

Space Weather Activities in Germany

Norbert Jakowski

Institute of Communications
and Navigation

German Aerospace Center



Knowledge for Tomorrow



Review of institutions

DLR Institutes

Institute of Communications and Navigation &
German Remote Sensing Data Center, Neustrelitz
Institute of Aerospace Medicine, Cologne

Geo Research Center (GFZ), Potsdam

German Space Situational Awareness Centre
(GSSAC), Kalkar

Institute of Atmospheric Physics, Kühlungsborn

Institute for Astrophysics, Göttingen

Leibniz Institute for Astrophysics Potsdam (AIP),
Potsdam

Leibniz-Institute of Atmospheric Physics (IAP),
Kühlungsborn

Max Planck Institute for Solar System
Research (MPS), Göttingen

Technical University of Munich

University of Kiel

University of Leipzig



4th National Space Weather Workshop at DLR



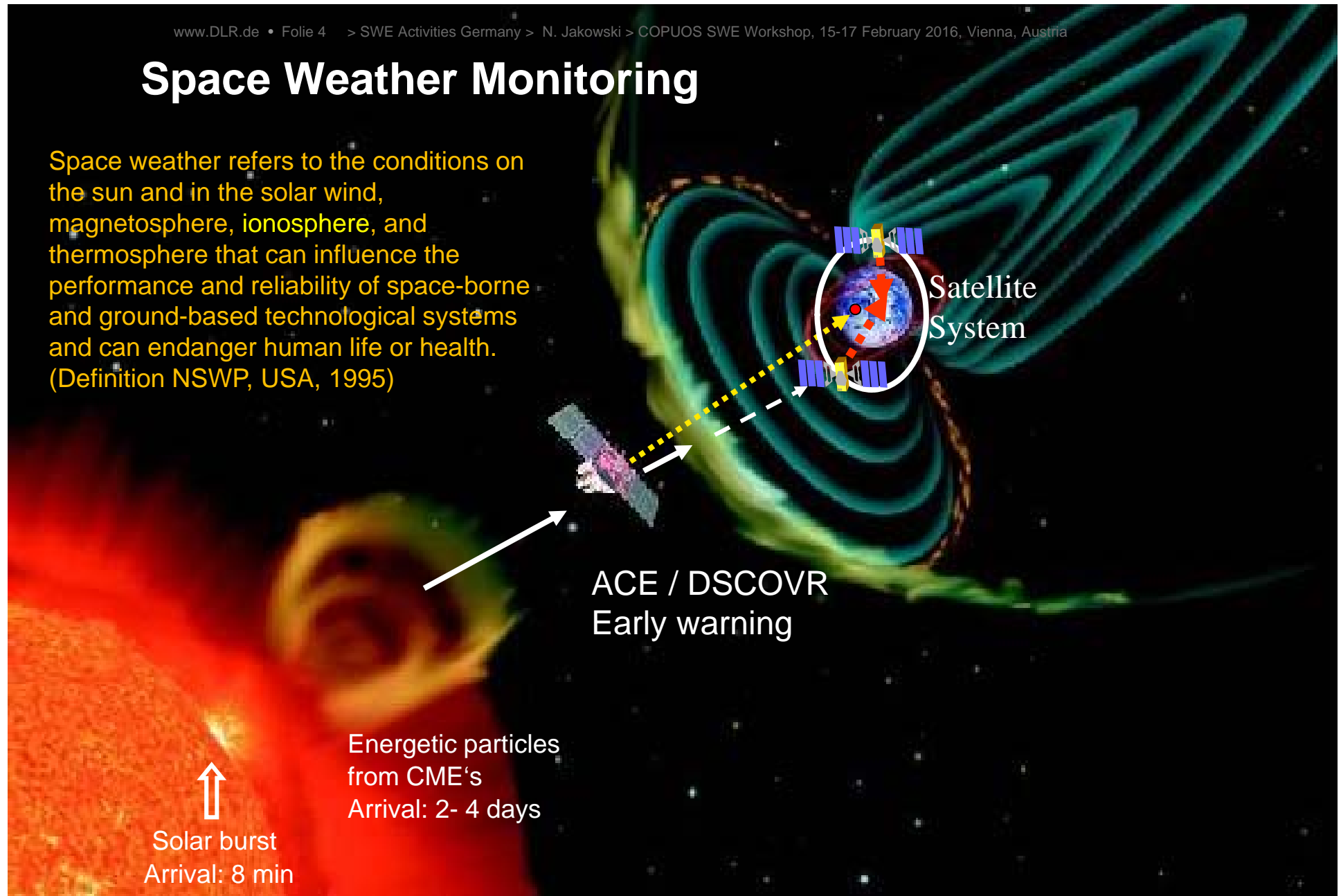
4th National Space Weather Workshop, organized by the German Aerospace Center in Neustrelitz

- 4th National Space Weather Workshop has demonstrated national capabilities in space weather research and activities to provide space weather services focusing on **ionospheric weather** and **geomagnetic activity**.
- The workshop participants have discussed aspects of a **national space weather strategy** and **international cooperation**.
- Related conclusions and recommendations initiated the elaboration of a **national position paper on space weather** currently being prepared taking into account the UNISPACE +50 process.

