U.S. Department of Energy | Office of Science
HYPERFACETS
A Framework for Improving Analysis and Modeling of Earth System and Intersectoral Dynamics at Regional Scales

U.S. DEPARTMENT OF ENERGY | Office of Science

Exploring climate change impacts on US hurricanes 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?

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

Methodology

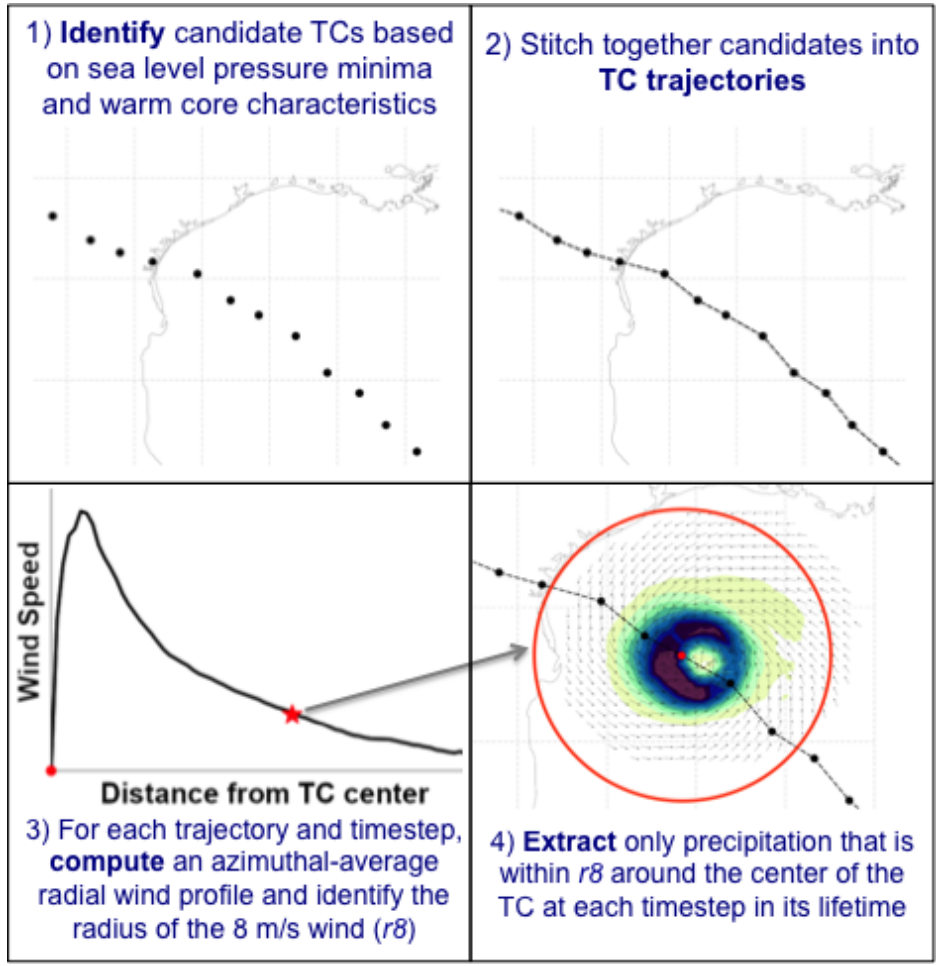
We use **TempestExtremes** to:

- identify,
- track, and
- analyze the storms

Available on Github:

https://github.com/ClimateGlobalChange/tempestextremes

[Ullrich et al. 2021, GMD]



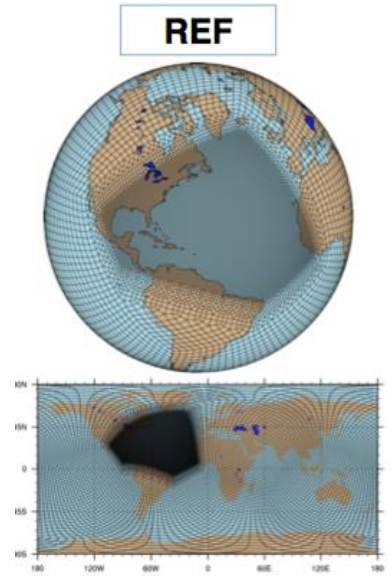
Storyline Approach

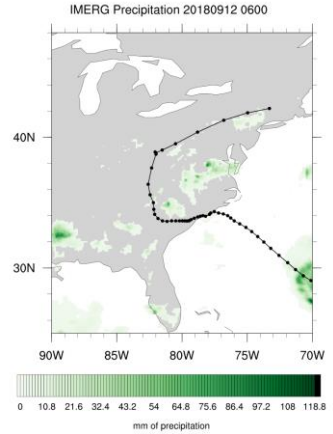
- Variable resolution (CESM or E3SM) is used over region of interest with 30 vertical levels is used at the local horizontal resolution of: Δx = ~100 > ~25 km

- **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 C20C+ or Large Ensembles).

- Prescribed observed SSTs, ozone,CO_2, solar forcing.

