Comparing Mesoscale Eddy to Internal Gravity Kinetic Energy from High-Resolution Global Ocean Models with Moored Current Meter Observations

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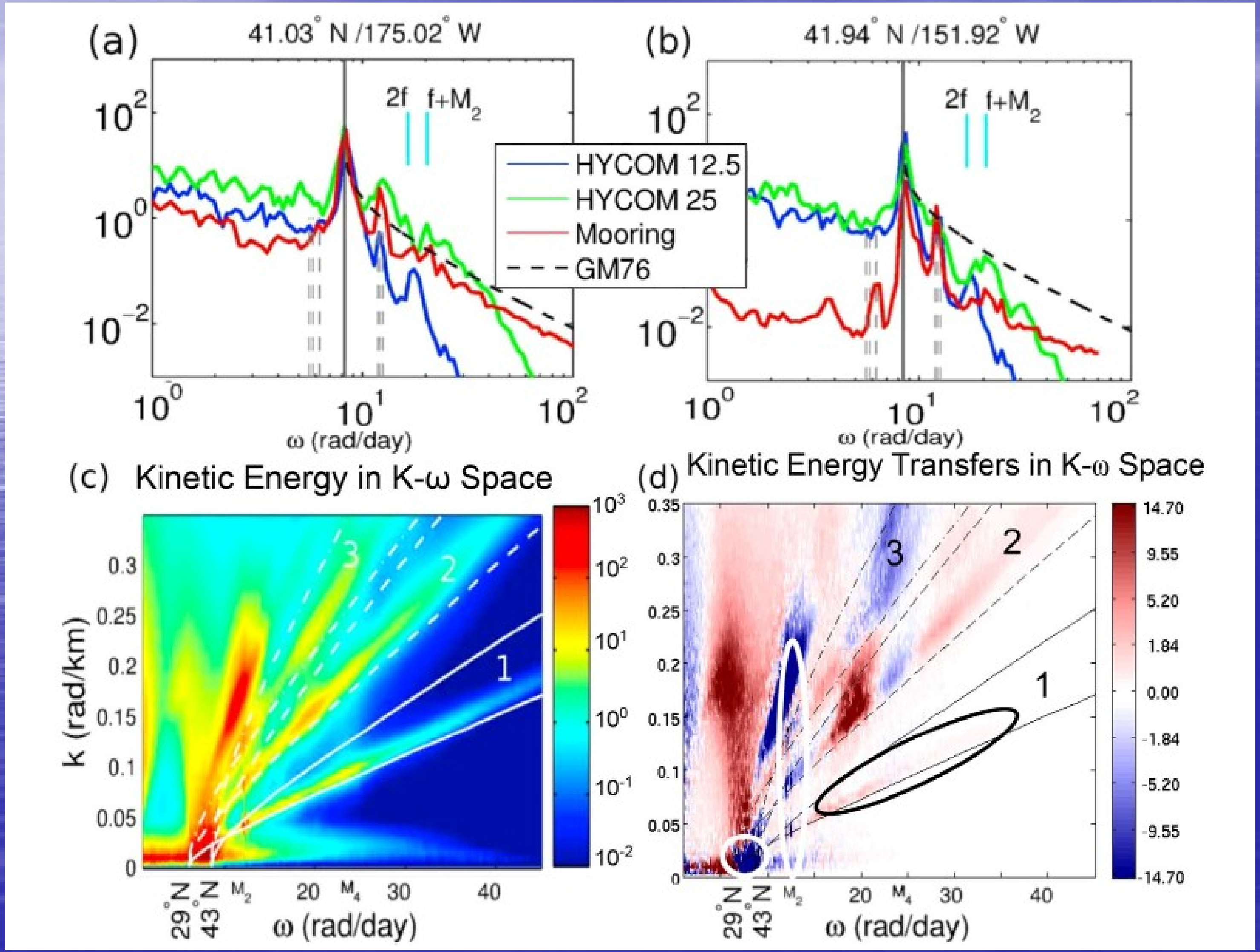
Adding the astronomical forcing of the sun and moon has opened new paradigm in global ocean models.



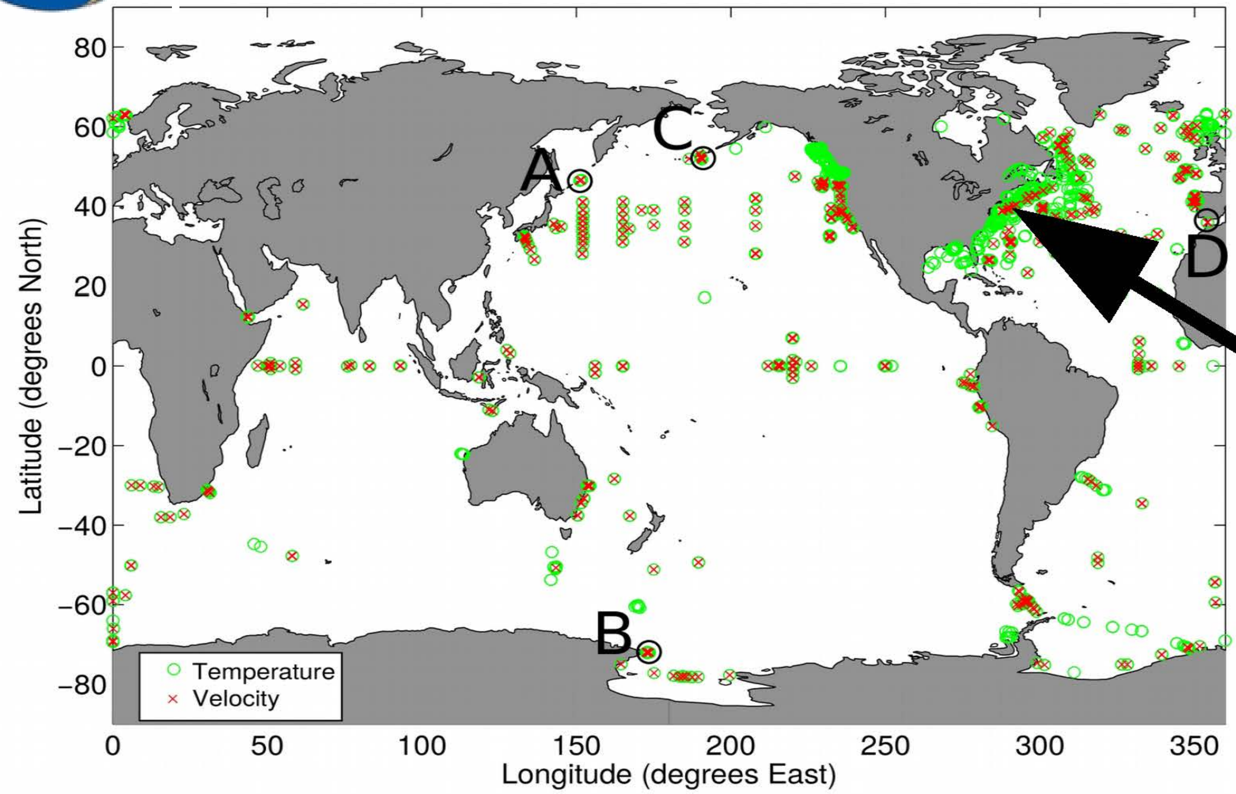
First evidence of IGW continuum in such models—analysis of surface kinetic energy in North Pacific region of global HYCOM (Müller et al. 2015; updated figure from Savage et al. 2017a)

