Altimeter as a High Resolution Imager of the Surface Roughness

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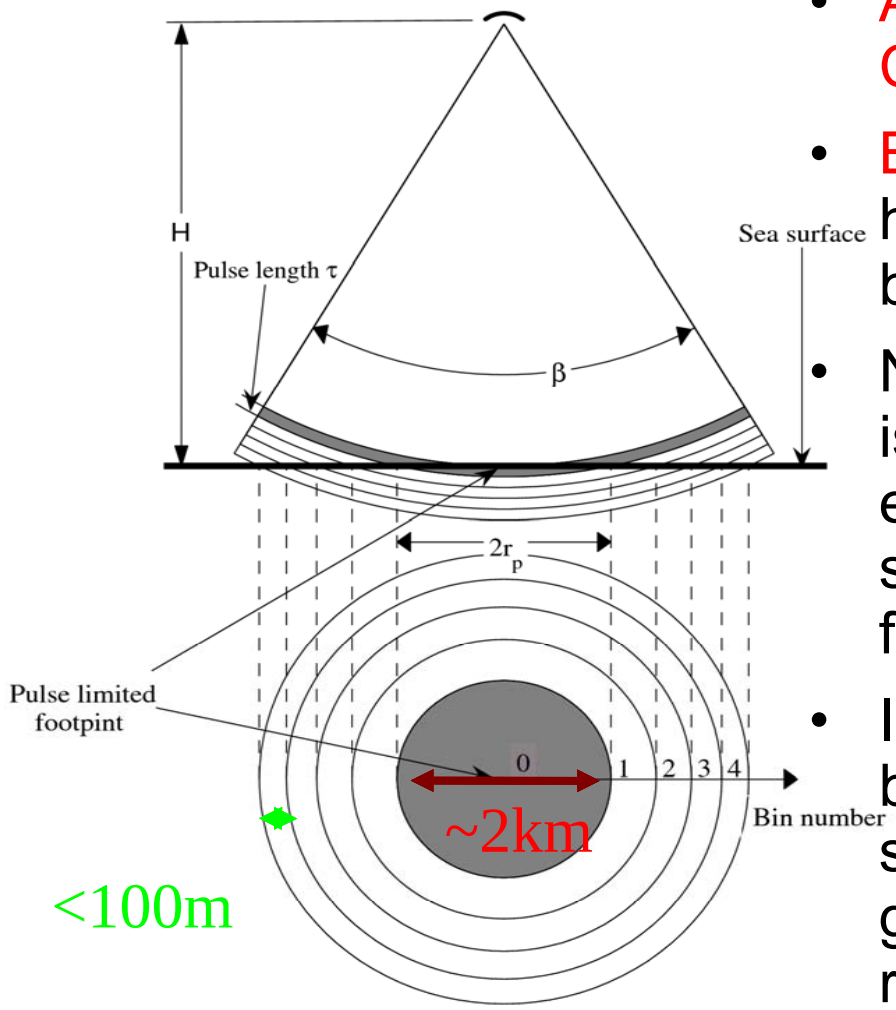
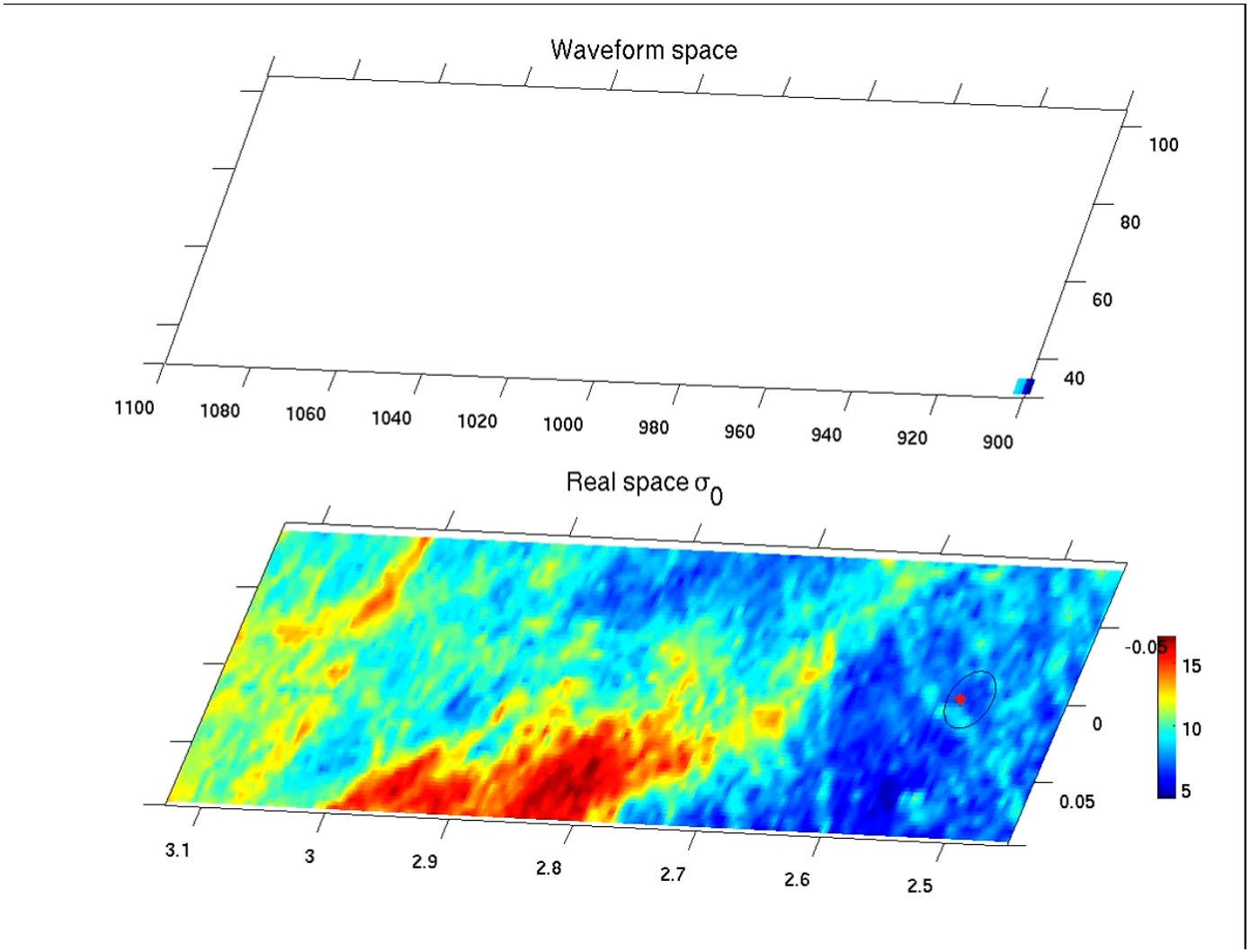


