The impact of vertical mixing schemes on the position of the ITCZ in the Eastern Tropical Pacific

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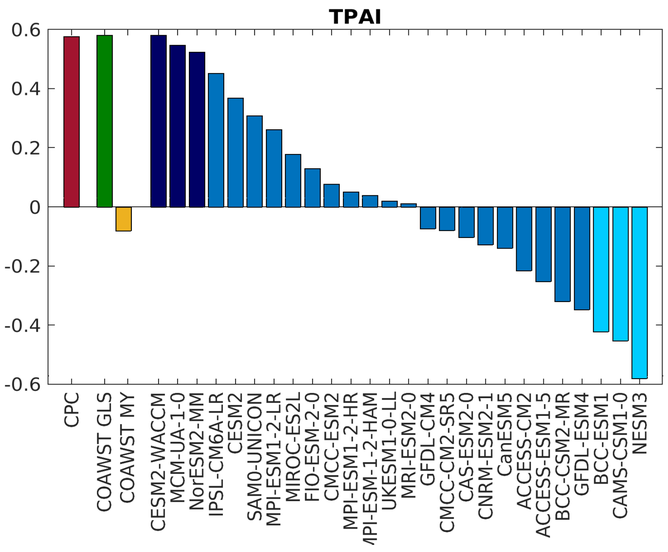
Introduction

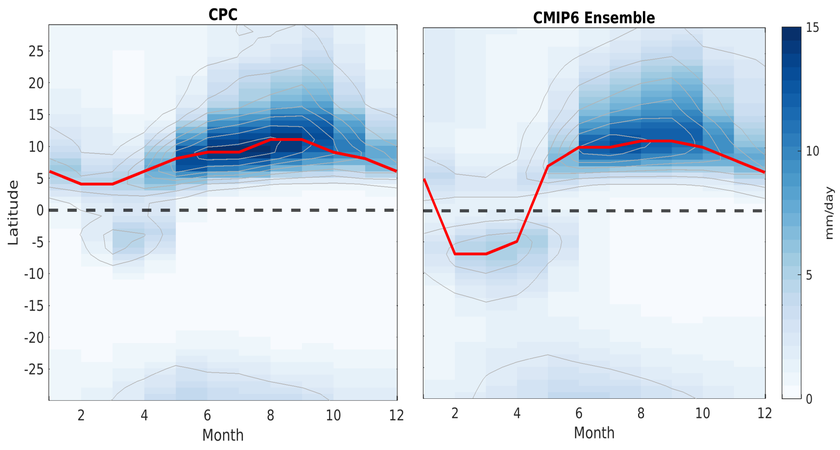
The double ITCZ is an ubiquitous bias that has displayed little to no improvement between the CMIP generations.



TPAI from January to May (1995-2014) for CPC satellite data (red), COAWST GLS (green), COAWST MY (yellow), and CMIP6 ensembles (blue).

The reasons remain unclear, the complexity of the air-sea interactions makes it difficult to identify the main processes behind this critical error.

The error is not evenly distributed throughout the year, but it mainly manifests late winter/early spring months.

