Mapping of Topographic Effects on Maximum Sustained Surface wind Speeds in Landfalling Hurricanes

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Observed Damage Due to Topographic Effects on Surface Wind Speeds

• Very little is known about the effects of topography on surface wind speeds in tropical cyclones
• What information we do have consists of largely qualitative observations from a number of storms, including:
  – Tropical Cyclone Winifred (1986)
  – Hurricane Iniki (1992)
  – Hurricane Marilyn (1995)
  – Tropical Cyclone Larry (2006)
Observed Damage to Structures in Tropical Cyclone Larry

Figure 5.4: Damage map for Innisfail East
(Map courtesy of Geoscience Australia)

Impact of Topographic Effects on Structures

Post-1982 structure built without allowance for topographic effects

Pre-1982 structure

Innisfail, Queensland after Cyclone Larry, March 2006
Factors That Influence Topographic Speed-up Effects

• Slope of topography in direction wind is blowing
• Surface roughness
  – increasing surface roughness leads to larger speed-ups
• Whether topography is 2-D (ridge) or 3-D (hill)
  – speed-up is reduced if topography is 3-D
• Onset of flow separation places an upper limit on the maximum speed-up
  – depends on both slope and surface roughness
Calculation of Topographic Effects

- Topographic effects calculated using MS-Micro linear model for boundary layer flow over small-scale topography, in combination with high resolution digital elevation models of Puerto Rico and the US Virgin Islands
- Directionally dependent speed-up factors calculated on a grid with a horizontal resolution of 240 m (USVI) or 990 m (Puerto Rico)
- Elevation of 10 m above local ground
- Eight wind directions spaced at 45° angles
Linear vs Non-linear Predictions of Speed-up over Askervein Hill, Outer Hebrides

Directional Speed-up Maps For St Thomas, USVI

Wind direction 90°
Directional Speed-up Maps For St Thomas, USVI

Wind direction 180°
Development of a Topographic Speed-up Mapping Tool

- Developed using MapWindow open source GIS package
- User selects an island, track heading and maximum sustained wind speed before plotting topographically enhanced wind speeds
- Wind speeds can be displayed in either 5 kt increments or by Saffir-Simpson category
- Major roads and population centres can be overlaid on wind speed map
- Potential to use surface wind fields from other sources (H*WIND, HWRF, etc)
Topographic Speed-up Mapping Tool
Topographic Speed-up Mapping Tool
Validation of Approach - Hurricane Fabian (2003) on Bermuda

- Eastern eyewall of Hurricane Fabian passed over the island of Bermuda on 5 September, 2003
- Topography of Bermuda consists of low rolling hills, rising to 76 m above sea level at their highest point
- Roof damage to structures mapped using high-resolution satellite imagery, and then correlated to 1-minute mean wind speeds obtained from H*WIND, with and without the effects of topography included
Mapping of Roof Damage

- Base layer showing building footprints from Bermuda Ministry of Works and Engineering combined with georeferenced Quickbird satellite imagery
- Calculated the percentage of the building footprint area covered by blue pixels (inferred to be tarpaulins)
Ground Truth
Calculation of Surface Wind Speeds

- Surface wind speeds calculated using H*WIND surface wind field analyses
- Data available at:
  - 13:30 Z
  - 19:30 Z
  - 20:00 Z
  - 23:03 Z
- Interpolated to 15 minute intervals to capture maximum 1-minute wind speeds
Correlation of Damage to Topographically Enhanced Wind Speeds
Summary

- Topographic speed-up effects can have a significant effect on surface wind speeds in landfalling hurricanes
- Linear model of boundary layer flow over topography used to map directional topographic speed-up factors for Puerto Rico and US Virgin Islands
- GIS based mapping tool developed to display topographically enhanced wind speeds given a track heading and maximum sustained over-water wind speed
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