- Altimeter over ocean: Classical Brown model
- Basic assumption: homogeneity of the surface backscatter over the footprint
- Not true in presence of small island, surface slick, currents etc.. i.e. Strong variations of surface backscatter at scale < footprint size
- In such cases: altimeter can be seen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

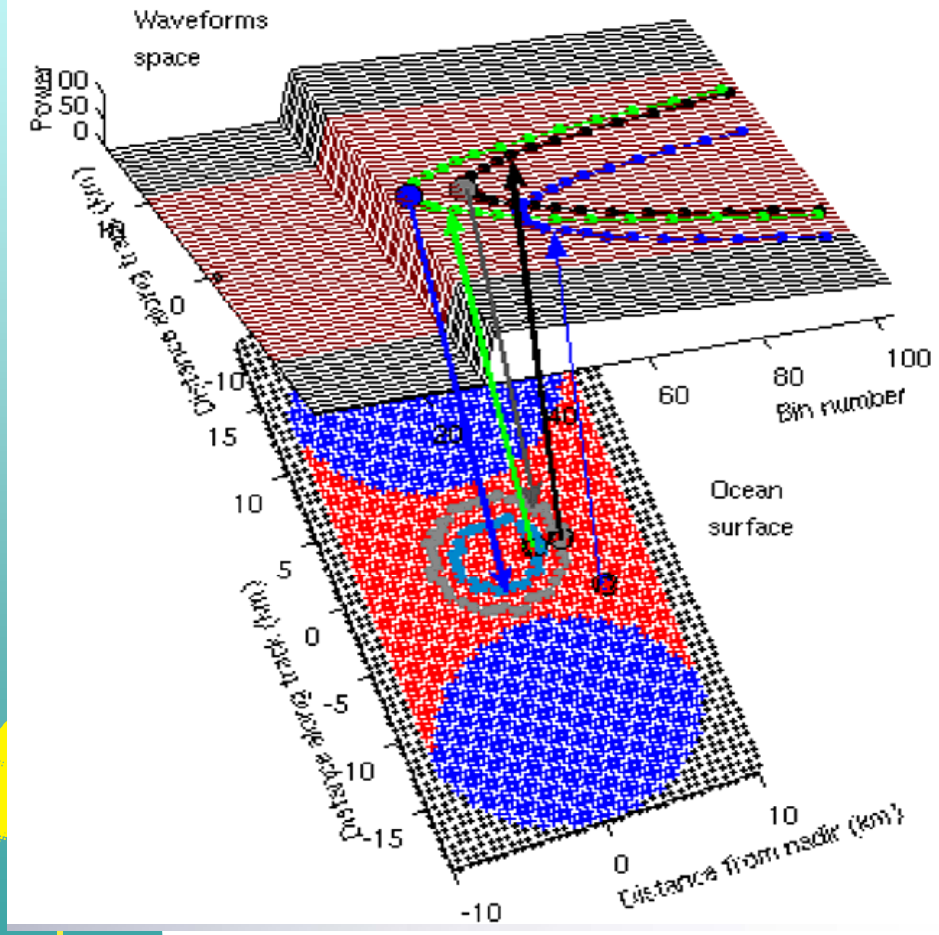
Imaging mechanism of an altimeter

WF

σ0



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

- Brown model

$$\sigma(t) = \frac{1}{2}(2\pi)^{3/2} H'' \sigma_\tau \sigma_0 \left(1 + \mathrm{erf}\left(\frac{ct/2}{\sqrt{2}\sigma_p}\right)\right) e^{-\frac{ct/2}{u_b}}$$

- If strong variations of surface backscatter (σ_s)
- In a first order approximation: waveform is modulated by σ_s
- In discrete form

$$\sigma_0(t) = \alpha \int_0^{2\pi} \int_0^{\infty} \sigma_s(u,\theta) e^{-\frac{u}{u_b}} e^{-\frac{(ct/2-u)^2}{2\sigma_p^2}} du d\theta$$

