A New Backscatter Histogram Method to Define an Ice/Rain Flag for Dual-Frequency Altimeters

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Abstract

The presence of rain or sea-ice within an altimeter's footprint causes distortion in the radar return waveform, leading to errors in range, wave height, and wind speed. Dual-frequency altimeters provide backscatter measurements, σ^0, at both the primary Ku-band and secondary C- or S-band frequencies. The primary effect of rain is an attenuation of the returned backscatter power, with more attenuation normally occurring for the Ku-band. Traditional dual-frequency rain flags have exploited this differential attenuation to define a rain flag based on a threshold below the mean σ^0 distribution at the two frequencies.

We have developed a new method that utilizes the cumulative two-dimensional histogram of backscatter measurements at the two frequencies for TOPEX, Jason-1, and Envisat. The raw backscatter measurements (with the atmospheric attenuation correction removed) are binned in σ^0(Ku) / σ^0(C or S) space and a cumulative distribution is formed by ranking the bins by the number of measurements in each bin. The resulting distribution is presented in terms of percentiles from 0% (bins with no data) to 100% (the bin with the largest number of values). The 2-D histogram is well behaved, with a single mode surrounded by uniformly decreasing closed contours. For all three altimeters, it is found that an edit criteria based on rejection of data outside the two-percentile level is reasonable.

Our technique provides a user-selectable edit criterion rather than a simple binary flag. It effectively removes outliers affected by both rain and sea-ice, which suffer attenuation of Ku-band relative to C/S-band as well as cases of 'reverse-attenuation' where the secondary band is attenuated relative to Ku-band. Finally, the choice of percentile cutoff level implies a restriction of acceptable backscatter values, thereby eliminating data affected by "σ^0 blooms".

The geographical distribution of data edited with a two-percentile flag agrees with our expectations for rain and sea-ice affected areas. Removal of suspect data using this flag results in a reduction in sea surface height variability, particularly in regions affected by heavy rain in the ITCZ and South Pacific Convergence Zone.

Creating the Ice/Rain Flag Histogram

Edit GDR data to create rain-free distribution

- 50°S < Latitude < 50°N
- Attitude < 0.2°
- Liquid Water Content < 0.6 kg/m^2
- GDR Flags: nominal; ocean-only; ignore GDR rain flag
- 1.5 < Peakiness < 1.8 (Envisat only)

Compute the cumulative 2-D histogram

- Remove atmospheric attenuation correction from GDR σ^0
- Bin σ^0(Ku) / σ^0(C or S) into 0.05 dB bins
- Rank bins by number of measurements in each bin
- Assign cumulative percentile to each bin:

$$S_j = \frac{100 \times \sum_{i=1}^{j} C_i}{N}$$ where C_i are ranked counts, N is total # points

- Percentiles range from 0% (no data) to 100% (max. # points)

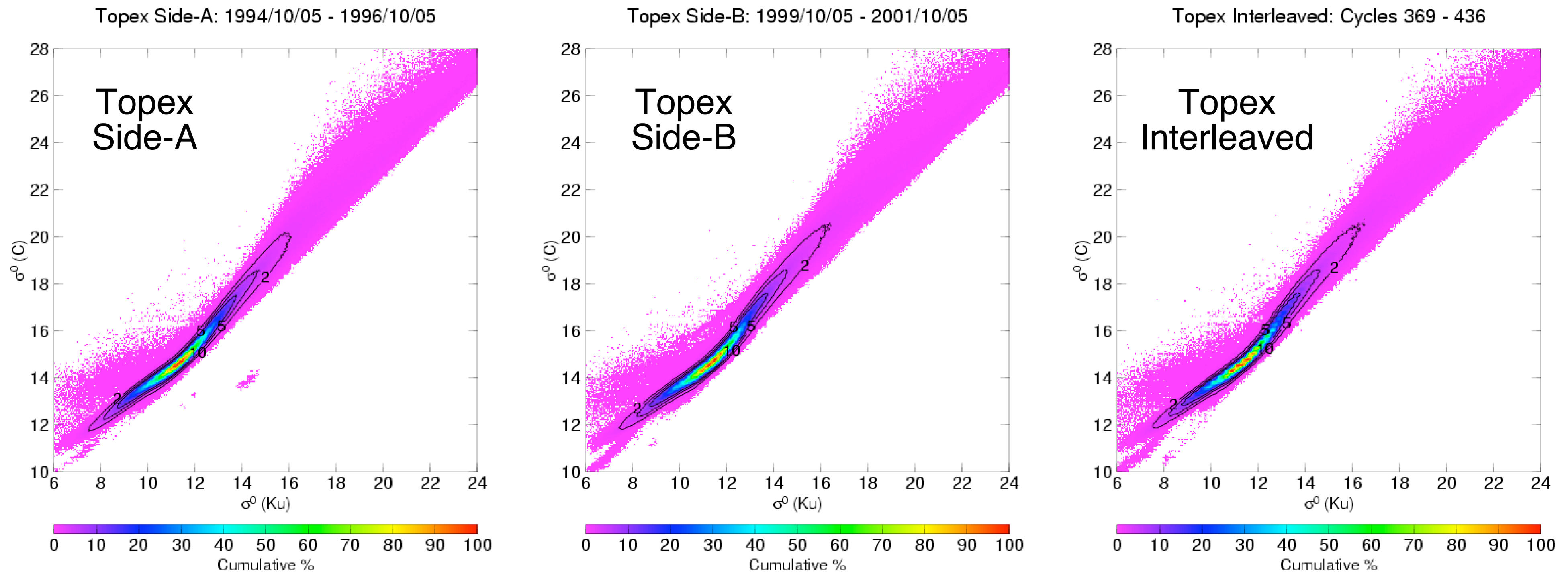
Compare histograms for all dual-f missions

