Quantifying climate impacts on recent events through storylines

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Motivation

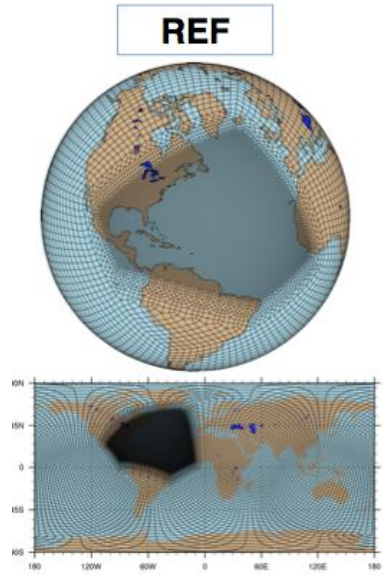
- Can the **impact of climate change (past and future) on the rainfall** associated with individual hurricanes or hurricane seasons be quantified?

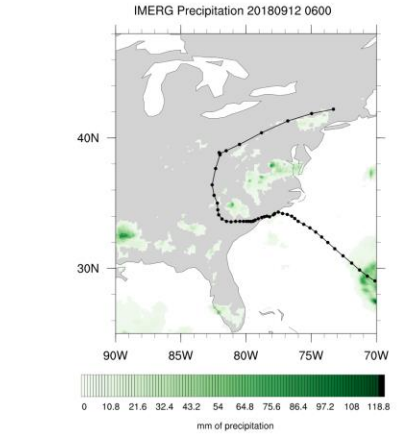
- Can **storyline frameworks** be utilized to help **translate the impacts of climate change** to the public, decision-makers, and other stakeholders?

Storyline Approach

- Utilize operational climate or weather model (Community Earth System Model - CESM).
- 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:** Simulation 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 or another large ensemble).
- Prescribed observed SSTs, ozone,CO_2, solar forcing.

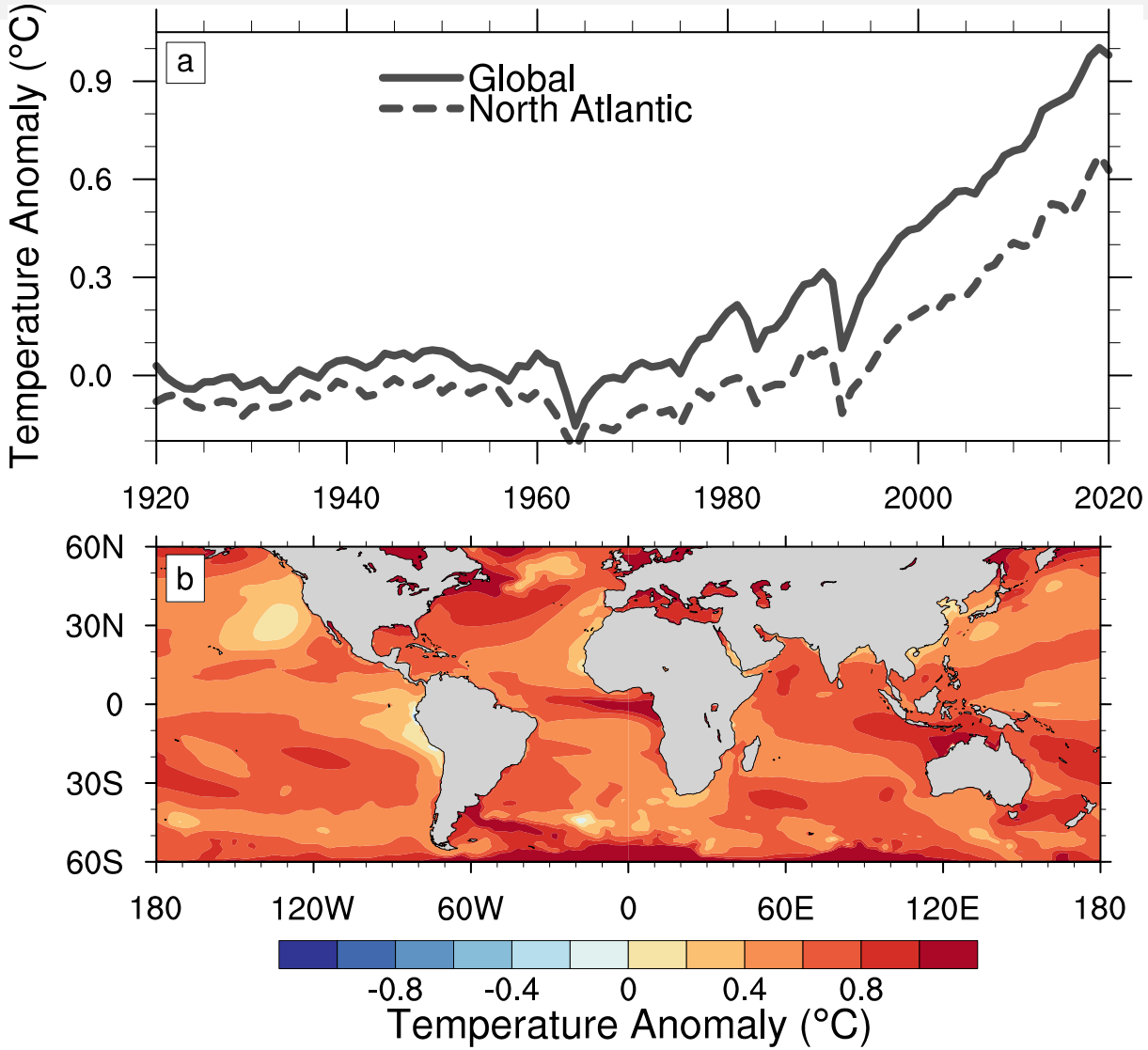




Building a Counterfactual

- Use the 40-member CESM Large Ensemble – routinely used in CMIP/IPCC process.

