AN ASTROPHYSICAL ANALYSIS OF WEATHER BASED ON THE SOLAR WIND PARAMETERS

by

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The paper represents an attempt to establish whether the specific processes on the Sun had preceded the sudden weather condition changes in Torino for a selected time period by using the method of analogy. The analysis represents a test on the heliocentric approach, *i. e.*, case analysis which is selected arbitrarily. The results of Mann-Whitney U test on the global level are the basis of the approach to the analysis. In case when 100 MeV protons are observed, the significant difference exists only between the day before the origin of the disturbance and the second day after the origin. At protons in the energy range of 10 MeV, the significant difference exists between the second and the first day before the origin of the disturbance, the day in which it came to the disturbance of the atmosphere, as well as the day after that. Observing 1 MeV protons, the significant difference exists between the second day before the origin of the disturbance in the atmosphere and the next three days (the day before the origin, the day of the origin, and the day after the origin of the disturbance).

Key words: atmospheric conditions, astrophysical parameters, proton, electron

INTRODUCTION

Many authors researched the connection between the solar activity and atmospheric disturbances on the global level [1-3] by applying appropriate statistical procedures. Mann-Whitney U test has been used in this analysis [3]. Based on daily data on the solar activity and cyclones on the whole planet, the results of the test on the global level in the period of 2004-2007 showed that the heliocentric approach could be justifiable. There is a statistically significant difference in the variables representing the solar activity, 1 MeV – protons, 0.6 MeV – electrons, and 2 MeV – electrons, *i. e.*, the solar activity presented by these variables is considerably higher in days when there is a disturbance of the atmosphere in relation to days in which such disturbances are not registered.

The paper represents an attempt to establish the justification of the heliocentric hypothesis about the solar wind (SW) impact on the development of atmospheric conditions for an arbitrary case on the basis of astrophysical parameters (charged particles-protons and electrons). A zero hypothesis is that the mentioned impact must have reflected on an arbitrarily chosen example.

The analysis includes selected weather conditions in Torino (the Piedmont Region, Italy) for February 10^{th} to 26^{th} 2005. The selection of weather conditions has not been tied to any limitations. The only condition was the existence of the relevant measures of representative astrophysical and meteorological parameters for the selected location in the observed time period.

The geographical position of the location chosen for the weather condition analysis in the observed period is given in fig. 1.

MATERIALS AND METHODS

Many papers were published in the last years indicating the connection between the Sun and weather conditions/climate from different aspects [4-8, as well as many others]. Corbyn [9] stated that "traditional forecasts can only go up ten days ahead for any meaningful forecast whereas the solar weather technique can give a detailed forecasts of the extreme weather many months ahead." Studying storms in Britain, Wheeler [10] relied on general aspects of the proce-

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Figure 1. The geographical position of the location chosen for the weather condition analysis (the Piedmont region)

dure Corbyn had used. Those aspects are based on the variations in the Sun's behaviour, its magnetic field, coronal eruptions, and the fluctuating character of the SW. Radovanović *et al*. [11], Stevančević *et al*. [12], and Radovanović [13] also pointed that by working out the heliocentric hypothesis, the long-term forecasts could be done with a special review on the possibility of practical application.

The significance of reconnection has been emphasized by some authors as the process of connecting the interplanetary magnetic field with geomagnetic field under the conditions of the negative resultant vector of the interplanetary magnetic field. Working out the heliocentric hypothesis about the hydrodynamic air mass spreading by the SW, Radovanović *et al*. [14] emphasized the reconnection as one of the most important factors in the weather condition development.

Regarding the previous results in the field on this problem, an attempt is made in this paper to perceive whether the changes in the flux of the energy from the Sun had preceded the sudden changes of weather conditions in Torino in the observed period arbitrarily selected from the 10th to 26th of February, 2005.

Meteorological and astrophysical analysis of atmospheric disturbances in Europe for the investigated period

The initial step in establishing the causality between the processes on the Sun and the disturbances in the atmosphere is to determine the position of coronal holes and/or energy regions. If they are in geo-effective position immediately before the occurrence of a disturbance, a certain linkage can be assumed in the sequence of events. The emission of energy from the geo-effective position has been a special problem in the context of working out the prognostic models. The geometry of some SW jet stream ejections is characterised, from case to case, by different dispersal of particles in space, so that the possibilities are limited for quantitative perception of the energy distribution through the atmosphere even under the assumption of unified dynamics, *i. e*., reduced pulsation. Meloni *et al*. [15] pointed out the significance of the non-static geo-effective position.

