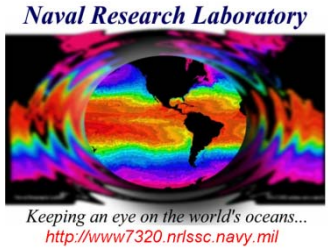

Sampling errors in the decomposition of vertical modes from current meter data estimated using an eddy-resolving ocean circulation model with embedded tides

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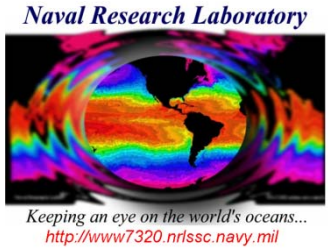
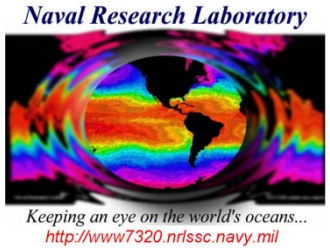


Comparison to SSH

- Modern data-assimilative tide models perform well, when the tidal elevations are compared to other models and to bottom pressure gauges and coastal tide gauges (Presentation by Stammer)
  - RMS errors ~0.5 cm for deep water BPRs
  - RMS errors ~4 cm coastal tide gauges
- However, recent work at parameter tuning for barotropic tide models shows that minimizing the RMS error in elevation doesn't guarantee a good tidal dissipation (Buijsman et al, JGR-Oceans, submitted)
- Dissipation is controlled by the tidal velocity, which is not an assimilated variable



Barotropic Tidal Velocity

- The tidal models predict a barotropic tidal velocity.
- The barotropic tidal velocity is not constrained by data.
- Unfortunately, there is not a database of observed barotropic tidal velocity for assimilation
  - Historical observations
    - Moored current meter moorings via mode fitting (Dick and Siedler, 1985; Siedler and Paul, 1985) or deep currents (Luyten and Stommel, 1991)
    - Bottom electric field measurements (Luther et al, 1991)
    - Acoustic tomography (Dushaw et al, 1994, 1995, 1997)

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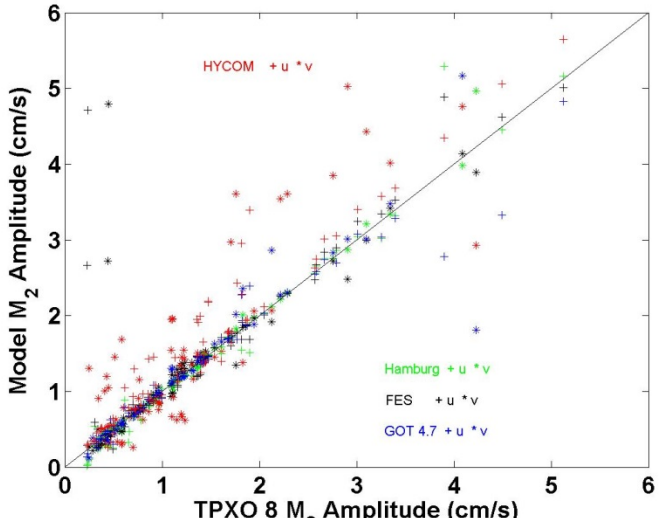
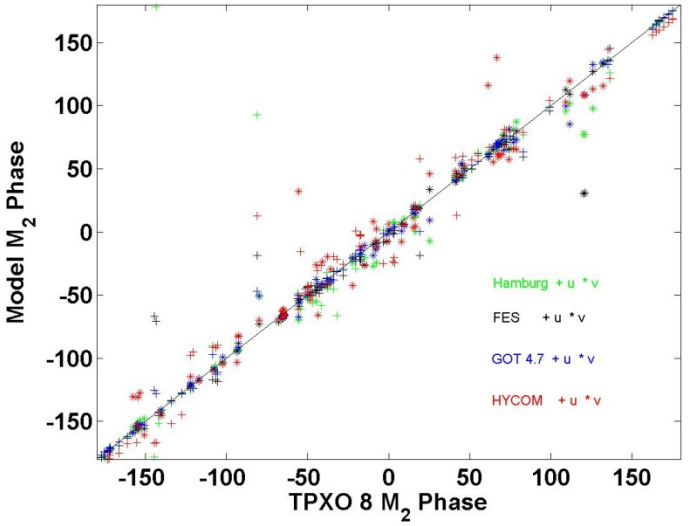
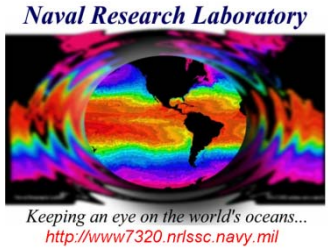
Comparison of Model Barotropic Velocities

