MESACLIP: Understanding the Role of MESoscale Atmosphere – Ocean Interactions in Seasonal-to-Decadal CLImate Prediction

Fred Castruccio (NSF NCAR)

Gokhan Danabasoglu (NSF NCAR) & Ping Chang (TAMU) & Dan Fu (TAMU)

NSF NCAR: Teagan King, Nan Rosenbloom, Justin Small, Steve Yeager

TAMU: Xue Liu, Greta Olson, Xiaoqi Wang, Gaopeng Xu, Qiuying Zhang

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CESM OMWG WINTER MEETING

27 FEBRUARY 2025

TEXAS A&M UNIVERSITY

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CESM High-Resolution Simulations (CESM1.3; 0.1º ocn; 0.25º atm)

500-year PI control;

80-year 1%CO_2; 150-year 4xCO_2;

10-member (1850) 1920-2005 historical;

10-member 2006-2100 transient w/ RCP 8.5;

10-member 2006-2100 transient w/ RCP6.0;

1-member 2006-2100 transient w/ RCP4.5;

1-member 2006-2100 transient w/ RCP2.6;

3-member 1970-2020 Ozone withholding;

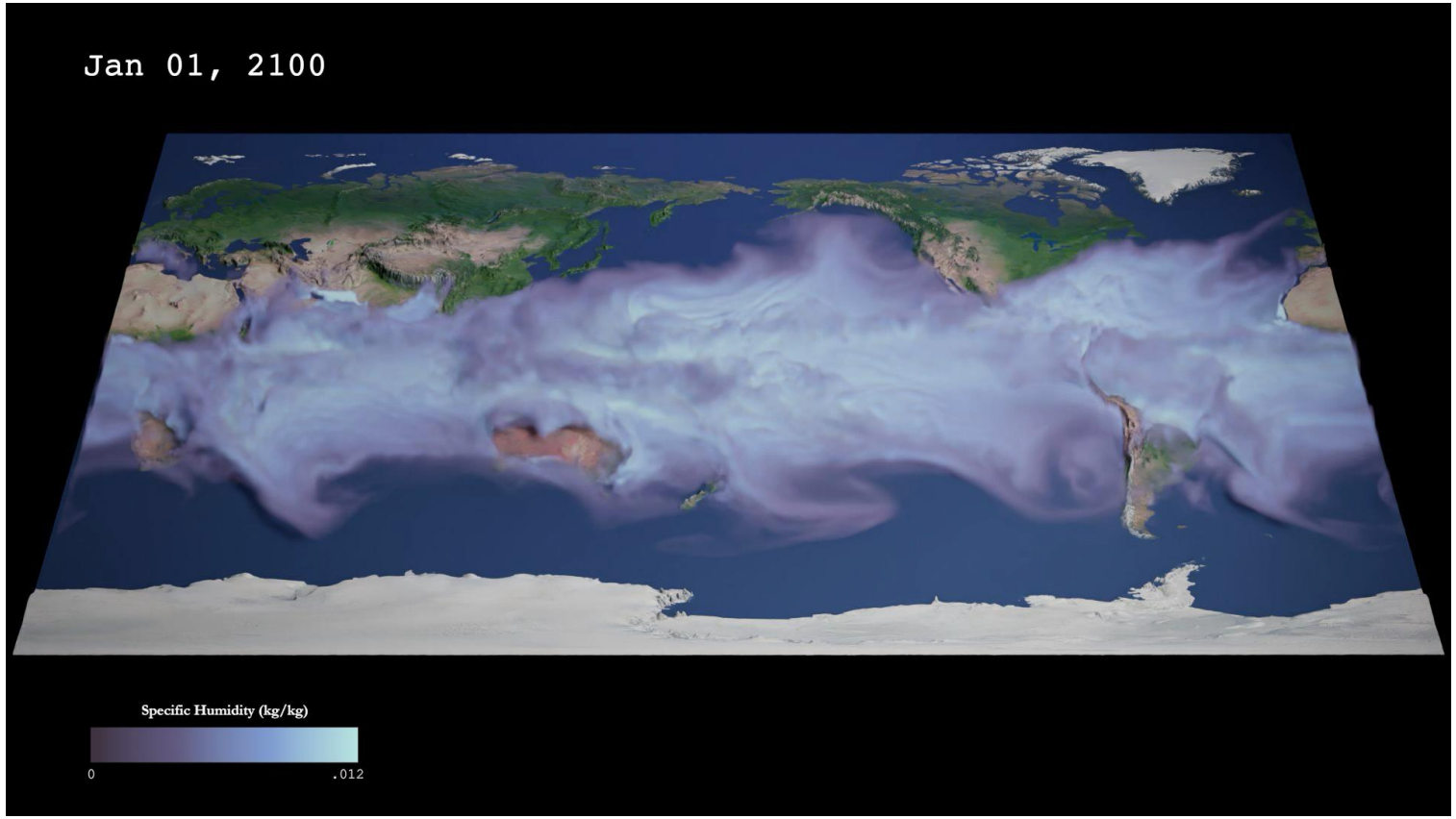
3-member 1950-2014 AMIP;

All HighResMIP coupled and AMIP;

5 cycles of 1958-2018 OMIP (w/ BGC);

