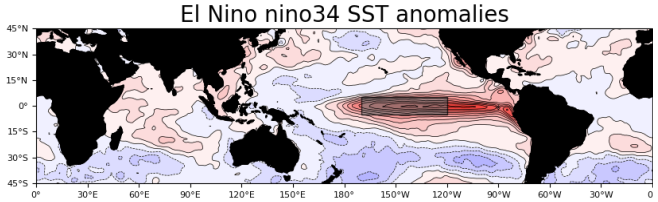
CVCWG - Teleconnections and the Variability of Tropical Pacific Diabatic Forcing in CESM and the E3SM Large Ensembles

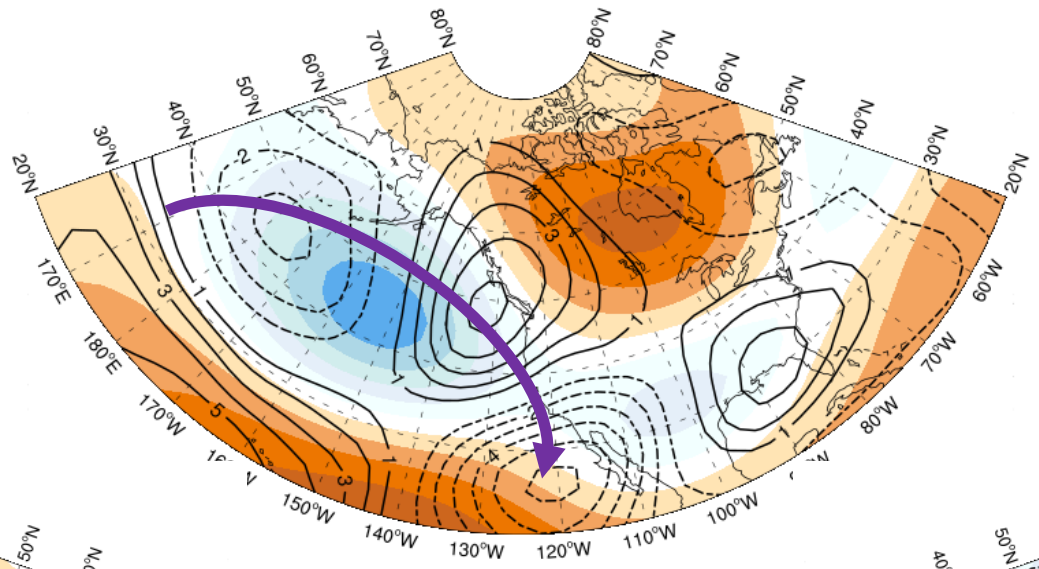
Rich Neale (rneale@ucar.edu)
Climate and Global Dynamics Lab. (CGD)
NSF National Center for Atmospheric Research (NCAR)
H. Annamalai, *U. Hawaii*

29th Annual CESM Workshop, Boulder, CO (June 10th, 2024)

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

Pacific North America (PNA) - Rossby Wave Radiation



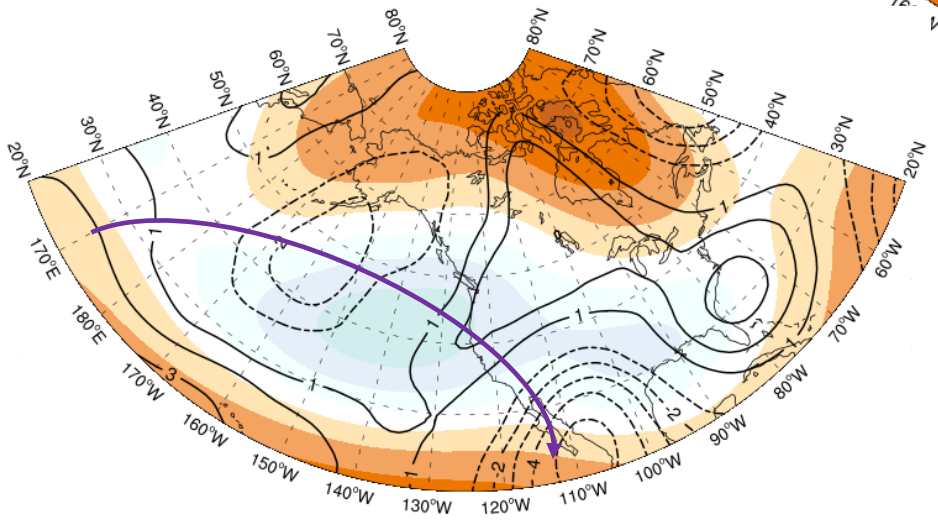


ERA5

200 hPa, composite El Nino, DJF

Geopotential Height (shaded)

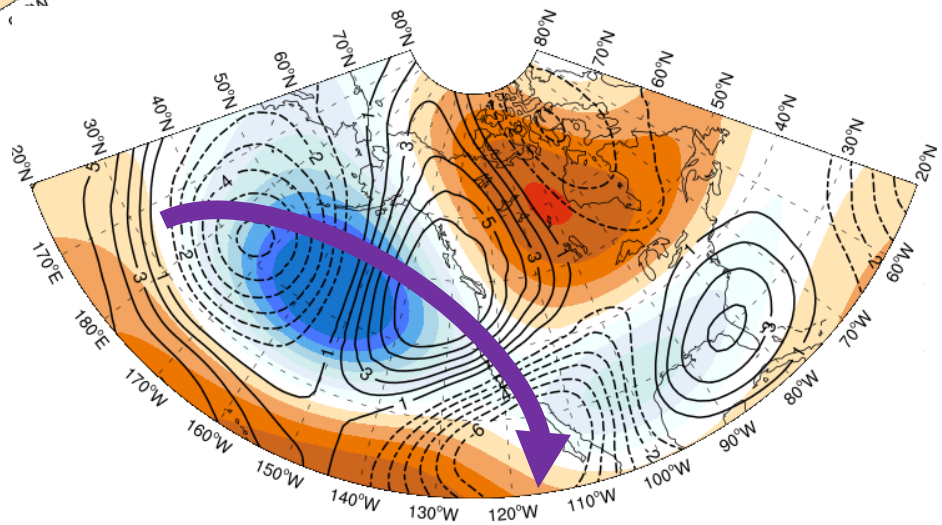
Meridional Wind (contours)



