SEIBERSDORF LABORATORIES

SEPRAD - Workshop

September 18th - 19th, 2017

BOOK OF ABSTRACTS

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HFSJG High Altitude Research Stations Jungfraujoch & Gornergrat

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Programme status at the editorial deadline.

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Programme status at the editorial deadline.

Space Weather Effects at Aviation Altitudes [Keynote]

Erwin O. Flückiger
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Abstract

Space weather can influence the performance and reliability of airborne systems in many ways and may endanger life or health of air crew and passengers. During the last few decades the increase in both global air traffic and public awareness initiated a challenging activity to identify and quantify possible risks. Great efforts have been made towards a better understanding, modelling, and forecasting of space weather, and for the development of operational space weather systems.

The causes of space weather are natural perturbations of our near-Earth environment coming from the sun, from space, and probably even from within our system Earth. After a short review of major causes the multitude of space weather effects at aircraft altitude and upon airborne systems is addressed. Main emphasis is laid to the particle radiation field and radiation dose due to galactic cosmic rays and to severe high-energy solar phenomena. Based on selected examples, e.g. the solar energetic particle events on 20 January 2005 and on 13 December 2006, the potential of operational and projected space weather service procedures is reviewed. In this context recent findings about extreme events and their occurrence frequency are discussed.

The presentation concludes with an outlook on ongoing and future development in the field, based e.g. on current discussions within EURADOS WG 11.

Session 1:
Nowcast of Radiation Effects for Aviation

Nowcast of Radiation Exposure at Aviation Altitudes with AVIDOS

Marcin Latocha
Seibersdorf Labor GmbH, Seibersdorf, Austria

Abstract

Radiation environment at aviation altitudes is formed mainly by galactic cosmic radiation (GCR) coming from outside of our solar system, yet solar influence cannot be neglected. The approximately 11-years cycle of solar activity modulates the flux of GCR resulting in a regular pattern of slightly lower and higher radiation exposure. Phenomena like solar flares or coronal mass ejections are sources of solar high-energy particles (SEP). These rare but intensive SEP events may lead to short-term but significantly enhanced radiation levels in the Earth's atmosphere. Radiation effects caused by strong SEP events that are detectable on the Earth's surface are called Ground Level Enhancements (GLEs).

Nowcasting and forecasting of space weather induced radiation environment in Earth's atmosphere is of great importance for radiation protection institutions, aviation, governmental organizations and research. There are already good methods and tools for a prediction of radiation exposure levels due to GCR. There is, however, no satisfactory prediction of radiation effects when considering SEP events. Therefore, investigations of the relations between events on the Sun and radiation effects in Earth orbits, atmosphere and on the ground are necessary to improve prediction models in order to timely provide reliable information.

Seibersdorf Laboratories developed the software AVIDOS (aviation dosimetry). AVIDOS is a web service of the Seibersdorf Laboratories federated with ESA's Space Weather portal [1]. It is an online, informational and educational software for the assessment of cosmic radiation exposure on-board aircrafts. In its current version, AVIDOS can assess radiation exposure in atmosphere due to GCR for up to one year in advance [2]. AVIDOS also provides nowcast information on radiation exposure due to SEP. The solution developed by Seibersdorf Laboratories is based on a simulation model coupled with real-time data from a neutron monitor station and a real-time GLE-alerting service [3]. The presentation will provide information on the latest advancements in AVIDOS – its usability, performance, implemented models, as well as future developments.

References

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Acknowledgements

The development of AVIDOS was supported by the European Space Agency (ESA Contract: No. 44000105734/12/D/MRP), the Austrian Federal Ministry of Transport and Innovation, and the Austrian Agency for Aviation and Space (ALR) as part of the Austrian Promotion Agency, FFG.

Linking Solar Eruptions to Space Radiation Storms: Solar Energetic Particle Events and Flares foretold

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Abstract

Solar eruptions, such as solar flares (SFs) and coronal mass ejections (CMEs) are the primary drivers of space radiation storms. A key element for the decoding of such storms is the establishment of empirical statistical relations between their characteristics and the observed properties of their parent solar events. These attempt to unfold patterns and relationships, using all observational evidence at hand, which in turn point to the underlying physical processes of the generation of space radiation storms [1].

