# A Preliminary Study on a Division of Seasons based upon JET Streams

Iware MATSUDA

## INTRODUCTION

A climatological division of seasons has been accomplished by means of synoptic analyses of climatic elements observed at the surface (Maejima, 1967, Sakata, 1952), or on the basis of appearances of typical pressure patterns (Takahashi, 1955). Seasons, however, must be regarded as a result of essential changes that take place in the whole atmospheric circulation. It is, therefore, necessary that seasons are determined not only by surface data but also by a three dimensional analysis of the atmospheric circulation.

Meanwhile, natures of jet streams have been investigated since the 1940's. It has been noted that jet streams are closely related to pressure patterns and fronts at the surface (Reiter, 1963, Nakajima, 1962). For this reason, it can be one step to a rational division of seasons to study the annual migration of jet streams.

In East Asia, there have been many studies on the relationship between the migration of jet streams and seasons. Some of them stated that seasons in this region are results of the discontinuous migration of jet streams which is due to the obstruction of the Plateau of Tibet (Trewartha, 1958, Academia Sinica Peking, 1957). It has been known that the Tibetan Plateau, the Rocky Mountains and the Andes are the only orographical barriers that affect the general circulation of atmosphere. However, the effects of the Cordilleras upon the atmospheric circulation must naturally be different from those of the Tibetan Plateau because the Cordilleras extend in the meridional direction, blocking the entire zonal flow while the Tibetan Plateau has a latitudinal extension of only about $15^{\circ}$.

This paper deals with the annual migration of jet streams over the eastern coast of North America, which is located to the east of the Rocky Mountains, for the purpose of showing the possibility of a division of natural seasons based upon the migration of jet streams. This paper is a preliminary report on a three dimensional analysis of seasons. The relation between jet streams and surface pressure patterns or climatic elements will be studied in the near future.

## DATA AND METHOD

"Climatological Data, National Summary" and "Northern Hemisphere Data Tabulations" for the year of 1962, both published by the U. S. Weather Bureau were used. There is no particular reason for selecting 1962. Drastic changes in the position of the axes of jet streams and the wind speeds were adopted to determine the boundaries of seasons. An attempt was made first by using the monthly mean charts and cross-sections. The determination of the boundaries and the subdivision of seasons were then accomplished by using daily data.

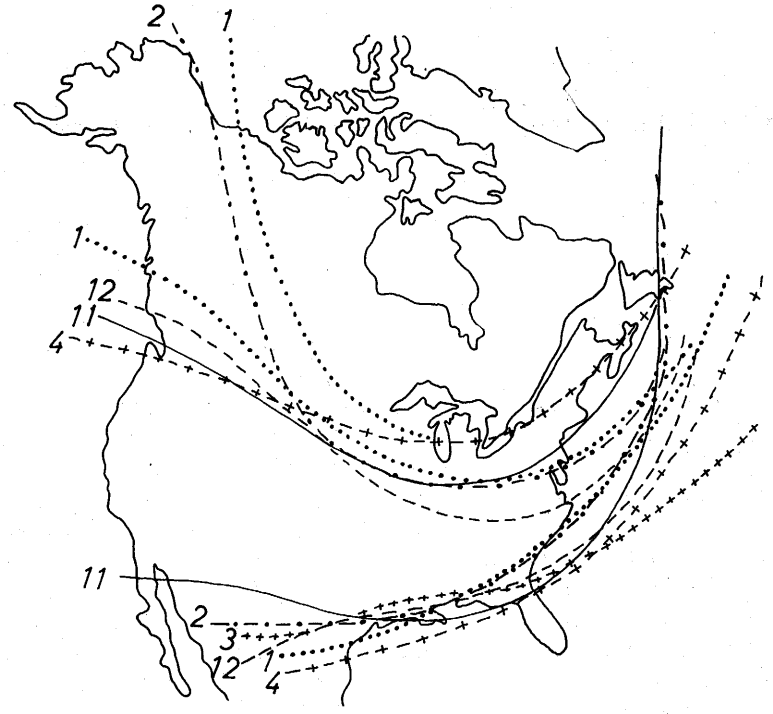



Fig. 1.a Monthly mean position of jet streams from November to April over North America.

