The importance of model mean state – a perspective on tropical teleconnections

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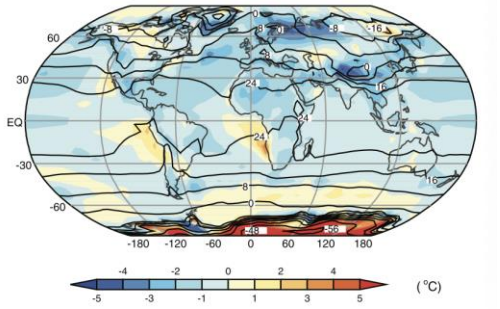
1. Introduction: coupled model mean state biases
2. An example: the role of SST mean state to Atlantic-Pacific teleconnection
3. On-going research

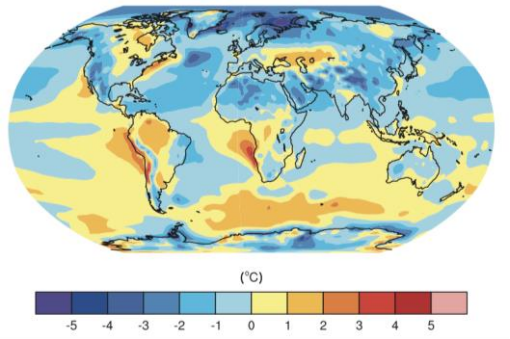
Introduction: coupled model mean state biases

Temperature biases

CMIP3
(IPCC-AR4)

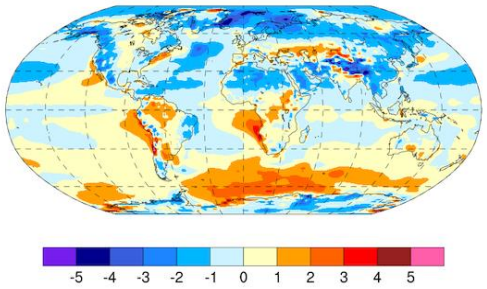


CMIP5
(IPCC-AR5)

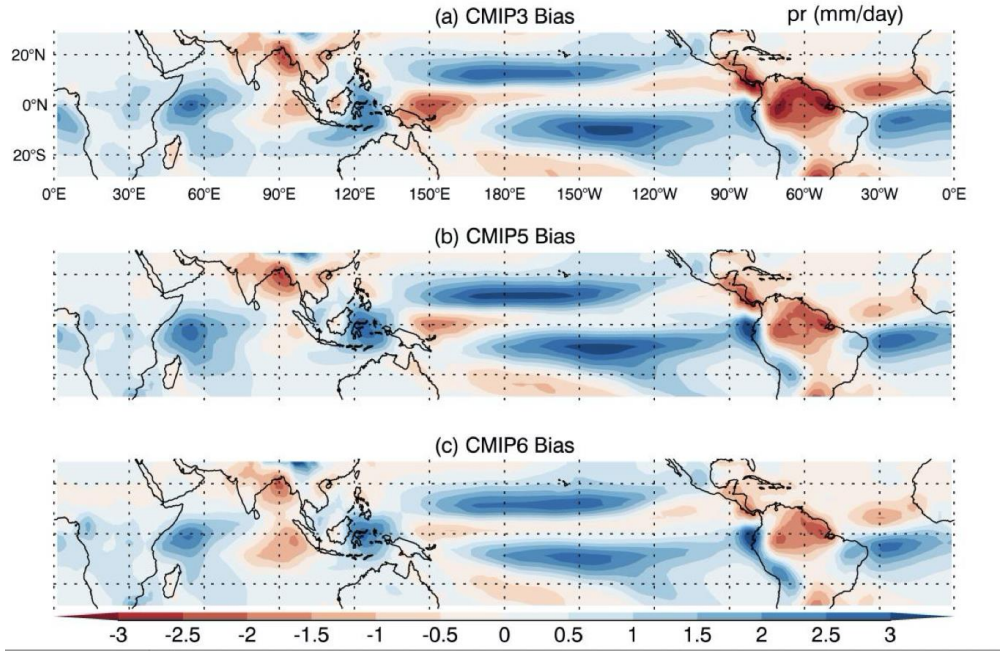


CMIP6

(44 models' historical run)



Precipitation biases



(Tian and Dong, 2020)

- Excessive equatorial cold tongue bias
- Warm SST biases in the eastern tropical Pacific/Atlantic;
- Too much ocean precipitation in the southern hemisphere (double ITCZ bias)

Origins and challenges in reproducing observed mean states:

- Representation of the tropical **convection** (cloud cover).

