1.3 The ocean

1.3.1 Composition and properties

The ocean has a major impact on the climate of the atmosphere. It covers approximately 71 per cent of the Earth's surface and thus has a dominant role for transfers of energy and other properties between the atmosphere and the Earth's surface. Its large heat capacity, made accessible for surface energy transfers by circulations within the ocean, provides a moderating effect on temperature variability in the atmosphere. Oceanic currents transfer large amounts of heat energy away from equatorial regions. Finally, the ocean is an important source for atmospheric water vapour, as well as a source and sink for other greenhouse gases.

The ocean's heat capacity exceeds that of the atmosphere by a factor of the order of 1000. This is due to differences both in heat capacity per unit mass (the specific heat of liquid water is about four times that of air), and in total mass between the ocean and atmosphere. The ocean's heat capacity bears upon atmospheric temperature through oceanic transports (both horizontal and vertical) that produce and maintain surface water temperatures warmer or colder than the atmosphere resulting in large heat transfers. The depth to which the oceans interact with the atmosphere depends on the time scale under consideration. For diurnal variations the depth is small, of the order of five to 10 meters. For seasonal variations, the depth is 20-200 meters (the depth of the well-mixed oceanic surface layer). The ocean is a major component in determining the climate and its variations for annual, annually-averaged and longer period conditions. The strong influence of the ocean on surface air temperature is clearly evident.

The oceanic condition is different from the atmosphere in two fundamental ways. First, the primary forcing of the ocean is at the upper boundary, whereas the primary forcing for the atmosphere is at its lower boundary.

Atmospheric winds above the ocean are a major factor in causing ocean surface currents through surface friction processes. In contrast, for the atmosphere frictional conditions at its lower boundary tend to reduce atmospheric motion. Second, the density of the ocean water is determined primarily by its salinity and temperature instead of pressure, temperature and water vapour content as in the atmosphere. The water vapour factor is relatively unimportant for atmospheric density except in hot and humid conditions. On the other hand, salinity can play a major role for ocean density especially when temperatures are near freezing in which case density changes very little with temperature. Salinity conditions in polar ocean regions are important for determining whether or not significant vertical motions occur in local areas (see figure 1.4).