- Comparison of the M_2 velocity amplitudes and phases for 5 barotropic tide models shows RMS errors ~0.6 cm/s for typical amplitude of ~1.7 cm/s and phase errors ~10°
- Tide Models
  - Data Assimilative
    - FES2012 (Lyard et al, 2004, updated)
    - GOT4.8 (Ray 1999, updated)
    - Hamburg2012 (Taguchi et al, 2013)
    - TPXO8 (Egbert and Erofeeva, 2002, updated)
  - Forward
    - HYCOM (Arbic et al, 2010, 2012)
      - Tides embedded in 3D circulation model
- Stammer et al (2013) compare 11 tidal models, but for brevity not all models are shown here







Estimating Barotropic Velocity

- While models can predict the barotropic velocity, barotropic tidal velocities are not observed directly and must be estimated
- Use a modal decomposition of the linear, flat bottom, normal modes

$$\frac{d}{dz}\left[\frac{\omega^2 - f^2}{N^2(z) - \omega^2}\frac{dF_n}{dz}\right] = -\lambda^2 F_n(z),$$

- Least squares fit to a barotropic plus first baroclinic sampled at the depths of the current meters (Siedler and Paul, 1991)

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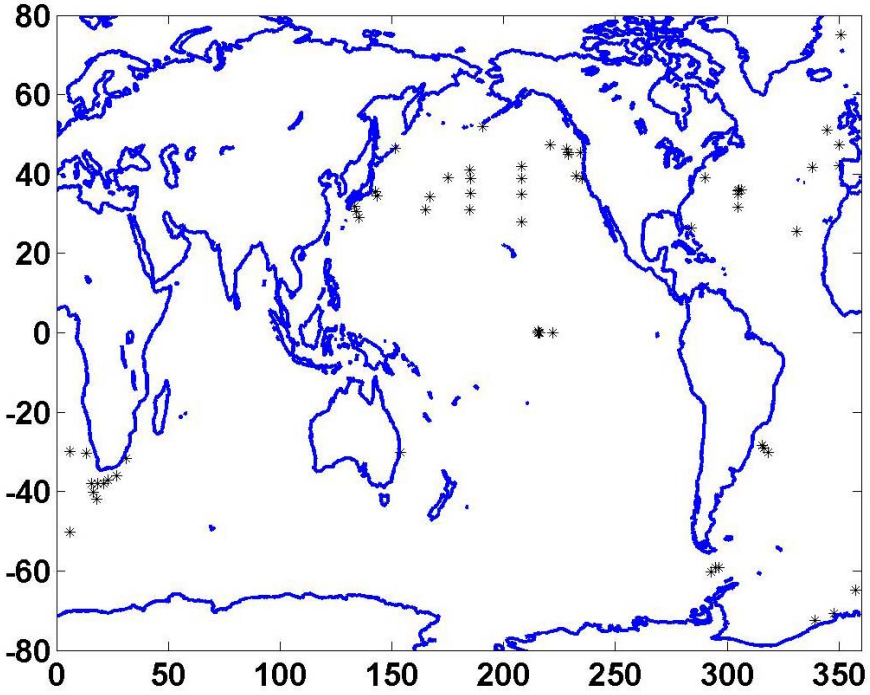
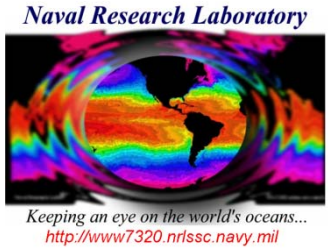
Observations of the Barotropic Tidal Velocity

