On the Processes of Transitions between Circulation Regimes during Winter over the Pacific and North America

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Abstract

A statistical investigation is made into the characteristics of different circulation regimes during winter over the Pacific and North America and processes of transitions between these regimes.

Using 5-day mean 500mb height data during the winters of 40 years (1946-1985), a principal component analysis was performed. Taking account of component stores, persistent circulation regimes of four types ($P1^+$, $P1^-$, $P2^+$ and $P2^-$) were derived. Investigation reveals that $P1^+$ and $P1^-$ regimes have no relation to the Southern Oscillation Index (SOI) and are formed and maintained by the stationary wave activity sources along the jet in mid-latitudes. On the other hand, $P2^+$ and $P2^-$ regimes have a close relation to the SOI and are consistent with the stationary wave propagation from low latitudes over the western Pacific to North America.

On the basis of a composite analysis, it is shown that wave trains appear from over the Atlantic to Eurasia, preceeding the occurrences of circulation regimes. However, features of the wave train preceeding the occurrences of $P1^+$ and $P1^-$ are different from those preceeding $P2^+$ and $P2^-$. In addition, two wave train indices (I_a and I_b) are proposed as measures for detecting transitions between these regimes.

1. Introduction

In geopotential height fields, there exist multiple quasi-stationary states that are frequently observed. These states are called different circulation regimes with a hemispheric spatial-scale. These have for the most part been approached by studies on *grosswetterlagen* (see e.g., Baur, 1948) or *analogs* (Lorenz, 1969; Gutzler and Shukla, 1984 and others) and much attention has been focused on their role in climatic change with time-scales of a few weeks to several decades.

Previously, some theoretical studies have been done on mechanisms for the different circulation regimes. Charney and DeVore (1979) showed the existence of multiple equilibrium states in a barotropic model containing topographical effects. Multiple equilibria in a baroclinic system were also investigated by Charney and Straus

(1980). Moreover, Reinhold and Pierrehumbert (1982) and Yoden (1983a,b) found different circulation regimes in the time-dependent behavior of baroclinic models.

As an alternative to these mechanisms for the origin of the different circulation regimes, are the teleconnections between equatorial sea surface temperature anomalies and atmospheric anomalies in the extra-tropics of the Northern Hemisphere. These teleconnections were first suggested by Bjerknes (1969). Hoskins and Karoly (1981) proposed the ray theory of stationary Rossby waves on a sphere and a dynamical background for the teleconnections was also given. Actually, Wallace and Gutzler (1981) showed five teleconnection patterns (the PNA pattern etc.) in the 500mb height fields during the Northern Hemisphere winter by means of a one-point correlation method. In recent years, the links between these teleconnection patterns and the *El Niño*/Southern

Oscillation (ENSO) have been studied extensively. For observational studies, Horel and Wallace (1981) pointed out that the PNA pattern is dominant in the mature stage of an *El Niño* event and van Loon and Madden (1981) showed similar relationships by use of the Southern Oscillation Index (SOI). Some numerical experiments (Shukla and Wallace, 1983; Lau and Lim, 1984; Tokioka *et al.*, 1986) confirmed the PNA response to the sea surface temperature anomalies associated with *El Niño*.

However, there are contradictory results to those above, found in numerical experiments (Lau, 1981; Simmons *et al.*, 1983). As observed in the 1972-1973 *El Niño* event, there exist cases that the PNA pattern does not always agree with the *El Niño* event. Hence the present study will assume that there is no clear understanding as to the linkages between the PNA pattern and ENSO, and when and how the PNA pattern occurs. Furthermore, there is, as yet, little understanding as to the relation between teleconnection patterns and multiple circulation regimes in the middle and high latitudes resulting from self-excitation only.