They were obtained from the monthly mean 200mb charts. Figures show months.

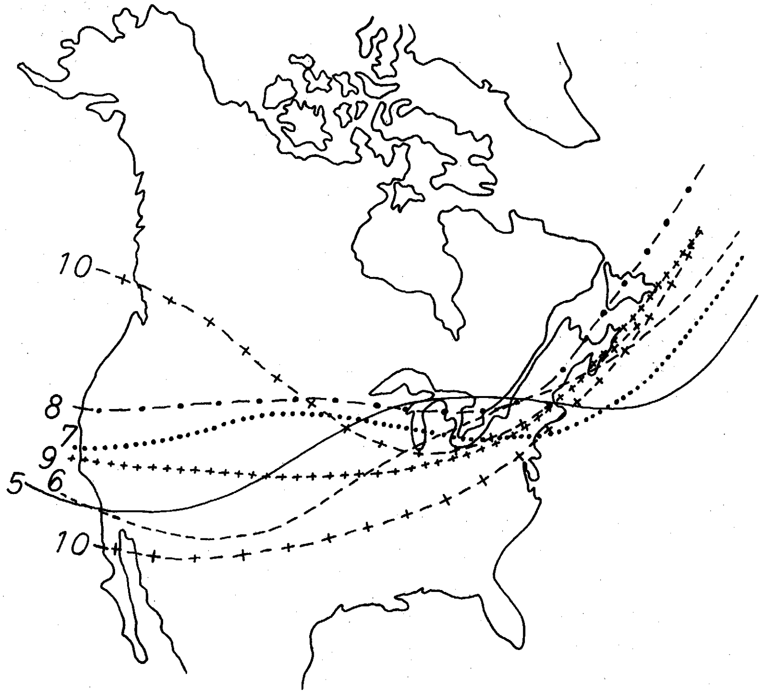



Fig. 1.b Same as Fig. 1.a, but from May to October.

It must be mentioned that the subtropical jet streams is the main object of this paper for the reason that the polar jet stream undergoes greater daily fluctuations in its position.

## THE ANNUAL MIGRATION OF THE SUBTROPICAL JET STREAM OVER NORTH AMERICA

The axes of strong winds were analyzed on the monthly mean 200mb charts shown in "Climatological Data, National Summary". In terms of their positions, a year can be divided into two parts, one being from November to April and the other from May to October.

The axes of strong winds in the months of November-April are shown in Fig. 1a. Every month except March has two axes, one along about 30°N parallel and the other in the northern part of the continent. The southern axis is the subtropical jet stream. It generally has stronger wind speeds and is more evident. The northern axis is, on the other hand, regarded as a polar jet stream. Its axis is more marked on the 300mb charts rather than on the 200mb charts. Their average positions over the western coast are about 50°N but they extend toward the southeast to form a trough at about 80°W meridian, which does not seem to be subject to the seasonal shift. Over the eastern coast, the polar jet stream again swings northeastward and leaves the coast at about 40°N. It finally joins the subtropical jet stream over the Atlantic Ocean.

In January and February, there is an axis extending southward from the northern position of Alaska, which may be designated as an arctic jet stream. In March, however, the northern jet stream does not appear on the 200mb chart. The isotachs drawn on the cross-section along the eastern coast (Fig. 3b) also show a pattern of concentric circles with a single center. Therefore, the axis of strong wind in March is thought to be formed as the result of the confluence of the two jet streams. The strong wind axes for the months from May to October are shown in Fig. 1b. These months except October are characterized by a single axis, or the subtropical jet stream, although its maximum wind speeds are remarkably weaker during these months. The polar jet stream does not appear except in October.

The subtropical jet stream remains stationary along about 30°N during the months from November to April. After an abrupt northward shift in May, it stays between 40°N and 45°N over the eastern parts of North America until October. Over the western parts, however, the northward shift continues until August when it takes the southernmost position. A southward shift occurs abruptly in November over the eastern parts, but over the western parts, it begins in September and the subtropical jet stream migrates southward gradually until November. This suggests that the annual change of jet streams and, therefore, the division of seasons are greatly different over the eastern parts from over the western parts of the continent.

