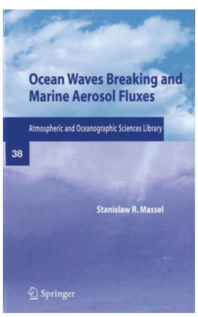
READINGS

BOOK REVIEWS

OCEAN WAVES BREAKING AND MARINE AEROSOL FLUXES

Stanislaw R. Massel, 2007, 323 pp., $129.00, hardbound, Springer-Verlag, ISBN 978-0-387-36638-8

Two books I recently purchased are *Waves in Ocean Engineering* (Tucker and Pitt 2001) and *Sea Salt Aerosol Production: Mechanisms, Methods, Measurements and Models—A Critical Model* (Lewis and Schwartz 2004). Stanislaw Massel's book, *Ocean Waves Breaking and Marine Aerosol Fluxes*, neatly fills the niche between them on my bookshelf (figuratively speaking). *Waves in Ocean Engineering* primarily discusses the basics of linear waves and is a recent contribution in a series of similar texts that began with *Wind Waves* (Kinsman 1965) and includes, among others, *Dynamics and Modelling of Ocean Waves* (Komen et al. 1994) and *Wind Generated Ocean Waves* (Young 1999), as well as an earlier book by Massel (1996), *Ocean Surface Waves: Their Physics and Prediction*. Each of these books spends only a few pages discussing breaking waves, which are nonlinear.



Meanwhile, *Sea Salt Aerosol Production* is the only book that deals exclusively with the sea-salt aerosol; it explains in its very first paragraph that this aerosol arises from breaking waves. Massel's new book describes how to model wave breaking and continues on to show how to use breaking wave models to estimate the production rate of the sea-salt aerosol at the ocean's surface. Sea salt and other marine aerosols are generating current research interest because of their influence on climate, their role in atmospheric chemistry, and sea spray's ability to enhance the air–sea exchange of heat and moisture in storm winds.

Standard texts on ocean waves say little about wave breaking because the subject is so difficult, both theoretically and experimentally. Yet Massel authoritatively attacks the subject head-on. Approximately two-thirds of his book addresses theory and observations of wave breaking and related phenomena, such as whitecaps. His approach is mathematically intense in places, but well balanced. For instance, for most topics, he does not just present his favorite theory but generally reviews several competing theories, which often yield disparate results. This diversity in predictions highlights the current state of the science.

Chapter 5, on breaking criteria, is a good example of Massel's approach and the complexities in this field. There, Massel explains that three distinct criteria have been used to judge when a wave will break. One criterion is wave steepness. When a wave is steeper than some limit, it is predicted to break—but the value of this limiting steepness is still uncertain. A second criterion postulates that a wave crest will break when it experiences a downward acceleration of, say, ½*g*, where *g* is the acceleration of gravity. Here, the limiting acceleration, roughly ½*g*, is still under debate, as is whether the criterion applies to the Lagrangian or the Eulerian acceleration. The third breaking criterion is a kinematic one. When the water velocity exceeds the phase speed of the wave crest, the wave must break. Waves on beaches, for example, break by meeting this criterion, but Massel's focus is on deep-water waves in the open ocean.

Massel links his first seven chapters on wave breaking and his closing four chapters on the sea-salt aerosol with a chapter that provides a very good review of ocean whitecaps. Whitecaps are the visual evidence of wave breaking and have long been recognized as the primary source of the sea-salt aerosol. Massel's whitecap chapter reviews newer data and is more theoretical than the review in Bortkovskii's (1987) book, *Air–Sea Exchange of Heat and Moisture During Storms*, but, naturally, does not cover the breadth of topics in the book, *Oceanic Whitecaps and Their Role in Air–Sea Exchange Processes* (Monahan and Mac Niocaill 1986).

This chapter on whitecaps is key to Massel's logic. Many models predict sea-salt production from whitecap coverage but predict whitecap coverage from just wind speed. Whitecap coverage depends on more than wind speed, however. Massel's contribution is to predict whitecap coverage by predicting wave breaking. He then invokes standard methods that relate the production of the sea-salt aerosol to whitecap coverage.

The closing chapters on the sea-salt aerosol are the weakest in this book. Massel seems to be somewhat out of his realm of expertise in these and, therefore, presents a limited review of select topics that contrasts with his thorough and authoritative review of wave breaking. Still, he does achieve his objective of closing the sequence from wave breaking to operational aerosol forecasting by finishing his book with a chapter in which he demonstrates seasonal predictions of sea-salt production for the entire Baltic Sea.

I like the production quality of this book. It has a comfortable size, pleasing font style and size, and sufficient white space to make for easy reading or scanning. The many figures are uniformly styled and formatted, thereby reinforcing the coherence of the presentation.

The book does have editorial weaknesses, however. Most figure captions are rudimentary at best; readers must scan the text on surrounding pages to obtain a full explanation of what the figures are presenting. Units are often nonstandard and violate the rules of SI usage to which readers of AMS journals are accustomed. Here are a few examples of unusual units: m*m/s (p. 37), m^{-2}/s (p. 163), $J/m^2/s$ (p. 167), $kg/(m^2\,s^1)$ (p. 207), and $kg/(m^2 year^1)$ (p. 227). The book has more typographic and proofreading errors than well-edited texts do. The subject index is too short—only four pages. In books such as this that are intended primarily as a reference, developing a comprehensive index is worth the effort. These are just a few terms that are key to the study of breaking waves but are not in the index: asymmetry parameter, breaking intensity, breaking rate, and wave steepness.

I have written before that discussions of the sea-salt aerosol are often unnecessarily confusing because sea spray droplets continually change size, but the aerosol community has agreed on no sizing convention for such evolving particles (Andreas et al. 2001; Andreas 2002). Massel potentially adds to that confusion. Starting on page 231, he reviews several published expressions for the radius-dependent rate of spray droplet production, denoting the droplet radius as *r* but not defining here what *r* represents. Readers scanning the book and finding these equations might logically assume that r is the radius of the droplet when it is created. Unfortunately, it is not. Twenty pages earlier (p. 213), Massel states that, henceforth and without further comment, r will always mean r_{80}, the radius a spray droplet has when it is in equilibrium at a relative humidity of 80%. Readers who have not read or carefully scanned the whole book will be unaware of this definition and could badly miscalculate the spray production rate by using the wrong radius in the equations here.

In closing, this book fills a heretofore empty niche by rigorously connecting breaking ocean waves with the sea-salt aerosol that they create. As such, it should be a valuable reference text for researchers studying air–sea interaction and marine aerosols. The book could also supplement a standard waves text in a graduate-level course on ocean waves.

—Edgar L Andreas

Ed Andreas is a senior research scientist with NorthWest Research Associates. His research focuses on air–sea interaction in the presence of sea ice and on air–sea interaction over the open ocean, especially in high winds when sea spray plays a significant role in mediating air–sea exchange. He is the current chairman of the AMS Committee on Air–Sea Interaction.

FOR FURTHER READING

Andreas, E. L, 2002: A review of the sea spray generation function for the open ocean. *Atmosphere–Ocean Interactions, Vol. 1*, W. A. Perrie, Ed., WIT Press, 1–46.

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Komen, G. J., L. Cavaleri, M. Donelan, K. Hasselmann, S. Hasselmann, and P. A. E. M. Janssen, 1994: *Dynamics and Modelling of Ocean Waves*. Cambridge University Press, 532 pp.

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