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 the turbulence statistics change with wind direction, wind shear, and static stability?

Instrumentation and Analysis Techniques

All measurements taken from the SGP CF.

Doppler lidar (DL)

- First deployed in 2011
- Maximum range of 2 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 an different threshold of SNR

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)

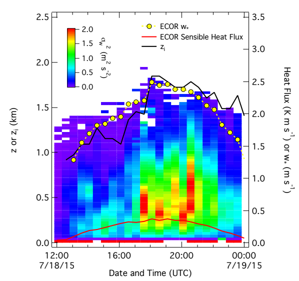
Surface met station

- Air temperature used in calculation of w_* and L

Radar Wind Profiler (RWP)

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

Analysis of vertical velocity variance (σ_w^2), skewness, and kurtosis limited to clear days, and is focused on data collected during afternoons with southerly winds. An example time series from the DL VAP and other data streams is shown below.

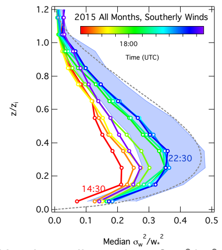


Time-height cross section of σ_w^2 from the DL VAP (colors), z_i (black), w_* (yellow), and kinematic heat flux (red) for 18 July 2015.

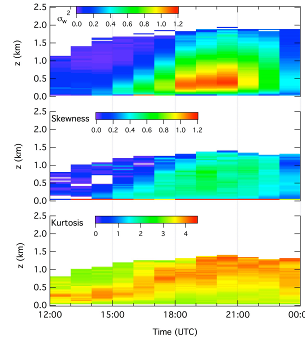
Diurnal Cycle

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

Analysis limited to data collected in the afternoon.



Hourly median value of σ_w^2/w_*^2 (colors). Shading indicates 75th and 25th percentile at 21:30 UTC.

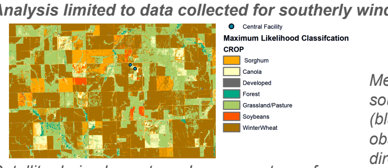


Composite time-height cross sections of σ_w^2, skewness, and kurtosis.

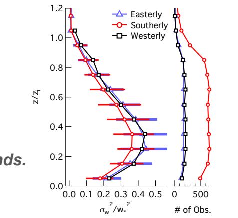
Sensitivity to Wind Direction

The value of σ_w^2 is found to be a function of the wind direction, even when the value is normalized by w_*. This suggests an issue with the representativeness of the flux measurements used to generate w_*.

Analysis limited to data collected for southerly winds.



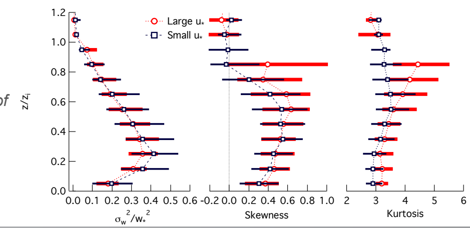
Satellite derived crop type. Image courtesy of Michael Mulqueen and Alice Cialella.



Median σ_w^2/w_*^2 for easterly (blue), southerly (red), and westerly (black) winds (left), and number of observations for each wind direction (right). Bars indicated 75th and 25th percentiles.

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.

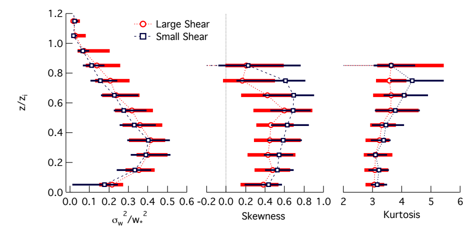
Summary

The long-term deployment of the DL at the 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 closer to steady state.
- The **normalized variance** (σ_w^2/w_*^2) is found to be a function of wind direction, u_*, and static stability
- The **skewness** is a function of u_* and wind shear across the PBL top
- The **kurtosis** is a function of u_*, wind shear, and static stability

Sensitivity to Wind Shear Across the PBL Top

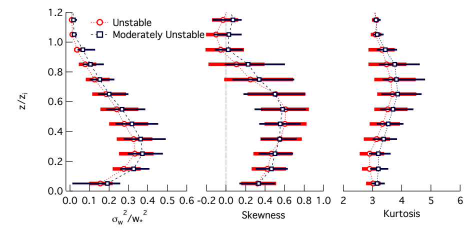
The magnitude of the wind shear across the boundary layer top derived from the RWP at the CF. Shear has been broken into cases with relatively large and small values. Differences in σ_w^2/w_*^2 are small, but cases with small shear are more skewed.



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.

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 values for unstable ($-z_i/L > 30$) and moderately unstable ($-z_i/L < 30$) (red). Bars indicate 75th and 25th percentiles.

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