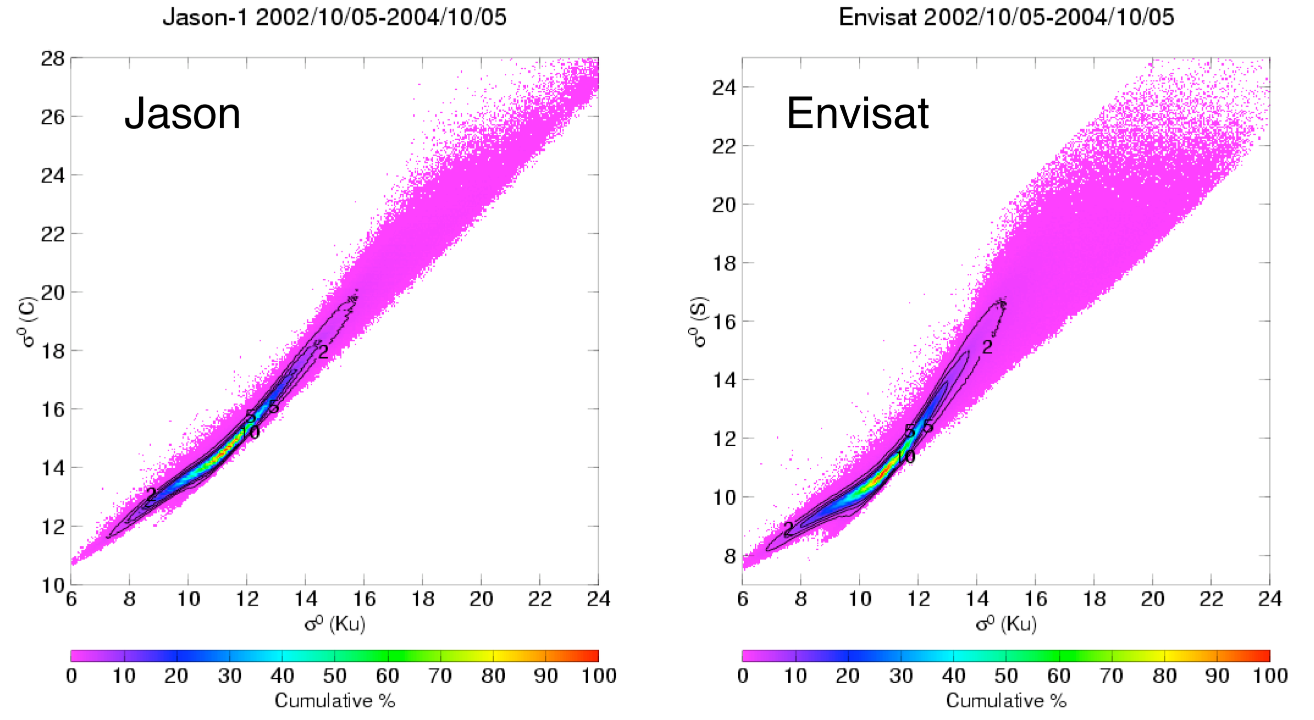
- Analyze two years of data for each mission segment
- Topex Side-A vs. Side-B in original orbit and Topex Side-B original vs. interleaved orbit
- Compare Topex & Jason (C-band) with Envisat (S-band)

