Remote sources of surface temperature cold bias over Tibetan Plateau: the role of tropical SST climatological bias

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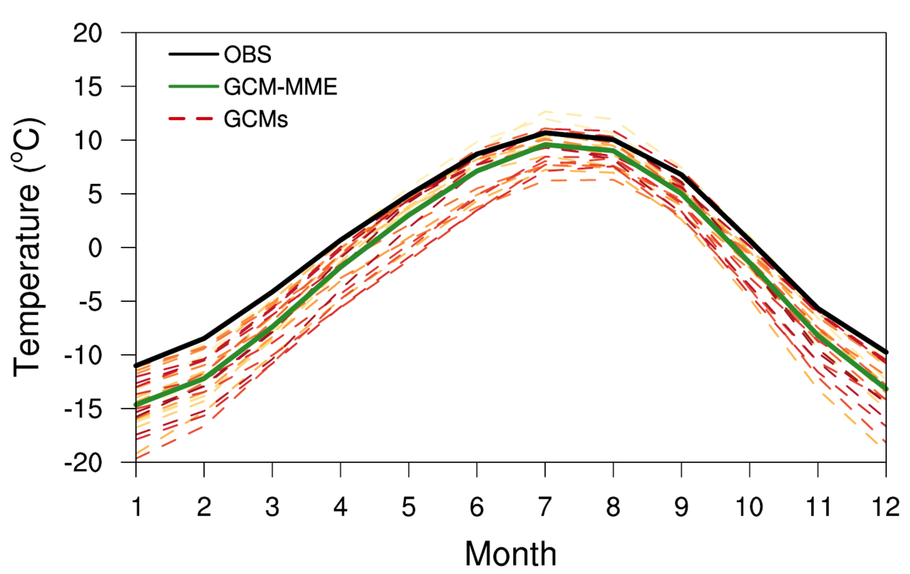
Introduction

We have known that:

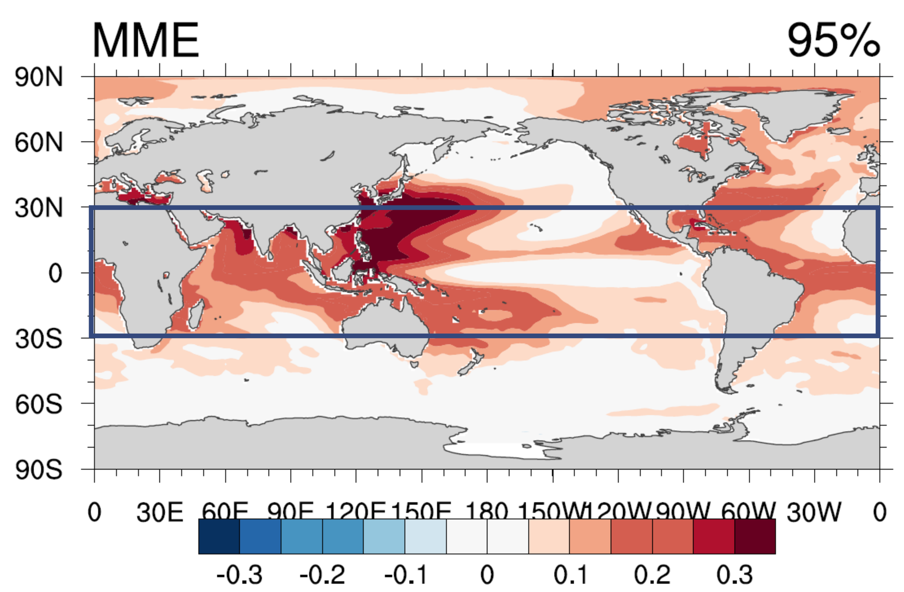
- Tibetan Plateau (TP) surface cold bias wildly exists in both reanalysis data and climate models (Wang and Zeng 2012; Duan et al. 2014).
- Previous studies have investigated the possible reasons for climate models underestimate the surface air temperatures (Ts) over the TP. From the local energy budget perspective, Chen et al. (2017) found that the TP cold climate models showed more snow cover, which is agreed with Chen and Frauenfeld (2014). Besides, Yang et al. (2007) attributed the surface cold bias to the absence of diurnal variations in the surface drag coefficient.
- From the remote source perspective, we try to find some other factors which are responsible for the cold bias over the TP.



The cold bias widely exists in CMIP5 climate models, and the cold bias is more obvious in winter than that in summer. Su et al. (2013) showed similar results.

Fig. 1 Mean monthly temperatures from 28 GCMs (dash line) and observation (black solid line) over the TP with the green solid line denoting the ensemble mean of the 28 GCMs.

