CHARACTERISTICS OF PRECIPITATION ANOMALIES IN NORTHEAST CHINA DURING THE SUMMER OF 2019

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Abstract

Using the NCEP/NCAR reanalysis data and the daily precipitation data of 237 meteorological stations in Northeast China (NEC), the characteristics of summer precipitation anomalies in 2019 are investigated, and the possible influence mechanism is also preliminarily discussed. Our statistical result shows that the overall precipitation of NEC in the summer of 2019 (∼448.3 mm) was remarkably higher than that in normal years (from 1981 to 2018, with the climate mean summer precipitation of 358.0 mm), in which the positive anomaly percentages of Heilongjiang Province and Songhua River basin were approximately 53% and 40%, respectively. The unusually high precipitation was the largest since the year 1961. During that period of time, the 500 hPa geopotential height field was distributed in a "- + -" pattern from west to east in the northern high latitudes, and the NEC region was fully controlled by a significant negative height anomaly field; the western Pacific subtropical high at low latitudes was significantly larger, stronger and more westerly than normal, and the ridge position was more southerly, which is conducive to the northward advance of summer monsoon and the transport of water vapour to...
NEC. Furthermore, the extremely active northeast cold vortex and northward typhoon are the dominant reasons for the abnormally increased precipitation over NEC.

**Key words:** Northeast China, precipitation, atmospheric circulation, cold vortex, typhoon

1. **Introduction.** Northeast China (NEC) is one of the main production areas of commercial grain in China, and it is also an important industrial and energy base. It is located in the northern edge of the East Asian summer monsoon, in the eastern part of the Eurasian continent, with the Pacific Ocean to the east, the Bohai Sea and the Yellow Sea to the south, surrounded by mountain ranges and a large plain in the centre. Summer is the main growing season of crops, and the growth of crops depends on the summer climate to a great extent. The prediction of summer climate has always been a major concern of meteorological authorities at all levels. Due to its unique geographical and topographic conditions, the influencing factors of climate are quite complex [1–3]. Under the background of global warming, extreme weather events occur frequently, which has a serious impact on the agricultural production, social and economic development, ecology and people’s general life [4,5]. Consequently, it is of great scientific significance and practical application value to study the mechanism affecting NEC summer climate anomaly change and improve the accuracy of seasonal prediction in this region [6].

Climate characteristics of summer precipitation over NEC have been extensively studied, and it is pointed out that drought and flood over NEC are characterized by interannual and interdecadal variability, especially the 27 yr, 10 yr and 2–3 yr cycles [1,7]. Meanwhile, the studies on the circulation system affecting summer drought and flood over NEC reveals that the East Asia trough, western Pacific subtropical high (WPSH) [8,9], blocking high [10,11], northeast cold vortex [12,13], upper level westerly jet [14], and the northern annular mode [15,16] are all closely related to summer precipitation over NEC. The location, pattern, east-west and north-south oscillation of the WPSH all have important influences on the precipitation over NEC [8,9]. The formation and maintenance of the blocking high can enhance the meridional circulation in the middle and high latitudes, which is conducive to the southward movement of cold air [10,11]. There are also significant differences in the effects of blocking high at different locations on NEC weather and climate [10,11]. In addition, the active northeast cold vortex usually contributes to heavy precipitation and low temperature in NEC [12,13]. A large number of studies on NEC summer precipitation provide an important reference for seasonal prediction, but compared with other regions in China, the level of seasonal prediction in NEC still needs to be further improved [17–19].

In the summer of 2019, under the joint influence of northeast cold vortex, typhoon and other factors, the precipitation in NEC significantly increased, which
is rarely seen in history. Heavy rainfall has a very serious impact on local industrial and agricultural production, transportation, education, tourism, water conservancy projects and residents’ lives. By investigating the abnormal characteristics of key members of the circulation system of the summer monsoon in middle and high latitudes and East Asia, this paper preliminarily discusses the possible causes of the NEC summer precipitation anomalies in 2019.

2. Dataset and method. The datasets used in this paper include: (1) the daily and monthly precipitation data in summer from 1981 to 2019 provided by the National Climate Center of China, with a total of 237 meteorological stations in NEC (as shown in Fig. 1b), (2) the daily and monthly NCEP/NCAR-I reanalysis data with a horizontal resolution of $2.5^\circ \times 2.5^\circ$ \cite{20}, and (3) three kinds of WPSH characteristic indexes obtained from the National Climate Center of China. The utilized WPSH characteristic indexes include: the index of the area of the WPSH ($110^\circ$E–$180^\circ$E), the index of the strength of the WPSH ($110^\circ$E–$180^\circ$E), and the ridge line of the WPSH ($110^\circ$E–$150^\circ$E) (see https://cmdp.ncc-cma.net/cn/download.htm for details).

