Spring 2020

Analysis of the Impact of Frontal Boundaries on the Ingredients Needed for Tropical Cyclone Tornadogenesis

L. Armstrong
North Carolina Agricultural and Technical State University

Y.-L. Lin
North Carolina Agricultural and Technical State University

Analysis of the Impact of Frontal Boundaries on the Ingredients Needed for Tropical Cyclone Tornadogenesis

Authors: L. Armstrong[1], and Y.-L. Lin[1,2]
[1]Applied Science & Technology PhD Program
[2]Department of Physics
Program: Applied Science and Technology(PhD)
Advisor(s): Dr. Yuh Lang Lin

Background

Previous research hypothesized that landfalling cyclones associated with the development of tornadoes in the United States typically fall into 1 of 3 categories.
They are:
Type A which interacted with a cold frontal boundary after landfall. These systems have produced the most outbreaks.
Type B which interacted with a stationary frontal boundary
Type C which had no frontal interaction and was more commonly seen in deep Texas and Mexico

Hypothesis

All tropical cyclones can produce tornadoes as the friction increases when the bands of convection move from the water onto land leading to low level shear conditions.
We hypothesize that this remains the main source for Type C tornado outbreaks
Type A and Type B gain additional energy and possibly increased shear from frontal boundaries being near the favorable right front tornado producing quadrant of the tropical cyclone.

Parameters Examined

A. Convectively Available Potential Energy (CAPE)- A measure of the amount of energy available for convection
B. 0-1 km Shear- Change in wind speed and/or direction with height. Higher shear leads to more rotation
C. 925 mb Vorticity- Amount of spin or rotation in the atmosphere
D. Omega (Lifting)- Vertical Motion. Negative Values mean upward motion
E. Helicity- Amount of rotation that is collocated with updraft

Data

National Hurricane Center
Severe Weather Prediction Center
ERA Interim 80 km Spatial Resolution 4 times daily (every 6 hours) 37 Pressure Levels
NARR 32 km Spatial Resolution 8 times daily 29 Pressure Levels

Type A- Hurricane Michael 2018

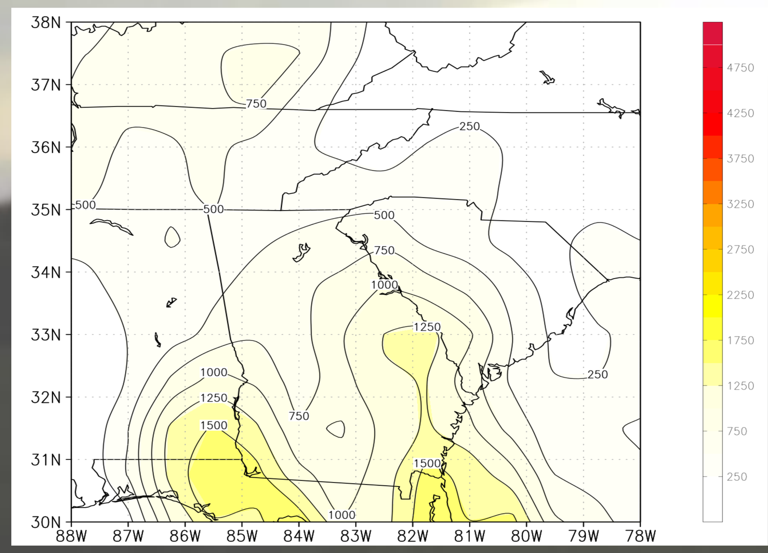

Figure 1A. CAPE values of over 1000 Joules/kg along and ahead of the circulation support supercell development .

