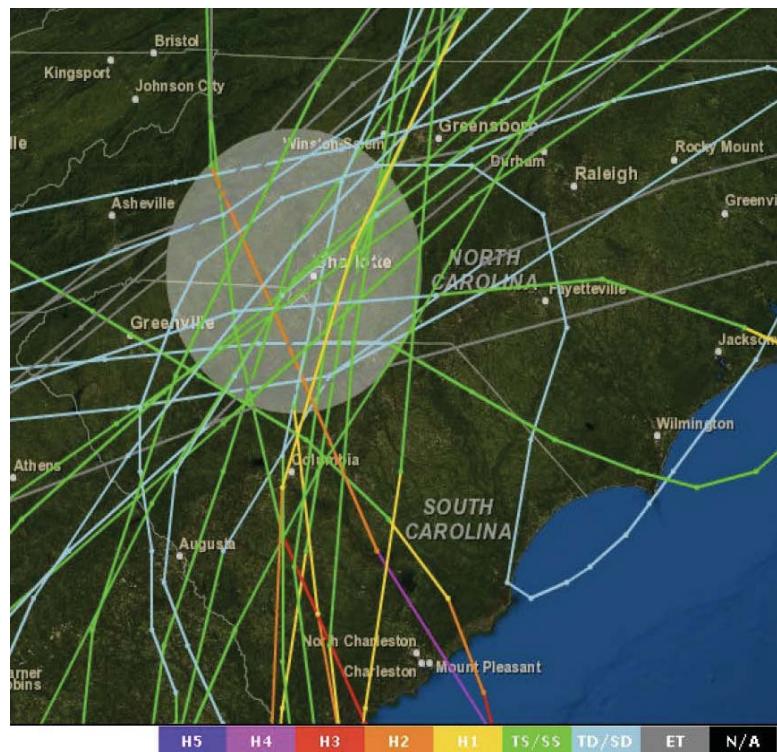


Evaluation of Hurricane Catastrophe Models Used in South Carolina



Prepared exclusively for:
**South Carolina Department of Insurance
Division of Actuarial and Market Services
Columbia, South Carolina**

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Proprietary Information and Trade Secret Material

This report is presented to the South Carolina Department of Insurance (SCDOI) in accordance with the Department's RFP for review of computer simulation models that are designed to produce hurricane insurance loss costs for insuring properties in South Carolina (SC).

Hurricane Catastrophe Modeling Companies (modelers) invest substantial resources in the development of their hurricane catastrophe models, modeling methodologies and databases. This document contains proprietary and confidential information and trade secret material and is intended for the exclusive use of SCDOI.

A panel of experts formed by SCDOI has prepared this report using information provided by these modeling companies:

- AIR Worldwide Corporation (AIR)
- Applied Research Associates (ARA)
- EQECAT
- Risk Management Solution (RMS).

The South Carolina Department of Insurance (SCDOI) also asked the South Carolina Wind and Hail Underwriting Association (SCWHUA) to complete modified versions of Forms SC-2 and SC-3. The modified forms were designed to provide loss costs and corresponding premiums for South Carolina to assist in developing a set of guidelines and recommendations to SCDOI for reviewing hurricane rate filings.

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Executive Summary

This report is presented to the South Carolina Department of Insurance (SCDOI) in accordance with the Department's Request for Proposal (RFP) for review of computer simulation models that are designed to produce hurricane insurance loss costs for insuring properties in South Carolina (SC).

A panel of three experts with extensive experience reviewing hurricane loss models reviewed the models submitted to the SCDOI. Each expert is a member of the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM, or Florida Commission), and has participated in at least ten years of hurricane model reviews for the State of Florida.

Former South Carolina Insurance Department Chief Actuary Martin M. Simons MAAA, ACAS, FCA provides property and casualty insurance actuarial consulting services throughout the United States and Canada. Dr. Jenni L. Evans, Professor of Meteorology at The Pennsylvania State University, and Dr. Masoud Zadeh, Owner of Risk and Reliability Engineering, both have extensive experience in reviewing hurricane models.

As the experience with Hurricane Hugo demonstrated, past insurance claims data is inadequate to produce insurance rates to cover catastrophes such as hurricanes. The insurance industry uses the results from computer models to produce the hurricane insurance loss costs (and thereby hurricane insurance rates) that are incorporated in their rate filings. The models are designed to produce many years of modeled hurricanes, based on the information available from the National Hurricane Center and the science we know about hurricanes

Once the hurricanes are produced, the models analyze the effects of the hurricane winds and other hazards on properties of varying types of construction. These effects are expressed in terms of monetary losses at each property, which include losses to damage to buildings, appurtenant structures and contents and losses due to additional living expenses (time element coverage) due to these hazards and damage to infrastructure

Finally, the loss estimates produced by the model must be adjusted to account for insurance contracts such as policy limits, deductibles, and coverage types and any local legal requirements to arrive at insurance loss estimates.

Due to the complexity of hurricane models, along with the their impact in the production of hurricanes insurance rates, the legislature of the State of Florida created the FCHLPM, an independent Commission charged with determining that



the hurricane models produce “accurate” and “reliable” loss costs from which the state’s hurricane insurance rates can be produced. To optimize the effectiveness of this review, information that is similar whether the model is run in Florida or in South Carolina is based on the work of the FCHLPM. In addition to consideration of this shared information, this report is built on information that is specifically relative to South Carolina.

Each model used in South Carolina for rate filings should simulate the hurricane risk most appropriate to South Carolina. To evaluate the models based on this requirement, the panel of experts produced a series of evaluation questions designed to examine whether the best scientific meteorological, structural engineering and actuarial knowledge and information available are implemented in the models appropriately for South Carolina (Appendix B). Along with the initial evaluation questions three Forms were developed to be completed by each modeler. These Forms are designed to address how each hurricane model address hurricane hazard, vulnerability of properties to hurricane hazards, and insurance contractual requirements specific to South Carolina. These evaluation questions and Forms were sent to all the participating modeling organizations (modelers) which develop, maintain, and update that have an interest in developing, maintaining, and updating hurricane models for use in South Carolina: AIR Worldwide (AIR), Applied Research Associates (ARA), EQECAT, and Risk Management Solutions (RMS).

Upon receipt and review of the responses to the initial evaluation questions from each modeler, the panel of experts produced a series of follow up questions specific to each modeler based on analysis of the modeler responses. The follow-up questions and responses to them are also contained in this report. Attachments 1, 2, 3, and 4 contain (1) the responses to initial questions, (2) the follow up questions and the modeler responses to the follow up questions, and (3) the initial draft evaluation of model, (4) the responses to the initial draft of this report and (5) the complete final evaluation by panel of experts for each model from AIR, ARA, EQECAT and RMS, respectively. A review by the panel of experts of information provided to the SCDOI by SCWHUA is included in Attachment 5.

The main body of this report and its Appendices A and B are designed to become public at the discretion of SCDOI. However, the modeler responses and the evaluations by the panel of experts (i.e., Attachments 1 through 5) contain proprietary information. ***Therefore, it is important to note that the Attachments to this document contain proprietary and confidential information and trade secret material and are intended for the exclusive use of SCDOI.***

The reviews of the panel of experts summarized here have determined that some revisions may be required in the way certain of the hurricane models produce loss costs for South Carolina so that they are in accordance with the statutory



requirements that rates not be excessive, inadequate or unfairly discriminatory.

Perhaps more important, this report provides a tool for future regulation of property insurance policies that include hurricane coverage.

In accordance with Standards established by the FCHLPM, each model must produce an “output report.” The output report provides a wealth of information regarding assumptions adjustments and inputs that have been used to produce the model output. Consistent with the Florida Commission, we suggest that to be deemed acceptable, a model must provide an output report containing detailed information on the conditions used to develop the modeled loss costs. This output report should be provided to the regulator and should contain sufficient detail for the regulator to determine whether the modeler or the filing insurer has made any adjustments or assumptions outside of the workings of the model. The output report is a vehicle of record for the modeler, their clients and the regulator; it contains all relevant data needed to document the assumptions and adjustments underlying the modeled loss costs presented in a rate filing, and also provides information in several areas where the regulator might be concerned in the future.



1. Introduction

1.1 Background

This report is presented to the South Carolina Department of Insurance (SCDOI) in accordance with the Department's RFP for review of computer simulation models that are designed to produce hurricane insurance loss costs for insuring properties in South Carolina.

There is a great deal of information that may be gleaned from the responses of the modelers, both to the initial questions and more importantly to the follow up questions. We have highlighted aspects of each modeler's responses in the following sections and followed those with a summary section. In this section, we describe the approach used and provide guidance on how to use this document.

1.2 Project Team

The authors of this report are each members of the Professional Team of the Florida Commission on Hurricane Loss Projection Methodology (hereafter referred to as FCHLPM, or simply Florida Commission, and to be described later in this report) and are well versed in the sciences and skills required for such a review. A short bio for each of the members of the panel of experts is given below. The more expanded curricula vitae for the members are given in Appendix A.

Martin M. Simons MAAA, ACAS, FCA provides property and casualty insurance actuarial consulting services to regulators, legislators, state agencies, and consumers throughout the United States and Canada. He is currently a member of the General Committee of the Actuarial Standards Board as well as the Extreme Events Committee of the American Academy of Actuaries. Since 1997, he has been the lead actuary on the Professional Team of the Florida Commission on Hurricane Loss Projection Methodology. He was the senior member of the Advisory Committee to the Hawaii Hurricane Relief Fund from its creation, to involvement in approving the industry filing to take back the hurricane risk. From 1985 to 1997, he was the Deputy Director and Chief Actuary for the South Carolina Department of Insurance.

Jenni L. Evans Ph.D. (Applied Mathematics) is a Professor of Meteorology and Interim Director of the Earth and Environmental Systems Institute at The Pennsylvania State University. She is a Fellow of the American Meteorological Society and, among many other roles, has previously served as a councilor for that



Society. Having joined the team in 2003, she has been the lead meteorologist on the Professional Team of the Florida Commission on Hurricane Loss Projection Methodology since 2004. She has also served as advisor to hurricane model evaluation inquiries for the states of Massachusetts and Maryland. She has over forty peer-reviewed journal articles on various aspects of tropical cyclones and has presented over 100 invited talks and conference papers on her research. She is presently the Chair of the World Meteorological Society (WMO, a branch of the United Nations) International Workshop on Tropical Cyclones, a quadrennial workshop designed to bring together researchers and forecasters from all across the globe.

Masoud M. Zadeh, Ph.D., provides engineering risk consulting services in the areas of natural and manmade hazard risk assessment and management to insurance and reinsurance industry, insurance regulators, nuclear industry, commercial and local, state, and Federal government sectors. He has developed, applied, reviewed and/or audited catastrophe risk models for natural hazards, such as hurricanes, tornadoes, high winds, and earthquakes. From 1997, he has been on the HAZUS Wind Committee overseeing the development of HAZUS-MH hurricane module for Federal Emergency Management Agency (FEMA). Since 2005, he has been the lead structural engineer on the Professional Team of the Florida Commission on Hurricane Loss Projection Methodology (FCHLPM). Before then, he led a team of engineers, scientists, and actuaries to submit a commercial hurricane catastrophe risk model to FCHLPM and to successfully obtain the model acceptance by FCHLPM three years in a row. He is an independent consulting engineer. Dr. Zadeh is a licensed Professional Engineer.

1.3 Project Approach

Hurricane catastrophe models are almost universally used by primary insurers and reinsurers, rating agencies and regulators, for ratemaking, risk analysis, catastrophic exposure and capacity management, reinsurance and catastrophe bond pricing, financial strength analyses, hazard mitigation analyses and other applications relating to the effects of hurricanes on properties.

It is virtually unanimously agreed by members of the actuarial profession that historical insurance claim data alone is an inadequate tool for estimating future property insurance loss costs from hurricanes, and that reliance solely on such traditional methods to estimate expected hurricane loss costs based on historical losses is actuarially unsound.

