Flux Measurements in Difficult Conditions, a Specialist Workshop

An Evaluation of In-Canopy Flux Measurements

Sean P. Burns[1,2], Jielun Sun[1], Steven P. Oncley[1], Andrew A. Turnipseed[1], Chuixiang Yi[2], Don H. Lenschow[1], and Russell K. Monson[2]

NCAR

(1) National Center for Atmospheric Research, Boulder, Colorado (2) Department of Ecology and Evolutionary Biology, University of Colorado, Boulder

I. Introduction:

Flux measurements within a canopy are complicated by conditions of low wind speed and (often) meandering wind direction. Flux data collected during the Carbon in the Mountains Experiment (details below) are used to examine the high-frequency (30-Hz) data. At this site during the summer the wind direction is nearly always downslope at night and bi-modal (upslope/downslope) during the day (Figs 1 and 2). For this poster, an example of a nocturnal turbulent event (and the relevant scales) is examined. In addition, the effect of the canopy on the high-frequency spectra is presented. For brevity only the sensible heat flux is considered.

Figure 1: *Frequency distributions of wind speed and direction (daytime).*

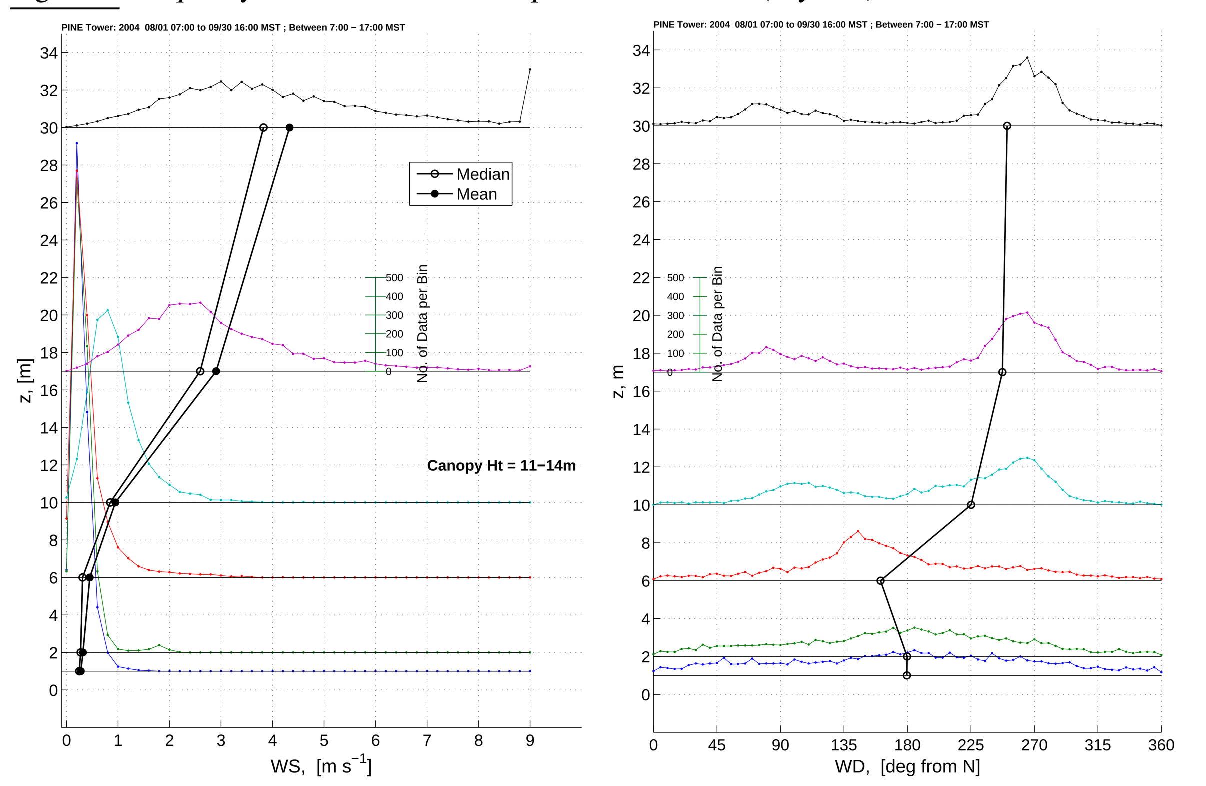
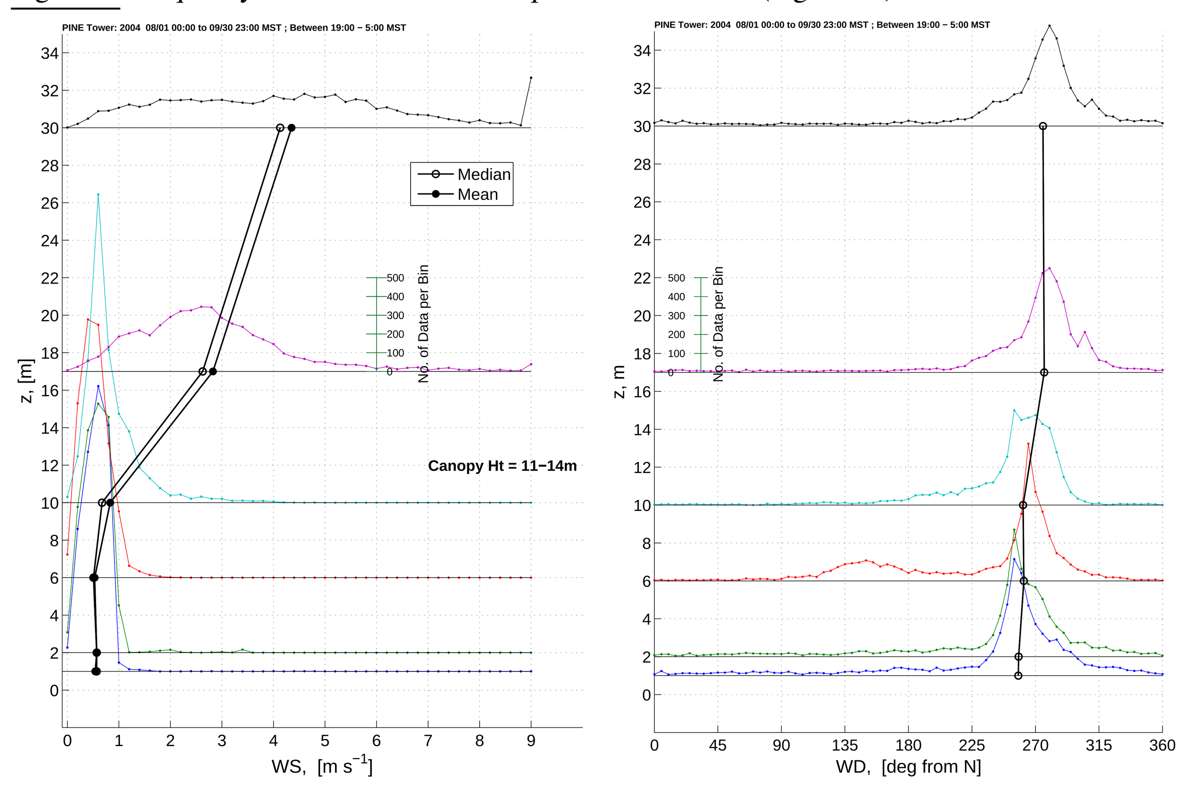


