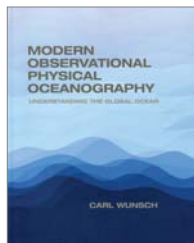


Modern Observational Physical Oceanography

Understanding the Global Ocean

Carl Wunsch

Princeton U. Press, 2015. \$99.50 (493 pp.). ISBN 978-0-691-15882-2



Oceanographer Carl Wunsch has based his career on the proposition that we can understand the physics of the global ocean's circulation and its forcing through observations. That's audacious, considering the ocean's volume is about 1.3×10^{18} cubic meters, horizontal scales of important dynamic processes range from submillimeter lengths to scales spanning the globe, and time scales for significant variations range from fractions of a second to millennia.

Observing the ocean is a challenge. Seawater's opacity to electromagnetic radiation limits remote sensing to the upper meters. Instruments are subject to corrosion and extreme pressures. And the violent storms likely to occur on the extended missions that are necessary to collect *in situ* data on global scales are sure to challenge the intestinal fortitude of most observers.

And yet, new observation methods, paired with new analytical techniques, have driven excellent progress in understanding the dynamics of ocean processes and circulation. Also driving progress is a greater appreciation, by the public and by policymakers, of the ocean's role in Earth's climate and the urgent need to understand our changing climate. For example, observations have been instrumental in quantifying the intimate connection between the ocean and atmosphere as a result of oceanic evaporation. Latent heat exchange drives evaporation of about 13 million tons of water per second; the resulting atmospheric energy flow (due to the moist atmosphere) is balanced by oceanic flows that, in effect, move freshwater around. Those coupled processes account for around one-third of the total meridional energy transport required to balance Earth's net radiative heating.

Modern Observational Physical Oceanography: Understanding the Global Ocean encapsulates a half-century of contributions by Wunsch, whose PhD adviser was the incomparable Henry Stommel. And

what an immense contribution the recently retired Wunsch has made: more than 250 papers, 5 books, and an astonishing list of master's and PhD students whose own merits are widely recognized.

His latest book breaks new ground for an oceanographic text in successfully describing what observations have taught us about the ocean as a time-varying system. It achieves that by explaining the directness with which observations and physics are connected, by placing the observations as the central element of the story, and by describing first their context and then the physics that explains the observed phenomenon. The book also stresses the importance of using observed ocean data to constrain models that predict climate change, which Wunsch views as a high priority for society.

A major strength of the book is its clear discussion of what can safely be concluded from observations. It also makes clear how the conclusions are to be defended as well as the corollary: when analysis becomes storytelling and plainly bad science (for example, the impact of aliasing). Reading this book leaves a very powerful impression of robust and serious science.

Wunsch covers global themes that span many major topics in large-scale physical oceanography. As stated in the preface, the intended audience is graduate students and working scientists, but I believe the text will benefit all observational oceanographers.

Where does this work sit in the bookcase of oceanography texts? If multidimensional books sit on the top shelf, then that's where you'll find *Modern Observational Physical Oceanography*. It combines theory—the focus of such texts as Adrian Gill's *Atmosphere–Ocean Dynamics* (Academic Press, 1982)—with a nice primer on analytical methods, which was the exclusive focus of Richard Thomson and William Emery's *Data Analysis Methods in Physical Oceanography* (3rd edition, Elsevier, 2014). The result of that combi-

nation is a product that goes beyond such texts as Lynne Talley and coauthors' excellent *Descriptive Physical Oceanography: An Introduction* (6th edition, Elsevier, 2011).

Wunsch's book also distinguishes itself from the others by placing observational data as the central character and by emphasizing the oceans' time-varying nature. And lecturers will appreciate that no additional consent is required to use the book's diverse figures and illustrations.

In several places in *Modern Observational Physical Oceanography*, I read with real pleasure about some new insight or neatly described analysis, and I enjoyed diversions such as the discussion of paleotides and the increase by 1.7 microseconds per century in a day's length mostly due to tidal friction. This widely interesting book will be of value to anyone wishing to know more about how to observe the ocean, interpret the data, and gain insights on ocean behavior and on how oceanographers reach their understanding of it.

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Nature's Third Cycle

A Story of Sunspots

Arnab Rai Choudhuri

Oxford U. Press, 2015. \$39.95 (281 pp.).
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The cyclic magnetic activity of the Sun is among the most intriguing phenomena in the universe. It results from complex interactions in a magnetized, turbulent plasma that cover a wide range of spatial and temporal scales. Solar activity is usually associated with an 11-year variation in the sunspot number and in strong, highly energetic events—for example, coronal mass ejections and flares—that release energy equivalent to a billion 10-megaton hydrogen bombs. The resulting flux of high-energy particles interacts with Earth's magnetosphere, causing auroras and geomagnetic storms that can disrupt electrical power systems, navigation systems, satellites, and more.

In *Nature's Third Cycle: A Story of Sunspots*, solar physicist Arnab Rai Choudhuri presents the history of empirical and theoretical studies of global solar variations and discusses the influence of that activity on Earth's environment.

