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Large-scale intraseasonal variability in the global ocean

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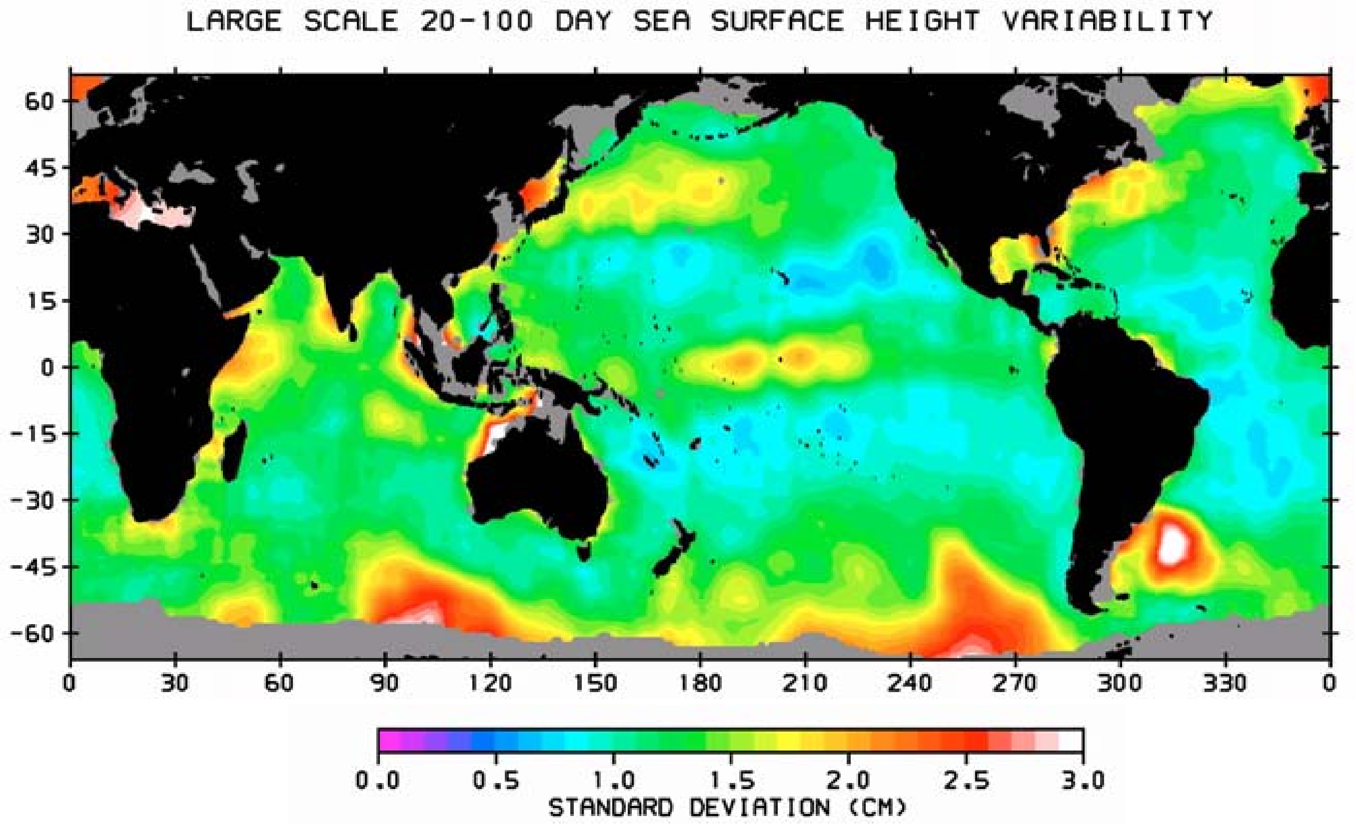
What are we talking about?

- Spectral domain
  - Scales of 500 km and longer, to differentiate from mesoscale
  - Periods shorter than 6 months (subseasonal, not just intraseasonal)

- Some signals treated elsewhere
  - Tropical waves (Picaut et al.)
  - Planetary waves (Chelton et al.)
  - Tides (Le Provost et al.)

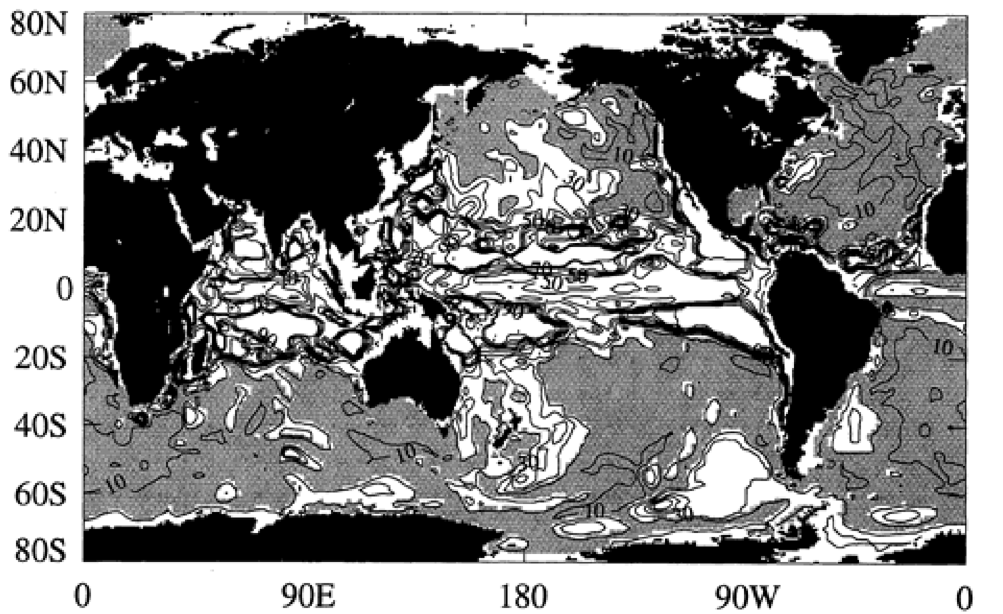
- Our neck of the oceans
  - Truly large-scale (basin, global)
  - Locally confined, mid and high latitudes
  - Barotropic
  - Down to daily periods

