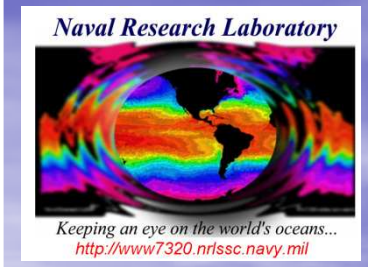

Internal Tides in a Global Ocean Circulation Model

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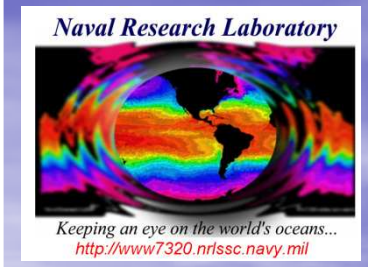
22 October, 2010

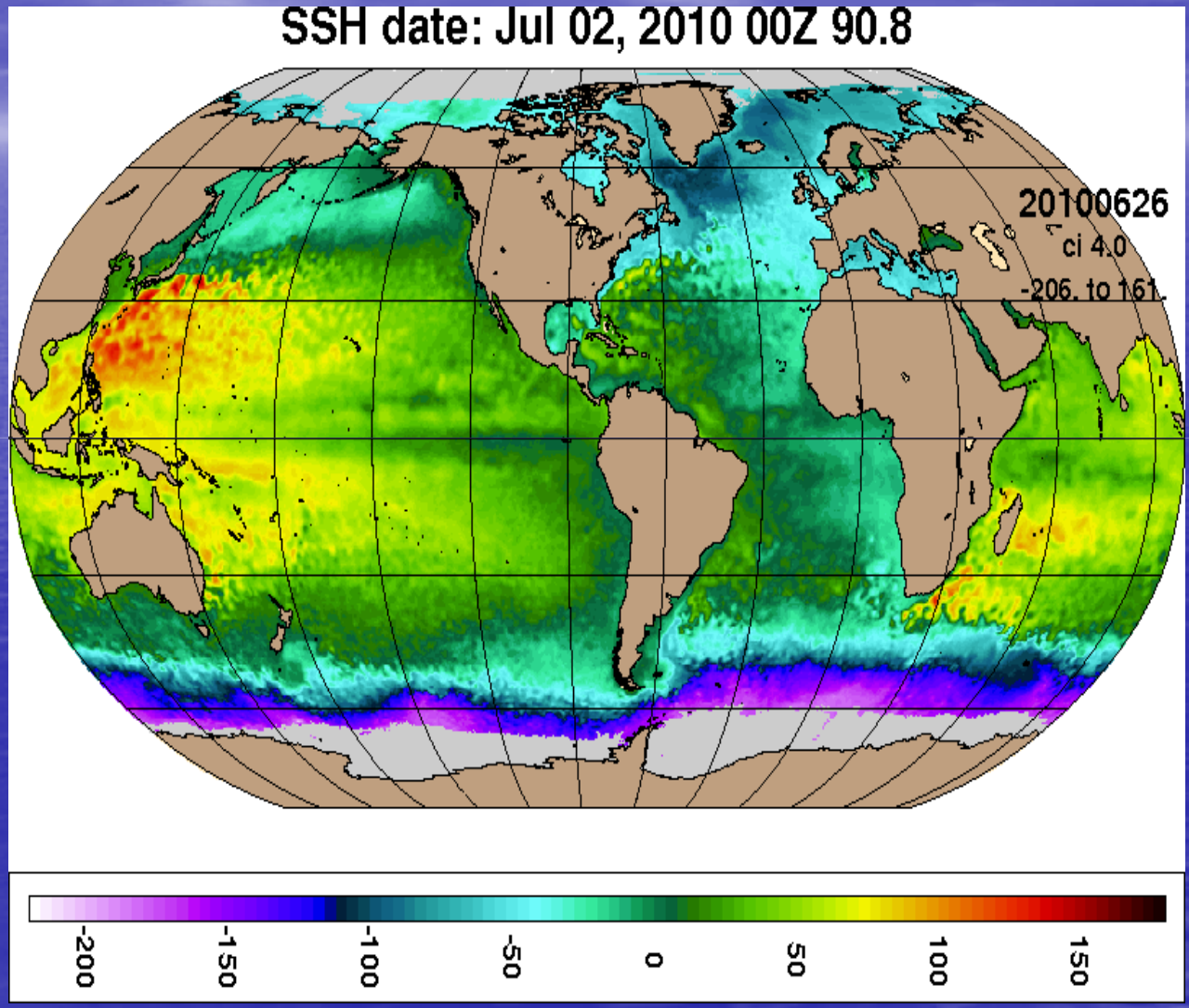


Internal Tides in a Global Ocean Circulation Model

- Today I will briefly describe the NRL effort to include tidal forcing in the global ocean forecast system
  - We have a long simulation with forcing by the tidal geopotential and realistic wind stress and buoyancy forcing with an equatorial resolution of 9 km
  - The model drag is tuned to give good agreement with the pelagic tide gauges
- The model shows localized generation of the internal tide and propagation for 1000's of km as seen by Ray, Alford and others
- The barotropic and internal tidal kinetic energy in the model compares well with historical current meters
- The modal comparison with the current meter moorings is problematic due to the difficulty in recovering the barotropic and baroclinic modes, intermittency of the internal tide and deep intensification of the tidal flow in the model
- The short wavelength SSH spectra scales as -11/3 which is quatlitatively similar to SQG theory, but the presence of energetic internal tidal beams can modify the spectrum with strong peaks near 100-150 km

Global HYCOM Ocean Forecast Model

- NRL runs a global ocean forecast system
- Uses the Hybrid Coordinate Ocean Model
- 1/12° horizontal resolution
- 32 vertical layers

