What's the Point of Mispointing?

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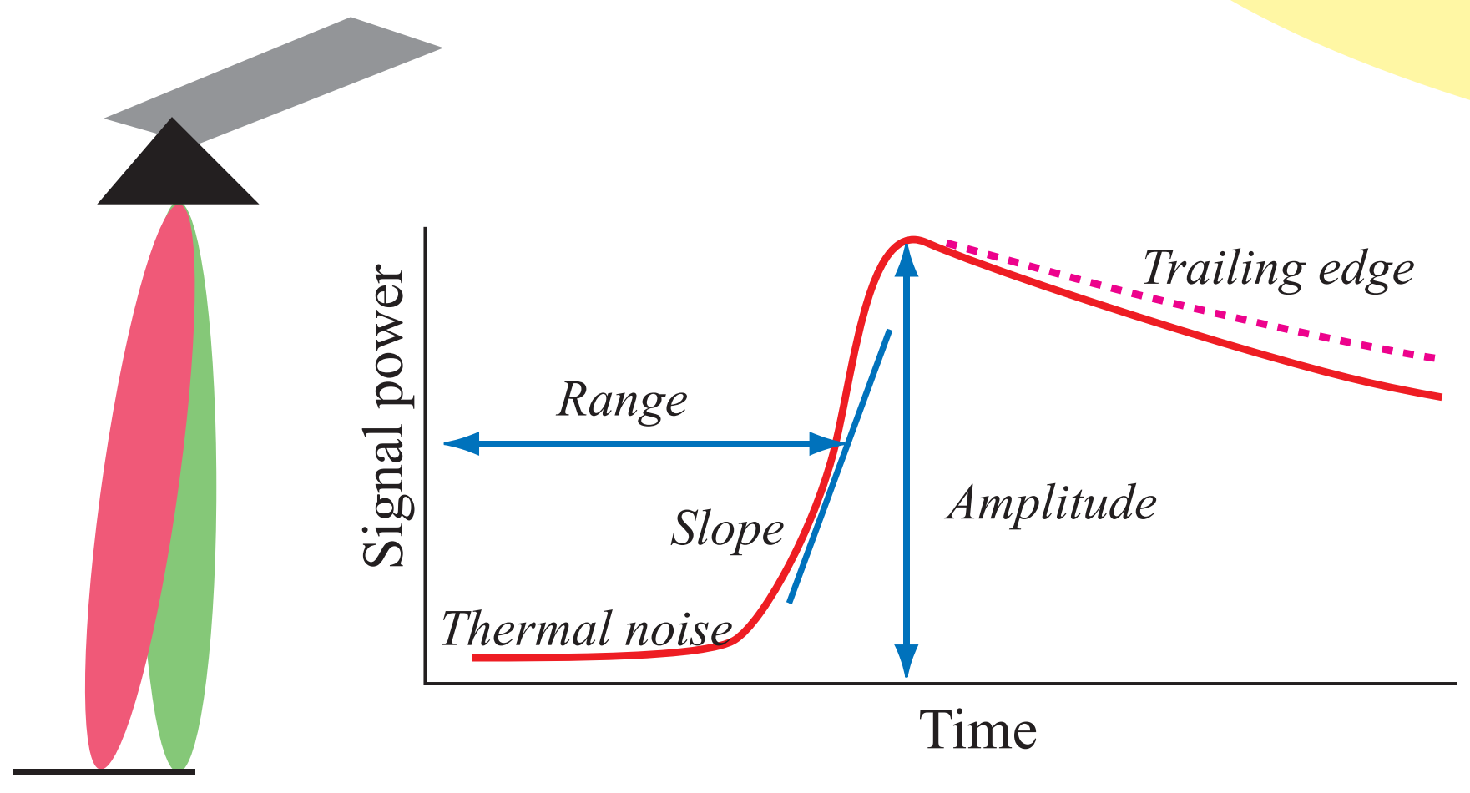
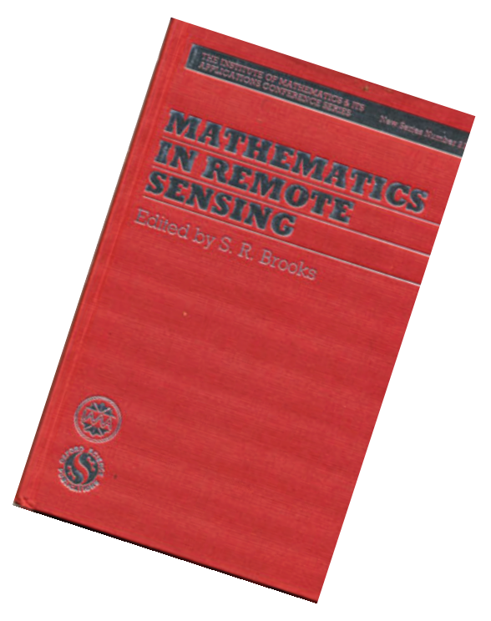
Abstract

Yes it's a silly title to cover up yet more work by your truly on sigma0 calibration and rain-flagging. The "motivation" is quite simple: I could not believe that problems in determining σ^0 with the recent MLE-4 retracker meant that dual-frequency rain-flagging would have to be based on AGC (not actually a measure of the signal received at all) — there had to be a better way!

History



It has been well-established (e.g. Brown, 1977) that if the antenna pattern of an altimeter is not pointing directly at nadir (i.e. the peak sensitivity of the antenna is not co-aligned with the surface giving the first returns) then there will be an effect on the slope of the trailing edge of the waveforms. Theoretically the effect is proportional to the square of the mispointing angle, ψ^2, but as other factors may affect the slope, the value derived for ψ^2 can be negative. This happens if nadir reflection is stronger than that just off-nadir leading to an increased negative slope. For most altimeters this effect is small, but Geosat had orbital oscillations of 1° or more i.e. of similar magnitude to the beamwidth.



Challenor & Srokosz (1989) had looked at the difficulties of determining extra parameters from the waveform shape, and concluded that any model including amplitude (σ^0) and mispointing (ψ^2) was poorly conditioned, because of the similarity in effect of these two parameters.

TOPEX GDRs had both waveform- and platform- derived estimates of mispointing. AGC, range etc. were determined separately, and there were corrections to range based on ψ^2 and H_s (Hayne et al., 1994).

For Jason-1 the platform mispointing was found to be larger than expected, with marked effects on the retrieval of parameters using a waveform model that assumed mispointing was close to zero. So the MLE-4 was introduced (Amarouche et al., 2004), and has been the default for Jason-1 and Jason-2 processing.

