Assessment of Tropical Cyclone Kinematic and Thermodynamic Structures in the North American Regional Reanalysis (NARR)

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Introduction

Long-term reanalysis datasets, such as the North American Regional Reanalysis (NARR), are data-rich resources for atmospheric science research. Due to their approximate consistency in time and space, these datasets can be used to study weather and climate phenomena, such as the interaction between a tropical cyclone (TC) and the large-scale environment. However, because of the relatively low horizontal resolution in these datasets, it is unclear whether these models can robustly represent TCs (Manning and Hart 2007, Schenkel 2012).

The ultimate goal of this research is to develop a better understanding of the influence of large-scale moisture on TC size and structure. Researchers have identified large-scale relative humidity as a primary controlling factor of TC size and outer rainband activity (Hill and Lackmann 2009, Matyas and Cartaya 2009) and subsequent redistribution of heating and angular momentum (Kimball 2005, Hill and Lackmann 2009). The NARR may provide a useful framework for studying the large scale processes associated with these phenomena, if the representation of TCs is determined to be adequate. In this study, we compare output from the NARR with output from the global Climate Forecast System Reanalysis (CFSR) and with precipitation derived from the Tropical Rainfall Measuring Mission (TRMM) satellite.

Objective

To determine the suitability of examining TC water budgets and large scale thermodynamics using the NARR based on:

1) TC location and intensity
2) Warm core, kinematic, and precip structure.

Data

• North American Regional Reanalysis (NARR) from NCEP/NCAR uses NCEP ETA Model
• Native grid projected to Lambert Conformal 3 km horizontal grid, with 29 vertical pressure levels, avail. 8 x daily
• Regional Data Assimilation System (RDAS) assimilates high quality 1-hour precipitation analyses (Mesinger et al. 2000)
• NARR Precipitable Water (mm) 18 UTC Jul 23 2008

From the scientific literature:

• Mesinger et al. 2000: “an improvement over previous global reanalysis data sets”
• Sun and Baoos 2009 & Knight and Davis 2009: reproduces spatial patterns of heavy precipitation well but underestimates magnitude and frequency of extreme events
• Royer and Potier 2010: North of 45°N, NARR data appear to be too warm by about 1°C
• Rauea 2010: 1) A ‘prime candidate’ for hydrometeorological applications & 2) In regions where precipitation draws largely from moisture convergence, the model is sensitive to dynamical processes.

To date, there is no comprehensive evaluation of TCs in NARR!

Objective 1: TC Location and Intensity

NARR TC location is compared with Best Track (2019-2012 US landfalling TCs. To locate the TC within the NARR dataset, three dynamic and thermodynamic criteria are used (Figure 2): A) min SLP (a), B) max 850 hPa vorticity (b), and C) max 700-200 hPa thickness (c).

Objective 2: Warm Core, Kinematic & Precip Structure

By Sawyer-Eliassen, a mid-tropospheric heat/momentum source induces outflow in the upper troposphere and inflow in the lower troposphere. In a warm core TC, this is the basis for the forced secondary circulation (e.g. Shapiro and Willoughby 1982), which transports low-level moisture inward. It is therefore crucial that the NARR physical parameterizations are able to capture sub-grid scales processes in order to develop a TC warm core, the primary and secondary circulations, and a realistic TC moisture budget.

Conclusion

Away from the domain boundary, the NARR dataset is a suitable resource for studying TC moisture budgets and large-scale thermodynamics.

References

https://www.rodts.com/