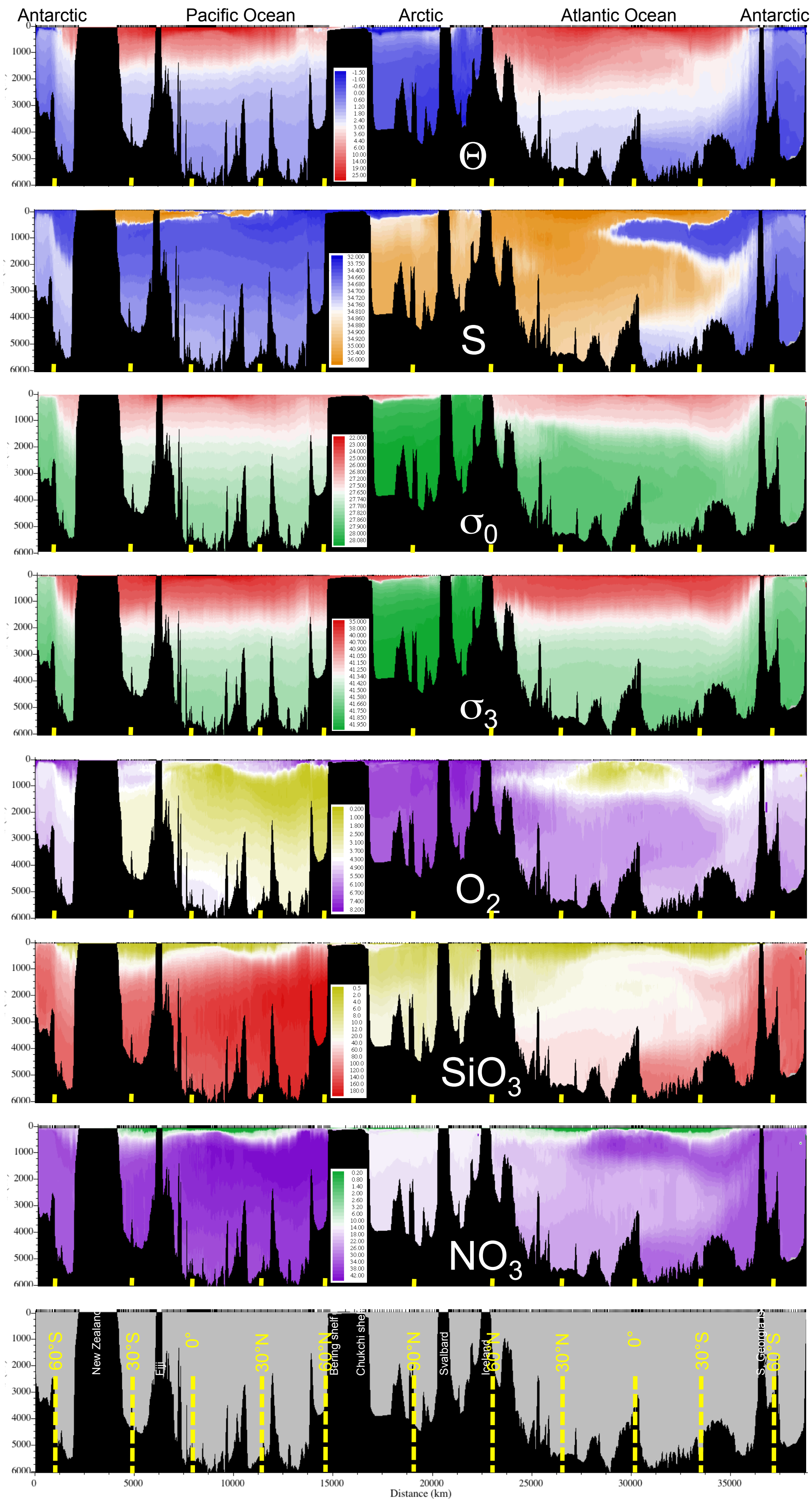
A 'Grand Tour' cross section of the World Ocean

The global section was assembled from 675 full-depth hydrographic profiles beginning northwest of the Ross Sea, north through the Pacific and Bering Sea, crossing the Arctic Ocean and Nordic Seas, south through the Atlantic Ocean, and on through the Weddell Sea. The results show clearly the primary physical regimes of the World Ocean in relation to source regions and bathymetry. [Vertical axis = pressure (db) (≈ meters), exaggeration ≈ 1300:1]



The global waters

The plot of potential temperature (potential temperature contains a small pressure-related correction to *in situ* measured temperature) shows what we expect for the surface waters: warmest in the tropics and coldest in the polar regions. (The extension into the Nordic Seas of warm water from the Atlantic is hidden by the section location but shows up near Svalbard.) Along with the plot of salinity this shows quite clearly that the North Atlantic Ocean is overall the saltiest and warmest of the oceans. The reasons for this are to some extent still debated but focus on geography: The Mediterranean Sea (not on this plot) takes relatively fresh surface waters in and returns very salty water to the Atlantic. And the Nordic Seas take in relatively salty surface waters, cool them, and return them at great density, filling the North Atlantic abyss with salty waters. Other factors include precipitation and circulation patterns.

