Dynamical and Statistical Modeling of Future Hurricanes

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1 Introduction

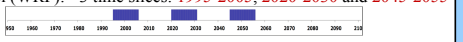
Impacts of weather events are proportional to the rarity of the event, yet our current ability to model high impact events is limited by not only rarity but also by the fidelity of current approaches and a lack of understanding of the underlying physical processes. This challenging conflict is driving fresh approaches to assess high impact weather and climate.

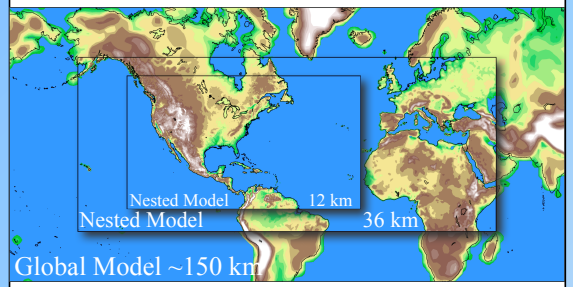
Many questions require predictions of the statistics of high impact weather on decadal timescales with regional clarity. To this end the Regional Climate Group within the NCAR Earth System Laboratory have conducted a modeling study, with current focus on tropical cyclones, using a powerful combination of the latest dynamical and statistical approaches to better understand how high impact weather will change over the coming decades.

2 Dynamical Modeling Approach

Dynamically downscale global climate data using the Nested Regional Climate Model

Global Model (CCSM3): - 1950 to 2100 under A2 scenario.
Nested Model (WRF): - 3 time slices: 1995-2005, 2020-2030 and 2045-2055





The nested model is driven by:
- Bias corrected[1] global model atmospheric data at the lateral boundaries;
- Bias corrected[1] global model sea surface temperature data.

1. Bias correction replaces the mean annual cycle from the global model with the mean annual cycle from NCEP-NCAR Reanalysis data. This method preserves climate variability and change from the global model.

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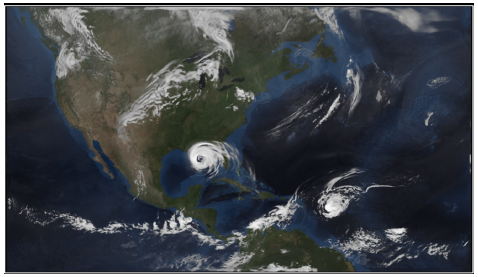
3 Dynamical Model Results

Figure 1: An example of a simulated hurricane in the Gulf of Mexico.



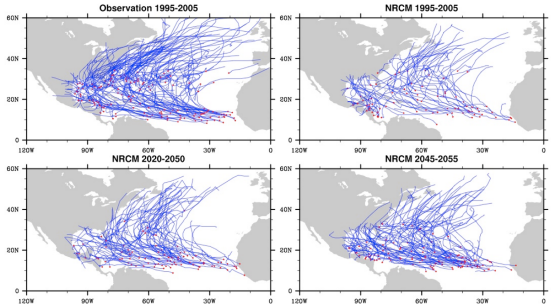


Figure 2: Tropical cyclone genesis locations (red) and tracks (blue).

Results:
- Reasonable simulation of tropical cyclone numbers and spatial distribution in base climate;
- Storm numbers increase from an average of 7.6/yr in the base climate to 10.4/yr in the 2050s;
- Future equator-ward shift in storm locations;
- An expected low bias in tropical cyclone intensities (not shown), and treated using extreme value approach (not shown).

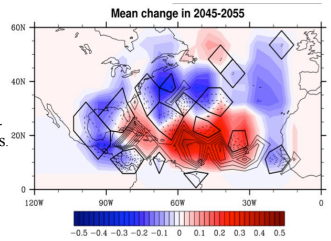


Figure 3: Future change in tropical cyclone track density (colors) and genesis density (contours, solid positive and dashed negative). Density defined as events per 5x5 degree boxes.

4 Statistical Modeling Approach and Results

Approach: Identify empirical relationships between storm numbers and the large-scale environment and then use the relationship to estimate storm numbers from large-scale datasets.

Using NCEP-NCAR Reanalysis data and IBTrACS storm data for Aug-Sept-Oct from 1960 to 2009, potential intensity and shear using the formulation in Eqn. 1 averaged over the Eastern tropical North Atlantic (10-20°N, 60-15°W) is found to explain 72% of the inter-annual variability in total basin tropical cyclone numbers.

Equation 1: $CGI = \left(\frac{PI}{70}\right)^3 (1 + 0.1V_{shear})^{-2}$

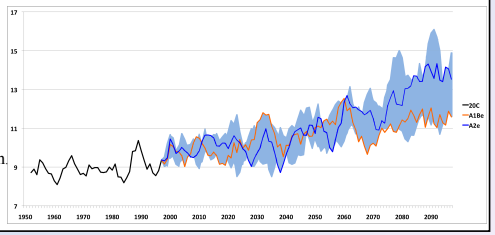


Figure 4: Annual tropical cyclone numbers calculated by application of CGI to an 8-member ensemble of future climate predictions using CCSM. Blue shading indicates the ensemble range. Data smoothed using a 5-year running mean.

- Both statistical and dynamical assessments indicate more tropical cyclones in the coming decades.

5 Future Directions

New modeling capability:
- Global simulations with adaptive mesh refinement capability.
- Include full atmosphere-ocean coupling.

Develop new statistical downscaling methods directly to tropical cyclone impacts.