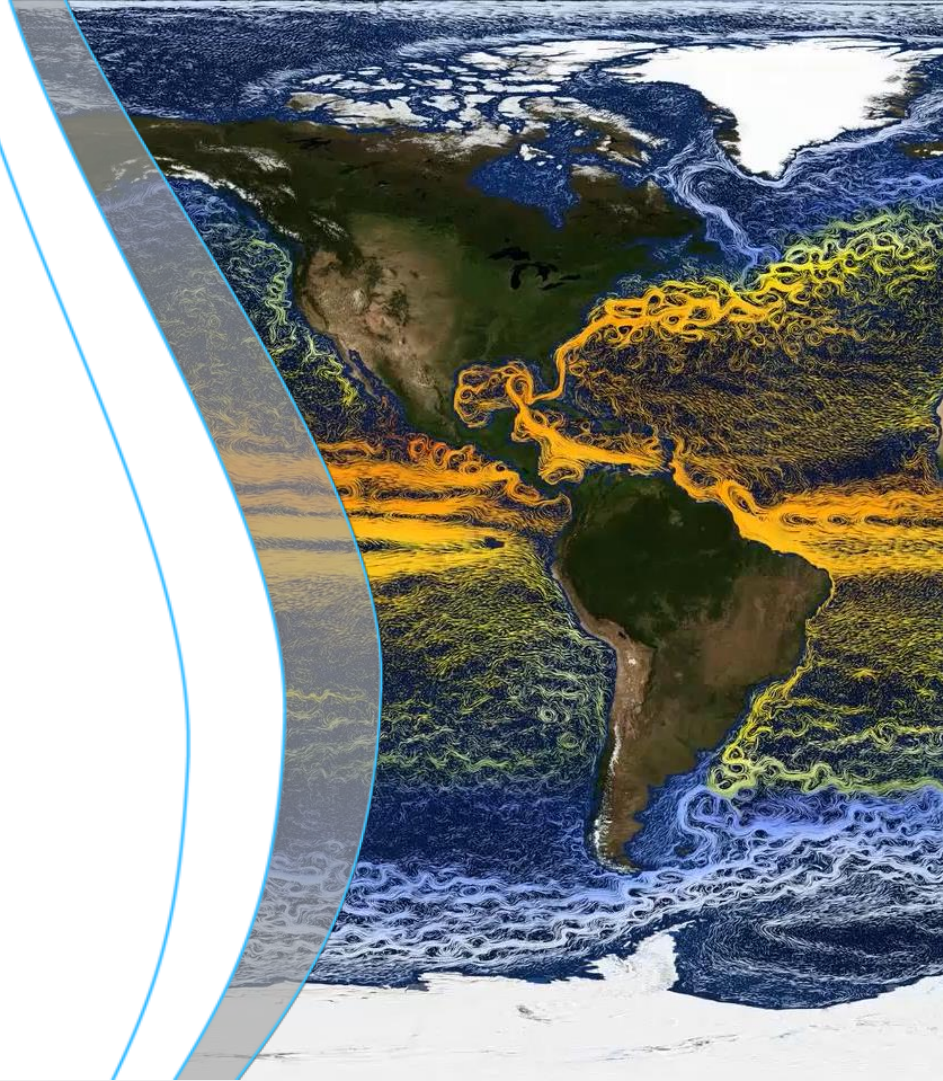


FEBRUARY 06, 2026

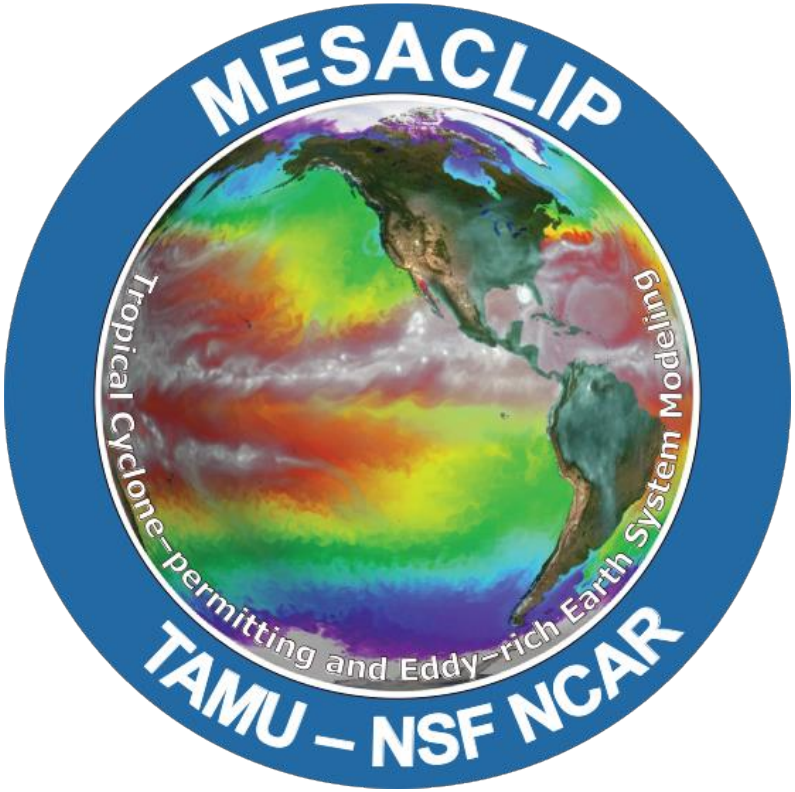
Recent advances with the High-Resolution version of CESM by the MESACLIP project

Fred Castruccio[(1)], Gokhan Danabasoglu[(1)], Ping Chang[(2)], and Dan Fu[(2)]