Some aspects of the signal



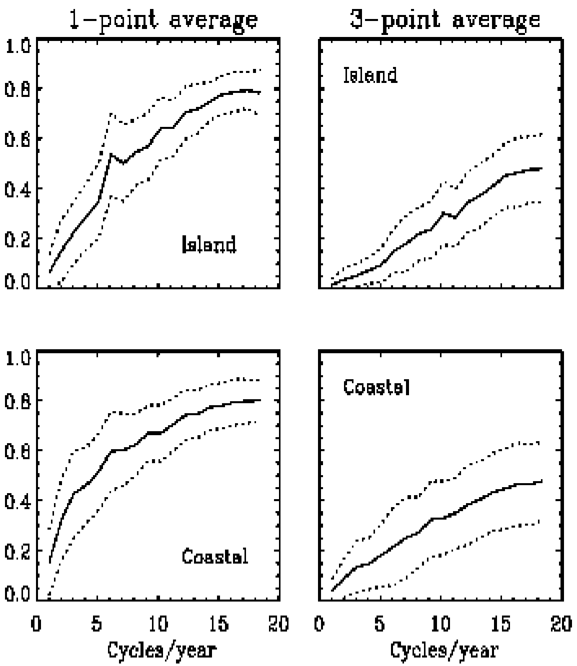
Global picture of the large-scale variability, missing before satellite altimetry, reveals clear patterns of enhanced energy and quieter regions, with strongest signals at mid and high latitudes and coastal regions (Fu & Smith 1996)

Strong short period signals



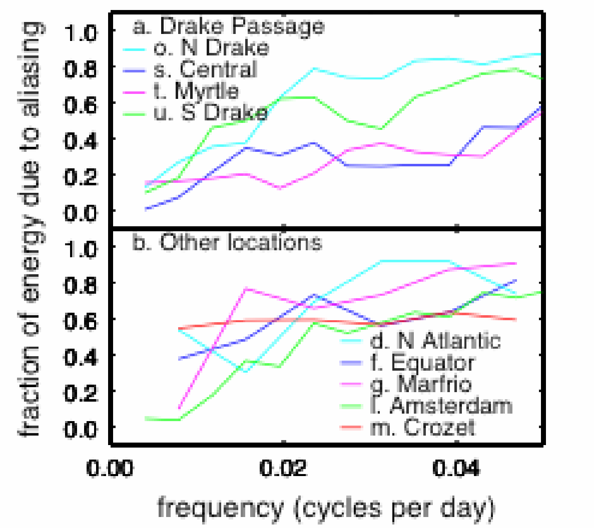
Model estimates of half-energy period for intraseasonal sea level fluctuations point to the presence of substantial variance at periods shorter than 20 days (Fukumori et al., 1998)

The story from tide gauges and BPRs



Ratio of the aliased variance to the observed variance as function of frequency based on analysis of tide gauge data

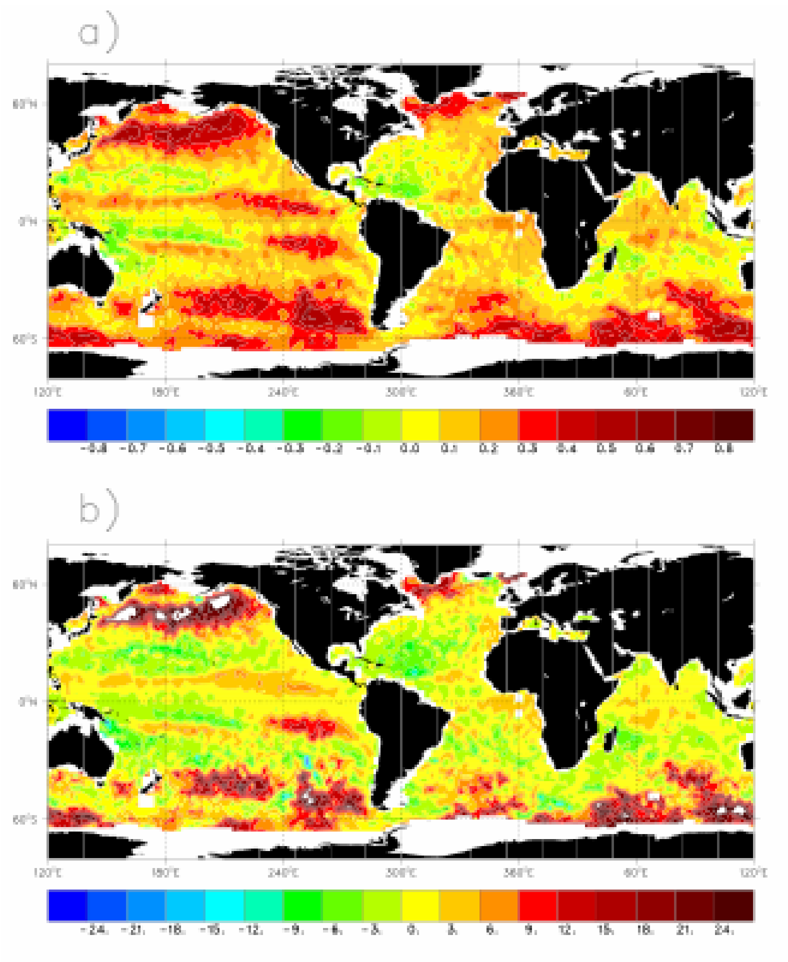
Ponte & Lyard (2002)



Similar results are seen from analysis of bottom pressure records

Gille & Hughes (2001)