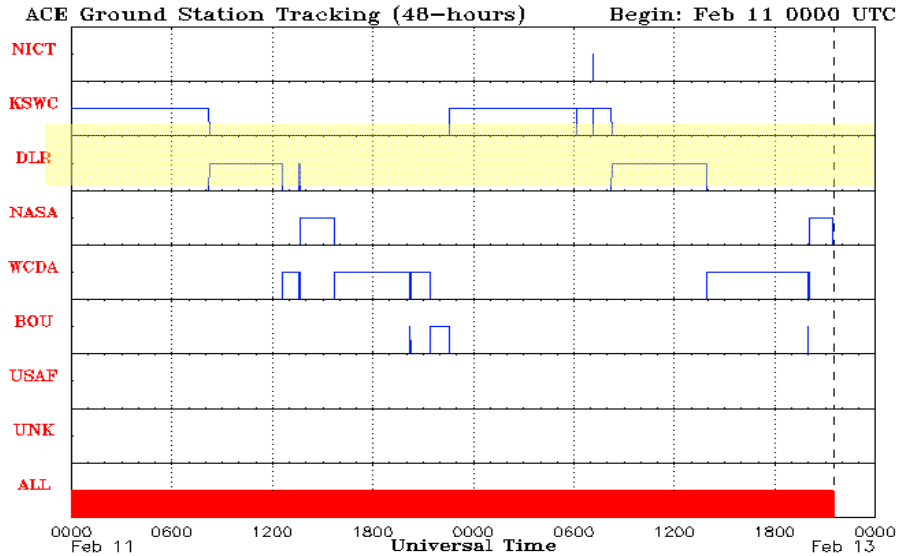


Space Weather Monitoring

Space weather refers to the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health. (Definition NSWP, USA, 1995)



ACE/DSCOVR Reception at DLR Neustrelitz



- Advanced Composition Explorer (ACE) at Lagrange point L1 (1.5 Mill. km distance from the Earth)
- DLR Neustrelitz contributes operationally to the Real Time Solar Wind Network of NOAA
- Deep Space Climate Observatory (DSCOVR) will replace ACE

Updated: 2016 Feb 12 21:30 UTC

NOAA/SWPC Boulder, CO US.

