Exploring the Response of Tropical Cyclone Precipitation to Idealized Warming in CAM Aquaplanet Simulations

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Extreme Precipitation and Climate Change

- From IPCC: *frequency* and *intensity* of heavy precip. events will likely increase on average (Kirtman et al. 2013)

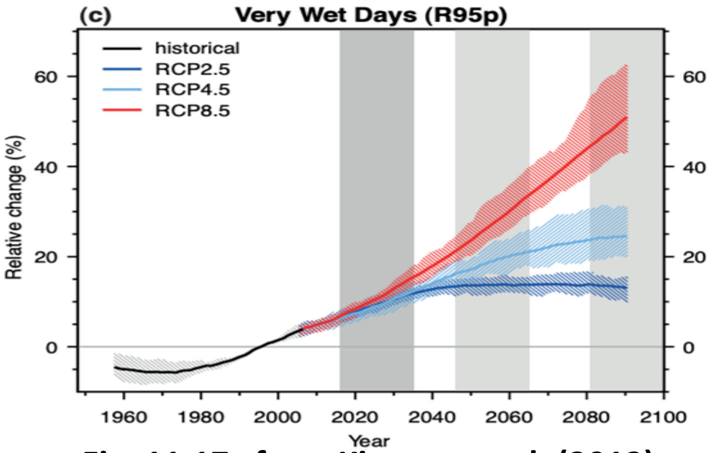
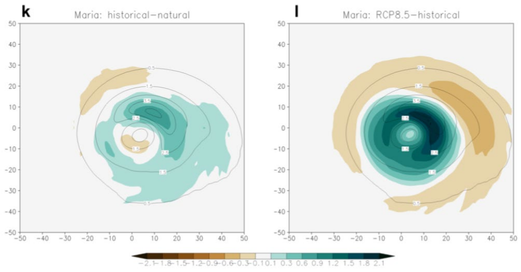


Fig. 11.17c from Kirtman et al. (2013)

- Leading theory behind increases in heavy precip. events: the Clausius-Clapeyron (C-C) relationship (Allen & Ingram 2002)
  - Every 1°C warming of atmosphere, air has capacity to hold ~7% more water vapor (assuming constant RH)
  - Some observational evidence that tropical heavy precip. exceeds C-C scaling (Allen et al. 2014)

What about Tropical Cyclone Precipitation?

- How is TC precipitation impacted by climate change?
  - Consensus: increasing (e.g., Villarini et al. 2014, Kim et al. 2014, Knutson et al. 2015, Patricola & Wehner 2018…)
  - By how much?: uncertain



From Fig. 4 in Patricola & Wehner (2018)

% Change in Area-Averaged TC Precip.

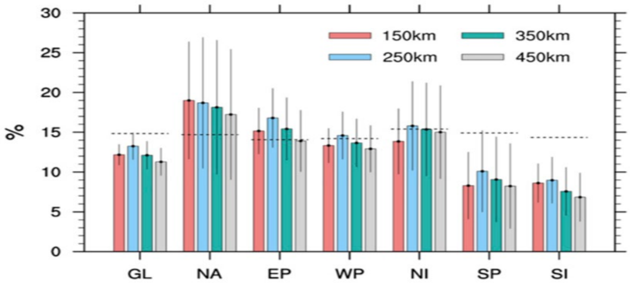


Fig. 9 in Kim et al. (2014)

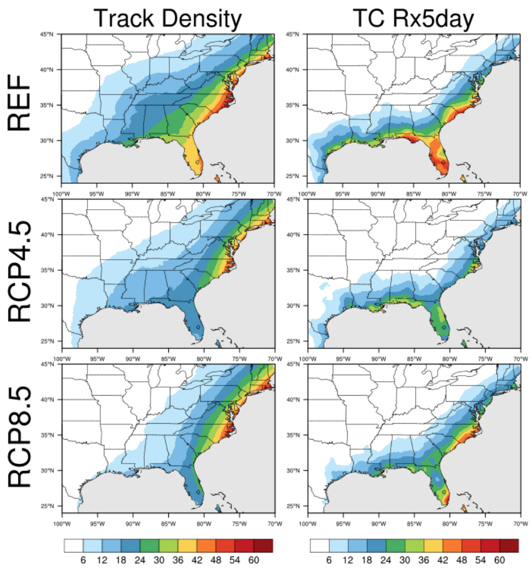


Fig. 2 in Stansfield et al. (2020)

Research Goal

- Utilize radiative convective equilibrium (RCE) simulations to better understand how interactions between thermodynamic and dynamic processes increase precipitation from TCs with climate change.

