Predicting the Safety of Aviation: How the HRRR Forecast Model Performs

Luis S. Flores Puentes[1,2], Lindsay R. Blank [3]

[1] Research Experience for Community College Students, [2]University of Colorado Boulder, [3]Colorado State University

Motivation

- Icing and turbulence are dangerous to aircraft and their passengers
- Prediction models such as the Domestic Aviation Forecast System (DAFS) are crucial to predicting icing and turbulence disturbances

Background

- The High-Resolution Rapid Response is a model used to forecast a variety of meteorological variables, though not all of them were looked at for this project
- The data collected by the HRRR combined with an algorithm, contribute to a system called the DAFS
- The algorithm uses HRRR data and calculates the possibility of icing and turbulence, this two attributes and process is the DAFS
- In the event the icing forecast is incorrect, it is important to know what caused the error
- I analyzed the HRRR's temperature forecast to help understand whether incorrect icing and turbulence forecasts stem from the HRRR or algorithm

Methodology

- The week of 06/25-07/02/2026 HRRR and Real Time Mesoscale Analysis (RTMA) data was analyzed
- Python was the main software used for aggregated statistics graphs. Model Evaluation Tools (MET) was used for spatial analysis heatmaps
- Key libraries: polars and NumPy: processing and visualization; xarray and cartropy: handling and plotting data
- Mean error and RMSE were calculated at 13 important pressure levels and were used in evaluation
- Data was stratified, evaluated, and plotted to find trends

Aggregated Statistics

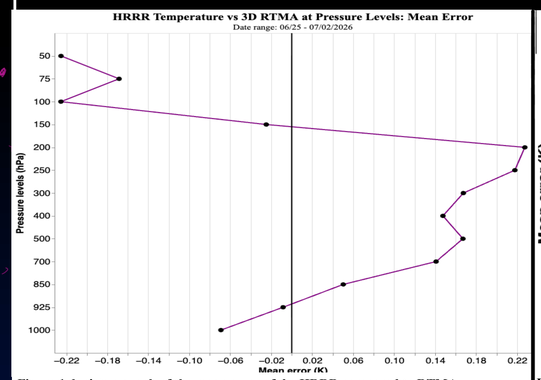

Figure 1 depicts a graph of the mean error of the HRRR compared to RTMA temperature data at different pressure levels

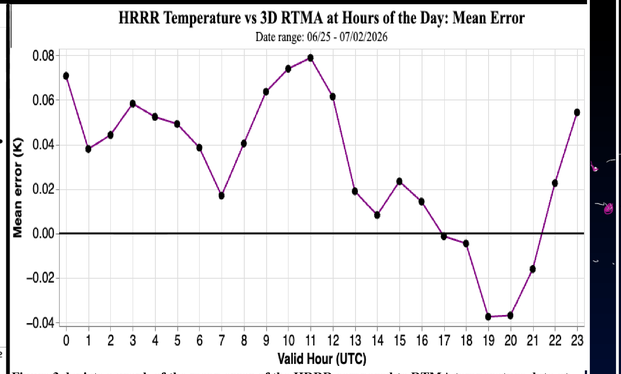

Figure 3 depicts a graph of the mean error of the HRRR compared to RTMA temperature data at times of day (UTC)

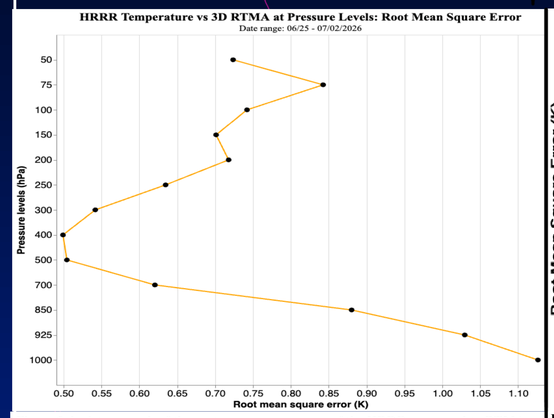

Figure 2 depicts a graph of the root mean square error of the HRRR compared to RTMA temperature data at different pressure levels

