Concurrent simulation of the eddying general circulation and tides in a global ocean model

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Motivation

• Ocean mixing driven partly by breaking internal gravity waves, which source partly from tides. First global models of internal tides, run with Hallberg Isopycnal Model (Arbic et al. 2004, Simmons et al. 2004; hereafter AGHS and SHA), included only tidal forcing and were run with horizontally uniform stratification.

• Desirable to have model in which generation and propagation of internal tides takes place in more realistic, horizontally varying stratification, and potential exists for interactions between tidal and non-tidal flows.

• Have recently completed a simulation which accomplishes this: 5-year global run of HYbrid Coordinate Ocean Model (HYCOM) with 32 layers in the vertical direction, $1/12.5^{\circ}$ horizontal resolution, and forcing of eight largest tidal constituents in addition to wind- and buoyancy-forcing.

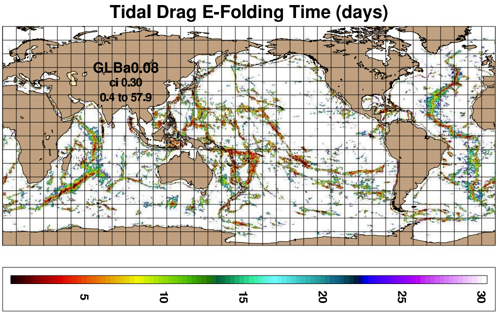
Need for parameterized wave drag in baroclinic tide models

• 2/3 of tidal energy dissipation takes place in shallow seas (mainly via quadratic BBL drag), and 1/3 takes place in abyss, via internal tide breaking over topography (Egbert and Ray 2000).

• Several recent studies: inserting parameterized topographic wave drag greatly improves SSH accuracy of forward barotropic tide models. Reason: strength of wave drag controls globally integrated energies of model.

• AGHS: wave drag still needed in baroclinic tide models. Drag of form $r(lat, lon)\mathbf{u_{bottom}}$ in bottom layer, (possibly) representing unresolved generation and breaking of high modes near bottom.

Tidal drag e-folding time

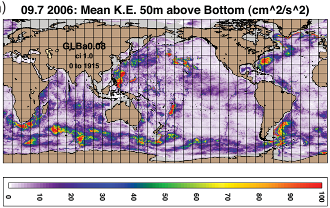


New complication for topographic drag in HYCOM simulation

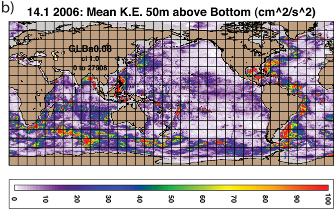
- Topographic wave drag probably acts on low-frequency motions (Nikurashin 2008) as well as tides.
- But the action is different for the two types of motions (Bell 1975).
- Therefore, a separation of the model bottom flows into tidal versus non-tidal components is desirable.
- This separation is done crudely with a 25-hour running average of the bottom flow.
- How does this affect non-tidal bottom flows?

Kinetic energy of non-tidal bottom flows: (TOP) without and (BOTTOM) with tides and topographic wave drag

a)



b)

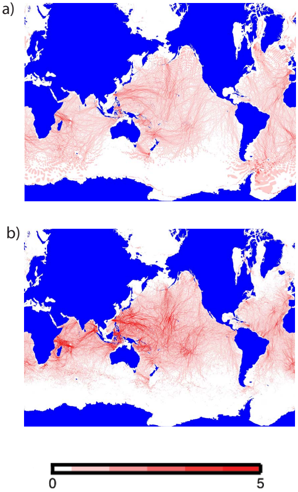


Elevation errors in HYCOM run

- Computed wrt standard set of 102 pelagic tide gauges (Shum et al. 1997)

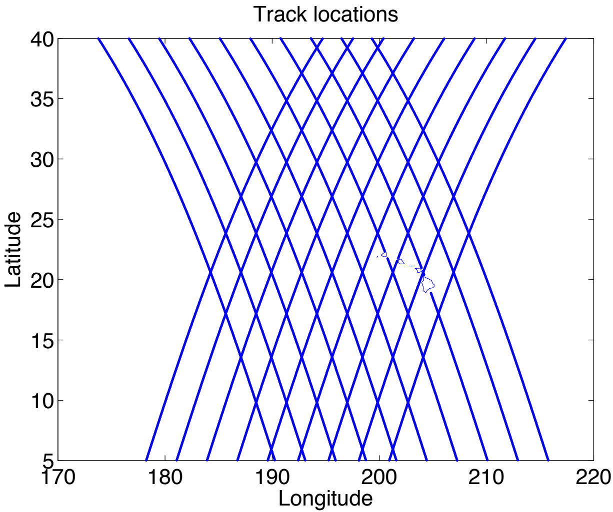
Constituent	Signal (cm)	Error (cm)
Q_1	1.62	0.68 (82.1)
O_1	7.76	2.48 (89.7)
P_1	3.62	0.79 (95.2)
K_1	11.26	2.48 (95.1)
N_2	6.86	1.40 (95.9)
M_2	33.22	8.26 (93.8)
S_2	12.62	5.17 (83.2)
K_2	3.43	1.65 (76.9)
RSS	39.04	10.63 (92.6)

