Capture and Characterization of Wind-Driven Rain during Tropical Cyclones and Supercell Thunderstorms

Carlos Lopez [a], Forrest J. Masters [b] and Katja Friedrich[c]

[a]*University of Florida, Gainesville, Florida, USA, masters@ce.ufl.edu*
[b]*University of Florida, Gainesville, Florida, USA, carlos06@ufl.edu*
[c]*University of Colorado, Boulder, CO, USA, katja.friedrich@colorado.edu*

1 INTRODUCTION

Accurate characterization of raindrop size distributions (RSD) is critical to many applications in atmospheric science and wind engineering, including the estimation of local precipitation rates from Doppler radar reflectivity and the quantification of rain deposition on the building façade. A significant amount or research has been directed toward wind-driven rain (WDR) effects on the built environment (e.g., Blocken and Carmeliet 2004, Blocken et al. 2010, Choi 1994, Rayment and Hilton 1977) because of water damage to building interior and contents during tropical cyclones and supercell thunderstorms, however very little field data have been analyzed to verify existing models and assumptions. The major issue preventing additional research in this area is that conventional surface-based particle measurement systems are known to lose accuracy in strong winds.

Today two types of sensors are used to measure RSD: impact and optical disdrometers. Impact disdrometers measure the induced voltage from the displacement of an aluminum covered styrofoam sensor. The voltage is amplified, and the droplet size is interpreted by fitting the voltage to predetermined voltage ranges corresponding to droplet diameters (Sheppard 1990, Joss and Waldvogel 1967). Optical disdrometers function by measuring the voltage drop from a photodiode, or series of photodiodes, caused by a raindrop passing through a light band (Loffler-Mang and Joss 2000). Impact disdrometers lose accuracy when droplets travel faster than terminal velocity (Sheppard 1990, Tokay 2008, Tokay 2003). For optical disdrometers to function properly, hydrometeors must travel very nearly perpendicular to the light plane. In little to no wind, this presents no issue for a stationary instrument. In the presence of strong winds, advection is a dominant component of particle trajectory.

Thus a major outstanding experimental challenge is the development and successful implementation of an observational system capable of accurately quantifying RSD during an extreme wind event. This paper presents two such efforts. The first observational platform was successfully deployed during Hurricane Ike (2008) on a Florida Coastal Monitoring Program (FCMP, fcmp.ce.ufl.edu) weather station, which prompted the development of a less expensive suite of instruments that were deployed repeatedly during a six week field campaign in the southern and central Plains through the Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2). This paper briefly discusses these programs, provides technical specifications on the WDR measurement stations, and presents preliminary results.

2 FIELD PROGRAMS

2.1 *Florida Coastal Monitoring Program*

The Florida Coastal Monitoring Program is a collaborative research program between multiple universities (Clemson University, University of Florida, Florida International University, and Florida Institute of Technology) and the Institute for Business and Home Safety focusing on the full-scale experimental study of tropical cyclone ground level wind fields and wind loads on residential structures (Balderrama et. al 2010). Since 1998 the FCMP has deployed portable weather stations to collect ground level meteorological observations and roof pressure sensors on single family homes to measure wind induced roof uplift pressures in tropical cyclones. FCMP data are used widely by meteorologists and emergency managers, as well as university researchers conducting computational and full-scale experiments.

In 2008, the tipping bucket rain gauge system on one of the five FCMP weather stations (T3) was replaced with a two-dimensional, aircraft-mounted Droplet Measurement Technologies (DMT) Precipitation Imaging Probe (PIP). Probe resolution is 100 μm with a particle sizing limit of 6.2 mm. The PIP was mounted to a two-axis mechanized turret located nominally 3 m above ground level (AGL). The orientation of the turret was actively controlled using wind speed and direction inputs from the anemometry on the weather station to determine the optimal elevation and azimuth angles to orient the sensor. The system was deployed successfully in Baytown, Texas during Hurricane Ike (2008). Simultaneous measurements of 3D wind velocity (from the weather station anemometry) and wind-driven rain data were collected leading up to and through the eyewall passage.

(a) FCMP Tower T3 (b) PIP and Turret

Figure 1. PIP-Based System

2.2 *Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2) Project*

The Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2) Project was a continuation of the original VORTEX project (Rasmussen 1994). Both projects were interdisciplinary multi-agency efforts to investigate tornado genesis, dynamics, kinematics, demise, supercell near-ground wind field, and how the environment regulates storm structure. VORTEX2 assets included 10 mobile radars, 12 mobile mesonet instrumented vehicles, and 38 deployable instruments including, disdrometers, surface level wind measurement stations, weather balloon launching vans, and unmanned aircraft that were deployed in the projected path of supercell thunderstorms minutes prior to their arrival.

