AFFECTS

A multi-institution research project to mitigate space weather hazards

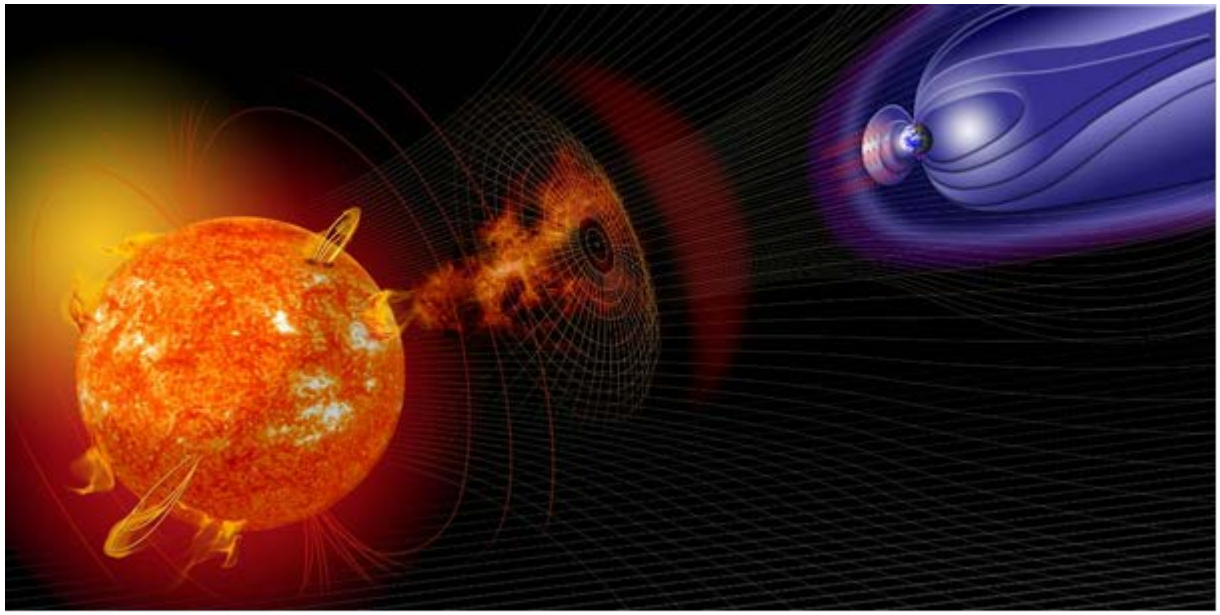
Jens Berdermann
for the AFFECTS consortium

03/2011 – 02/2014

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

Key objectives of the AFFECTS project

1. **Analysis and modelling of the Sun-Earth chain** of effects on the Earth's ionosphere and their subsequent impacts on communication and navigation systems based on multipoint space observations and complementary ground-based data.
2. Development of a prototype space weather **early warning and** reliable space weather **forecast system**, with specific emphasis on ionospheric applications.
3. **Dissemination** of new space weather products and services to end users, the scientific community and general public.



Sketch of a coronal mass ejection propagating towards Earth. Courtesy: NASA.

1. Analysis and modelling of the Sun-Earth chain

Solar Demon is a near real-time flare, dimming and EUV wave detector developed at ROB as part of collaboration between the FP7 projects AFFECTS and COMESEP. Solar Demon allows forecasters and other users to better detect and characterize flares, dimmings and EUV waves, which are precursors to CMEs.The Solar Demon website provides an online catalog of flares and dimmings with detailed light curves, movies, images and statistics on every detected event.

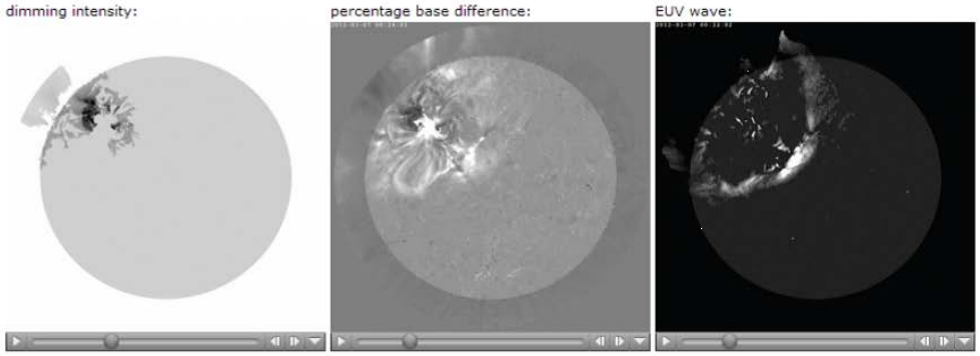
http://solardemon.oma.be/

Last processed image:
2013-02-15 21:15:00, which is 138 hours and 13 minutes ago
Last detected dimming:
2013-02-15 20:33:01, which is 138 hours and 55 minutes ago
Last detected flare:
2013-02-06 01:03:01, which is 374 hours and 25 minutes ago

Overview for dimming #:
2 go back to overview

Simultanous flares:
id: 3 **brightness:** 193.5 * 10^6 **lat:** 18.4 **lon:** -30.6

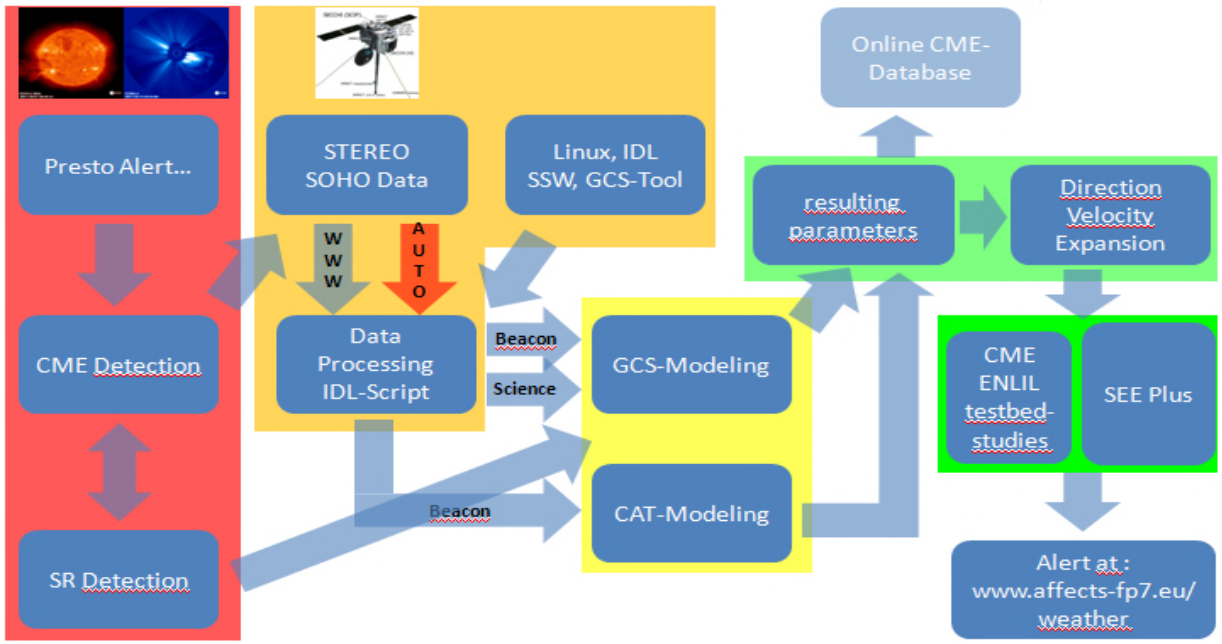
Dimming animations
dimming base difference
dimming percentage base difference
dimming mask
dimming intensity
wave percentage running difference
wave percentage base difference
wave base difference



