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

JHT Year 1 Progress Report
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Project Synopsis

While the effect of large-scale topography, such as that found on Hispaniola, on the overall structure of a hurricane passing over such topography is reasonably well understood, forecasters at the Tropical Prediction Centre/National Hurricane Centre (TPC/NHC) currently have no means available to them to assess the impact of small-scale topography on surface wind speeds in hurricanes making landfall over such terrain. This project uses the MS-Micro linear model for boundary layer flow over small-scale topography, described by Walmsley *et al.* (1982), Taylor *et al.* (1983), and Walmsley *et al.* (1986), in combination with the US Geological Survey's National Elevation Dataset (NED) to map the effects of topography on surface wind speeds at a height of 10 m for Puerto Rico and the US Virgin Islands. The intended primary outcome of the project is a set of maps showing contours of speed-up factors that can then be used by a forecaster to assess the effects of topography on maximum sustained surface wind speeds in hurricanes making landfall in Puerto Rico or the US Virgin Islands. It is anticipated that a successful conclusion to the project would lead to an improved ability to forecast maximum sustained surface wind speeds in areas with significant topography as identified in TPC/NHC hurricane forecaster priority TPC-6.

Progress Report

The past five months have focussed on the calculation of speed-up factors for the US Virgin Islands and Puerto Rico using the software tools described in the previous progress report. At the start of the project it was thought that speed-up factors would be calculated at an elevation of 10 m above local ground for 12 wind directions spaced at 30^o intervals and centred on 0^o, 30^o, 60^o, etc. At the suggestion of Jack Beven during discussions at the Interdepartmental Hurricane Conference in Mobile, Alabama in March, 2006, this was subsequently modified so that speed-up factors were calculated for 8 wind directions spaced at 45^o intervals and centred on 0^o, 45^o, 90^o, etc. The elevation above local ground at which they were calculated remained unchanged at 10 m. Speed-up factors were calculated assuming open-water conditions with a roughness length such that $z_0 = 0.003$ m, the latter value being based on the work of Powell et al. (2003). For the US Virgin Islands speed-up factors were calculated using a regularly spaced grid with a separation of 240 m in both directions between grid points, while for Puerto Rico a separation of 990 m between grid points was used. The choice of the grid point separation distance is largely dictated by the need to balance the horizontal resolution of the speed-up factors with the computational effort required to calculate them.

Figure 1 shows an example of the resulting speed-up factors for the island of St Thomas in the US Virgin Islands for a wind direction of 135^{o} overlaid on a contour map of the underlying topography. Reductions in the wind speed both at the foot and in the lee of the topography can be identified, together with marked increases in the wind speed along the main ridges running perpendicular to the wind direction. A certain amount of caution must be applied in interpreting the maximum and minimum values for the speed-up factors indicated in Fig. 1. This is because the MS-Micro model being used to calculate the speed-up factors is a linear model and on steeper slopes non-linear effects will become increasingly important. An attempt to indicate regions where the speed-up factors should be treated with caution has been made by adopting the use of a hatched, rather than a solid fill, for the speed-up contours in these regions. For forecasting purposes a conservative approach would be to neglect any indicated reduction in wind speeds and to concentrate on those areas where the speed-up factor is greater than 1, indicating an increase in wind speed relative to the reference wind speed at a height of 10 m above flat terrain.

One question that came up in the course of discussions during a visit to the TPC/NHC in June 2006 was the impact of changes in the underlying surface roughness, not just in transitioning from open-water to over-land conditions but also in the natural variations in surface roughness that one finds over land. In particular, although for a given hill slope increasing the surface roughness can lead to increases of up to 10% in the speed-up factor, at the same time the net effect of a change in surface roughness from open-water to over-land conditions will be to reduce the mean wind speed. The version of MS-Micro being used also includes a model for the effects of surface roughness changes on the mean wind speed, although to date this capability has not been used. To explore the impacts of surface roughness changes on the resulting speed-up factors we propose to repeat the already completed calculations by firstly considering the case in which we have two surface roughness values, one for open-water conditions, the other for open-terrain conditions. A check of the data available on the US Geological Survey's (USGS) seamless data server (http://seamless.usgs.gov) shows that a Land Use Land Cover (LULC) database with a horizontal resolution of 1 km is available for both Puerto Rico and the US Virgins Islands. Although the resolution of the database is rather coarse, particularly for the US Virgin Islands, it does allow us the possibility of then carrying out a third set of calculations using appropriate roughness length values mapped to the LULC classifications to explore the impact of the actual surface roughness variations.

