Precise Estimates of Ocean Surface Parameters from CryoSat

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Image Credit: ESA
Mission concept: Low Resolution Mode (LRM), Synthetic Aperture Radar (SAR) mode and SAR Interferometric (SARIn) mode.

CryoSat-2 SAR mode over the open ocean

• Can we see an improvement in the precision of the range measurement and significant wave height in the CryoSat-2 data?

We note here that CryoSat-2’s SAR mode is not designed to give the maximum number of looks possible in SAR mode, this experiment is designed to directly compare measurements taken in SAR mode and pulse limited mode. Raney (2012) has described the instrument set up required to obtain the maximum number of looks.
Data location and processing

Model

Fit

Parameters

Vk 1.0 Level 1B processor

Giles et al., in prep.
Model

\[ p_r(\tau) = p_t(\tau) \ast p_z(\tau) \ast I(\tau) \] General expression for the mean each power (Brown, 1977)

\[ p_t = p_0 g_s \text{sinc}^2 (\pi B \tau) \] Transmitted power pulse from CryoSat-2

\[ p_z = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}(\tau/\sigma)^2} \] Surface elevation pdf

\[ I(\tau) \] depends on the backscatter \((\sigma^0)\), antenna gain and range from the radar to the surface

One-way gain of a synthetic beam

\[ \int_0^{2\pi} d\phi d(\rho_k \cos \phi - \xi_k) \] Integration around a range ring

\[ \sum_{k=-\frac{N_b-1}{2}}^{\frac{N_b-1}{2}} \mathcal{H}(\tau + \frac{\eta h \xi_k^2}{c}) \] Summation over \(N_b\) looks

\[ \text{The pattern of a synthetic beam at an angle } (\rho_k \cos \phi - \xi_k) \] from its boresight in the along track direction.

\[ \exp \left[ -2 \left( \frac{(\rho_k \cos \phi - \mu)^2}{\gamma_1^2} + \frac{(\rho_k \sin \phi - \chi)^2}{\gamma_2^2} \right) \right] \] pitch Elliptical antenna pattern roll

Wingham et al., 2004
Pulse limited data

Giles et al., in prep.

SAR mode data

Figure 7.
Wingham et al. 2004
Power correlation coefficient

SAR mode burst separation (84 m)

Zero wave height

4 m wave height

PL correlations and a function of wave height 0, 2 and 4 m wave heights. The separation of the echoes is 0.41 m
Examples of the model fit to the data

Giles et al., in prep.
Results: Precision in the range and SWH

- SAR range noise at 1 Hz and SWH ~2 m is **1.1 cm**
- PL range noise at 1 Hz and SWH ~2 m is **2.3 cm**
- N.B. CryoSat LRM range noise is **1.3 cm** [Smith and Scharoo, OSTST 2011]

- SAR SWH noise at 1 Hz and SWH ~2 m is **7.5 cm**
- PL SWH noise at 1 Hz and SWH ~2 m is **17.0 cm**

Giles et al., in prep.
Results: Comparison between modes

Regression of the a) elevation and b) SWH from the SAR and PL modes. The fit to the data in a) is given by $Elevation_{PL} = 1.002Elevation_{SAR} + 0.009$ and in b) by $SWH_{PL} = 0.931SWH_{SAR} + 0.349$. Including the pitch and roll brought the values closer together.
Results: Comparison with the EGM08 geoid and SWH from ECMWF

ECMWF\_SWH=0.407244 + 0.872486 \text{SAR\_SWH}
ECMWF\_SWH=0.144844 + 0.903942 \text{PL\_SWH}

SWH data from Dr. Saleh Abdalla @ ECMWF
Results: Sigma-zero and wind speed from ECMWF

Sigma-zero was converted to wind speed using Abdalla’s formula for Envisat [Abdalla (2007), Proc. ‘Envisat Symposium 2007’].

Wind speed data from Dr. Saleh Abdalla @ ECMWF

ECMWF_U10 = 1.07156 + 1.09271PL_U10

PL U10 windspeed (m)

Latitude (degrees)

20 Hz Sigma0 (dB)

Degrees)
Conclusions

• We have directly compared the precision in the measurement of oceanographic parameters by re-tracking the data using a semi-analytical model.

• We have demonstrated that SAR processing can provide a two fold improvement to the precision compared to PL processing.

• The SAR mode precision of 1.1 cm is similar to the LRM precision of 1.3 cm found by Smith and Scharroo (OSTST 2011).

• The oceanographic parameters from CryoSat-2 compare well to the EGM08 geoid and data from ECMWF.

• There is a fixed offset in the sigma-zero estimates from our SAR data that may originate in the UCL SAR processing.

• For future missions, an approximate three fold improvement could be made on the precision achieved by CryoSat’s SAR mode and is described by Raney (2012).