RESULTS AND DISCUSSIONS

The data representation of the mean daily air temperatures and daily precipitation amounts in Torino [16] in the analysed period is given in tab. 1. It can be seen that the mean daily air temperature was gradually increasing in this town during the first four days. An exception is the 12th of February. Thereafter, there is a gradual decrease in the mean daily air temperatures with an exception of the 17th of February. From the 23rd of February to the end of the observed period, the mean daily air temperature was gradually increasing again. There was no precipitation in Torino from the 10th to 26th of February, 2005, except the 21st of February when the precipitation amount of 1 mm was measured.

The complex analysis of the synoptic situation was performed, which is significant for the weather in the observed region, through the use of surface

Table 1. Mean daily air temperatures and daily precipitation amounts in Torino

Date (February, 2005)	Mean daily air temeprature [°C]	Daily precipitation [mm]
10	4.6	0.00
11	6.6	0.00
12	5.8	0.00
13	7.4	0.00
14	4	0.00
15	3.1	0.00
16	1.7	0.00
17	2.2	0.00
18	1.7	0.00
19	1.1	0.00
20	–0.3	0.00
21	–1.8	1.02
22	–2.7	0.00
23	–1.6	0.00
24	–1	0.00
25	–0.6	0.00
26	0.1	0.00

weather maps (fig. 2) for the observed period, 850 hPa altitude maps (fig. 3) with geo-potential and temperature, as well as 500 hPa maps (fig. 4), with geo-potential and relative topography, H 500-H 1000 gpdm [17]. (Symbol gpdm represents geopotential decameter and corresponds to about 10 geometric meters).

Figure 2 shows the surface synoptic situation of the 10th (1), 14th (2), 16th (3), 21st (4), 24th (5), and 26th (6) of February 2005, relevant for the weather development in the observed region.

The North Atlantic oscillation (NAO) reflects the barometric systems which influence directly the weather and climate in Europe. On the other hand, NAO is related to solar wind variations [18]. In the initial days of the observed period, the NAO index was noticed to be positive when there was strong Azores anticyclone and deep Icelandic cyclone. Up to February 10th, the Piemonte Region was at the periphery of anticyclone with a centre above Ukraine, with simultaneous deep cyclone development over the North At-

