Coastal Troughs and Slope-Shelf Exchanges

PRISM Meeting

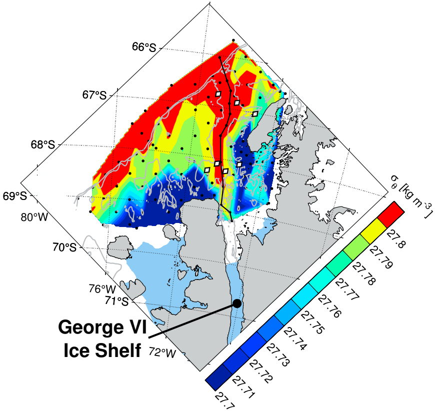
P. St-Laurent, J.M. Klinck and M.S. Dinniman

Center for Coastal Physical Oceanography

November 29, 2012

OCE0927797

Introduction



Recent observations support idea that glacial troughs are effective at channeling slope water onshore.

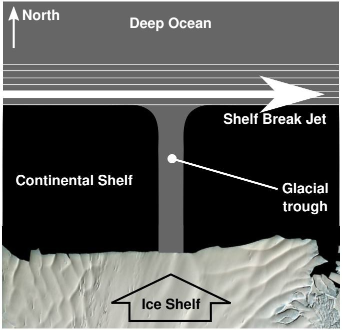
It can have impact on Fe budgets, but also on mass balance of the Antarctic ice sheet.

Many studies attribute the high ice melt rates in western Antarctica to warm CDW transported onshelf.

Moffat et al. 2009, Wåhlin et al. 2010, Walker et al. 2007, Rignot et al. 2011a,b.

Slope-Shelf Exchanges

Typical Antarctic shelves include a steep slope, a strong current at the shelf break (eastward or westward), glacial troughs, and the floating extension of the ice sheet (the ice shelf).



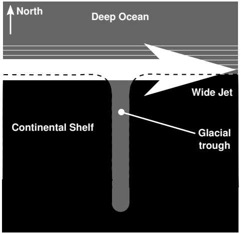
We recently conducted simulations of slope-shelf exchanges with an ice shelf-ocean coupled model (in press JPO)

Q. was: How do troughs influence the shelf circulation and lead to transport onshelf?

We examined each component of the system separately, and then together.

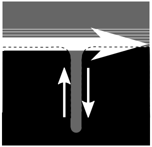
First case considered:

- Wide SBJ
- Trough
- No ice shelf



From Fennel & Schmidt 1991:

- Stretching on upstream side; Squashing on downstream side
- Mean flow advects cyclonic vorticity
- Clockwise cell ↻ over trough



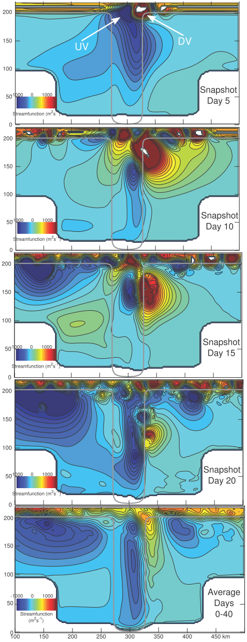


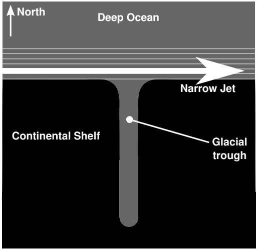
FIG. 6. As in Fig. 5, but for the case with a wide shelf break jet and no thermodynamics (run 3). White areas are where the isopycnal outcrops the bottom. UV (DV) means upstream (downstream) vortex.

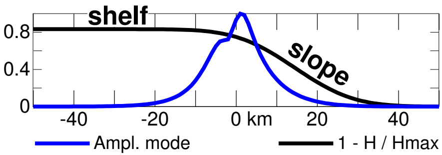
Observations suggest a vigorous, sheared, narrow SBJ:
$U_{\text{jet}} \sim 30\,\text{cm}\,\text{s}^{-1}$, $L_{\text{jet}} \sim 15\,\text{km}$, $L_{\text{R}} \sim 5\,\text{km}$

WOCE data, Moffat et al. 2008

2nd Case considered:

- Narrow SBJ
- Trough
- Jet too far offshore to directly interact with trough

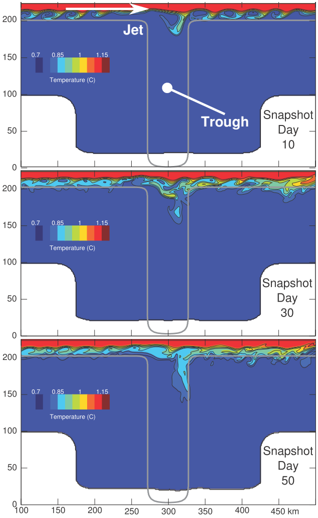




Jet is unstable according to theory
Wave should rapidly grow within jet
Wave wide enough to interact with trough

Case of a narrow SBJ (continued):

- Wave grows in few days
- Propagates $\rightarrow$
- Interacts with trough on its downstream edge
- Tongue of warm slope water grows over time
- Intrusion characterized by small eddy-like anomalies



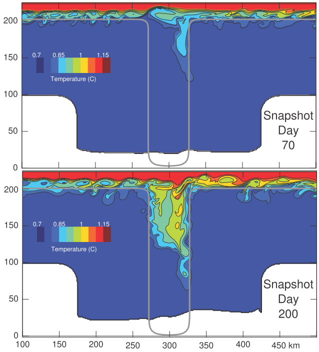


FIG. 8. Potential temperature θ of the deep isopycnal $\mathcal{V}_2$ for the case with a shelf break jet and no thermodynamics (run 5). The gray lines give the extent of the trough.