CAM5

CESM1

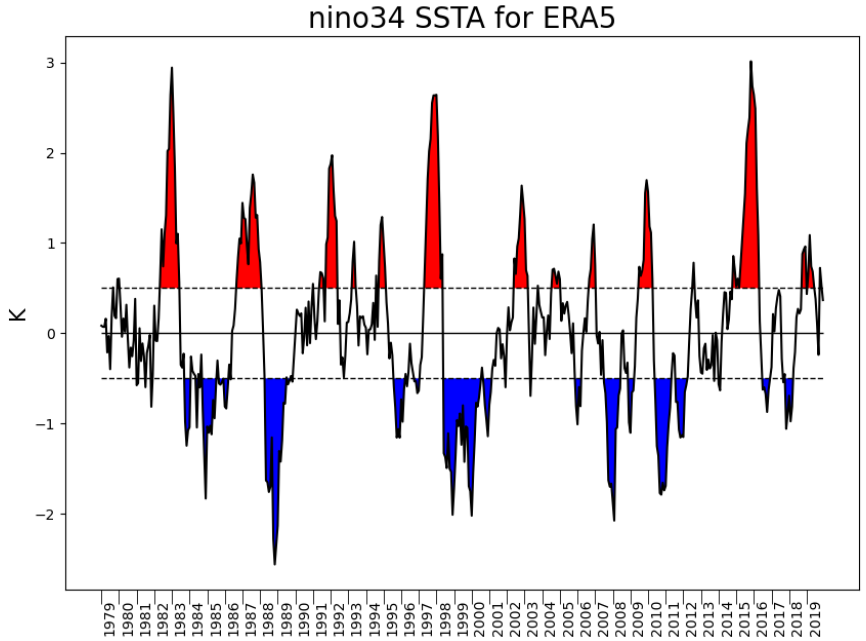
CAM – Community Atmosphere Model (AMIP)

