2. Summary of Lecture at CAW February 2017: SAR Altimetry Processing for Open Ocean Sea Level Monitoring/SLCCI Multi Mission Datasets

The aim of this lecture is to outline the improvement in sea level made possible by the new SAR methodology for coastal zone (< 10 km from land). We cover here the dedicated processing for coastal zone, the novelty in SAR for sea level monitoring, improvement assessment / validation and finally few results.

The presented results are from the analysis performed for the German Bight region (Fenoglio-Marc et al., 2015, 2015a and Dinardo et al., submitted) within the ESA Project Sea Level Climate Change Initiative (SLCCI). The German Bight region (GEC) offers a high-resolution coastal model and high quality 1-minute tide gauge during the complete CryoSat-2 mission 2010-2017. The corrections to be applied to altimetry before performing a cross-validation with model, an in-situ validation with tide gauge etc. are summarized on slide 5. See Wahr 1985 for corrections selected related to loading. The altimeter waveforms are contaminated in coastal areas and therefore dedicated retrackers for coastal areas are need.

The Synthetic Aperture Radar (SAR) mode in CryoSat-2 is expected to provide in coastal zone higher resolution long-track and more accurate altimeter-derived parameters, thanks to the reduced along-track footprint. In the study we regionally quantify the skills of CryoSat-2 SAR altimetry at different time and special scales by comparing SAR altimetry and conventional altimetry in the coastal zone, defined as the locations having distances to coast smaller than 10 km, and in open ocean. The validated geophysical altimeter parameter is sea surface ellipsoidal height (SSH).

The SAR data are extracted from ESA-ESRIN GPOD service "SAR Versatile Altimetric Toolkit for Ocean Research & Exploitation" (SARvatore) (Table 1) by selecting two set of options: the "GPOD Open Ocean Processing (GPODO)" and the "GPOD Coastal Processing (GPODC)". The second, GPDOC, is more suitable for coastal applications and the two differ slightly in Delay-doppler processing and retracking methodology. The extension of the radar receiving window is 128 and 256 range bins. The retracker models are SAMOSA2 in GPODO and SAMOSA+ in GPODC. Main differences between the two algorithms are in the first guess epoch selection and the land contaminated waveforms treatment (Dinardo et al., submitted).
The corrections in GPOD data are from the FBR cryosat products. The ocean tide TPXO8-ATLAS (http://volkov.oce.orst.edu/tides/tpxo8_atlas.html, Egbert et al., 2002) is additionally included. The geoid EGM2008 is in the data, use of the more recent geoid model EIGEN-6C4 is suggested. We substitute the standard wet tropo with the regionally improved GNSS-derived Path Delay Plus (GPD+) wet tropospheric correction (Fernandes and Lázaro, 2016). These SAR data sets are compared to each other and to reduced-SAR results based on the two coastal retracking approaches TALES (Buchhaupt et al., submitted), which has been developed at TU-Darmstadt and based on ALES (Passaro et al, 2015) and STAR (Roscher et al., submitted), developed at the University of Bonn. The RDSAR processing was developed at TU Darmstadt.

To evaluate the altimeter data described above we first cross-compare GPODO and the GPODC data and analyse their differences. Secondly we cross-compare altimetric GPODC/SAR, PLRM SSHs sea level anomalies and ocean model data, third perform an in-situ validation in coastal zone and investigate both instantaneous and seasonal behaviours. We have shown the comparison between GPODO and GPODC SLAs in the GEC region. The standard deviation of the sea level anomalies of each dataset was computed as function of distance to coast in bands of 200 meters. The GPODO is more affected by land contamination, which starts already at 3 km from coast (slide 18). The same ocean tide correction was applied to both BSH model and to the altimeter data. Differences between GPODC and GPODO are smaller in open sea than in coastal zone (stdd of the difference is 5 cm and 22 cm respectively, slide 19).

GPODO/SAM2	**Common options in GPOD**	**GPODC/SAM+**
	20 Hz	
	Hamming in coastal only	
	Exact beam forming approximated	
	FFT Zero-Padding	
128 range bins (radar receiving window)		256 range bins (radar receiving window)
	No antenna path correction	
	LUT	
SAMOSA2 (SAM2)		SAMOSA+ (SAM+)

Table 1: GPOD options used in GPODO and GPODC

Comparison between PLRM and GPODC/SAR SLA (Slide 14) gives skill metrics (bias, standard deviation of the differences and correlation) 2 cm, 52 cm and 0.78. They have therefore a good consistency.

Comparison with the regional ocean model (BSH) shows higher agreement with SAR than with PLRM instantaneous dynamic ocean topography (DOTi) above EIGEN-6C4 geoid. The standard deviation of the differences (stdd) with BSH is 24 cm for SAR and 55 cm for PLRM. The slope with the model is 0.96 for both altimeter products.

We conclude that sea level anomalies are affected by land contamination starting at 2 km from coast in SAR and at 3.5 kilometres in PLRM TALES (Fig. 14). SLA from GPODC and the reduced-SAR retracker STAR show the smallest standard deviations. The quality of the GPODC and STAR-based water heights is also confirmed by their good agreement to independently measured tide gauge data.

Using several in-situ stations, the average of STDD differences between in-situ and altimetry SLA are 5.7 cm and 7.5 cm respectively for SAR and PLRM/TALES. With open sea altimetry, the in situ cross-comparison gives an average stdd of 3.9 cm and 4.6 cm respectively for SLA retrieved from SAR and PLRM TALES.

Monthly mean dynamic topography and average of their standard deviation show that SAR Altimetry can measure the sea level annual cycle in coastal zone more accurately than PLRM (Figure 3.3.4.4).

Generally, the quality of coastal SAR data is better than conventional or reduced-SAR altimetry but new retracking methods such as STAR look promising in this context, but still require a more in-depth analysis

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