# The Effect of Statistical Abyssal Hill Roughness on the Generation of Internal Waves

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# Overview

- Motivation
- Generation of Bathymetry
- Model Initialization and Forcing
- Analysis of the Internal Wave Field
- Conclusions
- Future Work

# Motivation

- Internal waves important for dynamics/mixing
- Generation of internal waves limited:
  - Horizontal resolution
  - Knowledge of true bathymetry
- Recent Bathymetric Products at 30 arc sec
  - Large regions estimated due to lack of surveys
- Increase in model resolution requires additional bathymetric information

# Generation of Bathymetry

- Smith and Sandwell (1994,1997,2004) bathymetry
  - 30 arc second resolution (SRTM30)
  - Additional info identifying surveys (SRTM30_PLUS)
  - SRTM30 interpolated to 1/12° HYCOM grid
    - Radial Blackman Filter, *R* = 20 km
  - SRTM30_PLUS

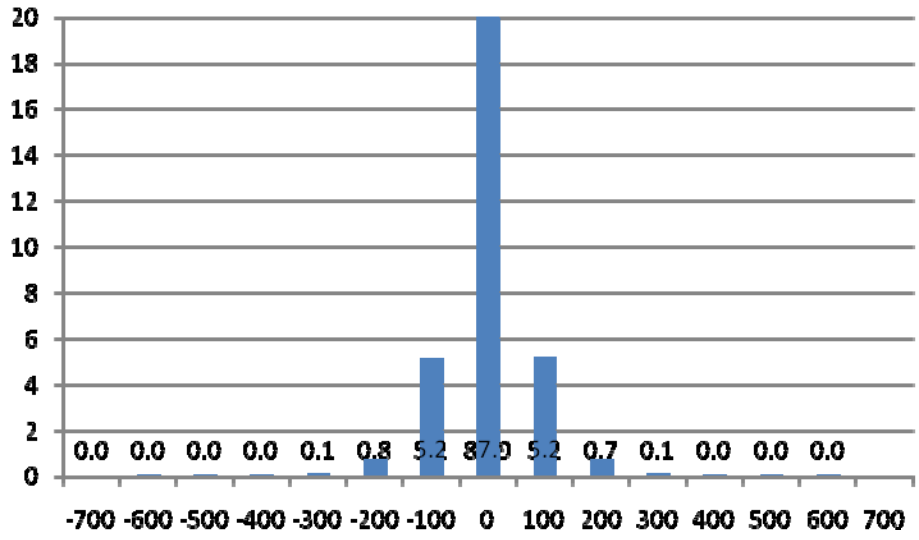
$$D(x,y)=\frac{\iint H(x',y')d(x,y,x',y')dA}{\iint d(x,y)dA}$$

$$d(x,y,x',y')=0.42+0.5\cos\left(\frac{\pi \mathrm{r}(x',y')}{R}\right)+0.08\cos\left(\frac{2\pi \mathrm{r}(x',y')}{R}\right)$$

$$r(x',y')=\sqrt{(y'-y)^2+(x'-x)^2}$$

# Statistical Abyssal Hills

- Goff and Arbic (2009 submitted)
  - Statistical Generation of Abyssal Hills on sea floor
    - Spreading rates and Direction of sea floor
    - Sediment Thickness
  - Abyssal Hills estimated on a 30 arc second grid
    - Characteristic length scale: 2-10 km
    - Amplitude: 0-600 m
    - Mean: 0 m
    - Std dev: 42 m



# Abyssal Hill Roughness on Hycom Grid

- 1/12° HYCOM has resolution ~ 5-10 km
- Generated Abyssal Hills length scale ~2-10 km
- Roughness Measure:
  - Directional semivariogram
  - Normalized by Mean Squared

