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ScienceDirect

Advances in Space Research xxx (2018) xxx–xxx

ADVANCES IN SPACE RESEARCH
(a COSPAR publication)

www.elsevier.com/locate/asr

SAR Retracking in the Arctic: Development of a year-round retrackers system

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Received 21 January 2017; received in revised form 23 January 2018; accepted 25 January 2018

Abstract

Given its polar orbit, CryoSat-2 provides frequent, high-resolution SAR altimeter measurements of the Arctic region over changing terrain (*e.g.* ice, water and sea ice). The purpose of this research is to improve SAR waveform retracking in the Arctic region by analysing different retrackers on their performance in varying (Arctic) conditions and combine the positive behaviours into one optimal retrackers system.

Based on the accuracy and precision performance, four retrackers are evaluated in order to determine this retrackers system: the empirical primary peak centre of gravity, the primary peak threshold and the ESA retracker, as well as the physical SAMOSA3 retracker. Empirical retrackers determine the retracking point depending on the retrieved waveform statistics, while physical retrackers take the system characteristics, the geometry and the surface properties into account.

Three sea surface types are considered in this research: ocean, sea ice, and ice leads. For the majority of the months, SAMOSA3 has the highest accuracy for ocean waveforms as its physical full-analytic approach provides a good fit for the predictable ocean waveforms. The primary peak retrackers have the best precision performance for irregular waveforms like sea ice and ice leads.

The year-round retrackers system includes per month the most accurate retracker for ocean waveforms and the best precision retracker for sea ice and leads. To remove the bias caused by combining different retracking algorithms, four bias removal strategies are developed and evaluated on their accuracy and precision performance. The retrackers system with the primary peak centre of gravity as a basis retracker and a mean bias removal approach performed best, as it has a precision improvement of 47.1% with respect to retracking all waveform classes with the primary peak COG retracker solely. By applying the developed optimal retrackers system and using the bias removal strategy, the mean standard deviation of the altimeter measurements in the Kara Sea study area is reduced from 6.7 cm to 3.6 cm.

Keywords: CryoSat-2; Altimetry; SAR; Retracker; Waveform classification; Arctic; Ocean; Sea ice; Leads

1. Introduction

The primary instrument of CryoSat-2 is the Synthetic Aperture Interferometric Radar Altimeter (SIRAL), which consists of a dual antenna system operating in SARin, SAR and LRM modes. With its altimeter and polar orbit, CryoSat-2 provides frequent, high-resolution altimeter observations over different surface types (e.g. water, and sea ice) of the Arctic and Antarctic regions (ESA-UCL, 2012), which affects the performance of the altimeter (Stenseng, 2011).

A year-round Arctic retracking system has been developed that is able to cope with different terrains and seasonal behaviour leading to an increased performance of

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https://doi.org/10.1016/j.asr.2018.01.037

Please cite this article in press as: Schulz, A.-T., Naeije, M. SAR Retracking in the Arctic: Development of a year-round retrackers system. Adv. Space Res. (2018), https://doi.org/10.1016/j.asr.2018.01.037

sea surface height, ice presence and ice sheet thickness measurements. The research is split into three parts: waveform classification, retracker performance analysis and the development of a year-round retrackers system. For the waveform classification, the effect of different terrains on SAR waveforms has been investigated together with what parameters could be used to identify their characteristics.

Kurtz et al. (2014) provided a classification of lead waveforms based on their pulse peakiness. The classification of Arctic waveforms has been further investigated by Stenseng (2014), who additionally determined the characteristics of the waveform peak by applying a Gaussian distribution to it. This knowledge is used to also classify sea ice waveforms.

Two retrackers have been developed to cope with the irregular waveforms caused by sea ice and leads (Jain et al., 2015). The performance of those retrackers will be discussed and implemented in the year-round retracking system. Furthermore, Wingham et al. (2006) and Satellite Oceanographic Consultants (2015) developed retrackers to cope with irregular waveforms. A first analysis and comparison of those retrackers is done in Jain et al. (2014, 2015). Evidently, a good retracker performance is critical for obtaining reliable sea level data. In this research, the retrackers are analysed per waveform class, and the seasonal performance of retrackers is assessed.

