A Data-assimilative Tidal Model for the NorthWest Atlantic

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Objectives

To develop a high-resolution, 3-D tidal model for the Northwest Atlantic (Fig. 1). The goal of the project is to provide improved tidal elevation and currents and to evaluate the results against *in situ* observations. The model results are to be used for ocean forecasts and for de-tiding satellite altimetry data.

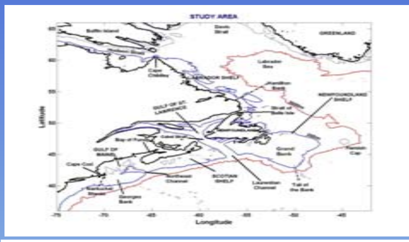

Figure 1 Map of the model domain (36 ⁰N to 66⁰N and -75⁰W to -42⁰W), showing the location of major features and regions and bathymetry (200m and 3000m).

Methods

The Princeton ocean model was run at 1/12 by 1/12 degree with 16 layers in the vertical. The model was forced at the open boundaries with M_2, N_2, S_2, K_1, O_1, P_1, Q_1 and K_2 elevation and depth-averaged velocity from a North Atlantic Model (Egbert and Erofeeva, 2002). A velocity radiation boundary condition was applied. ETOPO2 topography was enhanced by local bathymetric data for the Atlantic Canadian shelf and slope.

A 9-day spin-up period was chosen and the subsequent model results of 30 days, for elevation and current data, are analysed using Harmonic Analysis. The results are compared with *in-situ* observations at selected locations (Fig. 2). Observational currents with amplitudes < 2 cm/s are excluded from the comparison.

Two experiments were carried out: Pure Simulation vs. Data Assimilation. Multi-mission altimetric tides were assimilated using a nudging method with a nudging scale of half a day.

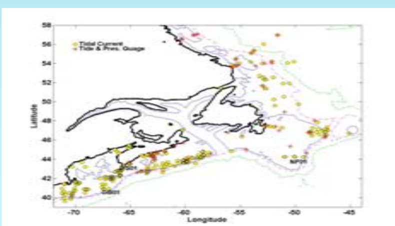

Figure 2 Observations for comparison with the model were taken primarily from the southern portion of the domain. Data were used from coastal tidal gauges, bottom pressure gauges (Han et al., 1996) and current meters (Drozdowski et al., 2002). There are 52 locations for elevation and 334 sites/positions for currents.

Model Results

Elevation

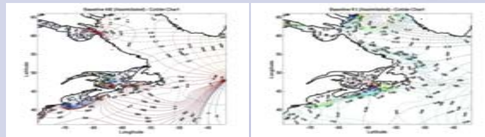

Figure 3 Model co-range and co-phase charts for M_2 and K_1 constituents. Model results show that M_2 dominates over K_1 in the Northwest Atlantic. The model is able to well reproduce amphidromic points for M_2 and K_1.

Currents

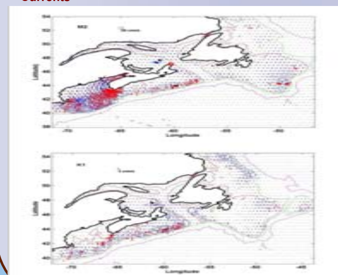

Figure 4 Model (blue) surface Tidal ellipses for M_2 & K_1 with observations (red).

The Model solutions show larger M_2 than K_1 currents in general. There are significant spatial variations in both M_2 and K_1 currents.

Model Validation

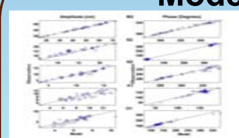

Figure 5 Scatter plots for M_2, S_2, N_2, K_1 & O_1 constituents: model vs. observation.

The average root mean square (RMS) amplitude & phase error for semi-diurnal constituents is 1.8 cm and 6.7 deg respectively. For diurnal constituents, the errors are 1.3 cm and 9.4 deg respectively.

