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Forecasting Geomagnetic Conditions in near-Earth space

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Abstract. Geomagnetic conditions in near-Earth space have been a constantly evolving scientific field, especially during the latest years when the dependence of our everyday life on space environment has significantly increased. The scientific community managed to implement centers for the continuous monitoring of the geomagnetic conditions which resulted into short and long term forecasting of the planetary geomagnetic index Ap. In this work, the centers that have been established and are in operational mode in Russia (IZMIRAN), Greece (Athens), Kazakhstan (Almaty) and Bulgaria (Sofia) are presented. The methods that have been used for the forecasting of Ap index are demonstrated and the forecasted results in comparison to the actual Ap measurements are also discussed.

1. Introduction

Near-Earth space is the term applied to describe Earth's spatial surroundings. The space environment and the conditions that are prevalent in it, result disturbances in the Earth's magnetosphere and ionosphere, which are the direct consequences of the interaction of solar wind and transient magnetic fields of coronal mass ejections (CMEs) with the Earth's magnetic field. The disturbances of the Earth's magnetic field are usually being quantified with indices [1]. The most familiar magnetic index is the Kp one, which is a decimal number between 0 and 9 measuring the world average of the magnetic disturbances recorded by observatories in each 3-hour universal time (UT) interval [2]. The Ap index is a measure of the global magnetic activity. It is based on the data from a set of specific stations [1]. The necessity of the long-term forecasting is being served well by the fact that there are records of Kp and Ap indices that go back to 1932 and thus cover a wide range of solar cycles.

2. Forecasting geomagnetic conditions

Human forecasters routinely estimate the Ap index with a set of rules that include a number of known parameters/properties of Ap index, as well as current observations of the Sun and near-Earth space.

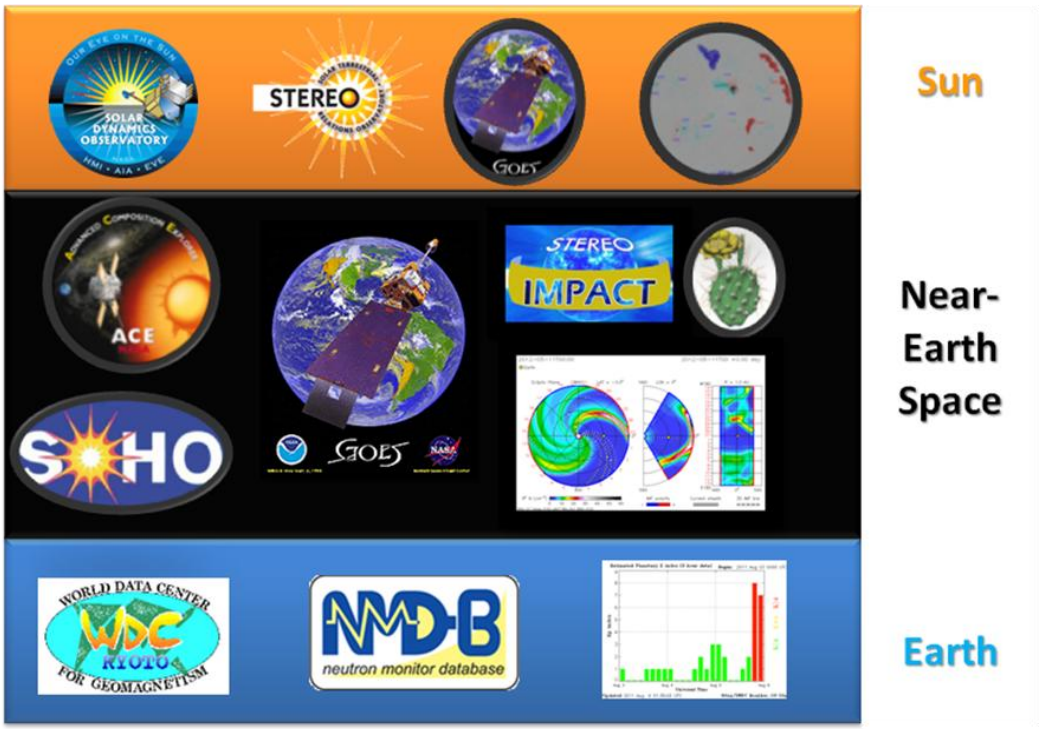

Figure 1. A subset of the available recordings that are being used for the forecasting of geomagnetic conditions in near Earth space. From top to bottom: the solar recordings of SFs, CMEs and CHs by SDO, STEREO and GOES; IP recordings from SOHO, ACE. GOES, STEREO, together with prediction models as the iSWA and Cactus; and measurements derived at Earth, i.e. Dst index (nT), neutron monitor data and Kp index.

The first item to note in the forecasting agenda is yesterday's Ap index. This is due to the fact that Ap index seems to be persistant in the sense that yesterday's Ap index may be the same today. Moreover, if a trend is being marked in Ap's behaviour, i.e., if Ap is being decreasing or in contrast if it has been increasing for several days, this trend may continue, as this may be due to a reccurent behaviour of the Sun or the passage of a transient magnetic field. The next item is the recurrent behaviour of the Sun, which is dominant within the heliosphere and acts as the ruler of the near-Earth enviroment conditions. Forecasters consider the magnetic activity 27-days before, when due to the solar rotation the same active region was facing the Earth. They also take into account the phase of the solar cycle, i.e. if they provide the forecast in solar minimum conditions, it is most likely for the Sun to produce reccurent behaviour. Finally, forecasters consult all available data from the Sun, near-Earth space and the Earth (Figs.1 and 2) that may demonstrate signs of intense activity which will result an increase of the geomagnetic conditions and the Ap index. The most prominent and characteristic events on the Sun that are being constantly monitored by the scientific community are solar flares (SFs), CMEs and coronal holes (CHs). The forecasters need to examine any sign that has revealed upon the Sun 3 to 4 days prior to the day they provide the forecasting. They need to estimate whether such solar activity will affect the Earth, depending on the location and strength of the solar event and they also need to

estimate for how long the impact of the solar event is likely to be delayed in its travel from the Sun to the Earth. Finally, in order to provide the forecast, a decision is made based on all the aforementioned information and on past experience.

