21 SEPTEMBER 2026

MESACLIP Project: Southern Ocean Trends and Eddy Compensation

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

Travis Prochko[2], Xue Liu[2], Qiuying Zhang[2], Gaopeng Xu[2], Steve Yeager[1], Clara Deser[1], & Pedro DiNezio[3]

[1]NSF NCAR; [2]TAMU; [3]UCB

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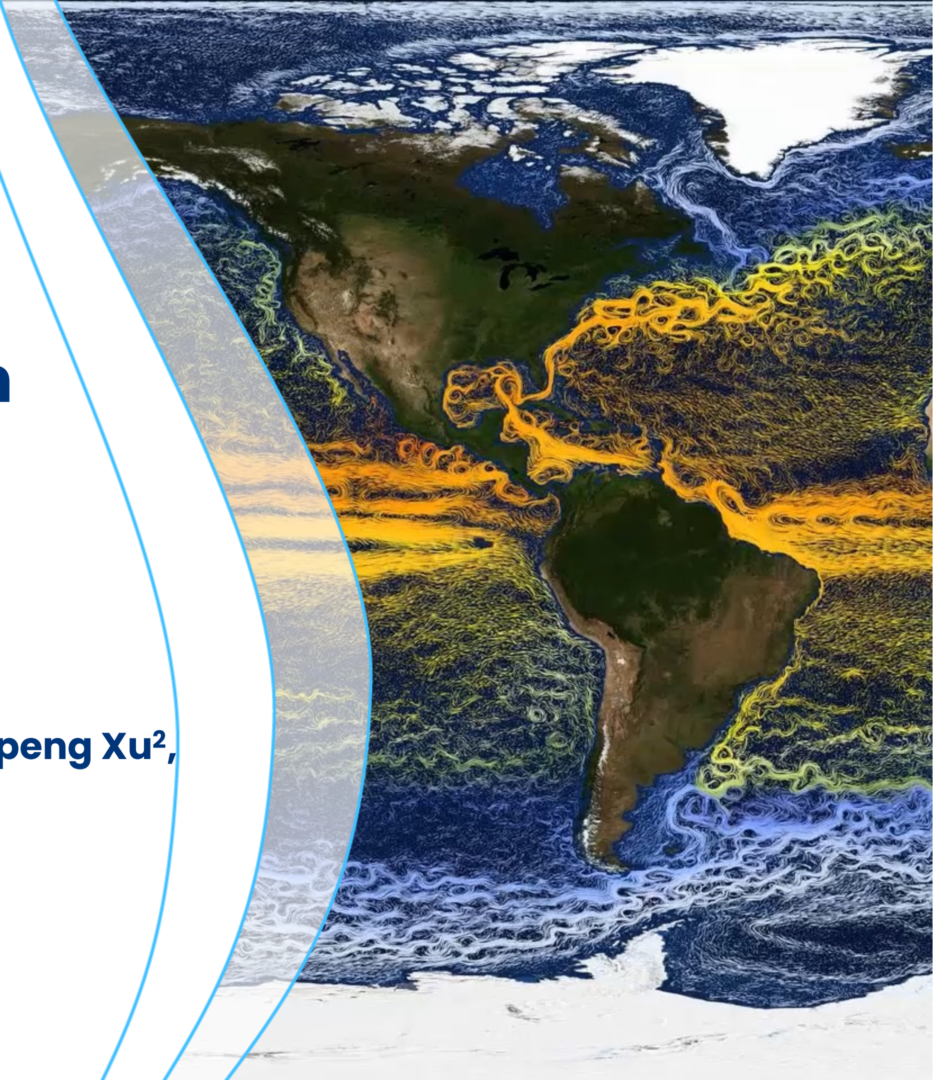
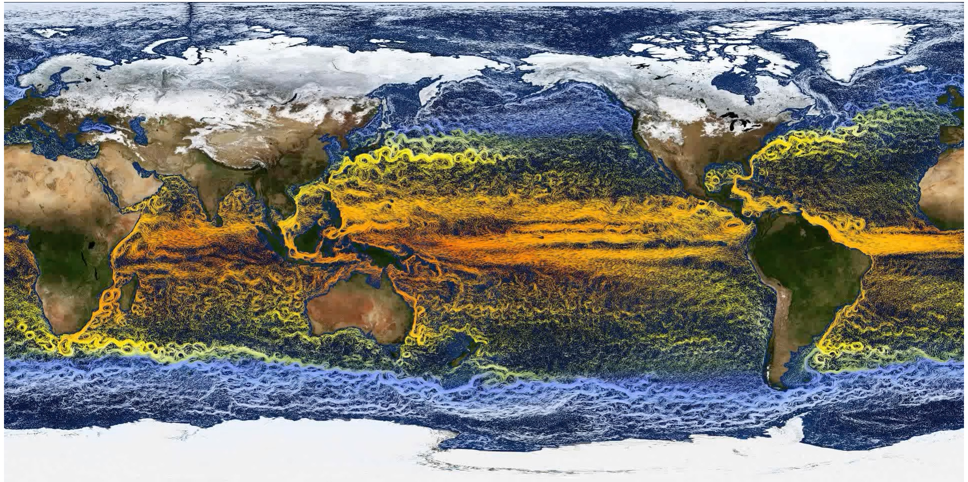


Outline

- Introduction to the CESM High-Resolution (CESM-HR) configuration and the MESACLIP Project;
- Southern Ocean trends and role of eddy compensation;
- Summary

Surface Currents Colored by Temperature



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

What is CESM-HR?

