Abstract: With the references for the mean value of the barometric pressure during the interval of 2008-2009, together with the count rate recorded by the neutron monitors, the barometric coefficient of cosmic ray neutron component for the neutron monitors located in Tibet, Tsumeb, Potchefstroom, Hermanus, Moscow, SANAE IV is obtained during the period of 1999-2011 years, one and a half of the solar cycle. The variation amplitude fluctuation of the barometric coefficient is much bigger when the sun is active in the period of 1999-2006 years than in the quiet state of 2007-2010 years, and the yearly variation of barometric coefficient for the neutron monitors in the quiet phase of solar activity is also discussed, which is very important for the interpretation of variation process of the barometric effect.

Keywords: cosmic ray; neutron component; barometric coefficient; variation of barometric coefficient bigger in sun activity; yearly variation.

1 Introduction

The galactic cosmic ray which comes from outside of the earth’s atmosphere is called primary cosmic ray. It consists of main ingredient high-energy protons and some alpha particles accompanied by little heavy nuclei. Galactic cosmic ray will be modulated by solar activity during its propagation in interplanetary space, and it will also interact with air molecules to produce secondary cosmic ray during its propagate process from outside atmosphere to ground level. So meteorological conditions all influence the intensity of cosmic ray, factors such as temperature, barometric pressure, humidity et al. The same primary cosmic ray intensity can cause the different count rate at different ground-based observatory stations due to the different atmospheric conditions besides the different vertical cut-off rigidities. So it is obligatory to correct the count rate derived from the detection facilities to eliminate meteorological effect before we demonstrate a phenomenon or other regular patterns. Therefore, the meteorological coefficients are particularly important in the calculation process.

Temperature effect is generally small and neglected, for neutron component, main consideration meteorological effect is the barometric pressure effect[1, 2, 3], in general the pressure-correction coefficient used at each neutron monitor stations is determined experimentally and empirically. Some articles expounded the cyclic variations of barometric coefficient[4, 5, 6, 7]. O.G. Rogava et al., 1991, released that barometric coefficient $\bar{\beta}$ of the cosmic ray neutron component had a 11-year cycle[4]. Massetti et al., 2001, pointed out that when solar activity was in strong phase, the barometric coefficient was lower than the one when the sun was in quiet state[5]. O.G. Rogava et al., 1984, noted that the barometric coefficient presented both annual and 2-year changes and also variations with a period close to the period of 3 to 4 solar rotations[6]. Shatashvili et al. 1995, indicated that barometric coefficient tended to biannual period[7].

We compute the barometric coefficient and correlation coefficient from 1999 to 2011 at a monthly interval, and 6 neutron monitor stations located in Tibet, Tsumeb, Potchefstroom, Hermanus, Moscow, SANAE IV. The detailed conditions are listed in the table 1.

2 Data and method

It is reasonable to use uncorrected data of observation on barometric effect of cosmic ray neutron component intensity of the stations of the world network and the corresponding data of the atmosphere pressure to derive the barometric coefficient monthly. We all know that high counting frequency, large amount of data, long-term serial ground-based detection and record will inevitably result in the losing of the data in a certain period of time. We use data to compute the barometric coefficient and correlation coefficient at a monthly interval and a point every hour, so a data file of the whole month consists of about 30*24 rows of data. If there is missing data of a specific month, use last month’s data. Atmospheric correction for neutron monitors are based on theory and experimental investigations of meteorological phenomena that affect the passage of particles through the atmosphere.

The original or following theory should be traced back to Dorman’s. The barometric coefficient derived equation can be described as:

$$dN = -\beta N dP,$$

where $\beta$ is the barometric coefficient, $dN$ is the change in the count rate $N$ and $dP$ is the change of the barometric pressure $P$. In the actual calculation process, the equation can be derived as:

$$\ln(N) - \ln(N_0) = -\bar{\beta}(P - P_0),$$

rewrite it as habit:

$$\delta\ln(N) = -\bar{\beta}\delta P.$$  

Here, it must be pointed out that it is desirable first to see the fluctuation of barometric coefficient, especially when
Table 1: detailed conditions of 6 stations.

<table>
<thead>
<tr>
<th>Location</th>
<th>Tibet</th>
<th>Tsumeb</th>
<th>Potchefstroom</th>
<th>Hermanus</th>
<th>Moscow</th>
<th>SANAEIV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>30.11°N</td>
<td>19.20°S</td>
<td>26.70°S</td>
<td>34.43°S</td>
<td>55.47°N</td>
<td>71.67°S</td>
</tr>
<tr>
<td>Longitude</td>
<td>90.53°E</td>
<td>17.58°E</td>
<td>27.09°E</td>
<td>19.23°E</td>
<td>37.32°E</td>
<td>2.85°W</td>
</tr>
<tr>
<td>Altitude(m)</td>
<td>4310</td>
<td>1240</td>
<td>1351</td>
<td>26</td>
<td>200</td>
<td>856</td>
</tr>
<tr>
<td>Pressure(hPa)</td>
<td>603</td>
<td>880</td>
<td>869</td>
<td>1013</td>
<td>1000</td>
<td>880</td>
</tr>
<tr>
<td>Cut-off rigidity(GV)</td>
<td>14.1</td>
<td>9.15</td>
<td>6.94</td>
<td>4.58</td>
<td>2.43</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Fig. 1: variation of sunspot data for the year 2008-2009, one month a point.