Mooring Locations



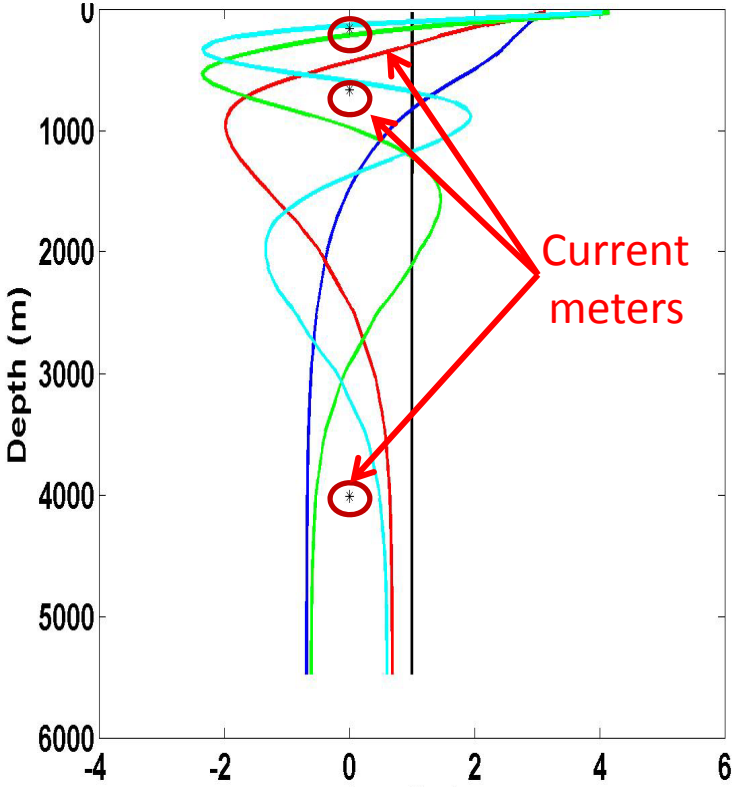
- Using a database of current meter observations identified 76 moorings with 2 hourly or shorter sampling for a duration of 180 days or longer with a minimum 3 meters on the mooring with at least one meter above 600m, one meter between 600-2000m and one meter below 2000m
  - 26 moorings with 3 meters
  - 21 moorings with 4 meters
  - 24 moorings with 5 to 9 meters
  - 5 moorings with 10 or more meters



Internal Tide Normal Modes

- At each mooring, the normal modes are calculated and sampled at the meter depths
- Moorings selected have at least one meter in the upper lobe of the first BC mode, one near the zero crossing and one in deep water
  - Example from North Pacific with 3 current meters shown on slide

Normal modes at mooring in North Pacific (35N 208E) with 3 current meters



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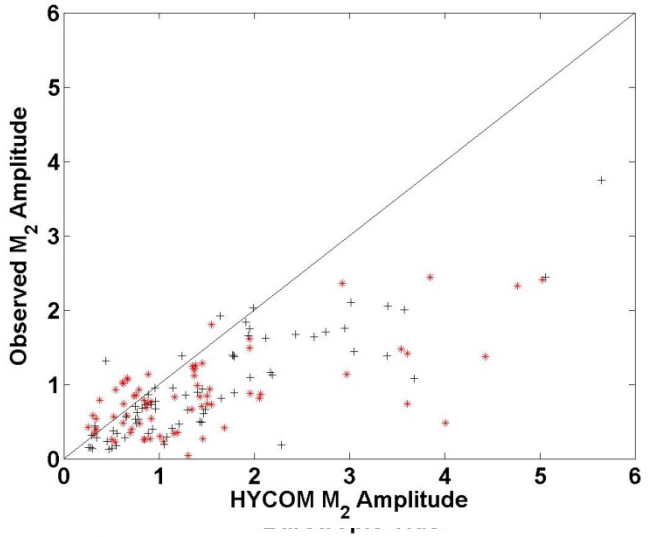
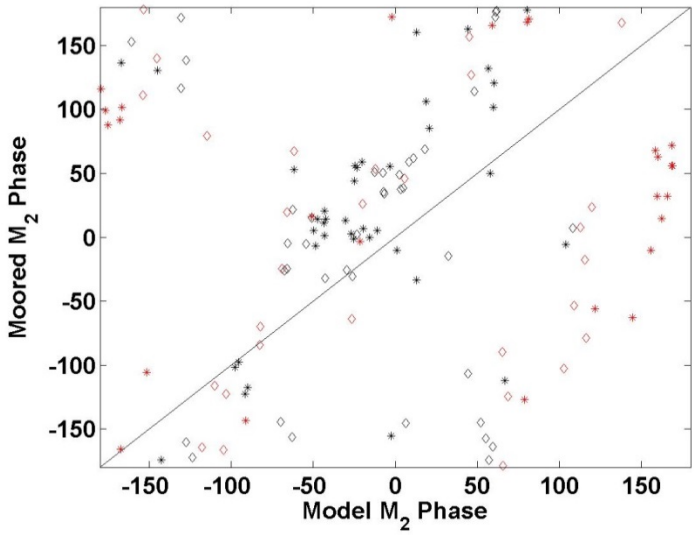
Barotropic Velocity Comparison with HYCOM

- Comparing the model barotropic M_2 velocity and phase with the estimated barotropic velocity and phase
- Estimated velocity is much weaker and large phase errors are observed
- Errors with estimated barotropic velocity much larger than errors between all of the barotropic models
- WHY?





