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Properties of solar X-ray flares and proton event forecasting

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Abstract

X-ray flares and acceleration processes are in one complex of sporadic solar events (together with CMEs, radio bursts, magnetic field dissipation and reconnection). This supposes the connection (if not physical, but at least statistical) between characteristics of the solar energetic proton events and flares. The statistical analysis indicates that probability and magnitude of the near-Earth proton enhancement depends heavily on the flare importance and their heliolongitude. These relations may be used for elaboration of the forecasting models, which allow us to calculate probability of the solar proton events from the X-ray observations.

The models of probability for different kinds of solar proton events are obtained on the basis of all accumulated data of X-ray flares on the Sun and solar proton enhancements near the Earth. These models describe well enough the available data, are suitable for practical use and, really, are already utilized in the IZMIRAN prognostic practice.

However, we should remember about the limitation of accumulated statistics. X-ray flares and proton enhancements have been observed for so short time that any new burst of solar activity is able to add something to our understanding of the relation “solar flares – proton enhancements”.

Keywords: Solar flares; Solar cosmic rays; Solar energetic particles; Proton enhancements; X-ray; Probability model

1. Introduction

The relation between characteristics of solar proton enhancements (SPE) and X-ray flares is a consequence of a simple fact: solar flares and accelerating processes are the parts of one complex of the sporadic solar phenomena (eg. Kahler, 1982). It assumes, that between characteristics of solar proton events and flares there exists, if not a direct physical relation, then, at least, statistical. Other phenomena, such as CMEs and shock waves, bursts in a radio emission, dissipation and reconnection of magnetic fields and so on, enter into the same complex. It seems plausible, that some of these phenomena are connected with energetic particle acceleration processes more obviously, than X-ray emission. However as a possible basis for the solar proton event modeling the X-ray flare observations have some advantages over the other relevant measurements. Thus, in comparison with CME, the observations of X-ray flares are longer, more systematic and more detailed.

For our group the additional benefit was a database which contains data of long term observations of the X-ray flares and solar proton enhancements (Belov et al., 2005a). Studies of the extensive experimental material collected in this database has shown, that the basic properties of the SEPs observable on the Earth, are closely connected with parameters of the associated X-ray flares on the Sun (first of all, with flare peak flux and heliolongitude).

The models, allowing to predict probability and properties of proton increases on the Earth by the data on solar flares and radio burst observations were actively elaborated in the 70-s 80-s of the last century (Belovsky and Ochelkov, 1979; Smart and Shea, 1979; Akinyan et al., 1980; Chertok, 1982; Heckman et al., 1984; Miroshnichenko, 1984; Smart and Shea, 1989; Smart et al., 1993;) and are used at present (for example, Balch, 1999, 2008; del Pozo, 2003; Kahler

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et al., 2007). Even the first versions of such models have proved their practical utility. Since the time of their creation a lot of new data about flares have been collected and more than 1000 new proton enhancements observable at Earth (Belov et al., 2005a) have been selected, that enables to specify parameters of models and expand the area of their application (Belov et al., 2008).

In the given work, the models of probability for various sorts of solar proton events in MeV and GeV energies are considered, which can be used, in particular, for short-term forecasting of energetic solar proton enhancement in a real time mode. For the model elaboration data about solar flares and the close to Earth and ground level SPEs, collected over the whole period of regular solar X-ray observations by satellites of series GOES have been used. Whether the accumulated data are enough to receive reliable prognostic models is one of the questions discussed below.

