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CESM as a tool for operational climate change event attribution

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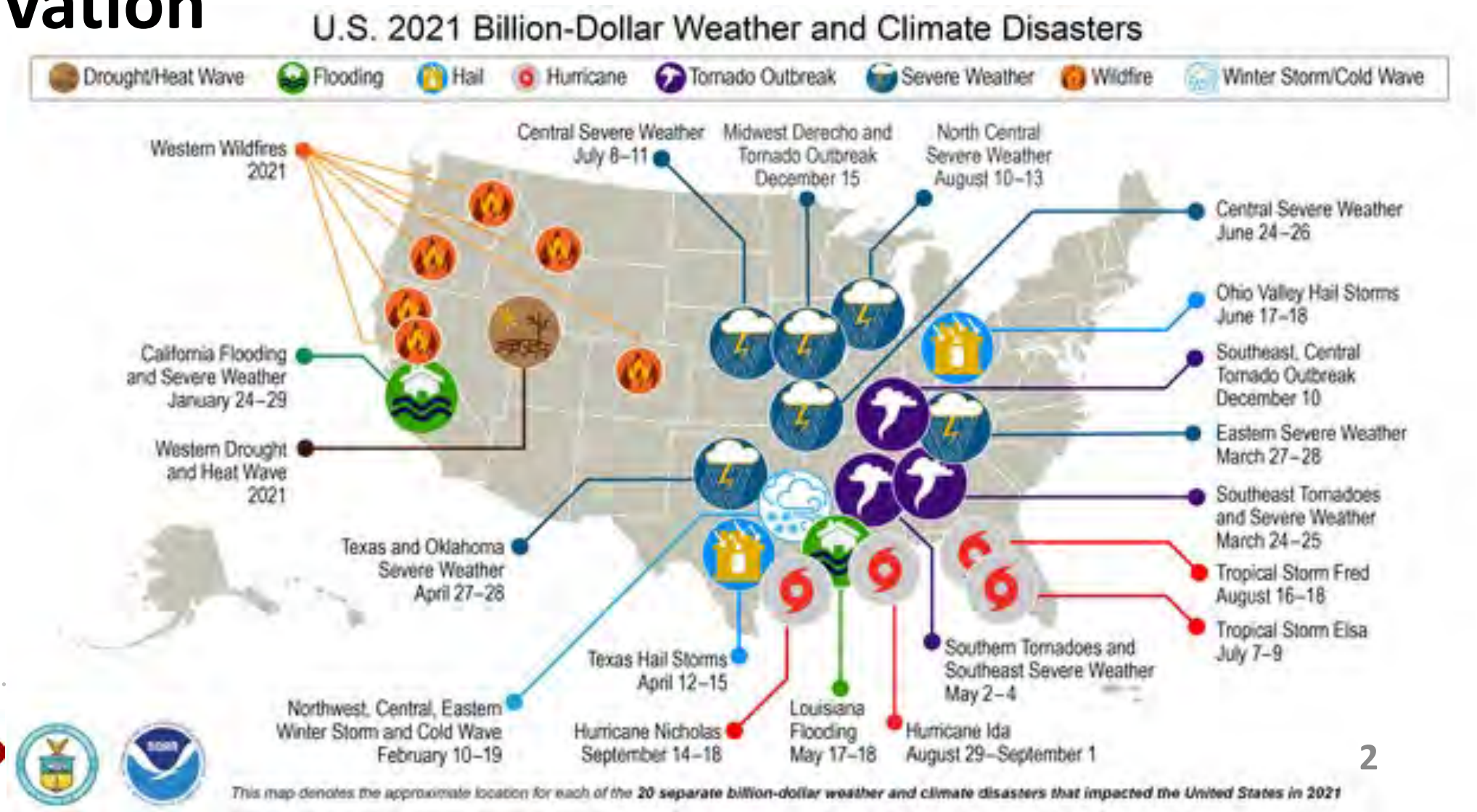
Motivation



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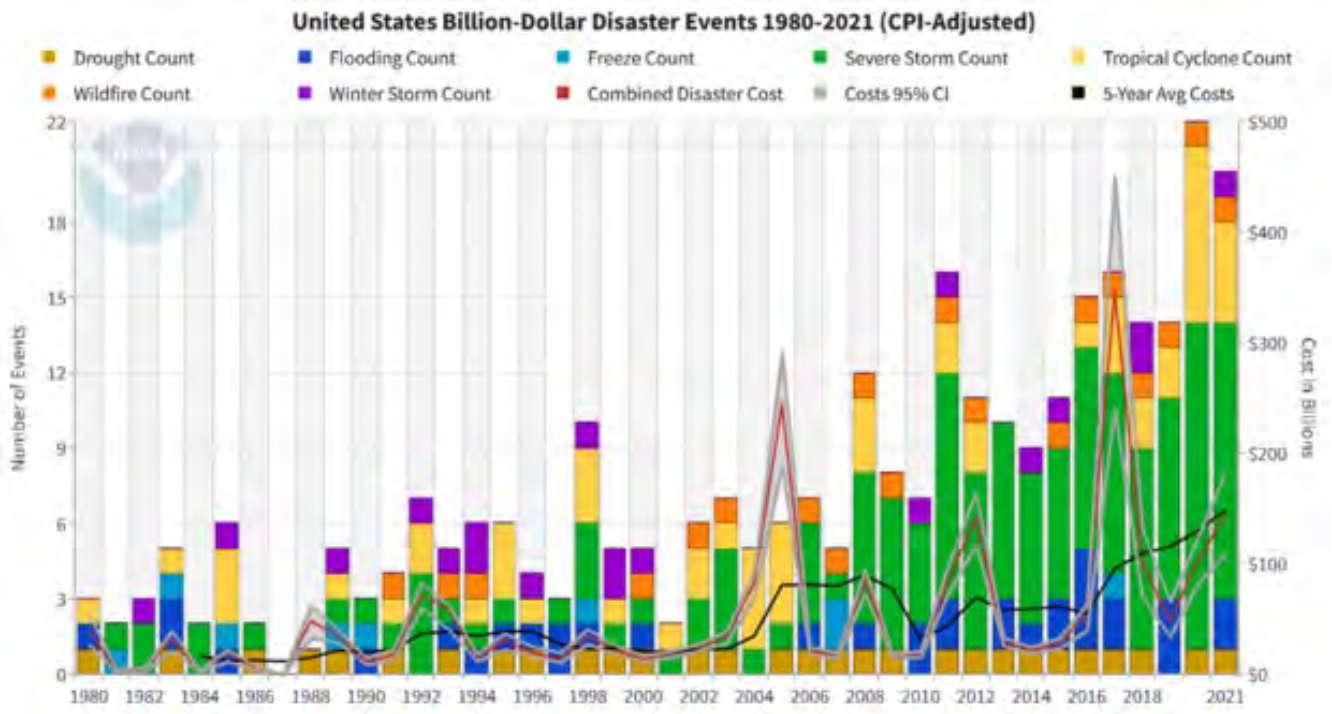
Motivation: Extreme Events and Climate Change

