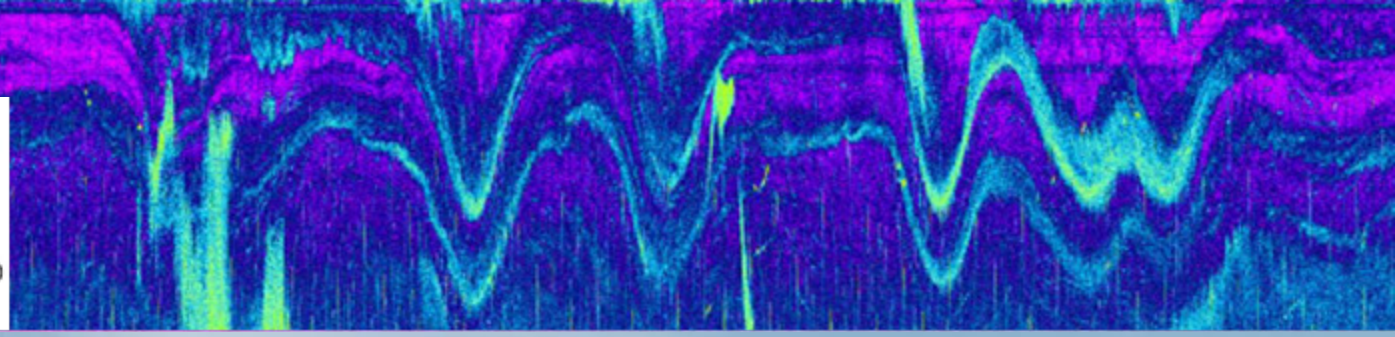

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UNIVERSIDADE DO PORTO

Jason-2 radar altimeter signatures of Internal Solitary Waves in the ocean

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Marinha e Ambiental

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Ifremer

Outline of this Talk

- Introduction
  - Internal solitary waves (ISWs)
  - SAR imaging of internal waves at oblique incident angles? (Bragg scattering)
  - Theoretical considerations about observability of ISWs with pulse-limited altimeters

- Some case studies
  - South China Sea
  - Sulu Sea
  - Andaman Sea

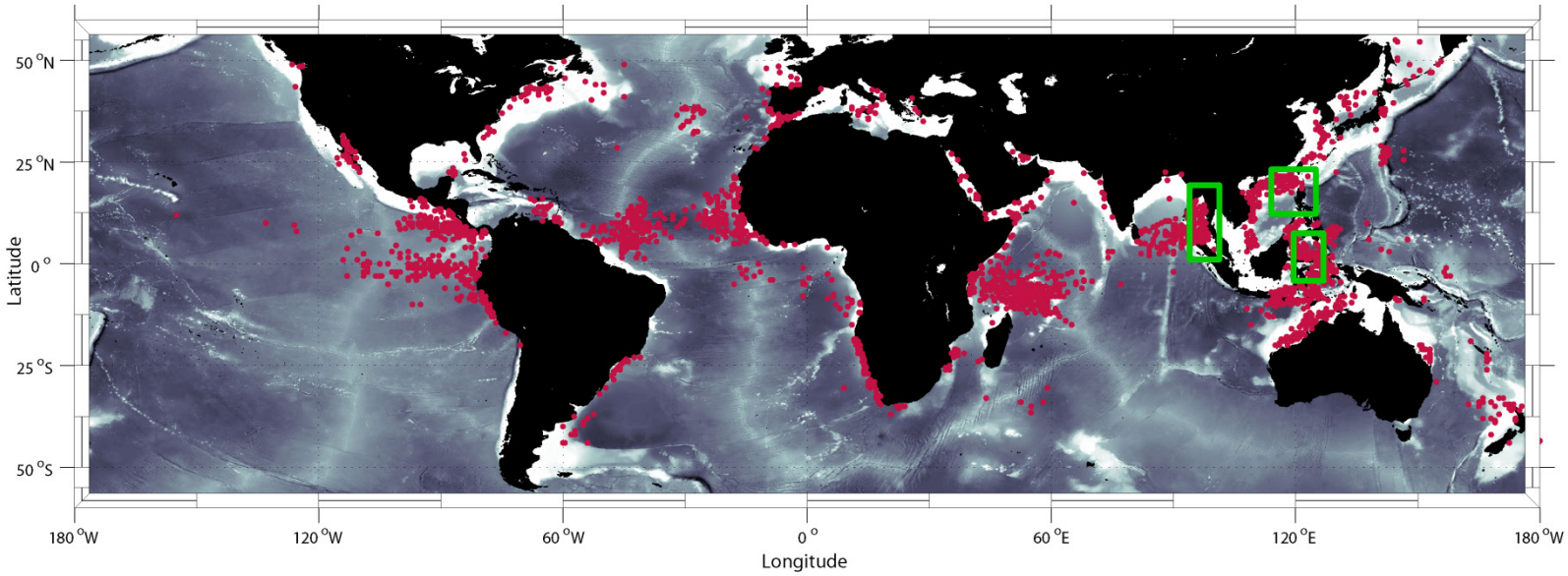
- Conclusions

Aim:

- *Develop a synergetic approach that enables the identification of large-amplitude, short-period ISWs from high-rate satellite altimeter data (Jason-2/3 20 Hz)*

Internal solitary waves (ISWs)

