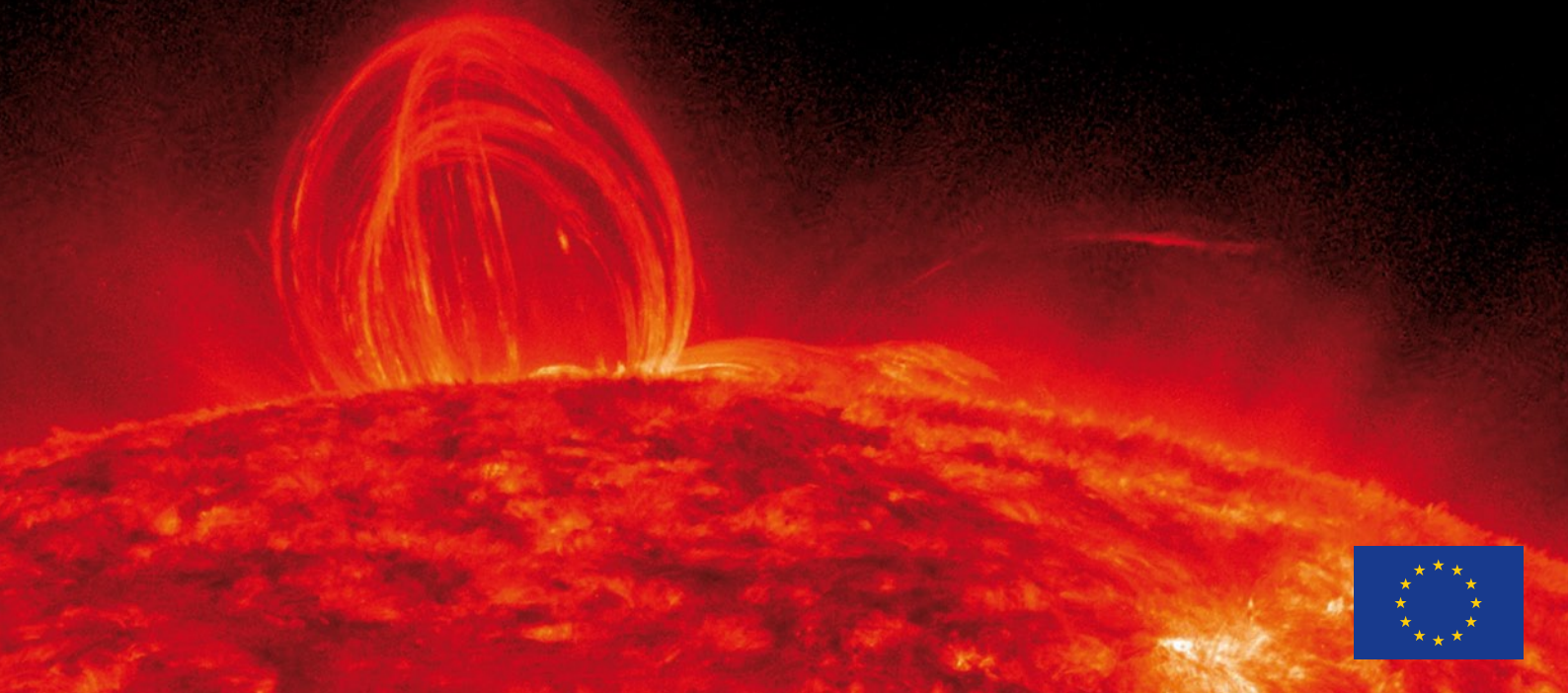
Services of AFFECTS

An introduction to the space weather services and forecast tools of AFFECTS – Advanced Forecast For Ensuring Communications Through Space




DON'T LET THE SUN
GO DOWN ON YOU
WATCH OUT
FOR SOLAR STORMS
GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN
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UNIVERSITY OF
TROMSØ UiT
UNIVERSITY OF TROMSØ
ASTRIUM
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Preface

