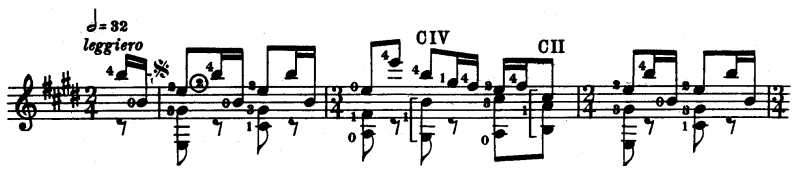
Chapter 5

THE WIND-DRIVEN CIRCULATION



Sailing on the Gulf Stream, but not too rough !
English Suite, J.W. Duarte.

An important problem in physical oceanography is to understand the physics of the time-mean surface ocean circulation and the variability of this circulation on time scales from several months to several years. Focus of this chapter is on the Kuroshio in the North Pacific Ocean and the Gulf Stream in the North Atlantic Ocean which are the major northern hemispheric western boundary currents. The mean position of these currents is important for the global climate system and for both regions relatively many observations are available. The midlatitude surface ocean circulation has also been extensively studied theoretically using a wide range of ocean models (Kraus, 1996). Although the basin of the North Pacific has larger dimensions than that the North Atlantic, the time-mean wind-stress forcing is very similar and a close dynamical correspondence between both western boundary currents can be expected.

In section 5.1, a brief description is given of the flow phenomena in both the Gulf Stream and Kuroshio regions motivating the problems studied later on. These problems are (i) the separation of the Gulf Stream near the North American coast, (ii) the different time-mean paths of the Kuroshio near the Japanese coast, and (iii) the variability of both the Gulf Stream and Kuroshio on subannual-to-interannual time scales. At the end of this introductory section, the questions related to these problems are formulated from a dynamical systems perspective.

Section 5.2 introduces a hierarchy of ocean models of the wind-driven circulation (WDC) using a 'top-down' approach, i.e., starting with the most complex model and ending with a very elementary model. In the sections 5.3 to 5.7, bifurcation analysis is applied to this hierarchy of models, using a 'bottom-up' approach. In this way, the consequences of the relevant physical processes on the behavior of the circulation in the North Atlantic and North Pacific can be systematically determined. In the last sections 5.8 and 5.9, it will be evaluated whether the bifurcation analyses provide a framework to understand results from high-resolution ocean models and phenomena deduced from observations.

5.1. Phenomena

A sketch of the global surface ocean circulation was given in section 1.2.1 (Fig. 1.12). In the North Atlantic Ocean, the Gulf Stream is seen as an eastward jet forming part of two recirculating gyres, the subtropical and subpolar gyre. The Kuroshio takes the same role as the western boundary current in the North Pacific. In this section, more detail of the flows in the Gulf Stream and Kuroshio regions is provided. The description below is very limited and readers can consult Wunsch (1996) and WOCE (2001) for more details and references.

5.1.1. Gulf Stream

A sketch of the geography and bathymetry in the region of interest with the different currents is given in Fig. 5.1. The time-mean position of the Gulf Stream has fascinated oceanographers since its early description by Benjamin Franklin and Timothy Folger (Richardson, 1980). From the enormous amount of data obtained since then, from ships and satellites, the time-mean path of the Gulf Stream is