As the community experience with Hurricanes Hugo, Iniki, and Andrew demonstrated, such information is inadequate to deal with the stochastic aspects of



catastrophes such as hurricanes. Because of the low frequency and high severity of hurricane claims, an extremely long period of time (many thousands of years) would be necessary for insurance claim data to be credible for producing hurricane loss costs. The actuarial credibility of the insurance claim data for producing hurricane loss costs is close to zero. That is, one can place no confidence in hurricane insurance loss costs derived from insurance company claims data alone. *The Insurance Department should refrain from accepting historical claim data for hurricanes as a basis for indicating rates that are not excessive, inadequate or unfairly discriminatory.*

In order to provide a regulatory review of filings that use stochastic models to derive hurricane loss costs at a level that is cost effective for South Carolina, the regulator may use the reviews performed by the FCHLPM as a basis for the South Carolina review. The Florida Legislature established the Florida Commission in 1995 to review the way hurricane insurance loss costs are produced for Florida properties. The mission of the Florida Commission is defined as (Page 11 of Report of Activities, Ref.1):

“The mission of the Florida Commission on Hurricane Loss Projection Methodology is to assess the efficacy of various methodologies which have the potential for improving the accuracy of projecting insured Florida losses resulting from hurricanes and to adopt findings regarding the accuracy and reliability of these methodologies for use in residential rate filings.”

The basis of the work of the Florida Commission are the terms “accurate” and “reliable” which are defined in said reference (Page 39 of Report of Activities, Ref. 1):

“In the context of computer simulation modeling, “accurate” means that the models meet the standards that have been developed to assure scientifically acceptable loss cost projections and probable maximum loss levels. However, “accurate” cannot necessarily mean that a model conform to known facts since that contradicts the nature of the modeling process. “Reliable” is defined for computer simulation models as meaning that the model will consistently produce statistically similar results upon repeated use without inherent or known bias.”

Loss costs represent the portion of the insurance rate that is applicable to claim payments, but not insurer expenses, reinsurance costs or profits. There are many aspects of hurricane modeling that are similar relative to producing Florida loss costs or South Carolina loss costs, so we were able to use the model reviewing background instituted by the Florida Commission to perform an analysis of hurricane insurance loss costs produced by catastrophe models for South Carolina at a very low cost.



In order to obtain the information needed to analyze whether a model produces results that are accurate and reliable for loss cost estimates in South Carolina, we went directly to each modeler. The modeler made available a comprehensive body of information, including information that they did not wish to be made available to the general public or their competitors. For this reason, the panel of experts agreed to keep the information marked “confidential” out of the public realm. By design, Attachments 1 through 5 contain all of the proprietary information. Finally, all Forms SC-1, SC-2, and SC-3 completed by the modelers and made available to the panel of experts in separate files are also proprietary. ***We sincerely advise that the confidentiality of all of these attachments and forms be ensured.***

A four-phase approach was taken to complete the review of hurricane models used in South Carolina:

- I. Development of generic initial questions and requests for information sent to all modelers;
- II. Review of each modeler's responses, formation of modeler-specific follow-up questions and submission to each modeler;
- III. Review of the responses to the modeler-specific follow-up questions and preparation of Draft report and submission to SCDOI; and
- IV. Review of responses of the modelers to the Draft report and development and issuance of the Final report.

The above four phases are described below.

Phase I – Initial Questions

In this phase, based on the advice of the panel of experts, the South Carolina Department of Insurance requested a suite of information from the modelers. Included were inquiries and exhibits relating to the meteorological, structural engineering, and actuarial aspects of the model. The focus of all inquiries was to determine how each model operates in developing loss costs appropriate to South Carolina. The inquiries and forms requested are provided in Appendix B of this report.



Phase II – Follow-up Questions

The panel of experts reviewed the responses to the initial inquiries by each of the modelers. A set of “follow up” questions was developed for each modeler based on reviews of the initial submissions by the panel of experts. The focus of all of these inquiries was to determine how each model operates in developing loss costs appropriate to South Carolina. At the request of the panel of experts, the “follow up” questions were submitted to the modelers by the South Carolina Department of Insurance. Since they were developed specific to each modeler’s submission, some of the information in the “follow up” questions is confidential.

The follow up questions and confidential responses to them from the modelers are provided in Attachments 1 through 4 of this report for AIR, ARA, EQECAT, and RMS, respectively. One of the modelers requested a one-month extension, which caused a significant delay in the completion of this report.

Phase III – Draft Report

Upon receipt of the second set of modeler responses, the panel of experts produced a draft report for the Department of Insurance. The panel of experts provided its findings and recommendations relative to regulating hurricane rates, and therefore the models used to create those rates in South Carolina (Section 6). The information throughout the Draft report was meant to provide a transparent view of the process to those who are responsible for regulating hurricane insurance loss costs. Proprietary information was present throughout the report.

Phase IV – Final Report

In this phase, at the request of the modelers and the public and in consultation with the panel of experts, SCDOI created a summary of the draft report, which did not contain proprietary information, and made it available to the public. Similarly, SCDOI created a set of modeler-specific reports and made these available to the corresponding modeler organizations. Each modeler-specific report contained proprietary information) of that modeler organization.

The modeling organizations each reviewed their modeler-specific report and provided further responses to their reports. In addition, some of the modeling organizations requested to have conference calls with SCDOI personnel and the panel of experts.

This final report was developed by incorporating and/or resolving the complete series of modelers written responses as well as comments during the conference calls.



1.4 Project Limitations

In estimating the future effects of hurricanes in South Carolina, reasonable procedures and standard actuarial, meteorological, and engineering techniques and methodologies have been applied in reviewing those models that produce hurricane insurance loss costs in South Carolina.

This was a very limited review of the hurricane models. It did not include either on-site reviews or interviews with modeler personnel. The review did not include completion of many Forms that generally are required for models submitted to Florida Commission for review. Moreover, the statistical and software development aspects of the models were not extensively reviewed. The implied assumption here is that these aspects of the models should not change from state to state and that these aspects have been reviewed extensively in Florida. Certain databases of the models that are state-dependent were not reviewed in this limited scope evaluation of hurricane models. These databases include, but are not limited to; ZIP Codes used in South Carolina, population weighted centroids of ZIP Codes, surface roughness and associated roughness factors, building stock distribution in South Carolina, and elevation databases for modeling topography effects, if used in a model.

The review also was limited in planned scope and resources allocated for the review. The panel of experts, however, easily went beyond the scope and resources allocated to complete its review and this report. This report, however, shall be reviewed and used, given the above limitations.

Projected hurricane effects are, by their very nature, subject to limitations of estimation as hurricane insurance costs are affected by projections of events and conditions that have not yet occurred. While it is widely agreed that catastrophe models provide the best estimates of potential hurricane costs, because of the limitation of the data available and the uncertainty of the statistical elements associated with the model components, there is no guarantee that loss costs produced by catastrophe models will prove to be adequate or not excessive.

1.5 Report Structure

Following this Introduction (Section 1), redacted evaluations of the individual hurricane models for South Carolina for AIR Worldwide Corporation (AIR; Section 2), Applied Research Associates (ARA; Section 3), EQECAT (Section 4), and Risk Management Solution (RMS; Section 5) are provided. Resumes of the panel of experts are given in Appendix A. The first set of evaluation questions and request for information sent to all modelers are given in Appendix B. The responses to all inquiries from the SCDOI and the model reviews for AIR, ARA,



EQECAT, and RMS are included in Attachments 1 through 4, respectively.

Attachment 5 includes the SCWHUA responses and the panel of experts review for the use of the hurricane insurance loss costs produced by the models in rate setting for South Carolina.

1.6 Using this Report

Each model reviewed here must satisfy a fundamental set of criteria for each of the three component modules: meteorology, vulnerability and actuarial. These criteria are captured in the review process implemented by the Florida Commission for use in Florida, and adapted in this review for South Carolina. Important considerations that must be satisfied for each model are summarized here to guide the reader as they review the remainder of this report.

Important Considerations in the Evaluation of the Meteorology Module

The Meteorology module of the model develops a picture of hurricane-related hazard based upon historical hurricane data. The historical hurricane data accepted by the Florida Commission for determining historical storm data for Florida is the HURDAT2 database (Refs. 2 and 3), which is created and maintained by the National Hurricane Center (NHC) of the National Weather Service (NWS). Any differences between the features of the historical hurricanes (intensity, track, frequency/return period, size) that are recorded in HURDAT and the features of the historical storms as used by the modeler must be justified. This is a very important step in determining whether a specific modeler's predictions relating to hurricane frequencies are appropriate.

To ensure that the Meteorology module is based on realistic hurricanes, the modelers produced maps of the historical hurricanes they used and then four maps of hurricanes calculated in their model. These maps should not look the same, but certain features of the maps should be similar: the hurricane tracks should have the same kinds of patterns and the distribution of hurricanes impacting South Carolina should be similar. For example, if most storms were moving due west from Bermuda, the model would not be considered realistic. The four samples of modeled storms can have very different numbers of storms, but they should not *all* have many more, or many fewer, hurricanes than observed in the historical record.

The Meteorology module produces a *spatial* distribution of hurricane wind risk that includes information on the intensity of the hurricane (maximum winds), its size (area of damaging winds) and its track (which gives the speed and direction of storm motion). A faster moving hurricane will have very different windspeeds to the right (faster) compared to the left (slower) if you are looking towards the direction it is moving; this asymmetry will be proportionately less in a slower moving hurricane. Topography can cause the winds to vary locally (for example,



to speed up through valleys), however this will only be important if the hurricane still has damaging winds when it travels over hilly areas.

The damaging winds calculated in the Meteorology module also reflect a *geographic* distribution of hurricane wind risk that incorporates information relative to the distance of the insured property from hurricane track and the current land use and land cover. Since many hurricanes affecting South Carolina cross the coast (make “landfall”) in other states, the treatment of hurricane weakening over land is important.

From the time a storm crosses the coast, the hurricane winds generally decrease as that storm moves further inland. This weakening of the hurricane will be modified by the properties of the land itself (referred to as “land use and land cover”). For example, the winds for a hurricane moving over a lake will remain faster than the winds for a hurricane moving over a forest or densely populated area, however, a rough surface can make winds gustier. The net effect is likely to be slower winds in general, but with the occasional very strong gust, as was experienced at relatively distant inland locations with Hurricane Hugo in 1989.

Another impact on the winds is topography: winds can be stronger than expected along narrow valleys or over hilltops, and weaker than expected in sheltered locations. The impacts of topography would be experienced in the far west of the state where storms are typically weaker and near the damaging wind threshold, so any effects should be small. Thus, this effect is of only secondary importance in evaluating the models for use in South Carolina.

An acceptable Meteorology module must capture all of these aspects in the simulation of each of the stochastic storms (those hurricanes created by the model).

Important Considerations in the Evaluation of the Vulnerability Module

The vulnerability module of a hurricane catastrophe model should address the vulnerability of insured properties to various hurricane hazards. Because of differing building standards and construction types, the vulnerability module is one of the areas of a hurricane model that can vary from state to state or even among regions within a given state. The vulnerability module typically addresses the following aspects of hurricane risk:

- Separation of property vulnerabilities and losses into vulnerability of buildings, appurtenant structures, and contents and additional living expenses (ALE) or time element (TE) loss. These categories of property vulnerability and losses are generally consistent across states.
- The construction practices in any given locality or state.
- Applicable building codes and enforcement.



- Building classification. A set of primary characteristics of a building that influences its vulnerability to hurricane hazards is used to classify building stock into various classes. Buildings in each class generally perform similarly in a given hurricane environment. For any state, such classification must be able to appropriately model the majority of building stock in that state. This aspect of the vulnerability module generally remains the same across southeast states.
- Secondary characteristics within a general building class that might influence the performance of buildings in that class.
- Mitigation features are those aspects of building that are added to a building at the initial time of construction or after the construction of the building to reduce potential losses from hurricanes.

The vulnerability module of each hurricane model is reviewed to determine if South Carolina specific issues are appropriately addressed. The most important aspects for review and evaluation of vulnerability modules are building code variations and their adaptation and enforcement in South Carolina, variation of building vulnerability across the state, and variation of building design wind speeds.

