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Towards Generalizing the Wind Machine Frost Protection Method

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Frost damage is one of the main contributors to economic losses in the agricultural sector. This damage often occurs during radiation frost events which happen under clear sky, low wind, night conditions, which lower the radiative budget and suppresses turbulent mixing. Near the surface, an inversion layer builds up with strong gradients in temperature. The wind machine method mixes away this inversion by transporting warm air downward and restoring turbulent mixing. Various studies have been done on this method, which have resulted in rules of thumb and linear regression prediction models. However, a grounds up understanding based on physical principles is lacking. In this study, we have done a field experiment in which a three-dimensional understanding of the temperature field is gathered. This was achieved by employing the novel Distributed Temperature Sensing technique, increasing spatial resolution by an order of magnitude as compared to recent literature. We were able to quantify the distance of influence and achieved temperature change both as a function of distance to the wind machine and height. Besides the field experiment, a stability analysis was done on different system configurations using Large Eddy Current Simulations (LES). First, this simulation was benchmarked and calibrated using the field experiment data. After which findings on the different parameters could be put in perspective. For this, a separation was made between design parameters such as rotation time, engine power and tilt angle, and physical forcings such as wind speed, inversion strength, and surface coupling. Identifying which of the system parameters are of importance.