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Assessing hurricane effects. Part 1. Sensitivity analysis

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Abstract

The Florida Commission on Hurricane Loss Projection Methodology (FCHLPM) performs an annual review of computer models that have been submitted by vendors for use in insurance rate filling in Florida. As part of the review process and to comply with the Sunshine Law, the FCHLPM employs a Professional Team to perform onsite (confidential) audits of these models. Members of the Professional Team represent the fields of actuarial science, computer science, meteorology, statistics and wind and structural engineering. The audit includes an assessment of modeler's compliance to a set of standards and modules established by the FCHLPM. One part of these standards requires the conduct of uncertainty and sensitivity analyses to the proprietary model. At the completion of the audit, the professional team provides a written report to the FCHLPM, who ultimately judges compliance by a vendor to the standards. To influence future such analyses, the Professional Team conducted a demonstration uncertainty and sensitivity analysis for the FCHLPM using a Rankine-vortex hurricane wind field model and surrogate damage function. This is the first of a two-part article presenting the results of those analyses. Part 1 presents sensitivity analysis results for wind speed and loss cost, while Part 2 presents the corresponding uncertainty analysis results.

Keywords: Sensitivity analysis; Uncertainty analysis; Latin hypercube sampling; Damage function; Loss cost; Hurricane; Rankine-vortex; Saffir–Simpson scale

1. Introduction

The Professional Team identified distributions of sample meteorology characteristics to serve as the basis for a demonstration uncertainty and sensitivity analysis (UA/SA) [1] with a simplified Rankine-vortex wind field model for hurricanes. Fig. 1 shows a schematic representation of the demonstration input–output process used in the demonstration analysis. A multivariate sample was used as input to a Rankine-vortex wind speed computer model. Wind velocity was computed hourly for 12 h for each of the 100 sets of four input characteristics. The calculated wind speeds were used as input to a surrogate damage function model and the damage was subsequently converted to loss cost. Saltelli et al. [3] state that sensitivity analysis studies the relationships between information flowing in and out of the model. Iman et al. [2] define sensitivity analysis as the determination of the change in response of a model to changes in model inputs and specifications. The goal of the sensitivity analysis in this paper is to determine the extent to which the input variables (the *X*s) influence wind velocity at time *t* and lost cost accumulated over time (governed at each exposure by the maximum wind velocity). Iman et al. [2] define uncertainty analysis as the determination of the variation or imprecision in model output resulting from the collective variation in the model inputs. The goal of the uncertainty analysis in this paper is to determine the relative contributions of the input variables to the overall uncertainty in the wind velocity and lost cost.

Results presented in this paper are intended to demonstrate the application of statistical sampling methods in the areas of meteorology and loss cost estimation by providing a concrete example using Latin hypercube sampling (LHS) methods. LHS was developed in 1975 by Conover [4] while consulting with Los Alamos National Laboratory. At the time of its development, LHS was applied to some computer modeling applications at Sandia National Laboratories [5]. The first published article on LHS appeared in 1979 [6]. A summary article on LHS was given in 1999 by Iman [7].

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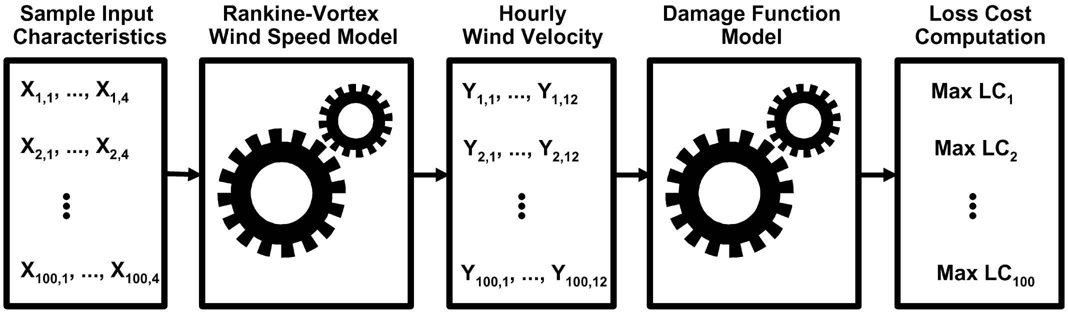

Fig. 1. Schematic representation of the input–output process for the UA/SA process.

