Ocean Circulation And Climate Volume 103 Second Edition A 21st Century Perspective International Geophysics

Formation of the deepest waters of the World Ocean occurs in limited regions of the global ocean, primarily in the northern North Atlantic where North Atlantic Deep Water (NADW) is formed, and at a number of sites around the continental margins of Antarctica where Antarctic Bottom Waters (AABW) are formed. The deepwater formation processes play a significant role in determining the large-scale physical and biogeochemical properties of the deep ocean. These limited regions provide a conduit from the surface into the vast volumes of water in the deep ocean. We report in this chapter on observed physical and biochemical changes in the deep ocean and discuss these in the context of deepwater formation. Intensive observation programs in the North Atlantic during the past decades have demonstrated that there have been significant changes in the volumes and properties of Upper and Lower NADW as well as AABW. Studies have found systematic warming of AABW during the past two decades along a number of its major flow pathways, as well as evidence for a reduction in overall volume of AABW in the global deep ocean. Lower NADW, on the other hand, has been undergoing systematic cooling for the past four decades, whereas Upper NADW (primarily Labrador Sea Water) has been exposed to large decadal variability, both in properties and formation rates. In total, the deepwaters of the World Ocean (beneath ca. 2000–3000m) have warmed during the past two decades. Changes in the deep ocean can have enormous influence on Earth's climate. Warming of the deep ocean makes a significant contribution to global sea level rise. The capacity of the deep ocean to take up and store anthropogenic CO2 has and will have a major impact on the CO2 content of the atmosphere now and far into the future. Paleooceanographic studies have provided evidence that despite the century-long timescales associated with renewal of deepwater, rapid, major changes in deepwater formation and deep ocean circulation have occurred in the past, resulting in rapid changes in Earth's climate. Continued monitoring and analysis are necessary to follow and understand the changes in the deep ocean—this is a very important component of Earth's climate.

Clouds play a critical role in the Earth's climate, general atmospheric circulation, and global water balance. Clouds are essential elements in mesoscale meteorology, atmospheric chemistry, air pollution, atmosphericradiation, and weather forecasting, and thus must be understood by any student or researcher in the atmospheric sciences. Cloud Dynamics provides a skillful and comprehensive examination of the nature of clouds--what they look like and why, how scientists observe them, and the basic dynamics and physics that underlie them. The book describes the mechanics governing each type of cloud that occurs in Earth's atmosphere, and the organization of various types of clouds in larger weather systems such as fronts, thunderstorms, and hurricanes.This book is aimed specifically at graduate students, advanced undergraduates, practicing researchers either already in atmospheric science or moving in from a related scientific field, and operational meteorologists. Some prior knowledge of atmospheric dynamics and physics is helpful, but a thorough overview of the necessary prerequisites is supplied. Provides a complete treatment of clouds integrating the analysis of air motions with cloud structure, microphysics, and precipitation mechanics Describes and explains the basic types of clouds and cloud systems that occur in the atmosphere-fog, stratus, stratocumulus, altocumulus, altostratus, cirrus, thunderstorms, tornadoes, waterspouts, orographically induced clouds, mesoscale convection complexes, hurricanes, fronts, and extratropical cyclones Presents a photographic guide, presented in the first chapter, linking the examination of each type of cloud with an image to enhance visual retention and understanding Summarizes the fundamentals, both observational and theoretical, of atmospheric dynamics, thermodynamics, cloud microphysics, and radar meteorology, allowing each type of cloud to be examined in depth Integrates the latest field observations, numerical model simulations, and theory Supplies a theoretical treatment suitable for the advanced undergraduate or graduate level

This book presents a global hydrographic description of the thermohaline circulation, an introduction to the theoretical aspects of this phenomenon, and observational evidence for the theory. The hydrographic description and the observational evidence are based on data sources available via internet, mainly from the World Oceanographic Experiment (WOCE). The book also offers an introduction to hydrographic analysis and interpretation.

