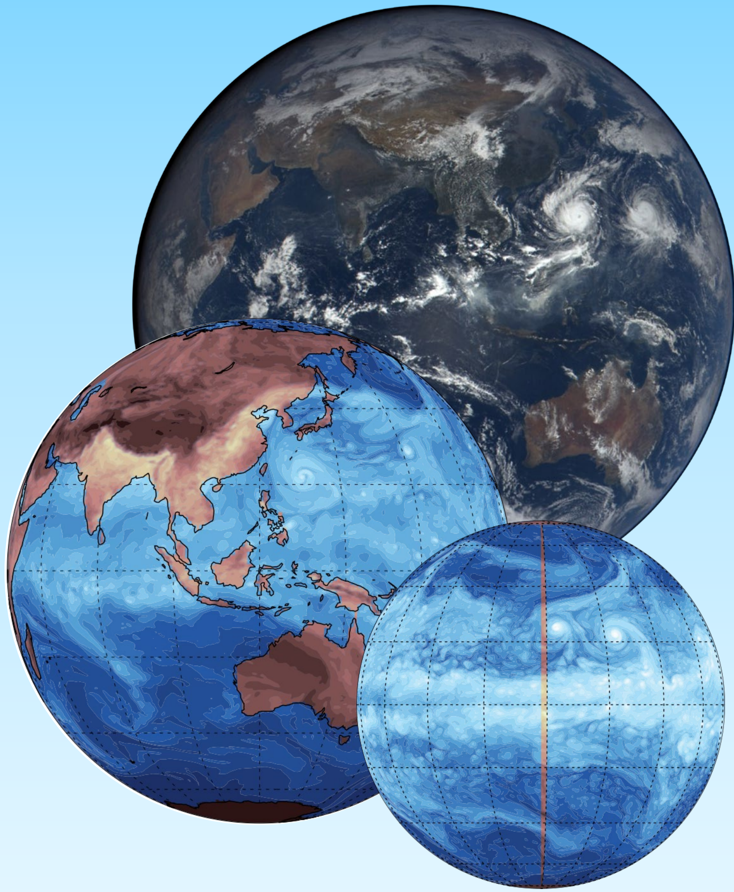
Idealized CESM for Understanding Tropical Cyclones and Ocean Heat Transport



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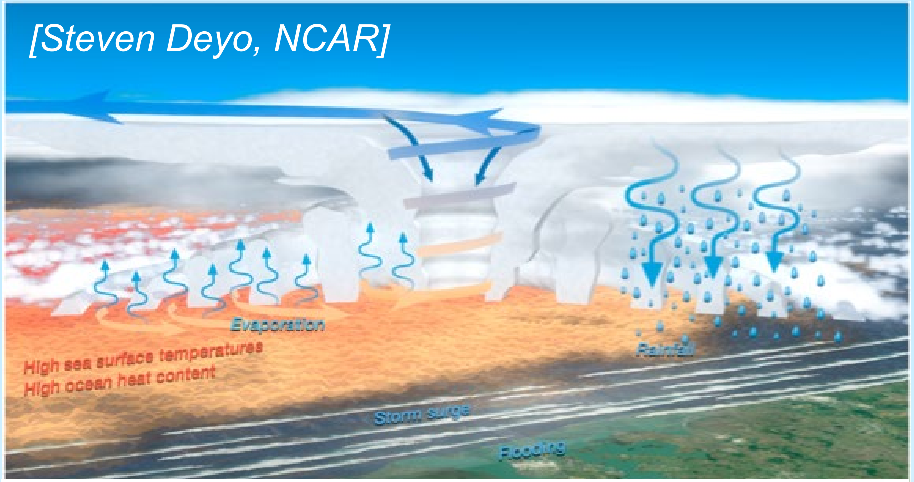
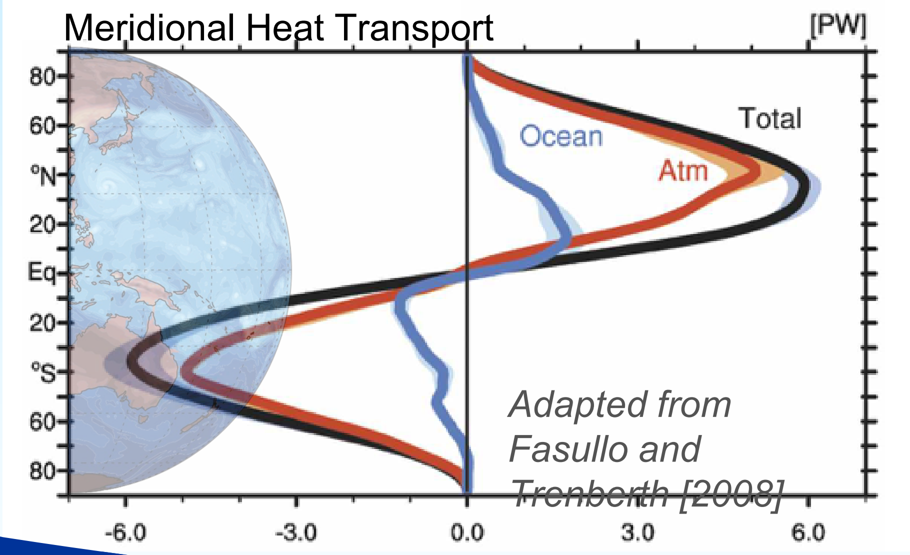
Satellite image: NASA; figure design adapted from B. Medeiros

Do tropical cyclones affect climate system energy transport?



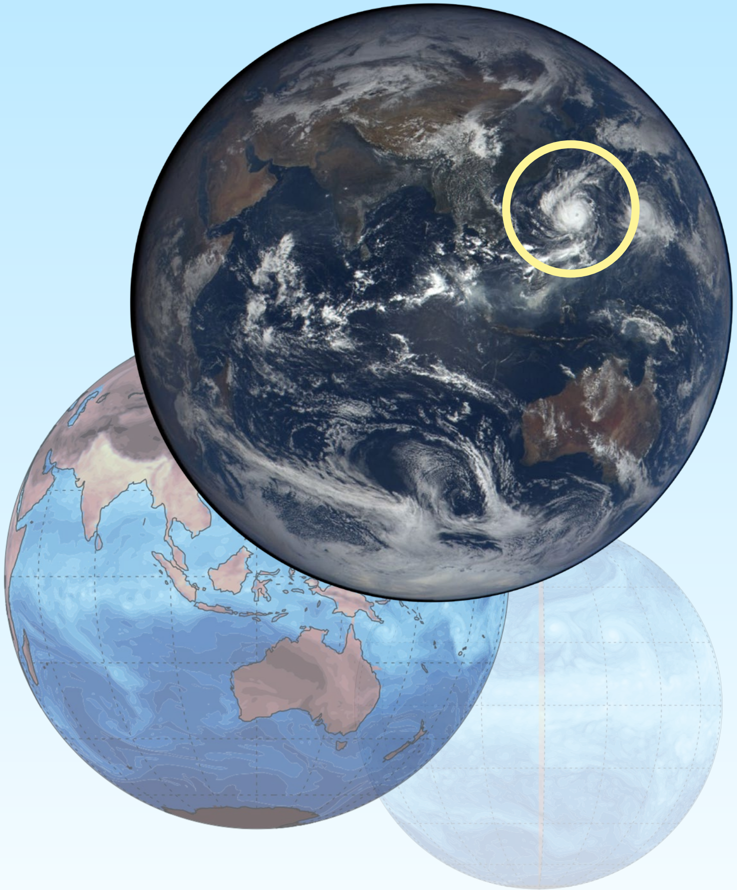
[Steven Deyo, NCAR]

