

# The equatorial Pacific cold tongue bias in CESM1 and its influence on ENSO forecasts

Xian Wu<sup>1</sup>, Yuko Okumura<sup>2</sup>, Stephen Yeager<sup>1</sup>, Clara Deser<sup>1</sup>, Pedro DiNezio<sup>3</sup>

*1 National Center for Atmospheric Research*

*2 The University of Texas at Austin*

*3 University of Colorado Boulder*

CVCWG 2021

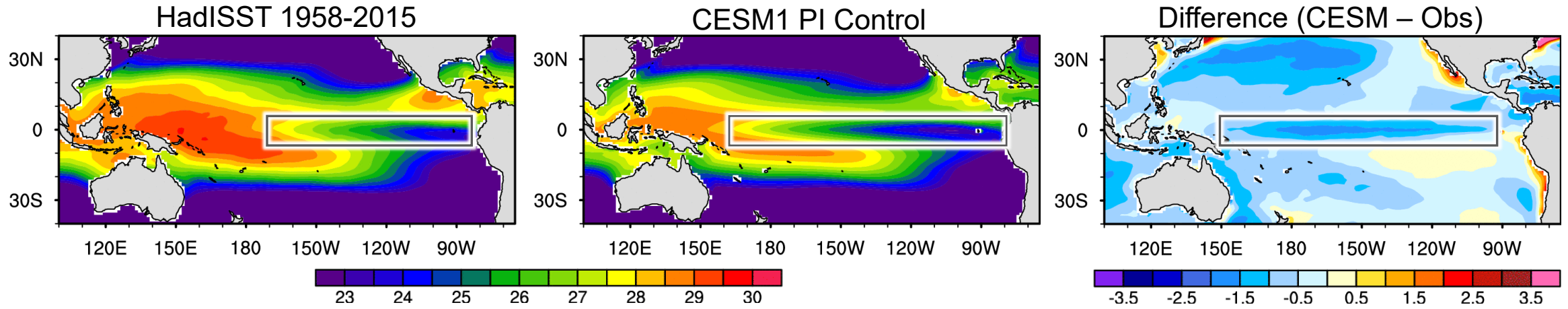


INSTITUTE FOR GEOPHYSICS  
JACKSON SCHOOL OF GEOSCIENCES



# Background

## Climatological SST



## Equatorial Pacific cold tongue bias in climate model simulations

*(Mechoso et al. 1995; Davey et al. 2002; Zheng et al. 2012; Vanni re et al. 2013; Brown et al. 2014; Bellenger et al. 2014; Planton et al. 2020; Guilyardi et al. 2020; Siongco et al. 2020; Jiang et al. 2021)*

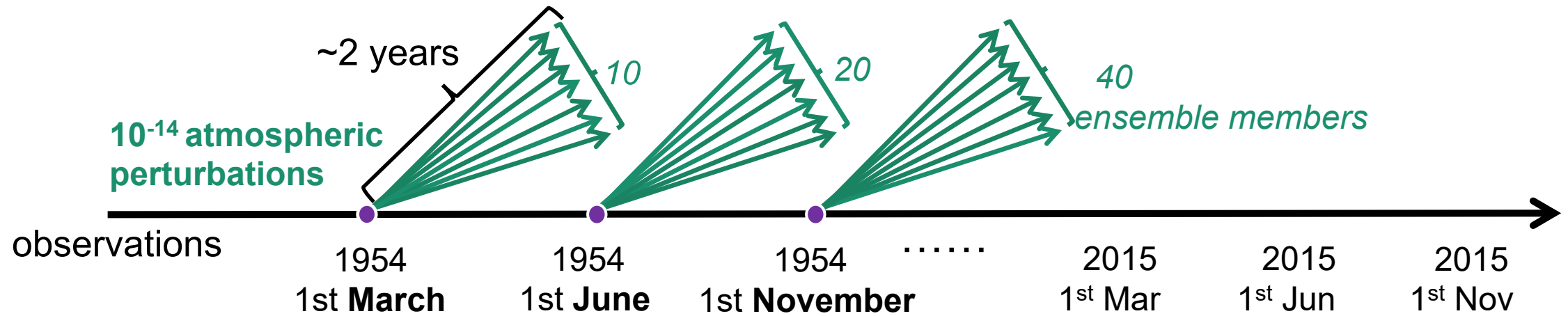
## ENSO simulation errors (spatial pattern and amplitude)

*(Taschetto et al. 2014; Graham et al. 2017; Planton et al. 2020; Jiang et al. 2021; Bellenger et al. 2014; Bayr et al. 2018)*

## ENSO forecast errors

*(Misra et al. 2008; Magnusson et al. 2013; Ham et al. 2014; Kim et al. 2017; Ding et al. 2020; Hu et al. 2020)*

# Two-year CESM1 forecasts during 1954-2015



**‘observed’ oceanic and sea ice states**

CESM Decadal Prediction Large Ensemble (Yeager et al. 2018)