Choudhuri's captivating narrative starts with the massive power blackout of 13 March 1989 in Quebec, an event caused by a strong solar flare from a few days earlier. Such strong solar eruptions are associated with sunspots, clusters of which form active regions with topologically complicated magnetic field structures.

The author details such historical highlights as the discovery of the 11-year solar cycle and makes a brief excursion into the solar interior's dynamics and evolution. His simple description of a turbulent plasma in a magnetic field serves as an introduction to the deep theoretical studies of magnetic field generation and to Eugene Parker, Horace Babcock, and Robert Leighton, the scientists who developed the foundation of solar dynamo theory.

The long record of solar observations shows that the duration and strength of solar cycles have varied over time. Our understanding of the solar cycle is determined by the ability of theoretical models to make reliable forecasts, and until recently, available models failed to correctly predict either a cycle's amplitude or the time of the next solar maximum. During the past 10 years, however, a new approach has emerged: Realizing that our knowledge of the Sun's interior is still incomplete, solar physicists are combining theoretical modeling with observational data.

Although Choudhuri does not detail the new "data assimilation" approach in the book, he has previously suggested a weather forecasting scheme that combines observational data with a type of Babcock–Leighton mean-field dynamo model. Because of the known correlation between the strength of global magnetic fields during a solar minimum and during the next solar maximum, the magnetic field forecast is updated once per solar cycle, at the solar minimum, by means of an empirically determined dipole magnetic index. The assimilation of that data with the dynamo model enabled physicists to correctly predict the observed amplitude of the current solar cycle, which began in 2008 and is the 24th since extensive recording of sunspot activity began in 1755.

Nature's Third Cycle includes approaches to model the solar cycles and

their predictions using rigorous mathematical methods that are briefly described in the appendices. The next step is to incorporate nonlinear magnetohydrodynamic models and data assimilation; the new prediction models that result may be considered as an ensemble of possible states sequentially adjusted with observational data. In my recent work with Alexander Kosovichev, we have applied that approach to describe the observed asymmetry of solar cycles, which grow faster than they decay (the so-called Waldmeier effect). Our initial results are in good agreement with the actual observed evolution of the current solar cycle—the good agreement suggests the possibility of making reliable predictions at least seven years forward after a solar minimum.

I strongly recommend *Nature's Third Cycle* to readers who are interested in learning about solar activity, its effects on Earth, and the history of the field. It includes technical details and references for delving deeper into a fascinating topic, yet it is easy and enjoyable to read.

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The Story of Collapsing Stars

Black Holes, Naked Singularities, and the Cosmic Play of Quantum Gravity

Pankaj S. Joshi

Oxford U. Press, 2015. \$49.95 (225 pp.).
ISBN 978-0-19-968676-6

What happens to a star after it has exhausted its nuclear fuel? If the star's initial mass is sufficiently small, it collapses gravitationally and becomes a white dwarf or a neutron star. For massive stars, the inevitable final state is a singularity hidden behind an event horizon—that is, a black hole. At least that is the story told by the cosmic censorship conjecture, which does not permit "naked" singularities void of an event horizon as the end state of gravitational collapse. However, the conjecture is still unproven.

In *The Story of Collapsing Stars: Black Holes, Naked Singularities, and the Cosmic Play of Quantum Gravity*, Pankaj Joshi presents the active field of research on gravitational collapse. He concentrates on possible outcomes of such collapses, probing the conditions under which collapsing stars form black holes, which are not visible to a distant observer, and naked singularities, which can be seen by a distant observer. He also asks how we should formulate the cosmic censorship conjecture so that it can be proved. Joshi outlines his and others' efforts in the past few decades to address those research questions.

The book starts out with a short, accessible exposition of general relativity. Joshi then describes singularities; in particular, he discusses the singularity theorems, which state the conditions under which singularities form in general relativity. He details the two possible kinds of singularity—black holes and naked singularities. Unfortunately, he neglects to include a short overview of the astrophysical evidence for their existence, as Fulvio Melia did in *The Black Hole at the Center of Our Galaxy* (Princeton University Press, 2003).

In the subsequent chapters, Joshi presents different models for the gravitational collapse of massive stars. He starts with the idealized collapse of a spherical, symmetric, and homogeneous dust cloud, which unambiguously does lead to a black hole. After that, Joshi relaxes all the assumptions gradually and considers inhomogeneous dust models, different matter models, deviations from spherical symmetry, generalized theories of gravitation, and more. He shows that naked singularities are indeed a viable end state of the collapse of a star whose matter satisfies the standard energy conditions. Unfortunately, the assumptions made beyond the energy conditions—for example, for velocity and density profiles—are not justified astrophysically, microphysically, or otherwise. Thus it might be difficult for readers to evaluate the applicability of the models to realistic collapse scenarios. Additionally, a reference list would have been helpful for expert readers.

Chapter 7, "Cosmic Conundrums," is a highlight of the book. Therein, Joshi brings together the material of the previ-