Decadal Predictions (1980-2023; HRDP); and

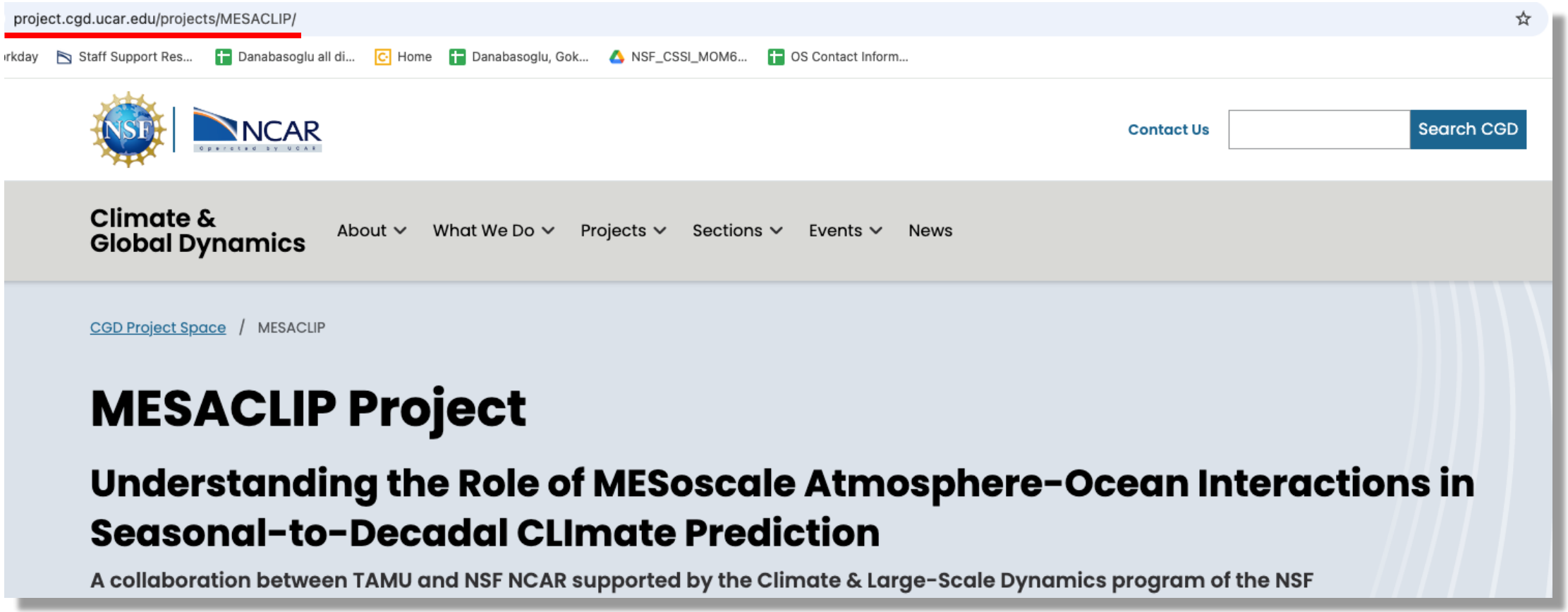
Corresponding low-res (~1º) simulations



Visualization Credit: Matt Rehme, Visualization Services and Research Group, NSF NCAR CISL

Chang et al. (2020, JAMES)

Datasets are available to the community.



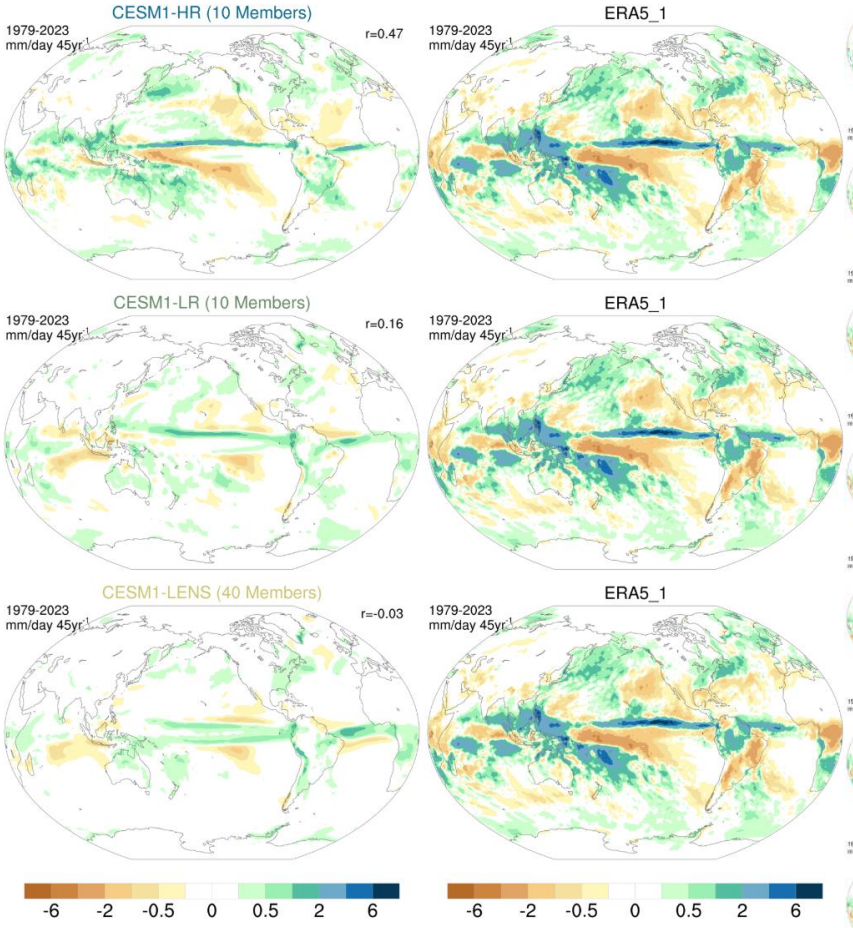
Data acquisition: The datasets are served to the community through the NSF NCAR Research Data Archive (RDA). Datasets archived on the RDA can be accessed within the CISL computing environment or downloaded over HTTP or Globus transfer for fast, secure, and reliable way to use elsewhere. A copy of the archive is stored in Campaign Storage and so is readily accessible by NCAR HPC system users and by individuals who have access to this system.

project.cgd.ucar.edu/projects/MESACLIP/CVDP/mesaclip_quadrmEM_1979-2023/index.

