

A SIMPLIFIED HURRICANE THREAT INDEX MODEL FOR COASTAL JURISDICTIONS

by Walter G. Green III, Ellen M. Walk, and Nezhil Altay

Copyright 2003 by Walter G. Green III, Ellen M. Walk, and Nezhil Altay. All rights reserved. Permission to reproduce copies for instructional use and individual copies for personal use as needed is granted to university faculty, researchers, and students.

PROBLEM:

(1) How can we compare the threat of hurricanes to the coastal states of the United States, and then compare that threat between coastline jurisdictions within a state? This paper suggests a first approach to the generalized modeling of such threats in order to better understand fundamental relationships and provide a point of departure for more detailed efforts.

(2) As an initial effort, this model concentrates on threat, rather than vulnerability or impact. It was designed to focus on coastal jurisdictions because the threat to these appears to be easier to characterize than that to inland jurisdictions, which may also fall within a hurricane's rain bands or wind fields. It is our intent to test this model for utility and then examine potential enhancements that may widen its ability to undertake more sophisticated threat analysis or to examine vulnerability or impact.

Table 1. Hurricane Incidence Data 1528-1995

	Florida	Georgia	South Carolina	North Carolina	Virginia
First year of data	1528	1752	1686	1586	1667
Coastline	1197 miles	100 miles	187 miles	301 miles	110 miles
Landfalling storms	198	30	41	30	16
Landfalling storm every	2.4 years	8.1 years	7.5 years	13.6 years	20.5 years

Note: Florida data reflects three coastal regions, the eastern Atlantic Coast, the western Gulf Coast and Florida Keys, and the Florida Panhandle. It is not unusual for a single storm to impact at least two of the three coasts.

Sources: Longshore, David, Encyclopedia of hurricanes, typhoons, and cyclones, New York, NY, Facts on File, Inc., 1998.

HURRICANE DESCRIPTIONS:

(3) Measures of hurricane threat are most frequently expressed in broad terms, for example, as the number of hurricanes or the frequency with which a hurricane impacts a state (see Table 1) (Longshore 1998, United States 1999), in terms of specific forecasts of numbers of events for individual hurricane seasons (Gray, Klotzbach and Landsea 2002, Saunders and Lea 2003) (although Elsner and Niu published a five year forecast in 2002), or in terms of the intensity of a given storm (Ludlum 1982). This data provides a sense of the level of threat, but does not provide a measure that allows comparison across time and location or analysis of alternative future threats.

(4) Threat may be defined as the operationalization of a hazard, the addition of some indication that a generalized hazard faced by a political jurisdiction on a conceptual level may be translated into a physical disaster impact. In the United States, all disaster response is initially and essentially local in nature, and the structure of policy and planning, communications, and resource allocation is driven by the individual states. Therefore, an examination of threat would seem to be most productive when based on local jurisdictions (counties and independent cities) and states.

THREAT INDEX METHOD:

Objective:

(5) Our objective was to create a threat analysis method that would provide a tool suitable for macro level comparisons, could use easily available data, required no advanced mathematical skills, and resulted in measures easily understood by practitioners without a mathematical or modeling background. The intent was to create a model that allowed comparison of data from differing time periods, not only because existing data reflects differences based on when storms started to be recorded, but also to allow the comparison of time periods for futures forecasting.

(6) In constructing a threat index, as in constructing any model, the difficulty becomes the identification of the specific parameters to include in the model's computations. This difficulty is increased in the case of hurricane threat modeling by the wide variety of parameters that contribute to the impact of a storm – including characteristics of the sea bed and shore line, speed of advance of the storm, rainfall, tide level including phase of the moon, wind field size, etc. The relationship of these parameters to impact and to each other is not completely understood; for example, the threat posed by inland winds and inland flooding (American Meteorological Society 1993) has only recently been examined. In addition, although increasingly accurate data is available describing these variables in the years from 1900 forward, data on earlier storms is sketchy at best in many cases (Brinkley 1999). Therefore, we deliberately used the simplest measures we could identify as the basis for the model.

(7) It is important to stress that the intent of this model is not to predict the probability of a hurricane event in a given year, or even to suggest a general probability

of hurricane landfall in a jurisdiction. Rather, based on either historical or futures data, it is intended to provide a general comparison of the threat level between states, and individual political jurisdictions. The futures application is important, we believe, because it provides the opportunity to examine the effects of changes in incidence of landfall either for a specific section of coastline or a specific time period.