Figure 2: *Frequency distributions of wind speed and direction (nighttime).*



II. Carbon in the Mountains Experiment Details:

As part of the 2004 Carbon in the Mountains Experiment (CME04), the NCAR Earth Observing Laboratory (EOL) installed three towers ("Pine", "Willow", and "Aspen") in a subalpine mixed-conifer forest near the existing University of Colorado (CU) and U.S. Geological Survey (USGS) Ameriflux towers. These five towers are in a relatively flat location (∼8 percent slope) about 10 km east of the continental divide near Niwot Ridge, Colorado. The towers are loosely arranged along the drainage of como creek to investigate the larger scale features of the flow along the drainage of this small creek (Figs 3 and 4). One tower ("Willow") is in a open area while the other four towers are in either aspen or mixed-conifer subalpine forest. The average canopy height within the forest is around 11 m.

Figure 3: *Map of the CME04 Towers.*

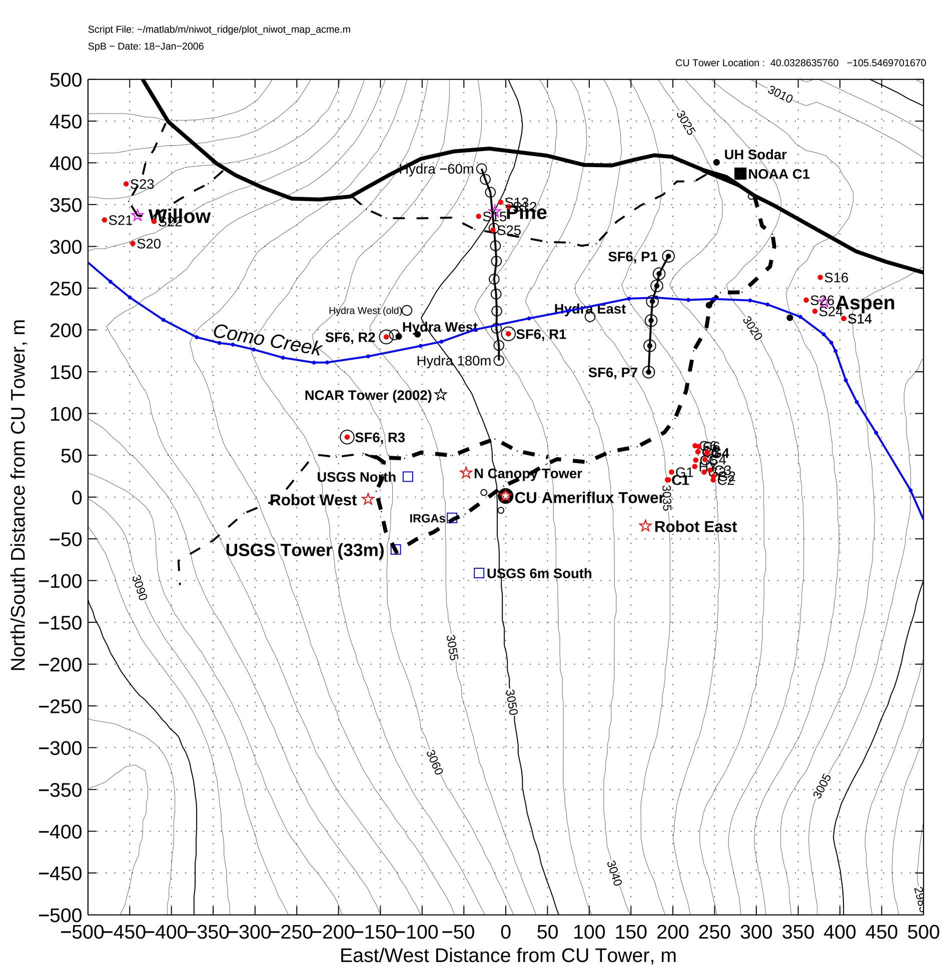
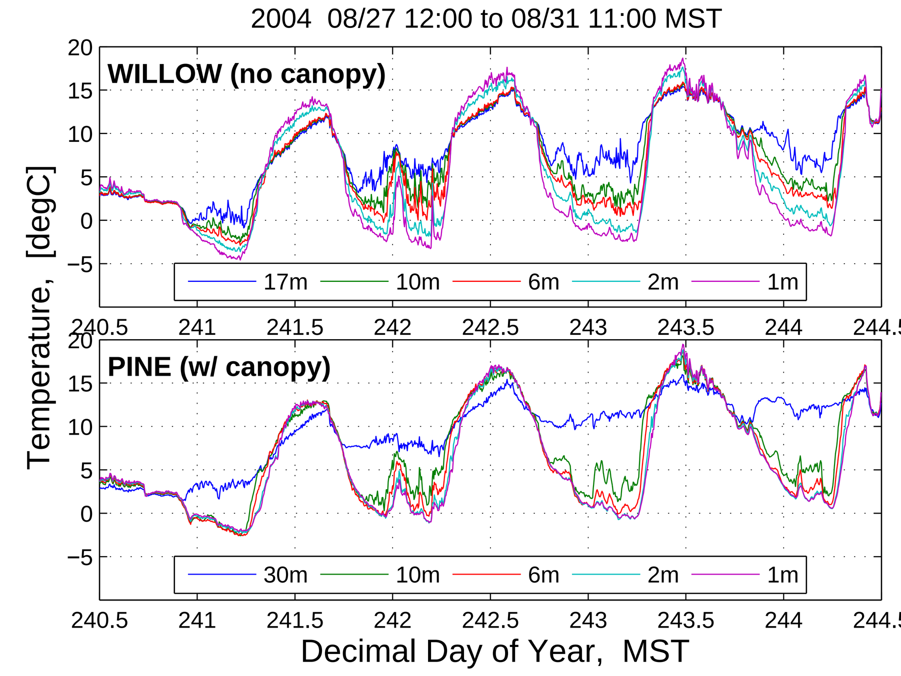


