The Remote Effect of the Tibetan Plateau on Downstream Flow in Early Summer

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Previous Studies：

1. Topography: Round flow to the north of the TP（Manabe and Terpstra 1974 and many others）
2. Asian mooson with the TP (Hohn and Manabe 1975)
3. Wave train along 40N by heating on the TP（Wang et al. 2008，Sato et al. 2007, Liu et al. 2007）
4. In early summer, there is a normal Rossby wave propagation which originates the Caspian sea, via the Okhotsk Sea to the area east of Japan (called the OKJ wave train, Wang 1992, Wang et al. 2007)

Question: is whether there is any relationship between OKJ propagation and the TP influence in early summer.

Purpose: This study examines the remote influence of atmospheric heating and giant topography of the TP on the OKJ propagation in early summer.

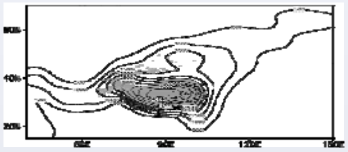

Fig. 1 The topographic height over 500 m with 500 m interval in CAM 3.1 (contour lines) and the locations for surface air temperature (full cycles). The shaded area indicates the Tibet territories in map board.

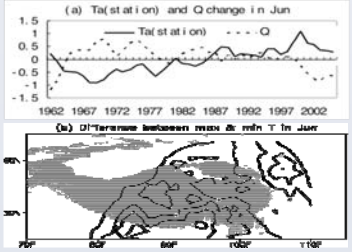

Fig. 2 The evolution of air temperature (Ta) at stations in TP and heat source (Q) averaged in the region of (27.5-37.5°N, 75-105°E) in June (units: ℃ and Wm^{-2}, a), the difference between maxima and minima of surface air temperature among the year of 1960-2005 (interval: 1℃, b). The time series for the indexes was normalized and applied for a 5 year running mean. The shaded area shows TP terrain.

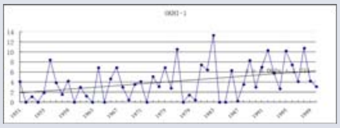

Figure 3 The evolution of the OKHI-1 in June (unit: blocked day). This was adapted from Figure 2 of Wang and Lupo (2009) with slight modification. The trend line (skew line) with the linear regression equation was plotted.

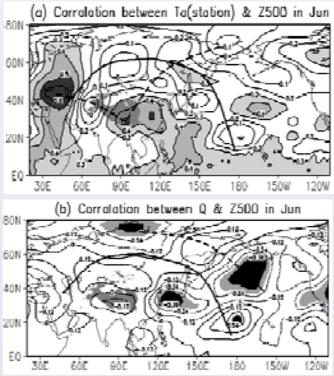

Fig. 4 The correlation between Z500 and Ta index (a) and Q index (b). Shaded regions indicate the confidence level exceeding 95%. TP terrain is embedded by gray shade.

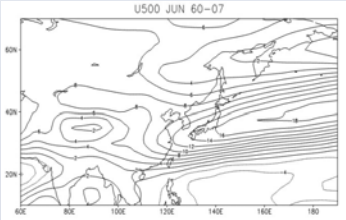

Figure 5 The distribution of the zonal wind at 500 hPa in June during 1960-2007 (interval: 2 m/s).

Simulation:

(1) Mechanical effect of the TP: Using CAM3.0, a control run (M-Ctr. run) was adopted by 50 years' integration with the original model initial condition dataset, A sensitivity test (M-ST run) was done in the same manner as the M-Ctr. run, except for cutting the TP to below 1000 m. Compare M-Ctr run and M-ST run in their last 30 years.

(2) Thermal effect of the TP: (a) Considering the global warming, we reduced and increased surface albedo to 95% and 105% to cause the surface warming and cooling for the TP correspondingly. Compare (H-W run) and (H-C run) in the 10 year integration (b) Using RegCM3.1, The TP warming was simulated by imposing a thermal source with the heating rate 2℃ day^{-1} to 8℃ day^{-1} with the 2 ℃ 's interval on the boundary layer of the TP area (H-Re2, H-Re4, H-Re6 and H-re8), respectively. Compare them with climatic run.

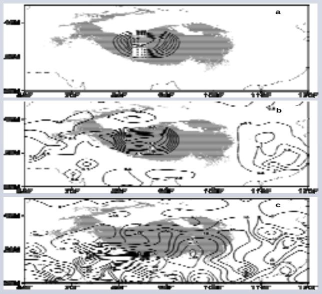

Fig. 6 The surface albedo (interval: 0.03, a), the surface temperature (interval: 0.5 ℃, b) and the heat source (interval: 10 Wm^{-2}, c) between the H-W run and H-C run.