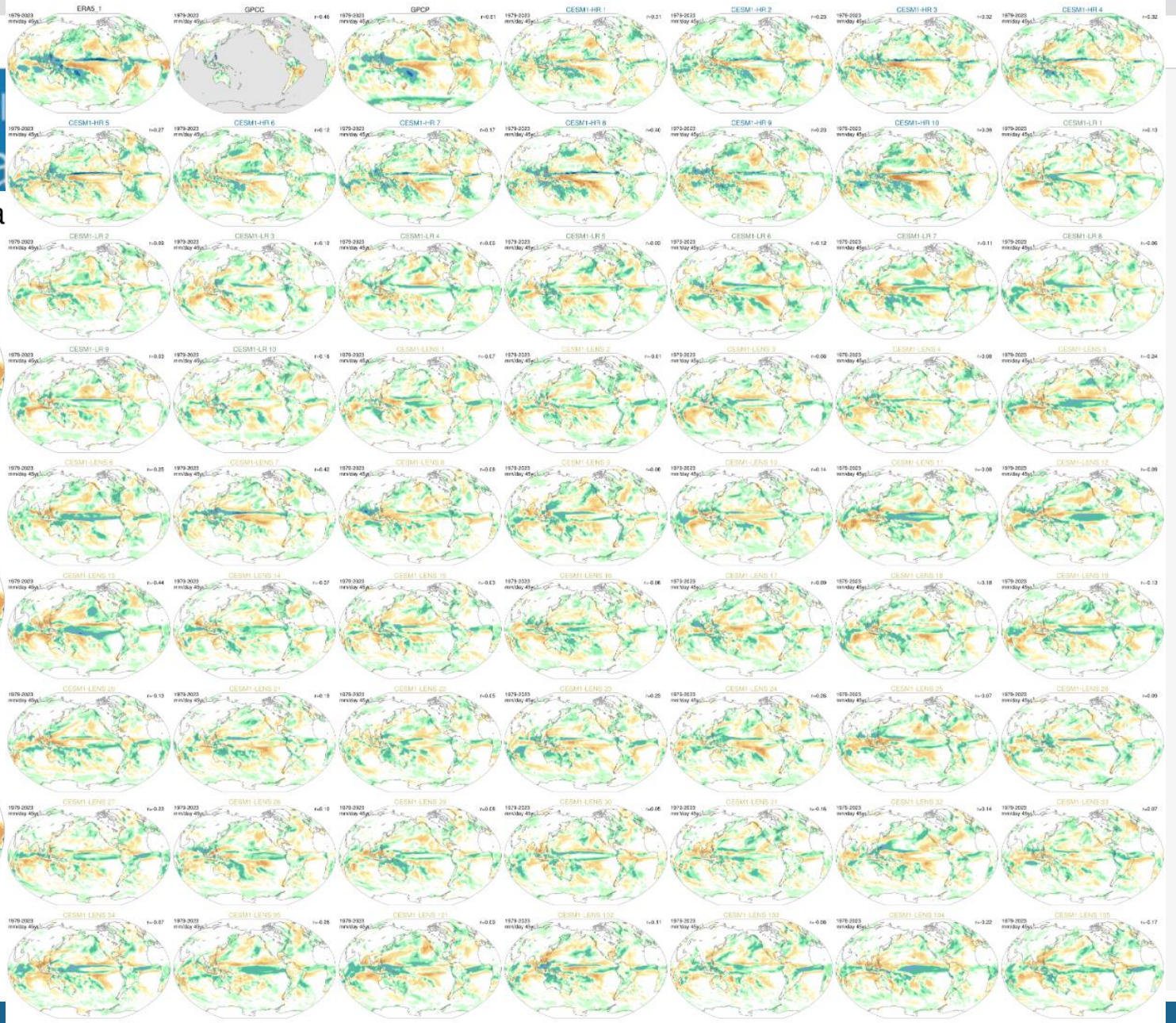
meso NCAR Library Proxy Workday

NCAR UCAR | CGD's Cl Clima

Ensemble Summa



PR Trends DJF



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