SAR mode altimetry and sea state bias

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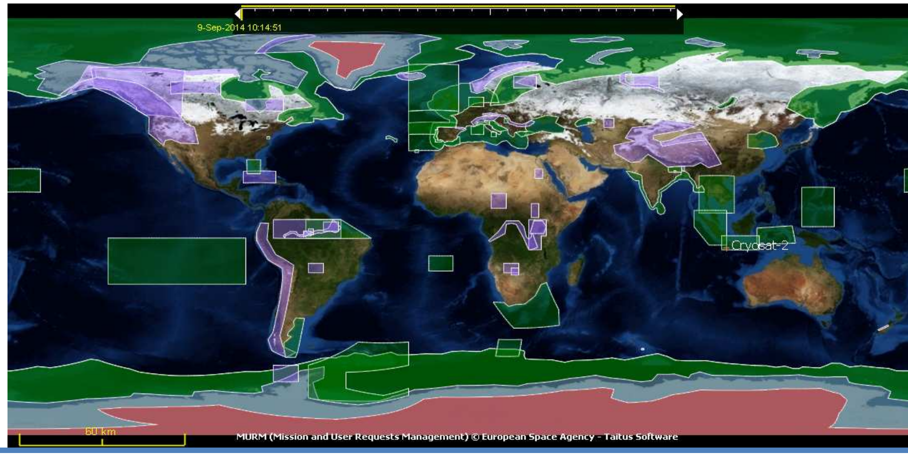
Motivation

- Sea State Bias (SSB) is the largest remaining error in ocean altimeter data
  - SSB = - ε Hs where Hs is the significant wave height and ε ~ 3-4%
  - ε usually estimated empirically for each satellite mission e.g. with Look-Up Tables (LUT) based on SSH residuals at cross-overs for large amount of globally-distributed altimeter data
    - In this case, ε includes SSH biases due to sea state effects (e.g. electromagnetic bias) and instrument effects (e.g. retracker bias)
    - So that the ε LUT is different for each satellite mission
  - Various forms of ε LUT:
    - ε (Hs, U10) where U10 is the wind speed at 10m
    - ε(Hs, σ0) where σ0 is the backscattered power
    - More recently, ε(Hs, U10, T) where T is a the wave period (usually from a numerical wave model)
- No SSB model currently available for SAR mode altimetry

SAR mode altimetry and SSB

- SAR altimetry provides demonstrated advantages
  - Improved precision for SSH, Hs and wind speed
  - Finer spatial resolution in along-track direction
    - improved description of short-scale ocean variability
    - Improved performance in coastal and sea ice covered oceans
  - All demonstrated in-orbit with Cryosat-2 SAR mode data over ocean
  - SAR Mode adopted for Sentinel-3 and Jason-CS/Sentinel-6

- But insufficient amount of Cryosat-2 SAR mode ocean data to develop reliable SAR SSB correction



Cryosat-2 mode mask v3.5 (since July 2014)
SAR Mode in green

SAR mode altimetry and SSB

- SAR altimetry footprint is strongly asymmetric
  - LXT ~ O(2-10 km) & dAT ~ O(300 m)
  - introduces uncertainty as to possible effects on SAR mode waveforms by ocean swell and swell direction, and possible swell induced biases in SSH.