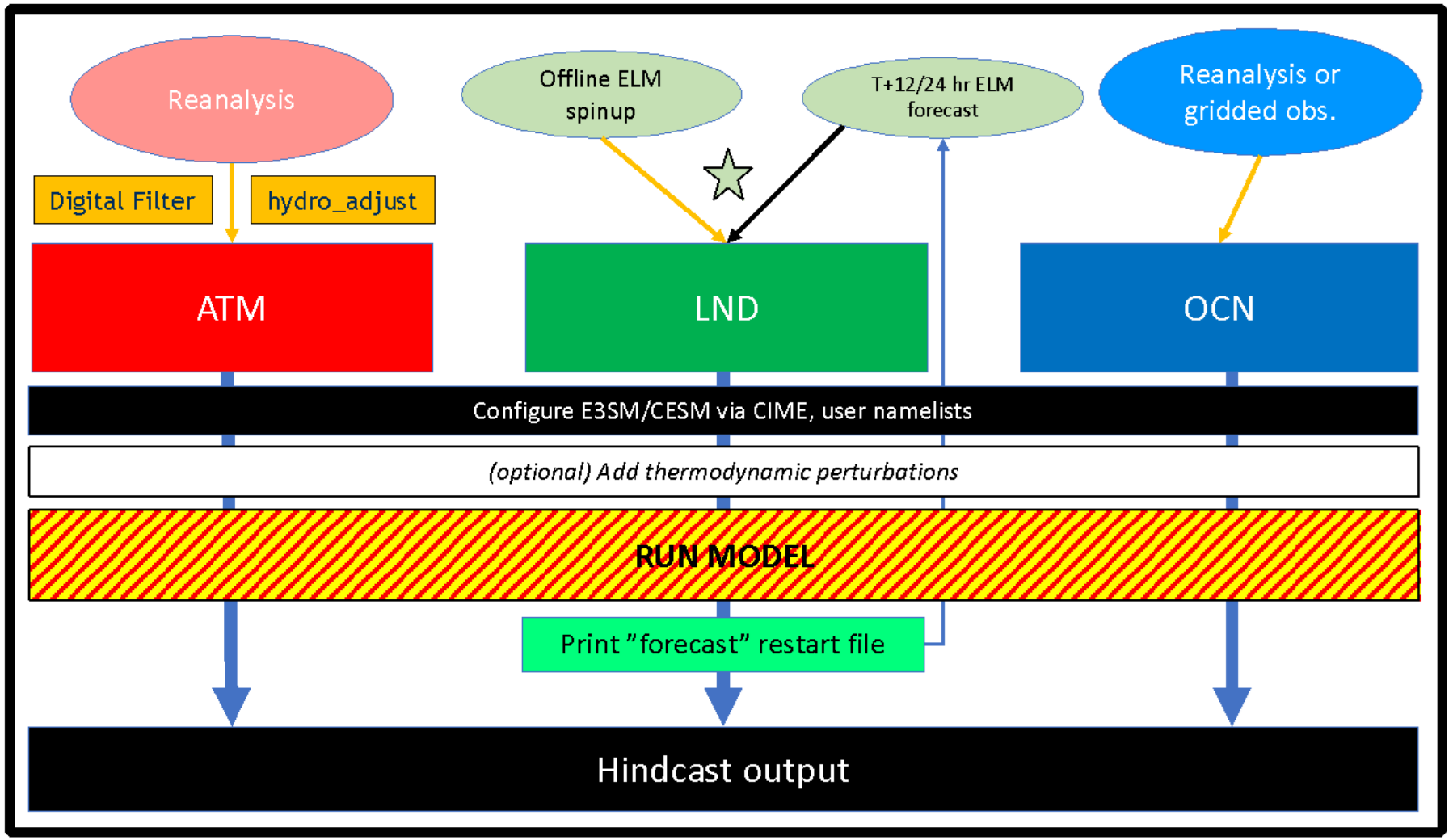




Utilize Betacast

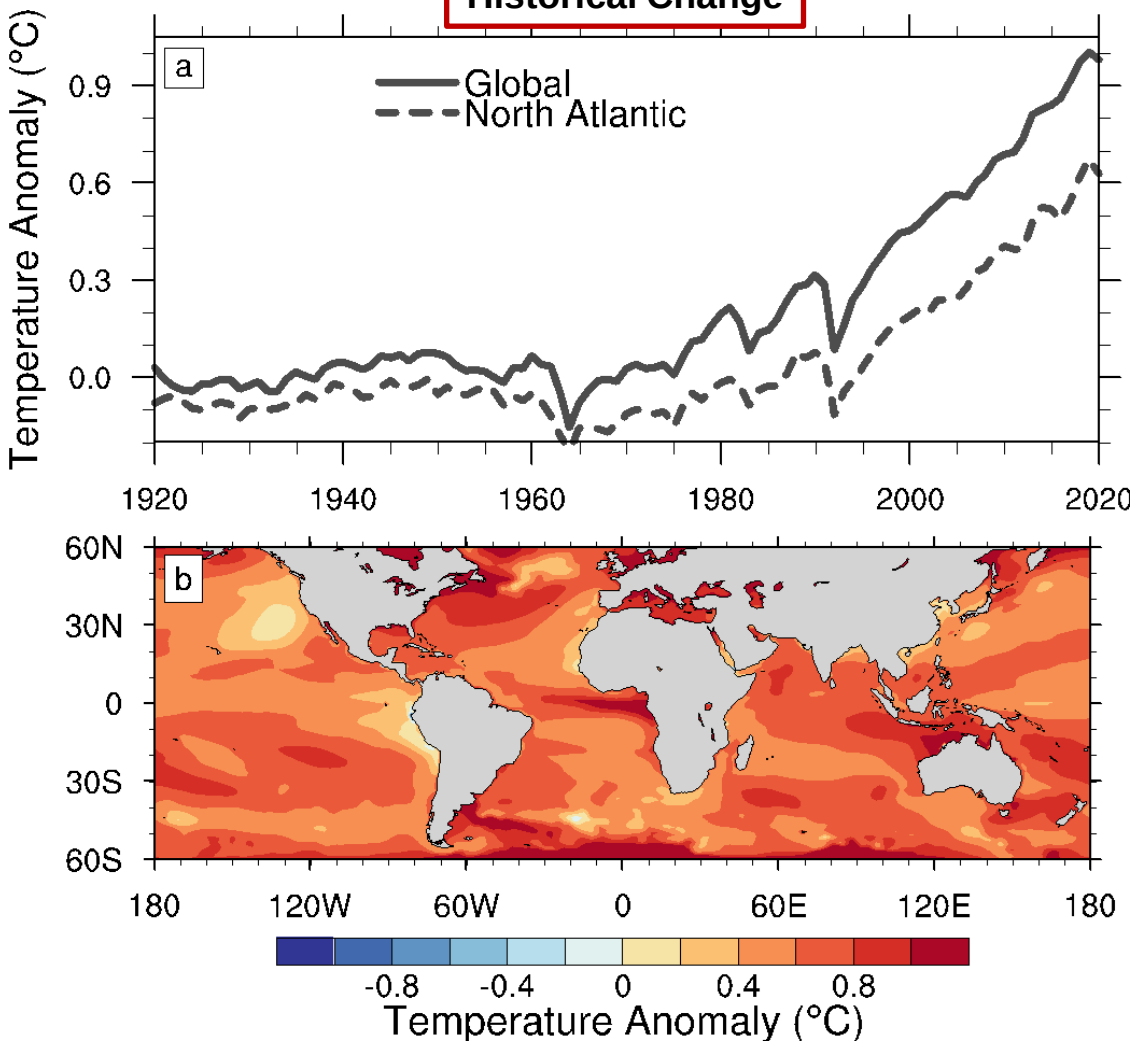
Available on Github:

https://github.com/zarzycki/betacast

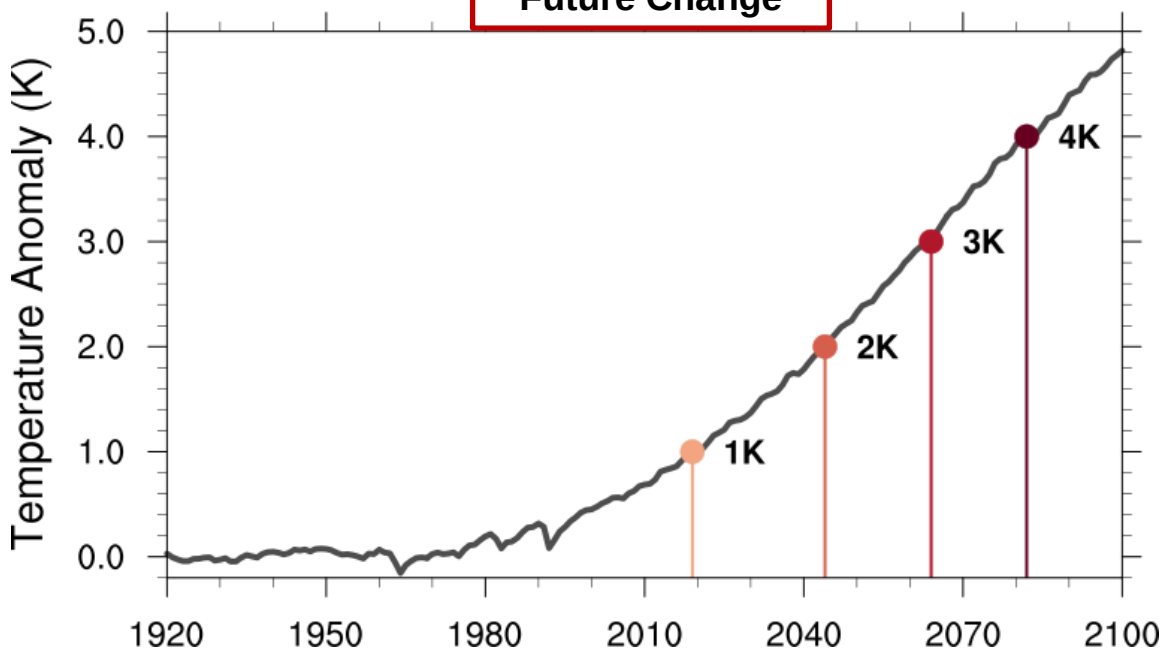


Building a Counterfactual

Historical Change

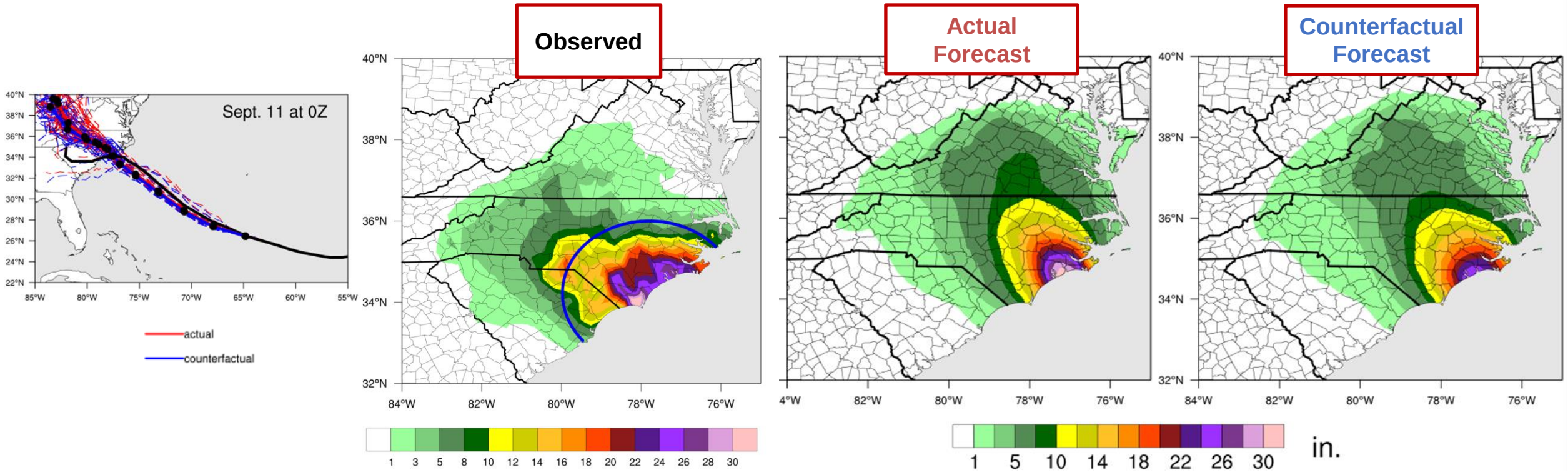


