APPENDIX I: HURLOSS HURRICANE WIND MODEL

I.1 Hurricane Models

The hurricane models used in this study were developed by Applied Research Associates, Inc. (ARA), over about the past five years through NSF Phase I and II SBIR grants. Results from the Phase I study are documented in Vickery and Twisdale (1995a, 1995b). The hurricane models have been significantly improved during the Phase II work and are summarized in Vickery et al. (2000a, 2000b) and Vickery and Skerlj (2000a). The latter three journal articles can be referred to for details about the hurricane wind field and hurricane simulation models. A brief description of the models will be given here.

I.1.1 Wind Field Model

The hurricane wind field model employs a slab representation of a translating hurricane where the non-linear equations of motion are solved using a finite difference approach with a telescoping grid. For rapid simulation purposes, the hurricane wind fields have been solved for a full range of the key hurricane parameters found in practice and stored on disk in the form of Fourier Series. The number of Fourier terms used to describe the wind field varies with the speed of translation of the storm (i.e., fast-moving storms with large asymmetries require more terms to adequately describe the wind field).

The vertically averaged wind speed solved using the finite difference technique is related to a surface level wind speed through a ratio that depends primarily on the thermal stability of the atmosphere and on surface roughness. The theoretically based hurricane boundary model is described in Arya (1988). In the case of hurricanes over water, the model accounts for the fact that the sea surface roughness depends on wind speed (i.e., the sea is rougher for faster wind speeds) and that the atmospheric stability is governed by the air-sea temperature difference. In the case of hurricanes over land, the model employs a neutral atmosphere.

The hurricane wind field model has been validated through comparisons with more than 100 full-scale wind speed traces recorded during twelve different US land falling hurricanes (Vickery et al., 1997). Example comparisons are given in Figure I-1 for wind data recorded during Hurricanes Andrew and Georges, both of which struck the state of Florida in 1992, and 1998 respectively. The plots compare observed wind direction, ten-minute average wind speeds, and peak gust speeds with modeled values. The station locations relative to the storm tracks are shown in Figure I-2a and I-2b.

Additional information on the hurricane wind field model can be found in Vickery, et al. (2000b) and Vickery and Skerlj (2000a).

I.1.2 Simulation Model

A large-scale empirical storm simulation methodology is used. The storm central pressure difference at each time step is modeled as a function of sea surface temperature using the relative storm intensity parameter as defined by Emanuel (1988) and first used in a hurricane simulation technique by Darling (1991) for Miami, Florida. The number of storms initiated in each simulated

