Observation-based estimates of the sea-surface height signature of the internal wave field

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Three approaches to estimating the SSH signature of the IW continuum

- Garrett-Munk (GM; Munk, 1981) IW spectrum extended to surface using vertical mode eigenfunctions (RMS)
- Mooring observations of upper-ocean T and S in IW frequency band converted to surface pressure using low-vertical-mode eigenfunctions (JTF)
- Array of mooring observations of horizontal current in IW frequency band converted to surface pressure using linear dynamics (JC)

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Garrett-Munk IW spectrum extended to surface using vertical mode eigenfunctions (RMS)

1. Compute vertical modes for exponential/constant $N^2(z)$, in WKB approximation

2. Impose GM spectrum at specific depths.

3. Compute surface pressure spectrum using hydrostatic dispersion relation with WKB vertical-mode phase speeds

4. Convert isotropic, radial-wavenumber GM spectrum to 1-d “along-track” wavenumber

5. NB: An amplification factor ($\alpha \geq 1$) enters from the modal structure; a 200-m vertical average is introduced to avoid singularities at the nodal (zero vertical displacement) points

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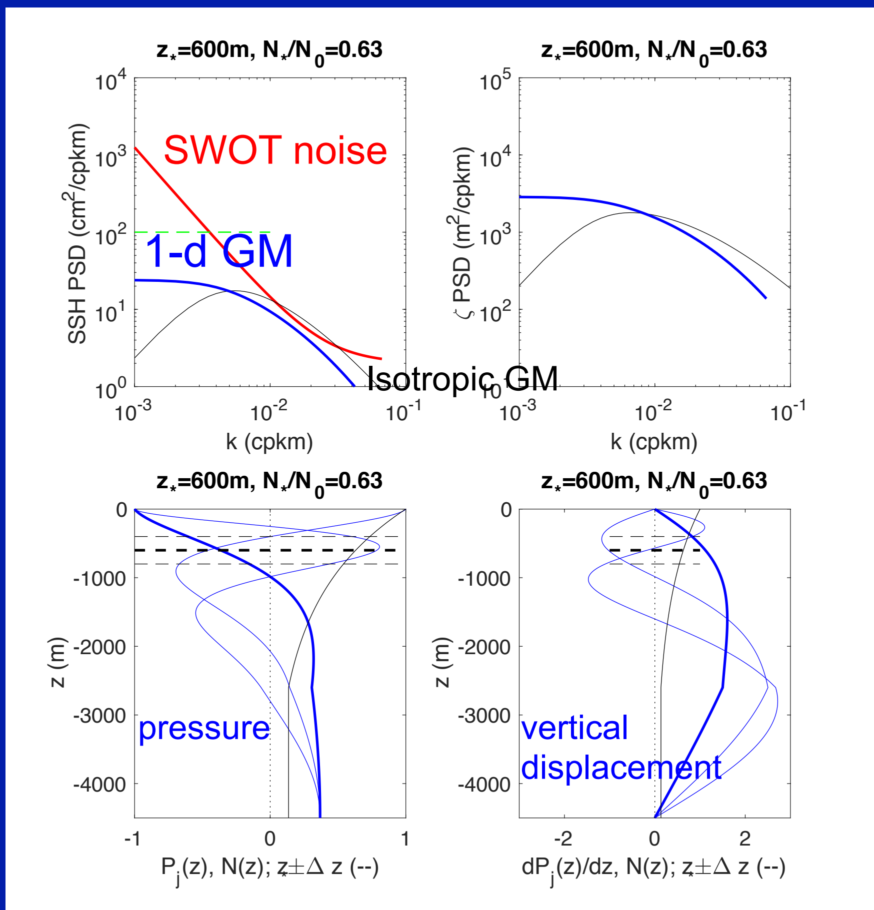
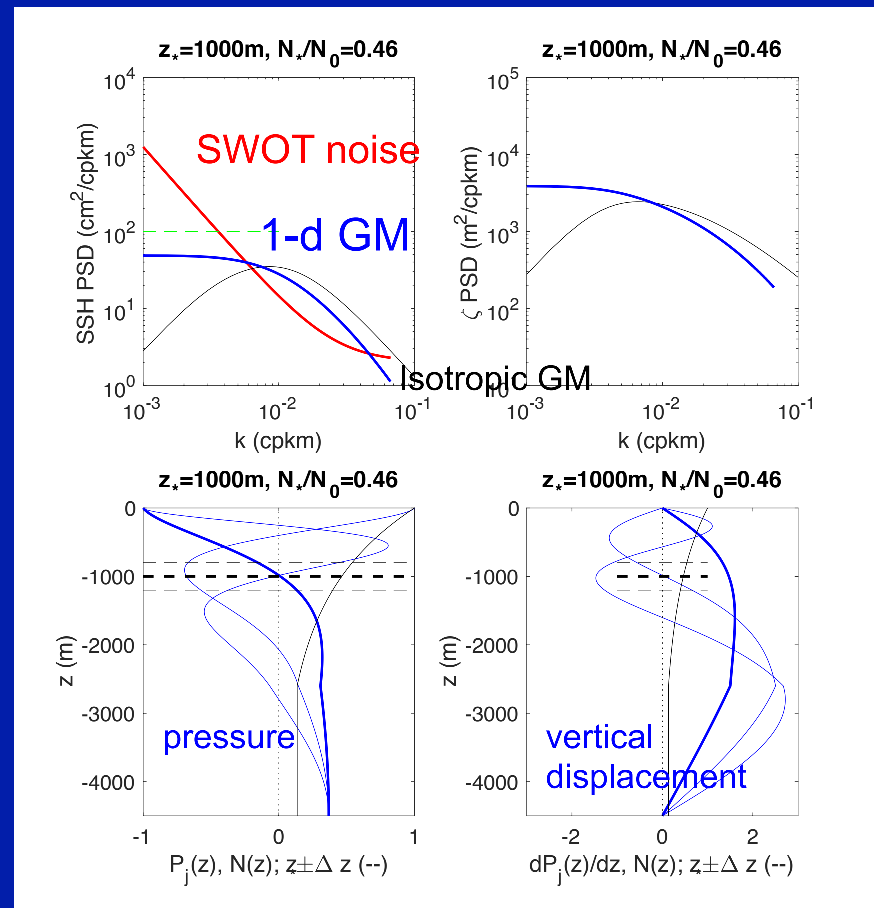
Garrett-Munk IW spectrum extended to surface using vertical mode eigenfunctions (RMS)