Why tropical SST?



Considering the sea surface temperature (SST) is one of the important forcing factors, we calculate the correlation coefficient between TP Ts and SST, the ensemble mean shows that the tropical SST (30ºS - 30ºN) are significantly correlated with TP Ts.

Fig. 2 The ensemble mean of 28 GCMs' correlation coefficient of TP surface air temperature and sea surface temperature.

Model Design

CESM-CAM4, 1.9º*2.5º, each run begins in 1979 and ends in 2005. We analyze the period of 1981-2005.

Experiments	SST Forcing
CTRL	OBS SST
HIST	OBS SST + Historical tropical SST Bias
Hist_IO	OBS SST + Historical tropical Indian Ocean SST Bias
Hist_PO	OBS SST + Historical tropical Pacific Ocean SST Bias
Hist_AO	OBS SST + Historical tropical Atlantic Ocean SST Bias
Hist_PIO	OBS SST + Historical tropical P&I Ocean SST Bias
Hist_PAO	OBS SST + Historical tropical P&A Ocean SST Bias
Hist_IAO	OBS SST + Historical tropical I&A Ocean SST Bias

HIST-CTRL: the impact of SST bias in the current climate

Hist_*-CTRL: the impact of each basin SST bias in the current climate

TP Ts

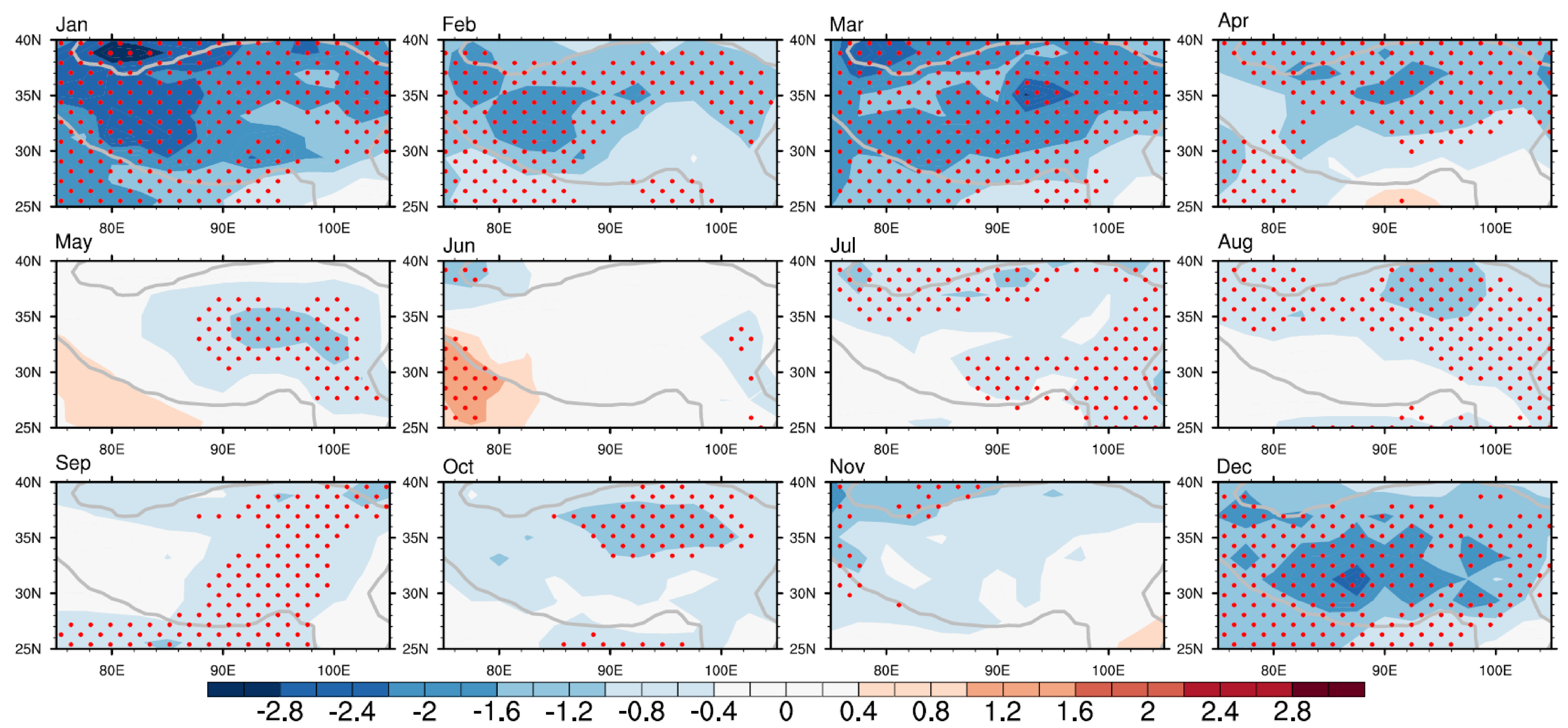


Fig. 3 Spatial distribution of Ts difference (units: K) between Hist run and Ctrl run from Jan to Dec. The dotted areas indicate the 95% confidence level of significance.

