# UAV-Enabled Neural Network Classification of Convective Flow Structures for Energy Flux Analysis in the Atmospheric Boundary Layer

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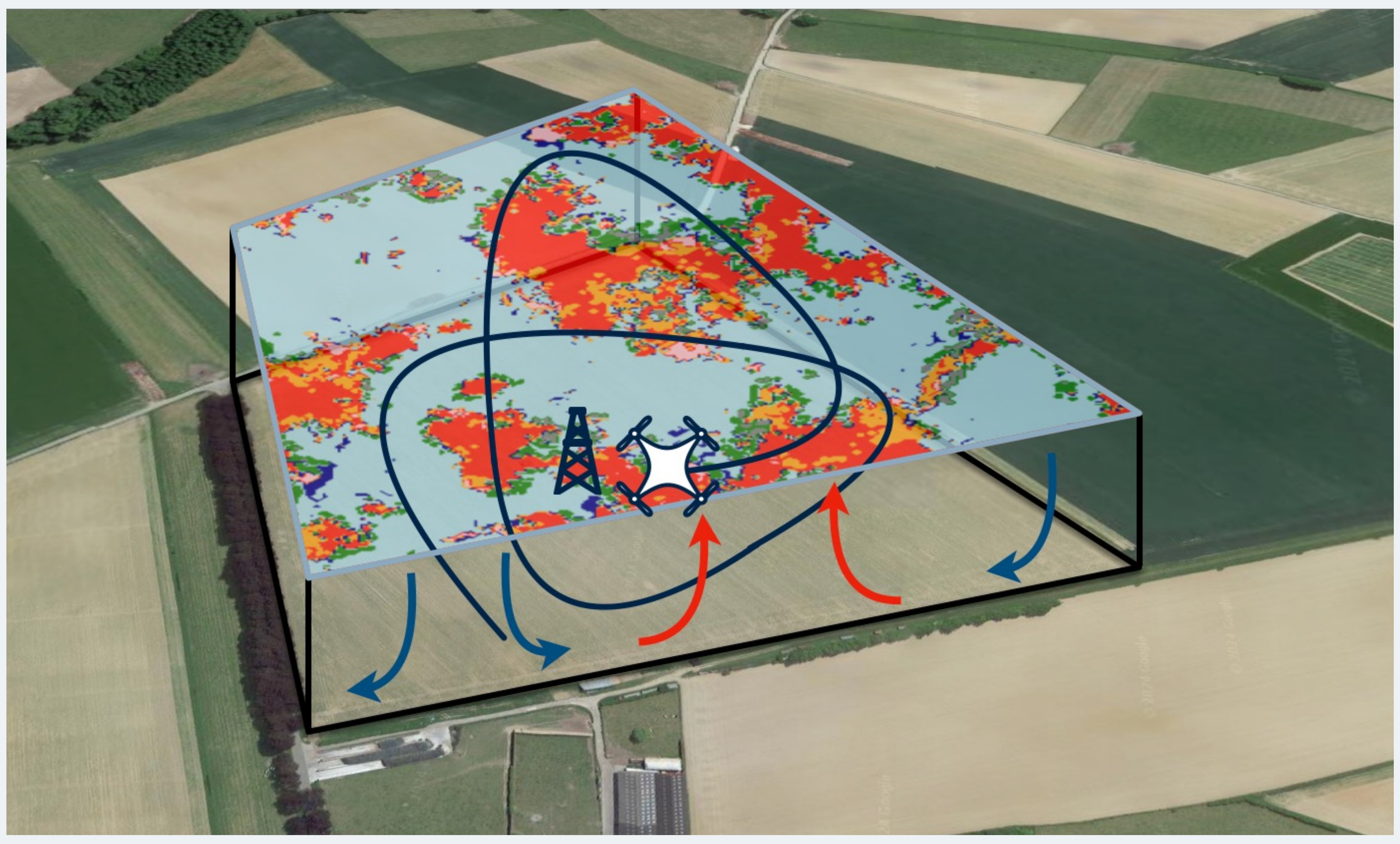
## 1 ⋄ AGROFLUX project

- Agroflux aims to contribute to the verification of **greenhouse gas exchange** carried out by Belgian **ecosystems** by improving our understanding of the **atmosphere dynamics**.
- Traditionally, the **Eddy-Covariance method (EC)** is used to estimate the **surface fluxes** but it struggles to achieve the energy balance closure in specific atmospheric conditions such as day-time **convective conditions**. This problem may be due to various large-scale flow structures, such as an updraft in the immediate **vicinity of the measurement tower**, which could violate some of the hypotheses made for the computation of the fluxes.
- 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 limitations of the EC.



