Challenges in Coastal Satellite Radar Altimetry

Second Coastal Altimetry Workshop; Pisa, Italy, 6–7 November 2008

A growing number of coastal observing systems are incorporating altimeter data. This requires new methods to reduce errors caused by land in the radar footprints and inaccuracies in atmospheric and geophysical corrections near land.

These issues are being addressed in individual research projects and by two major European initiatives. COASTALT (funded by the European Space Agency (ESA)) is developing processing tools for retrieving along-track altimeter data from the Envisat satellite in coastal regions, while Prototype Innovant de Système de Traitement pour l'Altimétrie Côtière et l'Hydrologie (PISTACH, funded by Centre National d'Etudes Spatiales (CNES), France) is doing the same for data from the Jason 1 and 2 satellites. To coordinate these efforts, a second workshop on coastal altimetry was held in Italy to review progress since the first workshop (see W. H. Smith et al., *Eos, 89*(40), 380, 2008). The second workshop was sponsored by ESA and CNES together with Consiglio Nazionale delle Ricerche (Italy) and the National Oceanography Centre, Southampton (United Kingdom). Seventy-eight participants from 16 countries attended this workshop.

Key findings from the workshop are as follows:

1. Reprocessing of the high-rate (20 or 18 hertz) ocean return signals, known as waveforms, is needed to recover the sea surface height (SSH) signal in the last 10 kilometers next to the coast. SSH is recomputed through a procedure called retracking, i.e., fitting a specific model to the raw waveforms, which also yields estimates of the wave height and wind velocity. Coastal retrackers should give better accuracy and precision than generic deep-ocean retrackers.

2. Farther from the coast, the wet tropospheric correction is a main source of error. Strong gradients in water vapor across atmospheric fronts near land produce changes in path delay equivalent to several centimeters over 20–50 kilometers, which must be corrected.

3. Large errors in tidal models also remain a problem. Coastal tidal models are improving, but these require detailed bathymetric data. The same considerations apply to models used to correct for high-frequency atmospheric effects such as winds and changes in atmospheric pressure. There is a need for coastal bathymetry with horizontal resolutions of at least 1 kilometer (preferably 200 meters), from the 200-meter isobaths to the coast.

4. The ionospheric correction is affected when the C-band (or S-band) footprint of the altimeter "sees" the coast prior to the Ku-band.

5. The correction due to the presence and shape of surface waves, known as sea state bias, is also a concern, although not the greatest error source.

6. Data products, systems, and services must be driven by usage. A dedicated effort should be made to provide for "less expert" users, possibly via regional centers.

The workshop also included a discussion of upcoming radar altimeters which are expected to contribute significantly to coastal altimetry and retracking at the land/sea interface, including (1) the delay-Doppler altimeters on board ESA's CryoSat 2/Sentinel 3 and (2) the AltiKa altimeter on the joint Indian Space Research Organization/CNES Saral mission. Participants agreed that continued support is needed for coastal altimetry and the transition to operational systems.

Workshop presentations and a final summary report can be found at http://www.coastalt.eu. Final recommendations can be also found in the electronic supplement to this Eos issue (http://www.agu.org/eos_elec/).

A third workshop on coastal altimetry will be held in September at the ESA Center for Earth Observation (ESRIN), Frascati, Italy (http://www.congrex.nl/09C32/).

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Supplementary material to “Challenges in Coastal Satellite Radar Altimetry”

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Recommendations from the workshop sub•topics (sessions at the workshop):

1 – USER REQUIREMENTS

The community recommends that the user list be broadened to include users who may not be aware of altimetry as a potential solution to their daily tasks in coastal oceanography, as well as present altimetry users.

The community recommends that outreach and community building presentations be made at major conferences such as AGU, EGU, etc., along with regional venues of opportunity, to inform and get feedback from a wide range of potential coastal altimeter data users.

The community recommends that at the 3rd Coastal Altimetry Workshop (Frascati, Italy, 16•18 Sept 2009), selected representative users with coastal applications be invited to the ‘showcase’ part of the event.

More specifically on product requirements (see also session 5):

- One clear need is the standardization of the data format (NetCDF or other).
- The standardization of data products is not recommended yet given the very wide range of possible applications.
- A clear explanation of the new/updated quantities in the coastal products like those from COASTALT and PISTACH must be provided to the users and potential users

2 – RETRACKING

The community agrees that the retracking of coastal altimetry data requires higher resolution coastlines and land DEMs than available currently from global models, and therefore recommends that better global coastlines and DEMs should be provided. Alternatively, local hi•resolution DEMs should be used where available. Coastal retrackers should be applied over an area with sufficient overlap with open• ocean retrackers, not just within few km from coast. This will allow users to assess their performance, analyze the transition between deep and coastal ocean regions, allow a careful evaluation of biases and thus ‘inspire confidence’. Coastal retrackers should be intercompared and compared against data on test sites. These include sites with the availability of accurate DEMs, along with fields of SSH and SSH gradients derived from glider and/or HF radar data.

3a – CORRECTIONS: WET TROPOSPHERIC

Requirements on the wet tropo path delay are identical as for the open ocean or even more stringent, because of shorter•scale atmospheric phenomena in coastal regions, producing changes in path delay equivalent to several cm over 30' / 50 km. Three main methods are being developed: (I) dynamic extrapolation methods, using high•resolution atmospheric models; (II) GNSS measurements of ZTD (Zenith Total Delay) (and met correction to ZWD — Zenith Wet Delay) and (III) land decontamination method. Continue focused efforts on this correction, which is the main source of error but shows very encouraging developments. Validation of the new techniques is a priority. Future missions should include radiometers with higher spatial resolution (standard frequencies with larger antennas or higher frequencies around 183 GHz). They should also consider scanning radiometers for swath altimeters and/ or radiometers with nadir + far side focal points.