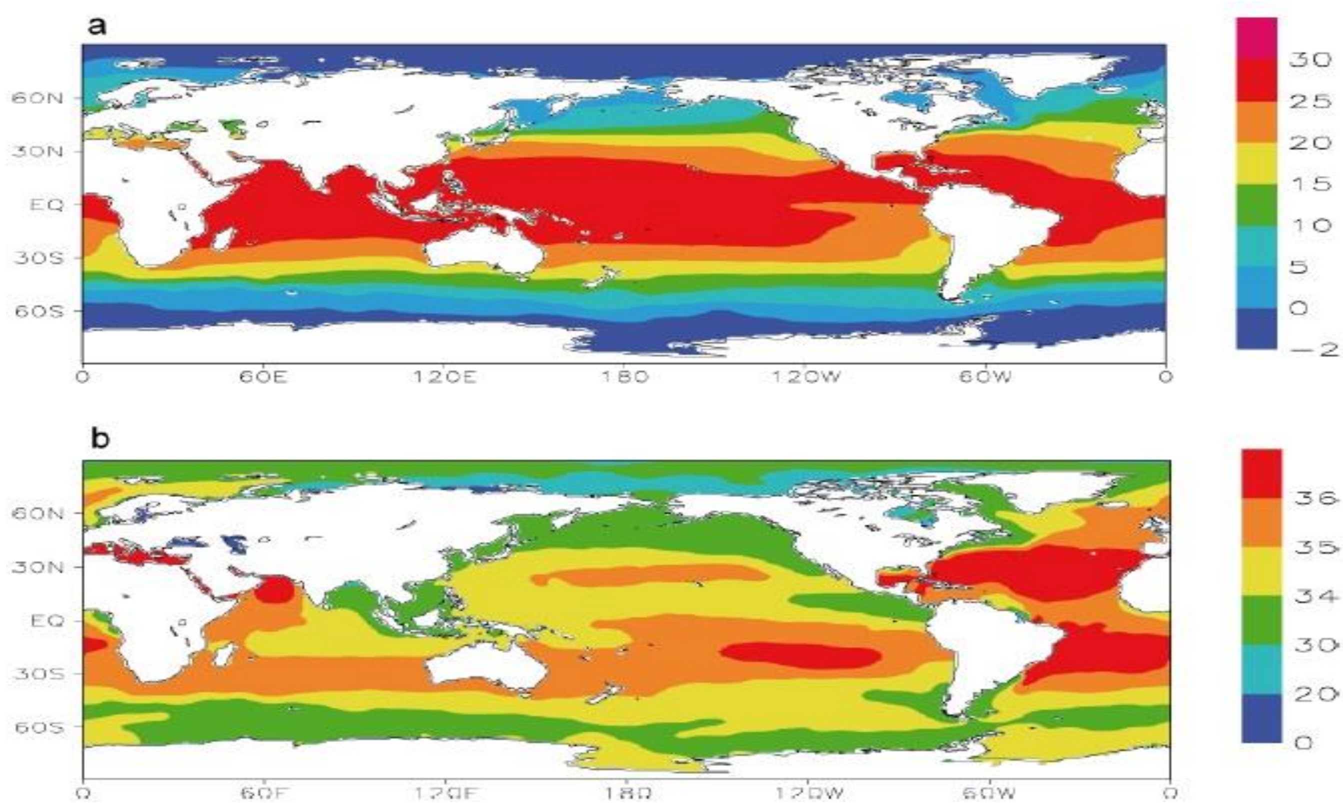

Figure 1.4: *(a) Annual mean sea surface temperature (°C) and (b) surface salinity (psu). Data source: Levitus (1998).*

1.4 The cryosphere

1.4.1 Components of the cryosphere

The cryosphere is the portion of the Earth's surface where water is in solid form. It thus includes sea ice, lake ice and river-ice, snow cover, glaciers, ice caps and ice sheets, and frozen ground. The snow cover has the largest extent, with a maximum area of more than 45 10^6 km2 (Table 1.1). Because of the present distribution of continents, land surfaces at high latitudes are much larger in the Northern Hemisphere than in the Southern Hemisphere. As a consequence, the large majority of the snow cover is located in the Northern Hemisphere (Figs. 1.5 and 1.6). The same is true for the freshwater ice that forms on rivers and lakes in winter. Both the snow cover and freshwater ice have a very strong seasonal cycle, as they nearly disappear in summer in both hemispheres (Table 1.1).

Table 1.1: Areal extent and volume of snow cover and sea ice. Data compiled in Climate and Cryosphere (CliC) project science and co-ordination plan (2001).

Component	Maximum area (10^6 km^2)	Minimum area (10^6 km^2)	Maximum Ice volume (10^6 km^3)	Minimum Ice volume (10^6 km^3)
Northern Hemisphere Snow cover	46.5 (late January)	3.9 (late August)	0.002	
Southern Hemisphere Snow cover	0.83 (late July)	0.07 (early May)		
Sea ice in the Northern Hemisphere	14.0 (late March)	6.0 (early September)	0.05	0.02
Sea ice in the Southern Hemisphere	15.0 (late September)	2.0 (late February)	0.02	0.002

The cryosphere — the ice component — has significant impacts on the climate system in several ways. It affects radiative and sensible heat transfers at the Earth's surface. It influences temperatures in the ocean and at the Earth's surface due to transfers between latent and sensible energy during melting and freezing. Finally, its melting and freezing influences water runoff from land and ocean salinity. Ice and snow exist primarily in the latitudes poleward of 30 degrees latitude and are thus are unfamiliar to the majority of the world's human population. Although only about two per cent of all the water on Earth is frozen, it covers an average of 11 per cent of the world's land surface and seven per cent of its oceans. There are many constituents to the cryosphere: land ice in polar ice sheets, glaciers, permafrost, frozen ground, seasonal snow cover and sea ice.