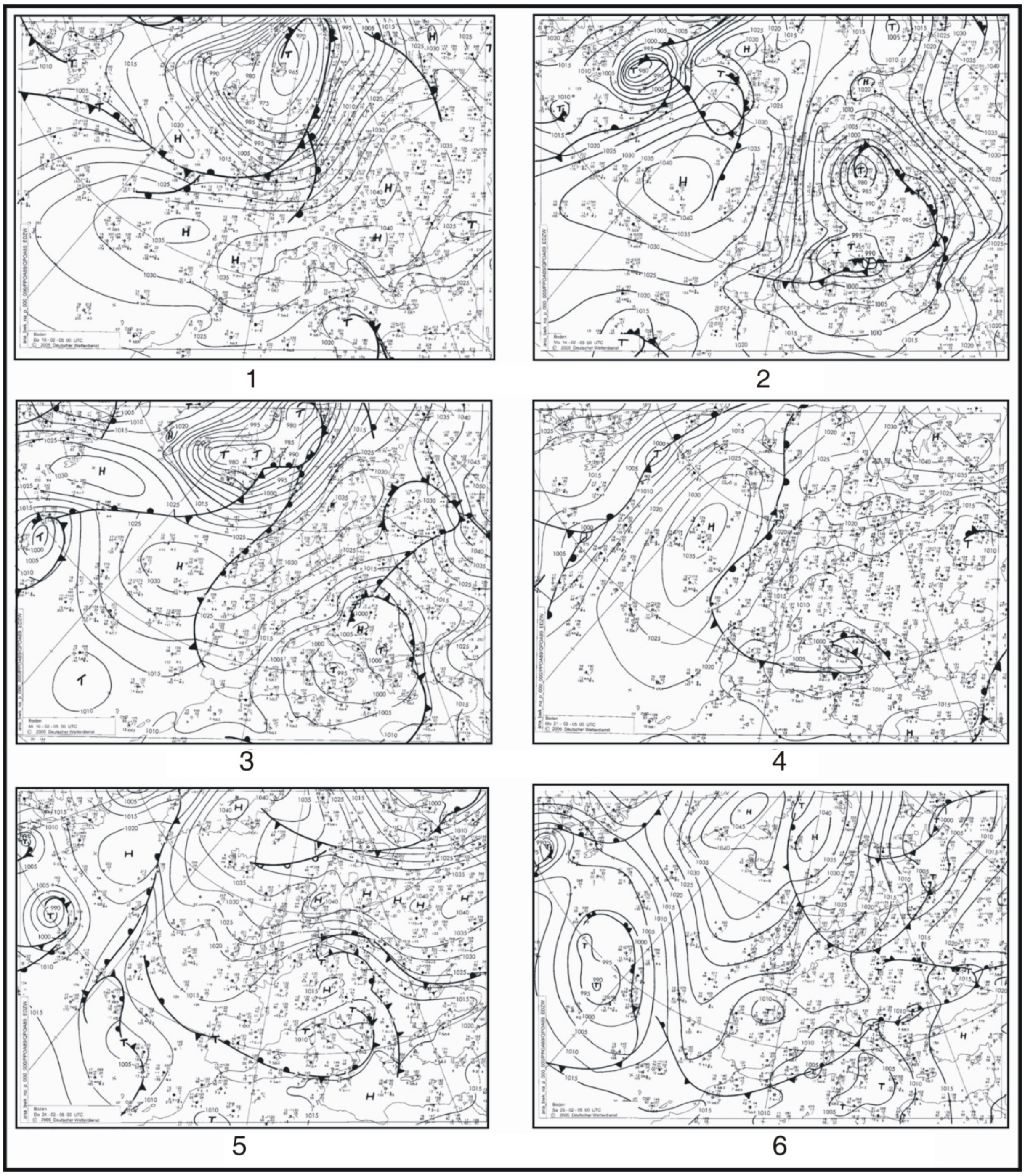

Figure 2. Illustration of an analysis of synoptic situation relevant for weather in the observed region for the investigated period

