An Evaluation and Application of Tropical Cyclones within Reanalysis Datasets

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The emergence of atmospheric reanalysis datasets has yielded tools of great utility for studying climate-scale processes that include the impact of large scale modes on tropical cyclones (TCs; e.g., Maloney and Hartmann 2000a,b) and the effects of TC passage upon the large scale environment (e.g. Hart et al. 2007; Hart 2010). Given that TCs typically occur in data void areas, reanalyses provide a unique opportunity to study these storms with complete spatial and temporal data coverage that is only affected by changes in the observing system (Thorne and Vose 2010). While reanalyses hold much promise, previous work has utilized these datasets without first quantifying whether the representation of reanalysis TC position, intensity, and structure is sufficiently robust to study interactions between the TC and its environment. Building upon the foundation of previous work (e.g., Manning and Hart 2007), the following study will evaluate the fidelity of TC position, TC intensity, and the life cycle of TC intensity (best-track TC age versus TC intensity) within five atmospheric reanalyses and compare these quantities to the best-track. The five reanalysis datasets chosen in this study include the 40-year ECMWF Re-Analysis (ERA-40), the Interim ECMWF Re-Analysis (ERA-I), JMA 25-year Japanese Reanalysis (JRA-25), the NASA Modern Era Retrospective-Analysis for Research and Applications (MERRA), and the NCEP Climate Forecast System Reanalysis (CFSR). Following this evaluation, a potential application of reanalyses will be presented that shows a significant weakening of the Hadley cell in response to the TC passage.

The results of this study show an underestimation of TC intensity beyond that expected from the coarse resolution of reanalyses. Further, reanalyses struggle to replicate the life cycle of TC intensity as seen by smaller pre-peak intensification rates and the delayed peak in TC intensity relative to the best-track. Reanalysis TC intensity is also found to exhibit strong, nonphysical correlations with quantities such as extended best-track TC size, best-track TC age, and best-track latitude. Differences in TC position between the best-track and reanalyses yield values on the order of several hundred kilometers depending on the TC location and the dataset examined. TC position differences in the ERA-40, ERA-I, and MERRA exhibit significant, nonphysical positive correlations with the location of the TC relative to most observation dense areas in the North Atlantic and Western North Pacific. Of the five reanalyses, the CFSR and JRA-25 have the smallest position differences and strongest TC intensities due to use of vortex relocation and TC wind profile retrievals respectively. Interestingly, EPAC TCs exhibit the largest position differences as well as the weakest intensities of the three basins within each reanalysis. The results presented here suggest that great caution should be exercised when using reanalyses to study TCs for work that strongly depends on replicating TC position or intensity. Finally, several cases of nonphysical TC structure argue that further work is needed to improve reanalysis TC representation.

For the reanalysis application, the NCEP CFSR is utilized to construct storm-relative composites of anomalies for WPAC major TCs in order to evaluate the large scale environmental response to TC passage. Preliminary results show that the passage of a major TC in the WPAC yields significant positive normalized mean sea-level pressure (MSLP) anomalies over an area 9000 km zonally by 3000 km meridionally centered near the mean location of the equator in the composite domain. These anomalies achieve maximum magnitudes of nearly 0.4σ five days after the passage of the TC and are significantly different from the pre-storm state for up to 11 days after TC occurrence. The presence of these positive MSLP anomalies at equatorial latitudes together with negative MSLP anomalies in the mid-latitudes is indicative of a weakening of the meridional pressure gradient and potentially the Hadley cell following the passage of the TC.

In an attempt to provide a physical explanation for these anomalies, calculations of zonally and vertically integrated meridional energy transports show a significant flux of energy out of the tropics and

into the mid-latitudes associated with the TC. The poleward transport of energy by TCs appears to yield a weakening of the regional meridional energy gradient by 2.2% per TC at a time when the gradient is typically strengthening at a rate of 0.4% per day. These computations imply that the passage of a major TC may locally delay the evolving climate calendar by 5.5 days. In their totality, these results suggest that TCs may serve as an efficient mechanism for equilibrating the equator-to-pole energy gradient with impacts lasting for weeks after TC passage.

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