

ON THE SHORT-TERM PROGNOSIS OF ANTICYCLONIC FORMATIONS IN VILNIUS BY THE HARD COSMIC RAY FLUX VARIATIONS

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Abstract. Measurements and analyses of variations of the hard cosmic ray flux (HCRF) were carried out in the energy range 1.2–1.6 MeV in Vilnius in 2002–2005, using gamma-spectrometer. The predictive connection between increase of HCRF and atmospheric pressure in 2–5 days was defined. Investigation of this connection was conducted into a period of time 14–19 h, which was divided into five hourly time intervals: 14–15, 15–16, 16–17, 17–18 and 18–19. For procession of experimental data, the empirical criteria of HCRF increase were suggested. These criteria indicate the HCRF increase in two or more number intervals with a condition of HCRF increase by 15 imp/h or more in every of them next day and total value has to exceed 40 and 50 imp/h. The efficiency of prognosis of atmospheric pressure increase by the increase of HCRF was 62–73% in 2002–2005, using the first criterion (40 imp/h) and 53–67% using the second one (50 imp/h). The illustration of atmospheric pressure formations confirm the results of prognosis of anticyclone transfer, which block the way to the motion of cyclones eastward from the Atlantic Ocean. Hence, the prognostic connection between atmospheric pressure increases in 2–5 days by HCRF increase was defined for the first time.

Keywords: hard cosmic ray flux, atmospheric pressure, cyclone, anticyclone, short-term prognosis.

1. Introduction

Currently, one of the major problems associated with external influence on the human body is an anthropogenic factor (Baltrėnas *et al.* 2007; Styra *et al.* 2007a), as well as natural processes, arising from a change in solar activity, variations of the geomagnetic field, changing meteorological processes, etc. Literature extensively analyses the consequences of these impacts, causing leaps of various diseases (Chizhevskiy 1976; Stoupel 1999; Juozulynas *et al.* 2000; Stoupel *et al.* 2002; Styra *et al.* 2005a, 2005b, 2007b). If emission of pollutants into the environment can be reduced by using improved technology, it is virtually possible to suspend the impact of natural processes. Therefore it is necessary to be able to predict abnormal phenomena that take early action to reduce moral and material damage from these effects to minimum.

However, there are positive external effects on the environment and the human body, particularly from the weakening of solar activity and thereby reduced intensity variations of the geomagnetic field, strengthening the anticyclonic activity. Increasing atmospheric pressure and its duration for some time and decrease of cardiovascular diseases and other diseases is observed (Chizhevskiy 1976). In this period of time, a good weather usually takes place. The above described processes are connected with variation in the HCRF at the ground surface, as well as the change of weather.

When an anticyclone approaches the point of observations, in particular – Vilnius, the HCRF increase is

registered mainly for 14 to 19 hours. It means that the formations of high atmospheric pressure will arrive in a few days and will remain over the observation station for some time.

However, the predictive connection between the increase of HCRF and the formation of an anticyclone as well as duration over the observation station is rather complicated, so the definition of this connection requires extensive statistical information on the experimental data. This prediction is of great practical importance, since, anticyclones bring good stable weather, and at this time there are minor variations of the geomagnetic field, which does not contribute to the deterioration of human health. On the other hand, a negative impact on people is possible, especially in a summer period during the formation of hot weather conditions that may adversely affect people suffering from a cardiovascular pathology.

On the day of observations between HCRF and high atmospheric pressure an inverse correlation was observed. It is a quite natural phenomenon, since the thickness of air layer increases and raises the absorption of cosmic particles coming to the ground surface.

Only a secondary cosmic radiation is registered, which consists of muons mainly at the ground surface (Ziegler 1998; Styra 2004). The maximum concentration of these particles is approximately at the altitude of 15 km (Ziegler 1998). Because of the relatively short lifetime of muons (2 μ s), they cannot reach the ground surface from that height, so at the ground surface only those particles are registered that are formed in the lower

atmosphere. Layers of air existing closer to the ground surface have a higher density, which has an additional impact on HCRF and its change near the ground surface. Moving air mass is accompanied not only by changing atmospheric pressure, but also a change in temperature, humidity and other parameters that also affect the human body (Lupo 1998; Huth *et al.* 2008).

It should be noted that before the arrival of pressure formations to the observation station, the frequent variations in the geomagnetic field are observed. Therefore, HCRF changes become a factor in determining the trend of the atmospheric pressure.

The studies conducted so far in relation to the variations of HCRF, predicting the decrease of atmospheric pressure, i.e. the arrival of cyclones to the observation point (Styro 1984, 1988; Styra *et al.* 2008). However, the application of the same criteria and time intervals, which were used to predict atmospheric pressure decrease by HCRF variations (Styra *et al.* 2008) had negative results in predicting the pressure increase. It is found that HCRF increase in the time interval of 8–13 h doesn't predict the atmospheric pressure increase in some days. This connection was discovered empirically in the time range of 14–19 h, using other criteria for processing of experimental information.

This method of experimental data processing was different, as compared with the forecast of occurrence of cyclonic activity over the observation station and variations of HCRF. Consequently, the purpose of this study is to determine the prognostic connection between an increase of HCRF and an increase of atmospheric pressure in a few days in Vilnius, as well as the possible duration of anticyclone-stay over the observation station.