AGU ADVANCING EARTH AND SPACE SCIENCE
Check for updates

JAMES | Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE
10.1029/2020MS002298

Key Points:
- An unprecedented set of multi-century high-resolution Community Earth System Model (CESM) simulations is described
- High-resolution CESM simulations reveal a potential role of Southern Ocean polynyas in multidecadal climate variability
- High-resolution CESM exhibits significantly improved simulations of extreme events, such as tropical cyclones and atmospheric rivers

An Unprecedented Set of High-Resolution Earth System Simulations for Understanding Multiscale Interactions in Climate Variability and Change

Ping Chang[1,2,3], Shaoqing Zhang[1,4,5], Gokhan Danabasoglu[1,6], Stephen G. Yeager[1,6], Haohuan Fu[1,7,8], Hong Wang[1,4,5], Frederic S. Castruccio[1,6], Yuhu Chen[9], James Edwards[1,6], Dan Fu[1,2], Yinglai Jia[1,5], Lucas C. Laurindo[1,6], Xue Liu[1,2], Nan Rosenbloom[1,6], R. Justin Small[1,6], Gaopeng Xu[1,2], Yunhui Zeng[10], Qiuying Zhang[1,2], Julio Bacmeister[1,6], David A. Bailey[1,6], Xiaohui Duan[8,11], Alice K. DuVivier[1,6], Dapeng Li[1,2], Yuxuan Li[11], Richard Neale[6], Achim Stössel[1,2], Li Wang[10], Yuan Zhuang[10], Allison Baker[1,6], Susan Bates[6], John Dennis[6], Xiliang Diao[1,2], Bolan Gan[1,4,5], Abishek Gopal[1,2], Dongning Jia[9], Zhao Jing[1,4,5], Xiaohui Ma[1,4,5], R. Saravanan[1,3], Warren G. Strand[6], Jian Tao[1,12], Haiyuan Yang[1,4,5], Xiaoqi Wang[1,2], Zhiqiang Wei[9], and Lixin Wu[4,5]

Funded by US NSF

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

Based on the Community Earth System Model version 1.3, CESM1.3;

Horizontal resolution: 0.1° ocean and sea ice, 0.25° atmosphere and land;

Parallel Ocean Program version 2 (POP2) with 62 vertical levels and no meso-, submeso-scale, or overflow parameterizations.

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CESM-HR code has been ported and optimized for multiple HPC systems, including Frontera at Texas Advanced Computing Center (TACC) and Derecho at NSF NCAR Wyoming Supercomputer Center (NWSC);

On 28 544 CPU cores on Derecho, CESM-HR achieves ~5 simulated years per day with IO;

CESM-HR / CESM-LR cost ratio ~ 100!

10 000+ yrs of CESM-HR simulations and ~7 PB data volume!

CESM-HR Simulations

500-year PI control;

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

600-yr North Atlantic hosing;

10-member (1850) 1920-2005 historical;

10-member 2006-2100 transient w/ RCP8.5;

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

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

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

6-member 1970-2020 Ozone withholding;

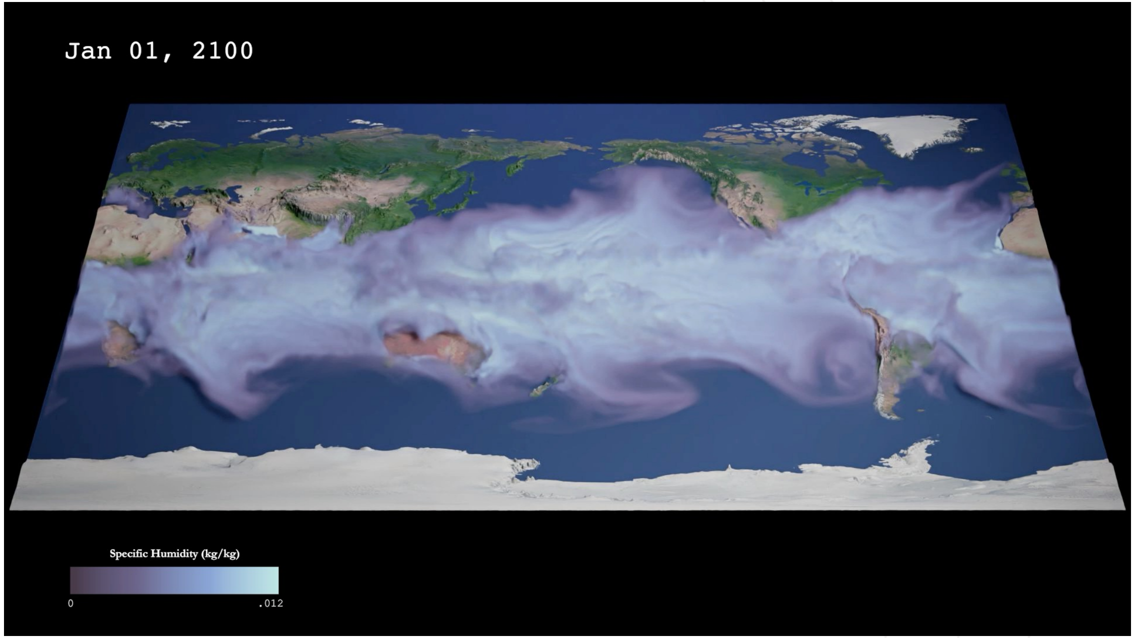
5-member 1950-2014 AMIP;

All HighResMIP coupled and AMIP;

5 cycles of 1958-2018 OMIP (FOSI);

