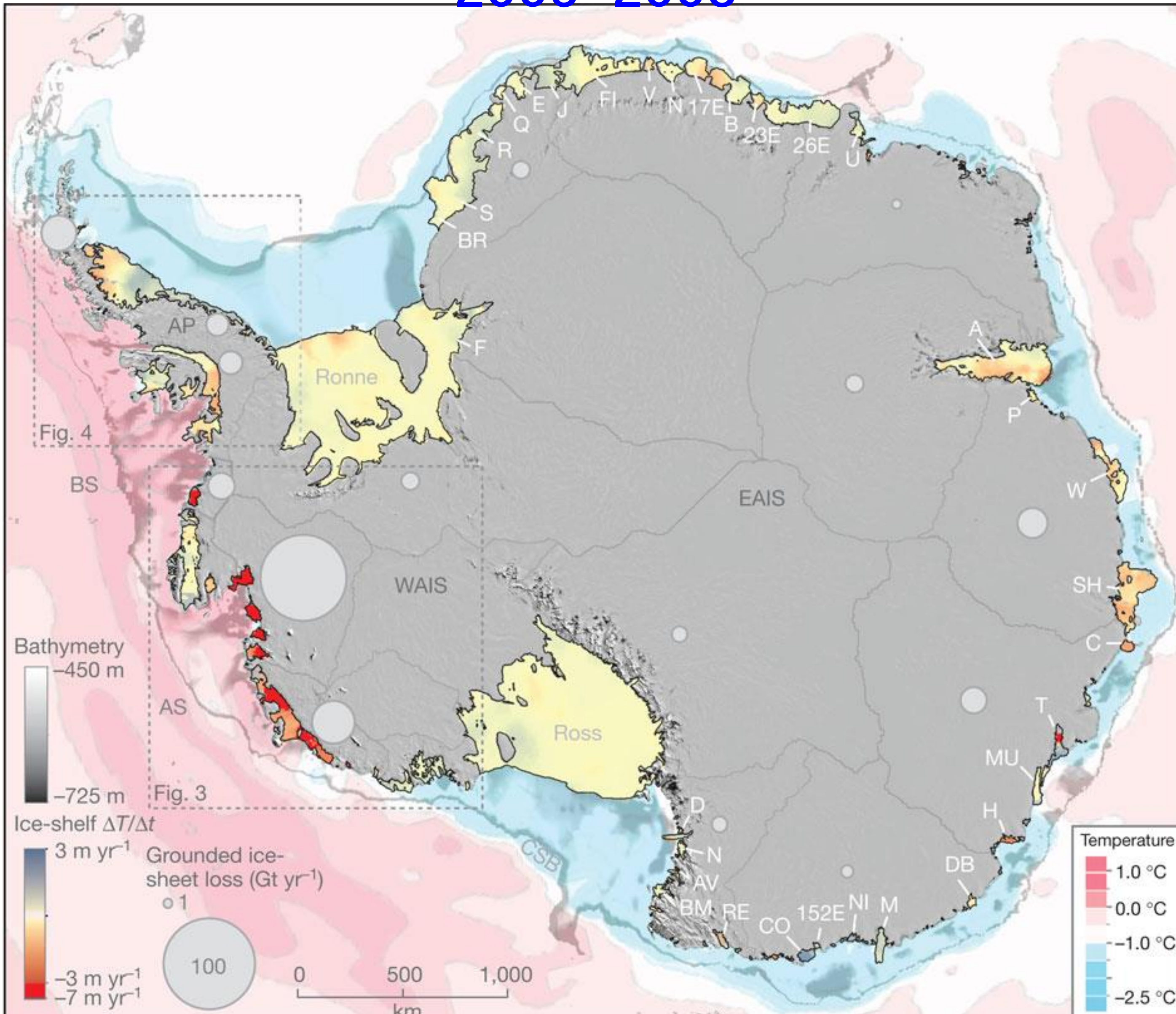
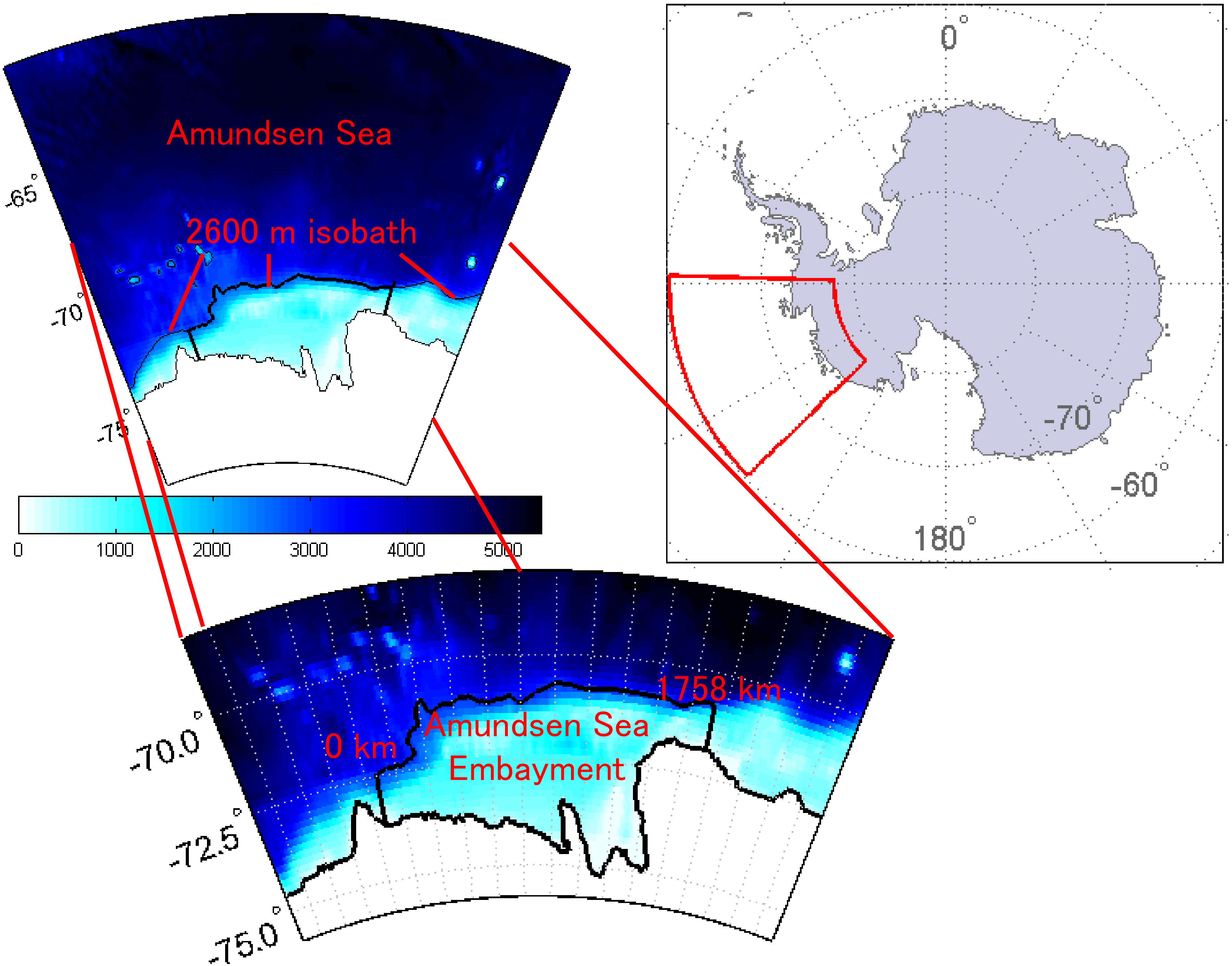
An Oceanic Heat Transport Pathway to the Amundsen Sea Embayment

Angelica Gilroy, Matt Mazloff, and Sarah Gille
Scripps Institution of Oceanography-UCSD
www-pord.ucsd.edu/~agilroy
agilroy@ucsd.edu

