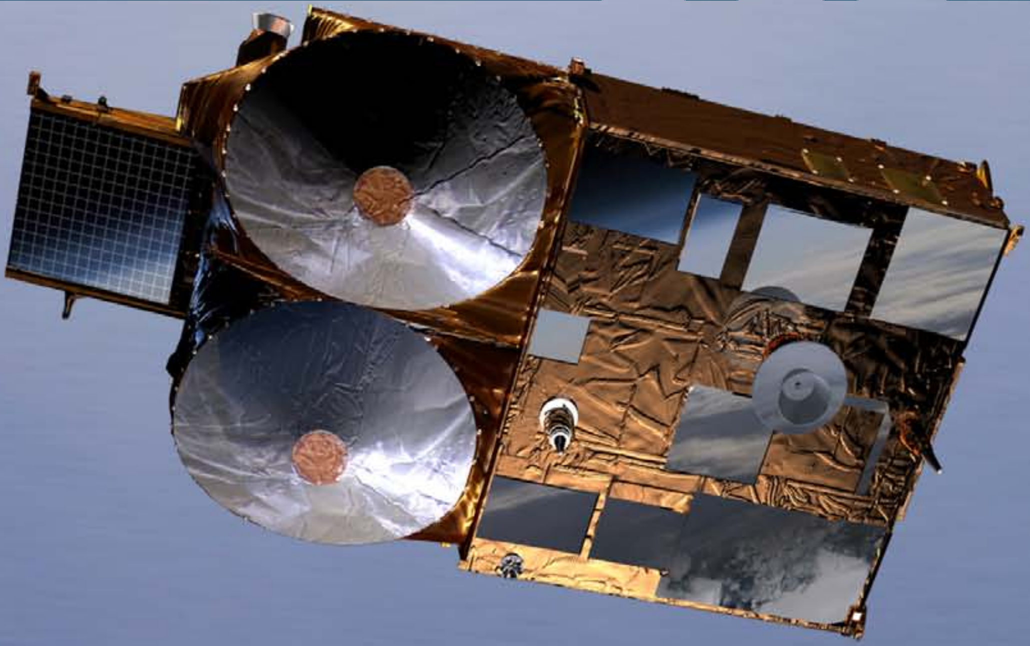
Precise Estimates of Ocean Surface Parameters from CryoSat



Katharine Giles[1], Duncan Wingham[1], Natalia Galin[1], Robert Cullen[2] and Walter Smith[3]

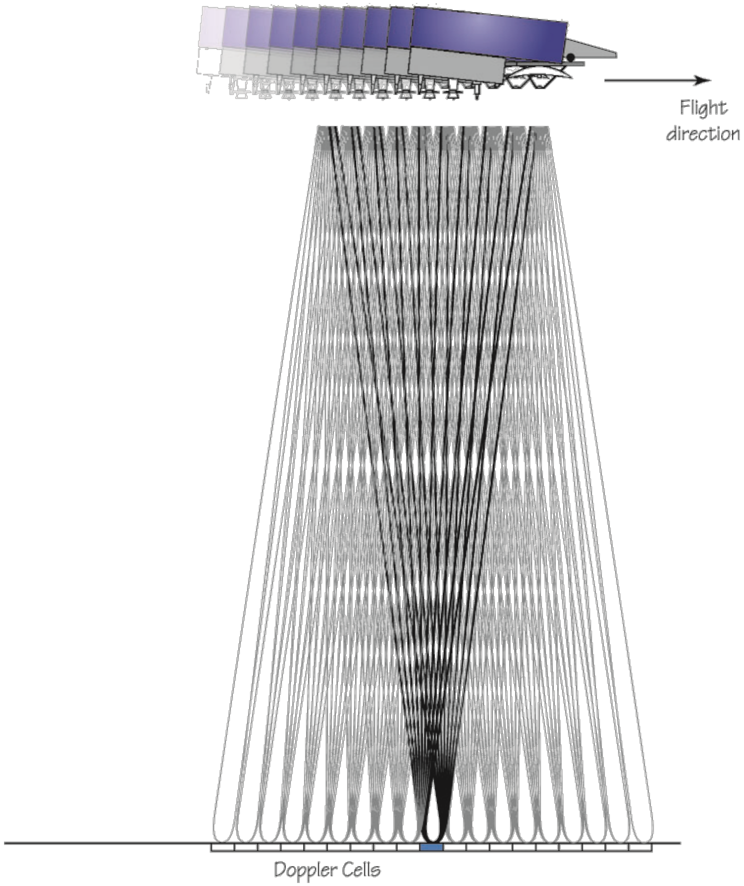
1.Centre for Polar Observation and Modelling (CPOM), Department of Earth Sciences, University College London