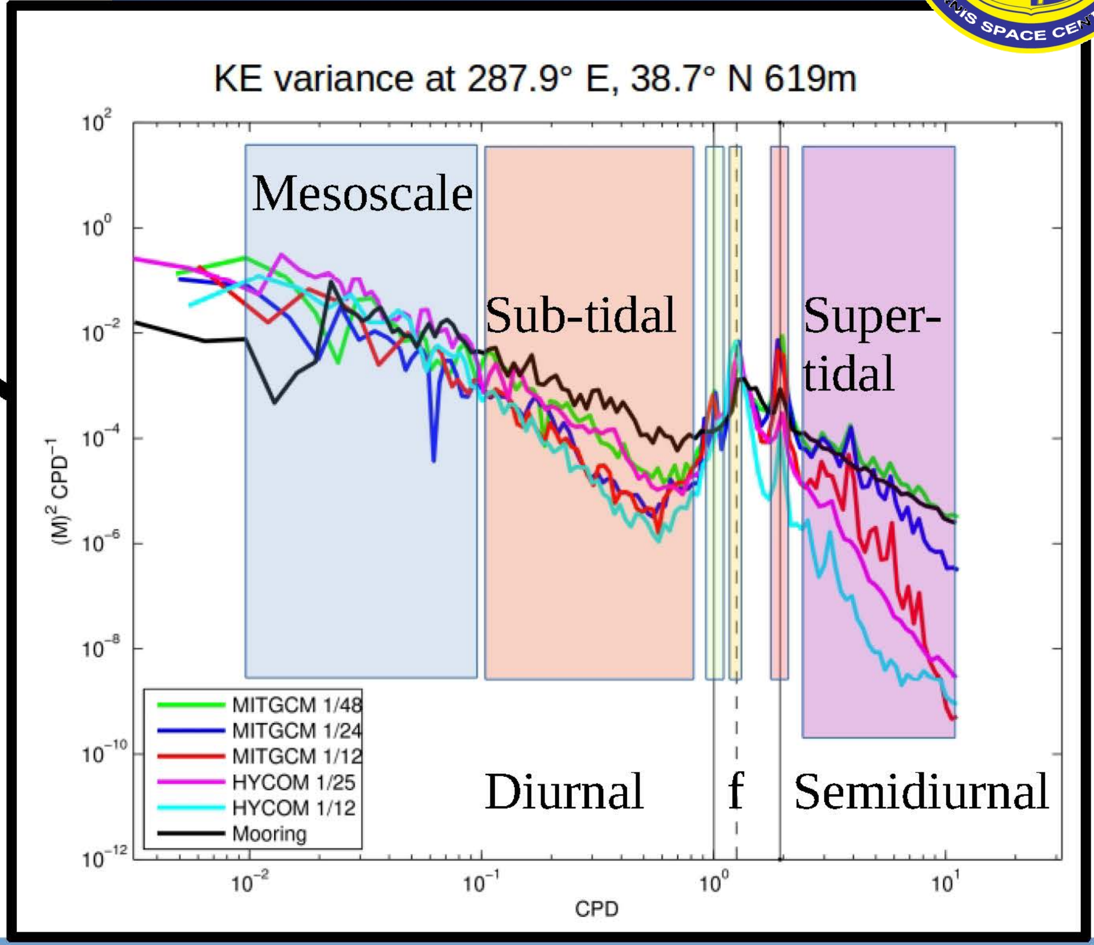
Horizontal resolution appears to be important to resolving the IGW continuum

High-Resolution Global Ocean Model with Tides

- Recently, simulations at various high resolution with two different models have been performed
  - HYbrid Coordinate Ocean Model (HYCOM)
    - Two resolutions—1/12.5° and 1/25°
  - MIT global circulation model (MITgcm)
    - Three resolutions—1/12°, 1/24° and 1/48°
- We will compare the kinetic energy in these simulations to ~3100 current meter observations at ~2000 locations
  - From high (IGW) to low (mesoscale) frequencies
- We will compare geostrophic kinetic energy calculated from SSH with AVISO

Current Meter Observations





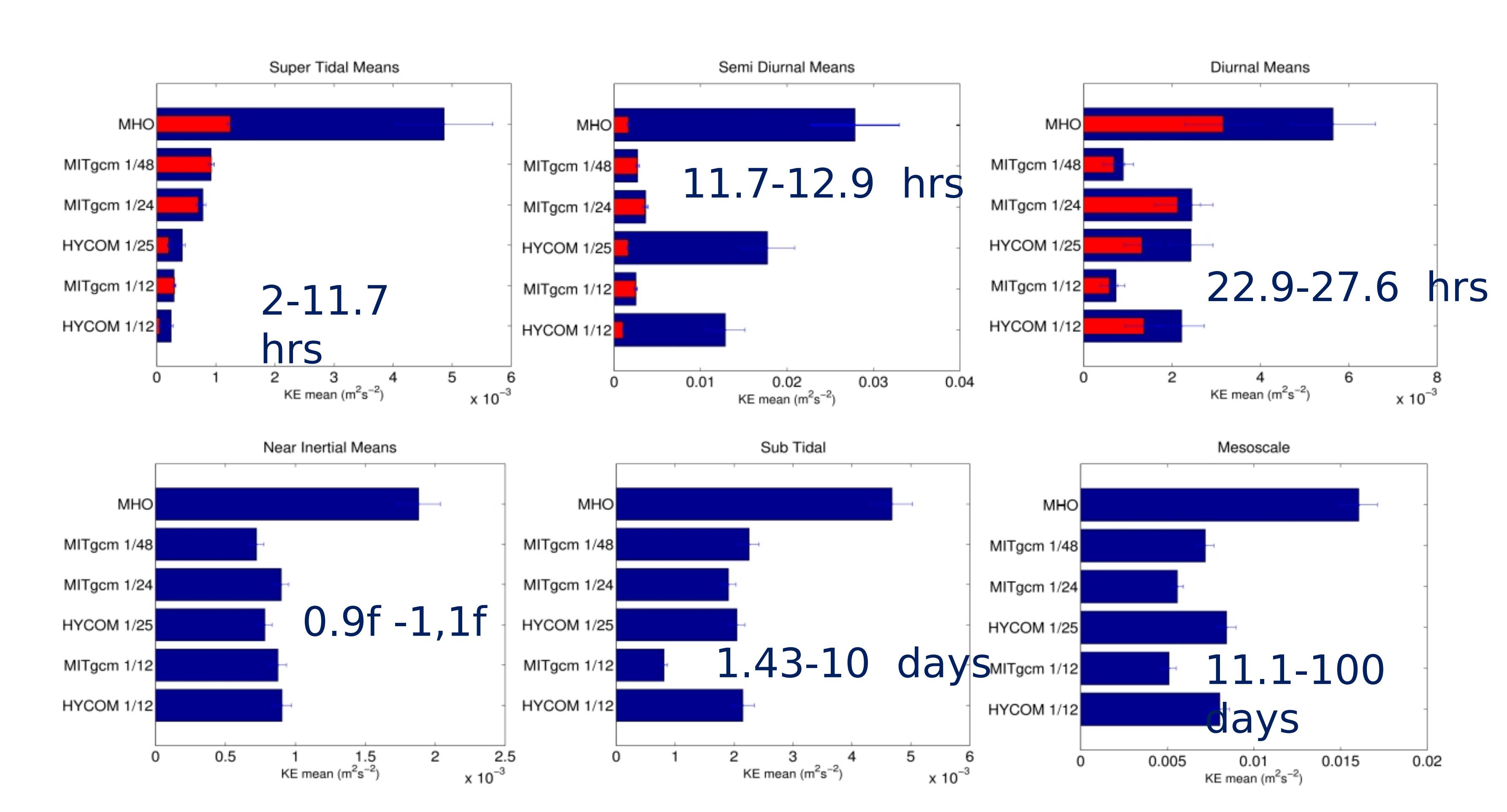
The regions A, B, C and D are locations (marginal seas) where MITgcm is under-energetic

