M.S. Defense Announcement
Tyler Barbero
Monday, May 8, 2023, at 11:30 am

Tyler Barbero
M.S. Defense

May 8, 2023
11:30 am

Defense
ATS Large Classroom (101 ATS) or via Zoom

Post Defense Meeting
ATS Community Space Conference Room (116 ATS)

Committee:
Michael Bell (Adviser)
Jan-Huey Chen (NOAA/Geophysical Fluid Dynamics Laboratory)
Philip Klotzbach
Elizabeth Barnes
Yongcheng Zhou (Mathematics)

A Potential Vorticity Diagnosis of Tropical Cyclone Track Forecast Errors

A tropical cyclone (TC) can cause significant impacts on coastal and near-coastal communities from storm surge, flooding, intense winds, and heavy rainfall. Accurately predicting TC track is crucial to providing affected populations with time to prepare and evacuate. Over the years, advancements in observational quality and quantity, numerical models, and data assimilation techniques have led to a reduction in average track errors. However, large forecast errors still occur, highlighting the need for ongoing research into the causes of track errors in models.

The piecewise potential vorticity (PV) inversion diagnosis technique is used to investigate the sources of errors in track forecasts of four high-resolution numerical weather models during the hyperactive 2017 Atlantic hurricane season. TC movement generally follows the atmospheric flow generated by large-scale environmental pressure systems, such that errors in the simulated flow cause errors in the TC track forecast. To understand how the TC is steered by its environment, the Shapiro decomposition was used which removed the TC PV field from the total PV field, and the environmental (i.e., perturbation) PV field was isolated. The perturbation PV field was partitioned into six systems: the Bermuda High and the Continental High, which compose the negative environmental PV, and quadrants to the northwest, northeast, southeast, and southwest of the TC, which compose the positive environmental PV. Each piecewise PV perturbation system was inverted to retrieve the balanced mass and wind fields. To quantify the steering contribution in individual systems to TC movement, a metric called the deep layer mean steering flow (DLMSF) is defined, and errors in the forecast DLMSF were calculated by comparing the forecast to the analysis steering flow. Lag correlation analyses of DLMSF errors and track errors showed moderate-high correlation at -24 to 0 hrs in time, which indicates that track errors are caused in part by DLMSF errors.

Three hurricanes (Harvey, Irma, and Maria) were analyzed in-depth, and errors in their forecast tracks can be attributed to errors in the DLMSF. A basin-scale analysis was also performed on all hurricanes in the 2017 Atlantic hurricane season. The DLMSF mean absolute error (MAE) showed the Bermuda High was the highest contributor to error, the Continental High showed moderate error, while the four quadrants showed lower errors. High error cases were composited to examine potential model biases. On average, the composite showed lower balanced geopotential heights around the climatological position of the Bermuda High associated with the recurving of storms in the North Atlantic basin. The analysis techniques developed in this thesis aids in the identification of model biases which will lead to improved track forecasts in the future.