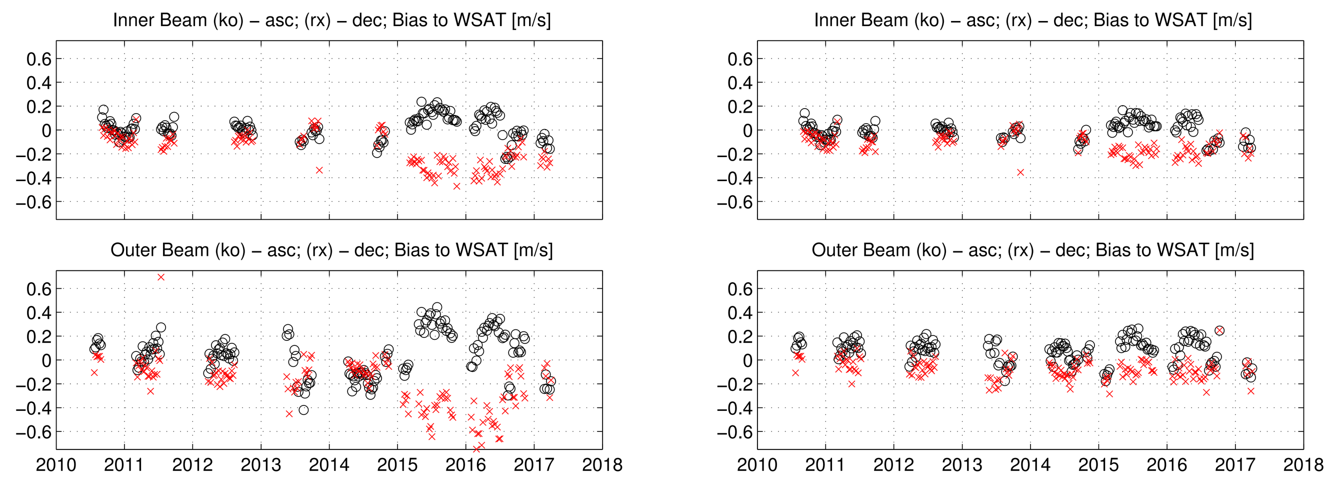
(left) 2012 non-spinning data (top) L1B frequency shifts in black, estimated from slice powers in red, (bottom) error in Xfactor due to mis-estimation of frequency shifts (right) same for 2016 data.

We see much larger differences between the L1B frequency shifts and those estimated from the slice powers on the right where the error in Xfactor is as large as 0.4 dB for inner beam and even larger for outer beam (not shown). Overall, we find that the error is quite significant in 2015 and 2016, which is the period of time used for RapidScat cross-calibration. To evaluate the Xfactor corrections, we plot the Amazon γ_0 as a function of time, for each beam and ascending/descending separately, after removing the diurnal variation of the Amazon:



Amazon $\gamma_0 = \sigma_0/cos(inc)$ as function of time with local time of day correction. (left) no re-estimation of Xfactor (right) with Xfactor re-estimation. (top) inner beam; (bottom) outer beam. Ascending - black circles, descending red x.

Note the large differences between ascending and descending in 2015 and 2016 in the left plot that are corrected in the right plot. After removing the diurnal variation of the Amazon γ_0 from the time series we do not expect any further ascending / descending differences. The large ascending / descending differences are corrected by our QuikSCAT re-calibration. Next we consider a similar analysis comparing the non-spinning QuikSCAT wind retrievals to WindSat.



Non-spinning QuikSCAT wind speed retrieval bias compared to WindSat. (left) no re-estimation of Xfactor (right) with Xfactor re-estimation. (top) inner beam; (bottom) outer beam. Ascending - black circles, descending red x.

Again note the large ascending / descending bias in 2015 and 2016 that is corrected for after re-estimation of frequency shifts. Both analyses indicate significant improvement of the QuikSCAT σ_0 calibration for 2015 and 2016 time periods by re-estimation of the baseband frequency shift and re-computation of the Xfactor.

RapidScat Reprocessing Plans and Status

Recalibration using Updated QuikSCAT Calibration

The changes to the QuikSCAT calibration will flow down to the RapidScat calibration. We have performed the Ocean and Amazon based cross-calibration analyses using the updated QuikSCAT calibration and obtained the results summarized in this table.

