Near-surface oceanic kinetic energy distributions from drifter observations and numerical models

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Submitted under title: Frequency dependence of ocean surface kinetic energy and its vertical structure from global high-resolution models and surface drifter observations

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Outline

- We will compare the surface (0 m) and 15 m velocities in global high-resolution HYCOM and MITgcm LLC4320 vs. undrogued (0 m) and drogued (15 m) drifters.
- We compare in different frequency bands ranging from low-frequency (subtidal) to semi-diurnal.
- We compute a vertical structure proxy ratio 0 m KE / (0 m + 15 m) KE.
- We follow work by Yu et al. (2019) who compared MITgcm LLC4320 to drifters and who did not emphasize the 0 m / 15 m contrast as we do. Yu showed that MITgcm near-inertial and semidiurnal KE is respectively too weak/too strong relative to observations.
- Relevance to Odysea will hopefully be clear!
  - Drifters and high-resolution models can both be used to examine the spatial geography and frequency content of near-surface KE.
  - Some knowledge of vertical structure will help to interpret the meaning of a surface velocity measurement for subsurface conditions.

Observations and models used

Observations from the Global Drifter Program (e.g., Lumpkin et al. 2017)

- Undrogued (~0 m) and drogued (~15 m) drifters

Global 1/25° HYCOM non-assimilative simulations with embedded tides

- 41 hybrid layers
- 7 z-levels in uppermost 30 m
- Includes parameterized topographic internal wave drag to roughly account for unresolved breaking internal waves
- 3-hourly atmospheric forcing
- Numerical instability in North Pacific

Global 1/48° MITgcm LLC4320 simulations with embedded tides

- 90 z-levels
- 13 z-levels in uppermost 30 m
- No wave drag
- 6-hourly atmospheric forcing; later in talk we will show preliminary results from a coupled atmosphere/ocean simulation with very frequent update intervals

Frequency spectra used to separate KE into different bands

Compare drogued drifter results to 15 m model results

Compare undrogued drifter results to 0 m model results

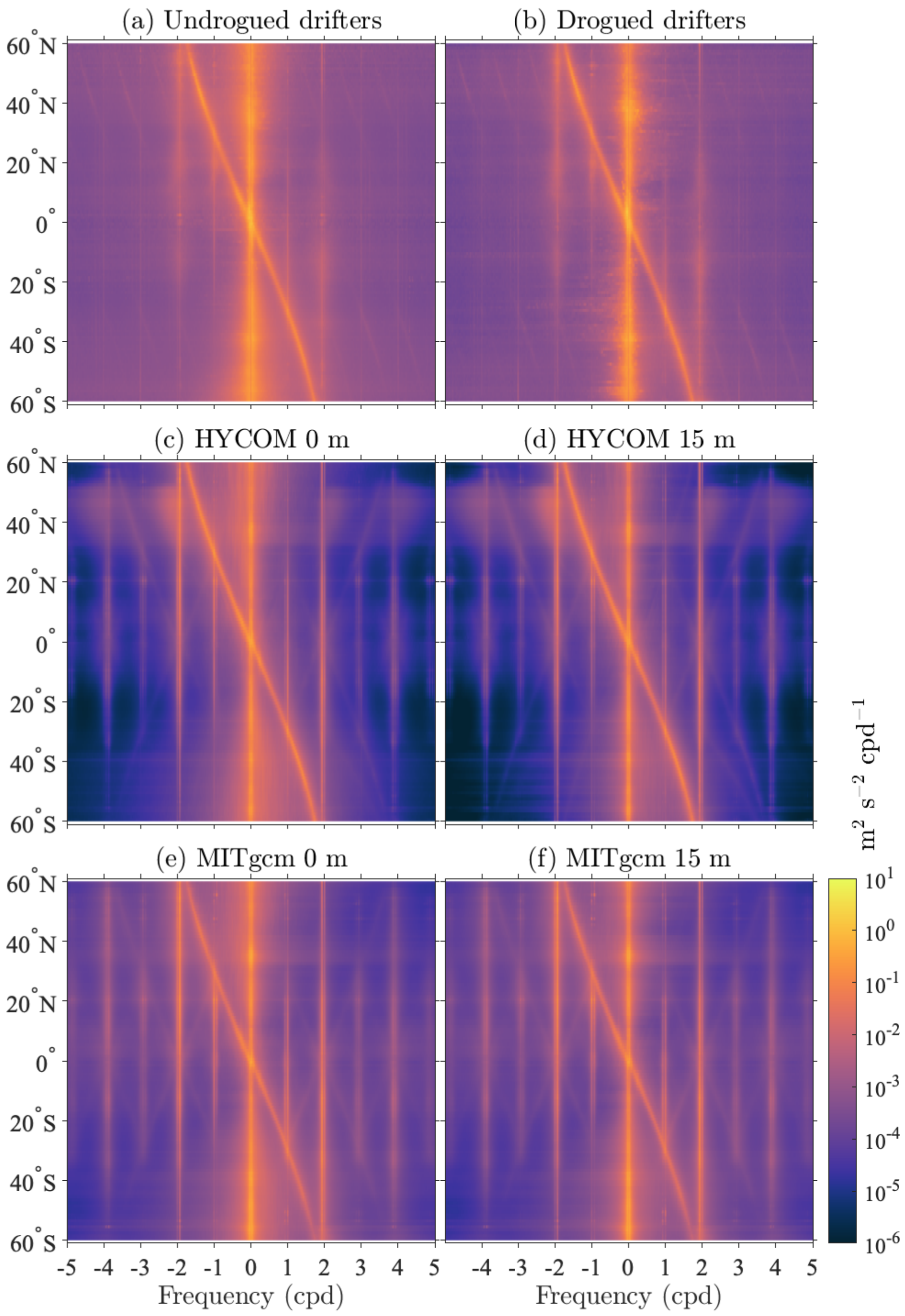
Examine vertical structure proxy ratio 0 m KE/(0 m KE + 15 m KE) in models vs. undrogued drifter KE /(undrogued drifter KE + drogued drifter KE)