Decadal Predictions (1980-2023; HRDP); and

Corresponding low-res (~1°) simulations



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

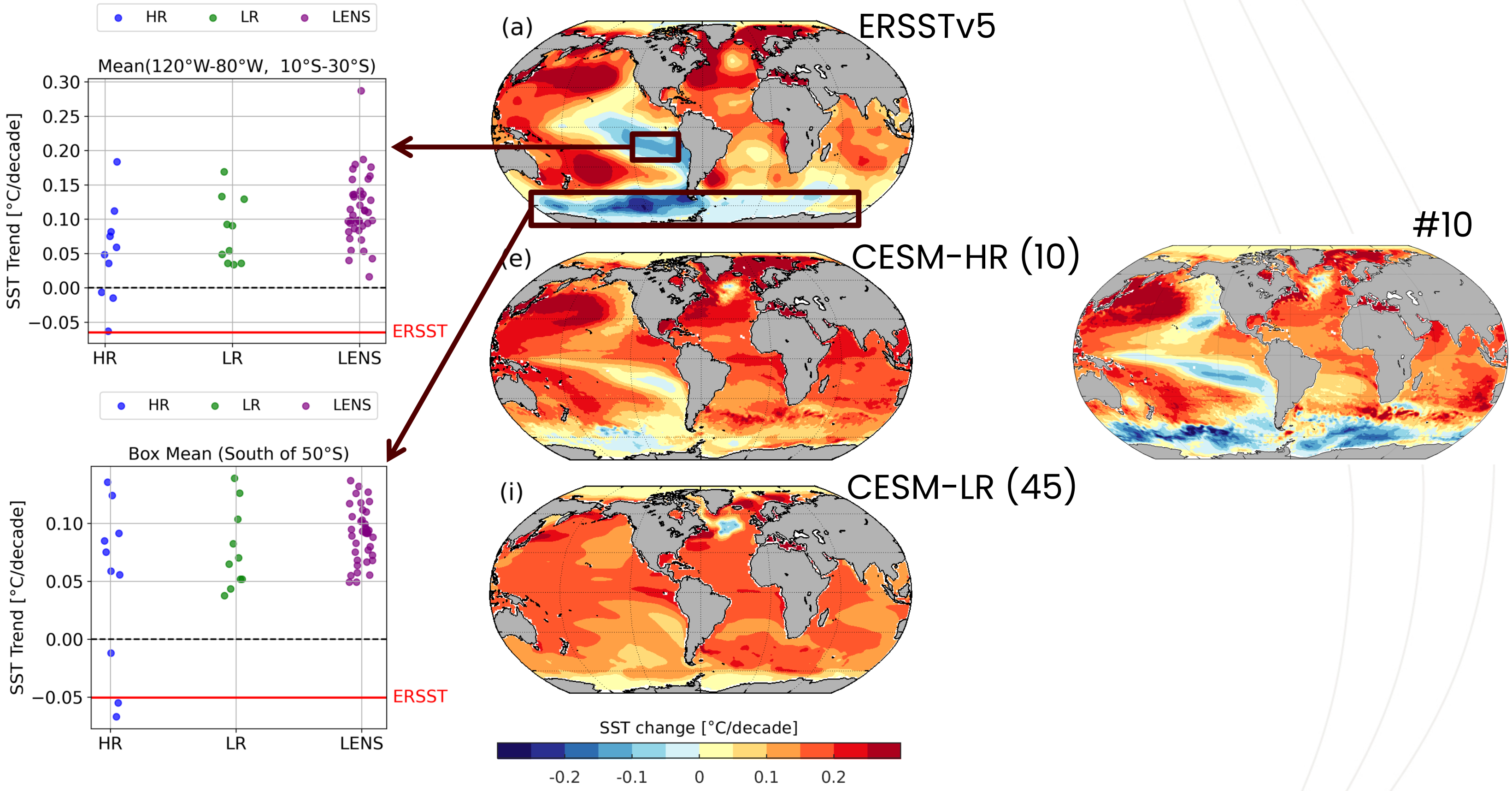
Datasets are available to the community!

Southern Ocean Trends (1980-2022)

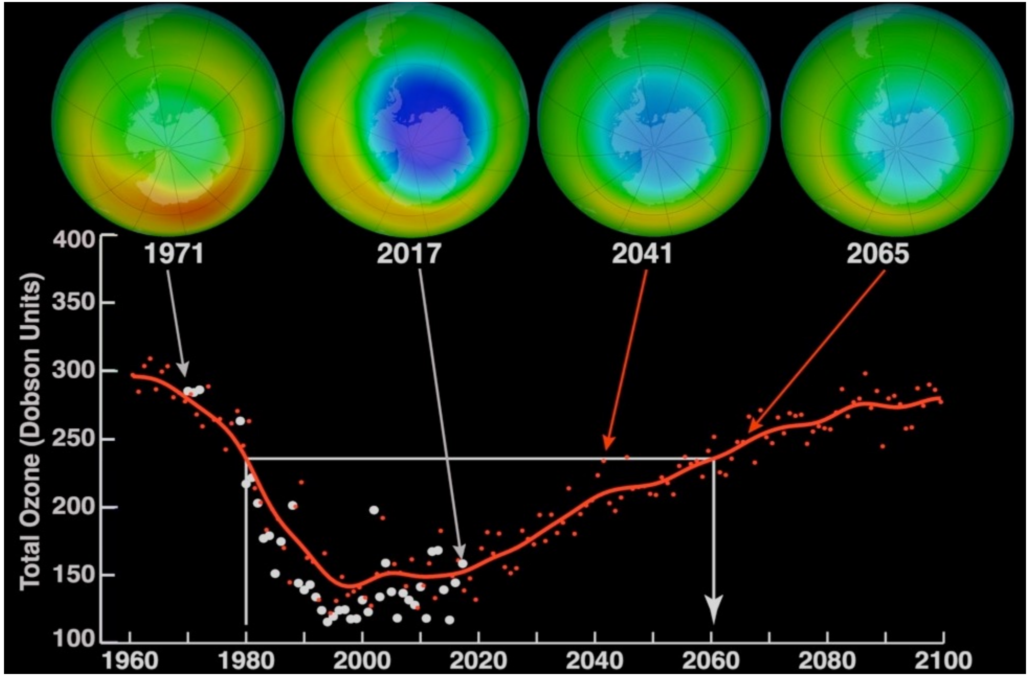
Manuscript in review in Nature Communications Earth & Environment