GM imposed at 600 m



GM imposed at 1000 m



Note: 1-d spectral estimate assumes isotropy; directionality could affect amplitude

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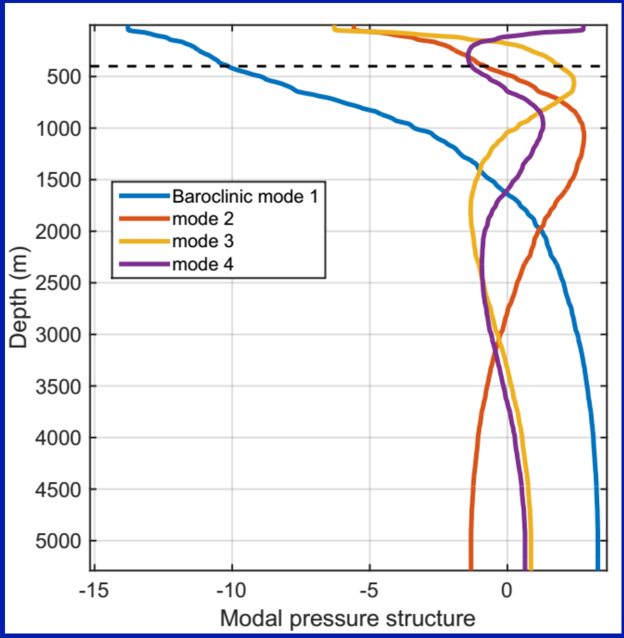
Mooring observations in IW frequency band extended to surface using low-vertical-mode eigenfunctions (JTF)

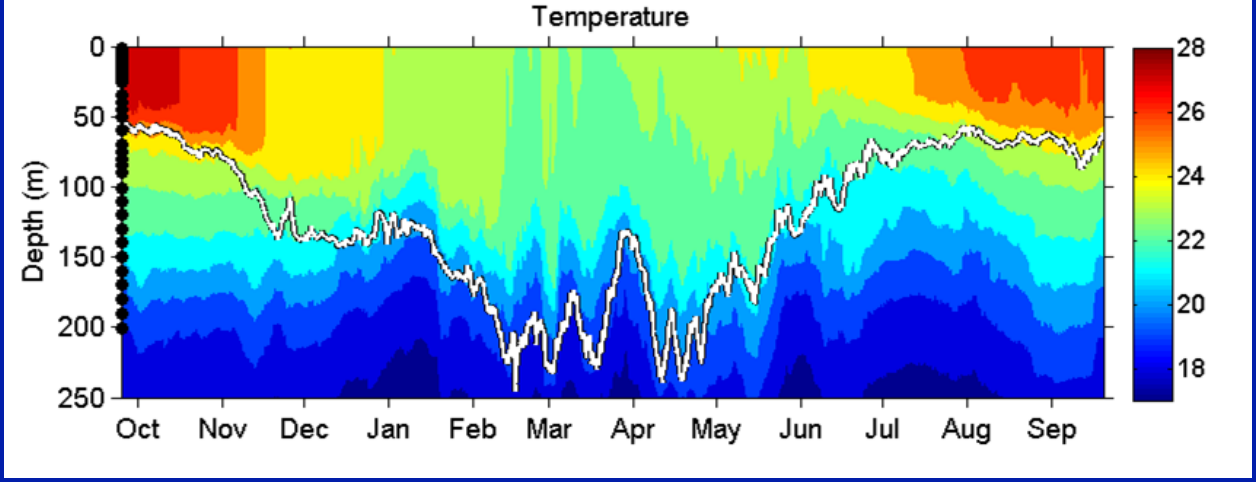
1. Compute low vertical modes for observed $N^2(z)$

