The impact of shelf-break currents on marginal sea overflows

Shin Kida (木田新一郎)

JAMSTEC

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Past studies on Overflows

Open Ocean

Marginal Seas

Entrainment

Source

Product water

Stream-tube Model is mainly used for understanding its dynamics. But this model neglects upper oceanic dynamics.
Upper Ocean is not quiescent

Various circulations exist in the open ocean, especially near the coast. Do they play any role on marginal sea – open ocean water exchange?
Weddell Sea, Ross Sea, etc.

- Cold and Fresh
- Warm and Salty
- Cold and Salty

The presence of a wide shelf-break and a slope current.

- Room for interaction?
Main Question: Does the Antarctic slope front (ASF) affect the AABW outflow?

• How is the transport and temperature of the source water (formation rate) controlled?
  – Mass balance: $M_s + M_i = 0$
  – Heat balance: $T_s M_s + T_i M_i = Q$
    $\rightarrow (T_s - T_i)M_s = Q$

• If ASF changes $M_s$, then $T_s$ is also likely to change
Transport of the AABW outflow (Cross slope transport at the sill)

- Observational estimate is from 2 to 5 Sv (e.g. Gordon et al. 1998)
- Mechanisms proposed (as far as I know)
  - Bottom Ekman layer: $dP/dx$
    - About 1 Sv (Tanaka & Akitomo 2000)
  - Geostrophic flow: $dP/dy$
    - About 1 Sv: Pressure gradient across the shelf (Gill 1973)
  - Tides
Bottom Ekman transport

\[ V_{EK} = \frac{\tau_x}{\rho f} \propto \frac{\partial p}{\partial x} = \frac{\partial (p_s + p_d)}{\partial x} \]

- \( P_d \): Baroclinic component.
  - Created by AABW outflow itself.

- \( P_s \): Barotropic component
  - Tanaka and Akitomo (2000) shows that the surface pressure field reduces the AABW descent rate (about 50%) than that estimated from stream-tube models.
  - Assumed 2D baroclinic flow with no wind-forcing.
  - Zero pressure gradient in the along slope (dpdy=0) direction may have resulted in creating a strong viscous upper layer return flow.

ASF is considered barotropic and is associated with a surface pressure gradient.

Can ASF enhance the AABW outflow transport?
Model Experiment

- Regional Ocean Modelling System (ROMS)
- MY vertical mixing parameterization
- 1km x 1km, dz 10-20m

Dense water formation Site

Open Ocean

Continental Shelf break

Q

100 km

500 m

0
• AABW transport increases when wind stress is present.
  \[Ms = 0.35 \text{ Sv} \rightarrow 0.6 \text{ Sv} \quad \text{and} \quad Ti = 0.5 ^\circ \text{C} \rightarrow 0.9 ^\circ \text{C}\]
• Behaviour matches well with the Hydraulic Theory: \(Ms = g' \cdot h^2/2f\)
• ASF is likely having an influence on the AABW formation
My goal is to…

• Learn whether the Antarctic slope current plays any role on the AABW formation rate.
• If so, what is the underlying dynamics?
  – Bottom friction? something else?
  – Do we need to consider similar effects for other overflow? or is Antarctic unique?
  – Requires more sensitivity study (Strait width, ASF structure, salinity)
• Understand how overflows interact with basin scale dynamics.
• Hydraulic Theory predicts
  → \( Ms = \frac{g'h^2}{2f} \) (Marginal Sea controlled)

\( g' = a*dT \)

\( Ms = a*dT*h^2/2f \)

• This is an estimate based on the temperature difference and stratification in the marginal sea

• The estimate neglects friction (absolute vorticity conservation)

• One layer and no external force

• However, \( dT \) and \( h \) is not an external parameter!
Overflows can affect the upper ocean

Open Ocean

Marginal Seas

Entrainment drives topographic $\beta$-plumes in the upper layer $\rightarrow$ Azores Current in the Atlantic Ocean