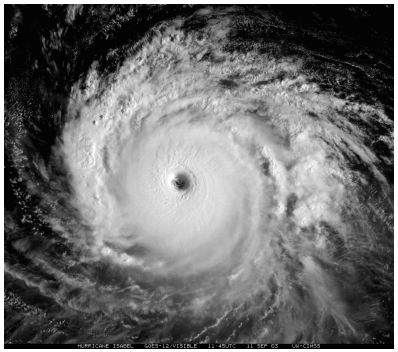

Stony Brook University

Refining Climate Change Event Attribution Capabilities in CAM

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School of Marine and Atmospheric Sciences

Stony Brook University, Stony Brook, New York

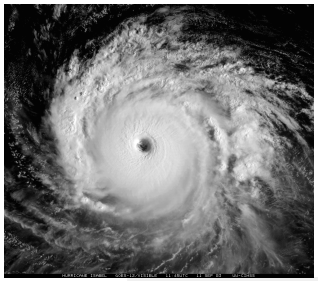
Some Collaborators:

Michael F. Wehner[1], Alyssa M. Stansfield[2], and Colin M. Zarzycki[3]

[1]*Lawrence Berkeley National Laboratory, Berkeley, CA*

[2]*Stony Brook University, Stony Brook, NY*

[3]*Penn State University, State College, PA*



Extreme Weather Impacts

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

Central Severe Weather - Derecho
August 10

North Central and Ohio Valley
Hail Storms and Severe Weather
April 7–8

Western Wildfires,
California, Oregon,
Washington Firestorms
Fall 2020

Western / Central
Drought and Heatwave
Summer-Fall 2020

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

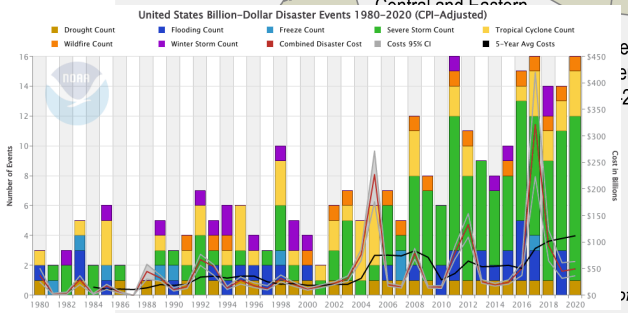
Southeast and Eastern
Tornado Outbreak
April 12–13

South Texas
Hail Storms
May 27

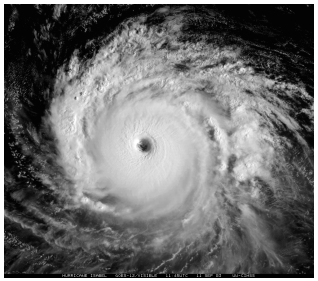
Hurricane Laura
August 27–28

Southeast Tornadoes
and Northern Storms
and Flooding
Jan 10–12

Hurricane Sally
September 15–17

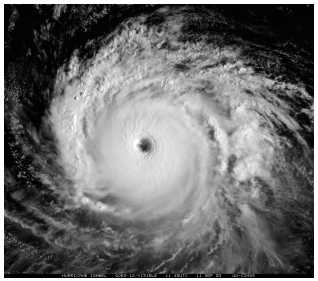


*of the **16 separate billion-dollar weather and climate disasters** that impacted the United States **from January–September 2020**.*



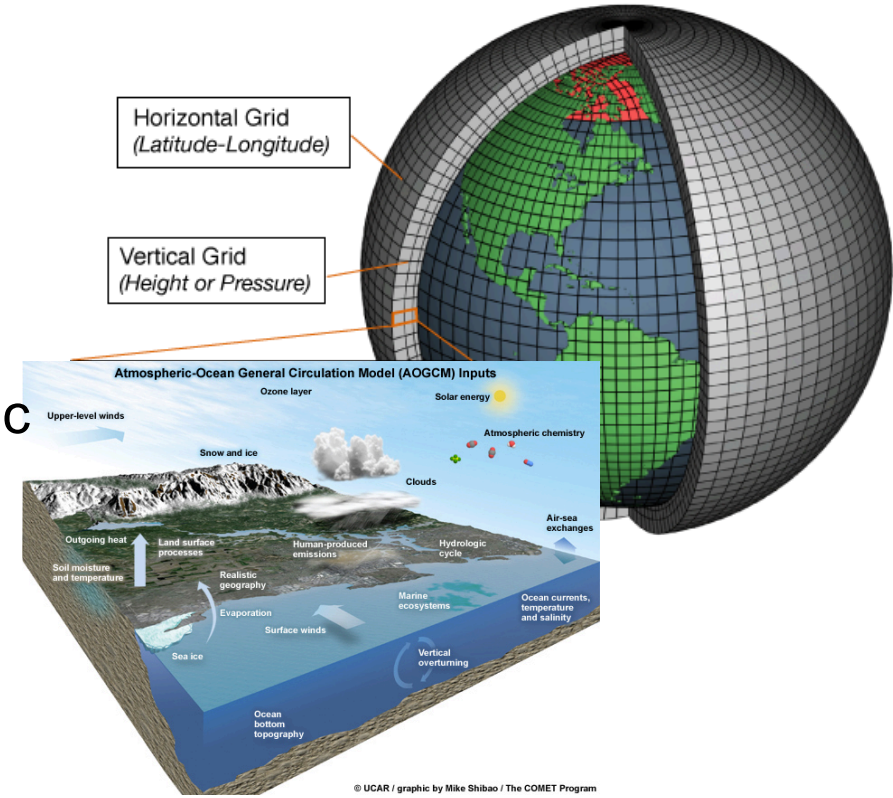
Motivation

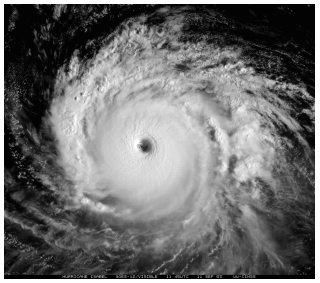
- Can the **impact of climate change on the rainfall** associated with individual hurricanes be quantified using CAM?
- How can these event attribution frameworks be utilized to help **translate the impacts of climate change** to the public and decision-makers?



