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THE RELATIONSHIP BETWEEN FLIGHT LEVEL AND 10 METER WINDS IN NUMERICALLY SIMULATED LANDFALLING HURRICANES

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1. INTRODUCTION

Because of safety considerations and instrument limitations, a hurricane's sustained surface (10 m) wind is difficult to measure (Franklin et al. 2003). Reconnaissance aircraft typically fly at 700 hPa and, therefore, the forecasters estimate the surface winds from observations made at flight level using 'reduction factors' (RFs). In order to investigate the variation of RFs over space and time, an idealized modeling study is conducted using a weakening storm moving at 4 m s^{-1} in a northeasterly direction. The storm makes landfall on a straight west-east oriented coastline of low, flat terrain with a height of 0.1 m above sea level, an initial temperature of 28°C, roughness length of 15 cm, and moisture availability of 50%. The 700 hPa and 10 m winds are compared and RFs before, during, and after landfall in different portions of the storm are investigated and compared to previous findings. Different methods of calculating the RFs are explored.

2. MODEL CONFIGURATION

The Penn State/NCAR mesoscale model (MM5) is initialized with 8 m s^{-1} southerly flow, which evolves to southwesterly flow and slows down to 4 m s^{-1}. Embedded in this flow is a hurricane vortex with initial radius of maximum winds (RMW) of 42 km and initial minimum surface pressure (PSMIN) of 970.6 hPa. The intensity and size properties of this vortex are based on the averaged properties of hurricanes making landfall in the north-central Gulf of Mexico during 1988 – 2002. Construction of such a vortex follows the technique outlined in Kimball and Evans (2002). A 42-hour simulation is conducted using a coarse mesh of 9 km horizontal resolution, a nested grid of 3 km horizontal resolution, and 38 vertical levels. The sea surface temperatures (SSTs) in the model are kept constant at 28°C and a straight, west-east oriented coastline is located at 30°N, 387 km north of the initial position of the vortex. The vortex is asymmetric since it is embedded in relatively strong southerly flow; therefore, it is larger on the eastern side than it is on the western side.

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3. METHOD

Two different methods of calculating the RFs are explored.

Method 1: $$\text{RF } 700(\Phi) = \frac{10 \text{ m wind } (\Phi, \text{Rmax } 700)}{700 \text{ hPa wind } (\Phi, \text{Rmax } 700)}$$

Method 2: $$\text{RF max } (\Phi) = \frac{10 \text{ m wind } (\Phi, \text{Rmax}10)}{700 \text{ hPa wind } (\Phi, \text{Rmax } 700)}$$

where: Φ = azimuth
wind = windspeed
Rmax 10 = radius of 10 m maximum wind
Rmax 700 = radius of 700 hPa maximum wind

From the center of the storm 24 radial azimuths are defined, starting in the east. Each of these azimuths is investigated individually at the different levels to determine where the maximum wind speed occurs throughout the storm. Both RFs along each of the 24 azimuths are examined. Two overall 'absolute' RFs are defined using the absolute maxima at 700 hPa and 10 m.

4. RESULTS

The storm is initially located 400 km south of the straight coastline and moves at 4 m s^{-1} in a northeasterly direction due to the environmental steering flow in combination with the Coriolis force. At t=15h into the simulation, the storm center crosses the coastline 400 km east of the original location.

Figure 1 shows the 10 m and 700 hPa winds for hours 15 and 24 in the simulation. At the 700 hPa level the maximum wind is consistently located in the southeast and gradually decreases as the storm weakens while approaching land. The 10 m maximum wind occurs on the southeast quadrant before landfall. During and shortly after landfall, the 10 m maximum wind remains over water in the southern part of the storm.

Within the RMW at 700 hPa, a ring of RF values greater than 1 is seen (Figure 2) because the 700 hPa winds in that area are near zero, while the 10 m winds are at their maximum ("stadium effect"). RFs over land are smaller because the 10 m wind reduces more drastically than the 700 hPa wind due to surface friction. Outside this ring, a different structure is observed. A relative RF minimum is seen in the southeast quadrant and a relative RF maximum in the southwest quadrant. This is caused by the fact that the 700 hPa wind maximum remains in the southeast, while the 10 m wind has the same values over the southern half of the storm. The same is seen over land for the same reason.

