On the impact of high-frequency wind variability on upper ocean stratification

Natalie M. Freeman, Donata Giglio, Sarah T. Gille, Momme C. Hell

Department of Atmospheric & Oceanic Sciences, University of Colorado, Boulder, CO, USA; Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA

Why high-frequency winds?

Winds modulate air-sea exchange and directly impact mixed layer processes, yet high-frequency winds (gusty, intermittent) are still poorly understood.

The stormy Southern Ocean is a perfect natural laboratory for investigating high-frequency winds.

We combine observations + 1-D model to explore impacts of high-frequency winds on upper ocean stratification in the Southern Ocean. **First, is our model fit for task?**

Our tool belt: mooring observations and 1-D process model

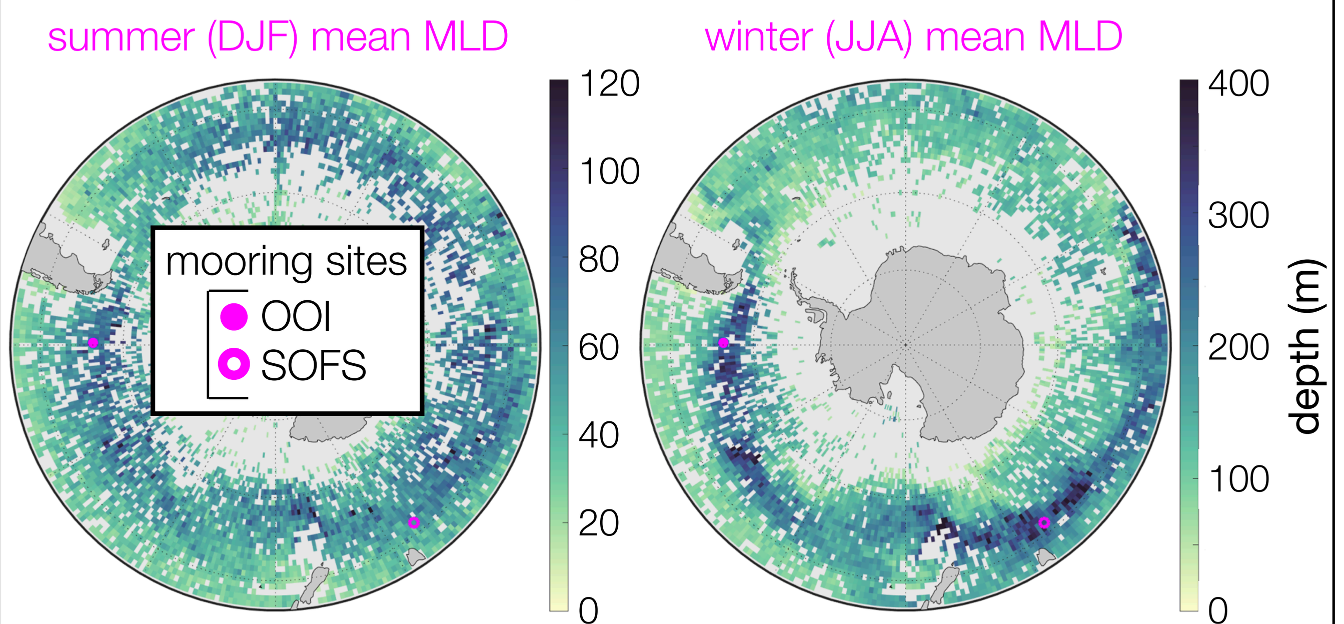
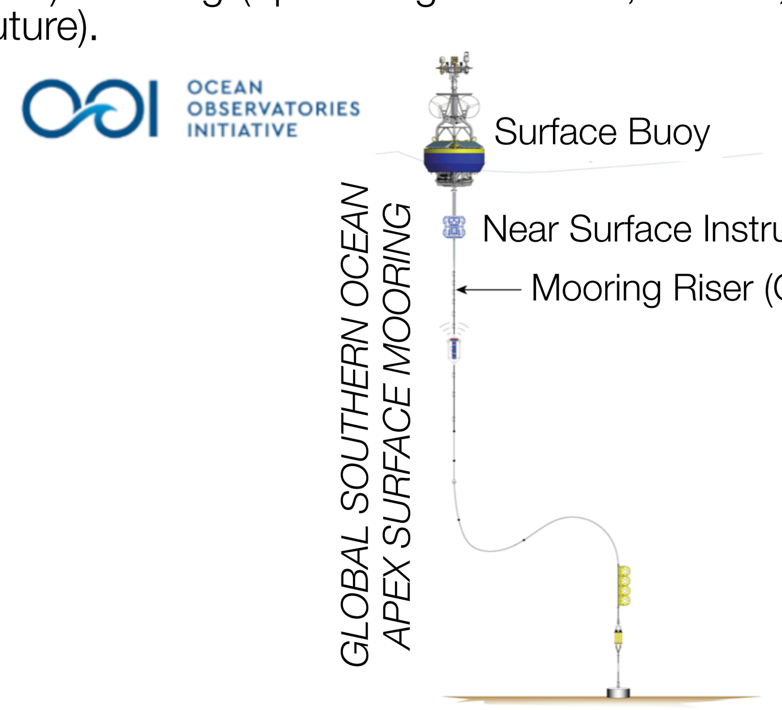