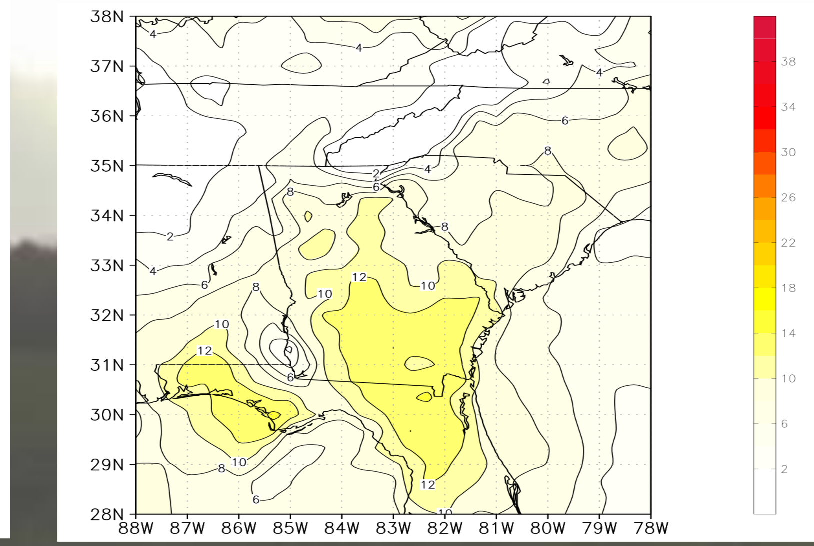

Figure 1B. Low Level Shear values peak in the same region as CAPE supporting rotating updrafts.

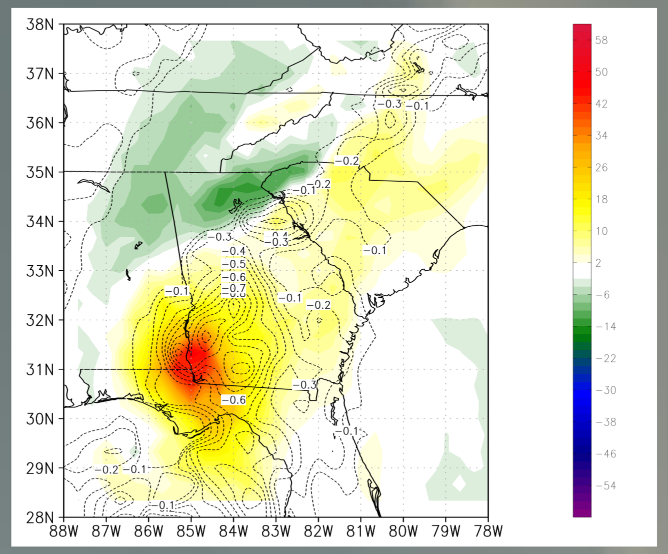

Figure 1C. Vorticity (Shaded) and Omega (Contours) Both extend northwards where the front interacts with the cyclone.

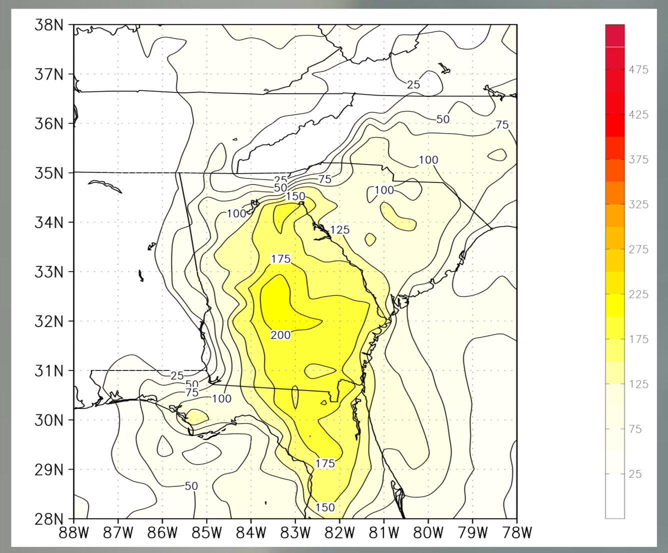

Figure 1D. Helicity Values peaking near 200 m^2/s^2 along and ahead of the cyclone with a pocket of higher values near the interaction point.

