Analysis of Tibet NM Data with Wavelet Transform Method

Tibet NM Collaboration
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Abstract

The China-Japan cooperative Tibet neutron monitor(90.53°E,30.11°N,4300 m a.s.l.)began to work in October 1998.Now we have about 4 years data covering the 23rd solar maximum period.This is a work on correlative study of solar activity and cosmic ray intensity(CRI) by means of wavelet transform method,which is more sensitive to detect sharp variation points of CRI than Fourier transform method,these points represent modulation to cosmic rays of solar activities,especially CME, which is thought as the main source of geomagnetic storm. After analysis,we find that CRI can provide some precursory imformation of CME.So CRI data can predict geomagnetic storm by wavelet transform analysis.

1. Introduction

Tibet neutron monitor(NM),which is located in Yangbajing,Tibet,began to work in October,1998 with 28 NM-64 counters.It is a China-Japan cooperative program and keep working stably all through these years.Because the geographic location of Yangbajing,Tibet NM has a rather high cutoff rigidity and count rate(1.07×10^7 *counts/hour*) within the world-wide neutron monitor network.

Altitude(m)	4300	Number of counters	28
Latitude	30.11°N	Cutoff rigidity(GV)	14.1
Longitude	90.53°E	Atomospheric pressure(hPa)	606

Table 1. General features of Tibet NM station.

Tibet NM is engaged in monitoring solar activities and observing variation of CRI.We use wavelet transform method to analyse data.Wavelet transform is more better than Fourier transform in local propertites analysis,which is important for data analysis.So we adopt wavelet transform in stead of Fourier transform.Here we will report data analysis result by wavelet transform method.

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2. Method

The discrete wavelet function is $\psi(x)=\frac{1}{a_0^j}\psi(\frac{x}{a_0^j})$.It is most popular to choose $a_0=2$,then we get discrete dyadic wavelet function $\psi_{2^j}(x)=\frac{1}{2^j}\psi(\frac{x}{2^j})$.The wavelet transform of $f(x)$ at the scale 2^j and at the position x is defined by the convolution product

$$W_{2^j}f(x) = f * \psi_{2^j}(x). \tag{1}$$

if $\theta(x)$ is a smoothing function,we suppose $\theta(x)$ is twice differentialble and define first-order derivative $\psi^{(1)}(x) = \frac{d\theta(x)}{dx}$ and second-order derivative $\psi^{(2)}(x)=\frac{d^2\theta(x)}{dx^2}$. We derive that

$$W_s^{(1)}f(x) = f * \psi_s^{(1)}(x) = f * (s\frac{d\theta_s}{dx})(x) = s\frac{d}{dx}(f * \theta_s)(x). \tag{2}$$

$$W_s^{(2)}f(x) = f * \psi_s^{(2)}(x) = f * (s^2\frac{d^2\theta_s}{dx^2})(x) = s\frac{d^2}{dx^2}(f * \theta_s)(x). \tag{3}$$

The local extrema of $W_s^{(1)}f(x)$ correspond to the zero-crossings of $W_s^{(2)}f(x)$ and to the inflection points of $f * \theta_s(x)$.Detecting zero-corssings or local extrema are similar procedures,but the local extrema approach has some important advantages.The maxima of the absolute value of the first derivative are sharp variation points of $f * \theta_s(x)$.So we can use $\psi^{(1)}(x)$ or $\psi^{(2)}(x)$ as the wavelet function to detect the sharp variation points of original data.The most used smoothing function is B-spline function.For more details,refer to [1][2].

3. Analysis

The range of Tibet NM data used for analysis is from October 1998 to August 2002.The barometric pressure coefficient for the single channel is $-0.60\%/hPa$. Pressure correction has been made to the raw data by this coefficient.We take quadratic B-spline function as wavelet function.It is the first-order derivative of cubic B-spline function.Table.2. shows the filter coefficients of this function.We detect the local modulus maxima as sharp variation points of CRI.To decide the actual singularity,it should be detected in multiscale.We detect from scale 2^1 to 2^8 here.After doing discrete dyadic wavelet transform,we do get some obvious sharp variation points from Tibet NM data.

n	$h_0(n)$	$h_1(n)$
-1	0.1250	0.0
0	0.3750	0.0
1	0.3750	2.0
2	0.1250	-2.0

Table 2. Filter coefficients.

- June 2000

Fig.1. shows the count rate of Tibet NM in Jun.2000.We can see that there was a Forbush decrease on 08,June.According to SWO PRF,a major geomagnetic storm occurred on 08 June due to a CME passing the Earth(the CME followed the X2/3B flare of 06/1525UT).The storm began with a sudden storm commencement(SSC) at 08/0909UT(Fig.3.).Major to severe storm levels occurred

during the storm with the most intense activity during 08/0900-1500UT.A magnetopause crossing was detected by the NOAA GOES-8 spacecraft during 08/1510-1615UT.Solar activity was at a high level.Fig.2. shows the result after wavelet transform.A sharp variation point was detected at 08/1200(Beijing Time).The time just corresponded to the Forbush decrease,and is about 5 hours earlier than SSC time(08/0909UT).

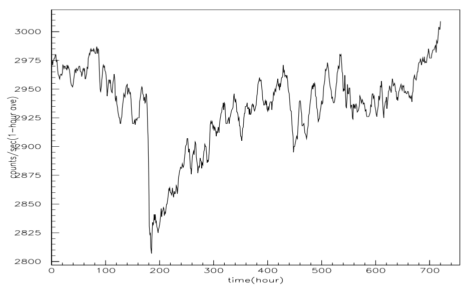

Fig. 1. Tibet NM count rate variation in Jun.2000.