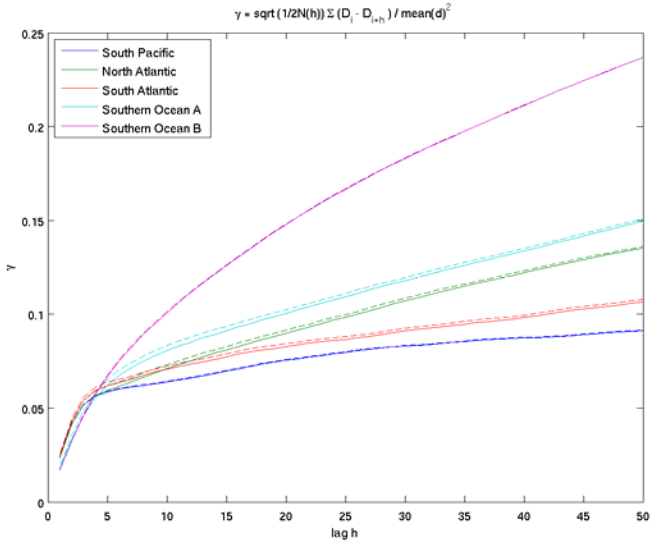
$$\gamma = \sqrt{\frac{\sum_{i}^{N(h)} (D_i - D_{i+h})^2}{2N(h)\overline{D}^2}}$$

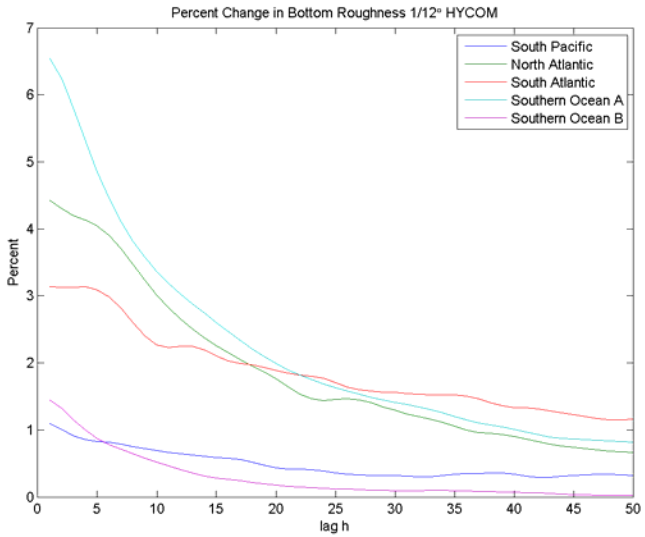
- Smith and Sandwell + Goff Abyssal Hills

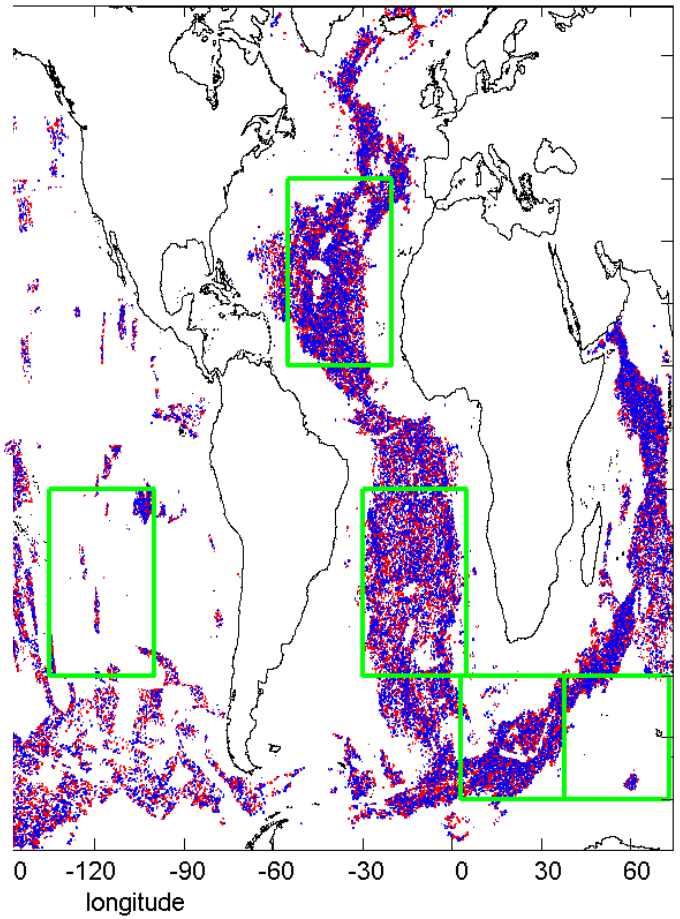
$$SSIJ_{ij} = \alpha_{ij} SS_{ij} + (1 - \alpha_{ij}) G_{ij}$$