time	seq #	intensity * 10^3	num pixels * 10^3	area km^2 * 10^9	volume * 10^9	lat	lon	AR	img	detection
2012-03-07 00:04:02	1	0.0	0.0	0.0	0.0			NaN	3503	0
2012-03-07 00:06:02	2	0.0	0.0	0.0	0.0			NaN	3504	0
2012-03-07 00:08:02	3	0.0	0.0	0.0	0.0			NaN	3505	0
2012-03-07 00:10:02	4	-1.4	0.1	0.3	-6.9	27.9	-43.2	AR 1429 (18, Beta-Gamma-Delta, 0)	3506	0
2012-03-07 00:12:02	5	-7.0	0.2	2.0	-40.4	32.6	-44.1	AR 1429 (22, Beta-Gamma-Delta, 0)	3507	0
2012-03-07 00:14:02	6	-56.7	1.9	12.6	-316.7	27.6	-45.1	AR 1429 (19, Beta-Gamma-Delta, 0)	3508	0
2012-03-07 00:16:02	7	-196.2	4.4	31.3	-1,030.6	25.9	-41.9	AR 1429 (16, Beta-Gamma-Delta, 0)	3509	1
2012-03-07 00:18:02	8	-276.1	5.0	43.8	-1,473.8	24.0	-42.2	AR 1429 (15, Beta-Gamma-Delta, 0)	3510	1
2012-03-07 00:20:02	9	-333.2	6.1	48.6	-1,757.3	24.7	-42.2	AR 1429 (15, Beta-Gamma-Delta, 0)	3511	1
2012-03-07 00:22:02	10	-410.3	8.3	52.9	-2,154.9	25.0	-41.3	AR 1429 (15, Beta-Gamma-Delta, 0)	3512	1
2012-03-07 00:24:02	11	-505.4	10.7	71.3	-2,655.0	25.1	-41.1	AR 1429 (15, Beta-Gamma-Delta, 0)	3513	1
2012-03-07 00:26:02	12	-563.7	9.5	84.3	-3,053.2	25.5	-41.7	AR 1429 (15, Beta-Gamma-Delta, 0)	3514	1
2012-03-07 00:28:02	13	-767.3	14.3	116.1	-3,999.7	24.6	-40.0	AR 1429 (13, Beta-Gamma-Delta, 0)	3515	1
2012-03-07 00:30:02	14	-856.4	15.3	110.1	-4,062.1	25.7	-42.1	AR 1429 (16, Beta-Gamma-Delta, 0)	3516	1
2012-03-07 00:32:02	15	-184.9	13.9	0.0	0.0			NaN	3517	1
2012-03-07 00:34:02	16	-979.4	15.1	151.8	-5,132.6	25.9	-42.2	AR 1429 (16, Beta-Gamma-Delta, 0)	3518	1
2012-03-07 00:36:02	17	-1,317.1	22.1	231.2	-6,985.5	25.5	-39.7	AR 1429 (14, Beta-Gamma-Delta, 0)	3519	1

1. Analysis and modelling of the Sun-Earth chain

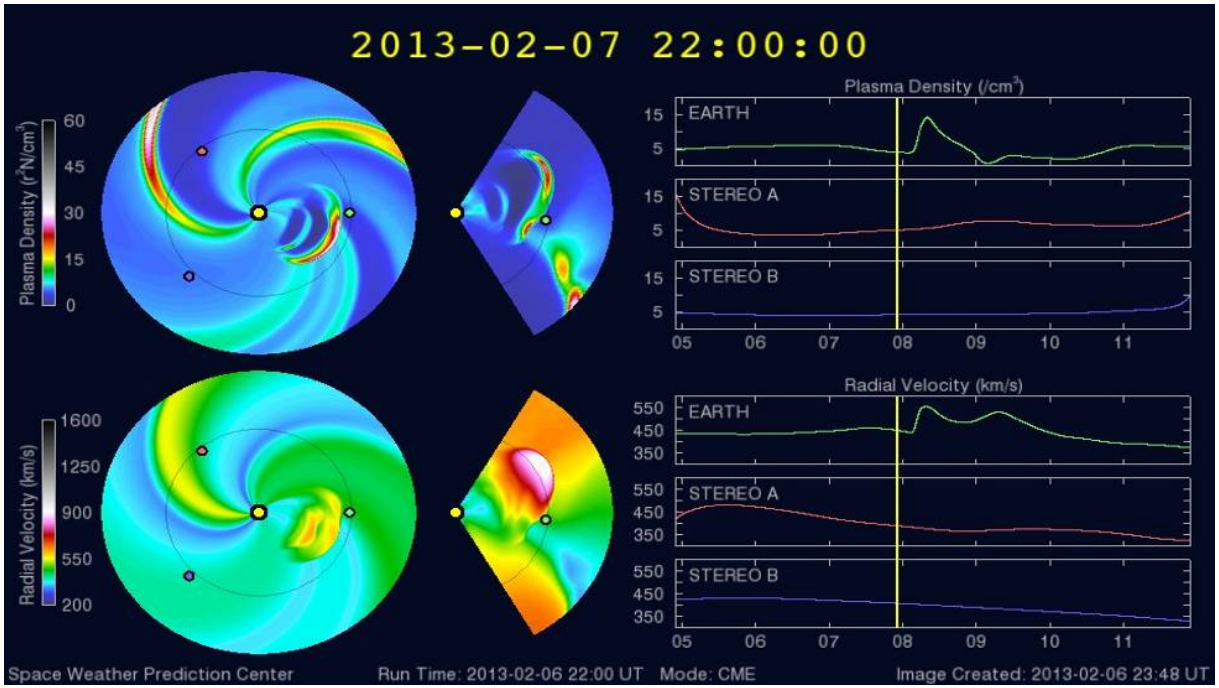
At the University of Göttingen, A CME forecast system has been set up, based on the analysis of CME parameters which allows a better estimation of CME arrival time and impact at Earth.



The final product resulting from this research (cooperation between UGOE, ROB, NOAA-SWPC, and NRL) is a real time application that currently provides a forecast of the arrival time, speed, geomagnetic strength (ap), and auroral position of a CME.

1. Analysis and modelling of the Sun-Earth chain

The Enlil model running operationally on the NOAA weather forecast computers providing continuous real-time updates on the solar wind conditions near Earth has been used to tracks the solar wind and CMEs at they propagate from the Sun to Earth.

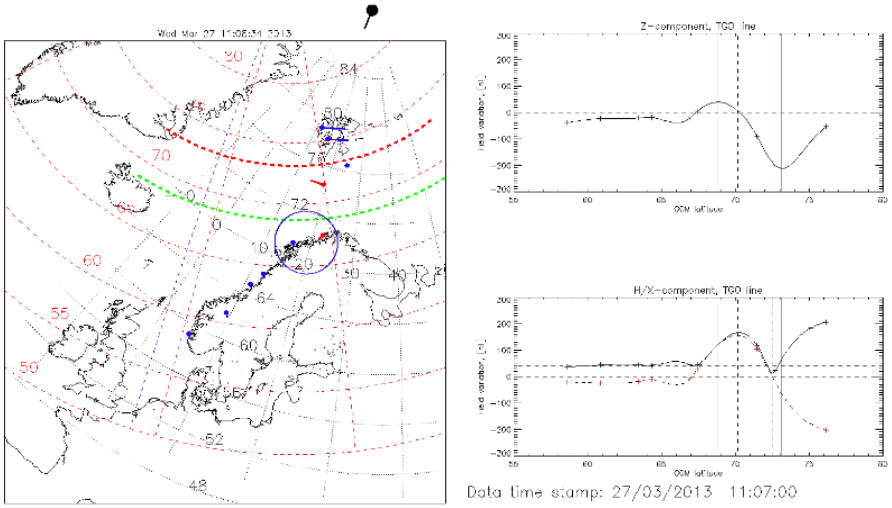


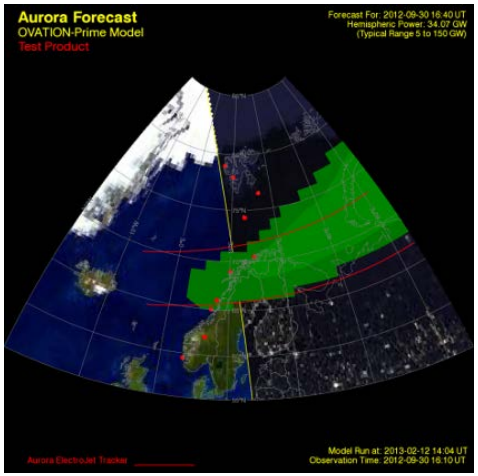
University of Goettingen is collaborating with the Enlil model developer (D. Odstrcil) to improve the model performance and to incorporate the magnetic structure of the CME based on its photospheric source region properties.