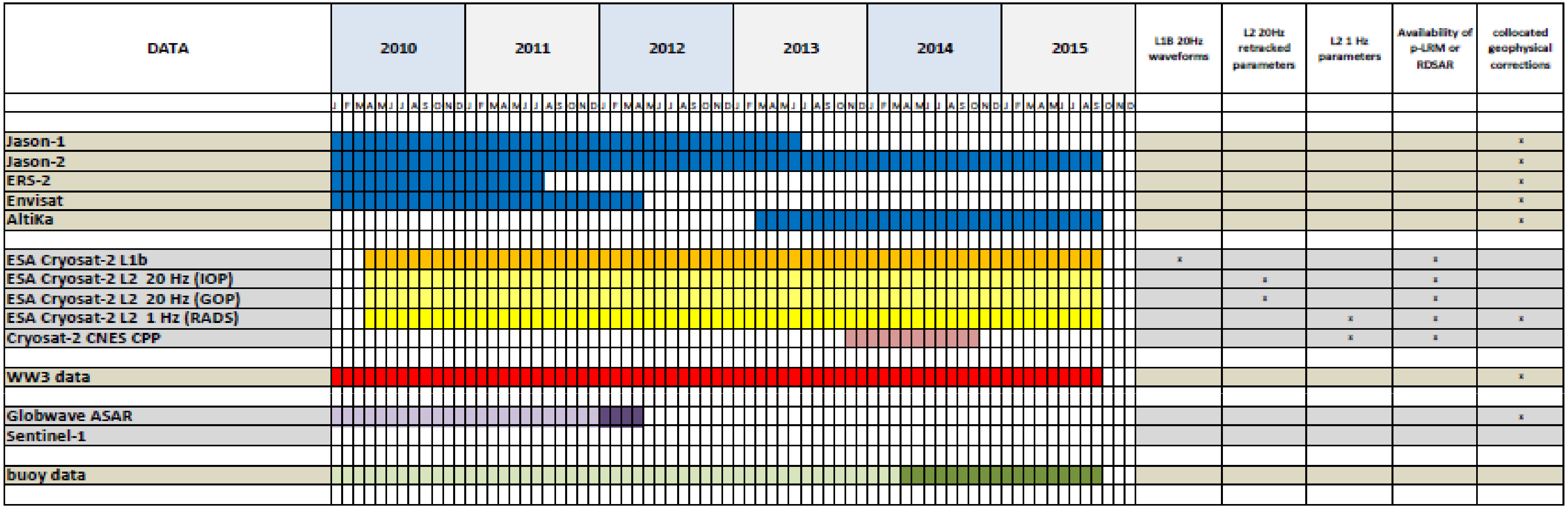
Context of this work

- Dedicated study on SAR mode SSB funded by EUMETSAT
  - Focus on SAR mode SSB correction for Jason-CS/Sentinel-6
  - 8 months study started 21 September 2015
  - Coordinated with parallel ESA-funded activity (SCOOP) on swell effects for Sentinel-3 SAR mode data
  - Technical Officer at EUMETSAT: Remko Scharroo

Content of the study

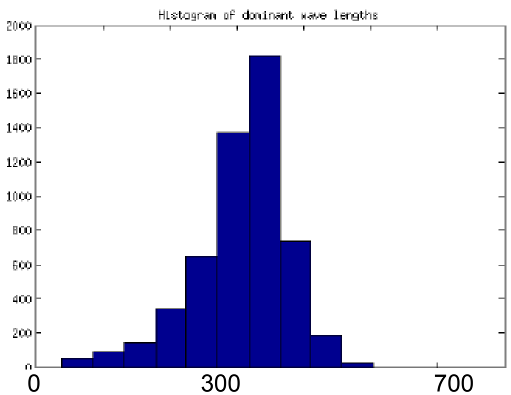
- Literature review and scientific investigations
  - Comprehensive review of methods to estimate SSB for conventional (LRM) altimetry
    - Empirical, experimental and theoretical methods
  - Effect of swell and swell direction on SAR mode data
    - Extend preliminary analysis by Gommenginger et al (2013) of Cryosat-2 SAR waveforms in swell/no-swell conditions
  - Impact of SAR Mode processing & retracking choices
- Algorithm Basis for SAR Mode SSB Correction
- Methods for calibration and validation of SAR Mode SSB

