**DIMES**: Diapycnal and Isopycnal Mixing Experiment in the Southern Ocean

- A US+UK experiment
- Diapycnal diffusion and isopycnal dispersion and eddy fluxes
- Improve eddy parameterizations in models of the MOC for climate variability

Read all about it: [http://dimes.ucsd.edu/](http://dimes.ucsd.edu/)
Why K? Dominant momentum balances:

\[
\begin{align*}
\tau_o & \quad \text{Side view of the ACC} \\
\rho_1 \quad -fV_1 &= \tau_o & \text{Surface} \\
\rho_2 \quad -fV_2 &= \eta_1' p_1' - \eta_2' p_2' & \text{zonally open} \\
\rho_3 \quad -fV_3 &= -h p_{bx} & \text{“blocked” layer}
\end{align*}
\]

\( V \) = net meridional volume flux, \( \tau_o \) = wind stress \( \eta \) = layer thickness, \( p \) = pressure, \( p_b \) = bottom pressure

...adapted from Olbers
Why K? Dominant momentum balances:

\[ \tau_o \rightarrow \text{Side view of the ACC} \]

\( \rho_1 \)

\[-fV_1 = \tau_o \] Surface

\( \rho_2 \)

\[-fV_2 = \eta'_1 p'_1_x - \eta'_2 p'_2_x \approx K \frac{dq}{dy} \] zonally open

\( \rho_3 \)

\[-fV_3 = -hp_{bx} \] “blocked” layer

\( V \) = net meridional volume flux, \( \tau_o \) = wind stress
\( \eta \) = layer thickness, \( p \) = pressure, \( p_b \) = bottom pressure

...adapted from Olbers
Different approaches to estimating $K$

- **Tracer release experiments (moment method)**
  \[
  K_{Tracer} = \frac{1}{2} \frac{d\sigma_y^2}{dt} , \quad \sigma_y^2 = \int (y - y_c)^2 c \, dA
  \]

- **Float release experiments (Taylor’s formula)**
  \[
  K_{Taylor} = \frac{1}{2} \frac{d}{dt} \left\langle (y(t) - y_0)^2 \right\rangle = \int_0^t \left\langle v(t)v(t') \right\rangle \, dt'
  \]

- **Velocity based estimates (Nakamura’s formula)**
  \[
  K_{Nak} = \kappa \frac{L_{contour}^2}{L_0^2}
  \]
DIMES Overview

US1: Initial deployment of sound sources, floats, tracer

US2: Tracer and microstructure survey, float deployment

UK1: Moored profiler, current meters, and sound sources

UK2: Hydrographic and microstructure survey

UK3: Tracer and microstructure survey mooring recovery

2009

2010

2011

2012

Drake Passage section

Drake Passage section

Drake Passage section
The tracer

• Trifluoromethyl-sulphur-pentafluoride. $\text{CF}_3\text{SF}_5$

• Inert, non-toxic.

• 1 milligram is detectable in a cubic kilometer of seawater, by gas chromatography with electron capture detection.

Ledwell Watson
US1
Cruise Track and Deployments

*R/V Revelle*, 5 Jan to 1 Mar 2009
Mean Concentration versus Depth (using mean density vs depth from CTD)
Now wait a year…

…but follow the evolution of the tracer with altimetry
Tracer Transects
Column Integral

Horizontal structure
Initial & 12-month profiles

Vertical structure

\[ k_z = 0.13 \text{ cm}^2/\text{s} \]
Scotia Sea
UK2  Dec 2010 – Jan 2011

*RRS James Cook*
2 years later

Depth (blue), Tracer sim (red), SSH (black), 02 Jan 11

JC054 Stations
Average Profiles

DP $k_z \sim 1 \text{ cm}^2/\text{s}$

Normalized Concentration

East of DP
West of DP
US2
DIMES Floats

- 11 sound sources for acoustic array
- ~150 Argos and Iridium Rafos floats
US1
Cruise Track and Deployments

*R/V Revelle*, 5 Jan to 1 Mar 2009

- CTD stations (red)
- Float deployments in triplets
- Tracer release
- Sound sources

Legend:
- SoSo large blue
- Solo small blue
- Rafos black
- CTD red
Neutral Density Section at 105 W
Deployment on 2 isopycnal surfaces
DIMES Floats as of Sept 2011

Dimes Trajectories (43) Orsi fronts
Drake Passage Fronts and Floats

SOSE mean speed

AVISO 7 yr mean speed + real floats + bathymetry
Tracer-Float Spreading

All stations
Deep float surfacings
PDFs

\[ K_{\text{diff}} = \frac{\sigma^2}{2\Delta t} \]
\[ = (400\text{km})^2/4\text{yrs} \]
\[ \approx 1200 \text{ m}^2/\text{s} \]

Also,
\[ d\langle X^2 \rangle/dt \sim 1000\text{m}^2/\text{s} \]
and
\[ dK_{\text{SSH}}/dz < 0 \]
Vertical Structure

Klocker et al; Speer et al.
Vertical Structure
Conclusions

1. Deep isopycnal mixing in the ACC is
   - about 1200 m²/s (uncertainties TBD)
   - associated with f/H
   - weaker away from topography?

2. DIMES float trajectories will provide direct but limited diffusivity estimates and other quantities, state estimates necessary

3. Need to observe vertical structure of mixing to discriminate theories

4. Flow splitting and merging: braided jets