LHS has enjoyed widespread application to uncertainty and sensitivity analysis since its development. Helton and Davis [8] provide a review of sampling-based methods for performing uncertainty and sensitivity uncertainty analysis. Helton and Davis [9] also give an extensive listing of 325 references to sensitivity and uncertainty analysis in an overview article of LHS and propagation of uncertainty in complex systems.

The approach advocated in this paper has been described as global sensitivity analysis [10], which implicitly includes the uncertainty analysis component provided in Part 2 of this paper. Global analysis is particularly appropriate in this context as the FCHLPM is interested in the most sensitive aspects of hurricane modeling and is particularly interested in the relative contributions to the overall variation. Local analysis methods [11] are relevant for internal model assessments to verify logical relations to risk. Non-parametric methods could also be considered [12,13] for future investigations in the hurricane risk context. Other applications of global sensitivity analysis techniques can be seen by Helton [14], Hamby [15] and Blower and Dowlatabadi [16]. Saltelli et al. [17] provide an investigation of new techniques.

A demonstration model is utilized to illustrate constructing the input variables (determining the settings at which computer runs are to be made) and to illustrate the graphical and numerical summary products possible for assessing the input–output variable relationships (both sensitivity and uncertainty). This demonstration utilizes a Rankine-vortex wind field model with linear temporal decay, a cubic damage function and a simple 1% deductible with 50% damage equating to 100% insured loss. Aspects of this simple model do not compete nor are they intended to compete with sophisticated modules in commercial modules. However, the process of performing the sensitivity and uncertainty analysis extends to such proprietary models. Of particular concern could be the cubic damage function, which has zero damage at 50 mph, complete damage at 140 mph and a cubic function in between (Eq. (11)). This damage function is provided to convert the UA/SA from the wind speed to loss cost arena. The intent is not to focus on the damage or insurance 'module' per se, but rather to consider the demonstration study as it relates to general sensitivity and uncertainty analyses. The demonstration study can serve to guide the application of UA/SA in proprietary vendor contexts.

The simulation of the hurricane (Sections 2–6) in this demonstration study involves a specification of the tracking grid (coordinates where data are to be generated), probability distributions of meteorological characteristics including their correlation, the wind field itself (Rankine-vortex) and the attendant generation of wind speeds at the grid points. Sensitivity analysis is conducted (Sections 7 and 8) using both partial correlation coefficients and standardized regression coefficients (SRC), each described in turn. Wind speed sensitivities are displayed in Section 9 and lost cost output is assessed in Section 10.

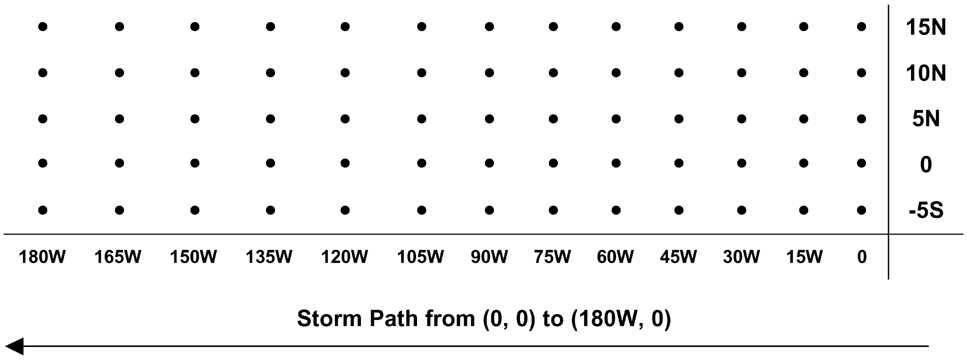

Fig. 2. Tracking grid along $(X, 0)$ for calculating hourly wind velocities.