The long-term changes of tropospheric lapse rate over China and Its Relations to Surface Warming

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Objective

The lapse-rate in the atmosphere defined as the change in temperature with height (−dT/dz) is most often used to characterize temperature changes because earth's surface temperature and the greenhouse effect tend to go up and down with the amount of the tropospheric lapse rate. The mean tropospheric lapse-rate is a balance between many processes of energy transfer, like radiation, convection, evaporation, cloud formation, and large scale air motions. The lapse-rate feedback is one of important feedback in the climate system, and If the temperature increases more in the upper troposphere causing a negative lapse-rate feedback (IPCC, 2007). In this study, both the long-term changes of tropospheric lapse-rate derived from the radiosonde dataset over China and its relations to the temperature are analyzed to explore what response the lapse-rate has to the climate warming.

Data and method

1. **The twice-daily radiosonde observations at 00 and 12 UTC used in this study came from the National Meteorological Information Center (NMIC) of the China Meteorological Administration (CMA). The air temperature was homogenized using the method of Haimberger et al. (2008).**
2. **The daily values of the tropospheric lapse-rate were derived on the basis of the linear regression between the geopotential height and the temperature from surface to 300mb at each station.**
3. **Monthly anomalies were computed as deviations from the long-term mean of the study period (1969-2011) for each month. Trends and their statistical significance at individual stations were estimated using the Mann-Kendall Tau-b non-parametric technique including Sen's slope method (Sen, 1968). To obtain regional mean values, the monthly anomalies were first interpolated onto a 1°×1° lat-lon grid using the ordinary Kriging technique (Phillips et al. 1992) and then the gridded data were averaged using the grid-box area as weight to derive regional means.**

