Monthly Difference in the Boreal Winter El Niño Precipitation Response over North America: Insights into why January is more difficult to predict than February

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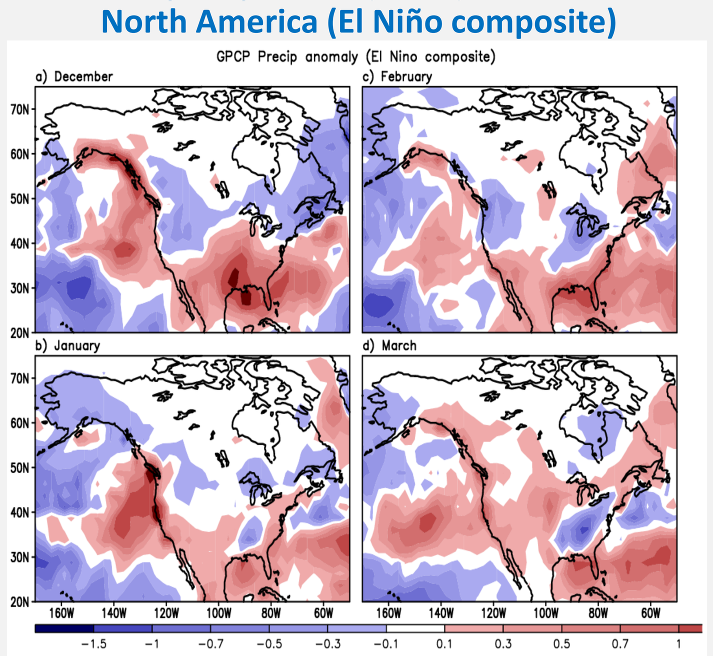
Introduction

The boreal winter precipitation during El Niño are not constant but vary during the course of the season (*left*). 1-month lead forecast shows the highest (lowest) correlation in February (January) based on the North American Multi-Model Ensemble (*right*).

Observed precipitation (GPCP) anomalies over North America (El Niño composite)

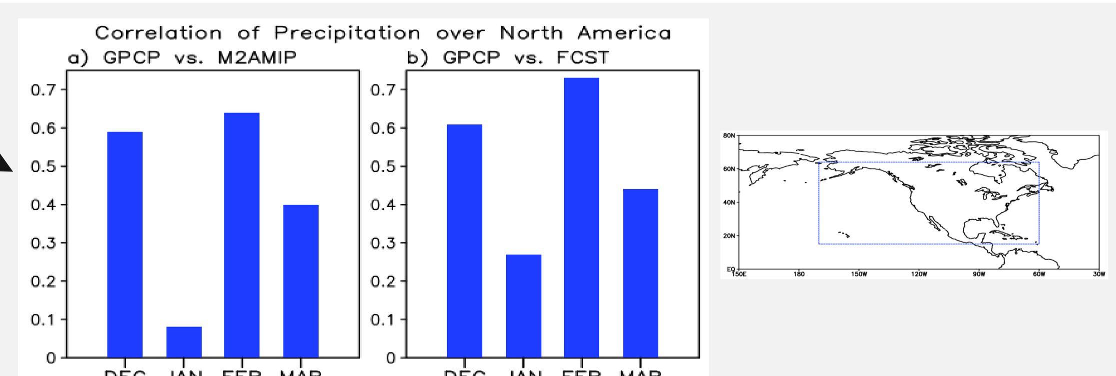


Pattern correlations (Chen et al. 2017, J. Climate) (observation vs. NMME seasonal prediction models, domain: 170°–60°W, 10°–70°N)