Important Considerations in the Evaluation of the Actuarial Module

The vulnerability section described above determines the damages to buildings in South Carolina from hurricanes. Those damage calculations must be converted into actuarial, insurance or financial results, inclusive of the effects of deductibles and policy limits.

The actuarial functions must be appropriately accounted for in accordance with the Actuarial Standards of Practice, and the results of the Actuarial Module are the hurricane insurance loss costs (i.e., the claims portion of the hurricane rate or premium) for various areas of the State. To be in accordance with the statutory requirements that rates “shall not be excessive, inadequate or unfairly discriminatory”, the differences in the hurricane insurance loss costs in the state should be based upon the exposure to hurricane losses and the damage to properties as determined in the meteorology and vulnerability modules.

Once again, the hurricane insurance loss costs produced by these hurricane models include only the claims portion of the hurricane insurance rate or premium. As with all loss costs, expenses, including loss adjustment expenses must be added to these loss costs as well as a determination of the appropriate profit and contingency factor to produce final hurricane insurance rates in accordance with the statutes.



2. Summary Review of the AIR Model (with redactions)

Subsequent to the issuance of the draft report of the panel of experts to the Department of Insurance, AIR provided a second set of responses, dated August 2013 and including new Forms SC-2 and SC-3. The summary report provided here and the complete series of reviews of the expert panel (included in Attachment 1) are based upon the entire volume of information provided by AIR over the course of this process.

2.1 General

Per the panel of experts' review and responses from AIR, it is recommended that the AIR Atlantic Tropical Cyclone Models v12.0.1 and v14.0.1 (subsequent to start of this evaluation accepted by FCHLPM) may be used for application to South Carolina rate filings. It should be noted that – consistent with all models currently accepted by the FCHLPM – these versions use a long-term prediction of hurricane risk. Thus, any implementation of the model that specifies warm water, medium-term and/or short-term variation of this model has not been accepted by FCHLPM and is not recommended to be used in South Carolina rate filings. It should be noted that, the acceptability by the FCHLPM of version v12.0.1 of the AIR model has expired on August 18, 2013. Rate filings in South Carolina with a filing dates prior to August 8, 2010 but after May 19, 2009, are acceptable, if the rates are based on AIR Atlantic Tropical Cyclone Model V11.0.0.

In response to the original AIR response, the panel of experts posed this follow-up question:

This follow-up question and its response have been redacted at the request of the modeler.

This comment by panel of experts is redacted at the request of the modeler. Note that AIR Tropical Cyclone Model, Version v14.0.1 had not been accepted by the FCHLPM as of the date of the initial response. *These comments by panel of experts are redacted at the request of the modeler.*

These comments by panel of experts are redacted at the request of the modeler.



2.2 Meteorology Module

The Meteorology module of the model develops a geographically varying picture of hurricane-related risk based upon the historical hurricane records for the region (not only for South Carolina).

Use of historical storms

AIR states that they incorporate information from *NOAA Technical Memorandum NWS NHC-6*. This report is issued by the National Hurricane Center, so use of this report to justify modifications to the historical storms by AIR is reasonable.

Landfalling hurricanes

The AIR model provides a reasonable representation of the distribution of hurricane intensities at landfall (by Saffir Simpson category) (their Table 3, page 14) for hurricanes *affecting* South Carolina. The Saffir Simpson scale (<http://www.nhc.noaa.gov/aboutsshws.php>; this is the NOAA National Hurricane Center website) was designed to provide guidance on the expected property damage resulting from the passage of a storm of given intensity. As such, it is a useful tool for exploring the results provided from a hurricane model.

AIR states “It should be noted that the SS categorization reported by the AIR model refers to storms over open waters. The model reports the SS category only at the point a hurricane passes from open ocean water to land (i.e. landfall).” A substantial fraction of hurricanes causing damage in South Carolina approach the state from over land. This lack of information about the intensity of hurricanes approaching over land is a limitation of our ability to validate the model hurricane intensity distributions against the historical record.

The consequence of AIR’s inability to report Saffir Simpson scale for storms over land is that they could not provide the categories of hurricanes that make landfall in the Gulf of Mexico, but subsequently cause damage in South Carolina. In their second report to the SCDOI, AIR noted that they “will work with our software product development teams to obtain windspeeds over land so that Table 3 and Figure 2 can be completed with more meaningful data” (page 12).

Lacking this information from AIR, the panel of experts applied two other tests to evaluate whether the AIR stochastic hurricane climatology is reasonable: South Carolina simulated hurricane landfalls and the overall pattern of hurricane activity in the region of South Carolina.



The number of AIR modeled hurricanes making landfall in South Carolina tends to have more storms in higher intensity categories than in the historical record (Table 4). However, the distribution is reasonable, with 64% of modeled storms making landfall as Cat 1 or Cat 2 (sustained winds less than 110 mph), compared to 72% of historical storms.

The second method for evaluating the AIR hurricane module is to compare the historical hurricane tracks affecting South Carolina (Figure 1) with tracks produced by the AIR model. Since the model is designed to simulate thousands of years of storms, the modeler was asked to produce four samples of the tracks of hurricanes affecting South Carolina (Figures 5 through 8). The modeled tracks are reasonable; the main difference is that the modeled storms are tracked for longer over land.

Finally, we consider the characteristics of the most intense modeled hurricane that makes landfall in South Carolina (page 25). The most intense modeled hurricane has similar maximum winds and central pressure to Hurricane Andrew (1992) and forward speed similar to Hurricane Hugo (1989) at landfall. Thus, this system is reasonable compared to historical U.S. landfalling systems.

Simulation of damaging winds associated with a modeled hurricane

The description of the modeled storm characteristics and how they are used to develop a spatial distribution of hurricane winds is consistent with the AIR model approved by the Florida Commission. Since many hurricanes affecting South Carolina will make landfall in other states, the treatment of hurricane weakening over land is important. AIR does not provide details of hurricane intensity for storms moving from another state into South Carolina, so it is difficult to judge this aspect of their model. Further, the Form SC-1 submitted by AIR (pages 51–55 of their original submission) was incomplete: the storm characteristics used in the model to simulate the winds of Hurricane Hugo were not provided in Part B; this information ensures that the winds plotted in Parts C and D (pages 54 and 55) are what the model would produce for a storm like Hurricane Hugo.

The comparison between the model winds and observations for Hurricane Hugo (Part E) was also omitted. This information is intended for use in evaluating the modeled wind distributions inland. AIR provided this information in the modeler responses to additional inquiries. Hourly data on the storm characteristics used to simulate the damaging wind distribution associated with Hurricane Hugo were provided (Part B). The map of modeled surface windspeed depicts an asymmetry of windspeeds from north to south, consistent with the combined effect of the cyclonic rotation of the winds with the storm's westward motion; reasonable agreement with point observations drawn from the NHC report on Hurricane Hugo is evident.



Summary of Meteorology Module

The pattern of tracks for stochastic storms produced by the AIR model is reasonable, as are the intensities of the stochastic storms that cross the South Carolina coast. The Florida Commission has approved this version of the AIR model, however, the SCDOI requested information on the intensities of stochastic storms entering South Carolina from other states; this intensity information was not provided. This means that information on the contribution of inland storms on damages in South Carolina is incomplete. A complete Form SC-1, demonstrating how the AIR model simulates the important recent case of Hurricane Hugo (1989), was provided in the second set of modeler responses. This reveals a realistic spatial distribution of surface winds in reasonable agreement with observations contained in the report on Hurricane Hugo issued by NHC.

2.3 Vulnerability Module

In general the building classifications for personal residential occupancy and primary characteristics used to model properties located in SC are reasonable. AIR, however, does not differentiate vulnerability functions among 1-, 2-, and 3-story building for low-rise constructions for SC. It is recommended that AIR continue its research to address the story height for low-rise buildings in its future versions.

AIR states that its vulnerability functions address damage due to hurricane hazards of wind speed/pressure, water infiltration, and wind borne debris impact and they do not explicitly include damage due to flood, or due to storm surge and wave action in the case of coastal properties.

These comments by panel of experts are redacted at the request of the modeler.

This response has been redacted at the request of the modeler.

These comments by panel of experts are redacted at the request of the modeler. Thus it is recommended that SCDOI require the filing companies to provide detailed justification for their rates when using the AIR model with regard to regional and temporal variations in vulnerability due to variations in building codes and regional wind speed; specifically pre- and post 2006 building code.

These comments by the panel of experts are redacted at the request of the modeler.

These comments by the panel of experts are redacted at the request of the modeler.



For example AIR states that:

This response has been redacted at the request of the modeler.

These comments by the panel of experts are redacted at the request of the modeler.

This response has been redacted at the request of the modeler.

These comments by the panel of experts are redacted at the request of the modeler. It is recommended that the SCDOI require the rate filing companies using the AIR model to declare whether surge losses are included in the loss costs used as basis for rates and provide the extent and justification of such inclusion.

In its revised report of August 2013, AIR states “We encourage the SCDOI to ask for the log to gain an insight into the storm surge assumption included in the rate making analysis.” This recommendation by AIR is in agreement with that of the panel of experts.

2.4 Actuarial Module

The Actuarial portion of the models uses policy information, such as policy deductible and limit, and converts the damage and ground-up loss calculations that were derived in the vulnerability module into insurance loss information and loss costs.

Demand surge:

AIR states in its response to the follow up questions

“During the course of validating the AIR hurricane model for the United States, demand surge is included in the modeled losses for historical events. The modeled losses compare well with reported losses, validating both the AIR models and the AIR demand surge function.”

The Florida Commission has reviewed the AIR demand surge calculations in detail, and they have been found to be reasonable.

AIR also states that

“Clients using the AIR model have the option to include or exclude demand surge in the analysis. If including demand surge, clients also have the option to modify the default demand surge assumptions in the model if they have more specific information about the effects of demand surge on their book of business.”

It is important that the regulator be made aware of whether or not demand surge is included in the submitted loss costs, and whether there have been any adjustments



made to the demand surge calculations in the model. This information should be provided with the model output report (AIR's report is called PIAF, product information and assumptions form) each time the model is used in a rate filing. It is also important that the modeler (or the filing insurer) provide details to the regulator as to how to locate the desired information from the output reports.

Adjustments to insurer input data:

AIR states in its responses to the follow up questions

“Insurer data, whether used as the exposure input to a loss analysis or for model validation, undergoes a set of structured processing procedures. These include checks to determine the quality and completeness of the data, its reasonability and the existence of any unique conditions or special reporting features. If data is excluded or adjusted, this is noted in a PIAF. (See Appendix 6 of the AIR response to the follow up questions for an example PIAF). Insurer approval of the form is required prior to analysis.”

Modelers or insurers should provide information so that the regulator is made aware of the information contained in the PIAF, and the regulator should be educated as to how to obtain the information from the PIAF, AIR's output report.



3. Summary Review of the ARA Model (with redactions)

3.1 General

During this evaluation of hurricane catastrophe models ARA HurLoss 6.0 Florida model was submitted to the FCHLPM for review, and has subsequently been accepted with expiration date of September 1, 2015. At this time, only HurLoss 6.0 should be used for filings in South Carolina. As a result of the panel of experts review and comments, ARA has proposed to make changes to its model to address the following three issues:

1. Treatment of tropical cyclones that do not reach hurricane strength,
2. Treatment of unknown masonry residential structures (i.e., masonry residential structures that are not identified as either unreinforced or reinforced), and
3. Treatment of the 2006 South Carolina Building Code.

The ARA HurLoss 6.0 model used for the US (including South Carolina) has a somewhat different hurricane simulation methodology than the methodology used for hurricane simulation in Florida. A smaller number of simulated hurricanes is retained in ARA's US hurricane model, which uses a 500,000-year importance sampling strategy, than in ARA's FCHLPM-accepted Florida-only model, which uses a 300,000-year full Monte Carlo simulation. The basis for this treatment of the US/South Carolina hurricane set has not been presented to FCHLPM (since it is not relevant there), neither has it been reviewed in detail by the panel of experts. The outline of the procedures and comparison charts provided by ARA indicate that the US Model should be reasonable for use in SC with the exception of the inclusion of tropical storms (discussed in the Actuarial Section below). However, it is recommended that the procedure used to develop the simulated hurricane set for the US Model (which includes South Carolina and Florida, but has not been submitted for review by the FCHLPM) should be closely examined in the near future.