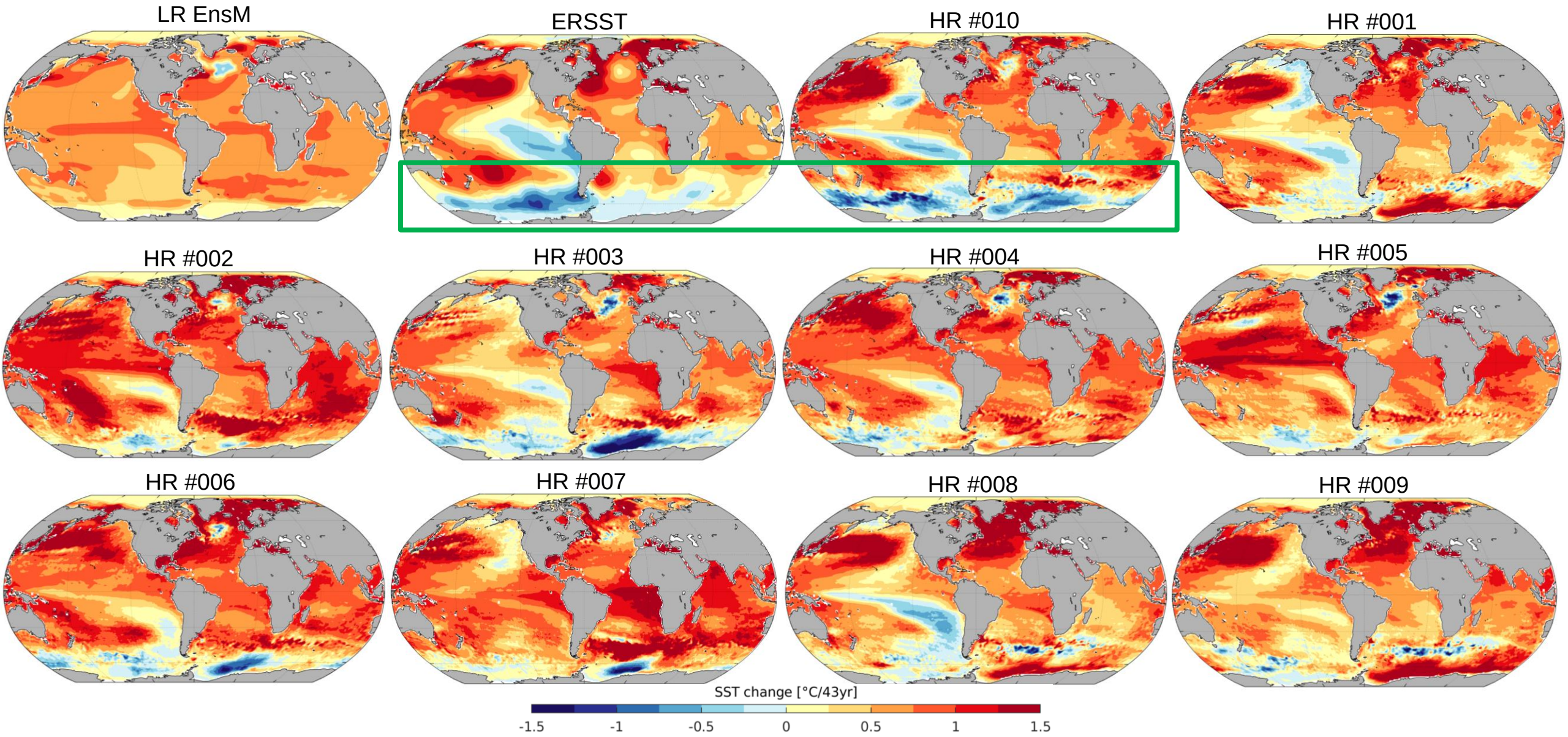
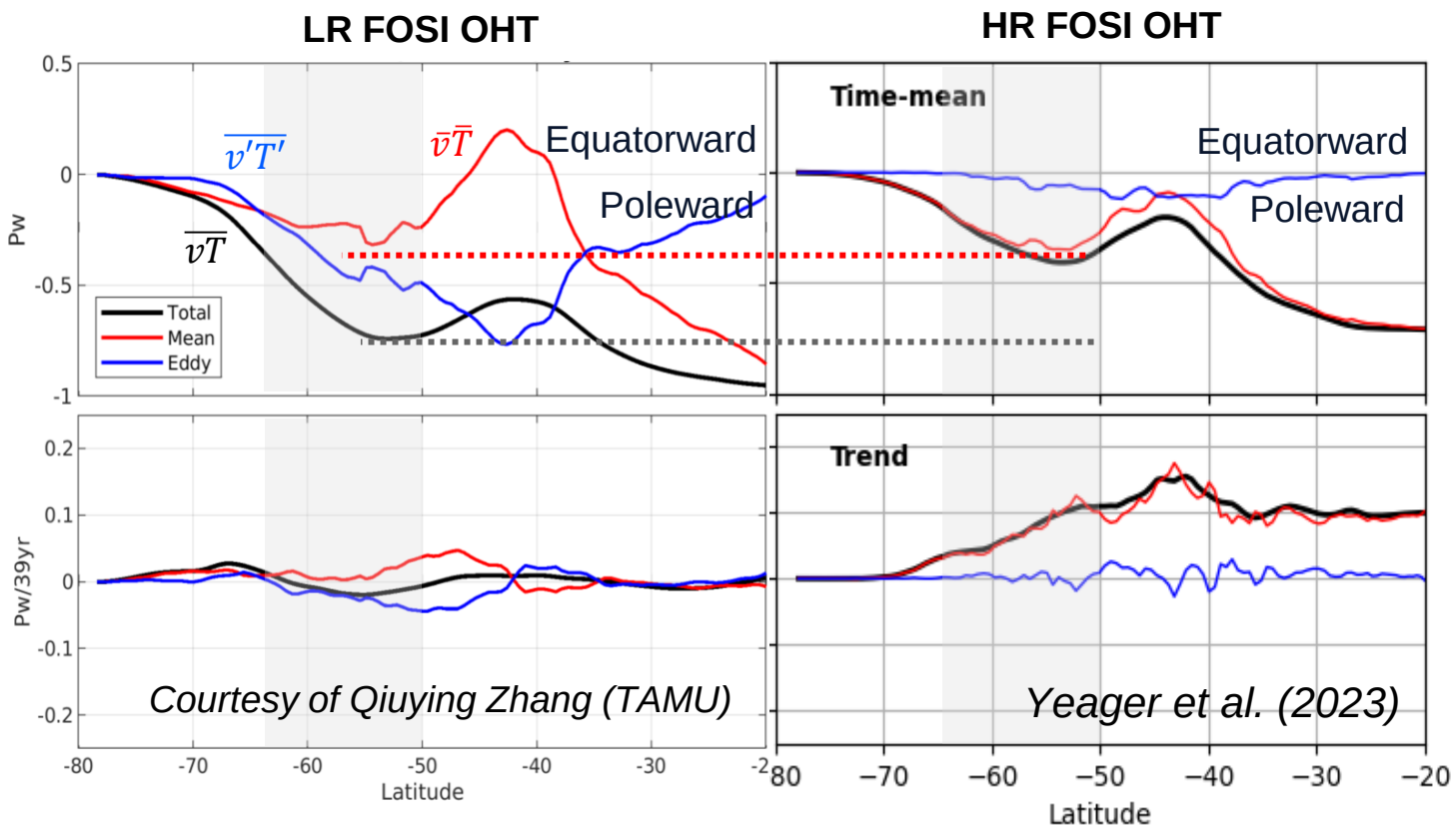
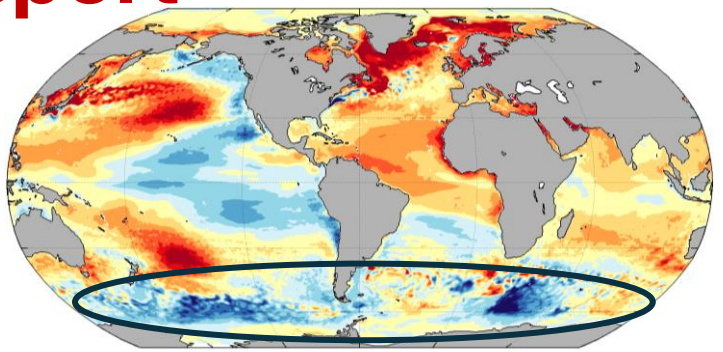
SST Linear Trend (1980-2022) in Each Ensemble Member



