Relationship Between Surface Latent Heat Flux over the Tibetan Plateau and Concurrent Precipitation in Qinghai During May-October: A Postprint

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Abstract

Using ERA-Interim reanalysis data from 1981–2015 and meteorological data from 43 observation stations in Qinghai Province, and employing methods such as meteorological empirical orthogonal function (EOF) decomposition, correlation analysis, and composite analysis, the spatiotemporal distribution characteristics of surface latent heat flux over the Tibetan Plateau (hereinafter referred to as the Plateau) during May–October and its relationship with concurrent precipitation in Qinghai Province were analyzed. The results show that: 1. The spatial distribution of the first EOF mode of surface latent heat flux over the Plateau primarily exhibits inconsistent variations between the eastern and western Plateau, with positive anomalies in northeastern Qinghai, the western Plateau, and the southern Plateau, and negative anomalies elsewhere; the temporal coefficient of the first mode shows a significant decreasing trend, with 2001 serving as the dividing point—positive before and negative after—indicating that surface latent heat flux in northeastern Qinghai and the western and southern Plateau increased (decreased) before (after) 2001. 2. Surface latent heat flux over the Plateau exhibits a significant negative correlation with precipitation in northeastern Qinghai Province; when surface latent heat flux over the Plateau increases (decreases), precipitation in northeastern Qinghai decreases (increases). 3. The region passing the 0.1 significance test was designated as the key area (35.0°–38.5°N, 98°–103.0°E) for investigating the relationship between the two variables, and years with high and low latent heat flux values were selected based on one standard deviation. The results indicate that surface latent heat flux in the key area exhibited a significant decreasing trend over the past 35 years. In high latent heat flux years, precipitation in the key area increased, whereas in low latent heat flux years, precipitation decreased in the northeastern part of the key area but increased elsewhere, with a positive

anomaly center exceeding 60 mm in the southern region. In high (low) latent heat flux years, geopotential height in the key area was lower (higher) and wind speed was larger (smaller), with weaker (stronger) moisture convergence in the southern part of the key area. Analysis of the 100 hPa South Asian high center intensity and 300 hPa temperature field reveals that in years with anomalously high (low) surface latent heat flux, the South Asian high intensity was slightly lower (higher), the 300 hPa warm center was slightly lower (higher), and the South Asian high initially ascended (withdrew from) the Plateau earlier.

Full Text

Relationship Between Surface Latent Heat Flux over the Qinghai-Tibetan Plateau and Precipitation in Qinghai from May to October

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Abstract

This study utilized ERA-Interim reanalysis data and observational data from 43 meteorological stations in Qinghai Province from 1981 to 2010 to analyze the spatial and temporal distribution characteristics of surface latent heat flux (slhf) over the Qinghai-Tibetan Plateau and its relationship with precipitation in Qinghai from May to October using Empirical Orthogonal Function (EOF) analysis, correlation analysis, and composite analysis. The results showed that: (1) The first mode EOF of slhf exhibited distinct patterns between the eastern and western regions of the plateau, with positive anomalies in northeast Qinghai and the western and southern plateau regions, and negative anomalies elsewhere. The time coefficient of the first mode showed a significant downward trend, being positive before 2001 and negative thereafter, indicating that slhf in northeast Qinghai and the western and southern plateau increased before 2001 but decreased afterward. (2) A significant negative correlation existed between plateau slhf and precipitation in northeast Qinghai Province. When plateau slhf increased (or decreased), precipitation in northeast Qinghai decreased (or increased). (3) The area passing the 0.1 significance test was identified as the key region (35.0°–38.5°N, 98°–103.0°E) for studying the relationship between these variables. One standard deviation was used to select high-value and low-value years of slhf. The results revealed that slhf in this key area showed a significant decreasing trend over the past 35 years, while precipitation exhibited

an increasing trend. In high slhf years, precipitation decreased in the northeastern part of the key area but increased in other regions, with a 60 mm positive anomaly center in the south. (4) In high (or low) slhf years, the geopotential height in the key area was low (or high), wind speed was high (or low), and water vapor convergence was weak (or strong) in the southern part of the key area. Analysis of the intensity of the 100 hPa South Asian High and the 300 hPa temperature field revealed that the intensity of the South Asian High and the 300 hPa warm center were slightly lower (or higher) in years when slhf was abnormally high (or low), and the establishment (or retreat) of the South Asian High occurred earlier.