Furthermore, as indicated by ARA, HurLoss 6.0 model for the rest of the US (i.e., South Carolina) is the first ARA model for insurance loss calculations outside the State of Florida, meaning that there are no previous models for use in comparison with current model.

In summary it is recommended that if ARA HurLoss 6.0 is used for rate filing, the filing company provide resolutions and justification with regard to the above issues. ARA has agreed to resolve the above issues in their next version. Once implemented the panel of experts suggests that the SCDOI review the above listed improvements.



3.2 Meteorology Module

The Meteorology module of the model develops a geographically varying picture of hurricane-related risk based upon the historical hurricane records for the region (not only for South Carolina).

Use of historical storms

The data sources utilized by ARA for developing the stochastic storm set produced by the model are all from National Oceanic and Atmospheric Administration (NOAA) documents and databases issued by the National Hurricane Center. This data provides comprehensive information of all historical hurricanes in the North Atlantic Ocean, including detailed information on storms crossing the U.S. coast. The tracks of the stochastic storms produced by the ARA model based on all of these data are reasonable for hurricanes affecting South Carolina.

Landfalling hurricanes

The ARA model provides a reasonable representation of the distribution of hurricane intensities at landfall (by Saffir Simpson category) for hurricanes affecting South Carolina, although they generally model lower rates of hurricanes occurrence than observed for Saffir Simpson Category 2 and higher. ARA explains the tendency for the modeled intensities to be lower than observed based on interpretation of minimum pressure versus winds for determining hurricane category and supports this argument with reference to their paper in the peer-reviewed scientific literature (Ref. 5). This explanation is reasonable in the context of their windfield modeling assumptions. However, the storms affecting South Carolina (both observed and simulated) are identified using a criterion (based on reproducing damaging wind distributions across the state) different from that required in the FCHLPM Standards. This difference is discussed below under *Actuarial*, but the salient point here is that it could result in retaining more weaker systems than would be retained using the definition of a hurricane as applied by the FCHLPM. In their March 2013 additional submission to the SCDOI, ARA provide an estimate that the damages resulting from the storm-selection approach used here would be reduced by between 2.5% and 5.1% if the method of storm selection followed the FCHLPM guidelines. They have undertaken to update their storm selection approach in subsequent submissions to the SCDOI.

The most intense modeled hurricane that makes landfall in South Carolina is similar in intensity and size to Hurricane Andrew (1992), with forward speed similar to Hurricane Hugo (1989) at landfall. Thus, this system is reasonable compared to historical U.S. landfalling systems.



Simulation of damaging winds associated with a modeled hurricane

The description of the modeled storm characteristics and how they are used to develop a spatial distribution of hurricane winds is consistent with the ARA model approved by the Florida Commission. Since many hurricanes affecting South Carolina will make landfall in other states, the treatment of hurricane weakening over land is important. The method used in the ARA model is based on observed differences in over-land weakening for storms making landfall on the Gulf of Mexico compared to the U.S. east coast.

Form SC-1 submitted by ARA includes many comparisons of their modeled winds with recorded winds for Hurricane Hugo distributed across the state. ARA discusses how the spatial distribution of land use land cover (LULC) contributes to determining the final modeled winds and justifies these distributions against observations.

Summary of Meteorology Module

The ARA “US Model” being reviewed here differs from the ARA model accepted by the Florida Commission in one respect: the method for identifying stochastic storms impacting South Carolina. The Florida Commission requires that loss costs be computed for all storms that reach hurricane strength and produce minimum damaging windspeeds or greater on land in Florida (Ref. 1). The method of storm definition employed by ARA for use in South Carolina is based on reproducing the spatial distribution of observed damaging winds produced by tropical cyclones (i.e., hurricanes and tropical storms instead of hurricanes only) across the state. This difference is not an inherent problem with the Meteorology component of the model, but will affect the frequency of storms impacting the state. It does not result in an excessive number of hurricanes over the state compared to the historical record, but it does have other implications (see the Actuarial review below).

The pattern of tracks for stochastic storms produced by the ARA model is realistic, as are the intensities of the stochastic storms affecting South Carolina. The winds simulated by the model for Hurricane Hugo show very good agreement with winds recorded all across the state of South Carolina.



3.3 Vulnerability Module

In general ARA approach to classification of building classes and development of building vulnerability functions are sound and based on engineering principals and supported by claims data, when available. ARA development of vulnerability functions for contents and additional living expenses is reasonable. The panel of experts believes that ARA properly addresses the variation of vulnerability functions across the state. In general the vulnerability module of the ARA model for use in South Carolina is appropriate. The panel of experts, however, identified the following three issues, one of which was properly addressed by ARA, and ARA has proposed to address the other two issues in its future versions.

(1) ARA revised its initial response to the follow-up question re building classification, specifically the Masonry, Unreinforced Masonry and Reinforced Masonry. Furthermore, in response to the follow-up question:

“Are hurricane vulnerability functions for Masonry, Unreinforced Masonry, and Reinforced Masonry classes different? Explain. What is their ranking?”

ARA replied:

“Unreinforced masonry is always weaker than reinforced masonry, all other factors held constant. For residential construction, the general or unknown masonry classification is modeled as reinforced masonry.”

As stated by ARA, unreinforced masonry is weaker than reinforced masonry. ARA however, uses “reinforced masonry” (i.e., the less vulnerable class) for the general or unknown masonry class. This might induce an underestimation of losses. In its draft report panel of expert recommended that rate filings based on the ARA model for masonry constructions be examined and justifications for use of reinforced masonry for the general or unknown masonry be provided.

As a result of the draft report by the panel of experts sent to ARA, ARA has proposed to make specific revisions to HurLoss U.S. Version 6.0 to address this issue:

Specifically, ARA has proposed the following:

“ARA will introduce an additional modifier for unknown masonry residential construction. The magnitude of the unknown masonry modifier will vary with construction era and construction region, and it will result in losses that fall between the losses currently produced by the model for reinforced and unreinforced masonry construction.”



The panel of experts believes that implementation of this proposed modifier will properly address the issue raised in its initial draft report. It is recommended that such implementation be reviewed by SCDOI when reviewing rate filings in the future. It should be noted the above issue concerns only a specific class of construction.

(2) In its initial draft report the panel of experts indicated that “ARA uses two vulnerability regions within South Carolina: coastal counties and interior counties. Although the panel of experts asked for the basis of these vulnerability regions, ARA did not provide the basis. Also it is not clear if these two vulnerability regions apply to all construction classes, occupancies and construction year or just a subset of them. For example it is not clear if ARA uses these two regions for post-1994 manufactured home constructions/installations or for high-rise engineered buildings. It is recommended that any rate filing using ARA model shall include the basis and scope of these two vulnerability regions.”

In its response to the above, ARA included:

“The two vulnerability regions used by the ARA model within South Carolina for site-built structures approximately reflect the boundary of the windborne debris region as defined by the ASCE 7-05 Basic Wind Speed map. These vulnerability regions are used in the ARA model to reflect differences in wind resistance of site-built construction in coastal counties vs. inland counties. The construction regions used in the ARA model for manufactured housing differ from the site-built construction regions and are based on the 1994 U.S. Housing and Urban Development (HUD) wind zones for manufactured housing. No changes are planned for HurLoss U.S. Version 6.1 with respect to the vulnerability region boundaries.”

The panel of experts believes the above response properly addresses the issue.

(3) In its initial draft report the panel of experts indicated that “ARA uses four year-bands for constructions in South Carolina, however the ARA model does not address the current 2006 South Carolina Building Code. It is recommended that rate filings for post 2006 constructions based on ARA model should include justification (by the modeler or filing insurer) for not implementing and addressing the effect of the current 2006 South Carolina Building Code.”

In its response to the above, ARA has responded with the following:

“ARA will revise the periods of our second, third and fourth construction eras to reflect the implementation of the 2000 IBC and IRC in approximately 2002 as the start of our third SC building code era and the implementation of the 2006 IBC and IRC in approximately 2009 as the start of our fourth SC building code era.”



The panel of experts believes that implementation of this proposed model update will properly address the issue. The panel of experts recommends that such implementation should be reviewed by the SCDOI. It should be noted that this issue applies only to construction classes built after adoption of the 2006 building code.

3.4 Actuarial Module

In general, the actuarial section is acceptable. However, in their initial response, Applied Research Associates (ARA) indicates that the ARA model includes losses from tropical depressions and tropical storms in addition to hurricanes. Therefore, if the model is used to derive hurricane insurance loss costs for South Carolina there will be a double counting of tropical storm and tropical depression losses: once in the underlying loss cost calculations for “other than hurricane” and again in the calculation of hurricane loss costs. This model should not be used to calculate the hurricane loss costs in a South Carolina property insurance filing until ARA corrects this problem.

For any filing, the regulator must be presented with an output report, delineating whether such things as demand surge or storm surge are included or excluded in the model loss costs proposed to be used in the rate filing. The output report also will provide information as to whether there have been any adjustments made in the input files or elsewhere that might affect the loss costs being requested by the insurer in the rate filing.

In their subsequent response (March 2013), ARA state

“ARA will add the following analysis option to HurLoss U.S. Version 6.1: (1) Include all tropical cyclone events, (2) Exclude events that never reach hurricane status, or (3) Include only those events that make landfall in the US or bypass the US as hurricanes. The selected analysis option will be identified in the model output report. An example of the impact of these three options on SC loss costs was provided on page 6 of our March 27, 2013 revised submission.”

Inclusion of this information on the output report provides the regulator with information adequate to ensure that the model loss costs do not double count losses relating to storms not classified as hurricanes. This modification to the ARA model addresses the concerns of the panel of experts. *Once this modification is made, and assuming no other changes to the revised model, the ARA model should be deemed appropriate for use in South Carolina rate filings.*



4. Summary Review of the EQECAT Model (with redactions)

4.1 General

In its initial draft report, the panel of experts indicated that

“In its responses to the initial and follow-up questions, EQECAT states that WORLDCACTerprise Versions 3.16 and 3.13 include Florida Hurricane Model 2011a and Florida Hurricane Model 2009, respectively. It should be noted that FCHLPM has reviewed and accepted the latter two Florida-specific models, not WORLDCACTerprise which includes other hazards and regions including hurricane hazards in South Carolina.”

Notwithstanding the above, per the panel of experts’ review of the responses from EQECAT it is recommended that EQECAT WORLDCACTerprise Version 3.16 which includes Florida Hurricane Model 2011a (accepted by FCHLPM with expiration date of September 2013) may be used for rate filings in South Carolina. It should always be determined that the version of the model used for rate filings in South Carolina should include only a long-term prediction of hurricane risk. All of the models currently accepted by the FCHLPM use only a long-term view of hurricane risk. Thus, *the FCHLPM has not accepted any implementation of the WORLDCACTerprise Version 3.16 model that specifies warm water, warm phase, medium-term, short-term, or any other variations of historical hurricane risk and so these are not recommended for use in rate filings in South Carolina.* As such, if these “larger” EQECAT models (WORLDCACTerprise Versions 3.16 and 3.13) are used for rate filing in South Carolina, we recommend that documentation be required in the rate filing to specify the view of risk (with adequate detail to ensure there is no variation from the long-term historical view of hurricane risk) and to document and justify the differences in hurricane risk models between the Florida specific models and the South Carolina models.

In response to the initial draft report, EQECAT has introduced the new version of their model. Specifically EQECAT states that:

“In addition, EQECAT will release a new model version entitled Risk Quantification and Engineering (RQE) v14 on August 9. The Florida Commission on Hurricane Loss Projection Methodology has certified the Florida portion of RQE v14 in June 2013. EQECAT is providing results in Forms SC2 and SC3 that are from RQE v14.”



