NOTES AND CORRESPONDENCE

**Long-term Variation of Upper Stratospheric Circulation
in the Northern Hemisphere in December****By Kunihiro Kodera and Koji Yamazaki***Meteorological Research Institute, Nagamine, Tsukuba, Ibaraki 305, Japan
(Manuscript received 17 July 1989, in revised form 21 November 1989)***Abstract**

Long-term variation of the mean zonal wind in the upper stratosphere in December is investigated using NMC geopotential height data from 1979 to 1987. The period of analysis is anteriorly extended until 1973 by combining the results of various investigators.

It was found that the mean zonal wind at 1 mb, 40°N shows outstanding long-term variation of the order of 10 years. Similar variation was also found in the rocket measurement of east-west wind component at Ryori (39°N, 142°E).

It is shown that the long-term variation of the mean zonal wind has a good correlation with the solar activity, ozone partial pressure and solar UV index.

1. Introduction

Upper stratospheric circulation has been investigated by various investigators (Quiroz, 1981; Smith, 1983; Hamilton 1982; Geller *et al.*, 1984). The periods of analyses of these authors were, however, relatively short (about 4 years) and long-term variation in the upper stratospheric circulation has not been well determined.

It has been believed (Smith, 1983) that interannual variability of mean zonal wind is relatively small in early winter compared to those of January and February, when large stratospheric warmings take place much more frequently. This may be true for limited periods of analyses or for lower levels of the stratosphere. We can, however, find the largest interannual variation of mean zonal wind in December in the upper stratosphere and stratopause.

In the present study, we focus our attention on investigating the interannual variation of the mean zonal wind in the upper stratosphere in December and discuss the possible origin.

2. Interannual variation of the mean zonal wind at 1 mb

The data used in the present study are US NMC (National Meteorological Center) geopotential height and temperature data for nine years 1979–

1987.

Figure 1 shows the standard deviation of the monthly mean geostrophic mean zonal wind for December (top), January (middle) and February (bottom). The largest interannual variability of mean zonal wind in December is found at about 30°N–50°N in the upper stratosphere and extended to the lower mesosphere. A secondary maximum is located at about 60°N–70°N in the middle stratosphere. This distribution of the standard deviation of mean zonal wind is characteristic in December. In January and February one maximum is found at the higher latitude. A similar result is found in Randel (1987).

In the present section, temporal variation of mean zonal wind in December at the center of large variability, 1 mb 40°N, is investigated for a longer period by combining the results of various investigators with the present results from 1979 to 1987 (Fig. 2a). Letters in the figure refer to the value of the geostrophic mean zonal wind of following authors: M; McGregor and Chapman (1979), Q; Quiroz (1981), S; Smith (1983), H; Hamilton (1982), G; Geller *et al.* (1984). Open circles indicate the results of the present study and the solid line indicates the arithmetic mean of the values by different authors.

Although the technique of measurement and the method of analysis are different from one investiga-

Fig. 1. a) Meridional cross section of the interannual variability (standard deviation) of the monthly mean geostrophic mean zonal wind in December (top), January (middle) and February (bottom) based on the US NMC data for the period from 1979 to 1987. Contour interval is 2.5 m/s.

Fig. 2. a) Time evolution of the geostrophic mean zonal wind at 1 mb, 40°N in December. Letters in the figure refer to the velocity of eastward zonal mean wind component of following authors: M; McGregor and Chapman (1979), Q; Quiroz (1981), S; Smith (1983), H; Hamilton (1982), G; Geller *et al.* (1984). Open circles indicate the result of the present study. The solid line indicate the arithmetic mean of different authors. b) December mean eastward wind component at 1 mb from rocket sonde observation at Ryori (39°02'N, 141°50'E). c) December mean sunspot numbers.

Fig. 3. December mean geopotential height field at 1 mb for 1981 (top) and 1984 (bottom). Contour intervals are 250 g.p.m. and the location of Ryori is indicated by a closed circle.

tor to another, the zonal wind speeds obtained show, for the overlapping period of analysis, rather good agreement between the different authors. A large variation in wind zonal speed is seen in Fig. 2a. In 1979 the mean zonal wind speed exceeded 100 m/s, while in 1984 it became less than 40 m/s. Another characteristic feature of the variation is a predominance of a long-term variation of the order of 10 years, though a 2–3 year variation is discernible. A strong wind period is found around 1980 and weak wind periods around 1975 and 1985. It is interesting to note that the weaker wind periods coincide with the minimum phase of solar activity (Fig. 2c).

3. East-west wind component at 1 mb at Ryori

To study the long-term variation, it is desirable to use a homogeneous data set. In this respect, the east-west wind component of rocket sonde observation at Ryori station situated close to 40°N (39°02'N, 141°50'E), is investigated.

Figure 2b shows the December mean 1 mb eastward wind component at Ryori from 1971 to 1987. The large amplitude of the long-term variation similar to that in Fig. 2a is noticeable. An excellent correspondence in wind speed variation is found between Fig. 2a and 2b. Note, however, that the amplitude of variation is much larger at Ryori. In particular, very small or even negative wind speed appear at Ryori, while the maximum of wind speed is almost the same for the two curves. These characteristics may be understood from the geographical situation of Ryori station. Figure 3 shows the December mean geopotential height field at 1 mb for the high-speed wind year, 1981 (top), and the low-speed wind year, 1984 (bottom). The location of

Ryori is indicated by a closed circle. In 1981, except for the polar region, a zonal structure is dominant, thus the spatial variation of the zonal wind is small along the latitudinal circle. On the other hand, in 1984, a large amplitude stationary wave is present. The meridional gradient of geopotential height locally reverses around Japan and this reversal corresponds to the easterly wind over there.