2. Methods and data

This work is performed with use the X-ray flare and proton enhancement database (see Belov et al., 2005a, where the technique of the event selection and identification with flares is described). Data on soft X-ray radiation are received on satellites of series GOES (ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA). Enhancements of solar cosmic rays are selected on the basis of measurements of protons with energy >10 and >100 MeV by satellites IMP-8 and GOES. For the given study the database is expanded and now it includes all X-ray flares (within a range 1–8 Å), observed from the end of 1975 till July, 2007. During this period 1274 enhancements of various size for solar protons with energy >10 MeV have been selected, 679 of which are associated reliably enough with solar flares. We will name further such flares as the proton flares. The first of them occurred in November 1975, the last in December 2006. Thus, our statistics span practically three complete solar cycles (21–23) and several events at the end of cycle 20 which is well seen in Fig. 1. For the model creation the 53159 flares of ⩾B5 importance have been used, but Fig. 1 demonstrates only part of this amount with ⩾C1 importance.

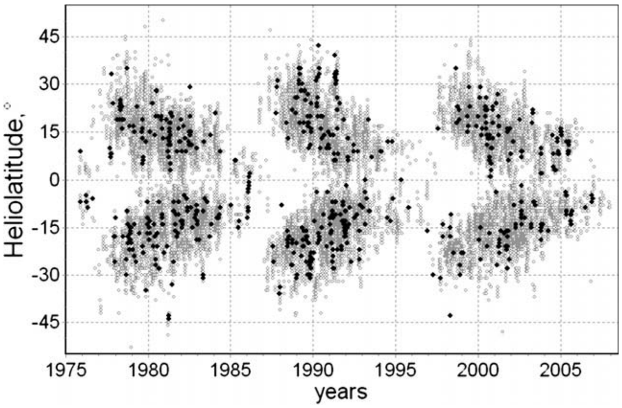

Fig. 1. Butterfly diagram for all X-ray flares with ⩾C1 importance (open circles), and for the flares associated with the proton events (filled circles) in 1975–2007.

The portion of identified enhancements essentially grows with the increasing of proton flux. Enhancements identified with the solar sources give a chance to study correlations and to search for the quantitative relations between characteristics of solar flares and energetic proton enhancements near the Earth. Such relations allow us, in particular, to elaborate the models of proton event probability.

Of many characteristics of X-ray flares which statistically are related to SPEs (Belov et al., 2005a) only two have been used in this work: flare X-ray peak flux and flare heliolongitude. Some other characteristics (for example, heliolatitude) have a relatively weak influence on the radiation conditions in the Earth vicinity. Some others it is difficult to measure in the real time mode.

3. Databases and extreme events

In the given work statistical relations between different phenomena are investigated and their practical utilization is discussed. The question may arise, why statistical analysis of data during many years accumulated is presented to Solar Extreme Event meeting, where recent, most outstanding events in solar–terrestrial physics are usually discussed? Of course, statistics of the large proton events is in fact the statistics of outstanding (and often extreme) events. But this statistics has been formed for a long time and probably is independent on several recent events. Is it so? To answer this question we can consider the events in 2005–2006, i.e. those exactly to topic of this symposium.

From the statistical analysis of the data before 2005 obtained, it is clear that proton events associated with far eastern sources are sufficiently rare and never very large. It is especially true for high energy particles. If study the events where proton flux with energy >100 MeV exceeded 5 pfu (pfu = p $\mathrm{cm}^{-2}\,\mathrm{sr}^{-1}\,\mathrm{s}^{-1}$), the most eastern flare associated with such a kind of events had a longitude of E43. However, flare X17/3B on 7 September 2005, after which proton flux of >100 MeV protons reached 7.4 pfu, occurred at longitude E77. Thus, heliolongitudinal range of sources for the enhancements under consideration widened abruptly by 34° (Fig. 2) and became more than 180°. The longitude E77 is taken from X-ray GOES

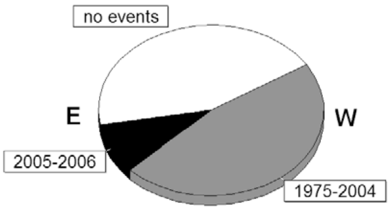

Fig. 2. Heliolongitude range of X-ray flares, associated with >5 pfu flux for >100 MeV protons. Boundaries of sectors are E77, E44 and W125.

observations; by the optical observations (ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA) this flare was located more close to limb, on the longitude E89. If to accept this longitude, which better corresponds to the location of parent active region 10808 at this time, then longitudinal range widening will be not 34° but 46°.