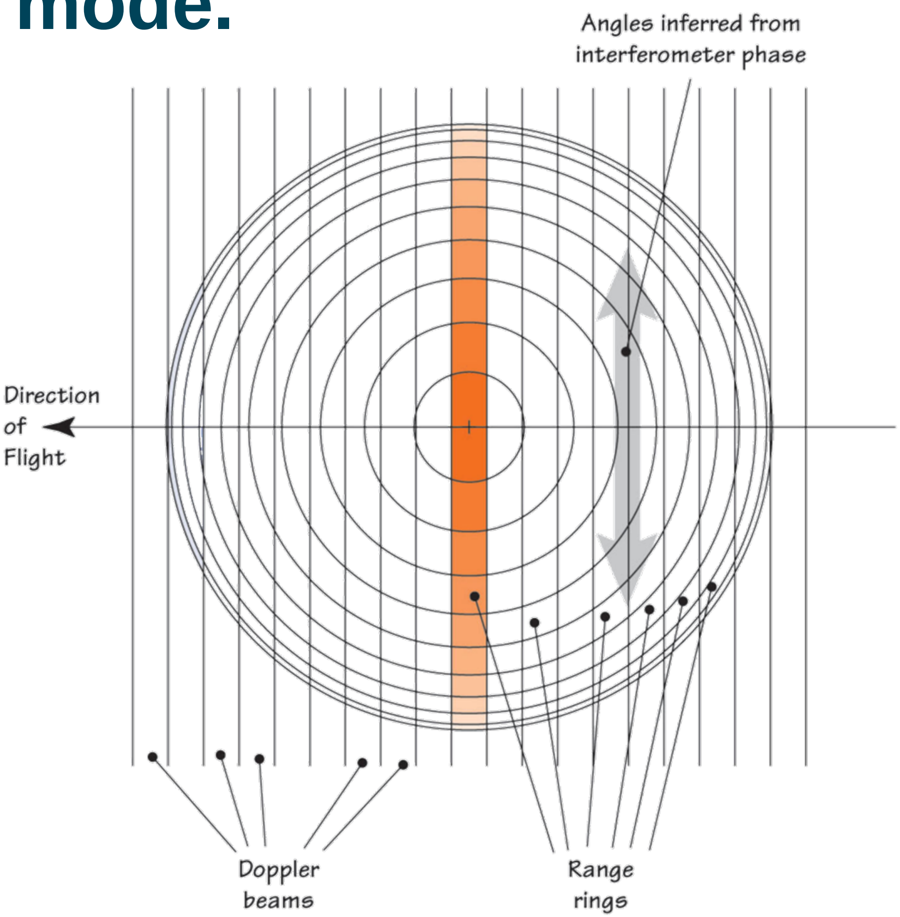
2.European Space Agency

3. NOAA

Image Credit: ESA

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





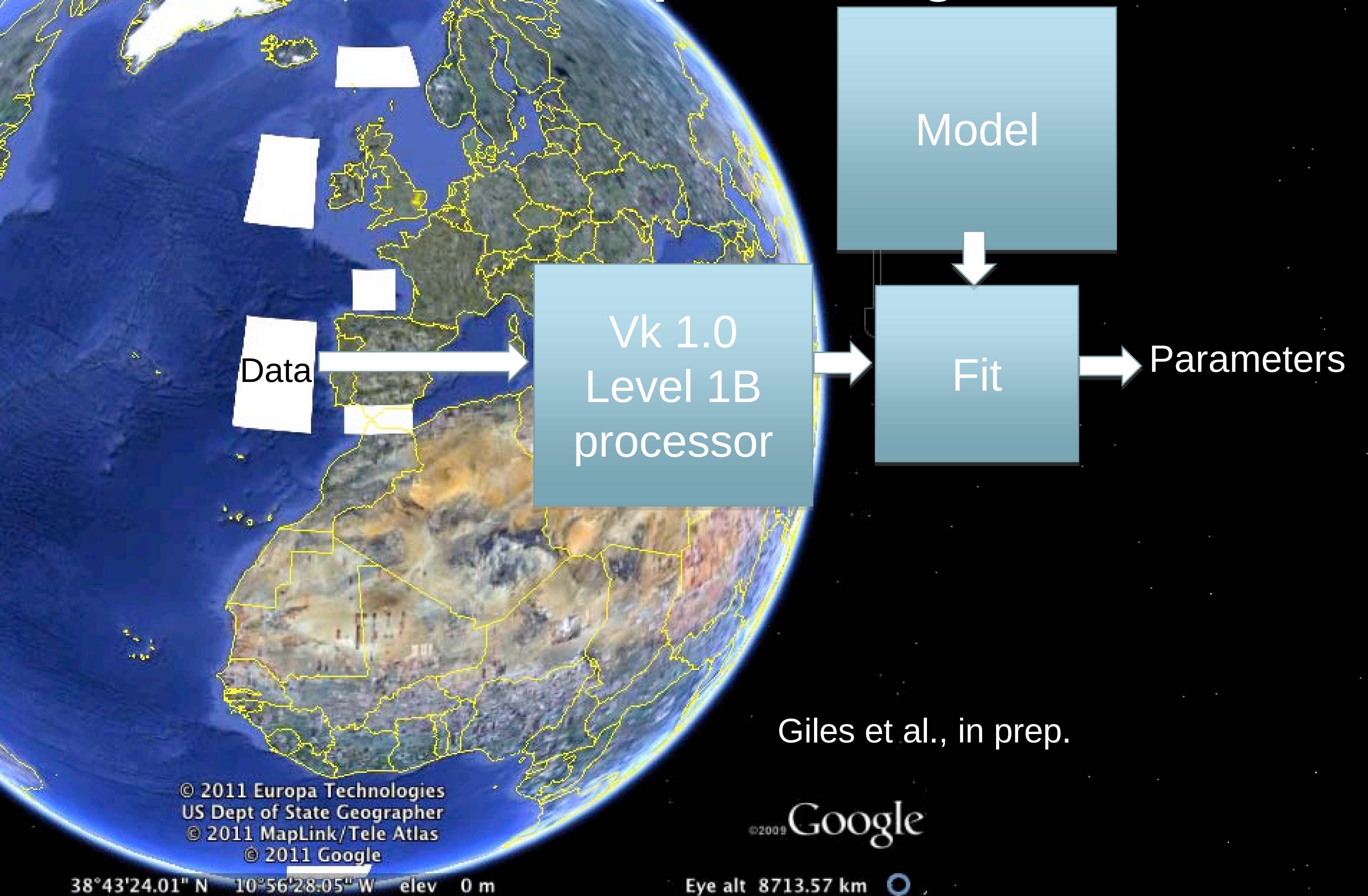
[Wingham et al., Adv. Sp. Res., 2006]

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



Giles et al., in prep.