EQECAT continues to summarize the differences between the new RQE v14 and WCe v3.16. Upon review and comparison of Forms SC-2 and SC-3 completed using these two versions of the model, the panel of experts encountered some inconsistent results. For example, where WCe 3.16 produced non-zero loss cost for ZIP Code 29390 for various construction types, RQE v14 produces zero loss costs. Similarly, where WCe 3.16 produced zero loss costs for ZIP Code 29503 for various construction types, RQE v14 produces non-zero loss costs. These discrepancies cannot be easily explained by the summary of differences between the two models provided by EQECAT. It is recommended that if and when RQE v14 is used for rate filing in South Carolina, these differences be satisfactorily detailed and explained.

In its initial draft report the panel of experts indicated that

“The variations of loss costs for the same ZIP Codes for various EQECAT model versions are relatively large. For example for ZIP Code 29458 the ratio of Version 3.13 loss cost to Version 3.16 loss cost is in the range of 2.5 to 3.0, whereas for ZIP Code 29810 the same ratio is in the range of 0.7 to 0.75. In other words, from version to version, loss costs have decreased and decreased substantially from ZIP Code to ZIP code. The regulator should require justification by the modeler for future changes as suggested in the Findings and Recommendations section of this report.”

In its response, EQECAT explained the differences are due to changes in updated roughness lengths in the model. Panel of experts believe that this explanation and the roughness lengths provided for the ZIP Codes in the two models are satisfactory.

4.2 Meteorology Module

The Meteorology module of the model develops a geographically varying picture of hurricane-related risk based upon the historical hurricane records for the region (not only for South Carolina).

Use of historical storms

The data sources utilized by EQECAT for developing the stochastic storm set produced by the model are all from NOAA documents and historical databases issued by the National Hurricane Center. The modeler states that the model versions submitted for review are based on the complete historical hurricane database for 1900-2009, without modification or frequency adjustment (pages 6 and 7 of their follow-up response).

In their August 2013 responses, EQECAT note that they have updated the historical hurricane database to include the 1900-2011 hurricane seasons and the coincident NHC reanalyses of earlier hurricanes in their new model (RQE v14).



EQECAT state that this updated hurricane database results in an increase in South Carolina statewide loss costs.

This increase in loss costs due to updates in the long-term historical hurricane database demonstrates why it is important that the long-term view of risk be used for rate filings: if shorter segments (or other subsets) of the historical record are used, the loss costs will be even more sensitive to changes in an individual event.

While the entire hurricane database has been used in developing the model, the landfall frequencies for the stochastic hurricane set are lower for weaker storms and more frequent for more intense hurricanes, including Cat 5 systems (page 11, follow-up responses). These frequency variations are acceptable, but should be examined with each new model submitted to the Department of Insurance.

Landfalling hurricanes

The definition of a hurricane used in the EQECAT model for compiling the stochastic storm set is the same as the definition used by the Florida Commission: the storm must be a hurricane when it is near or over the US mainland and must cause damaging winds in the state (but need not have hurricane winds in the state).

The EQECAT model has a tendency to produce a higher fraction of intense hurricanes (Category 3 and 4) at landfall and fewer weaker storms (table on page 10 and histogram on page 11 in the pdf of the EQECAT initial responses – the pages are not numbered).

The most intense modeled hurricane that makes landfall in South Carolina (page 16) is 20% more intense than Hurricane Andrew (1992) (30% stronger than the 140 mph of Hurricane Hugo). Its radius of maximum winds (R_{max}) is less than 5 miles; Hurricane Charley (2004) is the only historical landfalling hurricane with its strongest winds this close to the center at landfall. The forward speed of the model storm is similar to that of Hurricane Hugo (1989) at landfall. This model storm is very much an outlier compared to historical U.S. landfalling hurricanes, but the combination of a small maximum wind radius and unusually strong maximum winds is possible based on the physics governing these storms.

Simulation of damaging winds associated with a modeled hurricane

The description of the modeled storm characteristics and how they are used to develop a spatial distribution of hurricane winds is consistent with the EQECAT model approved by the Florida Commission, however, it differs in the treatment of hurricane weakening over land; since many hurricanes affecting South Carolina will make landfall in other states this component of the model is important. The method used in the EQECAT model has been shown by them to reproduce storm intensity over land to *within $\pm 20\%$ of another inland wind decay model* (page 14



in the original responses and page 4 in the revised responses); statistics on direct comparisons between observed storm weakening and inland decay produced by the model are not given.

In their August 2013 response (page 1), EQECAT note that the timestep used for inland decay has changed from 15 minutes to 5 minutes in their new model (RQE v14). The decrease in timestep (to 5 minutes) means that the model calculates the damaging winds three times more often, and so will sample the stronger winds near landfall more often. EQECAT state that this will result in a minor increase in loss costs in South Carolina. This timestep change has been reviewed and found acceptable for use in Florida by the FCHLPM. However, EQECAT do not provide any discussion on how the change affects windspeeds over land for South Carolina compared to historical storms.

While only applying to a single very intense storm, Form SC-1 gives some information on over-land weakening. The storm characteristics input to the EQECAT model to simulate Hurricane Hugo are reasonable and modeled winds simulated using these characteristics compare reasonably well with observed winds (comparing the top map on page 43 with the map on page 44 of their initial response).

EQECAT accounts for the effects of terrain by using a variation to the roughness factor (page 15, follow-up responses; “secondary friction factor”). Recall that the roughness factor is used to modify the winds based on the land use characteristics (lake, forest, field, town, etc.). This EQECAT variation to the roughness appears to be an effective approach for accounting for the topography in the west of the state, but has not been evaluated by the FCHLPM or the panel of experts. It is – understandably – not used in the model accepted by the Florida Commission and so has not been reviewed in the FCHLPM process. Comparison between the two maps on page 43 (original submission) is helpful in understanding the effects of this secondary friction factor. The factor should only be included in winds plotted in the top map (actual terrain), but not the other map (open terrain): comparison of these maps shows that the effect of the secondary roughness factor for topography is small in the case of Hurricane Hugo.

Summary of Meteorology Module

The stochastic storm tracks produced by the EQECAT model are reasonable; the intensities of the stochastic storms affecting South Carolina have a tendency to be higher than the past 110 years, but are within reasonable bounds. The strongest stochastic storm is 20–30 % more intense than historical landfalls, but the very small maximum wind radius means that the central pressure (876 mb) could be within the bounds of historical storms even though the winds are so intense. The modeler should be readily able to supply this central pressure information.



The spatial distribution of winds over South Carolina for Hurricane Hugo is in reasonable agreement with observations and shows only a small possible effect of the treatment of topography.

(**Redacted by modeler**) information has been provided in later communications from EQECAT. For example, EQECAT state that (1) the updated historical hurricane set used for development of the stochastic hurricanes and (2) the reduction in the timestep used for damaging wind reduction over land (August response) will both contribute to increases in the loss costs over South Carolina, yet we do not have the corresponding exhibits for this version of the model.

Assuming no other changes in the treatment of hurricanes between RQE v14 and the earlier model for which detailed exhibits were provided, the meteorology underlying RQE v14 should be deemed acceptable for use in South Carolina. The panel of experts recommends that the Department of Insurance request a complete set of exhibits for any new versions of models submitted.

4.3 Vulnerability Module

In its initial draft report the panel of experts indicated that

This section of the report has been redacted at the request of the modeler

In its response to the above, EQECAT indicated:

This response has been redacted at the request of the modeler

“You have stated that

This response has been redacted at the request of the modeler

How do you account for the building code development and enforcement differences in Florida and South Carolina?”

EQECAT stated that:

This response has been redacted at the request of the modeler

In its initial draft report the panel of experts continued its concern by stating that

This portion of the report has been redacted at the request of the modeler



In its response to the above comment, EQECAT responded:

This response has been redacted at the request of the modeler

The response by EQECAT continues to argue that

This response has been redacted at the request of the modeler

The panel of experts in its draft report states that

This portion of the report has been redacted at the request of the modeler

In response to Vulnerability Question 8, EQECAT states that:

“The model has no regional variations in the building characteristics in South Carolina due to the size of the state and the limited number of recent events with substantial claims data impacting the state. One may model known regional variations by use of the secondary modifiers discussed earlier.”

The panel of experts in its draft report, states that

This section of the report has been redacted at the request of the modeler

In its response to the above comments in the draft report, EQECAT has responded by:

“South Carolina used the 2006 modified International Residential Code up to June 30th, 2013. The 2012 IRC (with modification) became effective on July 1st, 2013. One of the major differences between the two codes is that the latter code requires wind rated exterior wall coverings and the use of event rated shingles based on ASTM D7158 which were not required in the 2006 building code. These building characteristics and others are handled in RQE using the SSM module both for pre- and post-2006 codes.”

For post 2006 building constructions, EQECAT suggests that the new RQE v14 can handle vulnerability differences through the Secondary Structural Modifier. This approach

This section of the report has been redacted at the request of the modeler



4.4 Actuarial Module

This model has gone through several revisions in the past few years, most of which resulted in decreases in the loss costs, and each of which have been reviewed by the State of Florida. Nevertheless, the South Carolina Department of Insurance should be notified when changes occur that impact upon South Carolina loss costs along with the estimated effect of such revisions, and whether the revisions have been accepted by the FCHLPM.



5. Summary Review of the RMS Model (with redactions)

5.1 General

In its draft report the panel of experts stated that “In response to General Questions 1 and 2 and the follow up questions, RMS states that acceptance of its model versions RiskLink 11.0 SP2 was rescinded March 7, 2013 and that versions SP3 and SP3a have not been submitted to the FCHLPM for review and acceptance. The version SP2c has been accepted by FCHLPM for the State of Florida. Per the panel of experts review and responses from RMS it is recommended RiskLink 11.0 SP2c be used for South Carolina rate filing. As with all of the hurricane risk models currently accepted by the FCHLPM, the accepted version (RiskLink 11.0 SP2c) uses the long term prediction of hurricane risk. Any implementation of the model that specifies medium-term, short-term, or “warm water” variation of this model has not been accepted by FCHLPM. Short and medium term or warm water models *are not recommended to be used in rate filings in South Carolina*. Any differences from Florida in modeling properties in South Carolina should be documented and justified in such rate filings.”

In its response to the initial draft of the report RMS states that:

“We are concerned that RiskLink 11.0, SP2c has been targeted as being the sole recommended version. Future updates, no matter how minor, are not addressed. For example, we have recently released RiskLink 13.0, which is substantially the same as RiskLink 11.0. There are no methodology changes. A few parameters have been updated, namely long-term event rates and vendor geographical data.

We recognize the limitations inherent with the available resources may preclude full review of each new software release. However, we encourage recognition of our outstanding offer to give reviewing regulators detailed information related to new releases. It would also be prudent to accept minimal changes resulting from updates.”

The panel of experts agrees that currently there is no mechanism to address future model revisions for South Carolina. This is true for all modelers, and not just RMS. It is recommended to SCDOI plan and develop a procedure to address future model revisions. The panel of experts has suggested one approach to ongoing model review in Section 6 (Findings and Recommendations) below.



In its response to General Question 3, RMS, states that

This response has been redacted at the request of the modeler

The follow-up question for General Question 4 to RMS is:

“You have indicated that you completed Form SC-2 & Form SC-3 using RiskLink 11.0.SP3a. Form SC-2 and Form SC-3 should now be completed once using RiskLink 11.0.SP2 and once using RiskLink 11.0.SP3.”

RMS responded:

“Forms SC-2 and SC-3 would show the same results for SP2 and SP3 as they do for SP3a since neither form’s input requires either secondary modifiers or reverse geocoding.”

In reality, Form SC-2 could feasibly have required reverse geocoding, since property locations for this form are given in terms of latitude and longitude. Thus the Forms might have been different. Regardless, it was the intent of the question, to identify whether the results given in Forms SC-2 and SC-3 are different and, if they are indeed different, that the difference be explained and justified. Moreover, RMS RiskLink 11.0 SP2c was accepted by the FCHLPM in 2012, and should have been used for completing Forms SC-2 and SC-3.

