Assessing Ocean Mixing Parameterizations in the GISS Model E Ocean

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Abstract

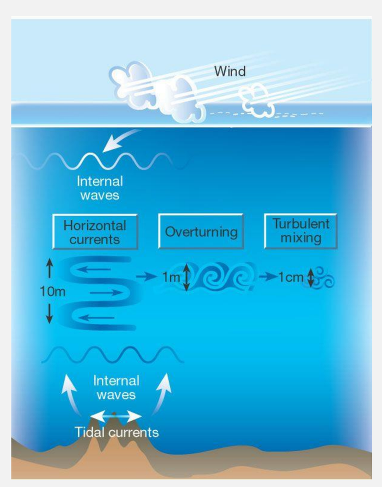
Understanding mesoscale mixing is essential to understanding Earth's climate and climate change, however, coarse resolution ocean models are unable to resolve such mixing. This requires introducing parameterizations into ocean models so the effects of mixing, including that by mesoscale eddies, are felt.

The goal of this research project is to assess the merits and deficiencies of the new GISS mixing model, particularly the ocean Mesoscale mixing model, through visualization and statistical analysis of its output. Potential temperature and salinity fields generated by previous mixing parameterizations in simulations with the GISS Model E Ocean, the Gent McWilliams isopycnal mixing model and the KPP vertical mixing model, and a new isopycnal mixing model created at GISS, the GISS Mesoscale mixing model, are analyzed and compared to observations using MATLAB R2016a, a program for both plotting and processing data. Visualizations and statistical analyses of the entire ocean, the region east of the Gulf Stream, the Southern Ocean, the northern Atlantic Ocean, and the Arabian Sea were conducted.

We found that the GISS Mesoscale model produced more accurate results than the widely used Gent-McWilliams model. Although the GISS Mesoscale model produced worse results in the Arabian Sea, significant improvements were found in the east of Gulf Stream region, Southern Ocean, and northern Atlantic Ocean.

Background

- Wind shear and occasional static instability causes mixing on the surface[1,2,7], mesoscale mixing is prevalent below the surface[4].
- Mesoscale mixing is powered by the winds and driven by gradients in water density[3].
- Water density is determined by salinity and temperature of the water
- Deep ocean mesoscale mixing occurs along isopycnal (constant density) surfaces[4].
- Mesoscale eddies are responsible for transporting heat and other properties across the global ocean.



(Garrett, 2003)[6]

Methods

- Models used: Gent McWilliams isopycnal mixing model[4,5] with KPP vertical mixing model[7] and GISS Mesoscale mixing model[8] with KPP vertical mixing model
- Modify and improve MATLAB scripts written by Medgar Evers College students Jovian Fells and Fari Lindo and create new ones to create maps and statistics, mean and root mean square, of potential temperature and salinity outputs and compare the models with observations for specific regions
  - East of Gulf Stream region
  - Southern Ocean
  - Northern Atlantic
  - Arabian Sea
- Compare models' vertical velocity field outputs