Future Change



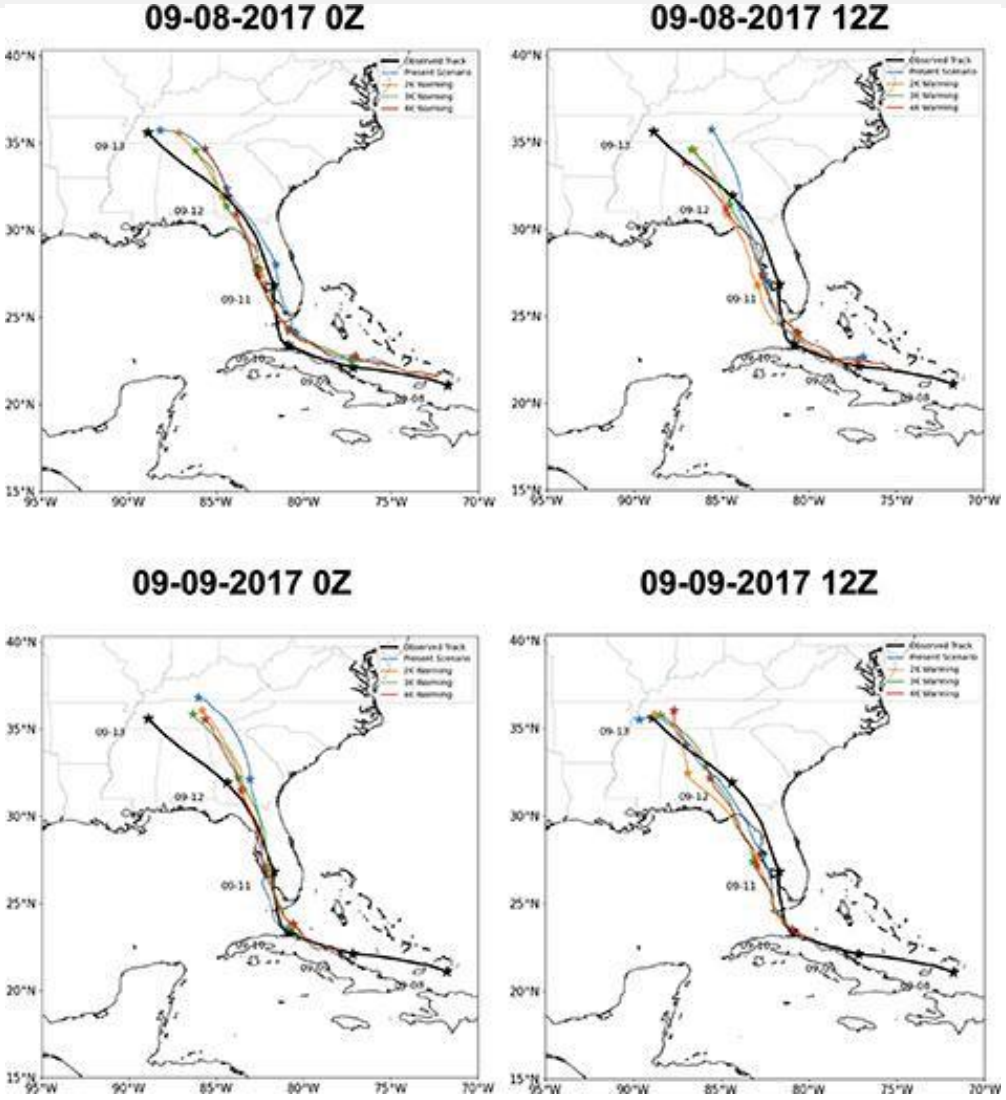
- Use the 40-member CESM Large Ensemble
- Update T, Q and PS for initial and boundary conditions.