5.2 Meteorology Module

The Meteorology module of the model develops a geographically varying picture of hurricane-related risk based upon the historical hurricane records for South Carolina and the surrounding region.

Use of historical storms

As the basis for their stochastic tracks, RMS utilize the HURDAT database of historical storm tracks and intensities, updated and published each year by the National Hurricane Center (NHC), as well as two other publically available data sources: H*Wind and the Extended Best Track. Both H*Wind and the Extended Best Track are well reviewed and accepted databases that provide a historical basis for other storm characteristics (size, distribution of winds) used in creating the stochastic storm set. The historical period used by RMS is 1900-2008 (page 10 of their follow-up responses, April 2013). RMS states that they have not modified information from these datasets as they were used to develop the RMS modeled storms.



Landfalling hurricanes

RMS identify two types of hurricane when compiling their stochastic storm set (consistent with the Florida Commission ROA): a hurricane that *crosses the US coast (anywhere)* is called a “*landfalling*” storm; if the hurricane storm *center stays over water*, it is called a “*by-passing*” storm. In either case, the storm must also cause damaging winds over South Carolina to be counted in the event set used to determine loss costs.

The following table was compiled by the panel of experts from data in Tables 1 and 2 on page 11 of the original RMS submission and Table 5 (page 11) of the updated (April) RMS submission.

SS Category	A. Historical # over SC	B. Simulated # over SC	C. Historical SC Landfall #	D. Simulated SC Landfall #	E. Simulated SC Landfall Rate
1	9	11	8	4.5	0.041
2	5	2	3	4.4	0.040
3	1	1	1	1.0	0.009
4	2	1	2	1.1	0.010
5	0	0	0	0.1	0.001

Comparing column B with column A, the RMS model reasonably reproduces the intensities of the storms that are still hurricane strength when they move through South Carolina. Comparing column D with columns A, B and C reveals that hurricanes affecting South Carolina in the RMS model have a stronger tendency than observed to approach the state from over land (coming from another state), than from sea to land (landfall). However, the overall storm frequencies over the state are reasonable, so this track climatology is acceptable.

Per RMS the most intense stochastic hurricane that makes landfall in South Carolina (page 17) is 40% more intense than the 140 mph of Hurricane Hugo, even though the central pressure is not as low as the 934 mb of Hurricane Hugo at landfall. The most extreme stochastic storm has an unusually large maximum wind radius of over 40 miles and the forward speed of the model storm is similar to that of Hurricane Hugo (1989) at landfall. Based on the combination of storm attributes recorded, the most intense stochastic hurricane making landfall in South Carolina is very much an outlier compared to historical U.S. landfalling systems.

Simulation of damaging winds associated with a modeled hurricane

The description of the modeled storm characteristics and how they are used to develop a spatial distribution of hurricane winds is consistent with the RMS model approved by the Florida Commission. RMS do not specifically account for terrain in the model, arguing that it is a small effect in the state. The lack of terrain is different



to distance from the coast. The major impact of making landfall will cause the majority of hurricanes to weaken substantially within a few miles of the coast whereas the effects on the winds due to hilly terrain will vary from place to place and storm to storm (depending on the direction of the track and other storm attributes).

The spatial distribution of modeled winds in Form SC-1 for Hurricane Hugo suggests that the model does a reasonable job in simulating this storm, however comparison with the observed winds (Part E) reveals that the modeled Hugo peak windspeeds are consistently less than observations. RMS discusses that this discrepancy arises based on the averaging method used to create the exhibits given in Form SC-1. By combining wind information from a number of locations and averaging this windspeed data, the average windspeed will always be lower than the top windspeeds from any single location. This explanation is reasonable.

Summary of Meteorology Module

The exhibits provided show reasonable spatial patterns of winds over South Carolina for Hurricane Hugo and distributions of modeled versus historical tracks and intensities.

5.3 Vulnerability Module

A follow-up question to Vulnerability Question 1:

Regarding Condo Association occupancy you have responded by stating “Intended to model only damage to the exterior shell (e.g., roof cover and cladding)”. What about damage to interior hallways, common areas within the buildings, elevators and elevator shafts, lobbies, interior electrical, and mechanical systems (HVAC) etc. Why is only “exterior shell” considered for Condo Associations? Who is responsible for extensive damage to these other interior components, which are typically not covered by condo unit owner policies (typically \$1000 limit)? This question applies to both mid- and high-rise as well as low-rise condominium buildings covered by Condo Associations.”

elicited the following response from RMS:

“All common areas, both internal and external, belong to Condo Associations.”

In its first draft of the report, the panel of experts indicated that the above response is not in agreement with the Condo Association description given in Table 3 of the RMS response, which for Condo Associations states:

“Intended to model only damage to the exterior shell (e.g., roof cover and cladding), as is the case for condo and homeowners association policies.”



Furthermore the panel of experts adds that “It is thus recommended that rate filings based on the RMS Condo Association policy not to be used without additional adjustment, clarification and justification, since it is unclear whether the Condo Association loss costs includes or excludes damage to interior hallways or common areas within the buildings.”

In its response to the above comments in the draft report, RMS has responded by:

“We apologize for the confusion related to the Condo Association common areas.”

And RMS goes on and responds by:

“It is not true that the model lacks treatment of the common interior areas of condo association areas. To clarify, the original response to this question should be revised to say:

Condo Associations: Intended to model only damage to the exterior shell (e.g., roof cover and cladding), as is the case for condo and homeowners association policies. It also includes losses to contents and structure owned by the association (e.g., common interior areas, furniture in common areas, pool equipment, etc.)

Condo Unit Owners: Intended to model only damage to the interior structure (e.g., drywall, flooring, cabinets, etc.), as is the case for Condo Unit Owner (HO6) policies. It can also be used to model losses to contents owned by the unit owner.”

The panel of experts is in agreement with the above modifications and believes that RMS has addressed the issue.

In the initial draft of the report the panel of experts stated “The RMS model does account for variations in building codes based on year of construction. RMS uses two year bands in South Carolina – pre-1998 and post-1998. RMS model, however, does not address the current 2006 South Carolina Building Code. Justification for the lack of consideration of the effects of the 2006 building code needs to be provided by the modeler as part of any rate filing in South Carolina.”

In its response to the initial draft of the report, RMS responds by:

“Rather than impose this requirement as a part of each rate filing, RMS would like to submit the following:

A year band corresponding to the adoption of the 2006 South Carolina building code is not included in the model because, while the provisions of the code are known, the compliance and enforcement of the provisions are not. It was the opinion of the panel of consultants engaged by RMS during the development of the current U.S. Hurricane model that workmanship, and building code compliance and enforcement are as important as the



building code provisions and design wind speeds when predicting the hurricane performance of a building.

However, the current (2006) South Carolina Building Code can be represented through the use of secondary modifiers that correspond to the wind provisions of the code, when they are verified as being present.

If more information becomes available to confirm the compliance with and enforcement of the 2006 South Carolina building code , then a new year band representing this code will be introduced in a future release of RiskLink.”

The panel of experts responds that, although it is difficult to determine if code compliance and enforcement has been considered for any given building unless a specific survey and inspection is done, once a code is adopted, a portion of the building constructions will be built according to the new code. This is especially true for the newer code changes such as 2006 after so many losses in Hurricanes Hugo (1989) and Andrew (1992) and the landfalling hurricanes of 2004 and 2005 seasons. Thus on average post 2006 construction should perform differently from constructions built before 2006.

The RMS argument regarding the use of secondary modifiers to address post 2006 puts the responsibility on the user of the model. The panel of experts argues that this is the modeler responsibility to address regional variations across various wind regions in South Carolina. The variation for various construction eras should be addressed by the modelers. The RMS suggests using an unclear secondary modifier procedure, but the use of the secondary modifiers to account for the 2006 building code is not appropriate. Thus it is recommended that SCDOI require the rate filing companies provide detailed justification for their rates when using RMS model with regard to temporal variations in vulnerability due to variations in building.

In its draft report, the panel of experts stated that “The RMS model uses two vulnerability regions in South Carolina: coastal counties and interior counties, with vulnerability generally being higher in interior counties relative to coastal counties. This vulnerability increase going inland applies to mobile homes built/installed after 1994. Given that the applicable code requires tie downs for mobile homes, it is not clear why mobile homes built and installed after 1994 should be more vulnerable for interior counties relative to coastal counties. RMS does not provide any supporting justification. It is recommended that rate filings based on the RMS model for post 1994 mobile home include justification for the use of higher vulnerability for these types of constructions for interior counties.” In its response to the above comment, RMS responded by:

“Rather than impose this requirement as a part of each rate filing, RMS would like to submit the following:



In South Carolina the boundary between the coastal and inland vulnerability regions coincides with the boundary between Wind Zones I and II in the Manufactured Home Construction and Safety Standards published by the U.S. Department of Housing and Urban Development (Zone I corresponds to “standard” wind areas and Zone II corresponds to high wind areas). The wind design requirements for Zone I are not as strict as those for Zone II. In particular, HUD requires that for manufactured homes in Zone II the wind resisting components (including, but not limited to tie-downs) and cladding materials be designed by a Professional Engineer or Architect. These requirements are not imposed in Zone I. Additionally, the design wind loads in Zone II are higher than those specified in Zone I. The difference in mobile home vulnerability between the coastal and inland vulnerability regions in South Carolina reflects the additional design requirements and higher design wind loads specified by HUD in wind Zone II.”

The panel of experts agrees with the above RMS justification.

5.4 Actuarial Module

In response to the follow up questions (see pages 5 thru 8 of the RMS responses to the follow up questions), RMS states that due to incorrect secondary modifiers for some construction types outside of Florida built after 2001 (described earlier), including wood frame and masonry, there were incorrect adjustments to the vulnerability functions and hence the loss costs that were produced were incorrect. According to the RMS response, these incorrect loss costs were *higher* than the loss costs produced by the corrected model for 54 separate categories and were *lower* than the loss costs produced by the corrected model for 3 separate categories. The problem identified was

“in the form of a SQL query that would update the vulnerability database such that the incorrect adjustments would no longer be made. This was provided to clients between the RiskLink 11.0.SP2 and RiskLink 11.0SP3 releases so that clients could update their RiskLink 11.0SP2 installation temporarily.”

The modeler did not provide any specific dates regarding the implementation of the SQL query, the overall levels of errors, or how or when the corrections were made.

Demand Surge

The RMS model can be run with or without demand surge (called loss amplification in the RMS submission).



“An Analysis Summary Report, which can be produced on demand from the software, will show whether or not demand surge has been selected in the analysis.”

The RMS Analysis Summary Report is equivalent to an “output report”.

Once again, it is important that the modeler or the filing insurer provide the regulator with information relative to understanding the Analysis Summary Report.

Methods used to calculate the loss amplification factors have been reviewed and found to be reasonable by the Florida Commission.

Adjustments to the input data

In response to the question,

“How is SCDOI informed when users make adjustments to the exposure data?”

RMS includes the following:

“Neither RiskLink nor RMS make any changes to exposure data, nor do we track exposure data input by clients. The SCDOI would need to request information from the company related to any adjustments made to exposure data.”

Since such assumptions or adjustments are made almost exclusively by the filing insurer, the regulator must be presented with an output report as a part of each rate filing using the RMS model, delineating whether such things as loss amplification or storm surge are included or excluded in the model loss costs proposed to be used in the rate filing as well as any adjustments made to the input or output of the model. *It is recommended that a filing that omitted these materials should not be approved.*



6. Findings and Recommendations (with redactions)

6.1 Findings

The panel of experts found that each of the reviewed models included the production of one or more “Output Report” and/or “Analysis Log” which provided a great deal of information relative to whether there were selections or adjustments to the input or output of the model; things that may have an impact on the loss costs but were outside of the actual operation of the model. These output reports and/or analysis logs may be referred to by different names by each modeler. There may be valid reasons for such adjustments, such as corrections to account for properties that are in ZIP-Codes that are invalid at the time the rate filer runs the model or has the modeler run the model. Regardless, the information on the output reports is extensive and *is necessary for identifying important assumptions and provisions inherent in any rate filing.*

Information relative to changes and/or adjustments to the input or output data is extremely useful, but we do not believe that filings submitted by individual insurers in South Carolina always included such information. The regulator should be aware of any adjustments to the input or output data, and it should be up to the modelers to provide detailed descriptions of what the regulator might look for in the output reports. Once the modeler has presented the output report to the regulator, a current output report should be submitted with each rate filing that bases its hurricane rates on that model.

