Summary of 2nd Coastal Altimetry Workshop, Pisa, Italy, 6-7 November 2008[1]

The Workshop was attended by 78 participants from 16 different Countries on five continents. The Coastal altimetry community has a clear international profile and coordination is sustained at the moment by the ESA COASTALT Project via the COASTALT-SWT mailing list. The two workshops held so far have been possible thanks to an effort by CIOSS and NOAA for the first workshop and by a joint CNR/NOCS/ESA/CNES action for the second workshop.

The findings and recommendations summarized in this report integrate those from the 1st Coastal Altimetry workshop available at:
http://www.coastalt.eu/pisaworkshop08/supplementary-EOS-WS-first-coastal-altimetry-30-sep-08.pdf

The first (and overall) recommendation is that the agencies should provide resources to sustain research and product development into coastal altimetry in the future, and support its transition to operational status as happened to open-ocean altimetry. Support for coordination of the community should also be provided, as crucial to progress in this very interdisciplinary field. A COST Action proposal has recently (Sept 2008) been submitted to secure that support, and following feedback from reviewers will be resubmitted in early 2009.

Findings and 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).

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[1] Collated by Paolo Cipollini and Stefano Vignudelli, with contributions by Jérôme Benveniste, Peter Challenor, Paolo Cipollini, Claire Dufau, William Emery, Christine Gommenginger, Sylvie Labroue, Franck Mercier, Estelle Obligis, Nicolas Picot, Cristina Martin-Puig, Keith Raney, Remko Scharroo, Walter Smith, Helen Snaith, Ted Strub, Stefano Vignudelli, Phil Woodworth, and by the rest of the community present at the Pisa workshop. Final review and edits by Ted Strub, Paolo Cipollini, Stefano Vignudelli.

- 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

Status

There is clear consensus that access to the 'last 10 km' next to the coast needs retracking, and an expectation that specific coastal retrackers should give better accuracy & precision than generic deep-ocean retrackers.

Currently there are multiple approaches:

- Parametric, physically-based algorithms; these inspire [rightly or wrongly] some confidence, due to the large amount of established experience from open ocean work and physical theory.
- Empirical algorithms; these may give results under a wider variety of conditions but those results are less certain and less well understood.
- Waveform classification; these methods select waveforms, which can be separated into Brown-like and non-Brown pieces. The Brown-like waveforms can be retracked in the usual way. (PISTACH)

Open Issues

- Is there a "one size fits all" coastal retracker? We need more research with multiple approaches to decide.
- Should coastal retracking employ [only] physical (parametric) retrackers? -- This is not at all clear; we need more research, with careful assessment of precision and biases.
- How do we assess track point and SSB biases of various retrackers? Non-parametric retrackers may not give estimates of SWH and SSB. More experience is needed.
- How do we assess the benefit of different approaches? We need benchmarks. One metric used is the amount of additional data that is recovered. This ignores the quality of the added data.
- Can we predict land effects on waveforms? – We may be able to do this in some places, but we need very good coastlines and DEMs.

Recommendations

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

Status

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 methods are being developed:

- Dynamic extrapolation methods, using high-resolution atmospheric models. This is conceptually simple and models are readily available. Global models, such as ECMWF or NCEP are not fully compatible with the requirements for horizontal resolution. Regional models that could be investigated are ALADIN, COAMPS (NRL), UCLA and other high-resolution atmospheric models.
- GNSS measurements of ZTD (Zenith Total Delay) (and met correction to ZWD – Zenith Wet Delay). The University of Porto is leading this effort. There is a need to correct for elevation of the stations and further study should investigate whether this approach is sufficient to fill the radiometer gap within 50km (perhaps less with Jason-2) of the coast.
- Land decontamination method. This is the operational algorithm in PISTACH, estimating the proportion of land, its temperature and emissivity in contributing to the brightness temperature measured at the satellite.
- JPL method. S. Brown is working on a variant of the land decontamination method that relies on inherent inter-channel correlations for the Land Brightness Temperature and the Land Fraction. Simulations and comparison with ECMWF indicate errors of less than 1.5 cm in coastal region globally.

An ancillary method uses MODIS-derived brightness temperatures. This works only in cloud-free regions, but could be very useful for comparisons.

***Open Issues*:**

- How well do these methods perform? Comparison areas and data sets are needed. Availability of PISTACH products is going to allow assessment of the land decontamination method
- Are these methods globally portable? Issues include GPS availability and algorithm applicability.

Recommendations
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

Status
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.

Recommendation
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

Status
Recent progress has been made with global and coastal modelling (GOT 4.7, EOT08a), including developments in advanced assimilation techniques.

Open issues
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.
Possible approaches to tackle this problem are:

- Form collections of local models using extensive local expertise (labour intensive).
- Further develop global models especially when more data (e.g. SWOT) become available.

Both approaches can take place but both need more detailed coastal bathymetric information

Recommendations

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

Status and open issues

Alternatives to tackle this correction are:

- Form collections of outputs from local models using extensive local expertise (not so labour intensive – suggested previously for GOOS)
- Further develop global surge models

Both approaches can take place. Again both need more detailed coastal bathymetric information.