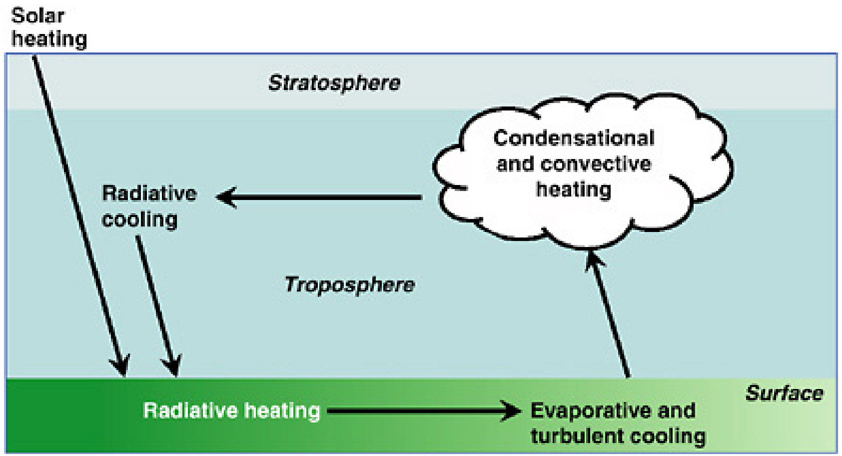


Fig. from *Radiative Forcing of Climate Change* (2005)

Advantages of RCE

- No impacts of land, sea surface temperature (SST) variability, general circulation on TCs
- Sole focus on TCs, not interactions with complex environments

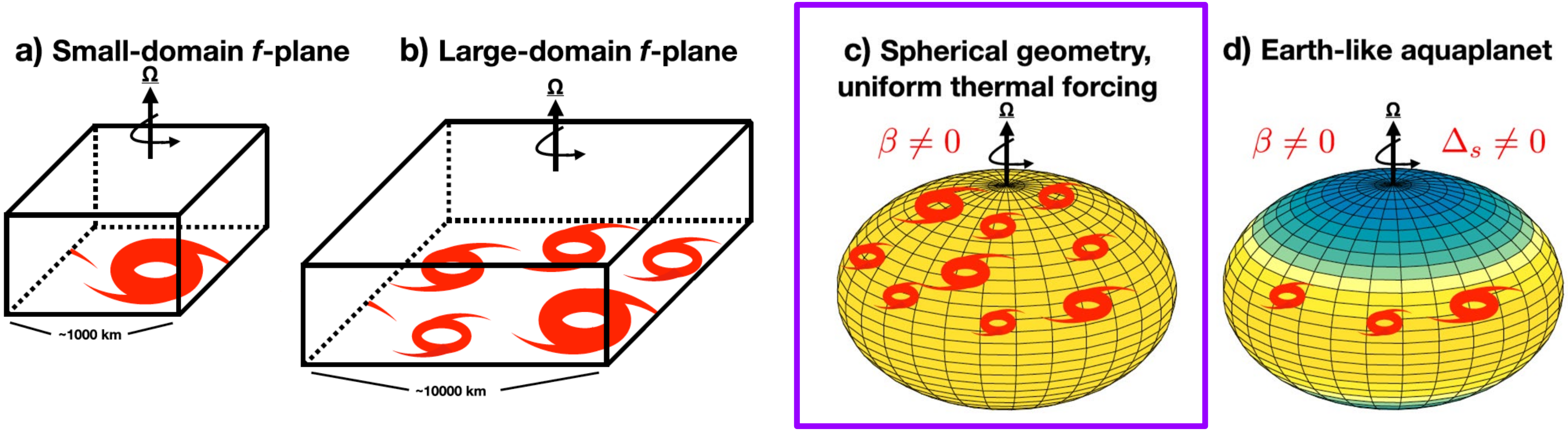
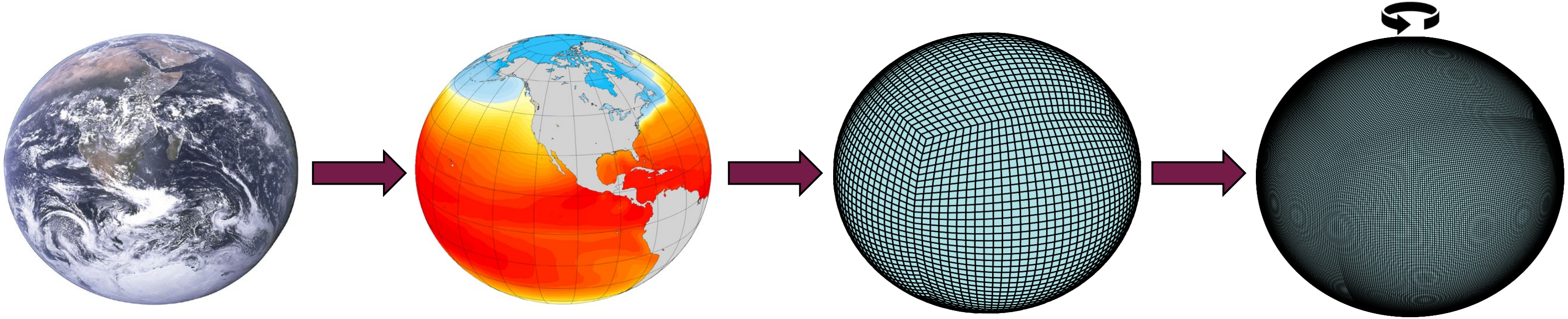


