



**NCAR**  
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FEBRUARY 06, 2026

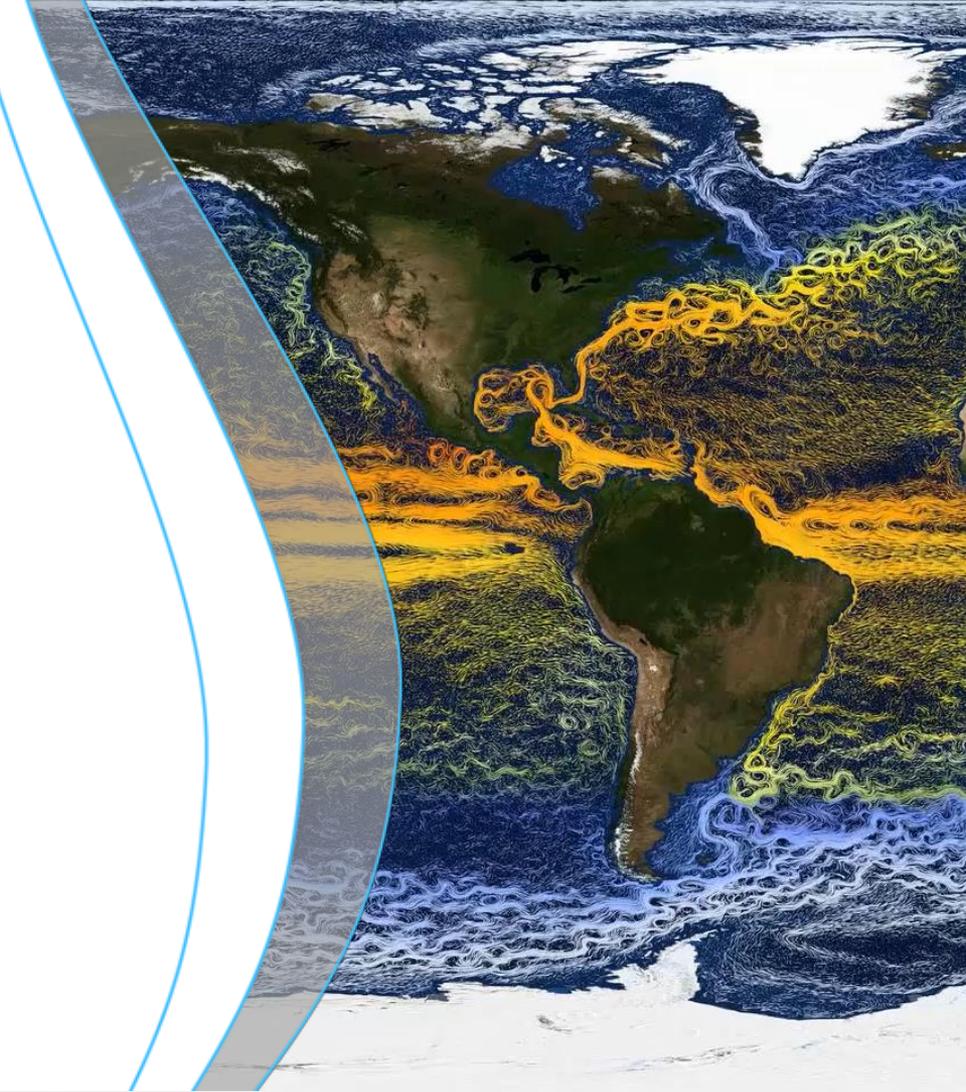
# Recent advances with the High-Resolution version of CESM by the MESACLIP project

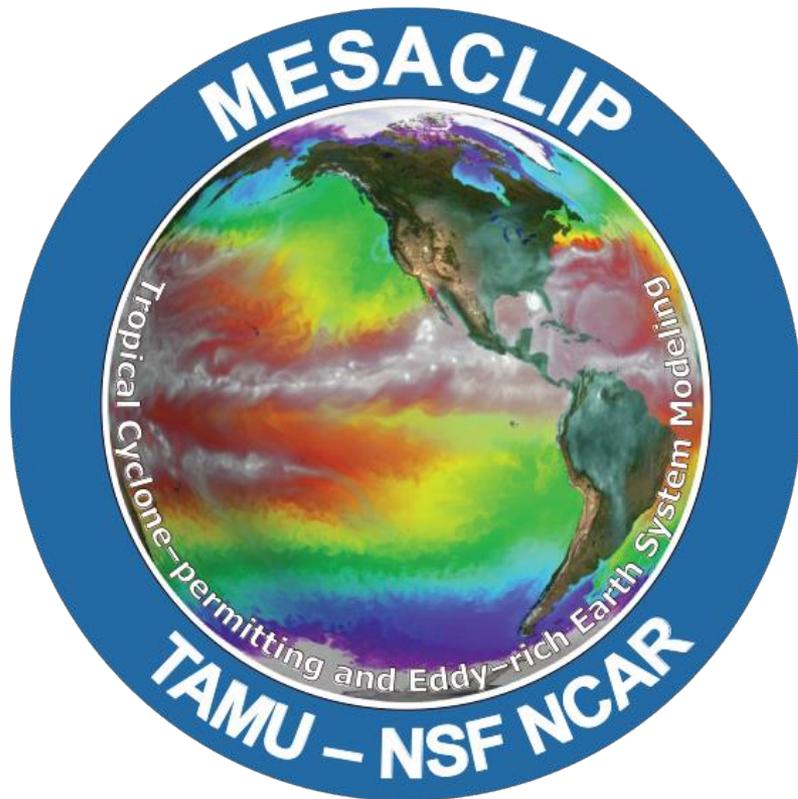
**Fred Castruccio<sup>(1)</sup>, Gokhan Danabasoglu<sup>(1)</sup>,  
Ping Chang<sup>(2)</sup>, and Dan Fu<sup>(2)</sup>**

