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Book review

Xuhui Lee, William Massman, Beverly Law (Eds.), Handbook of Micrometeorology—A Guide for Surface Flux Measurement and Analysis, vol. 29 Kluwer Academic Publishers, Atmospheric and Oceanographic Sciences Library, 2004, (250 pp., ISBN 1-4020-2264-6 (HB))

As stated in both the preface and the introduction (Chapter 1), this book volume is a collection of writings by guests of an international workshop hosted by AmeriFlux and sponsored by the U.S. Department of Energy in 2002. The stated goal is to provide micrometeorologists, ecosystem scientists, boundary-layer meteorologists and students of micrometeorology with the state of science on eddy-covariance measurements and analysis techniques of exchange of mass and energy between the terrestrial biosphere and the atmosphere. This book also seeks to provide useful advice for bringing some coherence to estimates of mass and energy exchange, and to stimulate (not "simulate" as a typo in the preface suggests) efforts to study phenomena that may fall outside the scope of the normal science of micrometeorology.

Chapter 2 reviews the main methods used to separate the active, turbulent transport that is treated as eddy-covariance flux from the slower, deterministic atmospheric motions and instrument drift. The interpretation of the latter, however, in my view, is less straightforward and still presents a challenge. For example, no definitive method can be recommended to distinguish sensor drift from true low-frequency atmospheric signal. The advantages and disadvantages of various algorithms used in averaging, detrending and filtering are discussed in terms of whether or not they obey Reynolds averaging rules and how their transfer functions behave in the lowest and highest frequencies. It is concluded that the best method is site-dependent, including the signal processing system. Ogives (integrations of cospectra) are recommended to determine the optimal averaging period (from 30 min to 4 h) at a given site. It also includes a more recent work that the high-pass filtering effect of the run-to-run rotation which forces the mean vertical velocity to zero, and that the high-frequency part of the vertical cospectrum may be contaminated by the horizontal cospectra.

Chapter 3 examines both theoretical and operational aspects of coordinate systems, which are necessary for meaningful interpretation of observed eddy-covariance fluxes. The theoretical discussion makes the distinction between the vector bases, a local property of a coordinate system as used in point measurements, and the overall coordinate frame consisting of the vector bases and coordinate lines, i.e. a global property of the flow which is determined by the flow field in 3-D. The latter is necessary since, in practice, the mass balance equation is integrated over a control volume of the representative ecosystem and underlying surface. The advantages and disadvantages of Cartesian and streamline coordinate systems are compared. Since many components of the mass balance in complex flows are under-sampled in field conditions, a properly chosen coordinate system for point measurements should optimize estimates of surface-air exchange and maximize information for diagnostics purposes. The strength and weakness of three operational coordinate systems for point measurement (instrumental, natural wind and planar fit) are discussed. A number of causes for coordinate tilt are given. Although the planar fit coordinate appears to be the preferred choice, cautionary notes are given for its application.

Chapter 4 discusses flux losses at both high and low frequencies. It begins by comparing the strength and weakness of the transfer function approach and the in situ methods, and then focuses on the estimate of uncertainties in spectral corrections using the transfer function approach. An analytical method is used to perform a formal error analysis to estimate model uncertainties on the correction factor due to errors or uncertainties in model parameters, which include the peak frequency, slope in the inertial subrange, broad-

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ness parameter and normalization parameter for the smooth cospectral model, as well as time constant for the transfer functions associated with block-average (low-frequency attenuation) and those for all the highest-frequency attenuations. It is perhaps not a surprise that spectral corrections and associated uncertainties are site-dependent because cospectral characteristics and measurement system vary from site to site, which calls for further investigation.

Chapter 5 focuses on the issue of low-frequency flux (greater than 1 h). It starts with a discussion on spatial and time scales in various characteristic layers in the atmospheric boundary layer, and then provides some empirical evidence of low-frequency flux based on wavelet analyses of turbulent fluxes measured at two contrasting sites. This is particularly the case in the tropics, days characterized with low mean wind speed, deep convective boundary layers and greater measurement height. It repeats the high-pass filtering effect of the run-to-run rotation forcing the mean vertical velocity to zero, and with the high-frequency part of the vertical cospectrum possibly contaminated by the horizontal cospectra, as briefly discussed in Chapter 2. Some cautionary notes are also given. One is that extending the averaging/rotation period from 1 up to 4 h may improve energy balance closure at some sites but not at other sites. A more general skepticism is whether these low-frequency fluxes are ''locally meaningful'' or representing features of the wider landscape that are not related to the local surface, or caused by wind direction variations that have nothing to do with flux transport. Separating the fluxes from larger-scale advection is still a challenge.

