Geophysical Research Abstracts
Vol. 21, EGU2019-8580, 2019
EGU General Assembly 2019


# Revisiting the Theoretical Formulations of the Mean Wind and Stress Profiles in the Neutral Ekman Boundary-layer

Khaled Ghannam and Elie Bou-Zeid

Department of Civil and Environmental Engineering, Princeton University, Princeton, NJ, United States (kghannam@princeton.edu)

A century after Ekman (1905) presented an approximate solution, predicting the vertical profiles of the mean wind and turbulent momentum fluxes in the atmospheric boundary-layer (ABL) remains an open research problem. Ekman's constant eddy-viscosity (K_m) closure to the mean horizontal momentum equations is known to present severe limitations in predicting the wind profile and cross-isobaric angle in the atmospheric surface layer (ASL). Since K_m is itself an intrinsic property of the flow, improvements that use a height-varying K_m have raised the question of its proper and case-specific parametrization, let alone obtaining tractable analytical solutions. An alternative approach has focused on asymptotic similarity based on the surface Rossby number (Ro) and dimensionless heights. The asymptotes lead to an ASL with a logarithmic wind profile (and a constant stress), and an outer Ekman layer where a velocity defect law holds. However, this framework cannot predict the functional form of the similarity laws, which has to be determined empirically. More broadly, these two approaches appear to be inconsistent and lead to distinct wind and stress profiles.

In this work, we combine a theoretical approach and a suite of high-resolution large eddy simulations (LES) to investigate the mean flow and turbulent flux profiles in both barotropic and baroclinic ABLs. We reformulate the problem into a closure framework for the angles ($\alpha$) and ($\alpha$_s) that the wind and the stress make with the surface geostrophic flow. This new framework is inherently more generalizable and sheds new insight on the dynamics that dictate the wind and stress profiles, and requires only the ratios of the mean component velocities and stresses rather than their individual profiles. When the two angles are assumed equal ($\alpha$=$\alpha$_s) in the ASL, we recover an exact correction to the constant stress assumption that is equivalent to the tolerance level used by Monin and Obukhov (1954). Deviations from the logarithmic mean wind profile in the barotropic and baroclinic ASL are discussed in the context of variations in the depth of the ASL. Implications on the turbulent kinetic energy budget will also be presented.