EVALUATION OF COASTAL SEA LEVEL OF JASON-2 ALTIMETRY OFFSHORE HONG KONG

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Abstract

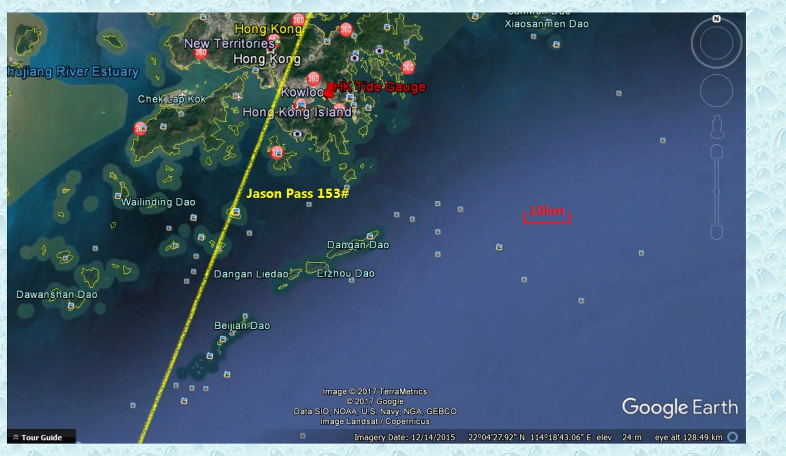
In the coastal zones, satellite altimeter radar echoes reflected to the satellite become much more difficult to interpret because of land contamination. In parallel, the quality of geophysical corrections we need to apply to altimeter range measurements also degrades significantly. This leads to an important decrease in the number of valid data when approaching the coast. In the recent years, a number of groups have developed different approaches to overcome those difficulties, either by improving the altimeter geophysical corrections or by developing retrackers to extract accurate range measurements from non-standard radar echoes. Thanks to these efforts, a number of experimental reprocessed coastal altimetry sea level data sets are now available. In this paper, we evaluate the Jason-2 satellite coastal products. We focus on the Hong-Kong region and consider high-resolution (20-Hz) along-track data for a specific Jason-2 pass that crosses the coast nearby the Hong-Kong tide gauge. Data of orbital cycles 1-238 (spanning 6.5 years) are analyzed. We compare sea surface height measurements obtained using the ALES retracker and the different retrackers of the PISTACH products with the official GDR data distributed by space agencies. We compare each near-coastal sea level estimate with data from the Hong Kong tide gauge (located 10km away). We also compute sea surface height bias and noise over both open ocean (>10km away from coast) and coastal zone (within 10km or 5km coast-ward). Finally, coastal sea level trends from the different retrackers are estimated over the 2008-2014 time span. The results show that, after outlier removal, in the coastal band, ALES performs better than the other retrackers considered in this study, both in terms of noise level and trend uncertainty. An interesting, but still preliminary result is that over the 6.5-year time span considered here, the altimetry-derived sea level trend is significantly larger within 5 km of the coastline than at larger distances from the coast.

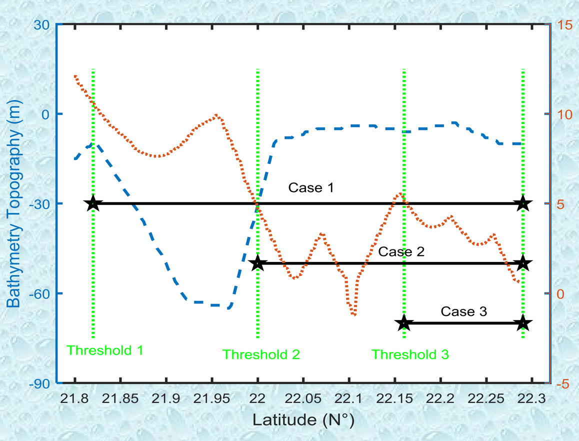
OBJECTIVE

Combine improved geophysical corrections of altimetry-based sea level with retracked radar waveforms in the coastal zone