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

- Where the range of k and l verifies

$$u(k,l) = \frac{(x_{kl} - x_i^0)^2 + (y_{kl} - y_i^0)^2}{H'' c\tau} = u_j$$

- Simplifies to

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

- W: waveforms detrended for beam-width and waves effects
- In M

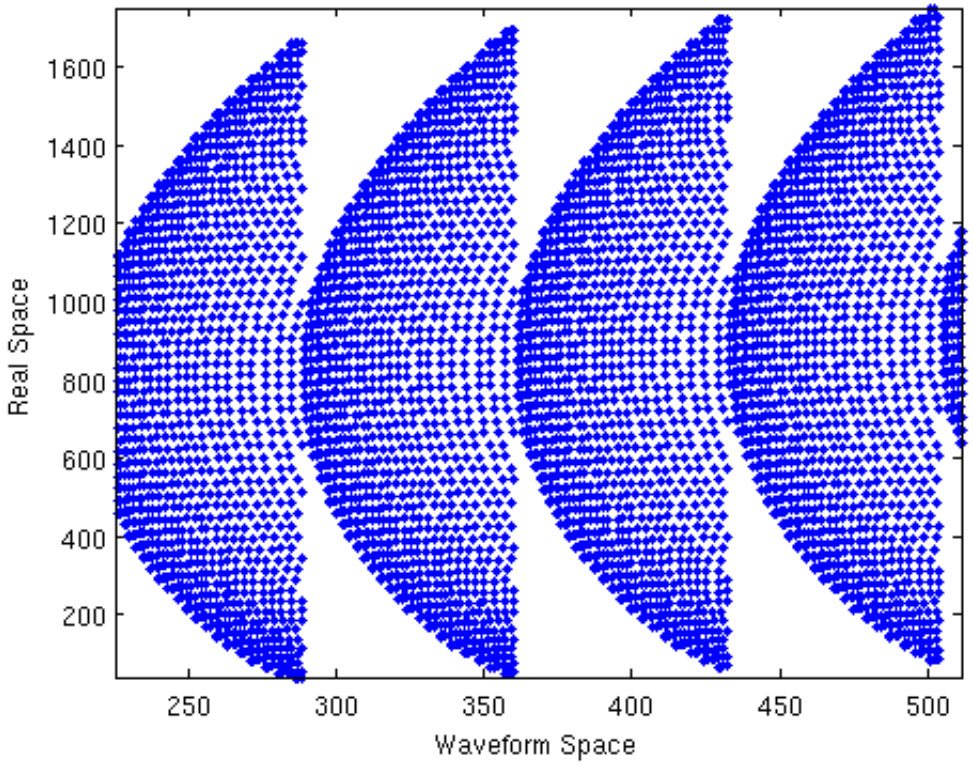
Might not be true for high SWH but small scale variation of $\sigma 0$ are quite unlikely for high SWH and winds!!

- ***A*: imaging matrix depending only on the altimeter geometry and the resolution of the surface grid**
- For groups of 65 waveforms and a 300 m resolution for the surface backscatter *A* is a 5400x3400 matrix
- As the system is over-determined: computation of pseudo (Moore-Penrose) inverse.

$$S = A^{+}W$$

M i g t h

The imaging matrix



The parabolae again!!

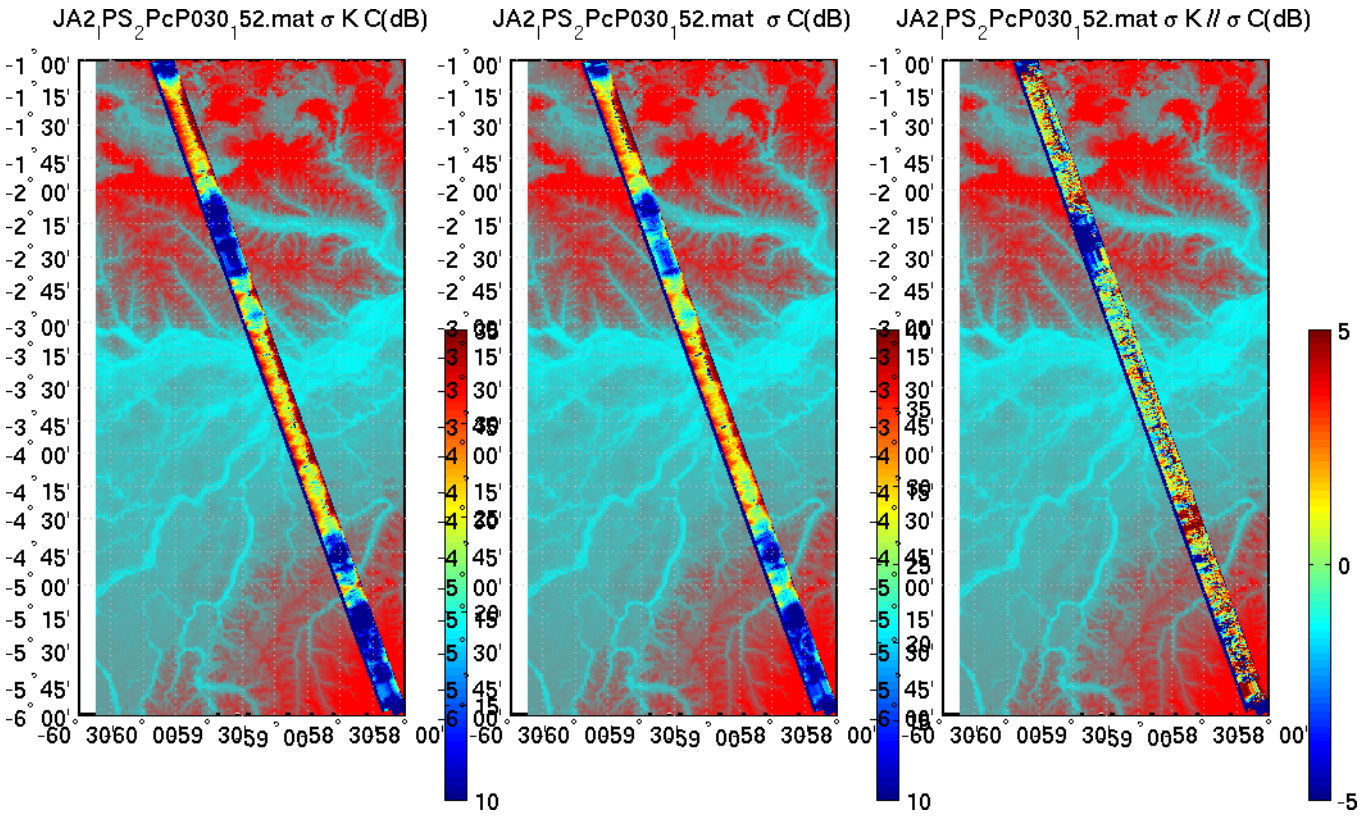
Validation

- Synthetic waveforms computed using
- Constant surface backscatter
- Noisy (white noise 0.25 dB rms)
- Very low bias and rms

What for?