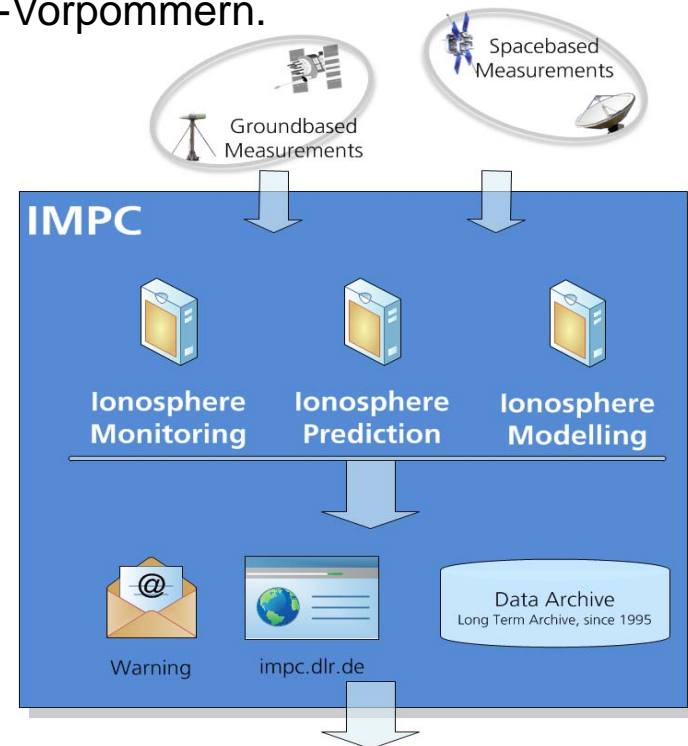


DSCOVR launch on Feb. 11, 2015

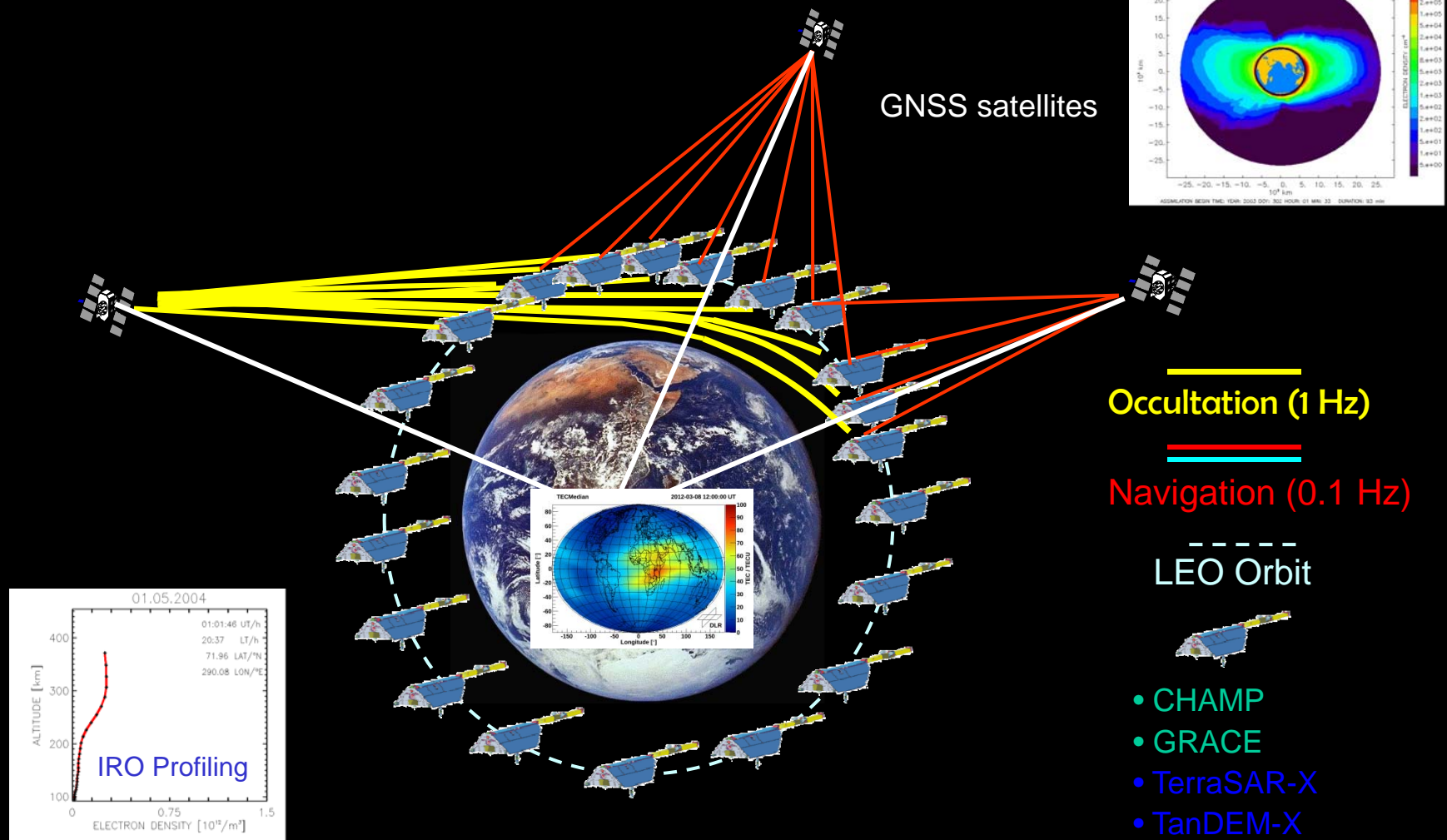


„Ionospheric Monitoring and Prediction Center“ (IMPC)

Establishment of the IMPC is based on the heritage of the former project „Space Weather Application Center Ionosphere“ (SWACI) that has essentially been supported by the state government of Mecklenburg-Vorpommern.