The current study is **numerical**, using the BigFlow framework. It aims at identifying convective flow structures based on **UAV measurements and artificial neural network (ANN).**

## 2 ⋄ Measurements devices

UAV
- Airolit S1
- Payload 5.6kg
- Equipment
  - 3D sonic anemometer
  - Temperature probe
  - Gaz analyser ($CO_2$ and water vapor concentration)
- Flight time : 20 minutes

**Provides spatial information for the classification**

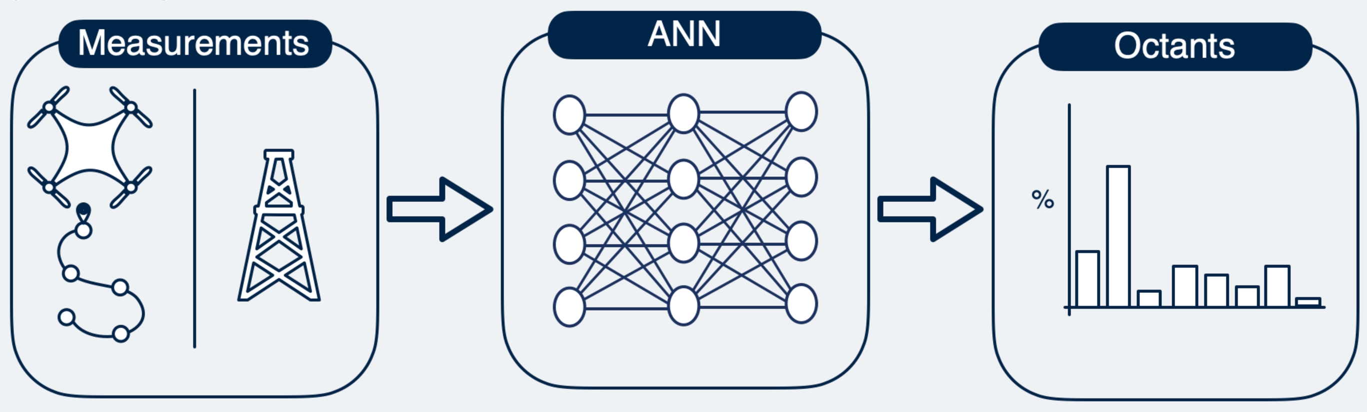
ICOS station
- Equipment
  - 3D sonic anemometer
  - Temperature probe
  - Gaz analyser ($CO_2$ and water vapor concentration)
- Average measurement over 30 minutes

**Provides mean flow measurements to identify the atmospheric conditions.**

## 3 ⋄ Flow structure identification

The identification is handled by the ANN trained on an extensive data sets of more than 100 million samples taken from Large Eddy Simulation of convective boundary layer with **various atmospheric conditions** (mean Temperature going from 13 to 25 [°], geostrophic wind speed ranging from 0 to 4 [m/s] and surface heat flux varying between 25-100 [W/m²]). The atmospheric condition are taken from data from **convective days** on the ICOS Lonzée site in Belgium. The identification is performed according to the classification of Park et al. [1] and the ANN is designed to reduce the number of scalar fields required.

Based on the measurements taken from the UAV at **5 different locations** along its trajectory (over a 5 seconds period of time), the ANN outputs the **most probable octant of the last point of the trajectory.**




The validation has been done on unseen atmospheric condition during the training process and compared to the classification of Park et al. [1]. This ANN demonstrated good performance reaching an accuracy of 82% in structure identification. When considering only the structures of interest (**updraft, downdraft, ascendance and subsidence**) the accuracy increases up to **89%**.