In this study, as a first step toward solving these problems, different circulation regimes during winter over the Pacific and North America (including circulation regimes relevant to the PNA pattern) were statistically extracted from observational data having a long time period (1946-1985). Characteristics of the regimes and processes of transitions between them were statistically investigated by the use of these long term data, taking into account influences of the ENSO. If premonitions of transitions between different circulation regimes or mechanisms for them can be clarified, they would appear to be valuable tools for long-range weather forecasting.

2. Data

The data used in this study consisted of two data set. First, the 5-day mean geopotential height data at the 500mb level during 40 years (1946-1985) of winter (December, January and February) and the pressure data at sea level during 11 winters (1975-1985) were used. These data had been provided by the Japan Meteorological Agency on a $10^\circ \times 10^\circ$ latitude-longitude

grid for the Northern Hemisphere from 20°N to 80°N .

The second data set consisted of monthly mean sea level pressure data at Darwin (12°S , 131°E) and Tahiti (15°S , 150°W) during 39 years (1946-1984). These data were derived from *World Weather Records* for the period from 1946 to 1960 and *Monthly Climatic Data for the World* for the period from 1961 to 1984.

3. Teleconnection patterns

The principal component analysis (*i.e.* empirical orthogonal function analysis) was adopted to extract teleconnection patterns of the 500mb height anomalies. The region over the Pacific and North America (region P) was established as the area used in this study, as shown in Fig. 1. This region is known for the frequent appearance of the PNA pattern which was first indicated by Wallace and Gutzler (1981). The 5-day mean 500mb height anomaly patterns during winter over the region P were reduced by means of the principal component analysis.

The variances and cumulative variances explained by the principal components are presented in Table 1. The first two components account for approximately 40% of the total variance. Therefore, these components were adopted in the present study. Hereafter, the first and second components for the region P are referred to as P1 and P2.

The spatial distributions of eigen-vectors for

Fig. 1. Region P used in this study.

Fig. 2. Distributions of eigen-vectors for P1 and P2.
Contour intervals are 0.05. The shade denotes the negative values. Arrows indicate inferred directions of stationary Rossby wave propagation.

Table 1 The variances (*var.*) and the cumulative variances (*cum.*) explained by the principal components.

compo.	var. (%)	cum.(%)
1st	22.3	22.3
2nd	15.9	38.2
3rd	13.0	51.2
4th	8.4	59.6
5th	6.7	66.3

these components are shown in Fig. 2. The features of the teleconnections obtained in P1 and P2 are as follows.

P1: There are negative values over the northern Pacific, positive values over the Arctic and western portion of North America and negative over the eastern part of North America. Although this resembles the so-called PNA pattern demonstrated by Wallace and Gutzler (1981), the positive Canadian center in P1 is located poleward compared with the positive center in the PNA pattern.

P2: There are positive values over the area southeast of Japan, negative values over the Aleutians extend southeastward and positive values are found over the center of North America.

Next, relationships between these teleconnection patterns and the ENSO were investigated. As an index which expresses aspects of the ENSO, the SOI (defined as the anomaly of

the sea level pressure difference between Tahiti and Darwin) was utilized. Large SOI means that convective activity over the equatorial western Pacific is strong, corresponding to an *anti-El Niño* period, while easterlies over the equatorial Pacific are relatively strong. Conversely, a small SOI means that convective activity over the equatorial western Pacific is weak, corresponding to an *El Niño* period, while Pacific equatorial easterlies are weak (Walker and Bliss, 1932; Bjerknes, 1966). Correlation coefficients between monthly mean scores (time coefficients) of respective components and the SOI for each month were then calculated.

Fig. 3 shows the correlation coefficients between the respective score and the SOI. Although P1 has a negative correlation throughout the winter, the absolute values are small and the correlation is not significant. In contrast, P2 has a higher negative correlation with the

Fig. 3. Correlation coefficients between respective component scores and the SOI.

correlation coefficients, reaching -0.45 in January and February. These facts indicate that a teleconnection pattern that has a close relation with the ENSO is not the pattern obtained in P1, but the one found in P2. Furthermore, the extratropical circulation pattern, which is strongly correlated with the central equatorial sea surface temperature suggested by Horel and Wallace (1981), resembles P2 more than P1.

