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ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters

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ABSTRACT

Water level from sea ice-covered oceans is particularly challenging to retrieve with satellite radar altimeters due to the different shapes assumed by the returned signal compared with the standard open ocean waveforms. Valid measurements are scarce in large areas of the Arctic and Antarctic Oceans, because sea level can only be estimated in the openings in the sea ice (leads and polynyas). Similar signal-related problems affect also measurements in coastal and inland waters.

This study presents a fitting (also called retracking) strategy (ALES+) based on a subwaveform retracker that is able to adapt the fitting of the signal depending on the sea state and on the slope of its trailing edge. The algorithm modifies the existing Adaptive Leading Edge Subwaveform retracker originally designed for coastal waters, and is applied to Envisat and ERS-2 missions.

The validation in a test area of the Arctic Ocean demonstrates that the presented strategy is more precise than the dedicated ocean and sea ice retrackers available in the mission products. It decreases the retracking open ocean noise by over 1 cm with respect to the standard ocean retracker and is more precise by over 1 cm with respect to the standard sea ice retracker used for fitting specular echoes. Compared to an existing open ocean altimetry dataset, the presented strategy increases the number of sea level retrievals in the sea ice-covered area and the correlation with a local tide gauge. Further tests against in-situ data show that also the quality of coastal retrievals increases compared to the standard ocean product in the last 6 km within the coast.

ALES+ improves the sea level determination at high latitudes and is adapted to fit reflections from any water surface. If used in the open ocean and in the coastal zone, it improves the current official products based on ocean retrackers. First results in the inland waters show that the correlation between water heights from ALES+ and from in-situ measurement is always over 0.95.

1. Introduction

Sea level is an Essential Climate Variable (ECV) regarded as one of the main indicators of climate variability (Cazenave et al., 2014). For more than 25 years, traditional measurements obtained by means of in-situ pressure gauges have been supported by the repeated global remotely sensed estimations from the radar signals registered onboard satellite altimeters. This has led to significant advancements in our knowledge of the seasonal and interannual sea level fluctuations (Vinogradov and Ponte, 2010; Ablain et al., 2016), of the regional distribution of trends in a changing climate (Palanisamy et al., 2015) and of the mid to large scales of geostrophic circulation (Pascual et al.,

2006).

The basic concept of this remote sensing technique considers the sea surface height (SSH) as the difference between the height of the satellite referenced to the earth ellipsoid and the distance (range) between the satellite centre of mass and the mean reflecting surface. The SSH has then to be corrected for instrumental, atmospheric and geophysical effects. For a full description of the corrections the reader is referred to Fu and Cazenave (2001). The progress of satellite altimetry has been fostered by the developments in orbit determination (Rudenko et al., 2014), in the corrections (Handoko et al., 2017) and in the range retrieval, based on the fitting of a functional form to the received signal in a procedure called retracking (Cipollini et al., 2017).