Density is shown with reference to both 0 and 3000 db (use the latter to compare deep densities.) The most obvious global deformation in the density field is the huge upward adjustment in the Antarctic region where the Antarctic Circumpolar Current runs from west to east around Antarctica. The deep isopleths are compelled by the field of motion and the earth's rotation to rise close to the surface around Antarctica, where they are cooled and exchange gases. A huge tongue of relatively fresh Antarctic Intermediate water intrudes from the Antarctic into the South Atlantic at ca. 1000 meters. A similar but less dramatic tongue in the South Pacific does not show in salinity with this color scheme. A slightly more subtle deformation in the density field is seen in the bowl shaped regions of less dense water in the upper layers in the subtropics of each of the oceans.

At any given level the densities of the Arctic Ocean and Nordic Seas are the greatest in the World Ocean. This occurs primarily because already-salty surface waters enter the Nordic Seas and are cooled there, so the unique combination of cold and salt makes them very dense. Winter convection can reach to near the bottom there, but the Greenland to Scotland Ridge retains the densest waters north of Iceland. Some very dense, cold, salty water does spill out. Where the overflows abut the remnants of Antarctic-source bottom waters in the North Atlantic these mix to form the lower North Atlantic Deep Water.

Where the salt carried by North Atlantic Deep Water influences the Antarctic circumpolar waters, and in turn where these relatively salty waters are brought near the surface by the patterns of circulation (for example in the Weddell Sea), the Antarctic forms its densest waters, aided by shelf processes there that provide extremely cold waters. The present vigor of the overturning circulation seems to owe much to the North Atlantic, although the volume of Antarctic-derived waters exceeds those of direct Atlantic origin.

The dissolved oxygen section is useful to better understand ventilation. Cold surface waters can absorb more oxygen than can warm waters, so surface oxygen concentrations are highest in the polar regions. Convection of the surface waters in the Nordic Seas has at times reached to near the bottom in the Greenland Sea. Thus within the Nordic Seas and Arctic Ocean the entire water column exhibits high concentrations of dissolved oxygen.

When this water spills over the Greenland-Scotland Ridge, it carries its high oxygen concentrations into the deep North Atlantic, where with other high oxygen dense waters (mostly from the Labrador Sea) and mixed-in bottom waters of Antarctic origin it forms the huge mass of high-oxygen North Atlantic Deep Water. This water spreads south into the South Atlantic and contributes high oxygen and high salinity to the Antarctic circumpolar region, traceable even to the South Pacific (note on the salinity section the very deep tongue of slightly higher salinity water — the lighter blue color — in the far South Pacific). The North Atlantic Deep Water thus refreshes or ventilates the deep World Ocean layer from about 1500-3000 meters.

But note the near-bottom tongues of dense water extending into the Atlantic and Pacific from the Antarctic. Although the Antarctic upper layer waters are as a whole relatively fresh, some are saltier than others and when they get very cold they can become quite dense. These are less severely restricted by submarine ridges in spreading north than the Arctic deep waters are in spreading south, so much of the abyssal World Ocean is filled from the densest available Antarctic waters. And the Antarctic Intermediate Water is a very important ventilator at its level of the oceans.

Where phytoplankton thrive they use up dissolved nutrients (such as nitrate, phosphate, and to some extent silicate) and produce oxygen. So the surface waters can become very low in nutrients and very high in oxygen. When these or other organisms die and decay, the process yields nutrients, which redissolve, and uses up oxygen. This decay often takes place in the subsurface waters, and so subsurface waters under and/or downstream from some productive regions can become very high in nutrients and very low (near zero concentrations) in dissolved oxygen. Mostly the siliceous organisms thrive in cold waters and so are more common in the polar regions, where their exoskeletons rain out of the upper layer to redissolve underneath or to join the sediment, which also re-dissolves into the ocean waters.

Recalling that the deep North Pacific is the farthest removed from the surface-generated sources from the Nordic Seas and the Antarctic, it is no surprise that the concentrations of these nutrients are highest in the deep North Pacific. The large proportion of siliceous organisms there and the high productivity of some North Pacific regions combine to generate a huge silicate tongue in the deep North Pacific. In contrast, the North Atlantic, though exhibiting some deep nutrient enrichment, is well ventilated by high oxygen, low nutrient surface waters convecting deep in the Nordic Seas and overflowing the Greenland-Scotland submarine ridge, so average nutrient concentrations in the North Atlantic Deep Water are much lower than in the deep Pacific Ocean. As the dense northern waters spread south the nutrient concentrations increase by regeneration and by mixing with Southern source waters.

Suggestions for further examination of the global ocean

Plots of anthropogenic substances such as CFC-11 and CFC-12 (and their ratio) are useful for visualizing some time scales related to the global circulation and exchanges. Also illuminating are plots of nutrient ratios (e.g., NO4/PO4 or NO/PO), ocean carbon parameters (total dissolved inorganic carbon and total alkalinity), dissolved oxygen saturation, and the relative contributions of temperature and salinity to density (α • dT/dz and β • dS/dz).

About this document

The sections and discussion were prepared by Jim Swift (Scripps Institution of Oceanography; jswift@ucsd.edu) using the Java OceanAtlas application. The data files and documentation are available at http://joa.ucsd.edu/data/best.html under 'Global Ocean'.