[(1)] NSF NCAR
[(2)] TAMU

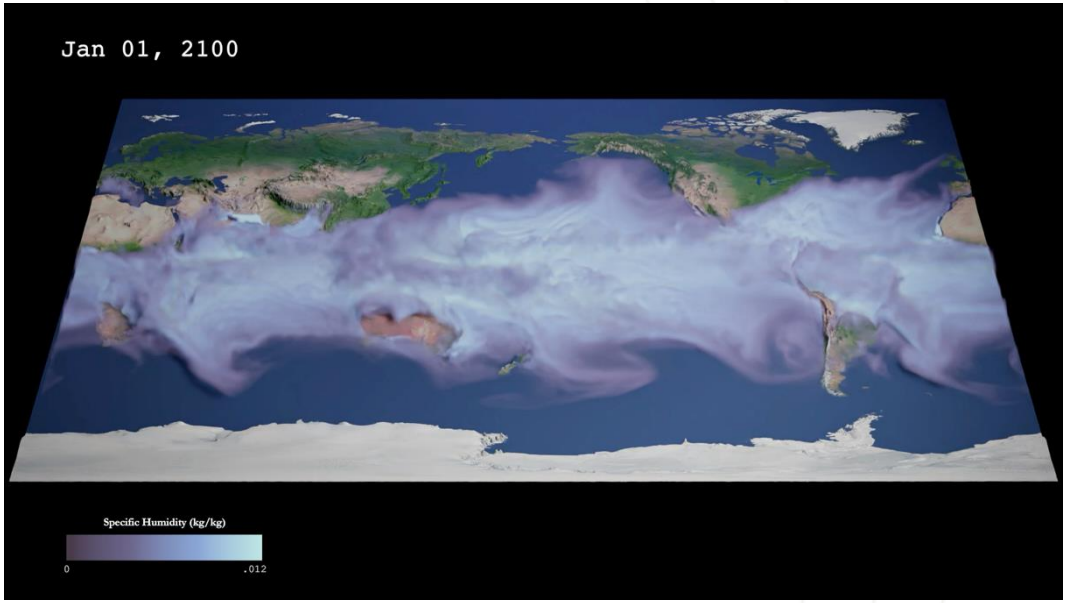
This material is based upon work supported by the NSF National Center for Atmospheric Research, a major facility sponsored by the U.S. National Science Foundation and managed by the University Corporation for Atmospheric Research. Any opinions, findings and conclusions or recommendations expressed in this material do not necessarily reflect the views of NSF.

MESACLIP logo



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

500-year PI control;
80-year 1%CO_2; 150-year 4xCO_2;
400+ years hosing experiment;
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;
6-member 1970-2010 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);
Corresponding low-res (~1°) simulations;

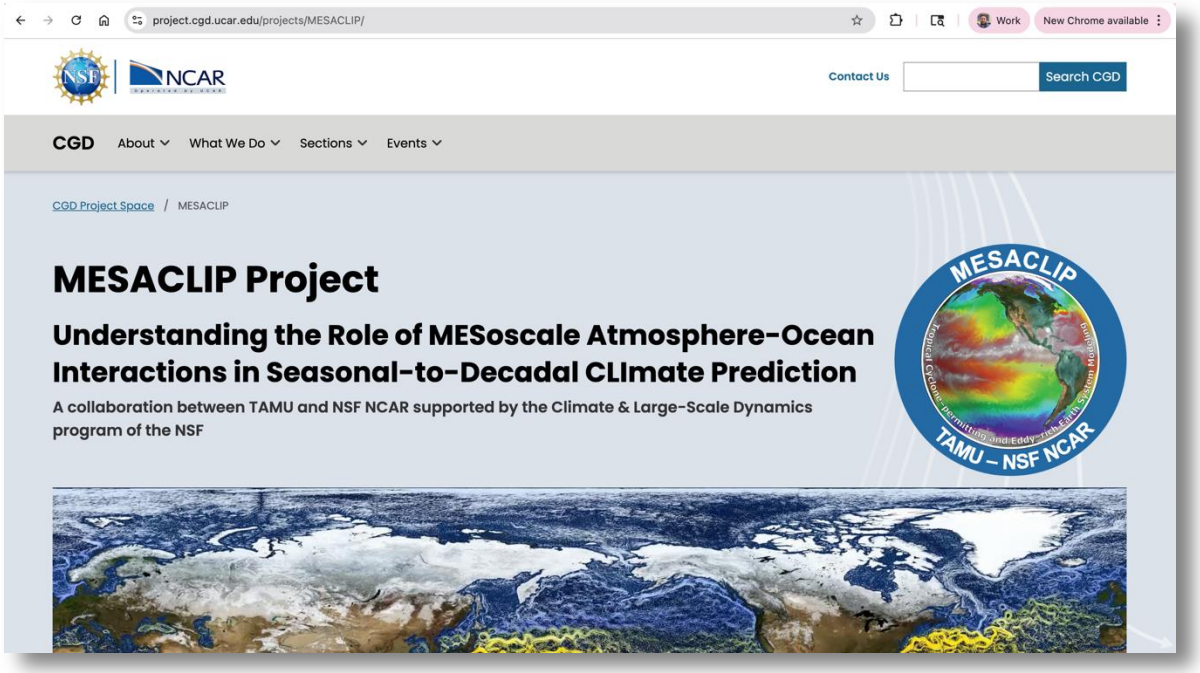


Visualization Credit: Matt Rehme, Visualization Services and Research Group, NSF NCAR CISL

Datasets are available to the community.

