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ON THE RELIABILITY OF THE AUTOMATIC MERCYRY BAROMETER CONSTRUCTED IN THE DEPARTMENT OF PHYSICS, UNIVERSITY OF OULU, EVALUATED ON THE BASIS OF COSMIC RAY PRESSURE CORRECTION CAPABILITY

by

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Abstract

The cosmic ray pressure correction capability has been used as a way of checking the long time reliability of a barometer. It seems that this method can be used for barometers located even at distances of more than 15 km from a cosmic ray station. The constructed automatic mercury barometer appears to have in long time use an accuracy at least as good as a mercury station barometer.

1. *Introduction*

An automatic mercury barometer has been constructed for cosmic ray pressure correction [3]. The reliability of the apparatus in a continuous operation can be tested by comparing the pressure correcting ability of our barometer to some normal instrument. We have used hourly pressure values from Oulunsalo airport at a distance of 15 km. Before comparison we must be convinced that the distance of 15 km does not make the pressure values incompatible in cosmic ray correction.

2. *The effect of distance of the pressure measurement station to the cosmic ray pressure correction capability*

The attenuation of cosmic ray nucleonic component in the atmosphere is approximately exponential [6] and can be expressed as

$$I = I_0 e^{-\alpha(p-p_0)}, \tag{1}$$

where I is the nucleonic intensity at the atmospheric pressure p and α the pressure coefficient. For cosmic ray correction one usually uses pressure values measured at the cosmic ray station. However, the nucleonic intensity recorded with the cosmic ray neutron monitor decreases with increasing Zenit-angle [5]. Thus the pressure values do not present the pressure for the whole region, through which the recorded nucleons penetrated the atmosphere. The barometer also exhibits dynamic fluctuations in its readings which are superimposed on the static pressure. In strong wind these can be several mb:s even for a barometer hanging in a room, and these variations are very difficult to evaluate [2].

As a consequence, a suitable pressure value for cosmic ray correction seems to be the average for some definite region lying around the cosmic ray station. The pressure readings anywhere within this region are valid for cosmic ray pressure correction. The barometer within this region which continually gives a better correlation in cosmic ray correction than any other gives consequently more reliable pressure readings.

As a measure to be used when one attempts to fix the region of pressure measurement one can use the correlation coefficient of logarithmic regression analysis between the cosmic ray intensity and the atmospheric pressure. The accurate determination of the region presupposes a close barometer network around the cosmic ray station. However, we can obtain a rough knowledge of the region by using the pressure readings of the following meteorological stations already existing in Finland: Oulunsalo airport (15), Hailuoto (35), Kuusamo (200), Sodankylä (270), Vaasa airport (280), Tampere airport (400), Utsjoki, Kevo (530), Mariehamn airport (620). Numbers in parentheses are distances from Oulu in km:s.

The best time for fixing is the quiet sun time because cosmic ray primary variations are little. We have chosen the periods of 1—31. 7. and of 1—31. 10. 1964. The pressure readings at Oulu have been measured by using a Lambrecht 253 Ua barograph. Pressure readings at 8, 14 and 20 o'clock and cosmic ray intensities at these times have been

