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The Florida Coastal Monitoring Program (FCMP): A review

J.A. Balderrama [a], F.J. Masters [a,*], K.R. Gurley [a], D.O. Prevatt [a], L.D. Aponte-Bermúdez [b], T.A. Reinhold [c], J.-P. Pinelli [d], C.S. Subramanian [e], S.D. Schiff [f], A.G. Chowdhury [g]

[a] Department of Civil and Coastal Engineering, University of Florida, 365 Weil Hall, Gainesville, FL 32611, USA
[b] Department of Civil Engineering and Surveying, University of Puerto Rico-Mayagüez, PR 00681, USA
[c] Institute for Business and Home Safety, 4775 E. Fowler Avenue, Tampa, FL 33617, USA
[d] Department of Civil Engineering, Florida Institute of Technology, 150 W. University Boulevard, Melbourne, FL 32901, USA
[e] Department of Mechanical & Aerospace Engineering, Florida Institute of Technology, 150 W. University Boulevard, Melbourne, FL 32901, USA
[f] Department of Civil Engineering, Clemson University, Lowry Hall, Box 340911, Clemson, SC 29634, USA
[g] Department of Civil and Environmental Engineering, Florida International University, 10555 W. Flagler St., Miami, FL 33174, USA

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A B S T R A C T

The Florida Coastal Monitoring Program (FCMP) is a multi-university field research program that was founded in 1998 to study the near-surface wind and rain characteristics of Atlantic hurricanes and their effects on coastal infrastructure. The FCMP has three research thrusts: (1) characterization of surface wind and wind-driven rain conditions, (2) quantification of wind induced component and cladding pressures, and (3) assessment of damage to evaluate the performance of single family homes and the building codes and standards that guided their construction. This paper presents an overview of the program, including the motivation for the field research, a review of the program's scientific objectives, the history of the program from 1999–2010, and descriptions of the instrument systems and supporting infrastructure. A case study of Hurricane Frances (2004) is presented, and the current and potential uses of the collected wind field data are discussed.

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1. Introduction

The Florida Coastal Monitoring Program (FCMP, fcmp.ce.ufl.edu) is a collaborative experimental program that studies the structure and intensity of hurricane surface wind fields and wind loads on residential buildings. Since the 1998 Atlantic Hurricane season, research teams comprised of faculty, undergraduate and graduate students, and industry participants have deployed rugged portable weather stations to collect meteorological observations, including 3D wind turbulence data (Yu et al., 2008; Masters et al., 2010). Signifcant upgrades to the platforms have included real-time transmission of weather data in 2003, and the collection of wind-driven rain data in 2008. The FCMP also collects hurricane-induced surface pressure data from single-family homes (Michot, 1999; Dearhart, 2003; Aponte-Bermúdez, 2006; Liu, 2006; Liu et al., 2009) and conducts damage assessments of the building stock in storm-impacted regions (Gurley and Masters, in press).

The FCMP was created by the State of Florida Department of Community Affairs (DCA) to provide quantitative evidence of the benefits of hurricane mitigation retrofits to single family dwellings. The program originates from research activities led by Dr. Timothy Reinhold at Clemson University in the 1990s that addressed the widespread damage caused by Hurricanes Hugo (1989) and Andrew (1992). In 1997, Clemson University developed a rugged instrumented tower system to collect high-fidelity surface wind measurements through support from the DCA and the Idaho National Engineering and Environmental Laboratory (INEEL). Wind load monitoring of occupied residential low-rise structures was added to the scope of the research in 1999. The University of Florida (UF) joined the program in 1999. The FCMP includes Florida Institute of Technology (FIT) (Subramanian et al., 2011, 2005, Pinelli et al., 2005), Florida International University (FIU) (Yu et al., 2008; Yu and Chowdhury, 2009), and Clemson University as principal research partners. The Institute for Business & Home Safety (IBHS) has provided logistical and developmental support since 2004.

This paper presents the motivation for the field research, a review of the program's scientific objectives, and the history of the program from 1999–2010. Technical information about the

* Corresponding author. Tel. +1 352 392 9537x1505.
E-mail addresses: jbalderr@ufl.edu (J.A. Balderrama), masters@ce.ufl.edu (F.J. Masters), kgurl@ce.ufl.edu (K.R. Gurley), dprev@ce.ufl.edu (D.O. Prevatt), luisd.aponte@upr.edu (L.D. Aponte-Bermúdez), treinhold@ibhs.org (T.A. Reinhold), pinelli@fit.edu (J.-P. Pinelli), subraman@fit.edu (C.S. Subramanian), schiffs@clemson.edu (S.D. Schiff), chowdhur@fiu.edu (A.G. Chowdhury).

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FCMP's observational assets and deployment strategies is provided as a reference for future papers written by the authors and other data users in engineering, atmospheric science, and storm surge modeling. These activities are summarized, and use of the data by the scientific community is also discussed.