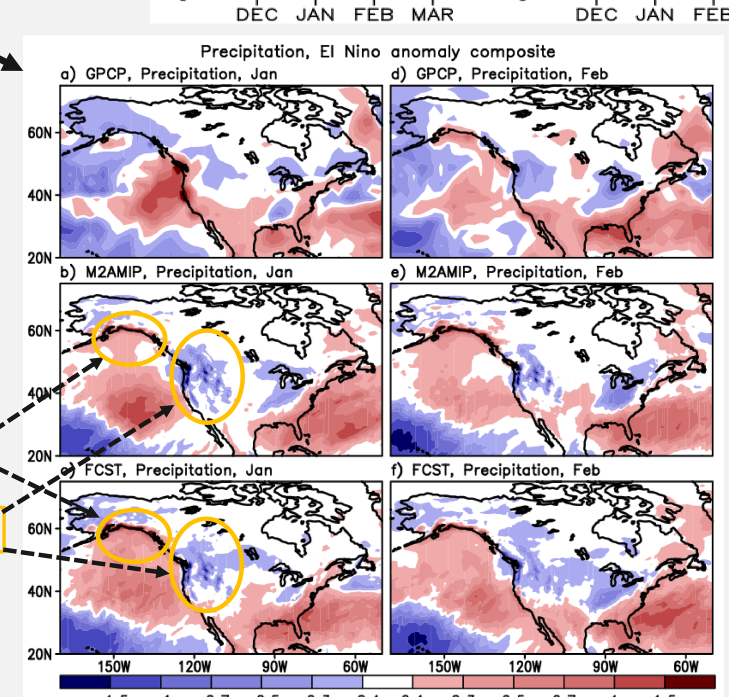
	D	J	F	M
CFSv2	64	59	70	60
CanCM3	76	26	53	53
CanCM4	73	37	62	51
FLOR	76	25	76	47
GEOS5	67	33	73	41
CCSM4	53	68	57	26
NMME	78	52	81	56

Model system: 1) Fully coupled (atmosphere, ocean, land, and sea-ice) NASA GEOS seasonal forecast model (**FCST**). 1-month lead forecast data are investigated in this study.
2) The GEOS AGCM employed in the development of MERRA-2. AMIP-type long-term (1981-2017, 10 members) integration (**M2AMIP**). FCST and M2AMIP have 0.5° lon.-lat. resolution.
Reanalysis data: MERRA-2, **Observed precipitation**: GPCP

Pattern Corr. of precip. During El Niño (obs. vs. model)



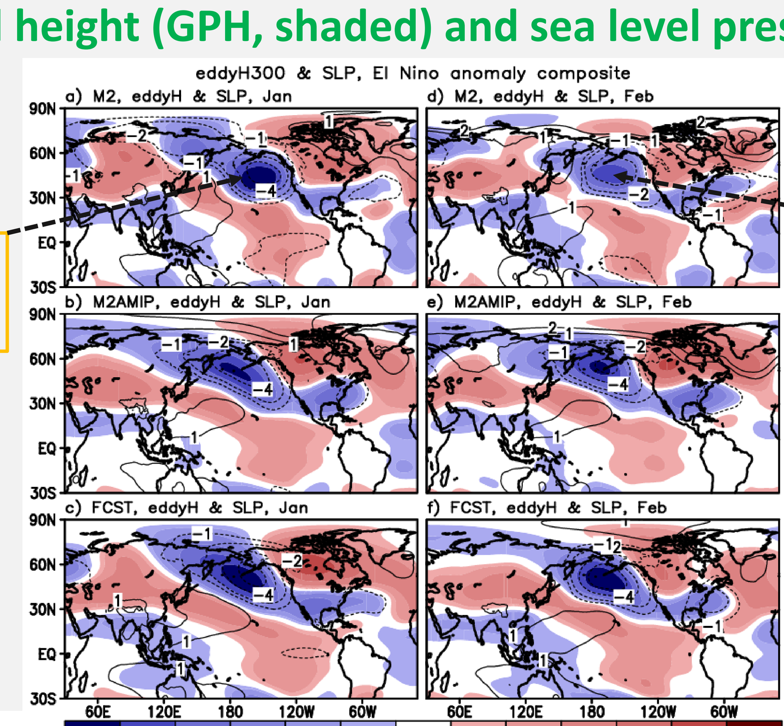
Precipitation anomaly (El Niño composite)



Models predict Feb. El Niño precipitation better (e.g., NA west, and southern tier of the US)

Why does the model imperfectly represent the precip. over the west NA?

300hPa geopotential height (GPH, shaded) and sea level pressure (SLP, contoured)



Strong negative anomalies quite close to the coast

(-) anomalies retreat to the west: Less (more) favorable for precip. in the W. US and Canada (S. Alaska).