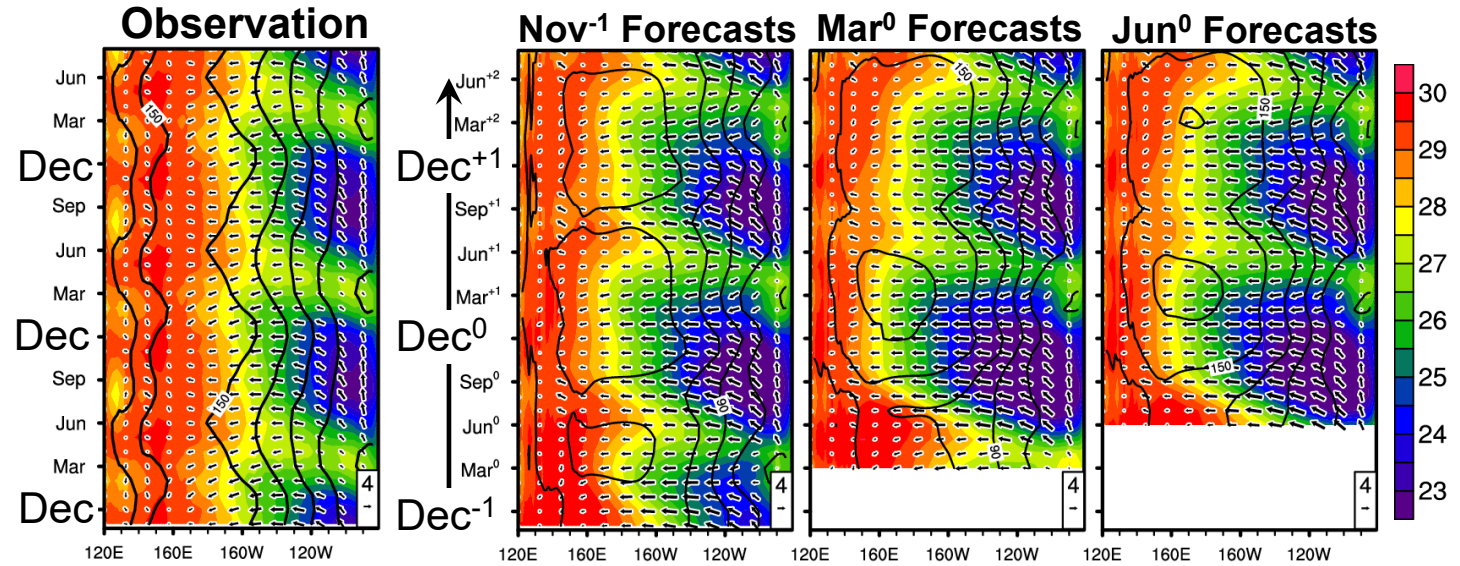
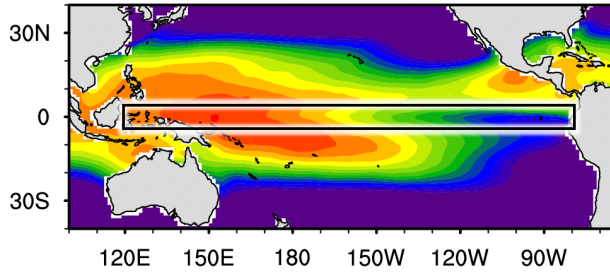
**Forced Ocean-Sea Ice simulation (FOSI):  
POP2-CICE4 simulation forced with observed atmospheric and surface flux fields**

**CMIP5 external forcing** (‘Historical’ 1954–2005, RCP 8.5 2006–2015)

Wu, X., Y. M. Okumura, C. Deser, and P. N. DiNezio, 2021: Two-year Dynamical Predictions of ENSO Event Duration during 1954–2015. *Journal of Climate*. accepted.

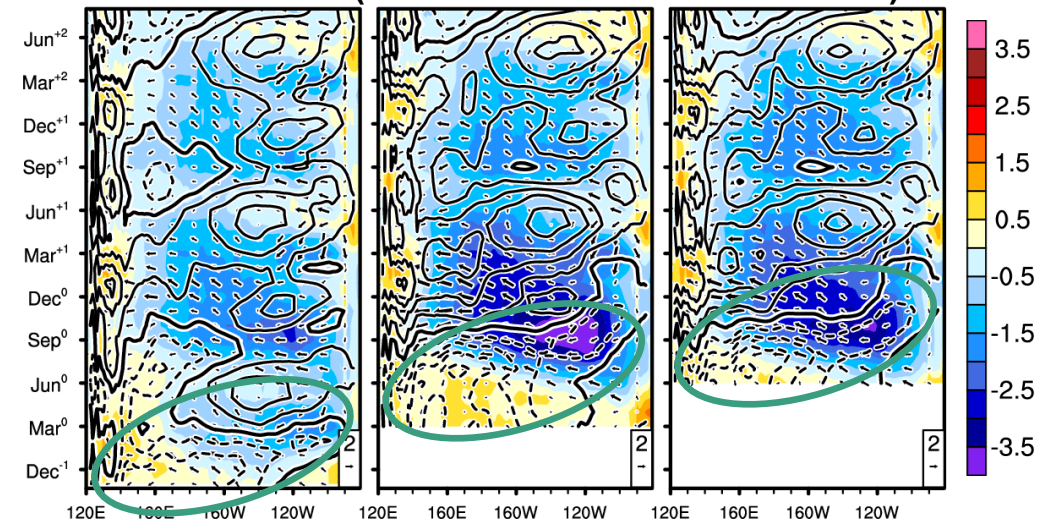
# Equatorial Pacific cold tongue bias in the CESM1 forecasts