The current meters are distributed around the globe with the majority in the North Atlantic and North Pacific with 2/3 of the observations in the upper 500 m

From Luecke et al. 2018, submitted

Comparing the Kinetic Energy for all frequency bands and resolutions

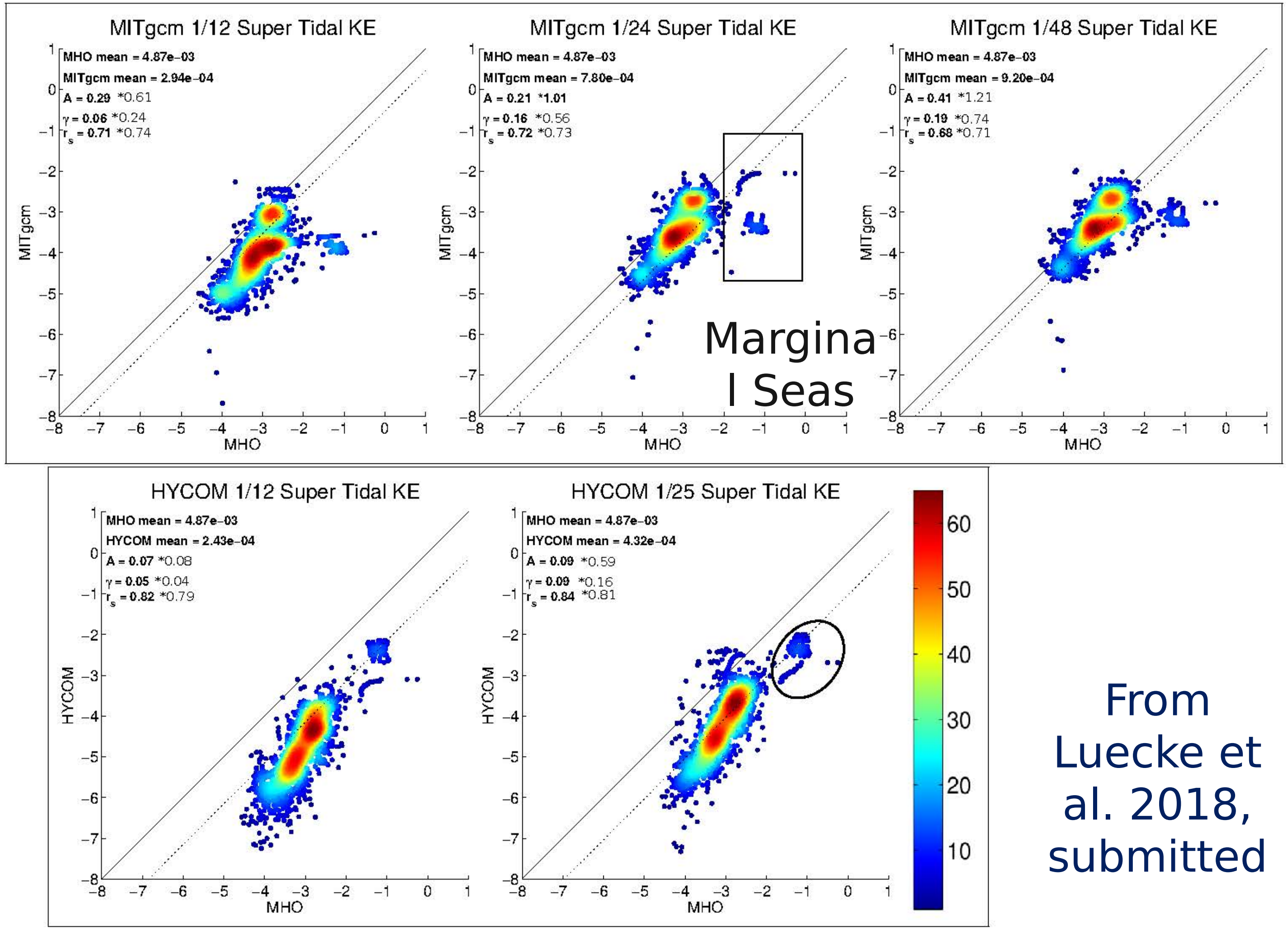
- Resolution doesn't improve the comparison in all frequency bands
  - Behavior with resolution increase isn't the same for the two different models
  - A few points can impact the apparent results for this gross metric
    - Red bars have the marginal seas (regions A,



From Luecke et al. 2018, submitted

Internal Gravity Wave Kinetic Energy

- Both models show increased energy as resolution increases
- HYCOM has higher spatial correlation with observations than MITgcm
- HYCOM:
  - Overall less energy than MITgcm, but marginal seas are more energetic and closer to observations
- MITgcm:
  - Better energetics overall
  - Marginal seas are under-energetic
  - Possible that better energetics may be due to overly energetic semi-diurnal tides (next slide)



