Mapping the sea surface signature of internal tides in global ocean models

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Motivation

- Current generation altimeters yield extremely accurate global models of the large-scale (barotropic) tides, which are used to remove tides ("noise") from altimeter signals.
- SWOT will measure sea surface height (SSH) at order 1 km resolution. Offers opportunities to map baroclinic tide at high resolution, challenges in that baroclinic tides must be removed before study of non-tidal submesoscale motions takes place.
- Best idea at present for tide removal is to perform a harmonic analysis on the data. Richard Ray and Ed Zaron (see previous talk) has shown that the temporal variability is small enough, to give confidence in this approach.
- What about using models?
- Global baroclinic tide models are not accurate enough yet to be used for operational removal of internal tides from SWOT, but can provide visualizations of the internal tide challenge/opportunity.

A history of global modeling of internal (baroclinic) tides

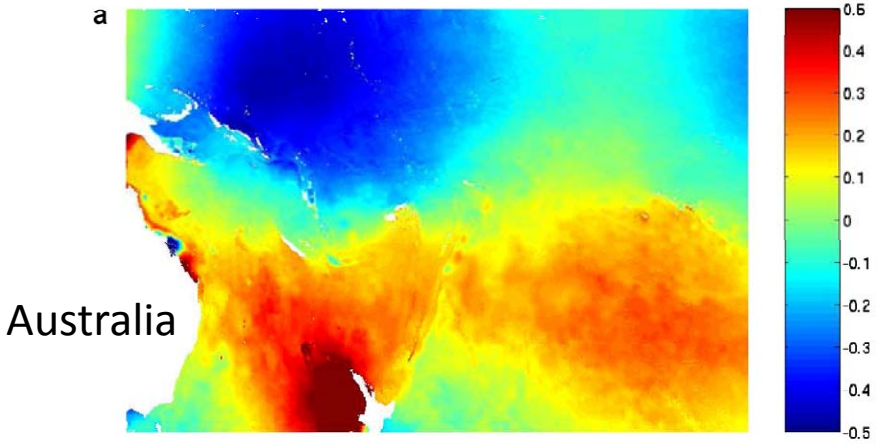
- First global baroclinic tide simulations (Arbic Garner Hallberg Simmons 2004, Simmons Hallberg Arbic 2004) were performed with tidal forcing only and with horizontally uniform stratification.
- Here we show a new 5-year global simulation of HYbrid Coordinate Ocean Model (HYCOM) with 32 layers in the vertical direction, $1/12.5^\circ$ horizontal resolution, and forcing of eight largest tidal constituents in addition to wind- and buoyancy-forcing (Arbic Wallcraft Metzger 2010).
- In contrast to earlier global baroclinic tide simulations, HYCOM run has a more realistic horizontally varying stratification.
- HYCOM simulations are funded as part of US Navy operational ocean modelling effort.

First analyses of HYCOM results and HYCOM/altimetry comparison

- Arbic et al. (2010) presented preliminary results of HYCOM simulations and of comparisons between HYCOM and satellite altimetry.
- We show these results over the next four slides.
- Although these results are published, they are ROUGH; based on analysis of one day of a run in which M_2 is the only tidal constituent present. A proper harmonic analysis of one year of the multi-constituent run will be shown later.

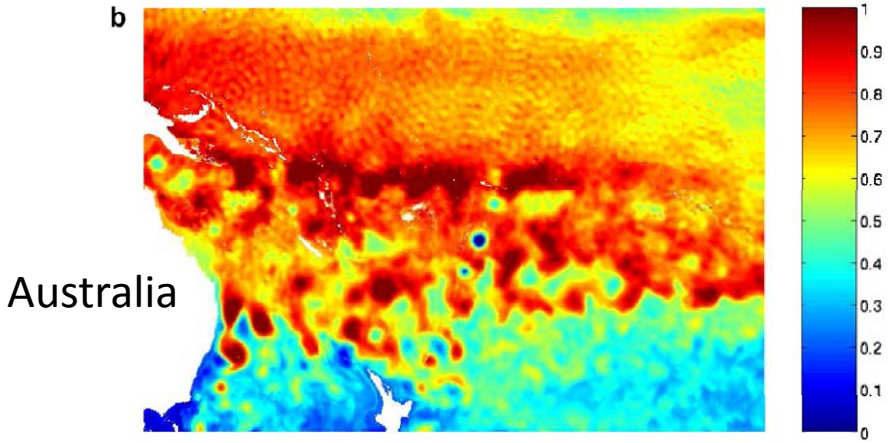
Snapshots of Southwest Pacific SSH in wind plus tides HYCOM

