Surface temperature cold bias in climate models over the Tibetan Plateau and the associated Asian monsoon

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Introduction

Surface energy balance

\[ Q = S_\downarrow - S_\uparrow + F_\downarrow - F_\uparrow - H - LE \]
\[ = (1 - \alpha)S_\downarrow + F_\downarrow - F_\uparrow - H - LE \]

where

\[ F_\uparrow \approx \sigma T_s^4 \]
\[ H \sim V(T_s - T_a) \]
\[ LH \sim V(q_{sg}(T_s) - q_a) \]

Q: How good do climate models describe Ts?
Ta Bias comparing to CRU

CMIP3

CMIP5

Chen and Frauenfeld (2014)
Site distribution

Ts in OBS, CSFR, WRF 30km

Gs <500m (328 sites)

Gs 1000-2000m (125 sites)

Gs >3000m (59 sites)

Zuo, Liu, Jing (2016)
Cold bias in Reanalysis

Possible contribution factors to cold bias in models:
Altitude difference (Wang and Zeng, 2012)
Friction velocity (Zeng et al., 2012)
Snow–albedo feedbacks in winter time (Chen and Frauenfeld, 2014)
Motivation:

1. Understand the processes of surface cold bias over the TP
2. Improve the Ts simulation
Outline

1. Introduction
2. Ts bais in CMIP5
3. Effect of 3-D topography in FAMIL
4. Summary
2. Ts bais in CMIP5

Data and models:

- 28 CMIP5-AMIP models
- Reanalysis (CRU, CFSR, REA-Interim)
- Period 1979-2005
- Interpolated to $2.5^\circ \times 2.5^\circ$
Ta/Ts Bias: AMIP – ERA/CFSR/CRU

Elevation over the TP >=2000 m

Individual model & MME
Choose models – modeling dispersion

Inter-model EOF (Li & Xie, 2012, 2014)

(a) The first mode in CMIP5-AMIP (63.20%)

Low Ts model:
- M18 inmcm4
- M25 MRI-AGCM3-2H
- M26 MRI-AGCM3-2S

High Ts model:
- M09 CSIRO-Mk3-6-0
- M22 MIROC5
- M28 NorESM1-M
Method (*Lu and Cai*, 2009)

\[ Q = S_\downarrow - S_\uparrow + F_\downarrow - F_\uparrow - H - LE \]

\[ = (1 - \alpha)S_\downarrow + F_\downarrow - F_\uparrow - H - LE \]

\[ 4\sigma T_s^3 \Delta T \approx \Delta F_\uparrow \]

\[ = - (\Delta \alpha) \left( S_\downarrow + \Delta S_\downarrow \right) + \Delta CRF_s + (1 - \bar{\alpha}) \Delta S_\downarrow, \text{clr} \]

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1. Surface albedo-induced (SAF)  
2. Cloud radiative forcing (CRF)  
3. Non-SAF-induced SW radiation diff. in clear-sky  
4. Downward clear-sky longwave rad (DLR)  
5. Heat store  
6. Surface heat fluxes
d_Ts

1 Albedo

2 Cloud Rad.

3 Short W Rad

4 Long W Rad

5 Heat store

6 Surface fluxes

1 + 6

Right of Eq. 1+2+3+4+5+6

Low_Ts– High_Ts

TP mean

Snow Cover

Low_T- High_T

Mon

Lon
High_T - Low_T

Column water vapor

T

K

Kg/m2
Physically interlinked processes in TP cold bias

- Larger Albedo
- Weaker surface fluxes
- Solar Rad.
- Lower Ts
- T
- Water Vapor
- Downward Longwave Rad in clear sky

Chen, Liu, Wu, 2017
Outline

1. Introduction
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FAMIL – CFSR (Ts anomaly)
3-D change surface net shortwave rad., induce snow-albedo positive feedback, increase Ts. In spring the most

Liou et al, 2013;
Lee et al, 2015

Nian, Bao et al., 2017
Effect of 3-D Topography

AGCM experiment: 3-D Rad. Scheme
- increase Ts over the TP
- stimulate Rossby wave
- increase Pre. in the subtropics
Summary

◆ A suite of physically interlinked processes contributing to the cold surface temperature bias over the TP in CMIP5 models. Within the processes, the albedo effects are very important.

◆ Improvements in snow-covered area parameterization and boundary layer parameterization and hence the surface turbulent fluxes may help to reduce the cold bias over the TP in the models.

◆ 3-D Topography can reduce the TP cold bias
Thank you!


Guokui Nian, Qing Bao, Yimin Liu and Guoxiong Wu, The Influence of 3-D Terrain Radiation Scheme on the Simulating Tibetan Plateau and Summer Asia Monsoon in FGOALS. To be submitted
Low-density air over the TP absorbs solar radiation weakly. Climatologically, the energy budget of the surface air is mainly from the underlying surface, the surface sensible heat flux, which is closely related with Ts.
Ts bias in ‘three pole’ - CGCM