Future Projections of Precipitation Extremes over Florida: Insights from Downscaled CMIP6 CESM2

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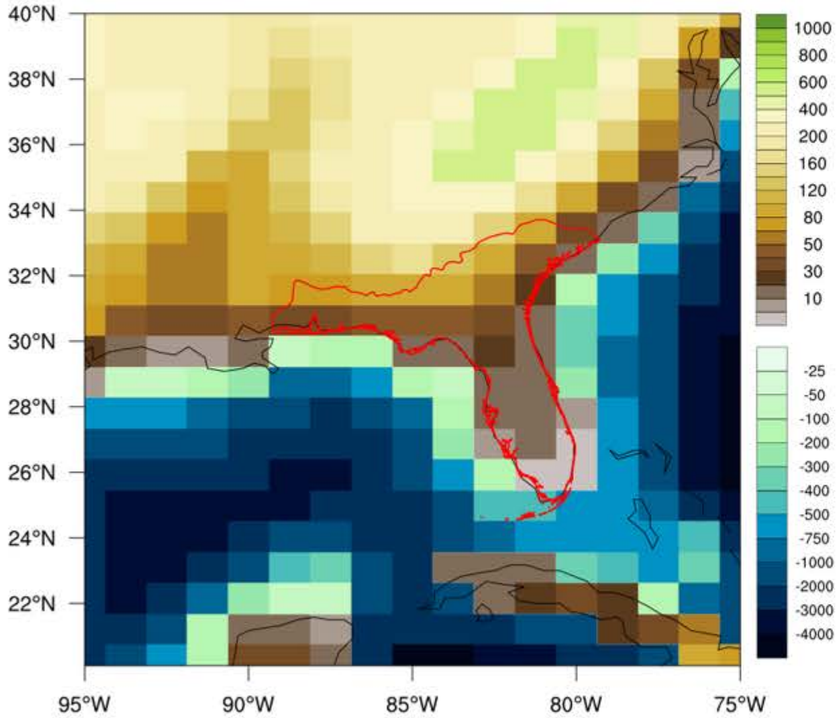
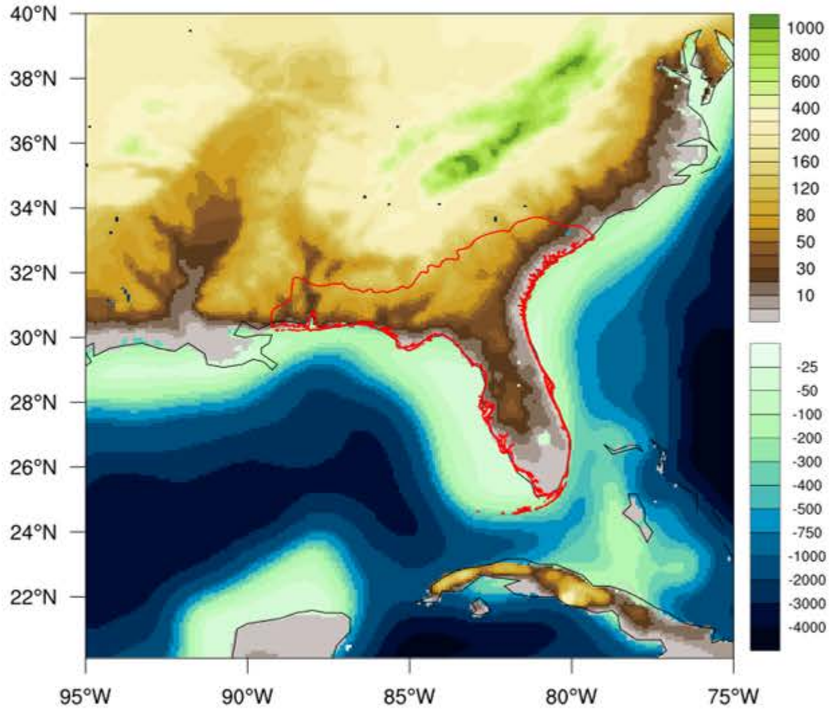
Why Downscaling is Necessary?

Global Model (CESM2)



Regional Model (RSM-ROMS)