Models and altimeter

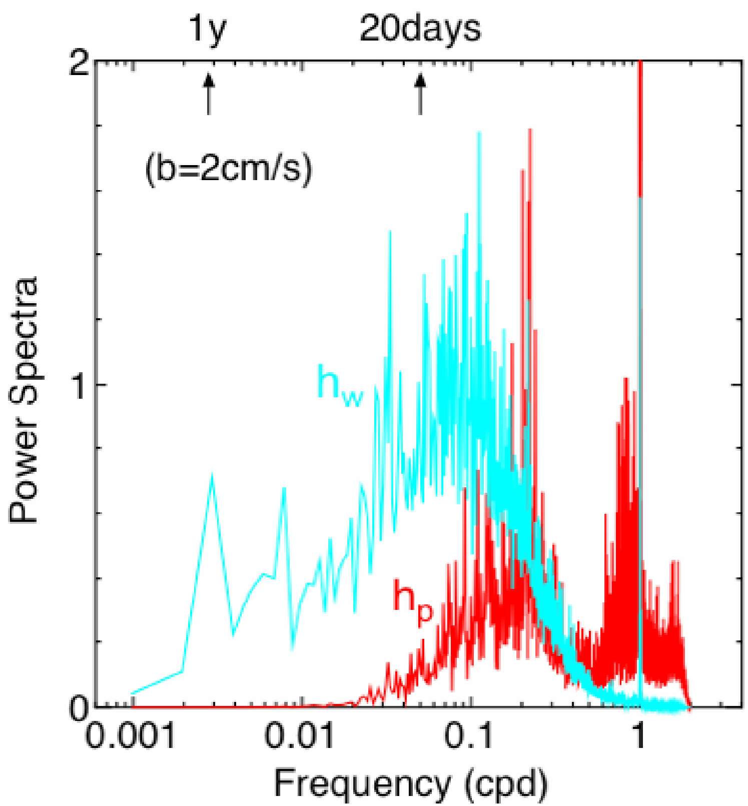


Sea level simulated by barotropic models correlate well with altimeter observations

Substantial variance reduction with model-based corrections

(Stammer et al., 2000; Tierney et al. 2000)

More than just wind forcing



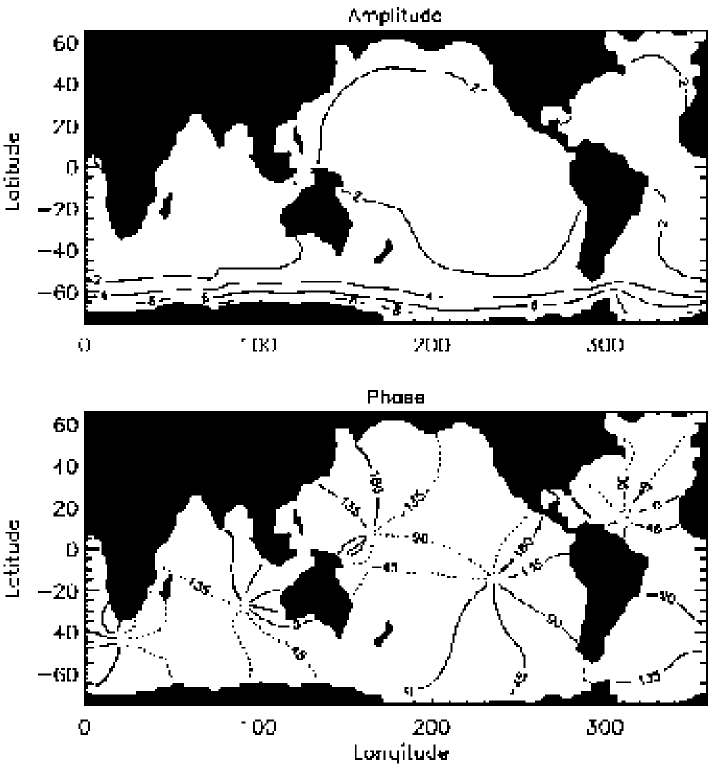
Dynamic response to barometric pressure is clear at weekly and shorter periods

Pressure-driven dynamic sea level signals are more important than wind-driven signals at the shortest periods

(Hirose et al. 2001; Tierney et al. 2000; Ponte 1994)

A hint of global resonance?

1st frequency domain EOF
(30-36 hour band)



Ponte & Hirose (2003)

EOF explains close to 60% of variance in model

- Trapping of energy to Antarctica, North Pacific and North Atlantic
- Zonal wavenumber one, westward phase propagation in the Southern Ocean
- Several amphidromic points

…resembles many of the features of several of Platzman et al. modes

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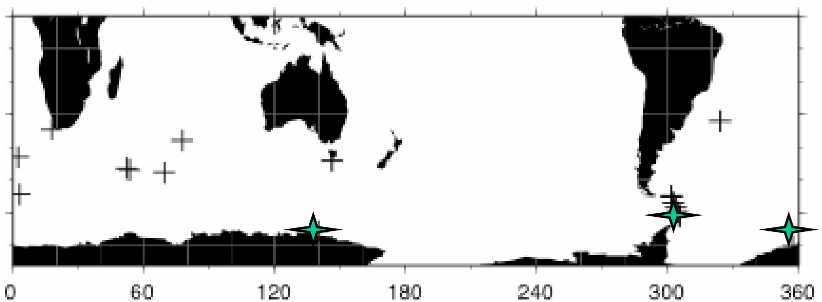
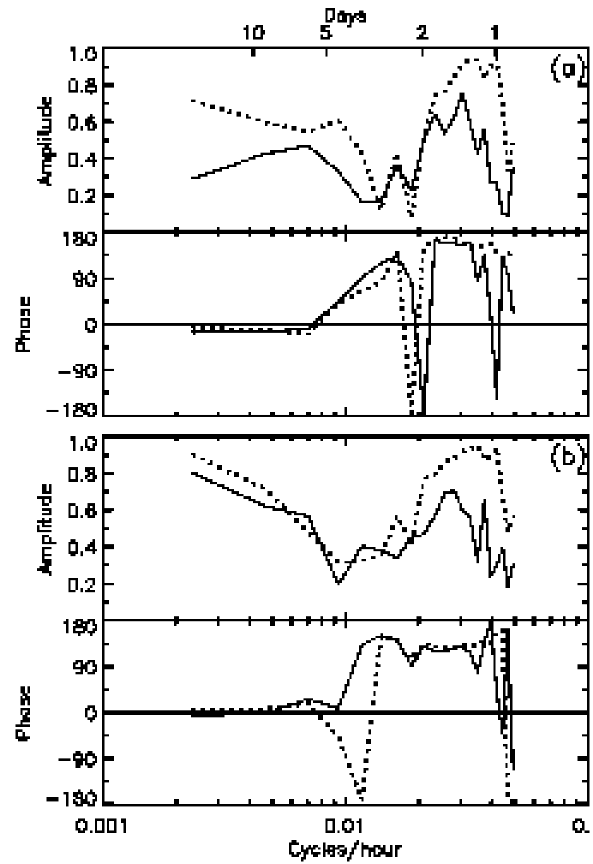
Have we seen an ocean mode lately?

