

European Space Weather Activities

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Abstract

Many space weather activities were carried out in the last ten years in Europe. These activities are several studies, projects and actions as well as different workshops, conferences, space weather weeks, outreach and educational initiatives. This paper also describes scientific and user orientated efforts towards an European Space Weather Programme (ESWP).

1.0 Introduction

This paper presents European space weather activities for almost the last decade. These activities were and are carried out by ESA, by EU funding as well as by many other high level national organizations and institutes in Europe. Over the years European industry became aware about space weather effects and started to develop space weather tailored products and services in cooperation with research labs all over Europe. Insofar space weather research elucidates risks to technological infrastructure and to society for Europe [1].

The activities described in this paper will sketch relevant studies, projects and actions: because Europe's space and ground based observational capabilities, theoretical and service orientated studies are placed on a very high level and used in coordinated actions directed towards the ESWP with the European Space Weather Center.

The aim of this paper is to describe in an appropriate manner the developments of technology (weather and climate related activities are excluded here) orientated space weather activities in Europe from the 1990th until now. Especially to avoid geographical less balanced viewing and under the aspect to underline the European wide character of activities plus strengthening the historical and content point of view, this paper is arranged in the following three chapters

- research, scientific and service activities,
- outreach, education, public and scientific awareness activities and
- user and market orientated activities.

2.0 Research, Scientific and Service Activities

For the first time European space weather research results were discussed at ESA in the workshop on space weather in 1998 [2]. Sessions on effects and users, physical processes, models and data as well as various world wide space weather initiatives came out of deliberations and discussions. There was a general support for the idea of an ESWP. Therefore two parallel ESA space weather feasibility studies were carried out between 1999 and 2001 by the Alcatel Space Industry (France) and Rutherford Appleton Laboratories (RAL, UK) consortia.

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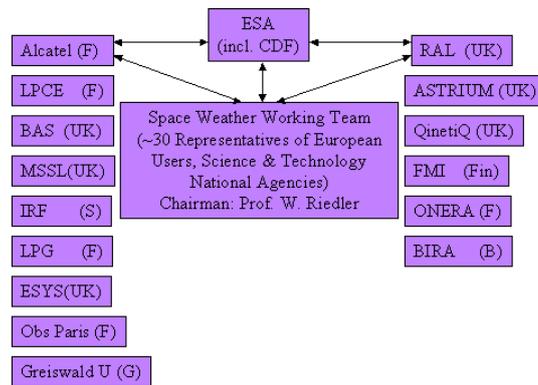


Figure 1: Main bodies of space weather activity in Europe at the beginning: ESA, members of the Alcatel and RAL teams, Space Weather Working Team (SWWT) and ESA's Concurrent Design Facility (CDF). For details see in the text.

The studies included for example

- the benefits, detailed rationale and details of an ESWP, including space and ground segment and prototyping of services,
- the definition of structures, which needs to be implemented by ESA and its member states and
- a draft programme, cost and risks.

The ground and space based available instruments in Europe and necessary capabilities for information about the Sun, interplanetary space, magneto-, iono- and thermosphere were overviewed. For example the status of ionospheric tools like SuperDARN coherent radars, ionosondes, incoherent scatter radars were judged as in a research status, but positional receivers were seen to be already operational for GPS applications. In addition a cosmic ray muon telescope required in the study for the European region was also proposed to forecast the onset of disturbances in the magnetosphere/ionosphere. MuSTanG (Muon Spaceweather Telescope for Anisotropies at Greifswald) is just in construction and will measure in real time the propagation of interplanetary CMEs and forecast their arrival time at Earth (see chapter 3).

For the space based segment an entire fleet of spacecraft and satellites including instrumentation, orbits and communication links are proposed finally by the two study consortia to ESA.