**(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.*

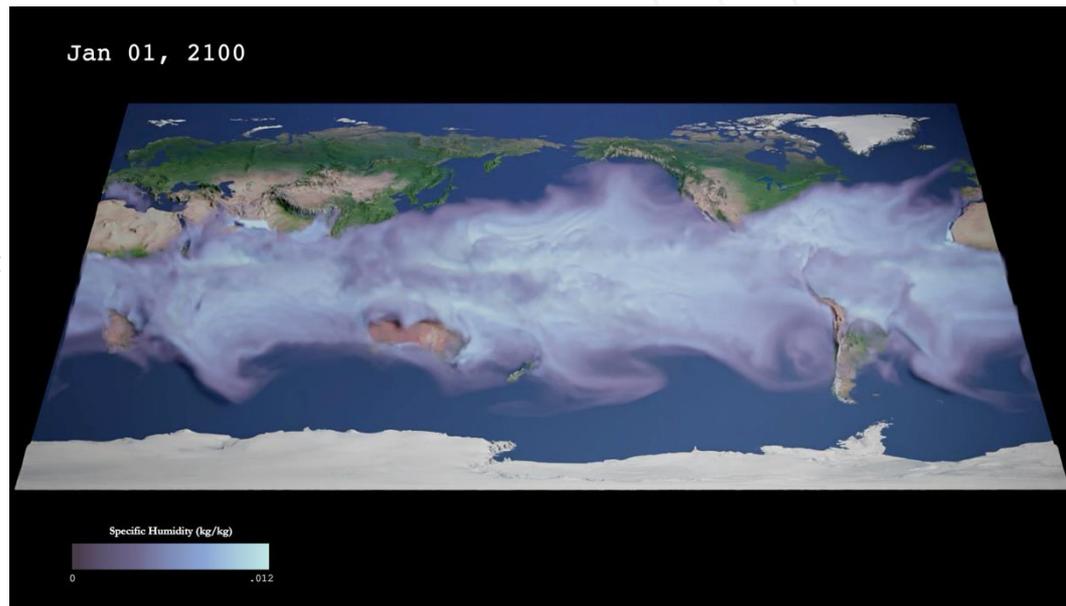




# CESM High-Resolution Simulations (CESM1.3; 0.1° ocn; 0.25° atm)

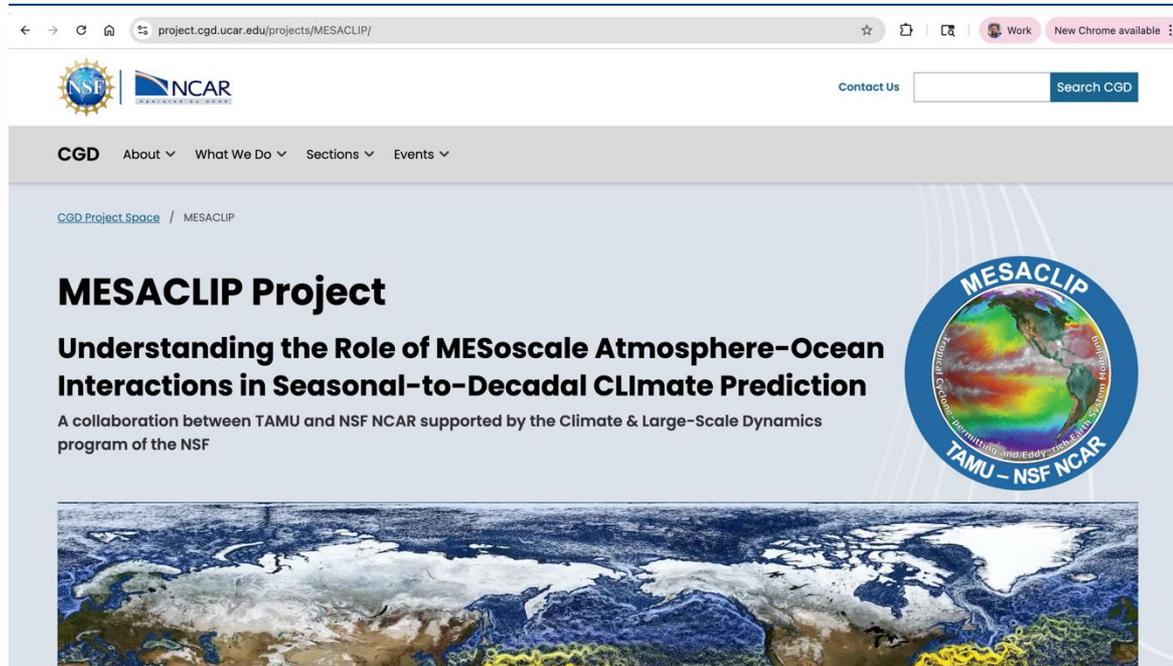
500-year PI control;  
80-year 1%CO<sub>2</sub>; 150-year 4xCO<sub>2</sub>;  
400+ years hosing experiment;  
10-member (1850) 1920-2005 historical;  
10-member 2006-2100 transient w/ RCP 8.5;  
10-member 2006-2100 transient w/ RCP6.0;  
1-member 2006-2100 transient w/ RCP4.5;  
1-member 2006-2100 transient 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;

Datasets are available to the community.