Fig. 1 from Merlis & Held (2019)

Model Simulation Descriptions

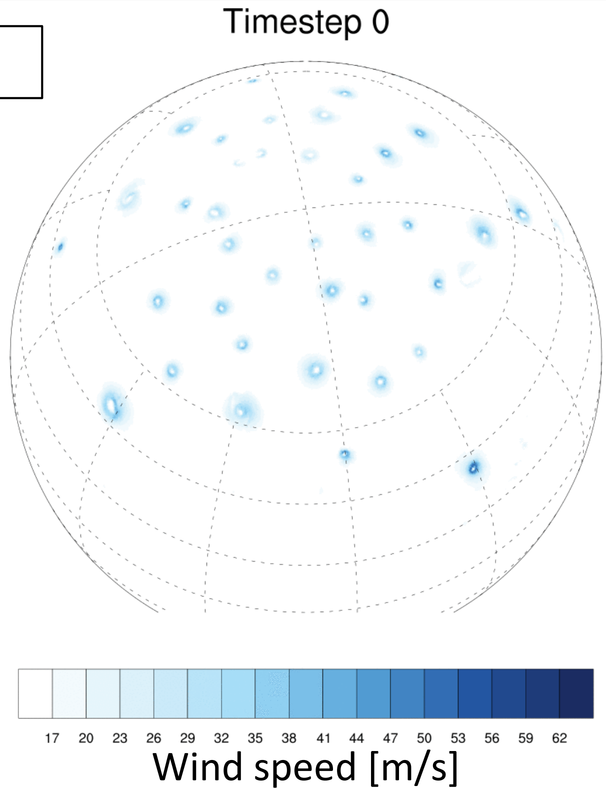
- Model: Community Atmosphere Model (CAM), version 5
  - CESM2, with new official RCEMIP compset (see Levi Silvers' talk on Tuesday)
  - using protocols of RCEMIP (Wing et al. 2018), except **adding rotation**
- 11 simulations with uniform SST varying from 295 - 305 K in 1 K increments
  - Simulation length = 2 years
  - Horizontal grid spacing: ~28 km, SE dynamical core

