A study of the impacts of late spring Tibetan Plateau snow cover on Chinese early autumn precipitation

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OUTLINE

1. Introduction
2. Data and methods
3. MCA analysis on the relationship between TP snow cover and precipitation
4. MRE analysis on the response of ASO precipitation to TP snow cover
5. Possible mechanism
6. Summary
Impacts of TP snow on Chinese precipitation

- Boreal summer rainfall in central China has a positive correlation, whereas that in northern and southern China has a negative correlation, with the Tibetan Plateau snow depth in the previous winter–spring. (Chen et al., 2000; Zhang and Tao, 2002; Wu and Qian, 2003; Zhao et al., 2007)

- The TPSC shows modulating effects on the ENSO teleconnections and in turn modify the ENSO–EASM relationship (Wu et al. 2012)
Impacts of TP snow on Chinese precipitation

- The negative correlations between the surface heating of Tibet plateau and precipitation of southwestern China in autumn (Chen et al. 2001).

Questions:

- ✓ A lot of researches about the relationship between TP snow and Chinese summer precipitation, how about that in other seasons?
- ✓ How to estimate the maximum atmospheric response to TP?
Assess atmospheric response to the surface forcing from observations

- **Equilibrium feedback assessment (EFA)** was introduced to estimate the stochastic atmospheric response to SST forcing. (Frankignoul et al. 1998)
- **Generalized equilibrium feedback assessment (GEFA)** was developed to calculate the contribution of different parts of SST basins to the atmospheric response. (Liu et al. 2008)
- **Maximum response estimation (MRE)** was devised to directly estimates the largest SST-forced atmospheric modes. (Frankignoul et al. 2011)

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Data

- Monthly geopotential height and zonal/meridional wind anomalies at different levels are from NCEP/NCAR reanalysis (Kistler et al. 2001).
- Snow cover is obtained from NESDIS. The snow cover data are binned into $2^\circ$ latitude $\times$ $2^\circ$ longitude grids to reduce regional uncertainties.
- Monthly rainfall data at 160 stations in China
- All data in the period of 1984~2010.
- The ENSO signal is removed for all atmospheric variables by regression onto the Niño-3 ($150^\circ$ -90$^\circ$ W, 5$^\circ$ S-5$^\circ$ N) SST anomalies of preceding 1 month.
Methods

- Maximum Covariance Analysis (MCA) based on singular value decomposition (SVD), determines the atmospheric and oceanic patterns that maximize the covariance between the two fields.
**MRE**

- Generalized equilibrium feedback assessment (GEFA, Liu et al. 2008)
  \[ H(t) = BS(t) + N(t), \]
  \(H\) the atmospheric data matrix, \(N\) stochastic forcing, \(S\) snow forcing (snow).

The feedback matrix \(B\)
  \[ B = C_{HS}(\tau)C_{SS}(\tau)^{-1}, \]

- Maximum response estimation (MRE Frankignoul et al. 2011)
  \[ BS(t) = \sum_i c_i(t)p_i, \]
  \(c_i(t)\) the principal components, \(p_i\) orthogonal patterns.
  The largest response is obtained by calculating the main EOFs of \(BS(t)\)
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The SC (Squared Covariance) of the first MCA mode between TP snow cover and precipitation (in China) anomalies at different lag time.
Heterogeneous precipitation covariance and homogeneous snow cover covariance for the first MCA mode between JJA precipitation and JFM TP snow cover.

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Heterogeneous precipitation covariance and homogeneous snow cover covariance for the first MCA mode between ASO precipitation and TP snow cover at different lags.
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First MRE mode between precipitation and TP snow cover in ASO at Lag–1.

E1 indicates statistical significance level
First MRE mode between geopotential height (shading) / wind fields at 850 hPa and TP snow cover in ASO at Lag−1
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• An increased Tibetan Plateau snow increases land surface albedo, and excessive TP snow can modify the surface thermal conditions, which suppresses the land surface heating on TP (Wu and Qian, 2003; Tao and Ding, 1981; Ye, 1981; Zhang et al., 2004; Flanner and Zender, 2005; Lin and Wu, 2011).

• Both observations and numerical experiments show that atmospheric heating induced by the rising TP temperatures is connected to two distinct Rossby wave (Wang et al. 2008).

Can increased TP snow cover excite two Rossby wave trains?
Correlation coefficients of 200-hPa, 850-hPa ASO geopotential height (wind) fields with respect to snow cover time series of first MCA mode. Dark shading denotes statistical significance at 90% level. Dashed arrow indicates Rossby wave trains.
ASO total stationary Rossby wavenumber at 200hPa and 850hPa. Thick line with an arrowhead shows the possible waveguide.
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Summary

• MCA analysis shows a significant correlation between early autumn (ASO) Chinese precipitation and the preceding TP snow cover.

• Maximum response estimation and diagnostic analyses show that lead positive snow cover anomalies over western TP signifies enhanced ASO rainfall over Yangze River basin and south China, and reduced rainfall over southeast coastline of China.

• The possible mechanism is as follow: positive early spring snow cover anomalies in TP can persist to summer, and modify the surface thermal conditions, which results in two distinct Rossby wavetrains propagating downstream along the westerly jet and the lower southwesterly airflow. The southerly flow strengthens abundant moisture transport to Southern China, the northerly flow contributes the southward moving of synoptic disturbances from the north. Both conditions lead to more rainfall in central and southern China.
Thanks for your attention!