10.1117/2.1200908.1797

Bringing satellite radar altimetry closer to shore

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A new signal processor can retrack waveforms in coastal areas and facilitate retrieval of accurate sea conditions.

Almost half of the world's population lives within 50km of the sea and exploits its resources through tourism, fishing, aquaculture, or industry. However, only a few countries have created effective in situ sea-level monitoring systems to base policy decisions on. For most of the global coastline, satellite-based observations may be the only reliable source of information. Exploiting radar altimetry close to the shore requires reprocessing high-rate ocean-return signals (averages of 100 individual radar echoes) in the final 10km between the open ocean and the shoreline. We achieve this using a 'retracking' data-retrieval algorithm, adapted to coastal-zone conditions.

Within coastal zones, climate-change effects can have a wide range of impacts, including many serious consequences due to rising sea levels (a crucial climate parameter monitored globally on the basis of satellite altimetry). Altimeters also sense the sea's state, providing along-track measurements of wave height and wind speed. Importantly, however, satellite altimetry—which has been generating a global record of sea-level changes for the past 17 years—does not cover coastal zones, so the technique is not exploited to its full potential.

In open-ocean regions, 1Hz observations (corresponding to approximately 7km along-track resolution) are usually sufficient, but the user can also access the original, highest-rate measurements (10–20Hz, which corresponds to ∼0.35–0.7km separation). The latter capture smaller spatial scales than routinely used. Space agencies usually provide processed data using a strategy optimized for open-ocean exploitation, but this is not always appropriate for coastal zones. Original-data retrieval is then required to address a range of problems, including proximity of land, seabed control, and rapid variations caused by tides and atmospheric effects. Figure 1 shows the Envisat satellite's ground-track coverage in the northwestern Mediterranean. The track segments outlined by ellipses show when the satellite

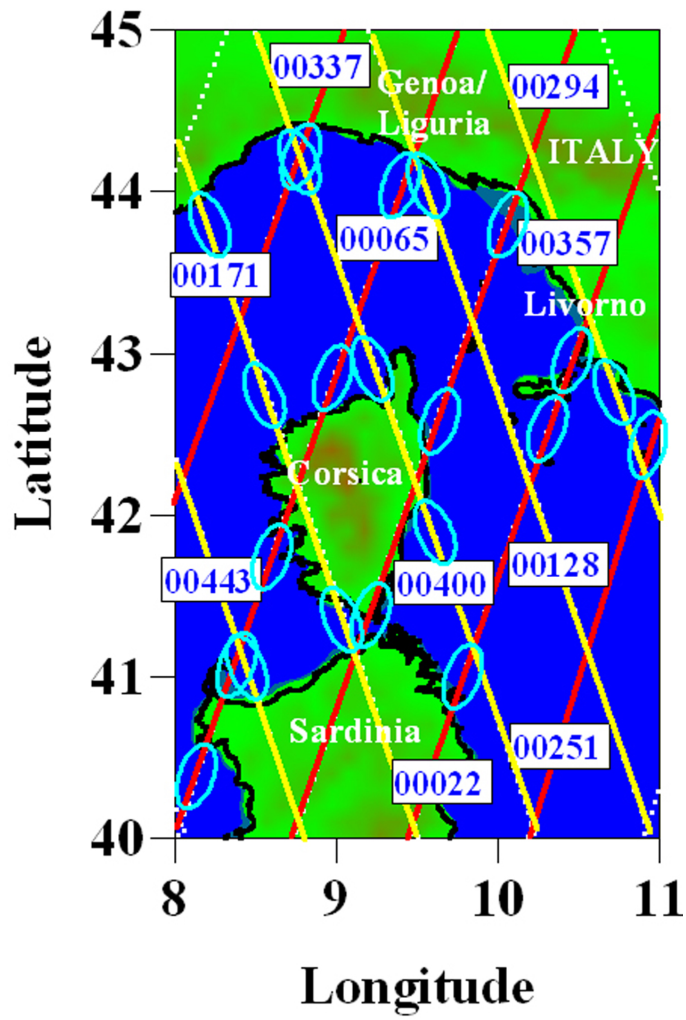

Figure 1. *Northwestern Mediterranean with Envisat radar-altimeter dual-frequency (RA-2) coverage with ascending (yellow) and descending (red) orbits. The relative orbit numbers are shown, while ellipses indicate the coastal areas of interest.*

is positioned over the continental shelves and shelf slopes. Reprocessing must start there to ensure that coastal-altimetry data

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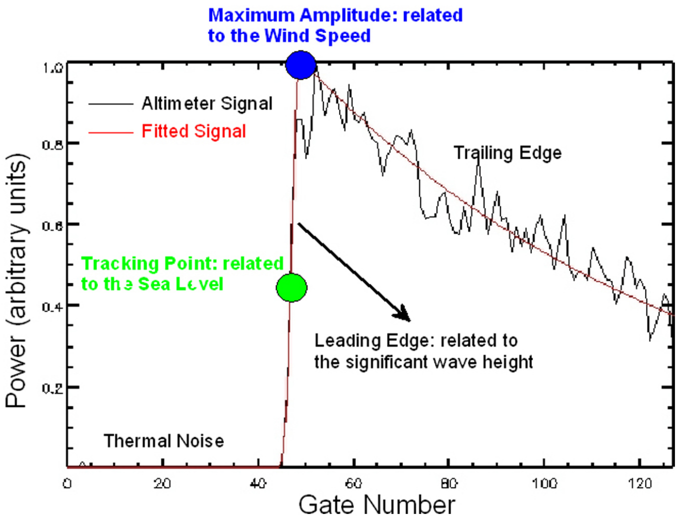

Figure 2. *18Hz RA-2 ocean signal (black) and best-fitting signal after retracking (red).*

can be used as a seamless extension to the currently available open-ocean product.