  - SSIJ Smith and Sandwell Bathymetry
  - Gij Goff Abyssal Hill Amplitude
  - αij Weight calculated to preserve true bathymetry

# Global View of Abyssal Hills

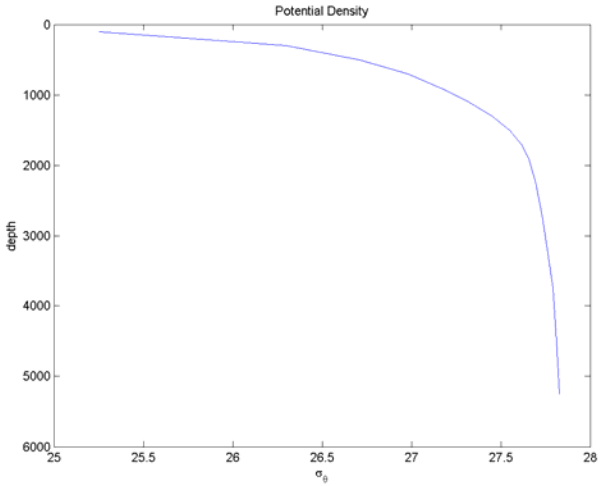


# Model Initialization and Forcing

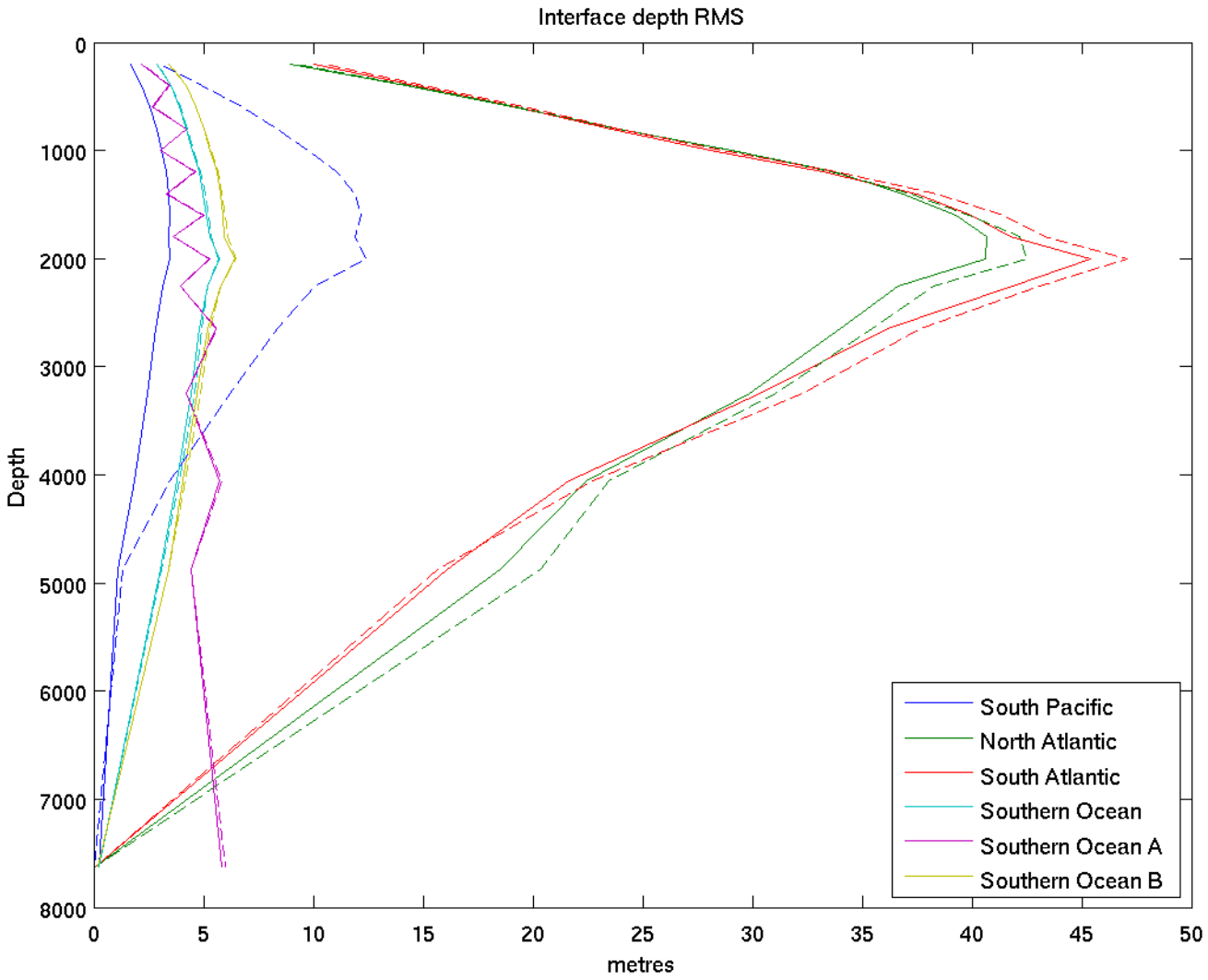
- Horizontally uniform Stratification (WOCE CTD)
  - WOCE line P15 (30° N and S)
- Started from Rest
- Tidal forcing:
  - $O_1$, $K_1$, $M_2$, $S_2$, $N_2$
  - 5-day ramp up for tide
- Last 30 days of 60 day model run analyzed



# Analysis of the Internal Wave Field

- RMS of interfacial heights calculated locally
- Local Regions:
  - N and S Atlantic, S Pacific, Southern Ocean
- Regions in Atlantic and Pacific:
  - Equal area and equal number of grid points
- Southern Ocean
  - Approx equal area and twice the grid points