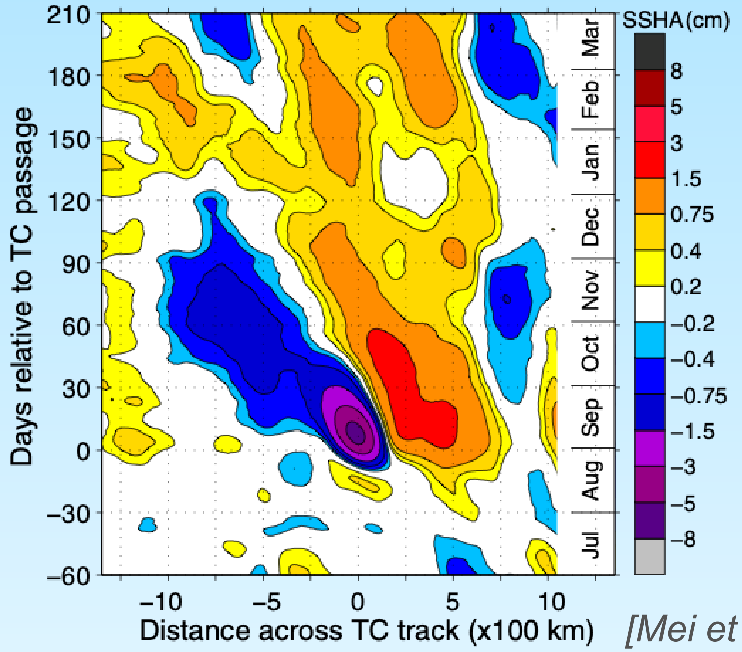


Adapted from Fasullo and Trenberth [2008]

- By **enhancing ocean heat transport**, tropical cyclones are hypothesized to:
  - Keep the poles warm during the Equable Climates, 146-34 Myr B.P. (Cretaceous - Eocene) (Emanuel, 2002; Korty et al., 2008);
  - Keep Eastern Pacific warm (permanent El Niño) during 5-3 Myr B.P. (early Pliocene) (Fedorov et al., 2010)
- For current and future climates: Can tropical cyclones be a significant agent of energy transport? If so, how?

Obs.: Tropical cyclones may account for ~15% of ocean heat transport

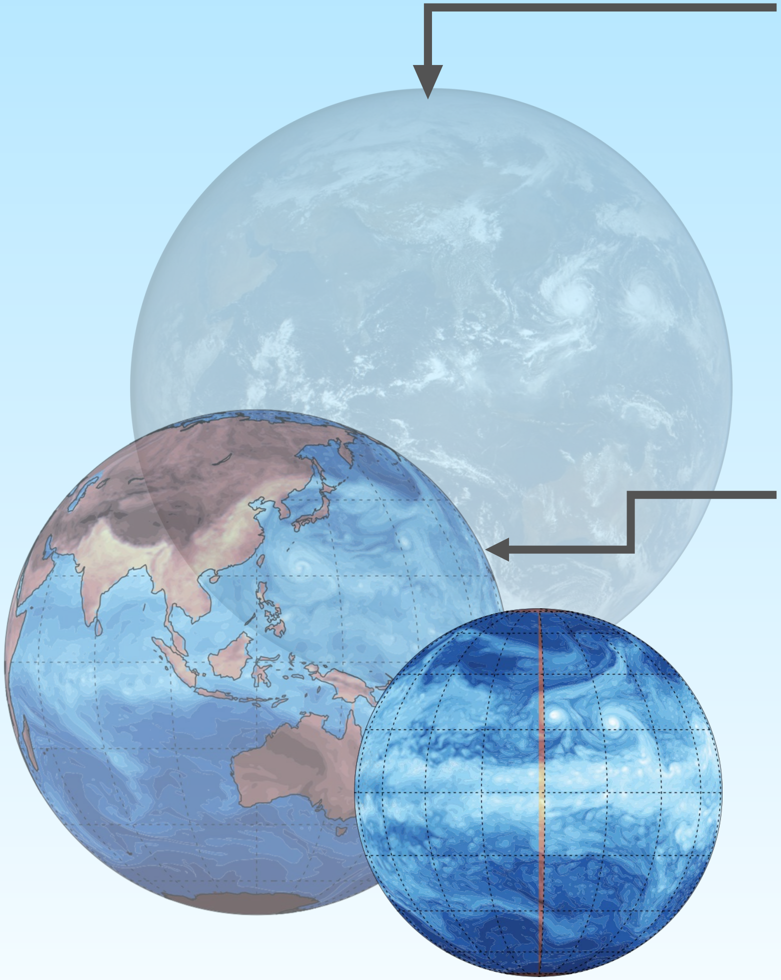




[Mei et al., 2013]

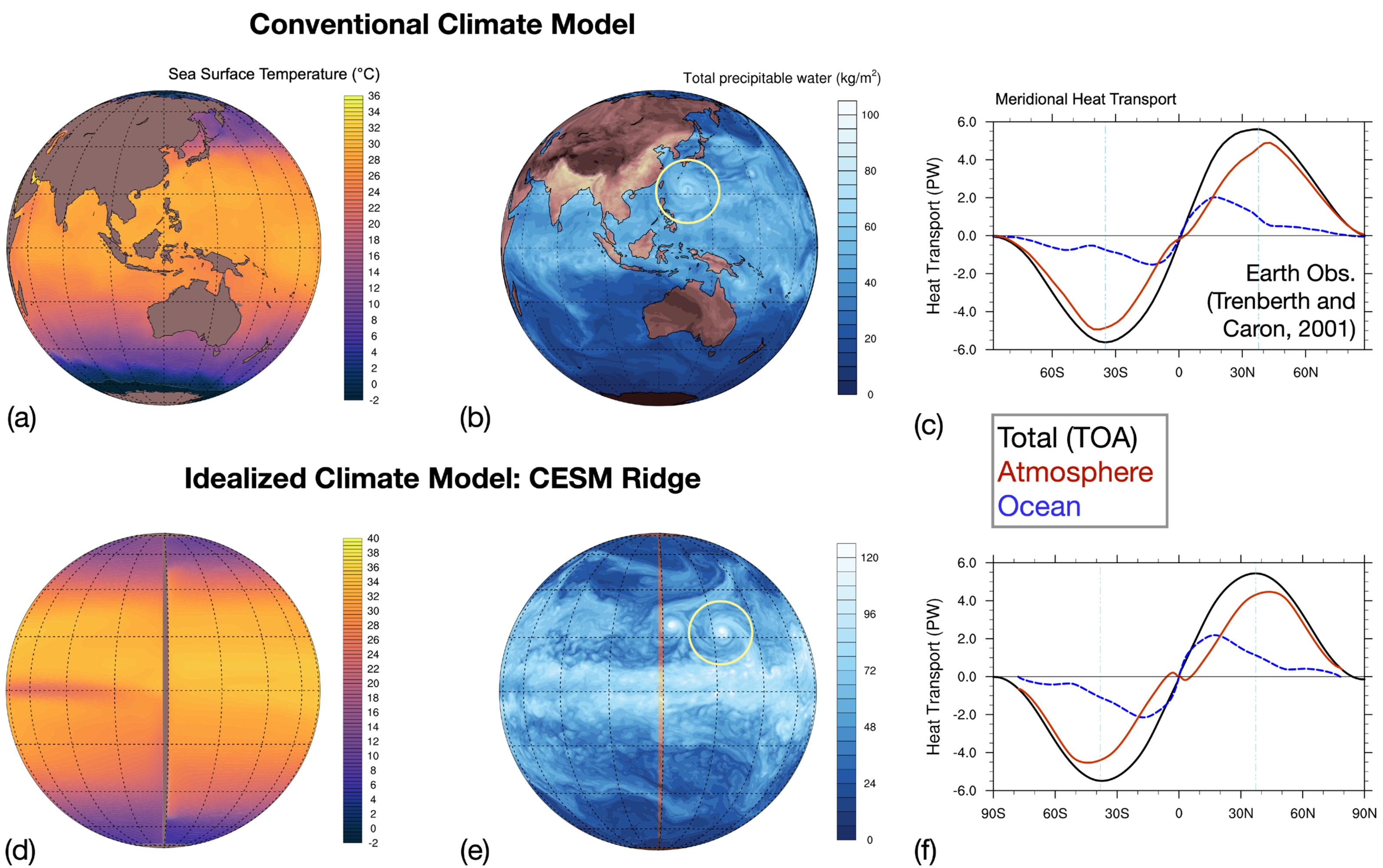
- Earlier estimates: anywhere between 5-50%
- Mei et al. (2013): Northern Hemisphere TCs contribute 0.32 ± 0.15 PW (~15 ± 7%) to poleward ocean heat transport
- BUT global tropical ocean heat transport (2.3 ± 0.4 PW) has a substantial error margin (Ganachaud and Wunsch, 2003)