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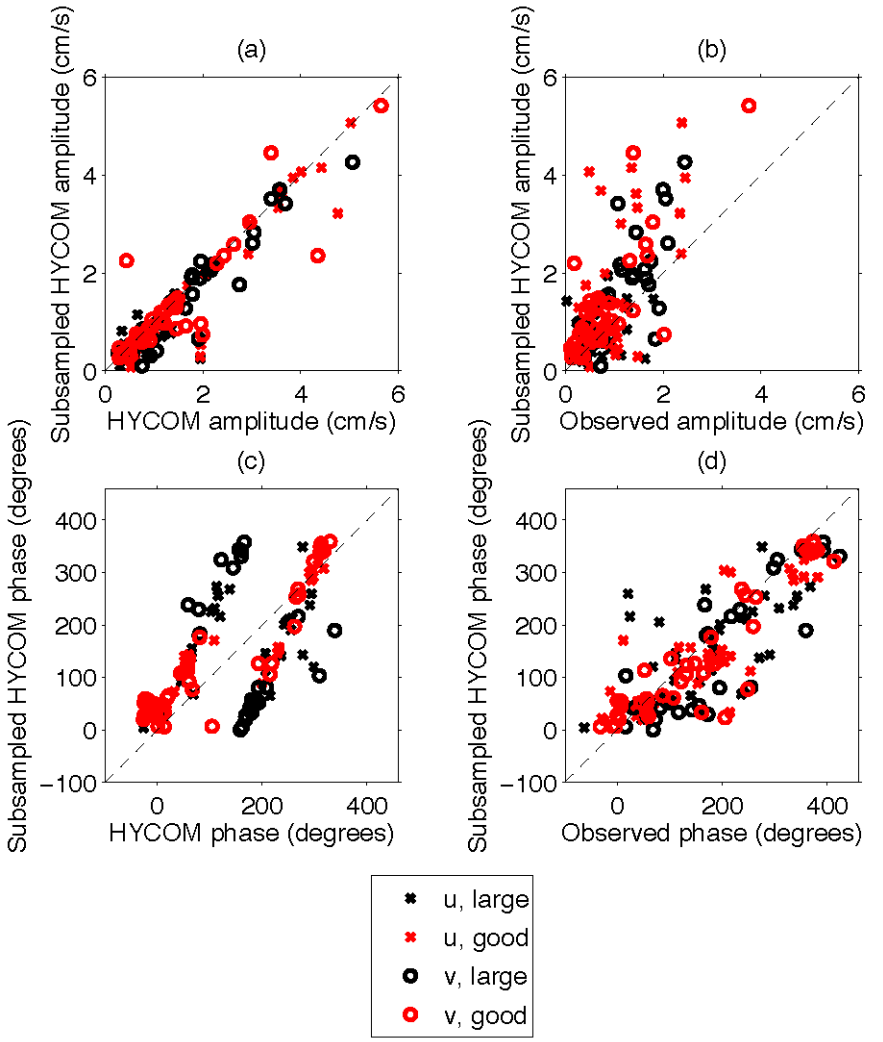
Sampling Errors in Estimating the Barotropic Velocity

- Our ability to estimate the barotropic velocity is affected by the number and distribution of the current meters and the internal tide variability
- HYCOM provides a complete profile of the velocity which can be sampled similar to the current meters to look at sampling errors
- Sampled HYCOM shows an under estimate of the barotropic tide and large phase errors at a subset of the mooring.
- Sampled HYCOM compares better with the estimated barotropic tide than the actual



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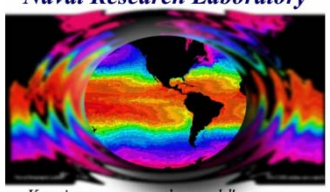

