Validation of Jason-2 altimeter by waveform retracking over coastal ocean

Hyongki Lee[1], C.K. Shum[1], William Emery[2], Stephane Calmant[3], Xiaoli Deng[4,*], Chung-Yen Kuo[5], Carolyn Roesler[2], Yuchan Yi[1]

[1]School of Earth Sciences, The Ohio State University, Columbus OH
[2]Colorado Center for Astrodynamics Research, University of Colorado, Boulder CO
[3]IRD, LEGOS, Toulouse, France
[4]School of Engineering, University of Newcastle, New South Wales, Australia
[5]Department of Geomatics, National Cheng-Kung University, Taiwan, ROC
*Presenter

Abstract

We validated Jason-2 satellite altimeter Sensor Geophysical Data Records (SGDR) by retracking 20-Hz radar waveforms over the California coastal ocean using cycles 7-34, corresponding to September 2008–June 2009. The performance of the ocean, ice, threshold and modified threshold retrackers are examined using a reference geoid based on Earth Gravitational Model 2008 (EGM08). Over the shallow ocean (depth < 200 m), the modified threshold retracker, which is developed for noisy waveforms with pre-leading edge bump, outperforms the other retrackers. It is also shown that retracking can improve the precision of sea surface heights (SSHs) for areas beyond 2–5 km from the shore. Although the ocean retracker generally performs well over the deep ocean (depth > 200 m), the ocean-retracked SSHs from some of the cycles are found to be less precise when the waveforms do not conform to the Brown ocean model. We found that the retrackers developed for non-ocean surfaces can improve the noisy ocean-retracked SSHs. The ice retracker, among the retrackers tested here, overall provides the most precise SSH estimates over the deep ocean in average using cycles 7-34 in the study region.

Satellite Radar Altimetry over Coastal Ocean

The SSH measurements from satellite radar altimetry in coastal region can be corrupted not only by less reliable geophysical and environmental corrections (Chelton et al., 2001), but also by the noisier radar returns from the generally rougher coastal sea states and simultaneous returns from reflective land and shallow water (e.g., Brooks et al., 1997; Deng and Featherstone, 2006). Therefore, the altimeter range measurements over the coastal ocean must be corrected for the deviation of the mid-point of the leading edge from the tracking gate of the on-board tracker.

In recent years, a waveform retracking technique, which has been originally developed for altimeter measurements over ice sheet, has extended its role into coastal ocean to reprocess the altimeter waveform data and improve the poorly estimated SSHs (e.g., Brooks et al., 1997; Anzenhofer et al., 1999; Deng and Featherstone, 2006; Hwang et al., 2006; Bao et al., 2009). A recent review of waveform retracking methods can also be found in Lee et al. (2008a) and Gommenginger et al. (2009). The goal of this study is to determine the optimal retrackers among "ocean" and "ice" retrackers used in Jason-2 Sensor Geophysical Data Record (SGDR), and the original (Davis, 1997) and modified threshold retrackers (Lee et al., 2008b) over the California shallow (depth < 200 m) and deep (depth > 200 m) oceans, respectively. While we perform retracking using the original and modified threshold retrackers, we directly use the ocean- and ice-retracked measurements available in the SGDR. The quality of ocean-retracked SSHs in the SGDR is also examined over the deep ocean.

In this study, we use the Jason-2 SGDR (product version "T"), which contains 20-Hz 104-sample waveform data, from cycles 7-34 (September 2008 – June 2009). No editing criteria related to the Ku-band range measurements recommended in the Jason-2 SGDR handbook are used.