The oceans play a crucial role in the Earth's climate system due largely to their ability to store and transport heat. The instrumental record, spanning an order of magnitude of 100 years, is short compared with some of the important timescales of climate variability. To understand the oceans' role in these long-term changes, proxy data from sediments, ice cores, and corals must be used. Using these proxy data, we examine the evidence for past ocean circulation and sea-level changes before instrumental oceanographic measurements began. We discuss what paleoclimatic data can tell us about past ocean states and what can be learned from ocean and climate models. Particular foci of the chapter are the ocean circulation and sea-level changes during the Quaternary and the Cretaceous, two particularly interesting periods in Earth's history. The Quaternary covers the past 2.5 million years and is characterized by periodic glaciations, while the Cretaceous, reaching back around 100 million years, had a warm greenhouse climate with a weak temperature gradient between the tropics and the poles.

Strong, persistent currents along the western boundaries of the world's major ocean basins are called "western boundary currents" (WBCs). This chapter describes the structure and dynamics of WBCs, their roles in basin-scale circulation, regional variability, and their influence on atmosphere and climate. WBCs are largely a manifestation of wind-driven circulation; they compensate the meridional Sverdrup transport induced by the winds over the ocean interior. Some WBCs also play a role in the global thermohaline circulation, through inter-gyre and inter-basin water exchanges. After separation from the boundary, most WBCs have zonal extensions, which exhibit high eddy kinetic energy due to flow instabilities, and large surface fluxes of heat and carbon dioxide. The WBCs described here in detail are the Gulf Stream, Brazil and Malvinas Currents in the Atlantic, the Somali and Agulhas Currents in the Indian, and the Kuroshio and East Australian Current in the Pacific Ocean.

Ocean Circulation and ClimateObserving and Modelling the Global OceanElsevier

Published by the American Geophysical Union as part of the Geophysical Monograph Series, Volume 173. The ocean's meridional overturning circulation (MOC) is a key factor in climate change. The Atlantic MOC, in particular, is believed to play an active role in the regional and global climate variability. It is associated with the recent debate on rapid climate change, the Atlantic Multi-Decadal Oscillation (AMO), global warming, and Atlantic hurricanes. This is the first book to deal with all aspects of the ocean's large-scale meridional overturning circulation, and is a coherent presentation, from a mechanistic point of view, of our current understanding of paleo, present-day, and future variability and change. It presents the current state of the science by bringing together the world's leading experts in physical, chemical, and biological oceanography, marine geology, geochemistry, paleoceanography, and climate modeling. A mix of overview and research papers makes this volume suitable not only for experts in the field, but also for students and anyone interested in climate change and the oceans.

The book represents all the knowledge we currently have on ocean circulation. It presents an up-to-date summary of the state of the science relating to the role of the oceans in the physical climate system. The book is structured to guide the reader through the wide range of World Ocean Circulation Experiment (WOCE) science in a consistent way. Cross-references between contributors have been added, and the book has a comprehensive index and unified reference list. The book is simple to read, at the undergraduate level. It was written by the best scientists in the world who have collaborated to carry out years of experiments to better understand ocean circulation.

Published by the American Geophysical Union as part of the Geophysical Monograph Series, Volume 147. It is more than 30 years since the publication of Jacob Bjerknes' groundbreaking ideas made clear the importance of ocean-atmosphere interaction in the tropics. It is now more than 20 years since the arrival of a massive El Niño in the fall of 1982 set off a cascade of observational and theoretical studies. During the following decades, the climate research community has made exceptional progress in refining our capacity to observe earth's climate and theorize about it, including new satellite-based and in situ monitoring systems and coupled ocean-atmosphere predictive numerical models. Of equal importance. is the expanding scope ofresearch, which now reaches far beyond the Pacific El Niño and includes climate phenomena in other ocean basins. In order to cover the now global context of ocean-atmosphere interaction we have organized this monograph around five principal themes, each introduced by one or more broad overview papers. Theme I covers interaction and climate variability in the Pacific sector, with extensive discussion of El Niño-Southern Oscillation, and with the possible causes and consequences of variability on both shorter and longer timescales. Theme II is devoted to interaction in the Atlantic sector. This basin exhibits complex behavior, reflecting its geographic location between two major zones of convection as well as neighboring the tropical Pacific. Theme III reviews the recent, exciting progress in our understanding of climate variability in the Indian sector. Theme IV addresses the interaction between the tropics and the extratropics, which are linked through the presence of shallow meridional overturning cells in the ocean. Finally, Theme V discusses overarching issues of cross-basin interaction.

