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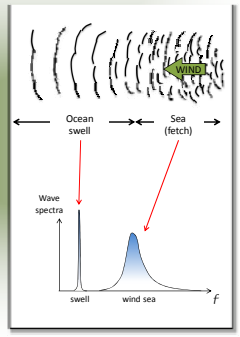
Investigation of swell impact on SAR-mode measurements

T. Moreau[1], L. Amarouche[1], P. Thibaut[1], F. Boy[2], N. Picot[2]
[1] CLS, [2] CNES

Abstract The ability of a SAR-mode altimeter to deliver important new ocean observing capabilities has been amply demonstrated through the exploitation of in-orbit Cryosat-2 data. As expected, this concept provides several advantages over conventional pulse-limited altimeters, such as improved range precision and finer along track spatial resolution. On board the Cryosat-2 mission, the synthetic aperture processing creates doppler bins as narrow as 300 meters in width. This allows to achieve high-resolution high-accuracy altimetric mapping of the ocean surfaces, and might potentially enable to detect some feature that are unresolved from low-resolution mode observations, in particular the ocean surface waves (swell). For example, it is currently unknown how the retrieved sea surface height elevations and other surface parameters derived from the SAR-mode are impacted and at what accuracy these data are in the presence of directional ocean waves, especially those whose wavelengths are close to the SAR along track sampling. Very few studies have investigated the sensitivity of the SAR-mode altimeter data to the swell, which is of high importance for the next missions (Sentinel-3 and Jason-CS). The results of this study constitute a preliminary attempt to characterize these effects through both simulation and flight data analysis.

Definition

- **Wind sea** is directly generated and affected by the local winds
  - subsequent wind waves differ in height, duration and shape: **randomness feature**
- Wind waves are called **swell** where there is a little or no wind sea:
  - **more stable** in direction and frequency
  - long wavelength surface wave (<150m in Mediterranean, >500m after major storm event)
  - narrow ranges in frequency and direction
  - travel long distances (>1000km) since their energy is weakly dissipated
  - create by storms or other wind systems



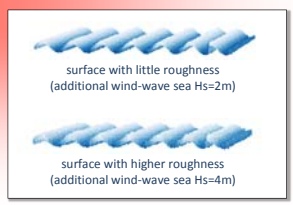
Modeling of ocean swell

- Smooth scene-surface

Sea state described with a swell component (no presence of wind-sea):
- **a sine wave pattern** (first approach)
- varied steepness (ratio of swell height to wavelength L) are analyzed: Hs = 4/8/12/16m, L = 100/300m
- high spatial resolution (5mx5m) to better shape sub-mesoscale structures

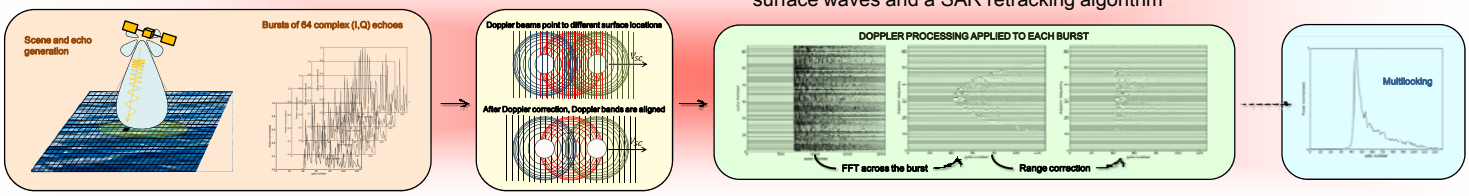
- Rough surface

superimposing a gaussian shaped wind sea spectrum on the sine swell wave, assuming no interaction between these 2 components



End-to-end simulation tool

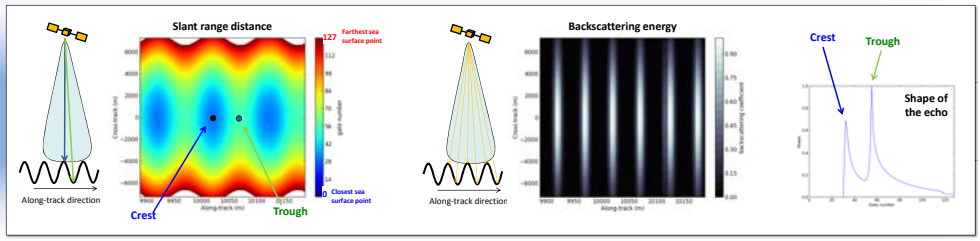
a SAR simulation capability with a generator of realistic models of long ocean surface waves and a SAR retracking algorithm



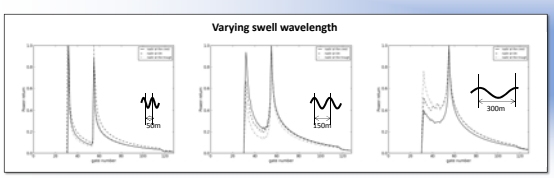
Numerical analysis

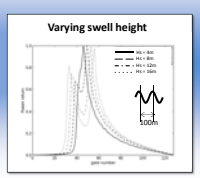
Pixels of maximum backscattered power are those
- with normal incidence illumination (crest and trough)
- at shortest distance (near the nadir)

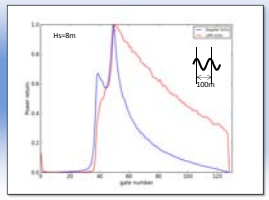
➔ **A « two-peaks » Doppler echo is obtained for:**
- **Doppler band width higher than the wavelength surface wave**
- **swells of high steepness**



Simulated Doppler echo



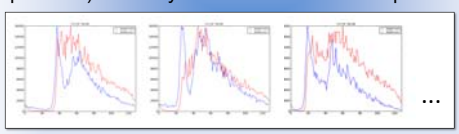




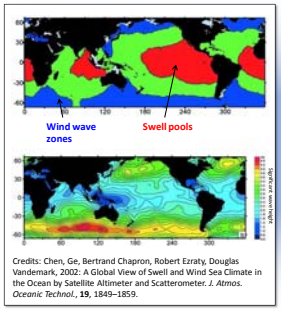
Note that the front edge of the LRM waveforms is also modified by the swell (more impacted by short-wavelength swell)

SAR-mode data analysis

We have picked up some "high-low-high" amplitude echoes that may be related to swell features in Pacific, summer 2012 (from L1b CPP CNES products). But very few cases have been reported.



Main difficulties reside in tracking swells over the ocean (by making evidence the persistence of swells along their propagation tracks).



Perspectives

- More data analyses to track high wave events are needed (e.g. North Atlantic, south of La Reunion)
- Comparison with high quality SAR image (Radarsat-2, Sentinel-1, …), directional buoys and/or fixed platform ground-truth measurements to assess the capabilities of SAR altimeter to observe swell events
- Investigations are on-going to examine the effects of different swell spectrum characteristics (in direction and frequency) on the surface geophysical estimated parameters

For further information please contact thomas.moreau@cls.fr
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