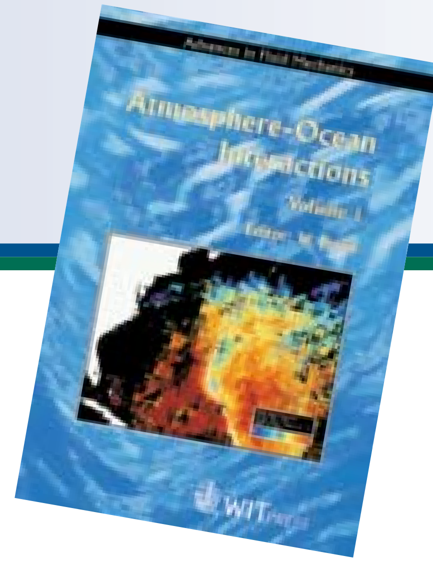
Book Reviews



Atmosphere-Ocean Interactions (Volume 1)

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This book is a valuable review of the field of atmosphere-ocean interactions, particularly as it relates to tropical cyclones and other marine storm systems. It presents a survey of several key mechanisms that are important for marine storms and their development. The book has nine chapters covering three topical areas including: basic considerations of marine storms regarding the interface, atmosphere, and the ocean (chapters 1-3); coupled models, including ocean-wave models (chapters 4-6); and, in chapters 7-9, issues of longer time scales and climate change in relation to marine storms.

The editor has gathered a strong cast of contributors who are at the forefront of their aspects of the field. They summarize recent work and discuss in a very enlightening way the path forward. The subject of atmosphere-ocean interactions and how it relates to marine storms has seen great advances in theory and modeling in the past 10 to 15 years, but very limited new data have been acquired. This state of affairs is recognized and some process type research programs are underway, for instance, the Coupled Boundary Layer Air-Sea Transfer (C-BLAST) program and future programs in the tropical Atlantic. The tone of the book, therefore, is often quite speculative, which is good under the circumstances. It will have great value due to its concise reviews, thorough and correct statements of the physics and processes that we understand, and a clear and honest evaluation of the missing links. I consider that it is vital reading for anyone planning future field programs, with the aim to really improve the forecasting of marine storms, extra-tropical as well as tropical (hurricanes, typhoons, their cousins in other ocean basins besides the Atlantic and Pacific Oceans, and their baroclinic cyclone descendants at higher latitudes).

Throughout, the authors emphasize air-sea interaction processes, especially the more sophisticated concerns, such as the role of sea spray, storm-generated waves, and their effects on momentum, energy, and mass transfer. These processes are not currently considered in most routine forecast models and, indeed, could not be since adequate formulations of parameterizations of their influence do not exist for a wide range of conditions. An exception for the case of momentum transfer is the use of the influence of the wave form drag on surface stress in a coupled wind-wave modeling system at the European Centre for Medium-Range Weather Forecasts (ECMWF). The authors of chapter 5, Janssen et al., illustrate that these processes are likely to have first or at least second order effects on storms, and they illustrate the magnitude and importance of these effects.

The first chapter by E.L. Andreas discusses the sea spray generation function for the open ocean. This author has spent well over a decade on this issue and has done a Herculean job of reviewing and bringing previous work into a consistent framework so that the results can be compared. I'm sure the small community involved in this work will continue to re-evaluate the few existing measurements until a comprehensive new data set is collected over the open ocean (at high enough wind speeds for sea spray to be created!) It's a tall order, but with this review in hand, I think the time has come for funding agencies to "bite the bullet" and push further work in this area. Why should we care? We should care a lot, because several chapters later in the book it is shown that the effects of the wave field (needed to generate spray) and the effects of these waves and the spray on momentum, energy, and mass transfer rates at the interface may have very strong consequences for the modeling of a storm.

For instance, J.-W. Bao, S.A. Michelson, J.M. Wilczak, and C.W. Fairall discuss the role of heat, mass, and momentum exchange coefficients in chapter 4, entitled "Storm simulations using a regional coupled atmosphere-ocean modeling system." They have used the best available models to include the wind/wave coupling and the role of spray in their simulations. They compare the effects of a half dozen possible formulations and find large differences in the maximum wind speeds achieved in a hypothetical tropical storm. Thus, this issue is an important one. P.A.E.M. Janssen et al. look at the large scale feedback of ocean waves on the atmosphere in their chapter 5 entitled "Impact and feedback of ocean waves on the atmosphere." The Bao et al. chapter and other earlier work by Doyle (1995, *Tellus,* "Coupled-ocean wave/atmosphere mesoscale model simulations of cyclogenesis") has shown that increased sea surface roughness and, therefore, greater momentum transfer, if waves are considered, reduces the wind speed in the atmosphere, as some of the momentum goes into wave generation. These feedback processes can modify the storm development models substantially. Janssen et al. suggest that the knowledge needed for the large scale models is mostly realized.

