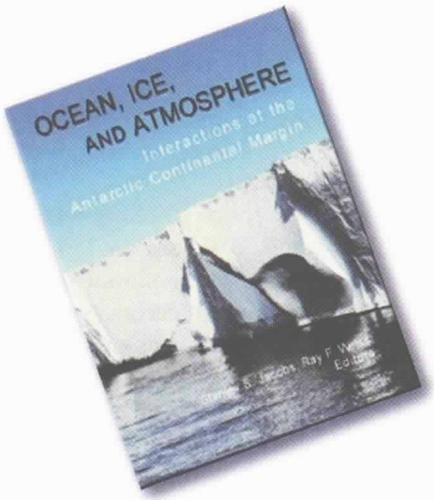
Book Reviews



Ocean, Ice, and Atmosphere: Interactions at the Antarctic Continental Margin

Stanley S. Jacobs, Ray F. Weiss, Editors
American Geophysical Union
380 pp. ISBN 0-87590-910-8

Review by
Tom Curtin
Office of Naval Research, Arlington, Virginia USA

This volume is the seventy fifth in the Antarctic Research Series published since 1963 by the American Geophysical Union. This volume is a 380-page collection of twenty peer-reviewed papers focused mostly on currents and water masses on the continental margin around Antarctica. The Antarctic shelf is unique in its extent and impact on the global ocean. Relatively deep, typically 400 meters, this shelf has a sill at the shelf break in many places. Seaward, the continental slope averages three to six degrees down to abyssal depths at four to five kilometers. In most places, the bathymetry is unresolved at less than ten kilometer scales. Smaller scale features such as submarine canyons are in evidence and of likely import to offshelf transport. The volume includes a composite 1:3,000,000-scale bathymetric chart of the entire southern Weddell Sea synthesized from a number of different data sources by Hinze and Hoppman. Six 1:1,00,000-scale component charts are included in the GEBCO Digital Atlas. Depth accuracies range from 50 to 200 meters.

Whitworth et al., in an analysis of 3544 historical hydrographic stations elucidates the subtleties of Modified Circumpolar Deep Water (MCDW) in its transit around the continent. Modifications occur at the Antarctic Slope Front, a ubiquitous feature near the shelf break associated with the Antarctic Circumpolar Current. Inshore of this Front, brine rejection from sea ice formation, particularly persistent in coastal polynyas, produces relatively dense High Salinity Shelf Water. MCDW mixes with saline Shelf Water to produce water found at the bottom of the shelf edge. Subsequent sinking of this water along the slope, entraining warmer, saltier CDW, produces Antarctic Bottom Water. This comprehensive analysis adds detail to and supports Gill's earlier (1973) hypothesis on the process of bottom water formation. Baines and Condie review both observational and modeling studies, and identify six possible mechanisms producing downslope transport of dense water. Evidence suggests the Weddell Sea as the site of the most active, persistent and largest downslope flows.

In the western Weddell Sea, Gordon concludes that bottom water formed in recent decades is less saline than previously, consistent with an increase in production of Ice Shelf Water, which in turn is a mixture of glacial meltwater and High Salinity Shelf Water. Chlorofluorocarbon and tritium data analyzed by Mensch et al. quantifies the production rate for Weddell Sea Deep and Bottom Waters at about five Sverdrups, and the mean residence time of contributing shelf waters at about six years. The tracer data clearly points to a large source area for bottom water in the western Weddell Sea.

In contrast, on the west Antarctic peninsula continental shelf, Hofmann and Klinck find no evidence for the formation of dense shelf water in 1993–1994. Water properties on the outer shelf here are influenced most by meandering of the Antarctic Circumpolar Current, which is closer to the shelf break in this region than any other around the continent. Wind forcing is minimal, and water properties seem to be determined by horizontal mixing.

In the Ross Sea, Jacobs and Giulivi synthesize a variety of data sources to describe interannual variability and trends over several decades in currents, water masses and sea ice extent. Regional air temperatures have increased by 0.25°C and shelf water salinities have decreased by 0.03°C per decade since the late 1950s. An Antarctic version of the "Great Salinity Anomaly" appears to be in the making, with consequences on deep convection and high latitude ecology. In Prydz Bay, Wong et al. speculate on a high salinity type of Antarctic Bottom Water, similar to Ross Sea Bottom Water, that may be formed locally. Along the Adelie coast, Rintoul finds that deep water cooled and freshened by bottom and near-bottom water ventilates the abyssal layers of the eastern Indian and South Pacific Oceans. Up to 25% of the global ocean volume cooler than 0°C can be attributed to an Adelie Land or equivalent source.