# RMS of the interfacial heights



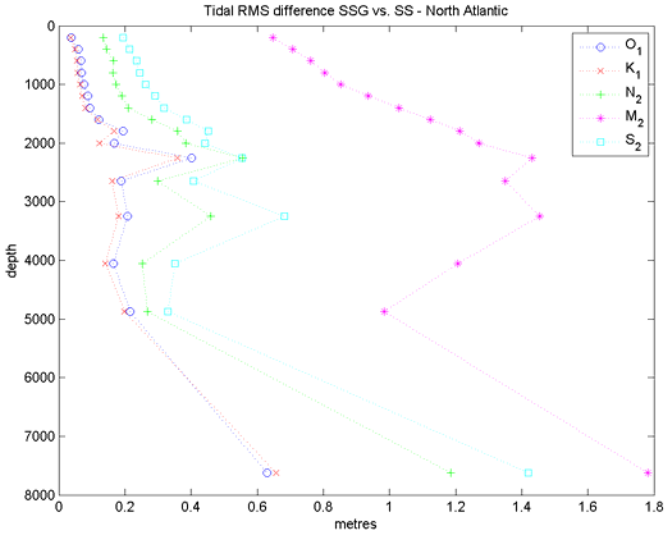
# Harmonic Analysis

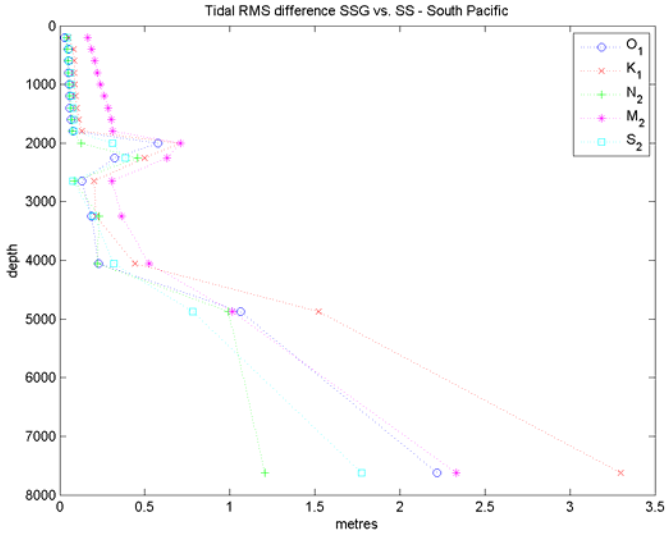
- Harmonic Analysis (matlab t_tide)
  - Constituents used for forcing can all be resolved using 30 days of hourly output
- RMS difference:

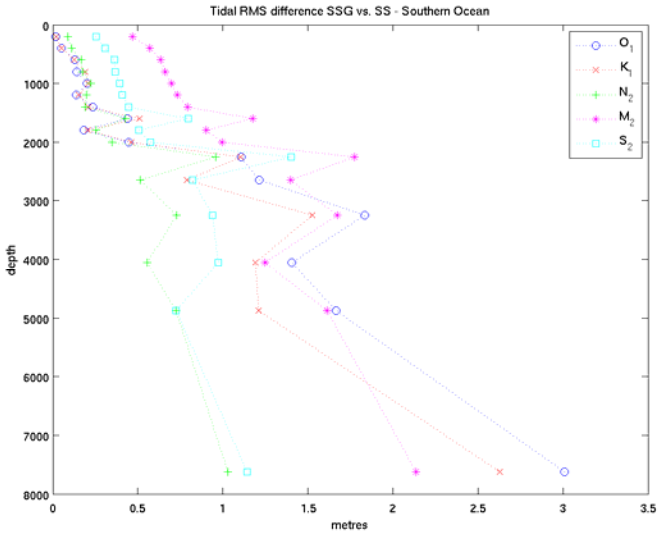
$$RMS_{difference} = \frac{\iint RMS_{elev}(A_1, \Theta_1, A_2, \Theta_2)dA}{\iint dA}$$

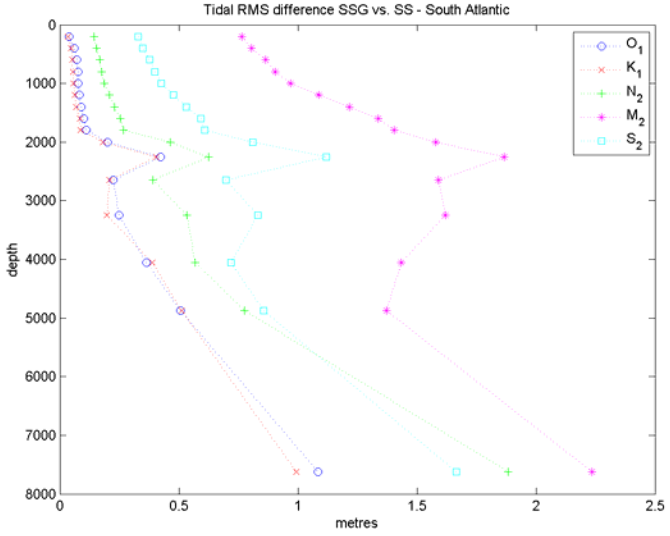
$$RMS_{elev}(A_1, \Theta_1, A_2, \Theta_2) = \sqrt{\frac{(A_1^2 + A_2^2)}{2} - A_1 A_2 cos\left(\frac{(\Theta_1 - \Theta_2)\pi}{180}\right)}$$