Approach & Datasets

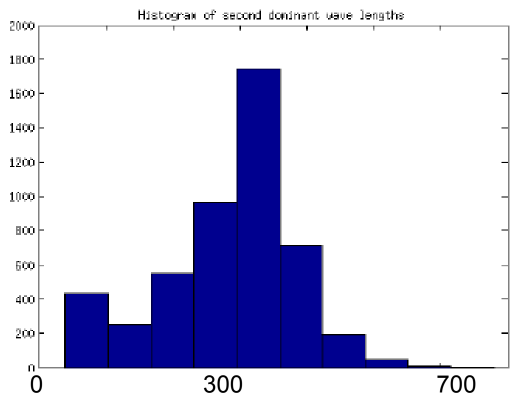


- Cryosat-2 L1B waveforms (different sources)
- Ocean swell data from imaging SAR (e.g. Envisat ASAR), numerical wave model (WW3) and buoys
- Comparisons with contemporary LRM missions and Cryosat-2 Pseudo-LRM

Collocating Cryosat-2 SAR & Envisat ASAR Preliminary results: Jan-April 2012



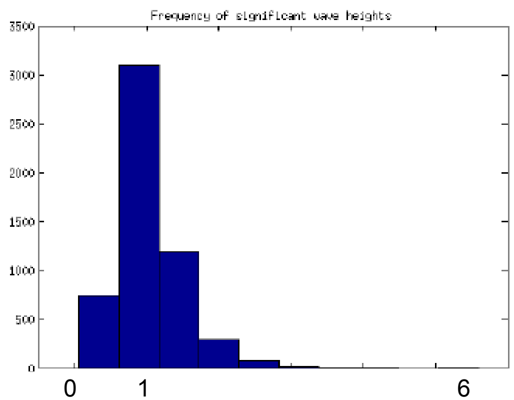
ASAR dominant swell length (m)



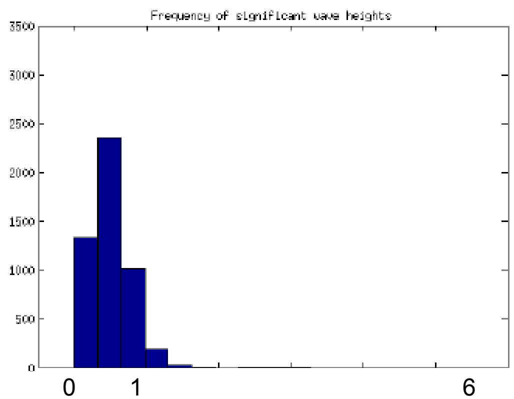
ASAR secondary swell length (m)

Histogram of Envisat ASAR dominant and second dominant swell wavelength

Initially selected extreme wavelengths (100-200 m and 400+ m)



ASAR dominant swell height (m)



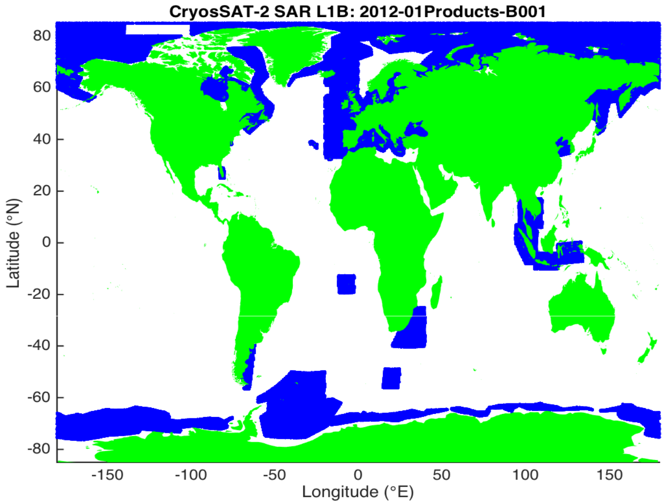
ASAR secondary swell height (m)

