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

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NCAR

Ocean Model Working Group Meeting

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MESACLIP

A collaboration between TAMU and NSF NCAR supported by the Climate & Large-Scale Dynamics program of the NSF

Overall objective:

- advance our knowledge and understanding of the multi-scale dynamical processes underlying S2D predictability and the benefits of increased model resolutions

Project deliverables:

- an ensemble of 10 high-resolution CESM (CESM-HR) historical and future (1920-2100) simulations
- a biannually initialized CESM-HR S2D prediction ensemble
- a set of process-level CESM-HR simulations including SST-filtered CESM-HR simulations and others

CESM-HR vs CESM-LR

Model Version:

based on an earlier version of CESM1.3 (Meehl et al., 2019) with many additional modifications and improvements, including the usage of the global eddy-resolving ocean model of Small et al. (2014).

Resolutions:

- **CESM-HR**:
  Horizontal resolution of 0.25° (~25 km) for the atmosphere and land models, and nominal 0.1° (~10 km at the Equator down to ~4 km at high latitudes) for the ocean and sea-ice models.

- **CESM-LR**:
  Horizontal resolution of ~1° (~100 km) in all components.

MESACLIP: CESM-HR simulation status

- **10 CESM-HR historical and future (1920-2100) simulations**
  => 9 out 10 members completed

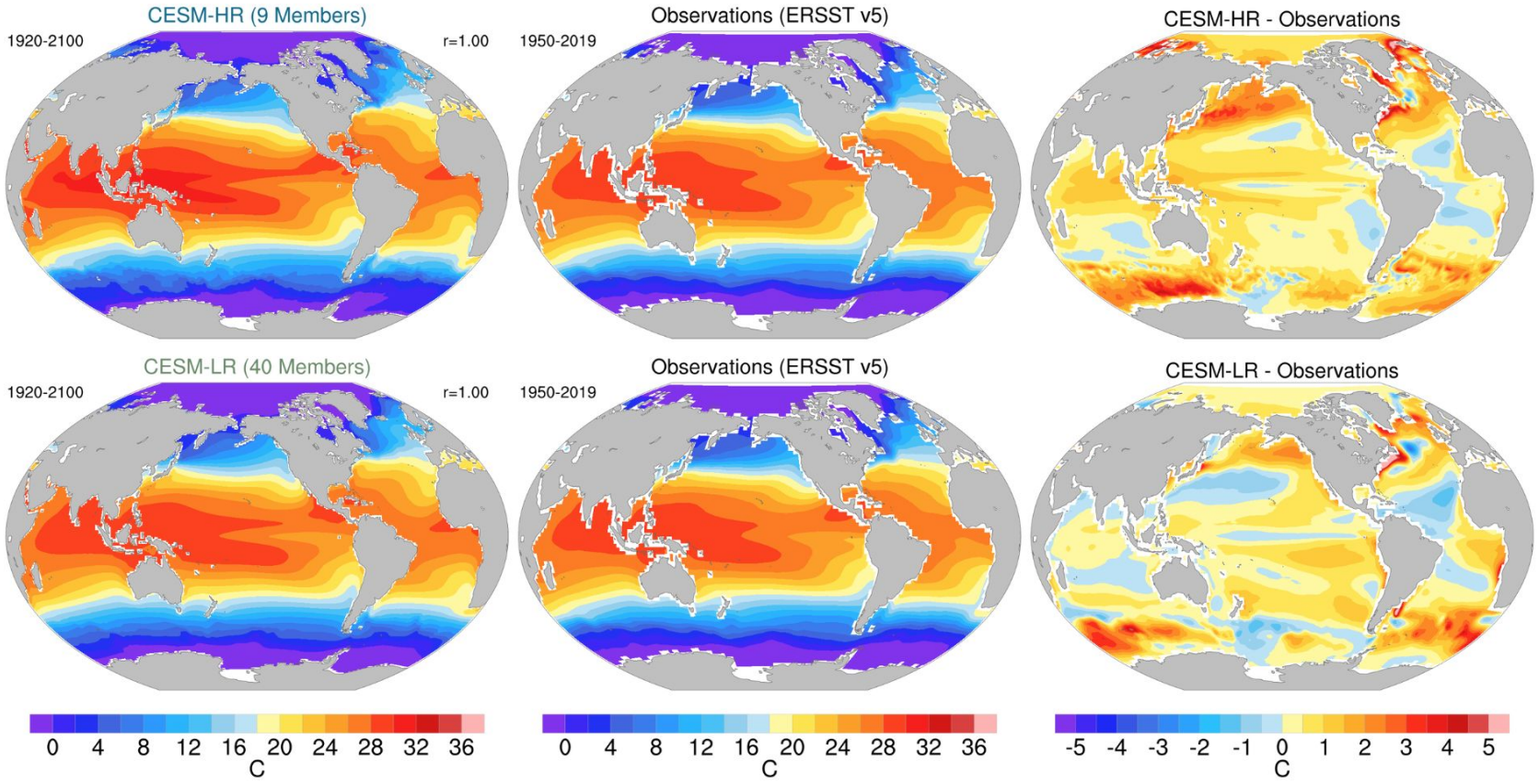
- **initialized CESM-HR S2D prediction ensemble**
  => 1976 to 2018 Nov 1st every other year completed (Yeager et al. 2023)

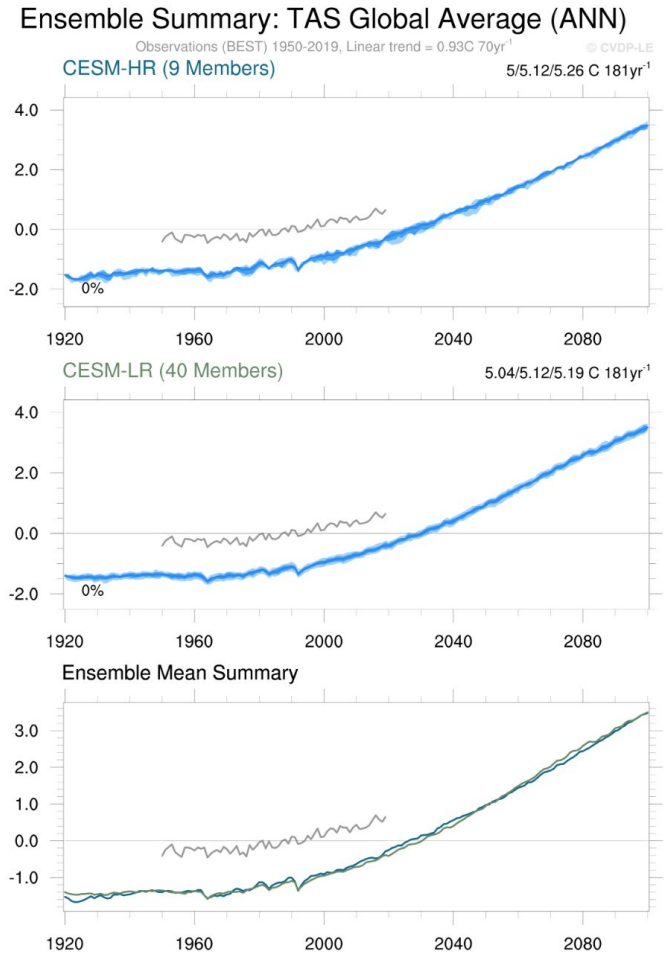
- **CESM-HR Ozone withholding experiment (1970–2020 simulation)**
  => 3 members completed

All the dataset will be will be made available to the community following the CESM Data Management & Distribution Plan.

Check our website for more details:
https://project.cgd.ucar.edu/projects/MESACLIP/