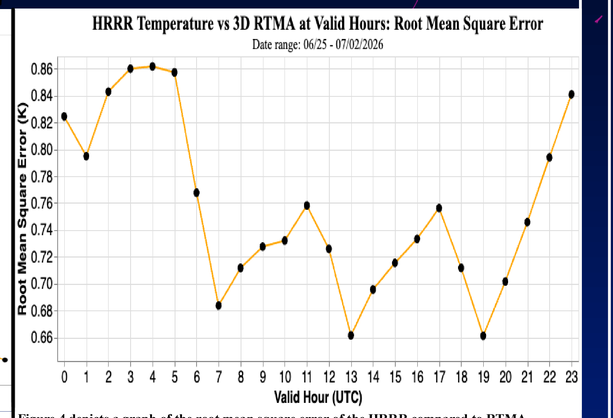

Figure 4 depicts a graph of the root mean square error of the HRRR compared to RTMA temperature data at times of day (UTC)

Spatial Analysis

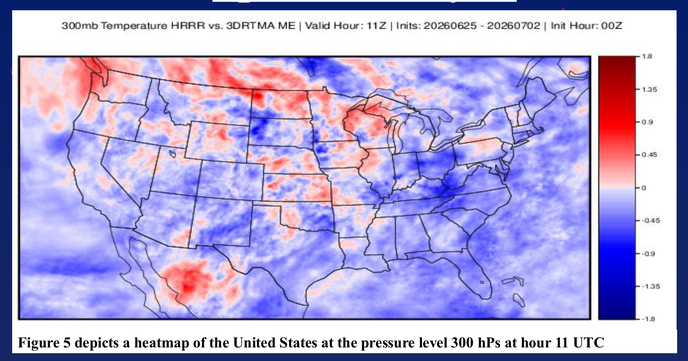

Figure 5 depicts a heatmap of the United States at the pressure level 300 hPs at hour 11 UTC

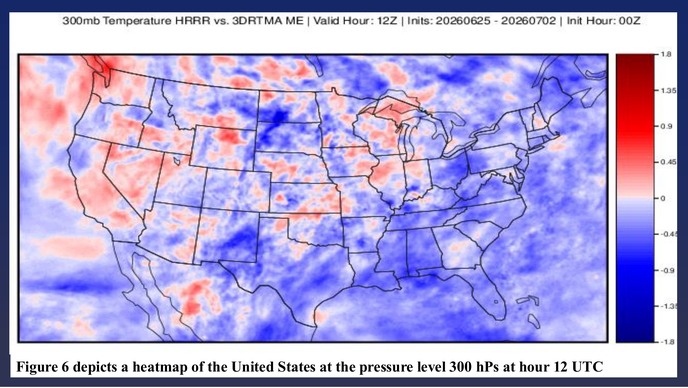

Figure 6 depicts a heatmap of the United States at the pressure level 300 hPs at hour 12 UTC

Discussion and Conclusion

Overall, the HRRR is producing accurate forecasts, with a typical error magnitude of ~0.5-1 K. We noticed that from overnight to early afternoon, the HRRR had a warm bias but conversely, from mid afternoon on the HRRR had a slight cold bias. This diurnal signal could be a sign of multiple environmental factors. We also noted that as the HRRR forecasts higher into the atmosphere, forecasts tended to have less error. Interestingly, at 150 hPa approximately around the tropopause, there is a noticeable flip in temperature error where the HRRR was forecasting hot and suddenly switched to forecasting cold in the higher levels. Spatially, temperature differences were not uniform across the contiguous United States. The largest bias tended to be centralized in the Great Plains. After 11 UTC (4:00 AM MST), the forecast shifted to almost exclusively a warm bias in the West or a cool bias in the East. Based on these results, large errors associated with the DAFS are most likely caused by the algorithm and not the underlying model.

References

Contact Me

Acknowledgements

Thank you to Laura Melling , Matt Wandishin, Karla Lemus, Madison Payne, Alicia Christensen, and Alex Hewett for contributing to the making of this project.

This project was generously funded by EARTh Center NSF grant number 2055370