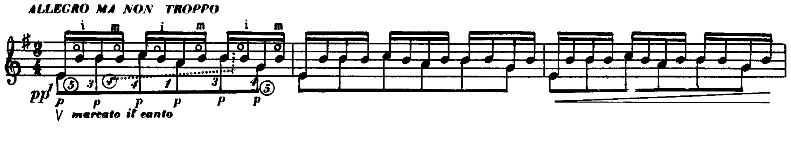
Chapter 6

THE THERMOHALINE CIRCULATION



Excitement from down the bottom right to the top.
Asturias, Isaac Albeniz.

In chapter 1, a caricature was provided of the three-dimensional circulation as a 'conveyor belt' driven by both the wind-stress forcing and buoyancy fluxes at the ocean-atmosphere interface. In this chapter, focus will be on the thermohaline component of this circulation, i.e., that associated with the transport of heat and salt. The motivation to study the thermohaline circulation (THC) in isolation is that the ocean flow transitions which may have been responsible for rapid climate changes in the past, strongly involved this component of the circulation.

In section 1.2, the mean state of the present global ocean circulation and its associated heat and freshwater fluxes were presented. This chapter starts with a slightly more detailed description of long term variability of this circulation, with focus on the North Atlantic (section 6.1). As in previous chapters, the description of observations is far from complete and other sources should be consulted to obtain an adequate feeling for the complexity of this circulation (Schmitz, 1995; Wunsch, 1996; Ganachaud and Wunsch, 2000; WOCE, 2001). In section 6.2, potential mechanisms of changes in the THC, both in the time-mean state as well as variability around this mean state are considered. The next sections, 6.3 to 6.9, follow a path through the model hierarchy of the THC, touching on two-dimensional models in the sections 6.3 to 6.5, zonally averaged models in section 6.6 and ending with low-resolution general circulation models in the sections 6.8 to 6.9.

6.1. North Atlantic Climate Variability

Over the years and with use of data from international measurement programmes, such as the World Ocean Circulation Experiment (WOCE, see http://oceanic.cms.udel.edu/woce/), a more and more detailed picture of the global ocean circulation is emerging. In WOCE (2001), many of the results from this programme are nicely summarized and put into context with historic observations and results from ocean models.

6.1.1. Observations

Properties of the zonally integrated time-mean flow at several sections in the Atlantic were briefly summarized in section 1.2. The strength of the Atlantic meridional overturning circulation (MOC) at 25°N is estimated to be 16 ± 2 Sv. The heat transport associated with the MOC is positive at every latitude in the Atlantic with a maximum of 1.3 PW at about 25°N. The freshwater transport is southwards in the Atlantic with a typical amplitude of 0.9×10^9 kgs^{-1} at 25°N.

The seasonal variability of the MOC and the physical mechanisms causing this variability are discussed in Jayne and Marotzke (2001). From the very few observations available, estimates of the peak-to-peak seasonal meridional heat transport variations in the midlatitude North Atlantic are about 0.6 PW $\pm$ 0.1 PW (Baringer and Molinari, 1999). At 36°N, the wind (Ekman) induced heat transport is the dominant contribution (Sato and Rossby, 2000), but at 24°N baroclinic processes are likely to be important since this latitude is near the node of the seasonal cycle of wind stress.