Calibration and Validation of ASCAT-B

Craig Anderson, Julia Figa-Saldaña & Julian Wilson

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Introduction

Metop-B launched in mid September 2012, ASCAT-B switched on at end of September.

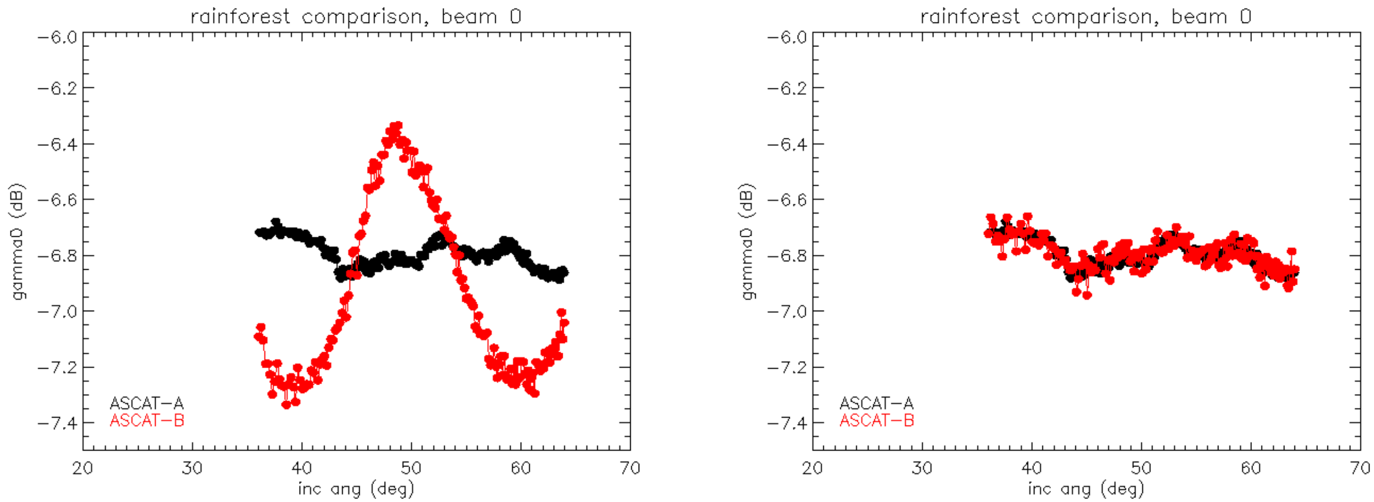
Preliminary calibration in October 2012 by tuning the ASCAT-B gain pattern so that it produces the same backscatter over the Amazon rainforest as ASCAT-A.

Calibration campaign using three transponders based in Turkey started in October 2012 with the last data being collected in January 2013.

Preliminary Calibration

Calibration using transponders takes several months so ASCAT-B was initially cross-calibrated with ASCAT-A.

Two weeks of data over Amazon rainforest were collected and the ASCAT-B gain patterns modified so that the backscatter looked similar to that from ASCAT-A.



Rainforest seen by ASCAT-A and ASCAT-B before and after cross calibration

Calibration Procedure

Transponder calibration has three main steps

- gain at angular position – convert transponder signal in ASCAT data into antenna gain in antenna coord system
- antenna gain pattern and orientation – fit a gain model and antenna pointing parameters to the data set
- Normalisation table generation – use gain model to generate normalisation values that can be used to convert ASCAT measurements into calibrated backscatter

NTG is now being run routinely as part of the operational processing rather than just once offline with a representative orbit.

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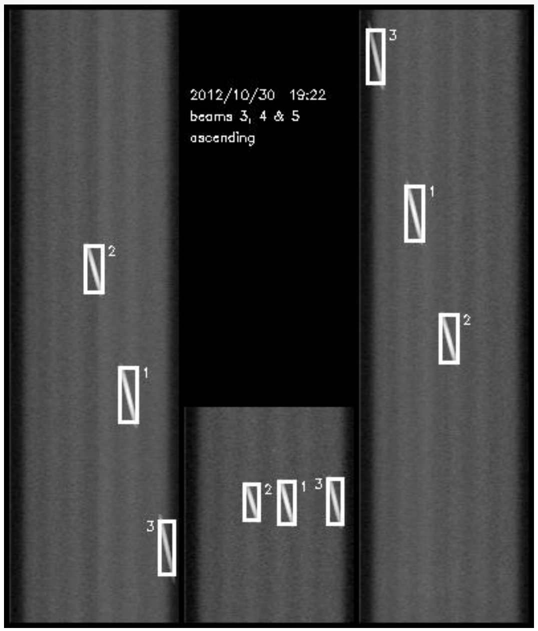
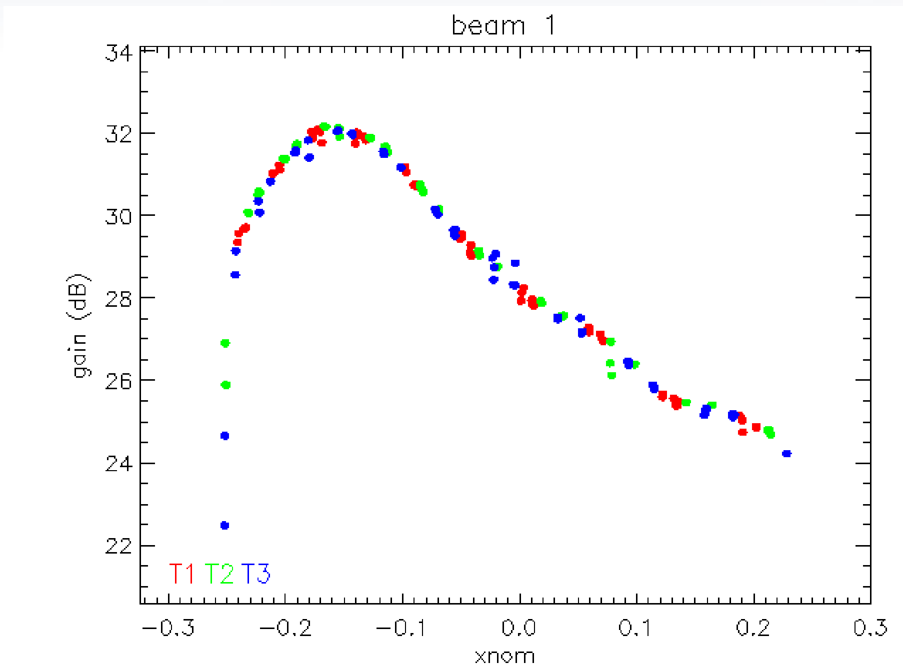
Gain at Angular Position