Gap: Uncertainty and complexity

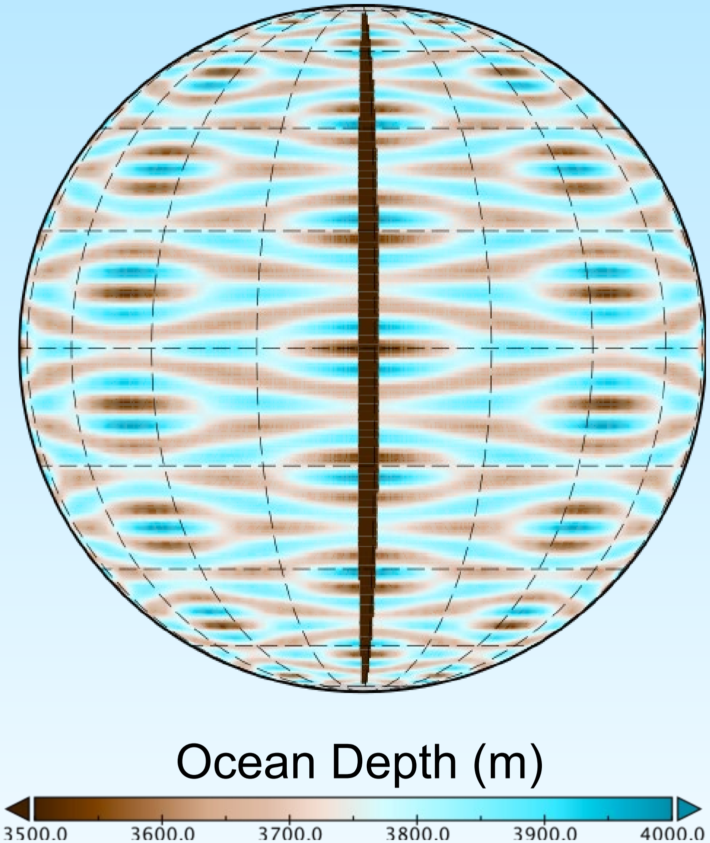


- Observation:
  - Limited records of TCs, especially of the ocean
  - Large error margin in ocean heat transport
- Conventional climate models:
  - Uncertainty from limited skills (atmosphere and ocean)
  - Complexity in components