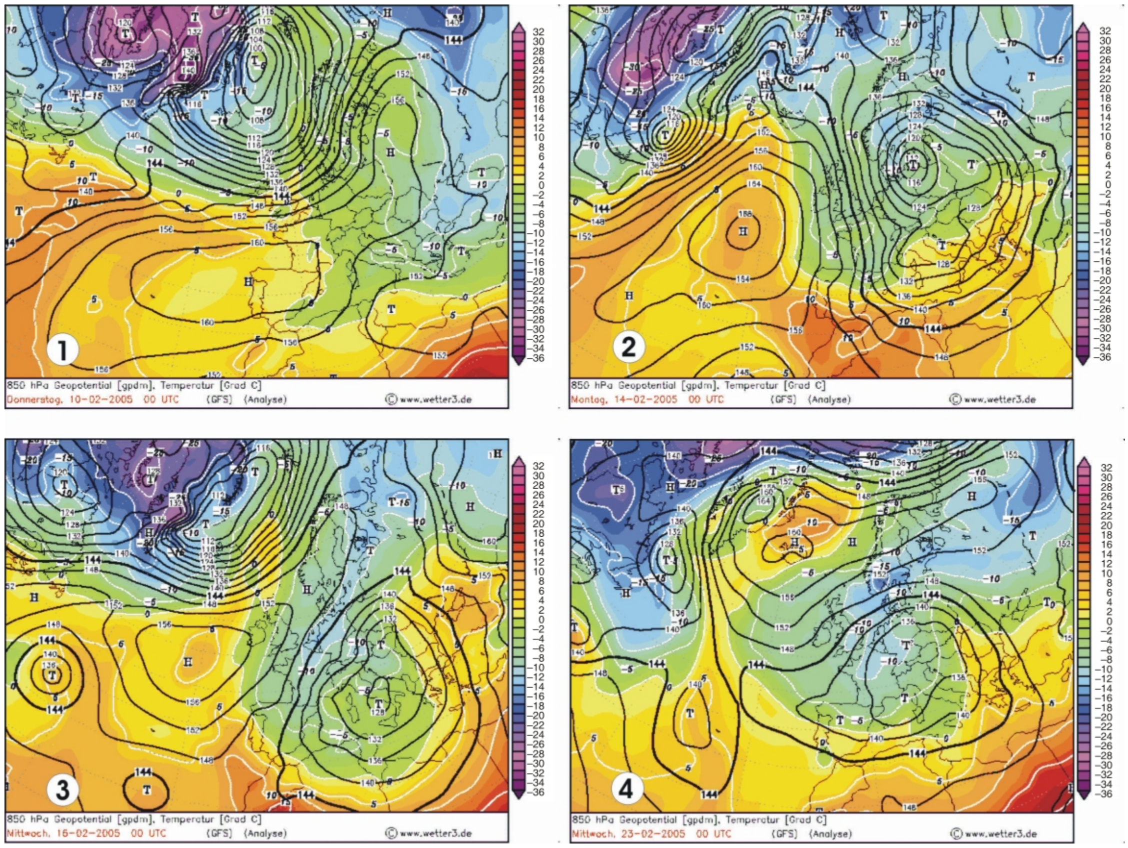

Figure 3. Analysis of geo-potential in gpdm and temperature in °C at 850 hPa for the selected dates in the observed region

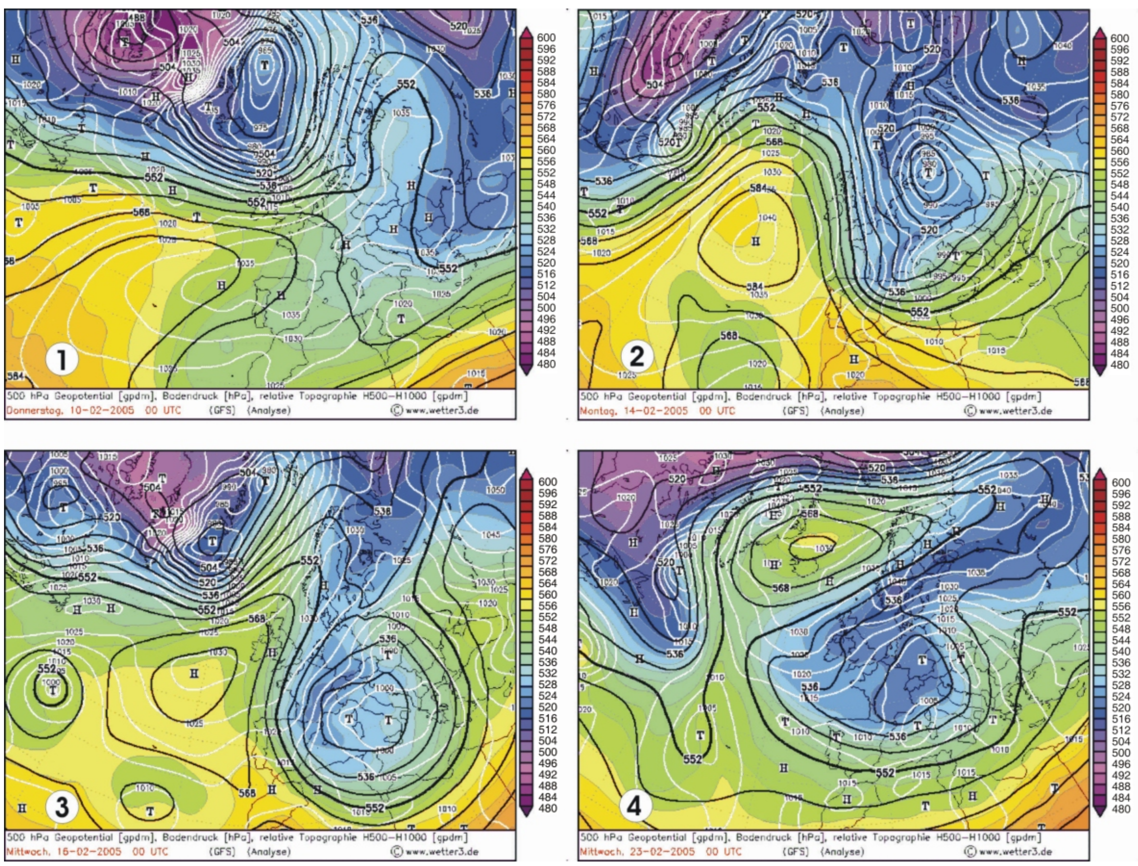

Figure 4. The analysis of geo-potential at 500 hPa and relative topography H500-H1000 gpdm for the selected dates in the observed region

lantic and frontal system spreading over the British Isles and Scandinavia. This situation caused the warm air advection over western and north-western Europe, causing the increase in near-surface air temperature in the area of Torino, fig. 3(1) and fig. 4(1).