Historical Climate Change: Hurricane Florence (2018)



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

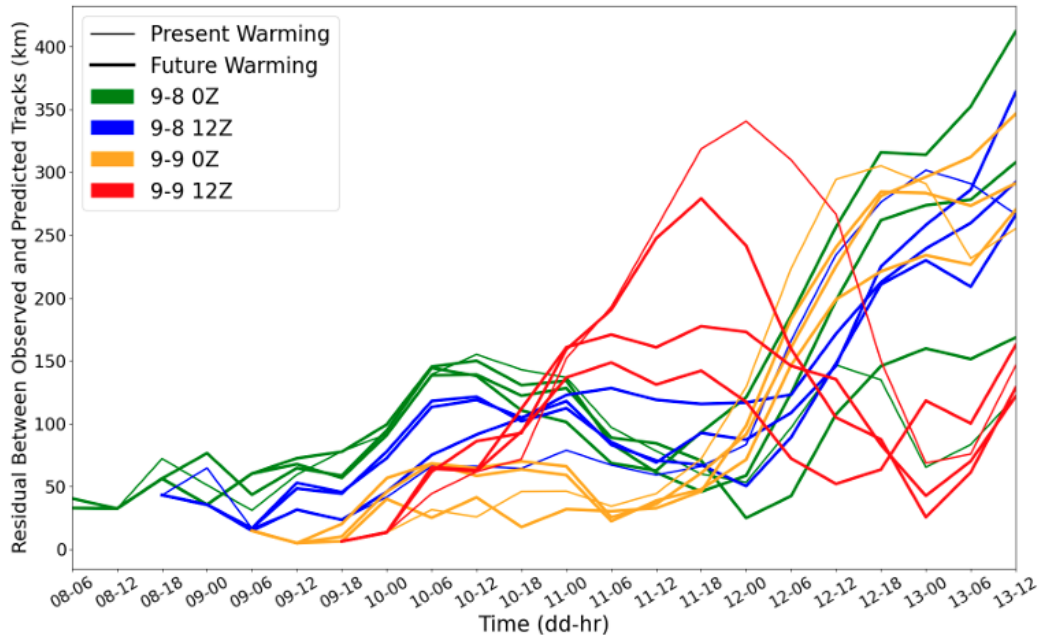
Future Climate Change: Hurricane Irma (2017)



Completed storyline simulations at:

