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APPLICATION OF STOCHASTIC AND DETERMINISTIC MODELING TO HURRICANE WIND RISK ASSESSMENT

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1. INTRODUCTION

Assessments of hurricane wind risk must necessarily focus on the most intense events, which cause a disproportionate share of hurricane-related wind damage. Yet there are too few such events in the historical record to infer robust probabilities from the data alone. One partial solution to this problem is to generate a very large number of synthetic hurricane tracks, whose most important statistical properties conform to those of historical tracks. Although this is an important step forward, it remains to estimate the evolution of the storm wind field along the tracks. We here present an overview of two methods we have developed for generating very large set of synthetic hurricane tracks, and describe a technique for running a deterministic coupled hurricane intensity prediction model along each track. Details may be found in Emanuel et al. (2006).

2. HURRICANE TRACKS AS MARKOV CHAINS

The first step in both track generation techniques is to form a space-time genesis probability distribution from historical data. Tracks are then initiated as random draws from this distribution.

In our Markov method, each track is then stepped forward in 6-hour intervals by drawing time rates of change of track direction and speed from a probability distribution conditioned on statistics of those properties from historical track data, and on prior speed and direction of the track. By this means, we develop large sets of tracks whose basic statistical properties conform to those of historical tracks, and which have 'memory', which is also constituted from historical track data. A comparison of some basic statistical properties of tracks thus synthesized with historical tracks confirms the validity of this technique.

3. BETA AND ADVECTION MODEL (BAM)

Our second track generator initiates tracks as in the Markov method, but no historical track data is used thereafter. Instead, tracks are stepped forward using the 'Beta and Advection Model' (Marks 1992). This assumes that the storm moves with a weighted mean background wind in the troposphere, plus a correction for drift owing to the beta effect. In this case, we use winds only at 250 and 850 hPa. The winds themselves are generated from synthetic time series whose statistics are taken from NCEP re-analysis data or, if desired, global climate models. Specifically, we represent time series of each wind component at each level as Fourier series of random phase, but whose monthly means, variances and co-variances among the components are constrained to be equal to those derived from re-analysis or global model data, and whose power spectrum is constrained to be that of geostrophic turbulence. This BAM method also produces realistic tracks whose statistical properties compare very well to those of historical tracks.

4. INTENSITY MODELING

Having created large numbers of hurricane tracks by either of the aforementioned methods, the wind distribution along each track is calculated deterministically using the Coupled Hurricane Intensity Prediction System (CHIPS), as described in Emanuel et al. (2004). The model in this context uses climatological monthly mean potential intensity from NCEP re-analysis. Values of the vertical shear, which is an important influence on intensity evolution in CHIPS, are taken from the same synthetic wind fields used to generate the tracks in the BAM method. We also use the synthetic wind fields to generate shears used in the Markov method, but in this case the shear is independent of the track direction and speed.

CHIPS is initialized with an arbitrary, weak warm core vortex as the beginning of each track, and the track is terminated when the maximum wind speed falls below 13 ms^{-1}.

4. RESULTS

With the techniques described above, it is possible to generate roughly five thousand tracks and associated wind fields in 24 hours of wall clock time on a standard PC. The tracks can be easily filtered to pass within some arbitrary region, such as a zip code. Wind statistics can then be accumulated for a point or region of interest.

Figure 1 compares the cumulative frequency distribution of storm lifetime maximum wind for 1000 synthetic events in the North Atlantic for

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each of the two track methods to maximum wind speeds from best track data. The statistics from both methods compare well with climatology.