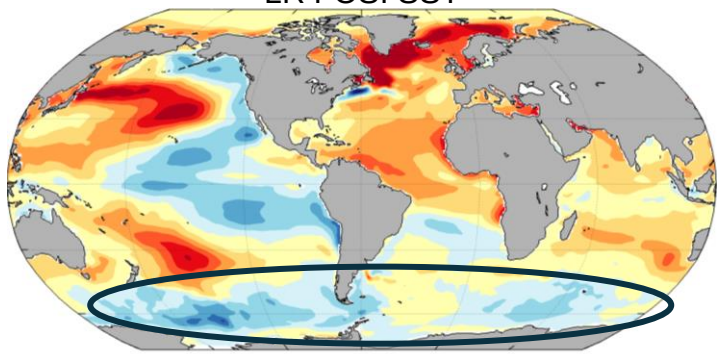
Meridional Ocean Heat Transport



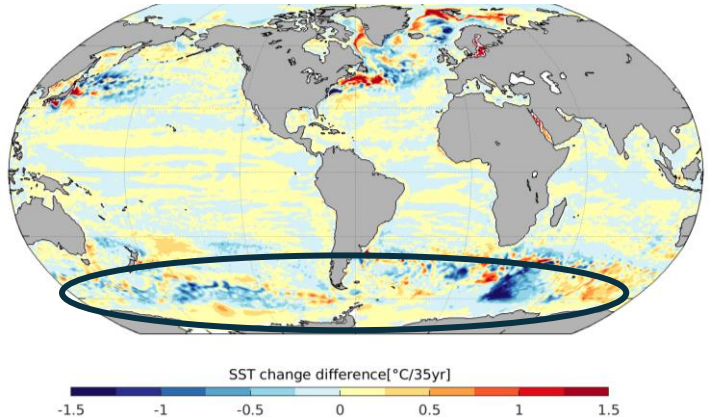
HR FOSI SST Trend



LR FOSI SST



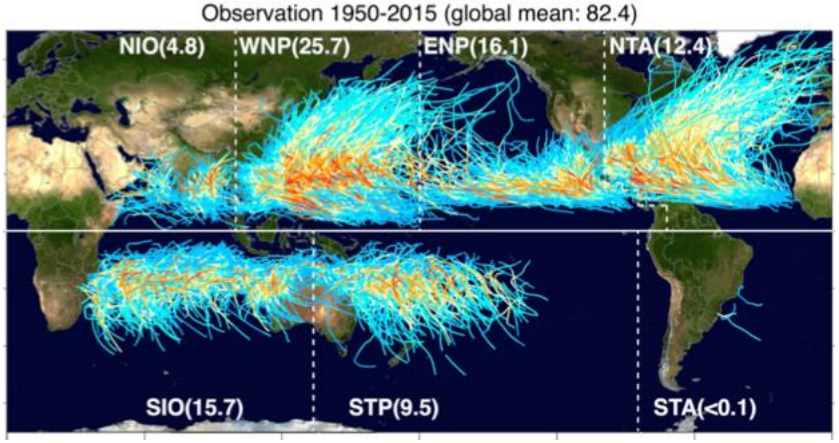
HR-LR FOSI SST



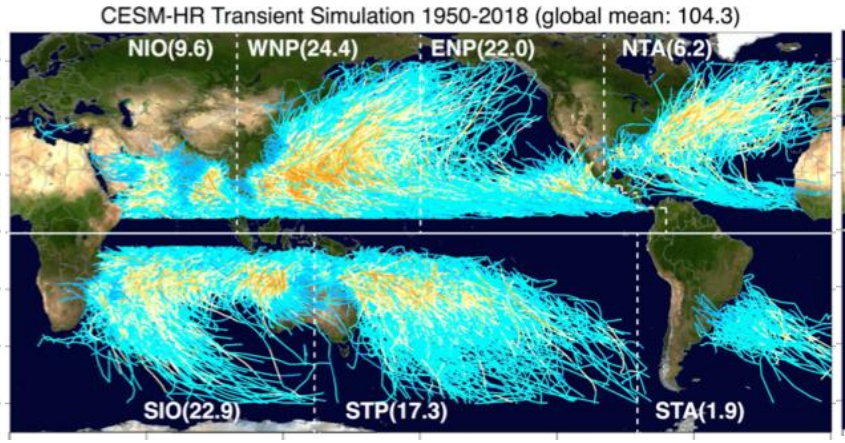
- HR transports less heat poleward than LR
- difference is primarily due to the difference in eddy heat transport
- HR also shows a much stronger positive trend in OHT

Tropical Cyclones (TCs)