U.S. National Climate Assessment:

"*Changes in **extreme weather events** are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events.*"



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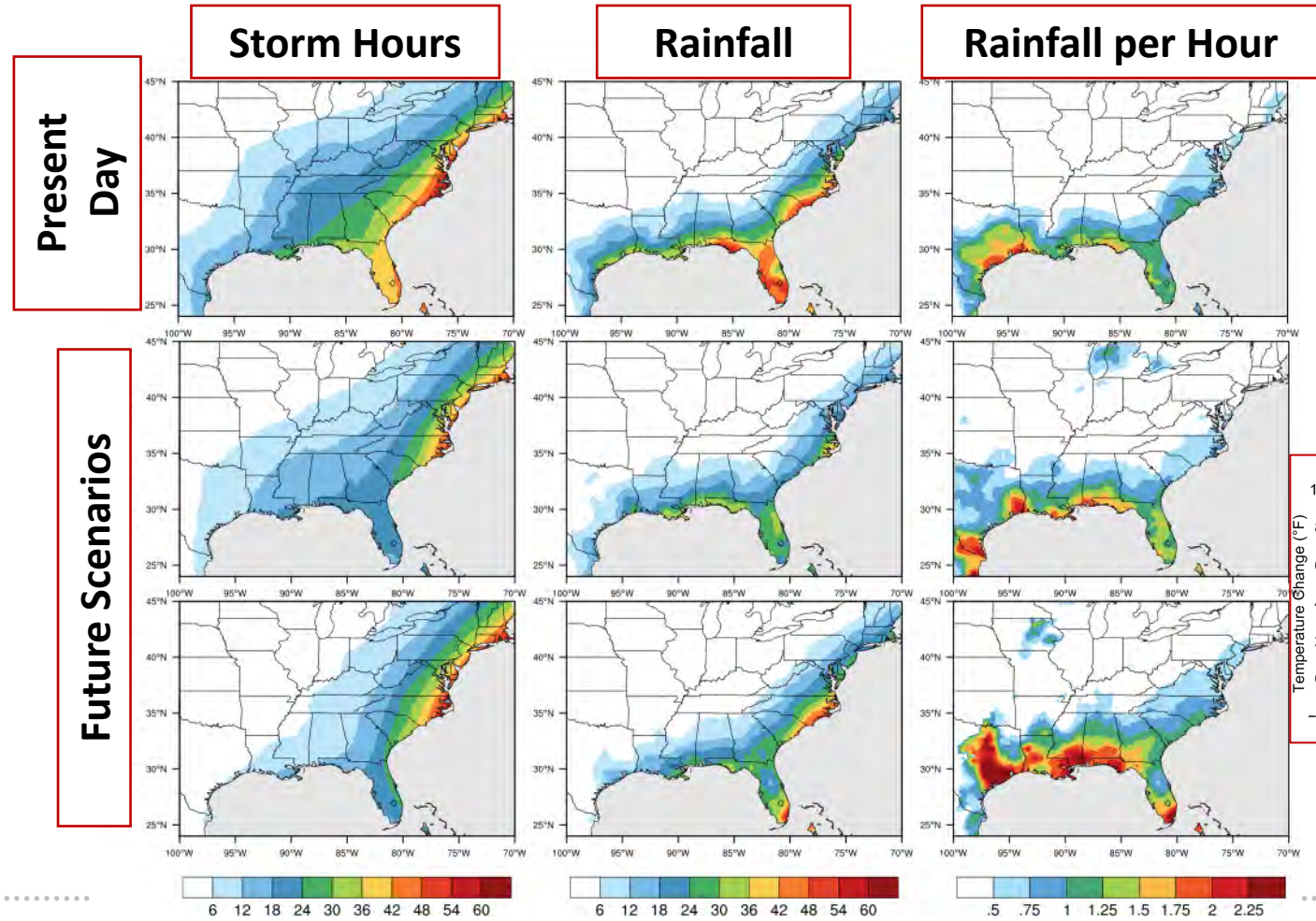
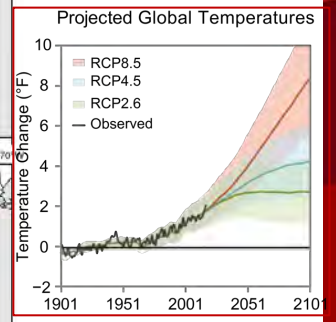
Traditional Approach: Hurricane Precipitation

General **decrease in storm hours** over land, which is consistent with a decrease in TC frequency.

Projections are mixed when looking at rainfall from TCs.

The amount of TC-related extreme precipitation (and TC-related precipitation in general) **increases per storm hour!**





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Motivation:

- Can the **impact of climate change on the rainfall** associated with hurricane seasons be quantified?

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

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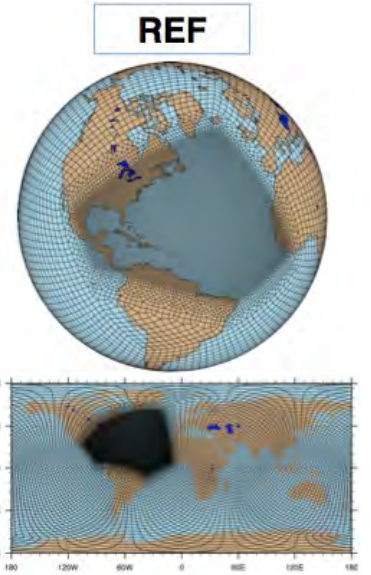
A Storyline Approach



- National Center for Atmospheric Research's (NCAR) Community Atmosphere Model version 5 (**CAM5**).
- Variable resolution is used over region of interest with 30 vertical levels is used at the local horizontal resolution of: Δx = ~100 > ~25 km
- **Actual:** Similar to full physics AMIP simulation, but initialized at specific times in advance of hurricane landfall. Initial conditions taken from operational **NOAA GFS**.
- **Counterfactual:** 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,CO_2, solar forcing.