4. Circulation regimes

4.1 Extraction of circulation regimes

Taking into account the values of scores for P1 and P2, four types of circulation regimes ($P1^+$, $P1^-$, $P2^+$, $P2^-$) were specified. The definition of each type is made following Fig. 4. Among all pentads (5-day means) in the analysis period, only those corresponding to the four types were extracted. The number of pentads classified into these four types constitutes about 75% of the total.

Fig. 5 shows the frequency of occurrence of the respective types. The frequency of circulation regimes that lasted for 1~3-pentads in all types is quite high, and at times the continuation of a given regime is even longer than 5-pentads except for $P2^+$. In order to exclude the behavior of transient waves, only circulation regimes that continued longer than 2-pentads were selected and applied to the analyses. Hereafter these will

Fig. 4. Classification of circulation regime type.

S_{P1} and S_{P2} are scores for P1 and P2. The hatched area denotes no specific regime occurs.

be called persistent circulation regimes.

4.2 Stationary wave behavior

Next, an investigation was made as to how the propagation of stationary Rossby waves contributes to the formation and maintenance of persistent circulation regimes. For this purpose, information on stationary wave propagation was obtained by the activity flux of stationary waves.

According to Plumb (1985) and Kanaya (1986), the activity flux of stationary waves in

Fig. 5. Frequency of occurrence of each circulation regime type for the continuous period.

Fig. 6. Composites of the 500mb height fields (left) and distributions of the vector $F(\lambda)$, $F(\phi)$ (right) computed for the composites of each persistent circulation regimes. The contour interval is 100m (left) and vectors below $30m s^{-2}$ are omitted (right).

spherical coordinates with pressure as the vertical coordinate and using the quasi-geostrophic approximation, can be written as

$$\mathbf{F} = \begin{Bmatrix} F(\lambda) \\ F(\phi) \\ F(p) \end{Bmatrix} = \cos \phi \times \begin{Bmatrix} v^{*2} - \frac{1}{2\Omega a \sin 2\phi} \frac{\partial(v^* \Phi^*)}{\partial \lambda} \\ -u^* v^* + \frac{1}{2\Omega a \sin 2\phi} \frac{\partial(u^* \Phi^*)}{\partial \lambda} \\ \frac{2\Omega \sin \phi}{[\theta]_p} \left\{ v^* \theta^* - \frac{1}{2\Omega a \sin 2\phi} \frac{\partial(\theta^* \Phi^*)}{\partial \lambda} \right\} \end{Bmatrix}, \quad (1)$$

where $[\]$ denotes the zonal average and $(*)$ the deviation from the zonal average. Here, u , v , Φ , θ , a and Ω are the eastward and northward components of geostrophic wind, the geopotential height, the potential temperature, the radius of earth and the earth's rotation, respectively. The notations λ , ϕ and p denote longitude, latitude and pressure, respectively. As shown in Plumb (1985), the vector $\mathbf{F}$ will be a useful diagnostic for the three dimensional propagation of stationary Rossby waves.

Fig. 6 shows composites of the 500mb height fields (left) and the distribution of the vector $\mathbf{F}\{F(\lambda), F(\phi)\}$ (right) computed for the composites of each type of the persistent circulation regimes. Although stationary Rossby wave behavior should be discussed from a three-dimensional standpoint, vertical components of the vector $\mathbf{F}$ were not computed due to data limitations. Therefore, in order to investigate features of baroclinicity, composites of pressure anomalies at sea level for each regime were used as shown in Fig. 7. Referring to Fig. 6 and Fig. 7, stationary wave behavior for each type is described as follows.