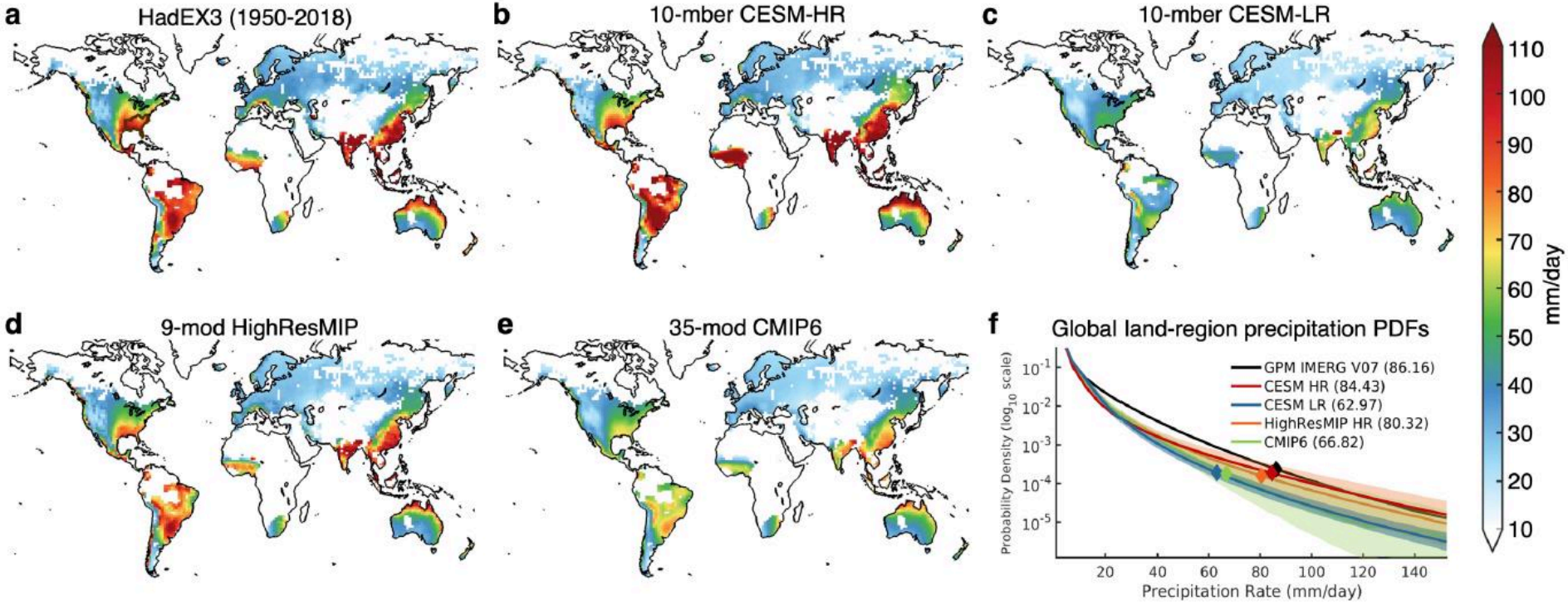
Chang et al. (2020, 2025)

MESACLIP website



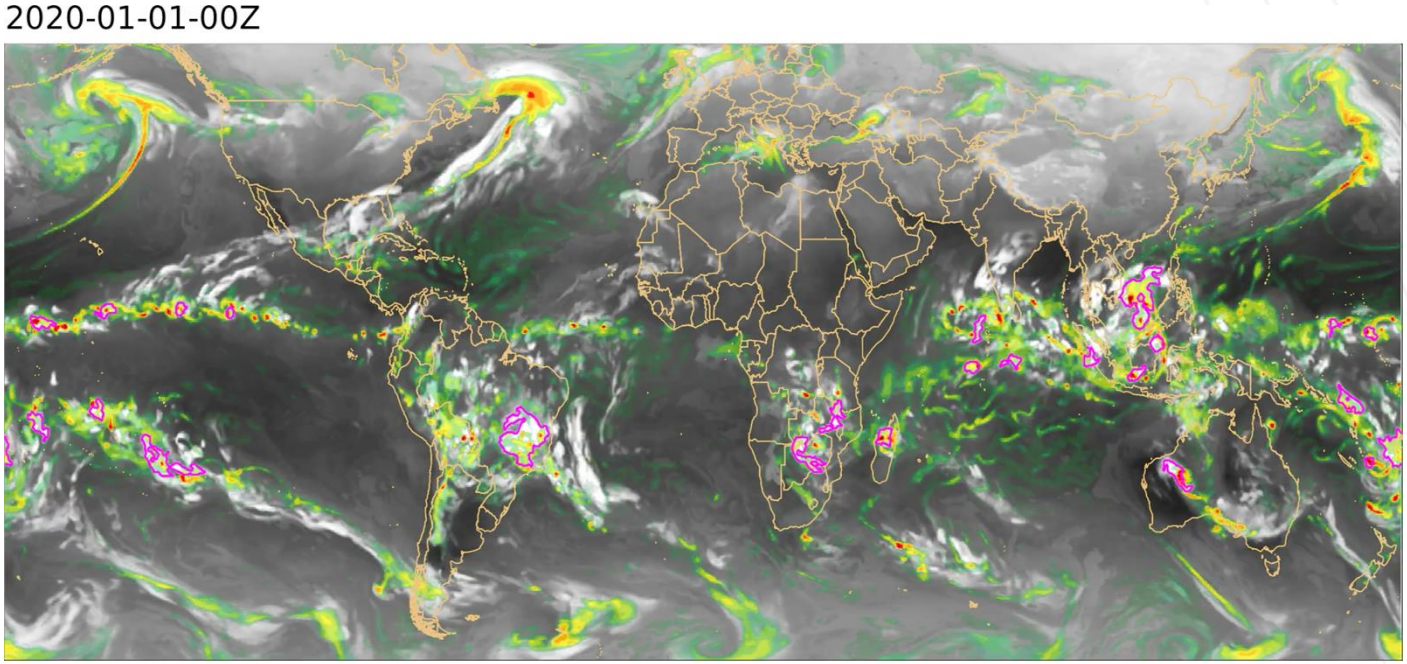
Data acquisition: The datasets are served to the community through the NSF NCAR Geoscience Data Exchange (GDEX) . By unifying datasets into a single, reliable platform, GDEX allows users to run analytics at scale with NSF NCAR's world-class High Performance Computing services, empowering scalable and collaborative science made accessible to US researchers through a range of allocations opportunities.

