# The Fidelity of Tropical Cyclone Representation in Atmospheric Reanalysis Datasets

Ben Schenkel (bschenkel@fsu.edu) and Robert Hart (rhart@fsu.edu)
Department of Earth, Ocean, and Atmospheric Science, Florida State University

## Introduction

The recent availability of atmospheric reanalysis datasets has provided an unprecedented opportunity to examine an assortment of processes ranging from the decadal variability of the large scale circulation (Bengsston et al. 2004) to trends in tropical cyclone (TC) intensity (Sriver and Huber 2006; Maue and Hart 2007). While reanalyses represent a powerful tool in studying the structure of the atmosphere, the caveats associated with using these datasets need to be properly acknowledged. Specifically with regards to TCs, no comprehensive study has been undertaken to determine how well the warm core of a TC is realistically depicted within each reanalysis. Utilizing the methodology of Manning and Hart (2007), the following study seeks to quantitatively answer to what extent the fidelity of TC structure is accurately represented within each basin for a given reanalysis dataset and how this structure varies among reanalyses.

## Data and Methodology

To examine the extent to which TCs are accurately represented within reanalyses, their structure is evaluated within 3 atmospheric reanalysis datasets: ERA–40 (Uppala et al. 2005), JRA–25 (Onogi 2007), and MERRA (Bosilovich et al. 2006). TCs from 1979–2001 in the North Atlantic, North Eastern Pacific, and North Western Pacific basins were manually tracked using minimum sea level pressure (MSLP) and 925 hPa vorticity fields. TC structure is evaluated in comparison with the NHC best-track (Jarvinen 1984) and JTWC ATCF (Chu et al. 2002) data using standard metrics such as MSLP and maximum surface winds in addition to alternative parameters such as those found in the cyclone phase space (Hart 2003). Absolute track errors within the reanalyses are presented as well.

To provide a more detailed analysis of TC structure, composites were constructed for all TCs equatorward of 36°N in each of the 3 basins examined. The composites were created by bilinearly interpolating the grid to a uniform horizontal resolution (30 km) centered upon the manually tracked storm position. The resulting grid was separated into 1 of 4 intensity groupings based upon its best-track intensity with the process repeated for all TCs. Vertical cross-sections of composited height, meridional wind, mixing ratio, and temperature anomalies are presented to show the extent to which the warm core varies between basins and among the reanalysis datasets.

## Spatial Variation of TC Track Error

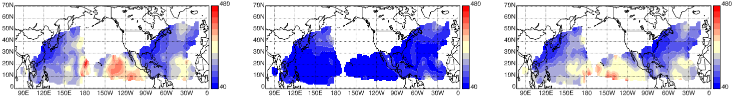


**Figure 1:** Plan view of absolute track errors (km) for (left) ERA40, (middle) JRA, and (right) MERRA for TCs between 1979–2001 in the North Atlantic, North Eastern Pacific, and North Western Pacific basins. Absolute track error is defined as the absolute value of the difference between the best-track and the reanalysis data. TC track in the reanalysis data was determined via manual tracking using MSLP and 925 hPa vorticity. Track error was interpolated to a 1.0° by 1.0° grid with each gridpoint representing the average of the track error weighted by its distance from the gridpoint. The grid was smoothed twice in order to reduce noise.

## TC Intensity within Reanalyses

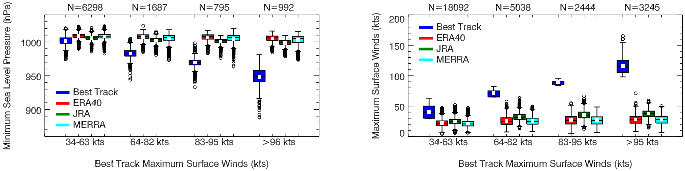


**Figure 2:** Box and whiskers plots of (left) best-track maximum surface winds (kts) versus reanalysis MSLP (hPa) in the North Atlantic and North Eastern Pacific basins and (right) best-track maximum surface winds (kts) versus reanalysis maximum surface winds (kts) in the North Atlantic, North Eastern Pacific, and North Western Pacific basins for TCs occurring between 1979–2001. White squares in the middle of the boxes represent the mean for each category. Numbers at the top of plot for each intensity bin denote the sample size.

