# Diagnosing the sources of systematic SST biases in CESM using ensemble seasonal hindcasts

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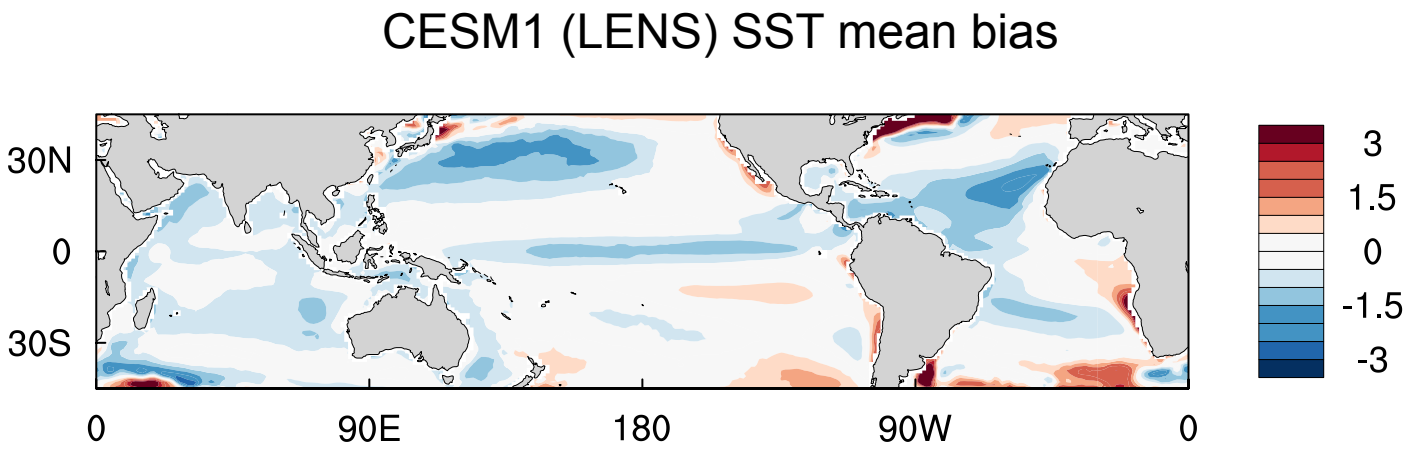
RGMA