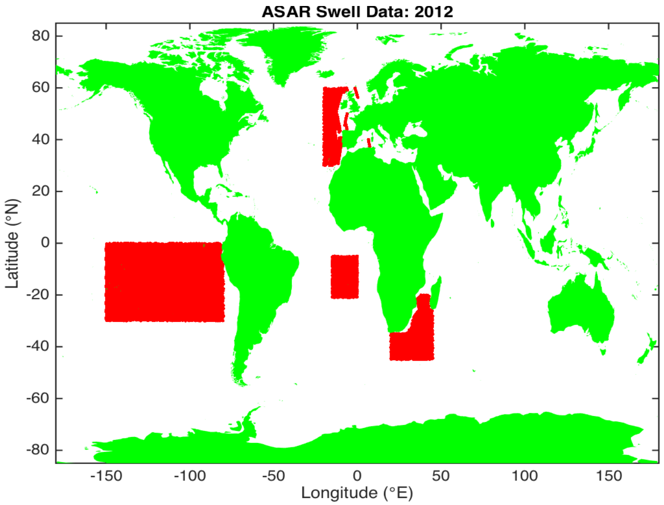
Histogram of wave heights.

Project will categorize similar physical conditions

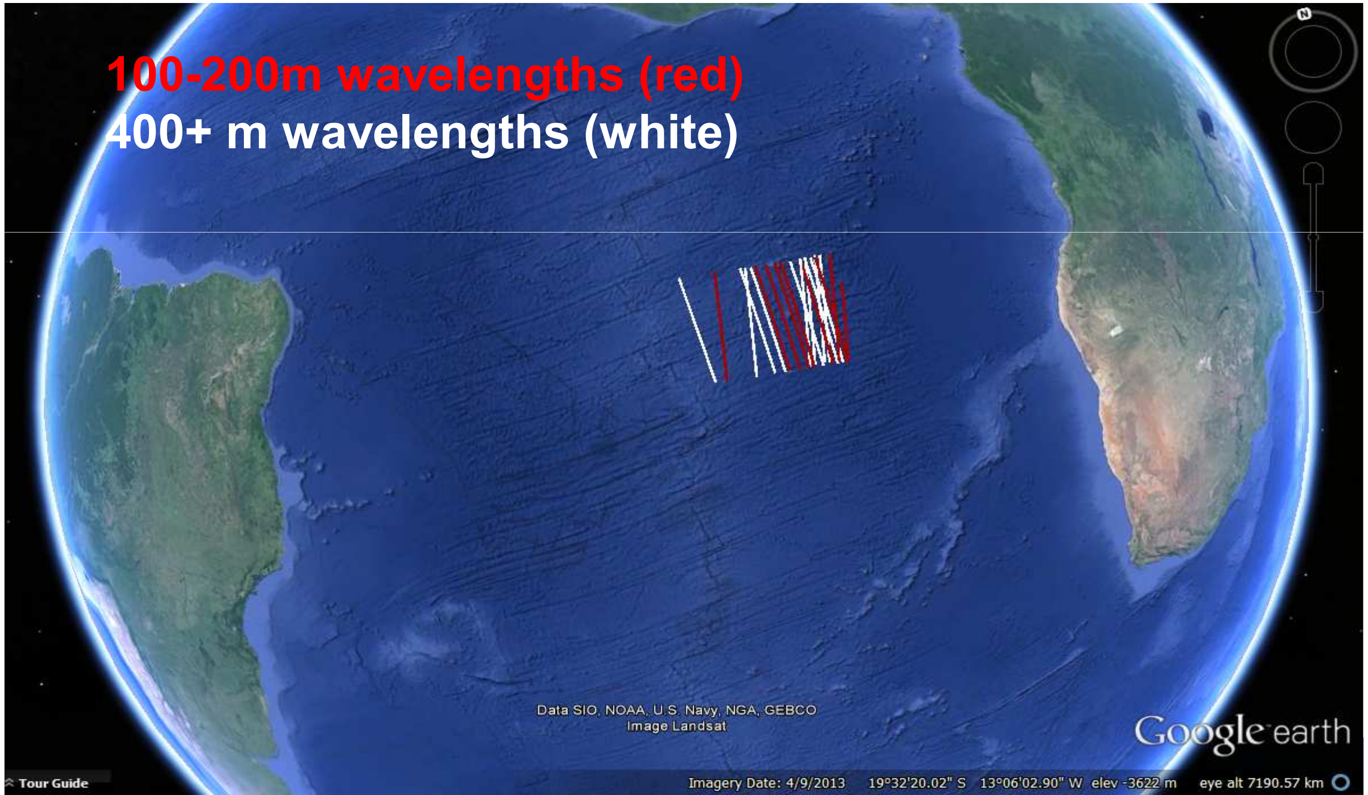
Swell cases in the South Atlantic

