TIME SERIES ANALYSIS IN METEOROLOGY AND CLIMATOLOGY: AN INTRODUCTION

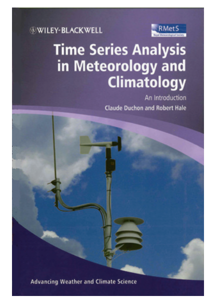
Claude Duchon and Robert Hale, 2012, 250 pp., $99.95, hardbound, Wiley-Blackwell, ISBN 978-0-470-97199-4

Weather, climate, oceanographic, and turbulence data are often collected as time series because the analyst's objective is to see what time scales contribute most to the total variance of the observable. Although many books are available that cover time series and spectral analysis, most emphasize the general mathematics of the analysis. While Duchon and Hale do lean heavily on one such text, Jenkins and Watts's classic *Spectral Analysis and Its Applications*, their book is one of the few that concentrates on practical analyses of meteorological time series. As such, it is a nice complement to the longer, broader treatment of meteorological statistics by Wilks in his *Statistical Methods in the Atmospheric Sciences*, because Wilks spends only about 20 pages on spectral analysis.

The book is divided into five chapters that flow logically from time series data to estimating spectra. Chapter 1, on "Fourier Analysis," is more than twice as long as any other chapter because it develops material used in all of the subsequent chapters. The crux is the discussion of Fourier transform pairs and the related calculation of the periodogram. Aliasing—the appearance of higher-frequency information at lower spectral frequencies—is a key concern in spectral analysis. The authors present several figures and examples to demonstrate aliasing, including the explanation that wagon wheels in old cowboy movies eventually appear to spin backwards as the wagon accelerates from rest because of the limited shutter frequency for film photography.

This chapter also develops the concept of a harmonic through discussion and illustrations. Although I took my first time series course almost 40 years ago and have played the guitar (badly) even longer, not until reading this chapter did I understand what a harmonic is: the integer number of times a full sine (or cosine) fits exactly in a data record.

On reading this chapter, we also infer the general focus of this book, which is on meteorological and climate time series. For these, the analyst may have had no part in determining the sampling strategy and, thus, must analyze the data as given. As a result, the time series may have few observations; the statistics are thus not well constrained. Or the sampling frequency may be smaller than the highest frequency in the observable—aliasing is then a concern. In effect, the authors are not necessarily treating turbulence time series in which an hour of data may contain 50,000 samples and knowledgeable observers can set the sampling frequency to be higher than the highest expected frequency in the observable. While most of the techniques in this book can be adapted to turbulence time series, Kaimal and Finnigan's shorter treatment (especially chapter 7) in *Atmospheric Boundary Layer Flows* is specific to turbulence and bridges some gaps.



Chapter 2 is on "Linear Systems." A concrete example of a linear system is a device that measures a physical variable such as wind speed. An anemometer senses the wind speed and puts out a digital (or analogue) representation of that variable. The system, thus, has three components: the physical variable, the sensor, and the output series. If the system is linear, the output is proportional to the physical variable. Linear systems, however, also manifest as mathematical filters; and the mathematics for such processing—namely, convolution integrals, the impulse response function, the frequency response function, and the Fourier transform of the convolution integral—form the core of this chapter.

Chapter 3, on "Filtering Data," naturally comes next. Filtering either the original time series or the computed spectrum is often necessary. For instance, we may want to smooth a time series, remove an unwanted frequency component, or focus on a particular time scale in the series. We can also filter spectra to smooth them or to isolate a particular frequency range. The chapter reviews four common one-parameter, nonrecursive filters that are represented as weights that multiply elements in the time series. The four filters are the running mean and the triangular, cosine, and difference filters; the one-parameter in each is the number of weights. The authors use mathematics and illustrations to demonstrate how each filter influences the frequency content of the resulting spectrum.

The chapter closes with a presentation of the Lanczos filter, a two-parameter filter; the parameters are the number of weights and the cut-off frequency. Because of its two parameters, the Lanczos filter creates a frequency response function that has a narrower frequency band between unit response and zero response and that also has smaller Gibbs oscillations above the cut-off frequency. The appendix to this chapter includes a Fortran program for computing Lanczos filters.