Real Earth | **AMIP Simulation** | **RCEMIP Simulation** | **This Study**



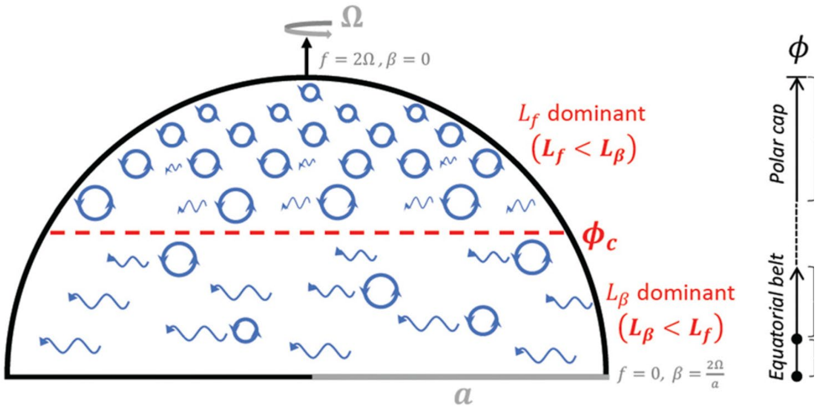
What do these simulations look like?

300 K

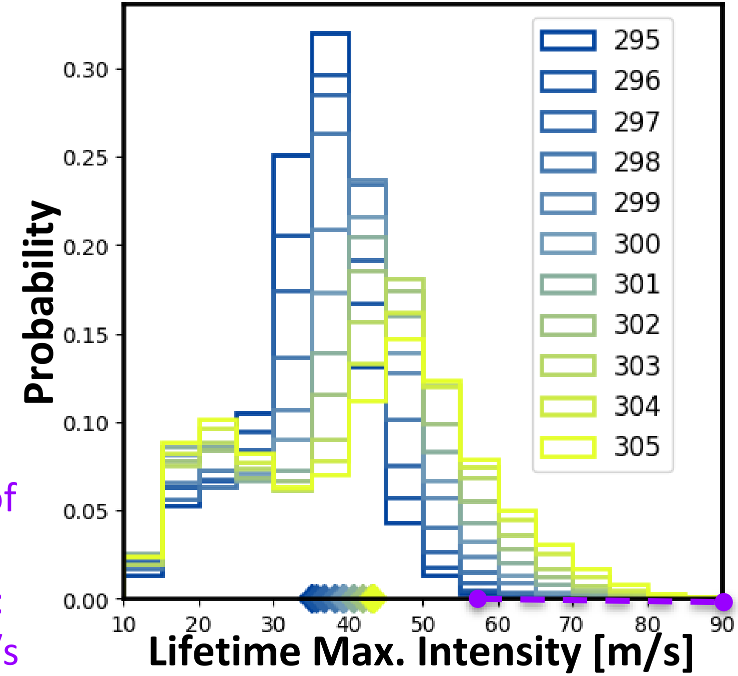


*TCs tracked using the TempestExtremes software (Ullrich & Zarzycki, 2017; Ullrich et al., 2021). Available on Github: https://github.com/ClimateGlobalChange/tempestextremes

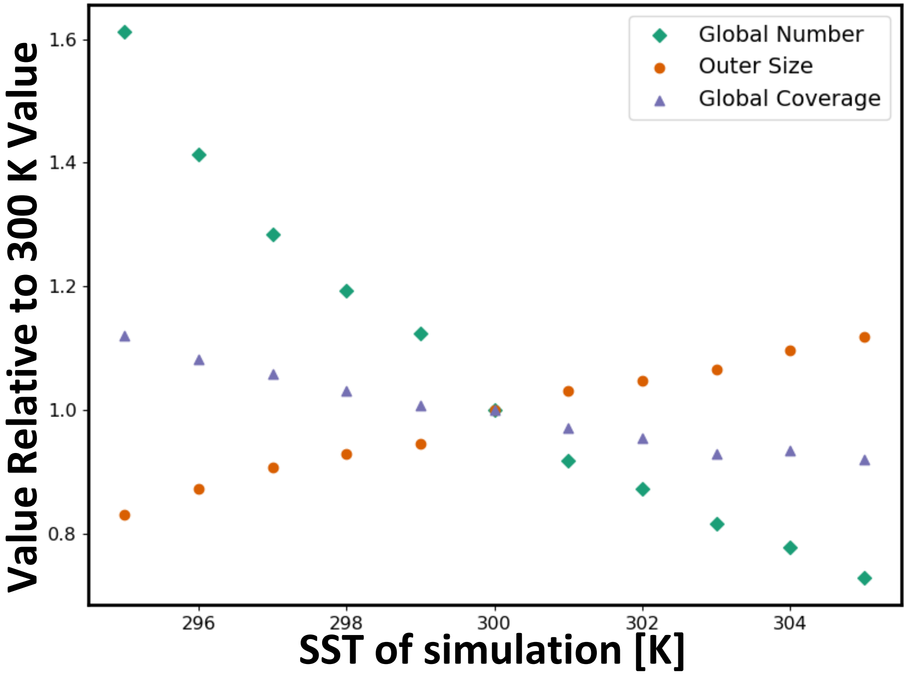
Fig. 11 from Chavas & Reed (2019)