One difficulty in simulating the effects of interfacial processes, surface waves in particular, is that, according to Janssen et al., the effects of waves on the atmospheric model (the feedback) depends in a sensitive manner on the resolution of the atmospheric model. They report this result from the ECMWF model that has used a coupled atmosphere-ocean wave model since 1998 for which resolution increased from about 100 km to 50 km. Wave growth and dispersion is a very non-linear phenomenon. One can easily understand that if the wave directions are too coarse and somewhat in error the resulting modifications in the atmosphere (compared to an atmospheric model not interacting with surface waves) can be large.

Chapter 2 by J.R. Gyakum discusses "The extratropical transformation: A scientific challenge." Through the extratropical transformation (ET) process, hurricanes and typhoons bring their dramatic effects to higher latitudes. Gyakum discusses how such storms follow typical baroclinic wave development, but have exceptional diabatic processes, such as a potential vorticity maximum developing in the lower troposphere. The copious amounts of moisture lead sometimes to explosive development and dramatic effects of strong winds and flooding as these storms reach land. Northeastern Canada has an interest in tropical cyclones, as does the United Kingdom, for this reason. In the northwestern United States, such storms are called the "pineapple express," as the rich moisture and energy source comes from the Hawaiian regions. This chapter discusses the climatology of recurving Atlantic cyclones and extratropical development, the structure and development of ETs, and the dynamics and modeling of such weather systems. Gyakum concludes with a section on the challenges in forecasting ETs, one of them being the difficulty in forecasting the influence of the storms' warm outflow on the steering flow. Similarly, explosive development as a TC interacts with larger-scale environmental troughs is also very difficult to predict. He says the problem may be reduced to "getting the PV (potential vorticity) right." Again, this author points to improvements in capturing the development when a very high resolution model (1.2 km in an inner grid) is used, and includes boundary layer processes and other physical parameterizations as part of the challenges in predicting extratropical transformations.

Chapter 3 by I. Ginis focuses on "Tropical cyclone-ocean interactions." Dr. Ginis comments that whereas the storm tracks are mostly influenced by the atmospheric environments, the intensity change is influenced to a greater degree by smaller-scale features in both atmosphere and ocean. He illustrates how recent developments of three-dimensional coupled atmosphere-ocean models allow the mutual interaction to be simulated. The crux, he points out, is getting the coupled air-sea-surface wave numerical models with improved surface flux parameterizations tested against high-quality observations. The complexity of sea surface temperature change due to a passing tropical cyclone is discussed in terms of mixing and upwelling and is shown to depend substantially on the translation speed of the storm. The sea surface cooling (of the order of 2 to 5°C) produced by one storm persists for about a week and can influence the development of a subsequent storm following the same track. Ginis devotes a large section to discussing the role of interfacial processes, such as spray and bubble formation, waves, and swell at angles to the wind sea with similar concerns as those discussed by Bao et al. The emphasis in this chapter is more on the changes occurring in the upper ocean due to a passing cyclone. Ginis illustrates the important role of this interaction by real case simulations and idealized modeling. The conclusion is that the ocean must be included for successful tropical cyclone intensity forecasting.

Chapter 6 by W. Perrie and Z. Long discusses "Regional atmosphere-wave-ocean impacts." These authors deal with the atmosphere-ocean surface coupling on a scale that may be relevant for regional climate modeling. These processes can lead to negative feedback, i.e., the additional momentum absorbed by the rough, wavy sea surface reduces the intensity of a storm, while enhanced energy fluxes (latent and sensible heat fluxes), which they also associate with the coupled situation, would increase the storm intensity.

By running coupled models for storms in the North Atlantic, these authors identify synoptic scale effects of the wave-atmosphere feedbacks. In agreement with other studies, they find a slight shift to the rear of the storm of the most intense region (higher wind speed) and a slight shift southward of the storm track compared to an uncoupled simulation.

The authors compare uncoupled to coupled and measured values, which illustrates the superiority of a coupled model run in reproducing nature. The interesting aspect of this chapter is the application of the air-sea interaction to synoptic scales, which they show takes about five days for substantial impacts.