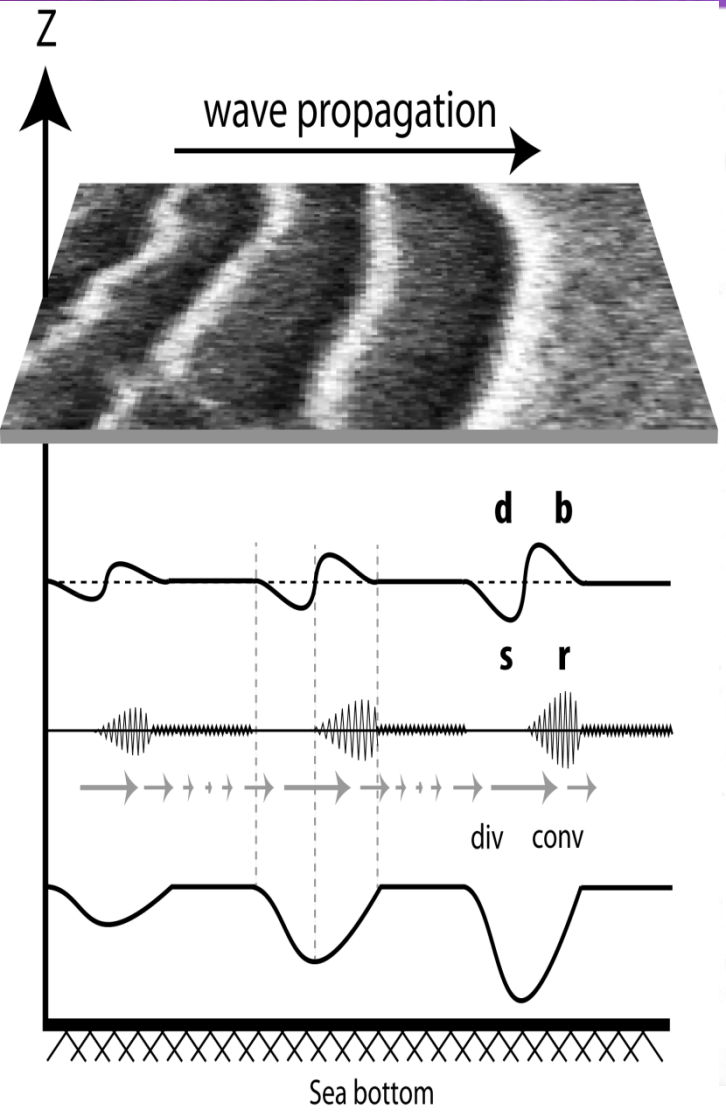
Global Map of ISWs

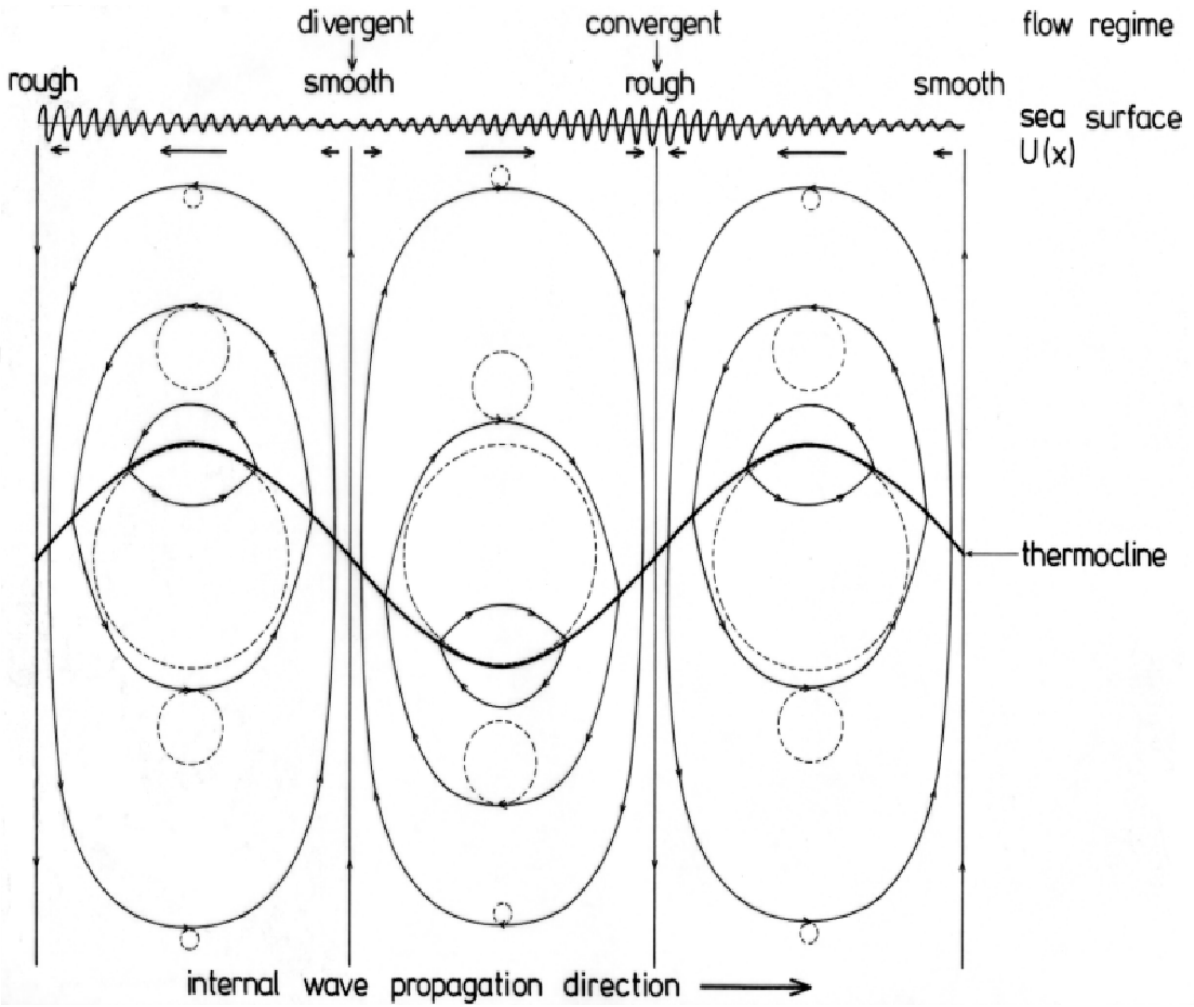


The location of nonlinear internal waves observed in 250 m resolution MODIS (Moderate-Resolution Imaging Spectroradiometer) satellite sunglint imagery acquired from August 2002 through May 2004.

Jackson et al. (2012)

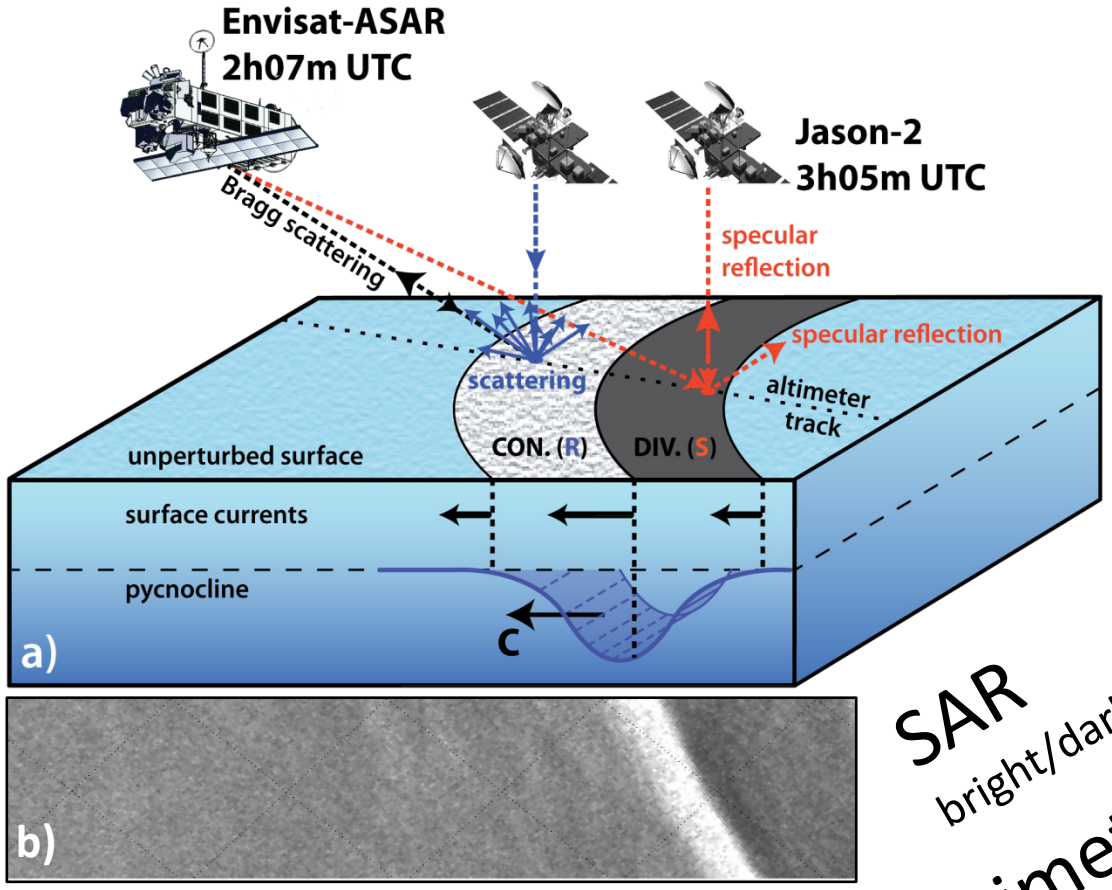
Introduction:
SAR imaging of internal waves at oblique incident angles





