Doppler lidar measurements of vertical velocity skewness profiles

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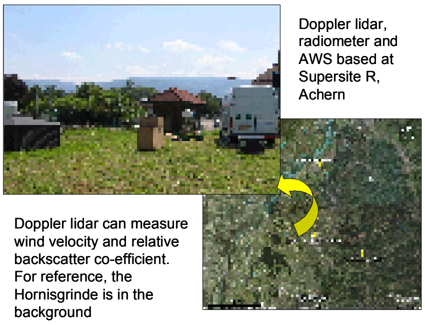
Location



Doppler lidar, radiometer and AWS based at Supersite R, Achern

Doppler lidar can measure wind velocity and relative backscatter co-efficient. For reference, the Hornisgrinde is in the background

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 downdrafts (fair weather, clear)
- Negative skewness suggests sharp, narrow downdrafts and larger areas of weaker updraft, rather like 'upside down' surface heating driven turbulence (on a cloudy day?)

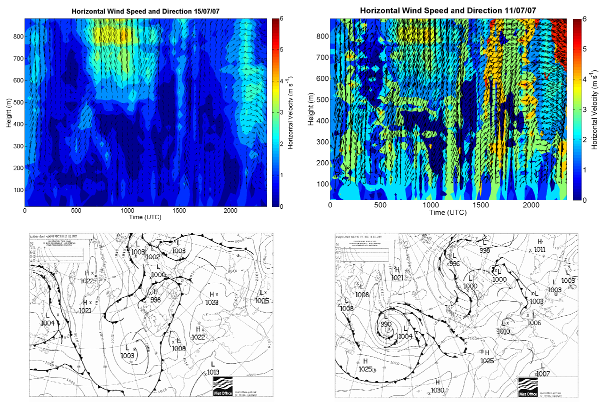
Skewness can be calculated using this equation:

$$S = \overline{w'^3} \,/\, \left(\overline{w'^2}\right)^{3/2}$$

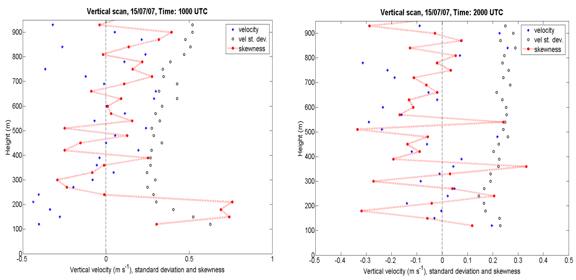
Since the Salford University Doppler lidar is capable of measuring vertical velocity it is considered an ideal instrument for measuring profiles of vertical velocity skewness throughout the boundary layer. Knowing the skewness can help understand the structure of turbulent convection within the boundary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

2 contrasting days, 11th and 15 July



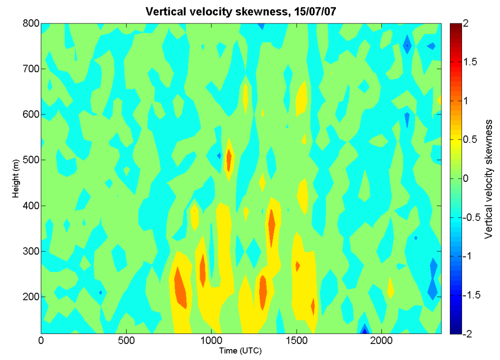
Skewness Profiles

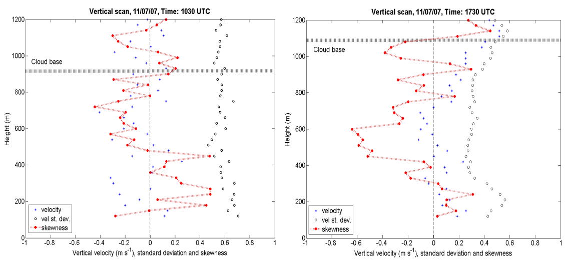


1000 UTC – Surface heating drives positive skewness near surface

2000 UTC – towards the end of the day neutral conditions present

- **15/07/07**
- High pressure system over the site
- Strong lid, lower Q_H
- Forcing from surface following diurnal cycle, low wind speeds
- **No clouds**

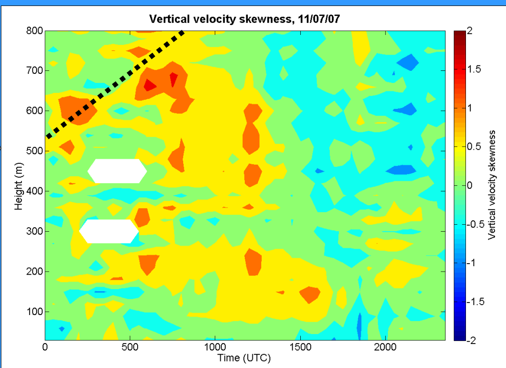




1030 UTC – Cloud top cooling, high surface heating, high Q_H

1730 UTC – Cold downdrafts, negative skewness, little surface heating

- **11/07/07**
- Low pressure over the site, higher wind speed
- Weak lid, more energy available, higher Q_H in the morning, low later
- Weak, large scale forcing from trough moving over the region
- **Clouds (indicated by dashed line), rain later in the day**



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.

A note on Q_H

Calculating Q_H from Doppler lidar data: $Q_H = \rho_0 C_P \overline{w'\theta'}$

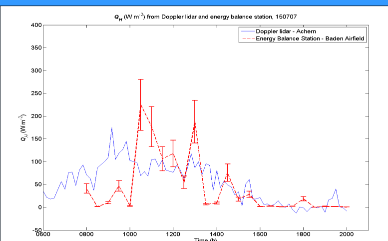
Under convective conditions, as suggested by the Doppler lidar scans and radiosonde ascents on the days of interest, the vertical velocity-potential temperature covariance, $\overline{w'\theta'}$ can be calculated from:

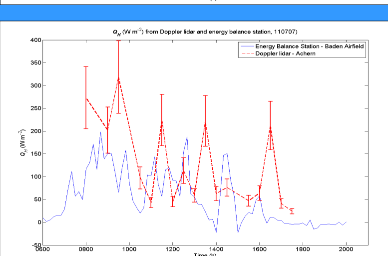
$$\frac{\partial}{\partial z}\left(\frac{1}{2}\overline{w'^3}\right) = \frac{1}{\rho_0}\left(\overline{w'\frac{\partial p'}{\partial z}}\right) - \frac{\varepsilon}{3} + \frac{g}{\theta_0}\overline{w'\theta'}$$

A traditional way to estimate ε is by examining the line Spectra of the longitudinal velocity correlation. In the inertial subrange, the expected relationship is:

$$\overline{f}(\kappa) = \alpha\varepsilon^{2/3}\kappa^{-5/3}$$

where κ is the wave number, α is a universal constant (0.5) and $\overline{f}(\kappa)$ 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 11/7/07
- Investigation of more cases is necessary to consolidate what has been learned so far

Acknowledgements:
The authors would like to acknowledge Dr N Kalthoff at IMK FZK Karlsruhe for supplying QH data from their energy balance station located at Baden Airfield (see figure top left).

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