## THE MONTHLY MEAN CROSS-SECTIONS ALONG THE EASTERN COAST

Cross-sections along the eastern coast showing winds and temperature were made by every month in 1962 to examine the vertical structure of the jet streams. Miami (station number 202), Tampa (211), Jacksonville (206), Charleston (208), Cape Hatteras (304), Norfolk (308), Washington, D.C. (403), New York (486),

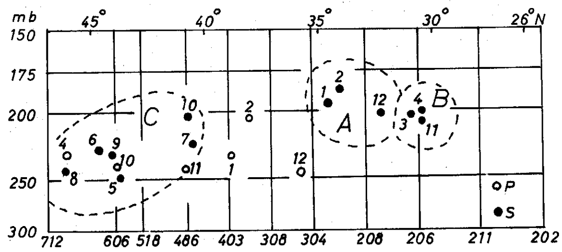



Fig. 2 Monthly mean location of cores of jet streams along the eastern coast.

S: subtropical jet stream, P: polar jet stream. They were obtained from the monthly mean cross-sections.

Albany (518), Portland (606), and Caribou (712) were selected for this purpose. The isotachs were drawn for every tenth knot. The center of the innermost isotach was then considered as a core of a jet stream. The location of the cores thus obtained for each month were plotted in Fig. 2. They can be grouped into three different types in terms of the position of the cores, the maximum wind speeds, and the isotach patterns.

December, January and February belong to the A type. The cross-section for February is shown as an example of this type (Fig. 3a). The innermost isotach shows a composite shape of two ellipses with double centers. The southern center, or the core of the subtropical jet stream is located between 32°N and 35°N at the level of about 200mb. On the other hand, the northern center, or the core of the polar jet stream is located between 36°N and 39°N at the level between 250mb and 200mb. The cross-sections for December and January have the same isotach pattern as for February, only with a weaker maximum wind in December.

March, April and November fall in the B type. Fig. 3b shows the cross-section for March as an example. The subtropical jet core takes the southernmost position of the year, being located at about 31°N at the 200mb level. The isotachs assume a pattern of concentric circles with one center. The strongest wind speed attains 100kts. In April and November, the isotachs are more elliptical with a weaker core of the subtropical jet stream; 80kts in April and 60kts in November. A weak core of the polar jet stream is recognized in the north.

The C type is manifested in the cross-sections for May to October. The core of the subtropical jet stream is found at the latitude between 40°N and 46°N, a distinctly higher latitude compared with the rest of the year, at the level between 250 and 200mb. The wind speeds are much weaker during this period and they rarely exceed 60kts. September is typical for the C type (Fig. 3c). There is no essential difference in the isotach pattern throughout the period. There is only a small displacement of the core. The jet stream takes the northernmost position in August when the wind speeds become the weakest in the whole troposphere (Fig. 3d).

If these three types correspond to different seasons, it is possible to divide a year into four seasons, i.e. A(December-February), B(March and April), C(May-October) and B(November). It must be noted that the seasonal march of the jet streams is different from that of the frontal zones at the surface. For instance, the frontal zone takes the southernmost location in mid-winter, while the southernmost location of the subtropical jet stream is found in March-April and in November. Thus, the seasonal division in terms of the jet stream may differ from what is done by other methods.

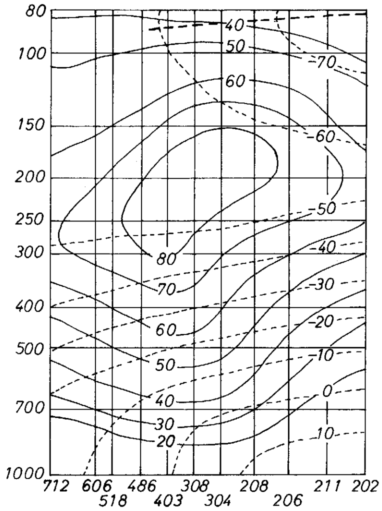



Fig. 3.a

Monthly mean cross-section along the eastern coast for February.