Location of Cryosat-2 SAR mode (blue) and Envisat ASAR (red) in Jan-April 2012

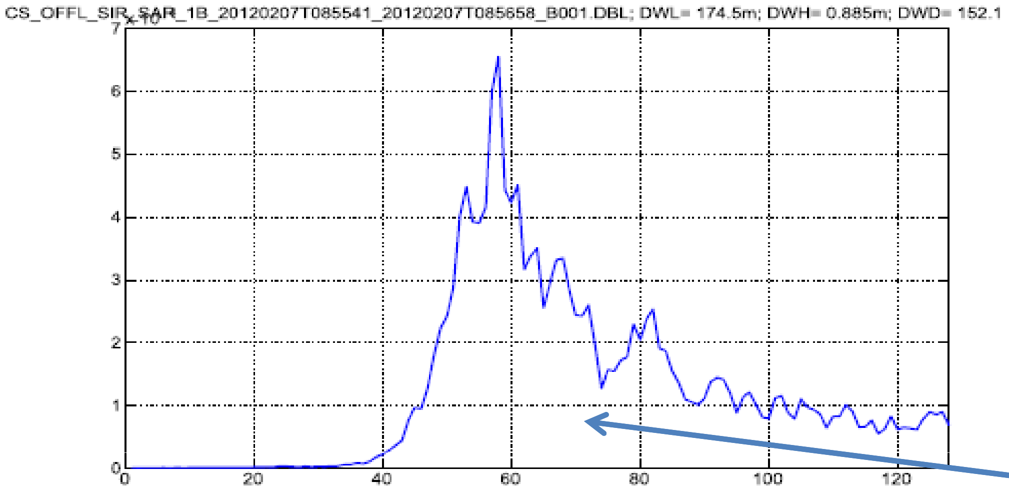


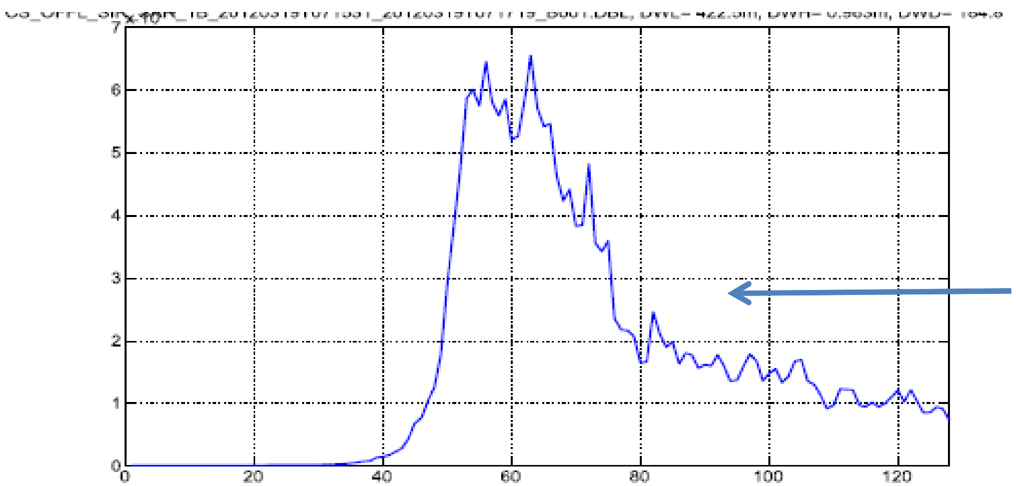


Cryosat-2 SAR data in South Atlantic collocated with Envisat ASAR for different swell conditions