2. Measurement methods

Measurements of HCRF were carried out by gamma spectrometer with scintillation detector NaI(Tl) (Styra 2008). The detector was placed into a lead reservoir, which was additionally surrounded by a lead protection. The total thickness of the protection was 12 cm, which completely absorbs the soft component of cosmic radiation. The majority of the hard cosmic rays are muons, which are penetrating the lead protection cause light flashes in the crystal NaI(Tl). Further, the quanta of light in the impulse analyzer are distributed by energies and are registered on a computer. Measurements of HCRF were carried out continuously and measured every 15 minutes. Meteorological data was obtained from the Hydrometeorological Service of Lithuania.

In these studies, the predictive connection between an increase of HCRF and atmospheric pressure in a few days was found in the energy range of 1.2–1.6 MeV, i.e. the attempt to implement a short-term forecast of anticyclonic activity and the pressure increase in cyclonic formations was carried out.

For the practical realization of this task, the time range of 14–19 hours was chosen. This range was divided into hourly intervals of 14–15, 15–16, 16–17, 17–18, and 18–19 h. The measurements of the HCRF course and difference analysis of obtained results (in the present day

minus the previous) were carried out in above mentioned time intervals. The criteria of HCRF values were proposed: the number of impulse differences in one time interval must be over 15 imp/h, while their sum in all time intervals must exceed 40 or 50 imp/h. Predicting atmospheric pressure increase, the initial meteorological situation has to be taken into account.

If the forecast of atmospheric pressure occurs under normal weather conditions, the predicted anticyclone over the observation station will occur in 4–5 days. However, anticyclone can stay for a relatively long time over the observation point. In this case, according to proposed criteria, the registered positive signals of HCRF predict the duration of this situation for additional 2–3 days.

In this investigation, over 700 000 measurement results of HCRF were processed. Values of atmospheric pressure corresponded to the daily average. Predicting increase of atmospheric pressure, the present pressure in observation station was taken into account.

3. Results

Near the ground surface, HCRF continuously varies and at a relatively calm situation, these variations do not deviate from certain values. However, due to external influence, HCRF values can exceed this limit and its deviation from the mean value is possible in the direction of larger or lesser value. It is found that before the appearance of anticyclone or increase of atmospheric pressure, the HCRF increase is observed within the time range of 14–19 hours. Variable HCRF values indirectly reflect the instability of the geomagnetic field, which is connected with the transfer of air masses. As far as detailed quantitative calculation of the correlation between these processes is problematic, the empirical connection only between the above mentioned parameters has a place. For the analysis of HCRF variation empirical criteria were proposed. Such a criterion could be the difference in values between a measurement result of HCRF in a certain time interval and the monthly average value or the difference between the two adjacent days in the same time interval. The first proposal is less perspective, as far as the HCRF has a seasonal course (Styro *et al.* 1988; Al-Dargazelli *et al.* 1989; Styro 1996; Kuleshova *et al.* 2001), which complicates the use of monthly mean value as a basis for the HCRF variations. Therefore in determining of prognostic connection between HCRF and atmospheric pressure increase, the second variant is used, i.e. the difference between the original data and the previous day in the range of energies 1.2–1.6 MeV, taking into account the above mentioned criteria.

Taking the present meteorological situation into consideration (in the absence of a cyclonic activity), the atmospheric pressure increase and anticyclones arrival to the observation point in 4–5 days was predicted using the criterion of +40 imp/h. Simultaneously, another criterion of +50 imp/h of HCRF increase was used to predict atmospheric pressure increase in 2–3 days at any meteorological situation.

The obtained results are presented in Tables 1–4.

Table 1. The efficiency of the predictive connection between the HCRF increase (initial minus the previous day) in 1.2–1.6 MeV interval of energies (criterion 40 imp/h or more in the two-hour intervals or more) and an increase in atmospheric pressure to a maximum value in anticyclones in 4–5 days in 2002–2003

Month	2002			2003		
	Number of cases	Realization number	Non-realization number	Number of cases	Realization number	Non-realization number
January	5	2	3	7	5	2
February	3	1	2	9	8	1
March	6	3	3	11	5	6
April	8	5	3	9	7	2
May	5	2	3	6	5	1
June	10	5	5	7	1	6
July	6	2	4	7	6	1
August	6	5	1	10	5	5
September	7	6	1	8	4	4
October	2	2	0	12	7	5
November	6	5	1	11	7	4
December	9	7	2	11	8	3
Total	73	45	28	108	68	40
Total, %	100	62	38	100	63	37

Table 2. The efficiency of the predictive connection between the HCRF increase (initial minus the previous day) in 1.2–1.6 MeV interval of energies (criterion 40 imp/h or more in the two-hour intervals or more) and an increase in atmospheric pressure to a maximum value in anticyclones in 4–5 days in 2004–2005

Month	2004			2005		
	Number of cases	Realization number	Non-realization number	Number of cases	Realization number	Non-realization number
January	9	8	1	9	9	0
February	5	2	3	9	6	3
March	10	5	5	10	4	6
April	7	5	2	8	6	2
May	9	5	4	7	4	3
June	10	7	3	9	7	2
July	9	7	2	9	6	3
August	2	2	0	9	7	2
September	1	1	0	9	6	3
October	6	4	2	6	4	2
November	11	8	3	11	9	2
December	12	9	3	7	6	1
Total	91	63	28	103	74	29
Total, %	100	69	31	100	72	28

Table 3. The efficiency of the predictive connection between the HCRF increase (initial minus the previous day) in 1.2–1.6 MeV interval of energies (criterion 50 imp/h or more in the two-hour intervals or more) and an increase in atmospheric pressure to a maximum value in anticyclones in 2–3 days in 2002–2003