Approach: Simpler models for better understanding



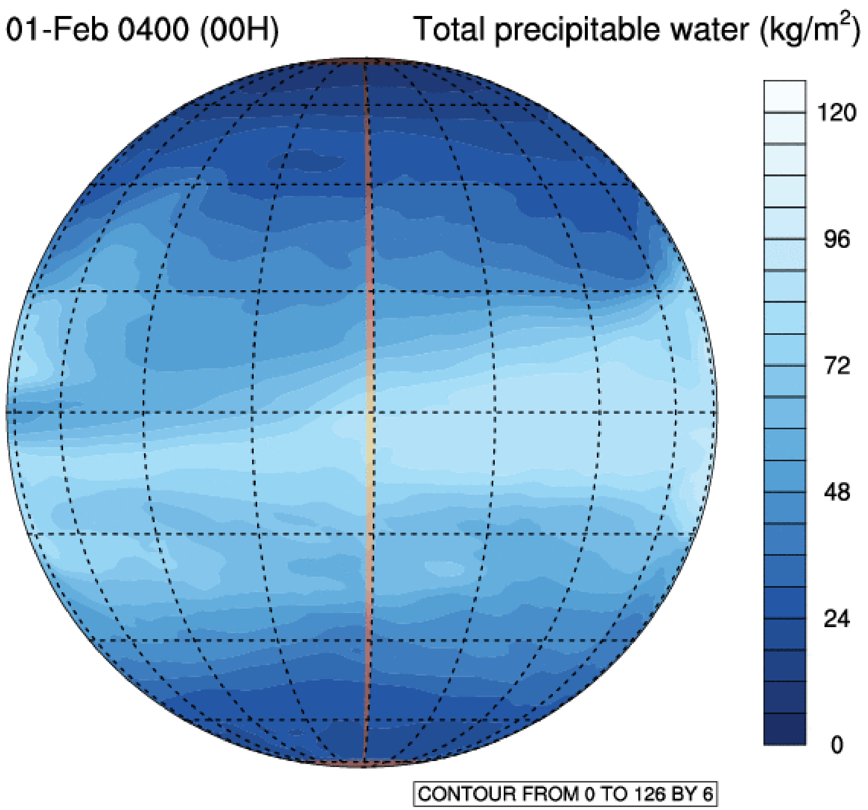
CESM Ridge: Coupled model set-up



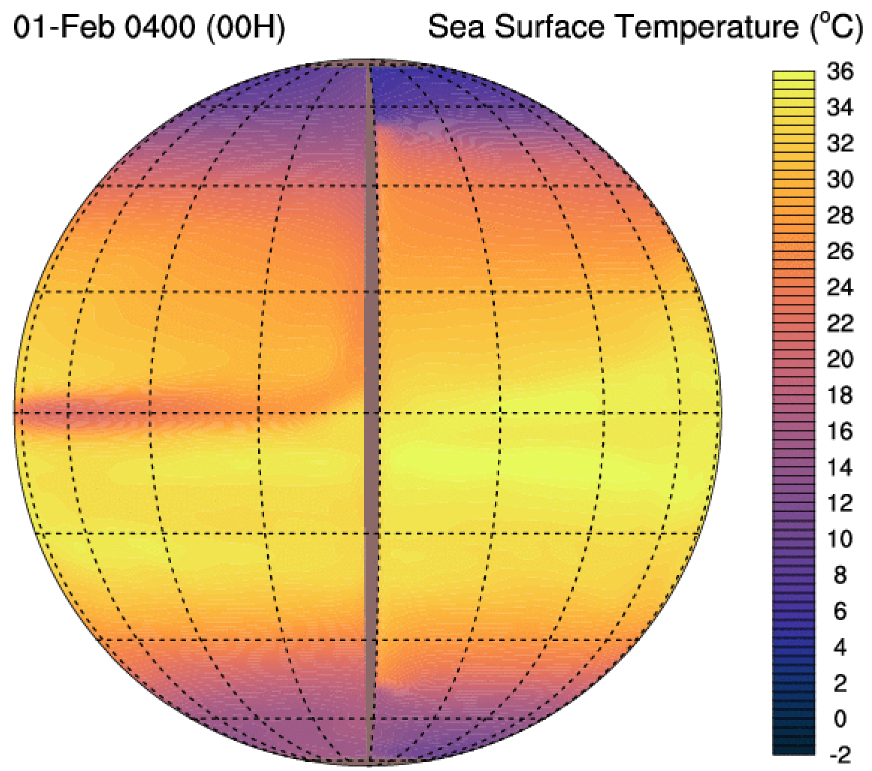
- **Atmosphere**: CAM4 @1°
- **Ocean**: MOM6 @nominal 2° with equatorial enhancement (1°); ~4000 m depth; symmetric bottom topography
- **Sea ice**: CICE
- **Land**: CLM5 wetland; one single pole-to-pole strip, known as Ridge (Enderton and Marshall, 2009)
- Fixed orbital parameters with seasonal cycle
- Initialization: Idealized climatology for ocean (courtesy Pedro Di Nezio), default for others

CESM Ridge: Preliminary climate (Yr 400)

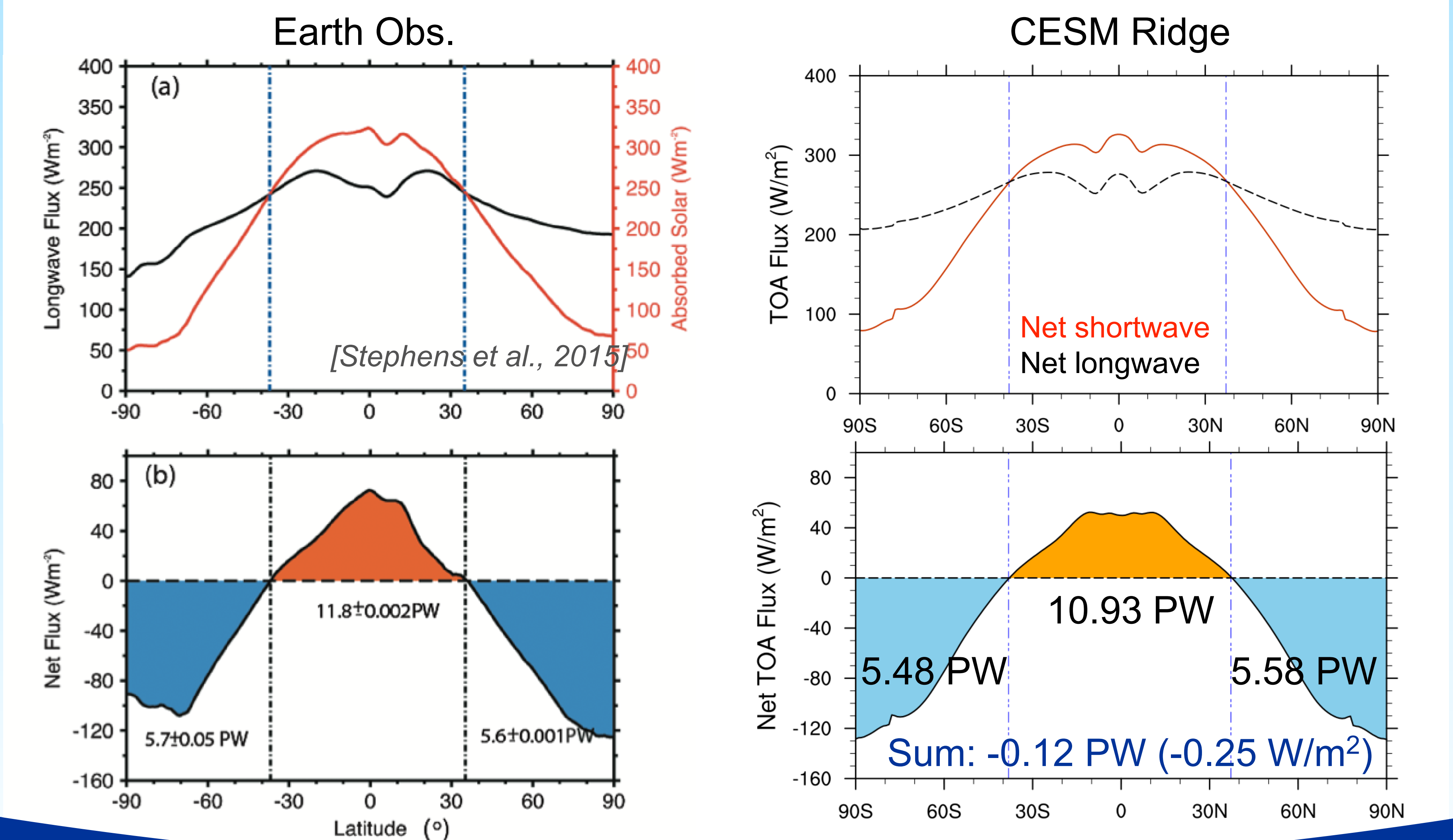
Atmosphere (CAM4)