Travis R. Prochko and Co-Authors

SST Linear Trends in the Southern Ocean



Role of Antarctic Ozone Hole



https://svs.gfsc.nasa.gov/30602

PNAS RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES

The Antarctic ozone hole and the pattern effect on climate sensitivity

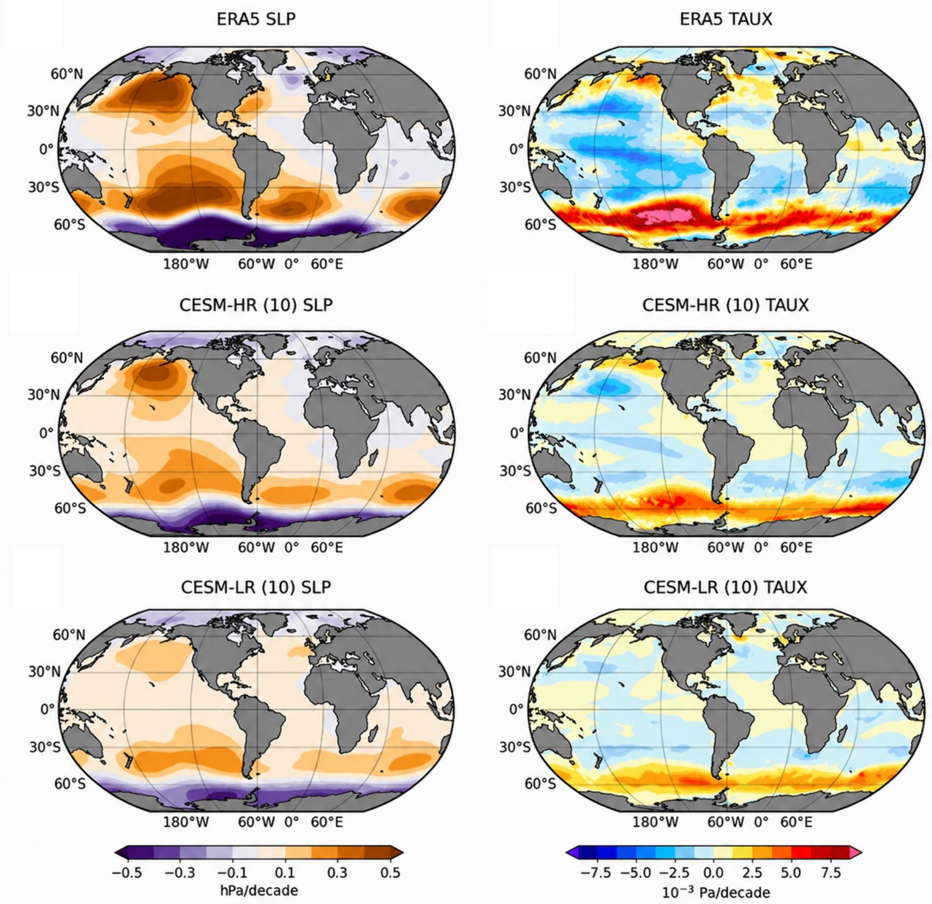
Dennis L. Hartmann[a,1]

2022

Ozone hole results in increased westerlies at the Southern Ocean (SO) latitudes, leading to cooling in the SO.

There is an associated cooling in the eastern tropical Pacific.

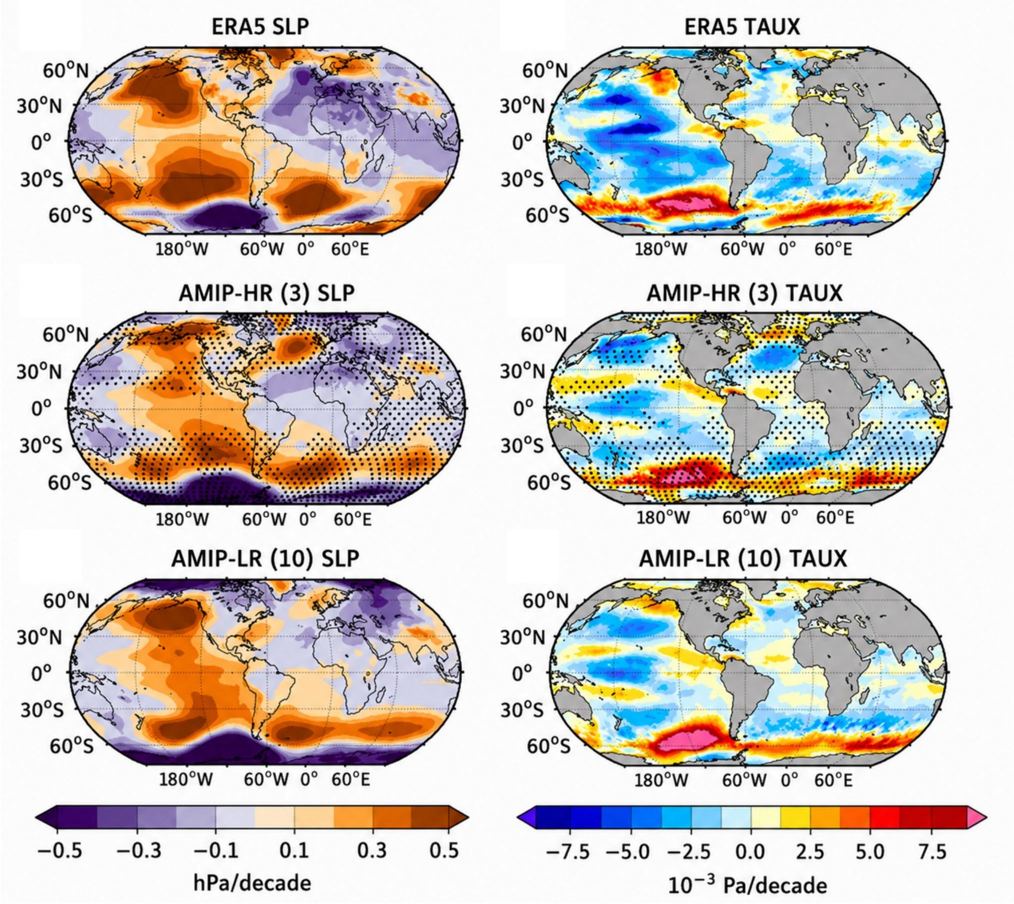
Sea Level Pressure and Zonal Wind Stress Trends