Nonsteric



(m)

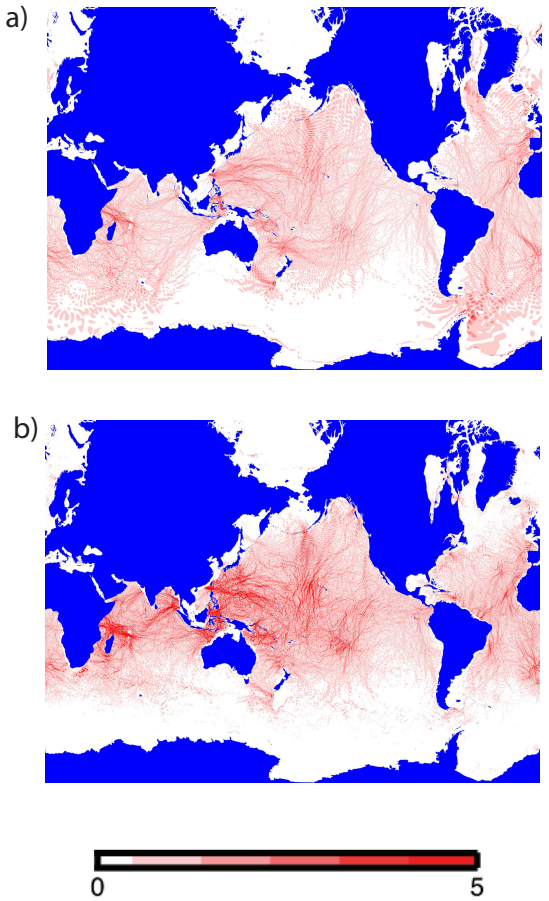
Steric



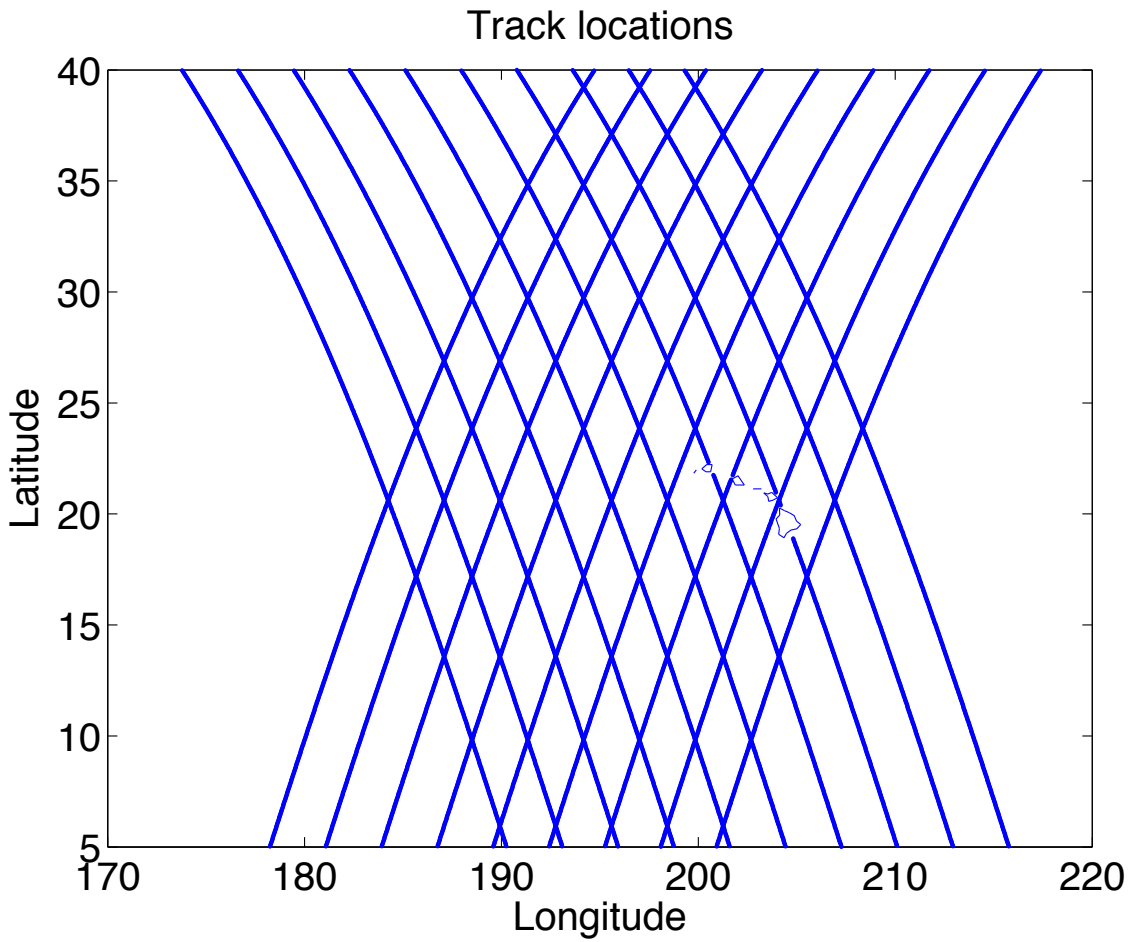
(m)

Fig. 8. Snapshot of (a) non steric and (b) steric sea surface heights (m) in the Southwest Pacific on June 30, 2006 at 00Z, from HYCOM 14.1 (Alltides).

