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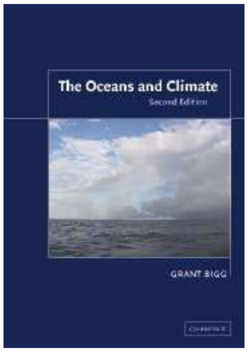

The Oceans and Climate by Grant Bigg, 2003, Cambridge University Press, Cambridge, UK, softcover, 273 p., USD65.00, ISBN: 0-521-01634-7.

Present, past, and future ocean-atmosphere interactions affecting climate are the central topic of this textbook, which is intended as a course and reference book for undergraduate and graduate students in several fields, including the earth sciences. The author, Grant Bigg, is a leading geographer with distinct physical, mathematical, and modelling background; he has dedicated his career to marine climate change, especially during the Quaternary. As he states in the preface to the first edition, oceanic links to climate are complex, involving physical, chemical and biological aspects. Each aspect, therefore, is tackled in separate chapters before climate-relevant ocean-atmosphere interactions and the role of the ocean in the past and future climates are discussed in greater detail. In general, the text is well supported by sketches, line drawings, tables, several appendices, and a very useful glossary.

An introductory chapter on the climate system explains how solar radiation drives the climate system and introduces its five components: the atmosphere, the ocean, the cryosphere, the biosphere, and the geosphere. Among others, the circulation in the troposphere, the greenhouse effect, and the chemical composition of the oceans are elucidated here as well. Differential modes of deep-water formation in the North Atlantic and Weddell Sea and the different time scales at which the components affect climate round up this short and sound introduction. The presentation of climate systems through Earth history emphasizes the influence of plate tectonics on long-term climate change, lists the few prolonged periods of extensive glaciations in the last billion years, and contrasts them with the Cretaceous period as an example for distinctly warmer climates than today. The repeated extensive glaciations of the last million years are exemplified in the context of periodicities of the Milankowitch cycle in Earth's orbit. Information on deglaciation during the last 18,000 years and the influence of humans on climate by increasing atmospheric concentrations of greenhouse gases over the last two centuries is briefly summarized. The final introduction to numerical modelling of the ocean and climate system remained largely enigmatic, at least to this reviewer.

Chapter 2 explains the exchange of energy and matter at the air-sea interface. Heat exchanges, the key to understanding the impact of the ocean on climate, are examined in detail, with a focus on solar radiation, latent and sensible heat transfer, and the oceanic heat balance. The basic forces within the atmosphere and ocean (e.g., Coriolis force, geostrophy) are introduced, and tidal forces and the impact of tides on coastal waters are explained. Wind is the main driver of ocean currents. Accordingly, the explanation of the process of momentum transfer by wind and the resulting drag from water forms the basis for introducing water motion at local scales (including waves, the Ekman spiral, and Langmuir circulation cells), at the basin scale (ocean gyres, coastal upwelling, tropical surface, circulation, and eddies) as well as global-scale thermohaline circulations. Monsoonal circulations and the formation of active weather systems in polar regions are explained in the context of basin-scale flows of the ocean. The section on oceanic impact on maritime atmospheric circulation strongly focuses on the formation and features of the impressive tropical cyclones; these, along with the smaller-scale mesocyclonal subpolar and polar storms, are all invariably generated over the ocean.

The solubility of atmospheric gases, especially those important for a greenhouse effect, as a function of molecular weight and temperature and transfer velocity—the rate of exchange due to sea state and atmospheric stability—are considered in chapter 3. This is followed by detailed explanations of the carbon cycle and the ocean as a carbon sink. Variation of oxygen concentration with depth and geography are explained, with special emphasis on upwelling and the role of decreasing oxygen levels as evidence for deep ocean circulation. Bigg then treats those aerosols in the marine atmosphere containing carbon, nitrogen, sulfur, phosphorus, and iron because they are likely to affect the nutrient supply of phytoplankton or the cycling of greenhouse gases. The hygroscopic, large, and abundant sea salt aerosols, in contrast, are climatically important because of their crucial role in cloud formation and in producing marine rainfall. Different modes of cloud formation, the role of ice crystals and snowflakes in clouds, and the formation and coalescence of droplets are briefly examined. Climatically important photochemical reactions in seawater, other than photosynthesis, must be considered in estimating fluxes of gases to the atmosphere (photo dissociation) and can be used to trace chlorophyll in the sea (fluorescence). A section on chemical tracers of deep-water movement, including the ratio of stable oxygen isotopes, radioactive isotopes, and several anthropogenic tracers, closes this part of the book.

