Refining Climate Change Event Attribution Capabilities in CAM

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Extreme Weather Impacts

U.S. 2020 Billion-Dollar Weather and Climate Disasters

- Western Wildfires, California, Oregon, Washington Firestorms Fall 2020
- Western / Central Drought and Heatwave Summer-Fall 2020
- Central Severe Weather - Derecho August 10
- North Central and Ohio Valley Hail Storms and Severe Weather April 7-8
- Midwest and Ohio Valley Severe Weather March 27-28
- Tennessee Tornadoes and Southeast Severe Weather March 2-4
- Hurricane Isaias August 3-4
- South, East and Northeast Severe Weather Feb 5-7
- South, Central and Eastern Severe Weather May 20-23
- Southeast and Eastern Tornado Outbreak April 12-13

Of the 16 separate billion-dollar weather and climate disasters that impacted the United States from January–September 2020.

Motivation

• Can the impact of climate change on the rainfall associated with individual hurricanes be quantified using CAM?

• How can these event attribution frameworks be utilized to help translate the impacts of climate change to the public and decision-makers?
Traditional Approach

- National Center for Atmospheric Research’s (NCAR) Community Atmosphere Model version 5 (CAM 5).
- Performed with 30 vertical levels is used at the horizontal resolutions of ~25 km.
- Full CAM 5 physics with Atmospheric Model Intercomparison Project (AMIP) protocols (with prescribed aerosol forcing).
- Individual storms are tracked using TempestExtremes (github.com/ClimateGlobalChange/tempestextremes)
General decrease in storm hours over land, which is consistent with a decrease in TC frequency.

[Stansfield et al. 2020, GRL]
Projections are mixed when looking at rainfall from TCs.

[Stansfield et al. 2020, GRL]
The amount of TC-related extreme precipitation (and TC-related precipitation in general) increases per storm hour!

[Stansfield et al. 2020, GRL]
Hindcast Attribution Framework

- National Center for Atmospheric Research’s (NCAR) Community Atmosphere Model version 5 (CAM 5).
- Variable resolution is used over region of interest with 30 vertical levels is used at the local horizontal resolution of: $\Delta x = \sim 100 > \sim 25$ km
- **Actual Forecast:** Similar to full physics AMIP simulation, but initialized at specific times in advance of hurricane landfall. Initial conditions taken from operational NOAA GFS.
- **Counterfactual Forecast:** Temperature, specific humidity, and SST from the observed initial conditions are modified to remove effects of climate change (using CAM5 C20C+ or the CESM Large Ensemble).
- Prescribed observed SSTs, ozone, $\text{CO}_2$, solar forcing.

TempestExtremes
Methodology

1) **Identify** candidate TCs based on sea level pressure minima and warm core characteristics.
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2) Stitch together candidates into **TC trajectories**
Example: Hurricane Florence (2018)

- CAM5 reproduces Hurricane Florence track and landfall location in both landfalls.
- Suggests that the model is fit-for-purpose.

[Reed et al. 2020, Science Adv.]
TempestExtremes

Methodology

1) Identify candidate TCs based on sea level pressure minima and warm core characteristics

2) Stitch together candidates into TC trajectories

3) For each trajectory and timestep, compute an azimuthal-average radial wind profile and identify the radius of the 8 m/s wind (r8)
## TempestExtremes Methodology

1. **Identify** candidate TCs based on sea level pressure minima and warm core characteristics

2. Stitch together candidates into **TC trajectories**

3. For each trajectory and timestep, compute an azimuthal-average radial wind profile and identify the radius of the 8 m/s wind ($r_8$)

4. **Extract** only precipitation that is within $r_8$ around the center of the TC at each timestep in its lifetime
Hurricane Florence (2018)
Accumulated Rainfall

- Actual forecast can reproduce Florence rainfall amounts reasonably well.
- Rainfall is increased due to observed warming.

Feb. 10, 2021
[Reed et al. 2020, Science Adv.]
Hurricane Florence (2018) Extreme Rainfall

- Clear shift of $\sim4 \pm 5.5\%$ in most extreme rainfall amounts due to climate change in Florence forecasts.
- Increase of $\sim5 \pm 4.5\%$ in overland land rainfall associated with core of storm (with 200 km of center).

[Reed et al. 2020, Science Adv.]
Hurricane Dorian (2019) Extreme Rainfall Rates

- Increase of \(~16 \pm 2\%\) in likelihood of maximum IMERG estimated rainfall amount.

Feb. 10, 2021 [Reed et al. 2021, BAMS]
Climate change increased the maximum total rainfall amount associated with Hurricane Laura by over 10%.

[Reed et al. 2021, in prep.]
Preliminary: Hurricane Season (2020)

- 20-member hindcasts ensembles are initialized every 3 days starting June 1 through November.

Feb. 10, 2021

[Reed et al. 2021, in prep.]
Preliminary: Hurricane Season (2020)

- Increase of $\sim 10 \pm 5\%$ in mean maximum accumulated rainfall amount.

Feb. 10, 2021

[Reed et al. 2021, in prep.]
• Hindcast attribution frameworks demonstrate that climate change has increased rainfall rates and accumulated amounts associated with recent Hurricanes (Florence, Dorian, 2020 storms, etc.) by 4-16%.

• This is consistent with projected changes in hurricane rainfall in decadal simulations of the future under various warming scenarios.

• Event attribution frameworks help to make the science more relatable to the public and practical for climate adaptation strategies.
Future Work

- There is a *growing effort* in the scientific community to refine the application of attribution frameworks for quantification of the impact of climate change on recent extreme events.

- We plan to adapt the hindcast attribution framework in CAM to project how the rainfall of recent events would change in the future.
To understand changes in extreme precipitation in the future, we need to understand the changes in the events responsible for extreme precipitation!

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