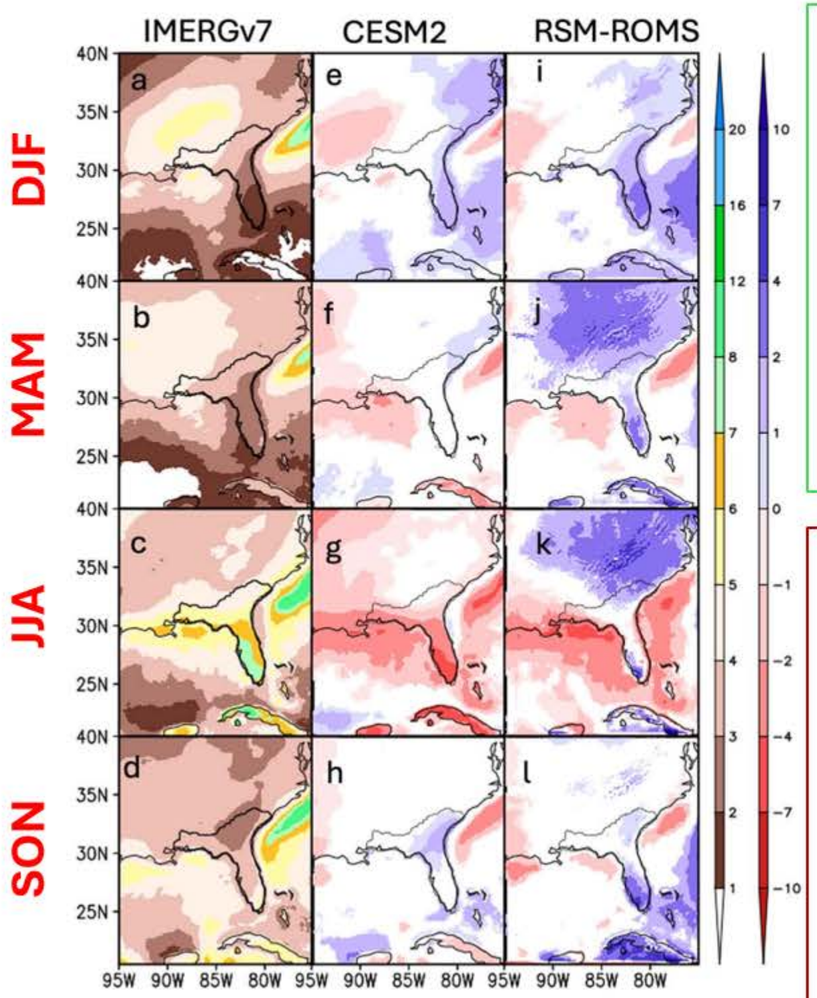
Experiment Setup

- Global Model : CMIP6 CESM2
- Regional Model : RSM-ROMS
- Historical Run : 1986-2014
- Projection : 2071-2100 (SSP 585)

- **Coarse GCM (CMIP6 CESM2):** ~100 km—misses local weather details, smooths rainfall, underestimates extremes.
- **Dynamical Downscaling (RCM):** Adds high-resolution physics (10 km) driven by GCM to capture realistic localized events and extremes.

Seasonal Climatology of Rainfall, Temperature and SST

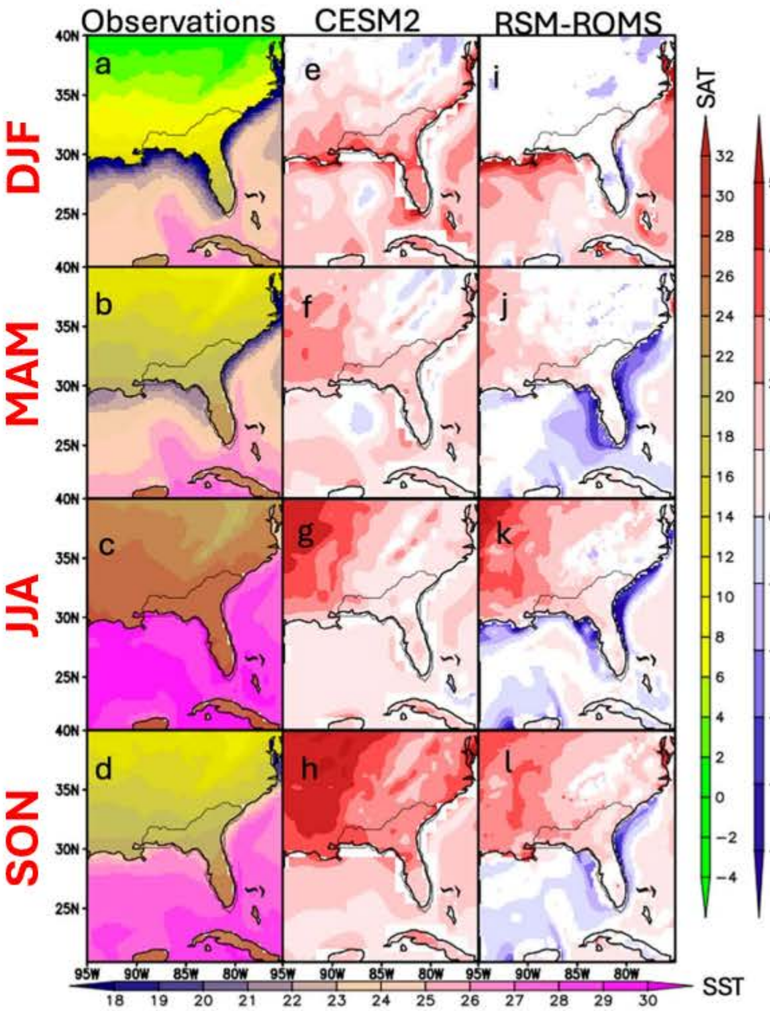
Rainfall



- The seasonal variation in precipitation is comparatively weak in CESM2, while RSM–ROMS largely restores the observed seasonal cycle.
- Although the summer dry bias over the Florida in CESM2 is substantially reduced in RSM–ROMS, the wet bias in the other three seasons is slightly more pronounced.