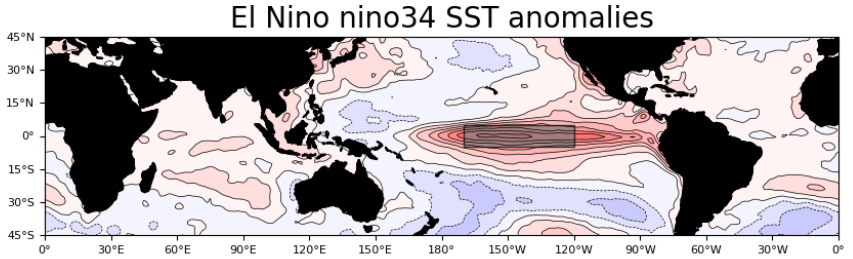


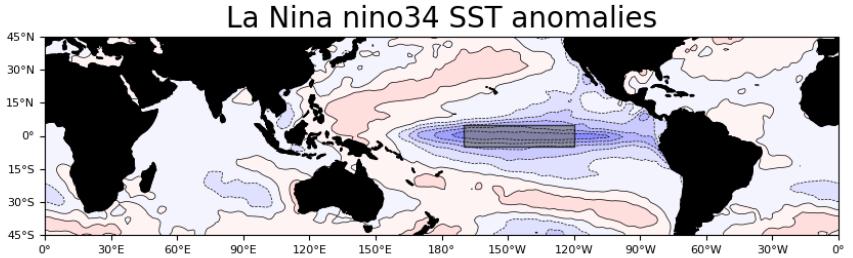
CAM6

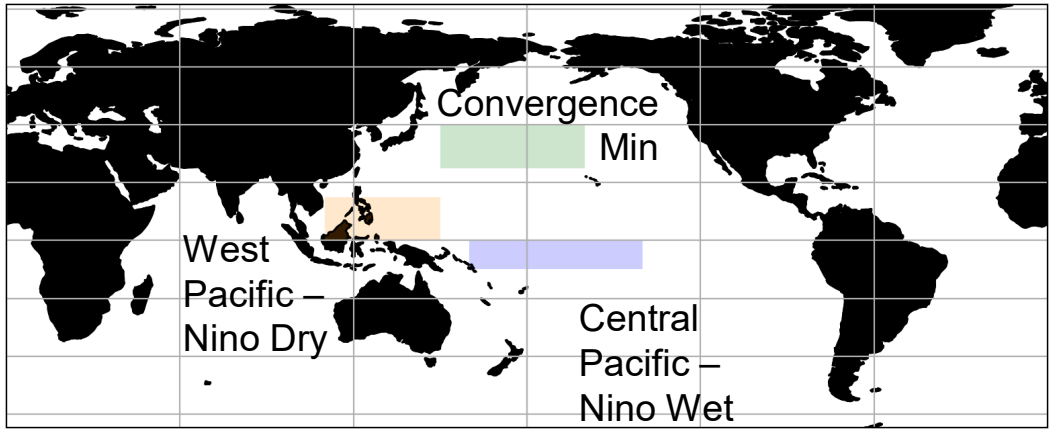
CESM2

El Nino Simulation and Divergence Regions



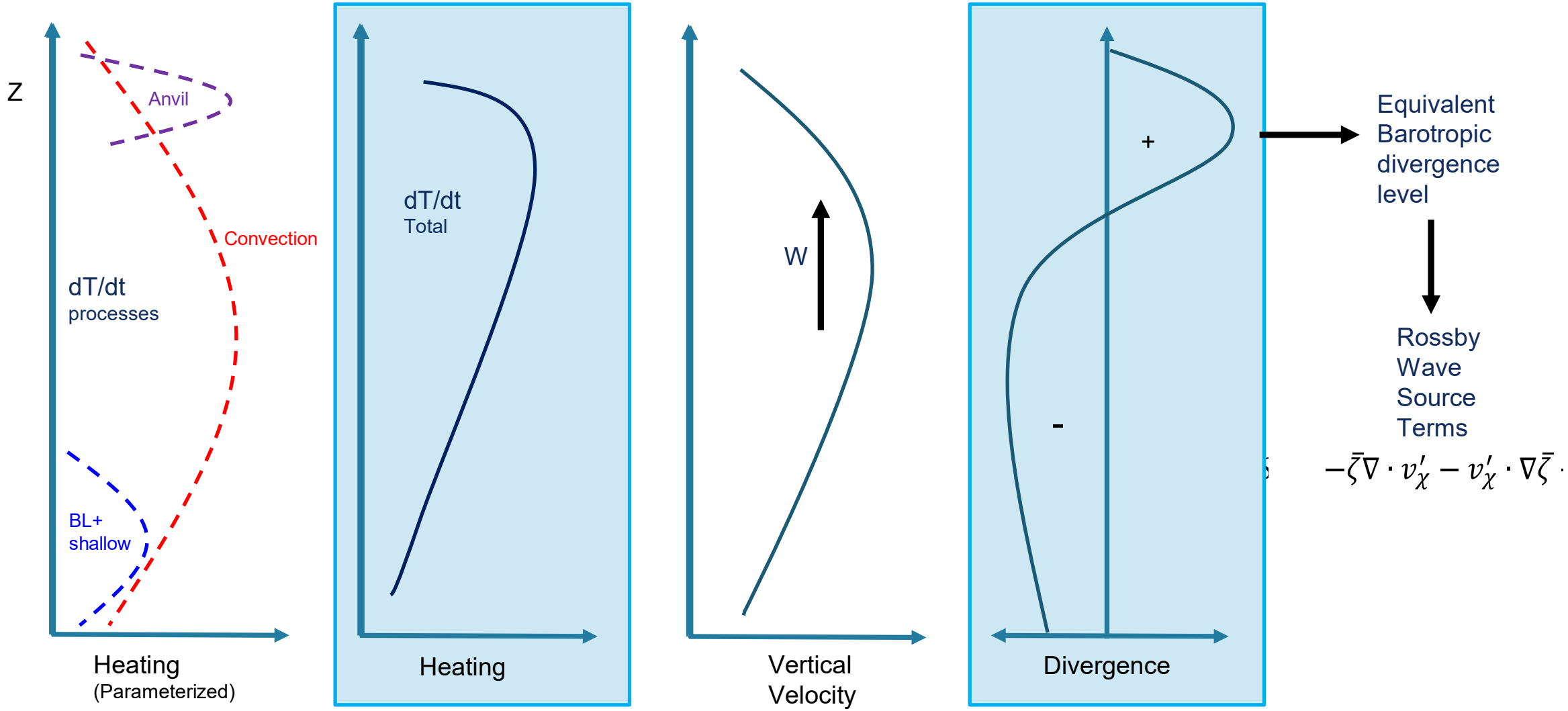




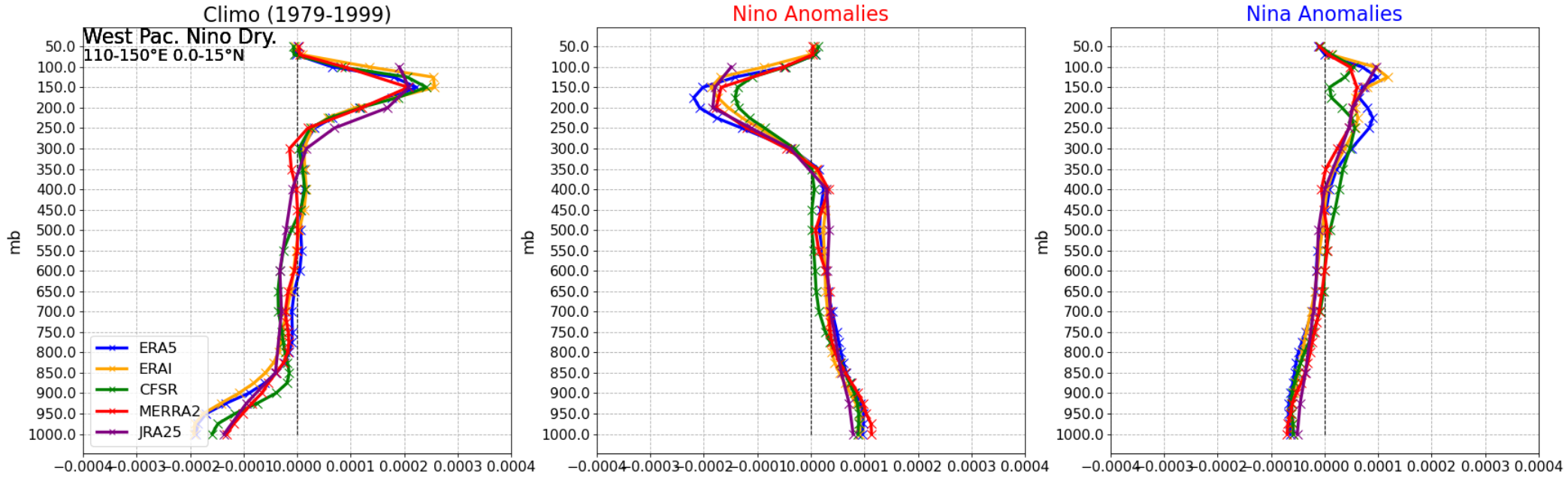


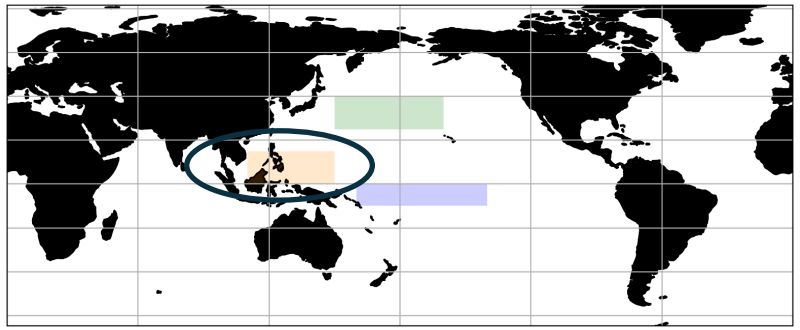
What are the tropical diabatic processes that determine the divergence source terms in the **Rossby Wave Source** response?