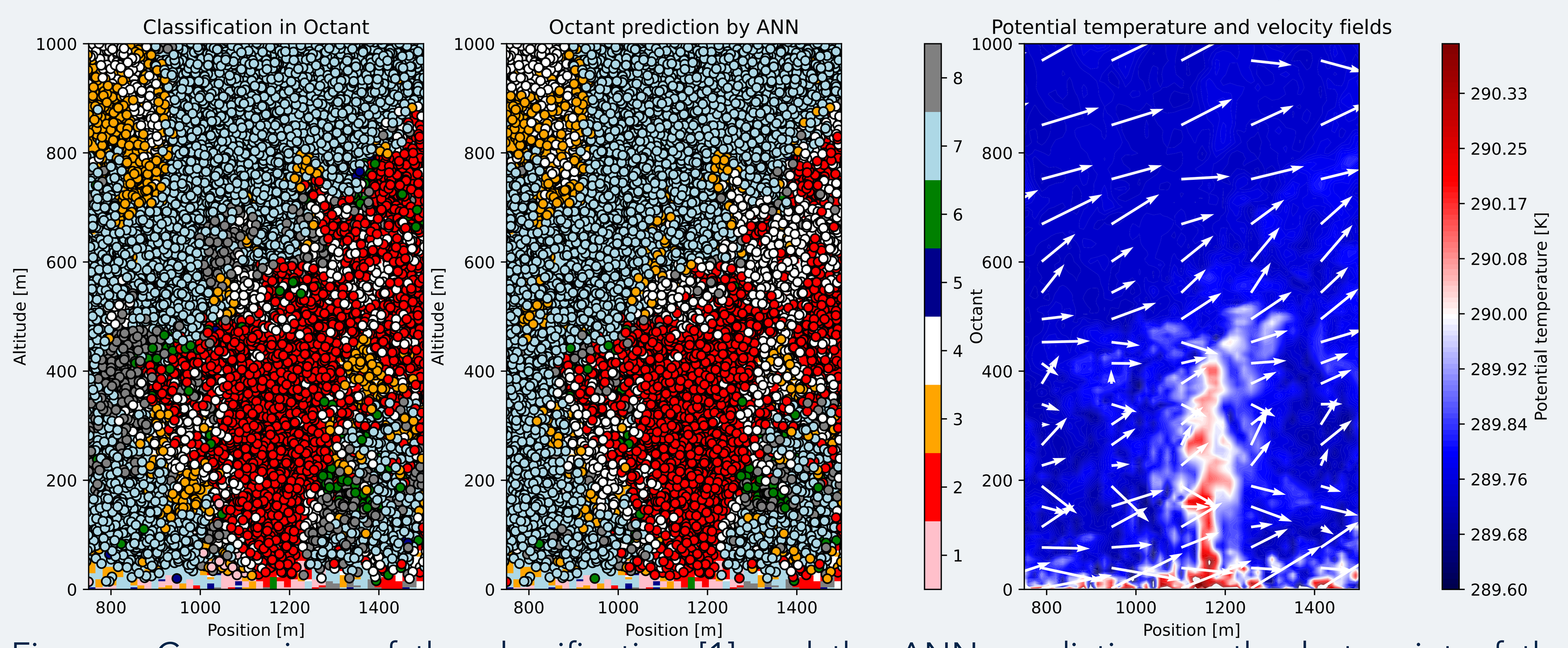



Figure : Comparison of the classification [1] and the ANN prediction on the last point of the trajectory (Left figures) and representation of the LES fields associated with the classification.

## 4 ⋄ Perspectives

- Applied the previously described method to real-world data during **experimental campaigns**.
- Combined the classification process with the **control of the drone** to increase the **observability of the atmosphere** based on a real-time adaptation of the UAV path.
- Combined the UAV observation with the LiDAR measurements.
- Flagged some convective flow structures and compute the energy balance to assess their impact.

## 5 ⋄ References

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[1] Park, S., P. Gentine, 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, doi:10.1175/JAS-D-15-0240.1.