The effect of stratification on the roughness length for vegetated and urban surfaces

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The concepts of the roughness length, , and displacement height, , have been introduces in engineering fluid mechanics to parameterize the effect of the flow interaction with the surface roughness elements in the wall law, in particular, to express the surface stress (or friction velocity,) with the mean flow velocity. It is recognised that depends on the typical height, , and the shape of roughness elements and, over smooth surfaces, on and the molecular viscosity ; is usually taken proportional to . These concepts have been adopted in environmental fluid mechanics, although land surfaces are often complex and extremely rough. Roughness elements, e.g. for the urban or forest canopies, could be as high as ~20-50 m, which is comparable with the Monin-Obukhov length scale, L, characterising typical sizes of turbulent eddies. In these conditions it is only natural to expect that the surface resistance, and therefore the effective values of the roughness length, , and displacement height, , could depend on the static stability / instability. We develop a theoretical model accounting for this mechanism and validate it against experimental data. It is demonstrated that the stability dependence is especially strong in stable stratification, where asymptotically ~L. Over boreal forest in winter time this leads to more than an order of magnitude smaller that . Recommended formulations are ready for use in modelling applications.