CAPT
Cloud-Associated Parameterizations Testbed

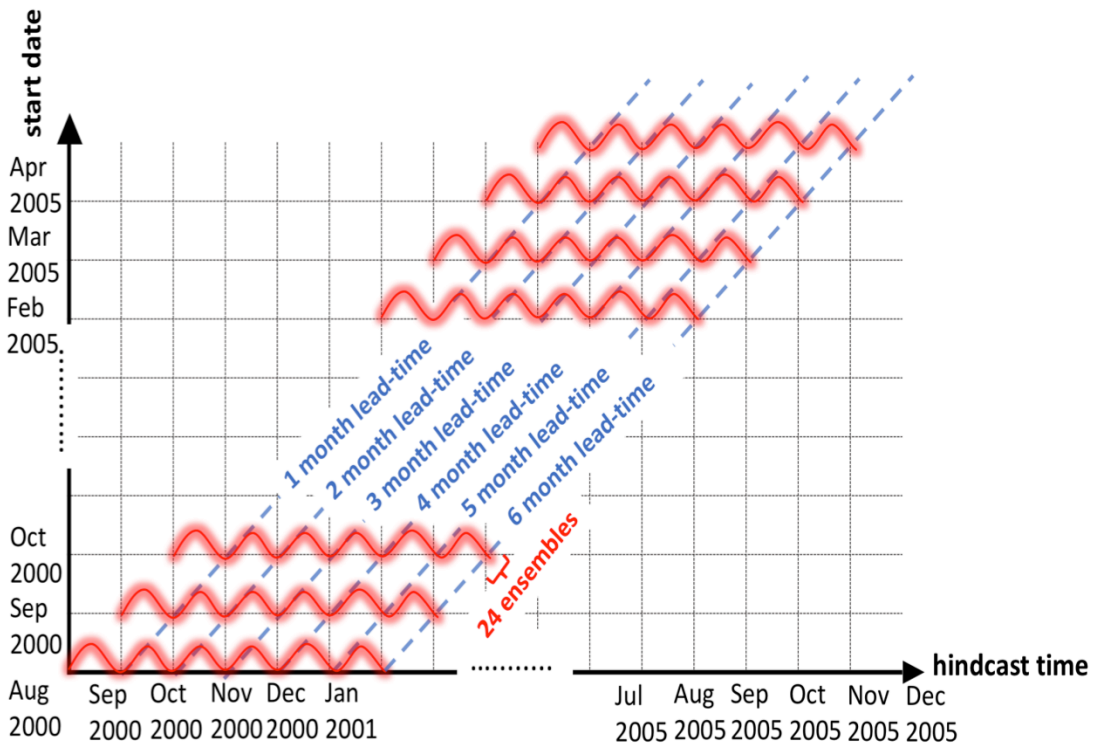
# SST biases in CESM1




- SST biases impact the fidelity of our seasonal and decadal forecasts.
- For instance, over the equatorial Pacific, a too cold SST in the mean state impacts the simulation of ENSO.
- Reducing SST biases requires an understanding of why and how SST biases develop

  → Can we use an ensemble seasonal hindcast approach?

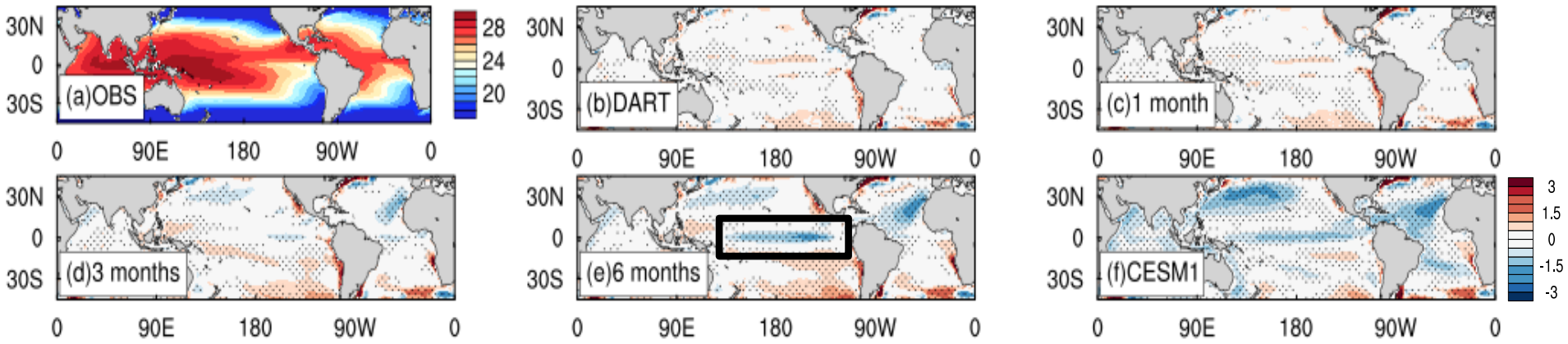
# The Coupled CAPT Framework




- 6-month-long, 24-ensemble member hindcasts covering the years 2000-2005
- Atmospheric and land initial conditions from Cloud Associated Parameterizations Testbed (CAPT) procedure (Ma et al. 2015)
- Ocean initial conditions from POP-DART (Karspeck et al. 2013)
- A reconstructed timeseries based on lead-time is used to study the annual cycle