SLP and TAUX Trends from AMIP Simulations

Both HR and LR AMIP simulations use the same 0.25° SST field

1980-2014 trends

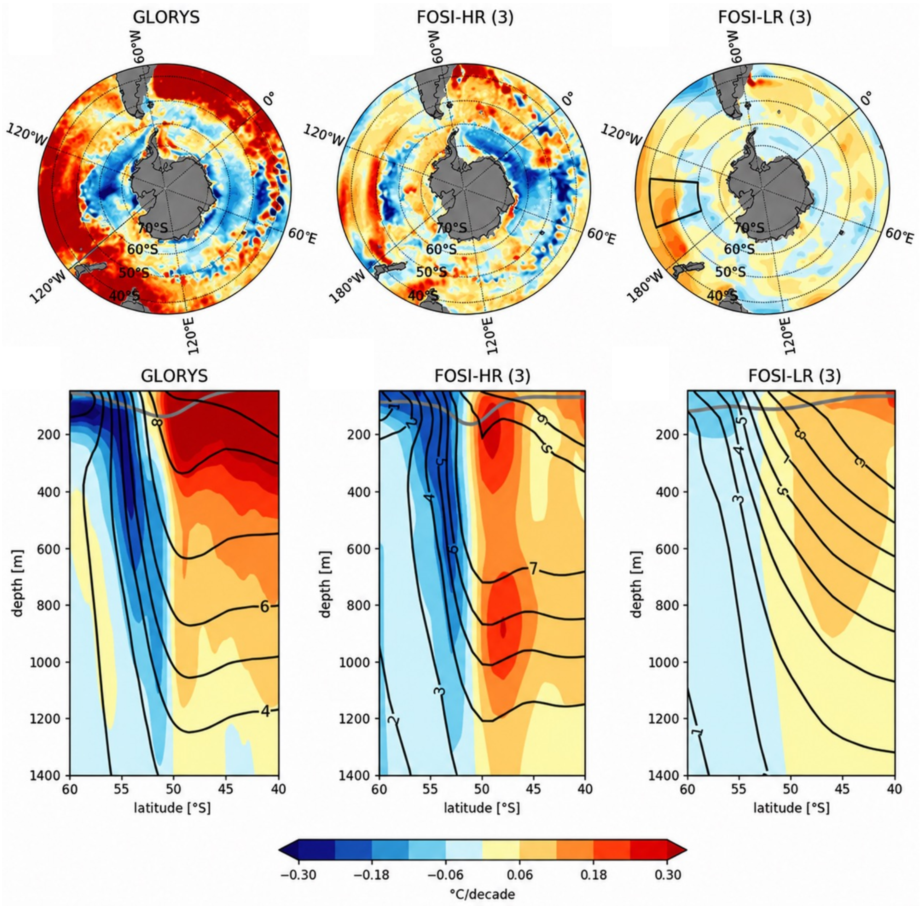


Stippling indicates no statistically significant differences between HR and LR AMIP