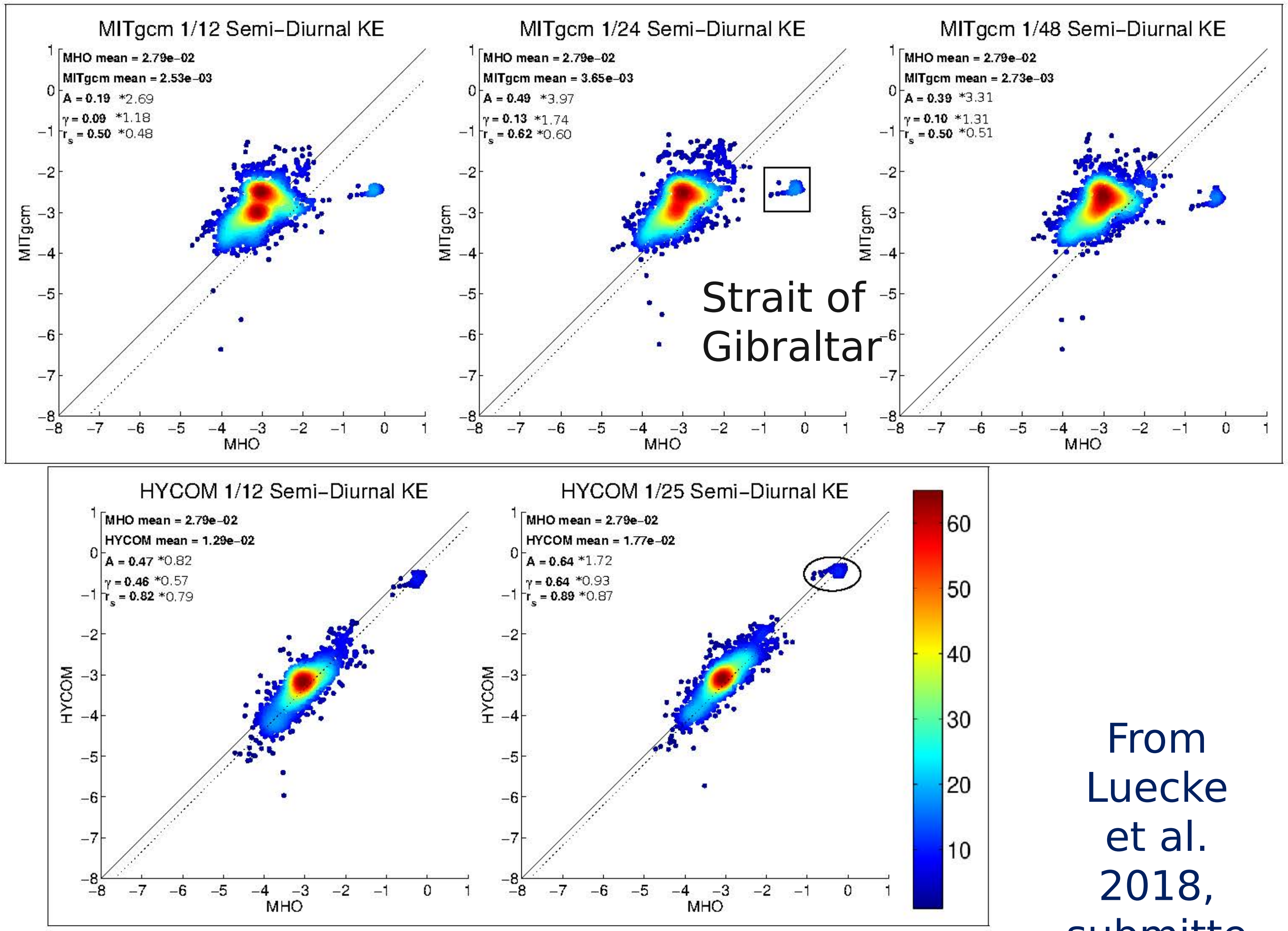
From Luecke et al. 2018, submitted

Semi-Diurnal Tidal Kinetic Energy

- The two models have very different methods to implement tidal forcing and damping.
  - Wave drag damping plays an important role in getting tidal energetics correct

- HYCOM:
  - Better spatial correlation than MITgcm
  - More realistic kinetic energy, with and without marginal seas

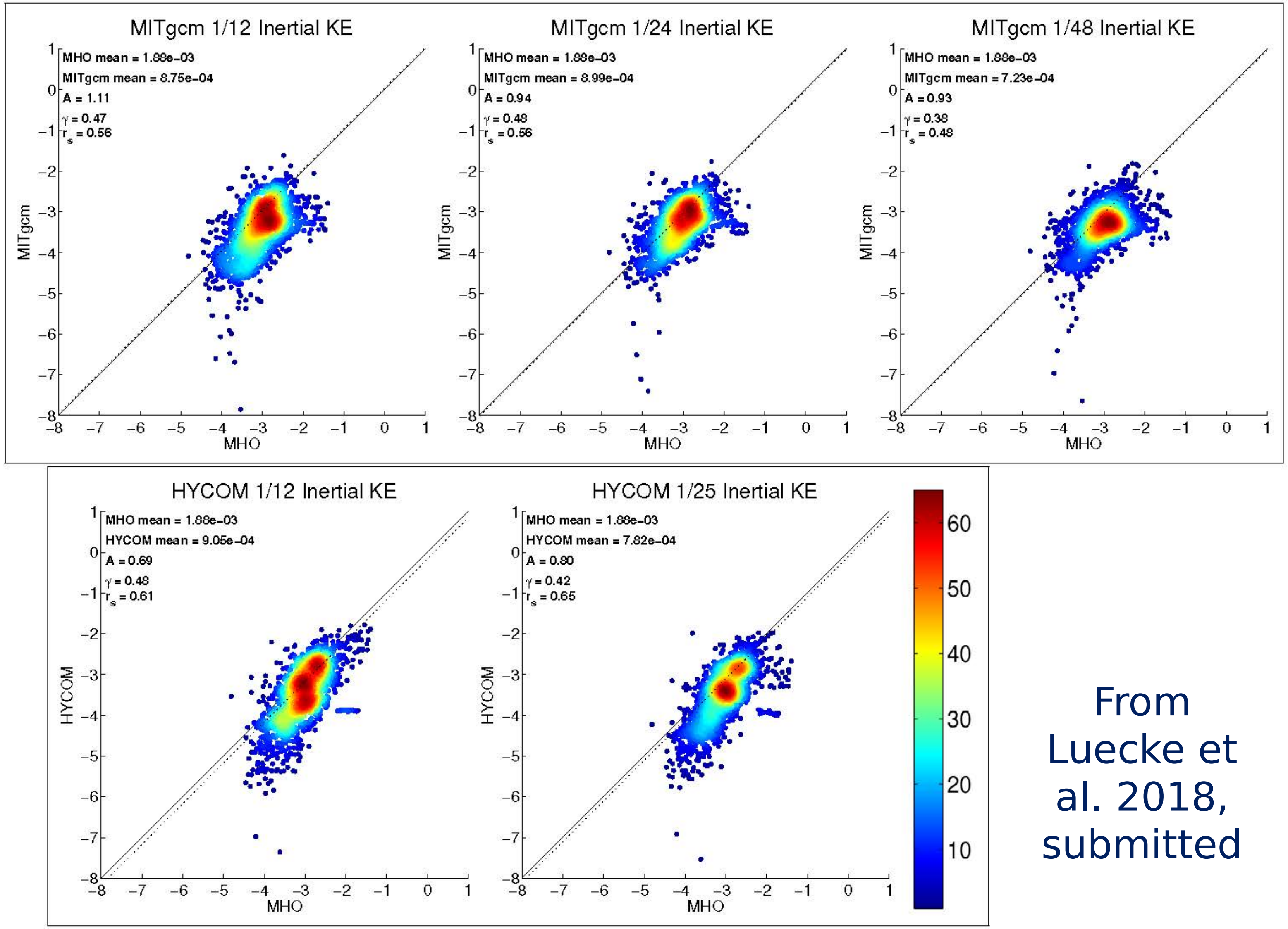
- MITgcm:
  - Under energetic in marginal seas
  - Too energetic when marginal



From Luecke et al. 2018, submitte

Near-Inertial Kinetic Energy

- Near-inertial KE is similar for both models
  - Possibly due to large horizontal scales of near-inertial KE (Simmons & Alford 2012)
  - Highest resolution MITgcm actually has the lowest near-inertial KE
- HYCOM has higher spatial correlation than MITgcm