Antarctic ice-shelf ice-thickness change rate ΔT/Δt, 2003-2008

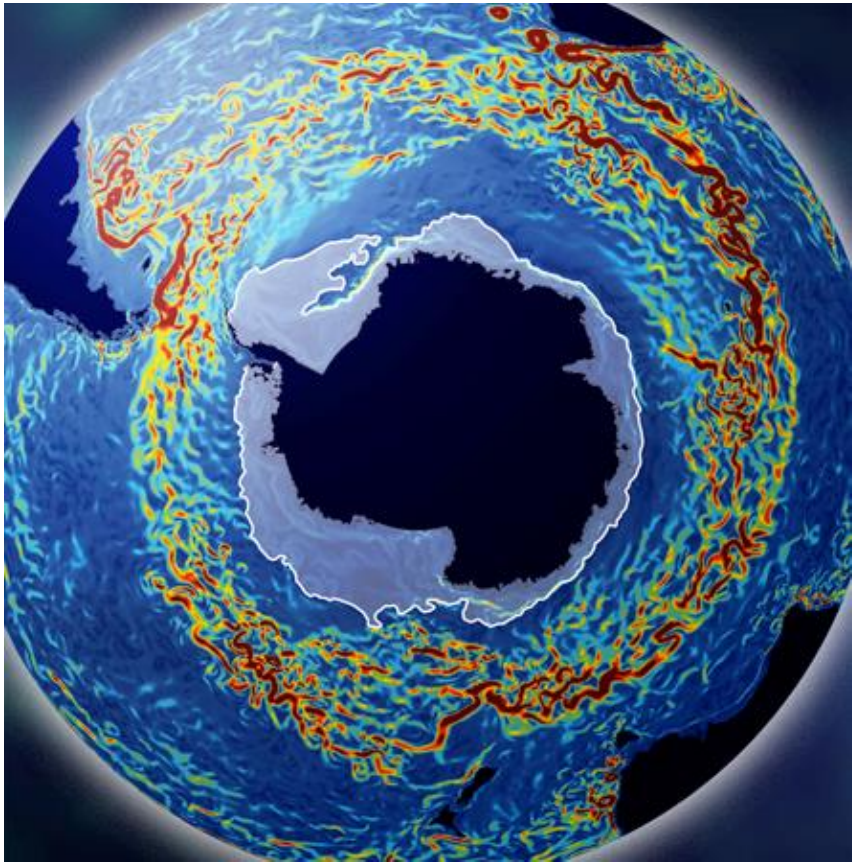


HD Pritchard *et al.* *Nature* **484**, 502-505 (2012) doi:10.1038/nature10968



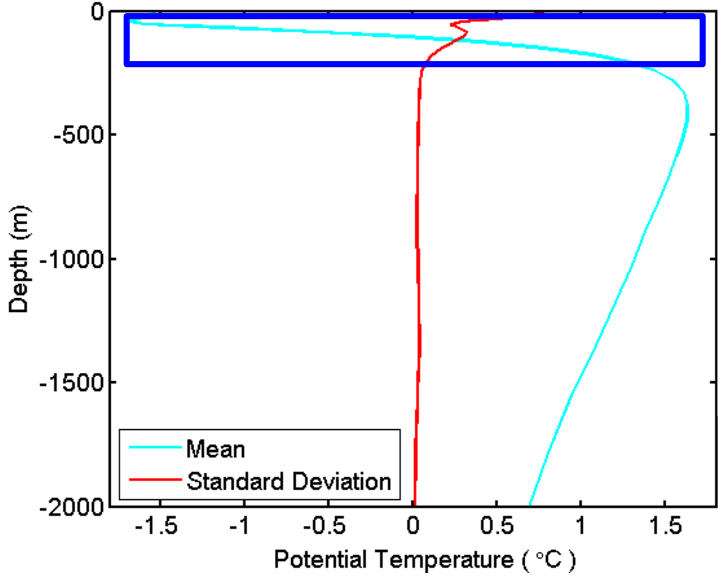
Amundsen Sea
2600 m isobath
-65°
-70°
-75°
0
1000
2000
3000
4000
5000
0°
-70°
-60°
180°
1758 km
Amundsen Sea
Embayment
0 km
-70.0°
-72.5°
-75.0°

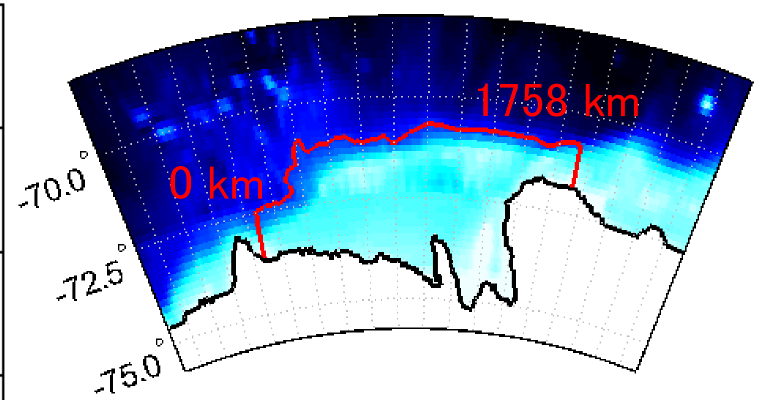
Southern Ocean State Estimate (SOSE)

