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Possible causes of the weak ENSO in ACME coupled runs

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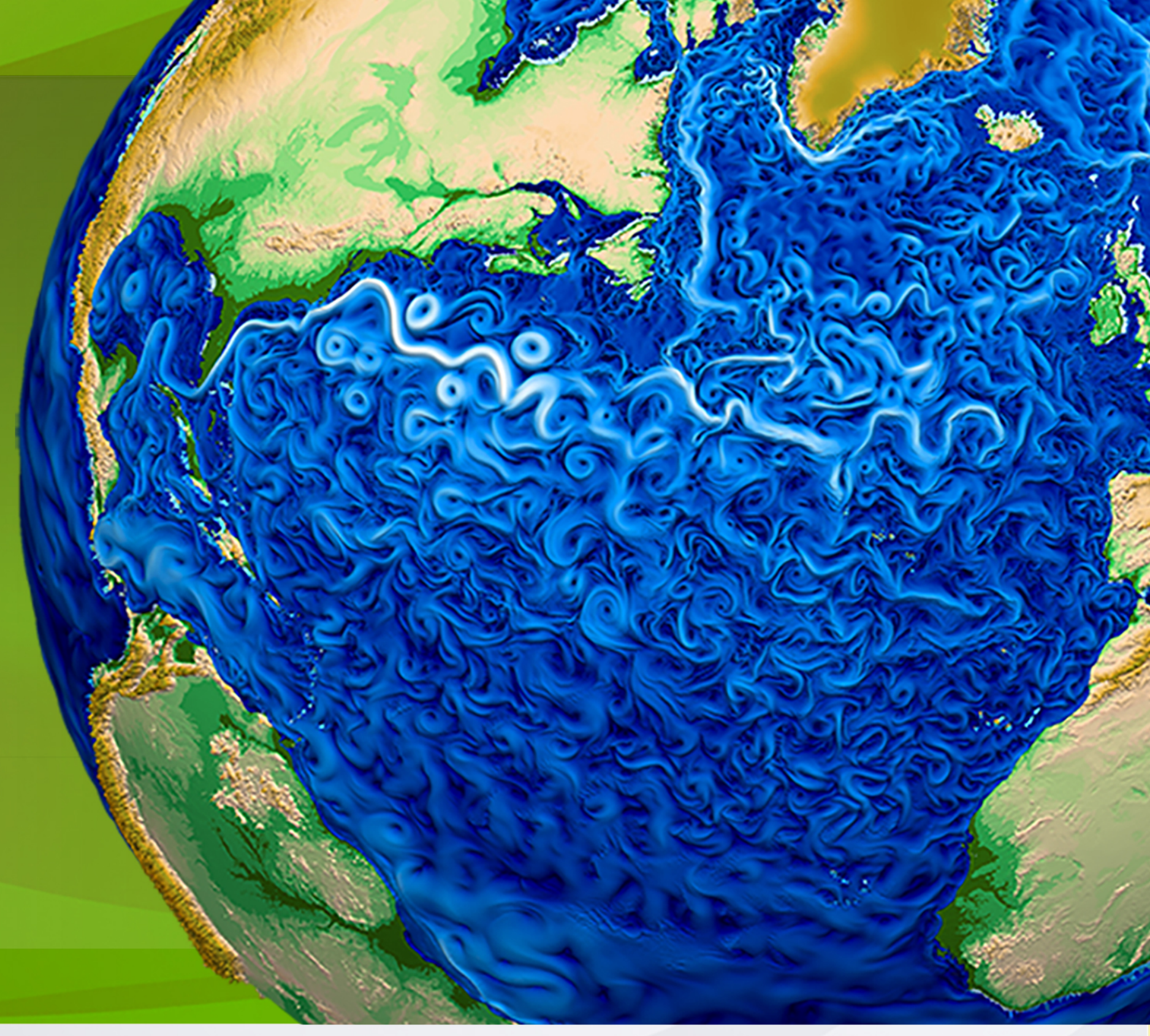