The Sun, our home star, appears commonly to us as a rather quiet object. Solar observations from space however reveal that its outer atmosphere, the solar corona, is the source of a continuous flow of charged particles referred to as "solar wind". It carries the Sun's magnetic field into space and generates electric fields that affect all planets and comets revolving around the Sun. Particularly strong gusts of solar wind are caused by giant eruptions in the solar corona. Such solar storms can cause a large variety of unwanted effects in the Earth space environment and on Earth itself: blackouts of radio waves, interruptions of satellite navigation and communication systems, radiation hazards to astronauts and airline crews and passengers, interruptions of airline traffic, corrosion in oil pipelines, effects on railway systems, and disturbances of electric power grids with the risk of widespread and longer lasting outages with detrimental consequences. Solar superstorms, such as the "Carrington Storm" in 1859, do occur seldom, but can have catastrophic impacts on world's societal infrastructure and economy. Current estimates indicate that the space weather effects of a solar superstorm can exceed several trillion Euro costs. It is therefore a challenging task, for both scientific and societal purposes, to develop technologies and mitigation strategies that will help to reliably forecast space weather and its impacts.

Through the AFFECTS project European and US scientists have developed an advanced prototype space weather warning system to safeguard the operation of telecommunication and navigation systems on Earth from the threat of solar storms. AFFECTS – Advanced Forecast For Ensuring Communications Through Space – is a space research project under the 7th Framework Programme of the European Union.

This brochure provides a USB flash drive with a brief introduction to space weather, the AFFECTS project trailer and multimedia guides to selected project tools and services, including their access and use. The QR codes within this brochure provide easy access to web pages with further information on specific topics. They can be accessed from smartphones with a camera and an installed QR code reader app. We hope you enjoy our dissemination materials.

www.affects-fp7.eu

DON'T LET THE SUN GO DOWN ON YOU – WATCH OUT FOR SOLAR STORMS!

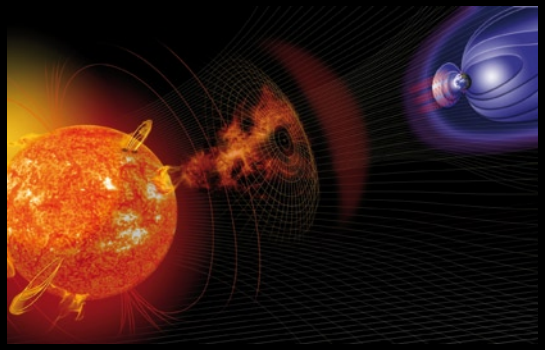
Dr. Volker Bothmer

Dr. Volker Bothmer
AFFECTS coordinator

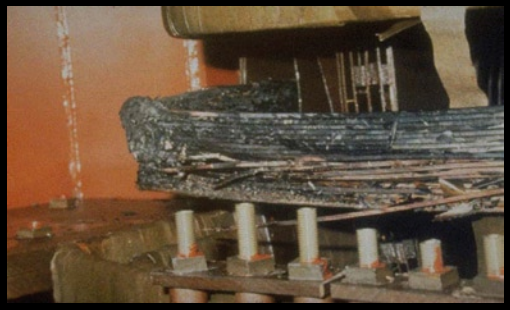
An Introduction to Space Weather and its Effects

Solar storms are sudden eruptions of magnetised gas in the Sun's outer atmosphere. They are caused by the variability of photospheric magnetic fields commonly associated with flashes of electromagnetic radiation – solar flares – ranging from X-rays to visible wavelengths, accompanied by an eruption of a giant cloud of magnetised plasma – a coronal mass ejection (CME). Fast CMEs drive shock waves which can accelerate particles to energies of several GeV, called solar energetic particle events.