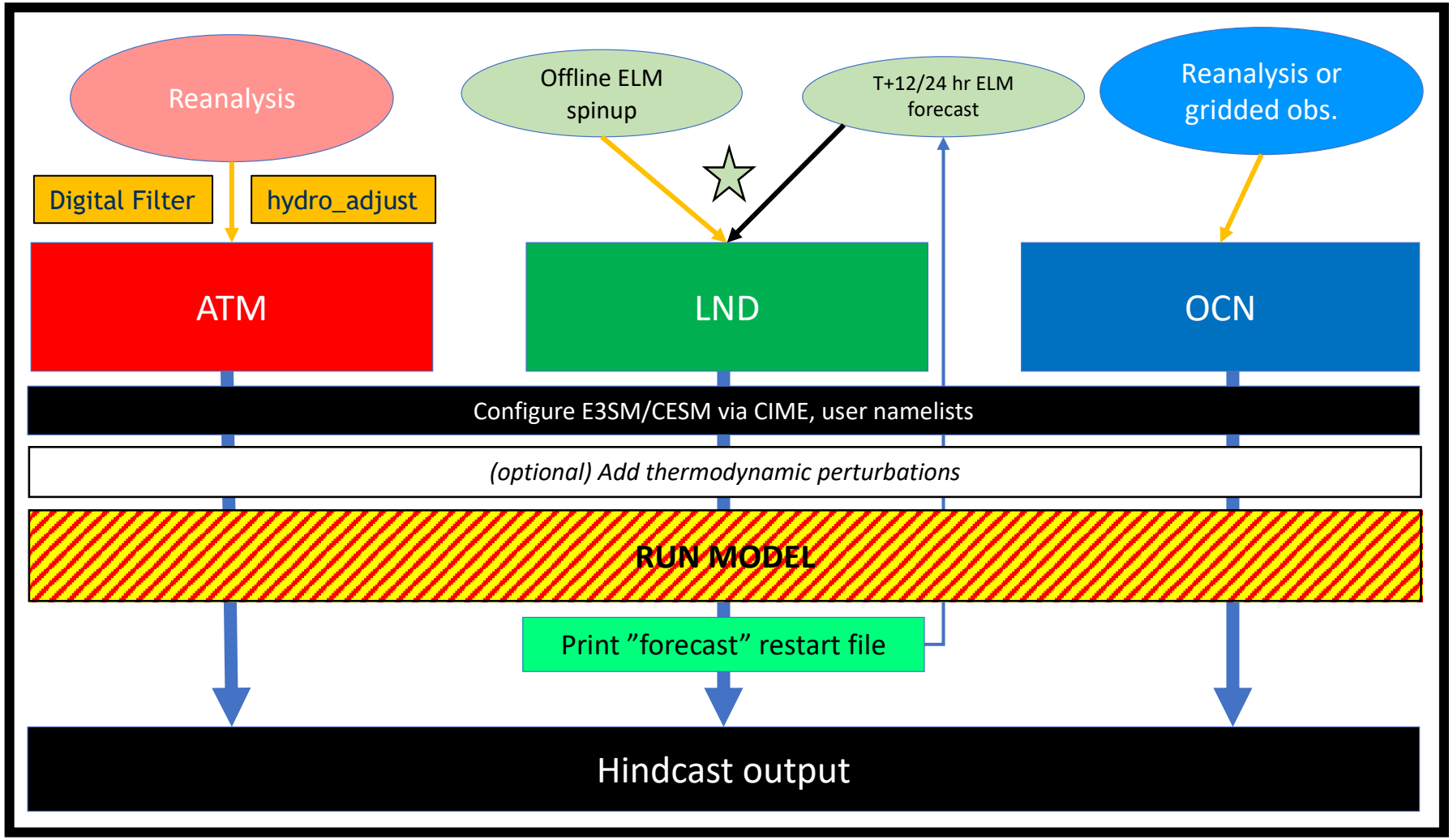
- Update temperature, specific humidity, and surface pressure in initial and boundary conditions.



Utilize Betacast

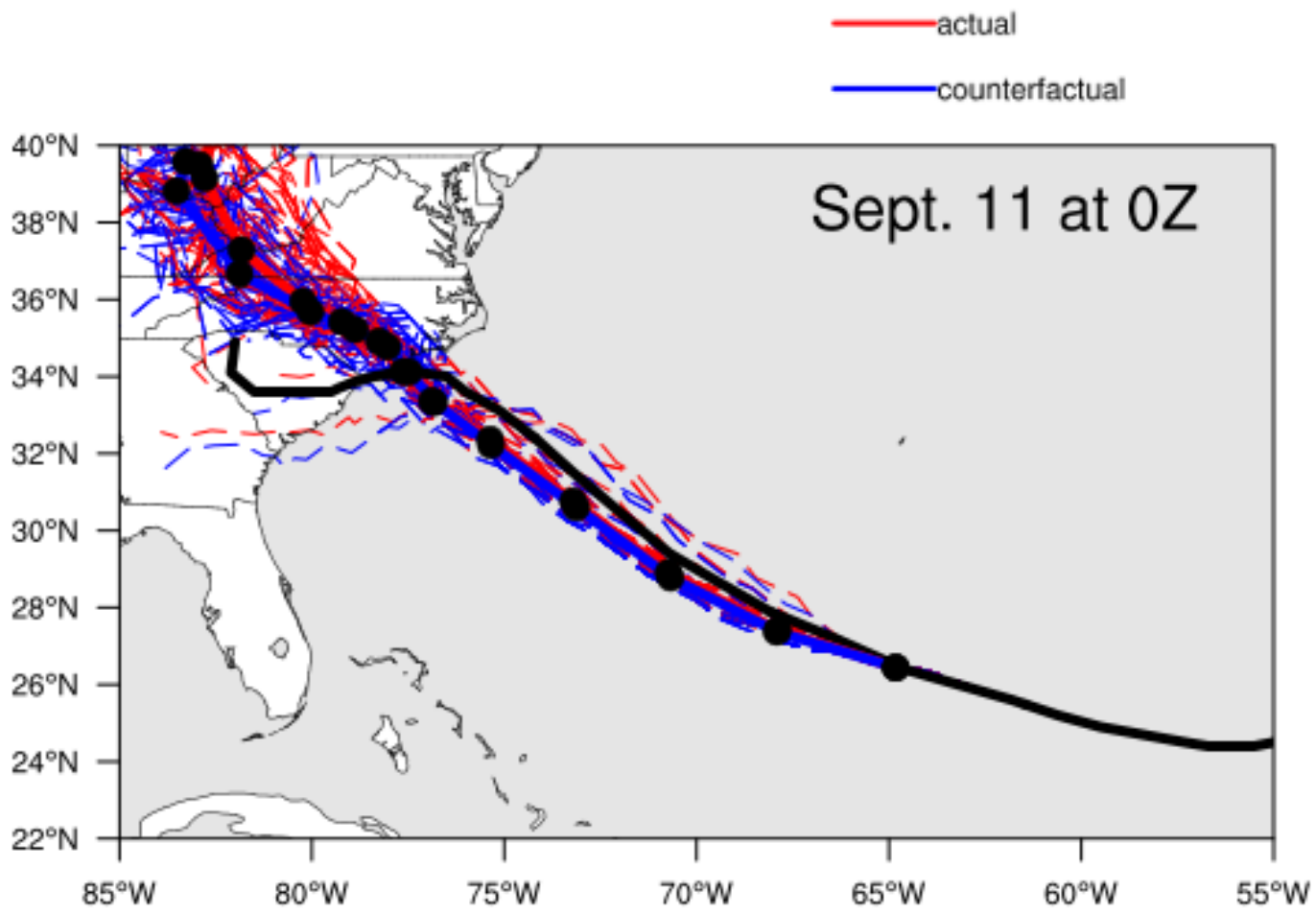
Available on Github:

https://github.com/zarzycki/betacast



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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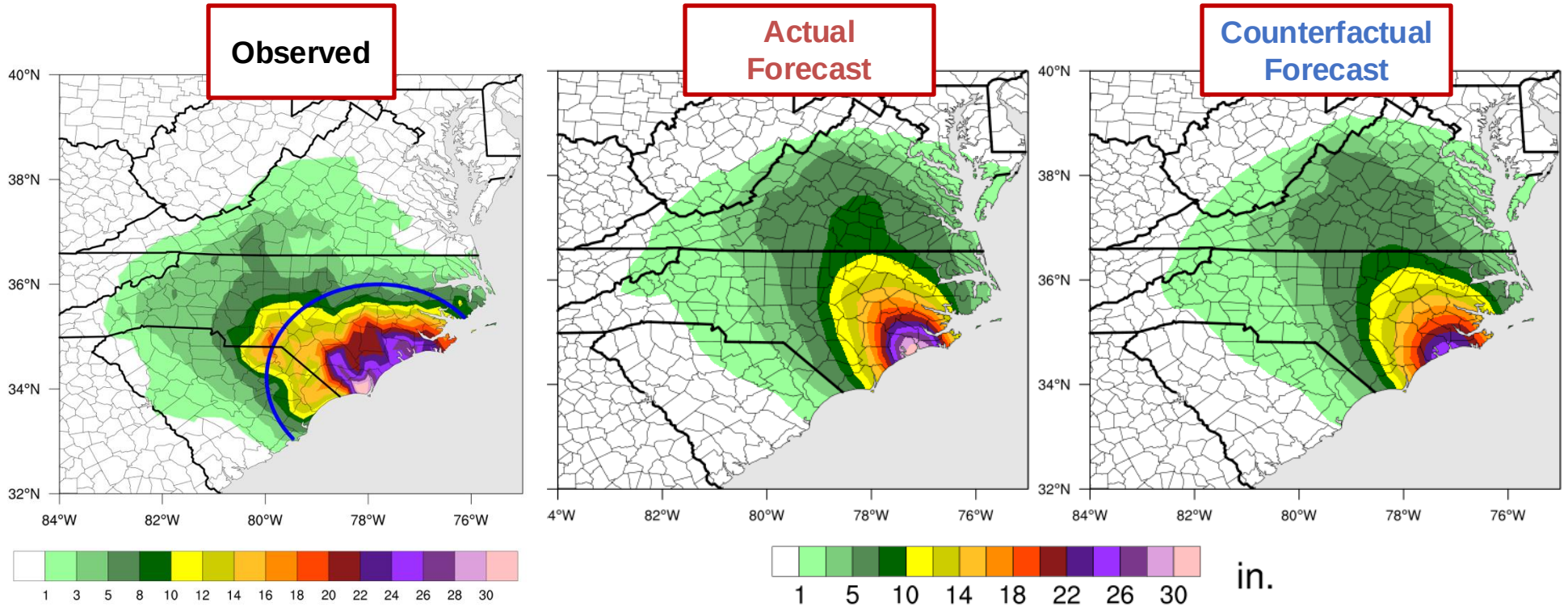
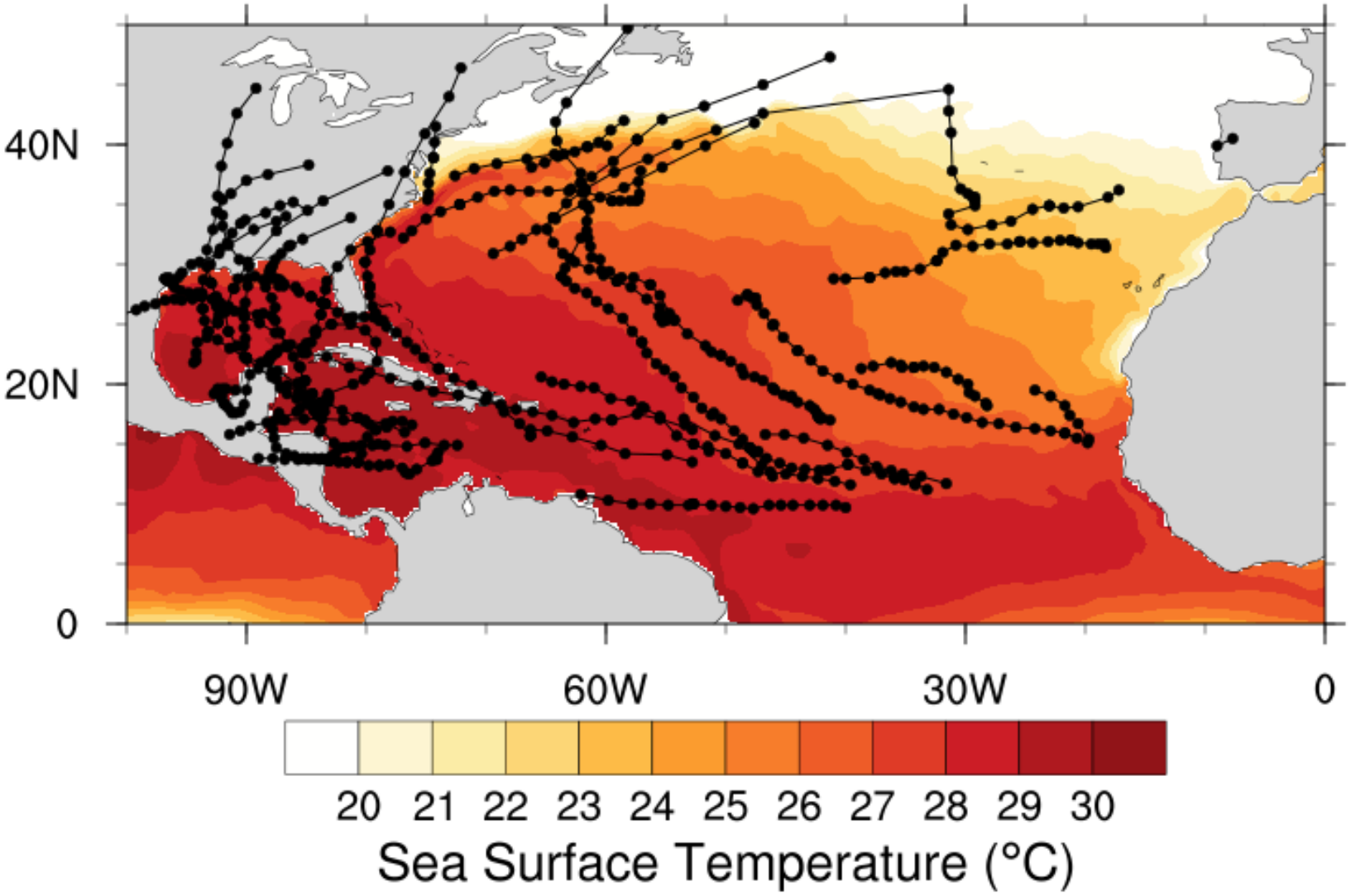