Oceans play a pivotal role in our weather and climate. Ocean-borne commerce is vital to our increasingly close-knit global community. Yet we do not fully understand the intricate details of how they function, how they interact with the atmosphere, and what the limits are to their biological productivity and their tolerance to wastes. While satellites are helping us to fill in the gaps, numerical ocean models are playing an important role in increasing our ability to comprehend oceanic processes, monitor the current state of the oceans, and to a limited extent, even predict their future state. Numerical Models of Oceans and Oceanic Processes is a survey of the current state of knowledge in this field. It brings together a discussion of salient oceanic dynamics and processes, numerical solution methods, and ocean models to provide a comprehensive treatment of the topic. Starting with elementary concepts in ocean dynamics, it deals with equatorial, mid-latitude, high latitude, and coastal dynamics from the perspective of a modeler. A comprehensive and up-to-date chapter on tides is also included. This is followed by a discussion of different kinds of numerical ocean models and the pre- and post-processing requirements and techniques. Air-sea and ice-ocean coupled models are described, as well as data assimilation and nowcast/forecasts. Comprehensive appendices on wavelet transforms and empirical orthogonal functions are also included. This comprehensive and up-to-date survey of the field should be of interest to oceanographers, atmospheric scientists, and climatologists. While some prior knowledge of oceans and numerical modeling is helpful, the book includes an overview of enough elementary material so that along with its companion volume, Small Scale Processes in Geophysical Flows, it should be useful to both students new to the field and practicing professionals. * Comprehensive and up-to-date review * Useful for a two-semester (or one-semester on selected topics) graduate level course * Valuable reference on the topic * Essential for a better understanding of weather and climate

Basic Concepts: Composition, Structure, and State. First and Second Laws of Thermodynamics. Transfer Processes. Thermodynamics of Water. Nucleation and Diffusional Growth. Moist Thermodynamics Processes in the Atmosphere. Static Stability of the Atmosphere and Ocean. Cloud Characteristics and Processes. Ocean Surface Exchanges of Heat and Freshwater. Sea, Ice, Snow, and Glaciers. Thermohaline Processes in the Ocean. Special Topics: Global Energy and Entropy Balances. Thermodynamics Feedbacks in the Climate System. Planetary Atmospheres and Surface Ice. Appendices. Subject Index.

A broad perspective of the ocean as a key component of the

Earth System and of its role in the past, present, and future climate change is provided. The ocean is a huge reservoir of heat, mass, carbon, and many other quantities, and their estimated exchange fluxes suggest characteristic timescales of adjustment ranging from decades to many thousands of years. Surface patterns and meridional fluxes of these quantities highlight the important role of the wind-driven circulation and the deep ocean flow systems through all ocean basins. Ocean-dominated phenomena of natural variability, in particular associated with the tropical oceans, are explained. The relevance of the ocean circulation for abrupt climate change, as recorded from a variety of paleoclimate records, is discussed. This includes the bipolar seesaw concept which explains many features of interhemispheric response during the sequence of rapid warmings in the past ice age. Finally, the ocean's role during the anthropocene, the time epoch which is dominated by the human-caused increase in greenhouse gases to levels unprecedented in the past 800,000 years, is explored. Both the warming and the increase in atmospheric transport of water polewards create conditions for the ocean that may induce large and irreversible changes in the Atlantic meridional overturning circulation.

Explores climate and oceans, providing a look at the basics of climate, a descriptive overview of the oceans, a brief introduction to dynamics, and coverage of other related topics.

