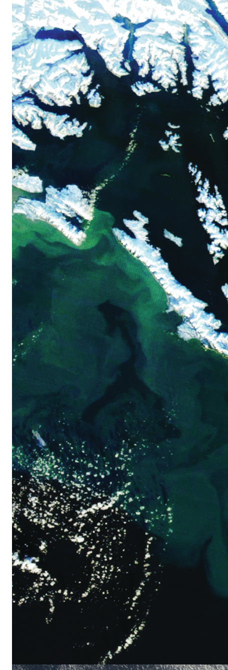

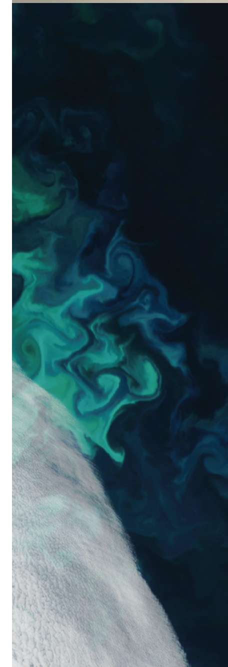

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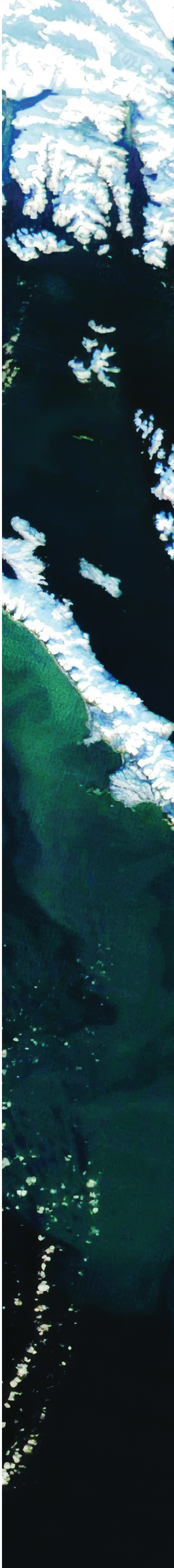
# PART I

# EARTH'S CLIMATE SYSTEM



# 1

# AN INTRODUCTION TO THE CLIMATE SYSTEM

*Climate dynamics* is the scientific study of how and why climate changes. The intent is not to understand day-to-day changes in weather but to explain average conditions over many years. Climate processes are typically associated with multidecadal time scales and continental to global space scales, but one can certainly refer to the climate of a particular city.

Climate dynamics is a rapidly developing field of study, motivated by the realization that human activity is changing climate. It is necessary to understand the natural, or unperturbed, climate system and the processes of human-induced change to be able to forecast climate so that individuals and governments can make informed decisions about energy use, agricultural practice, water resources, development, and environmental protection.

Climate has been defined as "the slowly varying aspects of the atmosphere–hydrosphere–land surface system."[1] Other definitions of climate might also explicitly include the biosphere as part of the climate system, since life on the planet plays a well-documented role in determining climate. Anthropogenic climate change is one example, but there are others, such as the influence of life on the chemical composition of the atmosphere throughout most of Earth's 4.5-billion-year life span.

The word *climate* is derived from the Greek word *klima*, which refers to the angle of incidence of the sun. This is a fitting origin because solar radiation is the ultimate energy source for the climate system. But to understand climate we need to consider much more than solar heating. Processes within the Earth system convert incoming solar radiation to other forms of energy and redistribute it over the globe from pole to pole and throughout the vertical expanses of the atmosphere and ocean. This energy not only warms the atmosphere and oceans but also fuels winds and ocean currents, activates phase changes of water, drives chemical transformations, and supports biological activity. Many interacting processes create the variety of climates found on Earth.

A schematic overview of the global climate system is provided in Figure 1.1. This diagram represents the climate system as being composed of five subsystems: the atmosphere, the hydrosphere, the biosphere, the cryosphere, and the land surface. It also

