Internal wave motions, precipitation variance, and spectral kinetic energy cascades in state-of-the-art high-resolution ocean and coupled ocean-atmosphere models

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The impacts of small-scale motions on air/sea coupling can be studied with high-resolution models, satellite missions, and in-situ measurements. Here we use high-resolution models to examine three topics of interest for satellite missions and models focused on air-sea interaction and mesoscale processes.

1) Simulation of near-surface near-inertial kinetic energy (KE)

Internal wave kinetic energy (KE) will be a source of "noise" in satellite missions such as Odysea that will focus on near-surface mesoscale KE. Models can be used to characterize near-surface internal wave KE. But, how accurate are these models? And, are they impacted by coupling to the atmosphere?

Arbic et al. (2022; JGR-Oceans; https://doi.org/10.1029/2022JC018551) compared the near-surface KE in two state-of-the-art global high-resolution ocean-only simulations:

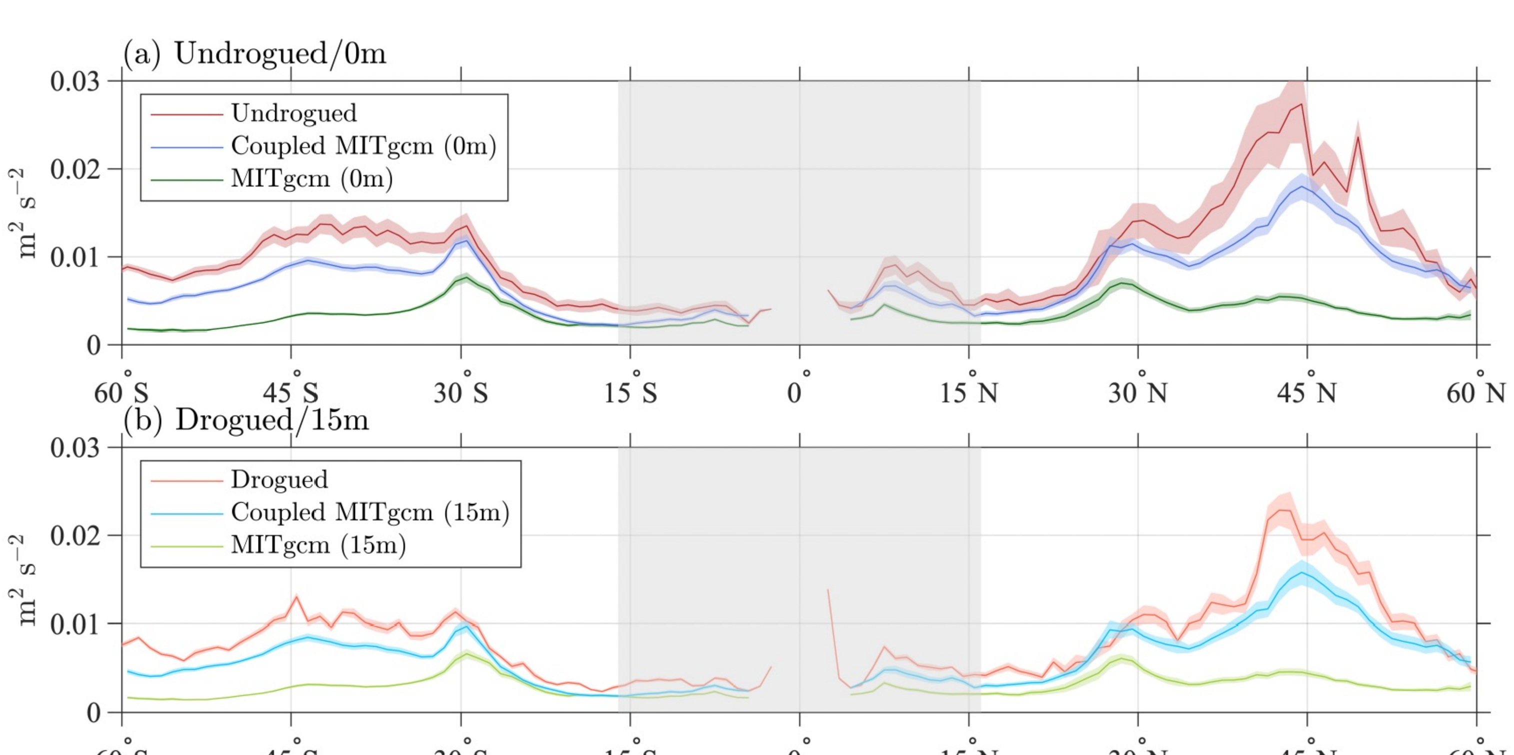
–HYbrid Coordinate Ocean Model (HYCOM) simulations run by the US Navy

–Massachusetts Institute of Technology general circulation model (MITgcm) simulations run by NASA

with observations from undrogued and drogued drifters, in low-frequency (< 0.5 cpd), near-inertial, semi-diurnal, and diurnal bands.