# RMS difference Tidal Frequencies

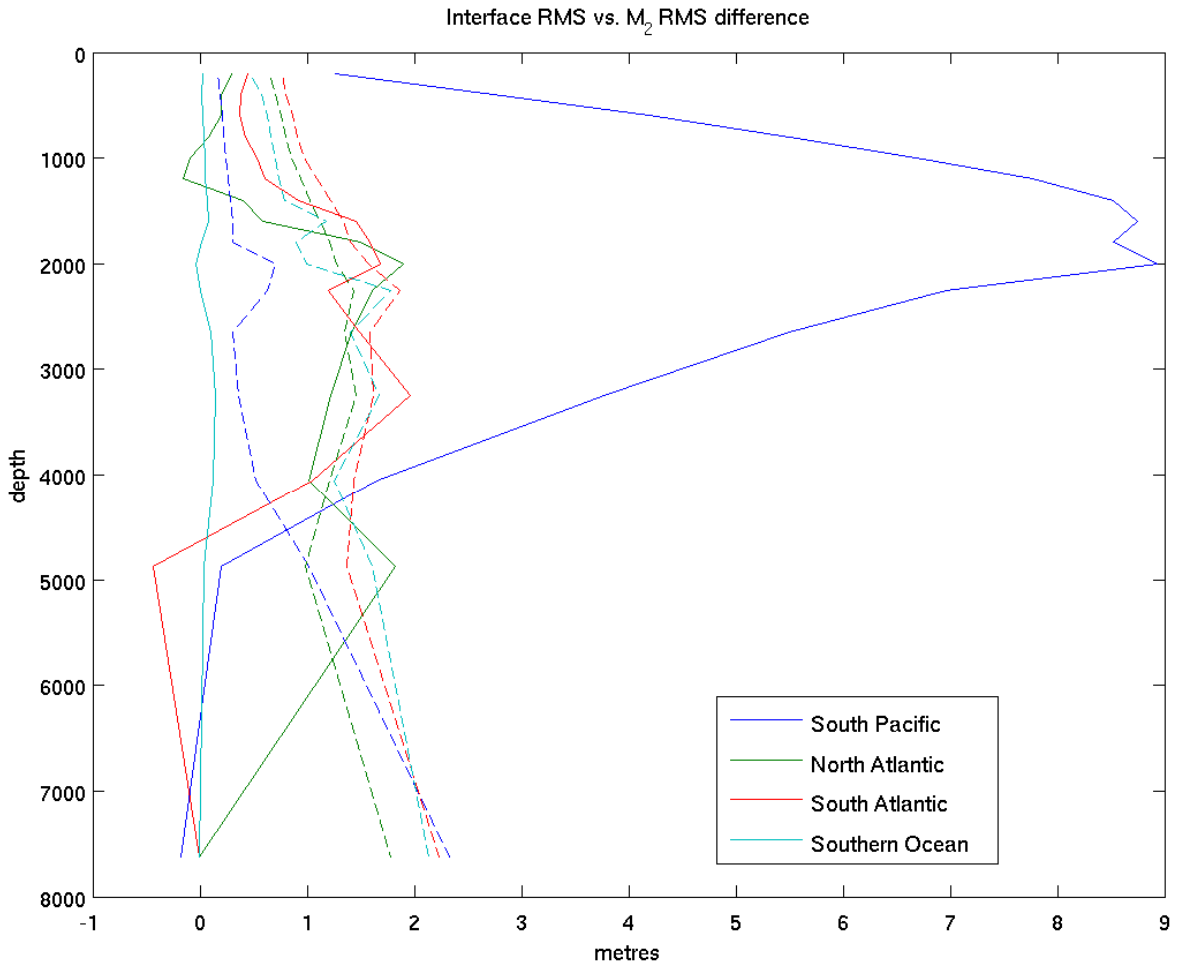


# Interface RMS vs. $M_2$ RMS difference




Changes in N and S Atlantic may be attributed to the change of the $M_2$ internal tide