Solar flares impact the Earth's upper atmosphere for several minutes to hours. Powerful flares disrupt radio communications and telecommunication and navigation systems. The Earth's upper atmosphere can even shortly expand after solar flares, perturbing the orbital motions of satellites through increased atmospheric density. Following the flare, solar energetic particles accelerated by the CME driven shock wave reach Earth within the next 10–20 minutes. They impact electronic systems of satellites and pose a radiation hazard to astronauts and airline crews and passengers. Finally, depending on its initial velocity, from half a day to five days later the coronal mass ejection will reach Earth's orbit.



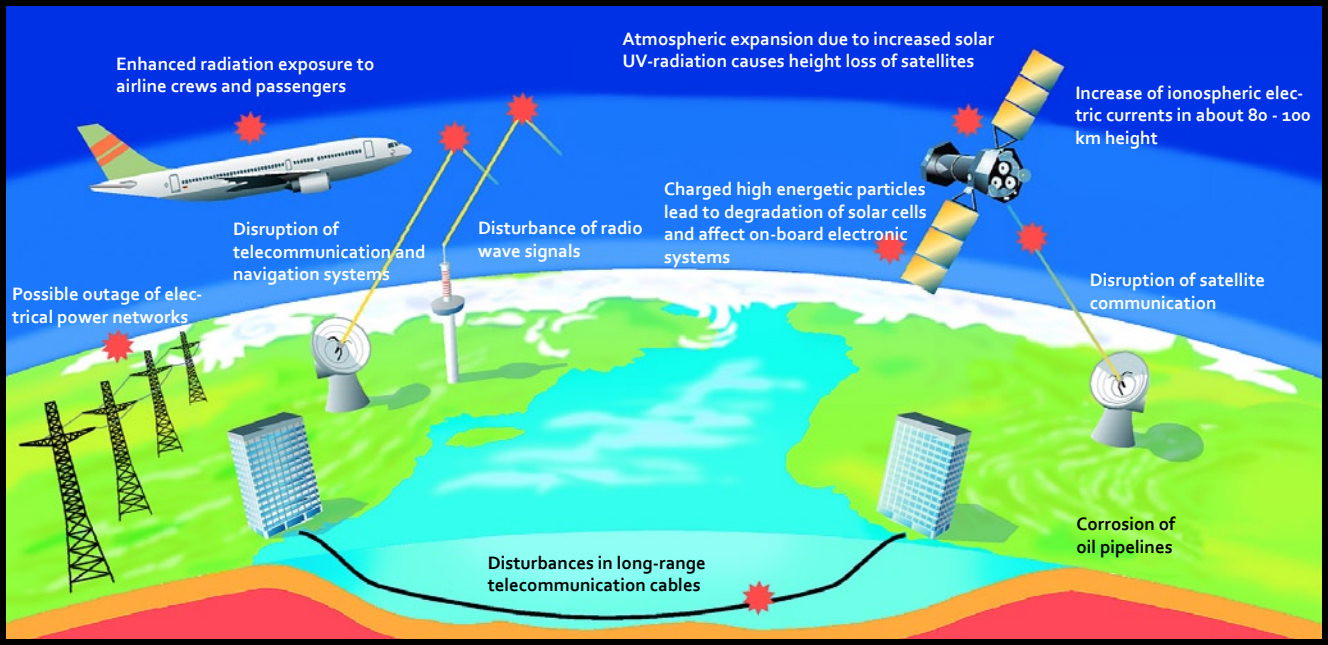
Solar events changing the conditions in near-Earth space
Image credit: NASA



Disrupted transformer after solar storm, Quebec, 1989
Image credit: Eskom, T. Makhosi, G. Coetzee

In case it hits Earth, electric fields will be induced in the Earth's magnetosphere by the CME, causing enhanced auroral activity, disturbances of navigation systems such as GPS and Galileo, and communication signals. Ground induced currents on Earth cause corrosion of oil pipelines, perturbations in long-distance communication cables and even outages of electric power systems through transformer damages, as happened in Quebec in March 1989.

Thus the natural hazards of severe space weather have the potential to catastrophically disrupt the operations of technological systems in space and on Earth.