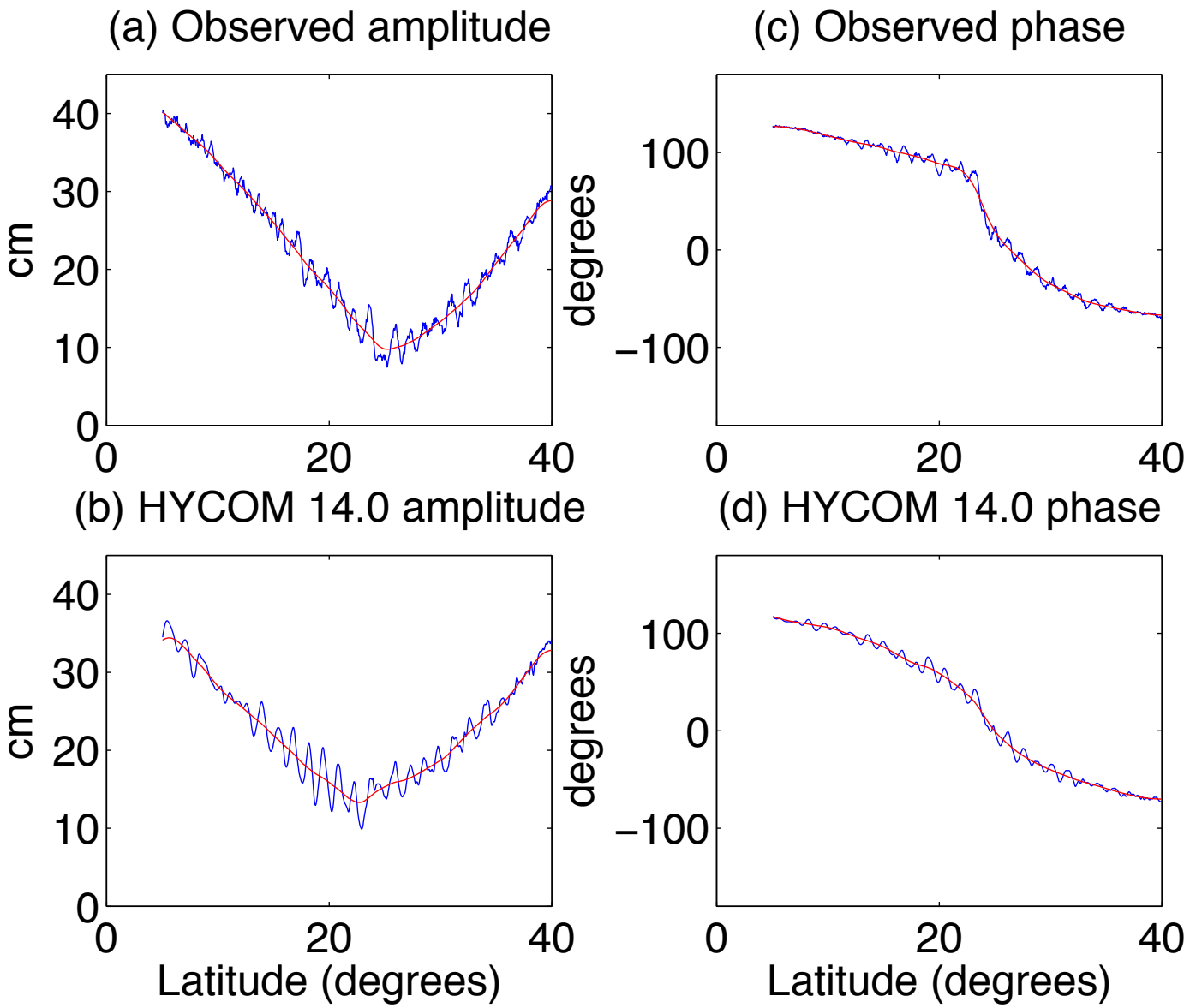
Importance of horizontally varying stratification: Amplitude (cm) of M_2 internal tide signature in steric ssh in (a) two-layer tide-only run and (b) 32-layer