Location of the model-produced (-) anomalies is off the west coast in both months, similar to the observed Feb. anomalies

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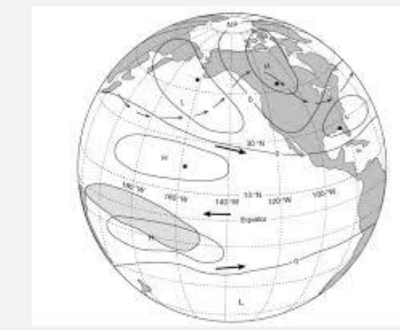
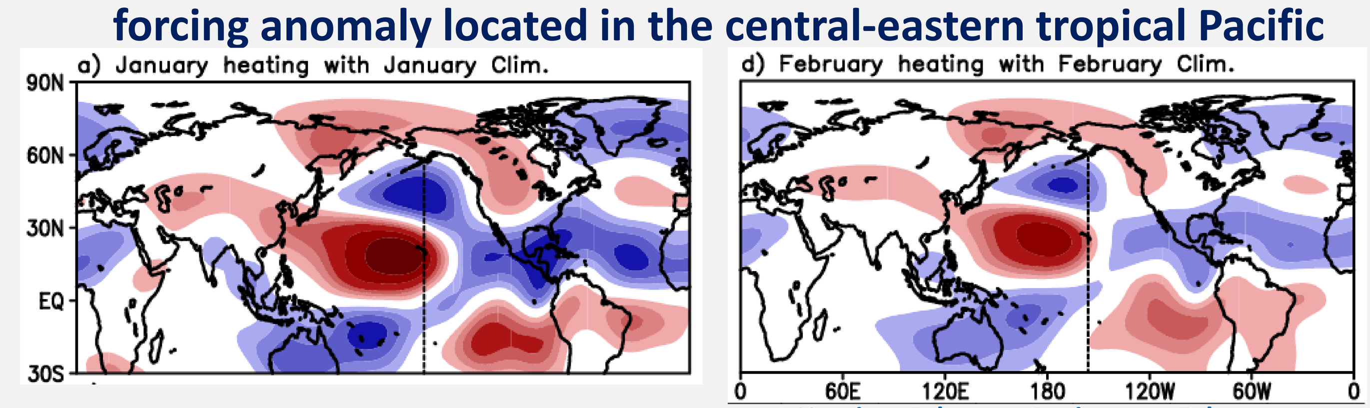
Is the GPH/SLP anomaly over the west NA a response to the tropical ENSO heating? Answer by stationary wave model (SWM) Exp.

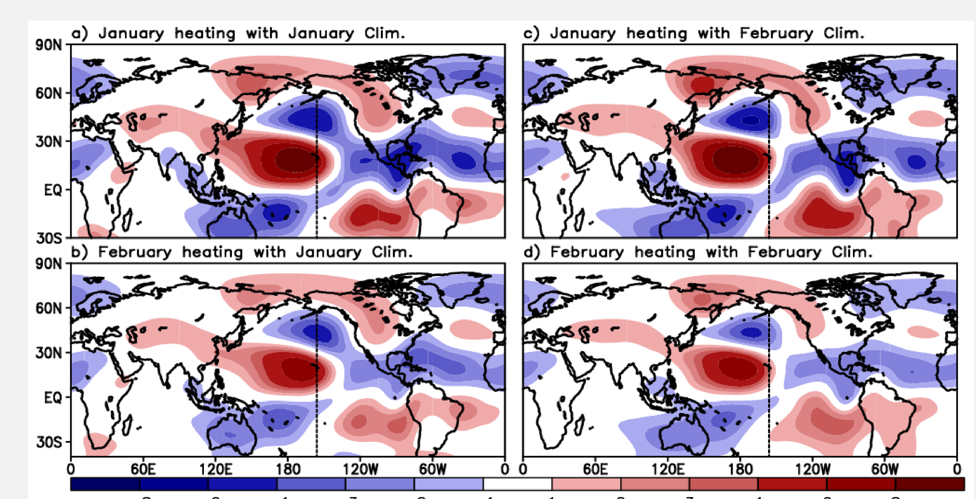
The SWM is the dry dynamical core of an AGCM and forced by an estimate of the diabatic heating/cooling.
The heating/cooling is estimated either from MERRA-2, M2AMIP or FCST runs.
The atmospheric basic state in the SWM is the 3-D climatological mean taken from either MERRA-2, M2AMIP, or the FCST runs. For simplicity we focus on the results from the M2AMIP for the SWM response to the model-estimated heat anomalies (FCTS results are very similar to the results from the M2AMIP).