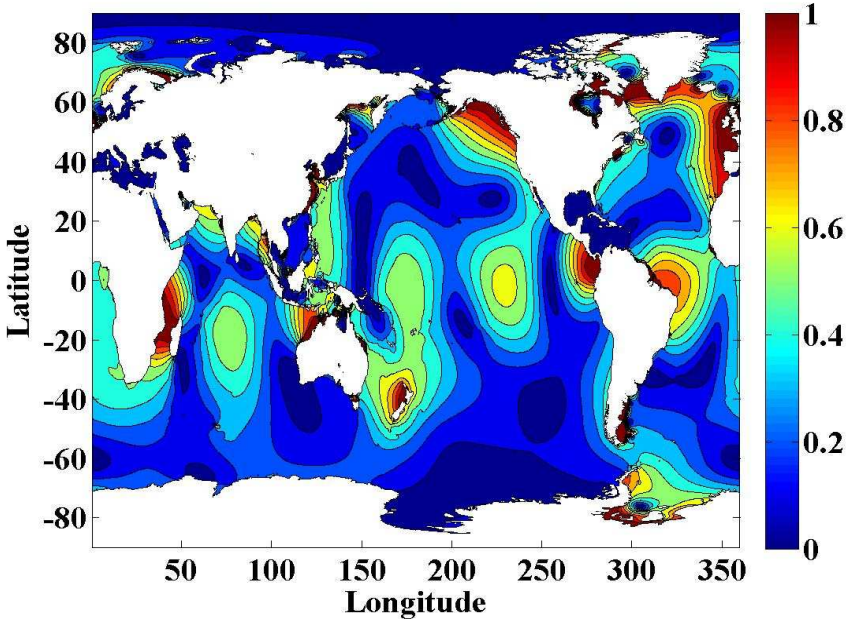


Modeling tides in the global model

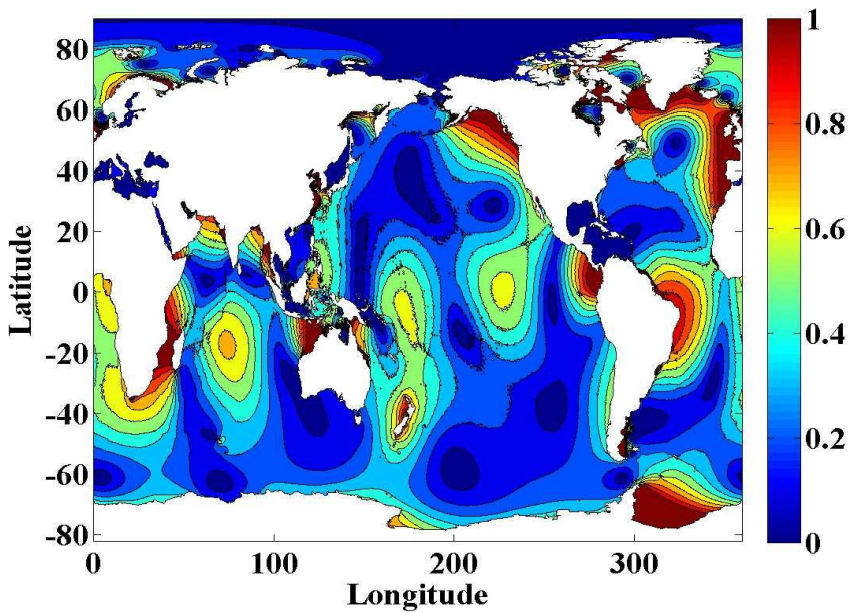
- In the global model, the body forces due to the tidal potential, self attraction and loading have been added
- Tidal Forcing with 8 constituents:
  - Semidiurnal M_2, S_2, N_2 and K_2
  - Diurnal O_1, P_1, Q_1 and K_1
- Topographic wave drag is applied to the tidal motions
  - The form of the drag is generalized from the linear topographic wave drag, but tuned to minimize the difference with the 102 pelagic tide gauges using a barotropic version of the model

Comparison of M_2 tide from Inverse Model (TPXO7.2) and HYCOM Simulation

TPXO7.2 M_2 Tidal Model



HYCOM M_2 Tide



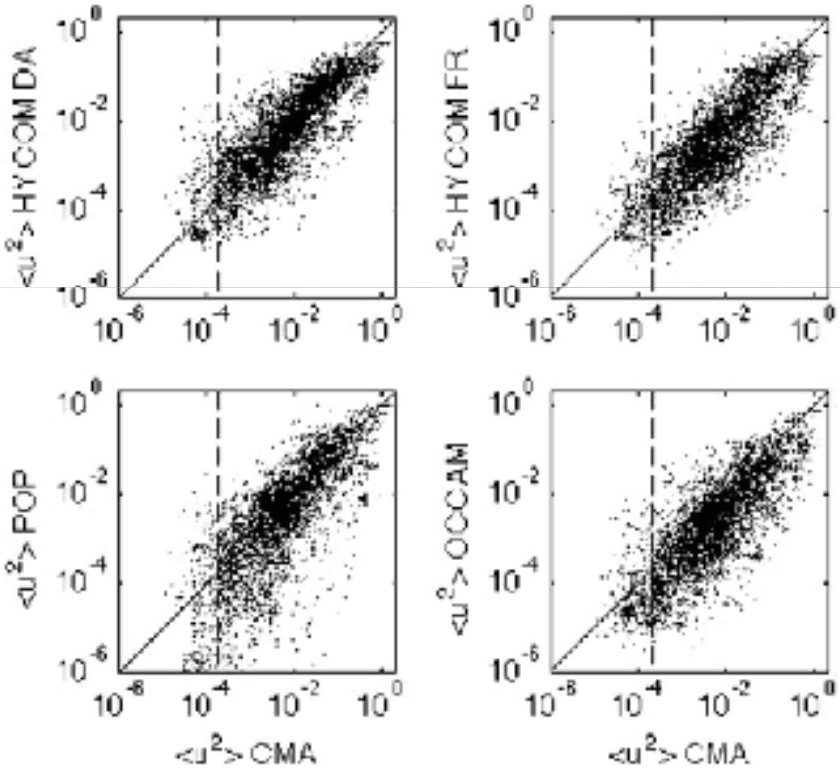
Difference with 102 pelagic tide gauges 7.8 cm rms
Difference with TPXO7.2 model 5.4 cm rms

Velocity comparisons

- Using a current meter data set compiled by Rob Scott, we will compare the tidal velocities of the model with the observed (but not contemporaneous) velocity
- First we will show scatterplots of the energy in the model versus the energy observed by current meters
- Then we will show attempts to characterize the vertical structure of the tidal velocities