Courtesy of **Erica Bower**

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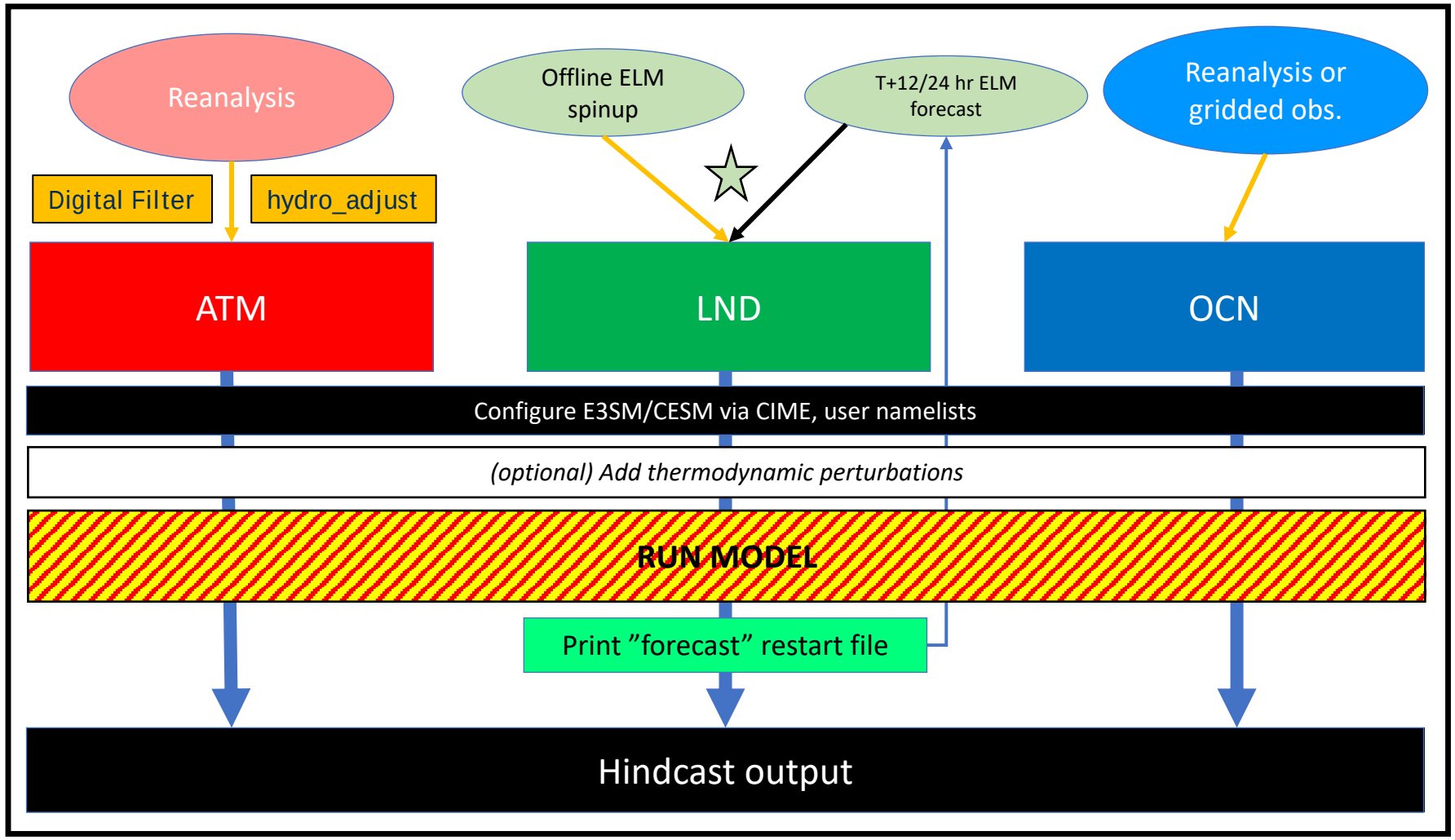
Betacast Implementation

Available on Github:

https://github.com/zarzycki/betacast



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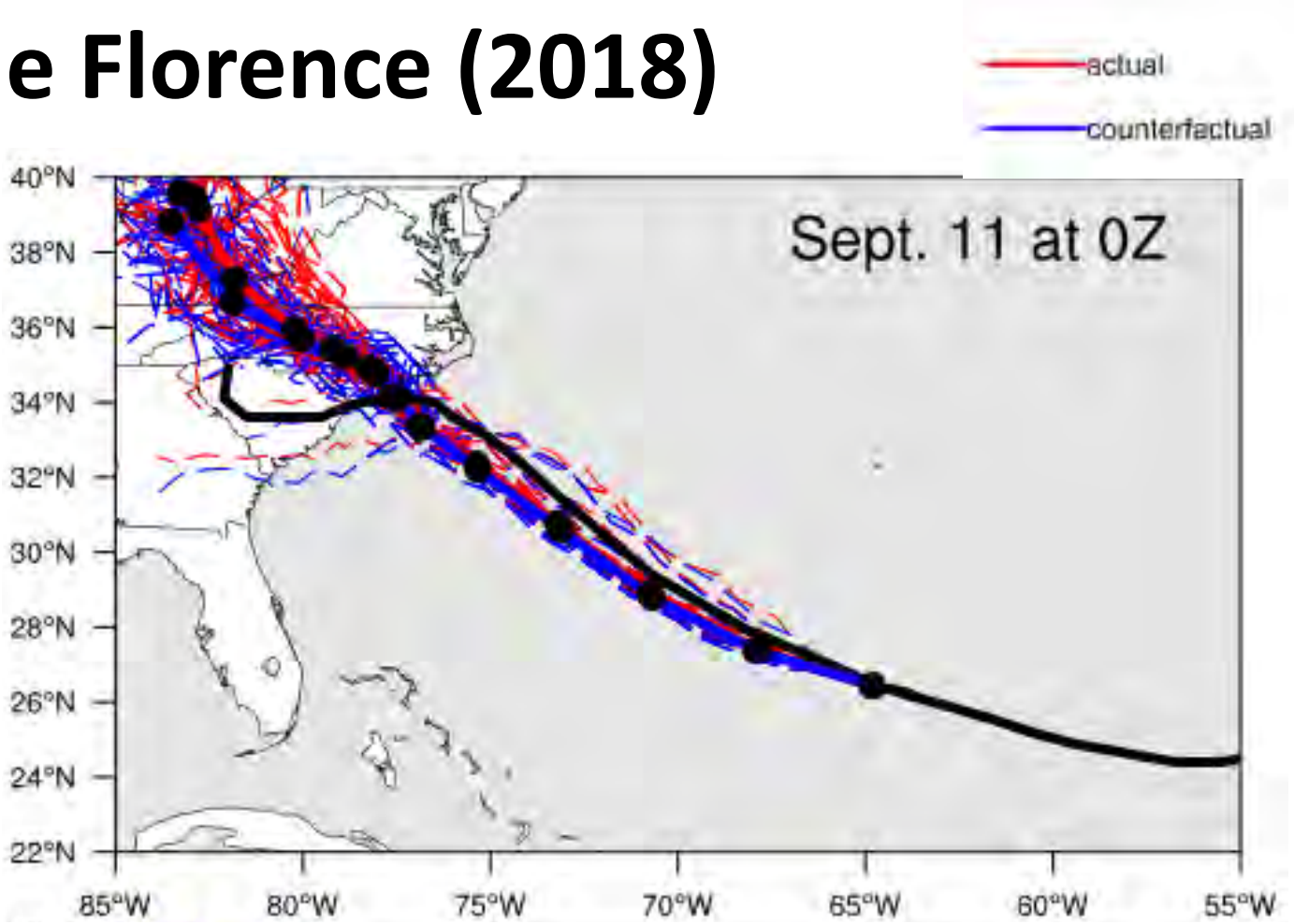
Prototype: Hurricane Florence (2018)

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



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[Reed et al. 2020, Science Advances]

