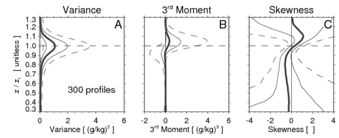
Water Vapor Turbulence Statistics in the Convective Boundary Layer

Research Highlight

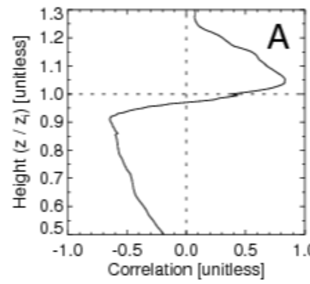
Turbulence is a process that redistributes water vapor and other atmospheric gases, sensible heat, and momentum in the atmosphere. It is a stochastic process, and is best represented by statistics of various moments. It has been shown that the Atmospheric Radiation Measurement (ARM) Raman lidar has the accuracy and noise level to measure the second- and third-order moments of the water vapor mixing ratio distribution in the convective boundary layer (CBL), from which profiles of variance and skewness of the water vapor (which serves as a passive tracer of atmospheric motion in cloud-free scenes) can be derived.

This study identified 300 afternoon cases observed by the Raman lidar at the Southern Great Plains (SGP) site over a 6-year period wherein the CBL was quasi-stationary (i.e., it had reached it maximum depth and the turbulent eddies could be assumed to be non-changing with time). From these cases, a “climatology” of variance and skewness profiles of water vapor in the CBL were derived. These cases demonstrated that the gradient of water vapor across the top of the CBL is strongly correlated with the magnitude of the water vapor variance at the top of the CBL, as has been suggested by analysis of large eddy simulation (LES) model output. However, the Raman lidar observations also suggest a relationship between the magnitude of the variance at the top of the CBL and the shape of the water vapor skewness profile throughout the CBL. This relationship can be used to evaluate LES models in a new way. Furthermore, while turbulence at the top of the CBL typically leads to drying of the CBL due to the mixing of drier free tropospheric air into the CBL, this data set showed about ten percent of the time, the CBL was actually moistening, and that the moistening/drying did not depend on the magnitude of the latent heat flux at the surface.

This study presented the first long-term data set of variance and skewness turbulent statistic profiles in the CBL, spanning a range of seasons and environmental conditions. These data will be extremely useful for evaluating turbulence parameterization schemes used in cloud resolving and general circulation models, as well as the more explicit representation of turbulence offered by LES models.



Average profiles of statistical quantities and their variability. The bold solid lines denote the median profiles of the (a) variance, (b) third moment, and (c) skewness of water vapor mixing ratio. The thin solid lines are the 25th and 75th percentiles, while the 10th and 90th percentiles are represented with dashed lines. The horizontal dashed line indicates the top of the CBL (all height profiles were normalized).



This figure shows correlation between the magnitude of the variance of water vapor at the top of the CBL and the profile of the third-moment of water vapor throughout and above the CBL.

Reference(s)

Turner DD, V Wulfmeyer, LK Berg, and JH Schween. 2014. "Water vapor turbulence profiles in stationary continental convective mixed layers." Journal of Geophysical Research – Atmospheres, 119, doi:10.1002/2014JD022202.

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Cloud Life Cycle