Seasonal cycle of climatological **SST**, thermocline depth, and **surface wind** in the equatorial Pacific ( $3^{\circ}\text{S}$ – $3^{\circ}\text{N}$ ), 1958–2015



Amplitude & pattern bias

## Difference (Forecasts minus Observation)

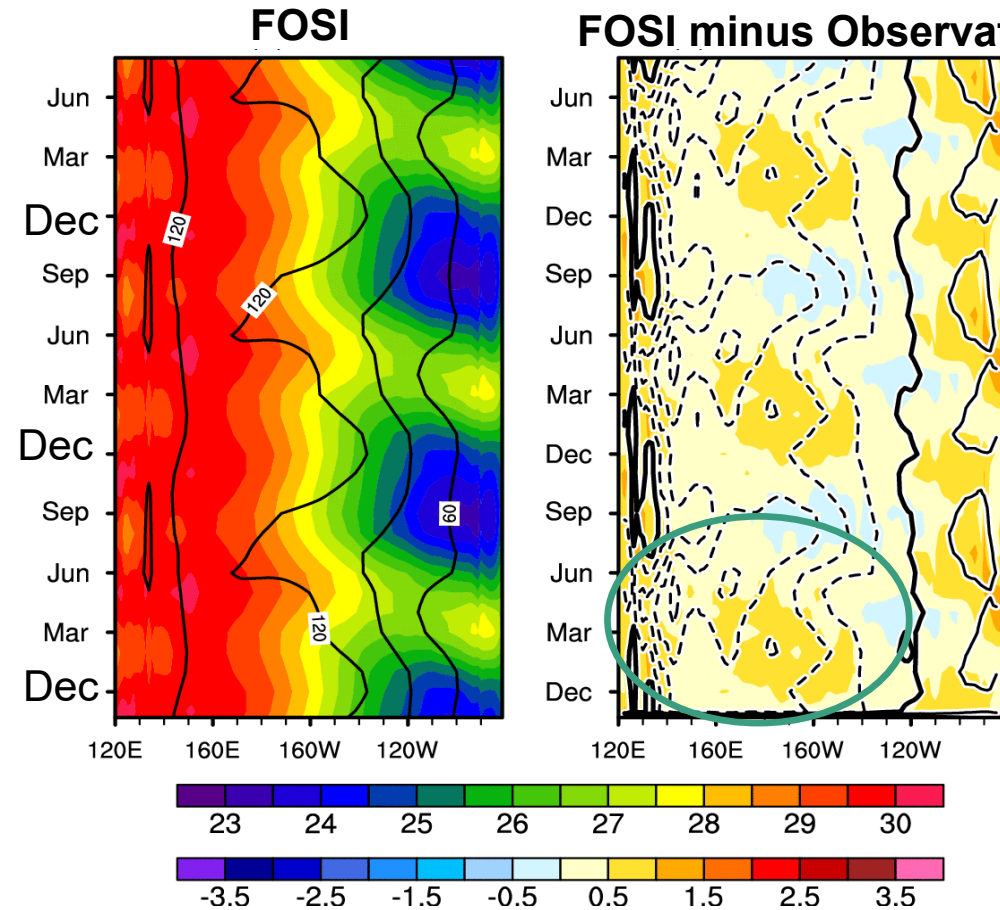


SST cooling bias  
 Initial thermocline shoaling bias

Larger Bias in the first year after initialization than longer lead times  
 Larger Bias in Mar and Jun than Nov forecasts

# Errors in the initial oceanic condition data (FOSI)

Seasonal cycle of climatological **SST** & thermocline depth  
in the equatorial Pacific, 1958–2015