CESM-HR simulation of extreme precipitation



Chang et al. (2025)

CESM-HR simulation of extreme precipitation



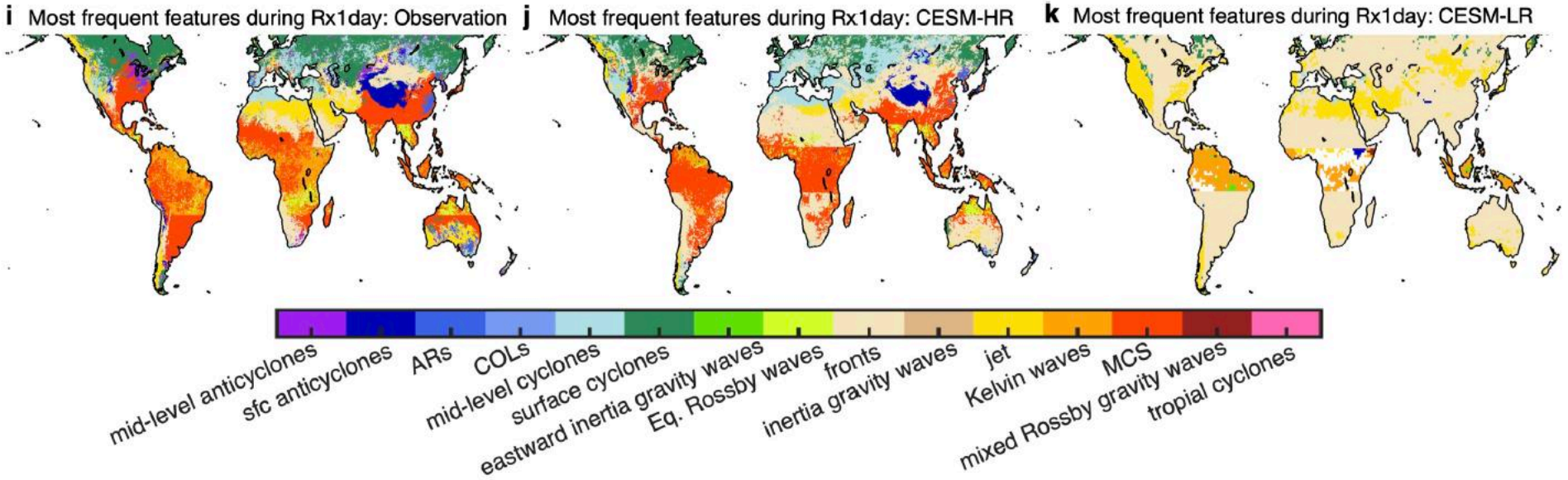
Visualization Credit: Dan Fu

Animation from a CESM-HR simulation showing clouds in gray, precipitation in color with extreme precipitation in red, and MOAAP-tracked mesoscale convective systems (MCSs) outlined in purple

CESM-HR simulation of extreme precipitation

Mesoscale Convective Systems (MCSs)

Jets & Fronts

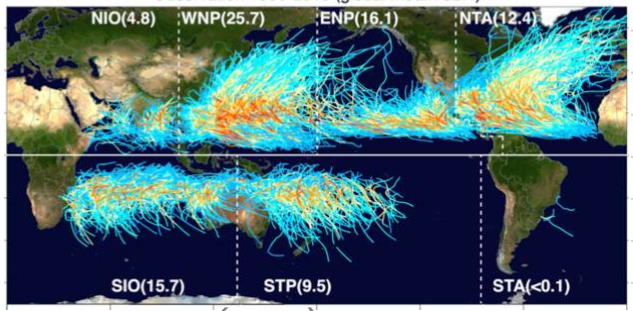


Detected by the Multi Object Analysis of Atmospheric Phenomenon (MOAAP; Prein et al. 2023) algorithm during Rx1day events over global land

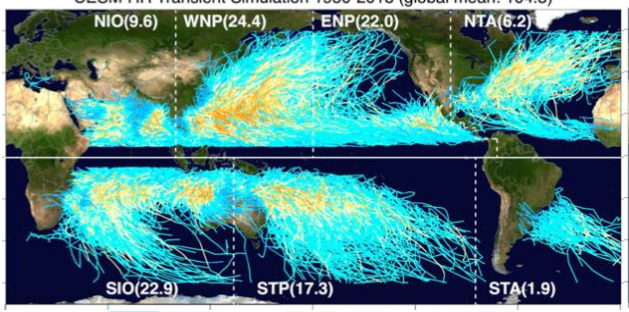
Chang et al. (2025)

Tropical Cyclones (TCs)

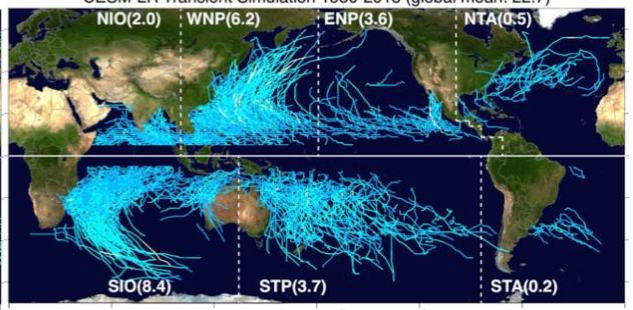
IBTrACS Observations

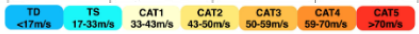


CESM HR

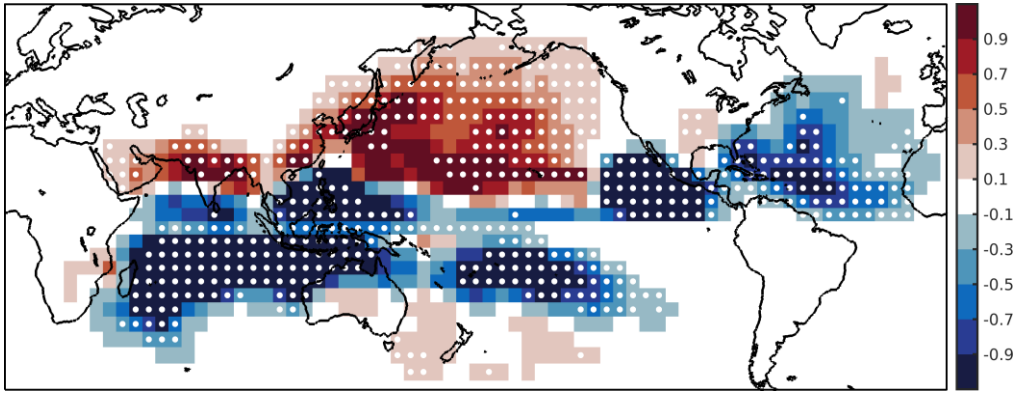


CESM LR



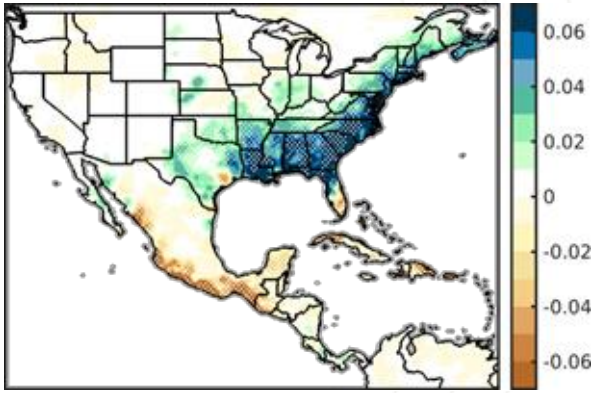


Chang et al. (2020)



