Jason-2 rain-flagging: Going back to basics

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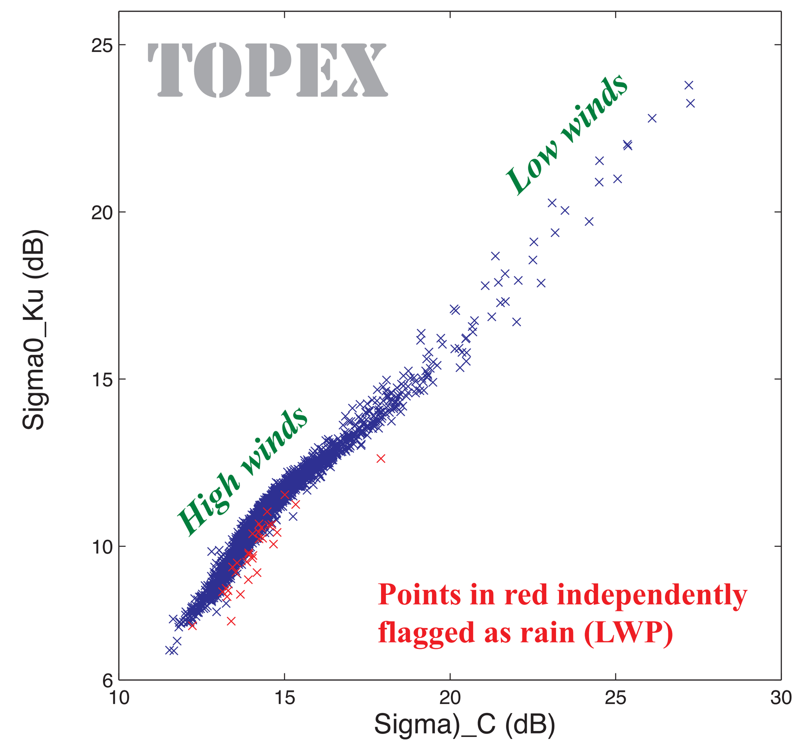
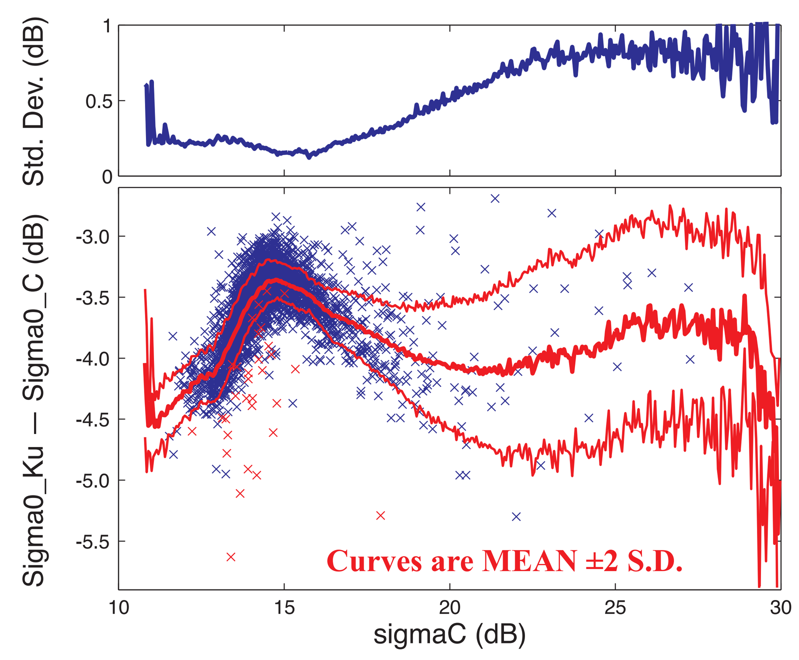




Top panel shows near-linear relationship between σ^0_C and σ^0_{Ku} for TOPEX; changes in wind speed affect Ku- and C-band to a similar extent, whereas rain mainly attenuates Ku-band signal. Lower panel emphasises the non-linearity by plotting σ^0_{Ku}-σ^0_C.