Sea surface roughness pattern generated by a linear internal wave

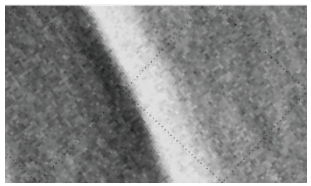
Introduction:
How does an Altimeter and a SAR see internal waves in the ocean?



SAR
bright/dark

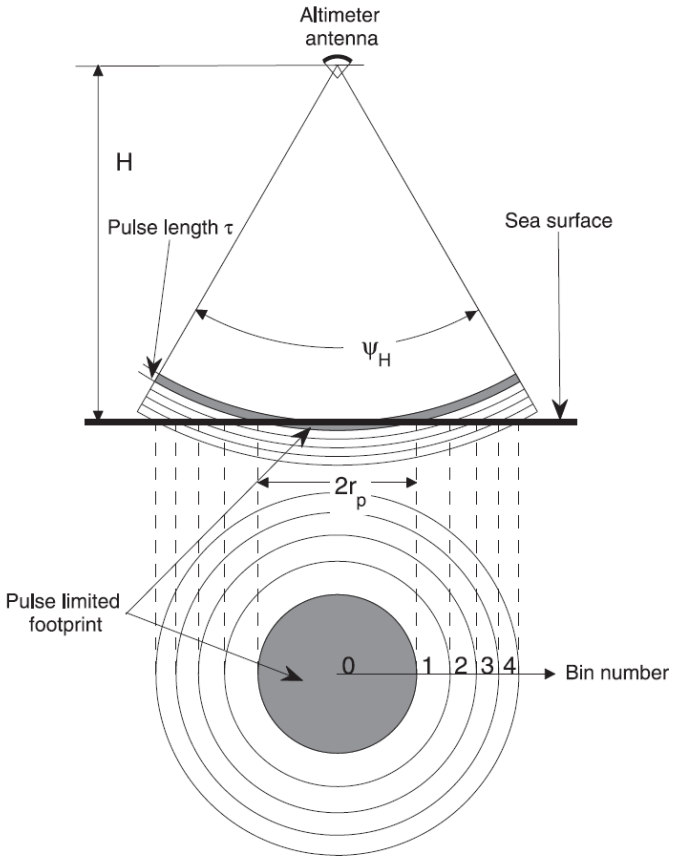
Altimeter
dark/bright

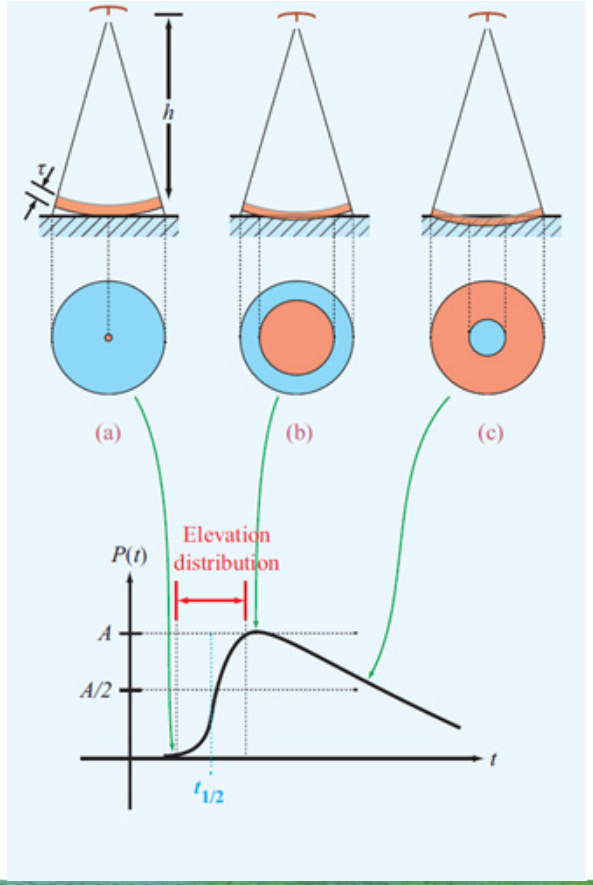
altimeter?



Theoretical considerations about observability of ISWs with pulse-limited altimeters

