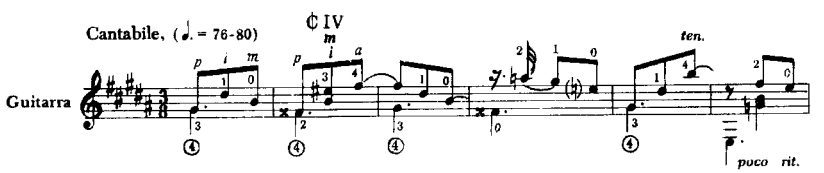
Chapter 1

INTRODUCTION



Patterns and their rhythms fill the spheres.
Evocation. Preludios Americanos I, A. Carlevaro

At the beginning of this century, the concept of 'climate' belonged to meteorologists and was considered to be a long term average state of temperature and precipitation. Later, other quantities were added to describing the average state of the atmosphere more accurately. At the moment, the atmosphere is considered to be only one of the components of a larger entity. The atmosphere (the world of air) together with the hydrosphere (the world of water), the cryosphere (the world of ice), the biosphere (the world of living beings) and the lithosphere (the world of the solid Earth) can be logically studied as one system: the climate system.

Earth's climate system displays variability on a multitude of time scales. Over long periods in Earth's history, large parts have been covered with ice, with warmer periods in between. On the very short time scale, the fluctuations of the weather on a day to day basis are experienced. In this first chapter, some motivating examples of climate variability are described. In particular, examples are chosen for which it is very plausible that changes in the ocean circulation are or have been involved.

In section 1.1, a short description of the history of Earth's climate sets the context for the discussion of the Younger Dryas event and the Little Ice Age period. Both phenomena illustrate that climate can undergo relatively rapid transitions which are not expected *a priori* from changes in the forcing conditions. In section 1.2, the present large-scale ocean circulation is introduced by sketching its forcing, the mean circulation patterns and the associated transport of heat and freshwater. Section 1.3 contains a brief description of two climate phenomena of current interest, the El Niño /Southern Oscillation in the Tropical Pacific and the Atlantic Multidecadal Oscillation. In both phenomena, there are significant changes in the sea-surface temperature and the ocean circulation. The central questions addressed in this book, and a motivation for the approach chosen towards possible answers, follows in section 1.4.

1.1. Past Climate Variability

Until fairly recently, the climates of the past had been described only qualitatively. At the moment, many techniques are available to construct climatic records from geological, biological and physical data (Bradley, 1999). Much information has been obtained through measurement of isotope content (such as oxygen and carbon isotopes) in material derived from ocean sediments and from ice cores. Accurate dating techniques are essential to interpret these measurements. For example, the carbonate in shells of marine organisms (e.g., foraminifera) and water in ice caps contain two isotopes of oxygen, ^{18}O and ^{16}O. The normalized isotope ratio $\delta^{18}O$ is calculated as a deviation from a reference sample as

$$\delta^{18}O = \frac{(\frac{^{18}O}{^{16}O})_{sample} - (\frac{^{18}O}{^{16}O})_{reference}}{(\frac{^{18}O}{^{16}O})_{reference}}$$

where the reference sample is different for ice cores (i.e., standard mean ocean water) than for carbonate shells (i.e., a specific fossil Cretaceous species). The isotope ^{16}O is lighter than ^{18}O so that water containing ^{16}O is preferentially evap-