Fig. 2: linear relationship between $\delta \ln(N)$ and $\delta P$.

Fig. 3: fluctuation of barometric coefficient of 6 stations during 1999-2010/2011.

3 Results and discussion

The fluctuation of the barometric coefficient and correlation coefficient of 6 stations are shown in Fig.3 and Fig.4 respectively. Mean value of barometric coefficient of the 6 stations does tend to about 0.75 percent per hPa and has a slightly fluctuation with local vertical cut-off rigidity as Equation.2 released, from Fig.3 we can see obviously that the absolute value of barometric coefficient of Tibet station is less than the one of Sanae IV’s for the year 2007-2009 because of its high vertical cut-off rigidity. We list the mean value of barometric coefficient and local cut-off rigidity for 6 stations while sun activity is in quiet phase in Table.2. It also can be seen clearly that the variation amplitude fluctuation of the barometric coefficient is much bigger when the sun is active in the period of 1999-2006 years than in the quiet state of 2007-2010 years and also the

\[
\beta = 0.983515 - 0.00698286P, \quad [8],
\]

where $\beta$ is in units of percent per mmHg and $P$ is in units of GV. It is equally in another units

\[
\beta = 0.737931 - 0.00523924P, \quad (2)
\]

here $\beta$ is in units of percent per hPa and $P$ is in units of GV too. In order to facilitate comparison in this article, we put the units of barometric coefficient of 6 stations into percent per hPa.
Fig. 5: barometric coefficient of 6 stations Superposition and fit diagram.
correlation coefficient.

As we can see in Fig.3, barometric coefficient of several stations in the quiet state present somewhat one year cyclical phenomenon, especially at Tsumeb and Moscow station, which impel the analysis of the quiet phase cosmic ray barometric coefficient for 3 years from 2007 to 2009 by superposition method. We take the average of corresponding three months (such as January of 2007, 2008, and 2009) fold to one point, their standard deviation as the error range and then we use the least square method to fit the scatter diagram, as shown in Fig.5. From Fig.5 we can see barometric coefficient fluctuation of Tibet station, Tsumeb station, Potchefstroom station and Moscow station in the quiet state of solar activity presents somewhat one year cyclical phenomenon. However, barometric coefficient fluctuation of Hermanus station and Sanae IV station does not present one year cyclical phenomenon, which remains to be further understanding.

M. Andriopoulou et al., in their article, solar activity and the associated ground level enhancements of solar cosmic rays during solar cycle 23, listed 16 ground level enhancements (GLEs) from year 1996 to 2008 by using data of SOHO/LASCO CME[9]. From Fig.4 we can see correlation coefficient curve of 6 stations all rapidly rise at July 2000, April 2001, October 2003, January 2005 and December 2006 points, coincidentally, there is a GLE event in these months, that is to say the correlation between \( \delta \ln(N) \) and \( \delta P \) become bad during the GLE event month at these points marked with fill black pentagram. In fact, while GLE event happened the neutron monitor count rate decline first and then sharply rise to present a peak pulse of the count rate curve. Meanwhile, the barometric pressure count rate increase fast, but in general, the barometric pressure count rate increase range is limited, it’s relative amplitude range couldn’t catch up with the relative amplitude range of count rate of neutron monitor’s. That is why the correlation coefficient dramatic changes. So by the calculation of correlation coefficient could we extend probable a way to determine the drastic GLEs.

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**References**


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**Table 2:** quiet phase mean value of barometric coefficient of 6 stations from year 2007-2009.

<table>
<thead>
<tr>
<th>Location</th>
<th>Tibet</th>
<th>Tsumeb</th>
<th>Potchefstroom</th>
<th>Hermanus</th>
<th>Moscow</th>
<th>Sanae IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean value of ( \beta ) (percent per hPa)</td>
<td>0.67</td>
<td>0.7224</td>
<td>0.7321</td>
<td>0.7296</td>
<td>0.7594</td>
<td>0.7560</td>
</tr>
<tr>
<td>Cut-off rigidity (GV)</td>
<td>14.1</td>
<td>9.15</td>
<td>6.94</td>
<td>4.58</td>
<td>2.43</td>
<td>0.73</td>
</tr>
</tbody>
</table>

**Fig. 4:** fluctuation of correlation coefficient of 6 stations during 1999-2010/2011, in the pentagram month GLE event happened.