Comparison of Observed and Model Energy levels

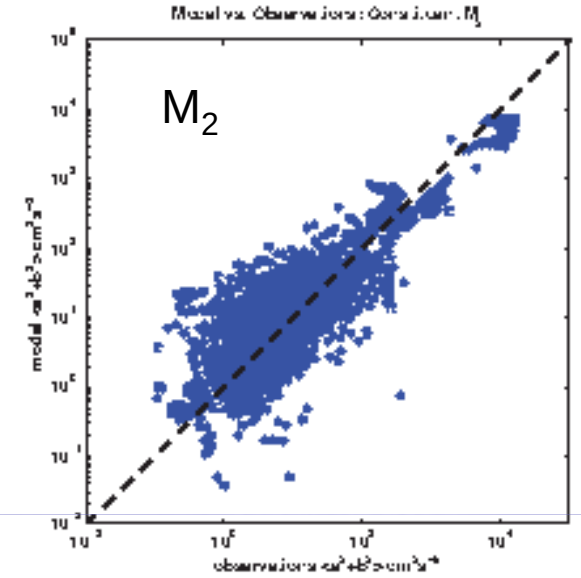
Low frequency currents



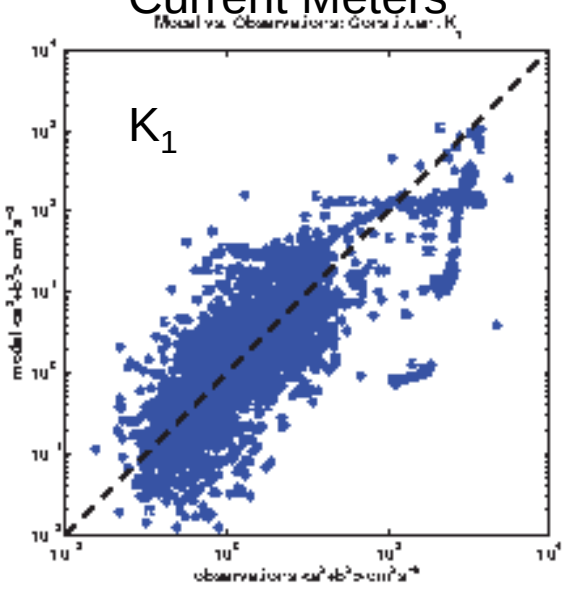
From Scott, et al 2010

Tidal Currents

Model



Current Meters

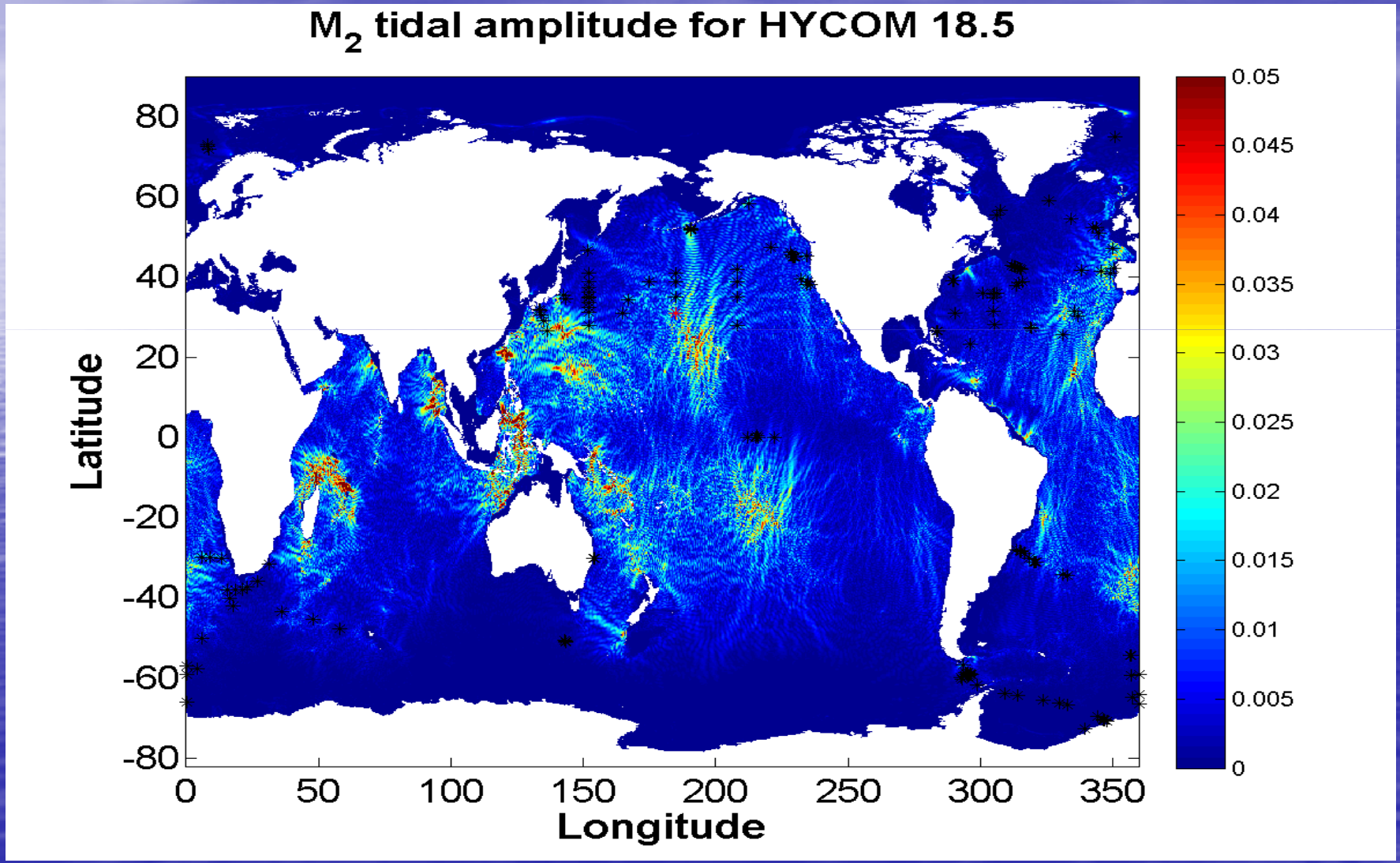


Current Meter Database

- Collection of approx 9000 current meter records accumulated by R.B. Scott:
  - OSU Buoy Group Archive
  - OSU Deep Water Archive
  - WHOI data
  - Additional moorings from other sources
- Existing records have lengths ~10 days to 2 years
- Records cover about 35 years ~1970-present
- Additional current meter records are continually being added to the database
- Record selection criteria:
  - Moorings with at least 3 instruments
    - One instrument above 800m and one instrument below 2000m
  - Observation interval:
    - Prefer hourly or shorter sampling
  - Length of Record:
    - Minimum of 180 days

173 moorings meet these criteria

M_2 tidal amplitude from global model steric sea surface height with the 173 comparison mooring locations