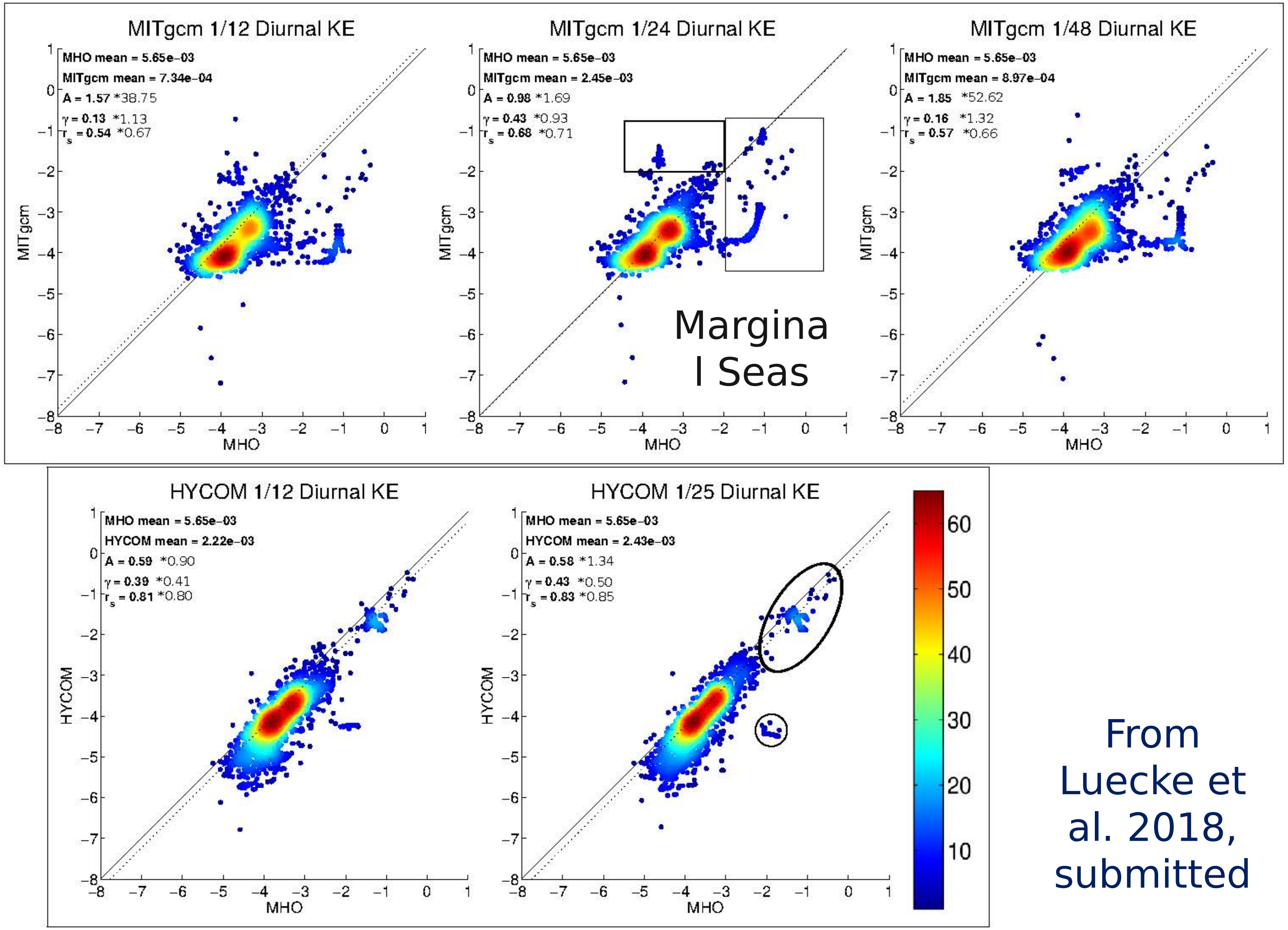
From Luecke et al. 2018, submitted

Diurnal Tidal Kinetic Energy

- Resolution doesn't have a big impact on the KE levels, although spatial correlation improves with resolution

- MITgcm:
  - Marginal seas are under-energetic
  - Highest resolution has weakest diurnal tides

- HYCOM:
  - Diurnal tides are probably overdamped (tuned for M_2)
  - Better spatial correlation than MITgcm
  - Better energetics in marginal seas

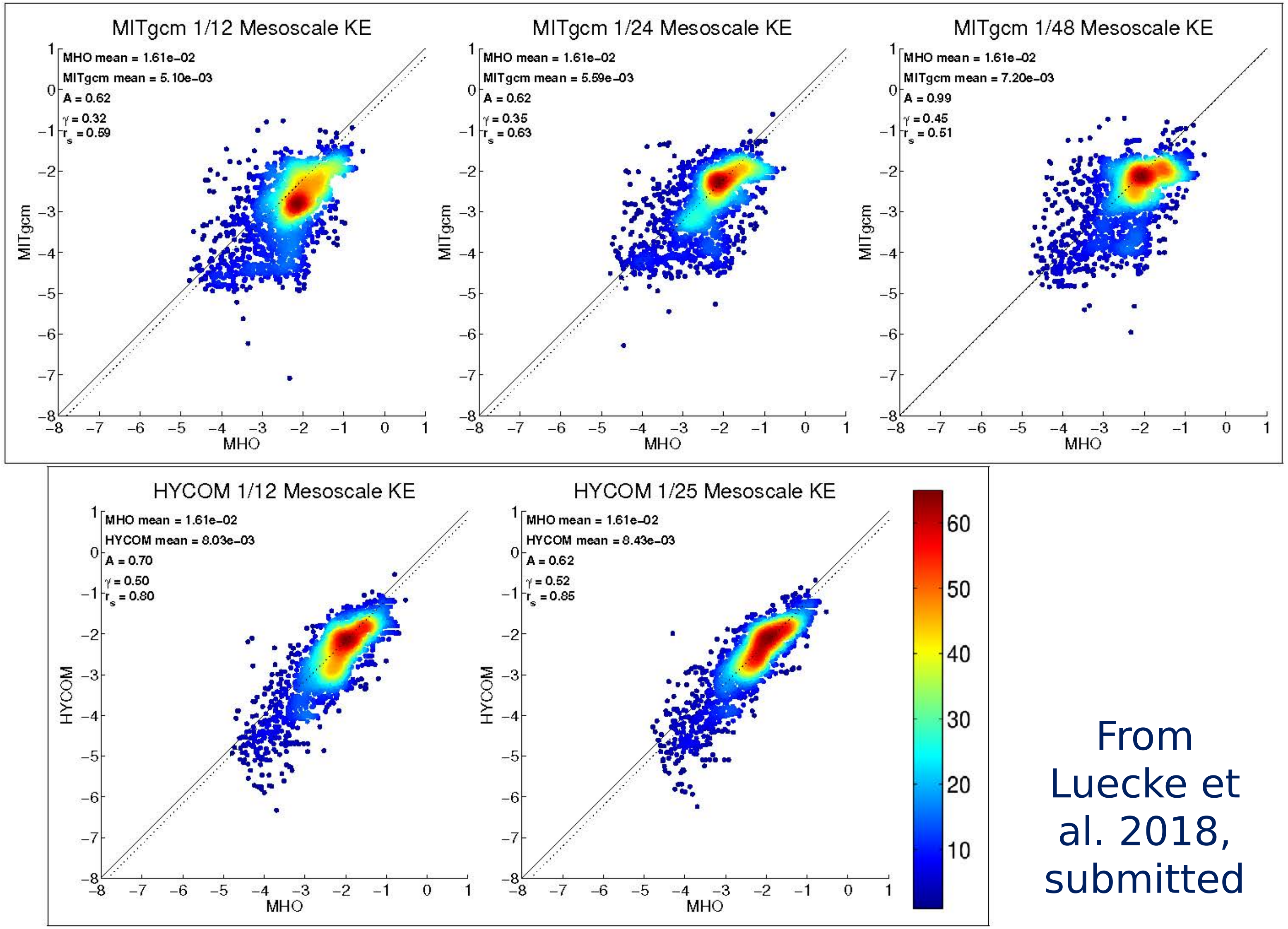


From Luecke et al. 2018, submitted

Mesoscale Kinetic Energy

- Resolution matters for the mesoscale KE with the higher resolution models have more KE, although all models have less KE than observations
  - HYCOM is more energetic than MITgcm
  - Doubling the resolution leads to ~4% to ~25% increase in KE