Objective

The concept of dual-frequency rain-flagging, introduced by Quartly et al. (1996) utilised the close correlation of C-band and Ku-band values of σ^0. Although not exactly a linear relation, the envelope for rain-free observations is well-defined, with rain events being marked by departures from this norm. The reliability of this detection was demonstrated by comparing with microwave radiometer data (Quartly et al., 1996) and ground-based rain radars (McMillan et al., 2001) and the fact that the geographical pattern matched other rainfall climatologies (Quartly et al., 1999; Tournadre, 2006, Béranger et al., 2006)

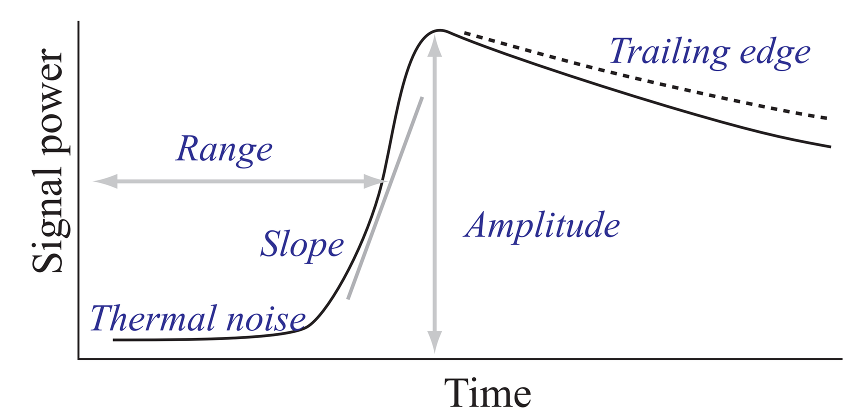
The adoption of a new waveform retracker for Jason-1, the MLE-4, has led to greater variability in σ^0 values and the decision to switch the operational rain-flagging to work on AGC rather than σ^0 (cal/val splinter, Hobart 2007). Here I consider 4 options for Jason-2, comparing their behaviour against various requirements for an altimetric rain flag.

Evaluation

To be useful for rain-flagging we require the dual-frequency measurements to have various useful properties:

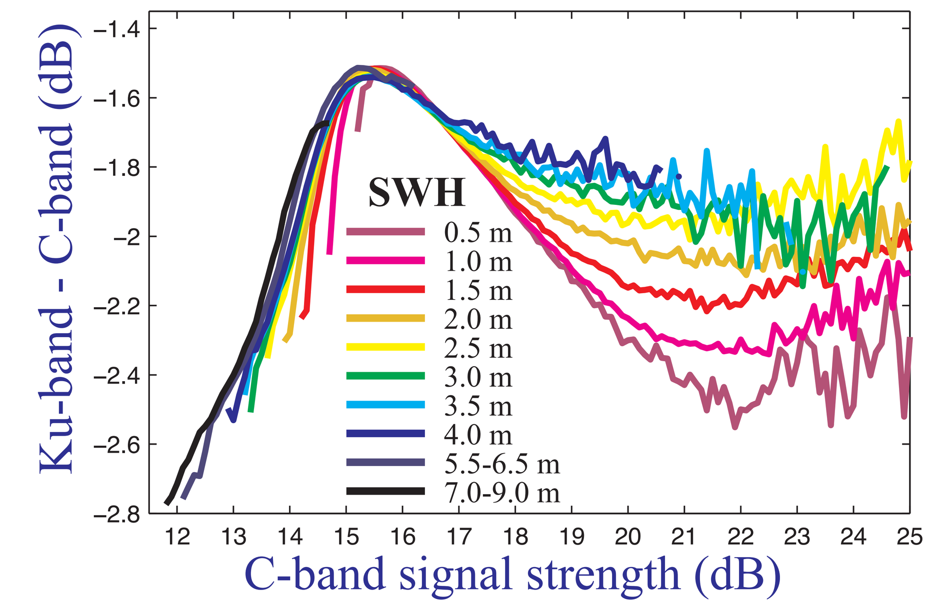
- i) well-defined mean relationship for rain-free observations with low scatter,
- ii) stable in time (so not need frequent adjusting, and can be used in NRT),
- iii) points flagged should be similar to those passing an LWP (Liquid Water Path) threshold (but not identical, else information is redundant),
- iv) match precipitation climatologies (although few show % time raining), and
- v) tally with records from Jason-1.

These tests have been done with all avaiable data (cycles 000-012), all wave heights and including in low wind conditions. Better performances can be obtained by discarding extreme conditions or selecting on wave height (see figure on right); the objective here is to evaluate a univeral algorithm.



Measures of signal strength for Jason-2

The default values (σ^0_{orig}) are the product of an MLE-4 retracker, which estimates off-nadir pointing, ψ^2 (affecting trailing edge slope), as well as range, leading edge slope (wave height) and amplitude. Because estimating ψ^2 introduces errors in σ^0, rain-flagging has also been proposed using AGC. Jason-2 provides an alternative measure of σ^0, based on an ice-retracker (here I average 20 Hz values to give σ^0_{ice}). Finally, an alternative is to determine the σ^0 values at zero mispointing (similar to output from MLE-3 retracker) — this is σ^0_{adj}.