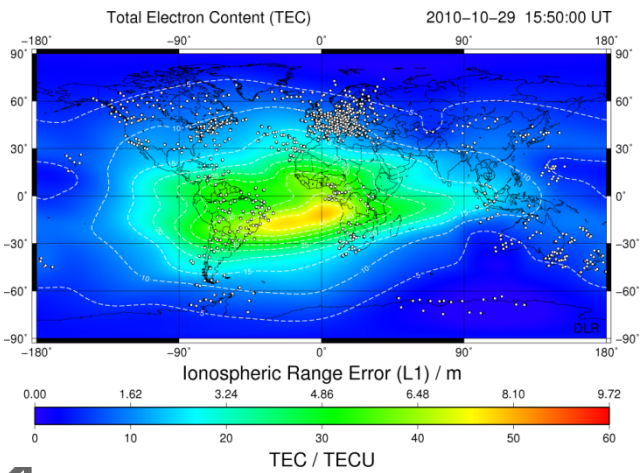
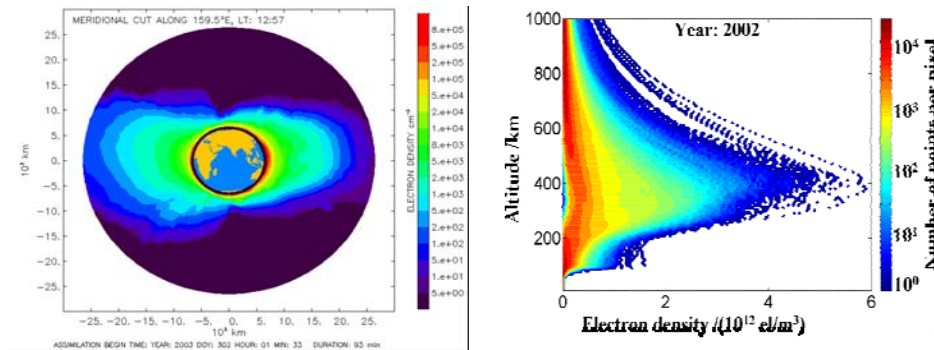


GNSS Based Sounding of the Ionosphere

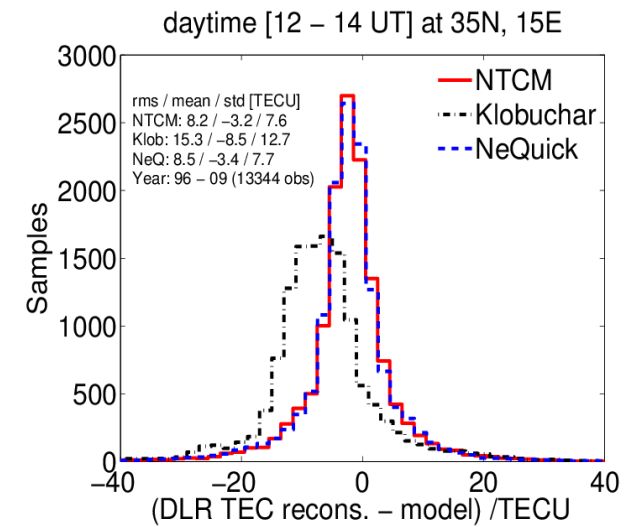


Ionospheric Modeling

Data base for ionospheric modelling



TEC model NTCM-GL (Neustrelitz TEC Model - global)



Klobuchar: current correction model for GPS
NeQuick: correction model for Galileo

[Jakowski et al., JOGE, 2011]