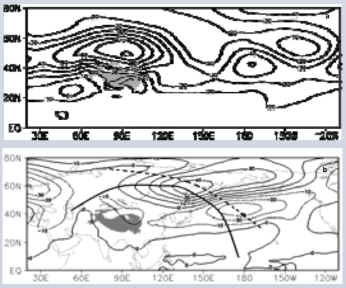

Fig. 7 The difference of Z500 between M-Ctr. run and M-TS run (a), and H-W run and H-C run (b). The interval of contour line is 10 gpm. The full line is the OKJ track and the full dashed line is the linkage of the wave train centers subjectively

Table 1 The model configuration

Model component	
Grid System	Horizontal: 120×88 grid with about 90 km resolution centered at (45°N, 120°E) Buffer zone: 18 Grids, with an exponential relaxation technique Vertical: 18 layers with sigma coordinate ,top pressure is 50 hPa
Physics	Surface physics: BATS; planetary boundary layer scheme: Holtslag, radiation scheme of the NCAR CCM3; Convective Precipitation Schemes: Grell
Artificial heat source	A heat source over the TP (27.5-37.5°N, 75-104°E) with an maximum heating rate in the boundary layer being from 2K /day to 8 K /day, and above the boundary with an e-folding height of about 2.5km
Boundary	The data averaged for June from 1979 to 2001, which was adopted by 40-yr Medium-Range Weather Forecasts reanalysis dataset
SST	The data averaged for June from 1979 to 2001, which was adopted by global ocean surface temperature (GISST) dataset
Duration	01 June-30 June

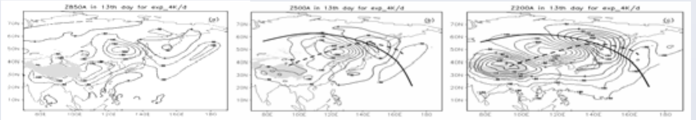

Fig. 8 The difference of the geopotential height between H-Re4 run and ReB run at 850 hPa (a), 500 hPa (b) and 200 hPa (c). The full line shows the OKJ track and the full dashed line is the linkage of the wave train centers subjectively.

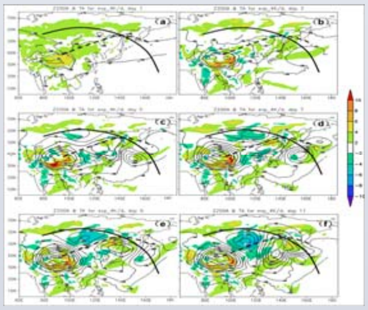

Fig. 9 The geopotential height at 200 hPa (contour lines with an interval of 50 gpm) and the surface temperature (color images with the interval of 2K) of H-Re4 run minus ReB run on day 1, 3, 5, 7, 9 and 11 respectively. The full line and the bold-dashed line were picked up from Figure 8c.

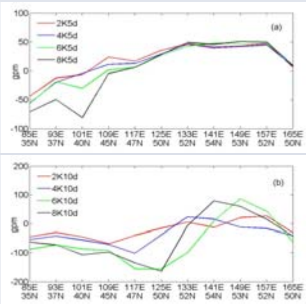

Figure 10 The anomalies of Z500 picked up along the dashed track in Figure 8 on day 5 (a) and day 10 (b) with the diabatic heating rates from 2K to 8K in the model experiments respectively. The unit is gpm.

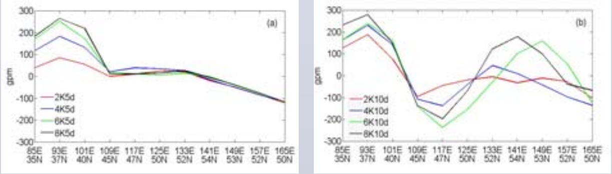

Figure 11 Similar as in Figure 10 except for the anomalies of Z200

Summary:

The mechanical effect of the TP in an atmosphere general climate model (AGCM), including air made warmer by the giant topography than its surroundings climatologically, results mainly in a local response in the atmosphere, i.e., a huge ridge north of the TP in the troposphere in June. There was no substantial seasonal change of the mechanical effect in this study from that reported in previous studies. However, simulation and statistic analyses strongly suggested that the anomalous TP atmospheric heating associated with global warming tends to excite a Rossby wave originating from the TP via the Lake of Baikal to continue to move through the Okhotsk Sea to downstream areas. The appearance of the Rossby wave coincides with the positive phase of the eastern part of a normal stationary wave originating in the Caspian Sea traveling via the Okhotsk Sea to the sea area east of Japan that often occurs in June. Thus the TP atmospheric heating acts as a secondary wave source in relaying and enhancing the eastern part of the normal wave propagation. Its path is usually lies beyond the latitude line of 40 ° N, which is where westerly jet stream takes over the role of waveguide.

Discussion:

(1) The differences between the simulation and observation.

(2) The generated wave train with a barotropic structure.

(3) OKJ wave does not follow the waveguide theory in the early summer