This book contains articles presenting current knowledge about the formation and renewal of deep waters in the ocean. These articles were presented at an international workshop at the Naval Postgraduate School in Monterey in March 1990. It is the first book entirely devoted to the topic of deep water formation in which articles have been both selected and reviewed, and it is also the first time authors have addressed

both surface and deep mixed layers. Highlighted are: past and recent observations (description and analysis), concepts and models, and modern techniques for future research. Thanks to spectacular advances realised in computing sciences over the last twenty years this volume includes a number of sophisticated numerical models. Observational as well as theoretical studies are presented and a clear distinction is established between open-ocean deep convection and shelf processes, both leading to deep- and bottom-water formation. The main subject addressed is the physical mechanism by which the deep water in the ocean can be renewed. Ventilation occurs at the surface in areas called the gills, where water is mixed and oxygenated before sinking and spreading in the abyss of the deep ocean. This phenomenon is a very active area for both experimentalists and theoreticians because of its strong implications for the understanding of the world ocean circulation and Earth climate. This major theme sheds light on specific and complex processes happening in very restricted areas still controlling three quarters of the total volume of the ocean. All articles include illustrations and a bibliography. This book will be of particular interest to physical oceanographers, earth scientists, environmentalists and climatologists.
Climate variability in different ocean basins can impact one another, for instance the El Niño/Southern Oscillation (ENSO) in the Pacific Ocean has remote effects on other tropical oceans around the world, which in turn modulate ENSO. With chapters by eminent researchers, this book provides a comprehensive review on how interactions among the climates in different ocean basins are key contributors to global climate variability. It discusses how interbasin interactions are mediated by oceanic and atmospheric bridges and

explains exciting new possibilities for enhancing climate prediction globally. The first part of the book covers essential theory and introduces the basic mechanisms for remote connection and local amplification. The second presents outstanding examples. The latter part discusses applications to cases of societal interest such as impacts on monsoon systems and expectations after climate change. This comprehensive reference is a useful resource for graduate students and researchers in the atmospheric and ocean sciences.
Encyclopedia of Ocean Sciences 2e is a new 6-volume online reference work, pulling together all the key information in one source from the leading publisher in the field. This second edition is online, offering the user greater flexibility, accessibility, and most importantly, usability with 24 hour access, multi-user access, remote access and excellent search functionality. Structured for success, each article contains a glossary, an introduction, a reference section and a wealth of cross-referenced links to premium and related material all accessible in a mouse-click, making complicated, time consuming research a thing of the past. *Approximately 500 articles covering the breadth and depth of the field with over 30% new and updated content reflecting the latest research *Greater coverage of climate, remote sensing, and data modeling, with greater consideration of economic and political aspects provides a broad view of the field *Structured for success, each article contains an introduction, a reference section, a glossary and a wealth of cross references to premium related journal and book content

Observations at and below the surface of the oceans are essential for understanding the ocean system and the role played by the ocean in earth's climate, for documenting changes and for initializing, validating, and improving ocean models. It is only since the late twentieth century that, thanks to advances in microelectronics, battery technology, and satellite communication, in situ observations (together with satellite observations) have reached a volume and spatial distribution that allow us to track a wide range of global and regional phenomena. This review traces the development of in situ ocean observations primarily from a physical standpoint and describes the internationally coordinated observing networks that now supply these observations. It considers the enormous changes that have occurred in the volume and distribution of these observations and the implication of these changes for defining the evolving state of the global ocean. Finally, there is discussion of the prospects for further improving sustained ocean observations and for the delivery of integrated information from interrelated observing networks.

The thermodynamic properties of seawater have recently been redefined as the International Thermodynamic Equation of Seawater—2010 (TEOS-10 for short), and here we summarize the changes to oceanographic practices that are needed to take advantage of this new international standard. A key feature of TEOS-10 is that the thermodynamic quantities are functions of a new salinity variable, Absolute Salinity, which incorporates the effects of spatial differences in seawater