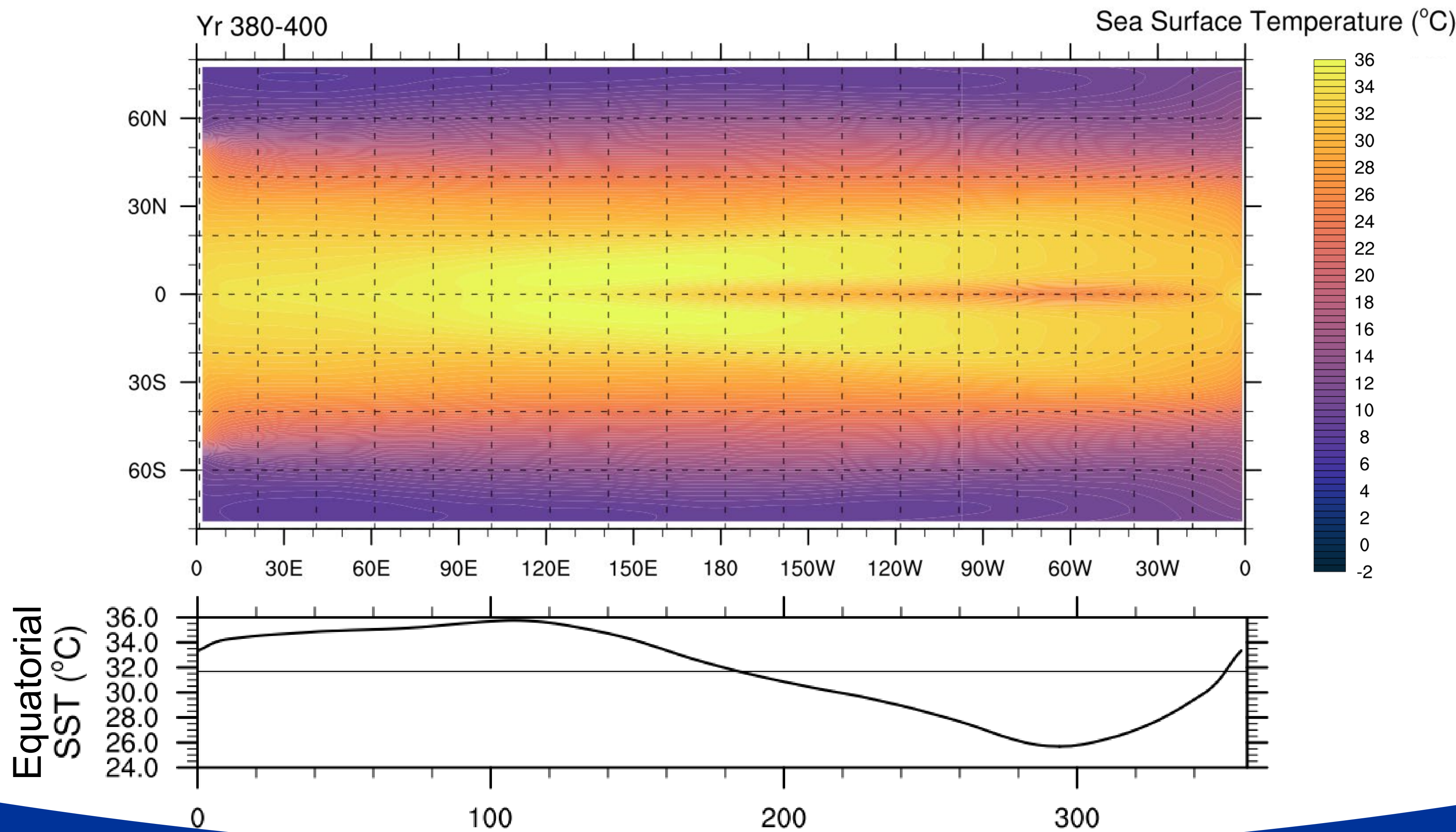
Ocean (MOM6)