wind-plus-tides run (Arbic et al. 2010)



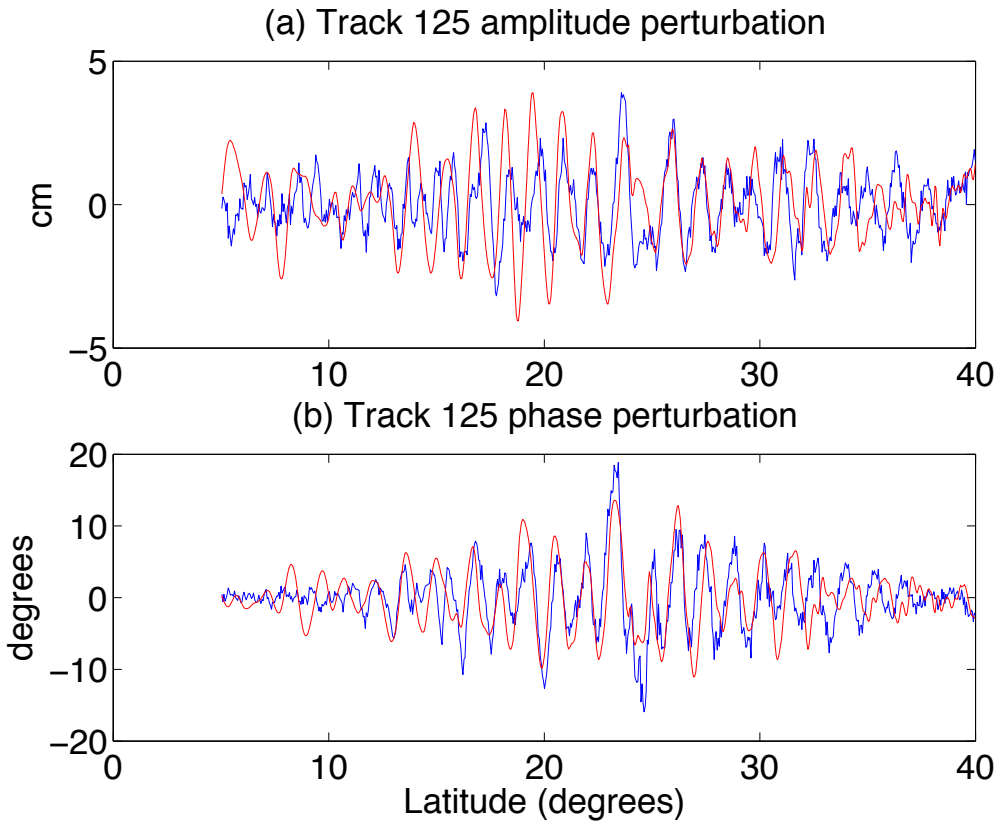
Altimeter tracks around Hawai'i–utilized in Arbic et al. (2010) and obtained via personal communication with Richard Ray



