Altimeter Sigmabloom, Surface Films and KU/C band sigma0 relationship

J. Tournadre[1], D. Vandemark[2]

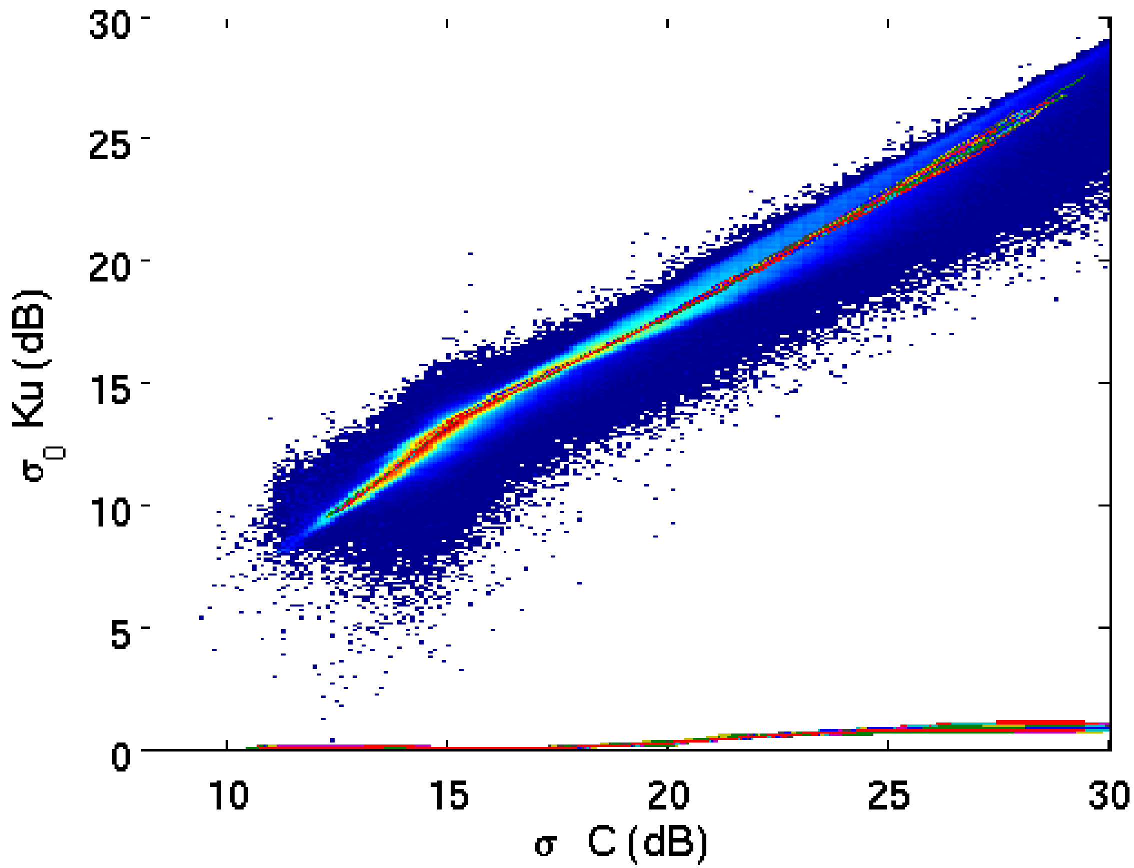
1-IFREMER, Laboratoire d'Océanographie Physique et Spatiale, Brest

2-University of New Hampshire

KU/C backscatter and relation

Since Topex/Poseidon most altimeters operate at Ku and C bands (except for Envisat S band) (for ionospheric corrections).

The relation between Ku and C σ0 is not linear but presents a change of slope near 14-15dB (4-6m/s) due to the change of hydrodynamic behavior of short capillary-gravity waves between 2 cm (Ku) and 6 cm (C band).



The dispersion around the mean relation increases with increasing σ0 (decreasing winds).

Below the mean relation σ0Ku is attenuated vs σ0C - used to rain flag if liquid water is present.

But above the relation Ku is enhanced vs C. i.e. 2cm waves are more attenuated than 6cm ones. What does it tells about the surface ?

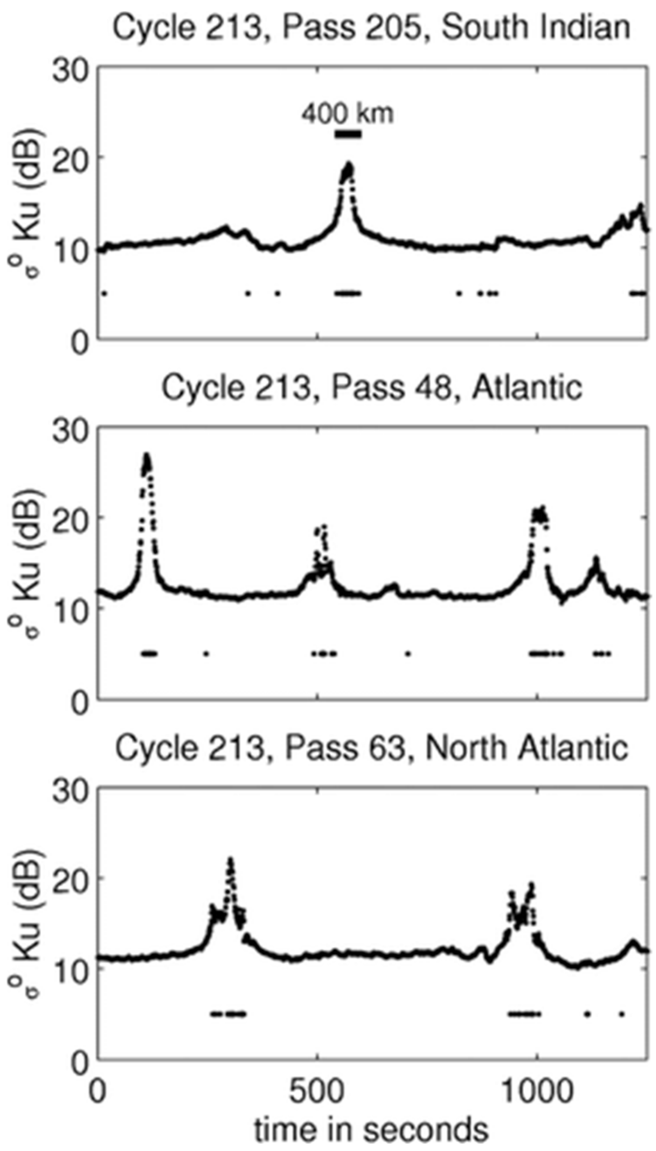
We defined the departure from the mean relation f as

$$\sigma_0^{Ku} - f\left(\sigma_0^{C}\right)$$

And the normalized departure as

$$\frac{\sigma_0^{Ku} - f\left(\sigma_0^{C}\right)}{rms_f\left(\sigma_0^{C}\right)}$$

Let's do a little bit of history



Examples of σ0 bloom events from 3 TOPEX passes
From Mitchum et al 2004

Since the launch of the first altimeters (GEOS 3, Seasat, Geosat .) zones of very large backscatter have been observed over the ocean.

sigma0bloom : zone of very low wind speed where the sea is « flatter than flat » and where the classical Brown model, mainly based on the assumption of incoherent radar scattering from a rough surface, might not be valid.

Studies by Garcia (1999) and Mitchum et al 2004.

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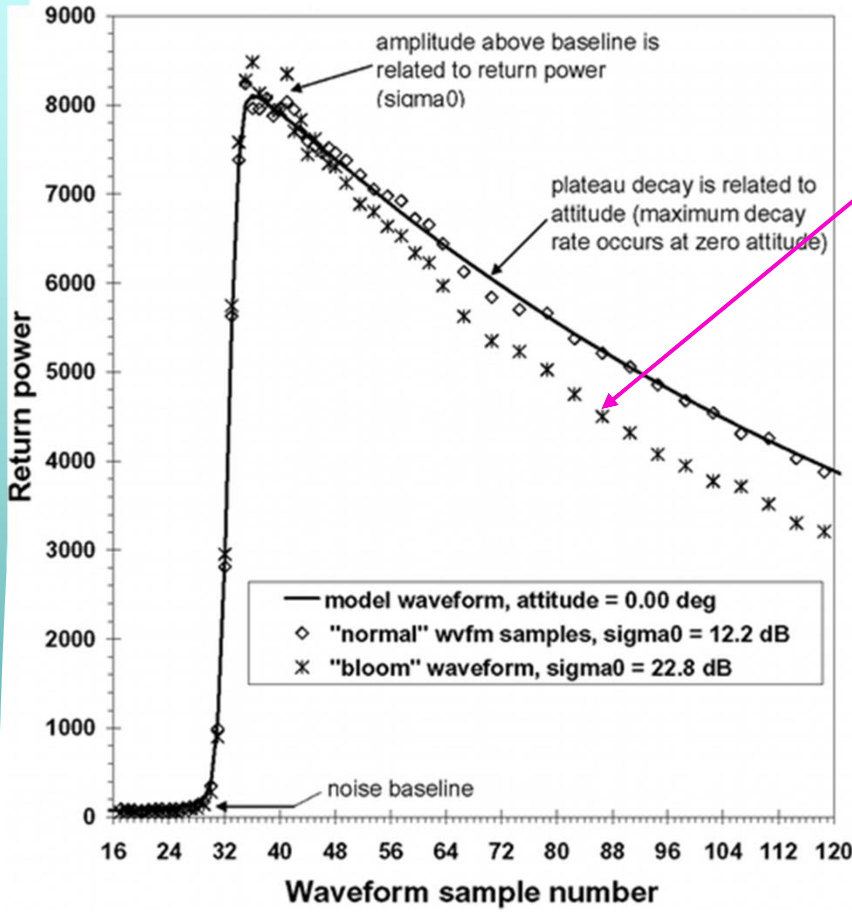


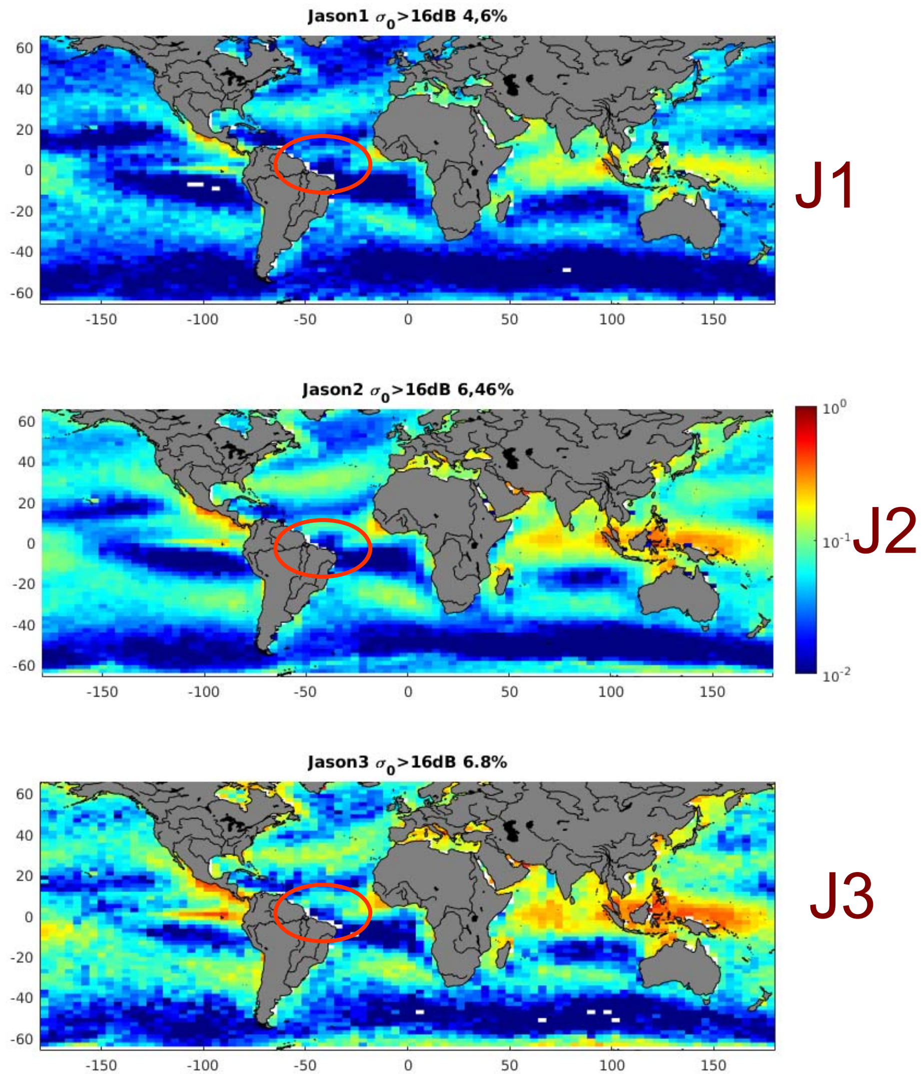
Mean waveforms during bloom events showed that the plateau decay is steeper than that of normal waveforms

This indicated that during sigmabloom the reponse of the ocean is strongly specular.

