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The International DOVETAIL Program

Robin D. Muench¹

Hartmut H. Hellmer²

¹*Earth & Space Research, 1910 Fairview E., Suite 102, Seattle, WA 98102, USA*

²*Alfred-Wegener-Institute for Polar and Marine Research, Bussestrasse 24, 27570 Bremerhaven,*

Germany

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Abstract

2 The “Deep Ocean Ventilation Through Antarctic Intermediate Layers” (DOVETAIL)
3program is an international field and modeling study of the dense deep and bottom waters of the
4northwestern Weddell Sea. A primary program goal has been to estimate the volume transport and
5pathways of these waters, long considered to be a major source of Antarctic Bottom Water, as they
6escape from the Weddell Sea over and through the South Scotia Ridge into the Scotia Sea.
7Corollary goals are to assess modification of the stratification during passage through the narrow,
8steep-sided and irregular channels that transect the Ridge. The program has evolved, since its start
9in 1997 as a primarily process-oriented project, into a multiyear observational study of the
10northwestern Weddell Sea-southern Scotia Sea including the Weddell-Scotia Confluence region.
11An additional program goal has, therefore, become the estimation of interannual variability in the
12physical system. This volume contains a collection of papers that present recent field and model-
13derived results from the DOVETAIL program.

11. Background

2 Dense water produced in the Weddell Sea is a significant, if quantitatively uncertain,
3 component of the global inventory of Antarctic Bottom Water (AABW) (Broecker *et al.*, 1998;
4 Orsi *et al.*, 1999; Hellmer and Beckmann, 2001). Field programs over the last several decades
5 have led to a consensus about how this dense water is produced. The two principal modes of
6 production are as follows. One process entails the addition of brine released during sea ice
7 formation to form a dense shelf-resident water mass called high salinity shelf water (HSSW). The
8 HSSW then mixes near the continental shelf break with Modified Warm Deep Water (MWDW),
9 which is a mixture of Warm Deep Water (WDW) and Winter Water (WW) (Foster and Carmack,
10 1976; Foster *et al.*, 1988). A second process invokes the additional step of cooling and freshening
11 of shelf water beneath ice shelves followed by downslope flow at the shelf break and mixing with
12 ambient waters (Foldvik *et al.*, 1985). The addition of fresh water through glacial melt provides a
13 characteristic isotope signal to the deep water formed through the second process, allowing the
14 relative importance of both processes to be assessed (Weppemig *et al.*, 1996).

15 Regardless of the production mechanism, dense water in the Weddell Sea is predominantly
16 a result of ocean/atmosphere or ocean/ice-shelf heat and salt exchanges that occur over the broad
17 southern and western continental shelves. Once formed, the dense waters flow down the adjoining
18 continental slopes as density currents. These dense “plumes” interleave with ambient deep water
19 masses or form broad, sheet-like bottom layers that can be up to several hundred meters thick and
20 in places extend over most of the continental slope (Gordon *et al.*, 1993; Gordon, 1998). The dense
21 sheet of bottom water flows northward along the western rim of the Weddell Sea, adjacent to the
22 Antarctic Peninsula, and is enhanced en route by additional sources along the Peninsula, such as
23 from the Larsen Ice Shelf (Muench and Gordon, 1995; Fahrbach *et al.*, 1995).

1 As these dense flows reach the northeastern tip of the Peninsula, slope currents deeper than
2 about 2000 m are primarily constrained by bottom topography to continue eastward along the
3 southern flank of the South Scotia Ridge (**Figure 1**). Subject to seasonal and interannual
4 variations, the plume splits, with part following a cyclonic path around Powell Basin and the
5 remainder proceeding directly toward the South Orkney Plateau (Gordon *et al.*, 2001). Shallow
6 fractions can exit into the Scotia Sea from northern Powell Basin, with deeper fractions entering
7 the Scotia Sea through passages in the South Scotia Ridge east of the South Orkney Islands. The
8 deepest, densest components are prevented by the topography from exiting the Weddell Basin
9 across the Ridge (Orsi *et al.*, 1993; 1999).

10 Additional dense water can form during winter on the shelves adjacent to the northern tip
11 of the Antarctic Peninsula (Whitworth *et al.*, 1994; Gordon *et al.*, 2000). There, local winds and
12 topography can cause divergence in the sea ice cover, creating open water areas that are subject to
13 high rates of sea ice formation. A significant fraction of these modified shelf waters flows
14 northward past the tip of the Peninsula and contributes to ventilation of the Bransfield Strait basins
15 (Gordon *et al.*, 2000).

