

A Study of 3D Turbulent Wind Flow at the Centre of Vertical Agrivoltaics in Full-Grown Wheat Condition

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1. Introduction

In the burgeoning field of sustainable energy solutions, the integration of photovoltaic modules into agricultural systems is a promising avenue. Agrivoltaics exerts an influence on air flows, orchestrating a symphony of effects that have repercussions on the crop microclimate and consequently growth and yield. This interaction encompasses changes in mean wind speed, shading patterns, turbulence levels and, finally control the process of evapotranspiration. Vertical agrivoltaics is a design of interest because of compatibility with agricultural equipment operation, bimodal electricity production profile and expected benefits of windbreak and shading effect on water balance [1]. Among the multitude of factors that condition the microclimate, the transport of scalars and momentum appears to be a key player, governed mainly by turbulent wind phenomena [2]. Therefore, this study investigates the impact of photovoltaic modules mounted on a vertical agrivoltaic structure on wind dynamics, with particular emphasis on the windbreak effect and turbulence pattern in a 111 kWc demonstrator.

2. Material and Methods

This study is based on a trial conducted in a TotalEnergies vertical agrivoltaic demonstrator located in Valpuseaux (France). The trial aims to study the windbreak effect and turbulence at the center of the demonstrator according to the wind direction. Data from a 3D sonic anemometer were collected at the center of the demonstrator, 2m above the soil. These were compared with another dataset collected on a second 3D sonic anemometer located in the reference zone 30m south of the last panel of the central array. The data were collected during the growing period of wheat. Turbulence is characterized by the friction velocity calculated according to Kaimal and Finnigan [3] with the speed eddy components.

3. Results and Conclusions

3.1. Results

Figure 1 presents the results of the study in terms of mean wind speed and direction and in terms of friction velocity (u^*) between the reference zone and the center of the demonstrator. The wind roses illustrate that the mean wind at the center of the demonstrator is deflected towards the direction parallel to the photovoltaic arrays. The wind rose for the reference area also shows that the wind rarely went from the north during the trial period. The line graph presents the evolution of the ratio between the mean speed at the center of the demonstrator and that of the reference, as well as the ratio for the friction velocity, according to the direction of the reference wind. The variation of the mean speed (in blue) between the reference zone and the center of the demonstrator appears to follow a sinusoidal law with a decrease in speed when the direction of the reference wind is perpendicular to the photovoltaic arrays and an

increase in speed when the direction is parallel. This increase is probably due to a Bernoulli effect caused by the channeling of the flow with the photovoltaic arrays. Friction velocity (u^* in red) seems to increase overall within the demonstrator compared with the reference zone, except when the direction is close to the parallel. In addition, the increase in friction velocity seems to have peaks at certain specific directions with a symmetry around the south direction. The confidence intervals are quite large for the reference wind coming from the north because of the low occurrence of this direction.

3.2. Conclusion

In conclusion, vertical agrivoltaics have a complex effect on the airflow measured at the centre of the demonstrator. Depending on the wind direction, they act by obstructing the flow, but in other directions, they channel the flow and accelerate it. In addition, turbulence increases to a greater or lesser extent depending on the direction of the reference wind. Since these two variables affect the hydric behaviour of crops [1,2,3,4], it is important to take them into account when analysing an agrivoltaic plant. Further work will investigate the spatial variability of these effects using further experimentations and numerical models to study the overall effect on crops.

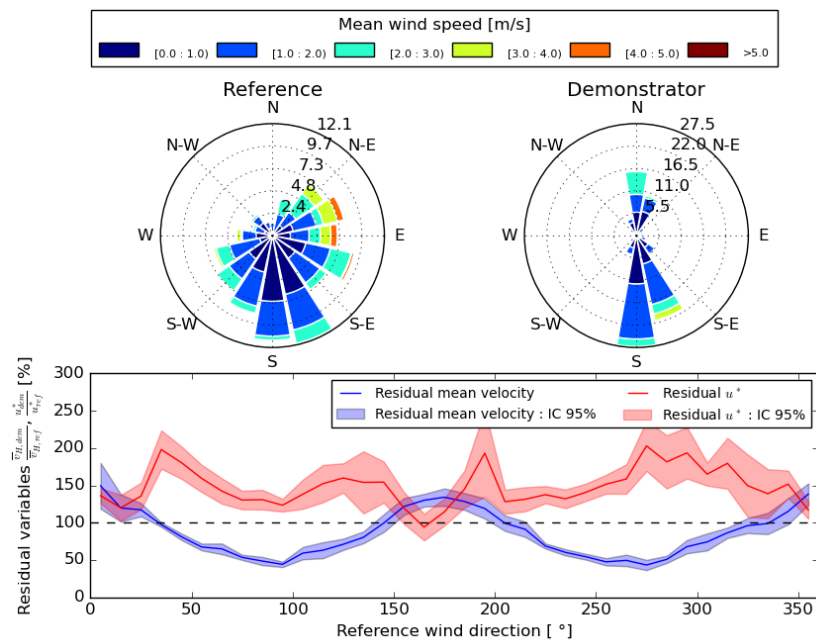


Figure 1. Wind roses inside reference area and vertical agrivoltaics demonstrator and change in mean wind speed and friction velocity as a function of reference wind direction.

4. References

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