1. Analysis and modelling of the Sun-Earth chain

UoT is running an auroral electrojet model which is driven by the data from its array of magnetometers. The magnetometer chain provides an excellent estimate of the location and intensity of the aurora in the European sector.

http://fox.phys.uit.no/AFFECTS/





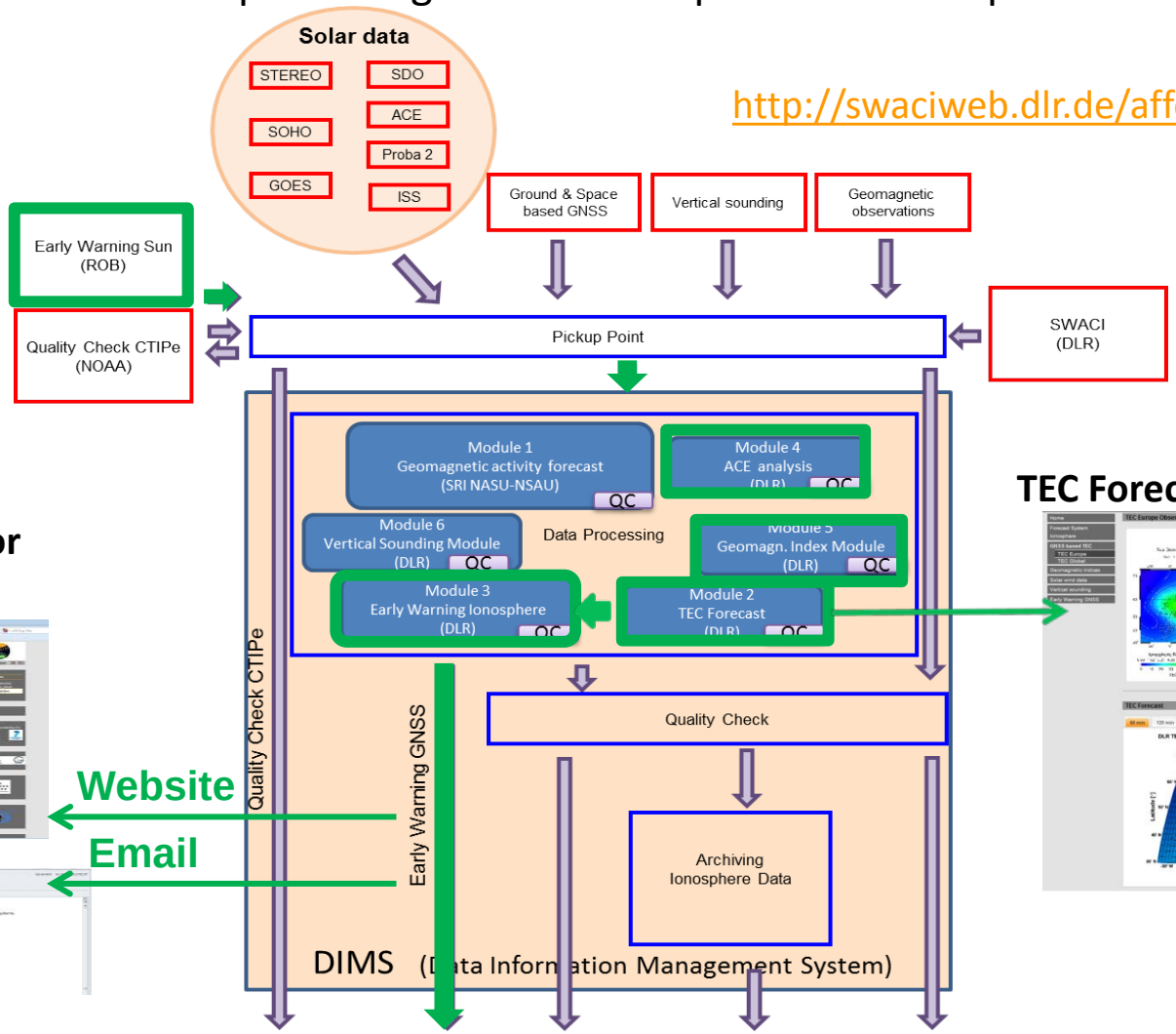
The UoT Auroral Electrojet Tracker (left and centre) and a comparison with the NOAA-SWPC Ovation model (right).

NOAA-SWPC performed side-by-side comparison of this tool with the Ovation aurora model which is driven by solar wind and interplanetary magnetic field measurements.

2. Early warning and forecast system

Forecast System Ionosphere (FSI) is a fully automated processing system developed at DLR combining measurements from the sun, the geomagnetic field and the ionosphere to generate ionospheric forecast products

http://swaciweb.dlr.de/affects/

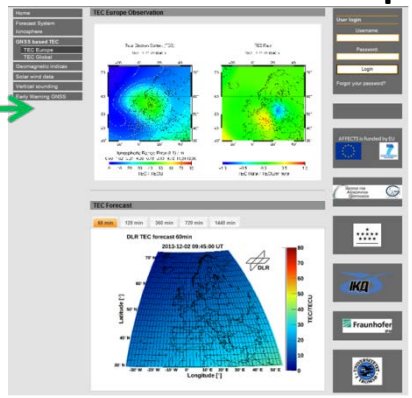


Early warning for GNSS users

Website

Email

TEC Forecast over Europe



2. Early warning and forecast system

Input data to the FSI

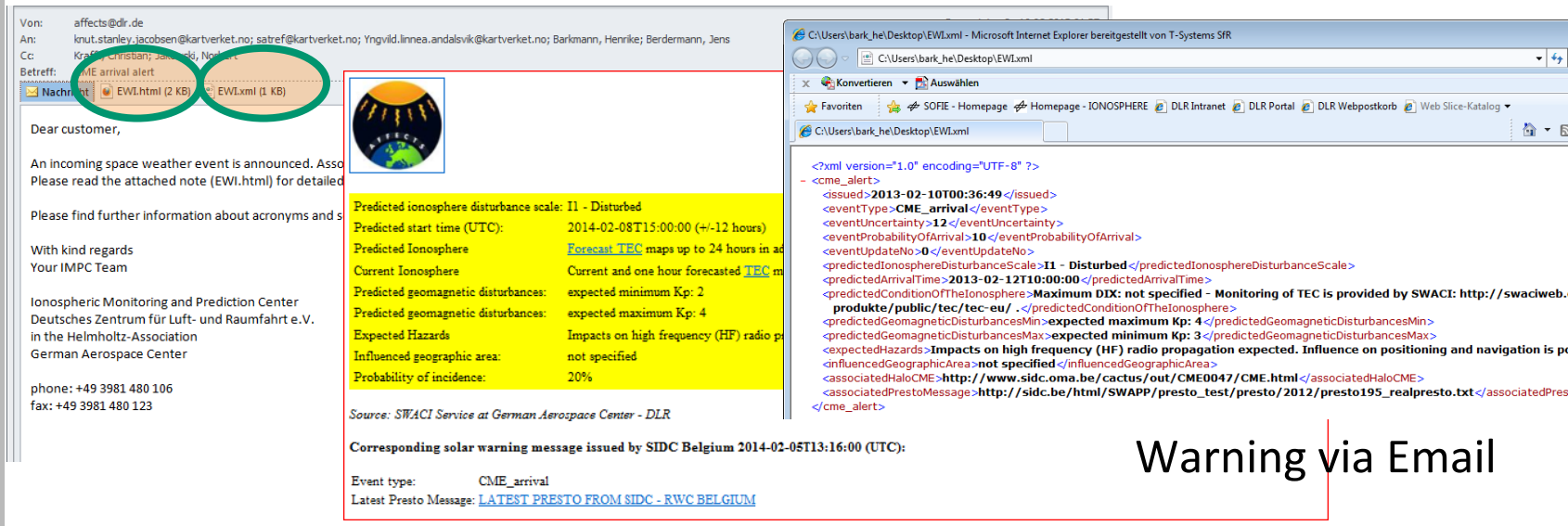
Solar Wind Data	• ACE data
Ground & Spaced based GNSS	• TEC maps
Vertical Sounding	• SAO Files
Geomagnetic Observation	• Geomagnetic indices
Early Warning	• Early Warning Message Sun
CTIPe	• TEC maps

- The FSI is based on a multi-institutional data basis and scientific expertise

2. Early warning and forecast system

Early Warning for GNSS users (2-3 days)

- Automated warning service designed for GNSS users
- Is based on solar information from the Royal Observatory of Belgium and complemented with additional information for GNSS users about possible influences on the ionosphere.
- Subscribe option at the SWACI-AFFECTS Early warning webpage to get automated warning mails about relevant space weather events.



Borries, C.; Berdermann, J.; Early Warning of ionospheric disturbances for GNSS users ; submitted as proceedings of the European Navigation Conference, GNSS, 2014

2. Early warning and forecast system

Early Warning for GNSS users (2-3 days)

Predicted ionosphere disturbance scale:	I1 - Disturbed
Predicted start time (UTC):	2014-02-08T15:00:00 (+/-12 hours)
Predicted Ionosphere	Forecast TEC maps up to 24 hours in advance. The onset of disturbances i
Current Ionosphere	Current and one hour forecasted TEC maps, provided by SWACI.
Predicted geomagnetic disturbances:	expected minimum Kp: 2
Predicted geomagnetic disturbances:	expected maximum Kp: 4
Expected Hazards	Impacts on high frequency (HF) radio propagation expected. Influence on
Influenced geographic area:	not specified
Probability of incidence:	20%

Source: SWACI Service at German Aerospace Center - DLR

Corresponding solar warning message issued by SIDC Belgium 2014-02-05T13:16:00 (UTC):

Event type: CME_arrival
Latest Presto Message: LATEST PRESTO FROM SIDC - RWC BELGIUM

AFFECTS
Advanced Forecast For Ensuring Communications Through Space

Kontakt
Printversion
DE | EN

Home
Forecast System Ionosphere
GNSS based TEC
Geomagnetic indices
Solar wind data
Vertical sounding
Early Warning GNSS

Early Warning Message for GNSS users

This Early Warning Message is a fast warning for space weather events potentially impacting GNSS measurements. The Early Warning Message for GNSS users is generated at the German Aerospace Center (DLR) Neustrelitz using presto alert and ursigram information from the Solar Influence Data Center (SIDC) Brussels.

