Ocean Circulation and Ventilation: Southern Ocean Hydrography and Circulation: Antarctic Intermediate Water and Subantarctic Mode Water formation in the southeast Pacific

Lynne D. Talley*, Brendan Carter*&, Teresa Chereskin*, Andrew Dickson*, Rana Fine+, Corinne Hartin+, James Holte*#, and Bernadette Sloyan@ (ltalley@ucsd.edu)

*Scripps Institution of Oceanography; &Princeton University; +RSMAS; #WHOI; @CSIRO

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International CLIVAR project
SubAntarctic Mixed layers, Fluxes and Overturning Circulation (SAMFLOC)

Abstract (in white boxes)

We highlight results from the 2005-2006 austral winter survey of Subantarctic Intermediate Water and Antarctic Intermediate Water formation in the southeastern Pacific. The salinity minimum of the Antarctic Intermediate Water (AAIW) is formed in the southeastern Pacific, as the densest, coldest, and freshest, but not necessarily thickest, Subantarctic Mode Water (SAMW). A wintertime hydrographic survey with follow-on summer survey in 2005-2006 explored the late winter mixed layers and subsequent restratified water column in the southeastern Pacific.

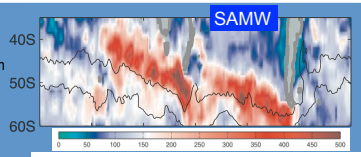
Background

Salinity minimum fills the Southern Hemisphere and tropics.

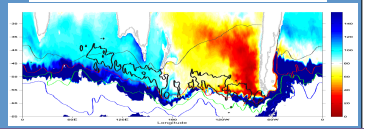
Hypothesis (*McCartney, 1977*): AAIW is the densest form of SAMW. Principal source of the salinity minimum is in the Drake Passage region.

Salinity and potential vorticity on an AAIW isopycnal (*Talley, 1996*): lowest salinity and lowest potential vorticity are in the southeast Pacific, reflecting formation of AAIW there.

Winter (Sept.) mixed layer depths in the Southern Ocean from Argo (*Dong et al., 2009*)

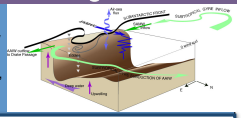


Subantarctic Mode Water (Southeast Pacific variety, close to AAIW) Potential vorticity at σ_θ = 27.1 kg/m^3 (*Cerovecki et al., in preparation* – see poster)



SAMW formation experiment goals

Evaluate relative importance of cross-frontal fluxes, Ekman transport, air-sea fluxes, eddy fluxes, diapycnal mixing (wind-driven), possibly upwelling driven by wind stress curl, preconditioning by higher surface salinity



References in order of publication

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Carter, B., A. Dickson, & L. Talley, 2011. A model for biogeochemical cycling in deep mixed layer waters entrained into Subantarctic Mode and Antarctic Intermediate Waters, (in preparation for GBC)

Cerovecki, I., L. D. Talley and M. R. Mazloff, 2011. Subantarctic Mode Water formation the eddy-permitting Southern Ocean State Estimate. (in preparation for JPO)

Holte, J.W., L. D. Talley, T. K. Chereskin, and B. M. Sloyan, 2012. Observed cross-frontal exchange at the Subantarctic Front. (in preparation for JGR)

PhD theses

Carter, Brendan (SIO 2011) "Methods for hydrographic data collection and use applied to infer biogeochemistry in the Southern Ocean"

Hartin, Corinne (RSMAS in progress) "Subantarctic Mode Water and Antarctic Intermediate Water in the South Pacific during the present and Last Glacial Maximum"

Holte, James (SIO 2010) "Subantarctic Mode Water formation: air-sea fluxes and cross-frontal exchange"

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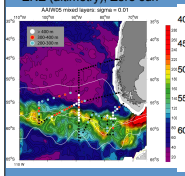
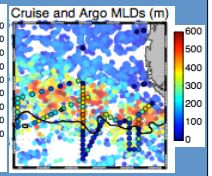
2005-2006 SAMW/AAIW observations

A large region of mixed layers greater than 400 m depth was bounded to the south by the Subantarctic Front (SAF), and bounded to the north by a secondary "subduction front" north of which SAMW and AAIW were subducted into the subtropical gyre. During the cruises, the SAF jet velocity amplitude was 40 cm/sec, decaying rapidly with depth but with an equivalent barotropic structure; meanders had wavelengths of 250-300 km and a vorticity structure indicative of a quasi-stationary Rossby wave (Chereskin et al., 2010).)

Austral winter cruise Aug. 23-Oct. 25, 2005 Austral summer cruise Jan.30—Mar14, 2006
Mixed layer depths, velocities with SAF (Aviso) Argo winter profiles (July-Oct, 2003-10)
EKE (altimetry), Zero curl



Holte et al., (in prep.)

