12C.2 PARAMETRIC WIND MODELLING AT THE CANADIAN HURRICANE CENTRE

Allan W. MacAfee
Atmospheric Science Division, Meteorological Service of Canada

1. INTRODUCTION

The wind field around any given tropical cyclone (TC) can be quite accurately depicted using a parametric wind model (PWM), if the driving parameters are accurately determined (Phadke et al. 2003). However, the dominant parameters in most formulations, radius of maximum winds and size are not readily available for historical storms and real-time TCs not traversed by research aircraft or within radar coverage. For cyclones moving into mid-latitudes additional complications arise due to synoptic interactions that lead to extra-tropical transition. As well rules-of-thumb and statistical relations developed for mostly southern latitude systems may not be appropriate at mid-latitudes (Vickery et al. 2000).

Techniques and validation methods used at the Canadian Hurricane Centre (CHC) to adapt PWM to mid-latitudes are presented.

2. MODELS AND PARAMETERIZATION

The PWM used at the Canadian Hurricane Centre (CHC) are: modified Rankine, SLOSH, modified Holland (C_0), as described in Phadke et al. (2003); a vortex simulation model (D_0) following DeMaria et al. (1992); a hybrid polynomial ramp model (H_1) following Willoughby (1995). Model D_0 was modified to use a gale radius to determine the *size parameter b* in Eq. 3.8 of DeMaria et al. (1992).

Each model requires the maximum wind (V_M), central pressure (P_C), motion vector ($\mathbf{V_{ST}}$), and radius of maximum winds (R_M). In addition, model C_0 requires the last closed isobar (P_N), model D_0 the gale radius (R_{34}), and model H_1 the e-folding radial distance (E_F). V_M and P_C were obtained from the HURDAT archive for historical storms and are forecaster-specified for real-time storms. P_N is extracted from a table of average monthly values for the Gulf of Mexico and four sub-basins in the Atlantic (< 25° N; 25–35°N; 35–45°N; > 45°N). $\mathbf{V_{ST}}$ is computed from the track positions and vectorially added to the model wind field. Other parameters were obtained through analysis of Hurricane Research Division (HRD) gridded wind fields from 1998–2003 (Fig. 1).

R_{34}, R_M , E_F, and the ratio of the wind speed at R_M to V_M (V_{RM}) were extracted from 16 storm-relative radial profiles and sorted into V_M categories. A normal distribution was applied to the random sample in each category to remove outliers (± 1.5 std dev).

Vickery et al. (2000) showed various equations for the variation of R_M with latitude but stated that north of 30°N the equations were inaccurate. The CHC deals frequently with rapidly moving TC north of 30°N. Hence, a statistical motion weighting function derived from the HRD dataset is applied to the independently computed, latitude-dependent value (Eg. 7 of Vickery et al. 2000), to inflate (deflate) R_M at high (low) latitudes.

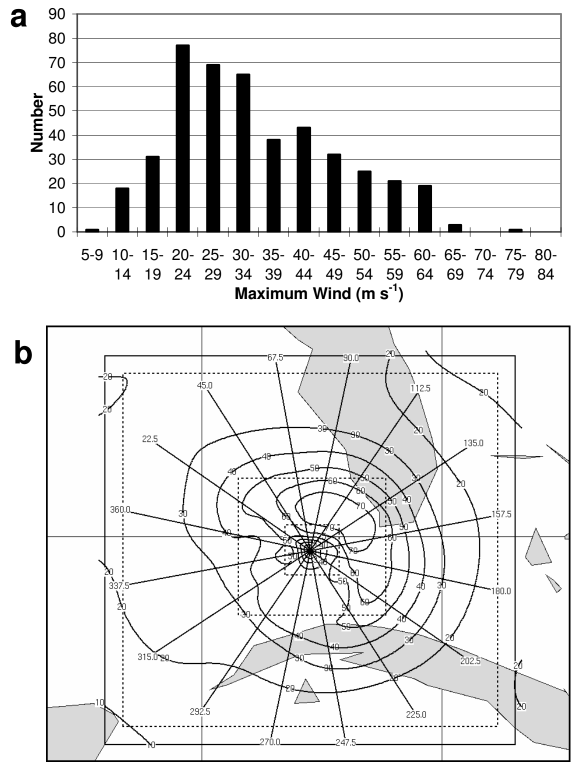

Fig. 1: (a) HRD data sample 1998-2003; (b) HRD analysis for Georges at 1930 UTC 25 Sep 1998 showing wind field ((kt) with storm-relative radials, model grid (solid), and verification grids (dotted).

In the model, each grid point's radial angle is computed then R_M, R_{34}, E_F, and V_{RM} (weighted by V_M) are determined at adjacent radial profiles, interpolated to that grid point, and input to the PWM equations. A slight adjustment was made in the mean boundary layer adjustment factors of Phadke et al. (2003) to account for stability variations at mid-latitudes.

3. VALIDATION METHODS

To assess parameter modifications, two methods are used. First, models are run for an independent test set of HRD analysis using a constant grid spacing of 8.3 km, but a domain automatically-fitted to each HRD analysis. Various scores are computed across three verification grids: inner, middle, and outer as in Fig 1b.