Two Cryosat-2 SAR waveforms in same conditions but different swell length





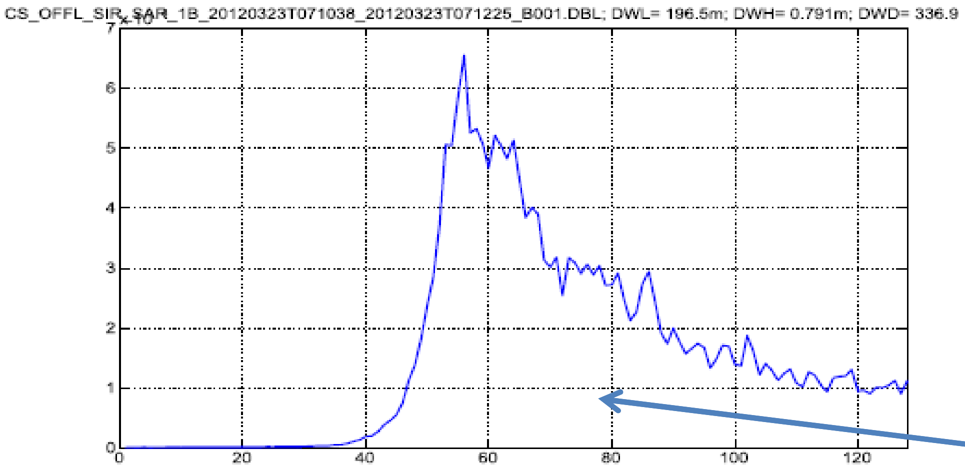
Same region, same ground-track orientation, same swell height, same swell direction but ≠ swell wavelength

Short swell wavelength (100 – 200m)
Wave height < 1m
Wave direction parallel to altimeter

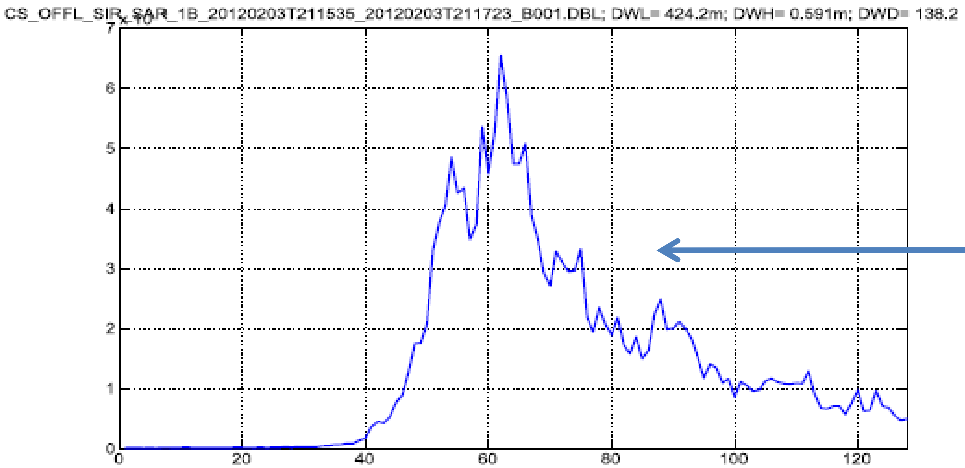
Long swell wavelength (400+ m)
Wave height < 1m
Wave direction parallel to altimeter

Two Cryosat-2 SAR waveforms in same conditions but different swell length

Same region, same ground-track orientation, same swell height, same swell direction but ≠ swell wavelength



Short swell wavelength (100 – 200m)
Wave height < 1m
Wave direction perpendicular to altimeter



Long swell wavelength (400+ m)
Wave height < 1m
Wave direction perpendicular to altimeter

Next

- Complete review of LRM SSB estimation methods
- Analyse and synthesize the impact of swell and swell direction on SAR waveforms for full Cryosat-2 SAR/Envisat ASAR collocated dataset (July'10-Apr'12)
- Repeat analyses with swell data from wave models
- Assess magnitude of the impact in different Cryosat-2 L1 products
- Assess impact on retracking and retrieved SSH
- Recommendation for SAR SSB estimation