3b – CORRECTIONS: IONOSPHERIC

While the Total Electron Content (TEC) is not affected by land/ocean transitions, the dual•frequency ionospheric correction is affected by the coast: the C•band (or S•band) footprint of the altimeter “sees” the coasts earlier than the Ku•Band footprint. The DORIS Beacon network coverage appears not to be dense enough to include all coastal areas; moreover research on this system has stalled on the last 10 years. And GPS•derived GIM models have been shown to represent the TEC more accurately, but they will have problems during periods of high solar activity in the normal 11•year solar cycles. GIM maps should be used over DORIS (especially during high solar activity). Space agencies should promote further work on this important contribution.

3c – CORRECTIONS: TIDES

Recent progress has been made with global and coastal modelling (GOT 4.7, EOT08a), including developments in advanced assimilation techniques. There are issues to do with high•resolution needs (short tidal wavelengths) and major omission errors (a limited number of constituents) for coastal tides, where errors are ~10•20 cm. The community recommends that better fields of global coastal bathymetry be made available. These should have horizontal resolutions of at least 1 km, and preferably 200 m or 0.1 nautical miles, from the 200 m isobath to the coast. Higher resolution will still be needed in particular areas where nested tide and surge models are required e.g. large estuaries.

3d – CORRECTIONS: HF/IB

The first recommendation is the same as in 3c — we need better global coastal bathymetry with higher horizontal resolution (at least 1 km and preferably 200 m or 0.1 nautical mile resolution, from the 200 m isobath to the coast). Higher resolution will still be needed in particular areas where nested tide and surge models are required e.g. large estuaries. We also recommend that a compilation of outputs from local models is made available, as also suggested by GOOS.

4 – WAVES AND SEA STATE BIAS

Need for more modelling:

- Invite wind/wave modellers to improve our understanding of wave physics in coastal regions.
- Enhance empirical knowledge through non•satellite•based (tower) experiments.
- Theoretical EM•bias modelling is important, but it will not address tracker bias issue which needs focused work. Better bathymetry is needed for coastal wave modelling aiming at inter• comparison with altimeter SWH estimates •preferably 200 m or 0.1 nautical mile resolution.

5 – DATA PRODUCTS, QUALITY AND DISSEMINATION

- Data must be simple to use — users will not invest time understanding complex products
- The current generation of products are for ‘expert users’, who then will need to recommend higher•level products
- Data need to be available on demand. We need the capability to generate tailored regional products; and the processing route must be traceable
- Data must contain, or link to, more complete metadata, including:
    - Data sources, references and algorithms
    - Quality Assessments

6 – SYNERGY WITH OTHER DATA AND MODELS

Users have started already to adopt altimetry (even if not specifically processed for coastal regions) in their coastal applications, and in many cases are eager to get data of higher quality (see also section 1). Altimeter + Tide Gauges can provide continuous alongtrack SSH to the coast. Alongtrack SSH and crosstrack geostrophic velocity may resolve positions of alongshore fronts and jets with offshore scales of 10+ km. We need further investigation of this and research on methods for computing gridded SSH and velocity fields from the alongtrack and ancillary data. Possible improvements are to add scatterometer wind Ekman components to produce total surface velocities, combine with MCC and Coastal Radar Surface Velocities, assimilate into coastal models. These combinations are needed to resolve features with shorter time scales: filtered tide gauge and model time scales are ~ 2+ days, while altimeter alone time scales are 20+ days. A community•wide effort should be made to integrate forthcoming coastal altimetry products into observing systems and other applications, quantifying the improvement resulting from the addition of the coastal altimetry data.

7 – FORTHCOMING TECHNOLOGIES

A number of technological developments in current and forthcoming altimetry missions can contribute to the improvement of coastal altimetry. These include:

- Progress on altimeter trackers at land/sea as well as sea/land transitions.
- Continuing evolution of wide•swath concepts.
- Data from confirmed missions i.e. the new Delay•Doppler Altimeters on Cryosat/Sentinel3 (for which no disadvantages were identified except nadir•viewing only) and Alti•Ka expected in near future.

We need better (possibly more quantitative) definitions of end•user requirements to drive future mission and instrument designs. There are different requirements for different applications, e.g. NRT near•shore significant wave height is only conceivable with constellations of nadir•viewing altimeters. Future missions should have better on•board DEMs.

8 – INTERNATIONAL COOPERATION

Space Agencies must to ensure that instrument information is available to all Coastal Zone data processors. For instance see AVISO documentation and RA-2 Product Control Service.

Space Agencies should disseminate waveform products in NRT (ftp).

We need to make provisions for merging all the data from future missions CryoSat, Altika, etc. into a single archive.

We need to deliver findings to other groups and conferences, like GODAE follow•ons, OceanObs'09, EGU, AGU, COSPAR (see also section1). We especially need two•way interactions (workshops, short courses, etc.) with those working in coastal fisheries, search and rescue, navigation, hazardous spills,

harmful algal blooms, etc., to educate altimeter experts on the needs of the users and to educate the users on the capabilities of altimetry (and other remotely sensed fields).

We need sustained capacity building effort in countries like India, China, Africa, South America, etc. (ALTICORE•India and ALTICORE•Africa are good examples).

The whole Group is encouraged to make further recommendations for Coastal Zone Oceanography on:

- Operating modes (e.g. Cryosat)
- Tracking mode (Jason•2)
- Phasing of flying formation

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