Amplitude (cm) of M_2 internal tide signature in steric ssh: (TOP) Two-layer tide-only run and (BOTTOM) 32-layer wind-plus-tides run

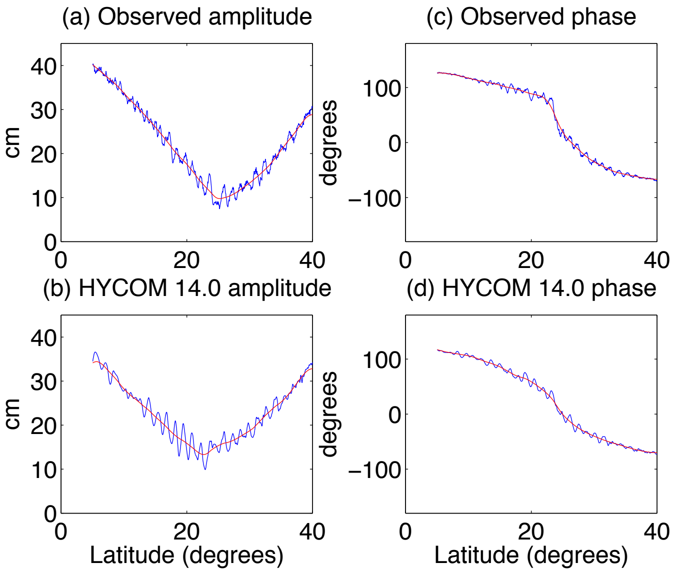


Altimeter tracks around Hawai'i

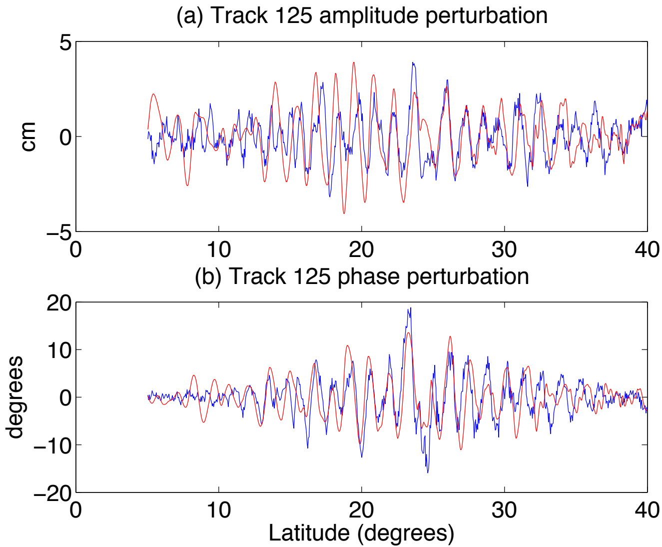
- Data obtained by personal communication with Richard Ray.



M_2 amplitudes and phases along track 125



Internal tide perturbations to M_2 sea surface elevation; blue/red is observations/HYCOM 14.0



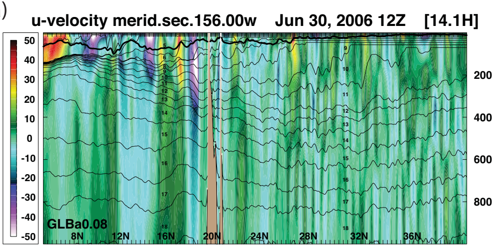
Rms of internal tide perturbations to M_2 sea surface elevations

Rms of model perturbations minus observed perturbations given in parantheses.

Source	Rms amplitude pert. (cm)	Rms phase pert. (degrees)
Observations	0.87	4.35
AGHS	0.40 (0.86)	1.91 (3.93)
SHA	1.07 (1.29)	4.66 (5.64)
HYCOM 14.0	1.03 (1.15)	4.42 (4.58)

Vertical section of model through Hawai'i

a)



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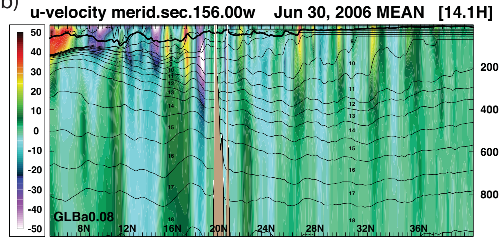

Summary

• Concurrent simulation of tides and eddying general circulation achieved in global HYCOM.

• HYCOM simulation has accurate barotropic tides (like AGHS, unlike SHA) and baroclinic tides that are at least of the correct magnitude (like SHA, unlike AGHS).

• In contrast to earlier global baroclinic tide runs, HYCOM run has horizontally varying stratification.

• 25-hour running average utilized to separate tidal from non-tidal motions in topographic wave drag scheme.

Ongoing and future work

• Data-assimilation in the presence of tidal and non-tidal motions.
• Feasibility studies of removing internal tide signals from planned wide-swath satellite altimeter.
• Comparison of three-dimensional structure of tidal currents with current meter data.
• Diagnosis of three-dimensional distribution of tidal mixing.
• Further investigations of optimal method for introducing topographic wave drag into a mixed tidal/non-tidal simulation.
• Is there a better way to remove energy from model (i.e. based on shear of resolved internal tides)?