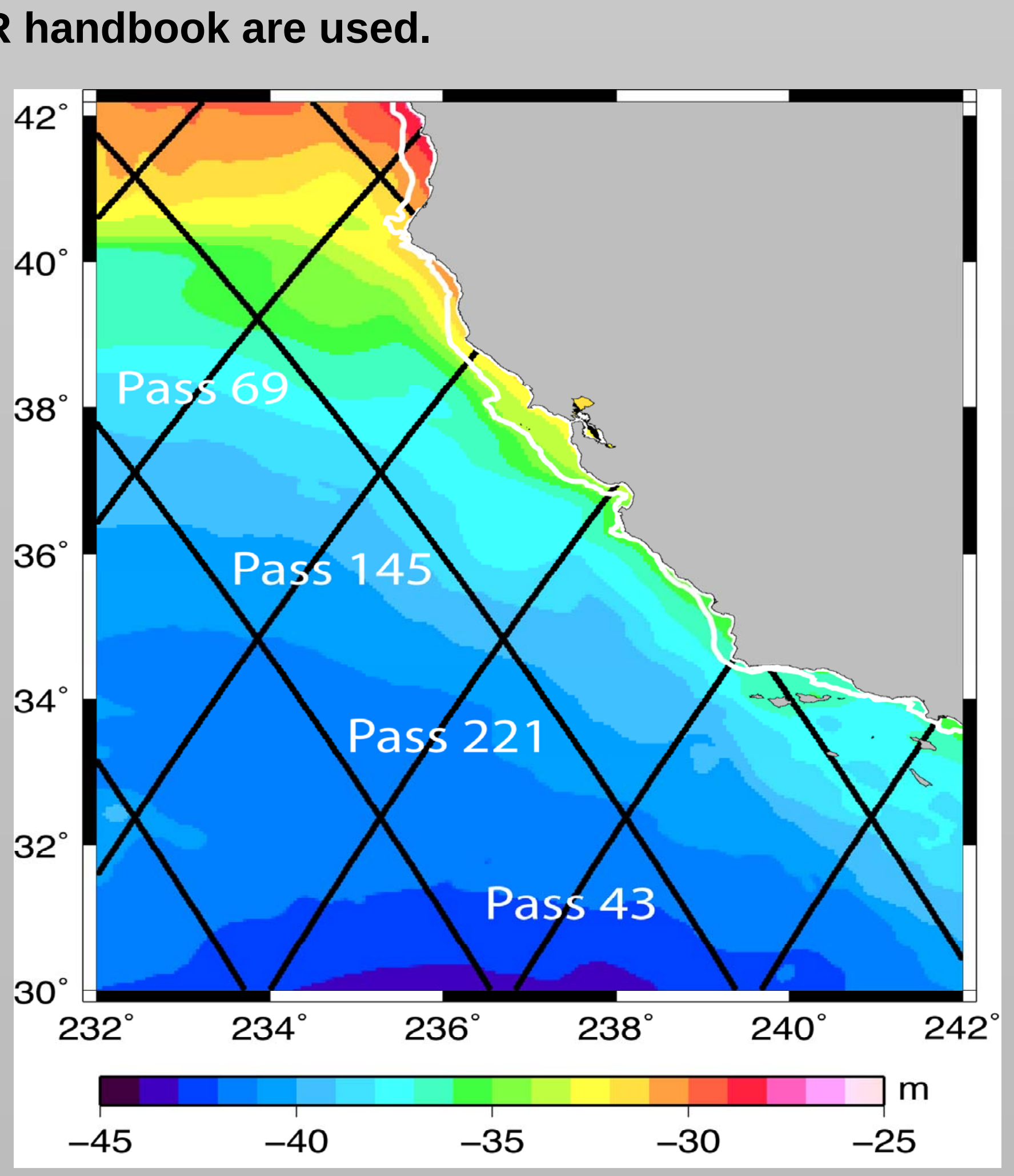

Figure 1 Study area with Jason-2 ground tracks over the California coastal ocean. We investigate the Ku-band radar waveforms along four ascending passes in this study. Background is the geoid computed using Earth Gravitational Model 2008 (EGM08), which is used as a reference to assess the performance of the retrackers. The white line along the coast represents a contour of ocean depth 200 m from ETOPO2.