Month	2002			2003		
	Number of cases	Realization number	Non-realization number	Number of cases	Realization number	Non-realization number
January	8	6	2	10	6	4
February	3	1	2	11	6	5
March	6	6	0	15	6	9
April	10	8	2	11	8	3
May	9	6	3	8	6	2
June	11	7	4	10	6	4
July	7	2	5	9	7	2
August	9	6	3	11	5	6
September	14	11	3	8	3	5
October	5	3	2	16	9	7
November	12	7	5	15	8	7
December	16	11	5	12	7	5
Total	110	74	36	136	77	59
Total, %	100	67	33	100	57	43

Table 4. The efficiency of the predictive connection between the HCRF increase (initial minus the previous day) in 1.2–1.6 MeV interval of energies (criterion 50 imp/h or more in the two-hour intervals or more) and an increase in atmospheric pressure to a maximum value in anticyclones in 2–3 days in 2004–2005

Month	2004			2005		
	Number of cases	Realization number	Non-realization number	Number of cases	Realization number	Non-realization number
January	13	8	5	14	7	7
February	5	3	2	13	7	6
March	14	10	4	12	7	5
April	8	3	5	12	4	8
May	10	5	5	12	7	5
June	14	7	7	13	8	5
July	14	6	8	13	7	6
August	4	2	2	11	7	4
September	2	2	0	12	5	7
October	6	4	2	10	4	6
November	11	7	4	12	8	4
December	12	11	1	10	6	4
Total	113	68	45	144	77	67
Total, %	100	60	40	100	53	47

An analysis of the presented data in the tables shows that the highest prognostic result of the atmospheric pressure increase refers to the case of the anticyclonic activity (Tables 1, 2). It is a natural fact since the development and formation of an anticyclone over the observation station takes a relatively long time (several days) and HCRF increase before 4–5 days determines the situation on the anticyclone’s periphery.

The forecast of atmospheric pressure is increase at any initial meteorological situation, including cyclonic activity. The process is random, thus the correlation between changes in these parameters is lower (Tables 3, 4). The efficiency of the prognostic connection between HCRF and atmospheric pressure is an increase in anticyclonic activity increase from 62 to 72% in 2002–2005 (Tables 1, 2). This fact is possibly connected with weakening of solar activity.

Similar results, forecasting the atmospheric pressure increase for any random situations have the opposite trend, i.e. they were reducing from 67% in 2002 to 53% in 2005 (Tables 3, 4). However, there is a large number of unrealized prognostic situations, i.e. using the criteria of analysis, the increase in atmospheric pressure did not occur (Tables 1–4). The examples of anticyclone formation and their movements towards Vilnius (observation station) are presented in Figs 1–18.

Meteorological situations from 18 April 2002 till 23 April 2002 are presented in Figs 1–8.

Before the start of an atmospheric pressure increase (April 16, 2002), the signals of HCRF 45, 16, 29 imp/h were registered in time intervals of 14–15, 17–18, 18–19 h, respectively. Since that time, there was a displacement of the anticyclone in the direction of the observation point, where the atmospheric pressure was increasing gradually (Figs 1–8).

Meteorological situations over the northern part of the Atlantic Ocean and Europe on 18–23 April 2002 (Figs 1–8).