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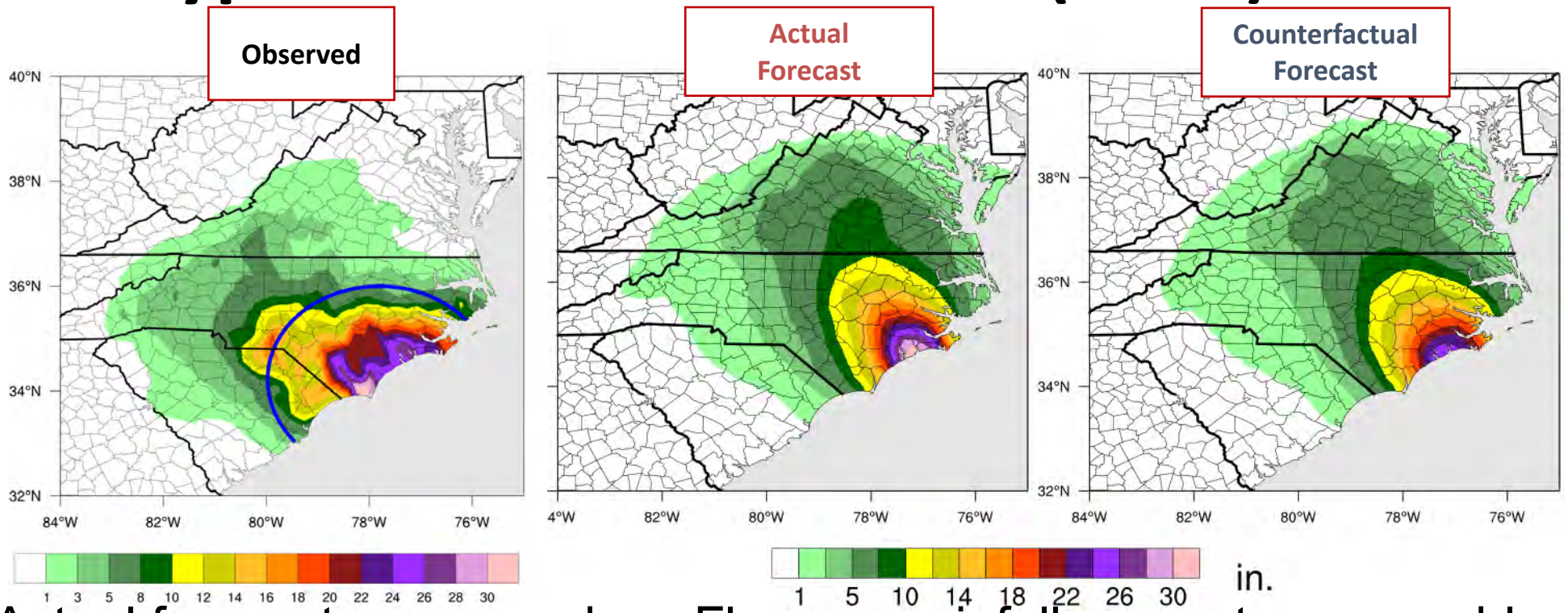
Prototype: Hurricane Florence (2018)



- Actual forecast can reproduce Florence rainfall amounts reasonably well.
- Rainfall is **increased by 5%** due to observed warming.

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[Reed et al. 2020, Science Advances]

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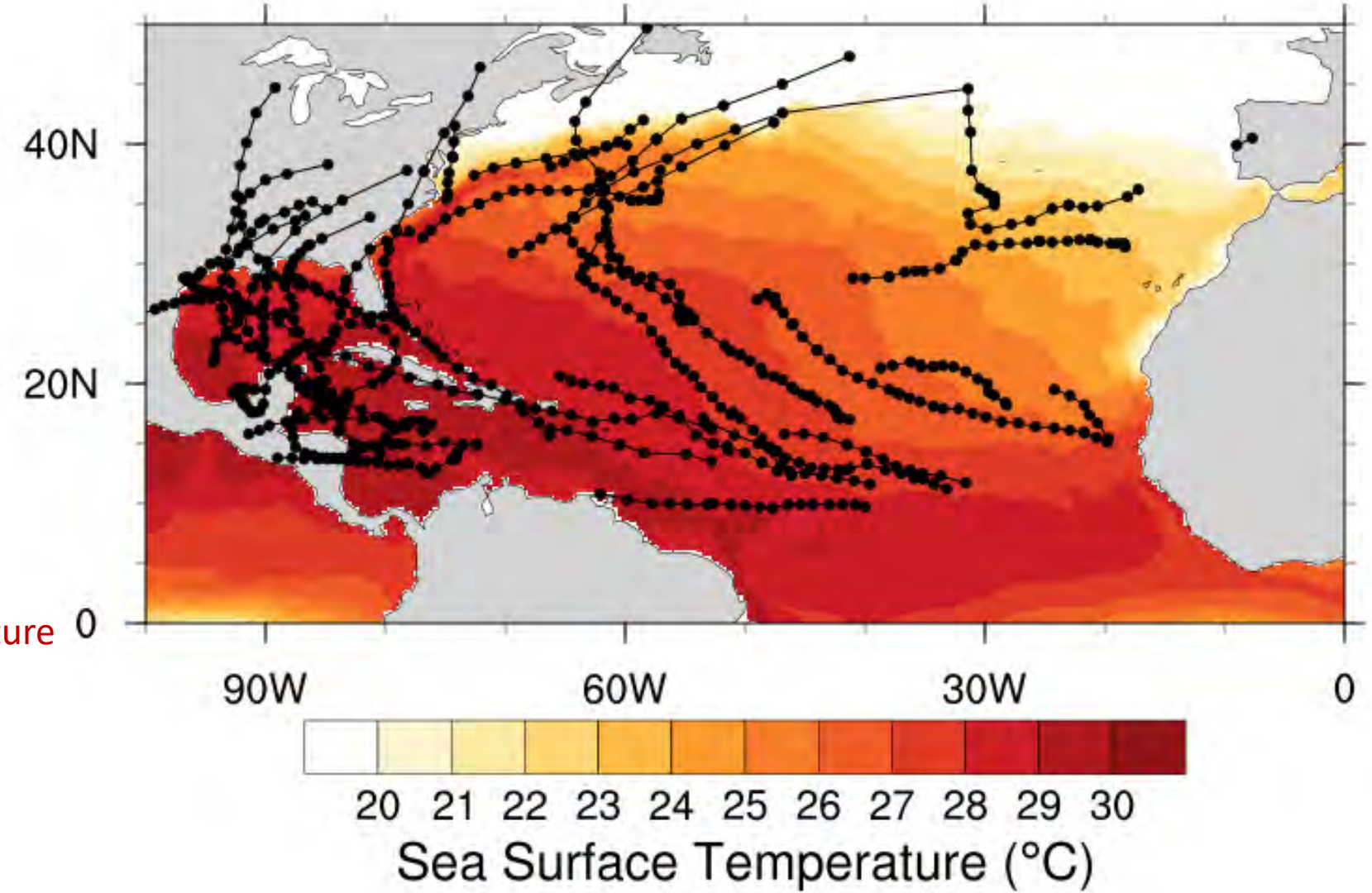
2020 Hurricane Season



[Reed et al. 2022, Nature Comm.]