Altimeters record radar signals that are bounced back from the ocean surface. However, these are of no use until they have been calibrated and validated by comparison with in situ sensors. The latter are usually located near coasts. While improved postprocessing strategies using new corrections can increase the amount of usable data,[1] in the 10km closest to the shore only reprocessing of the raw radar echoes can effectively increase the volume of exploitable altimeter measurements.

By reprocessing the Sensor Geophysical Data Records, the European Space Agency's (ESA) COASTALT project[2] has been producing a global coastal dataset at a resolution of approximately 350m along-track since the beginning of the Envisat mission. COASTALT will also work toward resolving the problem of retracking in coastal zones by developing and demonstrating new algorithms over a range of testbed areas. Retracking fits a specific model to the native (e.g., 18Hz for Envisat) ocean-return signals to retrieve geophysical information from the shape of the measured signal, such as range (distance of the satellite's center of mass from the surface), 'significant wave height,' and wind speed (see Figure 2).

As part of COASTALT, we have developed a new, robust retracking approach to reprocess Envisat's radar-altimeter dual-frequency signals. We aim to retrieve accurate, physical ocean parameters from the shape of the radar waveforms—even in coastal zones—with the same precision as achieved in the open ocean. Our new algorithm consists of two functional units, a baseline processor and a user-defined coastal geophysical-

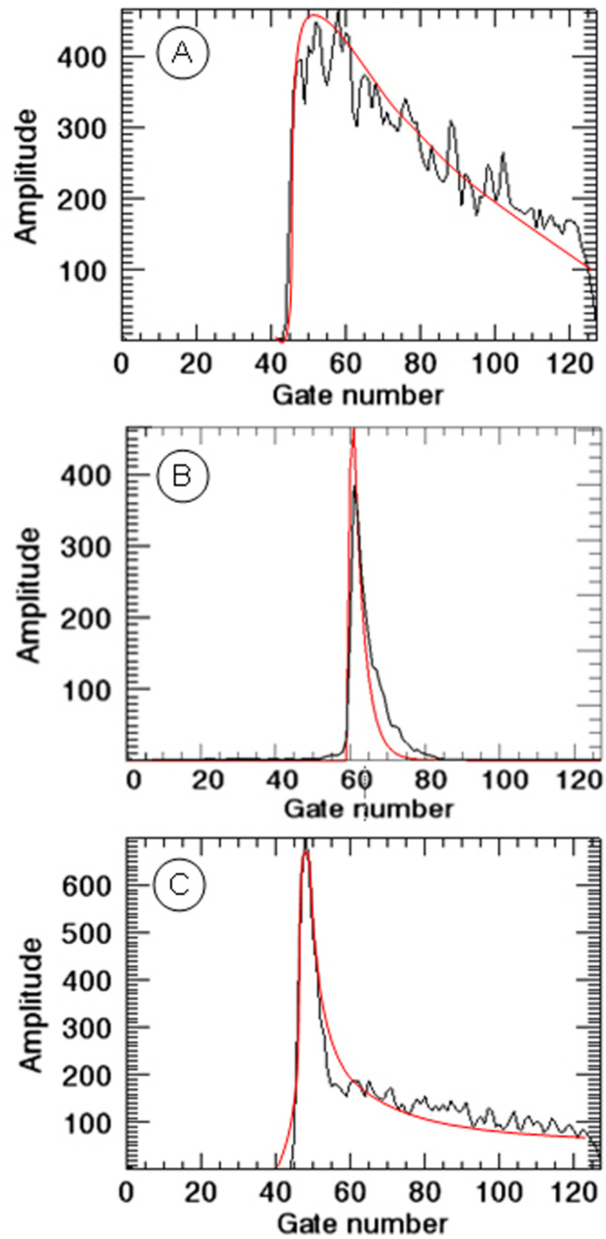

Figure 3. *(a) Brown-type RA-2 signal (black) and best fit after retracking (red). (b) Specular signal (black) and best fit (red). (c) Combined Brown and specular signal (black), and best fit (red).*

corrections module. The processor implements three physical waveform-retracker models that are running in parallel. These include a Brown-type theoretical ocean retracker, which is designed to reprocess signals from a uniform sea surface:[3] see Figure 3(a). In addition, the models contain a specular

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β-parameter retracker with exponential trailing edge,[4] shown in Figure 3(b), and an experimental mixed Brown-specular retracker: see Figure 3(c). The latter aims to retrack coastal waveforms, which display a specular peak embedded within a Brown-type ocean waveform, as is typical for coastal areas. The realistic representation of waveform data across the land/sea boundary demonstrates the potential for geophysical-parameter retrieval much closer to the coast than routinely achieved.

Without specialized retracking, altimeters cannot properly measure sea levels when there is any land within their footprint, because land and sea echoes are mixed and lead to confusing results. Thus, none of the sea areas within 10km of continental coasts, islands, or atolls are accurately covered by routine processing of altimeter data. In areas with a high island density, such as the Indonesian archipelago or the West Indies, the area without usable data covers distances up to several kilometers around each island, resulting in substantial exclusion zones for sea-level measurements. Retracking enables extraction of useful data and helps agencies and scientists to improve data calibration and provide more realistic sea-level scenarios, respectively. We are working on a variety of techniques to optimize this extraction of useful information from altimeter data near the coast. This will require development of innovative retracking techniques, using a model incorporating both standard ocean returns and additional bright or weak targets corresponding to reflections from land surfaces. We will then apply such techniques to all coastal environments and make the improved data publicly available.

This article has been provided in the framework of ESA's COASTALT project (contract 20698/07/I-LG).

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