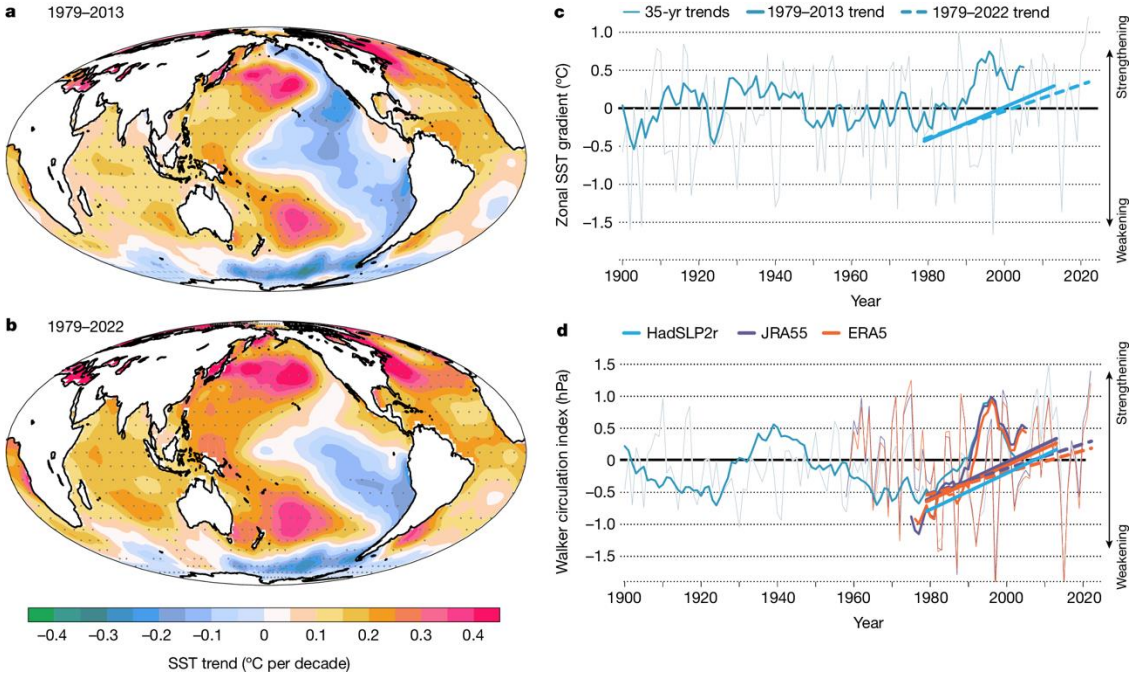
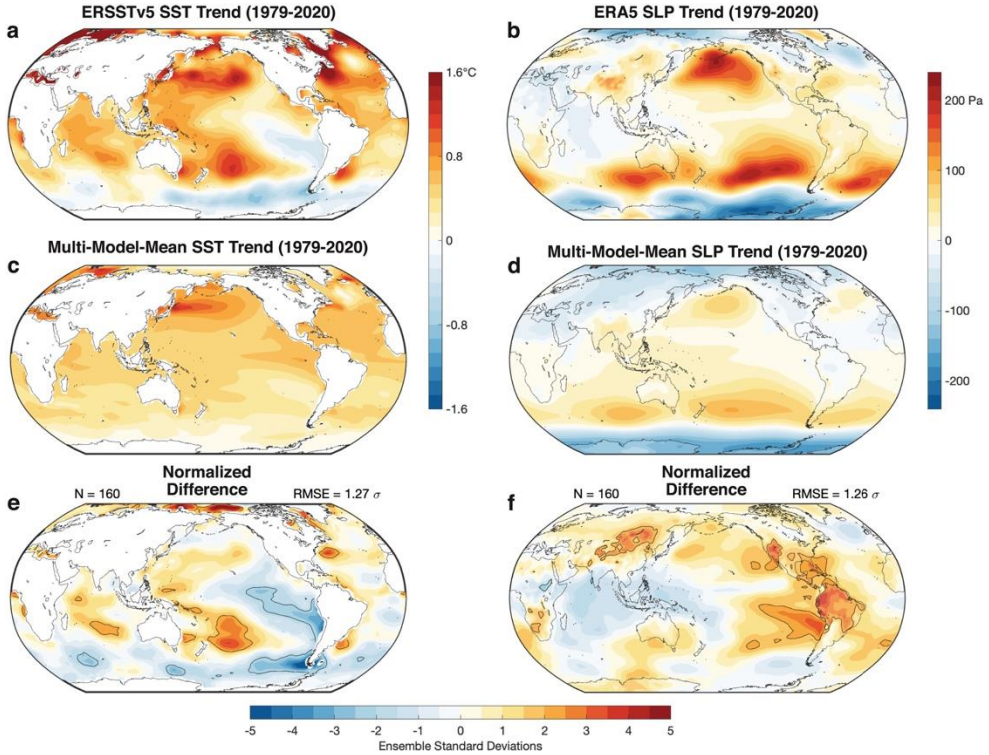
Tropical circulation has widespread global impacts:
It is important to understand what drives tropical circulation trends and understand how tropical atmospheric and ocean circulation is represented in climate models



