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Evaluating coastal sea surface heights based on a novel sub-waveform approach using sparse representation and conditional random fields

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Satellite radar altimeters allow global monitoring of mean sea level changes over the last two decades. However, coastal regions are less well observed due to influences on the returned signal energy by land located inside the altimeter footprint.

The altimeter emits a radar pulse, which is reflected at the nadir-surface and measures the two-way travel time, as well as the returned energy as a function of time, resulting in a return waveform. Over the open ocean the waveform shape corresponds to a theoretical model which can be used to infer information on range corrections, significant wave height or wind speed. However, in coastal areas the shape of the waveform is significantly influenced by return signals from land, located in the altimeter footprint, leading to peaks which tend to bias the estimated parameters. Recently, several approaches dealing with this problem have been published, including utilizing only parts of the waveform (sub-waveforms), estimating the parameters in two steps or estimating additional peak parameters.

We present a new approach in estimating sub-waveforms using conditional random fields (CRF) based on spatio-temporal waveform information. The CRF piece-wise approximates the measured waveforms based on a pre-derived dictionary of theoretical waveforms for various combinations of the geophysical parameters; neighboring range gates are likely to be assigned to the same underlying sub-waveform model. Depending on the choice of hyperparameters in the CRF estimation, the classification into sub-waveforms can either be more fine or coarse resulting in multiple sub-waveform hypotheses. After the sub-waveforms have been detected, existing retracking algorithms can be applied to derive water heights or other desired geophysical parameters from particular sub-waveforms. To identify the optimal heights from the multiple hypotheses, instead of utilizing a known reference height, we apply a Dijkstra-algorithm to find the “shortest path” of all possible heights.

We apply our approach to Jason-2 data in different coastal areas, such as the Bangladesh coast or in the North Sea and compare our sea surface heights to various existing retrackers. Using the sub-waveform approach, we are able to derive meaningful water heights up to a few kilometers off the coast, where conventional retrackers, such as the standard ocean retracker, no longer provide useful data.