2. Integrate mooring (SPURS, near 24.5°N, 38°W) specific volume anomaly obtain surface dynamic height relative to 400 m; convert to SSH assuming that the lowest 4 modes contribute equally (e.g., 25% in mode 1)

3. Compare with high-resolution (2-km) numerical model



Note (JTF): The SPURS mooring is probably the most densely instrumented fixed-depth sensor mooring ever deployed in the deep ocean. There were 40 temperature measurements in the upper 400 m and 33 salinity measurements.



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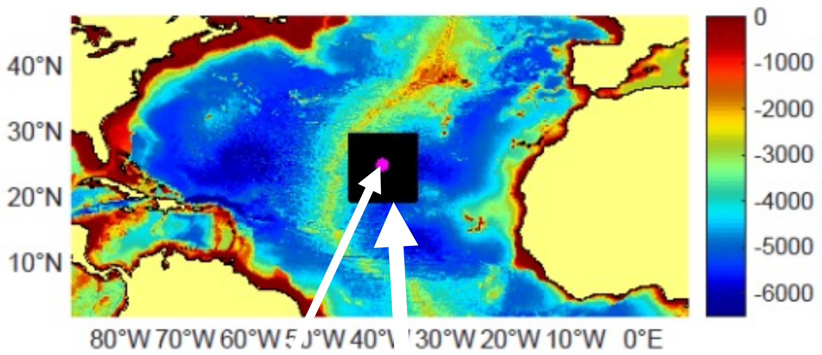
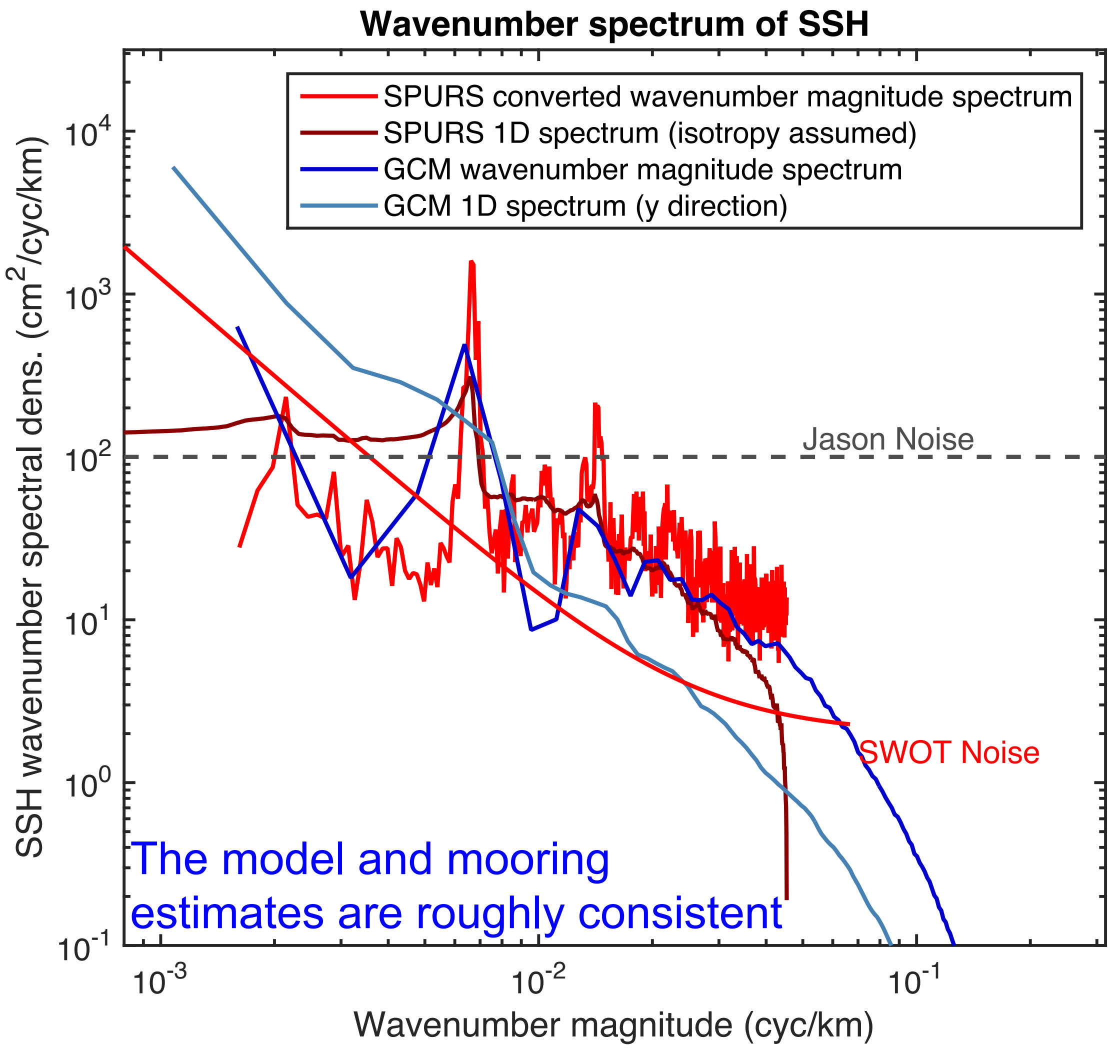