Solid line: isotachs (kts), broken line: isotherms (°C), heavy broken line: tropopause.

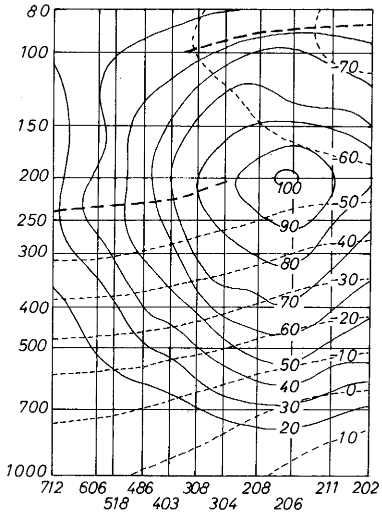



Fig. 3.b

Same as Fig. 3.a, but for March.

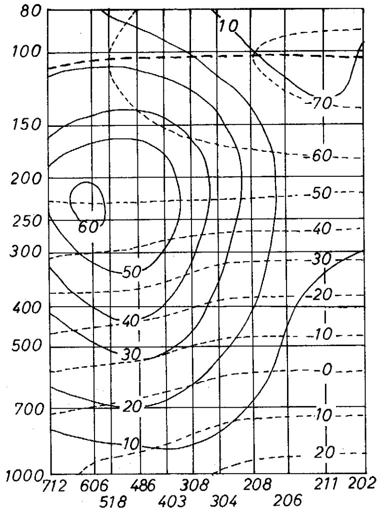



Fig. 3.c

Same as Fig. 3.a, but for September.

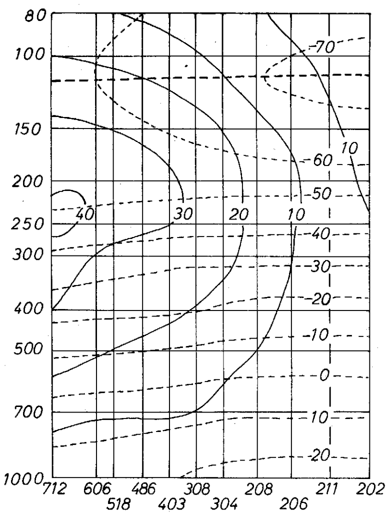
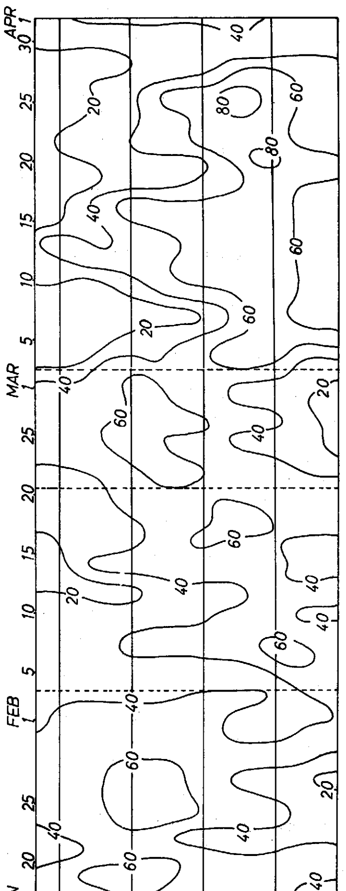



Fig. 3.d

Same as Fig. 3.a, but for August.