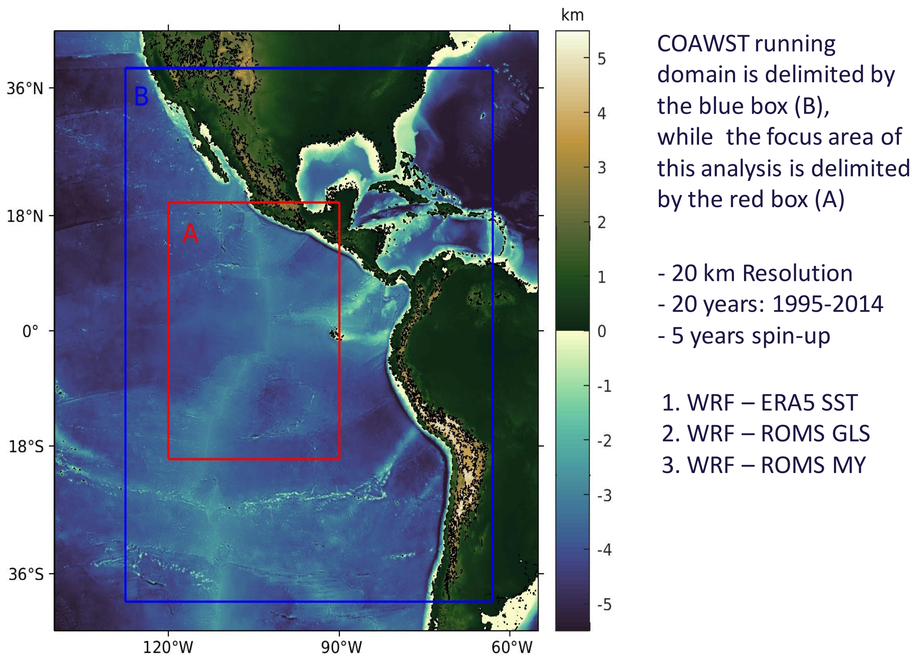


Zonally averaged precipitation seasonal cycle, from satellite data CPC and the CMIP6 ensemble.

Numerical experiments

Coupled Ocean-Atmosphere-Wave-Sediment Transport Modeling System (COAWST).

- Ocean Model: **ROMS** - Atmospheric Model: **WRF**

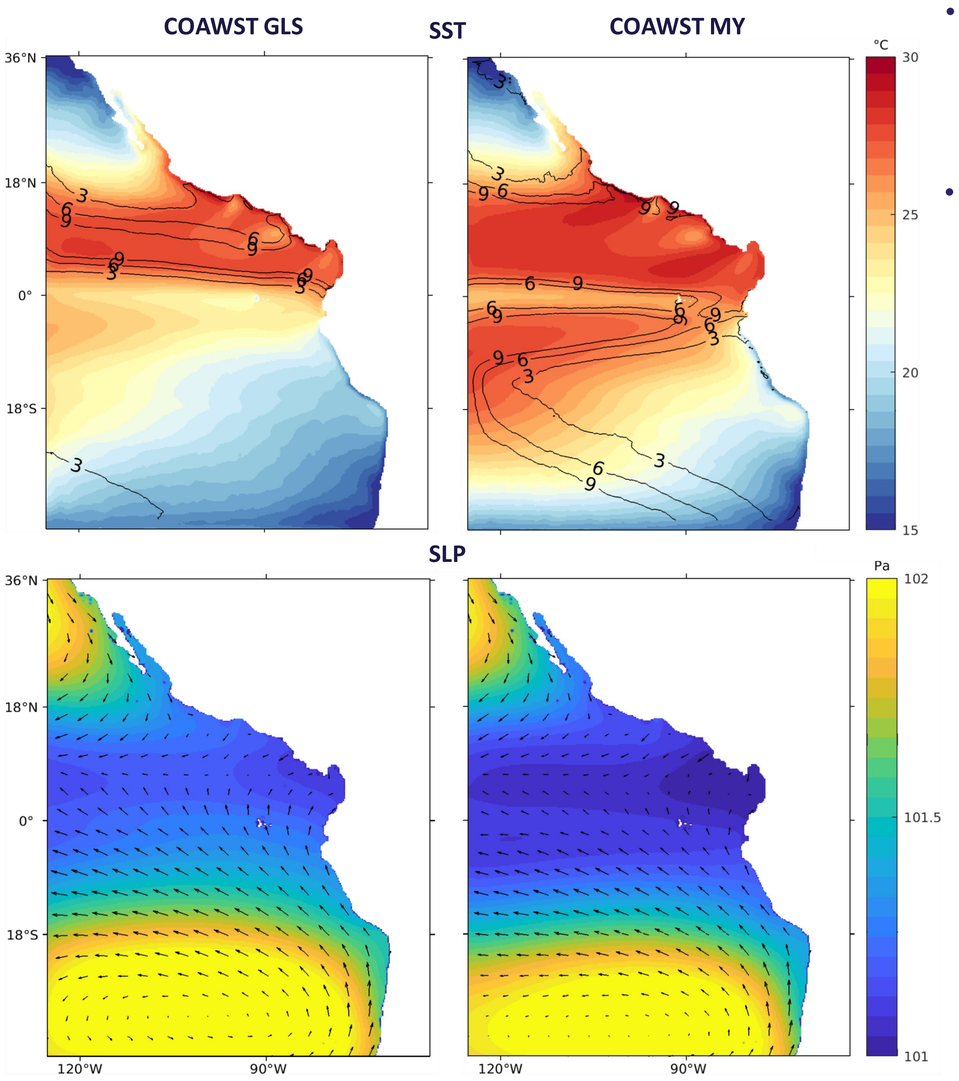


COAWST running domain is delimited by the blue box (B), while the focus area of this analysis is delimited by the red box (A)