In the first stage we convert the transponder signal measured by ASCAT-B into an antenna gain in the antenna coordinates system.



Raw data (annotated)



Data set obtained from multiple passes over transponders

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Gain at Angular Position

Some quality control is required to remove data that does not fit certain criteria:

- Passes where the transponder tracking is too large are excluded.
- Passes where the transponder signal only appears in one or two beams are excluded.
- Gain values in extreme near or far range are excluded.
- Gain outliers are excluded.

Initially a manual procedure but now automatic.

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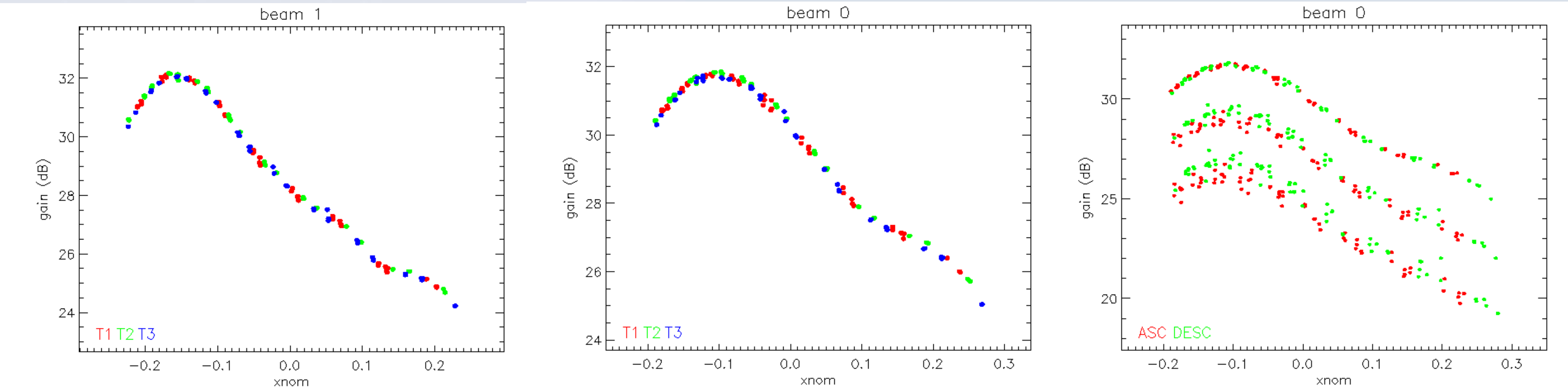
Gain at Angular Position

Example results



Beam 1 shows same near range distortion as ASCAT-A.

Beam 0 shows same type of differences between ascending passes at edge of beam as ASCAT-A.

Antenna Gain Pattern and Orientation

In the next step of the calibration process we essentially use the data set to find the antenna gain pattern:

- Fit a nominal gain model and three depointing angles to the data set.
- Remove any azimuthal depointing by shifting the data in azimuthal direction so that it aligns with nominal model.
- Determine and then remove transponder biases from the data.
- Extend the data set using nominal gain model.
- Calculate gain values on a regular two dimensional grid of antenna azimuth and elvation angles using interpolation and kernel smoothing.