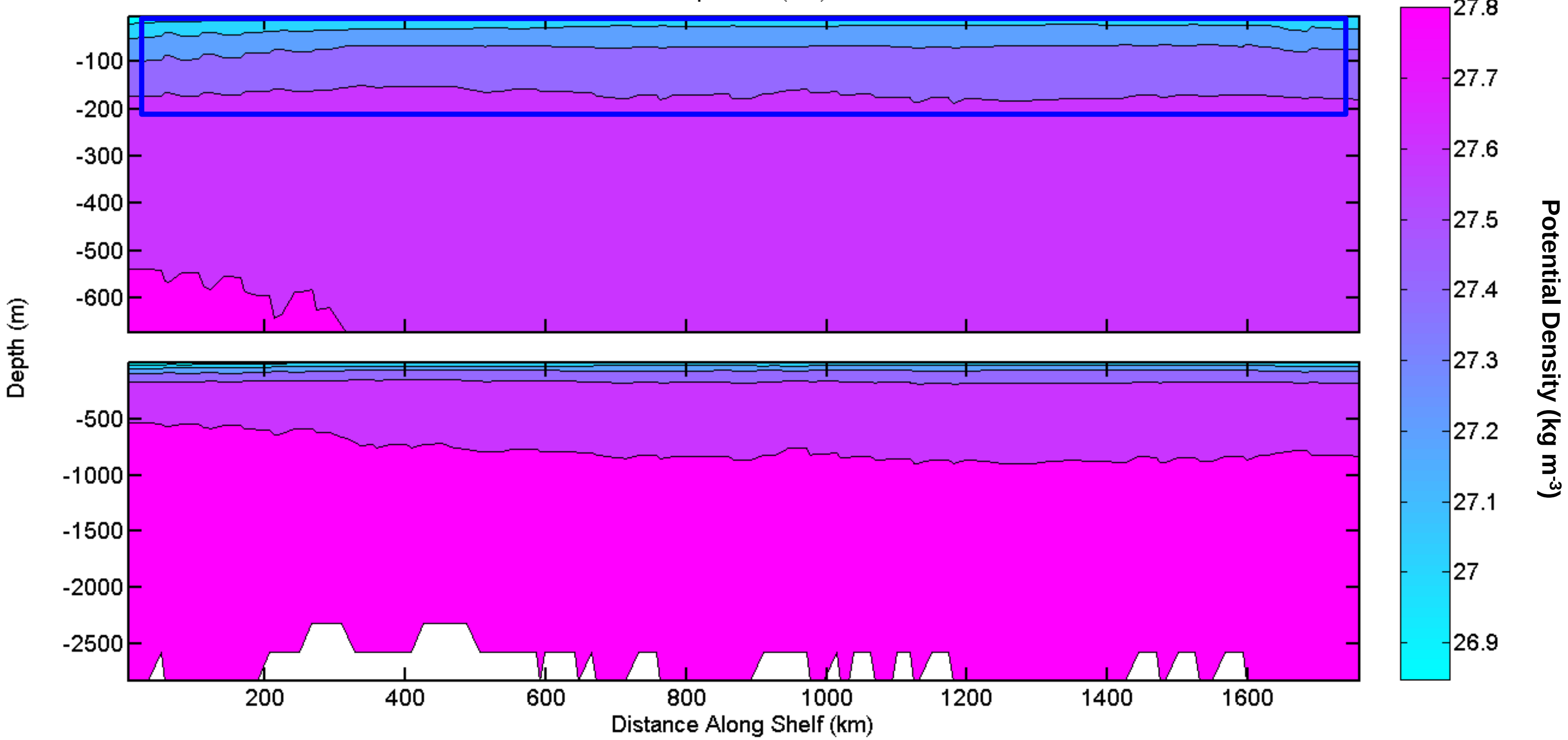


- Data assimilating model
  - 1/6° horizontal resolution
  - 42 depth levels
- Modeled time period: 2005–2010
- *http://sose.ucsd.edu*

Continental Shelf Slope Water Properties

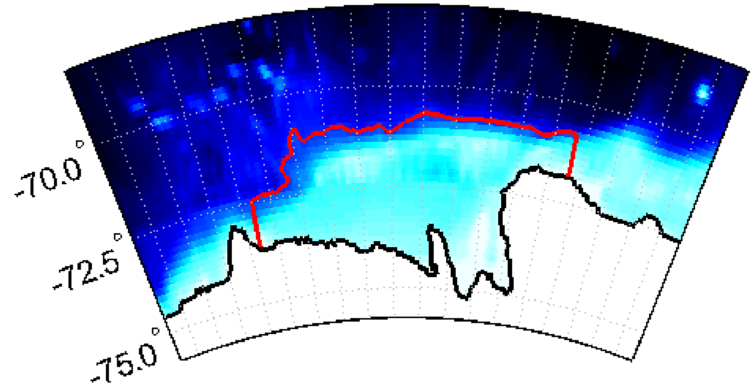


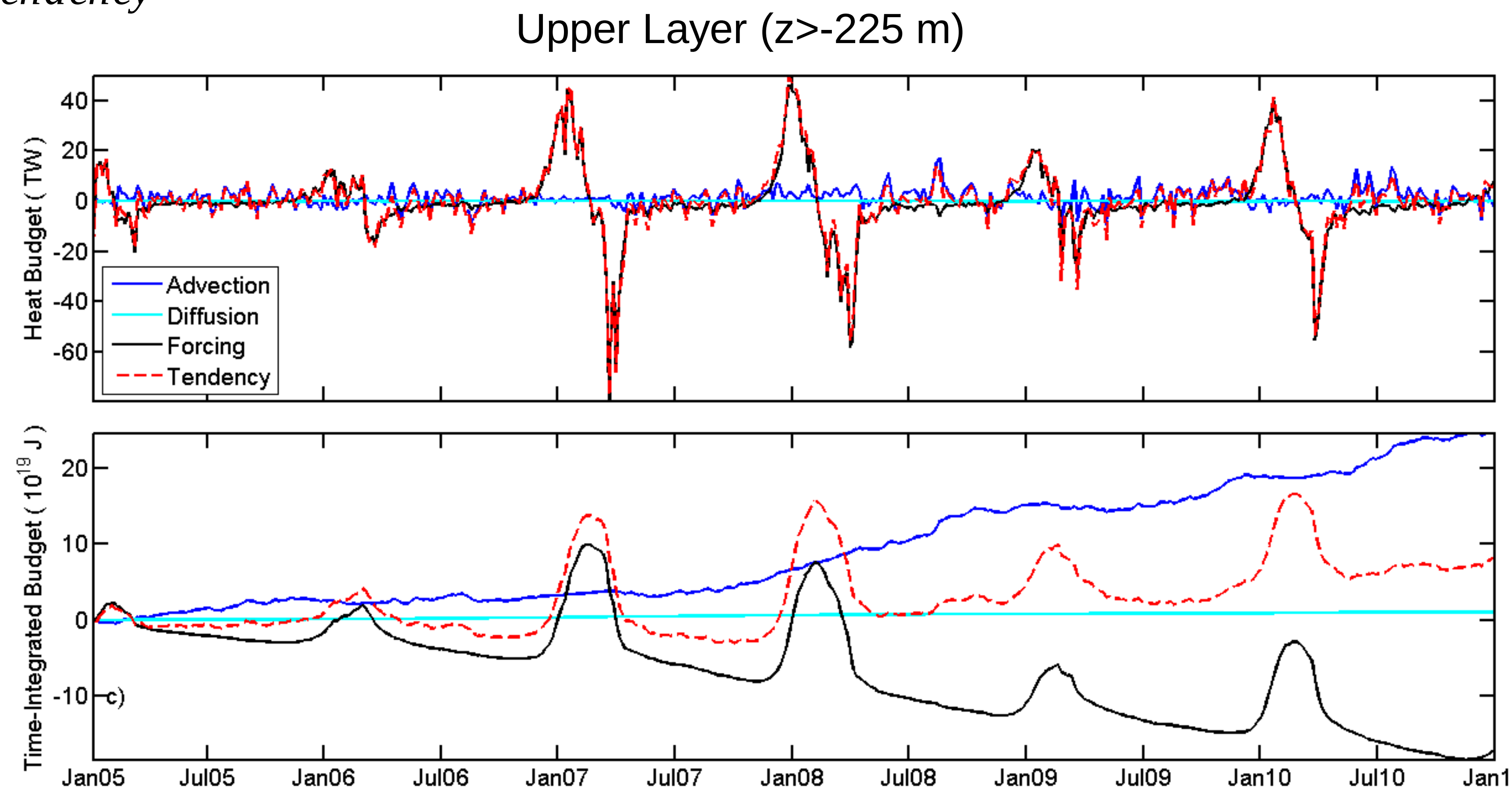




ASE Heat Budget

$$\underbrace{\frac{\partial \theta}{\partial t}}_{Tendency} = \underbrace{-\vec{u} \cdot \nabla \theta}_{Advection} + \underbrace{\nabla \cdot \kappa \nabla \theta}_{Diffusion} + \underbrace{F}_{Forcing}$$





