P2H.4 DISTRIBUTION OF SEVERE WEATHER INDICES IN LANDFALLING NUMERICALLY SIMULATED HURRICANES

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1. INTRODUCTION

Tornadoes associated with tropical cyclones have caused much damage in the United States, especially along the Gulf of Mexico. Due to the angle at which the hurricane makes landfall, Gulf of Mexico tornadoes have about a 70% chance of producing tornadoes (McCaul, 1991).

1.1 EARLY RESEARCH FINDINGS

Limited by technology, early discoveries using mainly climatological data have set the standard for the knowledge of hurricane tornado development. Early researchers noted that hurricane-spawned tornadoes are usually much smaller and weaker than their Great Plains counterparts (Smith, 1965). The preferred sector of tornado development within a hurricane is 350° to 120° with respect to storm motion, which corresponds to the front right quadrant. Greatest tornadic frequency tends to occur when the center of the hurricane is about 80 km onshore and the majority of tornadic activity occurs within 160 km of the coast. These events also tend to favor environments with a lack of strong thermal instability and a large vertical wind shear (20-25 m s^{-1}) from the surface to 850 hPa (Novlan and Gray, 1974).

1.2 MORE RECENT FINDINGS

As more research was performed on Great Plains tornadoes, new severe weather indices were developed. These can also be applied to hurricane-spawned tornadoes. The indices and parameters included in this study include the storm-relative helicity, lifted index, CAPE, and the 0-1 km vertical shear. Table 1 includes threshold values for these parameters as applied to the hurricane-spawned tornado (Schneider and Sharp, 2007).

Parameter	Low Threat	High Threat
Lifted Index	> -1	< -2
CAPE	< 500 J kg^{-1}	> 500 J kg^{-1}
0-1 km shear	< 20 m s^{-1}	> 20 m s^{-1}
0-1 km storm relative helicity	< 100 $m^2 s^{-2}$	> 100 $m^2 s^{-2}$

Table 1: Threshold values for severe weather parameters included in this study

Observational scarcity is an unfortunate but unavoidable characteristic of research employing real data. This has forced such studies to assume that single soundings represent larger scale environments. In this study, an idealized numerical model of a landfalling hurricane is used to test the validity of this assumption by exploring the spatial and temporal variation of the thermodynamic parameters in the model. Since the horizontal resolution in the model does not allow tornadoes to be resolved, typical tornado prone regions of landfalling hurricanes will be identified in the model using results from observational research. In those areas, model values of the thermodynamic parameters will be compared to previously determined threshold values.

2. MODEL CONFIGURATION

The Penn State/NCAR mesoscale model (MM5) is initialized with a southerly geostrophic wind of 8 m s-1. Embedded in this flow is a hurricane vortex with initial minimum surface pressure (PSMIN) of 970.6 mb and 42 km radius of maximum winds (RMW). 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 34-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. Convection is parameterized on the coarse mesh using the Kain-Fritsch scheme and is explicit on the fine mesh. Other parameterizations on both meshes include the Goddard Micro-physics (including graupel) scheme, the MRF boundary layer scheme, a 5-layer soil model, and a cloud-radiation scheme.

3. EXPERIMENTS

The west-east oriented coastline is located at 30 °N, 387 km north of the initial position of the vortex. The land surface is flat, has a height of 0.1 m above sea level, has an initial surface temperature of 28 ℃, and is covered by a single land-use category. Each experiment differs in land use type as listed in Table 2.

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Case Name	Description	Roughness Length (cm)	Moisture Availability (%)
irrigated	irrigated crop pasture	15	50
evergreen	evergreen broadleaf forest	50	50
savanna	savanna	15	15

Table 2: Land use types for each experiment

4. RESULTS

The hurricane makes landfall at approximately t= 15 h. This study is concentrated mostly on the 8 hours prior to the center of the storm making landfall and approximately 10 hours post-landfall.

4.1 *STABILITY INDICES*

For the duration of the simulation, the CAPE and lifted index values suggest that no areas of the hurricane can be categorized as more than marginally unstable, yet when applying the values from Table 1, the “high threat” areas of LI occur within the rainband for the irrigated and evergreen cases. CAPE falls into the “low threat” category for all cases. This finding agrees with the findings of Novlan and Gray (1973). Although values are not typically high, both CAPE and LI begin as a narrow spiral with strong gradients. Over time, the spirals broaden and in the case of CAPE, magnitudes decrease. This causes a decrease in the gradients in the spiral (See Fig. 1 and 2). There are no major differences in either parameters after landfall when comparing irrigated and evergreen (not shown) cases. The lack of moisture in the savanna case severely inhibits both stability parameters throughout post-landfall storm evolution.