For more information please read this link: INFO

Current Status

Source: SWACI Service at German Aerospace Center - DLR

Predicted ionosphere disturbance scale:	I0 - Normal
Predicted condition of the Ionosphere	Maximum DIX: not specified Monitoring of TEC is provided by SWACI.
Expected Hazards	none
Latest Ursigram	Ursigram, generated by Solar Influence Data Center (SIDC), provides 3-day-forecast of solar and geomagnetic activity.

Last Early Warning Issue

Predicted ionosphere disturbance scale:	I1 - Disturbed
Predicted start time (UTC):	2014-02-08T15:00:00 (+/-12 hours)
Predicted Ionosphere	Forecast TEC maps up to 24 hours in advance. The onset of disturbances in the ionosphere can be forecasted about 30 minutes in advance.
Current Ionosphere	Current and one hour forecasted TEC maps, provided by SWACI.
Predicted geomagnetic disturbances:	expected minimum Kp: 2
Predicted geomagnetic disturbances:	expected maximum Kp: 4
Expected Hazards	Impacts on high frequency (HF) radio propagation expected. Influence on positioning and navigation is possible.
Influenced geographic area:	not specified
Probability of incidence:	20%

Source: SWACI Service at German Aerospace Center - DLR

Corresponding solar warning message issued by SIDC Belgium 2014-02-05T13:16:00 (UTC):

Event type: CME_arrival
Latest Presto Message: LATEST PRESTO FROM SIDC - RWC BELGIUM

Warning Message by Email

Early warning messages can be distributed via Email. To subscribe/ unsubscribe please use the correspondent formulars.

Archive

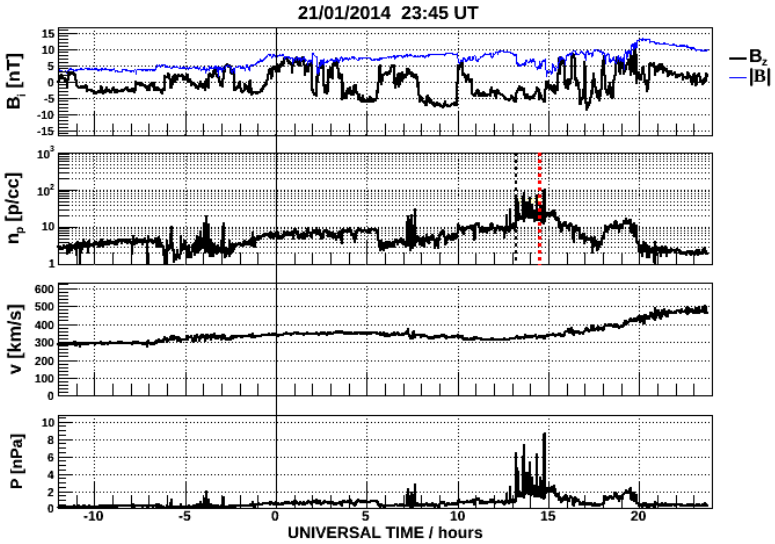
Archive_CME_arrival

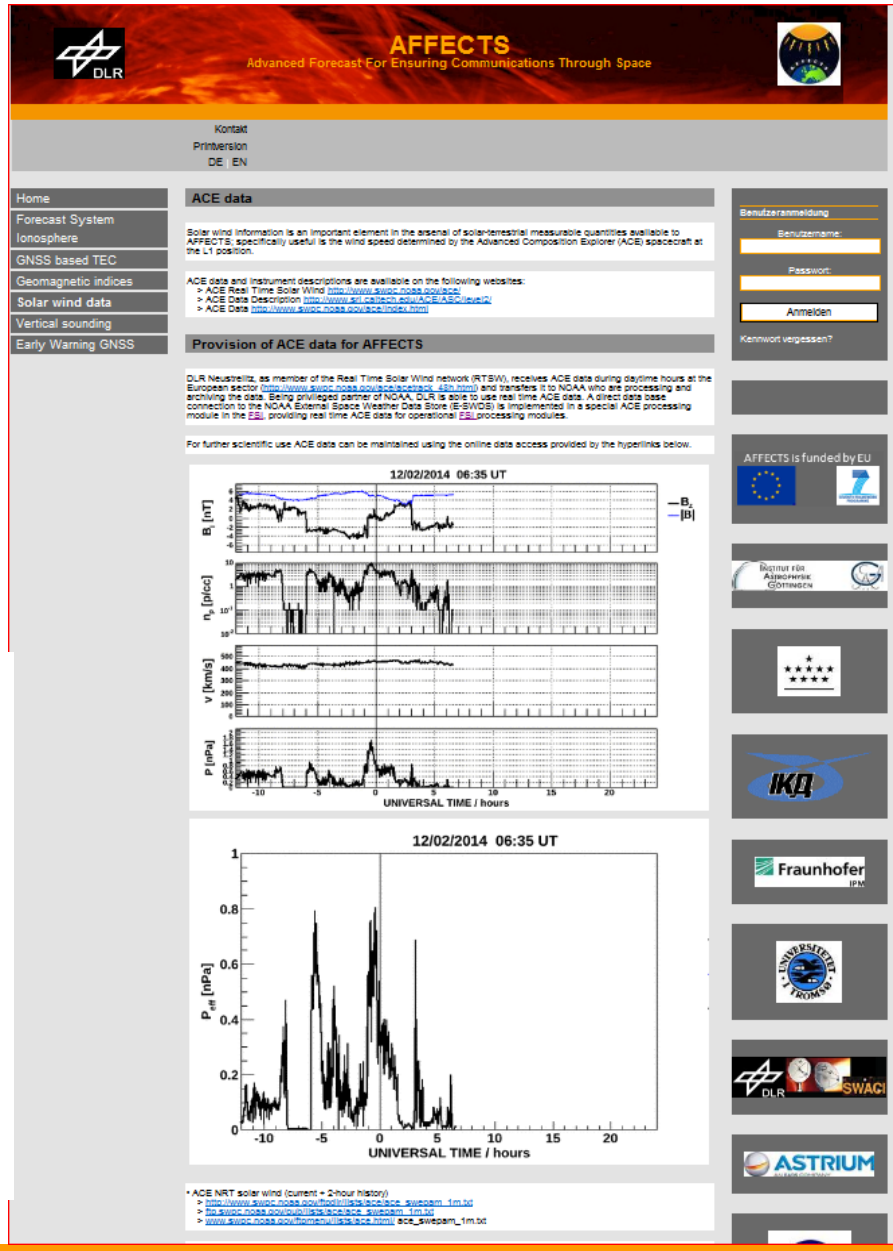
Benutzeranmeldung
Benutzername:
Passwort:
Anmelden
Kennwort vergessen?

AFFECTS is funded by EU

2. Early warning and forecast system

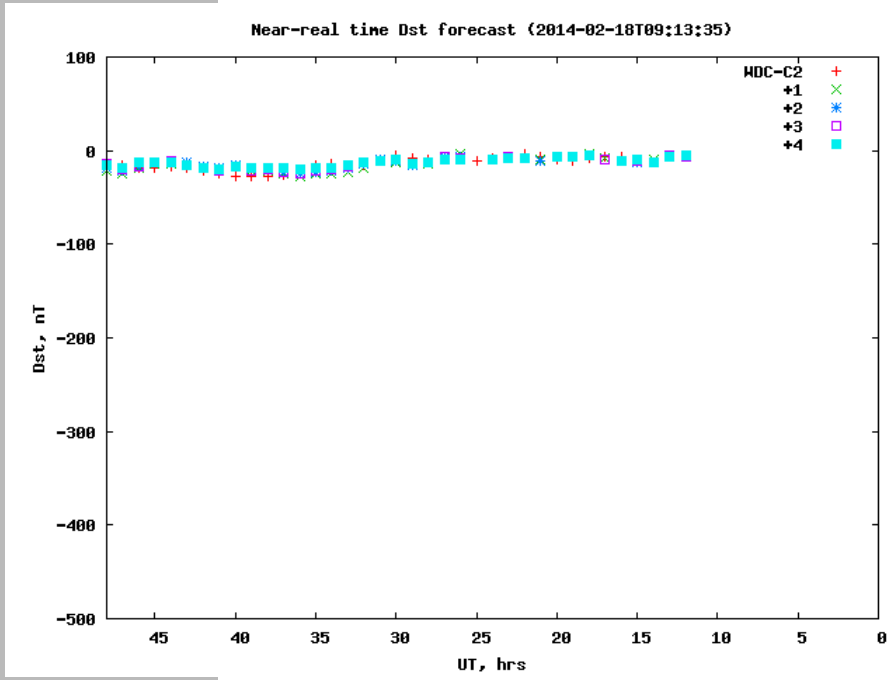
ACE Analysis (30-60 min)