Let us consider all proton events associated with flares located to the east from E60. The maximum >10 MeV proton flux throughout 1975–2004 was observed after X12/3B flare with longitude E70, which occurred on 4 June 1991, and it reached 43 pfu. On 7 December 2006 after flare X6.5/3B with longitude E64 this flux was 1980 pfu, i.e. it turned out to be five times larger. Analogously, maximum flux of >100 MeV protons measured in the same event in 1991 was found about 3.5 pfu, and that flux on 7 December 2006 reached 19 pfu (GOES-11 data), i.e. increased more than five times.

In 2005–2006, some other events have occurred, which may be defined as "record", "anomalous", "outstanding". Flare X9/2N on 5 December 2006 turned out to be the most powerful X-ray flare among all the others related to the phase of the solar activity minimum (we should remind that in December 2006 the smoothed sunspot number was 12.1 only, and monthly not smoothed – 13.6). Never before more than one ground level event (GLE) was recorded through two subsequent years with such a low solar activity (if to estimate it traditionally by sunspot number). During those 2 years we obtained three GLEs: 17 and 20 January 2005 and 13 December 2006. With this, in the event on 20 January the biggest count rate increase ever registered by standard neutron monitors (NM) was recorded. Not only GLEs, but SEP events were frequent enough during those years. Hudson (2007) paid attention to a big (for this phase of the solar cycle) number of SEPs in 2004–2006. In accordance with our data base during those three years 33 solar proton enhancements occurred, with maximum flux >10 pfu, 22 of which fell on the years of 2005–2006. For a comparison, there were eight such events in 1984–1985, and during 1994–1995 – only three events.

Thus, we see that the events in 2005–2006 essentially changed statistics of X-ray flares, of proton enhancements and the relationship between those events as well. Herewith, those changes concerned also our understanding of extreme events in this field. Does this mean some real long term shifts in solar activity? Hopefully we have not a reason for such assumptions. On the whole, the years of 2005–2006 is a relatively quiet period in solar life (by the number of sun spots, by solar radio flux and X-ray background), and consequently, quite a quiescent 2007 came after. The abundance of the news may be explained by the short history of the proton event observation, and especially, X-ray observation. In fact our database is small. It is a small random sample from the long solar history which does not allow us to make final conclusions about general distribution. Indeed, all the events have been collected for three solar cycles. But this is only three cycles of 24 numbered. And even 24 solar cycles, as the whole period of solar scientific observations, is a negligible small part of the solar history accounting billions years. It means, in particular, that those events which we name now as "extreme" in fact are placed deeply enough in a distribution of all events, and real extreme events are absent not only in our data base but probably unknown at all to the science. Indeed, proton events during the last years yield in the magnitude to proton enhancement on 23 February 1956 (Smart and Shea, 1990; Belov et al., 2005b). This is true at least for high energy solar particles. As Smart and Shea (1991) showed, the high energy proton events of even bigger power were observed in the 18 cycle by means of ionization chambers. The events with the biggest proton fluence for energy >30 MeV were discriminated by Shea et al. (2006) using indirect nitrate data over the last 450 years. In recent cycles the biggest fluence of such particles was observed in August 1972 – and, already this period is beyond the time boundary of our study. But in more remote history 19 events were found with bigger fluence than that in August 1972. The largest proton enhancement was likely associated with Carrington flare in 1859 (Carrington, 1860; Cliver, 2006; Smart et al., 2006). Extending of time interval increases the number of large proton events and confirms that extreme events included in our statistics are conventionally extreme events.

4. Some properties of the proton flares

If our sample were compatible with general distribution of SEP events, it would be possible to get reliable models, having used only a part of the accumulated data. But our sample includes only small part of events, and we have to study and use all available data.