Corresponding Author Address: Allan W. MacAfee
Atmospheric Science Division, 16th Floor, 45 Alderney Drive, Dartmouth, NS, Canada B2Y 2N6
e-mail: Al.MacAfee@ec.gc.ca

Score comparisons as in Fig. 2 are used to select the best parameterization. Second, HRD analysis are rare in mid-latitudes and an indirect validation method is used; the wind field is input to the CHC Lagrangian trapped-fetch wave (TFW) model for well-documented cases of waves-storm resonance (MacAfee and Bowyer 2004). The impact of modified wind fields on TFW trajectories is used as a measure of improvement in parameterization. For example, Fig. 3 shows dominant TFW trajectories from model C_0, using the formulations of Fig. 2, for Danielle (1998), a highly resonant TC. Although maximum significant wave heights are similar (21 m), the set in Fig. 3b are further advanced and in better agreement with downstream buoys (not shown).

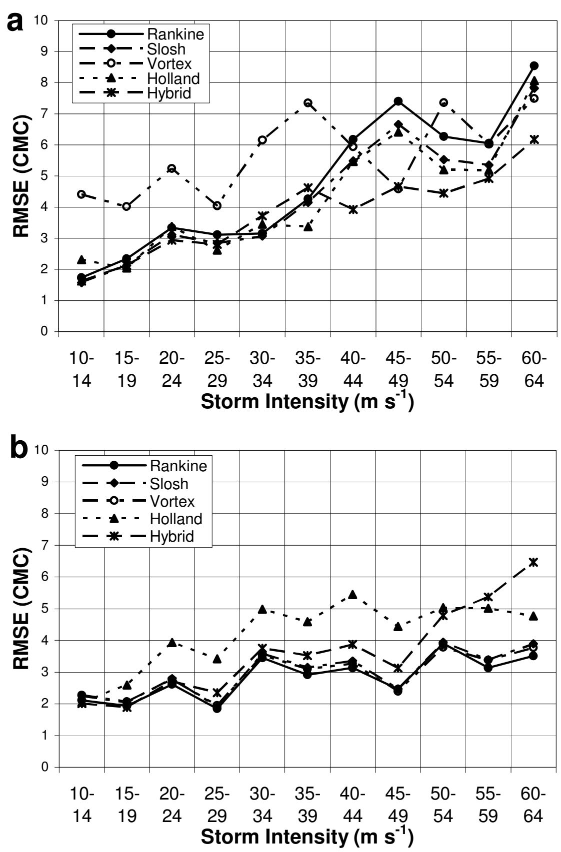

Fig. 2. Middle grid RMSE scores versus V_M for a 2003 test set: (a) non-adjusted PWM parameters (Vickery et al 2000; Phadke et al. 2000; V_{RM} = 1.0); (b) adjusted R_M, V_M, E_F, R_{34}.

4. CONCLUSIONS AND FUTURE WORK

Since the late 1990s the CHC has been investigating methods to adapt PWM to handle accelerating mid-latitude TCs (MacAfee and Bowyer 2000). The latest modifications have lead to improved quadrant gale and storm radii depiction and to development of the TFW model whose value to real-time forecasting is outlined in a companion presentation by Bowyer and MacAfee (2004b).

Future work will include: (1) using the NCEP gridded monthly-mean pressure data to add P_N asymmetries; (2) creating a TFW climatology; (3) using that climatology with buoy data to select cases to refine model parameters and/or identify storm intensity problems (e.g. Luis 1995).

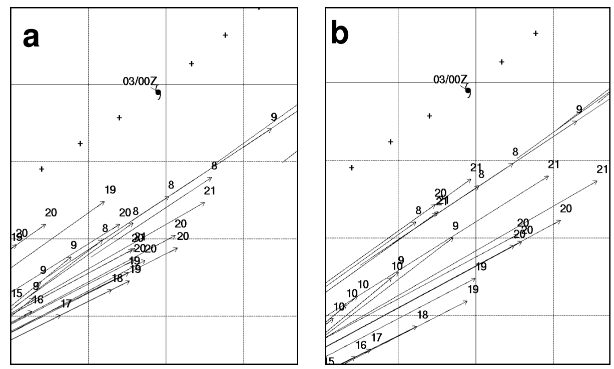

Fig. 3. Dominant TFW trajectories for Danielle using model C_o and the same parameters as in Fig. 2.

5. REFERENCES

Bowyer, P. J. and MacAfee, A. W., 2004a: The Theory of trapped-fetch waves with tropical cyclones-An operational perspective. *Manuscript submitted to Wea. Forecasting*.

______, _____ 2004b: Desktop hurricane-waves resonance modeling at the Canadian Hurricane Centre: output in 60 seconds. *Preprints 26th Conf. on Hurricanes and Tropical Meteorology,* Miami, Amer. Meteor.Soc

DeMaria, M., S. Aberson, K.V. Ooyama, and S. J. Lord, 1992: A nested spectral model for hurricane track forecasting. *Mon. Wea. Rev.*, **120**, 1628–1643.

MacAfee, A. W., and P. J. Bowyer, 2004: The modeling of trapped-fetch waves with tropical cyclones-A desktop operational model. *Manuscript Submitted to Wea. Forecasting*.

______, _____ 2000: Trapped-fetch waves in a transitioning tropical cylcone (Part II-Analytical and predictive model. *Preprints 24th Conf. On Hurricanes and Tropical Meteorology,* Fort Lauderdale, Amer. Meteor. Soc.

Phadke, A. C., C. D. Martino, K. F. Cheung, and S. H. Houston, 2003: Modeling of tropical cyclone winds and waves for emergency management. *Oc. Engrg.*, **30**, 553–578.

Vickery, P. J., P. F. Skerlj, and L. A. Twisdale, 2000: Simulation of hurricane risk in the U.S. using empirical track model. *J. Struct. Engrg.*, ASCE, 126(10), 1222–1237.

Willoughby, H. E., 1995: Normal-mode initialization of barotropic vortex motion models. *J. Atmos. Sci.*, **52**, 4501–4514.