CESM-HR vs CESM-LR

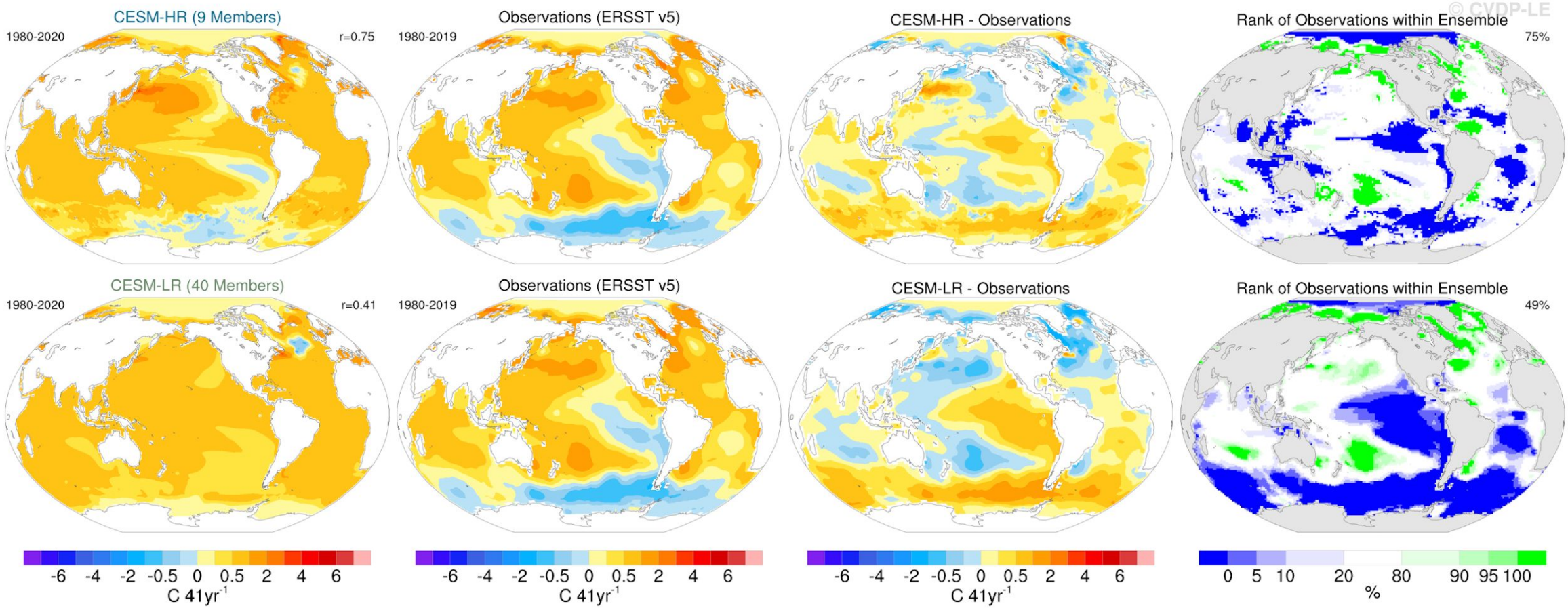




- Projected long term warming is similar between CESM-HR and CESM-LR

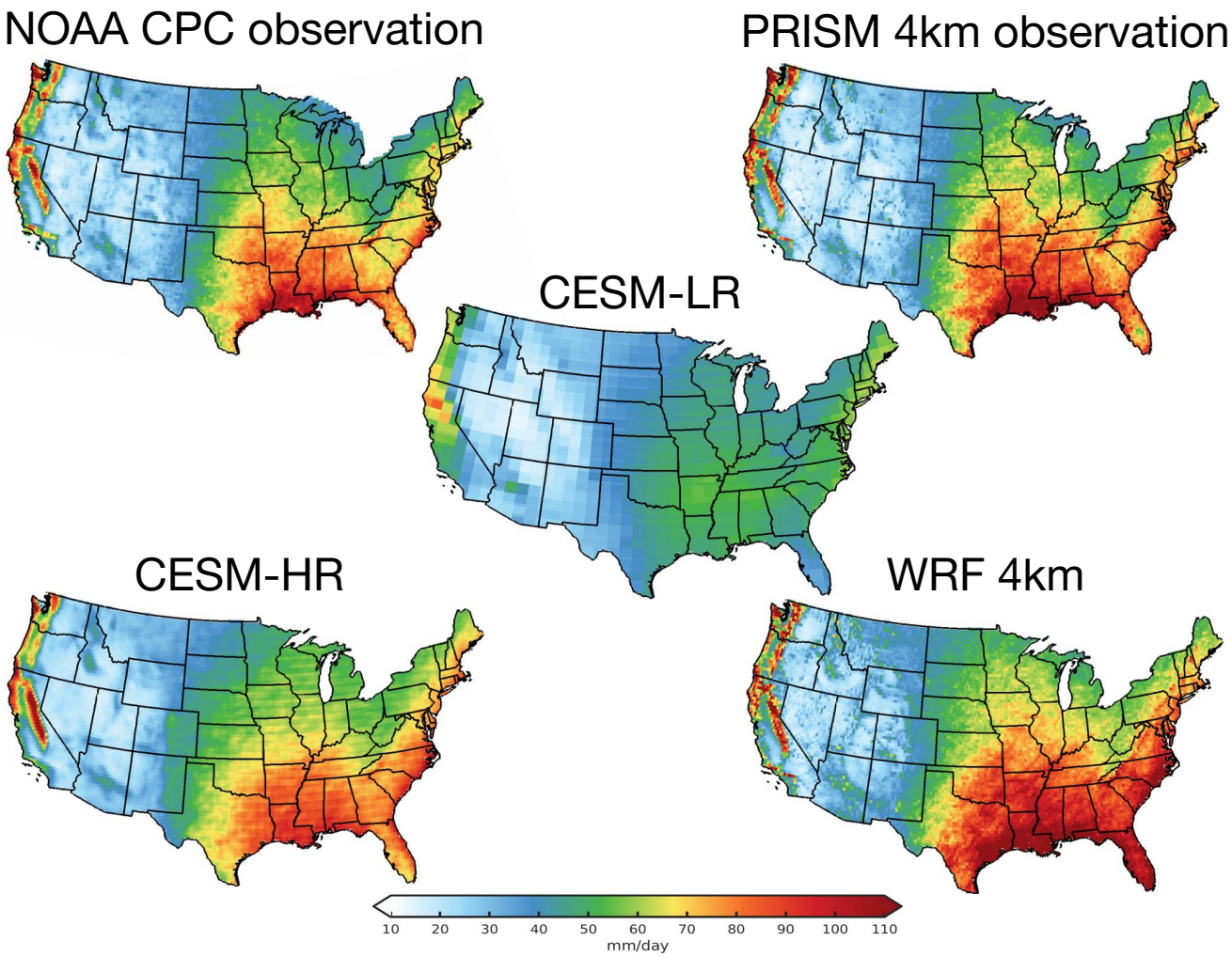
CESM-HR vs CESM-LR

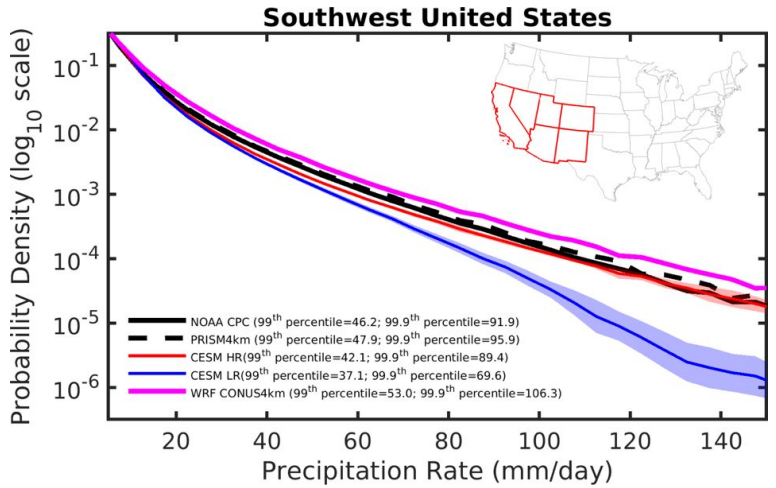
Ensemble Summary: SST Trends (ANN)

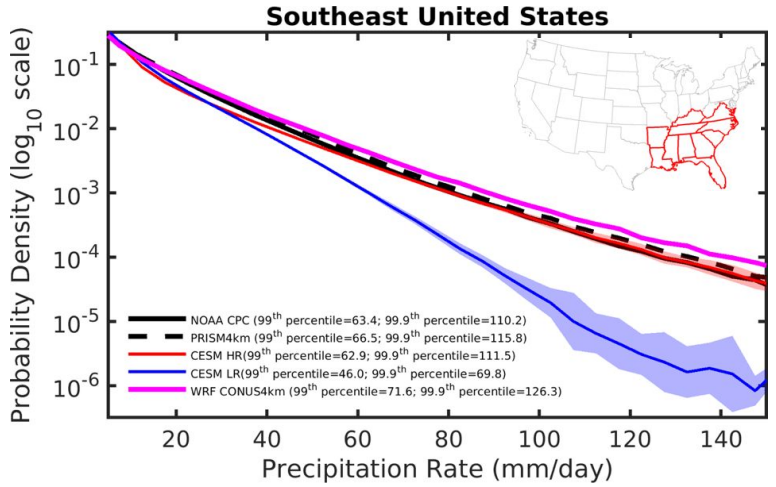


- But trend on shorter period are significantly different between the HR and LR ensemble

1981-2020 Rx1Day Precipitation over CONUS







- Vast improvements in simulated extremes in CESM-HR

Courtesy of Dan Fu (TAMU)

PCAST report and CESM-HR

PCAST: President's Council of Advisors on Science and Technology

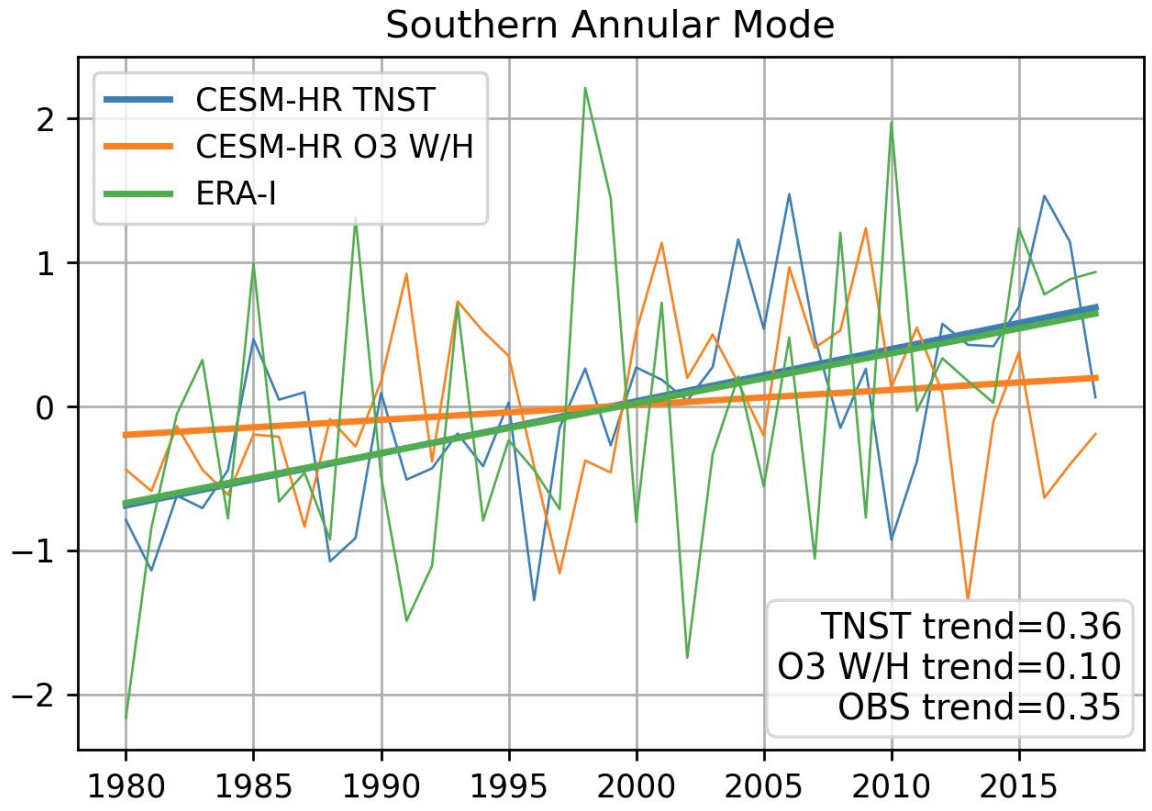
PCAST report on Extreme Weather Risk in a Changing Climate (April 2023):