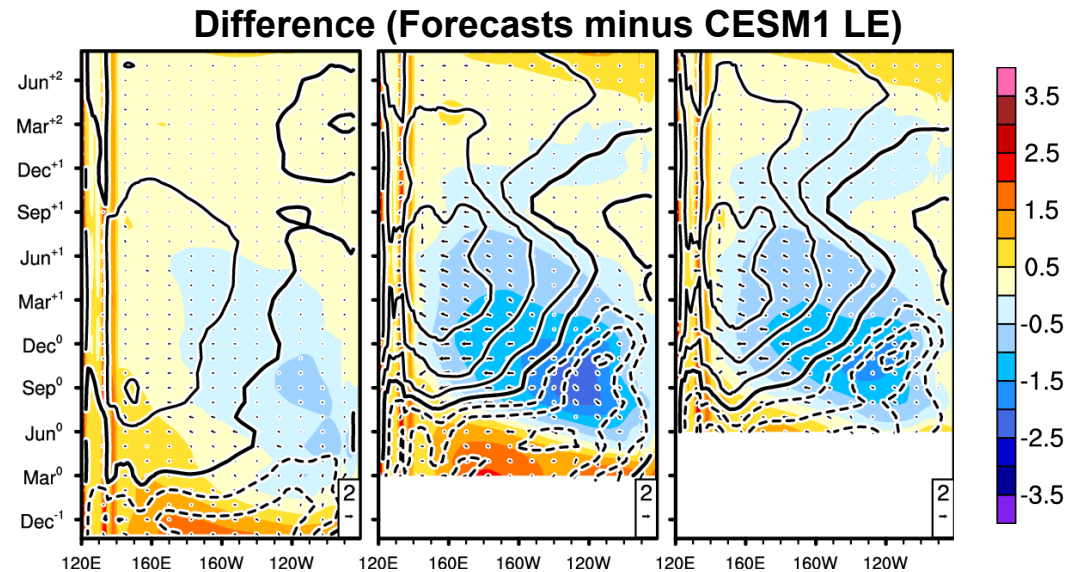
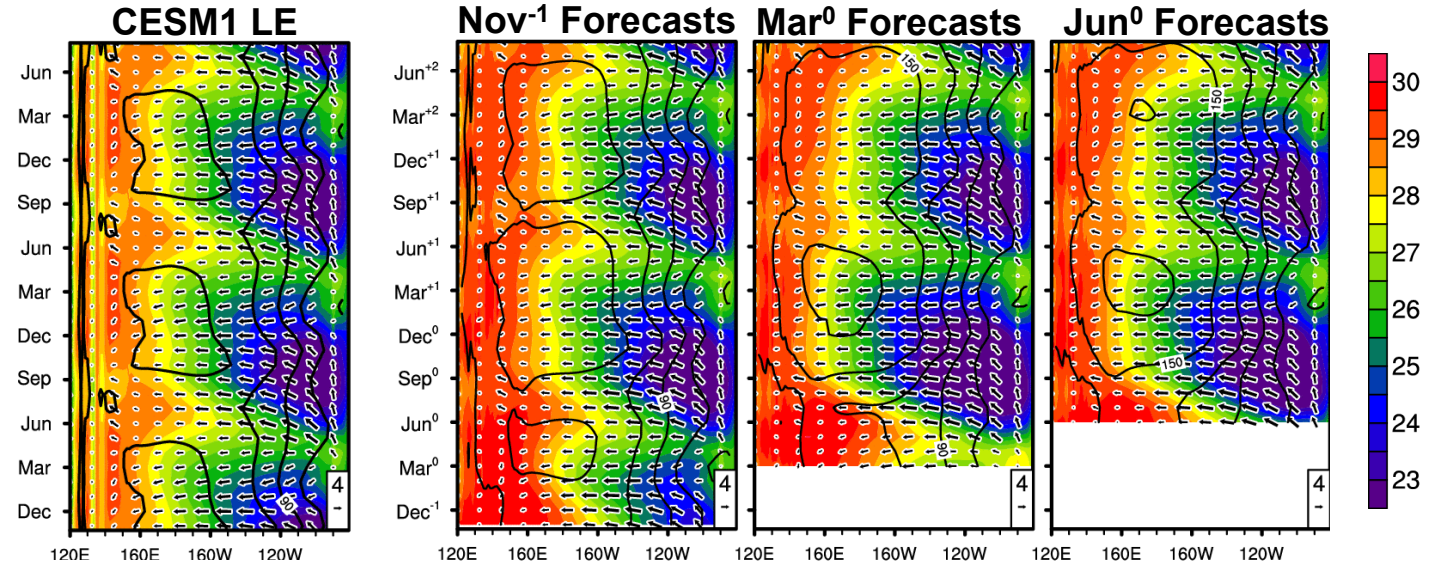


shallower climatological  
thermocline depth and  
warmer climatological SST



# Initialization shock

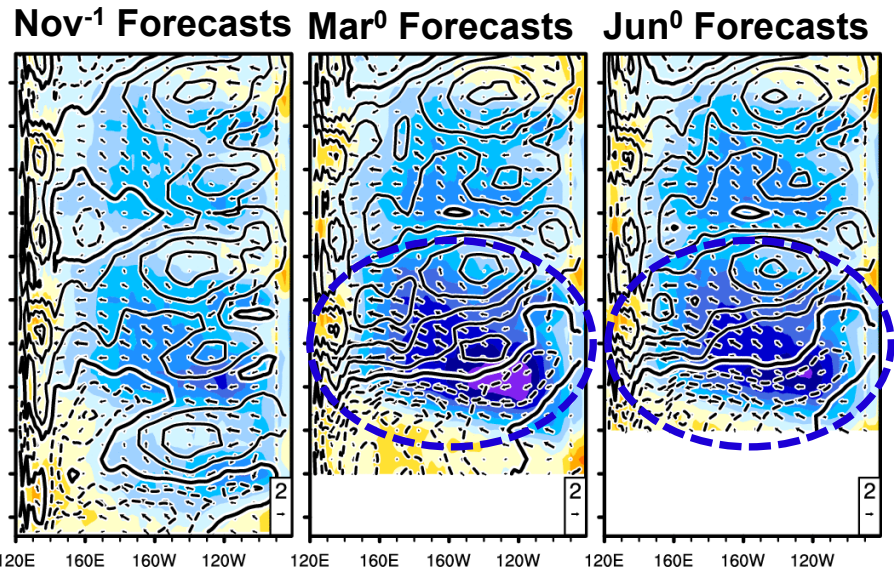
Seasonal cycle of climatological **SST**, thermocline depth, and **surface wind** in the equatorial Pacific (3°S–3°N), 1958–2015