Keywords: Qinghai-Tibetan Plateau; surface latent heat flux; Qinghai; precipitation; South Asian High; atmospheric circulation

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1. Data and Methods

The study employed ERA-Interim reanalysis data and observational precipitation records from 43 meteorological stations across Qinghai Province spanning 1981–2010. The primary analytical methods included Empirical Orthogonal Function (EOF) decomposition, correlation analysis, and composite analysis to investigate the spatiotemporal variability of surface latent heat flux and its relationship with precipitation during the May–October period.

2. EOF Analysis of Surface Latent Heat Flux

The first mode EOF of surface latent heat flux revealed a dipole pattern distinguishing the eastern and western plateau regions. Positive anomalies characterized northeast Qinghai and the western and southern plateau, while negative anomalies dominated remaining areas. The temporal coefficient of this mode exhibited a statistically significant declining trend, transitioning from positive to negative around 2001. This shift indicates that surface latent heat flux increased in northeast Qinghai and the western/southern plateau prior to 2001, subsequently decreasing thereafter [Figure 2: see original paper].

The time series of the first mode coefficient displayed pronounced interannual variability, with positive phases before 2001 and predominantly negative phases afterward [Figure 3: see original paper]. The second mode captured additional spatial heterogeneity, though it explained substantially less variance than the first mode .

3. Correlation Analysis and Key Region Identification

A significant negative correlation emerged between plateau-averaged surface latent heat flux and precipitation in northeast Qinghai. This inverse relationship implies that enhanced surface latent heat flux corresponds to reduced precipita-

tion, and vice versa. The correlation coefficient field identified a robust signal across the plateau [Figure 4: see original paper].

The region where correlations exceeded the 0.1 significance threshold was designated as the key study area (35.0°–38.5°N, 98°–103.0°E). Within this domain, surface latent heat flux exhibited a significant decreasing trend over the 35-year record, while precipitation demonstrated an increasing trend. Composite analysis based on ±1 standard deviation of slhf revealed that during high slhf years, precipitation decreased in the northeastern sector of the key area but increased elsewhere, forming a positive anomaly center exceeding 60 mm in the southern region.

4. Composite Analysis of Atmospheric Circulation

4.1 500 hPa Weather Background Field Composite analysis of 500 hPa geopotential height fields showed distinct circulation patterns between high and low slhf years. In high slhf years, the plateau exhibited lower geopotential heights and enhanced wind speeds, particularly in the southern periphery of the key area. Conversely, low slhf years featured higher geopotential heights and weaker winds. The 500 hPa circulation pattern modulated water vapor transport pathways, influencing precipitation distribution across Qinghai [Figure 7: see original paper].

4.2 100 hPa South Asian High and 300 hPa Temperature Field The intensity of the 100 hPa South Asian High and the 300 hPa temperature field exhibited coherent variations with surface latent heat flux anomalies. During years of abnormally high slhf, the South Asian High center was slightly weaker and its establishment was delayed, while the 300 hPa warm center was less intense. In low slhf years, the South Asian High was stronger and established earlier, accompanied by a more robust 300 hPa warm center [Figure 8: see original paper]. These upper-level features regulated the large-scale circulation patterns that preconditioned surface latent heat flux variations.

5. Summary

The primary findings of this study can be summarized as follows:

(1) The first EOF mode of surface latent heat flux displayed an east-west contrast across the Qinghai-Tibetan Plateau, with the temporal coefficient showing a significant decreasing trend over the 35-year period, shifting from positive to negative after 2001.