# The correspondence of the mean state bias in hindcasts and climatology

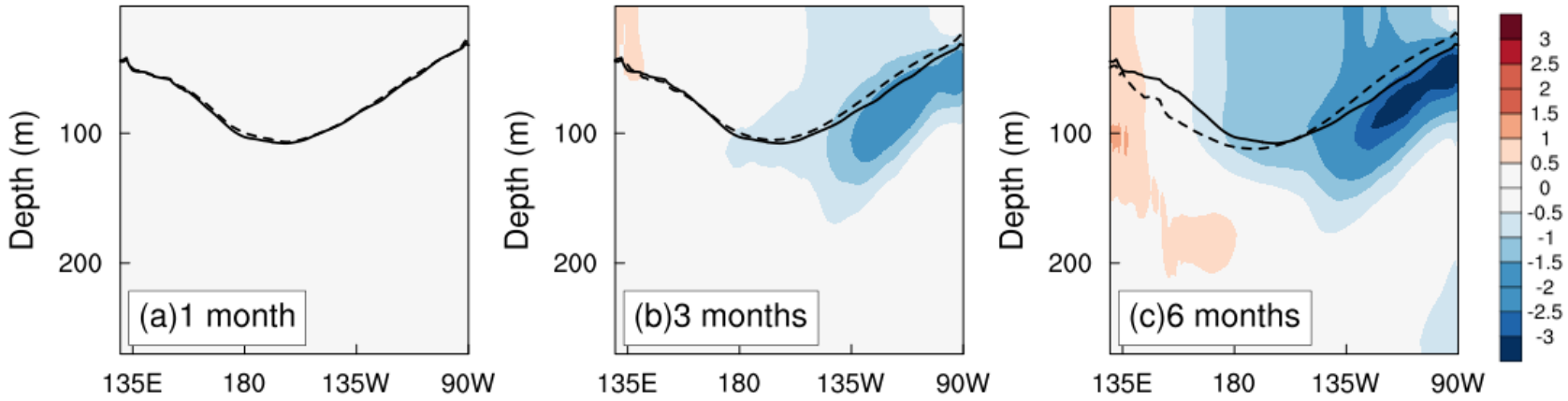
*Annual mean bias (2001-2005)*




- Small biases present in 1 month lead time are inherited from reanalyses.
- At 3 months of lead time, cold biases in the equatorial and in northern subtropical regions start to emerge.
- The cold biases increases in magnitude at later lead times and develop a similar bias pattern when compared to the CESM1 climatological bias.

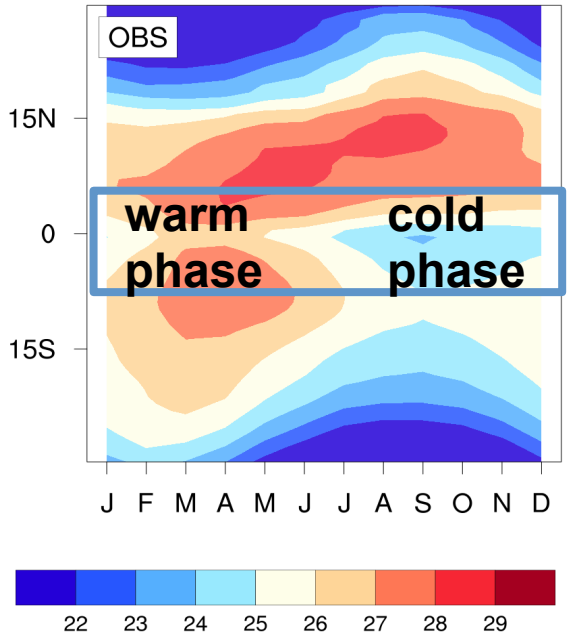
# The equatorial Pacific cold tongue bias growth in the hindcasts