4. Discussion

The interannual variation of the mean zonal wind in the upper stratosphere in December was investigated. It was found that a large amplitude of long-term variation of mean zonal wind of the order of 10 years is dominant in the middle latitude upper stratosphere and stratopause. This has not been detected before because of the shorter period of analyses.

The coherent large variation of the mean zonal wind in the middle latitude is mainly confined to the upper stratosphere and the stratopause, and shows little correlation with the lower atmosphere (Fig. 4), which suggests that the interannual variation is primarily produced by some process proper to the upper stratosphere.

One of the large difference between the upper and the lower stratosphere is the existence of a large radiative heat source due to the solar ultraviolet (UV) absorption by ozone in the upper stratosphere. This suggests that the long-term variation of upper stratospheric circulation can be caused by a change in the radiative heating.

Figure 5b shows the time series of ozone partial pressure at Umkehr layer 9 (about 2–1 mb levels) in the middle latitude Northern Hemisphere (solid curve) and the solar UV index (dashed curve)

Fig. 4. Meridional cross section of correlation coefficients ($\times 10$) between December-mean mean zonal wind at 40°N , 1 mb and December-mean mean zonal wind of each latitude from 10°N – 85°N and pressure level from 1000–0.4 mb, for the period from 1979 to 1987. Only contours of which absolute values exceed 0.6 ($\times 10$) are drawn on the figures and negative value regions are shaded.

(DeLuise *et al.*, 1989). Outstanding decreasing trends from 1979 to 1986 are found both in ozone and in the solar UV index and hence the radiative heating is decreasing for this period. Similar large decreasing trends are found in the December mean zonal wind at 40°N , 1 mb (Fig. 5a solid line) and also in the December mean equatorial (20°S – 20°N) temperature at 2 mb (Fig. 5a dashed line). This coincidence may be accidental. However we have shown that both the weaker zonal wind periods around 1975 and 1985 (Figs. 2a and b) coincide with a minimum period of sunspot numbers (Fig. 2c). Also, the upper stratospheric ozone of Umkehr layers 8 and 9 vary with solar cycle, at least at Arosa (Düth, 1979, 1983).

These results suggest that the long-term variation of zonal mean wind at middle latitudes in the upper stratosphere and the stratopause in December is caused by the change of radiative heating due to absorption of solar UV by ozone. Of course, the period of the present analysis is too short to obtain conclusive results. It is, however, noted that for short-term variations of solar UV such as are related to the solar rotation, there exists increasing evidence of ozone and temperature response in the upper stratosphere (Chandra, 1985; Hood, 1987; Keating *et al.*, 1987).

Fig. 5. a) Time series of December mean zonal wind at 40°N , 1 mb (solid line) and December mean zonal mean temperature at 2 mb averaged over 20°S – 20°N (dashed line). b) time series of ozone partial pressure at Umkehr layer 9 (solid curve) and the solar UV index based on MgII line (Heath and Schlesinger, 1986) (dashed curve). Annual cycles are filtered out. (after DeLuise *et al.*, 1989)

Another problem is how to explain the large amplitude of the variation of mean zonal winds to the assumed solar forcing (Fig. 5a). It is evident that such a large amplitude cannot be expected from simple two-dimensional model calculations (*cf.* Garcia *et al.* 1984; Callis *et al.*, 1985). A similar problem of large temperature response in winter to the solar forcing is discussed by Chanin *et al.* (1987). In a future study we need clarify the role of the wave-mean flow interaction in the response of stratospheric circulation to the change of radiative forcing (Fels, 1987).

Recently Labitzke (1987) has found that the north polar temperature at 30 mb in late winter is correlated with solar activity if one separates data according to the phase of equatorial quasi-biennial oscillation (QBO) of zonal wind at about 50 mb. In the more recent work Labitzke (1989, personal communication) notes that in early winter, separation with the phase of the QBO is not always necessary to get

good correlation between solar activity and the 30 mb geopotential height in the middle latitude. This result is consistent with the present result that the mean zonal wind at 1 mb, 40°N in December shows coherent variation with the solar cycle without separating with the phase of the QBO.

Acknowledgments

The authors would like to thank H. Komuro of Upper Air Section of the Japan Meteorological Agency for providing monthly mean rocket sonde data at Ryori station and Prof. K. Labitzke for providing information about QBO-solar activity relation in early winter. Thanks are also extended to K. Kawahira, T. Hirooka and T. Nagai for useful discussions and comments, and H. Kimura for drawing the figures.

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北半球 12 月における上部成層圏循環の長期変動

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北半球 12 月の上部成層圏中緯度の帯状平均東西風に約 10 年の大きな振幅を持つ長周期変動が見いだされた。この東西風の長周期変動は太陽活動及びオゾンの変動と良い相関が有る事が示された。