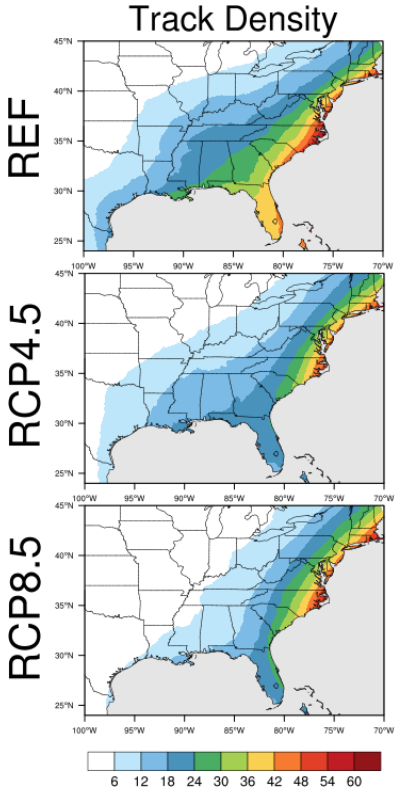
Traditional Approach

- 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)

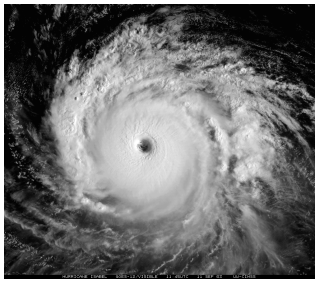




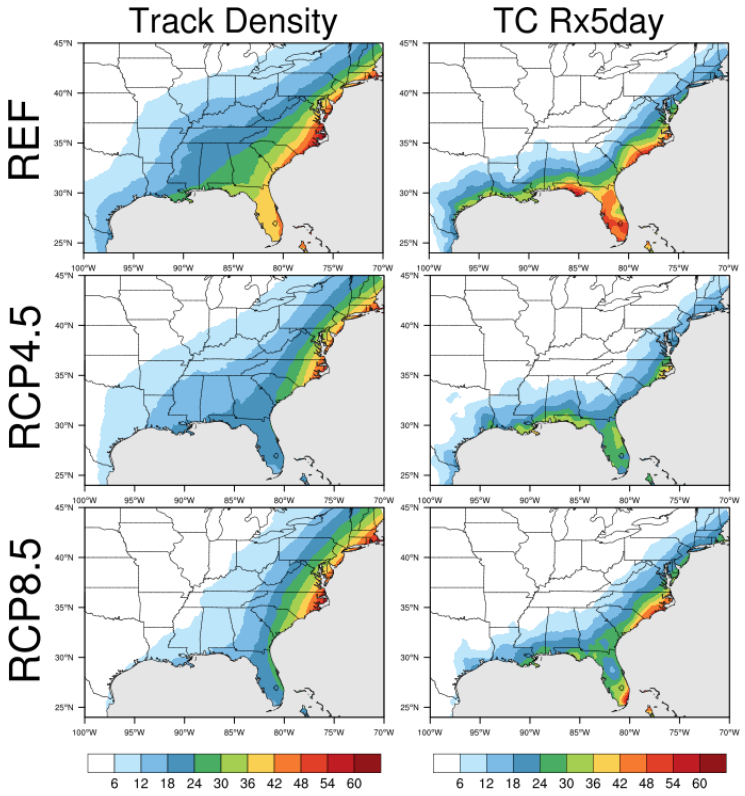
CAM5: Future TC Projections



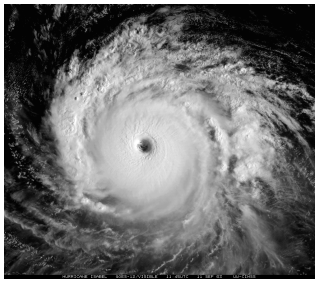
General decrease in storm hours over land, which is consistent with a decrease in TC frequency.



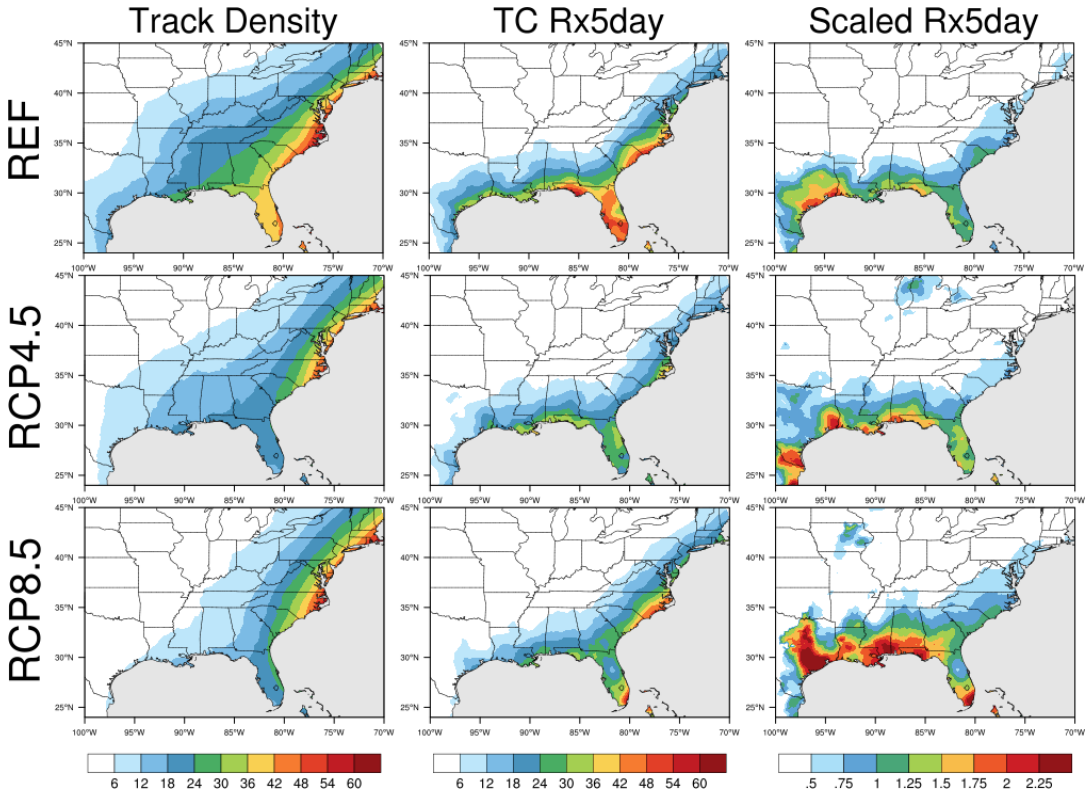
CAM5: Future TC Projections



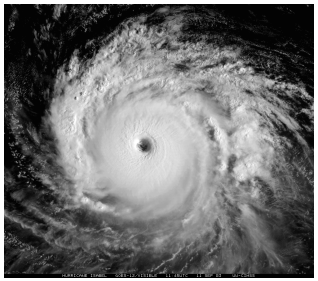
Projections are mixed when looking at rainfall from TCs.



CAM5: Future TC Projections

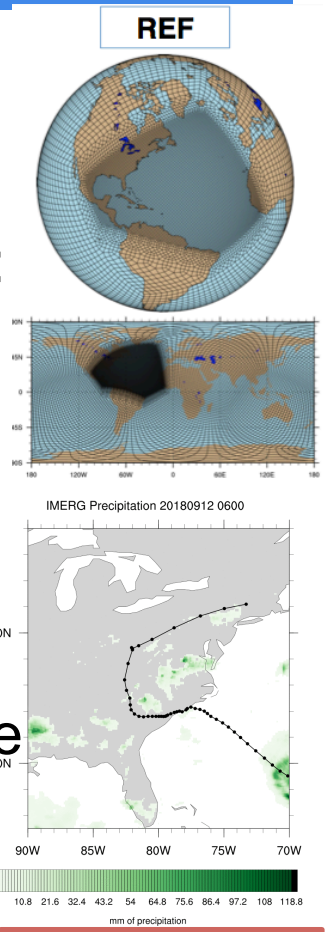


The amount of TC-related extreme precipitation (and TC-related precipitation in general) **increases per storm hour**!