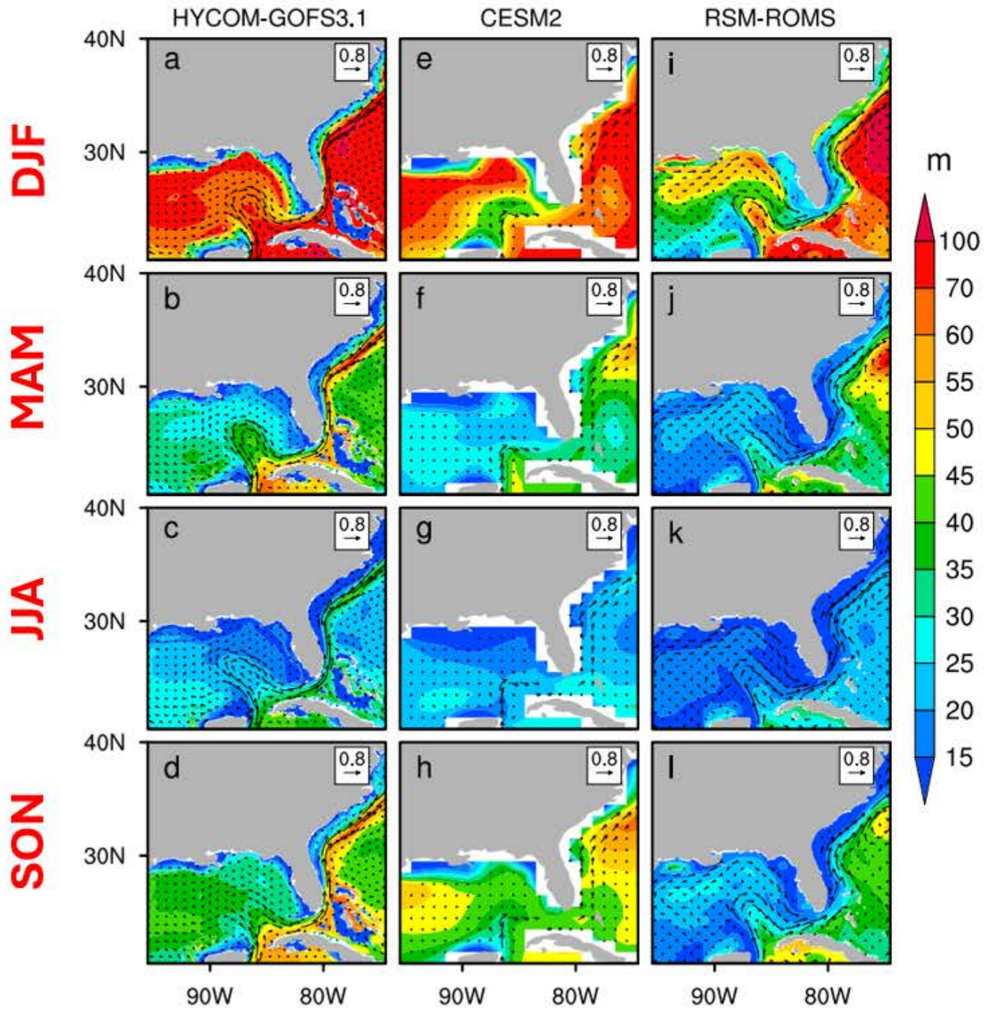
- CESM2 exhibits a warm Temperature bias over land and coastal oceans around Florida, which is reduced in RSM–ROMS, although the latter shows a stronger cold bias along the coastal oceans
- RSM–ROMS captures observed mesoscale features, including Appalachian cooling and Gulf of Mexico (Loop Current) SST gradients

Temperature/SST



Source: Misra and Jayasankar, 2025 [JAMC]