Issue

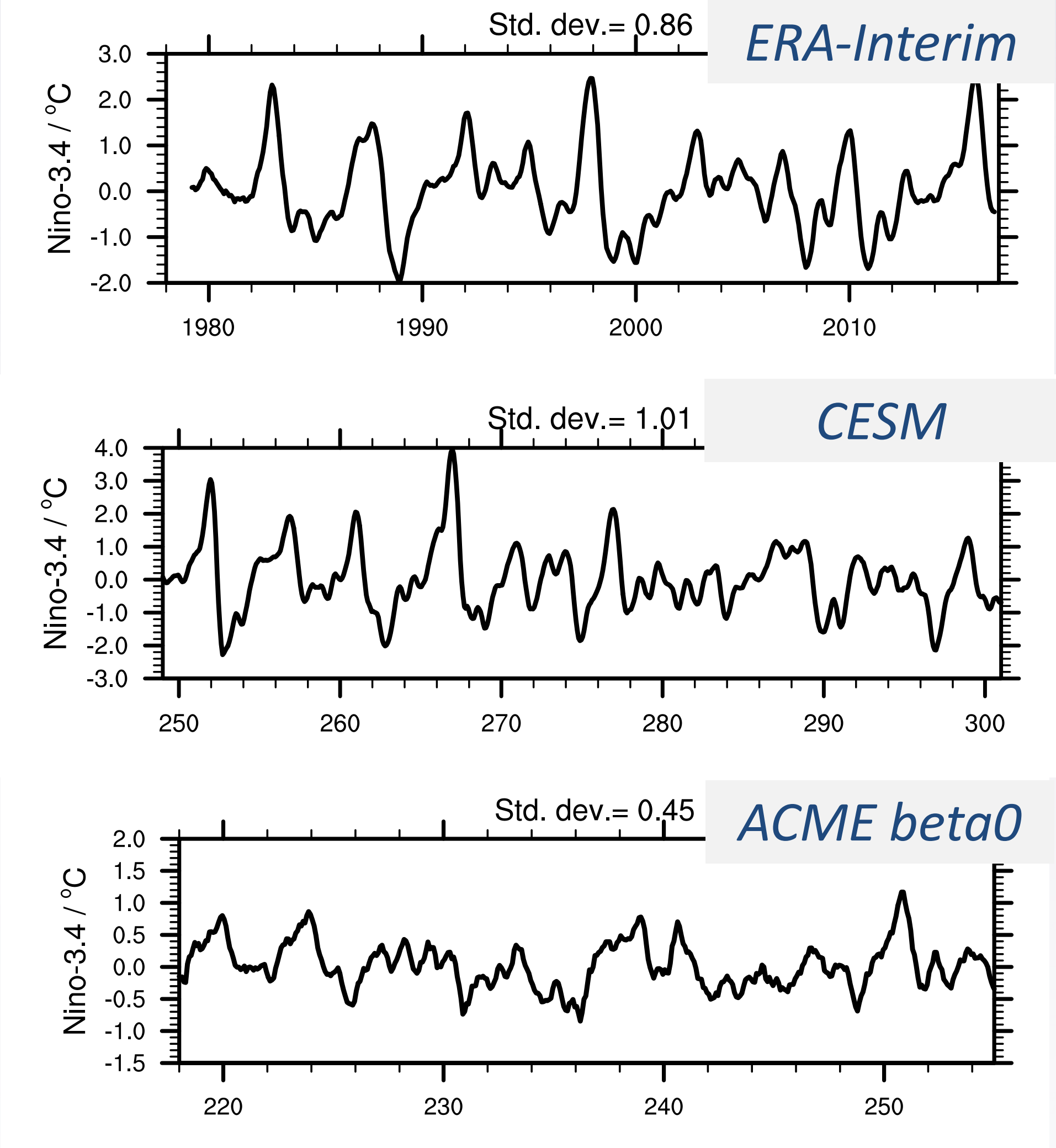


Figure 1: Niño 3.4 region average SST anomaly (relative to monthly climatology, and with 5-month smoothing) from ERA-Interim, CESM and ACME.

ACME has too little variability in the tropical Pacific:

El Niño Southern Oscillation (ENSO) is a major feature of observed interannual climate variability, with global effects in both the atmosphere and ocean.

In ACME v1 coupled model runs, the internnual variability in both atmosphere and ocean is too small.

In Niño 3.4 region (Figure 1) interannual standard deviation is too small.

In east Pacific, skewness is too small – there are no major El Niño events.

Analysis

Atmosphere and ocean, chicken and egg:

Atmosphere, ocean and surface fluxes all show biases that could potentially cause, or be caused by, SST biases in the Pacific. Determining the root of the problem is difficult.

