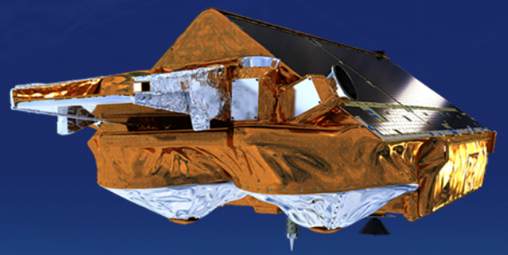
→ CRUCIAL

CryoSat-2 Success over Inland Water and Land



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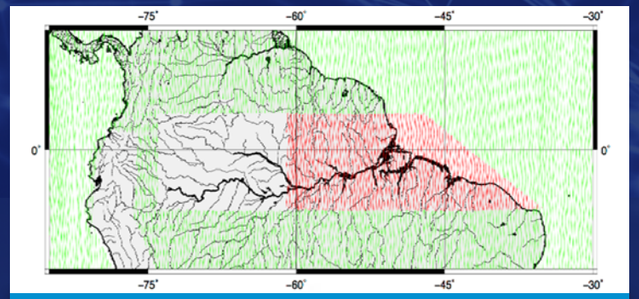
CryoSat-2's primary instrument is SIRAL (SAR Interferometric Radar Altimeter). SIRAL operates in one of three modes: Low Resolution Mode (LRM), Synthetic Aperture Radar (SAR) and Interferometric Synthetic Aperture Radar (SARin) as illustrated in Fig. 1 for the Amazon Basin.

CryoSat-2 FBR Level 1A complex valued quadrature data for the burst echoes have been processed over inland waters to derive altimetric virtual stage inland water heights. The processing chain uses an azimuth Fast Fourier Transform for beam formation and steerage towards a set of spatially equiangular ground track points every 300m along the ground track. By consideration of all burst echoes a stack of waveforms at each ground point (Fig. 2) was derived. High resolution river masks identified the inland water targets.

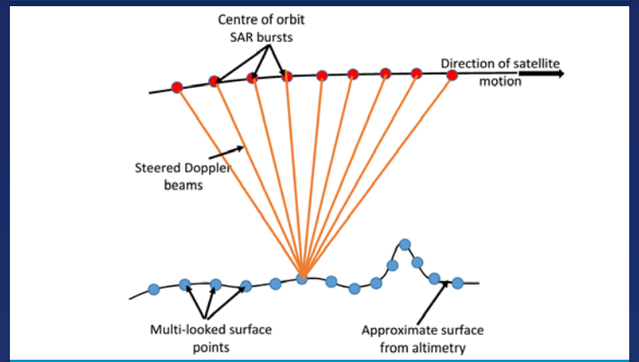
Utilising slant range multi-look waveforms were retracked using empirical waveforms designed for inland waters and the OCOG/Threshold retracker (Fig. 3).

Methodology validated against in situ data for the Mekong including Tonlé Sap, the Amazon (Fig. 4) and the Brahmaputra.

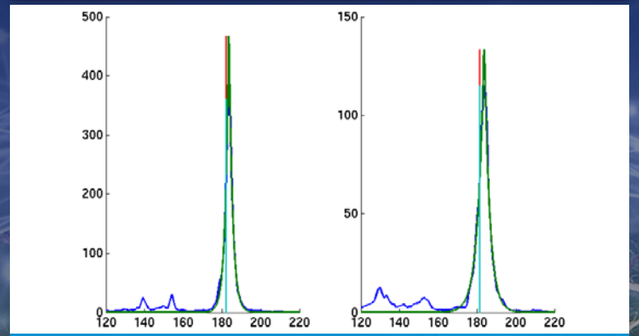
SAR virtual inland water heights near Óbidos show excellent agreement to gauge data (Fig. 5) with RMS 27.3 cm. This compares to 40.2 (57.7) cm for ENVISAT, for May 2002 – Oct 2010, and 17.4 (26.3) cm for AltiKa, May 2013 – Jun 2016, at ENV1 (ENV2).



↑ **Figure 1.** Amazon Basin: LRM (green), SAR (red) and SARin (blank) tracking.



↑ **Figure 2.** Schematic of bursts, the fan of Doppler beams, ground points and multi-looks.