Model

$$p_r(\tau) = p_t(\tau) * p_z(\tau) * I(\tau)$$

General expression for the mean each power (Brown, 1977)

$$p_t = p_0 g_p \mathrm{sinc}^2(\pi B \tau)$$

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 depends on the backscatter (σ^0), antenna gain and range from the radar to the surface

One-way gain of a synthetic beam

Summation over N_b looks

$$I(\tau) \sim \frac{\lambda^2 G_0^2 D_0 c \sigma^0}{32 \pi^2 h^3 \eta} \sum_{k=-\frac{(N_b-1)}{2}}^{\frac{(N_b-1)}{2}} H\left(\tau + \frac{\eta h \xi_k^2}{c}\right)$$

Integration around a range ring

$$\cdot \int_0^{2\pi} d\vartheta \; d(\rho_k \cos\vartheta - \xi_k)$$

The pattern of a synthetic beam at an angle $(\rho_k \cos\vartheta - \xi_k)$ from its boresight in the along track direction.

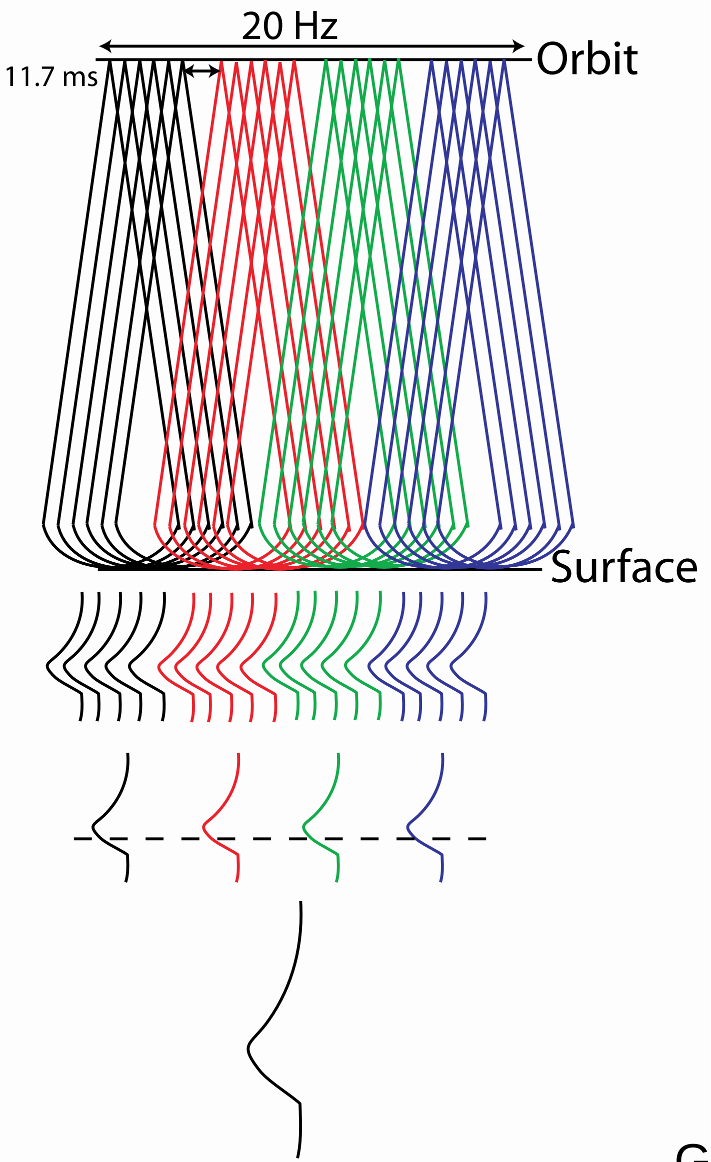
$$\cdot \exp\left[-2\left(\frac{(\rho_k \cos\vartheta - \mu)^2}{\gamma_1^2} + \frac{(\rho_k \sin\vartheta - \chi)^2}{\gamma_2^2}\right)\right]$$