Definitions of bands used…

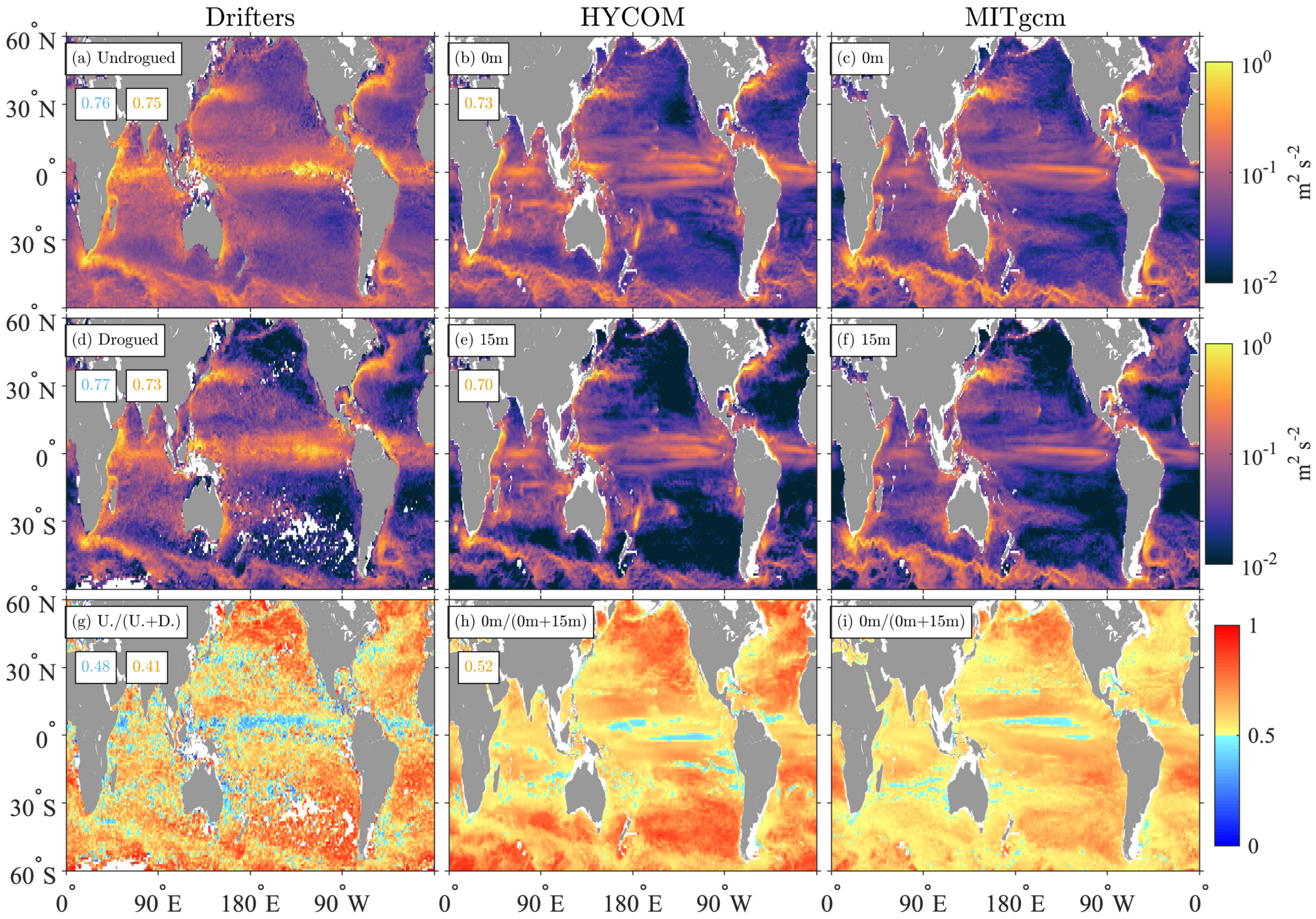
- Follow definitions used by Yu et al. (2019)
- Low-frequency: Less than 0.5 cpd
- Near-inertial: 0.9 f – 1.1 f
- Diurnal: 0.9 cpd – 1.1 cpd
- Semidiurnal: 1.9 cpd – 2.1 cpd
- Near-inertial and diurnal bands overlap near 30° latitude