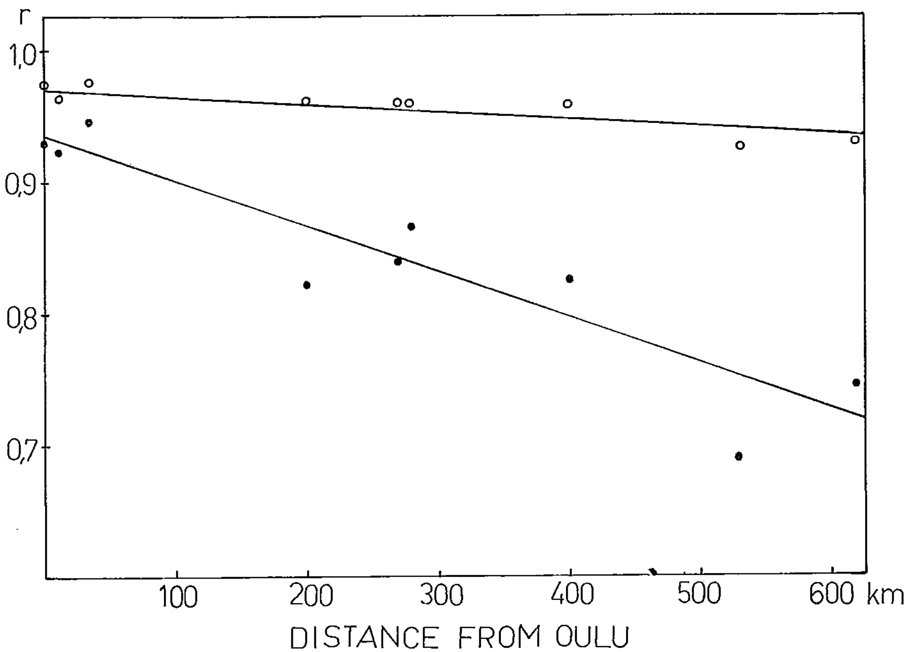

Fig. 1. The correlation coefficients r of logarithmic regression analysis between the cosmic ray intensity and the atmospheric pressure as a function of distance between the pressure measurement station and the cosmic ray station. Open circle July, solid circle October.

used because of the lack of hourly pressure readings from some stations.

Correlation coefficients are presented in the Figure 1. The correlation is very good for Oulu and the nearby stations at Oulunsalo and Hailuoto. It decreases thereafter with distance. In July the variations of atmospheric pressure are great, slow, and linear; in October they are rapid but small. This causes the correlation coefficients to slope steeper in October than in July. The stations Oulu, Oulunsalo, and Hailuoto give comparable correlation coefficients for both these periods. Thus the radius of the previously mentioned region seems to be more than 15 km and the pressure values of Oulu and Oulunsalo can be seen to be compatible in cosmic ray correction.

3. *The reliability of constructed barometer*

The mechanical function of the apparatus has been reliable during the whole recording time which began in November 1965. No systematic

