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Evaluation of the similarity functions ϕ_m and ϕ_h for the stable atmospheric boundary layer: Range of validity.

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Introduction

Turbulent transfer is one of the most important processes of the atmospheric or planetary boundary layer (PBL), showing many difficulties to study in stable conditions. Under this situation, far from the stationarity, the presence of internal gravity waves, the decoupling of the surface flux, intermittency, etc make quite complex to parameterize the dynamical properties of the PBL. In this context, the framework of the Monin-Obukhov Similarity Theory is very useful to present micrometeorological data and obtain predictions of meteorological variables as wind and temperature. This is fundamental in air pollution studies as the vertical profiles of wind, temperature and turbulence are the basic properties of the ABL influencing the dispersion of pollutants. Statistical characteristics of the turbulent flow in the ABL (such as surface fluxes) are often in terms of dimensionless forms which have certain universal characteristics. Universal similarity functions ϕ_m and ϕ_h for nondimensional gradients of wind and temperature are probably the most important. Turbulent fluxes can be obtained from these functions for a very different range of stability. They are also used in meteorological and climate models as well as in atmospheric pollution modelling. The similarity theory established the only dependence of these functions on a stability parameter (ζ=z/L), being z height and L the Monin-Obukhov length, which depends on friction velocity and heat flux, but the mathematical relationships between the similarity functions and the stability parameter are obtained from carefully conducted experimental campaigns. In this work, data from SABLES 98 (Cuxart et al., 2000) have been used to study the behaviour of ϕ_m and ϕ_h for a wide range of stability ($0< \zeta <50$), comparing them with those widely used in the literature. The limit of validity of these commonly used linear forms will also be analysed.

Results

- The main results concerning the similarity function for nondimensional gradient of wind are: a) ϕ_m increases with stability (ζ), although this increasing is not uniform for all the stability ranges. For ζ <1 (weak to moderate stability), the obtained function $\phi_m$is similar to that proposed by Businger et al. (1971). For stronger stability (ζ >1) $\phi_m$calculated are below the functions found in the literature, and then if these functions are used the values are overestimated. It must be applied the theory of z-less stratification and $\phi_m$is not controlled by the stability. b) The data are more scattered when z (3 levels are studied: 5.8, 13.5 and 32m) is increased, due to the increasing stability and intermittency.
- With regards to the similarity function for nondimensional gradient of temperature, it must be underlined: a) ϕ_h presents much more dispersion that $\phi_{m,}$ and the dependence on stability is not so clear. b) For the lower level (5.8 m) and for 0.1< ζ <2 the results are similar to other found in the literature. For greater stability, the z-less result is again found. c) For weak stability (ζ <0.1), ϕ_h shows quite large unexpected values, especially for the higher levels, which could be related with the interaction of turbulence-internal waves.

Conclusions

- Most of the universal similarity functions found in the literature can not be valid when the stable conditions are in the range of moderate to strong stability (ζ >1).
- For moderate to strong stability conditions the use of usual similarity functions can produce overestimation of the true value.

References

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