Zonally averaged rotary spectra

Note that tidal and tidal harmonic peaks rise above the background more in the models—"wider" drifter peaks will come up again



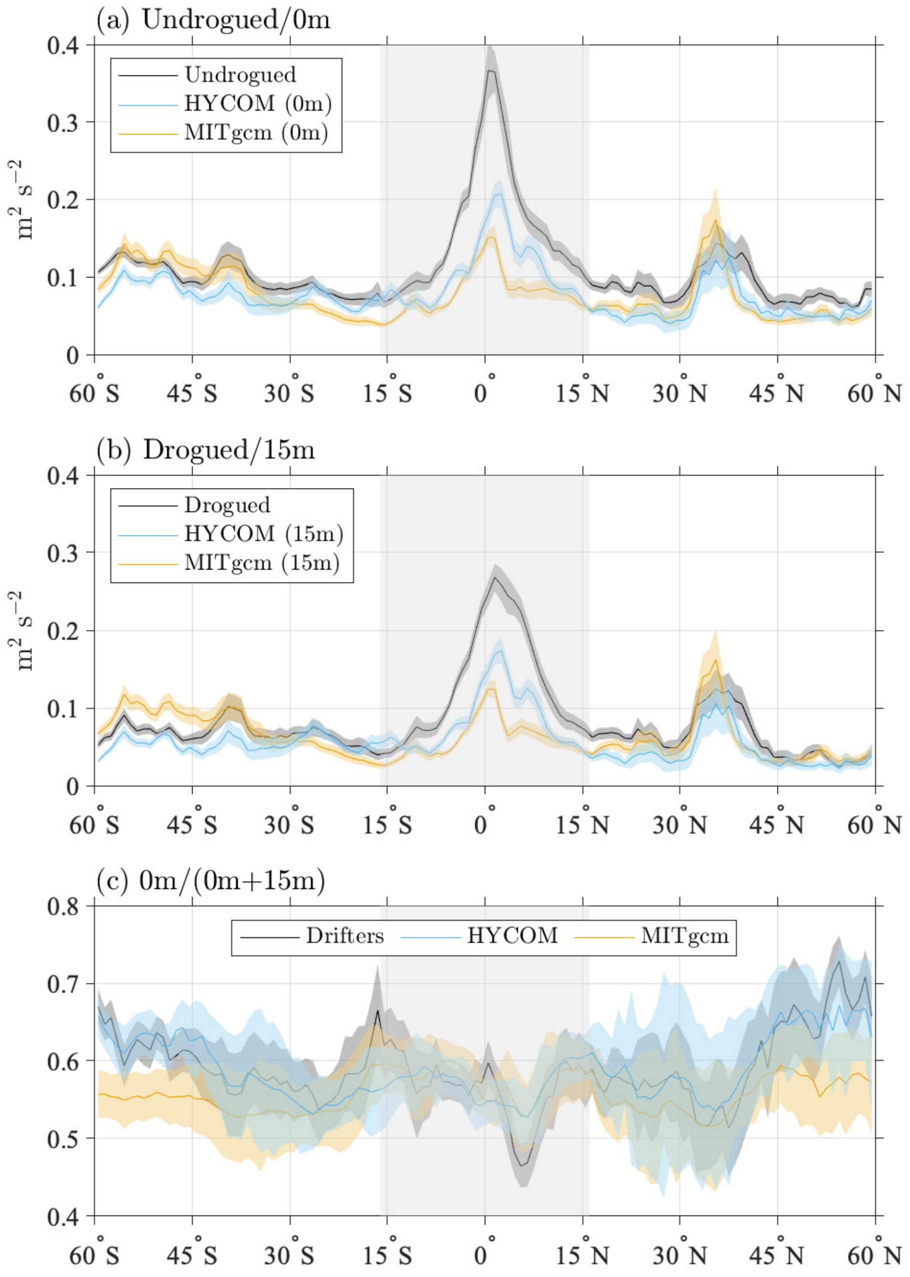
Maps of low-frequency KE