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

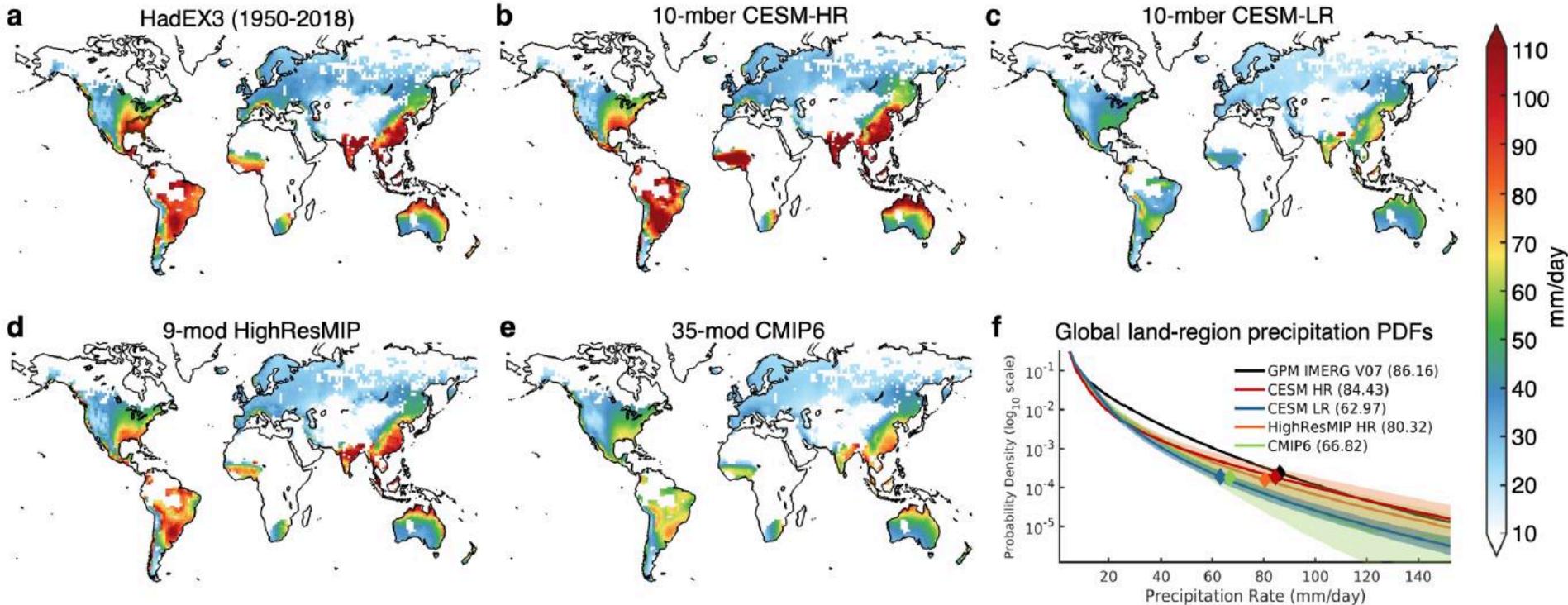
*Chang et al. (2020, 2025)*



The screenshot shows the MESACLIP website interface. At the top, there is a navigation bar with the NSF and NCAR logos on the left, a 'Contact Us' button, and a search bar labeled 'Search CGD'. Below the navigation bar is a main content area with a header 'CGD' and a menu with 'About', 'What We Do', 'Sections', and 'Events'. The main content area features a large banner for the 'MESACLIP Project' with the subtitle 'Understanding the Role of MESoscale Atmosphere–Ocean Interactions in Seasonal–to–Decadal CLimate Prediction'. Below the subtitle is a short description: 'A collaboration between TAMU and NSF NCAR supported by the Climate & Large–Scale Dynamics program of the NSF'. To the right of the text is a circular logo for the 'MESACLIP' project, which includes the text 'Mesoscale and Eddy Scale Climate Program' and 'TAMU – NSF NCAR'. Below the banner is a wide, horizontal image showing a satellite view of a coastal region with ice and water.

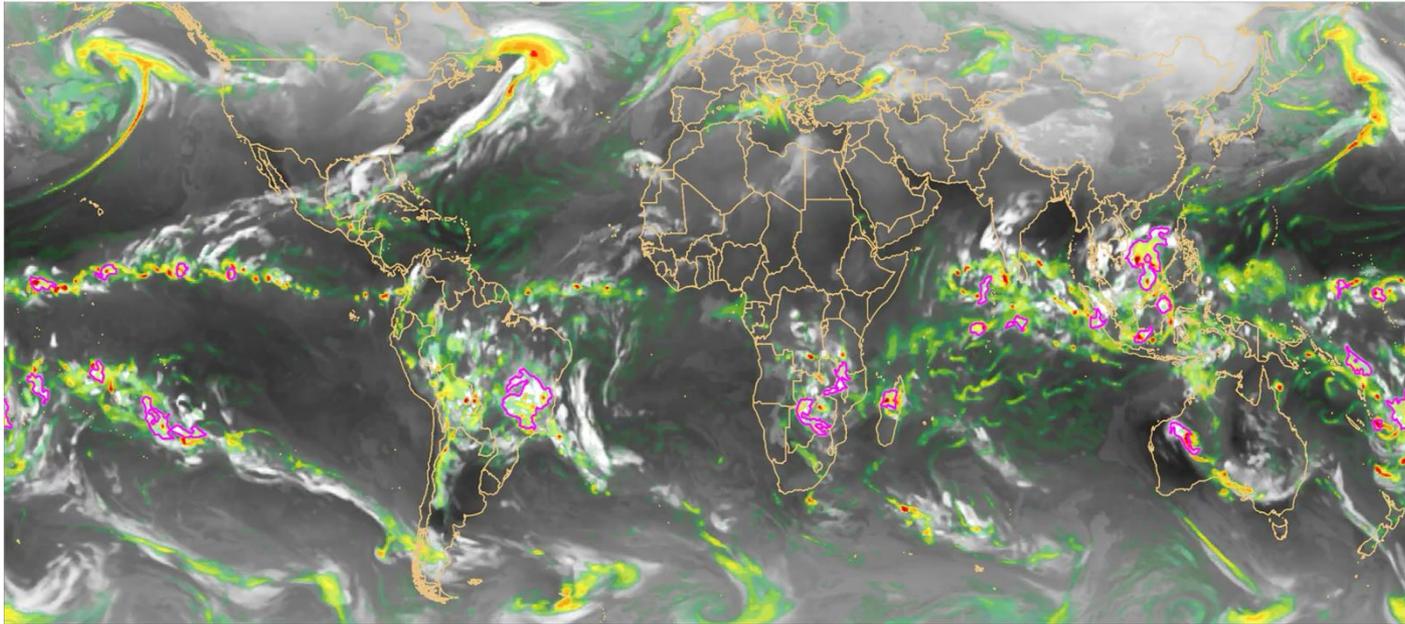
**Data acquisition:** The datasets are served to the community through the NSF NCAR Geoscience Data Exchange ([GDEX](#)). By unifying datasets into a single, reliable platform, GDEX allows users to run analytics at scale with NSF NCAR’s world-class [High Performance Computing services](#), empowering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