Figure 1: Locations of two Southern Ocean moorings used to assess fitness of 1-D process model overlain on seasonal mean mixed layer depth (MLD; Holte et al., 2017): Ocean Observatories Initiative (OOI) Apex Surface Mooring (filled magenta circle; 54.5°S, 89.3°W; currently being evaluated; schematic below) and Southern Ocean Flux Station (SOFS) mooring (open magenta circle; 46.8°S, 142°E; to be evaluated in future).



summer simulation

We initialize a January 2016 GOTM simulation with a temperature and salinity profile from OOI's cabled CTDs at depth (12 m, 60 m, etc.).

winter simulation

We initialize a June 2016 GOTM simulation with a temperature and salinity profile from a nearby Argo float (ID: D3901212_041).

General Ocean Turbulence Model (GOTM) setup

- meteo forcing: OOI
  - 10 m winds (u, v)
  - air temperature, pressure
  - humidity
  - sea surface temperature
  - shortwave, longwave radiation
  - precipitation rate
- resolution
  - 10 cm vertical
  - 5 minute temporal
- schema
  - bulk formulae: COARE (Fairall et al., 1996)
  - turbulence: KPP-CVMix (Li et al., 2019)

How well does GOTM reproduce observations?

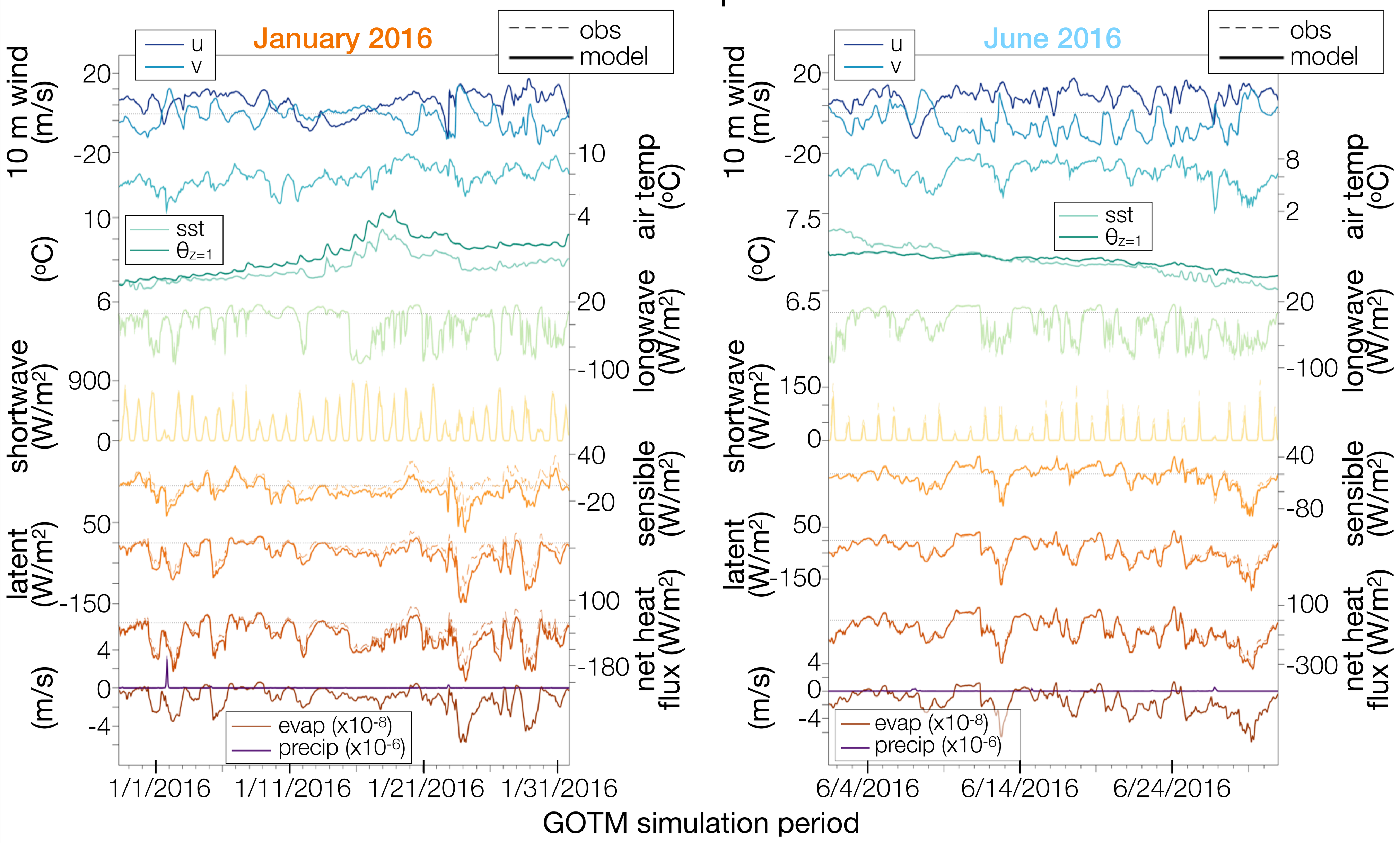
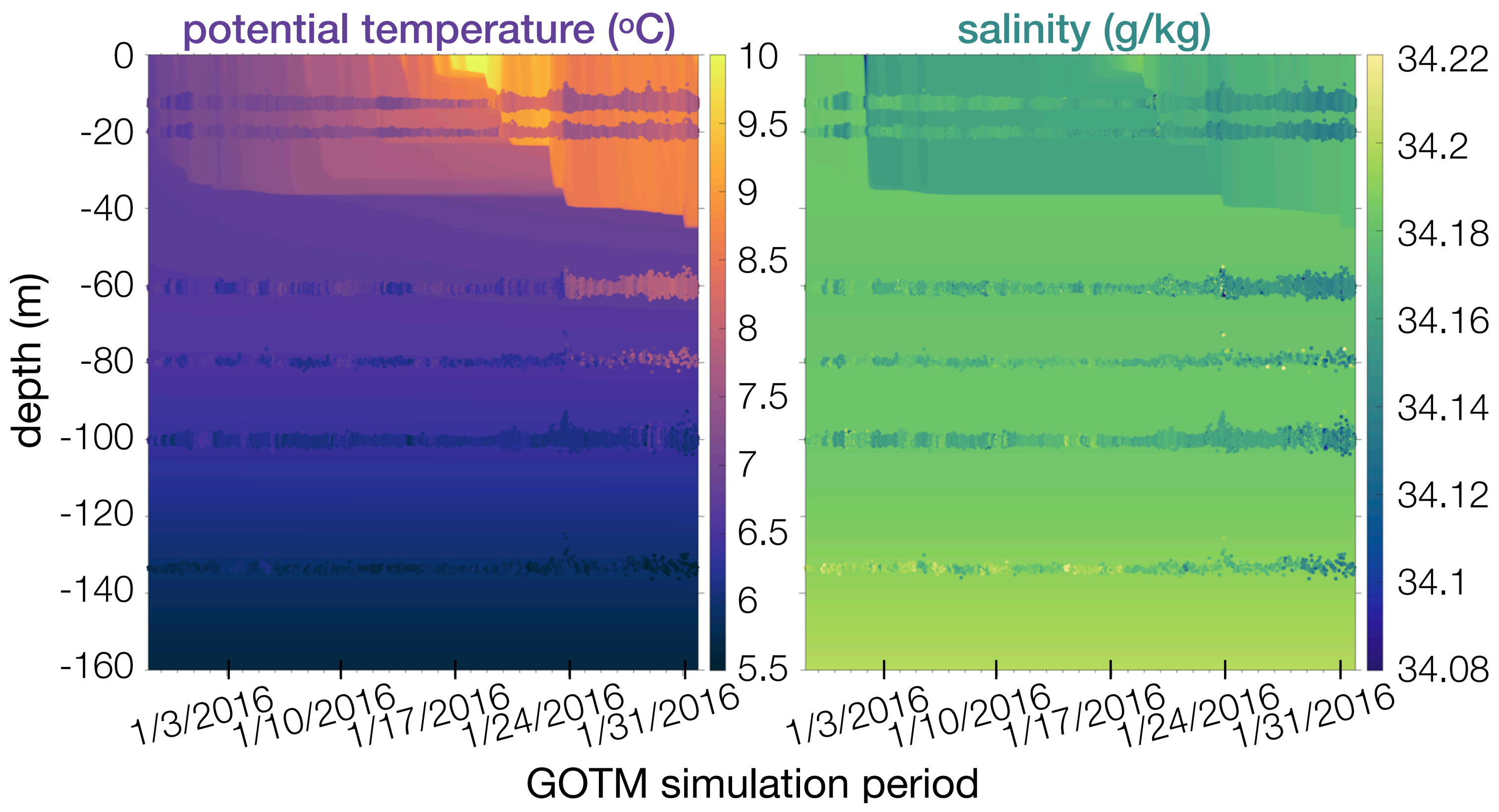