TC Counts, Intensities, and Sizes

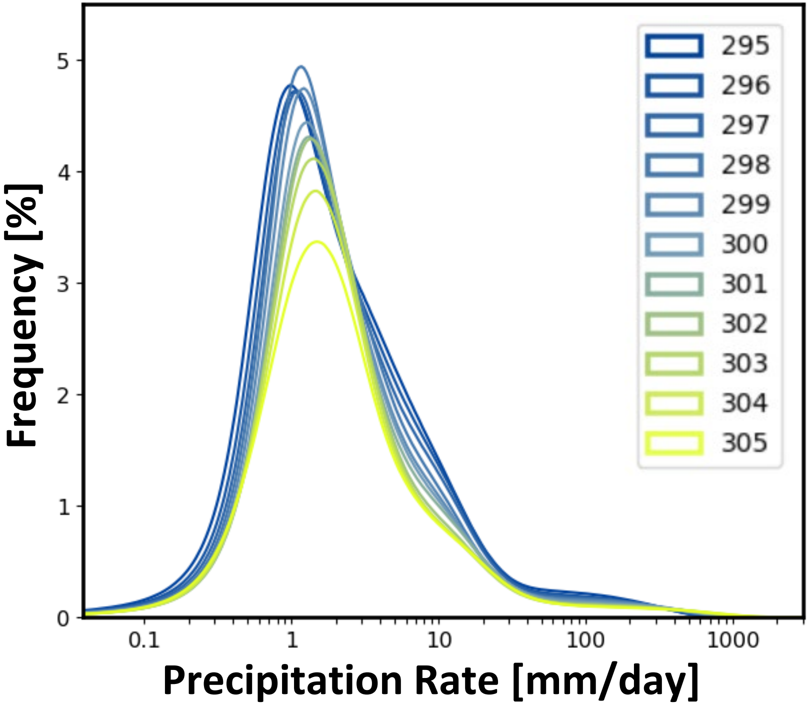


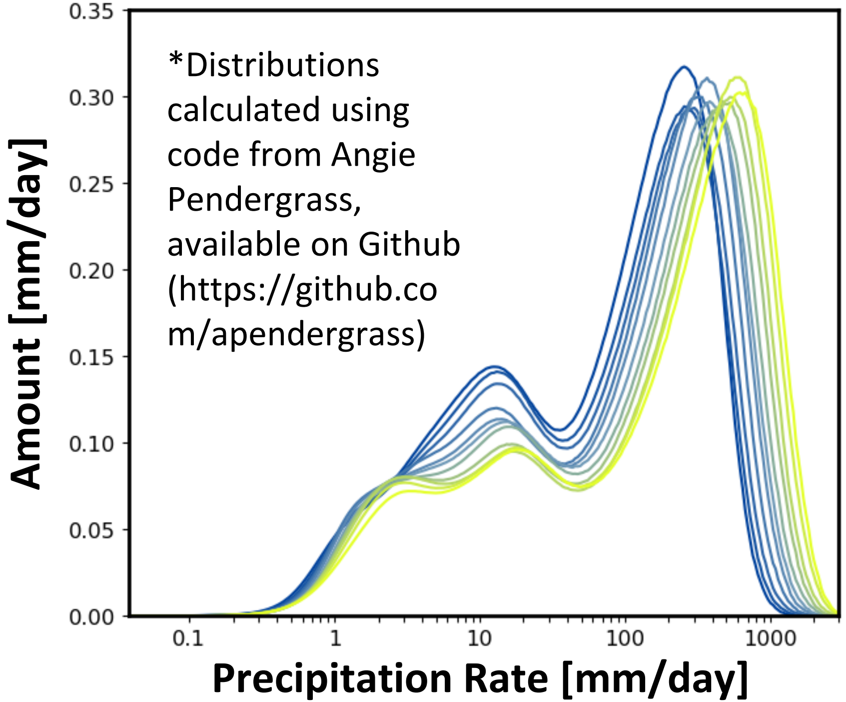
*Range of potential intensity: 57-90 m/s