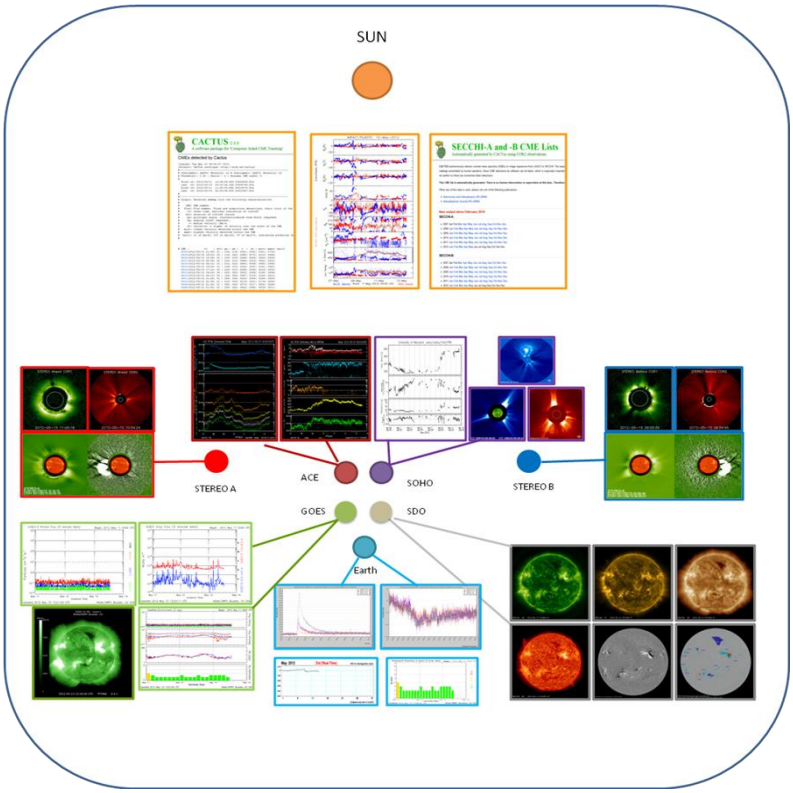

Figure 2. Daily elements that contribute to the forecasting of geomagnetic conditions in near-Earth environment from observations at the Earth (neutron monitors, geomagnetic indices), at L1 (ACE, SOHO, STEREO A &B), at GEO orbits (GOES & SDO).

Forecasting of geomagnetic conditions has been provided for three days in advance from Boulder Colorado [3], the Solar Influence Data Center (SIDC) [4], the Space Research and Technology Institute of the Bulgarian Academy of Sciences, the Physics Department of the National and Kapodistrian University of Athens, while other forecasting centers like the IZMIRAN and the Kazakhstan Institute of Ionosphere provide a forecast for six days in advance. There have also been proposals for a wider forecasting time interval which is based on the past behavior of Ap long time series in order to produce its future values, the so-called auto regression [1], and several centers do provide 45-days [5] or even 55-days [6] in advance forecast. Given the fact that geomagnetic conditions in near-Earth space have been a constantly evolving scientific field, especially during the latest years where the dependence of our everyday life on space environment has significantly increased. The accurate prediction of the Ap index is of fundamental importance. The scientific community has put into operation several space based experiments for the monitoring of the Sun and the space plasma which is emitted during solar extreme events. These experiments and their continious mesurements, together with ground observatories as neutron monitors and magnetometers has led to the the implementation of centers for the short and long term forecasting of the planetary geomagnetic index Ap (Fig. 3).

Figure 3: The websites of the operational Space Weather Prediction Centers, IZMIRAN (http://forecast.izmiran.rssi.ru/indexE.htm) displayed in the top left corner, the Institute for Space Research & Technology of the Bulgarian Academy of Sciences in the top right corner (http://www.space.bas.bg/SpaceWeather/), the Kazakhstan Institute of Ionosphere in the bottom left corner (http://www.ionos.kz/?q=en/node/21) and the National & Kapodistrian University of Athens in the bottom right corner (http://spaceweather.phys.uoa.gr)

3. Conclusion

In this work, four forecasting centers that have been established and are in operational mode in Russia (IZMIRAN), Greece (Athens), Kazakhstan (Almaty) and Bulgaria (Sofia) are presented and the methods that are being used for the forecasting of the planetary index Ap are discussed. The statistical results of the everyday issued report are very satisfactory. For example, the correlation coefficient between predicted and observed Ap indices (on the first day) for these centres is about 0.60-0.86.

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References

[1] McPherron R L 1999 *Phys. Chem. Earth (C)* **24** 45
[2] Mevielle M and Berthelier A 1991 *Revs of Geophys*. **29(3)** 415
[3] Joselyn J A 1995 *Revs of Geophys*. **33(3)** 383
[4] http://sidc.oma.be/products/meu/
[5] http://www.swpc.noaa.gov/ftpdir/latest/45DF.txt
[6] http://forecast.izmiran.rssi.ru/indexE.htm