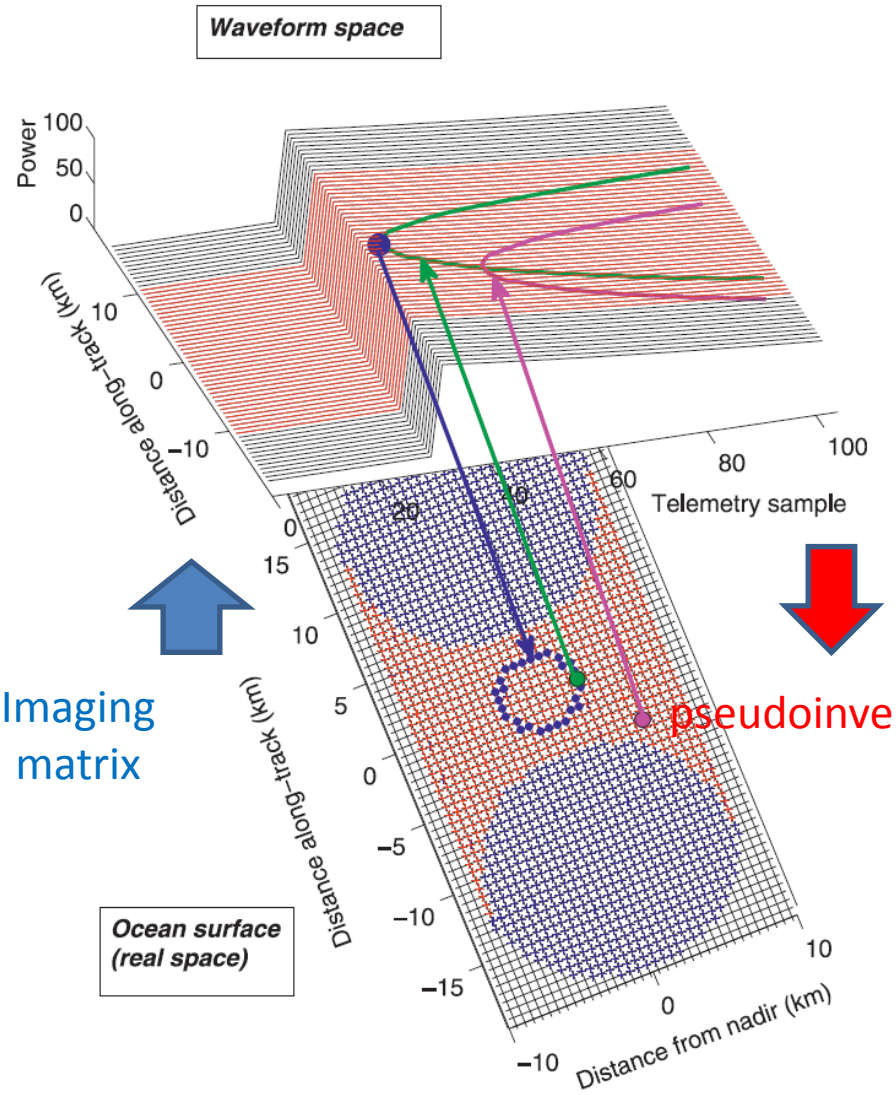
- Altimeter over ocean: Brown model assumes homogeneity of the surface backscatter over the footprint;
- Not true in the presence of high-frequency processes such as: Internal Solitary Waves and Slicks;





When the surface backscatter strongly varies at scales smaller than the altimeter footprint diameter: altimeter can be seen as an imager of the sea surface backscatter whose pixels are annular;

Theoretical considerations about observability of ISWs with pulse-limited altimeters



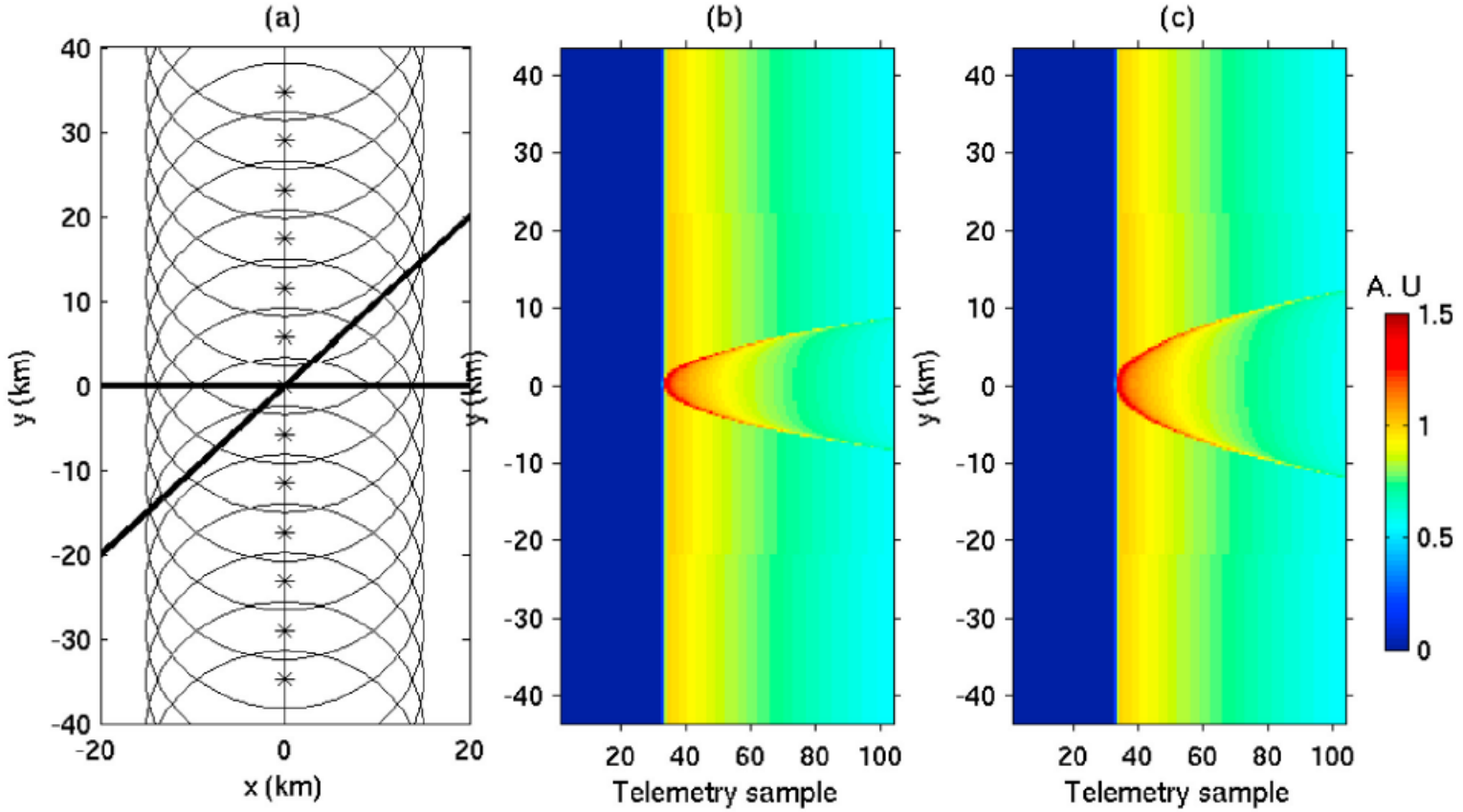
Imaging process

discussed in Tournadre et al. (2011)

- Waveform Space point associated to an annulus (or a disk) in Real Space; (i.e. points with the same range *u*)
- Real Space point associated to a parabola in the Waveform Space; (parabola determined by the satellite orbit and geometric feature on the ground)
- Minimum number of waveforms to be considered is constrained by the width of the “Real Space” image (about 3 s of data or 60 waveforms); there is a left/right ambiguity in the ground image (hence symmetry along nadir)