- HYCOM has higher spatial correlation with observations than MITgcm



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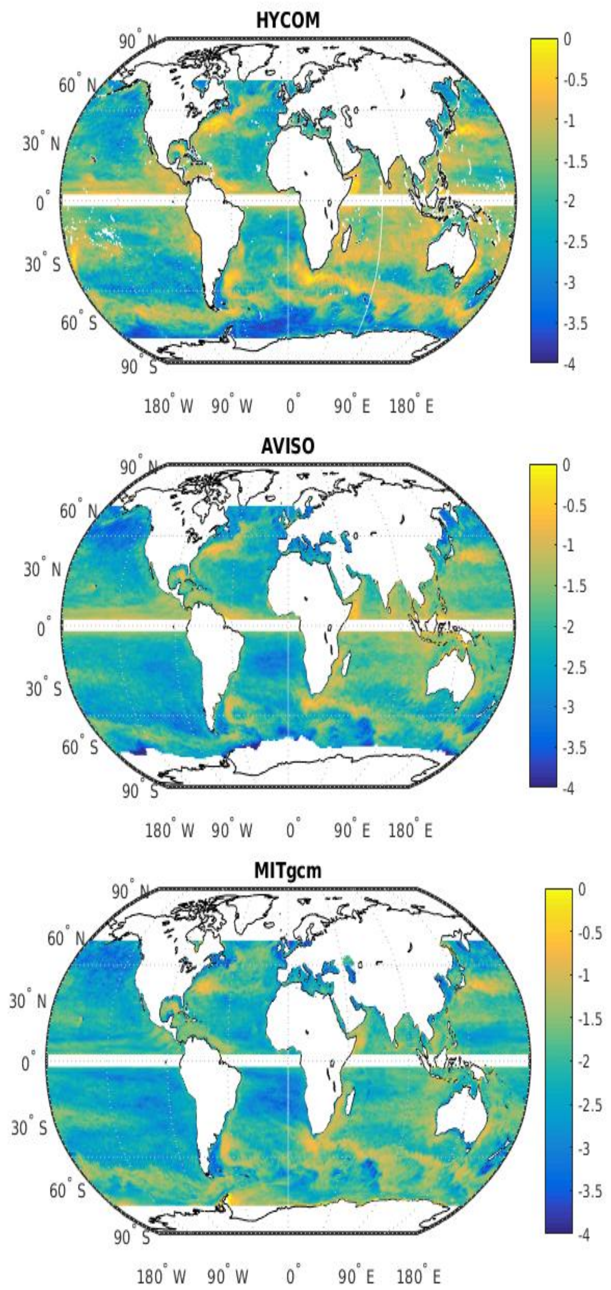
Summary of KE Comparison to Current Meter Observations

- Increasing the horizontal resolution of the ocean models doesn't improve comparison to observations across all frequencies
  - Biggest resolution impacts occur for highest (IGW) and lowest frequencies
- Models show significant differences
  - HYCOM consistently has higher spatial correlations
  - HYCOM and MITgcm have very different implementations of the tidal forcing
    - MITgcm underestimates the tidal energy in marginal seas.
    - Removing these regions, MITgcm has too much tidal energy
  - HYCOM has more mesoscale KE than MITgcm
- Historical observations are not uniformly distributed around the globe

Comparison of Geostrophic Kinetic Energy to AVISO

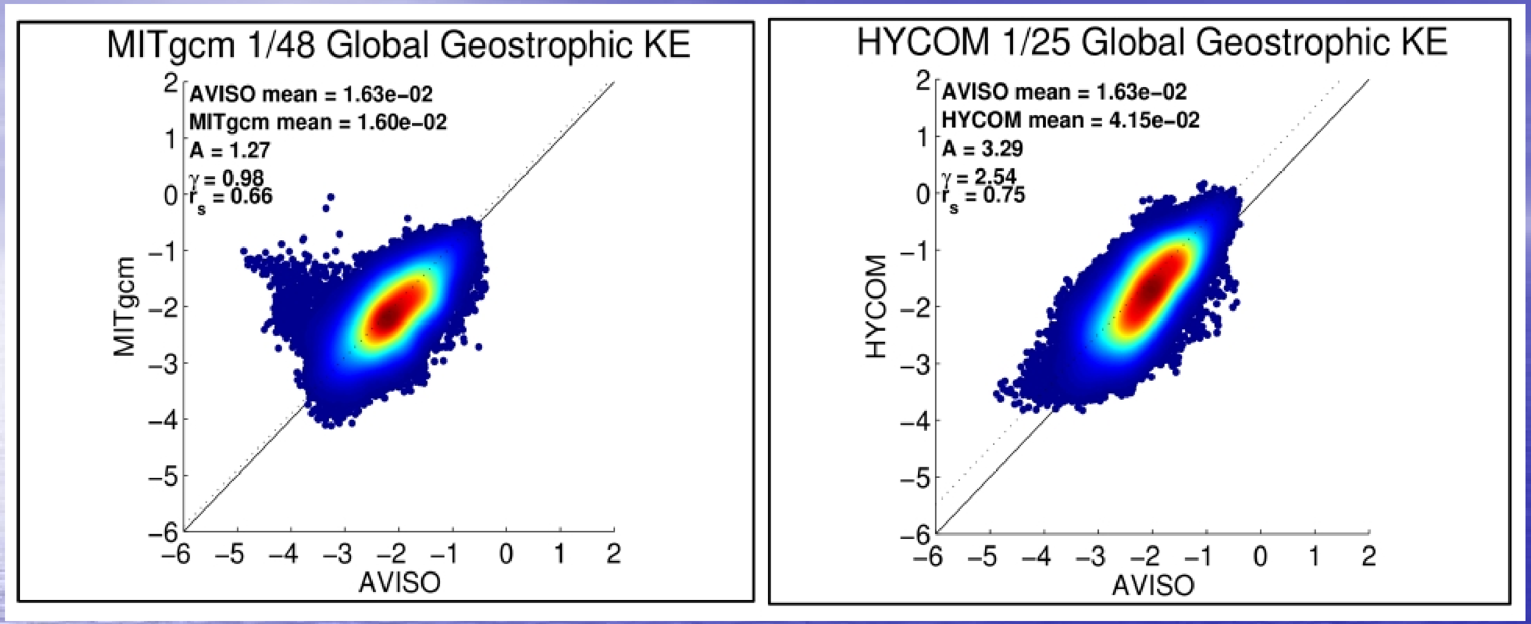


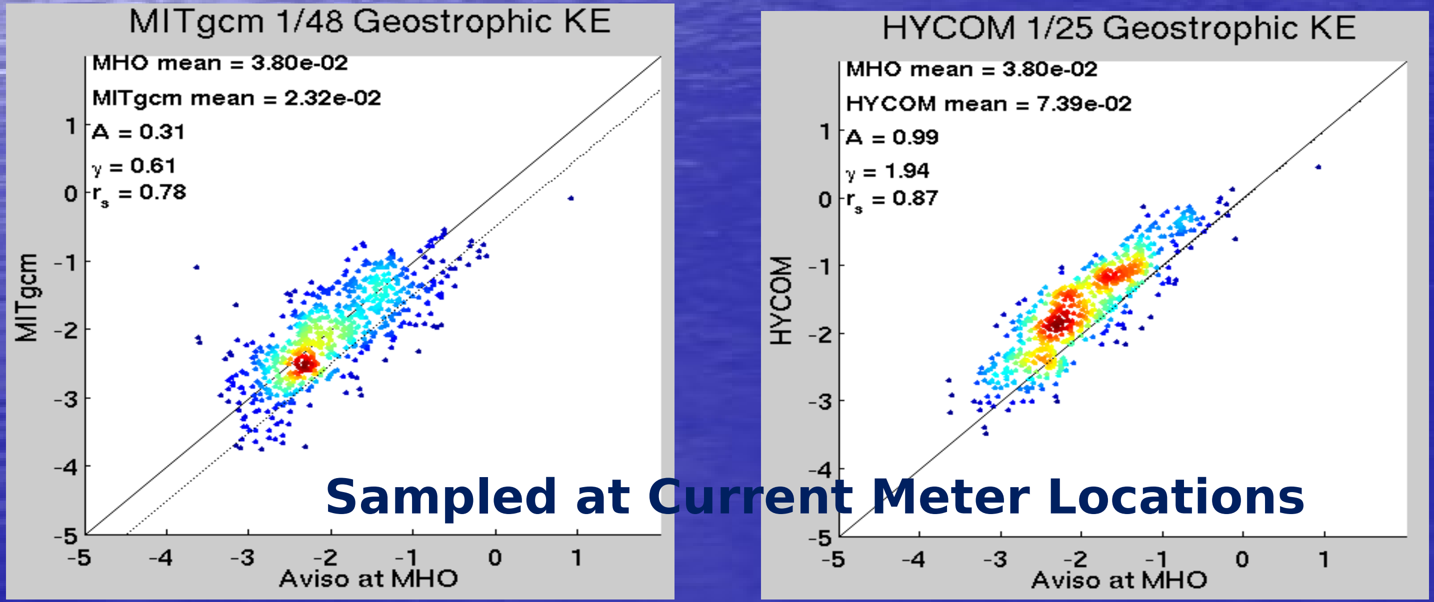
From Luecke et al. 2018, submitted

- Current meter observations are not uniformly distributed over the ocean
  - Small number of points can affect the gross statistics used in comparisons