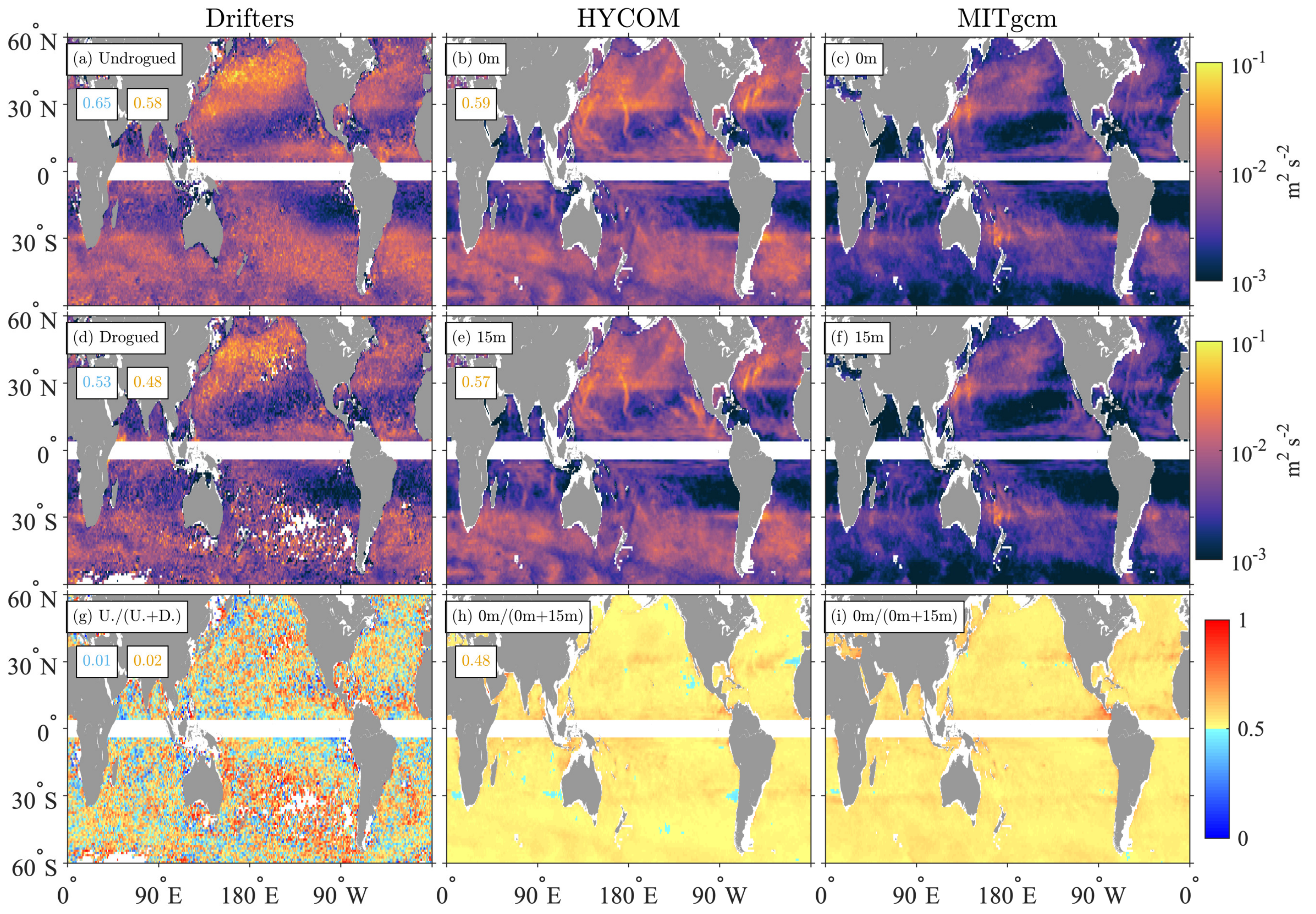
Inset numbers in plots represent spatial correlationcoefficientss between HYCOM and MITgcm (middle row) and between models and drifters (left row—HYCOM in cyan, MITgcm in gold)