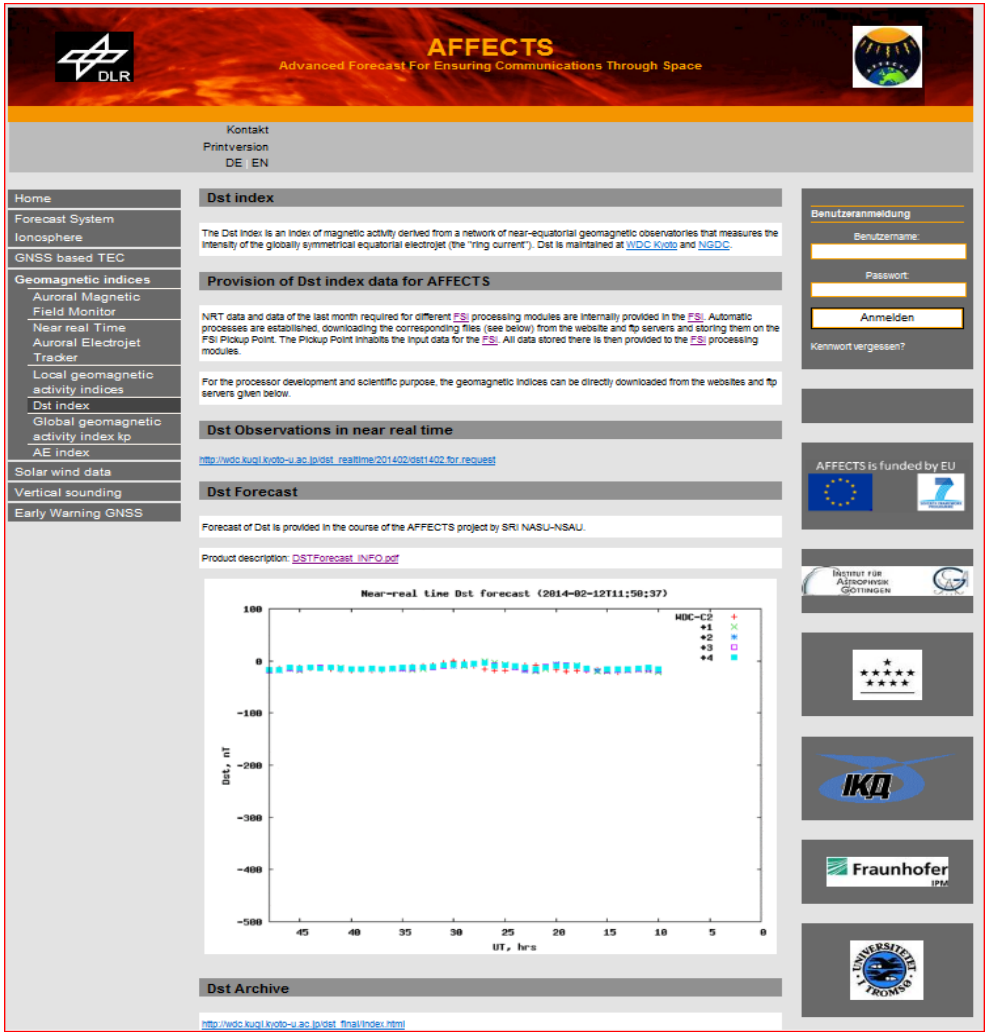




2. Early warning and forecast system

Geomagnetic activity forecast (next 4h)



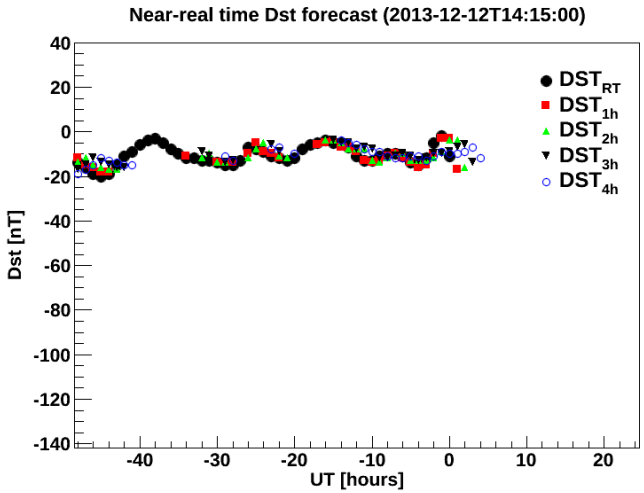


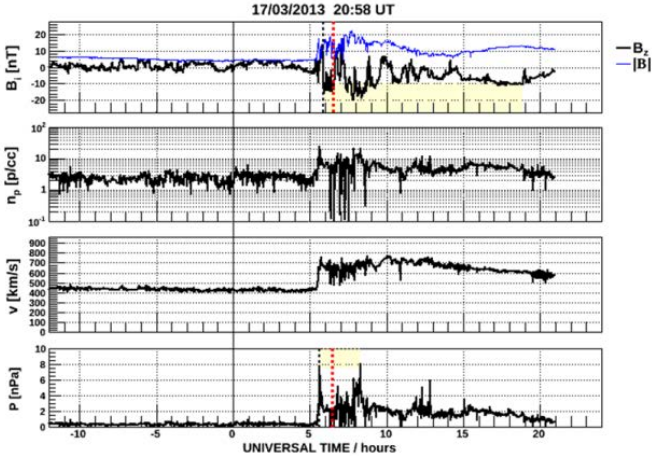
Parnowski, A.; Semeniv, O.; Polonska, A.; Malisse, V.; Verbeeck, C. ; Geomagnetic forecast tool ; submitted to Journal of Space Weather and Space Climate.

2. Early warning and forecast system

TEC forecast over Europe (next 24h)

The forecast predicts the total electron content over Europe up to 24 hours in advance also taking into account possible ionospheric perturbation caused by geomagnetic storms. The underlying empirical TEC storm model is based on identified storm patterns in the ionosphere from 1995 till 2011 over Europe and takes into account seasonal, local time, storm time and latitudinal dependencies. The TEC perturbation amplitude is estimated using an approach based on Dst and solar wind correlations.



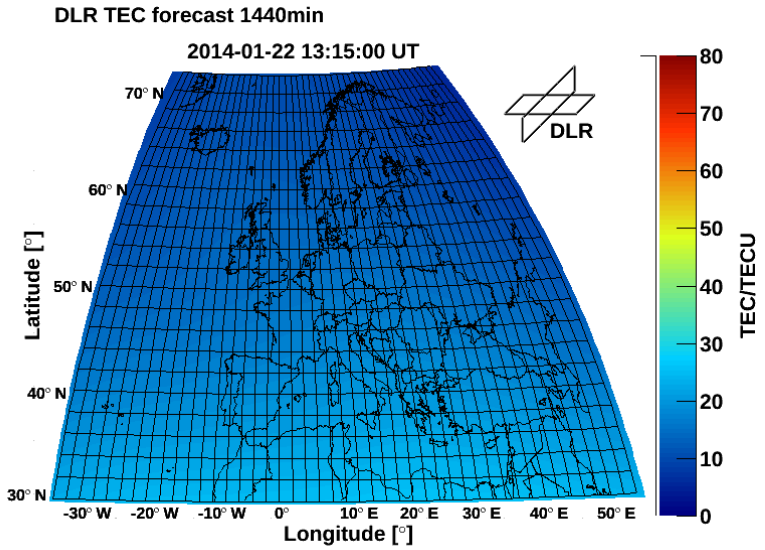


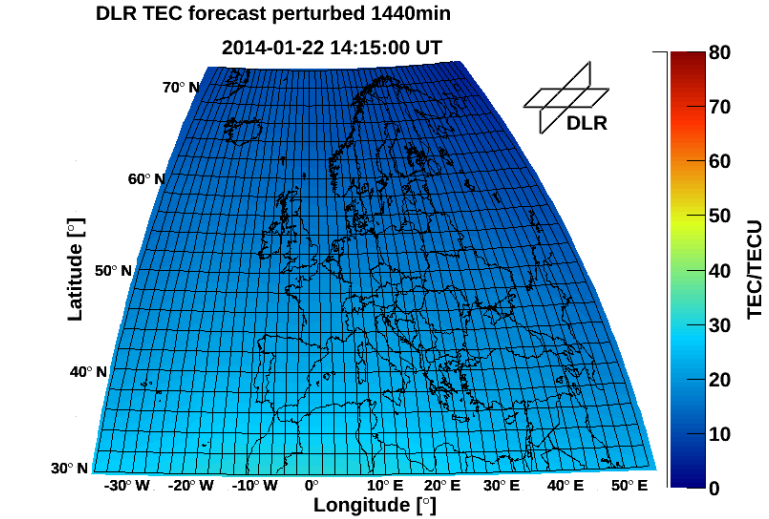
If a ionospheric storm is detected (threshold values in Dst or ACE are exceeded), the storm model is added to the undisturbed mean behaviour of TEC

