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Establishment and Analysis of the Early Summer Northeast Cold Vortex Index (1961–2010)

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Abstract: The Northeast Cold Vortex (NECV) is a major synoptic system at the mid and high latitudes of East Asia, of which the frequent activities have significant “climate effects”, that may cause temperatures and precipitation anomalies, not just in Northern China, but in the Haihe River Basin (HRB). NECV events were defined if the following three conditions were satisfied in the region of 35°N–60°N, 115°E–145°E: first, if a vortex center could be identified at 500 hPa geopotential height field; second, if a cold trough or a cold center existed around the vortex center at the same pressure level; and third, if the vortex center accompanied with the cold trough or cold core persisted for at least three days. Considering the geographical location of the HRB, a key area（38°N–48°N，115°E–125°E）of the NECV activities closely correlated with early summer precipitation in the HRB was determined by the southernmost locations of the low pressure center at 500 hPa during the NECV events in the western region of 115°E–125°E year by year. According to the weather conditions of the NECV processes, NECV events were identified using the daily reanalysis data with a horizontal resolution of 2.5°×2.5° came from the NCEP/NCAR (National Centers for Environmental Prediction/National Center for Atmospheric Research), and the early summer NECVI dataset was derived from the standardized frequency of the low pressure center in a key area during the NECV events, spanning from 1961 to 2010. The deposited dataset includes: (1) standardized NECVI in early summer; (2) southernmost locations of the low pressure center at 500 hPa geopotential height during the NECV events over 115°E–125°E in annual early summer. The dataset is archived in one excel file with data size of 12.5 KB.

Keywords: Northeast Cold Vortex; early summer precipitation; Haihe River Basin; climate effect

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2023.06.06.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2023.06.06.V1.

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1 Introduction

The Northeast Cold Vortex (NECV) is the most common cut-off low pressure system in the East Asia, characterized by quasi-stationary features. The "climate effects"[1] caused by frequent activities of the NECV not only affect the weather and climate in Northeast China[2–4], but also have important impacts on the climate anomalies in North China, the middle and lower reaches of the Yangtze River, and South China[1,5–7]. The Haihe River Basin (HRB) is located in northern China. In addition to being influenced by the tropical low latitude circulation system in early summer precipitation, the mid and high latitudes atmospheric circulation also has equally important impacts on it[8–10]. As an important component of the mid and high latitudes atmospheric circulation in East Asia, the NECV is most active in early summer. Establishing the early summer Northeast Cold Vortex Index (NECVI), analyzing the characteristics of its persistent activities, and studying its relationship with the abnormal precipitation in the HRB are crucial for improving the basin's precipitation forecasting capabilities.

The widely used definition of the NECV process in current business applications is based on the work of Zheng *et al*.[11] and Sun *et al*.[12]. The statistically defined activity range of the NECV is mainly located in the Northeast Asia (35°N–60°N, 115°E–145°E). Considering the significant differences in the impact of NECV activities at different locations on the precipitation in the HRB, this paper redefines the key region of NECV activities that significantly affects the early summer precipitation in the HRB, based on the southernmost position of the NECV low pressure center each year. The definition of the NECV is improved, and the early summer NECVI from 1961 to 2010 is established, combined with the weather conditions of the cold vortex processes. This not only provides a data basis for analyzing the climatological characteristics of NECV activities but also serves as a reference for improving the technology of early summer precipitation forecasting in the HRB.

2 Metadata of the Dataset

The metadata of the Early summer Northeast Cold Vortex Index dataset (1961–2010)[13] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

3 Methods

The study used the daily reanalysis data (Reanalysis 1) from the National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR)[1] during the years 1961 to 2010[15]. The horizontal resolution of the data is 2.5°×2.5°.

3.1 Algorithm

According to the definition of the NECV by Sun *et al*.[12], the NECV weather processes are identified by the following conditions: first, if a vortex center can be identified at 500 hPa geopotential height field; second, if a cold trough or a cold center exist around the vortex center at the same pressure level; and third, if the vortex center accompanied with the cold trough or cold core persist for at least three days.