composition. TEOS-10 also treats the “heat content” of seawater in a more consistent and natural fashion through the introduction of a new temperature variable, Conservative Temperature, which replaces potential temperature. Since TEOS-10 includes fundamental equations of state also for ice and for humid air, thermodynamically consistent and complete relationships now exist between all the thermodynamic properties of fresh water, seawater, ice and humid air.
General Circulation Models (GCMs) are rapidly assuming widespread use as powerful tools for predicting global events on time scales of months to decades, such as the onset of EL Nino, monsoons, soil moisture saturation indices, global warming estimates, and even snowfall predictions. While GCMs have been praised for helping to foretell the current El Nino and its impact on droughts in Indonesia, its full power is only now being recognized by international scientists and governments who seek to link GCMs to help them estimate fish harvests, risk of floods, landslides, and even forest fires. Scientists in oceanography, hydrology, meteorology, and climatology and civil, ocean, and geological engineers perceive a need for a reference on GCM design. In this compilation of information by an internationally recognized group of experts, Professor Randall brings together the knowledge base of the forerunners in theoretical and applied frontiers of GCM development. General Circulation Model Development focuses on the past, present, and future design of numerical methods for general circulation modeling, as well as the physical parameterizations required for their

proper implementation. Additional chapters on climate simulation and other applications provide illustrative examples of state-of-the-art GCM design. Key Features * Foreword by Norman Phillips * Authoritative overviews of current issues and ideas on global circulation modeling by leading experts * Retrospective and forward-looking chapters by Akio Arakawa of UCLA * Historical perspectives on the early years of general circulation modeling * Indispensable reference for researchers and graduate students

New edition of successful textbook that introduces the multi-disciplinary controls on air-sea interaction.

An innovative survey of large-scale ocean circulation that links observations, conceptual models, numerical models, and theories.

The oceans cover 70% of the Earth’s surface, and are critical components of Earth’s climate system. This new edition of Encyclopedia of Ocean Sciences summarizes the breadth of knowledge about them, providing revised, up to date entries as well coverage of new topics in the field. New and expanded sections include microbial ecology, high latitude systems and the cryosphere, climate and climate change, hydrothermal and cold seep systems. The structure of the work provides a modern presentation of the field, reflecting the input and different perspective of chemical, physical and biological oceanography, the specialized area of expertise of each of the three Editors-in-Chief. In this framework maximum attention has been devoted to making this an organic and unified reference. Represents a one-stop. organic information resource on the breadth of ocean science research Reflects the input and different perspective of chemical, physical and biological oceanography, the specialized area of expertise of each of the three Editors-in-Chief New and expanded sections include microbial ecology, high latitude systems and climate change Provides scientifically reliable information at a foundational level, making this work a resource for students as well as active researches

This volume offers a broad and comprehensive examination of observational, modeling and theoretical aspects of coastal sea level science. The collection of overview articles provides up-to-date information on the causes of coastal sea level variability and change, contributes to better understanding of the influence of large-scale climate signals and open ocean processes on the coast, and addresses effects of waves, storm surges, and tides on extreme sea level and coastal flooding. Projections of long-term coastal changes and associated uncertainties are also proposed. The volume contributes to better identifying priorities for the development of an optimal and integrated (satellite and ground-based) coastal observing system and highlights present modeling and observing challenges for monitoring and predicting coastal sea level on daily to multi-decadal time scales. Previously published in Surveys in Geophysics, Volume 40, Issue 6, 2019 The chapters "Concepts and Terminology for Sea Level: Mean, Variability and Change, Both Local and Global", "Forcing Factors Affecting Sea Level Changes at the Coast", "Sea Level and the Role of Coastal Trapped Waves in Mediating the Influence of the Open Ocean on the Coast", "Impacts of Basin-Scale Climate Modes on Coastal Sea Level: a Review", "Interactions Between Mean Sea Level, Tide, Surge, Waves and Flooding: Mechanisms and Contributions to Sea Level Variations at the Coast", "Uncertainties in Long-Term Twenty-First Century Process-Based Coastal Sea-Level Projections" and "Probabilistic Sea Level Projections at the Coast by 2100" are available as open