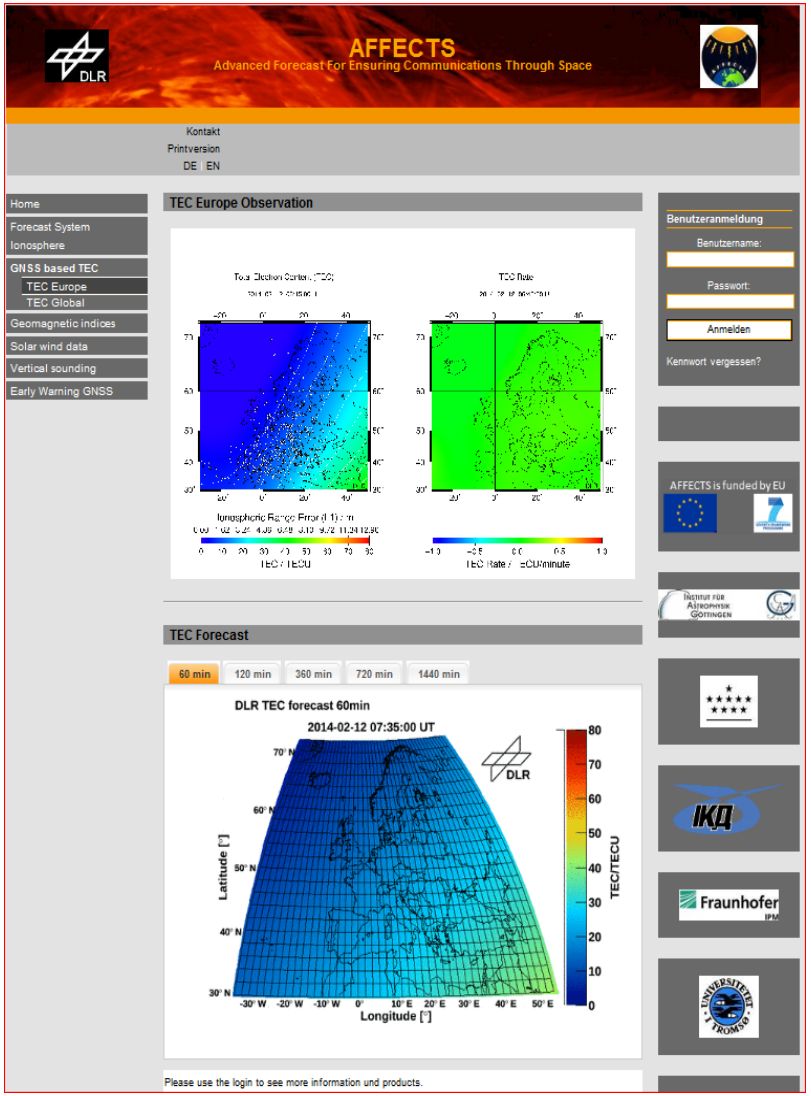
Borries, C.; Berdermann, J.; Jakowski, N.; Hoque, M. M.; Bothmer, V. ; Preparation of an advanced TEC forecast based on the statistical analysis of historical ionospheric storms ; Proceedings of the 4th international Galileo science colloquium, ESA publication WPP-335, 2013.

2. Early warning and forecast system

TEC now and forecast over Europe (next 24h)