- Actual forecast can reproduce Florence rainfall amounts reasonably well.
- Rainfall is increased by 5% due to observed warming.

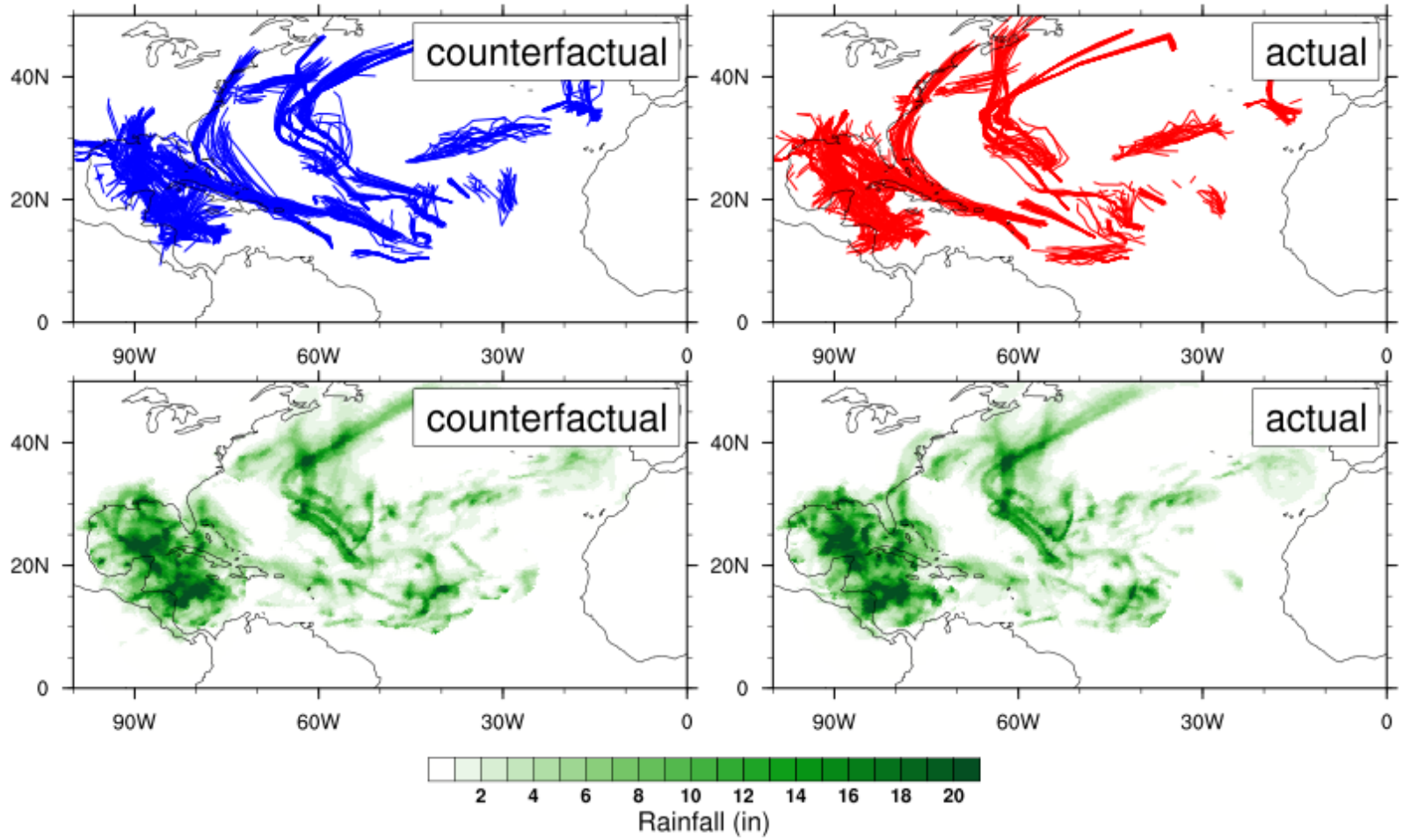
Seasonal Approach: 2020 Hurricane Season



Reed et al. (2022)