BPR locations



Zonally-lagged coherence

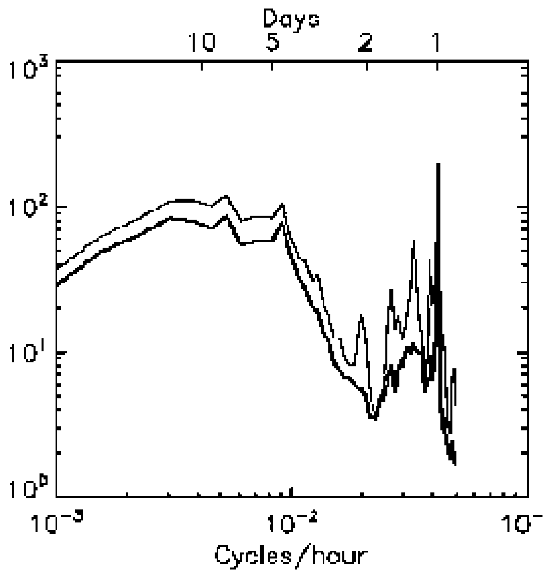


Peak in coherence over 1-2 day periods in both BPR data and model

Phase consistent with zonal wave number one disturbance westward propagation

Weak forcing, strong dissipation

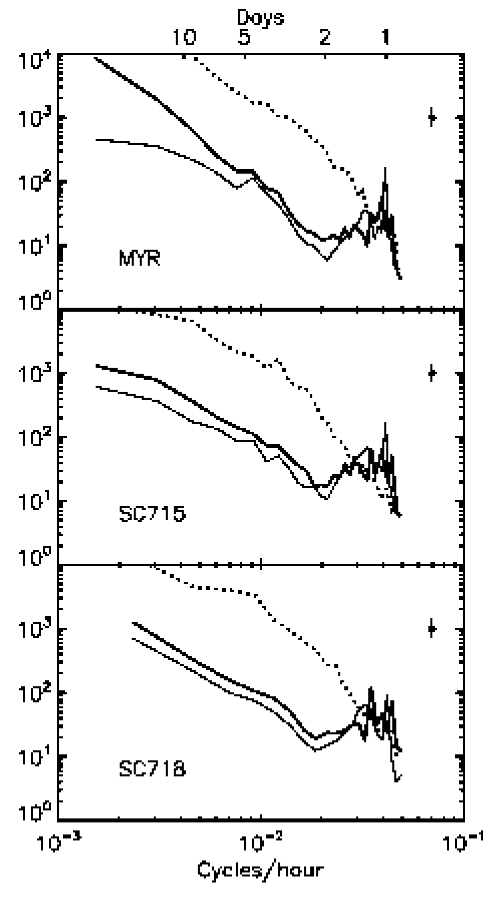
Model dependence on bottom friction



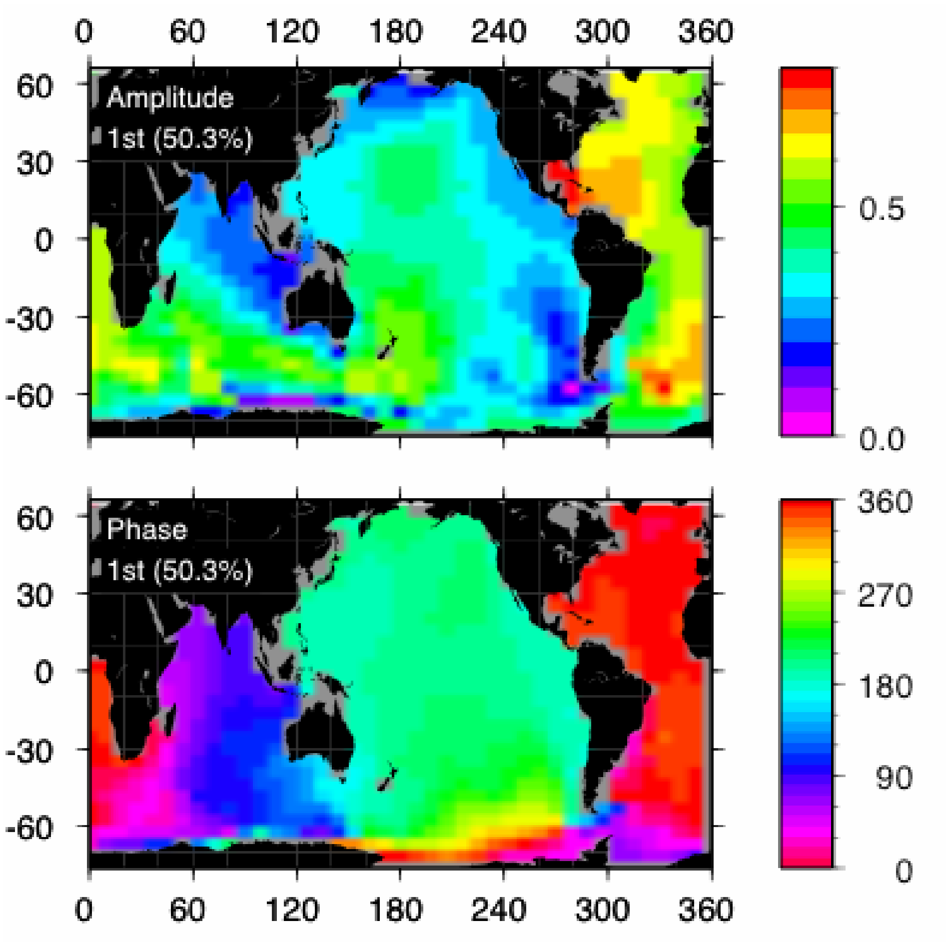
• Model Q~24, stronger dissipation observed

• Shallow regions and nonlinear bottom friction, damping by sea ice cover, scattering into baroclinic motion or other processes possibly important