Figure 2: Forcing variables from the Southern Ocean OOI mooring (dashed), either directly measured or calculated according to the COARE 3.5 algorithm (Edson et al., 2013; Ogle et al., 2018) as well as output from the (left) January 2016 and (right) June 2016 GOTM simulation (solid).

January 2016: How well does GOTM replicate the observed summer water column?



GOTM's MLD doesn't deepen enough toward the end of the month (i.e., shallow bias), likely due to a lack of mixing and horizontal advection.

This also manifests itself in salinity, where the ML struggles to recover from the precipitation (i.e., freshening) event on January 3rd.

Figure 3: Potential temperature (left) and salinity (right) as observed by the OOI CTD package (colored markers; at 12 m, 20 m, 60 m, 80 m, 100 m, and 130 m) overlain on the corresponding January 2016 GOTM simulation (colors).

June 2016: How well does GOTM replicate the observed winter water column?

GOTM's winter MLD is relatively well-represented. Nearby Argo profiles (as well as OOI CTD profiles, not shown) reveal a slight cooling in and deepening of the ML, which GOTM is able to reproduce.

However, the GOTM halocline is consistently too strong throughout the simulation; while a subsurface salinity max is characteristic of the OOI site, GOTM exhibits a high salinity bias here.

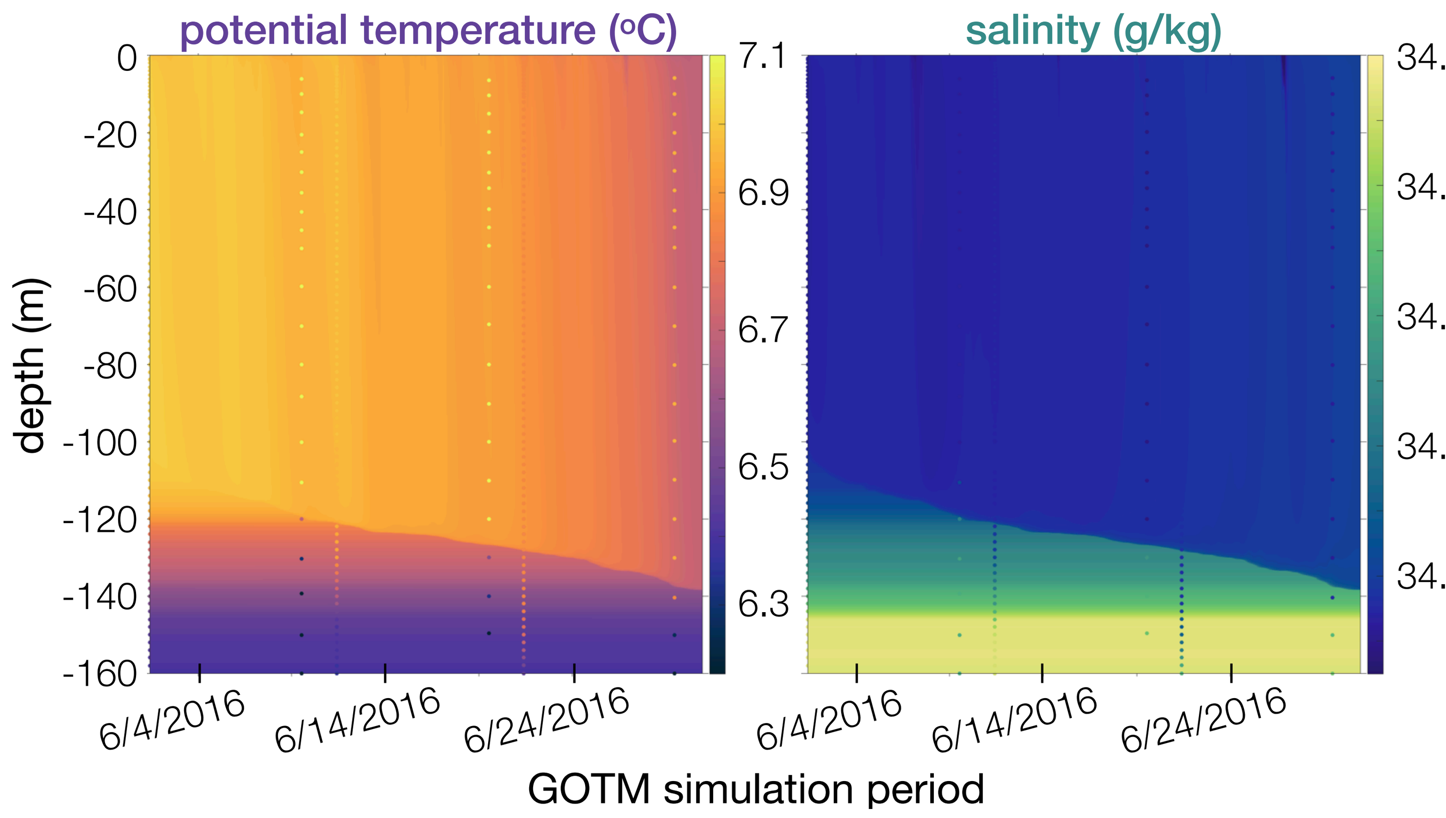


Figure 4: Potential temperature (left) and salinity (right) as observed by nearby (within ~230 km) Argo floats (colored markers) overlain on the corresponding June 2016 GOTM simulation (colors).

Is GOTM fit for task? Yes!

summer simulation

In summer, vertical mixing in GOTM is lacking, resulting in a shallow bias in mixed layer depth (MLD; Figure 3).

winter simulation

In winter, GOTM is able to replicate the wintertime cooling in and deepening of the ML (Figure 4).

Why the shallow ML bias?

Assessing the January 2016 heat budget terms from the Biogeochemical Southern Ocean State Estimate (B-SOSE; Figure 5) reveals that both mixing and advection (mostly driven by horizontal, right panel) are critical at the depths of MLD variability (40-100 m) at the OOI site.

Which terms are important in this region?