Wave height affects mean relationship between roughness scales for Ku-band and C-band scattering. The effect is most pronounced at low wind speed (<2 m s^{-1}).

Tight mean relation

Light blue crosses are rain-free; dark blue circles are those with LWP>0.4 kg m^{-2}. Red curves show mean and ±2 std. dev. in 0.05 dB bins.

Stable in time

Mean relationship calculated independently for each 10-day cycle. Note, as well as possible drifts, there can be changes due to different tracker modes on different cycles.

Match with LWP

Histograms (note logarithmic scale) of derived attenuations, and of those also with LWP>0.4 kg m^{-2}.

Realistic geographical pattern

Frequency of rain i.e. % of 1 Hz records for which attenuation ≤ -0.5 dB.

Consistency with Jason-1

Match-up of individual 1Hz attenuations (Jason-1 interpolated to Jason-2 locations).

σ^0_{orig}

AGC

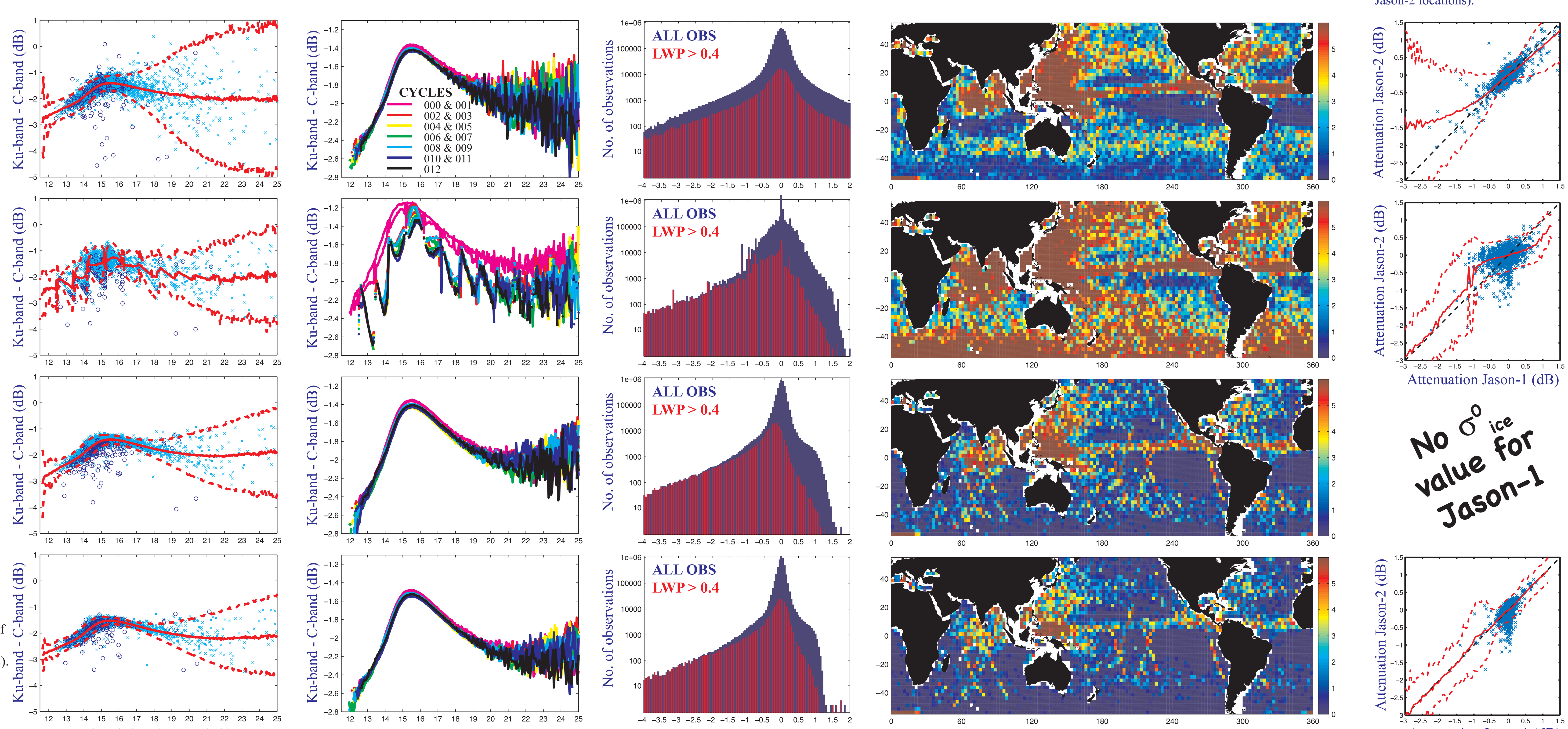
Here I use AGC_{Ku}-11.4 and AGC_C-1.7 to align with σ^0_{orig}.