# CESM-HR simulation of extreme precipitation



# CESM-HR simulation of extreme precipitation

2020-01-01-00Z



Visualization Credit: Dan Fu

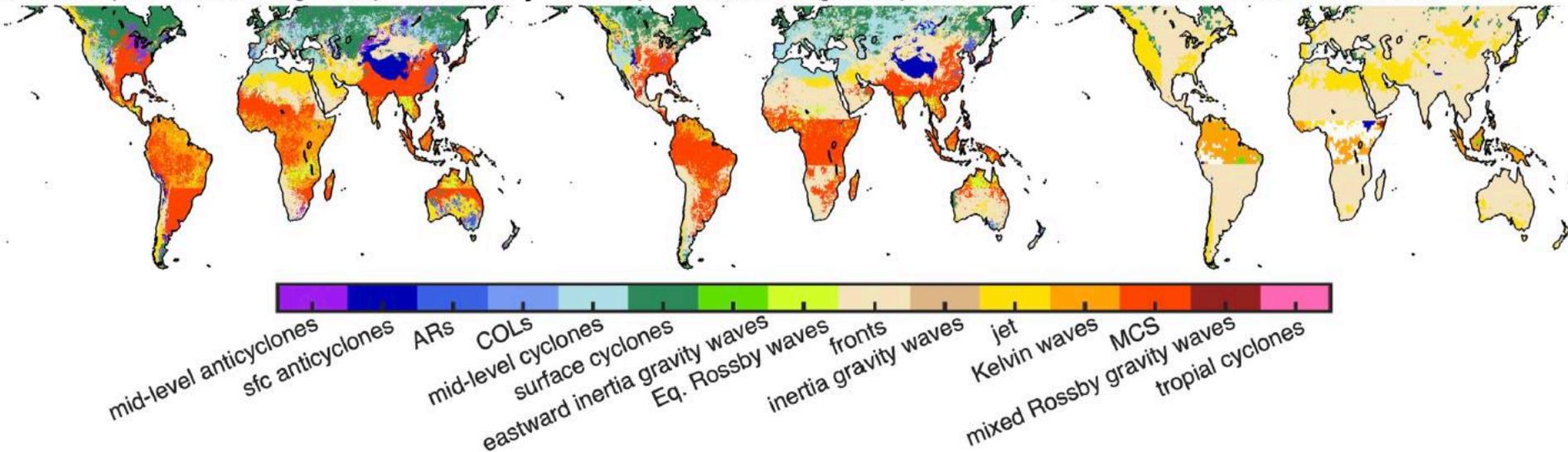
Animation from a CESM-HR simulation showing clouds in gray, precipitation in color with extreme precipitation in red, and MOAAP-tracked mesoscale convective systems (MCSs) outlined in purple

# CESM-HR simulation of extreme precipitation

## Mesoscale Convective Systems (MCSs)

## Jets & Fronts

**i** Most frequent features during Rx1day: Observation | **j** Most frequent features during Rx1day: CESM-HR | **k** Most frequent features during Rx1day: CESM-LR

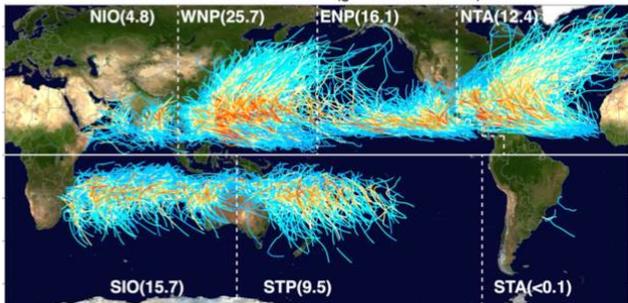


Detected by the Multi Object Analysis of Atmospheric Phenomenon (MOAAP; Prein et al. 2023) algorithm during Rx1day events over global land

# Tropical Cyclones (TCs)

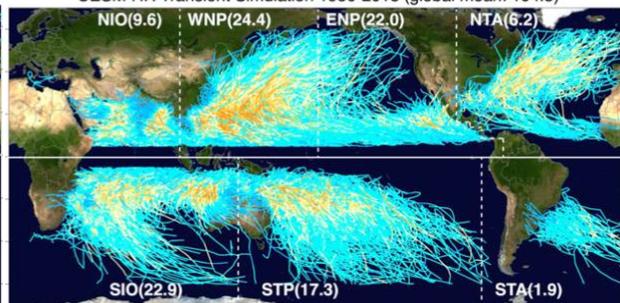
## IBTrACS Observations

Observation 1950-2015 (global mean: 82.4)



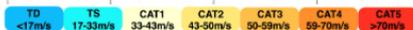
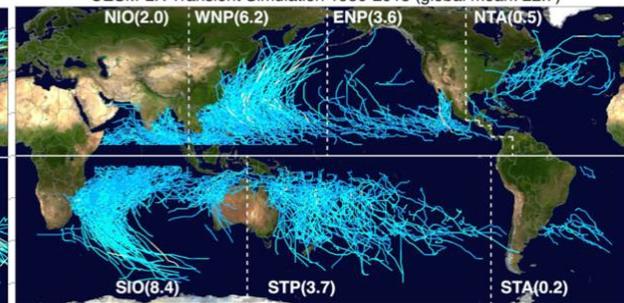
## CESM HR

CESM-HR Transient Simulation 1950-2018 (global mean: 104.3)