(*parameterizations required for subgrid-scale dynamics and other processes like cloud microphysics; limited in computation resources for global high-resolution simulations)*

- Representation of **the sharp vertical gradients** in the atmospheric boundary layer and oceanic thermocline.

- Representation of **land-surface processes**.

(*lack of observation data)*

Mean state biases issue will probably remain for a long time.

It's important to understand how model biases affect the seasonal forecasts and climate projections.

1

Mean state biases

Projections of regional climate change
(Zhou and Xie, 2015; Li et al., 2016)

ENSO-monsoon teleconnection
(Lau and Nath, 2000; Turner et al., 2005)

Seasonal prediction skill for the tropical SST anomalies
(Lee et al., 2010)

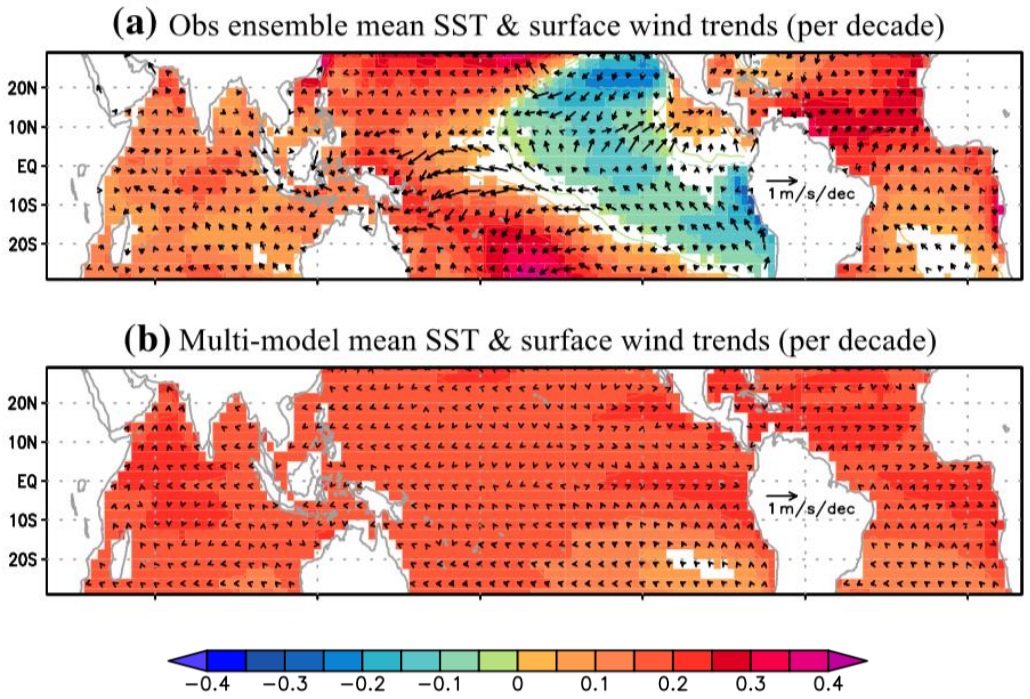
The propagation of Madden-Julian Oscillation (MJO)
(Klingaman and Demott 2020; Kang et al., 2020)

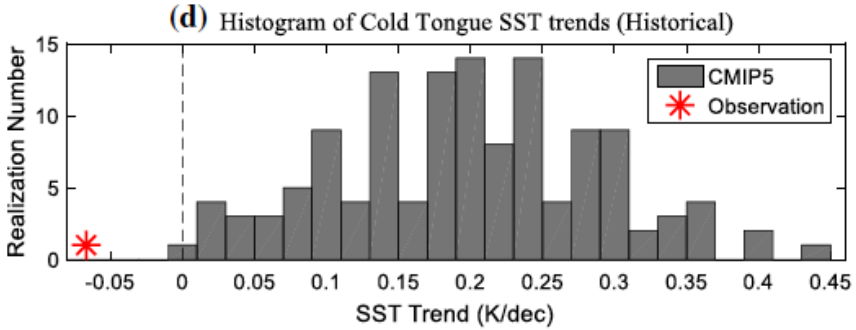
….