We report on new data driven statistical methods that have been developed for the identification of the likelihood of Solar Energetic Particle (SEP) event occurrence and their expected characteristics. These methods are based on precursor information of SFs [forecasting mode] and on actual data of SFs, CMEs and radio bursts [nowcasting mode]. A reductive statistical method for the SEP probability of occurrence has been implemented, using as input SF information. It makes use of, either, the expected full disk probability [forecasting mode] or of the location (longitude) and the size (maximum soft X-ray [SXR] intensity) of the flare [nowcasting mode] [2].

Moreover, employing CME parameters (velocity and angular width), proper functions per width (i.e. halo, partial halo, non-halo) have been identified. In addition, using as input the SXR and radio fluence, another (non-operational) algorithm for the probability of SEP occurrence, based on the ESPERTA concept [3], has been implemented.

We demonstrate the validation of each method using categorical scores constructed on archived data and we further present independent case studies [4].

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Part of this research was supported through the ESA Contracts No.4000109641/13/NL/AK „Improvement of Solar Particle Events and Flare Prediction“ and No. 4000120480/17/NL/LF/hh „Solar Energetic Particle (SEP) Advanced Warning System (SAWS)“.

Session 2:
Forecast of Solar Energetic Particle Effects

Prediction of the Occurrence and Intensity of SEP Events with Energies >100 MeV and >500 MeV Using the UMASEP Scheme

Marlon Núñez
Universidad de Málaga, Málaga, Spain

Abstract

Extreme solar events may accelerate solar particles to near the speed of light reaching the Earth in a few minutes. These particles may interact with the Earth's atmosphere to produce penetrating neutrons known as Ground Level Enhancements (GLEs) which may irradiate passengers and flight crews in commercial aircraft flying at extreme polar latitudes [1]. This presentation summarizes the model and results of two tools that are able to predict the occurrence and intensity of the first hours of Solar Energetic Proton (SEP) events with energies >100 and >500 MeV. These tools use the UMASEP forecasting scheme, which infers a magnetic connection, along which energetic protons are arriving in the near-Earth environment, by estimating a lag-correlation between solar soft X-ray (SXR) flux and differential proton fluxes at near-Earth; if this correlation is high and the associated solar flare is also strong, then this scheme issues a SEP event prediction.

This forecasting scheme has been successfully tested for predicting >10 MeV SEP events (using the Low-Energy UMASEP model) in an operational level since 2010, when NASA's integrated Space Weather Analysis system (iSWA) and the European Space Weather Portal started redistributing UMASEP forecasts. Since then, the developed tool (UMASEP-10) has predicted 83% of real SEP events, with a false alarm ratio of 25%.

The low-energy UMASEP model was the basis for the design of the high-energy UMASEP model, which was proposed for predicting >100 MeV events from 5-min GOES SXR and proton data. Recently, this model was also used to build the tool HESPERIA UMASEP-500 [4] for predicting >500 MeV SEP events (i.e. whose integral proton flux surpasses 0.8 pfu) from 1-min GOES SXR and proton data. The same predictions may be used for warning against GLE events before the detection by any neutron monitor station. The performance of this tool with historical data for the period 2000-2016 may be summarized as follows: the Probability of Detection (POD) was 58% for the case of >500 MeV SEP events and 50% for the case of GLE events; the False Alarm Ratio (FAR) was 30% for both types of events; and, the average warning time was 16 min with respect to the GOES detection times of >500 MeV SEP events, and 15 mins with respect to the GLE Alert Plus [5] warning times. Regarding the prediction of the intensity peak of >500 MeV SEP events, this tool obtained a mean absolute error of 0.73 in log10 of pfu units. In [4] authors speculate that UMASEP-500's high-energy predictions can possibly benefit from a >10 MeV electron contamination in high-energy proton detectors; for this reason, we conclude that an interesting research field is the correlation of SXR and relativistic electron data for predicting high-energy SEP events.