- Calculate Geostrophic KE from complete maps of SSH from AVISO and Models
  - Spatial correlation between the models (HYCOM and MITgcm) and Aviso map ‘look good’ globally.
  - HYCOM:
    - Overly energetic, particular in Tropics and ACC.
    - More accurate in some areas such as the Gulf Stream.
  - MITgcm
    - Better averaged energetics.
    - Has a few regions of poor performance

Comparison of Geostrophic Kinetic Energy to AVISO



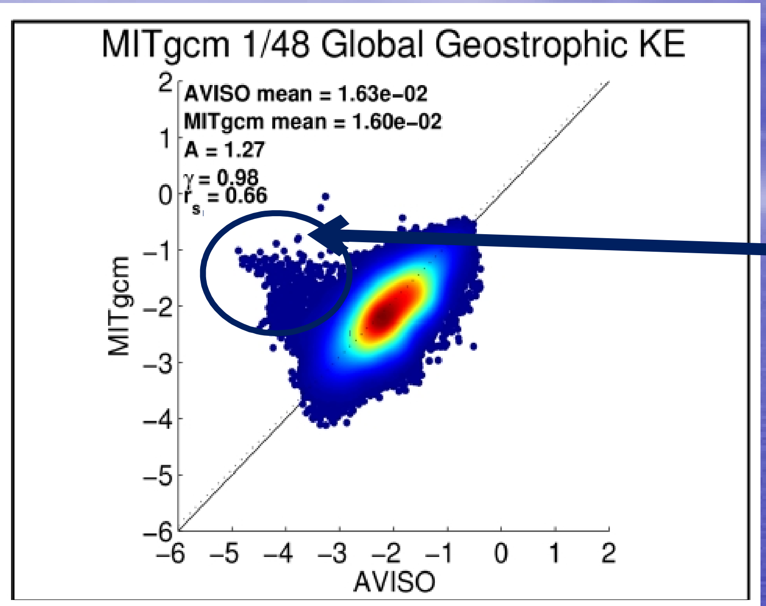


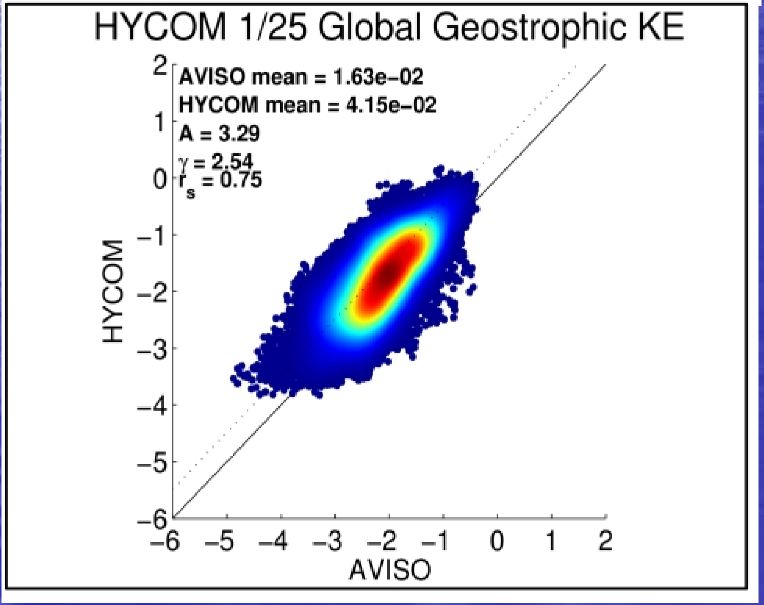
Sampled at Current Meter Locations

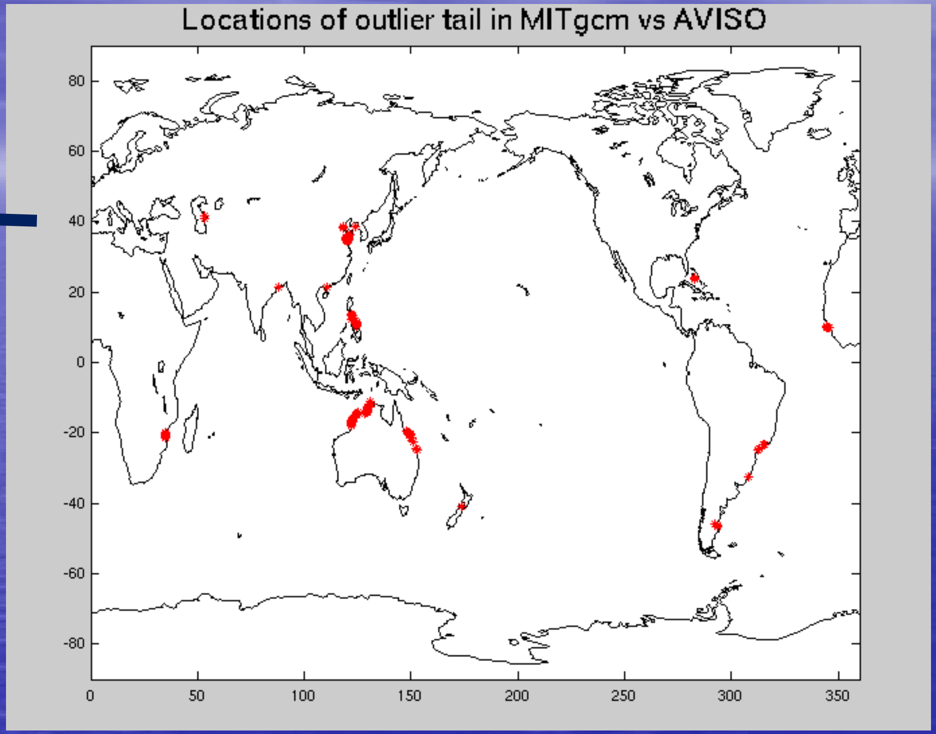
- Spatial correlations are generally good, but lower than moored observations
  - HYCOM has higher spatial correlations than MITgcm
  - When sampled at current meter locations, spatial correlations increase.
- HYCOM is more energetic
- MITgcm has regions with overly-energetic geostrophic velocities
  - These regions are not sampled by the historical observations