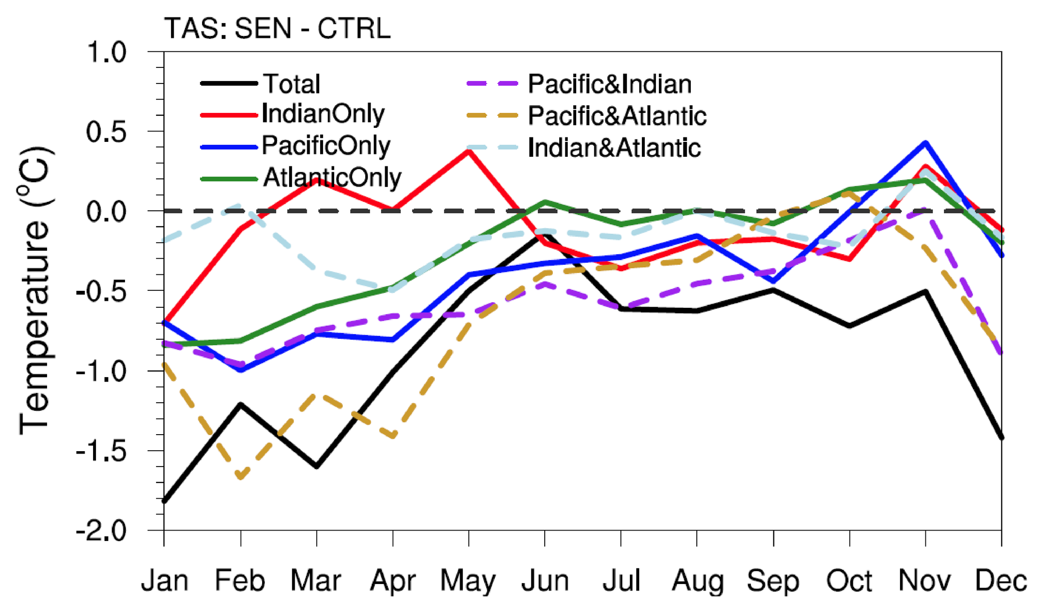


Fig. 4 Monthly mean Ts difference over the TP between sensitive runs and Ctrl run from Jan to Dec.

With the tropical SST bias forcing, the cold bias over the TP is more obvious in winter compared with that in summer, also, the western TP is colder than eastern TP (Fig. 3). Almost all the sensitive runs show a cold bias over the TP, the tropical Pacific SST bias is the largest contributor to the TP cold bias (Fig. 4).

The possible mechanism

Considering the Hist run shows the most obvious cold bias in winter, hereafter we analyze the DJF mean changes between the Hist run and Ctrl run to investigate the possible mechanism.

