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Real-time Damage Assessment in Hurricanes

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1. Introduction

The ultimate cost of a disaster is related to the amount of time taken for a community to recover; a faster, more organized recovery will help to reduce the losses associated with a tropical cyclone disaster. Mitigating a portion of the catastrophic recovery costs may be possible by effective use of meteorological monitoring information. During landfall of a tropical cyclone, real-time analyses of measurements gathered from reconnaissance aircraft, land, marine and space observation platforms can help to identify communities experiencing the most severe winds and storm surge. Real-time information on the actual areas impacted by a hurricane's eyewall and strongest winds (such as that depicted in Fig. 1) should help minimize confusion and assist search and rescue and recovery management at the earliest stages of a disaster. Real-time damage assessment modeling is now possible by using Geographic Information Systems to link meteorological field information to damage statistics from infrastructure databases. Damage assessment models based on correlations of observed damage from past storms with predictors derived from analyses of meteorological quantities can yield estimates of damage before there is opportunity to conduct visual surveys. These damage estimates can then be coupled with geographic information systems and infrastructure and demographics databases to estimate the impact of the disaster for emergency managers and decision makers.

2. Damage Estimation Modeling

In a project co-sponsored by Florida Power and Light Corporation, several meteorological products are being evaluated for use in estimating structural damage severity. Geo-referenced statistics on the damaged facilities in 16 subareas affected by Hurricane Andrew in south Florida were available for categories of uniform structures. Based on a fit of percentage damage within a given storm headquarters region (Fig. 2) to maximum sustained wind speed in

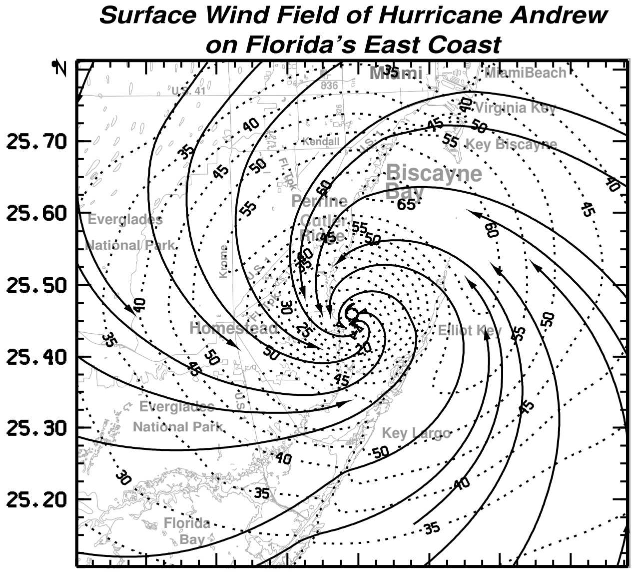

Figure 1. Analysis of maximum sustained surface wind speeds (dashed lines in m s^{-1}) and streamlines (open exposure) for Hurricane Andrew at landfall (0900 UTC).

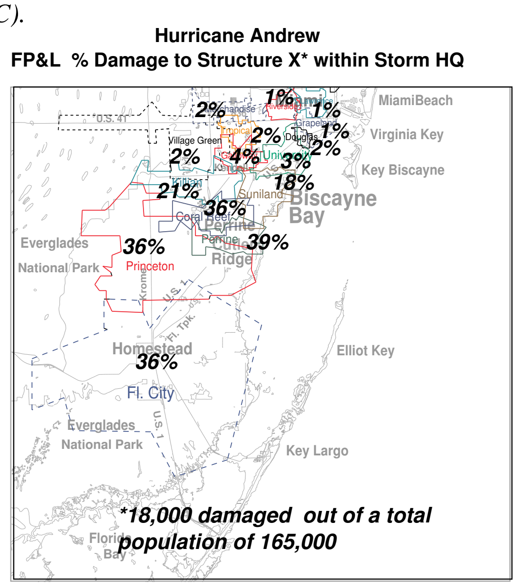

Figure 2. FPL Storm HQ areas and percentage damage to structure X.

Hurricane Andrew, prototype curve-fit models were constructed for classes of structures (Fig. 3). The hyperbolic tangent model has the desired characteristics of an exponential increase of damage followed by a leveling out at the most extreme wind speeds. The scatter in the damage values suggests that a combination of independent damage data sets and additional parameters or predictors is needed to better model the damage. Insurance loss data (Sparks and Bhinderwala, 1994) for 39 zip code areas in south Dade county (Fig. 4) were provided to test the estimation utility of additional meteorological quantities derived from the surface wind field. No data were available for the zip code area corresponding to Homestead Air Force Base.