Observations show strengthening Pacific SST gradients and associated strengthening of the Walker circulation

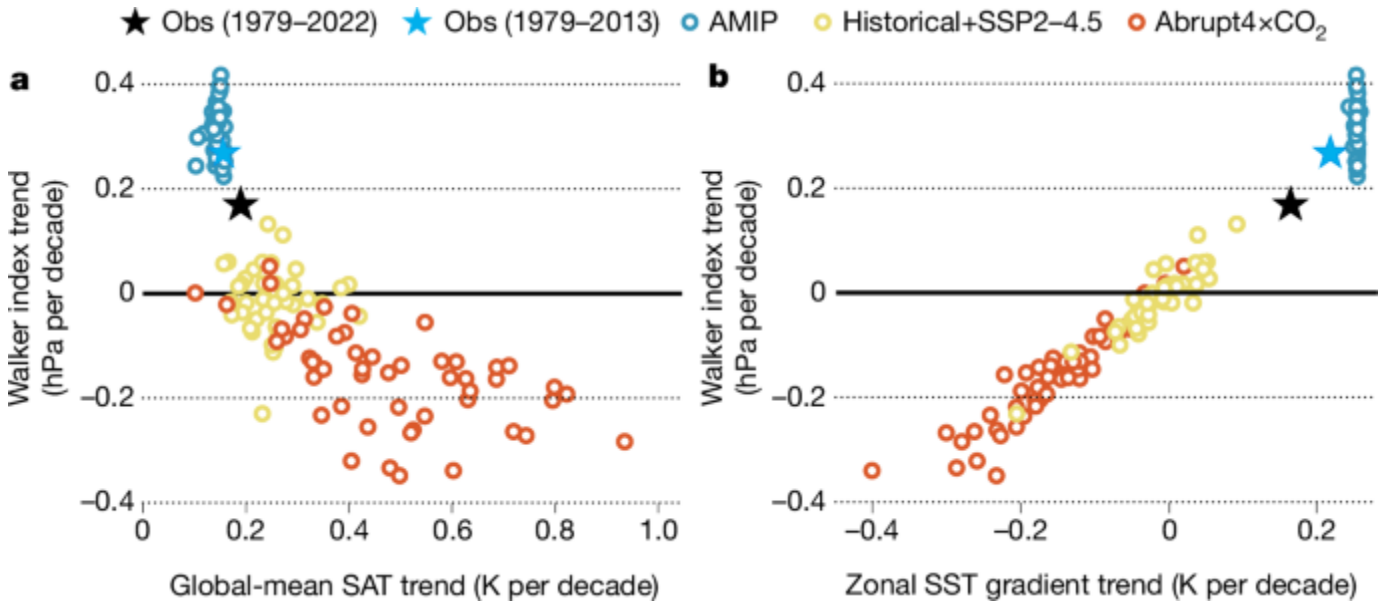
Watanabe et al., 2024, Nature

There are now well documented **discrepancies in modelled and observed Pacific SST gradients**



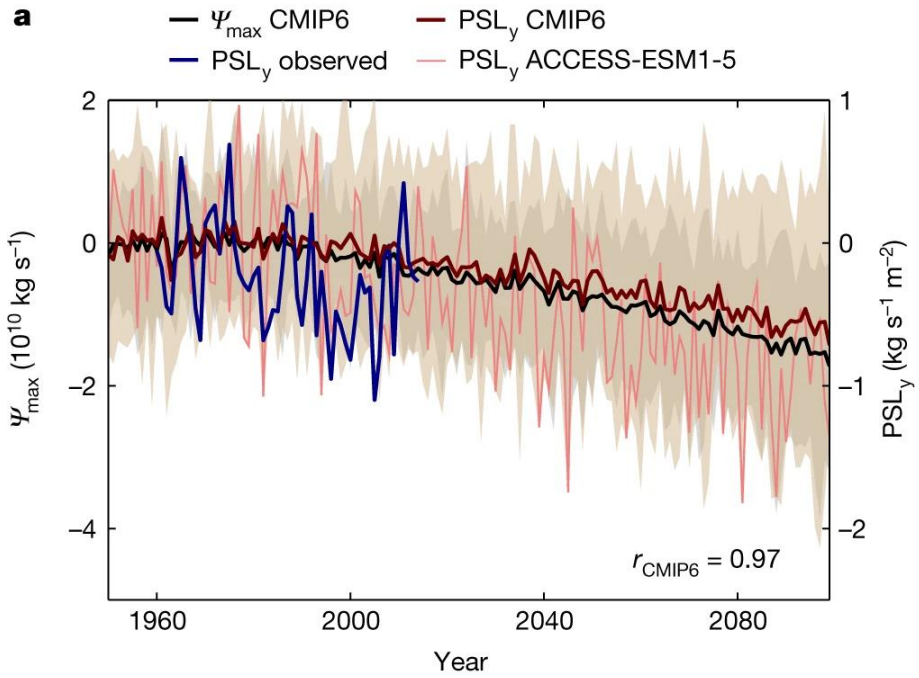
Wills et al. 2022, *GRL*

Observed strengthening in the Pacific SST gradients and associated strengthening of the Walker circulation