Zonally averaged low-frequency KE

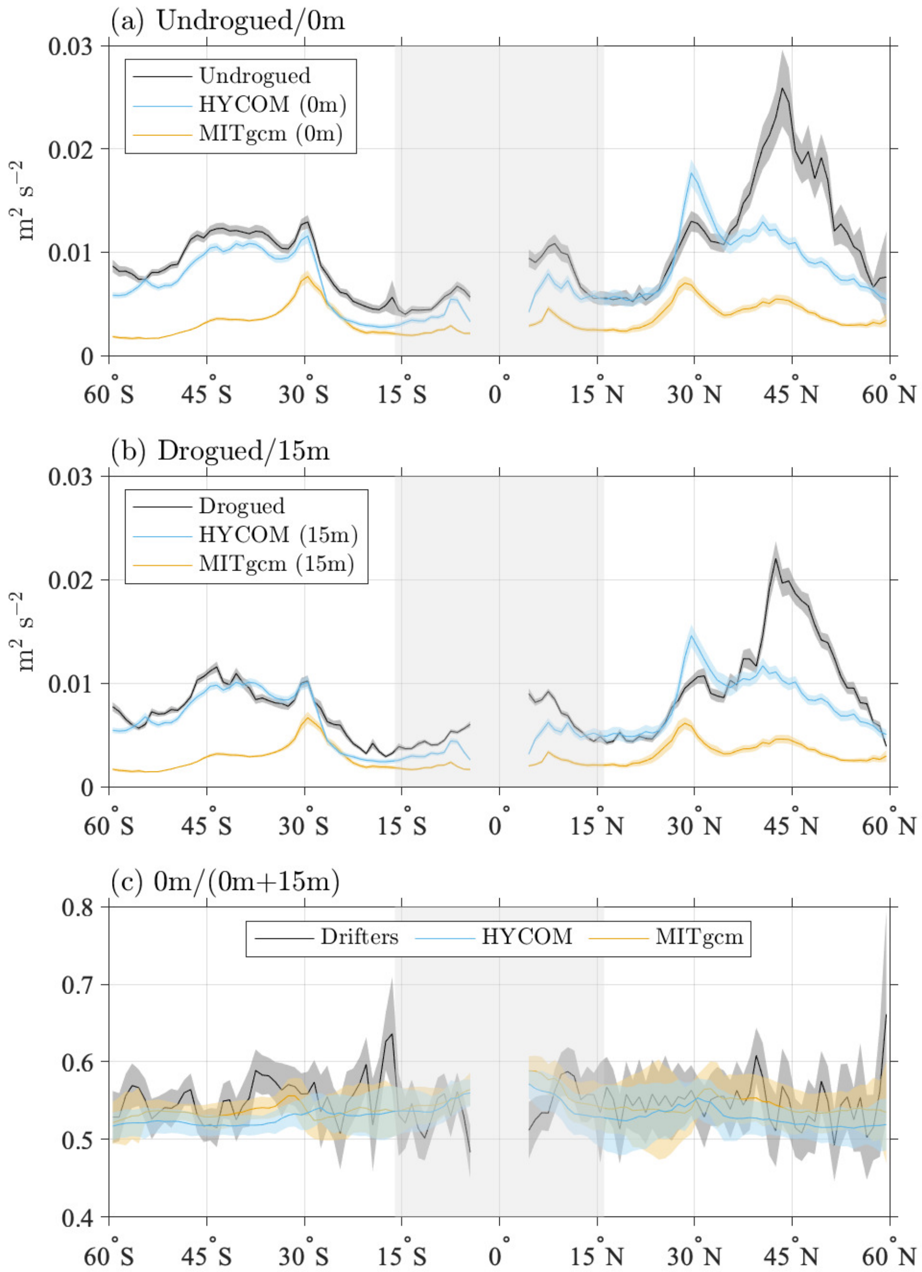
Low-frequency band includes Ekman flows, which have substantial vertical structure



