Supplementary material to “First Coastal Altimetry Workshop”

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[Full Article (pdf)]

During the final session of the workshop, all participants discussed and agreed on the following recommendations, findings, and provisional summary error budget as the consensus outcomes of the workshop.

Recommendations:

1. Study groups formed at the first Coastal Altimetry workshop, Feb 5–7 2008 in Silver Spring, should continue to collaborate with the goal of reporting progress at the second workshop in Pisa on 5 to 7 November, 2008.
2. Coastal zone altimetry is a secondary mission objective, after the open ocean, for the currently planned nadir altimeter missions. Coastal experts and coastal user needs should be more involved in pre-launch design and post-launch calibration and validation of missions. Future mission design should take advantage of technologies and enhancements that will further coastal applications.
3. In order to fulfill the need for long-term altimeter records, a global coastal ocean data set shall be produced containing all historical along-track and auxiliary data and meta-data. Ideally this will be: in a common data format; processed for multi-satellite consistency; at the highest sampling rate possible; seamless between coastal and open ocean; using the best available regional models to the extent possible.
4. The large footprint of water vapor radiometers is a major part of the error budget for coastal altimetry. Future missions should consider ways to improve the resolution, for example by adding higher frequency radiometers.
5. We need further studies that integrate altimetry with in situ data and models in the coastal zone, in

order to better understand coastal processes and demonstrate the value of altimetry in coastal observing systems.

Findings on tracking and retracking of altimeter waveforms:

1. Standard (Brown model) retracking should be adequate seaward of 20 km from the coast.
2. 90% of waveforms are Brown-like seaward of 10 km from the coast.
3. Constrained retracking can reduce sea surface height noise.
4. Adaptive (non-Brown) retracking can recover data closer to the coast. However, inter-calibration of the track point and wind- and wave-dependent biases will need study.

Findings on correction of radar propagation for the wet troposphere delay (“wet” in the table below):

1. Atmospheric “rivers” ~200 km wide increase water vapor near the coast.
2. Models with 0.5 degree, six hourly sampling lack structure with as much as 2 cm of sea surface height delay correction in Ku band.
3. Higher-resolution coastal models show model gradients of 5 – 6 cm / 100 km.
4. Water Vapor Radiometry (WVR) can be used seaward of 50 km from the coast. At closer distances, land emissivity causes several cm of error in the water vapor radiometer's sea surface height correction.
5. Land contamination in Special Sensor Microwave/Imager (SSM/I) data begins 200 km from coast.
6. Mitigation strategy 1: correct radiometer brightness temperatures for fraction of land contamination.
7. Mitigation Strategy 2: fill holes with model data, possibly adjusted for bias or bias and tilt.
8. Future missions may consider the use of higher-frequency channels.

Findings on tides:

1. Tides are strongly dependent on bathymetry.
2. Compound tides (e.g. M4) have significant amplitude in shallow water and may contribute 6.6 cm to the global root-mean-square misfit of models to gauges.
3. Root-mean-square errors in models are around 2.4 cm in deep water and ~12 cm in shallow water, but this value is highly dependent on locality.
4. Wavelength of the tide error depends on depth.
5. The best approach would be to merge local and global models, but this is resource and labor intensive.

Findings on the “inverted barometer” (IB) correction:

1. The ocean's response to pressure forcing at shorter than 20-day period is not as simple as an inverted barometer.
2. The MOG2D/DAC model shows improvement over simple IB, especially in coastal and high-

latitude areas. S1/S2 atmospheric tides need further investigation.
3. Local models should be developed.

Findings on the “sea state bias” (SSB) correction:

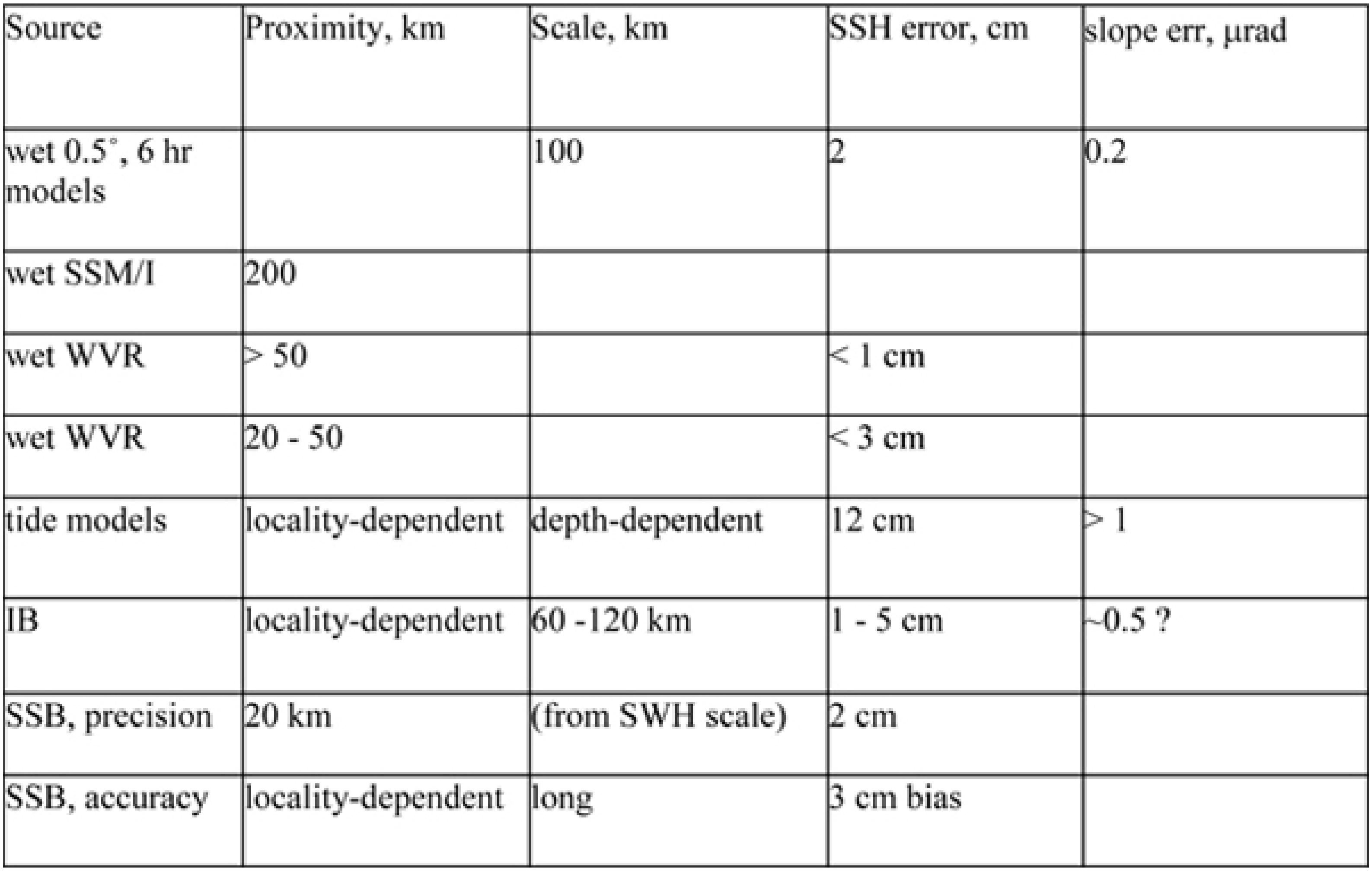
1. SSB is electromagnetic, skewness, and tracker dependent.
2. To first order, SSB is typically 3% of significant wave height (SWH).
3. Present models adjust SSB based on SWH and “U10” near surface wind speed.
4. New 3 parameter models (SSB, U10, age) differ from two-parameter models by 2 cm in shallow water and at SWH < 1.5 m.
5. Local empirical coastal models differ from global models by 3 cm.
6. Wave-current interactions are not yet accounted for.

Findings on significant wave height (SWH) measurements by altimeters:

1. Radar altimeter data are a useful source of SWH profiles in the deep ocean.
2. Deep-ocean altimeter SWH data typically are averaged for 6 seconds for comparability with large-scale wave models.
3. SWH correlation scales fit the Monaldo model in deep water.
4. In coastal areas, SWH correlation scales can be as short as the wavelength.
5. Orbit sampling issues show up as differences in apparent wave height climatologies.

Provisional summary error budget:

In order to obtain a fully calibrated and corrected absolute sea surface height from an altimeter, a number of error sources must be considered and corrections applied. However, many of these have large horizontal scales of correlation, so that they do not enter into the error budget for detecting local changes in sea surface height associated with frontal boundaries. Therefore, the workshop strove to classify error sources in terms of their horizontal correlation scale as well as their sea surface height (SSH) error magnitude. Where a horizontal correlation scale and an SSH error magnitude could be assigned, the ratio of these gives the expected error in sea surface slope, expressed here in micro-radians (1 mm of SSH error per 1 km of horizontal distance). 1 µrad of slope error is approximately 10 cm/second of geostrophic velocity error at mid-latitudes. Thus, for example, the first entry in the table can be read to say that, if the radar path delay due to the wet troposphere is corrected only by using a model with 0.5° and six-hourly sampling, the SSH error that will result will be about 2 cm, but the error in sea surface slope will be 0.2 µad, and thus the error in geostrophic velocity will be around 2 cm/sec.



Source	Proximity, km	Scale, km	SSH error, cm	slope err, µrad
wet 0.5˚, 6 hr models		100	2	0.2
wet SSM/I	200			
wet WVR	> 50		< 1 cm	
wet WVR	20 - 50		< 3 cm	
tide models	locality-dependent	depth-dependent	12 cm	> 1
IB	locality-dependent	60 -120 km	1 - 5 cm	~0.5 ?
SSB, precision	20 km	(from SWH scale)	2 cm	
SSB, accuracy	locality-dependent	long	3 cm bias	