SPURS mooring site

Domain used for analysis of JPL 2-km MIT-GCM simulation



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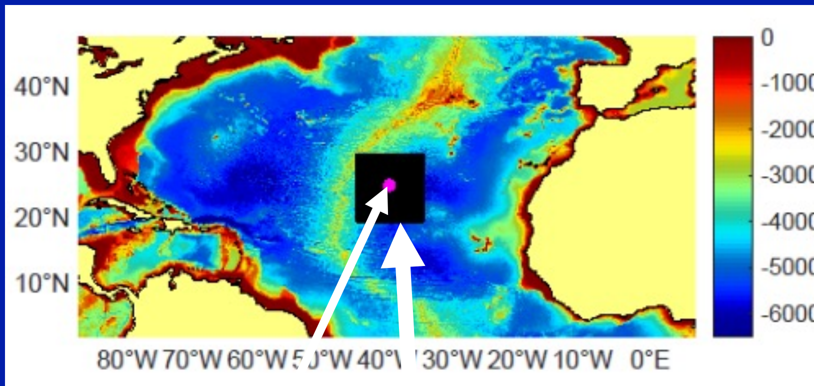

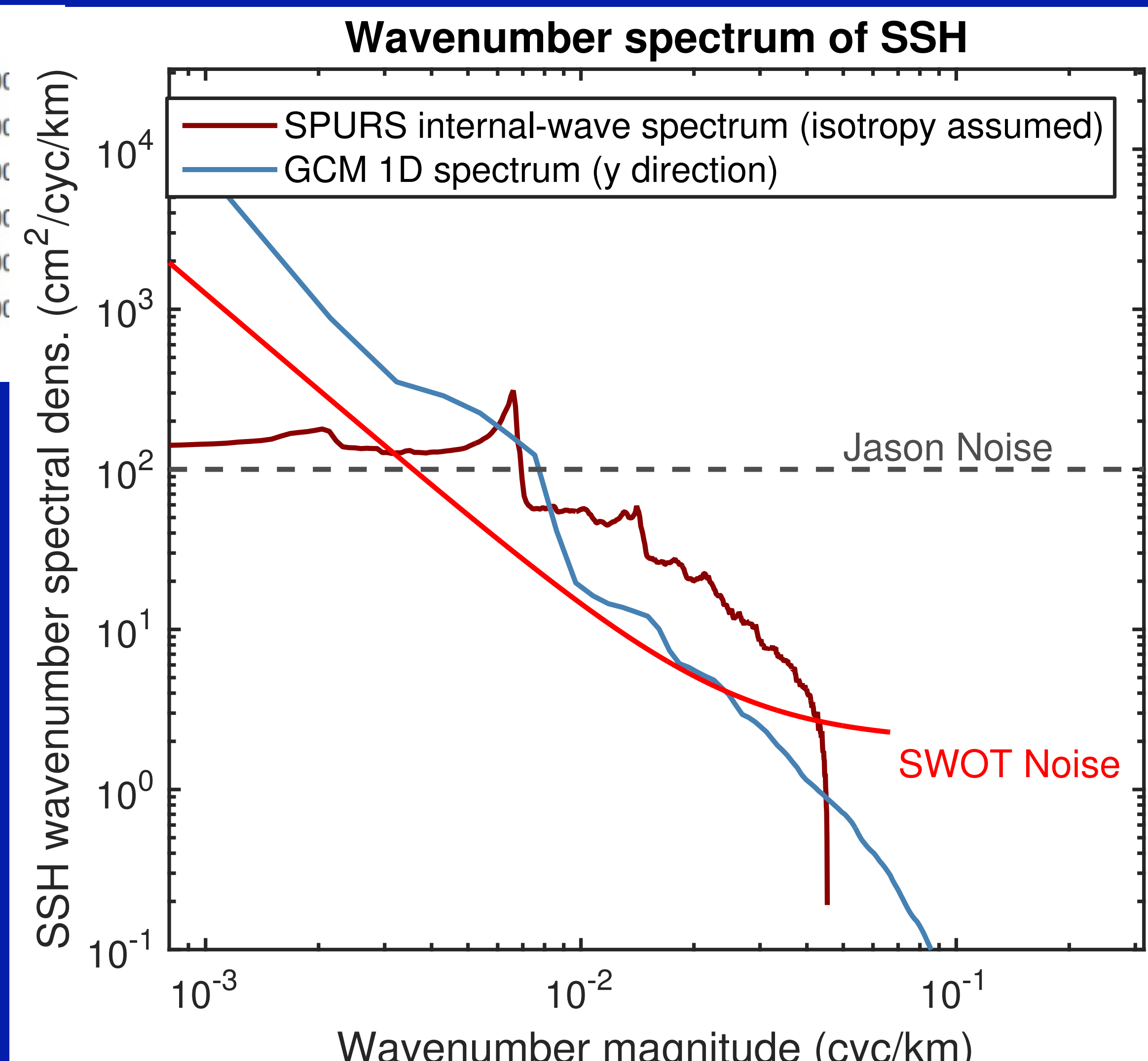