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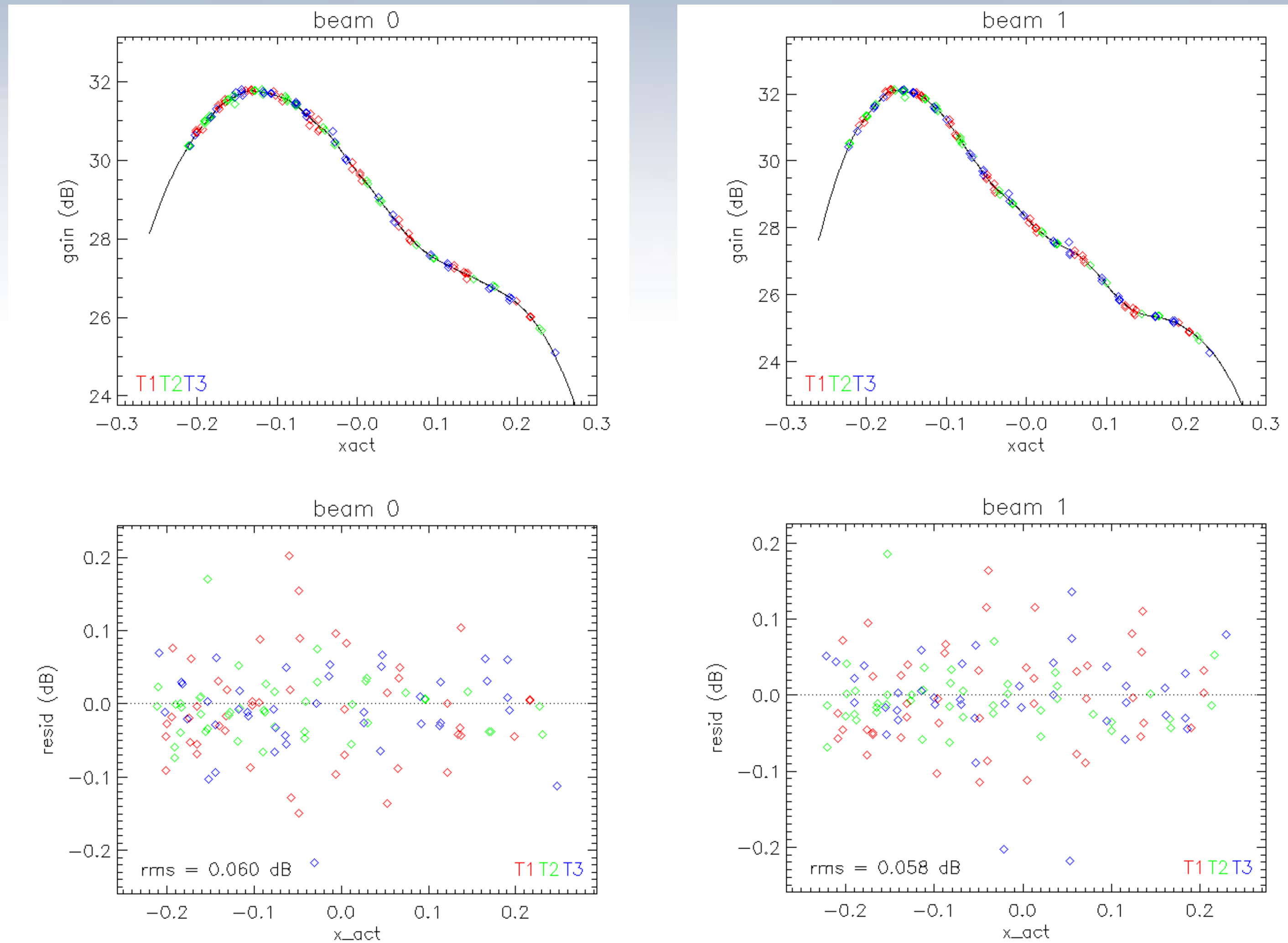
Antenna Gain Pattern and Orientation

Resulting gain patterns and residuals



Residuals seem slightly higher than those seen in previous ASCAT-A calibrations.

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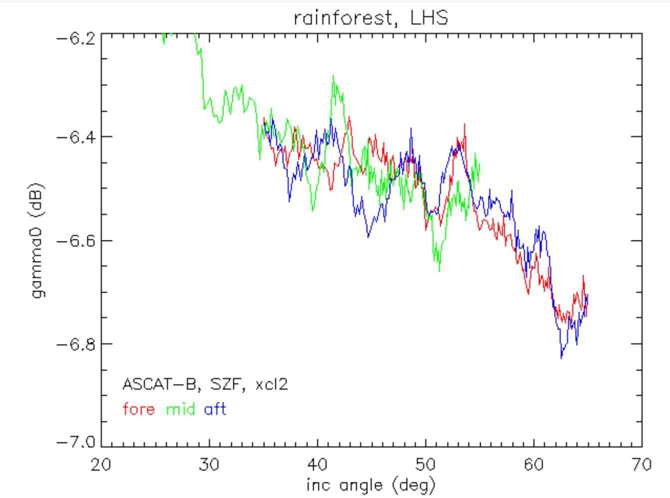
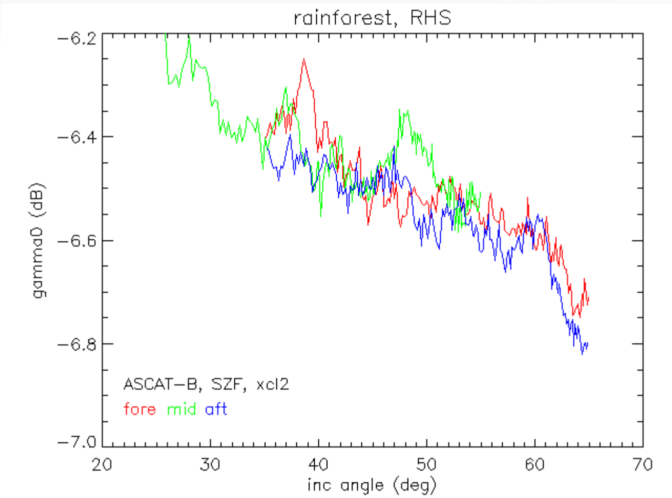
Check Calibration Using Rainforest

Test the new gain patterns by using them to process a months worth of data and examine the γ_0 over the Amazon rainforest.