Conventional signs: white thin lines – isobars in hPa, ■ – Vilnius city

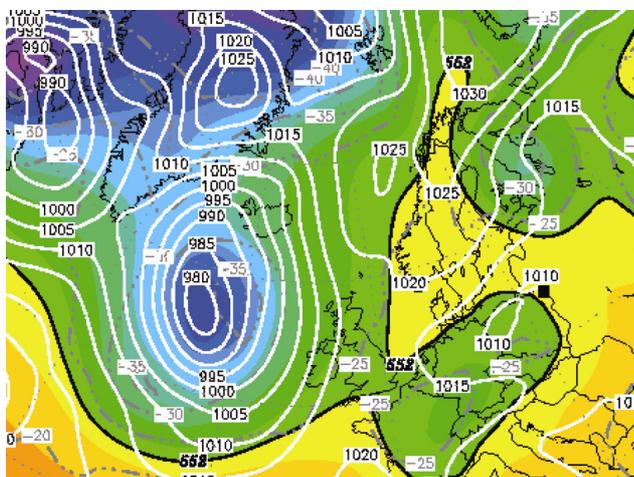


Fig. 1. 18 04 2002

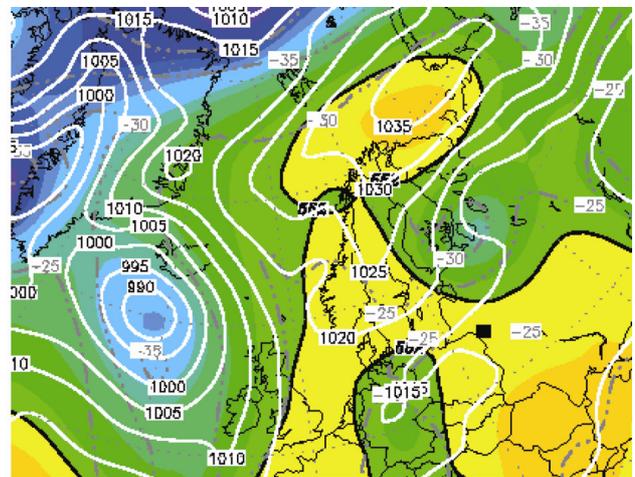


Fig. 2. 19 04 2002

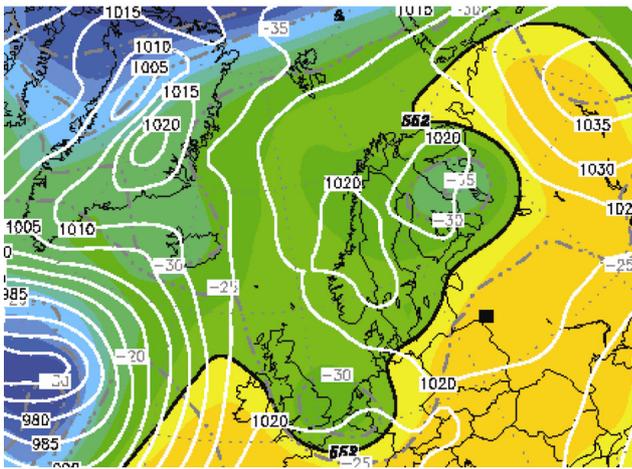


Fig. 3. 18 04 2002

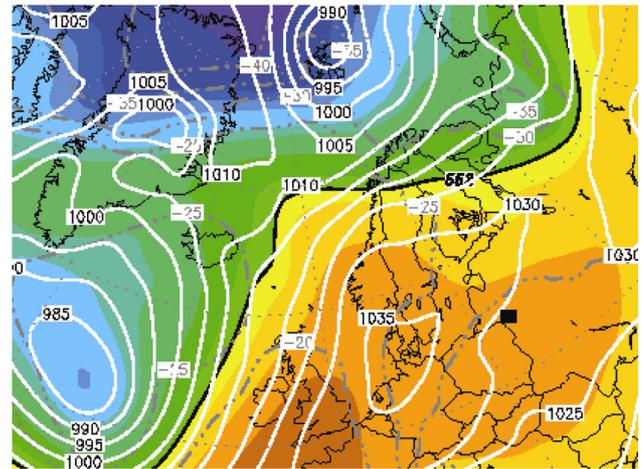


Fig. 6. 21 04 2002

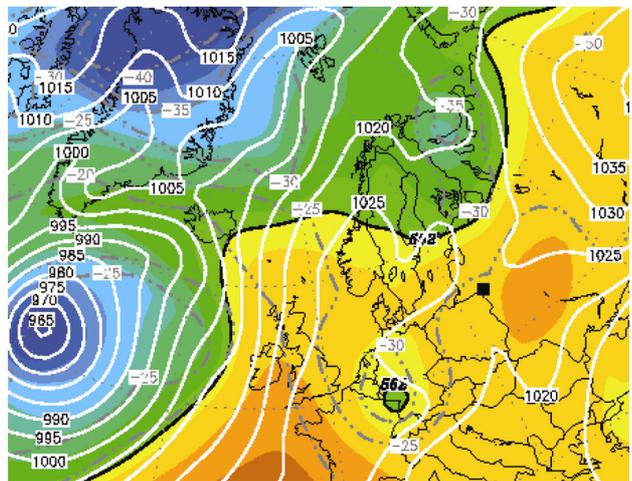


Fig. 4. 19 04 2002

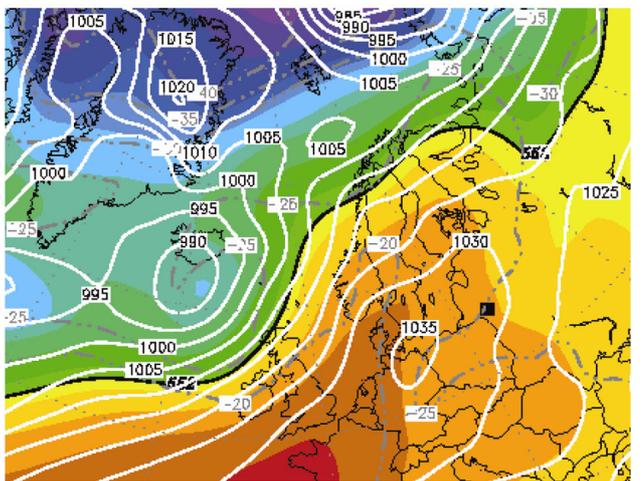


Fig. 7. 22 04 2002

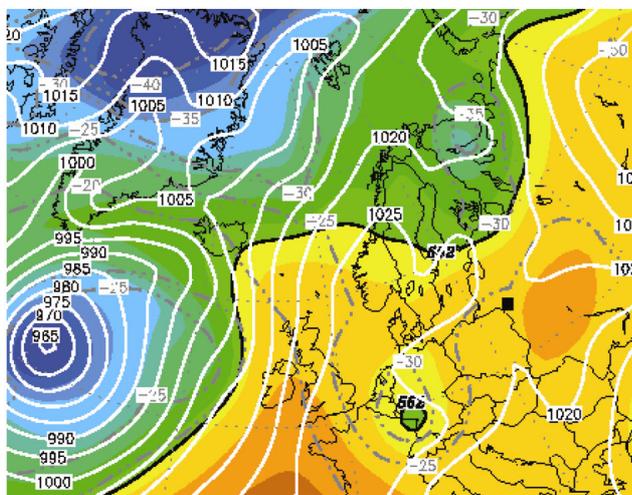


Fig. 5. 20 04 2002

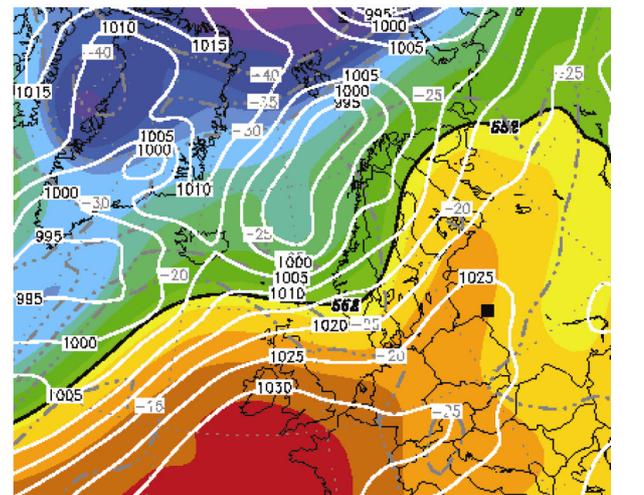


Fig. 8. 23 04 2002

At the HCRF signal registration moment (April 16, 2002) in Vilnius, the daily average atmospheric pressure was 1011 hPa, when the low pressure area was distributed over Lithuania (Fig. 1). This air mass was gradually displaced by the anticyclone moving from the south, which blocked the low pressure area that was formed near Iceland (Figs 4–7). As the anticyclone remained for additional 2–3 days, the positive impulses of HCRF of 21, 15, 17 imp/h were registered on 19 April 2002. This anticyclone gave way to an impending western cyclone on 23 April (Fig. 8).

Another example of a similar situation is presented in Figs 9–18. Here, information on intensive increase of atmospheric pressure in Vilnius was received on 1 November 2003 during the cyclonic activity by the positive impulses of HCRF of 28 and 31 imp/h in the time inter-

vals of 14–15 and 17–18 h, respectively (Fig. 9). Its gradual decrease was observed on 2–3 November under the influence of anticyclonic moving from the south (Figs 10, 11). It blocked the invasion of the next cyclone moving from Iceland and formed the greatest pressure (1040–1044 hPa) in Vilnius on 6–7 November. New information on continuation of anticyclonic activity for next 2–3 days was obtained on 7 November (29, 19 imp/h). Next HCRF signals of 40 and 20 imp/h on 9 November, and signals of 30 and 40 imp/h on 10 November predicted anticyclone’s activity for several additional days. Thus, time of increased pressure in Vilnius amounted to 10 days (Figs 9–18). Meteorological situations from 1 November 2003 till 11 November 2003 are provided in Figs 9–18.

Meteorological situations over the northern part of the Atlantic Ocean and Europe on 1–11 November 2003 (Figs 9–18).

