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Revisiting Monin-Obukhov Similarity Theory

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Monin-Obukhov similarity theory (MOST) is revisited in comparison with observations from two field campaigns: one over a homogeneous flat terrain and one over complex terrain. The analyses indicate that the neutral relationship between turbulent momentum fluxes expressed as $u_* = \sqrt{|\tau|/\rho}$ (the τ and ρ are turbulent stress and air density measured at an observation height z) and wind speed V at z described by the MO bulk formula is intended for the naturally neutral (even under weak winds) surface layer. When the surface layer is either stably or unstably stratified, the only way to achieve the neutral surface layer is through strong mechanically generated turbulent mixing to effectively transfer heat vertically. Under this situation, the neutral u_*-V relationship described by the MO bulk formula is observed to shift towards larger V. As the shift is relatively small when z is small ($\leq$ 10 m above the surface), the MO bulk formula is approximately valid. MO stability functions cannot be used to connect the transition between the stratified and the neutral regimes if the neutral u_*-V line is not naturally neutral. As the deviation of the MO neutral u_*-V line from the one resulted from mechanical turbulent mixing increases with z, the bulk formula becomes invalid with increasing z. The concepts of the surface drag coefficient and the associated surface roughness length are revisited as they are traditionally defined based on the MO neutral u_*-V relationship.