The NPO/NAO and Interdecadal Climate Variation in China

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ABSTRACT

This article discusses the interannual variation of the North Atlantic Oscillation (NAO) and North Pacific Oscillation (NPO), its relationship with the interdecadal climate variation on China which is associated with the climate jump in the Northern Hemisphere in the 1960's, using the data analyses. It is clearly shown that both the amplitudes of the NAO and NPO increase obviously in the 1960’s and the main period of the oscillations changes from 3–4 years before the 1960’s to 8–15 years after the 1960’s. Therefore, interdecadal climate variation in China or the climate jump in the 1960’s is closely related to the anomalies of the NAO and NPO.

Key words: North Atlantic Oscillation (NAO); North Pacific Oscillation (NPO); Climate Jump; Interdecadal climate variation

1. Introduction

The NAO is a large-scale north–south direction alternation of atmospheric mass with the centres of action near the Icelandic low and the Azores high (Walker and Bliss, 1932). It is most pronounced during winter and accounts for more than one-third of the total variance in sea level pressure. A similar alternation of the sea level pressure was also found over the northern Pacific and it is named North Pacific Oscillation (Walker and Bliss, 1932; Rogers, 1981). Based on the computation of the point-to-point correlation coefficient for the sea level pressure, both NAO and NPO can be clearly shown (Wallace and Gutzler, 1981).

An index of the NAO was defined by using sea level pressure anomalies from Ponta Delgada, Azores and Akureyri, Iceland (Rogers, 1984). The high–index pattern is characterized by an intense Icelandic low with a strong Azores high to its south, while for the low–index case, the signs of these anomalies are reversed. Some studies have shown that the NAO index is evidence of a long–period, decadal alternation (Hurrell, 1995), the late 1980’s/early 1990’s is the period with the highest values which is changed from the low–index in the 1960’s. The midlatitude westerly winds strength, the midlatitude precipitation (Bacon and Carter, 1993; Cayan and Reverdin, 1994) and the salinity on the West Greenland banks (Buch, 1995) also exhibit a similar variability feature.

Since the NAO has very clear interdecadal variation which impacts obviously the climate variation in the Northern Hemisphere, in the CLIVAR studying the NAO has been regarded...
as an important component of the DecCen (D1). Optimizing the NAO index, storm–surface interaction, the role of transients and the modelling will be main study contents (WMO, 1995). In fact, the NPO is also an important factor to the climate variation (especially decadal variation) in the Pacific region and the Northern Hemisphere though it is not written directly in the DecCen / CLIVAR. And except the decadal variation of ENSO, the decadal and interdecadal climate variation in the northern Pacific area has been indicated (Kawamura, 1994; Zhang et al., 1997; Li and Liu, 1996).

In the present paper, we will represent NAO using the sea level pressure difference between the region (25°–40°N, 10°–50°W) and the region (50°–65°N, 10°–50°W) region, and this large area averaged difference will be more representative. For the NPO, the studies is quite few, and we will represent it, similar to the NAO, using the sea level pressure difference between the region (25°–40°N, 130°–170°E) and the region (50°–65°N, 130°–170°E). The interannual variations of the NAO and NPO are analyzed by using the sea level pressure data set of the Hadley centre, and the discussion of their association with the interdecadal climate variation in China is helpful to our understanding the interdecadal climate variation and its relationship with the NAO and NPO.

2. Interdecadal climate variation in China

The climate jump in the 1960’s has been indicated in some studies and there was only one climate jump event represented completely by observational data until now (Yamamoto et al., 1986; Yan et al., 1990; Wang, 1990). In fact, the climate jump in the 1960’s showed clearly the feature of interdecadal variation of climate. For this climate jump, many elements, such as precipitation, temperature and surface pressure, all had obvious signal, the sudden variations were all in the period from 1962 to 1967, and a precedent large-scale jump signal occurred at 500 hPa height over the mid–latitude Atlantic region in the late 1950’s (Yan, 1992).

In order to understand the climate jump in the 1960’s, two examples in China can be shown as follows: one is shown by using temporal variation of the summer (June–August) precipitation anomaly (%) in North China (Fig.1), it is very clear that precipitation anomalies were mainly positive (on the more side) before 1964 but mainly negative (on the few side) from 1964; an obvious climate jump occurred in North China in 1964, the averaged summer precipitation changed suddenly from the stage more than normal to the stage less than normal. The second is shown in temporal variation of the surface air temperature anomaly in winter (December–February) in Sichuan Province (Fig.2), we can find that the winter temperature in Sichuan changed into the low one since 1962, because temperature anomalies were mainly negative after 1962, even though there existed positive anomalies during the shorter time, it still means that an obvious climate jump occurred in Sichuan in 1962, and the averaged surface air temperature in winter changed suddenly from warm stage to cold stage. The variation feature of winter temperature in Sichuan is similar to that given by Wang (1990).

Obviously, based on the above–mentioned analyses and the previous research results, it is very evident that a climate jump occurred in the 1960’s and the interdecadal climate variation in China was marked in the 1960’s.