Relatively small RF values are observed in the rainband to the south of the storm. This is because the 700 hPa wind retains relatively large wind values within the rainband while at 10 m the winds reduce more drastically in the rainband area.

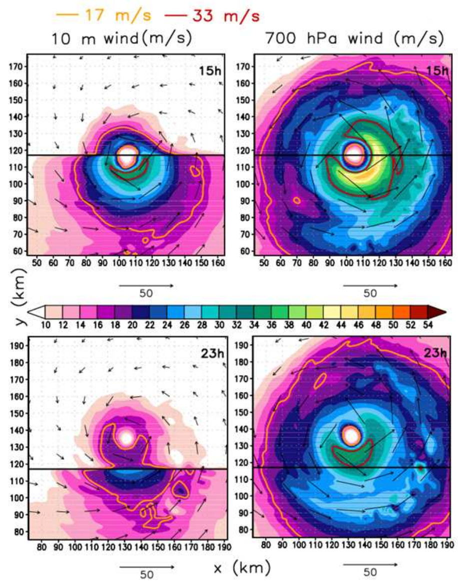

Figure 1: Hours 15 and 23 of the simulation. Left is 10-m windspeed. Right is 700 hPa windspeed.

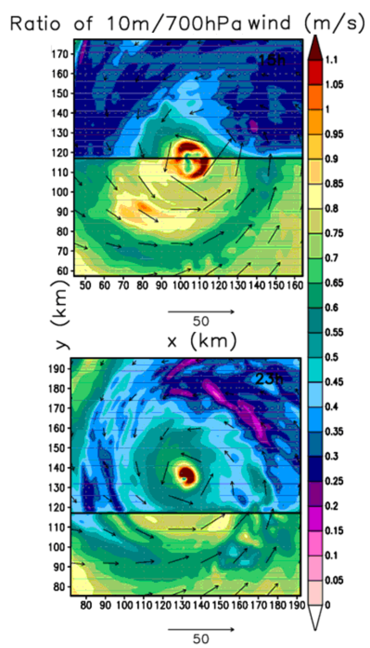

Figure 2: RF calculated using method 1 at hours 15 and 23.

When comparing the 700 hPa and the 10 m absolute maximum wind, the two are not located along the same azimuth. The RF calculated by method 2 is smaller than the RF calculated by method 1 (Figure 3) because the 10 m wind is a maxima at Rmax 10 and therefore 10 m wind at Rmax 700 is smaller.

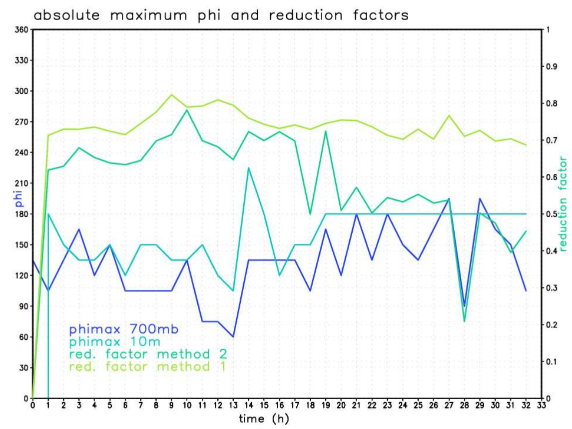

Figure 3: Time series of absolute winds at 700 hPa and 10 m; absolute RFs calculated two different ways.

Generally the maximum winds at both levels are located in the southeastern part of the storm until landfall. After landfall the storm is not as condensed so the maximum wind shifts to a more southern location. The location of the maximum wind varies every hour because the storm's structure is highly variable. The maximum 10 m wind is located over water (directly south) which means the radius of the 10 m maximum wind also increases after landfall due to the storm moving farther away from the water.

5. CONCLUDING REMARKS

While the storm is over water the average RF within the eyewall is 85% and outside the eyewall it drops to 60 to 75%. The RF reduces dramatically over land but can still vary spatially due to differences in wind patterns at each level. Further investigation, using modeling studies as well as real observations, into spatial RF variation is recommended in order to obtain more accurate RF values and recommendations for their variation over different parts of the storm. Method 2, shown above, is a first attempt towards a better way of determining RFs for this purpose.

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6. REFERENCES

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