M_2 amplitudes and phases along track 125



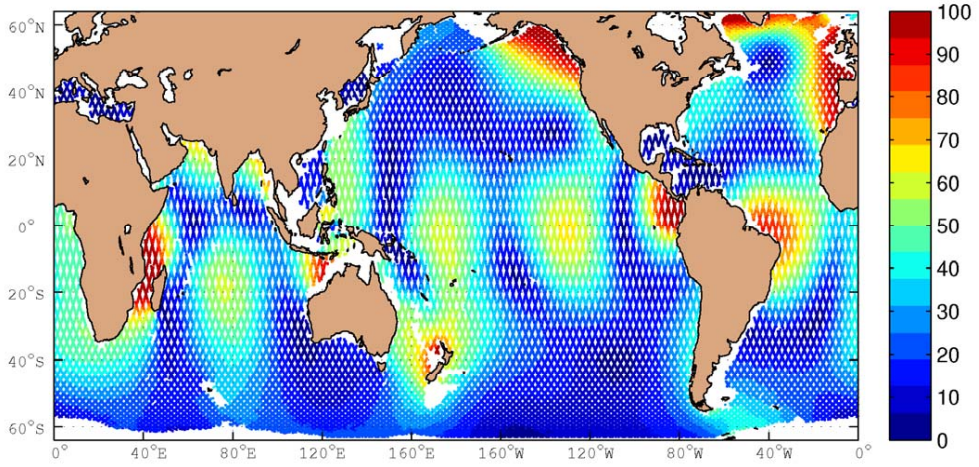
Internal tide perturbations to M_2 sea surface elevations: blue/red is observations/HYCOM 14.0



• RMS of perturbations to M_2 averaged over all altimeter tracks shown earlier is 0.87 (1.03) cm in amplitude and 4.35 (4.42) degrees in phase for observations (HYCOM).

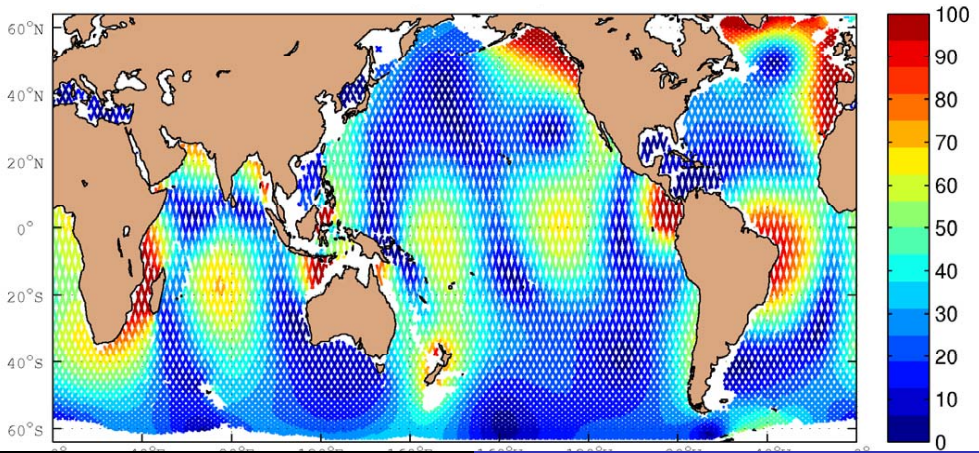
Global comparison of M_2 amplitudes: along-track altimetry data (Ray and Byrne 2010) vs HYCOM (work in progress with Richard Ray and Jay Shriver)

