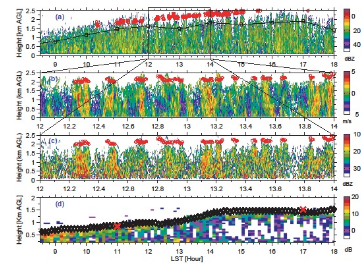
Long-Term Observations of Convective Boundary Layer Using Insect Returns at SGP

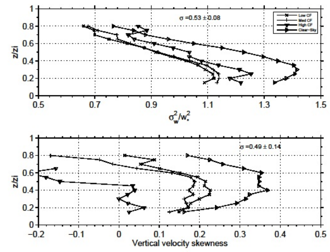
Research Highlight

A long-term study of the turbulent structure of the convective boundary layer (CBL) at the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility's Southern Great Plains (SGP) site is presented. Doppler velocity measurements from insects occupying the lowest 2 km of the boundary layer during summer months are used to map the vertical velocity component in the CBL. The observations cover four summer periods (2004–08) and are classified into cloudy and clear boundary layer conditions. Profiles of vertical velocity variance, skewness, and mass flux are estimated to study the daytime evolution of the convective boundary layer during these conditions. A conditional sampling method is applied to the original Doppler velocity data set to extract coherent vertical velocity structures and to examine plume dimension and contribution to the turbulent transport. Overall, the derived turbulent statistics are consistent with previous aircraft and lidar observations. The observations provide unique insight into the daytime evolution of the convective boundary layer and the role of increased cloudiness in the turbulent budget of the subcloud layer. Coherent structures (plumes and thermals) are found to be responsible for more than 80% of the total turbulent transport resolved by the cloud radar system. The extended data set is suitable for evaluating boundary layer parameterizations and testing large-eddy simulations (LESs) for a variety of surface and cloud conditions.



Example of time–height mapping of (a) MMCR re#ectivity factor during a cumulus-topped event: red dots (cloud base) and black dots with line (insect layer height). Subplots (b) and (c) are zoomed doppler velocity and reflectivity factor. Subplot (d) is CBL evolution from the 915-MHz wind profiler.

Insect radar returns at the ARM SGP site have been long considered a nuisance for efforts to use ground-based vertically pointing radars to detect and study boundary layer clouds. In this study, a different approach is adopted wherein the insect radar returns from vertically pointing Doppler cloud radar are used to monitor the properties of boundary layer turbulence. The study makes use of a multiyear summer data set from millimeter-wavelength cloud radar, a 915-MHz wind pro#ler, and #ux-measuring sensors at the surface. The Doppler velocity measurements from insects were corrected for insect motion using the GM05 formula. A clear strength of this study is the use of a large data set of four consecutive warm seasons of vertical velocity observations at the ARM SGP site. The large data set facilitates acquiring smoothed vertical structures of turbulence statistics and documenting their diurnal evolution. The large data set (2894 h of daytime CBL observations) is classi#ed into clear-sky and cumulus-topped conditions. During both clear-sky and cumulus-topped conditions, the 915-MHz wind pro#ler signal-to-noise ratio (SNR) is used to develop an automated algorithm for the detection of the mixed-layer top. The daytime evolution of the boundary layer is studied using the pro#les of vertical velocity variance, skewness, and mass-#ux ratio.



Classification of profiles of vertical velocity variance and skewness for clear-sky and cloudy conditions.

The cloud radar observations provided a unique daytime evolution of the convective boundary layer and indicate the role of increased cloudiness in the turbulent budget of the sub-cloud layer. The large SGP MMCR data set makes the observations suitable for evaluating boundary layer parameterizations for a variety of surface and cloud conditions. The basic analysis of the data provided in this paper gives support to using the cloud radar data in a number of different studies of greater complexity (a variety of surface and cloudy conditions). It is more straightforward to think of using these observations to test LESs. The study also provides the observational evidence to assess the boundary layer parameterizations by including the behavior of CBL statistics under different conditions.

Reference(s)

Chandra AS, P Kollias, SE Giangrande, and SA Klein. 2010. "Long-term observations of the convective boundary layer using insect radar returns at the SGP ARM Climate Research Facility." Journal of Climate, 23, 5699-5714.

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Cloud Life Cycle