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Large-Eddy Simulation of turbulent wind flow over heterogeneous landscape

S. Dupont and Y. Brunet
INRA, UR1263 EPHYSE, Bordeaux, France (sdupont@bordeaux.inra.fr)

Rural landscapes are often characterized by a large spatial variability due to the presence of clearings, roads, forest or crop patches of various heights, etc., added to topographic effects. Such fragmentation induces a three-dimensional variability in micrometeorological fields (wind, temperature, humidity) that may lead to the formation of local meteorological events (advective flows, fog, etc.). Although at this fine scale (few meters to few hundred meters) these surface heterogeneities are almost sub-grid scale heterogeneities in mesoscale models, they could influence physical processes within the all atmospheric boundary layer. As a consequence, modelling micrometeorological fields is important for improving sub-grid scale parameterization of surface heterogeneities in weather forecasting system but also for many environmental applications such as forest management, wind energy applications, forest-atmosphere scalar exchange, forest fire propagation, etc. Wind modelling at fine scale has remained until now limited because of the complexity of accounting in airflow models for surface heterogeneities.
In a first step to improve our knowledge on the impact of surface heterogeneities and small topography on micrometeorology, we focused on turbulent wind flow in neutral atmosphere by modifying the atmospheric model ARPS (Advanced Regional Prediction System) so as to simulate turbulent flow at very fine scale within and above heterogeneous vegetation canopies using a Large-Eddy Simulation (LES) approach. Conversely to usual approaches, LES not only allows to have access to the average wind flow but also to its non-stationary character, i.e. turbulent structures known as ‘coherent’ which dominate the turbulent flows and which ensure a large part of the exchanges (mass, heat, momentum) between the vegetation and the above atmosphere.
We will present a review of the recent validation and application of this model over two types of surface heterogeneity representative of the rural landscape, forest leading edge and forested hill. In these two configurations, we have analyzed in great details the dynamic of the wind flow as well as that of turbulent structures in order to characterise canopy-atmosphere exchanges along these heterogeneities. The next step to this work will consist in introducing a SVAT (Soil-Vegetation-Atmosphere-Transfer) model within ARPS in order to simulate in details the variability of the temperature and humidity fields at landscape scale. In future, such model should be able to improve the simulation of local meteorological events.