altimetry-based
Analysis (R. Ray, NASA)



(cm)

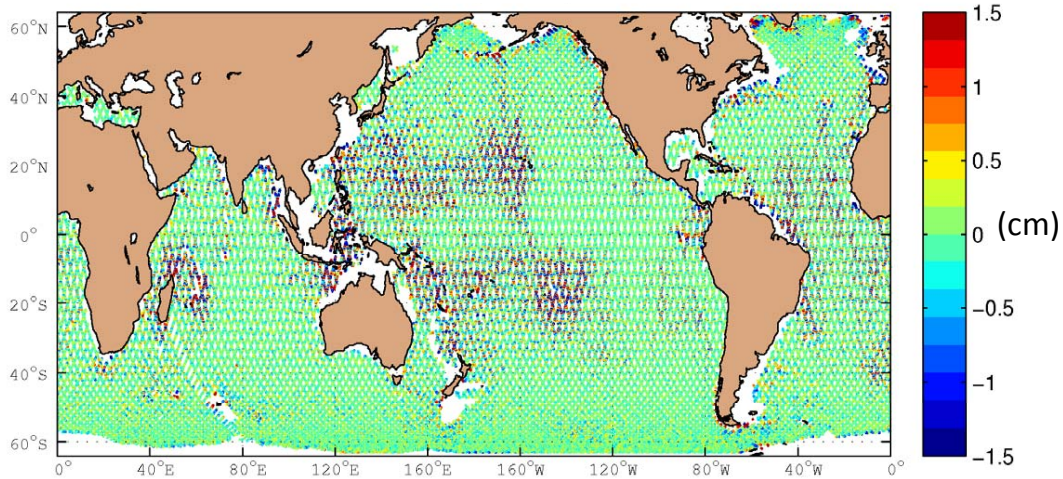
1/12° Global HYCOM



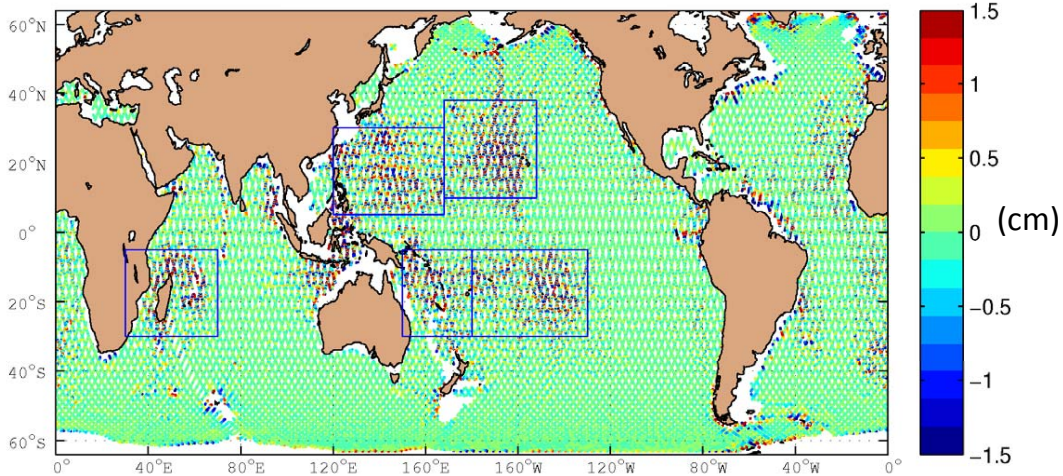
(cm)