Type B- Hurricane Florence 2018

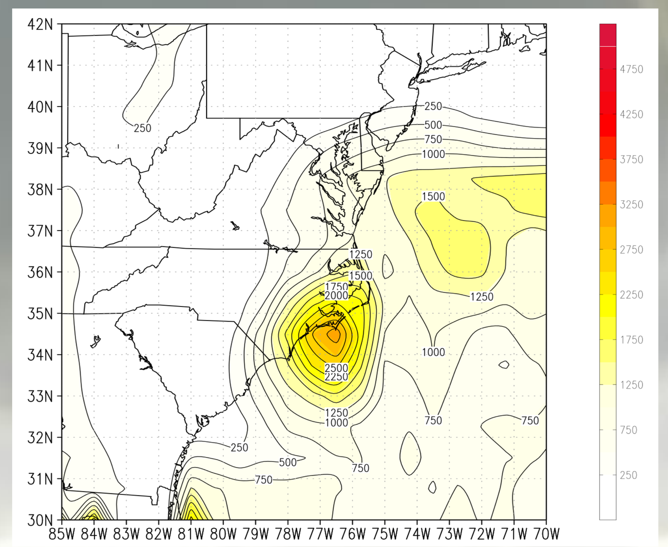

Figure 2A Extremely high CAPE for a tropical cyclone extend along and ahead of the circulation.

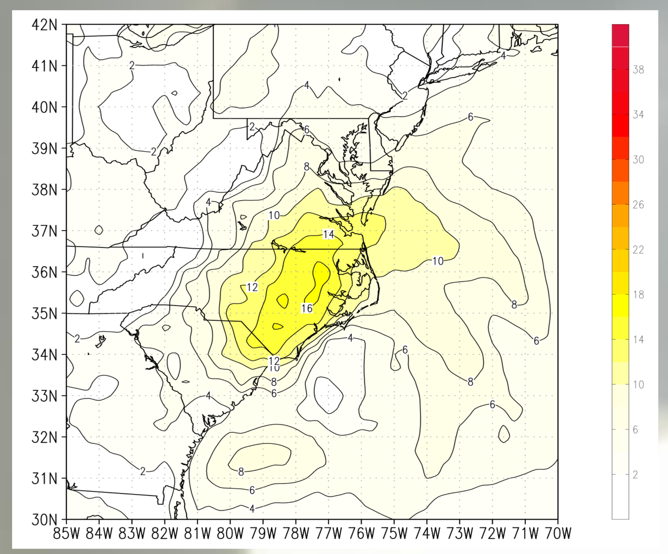

Figure 2B. Strongest Shear is shifted inland from the highest CAPE and is located between the storm and the frontal feature.

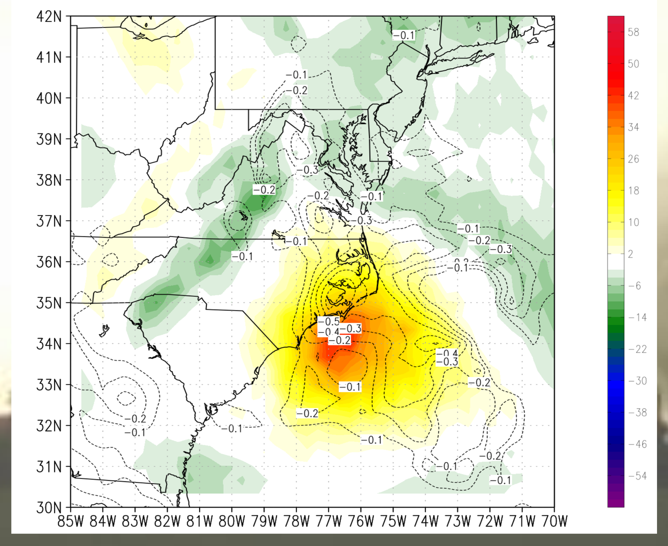

Figure 2C. Strong Vorticity approaches the North Carolina coast associated with the circulation. Omega values extend along and north of the circulation near the stalled frontal boundary. However with a stalled front there is less impact on vorticity.