Stationary wave response (streamfunction) to the observed El Niño diabatic heat forcing anomaly located in the central-eastern tropical Pacific

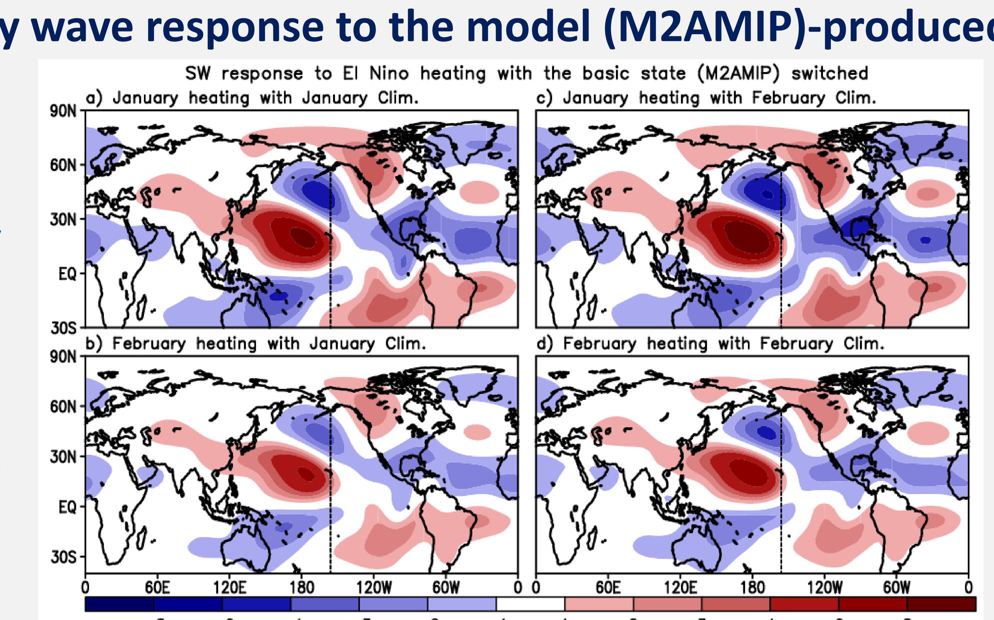


Is zonal shift over the NE Pacific (shown above) the result of tropical heating differences or differences in the basic state?



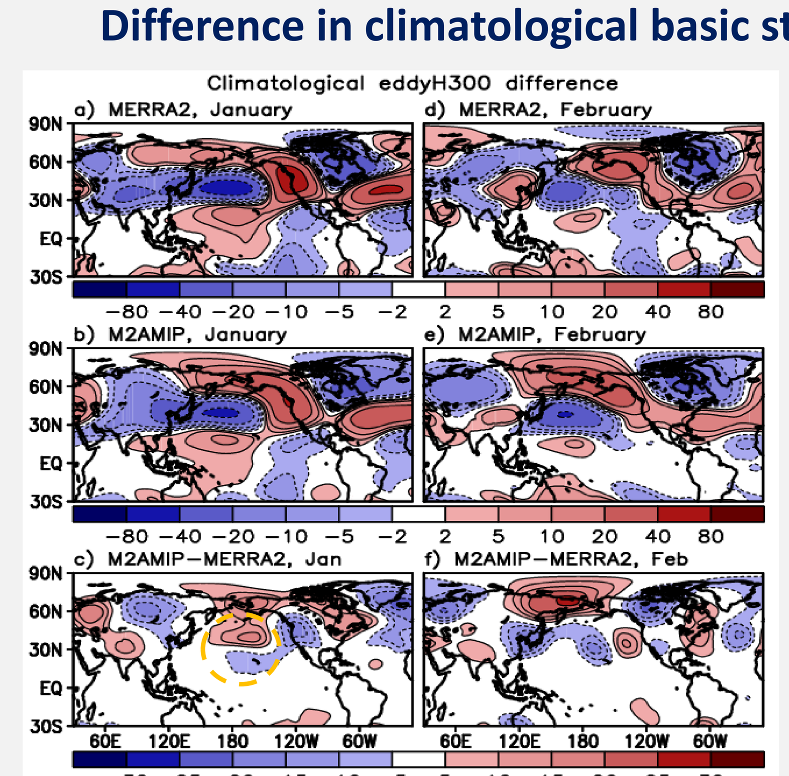
Jan./Feb. zonal shift of the GPH anomalies is to a large extent controlled by the changes in the basic state, rather than changes in the central-eastern tropical Pacific heat forcing.

