Some Properties of Intermittent Turbulence: Results from CASES99 and VTMX 2000

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As stability increases Monin-Obukhov theory breaks down so that, for example, the log-linear laws for velocity and temperature are no longer valid for z/L ~0.5 or larger. Turbulence becomes more and more intermittent and we do not have particularly useful tools to describe exchange mechanisms important for VTMX processes.

A number of investigators have and are studying processes that may trigger intermittent turbulence and substantial progress is being made. This discussion looks at a different aspect of the intermittent turbulence problem - a characterization of how intermittent turbulent fluxes behave so that we know what features we need to describe and replicate in a model that tries to reproduce their behavior. Some comments on a possible method of developing a parameterization or other empirical approach for use in mesoscale models are also given.

Under strongly stable conditions a time series of turbulent sensible heat fluxes exhibits extended periods with little or no apparent flux (lulls) punctuated by turbulent "events" with significantly larger flux values. For convenience, a turbulent event can be defined as occurring whenever the sensible heat flux exceeds a specified threshold value for a minimum duration; for purposes of this discussion a threshold value of –0.01 mK/s and a duration of 1 minute were chosen. Thus, whenever the sensible heat flux was more negative than –0.01 mK/s for a minute or more, an event is said to have occurred. The fraction of the total time in a turbulent heat flux record occupied by turbulent flux events would be expected to decrease as the average flux for the record decreases. Figure 1 shows results from five different measurement sites, two from the CASES99 experiment (Beauont and Smileyberg) and three from the VTMX 2000 experiment (Shay's Lounge, KCC, and NCAR sites). For convenience, the turbulent fluxes at each of these sites were calculated in 1-minute blocks. The ordinate in the figure, which is defined as the fraction f_1, is then the number of minutes with turbulent events divided by the total number of minutes in a data record on a given night. The abscissa is the average flux for the night. There is considerable scatter for larger average fluxes (e.g., more negative than –0.20 mK/s) but there is a remarkably linear decrease in f_1 (correlation coefficient of 0.96) as the average flux becomes more positive than –0.01 mK/s.

Several other intriguing features of the turbulent heat fluxes can be found in this linear region. The ratio of the average flux in a turbulent event to the average flux in the gaps between turbulent events has a median value of about 5.5, with 25 and 75 percentile values of about 5 and 7.5, and there is no obvious trend with the average flux value for the night. The median value of a turbulent flux event is –0.018 mK/s, again with little apparent dependence on the average flux for the night.

A tentative conclusion can be drawn from these and other statistics used to describe intermittent turbulent flux events: when intermittent turbulent fluxes do occur, they occur in episodes (groups of events separated by lulls of less than 10 minutes) with somewhat similar characteristics (e.g., average turbulence per event, average number of events per episode) regardless of the average flux for the whole night, but the episodes tend to last less and less as the average flux for the night decreases.

This finding suggests that it may be possible to develop an empirical modeling approach in which a turbulent flux time series might be generated as a Markov process, with probability P_e that an event will be immediately followed by another event and probability P_g that a lull or gap will be immediately followed by a second lull or gap. These probabilities can be calculated by examining the turbulent time series but at this point a useful functional relationship between the probabilities and, e.g., the average flux for the night has not been found.

Additional analyses with various thresholds, different durations for events, and other data series are planned.

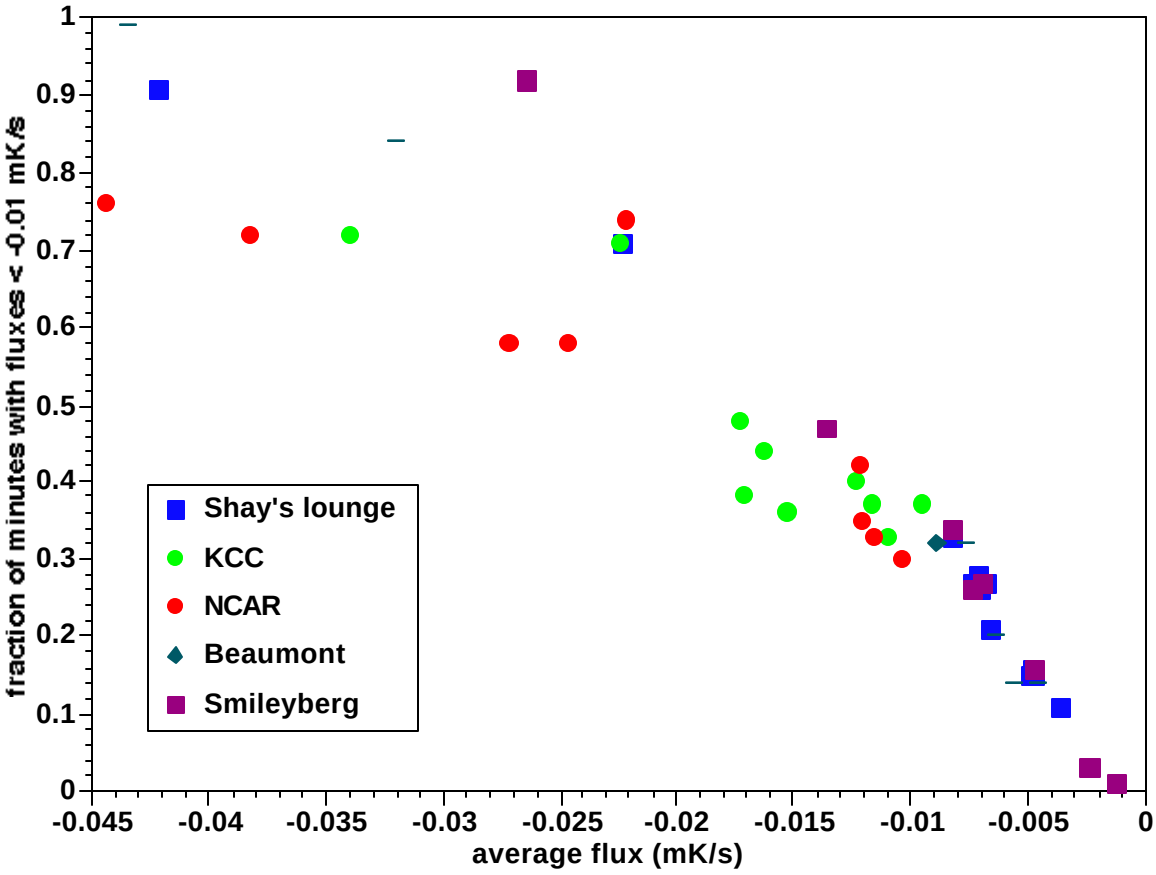

Figure 1. Fraction of time series occupied by turbulent flux events as a function of the average sensible heat flux for various nights at 5 instrumented sites in CASES99 and VTMX 2000.