Jason-2 Retracking over California Coastal Ocean

Figure 2 shows examples of the comparison of retracked SSHs using ocean (blue), modified threshold (black), original threshold (green), and ice (purple) retrackers with respect to the geoid (red) near the coast. It is clear that the ocean-retracked SSHs are generally unreliable and suffer from data loss when getting close to the coast. These examples show that the modified threshold retracker (Lee et al., 2008) can provide improved over the shallow ocean.

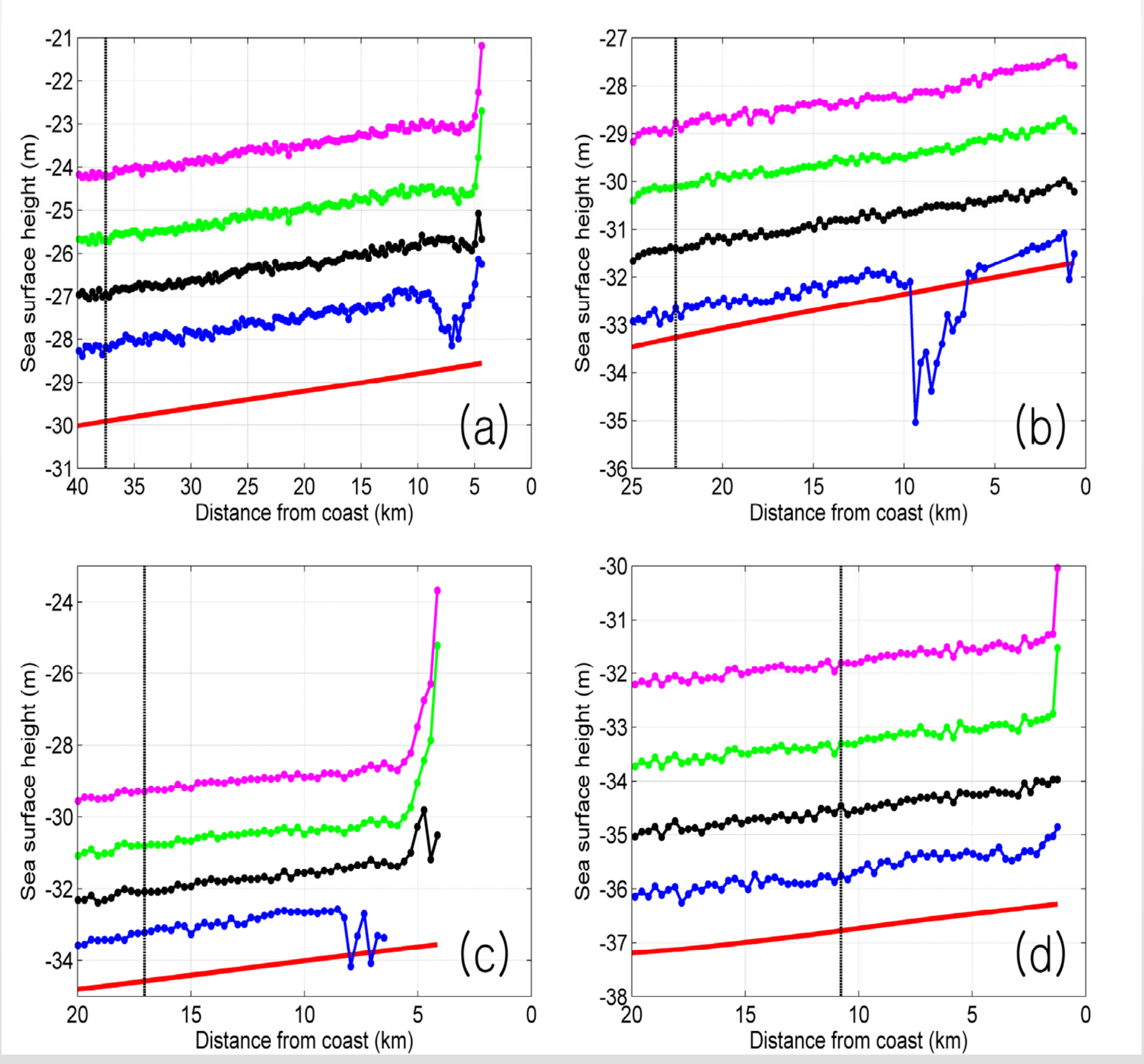

Figure 2 Retracked SSHs using (a) cycle 13 pass 69, (b) cycle 18 pass 145, (c) cycle 9 pass 221, and (d) cycle 32 pass 43. Dashed lines indicate the location where the ocean depth is 200 m. Arbitrary constants are added for visual clarity.

Figure 3 shows the retracked SSH profiles over the entire study area including the deep ocean from (a) cycle 34 pass 69, (b) cycle 33 pass 145, (c) cycle 13 pass 221, and (d) cycle 20 pass 43 as examples of noisy ocean-retracked SSHs. It can be seen that the ocean retracker (in blue) is less robust compared to the other retrackers along these passes, even several hundreds of kilometers away from the shore. It should be noted that these noisy ocean-retracked SSHs are mostly to be flagged based on the editing criteria ("range_rms_ku" or "alt_echo_type") as suggested by the Jason-2 (S)GDR handbook. The black rectangles in Figure 3 indicate the ocean-retracked SSHs that are to be edited out because their corresponding range_rms_ku values are larger than 0.2 m.