Vertical Processes -> Divergence -> RWS



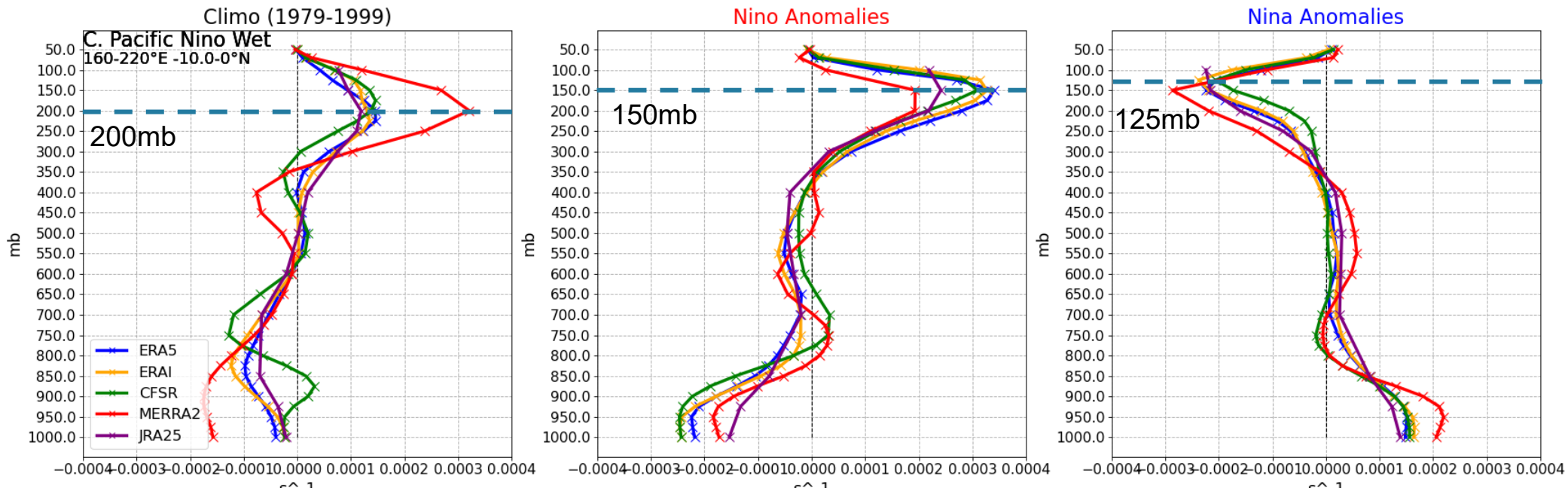
Climatology/ENSO over Divergence Regions - Reanalyses

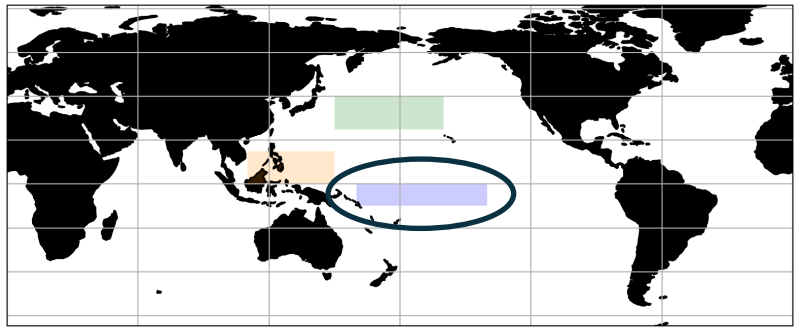




- Climatology agreement in West Pacific
- Strongly forced deep convection region
- Nino disagreements in key upper tropospheric region
- El Nino: **strength variations,** La Nina: **level variations**

Climatology/ENSO over Divergence Regions - Reanalyses



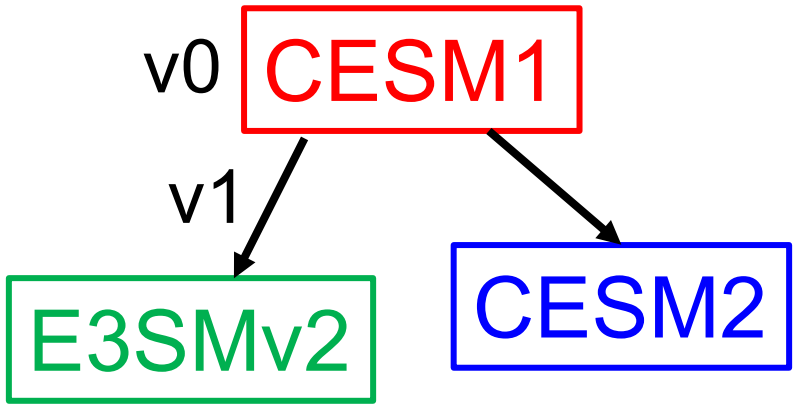


- Significant disagreement in profile of divergence (MERRA2, CFSR)
- Multiple min/max, **different levels of divergent outflow**
- Better agreement in nino responses
- Equatorial central Pacific is a **marginal deep convection region**

Large Ensembles and Internal Variability

A. If re-analyses are uncertain in their vertical profile patterns then how uncertain are model simulations?

B. How are multi-decadal variations in El Nino variability communicated through atmospheric diabatic processes



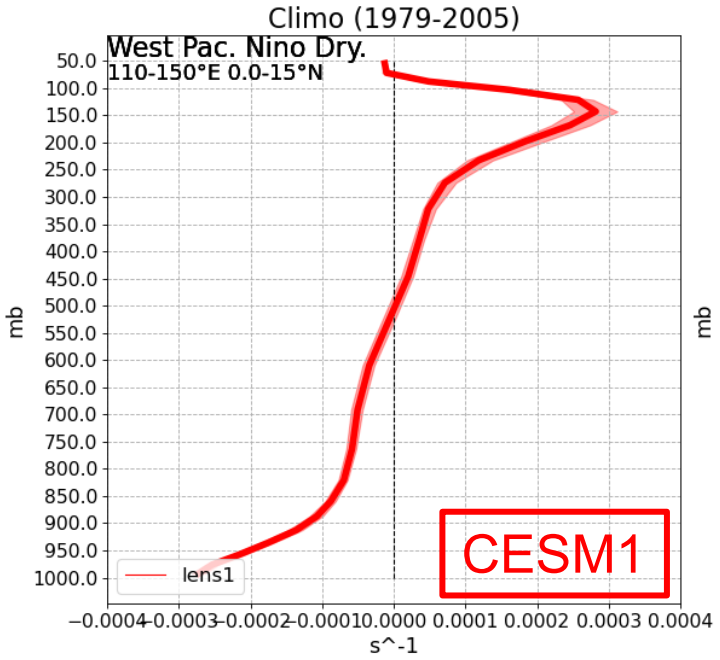
- NSF NCAR Community Earth System Model (CESM)
- DOE Energy Exascale Earth System Model (E3SM) v2
- CESM1 is the root model
- CESM2/E3SMv2 share a lot of atmos. Physics
- Different ocean model in E3SMv2 (MPAS vs POP)

