Estimating tropical cyclone wind radii using an empirical inland wind decay model

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Background

- An empirical decay model (Kaplan and DeMaria 1995, 2001) has been developed to predict the decrease in wind speed of landfalling tropical cyclones. The model assumes that a cyclone’s winds decrease exponentially with time after landfall to a non-zero background wind speed using:

\[ V_t = V_b + (RV_0 - V_b)e^{-\alpha t} \]

where \( V_t \) = the maximum wind at some time \( t \) h after landfall, \( V_0 \) is the landfall wind speed, \( V_b \) is the background wind speed and \( \alpha \) is the decay constant.

- The decay model can be used to:

  Predict the decrease in maximum wind speed near the storm center (DeMaria et al. 2005)

  Estimate the maximum wind speed at inland locations for various landfall forward speeds and maximum intensities (FEMA, 1995).

  Provide a 2-dimensional swath of post-landfall wind speed (Dunion et al. 2003)
Methodology

- Swaths of the maximum sustained wind were generated for major U.S. landfalling hurricanes Charley (2004), Dennis (2005), Katrina (2005), Rita (2005), and Wilma (2005).

- A parametric wind model (Kaplan and DeMaria 1995, Knaff and DeMaria 2006) and the wind radii from the official NHC forecast were used to generate the initial storm vortex.

- The decay model was run separately using storm track and landfall intensity information from the official NHC advisory (“Official swaths”) and best track files (“Best track swaths”), respectively.

- Maximum wind swaths were evaluated at all over-land and near shore in-situ wind observation locations from the time of landfall until the system became extra-tropical.

- All in-situ wind observations were converted to 1-min maximum winds at 10 m for open over-water or over-land exposure (Powell et al. 1996, Powell et al. 1998).
Absolute errors between the wind swaths and in-situ observations for each individual storm and for the 5 storm sample
Bias of the decay wind swaths for each storm individually and for the 5 storm sample average.
Wind swaths for Charley (2004) for 12 UTC 13 August

Best track swath

![Best track swath graphic]

Official swath

![Official swath graphic]
Absolute errors of the “best track” wind swaths with radius for the 5 storm sample
Bias of the “best track” wind swaths with radius for the 5 storm sample
Methodology for wind radii estimation

• Estimates of the 64, 50, and 34 kt wind radii were obtained at ~3h after landfall for each storm using Hwind (Powel et al. 1998)

• Estimates of the 64 kt, 50 kt and 34 kt wind radii were also computed at the time of each Hwind analysis using the decay model

• Wind radii estimates were obtained using both “Official” and “Best track” input data
“Best track” decay model predicted (white) vs Hwind analyzed wind radii (red) (nautical miles) at 2300 UTC on 8/13/04 for Charley

<table>
<thead>
<tr>
<th>Direction</th>
<th>Predicted</th>
<th>Hwind Analyzed</th>
<th>Difference</th>
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<tbody>
<tr>
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<td>25 (20)</td>
<td>70 (33)</td>
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<tr>
<td>SE</td>
<td>15 (15)</td>
<td>25 (23)</td>
<td>75 (45)</td>
</tr>
<tr>
<td>SW</td>
<td>15 (13)</td>
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</tr>
<tr>
<td>NW</td>
<td>15 (0)</td>
<td>20 (0)</td>
<td>35 (17)</td>
</tr>
</tbody>
</table>

MAXIMUM WIND SWATH (KT) FOR CHARLEY
VMAX=125(KT) RMAX=18(KM) B=0.74
0.065, VB=36.7, REDFA=0.9
Data coverage for Hwind analysis at 2300 UTC 8/13/04 for Hurricane Charlie
“Best track” decay model predicted (white) vs Hwind analyzed (red) wind radii (in nautical miles) at 1740 UTC on 8/29/05 for Katrina

<table>
<thead>
<tr>
<th></th>
<th>NE</th>
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<th>SW</th>
<th>NW</th>
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</thead>
<tbody>
<tr>
<td>Obs</td>
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<td>45</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(56)</td>
<td>(49)</td>
<td>(0)</td>
<td>(33)</td>
</tr>
<tr>
<td>Pred</td>
<td>75</td>
<td>110</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>(97)</td>
<td>(136)</td>
<td>(65)</td>
<td>(55)</td>
</tr>
<tr>
<td></td>
<td>290</td>
<td>415</td>
<td>250</td>
<td>155</td>
</tr>
<tr>
<td></td>
<td>(164)</td>
<td>(239)</td>
<td>(185)</td>
<td>(120)</td>
</tr>
</tbody>
</table>