Pressure forcing, observed and simulated bottom pressure spectra



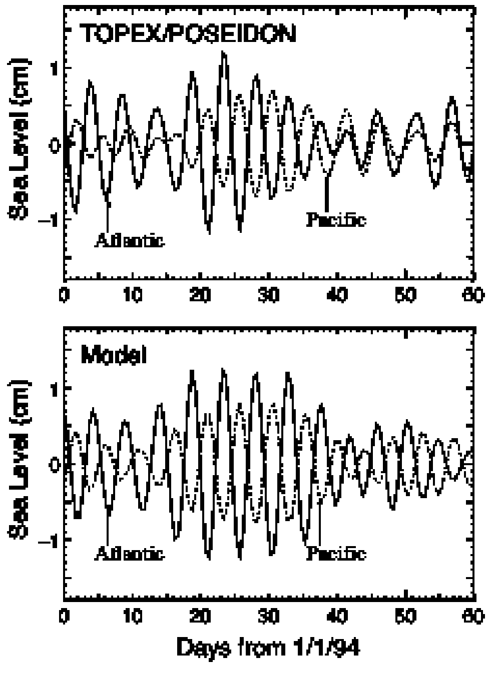
4-6 day non-equilibrium response revisited



- Not confined to the Pacific
- Nearly out-of-phase oscillation between Atlantic and Pacific
- Forced by Rossby-Haurwitz atmospheric pressure wave

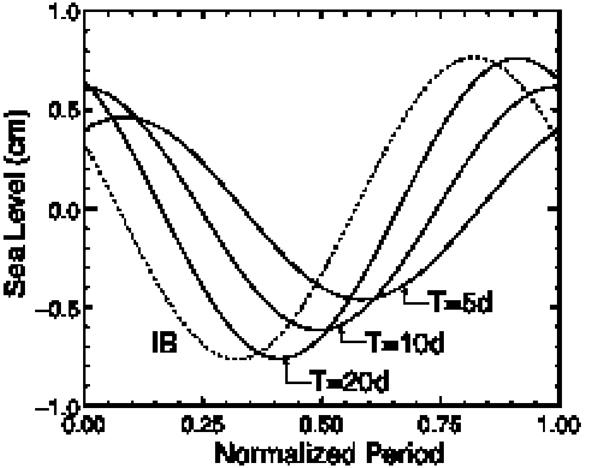
(Hirose et al. 2001; Ponte 1997)

Off-resonant, forced response

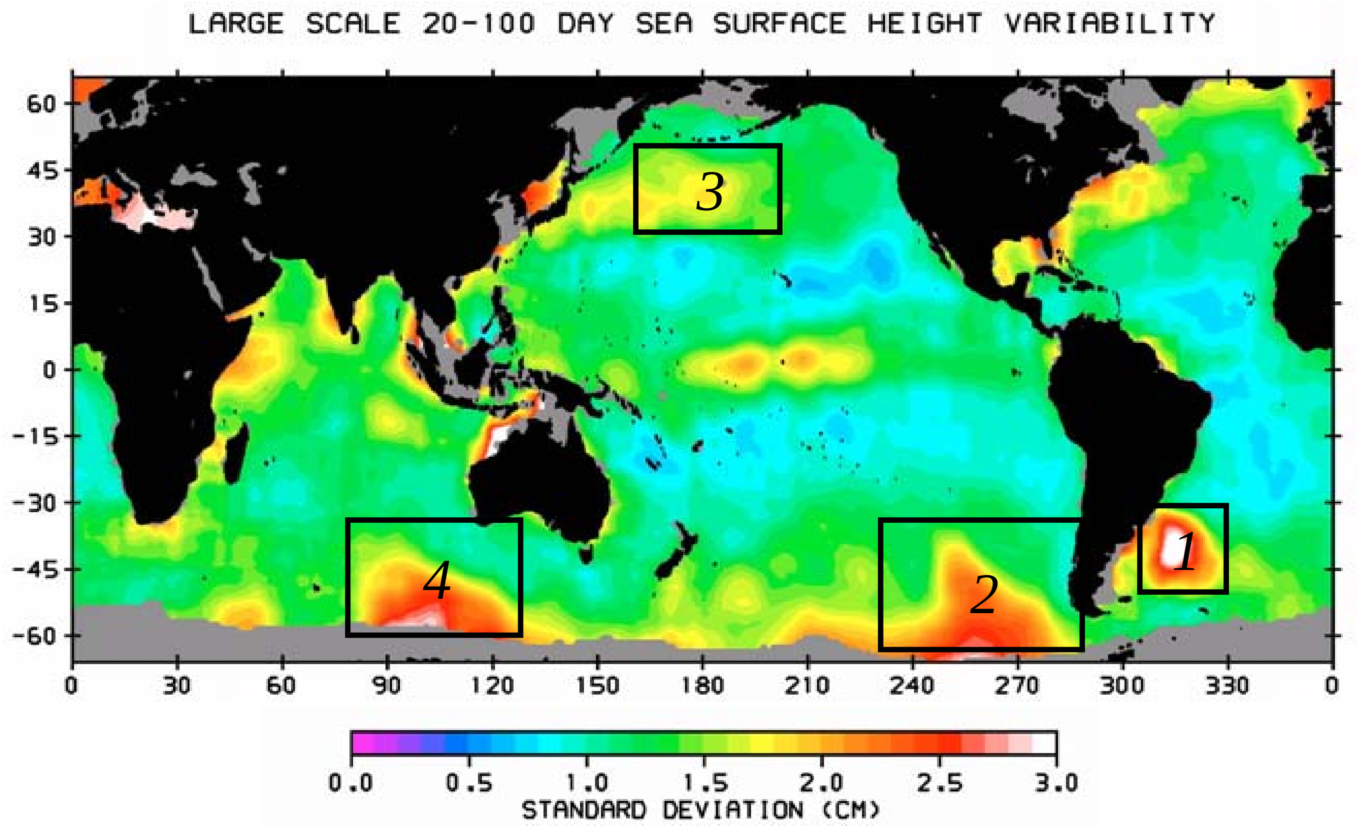


- Sufficiently large-scale to be seen in altimeter
- Dynamic model better than IB correction
- No strong dependence on friction or time scale
- Continents restrict inter-basin mass exchange
- Dynamics similar to long-period tides

(Hirose et al. 2001)