Space weather effects on Earth
Image credit: R. Michaelis, A. Grosse, V. Bothmer

To be able to mitigate space weather hazards we need:

- continuous dedicated observation of the Sun from space, currently provided by the scientific missions ACE, Proba-2, SDO, STEREO, SOHO and instruments on board the ISS;
- near real-time data analysis as input for dedicated models and simulations to provide reliable space weather forecasts;
- dedicated space weather programmes of the international space agencies ESA and NASA for developing operational space weather instruments and satellites and the required ground-based infrastructure.

The AFFECTS project has significantly advanced space weather research and state-of-the-art forecast methods.

Technologies affected by space weather
Image credit: NASA

AFFECTS Services

The AFFECTS project has developed dedicated space weather tools and services which are freely available at http://www.affects-fp7.eu/services/. An overview of these services and tools is given below.

Query Services

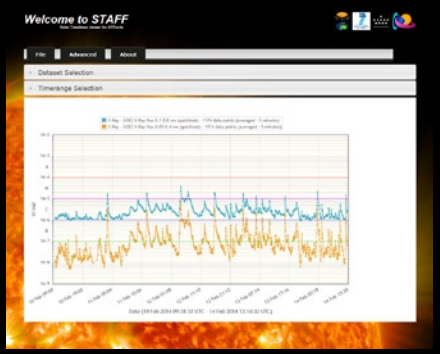
AFFECTS Space Weather Reports and Storm Warnings

http://www.affects-fp7.eu/weather

For severe space weather events we provide Space Weather Reports and Storm Warnings through the AFFECTS iOS app, the project website at Göttingen University and dedicated subscription services. The app provides real-time warnings of the National Oceanic and Atmospheric Administration (NOAA) for space storm levels of 3 and above via push messages. First warnings are commonly available within an hour after the onset of a strong event.

Solar Timelines viewer for AFFects (STAFF)

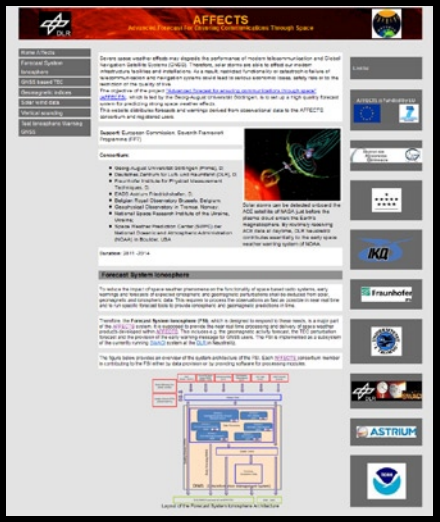
http://www.affects-fp7.eu/STAFF



Through the AFFECTS STAFF service, users can interactively generate plots of a variety of space weather data sets. These can be effectively used for space weather forecasting, data analysis correlation and to display extended time intervals. Additionally the data can be exported as image or data files for further usage. The application is developed by the Royal Observatory of Belgium (ROB) which also hosts the data sets.

Forecast System Ionosphere (FSI)

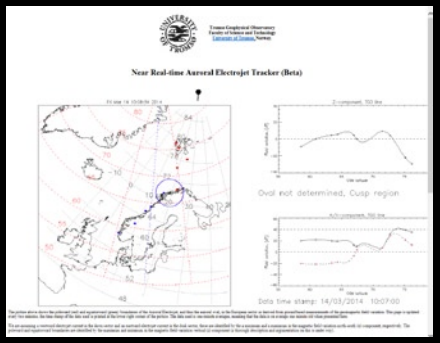
http://www.affects-fp7.eu/SWACI



The FSI website, running as part of the SWACI system, hosted by the German Aerospace Center DLR Neustrelitz, provides databases and new space weather products developed within AFFECTS. It aims at mitigating the impact of space weather events on communications and navigation systems. For this purpose the FSI provides a prediction of space weather related geomagnetic and ionospheric perturbations for Europe. Solar observations and measurements are used for forecasting geomagnetic activity and ionospheric total electron content (TEC) and subsequent signal error ranges. Additionally, high latitude geomagnetic monitoring and early warning for Global Navigation Satellite System (GNSS) users are provided.