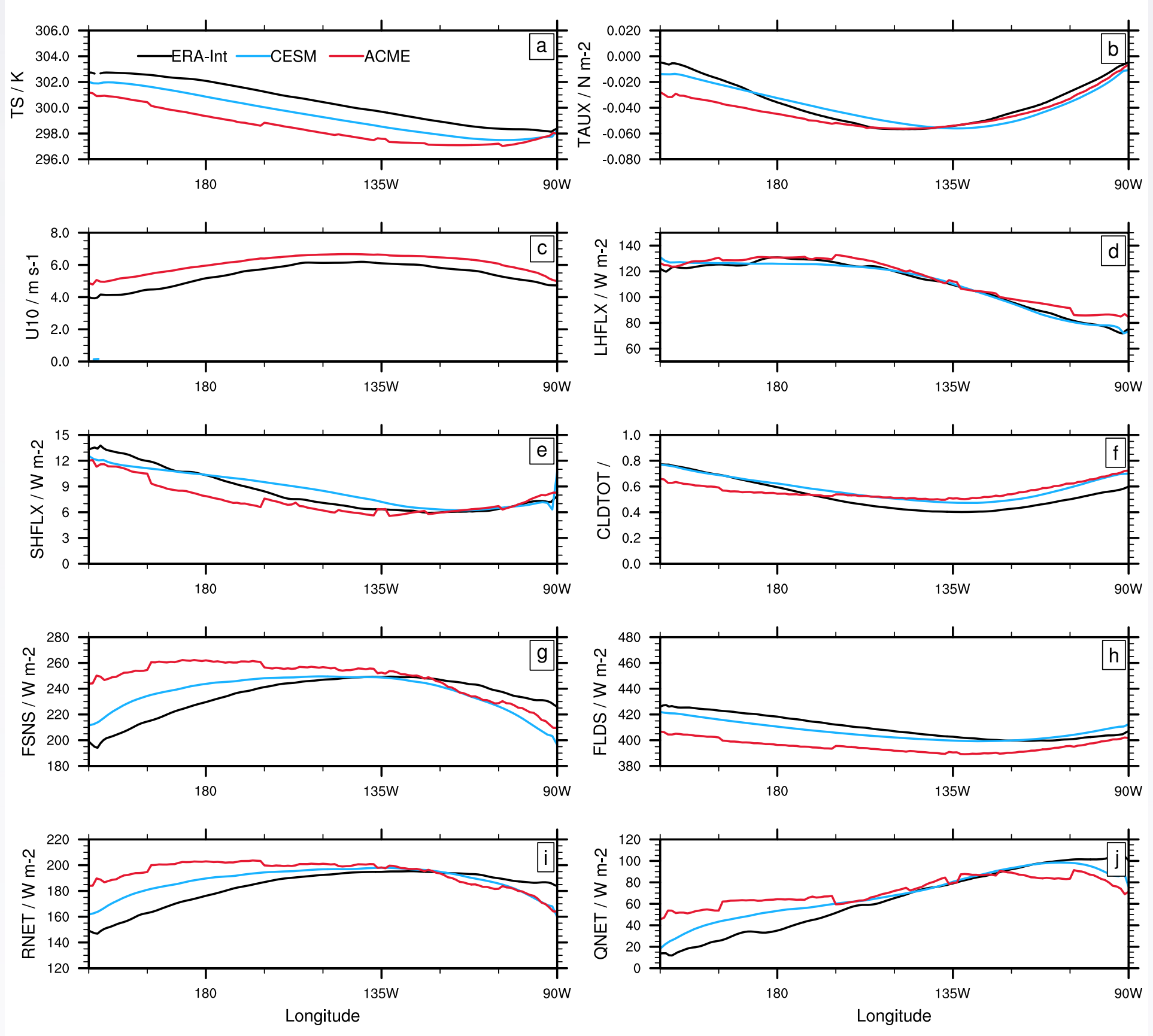


Figure 2: Long term annual averages of meridional mean (5° S to 5° N) for various quantities across the tropical Pacific from ACME beta0 and CESM coupled runs and ERA-Interim.