Stronger bias in the first year  
↑  
Initialization shock  
↑  
Model-observation imbalance & FOSI errors

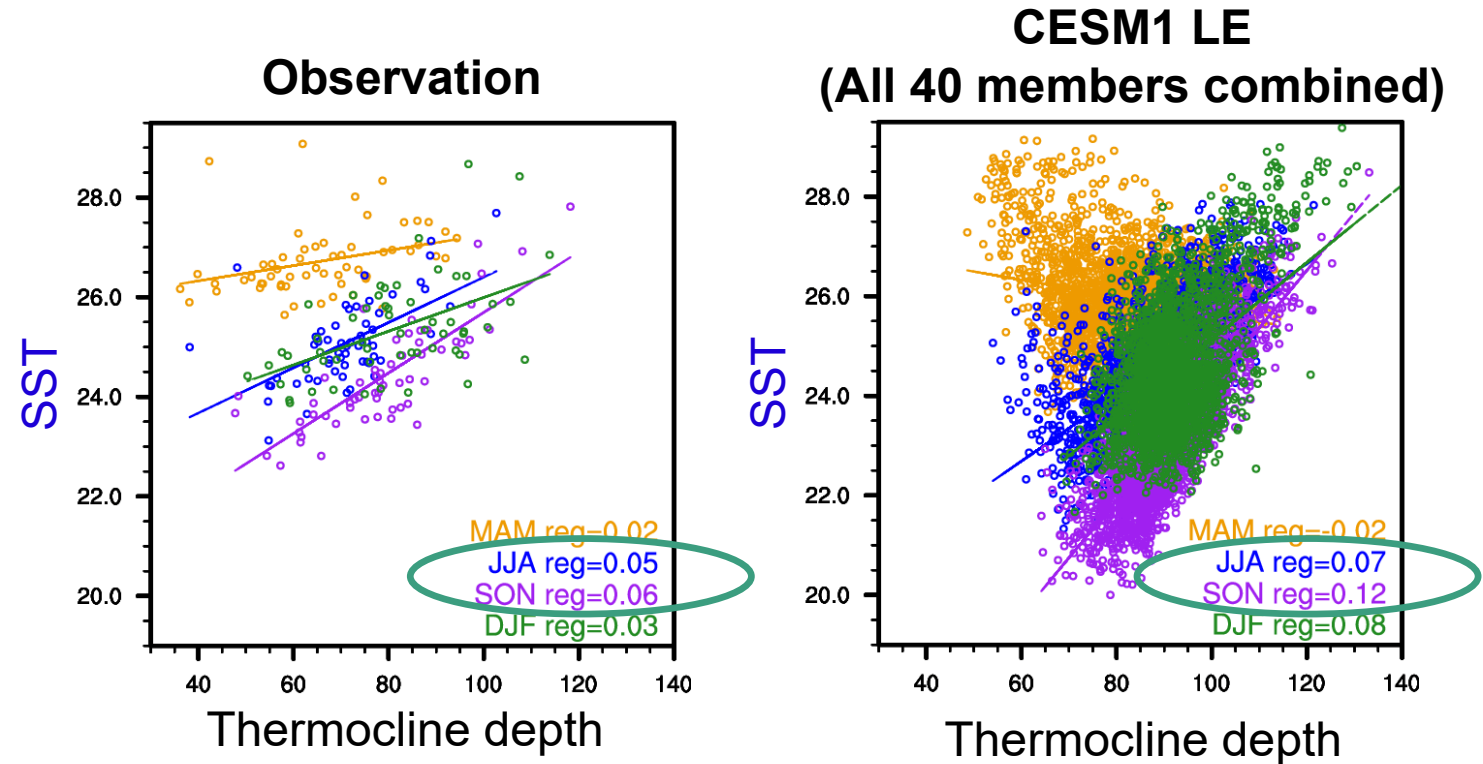
# Dependence of cold tongue bias on Initialization timing

Difference (Forecasts minus Observation)



Larger cold tongue bias in the March and Jun initialized forecasts than November forecasts