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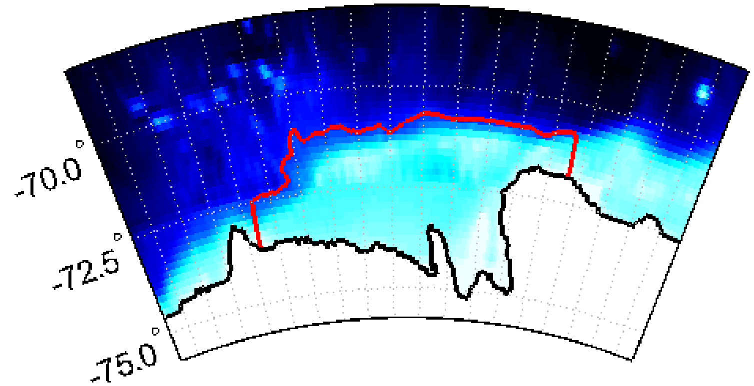
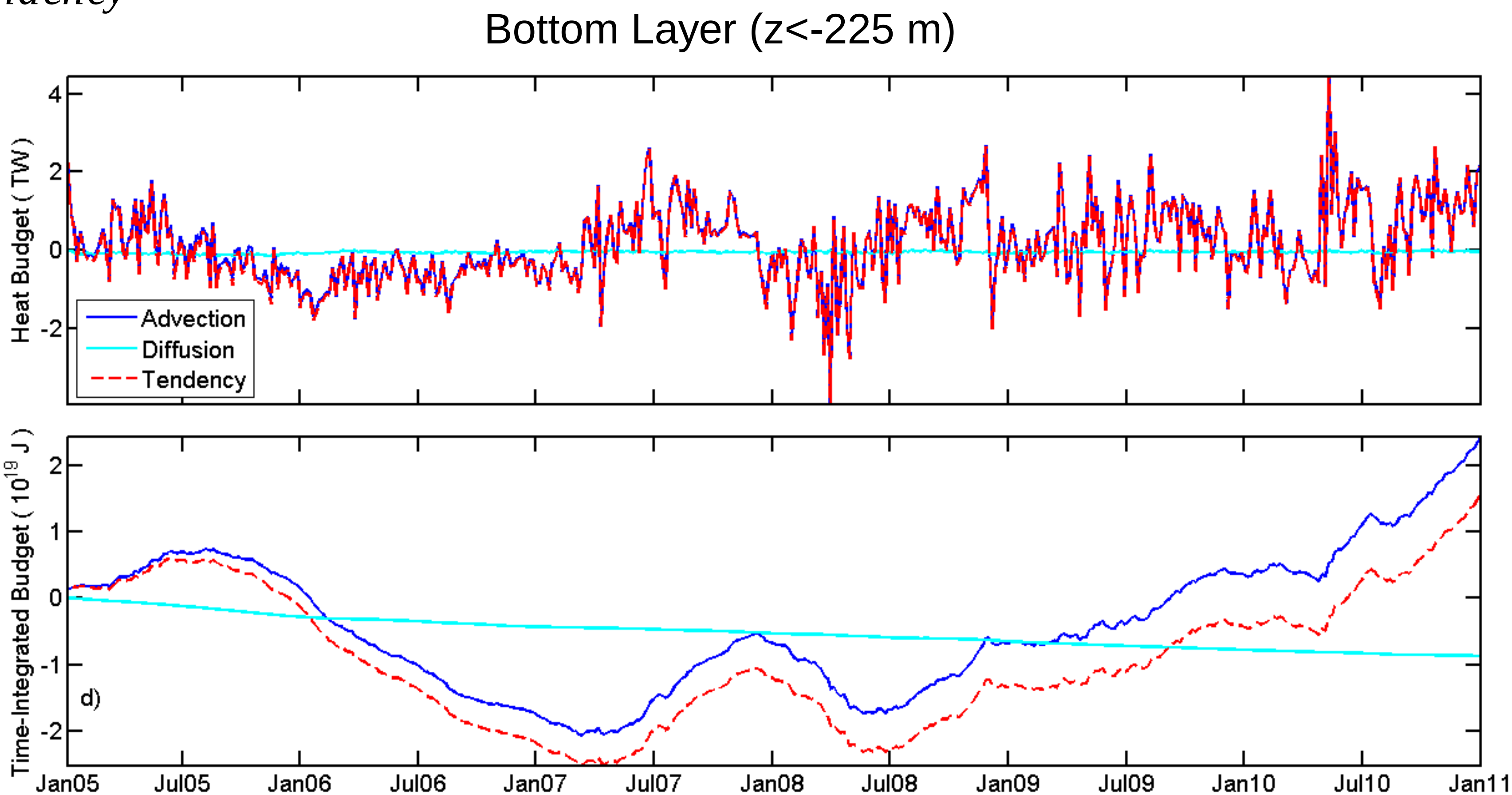
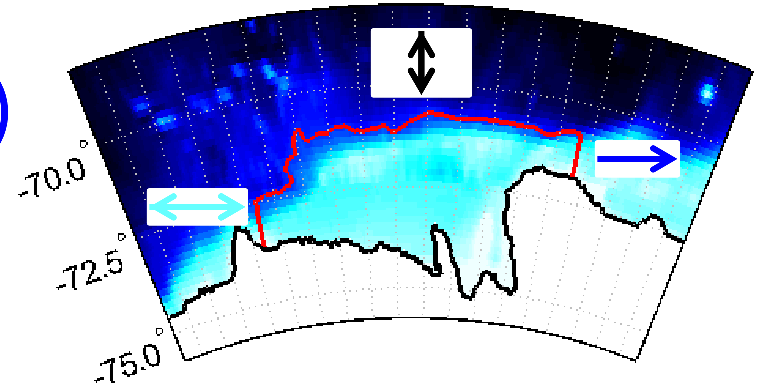
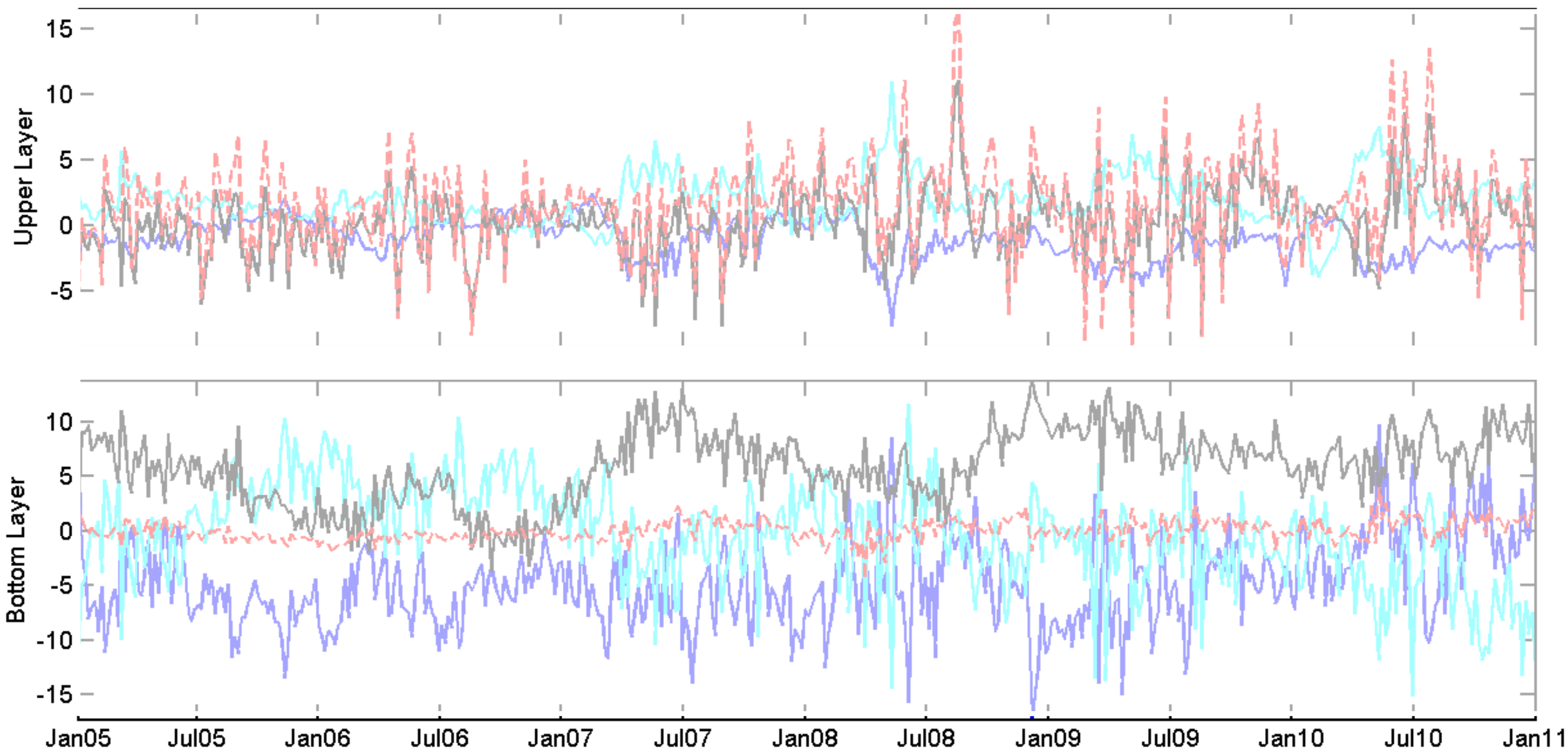




