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MMM SEMINAR *NCAR*

Canopy-Boundary Layer Coupling in Convectively Unstable Flows: A Tale of Interacting Instabilities

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The origin of the coherent eddy structures in and above tall plant canopies in neutrally stratified flow has for some years been known to result from the hydrodynamic instability of the inflected mean velocity profile that develops at the canopy top. A cascade of secondary instabilities yields canopy eddies of characteristic form and these are responsible for most of the turbulent kinetic energy and transport in the canopy's vicinity.

Above the surface layer, in neutral and weakly unstable flows, large-scale roll-like structures dominate transport throughout much of the larger atmospheric boundary layer (ABL). When buoyancy forces become dominant, these rolls transition into Rayleigh-Benard-like cells spanning the depth of the convectively driven ABL. At the canopy level, these ABL-scale structures modulate the near-surface wind and temperature fields so that canopy regions are alternately subjected to enhanced or reduced wind shear and diabatic stability at horizontal scales ranging from 100-1000 canopy heights.

Beneath these ABL-scale structures in regions of strong shear, the canopy eddy structure corresponds to the inflection point instability described above. However in regions of low shear, diabatic effects dominate and convective plumes develop, extending vertically to several canopy heights and with horizontal widths of order canopy height. These canopy plumes are a mode of buoyant instability with Rayleigh-Benard type eigenmodes, whose horizontal scale is related to the vertical profile of canopy air temperature.

The horizontally-averaged heat and momentum transfer between the canopy layers and the ABL above therefore results from two distinct coherent eddy structure types, according to whether the canopy is below ascending or descending regions of the larger ABL-scale structures. Because the structure of the large ABL-scale rolls or cells above the canopy depends upon the area-averaged heat and momentum transfer from the surface through the parameter zi/LMO (the ABL depth divided by the Obukhov length), these three modes of instability, two at canopy scale and one at ABL scale, are intimately coupled.

We have studied this situation using canopy-resolving large eddy simulation (LES) of the full ABL. In addition, we complement those full LES simulations with idealized studies of the canopy plume instability.

In this talk we will discuss the implications of this fully coupled picture of canopy-ABL turbulent exchange for Monin-Obukhov scaling in the surface and canopy-roughness sublayers, and for observational strategies for tower measurements of turbulent fluxes. We will also comment on the usefulness of linear and non-linear stability analysis in revealing attractors for dominant turbulence structures even in fully turbulent flows.

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PLEASE NOTE THE SPECIAL DAY OF THIS SEMINAR

Tuesday, 17 February 2015, 3:30 PM

Refreshments 3:15 PM

NCAR-Foothills Laboratory

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Bldg 2 Main Auditorium, Room 1022

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