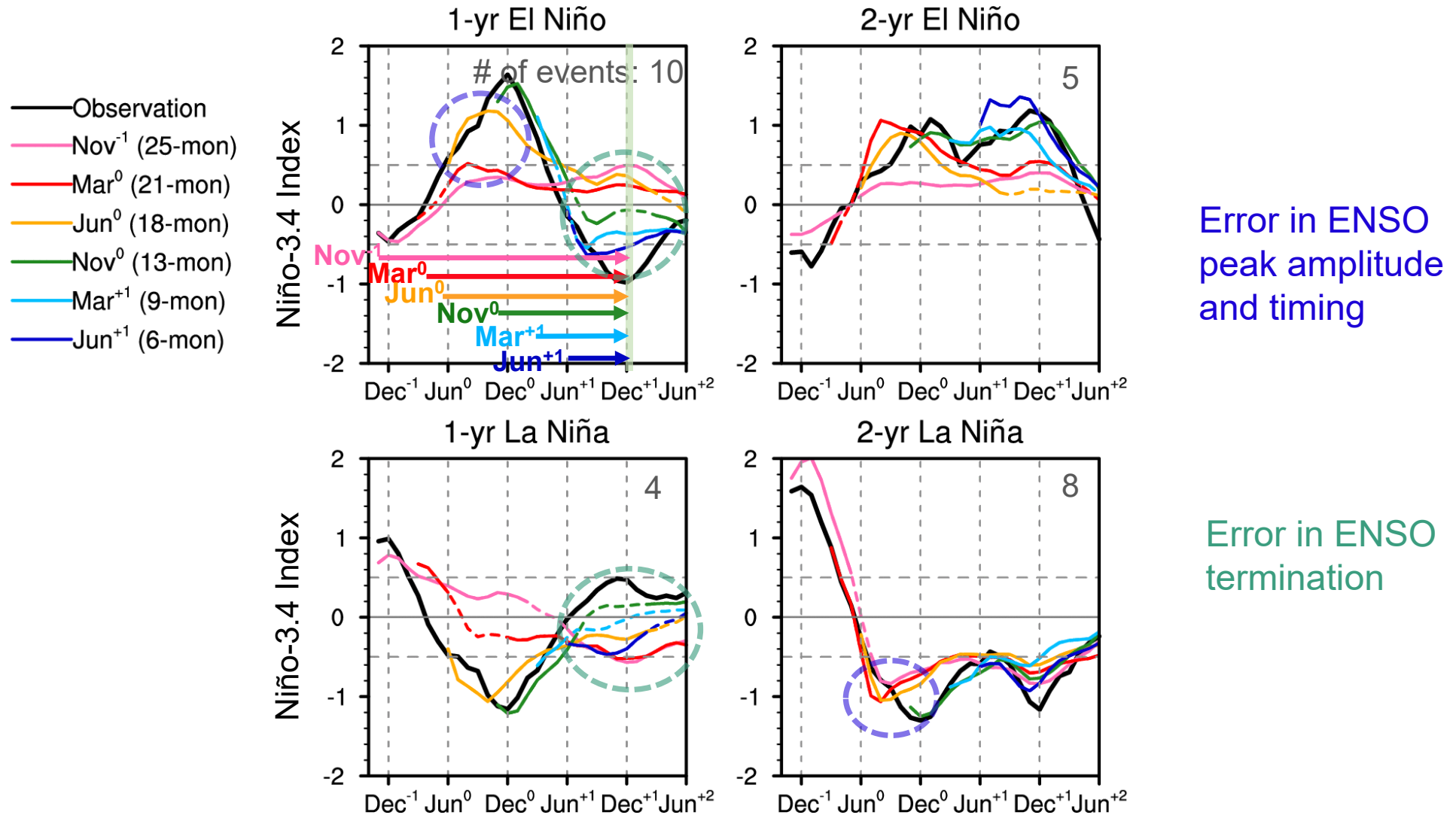
1958–2015, seasonal **thermocline depth** vs. **SST** in the Eastern Equatorial Pacific



Stronger thermocline-SST feedback in summer-fall

# Forecast error of ENSO amplitude and termination

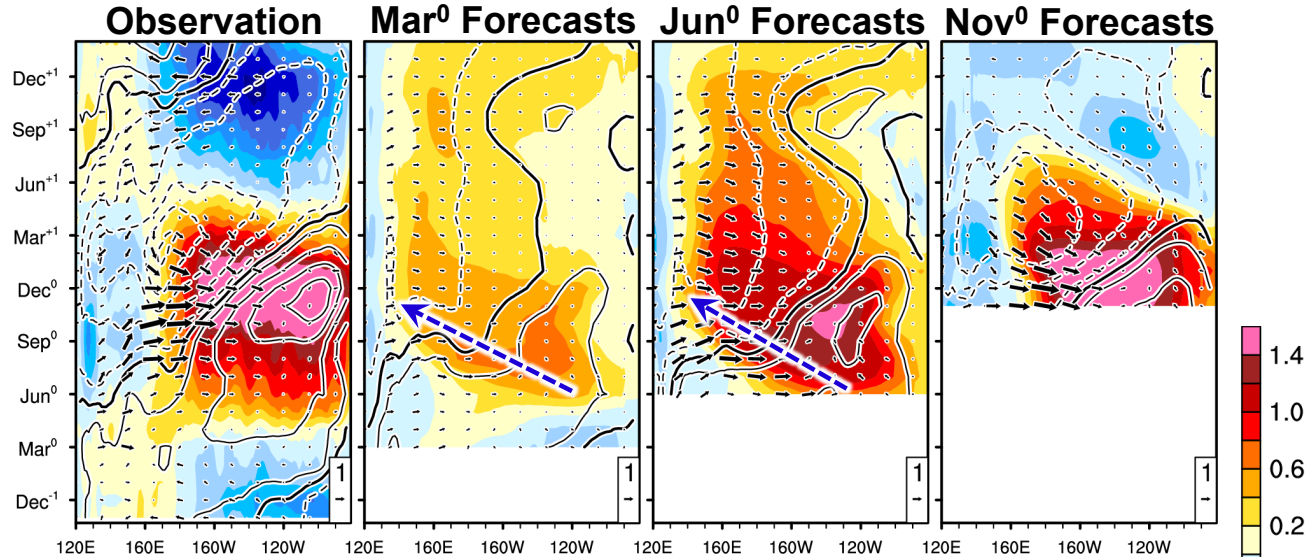
Observation and ensemble-mean forecasts  
composited for 1-yr and 2-yr ENSO events during 1954-2015