The criterion of northeast cold vortex is directly taken from reference \cite{21}, which is defined as follows: (1) at least one closed contour can be analyzed on the daily 500 hPa weather map at 20:00, and there is a low pressure circulation system with a cold centre or obvious cold trough; (2) the centre of the cold vortex appears in the range of 115–145°E, 35–60°N; (3) the life of cold vortex is maintained for at least 3 days or more.

3. Characteristics of summer precipitation anomalies. According to the statistical results based on the monthly precipitation data, we know that the total summer precipitation of NEC in 2019 was 448.3 mm, which is about 25% higher than the average summer precipitation from 1981 to 2018 (358.0 mm). The spatial distribution of precipitation anomalies was in-homogeneous, with positive anomaly percentages of 53% in Heilongjiang Province and 40% over the Songhua
Figure 2 shows the spatial distribution of the percentage of precipitation anomalies in NEC (relative to 1981–2010), with panels (a)–(d) for the whole summer, June, July, and August, respectively. We can see that in June, the precipitation in the middle NEC was increased significantly; in July, the precipitation increased significantly in the north NEC; in August, the precipitation in the whole NEC increased significantly.

There were mainly 10 major precipitation processes in NEC, namely, June 8–9, 13–15, 26–30, July 21–26, 28–30, August 2–3, 6–18, 21–22 and 26–30. The most severe precipitation processes occurred in August, including four severe precipitation processes. From July 21 to 22, Heilongjiang Province and Jilin Province were affected by the water vapour outside typhoon Danas and an obvious precipitation process occurred. From August 10 to 18, under the influence of Lekima and Krosa, the average precipitation in the whole NEC reached 104.0 mm, which was 178% higher than that in the same period of one normal year.

4. Overview of the main summer circulation systems. In the summer of 2019, the 500 hPa geopotential height was characterized by a “two troughs and
one ridge” circulation pattern over the middle and high latitudes of Eurasia (as shown in Fig. 2e–g). The Ural Mountain and its north area showed a negative height anomaly field, with a central value lower than $-40$ gpm (trough). Lake Baikal and its north area were under significant positive anomaly control, and the high pressure ridge was deep with a central value larger than 60 gpm. The height fields from the Okhotsk Sea to the Northwest Pacific and from the Yellow Sea to the Sea of Japan were all negative anomalies. NEC was in an obvious low value area, which was conducive to the southward movement of cold air. Meanwhile, the WPSH in the low latitudes was significantly larger and stronger than usual, its position is more westerly and the ridge line is more southerly.

From June to August, the circulation has been significantly adjusted month by month. In June (Fig. 2e), the Arctic Oscillation (AO) was dominated by a negative phase, and the meridional direction of Eurasian mid and high latitude circulation was large, showing a “two troughs and one ridge” distribution; The WPSH had large area and strong strength, the ridge line was generally more southerly, and the west extension ridge point was more westerly. In July (Fig. 2f), the AO was dominated by a negative phase, with the Eurasian mid- and high-latitude circulation having a large meridional direction; the height field in the mid- and high-latitude regions of East Asia to the subtropics showed a “negative-positive” anomalous distribution; the WPSH had obvious phase changes, and the overall intensity was strong, with the western extension ridge point normal at the beginning and westward at the end, and the ridge line position southward at the beginning and northward at the end. In August (Fig. 2g), the circulation in the middle and high latitudes of Europe and Asia also showed a “two troughs and one ridge” type distribution, with the East Asia trough obviously westward and strong; the height anomaly distribution in East Asia was “north-negative and south-positive”; the WPSH was strong and broke into two high-pressure centres on the mainland and at sea, with the average position slightly northward. From the 1th to the 8th, the WPSH was northward and water vapour was transported northward along the west side, with water vapour convergence in the western NEC; from the 9th to the 18th, under the influence of the northward typhoon, water vapour convergence was mainly in the eastern NEC; from the 19th to the 31st, under the influence of the northeast cold vortex, an obvious water vapour convergence zone was formed in the northern NEC.

From Table 1, it is obvious that the northeast cold vortex was unusually frequent in the summer of 2019, including a total of 11 active processes. Of these, there are 17 days in June, 14 days in July and 16 days in August, which are 3.5 days, 2.3 days and 7.5 days more than normal years (1981–2018), respectively. Generally, northeast cold vortex provides a good atmospheric circulation background for precipitation and can result in moderate to heavy rainfall and even widespread heavy rainfall under the premise of low-latitude systems and water vapour cooperation. Statistically, when the average position of the cold vortex
North east cold vortex activity and precipitation anomaly percentages in summer of 2019