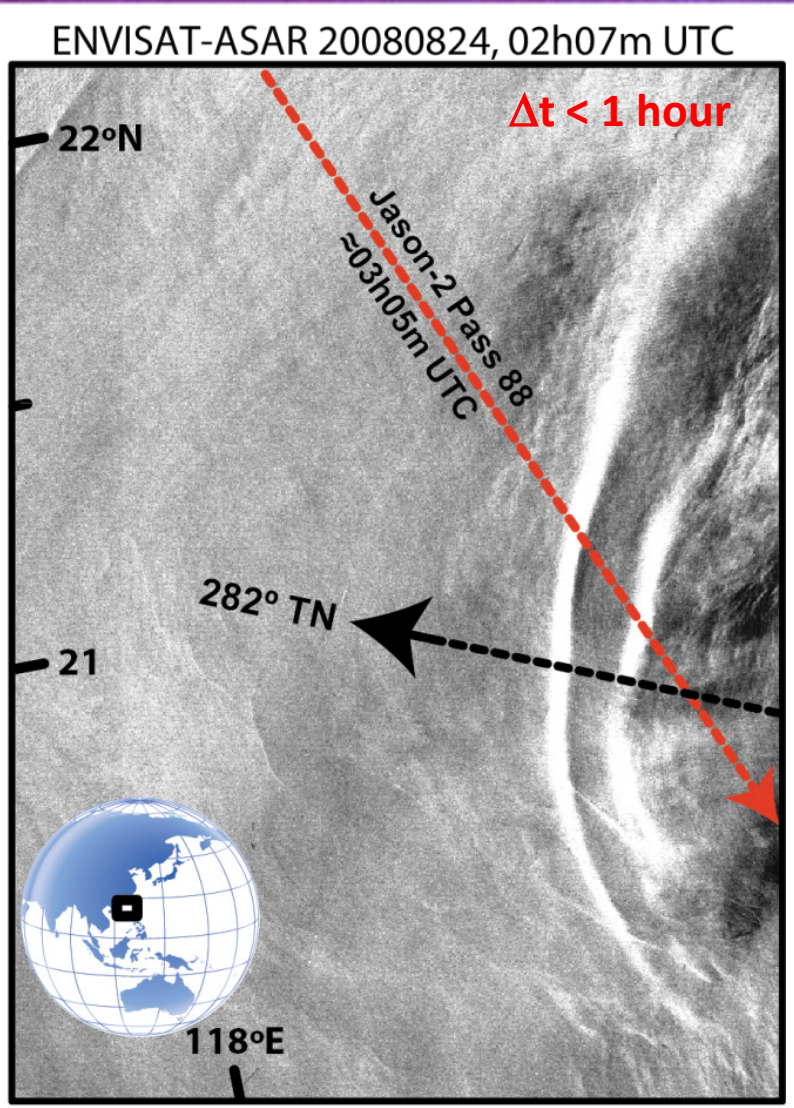
Theoretical considerations about observability of ISWs with pulse-limited altimeters

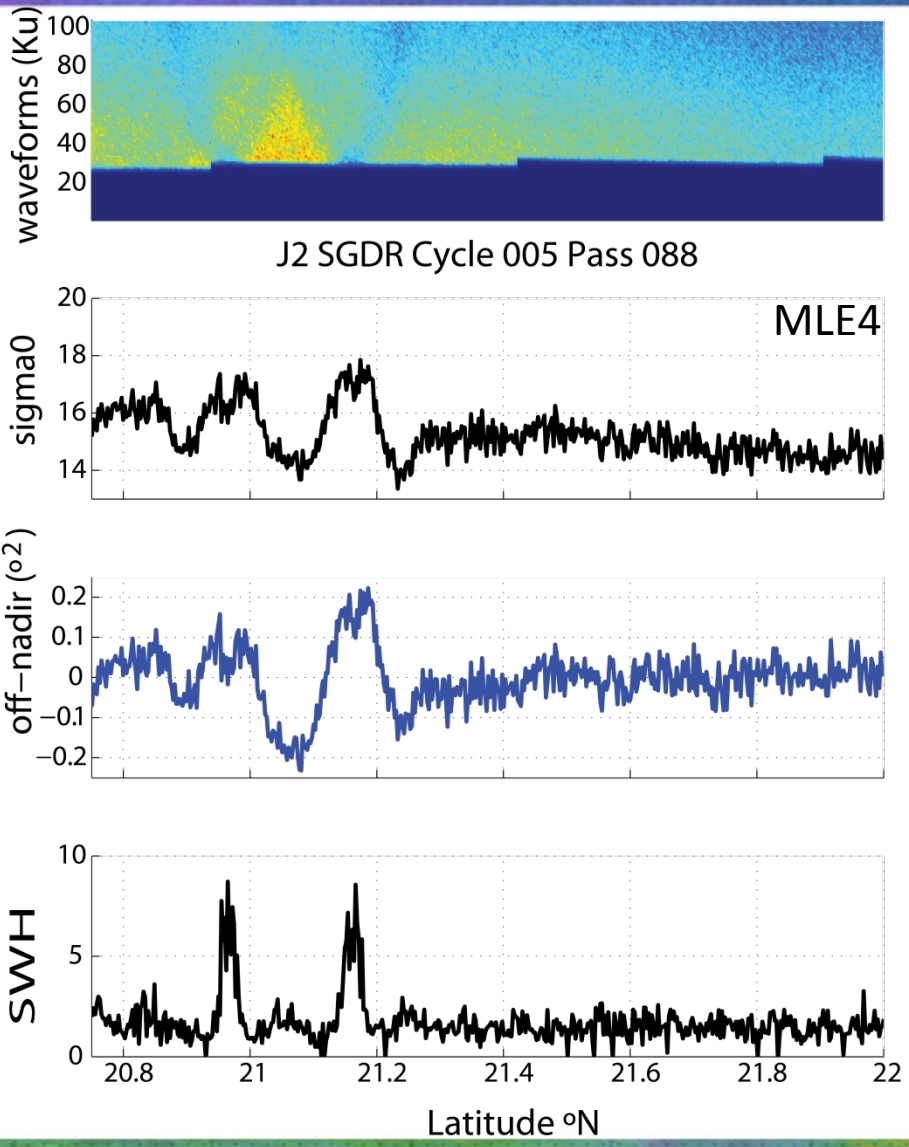
Jason altimeter echo waveforms in presence of Dirac-type surface slicks of +10 dB relative brightness and 100 m width (Tournadre et al., 2006).