# Forecast error of 1-yr El Niño

**SST, thermocline depth, and surface wind anomalies** in the equatorial Pacific



## Mar<sup>0</sup> and Jun<sup>0</sup> Forecast errors

**Spatial pattern:** westward shift of SST and wind anomalies

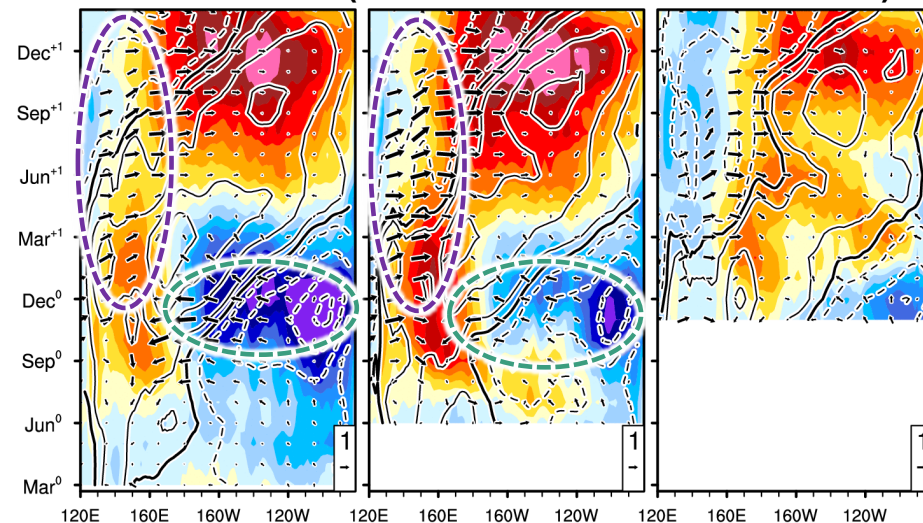
### Amplitude:

- weak SST anomalies over the central-eastern Pacific
- weak thermocline tilt (initial recharge)

### Duration

- Too persistent wind anomalies over the western Pacific
- Weaker thermocline discharge