« *This could be due to extremely calm surface conditions, or possibly to the presence of surface slicks that attenuate the short wavelength surface waves that contribute to the surface roughness.* »

Mitchum et al 2004

JASON 1, 2 and 3 1Hz data sigmabloom



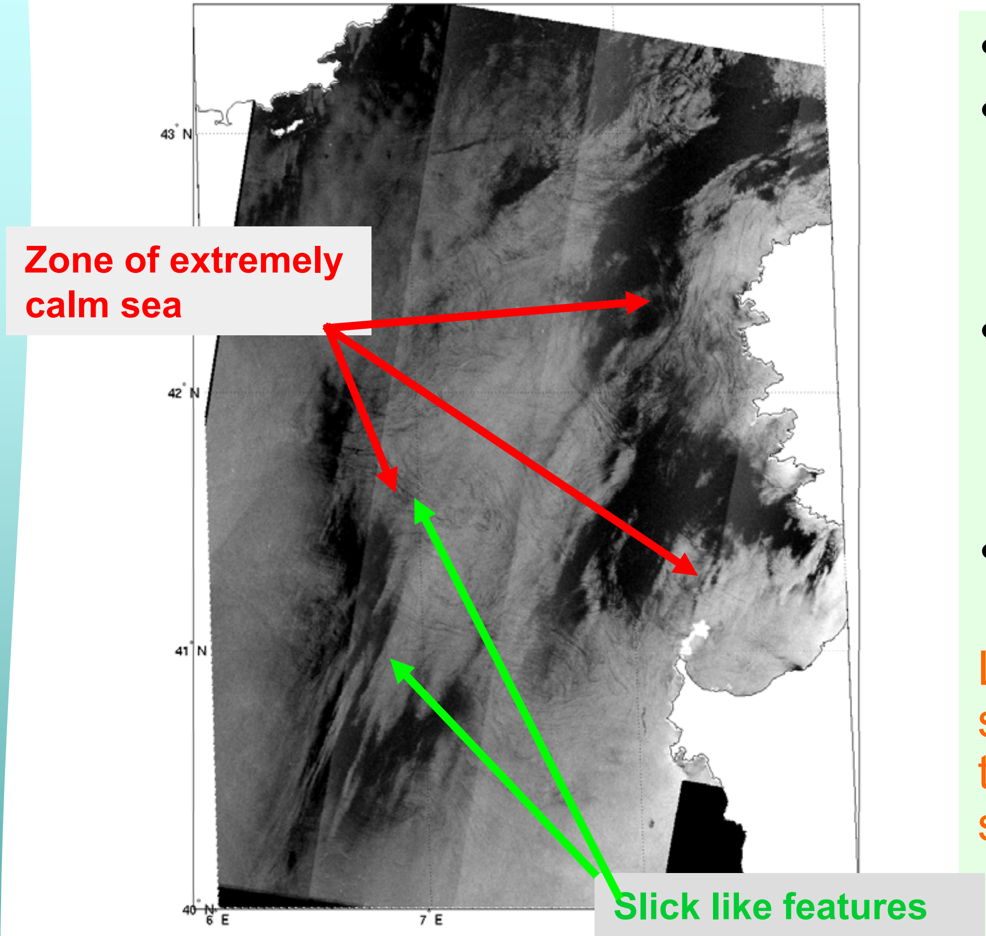
JASON Series little variation in the distribution and percentage (around 6%) of sigmabloom

Very similar to the results of Mitchum et al 2004 or Thibaud et al for Envisat

Defined as sigma0>16dB

Reflects mainly the low wind distribution but not only

Going to finer scales : analysing 20Hz altimeter waveform during sigmabloom Tournadre et al 2006



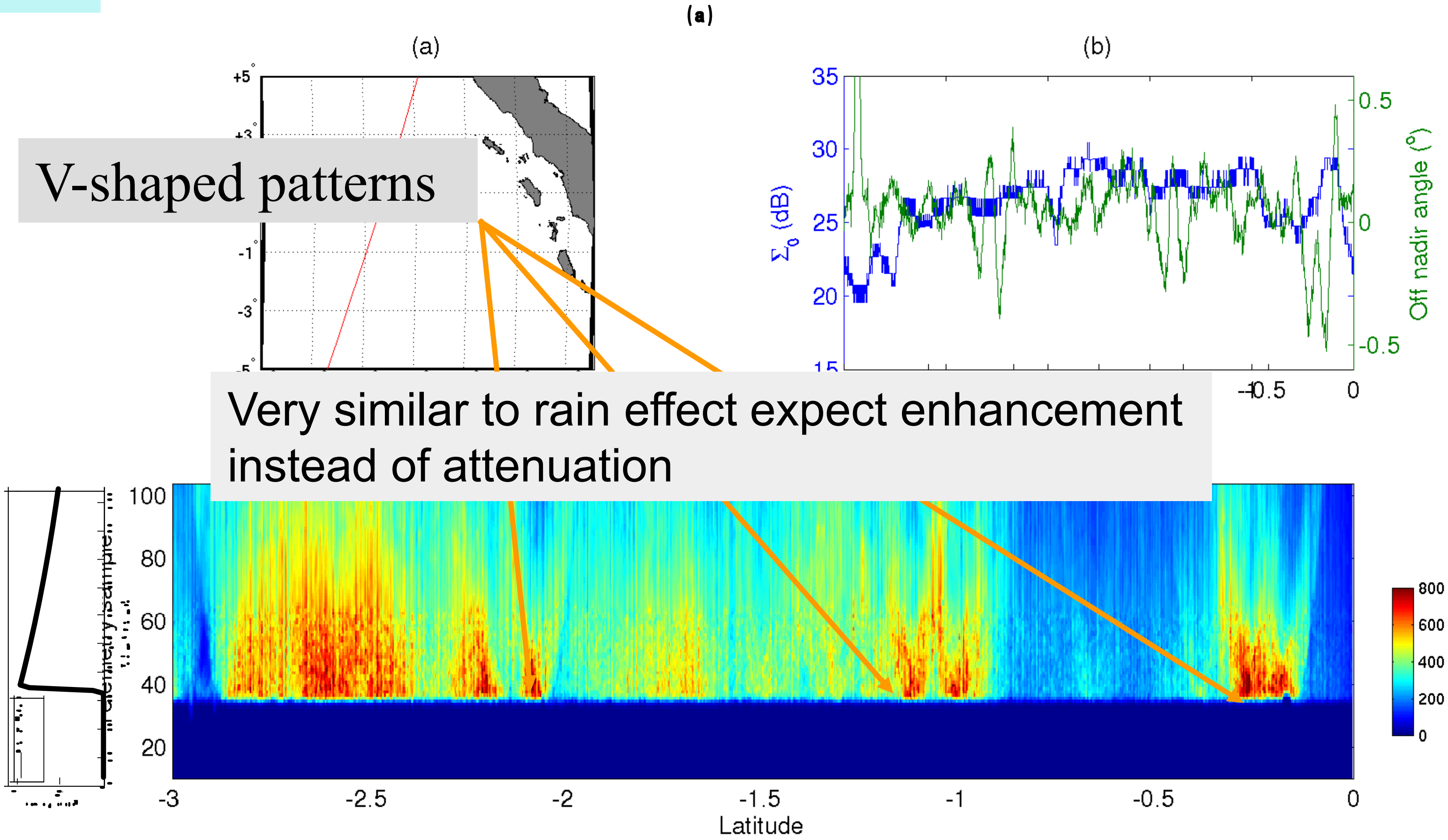
Fine scale structure of backscatter over the ocean as revealed by SAR images

- During blooms
- Mean altimeter return waveform shape significantly depart from its expected shape
- Off-nadir angle obtained from the shape of the return waveform can become unreliable.
- Can cause tracker and data losses

Likely to result from the strong in homogeneity of the surface backscatter at small scale

Example of waveform during bloom event

Jason1 off the coast of Sumatra 20 Hz waveforms σ0 and off-nadir angle



•Altimeter waveform model taking into account the short scale variability of surface backscatter

- Classical Altimeter waveform model : Barrick and Lipa 1985, Barrick, 1972, Brown 1977

$$\sigma(\frac{2x}{c}) = \frac{\pi^2 H''|R(0)|^2 \sigma_\tau \sigma_0}{2\sigma_p} \int_0^\infty e^{-\frac{u}{u_b}} e^{-\frac{(x-u)^2}{2\sigma_p^2}} du$$

- Simple way to take into account σ variations within the footprint : compound σ by a function A(u,θ)

- σ0 becomes

$$\sigma(\frac{2x}{c}) = \frac{\pi^2 H''|R(0)|^2 \sigma_\tau \sigma_0}{2\sigma_p} \int_0^\infty e^{-\frac{u}{u_b}} e^{-\frac{(x-u)^2}{2\sigma_p^2}} \left[\frac{1}{2\pi} \int_0^{2\pi} A(u,\theta) d\theta\right] du$$

- Modulation function in local coordinate system:

$$A(u,\theta) = A\left(\frac{x^2+y^2}{2H''}, \tan^{-1}\left(\frac{y}{x}\right)\right)$$