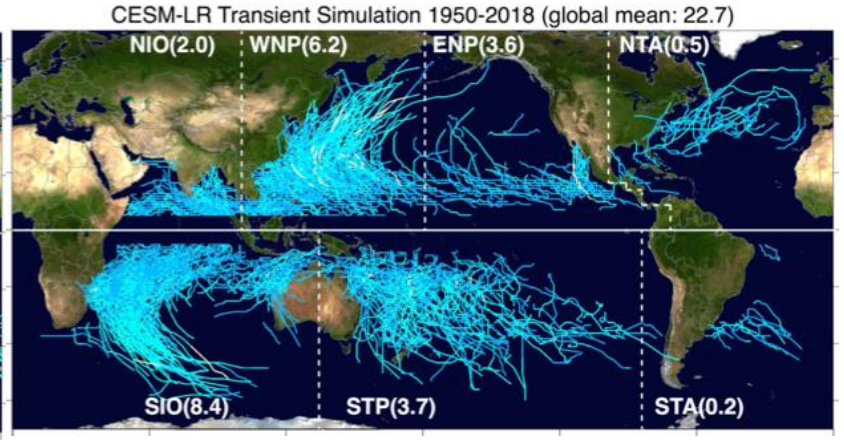
IBTrACS Observations



CESM HR

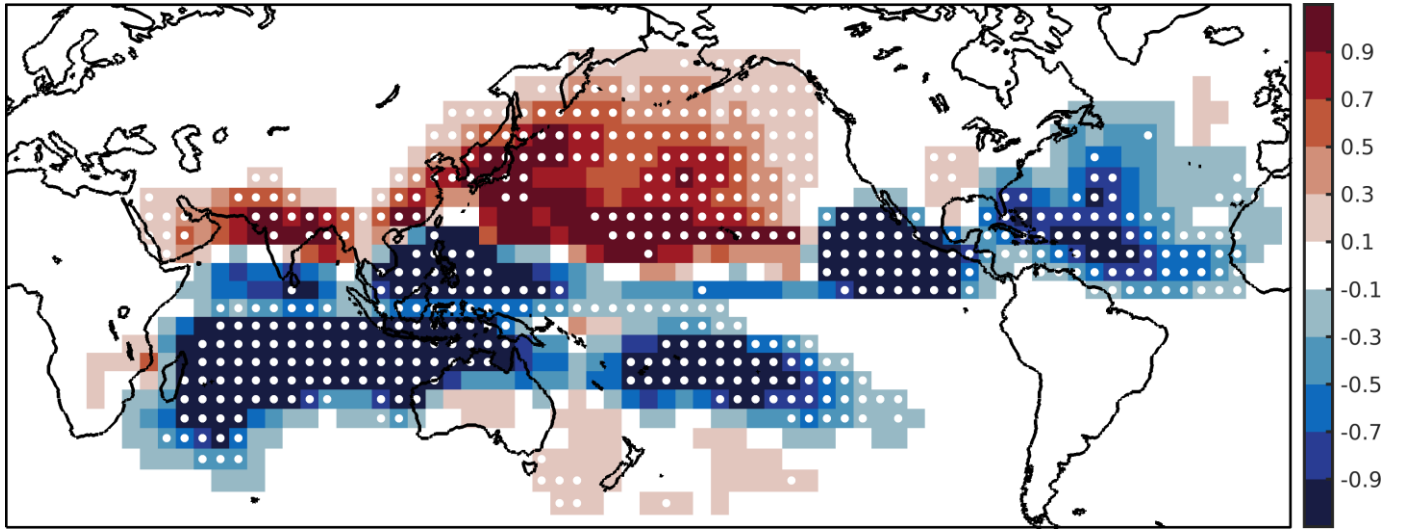


CESM LR



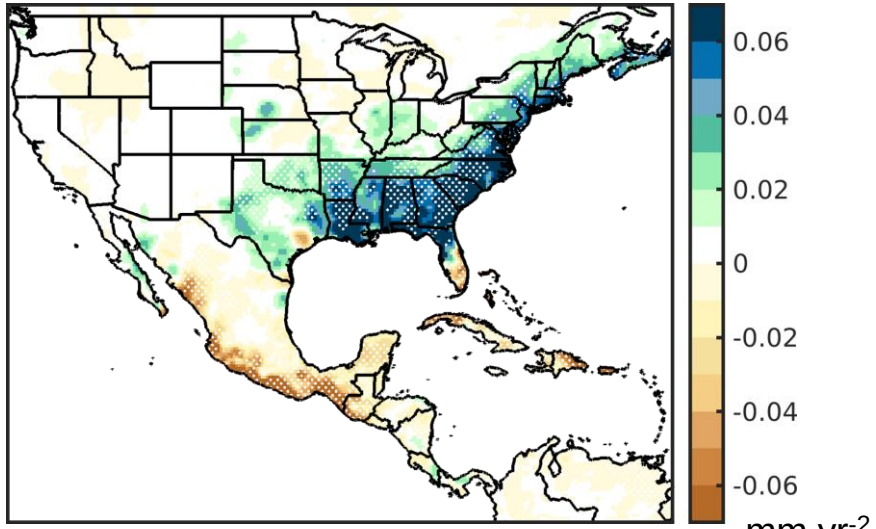
Chang et al. (2020, JAMES)

Change in TC Occurrence (2070-2100 minus 1950-1980)

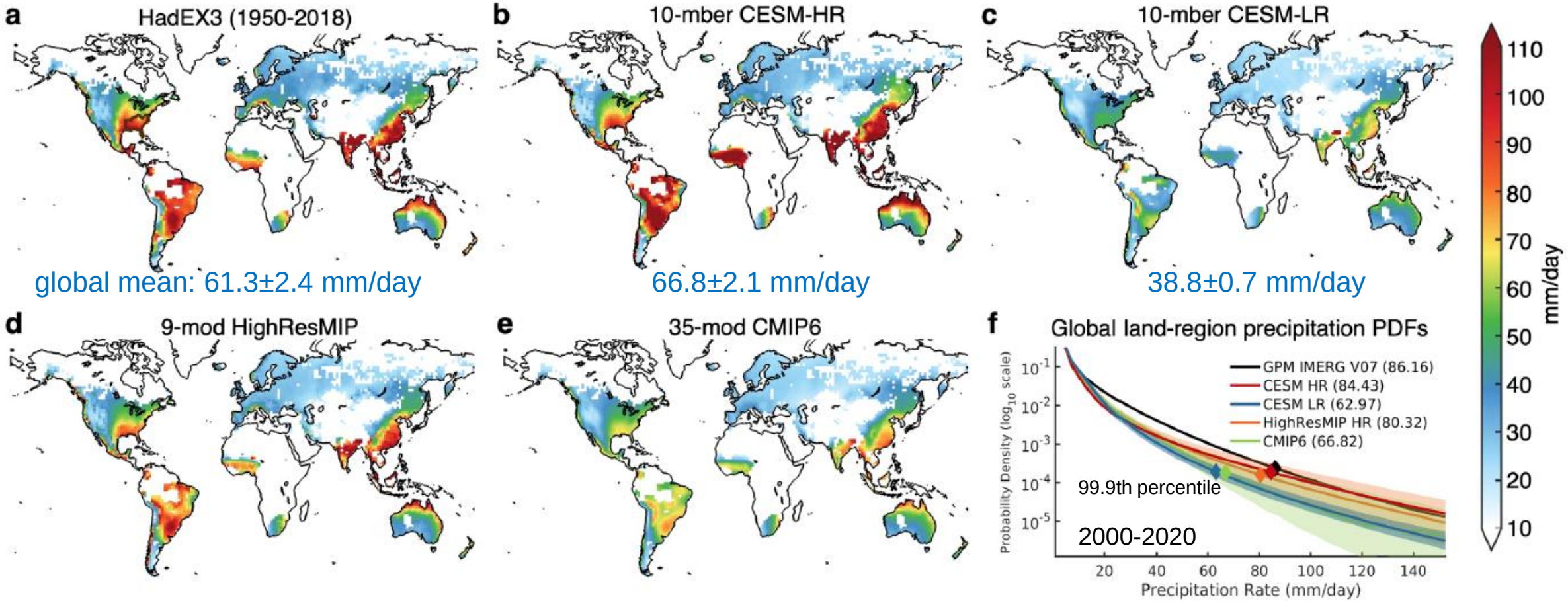


Fu et al. (2025, in preparation)

Trend of Annual-Mean TC-Induced Rainfall (1980-2100)

