Introduction

Extreme precipitation from tropical cyclones (TCs) is a serious threat to the lives of residents of the United States East and Gulf Coasts. Approximately 90% of TC-related fatalities from 1963-2012 occurred by drowning or other water-related incidents (Rappaport, 2014). Additionally, the economic costs of TC landfalls continues to rise, with the 2017 season coming in as the costliest U.S. hurricane season ever. Because the risks and costs associated with TC-related precipitation are so high, it is important to quantify how much precipitation occurs over the eastern U.S. comes from TCs so that society can best prepare for these events both now and in the future under the effects of climate change.

The complexity of current atmospheric general circulation models and increases in computational efficiency allow TC structure and climatology to be studied in high-resolution global climate model runs. A relatively recent innovation in climate models, variable-resolution (VR) grids, allows a high-resolution domain over a particular region to be nested within a coarser global grid. One question surrounding VR grids is how extensive the high-resolution domain must be to accurately simulate the phenomena of interest, in this case Atlantic TCs. This study explores the following questions:

1. How much of the annual mean and extreme precipitation in different regions of the eastern U.S. is due to TCs?
2. How far into the North Atlantic must the high-resolution domain in VR grids extend to accurately capture the track and precipitation climatologies of Atlantic TCs?

Model Simulations

The spectral element (SE) dynamical core option in the Community Atmosphere Model (CAM) version 5 (Neale et al., 2012) is utilized for this study. CAM is the atmospheric model component of the NCAR/DoE Community Earth System Model. CAM is set up in one global 1° configuration (GLOB) and three different variable-resolution configurations with a base grid spacing of ~111 km and a refined region with a grid spacing of 28 km (WAT, REF, and EXT) (see Fig. 1). Three ensemble members are run for each model configuration for 1985 to 2015 following AMIP protocols (Gates, 1992).

GLOB: Conventional global climate model grid (no grid refinement)

WAT: “W. Atlantic” only refines near coastline of Eastern U.S.

REF: “Reference” refines entire Atlantic.

EXT: “Extended” refines entire N. Atlantic and N. Africa

TC Tracking and Precipitation Extraction

TC tracking and TC-related precipitation extraction in the model simulations are performed using the recently updated TempestExtremes algorithm (Ullrich and Zarzycki, 2017).

1. TC candidates are first identified by searching for warm-core sea surface pressure minima.
2. These candidates are then stitched together to create TC tracks (black dotted line in Fig. 2).
3. After identifying TC tracks, this algorithm calculates an azimuthal-mean radial profile of the storm’s azimuthal wind speed at each time step in the life of the storm (black profile in bottom of Fig. 2).
4. From this profile, an outer size is estimated based on the radius of a specified wind speed that defines the outer limit of the TC’s region (the red star in Fig. 2), taken here to be 8 m/s following Chavas et al. (2017).
5. This outer radius is used to extract storm-related precipitation at each timestep of each storm’s lifetime (precipitation within the red circle in Fig. 2). TC-related precipitation can be summed over the lifetime of each storm to estimate the total accumulated precipitation from that storm, with a focus on overlaid precipitation here.

Regional Extreme Precipitation

<table>
<thead>
<tr>
<th>Region</th>
<th>WAT</th>
<th>REF</th>
<th>EXT</th>
<th>CPC</th>
<th>TRMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southeast</td>
<td>8.9</td>
<td>9.1</td>
<td>10.1</td>
<td>19.1</td>
<td>15.7</td>
</tr>
<tr>
<td>Southern Plains</td>
<td>5.1</td>
<td>5.5</td>
<td>4.8</td>
<td>4.6</td>
<td>2.4</td>
</tr>
<tr>
<td>Northeast</td>
<td>4.5</td>
<td>5.5</td>
<td>6.3</td>
<td>15.6</td>
<td>18.3</td>
</tr>
</tbody>
</table>

Table 2: Percent (%) of Rx5day events that are TC-related area-averaged over each U.S. region for 1985-2015. Model values are ensemble means. Observational datasets used are the Climate Prediction Center (CPC) 0.25° Unified Gauge-based Analysis of daily precipitation and the TRMM 3B42 0.25° Daily Multi-Satellite Precipitation Analysis. The TRMM data is only available for a 17 year subset (1998-2015).

Preliminary Results

- The three VR grids far outperform the GLOB grid in simulating TC track and intensity climatology and (TC-related precipitation).
- All model grids underestimate TC landfalls in the Southeast and Southern Plains.
- TC-related extreme precipitation and the percentage of TC-related extreme precipitation events are lower in the WAT grid than the REF and EXT grids.
- All VR grids slightly overestimate the percentage of TC-related extreme precipitation events in the Southern Plains and underestimate it in the Southeast and Northeast.
- WAT grid is not sufficient to capture Atlantic TC climatology.

References