References

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Acknowledgements

The development of the UMASEP-500 tool has received funding from the European Union's Horizon 2020 research and innovation programme under agreement No 637324. The development of the UMASEP-100 tool has received funding from the Plan Propio de Investigación of the University of Malaga (Spain).

Progress and Challenges Toward a Future Integrated Space Weather Forecasting System

Manolis K. Georgoulis
RCAAM of the Academy of Athens, Athens, Greece

Abstract

Humanity's ever-increasing dependence on space infrastructure and technology makes it paramount to implement ways, tools and services to forecast the continuously changing conditions of the near-Earth space in response to the driving of the solar wind. This is an intimidating task, spanning over a vast range of length and time scales in terms of physical effects involved. It is also a cross-disciplinary endeavor, requiring expertise from various areas of physics, computer science, mathematics and statistics [1], [2].

While current efforts focus on the three outcomes of adverse space weather, namely solar flares, coronal mass ejections (CMEs) and solar energetic particle (SEP) events, often tackling their prediction independently, it is important to acknowledge that the three manifestations share an intimate physical connection [3], [4]. Ideally, then, their forecast should be treated jointly and self-consistently, along the lines of an integrated space weather forecasting system that has yet to be implemented.

We present possible ways in which this could be achieved, in terms of computational effectiveness without severe loss of accuracy, credibility and complementarity to avoid effort duplication in the presence of redundancy and the use of partial advances in flare, CME and SEP forecasting around the world.

References

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Session 3:
Innovative Developments and Future Needs

Radio Observations and Innovative Developments and Future Needs on SEP Forecasting

Karl-Ludwig Klein
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Abstract

Solar energetic particles (SEPs) are accelerated in relationship with eruptive events in the solar corona, flares and coronal mass ejections (CMEs). Depending on the energy of the SEPs, the acceleration occurs in the corona or during the interplanetary propagation of a CME. Enhanced proton fluxes at energies above 10 MeV, the reference of SEP events categorised by NOAA, can be produced both by acceleration processes in the corona and by CME-driven shock waves as they approach and intercept the Earth. The CME-driven shocks often, but not always, produce very high fluxes at energies up to a few tens of MeV. The higher the particle energy, the closer the acceleration occurs to the Sun. At energies above 500 MeV, which are relevant for nuclear cascades in the Earth's atmosphere and for radiation doses at aircraft altitudes, the interplanetary and near-Earth shock acceleration plays no role.

The forecasting of SEP events relies presently on early observations of eruptive signatures in the solar corona. A number of features visible at radio frequencies is physically related to, and can be used in short-term forecasting of SEP events:

- Radio emission at metric and longer wavelengths, coming from the corona at heights above about 0.2 solar radii above the photosphere, seems to be a necessary condition for SEPs to be released to interplanetary space. Even strong soft X-ray bursts located in the western solar hemisphere may not be followed by SEPs when flare-accelerated particles remain confined in the corona and no CME occurs. The absence of radio emission is a tracer of this situation.

- Within the HESPERIA project (European-Union H 2020 programme), we (Zucca et al. 2017 JSWSC 7, A13) examined the possibility to use microwave whole Sun observations within the UMASEP forecasting tool developed at the University of Malaga. Microwaves turn out to be a useful ingredient of this forecasting scheme. The usefulness might still be enhanced if the forecasting could be combined with in situ information from energetic electrons, as in the RELEASE forecasting scheme.

- Within the HESPERIA project we also examined the idea (Chertok et al. 2009 Astron. Rep. 53, 1059) of an empirical relationship between the hardness of the SEP proton spectrum between 10 and 100 MeV and the ratio of the peak flux densities of the microwave burst at frequencies of 9-15 GHz. This relationship could be exploited in the forecasting of the hardness of the SEP spectrum. While we found similar trends in the data as Chertok et al., we found no convincing correlation in solar cycle 24.

Besides being a direct forecasting tool for SEP events, microwave emission can also serve as an early estimate of CME speed. The importance of this aspect in sophisticated models of CME propagation and CME shock-related particle acceleration in the interplanetary space will be briefly discussed.

While societal needs for forecasting are to be formulated by the relevant organisms, the usefulness of radio observations, which can be conducted from ground, should be considered. Dedicated patrol observations would be useful for SEP forecasting and other space weather applications.