Near Real-time Auroral Electrojet Tracker (NRAET)

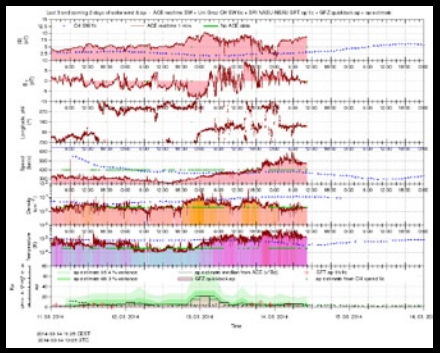
http://www.affects-fp7.eu/NRAET



The NRAET provides near real-time data about auroral activity in Europe. It shows the boundaries of the Auroral Electrojets, and thus the auroral oval, in the European sector as derived from ground-based measurements of geomagnetic field variations. The service was developed by the University of Tromsø, Norway, which also provides the data.

Solar Wind and ap Forecast Plot

http://www.affects-fp7.eu/Plot-SW-AP-Forecast/



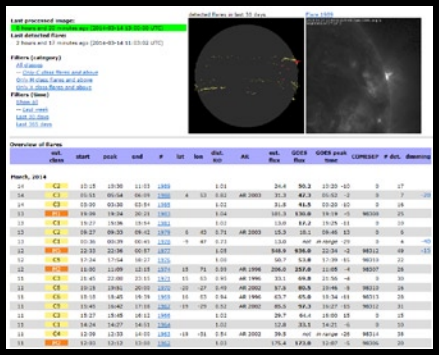
This link provides plots of the last three and upcoming two days of solar wind speed and ap-values. The plot updates every five minutes and displays:

- coronal hole solar wind forecasts in collaboration with Graz University/COMESEP
- ap forecasts based on the Geomagnetic Forecast Tool developed by SRI NASU-NSAU

- ap quick-look data from GFZ Potsdam
- ACE realtime solar wind data in collaboration with NOAA-SWPC and DLR
- ap estimates derived from ACE real-time data
- ap estimate forecasts derived from coronal hole solar wind speed forecasts

Solar Demon

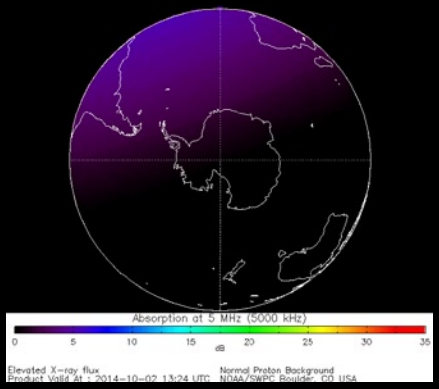
http://www.affects-fp7.eu/SD/



Solar Demon is a near real time dimming and EUV wave detector for quick-look SDO-AIA data. As dimmings and EUV waves are often the precursors of CMEs, careful detection and characterisation of these features helps space weather forecasters to derive more accurate forecasts. The tool was developed by the Royal Observatory of Belgium.

D Region Absorption Predictions (D-RAP)

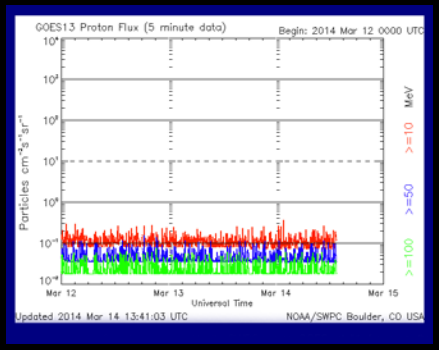
http://www.affects-fp7.eu/D-RAP/



Conditions in the D region of the ionosphere have dramatic effects on high frequency (HF) communications and low frequency (LF) navigation systems. This product, provided by NOAA-SWPC, is useful to customers from a broad base that includes emergency management, aviation and maritime users. D-RAP addresses the operational impact of the solar X-ray flux and SEP events on HF radio communication. It updates continuously, driven by one-minute GOES X-ray flux data and by five-minute GOES proton flux data.