- 4 different initialization times
- 4 different temperatures

We identify if model is fit-for-purpose



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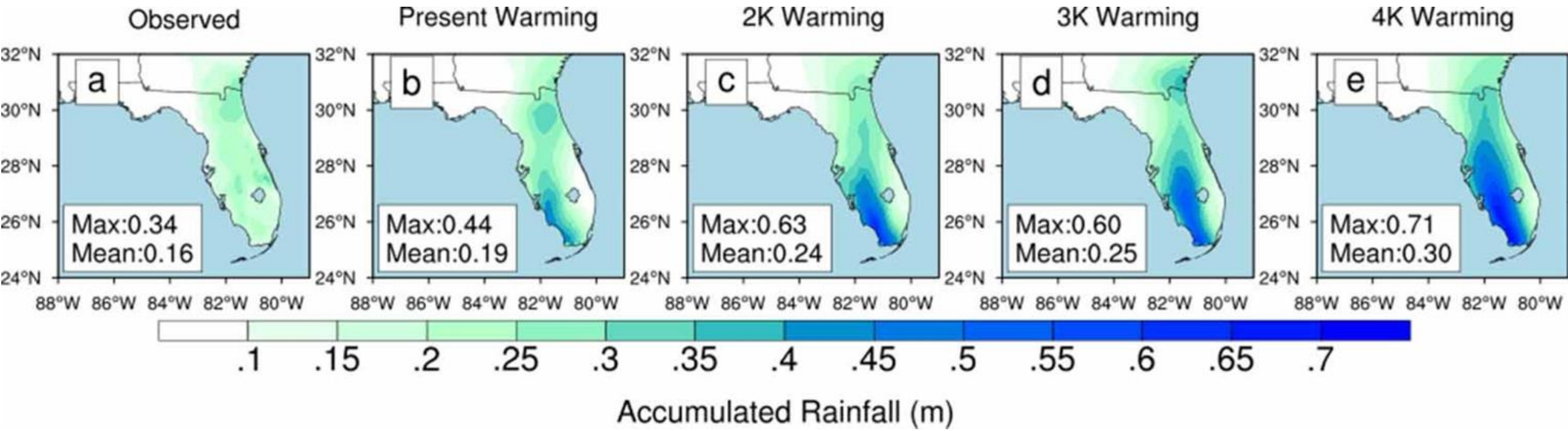
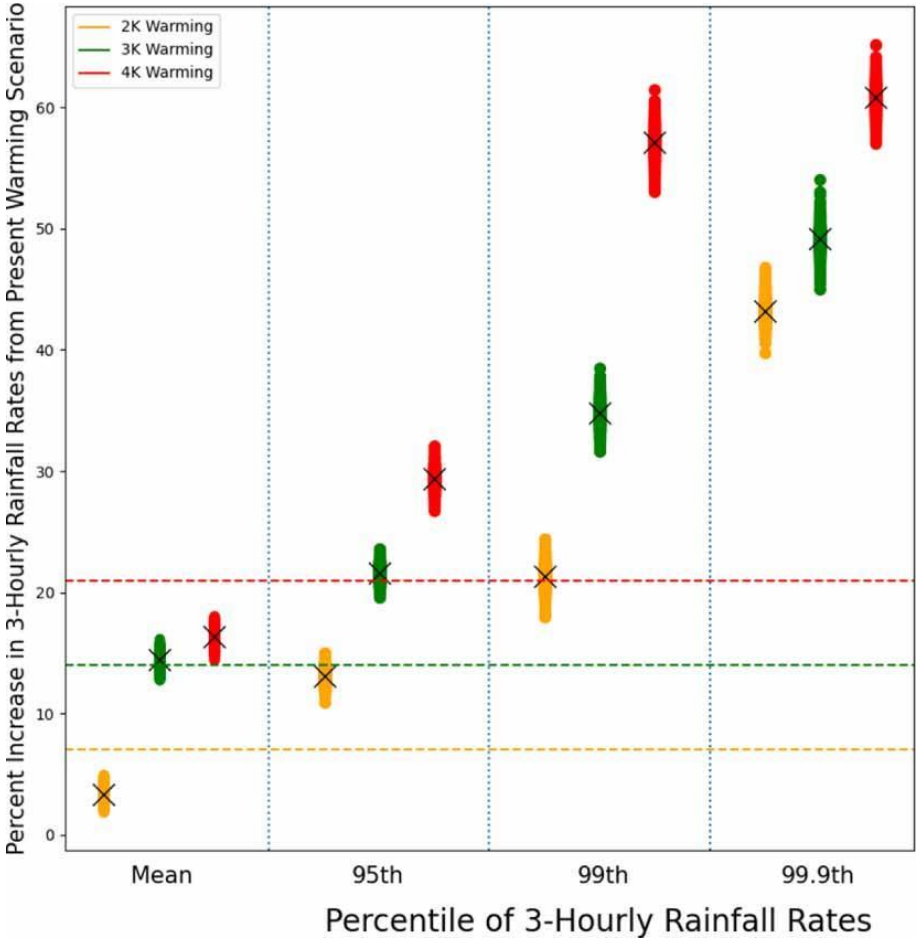


- Accumulated increases with warming!

Takeaways

- Storyline approaches suggest a consistent conclusion with conventional climate simulations: TC rainfall per hour of storm impact will increase under 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 will change in the future. Storylines are a promising approach.
- Work suggests there is a pathway toward more operational storyline frameworks in the future.

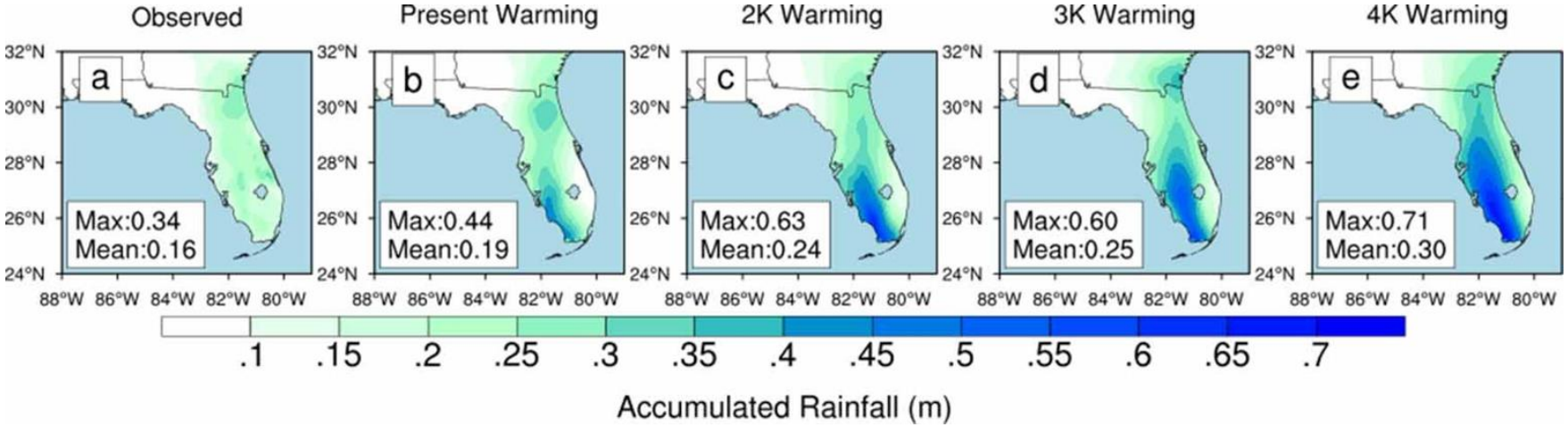
Future Climate Change: Hurricane Irma (2017)



