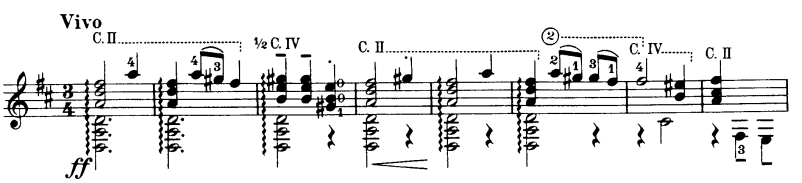
Chapter 3

A DYNAMICAL SYSTEMS POINT OF VIEW



Capturing all flavors of development.
Valse, M. Ponce

Transition phenomena which occur in model solutions as parameters are varied can be analyzed in detail using concepts and techniques of the theory of dynamical systems. Being a qualitative theory, its concepts are powerful and they provide a strong link to the physics associated with the transition behavior. It is through the latter that complexity in irregular flows can be understood. In section 3.1, the qualitative theory is introduced through an elementary but oceanographically relevant problem, dealing with different density-driven flows under similar forcing conditions. Although there are many textbooks available on dynamical systems theory, many of them are too mathematical to be readily accessible to oceanographers and other geoscientists. In the remainder of this chapter, an overview of the more abstract qualitative theory is given with such a reader in mind. Hence, quite elementary mathematics is used and where possible, links with the example in section 3.1 are given.

3.1. An Elementary Problem

As was discussed in chapter 1, there is heat input at low latitudes and heat loss at higher latitudes in the North Atlantic Ocean. This causes a density driven surface flow from the equator to the poles because of sinking of the colder water in the north (Fig. 3.1, left panel). On the other hand, there is substantial evaporation at low latitudes which increases the salinity of the low-latitude water and hence its density. If there was no meridional temperature gradient, an equatorward density-driven surface flow would result, because water would sink near the equator (Fig. 3.1, right panel). The fact that the surface freshwater flux and heat flux have opposing effects on the large scale ocean circulation raises the interesting question: What happens if the circulation is driven by both surface fluxes?

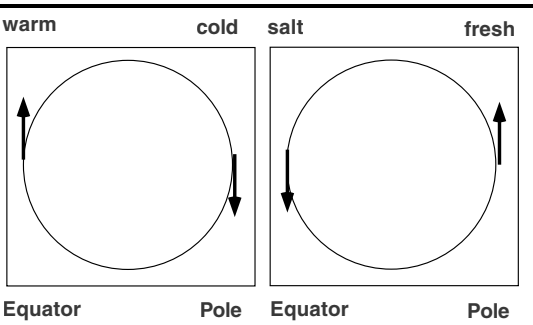


Figure 3.1. Sketch of temperature (left panel) and salinity (right panel) driven (ocean) circulation patterns in a single equator-to-pole basin.

3.1.1. The Stommel two-box model

In the model proposed by Stommel (1961), this problem is studied in its most essential form, using two boxes having volumes V_p and V_e. These contain well-