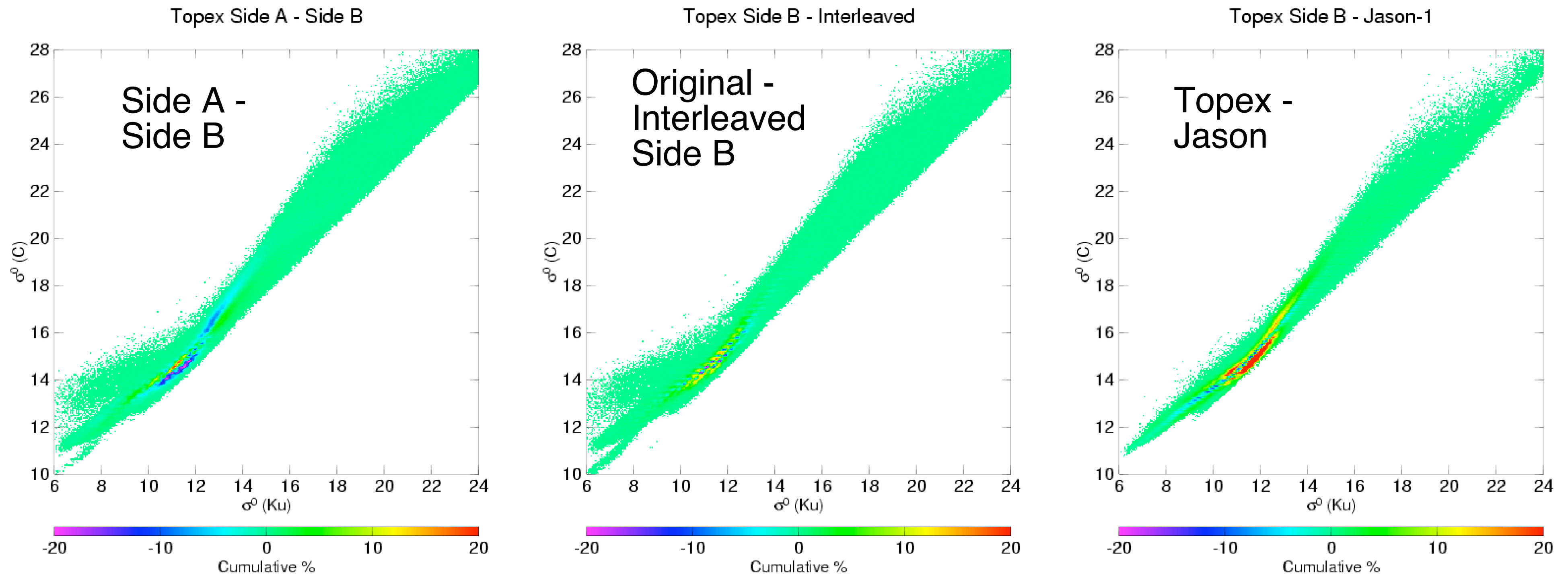
Results

- Smoothly varying closed contours around high density area
- Biases in either σ^0 must be carefully accounted for
- S-band Envisat data has more curvature near maximum
- More outliers at high σ^0 indicative of blooms