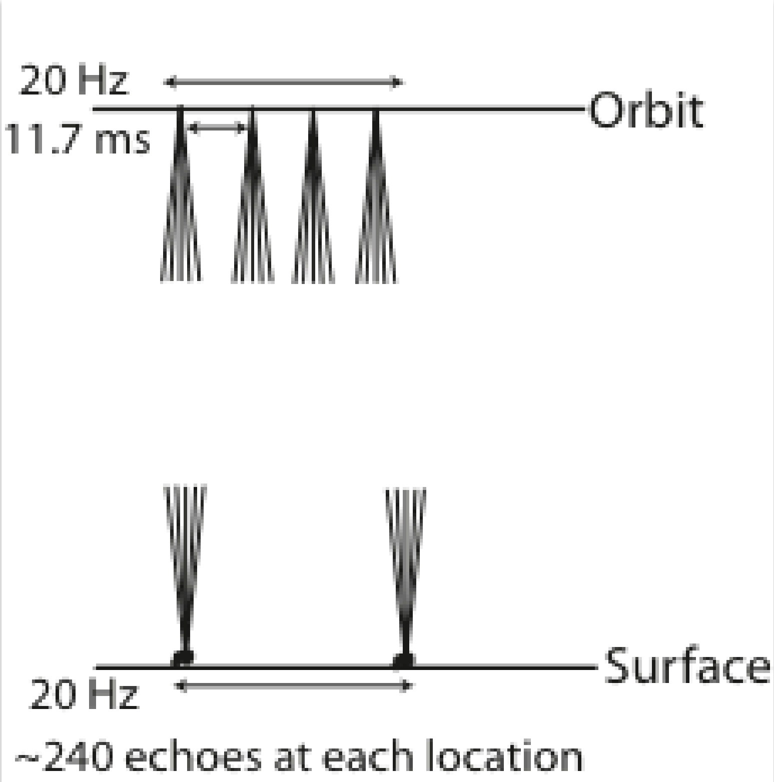
pitch Elliptical antenna pattern roll

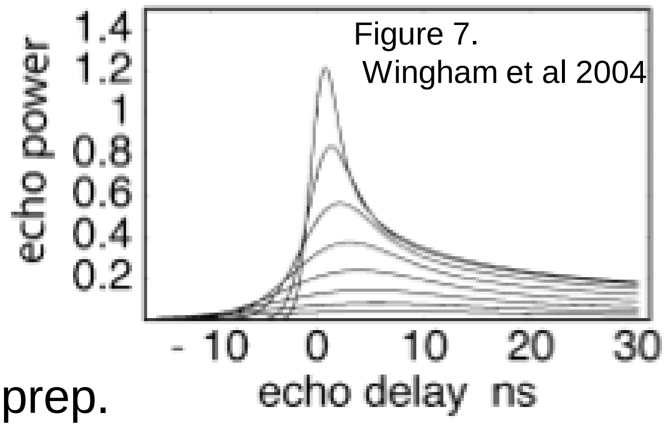
Wingham et al., 2004

Pulse limited data

SAR mode data

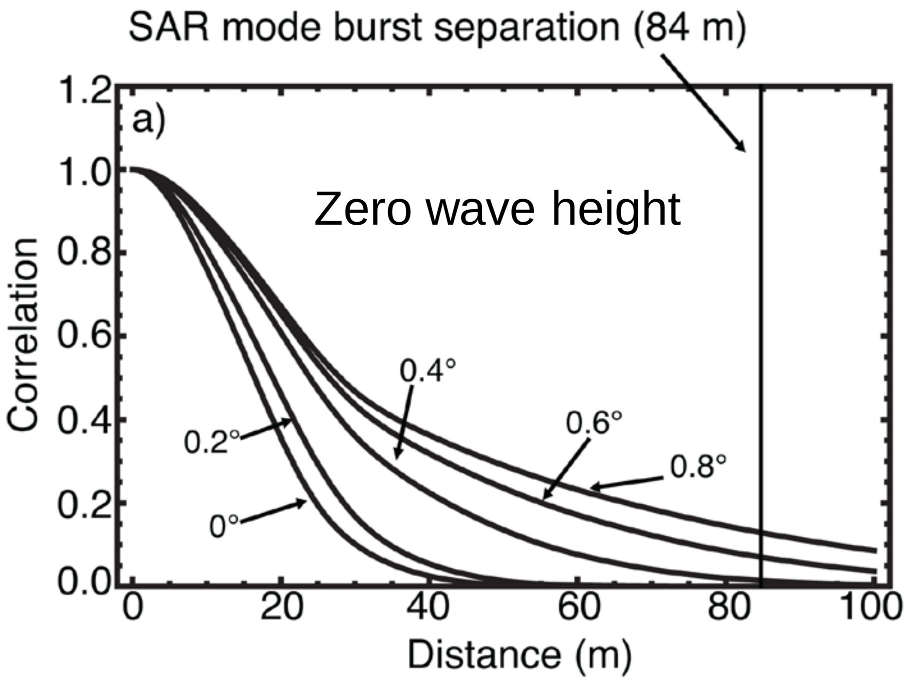


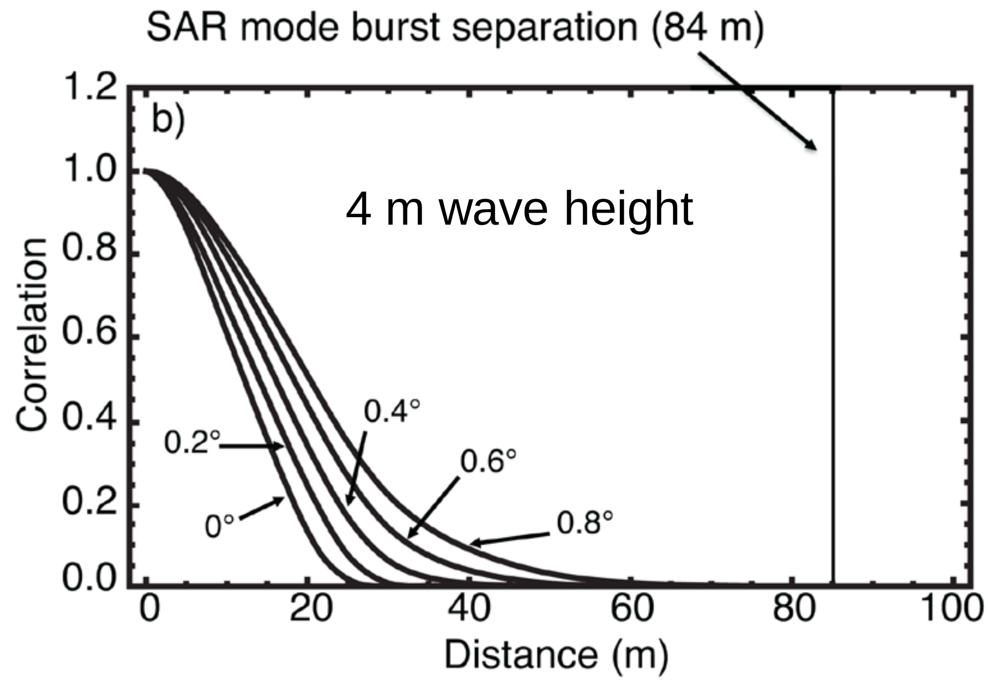


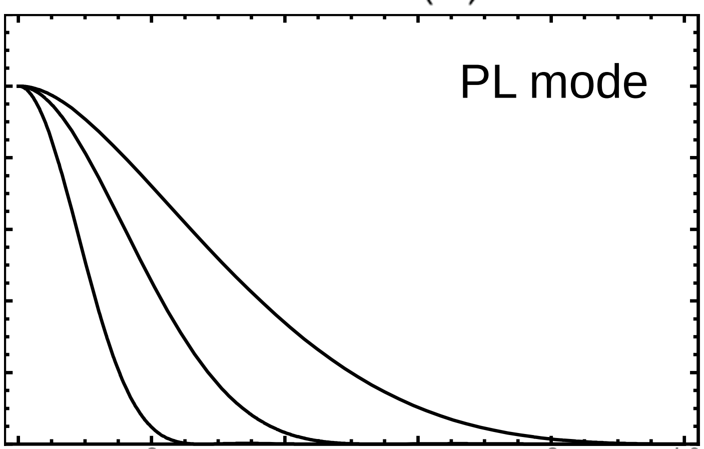