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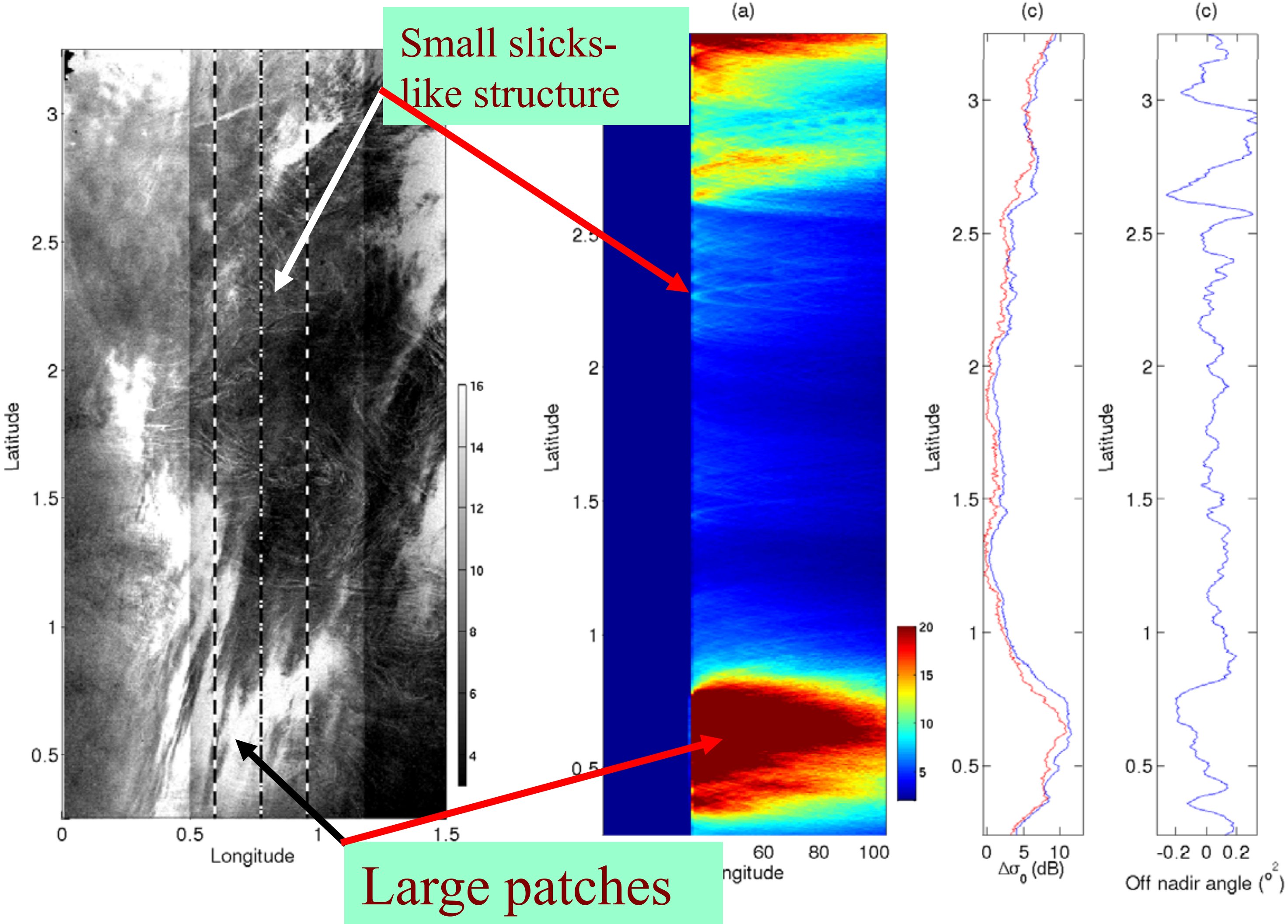
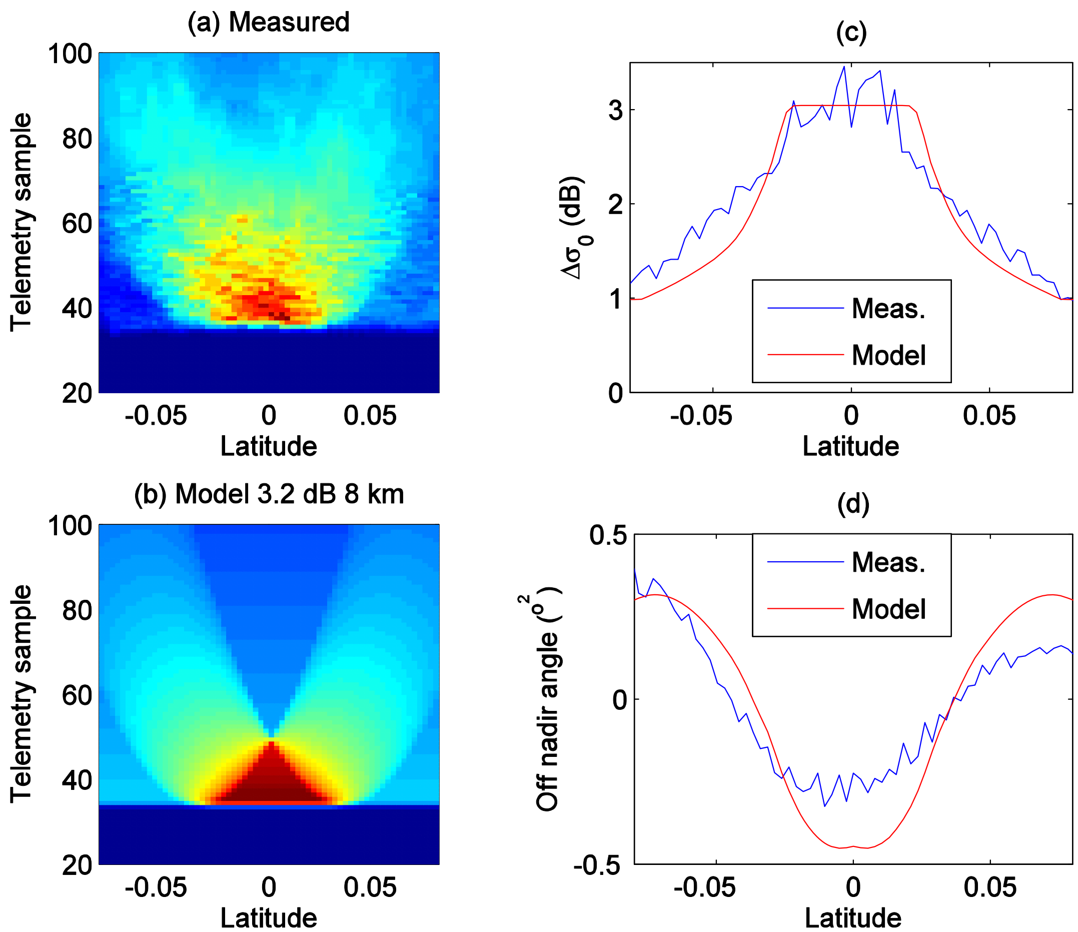
Using SAR surface σ data

The model reproduces very well the waveform behavior during bloom events

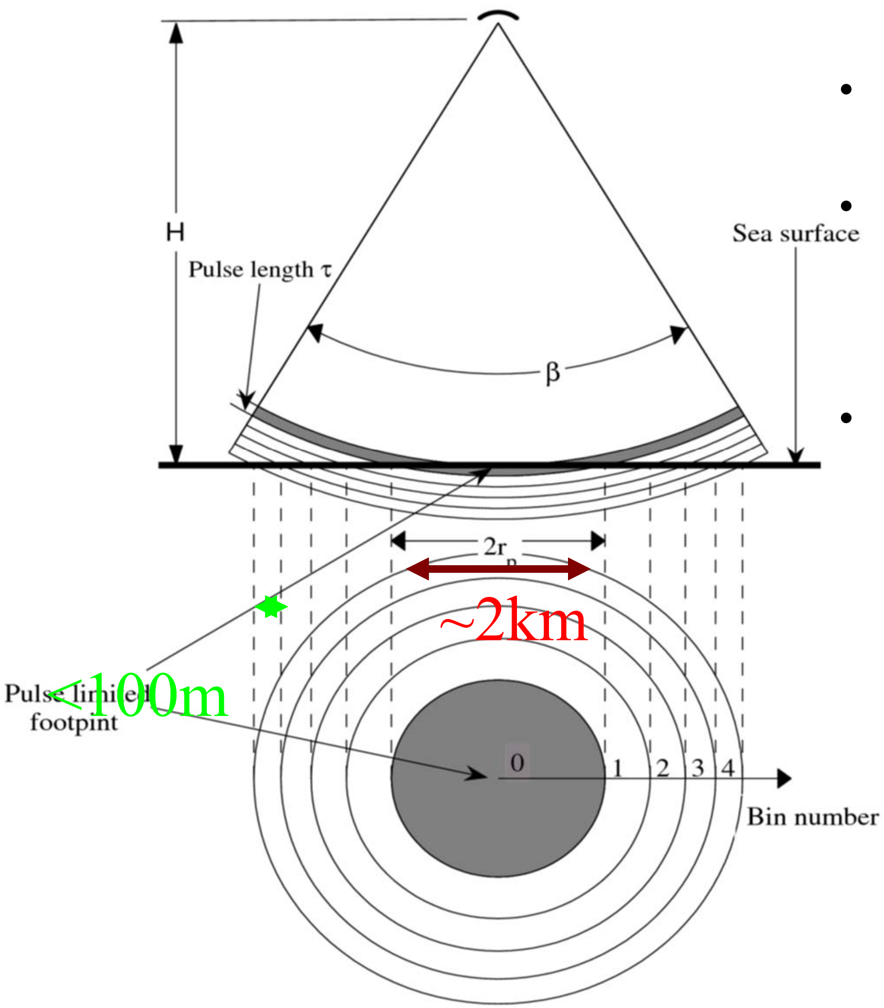


Analysis of waveforms during bloom events fitting model to observations

Minimizing distance between model and observations: Best fit circular patch 8 km radius 3.2 dB relative brightness



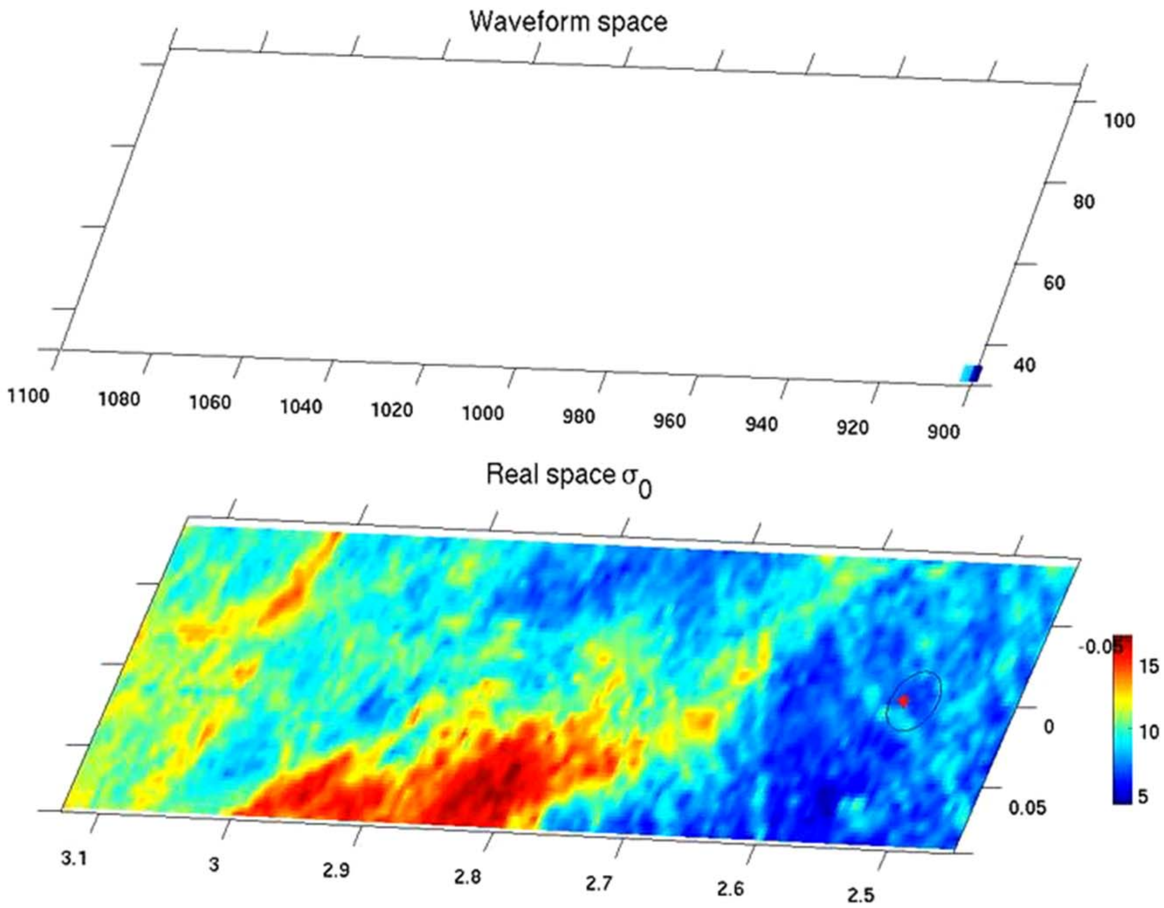
Going further :Is it possible to estimate the surface backscatter at higher resolution to have a better estimate of the sigmabloom distributions ?
Estimating surface backscatter at high resolution by waveform inversion - Tournadre et al 2011



- Altimeter over ocean: Classical Brown model
- Basic assumption: homogeneity of the surface backscatter over the footprint
- Not true in presence of small island, surface slick, currents etc.. i.e. Strong variations of surface backscatter at scale < footprint size
- In such cases: altimeter can be seen as an imager of the surface backscatter whose geometry is annular and not rectangular