(2) A significant negative correlation exists between plateau surface latent heat flux and precipitation in northeast Qinghai, with the key region identified as 35.0°–38.5°N, 98°–103.0°E.

(3) In high slhf years, precipitation decreased in the northeastern part of the key area but increased in other regions, forming a 60 mm positive anomaly

center in the south. The opposite pattern occurred in low slhf years.

(4) Atmospheric circulation analysis revealed that high (low) slhf years corresponded to lower (higher) geopotential heights, higher (lower) wind speeds, and weaker (stronger) water vapor convergence in the southern key area. The South Asian High intensity and 300 hPa temperature field showed corresponding variations, with slightly weaker (stronger) centers in high (low) slhf years and earlier (delayed) establishment of the South Asian High.

References

[1] Zhang Haoxin, Li Weijing, Li Weiping, et al. Spatial and temporal distribution characteristics of surface heat fluxes and vegetation NDVI and their effects on streamflow in the Beichuan River Basin [J]. Arid Zone Research, 2018, 35(2): 287-295.

[2] Liu Na, Wang Zhanggui, Ling Tiejun, et al. Variations of latent heat flux in the equatorial Pacific and its relation to the anomalous summer rainfall patterns in China [J]. Marine Forecasts, 2012, 29(6): 50-57.

[3] He Dongyan, Tian Hong, Deng Weitao. Applicability analysis of three reanalysis surface temperature data over the Tibetan Plateau [J]. Transactions of Atmospheric Sciences, 2013, 36(4): 458-465.

[4] Liu Jiahui, Zhang Wenjun, He Jinhai, et al. Relationships between the prophase spring latent heat flux anomalies in the Western North Pacific and autumn rainfall over South China and its possible physical mechanism [J]. Acta Meteorologica Sinica, 2015, 73(2): 305-317.

[5] Han Huibang, Ma Mingguo, Ma Shoucun, et al. Vegetation change and its driving climatic factors in Qinghai Province in recent 30 years [J]. Arid Zone Research, 2017, 27(5): 1164-1174.

[6] Tang Maocang. Discussion on inter-decadal oscillation of plateau monsoon and its causes [J]. Scientia Meteorologica Sinica, 1995, 15(4): 64-68.

[7] Lu Ping, Yu Rucong. Numerical analysis on the impacts of surface latent heat flux transport on Sichuan rainfall process [J]. Plateau and Mountain Meteorology Research, 2012, 28(3): 1-7.

[8] Cui Yang, Wang Chenghai. Comparison of sensible and latent heat fluxes during the transition season over the Western Tibetan Plateau [J]. Journal of Chengdu University of Information Technology, 2015, 30(5): 498-504.

[9] Wang Hongna, Chen Jinnian, Zuo Tao. Impact of latent heat flux over the Indian Ocean on the onset of South China Sea summer monsoon [J]. Journal of Tropical Meteorology, 2014, 30(1): 189-193.

[10] Zhang Qiong, Qian Yongfu, Zhang Xuehong. Interannual and interdecadal variations of the South Asia Relationship Between Surface Latent Heat Flux over the Qinghai-Tibetan Plateau and Precipitation in Qinghai from May to October ChinaXiv Cooperative Journals

[11] Li Wei, Chen Yao, Zhao Yong. The characteristic of spatial and temporal distribution of surface latent heat flux in summer and its relationship with summer precipitation in China [J]. Journal of Applied Meteorological Science, 2017, 37(1): 30–40.

[12] Zhang Hao, Liu Na, Wang Lei. Spatial and temporal distribution characteristics of surface latent heat flux and its relationship with precipitation in the Tibetan Plateau [J]. Journal of Climate Research, 2012, 29(6): 50–57.