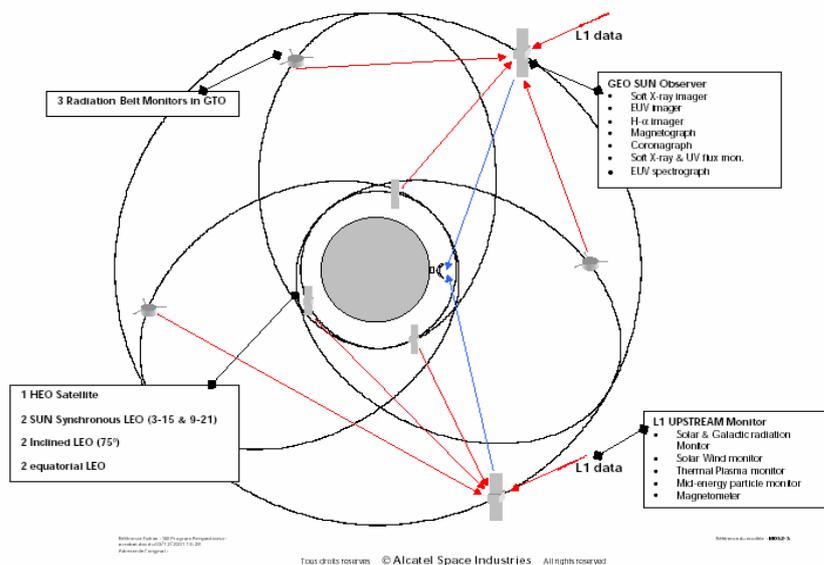


Figure 2: Full space based scenario with global data communication of the Alcatel Space Industry consortium: Sun observer and upstream monitor at L1, three radiation belt monitors in Geo Transfer Orbit (GTO) and seven additional satellites in High Eccentric Orbit (HEO) and Low Earth Orbit (LEO).

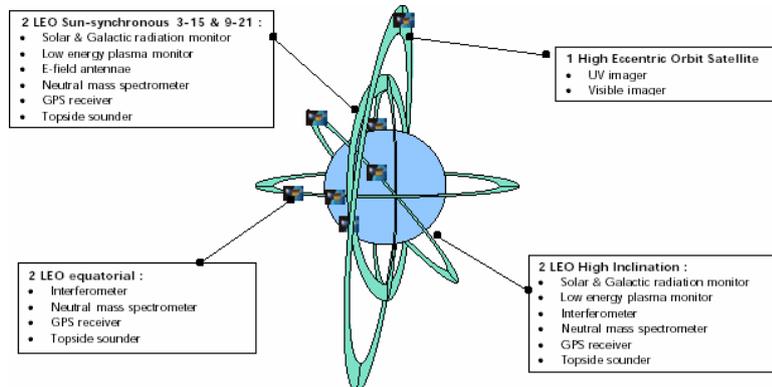


Figure 3: The Alcatel Space Industry consortium proposed to ESA this space based full scenario of satellites and instruments on HEO and LEO Sun-synchronous, equatorial and high inclination in the ionosphere and thermosphere.

Documents about space and ground segment, space weather effects and parameters, user requirements and market analysis as well as rationale and recommendations for the ESWP are online under http://esa-spaceweather.net/spweather/esa_initiatives/spweatherstudies/public_doc.html. In addition, the Space Weather Working Team (SWWT) was created (chairs from 2001 to 2006: R. Gendrin, W. Riedler, F. Lefeuvre and M. Hapgood) from about 30 European experts in a variety of both scientific and application oriented fields relating to space weather. The team members also evaluated the primary scientific orientated results of both consortia. Because the consortia proposed many interesting options for a space weather system (see also Figure 2 and 3) ESA's CDF further analysed these to establish their feasibility and costs.

On European level two further workshops were organised related to space weather: in 2000 "Space Storms & Space Weather Hazards" in Greece [3] and the SOLSPA Euroconference "Solar Cycle and Space Weather" in 2001 in Italy [4]. After 1998, the year of the first workshop on space weather in Europe, ESA has organised each year space weather workshops. In 2000 on the topic of the utilization of a future European space weather service [5], in 2001 the workshop looked towards a future European space weather programme [6], in 2002 potential space weather applications pilot project came into the discussions [7] and in 2003 the workshop were orientated towards developments of an European space weather service network [8]. A new level on space weather activities started with the European space weather week in 2004 [9] and in 2005 [10], carried out at ESA/ESTEC in the Netherlands. Moreover European Commission and ESA published an action plan for implementing the European Space Policy in 2003 [11]. This White Paper underlined specific efforts to ensure that Europe has the capacity to supply to the different users critical information on space weather predictions.