An example: the role of SST mean state to Atlantic-Pacific teleconnection

Motivation: the failure of the climate models in capturing the recent decades of Pacific cooling

Trends in 1980-2010





(Luo et al., 2017)

- The Pacific region internal variability cannot totally explain the observed cooling trend. The warming forcing from other two ocean basin is also important. *(e.g., Kucharski et al., 2011; Chikamoto et al., 2012; Han et al., 2014)*

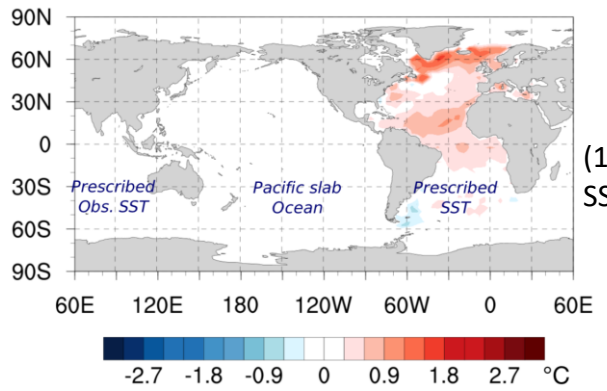
- Common model biases may contribute to the underestimated Pacific cooling.

Experiments design

UM7.3 (N48L38) + slab ocean in Pacific

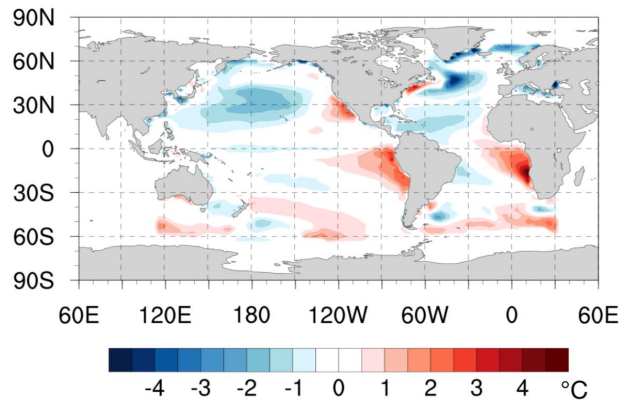
	PARCP (Partially coupled)	Pacific slab Ocean	Atlantic (prescribed)	Run length
Unbiased	EXP1_Obs.	Obs. climatology	Control: Obs. climatology	100 years (last 90 years are used)
			Atl-warm: Obs. Climatology + warm pattern	
Atlantic bias	EXP2_Atlantic_bias	Obs. climatology	Control: **CMIP5 climatology**	
			Atl-warm: **CMIP5 Climatology** + warm pattern	
Pacific bias	EXP3_Pacific_bias	**CMIP5 climatology**	Control: Obs. climatology	
			Atl-warm: Obs. Climatology + warm pattern	
Atl+Pac biases	EXP4_AltPac_bias	**CMIP5 climatology**	Control: **CMIP5 climatology**	
			Atl-warm: **CMIP5 Climatology** + warm pattern	

Atlantic warm pattern



(1992-2011 Atlantic SST trend * 20 years)

