Visualizing wind power at full-scale

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The complexities of wind turbine aerodynamics motivate their study at the scale of turbine operation. It is difficult to match both the Reynolds number (Re) and tip speed ratio (TSR) of real world wind turbines in laboratory settings without artificially driving the turbine to faster rotation. Additionally, the added complexity of operating in the atmospheric boundary layer is difficult to reproduce. Motivated by these facts, this work represents a validation for a novel seeding technique designed for in situ flow measurement around commercial, power producing wind turbines. In these images, the flow around a 2kW vertical-axis wind turbine (VAWT) was seeded using artificial snow encompassing a volume of approximately 9m x 6m x 6m at a $Re_D \approx 10^6$ and TSR≈1. While the goal of this work will be 3D particle tracking using multiple cameras, these images were taken using one camera positioned below and to the side of the VAWT over independent measurement campaigns. These images are composites over ~2s of footage to reveal the pathlines of the seeded particles. The shear layer separating the freestream from the more turbulent wake is clearly illustrated. Additionally, the side view below demonstrates the rapid entrainment of the above freestream flow into the wake which is believed to be responsible for the rapid energy recovery behind VAWTs.

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