As a result of the activities on ESA, EU and national levels, the European Science Foundation started in 2003 with the action 724 on the European Cooperation in the field of Scientific and Technical Research (COST). COST action 724 is currently developing the scientific basis for monitoring, modelling and predicting space weather. Presently 23 European and nearby countries and 4 participating institutions are involved in the action [12]. Among others, the main aims of the action are:

- to coordinate European research into modelling and prediction of space weather,
- to promote new instrument deployment to satisfy data requirements and development of new models and

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- to educate potential users.

The main benefit of this concerted space weather action towards an ESWP is that organisations which face hazards from space weather in their day-to-day operations will have a resource which will enable them to manage space weather risks. Especially the development of a coordinated European space weather network relevant to data, models, prediction and public outreach and education is foreseen. An educational output, an International advanced school on space weather was initiated by COST 724 action and realized in 2006 at the Abdus Salem International Centre for Theoretical Physics in Trieste [13]. The COST 724 action objectives described as tasks of the four working groups “Monitoring and predicting solar activity for space weather”, “The radiation environment of the Earth”, “Interaction of solar wind disturbances with the Earth“ and “Space Weather Observations and Services”. These objectives are the

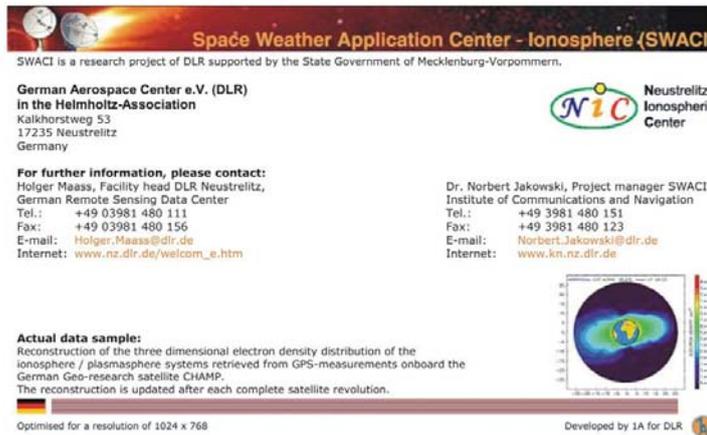
- use of solar observations (extreme ultraviolet images, X-ray observations, radio emissions) and models (magneto-hydrodynamic models of flux tubes) for predicting energetic particle events,
- use of solar observations and models for predicting coronal mass ejections (CMEs),
- to develop a quantitative model of the interaction of solar energetic particle events with the Earth's magnetosphere,
- to develop a quantitative model of the development of trapped radiation in the Earth's magnetosphere during geomagnetic storms,
- to develop a quantitative model of the variation of galactic cosmic radiation in response to solar activity,
- to study how electronic technology in satellites, launchers and aircraft is affected by the Earth's radiation environment,
- to study how humans (astronauts, aircrew, air passengers) are affected by solar and cosmic radiation in different activities,
- to develop a quantitative model of the propagation of CME through the interplanetary medium to predict their arrival at Earth and
- to develop a quantitative model to predict geomagnetic storms and ionospheric current systems.

COST 724 action will be finished at the end of 2007 and it is foreseen to bring the European space weather network in form of European space weather web portal on-line (see under <http://gauss.oma.be/COST724/ESWWS/>). COST 724 action intensively cooperates with the COST action 296 “ Mitigation of Ionospheric Effects on Radio Systems (MIERS)” [14].

A further European space weather related activity is DIAS (The Digital upper Atmosphere Server). DIAS is co-funded by the e-content programme of the EU and uses real-time information provided by seven operating digital ionospheric stations (ionosondes). DIAS is also based on historical data collections and has developed a pan-European digital data collections on the state of the upper atmosphere over Europe. The first release of the DIAS server prototype is now active on <http://www.iono.noa.gr/dias/>.