Figure 4: *Photo of the CU, Aspen, and Pine towers during CME04.*

III. Nocturnal Processes:

The vertical wind variance is examined using the Haar wavelet with Multiresolution Variation Decomposition (MVD) (Howell and Mahrt, 1997). A time series of the MVD can be useful to determine when energetic events occur and examine how the scales are modified at different levels. A night with a turbulent burst that occurs just after midnight is shown in Figures 6 (no canopy) and 7 (with canopy). The effect of the canopy is to dampen the energy of the burst and shift the energetic scales to a lower frequency. The corresponding heat flux plot (using different ogive cut-off frequency scales) highlights the sensitivity of the heat flux measurement to the choice of cut-off scale. During mesoscale events the sign of the flux can depend on the choice of cut-off frequency.

Figure 5: *Temperature time series at Willow and Pine Towers.*



The turbulent burst shown in Figs 6 and 7 is observed in Fig 5 to (temporarily) increase the temperature at the ground at both towers. After the mixing event has passed, the air temperature returns to the pre-event value. Composites of air temperature measured at the towers (not shown here) reveal these mixing events to be fairly common and often occur around midnight.

Figure 6: *Haar wavelet and heat flux at Willow Tower (no canopy).*

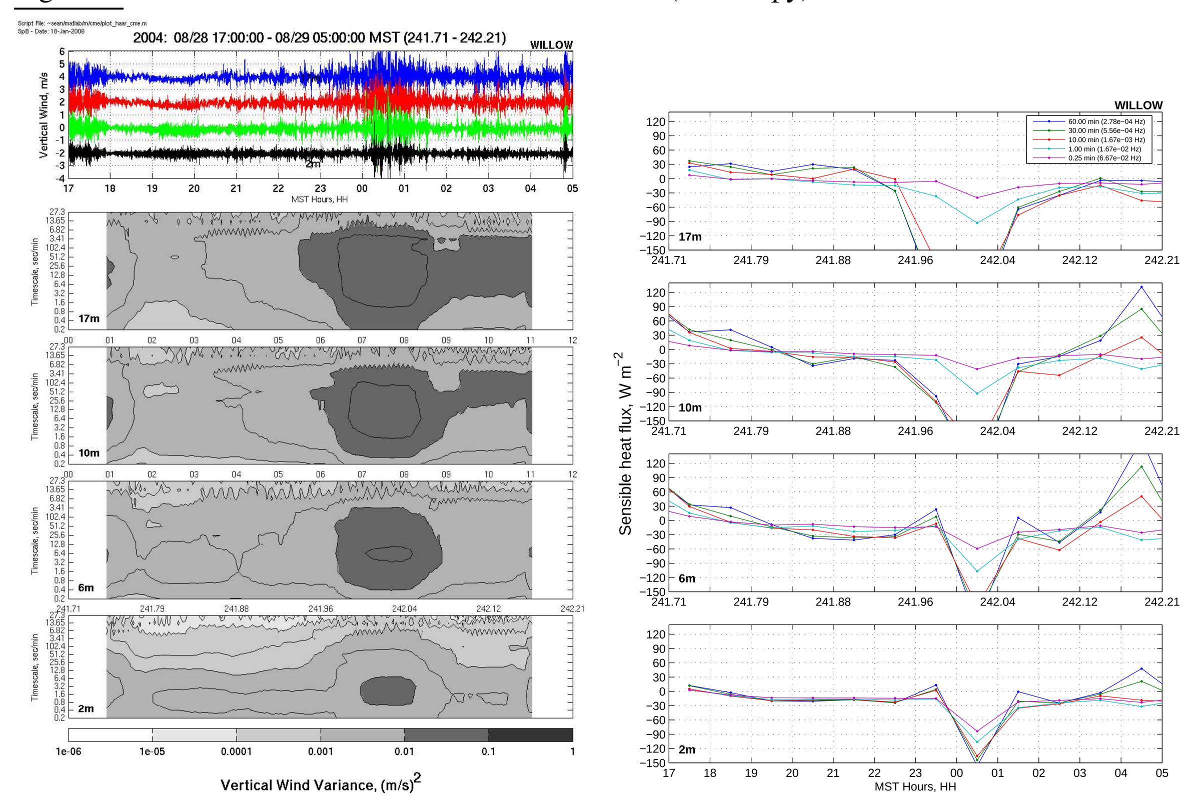
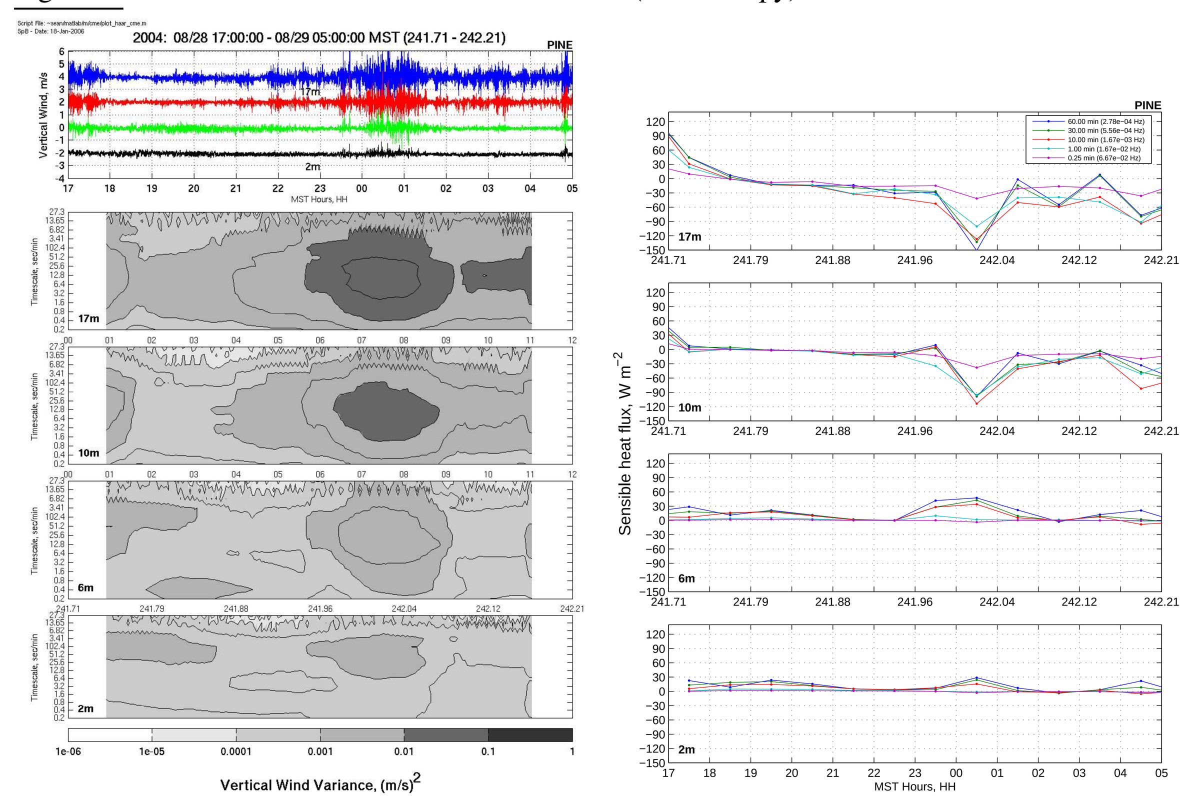