Conventional signs: white thin lines – isobars in hPa, ■ – Vilnius city

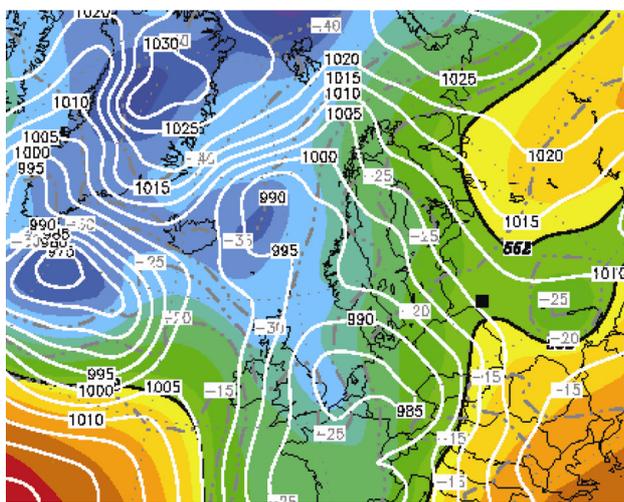


Fig. 9. 01 11 2003

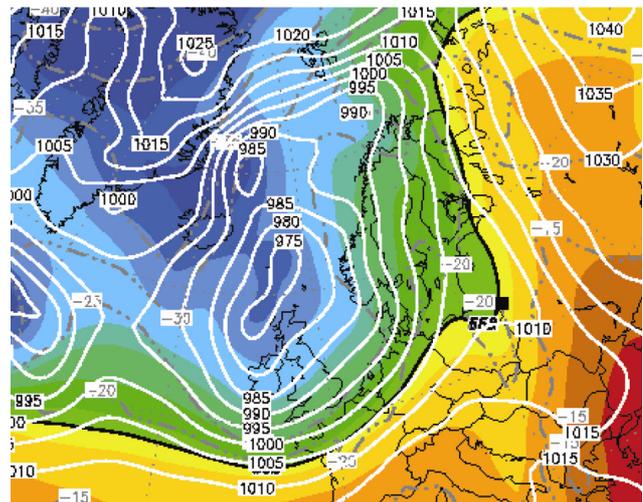


Fig. 11. 03 11 2002

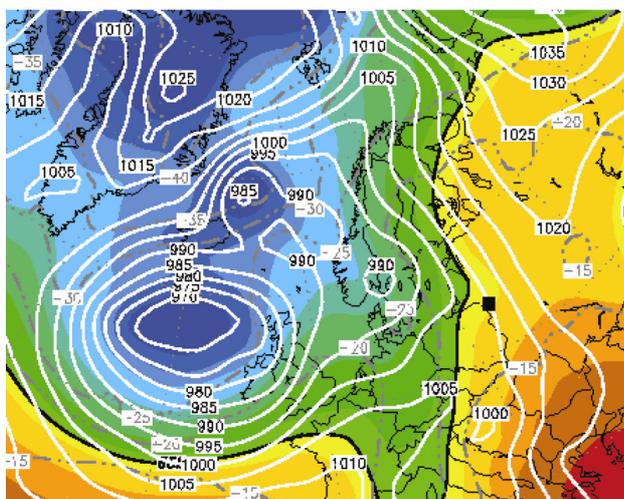


Fig. 10. 02 11 2002

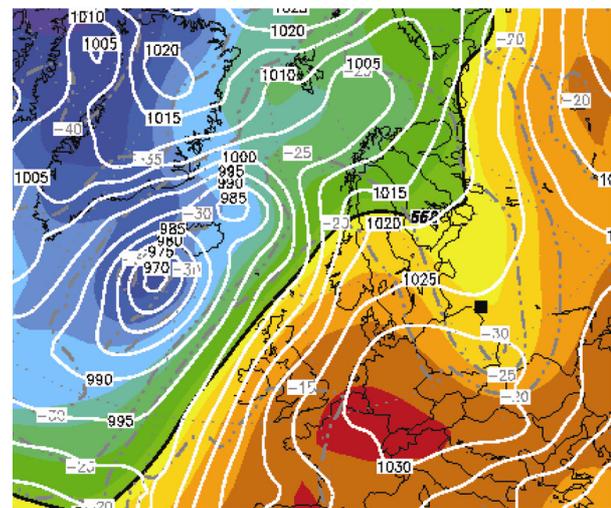


Fig. 12. 05 11 2003

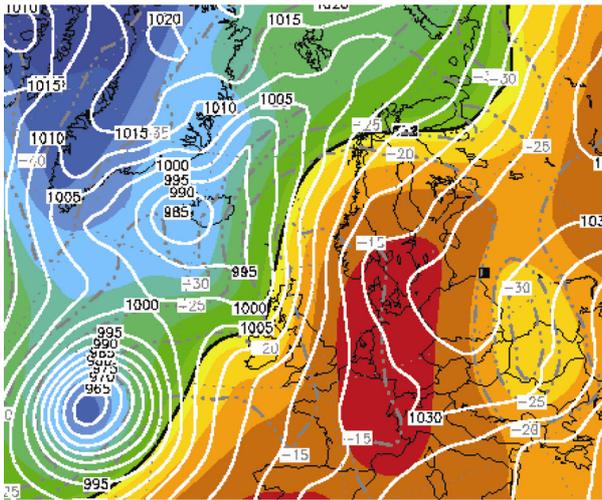


Fig. 13. 06 11 2003

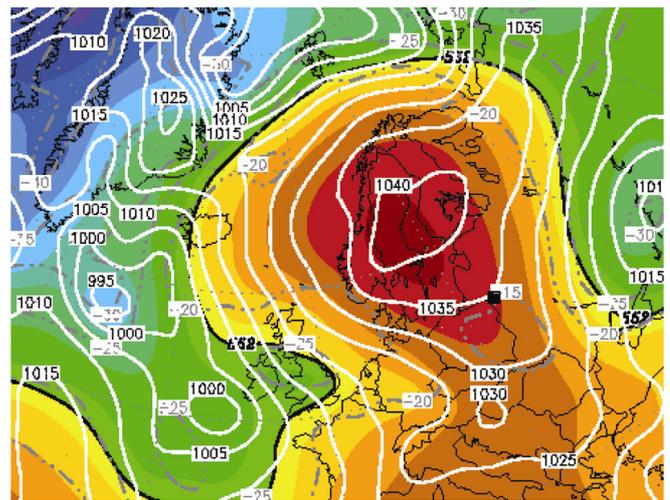


Fig. 16. 09 11 2003

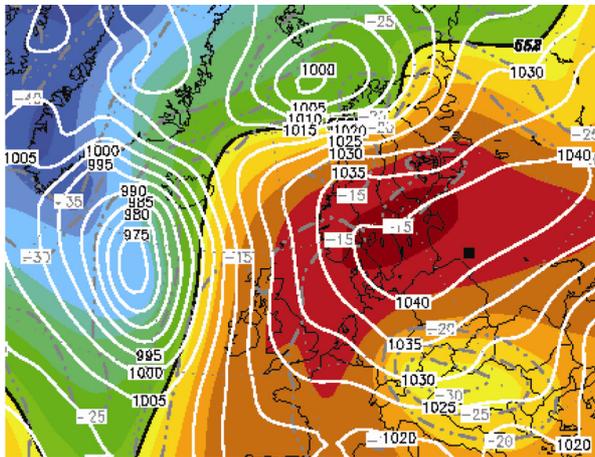


Fig. 14. 07 11 2002

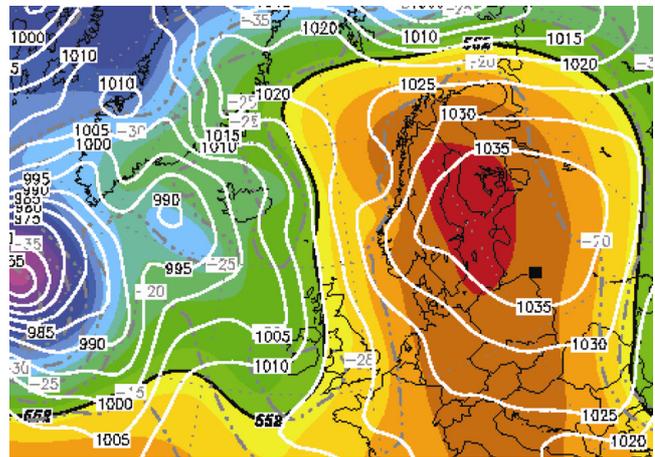


Fig. 17. 10 11 2003

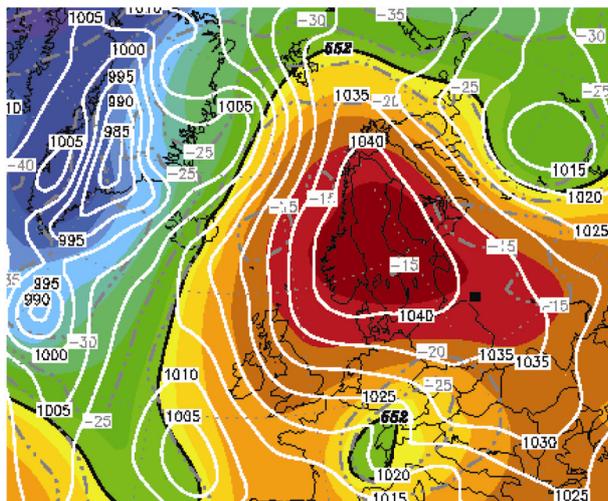


Fig. 15. 08 11 2003

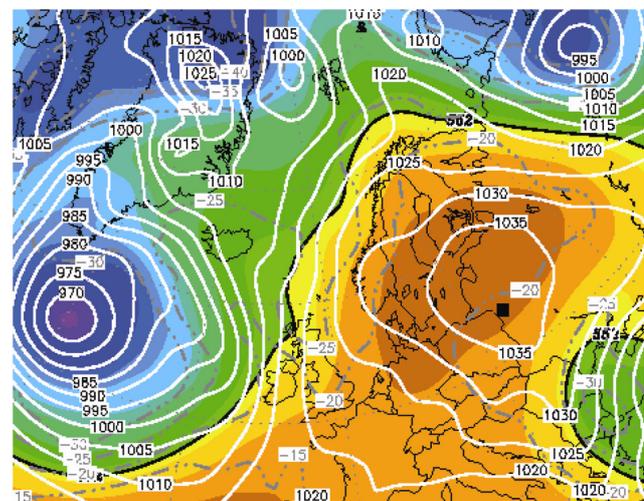


Fig. 18. 11 11 2003

4. Discussion

Any natural phenomenon can be predicted with certain accuracy. For this purpose, it is necessary to understand the information that comes at its formation. In particular, the solution of the problem of prediction of atmospheric pressure increase by HCRF variations is possible under some conditions. The problem of forecast in relation to a decrease in atmospheric pressure by HCRF variations was solved with the use of empirical criteria, i.e. from the numerical value when the investigated effect is the most clear (Styra 2004; Styra *et al.* 2008). A correlation between the HCRF decrease and the decrease in atmospheric pressure was found. In this case, four time intervals from 8 to 13 h. predict an effect (Styra *et al.* 2008). By the HCRF in each of the time intervals it was possible to predict the formation of the lowest atmospheric pressure in Vilnius in 3–6 days (Styro 1984; Styra 2004; Styra *et al.* 2008).

In this paper, the predictive connection between HCRF increase and atmospheric pressure increase in Vilnius (with anticyclonic activity increase) was investigated for the first time. However, the prediction method, which was used in the formation of cyclonic activity is unacceptable in this case. At first, the HCRF increase in the time range of 8–13 hours doesn't predict an atmospheric pressure increase in a few days. The empirical criteria of HCRF for the prognosis of atmospheric pressure decrease are not effective in this case. Thus, it was necessary to find another method for prediction indentifying the connection between the HCRF and atmospheric pressure increase.