Giles et al., in prep.

Power correlation coefficient





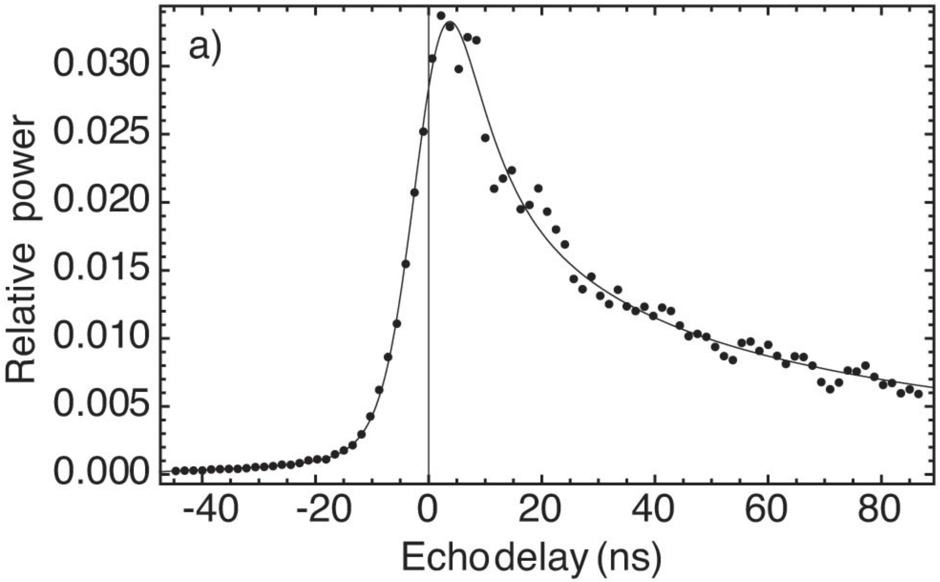


SAR mode correlations as a function of the look angle

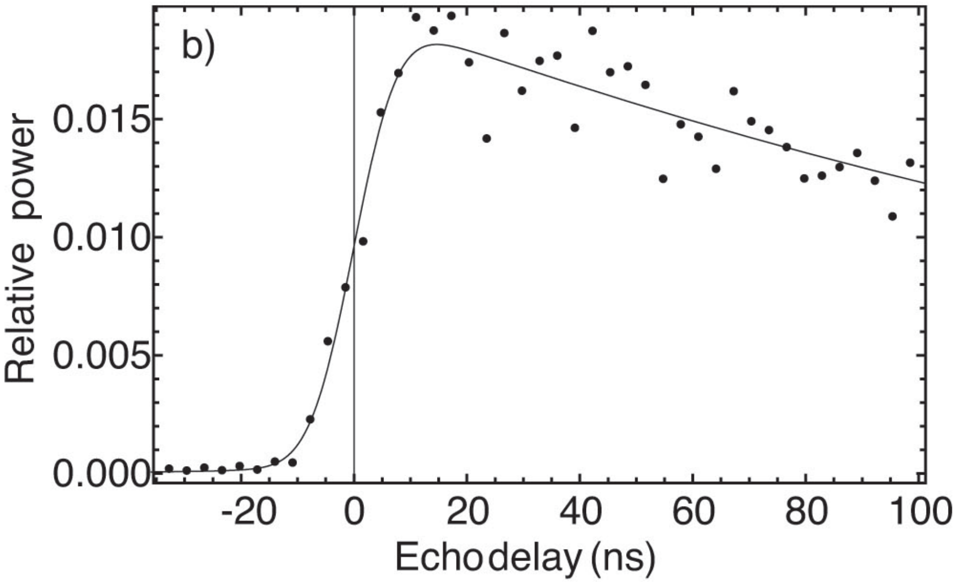
PL correlations and a function of wave height 0, 2 and 4 m wave heights. The separation of the echoes is 0.41 m