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

Fu et al. (2026)



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

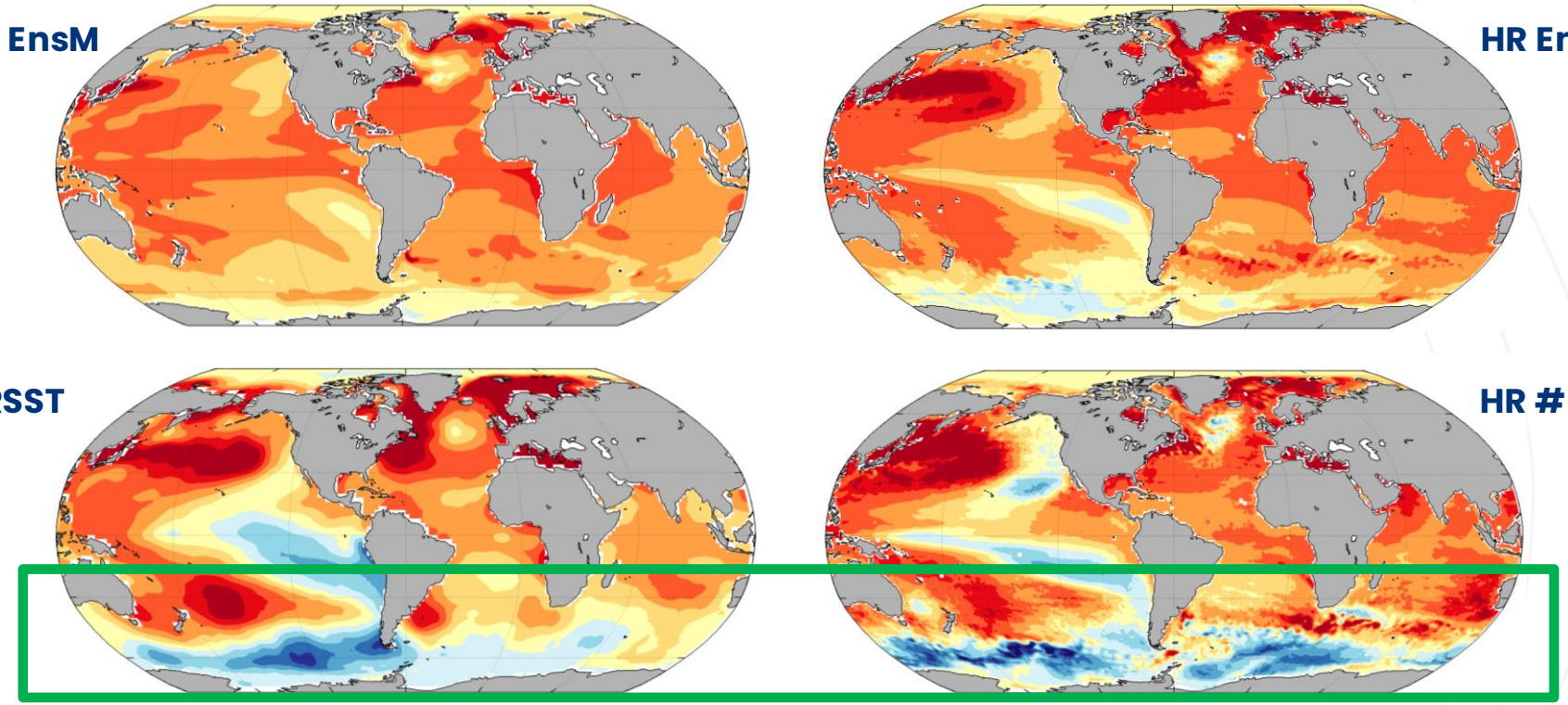
SST Linear Trend (1980–2022)