Results

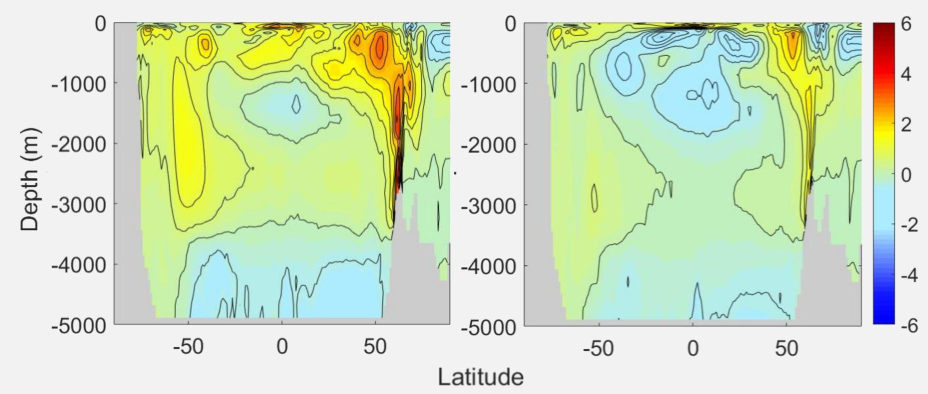


Figure 1: Potential temperature (°C) drift of zonally averaged vertical section. The drifts in this fig. & figs. 2-5 are calculated as the differences from observations (WOA) of the time mean of the last 3 years of a 360 year simulation. GM model (left) produced a mean value of 0.32316 and a root mean square value of 0.72478. GISS model (right) produced a mean value of -0.14209 and a root mean square value of 0.51686.

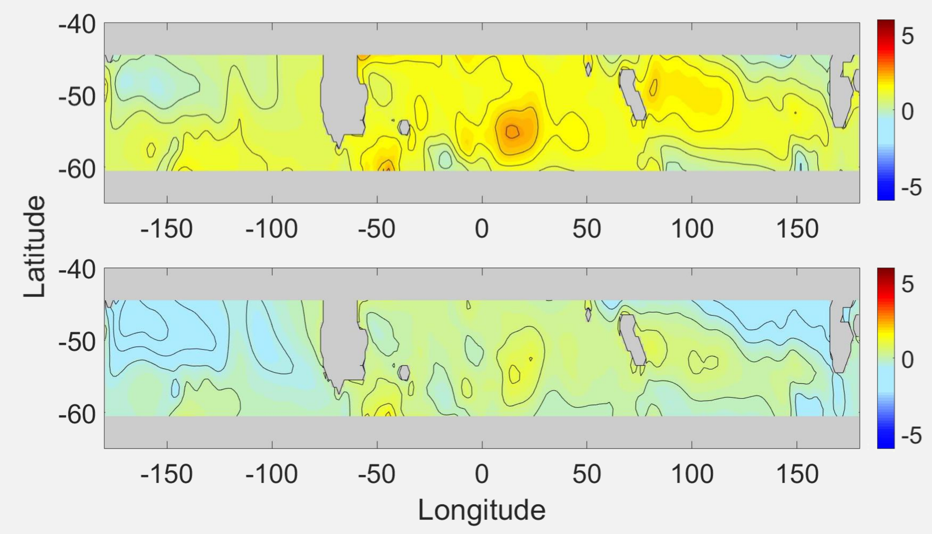


Figure 2: Potential temperature (°C) drift of the Southern Ocean at 1028 meters. GM (top) produced a mean of 1.0003 and an rms of 1.1512. GISS (bottom) produced a mean of -0.12233 and an rms of 0.5609.

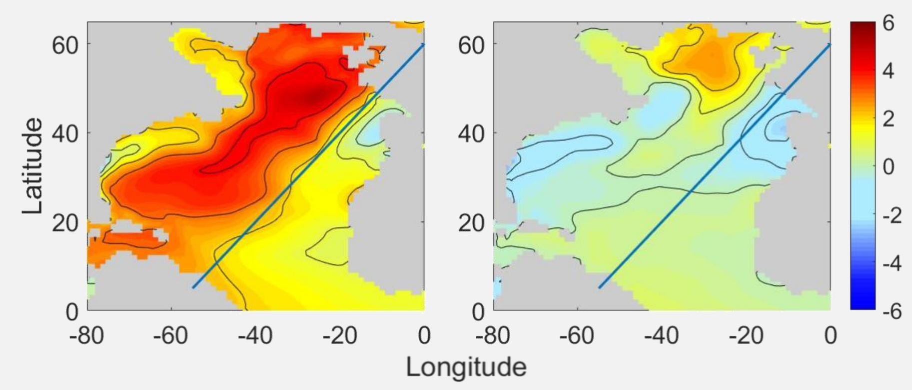


Figure 3: Potential temperature (°C) drift of the east of Gulf Stream region at 1028 meters. All computations done with data above the blue line. GM (left) produced a mean of 2.9069 and an rms of 3.0487. GISS (right) produced a mean of 0.13503 and an rms of 0.85253.