One of the challenges of this project has been finding a way in which the information can be packaged for use by forecasters at the TPC/NHC. To this end Jack Beven has suggested that implementing the maps using an approach similar to that currently used by TPC/NHC to display Maximum Envelope Of Water (MEOW) maps derived from SLOSH model runs would be an appropriate way of presenting the information. In this case one would select the island territory being considered, before then selecting the track of the storm. Rather than classify the storms by Saffir-Simpson category a more appropriate means would be to select the maximum sustained surface wind speed in kts, before applying this value to the speed-up factors to calculate the resulting wind speeds. At the time of writing a proof of concept model has been programmed using MapWindowGIS, an open source GIS package, a screen shot of the proposed layout being shown in Figure 2. The model still needs to be integrated with the underlying data files, but the intention is to deliver a prototype to TPC/NHC for testing and evaluation by the end of July 2006.

Other Issues

As noted in the midyear progress report a request for a copy of the report detailing the results of the wind tunnel study of Chock *et al.* (2002) had been made under the Freedom of Information Act to NASA's Goddard Space Flight Centre, the original sponsors of the study. A response was received in early June 2006 to the effect that this request had been forwarded to NASA's Office of Public Affairs for consideration. To date nothing further has been heard.

Future Work

Work for the next month will focus on the completion of the effects of surface roughness changes on the calculated speed-up factors and delivery of prototype software for the display of the speed-up maps to TPC/NHC for testing and evaluation. Of continuing concern is the lack of progress in obtaining a copy of the report detailing the results of the wind tunnel study of Chock *et al.* (2002), which was intended to form a major part of the validation process during the second year of work on the project. A limited amount of validation work may be able to be undertaken using observed wind speed data from events such as the passage of Hurricane Marilyn over the US Virgin Islands in 1995, and Super-Typhoons Paka and Pongsona over Guam in 1997 and 2002 respectively, but validation of the MS-Micro calculations using the results of the wind tunnel study of Chock *et al.* (2002) would be preferred

References

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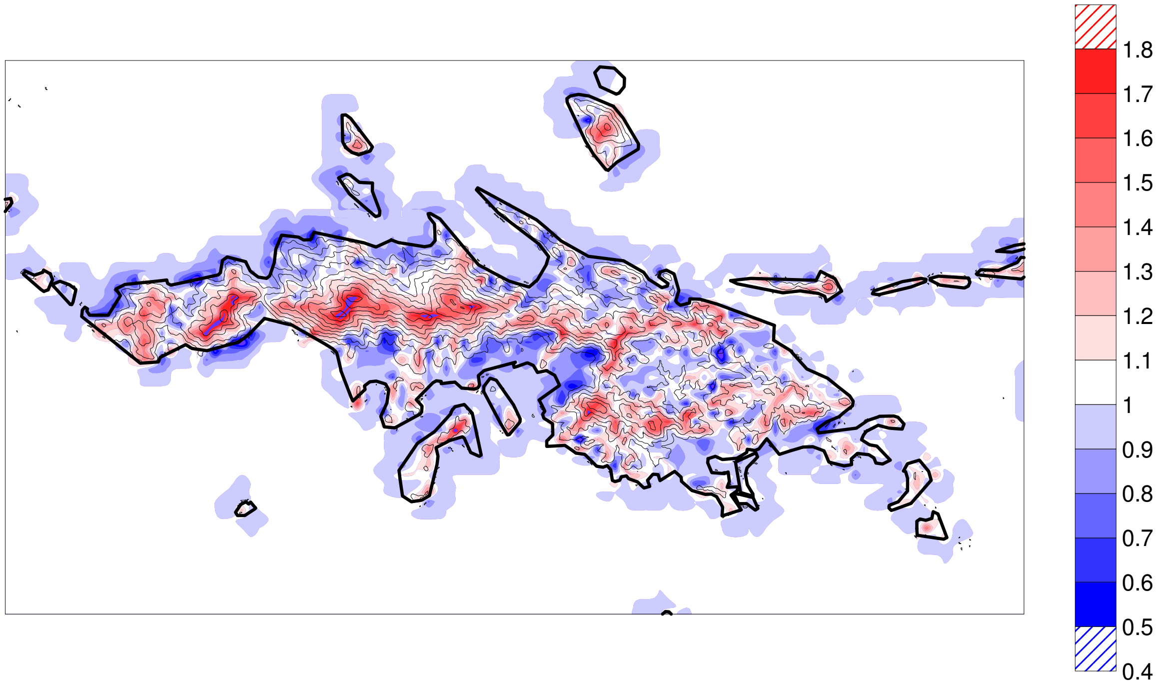