Seasonal Approach: 2020 Hurricane Season

Initialize hindcasts every 3 days starting June 1, 2020



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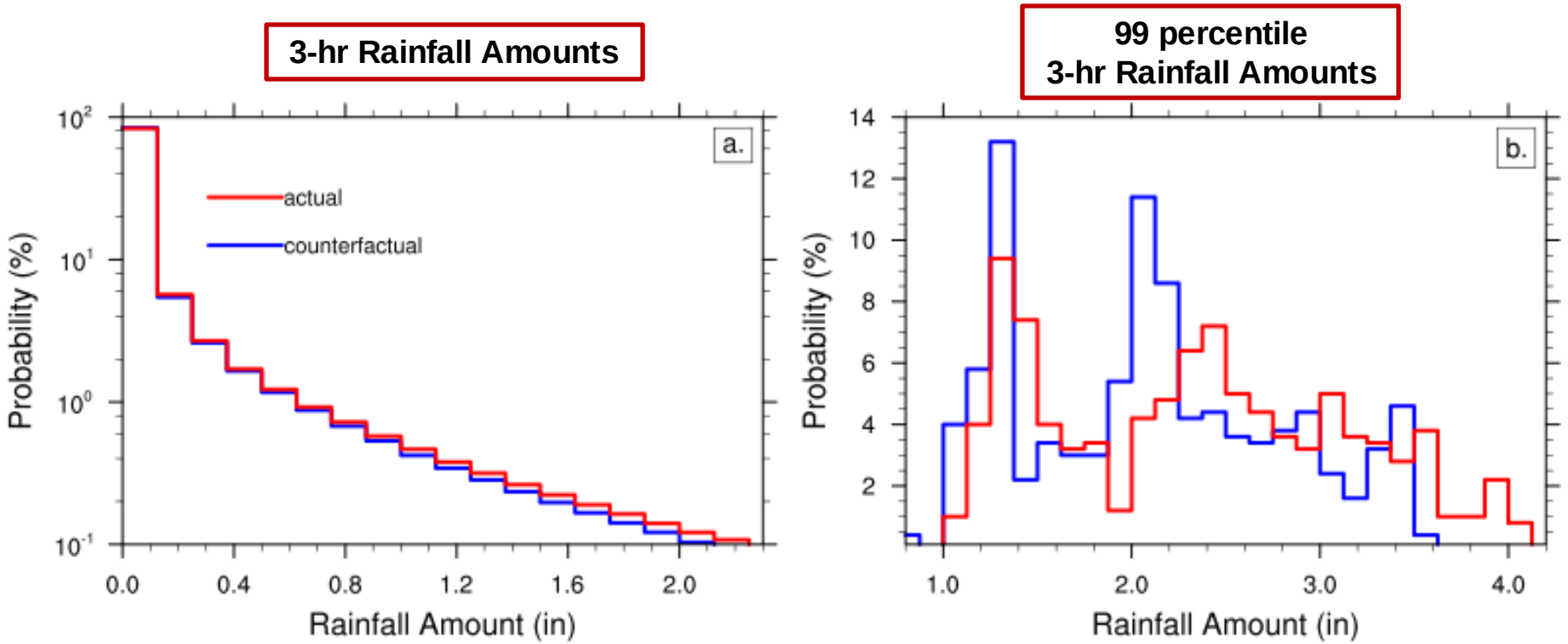
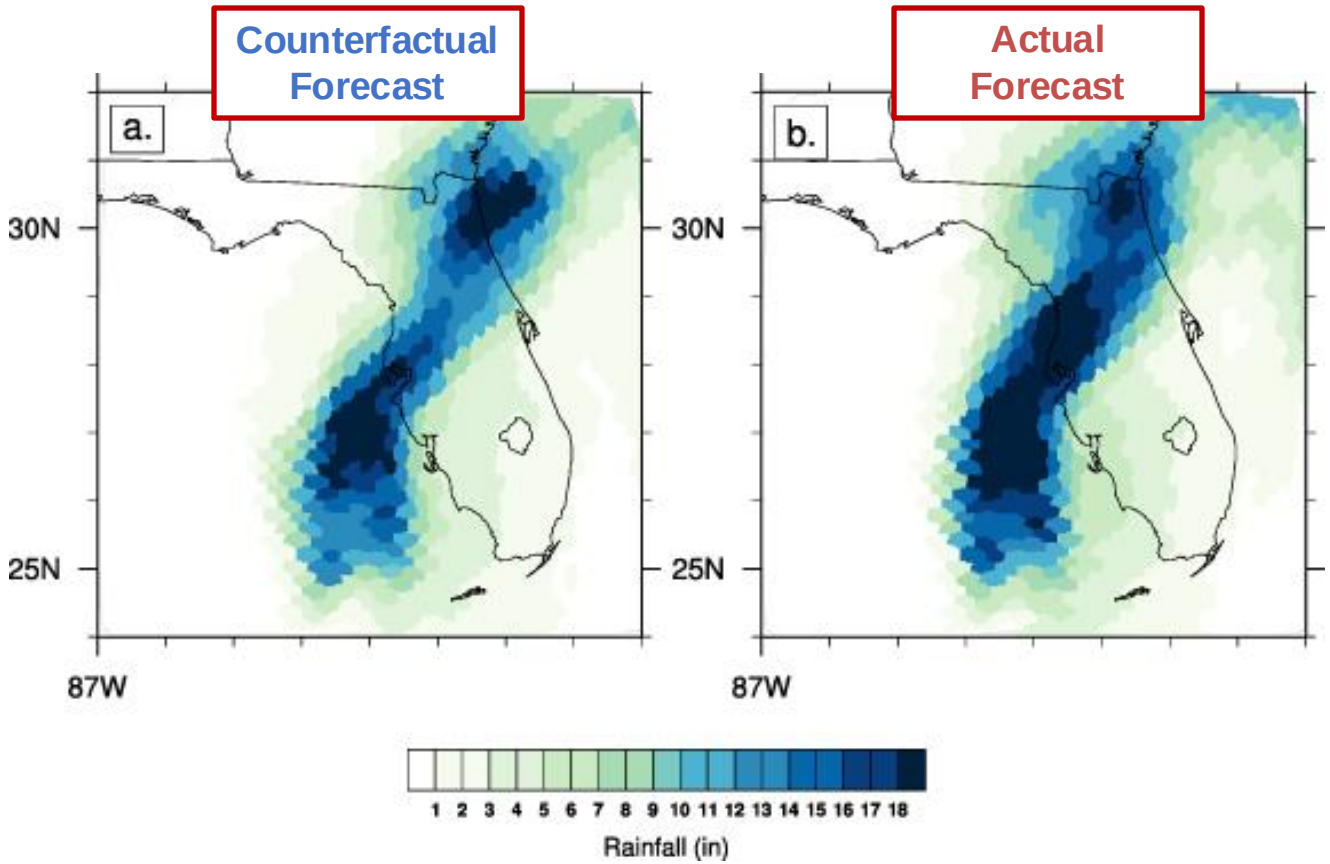
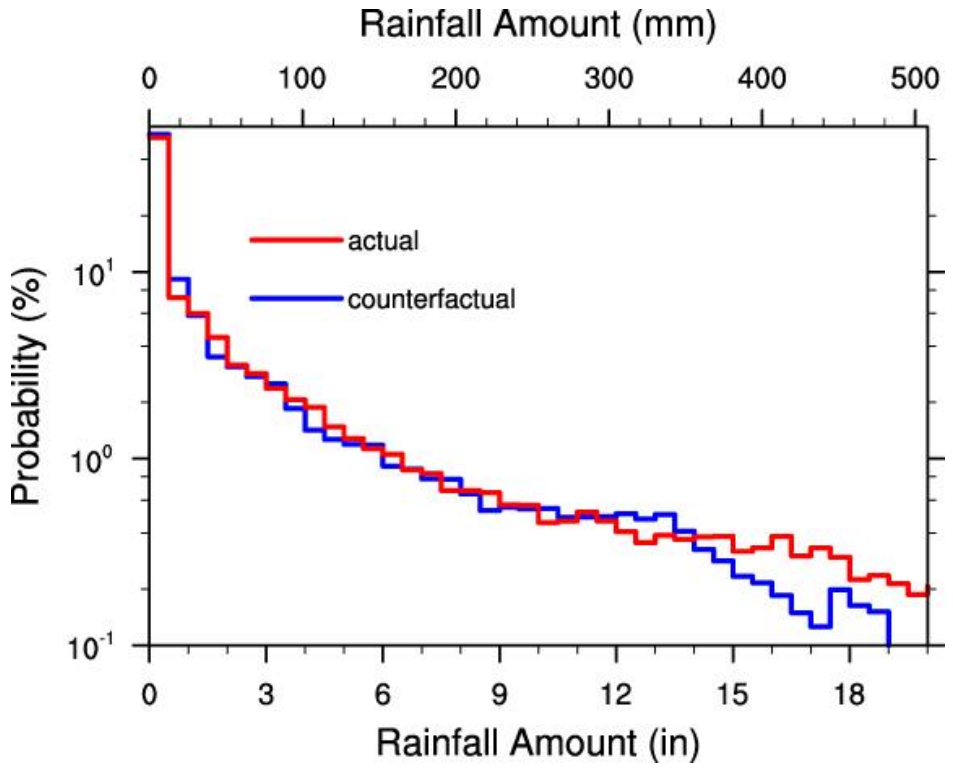
Seasonal Approach: 2020 Hurricane Season