The cyclonic field was moving from the Atlantic to the land causing the strengthened wind in broader area from the 11th to 15th of February. Cold air mass moved over the Alps into the central Mediterranean, forming the cyclonic field with a centre above the Adriatic. The deepening of high altitude depressions above greater part of Europe can be noticed from the altitude maps, as well as cutting-off of a deep cyclonic field at the ground over the area of Italy and the Adriatic, fig. 3(2) and fig. 4(2), and its movement towards the east (February 15th).

The 13th/14th of February was the first "critical" date when a cold spell occurred in relation to the previous days, caused by the frontal weather development. On the 13th of February, a relatively high air pressure was above the Apennine Peninsula. Figure 2(2) shows the frontal line that came from the north on the 14th of February. Moving towards the south, the cooled air over the Alps spread over by air masses was also transported towards Italy causing the decrease in air temperature. It is noteworthy that several locations with low air pressure were in the Atlantic on that day. The analysis indicated that advection existed at all heights in lower layers of the atmosphere (850 and 700 hPa) on the 13th, 14th , and 15th of February, and there were also conditions for precipitation to occur, but it did not happen in the analysed case. The reason might be the Foehn effect during the transport of cold air mass over the Alps and its descending in the hold-up zone when it came to the dynamic air warming in the area of Torino, fig. 3(2, 3) and fig. 4 (2, 3).

The geo-potential increase was noticed from the 15th of February, moving eastward with the cold air inflow from the north. On the 15th and 16th of February, the cutting-off of high-level cyclone was noticed at 500 hPa map. New frontal system from the Atlantic, which existed from the 18th of February, penetrated into the European land causing the new deepening of high altitude depression over western Europe and turning of high altitude wind to the south-western direction over the Apennine Peninsula. Simultaneously, deep cyclone was developing near the ground with the centre above the Gulf of Genoa, transferring slowly towards the east and causing advection of cold air over the Alps into the central Mediterranean. On the 21st and 22nd of February, the frontal system waved over Italy causing rain in Torino on the 21st of February. The frontal system was out of the area of Torino on the 23rd of February, when warm advection appeared ahead of the new front, as well as the temperature increase in Torino, fig. 2(5).

The penetrations of charged particles, especially protons, represent the cause of the origin of area of low

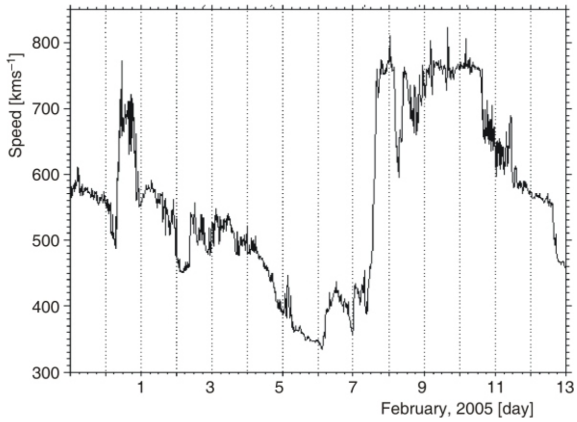

Figure 5. Speed of protons in the first half of February 2005

air pressure, that is cyclonic air mass moving [19]. Figure 5 shows the sudden increase in the speed of protons directed towards the Earth in the period from the 7th to 10th of February [20].

After February 7th, 2005, the speed of protons were noticed to have reached up to 800 km/s.

Beside the increase in speed, fig. 6 shows that an increase in temperature and density of protons also occurred [21].

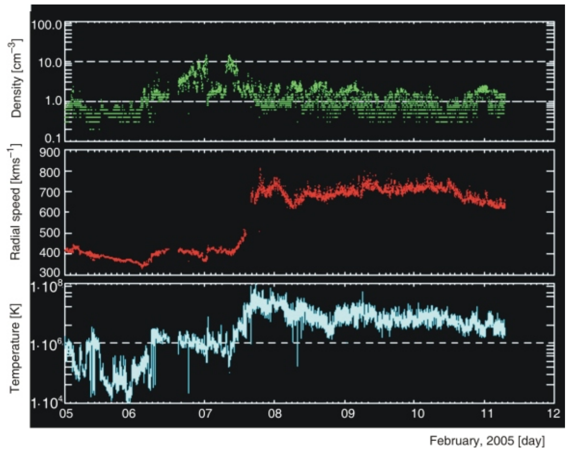

Figure 6. Sudden increase of temperature, speed, and density of protons after February 7th, 2005 [21]

Daily fluence of particles-protons/electrons in the examined period in Torino is given in tab. 2 [22]. It can be noticed that the decrease in the fluence of protons in the energy range of 1 MeV occurred from the 11th of February, while the fluence of protons in the range of 100 MeV continued increasing up to February 15th.