Belov et al., 2005a) showed that probability of proton events correlates with peak flux and heliolongitude of X-ray flare. Let us check this conclusion on the extended data base.

The Fig. 3 shows, that proton flares are met among powerful X-ray flares very often, and there are no flares among the most powerful (>X10, i.e. with maximal flux >0.001 Wt/m^2) which have not been associated with proton enhancements. With approach to east solar limb the quantity of proton flares quickly decreases, whereas at western limb a lot of such flares are observed (see also e.g. Bazilevskaya and Sladkova, 1986; Shea and Smart, 1996). Let us remember that hereinafter we name as "proton" only the flares associated with the protons registered at Earth. If to discuss all flares connected with accelerating processes, it would be necessary to assume, that their distribution on heliolongitude is close to uniform. Proton flares are mainly powerful flares, located in a definite longitudinal sector centered in the western part of a visible solar disk. The analysis shows, that there is a wide enough area of western longitudes inside of which the probability of proton event depends poorly on a longitude, but outside this strip with removal from it the probability falls quickly. Therefore far eastern flares and the majority of flares on the invisible part of the Sun have practically no

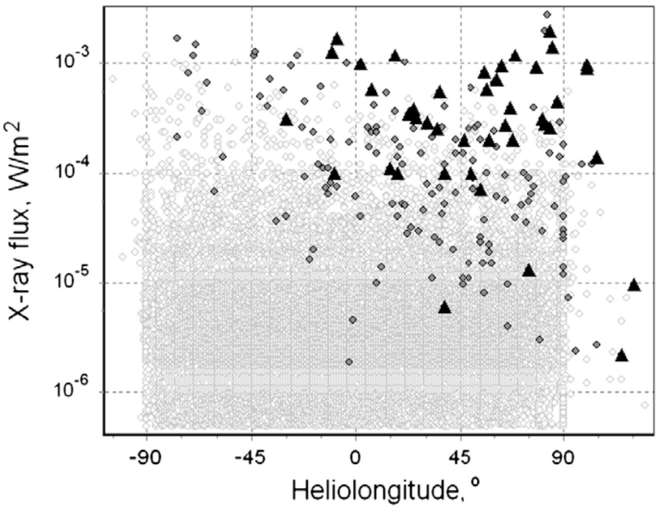

Fig. 3. Distributions by importance and by heliolongitude of all X-ray flares (open circles), flares associated with >10 MeV proton flux >10 pfu (diamonds), and flares associated with GLE (triangles) over the period 1975 September–2007 July.

chance to become proton flares. The dependence on the X-ray peak flux is more clearly seen in Fig. 4. In order to plot it the flares of western longitudes within W0–W80 have been selected. These flares were divided by groups with the following X-ray importance: <C1, C1–C2.9, C3–C9.9, M1–M2.9, M3–M9.9, X1–X2.9, X3–X9.9, ⩾X10, and for each group the portion of proton events of different type was calculated. It is possible to see, that with increase of flare power the probability of its association with high energy protons grows quickly and at certain, big enough X-ray power reaches 100% limit. It is clear, that the further increase of a peak flux cannot make the probability higher. Fig. 5 shows a dependence on heliolongitude of the mean power of all flares, of proton flares and flares associated with GLE. Some increase of averaged power to limbs at all flares appear due to the problem that limb flares are hard to identify optically: only the brighter X-ray flares are identified with Ha flares and determine their locations. Mean power of proton and essentially GLE flares depends more strongly on the longitude than power of all X-ray flares. Relatively weak flare on suitable western longitudes has more chances to be the proton one than more powerful eastern flare. If consider a quantity of flares registered on various longitudes it turns out to be a gradual falls with approach to limbs. However, directly at limbs, on the E90 and W90 this number is significantly higher than near limb and even in central regions. To the limbs, apparently, not only behind-the-limb flares are attributed, but also the part of near-the-limb ones. This fact should be considered in a definition of longitudinal dependence of models. Model calculations are performed for various types of proton enhancements and some properties of flares associated with various enhancements are given in the first columns of Table 1.