P1⁺: This regime is characterized by a trough over the Pacific, a ridge over the western coast of North America extending into Alaska and a trough over the eastern coast of North America, all rather well developed. The propagation of

stationary wave activity is largely from the Pacific to North America. However, since the activity flux is southward at 30°N over the Pacific, it appears that the activity source is not located in the tropical Pacific but is found near the jet in the mid-latitudes. On the other hand, the pressure anomaly pattern at sea level is almost in agreement with that of the 500mb level, though not in good agreement over eastern North America. Hence it is speculated that barotropic propagation is predominant.

P1⁻: This regime is characterized by a zonal flow being dominant over the Pacific and North America, with no development of troughs and ridges. It is seen that the activity of stationary waves propagates from near 50°N to the lower latitudes over the Pacific and North America. However, the pressure anomaly pattern at sea level is shifted eastward compared with that at the 500mb level. It can be interpreted that large upward propagation of stationary waves is taking place. Accordingly, baroclinic behavior of stationary waves is dominant for this regime.

P2⁺: This regime exhibits a jet near 50°N over

Fig. 7. Composites of pressure anomalies at sea level for each persistent circulation regimes.

The contour interval is 3mb. Netted and shaded areas denote areas where the values are above +3mb and below -3mb, respectively. The zero contour is omitted.

the Pacific which is stronger than the one over North America. The activity of stationary waves shows propagation from the low latitudes over the western Pacific to North America. In particular, it is of interest to note the large northward flux of wave activity around 30°N over the western Pacific. In addition, barotropic propagation is dominant.

P2⁻: This regime has a double jet over the Pacific and an intense single jet over North America. The activity of stationary waves propagates from the low latitudes over the western Pacific through the Aleutians to North America. Barotropic propagation seems to be dominate due to a lack of baroclinicity.

It is of interest to note that the activity propagations of stationary waves in P2⁺ and P2⁻, which have a high correlation with the SOI, are very similar in spite of fact that are out of phase with each other. For P1⁺ and P1⁻, which do not have a high correlation with the SOI, it should be noted that the stationary wave activity sources are not found in the low latitudes but appear the strongest near the jet in the mid-latitudes.

5. Transitions between circulation regimes

5.1 Statistical features

The characteristics of transitions between different circulation regimes were also statistically investigated. Here, only cases of transitions between different persistent circulation regimes were investigated, the intermittent pentads between both regimes were not considered as shown in Fig. 8. That is, only the drastic transitions between persistent circulation regimes were selected.

Table 2 shows the frequency of these transitions. Using Table 2, a transition diagram (Fig. 9) was constructed, the thick arrows indicating a frequency greater than 10 and thin arrows indicate greater than 5 but less than 10. The averaged SOI on months when the respective transitions occurred is also indicated in Fig. 9. Hereafter, a transition from the regime X to the regime Y is expressed as [X → Y] where X and Y are arbitrary among P1⁺, P1⁻, P2⁺ and P2⁻.

In Fig. 9, transitions [P1⁺ ⇌ P1⁻] and [P2⁺ ⇌ P2⁻] are not shown since they occur

Fig. 8. A transition from a persistent circulation regime of type X to one of type Y and over the corresponding time *t* in units of a pentad.

Here, X and Y are arbitrary among P1⁺, P1⁻, P2⁺ and P2⁻.

Table 2 Frequency of transitions between different persistent circulation regimes.

TO FROM	P1 ⁺	P1 ⁻	P2 ⁺	P2 ⁻
P1 ⁺		2	10	9
P1 ⁻	1		5	12
P2 ⁺	15	5		0
P2 ⁻	11	7	0

Fig. 9. Transition diagram.

Arrows indicate transitions where the frequency is greater than 5 and less than 10 (thin) and greater than 10 times (thick). Values near arrows are the SOI averaged for pentads when respective transitions occurred, with a unit of (mb).

infrequency, while [P1⁺ ⇌ P2⁺], [P1⁻ → P2⁻] and [P2⁻ → P1⁺] frequently do. When the SOI is positive, transitions [P1⁺ ⇌ P2⁻] and [P1⁻ ⇌ P2⁻] occur. On the other hand, when the SOI is negative, transitions [P1⁺ ⇌ P2⁺] and [P1⁻ ⇌ P2⁺] occur. Accordingly, P1⁺ and P1⁻ appear in the form of a transition from P2⁺ when the SOI is negative, and from P2⁻ when the SOI is positive. Since the standard deviation of the SOI is about 1.7, such characteristics of transitions that are dependent on the SOI must be very significant.