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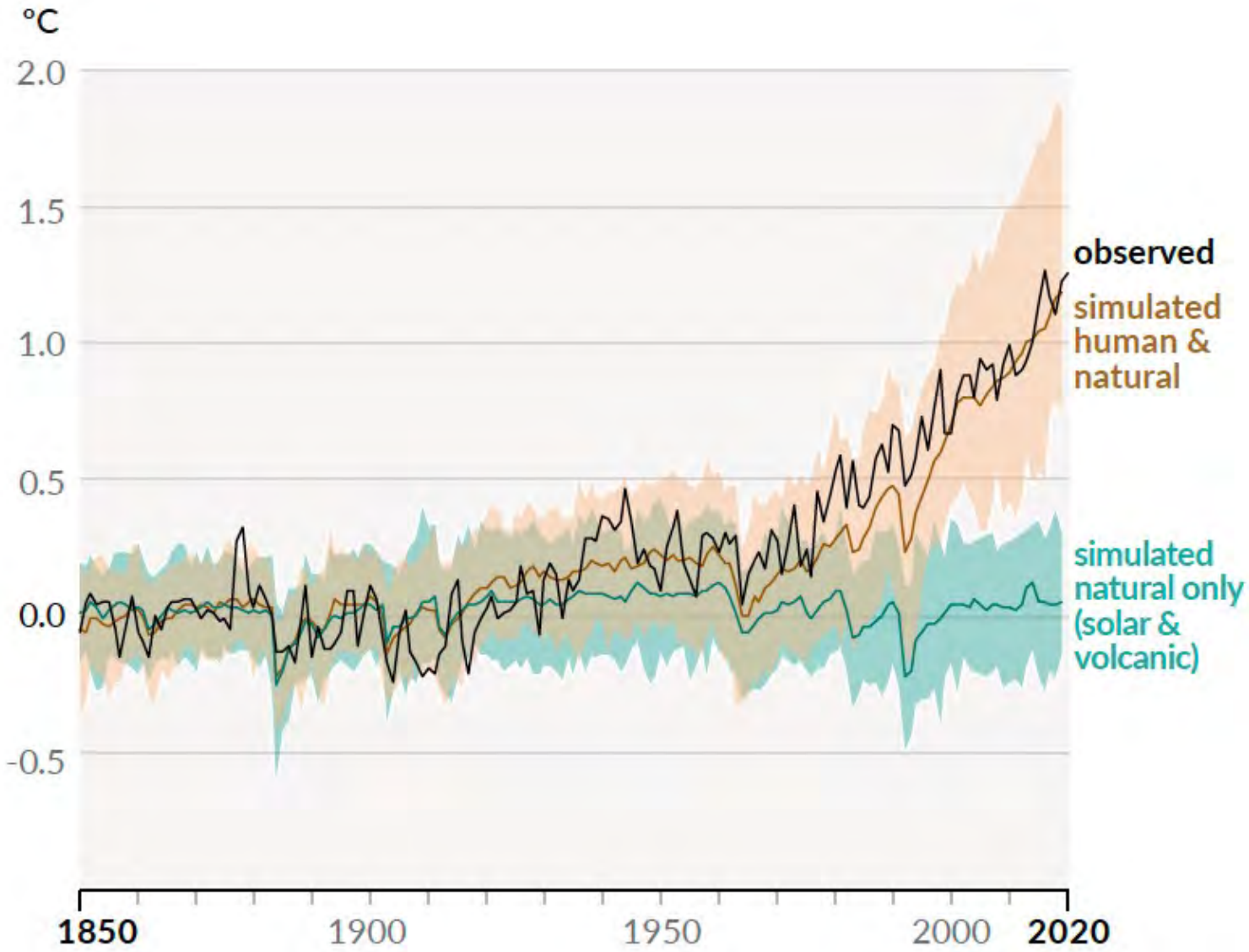
Building a Counterfactual

- Comparing 2020 to 1850
- Without human increases in GHG



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[IPCC AR6 WGI]

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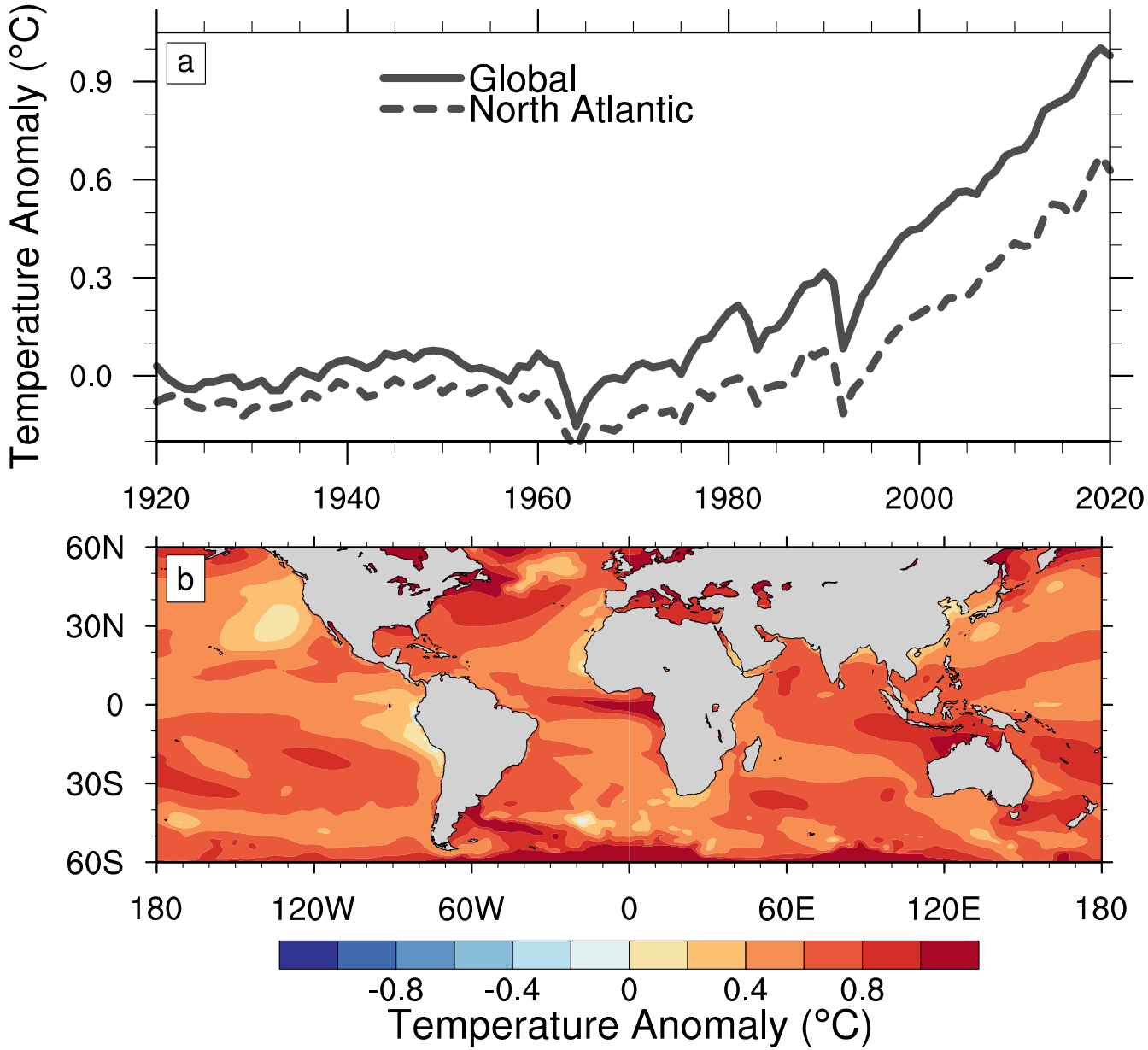
Building a Counterfactual