Case of a narrow SBJ (continued):

- The wave-topography interaction has a distinct signature
- Timescale $T \sim 7$ days
- Temperature anomaly $\Delta\theta \sim 0.1°$C at middepth
- These values are consistent with available mooring observations

Moffat et al. 2009

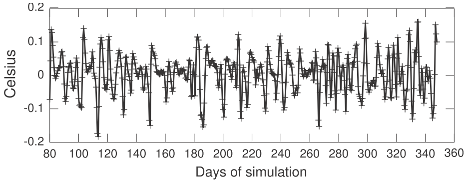


FIG. 12. (top) Temperature anomaly at 300 m at the entrance of the trough. The sampling interval is 0.5 days.

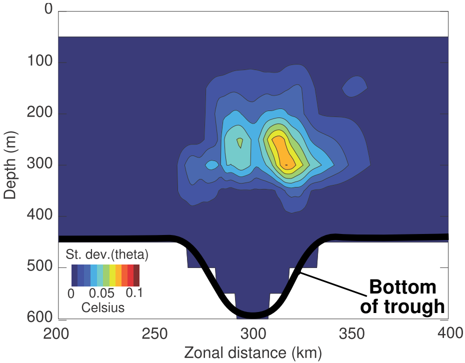


FIG. 14. (top) Standard deviation of potential temperature θ across the plane $y = 155$ km.

Case of a narrow SBJ (continued):

- The onshelf transport plummets when the jet is moved offshore or slows down
- $\searrow$ by 80% for $\Delta y = 10\,\mathrm{km}$ $(10\,\mathrm{km} \sim 1.5 L_{\mathrm{R}})$
- $\searrow$ by 80% for $U = U_0/3$
- Wave-topography interaction (and the onshelf transport it produces) cannot be reproduced by typical ocean models
- Transport is halved by passing from 1 km to 2 km
- Transport is 1/10th by passing from 1 km to 3 km

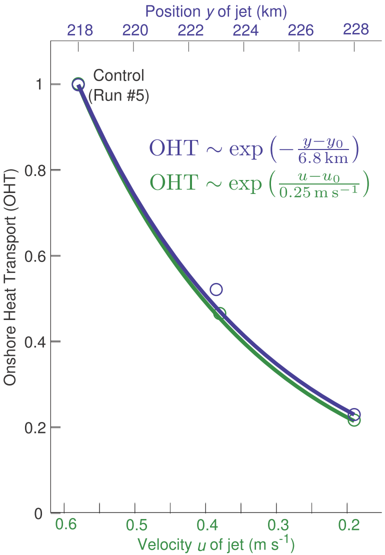
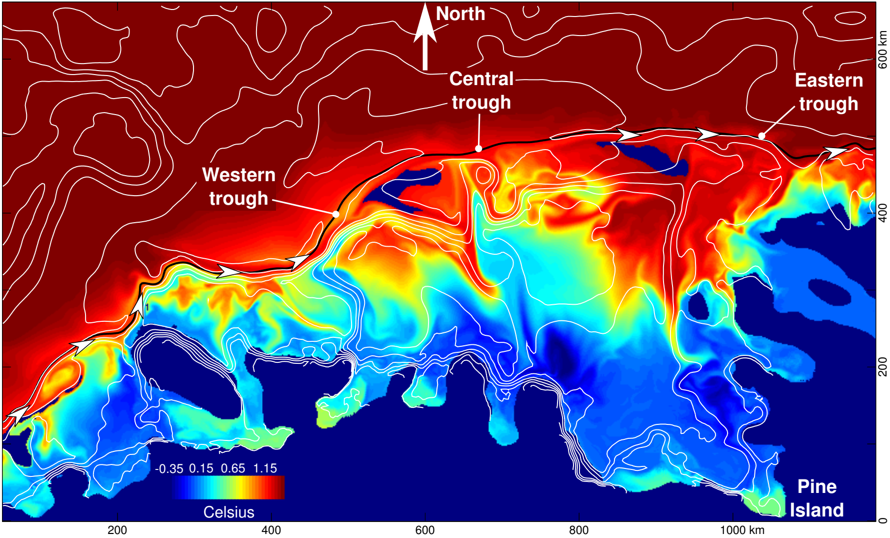


FIG. 10. Sensitivity of mean OHT to the position and velocity of the jet (mechanism 3; runs 5,13–16). The transport is nondimensionalized by its value from the control simulation (run 5). The solid lines are exponential regressions to the data points. The Rossby radius of deformation is 6.9 km at $y = 220$ km.

Application to real basins: Amundsen Sea



Summary

- Onshelf transport is sensitive to y_{jet} and U_{jet}
- We can expect significant time-variability at seasonal and interannual timescales
- Some of the intrusion signal can be lost when using typical model resolutions (5–15 km)
- Work in progress: How are these results modified when jet is $\leftarrow$? (Ross Sea)
- Work in progress: How do these results apply in realistic conditions? (Amundsen Sea, Ross Sea)