Maps of near-inertial KE



Zonally averaged near-inertial KE



Near-inertial band known to have vertical structure in upper ocean

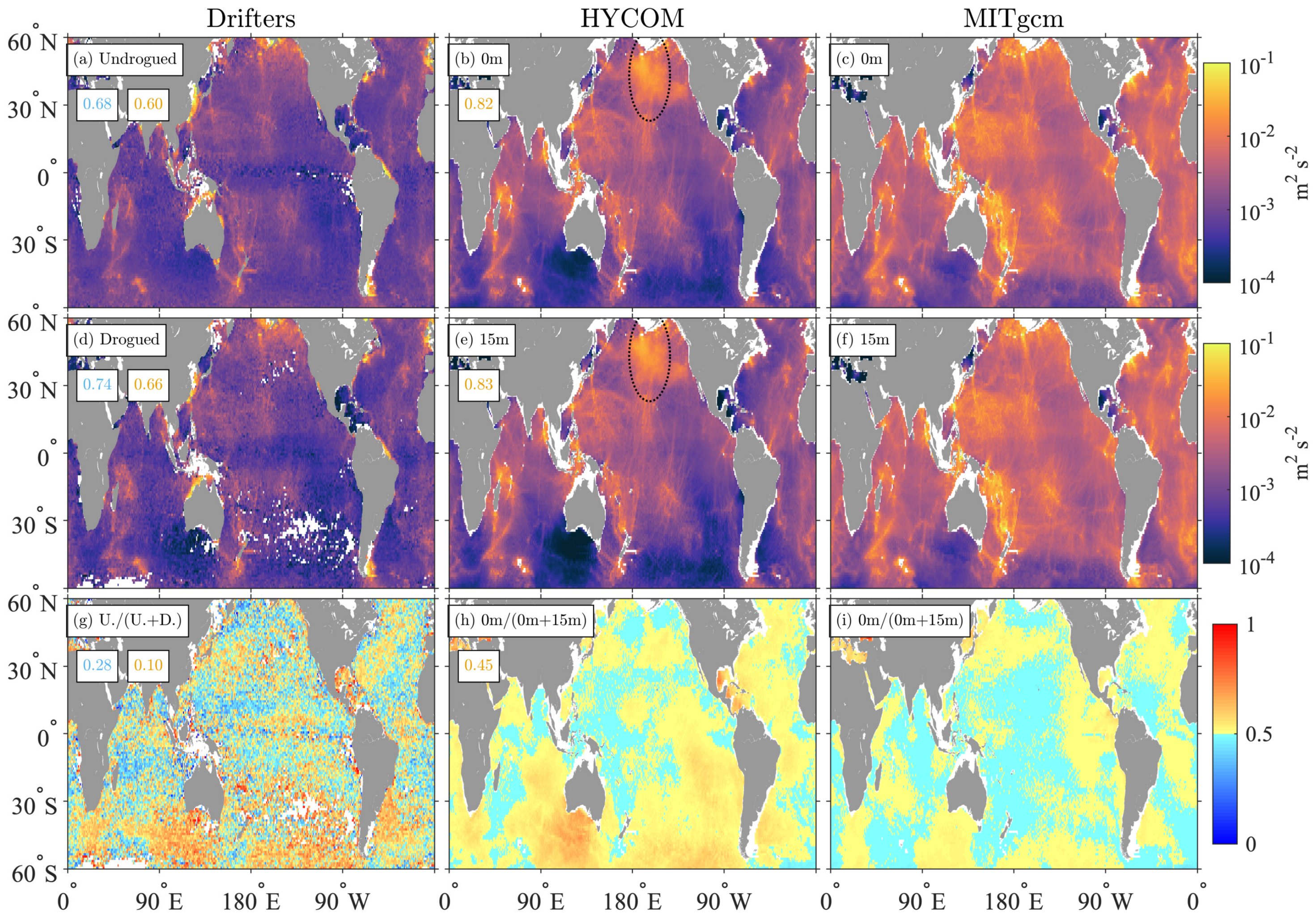
e.g., Large and Crawford 1995, Crawford and Large 1996, Dohan and Davis 2011

Diurnal band results

- Maps and zonal averages of diurnal KE (not shown for sake of brevity) are complex and interesting
- Comparison of diurnal KE inferred from tidal harmonic analysis to "full diurnal KE" results computed from frequency spectra → diurnal band isn't just tides!
- Diurnal band includes:
  - diurnal tides
  - overlap with near-inertial flows near 30° latitude
  - diurnal cycling of Ekman (Price et al. 1986, Price and Sundermeyer 1999, Sun and Sun 2020), near-inertial (Sun and Sun 2020), and submesoscale (Sun et al. 2020) dynamics

Maps of semi-diurnal KE

Circled regions
In HYCOM plots
represent a region of
numerical instability
in the North Pacific