In west Pacific

- Easterly wind stress too large (Fig. 2b)
- Net shortwave radiation too large (Fig. 2g)

In the ocean, mixed layer is too shallow, with little east–west gradient. However, profiles reveal a complex picture with many small steps (Figure 3)

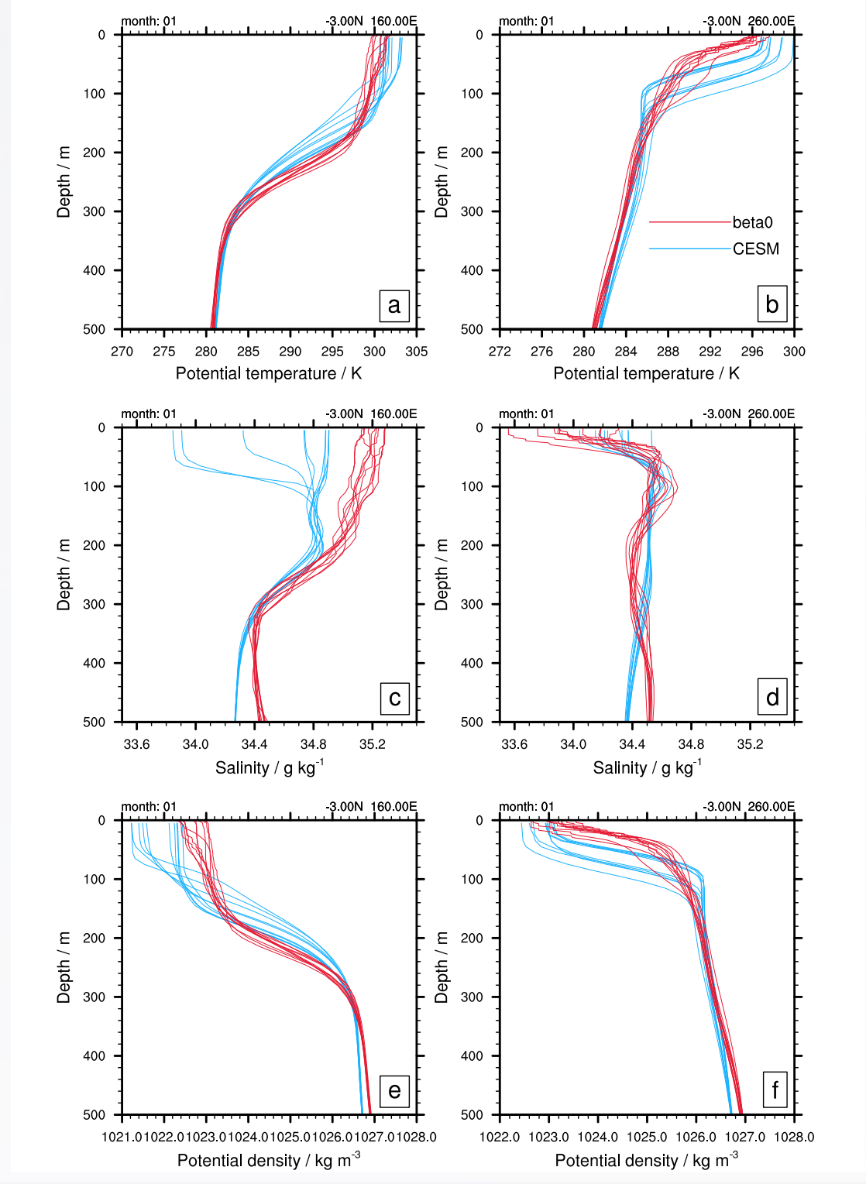


Figure 3: ACME and CESM upper ocean profiles of potential temperature (top), salinity (middle) and potential density (bottom) from two grid points in the west Pacific (left) and east Pacific (right) for January in 10 years.

Atmosphere & surface fluxes

Atmosphere-only runs

Using **climatological SSTs** in AMIP-like run:

- Net shortwave still too large despite similar cloud fraction to ERA-Int (Fig. 4g).
- Wind stress, speed and latent heat flux larger than in ERA-Interim, despite same SST gradient (Fig. 4a-d).

Using SSTs from a **CORE2-forced ocean-run:**

- Latent heat flux too large in central Pacific, due to over-strong SST gradient (Fig. 4d).