Stationary wave response to the model (M2AMIP)-produced basic state



Exp.: basic states from the M2AMIP, but again using the same MERRA-2 estimates of heating. The runs with the Jan. basic state (*left*) fail to shift the anomalies eastward closer to the coast.

Difference in climatological basic state (MERRA-2 vs. model) (300hPa GPH)



MERRA-2
Jan: Large (+) anomaly along the NA west coast with (-) anomaly to the west.
Feb: Weaker than January along the NA west coast and N. Pacific.

M2AMIP
January: Underestimates the strength of the NA west coast ridge and north/south dipole (dashed circle) – weaker Pacific jet at ~30°N.
February: The major biases found in January are less evident.

What significantly drives the Jan. climatology over the North Pacific/America?

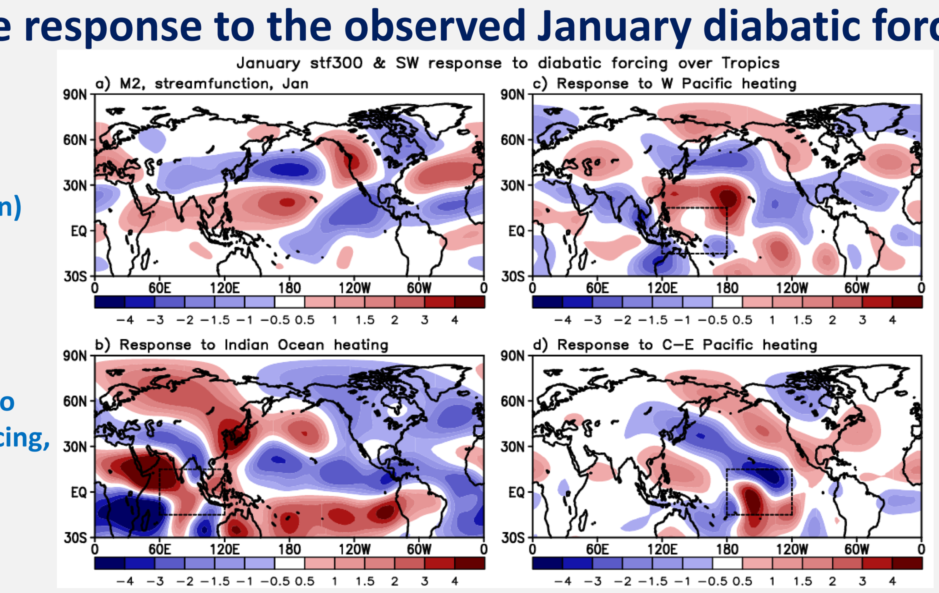
Focus on the observed stationary wave propagating to the Pacific. Examine the response of the SWM to the observed January heating anomalies (January minus the DJFM mean)

1. Diabatic source in three tropical regions (Indian Ocean: 60°-120°E, 15°S-15°N, W. Pacific: 120°-180°E, 15°S-15°N, and E. Pacific: 180°E-120°W, 15°S-15°N)
2. Diabatic source in the extratropical region near Tibet (70°-°100E, 25°-40°N).

The basic state employed in the SWM is the DJFM mean computed from MERRA-2.

We expect this Exp. can give us a clue as to the model deficiencies responsible for the January biases.

Stationary wave response to the observed January diabatic forcing over tropics



MERRA-2, Jan, Clim., (streamfunction)