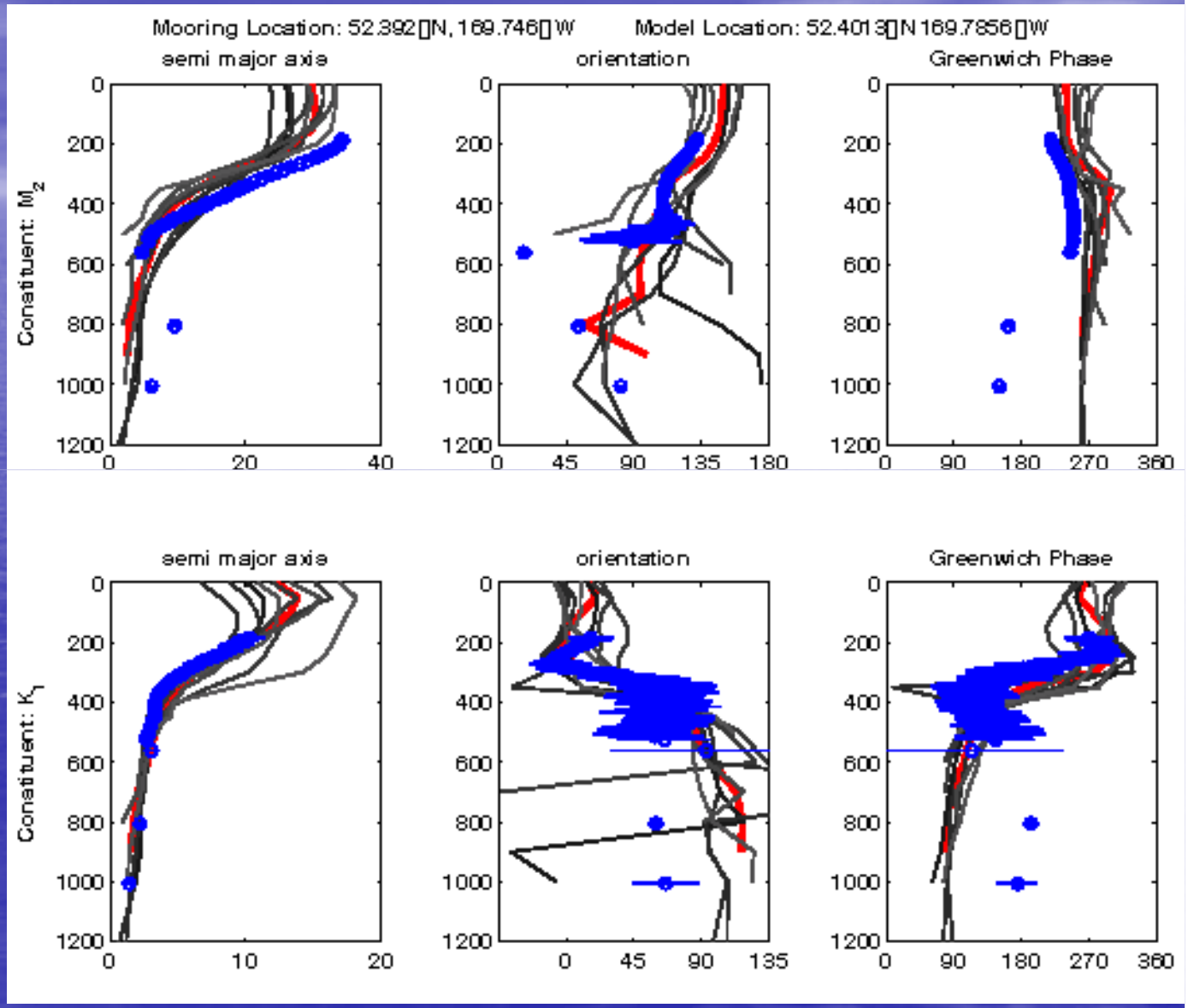


Tidal Ellipse parameters in the North Pacific

The tidal velocity can be characterized by an ellipse defined by five parameters.

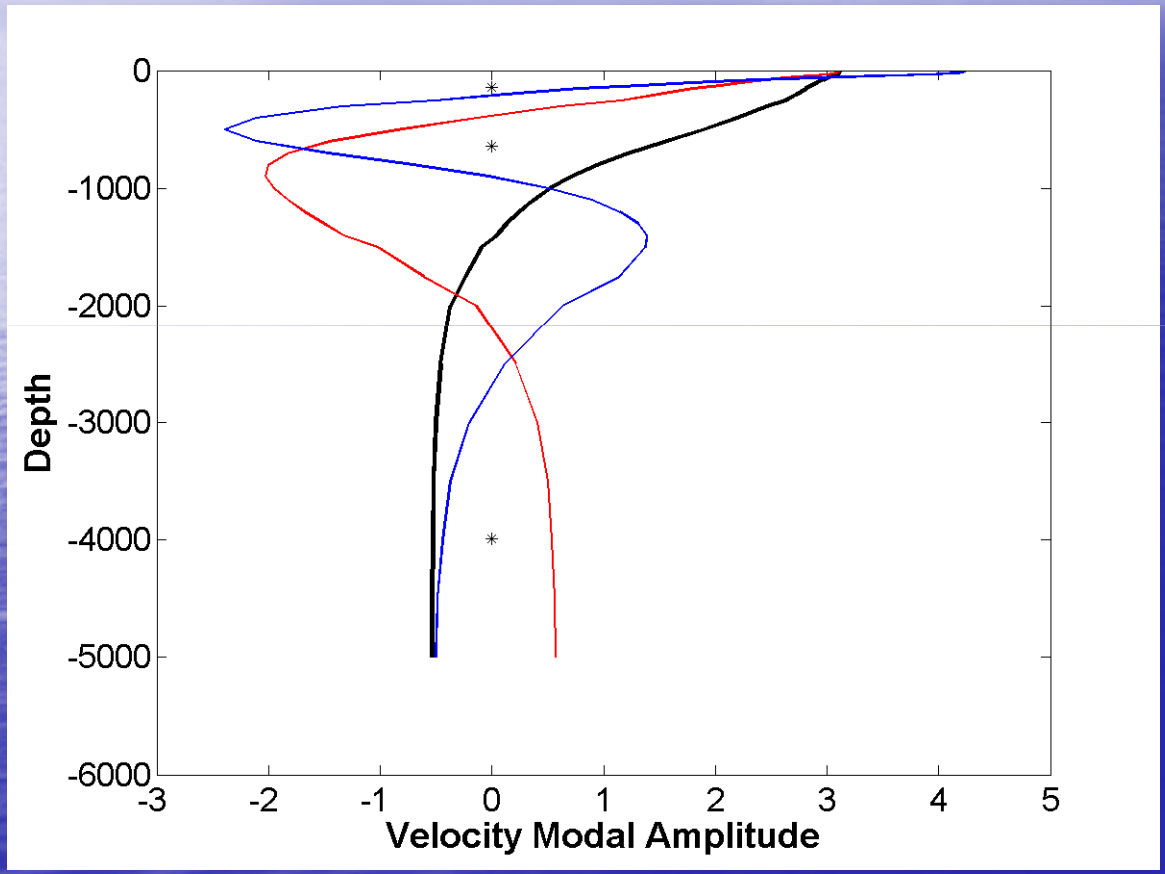
Three of these parameters, the semi major axis, the orientations and the time of maximum flow (Greenwich Phase) for the major semidiurnal and diurnal tidal constituents are shown