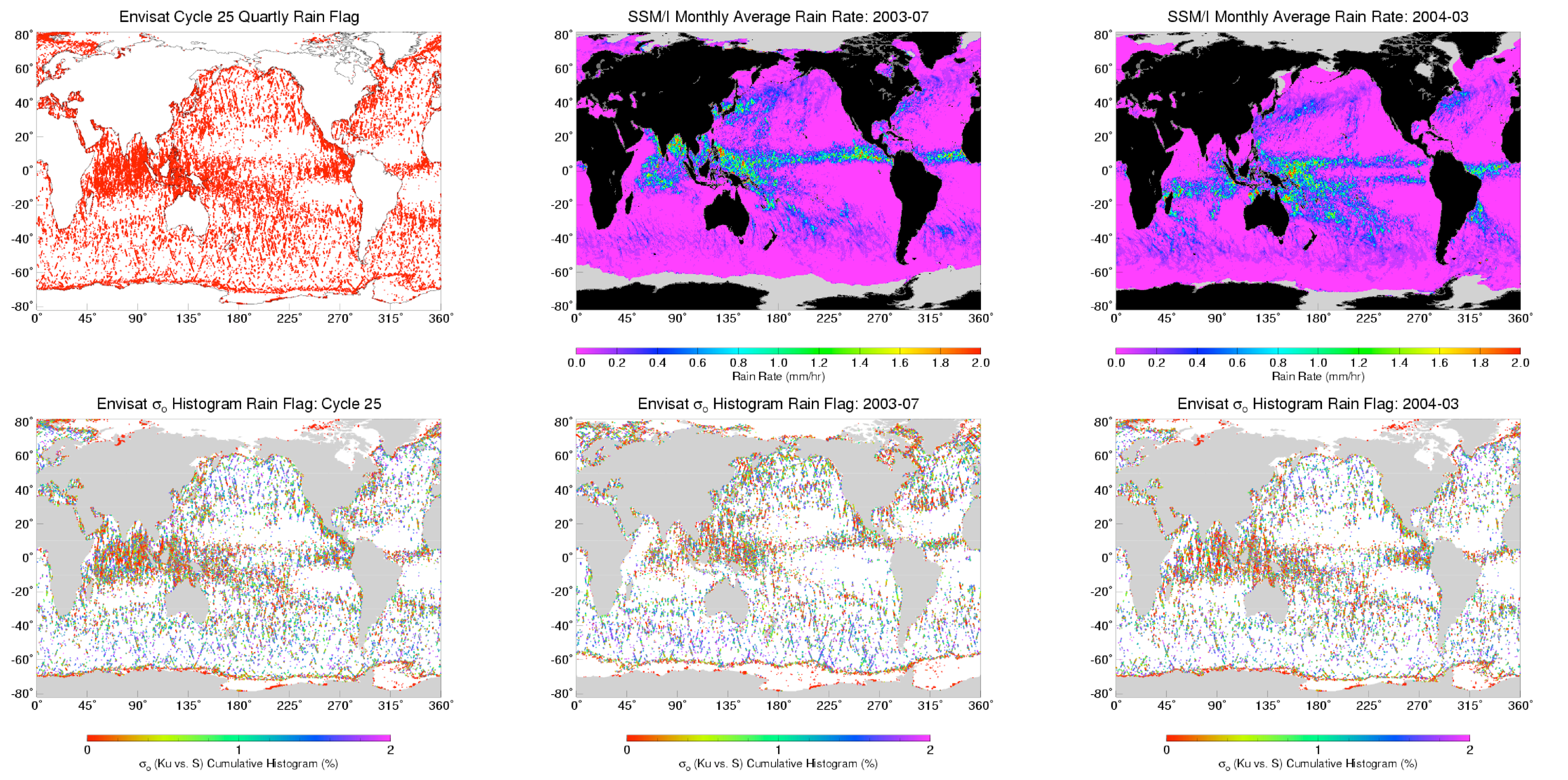
- Topex Side-A & B have different tilt around the maximum
- Side-B distributions similar for original & interleaved orbits
- Jason distribution narrower than Topex Side-B
- Away from peak, low percentile regions are similar







Ice/Rain flag (0-2%) compared to present Envisat rain flag



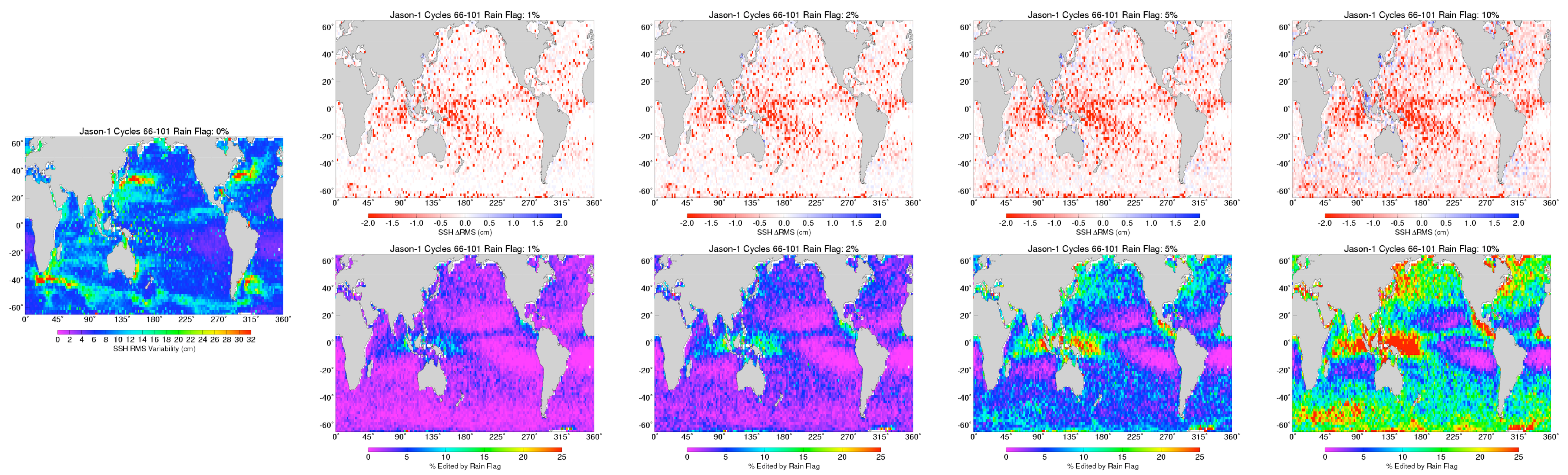
Ice/Rain flag (0-2%) compared to monthly SSM/I Rain Rate