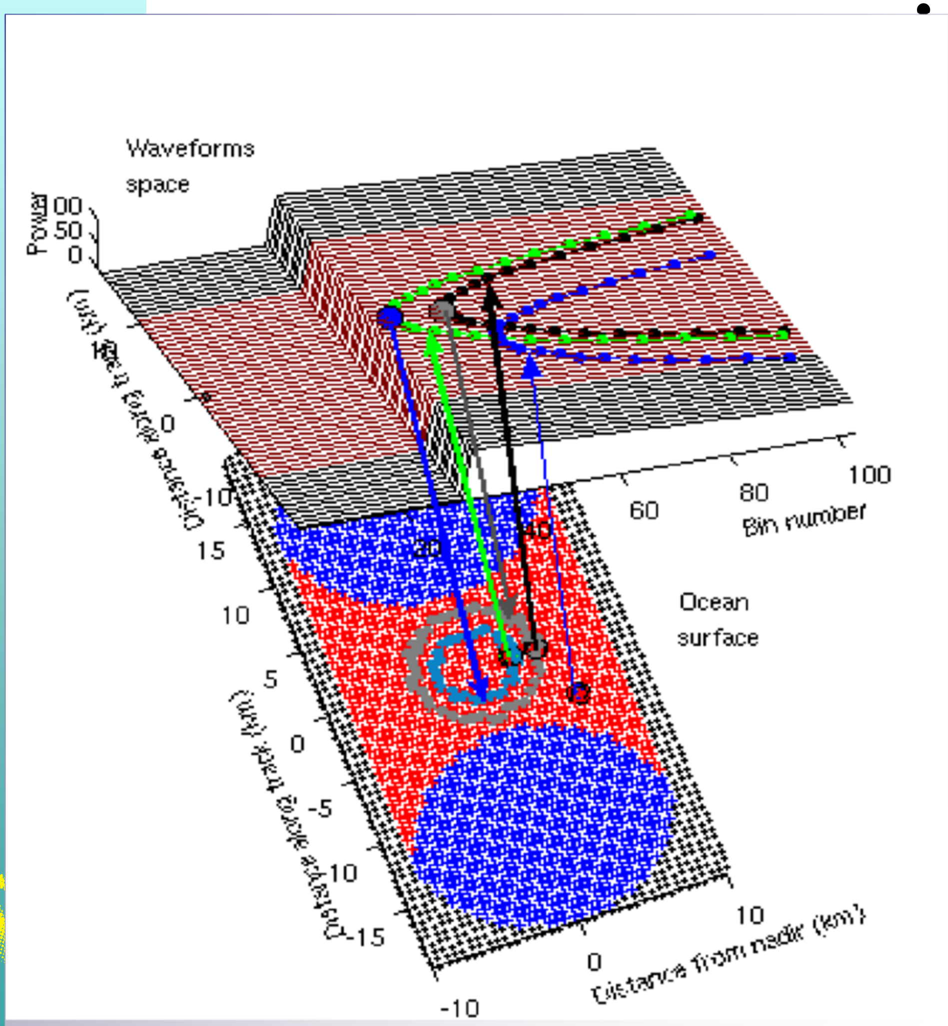
Imaging mechanism of an altimeter

W



σ(

Is it possible to retrieve the bacskcatter information from waveforms?



- Imaging process

Waveform space point associated to an annulus in real space

Real space point associated to a parabola in the wave form space

Left/rigth ambiguity

Red waveforms <==> blue surface

Red surface <==> surface points contributing only to the red waveforms

Inversion method

- Computation of the imaging matrix using the Brown model.
- Waveforms are in the form of
- $$w_f(i,j) = \alpha \sum_k \sum_l \sigma_s(k,l) e^{-\frac{u(k,l)}{u_b}} (1 + erf(\frac{u_j}{\sqrt{2}\sigma_p}))$$
- If we detrend the waveforms for beam-width and swh effects

$$W(i,j) = w_f(i,j) \frac{e^{u_b}}{(1 + erf(\frac{u_j}{\sqrt{2}\sigma_p}))} = \alpha \sum_k \sum_l \sigma_s(k,l)$$

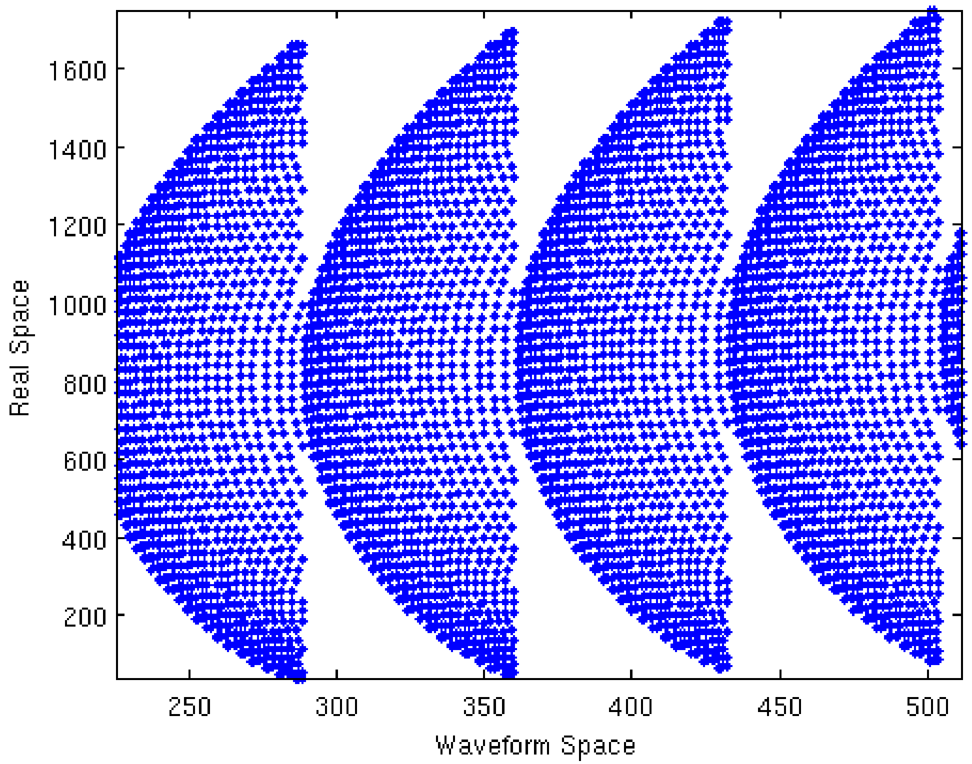
- I.e

$$\boxed{W = AS}$$

- Inversion gives

$$S = A^+ W$$

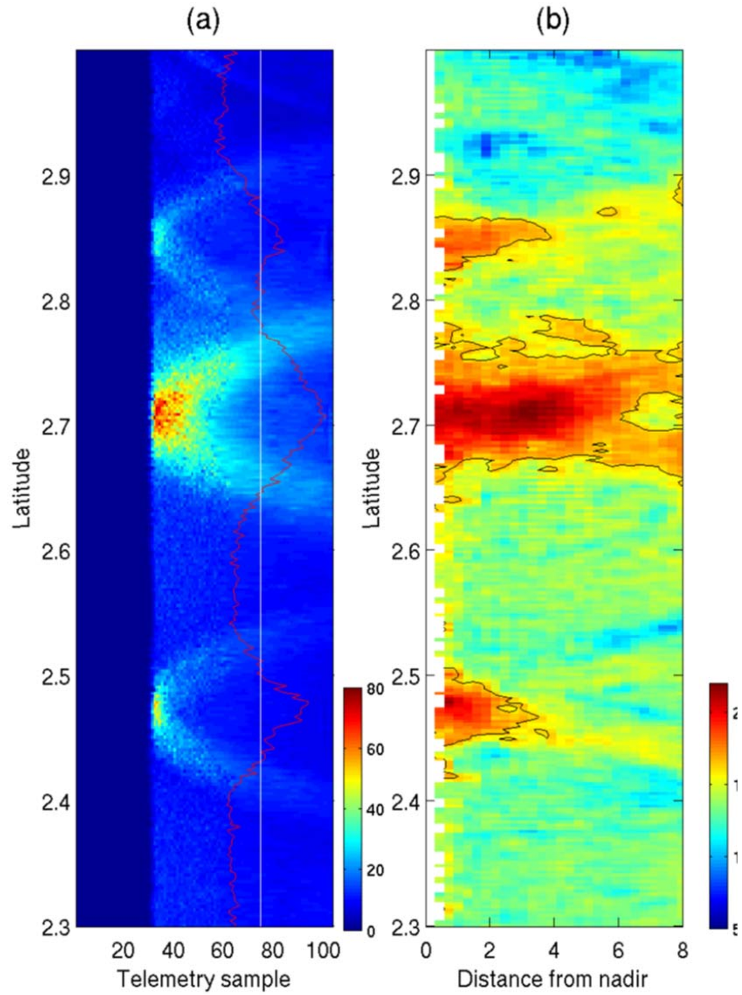
The altimeter imaging matrix



The parabolae again!! Range migration as for DDA

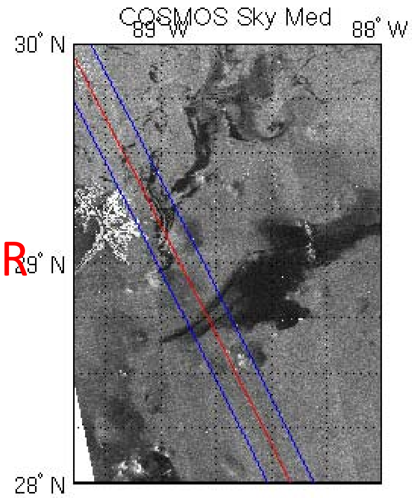
sigma0bloom

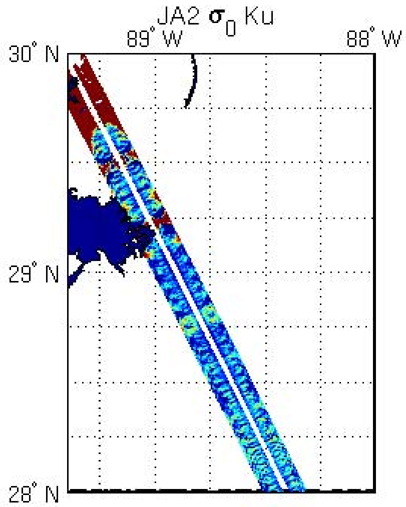
- Envisat pass south of Sumatra: sigma0bloom characterized by parabola patterns in the waveforms space.
- The inversion clearly shows the presence off small very bright zones of the surface
- Similar to SAR images. Presence of surface films
- But how can we discriminate between film and low wind?