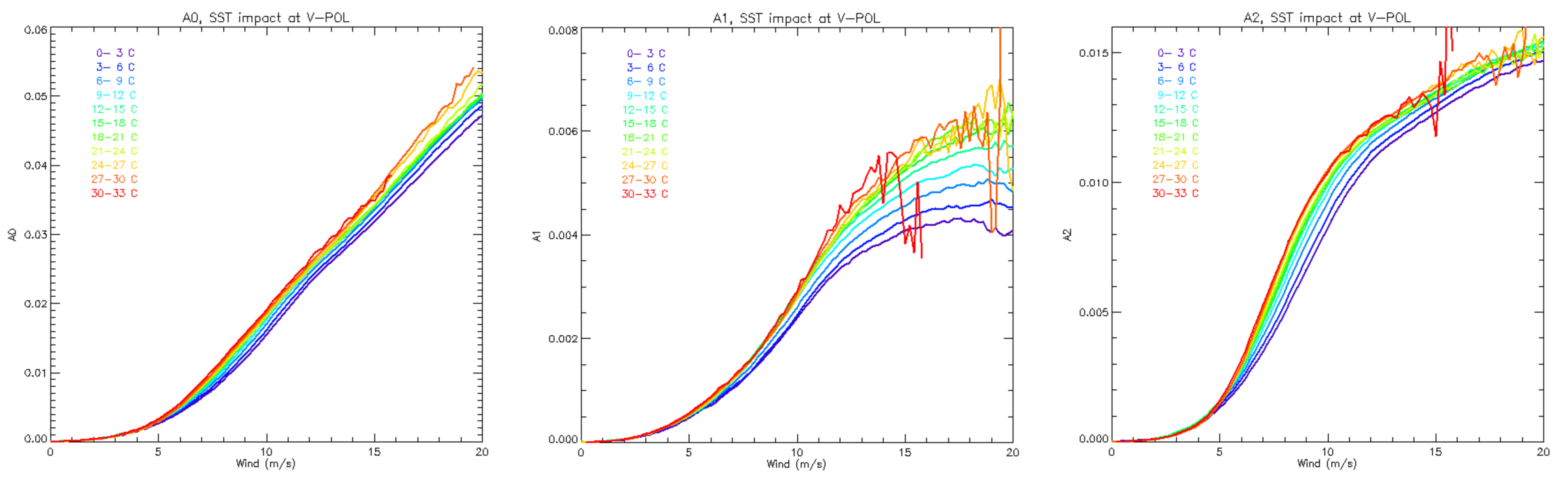
All in dB	HH Amazon	HH Ocean	HH Mean	VV Amazon	VV Ocean	VV Mean
High SNR	-0.024	-0.017	**-0.020**	-0.152	+0.064	**-0.044**
Low SNR 1	+0.056	+0.028	**+0.042**	-0.263	-0.068	**-0.166**
Low SNR 2	-0.066	-0.253	**-0.159**	-0.172	-0.284	**-0.228**
Low SNR 3	-0.045	-0.038	**-0.042**	-0.253	-0.333	**-0.293**
Low SNR 4	-0.055	-0.015	**-0.035**	-0.227	-0.269	**-0.248**

Calibration biases estimated from non-spinning QuikSCAT for RapidScat. These biases in this table will be subtracted from the RapidScat σ_0 to in the next processing.

We use two types of calibration analyses for calibration of RapidScat from QuikSCAT: an Amazon rainforest based analysis and an ocean histogram matching technique. Generally we find that the changes for HH will be small, with the largest being for Low SNR 2 by 0.15 dB. The changes for VV will be larger for the Low SNR periods, increasing it by 0.17 to 0.29 dB.

SST Dependent GMF

With Remote Sensing Systems we plan to implement a Sea Surface Temperature (SST) dependent model function for the next reprocessing. Preliminary results show significant dependance of Ku-band σ_0 with SST.



SST dependant model function for VV polarization from QuikSCAT data. (left) A0 - non-directional term, (middle) A1 term – first cosine harmonic, (right) A2 term – second cosine harmonic.

Summary

- We have found residual un-compensated frequency shifts in non-spinning QuikSCAT data requiring recalibration.
- We developed a method to estimate the echo mis-centering and resulting Xfactor errors.
- The effect was somewhat mitigated for RapidScat calibration as we average ascending and descending together for the overall calibration analysis.
- New RapidScat calibration numbers will result in little change to HH while generally increasing VV for all except High SNR.
- An SST dependent GMF is being developed and planned to be used in the next version of RapidScat data products.

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