



Real-time identification of flow structures in the atmospheric boundary layer using UAV-borne measurements and neural networks

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The accurate identification and classification of wind structures in the atmospheric boundary layer (ABL) are promising to address the challenges of surface fluxes estimations and improving our understanding of the atmosphere dynamics. Traditionally, the Eddy-Covariance method is used to estimate those fluxes but it struggles to achieve the energy balance closure in specific atmospheric conditions such as day-time convective conditions. Those inaccuracies are possibly due to the presence of localized wind structures such as updrafts or other coherent structures in the vicinity of the measurement tower.

The present study was performed on numerical simulation databases to develop the methodology and will be applied to field data in the upcoming future.

First, an innovative framework that combines real-time data acquisition using unmanned aerial vehicle (UAVs) and signal reconstruction via Fourier mode decomposition is going to be presented. The UAV is flying on a predefined path to gather measurements that are then used to reconstruct the velocity field based on a limited number of Fourier modes. The solenoidal constraint is applied to the velocity field to get more accurate results. The determination of the Fourier modes is handled as a minimization problem while the limited number of modes ensures a good computational efficiency while trying to preserve the key features of the flow. The time-history of the measurements is considered up to a certain sample age but the location of the samples from the past is advected in a Lagrangian fashion according to the reconstructed field. This reconstruction process is performed in near real-time which is critical for practical applications.

Second, we will focus on the identification of the flow structures. It is handled by a neural network trained on an extensive data sets of more than 100 million samples taken from Large Eddy Simulations (LES) of convective boundary layer with various atmospheric conditions (mean Temperature going from 15 to 25°, geostrophic wind speed ranging from 0 to 4m/s...). This neural network has demonstrated good performance reaching an accuracy of 84% in structure identification according to the classification of Park et al. [1], even for ABL conditions unseen during the training process. These results showcase the robustness of the neural network and its ability to adapt to varying convective scenarios and its ability to identify various structures such as updrafts, downdraft and other coherent structures.

Finally, the two approaches are combined. Within a LES flow field, a virtual UAV takes measurements on a predefined path, reconstructs the velocity field based on the Fourier modes approach and identifies the structures. The results of the identification problem are then compared to the actual features in the LES in order to evaluate the accuracy and effectiveness of the combined method.

[1] Park, S., P. Gentile, K. Schneider, and M. Farge, 2016: Coherent Structures in the Boundary and Cloud Layers: Role of Updrafts, Subsiding Shells, and Environmental Subsidence. *J. Atmos. Sci.*, **73**, 1789–1814, <https://doi.org/10.1175/JAS-D-15-0240.1>.