*Annual mean (2001-2005) hindcast minus DART averaged over 5°S-5°N*

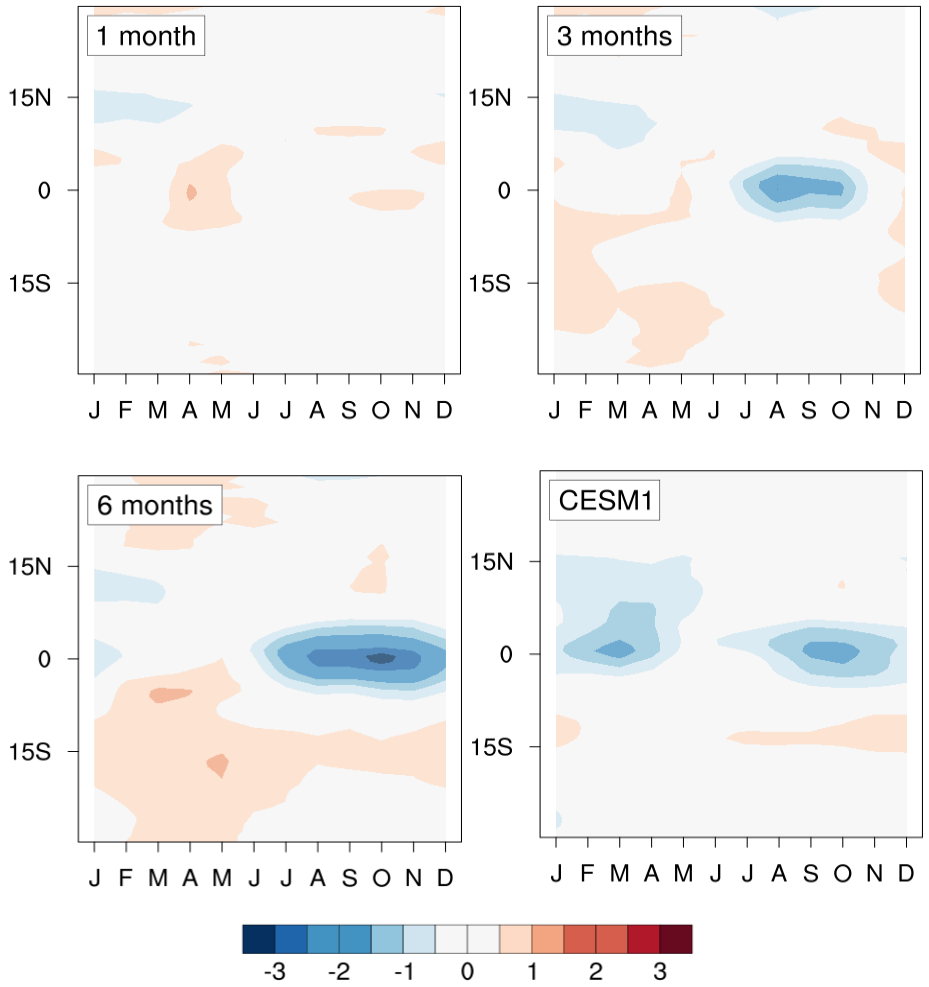



- With increasing lead time, cold bias below the mixed layer increases and extends westwards at surface. The mixed layer shoals in the east and deepens in the west

# The seasonal cycle of the equatorial cold tongue bias

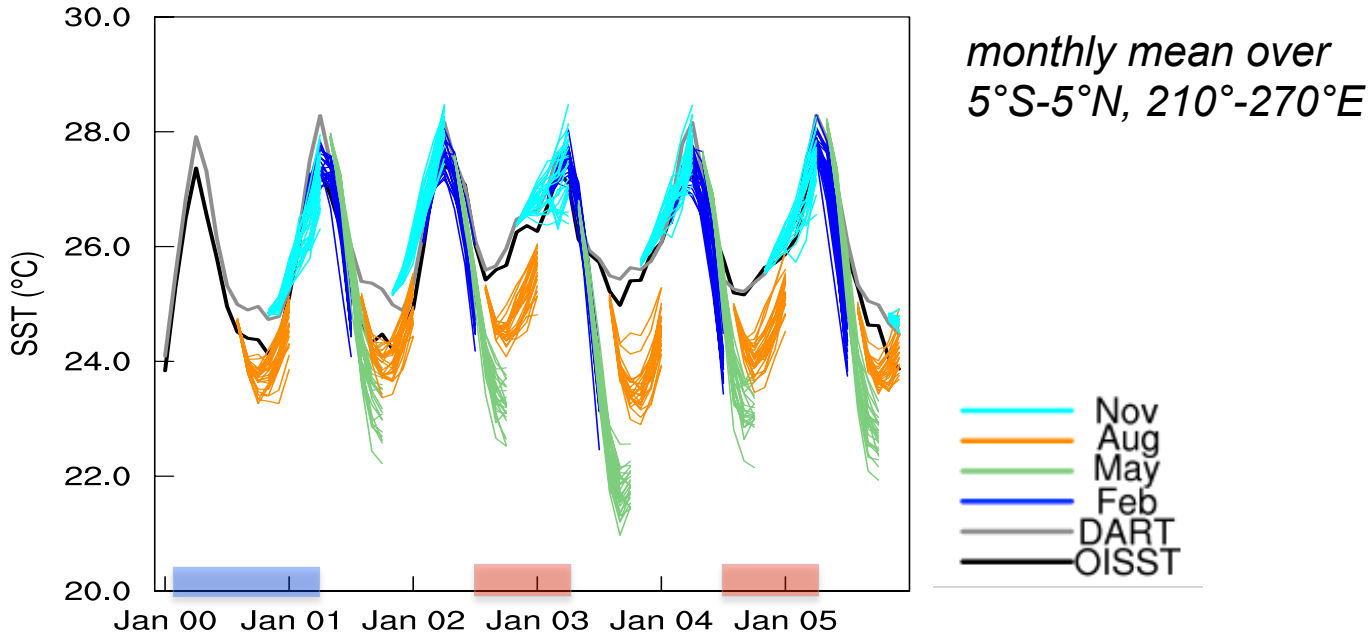



*Latitude-month mean bias over 210°-270°E*




- Cold phase cold bias develops within 6 months, but warm phase cold bias does not