Model mean SST biases



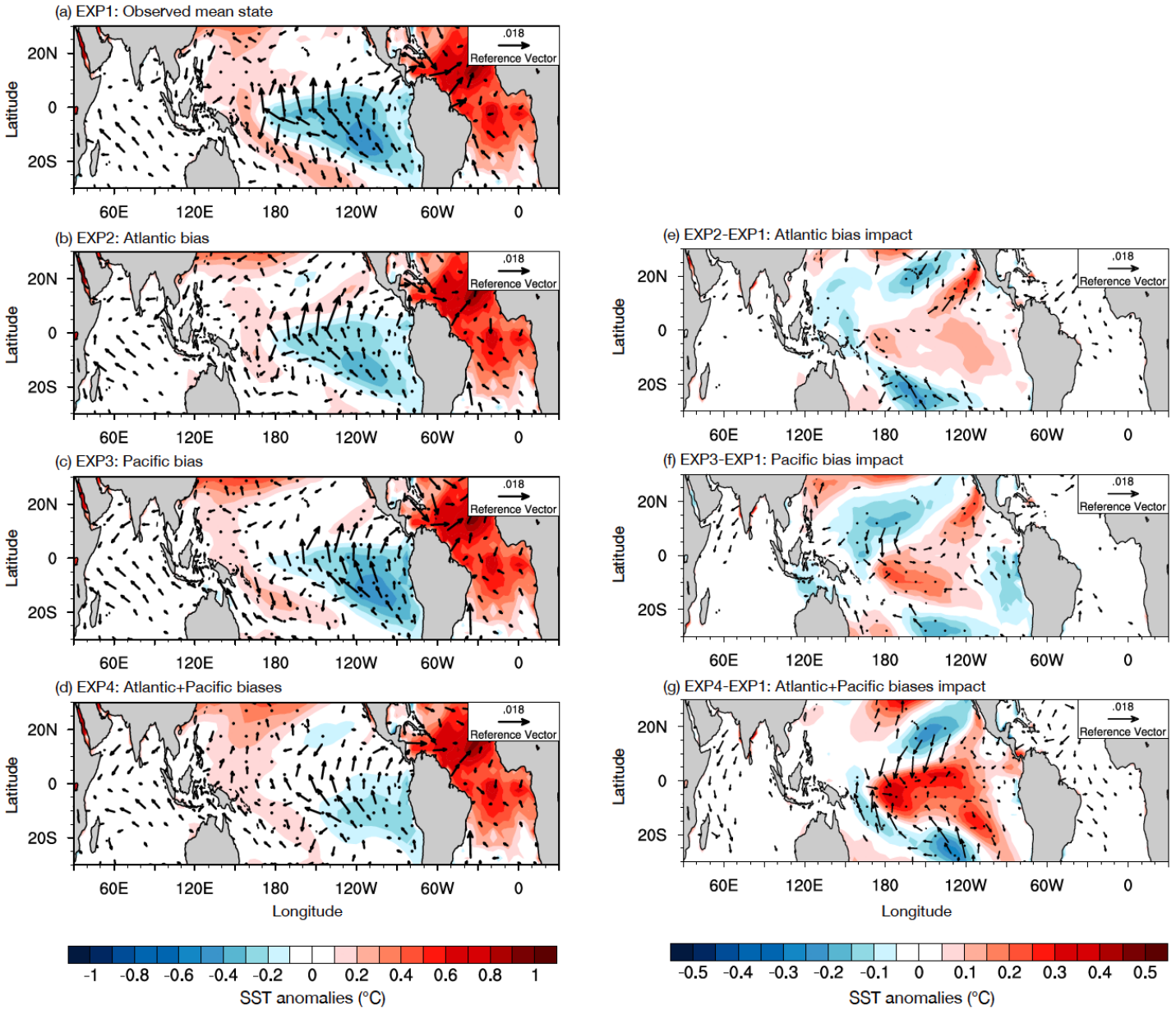
The cooling response under different background SST

Unbiased

Atlantic bias

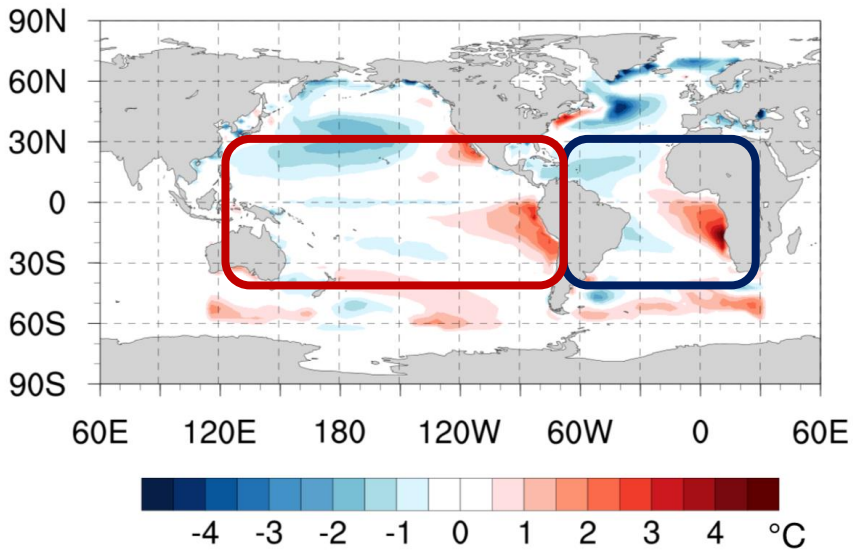
Pacific bias

Atl+Pac biases



Underestimated by ~89%

2 Mechanism



Atlantic region:

SST bias acts to alter the regions above/below the threshold for deep convection, causes a **weakening and eastward shift of Atlantic heating response**.