All applications that require high resolution description of the surface : land water, rain, coastal altimetry, meso sub-mesoscale ocean structures,...

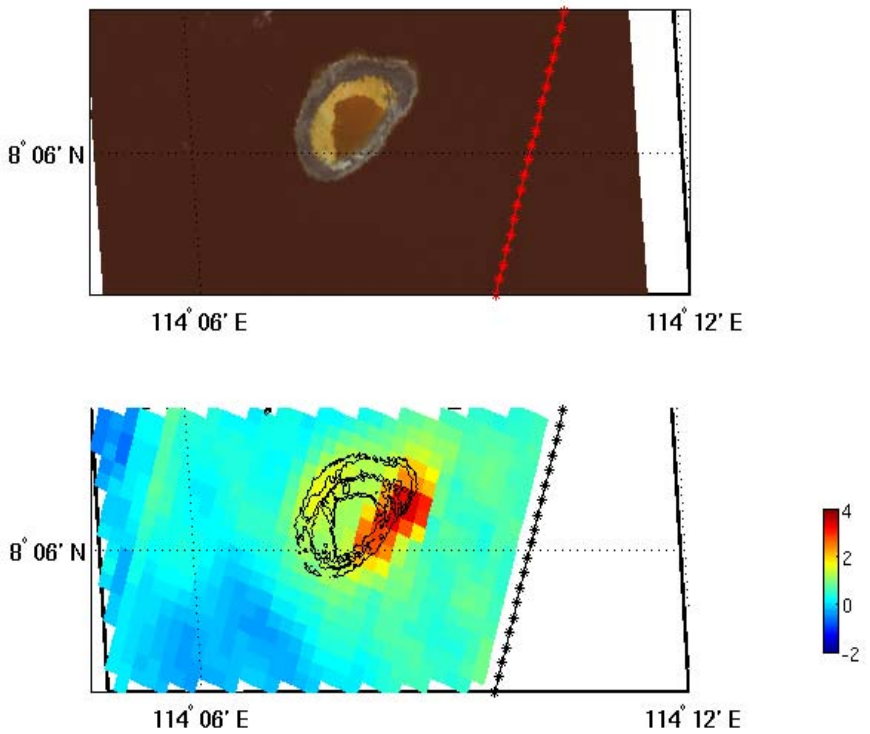
- Hydrology
- Estimation of the water covered surface
- Analysis of a Jason2 pass over the amazon basin near Manaus . High backscat on water covered surface
- Difference between Ku and C related to forest cover



Modification of surface roughness by submerged reef

- Erica reef in the Spratly islands
- ~1 m depth
- Tide amplitude ~1m
- Discovers at low tide (eastern side)
- Analysis of 255 Jason1 cycles