Fig. 10. Composite maps of 500mb height anomalies for pentads corresponding to $t = -2$, -1 and 0 for $[P1^+ \rightarrow P2^+]$, $[P1^- \rightarrow P2^+]$, $[P1^+ \rightarrow P2^-]$ and $[P1^- \rightarrow P2^-]$.

The contour interval is 30m. Netted and shaded areas denote areas where the values are above +30m and below -30m, respectively. The zero contour is omitted. Arrows indicate Rossby wave trains.

5.2 Processes of transitions

5.2.1 Processes for the appearance of $P2^+$ and $P2^-$

Processes of transitions between different circulation regimes were investigated by means of a composite analysis. Fig. 10 shows composite maps of the 500mb height anomalies for pentads corresponding to $t = -2, -1$ and 0 (indicated in Fig. 8) for respective transitions associated with the appearance of $P2^+$ and $P2^-$.

It can be observed that a wave train from the area near Central Asia to the low latitudes over the western Pacific begins to occur at $t = -1$ for all transitions. Furthermore, this wave train appears, preceeding the occurrence of $P2^+$ or $P2^-$. It can also be seen that the phase for the wave train preceeding the appearance of $P2^+$ is opposite to that for $P2^-$. Note that this wave train is distinguished from the EU pattern of Wallace and Gutzler (1981).

In order to assess the statistical significance of the above features, a wave train index I_a was defined as follows,

$$I_a = (Z_A/\sigma_A - Z_B/\sigma_B + Z_C/\sigma_C)/3. \quad (2)$$

Here, Z_A , Z_B and Z_C are 500mb height anomalies at point A, point B and point C as shown in Fig. 11(a), while σ_A , σ_B and σ_C denote the standard deviations of the 500mb heights at each respective point. When the index I_a is positive, the 500mb heights are relatively high (H) over Central Asia, low (L) over Siberia and H over the area southeast of Japan. On the other hand, when the index I_a is negative, the 500mb heights are L over Central Asia, H

Fig. 11. Points associated with (a) a wave train from Central Asia to the low latitudes over the Pacific and (b) a wave train from the Atlantic to the area near Tibet.

over Siberia and L over the area southeast of Japan.

Fig. 12 shows the distribution of the index I_a at $t = -2$ and -1 for the respective transitions. Although the distribution of the index I_a at $t = -2$ is mostly random for all transitions, at $t = -1$ it is almost always positive with an abrupt increase for $[P1^+ \rightarrow P2^+]$ and $[P1^- \rightarrow P2^+]$, related to the appearance of $P2^+$. Also at $t = -1$, it is negative with an abrupt decrease for $[P1^+ \rightarrow P2^-]$ and $[P1^- \rightarrow P2^-]$, related to the appearance of $P2^-$. It is noteworthy that the occurrences of $P2^+$ and $P2^-$ are responsible for the SOI and the value of the index I_a , and are irrelevant of whether the previous regime was $P1^+$ or $P1^-$. Therefore the index I_a may be used as a predictor of the occurrences of $P2^+$ and $P2^-$.

These aspects may be considered as a lag linkage between different teleconnection patterns (as discussed in Kanaya, 1988), and there may be some inferred mechanisms for these transitions. One mechanism is the coherent fluctuations which are associated with a wave train from Central Asia to the low latitudes over the Pacific, affecting tropical convective activities there and in turn exciting a teleconnection

Fig. 12. The wave train index I_a at $t = -2$ and -1 for respective transitions associated with occurrences of $P2^+$ and $P2^-$.