Ionospheric Weather Warning & Forecast

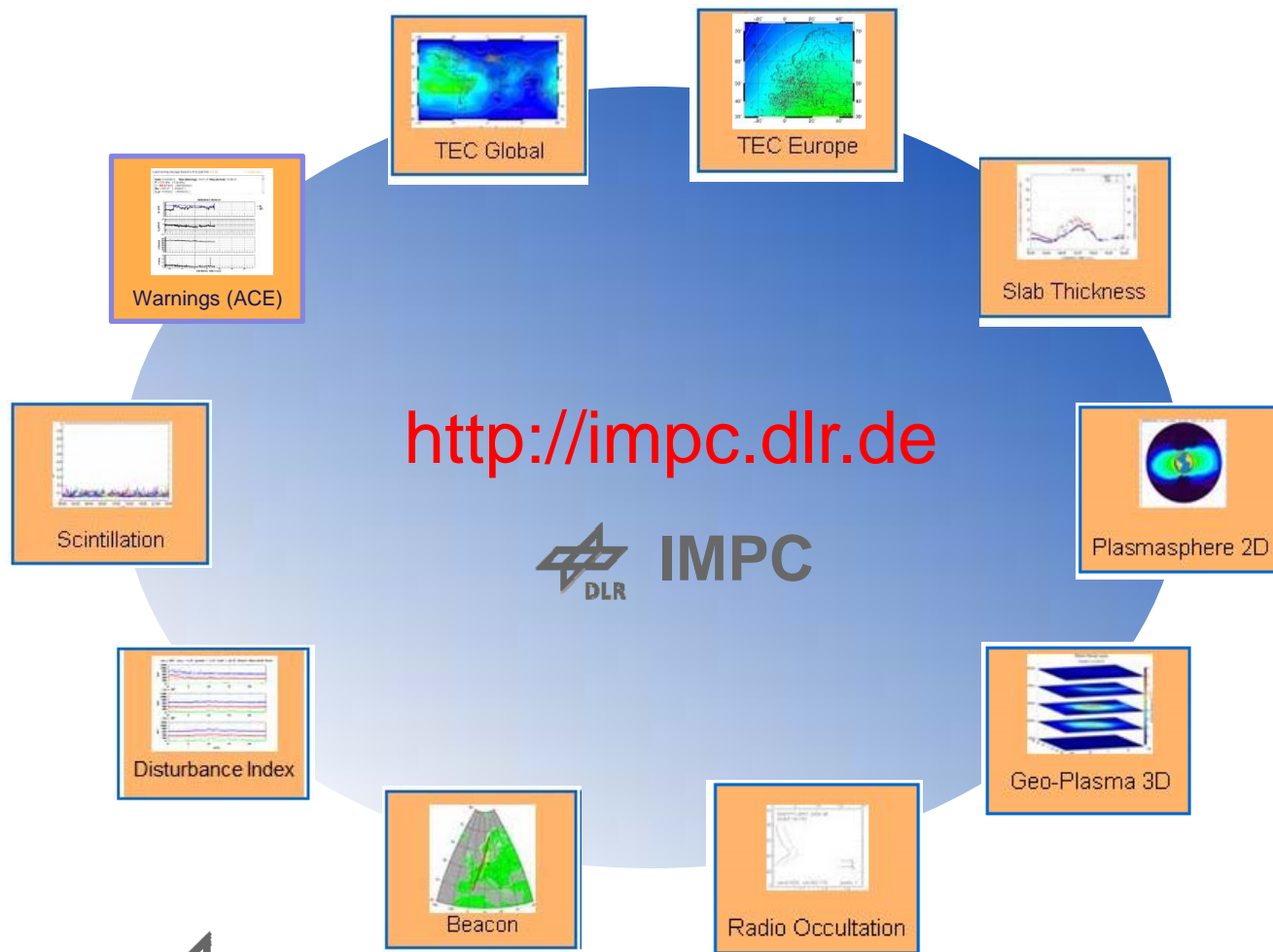
Predicted ionosphere disturbance scale:	I1 - Disturbed
Predicted start time (UTC):	2016-02-15T03:00:00 (+/-12 hours)
Predicted Ionosphere	Forecast TEC maps up to 24 hours in advance. The onset of disturbances in the ionosphere can be forecasted about 30 minutes in advance.
Current Ionosphere	Current and one hour forecasted TEC maps, provided by SWACI .
Predicted geomagnetic disturbances:	expected minimum Kp: 4
Predicted geomagnetic disturbances:	expected maximum Kp: 7
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:	70%

Source: *SWACI Service at German Aerospace Center - DLR*

Corresponding solar warning message issued by SIDC Belgium 2016-02-11T23:53:32 (UTC):

Event type: CME_arrival
Latest Presto Message: [LATEST PRESTO FROM SIDC - RWC BELGIUM](#)

Ionosphere Monitoring and Prediction Center (IMPC)



Main Tasks

- Monitoring
- Modelling
- Forecasting
- Operational service / distribution of products
- Ionospheric Research
- Development of new methods & techniques
- Quality control / upgrade of IMPC



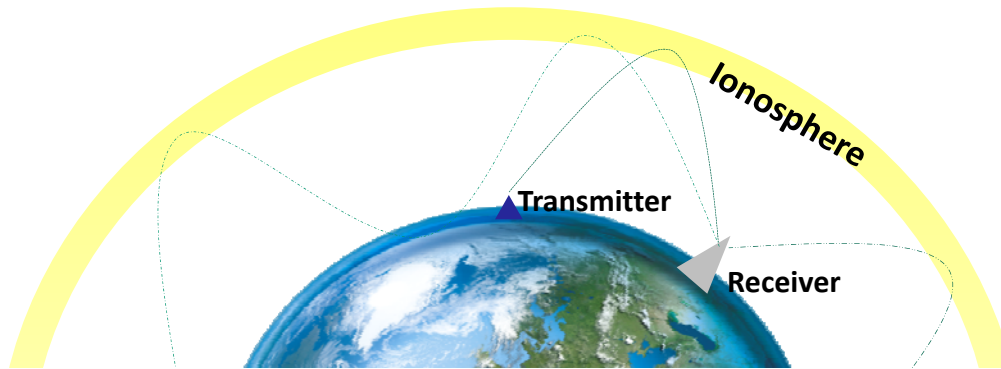
National / international coordination and collaboration

- Data exchange and international cooperation are crucial for operating the IMPC
- DLR is involved in the Space Weather European Network (SWENET) of ESA
- DLR maintains relationships to numerous international facilities in the space weather domain , e.g. NOAA Space Weather Prediction Center (USA), NMA (Norway), SANSO (South Africa), Jaxa (Japan), Bahir Dar university (Ethiopia) ...
- SWACI/IMPC products and expertise is applied in numerous national and international research-, infrastructural- and educational projects funded by EC, ESA and federal agencies.