Two new WDR measurement stations were constructed for deployment during VORTEX2. The instrument platform consisted of six components: (1) an OTT Parsivel optical disdrometer, (2) an RM Young Model 85106 2D Sonic Anemometer, (3) an articulating instrument support structure that is driven by two IMS M-17 stepper motors with an integrated controller and encoder (Model MDI4MRQ17C4-EQ-G1C3), (4), a Labview 8.5 software data acquisition system, which consists of a laptop computer connected to a four port RS-485 National Instruments serial interface (Model No. NI USB-485/4), (5) a battery array of 12V 35 AH Power Sonic

(PS-12350 NB) batteries to supply power to the instruments and (6) a substructure to provide lateral stability and to transfer the gravity and wind loads to the ground.

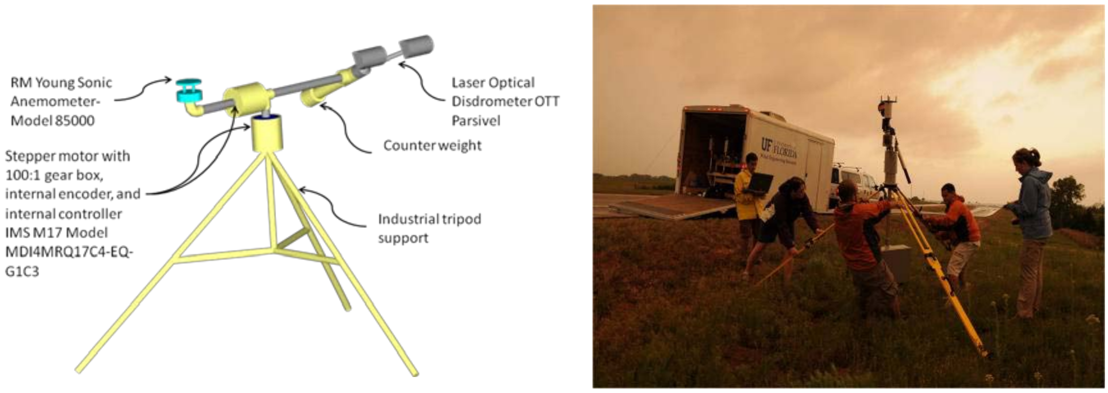

Figure 2. The articulating Parsivel system

The control system is functionally similar to the PIP-based system. Wind speed and direction are converted into "target" elevation and azimuth angles in real-time in order to align the light band with the rain vector. Figure 3 illustrates this process.

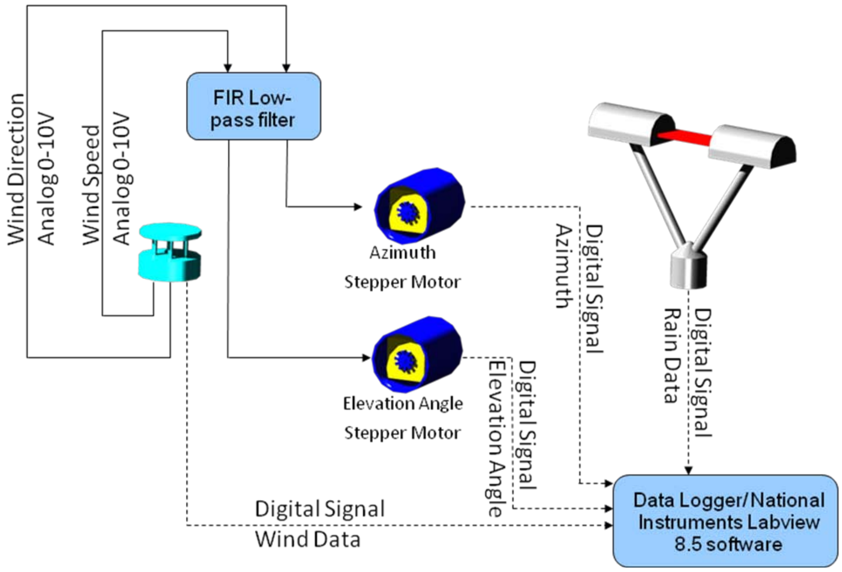

Figure 3. Active control system for the articulating Parsivel platform.

3 PRELIMINARY RESULTS

This paper will present results on stratiform and convective RSDs, reflectivity, rainfall intensity, total concentration and liquid water content measured from stationary and articulating instrumentation. These data will demonstrate the error introduced by measurements made from stationary instrumentation in high wind scenarios and the efficacy of the two introduced articulating systems. Additionally, reflectivity and rainfall measurements are compared to remotely sensed estimates from the National Weather Service WSR-88D Doppler Radars to observe if any biases manifest in extreme wind events.

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