Long-Term Vertical Velocity Statistics Derived from SGP Doppler Lidar During Convective Conditions

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Motivation

Much of our understanding of turbulence in the planetary boundary layer (PBL) is based on a small number of case studies conducted with research aircraft. The deployment of the Doppler lidar (DL) system at the SGP provides a unique opportunity to apply a long term data set.

How do turbulence statistics change with surface shear stress, wind shear at the PBL top, and static stability?

Instrumentation and Analysis Techniques

All measurements taken from the SGP CF.

DL system

Doppler lidar (DL)

- First deployed in 2011
- Maximum range of10 km
- Velocity statistics compiled from existing Value Added Product (VAP). Signal-to-noise (SNR) threshold applied to determine times/heights with good values
- Mixed-layer depth (z_i) determined using variance threshold

Surface fluxes

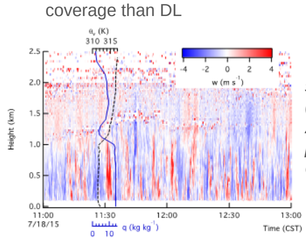
- Data from eddy-covariance (ECOR) and energy balance Bowen ratio (EBBR) systems
- Calculation of Deardorff velocity scale (w_*), friction velocity (u_*), and Obukhov length (L)

Surface met station

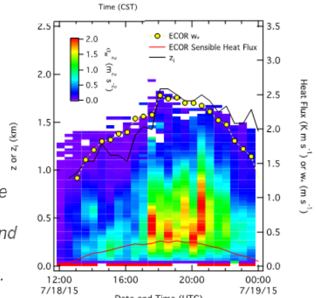
- Air temperature used in calculation of w_* and L

Radar Wind Profiler (RWP)

- Wind shear across the PBL top, greater height coverage than DL



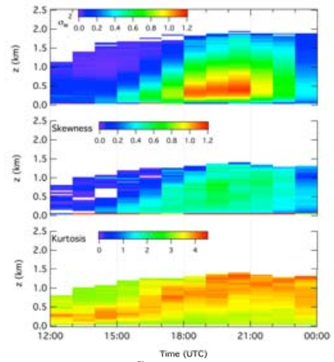
Time-height cross section of w (colors) for 18 July 2015; θ_v and q profiles from 11:30 CST sonde (inset)



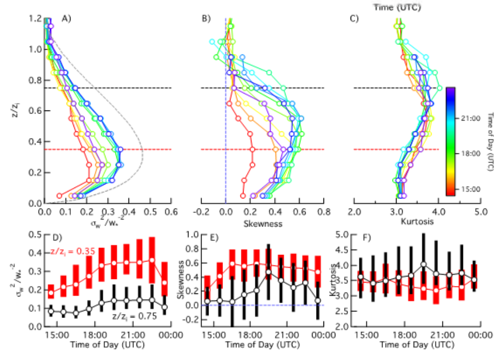
Time-height cross section of σ_w^2 from the DL VAP (colors), z_i (black), w_* (yellow), and kinematic heat flux (red) for 18 July 2015.

Diurnal Cycle

Daily composite of vertical velocity statistics constructed using data from 2015. PBL structure is seen in the results, but smoothing occurs because of different values of z_i.



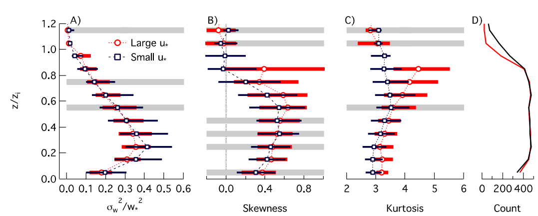
Composite time-height cross sections of σ_w^2 (top), skewness (middle), and kurtosis (bottom).



Hourly median values of σ_w^2/w_*^2, skewness, and kurtosis (colors) over the course of the day (top). Time series of median, 25th and 75th percentiles of σ_w^2/w_*, skewness, and kurtosis at 0.35 and 0.75 z/zi.

Sensitivity to u_*

Critical values of u_* determined from the distribution measured with ECOR. Instances with large values of u_* have decreased variance and increased skewness and kurtosis in the lowest range gates.



Median σ_w^2/w_*^2 (left), skewness (center), and kurtosis (right) for values of u_* greater than 0.59 (red) and less than 0.27 m s^{-1} (black). Bars indicate 75th and 25th percentiles. Shading indicates differences that are not statistically significant.

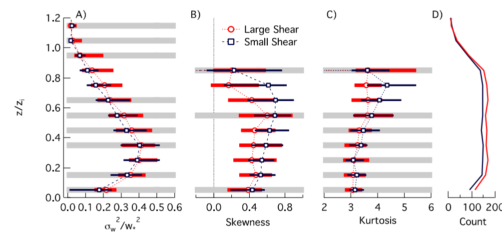
Summary

The long-term deployment of the DL at the SGP CF provides a unique opportunity to develop a climatology of turbulence statistics that can be used to improve our understanding of boundary-layer processes, as well as to develop and test new parameterizations and LASSO simulations. Key findings include:

- **Scaling** is most effective in the afternoon when the PBL is steady state
- **Normalized variance** (σ_w^2/w_*^2) is found to be a function of wind direction, u_*, and static stability
- **Skewness** is a function of u_* and wind shear across the PBL top
- **Kurtosis** is a function of u_*, wind shear, and static stability

Sensitivity to Wind Shear Across the PBL Top

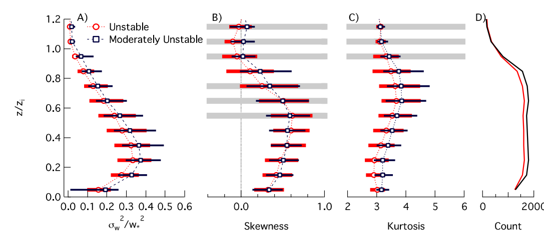
The magnitude of the wind shear across the boundary layer top is derived from the RWP at the CF. Shear has been broken into cases with relatively large and small values. Differences in σ_w^2/w_*^2 are small, but cases with small shear are more skewed.



Median σ_w^2/w_*^2 (left), skewness (center), and kurtosis (right) for values of wind shear greater than 1.4 (red) and less than -0.6 m s^{-1} (black). Bars indicate 75th and 25th percentiles. Shading indicates differences that are not statistically significant.

Sensitivity to Static Stability

The static stability is determined based on the value of z_i/L and cases that are moderately or largely unstable are identified. The σ_w^2/w_*^2 is slightly larger in moderately unstable conditions. Likewise the kurtosis is larger over much of the PBL. Differences in skewness are small.



Median σ_w^2/w_*^2 (left), skewness (center), and kurtosis (right) for conditions that are unstable (-z/L > 30) and moderately unstable (-z/L < 30) (red). Bars indicate 75th and 25th percentiles. Shading indicates differences that are not statistically significant.

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