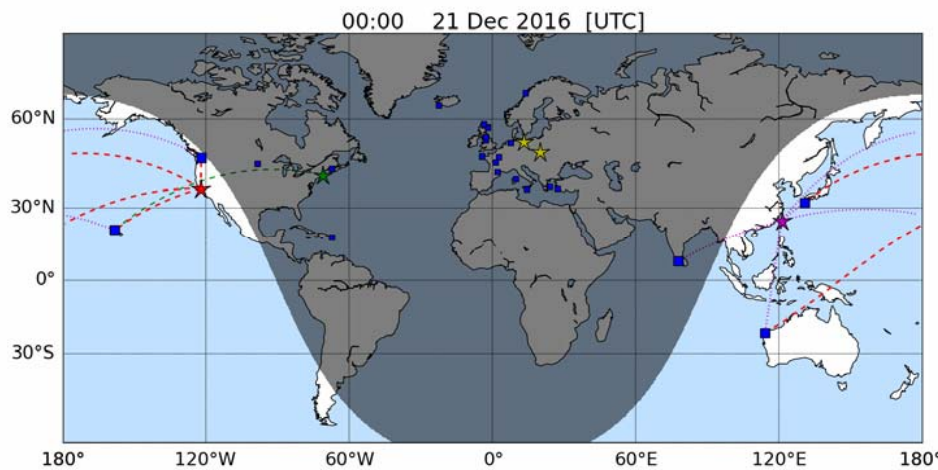


Source: N. Bobrisnky, J.-P. Luntama., *ESA SSA Programme (Period 2)*

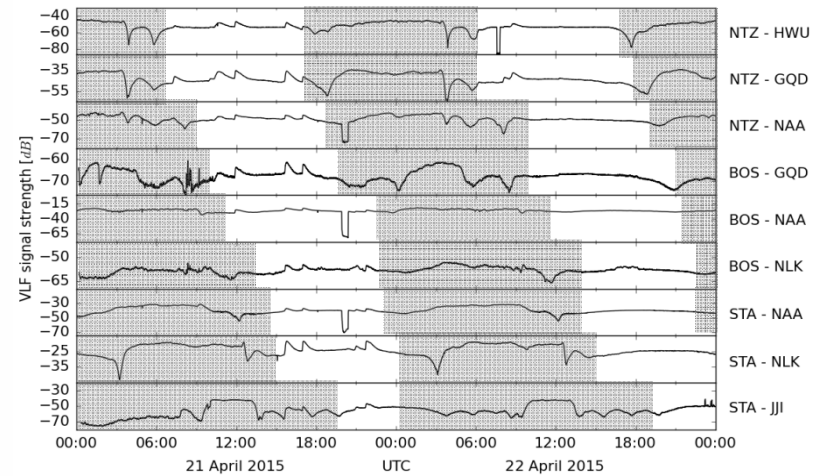
Global Ionospheric Flare Detection System (GIFDS)