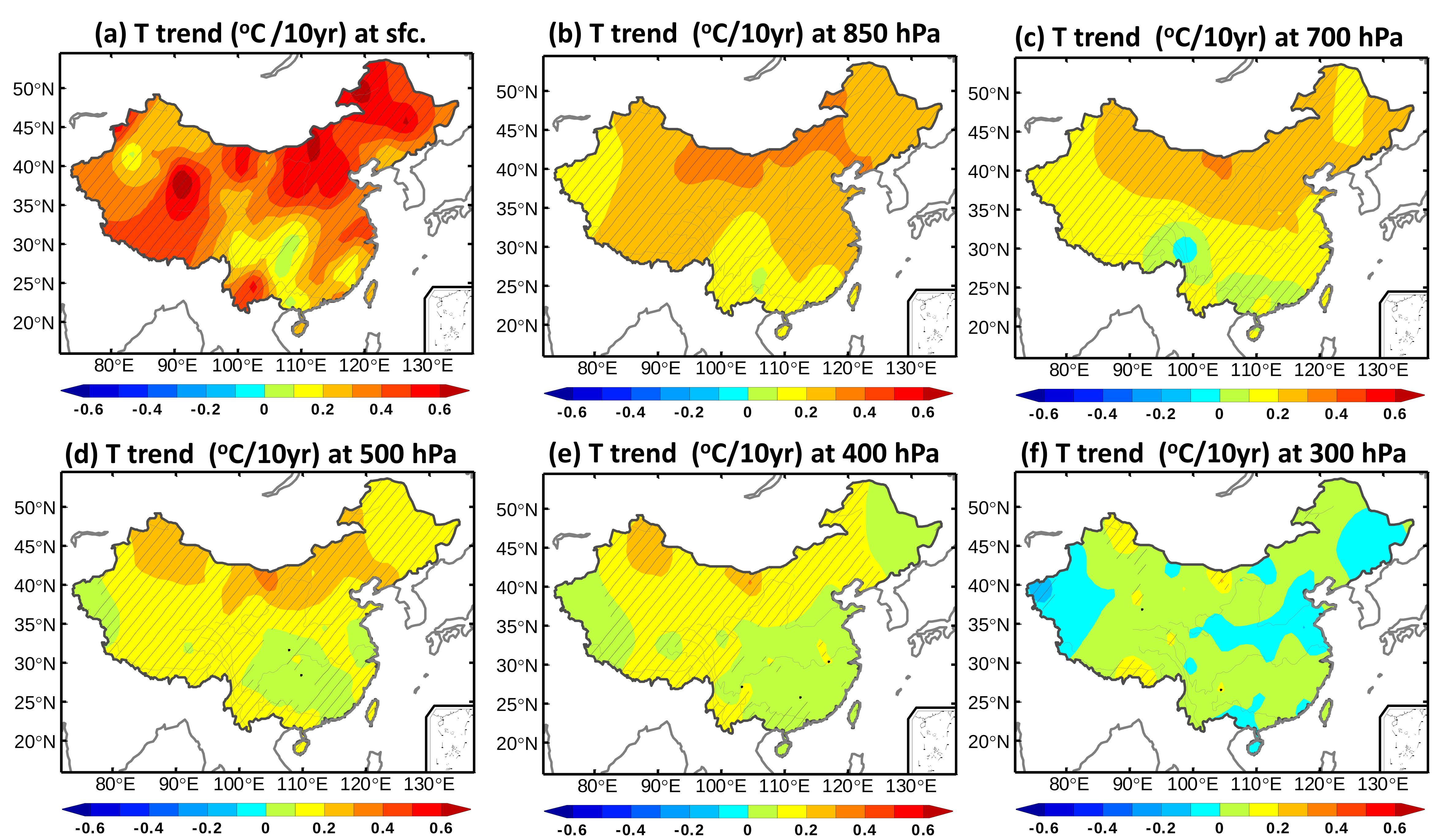

Figure 1. Spatial distributions of the linear trends of monthly air temperature anomalies from surface to 300mb during 1969-2011 over China. The stippled areas are statistically significant at the 5% level.

