Postprint: Response of Atmospheric Precipitable Water Distribution to the Central Asian Vortex in Xinjiang and Surrounding Central Asian Regions

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Abstract

The Central Asian vortex is a major precipitation system in Xinjiang and Central Asian regions. To elucidate the atmospheric precipitation potential under its influence, this study utilizes AIRS Version 6 Level 2 satellite data during Central Asian vortex occurrences in the summer half-year from 2003 to 2014 to analyze the inter-monthly variation of the Central Asian vortex precipitation system and the distribution patterns of atmospheric precipitable water for different path types. The results indicate that: The southern and northern vortices of the Central Asian vortex differ significantly in occurrence frequency. The northern vortex accounts for 68.31% of the total occurrence frequency of Central Asian vortices, while the southern vortex accounts for 31.69%. Among these, the occurrence frequency of Central Asian vortices is highest between July and August. According to the classification of different paths of the Central Asian vortex, the occurrence frequencies of various paths are significantly different, with the southeastward-moving Central Asian vortex exhibiting the highest occurrence frequency. In terms of inter-monthly variation, the overall distribution pattern of average atmospheric precipitable water from May to September shows that the Central Asian region is higher than China' s Xinjiang region. The Turpan Basin and Tarim Basin regions in Xinjiang are higher than areas along mountain ranges. In terms of path types, the distribution patterns of average atmospheric precipitable water for various paths of the northern vortex are generally similar. Each path features a large-scale high-value region exceeding 26 mm, while the values for various paths of the southern vortex are generally lower, mostly below 18 mm. This research will provide a reference for forecasting and early warning of sudden heavy precipitation events, as well as for artificial precipitation enhancement in Xinjiang and Central Asian regions.

Full Text

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Abstract: The Central Asian Vortex is the main precipitation system over Xinjiang and Central Asia. Based on AIRS Version 6 Level 2 data from the Aqua satellite during summer months from 2003-2014, we analyzed the monthly variation of Central Asian Vortex precipitation and the distribution of atmospheric precipitable water vapor from different paths to reveal atmospheric precipitation potential. The results showed that: (1) The occurrence frequency of the South Vortex and North Vortex over Central Asia differed significantly, with the North Vortex accounting for 68.51% and the South Vortex for 31.69% of total Central Asian Vortex events. The vortex frequency was highest in July and August. (2) According to the classification of different vortex paths, occurrence frequencies varied markedly, with southeastward-moving Central Asian Vortexes being most common. (3) Monthly variation analysis revealed that average atmospheric water vapor distribution from May to September was higher over Central Asia than over Xinjiang, and higher over the Turpan and Tarim basins in Xinjiang than over mountainous areas. (4) By path type, the North Vortex showed similar distribution trends, with large high-value areas (26 mm) along the paths. In contrast, water vapor content along South Vortex paths was low, mostly below 18 mm. These results could inform weather forecasting and artificial precipitation enhancement efforts in Xinjiang and Central Asia.

Keywords: Central Asian Vortex; precipitable water vapor; moving path; spatial distribution; Xinjiang

2. Data and Methods

The AIRS instrument has a spatial resolution of 13.5 km at nadir and 2.3 km vertical resolution, with spectral coverage from 3.74-15.4 m and a swath width of 1650 km. AIRS Version 6 Level 2 retrieval products provide atmospheric temperature and humidity profiles with high accuracy. The data used in this study covered summer months (May-September) from 2003-2014, regridded to 0.25°×0.25° resolution for consistency.

Vortex paths were classified based on their movement trajectories over Xinjiang and surrounding Central Asian regions. Statistical analysis focused on precipitable water vapor distribution along different path types, with particular attention to high-value centers and their relationship to topographic features.

2.1 Vortex Path Classification

The North Vortex and South Vortex represent two primary circulation patterns. Path classification considered both zonal and meridional movement components, with categories including northwestward, northeastward, southeastward, and southwestward trajectories. The southeastward path showed the highest occurrence frequency, accounting for approximately 55% of all vortex events.

2.2 Precipitable Water Vapor Distribution

Spatial analysis revealed distinct water vapor distribution patterns associated with different vortex paths. For the North Vortex, precipitable water vapor values exceeded 26 mm along the primary trajectories, particularly over the Tianshan Mountains and surrounding basins. The South Vortex exhibited lower moisture content, generally below 18 mm, with maximum values concentrated in the southern Tarim Basin.

Table 3. Statistical results of precipitable water vapor (mm) for different North Vortex paths over 12 years

Table 4. Statistical results of precipitable water vapor (mm) for different South Vortex paths over 12 years

[Figure 3: see original paper]
Fig. 3. Spatial distribution of precipitable water vapor from different North Vortex paths over Xinjiang and surrounding Central Asia in 12 years

[Figure 4: see original paper]
Fig. 4. Spatial distribution of precipitable water vapor from different South Vortex paths of Central Asian Low Vortex System over Xinjiang and surrounding Central Asia in 12 years

3. Conclusions

(1) During 2003–2014, the North Vortex occurred 97 times (68.31% of total events), while the South Vortex occurred 45 times (31.69%). The highest vortex frequency was observed in July and August, coinciding with peak summer precipitation over the region.

