18A.2 EVOLUTION OF THE VERTICAL TEMPERATURE STRUCTURE IN TROPICAL CYCLONES INFERRED FROM GPS RADIO OCCULTATION MEASUREMENTS

Louis Rivoire *, Thomas Birner
Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado

1. INTRODUCTION

Tropical cyclones (TCs) consist of a self-sustained vortex along with enhanced midlevel convergence into deep convective regions. Past literature has documented tropopause-level cooling above upper tropospheric warming in regions of active deep convection, e.g. within tropical cyclones (Biondi et al., 2013; Paulik and Birner, 2012). The tropospheric warming is a well-known feature and is understood as a direct response to the release of latent heat acquired from the ocean through deep convection (Emanuel, 1991) and the dynamic and thermodynamic response of the ocean to high wind speed (e.g. evaporation of sea spray described by Wang et al., 2001). In contrast, early investigations of the tropopause-level cooling (e.g. Arakawa, 1950; Jordan, 1960; Johnson and Kriete, 1982; Webster and Stephens, 1980) did not lead to a consensus on the mechanisms responsible for it. Holloway and Neelin (2007) described the "convective cold top" as a natural response to deep convective heating, and we suggest it can at least in part be understood as a hydrostatic adjustment. If the relatively large tropospheric heating and balanced circulation of TCs likely affect the cooling response near the tropopause, the effects of the cooling itself on the convection are yet to be determined.
This study is an observational analysis of the evolution of vertical temperature structures in intense TCs during their lifetime. Using high vertical resolution temperature measurements from GPS Radio Occultation data, we focus on the Upper Troposphere and Lower Stratosphere (UTLS), i.e. the region 5 km around the tropopause (Gettelman et al., 2011).

2. DATA AND METHODS

Measurements from the Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) processed by the COSMIC Data Analysis and Archival Center (CDAAC) provide all-weather temperature profiles in a random-like fashion all over the globe. These temperature profiles have a high accuracy, vertical resolution, and precision, especially between 5 and 25 km (Kuo et al., 2004). Preliminary results shown in Fig 1 reveal significant discrepancies between COSMIC temperature retrieval in the upper atmosphere (dry retrievals referred to as Atmprf, above the lowest 240 K isotherm near 10 km, Hunt et al., 2005) and in the lower atmosphere (wet retrievals, referred to as Wetprf, include data assimilation of operational weather reanalysis). Davis and Birner (2016) have also shown biases up to 8 K in the wet retrievals in the Northern Hemisphere subtropics and midlatitudes at an above the tropopause. This could be due to the relatively poor quality of the assimilated meteorological product in the vicinity of storm systems. Our study therefore focuses on the UTLS region, where the Atmprf product is most accurate. Overcoming the large variability in the vertical structure of TCs showed by Stern and Nolan (2009) necessitates the use of as many cases as possible. Using the Automated Tropical Cyclone Forecast System (ATCF) best-track archive for 2007-2014, we are able to gather about 60000 COSMIC profiles within 1500 km of roughly 300 intense TC systems. These profiles are composited about the time of first Lifetime Maximum Intensity (LMI) of storms to produce composite evolutions of the vertical temperature structure in TCs.

3. DISCUSSION OF KEY RESULTS

Preliminary results in Fig 1 confirm the expected middle and upper tropospheric warm anomaly and the tropopause-level cold anomaly of similar magnitude. The temporal evolution of this signal provides new insights into TC dynamics and how they influence their environment, in particular circulations near the tropopause. Using a climatological background, we find that anomalous structures persist for several days as TCs travel poleward. This is suggestive of the TCs potential to advect their own environment in the UTLS until they ultimately make landfall or weaken and mix with the midlatitude flow. Lastly, we show that relative to their environment (the temperature measured at the edge of TC systems), TCs display a strong lower stratospheric

* *Corresponding author address:* Louis Rivoire, Colorado State University, Dept. of Atmos. Science, Fort Collins, CO 80523-1371; e-mail: lrivoire@colostate.edu

cooling several days prior to the first LMI, before the warm core is established. This cooling increases the difference in temperature between the tropospheric and stratospheric reservoirs, leading to a higher Maximum Potential Intensity (Emanuel, 1987, 1991) and higher thermodynamic efficiency of the cyclones when examined as a classic Carnot engine (Holland, 1997). The upper-level cooling also increases the lapse rate, potentially destabilizing the atmosphere to convection and leading to higher cloud tops. This might contribute to the intensification of convection during the early stages of TC development.

Extending the present data analysis and conducting simple modelling experiments are our next goals in the quest for a better understanding of these mechanisms. The ingenuity and the relatively low cost of the radio occultation method, in addition to the imminent launch of COSMIC-2, are great incentives for this project.

4. FIGURES

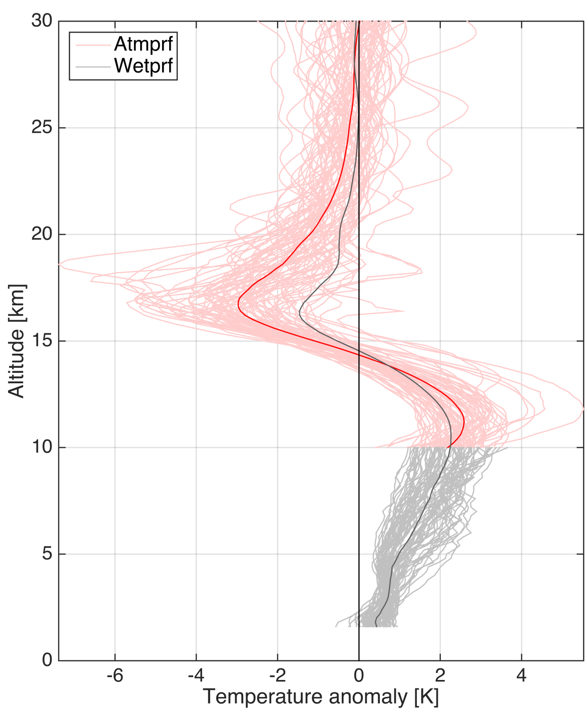

FIG. 1. Temperature anomaly for all COSMIC profiles gathered within 1000 km and 24 hours of the first LMI of hurricane-strength storms that occur within 35^o. Solid lines in dark colors are the mean. Anomalies are relative to the average observed temperature between 1300 and 1500 km away from storm center. Profiles are averaged in 45 angular bins and 100 km radial bins around storm center.

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