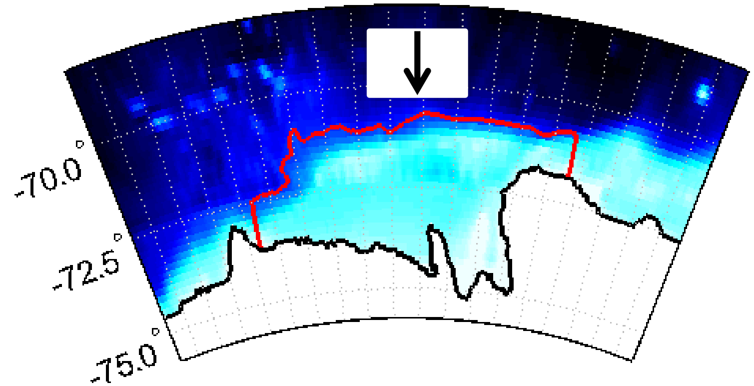
ASE Heat Fluxes (TW)



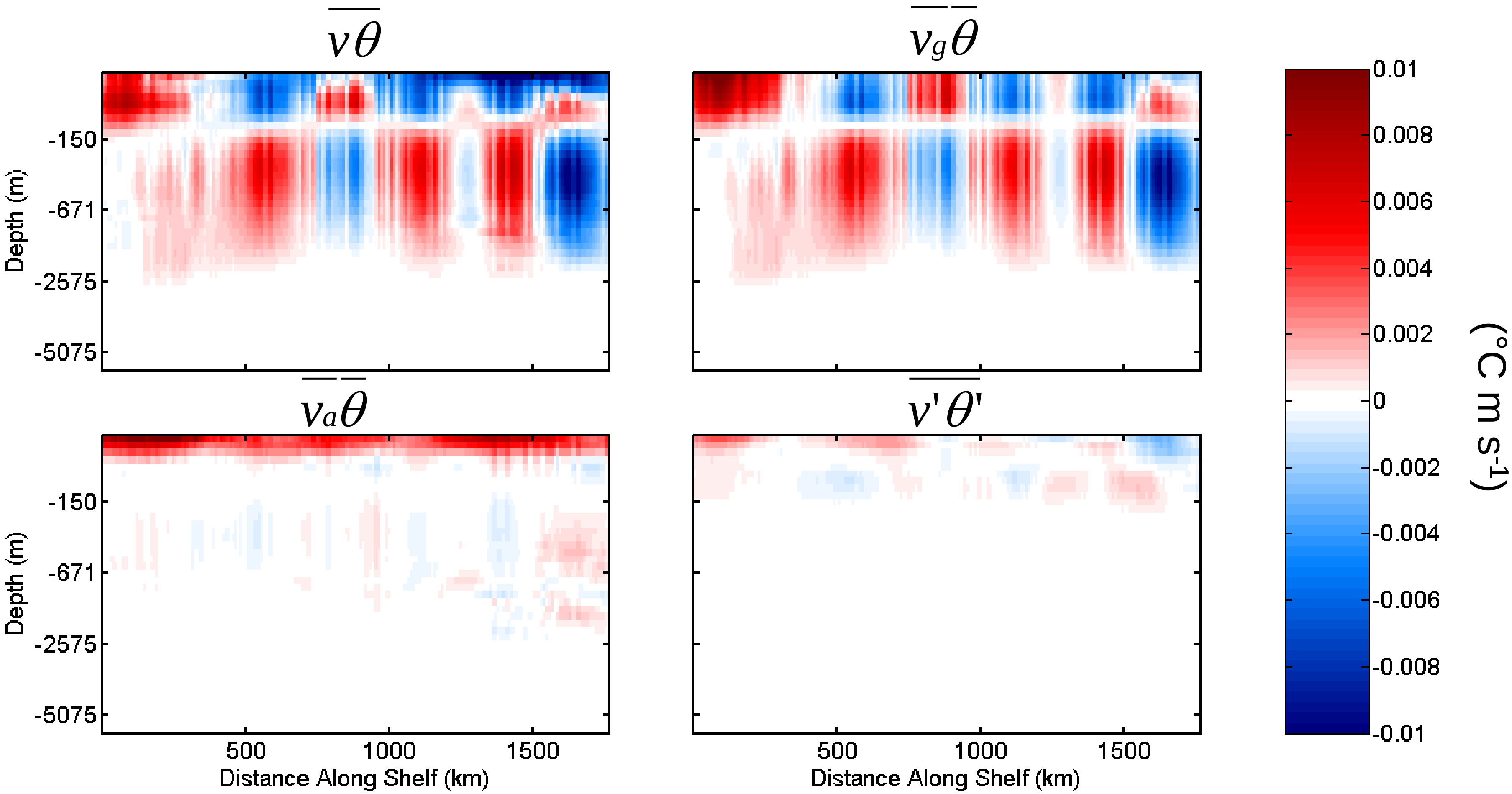
- Along-shelf from the east at 98.42°W
- Along-shelf from the west at 124.25°W
- Across-shelf
- Total net flux



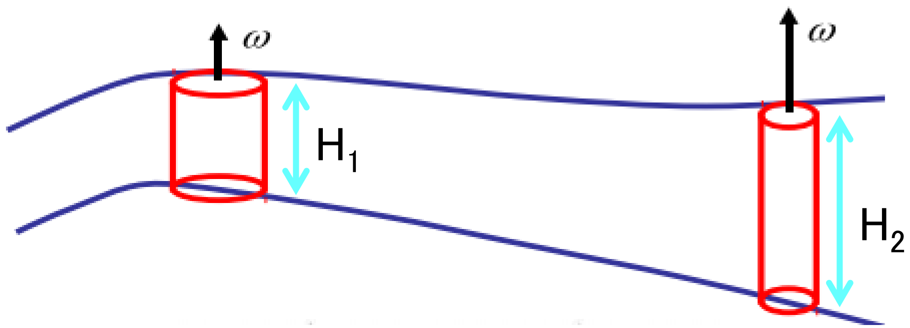
Heat Advection Across the Continental Shelf Slope



$$\overline{v\theta} = \overline{v_g}\,\overline{\theta} + \overline{v_a}\,\overline{\theta} + \overline{v'\theta'}$$