Results are as expected, i.e. around -6.5 dB in all beams.

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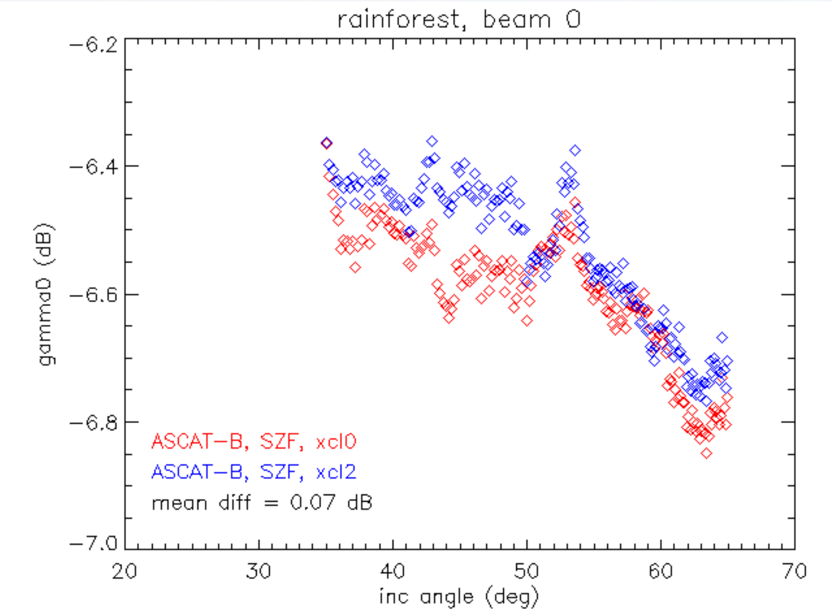
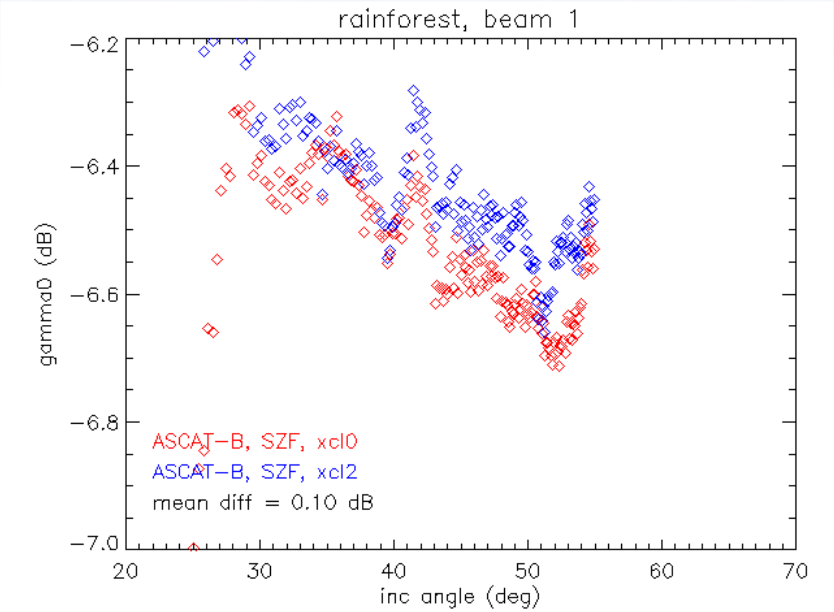
Check Calibration Using Rainforest

Can also compare the γ_0 given by the preliminary cross-calibration and the new transponder calibration.





Mean difference is around 0.07 to 0.15 dB.

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Check Calibration Using Rainforest

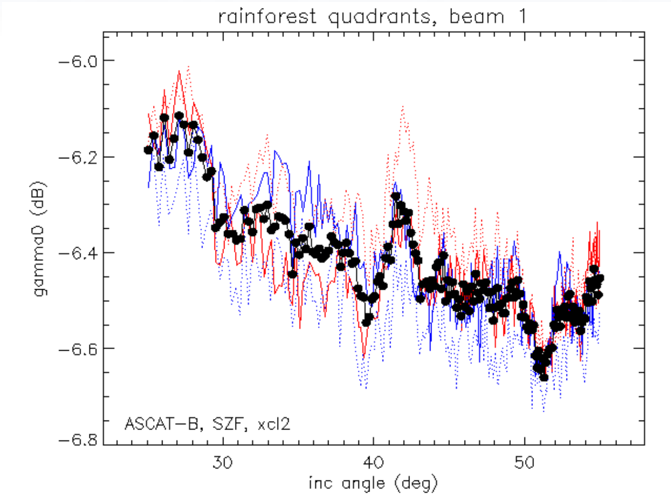
This result, 0.07 to 0.15 dB, is maybe slightly higher than expected.

