Coastal Ocean Tide Modeling

C.K. Shum1, Koji Matsumoto2, Yuchan Y1, Shin-chan Han1, Yoshiihiro Niwa3, Guoqi Han4, and Alexander Braun5

1Laboratory for Space Geodesy & Remote Sensing, Ohio State University, Columbus, Ohio, USA.
2Nisizawa Astrodynamics Observatory, Nisizawa, Iwate, Japan.
3Department of Earth & Planetary Science, University of Tokyo, Japan.
4Fisheries and Oceans Canada, St. John’s, Newfoundland, Canada.
5Dept. of Geomatics Engineering, University of Calgary, Alberta, Canada.

ABSTRACT
Ocean tides play a significant role in climate due to its complex interactions between ocean, atmosphere, and sea. Tidal currents create turbulent mixing, tidal dissipation affects ocean transport and thus climate, and internal tidal mixing affects general circulation. Due primarily to the availability of TOPEX/POSEIDON (T/P) satellite altimetry and advances in numerical modeling methodologies, semidiurnal and diurnal barotropic ocean tides are known in the deep ocean (depth > 1000 m) to within 2 cm rms and to mitigate tidal aliasing. 3-D hydrodynamic modeling and using additional data (T/P, ERS, GFO, JASON, ENVISAT, JASON-2) in the coastal regions, including Yellow Sea, East China Sea, Sea of Japan, Patagonia, Indonesian Sea, Atlantic, Canadian Shelf, and Hudson Bay. Multiple altimeter data are to be used to enhance spatial resolution and to mitigate tidal aliasing. 3D modeling and data assimilation will be conducted to improve M2 and K1 internal tides modeling over the Atlantic, Indian, and Pacific basins. The Jason-2 Wide-Swath Ocean Altimeter (WSOA) will be assessed for its potential to improve coastal tides by using the offseas data in the form of slope measurements. In this paper, we address issues of potential mitigation of tidal aliasing using dual-satellite crossover data and ocean pole tide modeling.

Improved Temporal Samplings at Crossover Locations
To study the feasibility of improving ocean tide modeling by use of multiple satellite altimeter data, we performed a frequency analysis for simulated T/P and ERS altimeter data at single- and multiple-satellite crossover points using periodograms defined for arbitrary sampling intervals (Moutz, 2002). A global optimization model was simulated in the time domain to estimate Lomb-Scargle periodograms of satellite altimeter data sampled at a crossover location having either mixed sampling periods (dual-satellite crossover) or a single sampling period with sampling at different phases (single satellite crossovers).

Periodogram of simulated T/P Single satellite crossover data. Gaussian noise of 3 cm added with bias or drift

ALONG with the inherent frequency folding of original spectrum. Thus, an even sampling results in aliasing for spectral contents whose frequencies are higher than the Nyquist rate. However, periodograms for unevenly sampled data are not periodic in frequency, so that they can reduce aliasing. Moutz’s global optimization algorithm for a sum of squared fit residuals (negative Lomb-Scargle periodogram) successfully finds for many of true tidal frequencies verifying this possibility of reduced aliasing. Thus, the numerical test results of frequency analysis herein indicate a clear advantage of using altimeter data at single- and dual-satellite crossover locations in tidal analyses to mitigate tidal aliasing problems.

Periodogram of simulated T/P and ERS-2 Dual satellite crossover data. Gaussian noise of 3 cm added to T/P data and 8 cm added to ERS-2 data without bias or drift

An Approach to Quantify Improvement of Tidal Data Analysis
For single satellite crossovers, Smith (1999) discusses in detail through the concept of the aliased phase advance of a tide within one repeating cycle between measurements along two crossing tracks. The aliased phase advance of a tidal harmonic depends on the repeating period and latitude of a crossing point. Also, he explains further advantages of using single satellite crossover data over along-track data in terms of separating aliased frequencies that are very close to each other. In our study of improving ocean tide models, we will extend Smith’s study on the use of single crossover data in ocean tide modeling to the case of dual satellite crossover data.

Tidal Solutions at Crossover Locations
In this study, a point-wise tidal analysis was performed using the TOPEX and ERS-2 altimeter data in the Southern Ocean below 58 S at each of crossover locations. Ole Andersen’s (1994) orthid tide analysis software was used to fit 8 dominant short period tidal constituents along with 4 long period tidal data of TOPEX cycles 4-364 and ERS-2 cycles 1-79 were processed.

Performance comparison of ocean tide models in the Southern Ocean below 58 S in terms of standard deviation of crossover SSH residuals after correcting for ocean tide of each model in cm (SS stands for Single Satellite and DS Dual Satellite)

Conclusions and Future Work
- Preliminary orthidite tide solution using ERS-2 and T/P crossover data in the Southern Ocean and the Arctic Ocean indicates improvement over contemporary tide models.
- Future tide solution improvement is anticipated using data assimilation technique with hydrodynamic modeling and using additional data (ENVISAT, GFO, JASON, etc.).

The point-wise tidal solution of this study performs well in the Arctic Ocean region also. For 6,658 ERS-2 single satellite crossover points above 50 N, residual ERS-2 SSH data has an average standard deviation of 10.5 cm after removing 8 short-period constituents of the tidal solution of this study. The Oregon State regional tide model Arcsine differs from ERS-2 SSH data by 15 cm (standard deviation) for 4,196 single satellite crossover data points.