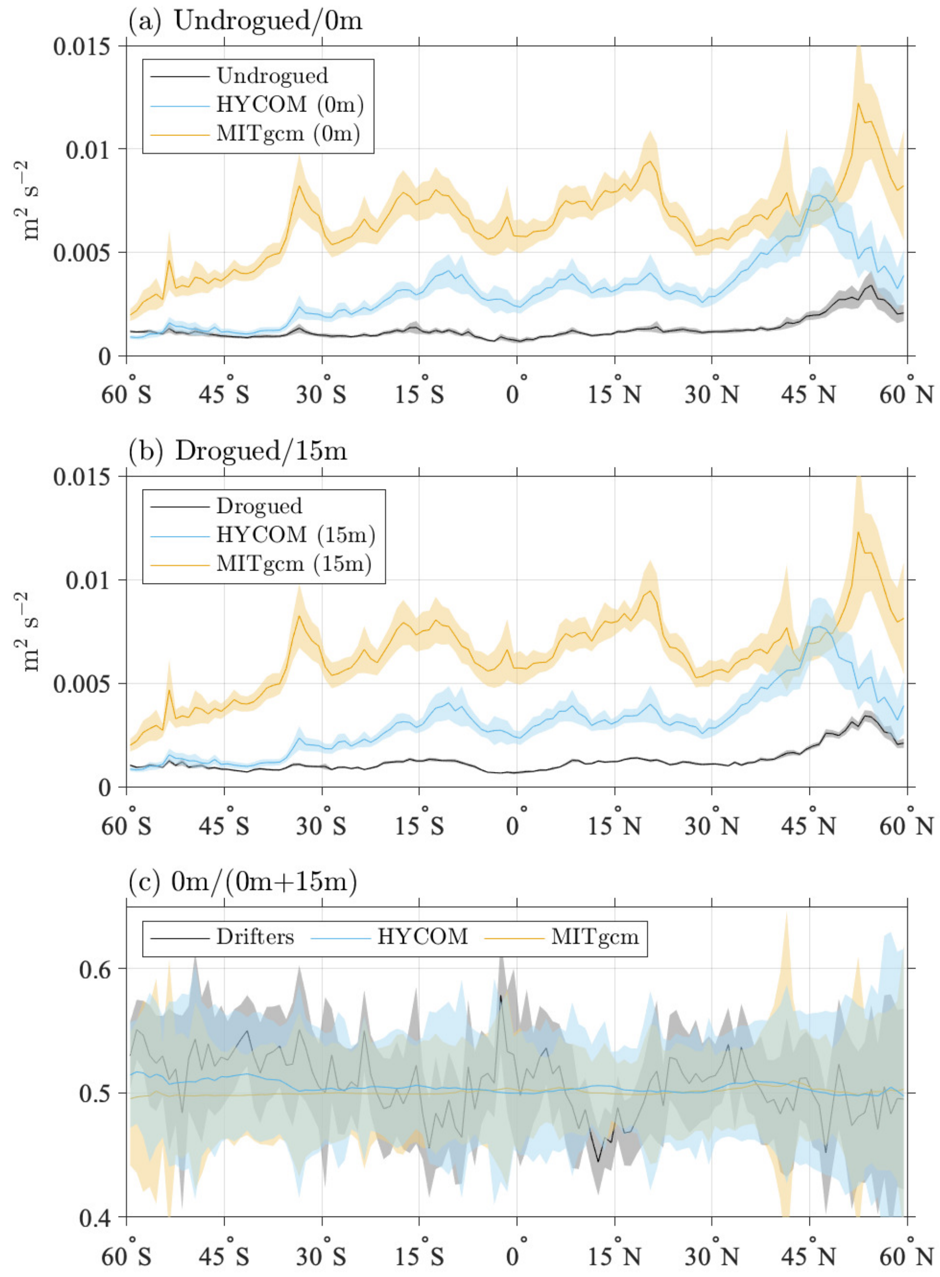


Zonally averaged semi-diurnal KE: Part 1

Only 17% of MITgcm LLC4320 discrepancy can be explained by mistakes in tidal forcing