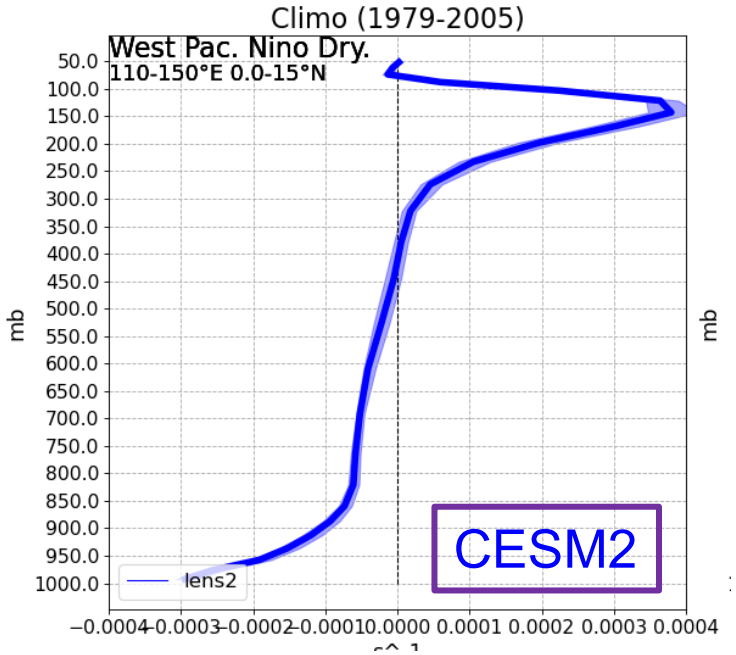
- 1979-2005
- ~1 deg (C1/C2/E2 - > 30/32/72 levels)
- 20 ensembles each

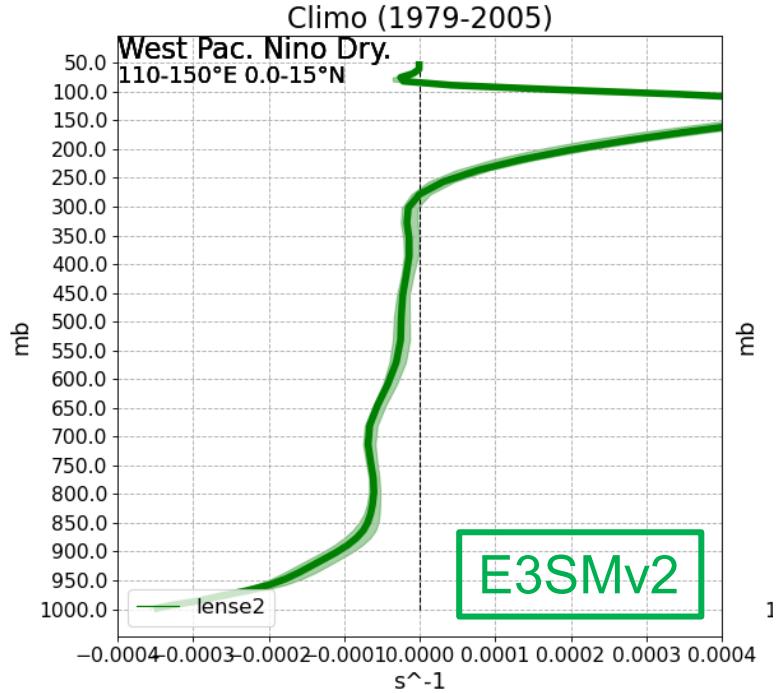
CESM1: Kay et. Al (2015) https://doi.org/10.1175/BAMS-D-13-00255.1

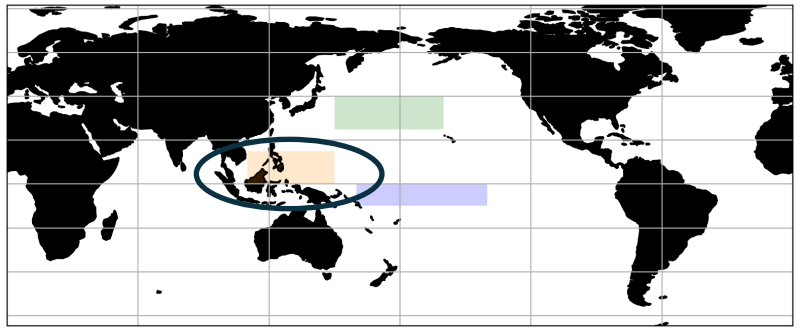
CESM2: Rogers et al. (2021) https://doi.org/10.5194/esd-12-1393-2021