GOES Proton-Flux

http://www.affects-fp7.eu/Proton-Flux/



Display of GOES 5-minute averaged integral proton flux (protons·s^{-1}·ster^{-1}·cm^{-2}) from NOAA-SWPC as measured by the SWPC primary GOES satellite for energy thresholds of ≥10, ≥50, and ≥100 MeV. SWPC's proton event threshold is 10 protons·s^{-1}·ster^{-1}·cm^{-2} at energies ≥10 MeV.

Overview of Space Weather Subscription Services

AFFECTS Space Weather Reports and Storm Warnings http://www.affects-fp7.eu/weather/
Warnings and reports for severe space weather conditions.

L1 Solar Wind Alert http://www.affects-fp7.eu/RSS-L1-SW/ *
L1 real-time ACE data solar wind alert. This RSS feed creates a new alert if one defined threshold of B, Bz or V is exceeded.

L1 Kp Alert http://www.affects-fp7.eu/RSS-L1-Kp/ *
L1 real-time ACE data alert used for Kp prediction. This RSS feed creates a new alert if the predicted Kp value exceeds a given threshold.

L1 Aurora Alert http://www.affects-fp7.eu/RSS-L1-Aurora/ *
L1 real-time ACE data alert used for Kp prediction with additional auroral boundary information. This RSS feed creates a new alert if the predicted auroral position reaches defined thresholds.

L1 GNSS Alert http://www.affects-fp7.eu/RSS-L1-GNSS/ *
L1 real-time ACE data alert creates a new alert if the solar wind influence on GNSS accuracy may be significant. It is derived from the estimated Kp value based on the NOAA Space Weather Scale for Geomagnetic Storms.

NOAA Product Subscription Service http://pss.swpc.noaa.gov/
Yields alerts, warnings, watches, forecasts and summaries via e-mail within moments of issue. To sign up: register, select products of interest from various categories, then review your choices.

ROB SIDC Product Subscription Service http://sidc.oma.be/registration/registration_main.php
Yields bulletins, forecasts and real-time alerts from Solar Influences Data Center (SIDC) products via e-mail.

UGOE AFFECTS Newsletter Solar Storm Warning http://www.affects-fp7.eu/Newsletter/
Newsletter for severe space weather reports and solar storm warnings issued by the Georg-August University Göttingen.

* Please note that a RSS feed compatible browser is required.

AFFECTS Mobile Apps

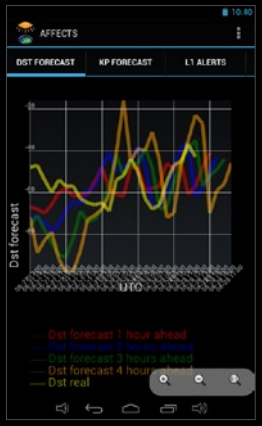
AFFECTS space weather services are also available through the AFFECTS mobile apps. They have been developed for the two most widespread platforms Apple iOS and Android. Please note that they have been developed independently and therefore differ. Solar images can only be viewed in the iOS app.

Apple iOS

The AFFECTS space weather app for the iOS system features near real-time observations of the Sun and solar wind and provides space weather tools, services and warnings, including a push service for NOAA (National Oceanic and Atmospheric Administration) space weather alerts of level 3 and above.

Download the AFFECTS iOS app from the Apple App Store. Use the QR code below or follow the redirect-link http://www.affects-fp7.eu/App-iOS/

Android



The AFFECTS Android app provides forecast and nowcast information on selected space weather conditions, covering quicklook Dst and Kp forecasts, real-time alerts of L1 parameters with scalable thresholds, the auroral oval position in the European sector, SIDC Presto and Ursigram reports and information on the TEC over Europe.