Mounting evidence that human activities are substantially modifying the Earth's climate brings a new imperative to the study of the ocean's large-scale circulation. This textbook provides a concise but comprehensive introduction to the theory of large-scale ocean circulation, as it is currently understood and established. Students and instructors will benefit from the carefully chosen chapter-by-chapter exercises. This advanced textbook is invaluable for graduate students and researchers in the fields of oceanic, atmospheric and climate sciences and other geophysical scientists, as well as physicists and mathematicians with a quantitative interest in the planetary fluid environment.
This chapter focuses on numerical models used to understand and predict large-scale circulation, such as the circulation comprising basin and global scales. It is organized according to two themes. The first addresses physical and numerical topics forming a foundation for ocean models. We focus here on the science of ocean models, in which we ask questions about fundamental processes and develop the mathematical equations for ocean thermo-hydrodynamics. We also touch upon various methods used to represent the continuum ocean fluid with a discrete computer model, raising such topics as the finite volume formulation of the ocean equations; the choice for vertical coordinate; the complementary issues related to horizontal gridding; and the pervasive questions of subgrid scale parameterizations. The second theme of this chapter concerns the applications of ocean models, in particular how to design an experiment and how to analyze results. This material forms the basis for ocean modelling, with the aim being to mechanistically describe, interpret, understand, and predict emergent features of the simulated, and ultimately the observed, ocean.

This revised text presents a cogent explanation of the fundamentals of meteorology, and explains storm dynamics for weather-oriented meteorologists. It discusses climate dynamics and the implications posed for global change. The Fourth Edition features a CD-ROM with MATLABÂ® exercises and updated treatments of several key topics. Much of the material is based on a two-term course for seniors majoring in atmospheric sciences. * Provides clear physical explanations of key dynamical principles * Contains a wealth of illustrations to elucidate text and equations, plus end-of-chapter problems * Holton is one of the leading authorities in contemporary meteorology, and well known for his clear writing style * Instructor's Manual available to adopters NEW IN THIS EDITION * A CD-ROM with MATLABÂ® exercises and demonstrations * Updated treatments on climate dynamics, tropical meteorology, middle atmosphere dynamics, and numerical prediction

For advanced undergraduate and beginning graduate students in atmospheric, oceanic, and climate science, Atmosphere, Ocean and Climate Dynamics is an introductory textbook on the circulations of the atmosphere and ocean and their interaction, with an emphasis on global scales. It will give students a good grasp of what the atmosphere and oceans look like on the large-scale and why they look that way. The role of the oceans in climate and paleoclimate is also discussed. The combination of observations, theory and accompanying illustrative laboratory experiments sets this text apart by making it accessible to students with no prior training in meteorology or oceanography. * Written at a mathematical level that is appealing for undergraduates and beginning graduate students * Provides a useful educational tool through a combination of observations and laboratory demonstrations which can be viewed over the web * Contains instructions on how to reproduce the simple but informative

laboratory experiments * Includes copious problems (with sample answers) to help students learn the material.
The book represents all the knowledge we currently have on ocean circulation. It presents an up-to-date summary of the state of the science relating to the role of the oceans in the physical climate system. The book is structured to guide the reader through the wide range of world ocean circulation experiment (WOCE) science in a consistent way. Cross-references between contributors have been added, and the book has a comprehensive index and unified reference list. The book is simple to read, at the undergraduate level. It was written by the best scientists in the world who have collaborated to carry out years of experiments to better understand ocean circulation. Presents in situ and remote observations with worldwide coverage; Provides theoretical understanding of processes within the ocean and at its boundaries to other Earth System components; and Allows for simulating ocean and climate processes in the past, present and future using a hierarchy of physical-biogeochemical models

The modeling of ocean circulation is important not only for its own sake, but also in terms of the prediction of weather patterns and the effects of climate change. This book introduces the basic computational techniques necessary for all models of the ocean and atmosphere, and the conditions they must satisfy. It describes the workings of ocean models, the problems that must be solved in their construction, and how to evaluate computational results. Major emphasis is placed on examining ocean models critically, and determining what they do well and what they do poorly. Numerical analysis is introduced as needed, and exercises are included to illustrate major points. Developed from notes for a course taught in physical oceanography at the College of Oceanic and Atmospheric Sciences at Oregon State University, this book is ideal for graduate students of oceanography, geophysics, climatology and atmospheric science, and researchers in oceanography and atmospheric science.