Chapters 6 extends the original Webb–Pearman–Leuning (WPL) theory from 1- to 3-D and concludes that the mass conservation equation is relatively simple when concentrations are expressed as molar mixing ratios relative to dry air, in contrast to more complex expressions when absolute concentration is used. Advective mass fluxes are written as products of fluxes of dry air and gradient in mixing ratio, while turbulent eddy flux is defined as the covariance of turbulent velocity and mixing ratio. The original WPL correction for 1-D flow is still applicable for the vertical eddy-covariance flux.

Chapter 7 examines how eddy-covariance instrumentation, particularly spectral attenuation and an instrument's basic technology influence the application of the WPL corrections. For the closed-path system, it is suggested that (1) spectral corrections be made before the WPL correction, (2) high-frequency point-to-point conversions from mass density to mixing ratio is not the preferred method for estimate eddy-covariance flux, (3) spectral correction for the WPL covariance terms are not the same as the density covariance term and (4) using the same spectral corrections for the density covariance term and the water vapor covariance term can introduce biases into the annual estimates of the carbon sequestration. It also indicates that WPL pressure covariance term and contamination of closed-path chamber by low-frequency temperature fluctuations may be significant sources of bias.

Chapter 8 departs from previous chapters, which focus more directly on the calculation of eddy-covariance fluxes, and presents an elementary review of stationarity, homogeneity and ergodicity. It argues that the canopy sublayer (CSL) is intuitively non-homogeneous, which may be reduced by spatial averaging, moving equilibrium hypothesis, natural variation in wind direction when integrated over sufficiently long periods. The intermittent nature of very stable CSL flow leads to the violation of both stationarity and ergodicity. It suggests that averaging over longer time periods across various wind directions is necessary for reducing the non-homogeneity inherent to all CSL flows. In my view, however, this is not without complication as indicated in Chapter 5.

Chapter 9 summarizes some of the procedures used in post-field data quality control. It includes a review of methods used in identifying instrumental errors in the raw data, a steady-state test, a well-developed turbulence test using integral turbulence characteristics based on similarity theory, and an overall quality flag system. A site-specific quality analysis using footprint modeling is also discussed. The presented quality control tools are said to work in most meteorological conditions and especially over short vegetation. Further investigation is called upon to find adequate algorithms to check data quality over forests. A general discussion on further problems of quality control is also given, ranging from energy balance closure, coordinate rotation, gap filling, to coherent structures and advection and to physiological tests. Some casual and questionable statements are made, however, for example, ''The contribution of coherent structures to the whole flux is generally unknown''. ''In contrast, single coherent structures can indicate non-stationary conditions and be identified falsely as low quality data''.

The focus of the final Chapter 10 is on scalar advection due to topography. Vertical profiles of mean velocity along 2-D ridges covered with uniform canopy are presented from both analytical solutions and wind tunnel experiments. It is shown that both the turbulent wind field and the scalar field and transport in the canopy on a hill have a two-layer asymptotic structure with quite different dynamics. Their matching through the upper canopy leads to strong modulation of turbulent transport over the hill and substantial advective flux divergence (up to 40%). Hill-induced perturbations on photosynthesis are also calculated and found to be small (on the order of hill slope). As pointed out by the author, there are an enormous number of possible configurations of 2- or 3-D underlying topography and inhomogeneous canopy sources and sinks. Modeling has and will always play a bigger role in advection studies than field studies because of the expense and difficulty of making measurements in inhomogeneous terrain.

Overall, this book presents the most relevant, if not all, aspects of the state of science concerning eddy-covariance measurement and analysis of land–biosphere–atmosphere exchange of mass and energy, based on the work by the authors and others involved in the FLUXNET community. Throughout the book, several conclusions on key issues are described as site dependent and thus lack of uniformly accepted rules, and there are still many unresolved questions calling for further investigation, from as fundamental as data quality control to as complicated as advection. There are also quite a few cross-references between the chapters, indicating the intertwine nature among the issues discussed. The organization of this book is similar to a special issue of a journal. In these regards, perhaps "Workshop on Surface Flux Measurements" (analogous to the book titled "Workshop on Micrometeorology") would be a more appropriate title than "Handbook of Micrometeorology", albeit a less attractive one. Nevertheless, it is a useful collection for both teaching and research involving micrometeorology.

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