- 20 km Resolution
- 20 years: 1995-2014
- 5 years spin-up

1. WRF – ERA5 SST
2. WRF – ROMS GLS
3. WRF – ROMS MY

Model Results



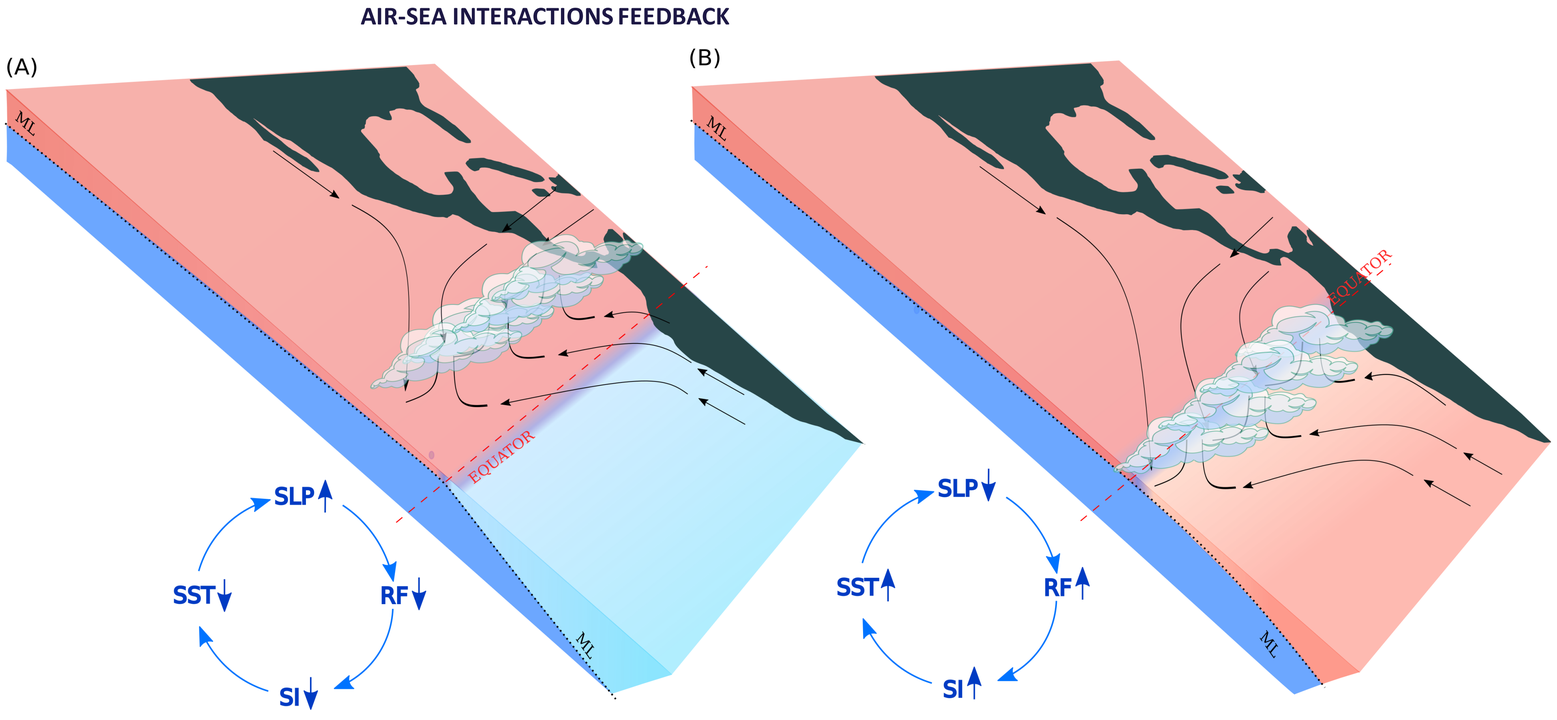
First row, SST climatologies with precipitation isolines. Second row, mean sea level pressure and wind direction.

- Since the WRF -ERA5 can reproduce correctly the ITCZ, we exclude the convection parametrization from the possible causes.
- GLS and MY vertical mixing schemes, with the same atmospheric configuration display completely different rainfall and sea level pressure patterns.

