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# Building a new space weather facility at the National Observatory of Athens

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**Abstract**

The PROTEAS project has been initiated at the Institute of Astronomy, Astrophysics, Space Applications and Remote Sensing (IAASARS) of the National Observatory of Athens (NOA). One of its main objectives is to provide observations, processed data and space weather nowcasting and forecasting products, designed to support the space weather research community and operators of commercial and industrial systems. The space weather products to be released by this facility, will be the result of the exploitation of ground-based, as well as space-borne observations and of model results and tools already available or under development by IAASARS researchers. The objective will be achieved through: (a) the operation of a small full-disk solar telescope to conduct regular observations of the Sun in the H-alpha line; (b) the construction of a database with near real-time solar observations which will be available to the community through a web-based facility (HELIOSERVER); (c) the development of a tool for forecasting Solar Energetic Particle (SEP) events in relation to observed solar eruptive events; (d) the upgrade of the Athens Digisonde with digital transceivers and the capability of operating in bi-static link mode and (e) the sustainable operation of the European Digital Upper Atmosphere Server (DIAS) upgraded with additional data sets integrated in an interface with the HELIOSERVER and with improved models for the real-time quantification of the effects of solar eruptive events in the ionosphere.


*Keywords:* Solar activity; Space weather; Monitoring; Ionosphere; Ionospheric disturbances; Solar Energetic Particles

## 1. Introduction

The near-Earth space environment is subject to the abrupt events of solar activity, the most dramatic of which are solar flares and Coronal Mass Ejections (CMEs). Flares are sudden and intense brightenings that occur in Active Regions (ARs). They are visible across the entire electromagnetic spectrum, quite prominent in UV, X-rays and optical lines, like Hα (Fletcher et al., 2011). Often associated with flares are CMEs, although no causal relationship has been established between them. CMEs reach very high velocities (Webb and Howard, 2012) disrupting the constant flow of solar wind, and affecting the near-Earth space environment in numerous ways. Both flares and CMEs are sources of Solar Energetic Particles (SEPs) produced as a result of the diffusive processes on the solar atmosphere and/or acceleration on the interplanetary shock fronts of Interplanetary CMEs (ICMEs).

Solar flares eject enormous amounts of energy into outer space in a very short time ranging from a few minutes to a few hours that can affect the near-Earth space environment in numerous ways. Energetic particles (ions) of 10 keV to

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GeV energies are accelerated at the flare site, while electrons with energies up to several MeV are also created (Anastasiadis, 2002). Fast ICMEs that may be associated with solar flares have upstream shocks which accelerate ions to ∼10 keV to ∼10 MeV. In the case of solar flares the energetic particles reach the Earth's ionosphere shortly after the flare photons, while in the case of CMEs, energetic particles are continuously produced and bombard the Earth's upper atmosphere following the formation of the ICME at a distance of ∼3–10 $R_S$ from the Sun and its propagation from the formation site to 1 AU and beyond (from about 1 hr up to 4 days) (Tsurutani et al., 2009). When the ICME reaches the magnetosphere about 1 to 4 days later, shock compression of the magnetosphere energizes preexisting 10–100 keV magnetospheric electrons and ions, causing precipitation into the dayside auroral zone ionosphere. Shock compression can also trigger supersubstorms in the magnetotail with concomitant energetic particle precipitation into the nightside auroral zones (Tsurutani et al., 2009). It should be further noted that the origin, acceleration and propagation of energetic particles is still unresolved and that apart from the dominant accelerators (i.e. solar flares and CME-driven shocks), the interplay of two variable factors, e.g. shock geometry and seed population, provide a framework for understanding the variability at high energies in large SEP events (Tylka et al., 2005).

In the Earth's ionosphere, geoeffective CMEs can lead to positive and negative ionospheric storms, depending on the local time of the observing location in the ionosphere and the geomagnetic latitude. According to the Prölss phenomenological scenario (Prölss, 1993; Prölss, 1995), solar wind energy input injection to the polar upper atmosphere, activates the meridional winds system, launching a so-called traveling atmospheric disturbance (TAD) that causes at middle latitudes daytime positive storm effects (enhancement of ionization) of short duration by an uplifting of the F2 layer. On the other hand, the dissipation of solar wind energy input changes the neutral gas composition, generating a permanent composition disturbance zone at polar latitudes that causes negative storm effects (depletion of ionization). During disturbed conditions this zone expands toward middle latitudes in the early morning sector due to winds of moderate magnitude, designated as midnight surge (Szuszczewicz et al., 1998; Tsagouri et al., 2000; Belehaki and Tsagouri, 2002).

Even in the absence of CMEs, solar flares have direct and immediate consequences on the ionosphere. The enhanced EUV and X-ray emissions create, at a very short time scale of a few minutes, extra ionization of the neutral components in the Earth's upper atmosphere and, hence, immediate increases in the electron density over a wide altitude range from the ionospheric D region up to the F region (Thomson et al., 2004; Liu et al., 2007). This consequently leads to various Sudden Ionospheric Disturbances (SIDs) that have important effects on radio communications and navigations over the entire radio spectrum (Liu et al., 2004). In particular shortwave fadeouts (SWF), abnormally strong absorptions in the ionosphere, occur as the immediate result of solar flare eruptions, leading to fadeouts in high-frequency radio propagation. The SWF is attributed to the X-rays emitted from the flare. The EUV radiation also contributes to other types of SIDs. In fact, different effects are observed during the various phases of a solar flare: the EUV radiation and the hardest X-rays tend to be enhanced early in the flare, whereas the softer X-rays last longer and correspond more closely with the optical flare. Though the effects are mostly registered in the D region, E and F region effects can also be detected. The D-region effect is due to the hardest X-rays. The electron content, governed mainly by the F region, is increased by a few per cent and it is due to the EUV radiation. Another effect of the EUV radiation is the reduction of the reflection height in E and F layers.

To recapitulate, the chain of events and interconnections described so far demonstrate the dynamic nature of the geospace environment. The time scales characteristic of the evolution of these phenomena vary from a few minutes up to days. Due to the rapidly growing interest and dependence of human activities on space technologies this gamut of time scales complicates prediction and modeling of the effects relevant to space weather. To successfully forecast space weather, first of all, a better understanding of the physical processes involved is needed. Apart from that and in order to minimize its impacts, a robust capability of monitoring the Sun, the interplanetary medium and the ionosphere with ground- and space-based observing instruments is needed to support operational space weather forecasting. Observations and extracted parameters from these observing systems can be used as input to prediction models to produce nowcasts and short- or long-term forecasts.

To facilitate progress in the field, the scientific community has been very active in putting together archives with diverse data from solar and space observations and measurements, such as the Heliophysics Event Knowledgebase (HEK[1]), the Solar Influences Data Analysis Center (SIDC[2]), the European Near-Earth Space Data Infrastructure for e-Science (ESPAS[3]), the Heliophysics Integrated Observatory (HELIO[4]), etc. In parallel, a number of targeted services has been established aiming at the specification of the space weather effects in the Earth's magnetosphere and ionosphere to meet the users' requirements. Such services have been integrated into the Space Weather Prediction Center (SWPC[5]) of the National Oceanic and Atmospheric Administration (NOAA) in the USA, and the Space Weather Service Network developed under the Space Situational Awareness (SSA[6]) programme of

[1] http://www.lmsal.com/hek/.
[2] http://sidc.oma.be/.
[3] http://www.espas-fp7.eu.
[4] http://www.helio-vo.eu/.
[5] http://www.swpc.noaa.gov/.
[6] http://swe.ssa.esa.int/.