# Determining Surface Winds from Doppler Radar Data during Hurricane Passages over Florida

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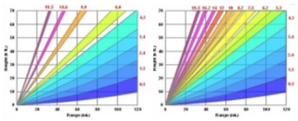
## Introduction

- Hurricanes are one of the most destructive natural phenomena affecting the United States. Not only do hurricanes cause deaths and injuries, but they destroy personal property, electrical systems, and other vital infrastructure.
- Being able to diagnose the damage potential to electrical systems will allow electrical companies to provide a more efficient response to areas that are in greatest need of repairs.
- Damage surveys have shown that high resolution data are needed to capture the various types of mesoscale features (tornadoes, roll clouds, downbursts, etc…) that are embedded within the hurricane's wind field.
- The only viable way to obtain high resolution near surface winds is by using Doppler radar.
- The primary objective of this research is to produce high resolution spatial field estimates of surface (10 m) winds and 3 s gusts using Level II archived Doppler radar data.
- Top image taken from: http://news.mongabay.com/2005/0901-noaa.html
- Bottom image taken from: http://encarta.msn.com/media_461536207/Hurricane_Opal_Destruction.html

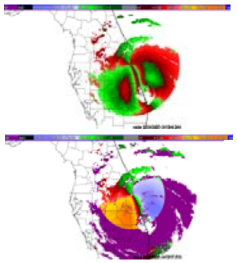
## Data and Methodology

### Level II Doppler Radar Data

- Data contains reflectivity and radial velocities at a horizontal resolution of 1 degree radial, 0.27 n mi (0.5 km) range gates, and a temporal resolution of approximately 6 min.
- Right: Depending on the Volume Coverage Pattern (VCP) of the radar, the data can contain up to 14 elevation scans ranging from 0.5 to 19.5 deg.
- Images on right taken from: http://weather.noaa.gov/radar/radarinfo/vcp11.html http://weather.noaa.gov/radar/radarinfo/vcp21.html



### Quality Control and Velocity Aliasing

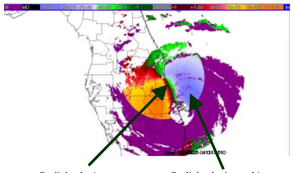


- To provide a "clean" version of reflectivity data, quality control steps must be applied.
- Quality control and de-aliasing techniques performed by the Warning Decision Support System – Integrated Information (WDSS-II) that was developed at the National Severe Storms Laboratory and the Cooperative Institute for Mesoscale Meteorological Studies at the University of Oklahoma.
- WDSS-II quality controls reflectivity data by using a neural network that eliminates the contamination associated with anomalous propagation, ground clutter, and clear-air returns.
- There is an upper limit to the magnitude of the target velocity (the *Nyquist velocity*) that stationary radars can detect unambiguously. Velocity aliasing occurs once that limit is exceeded.
- The maximum aliased radial velocity of 27.21 kt corresponds only to marginal tropical depression force winds, which are generally underestimates for hurricanes. The de-aliased velocity field contains wind speeds exceeding 188 kt, a more realistic portrait of the radial velocity field.

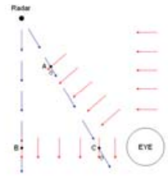
## Radial Velocity Dilemma

### Radial Velocity Dilemma

- Doppler radars only measure the component of the wind that is directly along the radar beam.
- Any wind component that is tangential to the beam will be seen as zero, only if the total wind is parallel to the beam will it be fully measured.
- Presents a major problem when diagnosing the location of the strongest winds of a tropical cyclone since the radial velocity problem produces data gaps throughout the velocity field.
- To calculate the true surface winds using only Level II Doppler data, an algorithm must be created to convert the radial velocity field into a total wind field.



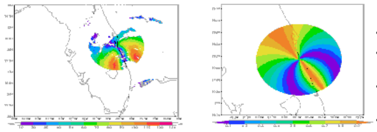

## Total Wind Estimation



### Total Wind Estimation

- Assume that winds are oriented 90 deg counter-clockwise from the radial vector, producing cyclonic tangential winds along a constant radius from the center of the eye.

* This assumption is a source of error since frictional effects along with natural inflow of tropical cyclones typically direct winds inward with respect to radius.



- Thus the percentage angle represents the amount of the total wind that the radial velocity detects.

### Percentage Angle

- The next step is to calculate the angular difference, θ, between the radar beam and the wind direction at each grid point.
- For θ = 90 the radial velocity is zero
- For θ = 0 the radial velocity is the total wind
- For 0 < θ < 90 the radial velocity is a percentage of the total wind.
- Using a percentage angle, α, we can calculate how much the radial velocity needs to be adjusted. Where α is defined as:

$$\alpha = \frac{\theta}{90}$$

### Total Wind Equation

- Before the total wind is calculated, the algorithm determines the nearest grid point, in terms of both radius and height above the ground, that has a percentage angle less than 5%.
- This grid point is assumed to best represent the surrounding wind, and assumes that this grid point is a reliable source of information to use in calculating the total wind.