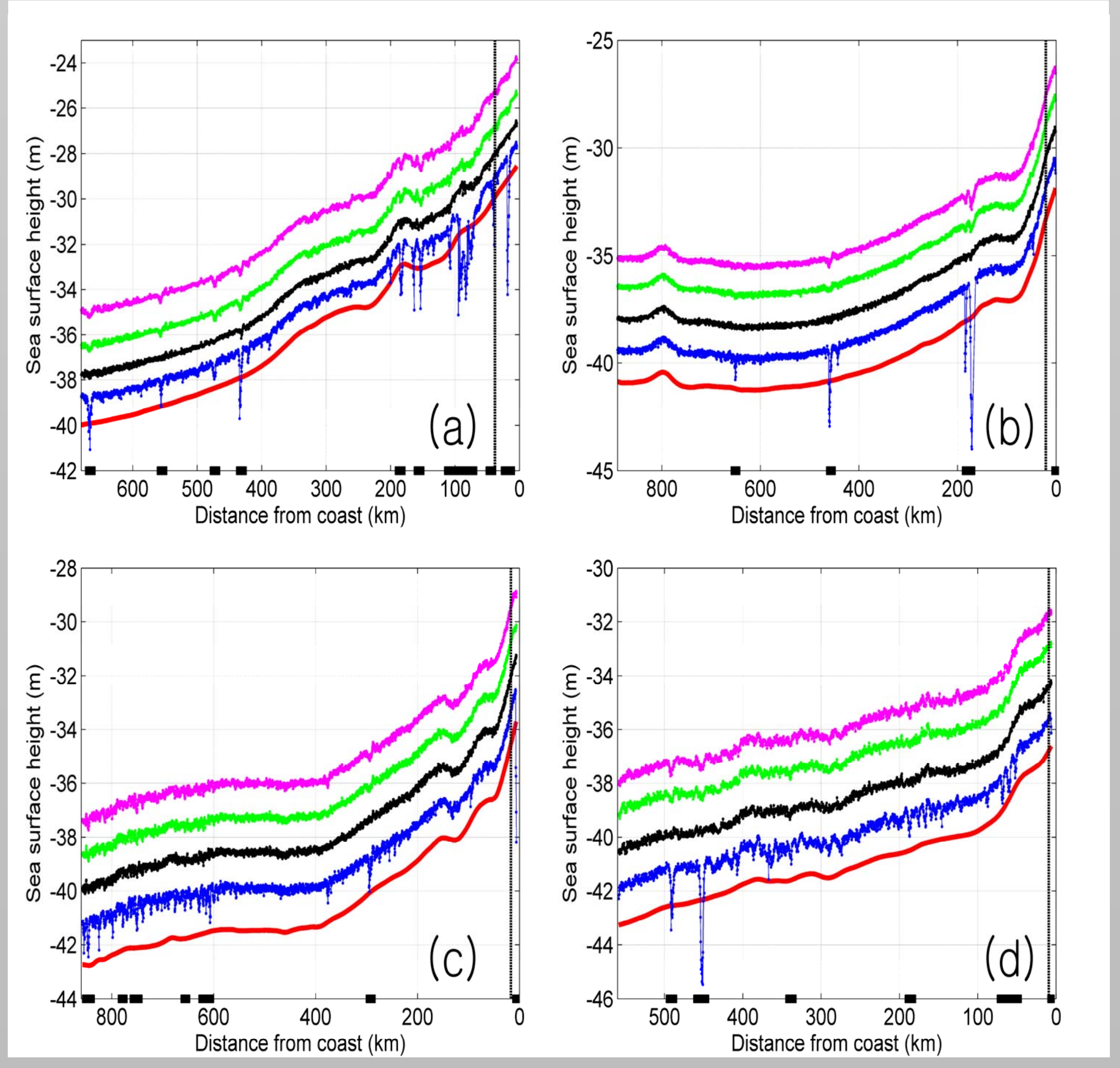

Figure 3 Rtracked SSHs using ocean (blue), modified threshold (black), original threshold (green), and ice (purple) retrackers with respect to the geoid (red).

Acknowledgements

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Jason-2 Waveforms over Deep Ocean