Regional Warning Centres (RWCs) of “The International Space Environment Service” (ISES) deliver tailored space weather forecasts within their own regions [15]. At present there exist seven RWCs, associated RWCs and collaborative expert centres in Europe. These centres are located in the following countries - in Belgium (Brussels), Czech Republic (Prague), France (Toulouse) , Netherlands (Noordwijk, ESA), Russia (Moscow), Poland (Warsaw) and Sweden (Lund). RWC Warsaw and partially RWC Prague inform users about ionospheric forecasts.

Space Weather Application Center – Ionosphere (SWACI) is a research project at DLR in Germany, which provides in particular now- and forecast of the ionospheric state to improve the accuracy and reliability of impacted communication and navigation systems for the European user community on a routine basis [16].



Space Weather Application Center - Ionosphere (SWACI)
 SWACI is a research project of DLR supported by the State Government of Mecklenburg-Vorpommern.

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Actual data sample:
 Reconstruction of the three dimensional electron density distribution of the ionosphere / plasmasphere systems retrieved from GPS-measurements onboard the German Geo-research satellite CHAMP.
 The reconstruction is updated after each complete satellite revolution.

Optimised for a resolution of 1024 x 768
 Developed by IA for DLR

Fig. 4: SWACI has 10 partners from industry (Allsat Hannover, 1A Greifswald), governmental (like the Federal Agency for Cartography and Geodesy and others) and scientific organisations and institutes (like ESA (SWENET), Space Environmental Center (SEC) Boulder, GeoForschungsZentrum (GFZ) Potsdam and others).

On national level several meetings, workshops and conferences took place like in Belgium, Denmark, Finland, France, Germany, Italy, Sweden, UK and other countries. For example in Germany two workshops were organised in 2000 [17] and 2005 [18]. The first workshop delivered a space weather recommendation to industry and organisation in Germany. On the 2005 workshop the space weather community in Germany proposed activities to German authority for a space weather satellite with international cooperation. Discussions on the equipment are directed towards a space weather service related to users from satellite navigation, telecommunication and aviation industry.

2.0 Outreach, Education, Public and Scientific Awareness Activities

The EU funded European Science and Technology Week in 2002 organized the project “Space Weather and Europe” (SWE) to increase the public awareness all over Europe. Several novel products were produced and world-wide distributed [19]. Among them belong advertisement products such as the world-wide first space weather CD-Rom, the first European space weather planetarium show “Thunderstorms in Space Weather” shown in the Zeiss-Großplanetarium in Berlin (ZGP) and a cosmic ray spark chamber also mounted at ZGP. A real time video stream in the internet was distributed from a public space weather forum at ZGP, which included a live video link with ESA astronaut Frank de Winne on board International Space Station (ISS) about space weather and radiation effects to the forum participants (Figure 5). Additional space weather forum of SWE in several scientific institutes and public outreach facilities in Finland, Germany, Italy, Poland, Portugal and Slovakia attracted several ten thousands of visitors and users.

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Figure 5: Astrophysics and ionosphere physics, but also as much as possible effects on technological systems (satellite navigation, telecommunication, aviation and others) and humans are described on the science and science museum edition of the space weather CD-Rom. This English-French-German version is available on request [19] and also contains several images and movies like a video link with the ISS.

A new quality of space weather promotion is in progress: in April 2006 the first performance of “Sonnensturm” (the German word for solar storm) took place. “Sonnensturm” is the first European space weather dance show. The professional dancer company “Deutsche Tanzkompanie Neustrelitz” combines science, education and culture in an emotional performance. Between 2006 and 2007 “Sonnensturm” can be hired directly from the professional dancer company “Deutsche Tanzkompanie Neustrelitz” (contacts under http://www.deutsche-tanzkompanie.homepage.t-online.de/repertoire_7.htm).



Figure 6: “Sonnensturm” was already very successful shown for a COST 296 meeting at DLR in Neustrelitz/Germany. Therefore “Sonnensturm” is not only usable for public houses, but also ideal for science festivals and social events on space weather related conferences.