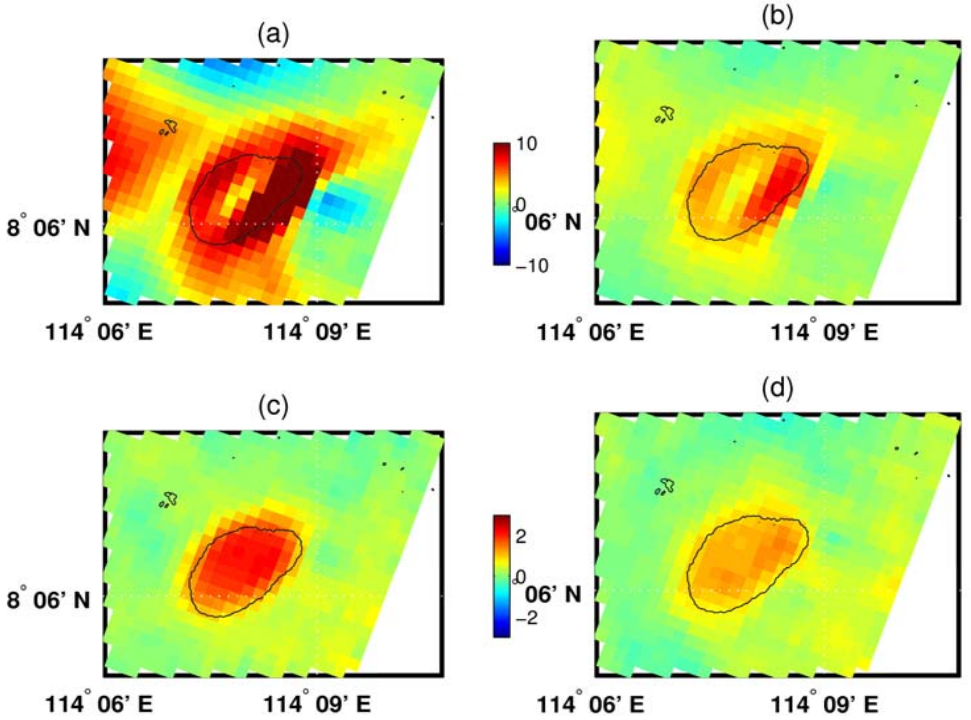
and 57 Jason2 cycles



- Mean change of surface backscatter as function of tide

Tide<-60cm

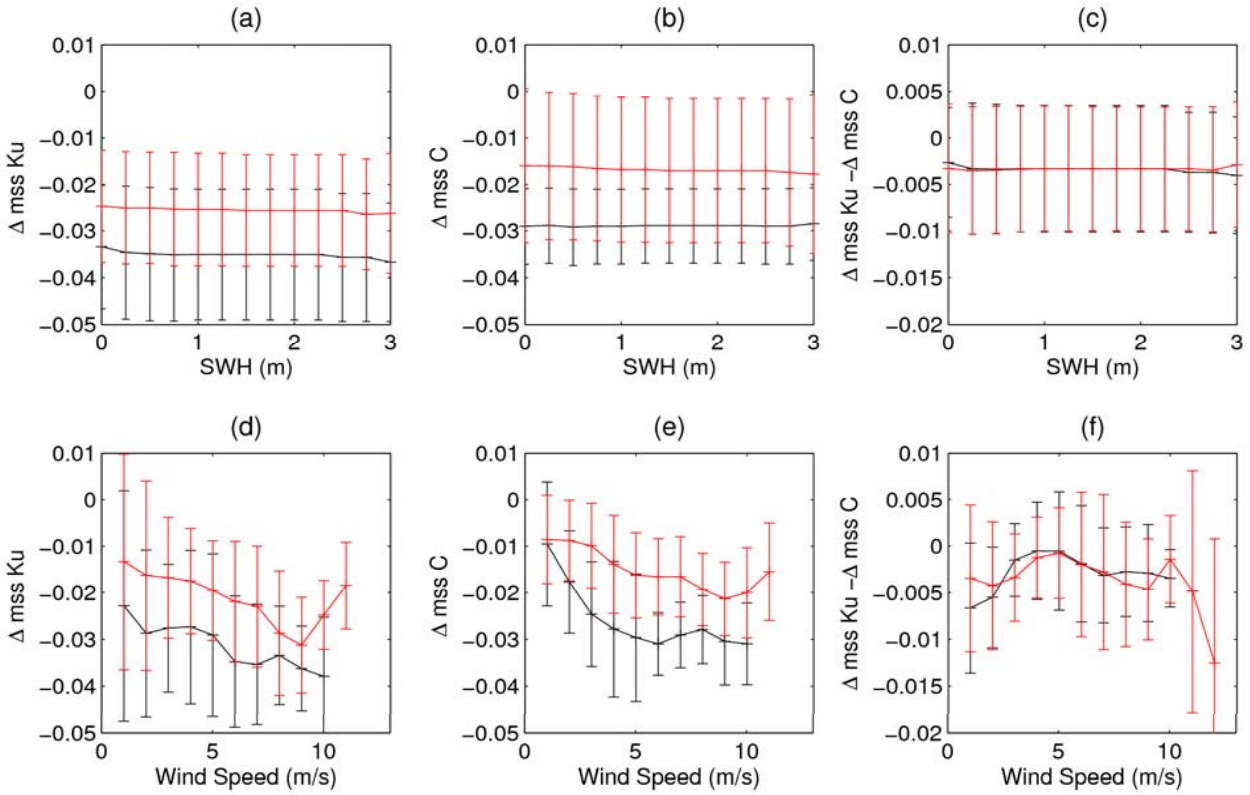
-60<Tide< 0cm



0<Tide<60cm

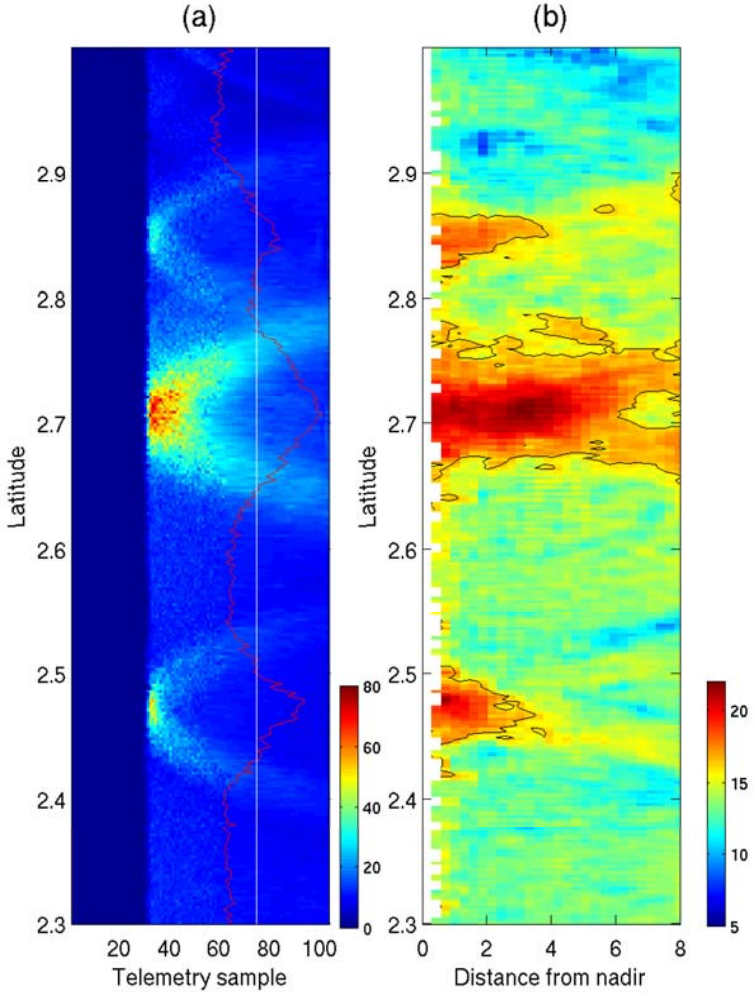
Tide>60cm

- Change of mean square slope as function of wind speed and SWH for Ku and C band
- Red lines (-40 cm <Tide<10 cm) Black lines Tide>10 cm