Sea ice formation processes producing High Salinity Shelf Water include dramatic surface polynya factories and subtler centimeter scale ice platelet formation at depths of hundreds of meters due to rising supercooled water. Bombosch's model shows that the interactions between rising ice crystals and ambient water depend strongly on prevailing thermohaline conditions. Certain recirculation conditions can result in steady salinization of the water masses, as well as a thickening of the ice cover. Observed five-meter thick aggregations of ice platelets containing deep microorganisms indicate that this process may be significant at times. The production of High Salinity Shelf Water can also be suppressed by inhibiting sea ice formation. One mechanism affecting this is an increase in sea ice concentration in the convergence zone upstream of large grounded icebergs. Nost and Osterhus document such a case on the Berkner Shelf. The transient nature of this event allows estimation of residence times. Within the Filchner Depression, the residence time of High Salinity Shelf Water is less than two years, less than a third lower than on Weddell Sea shelves. Clearly, mixing processes are more energetic in this region.

Besides producing icebergs that modulate sea ice formation, glaciers impact Antarctic Surface Water properties by subsurface melting processes. In addition to its role in frontogenesis at the shelf break, Circumpolar Deep Water brings heat to the base of calving, deep-rooted glaciers such as in Pine Island Bay. Hellmer et al. estimate melt rates in excess of 10 m/yr based on observations and a two dimensional model.

In the eastern Weddell Sea, Heywood et al. document the importance of glacial ice melt using its oxygen isotope signature which is associated with a temperature minimum core strongest in summer above the continental slope around 17°W. They suggest monitoring the volume transport of this water mass as a climate change indicator.

About 44% of the area of the Antarctic continental shelf is covered by ice shelves. Williams et al. review the state-of-the-art in modeling ocean circulation beneath ice shelves, identifying the current need for a high resolution, three dimensional, thermohaline model with tidal forcing. Although there is some consensus among models on melting and freezing patterns, assessment of model accuracies is critically limited by sparse observations. Insight to date relies on observations such as those by Nicholls and Makinson through three drilled holes on the Ronne Ice Shelf. They find deep, seasonal variability hundreds of kilometers inshore of the ice front. The associated flow appears to be a fully developed baroclinic eddy field. Further evidence of sub-ice-shelf, energetic ocean circulation is provided by Grosfeld et al. who add the Filchner Ice Shelf to the Amery and Ronne Ice Shelves as one that is underlain by a large body of marine ice, which, in the mean, is estimated to be melting at a rate of 0.35 m/yr. In Prydz Bay, Wong et al. clearly demonstrate that all the mass divergence of the Lambert Glacier-Amery Ice Shelf system can be accounted for by melting of the ice shelf by warm ocean waters.

Wind, buoyancy and tides force local circulation and mixing. Using a two-dimensional, primitive equation, coupled air-ice-ocean model of the Antarctic katabatic wind system, Goodrick et al. identify two scales of atmosphere-ocean interaction. On the geostrophic adjustment scale, the atmospheric easteries produce both a barotropic and baroclinic westward flowing current resulting from shoreward Ekman transport.. Offshore, the curl of the wind stress contributes substantially to upwelling. Locally, offshore winds initially open coastal polynyas, but geostrophic adjustment and convective circulation make these short lived. While the model results seem anecdotally consistent with observations, no attempt is made to rigorously compare them with data. For the Ross Sea polynya, Bromwich et al. show that 60% of the polynya events (open-water-fraction anomalies) are correlated to katabatic surge events for the winters of 1988-1991. Their study documents the high interannual and spatial variability of the atmospheric forcing fields, implicating the limitations of a two dimensional model.

Robertson et al. provide a carefully validated, four constituent tidal model of the Weddell Sea. Typical tidal currents (10 to 75 cm/sec) are two to ten times greater than mean flows associated with wind and thermohaline forcing. Amplitudes exceed one meter under the ice shelves nearshore. The energy loss to bottom stress over the entire domain is 86 GW. An additional 33 GW may possibly be lost by the generation of baroclinic tides.

Readers should approach this book as they do thematic, special issues of journals. The collection represents the state-of-the-art in specific interactions at the Antarctic continental margin. It is not a comprehensive, cohesive review of the subject. The volume could be better organized around water mass, ice shelves, glacier, sea ice and forcing themes. Out of place is a paper by Penrose who reviews the role of various acoustical observation methods in Antarctic oceanography without presenting any new results.

I came away impressed with how far we have come and how far we have to go. High resolution portraits provide new insight into the structure and dynamics of some important processes, consistent in most cases with mechanisms postulated by early pioneers based on sparse bottle casts. Yet existing data sets are still too sparse to test dynamical hypotheses, and the resolution of ocean general circulation models is still too coarse to resolve the candidate mechanisms producing the water masses occupying most of the oceans.