Particle Image Velocimetry Measurement of Tornado-like Vortices Compared with Doppler Radar Data

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An exploratory research attempt is made to compare the velocity field of tornadic flows obtained through Particle Image Velocimetry (PIV) and Doppler radar measurements. To achieve this, the velocity field of tornado-like vortices simulated in Model WindEEE Dome was characterized using PIV. The experimental data was obtained at eight different horizontal planes above the surface and over a wide range of swirl ratios. Nine volumes of single-Doppler radar data collected from five tornado events were analyzed using a well-established mathematical method - the Ground-based Velocity Track Display (GBVT) – to reconstruct three-dimensional and axisymmetric wind field of field tornados. The full-scale dataset consists of tornadoes of various intensities. The very small length scale of the simulation along with the low sampling rate of the PIV system result in a significant mismatch between the averaging time of the full-scale data and the scaled up laboratory data. Durst curve was implemented to adjust the averaging time. After considering the limitations of each measurement method and the Durst curve, the complete set of experimental and full-scale data was implemented for comparison purposes.

One volume of the Happy, TX 2007 tornado (from 0203:20 to 0204:17 UTC) was selected to assess the feasibility of comparing field data with laboratory data. Using the method proposed by Refan and Hangan [1], the swirl ratio of the full-scale tornado and the length scale of the simulations were approximated. The Durst curve was implemented to adjust the full-scale data for the averaging time. Afterwards, the velocity scale of the simulation was identified and the scaled up tangential velocity profiles obtained from PIV measurements were compared with the adjusted tangential velocity field of the Happy, TX 2007 tornado.

Fig. 1 shows that radial profiles of the tangential velocity obtained through PIV measurements match well with the full-scale measurements at different heights. The agreement is observed inside and outside of the tornado core region as well as for the core radius and the maximum tangential velocity. This practice was performed for other volumes of full-scale data which resulted in a good agreement between simulations and field data.

To better address the issue of averaging time mismatch, the next set of experiments will be performed in WindEEE Dome which will result in a geometric scaling 11 times larger than the MWD. In addition, a high-speed PIV system will be used to carry out experiments which allows for lower sampling time.

Fig. 1 Comparison between simulated (solid lines) and full-scale (dotted lines) tangential velocity profiles at various heights for volume a of Happy, TX 2007 tornado from 0203:20 to 0204:17 UTC after applying the velocity and length scales

References