- Use the 40-member CESM Large Ensemble
- Update T, Q and PS for initial and boundary conditions.



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[Reed et al. 2022, Nature Comm.]

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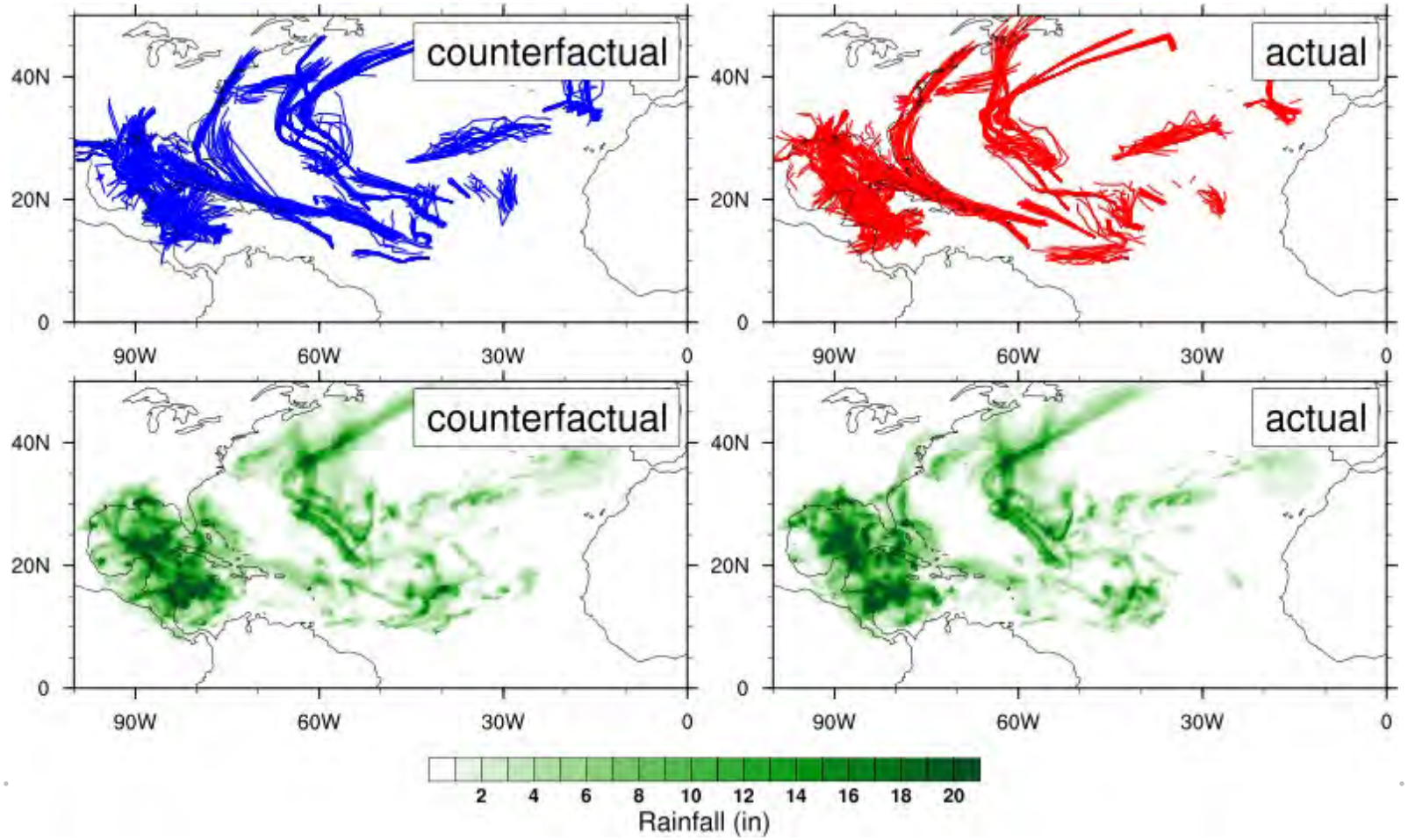
2020 Hurricane Season

Initialize hindcasts every 3 days starting June 1, 2020



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[Reed et al. 2022, Nature Comm.]

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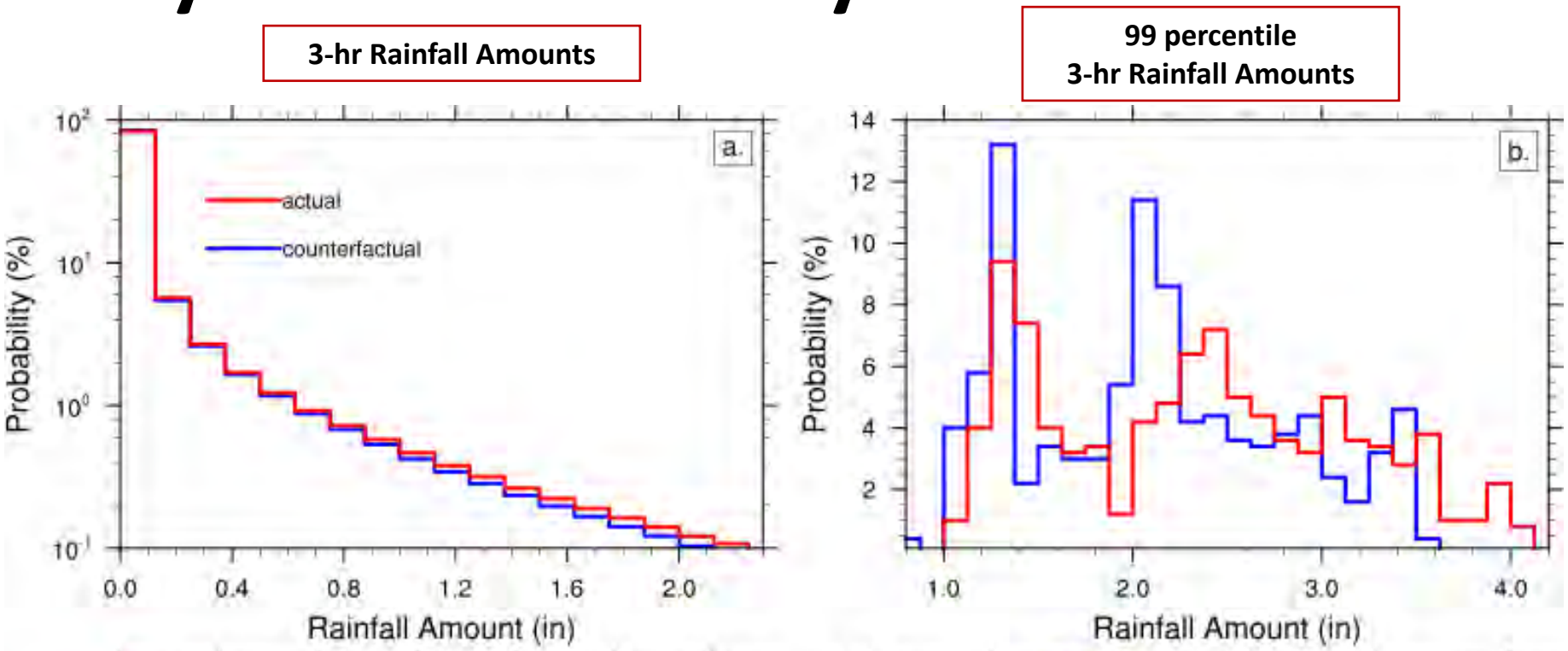
3-Hourly Rainfall Intensity



