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An online application for the barometric coefficient calculation of NMDB stations

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Abstract. One of the most important data corrections related to the primary data processing of the neutron monitors is the pressure correction due to the barometric effect. This effect induces considerable variation in the counting rate of a cosmic ray detector which is not related to the real variation of the cosmic rays flux but only to the local atmospheric pressure of the station. In order to provide the worldwide neutron monitor network with good quality data, a correction has to be made that requires the calculation of the barometric coefficient. A new method that effectively calculates the barometric coefficient for a station using data of a reference station in order to subtract the primary variations of cosmic rays is presented in this work. Moreover, this method is the prototype of an online tool that uses data of the NMDB stations and calculates the barometric coefficient for any available station. This tool is also presented.

1. Introduction

It is known that the barometric effect of cosmic ray intensity is the influence of atmospheric pressure on the observation of the secondary cosmic rays at the Earth. This effect induces considerable variation in the counting rate of a cosmic ray detector that is not related to the primary variation of the cosmic rays flux but only to the local atmospheric pressure of the station. For this reason, the correction of the counting rate for the barometric pressure is one of the main tasks of the primary data processing [1], [2].

The dependency of the counting rate on the atmospheric pressure was studied from both theoretical and experimental points of view in the past. Presently all cosmic ray stations correct their data by using a parameter, named barometric coefficient, which is calculated experimentally. This work presents the implementation of an online application that calculates the barometric coefficient of a neutron monitor station included in the worldwide neutron monitor network. This implementation is possible due to the NMDB database which provides real time data of the neutron monitor (NM) stations in a common format (http://www.nmdb.eu).

2. Barometric coefficient calculation

The method of defining the barometric coefficient of the different components of secondary cosmic rays has been studied to a large extent [2], [3] and [4]. Specifically, the affection of the barometric pressure on the counting rate of neutron monitors can be represented by:

$$\mathrm{d}N = -\beta \cdot \mathrm{d}P \tag{1}$$

where dN is the change of detector counting rate, dP is the change of pressure and β is the barometric coefficient. By integrating this expression (1) and supposing for pressure P_0 the counting rate N_0, the counting rate N of the detector is:

$$\ln N - \ln N_0 = -\beta \cdot (P - P_0) \tag{2}$$

where P is the current atmospheric pressure. The equation (2) is valid when the incoming cosmic ray flux is stable, so any variation of the detector counting rate is only due to the change of barometric pressure. In the case that there are variations in the cosmic ray flux, the equation (2) has the form:

$$\ln N - \ln N_0 - \ln(1+\nu) = -\beta \cdot (P - P_0) \tag{3}$$

where v is the variation of the cosmic ray flux. In order to calculate this variation v, the corrected for pressure data of a reference station S are used [5]. The reference station should have similar rigidity to the main station in order to assume that they both have similar cosmic ray spectra. The primary variation of cosmic rays for the reference station is:

$$v_S = \frac{N^S_{pcorr} - \overline{N^S_{pcorr}}}{\overline{N^S_{pcorr}}} \tag{4}$$

The equation (4) includes the corrected for pressure data of the reference station, so the change of v has a relation exclusively with the cosmic ray flux. The transformation of the primary variation of the reference station to the variation of the main station is possible by using coupling coefficients [1]. If the coupling coefficients of the zero harmonic are C_0 and C_0^S for the main and reference stations respectively, equation (3) turns into:

$$\ln N - \ln N_0 - \ln\left(1 + \frac{C_0}{C_0^S} v_s\right) = -\beta \cdot (P - P_0) \tag{5}$$

Conclusively, equations (2) and (5) can be used to calculate the barometric coefficient β experimentally by applying a linear regression fit on the measured values of N and P for a specific time period. The parameters N_0 and P_0 are the average values of counting rate and atmospheric pressure, respectively, over the defined time period. An extended report of this method is given in [6].

3. Implementation

The online application uses the two basic equations (2) and (5) of the previous section in order to calculate the barometric coefficient. Each station input data are provided from the NMDB mirror server, located in Athens cosmic ray station. The application is divided into three main parts:

1. The input form where the online user determines the necessary parameters for the application. The form has been implemented in HTML with the support of javascript. The input form of the online application, running in Athens NM website, is shown in the Figure 1 (http://cosray.phys.uoa.gr/Local_Data/barometricForm.html).
2. The main program, according to the parameters set in the form, calculates the values that correspond to the left and right parts of the equation (2) or (5). The procedure is implemented in PHP and the required data are retrieved by sending SQL queries to the NMDB mirror server.

3. The graph where the calculated values from the previous step are plotted. The graphs are drawn by using the Jpgraph library which is written in PHP (http://jpgraph.net). Apart from the points that are plotted, the graph also shows the regression line, the slope of which corresponds to the barometric coefficient of the station.