In the final section, the development of a retracking system for the Arctic region is elaborated. When combining different retrackers into one comprehensive retracking system, a relative offset between the different retrackers sea level anomaly occurs, when switching from one retracker to the other. To remove this offset, appropriate bias removal strategies are used in order to have a coherent and consistent retrackers system for the Arctic region. Jain (2015) analysed a retracking system using a linear relationship of the significant wave height, SWH, to remove this relative offset. This analysis is extended here by considering different functions of SWH leading to, in total, five different bias removal strategies.

The CryoSat-2 data used in this research are the level 1B data available on the ftp server of the European Space Agency for the year 2011, at the time so-called Baseline B data. Furthermore, a study region in the Kara Sea is chosen, due to the high seasonality in this area, making it suitable for this research. Fig. 1 shows the study region indicated by the thick line as well as the location of the tide gauges used for the determination of the accuracy of the measurements.

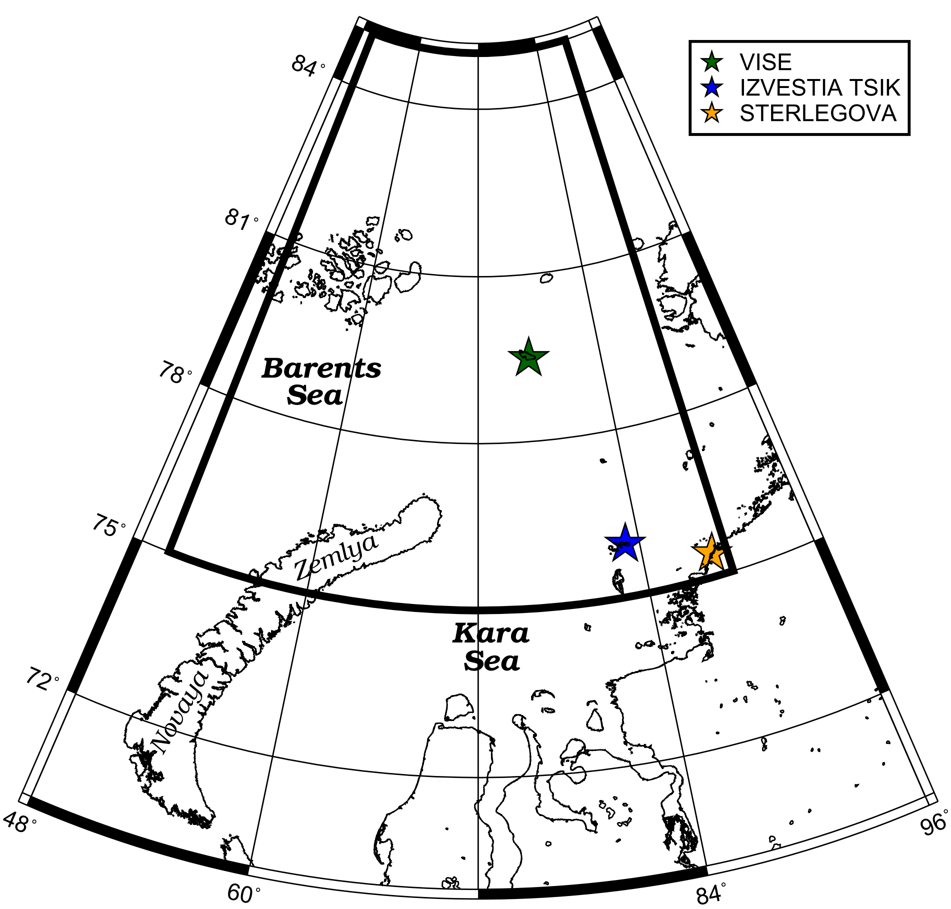

Fig. 1. The study region in the Kara Sea and the tide gauge locations (stars).