- A shift of **~10 ± 5%** in most extreme rainfall rates.

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[Reed et al. 2022, Nature Comm.]

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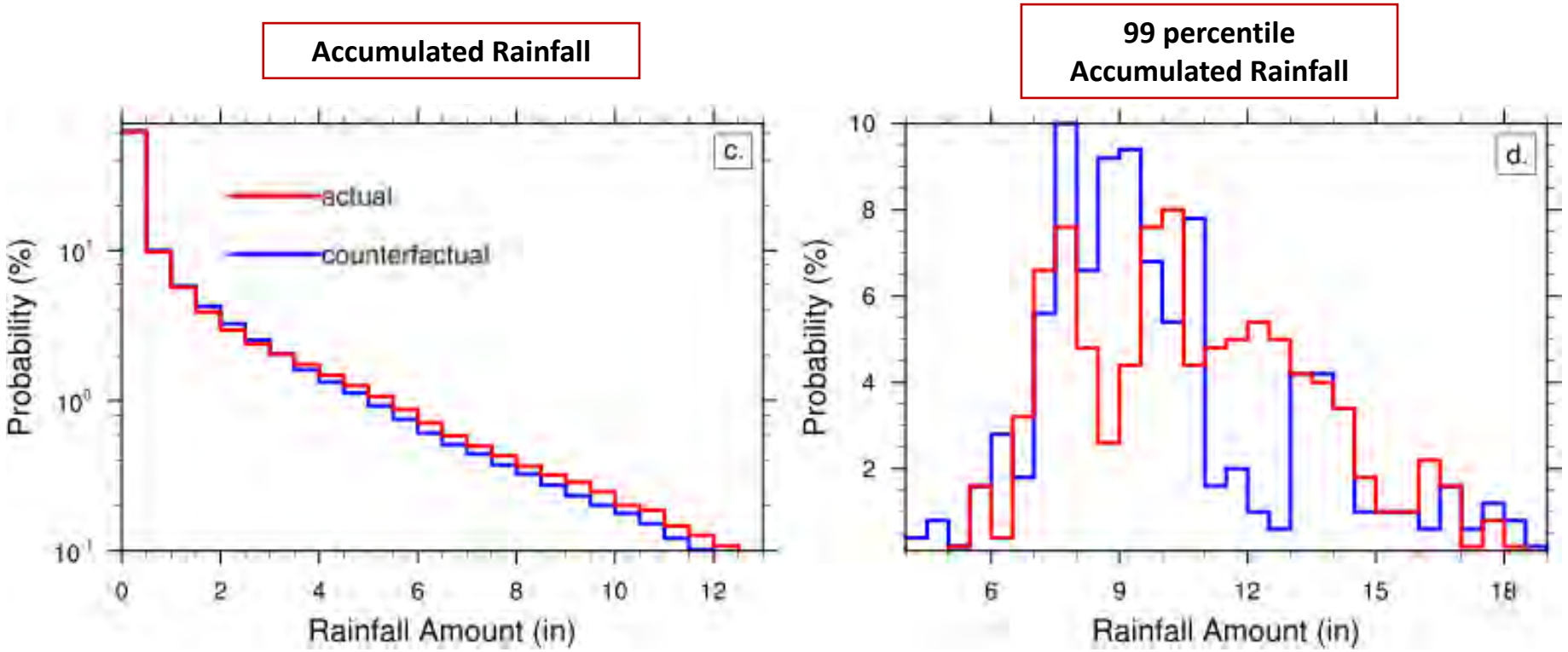
Accumulated Rainfall



- A shift of **~5 ± 5%** in extreme rainfall accumulation.

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[Reed et al. 2022, Nature Comm.]

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Summary

- This work demonstrates that human-induced climate change increased the extreme precipitation rates and accumulations by **5-11% for the entire 2020 hurricane season**.
- This represents the first study to **objectively apply the hindcast attribution method** to all storms of a given hurricane season, regardless of intensity or coastal impact.
- Suggests there is a pathway toward **operational forecast attribution frameworks**, even beyond hurricanes, in the future.

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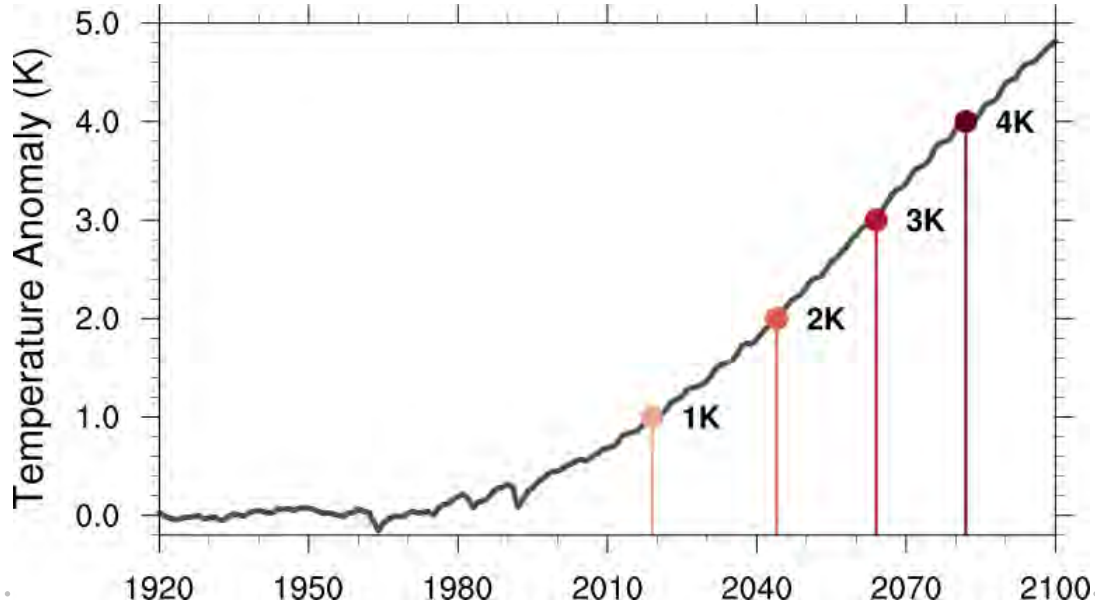
Ongoing Work

- 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 hurricanes or seasons would change in the future**.