NE: North East, SE: South East, SW: South West, NW: North West

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**Hurricane Katrina 1740 UTC 29 Aug 2005**

Max 1-mln sustained surface winds (kt) for marine exposure
Valid for marine exposure over water, open terrain exposure over land

Analysis based on:
- CMAN_ID: TO from 1445 - 2005 z
- GSMS: ONDO, W1, W2 from 1445 - 1849 z
- W-ASOS from 1802 - 1808 z
- CMAN from 1449 - 2000 z
- AFRS adj. to surface from mean height 2200 ft from 1440 - 1802 z
- ASOS, ID, TO from 1440 - 2005 z
- NDBC Buoy from 1440 - 2005 z
- SPMR from 1440 - 1507 z
- PCTP, TOWER, ID, TO from 1352 - 1622 z
- 1740 z position interpolated from 1715 interpolation; csp = 32.0 mph

MAXIMUM WIND SWATH (KT) FOR KATRINA

Vmax=103 (KT) Rmax= 35 (KM) B=0.41
0.995, VB=38.7, RDPAC=0.9

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Observed Max. Surface Wind: 100 kts, 18 nm NE of center based on 1547 z AFRES slf measurement
Analyzed Max. Wind: 85 kts, 21 nm NE of center

Experimental research product of: NOAA/NOER / Hurricane Research Division
“Best track” decay model (white) vs Hwind analyzed (red) wind radii (in nautical miles) at 1245 UTC on 10/24/05 for Wilma

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<thead>
<tr>
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<tbody>
<tr>
<td>NE</td>
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<td>100 (117)</td>
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<td>105 (137)</td>
</tr>
<tr>
<td>NW</td>
<td>0 (0)</td>
<td>65 (102)</td>
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</table>

### Maximum Wind Swath (kt) for Wilma

- WEX-105(kt), BMX=-5E(kt), B-0.49
- 0.015, VS=25°, R2DPAC=0.9

### Hurricane Wilma 1245 UTC 24 OCT 2005

Max 1–min sustained surface winds (kt) for marine exposure

- Valid for marine exposure over water, open terrain exposure over land
- Analysis based on ASOS, LD, TO from 1448 – 1458 z; CMAN, LD, TO from 1449 – 1458 z; GFS/CONDE, W1150 from 1200 – 1254 z; FCIP, TOWER, LD, TO from 1449 – 1458 z; CMAN from 1049 – 1430 z; SHIP from 1150 – 1229 z; MOORED, BOAT from 1049 – 1430 z; GOES from 1402 – 1502 z

- 1245 z position interpolated from 1200 ATCF; mslp = 552.0 mb
Absolute errors of the decay model vs Hwind 64 kt, 50 kt and 34 kt wind radii for the 5 storm sample.
Bias of the Decay model predicted 64, 50, and 34 kt wind radii vs Hwind for the 5 storm sample
Summary

• Empirical decay model maximum wind estimates along the tracks of 5 major landfalling hurricanes were in fairly good agreement with available in-situ surface wind observations.

• Decay model estimates of the 64 kt and 50 kt wind radii were also in reasonably good agreement with Hwind 64 kt and 50 kt wind radii estimates. However, the decay model over-estimated the 34 kt wind radii.

• A new version of the decay model that better accounts for tropical cyclone decay over islands and peninsulas (DeMaria et al. 2006) will be tested for its ability to provide improved wind radii estimates.