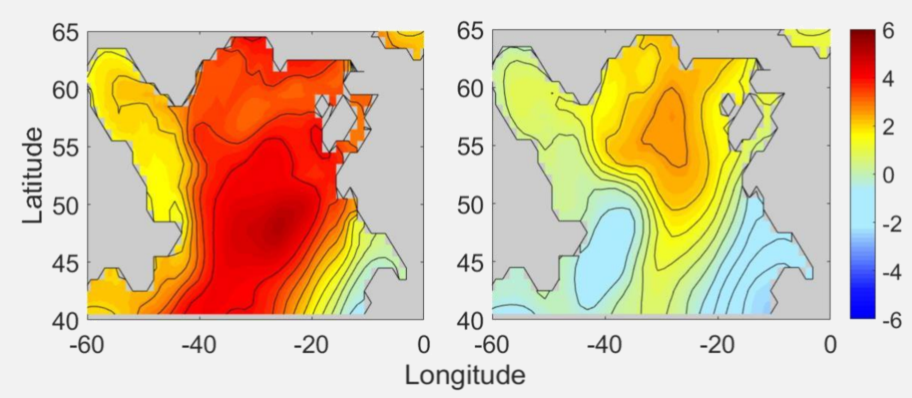


Figure 4: Potential temperature (°C) drift of the northern Atlantic Ocean (containing deep convection region) at 1028 meters. GM (left) produced a mean of 2.9079 and an rms of 3.1589. GISS (right) produced a mean of 0.50507 and an rms of 1.3311.

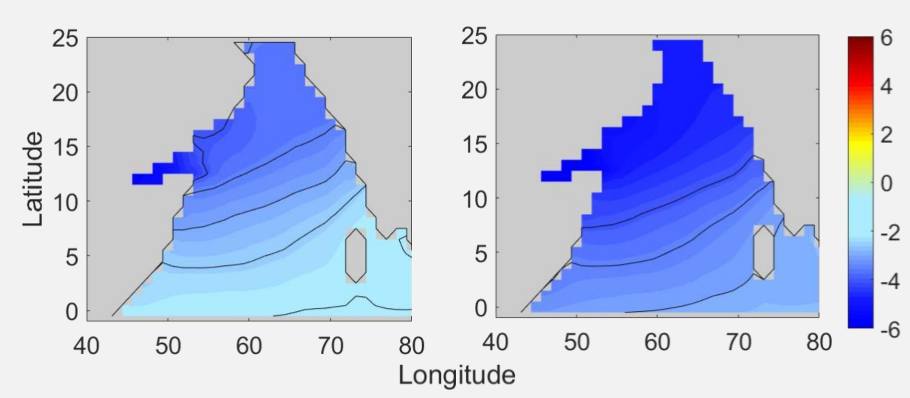


Figure 5: Potential temperature drift of the Arabian Sea at 1028 meters. GM (left) produced a mean of -2.8687 and an rms of 2.9727. GISS (right) produced a mean of -3.854 and an rms of 3.9453.