At longer periods, vorticity matters

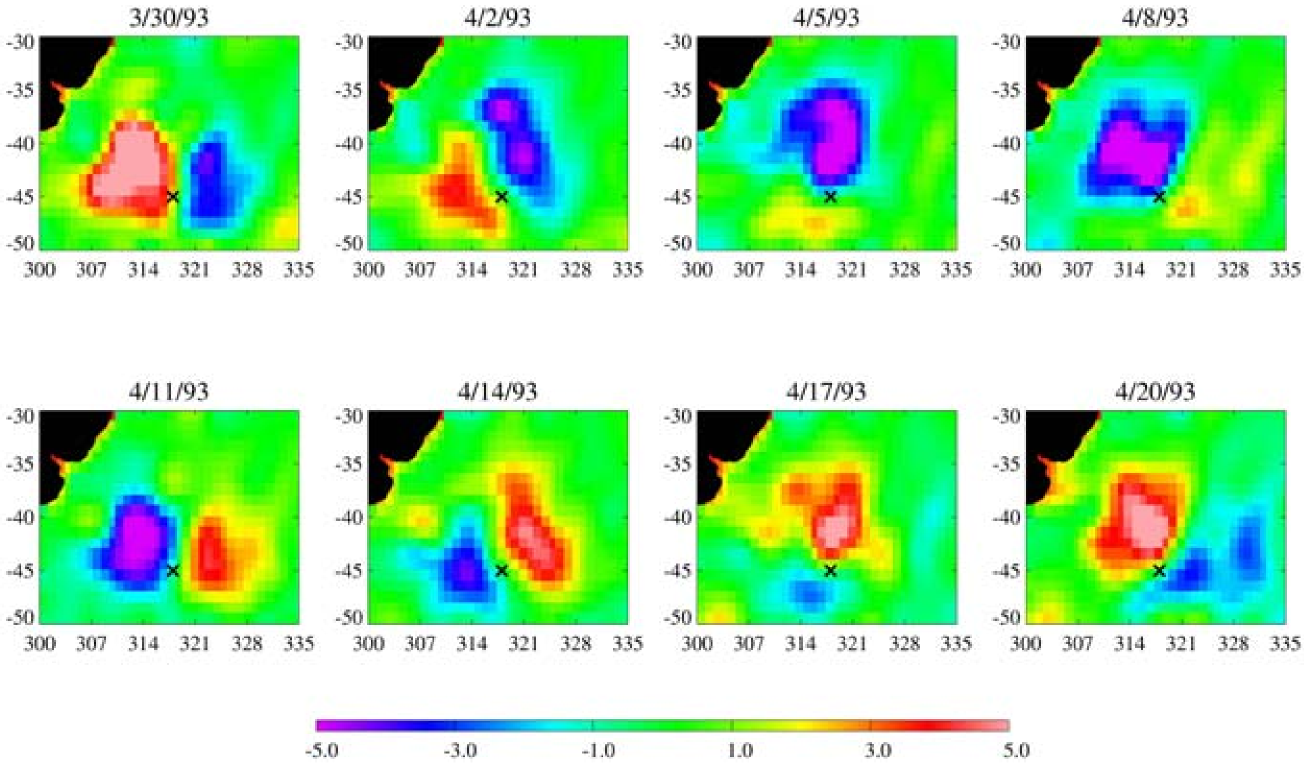


(Fu & Smith, 1996)

Area 1 – free barotropic waves around a seamount

Areas 2, 3, 4 – relative vorticity driven by wind stress curl

A propagating dipole in the Argentine Basin



Fu et al. (2001)