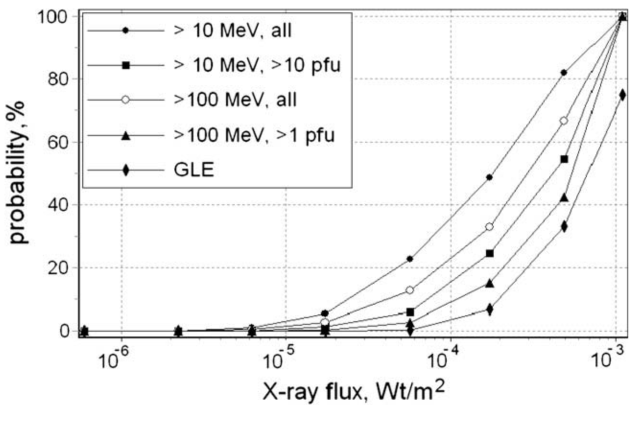

Fig. 4. SEP probability versus X-ray flare peak fluxes for western flares (W15–W75). Flux 10^{-4} Wt/m^2 = X1 importance.

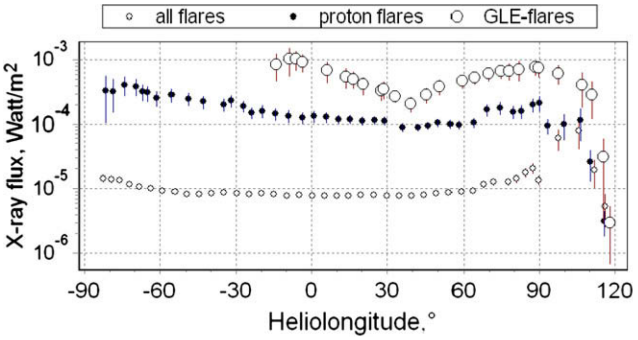

Fig. 5. Heliolongitudinal dependence of the mean importance of all X-ray flares, flares associated with >10 MeV proton enhancements and flares associated with GLEs.

5. Model of SEP probability

The model of proton enhancement probability p_{s} has been searched as

$$p_{\mathrm{S}}(I_{\mathrm{x}},\varphi)=f_{\mathrm{x}}(I_{\mathrm{x}})f_{\varphi}(\varphi),\qquad(1)$$

where $f_{\mathrm{x}}(I_{\mathrm{x}})$и$f_{\varphi}(\varphi)$ are the functions of importance and longitude of flare. For function $f_{\mathrm{x}}(I_{\mathrm{x}})$ the forms $(I_{\mathrm{x}}/I_0)^{\gamma}$ and $1-\beta\exp(-\alpha I_{\mathrm{X}})$ have been checked, the results for first of them turned out to be definitely superior. For longitude dependence $f_{\varphi}(\varphi)$ the next functions were checked: $\cos^n((\varphi-\varphi_0)/(2\pi\sigma_{\phi}))$ and $\exp\left[-\left(\frac{(\varphi-\varphi_0)}{\sigma_{\varphi}}\right)^k\right]$, where k parameter was equal 2 or 4. Exponential form was found surely more preferable, the models with $k=2$ and $k=4$ demonstrated almost the same quality with small advantage for $k=4$. The following description of probability was finally chosen:

$$p_{\mathrm{S}}(I_{\mathrm{x}},\varphi)=\begin{cases}\left(\frac{I_{\mathrm{x}}}{I_0}\right)^{\gamma}\exp\left[-\left(\frac{(\varphi-\varphi_0)}{\sigma_{\varphi}}\right)^4\right] & (I_{\mathrm{x}}<I_0)\\ \exp\left[-\left(\frac{(\varphi-\varphi_0)}{\sigma_{\varphi}}\right)^4\right] & (I_{\mathrm{x}}>=I_0)\end{cases}\qquad(2)$$