Chapter 4, on "Autocorrelation," speaks most to me. The feature that distinguishes time series data from other random data is that nearby points are correlated. As a result, the degrees of freedom used to calculate various statistics for a time series is not *N*, the number of samples, as is taught in all statistics books. Rather, it is some smaller number (often much smaller). The book logically develops all the pieces necessary for formally deducing in sections 4.5 and 4.6 what these effective degrees of freedom are. A similar expression, for example, is buried (p. 327) in Priestley's massive book, *Spectral Analysis and Time Series*, and is presented only as a heuristic result by Wilks (p. 145). Duchon and Hale's result, on the other hand, is clear, obvious, and rigorously derived.

Chapter 5, "Lagged-Product Spectrum Analysis," brings everything together for calculating the so-called "variance density spectrum." A key result here is that the autocovariance function and the variance density spectrum are Fourier transform pairs. As a consequence, weighting the autocovariance function with a lag window (here, the Tukey window) accomplishes spectral smoothing as if the spectrum were multiplied by the Fourier transform of the lag window.

The book is narrowly focused on getting from time series data to the autocorrelation function or the spectrum. The analysis is based solely on the Fourier transform; there is no discussion of other basis functions, such as wavelets, which are seeing increasing use in the atmospheric sciences.

Early in the book, the authors mention that they will not consider nonstationary time series; and, in keeping that promise, they say nothing about trend removal. A trend is the easiest manifestation of nonstationarity to treat, and other books that likewise presume stationary time series discuss removing trends (e.g., Bendat and Pierson 1971; Priestley 1981; Kaimal

NEW PUBLICATIONS

PHYSICS OF THE ATMOSPHERE AND CLIMATE

M. L. Salby, 2012, 666 pp., $90.00, hardbound, Cambridge University Press, ISBN 978-0-521-76718-7

This book provides an integrated treatment of the processes controlling the Earth–atmosphere system, developed from first principles through a balance of theory and applications. It provides a conceptual yet quantitative understanding of the controlling influences, and leads readers through a methodical development of the diverse physical processes that shape weather, global energetics, and climate. The presentation of the book has been streamlined for undergraduates in science, mathematics, and engineering, and end-of-chapter problems help to develop student knowledge.

MISSISSIPPI WEATHER AND CLIMATE

K. Sherman-Morris, C. L. Wax, and M. E. Brown, 2012, 202 pp., $26.00, hardbound, University Press of Mississippi, ISBN 978-1-61703-260-8

This title looks at the science behind the weather and how natural events affect the people and land in the Magnolia State. It discusses the factors that shape Mississippi's climate and what "normal" weather conditions are in the state; looks at some of Mississippi's most dramatic meteorological catastrophes, such as the Candlestick Park tornado, Hurricanes Camille and Katrina, and the ice storms of 1994 and 1998; and also explores what the state's future weather may look like.

THE FUTURE OF THE WORLD'S CLIMATE

A. Henderson-Sellers and K. McGuffie, 2012, 650 pp., $134.95, hardbound, Elsevier, ISBN 978-0-12-386917-3

This book attempts to present a complete picture of the Earth's future climate by placing predictions by climatic models into their geological, paleoclimatic, and astronomical context. It summarizes our current understanding of climatic prediction and examines how that understanding depends on a grasp of integrated Earth system models and human interactions with climate. It includes more than 300 tables, diagrams, illustrations, and photographs that depict climatic conditions globally, regionally, and locally.

and Finnigan 1994) because trends are common and have confounding effects on spectra and autocorrelation functions (e.g., Panofsky and Dutton 1984, p. 174ff.; Kaimal and Finnigan 1994, p. 264ff.).