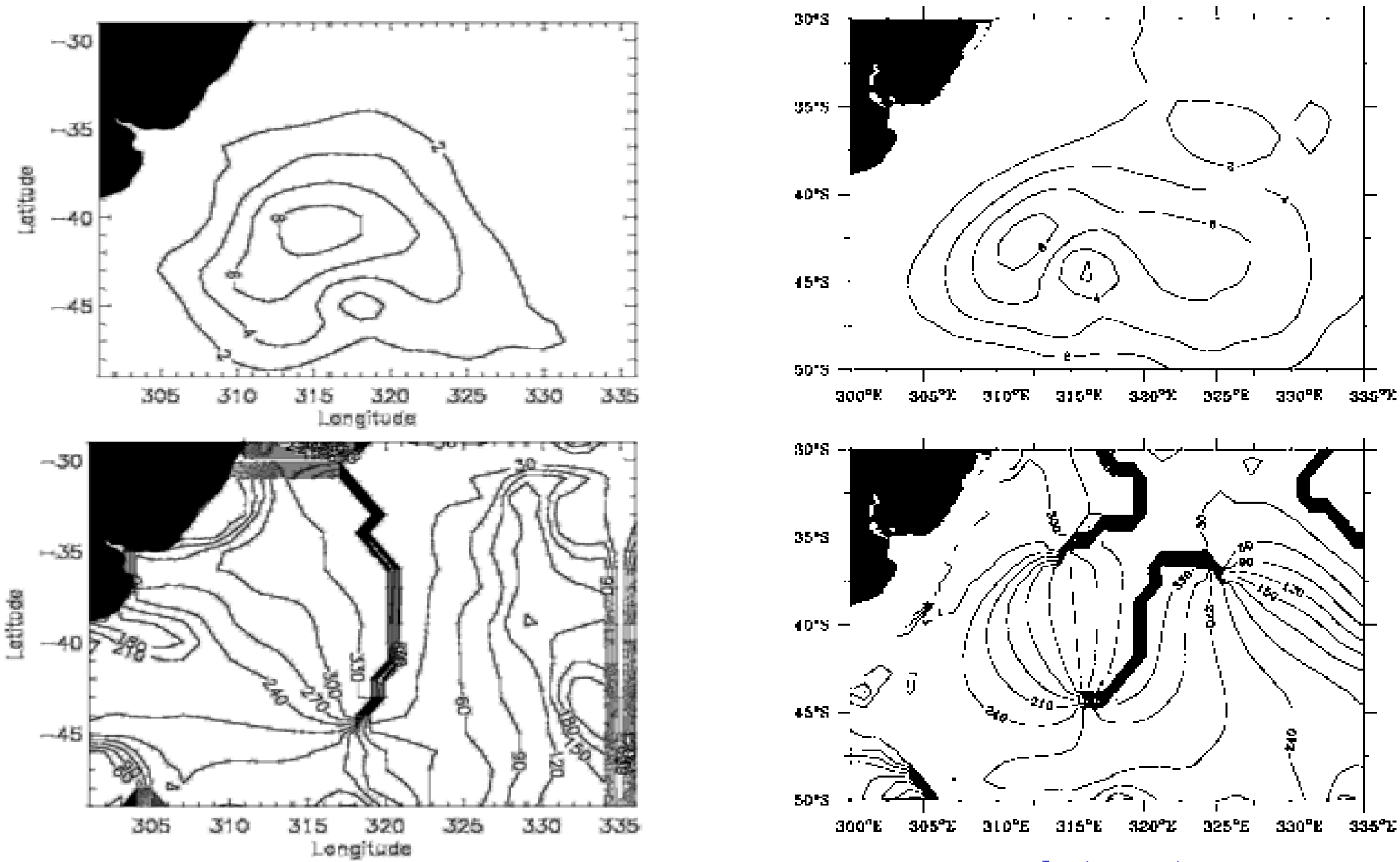
Topographic mode at 25-day period

CEOF

Observation | **Model simulation**

Spatial amplitude

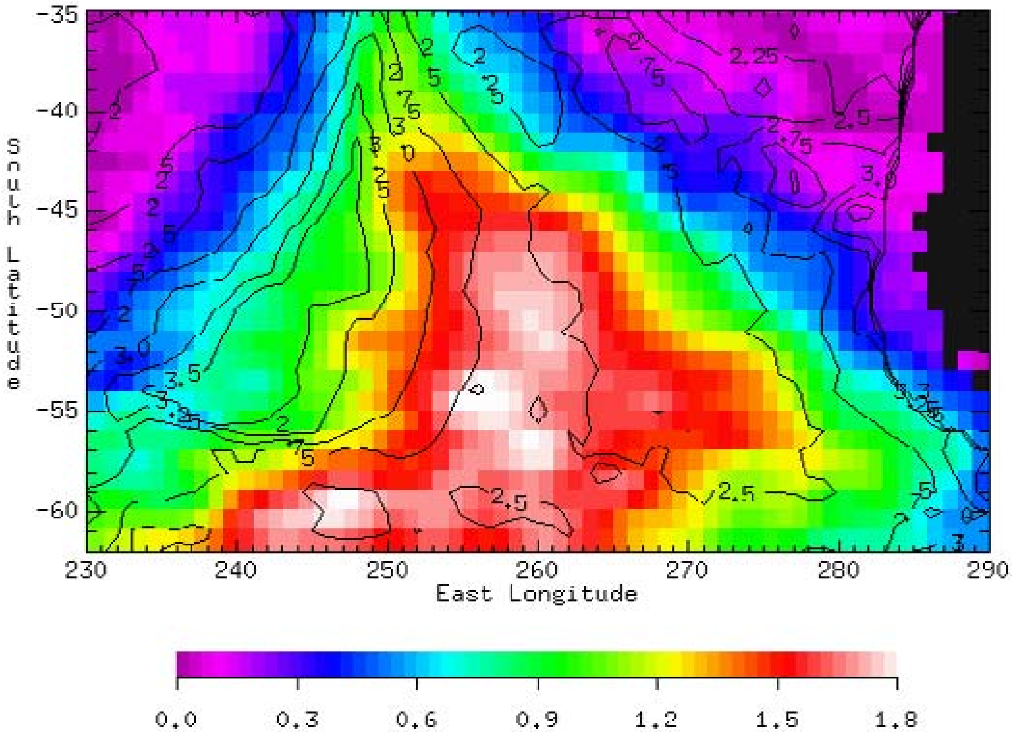
Spatial phase



Fu et al. (2001)

Variability in the Bellingshausen basin

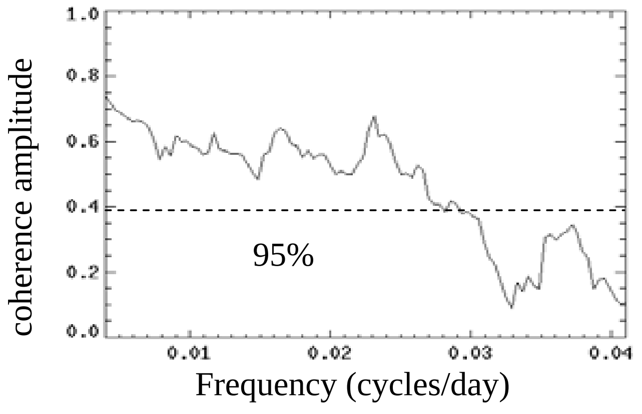
1st CEOF (high-passed sea level anomalies)