Examples of the model fit to the data

SAR

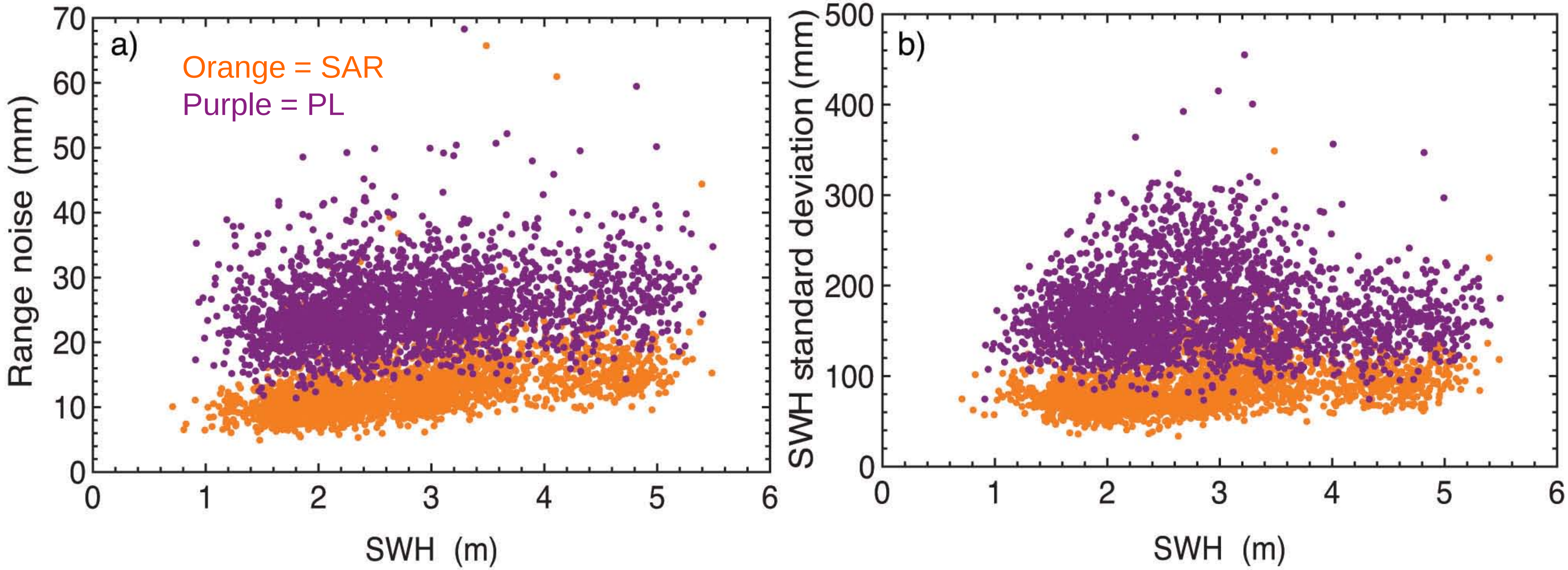


Pulse limited



Giles et al., in prep.