## Difference (Forecasts minus Observation)

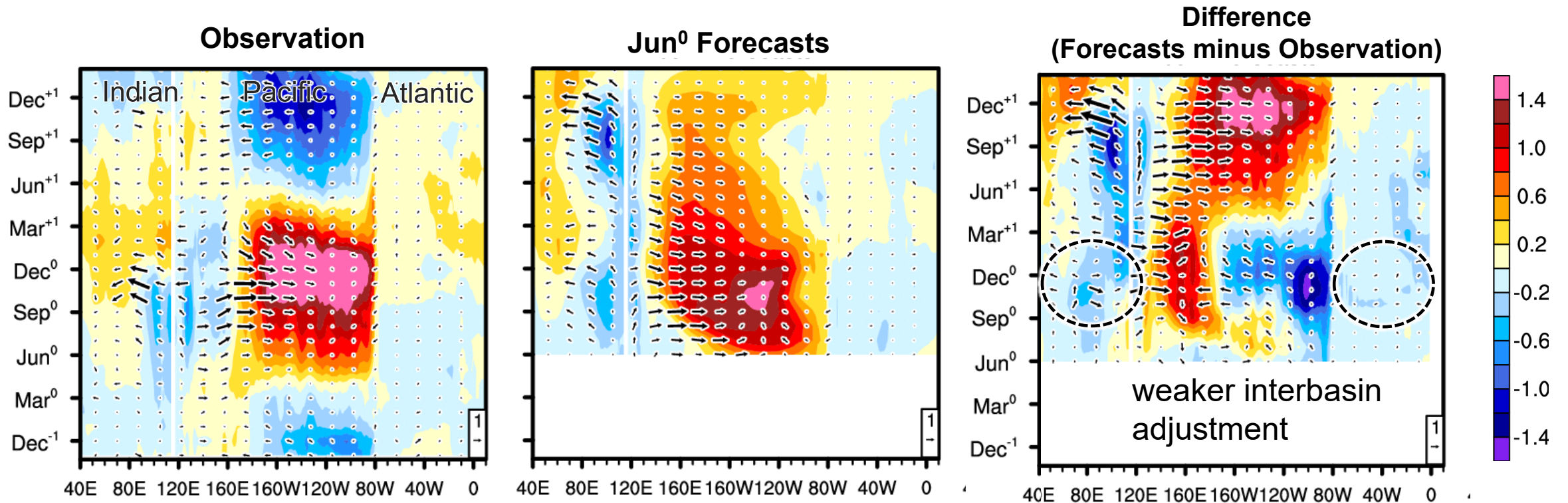


**Improved in Nov<sup>0</sup> Forecast**

# Forecast errors of tropical interbasin teleconnection

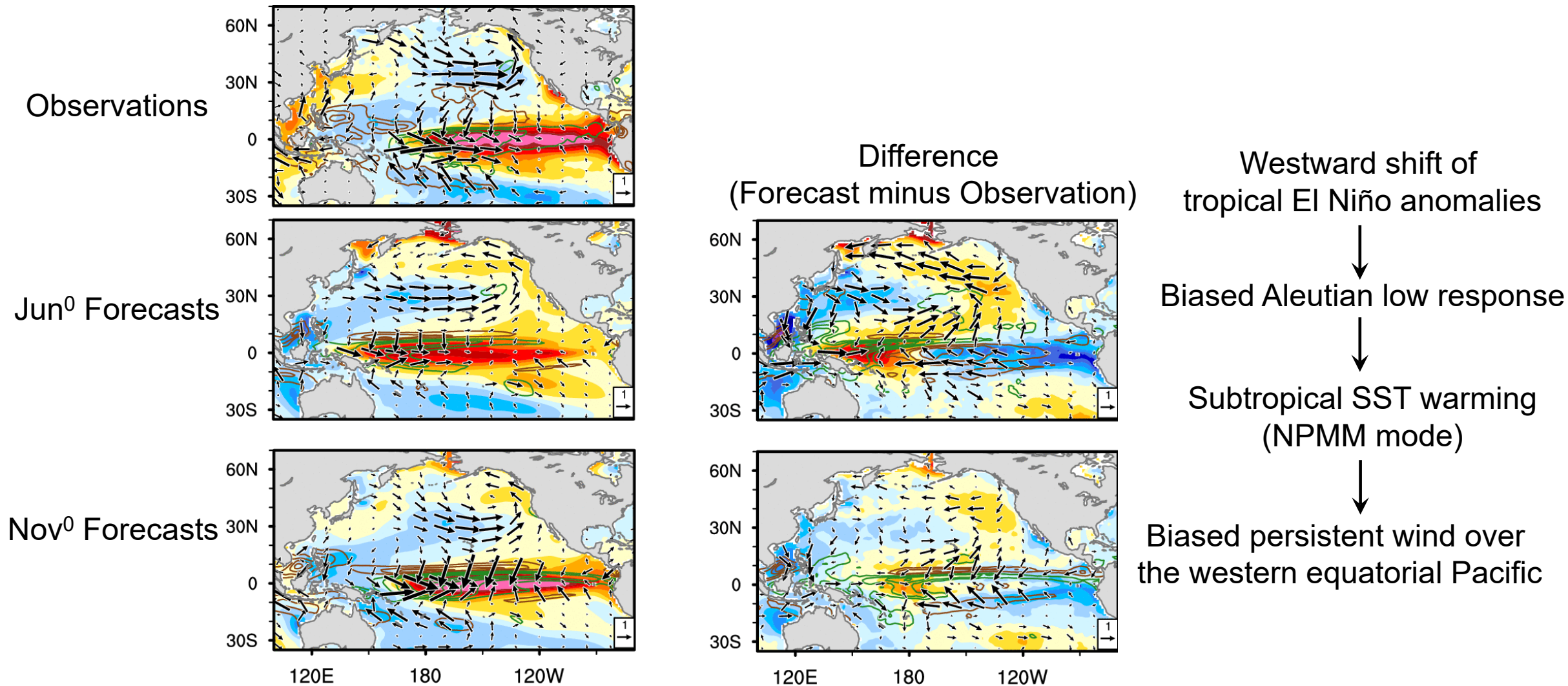
## SST and surface wind anomalies

in the Indian (10°S–0°), Pacific (3°S–3°N), and Atlantic (0°–30°N) Oceans



# Forecast errors of North Pacific teleconnection in boreal winter

Dec<sup>0</sup>–Feb<sup>+1</sup>, **peak of 1-yr El Niño**, SST, precipitation, and surface wind anomalies



# Summary

## **Cold tongue Bias in CESM1 Forecasts**

- CESM1 intrinsic mean-state bias
- Initial condition data error
- Initialization shock leads to larger bias in first year after initialization
- Dependence of bias on initialization timing is related to the seasonality of SST-thermocline feedback

## **Forecast errors of ENSO characteristics**

- Westward extension of ENSO anomalies in the equatorial Pacific
- Weaker ENSO amplitude in the central-eastern Pacific
- too persistent 1-yr ENSO events
- Biased tropical interbasin and North Pacific teleconnections