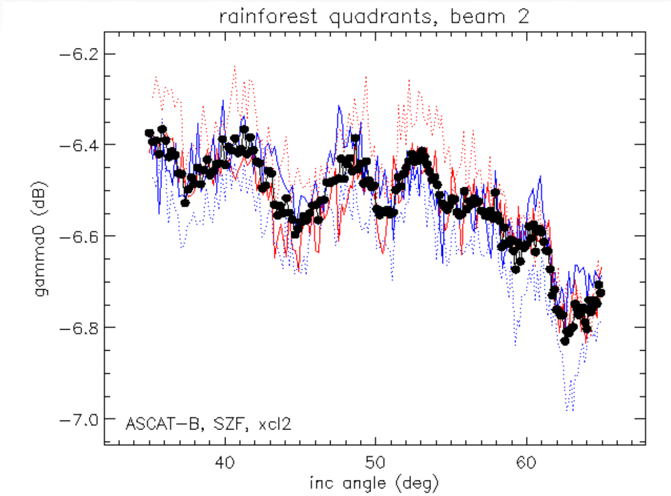
But ASCAT-A (and hence the cross calibrated ASCAT-B) is currently calibrated using transponder data from 2010 and produces backscatter that is slightly lower than it does when calibrated using transponder data from the more recent 2012 calibration campaign.

If this is taken into account then the difference between ASCAT-A and ASCAT-B reduces to 0.02 to 0.08 dB.

Oscillations in Calibration Across Swath

The rainforest results show some oscillations across the swath. To test if this is real, or just a characteristic of the test site, we split the test site into four quadrants and examine γ_0 in each.

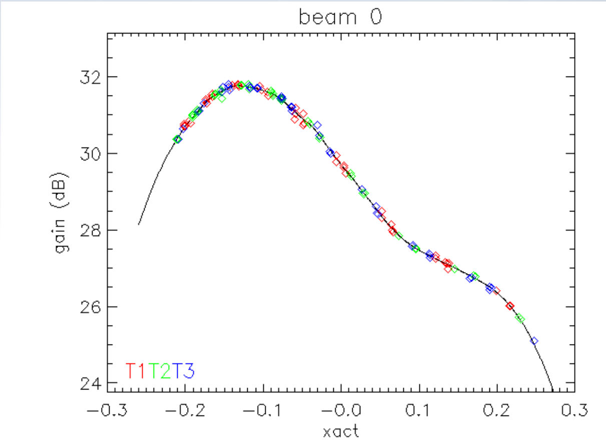


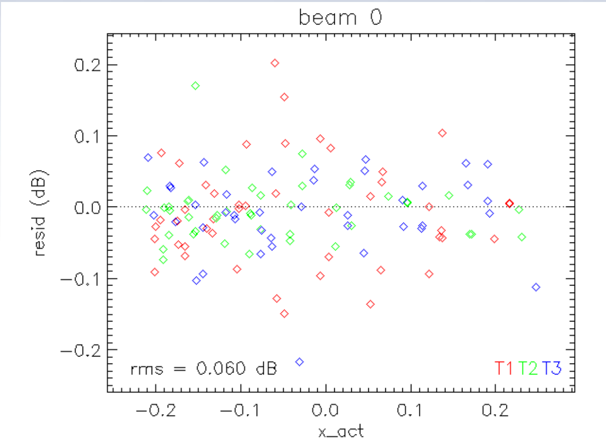


Same behaviour seen in all quadrants.

Error Analysis

In the calibration results we have a RMSE around 0.07 dB.





129 data points and RMSE given by cross validation is 0.068 dB

For N data points with mean m and standard deviation s the error in the estimate of the mean is $s/\sqrt{N}$.

So the error in the gain pattern is $0.07/\sqrt{129} = 0.006$ dB

Doubling to convert to a gain error to a backscatter error gives an calibration accuracy of 0.012 dB.

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Error Analysis

This value seems low and is inconsistent with ocean and rainforest analyses which report oscillations in the backscatter across the swath of about ± 0.05 dB. But is N actually 129?

In the antenna gain pattern and orientation step we fit a function to data by using kernel smoothing (i.e. for each value at which we require the function we find the data points within a distance Δ, weight them according to how close they are to the required value, fit a low order polynomial to the weighted data and use it to estimate the function).

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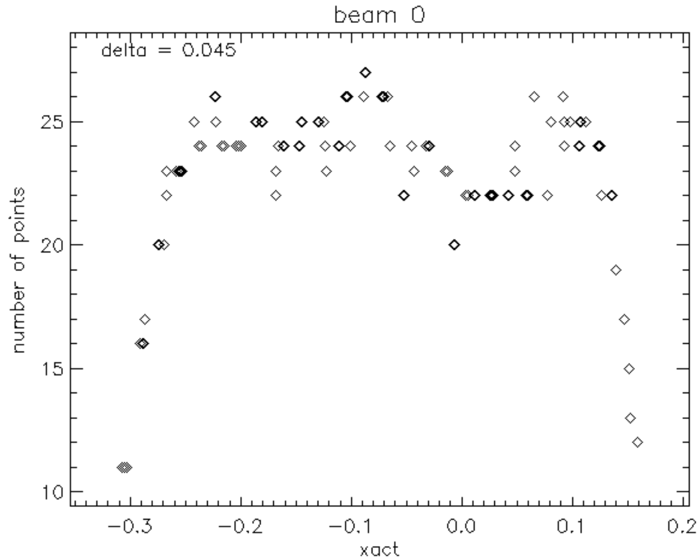
Error Analysis

Optimum value of Δ id determined by cross validation and is typically around 0.045.

