Preface

When my children were little, I found myself several times watching them with wonder and admiration while they were playing with mechanical toys. In fact, if you give a child a toy, and the child is curious enough and has enough time, he or she will eventually open it up in order to see how it works, then will try to reconstruct it in order to play with it again. This childish attitude is usually lost with age; but modern scientists behave exactly like this with the systems they are studying: it is not by chance that they are often called "grown-up babies".

In a certain sense, this book means to be precisely a journey into the ideas that have led the scientists who study the weather and climate to recover this childish outlook.

In the history of science, after the period of Greek philosophers and their medieval Epigones (during which people confined themselves to observing reality, looking for regularities that might explain its behaviour), with Galileo Galilei scientists began to control and manipulate reality in the laboratory, in order to induce nature to give specific answers to specific questions. This led to great cognitive progresses in the domain of the so-called "hard sciences", such as physics and chemistry.

Obviously, this childish tendency to open up a toy in order to look inside it — to disassemble it, then to reassemble its parts — is pursued nowadays in all the areas of science, including the study of the atmosphere and climate. As a rule, the activity of decomposing a system in order to study its individual elements and their basic interactions does not pose any particular problem: in the laboratory, for instance, we can easily study the absorption of infrared radiation by carbon dioxide

molecules (which contributes to the so-called "greenhouse effect"); or, regarding air as a fluid or as a mixture of gases and water, we can analyse the movements of portions of air in simplified cases or study the main thermodynamic processes that take place in the atmosphere. But when we try to reconstruct the whole "toy" in the laboratory, though this is usually possible for mechanical systems, we find that it is extremely difficult for the atmosphere and for the Earth system: we will see this in the course of our journey.

So, up to a few decades ago, meteorology and climatology were still purely observational disciplines, characterised by a lot of difficulties in achieving theoretical syntheses. Then the fruitfulness of the Galilean experimental method (though transferred to a different set-up) was retrieved in these fields too, and now computers and simulation models may be regarded as "virtual laboratories" where the weather and climate are studied. In a model, formed of equations that represent our theoretical knowledge (and can be solved numerically) and of variables that refer to the real data, it is possible to reconstruct the complexity of reality, though in a simplified manner. In particular, we can simulate the evolution of the climate system on the basis of scenarios observed in the past or surmised for the future; and all this can be done in very little time (tens of hours for decades of real evolution) and with the possibility of carrying out "numerical experiments".

In this book we will deal precisely with this "methodological revolution", which underlies our present understanding of the behaviour of many complex systems, including the climatic one.

In our journey from observations to simulations, we will follow the typical route of a scientific investigation, and will encourage the reader to become qualitatively aware of the characteristics of the atmosphere and of the Earth system, gradually finding different explanatory schemes. We will also re-examine some classical, well-known concepts such as "causality" and "prediction", in the light of the models and of new concepts pertaining to the theory of dynamical systems.

To sum up: this book presents a research into complex systems that has a huge range of practical applications, and is also contributing to a substantial change in our outlook on nature.

A. Pasini