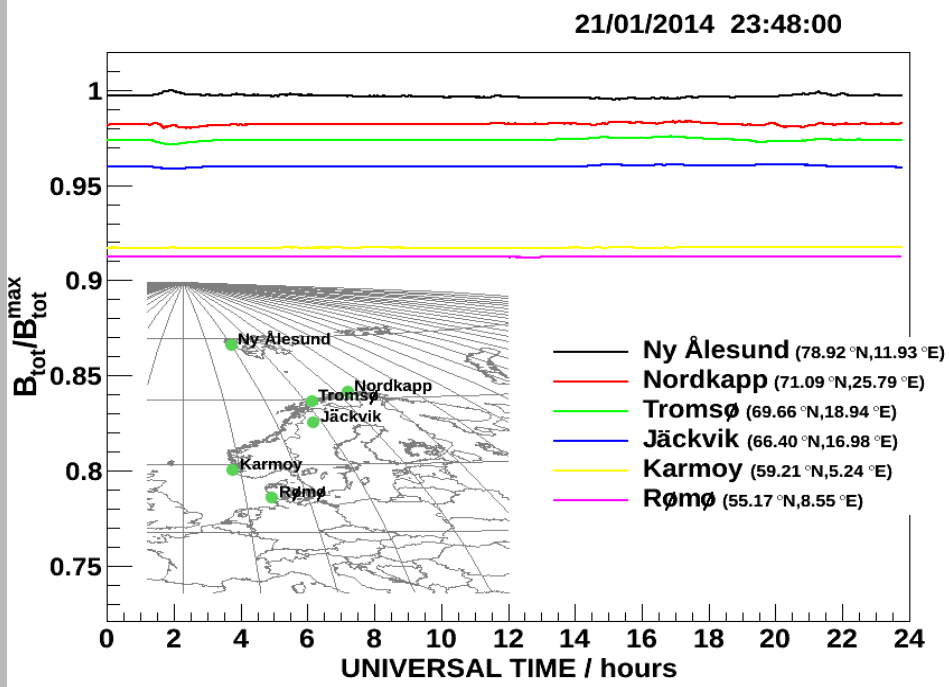


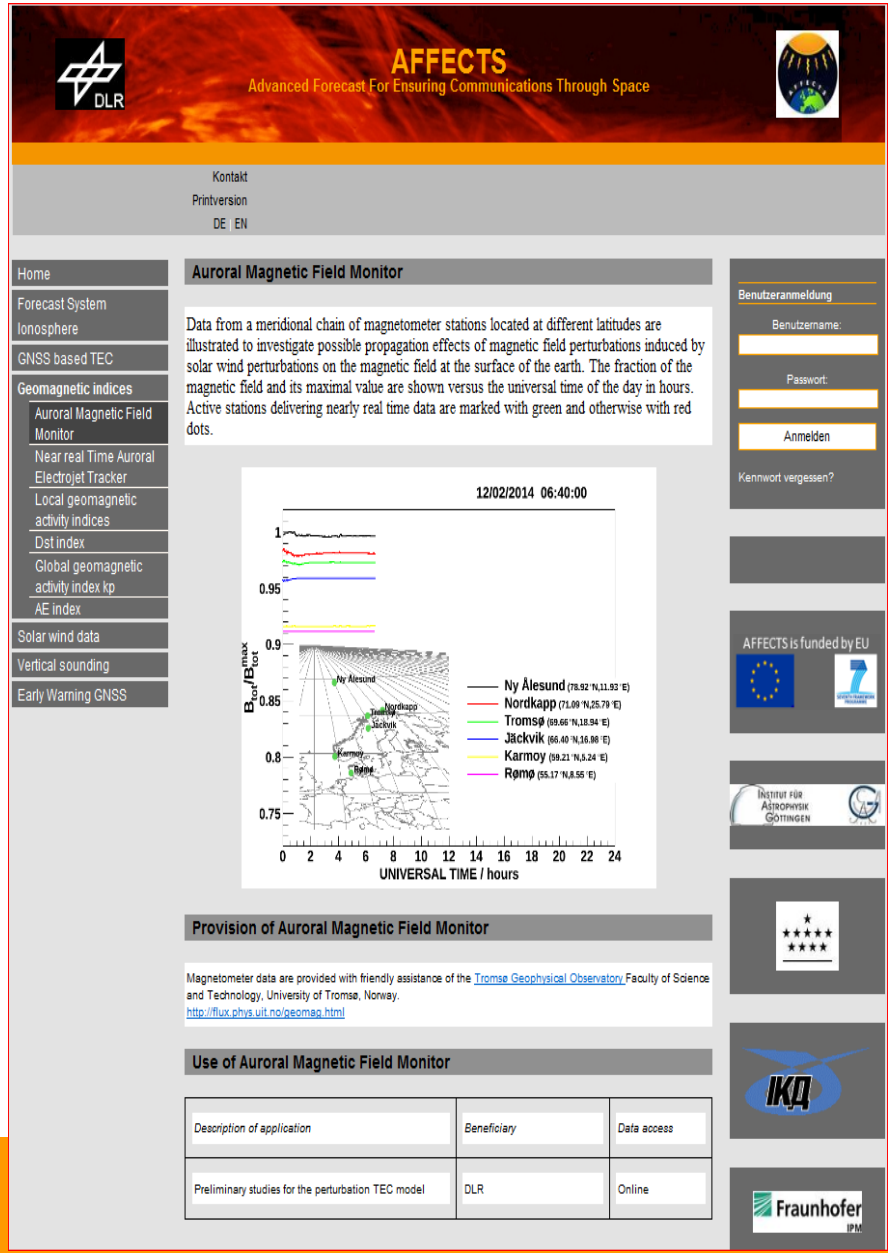




2. Early warning and forecast system

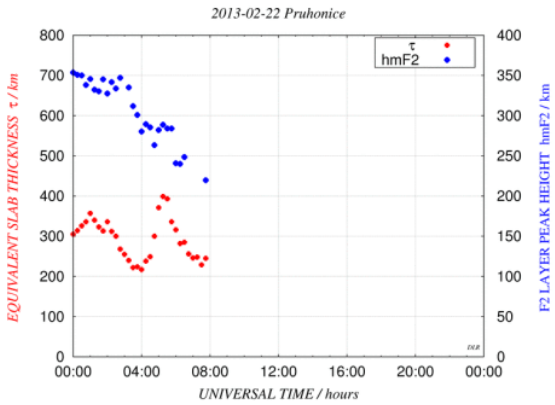
Auroral Magnetic Field Monitor (nowcast)

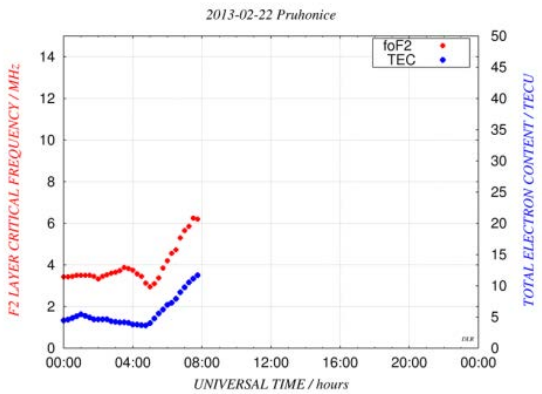




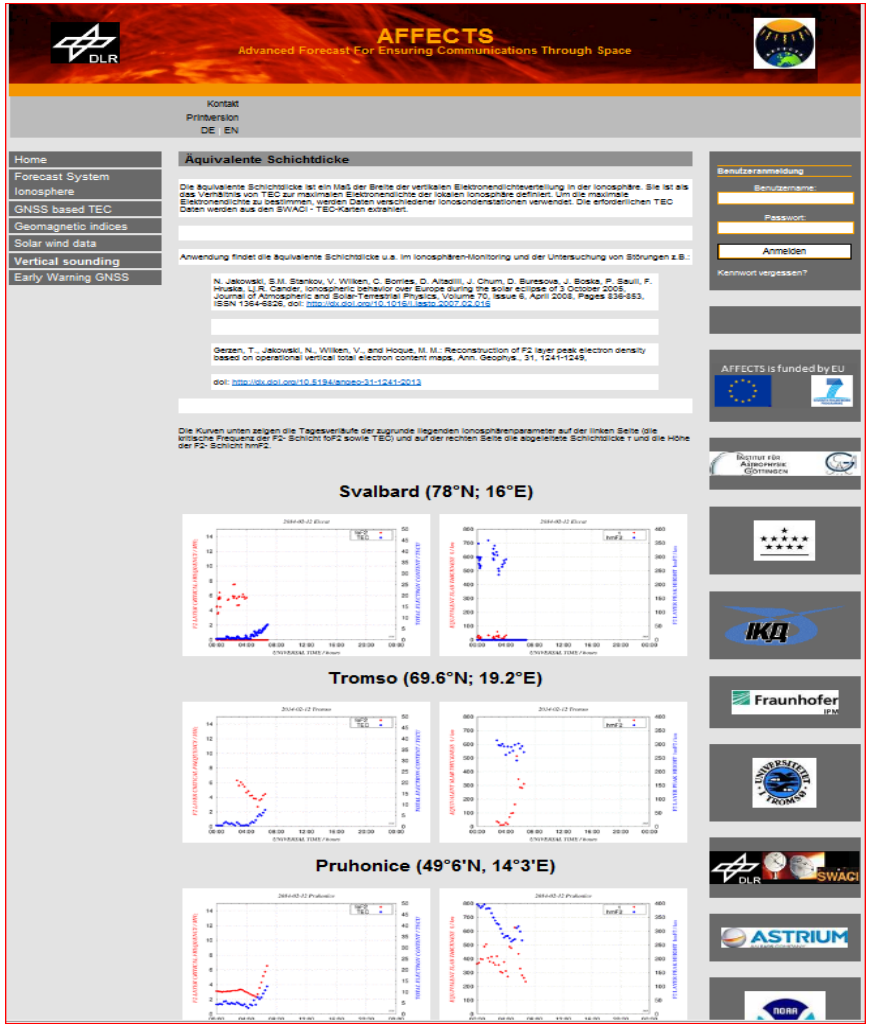
2. Early warning and forecast system

Vertical sounding (nowcast)





Example Pruhonice (49.1°N, 14.1°E)
Vertical Sounding Data supplied by Ionospheric observatory Pruhonice of the Institute of Atmospheric Physics ASCR

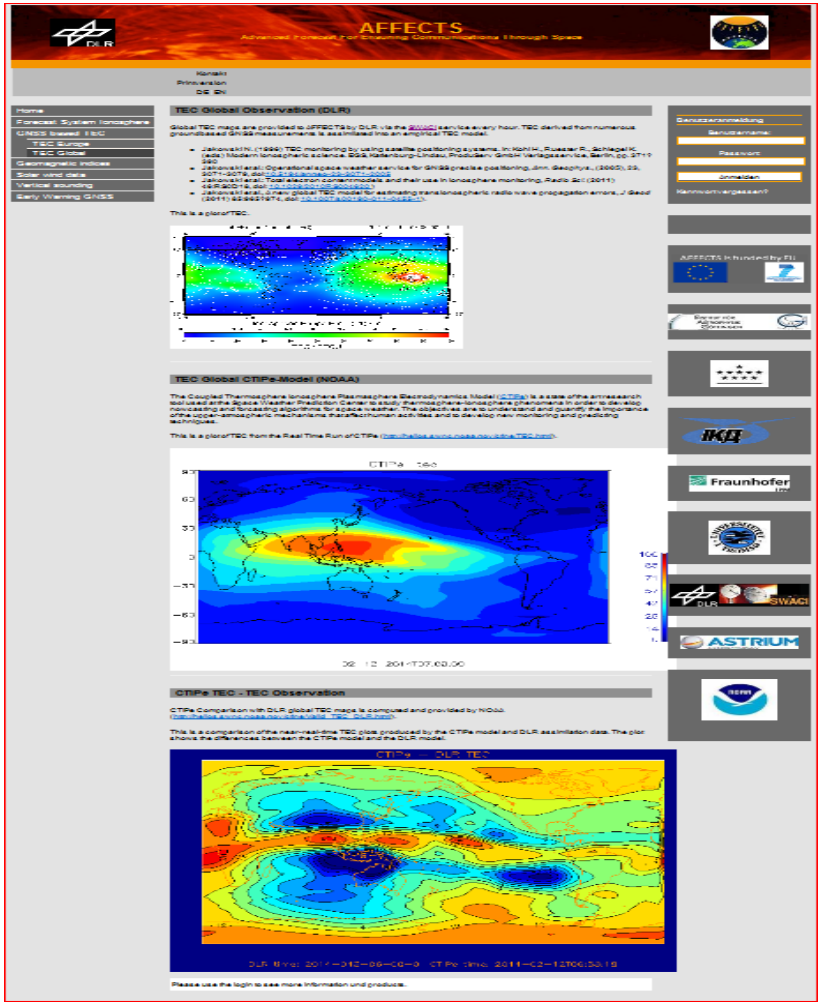


Jakowski, N., Mielich, J., Hoque, M. M., Danielides, M.; Equivalent slab thickness at the mid-latitude ionosphere during solar cycle 23, 38th COSPAR Scientific Assembly, 18-25 July 2010, Bremen, Germany

2. Early warning and forecast system

NOAA CTIPe comparison with DLR global TEC maps (validation)

- Real Time comparison
- Shows differences between NoAA's physical model and DLR Global assimilated TEC maps
- Use for validation and to better understand the physical phenomena that cause perturbations in TEC