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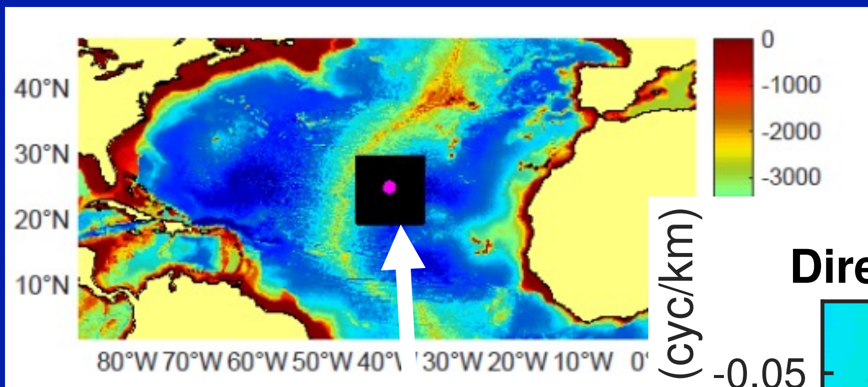
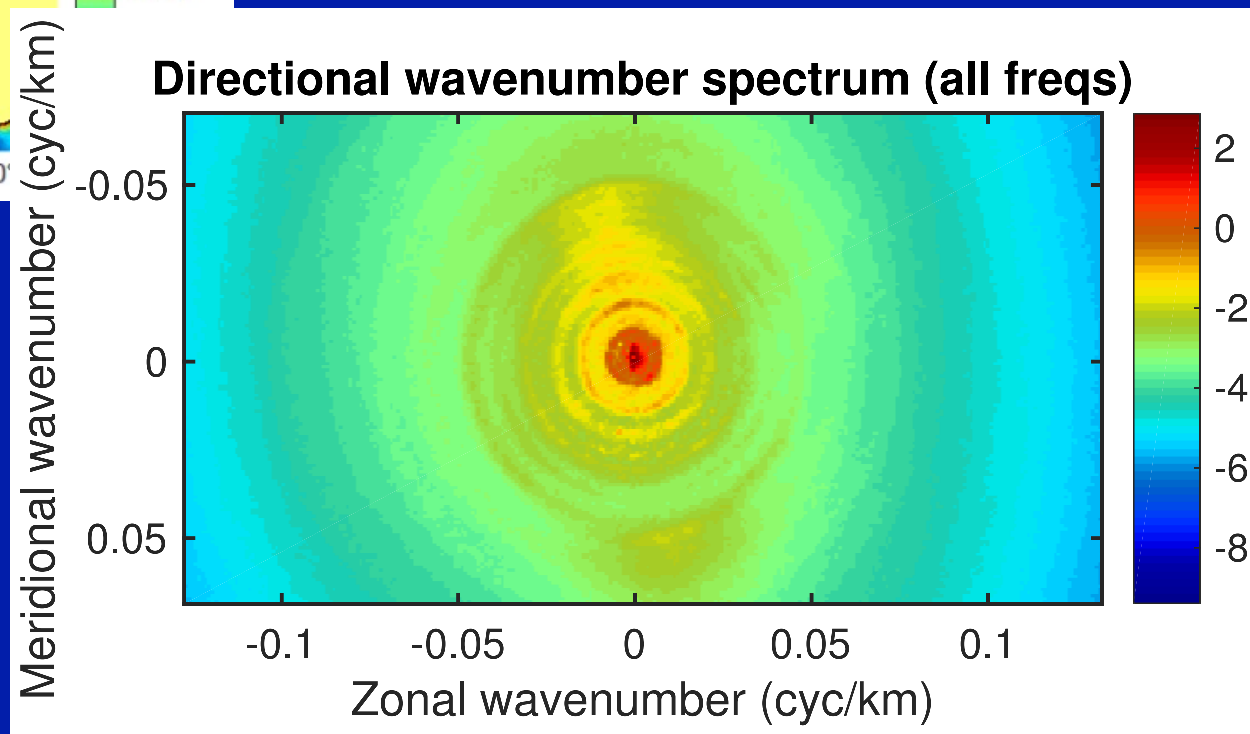
Mooring observations in IW frequency band extended to surface using low-vertical-mode eigenfunctions (JTF)