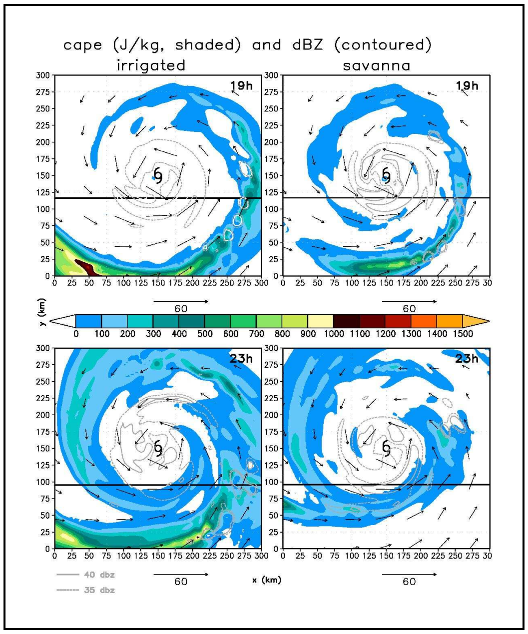

Figure 1: CAPE at t=19h and t=23h for irrigated (left column) and savanna (right column).

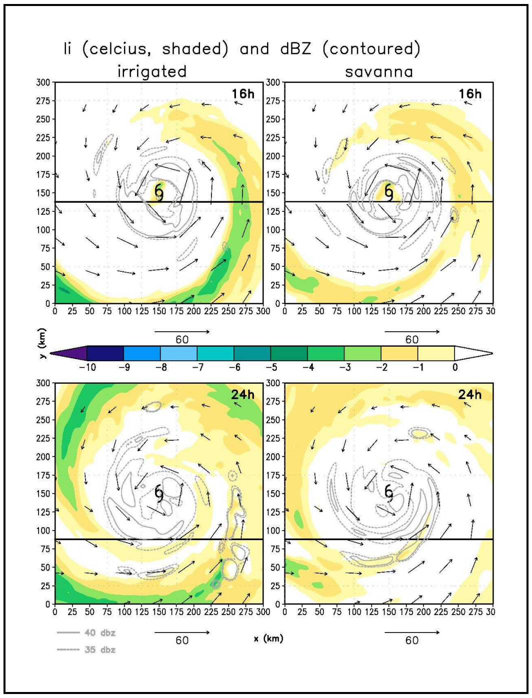

Figure 2: Lifted index at t=16h and t=24h for irrigated (left column) and savanna (right column)

4.2 *DYNAMIC PARAMETERS*

After making landfall, there is asymmetry favoring the front right quadrant of the hurricane for both the 0-1 km vertical shear and the 0-1 km storm-relative helicity. Referring to Table 1, this means the front right quadrant falls into the “high threat” category. At t=11 h, it is first evidenced that friction plays a significant role in vertical shear (Fig. 3) due to the roughness of the land surface slowing the low level winds. The winds aloft do not experience this retarding force, creating a larger difference between the wind speeds at these two levels. At 14h, a significant difference in shear is seen between the irrigated and savanna cases. The drier, savanna case has larger values of shear even though roughness length (RL) is the same as that of irrigated (comparing Fig. 4 and 5). This is possibly due to a lack of convection in the savanna case, whereas in irrigated, the moisture availability (MA) would aid in convection, bringing stronger winds aloft down to the surface through vertical mixing.

As the storms move inland, dry case savanna retains relatively high values (> 26 m s^{-1}) of vertical shear until 8 hours after landfall. In case evergreen, relatively large values disappeared around 6 hours after landfall. In case irrigated, high shear values lasted only 5 hours after landfall. Helicity tendencies (not shown) are generally similar to the vertical shear distributions for all cases, but are not as pronounced.