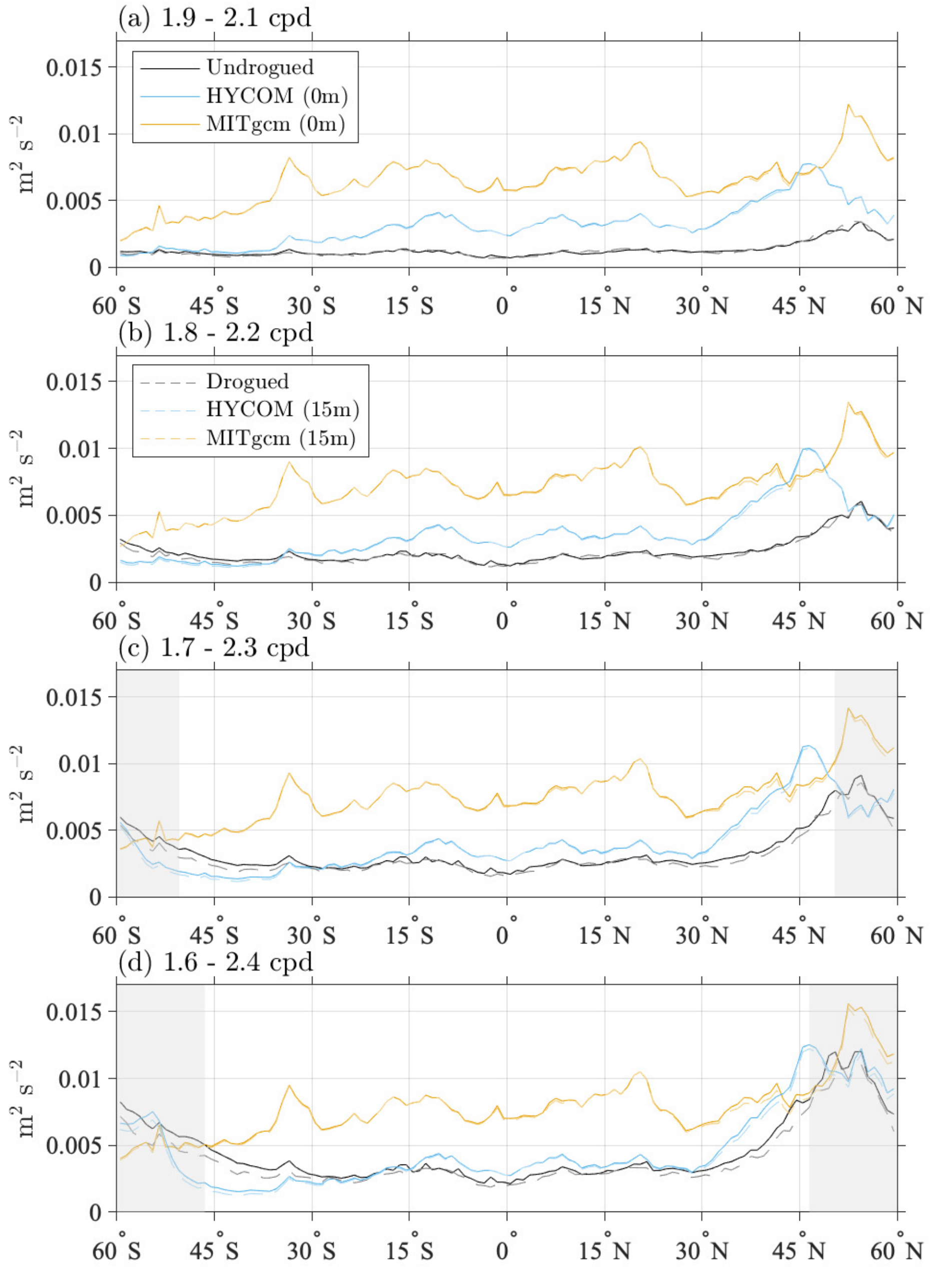
More important factor is likely to be the absence of parameterized topographic wave drag in MITgcm LLC4320

See Ansong et al. (2022), in advanced preparation



Zonally averaged semi-diurnal KE: Part 2

If definition of band is widened, agreement between HYCOM and drifters improves, while MITgcm LLC4320 is still too large



Conclusions

- Drifters provide a global dataset to discriminate differences between models.
- HYCOM lies closer to drifters in near-inertial and tidal bands than MITgcm LLC4320 does, and the likely reasons differ between the two bands (atmospheric forcing update intervals, vs. inclusion of parameterized topographic wave drag).
- Most notable failing of both HYCOM and MITgcm LLC4320 appears to be insufficiently energetic low-frequency flows near the equator→this is a highly interesting region for Odysea!
- With some noted exceptions, zonal averages of model 0 m KE / (0 m KE + 15 m KE) track latitude and frequency dependence in the same ratios computed from undrogued drifter KE / (undrogued drifter KE + drogued drifter KE), with some degree of skill.
- Ongoing/future work
  - In-depth examination of complex and interesting diurnal band (Elipot/Whitt + Menemenlis/Arbic proposal)
  - Examination of
    - coupled ocean/atmosphere simulation of MITgcm/GEOS
    - coupled US Navy ocean/atmosphere simulations
    - assimilative (operational) HYCOM simulations