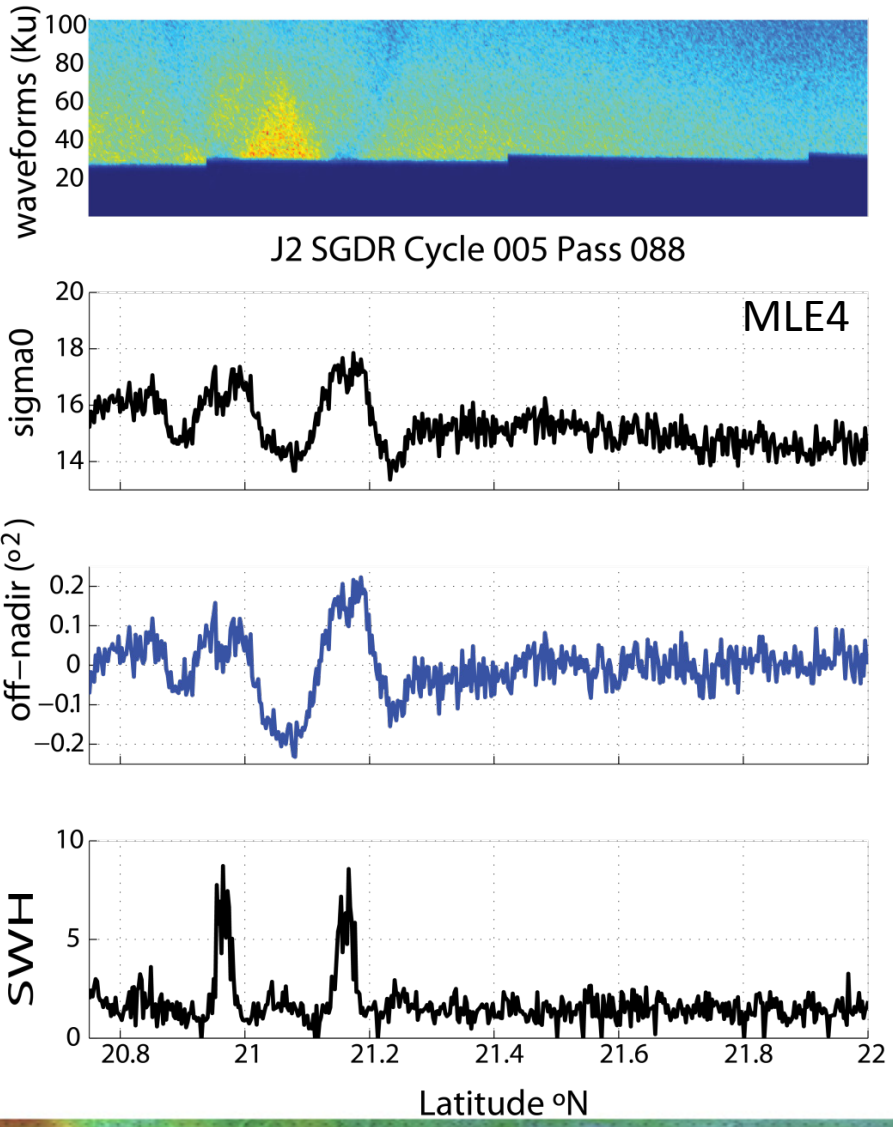
(a) slicks bands (thick solid lines) and the altimeter footprint (circles, 1 per second). Modeled waveforms for (b) perpendicular slick and (c) the 45° oblique slick.