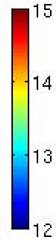
And then come the Gulf Oil slick

Cosmos
SKYMED SAR

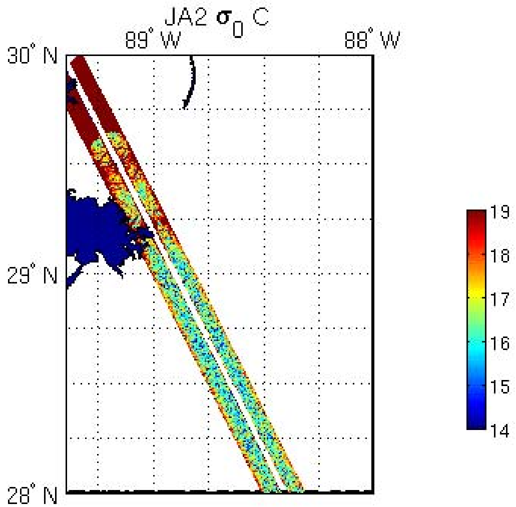


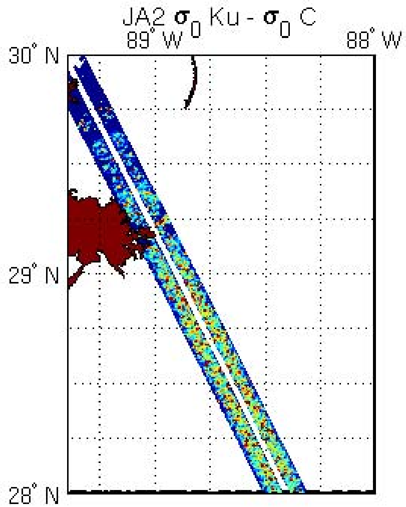


Jason2 Ku
Band s0

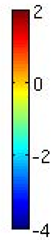


Jason2 C
Band s0





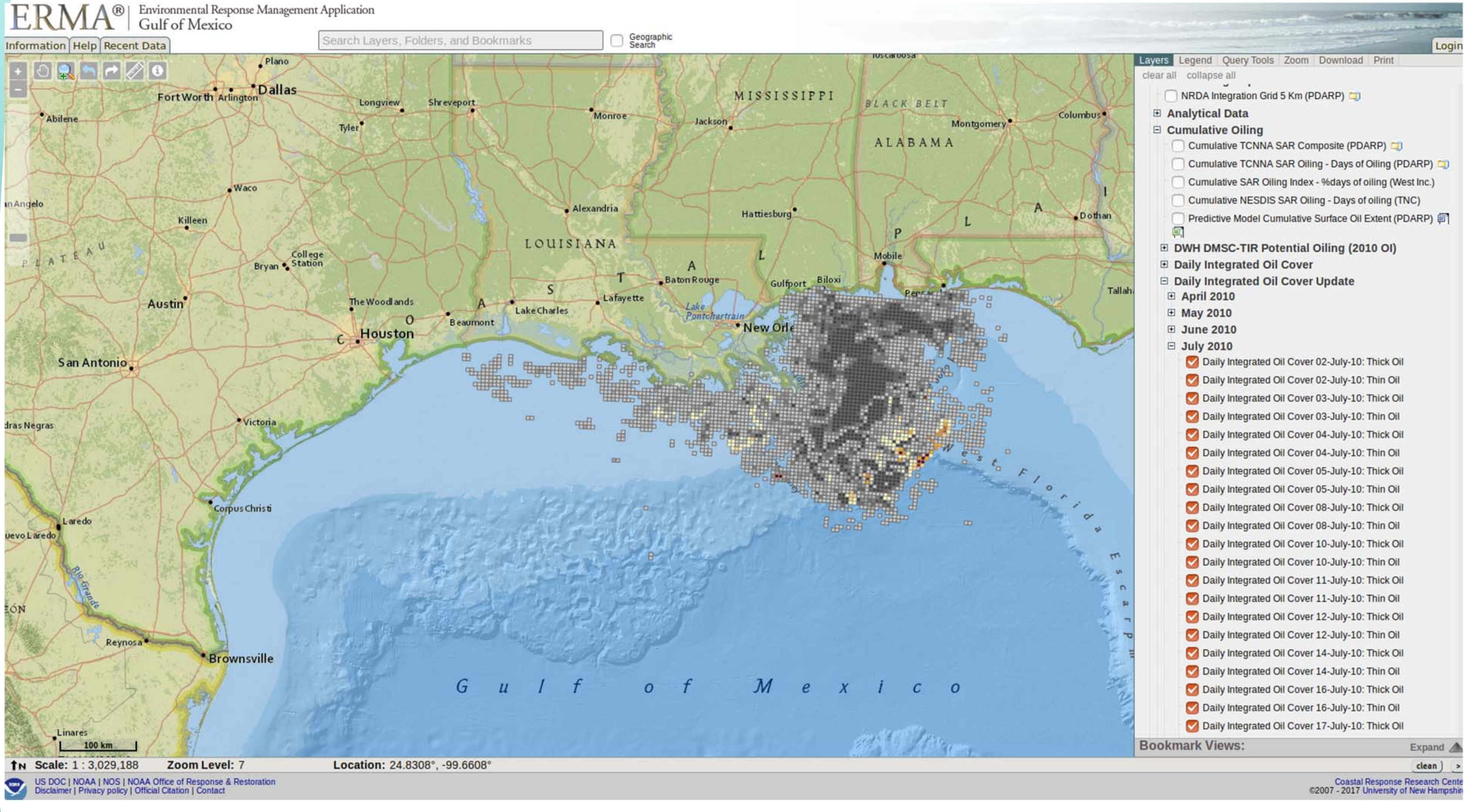
Jason2 Ku-C
s0



ERMA Data set

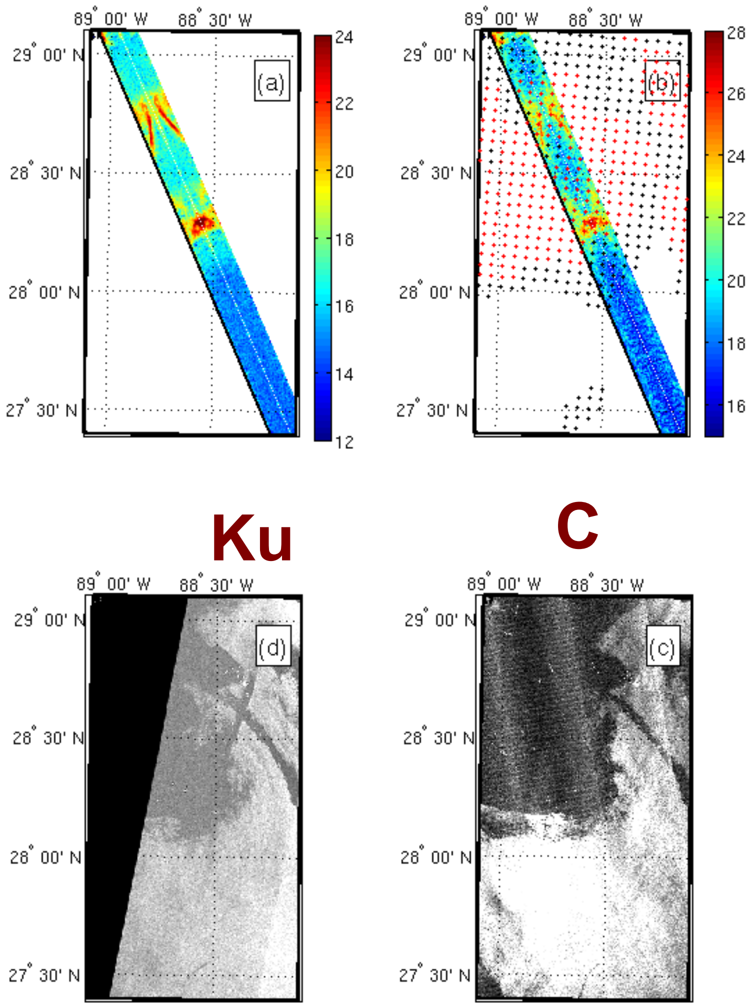
Analysis of oil slick extent and thickness from SAR and visible (sun glint) images

