An Exploration of Extreme Precipitation from Tropical Cyclones over the Eastern United States in Variable-Resolution CAM

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Introduction: Precipitation from tropical cyclones (TCs) poses a serious threat to the residents of the U.S. East and Gulf Coasts; approximately 90% of the TC-related fatalities in the U.S. from 1961–2012 occurred by drowning or other water-related incidents (Rappaport 2014). This work uses the Community Earth System Model (CAMS; Neale et al. 2012), the atmospheric component of the Community Earth System Model, to explore the influence of model resolution on the climatology of TC precipitation over the eastern U.S. as well as how TC-related extreme precipitation may change due to climate change.

Methodology: The Low-Res CAM has 1° horizontal grid spacing over the whole globe while the High-Res CAM is a variable-resolution version of the model, with a high-resolution (~28 km) domain over the North Atlantic basin and 1° grid spacing over the rest of the globe. These two versions of CAM are run from 1985–2014, with AMIP-style (Gates 1992) boundary conditions, and three ensemble members are created by slightly varying the initial conditions. Additionally, the High-Res CAM is run for 30 years under two climate change scenarios (RCP4.5 and RCP8.5) to explore the influence of climate change on TCs. TCs are tracked and TC-related precipitation is extracted from the model output using the updated TempestExtremes package (Ullrich & Zarzycki, 2017). The process of TC tracking, size estimation, and precipitation extraction is depicted in Fig. 1. In this work, the model output is compared to precipitation observations from the Climate Prediction Center (CPC) Unified Gauge–Based Analysis of Precipitation and the Tropical Rainfall Measurement Mission (TRMM) satellite product. Additionally, model TC frequencies are compared to observed TC frequencies from the International Best Track Archive for Climate Stewardship (IBTRACS) dataset and from the European Centre for Medium-Range Weather Forecasting ReAnalysis (ERA5) product. For consistency, TempestExtremes is used to track TCs in the ERA5 data.

Results:
- The total Rx5day is underestimated in the model compared to CPC and TRMM, especially in the Southeast and along the Gulf Coast.
- The Low-Res CAM underestimates TC-related Rx5day and the percentage of TC-related Rx5day events compared to High-Res CAM and CPC/TRMM, in part because it simulates very few landfalling TCs.
- Using a variable-resolution model configuration with high-resolution over the North Atlantic is superior in studying North Atlantic TC climatology to a conventional low-resolution global model.


Comparison of TC Frequency

<table>
<thead>
<tr>
<th></th>
<th>IBTRACS</th>
<th>ERA5</th>
<th>Low-Res CAM</th>
<th>High-Res CAM</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
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<tbody>
<tr>
<td>North Atlantic Annual Average</td>
<td>12.9</td>
<td>8.1</td>
<td>2.7</td>
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<tr>
<td>U.S. Landfall Annual Average</td>
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<td>0.5</td>
<td>2.0</td>
<td>1.5</td>
<td>1.3</td>
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</table>

Influence of Model Resolution

**CPC**
- Total:
  - Low-Res CAM: 30-year mean CPC, TRMM, High-Res CAM, and Low-Res CAM Rx5day (annual maximum 5-day accumulated precipitation) [mm/yr] (left column), TC-related Rx5day [mm/yr] (middle column), and percentage of Rx5day events due to TCs (right column).
- **High-Res CAM**:
  - Track Density: 30-year mean TC track density [hours of impact/yr] (left column), TC-related Rx5day [mm/yr] (middle column), and scaled Rx5day [mm/hours of impact] (right column) for the REF, RCP4.5, and RCP8.5 simulations.

**Influence of Climate Change**

**Fig. 4:** Precipitation rate [mm/hr] probability distribution functions for total precipitation (solid lines) and TC-related precipitation (dashed lines) for the REF (same as High-Res CAM AMIP simulation in model resolution section), RCP4.5, and RCP8.5 simulations. Notice that the most extreme precipitation rates in TCs become even more extreme in the warmer climate simulations (RCP4.5 and RCP8.5) compared to the historical simulation (REF).

**Fig. 5:** 30-year mean TC track density [hours of impact/yr] (left column), TC-related Rx5day [mm/yr] (middle column), and scaled Rx5day [mm/hours of impact] (right column) for the REF, RCP4.5, and RCP8.5 simulations.