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Towards numerical simulation of a wind machine during spring frost calibrated with field measurements

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Spring frost has been recognized as the most harmful weather hazard for agriculture. One way to fight it back is using a wind machine - a 6-m diameter blowing fan atop a 10-m mast. It rotates on itself in approximately 4min30s and blows a slightly positive air using the strength of the nocturnal thermal inversion to mix cold air near the ground with warmer air above. Previous studies have focused on the protection area of the wind machine under different weather conditions or propeller designs. However, while weather conditions are undergone and field measurements are sparse, effects like the topography, the synergy between devices, or the addition of a burner are hard to catch and separate and are, therefore, not yet well understood.

In this study, we present field measurements dedicated to the future calibration of a computational fluid dynamics model (PALM) involving an actuator disk to simulate a wind machine operating during radiative frost conditions. This numerical model will aim to understand better such tower's external effects, for which field measurements are challenging to implement.

To characterize the jet of the propeller at the onset, vertical profiles were measured with a 3D sonic anemometer at high frequency (100Hz) 10 m away from the wind machine every meter between 3 and 15 m heights. Mass flow and momentum rates of about 500m3/s and 5000N were deduced for some different designs of wind machines.

To characterize how the jet interacts with the ground regarding the distance from its source, 2D sonic anemometers were placed in a row in front of the wind machine. Results highlight three different zones where the jet behaved distinctively:

- A dead zone, where the jet passed over the ground (0 to 30 m away from the WM);
- An impact zone where the jet directly hit the ground with maximum velocity (40 to 60m away from the WM);
- A spreading zone where the protection mixing was due to eddies spreading in the inter-rows and breaking into smaller eddies in contact with posts and vine plants (70m away from the WM and beyond). As the distance from the machine increased, the jet velocity decreased before

vanishing.

From these results about the onset condition and development of the jet, it will be possible to tune the rotating actuator disk to reproduce with PALM (an LES meteorological-oriented modeling system) an acceptable behavior of the flows (gust and weather interacting with the ground) despite several simplifications of the underlying physics.

While calibrations are still ongoing, the first results are encouraging, whether it be on a wind machine in a free environment or with the reproduction of a radiative night situation. The primary analysis will focus on the animation of state variables to assist in analyzing statistical results on field measurements. As little knowledge is available about the combined use of a burner with a wind machine, several strategies for a burner location will be tested in order to initiate a research topic that the authors believe is currently unexplored.