- Recognized risk associated with the worsening of extreme weather due to climate change
- Recognized that high-resolution simulations, in the range of 10–25 km, would capture extreme events more accurately
- Recommends that ensembles of climate simulations at 10–25 km resolution spanning the 20th century and extending through 2050 are carried out by various modeling centers

NSF NCAR is able to meet key aspects of the PCAST report recommendations by providing a subset of output from CESM-HR 10-member ensemble

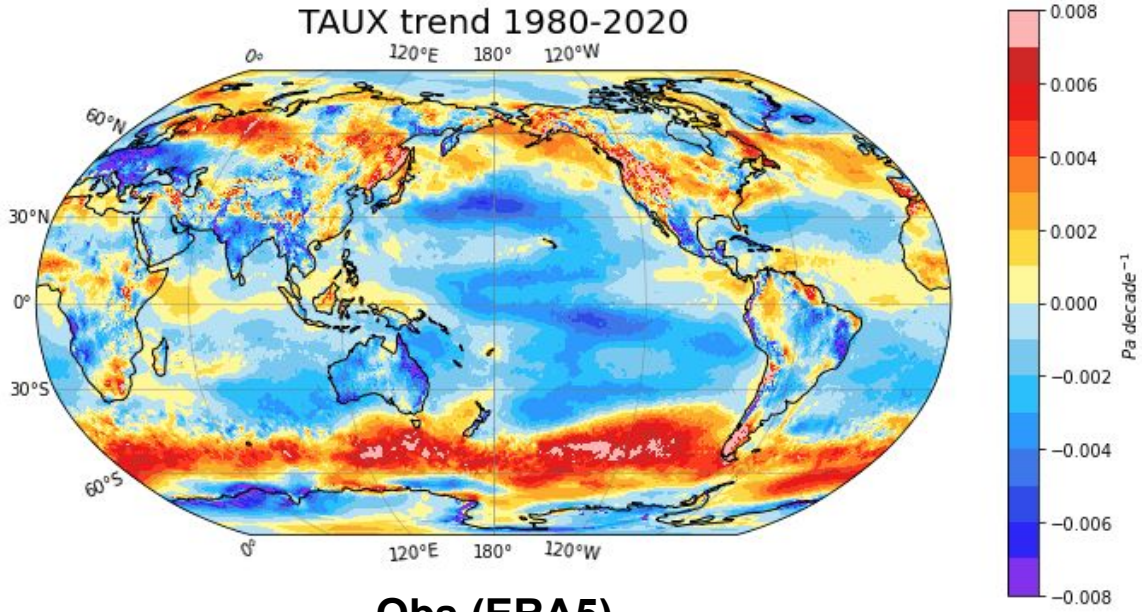
Ozone withholding experiment

- Southern Ocean (SO) has experienced substantial cooling in recent decades
- SO SST trend are poorly simulated by CMIP5 and CMIP6 climate models
- CESM-HR ensemble shows realistic SO cooling trend
- Previous studies have proposed that observed SO cooling is caused by the strengthening of surface westerlies associated with a positive trend of the SAM forced by ozone depletion



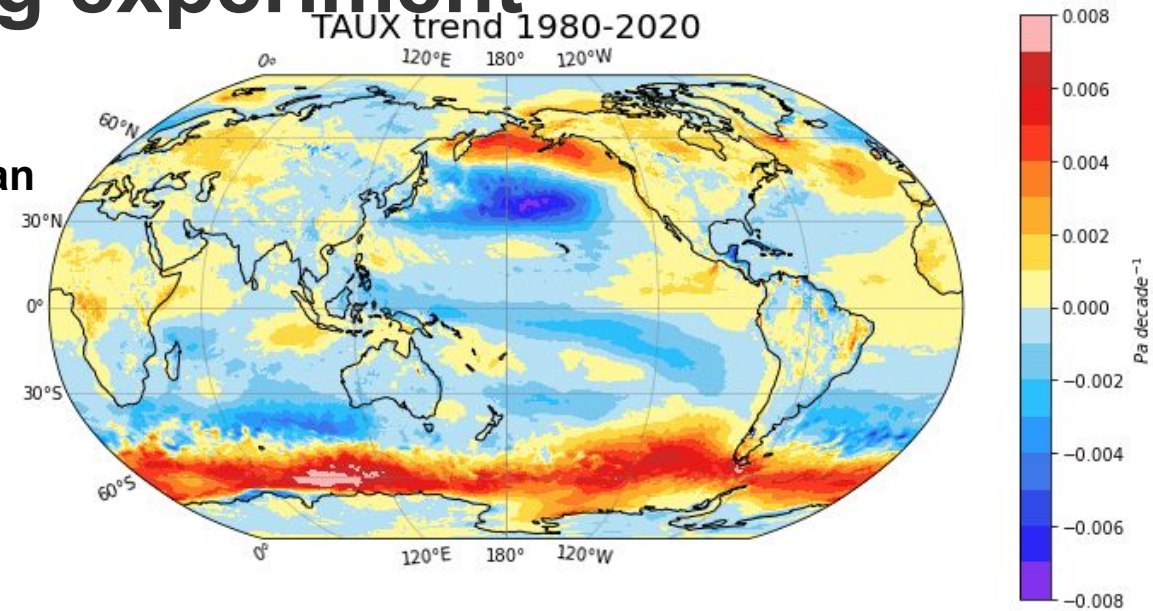
- A 3-member ozone withholding CESM-HR ensemble (1970-2020) has been performed in order to test this hypothesis. Ozone is fixed at pre 1970 level.

Ozone withholding experiment

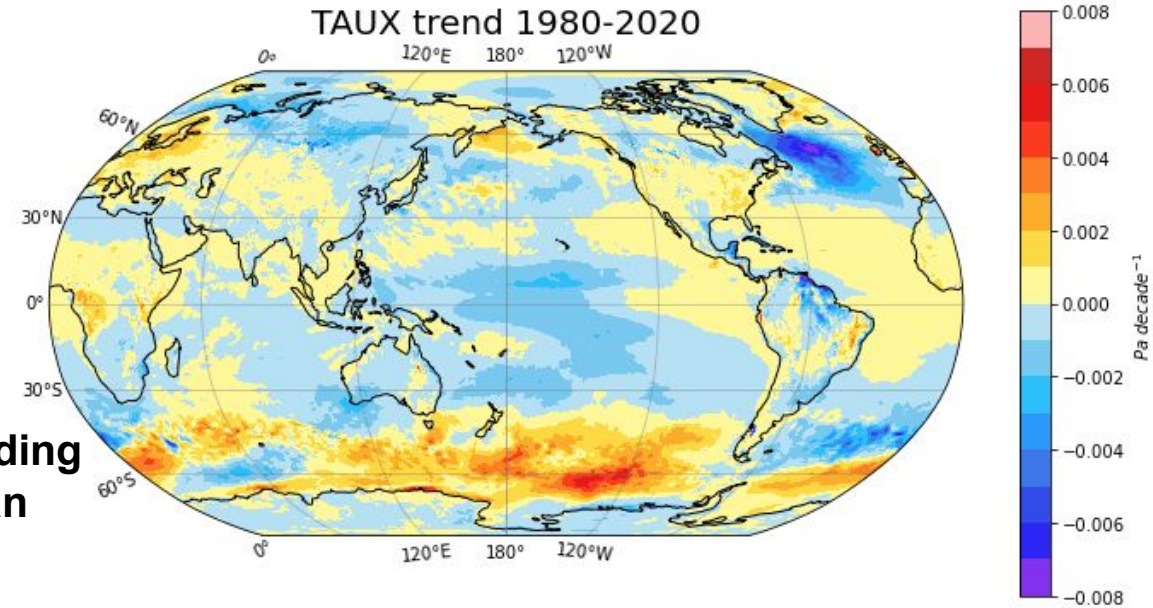


Obs (ERA5)