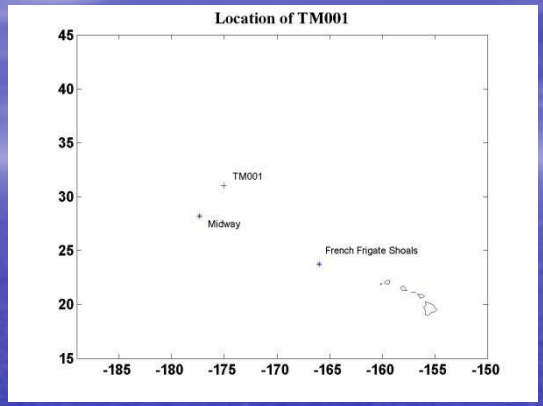
Timko, et al, in prep



Blue-Observations Red-Nearest Model Point Black Neighboring Model Points

Normal Modes for mooring near Midway Island

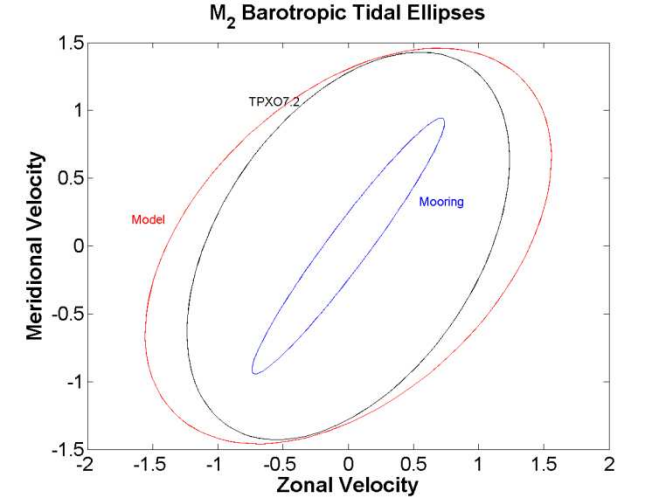


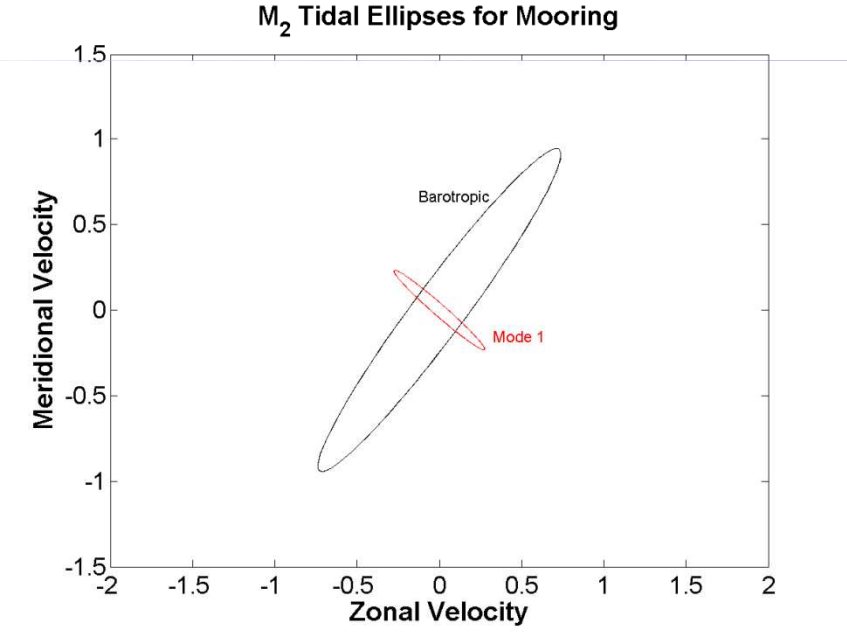


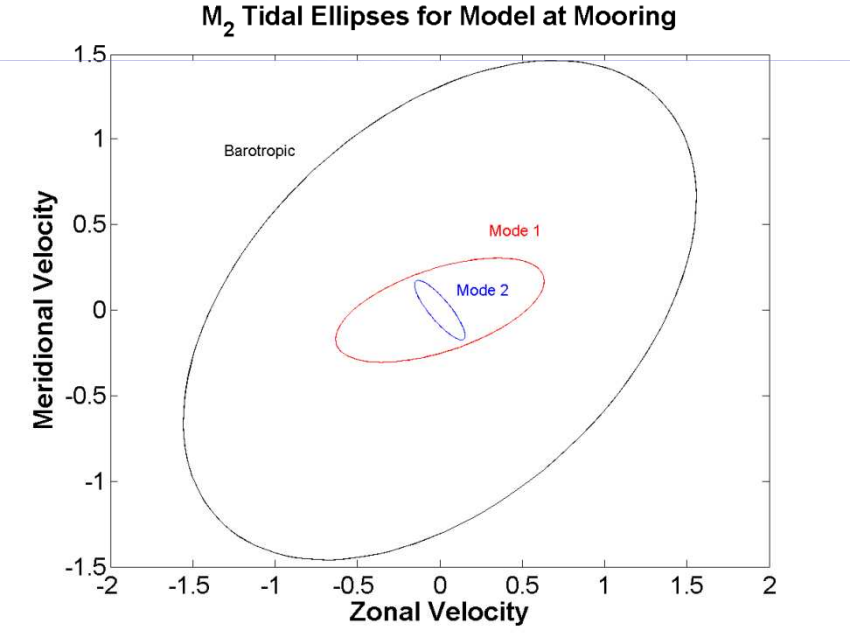
The distribution of current meters is marginal, barely able to resolve the first mode.

The poor resolution of the mooring data is a common and serious problem with leakage from high modes and poor estimates of the barotropic mode