The authors also examine the effect of air-sea coupling on monthly time scales based on a two-month numerical experiment, which overlaps a field program in the Labrador Sea. Similar to the discussion by Janssen et al. in chapter 5, they find a slight weakening of the storm climate in the wave coupled case. Differences in horizontal wind speed at 10 m (U10) are only about 10% between coupled and uncoupled models. Differences in the turbulent energy flux are only of the order of 5% of the flux. Significant wave height effects are maximum near the storm center and large (1.4 m), based on these parameterizations.

C. Tang, N.A. McFarlane, and S.J.D. D'Alessio discuss the "Boundary layer models for the ocean and the atmosphere" in chapter 7. These authors review the bulk versus various turbulence closure models of first, second order, and even third order, for both the oceanic mixed layer and the atmospheric surface layer and the complete atmospheric boundary layer (ABL). They devote substantial discussion to convective and counter gradient fluxes (also referred to as non-local) and the difficulty of incorporating such complex formulations in the atmospheric general circulation models (AGCMs). This chapter is valuable in that it treats both the oceanic and atmospheric boundary layers with the same terminology and refers to similar modeling needs (formulation of stratification effects, turbulent closure via turbulent kinetic energy, and features such as skewness [third moments]).

Tang et al. also discuss the important issue of cloudy boundary layers and include equations for liquid water potential temperature, allowing the heating term due to latent heat of condensation. They discuss the nonhomogeneity of cloud properties due to cloud-generated turbulence and how this feature of cloudy boundary layers has often been handled with statistical cloud schemes. The conclusion of this chapter repeats the age-old observation that there is a lack of fundamental understanding of turbulence among many other processes insufficiently known. A similar observation could be made concerning the ABL, in particular, the problem of the large organized motions that are neither part of the mean flow nor turbulence (and could provide "non-local" or counter gradient fluxes). Furthermore, they are not usually included in models. I missed references to the work of Robert Brown, Ralph Foster, and others on the role of atmospheric organized eddies. The latter researchers have included secondary flows in ABL models showing a 10 to 20% increase in the surface fluxes compared to simple bulk models and they have attempted including them in general circulation models.

Chapter 8 on "The influence of air-sea interaction on tropical cyclones" by K.J.E. Walsh discusses the importance of atmosphere-ocean interaction on a larger scale to tropical cyclone development. Like Ginis in chapter 3, he brings in the importance of the sea surface temperature, the heat content of a deep layer, and cites the now famous example of warm eddies in the Caribbean or Gulf of Mexico being required for greater intensification, since shallower warm layers become depleted when an already intense tropical cyclone passes. In those cases, the storm leaves a substantially colder sea surface in its wake. Such a cold wake from a previous storm is thought to be responsible for the lack of intensification of Hurricane Danielle, which followed Hurricane Bonnie, in 1998.

The atmospheric circulations of 30 to 60 days, the Madden-Julian Oscillation, and its role in modifying tropical cyclone development is discussed, as well as the El Niño-Southern Oscillation. Both have been linked empirically to hurricane development, but modeling of either is still not complete and realistic, although some would claim successes for ENSO simulations. The author also reviews work on the influence of decadal variability and climate change on tropical cyclone frequency, track, and intensity.

R.E. Tuleya and T.R. Knudsen go further with this subject in their chapter "Impact of climate change on tropical cyclones," the last chapter in the book. They report results of a nested regional three-dimensional model, since global models do not handle mesoscale storm structure well. In a warmer climate, with approximately 2.5°C higher tropical sea surface temperatures, tropical cyclones would be more intense. They report under this scenario a 3–10 percent increase in surface wind speed and 20–30 percent more rain. Storm track and frequency changes in a warmer climate they consider too problematic to predict.

In conclusion, the book is a very valuable review of the state of knowledge in many aspects of atmosphere-ocean interactions. The chapters are somewhat uneven in scope, size, and depth, but the science covered is also of varying maturity. There is some overlap between chapters. The book is generally well written. I found only a few typos, but I must express my regret that some illustrations are quite poor. Photographs and pressure maps have poor resolution, and some figures have been reduced so much that labels are hardly readable. These flaws are mostly cosmetic and do not substantially limit the readers' ability to follow the discussion, but these serious authors deserve better reproductions. Nonetheless, researchers in the field of atmosphere-ocean interactions on all scales, and not just those who focus on storms, would find this book a valuable reference source. The editor, W. Perrie, and all the authors should be congratulated!