Download the AFFECTS Android app from the AFFECTS website. Use the QR code below or follow the redirect-link http://www.affects-fp7.eu/App-Android/

To install the Android app, Android version 4.1 or higher is required. Please note that you have to accept installations from "Unknown sources" in the security settings of your Android device.

AFFECTS Interactive Service Guide

Detailed descriptions of the AFFECTS services and instructions on how to use them are provided through the digital AFFECTS Interactive Service Guide, which is included as an interactive PDF file on the USB flash drive, attached below.

The AFFECTS Interactive Service Guide requires a PDF reader software, e.g. Adobe Reader 9.0 or later. Adobe Reader can also be found on the USB flash drive, together with the AFFECTS Project Trailer. Please note that the interactive PDF features might not work with other readers and with other smartphone apps.

Peel off the AFFECTS flash drive now and flap out the lash to reveal the USB connector to start your personal space weather programme.

The AFFECTS Interactive Service Guide (filesize about 350 MB) can also be downloaded under:

http://www.affects-fp7.eu/InteractiveServiceGuide/

The videos included in the Interactive Service Guide can also be found on the AFFECTS YouTube channel:

http://www.youtube.com/AFFECTSEU

How to use the Services and Information

The AFFECTS space weather tools and services can be used for free and are directly provided in its easiest form through the AFFFECTS iOS mobile app available in the Apple App Store at the following redirect link: http://www.affects-fp7.eu/App-iOS/.

The app provides a homescreen which allows quick-looks of the latest solar images from SDO and STEREO, and solar wind data taken near the L1 Lagrangian Point, 1.5 million km ahead of Earth in the sunward direction, by the ACE satellite. The solar wind data can further be found under "Alerts", "Data and Simulations" where the data plots are resizable. In this section also the GOES flare measurements can be investigated. The app homescreen provides up to date information on the NOAA scales for radio blackouts (R), geomagnetic storms (G) and solar energetic particle radiation storms (S). If enabled by the user, the app sends out alerts via push messages for the individual categories from level 3 on. The buttons on the homescreen will provide the corresponding values and colours, and the waves between Sun and Earth will lighten up in red. The "Sun" button provides access to selected observations from STEREO, SDO, SOHO and information on the status of the sunspot cycle.

AFFECTS services and tools and additional information on space weather are available through the "Space Weather" button. "Alerts" provides links to the RSS feeds sent for near real-time L1 solar wind, geomagnetic activity, aurorae and GNSS error as alerts if ACE solar wind data exceed specified thresholds. For the use of these alerts a RSS feed reader is required. "Services" provides links to the individual subscription services of ROB, NOAA-SWPC, UGOE and DLR. Here you can subscribe to e-mail alerts for flares, CMEs or energetic particle events, the FSI system messages and severe space weather forecast reports issued by UGOE as newsletter. For more information on the individual space weather effects and the provided tools and services the user is referred to the NOAA scales and the AFFECTS website.

NOAA Space Weather Scales

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).**	Kp=8	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).**	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).**	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).**	Kp=5	1700 per cycle (900 days per cycle)

* Based on this measure, but other physical measures are also considered.
** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.swpc.noaa.gov/Aurora)

Radio Blackouts			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extreme	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 (2×10^{-3})	Fewer than 1 per cycle
R 4	Severe	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. Navigation: Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	3 per cycle
R 3	Strong	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. Navigation: Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	10 per cycle
R 2	Moderate	HF Radio: Limited blackout of HF radio communication on sunlit side of the Earth, loss of radio contact for tens of minutes. Navigation: Degradation of low-frequency navigation signals for tens of minutes.	M5 (5×10^{-5})	25 per cycle
R 1	Minor	HF Radio: Weak or minor degradation of HF radio communication on sunlit side of the Earth, occasional loss of radio contact. Navigation: Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	50 per cycle

* Flux, measured in the 0.1-0.8 nm range, in W·m-2. Based on this measure, but other physical measures are also considered.
** Other frequencies may also be affected by these conditions.