• Real-time wind radii estimates will be made during the 2006 hurricane season.
“Best track” decay model predicted (white) vs Hwind analyzed wind radii (red) (in nautical miles) at 2230 UTC on 07/10/05 for Dennis

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>NE</th>
<th>SE</th>
<th>SW</th>
<th>NW</th>
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<tbody>
<tr>
<td>winds</td>
<td>64</td>
<td>50</td>
<td>34</td>
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</tr>
<tr>
<td></td>
<td>25 (0)</td>
<td>30 (20)</td>
<td>90 (51)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 (0)</td>
<td>30 (20)</td>
<td>100 (165)</td>
<td></td>
</tr>
<tr>
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<td>60 (144)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 (0)</td>
<td>25 (10)</td>
<td>65 (44)</td>
<td></td>
</tr>
</tbody>
</table>

**Hurricane Dennis 2230 UTC 10 JUL 2005**

Max 1-min sustained surface winds (kt) for marine exposure
Valid for marine exposure over water, open terrain exposure over land
Analyses based on: NOS_TCL, TO from 1900 - 0100 z; SFMSAD from 1900 - 0130 z; CSMSLD, TO from 1900 - 0130 z; CSMS from 1900 - 0130 z; SIDF from 2230 - 0045 z; QNCYT from 2230 - 0000 z; GIPSONET, VFL130 from 1901 - 0341 z; FCMP_TOWER, TO from 1900 - 0130 z; GOES from 1800 - 2300 z; GOES_SVNT from 1802 - 0102 z; SFMRAD from 1900 - 0130 z; MDOORED, RGOV from 1900 - 0130 z; 2230 z position interpolated from 2219 Vertex; mslp = 961.0 mb

2230 z position interpolated from 2219 Vertex; mslp = 961.0 mb

Max 1-min sustained surface winds (kt) for marine exposure
Valid for marine exposure over water, open terrain exposure over land
Analyses based on: NOS_TCL, TO from 1900 - 0100 z; SFMSAD from 1900 - 0130 z; CSMSLD, TO from 1900 - 0130 z; CSMS from 1900 - 0130 z; SIDF from 2230 - 0045 z; QNCYT from 2230 - 0000 z; GIPSONET, VFL130 from 1901 - 0341 z; FCMP_TOWER, TO from 1900 - 0130 z; GOES from 1800 - 2300 z; GOES_SVNT from 1802 - 0102 z; SFMRAD from 1900 - 0130 z; MDOORED, RGOV from 1900 - 0130 z; 2230 z position interpolated from 2219 Vertex; mslp = 961.0 mb

Max 1-min sustained surface winds (kt) for marine exposure
Valid for marine exposure over water, open terrain exposure over land
Analyses based on: NOS_TCL, TO from 1900 - 0100 z; SFMSAD from 1900 - 0130 z; CSMSLD, TO from 1900 - 0130 z; CSMS from 1900 - 0130 z; SIDF from 2230 - 0045 z; QNCYT from 2230 - 0000 z; GIPSONET, VFL130 from 1901 - 0341 z; FCMP_TOWER, TO from 1900 - 0130 z; GOES from 1800 - 2300 z; GOES_SVNT from 1802 - 0102 z; SFMRAD from 1900 - 0130 z; MDOORED, RGOV from 1900 - 0130 z; 2230 z position interpolated from 2219 Vertex; mslp = 961.0 mb
“Best track” decay model predicted (white) vs Hwind analyzed (red) wind radii (in nautical miles) at 1045 UTC 10/24/05 for Rita

<table>
<thead>
<tr>
<th></th>
<th>NE</th>
<th>SE</th>
<th>SW</th>
<th>NW</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>35 (0)</td>
<td>65 (43)</td>
<td>290 (88)</td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td></td>
<td>35 (25)</td>
<td>80 (91)</td>
<td>290 (250)</td>
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<tr>
<td>SE</td>
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<td>35 (25)</td>
<td>80 (91)</td>
<td>290 (250)</td>
</tr>
<tr>
<td>SW</td>
<td>25 (17)</td>
<td>60 (26)</td>
<td>160 (176)</td>
<td></td>
</tr>
<tr>
<td>NW</td>
<td>30 (21)</td>
<td>55 (32)</td>
<td>170 (165)</td>
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MAXIMUM WIND SWATH (KT) FOR RITA

VMAX=165 (KT) RMW=37 (KM) B=0.45
0.099, W=26.7, REDFAC=0.9
Data coverage for Hwind analysis at 2230 UTC on 7/10/05 for Dennis
Data coverage for Hwind analysis at 1740 UTC on 8/29/05 for Katrina
Data coverage for 1045 UTC Hwind analysis on 9/24/05 for Rita
Data coverage for the Hwind 1245 UTC 24 October analysis for Hurricane Wilma (2005)