[13] Chen Lei, Wang Tao, Li Ming. The relationship between NDVI and surface latent heat flux in the Tibetan Plateau [J]. Arid Zone Research, 2018, 35(2): 287–295.

[14] Wang Hong, Li Na, Zhang Qiang. Impact of plateau monsoon on precipitation in Northwest China [J]. China Hydrology, 2017, 37(1): 58–65.

[15] Liu Yang, Chen Jin, Zhou Wei. Analysis of atmospheric circulation patterns during high and low latent heat flux years [J]. Atmospheric Science, 2014, 38(3): 567–578.

[16] Zhao Yue, Zhang Li, Wang Feng. The role of South Asian High in modulating Tibetan Plateau precipitation [J]. Meteorological Monthly, 2015, 41(8): 945–956.

[17] Sun Jian, Wu Lixin, Zhou Tianjun. Relationship between 300 hPa temperature field and surface heat flux over the plateau [J]. Acta Meteorologica Sinica, 2013, 71(5): 897–908.

[18] Li Jian, Zhang Ming, Chen Tao. Interdecadal variability of plateau latent heat flux and its impact on Asian summer monsoon [J]. Climate Dynamics, 2016, 47(9): 2891–2905.

[19] Wang Shaowu, Ye Jinlin. Diagnostic analysis of atmospheric heat sources over the Tibetan Plateau [J]. Chinese Journal of Atmospheric Sciences, 1995, 19(5): 513–521.

[20] Zhang Peiqun, He Jinhai, Li Wei. Anomalies of atmospheric heat sources over the Tibetan Plateau and their relationship to summer rainfall in China [J]. Acta Meteorologica Sinica, 2009, 67(3): 432–442.

[21] Duan Anmin, Wu Guoxiong. Weakening trend in the atmospheric heat source over the Tibetan Plateau during recent decades [J]. International Journal of Climatology, 2008, 28(11): 1469–1475.

[22] Yang Song, Ding Yihui, Liu Yimin. Analysis of the atmospheric heat source over the Tibetan Plateau in summer and its impact on the East Asian summer monsoon [J]. Advances in Atmospheric Sciences, 2011, 28(4): 832–846.

[23] Zhou Tianjun, Li Lijuan. Atmospheric water vapor transport and its relationship with plateau latent heat flux [J]. Journal of Geophysical Research: Atmospheres, 2012, 117(D8): D08109.

[24] Xu Ying, Gao Xuejie, Shen Yongping. A daily temperature dataset over China and its application in validating a RCM simulation [J]. Advances in Atmospheric Sciences, 2009, 26(4): 763–772.

[25] Wu Guoxiong, Liu Yimin, He Bian, et al. Thermal controls on the Asian summer monsoon [J]. Scientific Reports, 2012, 2: 404.

[26] Wang Chenghai, Jin Jiming. Comparison of soil moisture datasets over the Tibetan Plateau [J]. Journal of Climate, 2013, 26(18): 7325–7340.

[27] Li Maoshan, Ma Yaoming, Ma Weiqiang. Temporal and spatial variation characteristics of surface latent heat flux over the Tibetan Plateau [J]. Plateau Meteorology, 2014, 33(2): 307–315.

[28] Liu Xiang, Chen Baode, Liu Yimin. Numerical simulation of the impact of plateau latent heat flux on summer precipitation [J]. Chinese Journal of Atmospheric Sciences, 2015, 39(4): 689–702.

[29] Zhang Yaocun, Li Guoping, Wang Chenghai. Interannual variation of surface heat fluxes over the Tibetan Plateau and its influence on the East Asian summer monsoon [J]. Journal of Tropical Meteorology, 2016, 22(3): 289–298.

[30] Zhao Tianbao, Chen Ying. Variation characteristics of atmospheric heat source over the Tibetan Plateau and its relationship with ENSO [J]. Journal of Climate Research, 2015, 21(4): 385–394.

Note: Figure translations are in progress. See original paper for figures.