* This assumption is weakest for grid points near the region where the winds are perpendicular to the radar beam since the "best representative" grid point will be farther away.

- The total wind then is calculated at each grid point using the following equation:

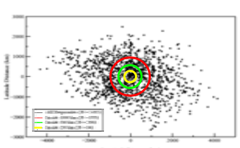
$$V_{TOT} = V_{RAD} + \alpha \times [V_{RAD*} + (\alpha_* + V_{RAD*})]$$

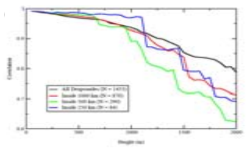
where $V_{TOT}$ is the total wind and $V_{RAD}$ is the radial velocity at the grid point in question. Variables denoted by an asterisk are values at the best representative grid point

## Reduction Factor

### Dropwindsonde Data

- Once the total wind field has been calculated at the altitude of the radar beam, these values must be brought down to the surface using a reduction factor.
- To properly reduce the upper level wind field we must first find the vertical level where the wind fields at the surface and aloft are not well correlated.
- GPS dropwindsondes during the 1999-2005 Atlantic hurricane seasons were processed.
- 1, 2447 dropwindsondes were launched during the 1999-2005 time period.
- Dropwindsondes that do not contain a wind speed at 20 m or below were not used for the correlation calculation.
- After these dropwindsondes were removed a total of 1455 dropwindsondes remained.
- Correlations between surface wind speeds and wind speeds above the surface are calculated and broken down into subsets for 1) all dropwindsondes, 2) dropwindsondes inside of 1000 km, 3) inside of 500 km, and 4) inside of 250 km.
- Correlations below 1.1 km are between 0.99 and 0.97. This explains, at the minimum, 94% of the variance for dropwindsondes within 250 km of the storm's center.

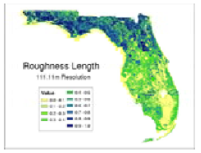




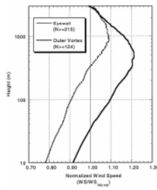
## Roughness Length Parameter

### Roughness Length Dataset

- To compensate for the variability of the boundary layer over the land, a roughness length dataset is used to calculate the reduction factors.
- Dataset was obtained by the Florida water management districts.
- Right: HAZUS roughness length dataset for the state of Florida. Spatial resolution of 111.11 m.




### Roughness Length Reduction



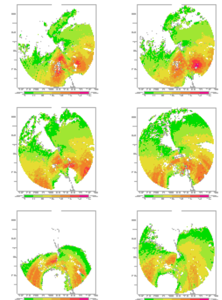
- Between the surface and the top of the boundary layer, the wind profile in the tropical cyclone environment increases nearly logarithmically with height.
- Left: Figure of wind speeds in boundary layer of tropical cyclone. Figure taken from Franklin et al. (2003).
- Winds above the climatological boundary layer are reduced to the top of the boundary layer using the reduction factor set by Franklin et al. (2003).
- Once at the top of the boundary layer the winds will be reduced logarithmically using the Monin-Obukhov similarity theory.
- The reduction equation is then:

$$U_{10} = U_{300}\frac{\log\left(\frac{300}{z_o}\right)}{\log\left(\frac{Z}{z_o}\right)}$$

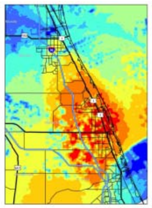
## Results

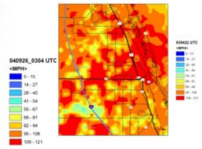
### Total Wind Estimation (Before Reduction)

- Initial case study for present research is Hurricane Jeanne (2004).
- The isotach interval in the figure remains constant through time to show how the storm weakens as it progresses inland.
- There is a 5 hour difference between the first and last figures. Maximum wind speeds are nearly 30 knots slower between the two.
- Unlike the radial velocity field, the algorithm produces a total wind field with reasonable features throughout the domain.
- The strongest wind speeds are just offshore of Florida which is expected due to the diminished impact of friction over the water.



### GIS Surface Winds





Surface winds using a 70% reduction factor throughout the domain.

- Final product will be in GIS format and provide street-level winds along with error estimates for each value.
- 3 s gusts, as well as a composite of the max values in total wind and 3 s gusts

## Summary and Conclusions

- Radial velocities obtained from archived Level II Doppler radar data were used to estimate the surface wind speeds during a landfalling tropical cyclone.
- An algorithm was then created that "corrected" the radial velocities so that the full component of the wind was determined.
- Techniques were then discussed for applying a reduction factor as a function of height and roughness length.
- The final product will contain sources of error that will be taken into account and finally applied to an error estimate of the surface wind speeds.

- Research funded by Florida Power and Light.
- Special thanks to Dr. Lakshmanan and the National Severe Storms Laboratory for WDSS-II training.

- Franklin, J., M. Black and K. Valde. 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications. *Wea. Forecasting*, **18**, 32-44.