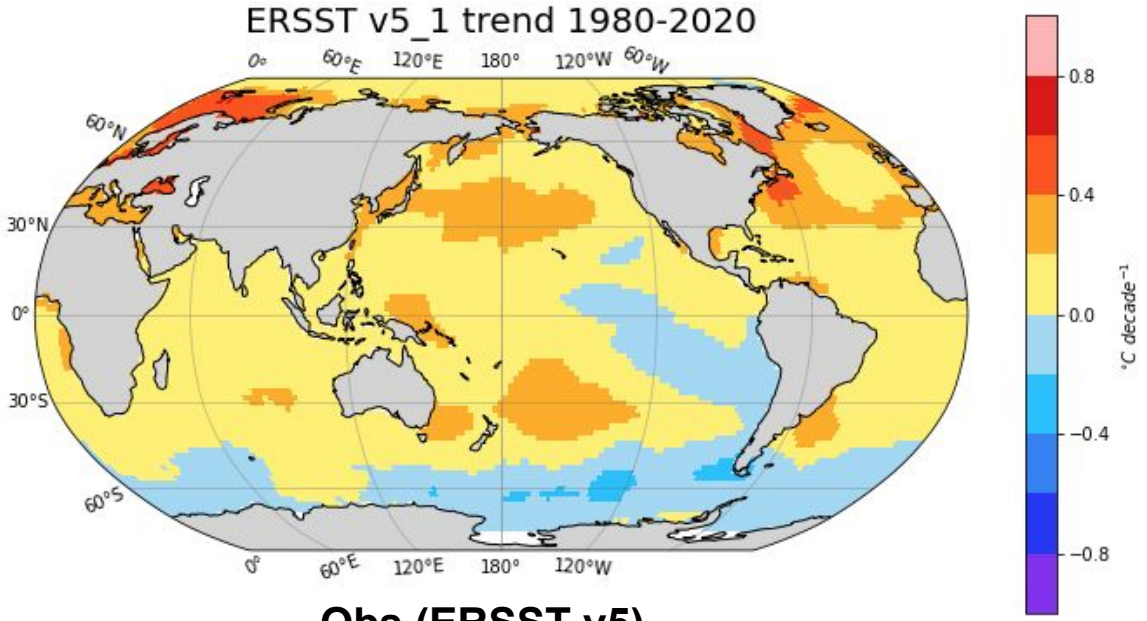
HF-TNST
3-member mean



Ozone withholding
3-member mean

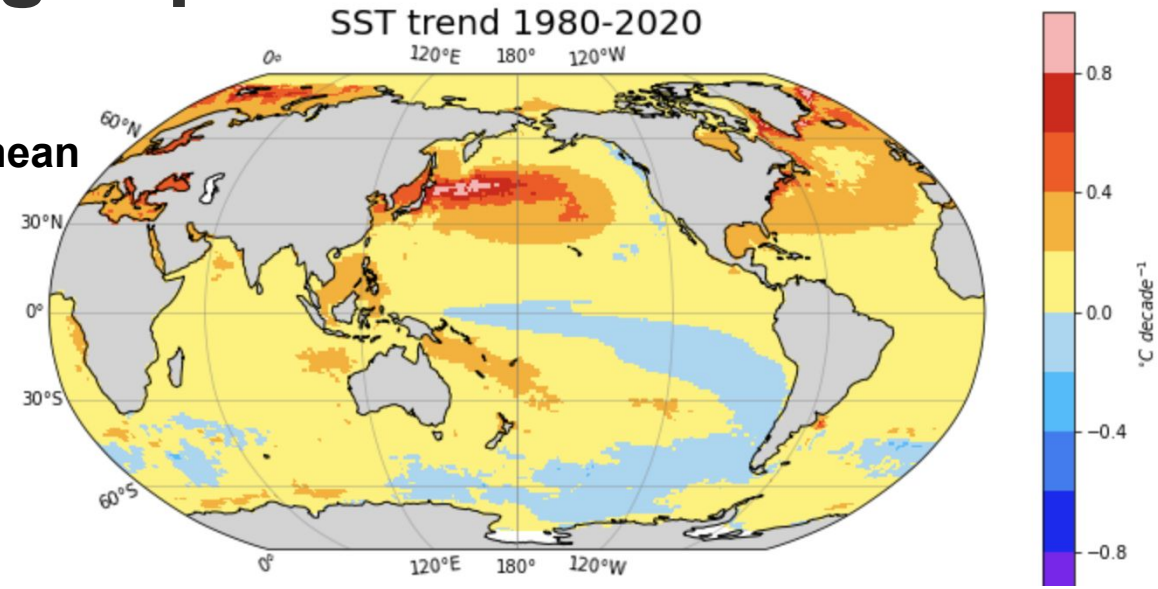


Ozone withholding experiment

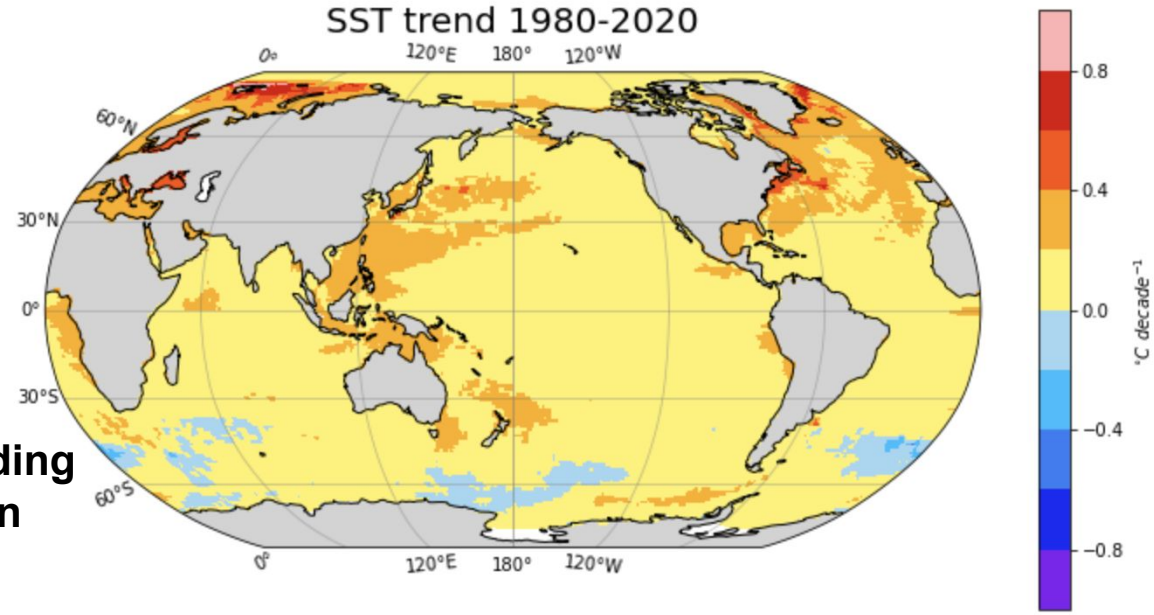


Obs (ERSST v5)