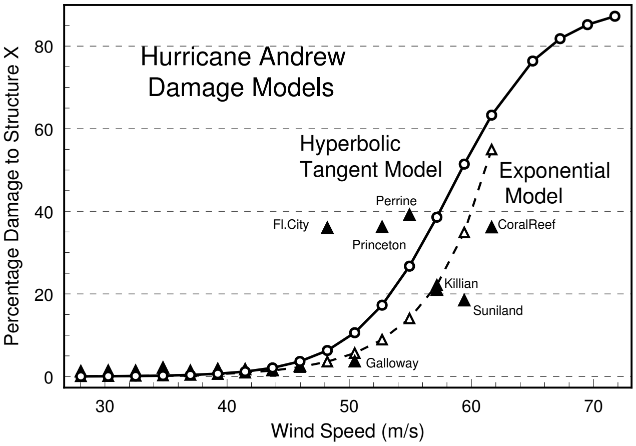

Figure 3. Prototype curve fit models for damage estimation as a function of wind speed.

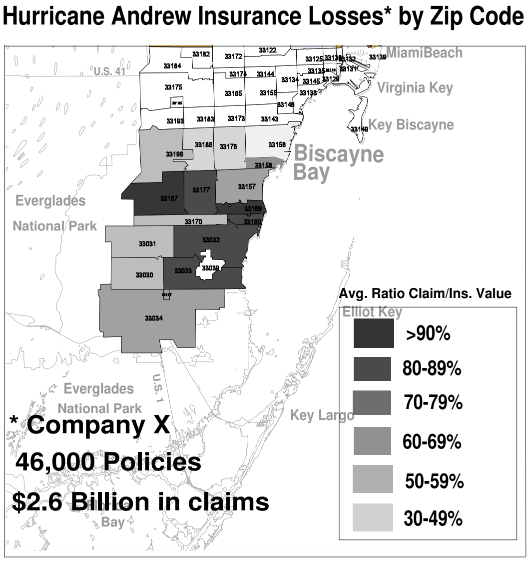

Figure 4. Dade insurance ratio of loss claim to insured value from Hurricane Andrew.

As a first stage toward screening predictors, all quantities were area averaged for the storm HQ and zip code areas. Fields examined included maximum sustained wind speed, sustained wind pressure (Fig. 5), peak gust, peak gust pressure, duration of sustained wind above 34 m s^{-1} (Fig. 6), duration of sustained wind over 50 m s^{-1}(Fig. 7), wind steadiness (Fig. 8), and peak radar reflectivity (not completed at the time of submission). Since the peak gust is within a gust factor of the sustained wind, it provides little additional information. The wind duration quantities were believed to be relevant to damage caused by repeated loading and unloading caused by cycles of gusts and lulls in a turbulent wind field. The wind steadiness is the ratio of the vector mean to the scalar mean over the time period required for the storm to traverse the region. Areas receiving large wind direction shifts due to the passage of the eye experienced low values of steadiness on the order of 10-20%. Strong winds, combined with low steadiness are critical for estimating damage to structures that are susceptible to loading from a given direction. For example, wind tunnel tests indicate that very large suction pressures build up at roof corners for certain wind orientations. The plots in Figs. 5-8 suggest very similar behavior for different types of damage. The wind pressure and duration of > 34 m s^{-1} sustained winds show exponential behavior above thresholds of 2000 Nt/m^2 and one hour, respectively. The duration of > 50 m s^{-1} winds shows considerable scatter. Much damage occurred in regions close to the western and southern eyewall where the duration was low (< 30 min). The wind steadiness plot suggests that the greatest damage occurs for values < 45%; areas receiving high damage but moderate wind speeds experienced very low values of steadiness. These are the same areas that contributed to the scatter of Fig. 3. An alternative indicator of damage may be associated with quantities derived from time series of radar reflectivity for each area. These quantities are currently being processed. The next step is to construct a new model to replace Fig. 3 using multiple regression techniques. Once the new model is constructed, we will test it on independent insurance loss data and wind and radar analyses from Hurricane Hugo of 1989.

3. Conclusions

Several meteorological quantities show promise for use as predictors in a damage assessment model. The predictor quantities are all derived from analyses that may be conducted in real time. The goal is to create a damage assessment model that can be implemented in real time during a disaster. In the case of an electrical utility, such a tool can save millions of dollars in recovery costs by reducing overestimates of replacement supplies. Even a 10 % reduction in overstock can save on the order of $1 million. Similar models are possible for other segments of the transportation, communication and utility infrastructure. These damage assessments could then be linked to demographics databases to help manage emergency response and recovery.