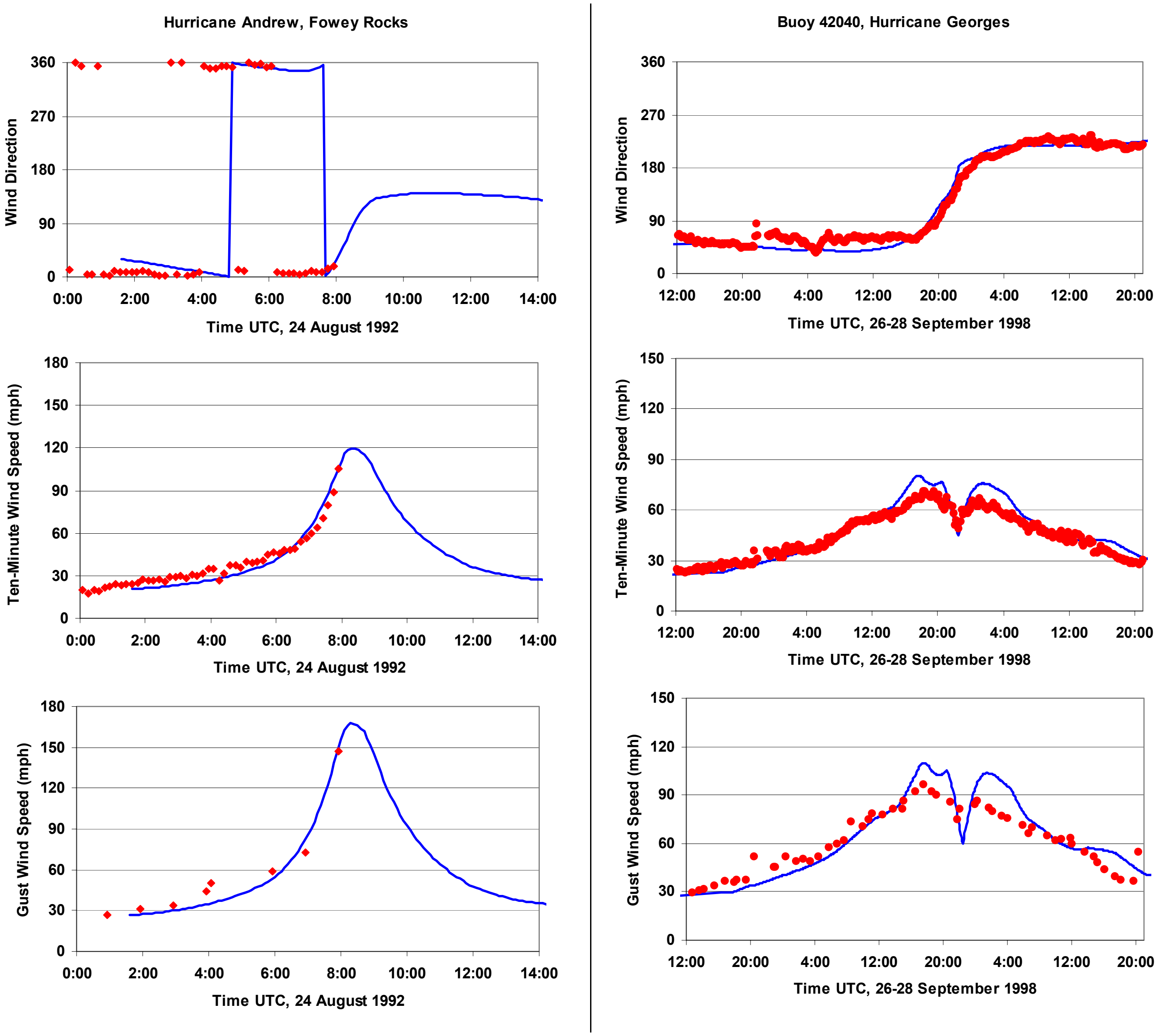

Figure I-1. Comparisons of Modeled (line) and Observed (points) Hurricane Wind Speed and Direction Traces

year is modeled using a negative binomial distribution matching the observed statistics. The start position, time and day of each storm is obtained by sampling directly from the start positions, times and days of historical storms. The track of the storm is modeled using a statistical persistence model whose parameters vary over the Atlantic Ocean as described in Vickery et al. (2000a). Using the relative intensity approach combined with the actual start dates ensures that the simulated hurricanes do not contain unrealistic values of central pressure difference.

Additional information on the hurricane simulation methodology can be found in Vickery, et al. (2000a).