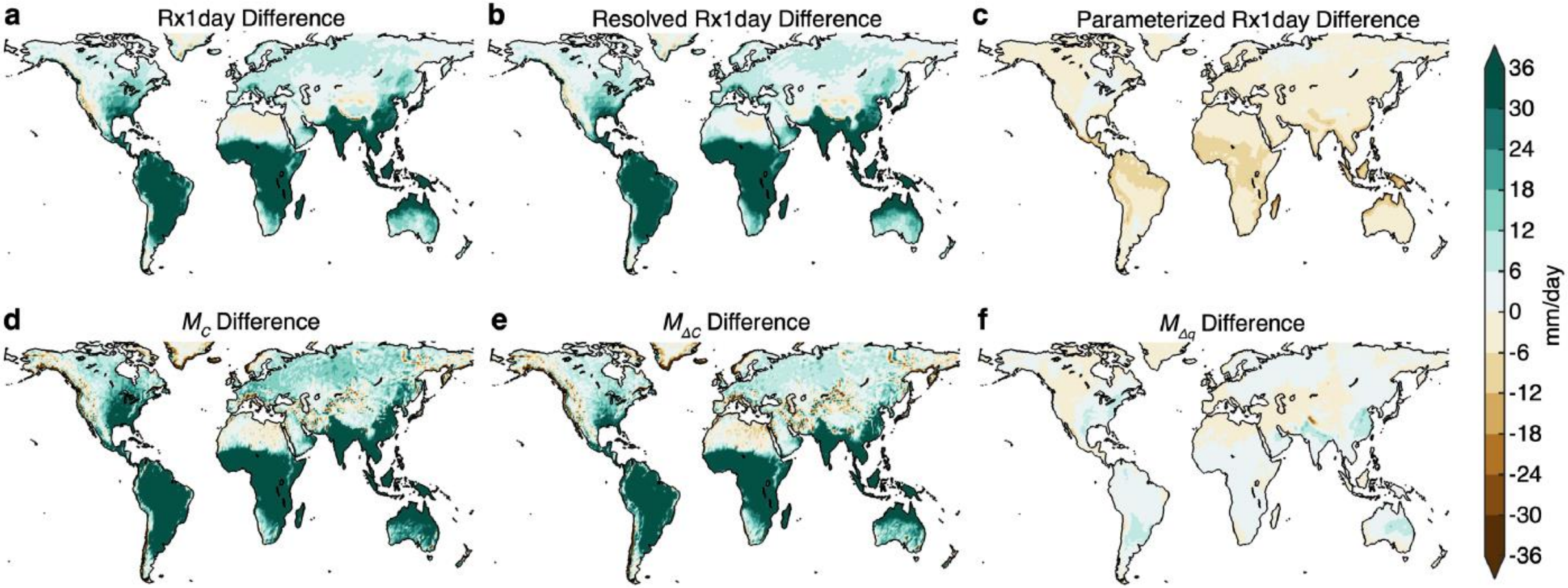


Observed and Simulated Annual Maximum Daily Precipitation (Rx1day)



Chang et al. (2025, PNAS, submitted)

Moisture Budget for Rx1day HR – LR Differences



Horizontal flow convergence

Dynamical tendency

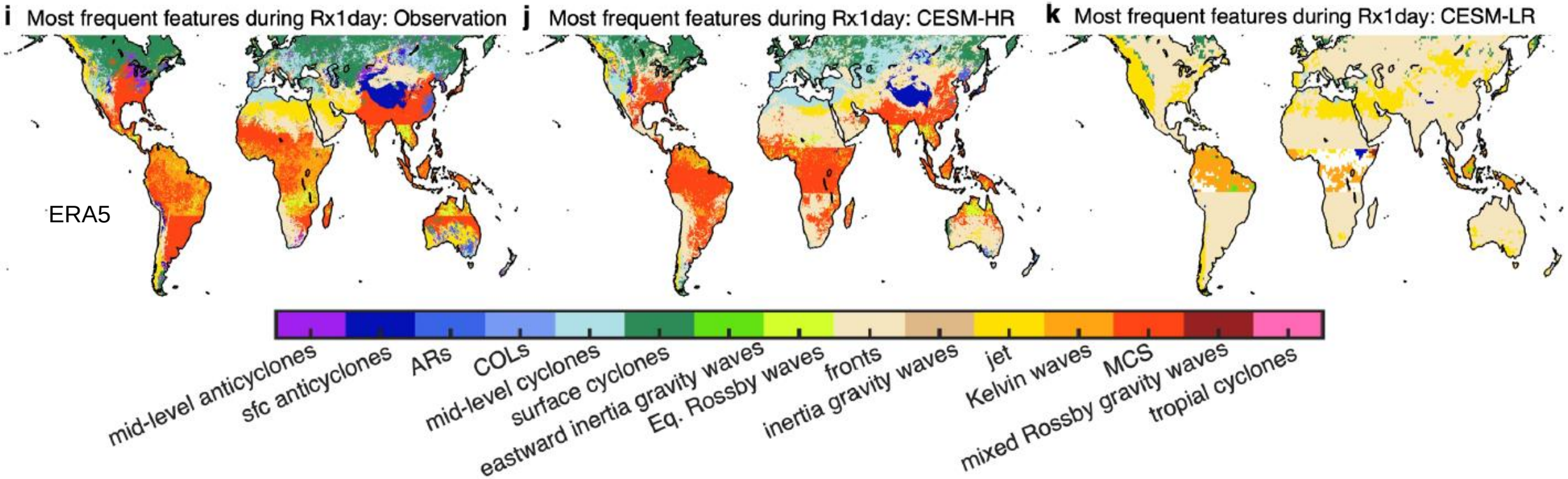
Thermodynamical tendency

Chang et al. (2025, PNAS, submitted)

Most frequently Occurring Atmospheric Phenomenon Driving Extreme Precipitation

Mesoscale Convective Systems (MCSs)