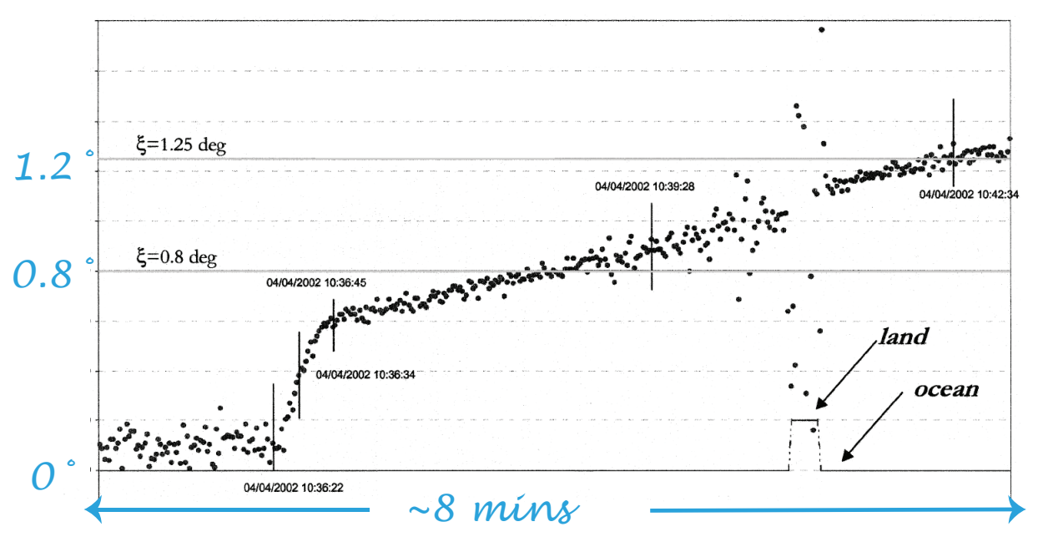


Fig. 1 from Amarouche et al. (2004) showing an incident when Jason-1 attitude changed sharply.

OSTST 2007 : σ^0 values from MLE-4 were found to be too "flighty", so it was recommended that AGC be used for rain-flagging.

References

Amarouche, L., P. Thibaut, O.-Z. Zanife, J.P. Dumont, P. Vincent, and N. Steunou (2004) Improving the Jason-1 ground tracking to better account for attitude effects, *Marine Geodesy*, **27** (1-2), 171-197.
Brown, G.S. (1977) The average impulse response of a rough surface and its applications, *IEEE J. Oceanic Eng.*, **2**, 67–74.
Challenor, P.G. and M.A. Srokosz (1989) The extraction of geophysical parameters from radar altimeter returns from a non-linear sea surface, in *Mathematics in Remote Sensing (ed. S.R. Brooks)*, Clarendon Press.
Hayne, G.S., D.W. Hancock, C.L. Purdy, and P.S. Callahan (1994) The corrections for significant wave height and attitude effects in the TOPEX radar altimeter, *J. Geophys. Res.*, **99**, 24 941-24 955.

Quartly, G.D. (2009a) Optimizing σ^0 information from the Jason-2 altimeter, *IEEE Geosci. Rem. Sens. Lett.*, **6**, 398-402.
Quartly, G.D. (2009b) Improving the intercalibration of σ^0 values for the Jason-1 and Jason-2 altimeters, to appear in *IEEE Geosci. Rem. Sens. Lett.*
Quartly, G.D. (2009c) Optimizing the altimetric rain record from Jason-1 & Jason-2 (in prep.)

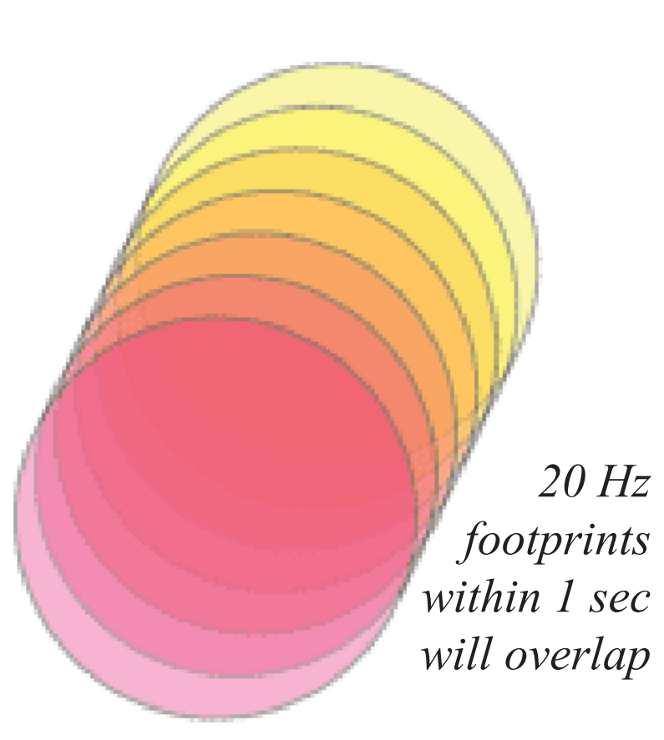
Effect on sigma0

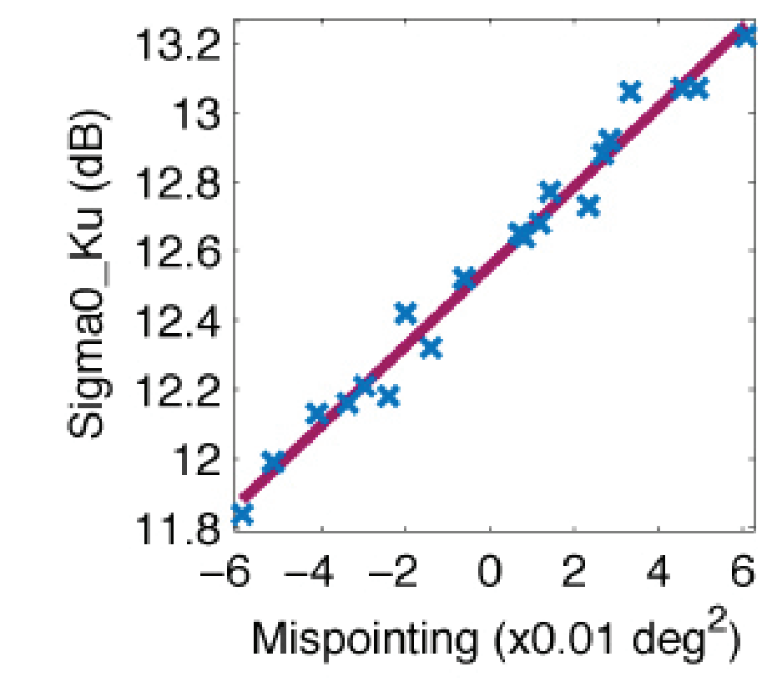
Sigma0 values output from the standard MLE-4 tracker show great small-scale variability, associated with the retrieval of mispointing, ψ^2. This makes them less useful in a number of contexts. The analysis here is simply on how to overcome this problem. To cut a long story short, a good correction can be achieved by defining an adjusted value, σ^0_{adj}:

$$\sigma^0_{adj} = \sigma^0 - \alpha\, \psi^2_{hi} - \beta\, \psi^2_{lo}$$

where ψ^2_{lo} is a low pass (140-sec) moving average, and $\psi^2_{hi} = \psi^2 - \psi^2_{lo}$. Various analyses (below) produce the following values for K_u-band :