HF-TNST
3-member mean

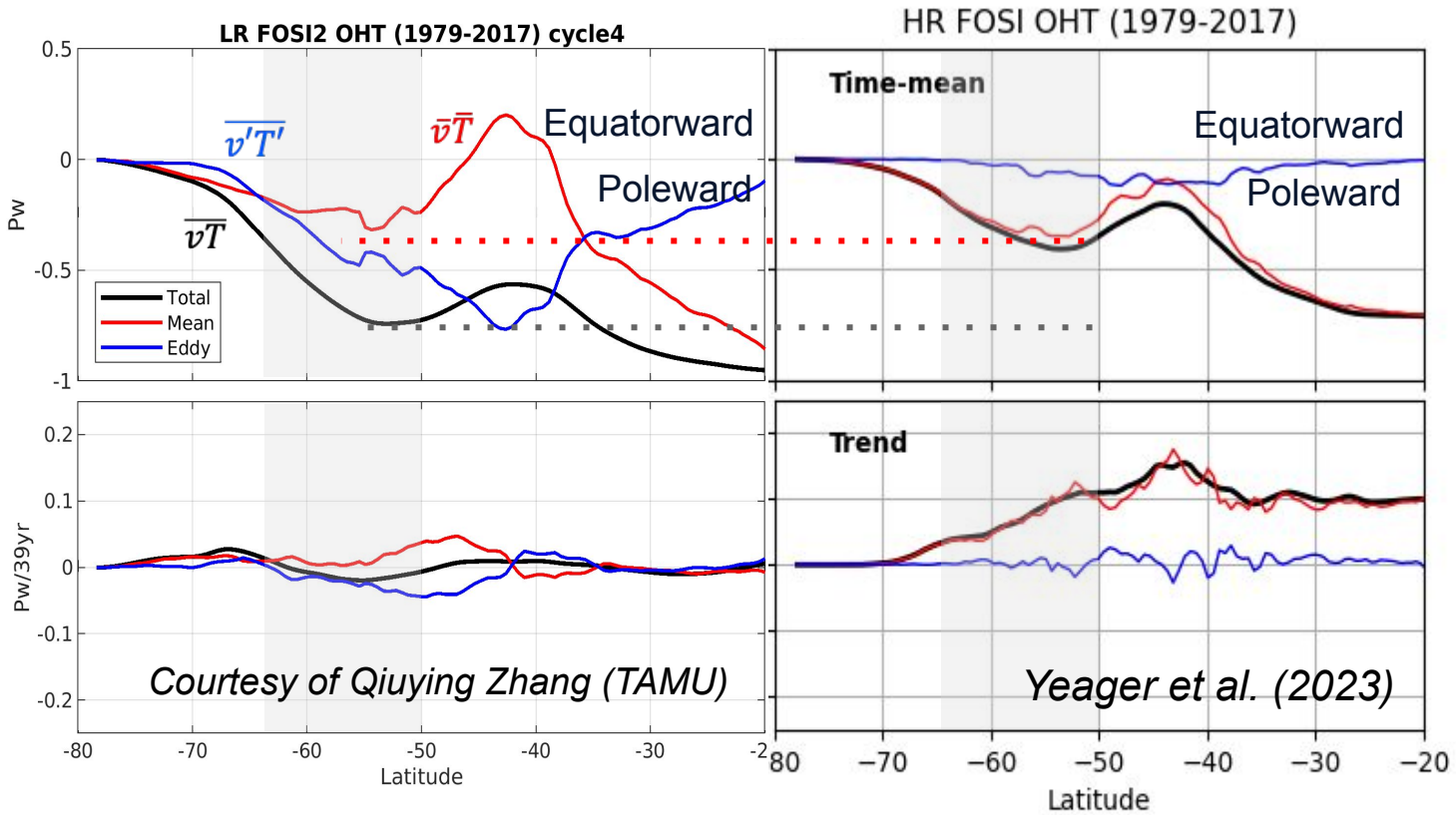


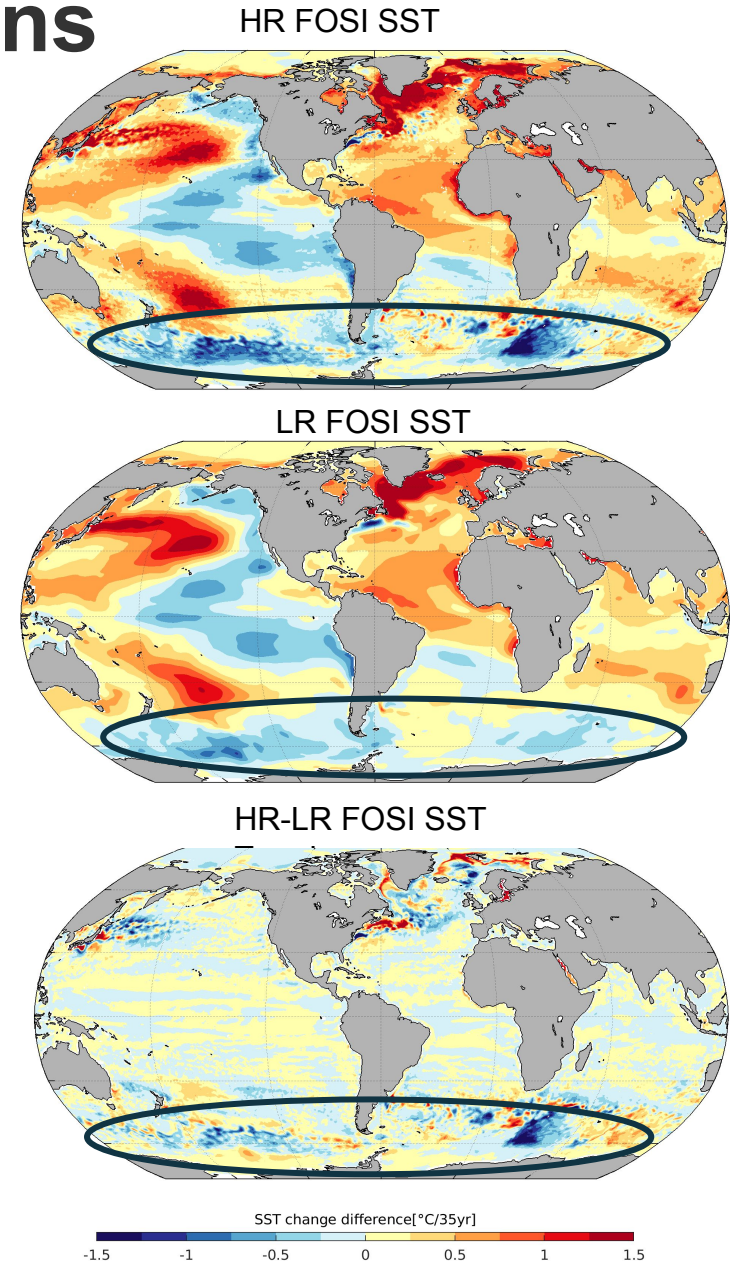
Ozone withholding
3-member mean



HR and LR FOSI Simulations

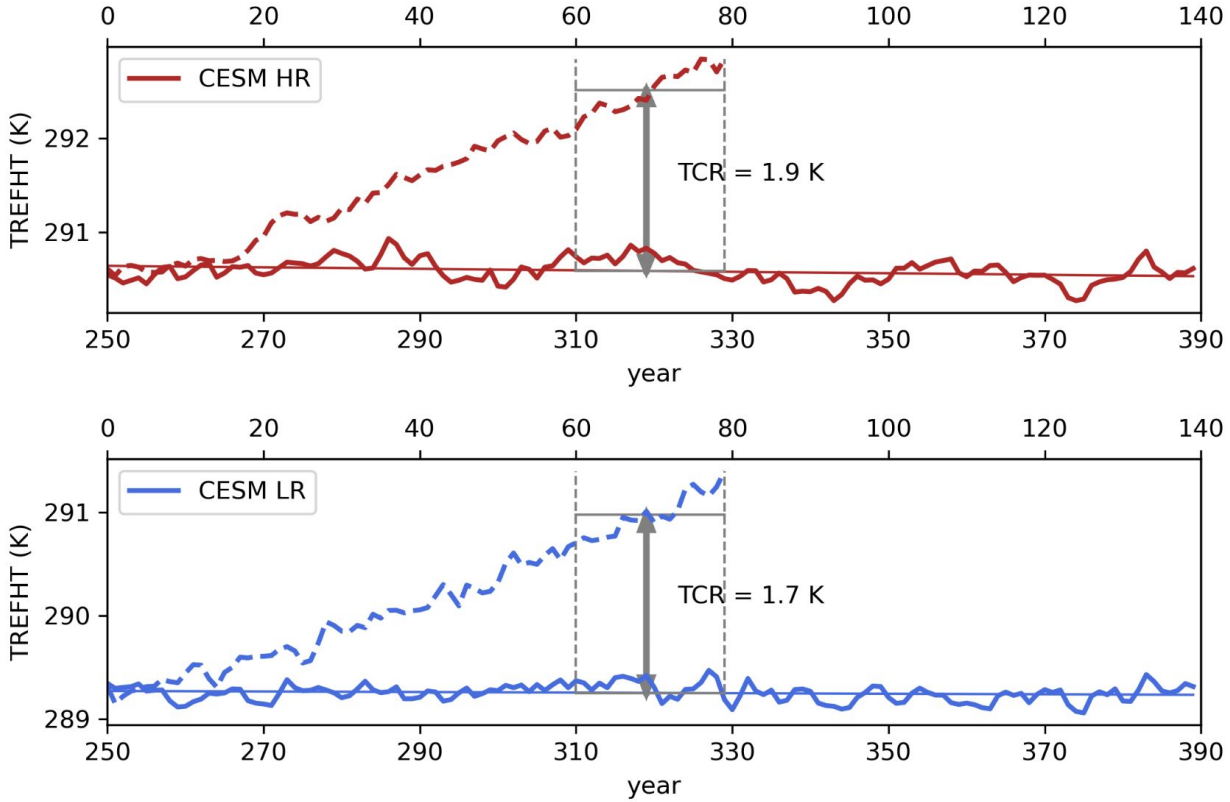
Meridional Ocean Heat Transport

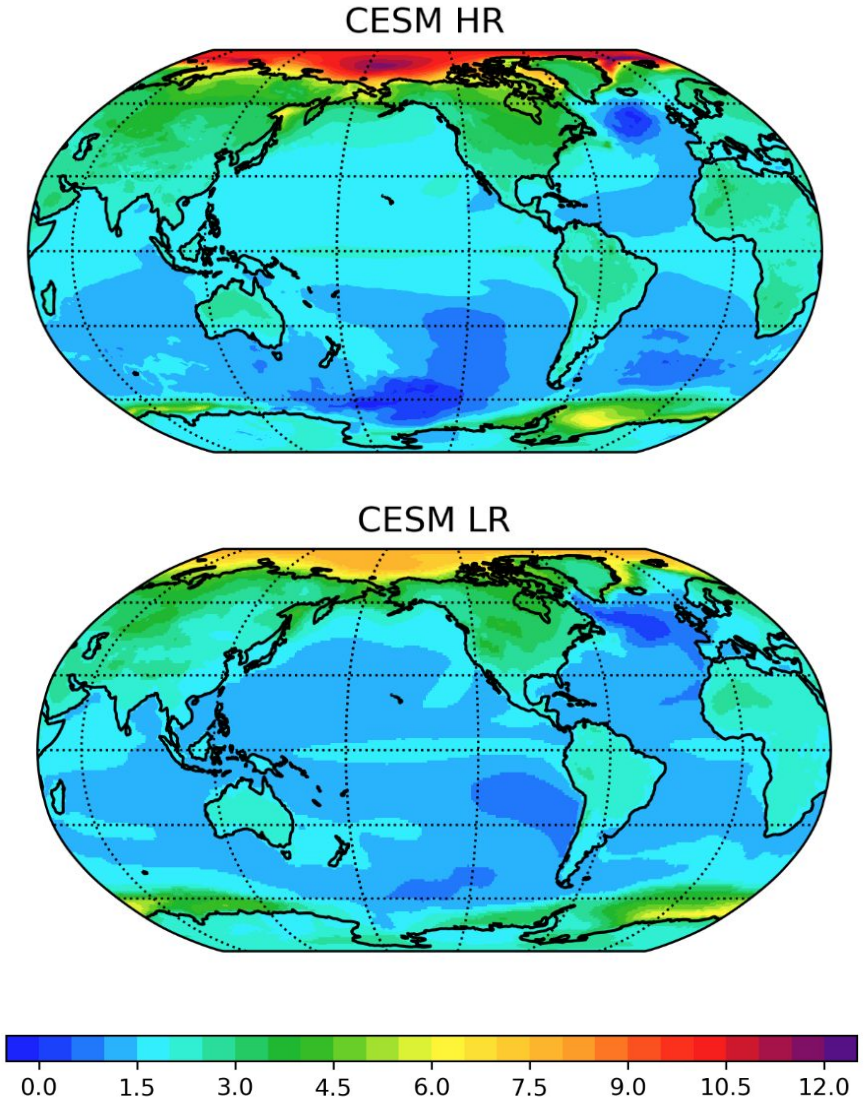




- HR transports less heat poleward than LR
- difference is primarily due to the difference in eddy heat transport
- HR also shows a much stronger positive trend in OHT

Transient Climate Response (TCR)