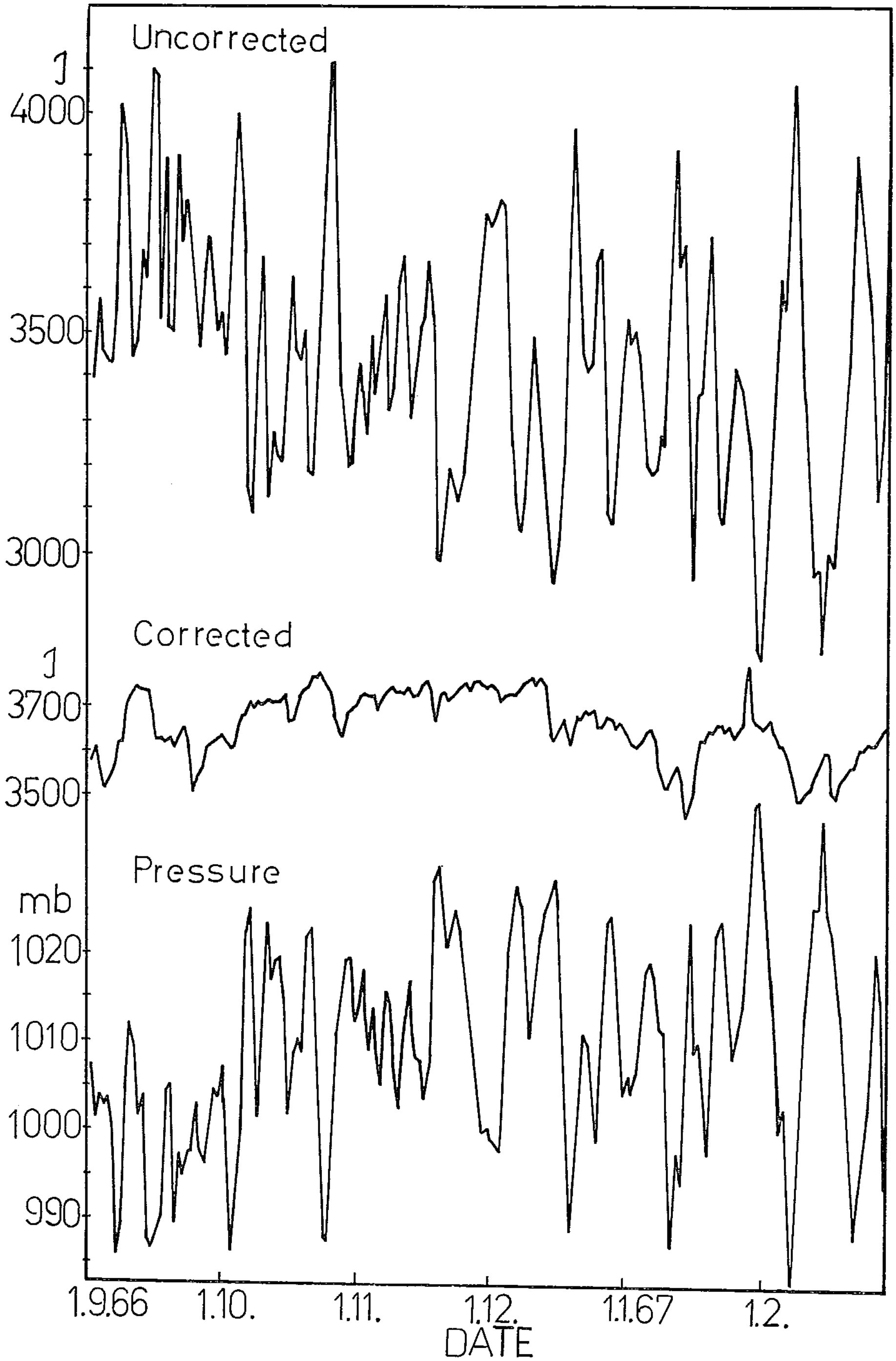

Fig. 2. The uncorrected and corrected daily neutron intensity and the daily pressure values for the period of 1. 9. 1966—28. 2. 1967.

errors have appeared except in some periods in the summer 1967 when our air conditioning system was out of order. It has not been necessary to change the system, which determines the height of the mercury column. It seems that the age of the lamp is some years when the voltage used is lower than the normal usage voltage. This can be done because phototransistors are particularly sensitive for red and infrared radiation [1].