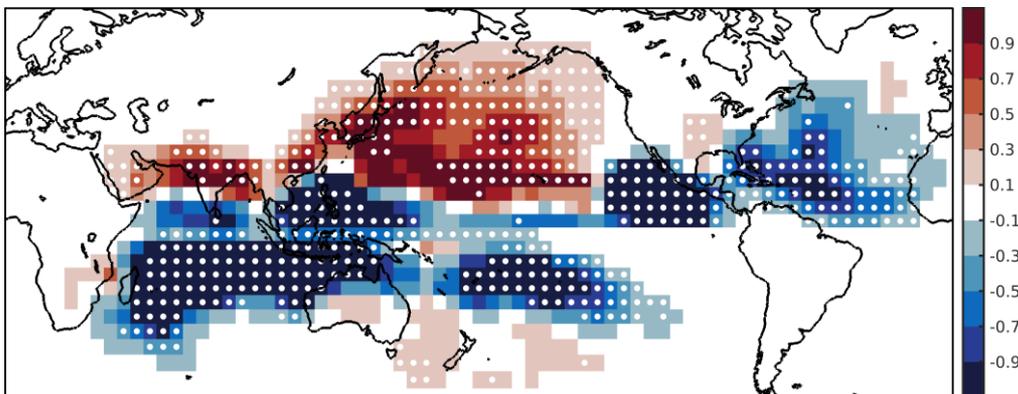


## CESM LR

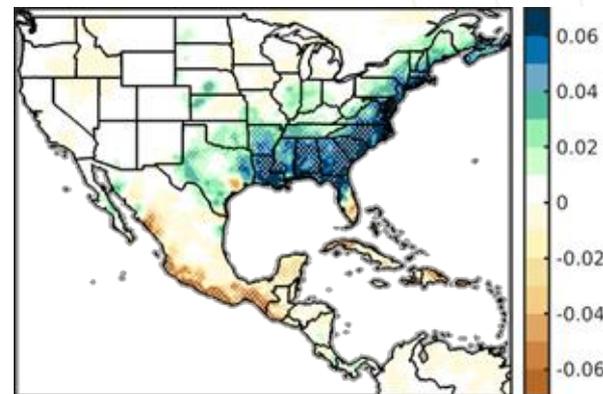
CESM-LR Transient Simulation 1950-2018 (global mean: 22.7)



Chang et al. (2020)



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



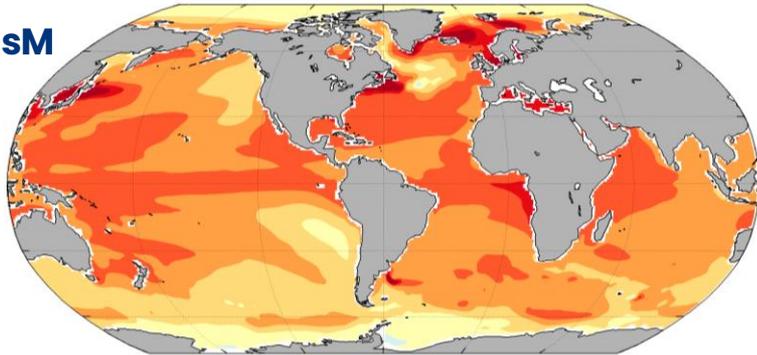
Trend of Annual-Mean TC-Induced Rainfall (1980-2100)

Fu et al. (2026)

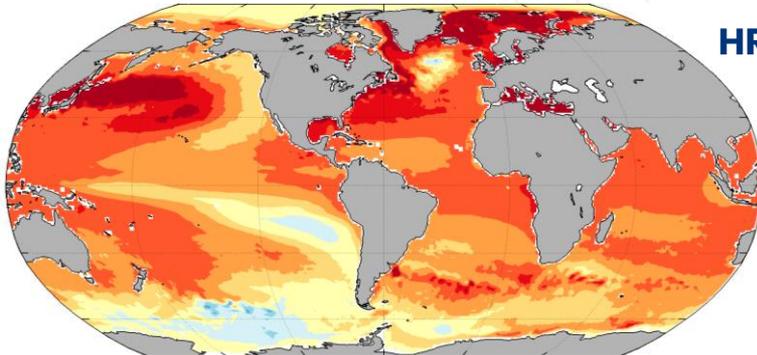
# SST Linear Trend (1980–2022)