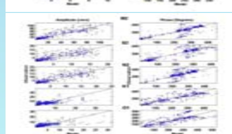

Figure 6 Scatter plots for M_2, S_2, N_2, K_1 & O_1 constituents: model vs. observation.

The average RMS amplitude and phase errors for semidiurnal constituents are 4.6 cm/s and 37 deg respectively. For diurnal constituents the errors are 2.3 cm/s and 47 deg respectively.

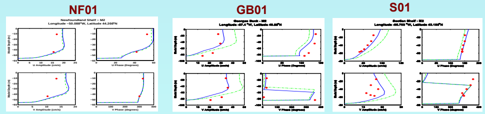

Figure 7 Comparison of the vertical structure of the unassimilated (dash-dotted line) and assimilated (blue) model M_2 currents with observations (stars) at three selected sites. (See Fig. 2 for the locations).

Discussion

Previous Work

There have been several modeling studies on tidal currents off Atlantic Canada, mostly focused on one of its sub-regions, e.g., Petrie et al.'s (1987) 2D and Han's (2000) 3D models for the Newfoundland Shelf, Han and Loder's (2003) simulation for the Scotian Shelf. Most recently, a 2D finite-element model with M_2, S_2, N_2, K_1 & O_1 constituents was developed for the Northwest Atlantic (Dupont et al., 2002).

Present Model

We provide high-resolution 3D solutions that include equilibrium and load tides, assimilate latest multi-mission altimetric tides and include more tidal constituents.

•The M_2 tidal currents dominate tidal current variability over the study region, especially over the shallow areas such as the Georges Bank and the southeast Grand Bank. The diurnal currents are generally weak but intensified in some outer shelf and shelf break zones, resulting from resonance with the continental shelf wave.

•The model tidal elevations are in good agreement with *in situ* observations for the five constituents (Fig. 5). The computed semi-diurnal tidal currents agree approximately with *in situ* observations, though with notable discrepancies for some constituents and at some locations (Figs. 4, 6, and 7).

▪The assimilation significantly improves the model elevations and currents, especially over the Scotian Shelf, in the Gulf of Maine and over Georges Bank (Fig. 7). The root-mean-square amplitude errors for M_2, S_2, N_2, K_1 & O_1 are reduced from 3.2, 1.7, 0.6, 1.3, 0.8 cm (unassimilated) to 0.8, 1.4, 0.6, 1.1, 0.6 cm (assimilated), respectively.

Ongoing Work

To account for effects of baroclinicity.

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References

Drozdowski, A., C.G. Hannah and J.W. Loder, 2002. The Northwest Atlantic Tidal Current Database. Can. Tech. Rep. Hydrogr. Ocean Sci. 222: v+35 pp.

Dupont, F., C. G. Hannah, D. A. Greenberg, J. Y. Cherniawsky, and C. E. Naimie. 2002. Modelling System for Tides. Can. Tech. Rep. Hydrogr. Ocean Sci. 221: vii + 72 pp.

Egbert, G.D., and S.Y. Erofeeva., 2002. Efficient inverse modeling of barotropic ocean tides, J. Atmos. Oceanic Technol., 19(2), 183-204.

Han G. 2000. Three-dimensional modeling of tidal currents and mixing quantities over the Newfoundland Shelf. J. Geophys. Res., 105(C5), 11,407-11,422.

Han G., M. Ikeda and P.C. Smith. 1996. Oceanic tides on the Newfoundland and Scotian Shelves from TOPEX/POSEIDON altimetry, Atmosphere-Ocean, 34(4), 589-604.

Han G. and J.W. Loder. 2003. Three-dimensional seasonal-mean circulation and hydrography over the eastern Scotian Shelf, J. Geophys. Res., 108(C5), 3136, doi:10.1029/2002JC001463.

Petrie, B., K. Lank, and S. de Margerie. 1987. Tides on the Newfoundland Grand Banks, Atmos-Ocean, 25, 10-21.