Potential Vorticity

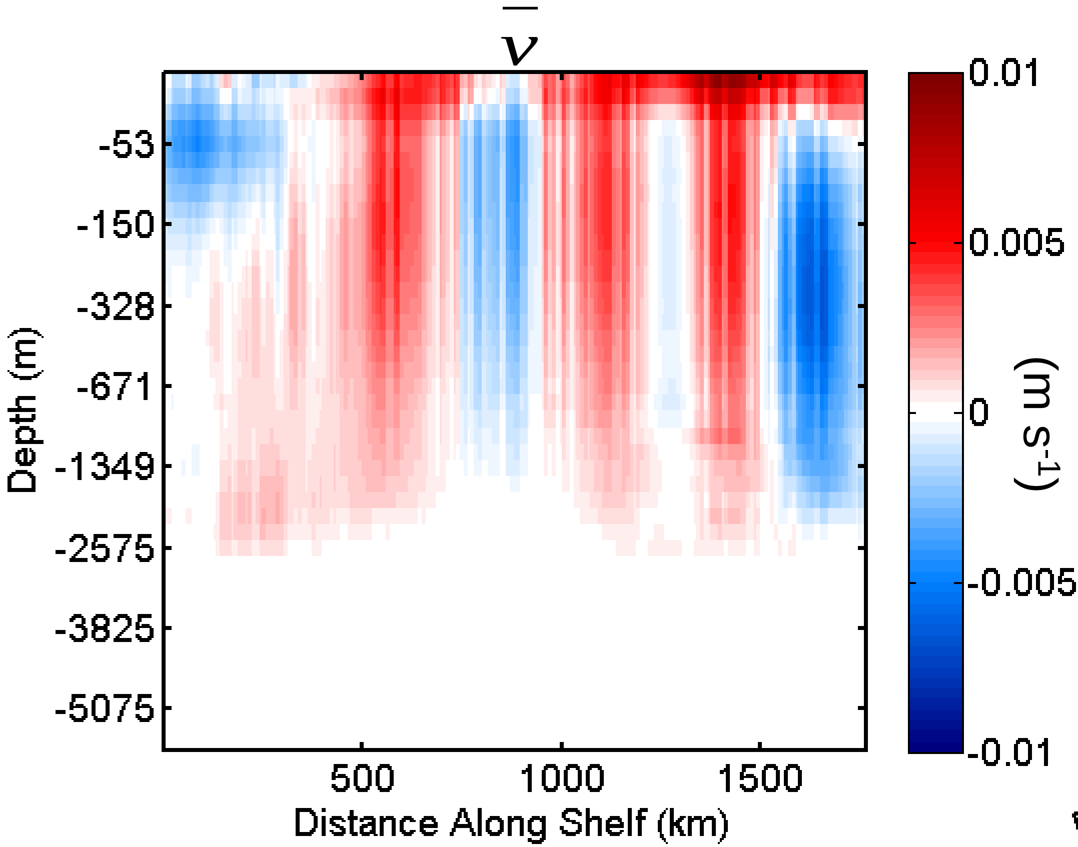


•Conservation of potential vorticity requires fluids to follow contours of f/H.

•In both hemispheres, poleward motion, toward larger magnitude f, requires stretching. Equatorward motion requires squashing.

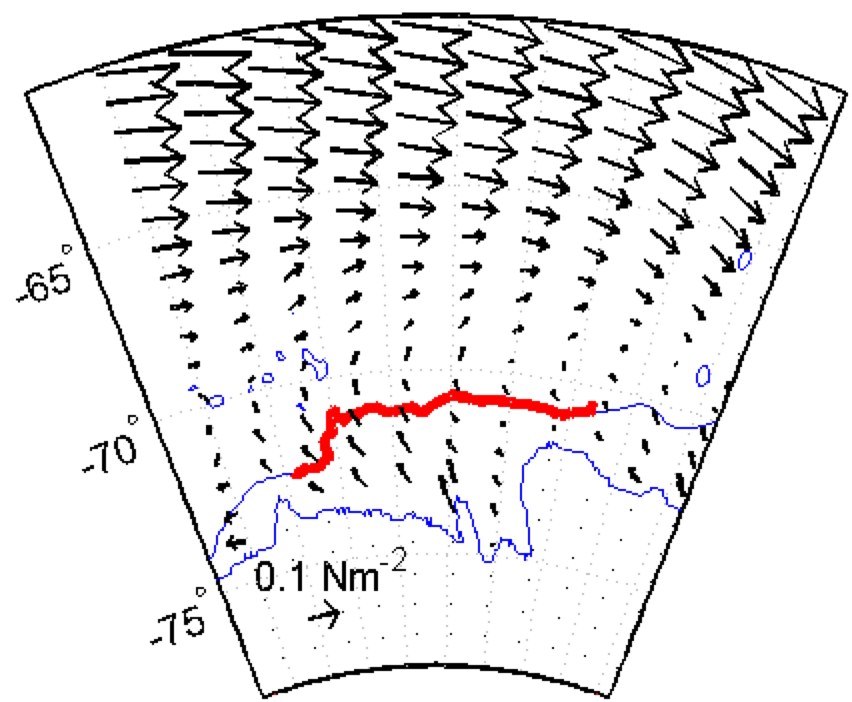
•Here, we see that potential vorticity is not conserved.

Adapted from http://www.columbia.edu/~irs2113/3_Circulation_Vorticity_PV.pdf



What is driving fluid into the ASE across the continental shelf slope?

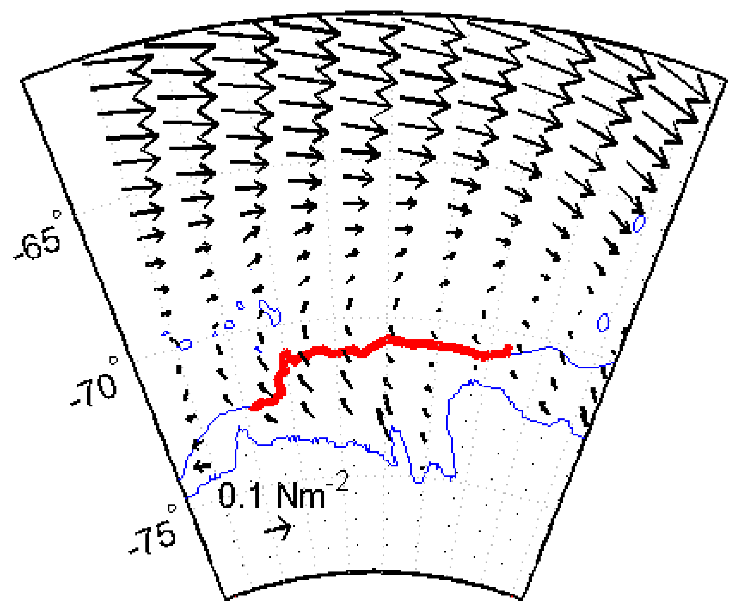
2005-2010 Mean Wind-Stress



Vorticity input from the wind-stress curl to the ocean

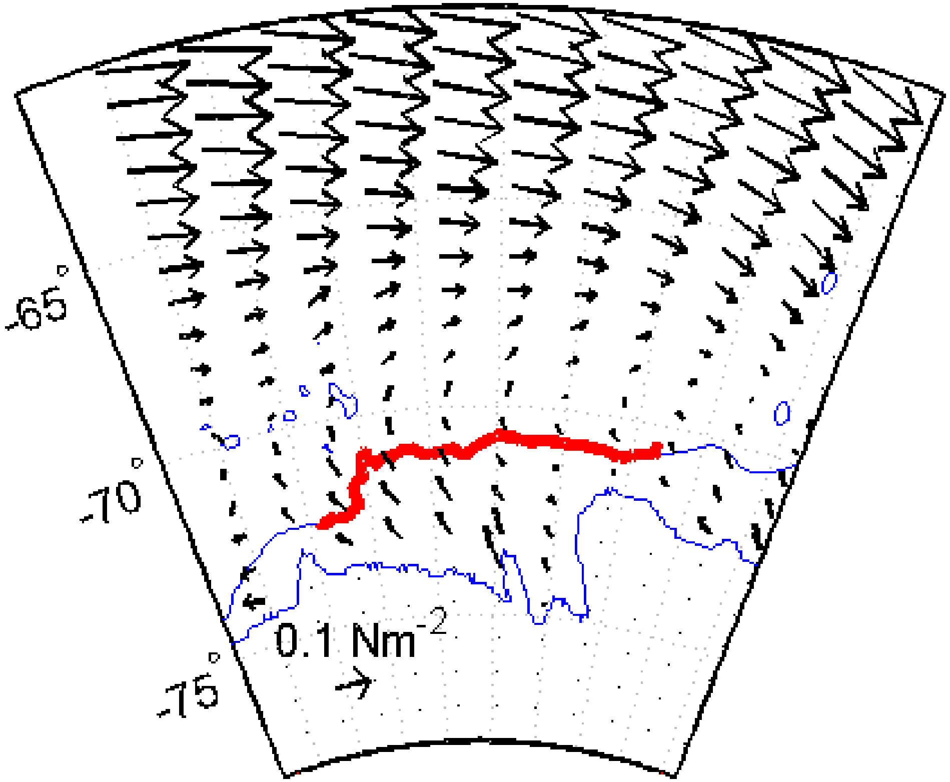
Conclusions

- Waters that most likely contribute to the melting of floating ice-shelves are found below the permanent pycnocline (z<-225 m)
- At depths greater than 225m, advection of warm, dense water from offshore is the primary source of heat in the ASE
- Heat is advected by the geostrophic flow across the continental shelf slope to the ASE
- The strength and location of heat transport across the continental shelf is forced by the wind-stress curl