This book is a pleasant read. The size is comfortable: 7" by 10" and 250 pages. The design makes good use of white space, and the text is not so densely packed that scanning for key words is difficult. The figures are all crisp and in black and white. They are all similarly formatted, as if they were prepared specifically for this volume and were not simply a potpourri of figures reused from the authors' previous publications. I found very few typographical and math errors.

The writing style, however, is inconsistent and occasionally at odds with recommendations from writing authorities. The text often does not include a comma after prepositional phrases, infinitive phrases, and dependent clauses that open sentences—but sometimes it does. Admittedly, some such commas are a matter of choice, but omitting the comma after a dependent clause is a grammar error.

The authors frequently use the "A and/or B" construction. Most writing authorities decry the use of "and/or" as ambiguous. Fowler's *A Dictionary of Modern English Usage* calls it an "ugly device" (p. 29). For Day and Gastel (in *How to Write and Publish a Scientific Paper*, p. 190), it is a "mental monstrosity that should be avoided." Furthermore, the "and" is redundant. In English, "or" is not an exclusive or (cf. Garner 2003, p. 45). That is, readers will usually interpret "A or B" to mean "A or B or both," not "A or B but not both."

This book is designed for an introductory course to introduce graduate and advanced undergraduate students to time series analysis. Calculus is a prerequisite, and a course in probability and statistics would also be good background. Each chapter ends with several problems for students to solve. A website dedicated to this book includes teaching aids and datasets that are used in the illustrations and in the problems.

In summary, I unequivocally endorse this book as a valuable contribution to the literature of time series analysis in the geosciences. It is clear and includes examples that make it accessible for students; knowledgeable practitioners will also gain new insights from this book.

—Edgar L Andreas

Ed Andreas is a senior research scientist with NorthWest Research Associates; his office is in Lebanon, New Hampshire. In his research on air–sea interaction, air–sea–ice interaction, and boundary-layer turbulence, Ed uses statistics obtained through time series analysis almost daily.

REANALYSIS

Looking back at the *Bulletin* of November 1948:

Weathermen Contract with Airline on Basis of Forecast Accuracy

Continental Air Lines meteorologists have to be 90% right or lose their jobs. That clause was written into a unique union contract that took effect last March. The union: a new Society of Airline Meteorologists, which is out to organize airline weathermen nationally.

The contract provides that, for safety's sake, Continental meteorologists must give accurate forecasts (1) of height of ceiling and visibility at the Denver airport four hours in advance, and (2) of weather conditions on the company's 2,900 miles of routes. Meteorologists are to be graded on their forecasts (0%–100%) by pilots. The union has set 90% as a "fair" standard. If a member at Continental fails to keep that grade, he may be discharged without recourse to grievance procedures. Union members must also swear annually that they are not Communists. The contract bars them from striking or hampering company operations. . . .

—*Bull. Amer. Meteor. Soc.*, **29,** 480

FOR FURTHER READING

Bendat, J. S., and A. G. Piersol, 1971: *Random Data: Analysis and Measurement Procedures*. Wiley-Interscience, 407 pp.

Day, R. A., and B. Gastel, 2006: *How to Write and Publish a Scientific Paper*. 6th ed. Greenwood Press, 302 pp.

Fowler, H. W., 1973: *A Dictionary of Modern English Usage*. 2d ed. Oxford University Press, 725 pp.

Garner, B. A., 2003: *Garner's Modern American Usage*. Oxford University Press, 879 pp.

Jenkins, G. M., and D. G. Watts, 1968: *Spectral Analysis and Its Applications*. Holden-Day, 525 pp.

Kaimal, J. C., and J. J. Finnigan, 1994: *Atmospheric Boundary Layer Flows: Their Structure and Measurement*. Oxford University Press, 289 pp.

Panofsky, H. A., and J. A. Dutton, 1984: *Atmospheric Turbulence: Models and Methods for Engineering Applications*. John Wiley and Sons, 397 pp.

Priestley, M. B., 1981: *Spectral Analysis and Time Series*. Academic Press, 890 pp.

Wilks, D. S., 2006: *Statistical Methods in the Atmospheric Sciences*. 2d ed. Academic Press, 627 pp.