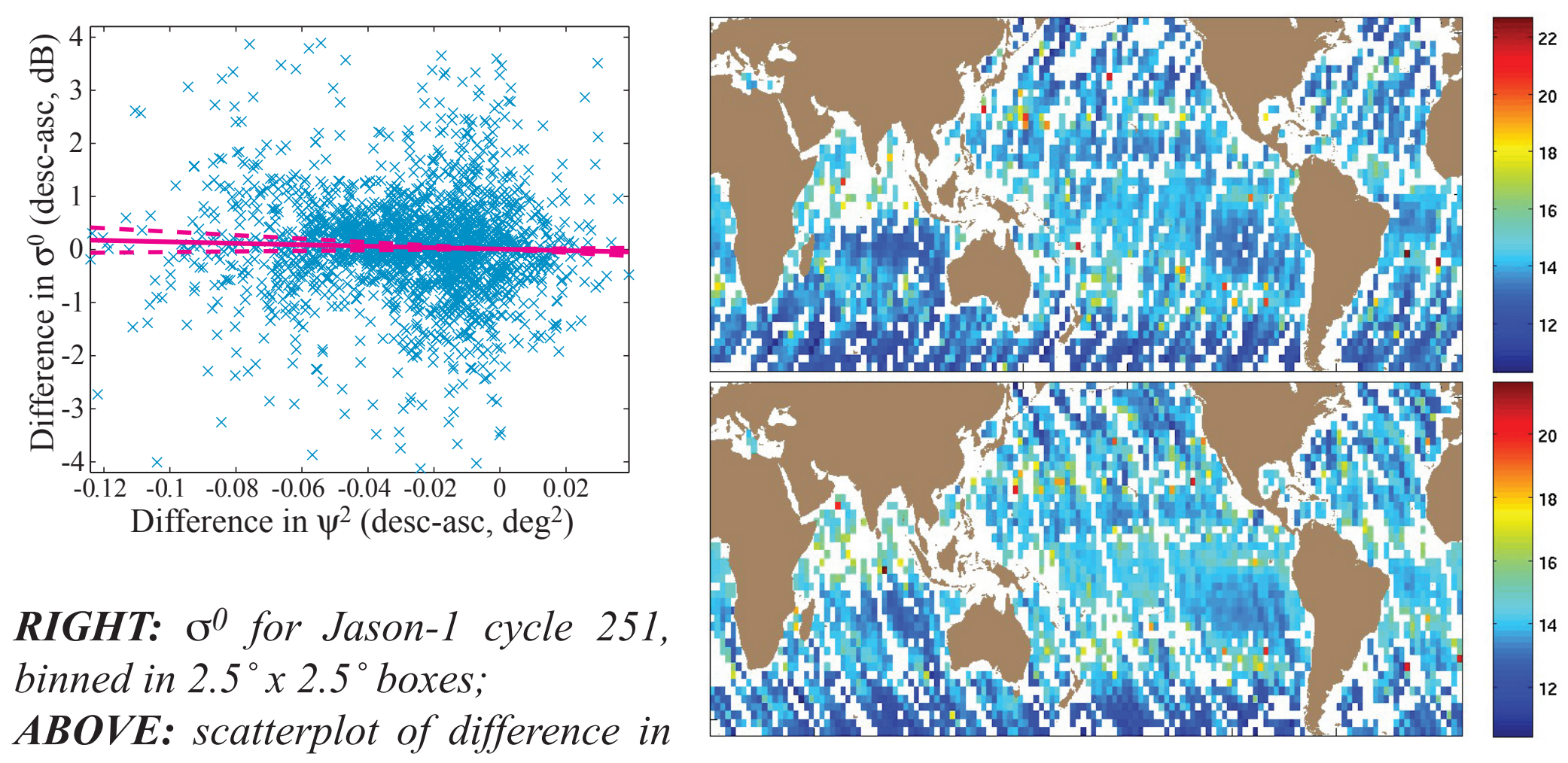
$$\alpha_{J1} = 11.14\,; \quad \alpha_{J2} = 11.30\,; \quad \beta_{J1} = -1.40$$


20 Hz footprints within 1 sec will overlap



For Jason-2, the high-pass term, α, is easily found by looking at the 20 Hz records of σ^0 and ψ^2. For overlapping footprints there should be little real change in σ^0, so the differences there are represent problems with the waveform model.

For Jason-1, a *crude* estimate of the low-pass term, β, is obtained by binning σ^0 values separately for ascending and descending passes. Although there is much day-to-day variability, the changes in σ^0, show a *weak* correlation with changes in ψ^2.



RIGHT: *σ^0 for Jason-1 cycle 251, binned in 2.5° x 2.5° boxes;*
ABOVE: *scatterplot of difference in σ^0 vs. difference in ψ^2.*