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

Real-Time Approaches: Hurricane Ian (2022)





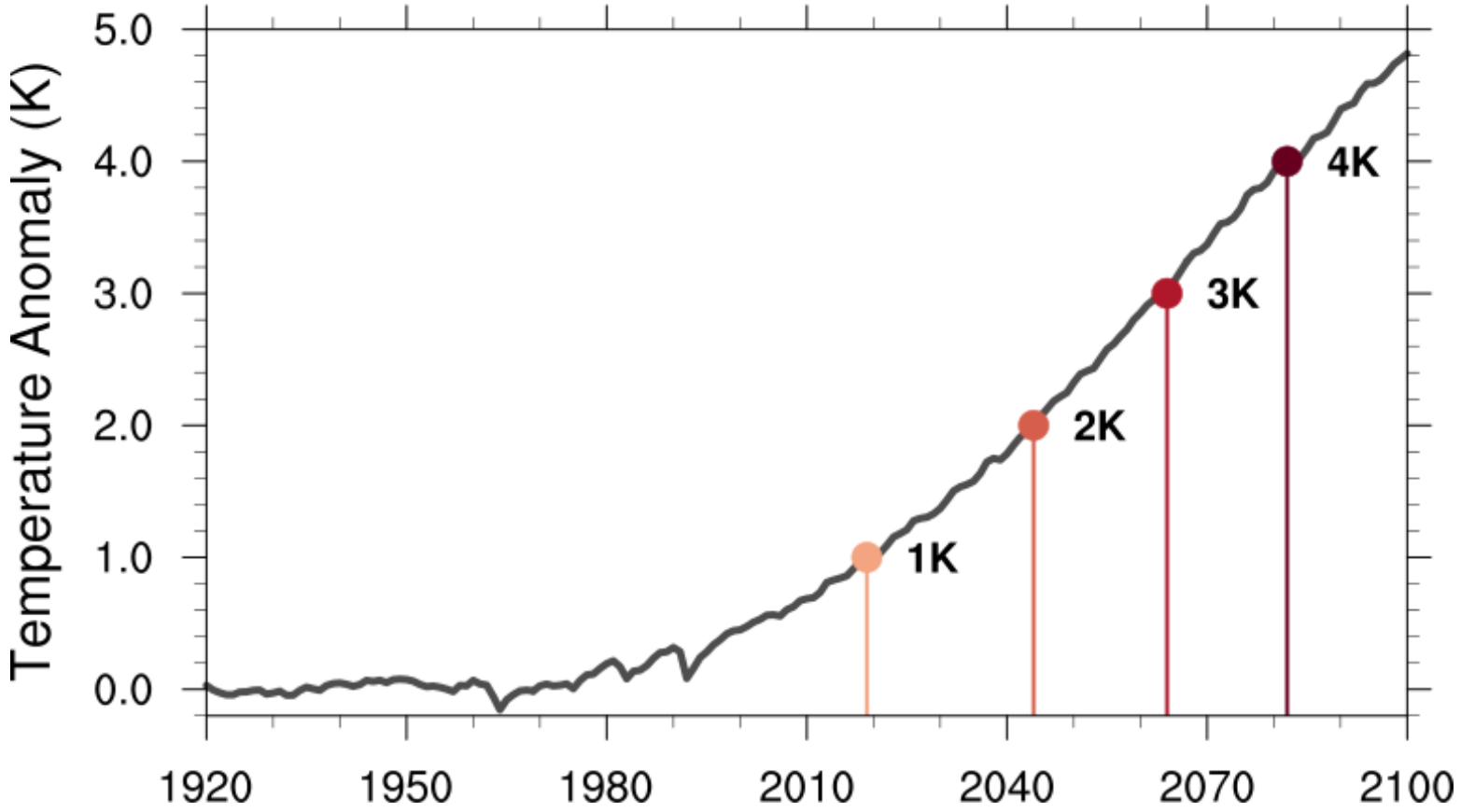
- Extreme accumulated rainfall amounts associated with Hurricane Ian increased by 18%.