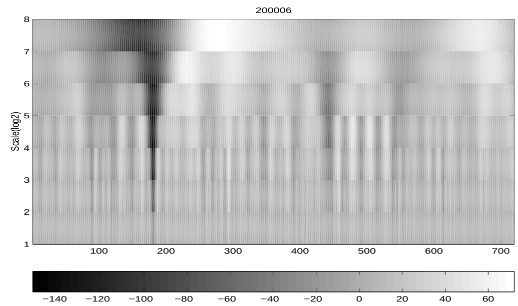

Fig. 2. The deconstruction coeffients of Jun.2000.

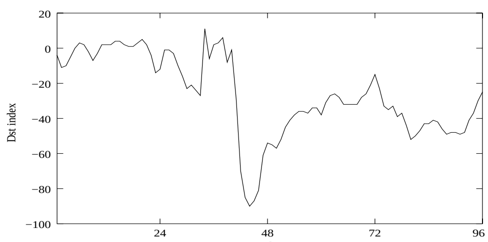

Fig. 3. 2000.6 Dst index figure(from 7,Jun.2000)

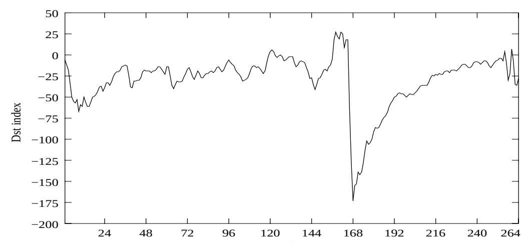

Fig. 4. 1999.9 Dst index figure(from 16,Sept.1999)

• September 1999

Fig.4. is the Dst Index from 16 to 26 Sept.1999.We can see that a sharp decrease occured on NO.168 hour.It means a geomagnetic storm occured on 22 Sept.1999.The Dst Index reached -175,this is an intense storm.According to SWO PRF,there was a magnetic field disturbance was detected during 22-23 September.It began with an 8 nT sudden impulse at 22/1222UT followed by active to major storm periods at all latitudes and brief severe storm periods at high latitudes.The Dst Index reached smallest value -175 at 22/2400UT.

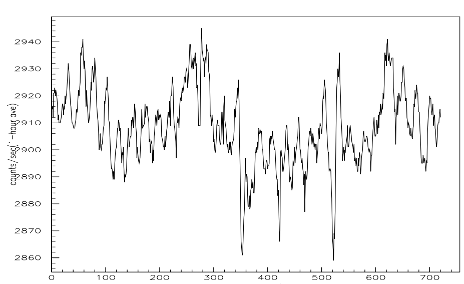

Fig. 5. Tibet NM count rate variation in Sept.1999.

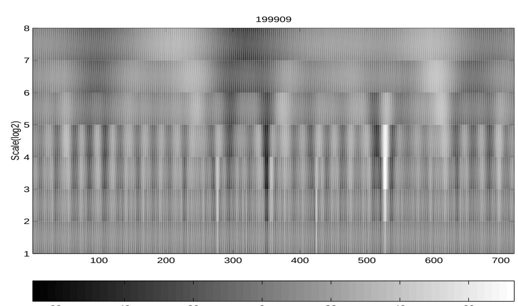

Fig. 6. The deconstruction coeffients of Sept.1999.

We cannot get any obvious imformation directly from count rate curve(see Fig.5.).After wavelet transform(see Fig.6.),the sharp variation point occured at 22/2300 (Beijing Time).It just occured during the storm.

• July 2000 and April 2001

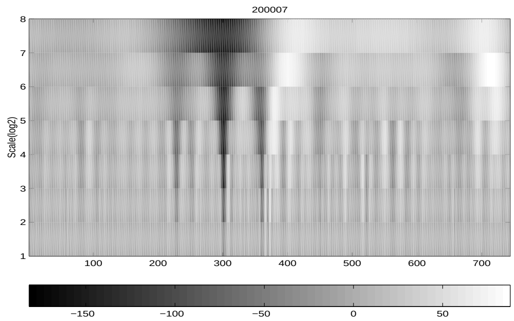

Fig. 7. The deconstruction coeffients of Jul.2000.

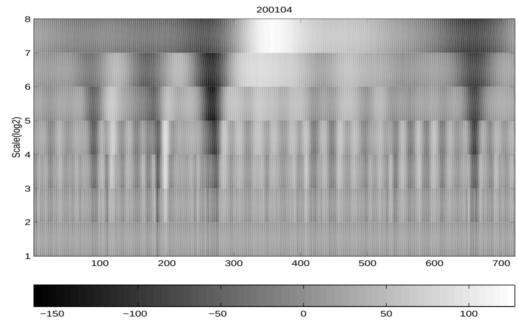

Fig. 8. The deconstruction coeffients of Apr.2001.

Solar activity was in a rather high level in these two months.From Fig.7. and Fig.8. we can see it is complex indeed.

4. Summary

Wavelet transform is effective for detecting singularities.Using wavelet transform method to analyse Tibet NM data,we can get some imformation which we cannot see directly from original count rate curve.The sharp variation points show that CRI was modulated by disturbance of interplanetary space.We detect a sharp variation point at 08/1200(Beijing Time),June 2000,it is about 5 hours earlier than SSC time.Another sharp variation point is detected at 22/2300(Beijing Time),September 1999.We don't get an earlier sharp variation point this time.And the period when solar activities is much active need further analysis,such as July 2000 and April 2001.

We know that there are many signs of CRI before a geomagnetic storm.The sharp variation of CRI may be one of the signs.Getting the exact precursory imformation is helpful to predict the big catastrophic magnetic storms.This paper just begins to make the study.The further research should be made to see whether the method could be used to predict geomagnetic storms or not.

5. References

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