7A.3 - Baroclinicity and Stability in the Atmospheric Boundary Layer: Characterizing Their Interacting Effects via Large-Eddy Simulations and Reduced Models (Invited Presentation)

Tuesday, January 10, 2023

2:00 PM - 2:15 PM

502 (Meeting Room Level, Colorado Convention Center)

Abstract

Baroclinicity adds another layer of complexity to the much-studied barotropic atmospheric boundary layers (ABLs) by modulating the pressure gradient in height. Despite the prevalence of baroclinicity in real-world ABLs, our knowledge of the interacting effects of baroclinicity and atmospheric stability is limited. In this talk, we aim to address this knowledge gap by systematically varying baroclinicity and stability using the large-eddy simulation (LES) technique.

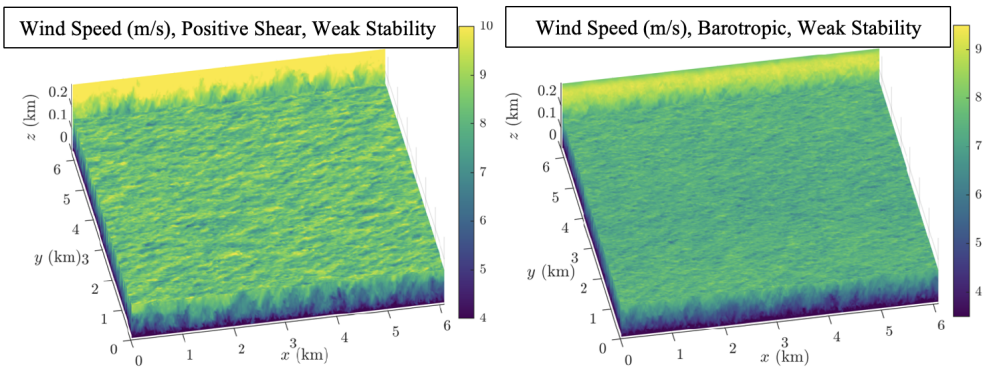
We will present how baroclinicity alters the friction velocity, Obukhov length, shear production, ABL height, and low-level jet (LLJ) in diabatic baroclinic atmospheric flows. It will be shown that while baroclinicity significantly impacts unstable, neutral, and weakly stable ABLs (see the attached figure and Momen et al 2018), its effects reduce with increased stratification in the ABL. In strongly stratified ABLs, the LLJ height, friction velocity, and Obukhov length converge to a constant asymptote independent of the baroclinicity regime (Momen 2022). We will demonstrate that this behavior is attributed to the strong turbulence destruction in very stable ABLs that decouples the surface from higher elevations where baroclinicity is more important.

Finally, two rescaling methods in the inner and outer layers of stable baroclinic ABLs will be presented to non-dimensionalize and collapse the wind profiles in baroclinic environments. The developed reduced model for different baroclinic wind profiles will be shown against the LES results. The findings of this research elucidate the underlying physics of baroclinic diabatic ABLs and are useful for characterizing the wind profiles in weather/climate models, field measurements, and various industrial applications.

References:

Momen M (2022) "Baroclinicity in stable atmospheric boundary layers: Characterizing turbulence structures and collapsing wind profiles via reduced models and large-eddy simulations," Quarterly Journal of the Royal Meteorological Society 148:76–96. https://doi.org/10.1002/qj.4193

Momen M, Bou-Zeid E, Parlange MB, Giometto M (2018) "Modulation of Mean Wind and Turbulence in the Atmospheric Boundary Layer by Baroclinicity," Journal of Atmospheric Sciences. https://doi.org/10.1175/JAS-D-18-0159.1



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