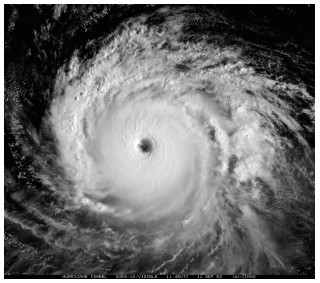
Hindcast Attribution Framework

- 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: Δx = ~100 > ~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,CO_2, solar forcing.



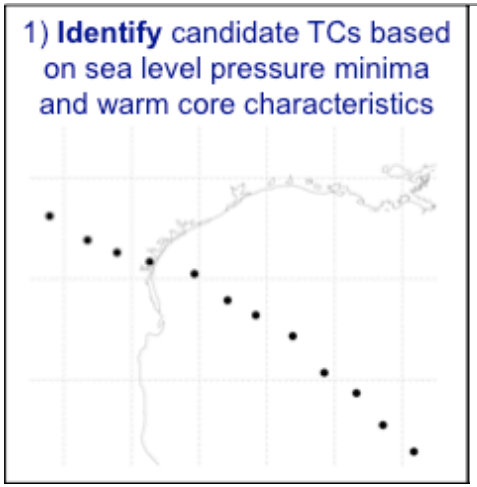
Courtesy of **Erica Bower**

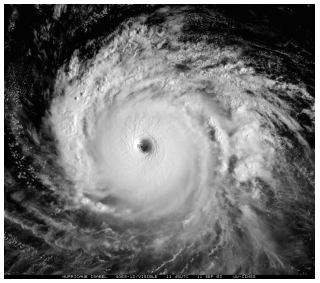
[Reed et al. 2020, Science Adv.]



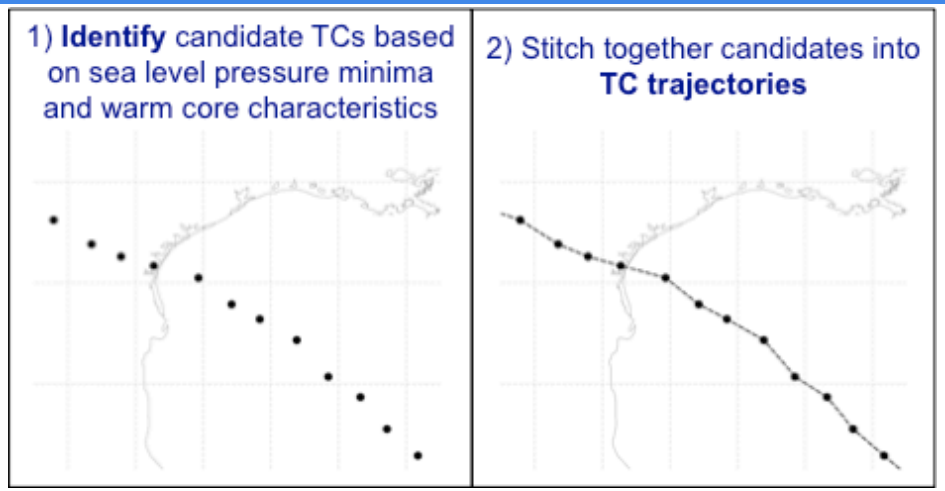
TempestExtremes Methodology

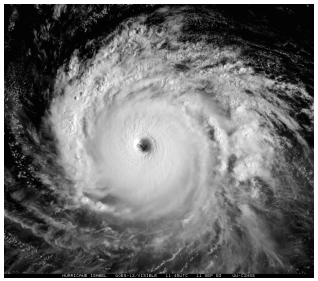
1) **Identify** candidate TCs based on sea level pressure minima and warm core characteristics



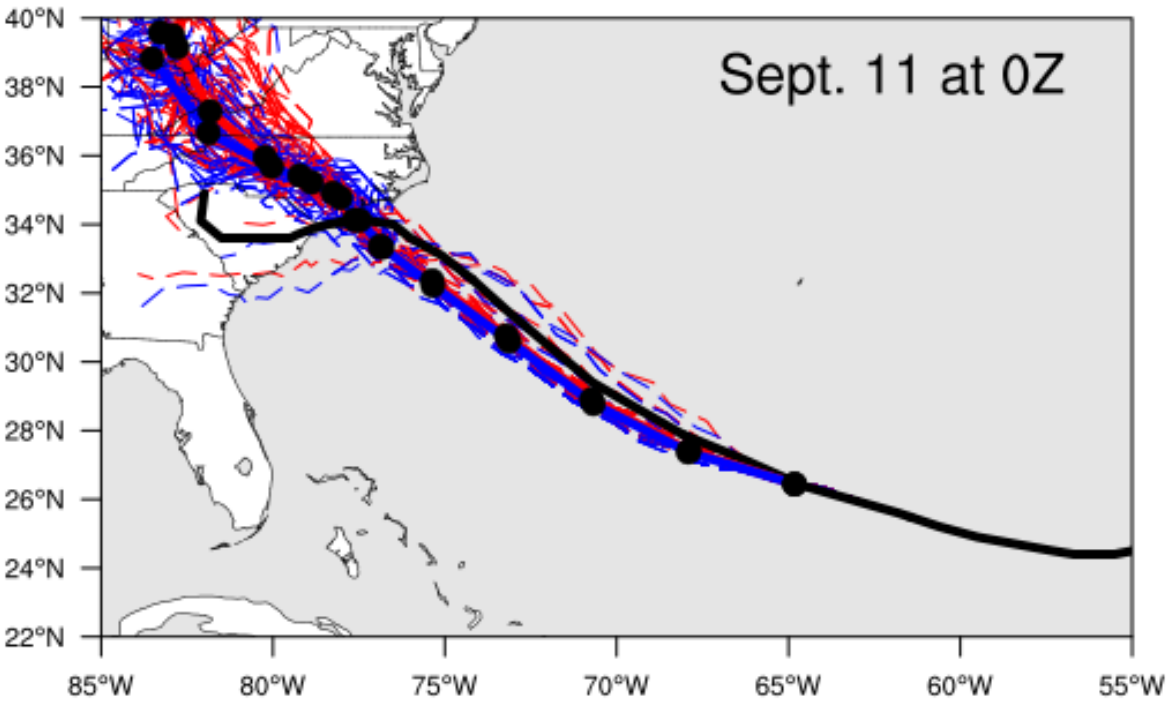


TempestExtremes Methodology

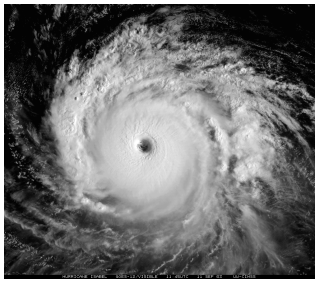




Example: Hurricane Florence (2018)