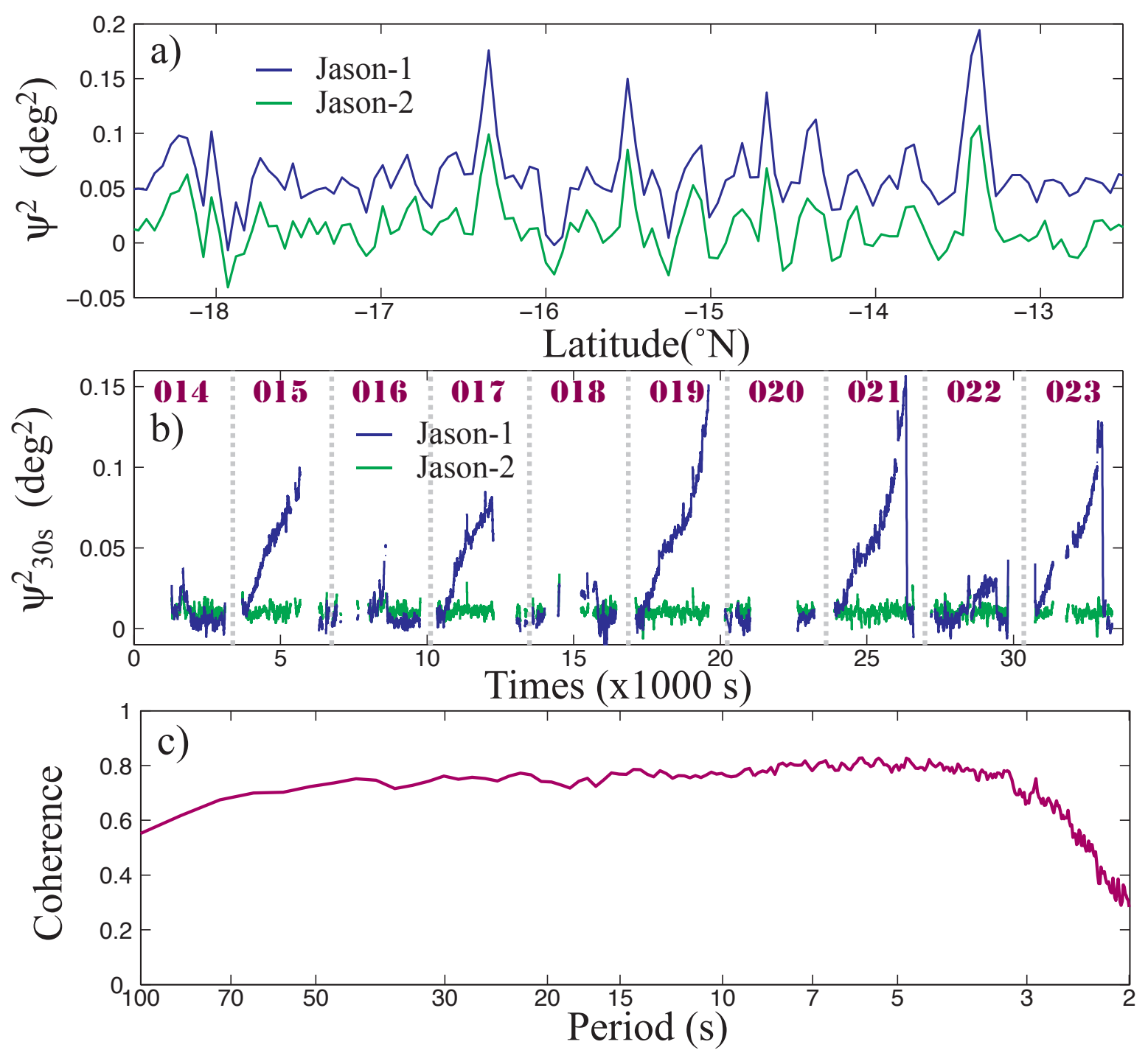
However, given nearly 6 months of Jason-1/2 match-ups, a simple least mean square analysis yieds the results given above. Note, for Jason-2, ψ^2_{lo} is almost constant, and thus β_{J2} not readily estimated.

Nota Bene

In all this I am reflecting on issues relating to σ^0 (with possible repercussions for estimates of wind speed, spatial spectra, rain-flagging and SSB). I am not impugning the MLE-4's ability to estimat range.

Statistics

Below are a few plots to show the characteristics of the mispointing estimate, ψ^2. Data shown are from Jason-1 cycle 251, and Jason-2 cycle 012, during the Tandem Mission when altimeters observed the same points only 55 s apart.

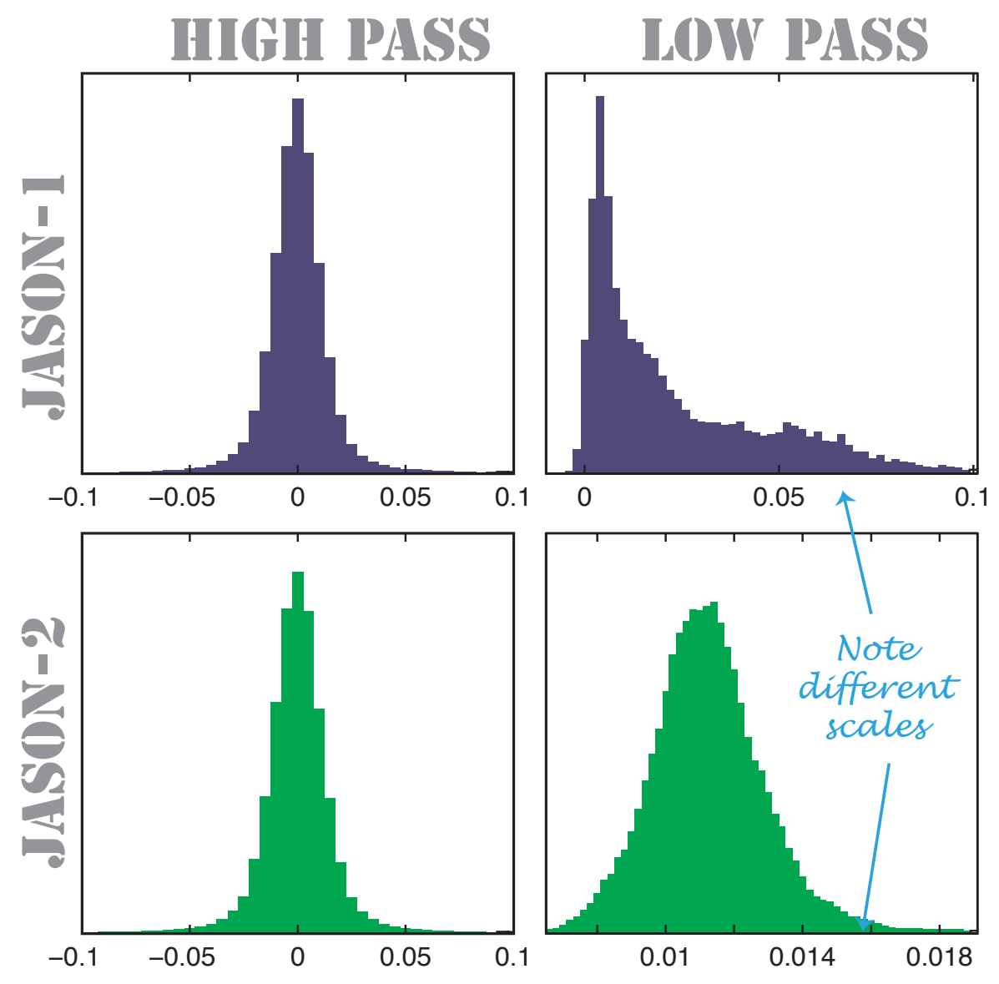


a) Section of pass 015 showing 1 Hz data, with good agreement on small scales, but Jason-1 values larger.

b) Broad perspective from passes 014-023, with 30s averages showing Jason-2 nearly constant, but Jason-1 showing regular migrations (gradual change due to loss of star trackers, followed by abrupt returns mediated by reaction wheels).