Some models may include a certain percentage increase in the loss costs to allow various items, such as storm surge losses that are considered as wind losses in the actual claims data. These adjustments are outside of the review by the panel of experts and are not generally permitted by the FCHLPM in Florida. While an argument may be made that some storm surge losses were coded as wind losses, there is also an argument that some wind losses may have been coded as storm surge losses. If there is an amount to be added to all South Carolina hurricane insurance rates, that amount should be determined by the regulator with input from those that are affected, including the modeler, but not by the modeler alone.

Models that include tropical storms and tropical depressions in their stochastic storm sets should not be approved for use in South Carolina. The way the regulatory system operates, the effects of tropical storms and depressions are included in the “other than hurricane” loss costs. Inclusion of losses from tropical



storms and depressions in the modeled hurricane portion are completely outside of the general application of hurricane models in the ratemaking process, and they are disallowed by the FCHLPM. Such inclusion of tropical storms and depressions would result in a double counting of the effects of those storms; once in the modeled “hurricane” losses and once again in the rate development for “other than hurricane” portion of the ratemaking process using insurance industry experience calculated using normal actuarial ratemaking processes.

All models currently found to be acceptable by the Florida Commission for use in Florida are termed “long term” models. Long term models are those that use the full HURDAT dataset, without modification, from 1900 to the current date as the basis for the development of their stochastic hurricane event set. Each of the models reviewed by the panel of experts was the “long term” version of that model. The findings contained in this report apply only to the long-term models; they do not apply to “medium term”, “short term”, “warm water” or any other versions of the model. *Only “long term” models have been found acceptable by the Florida Commission for use in Florida.*

The hurricane models reviewed by the panel of experts tend not to address the effects of the South Carolina building code. This is especially important for South Carolina structures built subsequent to 2006, the year of current building code. Among other features of the codes that might impact the performance of buildings subject to hurricane hazards, the wind maps play an important role. The wind maps provide basic design wind speed for design of buildings to for wind. The 2006 building code wind maps are different from previous codes. As such, the structures, designed and built subsequent to 2006 will have different performance than similar buildings designed and built based on building codes prior to 2006. Modelers, however, generally assume that local building code enforcement is very weak or non-existent. Therefore, owners of structures designed and built after 2006 – and expected to resist higher wind speeds – may not benefit from the potential for lower loss costs that would have been produced if the provisions of 2006 building code were considered in the hurricane catastrophe model. When considering filings for the coastal areas affected by the post 2006 windspeed criteria, the loss costs produced should account for the potential of greater wind resistance for newer structures in these areas (and hence, the potential lower hurricane insurance costs) or provide substantive justification for ignoring the post-2006 construction codes. *Otherwise the filing should not be approved for structures built subsequent to 2006 until appropriate adjustments are made.*

In lieu of a complete review, when modelers wish to present the regulator with a new version of a model, the regulator must receive documentation of all of the differences between the old and the new version of that model and the effects on South Carolina loss costs resulting from *each* individual change.



Once a process is established that gives the regulator streamlined access to the information he or she needs to make decisions, then efficient regulation of hurricane insurance rates becomes almost automatic.

6.2 Recommendations

It is fundamentally true that model results produced for rate filings are as good as:

- How the model is used,
- The quality and accuracy of the model inputs,
- The choice of control variables and optional parameters (e.g., building code, hurricane climatology, inclusion of surge losses, demand surge, policy conditions) used to run the model,
- Whether default values for certain input variables are used or their values are selected and set by users,
- How the results are interpreted, and
- How model outputs (loss costs and probable maximum loss levels) are used to arrive at rates that are submitted to SCDOI for review and approval.

Intimate knowledge and expertise with how hurricane models should be developed and used is of utmost value to the review and evaluation of hurricane rate filings. Therefore, although it is not part of the scope of work, the panel of experts extended its evaluation of hurricane models used in South Carolina to provide guidelines and recommendations for the review of hurricane rate filings, when hurricane catastrophe model(s) output are used.

In the following, a set of guidelines and recommendations is provided to SCDOI. These recommendations are not exhaustive, and are not meant to be a replacement for the current processes and procedures in place at SCDOI for review and approval of hurricane rate filings; rather, the recommendations provided below are intended to provide additional insights into how the hurricane catastrophe model should be properly used and how its outputs can be utilized in rate filings.

To support these guidelines, whenever possible and appropriate, in its draft report the panel of experts made reference to a sample of rates based on the output of one of the hurricane models provided to the panel of experts by the South Carolina Wind and Hail Underwriting Association (SCWHUA). The panel of experts appreciates the willingness of the SCWHUA to complete a set of forms designed to facilitate analysis of the SCWHUA rates along with the various individual model outputs. This contribution by SCWHUA supported this process of



evaluation of hurricane catastrophe models relating to South Carolina. Also the panel of experts understands the forms completed by SCWHUA are subject to typos and mistakes.

In its initial draft the panel of experts stated “the analyses reported here are by no means a complete and thorough review of SCWHUA rate filing and are not meant to be a critique of SCWHUA rate filings in South Carolina. The panel of experts performed a very quick review of the rates provided by SCWHUA; the schedule of the review did not provide time for any discussion or additional follow up questions to the SCWHUA for clarification. Thus, some of the interpretations of SCWHUA rates, assumptions, loss costs used, analyses performed and conclusions made and reported below may benefit from additional analysis. Again this quick review of the SCWHUA rates is to help SCDOI to ask the right questions, make requests for information and analyze the filing rates.”

The SCDOI sent the initial draft of these recommendations and guidelines to SCWHUA for their review and comment. SCWHUA provided a response to SCDOI on July 13, 2013. This response is included in Attachment 5 of this final report. Whenever appropriate the remaining part of this Recommendation subsection was revised to address the cited response from SCWHUA.

The panel felt that even if the models used in South Carolina are based on sound meteorological, engineering and actuarial principals, and employ appropriate methods and data – and thus are reasonable and acceptable for use in South Carolina – the important questions to ask are how the outputs of these models are generated and used in setting the rates for South Carolina. These guidelines and recommendations are based on the expertise of the panel on the development and appropriate use of hurricane catastrophe models, how the input data should be prepared, and how the output should be interpreted and used in a rate filing. The intent here is to generate a set of generic guidelines and recommendations for SCDOI to use when they are reviewing the submitted rates for approval. The guidelines and recommendations provided by the panel of experts are mostly in terms of questions to be asked and information to be requested regarding rate filings that include hurricane catastrophe models.

Assuming that appropriate model(s) are used for loss costs and probable maximum loss level computations, there are three broad areas the panel recommends to SCDOI to consider, when reviewing hurricane rate filings:

- What are the values used for inputs and options into the model(s) that affect the outputs (loss costs and probable maximum loss levels)? The variables typically include risk characteristics such as policy information, risk location, primary and secondary characteristics for different construction classes, mitigation features, and unknown vs. known parameters;



- What control variables are used? These might include, but are not limited to, whether short-term, mid-term, and long-term views of the hurricane frequencies are used; inclusion or exclusion of demand surge; inclusion or exclusion of losses due to storm surge, waves, and flooding; whether or not users have provided their own vulnerability functions or modified the “standard” vulnerability functions in the approved model; damage or loss level(s) (in terms of total percentage of total loss) determining what is regarded as a “total loss”; replacement value vs. insurance limit, and whether or not deductibles are a percentage of limit, or replacement value; whether or not losses due to tropical storms which never become hurricanes are included in the analysis; whether or not default values preferred or suggested by modeling companies are used or the values are selected or set by users; and any other factors that might impact loss costs.
- How the results output from the model(s) were interpreted and used to arrive at rates.

The panel of experts has developed the following list of typical questions that the SCDOI might consider asking for addition information in a rate filing, based on a review of premiums for the sample properties provided by SCWHUA:

1. **Are the rates based on model(s) that have been reviewed and accepted by the Florida Commission (FCHLPM), but with appropriate modifications for hurricane frequencies and characteristics and vulnerability models (building codes, etc.) appropriate for South Carolina?** It should be noted that the panel of experts does not sanction one model over another. Moreover, the panel of experts does not recommend that one model to be used or more than one model to be used for rate filing. These decisions are up to the filing companies subject to review by SCDOI.

In its initial draft the panel of experts notes that “in the example case of SCWHUA rates, it is stated “AIR CLASIC\2 version 13.0.0 with the US Standard 10k Hurricane event set was used for modeling.” (*information redacted*) The rate filer should describe the characteristics of the version being used for loss costs (*information redacted*). This description should clearly document any differences in the model inputs, options or control variables between the versions approved by the FCHLPM and the model being used in the rate filing.”

SCWHUA responded to the above by:

“AIR CLASIC/2 v13.0.4 was accepted by the Florida Commission on January 13, 2012. SC Wind used the v13.0.0, which is essentially the same model.”



Note that in the SCWHUA correspondence, “SC Wind” is the same as SCWHUA, and SC DOI corresponds to SCDOI (South Carolina Department of Insurance) used throughout this report.

Again, AIR in its submission (*information redacted*). So even if AIR CLASIC/2 v13.0.4 and v13.0.0 model versions are essentially the same model, (*information redacted*).

The panel recommends that for such cases the equivalency of the two versions, in this case CLASIC/2 v13.0.4 and v13.0.0 be demonstrated as a minimum following FCHLPM procedure (i.e., reproducing Forms A-4, A-8, and S-5 by the two versions) plus reproducing Forms SC-2 and SC-3 by the two versions and demonstrating that the results are the same. In a similar manner, it is also recommended that any model version, used for SC rate filing, other than the once(s) accepted by FCHLPM, be demonstrated to produce same results.

It is understood the loss costs produced and used to arrive at rates (premiums) are pure premiums and do not account for reinsurance.

In its response to initial draft of the report, SCWHUA make the following statement as QUESTION 1:

*There is no requirement in South Carolina that insurers use
“Florida Approved Models.””*

Although the above is currently true and applies to previous rate filings, it is the recommendation of the panel of experts to require such approval as a starting point for models used South Carolina rate filing. The panel also recommends in addition to such required approval, certain other aspects of the models specific to South Carolina be examined, e.g., hurricane rates and characteristics impacting South Carolina, roughness lengths/databases used for South Carolina, characteristic of constructions and building stock in South Carolina, building codes etc. One reason for the panel of expert to make such recommendation was to reduce the extensive effort needed to completely review each mode anew and from scratch for South Carolina. By building upon the results of FCHLPM, the review of models approved by FCHLPM for application to South Carolina is reduced extensively. It is as SCDOI discretion to whether or not to follow the panel recommendations.

SCHWUA makes the following statement in response to the draft report:

“Our modeler noted that the use of Near Term models for ratemaking is more consistent with actuarial standards for rate making, but their standards always allow for regulatory compliance. SC Wind is aware that SC DOI requires the use of long-term models.”



It is not clear to the panel of experts whether or not long term or near term models have been used by SCWHUA “modeler” or what is the intent of the above statement. The panel of experts, consistent with FCHLPM, recommends the use of long term models for rate filings in South Carolina.

SCHWUA also makes the following statements in response to the draft report:

“It is important to note the Florida review process slows the implementation of new models, so there will often be timing differences. This is a challenge for insurers who must deal with reinsurers, catastrophe bond markets, financial organizations offering lines of credit, and other alternative risk transfer mechanisms who are able to implement newer models at a much faster rate.”

Although the panel of experts generally agrees with the above statement, it should be noted the Florida review cycle used to be annual, and the cycle was changed to biannual, which was supported by the modelers. However, as mentioned before, FCHLPM has a well defined procedure in place for demonstration of equality among various versions.

