Column Water Vapor Variability and Its Impacts on Tropical Cyclone Activity over the Atlantic Basin

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Introduction

Column water vapor (CWV) in the tropics is well known to affect tropical deep convection. It has been established that the tropical deep convection required for tropical cyclone formation markedly increases after reaching a critical CWV threshold (Holloway and Neelin 2009). Therefore, CWV values below this threshold represent an atmosphere that is too dry for tropical cyclone formation. Some previous studies indicated/suggested the impacts of dry air (Hopsch et al. 2010; Fritz and Wang 2013, Hankes et al. 2014). In the Atlantic basin, the dry air may be associated with the Saharan Air Layer (SAL) or mid-latitude frontal systems via subsidence/advection around anticyclones (Braun 2010). The interannual variations of the dry air frequency in the tropical North Atlantic, however, remain unclear.

In this study, we examined 1) the interannual variations of dry event frequency over the Atlantic basin, 2) their relationship with the large-scale circulation, 3) possible impacts on the variability of the Atlantic tropical cyclone activity, and 4) the origin of dry air.

Data and Methods

The 6-hourly ERA-Interim reanalysis data were used to evaluate dry air frequency over the Atlantic basin during peak hurricane season (Aug-Oct; ASO). CWV variability is examined using Empirical Orthogonal Function (EOF) analysis from 1979-2014. Best Track data were used to examine the genesis locations and tracks of the storms. The dust optical depth (DOD) dataset developed by Amato et al. (2009) and Hankes et al. (2013) was used to evaluate the origin of dry air.

A dry event needs to satisfy the following three criteria:

- CWV <= 50mm
- CWV is at least half a standard deviation below the average
- The above two criteria are satisfied continuously for at least one day.

Results

A pattern of inter-annual variability of dry events is centered over the Central Atlantic along and north of 15N, while the mean CWV peaks over the East Atlantic.

The first EOF mode (EOF1) explains ~35% of the observed variance for CWV as the singular dominant mode.

Table 1: Correlations between CWV EOF1, ACE, and TC Activity

<table>
<thead>
<tr>
<th>Metric</th>
<th>CWV EOF1</th>
<th>ACE</th>
<th>TC Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>POS</td>
<td>2.271</td>
<td>758</td>
<td>45</td>
</tr>
<tr>
<td>NEG</td>
<td>78</td>
<td></td>
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</tbody>
</table>

Conclusions

When dry events occur more frequently, TC activity tends to be reduced over much of the Atlantic basin, and many fewer major hurricanes form.

The dry event frequency shows no significant correlation to DOD.

The CWV EOF1 displays a weakened or southward shifted Hadley Cell, as large-scale subsidence and anticyclonic vorticity are stronger over the MDR during the positive phase.

Dry air is associated with an enhanced, westward extended subtropical high. This acts to increase VWS over the Caribbean and to steer cyclones toward the West Atlantic. The modulation of the steering flow is also supported by the correlation to the Pacific North American Pattern (PNA).

The CWV EOF1 shows relationships to several large-scale climate oscillations through significant SST correlations, including the Atlantic Multi-decadal Oscillation (AMO), Atlantic Meridional Mode (AMM), Atlantic Tripole pattern, Pacific Decadal Oscillation (PDO), and western pole of the Indian Ocean (WIOD).

References