Parameter I_0 in $f_{\mathrm{x}}(I_{\mathrm{x}})$ is the threshold peak flux. On the suitable longitudes the probability p_{s} reaches 100% limit at $I_{\mathrm{x}}=I_0$ and increase of X-ray power above I_0 has no influence on p_{s}. It means, in particular, that in real time

Table 1
Characteristics of proton enhancements and associated solar flares

Ep (MeV)	I_{PC}, pfu	N	N_I	I_{XM}	φ_m°,	γ	I_0	φ_0	σ_φ,°	$p_s > 50$	$p_s < 1$	P_1, X1 45°W
>10	0.05	1274	679	M4.9	36	0.91 ± 0.10	2.4 ± 0.7	35 ± 12	82 ± 12	72	0.24	45.9
>10	1	595	430	M7.5	37	0.93 ± 0.10	5.3 ± 1.0	30 ± 12	97 ± 13	72	0.11	21.2
>10	10	275	215	X1.3	42	1.06 ± 0.12	8.0 ± 1.3	34 ± 12	101 ± 13	76	0.05	11.0
>10	100	100	94	X2.6	46	1.41 ± 0.18	7.8 ± 0.9	42 ± 8	87 ± 8	72	0.04	5.5
>100	0.01	637	399	M7.5	43	0.88 ± 0.10	6.4 ± 1.3	35 ± 14	103 ± 14	72	0.15	19.5
>100	1	120	107	X2.4	52	1.30 ± 0.16	9.3 ± 1.3	43 ± 14	99 ± 12	79	0.03	5.5
>100	10	46	45	X3.3	51	2.00 ± 0.33	8.8 ± 0.7	54 ± 5	63 ± 5	72	0.02	1.3
GLE	–	44	44	X3.2	55	2.02 ± 0.30	8.8 ± 0.6	54 ± 5	63 ± 5	72	0.02	1.2

Explanations: Ep – kinetic proton energy; I_{PC} – minimum threshold of the proton flux; N and N_I – number of all and flare associated solar proton events; I_{XM} – mean importance of the X-ray flares (averaged by logarithms), estimated for the events within E85–W85 longitude range; φ_m – is taken as mean longitude of the flares, associated with GLE and large SEP events, and as median longitude for all other events, magnitudes of I_0 are given in 10^{-4} Wt/m^2 and all probabilities (p_s, p_1) – in %.

mode we could obtain the final evaluations for efficiency of the solar event before X-ray maximum if the X-ray flare reached sufficient power.

Parameters I_0, γ, φ_0, σ_φ were derived by the least square method using all flares with importance >B5. The observed probability was taken as 1 if flare was associated with observed proton event, and it was attributed to 0 for all other cases. As has been obtained in the test calculations it is insufficient to use the visible flares only. In this case the solution is not stable and strongly dependent on the longitudinal distribution. It is necessary to use the fact: for majority of invisible longitudes the proton flares are absent. We assumed that on such longitudes only nonproton flares occur and these flares are distributed by importance as all visible flares. The contribution from majority of invisible flares is 0 independently on longitude. The exclusion is the western behind limb sector (conditionally, W90–W150) where proton flares occur sometimes. Their longitudinal distribution is obviously not homogeneous, but we do not know this distribution. Therefore we were forced to exclude the western behind limb sector from calculations. It was possible to use the nearest western behind limb sector only for two high energy kinds of proton events (GLEs and >100 MeV, >10 pfu), where we know the longitudes of associated flares. For these two kinds of proton enhancements the calculations were accomplished within E103–W103 longitude range. For all other kinds the calculations were performed in the range E210–W90. Parameters I_0, γ, φ_0, σ_φ calculated for a model presented by Eq. (2) are given in Table 1.