Domain used for analysis of JPL 2-km MIT-GCM simulation



The model wavenumber spectrum is not isotropic

Array of mooring observations of horizontal current in IW frequency band converted to surface pressure using linear dynamics (JC)

1. Group pairs of nine moorings from array (OMOSIS, near 48°N, 16°W) by separation distance (1.3 – 18.7 km) and compute velocity differences between pairs at 50-m depth

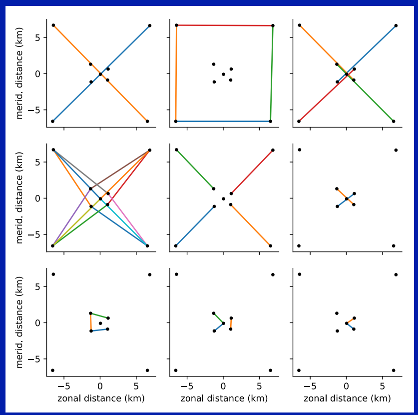
2. Compute "geostrophic velocity" ("sea-surface slope") and "geostrophic velocity" differences assuming linear momentum balance: $u_{\mathrm{g}} = -\frac{g}{f}\frac{\partial h}{\partial y} = u + \frac{1}{f}\frac{\partial v}{\partial t}, \qquad v_{\mathrm{g}} = \frac{g}{f}\frac{\partial h}{\partial x} = v - \frac{1}{f}\frac{\partial u}{\partial t}.$

3. Fit model spectral form for velocity (KE), velocity differences, "geostrophic velocity," and "geostrophic velocity" differences to observed 50-m spectra, as functions of separation distance; spectral form is obtained from GM by adjusting vertical-mode parameter j_*

4. Evaluate resulting SSH spectrum by converting pressure to hydrostatic SSH

Note (JC): OSMOSIS array is a unique opportunity to assess simultaneously the time and space scales within the range of scales relevant for SWOT.