The proton fluence in the period after February 16th 2005 is shown in fig. 7. In the period from the 17th to 20th of February 2005, the proton fluence showed sudden rises in all energy ranges.

Table 2. Daily particles data [22]

Proton fluence per day and sr [cm^{-2}]				Electron fluence per day and sr [cm^{-2}]
Date	>1 MeV	>10 MeV	>100 MeV	>2 MeV
7 February	1.5E+6*	1.5E+4	2.8E+3	3.0E+6
8 February	4.7E+6	1.4E+4	2.8E+3	9.8E+7
9 February	5.2E+6	1.4E+4	2.8E+3	3.4E+8
10 February	6.3E+6	1.3E+4	2.6E+3	4.7E+8
11 February	3.2E+6	1.3E+4	2.7E+3	6.3E+8
12 February	1.2E+6	1.3E+4	2.8E+3	4.2E+8
13 February	1.6E+6	1.4E+4	2.9E+3	7.8E+8
14 February	1.7E+6	1.3E+4	3.0E+3	4.5E+8
15 February	1.5E+6	1.3E+4	3.1E+3	1.2E+8
16 February	9.1E+5	1.4E+4	3.0E+3	4.7E+7
17 February	3.0E+5	1.4E+4	3.0E+3	2.9E+6
18 February	1.4E+5	1.4E+4	3.0E+3	4.7E+6
19 February	1.6E+ 5	1.4E+4	2.8E+3	3.4E+7
20 February	5.7E+5	1.3E+4	2.8E+3	5.2E+7
21 February	2.7E+5	1.3E+4	2.8E+3	3.9E+7
22 February	3.2E+5	1.3E+4	2.9E+3	6.9E+7
23 February	3.5E+5	1.4E+4	3.1E+3	9.9E+7
24 February	5.0E+5	1.4E+4	3.2E+3	7.3E+7
25 February	3.9E+5	1.4E+4	3.2E+3	7.5E+6
26 February	3.0E+5	1.4E+4	3.5E+3	3.8E+6
27 February	3.7E+5	1.4E+4	3.4E+3	8.3E+6

* Read as 1.5 10^6

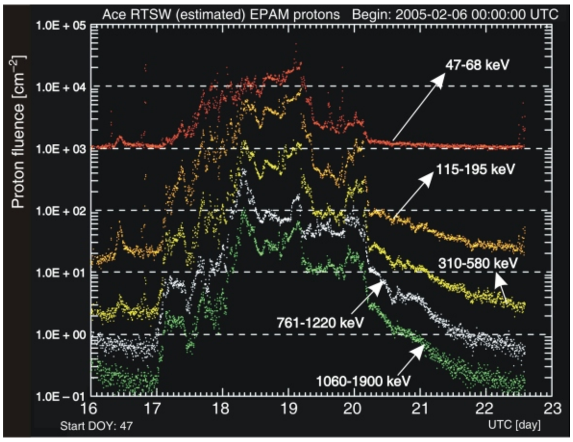

Figure 7. The proton fluence in different energy ranges in the observed period [21]. (UTC means the universal time co-ordinated)

It can be seen from tab. 2 that the air temperature decrease occurred in Torino exactly from the 17th of February, lasting the several following days. The question justifiably arises as to whether the sudden proton flux decline coincided with the air temperature increase in the period up to February 13th.

Figure 8 shows a graphical representation of the mean daily temperatures measured in Torino and the

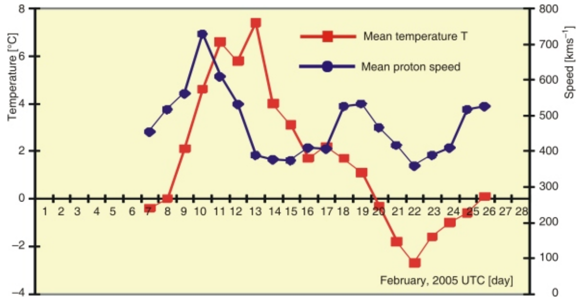

Figure 8. Graphical representation of mean daily temperature measured in Torino and mean daily proton speed obtained on the basis of hourly values

mean daily proton speeds obtained on the basis of hourly values [23]. The use of one station in research is justified in scientific terms [24].