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



TempestExtremes Methodology

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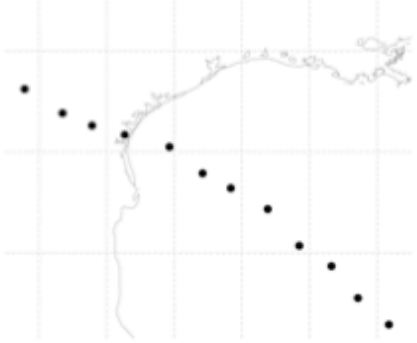
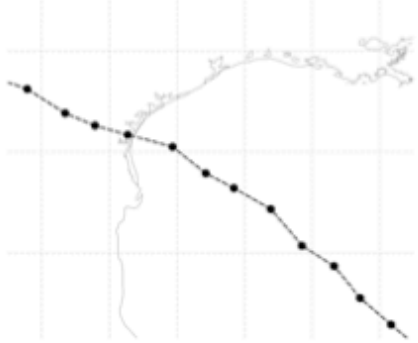
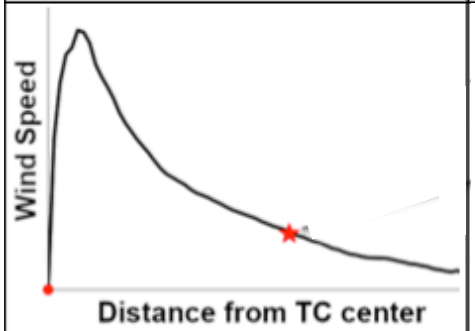
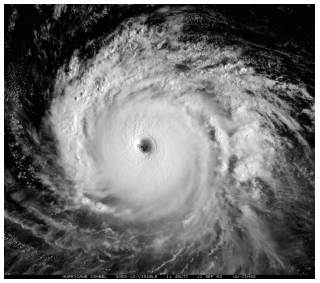


2) Stitch together candidates into **TC trajectories**

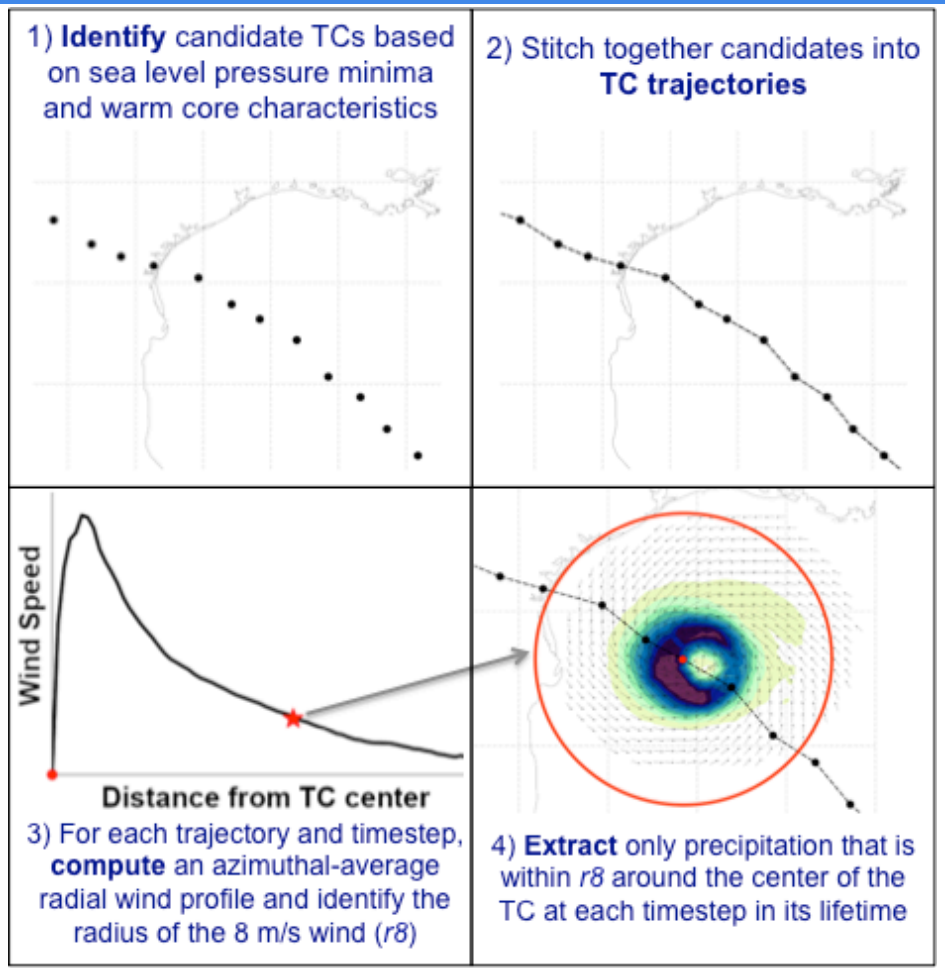


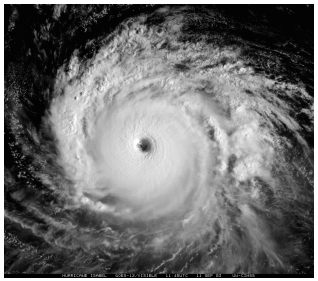


3) For each trajectory and timestep, **compute** an azimuthal-average radial wind profile and identify the radius of the 8 m/s wind (*r8*)