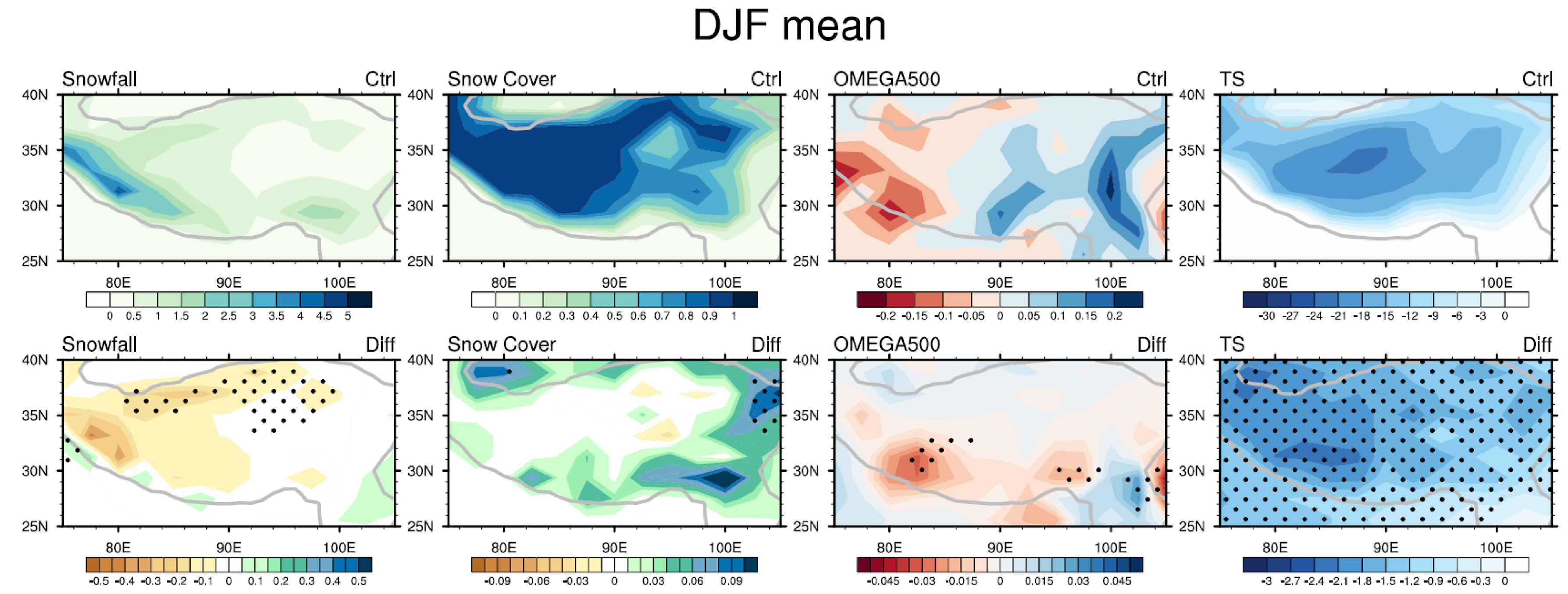


Fig. 5 Spatial distribution of DJF mean snowfall (units: mm/day), snow cover, omega at 500 hPa and Ts in Ctrl run (upper panel) and differences between Hist run and Ctrl run (bottom panel). The dotted areas indicate the 95% confidence level of significance.

The changes in snowfall and snow cover are not consistent with changes in Ts, which means the snow-albedo feedback process cannot explain the cold bias over the TP.

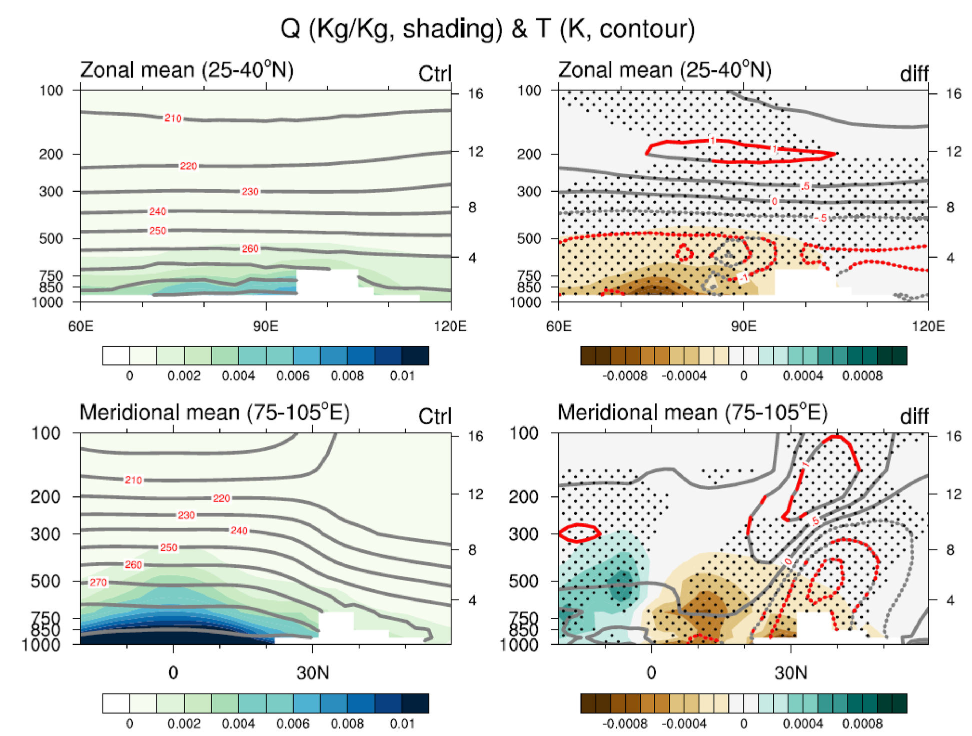


Fig. 6 Vertical profile of DJF mean specific humidity (shading, units: Kg/Kg) and temperature (contour, units: K) in Ctrl run (left panel) and the difference between Hist run and Ctrl run (right panel). The dotted areas (red contour) indicate the 95% confidence level of significance.

