Validation and use of operational coastal satellite altimetry observations for storm surges

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Abstract

The North Sea – Baltic Sea area is an ideal region for validation of coastal altimetry due to the dense network of tide gauge data, varied coastline and high natural sea level variability. Within the ESA DUE eSurge project, we have prepared for data assimilation of coastal sea level into the DMI hydrodynamic model for the North Sea – Baltic Sea area, focusing on storm surge situations (See poster 2-P-190 by W. Fu et. al.).

Standard along-track altimetry products have reduced quality closer than approximately 50 km from the coast, and are not available within approximately 10 km of the coast. Envisat data from the coastal zone has now been processed for a selected track in the North Sea/Baltic Sea. Here we investigate how to construct the high resolution sea level anomaly for coastal applications and validate the coastal altimetry products from the CoastAlt and eSurge projects against tide gauge data.

The coastal altimetry data will be used to develop a revised and operationalized version of our statistical sea level model (Madsen et. al. 2007) within eSurge.

Study area

- Dense network of tide gauges suitable for validation
- Varying coastline (flat or steep topography)
- Tides varying from a few cm to several meters
- Large natural variability
- Validated storm surge models

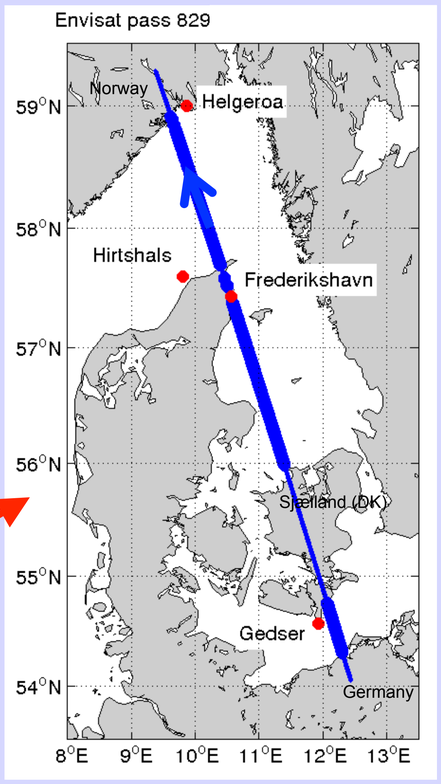

Figure 1. Left: Study area with tide gauges within the NOOS and BOOS networks. Right: Envisat pass 829 and 4 nearby tide gauges used for validation. The Gedser station lays about 15 km from the track, in an area with flat coastline and low tides. The closest altimetry data are about 9 km offshore.. The Frederikshavn station represents an area where the track runs parallel to the coast. The Hirtshals station is about 37 km from the track, and represents an area with shallow coastline and large natural variability from wind and tides. The Helgeroa station is about 18 km from the track, and represents an approach to the steep Norwegian coastline.

Data sources, processing and example

Our construction of sea level anomaly:

- Envisat pass 829.
- CoastAlt (Brown) and ALES retrackers with 18 Hz data, RADS 1 Hz data.
- Corrections as recommended for each product, except no ocean tidal correction or inverse barometer correction, and ECMWF wet tropospheric correction for RADS.
- Mean sea surface: CLS11 for ALES & RADS, interpolated GDR standard for CoastAlt.

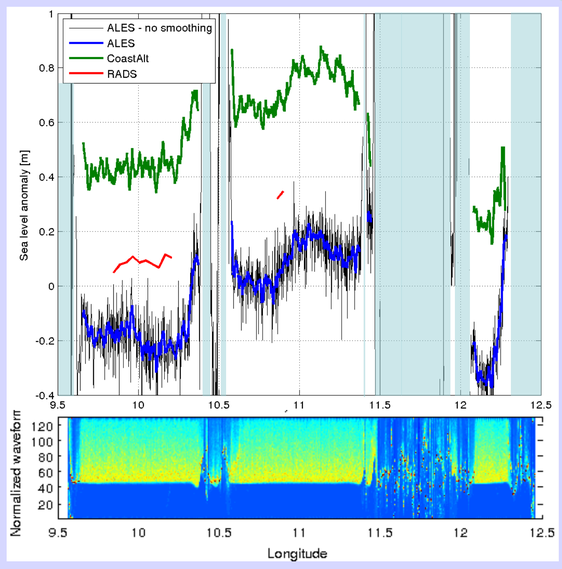

Figure 2. Top: example of sea level anomaly, Envisat cycle 27 for selected study area. Thick lines: cutoff distance 3 km from coast, 3 km smoothing, and spikes removed. Thin lines: no cutoff, smoothing, or spike removal. Shaded areas are on land.
Bottom: corresponding normalized waveform.

Mean sea surface

- GDR mean sea surface has a general offset of 50 – 80 cm.
- DTU10 and CLS11 differ with up to 20 – 30 cm in coastal regions.
- DTU10 shows large slope changes within 10 – 15 km of the coast.

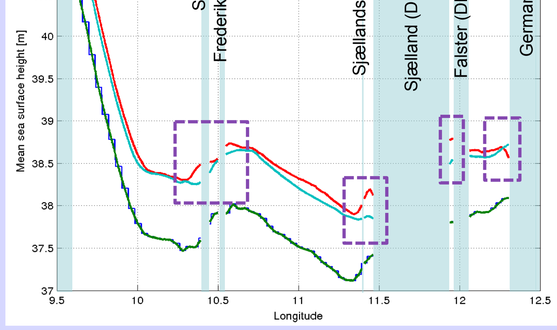

Figure 3. Mean sea surface products. Shaded areas are on land.