# Start-date dependence of the cold tongue bias

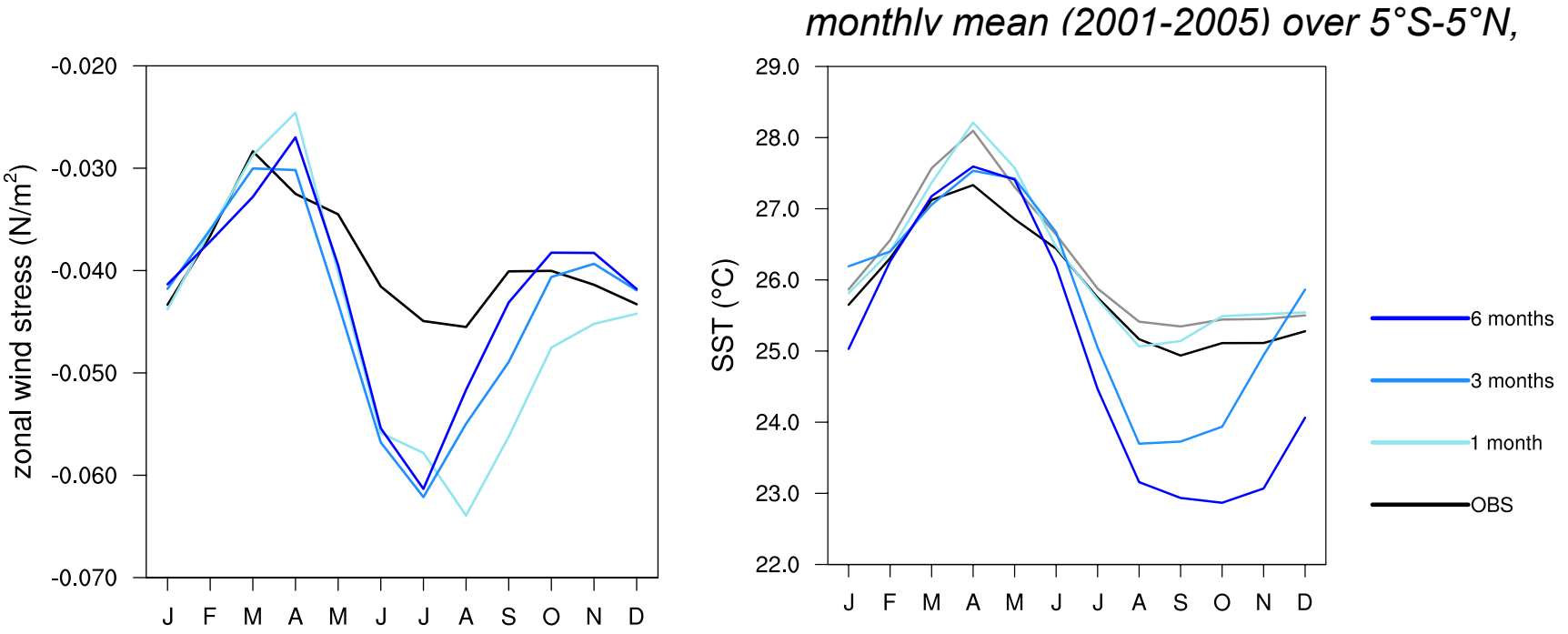



- The start date has an influence on the SST drift and ensemble spread
- For all years, strong drift occurs with August and May start dates

→model biases develop quickly during cold phase (boreal summer to fall)

→ heat budget analysis indicate that anomalous cooling in May hindcasts comes from too strong vertical advection