(McGregor et al., 2018)

Pacific region:

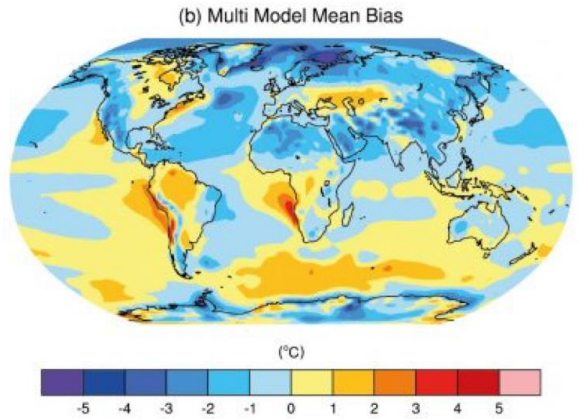
Warm bias in southeastern Pacific tends to **reinforce the atmosphere stability over the tropical Atlantic**, leads to a weakened Atlantic heating response;
Cold bias in central Pacific acts to **suppresses the positive zonal wind-SST atmospheric feedback.**

(Li et al., 2020)

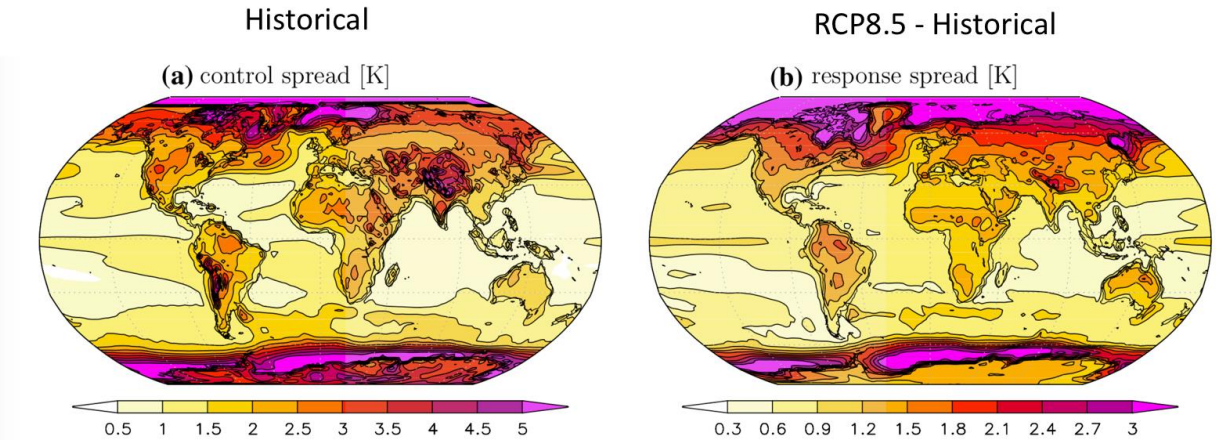
Reducing the model mean state biases in both Atlantic and Pacific regions may significantly help to improve the simulated trans-basin teleconnection.

On-going research

Land surface mean state

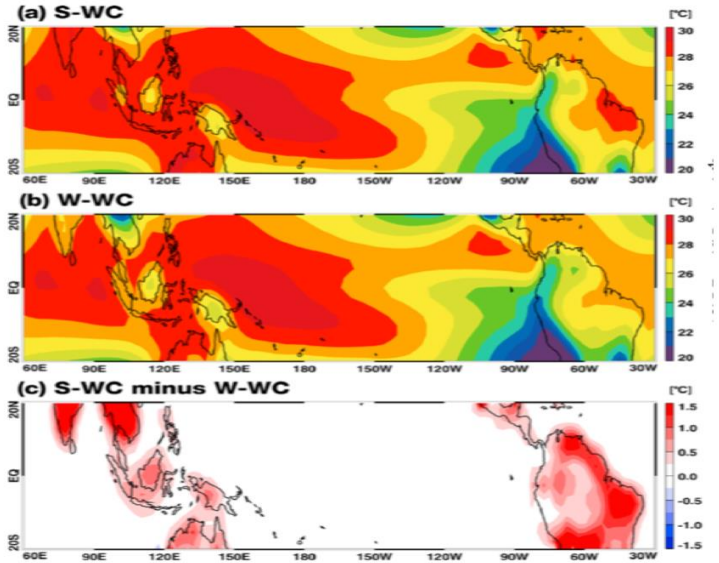


(IPCC AR5)