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The polar oceans interact with both sea ice, formed in situ at the ocean surface, and land ice, flowing under gravity from the land onto the ocean surface. This ice–ocean interaction has profound consequences for the ocean and climate in a number of ways: a change in ocean surface albedo and surface energy balance where there is ice cover compared with open ocean, a change in global sea level when land ice flows into the ocean, and a transformation of water masses through melting or freezing of ice which subsequently influences the global conveyor belt. Another type of ice–ocean interaction, less well understood, is that between marine permafrost at the seafloor and the overlying ocean waters. Collectively, we refer to sea ice, land ice, and marine permafrost as the marine cryosphere. In this chapter, we review current understanding of the interaction of the marine cryosphere with the global ocean and discuss emerging technologies to improve observations and numerical modeling of these interactions. Projections for the state of the marine cryosphere into the current century and beyond are reviewed.
Comprehensive and up-to-date information on Earth's most dominant year-to-year climate variation The El Niño Southern Oscillation (ENSO) in the Pacific Ocean has major worldwide social and economic consequences through its global scale effects on atmospheric and oceanic circulation,

marine and terrestrial ecosystems, and other natural systems. Ongoing climate change is projected to significantly alter ENSO's dynamics and impacts. El Niño Southern Oscillation in a Changing Climate presents the latest theories, models, and observations, and explores the challenges of forecasting ENSO as the climate continues to change. Volume highlights include: Historical background on ENSO and its societal consequences Review of key El Niño (ENSO warm phase) and La Niña (ENSO cold phase) characteristics Mathematical description of the underlying physical processes that generate ENSO variations Conceptual framework for understanding ENSO changes on decadal and longer time scales, including the response to greenhouse gas forcing ENSO impacts on extreme ocean, weather, and climate events, including tropical cyclones, and how ENSO affects fisheries and the global carbon cycle Advances in modeling, paleo-reconstructions, and operational climate forecasting Future projections of ENSO and its impacts Factors influencing ENSO events, such as inter-basin climate interactions and volcanic eruptions The American Geophysical Union promotes discovery in Earth and space science for the benefit of humanity. Its publications disseminate scientific knowledge and provide resources for researchers, students, and professionals.
This book addresses the problem of inferring the

state of the ocean circulation, from a mathematical perspective.

Ocean Mixing: Drivers, Mechanisms and Impacts presents a broad panorama of one of the most rapidly-developing areas of marine science. It highlights the state-of-the-art concerning knowledge of the causes of ocean mixing, and a perspective on the implications for ocean circulation, climate, biogeochemistry and the marine ecosystem. This edited volume places a particular emphasis on elucidating the key future questions relating to ocean mixing, and emerging ideas and activities to address them, including innovative technology developments and advances in methodology. Ocean Mixing is a key reference for those entering the field, and for those seeking a comprehensive overview of how the key current issues are being addressed and what the priorities for future research are. Each chapter is written by established leaders in ocean mixing research; the volume is thus suitable for those seeking specific detailed information on sub-topics, as well as those seeking a broad synopsis of current understanding. It provides useful ammunition for those pursuing funding for specific future research campaigns, by being an authoritative source concerning key scientific goals in the short, medium and long term. Additionally, the chapters contain bespoke and informative graphics that can be used in teaching and science communication to convey the complex concepts and phenomena in easily accessible ways. • Presents a coherent overview of the state-of-the-art research concerning ocean mixing • Provides an in-depth discussion of how ocean mixing impacts all scales of the planetary system • Includes elucidation of the grand challenges in ocean mixing, and how they might be addressed

Fluid dynamics is fundamental to our understanding of the atmosphere and oceans. Although many of the same principles of fluid dynamics apply to both the atmosphere and oceans, textbooks tend to concentrate on the atmosphere, the ocean, or the theory of geophysical fluid dynamics (GFD). This textbook provides a comprehensive unified treatment of atmospheric and oceanic fluid dynamics. The book introduces the fundamentals of geophysical fluid dynamics, including rotation and stratification, vorticity and potential vorticity, and scaling and approximations. It discusses baroclinic and barotropic instabilities, wave-mean flow interactions and turbulence, and the general circulation of the atmosphere and ocean. Student problems and exercises are included at the end of each chapter. Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-Scale Circulation will be an invaluable graduate textbook on advanced courses in GFD, meteorology, atmospheric science and oceanography, and an excellent review volume for researchers. Additional resources are available at www.cambridge.org/9780521849692.