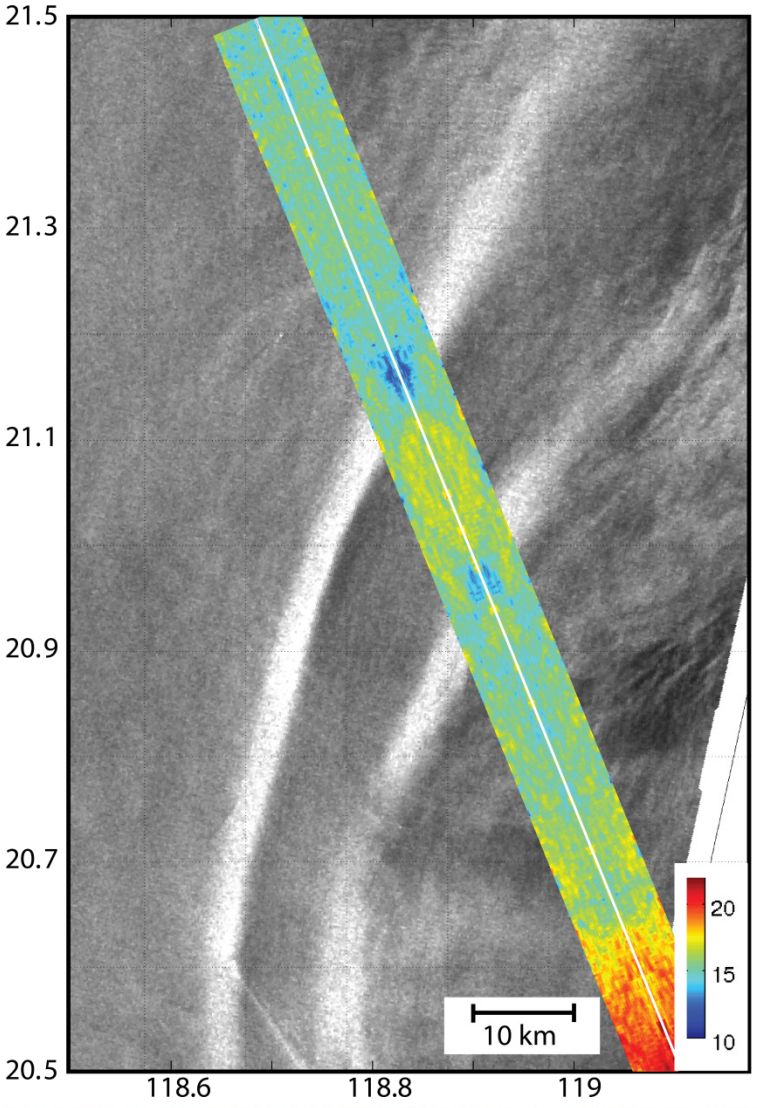
Some case studies: South China Sea



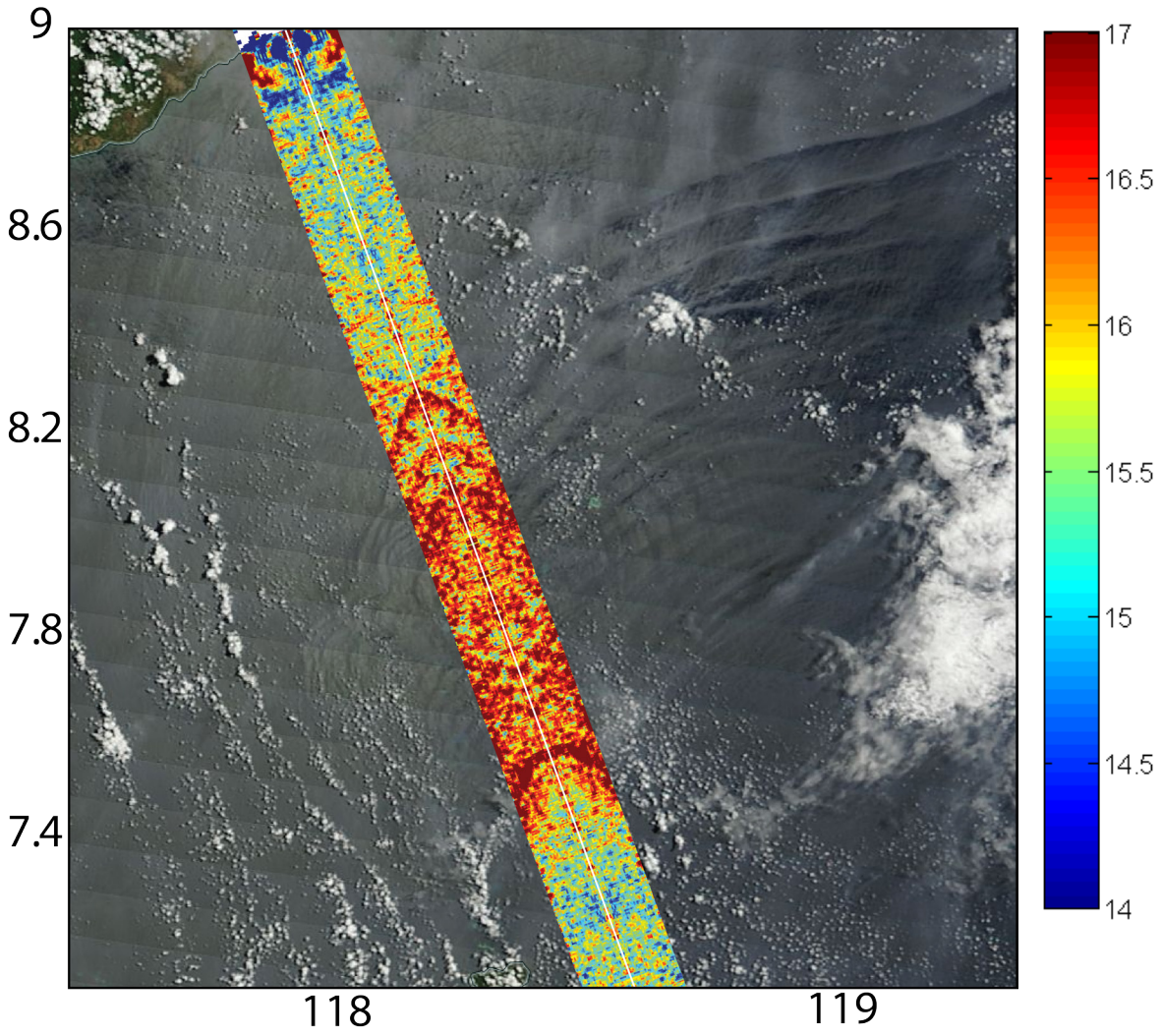


Some case studies: South China Sea





Some case studies: Sulu Sea



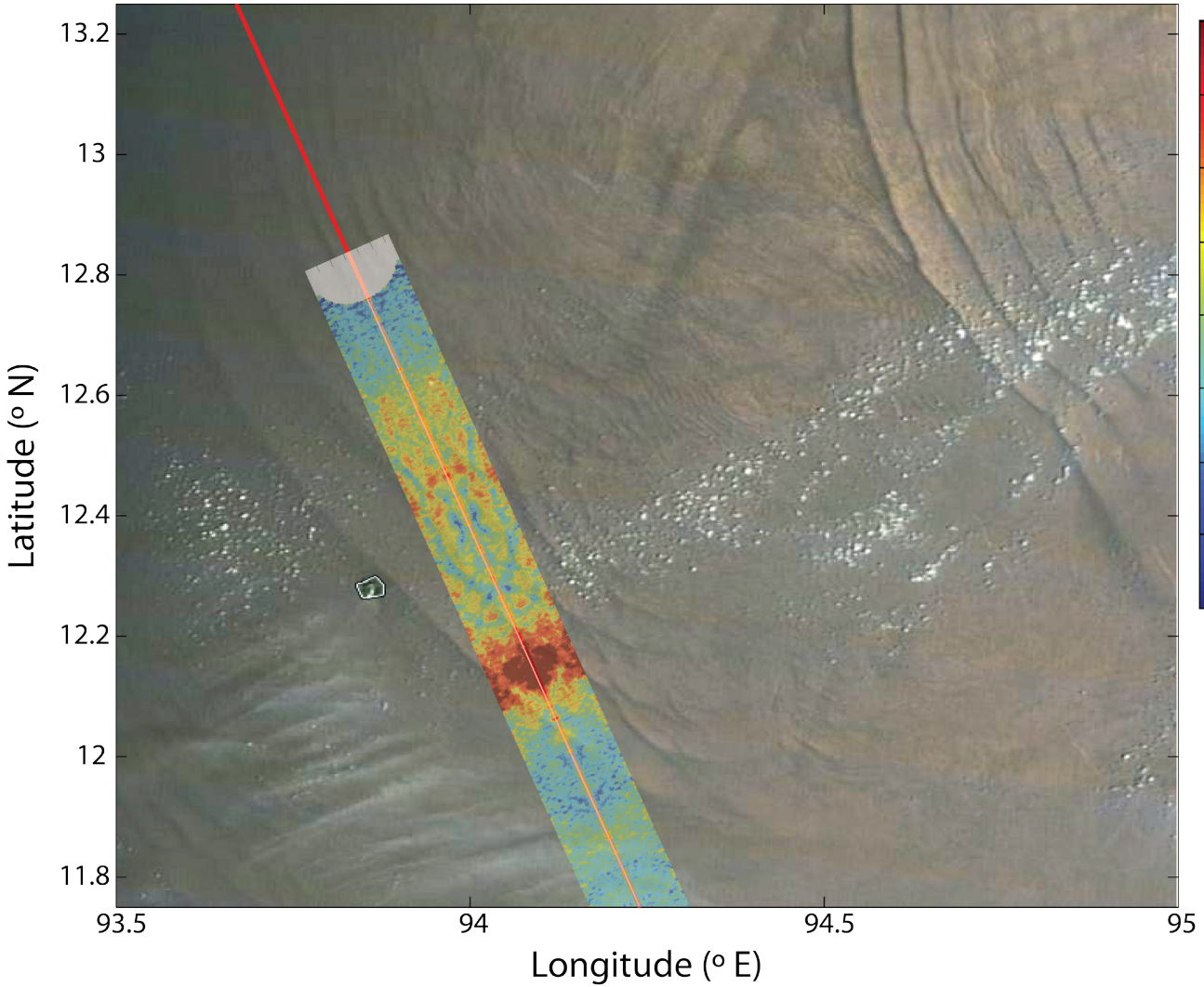
Sulu Sea
Synergy Terra/J2

23.05.2015

Jason-2 04h13 UTC
MODIS 02h45

Δt = 01h28m

Some case studies: Andaman Sea



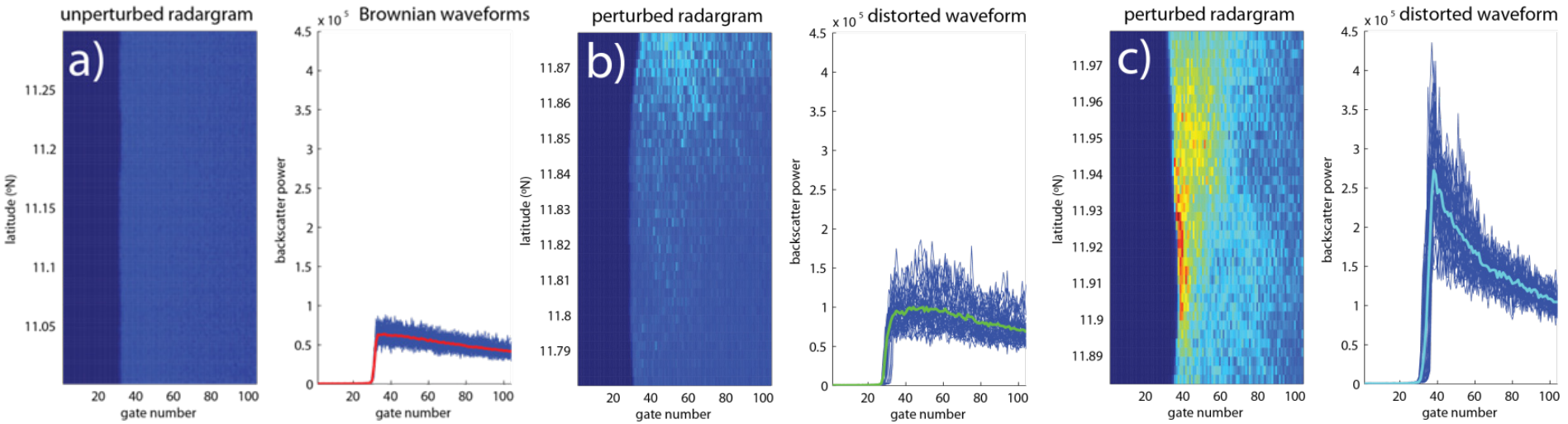
Andaman Sea
Synergy Terra/J2

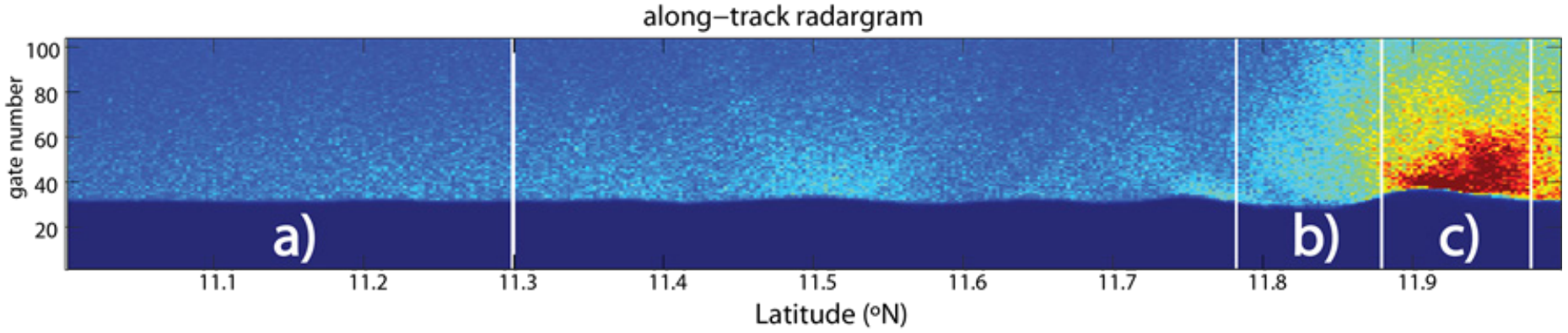
20.03.2015

Jason-2 18h40 UTC
MODIS 04h25

$\Delta t = 14h$

Some case studies: Andaman Sea

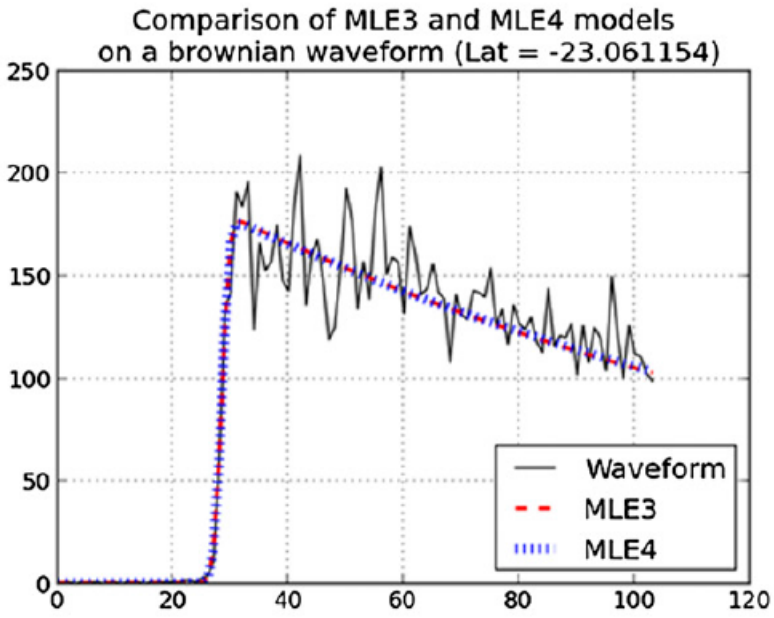




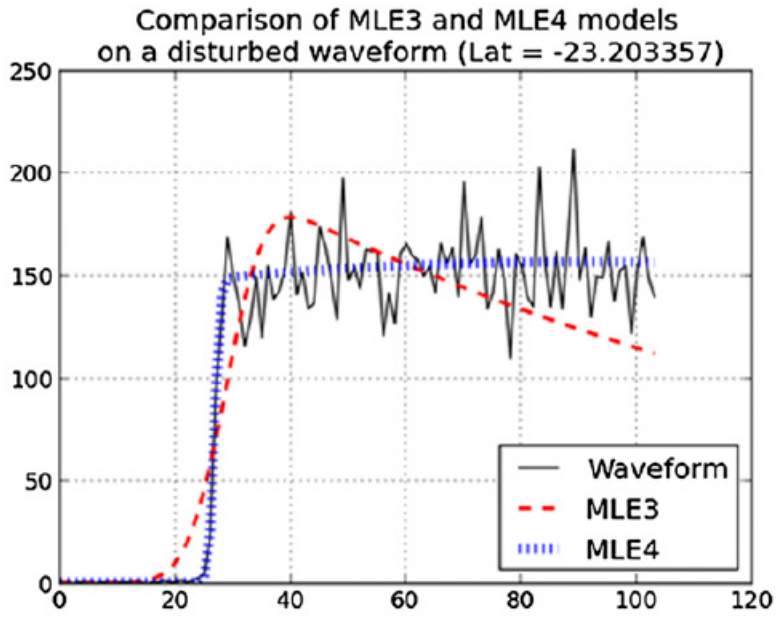
Conclusions:

Retracking Algorithms: Maximum Likelihood Estimator MLE3 & MLE4

σ_0 and **off-nadir angle** affected by inhomogeneous surface and detected in MLE4



Standard ocean waveform



Waveform affected by a sigma0 bloom

➡ MLE4 performs better than MLE3 for inhomogeneous surfaces affetced by internal waves

from Dibarboure et al., 2014

Conclusions:

Take home messages:

- Synergetic approach enables the identification of large-amplitude, short-period internal waves from high-rate Jason-2 data

- Oceanographers interested in short-period internal wave signals may find useful information in the 20Hz-rate Jason-2/3 altimeter products currently being generated

- ISW signatures apparent in parabolic-like features in the radargram, radar power (sigma0), “off-nadir angle”, SWH, and inversion of altimeter waveforms