LR EnsM

HR EnsM

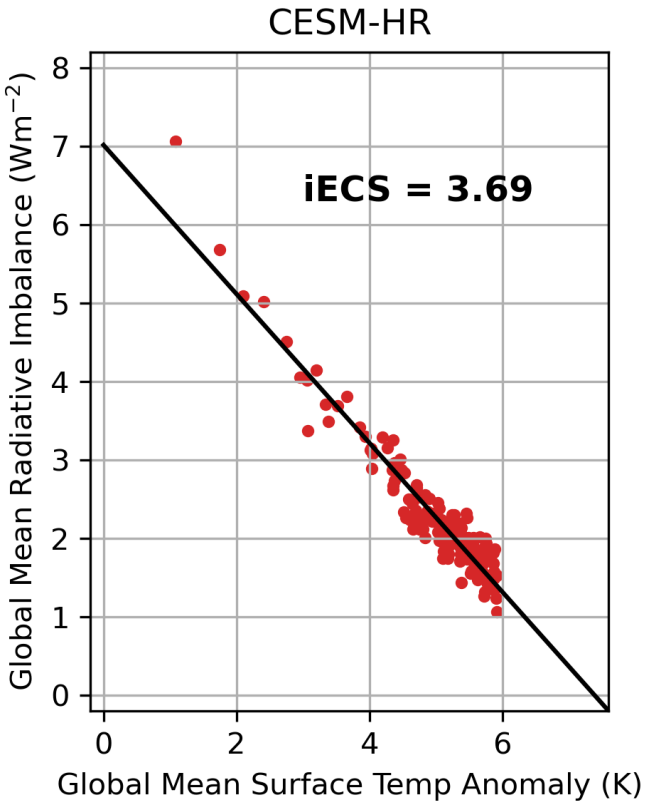
ERSST

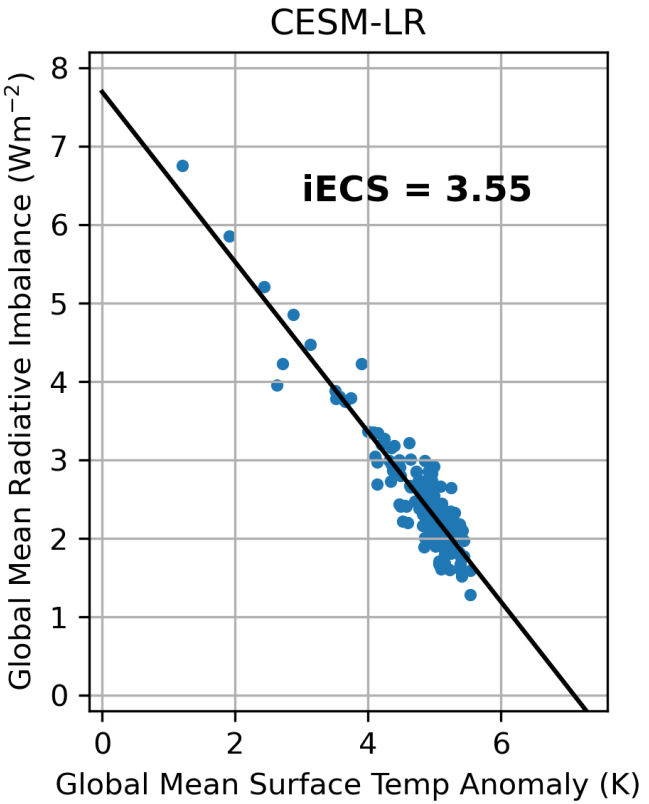
HR #010



Prochko et al. (2026)

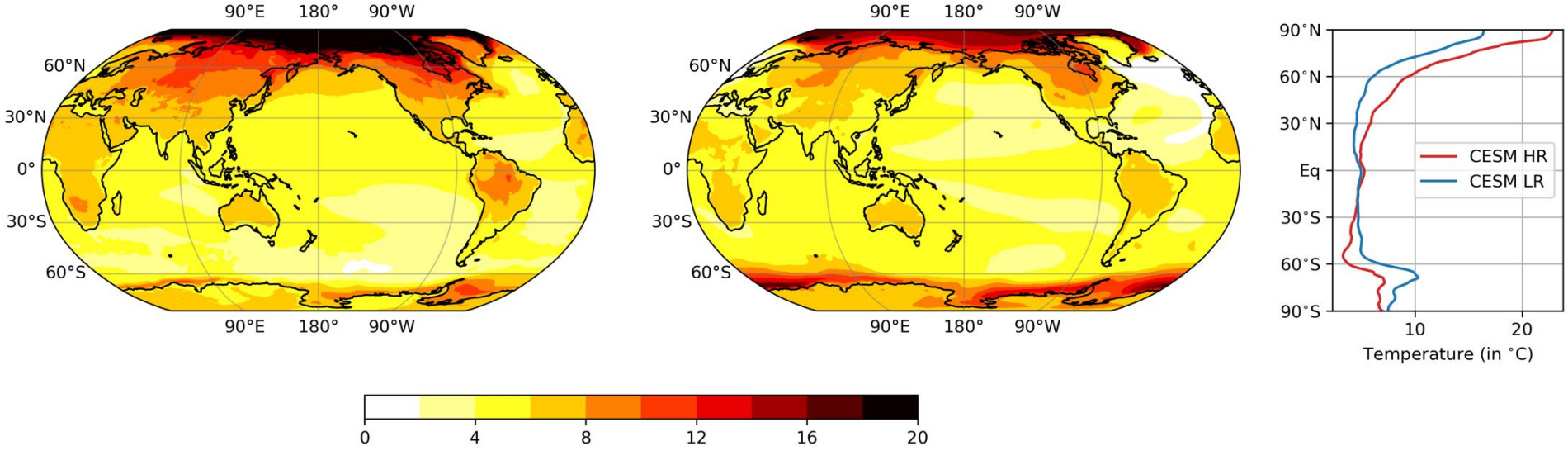
Equilibrium Climate Sensitivity from 4xCO2





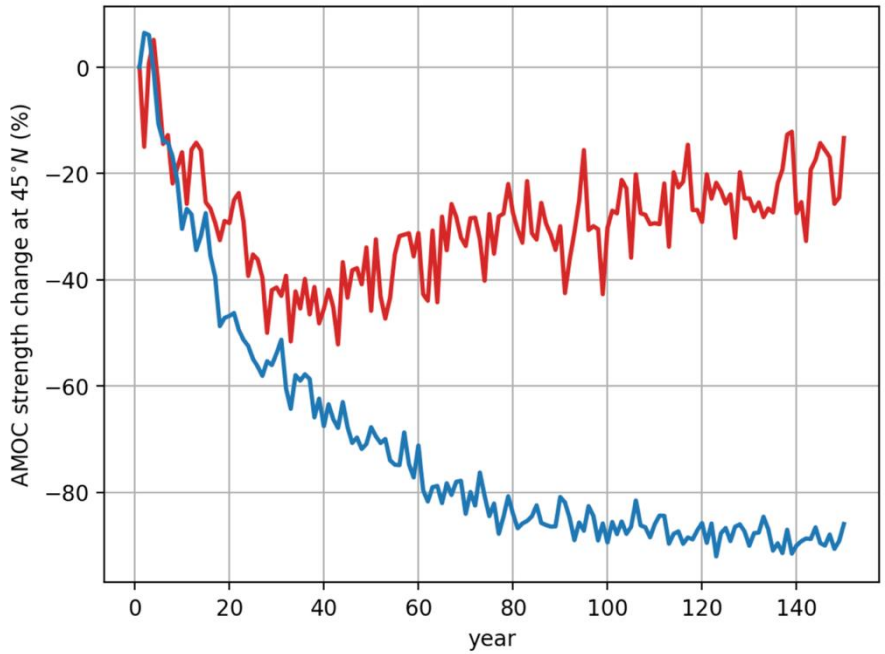
Gregory et al. (2004)