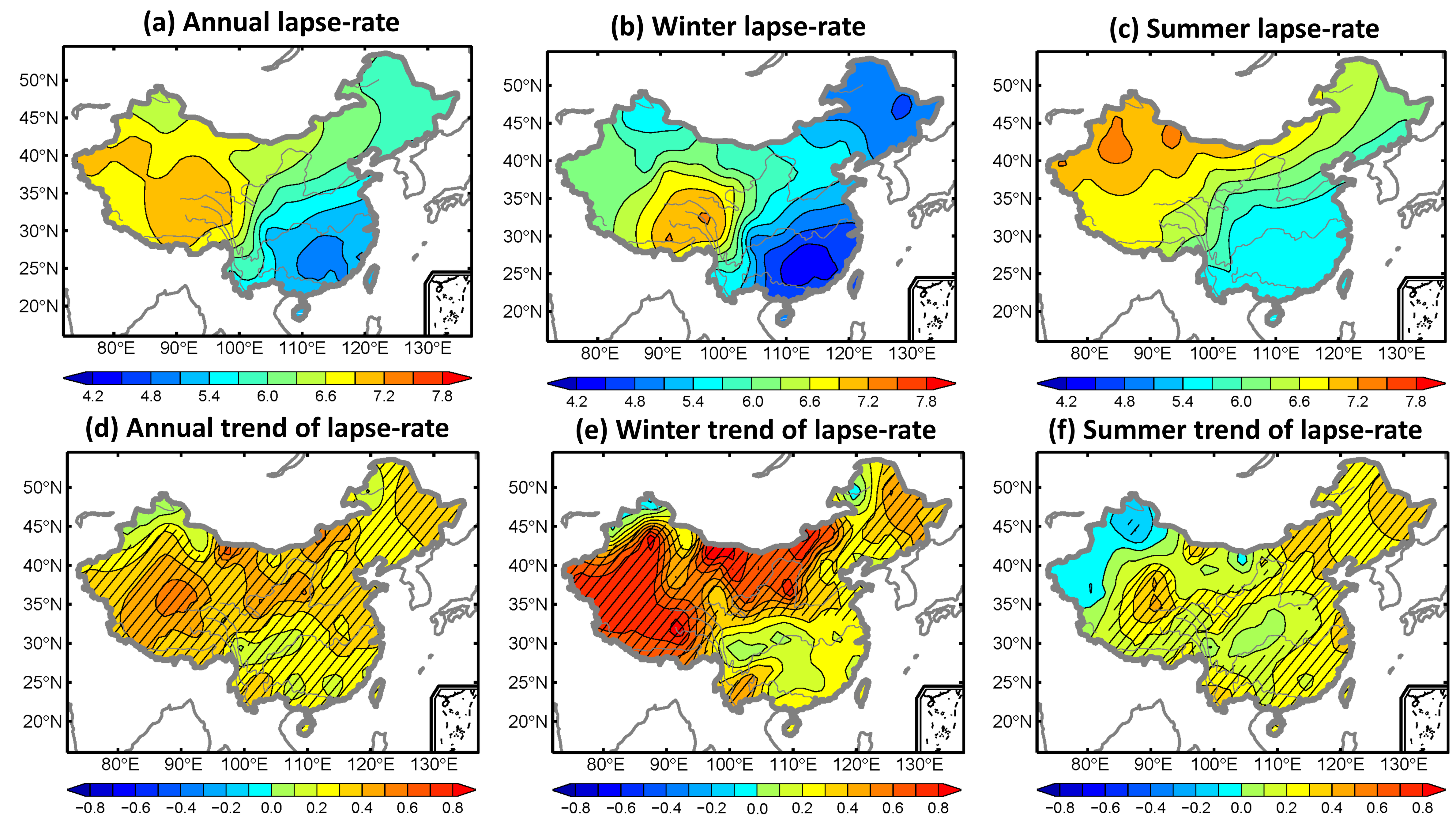

Figure 2. Spatial distributions for annual **(a),** winter **(b)**, and summer **(d)** tropospheric lapse -rate (°C /km) over China during 1970-2011 derived from the radiosonde temperature with the geopotential height . Their linear trends (°C/km per-50-year) are also shown in **(d-f)**, and the stippled areas are statistically significant at the 5% level.

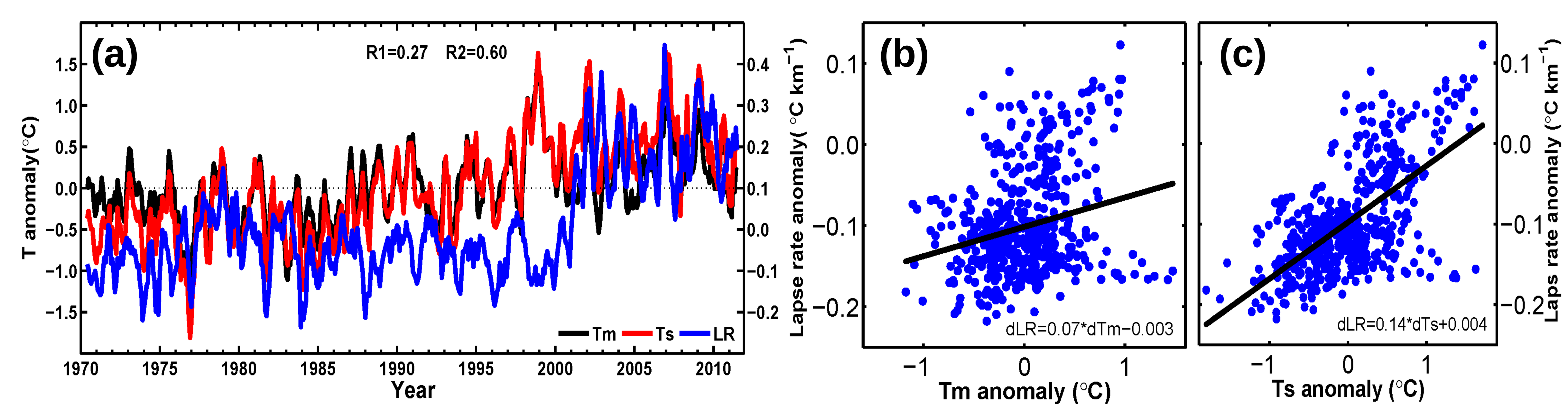

Figure 3. **(a)** Time series of 11-point moving averaged the surface-to-300mb mean temperature anomalies (Tm, °C, thin black line), surface temperature anomalies (Ts, °C, red line) and the tropospheric lapse-rate (LR, °C km^{-1}, blue line) for the whole of China; the R1, R2 and R are the correlation coefficients between the smoothed lines of Tm and LR anomaly, and Ts and the LR anomaly, respectively; **(b-c)** are the scatterplots of LR .vs. Tm and Ts anomalies.

Results and conclusion

1. **Together with obvious regional and seasonal dependency during 1969-2011, the tropospheric lapse-rate shows significant upward changes, with the −dT/dz increasing by about 0.2~0.6°C/km per 50-year over the most China and by more than 0.6°C/km per 50-year over northern China in winter, which result mostly from a faster increases in temperature at the ground and mid-lower troposphere than at the mid-upper troposphere, with most of the increase occurring after mid-1980s.**
2. **The changes of −dT/dz are higher correlated with the variations of surface temperature (r~=0.60) than with the surface-to-300hPa mean temperature (r~=0.30). This indicates that the long-term changes of the tropospheric lapse-rate has an obviously positive response to the surface warming over China.**