Seasonal Climatology of Surface Ocean Currents and MLD

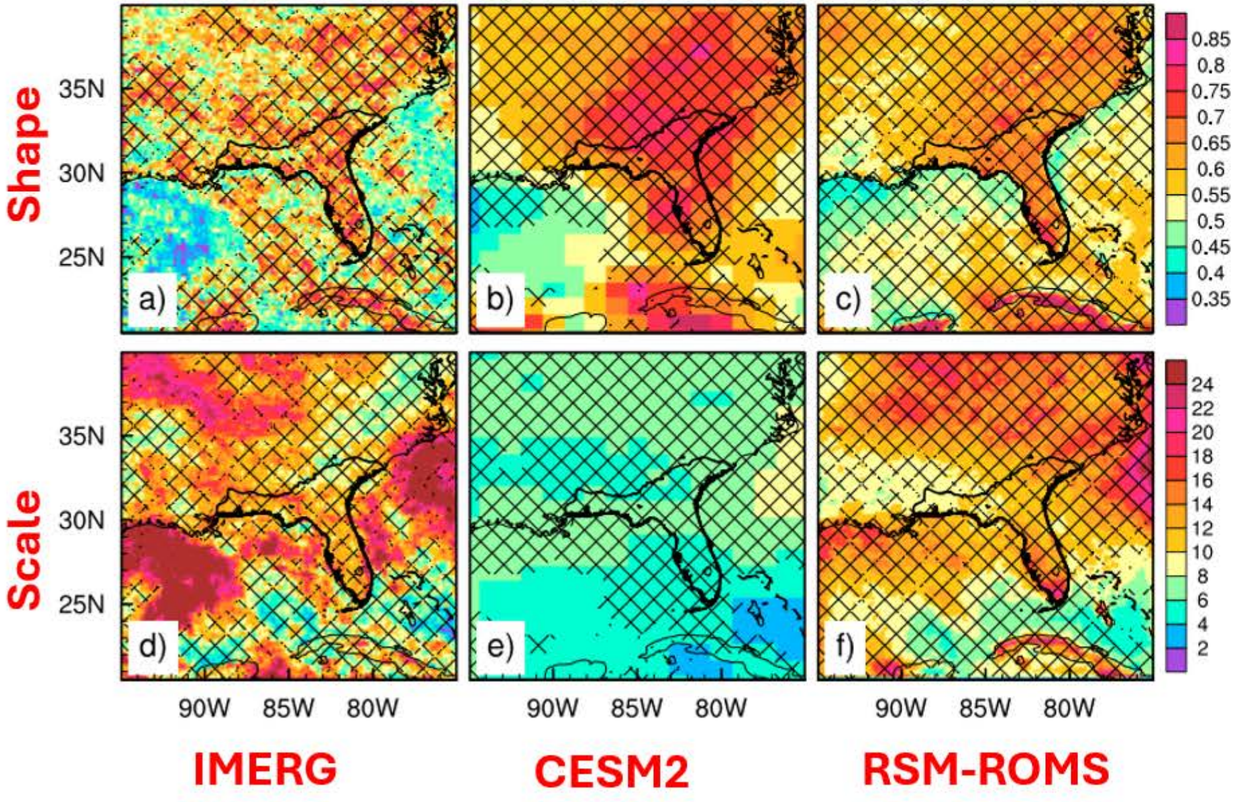


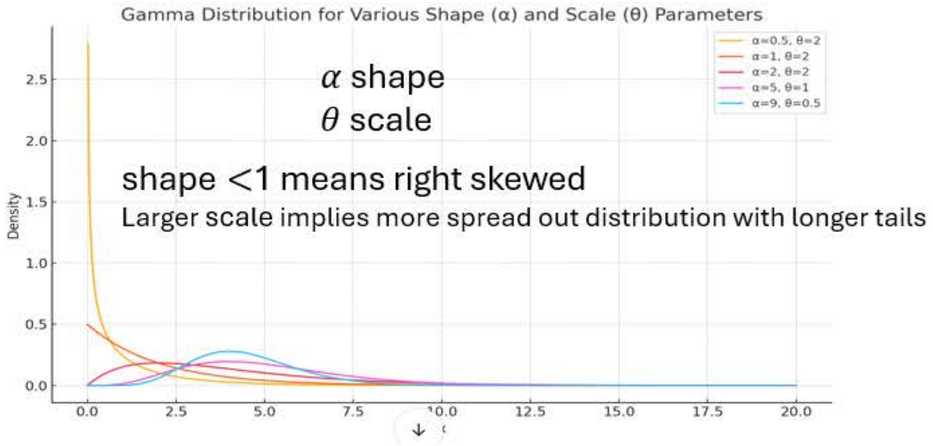
Source: Misra and Jayasankar, 2025 [JAMC]

- The Loop Current, the upper branch of the AMOC transporting warm Caribbean water into the Gulf, is captured in both model simulations, but its northward intrusion and tilt are more prominent in RSM–ROMS.
- CESM2 largely misses these features, highlighting that global models poorly simulate the Loop Current's seasonality due to coarse resolution.
- RSM–ROMS reduces CESM2's shallow mixed-layer bias around the Loop Current overall, but amplify it in fall due to slower seasonal recovery compared to reanalysis

Shape and Scale Parameters

Distribution of daily rainfall by fitting a gamma distribution to the rainy days in JJA



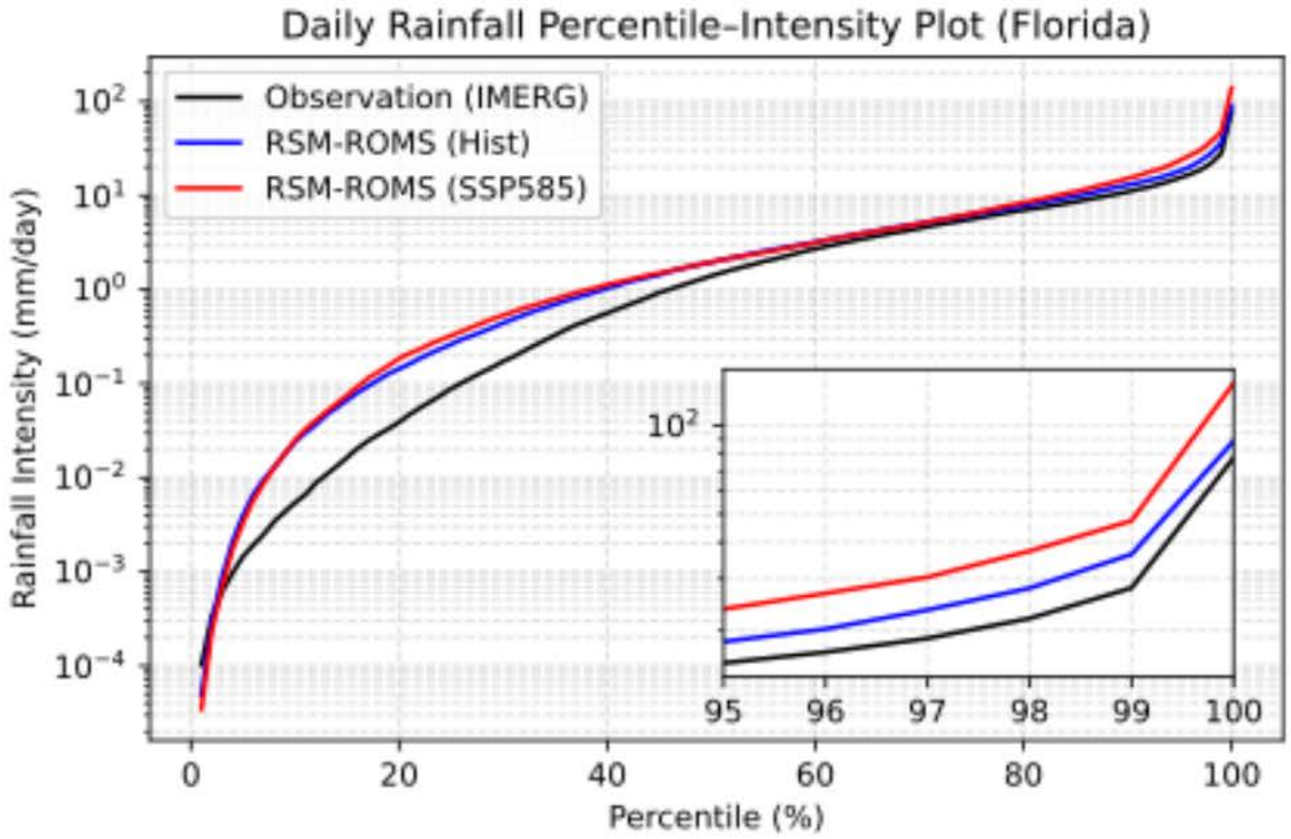


- IMERG shows that the shape and scale parameters of daily rainfall are far more spatially inhomogeneous, i.e., summer rain comes from smaller-scale weather systems.
- CESM2 underestimates the scale parameter and overestimates the shape parameter across much of the domain, producing less frequent moderate-to-heavy rainfall.
- RSM–ROMS improves on CESM2, producing shape and scale parameters closer to observations over Florida and surrounding oceans, though some regional biases remain.