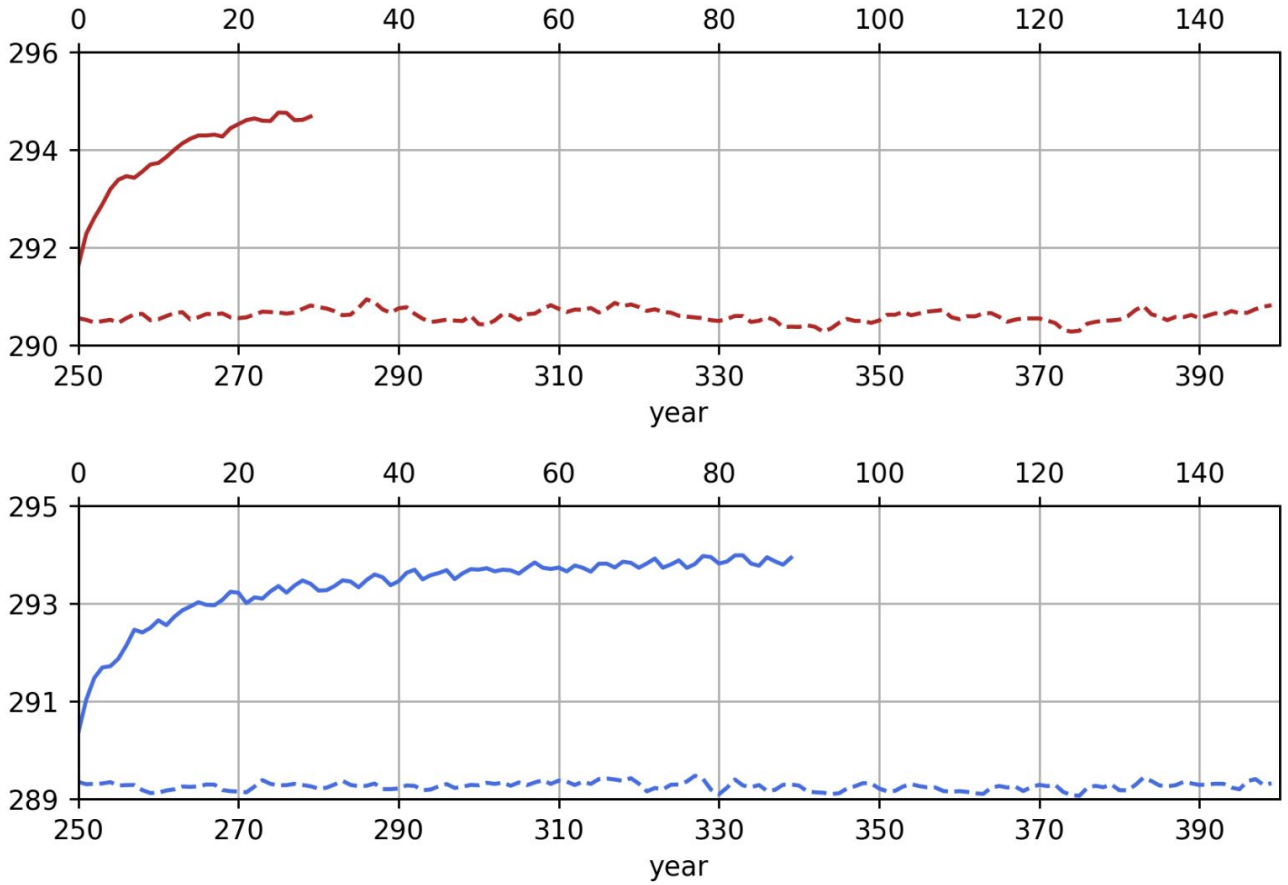




TCR: global warming to 1%CO2 year^{-1} increase around the time of doubling

Equilibrium Climate Sensitivity (ECS)

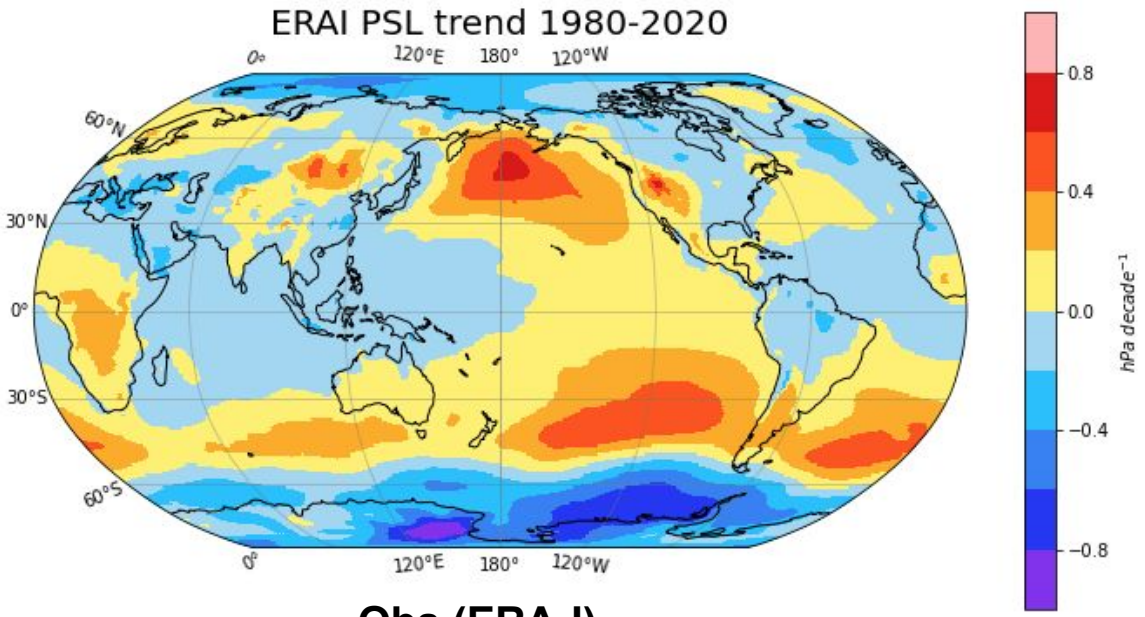
ECS: global warming to quadrupled CO_2 after the sea surface temperature (SST) response has come to equilibrium



Many exciting results are forthcoming!

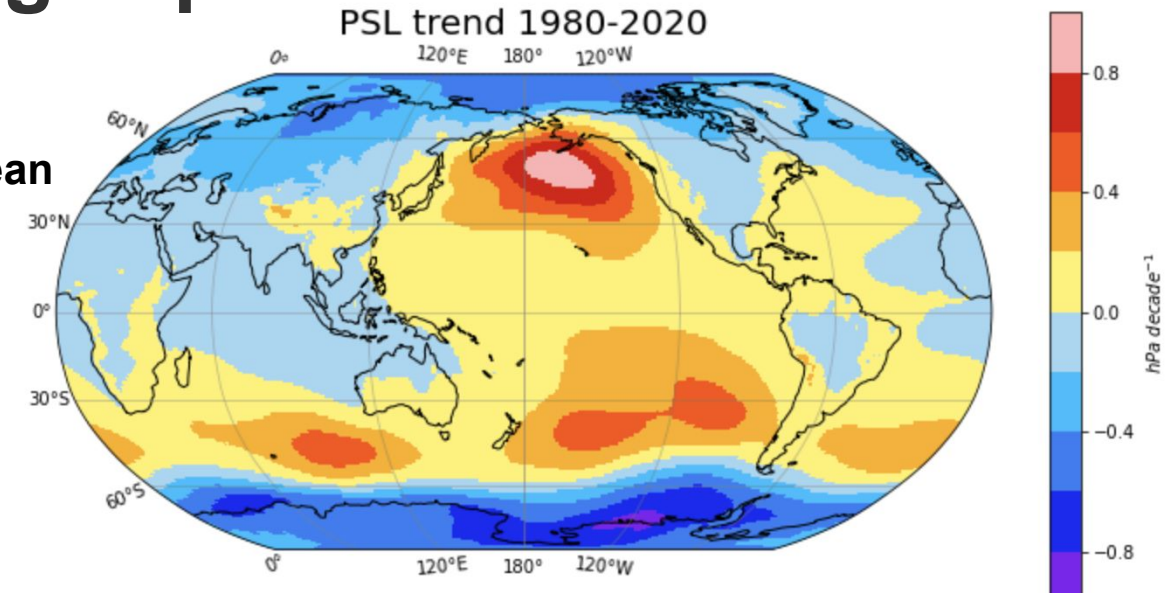
Thank You!