Note that some users may not want these corrections to be applied to the SSH fields for their applications.

Recommendations

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

Status

The SSB correction is of great concern (although not the greatest error source in coastal regions), but research seems to have reached a stalemate.

It has long been known that some degree of spatial low-pass filtering of the SWH estimates is needed to improve the quality of the SSB correction, but it is still unclear which cut-off scales should be used for the filter in the coastal zone.

Open issues

- Parameter space (currently SWH, wind) needs to be extended with wave age, but where can we get that parameter?
- SSB is expected to be different in coastal areas, but regional biases prevent direct estimation of SSB.
- Evaluation of tracker bias – this is not specific to the coastal area.

Recommendations

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 as in 3c, 3d.

5 - DATA PRODUCTS, QUALITY AND DISSEMINATION

Status

Data products, systems and services must be driven by usage. Trends in usage identified include:

- A move towards regional tailored products
- A move towards altimetry as a significant component of observation systems
- An increase in operational applications

Open Issues

- Provision for 'less connected' users – via regional centres?

Recommendations

- 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

Status

This section concerns the application of coastal altimetry and ultimately motivates the development of the field. 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)

Open issues *(and some tentative answers)*

- How do models and other data combine with altimeter SSH to produce better SSH data sets (along-track and gridded 2D fields) in the coastal region (within 50 km of the coast)? What scales are resolved by these fields (space and time)?

Altimeter + Improved Wet Tropo (+ Improved Tides) (+ Retracking) + 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.

- How can combinations of altimeter SSH with other data sets and model fields reduce the terms in the altimeter error budgets? Consider individual terms in the altimeter error budgets. How can we reduce the largest error budget terms?

The largest are wet tropo and tides – see relevant sections above. Data Assimilation methods have the potential to quantify regional and time-dependent error fields, allowing the diagnosis of error terms. This needs to be further investigated.

- Do altimeter data provide better "constraints" on models than "traditional" data sources? Do SSH or surface geostrophic velocity fields provide better constraints? Are altimeter data better used in data assimilation within the models or in quantifying errors in the final model fields?

Altimeter data may provide better "constraints" on locations and strengths of alongshore fronts/jets. Modeling studies can assess whether surface (geostrophic, with and without Ekman) velocities provide better constraints than SSH. Altimeter data can also quantify errors in the final model fields.

- Can other types of satellite data (SST, color, winds, SAR) be used to improve SSH fields from altimeters (in a purely remote-sensing approach)?

Other types of satellite data (like SST and color sequences for MCC velocities, winds for Ekman components) can provide more complete field; moreover MODIS can provide a high-resolution wet-tropo useful to compare the new correction in cloud-free conditions

- Will improved spatial sampling (by SWOT or other technology) improve model SSH or velocity fields, without improved temporal sampling (5-10 day repeats)?

This question requires further investigation and should be an emphasis in preparing to effectively use the SWOT data when it becomes available.

- There was some discussion on the appropriateness of a gridded DUACS + Tide gauge merged product. Maybe we could require that some level 3/4 products been produced as demonstration products for specific applications and regions?

This could be feasible in few months if support were given.

Recommendations

A common, 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

Status

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. For instance DIODE/DEM on Jason-2 looks good (but on-board DEM is not so good). These will be evaluated in the present OSTM teams.
- 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.

HF radars constitute a great dataset for validation of surface velocities. However, relating these total velocities to geostrophic and Ekman components from altimeters and scatterometers is still a matter for ongoing research.

Open issues

- The Iridium NEXT opportunity: this is an exciting prospect, but is it too much too soon? Timing constraints and funding issues seem to make it highly unlikely that the opportunity be seized.
- Could GNSS-Reflectometry constitute a feasible contribution to coastal applications?
- What requirements for coastal applications should drive future mission and instrument designs?
- Geographically-correlated errors are a potential limiting factor for data use for practical applications.

Recommendations:

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

Status

We have seen the coalescence of **an international community of scientists** working on the new topic of coastal altimetry, with support from the main Space Agencies. This community has developed over the past years through support from several European initiatives and an increase in interest following presentations at the OSTST meeting Hobart (2006). After two international workshops during 2008, the coastal altimetry community is now firmly established, has a clear international profile and reports to OSTST as its parent group.

Open Issues

How can we ensure sustained funding for research in coastal altimetry?

How can we sustain coordination of efforts in coastal altimetry after COASTALT and PISTACH have finished? One step to aid coordination was the submission (in Sept 2008) of a European COST-Action to Network proposal – after encouraging feedback from reviewers this will be updated and resubmitted in early 2009.

Recommendations

- Space Agencies must to ensure that instrument information is available to all Coastal Zone data processors. For instance see AVISO documentation and http://earth.esa.int/pcs/envisat/ra2/.
- 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

NEXT WORKSHOP

- The group will meet again in Fall 2009. The date and location are now confirmed for 16-18 September 2009, ESA/ESRIN Frascati, Italy. At this 3rd Coastal Altimetry Workshop, we will review progress, especially in the context of the completion of the PISTACH and COASTALT projects, making use of reprocessed data from those projects.

End of Summary