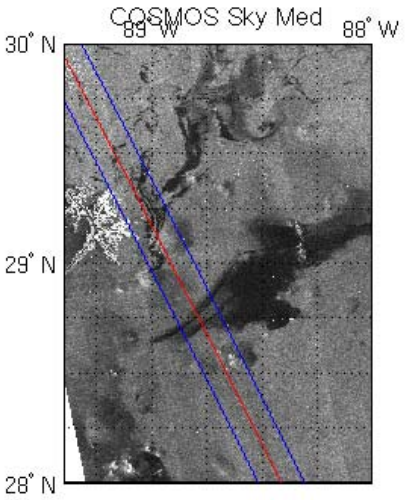
Surface slicks (sigma0bloom)

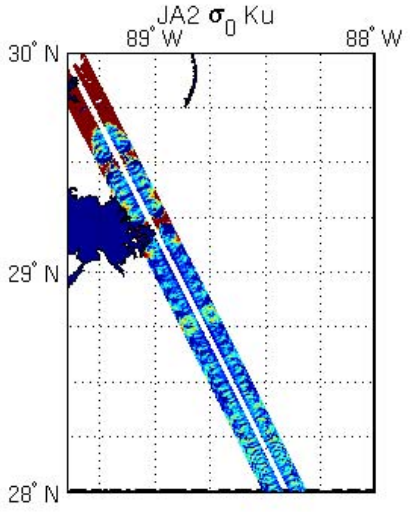
- Envisat pass south of Sumatra: sigma0bloom characterized by parabola patterns in the waveforms space.
- Results from lines and patches of very high surfa backscatter : surface films very low winds
- Detailed view of the bright zones of the surface
- Possibility of statistical analysis of occurences