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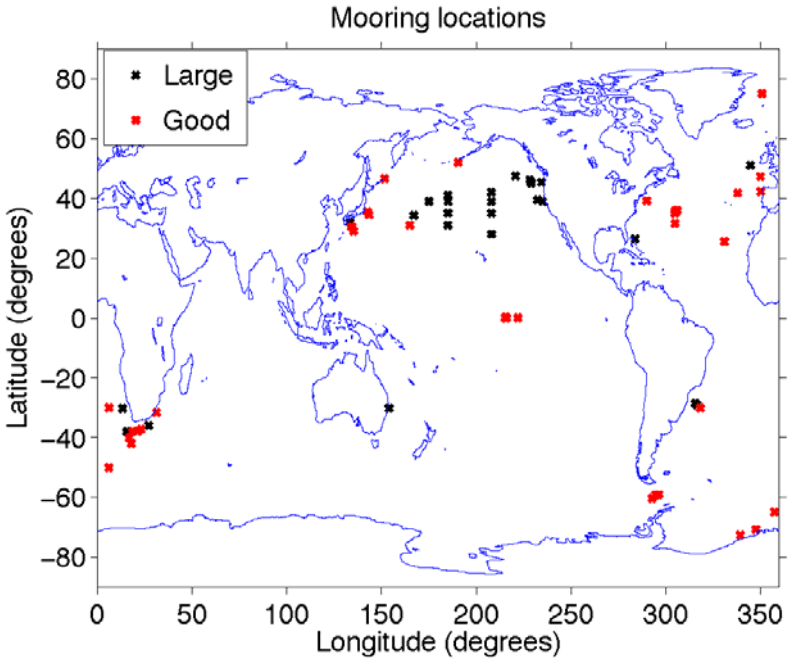
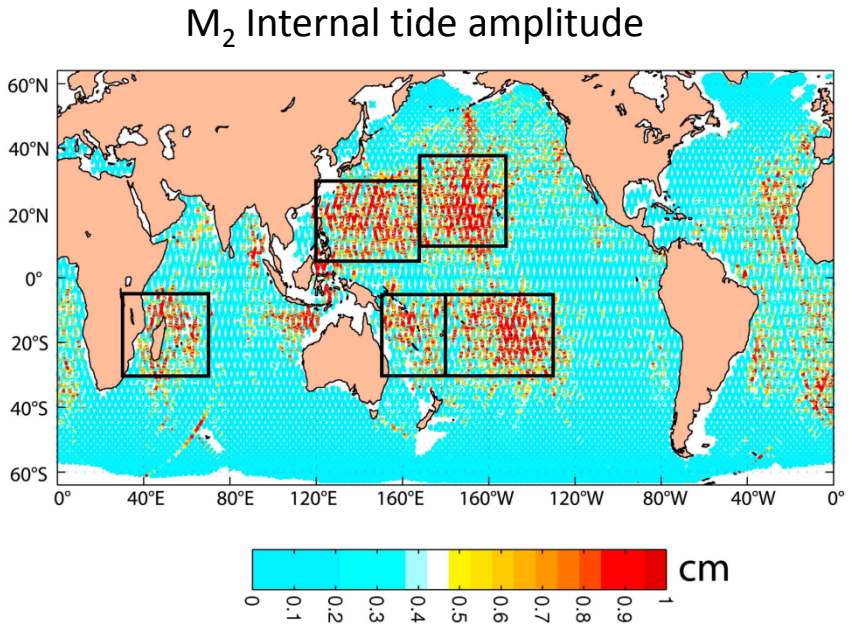
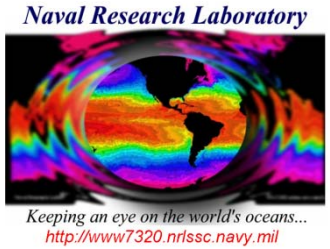
Sampling Errors in Estimating the Barotropic Velocity





The sampling errors result from poor vertical placement of the current meters and aliasing of higher vertical modes. Thus, regions of strong internal tides such as north of Hawaii are regions with large barotropic phase errors. More than half of the moorings with large phase errors have only 3 current meters on the mooring.



Barotropic Tidal Velocity

- The barotropic tidal velocities between 5 different tidal models compare well in amplitude and phase
- Estimating barotropic velocity from historical current meter moorings is problematic.
  - Poor vertical sampling and aliased high model internal tides causes large phase errors and underestimation of the amplitude
  - Sampling the currents in a 3D circulation model confirms the sampling issues
- Dushaw will present a barotropic tidal velocity comparison based upon acoustic tomography