3. Temporal variation feature of the NAO and NPO

It is known that the NAO and NPO are important atmospheric circulation systems and teleconnection patterns, their variability should be closely related to the anomalies of
atmospheric circulation and climate, particularly the climate variation for interannual and longer time scale. The temporal variation of NAO, which is represented by using the monthly sea level pressure difference between the region (25–40°N, 10–50°W) and the region (50–65°N, 10–50°W), is shown in Fig. 3. The interannual variation feature of the NAO is clear. A most evident feature can be found in Fig. 3 that the amplitude of NAO is very different after the 1960s from that before the 1960s. The amplitude was not greater than about ±1.5 hPa before the 1960s, but it was over ±4 hPa since the 1960s, in other words, the amplitude of NAO since the 1960s had exceeded that before 1960s by a big margin.

The temporal variation of the NPO, which is represented by using the monthly sea level pressure difference between the region (25–40°N, 130–170°E) and the region (50–65°N, 130–170°E), is shown in Fig. 4 and the interannual variation of the NPO is also evident. The amplitude of NPO since the end of the 1950s was obviously greater than that before that
time. Of course, it is still clear that the amplitude of NPO was also different before and after the 1920's, the NPO index was mainly negative (mean value is about \(-1.0\) hPa) before the end of the 1920's but positive (mean value is about \(+0.3\) hPa) during the end of 1920's to 1950's. It is interesting that some studies have indicated the existence of climate jump in the 1920's (Yamamoto et al., 1986; Ye and Yan, 1993), although we do not want to discuss that associated with the climate jump in the 1920's in this paper.

It is very evident that the sudden variation occurred in both NAO index and NPO index in the 1960's, their common characteristics were represented by the abnormal rising of the amplitude, the amplitude after the 1960's was about 2–3 times as much as that before the 1960's. Although it is difficult to say that the climate jump in the 1960's, or interdecadal climate variation in China, resulted from atmospheric circulation variation, particularly from the interdecadal variation of the NAO and NPO, because the mechanism of interdecadal climate variation has not been understood very well, at least, the above-mentioned analyses can suggest that the climate jump in the 1960's, or interdecadal climate variation in China, is closely related to interdecadal variation of the NAO and the NPO.

4. Wavelet analysis of the NAO and NPO

In order to expose further interannual variation feature of the NAO and NPO, the wavelet analyses, which have been used widely to study the features of different time-scale climate variations and their relationship between each other, are completed in this paper.

In Fig.5 and Fig.6, the wavelet analyses for temporal variations of the NAO and NPO are respectively shown and interdecadal variations of the NAO and NPO are represented very clearly. At first, the amplitudes of the NAO and NPO increased abnormally since the 1960's, which is the same as the results shown in Fig. 3 and Fig. 4. Secondly, it is very evident that the interannual variations with 3–4-year period were fundamental whether for the NAO or

![Graph](image-url)

**Fig. 3.** Temporal variations of monthly sea level pressure difference (hPa) between the region (25–40°N, 10–50°W) and the region (50–65°N, 10–50°W), which represents the NAO.
The difference between (25°N–40°N, 130°E–170°E) and (50°N–65°N, 130°E–170°E) represents the NPO.

Fig. 4. Same as Fig.3 except for the pressure difference (hPa) between the region (25°–40°N, 130°–170°E) and the region (50°–65°N, 130°–170°E), which represents the NPO.

for the NPO before the 1960’s, but the decadal variations with 8–15–year period were fundamental since the 1960’s. Therefore, the abnormal variations occurred in both NAO and NPO, which were represented not only in the amplitude increasing but also in the changing of period for the dominant mode from 3–4 years to 8–15 years.

The above-mentioned results showed clearly that the interdecadal variations of the NAO and NPO are closely related to the climate jump in the 1960’s. The interdecadal variation of the NAO and NPO is a possible important reason for causing climate jump in the 1960’s, even though the study is very necessary to understand the mechanism of interdecadal variation for the NAO and NPO and their impact process to climate jump.

In recent years, some studies have indicated that the interdecadal variation of the NAO showed a rising trend (Hurrell, 1995; Jones et al., 1997). The above analyses show that the increasing of amplitude since the 1960’s is represented not only in the NAO but also in the NPO. Therefore, this kind of interdecadal variation does not exist only in the North Atlantic region, it seems to be a global feature.

5. Discussion and conclusion

The temporal variations of the NAO and NPO very clearly show that the amplitudes of these two oscillations increased suddenly in the 1960’s and their main period of interannual variations changed from 3–4 years to 8–15 years. These evident variations of two oscillations in the 1960’s represented fundamental anomaly of the atmospheric circulation in the 1960’s.

Based on the climate jump occurred in the 1960’s and its relationship to the anomalies of the NAO and NPO, it can be suggested that the atmospheric circulation anomaly, which is represented by the NAO and NPO, is also an important factor to cause interdecadal climate variation in China. Although we aim at the interdecadal time-scale climate variation, the relationship between the circulation feature and the climate pattern is evident and it may be the same as the case in which the short-term climate or weather variation feature in any
Fig. 5. The wavelet analyses for temporal variation of NAO index.

Fig. 6. The wavelet analyses for temporal variation of NPO index.

region is corresponding to certain atmospheric circulation pattern.

Although the long-term variation or anomaly of atmospheric circulation resulted not only from the atmospheric internal processes but also from the external forcing (such as the anomaly of sea surface temperature, solar activity and so on), the research on the atmospheric circulation anomaly can give certain reasonable explanation for different time-scale climate variations. The analysis study of the atmospheric circulation anomalies can also be regarded as an important way to understand the interdecadal climate variation and the climate jump.

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