Here the 14–19 h period of time was chosen and divided into five-hour time intervals. Forecast of anticyclonic activity was carried out by two or larger number time intervals, corresponding to the proposed HCRF empirical criteria.

It is known that anticyclonic formation is stable, having a low rate of translational motion (relative to the cyclone velocity), therefore to predict exactly a maximum atmospheric pressure formation in Vilnius is impossible. Therefore, this prediction is proposed extension for two days, when maximum pressure takes place.

Using two criteria of HCRF increase, it is possible to predict an atmospheric pressure increase in 2–3 and 4–5 days respectively. The results of information processing are presented in Tables 1–4.

In general, the efficiency of prediction was 53–72% for 2002–2005. However 28–47% of forecasts turned out to be unfulfilled. This is apparently related to those situations where there is a direct transfer of anticyclones.

Sometimes, registering HCRF signals during anticyclonic activity in some cases the next anticyclone moves, but with a lower value of maximum air pressure. Therefore the result is considered as a decrease in pressure, which naturally reduces the efficiency of a forecast. Sometimes anticyclones approach Vilnius to which before 2–5 days positive HCRF signals do not observe corresponding to proposed criteria. It is possible that the used criteria of HCRF increase are not optimum. Since such comparison was conducted for the first time, the

statistics for the four-year period may be insufficient for the choice of the optimal test. In addition, there are possible numbers of factors that directly influence the geomagnetic field and on the primary cosmic radiation and further – on HCRF at the ground surface. The data on the prediction of anticyclonic activity, apparently can be applied in practice in the future. In particular, weather conditions are frequent, when moving from Iceland towards Europe a cyclone lowers its speed. In such situation, errors might occur when predicting the weather in Europe upon the cyclone moving eastward or a blocking anticyclone appears in front of it, which blocks the way. In particular, these examples are shown in Figs 1–18. Unfortunately, information on the formation of blocking anticyclones by the HCRF variations is not always received. Therefore, conclusions regarding these processes can be given with a certain degree of probability, based on statistical observations.