Source: Misra and Jayasankar, 2025 [JAMC]

Intensity Vs. Percentile of Daily Rainfall

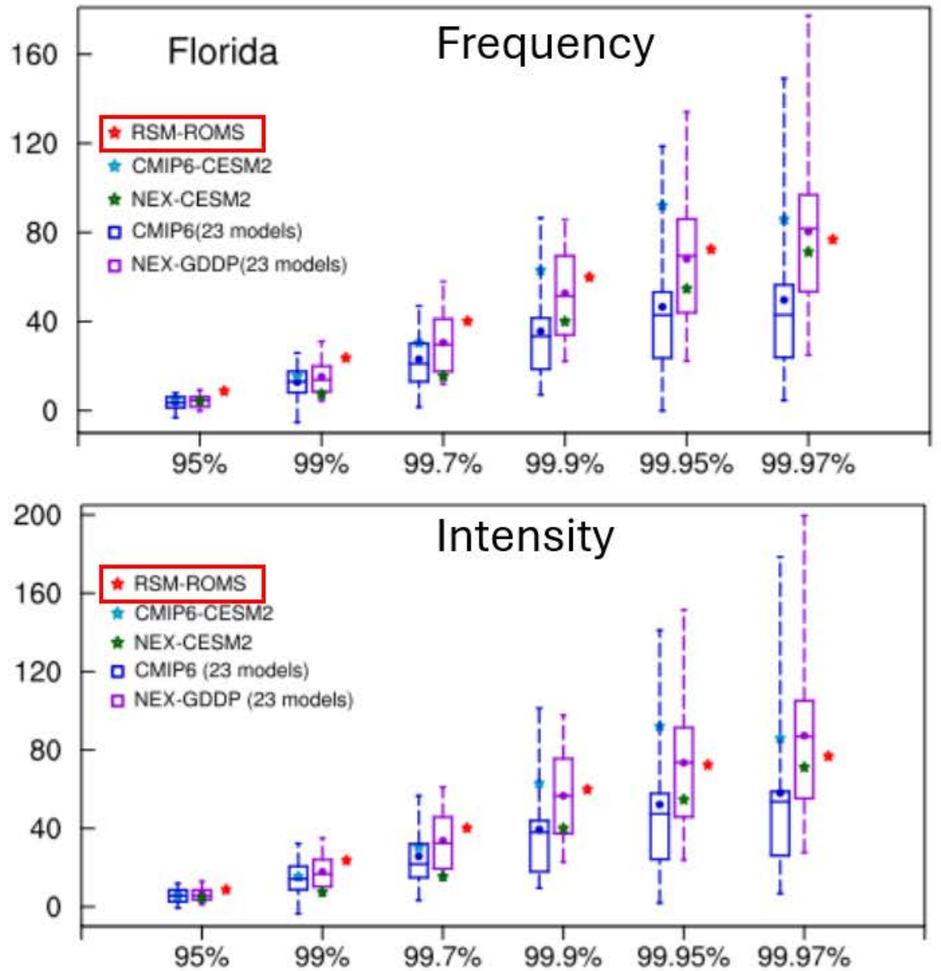
Intensity of annual rainfall from RSM-ROMS and IMERG against different percentiles



- The RSM-ROMS **overestimates rainfall intensity** compared to IMERG observations across majority of the distribution
- Under the high-emissions future scenario (SSP585), the model projects a **significant and non-linear increase in the intensity of extreme rainfall events** in Florida.
- The intensity of rainfall increases disproportionately in the high percentiles, meaning that the **wettest days get much wetter** in the future

Projected Changes in the Extreme Precipitation

- **Extreme Rainfall Analysis:** Six percentile thresholds (95%, 99%, 99.7%, 99.9%, 99.95%, 99.97%) considered.
- **Projections:** Changes shown relative to present-day, scaled by annual temperature increase.
- All the model considered in this study consistently shows that the projected increase in frequency and intensity of extreme rainfall events over Florida in the end of the 21st Century.