In a follow-on result (below), we have found that zonally averaged near-inertial KE in coupled ocean-atmosphere simulations with frequent coupling to the atmosphere lie much closer to drifter observations than ocean-only simulations with infrequent coupling. Thus an added benefit of high-resolution coupled ocean-atmosphere models, arising from the frequent coupling, is more accurate near-inertial motions.

The accurate near-inertial motions in this coupled model imply that it could be used to probe aliasing impacts of near-inertial motions for the Odysea mission.

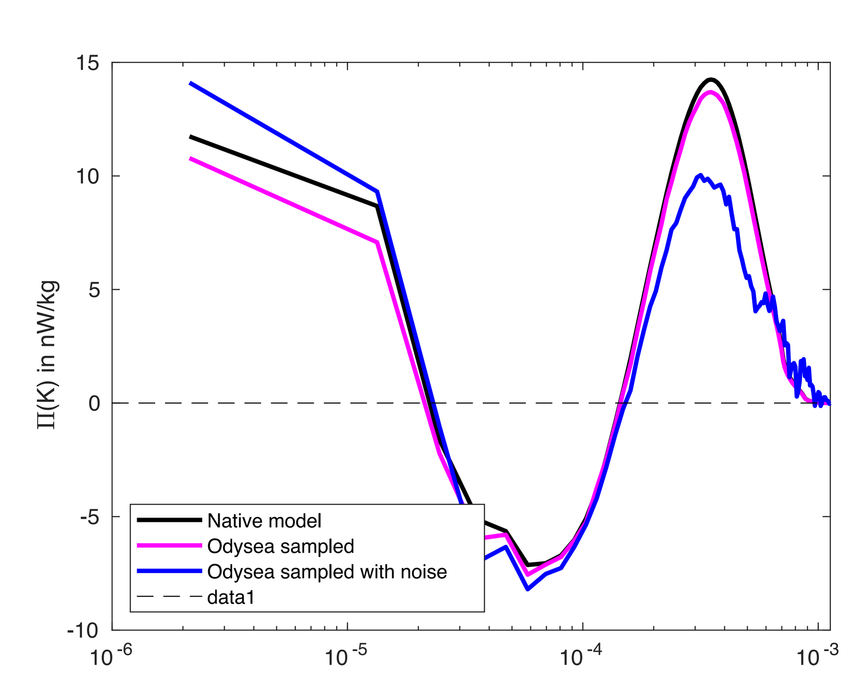


2) Simulating spectral KE cascade computed from Odysea

Spectral KE fluxes $\Pi(K)$ measure the direction of spectral KE cascade as a function of wavenumber K. Spectral KE fluxes computed from altimetry (Scott et al. 2005; Arbic et al. 2013, and others) apply the geostrophic assumption to sea surface heights. The proposed Odysea mission would enable the computation of spectral KE fluxes directly from velocities.

(Right) We computed spectral KE flux $\Pi(K)$ from 1731 hourly snapshots of coupled MITgcm ocean/GEOS atmosphere in Kuroshio region, 2020-01-19 to 2020-03-29. Spectral fluxes were also computed from 90 snapshots of "Odysea samples" of this region during the same time period, with and without noise, prepared by Alexander Wineteer of NASA JPL.

The spectral fluxes computed with simulated instrument noise and infrequent sampling lie close to those computed from the "model truth". Thus Odysea can probably be used to compute spectral energy transfers that include ageostrophic as well as geostrophic motions.



3) High-frequency precipitation variance

Most precipitation variance is in sub-daily time scales, and low-resolution climate models do not capture this high-frequency activity (Covey et al., 2018).

Light et al. (2022; Climate Dynamics, https://doi.org/10.1007/s00382-022-06257-6) examined high-frequency precipitation variance in high-resolution coupled ocean-atmosphere models. The plot below shows frequency spectra of precipitation variance in the US Atlantic coast region, from several models, an average over several rain gauges in the region, and satellite products.

Generally, a decrease in atmosphere or ocean model grid spacing leads to higher precipitation variance at high frequencies.

Ocean model grid spacing also matters,especially when the atmospheric model has fine grid spacing.