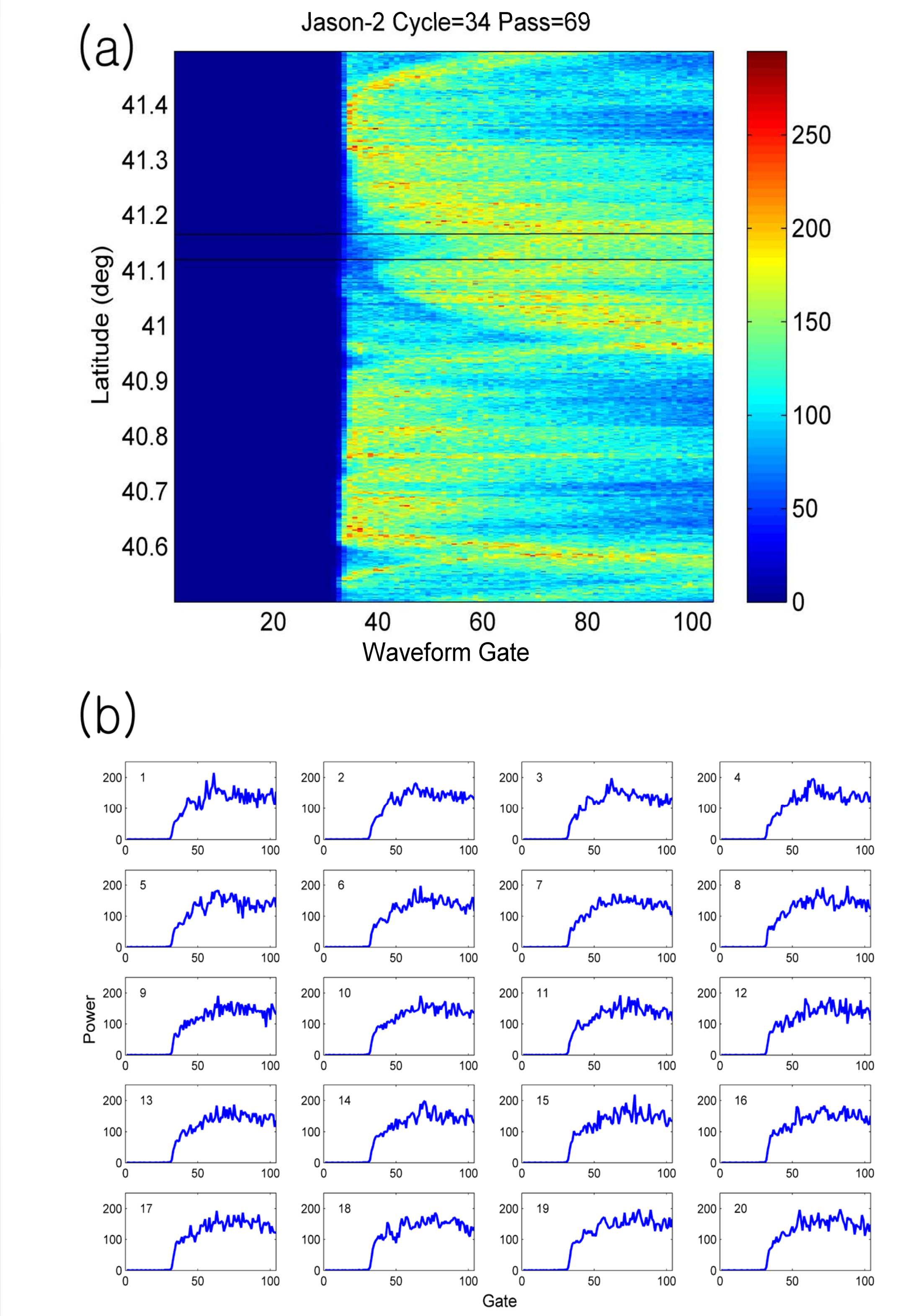

Figure 4 (a) Waveforms from cycle 34 pass 69. (b) waveforms over the region indicated with a black box in (a). The waveform sequence, numbered from 1 to 20, follows the satellite flight direction.

We further investigate the waveform shapes along these individual tracks. It is found that the problem of noisy ocean-retracked SSHs comes from the waveforms. Figure 4 illustrates the waveforms from cycle 34 pass 69. It can be seen from Figure 4(a) that some of the waveforms do not show distinct leading edge around the tracking gate 32. Examples of those waveforms in Figure 4(b) differ considerably from the ocean waveforms. They have a noisy leading edge or increasing returned power after the leading edge, which persists until around gates 70–80. Hence, these waveforms do not conform to the Brown ocean model, which is the physical basis for the ocean retracking algorithm, thus causing the erroneous SSH estimates. Over the deep ocean, ice-retracked SSHs show improvement (averaged Improvement Percentage = ~8%) over the ocean-retracked SSHs in average using cycles 7-34, while the other retrackers do not generally improve the precision of SSHs. This suggests that careful retracking of Jason-2 waveforms also has a potential, even over the deep ocean, to improve noisy SSHs which are to be edited out.

Conclusions

In this study, we evaluated Jason-2 SSHs retracked by the ocean, ice, original threshold, and modified threshold retrackers over the California coastal ocean attempting to extract precise SSHs from both land-contaminated and ocean-dynamics distorted coastal radar altimeter waveforms. Over the shallow ocean, the modified threshold retracker outperforms the other retrackers by providing more precise SSHs beyond 2-5 km from the coastline. This may also indicate the capability of Jason-2 to retrieve more precise SSHs closest to the coastline compared to TOPEX (Brooks et al., 1997) or ERS-2 (Deng and Featherstone, 2006). Over the deep ocean, the ocean retracker used in (S)GDR is less robust in estimating precise SSHs for some cycles due to the waveforms not conforming to the Brown ocean model. Those noisy ocean-retracked SSHs are recommended to be flagged according to the editing criteria in the Jason-2 (S)GDR handbook (OSTM 2009). However, the retrackers developed for non-ocean surfaces are tested to check if they can improve the SSH precision over the deep ocean. It is found that the ice retracker outperforms the ocean retracker when the return waveforms do not conform to the Brown model.

For more details, see Lee et al., Marine Geodesy, 33, 304-316, 2010