Opinion

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On space weather prediction

Abstract

One of the important tasks of space weather prediction is to forecast the arrival of sub–cosmic ray particles and the onset/intensity of geomagnetic storms after solar flares. For these purposes, it is necessary to predict the onset/intensity of solar flares, to track the transit (or propagation) of coronal mass ejections (CMEs) in interplanetary space and finally to estimate the power (erg/s or w) produced by the interaction between CMEs and the magnetosphere. I find that a much more integrated and coordinated effort is needed than in the past in advancing the present space weather prediction. A few suggestions are provided for this purpose.

Keywords: space weather prediction, solar flares, CME, geomagnetic storms

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Syun Ichi Akasofu
International Arctic Research Center, University of Alaska Fairbanks, Alaska, USA

Correspondence: Syun Ichi Akasofu, International Arctic Research Center, University of Alaska Fairbanks, PO Box–757340 930, Koyukuk Dr. 415, Akasofu bldg Fairbanks, Alaska 99775–7340, USA, Tel 9074746012,
Emails sakasofu@iarc.uaf, sakasofu@alaska.edu

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Opinion

Solar flares

Unfortunately, the prediction of the onset time/ intensity is in a poor state. So far, there has been no quantitative effort, and only possible precursors have been discussed.[1] In general, it is firmly believed in solar physics that an anti–parallel magnetic configuration for magnetic reconnection is supposed to produce flare energies, so that the main efforts have been devoted to find such a magnetic configuration. However, Sheeley NR et al.[2] had already pointed out: "reconnection occurs much more often than flares, thus usually occur without them".

Instead, in order to advance the prediction capability, it is important to recognize that solar flares are a manifestation of electromagnetic energy dissipations, so that they require the power $P\left(erg/s \ or \ w\right) = V\left(B^2/8\pi\right)S$, where B is the speed of photospheric plasma, B the magnetic field intensity and S the dimension of interaction; assuming a plasma flow in a magnetic arcade and taking a typical set of these quantities (V = 1 km/s, B = 100 G, the area S = [(L = rectangular size = 5x 10^4 km) x (depth d = 1000 km)], the resulting power is P = 2.0 x 10^{26} erg/s. This is the amount of power which is needed for the minimum energy of flares 10^{30} erg which last for one hour.[3]

Thus, an important task in predicting solar flares is to monitor the power P and resulting accumulated energy. If the power (P x the [the duration of magnetic shear *before flare onset in an active region or where the precursors are present*] reaches 10^{30} erg, the occurrence of weak flares could occur. If the accumulated energy (P x the duration) exceeds 10^{30} erg, a more intense flare is expected. If the accumulated energy exceeds 10^{32} ergs, a great flare might be expected. For a practical purpose, it is important to monitor VB^2L for a number of events and get some idea about the accumulated energy, since the depth d may not be readily available.

It is known that sub–cosmic ray particles are produced by most intense flares. Since their arrival time is not so much different from the arrival of light, it is crucial to make the power/energy estimate of flares (say, 10^{32} ergs), particularly for the safety of future lunar basis and the polar cap absorption, which disturbs radio communication across the polar region.

CMEs

At the present time, there is no definitive theory as to how CMEs are launched, so that the initial density n and the magnetic intensity B cannot be initialized in simulating them when CMEs arrive at the front of the magnetosphere. In order for CMEs to leave the sun, their acceleration must exceed 2.7 x 10^4 cm/s^2. Chen J et al.[4] suggested the Lorentz force; in this respect, it is useful to know that a dark filament above a magnetic arcade disappears or erupts at flare onset and that electric currents flow in the filament.[5]

Simulation studies of the transit of CMES have been made by many researchers and are partially successful in predicting the arrival time of CMEs at the front of the magnetosphere. The trackings of CMEs after leaving the sun by space probes are useful, but for a practical purpose, space probes do not stay too long between the sun and the earth, so that a continuous ground–based observation is needed. So far, radio star scintillation has been considered in detecting CMEs in their midcourse,[6] but an internationally coordinated effort is needed for continuous observations during their transit.

Geomagnetic storms

The power resulting from the CME–magnetosphere interaction is given by $V\left(B^2/8\pi\right)S$, where $S = \sin^4\left(\theta/2\right)l^2$, where θ is the polar angle of the IMS and l is 5 Re (Re= the earth's radius). The polar angle θ is the most crucial quantity, because even if VB^2 is very large, the power P = 0, if $\theta = 0°$.

At the present time, the prediction of such a crucial quantity θ (or even the IMF Bz component) is not possible. This is the reason of many failures of predicting the intensity of geomagnetic storms and the occurrence of the aurora in the past. Tang F et al.[7] attempted to examine the relationship between the orientation of north–south–oriented sunspot pairs and θ, but there does not seem to have any relation. Burlaga L et al.[8] found that CMEs tend to have a helical magnetic field, suggesting a loop field–aligned current in CMEs.

The compression of the front of the magnetosphere by shock waves/CMEs can be estimated by the relation between the kinetic pressure of the solar wind $p = b^2 / 8\pi$; if the pressure $p = (1/2)nmV^2$ can be predicted; the distance of the front of the magnetosphere can be given $\left[(0.3G/2)/(8\pi p)^{1/2}\right]^{1/3}$ in unit of Re, where $b = (0.3\,G/2)/\,Re^3$. If this distance is less than 6 Re, geosynchronous satellites will be exposed to CMEs.

Conclusion

From the above considerations, the present space weather prediction requires now specifically a well integrated and coordinated effort, as well as advancing studies of solar flares, CMEs and geomagnetic storms.

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Conflict of interest

Author declares there is no conflict of interest.

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