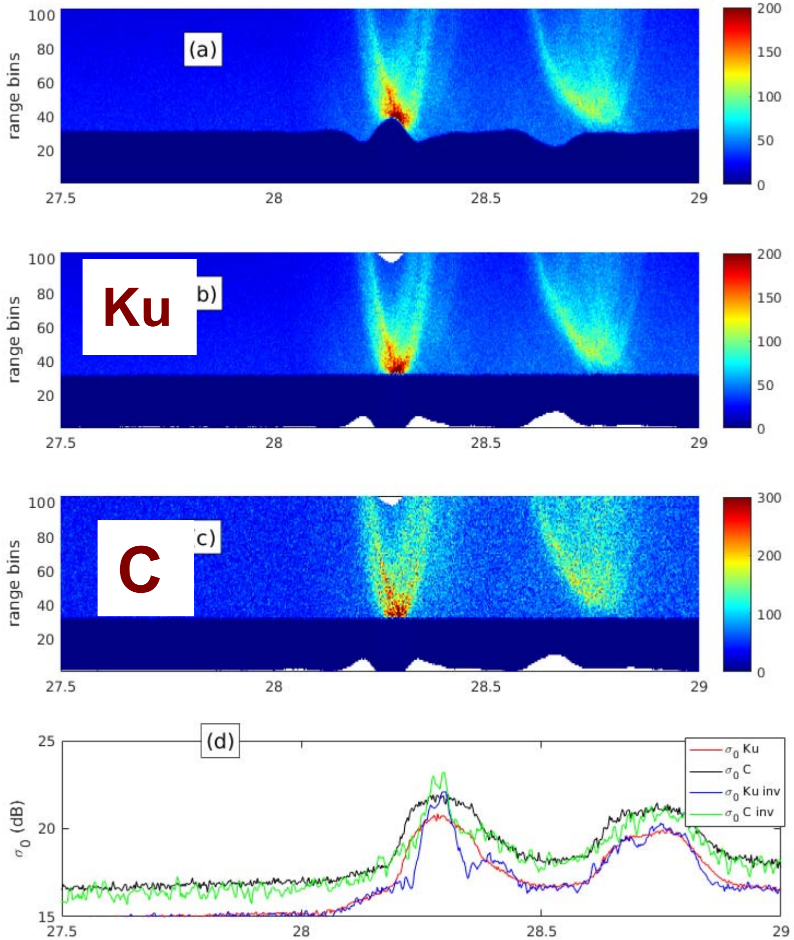
Only 5x5km grid



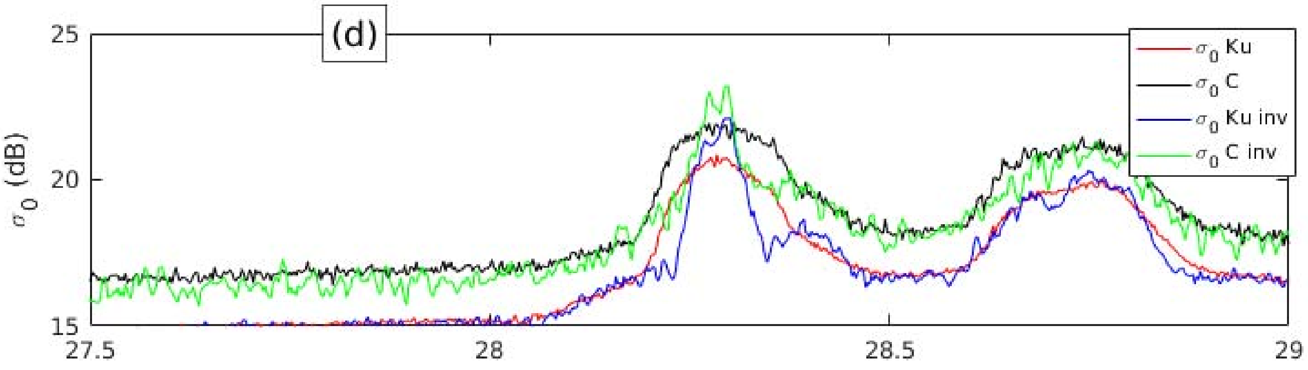
Thick oil

Thin oil



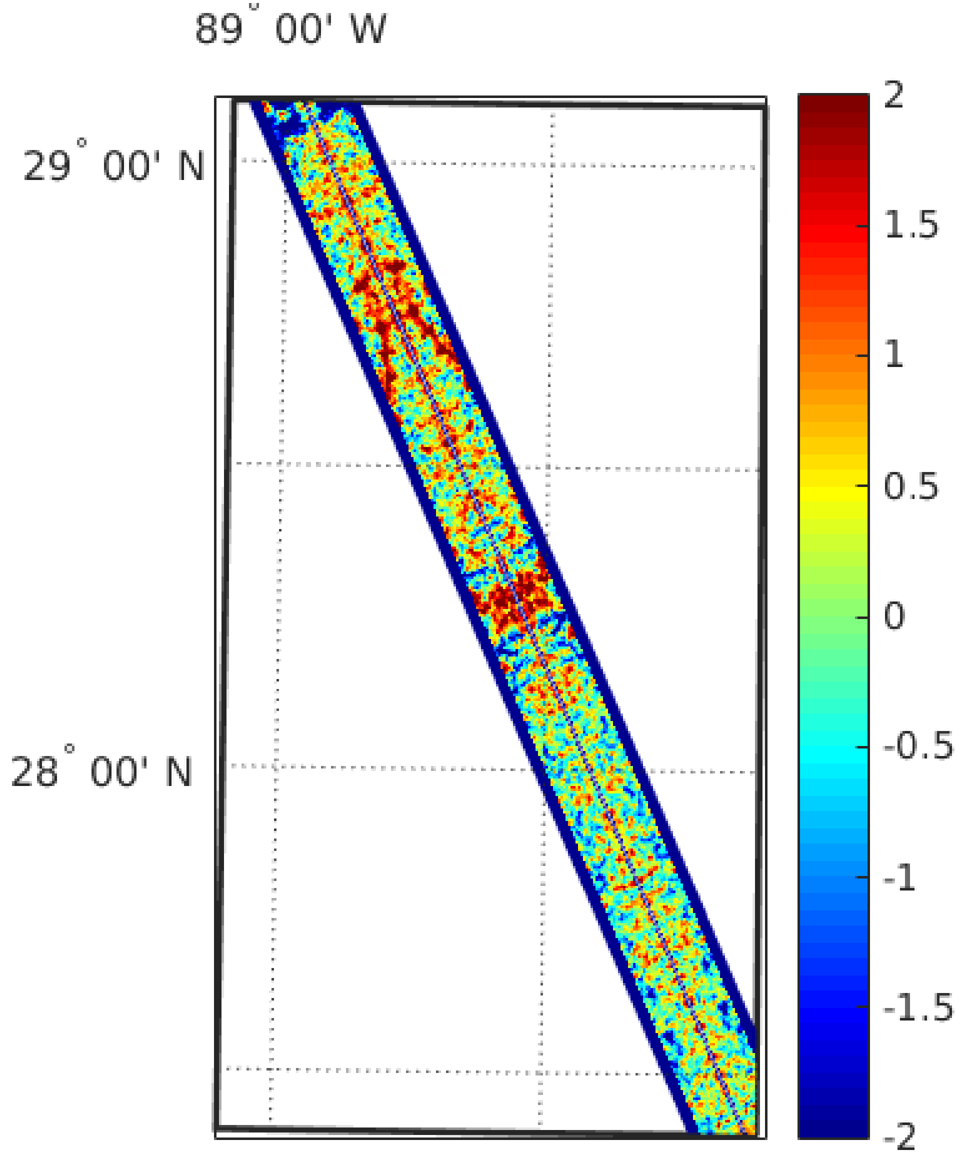


20 passes from Jason2, 20 from Jason1 end 10 Envisat

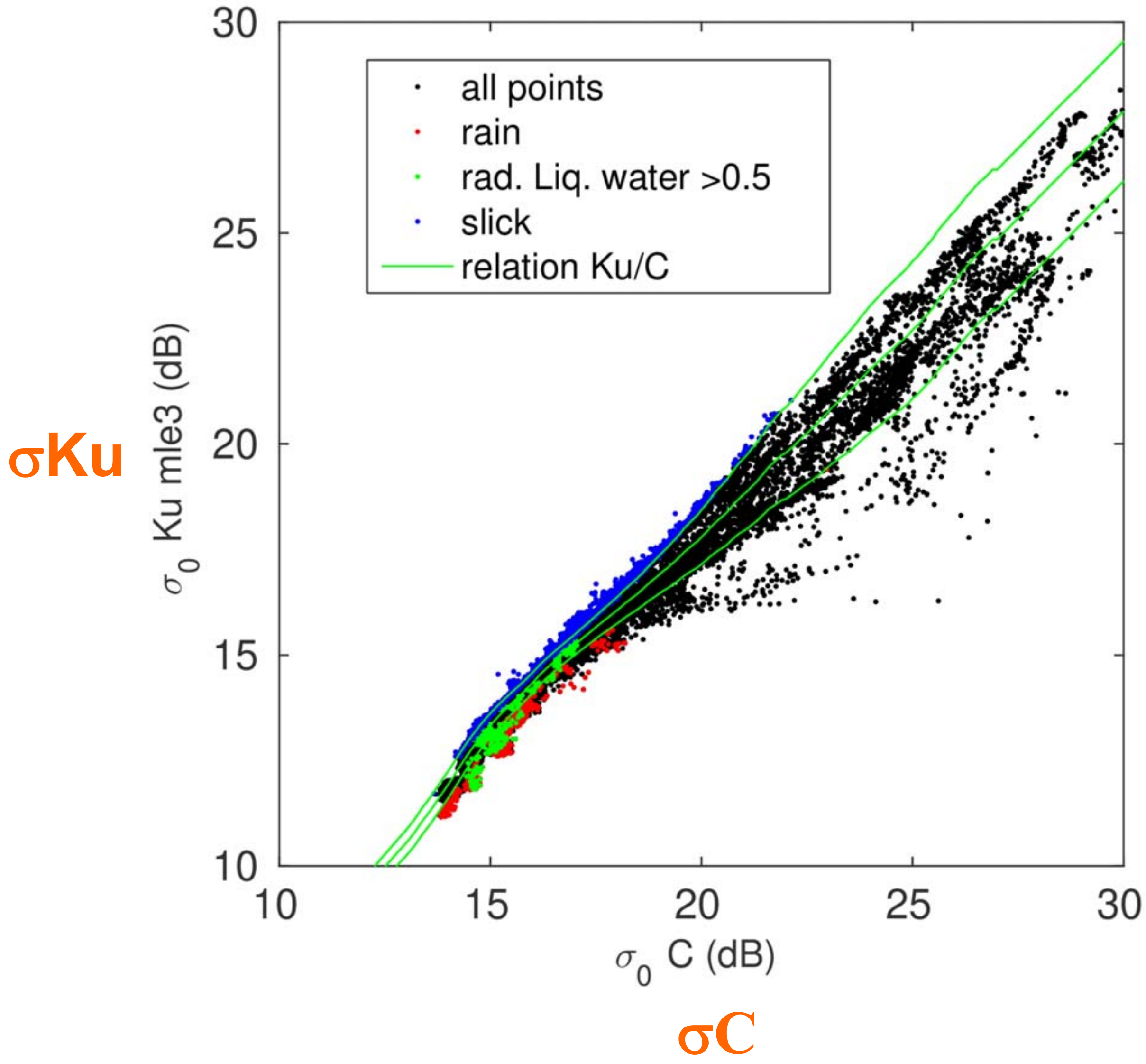


Ku and C band backscatter :
Sigmabloom directly related to oil film

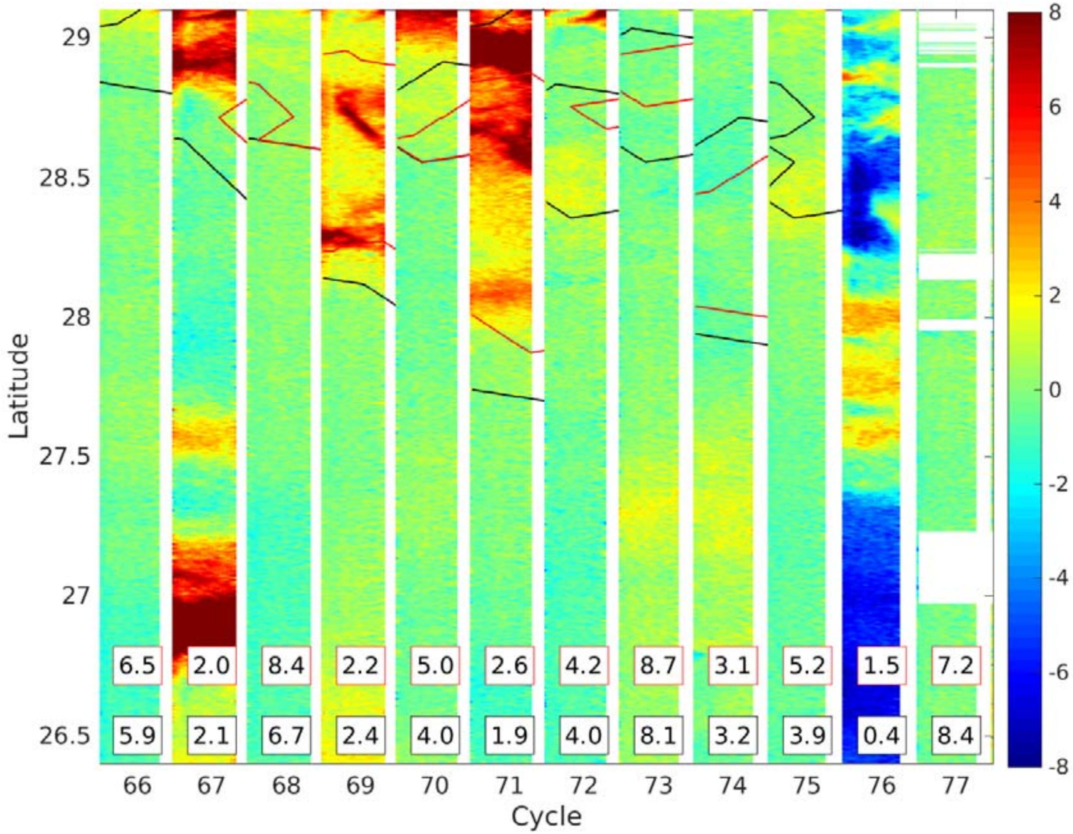
A look at the Ku/C band difference



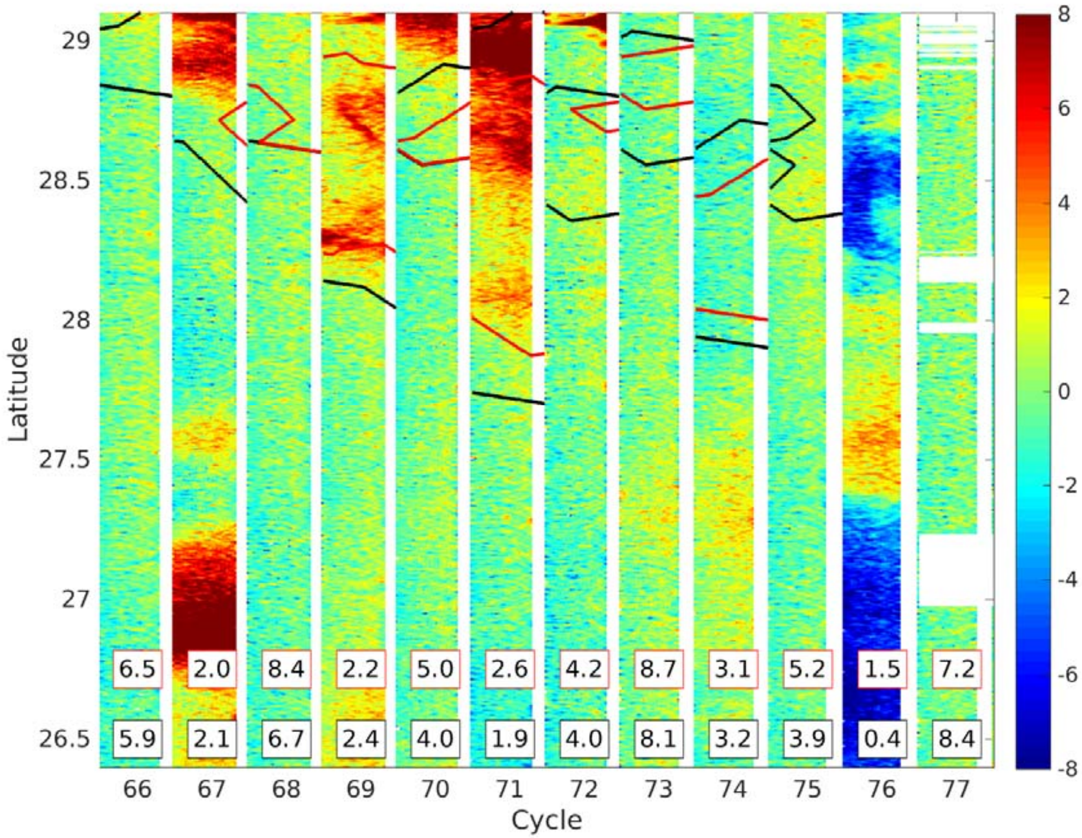
Distribution of σ_0 Ku (mle3) and C
Mean relation and rms
Oil spill thickness Departure from relation