Figure 9 illustrates the histogram of daily electron fluence per day and sr in the examined period.

Pearson's correlation coefficient shows the best statisticly significant relationship (p = 0.01) between electron fluence per day and sr > 2 MeV and mean daily air temperatures, from 0.85, without phasal movements.

Figure 10 shows daily proton fluence in the energy range of 1 MeV.

The decrease in the proton fluence in the energy range of 1 MeV can be noticed after February 10th.

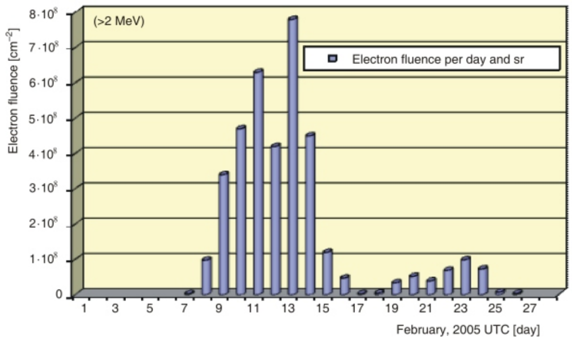

Figure 9. Histogram of daily electron fluence per day and sr, in the examined period

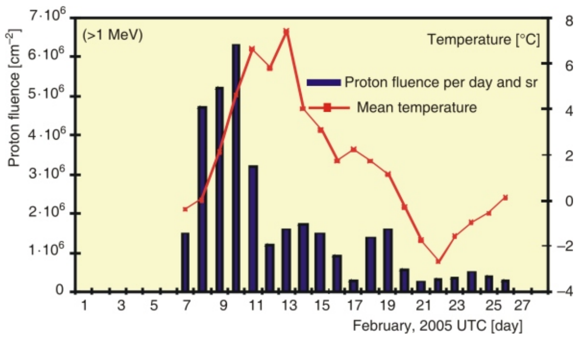

Figure 10. Daily proton fluence in the energy range of 1 MeV

CONCLUDING REMARKS

Assuming that charged particles can be associated with the origin of any form of cyclonic air mass moving, it is necessary to bear in mind the existence of certain temporal difference between the moment when it came to the flux of protons and/or electrons and the origin of a disturbance. A design of superimposed epochs is used with that aim and, considering that it is about the statistically dependent data, the Mann-Whitney U test. The selected level of significance is $p < 0.1$ by which it can be concluded that the statistically significant difference exists. The statistically significant differences between some days are indicated to be appearing at protons only. When 100 MeV protons are observed, the significant difference exists only between the day before the origin of the disturbance and the second day after the origin. At protons in the energy range of 10 MeV, the significant difference exists between the second and the first day before the origin of the disturbance, the day in which it came to the disturbance of the atmosphere, as well as the day after that. Observing 1 MeV protons, the significant difference exists between the second day before the origin of the disturbance in the atmosphere and the next three days (the day before the origin, the day of the origin, and the day after the origin of the disturbance).

Regarding the causative-effective connection at the examined time period, one of the problems in making the conclusions has been the fact that the number of samples (17 days) is relatively small in statistical terms.

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АСТРОФИЗИЧКА АНАЛИЗА ВРЕМЕНА ЗАСНОВАНА НА ПАРАМЕТРИМА СУНЧЕВОГ ВЕТРА

Рад представља покушај да се методом аналогије утврди да ли су у Торину, за одабрани временски период, наглим променама временских стања претходили специфични процеси на Сунцу. Анализа представља тест хелиоцентричног приступа за произвољно изабран случај. Основ приступа анализи представљају резултати Ман-Витнијевог У теста на глобалном нивоу. Код 100 MeV протона значајна разлика постоји само између дана пре настанка поремећаја и другог дана након настанка. Код протона у енергетском опсегу изнад 10 MeV значајна разлика постоји између другог и првог дана пре настанка поремећаја, дана у коме је дошло до поремећаја атмосфере, као и дана након тога. Када се посматрају 1 MeV протони, значајна разлика постоји између другог дана пре настанка поремећаја у атмосфери и наредна три дана (дана пре настанка, дана настанка и дана након настанка поремећаја).

Кључне речи: атмосферска стања, астрофизички параметри, протон, електрон