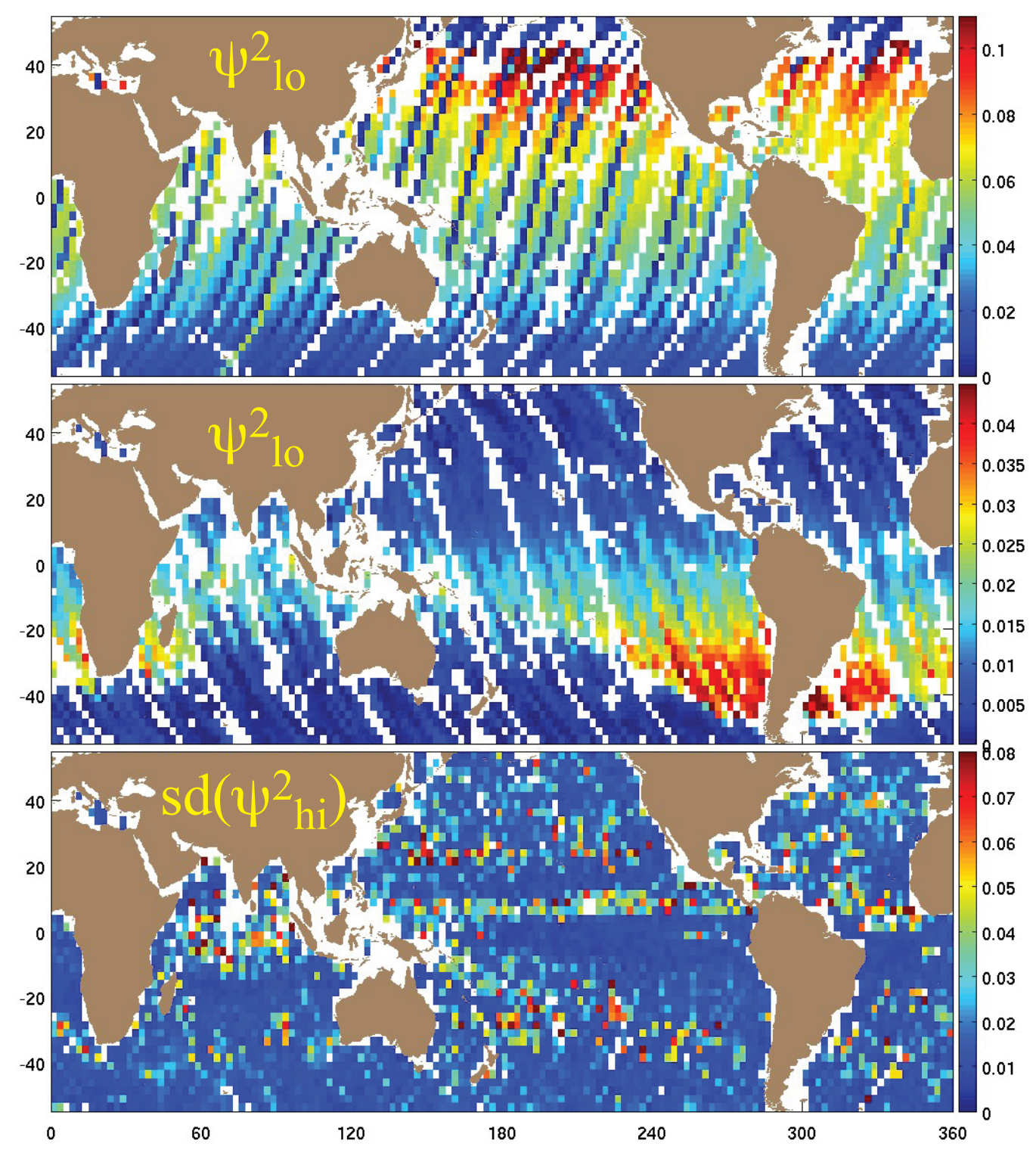
c) Coherency of Jason-1 and Jason-2 variations is > 0.7 for periods between 3 and 70s (length scales of 17 to 400 km).

Scales of variations are separated using a 140-second filter to give the long-term (low pass) value ψ^2_{lo}, with the high-frequency component, $\psi^2_{hi} = \psi^2 - \psi^2_{lo}$



The distribution of long-term values is very different for Jason-1 and Jason-2; Jason-2 has no problems with platform mispointing and the mean of 0.012 deg. sq. probably represents an initial calibration (uncertainty in correct trailing edge slope to be modelled), whereas cycle 251 was one when the Jason-1 satellite had genuine attitude problems. The distributions of ψ^2_{hi} are similar, representing common measurements of sub-footprint backscatter inhomogeneity.

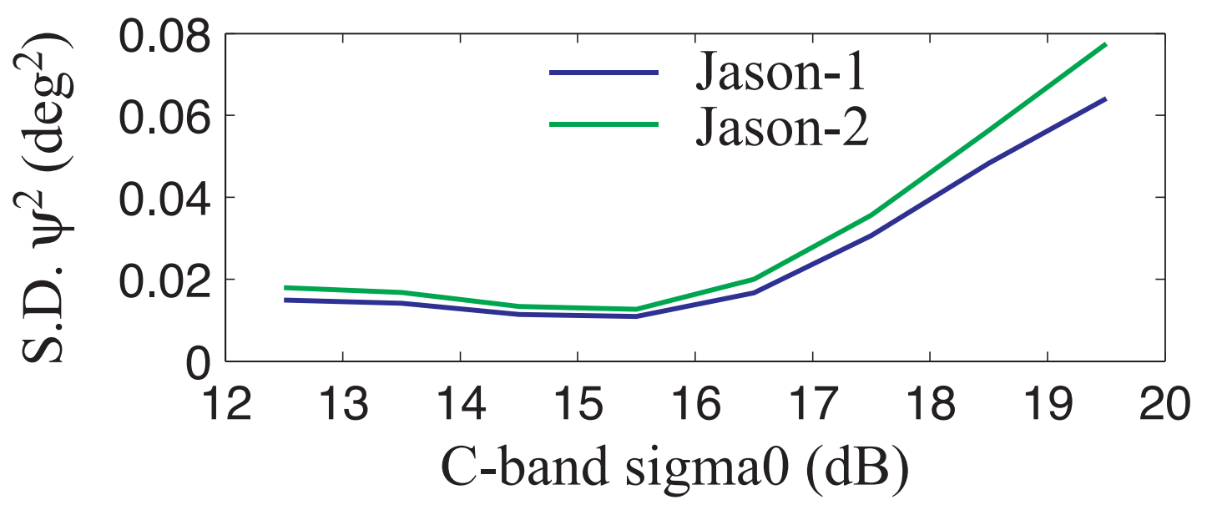
To look at the spatial patterns associated with ψ^2_{lo} and ψ^2_{hi}, I bin the Jason-1 distribution for cycle 251 in 2.5° x 2.5° boxes.