In its draft report, the panel of experts notes “it is also not clear what is meant by “10k hurricane event set”. As stated in the AIR response to the panel of experts, (**information redacted**). In their submissions to the Florida Commission (Ref. 3), AIR uses 50,000 years of simulated hurricanes; this same approach would result in roughly (**information redacted**) stochastic hurricanes making landfall in South Carolina. So one might ask what the relation of 10k hurricane event set is to the 50,000 year event set developed for Florida. If “10k event set” means 10,000 years of simulated “South Carolina” hurricanes, the SCDOI might be concerned as to whether the model has enough South Carolina events to be sure that its results are stable, given that the state with fewer landfalls than Florida. The SCDOI might ask for evidence that the results are reproducible to a pre-determined level of accuracy (e.g., Ref. 3 under the Statistical Standards).”

SCWHUA makes the following statements in its response to the draft report:

“The 10k refers to 10,000 years of simulation. This is the same time period used by SC Wind in all rate filings, reinsurer submissions and PML studies. The years of simulation certainly can be increased at the request of the South Carolina Department of Insurance.

It is important to note that South Carolina’s coastline is 14% of the length of the state of Florida coastline. It is also much less complex. It is plausible that the 10,000 event set produces roughly the same accuracy in South Carolina as the 50,000 event set does in Florida. This is especially true when you consider that AIR uses importance



sampling, which implies that the 50,000 event set isn't five times as accurate as the 10,000 set.

The modelers at Aon Benfield note that the 50,000 year event set isn't used anywhere by any company except in Florida.

Unfortunately, if the SC DOI requires the 50k event set to be used, modeling for multi-state companies becomes considerably more time-consuming. While increasing the number of years of simulation would not be a major inconvenience for single-state companies such as SC Wind and South Carolina Farm Bureau, it most likely will be an issue for other companies.”

The discussion regarding small size of South Carolina relative to Florida does not necessarily support using less number of years of simulations. As a matter of fact the smaller the geographical size of polygon the more number of years of simulation needed for same level of accuracy. Regardless, if it can be demonstrated that 10,000 year event set and 50,000 year event set produce the same results for FCHLPM Forms A-4, A-8 and S-5 as well as Forms SC-2 and SC-3, then the panel recommends accepting the 10,000 year event set model for South Carolina rate filing.

In its draft report the panel of experts notes that “the model output loss costs submitted by AIR are different from loss costs used by SCWHUA, which were also produced by a version of the AIR model.

Section redacted

SCWHUA makes the following statements in its response to the draft report:

“QUESTION 2: We are not aware of what model versions were used by the panel. We are not aware of the options and settings used by the panel. We do not have access to the output. For that reason, we cannot reconcile any differences. We will be glad to look at any provided data.

The example cited referenced the 3% deductible. SC Wind deductible factors were set several years ago. There is a need for stability in the rating mechanism. We do not re-model such factors every year.

It should not be a surprise that SC Wind's model results differ from AIR's. While the panel was extremely helpful to us in the process, they gave very little direction in terms of specifics. We were informed that we should fill in gaps with whatever assumptions we wanted and document what we did.



SC Wind believes that the assumptions used in our filing are equal to or better than the assumptions used by AIR. We feel that we have a good understanding of our book of business. We should be able to reconcile the differences if given access to both input and output data sets.”

Each model has various input parameters that are set or selected from available options by the user of the model. The user may be the modeling company personnel, insurance company personnel, insurance brokers, reinsurers, or any other applicable third party. Even working within reasonable constraints, different users may set or select different values for these input parameters. Different inputs will quite possibly result in different model outputs, e.g., loss costs, for the same property.

Section redacted

These large deviations could be due to differences in the specific input variables selected. It is recommended that the SCDOI request from insurers submitting a rate filing ALL of the model inputs set by the user, along with the reason and justification for each selection. If the model options chosen deviate from those prescribed in model versions approved by the FCHLPM, and that difference is not due to state-specific constraints (e.g., building code), this could warrant additional scrutiny by the SCDOI.

3. SCDOI should request a description of the methodology and its basis for converting between the model output (loss costs) and the premiums (rates).

For example out of 33 properties located in Zone 1, the premium for wood frame owner construction is \$6,470 for 20 of properties, \$5,823 for 5 of the properties, and \$4,788 for 8 of the properties. Moreover, the loss costs associated with these 43 properties do not necessary support such a reduction, i.e., there are properties with a \$6,470 premium which have lower loss cost than some of the properties with \$5,823 premium.

Although models may have the capability to provide different loss costs based on different characteristics of each insured property, the properties may be lumped together and averaged into a class of properties. However, some of these characteristics may demonstrate distinct behavior with sharply different loss costs; these characteristics should not be lumped together. One example is year of construction, which might be a proxy for the building code in place at the time of construction of a property. For example SCWHUA rates ignore the building construction and provide the same premium for 68 sample properties. So a property built in 1970 has the same premium as one built in 2012, everything else the same (e.g., roof shape, roof cover, opening reinforcement, location, etc.). Properties built at later dates should generally be assessed a lower loss cost (rate),



but this is not the case with the SCWHUA rates. SCWHUA also makes the following statement in its response to the draft report:

“It should be noted that the Florida Commission has no role in determining how the models they accept are used in ratemaking.”

Although the panel generally agrees with the above statement, one role of this report is to provide the SCDOI with some guidelines on how the accepted models are used for rate filing and how to evaluate the rates considering the features and characteristics of hurricane catastrophe models and how the accepted models might be misused.

Finally, SCWHUA makes the following statement in its response to the draft report:

“Year of Construction (YOC) is reported in the modeling process. If YOC was used in rating, there would be a mass conversion to newer construction dates. SC Wind would then need to undertake a major project to verify YOC.”

Although the panel of experts understand the issue raised by SCWHUA, it still has the question that then what YOC has been used or should be used for all properties and why? Such a constant year penalizes possibly better constructions (newer constructions). The panel of experts believes it is very important to use appropriate year of construction when it is available. This is a recommendation, and the final decision should be made by SCDOI.



7. References and Further Information

1. Florida Commission on Hurricane Loss Projection Methodology, “Report of Activities as of December 31, 2011”, published by Florida State Business Administration, Tallahassee, Florida, December 31, 2011, website: www.sbafla.com/methodology National Hurricane Center (NHC) of the National Weather Service (NWS), “Atlantic Hurricane Database 1851-2012 - Best Track Data (HURDAT2)”, (<http://www.nhc.noaa.gov/data/hurdat/hurdat2-atlantic-1851-2012-021513.txt>), NOAA, February 2013.
2. Landsea, Chris, James Franklin, and Jack Beven, “The revised Atlantic Hurricane Database (HURDAT2)”, <http://www.nhc.noaa.gov/data/hurdat/hurdat2-format-atlantic.pdf>, published by NOAA, February 2013.
3. The most recent Professional Team Reports as of the expected publication of this Report may be found at the following site:
<http://www.sbafla.com/methodology/Meetings/tabid/783/method/Meetings/PreviousYears/tabid/800/method/Meetings/PreviousYears/2011MeetingMaterials/tabid/1411/Default.aspx>
4. National Hurricane Center (NHC) of the National Weather Service (NWS), “The Saffir Simpson Hurricane Wind Scale”, (<http://www.nhc.noaa.gov/aboutsshws.php>), NOAA, February 2012.
5. Powell, M.D., E. W. Uhlhorn and J. D. Kepert, 2009: Estimating Maximum Surface Winds from Hurricane Reconnaissance Measurements. *Weather and Forecasting*, **24**, 868-883.



8. Definitions and Acronyms

Accurate

A model that meets standards that have been developed to assure scientifically acceptable loss cost projections and probable maximum loss levels is determined to be accurate.

Additional Living Expense (ALE)

Additional living expense is the cost to a resident of not being able to inhabit their usual place of residence. ALE may be claimed even if a structure is intact, for example, if access to infrastructure (power, water, bridges and roads) is lost to the location.

Appurtenant Structure

An outbuilding or additional structure (for example, carport or pool enclosure) that is not integral to the main building being insured.

Central Pressure

See Minimum Pressure.

Climatology

Long-term behavior of (in this case) hurricanes.

Damaging Wind

The windspeed at which damage begins to accumulate in the hurricane loss model. Damaging wind may be based on *sustained wind* or *gust windspeed*.

FCHLPM

Florida Commission on Hurricane Loss Projection Methodology, also referred to here simply as the *Florida Commission*.

Gust

Windspeed measured over a time much shorter than one minute (typically 2–3 seconds).

HURDAT

An older version of the *HURDAT2* database. HURDAT includes only track and intensity information for all known North Atlantic tropical cyclones since 1851. HURDAT was replaced by the more comprehensive *HURDAT2* database in February 2013 (Refs. 2 and 3).



HURDAT2

A database that includes the track, intensity, and various size measures of all known North Atlantic tropical cyclones (this includes all tropical storms, hurricanes and subtropical storms) since 1851. HURDAT2 is created and maintained by NHC. More information on HURDAT2 is given in Refs. 2 and 3.

Hurricane Loss Model

Computer simulation models designed to calculate loss costs specific to the hurricane risk at an insured location. Also referred to variously as: *Hurricane models*, *Hurricane risk models*, *Hurricane simulation models*, *Stochastic models*.

Hurricane Risk

As simulated by the *hurricane loss models*, hurricane risk is the most likely average loss due to hurricane wind damage, when taken over a length of time (centuries to millennia) adequate to ensure that the full range of hurricanes has passed through that location.

Intensity

The intensity of the hurricane, measured as the maximum windspeed associated with the storm. The *maximum winds* (V_{max}) are (by definition) found at R_{max} . In other studies, the *minimum pressure* at the storm center (p_{min} or P_{min}) is also used as a measure of intensity.

IBC

International Building Code.

Land Use and Land Cover (LULC)

Description of the land surface properties that impact the surface winds being simulated to estimate hurricane wind-driven property damage.

Landfall

When the center of a hurricane or tropical storm crosses the coast from sea to land.

Maximum Wind

The fastest 1-minute averaged windspeed measured at a height of 33 feet (10 meters) above the ground (referred to as V_{max}).

Minimum Pressure

An alternative measure of the intensity of the hurricane based on the lowest surface pressure in the storm center (referred to as p_{min} or P_{min}), and measured in units of mb (millibars). The use of *maximum wind* for intensity is recommended here. Another term for this is *central pressure*.



Mitigation Feature

A feature added to a building that is intended to strengthen that building in the event of a hurricane. One example is hurricane shutters.

NHC

U.S. National Hurricane Center of the NWS.

National Oceanic and Atmospheric Administration (NOAA)

NOAA is a branch of the Department of Commerce and is the oversight body for the National Weather Service, the NOAA Corps (Hurricane Hunters) and various other weather and climate agencies, as well as fisheries and ocean services.

NWS

U.S. National Weather Service, tasked with weather and climate forecasting for the nation.

Radius of Maximum Winds (Rmax)

The distance from the storm center at which the strongest rotating winds are found.

Reliable

The model will consistently produce statistically similar results upon repeated use without inherent or known bias.

Saffir Simpson Hurricane Scale

A windspeed classification system originally designed to provide an estimate of expected property damage due to passage of a hurricane (<http://www.nhc.noaa.gov/aboutsshws.php>).

SCWHUA

South Carolina Wind and Hail Underwriting Association.

Secondary Characteristic

An additional feature within a general building class that might influence the performance of a building in that class. For example, a masonry home with a gable roof might respond differently to hurricane winds than the same construction with a hip roof.

Size

A measure of the area of dangerous or damaging winds. Size measures in the HURDAT2 database include *Rmax* as well as the radii of hurricane-force and storm-force winds and gales.



Stochastic Model

Another name for *Hurricane loss model*, used because it describes the stochastic (statistical) methods that are the basis of current hurricane loss models.

Stochastic Storm

A hurricane simulated by the hurricane loss model.

Subtropical Storm

A cyclone that forms in the subtropics (north of 20° N). Many of these are included in HURDAT2 since they often evolve into *tropical cyclones*.

Sustained Wind

Windspeed at a height of 10 meters above ground, averaged over one minute.

Time element (TE) Loss

See *Additional Living Expense (ALE)*.