Figure 1: Calculated speed-up factors for the island of St Thomas, US Virgin Islands, for a wind direction of 135^{o}

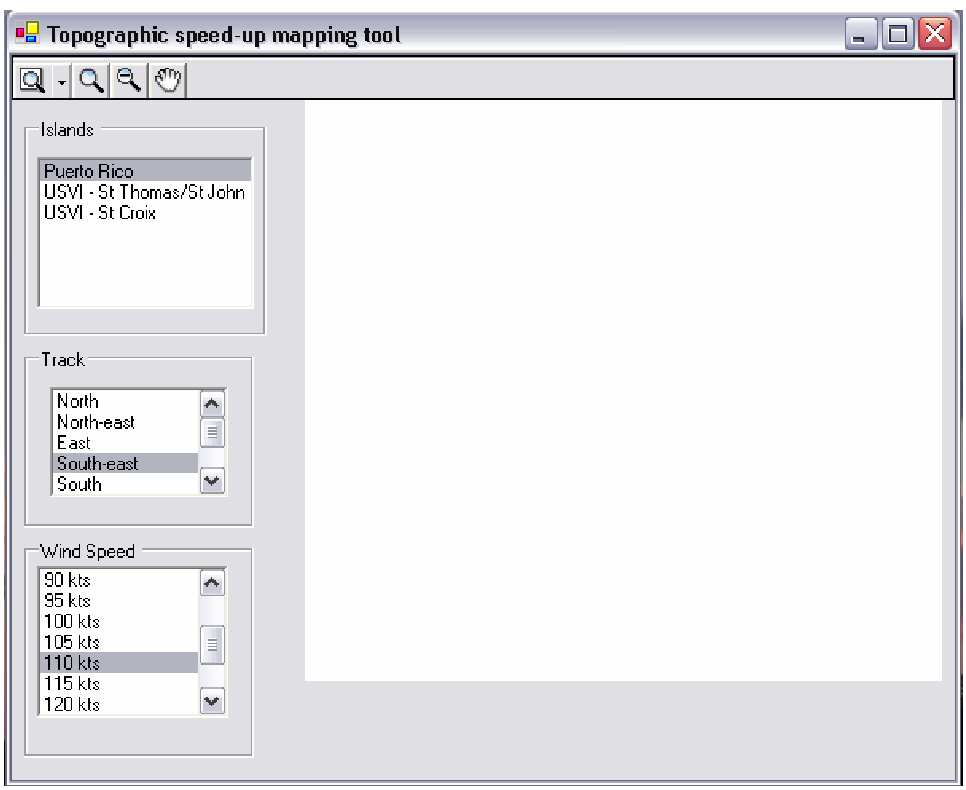

Figure 2: Prototype speed-up mapping tool interface