Results: Precision in the range and SWH

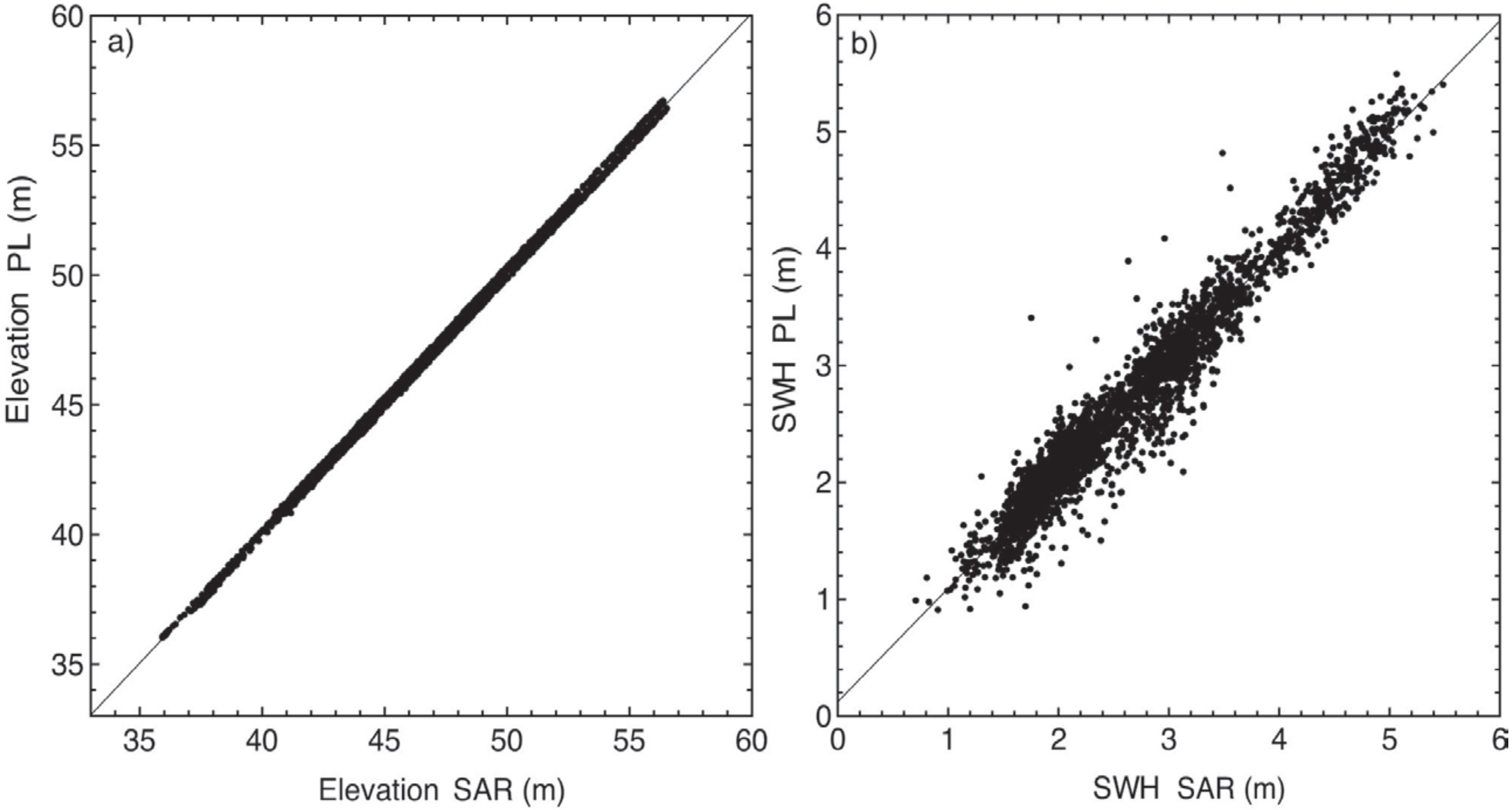


- SAR range noise at 1 Hz and SWH ~2 m is **1.1 cm**
- PL range noise at 1 Hz and SWH ~2 m is **2.3 cm**
- N.B. CryoSat LRM range noise is **1.3 cm** [Smith and Scharoo, OSTST 2011]

- 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**

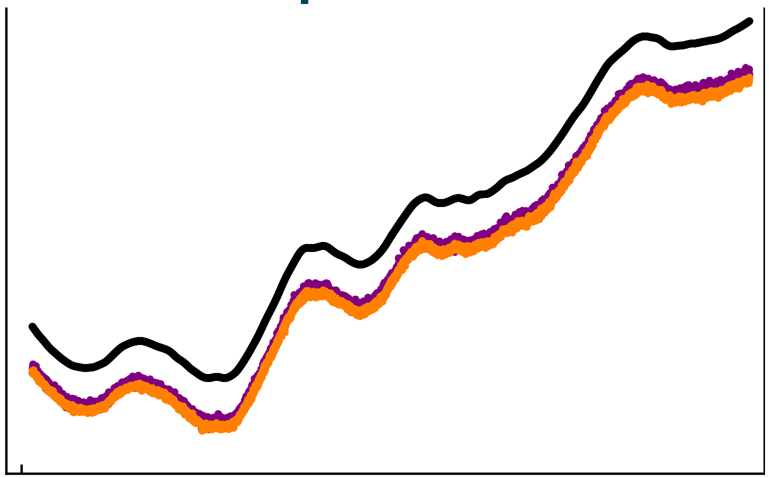
Giles et al., in prep.