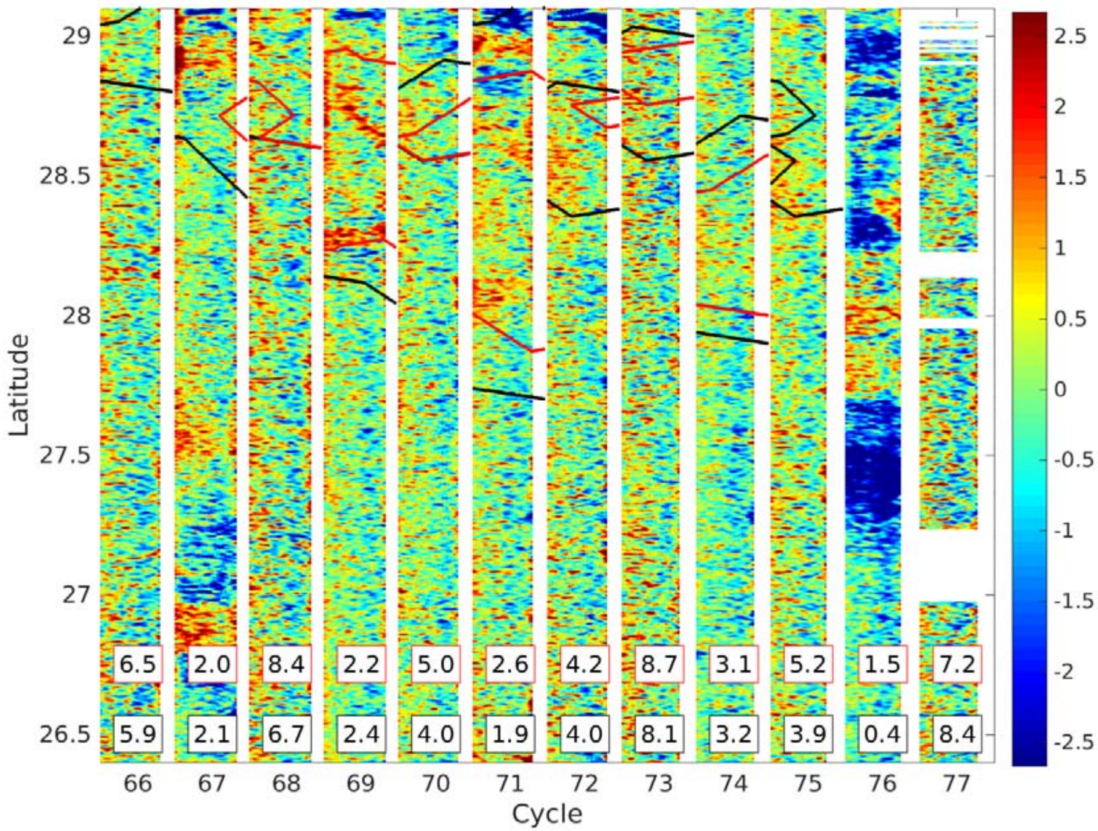
$\sigma0^{Ku}$ inverted pass 204 cycles 66-77



σC inverted pass 204 cycles 66-77



σKu-f(σC)



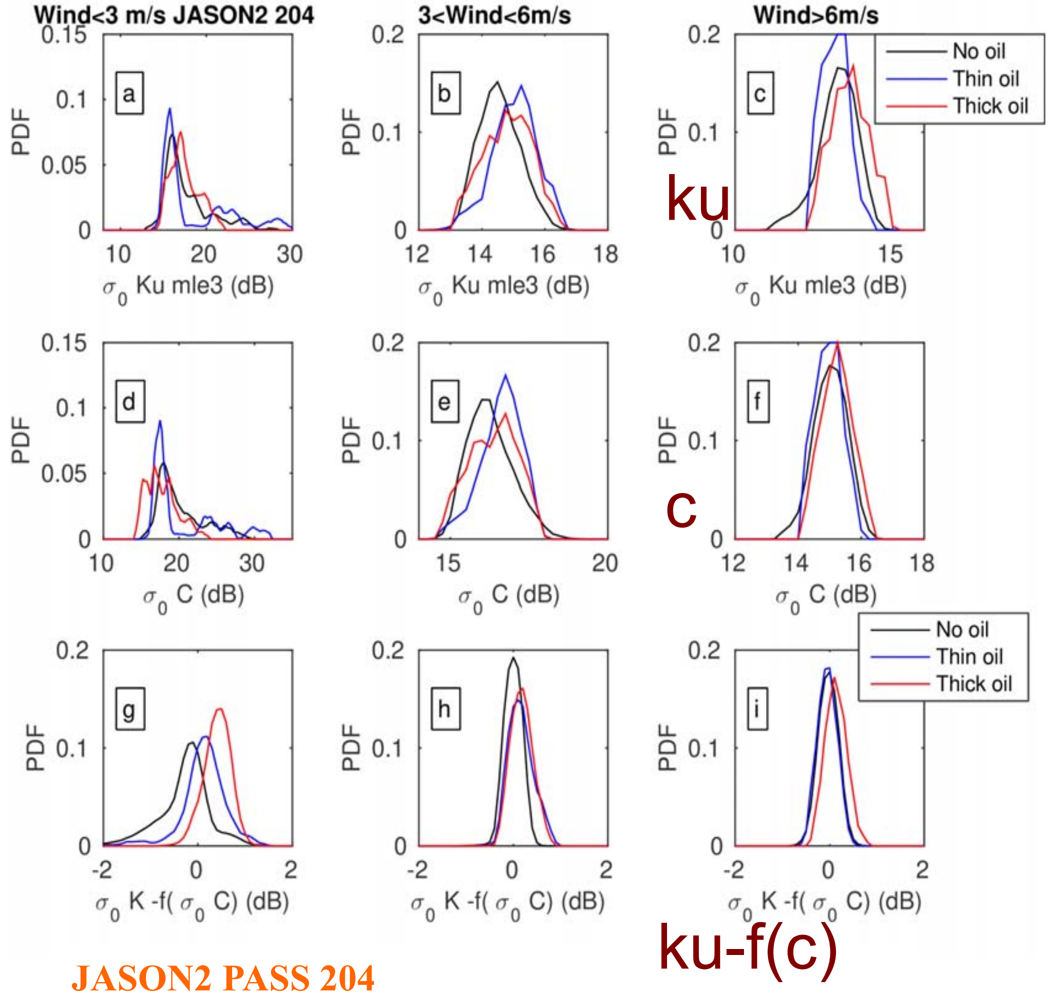
29
28.5
28
27.5
27
26.5
Latitude
66
67
68
69
70
71
72
73
74
75
76
77
Cycle
6.5
2.0
8.4
2.2
5.0
2.6
4.2
8.7
3.1
5.2
1.5
7.2
5.9
2.1
6.7
2.4
4.0
1.9
4.0
8.1
3.2
3.9
0.4
8.4
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5

Histograms of $\Delta\sigma0$ for J2 pass 204 and J1 (versionE) Pass 015

-At low wind speed (<3m/s) strong departure from relation, **~1-1.5 dB for thick oil ~0.4-1dB dB for thin oil.**

-At medium winds (3 – 6 m/s) the departure is of the order **0.4 dB weak difference between thick and thin oil**

-At high winds (>6m/s) weak departure of **0.2 dB**



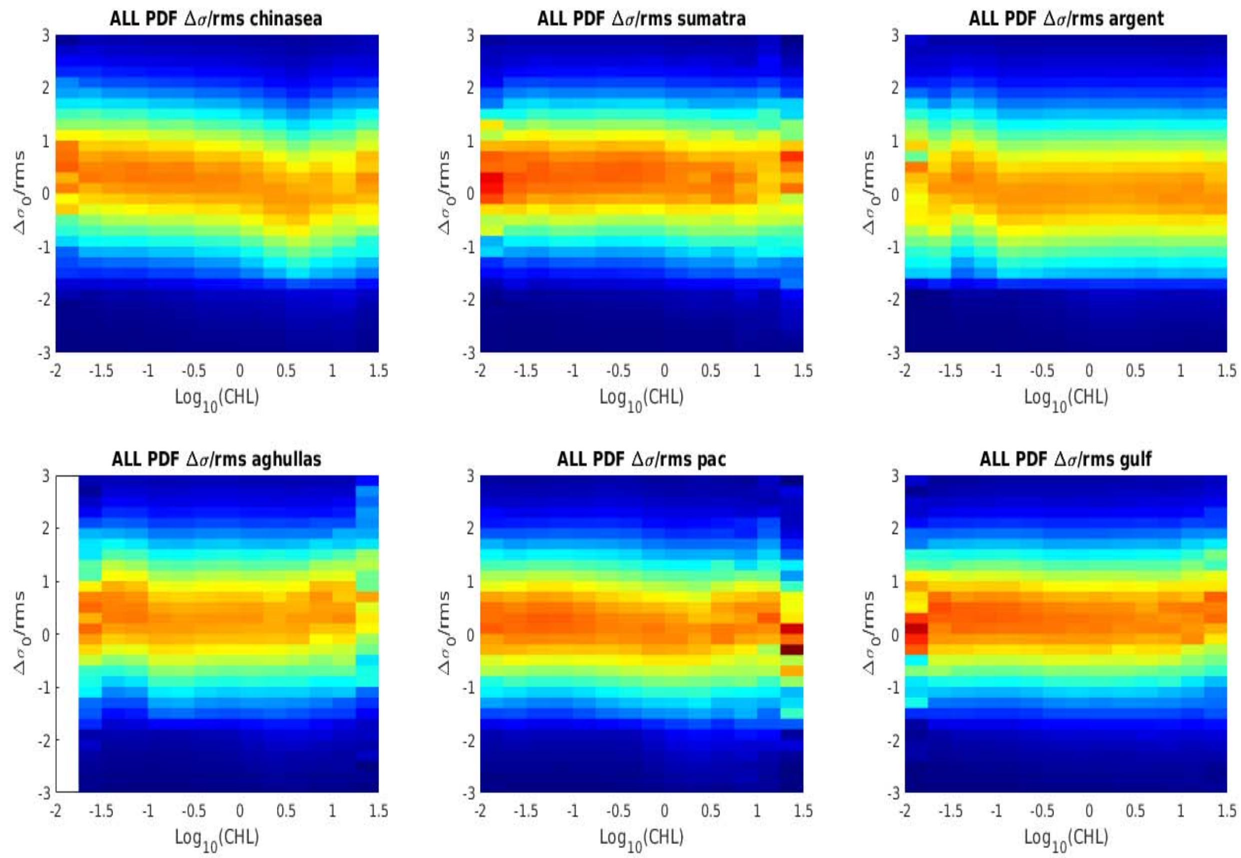
JASON2 PASS 204

At low wind speed the departure from relation could be used to detect surface films, i.e. to discriminate between low winds and film

Pdf of $\Delta\sigma$/rms by bin of $\log_{10}$(CHL)
for all winds for 6 regions

$\Delta\sigma$/rms

$\Delta\sigma$/rms



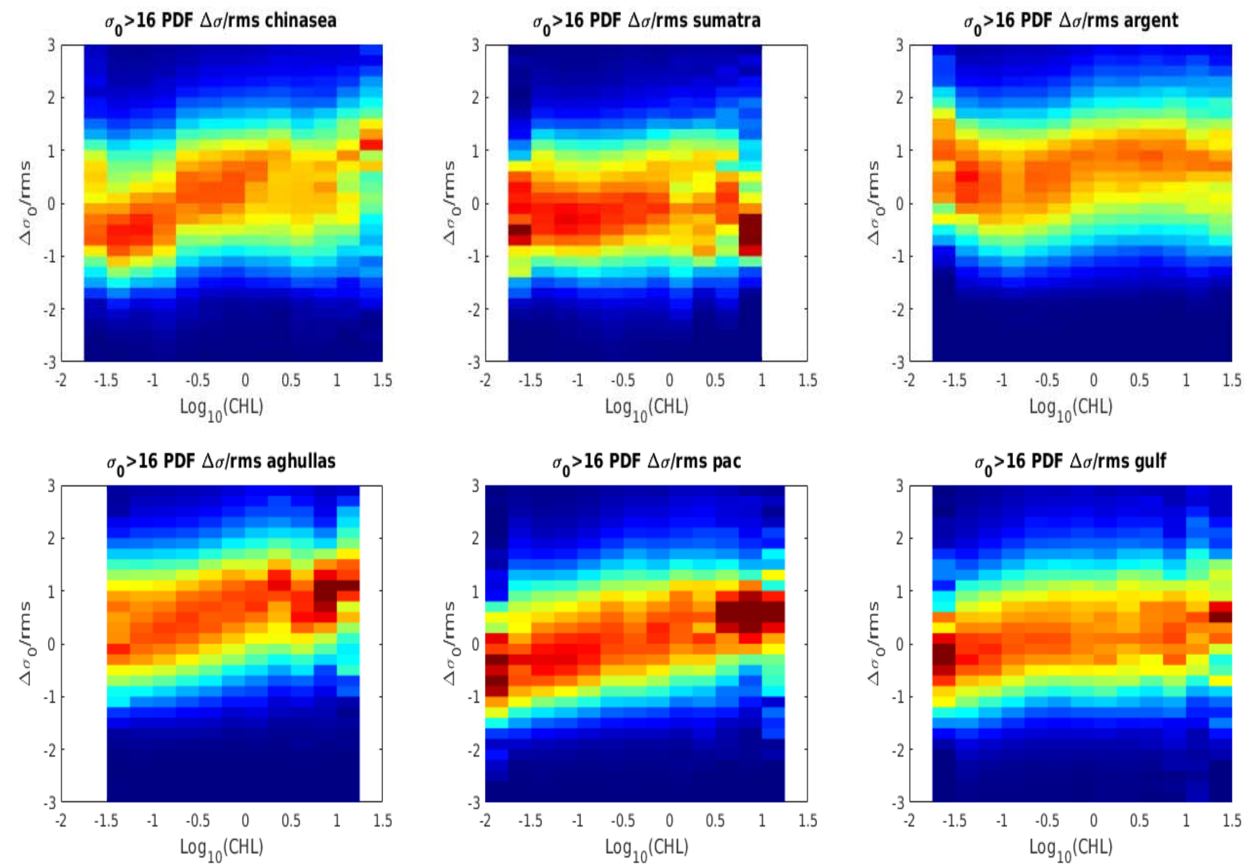
Log_{10}(CHL) Log_{10}(CHL) Log_{10}(CHL)