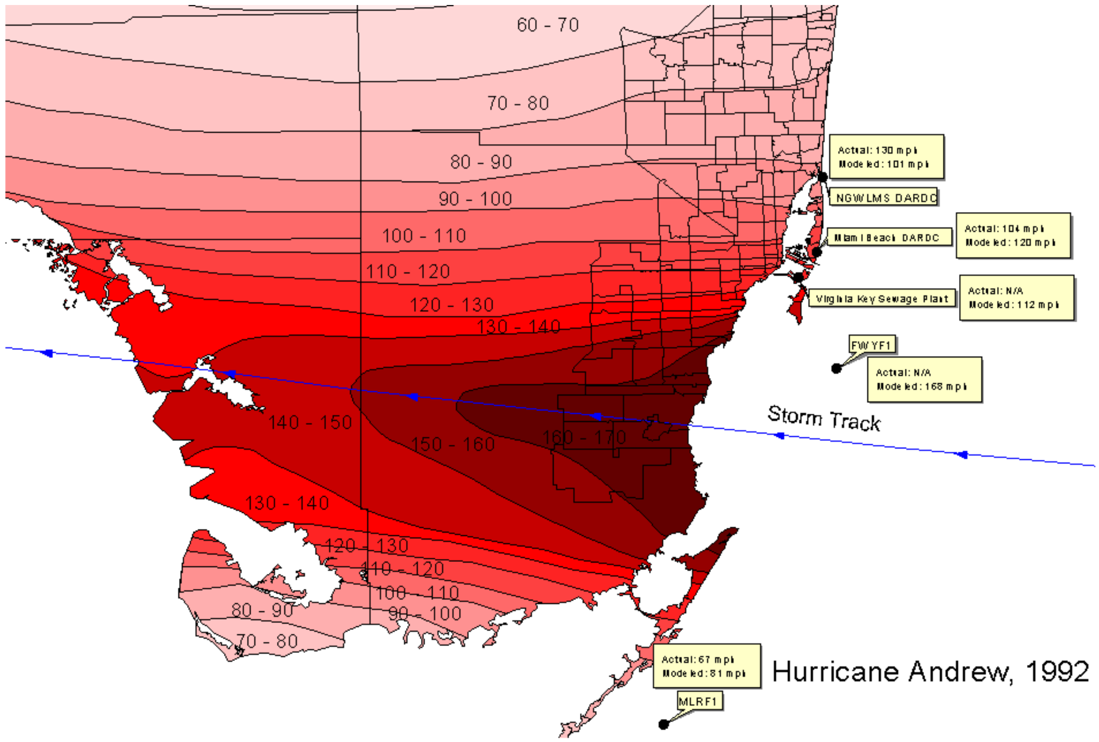

Figure I-2a. Wind Speed Swath and Anemometer Locations for Hurricane Andrew

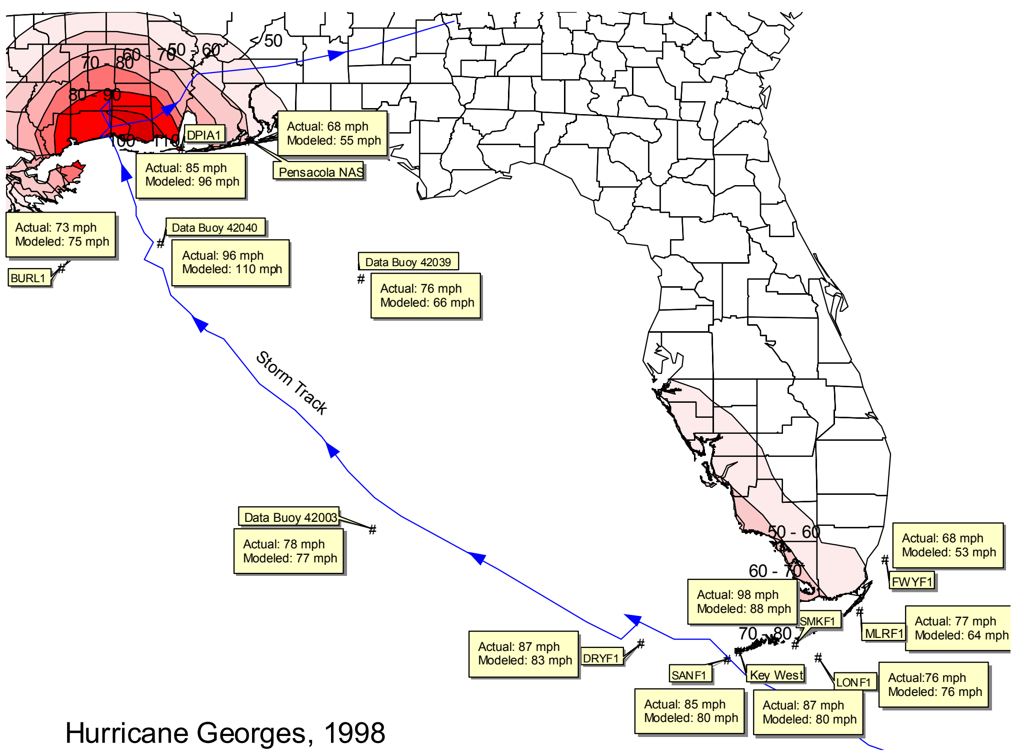

Figure I-2b. Wind Speed Swath and Anemometer Locations for Hurricane Georges

I.2 References

Arya, S.P.S. (1988), *Introduction to Micrometeorology*, Academic Press.

Darling, R.W.R. (1991), "Estimating Probabilities of Hurricane Wind Speeds Using a Large-Scale Emperical Model", Journal of Climate, Vol. 4, No. 10, pp. 1035-1046.

Georgiou, P.N., Davenport, A.G. and Vickery, B.J. (1983), "Design Wind Speeds in Regions Dominated by Tropical Cyclones", *6th International Conference on Wind Engineering*, Gold Coast, Australia, 21-25 March and Auckland, New Zealand, 6-7 April.

Vickery, P.J. and Skerlj, P.F. (2000a), "Hurricane Gust Factors Revisited", Accepted (subject to revision) for publication in *Journal of Structural Engineering*, ASCE.

Vickery, P.J. and Skerlj, P.F. (2000b), "On The Elimination of Exposure D Along The Hurricane Coastline in ASCE-7", Journal of Structural Engineering, Vol. 126, No. 4, pp. 545-549.

Vickery, P.J. and Twisdale, L.A. (1995a), "Prediction of Hurricane Wind Speeds in the United States", Journal of Structural Engineering, Vol. 121, No. 11, pp. 1691-1699.

Vickery, P.J. and Twisdale, L.A. (1995b), "Wind-Field and Filling Models for Hurricane Wind-Speed Predictions", Journal of Structural Engineering, Vol. 121, No. 11, pp. 1700-1709.

Vickery, P.J., Skerlj, P.F. and Twisdale, L.A. (2000a), "Simulation of Hurricane Risk in the United States Using an Empirical Storm Track Modeling Technique", Accepted for publication in *Journal of Structural Engineering*, ASCE.

Vickery, P.J., Skerlj, P.F., Steckley, A.C. and Twisdale, L.A. (2000b), "Hurricane Wind Field Model for Use in Hurricane Wind Speed Simulations", Accepted for publication in *Journal of Structural Engineering*, ASCE.

Vickery, P.J., Twisdale, L.A., Skerlj, P.F. and Steckley, A.C. (1997), "Hazards and Design Risks in the United States", National Science Foundation, Arlington, VA, Report, SBIR Grant ISI 9304222, July.