April 10, 2025

Failure of the Constant Flux Layer Assumption Caused by Asymmetric Turbulent Flux Transport of Scalars by Large Eddies in the Unstable Atmospheric Surface Layer

Heping Liu

Professor, Department of Civil and Environmental Engineering

Washington State University

ABSTRACT:

The constant flux layer assumption is vital in Monin-Obukhov Similarity Theory and interpreting eddy covariance (EC) flux measurements in the atmospheric surface layer (ASL). It has been demonstrated that the asymmetric turbulent flux transport of scalars (e.g., heat and water vapor) by the sweeps and ejections of large eddies under unstable atmospheric stability conditions reduce scalar fluxes. However, how changes in such an asymmetry affects flux divergence and convergence (FDFC) in the ASL—leading to the breakdown of the constant flux layer assumption—remains underexplored. Using turbulence data collected at multiple levels over a sagebrush surface, it is demonstrated that sweeps and ejections of large coherent eddies influence changes in turbulent fluxes of heat and water vapor with height, leading to flux divergence and convergence in the unstable ASL. Asymmetric turbulent flux transport of large eddies leads to imbalanced contributions between sweeps and ejections to fluxes, as quantified by the third-order moments in the turbulent flux budget equations. Additionally, this imbalance varies with height, resulting in disproportional contributions to fluxes across layers, thereby contributing to the failure of the constant flux layer assumption. Large coherent eddies are essential components of turbulence in convective boundary layers, and the failure of the constant flux layer assumption across instability ranges, along with its links with the asymmetry, deserves further studies at different sites.

BIOGRAPHY:

Dr. Heping Liu is a professor in the Department of Civil and Environmental Engineering at Washington State University (WSU). He earned his Ph.D. from Peking University in 1997 and completed postdoctoral research at the University of Bayreuth, Germany, and the California Institute of Technology. Before joining WSU, he was an assistant and associate professor at Jackson State University, Mississippi. Dr. Liu's research focuses on boundary-layer meteorology, micrometeorology, and terrestrial ecosystem-climate interactions, with a particular emphasis on how land surfaces influence boundary layer processes and dynamics. A recipient of the prestigious NSF CAREER Award, Dr. Liu has strived to integrate his research with education, aiming to inspire and train the next generation of scientists. He currently serves as an Associate Editor for the Journal of Geophysical Research-Atmospheres and an Editor for both Advances in Atmospheric Sciences and Agricultural and Forest Meteorology.