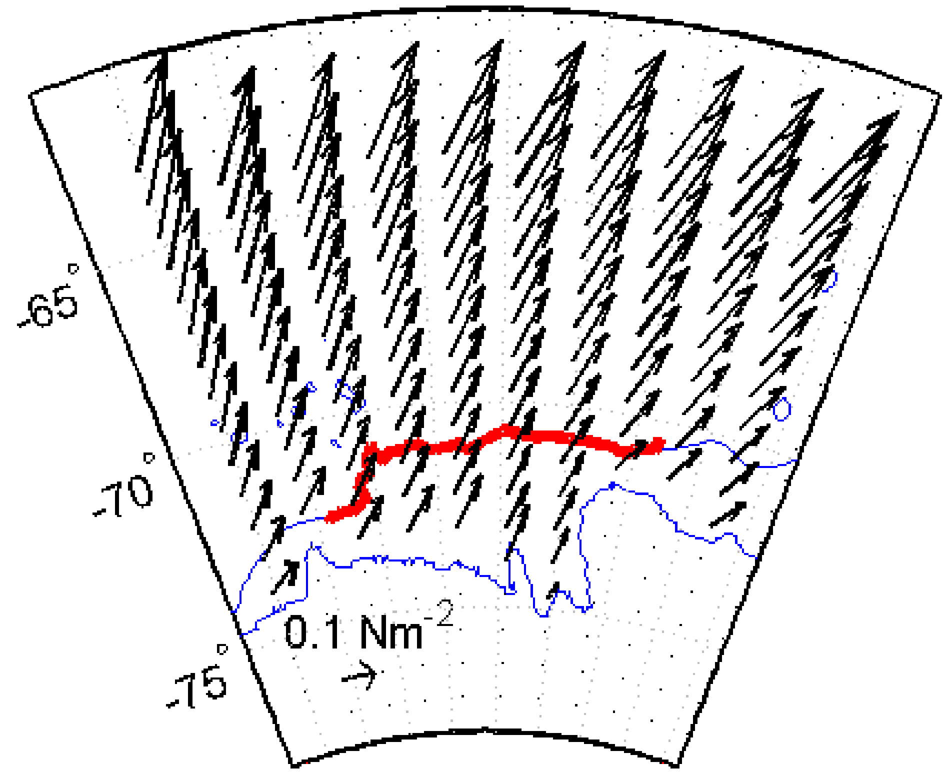


2005-2010 Wind Stress

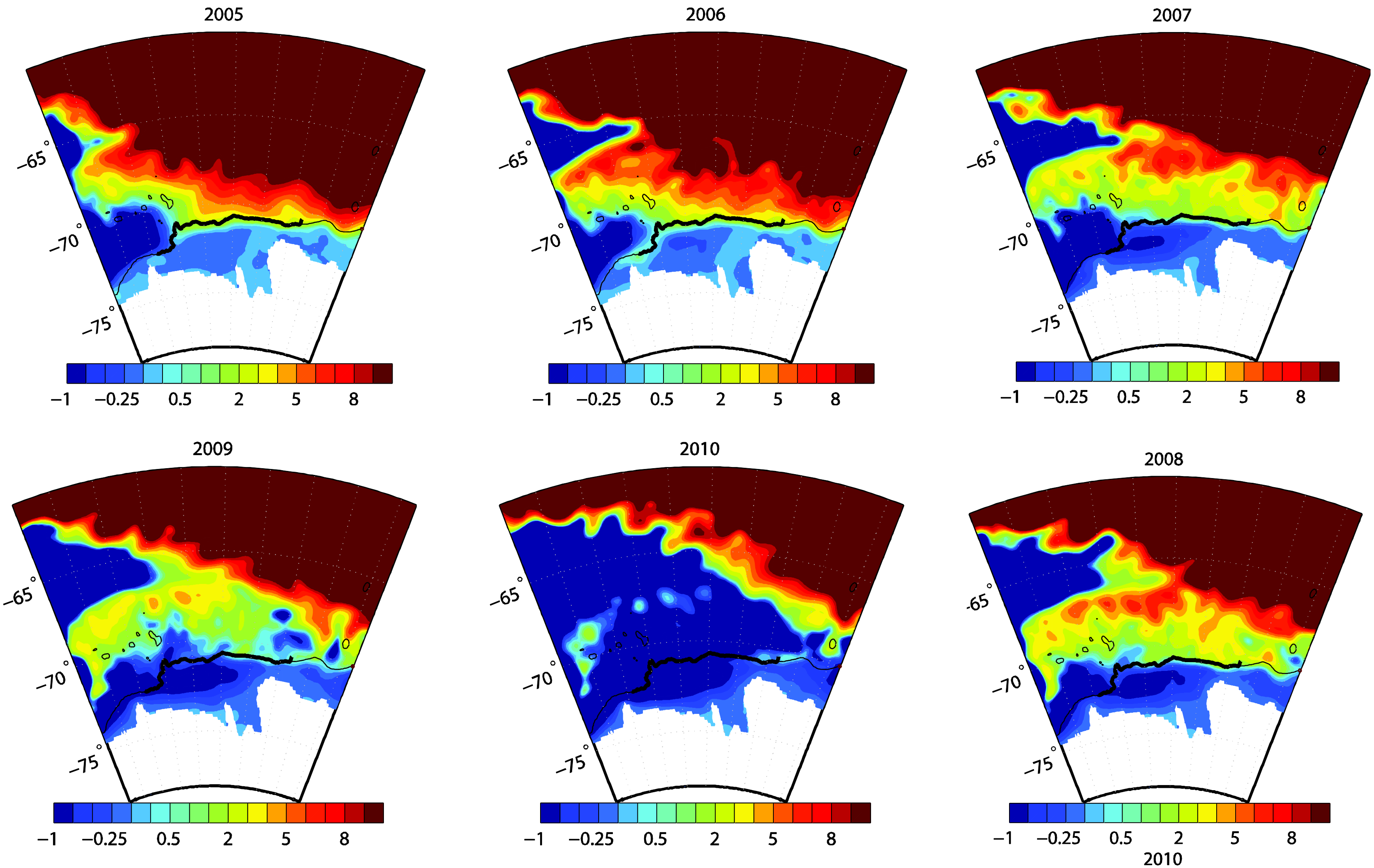
Mean Wind-Stress

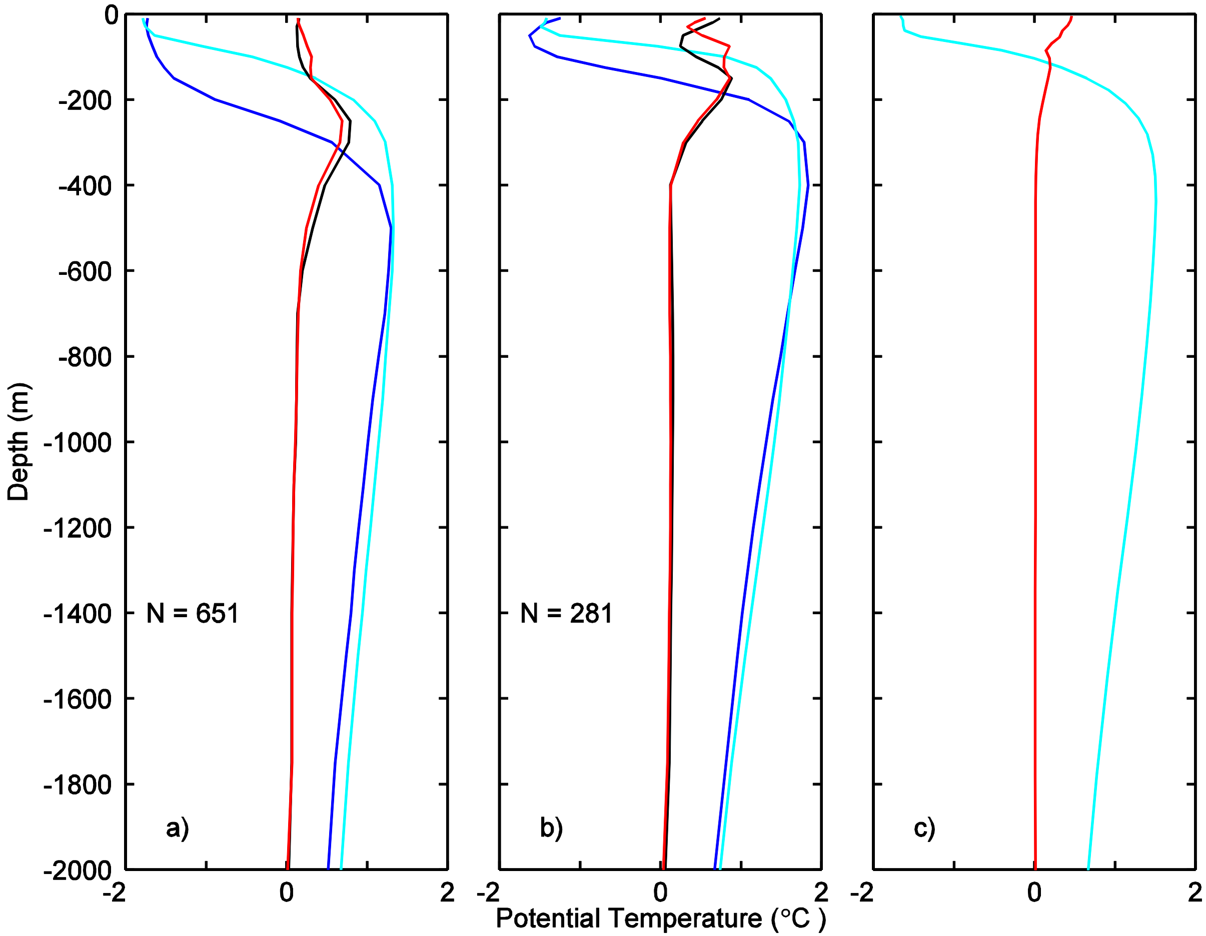


Standard Deviation of the Mean Wind-Stress



Annually Averaged Stream Function





The blue line is the mean potential temperature profile of the 2008-2010 observations at a) shallow locations in Figure 1 plotted as filled diamonds and b) deep locations in Figure 1 plotted as unfilled diamonds. N is the number of observed profiles for each regime. The black line is the standard deviation of the mean profile. The cyan line is the mean potential temperature profile of the model equivalents to the observations. The red line is the standard deviation of the model mist ($model_i$-$observation_i$). c)The cyan line is the 2008-2010 mean potential temperature averaged along the 2600 m depth contour within the lateral boundaries of the study domain, shown in Figure 1. The red line is the temporal standard deviation of the mean.

ASE Mass Transports

Transports (Sv)	Along-shelf from the west at 124.25°W	Along-shelf from the east at 98.42°W	Across-shelf
2005	-0.05±2.22	-1.27±0.93	1.32±0.64
2006	0.72±0.72	-1.36±0.69	0.64±0.51
2007	-0.65±1.08	-0.75±1.00	1.40±0.81
2008	-0.71±1.30	-0.33±1.22	1.04±0.58
2009	-1.02±1.20	-0.25±1.00	1.27±0.65
2010	-1.81±1.13	-0.10±0.94	1.71±0.67
6 year	-0.59±1.36	-0.64±1.10	1.23±0.73

ASE Heat Fluxes

Upper layer fluxes (TW)	Along-shelf from the west at 124.25°W	Along-shelf from the east at 98.42°W	Across-shelf	Total net flux