NOAA Space Weather Scales, including radiation storms (S):
http://www.swpc.noaa.gov/NOAAscales/.

About AFFECTS

AFFECTS is an international research team under the lead of the Institute for Astrophysics of the Georg-August-University Göttingen in Germany, funded under the 7th Framework Programme of the European Union. During the years 2011 to 2014 the AFFECTS institutions have developed the first prototype of a European space weather early warning system.

This warning system analyses data of current space missions in near real-time and calculates the strength, direction, speed and course of solar storms as well as their effects on Earth.

Partners of the AFFECTS project are besides the Georg-August-University Göttingen, the Institute of Communications and Navigation of the German Aerospace Center in Neustrelitz, Germany, the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg, Germany, the company ASTRIUM in Friedrichshafen, Germany, the Planetarium Hamburg, Hamburg, Germany, the Solar Influences Data Analysis Center of the Royal Observatory of Belgium, Brussels, Belgium, the Tromsø Geophysical Observatory of the University of Tromsø, Tromsø, Norway, the Space Research Institute of the National Academy of Sciences of Ukraine and the National Space Agency of Ukraine, Kyiv, Ukraine and the Space Weather Prediction Center of the National Oceanic and Atmospheric Administration, Boulder, United States.

Contact Information:
Dr. Volker Bothmer
Georg-August-University Göttingen
Institute for Astrophysics
Friedrich-Hund-Platz 1
D-37077 Göttingen
Germany

E-mail: bothmer@astro.physik.uni-goettingen.de
Phone: +49 (0) 551 39 5044
Fax: +49 (0) 551 39 5043
AFFECTS website: http://www.affects-fp7.eu
AFFECTS YouTube Channel:
http://www.youtube.com/AFFECTSEU

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AFFECTS thanks Fred Sigernes of The Kjell Henriksen Observatory, Svalbard for permission to distribute the Auroral Forecast service.

We are grateful for the open data policy in the NASA STEREO, SDO and ACE missions.

List of Acronyms

ACE	Advanced Composition Explorer
AFFECTS	Advanced Forecast For Ensuring Communications Through Space
AIA	Atmospheric Imaging Assembly
Ap	Amplitude planetary daily average magnetic activity index (equivalent daily amplitude)
ap	Amplitude planetary 3-hour range magnetic activity index
CME	Coronal Mass Ejection
COMESEP	COronal Mass Ejections and Solar Energetic Particles
DLR	Deutsches Zentrum für Luft- und Raumfahrt e. V. (German Aerospace Center)
D-RAP	D Region Absorption Predictions
Dst	Disturbance storm time
ESA	European Space Agency
EUV	Extreme UltraViolet
FP7	Seventh Framework Programme
FSI	Forecast System Ionosphere
GFZ Potsdam	Deutsches GeoForschungsZentrum (German Research Centre for Geosciences)
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
IPM	Institute for Physical Measurement techniques
ISS	International Space Station
Kp	planetary 3-hour-range magnetic activity K-index
L1	Lagrangian point 1
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NRAET	Near Real-time Auroral Electrojet Tracker
Proba-2	Project for On-Board Autonomy-2
ROB	Royal Observatory of Belgium
SDO	Solar Dynamics Observatory
SEP	Solar Energetic Particles
SEU	Satellite single Event Upset
SIDC	Solar Influences Data Analysis Center
SOHO	SOlar and Heliospheric Observatory
SRI NASU-NSAU	Space Research Institute of the National Academy of Sciences of Ukraine and the National Space Agency of Ukraine
STAFF	Solar Timelines viewer for AFFects
STEREO	Solar TErrestrial RElations Observatory
SWACI	Space Weather Application Center Ionosphere
SWPC	Space Weather Prediction Center
TEC	Total Electron Content
UGOE	University of Göttingen

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