Barotropic and Baroclinic tidal ellipses







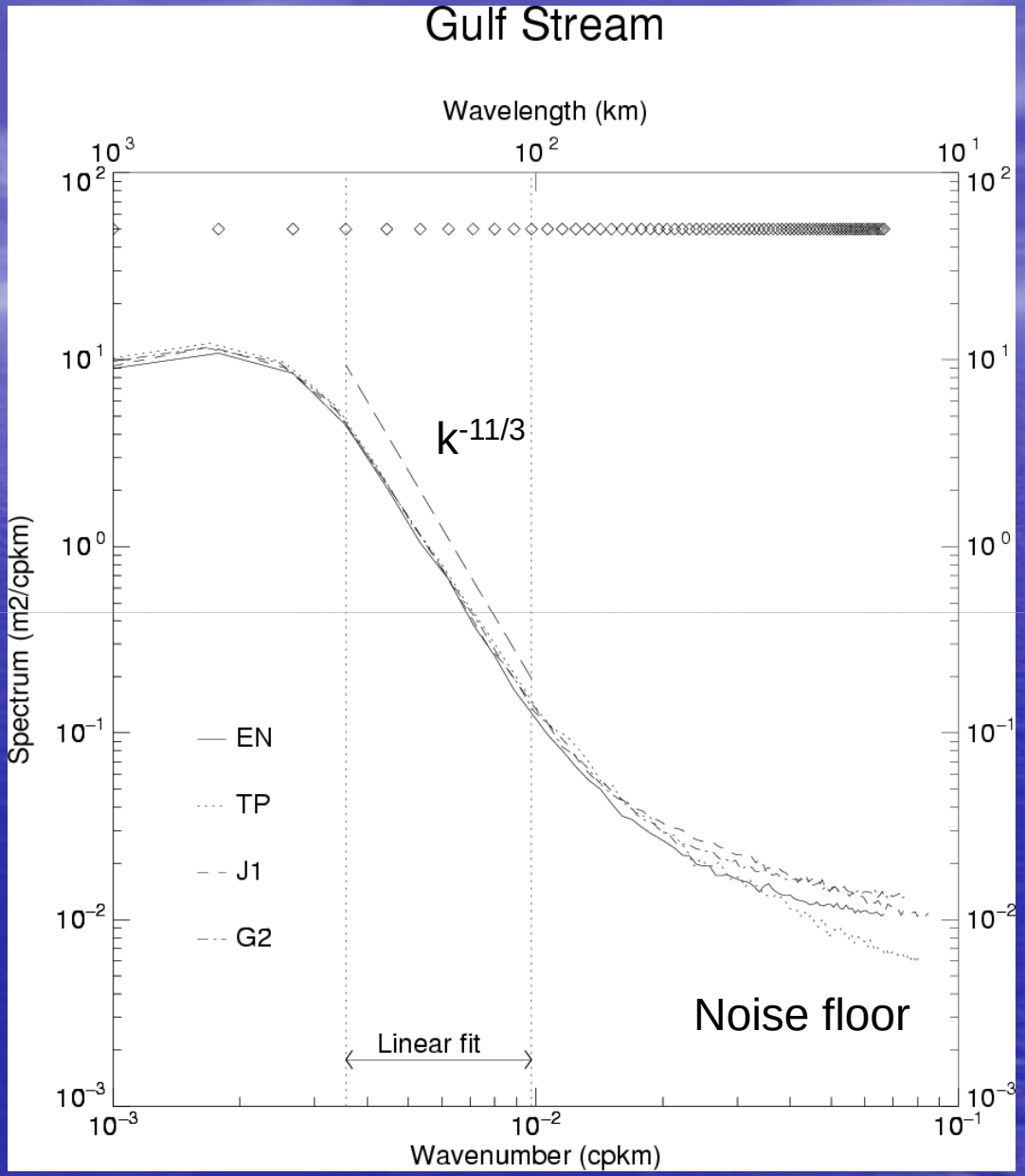
The barotropic tidal velocity is much weaker at the mooring and the orientation of the baroclinic ellipse is off by 90°. The model comp ares well with TPXO7.2

Tidal velocity comparisons

- The barotropic tidal velocities compare well with the TPXO7.2 velocities
- The vertical distribution of the tidal velocities in the model scales well with the current meter observations
  - But the detailed modal comparison is not as good
  - More work needs to be done

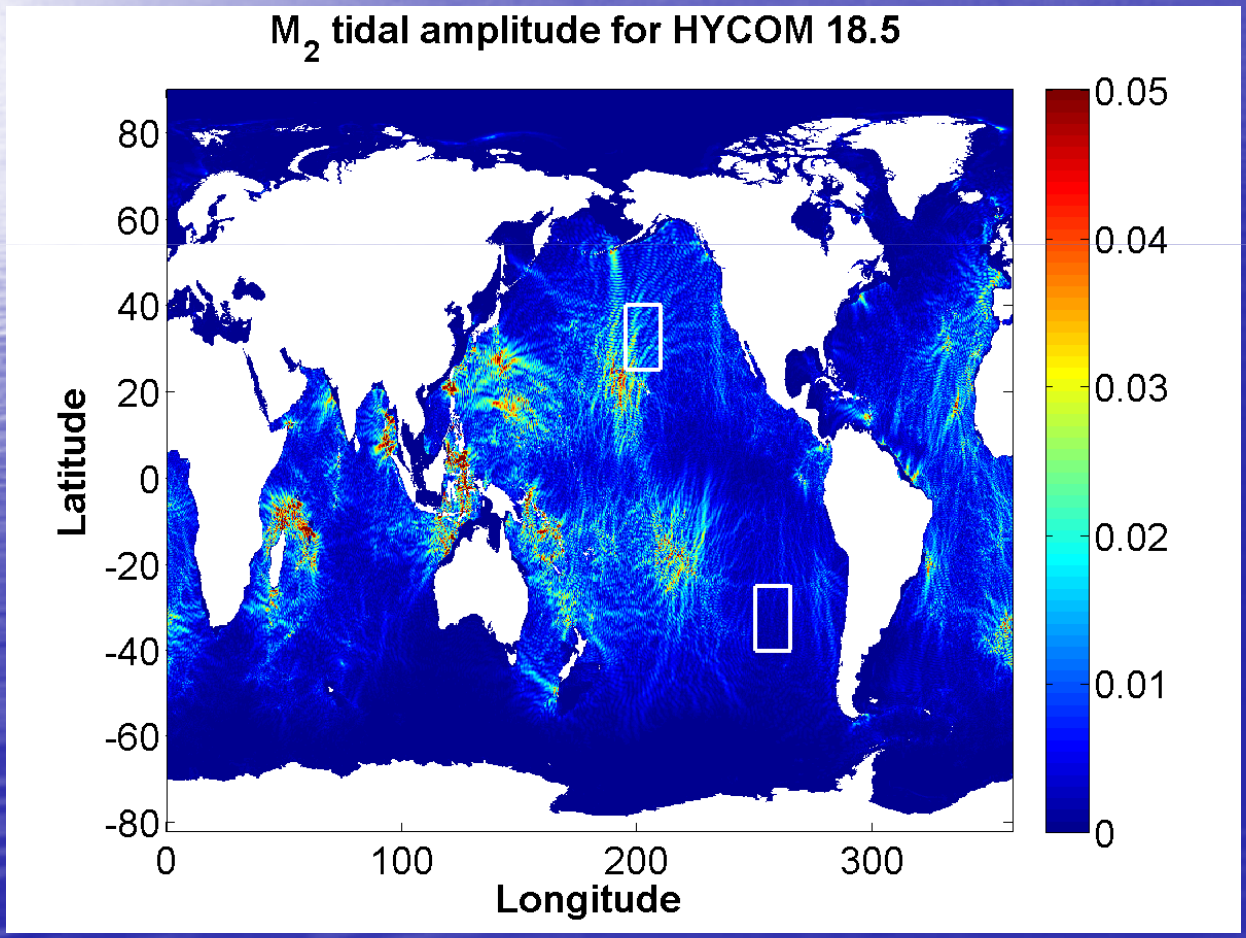
Altimeter Along-Track Wavenumber Spectra