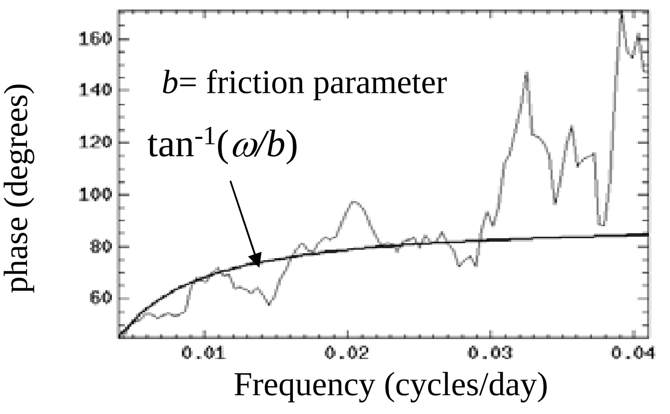


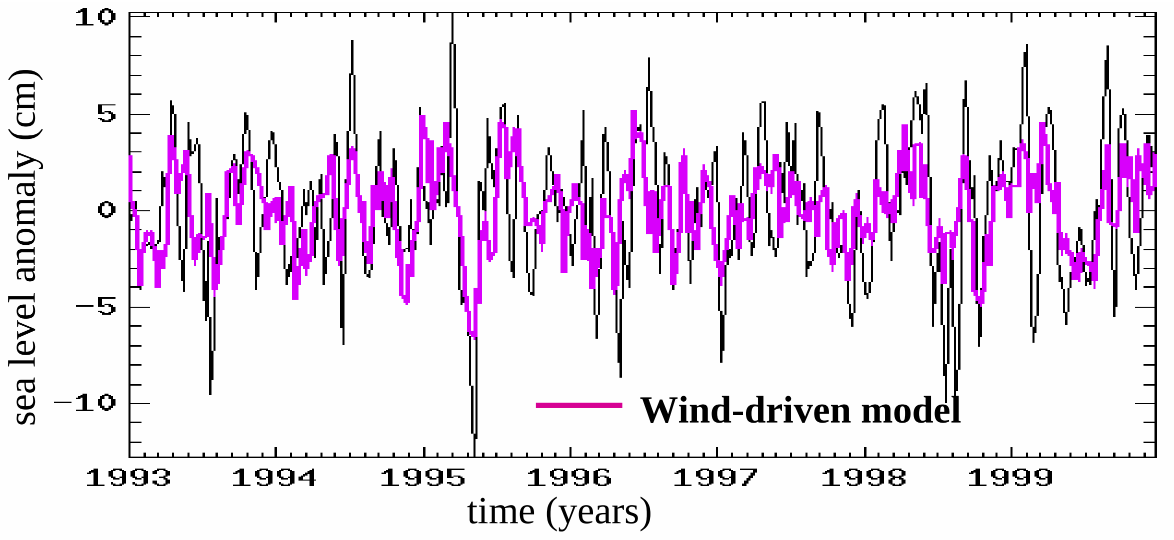
- Homogeneous phase
- Largest variability over weakest f/H gradients
- Well correlated to wind stress curl

Fu (2003)

Sea level and wind curl



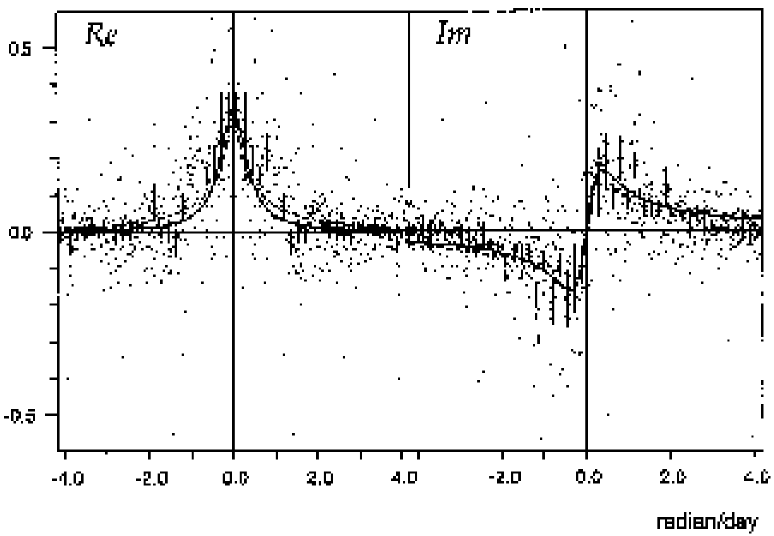




Fu (2003)

Geostrophic modes or something else?

Model response function (sea level/wind curl)



Webb & de Cuevas(2003)

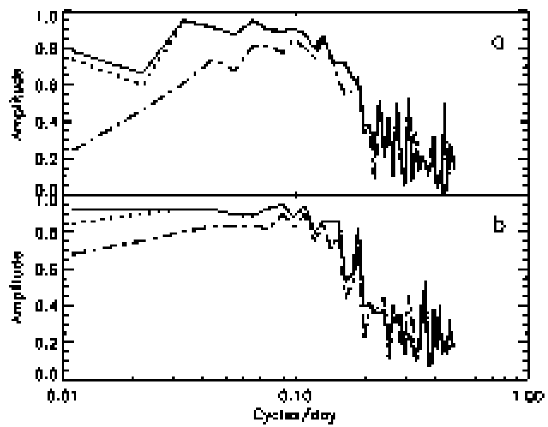
- Response function suggestive of a resonance close to zero frequency
- Strong damping (time scales ~ 3 days) but poor resolution at long periods
- Possible role of baroclinic effects and higher order dynamics at long periods

The Earth's bulge and wobble

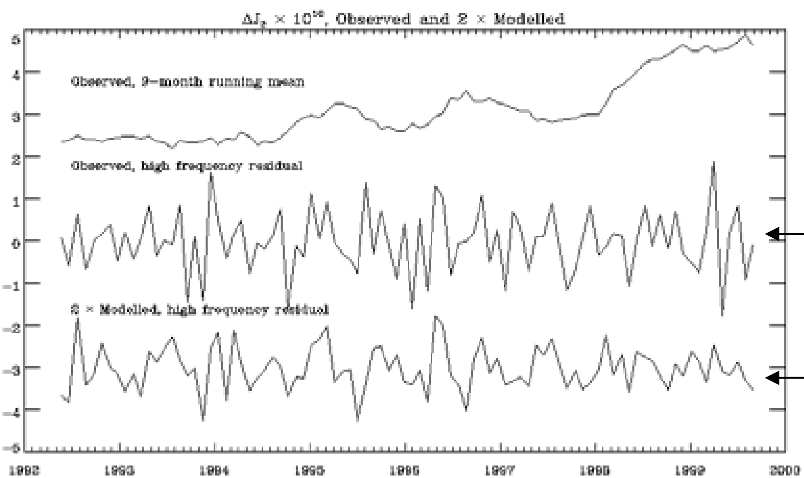
- Oceans can push the Earth around and contribute significantly to its wobble

- Variations in the Earth's oblateness can come from large-scale ocean mass signals

Coherence with polar motion



Ponte et al. (2001)



Observed J_2

Modeled ocean J_2

Hughes & Stepanov

The highlights

- Much new knowledge from ability to observe and model large-scale variability globally
- Strong variability at shortest periods and some aliasing surprises
- Excitation of resonances in a variety of regimes and time scales
- More than just inverted barometer response at short periods, dynamical importance of pressure forcing
- The oceans as big player in the Earth's affairs