Summary Paper: “Similarity of Structure-function Parameters in the Stably Stratified Boundary Layer”

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Summary Paper

This paper is a study about the boundary layer. The paper begins with a look into the existing models of obtaining information about the nocturnal boundary layer. It first looks at the 1969 paper by McAllister and then shifts to the overview of the 1972 study by Deardorff. Comparisons are also made on the models and studies by Delage (1974), Wyngaard (1975), Broost and Wyngaard (1978), and Nieuwstadt of 1984. The hypothesis is that for most of the nocturnal boundary layer, turbulence is close to its critical Richardson number.

The paper then explores the structure function parameters, such as the refractive index function, and finds that the layer’s length, temperature, and velocity scales are dependent on local stress and buoyancy flux. Next, the paper delves into the similarity structure and uses studies by Panofsky and Dutton (1984) and Wyngaard et al. (1978) to find a balance in unstable surface layer. The literature is sufficient to assume that the local balance for the Oq budget continues to stable conditions too.

After this follows an overview of the surface layer similarity, the stable surface-layer asymptote (under the most stable conditions, stability limits turbulent eddy sizes and the effect of length and temperature scales on the turbulence) and the outer-layer similarity (using evidence to look at the support of the idea of local scaling of turbulence in the stably stratified boundary layer). All this is done using data collected from field experiments and also from direct and large-eddy simulations to reach the conclusion that the structure-function parameters for velocity and temperature are in line with local scaling.

Next is a discussion of vertical profiles noting the importance of kinematic stress magnitude and temperature flux being the most vital components of the similarity relations. A survey of these parameters under ideal conditions (nearly steady, horizontally homogeneous), considers the factors that are dependent on the prerequisite for a balance in these conditions. Departures from these ideal conditions are then analyzed. The first time where changes to the surface energy balance affect a change from positive to negative are in the surface heat flux. Besides, departures from linearity induced by changes in time have a strong effect on C2T. The second factor, baroclinity, can also affect the profile. Third is terrain slope, whose changes have significant effects on stress profile. Internal gravity waves also affect turbulence levels and time scales. All these factors cause high variability on the vertical profiles of the structure-function parameters due to the sensitivity of the temperature flux and stress profiles. The sensitivity to these factors prevents these profiles from being universal in the typical nocturnal case. Thus, the steady state models of Sorbjan (1986) and Nieuwstadt (1984, 1985) did not fit well the measured profiles in the nocturnal boundary layer. However, the numerical models of Duynkerke and Driedonks (1987), which apply the same closures as those of Nieawstadt while allowing for time evolution of the boundary layer, had the best results.

Simultaneously, similarity expressions that connect the structure function parameters to local values of turbulent stress and temperature flux are in line with observations, LES results, and model predictions. Therefore, evidence suggests that the similarity relations linking the structure-function parameters to the turbulence are better than similarity relations of vertical profiles of structure-function parameters. The local scaling result gives the possibility of stress and temperature flux profiles being inferred from measuring the structure-function parameter profiles.

References

Wyngaard, J., & Kosovic, B. (1994). Similarity of structure-function parameters in the stably stratified boundary layer. *Boundary-Layer Meteorology*, *71*(3), 277-296.