Projected Changes in the Extreme Precipitation

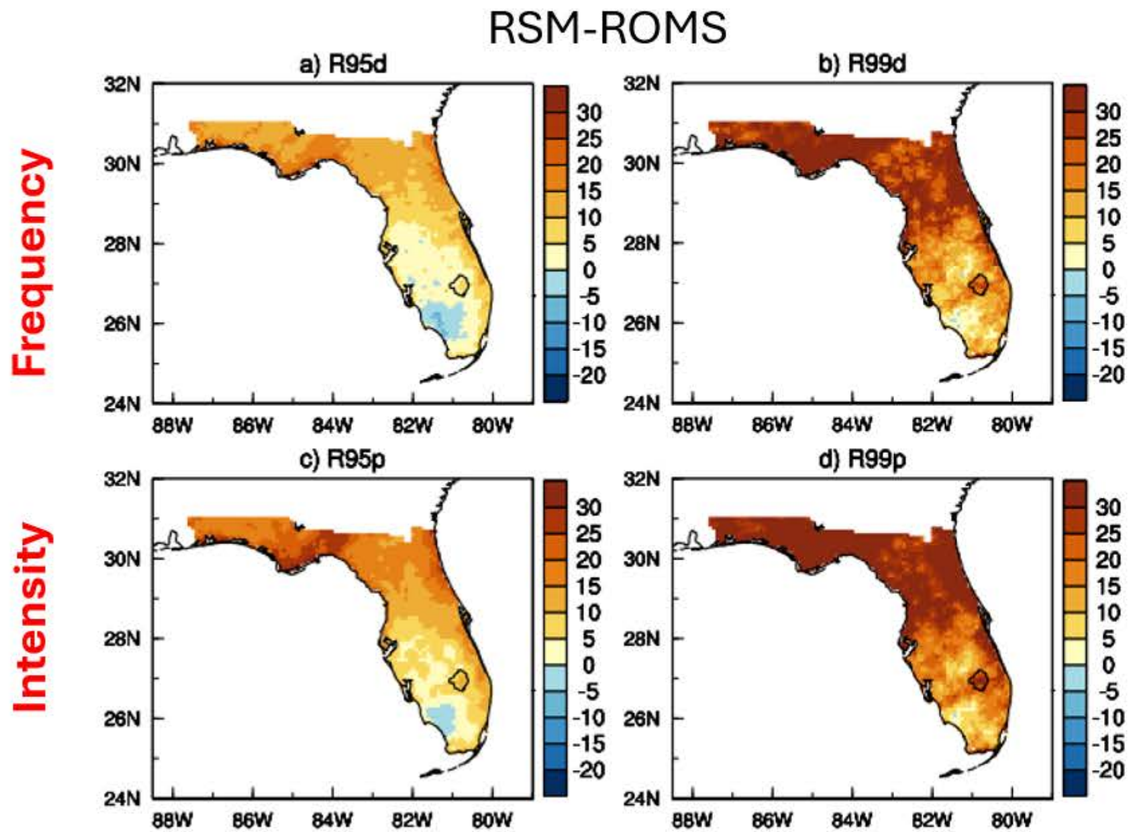


Figure: Projected changes (% change with respect to present day scaled by annual temperature change) in the annual a) R95p, b) R99p, c) R95d, and d)R99d.

- Majority of the Florida experience increase in intensity and frequency of R95 and R99 some parts of the southern Florida shows decrease in the R95d and R95p
- Northern Florida is projected to experience more intense and frequent extremes than Southern Florida.

Projected Changes in the Extreme Precipitation

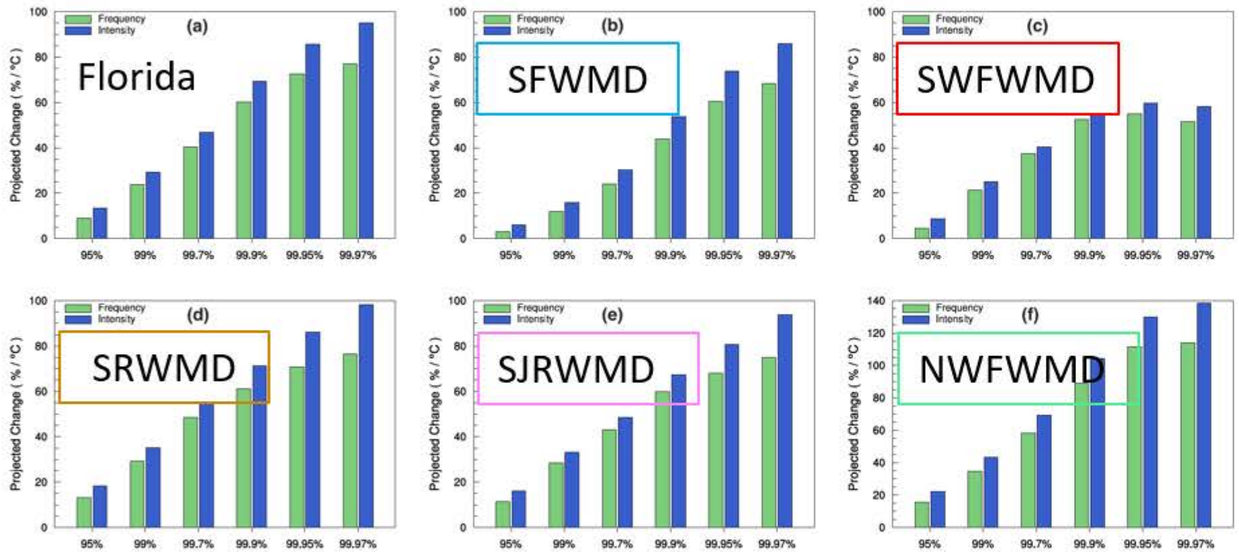
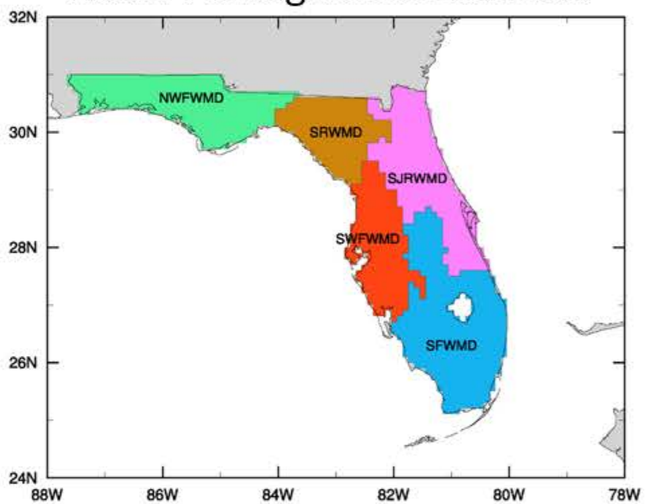


