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Diapycnal mixing in an outflow of dense Antarctic shelf water in a tidally active region

R. Muench (1), L. Padman (2), **A. Bergamasco** (3)

(1) Earth & Space Research, Seattle, USA, (2) Earth & Space Research, Corvallis, USA, (3) CNR ISMAR, Venice, Italy (rmuench@esr.org / Fax: +1-206-726-0522 / Phone: +1-206-726-0522)

We describe the mixing dynamics influencing volume flux and scalar characteristics of the outflow of dense shelf water from the NW Ross Sea, using CTD and microstructure data collected as part of the U.S. AnSlope project that was carried out in collaboration with an Italian CLIMA project. Measurements were made in late summer 2003 using a scalar microstructure profiler that was attached to the shipboard CTD system, and again in late winter 2004 using a tethered, free-falling vertical microstructure profiler (VMP) measuring scalars and velocity shear. The outer shelf was occupied in many locations by a benthic layer of dense High Salinity Shelf Water (HSSW). During the first cruise we measured entrainment rates exceeding 100 m/day in the outflow of HSSW onto the upper slope, consistent with the inferred downstream gradients of outflow characteristics based on multiple CTD transects. Froude numbers were consistently high, order 1, within the outflow. A simple model of the outflow "plume" stress balance indicates that the strong local diurnal tidal currents (up to 1.3 m/s at spring tide) can double the time-averaged along-flow benthic stress and cross-flow (roughly downslope) Ekman volume flux. The impact of tidal currents on outflow dynamics implies a modulation of outflow characteristics and flux on both daily and fortnightly (spring-neap cycling) time scales, with implications for both data interpretation and modeling the contribution of Antarctic HSSW to the Southern and Global oceans. In contrast to summer 2003, in winter 2004 we found no downslope flow of HSSW. Instead, the outer shelf contained a significant intrusion of Modified Circumpolar Deep Water (MCDW) overlying the HSSW. A one-day time series of VMP profiles allows us to identify tide-modulated mixing between MCDW and HSSW as a source of variability in the T-S characteristics of the HSSW before it reaches the shelf break.