Pdf of $\Delta\sigma$/rms for bin of $\log_{10}$(CHL)for σ0>16 dB (low winds) for the 6 regions

The pdf moves to higher normalized departure values with log10(CHL)

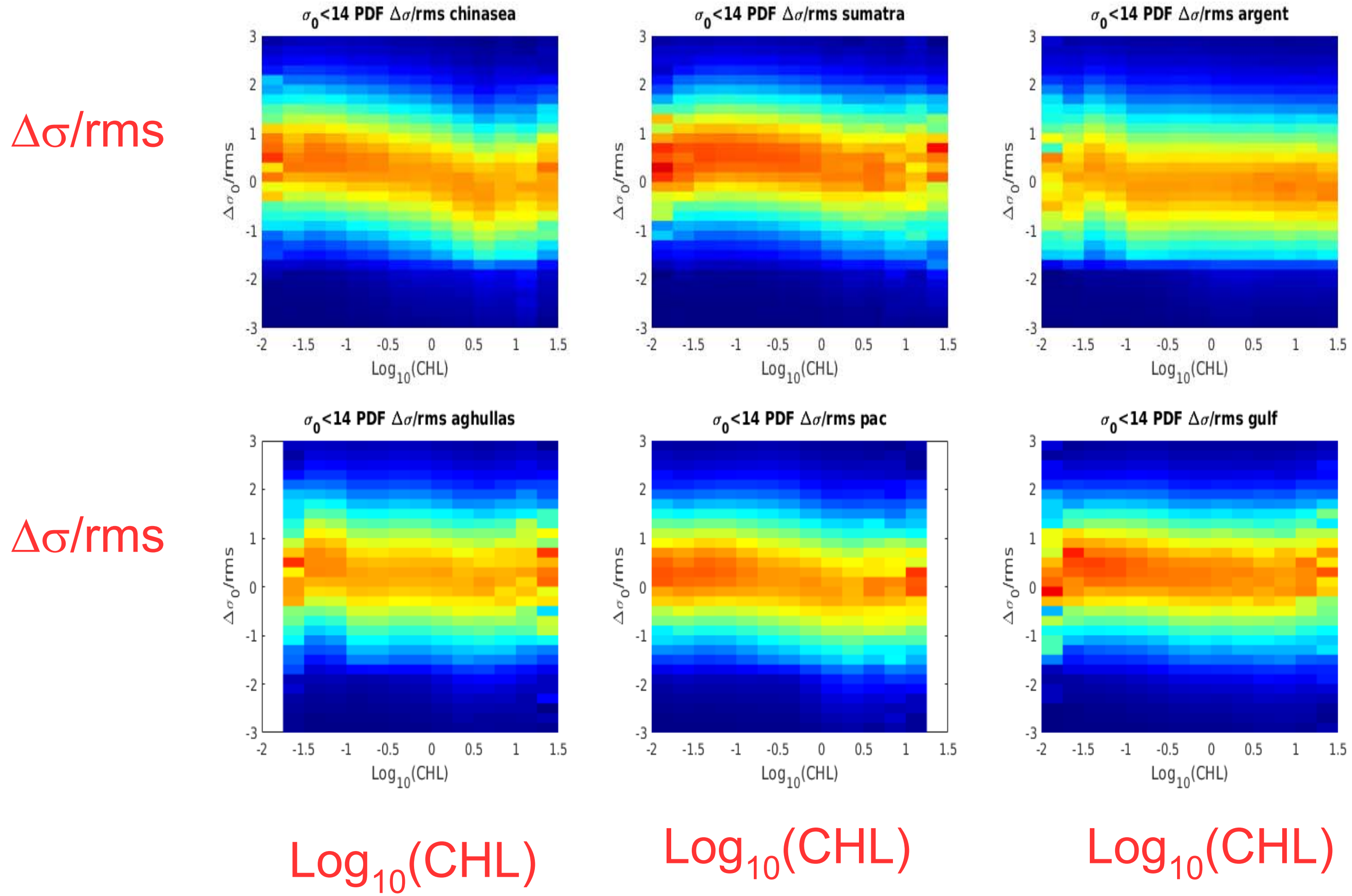
$\Delta\sigma$/rms

$\Delta\sigma$/rms



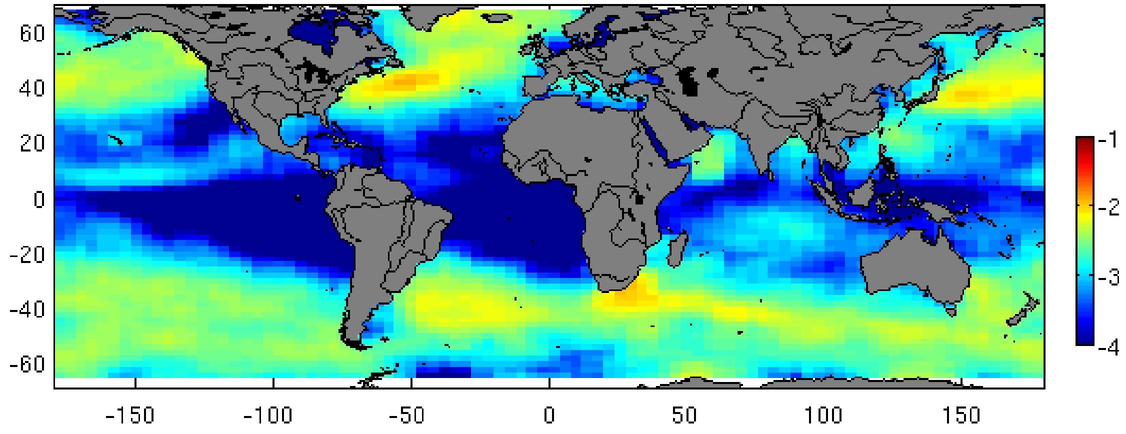
Log_{10}(CHL) Log_{10}(CHL) Log_{10}(CHL)

Pdf of $\Delta\sigma$/rms for bin of log_{10}(CHL) for σ0<14 dB (medium to high winds)



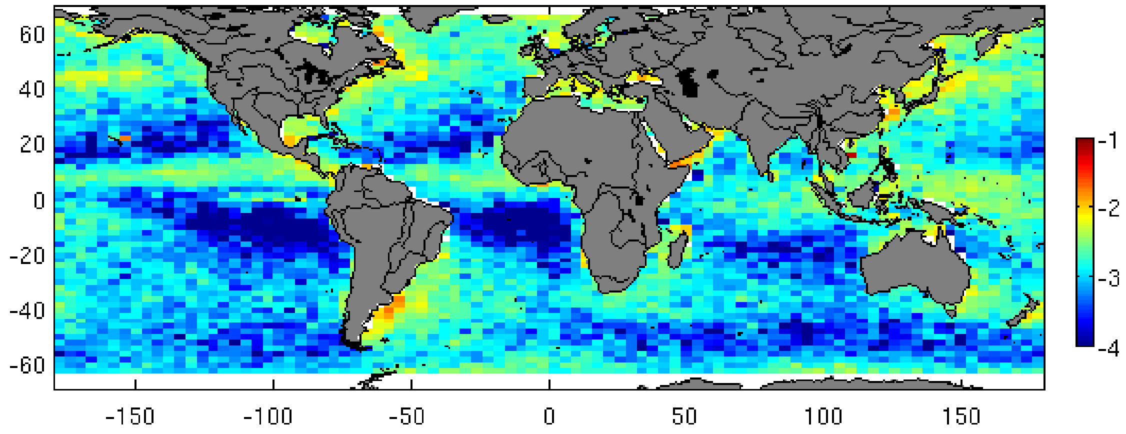
Geographical distribution of %age of samples of normalized departure larger than 2

J2 σ0<14dB 2rms

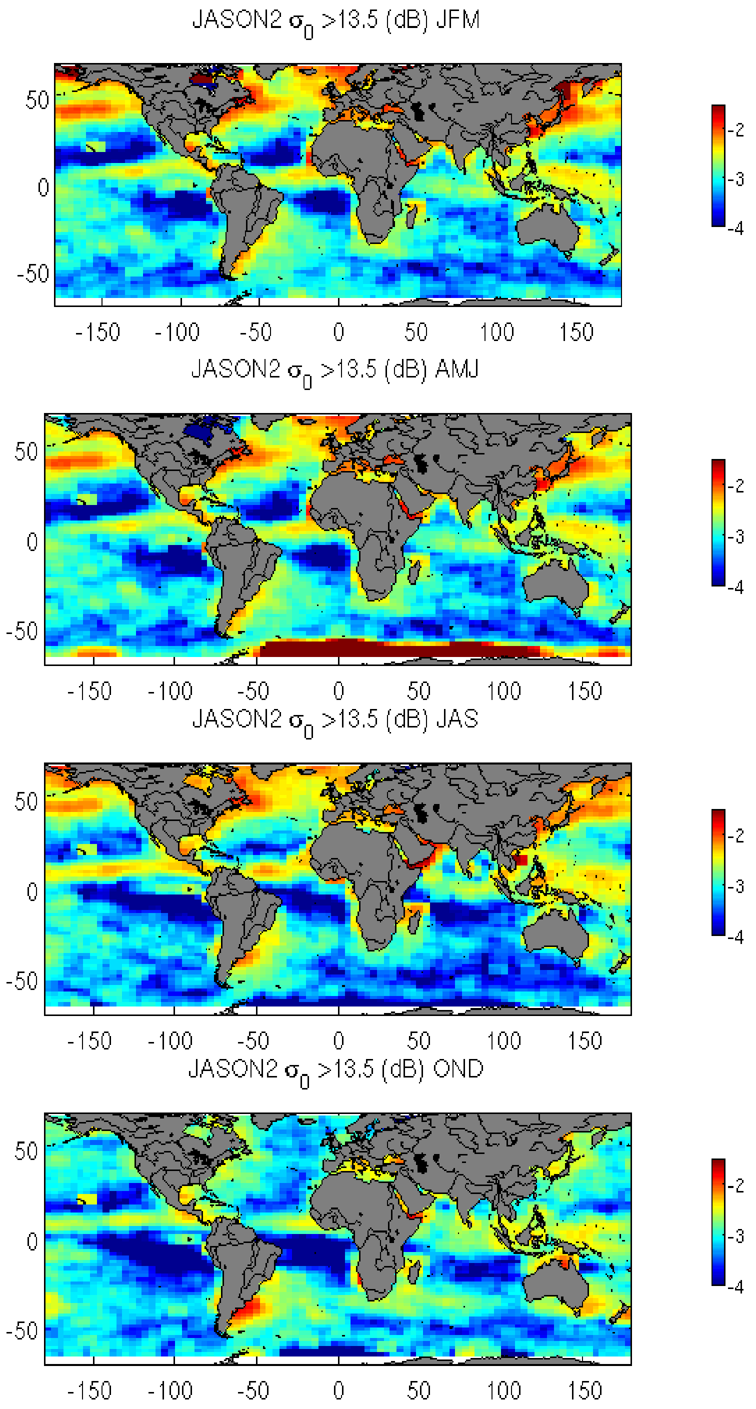


High winds
Clear association with strong currents.
Hydrodynamic modulation of surface waves

J2 σ0>16dB 2rms



Low winds
Tropical and equatorial regions (surface films)
Low winds and strong mesoscale activity



Seasonal variability low winds

Appears to be at least partly related to the distribution of ocean Chlorophyll
See in particular the patterns in Malvinas bassin.

Analysis of 6 different regions of the ocean using 20 Hz data.

Gulf of Mexico, Pacific plastic Pool, aghullas current, East of Sumatra, China Sea, Argentinian Basin.

Climatology of film using J1 J2 J3 and now S3