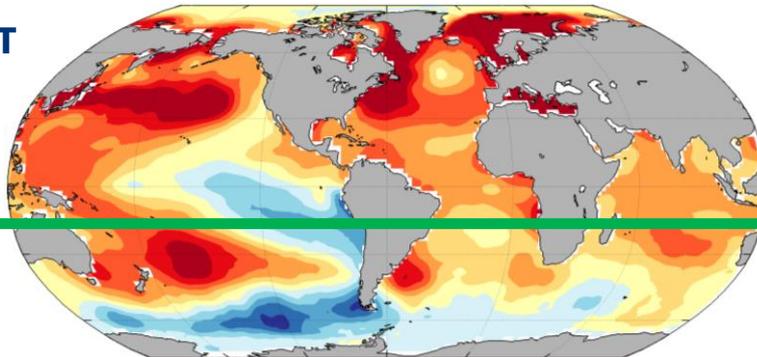
LR EnsM



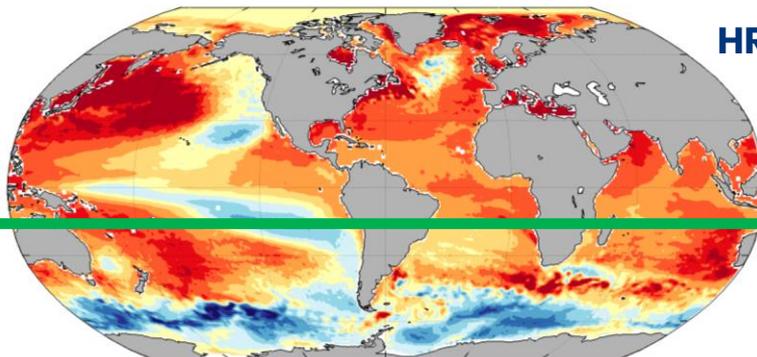
HR EnsM



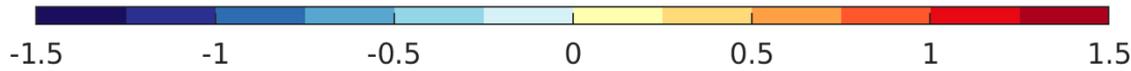
ERSST



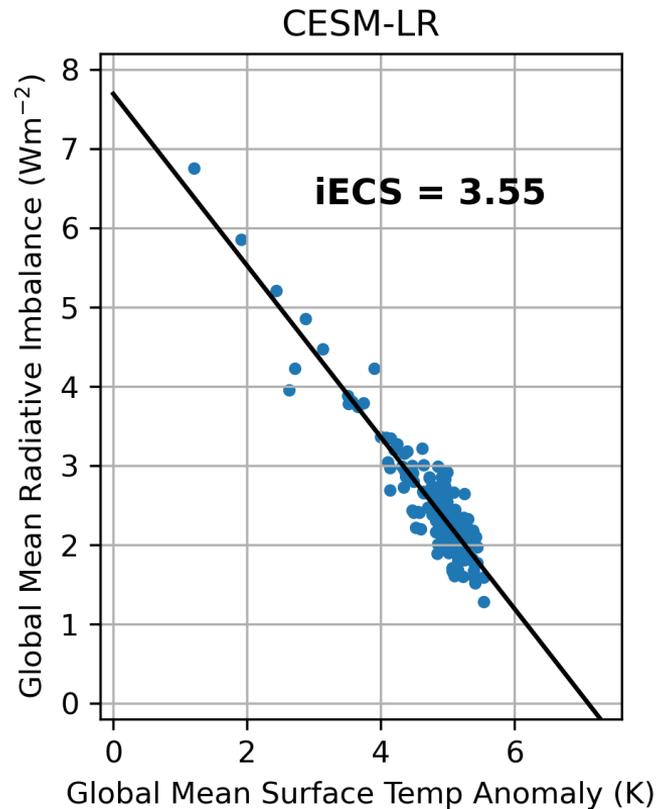
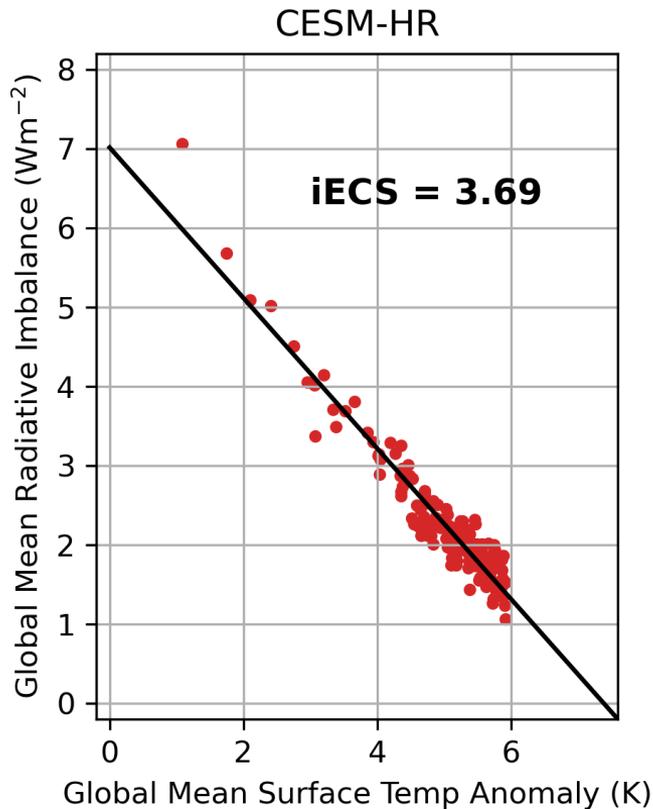
HR #010



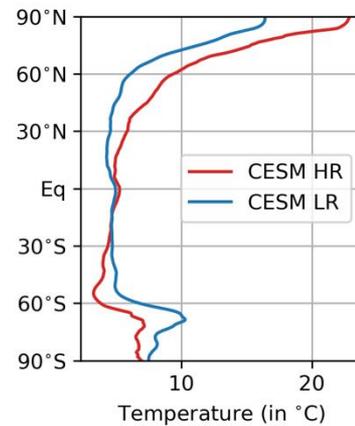
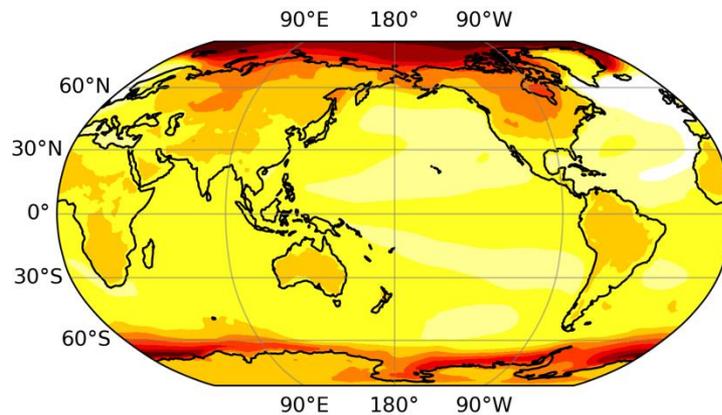
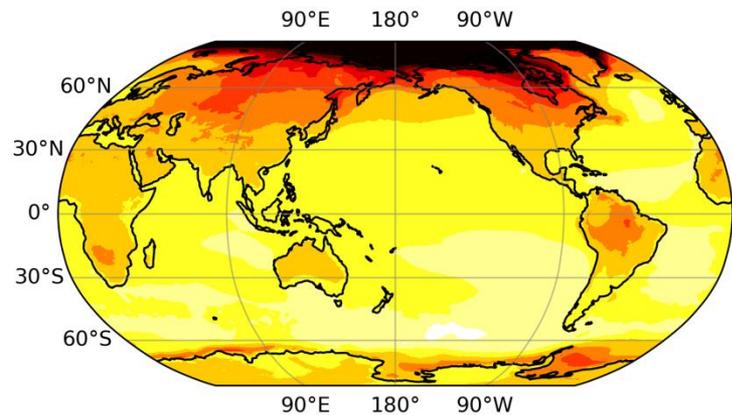
SST change [ $^{\circ}\text{C}/43\text{yr}$ ]