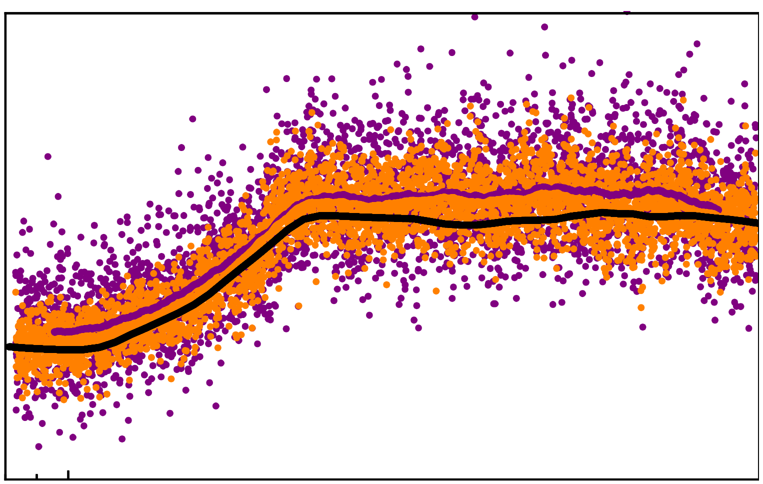
Results: Comparison between modes



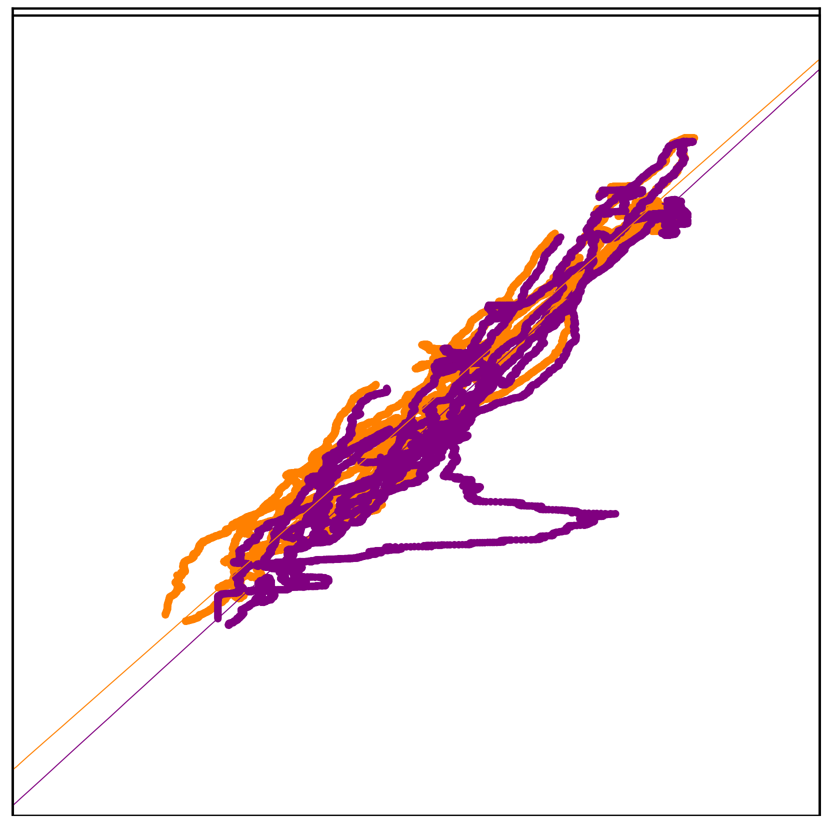
Regression of the a) elevation and b) SWH from the SAR and PL modes. The fit to the data in a) is given by $Elevation_{PL}$= 1.002$Elevation_{SAR}$+0.009 and in b) by SWH_{PL}=0.931SWH_{SAR}+0.349 . Including the pitch and roll brought the values closer together

Results: Comparison with the EGM08 geoid and SWH from ECMWF



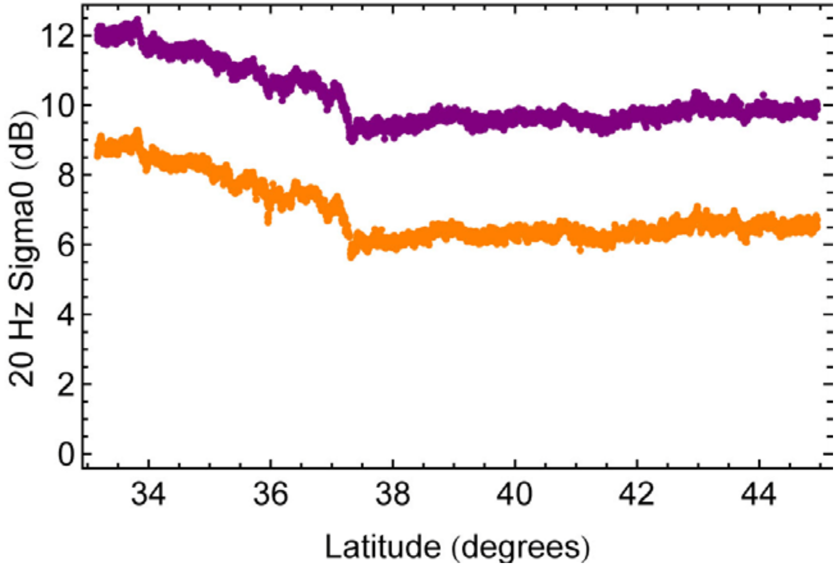


ECMWF_SWH=0.407244 + 0.872486 SAR_SWH
ECMWF_SWH=0.144844 + 0.903942 PL_SWH

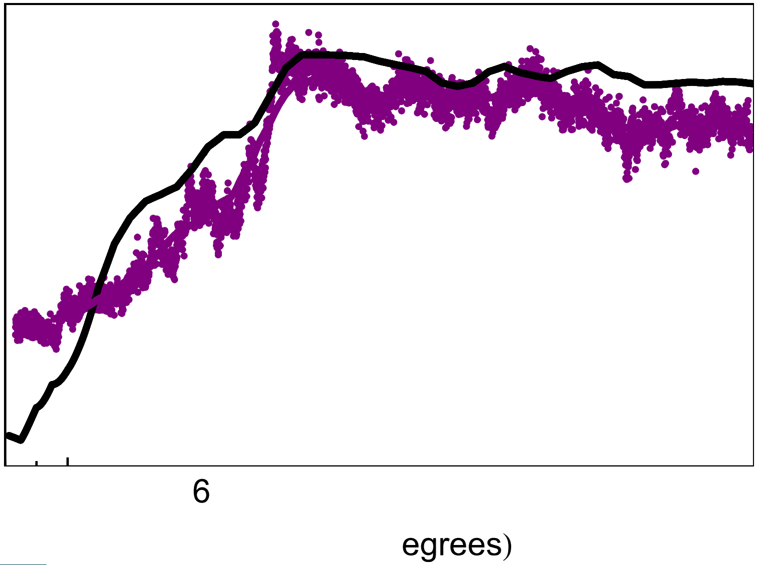


SWH data from Dr. Saleh Abdalla @ ECMWF

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

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).