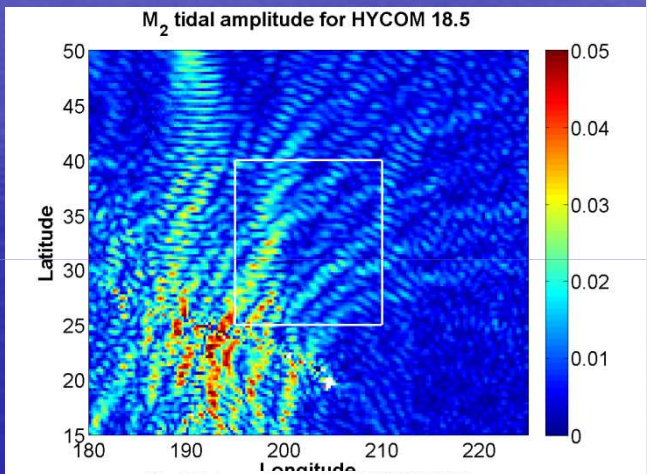
LeTraon, et al (2008) found a $k^{-11/3}$ spectrum between 100-300 km which they suggest is consistent with Surface Quasigeostrophic (SQG) theory with the altimeter noise floor flattening the spectrum at shorter scale

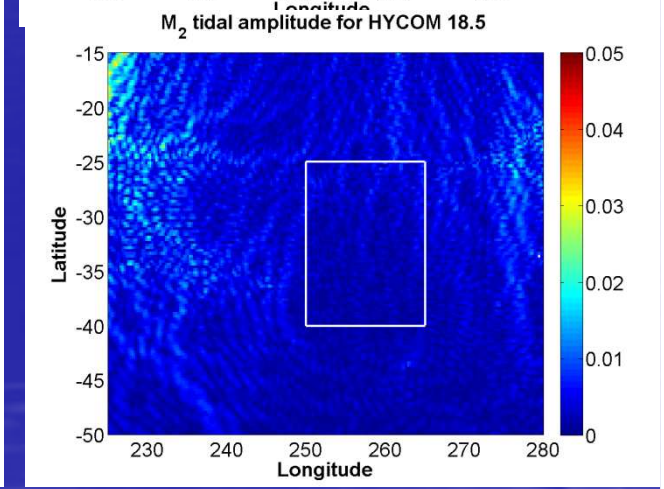


From LeTraon, et al (2008)

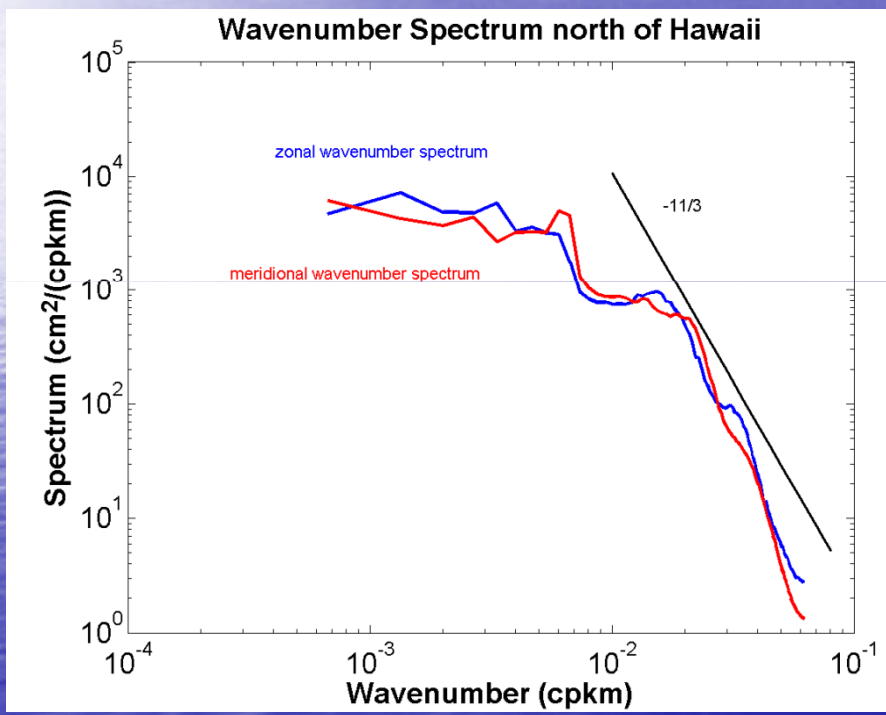
Properties of the model internal tides in the Pacific Ocean