# Equilibrium Climate Sensitivity from 4xCO<sub>2</sub>

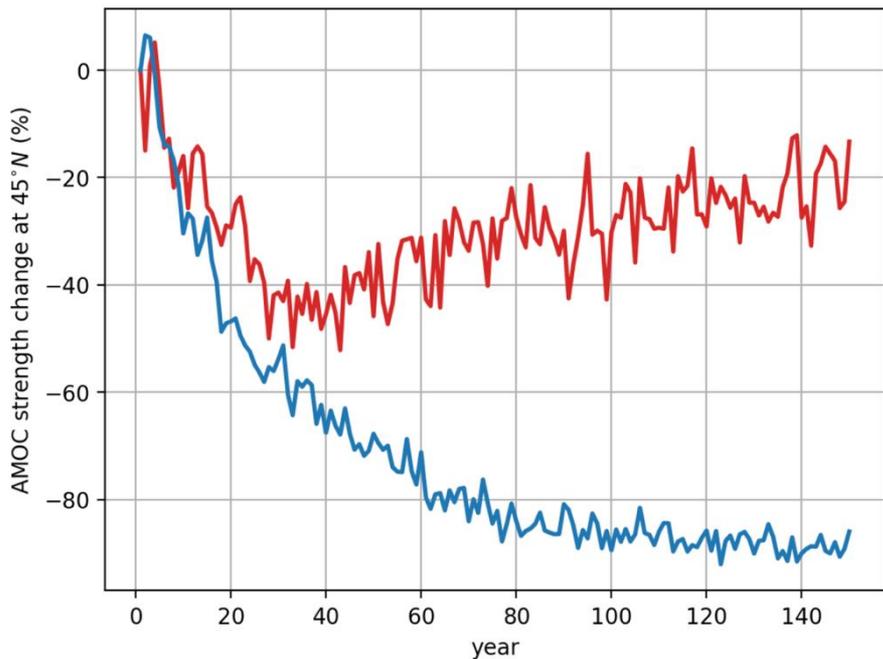


# Surface warming under abrupt 4xCO<sub>2</sub>

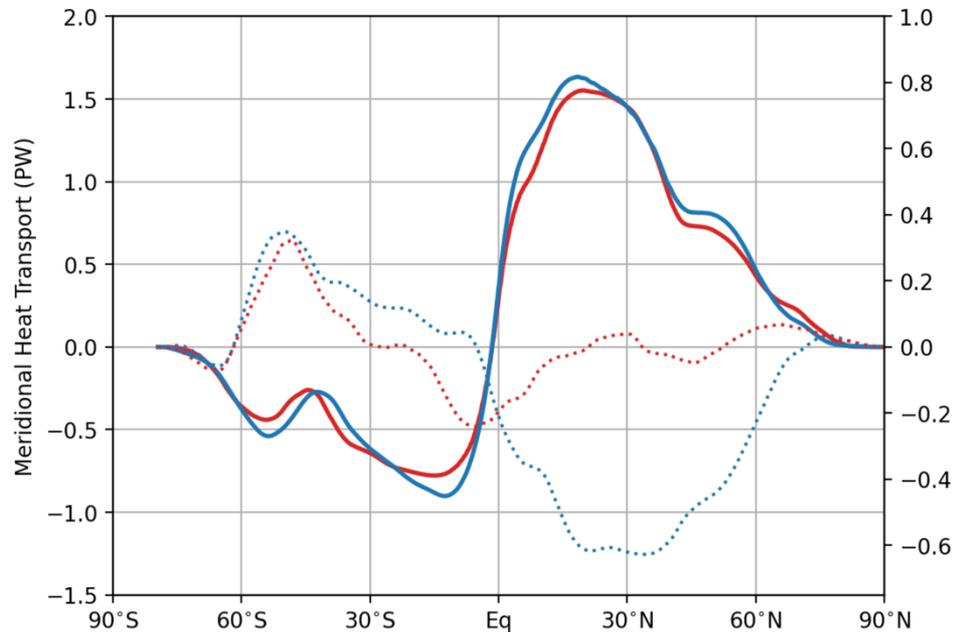


# Ocean response under abrupt 4xCO<sub>2</sub>

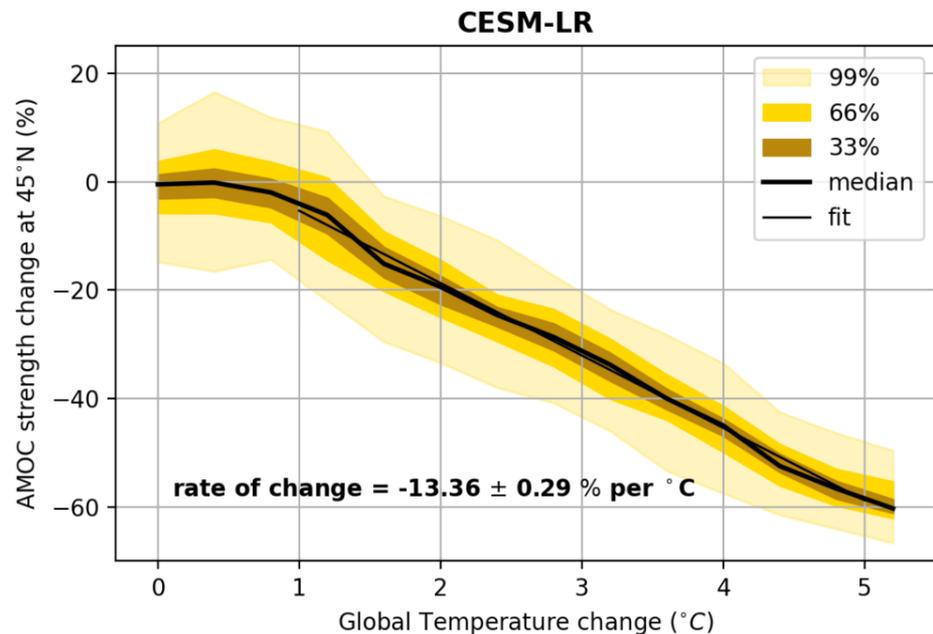
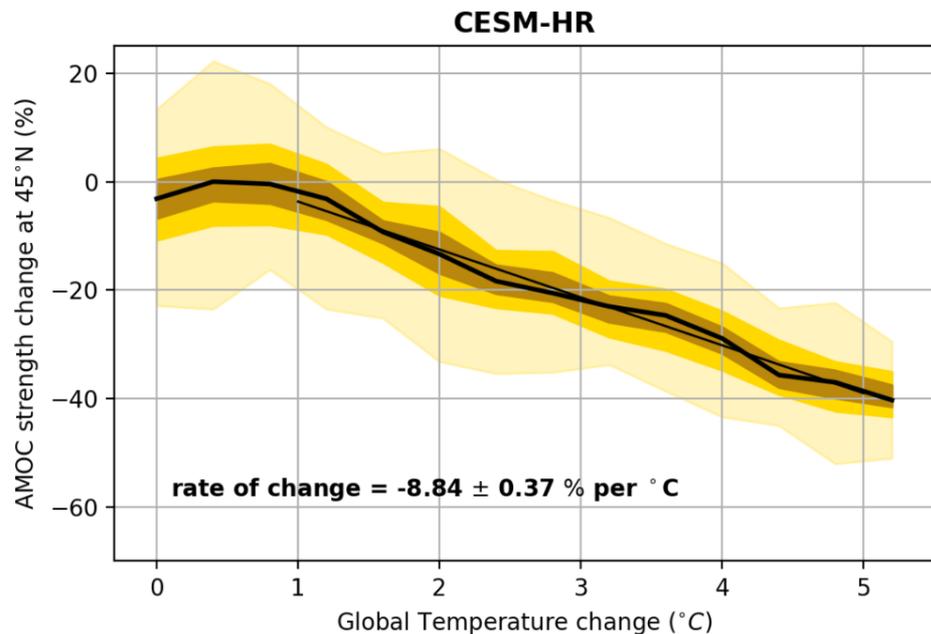
## Annual mean AMOC at 45°N



