CORRELATION OF TOPOGRAPHIC SPEED-UP FACTORS AND BUILDING DAMAGE RATIOS FOR HURRICANE FABIAN IN BURMUDA

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1. INTRODUCTION

While an extensive body of literature on the topic of boundary layer flow over small-scale topography has been published over the past 30 years, the paper by Walker *et al.* (1988) is one of the very few studies that has explicitly considered the effects of topography on surface wind speeds in landfalling tropical cyclones. This paper, which deals with the landfall of Cyclone Winifred on the North Queensland coast of Australia in February 1986, discusses topographic effects on surface wind speeds in a largely qualitative manner. In the case of one residential structure, however, which was located on the crest of a ridge that rose 70 m above the surrounding terrain and lay perpendicular to the direction associated with the strongest winds, it proved possible to quantitatively estimate the likely surface wind speeds. The resulting wind speeds were found to be sufficient to explain the damage observed to the structure,

In this study we use a linear model for boundary layer flow over topography to map the effects of topography on surface wind speeds during the passage of Hurricane Fabian over Bermuda on September 5th, 2003, and attempt to correlate the resulting wind speeds with the observed damage. In accounting for the effects of topography on surface wind speeds the standard method is to define a speed-up factor, which then acts as a multiplier on the equivalent surface wind speed above flat terrain. In areas where the speed-up factor is greater, the surface wind speed will be higher, thus one would expect more damage to structures in these areas, all other factors being equal. The goal of this project is to quantify the impact of topographic speed-up effects on the observed damage to structures.

2. HURRICANE FABIAN

Hurricane Fabian was a very strong, long-lived Cape Verde hurricane that made landfall on the island of Bermuda on September 5th, 2003.

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Although the eye of Fabian did not pass over Bermuda, the eastern eyewall did, with an intensity of approximately 100 kts, constituting a direct hit on the island. Hurricane Fabian was considered to be the most dangerous storm to affect Bermuda for more than fifty years. Although most of the prevalent limestone and concrete buildings successfully withstood the sustained winds, a significant portion of those buildings with traditional limestone slate roofs suffered partial roof failures (Rowe, 2003). It is the failure of these roofs, and the ability to properly identify these failures, that constitute a major data source for this project.

3. OVER-WATER SURFACE WIND FIELDS

The first step in this project is to accurately reconstruct Hurricane Fabian's wind field as the storm impacted the island of Bermuda. The starting point for the reconstruction is the Hurricane Research Division's (HRD) over-water surface wind analysis. An HRD wind analysis requires input from all available surface weather observations. This includes ships, buoys, coastal platforms, surface aviation reports, and reconnaissance aircraft data adjusted to the surface. Furthermore, all available satellite derived wind observations are processed, including Stepped Frequency Radiometer measurements of surface winds, and remotely sensed winds from SSMI, ERS, QuikScat, TRMM, and GOES cloud drift winds. All data from a 4 to 6 hour period are composited to a storm relative framework and quality controlled.

The damage to a building is assumed to be strongly correlated with the maximum wind experienced at that location. Therefore, in order to correlate speed-up factors to damage ratios, the maximum surface wind (speed and direction) at a location is a required input. The HRD wind analyses are only available for September 5th at 13:30Z, 19:30Z, 20:00Z and 23:03Z, however it is likely that the maximum surface winds in Bermuda were experienced sometime between the times at which synoptic wind field reconstructions were performed. Therefore, a series of snapshot wind fields were created at 15 minute intervals, using linear interpolation between reconstructed H*WIND wind fields. By doing this we are able to derive an over-water wind speed time history at each point on the island of Bermuda for which the topographic speed-up factors were defined

4. ROOF DAMAGE DATA

QuickBird is a high resolution satellite owned and operated by DigitalGlobe. Using a state-of-the-art BGIS 2000 sensor, QuickBird uses remote sensing to a 0.61m pixel resolution degree of detail. Following the landfall of Hurricane Fabian in Bermuda, the QuikBird satellite captured fine resolution digital imagery of structures on the island, as well as the damage sustained to such structures, mainly in the form of damage to the roof of the building, identified by tarps (mostly blue) (Fig 2a). An algorithm was developed to derive a damage ratio sustained for each building based on the percentage of rooftop covered by a blue tarp, indicating a specific level of structural destruction (Fig 2b). This data is coupled with a detailed building inventory to correlate damage ratios with speed-up factors derived from the topography model. A cross check of the imagery analysis was performed by comparing results against a field survey conducted 48 hours after the hurricane struck the island. Regions of the island where damage was underreported (not visible from the sky or not covered by tarps) were excluded from the analysis.

Figure 2a: QuikScat imagery of building damage on Bermuda

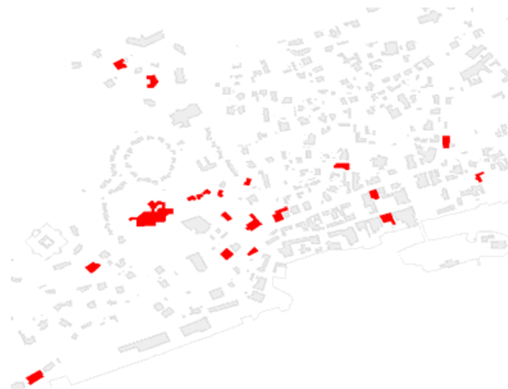

Figure 2b: Properties with roofs covered by tarpaulins mapped on a high resolution building inventory

5. TOPOGRAPHIC SPEED-UP FACTORS

To calculate the topographic speed-up factors we use the MS-Micro linear model for boundary layer flow over small-scale topography, described by Walmsley et al. (1986), in combination with a high resolution digital elevation model (DEM) of Bermuda. For the purposes of this study, the speed-up factors were calculated by first generating a grid of regularly spaced points with an interval of 100 m between grid points in both horizontal and vertical directions covering the over-land areas of Bermuda. MS-Micro was then used to calculate a set of directionally dependent speed-up factors for each grid point at an elevation of 10 m above local ground for 12 wind directions spaced at 30^o intervals and centered on 0^o, 30^o, 60^o, etc.

6. CONCLUSIONS

The maximum wind speed and wind direction derived using the HRD interpolated surface wind analyses are retained at each grid point for which topographic speed up factors have been calculated. The directionally dependent speed-up factor derived using MS-Micro is then applied as a multiplier of the given maximum wind speed at each location. These topographic speed-up factors are correlated to the observed damage of buildings derived using a QuikScat algorithm that identifies the percentage of roof covered by blue tarp. Final results will be presented at the conference.

This is one of the few times that research of this nature has been undertaken with such level of details. It is expected that this study will lead to a better assessment of uncertainty and limitations of models for understanding speed-up and the associated impact on structures.

7. REFERENCES

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