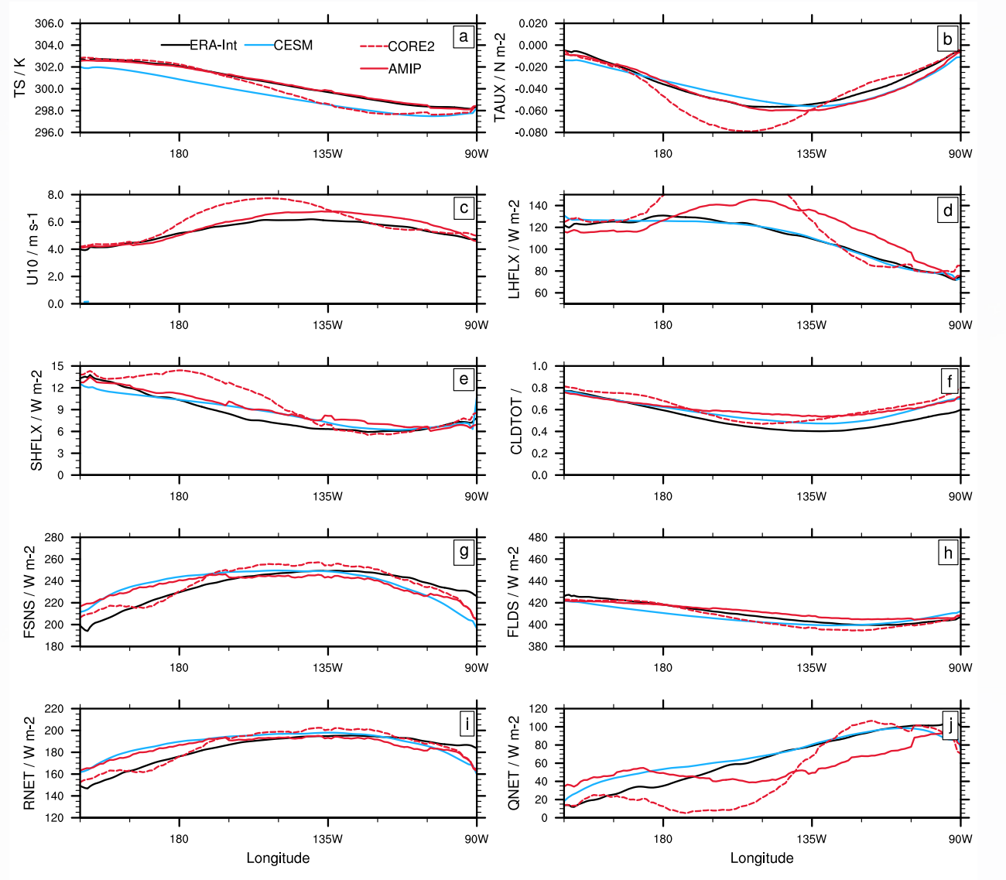


Figure 4: As in Fig. 2 but with two atmo-only runs: AMIP-like with observed SSTs (solid red) and SSTs from ocean-only run that was forced by CORE2 data.