18.7 km



1.3 km

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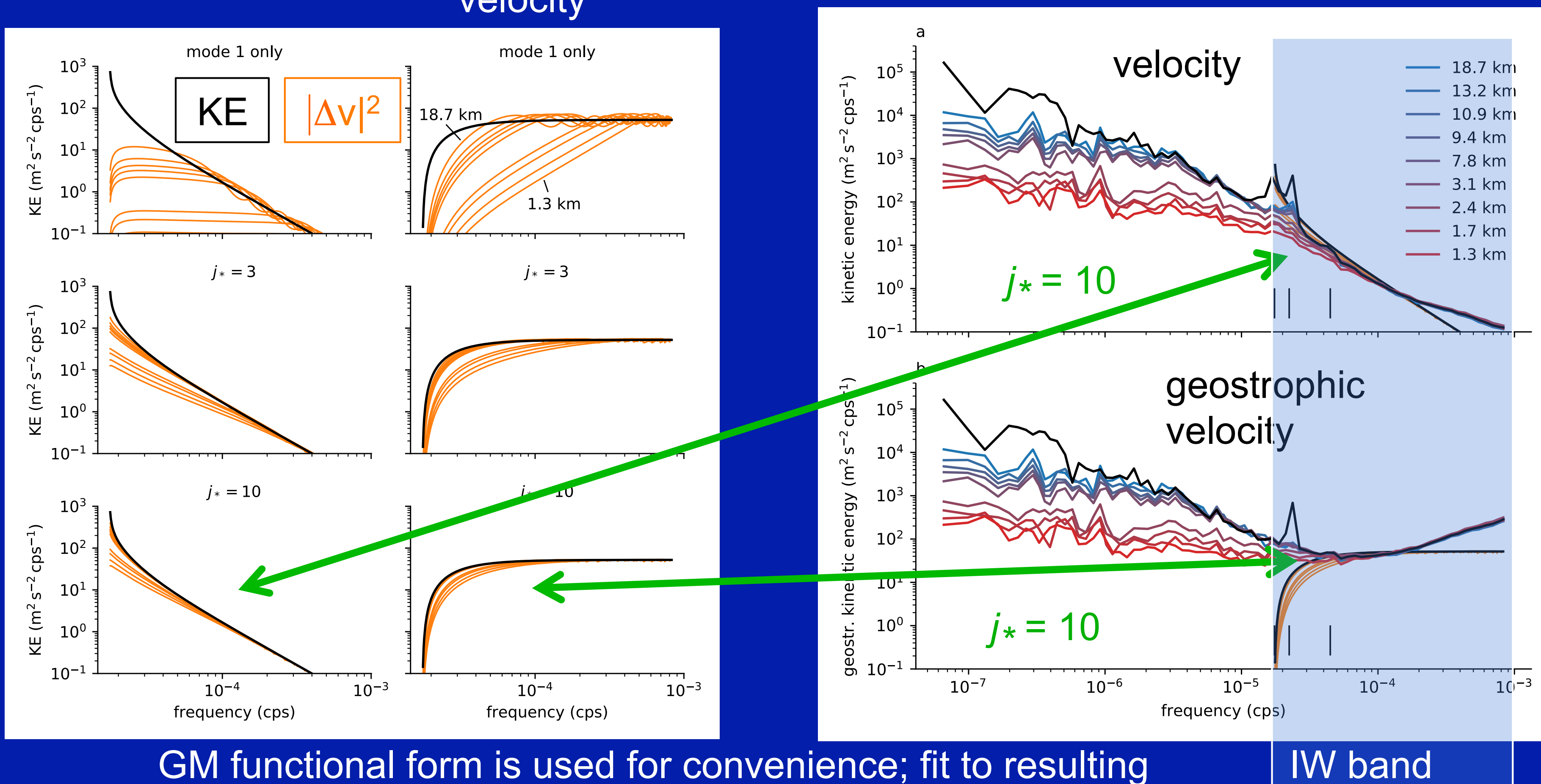
Array of mooring observations of horizontal current in IW frequency band converted to surface pressure using linear dynamics (JC)

velocity

geostrophic velocity



GM functional form is used for convenience; fit to resulting model spectrum depends on mode parameter j_*.

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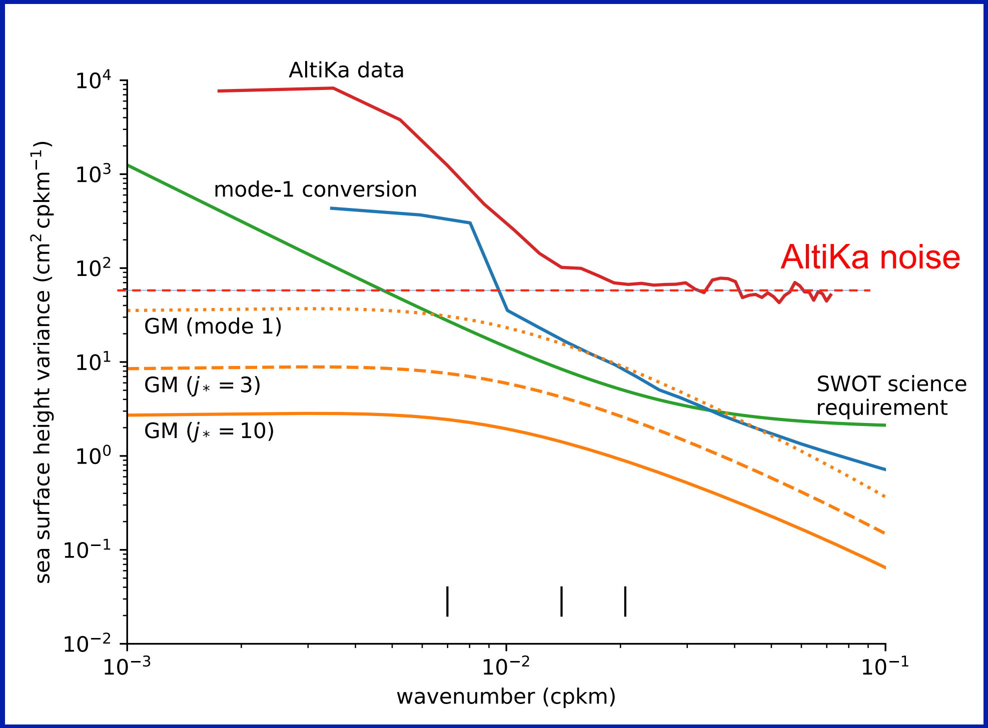
OSMOSIS



Note (JC): Mode-1 conversion is probably a good assumption only for the internal tide.