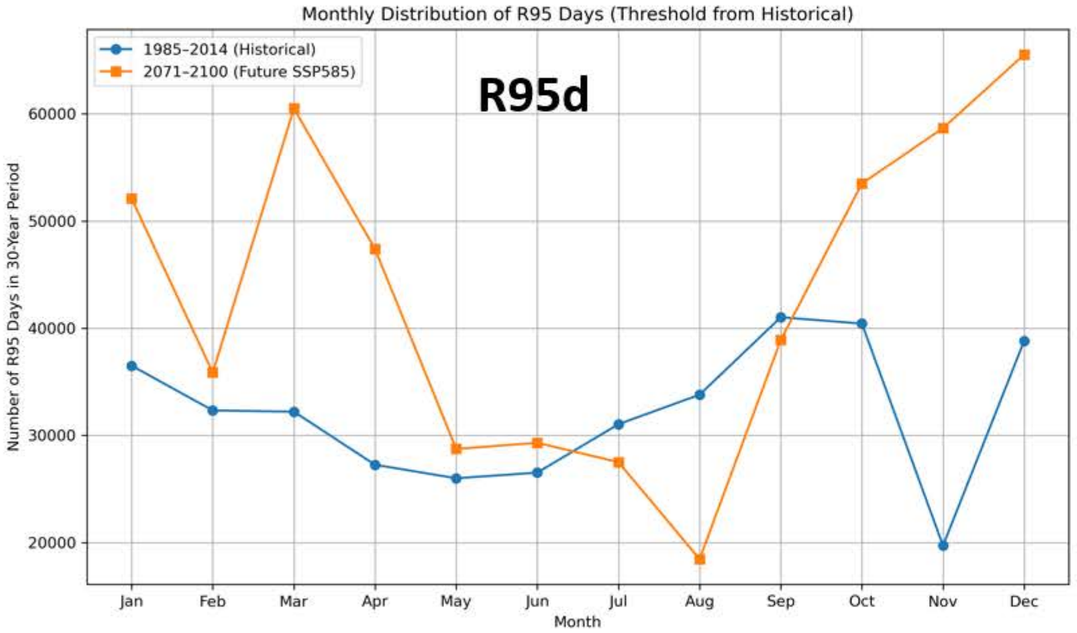
Figure: *Projected changes in the frequency and intensity of annual rainfall (%/°C) for different categories of extremeness in extreme rainfall events over the Florida and its five water management districts.*

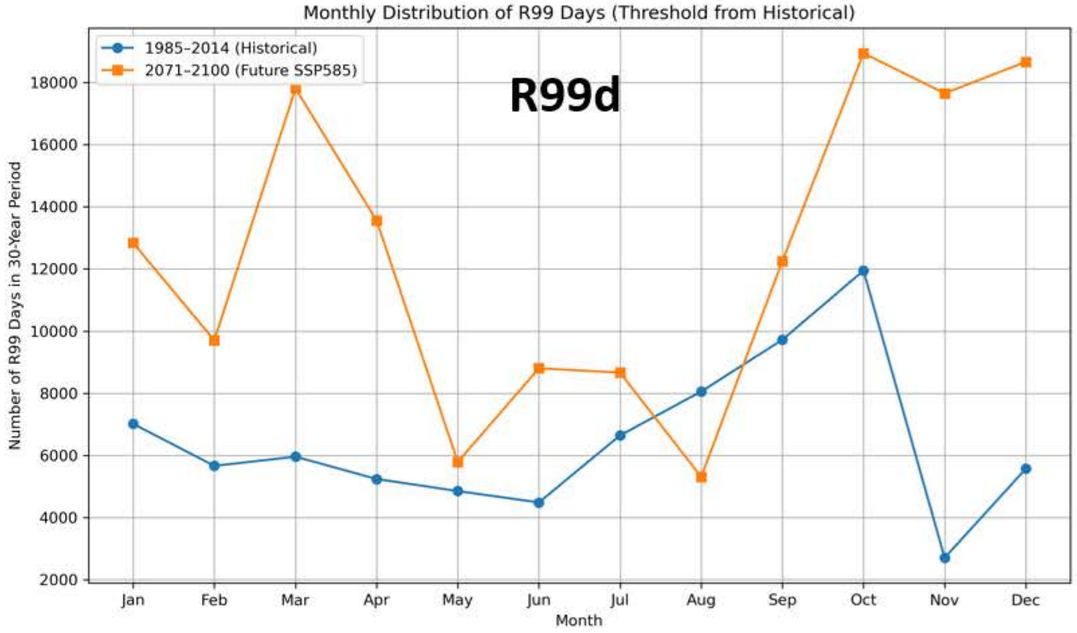
Water Management Districts



- There is a steady increase in both the intensity and frequency of extreme precipitation from R95p to R99.97p in over all regions.
- SFWMD and SWFWMD shows slightly less changes compared to other three WMDs