As in previous, but AFTER high-pass filter has been applied to remove barotropic tides and reveal baroclinic tides

altimetry-based
Analysis (R. Ray, NASA)

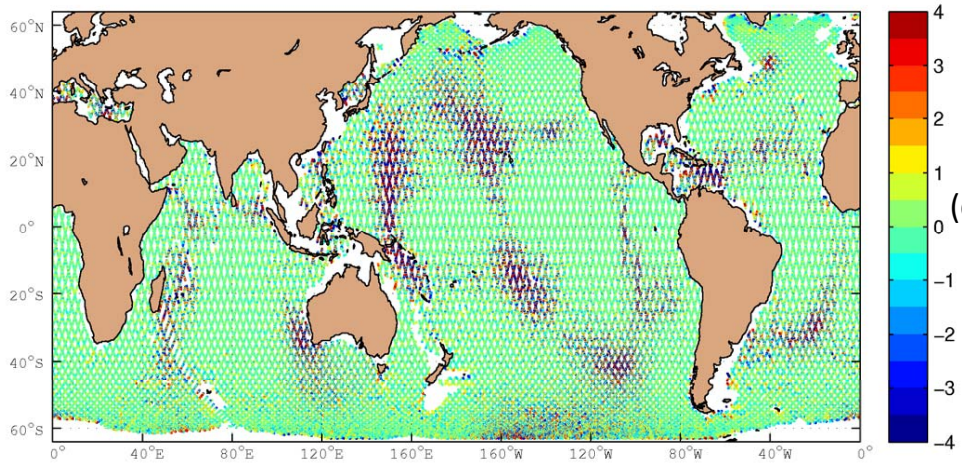


1/12° Global HYCOM

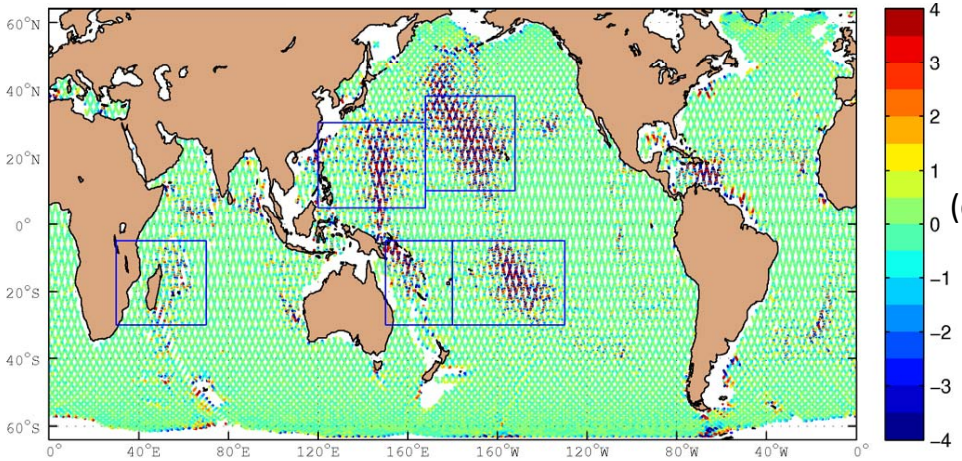


Map of perturbation phases

altimetry-based
Analysis (R. Ray, NASA)



1/12° Global HYCOM



RMS perturbation amplitudes and phases in altimeter/HYCOM, averaged over five hotspots

Region	Amplitude (cm)	Phase (degrees)
Hawaii	0.67/0.74	2.73/3.91
Western North Pacific	0.76/0.76	6.71/5.28
Central South Pacific	0.73/0.63	2.81/2.84
Western South Pacific	0.83/0.76	6.97/5.64
Madagascar	0.82/0.78	1.67/1.05

