Predicting the Evolution of Hurricane Risk with Climate Change

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Hurricane Risks
Average of 10,000 deaths per year globally

- Wind
- Storm Surge
- Rain
Tropical Cyclone Climatology
Basic Theory: Implications for Hurricane and Climate Change
Energy Production

Theoretical Steady-State Maximum Hurricane Wind Speed:

\[ V_{pot}^2 = \frac{C_k}{C_D} \left( \frac{T_s - T_o}{T_0} \right) \left( h_0^* - h_e^* \right) \]

- \( T_s \) - Surface temperature
- \( T_o \) - Outflow temperature
- \( h_0^* \) - Air-sea enthalpy disequilibrium of moist static energy
- \( h_e^* \) - Ratio of exchange coefficients of enthalpy and momentum
Annual Maximum Potential Intensity (m/s)
MIT Single Column Model

![Graph showing the relationship between potential intensity (m/s) and the number of CO₂ doublings. The graph shows a significant increase in potential intensity as the number of CO₂ doublings increases.](image-url)
Trends in Thermodynamic Potential for Hurricanes, 1980-2010
(NCAR/NCEP Reanalysis)
Projected Trend, 2006-2100: GFDL model
RCP 8.5
Time series of the latitudes at which tropical cyclones reach maximum intensity.

From Kossin et al., *Nature*, (2014)
Projections of Future Hurricane Risk
Problems with direct numerical simulation of tropical cyclones globally

Histograms of Tropical Cyclone Intensity as Simulated by a Global Model with 30 mile grid point spacing.

Global models do not simulate the storms that cause destruction

(Courtesy Isaac Held, GFDL)
Our Approach:

Embed highly detailed computational hurricane models in large-scale conditions produced by climate analyses or climate models. Generate 1000-100,000 events.

Sample Storm Wind Swath

Track number 7940, September
Accumulated Rainfall (mm)
Storm Surge Simulation (Ning Lin)

SLOSH mesh ~ $10^3$ m

ADCIRC mesh ~ $10^2$ m

Battery

(Adapted from Colle et al. 2008)
A Grey Swan: Dubai

Return Periods

New England

Wind Speed (knots)

Return Period (years)

- Theory
- Synthetic events
- 59 Best tracks, 1900 - 2007
Projections of Global TC Power Dissipation using 6 CMIP5 Climate Models

Eocene hurricane making landfall in the Yukon
Surge Return Periods for The Battery, New York

GCM flood height return level, Battery, Manhattan
(assuming SLR of 1 m for the future climate)

Blue: A1B future climate (2081-2100)
Red: A1B future climate (2081-2100) with $R_0$ increased by 10% and $R_m$ increased by 21%

TC Intensity Forecast Nightmares
Summary

The weight of existing evidence supports the conclusion that unmitigated climate warming presents significant risk to future generations.

Scientific uncertainty about the nature and magnitude of climate change entails a low but not tiny risk of catastrophic outcomes.

Among the myriad risks posed by climate change are changes in extreme events, including hurricanes.

There is now a strong consensus that the frequency of high category events should rise, producing a greater number of storms (like Haiyan) that exceed empirical tolerance levels.
There is also a strong consensus that tropical cyclone rainfall and associated flood hazards will increase with temperature.

Increased high category events coupled with sea level indicate a strong risk of increased storm surge hazard.