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Tropical Cyclone Wind Characteristics for the Bangladesh Coast Using Monte Carlo Simulation

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Introduction

Wind and storm surge are crucial factors in the determination of how much damage occurs in the coastal regions in association with any particular hurricane or tropical cyclone. Since very few tropical storms actually strike at a particular site and historical records only exist for the past hundred years or so, there exist a limited number of observations at each site. This is a major problem when considering cyclone wind statistics for research. Batts et al. (1980) determined that it is not possible to use statistical analysis of the highest annual wind speeds at a particular site in order to determine the extreme wind speeds in hurricane-prone regions. Monte Carlo simulation is, therefore, used in this study as an indirect method to obtain the cyclone wind statistics for the Bangladesh coast.

The Holland (1991) wind field model is chosen and used to complete the Monte Carlo simulations. The essential parameters needed to generate a hurricane wind field in the Holland model are: storm heading or angle of attack, forward translation speed, radius of the maximum wind and central pressure. This paper describes the methodology of the Monte Carlo simulation and the probability distributions of the hurricane wind field parameters used in this study.

Data Resources

The primary data collected for central pressure dated from 1971 to 2003 and for the radius of maximum wind dated from 1981 to 2000. The corresponding data for the earlier storms are not available. The data of the radius of maximum wind are obtained from the Statistical Year Book of Bangladesh 2000 provided by The Bangladesh Meteorological Department (BMD). Data for other parameters are obtained from the Global Tropical Cyclone Climatic Atlas (GTCCA 1.0) database. The primary data collected for angle of attack and forward translation speed are dated back from 1877 to 2003.

The Sites

The sites chosen for the simulations are: Khulna, Barisal, Noakhali, Chittagong and Cox's Bazar. (Figure-1)

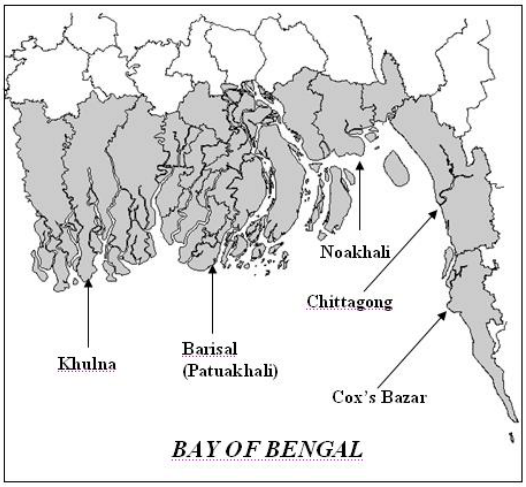

Figure-1 Sites used in simulations

Methodology

In order to use the primary data in the simulation probability density functions of the storm parameters must be specified. Best fit 4.5 software from Palisade is used to find the best fit distributions of the primary data. After obtaining the best fit distribution, a probability distribution table for each parameter is constructed (Table 1-Table 4).

The programs for the Monte Carlo simulation are written in FORTRAN. The first program randomly selects the four parameters needed to generate a storm and creates an output file of the 1000 randomly generated variables.

The second program runs the actual Monte Carlo simulation for each site using the storm information generated by the first program and the site information, which includes the bathymetry of the Bay of Bengal obtained from the nautical chart. This program generates 1000 simulated storms with maximum wind speed and

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surge height at landfall. Each storm is initially generated offshore a distance, which requires 20 hours for the storm to move ashore. After the landfall, the simulation lasts for 10 more hours in inland.

Data Distributions

Three different methods are used to find the best fit distributions. These are: Chi-Square, Anderson-Darling and K-S methods.

Table-1 Storm heading distributions. Units are in degrees clockwise from north. The percentages represent the probability the storm heading will be less than the given value.

Site	95%	83.33%	50%	16.67%	5%	Lower bound
Khulna	359	345	186	19.3	3.9	3
Barisal	359	354	183	21.6		3
Noakhali		203.6	57.5	19.94	11.18	7
Chittagong	151	97	60	40	30.76	17
Cox'sBazar	86	68.45	43.27	18.09		9

From Table-1, at Khulna the storm heading is sampled so that there is a 5% chance of selecting a storm heading of 359°, a 11.67% chance of selecting a storm heading of 345°, a 33.33% chance of selecting a storm heading of 186° and 19.3°, a 11.67% chance of selecting a storm heading of 3.9°, and a 5% chance that a storm heading of 3° will be selected for any simulation (the directions are in the meteorological system, where 0° was a storm which moved out of the true north, 90° was a storm which moved from east to west, 180° was a storm which moved from south to north, etc.). This same process is used in selecting the storm heading for all of the other sites.

Table-2 Forward speed distributions of five locations. Units are in knots.

Site	95%	80%	60%	40%	20%	5%	L.B.
Khulna	14.93	10.08	7.06	4.88	2.89	1.14	1
Barisal	15.19	12.09	9.82	7.87	5.59	2.49	2
Noakhali	15.48	12.55	10.39	8.55	6.39	3.46	2
Chittgong	24.47	18.25	15.35	13.41	11.51	9.27	4.2
Cox's Bazar	19.85	15.66	12.61	10.08	7.34	4.17	2

From Table-2, at Khulna the forward speed is sampled so that there is a 5% chance of selecting a speed of 14.93 knots, a 15% chance of selecting a speed of 10.08, a 20% chance of selecting a speed of 7.06, 4.88 and 2.89 knots, a 15% chance of selecting a speed of 1.14 knots, and a 5% chance that a forward speed of 1.0 knots is selected for any simulation. This same set of steps is used in selecting the forward speed for all other sites.

Since each site individually has too few data for the radius of the maximum wind (RMW) and central pressure, it is difficult to get any distribution from the data for each site. In order to get a distribution, data for the sites located at the western part (Khulna, Barisal and Noakhali) are combined together under 'west coast' and for the eastern part (Chittagong and Cox's Bazar) under 'east coast.' These distributions are then used for each site according to their respective location.

Table-3 RMW distributions. Units are in nautical mile.

Site	95%	83.33%	50%	16.67%	5%	Lower bound
West Coast	42.78	39.39	34.56	29.72	26.34	10
East Coast	46.08	41.98	37.03	32.08	27.98	10

From Table-3, at 'west coast', i.e. for Khulna, Barisal and Noakhali, the sample was such that there is a 5% chance of selecting radius of maximum wind of 42.78 nmi, a 11.67% chance of selecting a radius of maximum wind of 39.39 nmi, a 33.33% chance of selecting a radius of maximum wind of 34.56 nmi and 29.72 nmi, a 11.67% chance of selecting a radius of maximum wind of 26.34 nmi and a 5% chance that a radius of maximum wind of 10.0 nmi for any simulation. The same process is used in selecting the radius of maximum winds for the sites in 'east coast'.

Table-4 Central pressure distributions. Units are in milibars.

Site	90%	70%	50%	30%	15%	5%
West Coast	1001.22	987.56	978.09	968.82	959.38	948
East Coast	1014.56	985.72	965.75	945.78	926.27	903

From Table-4, the central pressure is sampled for the sites through the process as described above.

References: Available upon request.