Chapter 4 discusses biological processes that potentially influence climate. Phytoplankton contributes to the oceanic uptake of atmospheric carbon; this pathway draws much more gas into the ocean than would otherwise be the case. In this context, Bigg outlines the influence of solar radiation and nutrient limitation on plankton growth, and then goes on to discuss seasonal, geographical, and vertical variations in this growth. Climatically active by products of marine biological processes that are rare but nonetheless important players in climate processes include several carbon , nitrogenous, sulphurous, and iodine compounds. They are briefly discussed with respect to their origin, including anaerobic decay, incomplete respiration, oxidation of organic matter, or cell protein decomposition. Bigg then discusses the role of marine organisms in the cycles of selected natural elements; he emphasizes the seafloor as a sink for carbon and sulfur and the predominant recycling of nitrogen and phosphorus in the ocean. A relatively long discussion on the potential role of dimethyl sulphide (DMS) in global cooling closes this chapter.

Large-scale, air-sea interactions, which are found quasiperiodically (longitudinal biases in the positioning of tropospheric pressure systems, El Nino, and Southern Oscillation) or episodically due to abrupt changes in the thermohaline circulation, are the core of the book (chapter 5). Here, Bigg explains the introduction of moisture and the moderation of temperature extremes as general features of maritime climate regimes in the context of the classical biome types; temperature and precipitation are the key variables. Cyclones are a major means of transferring heat poleward but also have a significant impact on the ocean biosphere by destabilizing the upper ocean and bringing more nutrient-rich water to the surface layer. The general interannual relationship between atmospheric circulation and oceanic surface conditions is introduced with examples from western Africa (droughts in the Sahel zone), western Europe (North Atlantic oscillations), and western North America (Pacific North American pattern). This is followed by an in-depth discussion of the most significant coupling between the ocean and the atmosphere on interannual time scales: the tropical Pacific El Nino. Variations in the intensity of the Walker circulation as drivers of the Southern Oscillation index, the role of Kelvin and Rossby waves in the upper ocean for Trade winds and upwelling, background conditions, and potential triggers of ENSO (El Niño–Southern Oscillation) and its impact on the tropics and extratropics (teleconnections) are explained in great detail. Iceberg melt and resulting freshwater input can significantly impact the thermohaline circulation. Bigg outlines that the climate system appears to be stable with respect to small perturbations. Short-lived, massive input of icebergs to the northern Atlantic during Heinrich events, however, led to totally different climate systems during the last glacial period and during deglaciation and the Younger Dryas. In contrast, warm and salty Mediterranean outflow water, whose formation ceases during sapropels and is enhanced during periods of increasing evaporation in the eastern Mediterranean, may influence intermediate water density in the main Atlantic. This potentially impacts North Atlantic deep-water formation.

The two final chapters discuss the role of oceans in the climate history of the Phanerozoic, explore the natural and anthropogenic causes of present climate change, and make some predictions for the climate of the near future. The Paleozoic and Mesozoic, however, are treated very briefly, mainly under consideration of the Upper Carboniferous icehouse conditions; like in the introduction—without much more information—the Cretaceous is the only short greenhouse climate example. The treatment of climates in the Cenozoic focuses mainly on the cooling from the Oligocene onward, and even the exciting Eocene thermal maximum is only mentioned with a few sentences. The use of a completely outdated geological time chart is a bit odd and may reflect Bigg's primary interest in the role of oceans in Quaternary glaciations, the Holocene climate, as well as climate change during the last century and in the near future, the main focus of these chapters as well.

I recommend this book as a very concise and well-structured introduction to principles of ocean-atmosphere interactions and to oceanographic links to Quaternary climate change. Those who expect insights into such processes in deeper time, especially during greenhouse climates, might be a bit disappointed.

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