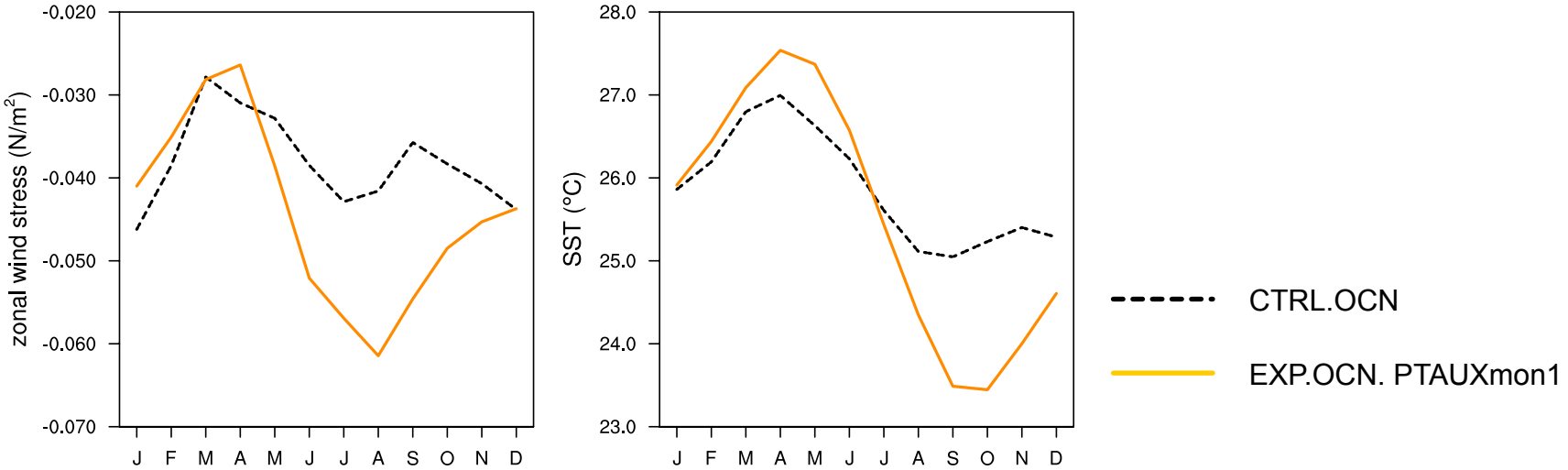
# The cold phase cold bias: a wind-driven upwelling bias




- The zonal windstress bias is present since the first month of leadtime and drives the cold bias during the cold phase.

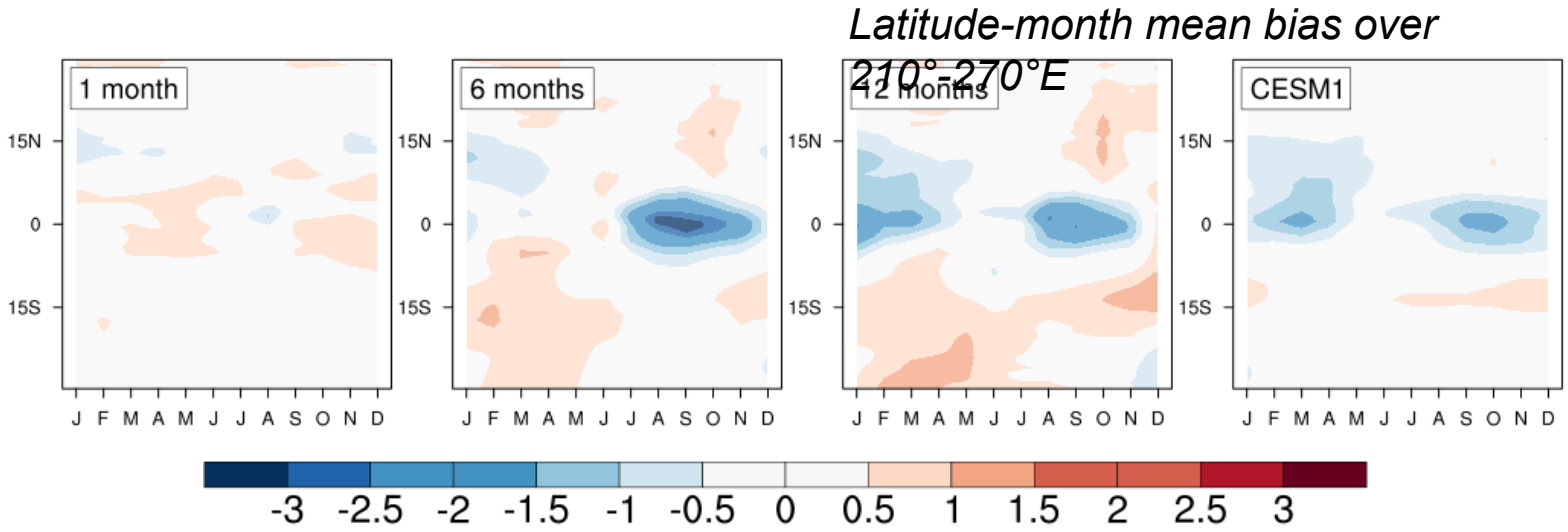
# Test: biased zonal wind stress over the eastern equatorial Pacific