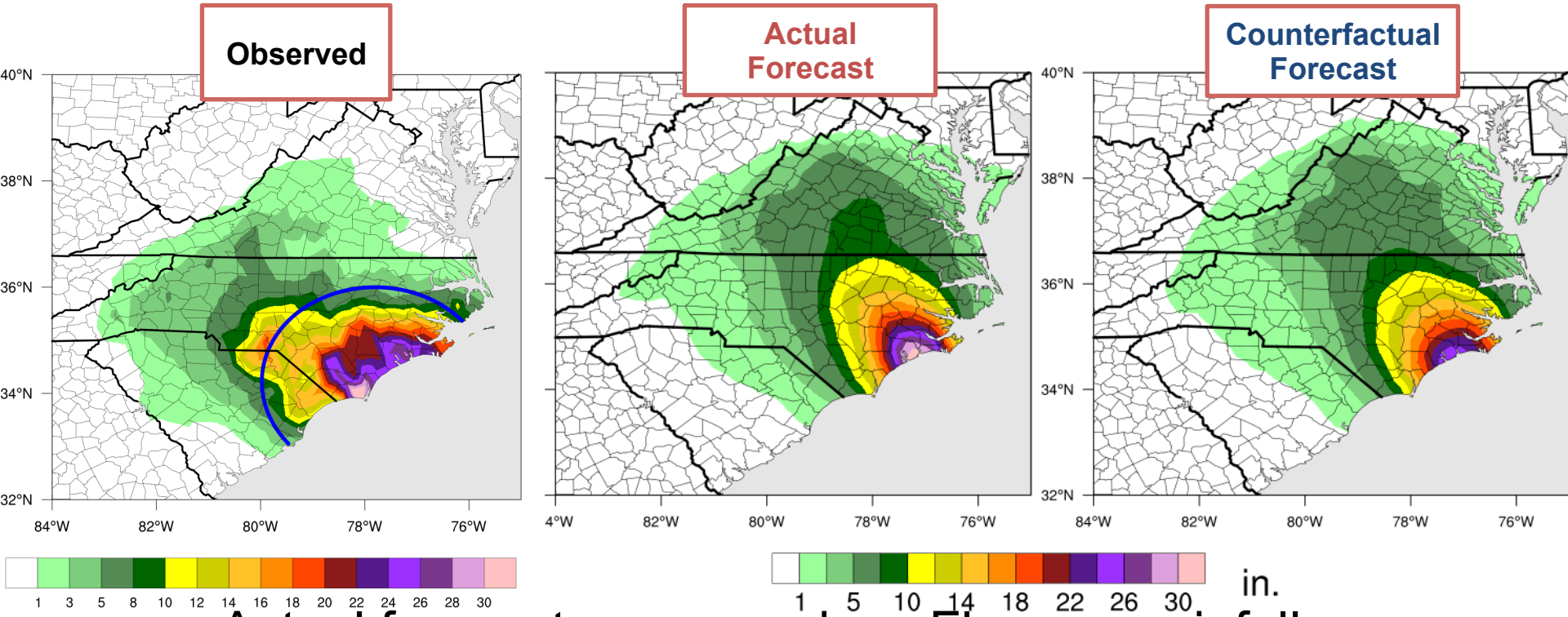


TempestExtremes Methodology

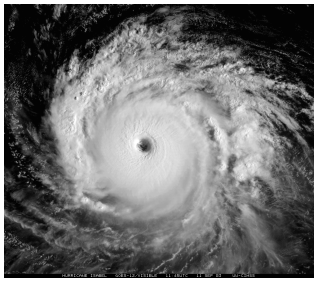




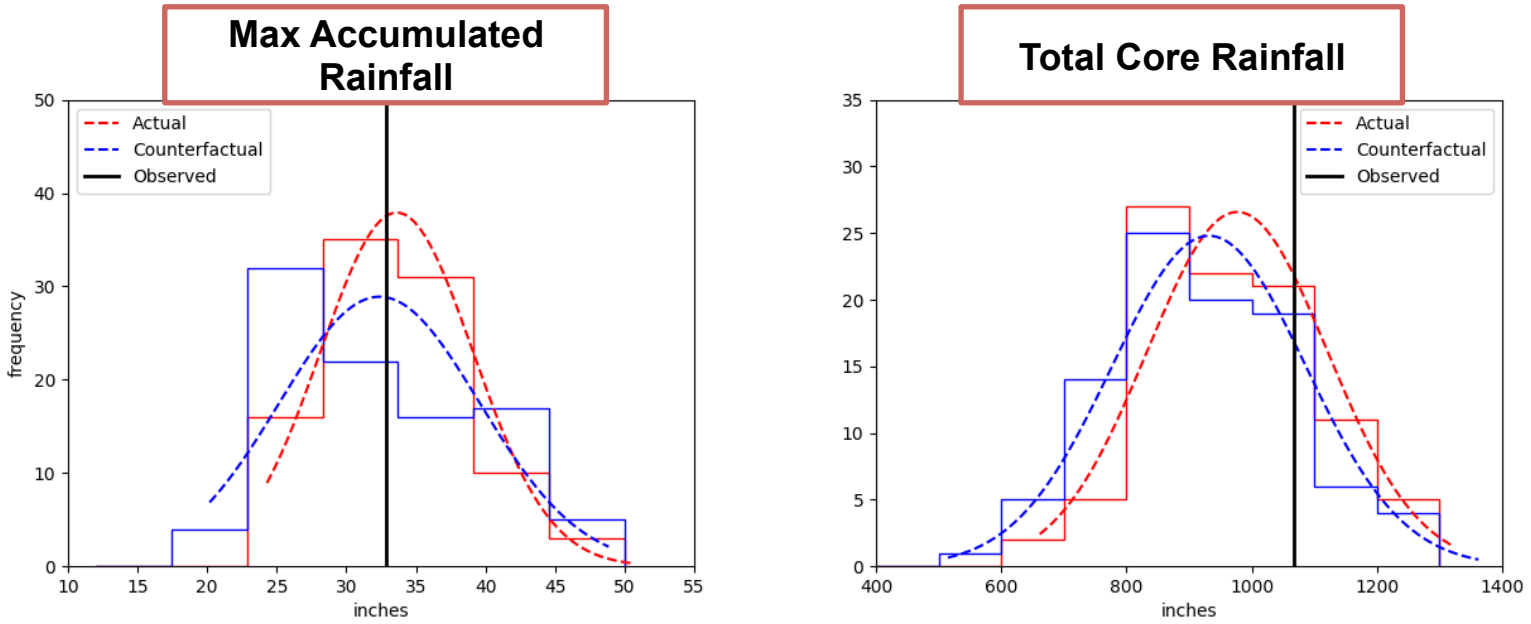
Hurricane Florence (2018) Accumulated Rainfall



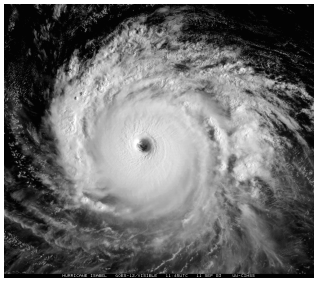
- Actual forecast can reproduce Florence rainfall amounts reasonably well.
- Rainfall is **increased** due to observed warming.



Hurricane Florence (2018) Extreme Rainfall

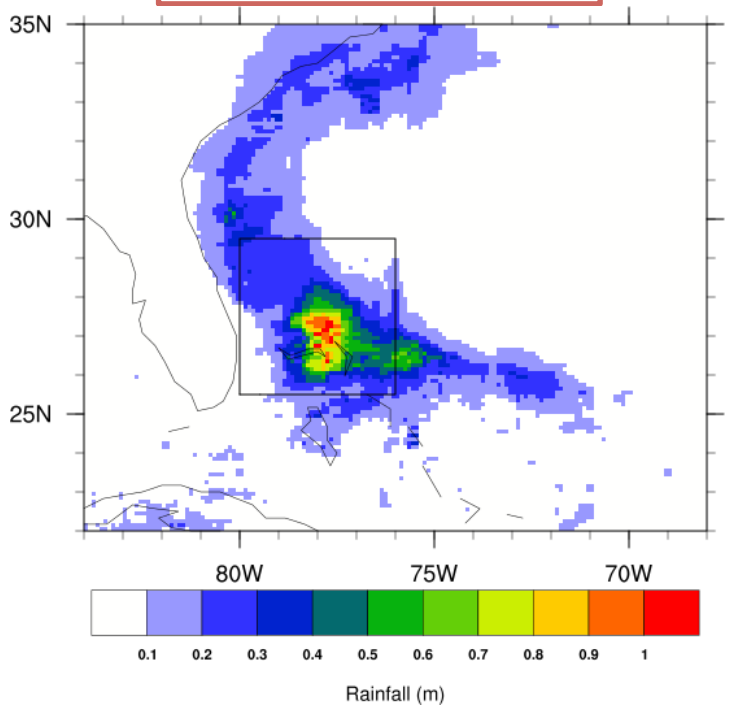


- Clear shift of **~4 ± 5.5%** in most extreme rainfall amounts due to climate change in Florence forecasts.
- Increase of **~5 ± 4.5%** in overland land rainfall associated with core of storm (with 200 km of center).