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Central location</th>
<th>Precipitation anomaly percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jun 7–11</td>
<td>(127.80°E, 42.80°N)</td>
<td>above 100% in Jilin and Heilongjiang Province</td>
</tr>
<tr>
<td>2</td>
<td>Jun 12–17</td>
<td>(142.67°E, 54.17°N)</td>
<td>above 50% in Jilin and Heilongjiang Province</td>
</tr>
<tr>
<td>3</td>
<td>Jun 18–20</td>
<td>(133.67°E, 50.00°N)</td>
<td>above 50% in Jilin and Heilongjiang Province</td>
</tr>
<tr>
<td>4</td>
<td>Jun 28–30</td>
<td>(123.33°E, 46.33°N)</td>
<td>above 50% in most area of NEC</td>
</tr>
<tr>
<td>5</td>
<td>Jul 2–4</td>
<td>(131.00°E, 47.33°N)</td>
<td>above 50% in Jilin and Heilongjiang Province</td>
</tr>
<tr>
<td>6</td>
<td>Jul 5–8</td>
<td>(122.50°E, 41.253°N)</td>
<td>above 100% in most area of NEC</td>
</tr>
<tr>
<td>7</td>
<td>Jul 24–27</td>
<td>(130.00°E, 53.00°N)</td>
<td>above 100% in Jilin and Heilongjiang Province</td>
</tr>
<tr>
<td>8</td>
<td>Jul 29–31</td>
<td>(120.00°E, 50.00°N)</td>
<td>above 100% in most area of NEC</td>
</tr>
<tr>
<td>9</td>
<td>Aug 14–18</td>
<td>(120.60°E, 53.80°N)</td>
<td>above 100% in most area of NEC</td>
</tr>
<tr>
<td>10</td>
<td>Aug 20–24</td>
<td>(129.40°E, 47.00°N)</td>
<td>above 100% in eastern Inner Mongolia and Heilongjiang Province</td>
</tr>
<tr>
<td>11</td>
<td>Aug 26–31</td>
<td>(124.67°E, 50.00°N)</td>
<td>above 100% in Jilin and Heilongjiang Province</td>
</tr>
</tbody>
</table>

centre appears to the east of 130°E, the precipitation in Heilongjiang and Jilin will be significantly heavier, whereas the precipitation in most areas of NEC will be significantly heavier when the average position of the cold vortex centre appears to the west of 130°E.

Based on the three selected WPSH characteristic indexes (area, strength, and the ridge line) from the National Climate Center of China (https://cmdp.ncc-cma.net/cn/download.htm), the characteristics of the WPSH in summer 2019 were obtained. In June, the area of WPSH was significantly larger, the intensity was abnormally strong, the ridge line was southward (located at 20°N), and the westward extension ridge point was westward (located at 105°E). In July, the area of WPSH was large, the intensity was strong, the ridge line was slightly southward (located at 26°N), and the west extension ridge point was slightly east (located at 122°E). In August, the WPSH area was larger, the intensity was stronger, the ridge line position was slightly north (located at 31°N), and the western extension ridge point was abnormally west (located at 89°E). Overall, the WPSH was large, strong, with a southerly ridge line and a westerly ridge point in summer 2019, which was conducive to the northward advance of summer winds and the transport of water vapour to NEC.

One of the necessary conditions for precipitation generation is sufficient water vapour. From the monthly water vapour flux anomalies in June (as shown in Fig. 3a), NEC region was dominated by water vapour convergence and dispersion except for a small amount of water vapour from the Sea of Japan in the north of NEC, with cyclonic circulation in the north of Japan and northerly flow in NEC. In July, the Heilongjiang province was a clear water vapour convergence zone, with cyclonic circulation in NEC (Fig. 3b). Due to the influence of northward
typhoons and the WPSH, a great quantity of vapour was transported to NEC in August (Fig. 3c).

5. Conclusion. In this paper, we provide a brief review of the precipitation and circulation systems over Northeast China during the summer of 2019, and preliminarily discuss the possible causes of the precipitation anomalies. The main points are summarized as follows.

The precipitation in NEC during the summer of 2019 was significantly higher (~25%) than that in the same period of normal years (1981–2018), and the spatial distribution of precipitation was in-homogeneous. During the summer of 2019, the strong blocking high in the middle and high Eurasian latitudes along with the frequent activities of the northeast cold vortex formed a “two troughs and one ridge” circulation pattern over the middle and high Eurasian latitudes. The northeast Asian region was in the obvious low value area. From late July to early August, the northward typhoons were unusually active resulting in NEC precipitation anomalies.

It is worth noting that the factors affecting summer precipitation in NEC are
very complex. Even the completely opposite external forcing field and circulation fields may lead to a similar precipitation distribution pattern. In addition, the increase of extreme weather conditions, such as the increased northward typhoons, will naturally lead to an increase in precipitation over NEC, but the mechanisms behind these anomalies still need to be studied in depth.

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REFERENCES