- Average TC more intense and larger in warmer simulations

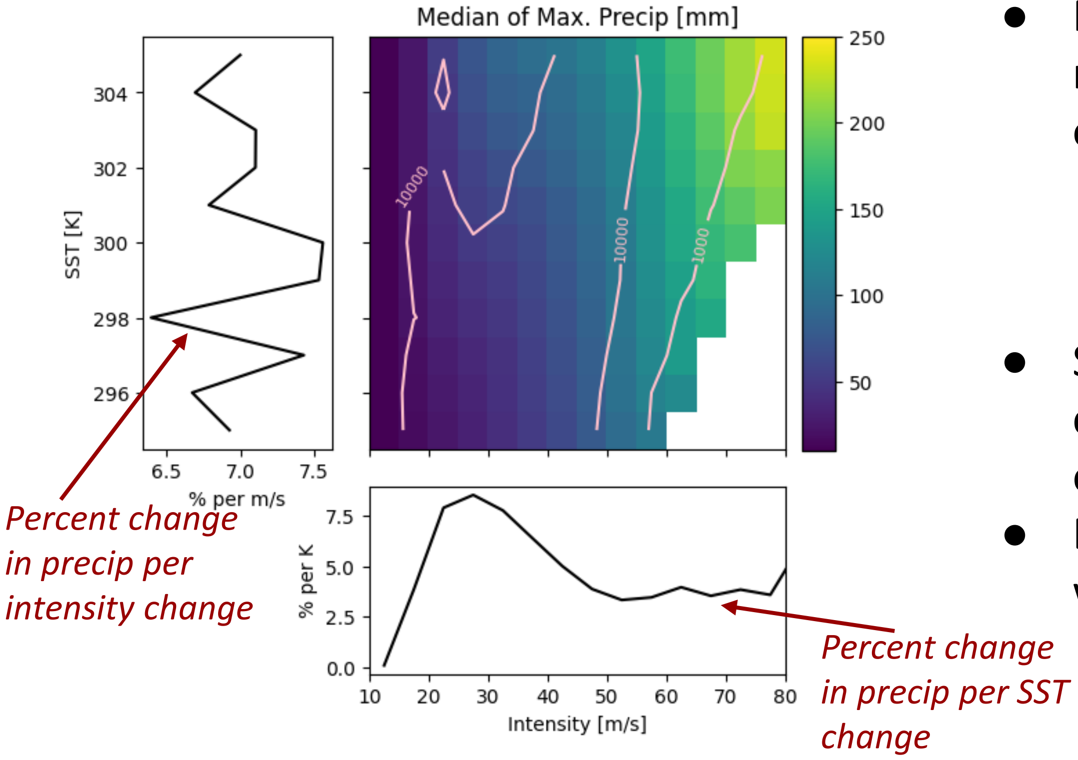
TC Precipitation Distributions





- More frequent extreme TC precipitation rates in warmer simulations

TC Precipitation Dependence on SST and Intensity



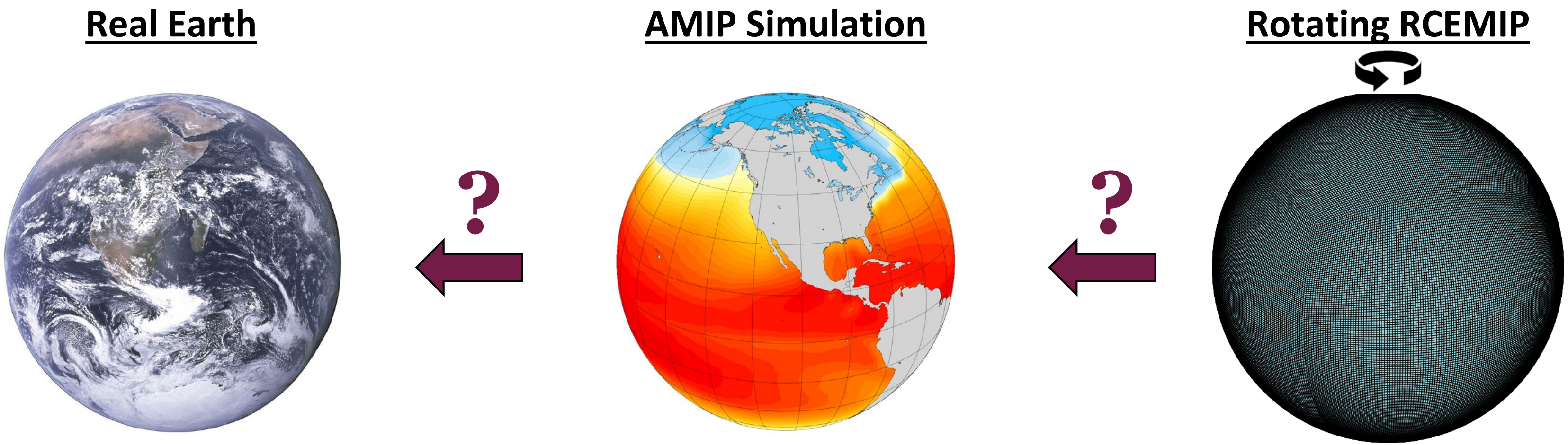
- Main figure shows joint dependence of maximum precipitation (colored boxes) on SST (y-axis) and TC intensity (x-axis)
  - Each box shows median of distribution of thousands of TCs at that SST/intensity combination
- Side figures show the mean percentage change in precipitation, calculated in each row or column
- Basic result: TC precipitation increases with increasing SST and TC intensity

Preliminary Results/Next Steps

- In CAM RCE aquaplanet simulations, warmer SSTs lead to:
  - less TCs at any one time
  - average TC is more intense and larger
  - more extreme precip. rates + more precip. coming from the extreme rates
- Working on now:
  - How much of the precip. increase comes from thermodynamic (increase in q) vs dynamic changes (increase in TC intensity/size)?

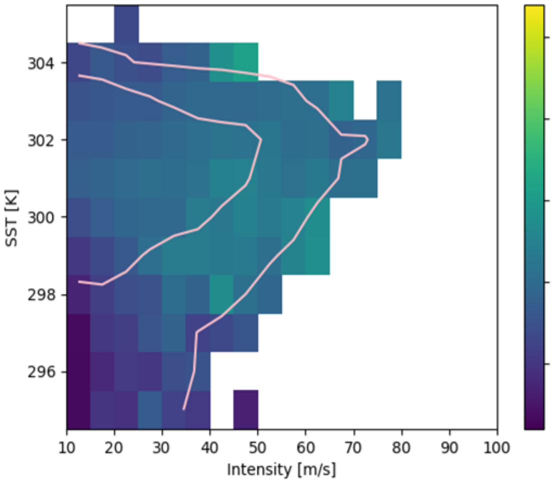
Future Work

- Evaluate how well TC precip. results from the RCE simulations translate to more realistic GCM simulations and observations.
  - Results from Chavas et al. (2017) suggest that TC structure in RCE simulations, AMIP simulations, and observations are consistent

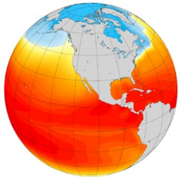


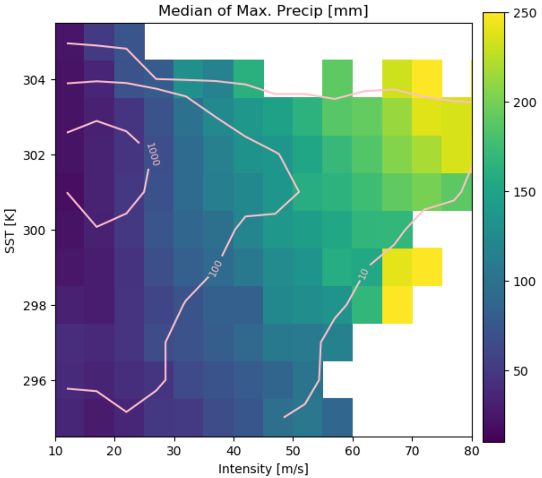
Linking Idealized to Real World

Real Earth



AMIP Simulation





Rotating RCEMIP