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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of this article.

Figure S1. Future 'central estimate' projection of snow cover for the 2041–2060 period based on the logistic curve for snow cover to mean temperature relationship (Figure 4). This 'central estimate' is based on the mean of data from the ensemble of 12 HadGEM/HadREM RCP8.5 model runs used to provide regional details in the UK Climate Projections 2018 (see https://ukclimateprojections.metoffice.gov.uk). NB. Further downscaling to 1km has been applied through a delta change method using the local detail provided for the baseline period (main paper: Figure 5) to show relationship with local topography (see Brown, 2019, for further explanation).

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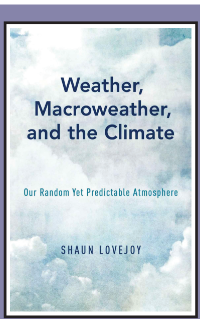
Book reviews



Weather, Macroweather, and the Climate

S. Lovejoy

Oxford University Press, 2019

ISBN: 978-0-19-086421-7

Hardback, £22.99

352 pp

This semi-popular book should be compelling reading for scientists of all stripes, in that while it is beyond a non-scientific audience, it is designed to be accessible to the wider scientific audience who, while they are engaged in their own highly specialised areas, are nonetheless interested in weather and climate. It will also be a very useful primer for atmospheric professionals who are in need of an introduction to specialised topics such as scale invariance, multifractality and the concomitant non-Gaussian probability distributions.

The central theme of the book is that the traditional division of meteorology into weather and climate is wrong, and should be superseded by the three given in the title. That conclusion is based on temporal and spatial analyses using nonlinear techniques that reveal different régimes in the present era: weather up to 10 days, macroweather from 10 days (approximately the time for air to circumnavigate the globe) to about 30 years, and climate from 30 years to the maximum analysed, hundreds of millions of years. Of course, extension beyond the mid-19th Century means using proxy data everywhere except central England, which is done with care and insight. The key analysis of fluctuations is via the *H* exponent, named for Hausdorff, Hölder or Hurst, according to discipline. It is a well proven method, and has positive values between 0 and 1 for weather and climate, meaning that fluctuations wander and means can amplify. The observed negative values of *H* between 0 and –0.5 that characterise macroweather show that fluctuations dampen and means stabilise. Lovejoy points out some important consequences of the approach and its results, which are derived from observations and are independent of numerical modelling. Indeed, one of the conclusions is that general circulation models predict macroweather and not climate. Another conclusion is that the rise in global mean surface temperature since mid-19th Century is attributable very largely to carbon dioxide increases from fossil fuel burning and other industrial and agricultural gases such as methane, nitrous oxide and chlorofluorocarbons; the rise cannot be a giant natural fluctuation. That concept is reinforced by the positive feedback of more water vapour rising from the warmer sea surface. The central role of fat-tailed probability distributions is emphasised, and the concomitant non-existence of Gaussianity discussed. Richardson's fractional $^4/_3$ power law of atmospheric diffusion is vindicated.

The first three chapters are a well-written, accessible introduction to the nonlinear techniques employed, with selected examples connecting observations with the basic mathematical principles. Among the major points is an emphasis on the difference between scale-bound mechanisms – the invocation of specific processes for phenomena at specific scales – and scaling, which covers all scales. Scaling is driven by a cascade of fluxes of energy density, with the observed absence of white noise being accompanied by prevalent long range correlations and power law probability distributions. Chapter 4 starts to discuss applications and results, beginning with turbulence as observed from aircraft and proceeding through macroweather to climate scales. Among the casualties is the so-called mesoscale gap between two dimensional and three dimensional régimes, which is shown to be non-existent. Because the book is semi-popular, the author has licence to discuss events at the science-politics interface, and the sociology of the denial of global heating, which he does in this fourth chapter. It will both entertain and ring bells for the vast majority of scientists, with the dishonesty of denial revealed on the basis of observational analysis. Chapter 5, Macroweather, the Climate and Beyond is in many ways the heart of the book, with an incisive analysis of where we are in our understanding of the observed past and present behaviour of our fluctuating atmosphere. It comprises nine sections ranging up to Ice Ages (5.8) and the Death of Gaia (5.9). There is adequate scope for debate in the chapter, along with the need to recognise the force of the analysis. Chapter 6, 'What Have We Done?', uses the analysis techniques developed to refute climate change denial as a whole, demolishing en route the denialists' idea that the warming prior to and the 'pause' after 1998 was a giant natural fluctuation. The final chapter, 7, essays predictions of future macroweather and projections of climate. It is properly cautious but will be of great interest as reading material and as a potential guide to those who wish to add a new branch to the prevailing canon of numerical modelling. The condensed conclusions are presented in two pages under the heading 'Richardson's Dream'. There is an acknowledgement that the nonlinear revolution is not complete, and that there is room for improvement. Given the prominent place Richardson has in the Royal Meteorological Society's pantheon, it is appropriate that if any busy professional reads nothing else, it should be these two pages.