Mean Simulation and Divergence Uncertainty

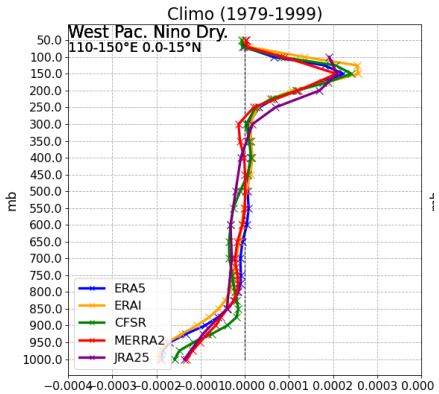




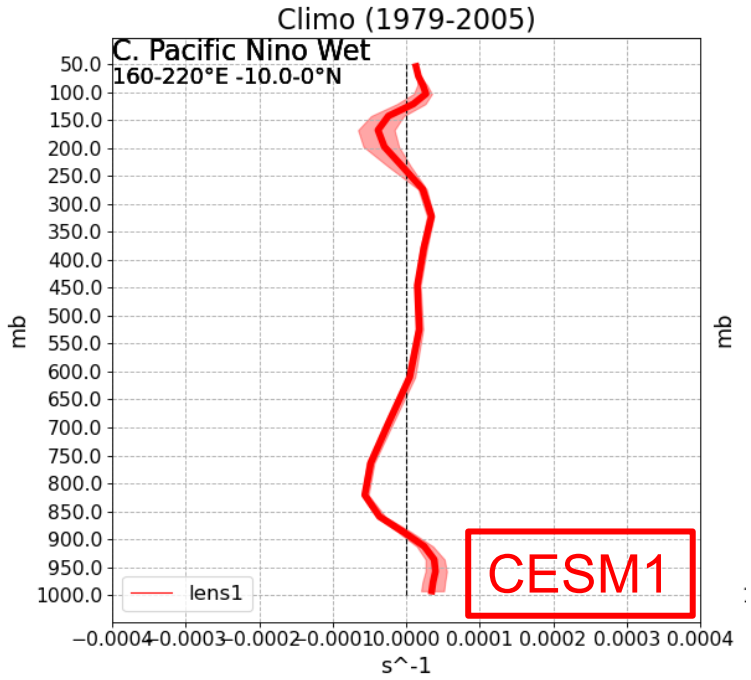


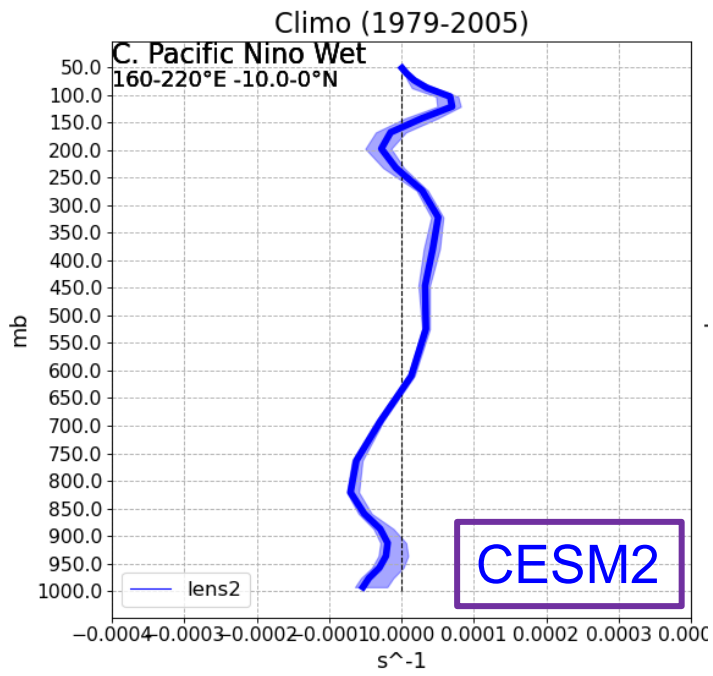


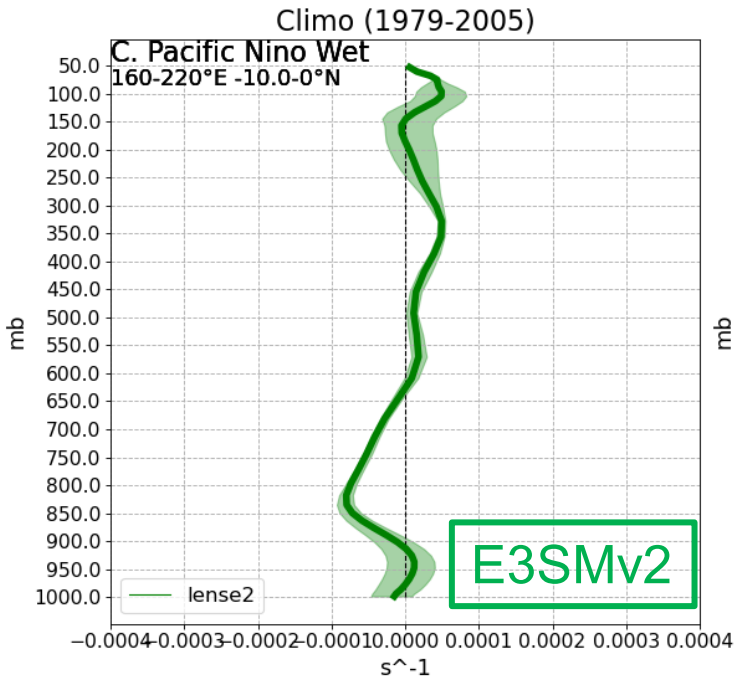
- Little variation among ensembles
- 10% variation at max divergence level
- Increased divergence in CESM2 and E3SM – too intense
- Max level similar to ERA5