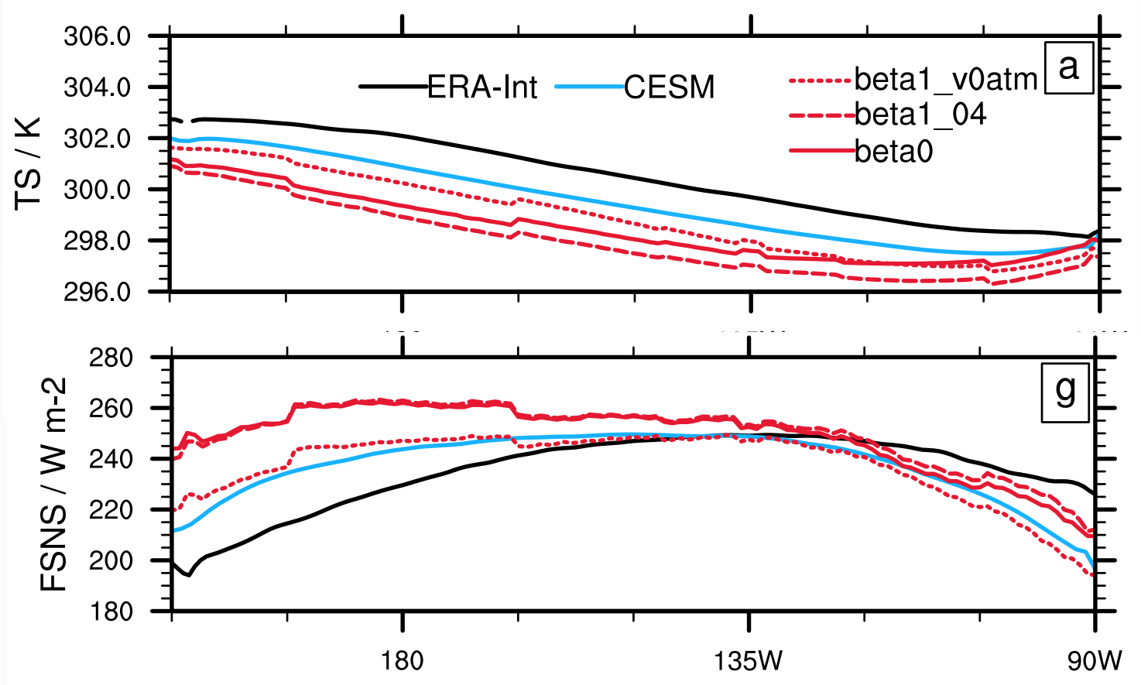


Figure 5: As in Fig. 2 but for SST and net shortwave at surface only, with beta1_04 coupled run (different ocean to beta0) and beta1_v0atm (same ocean as beta1_04 but different atmosphere).

Coupled run with v0 atmosphere:

With atmosphere model tunings from v0 (like CESM large ensemble; Fig. 5):

- Biases in atmosphere and surface variables are reduced
- The change has more effect than changing ocean model tuning (beta0 vs. beta1_04)
- Mean state (including SST) is similar to CESM
- Variability is still too small in the equatorial Pacific.

Surface flux biases mostly caused by atmosphere model, but not primary cause of weak ENSO

Possible causes of weak ENSO

Ocean vertical resolution:

Steps in ocean profiles and strong near surface temperature gradient (Figure 3) led us to **hypothesize that lower vertical resolution may help ENSO**. With lower res. 60-level ocean ($\triangle z$ = 10m near surface):

- Ocean mixed layer depth more realistic (Fig. 6).
- No great improvement in ENSO: variability not much larger than in high vertical resolution cases.