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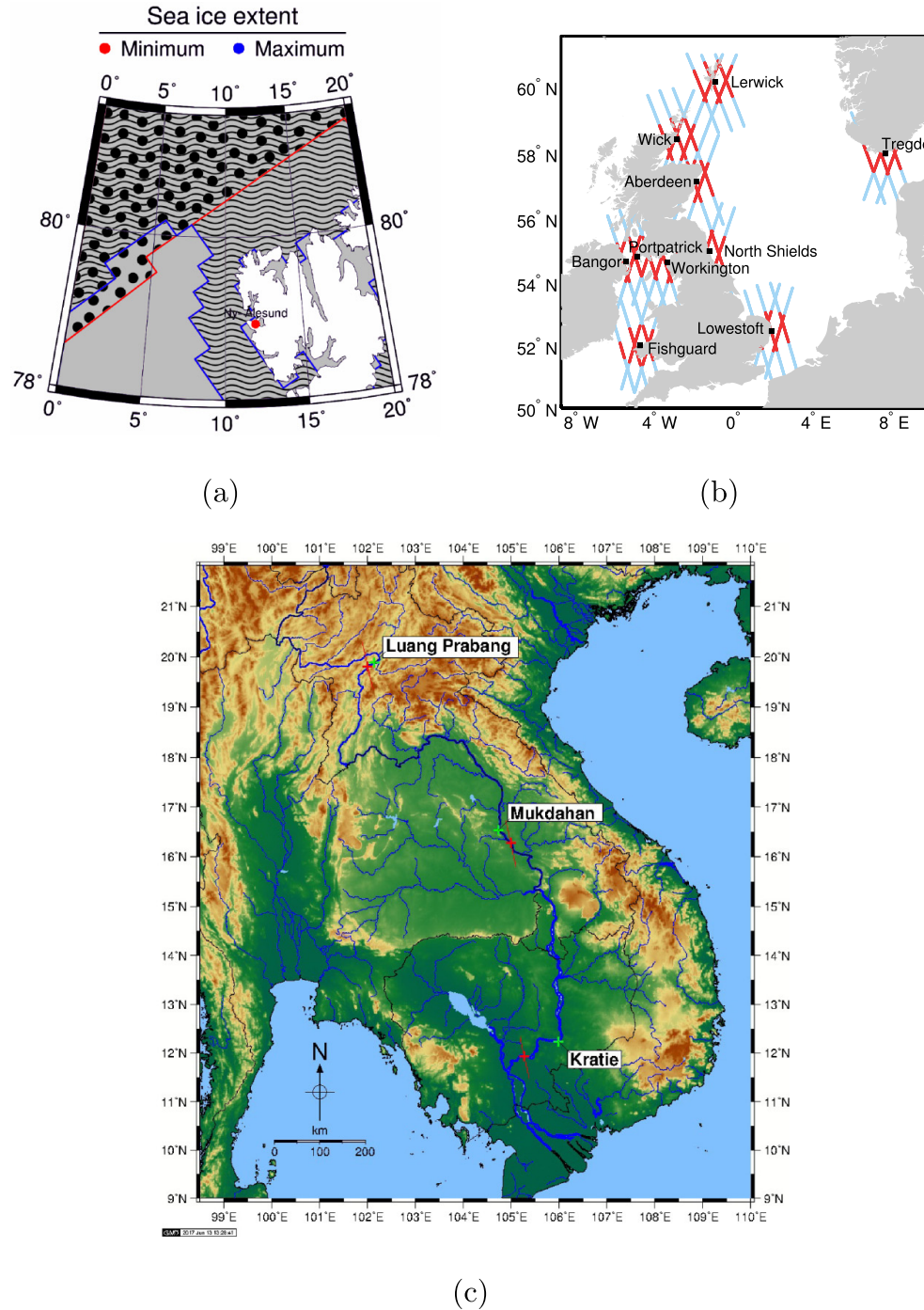


Fig. 1. (a) The Svalbard test area in the Arctic Ocean. The dotted area with red border is the minimum sea ice cover, while the wavy area with blue border is the maximum. The red dot indicates the location of the Ny Ålesund TG used for validation. (b and c) Location of the TGs used for coastal and inland waters validation and (red) along-track extension of nominal Envisat and ERS-2 tracks used for comparison with in-situ data.

The processing of the echoes sent by pulse-limited radar altimeters (i.e. every radar altimeter before the launch of CryoSat-2 in April 2010 and, more recently, Sentinel-3A) is well known in the open ocean, where the shape of the received signal resembles the Brown-Hayne (BH) model (Brown, 1977; Hayne, 1980) perturbed by Rayleigh noise (Quartly et al., 2001), characterised by a steep leading edge and a slowly decaying trailing edge. Departures of the received signal (also called ‘waveform’, a sampled time series whose resolution cell is called ‘gate’) from the BH shape are instead found in the presence of sea ice and in the proximity of land (i.e. both in coastal and inland waters)

(Boergens et al., 2016; Laxon, 1994b). The common feature is the presence of the so-called ‘bright targets’ or ‘hyperbolic targets’: points with a higher backscatter coefficient that perturb the expected shape travelling along the trailing edge as they appear in the illuminated area, eventually constituting the main leading edge.

These retracking issues, together with the degradation of some corrections in the same areas, have been a major impediment in expanding our knowledge of sea level variability in the coastal ocean and in the Arctic Ocean. These are regions of primary importance, since a growing number of people and infrastructures are located at the coast

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