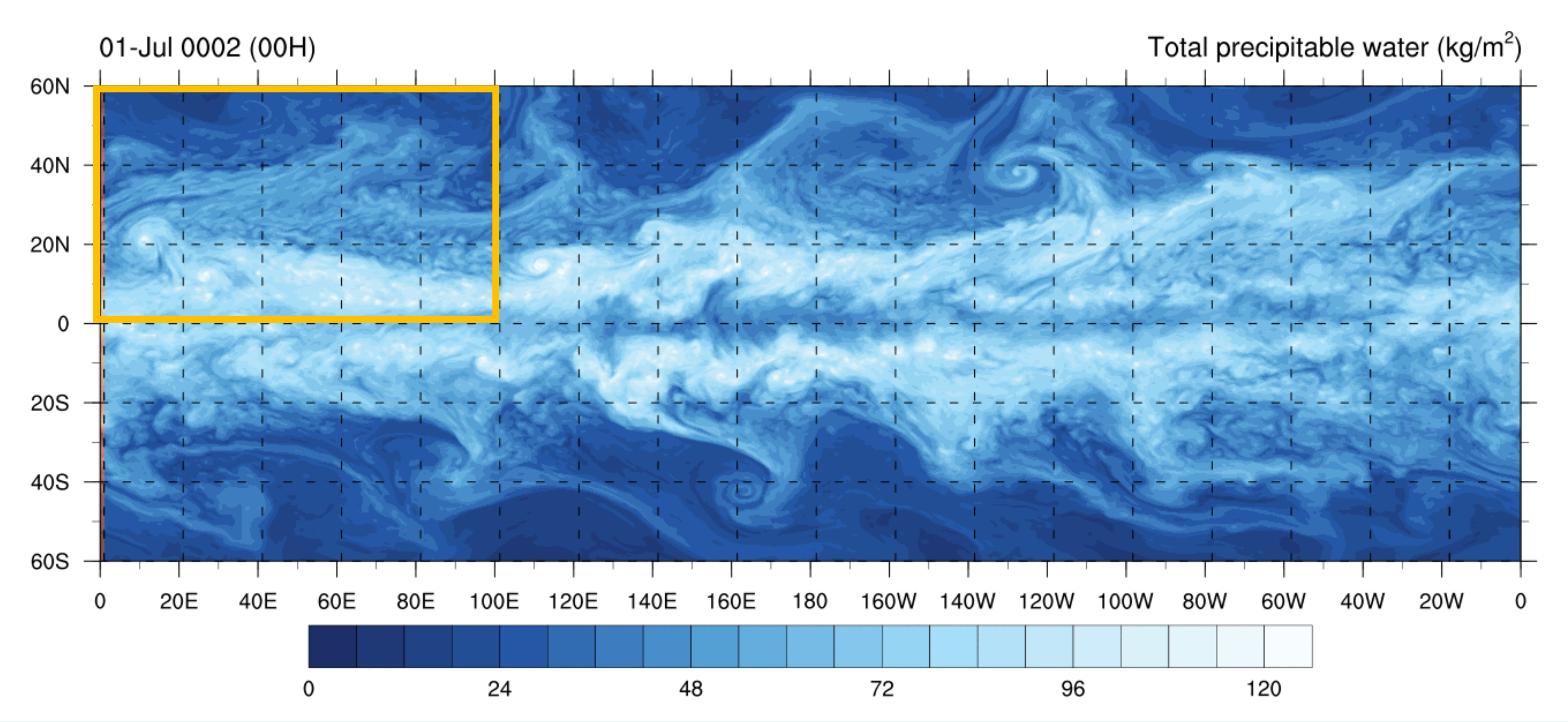
CESM Ridge: Reasonable TOA by Yr 400



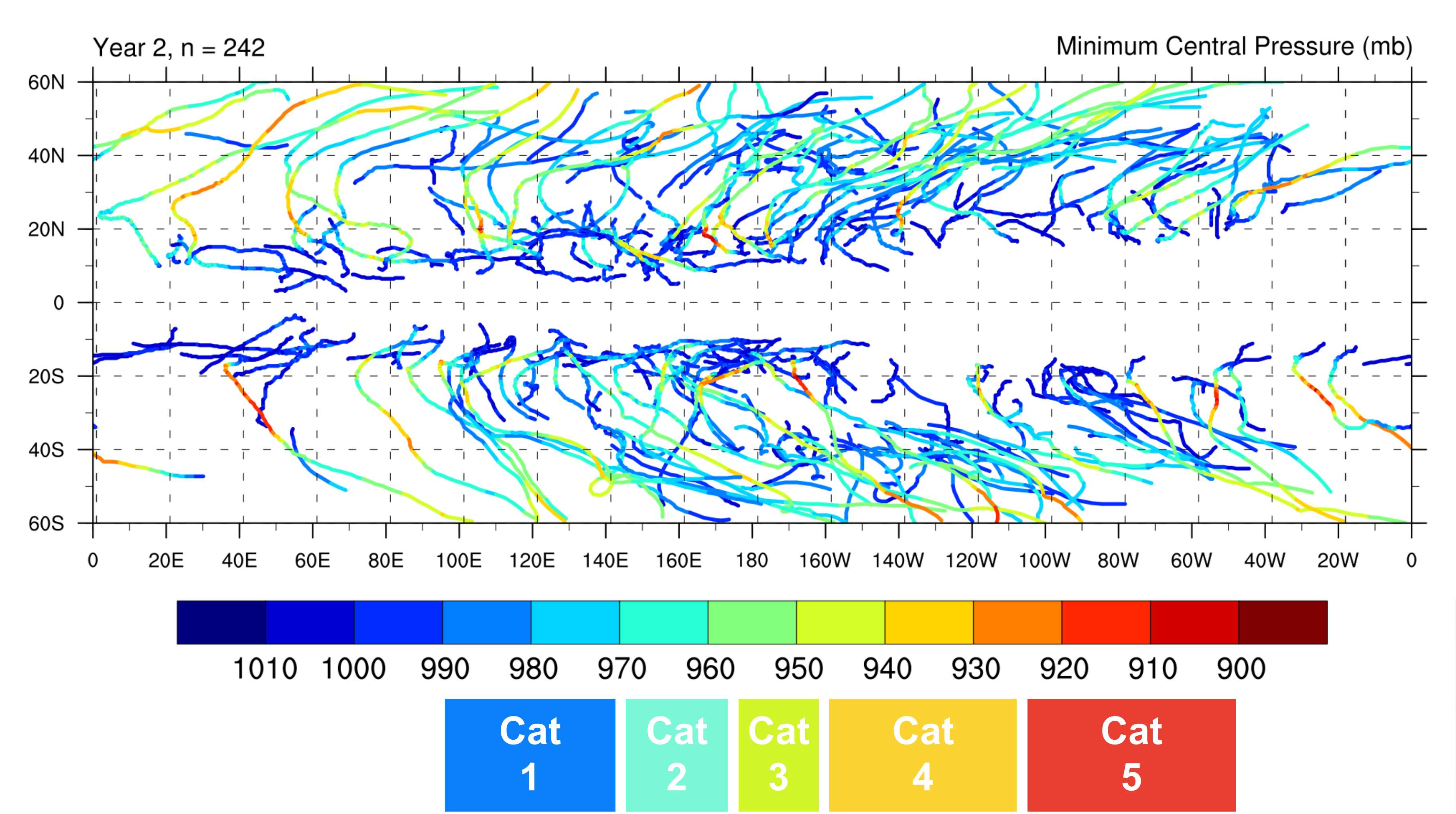
CESM Ridge: SST pattern (Yr 400)



Ridge SST -> CAM4 Aquaplanet @ 0.25°



Tropical cyclone tracks with Ridge SST



Genesis Potential Index (Emanuel, 2010)

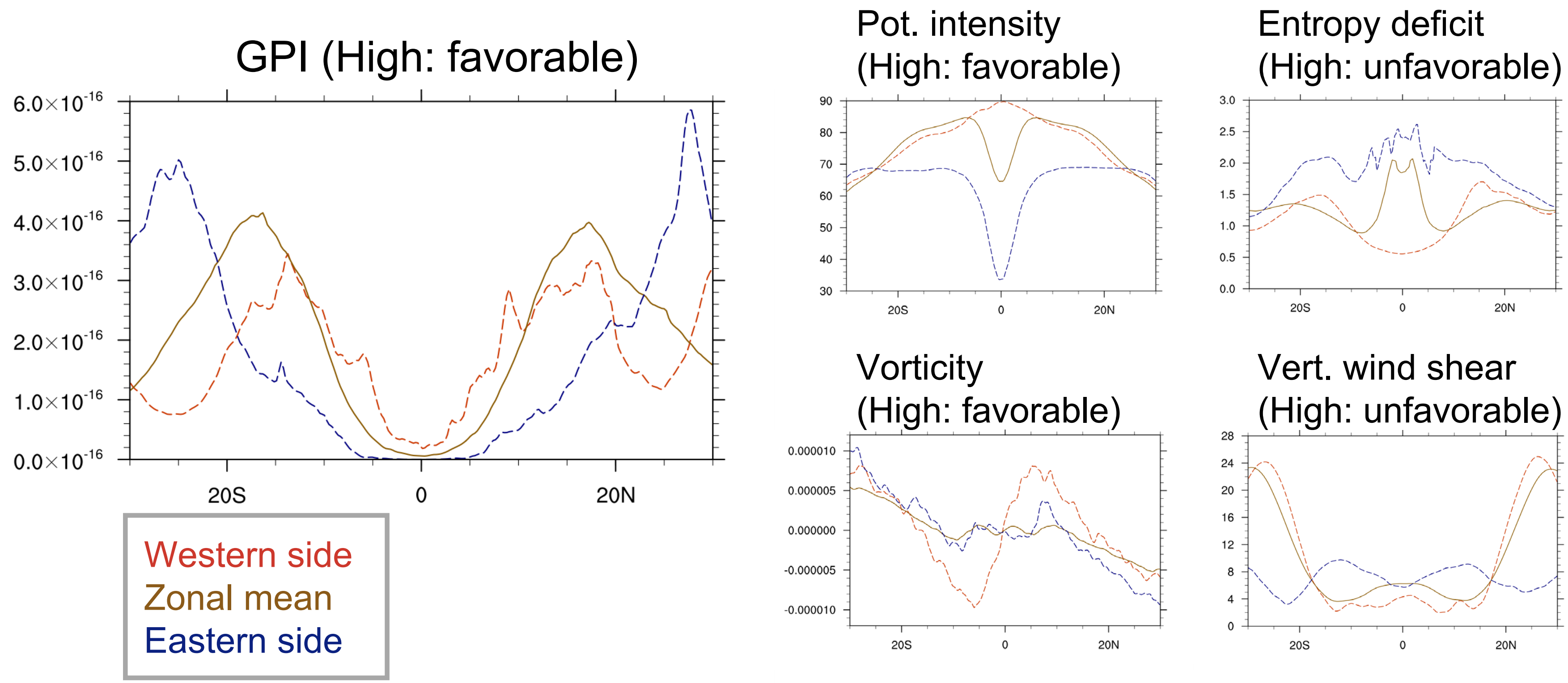
$$GPI = \underbrace{(|Vort._{850}|)^3}_{Abs.\ Vort.} \times \underbrace{\chi_{600}^{-4/3}}_{Entropy\ Deficit} \times \underbrace{[Max(PI - 35,0)]^2}_{Pot.\ Intensity} \times \underbrace{(25 + VWS)^{-4}}_{Vert.\ Wind\ Shear}$$

Empirically determined relationship between TC genesis and large-scale environmental controls