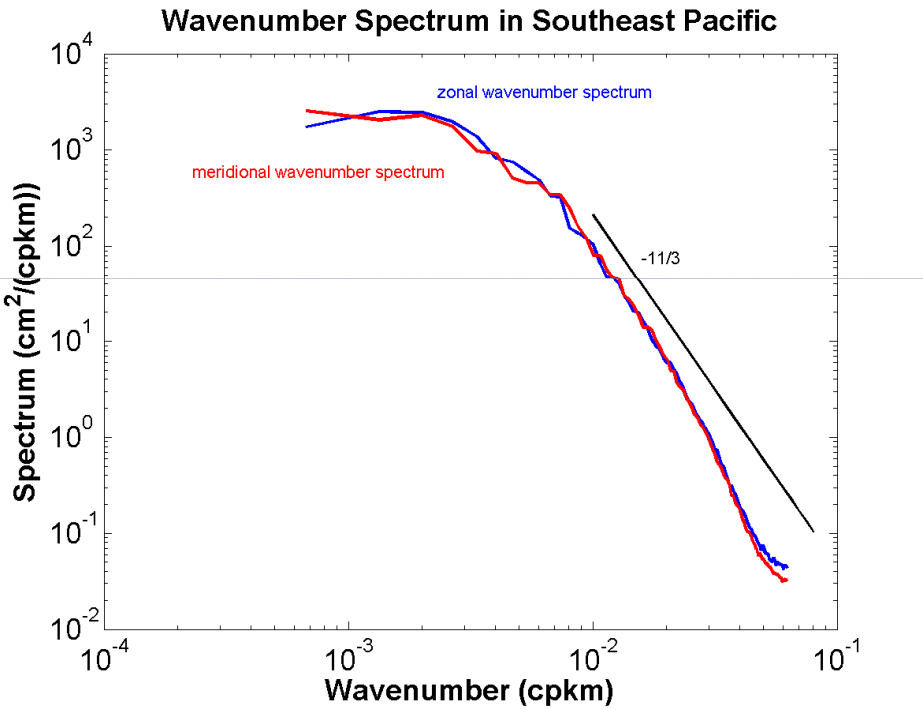






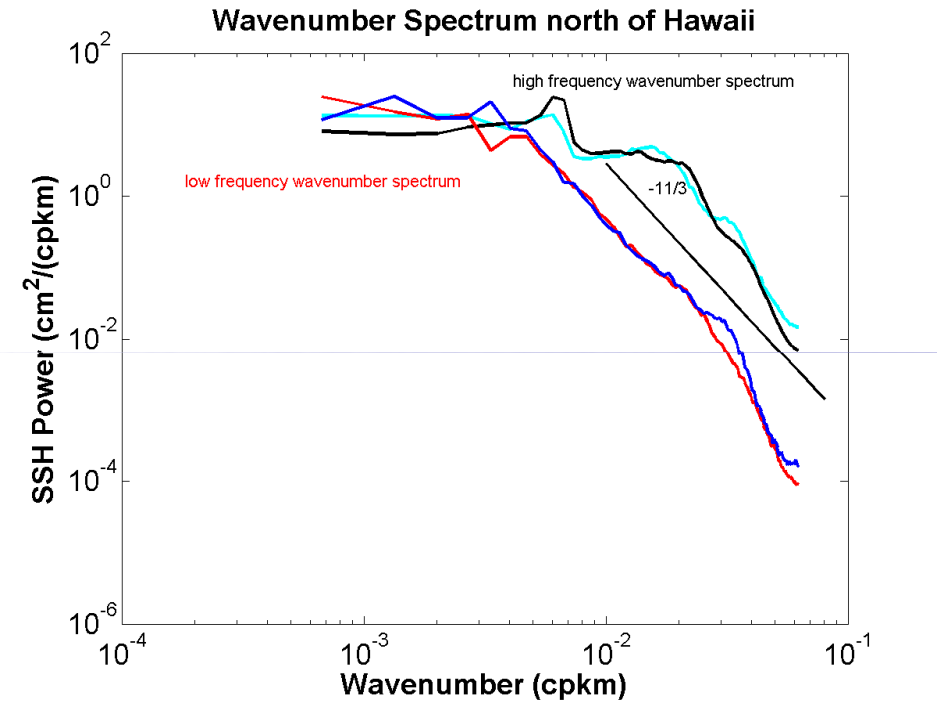
Wavenumber spectrum for the Steric SSH in the Pacific Ocean

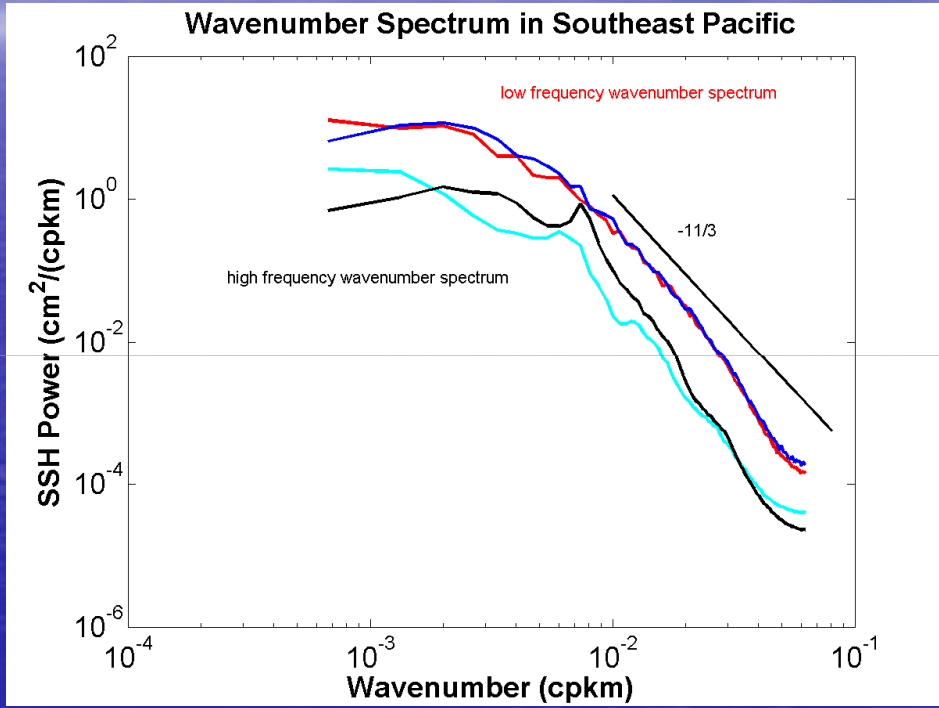




The short scales are slightly steeper than -11/3 which is the prediction for Surface QuasiGeostrophic flow (SQG) as noted for the altimeter data by LeTraon, et al 2008 and the poster by Zaron. The peak around 150 km is associated with the M_2 beams generated near Hawaii.

Wavenumber Spectrum of the internal tide and mesoscale





North of Hawaii in a high internal tide energy region, the spectra are nearly identical for scales greater than 250km. The presence of the M_2 beam is evident in the peak near 140 km and the greater power in the high frequency.

In the Southeast Pacific, a region of low mesoscale and internal tide energy, the high frequency power is much less than the low frequency and a M_2 peak is seen at 120 km

Internal Tides in a Global Ocean Circulation Model

- LeTraon, et al (JPO, 2008) found that the along-track wavenumber spectrum had a $k^{-11/3}$ shape between 100-300 km which is consistent with SQG theory with the altimeter noise floor flattening the spectrum at smaller scales
- The model spectra show a similar $k^{-11/3}$ shape over a larger range 20-300 km with an important difference that the internal tides create a broad peak around 140 km
- The internal tide energy levels can exceed the mesoscale energy which changes the shape of the spectrum

Internal Tides in a Global Ocean Circulation Model

- A tidal prediction model has been inserted within an OGCM which generates realistic surface barotropic and internal tides
- The internal tidal kinetic energy and the tidal ellipses compare well with historical current meter observations, but the modal comparison is problematic due to the poor sampling of the moorings
- The model SSH spectra show a similar $k^{-11/3}$ shape over a larger range 20-300 km with an important difference that the internal tides create a broad peak around 140 km
- The internal tide energy levels can exceed the mesoscale energy which changes the shape of the spectrum