## AN ANALYSIS OF DAILY WIND SPEEDS AT 200mb LEVEL ALONG THE EASTERN COAST

Daily wind data were scrutinized to determine the more exact boundaries and to make subdivision of seasons. The 200mb level was chosen for this purpose, because it is at this level where both the polar and the subtropical jet streams are best illustrated. The daily variations of wind speeds at 200mb level along the eastern coast are shown in Fig. 4.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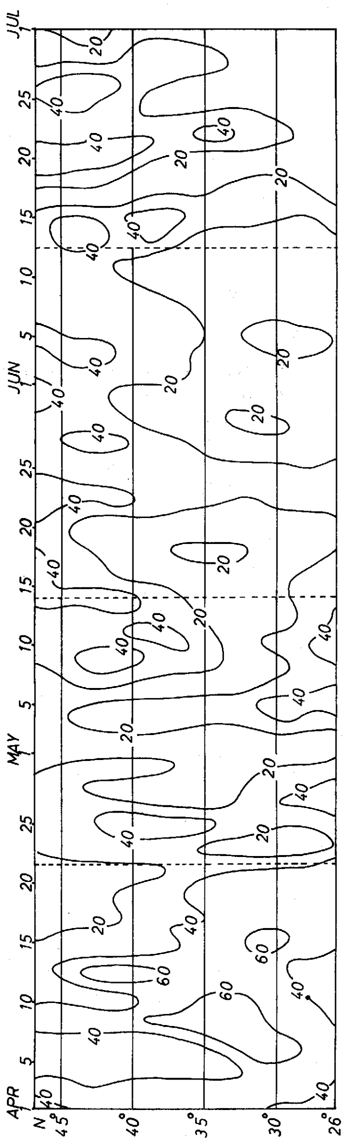
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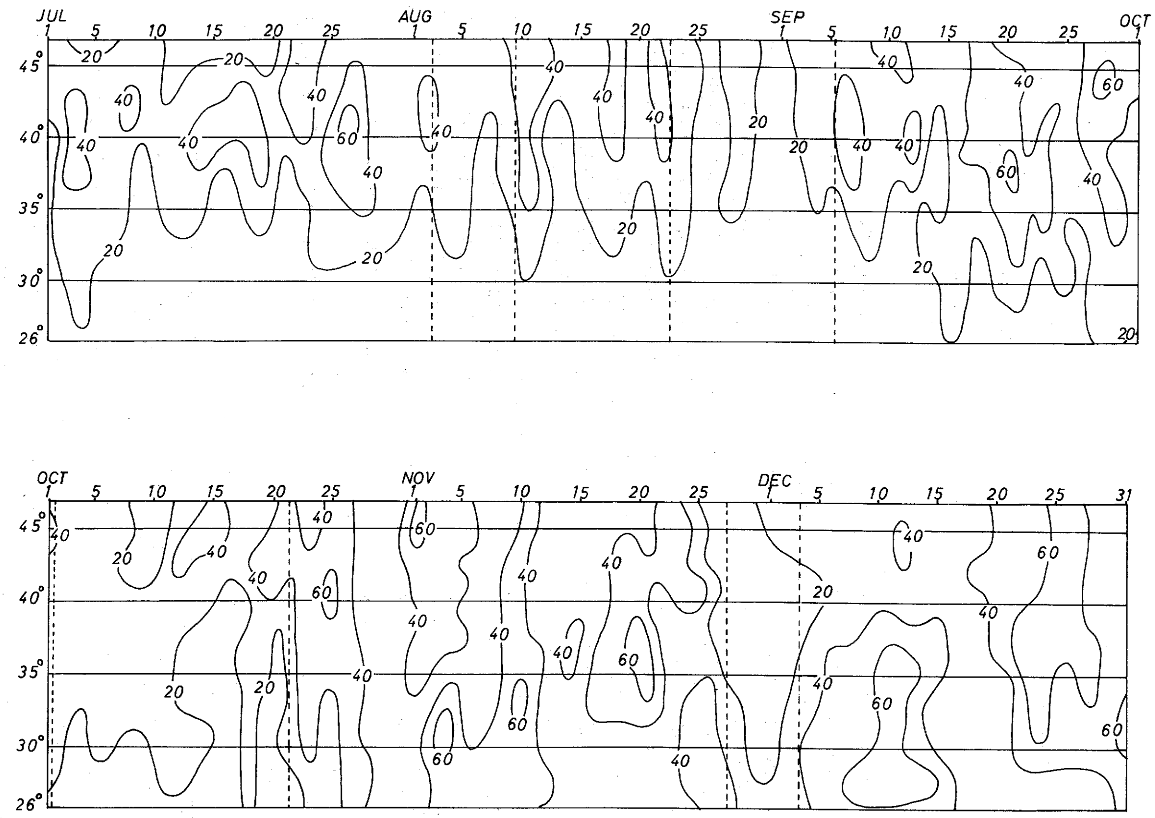


Fig. 4 Time-section of wind speeds at the 200mb level along the eastern coast.