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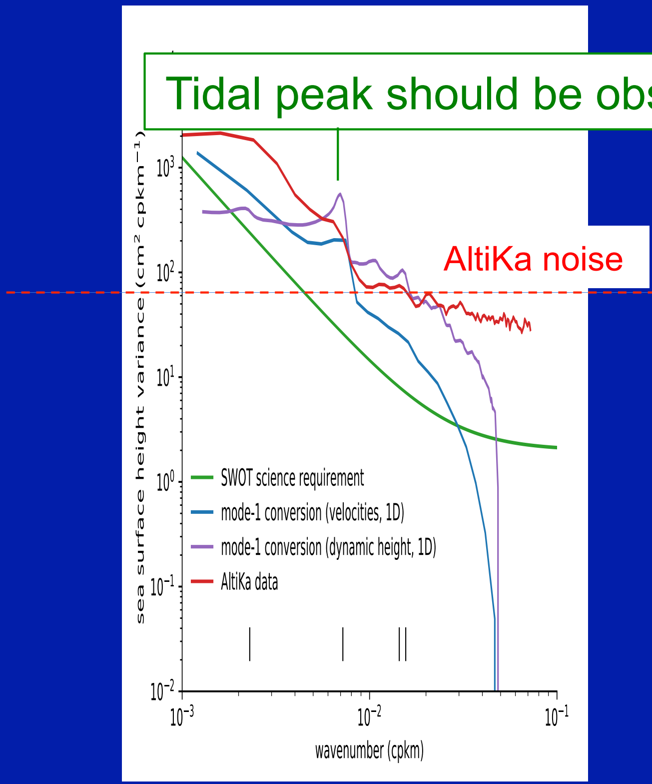
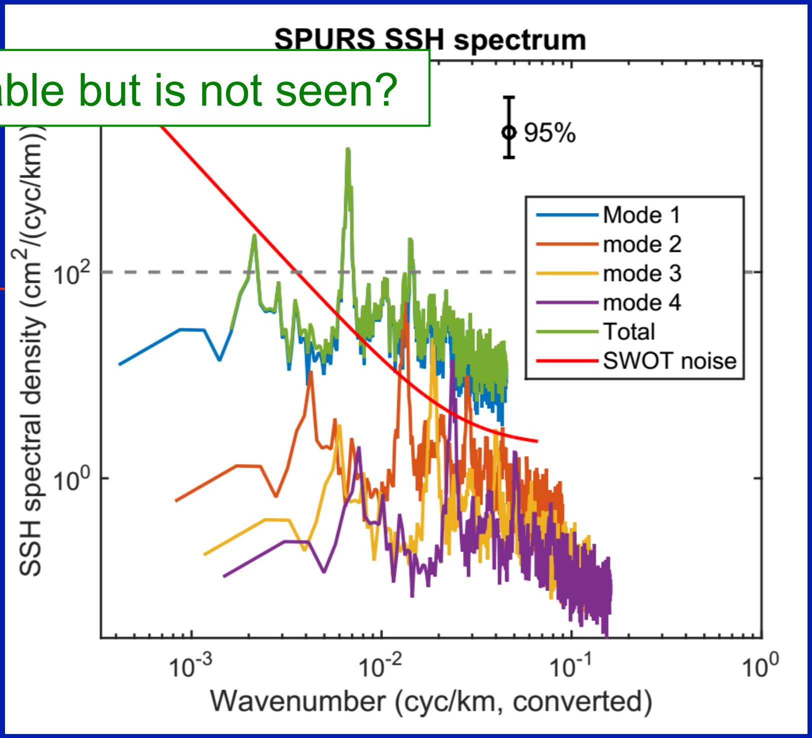
Array of mooring observations of horizontal current in IW frequency band converted to surface pressure using linear dynamics (JC)

SPURS





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Conclusions

- It is plausible that the SSH signature of the IW continuum will be above the SWOT detection limits at some places and at some times.

- It appears unlikely and probably implausible that the SSH signature of the IW continuum will be above the SWOT detection limits at most places and at most times.

- Considerable uncertainty remains regarding the SSH signature of the IW continuum. There is difficulty extending the GM framework to the surface; estimates from mooring observations are indirect and rely on assumptions regarding vertical structure or dynamics; and numerical ocean circulation models likely do not yet properly simulate the IW continuum because of limits on resolution and representation of generation, interaction, and decay processes.