Ozone withholding experiment

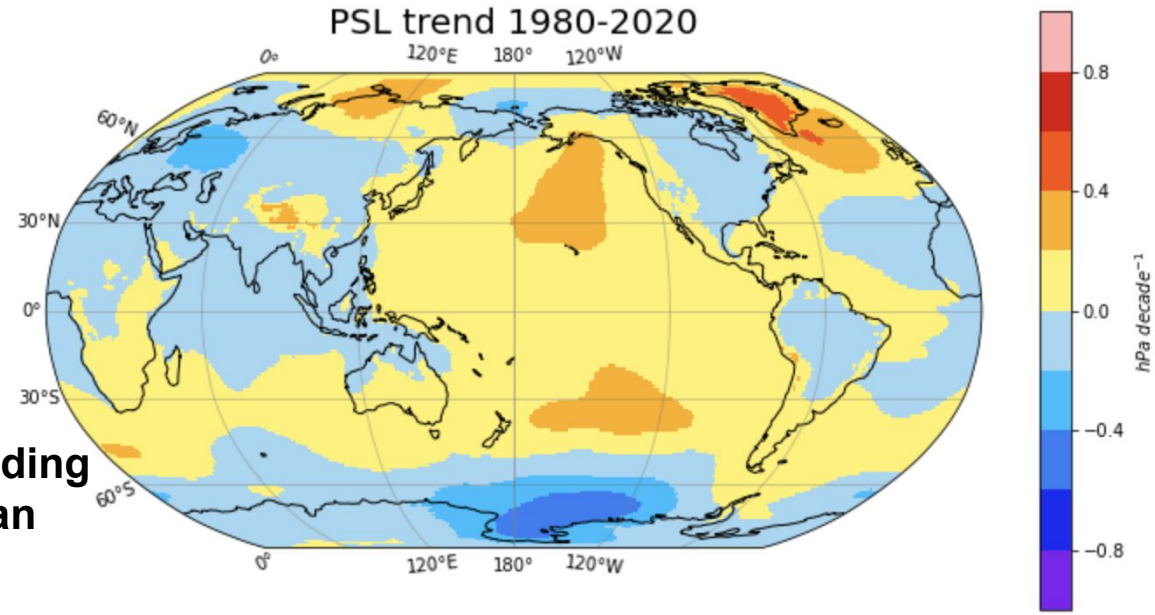


Obs (ERA-I)

HF-TNST
3-member mean

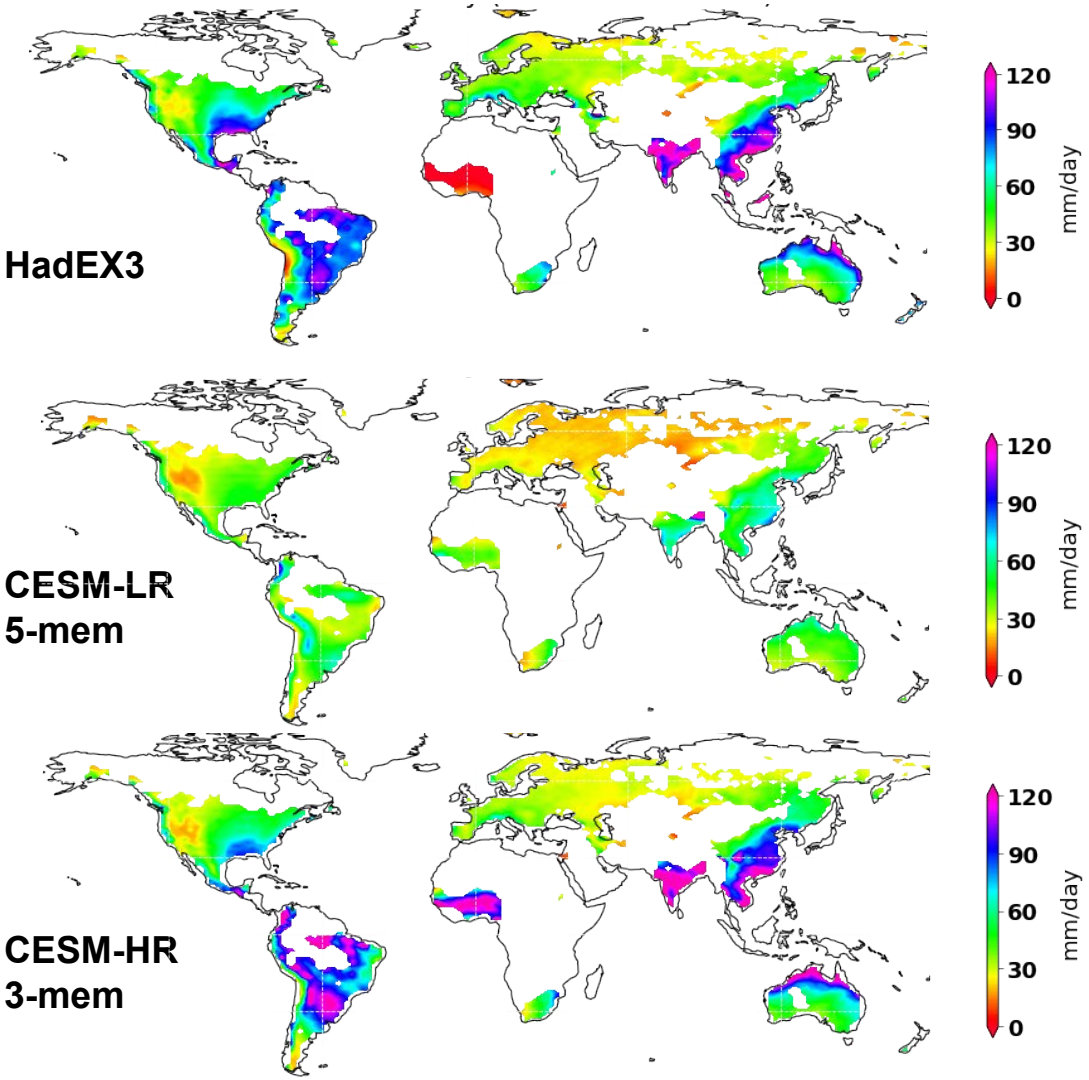


Ozone withholding
3-member mean

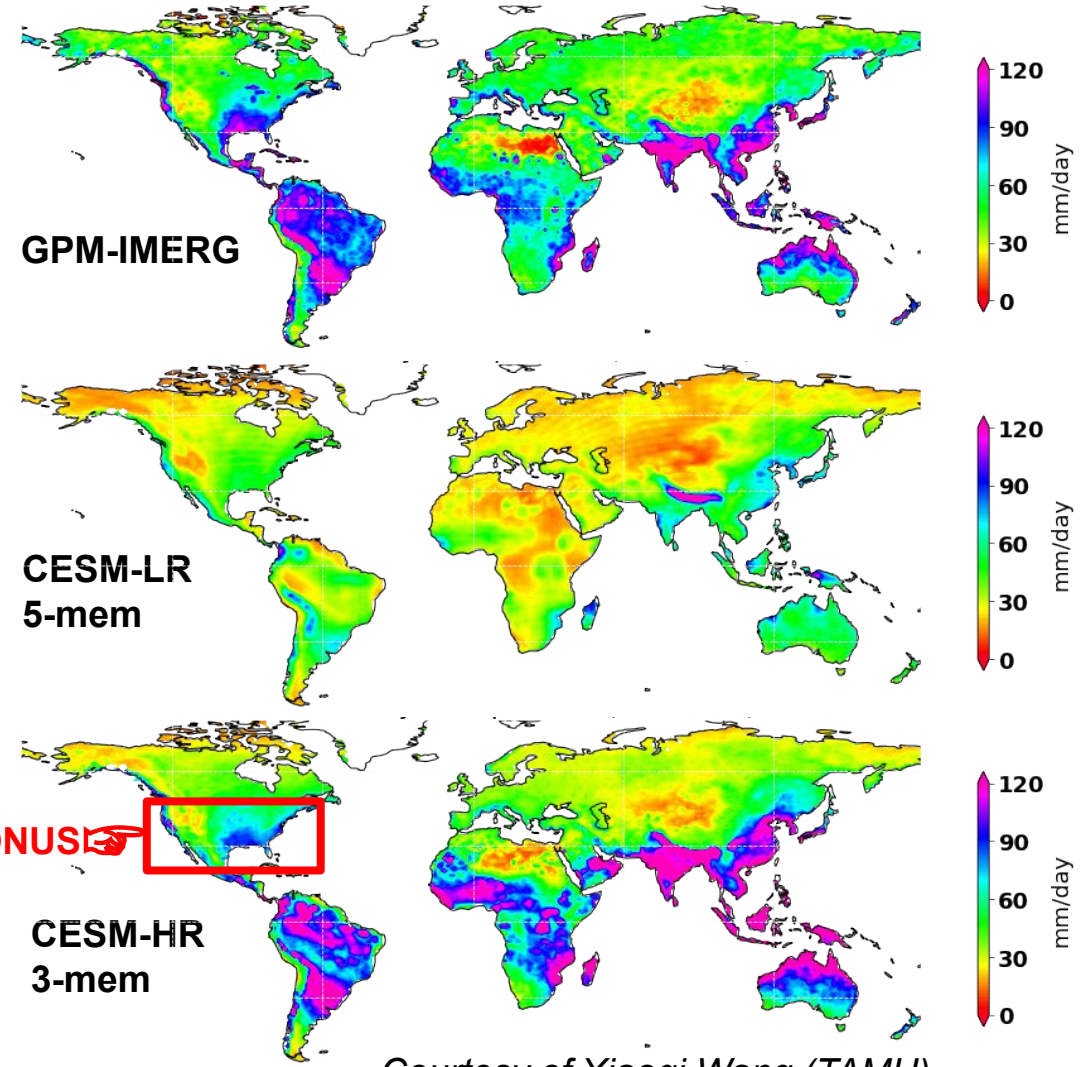


Observed and Simulated Extreme Precipitation

Annual Maximum Daily Precipitation (Rx1day)

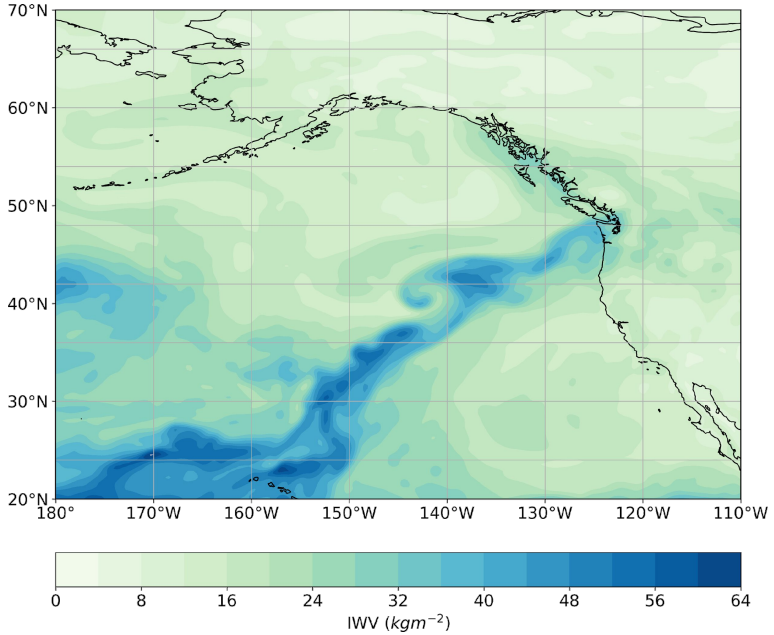


Above 99th Percentile Mean Daily Precipitation (>PR99)