1. From the Glossary of Meteorology, published online by the American Meteorological Society.

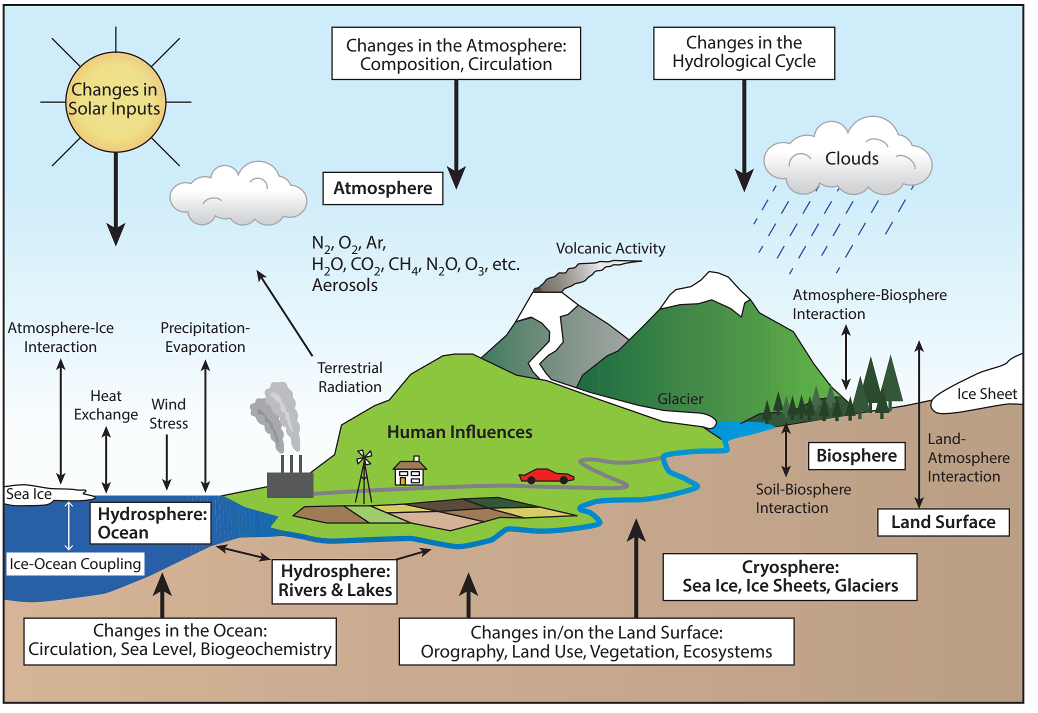



**Figure 1.1:** Schematic overview of the climate system, with some of the interactions among its subsystems indicated by arrows. From "Climate Change 2001: The Scientific Basis." Intergovernmental Panel on Climate Change.

depicts some of the processes that are important for determining climate, such as the exchange of heat, momentum, and water among the subsystems, and it identifies some of the agents of climate change.

Figure 1.1 provides a rough overview of the climate system, and it is useful as a first-order, nontechnical description of the system. At the other end of the spectrum is the *Bretherton diagram*, shown in Figure 1.2. This detailed, perhaps a bit overwhelming, schematic was constructed to characterize the full complexity of climate. It is a remarkable and rich representation of the system, illustrating the many processes that influence climate on all time scales. It coalesces historically separate fields of scientific inquiry, demonstrating that not only atmospheric science and oceanography are relevant to climate science, but that various subdisciplines of geology, biology, physics, and chemistry—as well as the social sciences—are all integral to an understanding of climate.

This is a very exciting and critical time in the field of climate dynamics. There is reliable information that past climates were very different from today's climate, so we know the system is capable of significant change. We also understand that it is possible for the system to change quickly. The chemical composition of the atmosphere is changing before our eyes, and satellite- and Earth-based observing networks allow us to monitor changes in climate fairly accurately.

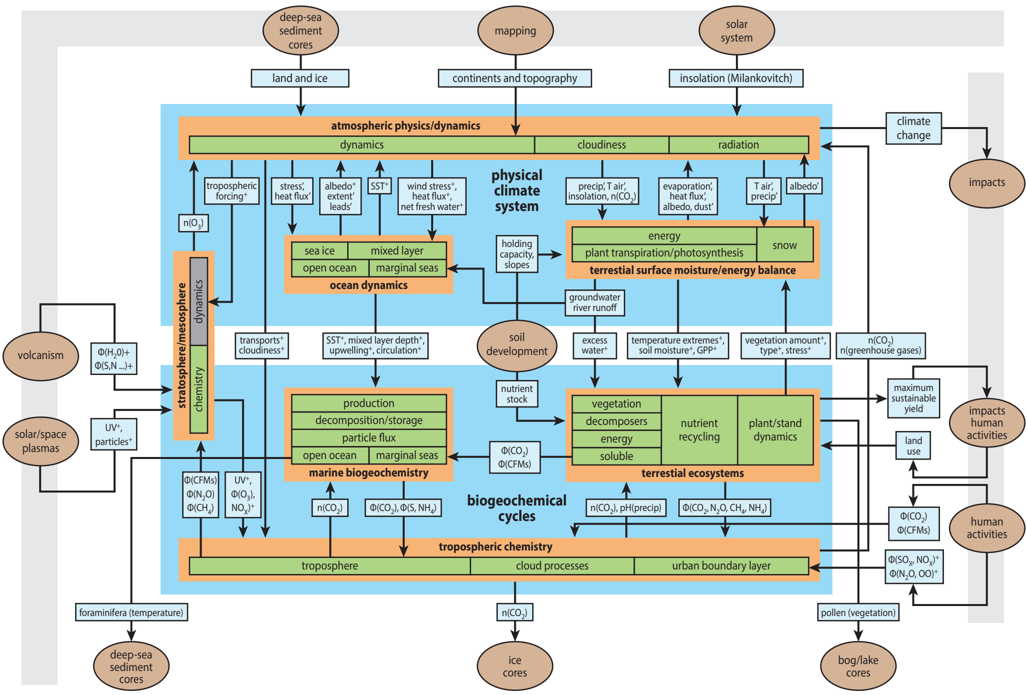



**Figure 1.2:** The Bretherton diagram, illustrating the components of the climate system and the interactions among them. (′ = on time scale of hours to days; + = on time scale of months to seasons; Φ = flux; n = concentration; SST is sea surface temperature.)

Clearly, this one text on climate dynamics cannot cover the full breadth of this wide-ranging and rapidly developing field of study, but it provides the reader with the fundamentals—the background needed for a basic understanding of climate and climate change, and a launchpad for reading the scientific literature and, it is hoped, contributing to the profound challenge facing us of managing climate change and avoiding its worst impacts. With this fundamental understanding, science can address the questions, needs, and constraints of humanity in a reasonable and useful way, and offer informed answers to guide society's behavior.

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