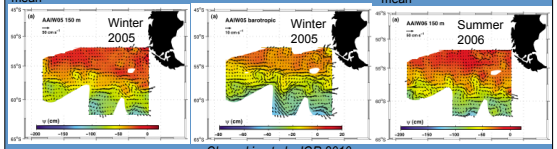


Holte et al., (JGR submitted)

Mapped velocities at 150 m (SADCP), using Maximenko et al. dyn. topo as background mean

Depth-averaged velocities (LADCP), using Davis floats as background mean

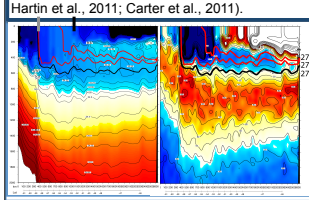
Mapped velocities at 150 m (SADCP), using Maximenko et al. dyn. topo as background mean



Chereskin et al., JGR 2010

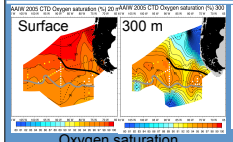
Origins of AAIW and SAMW; mixed layer gases

The late winter mixed layers within the study region were colder, fresher and denser downstream to the east; the greatest mixed layer depths and hence most well-developed SAMW coincided with higher surface salinity some distance north of the SAF while the freshest deep mixed layers adjacent to the SAF coincide with the new AAIW salinity minimum. Within the region of new SAMW, surface oxygen and chlorofluorocarbon saturations were reduced to ~95%, indicating active entrainment of older waters from below the mixed layer, but also not indicating extraordinarily deep penetration of mixing which would result in even lower saturations (Holte et al., 2011; Hartin et al., 2011; Carter et al., 2011).

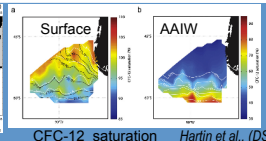


AAIW salinity minimum (black) originates at the Subantarctic Front

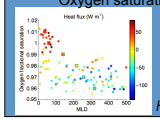
SAMW PV minimum (red) originates in higher salinity deepest mixed layers



Oxygen saturation



CFC-12 saturation *Hartin et al., (DSR 2011)*

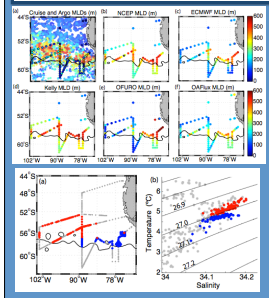


Surface waters in SAMW formation region are undersaturated in oxygen and CFC's. AAIW layer is much less saturated north of subduction region. High heat loss is associated with deep mixed layers and amount of undersaturation (hence entrainment).

Holte et al., (JGR submitted)

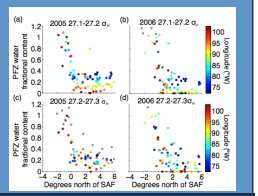
Air-sea and cross-frontal fluxes

Air-sea fluxes are capable of creating the deep winter mixed layers with no other direct forcing, starting with restratified summer SAMW, but cross-SAF fluxes of fresher, colder waters are essential for the downstream evolution in SAMW properties. These can be associated with major intrusions around meanders of the SAF (Holte et al., 2011; Holte et al., submitted).



Air-sea buoyancy fluxes from 5 different products, run with KPP mixed layer model and summer stratification, reproduce the observed winter mixed layer depths (NCEP is best), but not the zonal variation in salinity, temperature. (Holte et al., submitted)

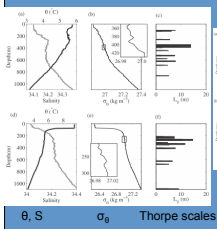
Winter mixed layer properties: two distinct SAMW pools; eastern one is cooler, fresher, denser (Holte et al., submitted)



OMP analysis: contribution of upstream Subantarctic water versus Polar Frontal Zone water to properties as a function of longitude and distance from the Subantarctic Front: more PFZ water contribution in the east, reflecting cross-SAF flux (Holte et al., in preparation)

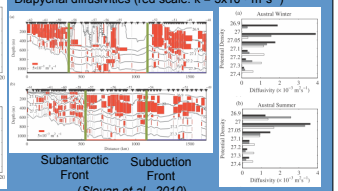
Enhanced diapycnal diffusivity

Diapycnal diffusivities were enhanced, up to 10^{-4} to 10^{-3} m^2/sec, near the SAF, north of the subduction front, within the capped SAMW in summer, and below the deep winter mixed layers (proto-SAMW) in winter; the diffusivities decayed rapidly with depth. Associated high rates of mixing within the summer SAMW suggests that the low stratification is partially actively maintained outside the winter (Sloyan et al., 2010).



θ, S σ_θ Thorpe scales

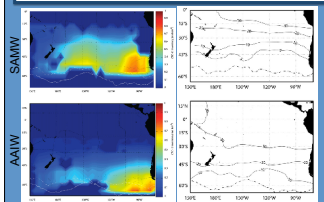
Diapycnal diffusivities (red scale: $\kappa = 5x10^{-3}$ m^{2}s^{-1})



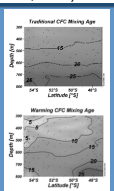
(*Sloyan et al., 2010*)

SAMW and AAIW formation rates and ages

Southeast Pacific SAMW and AAIW formation rates estimated from chlorofluorocarbon inventories from the 2005-2006 cruises and from WOCE data are 11.7 Sv and at least 5.8 Sv, respectively (Hartin et al., 2011).



CFC-12 inventory CFC age (yrs)
(*Hartin et al., 2011*)



Alternative CFC age estimate (younger) assuming warming
(*Carter et al., in preparation*)