A successor of SWE is called SWEETS (Space Weather and Europe an Educational Tool with the Sun) and submitted for funding by the European Commission. By means of support from the COST actions 724 and 296 SWEETS will be one of the main European funded space weather orientated public outreach activity during the International Heliophysical Year in 2007 (for IHY see under http://calys.obspm.fr/IHY/IHY_colloque/).

SWEN (Space Weather Euro News) is published by ESA and distributes online information news about space weather already since 1997. Since 2000 several outreach and educational books are published on space weather in Europe like [20], [21] and [22].

3.0 User and Market Orientated Activities

On the frontier of user activities Swiss Re-insurance started in 1999/2000 a space weather study. Jansen, Pirjola and Favre [23] studied from an insurance point of view space weather effects on products of global acting companies like Siemens, Ruhrgas or Swiss Air.



Fig. 7: Cover of the Swiss Reinsurance brochure about space weather.

For example, Siemens produced high voltage semiconductor devices for usage as engine drive in the German fast speed train (ICE), which were completely destroyed by secondary cosmic ray shower. Ruhrgas pipelines in Germany may be treated as space weather detectors, because geomagnetically induced currents (GICs) do not disturb pipeline potential only in Scandinavian pipelines, but changes pipeline potential also at lower European geographic latitude like in Germany, if the Earth is inside a CME. Swiss Air pilots reported several failures in onboard electronic equipment.

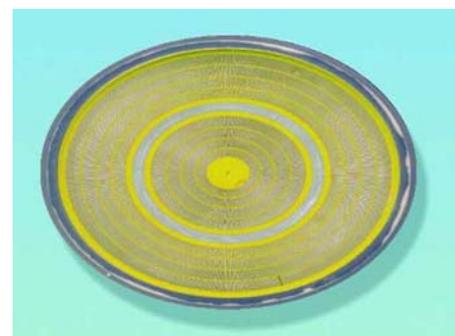
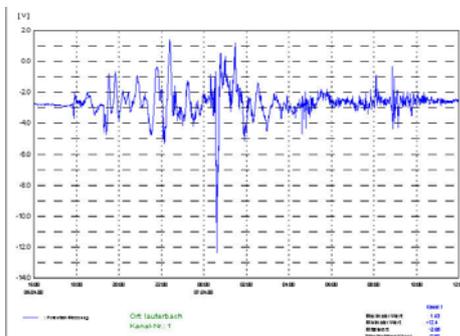


Fig. 8: From left to right: GIC changed pipeline potential in Hessen/Germany (image: Ruhrgas) and GTO semiconductors used in the ICE train, which were destroyed by secondary cosmic rays (image: Siemens).

In addition to the primary space weather source - the Sun-, the galactic cosmic rays are treated as the secondary space weather source. By means of several EU funded projects like DOSMAX and ACREM carried out in the 1990th, the radiation dose on aircrew induced by secondary cosmic ray particles were measured. In France a similar study was done within the Sievert project. All these projects contributed to the EU Directive 96/29/Euratom. This EU Directive became the first legal law related to space weather in EU member states – for instance in Germany since 2001. The airlines have to monitor their flying crew members, which are not allowed to exceed an upper limit of 20mSv yearly radiation exposure.