Summary–global internal tide modeling

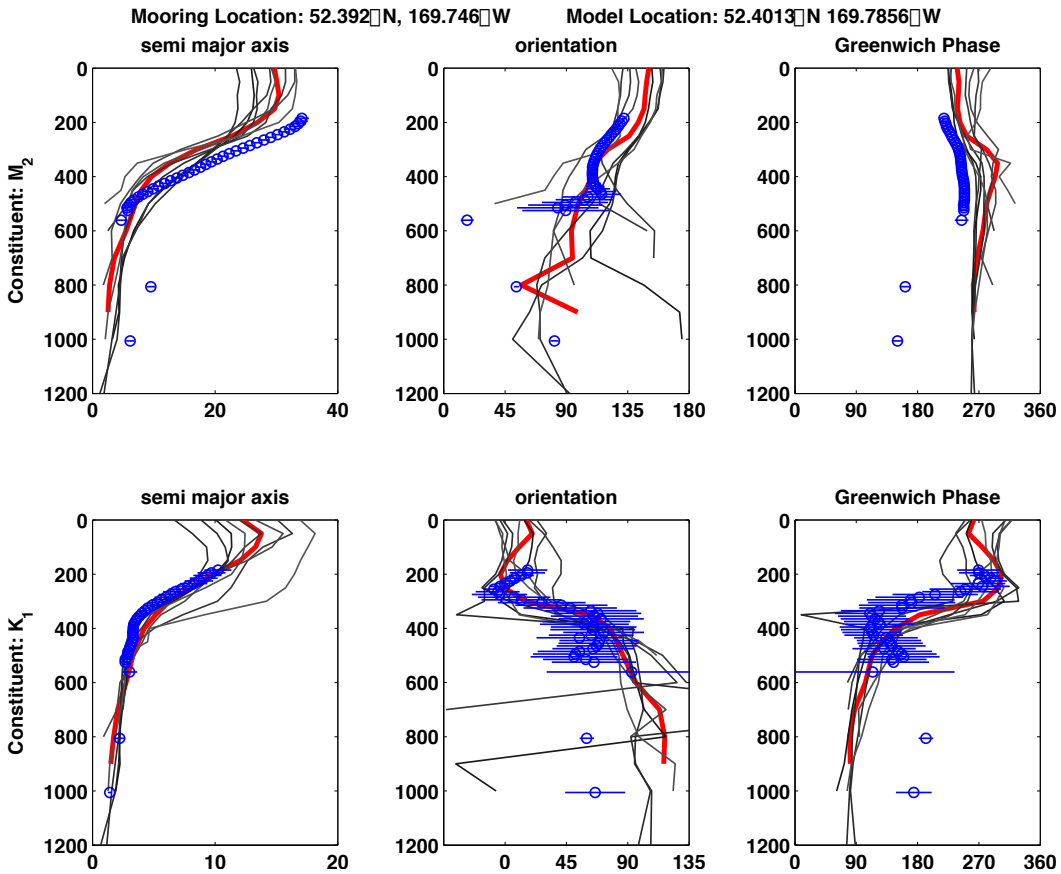
- Best current idea for extracting internal tides from SWOT is harmonic analysis on data (as in Ray and Mitchum 1996, 1997).
- Models: concurrent simulation of tides and eddying general circulation achieved in global HYCOM (Arbic Wallcraft Metzger 2010).
- Funded as part of US Navy operational ocean modelling effort.
- In contrast to earlier global baroclinic tide runs, HYCOM run has horizontally varying stratification.
- Comparison with along-track current generation altimeter data shows that HYCOM simulation has baroclinic tides of approximately correct magnitude, but does not yet place peak and trough locations well enough to be used for operational removal of internal tides from SWOT.
- Data assimilation planned for HYCOM runs–may improve predictive capability for internal tides.
- Forward models can be used to study temporal variability of tides–study with Richard Ray is planned.

Visual validation of tidal current vertical structure (Timko et al. in prep)

Blue: ADCP data

Red: nearest model point

Black: 8 surrounding model points



Global model-current meter comparisons: Low-frequency (left; Scott et al. 2010) and t idal (right; Timko et al. in prep)