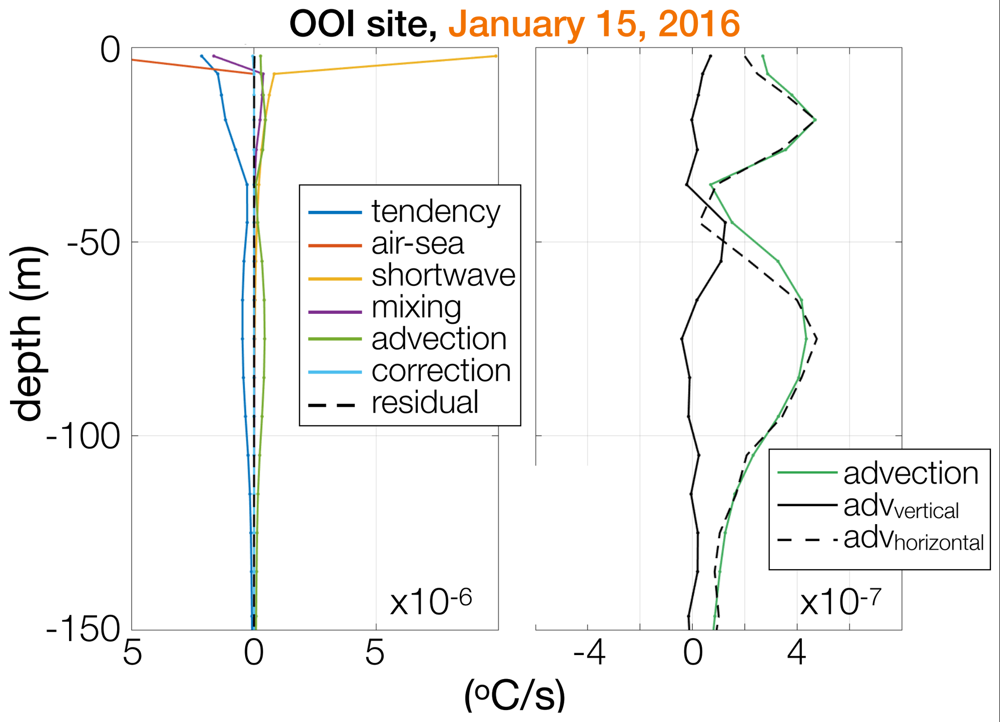


Figure 5: Biogeochemical Southern Ocean State Estimate (B-SOSE; Verdy & Mazloff, 2017) upper 150 m heat budget at OOI mooring site (54.4S, 270.8E; iteration 133 available at http://sose.ucsd.edu/BSOSE6_iter133_solution.html) on January 15, 2016. (left) Heat budget terms include total tendency (dark blue), air-sea flux (orange), shortwave radiation (yellow), mixing (purple), advection (green), correction due to a linear free surface (cyan), and the residual (dashed black). (right) Advection (green) and its components, vertical (black solid) and horizontal (black dashed).

What's next?

Project to-do list:

OOI ✔ SOFS ☐ — Assess model fitness for our regions of interest.

☐ Explore impacts on upper ocean in GOTM through idealized wind experiments.

**Moving forward, we have the potential to improve vertical mixing by continuing to fine-tune the setup GOTM mixing parameters.

However, the 1-D nature of GOTM precludes the representation of horizontal advection so we will confidently move forward armed with this knowledge.

References

Argo, 2000, doi:10.17882/42182. *These data were collected and made freely available by the International Argo Program and the national programs that contribute to it. (https://argo.ucsd.edu, https://www.ocean-ops.org). The Argo Program is part of the Global Ocean Observing System;* **Edson** et al., 2013, doi:10.1175/JPO-D-12-0173.1; **Fairall** et al., 1996, doi:10.1029/95JC03205; **Holte** et al., 2017, doi:10.1002/2017GL073426; **Li** et al., 2019, doi:10.1029/2019MS001810; **NSF Ocean Observatories Initiative Data Portal**, http://ooinet.oceanobservatories.org, Southern Ocean Apex Surface Mooring (GS01SUMO) data from 1 December 2015 to 30 June 2016. *This material is based upon work supported by the National Science Foundation under Cooperative Agreement No. 1743430 (which supports the OOI) or other relevant NSF award number.;* **Ogle** et al., 2018, doi:10.1029/2017GL076909; **Verdy & Mazloff**, 2017, doi:10.1002/2016JC012650

natalie.freeman@colorado.edu