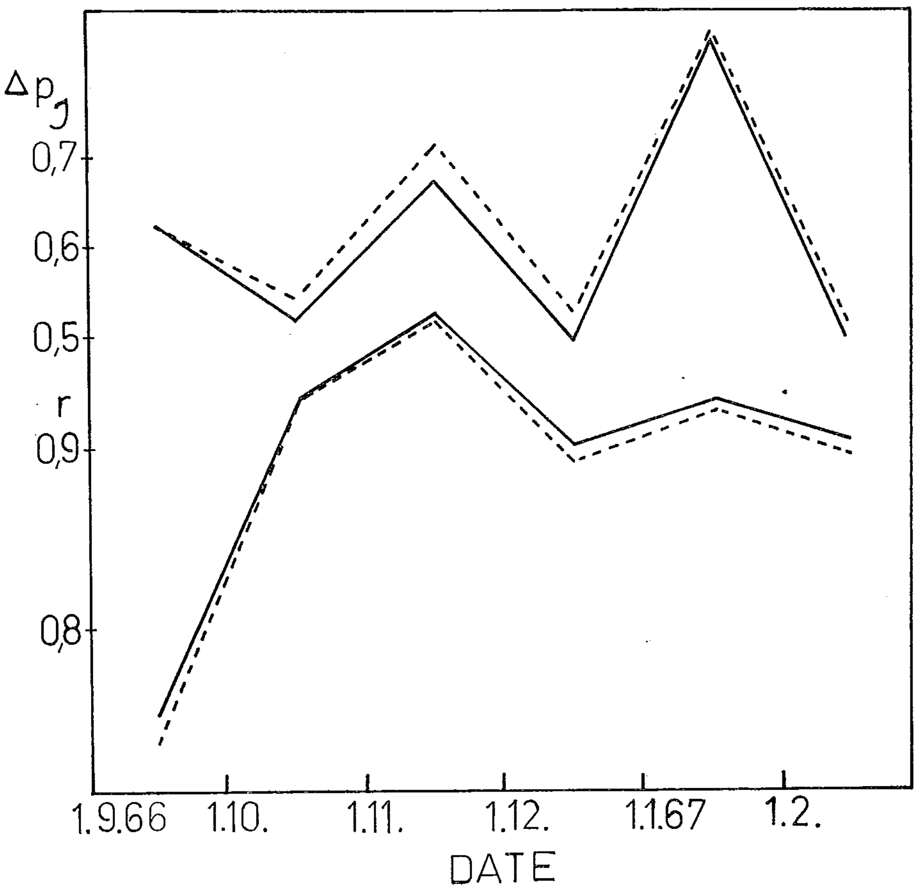

Fig. 3. The monthly averages of correlation coefficients r and the monthly averages of standard error of estimate of the hourly pressure Δp_I on relative intensity for the period of 1. 9. 1966—28. 2. 1967. Dashed line for the Oulunsalo airport barometer, full line for our automatic barometer.

The half year period 1. 9. 1966—28. 2. 1967 has been chosen for a subject of critical examination. The uncorrected and corrected daily neutron intensity and the daily pressure values for this period are presented in the Figure 3. The monthly averages of correlation coefficients of the logarithmic regression analysis between cosmic ray intensity and atmospheric pressure are presented in the Figure 3. The correlation for our automatic barometer is always at least as good as for the Oulunsalo airport barometer. The average correlation coefficient for our barometer for this period is 0,899 and for Oulunsalo barometer 0,891.

The monthly averages of standard error of estimate of the hourly pressure Δp_I on relative intensity for both barometers are also presented in the Figure 3. The scatter about the regression line of pressure on intensity is for the whole time smaller for our automatic barometer. The mean hourly standard error of estimate of pressure for this period for our automatic barometer is 0,603 mb and for Oulunsalo airport barometer 0,624 mb.

When we examine these standard errors of estimate we must take into account:

1) The super neutron monitor recording has a standard deviation of $\sigma = \pm 1{,}38 \frac{\sqrt{N}}{N}$ [4], where N is the number of neutron counts.

2) The primary cosmic ray variations.

The pressure coefficient for the nucleonic component is approximately 0,74%/mb and the hourly recording of our neutron monitor on the average $3{,}6 \cdot 10^5$ counts/hr. According to equation (1) this causes an uncertainty of 0,3 mb in the hourly pressure estimate. The additional uncertainty arises mainly from cosmic ray primary variations.

As a result of this study we conclude that the automatic barometer constructed by us gives in long time use pressure readings for cosmic ray correction which are at least as usable as a normal Hg station barometer. Thus even the accuracy of pressure readings of our automatic barometer is at least as good as those of the Hg station barometer.

REFERENCES

1. Hunter, L. P., 1956: *Handbook of Semiconductor Electronics 5—1*, McGraw-Hill Book Company, Inc.
2. Middleton, W. E. K. and A. F. Spilhaus, 1953: *Meteorological Instruments*, University of Toronto Press.
3. Niemi, S. P. A., 1966: A solution to the numerical recording of a mercury barometer. *Geophysica*, **8**, 319—324.
4. —»— , 1967: *Oulu Cosmic Ray Neutron Monitor 9-NM-64, Data and Comments — 1*, Department of Physics, University of Oulu, Oulu.
5. Rao, U. R., K. G. McCracken and T. Venkatesan, 1963: Asymptotic cones of acceptance and their use in the study of the daily variation of cosmic radiation. *J. Geophys. Res.*, **68**, 345—369.
6. Rossi, B., 1961: *High Energy Particles*. Prentice-Hall, Inc.