Fig. 13. Same as Fig. 10 but for $[P2^+ \rightarrow P1^+]$, $[P2^- \rightarrow P1^+]$, $[P2^+ \rightarrow P1^-]$ and $[P2^- \rightarrow P1^-]$.

pattern over the Pacific and North America. This idea is similar to one discussed by Lau and Phillips (1986). Another mechanism is the fluctuations in the sensitivity of an extra-tropical circulation response to tropical convection over the Pacific (as shown in Kuma, 1985). The overreflection theory (Lindzen and Tung, 1978) may also be considered as a candidate for the explanation of this mechanism. However, the mechanism which causes the lag linkage between teleconnection patterns can not be established from only these analyses above.

5.2.2 Processes for the appearance of $P1^+$ and $P1^-$

Processes for transitions associated with the appearance of $P1^+$ and $P1^-$, were investigated. Fig. 13 shows composite maps of 500mb height anomalies for pentads corresponding to transitions $[P2^+ \rightarrow P1^+]$, $[P2^- \rightarrow P1^+]$, $[P2^+ \rightarrow P1^-]$ and $[P2^- \rightarrow P1^-]$.

It can be seen that a well established wave train from the Atlantic to the area near Tibet occurs at $t = -1$ for all transitions. The wave train appears preceding the occurrence of $P1^+$ or $P1^-$ and is somewhat similar to the EA pattern of Wallace and Gutzler (1981). However, it should be noted that the phase of the wave train for $[P2^+ \rightarrow P1^+]$ is opposite to that of $[P2^- \rightarrow P1^+]$. In addition, the phase of the wave train for $[P2^+ \rightarrow P1^-]$ is also opposite to that of $[P2^- \rightarrow P1^-]$. These features are different from those preceding the occurrences of $P2^+$ and $P2^-$.

Furthermore, a wave train index I_b was defined as follows,

$$I_b = (Z_D/\sigma_D - Z_E/\sigma_E + Z_F/\sigma_F)/3. \quad (3)$$

Here, Z_D , Z_E and Z_F are 500mb height anomalies at point D, point E and point F as shown in Fig. 11-(b), while σ_D , σ_E and σ_F denote the standard deviations of 500mb heights at each respective point. When the index I_b is positive, the 500mb heights are relatively **H** over the Atlantic, **L** over northern Europe and **H** over the area near Tibet. When the index I_b is negative, the 500mb heights are relatively **L** over the Atlantic, **H** over northern Europe and **L** over the area near Tibet.

Fig. 14. Same as Fig. 12 but for I_b for respective transitions associated with occurrences of $P1^+$ and $P1^-$.

Fig. 14 shows the distribution of the index I_b at $t = -2$ and -1 for the respective transitions. It can be seen that the index I_b at $t = -1$ is almost always positive for $[P2^- \rightarrow P1^+]$ and $[P2^+ \rightarrow P1^-]$, and negative for $[P2^+ \rightarrow P1^+]$ and $[P2^- \rightarrow P1^-]$. The tendency of this index is not the same for occurring regimes $P1^+$ or $P1^-$, and is dependent on the previous regime. Stated another way, it was interpreted as follows: when a regime is $P2^+$ (corresponding to a negative SOI) and the index I_b becomes positive or negative, a transition occurs to $P1^-$ or $P1^+$, respectively. On the other hand, when the regime is $P2^-$ (corresponding to a positive SOI) and the index I_b becomes positive or negative, a transition occurs to $P1^+$ or $P1^-$, respectively.

As the features for the appearance of $P1^+$ and $P1^-$ are different from those for $P2^+$ and $P2^-$, dynamical processes for the former also seem to be different from those of the latter. It is assumed that the wave train from the Atlantic to the area near Tibet affects the circulation over East Asia and the western Pacific. Changes in the circulation then trigger the occurrences of $P1^+$ or $P1^-$ through barotropic or baroclinic instability associated with orography. Thus, $P1^+$ and $P1^-$

may be considered as multiple equilibria or quasi-equilibrium states of a baroclinic atmosphere related to orography (as shown in Charney and Straus, 1980; and Yoden, 1983 and others). However, this point should be further investigated in future studies.