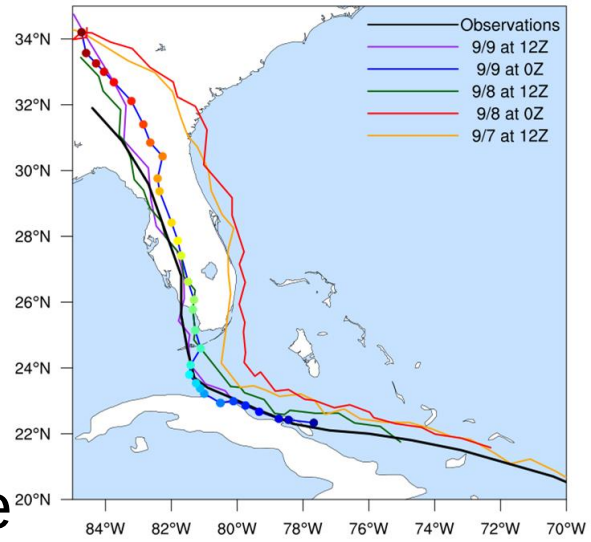
- Mean 3-hourly rainfall rates in the simulated storms increase by 3–7%/K compared to present!
- 95th and 99th percentile 3-hourly rates, intensify by 10–13%/K and 17–21%/K, respectively.
- All percent changes increase monotonically with warming level.

Ongoing Work

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



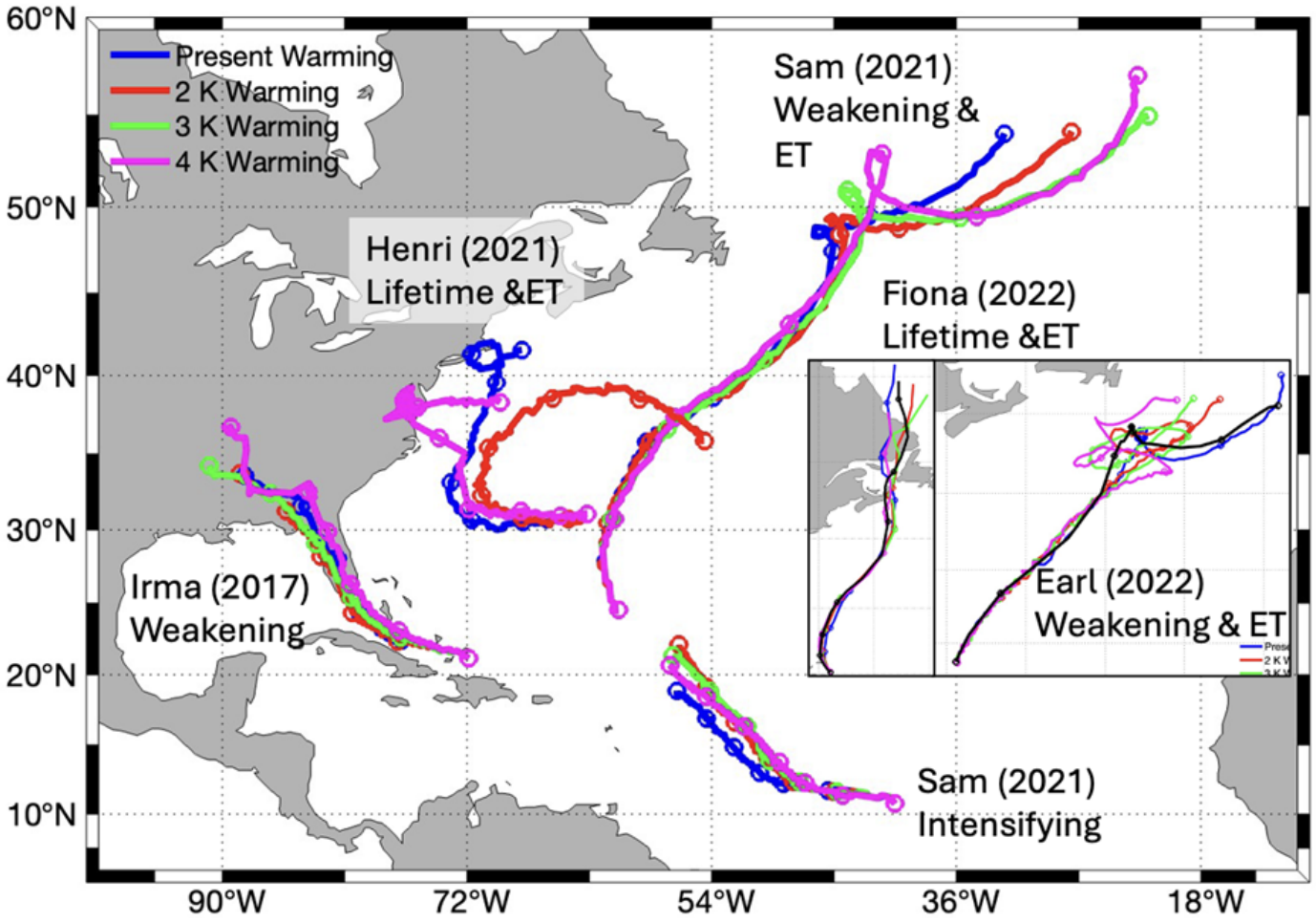
Hindcasted tracks for Irma compare well to observations (black) for certain initializations:



This work will shift focus to the other initialization times, when the **simulated storm impacts eastern Florida**, to explore the impact of "what if" events from last 10 years and in the future.

Ongoing Work

How to choose a hurricane case for a storyline study?
(To get a reasonable track simulation)



Henri & Earl (NO)
- Relatively weak
- Tracks change significantly for different initial times/operational models.

Fiona, Sam & Irma (YES)
- Major hurricane
- Forecast tracks change less

Small track uncertainty
-> Large-scale circulation is easier to be captured/not such easy to be influenced

Thanks!

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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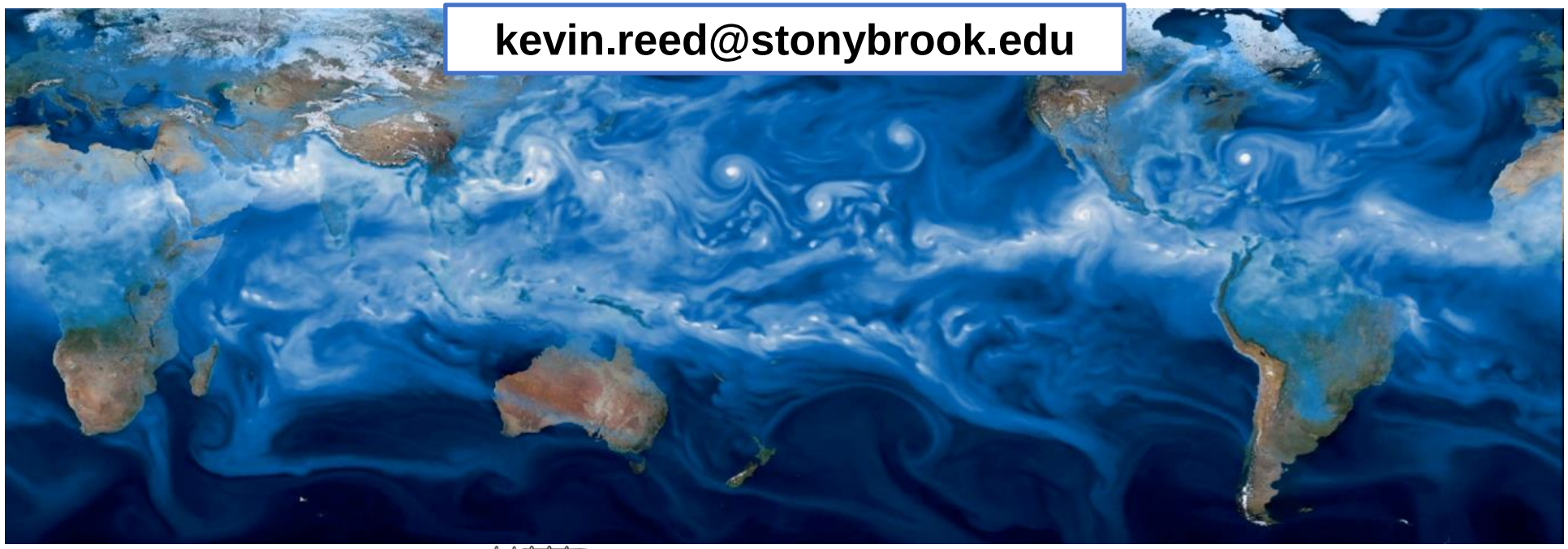

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- Huprikar, A., A. M Stansfield, and K. A. Reed (2023), **A Storyline Analysis of Hurricane Irma's Precipitation Under Various Levels of Climate Warming**, *Environ. Res. Lett.*, 19, 014004, doi: 10.1088/1748-9326/ad0c89.
- Reed, K.A and M. F. Wehner (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.