From Luecke et al. 2018, submitted

Comparison of Geostrophic Kinetic Energy to AVISO







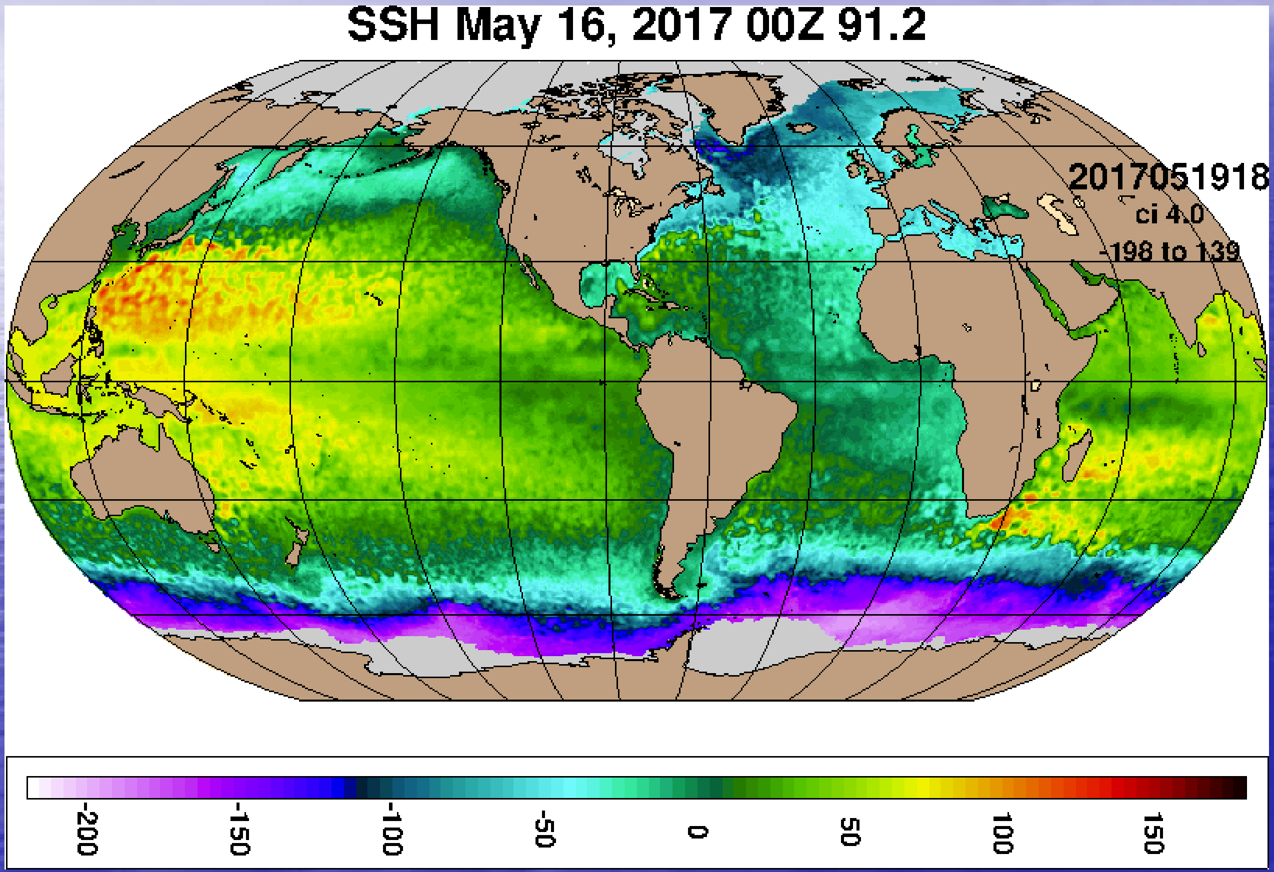
- The geostrophic KE in MITgcm is overly-energetic in regions near continental margins, straits and marginal seas
- This behavior is opposite of the high frequencies, which were under-energetic
- HYCOM doesn’t have the same tendencies in these regions

From Luecke et al. 2018, submitted

Summary of KE Comparison to Observations

- Increasing the horizontal resolution of the ocean models doesn’t improve comparison to observations across all frequencies
  - Biggest resolution impacts occur for highest (IGW) and lowest frequencies
- Models show significant differences
  - HYCOM consistently has higher spatial correlations
  - HYCOM has more mesoscale KE than MITgcm
- Historical moored observations are not uniformly distributed
  - Small number of points can impact the ‘global’ statistics
- Comparison of geostrophic KE calculated from SSH to AVISO, where the coverage is more uniform, show similar results
  - HYCOM more energetic with better spatial correlation
  - MITgcm doesn’t resolve Gulf Stream, continental margins, marginal seas as well

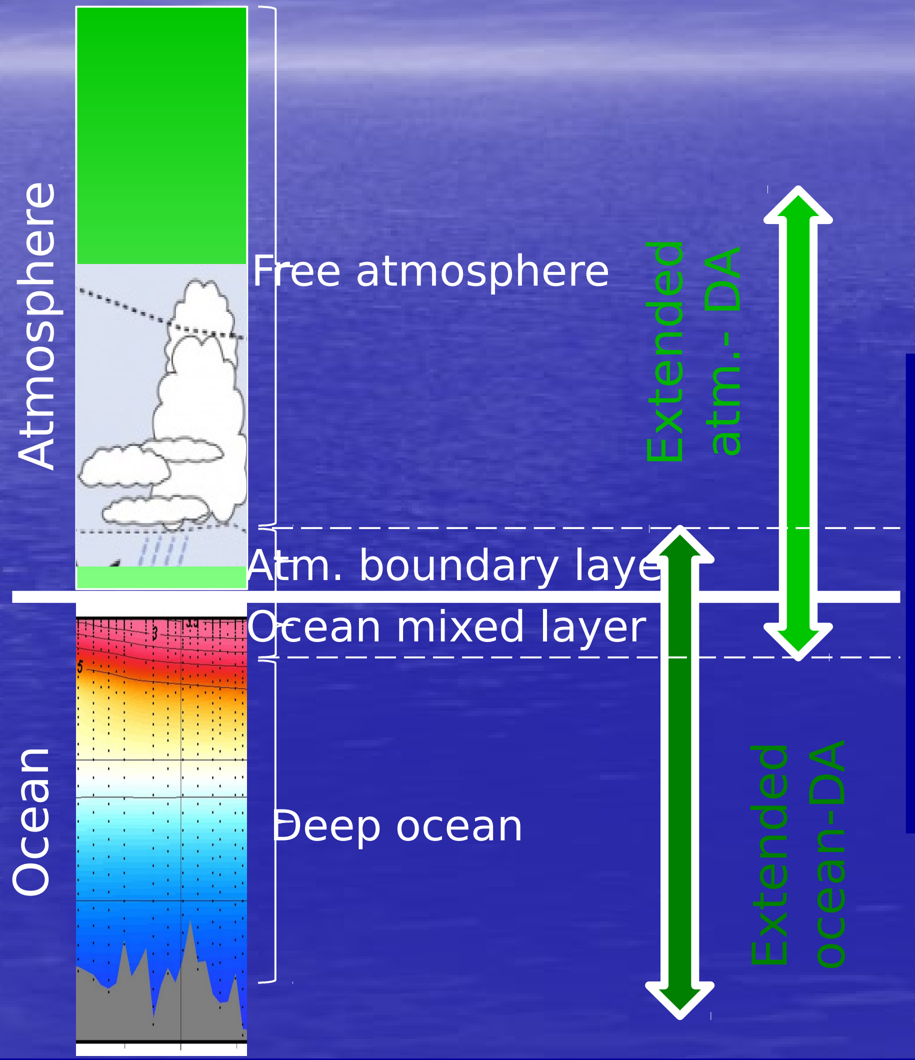
Modeling the tides and internal waves in a global ocean circulation model



- HYCOM is the operational ocean forecast model for the US Navy
  - Current system is 1/12.5° with 41 layers and T/S profile assimilation
  - In a year, system should move to 1/25°
  - In about 3 years, the system will move to a coupled atmosphere, ocean, sea ice system with longer range forecasts
    - Surface gravity waves will be added in similar time frame
- Major upgrades to data assimilation are planned
  - In 2 years, Hybrid 3D Var using model covariances, capable of assimilating velocity

Data Assimilation in future Coupled Atmosphere-Ocean System

Information in the boundary layer of the atmosphere will influence the ocean DA and similarly ocean mixed layer information will feedback into atmospheric DA.



New interface solver

Existing solvers modified to accept observation-model differences from the other fluid in the interface layer.

Frolov, S., et al., 2016: Facilitating strongly coupled ocean-atmosphere data assimilation with an interface solver.

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Questions?