4. Acknowledgments

This work was supported through FP&L research grant 93MGD03. The real-time analysis work was partially supported by the Coastal Hazards element of NOAA's Coastal Ocean Program.

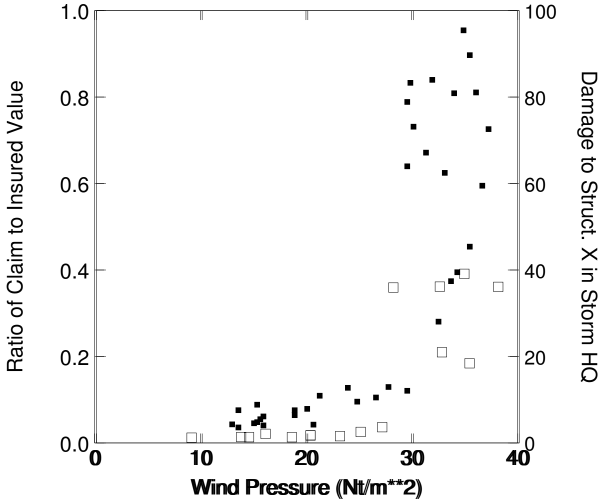

Figure 5. Damage vs. sustained wind pressure (newtons/m² /100).

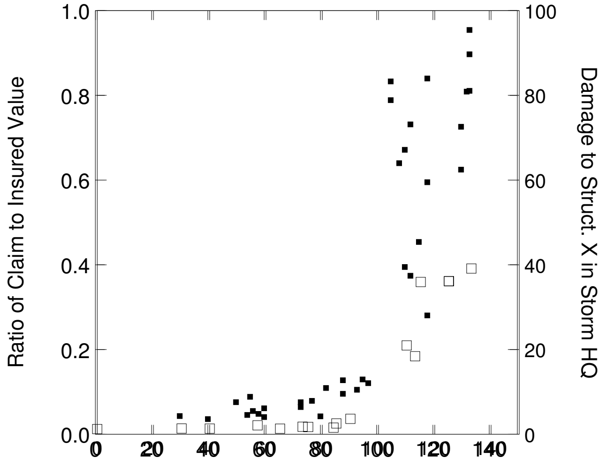

Figure 6. Damage vs. duration of sustained wind > 34 m s⁻¹ (min).

5. References

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Sparks, P.R., and S. A. Bhinderwala, 1993: Relationship between residential insurance losses and wind conditions in Hurricane Andrew. Proceedings, ASCE Conference on Hurricanes of 1992, Dec. 1-3, 1993 Miami, Fl.

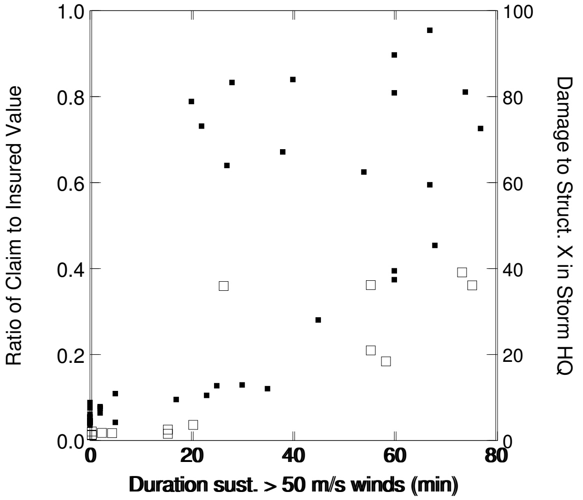

Figure 7. Damage vs. duration of sustained wind > 50 m s⁻¹ (min).

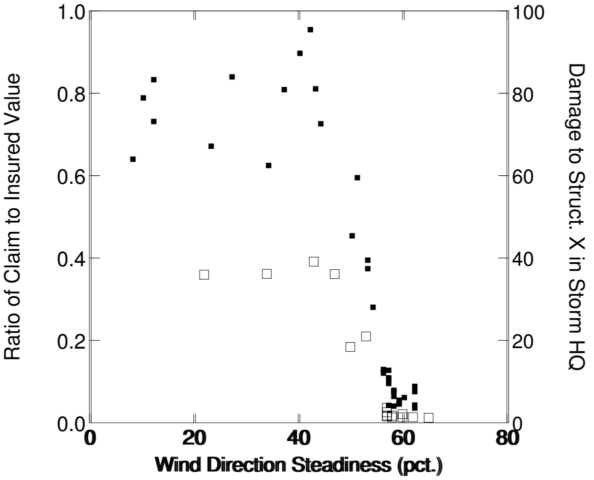

Figure 8. Damage vs. wind steadiness (%).