The NECV occurring in the regions of 115°E–125°E, 125°E–135°E, and 135°E–145°E

[1] NCEP/NCAR Reanalysis 1. https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.html.

Table 1 Metadata summary of the Early summer Northeast Cold Vortex Index dataset (1961–2010)

Items	Description
Dataset full name	Early summer Northeast Cold Vortex Index dataset (1961–2010)
Dataset short name	NECVI_Early Summer_1961-2010
Authors	He, L. Y. L-4778-2016, Tianjin Climate Center, heliyehly@163.com Ma, N., Tianjin Climate Center, esmaning@gmail.com Guo, J. L-4876-2016, Tianjin Climate Center, guojun@cma.gov.cn
Geographical region	The key region of Northeast Cold Vortex activities (38°N–48°N, 115°E–125°E)
Year	1961–2010
Temporal resolution	Year
Data format	.xlsx
Data size	12.5 KB
Data files	(1) standardized NECVI in early summer; (2) southernmost locations of the low pressure center at 500 hPa during the NECV events over 115°E–125°E in annual early summer
Foundations	Ministry of Science and Technology of P. R. China (GYHY201506001–1); Tianjin Meteorological Service (201628bsjj01)
Computing environment	Fortran; Microsoft Excel
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing, 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten percent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[14]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

are respectively defined as the Western Vortex, Central Vortex, and Eastern Vortex[16].

Due to the HRB being situated to the southwest of the NECV activity areas, the key region of NECV activities, which significantly affects the early summer precipitation in the HRB, has been redefined based on the southernmost position reached by the low pressure centers of the NECV in the Western Vortex region of 115°E–125°E. By combining the conditions of NECV weather processes, the frequency standardized values of the cold vortex centers have been statistically calculated, and the dataset of the NECVI during early summer from 1961 to 2010 has been established.

3.2 Data Processing

(1) Using the NCEP/NCAR daily reanalysis data, according to the weather conditions of the NECV processes, the NECV events have been calculated, including the occurrence dates, positions (longitudes and latitudes), and the intensity of the cold centers (inner ring values and trough intensity), from 1961 to 2010. The monthly number of NECV days should be counted based on the month in which the cold vortex occurrence day falls.

(2) Over the Western Vortex region of 115°E–125°E, southernmost positions of the low pressure centers at 500 hPa geopotential height during the NECV events have been recorded in annual early summer. Based on the above-mentioned longitudes and latitudes of the southernmost positions, the key region of NECV activities that significantly affects the early summer precipitation in the HRB, is defined as the area between 38°N–48°N and 115°E–125°E.

(3) Based on the results of step 1, the number of days with the cold vortex center within the region of (38°N–48°N, 115°E–125°E) has been calculated, and the early summer NECVI dataset is derived from these standardized results.

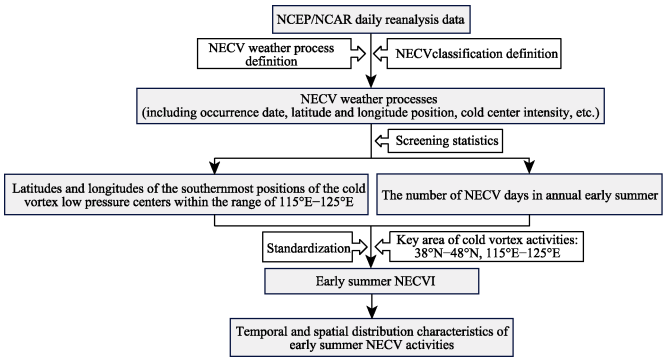

Figure 1 Flowchart of the early summer NECVI dataset development

4 Data Results and Validation

4.1 Data Composition

The early summer NECVI dataset includes: (1) standardized NECVI in early summer; (2) southernmost locations of the low pressure center at 500 hPa geopotential height during the NECV events over 115°E–125°E in annual early summer. The dataset is archived in one excel file with data size of 12.5 KB[13].