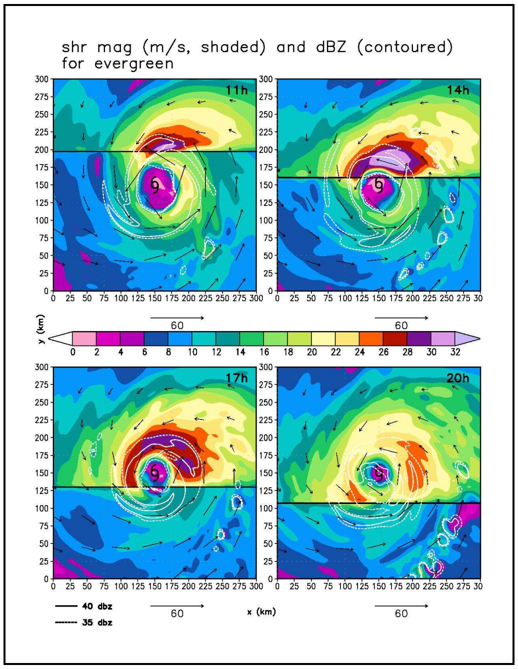

Figure 3: Magnitude of 0-1 km vertical shear for the evergreen case

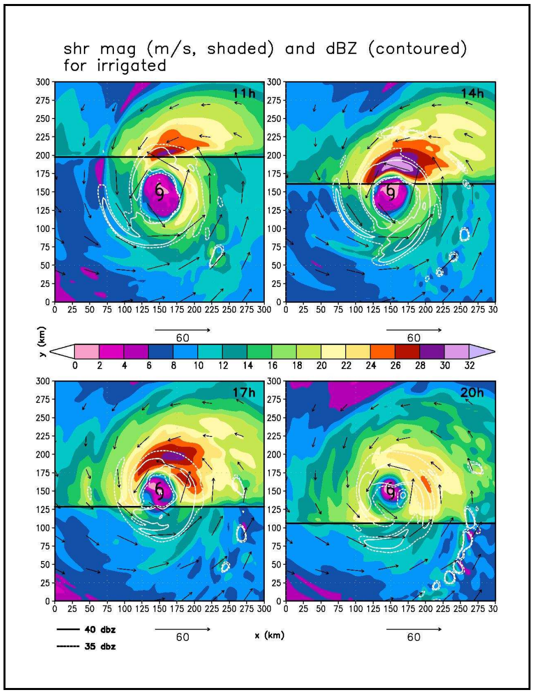

Figure 4: Magnitude of 0-1 km vertical shear for the irrigated case

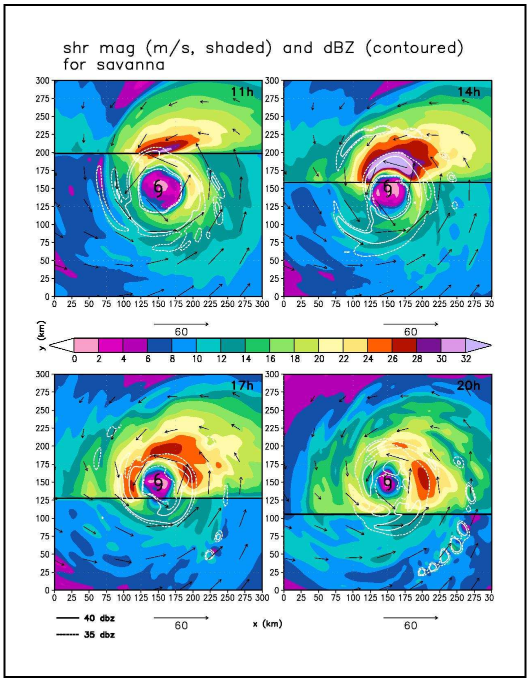

Figure 5: Magnitude of 0-1km vertical shear for the savanna case

5. PRELIMINARY CONCLUSIONS

Favorable values (from Table 1) of the parameters investigated in this study seem to coincide heavily with the rainband in the front right quadrant, which agrees with many of the previous studies. The simulation shows that the temporal and spatial distributions of these parameters are such that assumptions (using a single sounding to represent a large portion of the atmosphere both in time and area) used in applying observational data can lead to high uncertainties. Goals for future research of this topic are to further investigate the cause for the duration of higher shear values due to a lack of available land moisture as speculated in section 4.2, as well as applying more parameters to each case, for example Bulk Richardson number and the terms of the vorticity equation. Also, the study would benefit greatly by comparing these experiments with a simulation of an actual tornado-producing hurricane.

6. REFERENCES

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