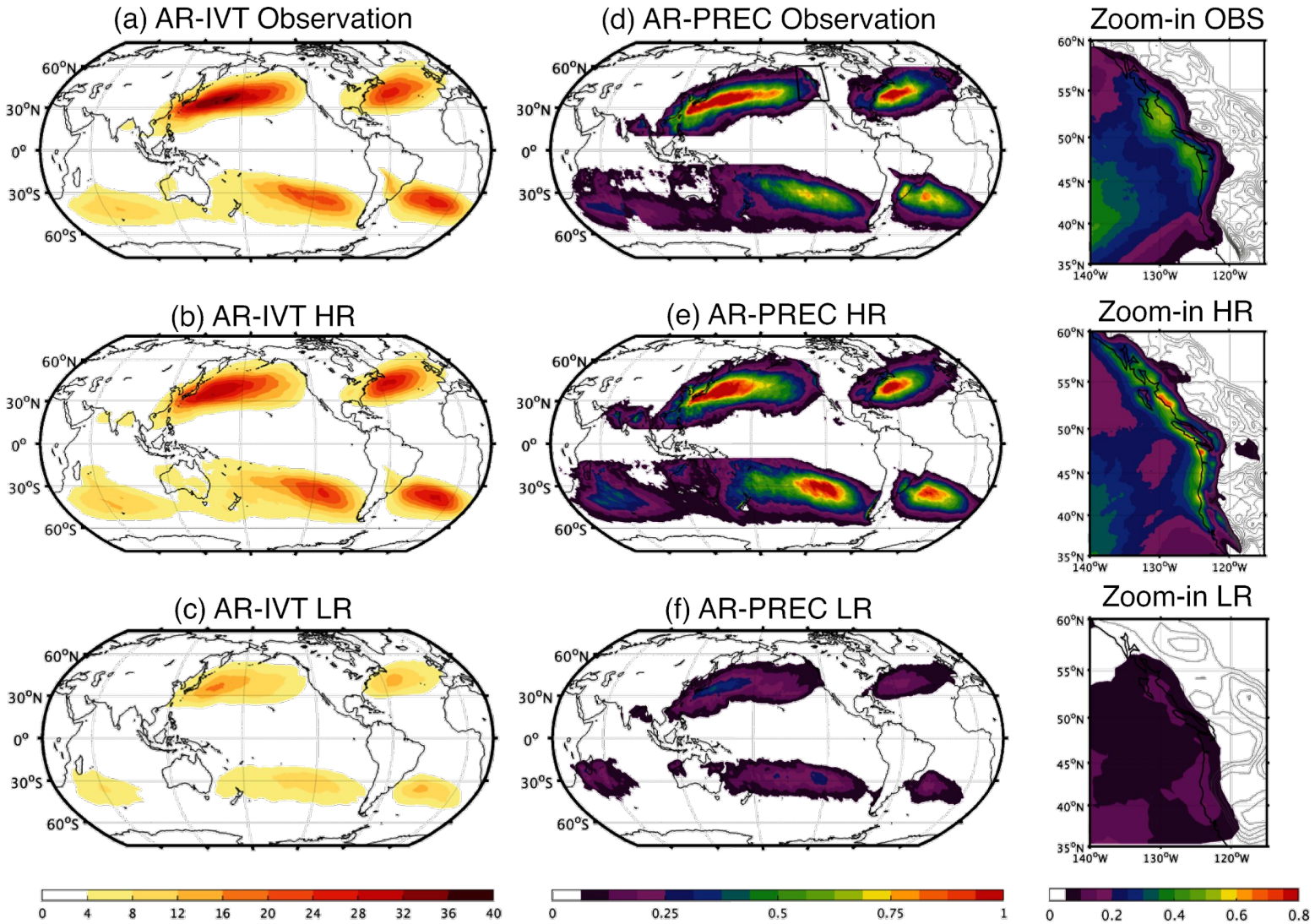


Courtesy of Xiaoqi Wang (TAMU)

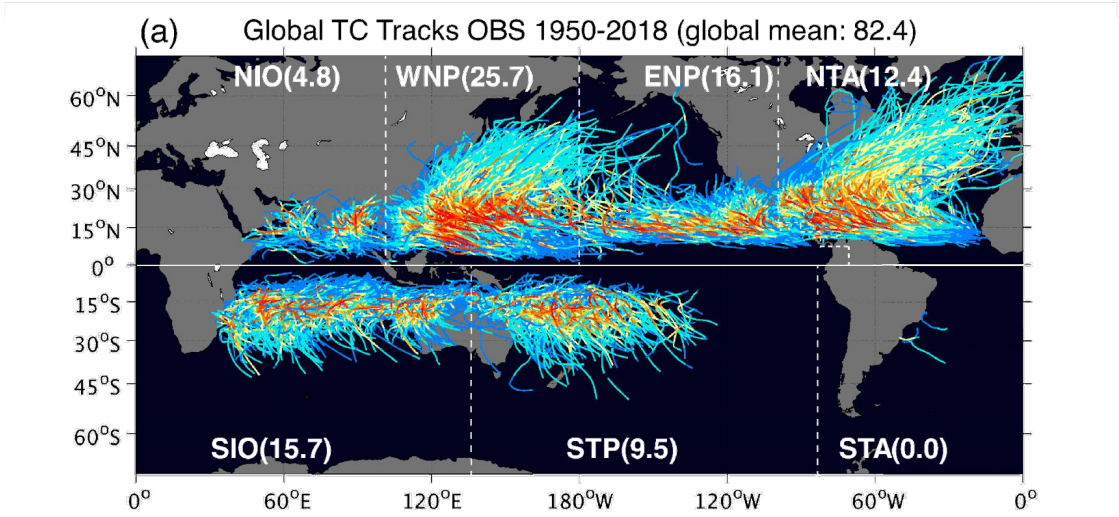
ARs

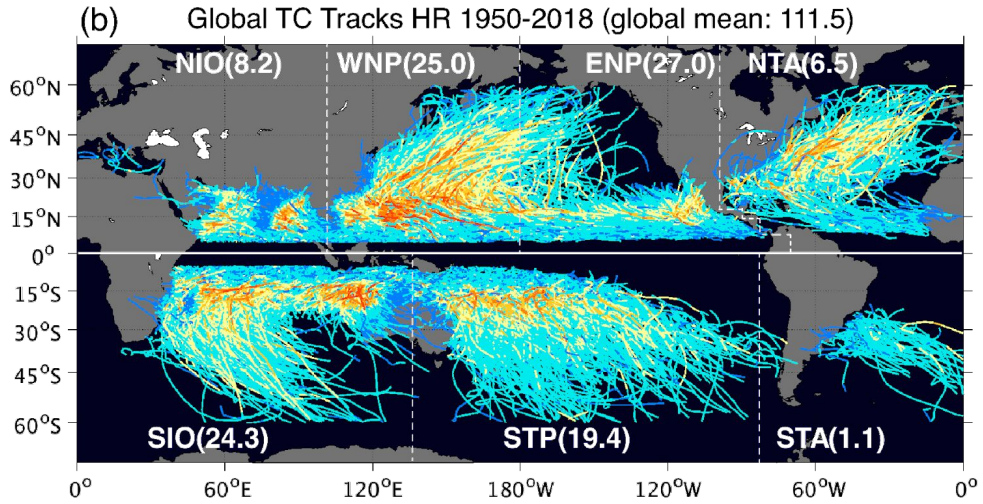


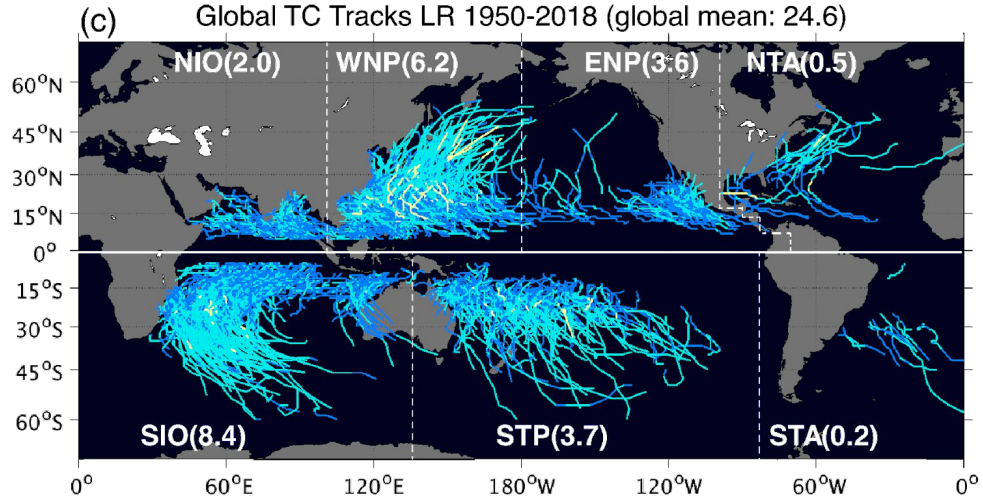
- Sample AR as simulated by CESM-HR
- Mean IVT associated with ARs and averaged precipitation concurrent with ARs in observations



TCs







Observed and simulated TC tracks from CESM-HR and CESM-LR during 1950 to 2018. Different colors indicate different storm intensity categories

from Chang et al. (2020)