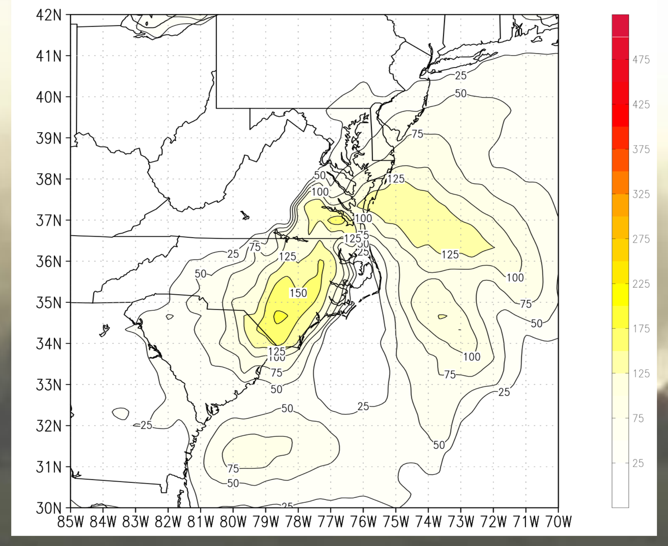

Figure 2D. Helicity Peaks with Values around 150 m^2/s^2 in the area where the tropical cyclone and front interact.

Type C- Hurricane Allen 1980

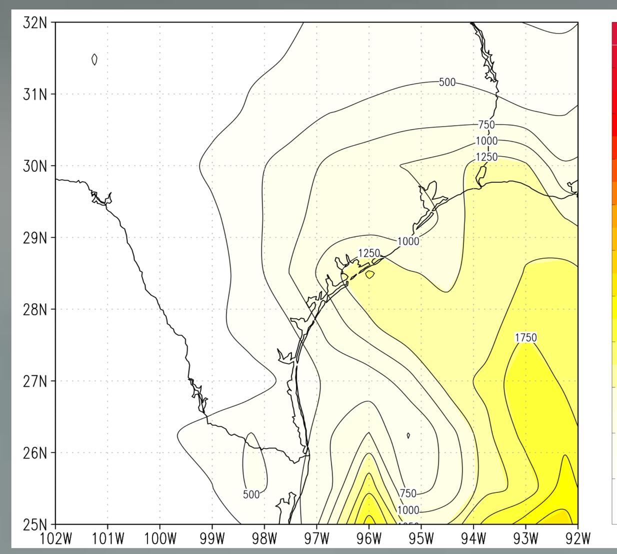

Figure 3A. CAPE values are lower and more confined to the coastal area in the no front case.

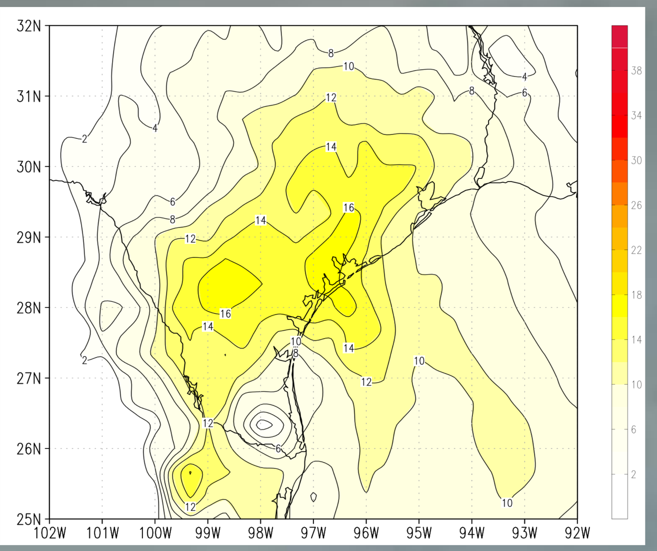

Figure 3B. Plenty of low-level Shear associated with the strong circulation of the hurricane. This spreads inland as the vortex gets slowed by the friction of the land surface.

