# Relationship of environmental relative humidity with North Atlantic tropical cyclone intensity and intensification rate

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[1] Quantifying the relationship of large-scale environmental conditions such as relative humidity with hurricane intensity and intensity change is important for statistical hurricane intensity forecasts. Our composite analysis of 9 years of Atmospheric Infrared Sounder (AIRS) humidity data spanning 198 Atlantic tropical cyclones (TCs) shows that environmental relative humidity (ERH) above the boundary layer generally decreases with time as TCs evolve. Near the surface, ERH stays approximately constant. ERH generally increases with increasing TC intensity and intensification rate. Rapidly intensifying TCs are associated with free tropospheric ERH more than 10% (relative to the averaged ERH for all TCs) larger than that for weakening TCs. Substantial azimuthal asymmetry in ERH is also found, especially for the TCs attaining the highest intensities and largest intensification rates at distances greater than 400 km away from the TC center. In the front-right quadrant relative to TC motion, rapid intensification is associated with a sharp gradient of ERH in the upper troposphere, with a decrease from the near to the far environment between 400 hPa and 300 hPa. The ERH gradient weakens with the decrease of intensification rate. This radial ERH gradient might be a useful predictor for the statistical forecast of TC intensification. **Citation:** Wu, L., H. Su, R. G. Fovell, B. Wang, J. T. Shen, B. H. Kahn, S. M. Hristova-Veleva, B. H. Lambrigtsen, E. J. Fetzer, and J. H. Jiang (2012), Relationship of environmental relative humidity with North Atlantic tropical cyclone intensity and intensification rate, *Geophys. Res. Lett.*, *39*, LXXXXX, doi:10.1029/2012GL053546.

## 1. Introduction

[2] While our understanding of tropical cyclones (TCs) has improved tremendously in the past several decades, forecasts of TC genesis, spin-up and subsequent (especially sudden) intensity changes still present significant challenges. Official intensity forecasts from the National Hurricane Center (NHC) for Atlantic and Eastern North Pacific TCs have not shown much improvement in the last 20 years [*DeMaria et al.*, 2007]. This is because TCs are sensitive to many factors, within the storm and in its surrounding environment. For example, TC structure and intensity are sensitive to vertical wind shear in the environment [*DeMaria*, 1996; *Frank and Ritchie*, 2001; *Zehr*, 2003], which may be poorly forecasted by operational and research models. Also, relatively subtle variations in sea-surface temperature (SST) or ocean heat content can cause a TC intensity to shift several categories on the Saffir-Simpson scale within a short period of time [*Sun et al.*, 2007].

[3] The available moisture of the TC's environment represents another poorly understood influence on intensity, thereby presenting a limit to predictability. While high mid-tropospheric relative humidity (RH) appears to be necessary for rapid intensification and the attainment of maximum intensity [e.g., *Kaplan and DeMaria*, 2003; *Emanuel et al.*, 2004; *Hendricks et al.*, 2010; *Kaplan et al.*, 2010], dry air intrusions have a negative influence on TC intensification as dry air ingestion promotes the formation of cold downdrafts, which transport low $\theta_e$ air into the sub-cloud layer and storm inflow [e.g., *Emanuel*, 1989]. In an idealized modeling study, *Braun et al.* [2012] showed that low humidity air reaching the inner core induces asymmetric convective activity which weakens TCs [e.g., *Nolan and Grasso*, 2003; *Nolan et al.*, 2007]. They further showed that the time for TCs to reach maturity varies with the proximity of dry air to the center of circulation. When dry air is located 270 km away or further from the center of the vortex, its impact on TC intensity is insignificant.

[4] Some studies [e.g., *Barnes et al.*, 1983; *Wang*, 2009] have shown that substantial and extensive moisture may also promote a net negative influence on TC strength by facilitating the formation of TC rainbands. The idealized modeling study of *Hill and Lackmann* [2009], which varied the environmental RH (ERH) in the region ≥100 km beyond the TC core, suggests that larger ERH results in the establishment of wider TCs with more prominent outer rainbands. However, TC development, as measured by time series of maximum 10 m wind speeds, was nearly insensitive to ERH despite the variation in rainband activity.

[5] *Kaplan and DeMaria* [2003] examined the mid-tropospheric (850–700 hPa) ERH relation with rapidly intensifying (RI) TCs in the North Atlantic basin using the NHC HURDAT file [*Jarvinen et al.*, 1984] and the Statistical Hurricane Intensity Prediction Scheme (SHIPS) [*DeMaria and Kaplan*, 1999] database. *Hendricks et al.* [2010] conducted composite analyses using the Navy Operational Global Atmospheric Prediction System (NOGAPS) global analysis. Both studies found that RI events over the Atlantic basin are associated with larger RH in the middle troposphere than non-RI events.

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