- Thermodynamic (T, Q): Moist entropy deficit, potential intensity (Bister and Emanuel, 1998)
- Dynamic (U, V): Absolute vorticity, vertical wind shear

$$\chi_{600} \equiv \frac{s_{600}^{sat.} - s_{600}}{s_{surf.}^{sat.} - s_{600}^{sat.}}, \; s \equiv c_p lnT - R_d lnP + \frac{L_v Q}{T} - R_v Q lnRH$$

Zonal gradient in TC genesis environment



The large-scale environment favors TC genesis at lower latitudes on the western side of the idealized ocean basin

Discussion

- Tropical cyclones on idealized planets: SST from dynamic ocean allows representation of zonal asymmetry (e.g. Pacific)
- Next step: Isolating the effect of tropical cyclones in ocean heat uptake and transport
- For more general science questions: Coupled simpler models planned to be released, potentially with other land geometries (e.g. Aqua)

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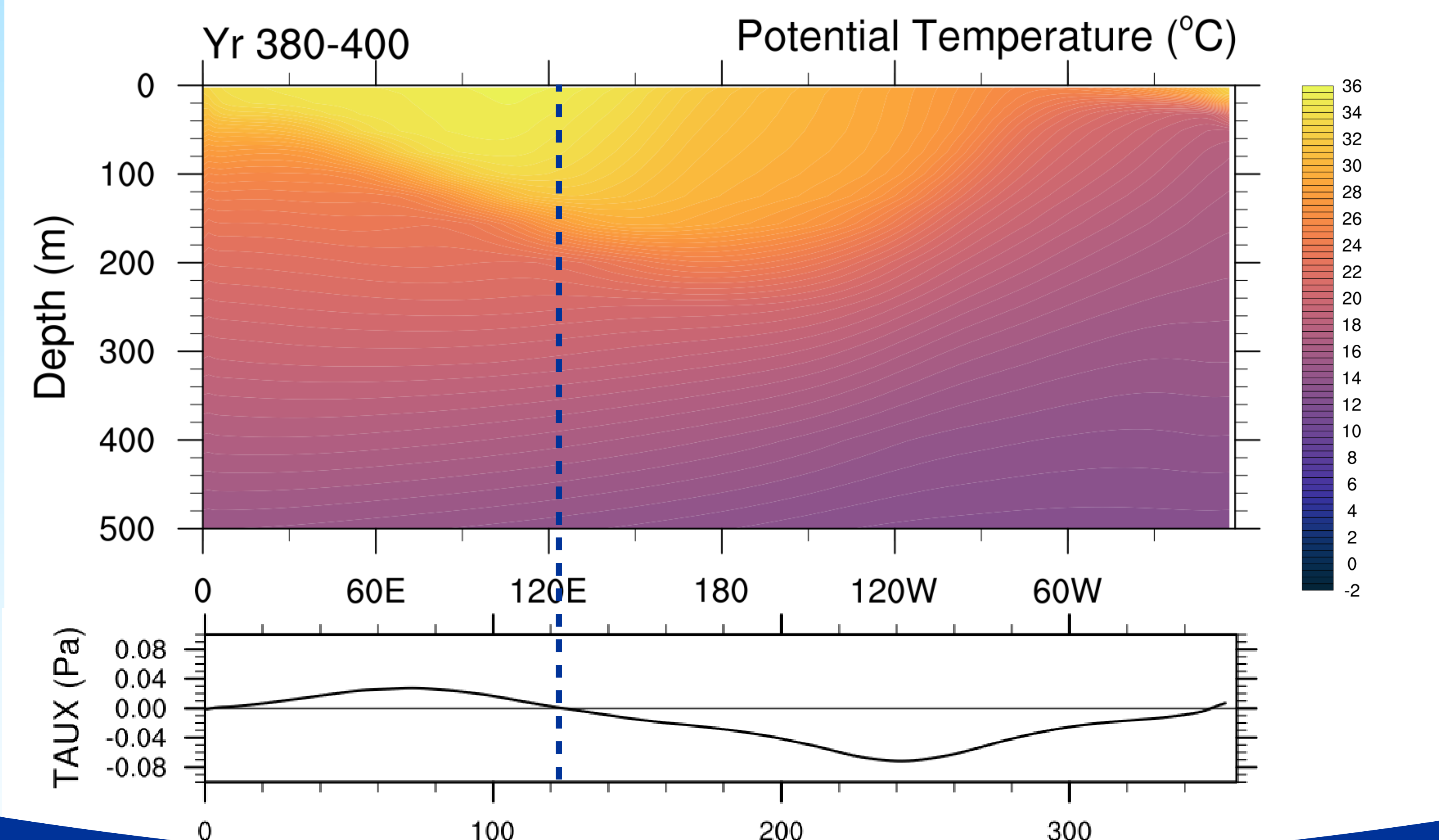
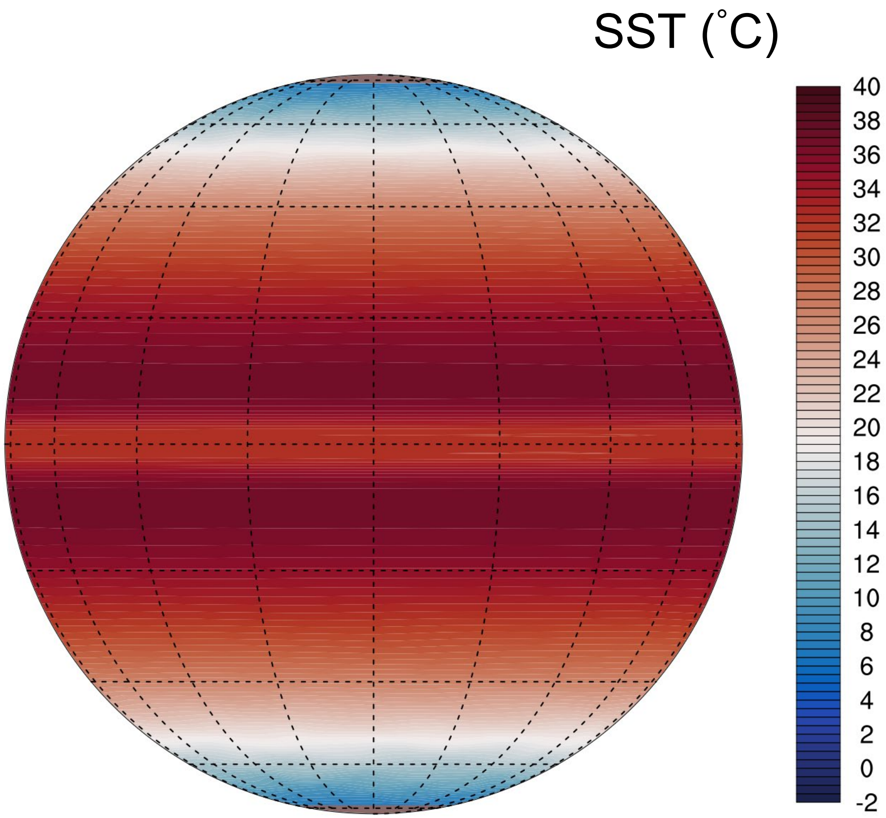
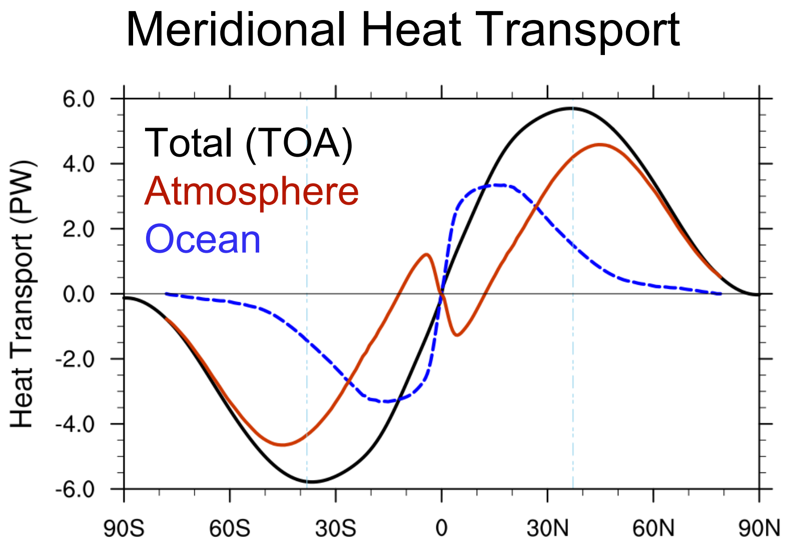
CESM Ridge: Equatorial thermocline (Yr 400)