The figure below shows the number of data points within a distance 0.045 of each data point and we see that it is around 24.



So the gain error becomes $0.07/\sqrt{24}$ or ±0.015 dB and backscatter error is around ±0.03 dB.

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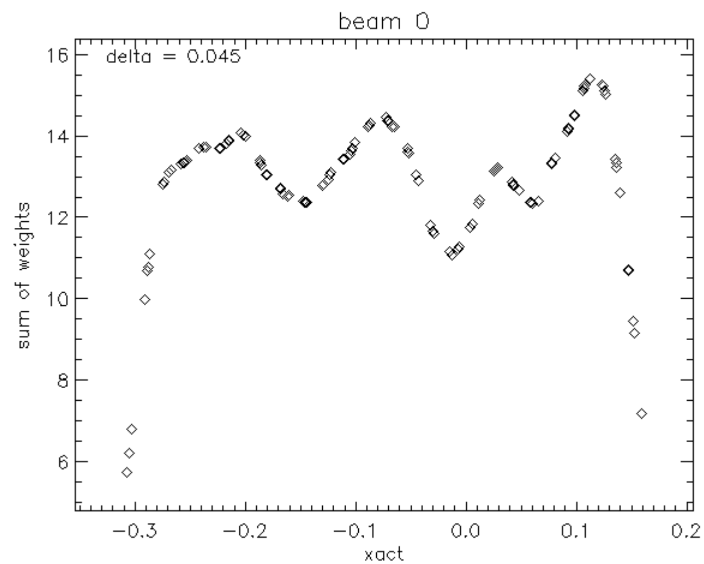
Error Analysis

But the fitting uses weighted data so we could use the sum of the weights rather than the number of data points.

As shown in the plot below, this is approximately 13.

So gain error is $0.07/\sqrt{13}$ or 0.02 dB and backscatter error is around 0.04 dB which is similar to the observed 0.05 dB.

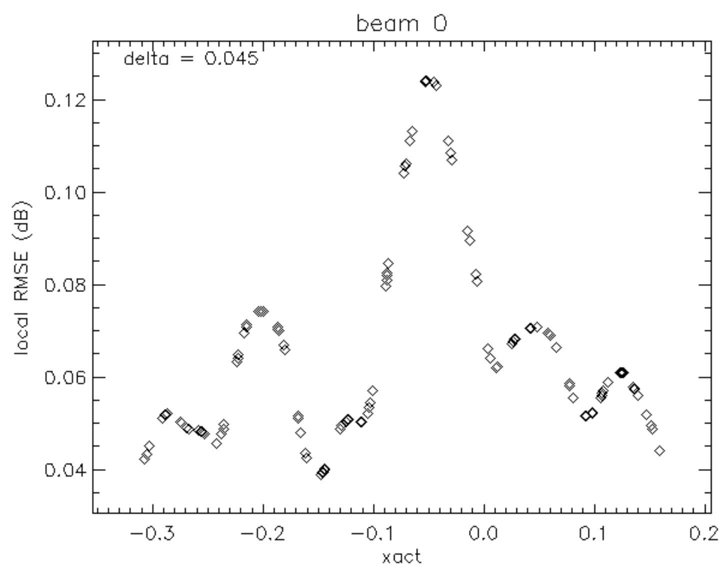


Error Analysis

Instead of using the global value for the RMSE we could look at the RMSE of the data within a distance Δ of each data point.

Plotted below and can be up to 0.125 dB.

So the worst case error in the gain is $0.125/\sqrt{13} = 0.035$ dB and worst case error in the backscatter is around 0.07 dB.



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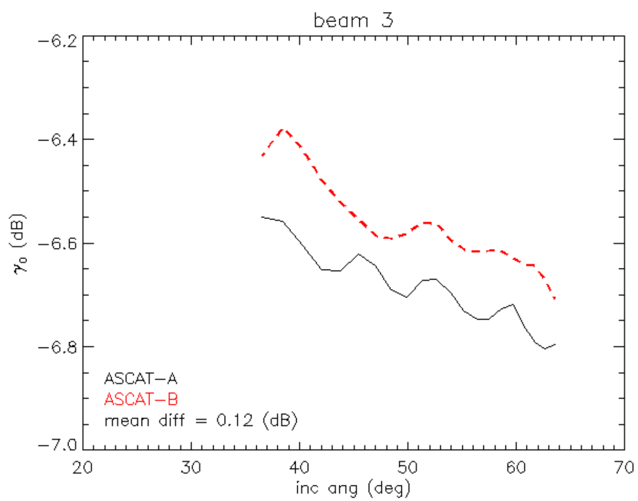
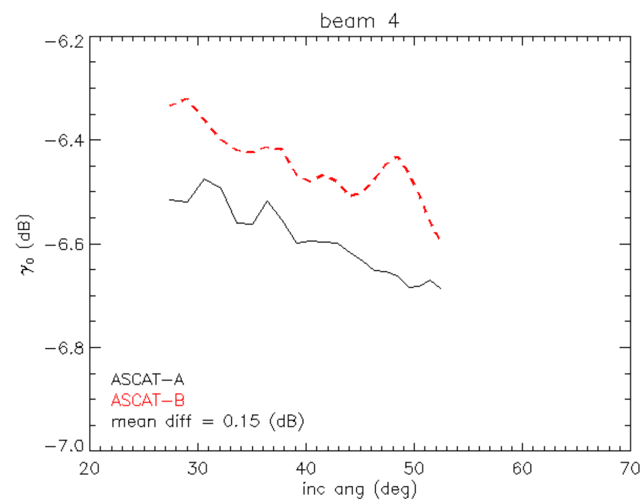
Validation using Rainforest

The gain patterns derived from the transponder calibration have been used the validation processor since early April.