SW response to Indian Ocean forcing, Corr.=−0.6

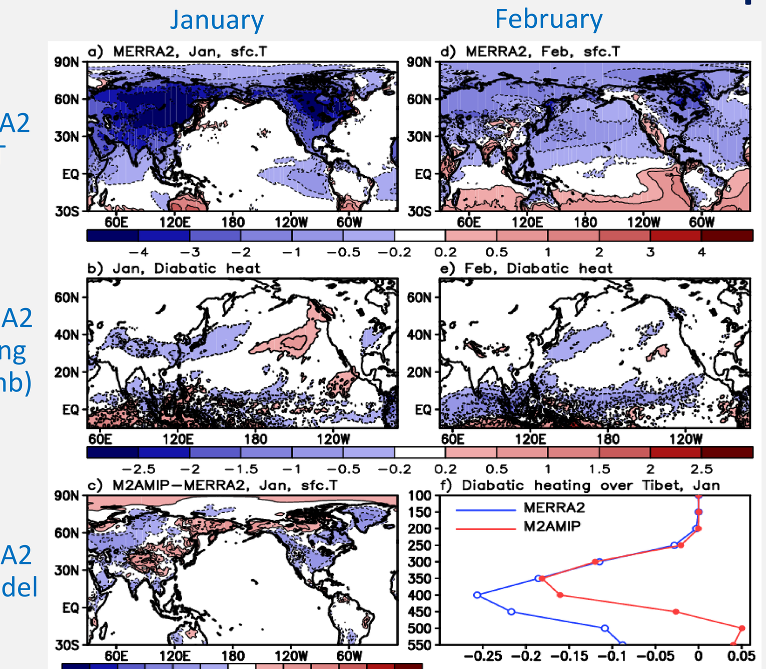
SW response to W. Pacific forcing, Corr.=0.37

Corr. domain: 120°E–120°W, 15°–90°N

SW response to C.-E. Pacific forcing, Corr.=0.34

Role of the W. Pacific? A little shifted to the north over the N. Pacific, compared to observed (a)

What about the extra-tropical diabatic heating?

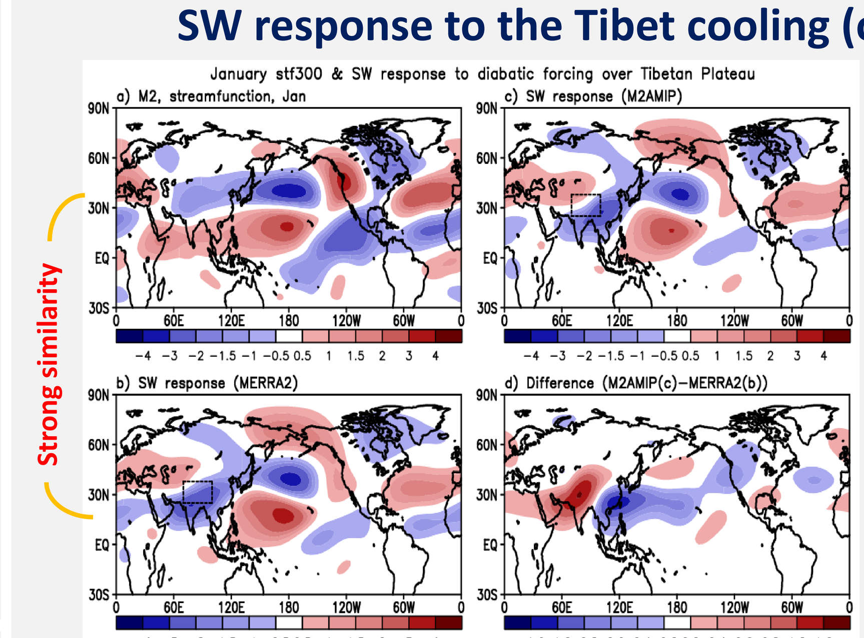


Lin and Wu (2011), Liu et al. (2017) (J. Climate): The role of the Tibet thermal condition for determining the SW response over the N. Pacific.

The diabatic cooling is specifically larger over the Tibet region in January.

The M2AMIP model is both too warm and has insufficient cooling over the Tibet region.

SW response to the Tibet cooling (observed vs. M2AMIP-produced)



(b) SW response to the observed January cooling over the Tibet region. good similarity to the observed January climatology (a) (Jan – DJFM) (cor.=0.76).

(c) The SW response to the diabatic forcing (insufficient cooling) estimated from the M2AMIP: generally smaller amplitude.

(d) difference field: Weakening of the NA west coast ridge and meridional dipole over the North Pacific when using the M2AMIP forcing.

Conclusions

1. The Jan. predictions of precipitation over North America during El Niño are significantly less skillful.
2. The model produces circulation anomalies that lie off the coast during both January and February (only true for February in the obs.).
3. The model problem with the westward shift in the Jan. El Niño response over the NE Pacific is the result of biases in the Jan. climatological state and stationary waves, rather than errors in the Jan. tropical Pacific heating anomalies.
4. Relatively poor simulation of the observed Jan. climatology, characterized by a strengthened North Pacific jet and enhanced ridge over western NA, can be traced back to biases in the Jan. heating over the Tibet region.

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