Distance to coast statistics

When examining the noise level of the altimetry data as a function of distance to the coast, we see that

- The standard deviation is approximately 0.2 m more than 5 km from the coast and is slightly improved with alongtrack smoothing.
- The standard deviation increases dramatically within 3-5 km of the coast, but with spike removal and alongtrack smoothing, data may be used until 3 km of the coast.

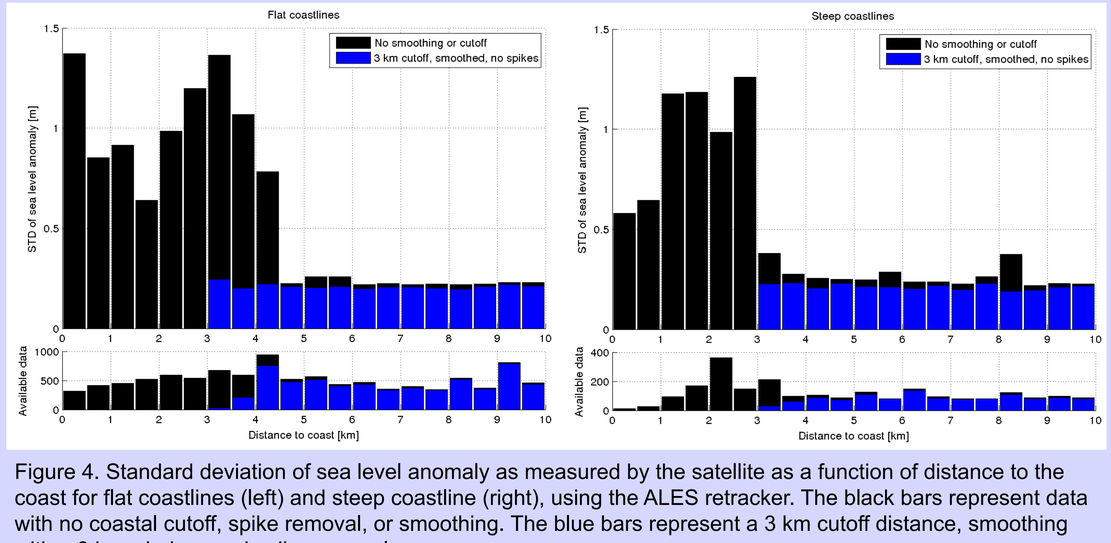

Figure 4. Standard deviation of sea level anomaly as measured by the satellite as a function of distance to the coast for flat coastlines (left) and steep coastline (right), using the ALES retracker. The black bars represent data with no coastal cutoff, spike removal, or smoothing. The blue bars represent a 3 km cutoff distance, smoothing with a 3 km window, and spike removal.

Validation against in situ data

When validating the altimetry data against tide gauge observations, we see that

- ALES is generally preforming better than the CoastAlt retracker within 10 km of the coast.
- The correlation coefficient decreases closer than 3-5 km from the coast.
- With along-track smoothing and spike removal, data can be used within 1-3 km of the coast. Use of the data closer to the coast requires individual processing of the data.

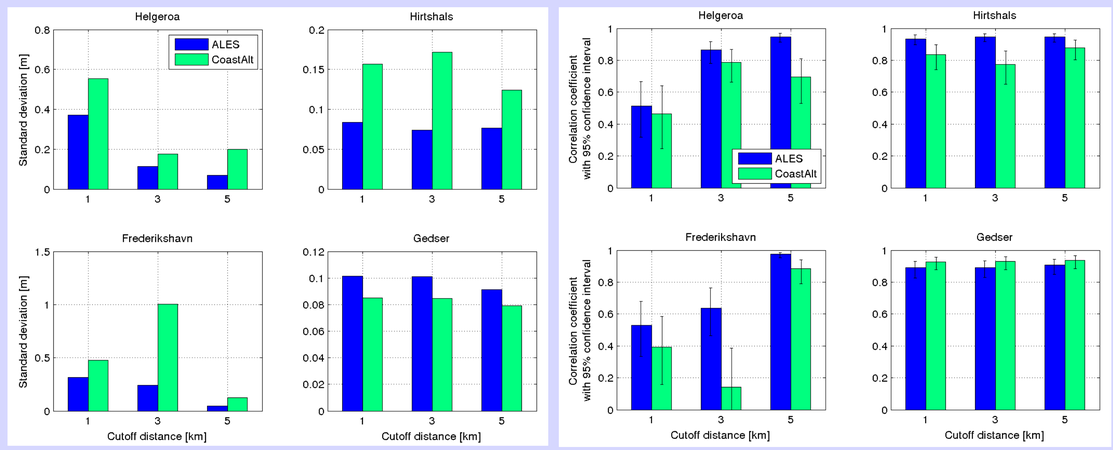

Figure 5. Standard deviation of the difference between in situ observations and the nearest available satellite data (left, note varying scale) and corresponding correlation coefficient with 95% confidence intervals (right) for the 4 tide gauges marked in figure 1. For each station, statistics are shown for the ALES and CoastAlt retrackers, using 1, 3, and 5 km cutoff distance to the coast for the satellite data. All satellite data have been smoothed with a 3 km window and spikes removed.

Future work

- We will validate Jason 2 data for the study area using Pistach and eSurge 20 Hz products.
- The coastal altimetry products will be used with the post processing methods developed here to improve our statistical sea level model, blending satellite and tide gauge observations. The model results will be available within the eSurge project for selected storm surges.

Acknowledgements

Satellite data were obtained from the eSurge and CoastAlt projects and the RADS data base. In situ data were obtained from DMI and Statens Kartverk / met.no.