Gulf Oil slick

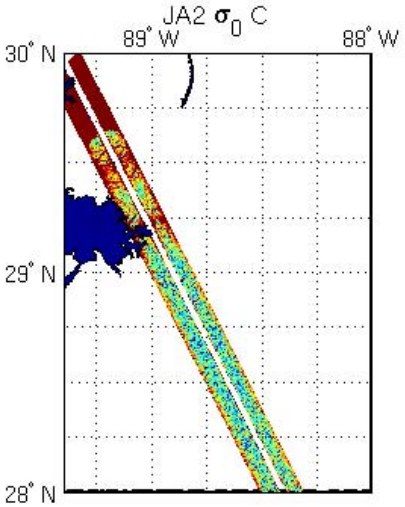
Cosmos SKYMED SAR

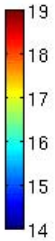


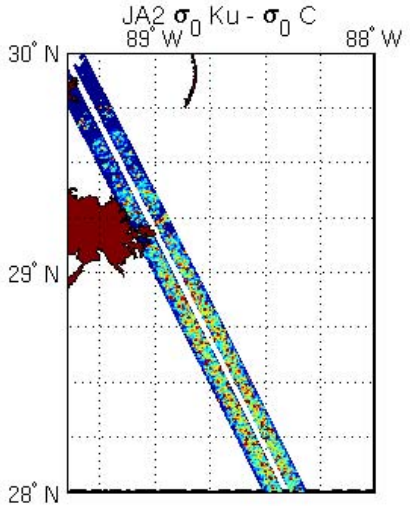


Jason2 Ku Band s0

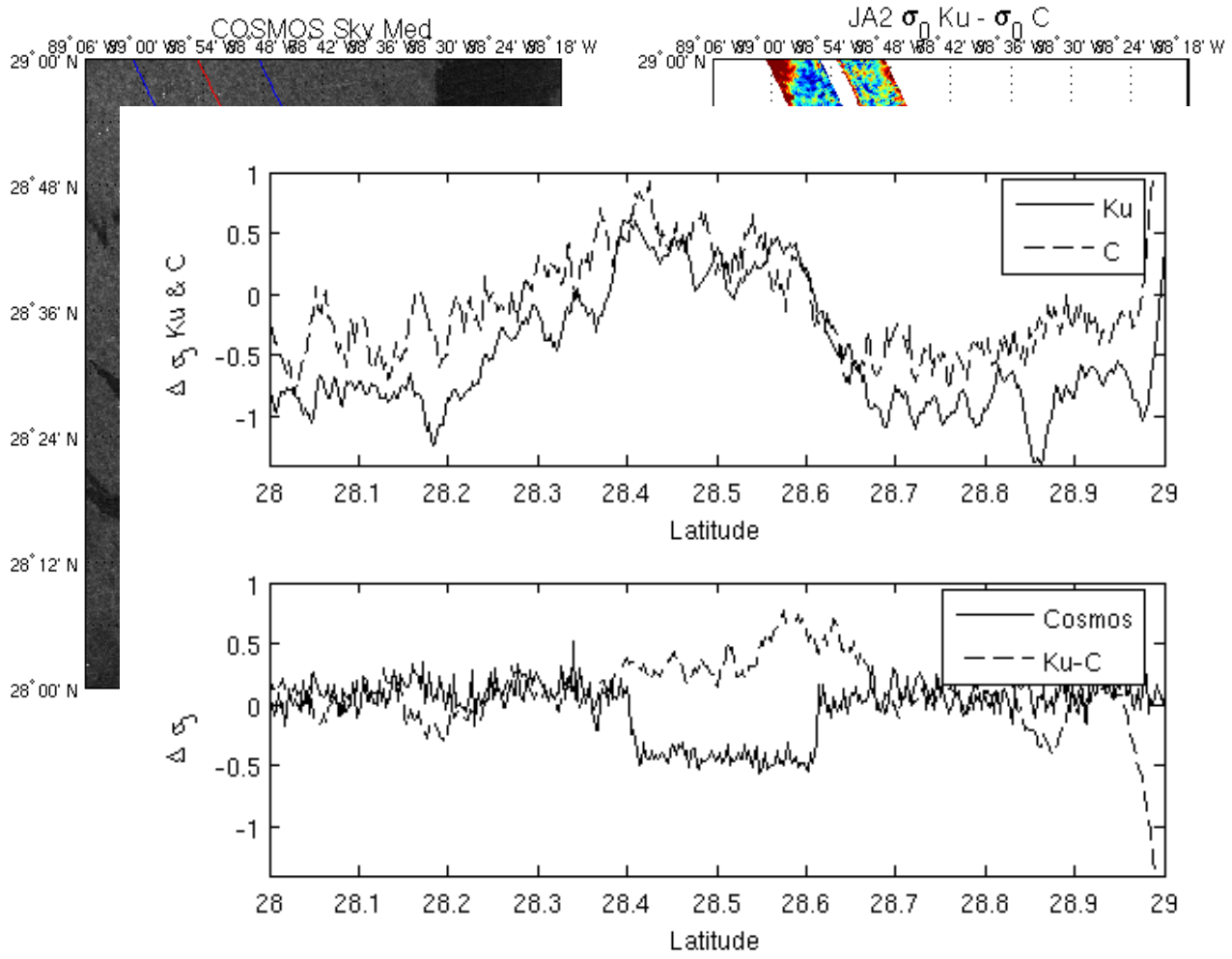
Jason2 C Band s0







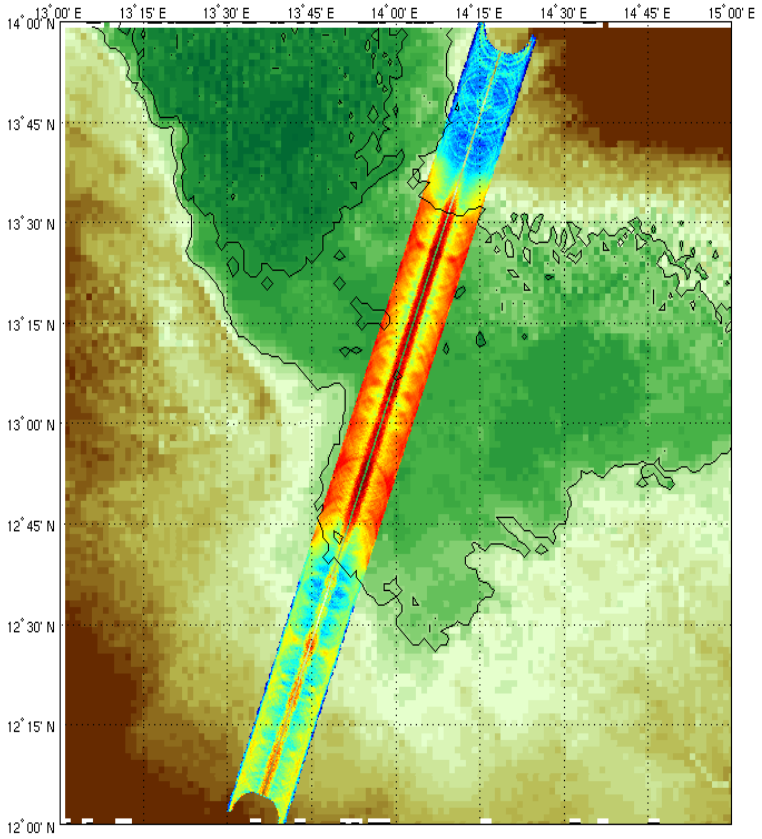
Jason2 Ku-C s0


COSMOS Sky Med
JA2 σ0 Ku - σ0 C
29° 00' N
28° 48' N
28° 36' N
28° 24' N
28° 12' N
28° 00' N
Δ σ0 Ku & C
Ku
C
Latitude
Δ σ0
Cosmos
Ku-C
Latitude

Conclusion

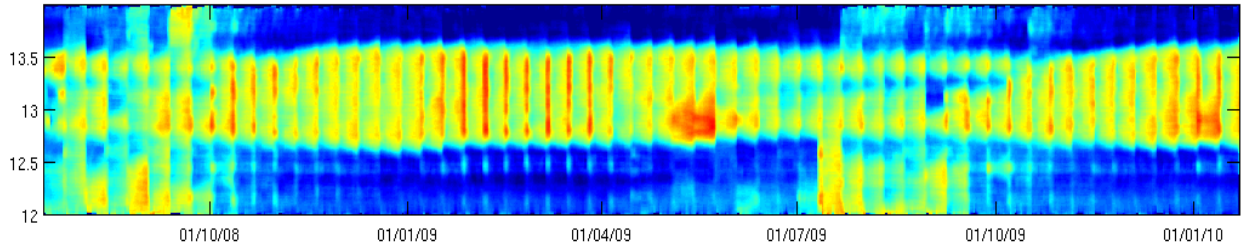
- High resolution altimeter waveforms; good imager of the surface backscatter at high resolution
- Possibility to define a new operational product in particular to analyse surface slicks and to help the analysis on inland waters.