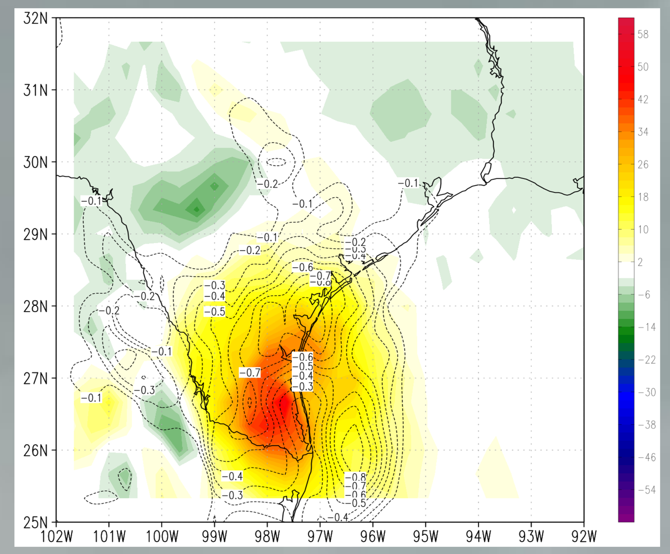

Figure 3C. Large area of vorticity associated with the circulation of the storm. However vorticity and omega remain more concentrated near the circulation unlike with a frontal impact.

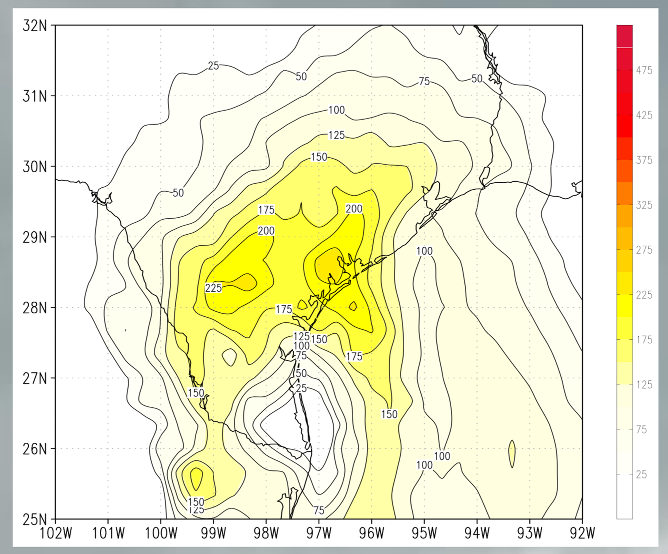

Figure 3D. Helicity values peak near 225 m^2/s^2 in the front right quadrant of the cyclone.

Summary

Tropical Cyclones all start out with vorticity and shear from the cyclone. Type A and B typically have extra shear from outside of the system coming from the front being in the area.
Type C typically have frictional shear and its tornado outbreaks peak near the coastline because as the circulation moves inland, it quickly loses vorticity and eventually shear. This kind of outbreak appears to stay near the coast.
Type A's and B's continue to thrive because of an influx of vorticity from the frontal boundary.
Type A tends to see the greatest impact by the cold front while B tends to see less impact in vorticity but still receives an increase in lifting.

References

1. Pete. P. (2013) *An Investigation of Tornado Development in Landfalling Tropical Cyclones* (Masters Thesis, North Carolina A&T State University, Greensboro, United States)
2. Lin Y.L. (2007) *Mesoscale Dynamics*. Cambridge University Press

Acknowledgements

Special thanks to Patrick Pete whose previous research was the catalyst for this project and my Advisor Dr. Lin