There is a strong geographical pattern to ψ^2_{lo}, with clear differences between ascending and descending passes (top two panels). This is presumably due to the different performance of the star tracker on the day / night sides of the Earth.

By definition the ψ^2_{lo} has a local mean near zero everywhere, but lowest panel shows that it has greater variability in some regions.

Although this pattern looks similar to that for rainfall, it appears that actually the variability in ψ^2_{lo} is a function of wind speed. At very low wind speeds the scales of spatial variability are smaller and the backscatter sensitivity much greater.



Implications

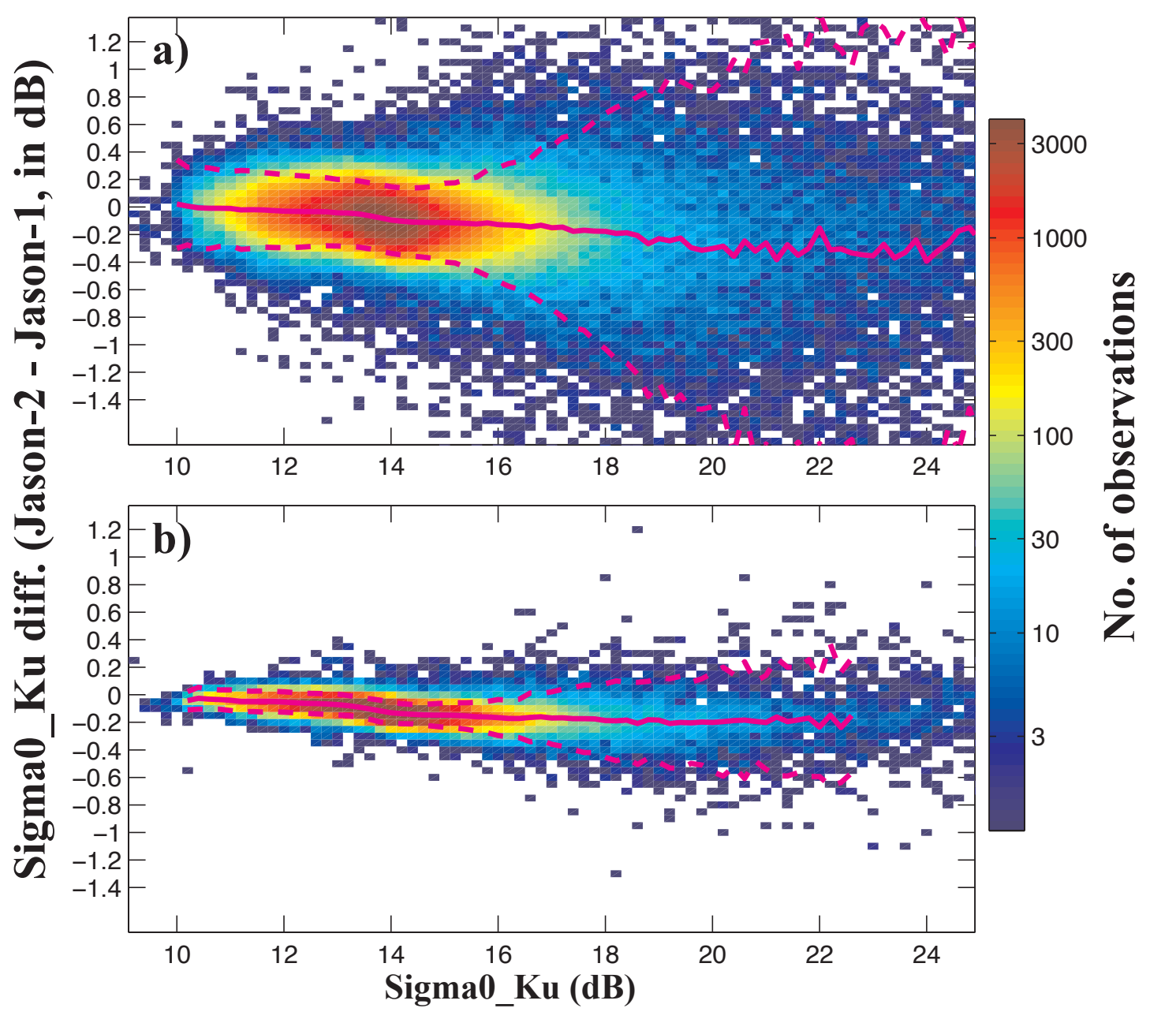


Figure: 2-D histogram of match-ups of Jason-1/2 data, with pink lines showing mean and ±2 std. dev. a) Original, b) Adjusted σ^0.

Finding: Adjustment greatly improves match-ups (std. dev. reduced by a factor of 3).

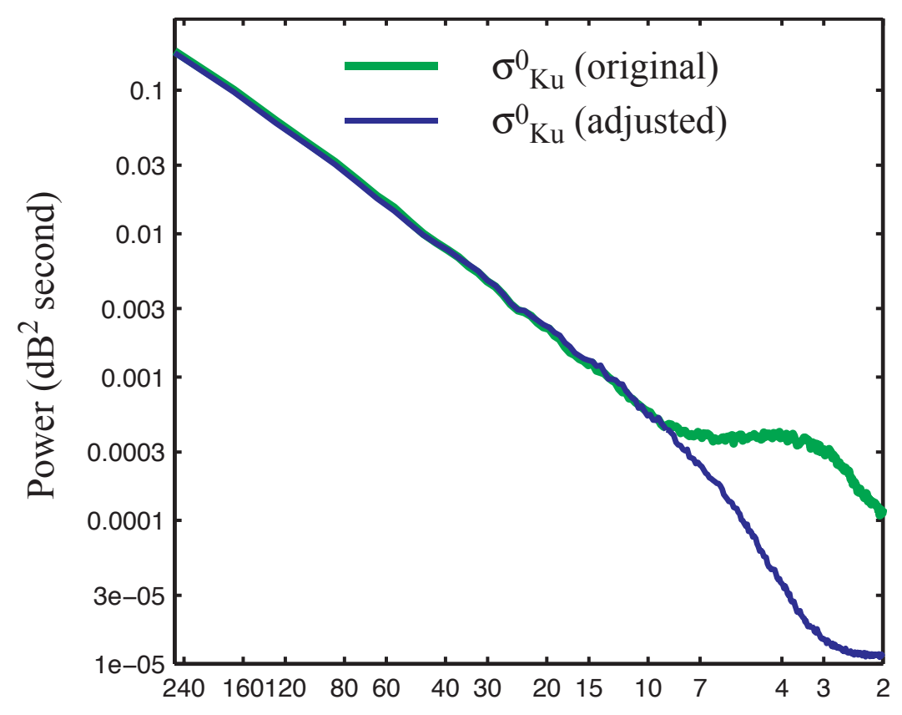


Figure: Spectra of σ^0 variation for Jason-2 (averages over many 512-point consecutive records).