Surface warming under abrupt 4xCO2

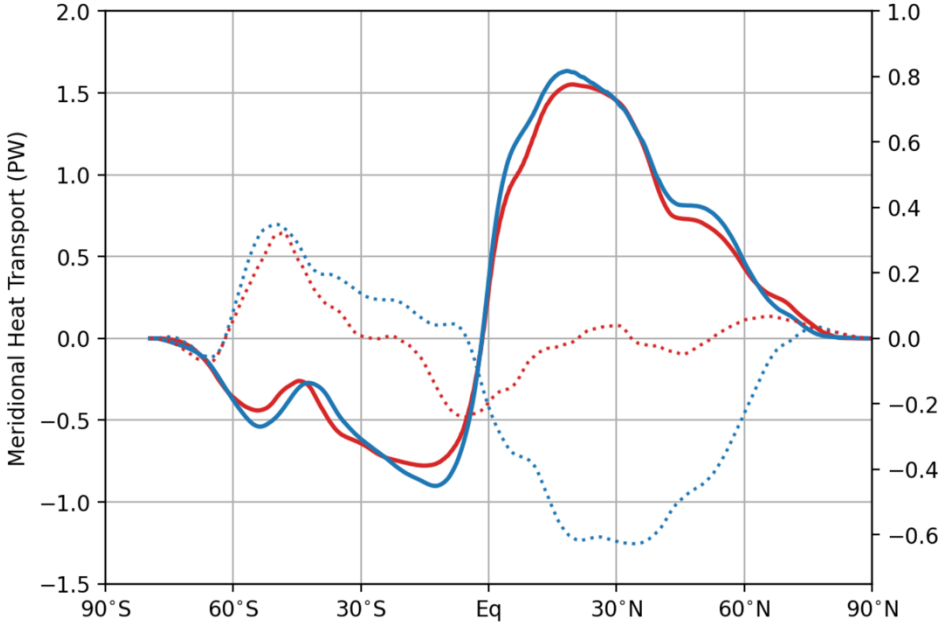


Ocean response under abrupt 4xCO2

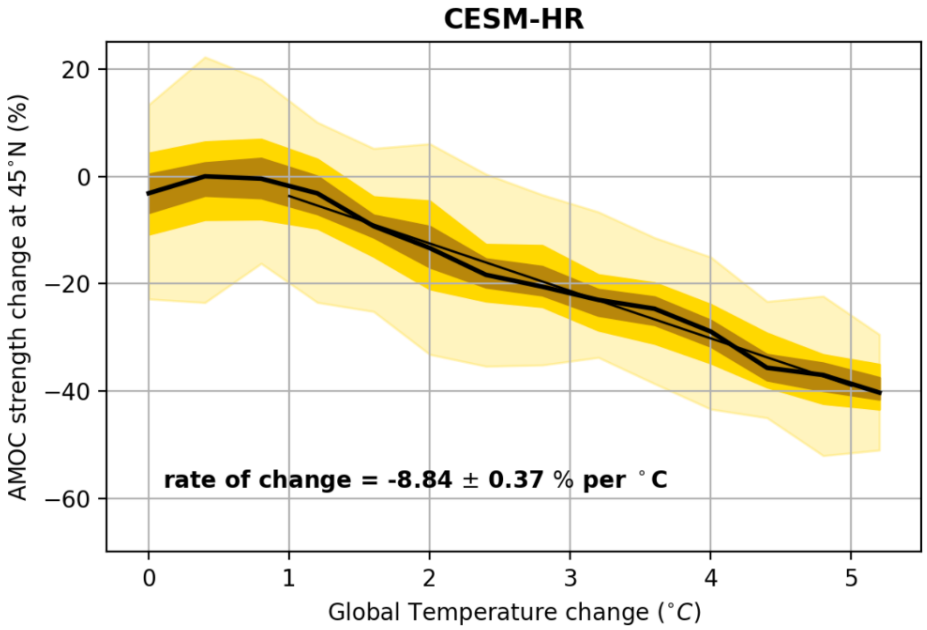
Annual mean AMOC at 45°N

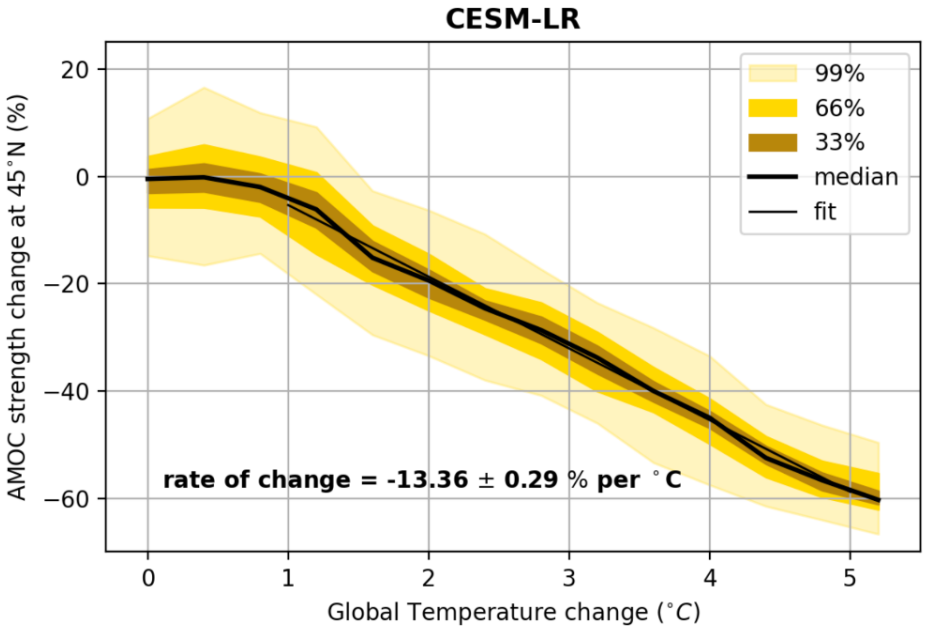


Mean meridional Ocean Heat Transport



A more stable AMOC in CESM-HR





Rate of AMOC change per ˚C is ~50% stronger in CESM-LR in transient simulations

CESM-HR Hosing Experiment & Protocol

Questions:

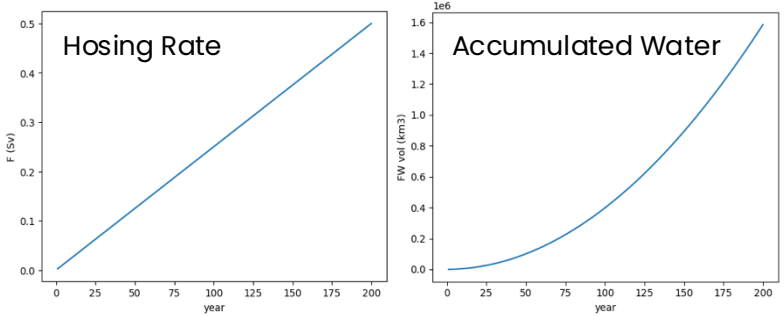
- Where is the AMOC stability threshold with respect to Greenland (ice sheet) freshwater fluxes in strongly eddying climate models?
- How does the explicit representation of eddies affect AMOC stability?

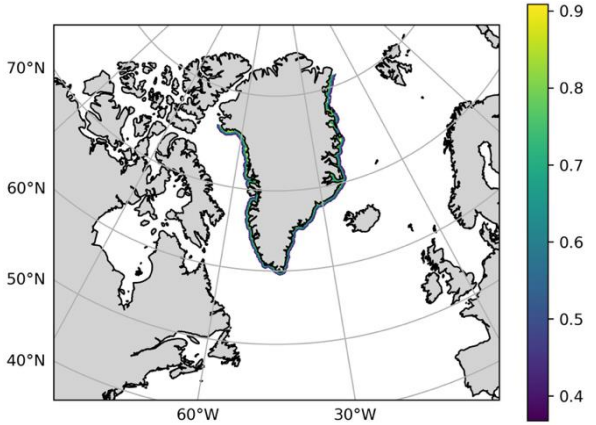
Experiments:

- A 200-year simulation with 0.25 Sv / century (IC: PI control)
- A 200-year continuation simulation with no hosing
- Corresponding low-resolution (~1°) experiments

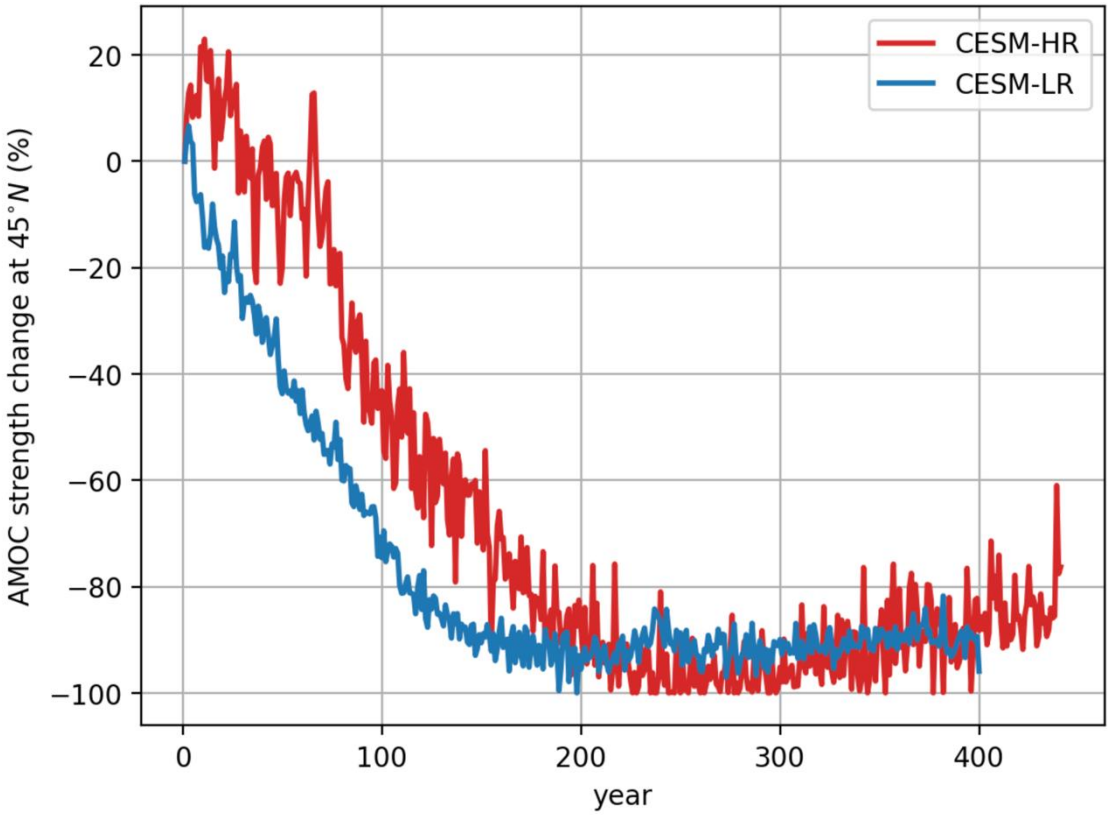
A few details:

- 50-km exponential spread off the coast
- Exponential decay in the vertical with e-folding length of ~50 m
- No salinity compensation
- No seasonal cycle





AMOC strength at 45˚N in the hosing experiment



Summary

- An unprecedented set of TC-permitting and eddy-resolving has been performed
- Most of the simulations are available to the community on NSF NCAR Geoscience Data Exchange (GDEX)
- Major breakthroughs in advancing high-resolution global climate modeling and prediction
- CESM-HR shows many improvements over CESM-LR
- Despite not resolving clouds and deep convection, CESM-HR more accurately captures extreme precipitation by improving representation of MCSs and the multi-scale interactions driving extreme events
- Significant differences in simulated AMOC behaviors between CESM-HR and CESM-LR

Thank you!

Any Questions?