Usual criteria of the model quality, such as residual dispersion or correlation coefficient, are not very informative in the case of the probability model. One of the criteria very often applying to an estimation of such models quality is a climatological skill score (e.g. Murphy and Epstein, 1989):

$$SS = 1 - \frac{\sum (p_s - p)^2}{\sum (\langle p \rangle - p)^2} \tag{3}$$

where $\langle p \rangle$ – is average occurrence rate (number of proton events/number of flares). The magnitude of SS criteria was calculated for all flares observable within longitude range E85–W85 and for different types of proton events it turned out to be ranged from 0.206 (all proton enhancements with energy >100 MeV) up to 0.283 (proton enhancements with energy >100 MeV and maximum flux >1 pfu). For the SPEs with energy >10 MeV and maximum flux >10 pfu it was obtained $SS = 0.246$. This value is close to $SS = 0.230$, estimated by Balch (2008) for the same sort of enhancements. Balch implemented the model SWPC/NOAA to the 3783 X-ray flares, recorded over the 1986–2004, 127 of which were associated with significant proton enhancements.

To estimate a model quality under extremes of probability p_s we calculated mean observed probabilities of the solar proton events for the cases when $p_s > 50\%$ and $p_s < 1\%$. These values are present in Table 1 (in percentage), and they testify sufficiently successful work of the models for all types of the enhancements. For example, in 13 of 18 events where calculated model probability gave for GLE >50%, the ground proton enhancements were really observed. And of 31231 events with $p_s < 1\%$ the GLEs were recorded only in five cases. We can judge about the accordance of simulated and experimental probabilities of proton events by Figs. 6 and 7. The treated models are approximately equally effective to all types of enhancements. However, the parameters of these models strongly differ. One can see that probability dependence on the SXR flare importance is stronger for the large SEP enhancements than for the small ones. Index γ for the smallest enhancements is ≈0.9, and it is about 2 for the largest events. By the similar way (from X2.4 to ≈X9) changes critical peak flux I_0 of the SXR flare, which is sufficient to provide the 100% probability of the small and large proton enhancements after ideally located flares. On the whole, the weaker proton enhancements the wider longitudinal range of associated flares (parameter σ_φ varies from 63° for large (>100 MeV, >10 pfu) proton events and GLEs up to ≈100° for a greater part of the remained enhancements).

The sector of the effective heliolongitudes is located mostly to the west ($\varphi_0 = 54°$) for large and ground level enhancements. For relatively small enhancements this region is shifted closer to the central meridian and

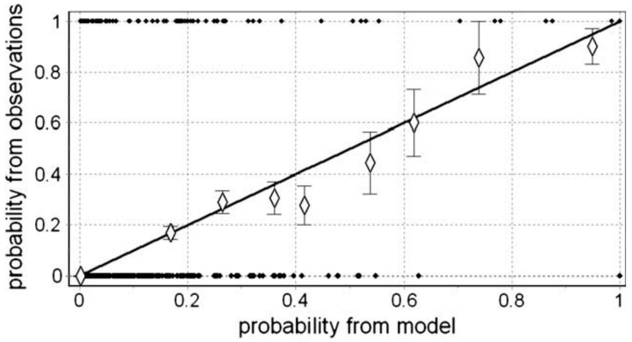

Fig. 6. Correlation between simulated p_s and observed probabilities of the >100 MeV proton enhancements with flux >1 pfu. Points mark flares associated (upper line) and not associated (lower line) with this kind of proton events. Diamonds are averaged experimental probabilities corresponded to different ranges of p_s.

