The International DOVETAIL Program

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Abstract

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

1. Background

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

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

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

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

Topography is a major factor in determining the pathways through which dense water formed in the Weddell Sea can escape into the Scotia Sea. The constraint applies throughout the water column: the weak stratification in this region implies that the currents include a significant barotropic component that is steered along f/H contours due to vorticity conservation. Several processes can overcome this topographic steering to allow property and mass transport across sloping bathymetry. These processes include isopycnal mixing (intrusions at water mass boundaries, and mesoscale instabilities in the circulation), channelization by cross-slope canyons, buoyancy modification by ocean-atmosphere and ocean-ice interactions, and diapycnal (quasivertical) mixing that transports properties from one density range to another. These processes are not well documented in the Weddell-Scotia region.

2. The DOVETAIL Program

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

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

3. The Collection

The following collection is comprised of eight contributions. Three of these present conclusions that are based primarily on results from numerical models. Five present analyses derived primarily from field observations, one supplemented by the results of an inverse box model study. Two of the model-based studies utilize large-scale ocean circulation models of different complexity and resolution and discuss results over a broad region centered on the South Scotia Ridge. These studies emphasize flow pathways and attempt to better quantify the transport of Weddell Sea waters across the South Scotia Ridge. Seasonal circulation and upper ocean variability is also assessed. A third model-based study utilizes a vertical model to assess upper ocean water mass modifications due to interactions with a sea ice cover. The field-based studies, like the model studies, address DOVETAIL objectives by attempting to better quantify the pathways and exports of deep and bottom waters in the northwestern Weddell Sea. The ongoing field activities already have provided an extensive database which, together with future field work, will be used in an assessment of interannual to decadal variability. Deep and bottom water transports are shown to vary with the regional sea ice cover extent and with the magnitude of shelf water formation farther south. Simple analytical models for diapycnal mixing are applied to field data and yield new insight into processes that can modify the water masses during their northward transit through the South Scotia Ridge region. The energy for mixing results in part from the interaction between tidal currents and the steep local topography.

We believe that these works significantly enhance our understanding of processes that influence the production of dense water in the Antarctic Zone of the Southern Ocean and its spreading into the world ocean. However, they raise additional questions which we continue to address by expanding the international DOVETAIL field program beyond 2002. The initial intensive, process-oriented program thrust has been replaced by a long-term, lower level effort. An ongoing U.S. program of deep moored observations in the region south of South Orkney Island is providing measurements of seasonal and interannual variability in the currents, temperature and salinity characteristics of the deep waters there. An ongoing annual sequence of summer cruises to the region as part of a Brazilian-German collaboration provides a more detailed glimpse of the regional, full-depth temperature and salinity fields and allows a continued observation of interannual changes. Data analysis and modeling efforts will be performed in parallel with the field work.

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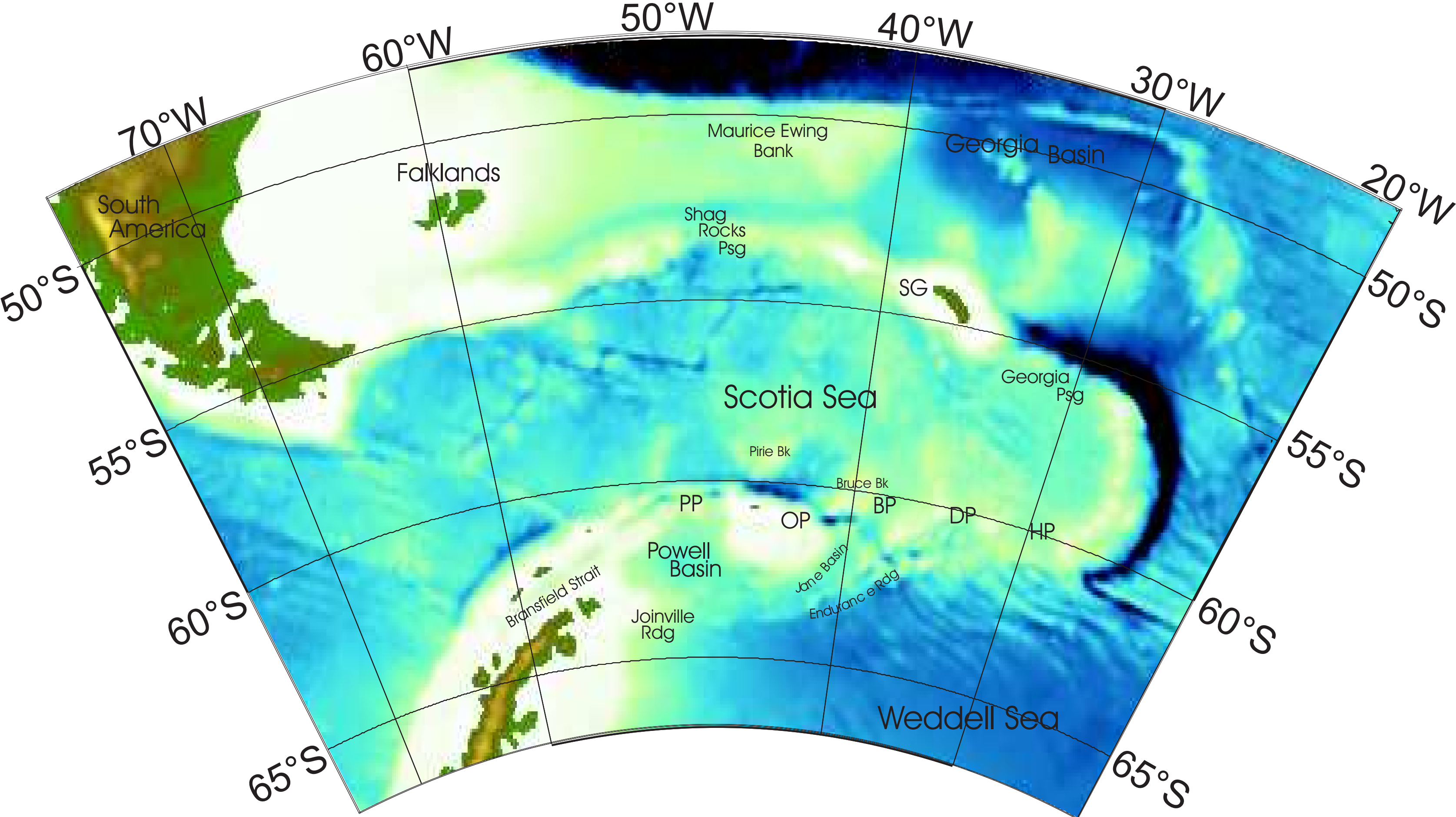
Figure Legend

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



50°W
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Maurice Ewing
Bank
Georgia Basin
Falklands
South
America
Shag
Rocks
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50°S
50°S
Georgia
Psg
Scotia Sea
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Pirie Bk
Bruce Bk
PP
OP
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Powell
Basin
Jane Basin
Endurance Rdg
Bransfield Strait
Joinville
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