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CESM Large Ensemble

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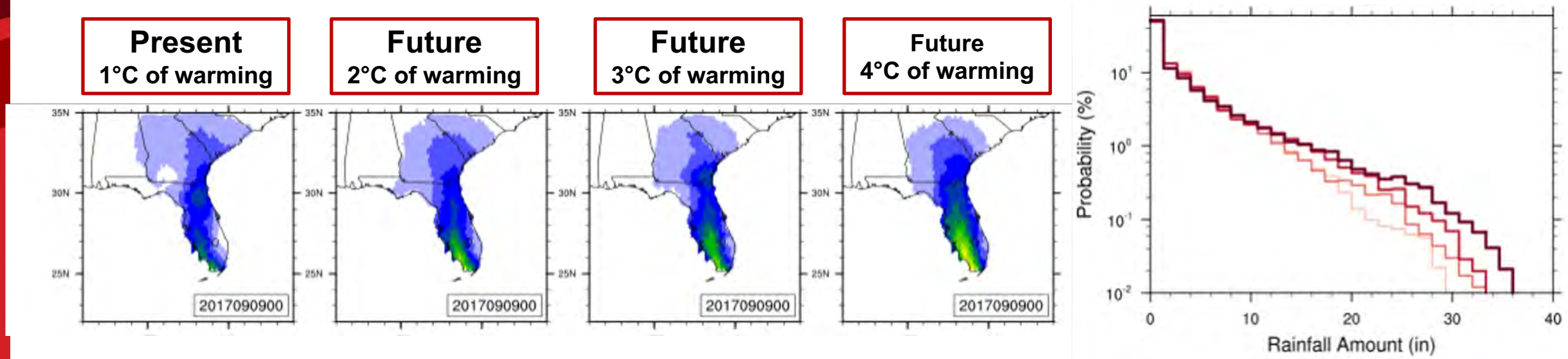
We are looking for a Postdoctoral Researcher! Please contact me.

Ongoing Work: Example Hurricane Irma (2017)

Simulations of Irma project an **increase in the mean and extreme precipitation** when forced with future thermodynamic signals:



~26 ± 6% increase in simulated extreme rainfall amounts.

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Questions?

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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HYPERFACETS
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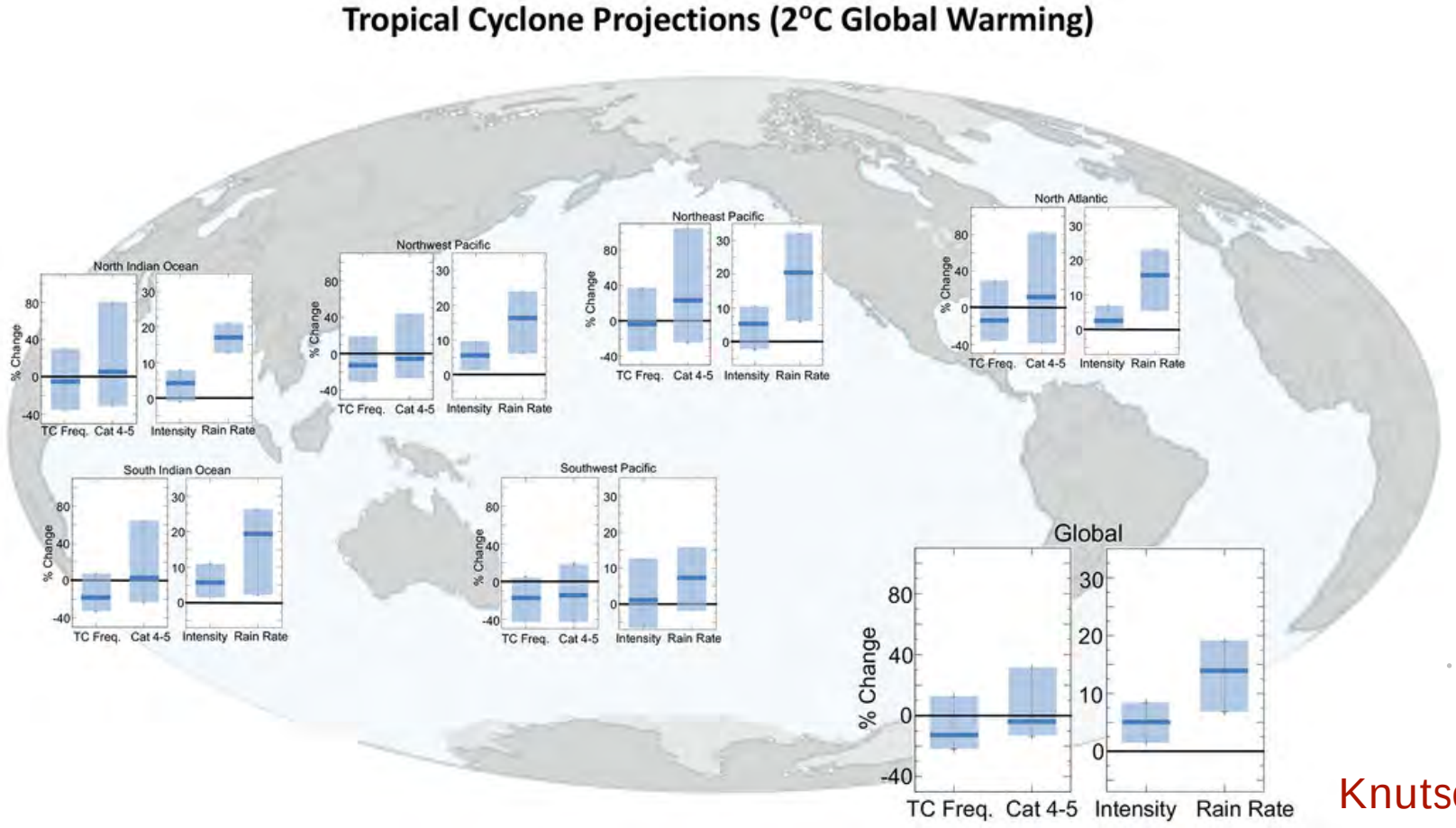
Global Assessment: Tropical Cyclones

Climate model generally show an increase in TC rain rates.



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Knutson et al. 2020