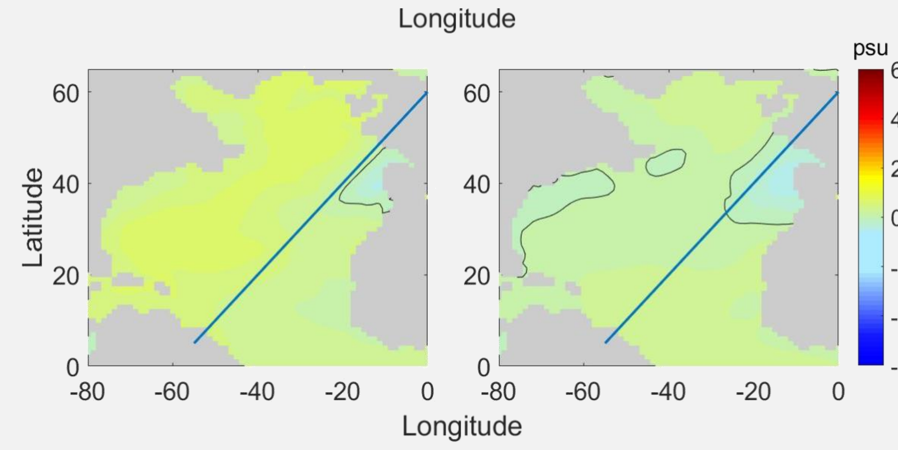


Figure 6: Salinity drift of the east of Gulf Stream region at 1028 meters. All computations done with data above the blue line. GM (left) produced a mean of 0.49815 and an rms of 0.51715. GISS (right) produced a mean of 0.11185 and an rms of 0.15295.

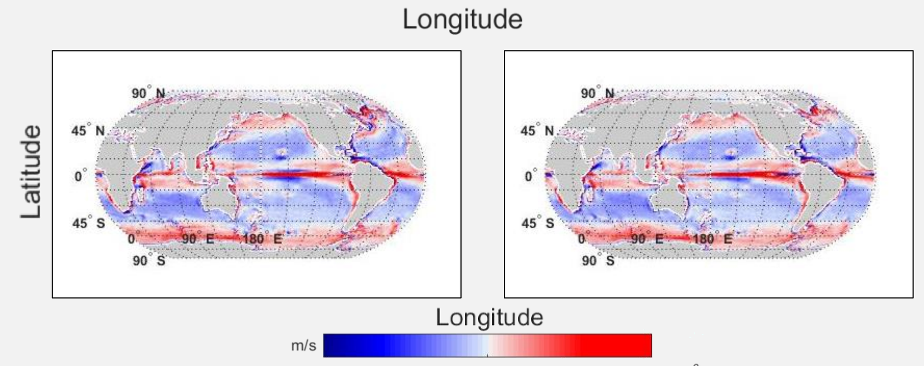


Figure 7: Robinson projection of the vertical velocity field at 202 meters. GM (left) produced a mean of -2.451e-12 m/s. GISS (right) produced a mean of -6.984e-13 m/s.

Discussion/Conclusions

- Analyzed potential temperature & salinity drift in GISS Model E[9,10] simulations: mean & root mean square (rms) significantly reduced, except in Arabian Sea.
- Zonally Averaged Vertical Slice
  - Showed improvements, gave an idea of regions to focus on based on improvements seen.
  - Mean potential temperature drift reduced by 0.076 degrees and rms potential temperature drift reduced by 0.277 degrees.
- Southern Ocean
  - Saw expected improvements – ACC has strong eddies.
  - Mean potential temperature drift reduced by 1.123 degrees and rms potential temperature drift reduced by 0.590 degrees.
- East of Gulf Stream
  - Showed significant improvement between models.
  - Mean potential temperature drift reduced by 2.771 degrees and rms potential temperature drift reduced by 2.196 degrees.
  - Mean salinity drift reduced by 0.3863 psu and rms reduced by 0.3642 psu.
- Northern Atlantic Ocean
  - Showed significant improvement, like the Gulf Stream region.
  - Mean potential temperature drift reduced by 2.403 degrees and rms potential temperature drift reduced by 1.828 degrees.
- Arabian Sea
  - GISS model produced worse values than GM.
  - Mean potential temperature increased 0.985 degrees and rms potential temperature increased by 0.973 degrees.
- We mainly see improvements – the new GISS Mesoscale model produces more accurate parameterizations for mesoscale mixing than the previously accepted Gent McWilliams model.
- From all this we can see that the changes made in the model have strong regional effects.
- Further research is required to determine the sources of error in the Arabian Sea and to understand which specific features of our mesoscale model are causing the improvements.
- All models were run with the widely used KPP vertical mixing model, the next step is to test the GISS Vertical mixing model with the mesoscale models.

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