## 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:

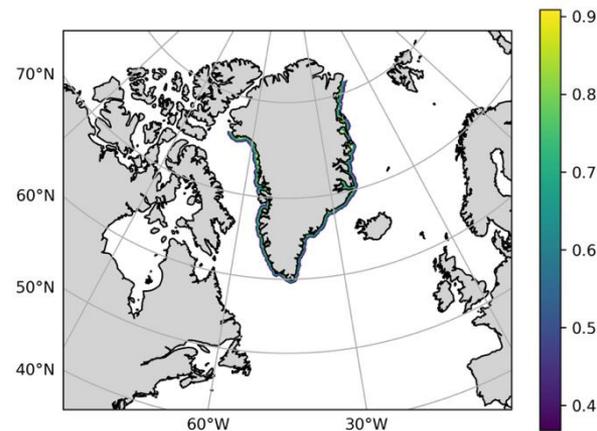
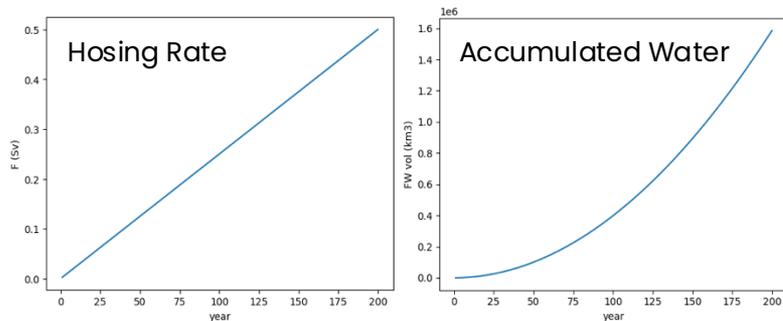
- ❖ Where is the AMOC stability threshold with respect to Greenland (ice sheet) freshwater fluxes in strongly eddying climate models?
- ❖ How does the explicit representation of eddies affect AMOC stability?

## Experiments:

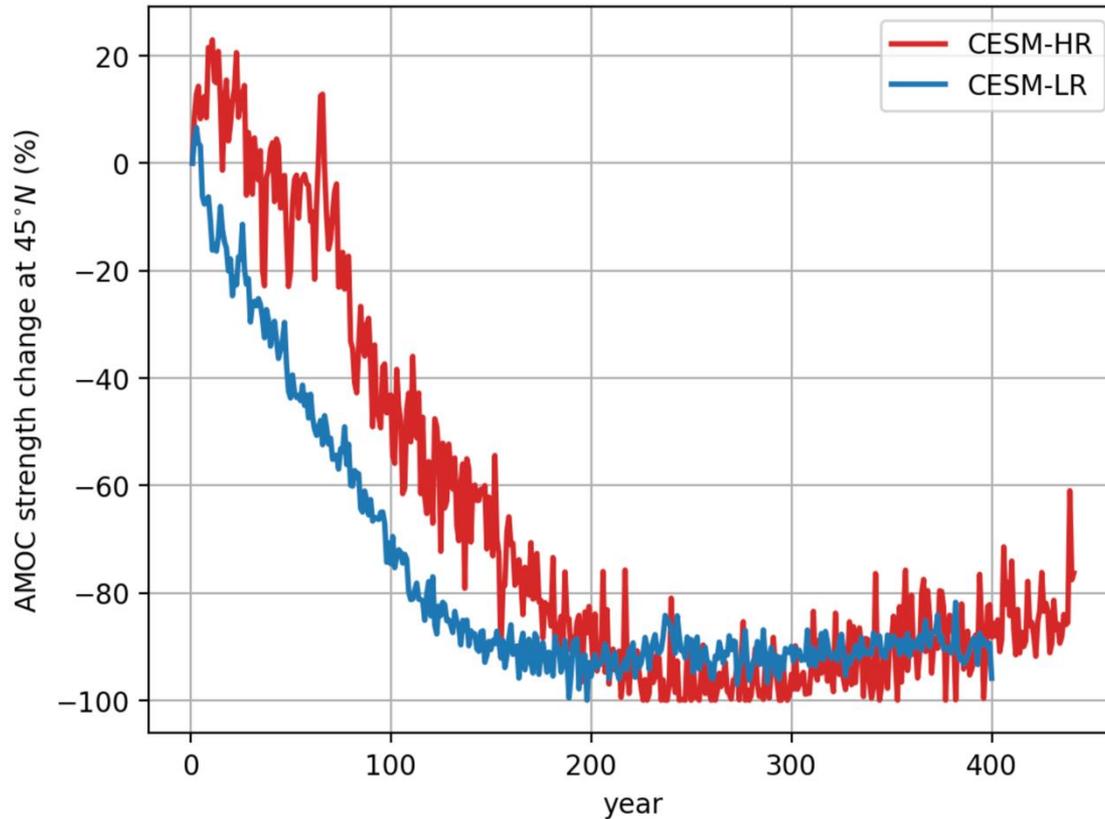
- A 200-year simulation with 0.25 Sv / century (IC: PI control)
- A 200-year continuation simulation with no hosing
- Corresponding low-resolution ( $\sim 1^\circ$ ) experiments

## A few details:

- 50-km exponential spread off the coast
- Exponential decay in the vertical with e-folding length of  $\sim 50$  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?**