We now have 29 days of data so we can check the results against operational ASCAT-A over the rainforest:





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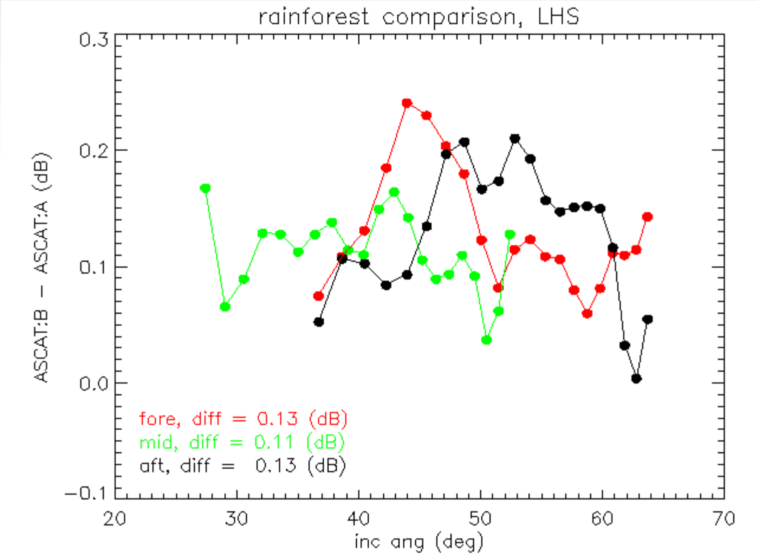
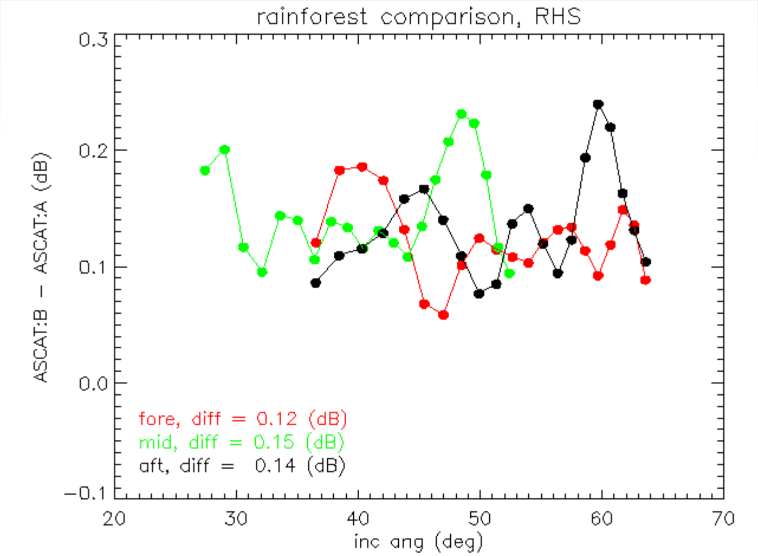
Validation using Rainforest

The difference between ASCAT-A and B in each beam is show below.



