Doppler lidar measurements of vertical velocity skewness profiles

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Skewness

- Skewness is a measure of asymmetry in distribution of vertical velocity of perturbations.
- Positive skewness at the surface suggests narrow, intense updrafts from the surface and broad downdraughts (fair weather, clear).
- Negative skewness suggests sharp, narrow downdraughts and larger areas of weaker updraft, rather like 'upside down' surface heating driven turbulence (on a cloudy day)?

Skewness can be calculated using this equation:

\[ \xi = \frac{\langle w^3 \rangle}{\langle w^2 \rangle^{3/2}} \]

Since the Salford University Doppler lidar is capable of measuring vertical velocity it is considered an ideal instrument for measuring profiles of vertical velocity skewness throughout the boundary layer. Knowing the skewness can help understand the structure of turbulent convection within the boundary layer.

The Salford University Doppler lidar is also capable of measuring sensible heat flux \( Q_H \), knowledge of which may be useful when interpreting skewness profiles.

A note on \( Q_H \)

Calculating \( Q_H \) from Doppler lidar data: \( Q_H = \rho c_p \langle \frac{\partial w}{\partial z} \rangle \)

Under convective conditions, as suggested by the Doppler lidar scans and radiosonde ascents on the days of interest, the vertical velocity-potential temperature covariance, \( \langle \frac{\partial w}{\partial z} \theta \rangle \) can be calculated from:

\[ \langle \frac{1}{2} \frac{\partial w}{\partial z} \theta \rangle = \frac{1}{2} \frac{\partial \langle w \rangle}{\partial z} \theta + \frac{1}{2} \frac{\partial \langle \theta \rangle}{\partial z} w \]

A traditional way to estimate \( w \) is by examining the line spectra of the longitudinal velocity correlation. In the inertial subrange, the expected relationship is:

\[ \tilde{\langle w \rangle} = C_w \approx 2 \eta / \nu \]

where \( w \) is the wave number, \( v \) is a universal constant (0.5) and \( \tilde{\langle w \rangle} \) is the Fourier transform of the longitudinal velocity correlation.

Conclusions / Future work:
- Measurements of skewness profiles through the boundary layer are rare, but can be measured using Doppler lidar.
- Knowledge of \( Q_H \) may help understand unexpected skewness values on 11/07.
- Investigation of more cases is necessary to consolidate what has been learned so far.

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References:
- Davis et al., 2005, "Spatial variations of sensible heat flux over an urban area", Meteorol. Appl. 12, 337-349

The 15th July (top) appears to be a straightforward case of surface-driven convection, yielding positive skewness near to the surface in the morning. The 11th July is more complex, and to understand the situation better, it is useful to look at values of \( Q_H \) throughout that day.