Evolution of lake Chad

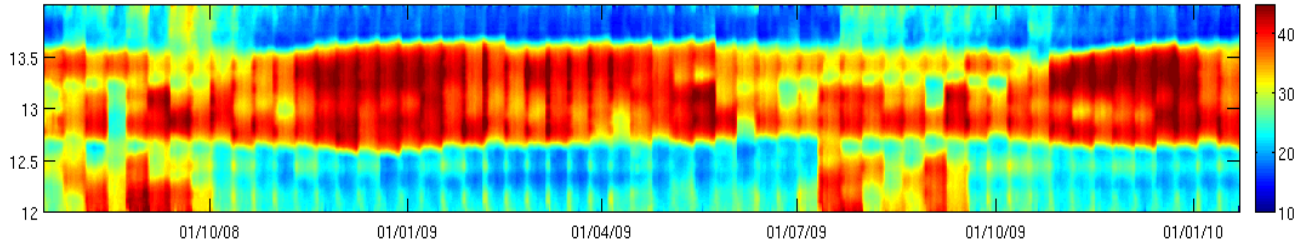


Evolution of Lake Chad

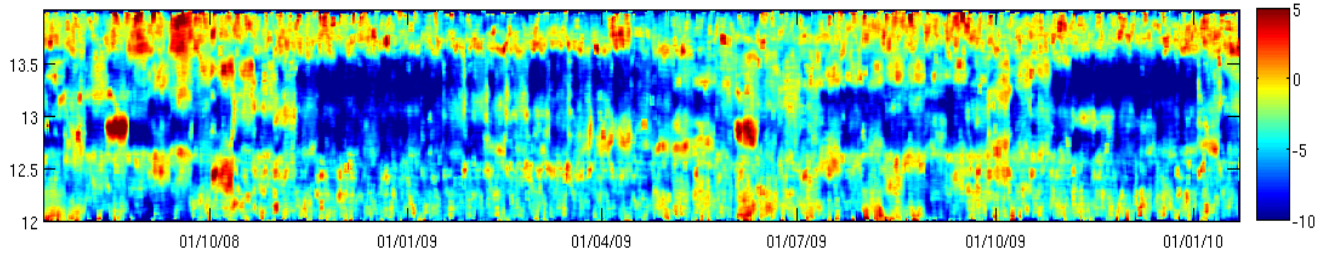
Ku



C



Ku-C



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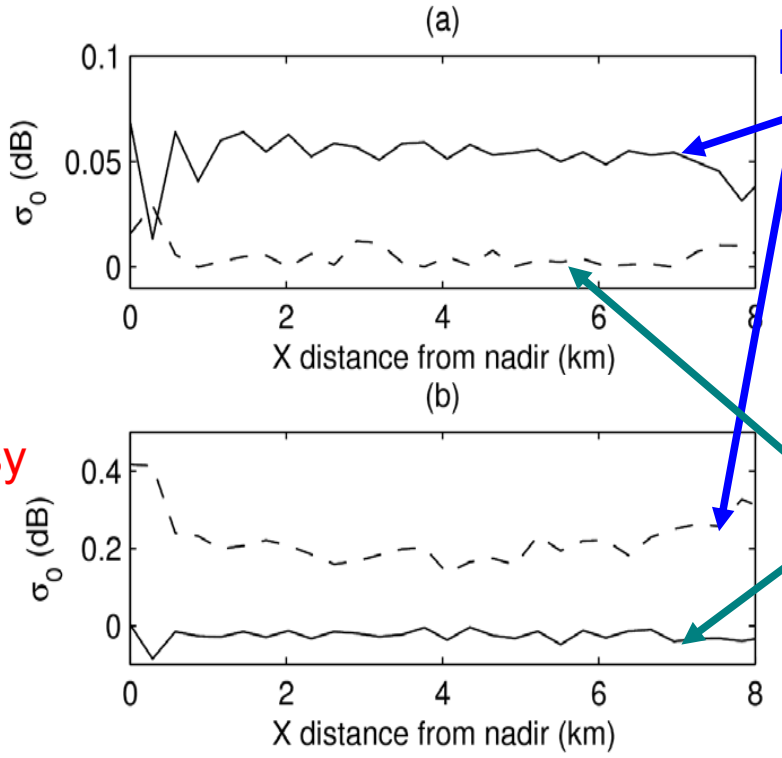


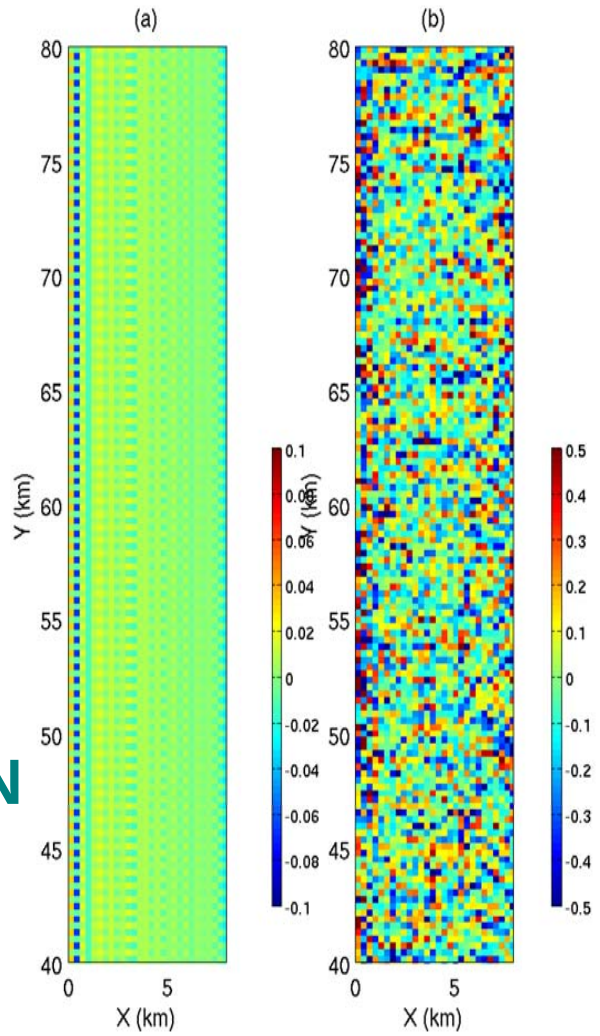
Cst

Noisy

RMS

MEAN

Bias <0.05 dB rms<0.25dB



Cst

Noisy