My penultimate paragraph is devoted to the need for better sub-editing: one substantial error is the transposition of the upper left and lower right parts of Figure 3.10. There are several problems with the names of cited authors, including Arrhenius (not Arhennius), George (not Gershon) Robinson and confusion between Walter and Tim Palmer. Also, I have to register some points of scientific questioning. There is evidence from theoretical physical chemistry that dissipation from larger scales to randomness does not start at millimetres in the atmosphere, but continues to cascade down another three orders of magnitude to a few mean free paths. In my view, too much is made of deterministic chaos and the 'butterfly effect'. The latter will be lost in one or two flaps because of dissipation, and it seems to this reviewer that there is a question of the lack of observed meteorological consequences when millions of Monarch butterflies migrate between Mexico and Canada. The appeals to what is called 'thermodynamic equilibrium' really ought to be to 'steady state': the planet's fluid envelope has never been, is not and never will be at true thermodynamic equilibrium. Lastly, I could find no mention of human population growth as a factor in the rise of greenhouse gases, via its interaction with economic growth.

My conclusion is that this book is a well-written, incisive analysis of the atmosphere's behaviour over a wide range of spatial and temporal scales, aimed at the wider scientific audience. It is highly recommended to professional meteorologists too, and this reviewer certainly benefited from reading it. I conclude with the thought that if a few percent of the resources currently being invested in numerical modelling were to be invested in these nonlinear, scale invariant methods, the dividends might be large. Finally, I point out that I was a co-author of Lovejoy's on ten papers between 2004 and 2012 on the interpretation of aircraft and dropsonde observations.

Adrian Tuck

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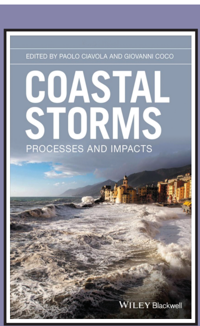

Coastal Storms – Processes and Impacts

Editors: Paolo Ciavola, Giovanni Coco

Wiley-Blackwell, 2017

Hardback £90.00

288pp

ISBN 978-1118937105

The news bulletins during the opening days of September 2019 were full of detailed reports of Hurricane Dorian, at the time the strongest Atlantic hurricane ever to make landfall as measured by sustained winds. Because of the prolonged and intense storm conditions, damage in the Bahamas was catastrophic. In an age of climate change, these extreme events may well become more frequent.

Coastal Storms – Processes and Impacts is part of a series on hydrometeorological extreme events which primarily discuss the science behind these events and develop specific discussions about floods, coastal storms and storm surges, droughts, resilience and adaptation. This book is aimed at undergraduate students and professionals in the field, providing a first-of-its-kind, in-depth overview of the effects of storms on a variety of coastal environments. Following a short introduction, the opening chapter attempts to define what is classified as a 'coastal storm', thus laying the platform for discussion in the remainder of the book. Subsequent chapters explain the physical processes operating during storms from detailed hydrodynamics and sediment transport that occur in coastal storm conditions to coastal storm impacts on sandy beaches, barrier islands, cliffed coastlines, tidal flats and coral reefs, highlighting that there is still much to learn.

Chapter 9 is devoted to the role played by storm clustering while chapter 10 looks in detail at the most up-to-date advances in the numerical modelling of storm dynamics and effects. This chapter illustrates vividly that the increased knowledge and development of numerical models has not readily translated into improved predictions of storm impacts. This failure is due not just to how the models operate but also to the differing properties of individual storms, such as duration and movement, wave height and period, and the angle at which a storm approaches the coast. Other important factors include the breaking of waves as a result of coastal bathymetry as well as water level and tidal effects. Research on these issues is ongoing. The book's final two chapters focus on the societal aspects of storms and suggest ways to develop frameworks to assess hazards and risk management.

Each chapter is well constructed, with an introduction followed by the main argument and then a conclusion, often highlighting future challenges. The text is backed up by numerous clearly annotated graphs, illustrations and photographs. The 30 contributing researchers are all internationally recognized experts from research institutions in Europe, the USA and Australia. Their work reflects the science and policy advances in this field up to 2017. The editors are Paolo Ciavola, an Associate Professor of Geomorphology at the University of Ferrara, where he teaches courses on geomorphology and coastal risk, and Giovanni Coco, an Associate Professor in the School of Environment at the University of Auckland, where he teaches courses on modelling environmental systems.

In the concluding chapter, the editors quite rightly highlight that the book covers only the marine aspects of storm processes, mainly waves and surges, and the part that the wind can play in these phenomena. Coastal impacts can also be generated by meteorological and hydrological processes such as torrential rain, hail, snow, flash floods and river flooding, but these are not discussed in this book.

This is a book I highly recommend; it should stimulate students and scientists to advance their understanding of coastal storms. The introduction states, 'We hope this book contributes to a better planning of measures to increase resilience of coastal communities'. I believe it will.

Graham Denyer

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