## Spatial Variation of Low Level TC Structure

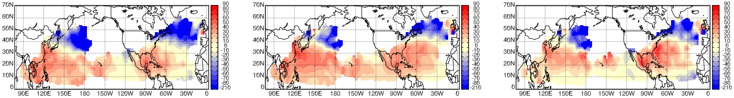


**Figure 3:** Same as Figure 1, but for low level thermal wind (900–600 hPa) in the (left) ERA40, (middle) JRA, and (right) MERRA.

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## Variability of Composited Category 3-5 TC Structure between Basins within MERRA

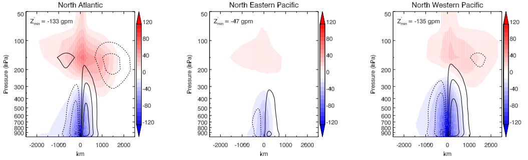


**Figure 4:** Vertical cross-sections of composited geopotential height anomalies (gpm, shaded) and composited meridional wind anomalies (m s$^{-1}$, black contours) in the (a) North Atlantic, (b) North Eastern Pacific, and (c) North Western Pacific for the MERRA for Category 3–5 TCs. Meridional wind anomalies are contoured every 5 m s$^{-1}$. The cross-sections are taken from West to East across the composited TC.

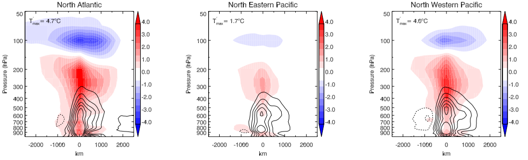


**Figure 5:** Same as Figure 4, but for composited temperature anomalies (°C, shaded) and composited mixing ratio anomalies (g kg $^{-1}$, black contours). Mixing ratio anomalies are contoured in black every 0.5 g kg$^{-1}$.

## Variability of Composited Category 1–2 TC Structure between Reanalyses in the North Eastern Pacific

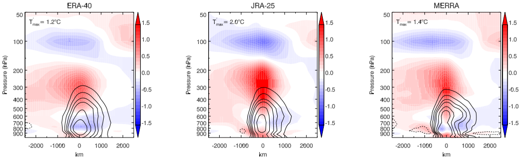


**Figure 6:** Vertical cross-sections of composited temperature anomalies (°C, shaded) and composited mixing ratio anomalies (g kg$^{-1}$, black contours) for the (a) ERA–40, (b) JRA–25, and (c) MERRA in the North Eastern Pacific for Category 1–2 TCs. Note that the shaded contours representing temperature anomalies are over a smaller range than in Figure 5. Mixing ratio anomalies are contoured in black every 0.25 g kg$^{-1}$ up to ±1 g kg$^{-1}$ and at intervals of 0.5 g kg$^{-1}$ afterwards. The cross-sections are taken from West to East across the composited TC.

## Discussion

Given the coarse spatial resolution of the current generation of reanalyses, it is unreasonable to expect that these datasets will depict the true intensity of TCs. In spite of this limitation, each reanalysis is able to capture the large scale effects of TCs in select portions of the 3 basins examined. Using TC structure and track as metrics, the JRA–25 was shown to agree more closely with observations than the other two datasets due to its use of TC wind profile retrievals. Although there were similarities between the remaining two datasets, the MERRA is shown to be more realistic than the ERA–40 primarily due to its increased spatial resolution. Of the 3 basins, the North Atlantic has the best structural representation of TCs in all 3 reanalyses likely due to a greater density of observations being assimilated. In all 3 basins, the representation of TCs degrades as the distance from land increases due to insufficient observations both upstream and over these regions. Additionally, all three reanalysis datasets depicted the presence of a cold core around 700 hPa in the North Eastern Pacific yielding a structure that more closely resembled a subtropical storm. This particular result may be attributable to a deficiency in the density and quality of observations assimilated in this basin. In spite of the ability of reanalysis to capture the gross structure of TCs, their inability to represent the "true" magnitude of the warm core begs the question as to whether the response of the surrounding environment is incorrect as well. Given that the representation of TCs within reanalyses has improved over time with the increasing coverage of satellite observations (Manning and Hart 2007), the possibility remains that reanalyses, as well as long term climate simulations, may contain false decadal trends due to a changing environmental response to the evolving structure of TCs.

## Acknowledgments and References

The authors acknowledge funding from NASA's Earth and Space Science Fellowship as well as a grant from the NSF. The authors also would like to thank Michael Bosilovich for fruitful discussions regarding MERRA.

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