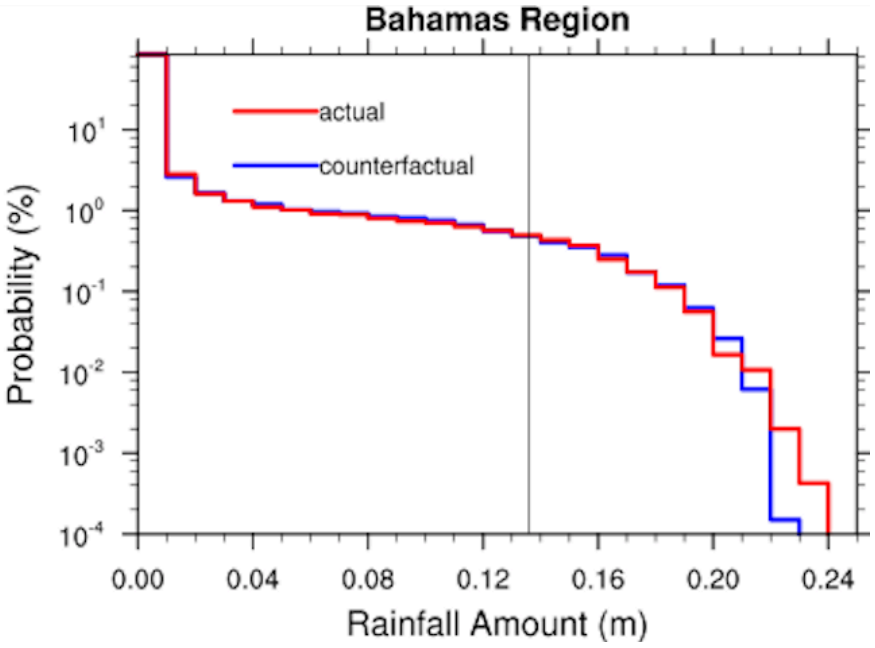


Hurricane Dorian (2019) Extreme Rainfall Rates

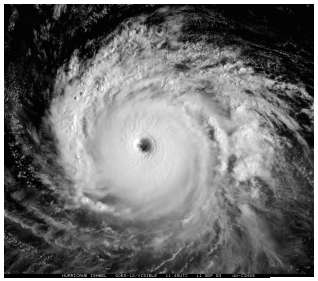
Observed Rainfall



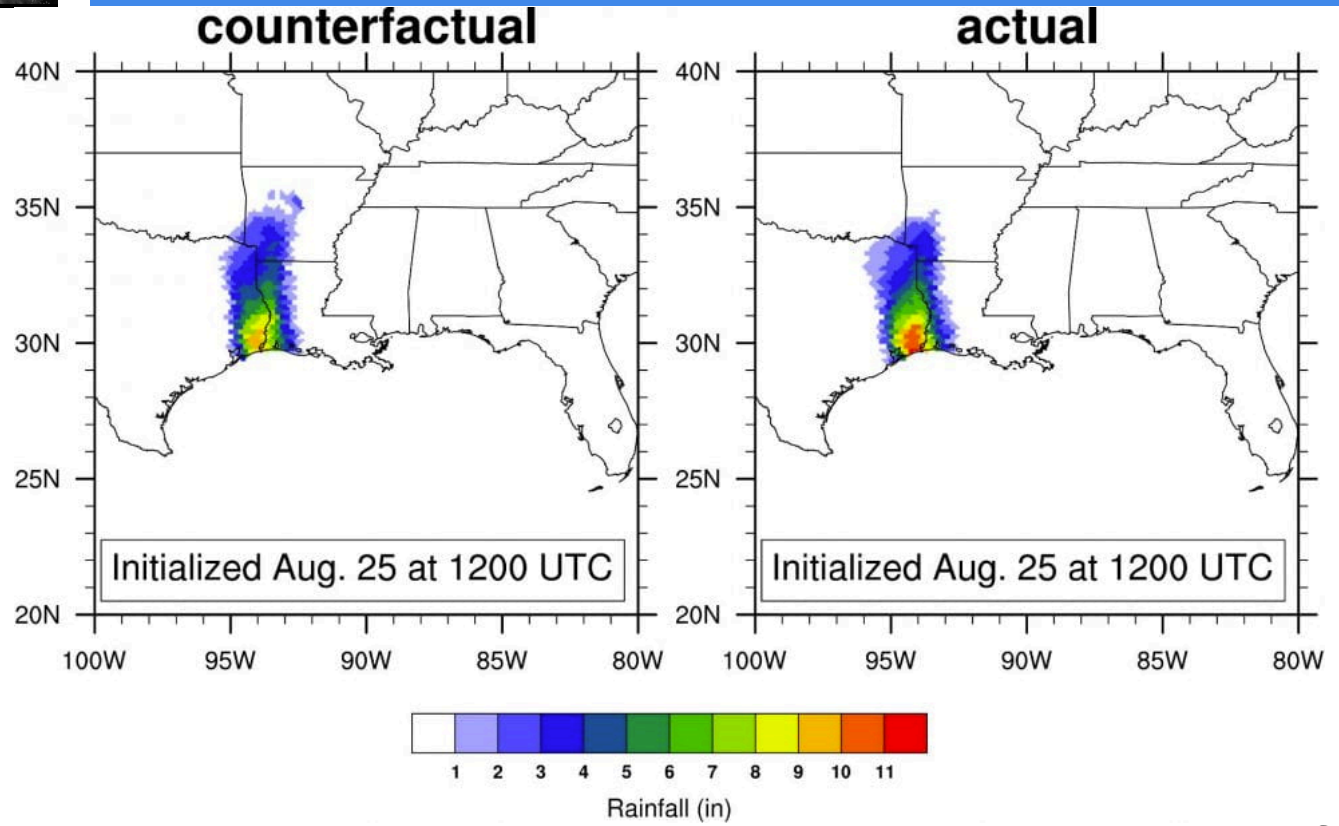
3-hr Rainfall Amounts



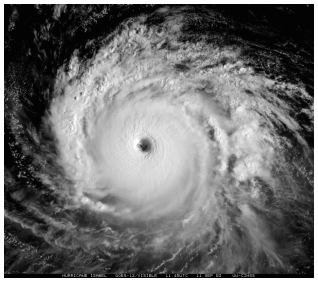
- Increase of **~16 ± 2%** in likelihood of maximum IMERG estimated rainfall amount.