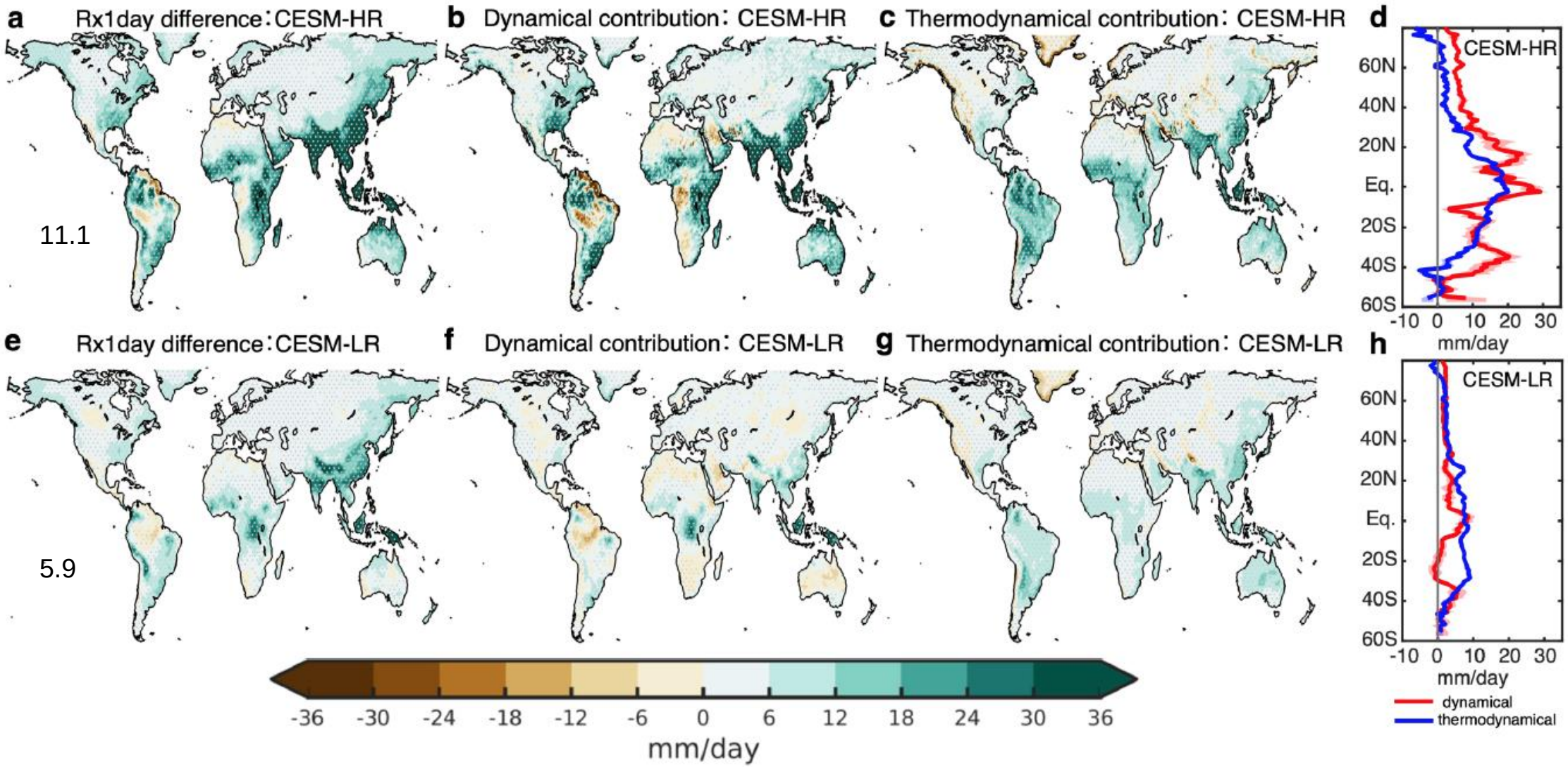
Jets & Fronts



Detected by the Multi Object Analysis of Atmospheric Phenomenon (MOAAP; Prein et al. 2023) algorithm during Rx1day events over global land

Chang et al. (2025, PNAS, submitted)

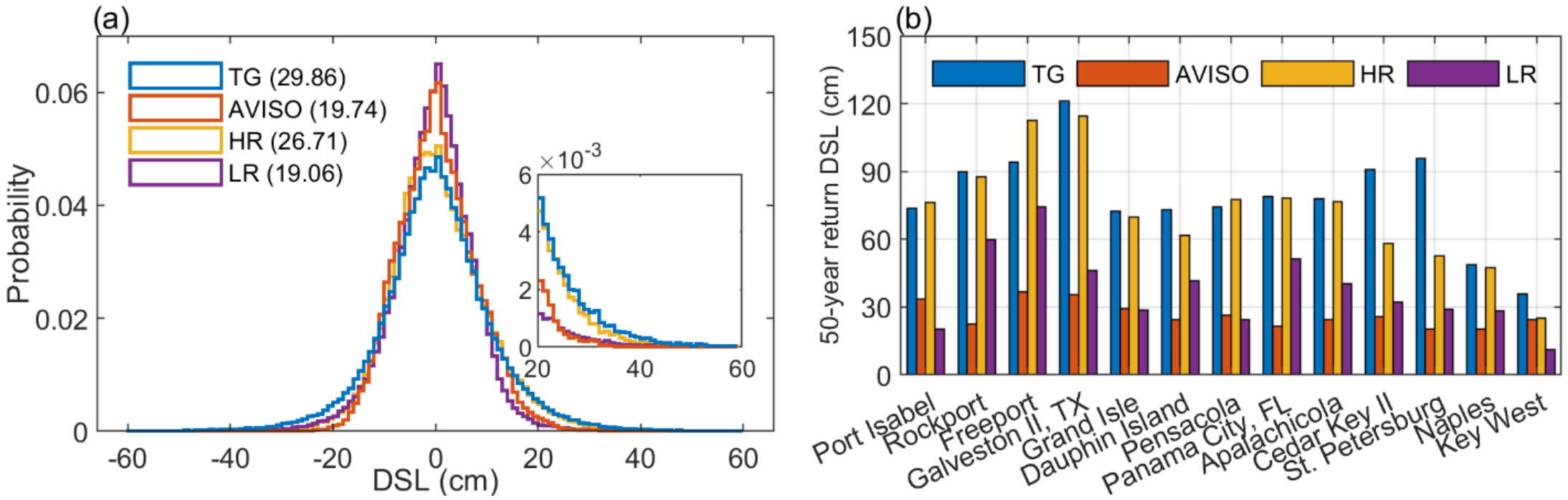
Projected Rx1day Changes and Their Drivers



Chang et al. (2025, PNAS, submitted)

(2071-2100) – (1981-2010)

Daily mean Sea Level Extremes in the Gulf of Mexico



- CESM-HR more realistically simulate daily mean extreme sea levels in the Gulf of Mexico compared to CESM-LR

Xu et al. (2025, GRL, submitted)

Summary

- A large volume of datasets have been made available
- HRDP expansion simulations are ongoing
- Analysis of simulations are continuing, e.g., Southern Ocean trends, AMOC-related aspects, TCs, extreme sea levels, ….
- CESM-HR shows many improvements over CESM-LR
- But it is not the panacea (e.g. ENSO, summer precipitations)
- While unable to explicitly resolve clouds and deep convection, HR simulations markedly outperform standard LR simulations, more accurately replicate observed extreme precipitation statistics by improving representation of mesoscale phenomena, such as MCSs, and the multi-scale interactions essential for capturing extreme events

Thank you!