Using the Dual-Frequency Ice/Rain Flag

Histogram used as lookup table based on σ^0 (Ku) and σ^0 (C or S) value
User-selectable percentile 'cutoff' edit criterion - compare 1, 2, 5, 10% for Jason & Envisat
Chosen percentile cutoff corresponds to amount of *extra* data edited by ice/rain flag
Not strictly a rain flag: also edits data where C- or S-band attenuated relative to Ku-band
Inherently limits range of acceptable σ^0 values in both bands: eliminates σ^0 blooms
Reduction in SSH variability in regions impacted by rain, such as ITCZ and SPCZ
User must compromise between reduction in SSH variability vs. amount of data rejected
Recommended ice/rain flag value of 2% based on comparisons with current rain flags

1% 2% 5% 10%

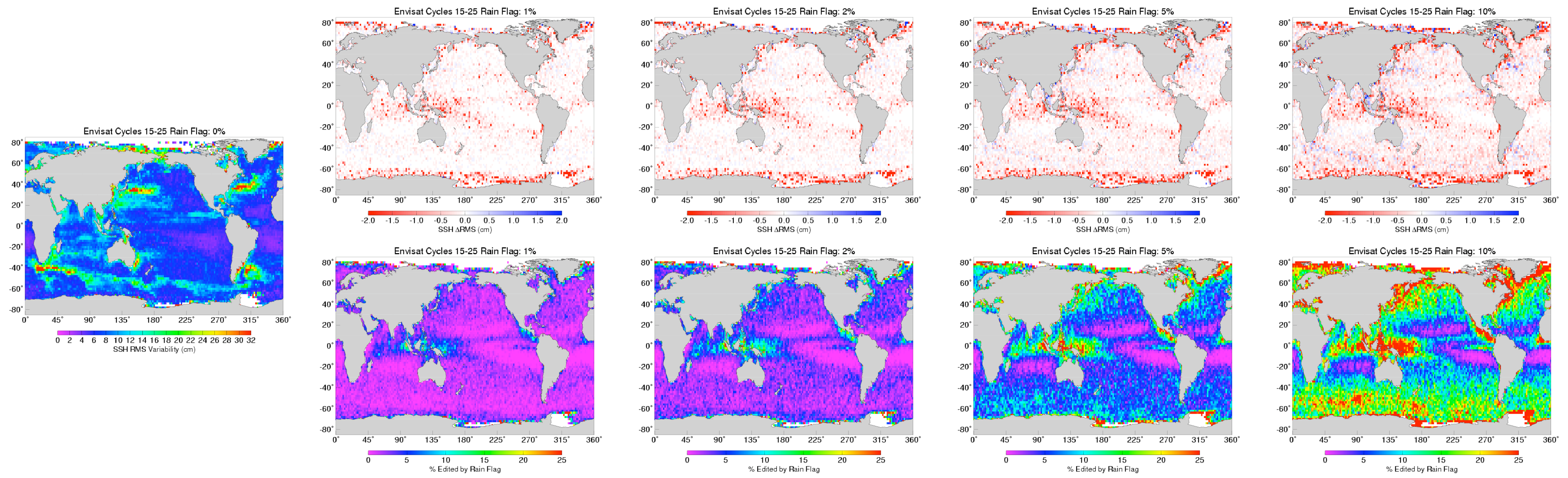
Jason



Reduction in SSH Variability

Percent of Data Edited

Envisat



Reduction in SSH Variability

Percent of Data Edited