6. Summary

On the basis of 5-dy mean 500mb height data over the Pacific and North America during the 1946-1985 winters, the teleconnection patterns for two principal components (P1: negative over the northern Pacific, positive over the area near Alaska and negative over eastern North America; P2: positive over the area southeast of Japan, negative over the area near the Aleutians and positive over central North America) were obtained by means of a principal component analysis. The teleconnection pattern that has a close relation to the SOI, called P2 in this study, was obtained.

Taking into account the phase and persistency of component scores, persistent circulation regimes of four types ($P1^+$, $P1^-$, $P2^+$ and $P2^-$) were specified. Stationary wave behavior for the persistent circulation regimes of each type was investigated. It was found that sources of stationary wave activity are located near the jet in the mid-latitude for $P1^+$ and $P1^-$, while the activity of stationary waves propagates from the low latitudes over the western Pacific to North America for $P2^+$ and $P2^-$.

Processes of transitions between different persistent circulation regimes were also investigated by use of a composite analysis. Appearance of a wave train from Central Asia to the low latitudes over the Pacific, preceeding the occurrences of $P2^+$ and $P2^-$, were found. Occurrences of $P2^+$ and $P2^-$ were mainly determined by the SOI and the phase of this wave train, and were independent of the previous regime. Therefore, these facts were interpreted as a lag linkage between teleconnection patterns separated by periods of tropical convective activity.

On the other hand, the appearance of a wave train from the Atlantic to the area near Tibet preceeded the occurrence of $P1^+$ and $P1^-$. However, the phase of this wave train is

dependent on the previous regime.

In addition, two wave train indices (I_a , I_b) are proposed as indices that predict rather well the transitions between different circulation regimes.

Relationships between circulation regimes during winter over the Pacific ~ North America and the ENSO, as well as processes of transitions between different circulation regimes were clarified. However, the low frequency variability of the general circulation can not be explained from only a consideration of multiple circulation regimes (quasi-stationary states that frequently occur) and transitions between them. Moreover, the existence of transient circulation regimes omitted in this study may also contribute to the above. It should be noted that almost all the results obtained in this study are highly statistical. Nevertheless, it is of interest and significant that the wave trains were found to serve as predictors of transitions between regimes. Further study should focus on the exact role played by the wave trains in the dynamical processes of transitions between the circulation regimes.

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冬季の太平洋と北アメリカにおける 異なった天候レジーム間の遷移過程

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冬季の太平洋と北アメリカにおける異なった天候レジームの特徴とそのレジーム間の遷移過程を、主に統計的に調べた。

最近40年間(1946年–1985年)の冬季における半月平均500mb面高度データをもとにして、主成分分析が施された。さらに、成分スコアを考慮して、4つのタイプ(P1⁺, P1⁻, P2⁺, P2⁻)の持続性のある天候レジームを抽出した。P1⁺とP1⁻は、南方振動指数(SOI)とは無関係に出現し、中緯度ジェット付近における定常波アクティビティのソースによって形成、維持されている天候レジームである。これに対し、P2⁺とP2⁻はSOIと密接な関係をもち、低緯度西太平洋から北アメリカへの定常波アクティビティの伝播によって維持されている天候レジームである。

コンボジット解析により、これらの天候レジームの出現に先行して、大西洋～ユーラシア大陸上にそれぞれ特徴的な波列が現われはじめていたことがわかった。しかし、P1⁺, P1⁻のレジームの出現に先行して現われている波列とP2⁺, P2⁻のレジームの出現に先行して現われている波列とは、全く異なった様相を示している。さらに、これらのレジーム間の遷移の兆候を表わす指標として、二つの波列指数(Ia, Ib)も提案された。