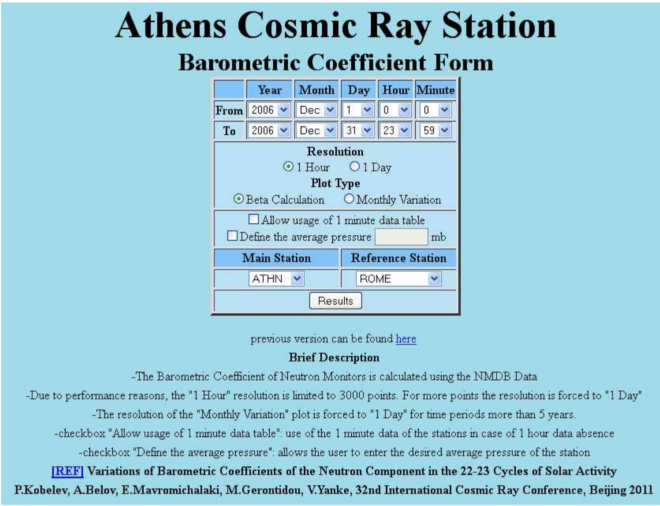

Figure 1. Application form running in Athens NM website

4. Results

The calculation of the barometric coefficient for Athens NM station for December 2006, which was an active period, is shown in the left panel of Figure 2. In this case, the calculation of barometric coefficient without a reference station is not very accurate. The plotted points are far from the regression line and this is reflected on the correlation coefficient which is 0.94. The same calculation, taking into account the Rome station as the reference one, is given in the right panel of the same figure. It is obvious that all the points are close to the regression line, which means that the proposed method calculates the barometric coefficient more effectively.

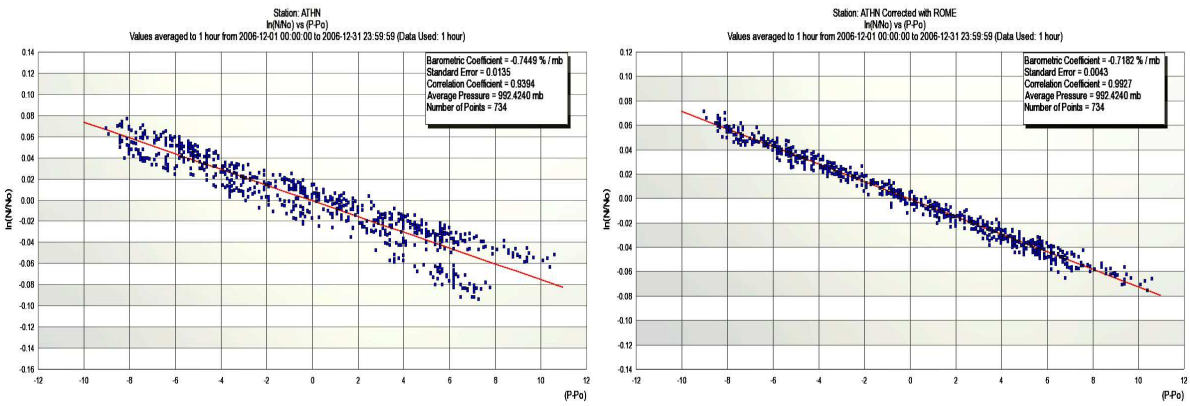

Figure 2. The barometric coefficient calculation for the Athens NM station during the disturbed period of December 2006 without using a reference station (left panel) and with a support station (right panel) is presented. The importance of the proposed method is obvious.

Moreover, the presented tool provides the option of plotting the monthly value of the barometric coefficient and the corresponding correlation coefficient for a defined time period. An example of this kind of plot, for the Athens NM station from 2001 until January 2012, is shown in Figure 3.

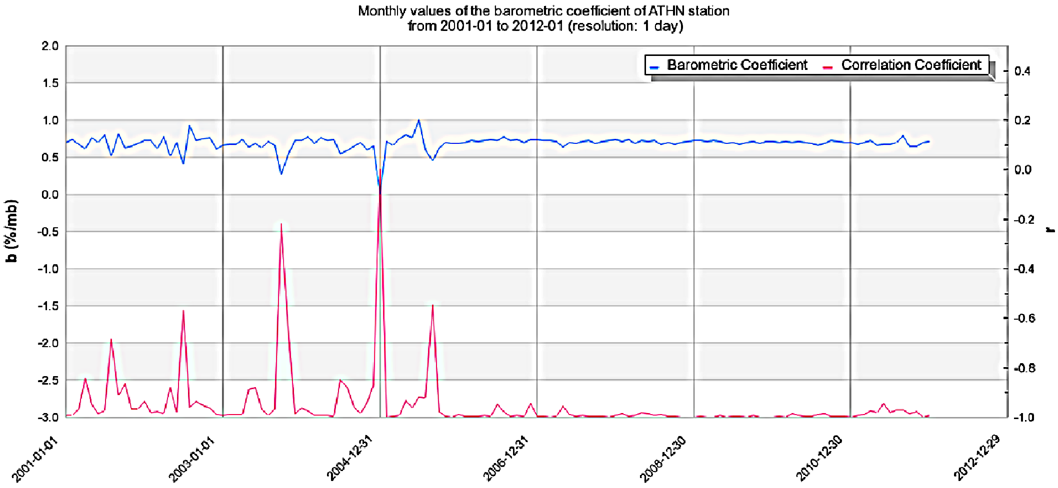

Figure 3. Monthly values of the barometric coefficient of the Athens station together with the correlation coefficient from January 2001 to January 2012. The axis for the correlation coefficient is at the right side of the plot and inversed.

It is important to note that in the cases where the monthly value of the barometric coefficient differs significantly from the neighboring values, the corresponding correlation coefficient is too low, which means that the data of this time period do not lead to a successful linear regression.

5. Conclusion

The above described online application has the following advantages:

- It can effectively determine the barometric coefficient of a cosmic ray station for a specific time period.
- The use of a reference station leads to satisfactory results even in active cosmic ray periods.
- Each station is able to easily check if the barometric coefficient used for primary data processing is correct.
- It can check the stability of the barometric coefficient over time. It is important to highlight that the correct calculation of the barometric coefficient highly depends on the correct setting of the application’s parameters.
- To sum up, the new online application is going to be very useful for testing the data quality of the stations.

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