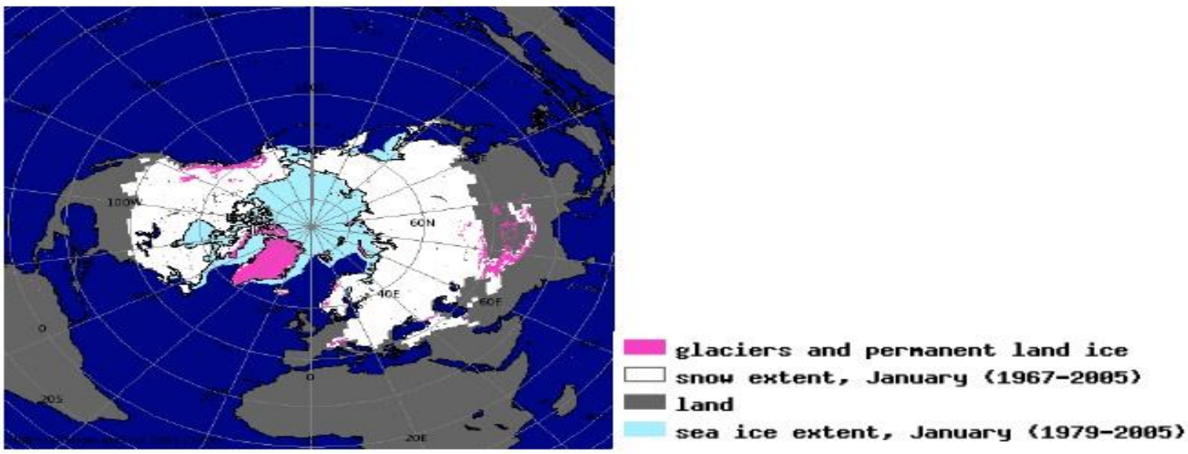

Figure 1.5: *The distribution of sea ice, snow and land ice in January in the Northern Hemisphere.*

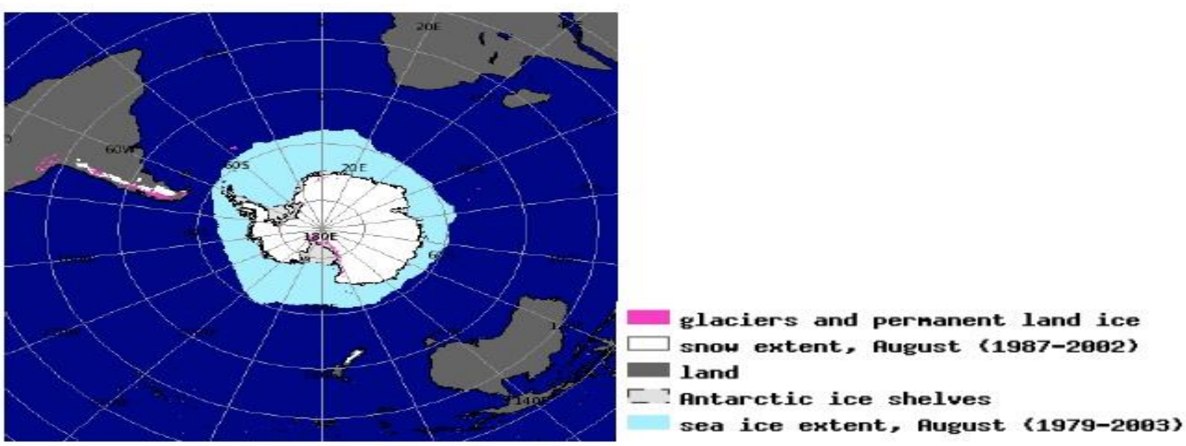

Figure 1.6: *Location of sea ice, snow and land ice in August in the Southern Hemisphere.*