Chapter 1

Basic processes near the air–sea interface

1.1 Introduction

The ocean–atmosphere system is intrinsically coupled, although feedbacks across the air–sea interface are often masked by temporal and spatial differences. Interactions between the ocean and atmosphere occur at the air–sea interface. The ocean surface forms a barrier to the exchange of heat, moisture, momentum and trace constituents (Rogers, 1995). The fundamental processes that connect the atmosphere and ocean are the energy input to the ocean by the wind, the net freshwater flux, expressed as precipitation and evaporation, and the net surface heat flux. The oceans play a substantial role in the changing radiative balance of the Earth and the climate. In particular, they affect gas and aerosol concentrations in the atmosphere as well as contemporary fluxes from the atmosphere to the ocean and from the ocean to the atmosphere. The energy from the atmosphere to the ocean surface enhances mixed layer during the circulation of the upper ocean. On the other hand, energy from the ocean affects atmospheric circulation, weather and climate. Among the influences of the oceans is their effect on gas and aerosol concentrations in the atmosphere. The global ocean is known to be a net sink of anthropogenic CO$_2$ and hence the oceans have effectively slowed the build-up of this greenhouse gas in the atmosphere.

Recently, the importance of connecting small-scale process studies, investigating the exchange of heat, moisture momentum and trace constituents across the air–sea interface, with the large-scale processes of global climate change and ocean circulation has been highlighted. The small-scale exchange processes are related to the global-scale problems via flux parameterizations measured at the sea surface or from satellites. It is convenient to divide air–sea interaction studies into two categories: small- and large-scale ocean–atmosphere interactions. From the large-scale perspective, quantifying and understanding the sources and sinks in the coupled ocean–atmosphere system and corresponding fluxes is
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a key to determining the role played by the ocean in the global climate system. Through the late 1950s, large-scale field programmes and open ocean measurements of the fluxes were carried out, such as the Barbados Oceanographic and Meteorology Experiment (BOMEX), Atlantic Trade Winds Experiment (ATEX), Global Atmospheric Research Program Atmospheric Tropical Experiment (GATE), Joint Air-Sea Interaction Experiment (JASIN), Marine Remote Sensing Experiment (MARSEN), Storm Transfer and Response Experiment (STREX), Humidity Exchange Over the Sea (HEXOS), Marginal Ice Zone Experiment (MIZEX), Frontal Air-Sea Interaction Experiment (FASINEX), TOGA COARE experiment, and the Surface of the Ocean, Fluxes and Interactions and Atlantic Stratocumulus Transition SOFIA/ASTEX experiment (Rogers, 1995). The reader is referred to Geernaert (1990) for a more detailed overview of these studies and their results.

For the purpose of this book, the connecting small-scale processes such as the exchange of mass, heat, moisture, momentum and trace constituents across the air–sea interface are the most important. An understanding of the processes at the air–sea interface requires knowledge of how energy is transferred across the stable layers connecting the interiors of the ocean and atmosphere with their respective boundary layers.

1.2 Sea water

1.2.1 Water on Earth

The most important liquid on Earth is water. Water is a ubiquitous, life-sustaining substance covering 71% of the Earth surface. Of the Earth’s total water content, some 97.2% is contained in the oceans, 2.15% is stored in ice sheets and glaciers, 0.62% is ground water, and only 0.03% flows through rivers, streams and fresh-water lakes (Strahler and Strahler, 1992). For major portions of the Atlantic, Pacific and Indian oceans, the average depth is nearly 4 km, but it is the surface water, together with the very small amount of ground water, that supports all life on land and in the oceans.

Evaporation from the oceans, which are the basic reservoirs of free water, is approximately 419,000 km$^3$/year, while evaporation from soil, plants and water on the continents is only about 69,000 km$^3$/year. The total quantity of the evaporated water, 488,000 km$^3$/year, must be returned annually to a liquid or solid state through precipitation over the oceans and continents. Precipitation over continents is about 37,000 km$^3$/year greater than evaporation. This excess of quantity flows over or under the ground to reach the sea. The hydrologic cycle is pronounced evidence of the strong link between the atmosphere and ocean. The input of energy from the atmosphere drives water motion in the form of waves and currents. Moreover, through the ocean surface, oxygen and carbon dioxide – gases vital for the growth of marine organisms – enter the ocean from the atmosphere. In contrast to the upper ocean layer, at great ocean depths