4.2 Data Results

4.2.1 Spatial Distribution of Early Summer NECV Activities

According to the weather conditions of the NECV processes, the cumulative frequency distribution of the positions of the low pressure centers during all cold vortex processes in early summer from 1961 to 2010 was statistically analyzed on 2.5°×2.5° grids, as shown in Figure 2. It can be observed that the key region of the NECV activities (38°N–48°N, 115°E–125°E) closely correlated with early summer precipitation in the HRB, includes the areas with the cumulative occurrences of the low pressure centers exceeding 10 times. In this region, the main characteristics of early summer NECV activities can be well reflected. Additionally, the spatial distribution characteristics of the early summer NECV and the location of high frequency cold vortex activity areas are consistent with some previous research findings[12].

4.2.2 Temporal Variation of Early Summer NECVI

The time series of the early summer NECVI from 1961 to 2010 is shown in Figure 3. It can be observed that the NECVI exhibits significant interannual variation characteristics. A higher value of the NECVI corresponds to the more cold vortex activities, while a lower value corresponds to less cold vortex activities. Over the past 50 years, in 1962, 1979, 1986, 1991, 2001, and 2005, the cold vortex index values were greater than one standard deviation, indicating abnormally high NECV activities in these six years. On the other hand, in 1965, 1970, 1981, 1982, 1990, 1994, 2007, and 2010, the cold vortex index values were less than one standard deviation, indicating abnormally low NECV activities in these eight years. On a decadal scale, the early summer NECVI shows an increasing trend, suggesting an increase

in cold vortex activities. This long-term trend is consistent with the results of statistical analyses conducted by Hu *et al*.[6].

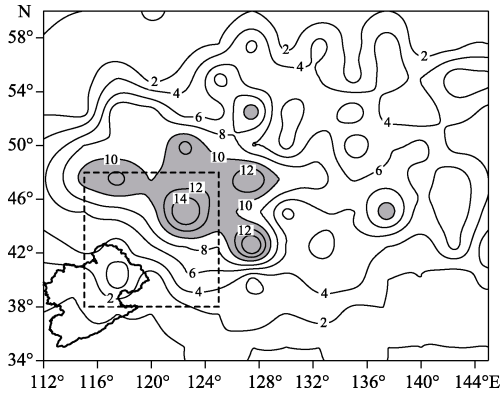

Figure 2 The cumulative frequency distribution of the low pressure centers at 500 hPa geopotential height during the NECV events in early summer from 1961 to 2010
(Note: Shaded areas denote the cumulative occurrences of the low pressure centers exceeding 10 times; Dashed lines denote the key areas of the NECV activities)

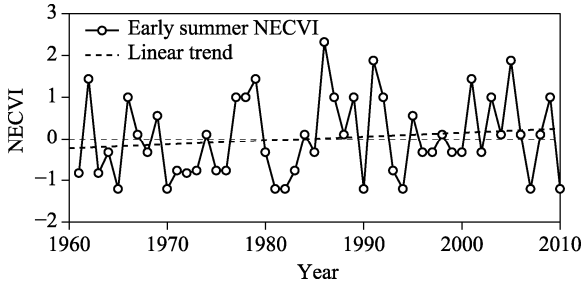

Figure 3 The time series of the early summer NECVI from 1961 to 2010

5 Discussion and Conclusion

The persistent activities of the NECV play a crucial role in the anomalous climate prediction of Northeast China, North China, the Huai River Basin, the Yangtze River and areas to the south. In order to study the variation patterns of the NECV and its impacts, based on the widely used definition of the NECV in operational practice, this paper redefines the key region of the NECV activities that significantly affects the early summer precipitation in the HRB, according to the southernmost position of the NECV low pressure center each year. The definition of the NECV is improved, and combined with the weather conditions of cold vortex processes, the early summer NECVI from 1961 to 2010 is established. These studies provide a scientific reference for analyzing the temporal and spatial characteristics of the NECV and improving the early summer precipitation forecast techniques in the HRB.

Author Contributions

He, L. Y. and Guo, J. designed the algorithms of dataset. He, L. Y. and Ma, N. contributed to the data processing and analysis. He, L. Y. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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