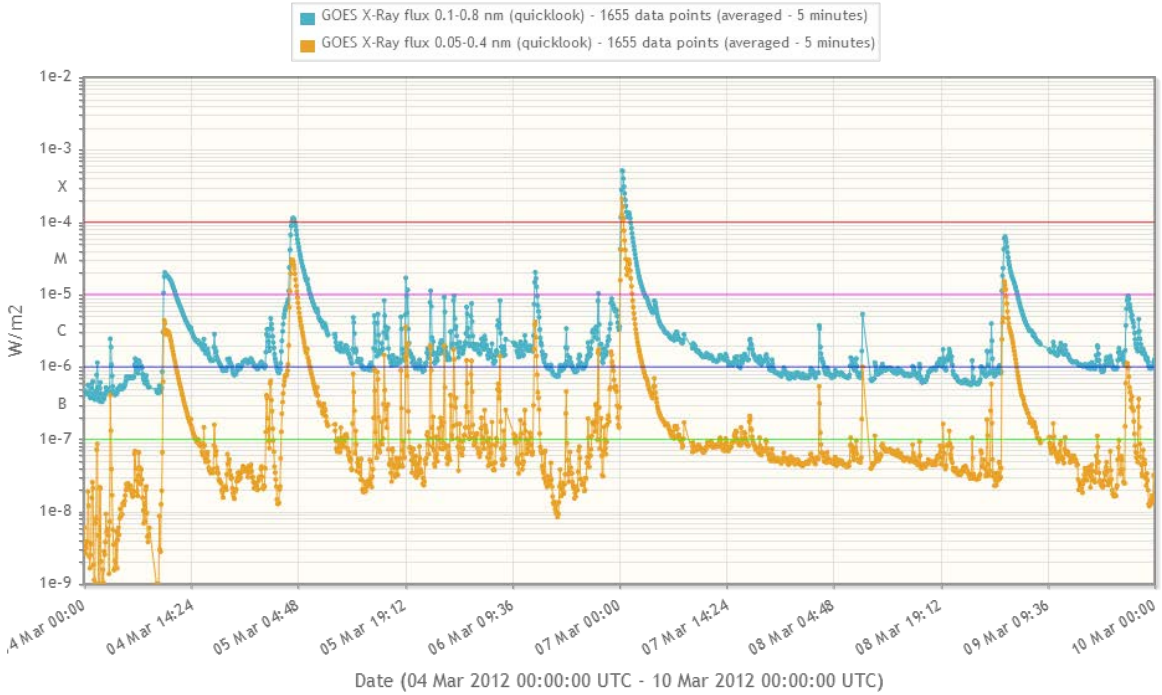
Visit Poster I15
for more detailed information on the FSI
Poster Session 1:00 – 2:30 pm

Codrescu, M. V.; Negrea, C.; Fedrizzi, M.; Fuller-Rowell T. J., Dobin, A.; Jakowsky, N.; Khalsa, H.; Matsuo, T.; Maruyama, N. ; A real-time run of the Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe) model ; Space Weather, 2012, Volume 10, S02001, DOI: 10.1029/2011SW000736.

3. Dissemination – STAFF viewer

STAFF developed by ROB is a dynamical software application which allows scientists and forecasters to consult a whole gamut of solar, geomagnetic, and ionospheric timelines. These timelines, which were previously spread over the internet, are now being brought together in one database, enabling easy viewing, plotting and exporting of any combination of timelines.

http://www.staff.oma.be



Example: STAFF export of a GOES X-Ray curve from March 4 until 10, 2012.

1. Large datasets
2. Speed
3. Accessibility
4. Usability

3. Dissemination – User Workshop

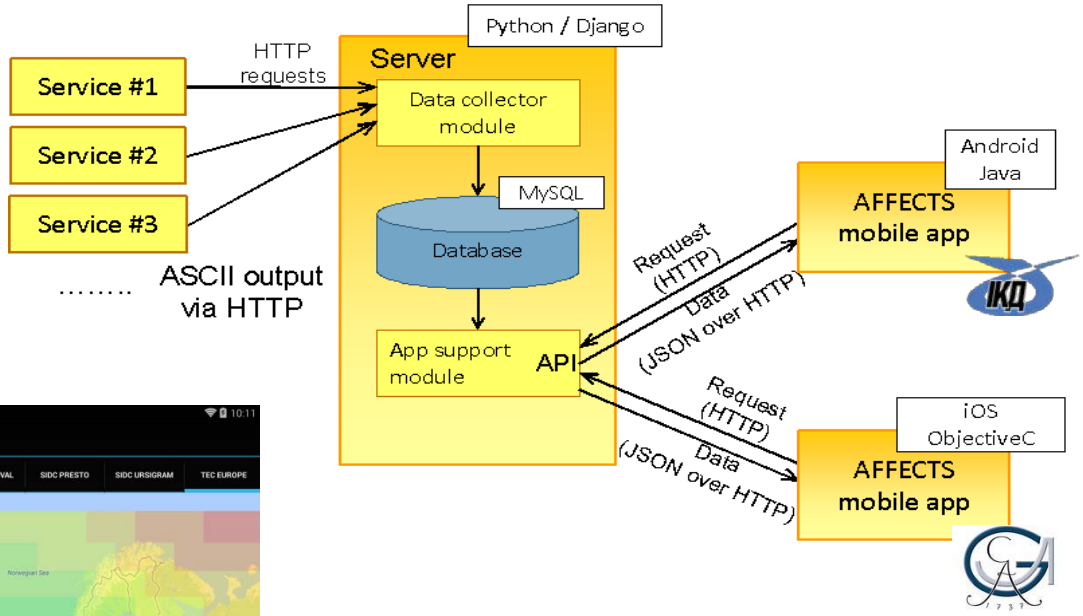
The following topics were addressed in the workshop:

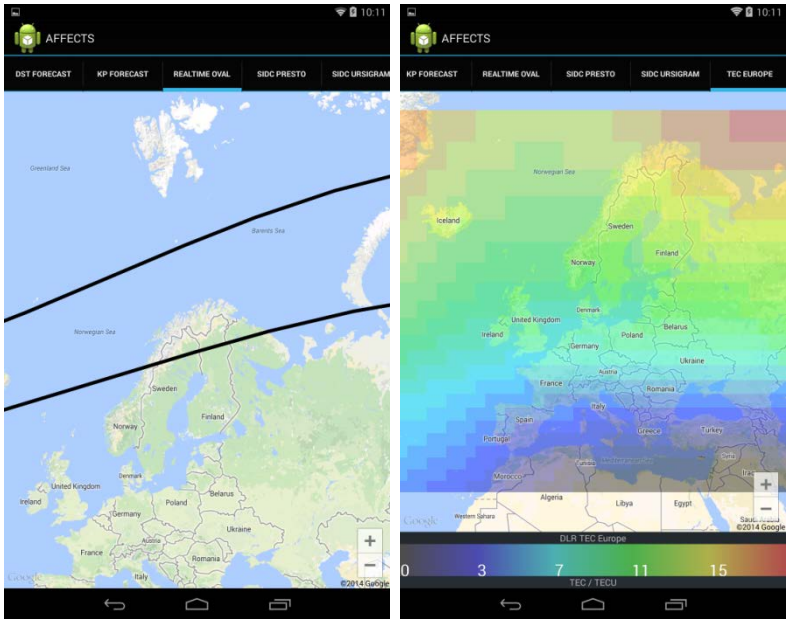
- Near real time dimming and EIT wave detection
- 3D CME analysis tool
- Coronal analysis tool
- CME & solar wind arrival and impact forecast tool
- Flare, CME, geomagnetic, auroral, ionospheric forecasts & alerts
- Forecast of perturbed TEC
- Solar activity and space weather timelines viewer

Forty-four persons participated to the workshop, which was a great success judging from the contacts during and after the workshop as well as from the questionnaires that we asked our users to fill in.

3. Dissemination – Mobil phone app

To ensure the coverage of as broad user community as possible, it was decided to develop two versions of the app for Google Android and Apple iOS platforms with slightly different content to better target relevant user communities.





Example: Realtime oval (left) by UoT and TEC Europe (right) by DLR in the Android AFFECTS mobile app.

Summary

- In the EC FP7 project AFFECTS, European and US scientists have developed an advanced prototype space weather warning system to help mitigate space weather effects on the operation of telecommunication and navigation systems
- The EC programmes (e.g. FP7, recently H2020) are a great opportunity for teaming up an international consortium to face European and even Global problems or hazards
- The AFFECTS team is especially thankful to the NOAA-SWPC colleagues for joining the consortium as EU-U.S. research collaborators

The research leading to these results has received funding from the European Commission's Seventh Framework Programme (FP7/2007-2013) under the grant agreement n° 263506 (AFFECTS project, www.affects-fp7.eu).

Thanks for your attention!

Contact:
German Aerospace Center
Institute of Communication and Navigation

Dr. Jens Berdermann
Kalkhorstweg 53
D-17235 Neustrelitz
Germany

fon: +49 3981 480 106
fax: +49 3981 480 123
mail: jens.berdermann@dlr.de

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