Watanabe et al., 2024, Nature

Changes also need to be understood in the Hadley circulation strength, among other tropical circulation components



Chemke and Yuval, 2023, Nature

In EPESC WG2 and LEADER, we analyse the Large Ensemble Single Forcing MIP (LESFMIP, Smith et al. 2022) to understand the causes of model trends and model differences / errors

World Climate Research Programme

WCRP Lighthouse Activity Explaining and Predicting Earth System Change
Working Group 2 - Integrated Attribution, Prediction and Projection

Activity: Tropical circulation variability and trends

Contributions: David Avisar, Annalisa Cherchi, Andrea Dittus, Chaim Garfinkel, June-Yi Lee, Scott Osprey, Holger Pohlmann, Penny Maher, Doug Smith, Jonathon Wright

WCRP EPESC LHA WG2 Activity: Tropical circulation variability & trends

Co-leads: Annalisa Cherchi (CNR-ISAC, Italy) and Andrea Dittus (U. Reading, UK)

Overarching objectives:

- To understand the causes of recent tropical ocean and atmospheric circulation changes and assess their representation in climate models.
- To identify model differences and errors in the forced response to e.g. greenhouse gases, aerosols and natural external forcings and internal variability.

WCRP EPESC LHA WG2 Activity: Tropical circulation variability & trends

Key questions to be addressed:

- What are the roles of individual forcings and internal variability in driving recent multidecadal trends in the Walker circulation; the Hadley circulation; the Monsoons?
- How are changes in circulation of the tropical atmosphere coupled to changes in the circulation of the tropical oceans (e.g. link to tropical SST patterns)?
- What are the implications for near-term predictions and projections of tropical circulation change?

Expected outcomes: Overview paper on model differences/errors in tropical circulation in the LESFMIP ensemble (work in progress).

Open questions of interest to our WG:

What are the causes of recent observational trends in tropical circulation and SSTs?

1. Are the responses to adding and removing individual forcings linearly additive in climate models?
2. Are there signal-to-noise problems in the response of the tropical atmospheric circulation that contribute to errors in SST trends?

Update on activities so far:

LESFMIP analysis sprint, March 2025:

- 4 half-days of dedicated analysis time on JASMIN across WGs for all of LEADER-EPESC

- 2x 1 hour discussion slots on Zoom per day, spanning different timezones (12pm and 22pm UTC)

- Discussion platform on Slack (there were issues with licenses for some people)

Update on activities so far:

LESFMIP analysis sprint, March 2025:

- ~50 registrations, 15-20 active participants
- Figures were made during the week and active discussions about results, common colour scales, data gaps etc.

- Your feedback is requested: is there in doing it again sometime?
- Your feedback is requested: is there in setting up a discussion platform (e.g. Mattermost or Zulia)?

SST gradient trends 1950-2014

Penny Maher, from Maher et al. in prep.

- Model mean SST gradient trends are weaker than observations in all cases
- Half the models have strengthening ensemble means (like obs).

SST gradients

Contributed by Holger Pohlmann

- Simulated increase in both WP and Nino3 SSTs driven primarily by GHG forcing in LESFMIP models
- Plateau in NINO3 SSTs after ~mid 1980s, not reproduced in LESFMIP model means

ENSO

WP - Historical

NINO3 - Historical

Contributed by Holger Pohlmann

Pacific SLP trend discrepancy

Contributed by Chaim Garfinkel

Pacific SLP trend discrepancy

Contributed by Chaim Garfinkel

Walker Circulation

Observations show a **strengthening Walker circulation,** whereas most models show a weakening, but there are notable exceptions: e.g. NorESM2-LM

Contributed by Jonathon Wright (left) and Andrea Dittus (right)

Global monsoon precipitation & NH monsoon circulation

- Global monsoon intensity decrease in historical LESFMIP simulations (MMM) primarily driven by aerosol forcing

MJJAS minus NDJFM

Eyring et al 2021

Contributed by Jonathon Wright and Annalisa Cherchi

Global monsoon precipitation & NH monsoon circulation

NHSM index
(u850 minus u200, 0-20N, 120W-120E)

- GHGs drive a weakening of the NH monsoon circulation in LESFMIP, while the AER forcing drives a weakening

Contributed by Jonathon Wright and Annalisa Cherchi

Preliminary conclusions & suggested focus for community paper:

- Over the equatorial Pacific, metrics for SST and SLP gradients show important discrepancies in the models in representing the observed trends

- For monsoons, the counteracting effect of GHG and aerosols in shaping the 20th century trend of global monsoon precipitation and circulation is evident

Future focus:

- Identify models with similar forced responses and consistency across multiple circulation metrics: E.g. NorESM model and others that show the same sign response. Are they getting the right response for the right reasons?

- For each metric, evaluate:
  - additivity of individual forcing agents
  - consistency with observations (or not)

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