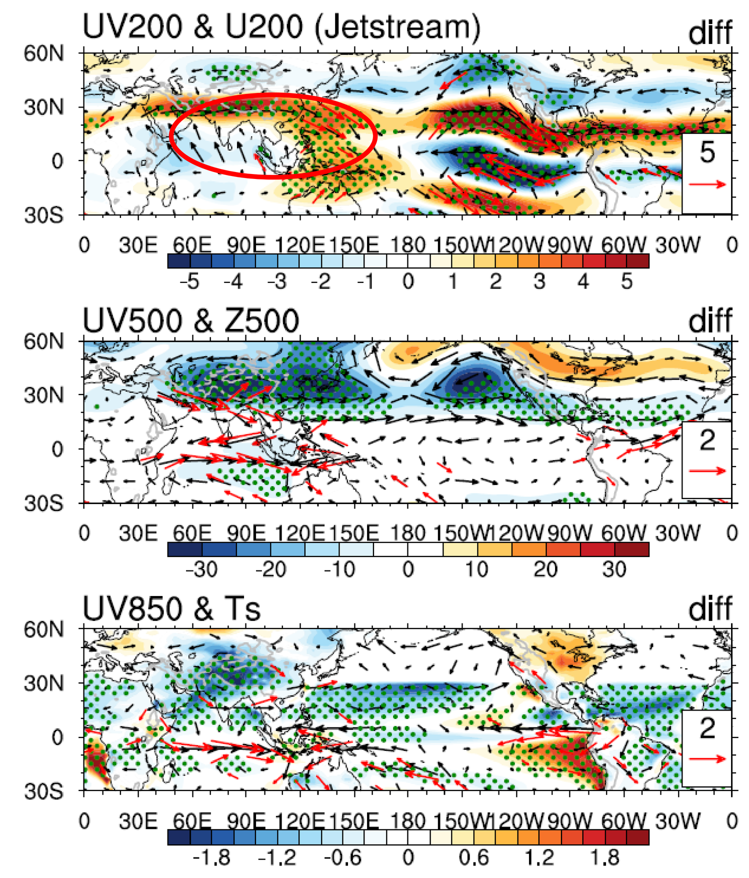


Fig. 7 Changes in DJF mean of upper, middle, and lower level circulation. The dotted areas and red vectors indicate the 95% confidence level of significance.

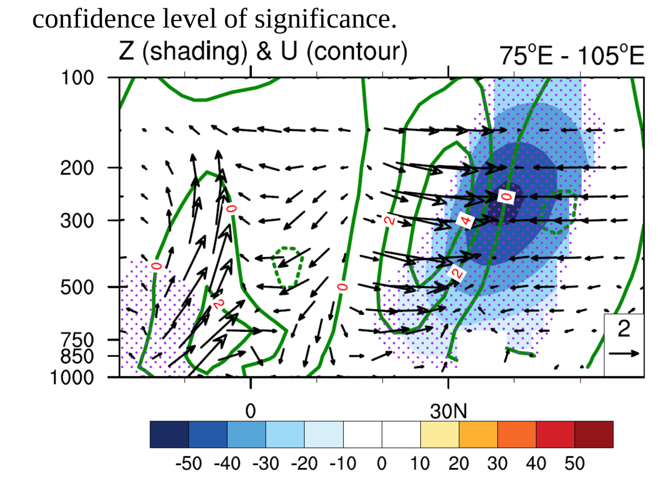


Fig. 8 Differences of vertical circulation (vectors), vertical profile of geop. height (shading) and U (contour) between Hist run and Ctrl run in DJF mean. The dotted areas indicate the 95% confidence level of significance.

The lower troposphere has a remarkable cooling, with the water vapor decreased over the TP (Fig. 6). At the upper level, an anticyclone appears to the south of TP, while at the lower level, the maritime continent shows obvious wind convergence (Fig. 7). Fig. 8 shows that the Hadley cell and the westerly jet has intensified clearly, with a strong negative geop. height over the TP.

Summary:
The systematic tropical SST bias in CMIP5 models will lead to cold bias over the TP. The cold bias is more obvious over the western TP than over the eastern TP in winter. The possible mechanism needs further investigation.