Forecasting of Solar Energetic Particle Radiation Effects

Volker Bothmer
Georg-August-Universität Göttingen, Institut für Astrophysik, Göttingen, Germany

Abstract

Radiation hazards by intense solar energetic particle events (SEPs) pose a serious threat to satellite systems, aircraft crews and astronauts. To help better understanding the dependence of intense SEP fluxes on the location of the onset site of their solar drivers, a specific study has been carried out taking into account the magnetic connection to the associated CME and its plane of the sky speed. The NOAA solar proton event list „Solar Proton Events Affecting the Earth Environment (http://www.swpc.noaa.gov/ftpdir/indices/SPE.txt), classified by the NOAA space weather scales was investigated for the time period after launch of ACE in order to be able to analyze the solar wind plasma and IMF conditions measured near Earth orbit at event onset. The whole NOAA proton event list comprised 252 events from April 1976 to June 2013, for which integrated 5 minutes averages of the various GOES proton flux measurements at energies > 10 MeV had reached three consecutive values of 10 pfu or above. Events which occurred temporarily connected have been treated in this study as one single event. The time period with information on major SEP events provided by the list, together with the solar wind data, span the period November 1997 to March 2012, with 105 SEP entries. These events were then compared with information on CMEs and flares listed in the SOHO LASCO CME catalogue. Taking into account times with missing SOHO data and events without determined CME speeds, the established SEP event list includes 81 proton events and a total of 100 associated CMEs. For these events the proton flux data for energies >10 MeV measured by the GOES satellites were used to determine the characteristic proton event parameters, such as peak flux, event duration and the number of total measured protons per event. The parameters of solar activity were compiled from the SOHO/LASCO CME catalogue. The source regions of the CMEs were identified using images and movies of the SOHO/LASCO/EIT and MDI, SDO/AIA and HMI, and STEREO/SECCHI instruments. Solar wind data from the ACE and in a few cases as substitutes, from the WIND satellites were used to determine the two-dimensional (in longitude) and three-dimensional magnetic connection (the real solar wind source region) to the Sun at the onset of the solar proton events. Results for the dependence of the intensities of the particle events on the location of the CME onset sites, their lateral expansions and outward plane of the sky propagation speeds are presented and the implications are discussed for the development of state-of-the-art forecast capabilities.

References

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Acknowledgements

Part of this work was funded by the European Union in the FP7-Project eHEROES (Environment for Human Exploration and RObotic Experimentation in Space). The University of Göttingen led eHEROES Task 3.6 “Source region, acceleration mechanisms and interplanetary propagation of SEPs”, as part of eHEROES Work Package 3 ”Solar and Space Events and their Evolution“. The achievements of this task are summarised through the eHEROES deliverable D3.5 „Source region, acceleration mechanisms and interplanetary propagation of SEPs”, available at http://www.affects-fp7.eu/services/eheroes-seps/. Contributing partners to D3.5 were UCL, UCT, LPI. Volker Bothmer acknowledges support of the CGAUSS (Coronagraphic German And US Solar Probe Plus Survey) project for WISPR by the German Space Agency DLR under grant 50 OL 1601.

Future Needs in Understanding and Forecasting Extreme Solar Energetic Particle Events

Bernd Heber
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Abstract

Solar Energetic Particle (SEP) events may provoke extreme radiation conditions near Earth outside the magnetosphere but also in polar latitudes even in the stratosphere. High Energy Solar Particle Events foRecastIng and Analysis (HESPERIA) is an H2020 project that investigated aside scientific exploitations technical constraints of space and ground based instrumentation. During the project we identified measurement capabilities that enables a better determination and forecasting of the radiation environment. Concepts are proposed to bridge not only the current lack of measurements but also an optimization of techniques and data analysis based on the scientific studies performed within HESPERIA. For example “novel” data sets into SEP forecasting schemes were identified that potentially will lead to new forecasting capabilities. In my presentation I will summarize the corresponding physical background and recommendations.

Acknowledgements

The HESPERIA has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement No. 637324.

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