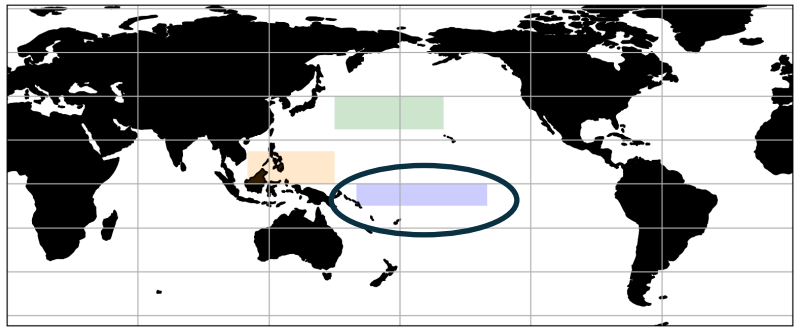


Mean Simulation and Divergence Uncertainty

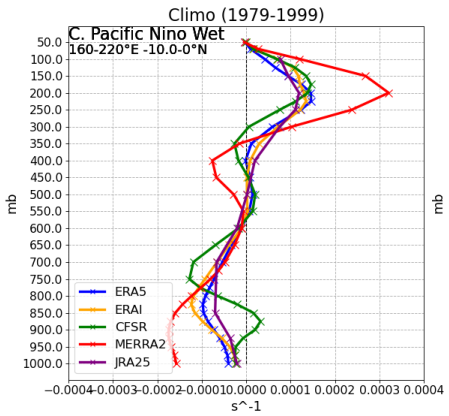




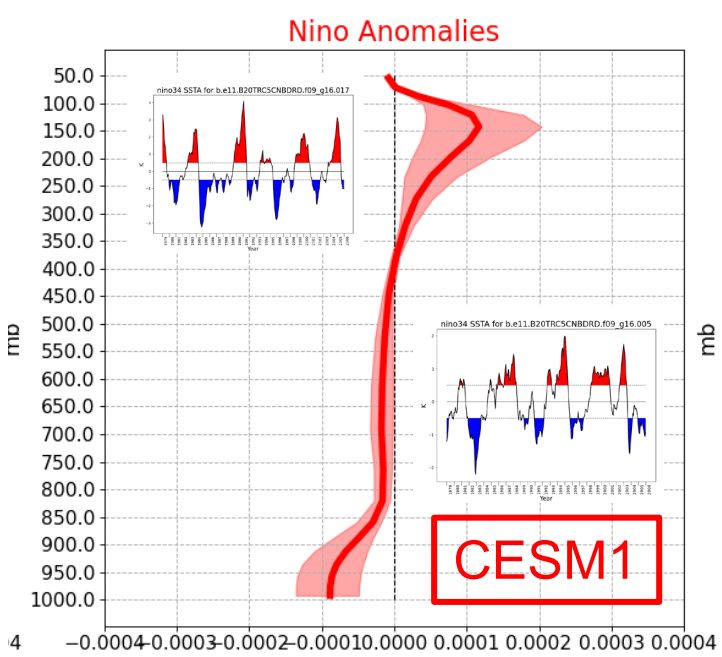


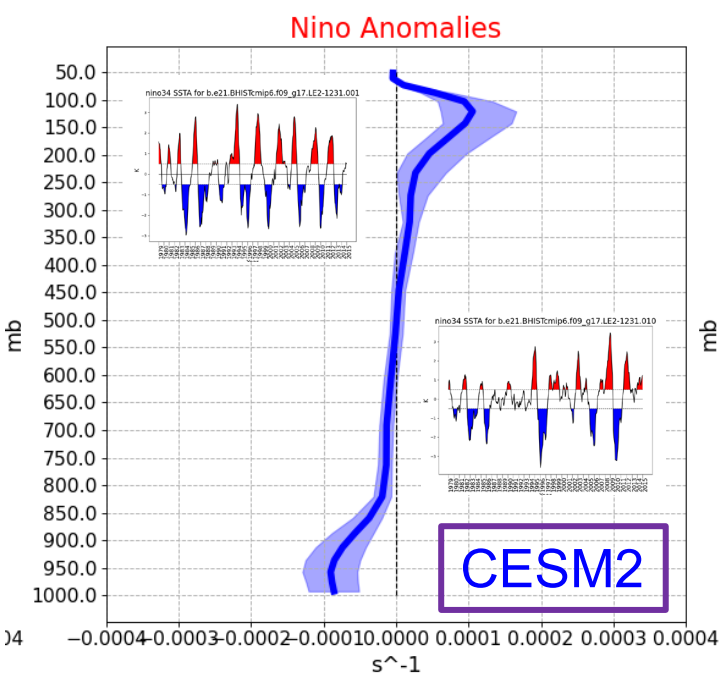


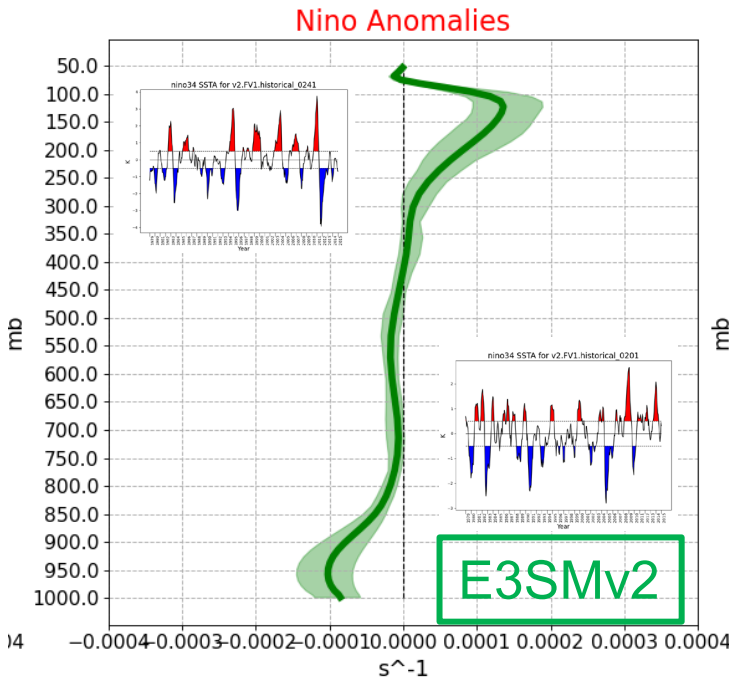
- Weak divergence over this region
- Lack of convergence near-surface
- Largest variability in upper troposphere
- Models underestimate precip. in this region