5. Conclusions

1. A predictive connection was found between the HCRF increase in the energy range of 1.2–1.6 MeV and increase of atmospheric pressure to the maximum value in Vilnius. This connection occurs when the HCRF increase has a place in an hourly time intervals from 14 to 19 hours.

2. HCRF increase in intervals of 14–15, 15–16, 16–17, 17–18 and 18–19 h under the proposed criteria of 40 and 50 imp/h forecasts the atmospheric pressure in the observation point in 2–5 days.

3. The efficiency of short-term prognosis of anticyclonic activity in the city of Vilnius in 2002–2005 was in the range of 62 to 72% when using the criterion of HCRF increase of 40 imp/h and more. Using the criterion of 50 imp/h and more, the efficiency of the forecast of pressure increase was lower, i.e. from 53 to 67%.

4. As the anticyclonic formation prediction by HCRF variations is carried out for the first time, the proposed criteria and conclusions in this paper should be considered preliminarily.

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TRUMPALAIKĖ ANTICIKLONŲ FORMAVIMOSI TIES VILNIUMI PROGNOZĖ PAGAL KIETOSIOS KOSMINĖS SPINDULIUOTĖS SRAUTO SVYRAVIMUS

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Santrauka

2002–2005 m. gamą spektrometru Vilniuje atlikti 1,2–1,6 MeV energinio intervalo kietosios kosminės spinduliuotės srauto (KKSS) matavimai. Nustatytas prognostinis ryšys tarp KKSS didėjimo ir atmosferos slėgio padidėjimo po 2–5 parų. Tirta laiko intervalas nuo 14 iki 19 h. Rezultatų analizei šis tarpnis padalytas į penkis laiko intervalus: 14–15, 15–16, 16–17, 17–18 ir 18–19 h. Gautiems duomenims realizuoti praktiškai buvo pasiūlyti dviejų ar didesnio nurodyto laiko intervalų skaičiaus KKSS didėjimo empiriniai kriterijai su sąlyga, kad kiekvieno iš jų KKSS padidėjimas ne mažesnis kaip 15 imp./h, o suminė reikšmė turi viršyti 40 imp./h, arba 50 imp./h. Esant šioms sąlygoms buvo ieškomas koreliacinis ryšys tarp KKSS variacijų ir atmosferos slėgio padidėjimų. Prognozės efektyvumas 2002–2005 m., taikant pirmąjį kriterijų (40 imp./h), buvo 62–72 %, o taikant antrąjį (50 imp./h) mažesnis – 53–67 %. Barinių formacijų iliustravimas patvirtina blokuojančių anticiklonų, kurie užtveria kelią nuo Atlanto vandenyno judantiems į rytus ciklonams, judėjimo prognozės rezultatus. Pirmą kartą nustatytas prognostinis ryšys tarp KKSS didėjimo ir atmosferos slėgio padidėjimo po 2–5 parų.

Reikšminiai žodžiai: kietosios kosminės spinduliuotės srautas, atmosferos slėgis, ciklonai, anticiklonai, trumpalaikė prognozė.

О КРАТКОВРЕМЕННОМ ПРОГНОЗЕ АНТИЦИКЛОНИЧЕСКИХ ОБРАЗОВАНИЙ В Г. ВИЛЬНЮСЕ ПО КОЛЕБАНИЯМ ПОТОКА ЖЕСТКОГО КОСМИЧЕСКОГО ИЗЛУЧЕНИЯ

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Резюме

Измерения и анализ вариаций потока жесткого космического излучения (ПЖКИ) проводились в энергетическом интервале 1,2–1,6 МэВ в г. Вильнюсе в 2002–2005 гг. с помощью гамма-спектрометра. Определялась прогностическая связь между ростом ПЖКИ и увеличением атмосферного давления спустя 2–5 суток. Исследования такой связи проводились ежедневно от 14 до 19 часов. Этот временной диапазон разделялся на пять временных часовых интервалов: 14–15, 15–16, 16–17, 17–18, 18–19 час. Для обработки опытных данных предложены эмпирические критерии, которые определяют ПЖКИ в двух или большем количестве временных интервалов при условии, что его рост в каждом из них на следующие сутки должен быть не менее 15 имп/час, а суммарное значение должно превышать 40 или 50 имп/час. При этих условиях была установлена корреляционная связь между ростом ПЖКИ и увеличением атмосферного давления, эффективность которой для 2002–2005 гг. оказалась 62–72 % с применением первого критерия (40 имп/час), а при использовании второго эффективность оказалась ниже – 53–67 %. Приведенная иллюстрация барических образований подтверждает результаты прогноза смещения блокирующих антициклонов, которые перекрывают путь циклонам, движущимся в восточном направлении со стороны Атлантического океана. Таким образом, впервые установлена прогностическая связь между возрастанием ПЖКИ и ростом атмосферного давления спустя 2–5 суток.

Ключевые слова: поток жесткого космического излучения, атмосферное давление, циклоны, антициклоны, кратковременный прогноз.

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