Takeaways

- Storyline attribution approaches offer a consistent conclusion with conventional climate simulations: TC rainfall per hour of storm impact increase in a warming climate.
- There is a growing effort in the scientific community – with direct stakeholder needs – to quantify the impact of climate change on recent extreme events and how these events have changed (or will change in the future). Storylines are a promising approach.
- Work suggests there is a pathway toward operational storyline frameworks in the future.

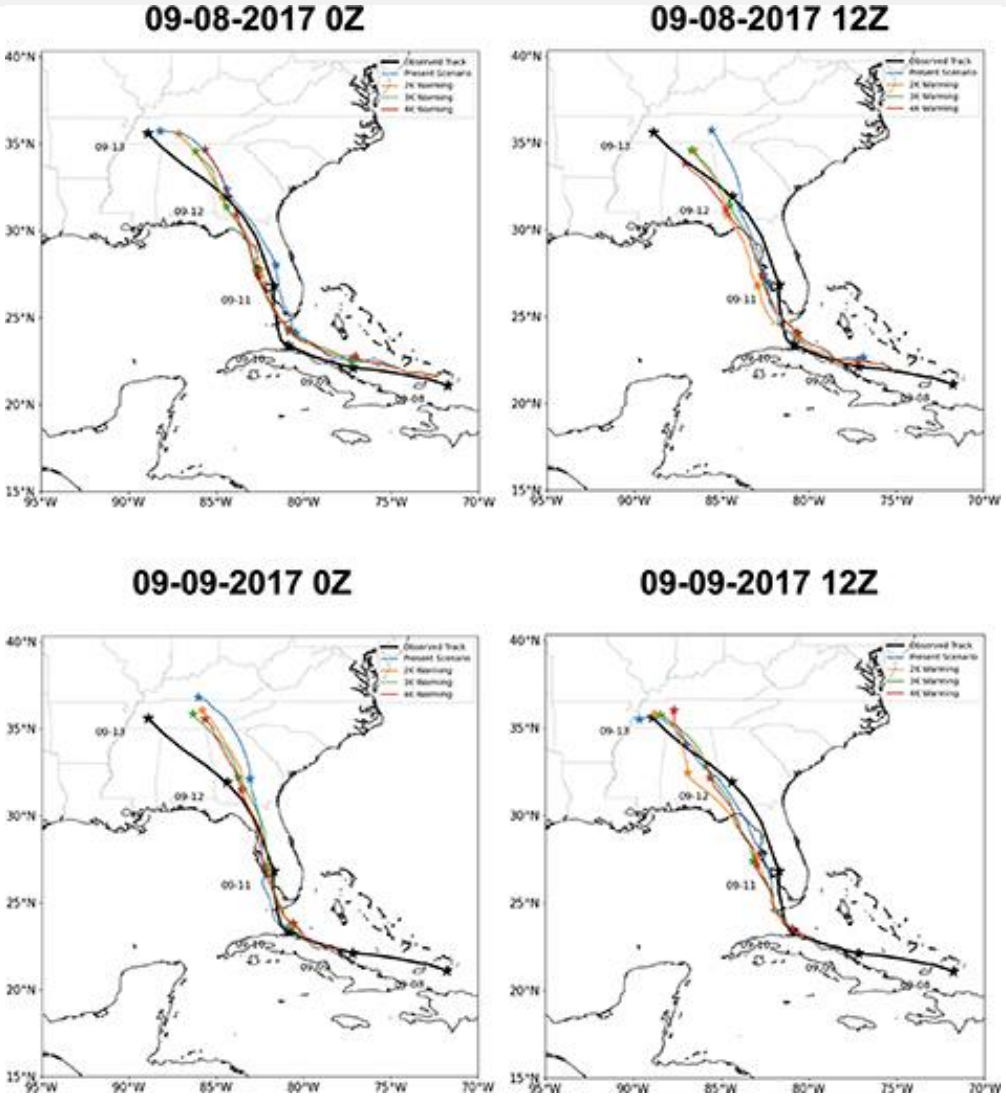
Extra Slides

Future Counterfactuals



CESM Large Ensemble

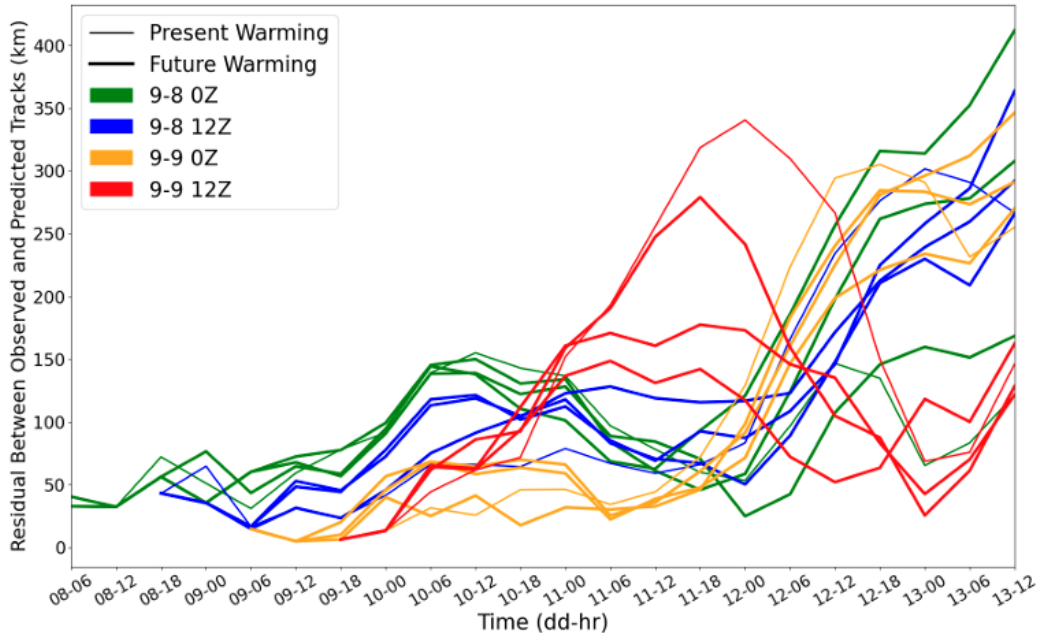
Future Climate Change: Hurricane Irma (2017)



Completed storyline simulations at:

- 4 different initialization times
- 4 different temperatures

We identify if model is fit-for-purpose



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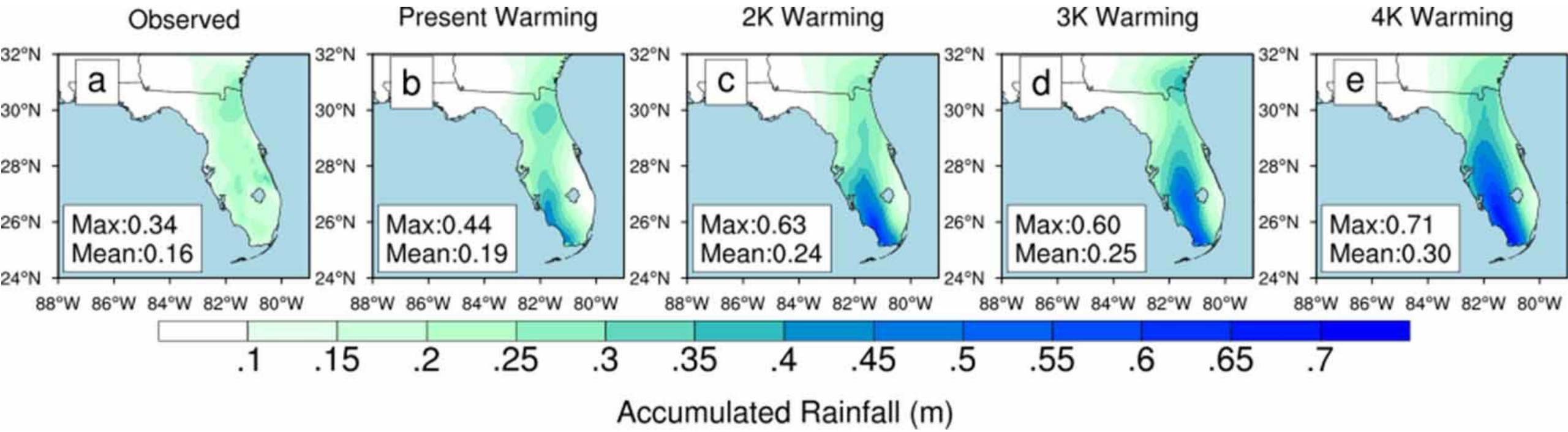
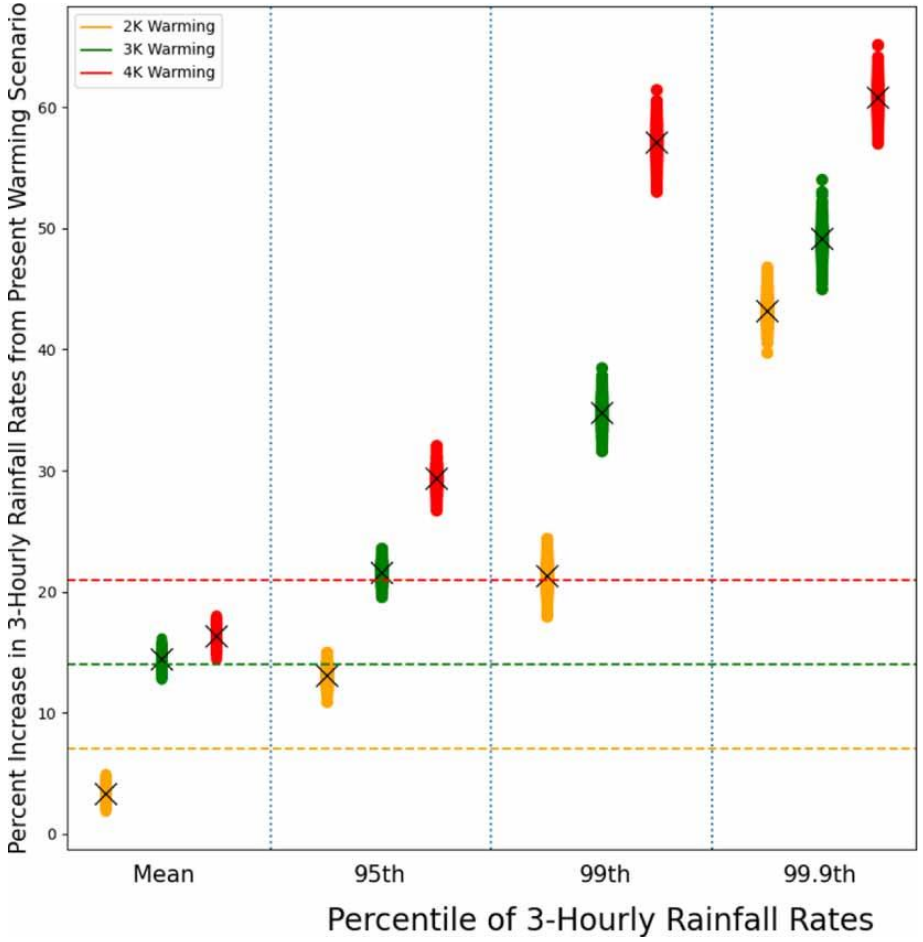


- Accumulated increases with warming!

Future Climate Change: Hurricane Irma (2017)



- Mean 3-hourly rainfall rates in the simulated storms increase by 3–7%/K compared to present!
- 95th and 99th percentile 3-hourly rates, intensify by 10–13%/K and 17–21%/K, respectively.
- All percent changes increase monotonically with warming level.

References

- Huprikar, A., A. M Stansfield, and K. A. Reed (2023), **A Storyline Analysis of Hurricane Irma's Precipitation Under Various Levels of Climate Warming**, *Environ. Res. Lett.*, 19, 014004, doi: 10.1088/1748-9326/ad0c89.
- Reed, K.A and M. F. Wehner (2023), **Real-time attribution of the influence of climate change on extreme weather events: A storyline case study of Hurricane Ian rainfall**, *Environ. Res.: Climate*, 2, 043001, doi: 10.1088/2752-5295/acfd4e.
- Reed, K. A., M. F. Wehner, and C. M. Zarzycki (2022), **Attribution of 2020 hurricane season extreme rainfall to human-induced climate change**, *Nature Communications*, 13, 1905, doi: 10.1038/s41467-022-29379-1.
- Reed, K. A., A. M. Stansfield, M. F. Wehner and C. M. Zarzycki (2020), **Forecasted attribution of the human influence on Hurricane Florence**, *Science Advances*, 6, 1, doi: 10.1126/sciadv.aaw9253.