(2) Path analysis revealed significant differences in occurrence frequency. For the North Vortex, paths 1B and 1C accounted for 31 and 38 events respectively. For the South Vortex, paths 2C and 1C occurred 55 and 28 times respectively, indicating the dominant southeastward movement pattern.

(3) Monthly variation analysis from May to September showed that precipitable water vapor was consistently higher over Central Asia than over Xinjiang. Within Xinjiang, the Turpan and Tarim basins exhibited higher moisture content (18–30 mm) compared to mountainous regions. The water vapor distribution peaked in July and August, gradually decreasing in September.

(4) Path-type analysis demonstrated that North Vortex paths maintained similar distribution trends with extensive high-value areas (26 mm). In contrast, South Vortex paths featured lower water vapor content, predominantly below 18 mm, with localized maxima in basin areas. These characteristics reflect the influence of topographic forcing and moisture transport mechanisms on vortex development and precipitation potential.

References

[1] Zhang Xuewen. A relationship between precipitable water and surface vapor pressure [J]. Meteorological Monthly, 2004, 30(2): 9–11.

[2] Han Juncai, Zhou Shunwu, Wu Ping, et al. A method for estimating precipitable water and effective water vapor content from ground humidity parameters [J]. Chinese Journal of Atmosphere, 2002, 26(1): 9–22.

[3] Yang Lianmei, Zhang Yunhui, Tang Hao. Analyses on water vapor characteristics in three heavy rainstorm processes of Xinjiang in July 2007 [J]. Plateau Meteorology, 2012, 31(4): 963–973.

[10] Zhang Xuewen, Liu Min, Sun Tong. Spatiotemporal variation of water vapor in upper troposphere over Central Asia based on AIRS satellite retrieval [J]. Arid Zone Research, 2013, 30(6): 951–957.

[11] Yang Lianmei, Zhang Yunhui, Tan Hao. Analyses on water vapor characteristics in three heavy rainstorm processes of Xinjiang in July 2007 [J]. Plateau Meteorology, 2012, 31(4): 963–973.

[12] Liao Xiaonong, Ni Yunqi, He Na, et al. Analysis of the synoptic-scale dynamic process causing the extreme moisture environment in the "7 • 21" heavy rain case [J]. Acta Meteorologica Sinica, 2013, 71(6): 997–1011.

[14] Hu Liequn, Li Shuai, Zheng Peiwen. Analysis of the impact factors of atmospheric transparency in Xinjiang [J]. Arid Zone Research, 2015, 32(2): 297–303.

[16] Chen Yonghang, Peng Kuanjun, Shi Yuguang, et al. Comparison of cloud water resources over Tianshan Mountains and Taklimakan Desert [J]. Arid Land Geography, 2009, 32(6): 886–891.

[21] Huang Chuhui, Gu Qingyuan, Li Guoping, et al. Mechanism analysis of Plateau vortex moving east trigger rainstorm in Sichuan Basin [J]. Plateau Meteorology, 2010, 29(4): 832–839.

[24] Zhang Yunhui, Yang Lianmei, Xiaokaiti Duolaite, et al. The Central Asian vortex activity during 1971–2010 [J]. Journal of Applied Meteorological Science, 2012, 23(3): 312–321.

[25] Wang Jiajin, Wang Chunxue, Chen Chaoping, et al. Analysis of a summer rainstorm water vapor paths and sources in Sichuan Basin based on HYSPLIT4 model [J]. Meteorological Monthly, 2015, 41(11): 1315–1327.

[32] Peng Kuanjun, Zhang Yunhui, Yang Lianmei, Xiaokaiti Duolaite, et al. The Central Asian vortex activity during 1971-2010 [J]. Journal of Applied Meteorological Science, 2012, 23(3): 312-321.

[33] Aumann H H, Chahine M T, Gautier C, et al. AIRS/AMSU/HSB on the Aqua mission: Design, science objectives, data products, and processing systems [J]. IEEE Transactions on Geoscience & Remote Sensing, 2003, 41(2): 253-264.

[35] Zhang Xueqin, Li Minjiao, Sun Tong. Spatiotemporal variation of water vapor in upper troposphere over Central Asia based on AIRS satellite retrieval [J]. Arid Zone Research, 2013, 30(6): 951-957.

[36] Chen Yonghang, Peng Kuanjun, Shi Yuguang, et al. Comparison of cloud water resources over Tianshan Mountains and Taklimakan Desert [J]. Arid Land Geography, 2009, 32(6): 886-891.

[40] Ding Xianrong. Water increasing effect of mountains and its value of water resources [J]. Journal of Mountain Research, 2003, 21(6): 681-685.

[41] Yu Yaxun, Wang Jinsong, Li Qingyan. Spatial and temporal distribution of water vapor and its variation trend in atmosphere over Northwest China [J]. Journal of Glaciology and Geocryology, 2003, 25(2): 149-156.

[43] Hu Li, Li Shuai, Zheng Peiwen. Analysis of the impact factors of atmospheric transparency in Xinjiang [J]. Arid Zone Research, 2015, 32(2): 297-303.

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