Product	X-TRACK	ALES	PISTACH
Affiliation	LEGOS-CTOH	NOC (UK)	CLS
Reference	Birol et al., 2016	Pasarro et al., 2014	Mercier et al., 2010
Style	Concise	Similar to SGDR (CGDR)	Similar to SGDR (IPC)
Classification	NO	NO	16 classes
Retracking	NO	ALES	ICE1 + ICE3 + OCE3 + RED3
Ocean Tide	FES12 + 73 empirical harmonic constants based on altimetry data	=GDR	GDR+GOT 4.7
Wet Troposphere	composite correction (ECMWF)	=GDR	composite correction or decontaminated correction

STUDY AREA





Jason-2 Pass 153# corossing the Hong Kong Coast. The Quarry Bay tide gauge is ~10km across-track of Jason-2 track.

3 cases considered (different along-track distances to the coast)

DATA

- Jason-2 altimetry data
- Time span: 2008.07-2014.12 (6.5 years)
- Hong Kong tide gauge (hourly data from UHSLC database.
- Coastal altimetry products: XTRACK / ALES / PISTACH
- Regional sea level data from ESA Climate Change Initiative

METHODOLOGY

- Altimetry data processing

SLA = alt - range_ku - iono_corr_alt_ku - model_dry_tropo_corr - wet_tropo_corr - sea_state_bias_ku - solid_earth_tide - ocean_tide_sol1 - pole_tide - inv_bar_corr - hf_fluctuations_corr - mean_sea_surface

The "*range_ku*" is usually default value near coast

*range_ku = tracker_ku + epoch_ku * (c/2) + doppler_corr_ku + modeled_instr_corr_range_ku + 0.180 (m)* Calibration bias

Range_ku or Epoch_ku is dependent on the retracker

Retracker	Product	Idea	Sub-waveform	Comments
MLE4	SGDR	Brown model	No	Official standard retracker.
MLE3	SGDR	Brown model	No	
OCE3	PISTACH	Brown model	No	Same to MLE3
RED3	PISTACH	Brown model	Fixed: bins： t_0±[-10:20]	Simplified version of ALES
ALES	ALES	Brown model	Adaptive to the SWH	Two-pass retracker
ICE1	PISTACH	Modified threshold	No	
ICE3	PISTACH	Modified threshold	Fixed: bins： t_0±[-10:20]	

Ionospheric delay: LEOSS filtering (cutoff： ~100km)

Wet tropospheric delay：Composition & RAD Decontamination

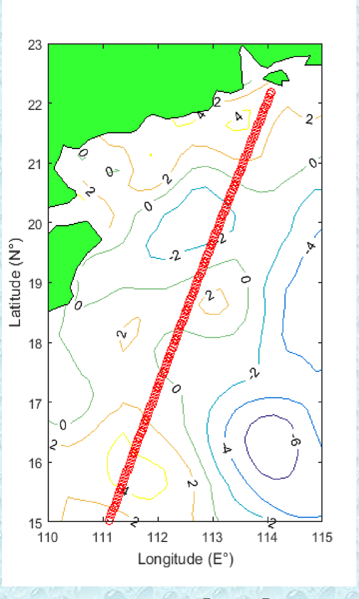
Ocean Tide: GOT family by Ray et al. & FES family by Lyard et al.

Sea State Bias: MLE3 SSB have many outliers which are often related to large off-nadir angle values. We always adopted MLE4 SSB in SLA computation, resulting in a relative bias <1cm for all retrackers.