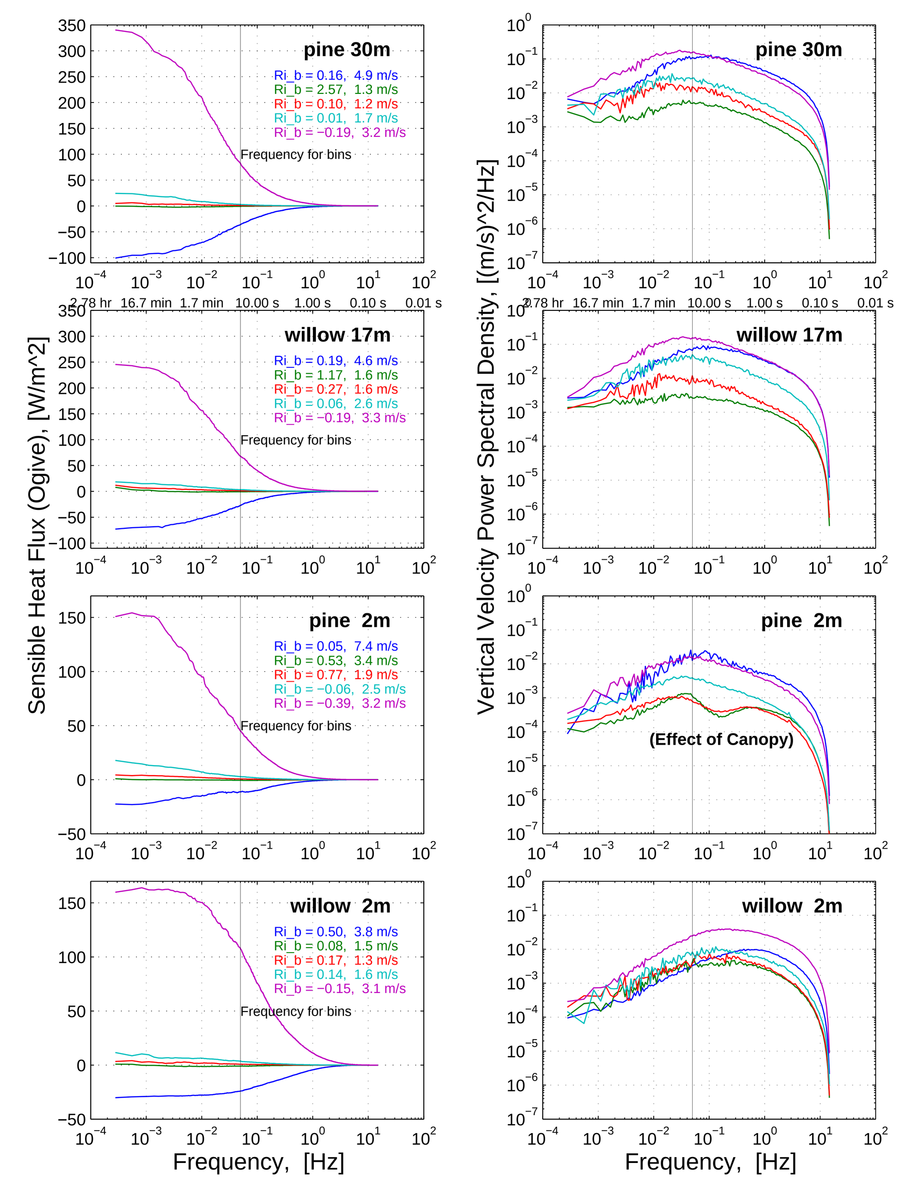
Figure 7: *Haar wavelet and heat flux at Pine Tower (with canopy).*



IV. Ogives and Spectra:

Composites of above-canopy and within-canopy heat flux ogives and the corresponding vertical wind velocity power spectra are shown to the right. The ogive data are binned according to the magnitude of the heat flux ogive at a freq of 0.05 Hz (20-second period). This effectively separates the data by stability. The bulk Richardson number and wind speed (at 30m) for each curve is identified by color. For the light wind and stable conditions (green line) the composite heat flux is negative at the higher frequencies and positive at lower frequencies (difficult to see on this figure due to the scale). A method to separate the "turbulent" flux from the mesoscale (or low-frequency) flux (eg, Vickers and Mahrt, 2005) was explored, but is still being evaluated.

The effect of a canopy on the measurements is apparent by comparing the 2 m vertical wind spectra at the Pine tower (with a canopy) with Willow tower (no canopy). Also, note that a typical sonic anemometer is not able to respond to the highest frequencies in the spectrum (primarily due to path-length averaging limitations)



References:

Howell, J. F., and L. Mahrt, 1997: Multiresolution flux decomposition. *Boundary-Layer Meteorol.*, **83**, 117-137.

Vickers, D., and L. Mahrt 2005: A Solution for Flux Contamination by Mesoscale Motions With Very Weak Turbulence, *Boundary-Layer Meteorol.*, **117**, doi:10.1007/s10546-005-9003-y.