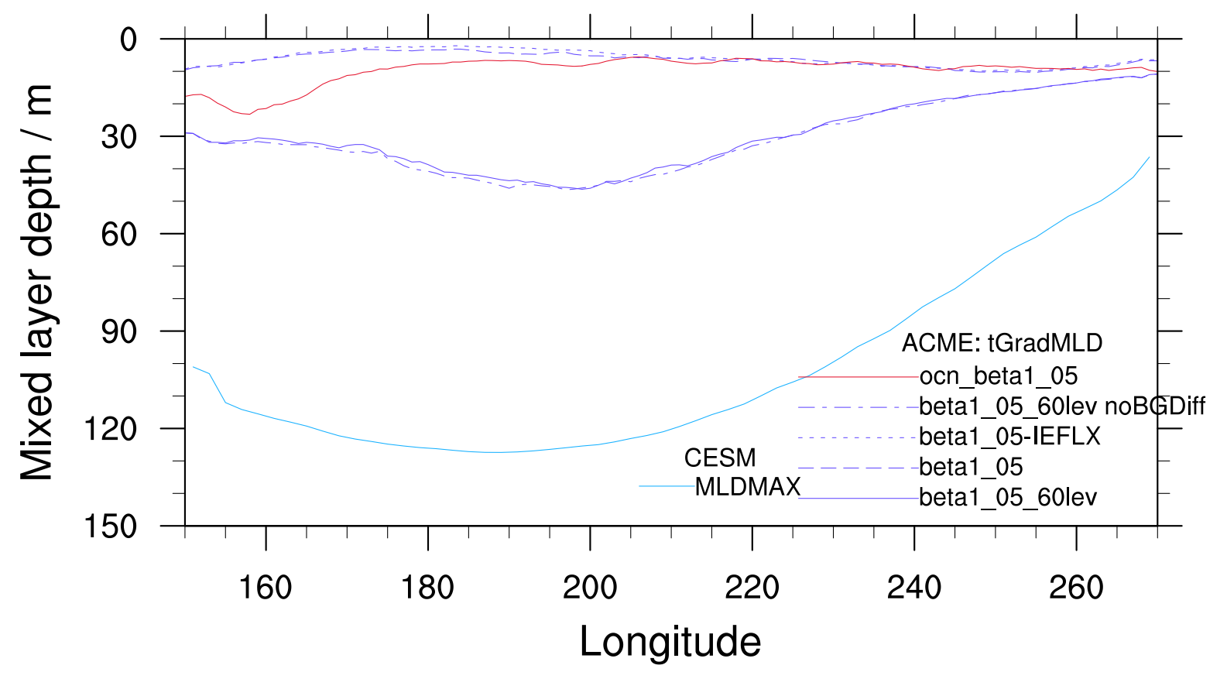
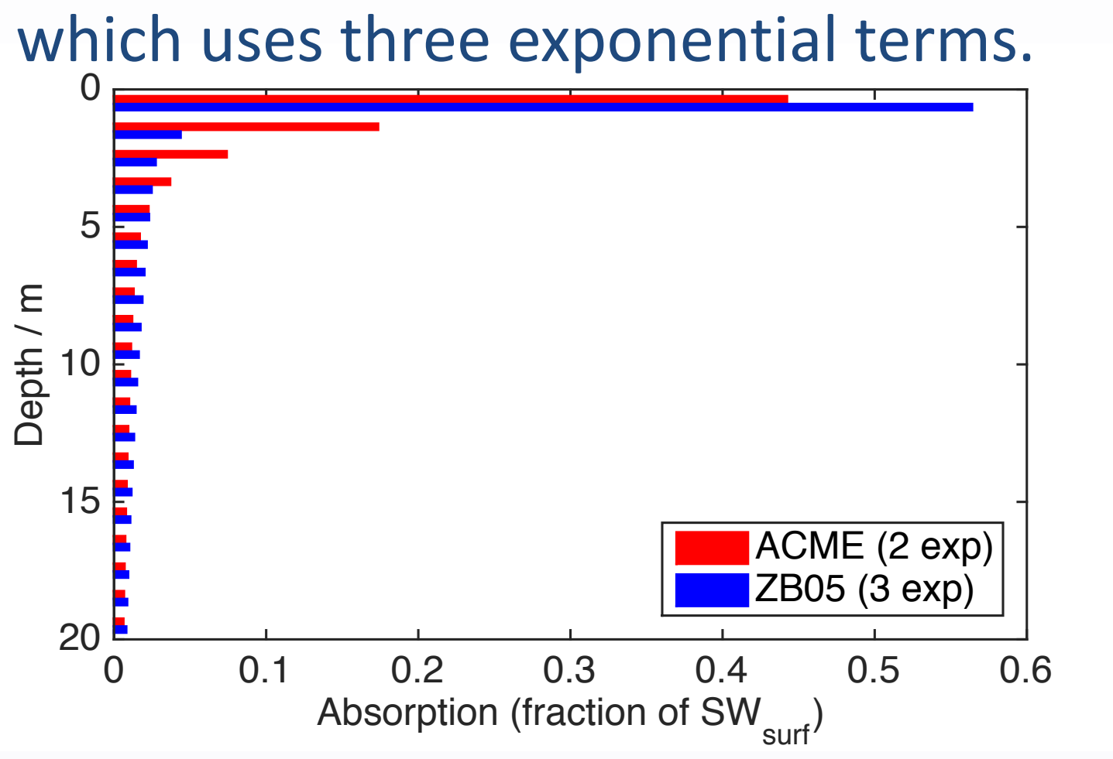


Fig. 6: As in Fig. 2 but for mixed layer depth from four ACME coupled runs, one ACME ocean-only run and CESM. Mixed layer depth is here defined using temperature gradient method: results differ between methods but generally 60-level ocean runs have deeper mixed layer.

Figure 7: Fraction of surface net shortwave radiation that is absorbed in 1-meter layers near the ocean surface, from ACME, which uses two exponential terms in its formulation, and Zeng and Beljaars (2005), which uses three exponential terms.



Shortwave absorption in the ocean:

- Coupled runs with 100-level ocean show a strong diurnal warm layer; this is not as apparent in 100-level ocean-only runs, leading us to ask whether handling of shortwave radiation in ocean may play a role.
- **Absorption of SW radiation in top three ocean layers in ACME differs from a commonly used alternative (Zeng and Beljaars, 2005; Fig. 7).**
- This could be a new path to investigate….

ACME Accelerated Climate Modeling for Energy

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