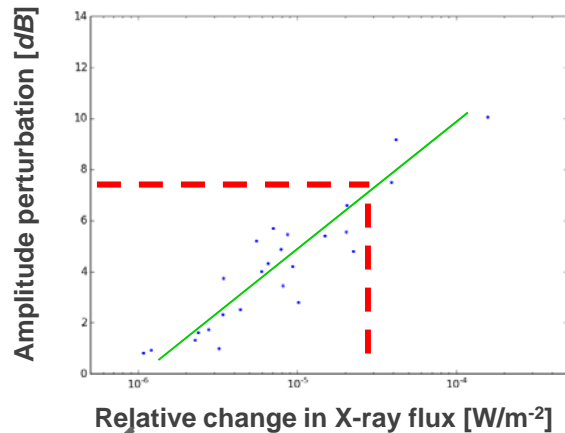
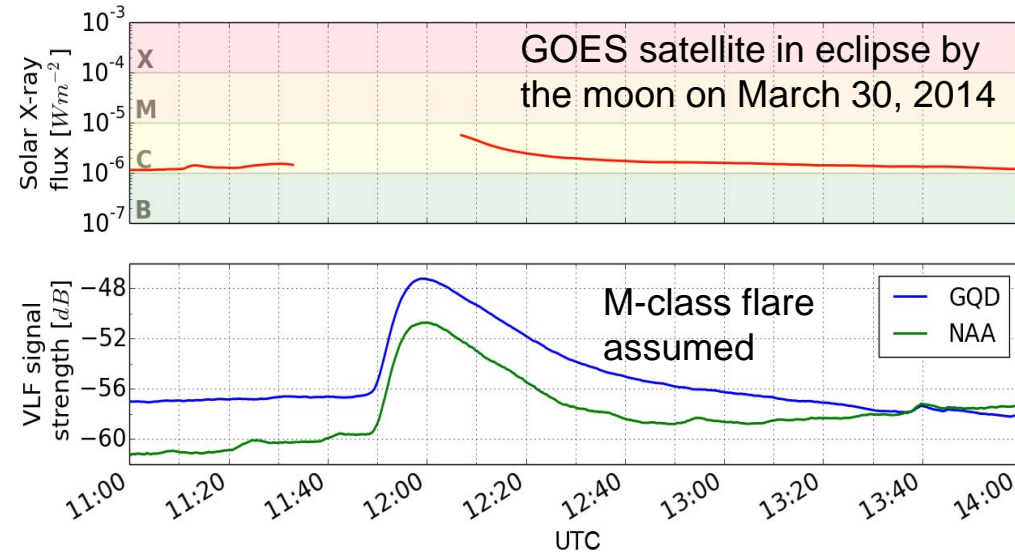
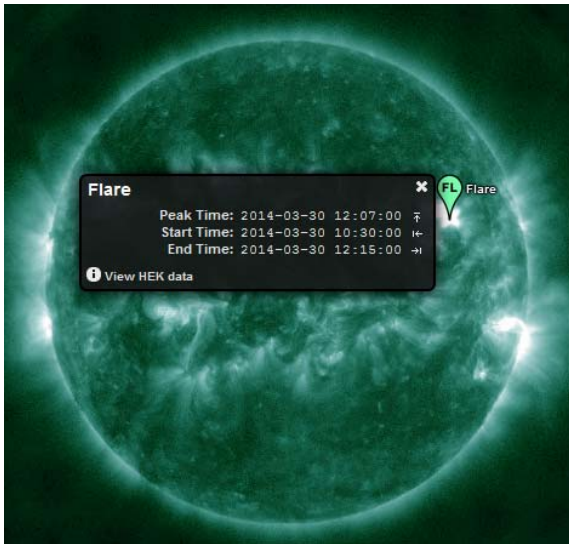
- Solar flares modify the ionospheric state that impacts terrestrial and transionospheric radio communication
- DLR is establishing a global VLF receiver network for continuously receiving information on the occurrence of solar flares by recording and analyzing VLF measurements



[Wenzel et al., JASTP, 2016]



X ray flares - VLF signal amplitude of GIFDS



The same measurement technique is applied in the students project „Solar Flares by Ionospheric Effects“ (SOFIE) led by the DLR School_Lab Neustrelitz.

GIFDS and SOFIE participate in the International Space Weather Initiative (ISWI).



6th International Space Weather Camp 2016

UA Huntsville, SANSA/Hermanus, DLR/Neustrelitz



Geo Research Center (GFZ) Potsdam

- Provision and analysis of space weather products based on ground based geomagnetic observations from a global network (Kp-index, local geomagnetic variations from a network of global observatories - e.g. in mid and low latitudes)
- Identification, development and provision of Space Weather products from LEO satellites, such as ESA's Swarm constellation mission (Germany (GFZ) is prime in a ESA' feasibility study for Swarm space weather application, example products: TEC, ionospheric irregularities, geomagnetic variations, among other products)
- Modelling and observation of magnetospheric radiation belts and ring current activity



Geo Research Center (GFZ) Potsdam



- Fifth Earth Explorer Mission of ESA
- Three satellites, launched 22/11/2013
 - Satellite A & C $i: 87.4^\circ$, $h: 470\text{km}$
 - 160 km distance
 - Satellite B: $i: 86.8^\circ$, $h: 510\text{km}$

Space Weather Products

- High-precision magnetic field
- Electron and ion density and temperature
- Ion drift velocity, electric field (2Hz)
- Radial and magnetic-field-aligned currents
- Equatorial “bubble” index (plasma depletions)
- Dayside equatorial eastward electric field
- Slant Total Electron Content
- Thermospheric density and winds
- Magnetic signal of magnetospheric currents (Dst-like)
- Magnetic field models
- Mantle conductivity (1D-3D)



