EGU21-15113
https://doi.org/10.5194/egusphere-egu21-15113
EGU General Assembly 2021

Direct Numerical Simulation of turbulent canopy flow

Ganapati Sahoo[1,8], **Soumak Bhattacharjee**[2], Andrey Debolsky[3,4,5], Evgeny Kadanstev[8,6], Evgeny Mortikov[3,4,7], Rahul Pandit[2], and Timo Vesala[8]

[1]Department of Mathematics and Statistics, Faculty of Science, University of Helsinki, Finland (ganapati.sahoo@helsinki.fi)
[2]Department of Physics, Indian Institute of Science, Bangalore, India
[3]Lomonosov Moscow State University, Moscow, Russia
[4]Moscow Center for Fundamental and Applied Mathematics, Moscow, Russia
[5]A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia
[6]Finnish Meteorological Institute, Helsinki, Finland
[7]Marchuk Institute of Numerical Mathematics RAS, Moscow, Russia
[8]Institute for Atmospheric and Earth System Research/Physics, Faculty of Science, University of Helsinki, Finland

Turbulent flows within and above urban and vegetative canopies in the atmospheric boundary layer have profound implications for a variety of important problems in agricultural and urban meteorology, such as the spreading of pollens and pollutants. We study such turbulence via Direct Numerical Simulations (DNSs), by using the code developed in (2019 Mortikov), in which there is a closed channel between two parallel walls and a canopy of constant areal density profile on the lower wall. We impose periodic boundary conditions in the horizontal directions and a no-slip impenetrable boundary condition in the wall-normal direction. For the canopy, we use different formulations of the Forchheimer drag. We assess the role of the canopy on the turbulent flow. In particular, we show the influence of added drag on the mean profiles, balance equations of the second-order moments, and the local anisotropy of the flow.

We observe that the turbulence transport profile undergoes an abrupt transition at the canopy top and transfer of energy from the roughness sublayer above the canopy to inside the canopy.
The pressure-strain correlation removes energy from the wall-normal fluctuations, which has the least share of the turbulent kinetic energy and distributes it among the other components in the bulk of the canopy. In the inertial range, within and above the canopy, the energy spectra for the streamwise component is steeper than the spanwise and the wall-normal components and is closer to the Kolmogorov -5/3 spectrum as observed in the eddy covariance measurements in the roughness sublayer (2020 Bhattacharjee).

We thank the DST, CSIR (India), SERC (IISc) for computational resources, the AtMath Collaboration at the University of Helsinki, and ICOS by University of Helsinki for their support. This study was also partially funded by RFBR project number 20-05-00776.

Reference

2019, Mortikov, E. V., Glazunov, A. V., & Lykosov, V. N. Numerical study of plane Couette flow:

turbulence statistics and the structure of pressure–strain correlations, Russian Journal of Numerical Analysis and Mathematical Modelling, 34(2), 119-132. doi: https://doi.org/10.1515/rnam-2019-0010.

2020, Bhattacharjee S., Pandit R., Vesala T., Mammarella I., Katul G., and Sahoo G. Anisotropy and multifractal analysis of turbulent velocity and temperature in the roughness sublayer of a forested canopy, arXiv:2010.04194.