2. Motivation

Inadequate performance of homes during Hurricanes Hugo (1989) and Andrew (1992) resulted in changes to wind load provisions and structural design requirements in building codes and standards. These changes exposed the need for new research in two major areas:

Hurricane Surface Wind Field Intensity. Hugo and Andrew created a scientific rift between engineers and atmospheric scientists over hurricane landfall intensity. After Andrew, this culminated in public disagreement between the Wind Engineering Research Council (now the American Association for Wind Engineering) and the National Hurricane Center (NHC). The NHC estimated wind speeds to be 20–30% higher than wind speed estimates made from damage observations by engineers (Rappaport, 1993; WERC, 1992). This difference translates to an increase in load between 30% and 50%. A major impediment to reconciling this issue was lack of direct measurements of ground level winds, or "ground truth", as only 10 of 34 weather stations survived Andrew with continuous anemometric records (Powell et al., 1996). Lack of reliable surface wind speed observations is problematic for many disciplinary efforts outside of atmospheric science. Sparse ground truth makes it difficult to assess landfall intensity over the impacted region, which introduces errors into catastrophe modeling (Powell and Houston, 1996; Vickery et al., 2006; Hamid, et al., 2010). Incomplete data can introduce biased pricing in hurricane index insurance and weather derivatives markets (e.g., Pai, 2010). Lack of near-surface hurricane wind data also hinders adequate wind simulation in full- and large-scale facilities focusing on hurricane simulation and wind-structure interaction (Lopez et al., 2011; Smith et al., 2010; Huang et al., 2009).

Hurricane-Induced Wind Loading on Residential Homes. Experiments on scaled generic building models in boundary layer wind tunnels are the basis for determining the design wind pressures prescribed in the ASCE 7 load provisions (ASCE, 2010). Comparative studies of wind tunnel modeling and experiments on full-scale buildings (e.g., Marshall, 1975, 1977; Tieleman et al., 1978; Holmes, 1982; Sill et al., 1989, 1992; Richardson et al., 1990, 1997; Cochran and Cermak, 1992; Okada and Ha, 1992; Surry, 1992; Jamieson and Carpenter, 1993; Richardson and Surry, 1994; Richardson and Blackmore, 1995; Robertson et al., 1997; Cheung et al., 1997; Ginger, 2000, 2001; Porterfield and Jones, 2001; Sharma and Richards, 2003; Endo et al., 2006; Doudak et al., 2009; Zisis and Stathopoulos, 2009; Caracoglia and Jones, 2009) have been a critical means to validate that peak load definitions and pressure cycling rates (used in the building product approval process) are representative of naturally occurring conditions. By the late 1990s, the available facilities to measure full-scale wind loads were few and seldom located in hurricane-prone areas (e.g., Marshall, 1975, Levitan and Mehta, 1992a, 1992b; Porterfield and Jones, 2001; Caracoglia and Jones, 2009), making it difficult to gage the ability of the standard wind tunnel testing procedures (which are calibrated against extra-tropical conditions) to characterize hurricane wind loading. In addition, few wind tunnel studies have been conducted on typical coastal homes with complex geometries and heterogeneous upwind terrain conditions.

The major impediment to advancing research in these areas was identified as a lack of field measurements of wind speed and pressure on buildings in coastal communities during landfall. The FCMP was formed to address these issues and contribute to prior efforts to characterize boundary layer flows and wind loading on low-rise structures.

3. Background

3.1. Boundary layer research

The objective of the FCMP is to collect ground-level wind speed information to directly relate building performance to wind speeds. These data are also used in the production of wind field models, which provide wind speed estimates over the entire region affected by a hurricane impact (e.g., Powell et al., 1998). Reducing the uncertainties in wind speed estimation reduces the expected range of wind speeds associated with a particular damage level. Damage levels describe the percent of damage observed for a given component within the structure or building envelope (e.g., 30% damage to roof sheathing) and can be related to a damage class, which classifies the general state of the building (e.g., Vann and McDonald, 1978; FEMA, 2008). Another objective of the FCMP and other ground level wind field experimental programs (e.g., Wurman and Winslow, 1998; Schroeder and Smith, 2003) is to identify fundamental differences between hurricane and extra-tropical wind behavior. The latter has been the basis for achieving similarity between model and full-scale wind loading in wind tunnels for the last 60 years. Notable non-hurricane boundary layer meteorology research projects (e.g., Lettau and Davidson, 1957; Clark et al., 1971; Izumi, 1971; Izumi and Caughey, 1976; Taylor and Teunissen, 1987; Baas et al., 2009) have resulted in validation of Rossby similarity theory and its scaling parameters and Monin–Obukhov similarity theory, which are fundamental to the logarithmic wind velocity profile and turbulence models (e.g., Deaves, 1980; Deaves and Harris, 1982). These studies have primarily focused on stationary, horizontally homogeneous flows over homogenous, flat terrain during non-hurricane wind events, whereas the goal of the FCMP is to characterize the near surface inertial sublayer in marine and open conditions and the roughness sublayer in suburban terrain in hurricanes. It has been speculated that the convective features aloft may modulate or enhance the gustiness of the surface wind field (e.g., Krayer and Marshall, 1992; Powell et al., 1996). However, it is at present not clear if these phenomena produce larger peak wind loads than those predicted by conventional boundary layer theory and bluff-body aerodynamics (e.g., Bradbury et al., 1994). Although there is some preliminary evidence to suggest that the assumption of neutral boundary layer conditions is adequate (Vickery and Skerlj, 2005), more work remains to determine the effects of wind structure aloft, particularly in suburban areas where the building stock is concentrated.

3.2. Characterization of wind pressures on full-scale, low-rise Buildings

The primary motivation for the collection of wind pressure loads on full-scale structures is to provide a benchmark to compare wind tunnel estimates of wind loads on low-rise buildings. Several important studies have improved wind tunnel wind load simulation techniques for low-rise buildings. The Aylesbury House Experiment (Eaton and Mayne, 1975) provided validation data for wind tunnel test results using models at various scale ratios (e.g., Holmes, 1982; Sill et al., 1989, 1992). Marshall (1975, 1977) conducted two studies on a traditional residence and a mobile home. The Silsoe Structures Building experiment measured wind loads on a steel, gable-roof, portal framed structure (Richardson