Assumptions:

(8) The model assumes that landfall frequency is an accurate predictor of relative threat posed by hurricanes to a coastal jurisdiction. This in turn assumes that nearby landfalls (in which a segment of coastline is within the wind field of hurricane force winds), off-shore passage, and inland passage hurricane events will be approximately evenly distributed with approximately the same relative incidence as landfall events. A related assumption is that, for the purpose of macro analysis, landfall represents the most dangerous impact. Because one reaction to threat is the implementation of population protection measures, including evacuation (Gavin 1996, United States n.d.), that are largely coastline related, this assumption appears to be justified by operational practice.

(9) The model also assumes that hurricanes represent a jurisdictional threat that can be segmented by states, and then by local jurisdictions. This segmentation is assumed to result in an essentially even and random distribution of landfalls along the coastline of a given state. It is important to note that this model does not incorporate historical landfall probabilities within the boundaries of a state.

Formulas:

(10) We created two formulas for the model, a very simple one for assessment of threats to a state, and a slightly more complex one for threats to a political jurisdiction within a state. To determine the threat index for a state:

$$I = \frac{H}{T} \times 100$$

Where:

- I is the state threat index
- H is the number of hurricanes in the given time period
- T is the time in years of the time period

(11) This formula suggests that the threat of hurricane landfall in a state is defined by the relationship between the number of hurricanes and the length of the time period. The result is multiplied by 100 to provide a number that may be easier for a field practitioner to understand as a relative measurement. Based on the data in Table 1, Table 2 provides approximate state threat indices for the southeast United States coast. Note that these indices were developed to validate the process, and that improvements in the quality of the data will result in improvements in the accuracy of the index.

Table 2. State Threat Indices

	Florida	Georgia	South Carolina	North Carolina	Virginia
First Year of Data	1528	1752	1686	1586	1667
Exposure Period in Years	467	243	309	409	328
Landfalling Storms	198	30	41	30	16
State Threat Index	42.4	12.3	13.3	7.3	4.9

(12) To determine the threat index for a given jurisdiction within a state, for example, a city or county:

$$J = \frac{I}{M} \times L$$

Where:

- J is the local jurisdiction threat index
- I is the state threat index
- M is the length of the coastline of the state in miles
- L is the length of the coastline of the local jurisdiction in miles

(13) This formula apportions the state threat index to the coastlines of coastal jurisdictions within the state. It first identifies the contribution of each mile to the overall total and then multiplies that individual contribution by the miles of coastline in the jurisdiction. The relationship between the local jurisdiction's coastline and that of the state describes what portion of the overall hurricane target the local jurisdiction provides. Table 3 provides examples for coastal counties in each state.

A Comparison by Years for 1528-1995 and 1900-1996:

(14) The indices identified in Tables 2 and 3 are drawn from between 200 and 400 years of data (Longshore 1998). To triangulate this data, Table 4 provides the same indices for the period 1900-1996 (United States 1999), adjusted to reflect only the east coast of Florida. The information in this table should reflect the most accurate available storm data, as it represents the same time span for each state and data gathered through modern observation techniques.

Table 3. Example Coastal Jurisdiction Threat Indices

	Palm Beach County Florida	McIntosh County Georgia	Charleston County South Carolina	New Hanover County North Carolina	Accomack County Virginia
State threat index	42.4	12.3	13.3	7.3	4.9
Coastline	1197 miles	100 miles	187 miles	301 miles	110 miles
Jurisdiction coastline	42 miles	26 miles	73 miles	31 miles	42 miles
Jurisdiction threat index	1.5	3.2	5.2	0.8	1.9

Note: Coastline miles were measured from a commercially prepared roadmap book and should only be taken as illustrative.

Table 4. Threat Indices 1900-1996

	Florida	Georgia	South Carolina	North Carolina	Virginia
Landfalling storms	35	4	14	25	4
Threat index	36.5	4.2	14.6	26	4.2
Local jurisdiction	Palm Beach County Florida	McIntosh County Georgia	Charleston County South Carolina	New Hanover County North Carolina	Accomack County Virginia
Threat index	3.4	1.0	5.7	2.7	1.5

Source: United States, Department of Commerce, National Oceanic and Atmospheric Administration, National Center for Environmental Prediction, Tropical Prediction Center, National Hurricane Center, "U.S. Mainland Hurricane Strikes by State, 1900-1996," 1999, available at <http://www.nhc.noaa.gov/paststate.html>, accessed January 30, 2003.

(15) A comparison of the indices suggests that these do not stay stable over time, even when reasonably long time blocks are considered that should account for the effects of ocean oscillations. Indices for South Carolina (13.3 versus 14.6) and Virginia (4.9 versus 4.2) appear generally consistent. However, North Carolina (7.3 versus 26) represents what appears to be a major increase in threat, and Georgia a large decrease (12.3 versus 4.2). Given the number of Florida's events and differences in the data resulting from one pool representing the entire state and the other only the east coast, it is difficult to assess

the change in Florida's indices, but again the decrease (from 42.4 to 36.5) appears interesting.