Finding: Adjustment has major impact (reduces spectra) between 2 and 10s (i.e. at scales ≤ 60 km).

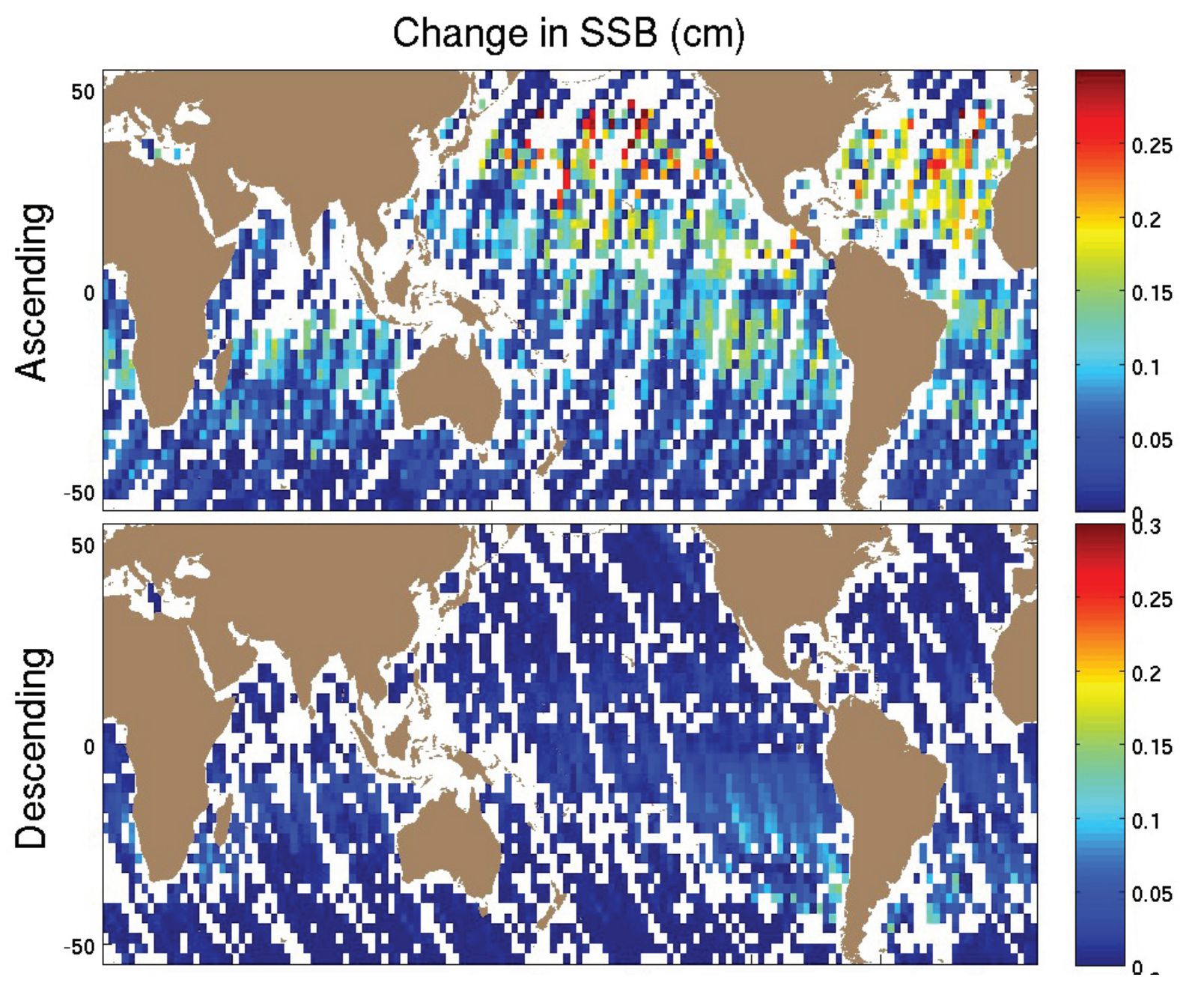


Figure: Change in sea state bias (a function of σ^0 and H_s) for Jason-1 cycle 251.

Finding: Regional averages peak at ~0.2 cm; different SSB corrections for ascending and descending passes.