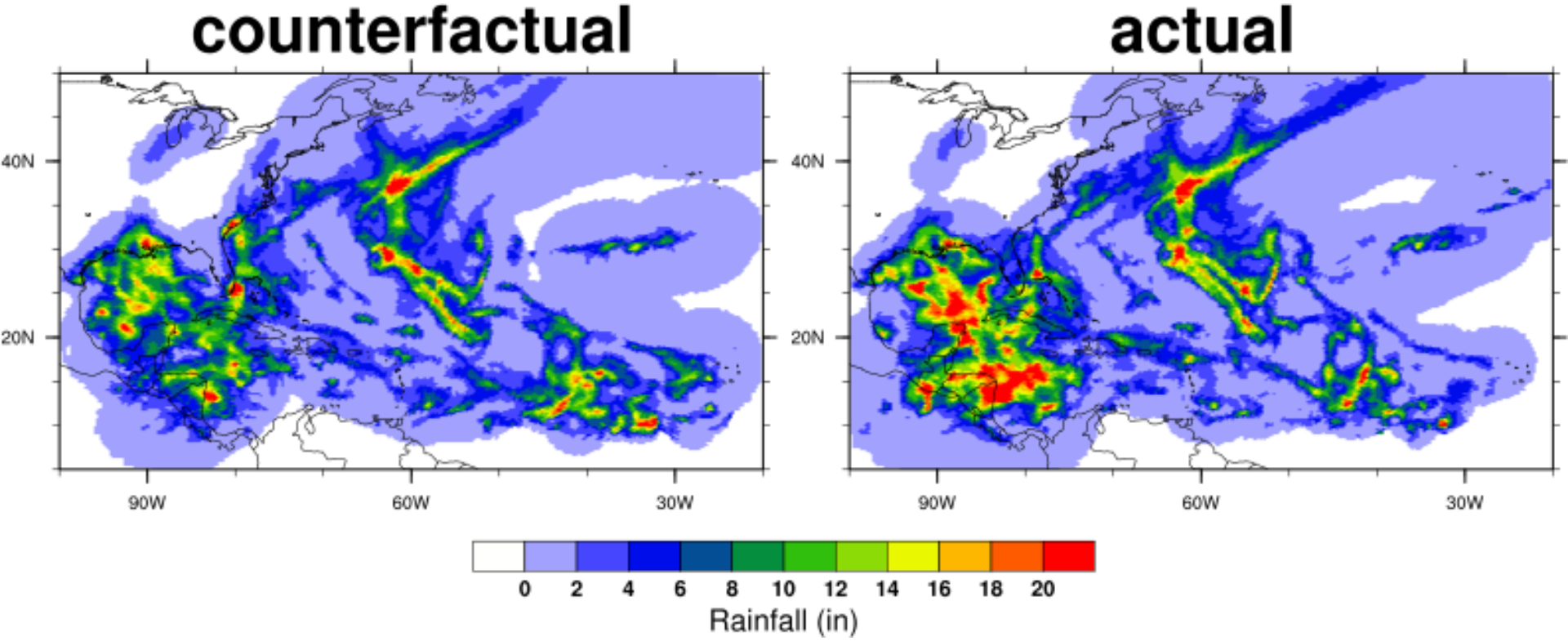
Hurricane Laura (2020)



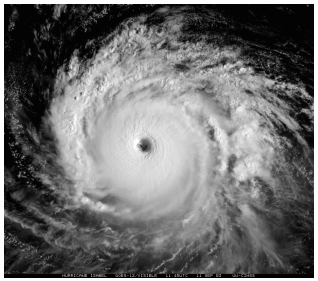
- Climate change increased the maximum total rainfall amount associated with Hurricane Laura by over **10%.**



Preliminary: Hurricane Season (2020)

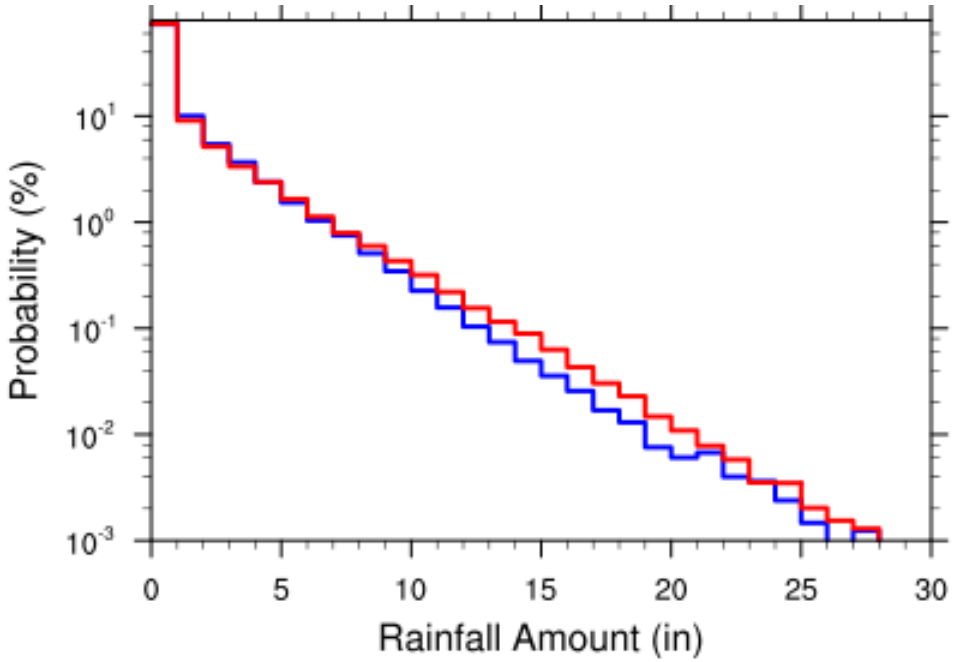


- 20-member hindcasts ensembles are initialized every 3 days starting June 1 through November.

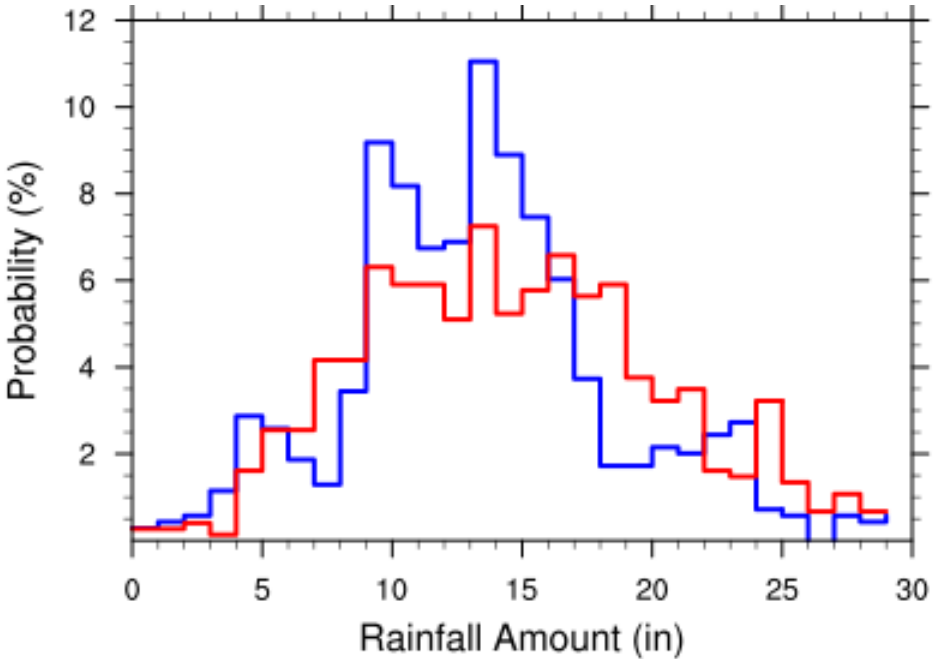


Preliminary: Hurricane Season (2020)

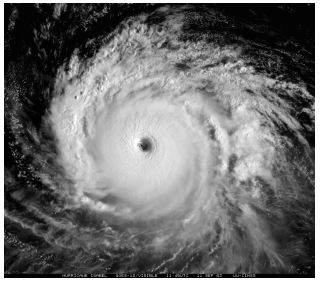
Accumulated Rainfall Amounts



Maximum Accumulated Rainfall

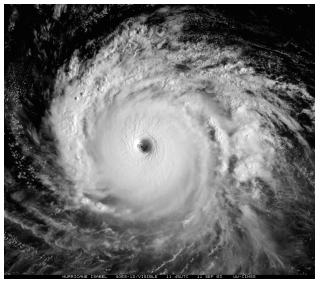


- Increase of **~10 ± 5%** in mean maximum accumulated rainfall amount.