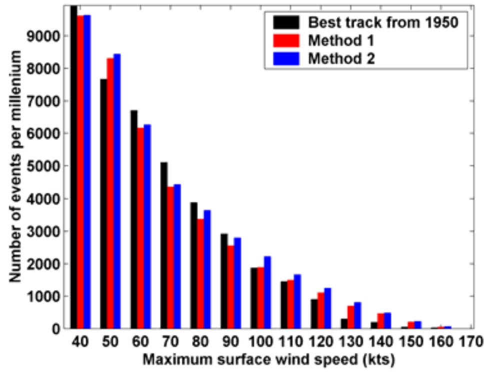

Figure 1: Cumulative histogram of maximum surface wind speed achieved along 1000 tracks generated by the Markov method (red) and the BAM technique (blue), compared to post-1950 HURDAT (black).

A cumulative histogram for maximum winds within 100 km of downtown Miami is shown in Figure 2, comparing 3000 events each for both track methods to the 29 events in HURDAT since 1920. Given the probably large error bars on HURDAT, owing to the small sample size, the comparison is quite good.

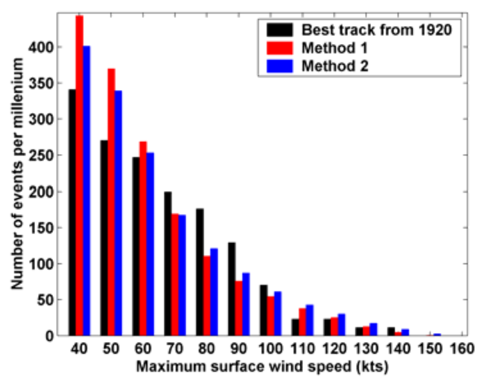

Figure 2: Histograms of frequency of exceedence of wind speed within 100 km of downtown Miami. Results from HURDAT data (black) are compared to model data for the Markov method (red) and the BAM method (blue). There are 29 events in the HURDAT sample versus 3000 in each track method.

Figure 3 shows the 100 storms that produced the greatest wind speed in downtown Boston out of 3000 events coming within 100 km of Boston as generated using the BAM method. For comparison, the track of Hurricane Bob of 1991 is also shown.

The BAM method can be used to generate wind risk statistics in any given climate state, as long as the statistics of the general circulation and potential intensity are available and if one can formulate a space-time genesis probability.

As a preliminary illustration of the power of this technique, we simulated 3000 events in a climate identical to our own (and with the same genesis statistics), but with the potential intensity arbitrarily increased by 10% everywhere.

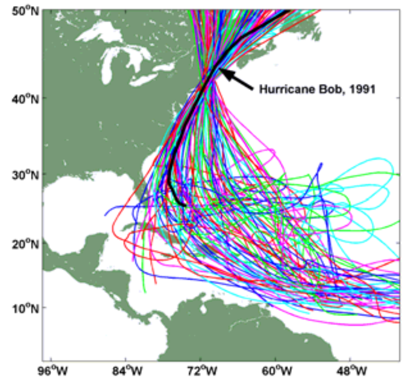

Figure 3: Tracks of the 100 most intense of the 3000 storms in the sample of storms affecting downtown Boston, using th BAM method. Shown for comparison (in black) is the observed track of Hurricane Bob of 1991.

Figure 4 compares the annual probability of U.S. landfall of storms by Saffir-Simpson category of the two climate states with inferences from HURDAT.

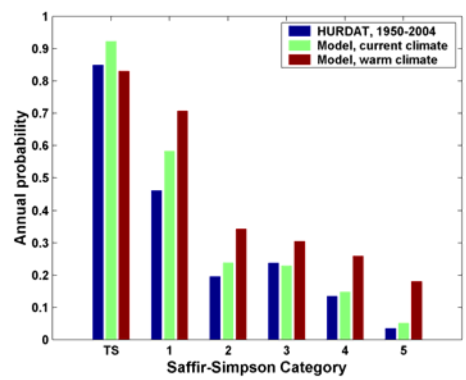

Figure 4: Annual probability of U.S. east coast landfall by category based on 3000 BAM tracks for HURDAT (blue), present climate (green) and 10% increase in potential intensity (red).

5. REFERENCES

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