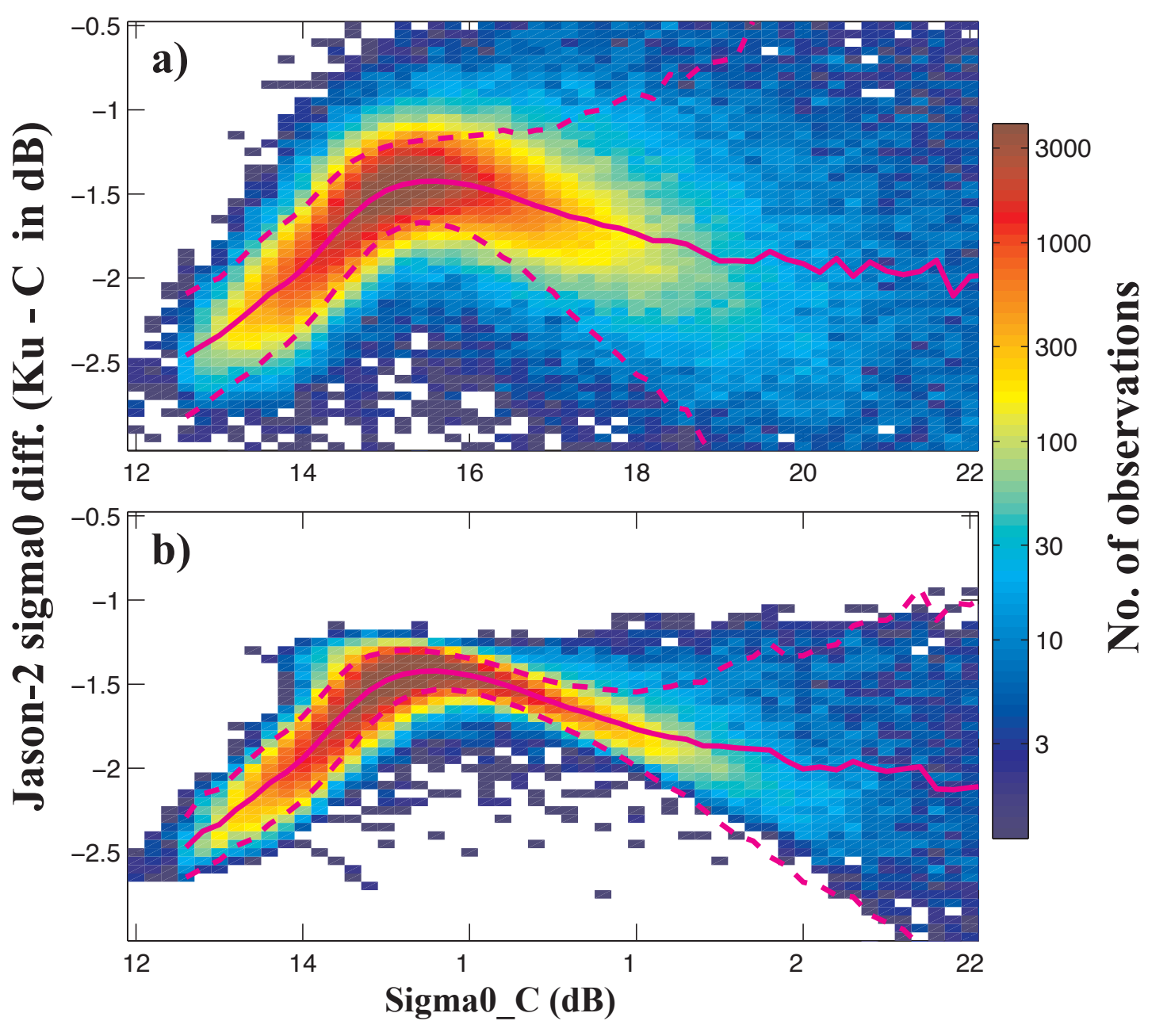


Figure: 2-D histogram of simultaneous K_u/C-band σ^0 data for non-raining Jason-2 data (cycle 012), with pink lines showing mean and ±2 std. dev. a) Original, b) Adjusted σ^0.

Finding: Adjustment reduces scatter for all wind regimes, though particularly at low winds. Allows for more reliable flagging of rain.

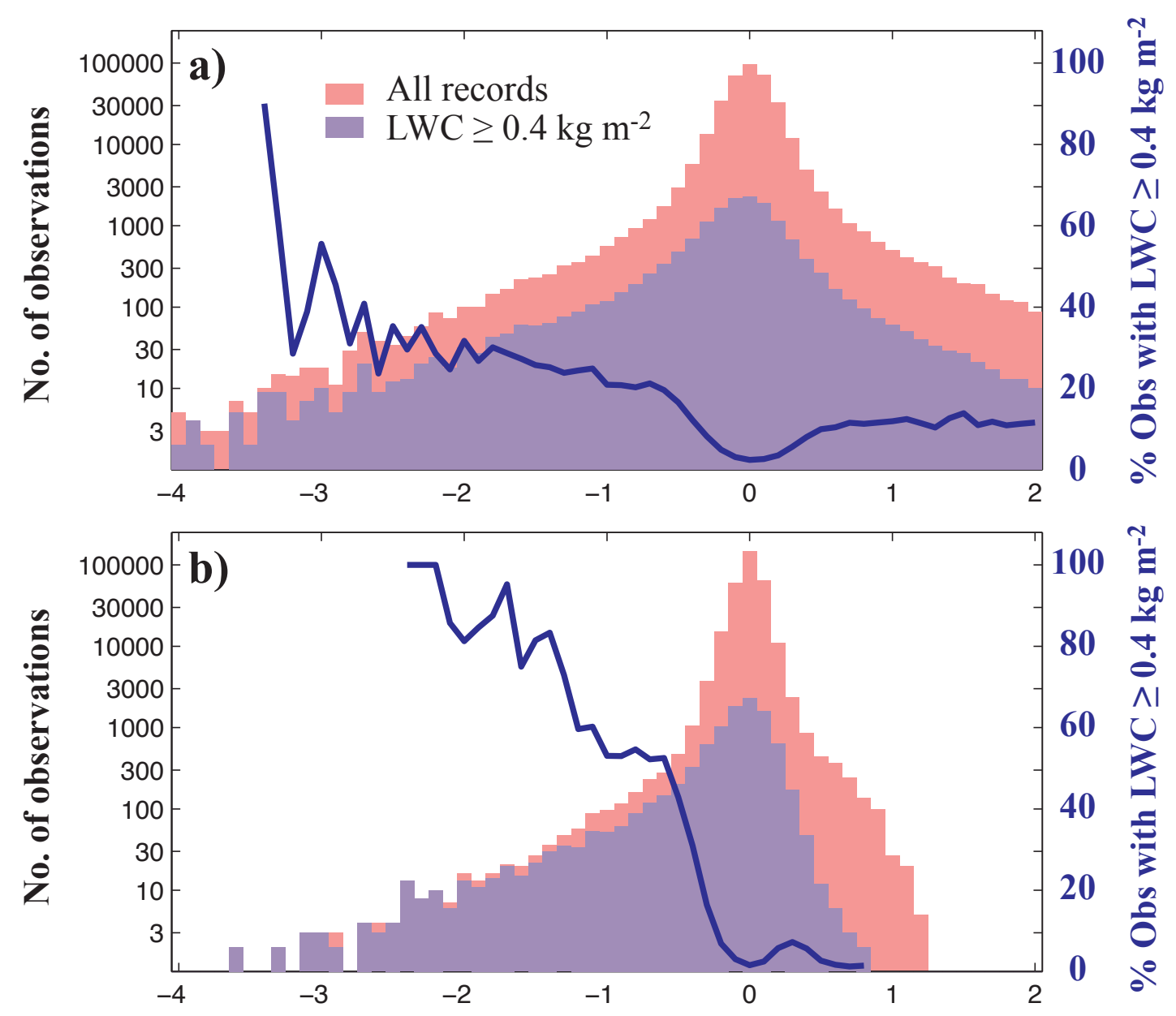


Figure: Histograms of sigma0 anomaly (departure from mean curve in figure to left) for both all data and those passing a passive microwave threshold. Note logarithmic axes. a) Original, b) Adjusted σ^0.

Finding: Adjusted dataset shows far less extremes (both positive and negative). For anomalies calculated from adjusted σ^0, those below a threshold of -0.5 dB match AMR (microwave) on at least 50% of occasions. *Mission accomplished. Phew!*