Upper-Ocean Temperature Trends from FOSI

100-500 m average

Zonal average within the box shown

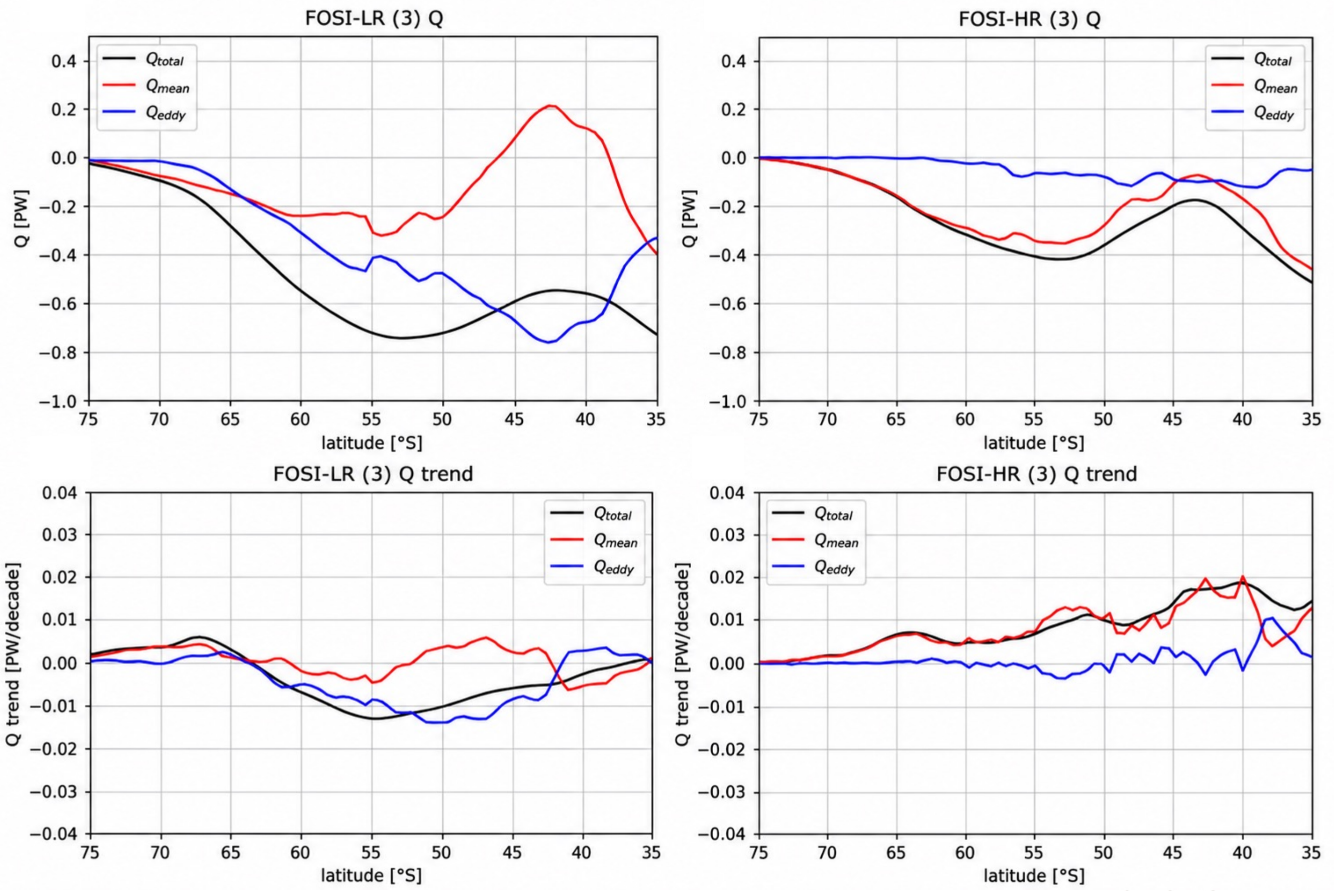


Temperature is shown in black contours

Meridional Heat Transports from FOSI

Time-mean

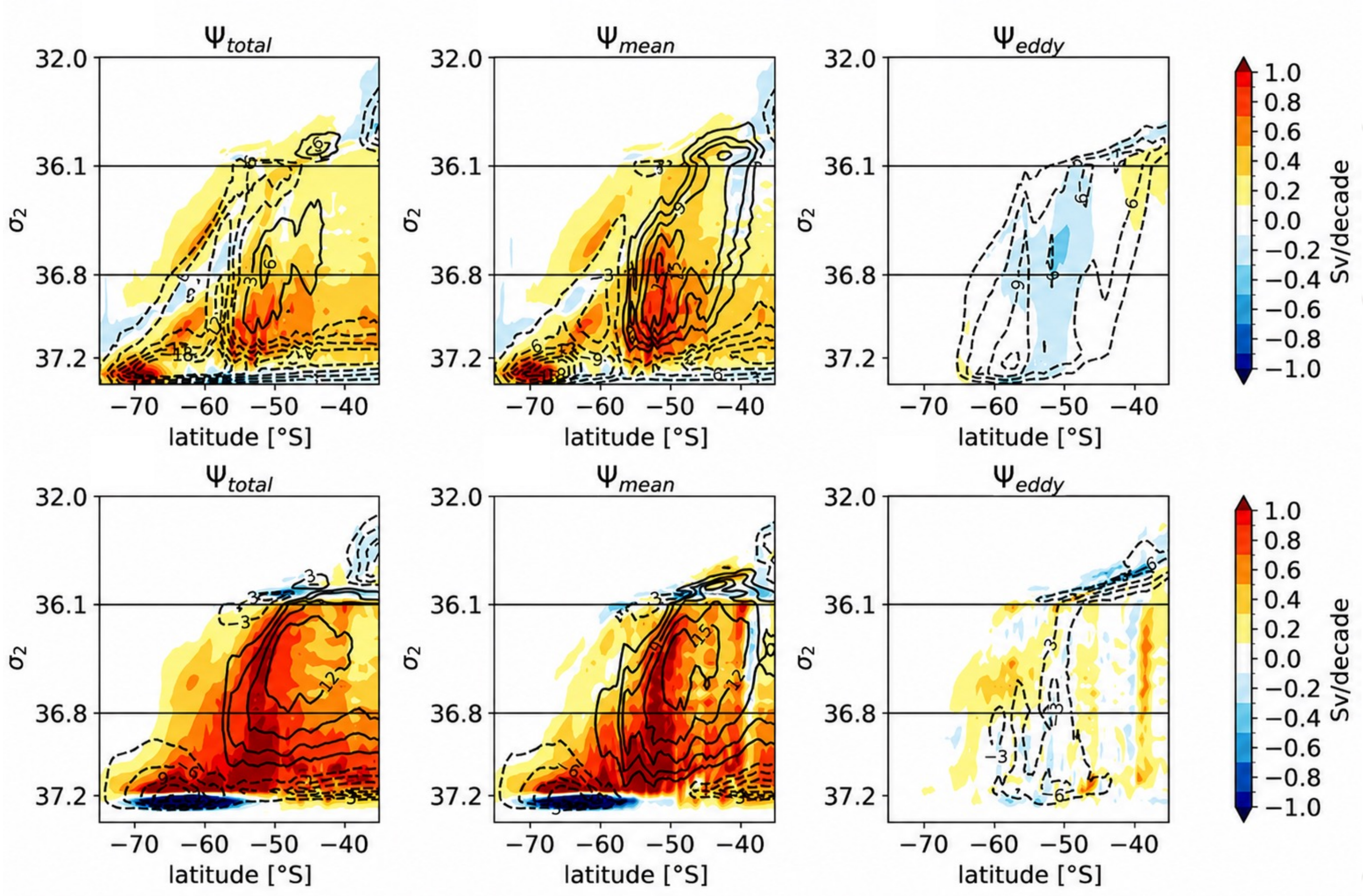
Linear trends



Meridional Overturning Circulation in FOSI

LR

HR

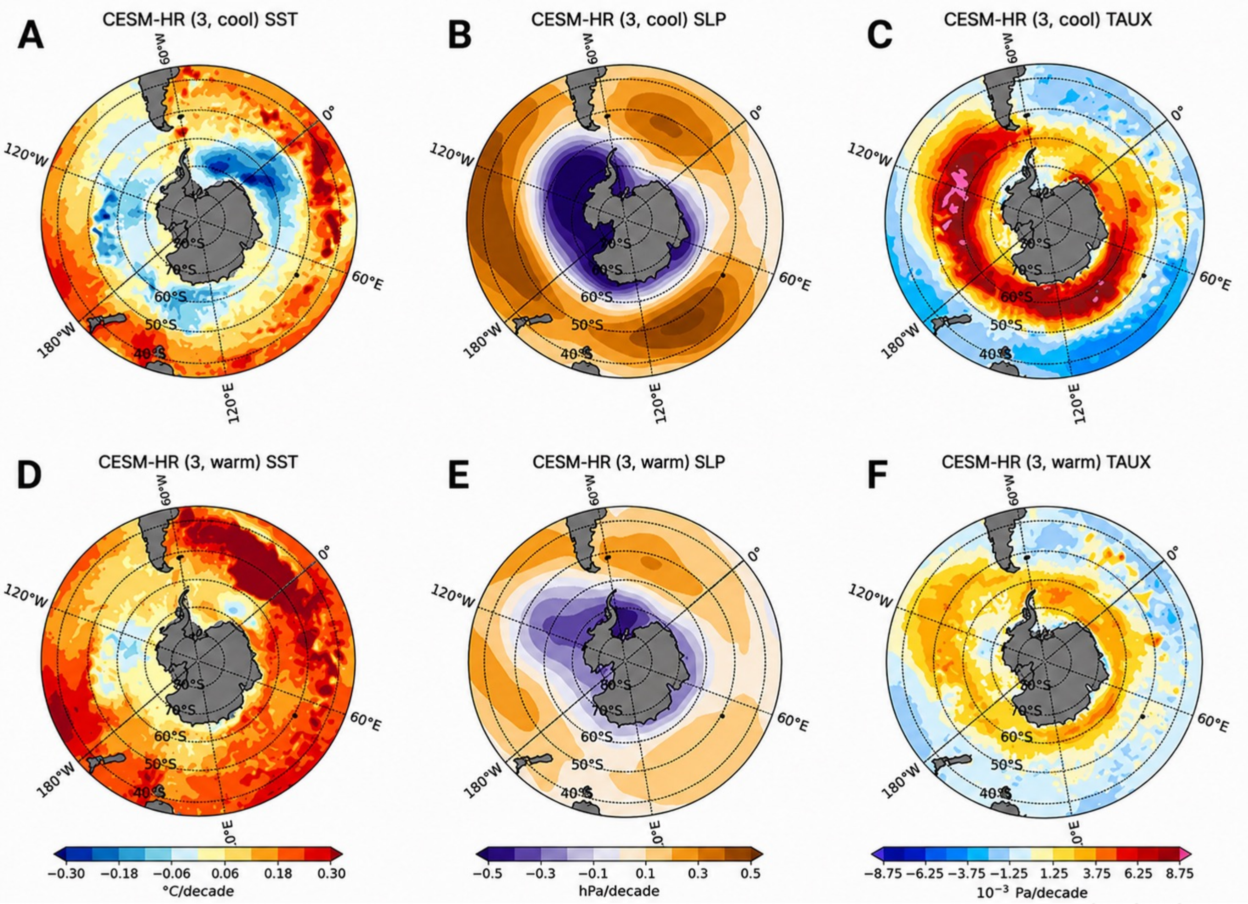


Color: Trends
Contours: MOC

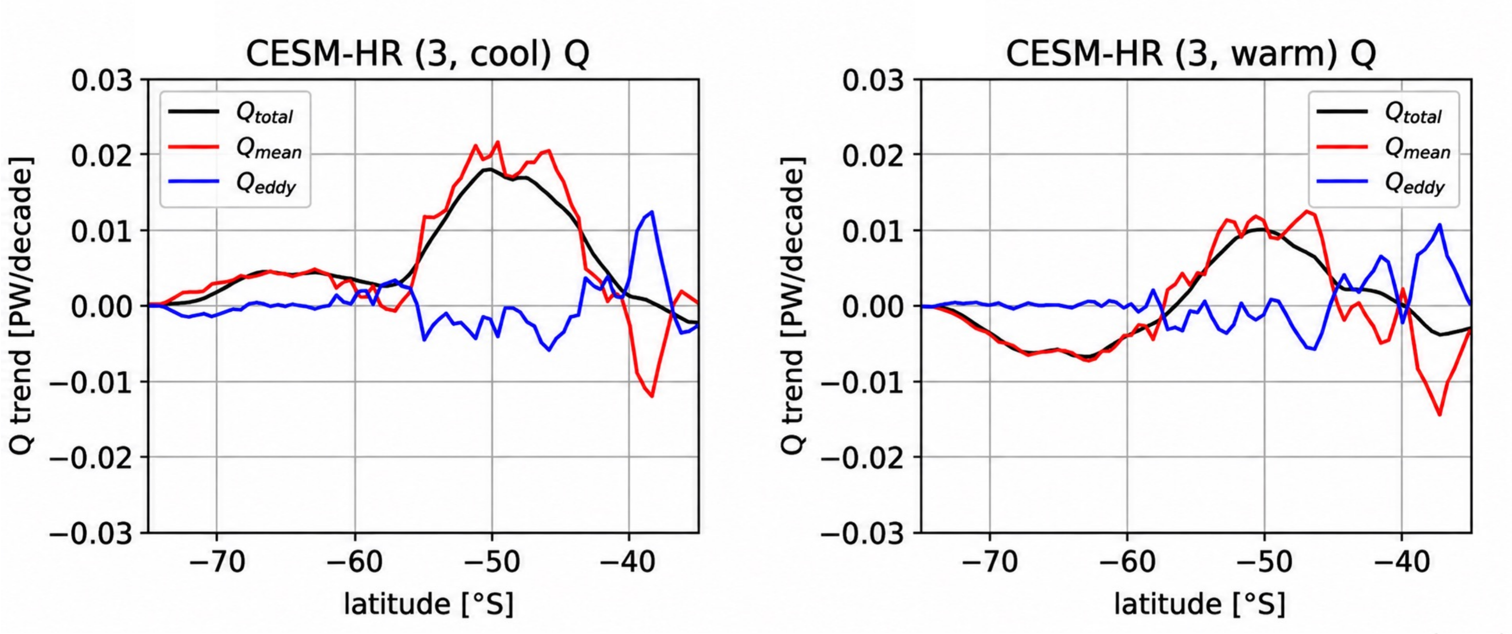