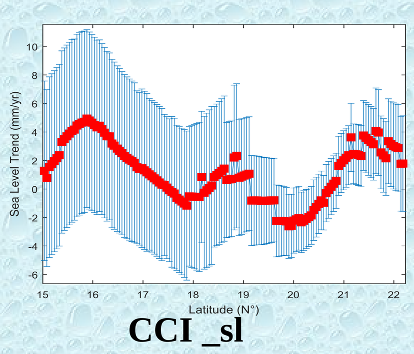
Data editing strategy: Median±3.52×MAD (more robust) & SLA<2m

RESULTS

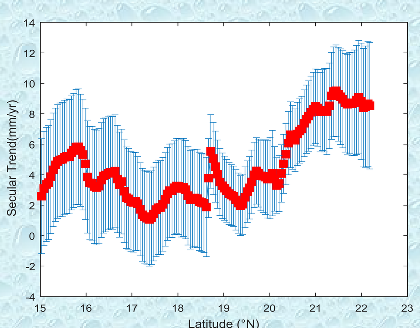
Regional trends (mm/yr) from ESA CCI_sl and XTRACK sea level data



CCI sea level trend map

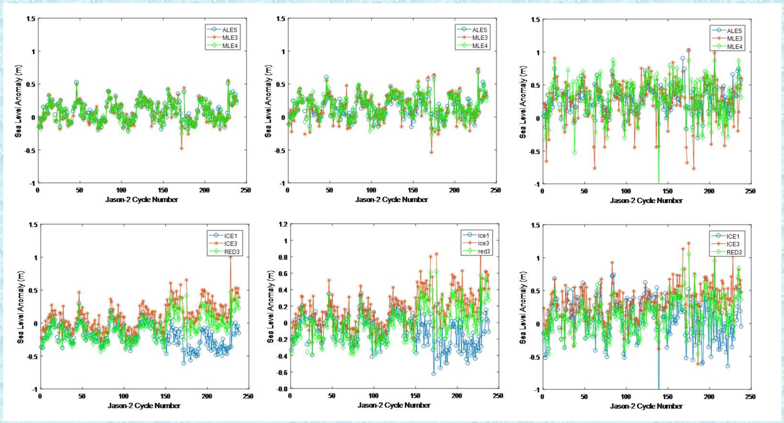


CCI _sl

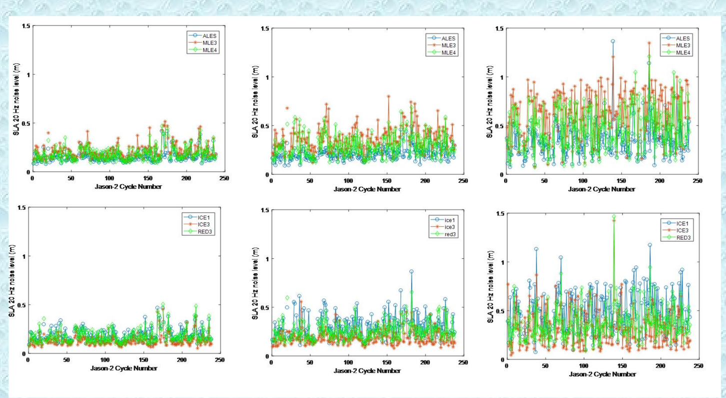


X-TRACK

Sea level time series for different retrackers



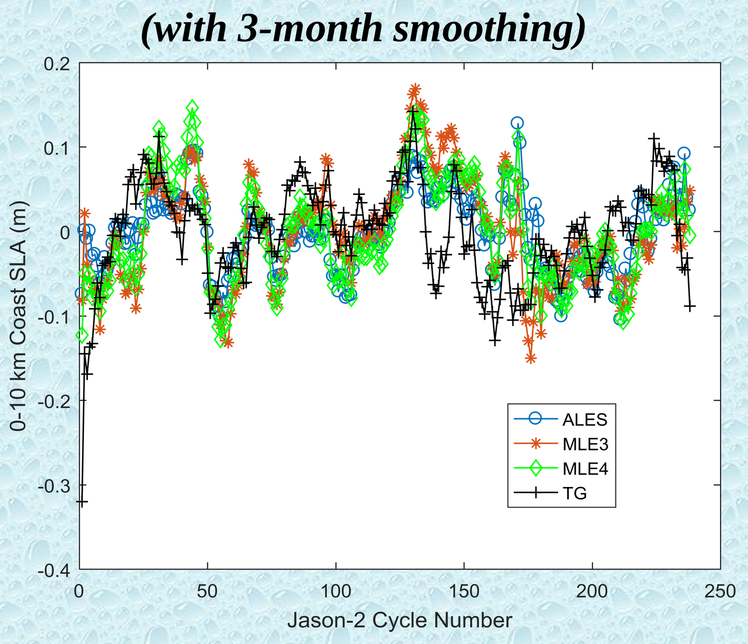
20Hz Noise Levels



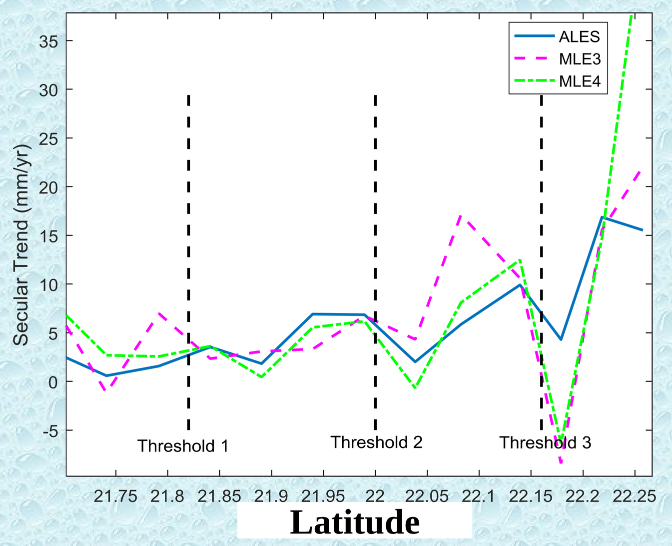
Estimated linear trend uncertainty (mm/yr)

Data source	Case 1	Case 2	Case 3
ALES	+5.7±3.7	+9.5±4.5	+16.9±6.6
MLE3	+4.8±4.1	+8.0±5.5	+2.7±9.5
MLE4	+4.0±3.8	+4.2±4.9	+6.2±8.5
ICE1	-29.4±4.2	-27.7±5.3	-22.2±9.8
ICE3	+57.7±4.7	+60.3±5.4	+54.3±7.9
RED3	+55.4±4.1	+58.0±5.2	+58.9±7.6
XTRACK	+10.3±4.5 (Raw); +8.5±4.2 (Filtered)		
Tide Gauge (in-situ reference)	*+8.3±5.1*		
Tide Gauge (After CVM correction)	*+8.6±5.1*		
CCI	+2.7±3.4		

Detrended sea level time series (with 3-month smoothing)



Along-track sea level trends for 3 retrackers



Standard deviation of the sea level differences with the Hong Kong tide gauge (in cm)

SLA series	ALES	MLE3	MLE4
Before 3-month smoothing	13.04	14.21	13.98
After 3-month smoothing	6.10	6.47	6.41

CONCLUSIONS

The three most advance coastal altimetry products for Jason-2 satellite altimetry (ALES, PISTACH and XTRACK) have been integrated for the first time. We considered six retrackers: MLE4, MLE3, ALES, ICE1, ICE3 and RED3 and computed Jason-2 sea level for each retracker over a 6.5 years time span offshore Hong Kong. 3 cases were considered, each covering different spatial scales. Case 2 is a good compromise between coherence and accuracy, and can best estimate sea level at the Hong Kong coast.

ICE3 and RED3 retrackers show surprising large jumps (~+0.2m) around Jason-2 cycle #150, preventing for further quantitative analysis. Despite the presence of large outliers in ALES sea level, after outlier-editing, ALES performs better than MLE4 and MLE3 both in terms of noise level and uncertainty in sea level trend estimation. In the near future, it will be highly beneficial to merge current ALES and X-TRACK products globally to get better sea level data in the coastal zones worldwide. With a 3-month smoothing, agreement between retracked altimetry and tide gauge sea level is within 6 cm, quite encouraging given the complexity of the study area. Another interesting result is that the retracked sea level trend within 5 km from the coast (in the range 8-9 mm/yr) is significantly larger than the open ocean trend, offshore Hong Kong (about 3 mm/yr).

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