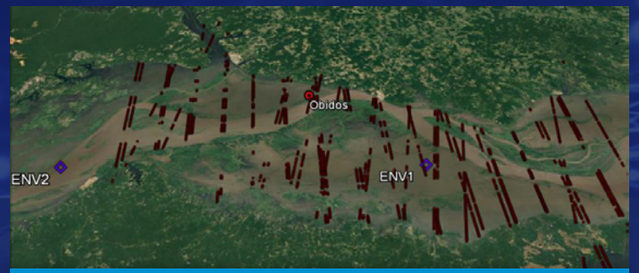


↑ **Figure 3.** Waveforms (blue curve) across the Mekong with empirical retracker (green curve), the retracked bin given by red line. Cyan line shows OCOG/Threshold retracked bin. X axis bin number, Y axis power.

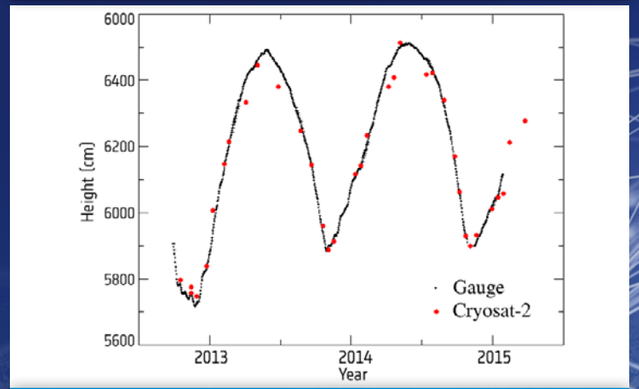
Amazon and Mekong comparisons show that river heights from CryoSat-2 are more accurate than TOPEX/Poseidon and Envisat heights but less accurate than SARAL/AltiKa. The CryoSat-2 SAR altimeter performs better than conventional Ku band altimeters, due to the drastically increased resolution of the footprint in the along-track direction. The Ka band SARAL altimeter onboard AltiKa is the most accurate satellite data, due to the reduced footprint size, although a number of heights are outliers which probably reflects the susceptibility of the Ka altimeter to rain and clouds.

CRUCIAL has assessed the value of CryoSat-2 radar altimetry data for river analysis and modelling with application to the Brahmaputra River. With a sliding ground-track in the 12 monthly sub-cycles, processing, outlier removal and quality control of river levels are more complicated than for classical short repeat-orbit missions (10 or 35 days).
Ingestion of CryoSat-2 data into hydrodynamic models required a novel approach. CRUCIAL developed methods for filtering, processing and aggregating CryoSat-2 data over rivers and implemented a data assimilation (DA) system consisting of a one-dimensional hydrodynamic model and an ensemble transform Kalman filter.

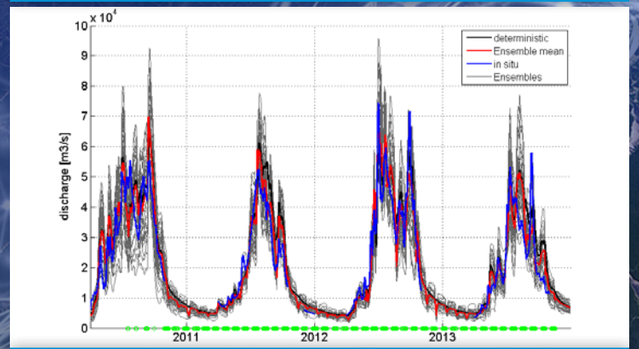
The Continuous Ranked Probability Score (CRPS) is improved by approximately 15% in the DA run over the open loop run (Fig. 6). The data assimilation system developed in CRUCIAL is generic and can be applied to any river system using data from any mission or combination of missions. It is a useful tool to compare data value across missions and river systems and a significant step towards a global real-time inland water forecasting system.



↑ **Figure 4.** Google Earth image overlaid by CryoSat-2 passes across the Amazon near the Obidos gauge (red circle) with two Envisat/AltiKa crossing points (ENV1 and ENV2).



↑ **Figure 5.** Comparison of gauge and CryoSat-2 heights in vicinity of Óbidos gauge.



↑ **Figure 6.** Results of DA of CryoSat-2 data in terms of discharge at Bahadurabad on the Brahmaputra River. Times of observations are marked with green dots on the x-axis.