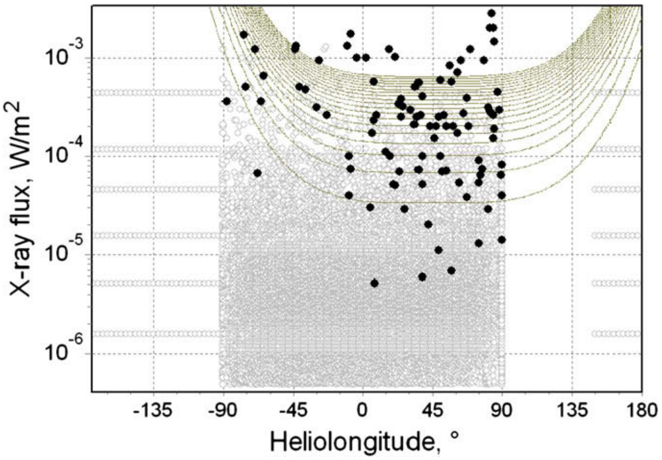

Fig. 7. X-ray flare distribution (light points) by flare importance and heliolongitude. Dark points of larger size represent the flares, associated with the >100 MeV proton enhancements with flux >1 pfu. Contour curves are depicted for equal simulated probability p_s; inside contour corresponds to probability of 50%, outer one – to 1%.

$\varphi_0 = 30–35°$. To make the dependence of calculated probability on energy threshold and magnitude of the proton enhancement more presentable, we added in Table 1 a probability p_1, calculated for definite flare of importance X1 and longitude W45. For such flares model forecasts weaken proton enhancements (above the background for >10 MeV) almost in a half of events. At the same time for such flares the most outstanding enhancements (>100 MeV, >10 pfu and GLE) are expected only in one case from 80.

6. Conclusion

The models of probability for different kinds of solar proton events are obtained on the basis of all accumulated data on X-ray flares on the Sun and solar proton enhancements near the Earth. These models describe well enough the available data, are suitable for practical use and, really, are already applied in the IZMIRAN prognostic practice. It is important to note that the model does not use an assumption about flare generation of all or the majority of solar cosmic rays, and the resulted statistical relations are not fruitful to use as an argument for such an assumption. However, the received results can speak well for two others, less strong, statements. The first one is that greater part of high energy protons near Earth observed arrives from the area of intermediate size and with the centre located closely enough to the associated flare. The angle size of this area is less than minimal value of σ_ϕ in probability models, but at the same time it can be much more than the size of flare. The example of such area could be a zone above the whole parent active region or its significant part. The second statement is that inside of complexes of the solar sporadic phenomena there is a steady enough proportionality between energies released in the soft X-ray radiation and in the high energy protons.

In any case it is possible to use this model as directly for a short time forecast based on X-ray observations, and for the long term forecasting in a combination with the forecast of X-ray flares. At the same time, the given model is far from perfect; it is possible and necessary to be improved. Only several of possible dependencies of probability on the flare peak flux and its longitude have been checked. The longitudinal dependence may be very likely improved. Apparently, the model can be improved if to use additional information on initial phase of X-ray flare and flare latitude. We may also hope to make a better model quality if to replace or add to X-ray power the characteristics of high frequency solar radio bursts, which are more directly connected to accelerating processes than soft X-rays. Obviously the spectral radio bursts are useful as additional input to the models (type II burst, in the first turn), and NOAA model (Balch, 2008) incorporates it successfully. Unfortunately, this information is not always accessible in real time and is often delayed relatively to X-ray measurements.

We should not forget about limitation of our statistics. Our data set is still so short that the coming next years are able to change it. We were able to obtain sufficient amount of data on the solar–terrestrial relations to create working and useful model. However, it does not mean that we know the exact law combining X-ray flares and solar proton enhancements. We studied too small part of solar life, and have rather poor information to get accurate quantitative relations between solar and near Earth events. We can apply our models with high efficiency but not because we know well the “eternal” dependencies. The performance of such kind of models is based mainly on the inertness of the described system – this allows us to hope that, for example, the models calculated by the data for over 32 years will only be slowly changing during the next several years. However, they may be noticeably varied for the next solar cycle. The models of such a kind need to be often reconsidered and refined, and it should be possibly done after each new proton event.

It is clear that the model of probability should be added with the estimations of maximum proton flux near the Earth (or in some other points) and its time delay relatively to solar event. It may be realized using the same data and similar approach to their processing. In result the chance of more detailed prognosis of proton enhancements (in particular, an estimation of their full fluence and prognosis of their full time profile) may be obtained.

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