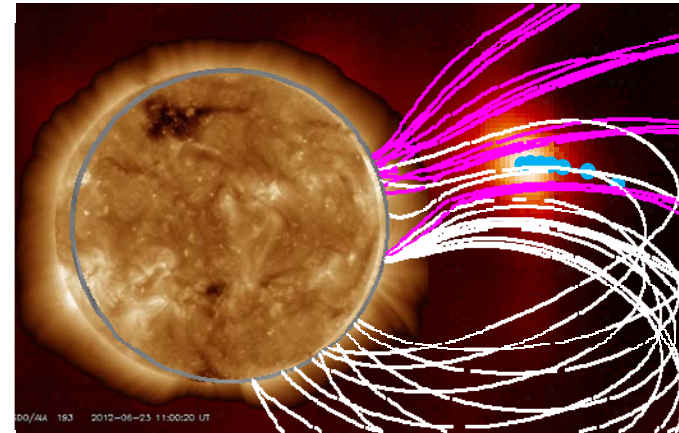
earth.esa.int



Leibniz Institute for Astrophysics Potsdam (AIP)

Physics of the Sun

Determination of the evolution of magnetic structures in the solar atmosphere with optical observations; coronal plasma processes studied by solar radio physics



Coordination of the Key Science Project
Solar Physics and Space Weather with
LOFAR: **LO**w **F**requency **AR**ray

European antennae array for
interferometry by super-computational
treatment of the data stream.

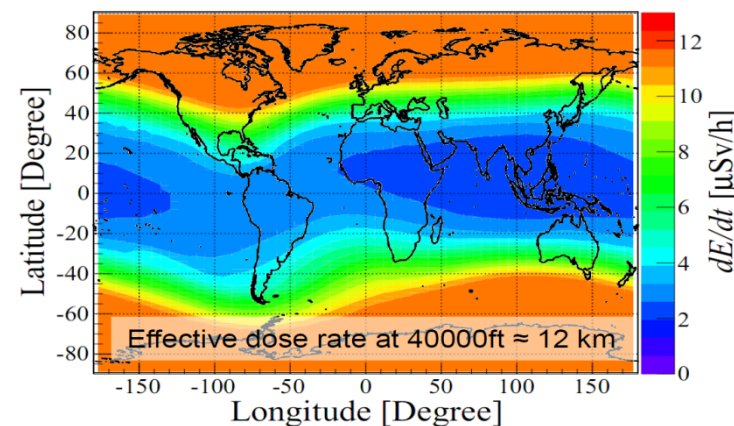
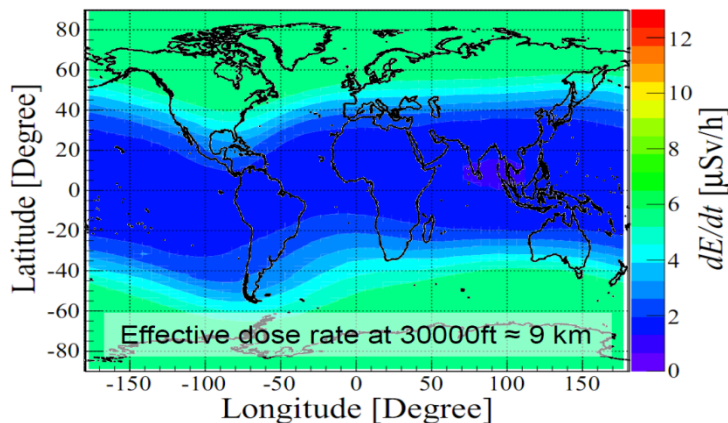
- 30 – 240 MHz
- 22 core stations in NL



DLR Institute of Aerospace Medicine

Radiation Biology

Relevant aviation and space travel questions with regard to the effects of radiation on humans and the biosphere. Experimental and theoretical conditions necessary to provide effective protection from radiation in aviation and space flight.



Dose rate based Space Weather Index D can be determined using measurements or model calculations.

Several models which permit a near real-time assessment are already available or under development, e.g. PANDOCA.




University of Göttingen – Institute for Astrophysics



V. Bothmer

Solar and Heliospheric Physics, Solar Activity and Space Weather, Space Instrumentation and Missions





Thank you for your attention!

Contact:

Dr. Norbert Jakowski
Kalkhorstweg 53
D-17235 Neustrelitz
Germany

Tel. +49 (0)3981 480 - 151

Fax. +49 (0)3981 480 - 123

Email: Norbert.Jakowski@dlr.de

Web: www.dlr.de/kn <http://swaciweb.dlr.de>