2005	1.54±0.96	-0.38±1.06	-0.79±2.03	0.78±2.85
2006	0.77±0.89	-0.30±0.96	-0.30±2.32	0.32±3.00
2007	1.91±1.91	-0.56±1.57	-0.40±2.40	1.11±2.84
2008	2.42±2.07	-1.37±1.65	1.03±3.07	2.67±3.84
2009	2.28±1.63	-2.18±1.20	0.80±3.17	1.19±4.26
2010	2.11±2.47	-1.61±1.15	0.85±2.74	1.86±3.64

Bottom layer fluxes (TW)	Along-shelf from the west at 124.25°W	Along-shelf from the east at 98.42°W	Across-shelf	Total net flux
2005	1.12±4.12	-5.80±3.49	4.88±2.76	-0.21±0.71
2006	3.84±2.81	-5.64±2.72	1.40±2.31	-0.54±0.46
2007	-0.77±3.66	-6.19±3.21	7.37±2.70	0.22±0.86
2008	-0.71±4.39	-4.85±4.67	6.06±2.90	-0.10±1.16
2009	-2.06±3.81	-5.56±3.75	8.17±2.00	0.26±0.80
2010	-4.81±4.22	-1.27±4.06	7.13±2.20	0.53±1.06

In situ observations

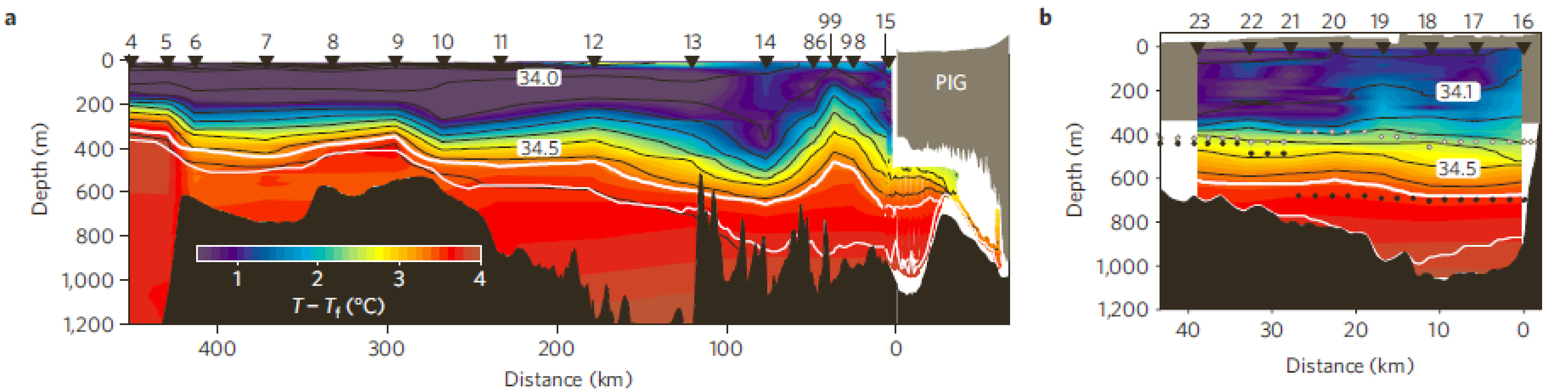


Figure 2 | Vertical temperature and salinity sections. a,b, Vertical temperature and salinity sections (**a**) from the CTDs shown in the Fig. 1 inset and extended beneath the PIG and (**b**) along the PIG calving front, looking toward the ice shelf. Both panels show temperature in colour relative to the *in situ* freezing point, salinity by black contours and the surface-referenced 27.75 isopycnal and potential temperature maximum by thick and thin white lines. Open circles in **b** show ice draft above the ridge crest (black dots) beneath the PIG, from airborne radar and Autosub measurements[11].

Jacobs, S. S., Jenkins, A., Giulivi, C. F., & Dutrieux, P. (2011). Stronger ocean circulation and increased melting under Pine Island Glacier ice shelf. *Nature Geoscience*, *4*(8), 519–523.