16 Topography is a major factor in determining the pathways through which dense water
17 formed in the Weddell Sea can escape into the Scotia Sea. The constraint applies throughout the
18 water column: the weak stratification in this region implies that the currents include a significant
19 barotropic component that is steered along f/H contours due to vorticity conservation. Several
20 processes can overcome this topographic steering to allow property and mass transport across
21 sloping bathymetry. These processes include isopycnal mixing (intrusions at water mass
22 boundaries, and mesoscale instabilities in the circulation), channelization by cross-slope canyons,
23 buoyancy modification by ocean-atmosphere and ocean-ice interactions, and diapycnal (quasi-

1vertical) mixing that transports properties from one density range to another. These processes are
2not well documented in the Weddell-Scotia region.

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42. The DOVETAIL Program

5 The international “Deep Ocean Ventilation Through Antarctic Intermediate Layers”
6(DOVETAIL) program was organized in response to our uncertainty concerning the northward
7volume transport of Weddell Sea deep and bottom waters over the South Scotia Ridge and the
8pathways for this flow. DOVETAIL combines a multi-year field data collection program with
9numerical modeling efforts. The basic hypothesis driving the scientific investigations holds that
10the South Scotia Ridge, a topographically complex, zonally-trending ridge cut by several deep
11passages, exerts a strong control over the magnitudes and pathways of the deep water transports.
12Consequently, the program has focussed on the northwestern Weddell Sea and southern Scotia
13Sea, which includes the Weddell-Scotia Confluence region (Patterson and Sievers, 1980), and the
14passages through the South Scotia Ridge (**Figure 1**).

15 Some early DOVETAIL field results have been published (Gordon *et al.*, 2000; 2001;
16Fahrbach *et al.*, 2001). The collection of papers contained in this issue presents additional field
17results along with conclusions based on numerical modeling studies.

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193. The Collection

20 The following collection is comprised of eight contributions. Three of these present
21conclusions that are based primarily on results from numerical models. Five present analyses
22derived primarily from field observations, one supplemented by the results of an inverse box
23model study. Two of the model-based studies utilize large-scale ocean circulation models of

1 different complexity and resolution and discuss results over a broad region centered on the South
2 Scotia Ridge. These studies emphasize flow pathways and attempt to better quantify the transport
3 of Weddell Sea waters across the South Scotia Ridge. Seasonal circulation and upper ocean
4 variability is also assessed. A third model-based study utilizes a vertical model to assess upper
5 ocean water mass modifications due to interactions with a sea ice cover. The field-based studies,
6 like the model studies, address DOVETAIL objectives by attempting to better quantify the
7 pathways and exports of deep and bottom waters in the northwestern Weddell Sea. The ongoing
8 field activities already have provided an extensive database which, together with future field work,
9 will be used in an assessment of interannual to decadal variability. Deep and bottom water
10 transports are shown to vary with the regional sea ice cover extent and with the magnitude of shelf
11 water formation farther south. Simple analytical models for diapycnal mixing are applied to field
12 data and yield new insight into processes that can modify the water masses during their northward
13 transit through the South Scotia Ridge region. The energy for mixing results in part from the
14 interaction between tidal currents and the steep local topography.

15 We believe that these works significantly enhance our understanding of processes that
16 influence the production of dense water in the Antarctic Zone of the Southern Ocean and its
17 spreading into the world ocean. However, they raise additional questions which we continue to
18 address by expanding the international DOVETAIL field program beyond 2002. The initial
19 intensive, process-oriented program thrust has been replaced by a long-term, lower level effort. An
20 ongoing U.S. program of deep moored observations in the region south of South Orkney Island is
21 providing measurements of seasonal and interannual variability in the currents, temperature and
22 salinity characteristics of the deep waters there. An ongoing annual sequence of summer cruises to
23 the region as part of a Brazilian-German collaboration provides a more detailed glimpse of the

1 regional, full-depth temperature and salinity fields and allows a continued observation of
 2 interannual changes. Data analysis and modeling efforts will be performed in parallel with the
 3 field work.

4

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20 **Figure Legend**

21 **Figure 1.** Bathymetric details and geographical placenames within and surrounding the
22 DOVETAIL study region.