Feedback Loop

A. The SST contrast between the Northern (NH) and Southern Hemisphere (SH) gives rise to a sea level pressure (SLP) gradient, with the minimum north of the equator. The SLP pattern favors the south-easterlies, allowing them to cross the equator, locating the ITCZ in the NH.

B. Increased stratification (SI) in the SH gives rise to higher SST and decreases the interhemispheric temperature contrast. The SLP gradient change, the minimum is not located north the of equator anymore. The south-easterlies are not able to cross the equator and the ITCZ shift towards the south.



Schematic of the feedback loop between stratification (SI), SST, sea level pressure (SLP) and rainfall (RF) south of the euqator. ML represents the mixed layer latitudinal profile. (A) Correct sea-air interactions, with the ITCZ north of the equator, (B) excessively stratified ocean in the Southern Hemisphere shifts the ITC position south of the equator.

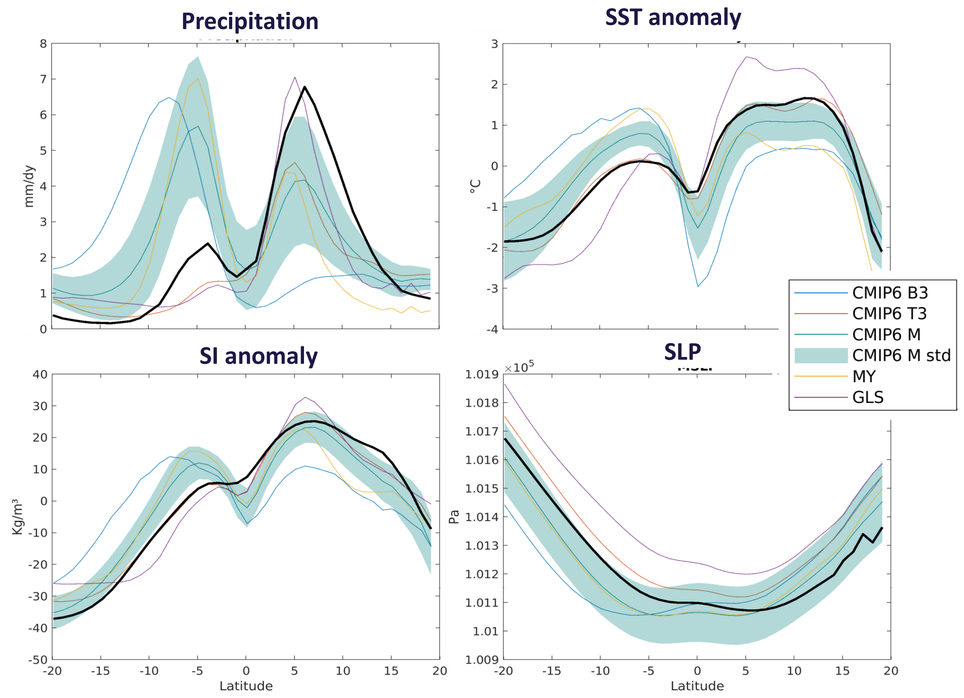
CMIP6 Analysis

Methods

Tropical precipitation asymmetry index (TPAI) is the difference between rainfall in the NH (0 to 20°N) and rainfall in the SH (0 to 20°S), normalized by the total rainfall (20°N to 20°S).

The upper ocean (top 200 m) stratification of each model has been evaluated using the Stratification Index (SI), the cumulated density anomaly with respect to the surface density layer over the top 200 m.

26 CMIP6 ensemble members have been divided in three groups, using the TPAI index . Top 3 (red), bottom 3 (blue) and the middle members.



Zonally averaged RF, SST and SI anomalies with respect to the zonal mean, SLP latitudinal profiles (calculated over box A). For the Top 3 (T3), Bottom 3 (B3), and Middle members (M), for the 26 CMIP6 ensembles. Black lines represent data from CPC, GHRSST, WOA, and ERA5 respectively. Compared with the numerical experiments, COAWST MY and COAWST GLS.

The latitudinal profiles enlighten the key role of the SST interhemispheric contrast in defying the precipitation patterns and the position of the ITCZ.

Air-sea interactions give rise to a complex feedback loop. The processes behind the error can be several, from cloud biases to convective parametrization schemes inaccuracies. **Our numerical experiments point towards the importance of an underestimated factor: mixing parametrization schemes.**

References

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