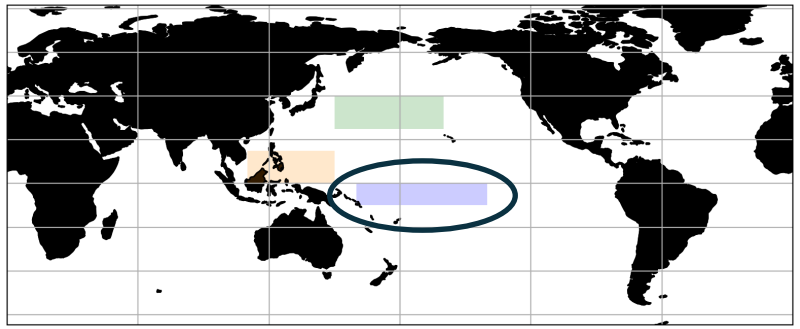


El Nino Simulation and Divergence Uncertainty

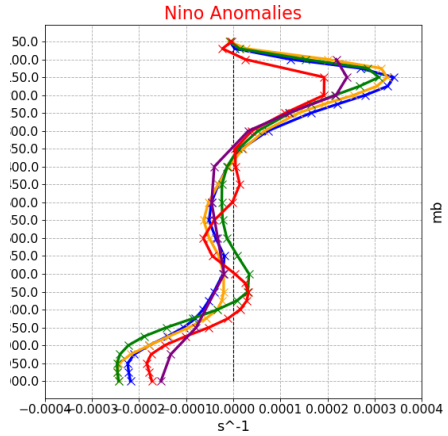




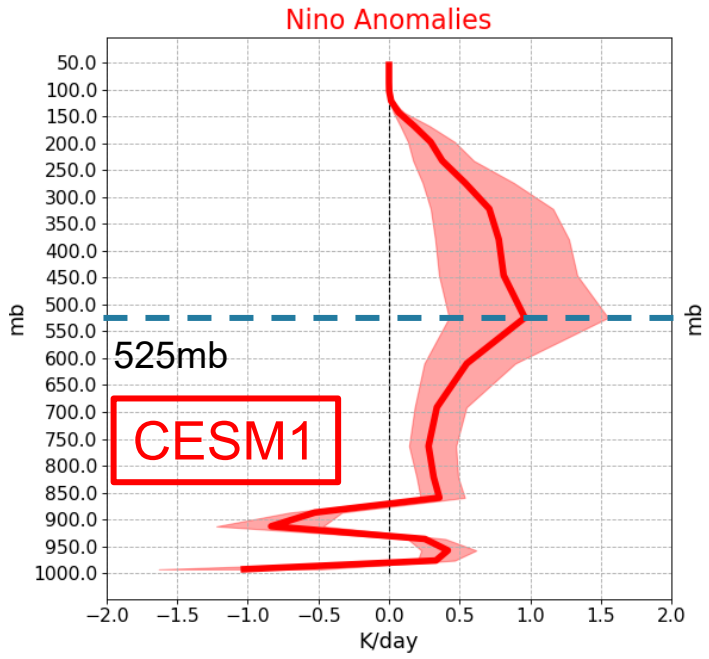


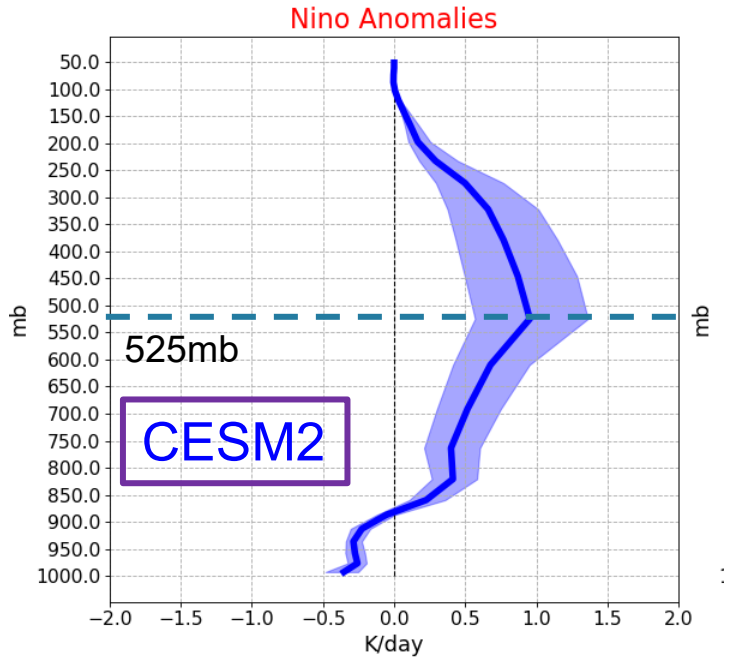


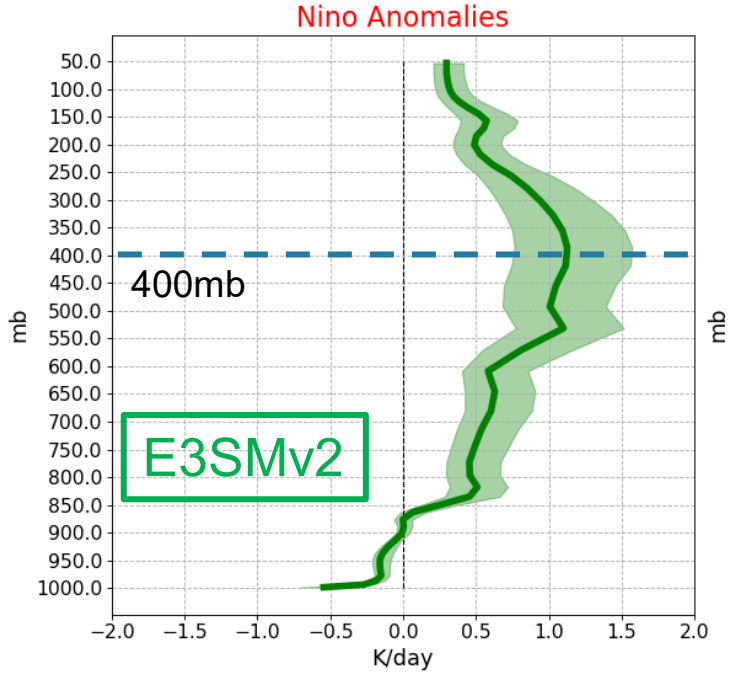
- CESM1 variation x2 in divergence region
- Mean signal now too weak
- Diverse ENSOs may play a role in the magnitude of the uncertainty

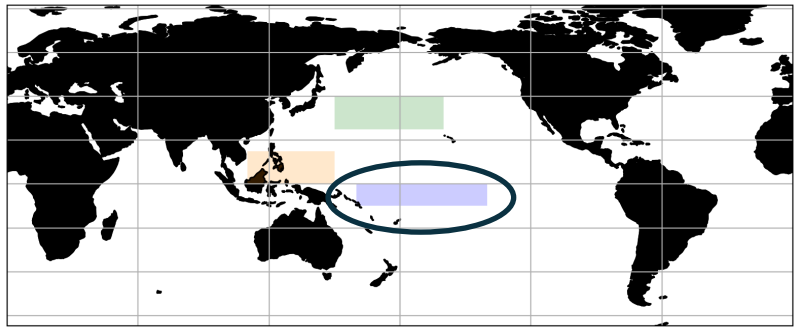


El Nino Simulation and Diabatic Heating Uncertainty









- Variability in heating is through the whole column
- Only marginally elevated in CESM1
- E3SM with high vertical resolution has fine scale structure
- Its response is elevated compared to CESM

Summary

Motivation

Tropical vertical processes are key to understanding ENSO RWS-related teleconnections

Re-analyses disagree substantially in key source regions (esp. Central Pacific)

Talk

Significant model internal variability in the magnitude of the tropical response in this region

ENSO-related divergence variability has decreased in CESM2/E3SMv2

Models lack a strong central Pacific upper-tropospheric divergence response during El Nino

Next Steps

Examine if/how ensemble tropical variability translates to teleconnection strength

Further analysis (experiments?) to break down the role of individual processes in ensemble spread