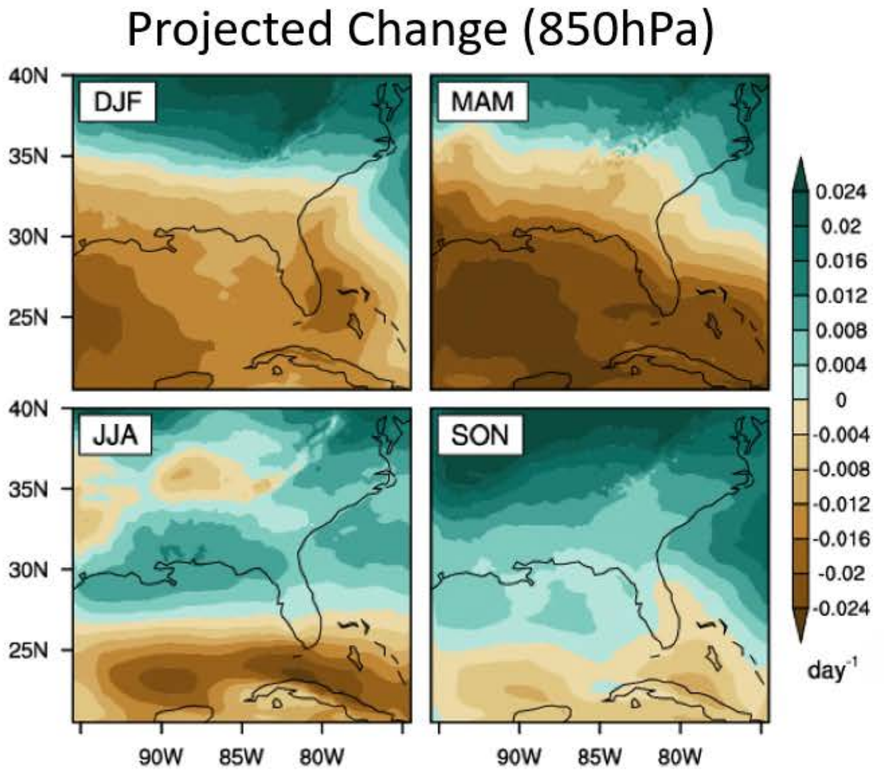
Monthly Mean Climatology of Extreme Precipitation Days

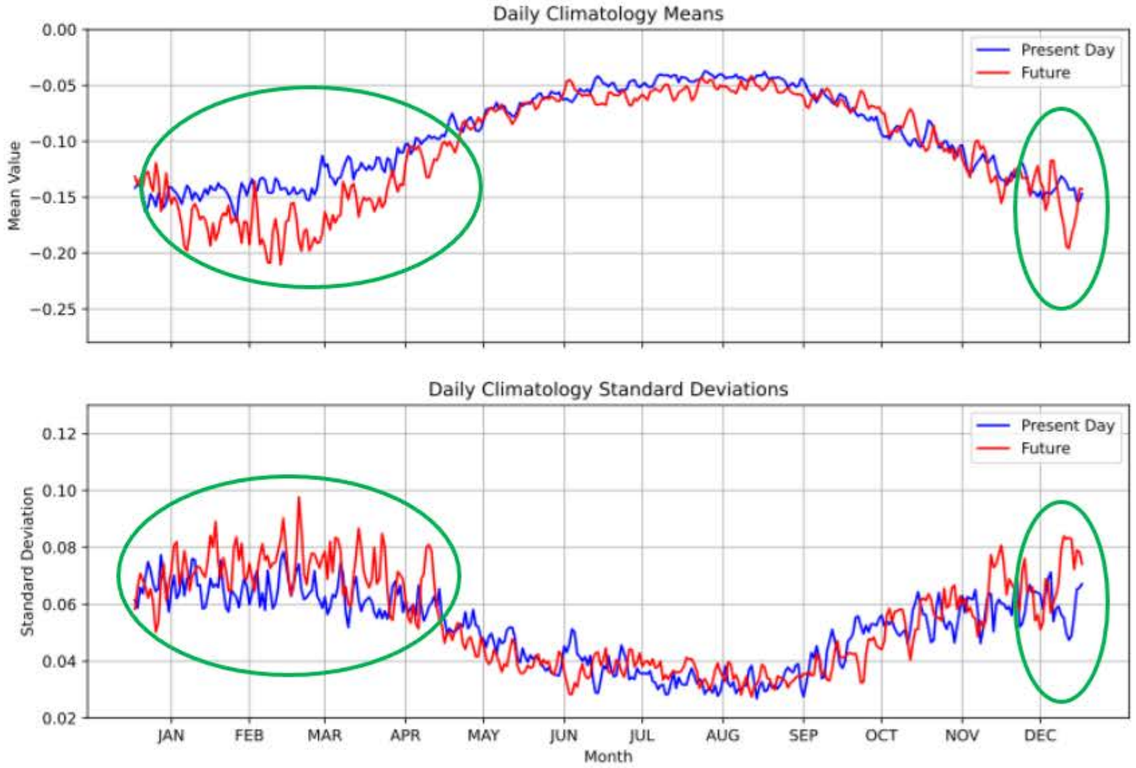




- Monthly mean climatology of extreme rainfall events (R95d and R99d) shows that in most of the months outside JJA (outside the rainy season) is increasing in future.

Projected Eady Growth Parameter





- Weaker Eady growth over southern Florida and nearby oceans indicates reduced vertical wind shear and/or greater stability, leading to fewer or less intense storms and consequently lower extreme rainfall.
- Weaker Eady growth during DJF, MAM, and SON in the future indicates increased variability, suggesting that extreme events are more likely to occur during traditionally non-rainy seasons.

Key Takeaways

- **Intensification:** All models project stronger and more frequent extreme rainfall events over Florida
- **North–South Contrast:** North Florida sees a larger increase in extreme precipitation activity than South Florida in a future climate, which is suggestive of the contrast in the frontal activity in the winter and late fall seasons.
- **Non-Rainy Season Risk:** More extremes projected during DJF, MAM, and SON, increasing unseasonal flood risks.
- **Physical Drivers:** ~7% more atmospheric moisture per °C (Clausius–Clapeyron) fuels extreme rainfall.
- **Dynamical Change:** Weaker **Eady Growth Rate** and altered circulation patterns reduce storm activity in the south but enhance it in the north.

Thank You