σ^0_{ice}

Here I use σ^0_{ice-Ku}+1.1 and σ^0_{ice-C}-0.5 to align with σ^0_{orig}.

σ^0_{adj}

Compensated for MLE-4 estimate of mispointing, ψ^2 (see Quartly, 2008).



Tracker control of AGC changes leads to a complicated relationship. For all 4 measures, LWP-flagged points are mainly below the mean curve.

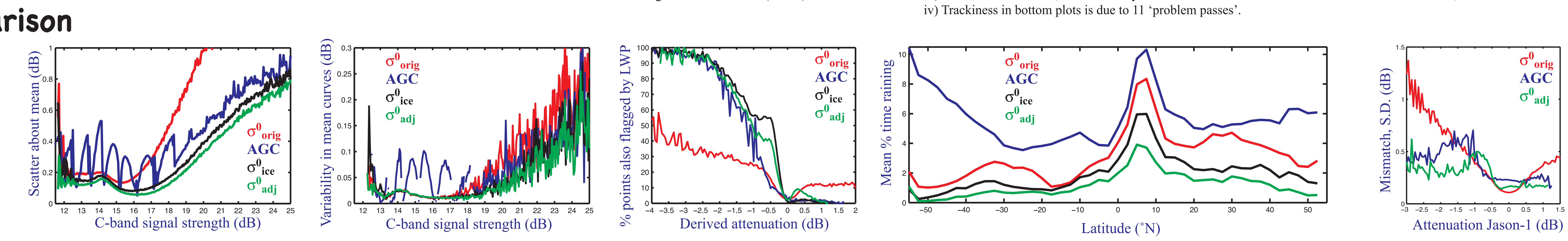
AGC behaviour very different for cycles 000 & 001 (split-gate tracker); no clear difference between use of other tracker modes.

Histogram for AGC has discrete peaks; σ^0_{ice} and σ^0_{adj} have the narrowest main lobes, with very few large σ^0 enhancements (>1 dB).

i) Many spurious detections in low wind regions (natural variability of σ^0).
ii) Patch at 55˚S south of Africa is probably sea-ice.
iii) With chosen criterion, AGC is overly sensitive.
iv) Trackiness in bottom plots is due to 11 ‘problem passes’.

Mean relationship for σ^0_{orig} shows Jason-2 is underestimating attenuation relative to Jason-1; others are unbiased.

Comparison



σ^0_{ice} and σ^0_{adj} give tightest relationships.

The above plot is for cycles 2, 4, 6, 8-12 only (Diode median tracker), but even so the AGC shows much more variability between cycles than the other measures.

σ^0_{ice} most clearly matches LWP flagging. Over half of large attenuation values for σ^0_{orig} are NOT associated with high values of LWP..

Latitudinal avergaing shows very different values according to the measures of signal strength used. Instead of -0.5 dB, one could use a variable threshold (function of observed scatter, see Tournadre, 2004) to ‘balance’ results, but unlikely to overcome AGC’s over-estimation in Southern Ocean.

σ^0_{adj} shows the most consistency between Jason-2 and Jason-1.

Summary

Rain-flagging using the standard GDR values (σ^0_{orig}) is compromised by the increased short-scale variability induced by the MLE-4 retracker. Performance of the AGC depends upon the on-board tracker mode, with the main modes inconsistent with that on Jason-1, and leading to a complicated relationship plus spiky histograms.

The other two measures are much more robust. σ^0_{ice} best matches the LWP performance, and is readily available (but only at 20 Hz). σ^0_{adj} requires a simple computation from 1 Hz GDR data, but has the advantage of a slightly tighter relationship, and being readily used for Jason-1.

Post Script

If you're confused about the pictures, want details of the references, or to generally argue the merit of rain-flagging, then contact the author (gdq@noc.soton.ac.uk). I acknowledge Pierre Thibaut's help in comprehending the details of the Jason-2 on-board trackers and the ground reprocessing.