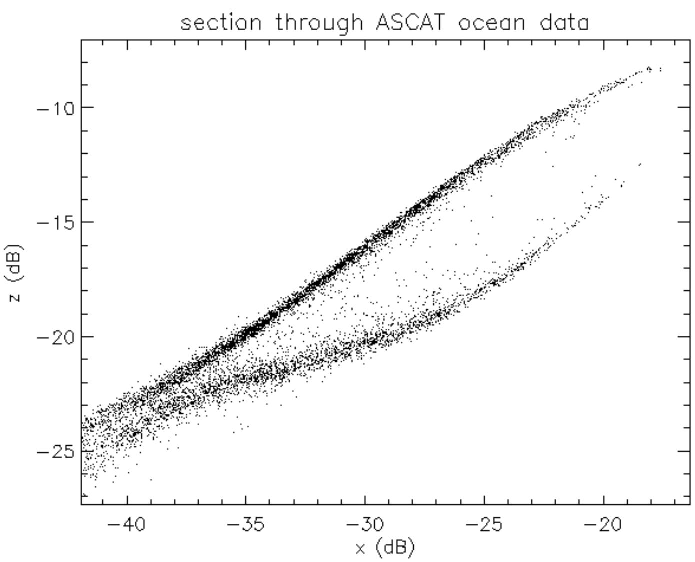


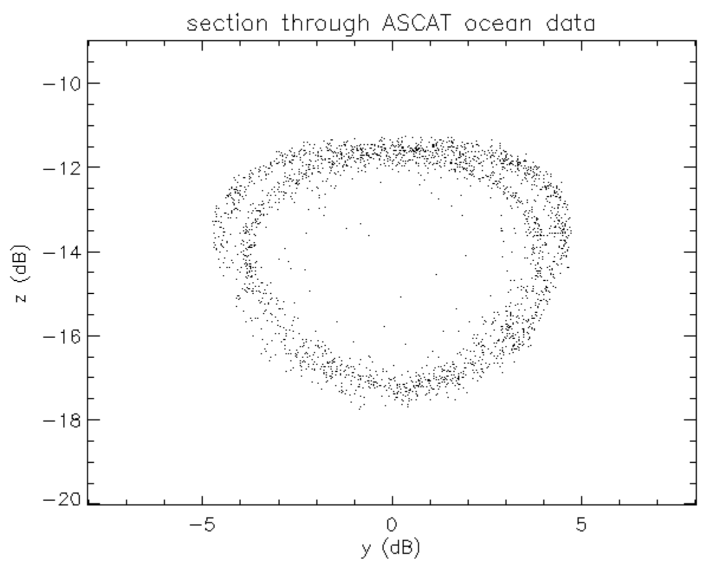
Difference is around 0.11 – 0.15 dB, slightly larger than the early analysis (but ASCAT-A and ASCAT-B are seeing different rainforest at different times).

Validation using Ocean

We can also check the results using an ocean validation technique.

When backscatter triplets from the open ocean are plotted as points in a three dimensional space they form a cone shape.





Sections through ASCAT-B ocean data

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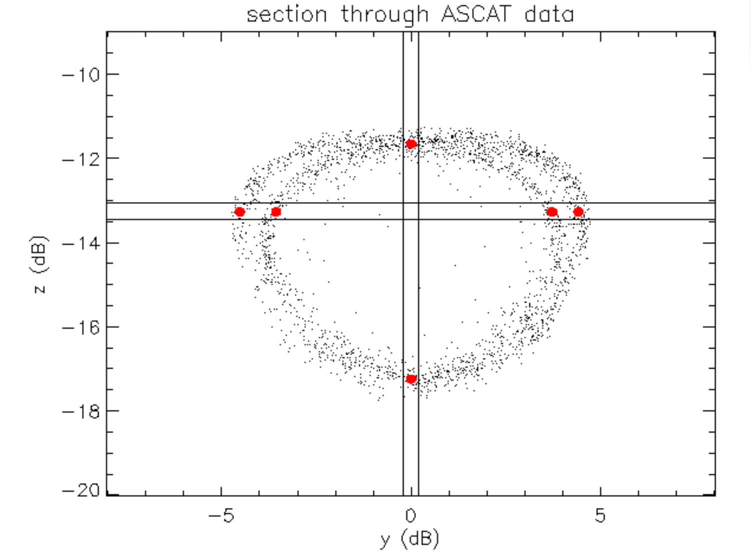
Validation using Ocean

We can take slices through the three dimensional space and locate the position of the cone by finding where the density of data points is largest.



Locating the position of the ocean cone by taking slices through data

This allows the position of the cone to be determined and we can then compare its position in ASCAT-A data with its position in ASCAT-B.

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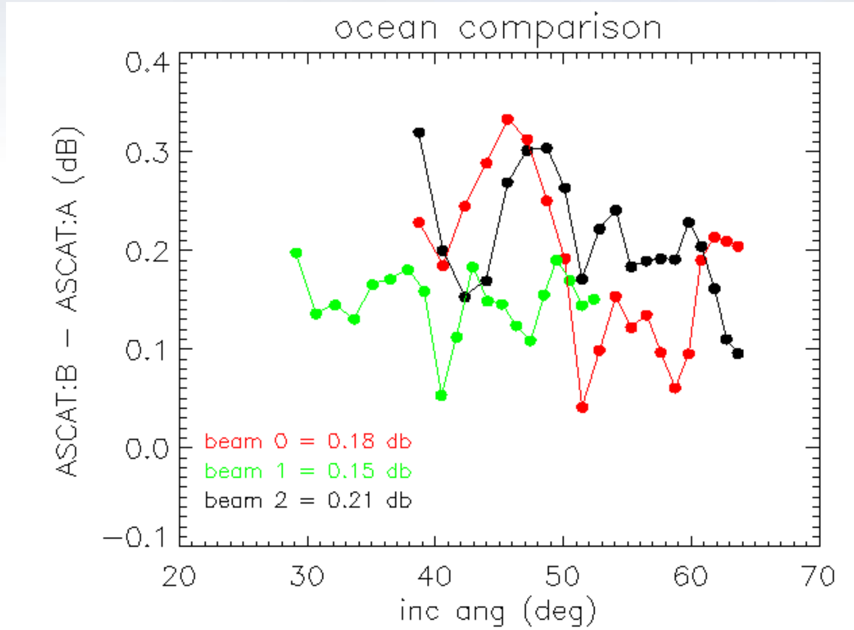
Validation using Ocean

The difference in cone position between ASCAT-A and B can be converted to a difference in backscatter in each beam and is shown below.



Similar across swath behaviour to rainforest results, but slightly larger at around 0.15 – 0.2 dB.

Summary, Conclusions and Next Steps

External calibration of ASCAT-B has been completed.

Results are good, with an estimated calibration accuracy of ±0.04 dB and a typical difference to ASCAT-A of 0.1-0.15 dB (although some minor concerns regarding residuals and across swath oscillations).

New calibration goes live on the operational processor on 28th May (new product formats go live on 16th May).

Next steps are to investigate the across swath oscillations (and also reprocessing of all ASCAT-A data).

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