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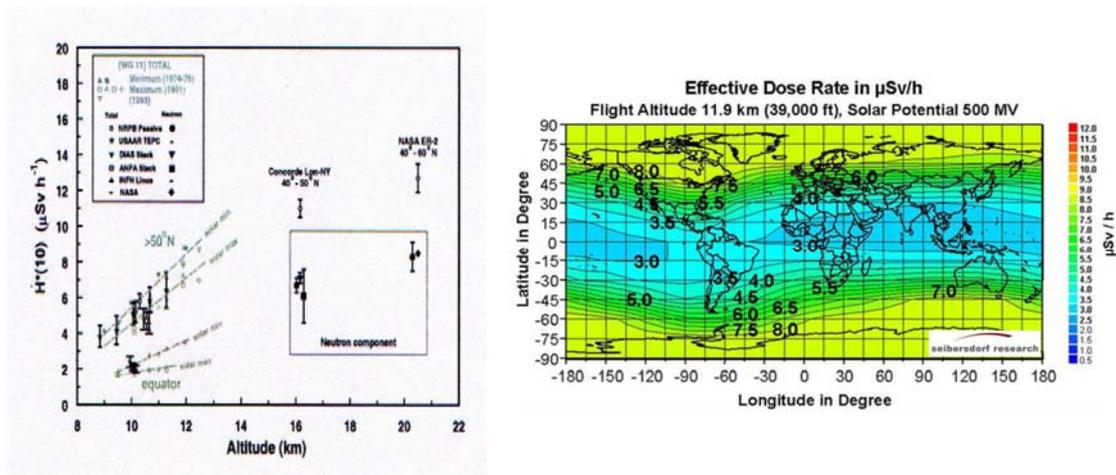


Fig. 9 Two results from the DOSMAX and ACREM projects. Left: the dose rate for solar maximum and minimum conditions on different cruising altitudes of aircraft. Right: the world-wide effective dose rate on 11.9 km flight altitude.

ESA has co-funded space weather applications pilot project [24]. These projects included three complimentary parts: service development activities (SDAs), in which users from different branches participate. The second part contains a network of supporting infrastructure for the SDAs and a third part is a study of the benefits experienced by European users as a result of the SDAs and the economic benefits to the European market from a future ESWP. The SDAs belong to the following branches

- solar and interplanetary monitoring and warnings,
- spacecraft hazards,
- operational airline risks
- GNSS reliability
- ionospheric forecasting and nowcasting
- use of space weather data in natural hazard warnings
- geomagnetic index forecasting
- GIC simulation and prediction and
- aurora tourism.

The users of the different SDAs represent private companies, national defence and security organisations, space agencies, the scientific community and others as well. The SDA support infrastructure was created and is called SWENET (Space Weather European Network). One main objective of SWENET is to federate existing and newly created space weather service activities. As such the first European space weather telescope MuSTAnG (Muon Spaceweather Telescope for Anisotropies at Greifswald) is just under construction in Germany. MuSTAnG will be part of

a world-wide network of cosmic ray muon telescopes in Australia, Japan, Brazil, Kuwait and Armenia to observe in real time the interplanetary propagation of CMEs respectively shock waves and to forecast the arrival time of these disturbances in the magnetosphere and ionosphere.

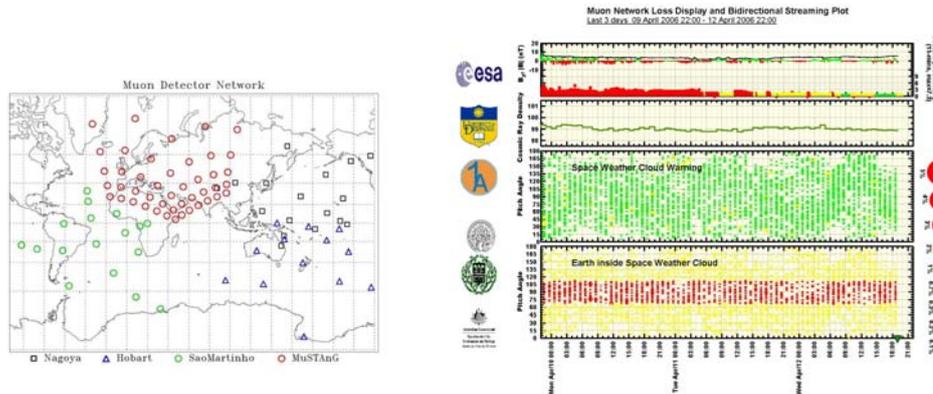


Fig. 10 Left: MuStanG will have a viewing angle from about Ural mountain nearly to the Atlantic Ocean. Right: These circle plots will be displayed on-line from the international muon telescope network and inform users about cosmic ray anisotropies due to Earthward directed CMEs.

ESA is just carrying out an independent study of the benefits of each SDA to prepare a roadmap for future space weather applications business strategy.

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