Limitations:

(16) The resulting model has significant limitations. It does not differentiate based on characteristic storm tracks and does not account for the beach erosion, flooding, and other impacts of storms which pass off shore due to recurvature. Because it highlights landfall as the measure of storm impact, it does not account for significant events, such as Hurricane Camille (Longshore 1998), Hurricane Andrew (Rappaport and Sheets 1993), or Hurricane Floyd (Barnes 2001) (Green 2000), that cause considerable damage in other states subsequent to landfall, and that may actually do their most significant damage as they travel inland. Specifically it does not account for inland wind or rainfall effects, both of which have been increasingly recognized as major impact contributors. The model is designed for application to jurisdictions on a continuous continental coast; it does not appear to be particularly useful for examining threats to smaller islands. And the model does not attempt to differentiate between the size and physical impact of individual hurricanes, or the differences in these impacts due to public policy, beach and barrier island conditions, tide, or storm quadrant at impact.

AREAS FOR IMPROVEMENT:

(17) It may be that the value of the model could be increased by identification of the historical weighting of hurricane impacts for each segment of the coast through identification of actual landfalls of all available storms. However, the relatively small pool of available data in which it is possible to have high confidence suggests that landfall in specific segments may be an artifact of statistical chance and record keeping. In addition, it may be possible to refine the threat index by increasing sensitivity to hurricane category and accounting for the actual width of the hurricane force wind-field on landfall.

(18) It also may be possible to develop macro vulnerability and impact information from this model by the identification and inclusion of appropriate indicators. Vulnerability could be assessed by incorporation of population data, property values, and road network assessments. Impact information could be incorporated by comparing property value and loss data for prior events, adjusted against a baseline year, with the understanding that continued population growth in coastal areas makes such comparisons as much a comparison of demography and economics as it does of storm characteristics.

WORKS CITED:

American Meteorological Society. Hurricane Detection, Tracking, and Forecasting. Available at: <http://www.ametsoc.org/ams/policy/hurr2.html>. 23 April 1993.

Barnes, Jay. North Carolina's Hurricane History. 3d ed. Chapel Hill, NC: University of North Carolina Press, 2001.

- Brinkley, M. Kent. "The Hurricane History of Colonial Virginia to 1775." The Electronic Journal of Emergency Management, no. 1 (1999). Available at: <http://www.richmond.edu/~wgreen/ejem0102.htm>.
- Elsner, James B. and Xufeng Niu. Multi-Season Forecasts of North Atlantic Hurricane Activity: 2002-2007. Tallahassee, FL: Florida State University, 2002.
- Gavin, Joseph P. "Hurricane Evacuation Studies." Paper presented at the 18th Annual National Hurricane Conference. Orlando, FL, 2-5 April, 1996.
- Gray, William M., Philip J. Klotzbach, and Christopher W. Landsea. Extended Range Forecast of Atlantic Seasonal Hurricane Activity and US Landfall Strike Probability for 2003. Fort Collins, CO: Colorado State University, Department of Atmospheric Science, 2002.
- Green, Walter G., III. "And the Water Kept Rising: The Virginia Health and Medical (ESF-8) Response to Hurricane Floyd." The Journal of the American Society of Professional Emergency Planners (2000): 23-34.
- Longshore, David. Encyclopedia of Hurricanes, Typhoons, and Cyclones. New York, NY: Facts on File, Inc., 1998.
- Ludlum, David M. The American Weather Book. Boston, MA: Houghton Mifflin Company, 1982.
- Rappaport, Edward N., and Robert C. Sheets. "A Meteorological Analysis of Hurricane Andrew." Paper presented at the 15th Annual National Hurricane Conference. Orlando, FL, 13-16 April, 1993.
- Saunders, Mark, and Adam Lea. January Forecast Update for Atlantic Hurricane Activity in 2003. London, United Kingdom: University College London, Benfield Greig Hazard Research Centre, 2003.
- United States. Department of Commerce. National Oceanic and Atmospheric Administration. National Center for Environmental Prediction. Tropical Prediction Center. National Hurricane Center. "U.S. Mainland Hurricane Strikes by State, 1900-1996." Available at: <http://www.nhc.noaa.gov/paststate.html>. 1999.
- United States. Department of Transportation. Federal Highway Administration. "Hurricane Floyd Evacuation." Available at: <http://ops.fhwa.dot.gov/Weather/cases/EmergencyManagement/HurricaneFloydEvacuation.asp>.