(Dommenget 2016)

- Larger uncertainty in simulating the land surface mean state



(Yim et al. 2017)

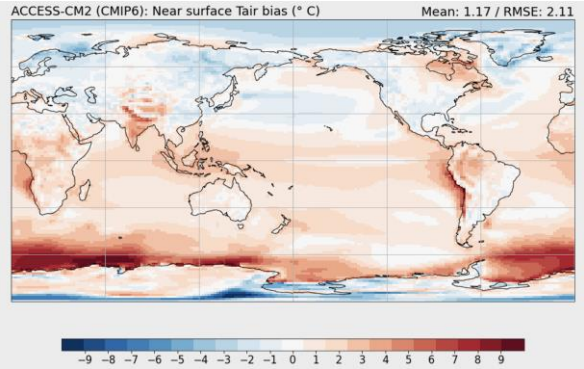
- The differences of Walker Circulation trends in AGCMs might be linked to land surface temperature mean state.

Model resolution vs. computing speed

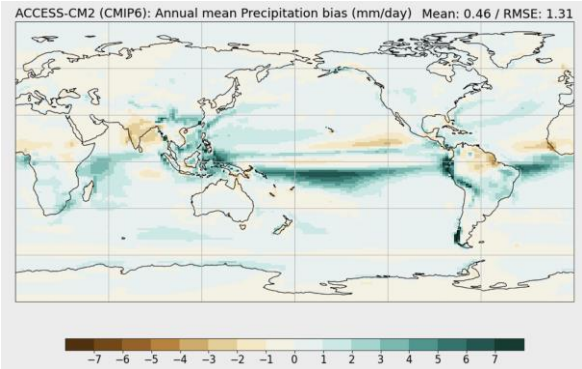
	MOM timestep	UM timestep	UM Horizontal resolution	UM Vertical levels	
ACCESS-CM2 (CMIP6)	30min	20min	N96: 192*144	L85	~6 model years/day
ACCESS-CM2 N48	60min	30min	N48: 96*72	L38	~30 model years/day

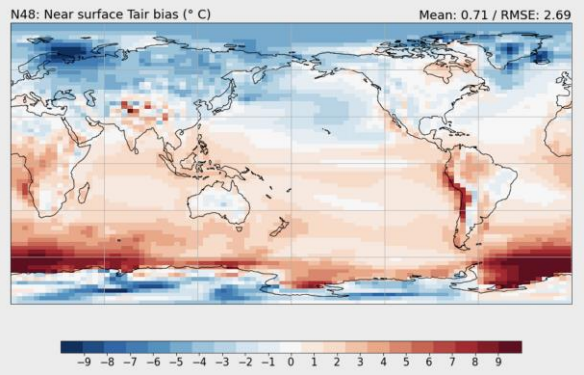
T2m bias

Precip. bias

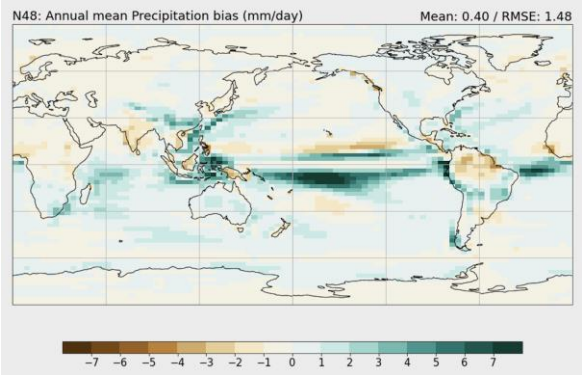


N96





N48



References:

- McGregor, S. et al. Model tropical Atlantic biases underpin diminished Pacific decadal variability. *Nat Clim Change* **8**, 493-498 (2018)
- Li, C., Dommenget, D.,& McGregor, S. Trans-basin Atlantic-Pacific connections further weakened by common model Pacific mean SST biases. *Nat commun* ***11***, 5677 (2020)

Thanks !