| Name | Ocean IC | Wind stress forcing | Simulation years |
|---|---|---|---|
| CTRL.OCN | DART | COREv2 | 2001-2005 |
| EXP.OCN.PTAUXmon1 | DART | Prescribed monthly wind stress output from coupled CAPT (1-month lead-time) | 2001-2005 |

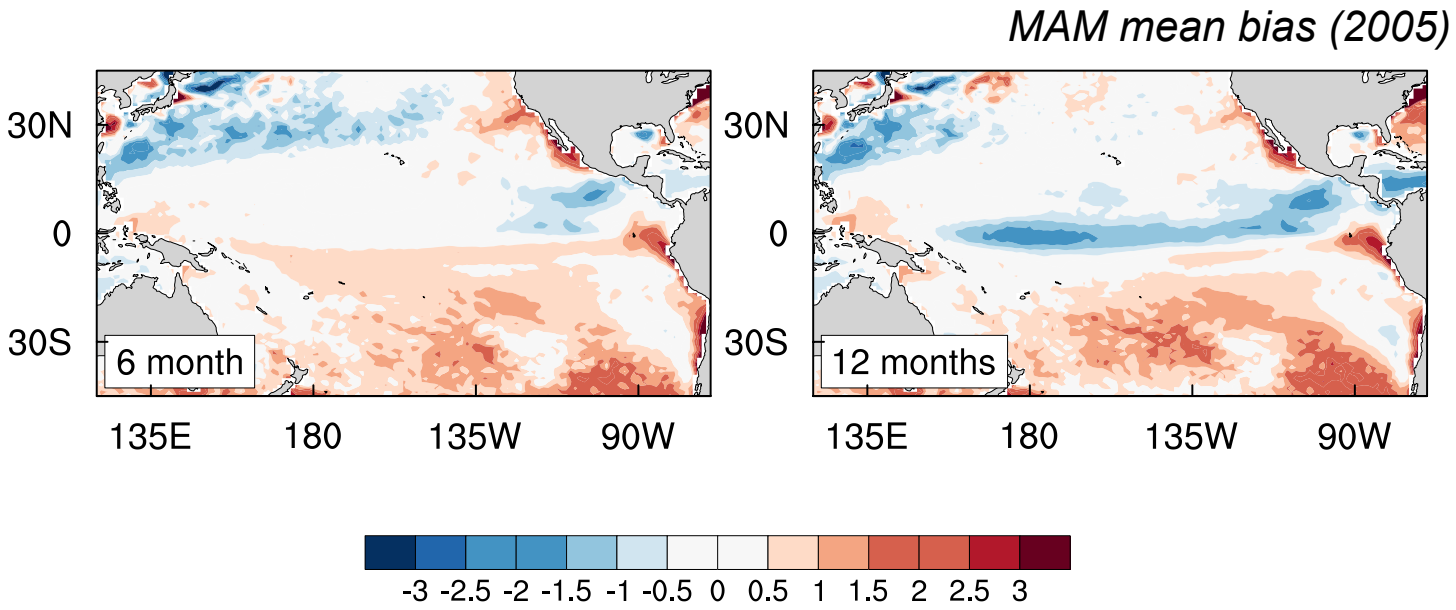


# The warm phase cold bias

- Does the warm phase cold bias develop in later lead times?
  → extend the hindcasts for year 2005 from 6 to 12 months lead time



# The warm phase cold bias




- Possibly related to northeastern Pacific warm pool cold bias, which contributes to the anomalous southward ITCZ and northerly winds that would advect the cooling equatorwards (deSzoeke and Xie, 2008)

# Summary

1. The cold bias emerges within 3 months of lead time, and first develops during boreal summer-fall (cold phase cold bias)
2. The cold phase cold bias is associated with a too strong surface zonal wind stress that leads to too strong upwelling.
3. The warm phase cold bias develops after 6 months of lead time, possibly linked with equatorward advection of northeastern Pacific cold bias.
4. Coupled ensemble hindcasts can be utilized in understanding how SST biases emerge and develop.