Solid line: isotach (m/sec), broken line: boundary of seasons.

January and February are further subdivided into three periods with essentially different isotach patterns: January 16 to February 3, February 4 to February 20, February 21 to March 2. In the first and the third periods, winds of more than 40m/sec prevail over the regions from Jacksonville to Caribou, and the maximum wind speed exceeding 60m/sec is at about 40°N. In the second period, the strong wind axis seems to be displaced as far south as 30°N, and the wind speeds are substantially reduced over the northern region where the tropopause is well below the 200mb level.

The season beginning March 3 continues until an abrupt change in the isotach pattern takes place on April 22. This season is subdivided into two periods by the general weakening of winds on March 29 and 30. The former period is characterized by the greatest expansion of the area encircled by the 60m/sec isotach. The maximum wind speeds reported during this period is 88m/sec. This implies that, as shown in Fig. 3b, a very strong jet stream results by the confluence of the polar and the subtropical jet streams at this period, with the result of weaker winds over the northern region.

Strong winds suddenly disappear on April 22, suggesting that an essential change in the general circulation occurs on this date. The season predominantly governed by weak winds continues until September 5. Though this can be regarded as one season, a close examination reveals that there are three different circulation patterns: one with 40m/sec between 25°N and 30°N (April 22 - May 13), another with extremely weak winds (May 15 - June 12, August 3 - August 9, and August 23-September 5), and the short intervening periods with winds of more than 40m/sec.

A strong circulation system is re-established on September 6. Wind speeds of over 40m/sec are observed recurrently at short intervals, and the strong wind area expands to the south. However, this is by no means the beginning of the winter circulation because this season is followed by a period of very calm circulation, which lasts from October 1 until the 21st of the same month.

A substantial change in the atmospheric circulation takes place on October 21. A similar isotach pattern is recognized until November 27. In terms of the monthly mean cross-section, March, April and November are grouped into the same category. But the period from October 21 to November 27 differs from the spring in that this period is characterized by periodic appearances of strong winds and at the same time by double jet streams with cores of 60m/sec.

After a short period of very weak winds, the true winter pattern is established on December 4, which was already described.

## POSSIBILITY OF THE SEASONAL DIVISION BASED UPON THE JET STREAMS AND THE REMAINING PROBLEMS

The annual migration of the positions of jet streams over North America was investigated. The monthly mean 200mb charts reveal that a year is divided into two major seasons mainly by the location of the subtropical jet streams. The abrupt movements of the subtropical jet stream occurring in April to May and again in October to November bisect a year, although the western portion of the continent is greatly different from the east.

The cross-sections of the monthly mean wind speeds along the eastern coast disclose a characteristic migration of the subtropical jet stream, which takes the southernmost location not in mid-winter, as are the frontal zone at the surface, but in March-April and in November. Hence, these months may as well be separated as independent seasons.

The daily data of wind speeds at the 200mb level can also be used as a useful guide to determine the precise boundaries of seasons and to make a subdivision. According to the daily data, the major divisions of seasons are not so much evident in the displacement of the jet stream axes as in the general weakening or strengthening of the atmospheric circulation. It is interesting to compare this with the fact that the end of the Baiu rainy season is coincident with the sudden northward shift of the jet stream, while the core remains evident in the north in the following season (Murakami, 1951). April 22 and October 22 are the most important boundaries. Many subdivisions are made possible. If the surface pressure patterns, frontal activities, weather phenomena etc. are investigated in connection with the thus determined subdivision, then each subdivision may be considered as an independent natural season.

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