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Organized turbulent motions in a hedgerow vineyard: effect of evolving canopy structure

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Vegetation-atmosphere exchanges are determined by functional and structural properties of the plants together with environmental forcing. However, a fundamental aspect is the interaction of the canopy with the lower atmosphere. The vegetation deeply alters the composition and physical properties of the air flow, exchanging energy, matter and momentum with it. These processes take place in the bottom part of the atmospheric boundary layer where turbulence is the main mechanism transporting within-canopy air towards the mid- and upper atmospheric boundary layer and vice versa. Canopy turbulence is highly influenced by vegetation drag elements, determining the vertical profile of turbulent moments within the canopy. Canopies organized in rows, like vineyards, show peculiar turbulent transport dynamics. In addition, the morphological structure (phenology) of the vineyard is greatly variable seasonally, shifting from an empty canopy during vine dormancy to dense foliage in summer.

The understanding of the canopy ventilation regime is related to several practical applications in vineyard management. For example, within-canopy turbulent motion is very important to predict small particles dispersion, like fungal spores, and minimize infection studying the effect on leaf wetness duration. Our study aims to follow the continuous evolution of turbulence characteristics and canopy structure during the growing season of a hedgerow vineyard, from bud break to fully developed canopy. The field experiment was conducted in a flat extensive vineyard in North-Eastern Italy, using a vertical array of five synchronous sonic anemometers within and above the canopy.

Turbulent flow organization was greatly influenced by canopy structure. Turbulent coherent structures involved in momentum transport have been investigated using the classical quadrant analysis and a novel approach to identify dominant temporal scales. Momentum transport in the canopy was dominated by downward gusts showing increasing importance throughout the growing season. At the same time, transport intermittency increased with developing leaf density. The contribution by interaction terms, acting opposite to downward momentum flux, increased in the lower canopy. The analysis of event time scales revealed that momentum transport in the vineyard was dominated by sweeps of 2-4 s duration and ejections of 4-6 s duration, which can be summed to estimate an average duration of dominating coherent structures in the order of 6-10 s. The evolution of canopy morphology did not have any clear influence on structure duration.