MMM SEMINAR SERIES

Mesoscale & Microscale Meteorology MMM LABORATORY

Vegetation-Atmosphere Coupling in Neutral to Free Convective Stability

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We present a new mechanism for turbulent transport between the atmospheric boundary layer (ABL) and vegetated surfaces resolved at the level of turbulent eddy structure. The mechanism is based on the essential interaction between the ABL-scale eigenmodes, which organise turbulence in the ABL, and the coherent eddies, which dominate the canopy-roughness sub layer (RSL). At both ABL and RSL scale, the dominant eddy structure is well described by linear eigenmodes, which act as attractors for the turbulence.

The ABL-scale structures evolve from streamwise rolls to closed cells as the parameter -zi/<L> increases, where zi is ABL depth and <L> the area-averaged Obukhov length. They organise the near-surface flow into contiguous regions of locally high or low stability, which are tens to hundreds of canopy heights in horizontal extent. When -zi/<L> is small (near neutral), regions of high shear and low gradient Richardson Number (Ri) are located in the downwelling regions between the ABL-scale rolls. As -zi/<L> increases and the rolls transition towards closed cells, the regions of strong near-surface shear and -Ri<<1 shrink to the downwind regions of the cells.

In the regions of high shear (-Ri<<1), canopy-RSL turbulence is dominated by 'mixing-layer' type coherent eddies (ML), which are related to the hydrodynamic instability of the inflected mean velocity profile at canopy top. In regions of low shear (-Ri>>1), canopy-RSL turbulence is dominated by previously undescribed eddy structures, which we have termed canopy plumes (CP). The canopy plumes are eigenmodes of a Rayleigh-Benard type instability, modified by the canopy drag and heat source distribution. In unstable conditions they enhance turbulent transport above the predictions of Monin-Obukhov stability theory (MOST) in a thermal roughness sublayer just as the ML eddies do in a momentum RSL in nearer neutral conditions.

Because both the ML eddies and the CP eddies are eigenmodes of the background wind and buoyancy fields, they are spatially mutually exclusive and the transition between the two modes as local stability changes is relatively abrupt. This implies that smooth changes in properties like MOST Phi functions or turbulent Prandtl and Schmidt Nos as stability changes result from smooth changes in the area fraction occupied by ML or CP eddies rather than a smooth evolution of RSL eddy form. Since these area fractions are determined by ABL-scale structures, the surface and ABL-scale eddy structures are intimately coupled.

Our model explains a series of otherwise anomalous results such as the observed decorrelation of the eddy fluxes of heat and momentum as instability increases. More fundamentally, it questions our ability to model the ABL as a stack of horizontal slabs with distinct properties but also introduces a new closure problem because of the interdependence of ABL and RSL eddy types. This closure can be resolved by assuming the boundary layer as a whole maximises energy dissipation or entropy production.

Thursday, 02 February 2023, 2:00pm

Refreshments 1:45pm

Please also join colleagues for refreshments and informal discussion after the seminar until 3:30pm

NCAR-Foothills Laboratory, 3450 Mitchell Lane
FL2-1022, Large Auditorium

Seminar will also be live webcast

https://operations.ucar.edu/live-mmm

Participants may ask questions during the seminar via Slido.

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