Little change in the RMS in the southern ocean changes in the M2 internal tide may be attributed to a phase shift

Change in the M2 tide does not account for change in RMS of South Pacific
effect may be:

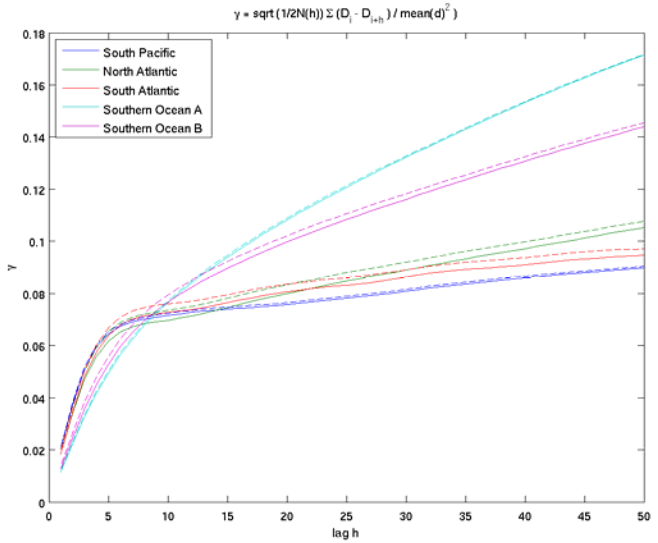
- non-local
- over-tides
- nonlinear

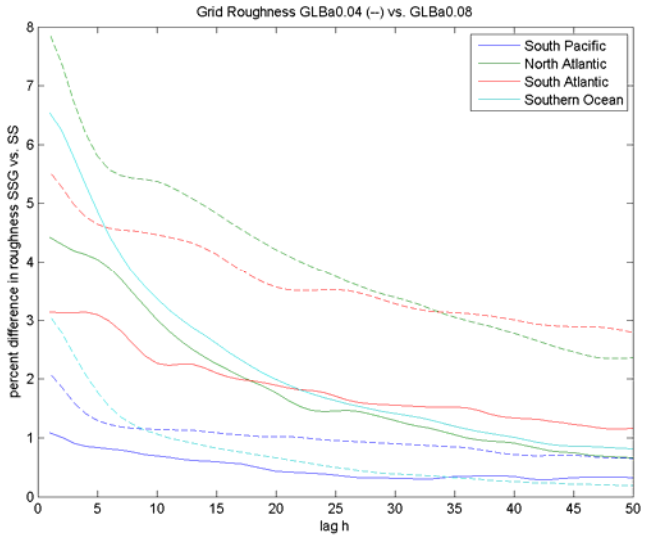
# Conclusions

- Addition of Abyssal Hills to Bathymetry does increase internal wave activity
- Evidence of both Local and Non-Local effects
  - North and South Atlantic regions show an increase driven by tides
  - Increase in internal wave activity in South Pacific cannot be explained by local tides
- Increase in internal wave activity is expected to increase mixing in the ocean interior
  - Non-local effects may significantly increase estimates of mixing rates

# Future Work

- Higher Resolution
  - 1/25° HYCOM
  - Horizontal resolution: 2-5 km
  - Should resolve most of the abyssal hills estimated
  - Higher Resolution does have greater increase in roughness



# But first
# Problem with Initialization

- Using a horizontally ur
  produces strong curre
  coastline
- This will contaminate t
  of internal waves
- Still trying to decide if
  algorithmic or can be r
  input parameters