SST, SLP, and TAUX Trends in CESM-HR

3 Cool Members

3 Warm Members



Meridional Heat Transport Trends in CESM-HR



Summary

A large volume of high-resolution simulation datasets is available to the community.

HR simulations capture the observed Southern Ocean surface cooling trends which are missing in the LR simulations.

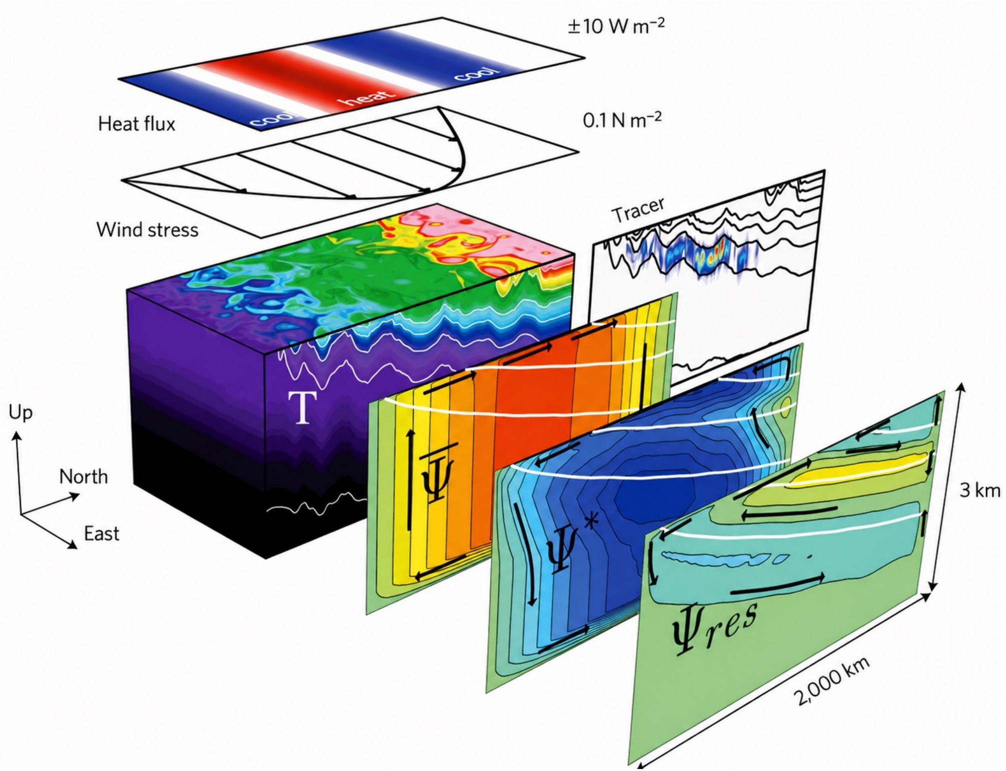
In LR, eddy compensation is strong, impacting southward heat transport significantly.

In contrast, eddy compensation / contribution is rather small in HR; the total heat transport is largely dictated by the mean flow.

While the ozone-driven intensification of the westerlies initiates surface cooling through enhanced equatorward Ekman transport, the persistence and amplification of this cooling is regulated by oceanic eddy compensation.

Both external forcing and internal variability are important!

Eddy Compensation



Marshall & Speer (2012, Nat. Geosci.)