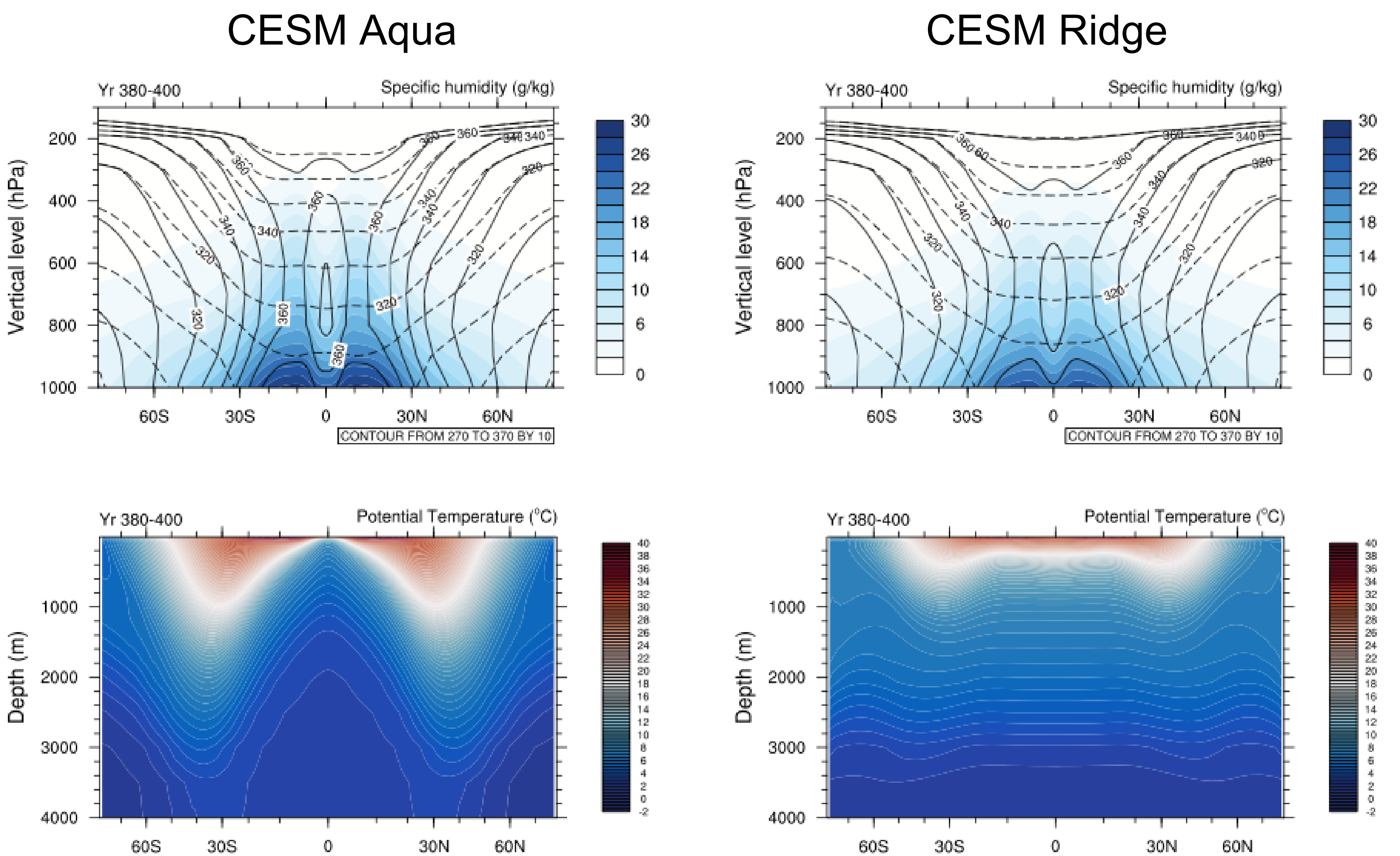


CESM Coupled Aqua: Global equatorial upwelling



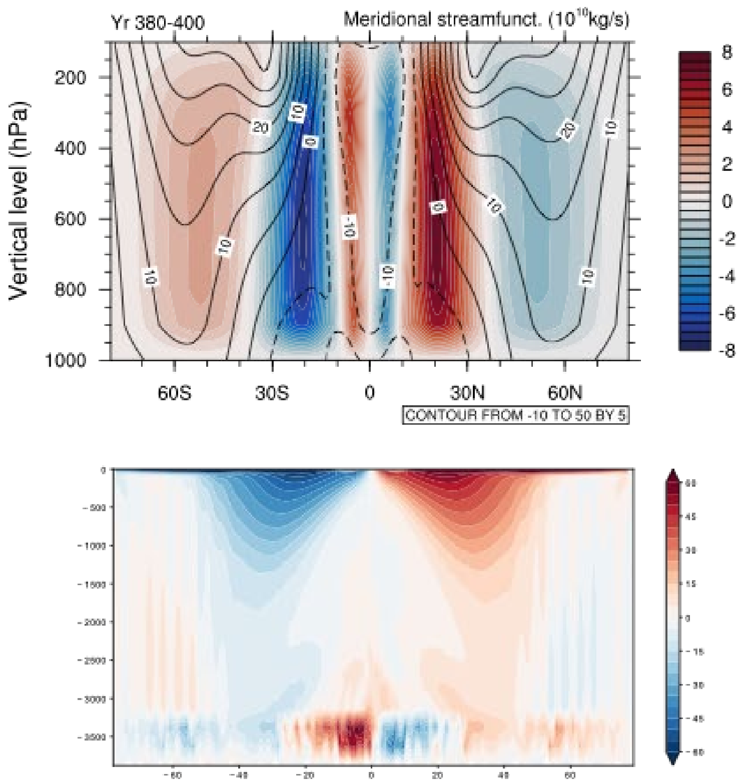


Aqua vs. Ridge: Temperature and moisture



Aqua vs. Ridge: Meridional overturning

CESM Aqua



CESM Ridge