Final Thoughts

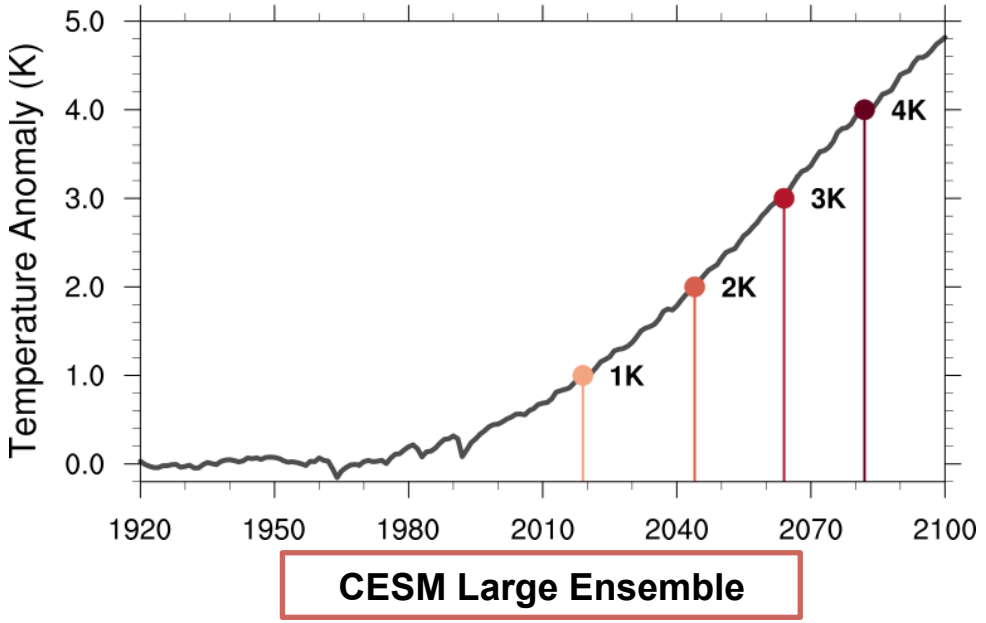
- Hindcast attribution frameworks demonstrate that climate change has **increased rainfall rates and accumulated amounts** associated with recent Hurricanes (Florence, Dorian, 2020 storms, etc.) by 4-16%.
- This is **consistent with projected changes** in hurricane rainfall in decadal simulations of 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**.

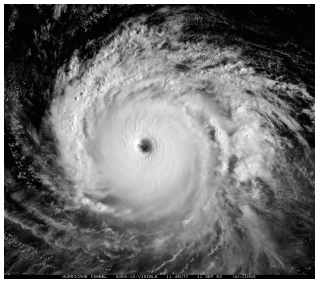


Future Work

- 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**.

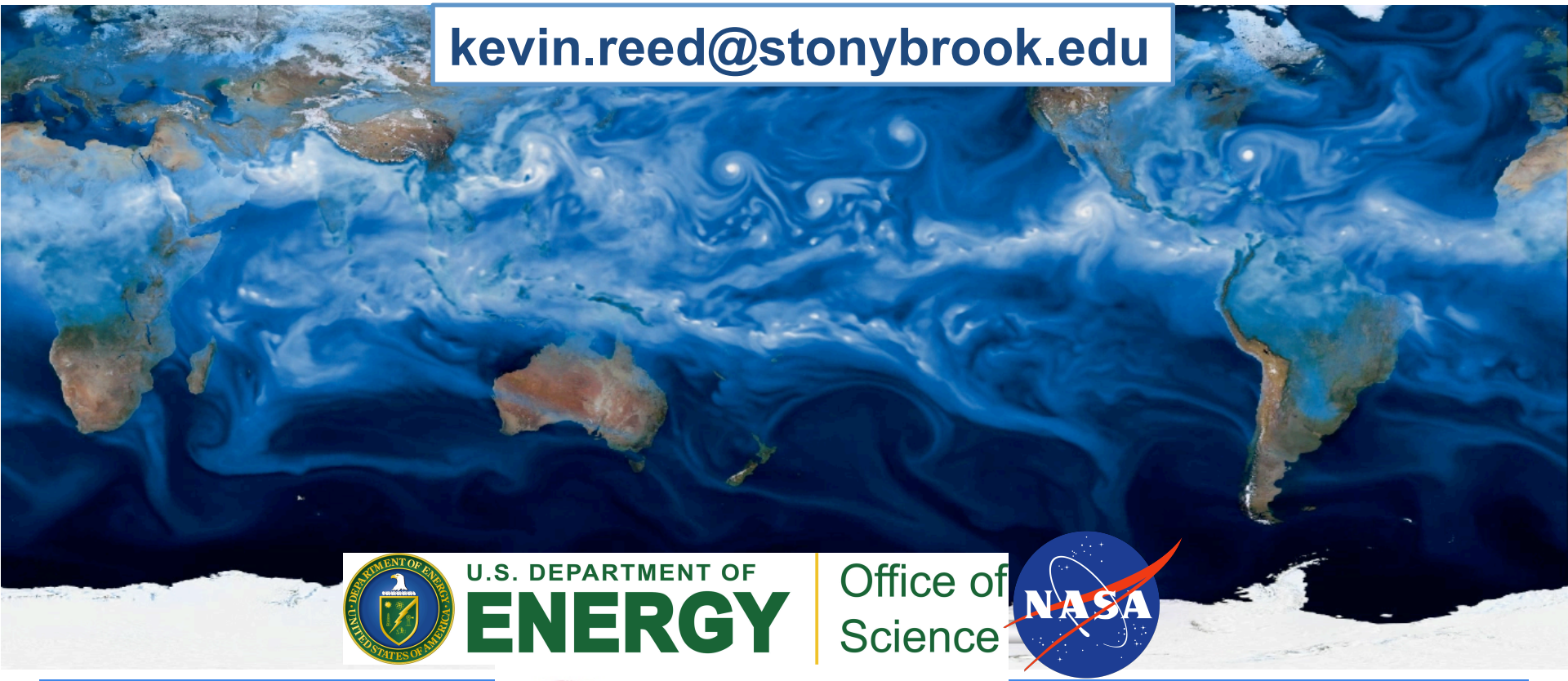




Thank You!

To understand changes in extreme precipitation in the future, we need to understand the changes in the events responsible for extreme precipitation!

kevin.reed@stonybrook.edu



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