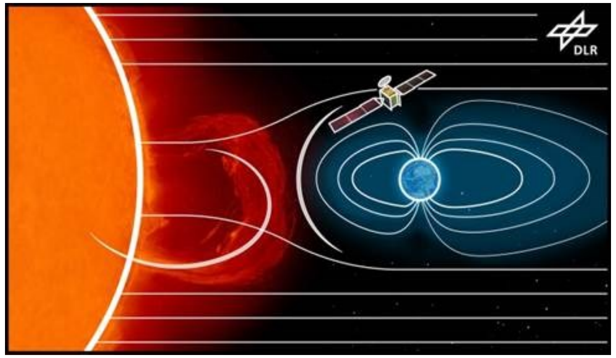
Erforschung des Weltraumwetters am DLR Institut für Solar-Terrestrische Physik

Space Weather Research at the German Aerospace Center Institute for Solar-Terrestrial Physics

Jens Berdermann



DLR

German Aerospace Center - Site Neustrelitz


DLR site Neustrelitz (today)

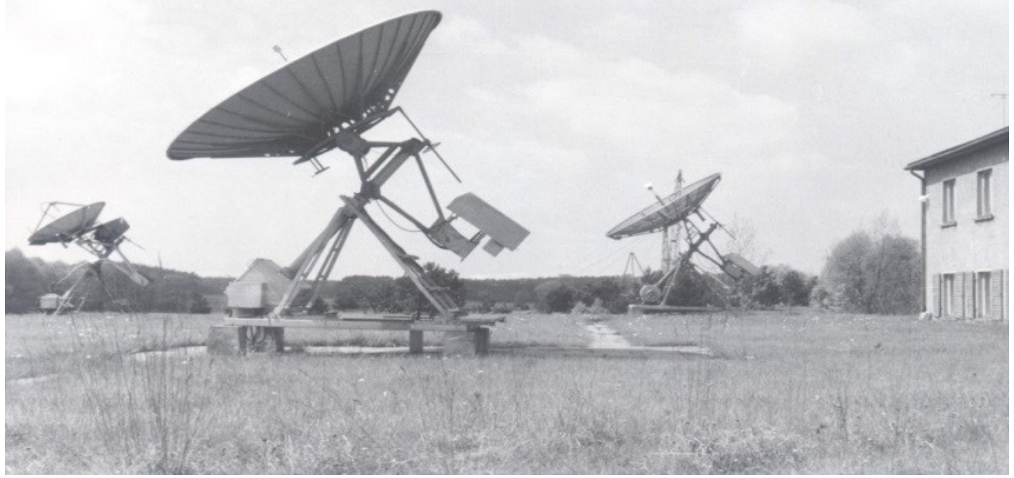
Over **100 years research on** the interaction of electromagnetic waves with the **atmosphere/ionosphere**.

20 years of **space weather research** with a focus on the ionosphere (preoperative ionospheric service since 2004).

On 27.06.2019 the **new DLR Institute for Solar-Terrestrial Physics** is put into operation by decision of the DLR Senate.

Range measurements of radio waves at the "Versuchsfunkstelle Strelitz – VFSS" of the Telegraphen-Versuchsamt (TVA) Berlin (1913)

Site of the **Heinrich-Hertz-Institute for Solar-Terrestrial Physics** Berlin-Adlershof (Academy of Sciences GDR)



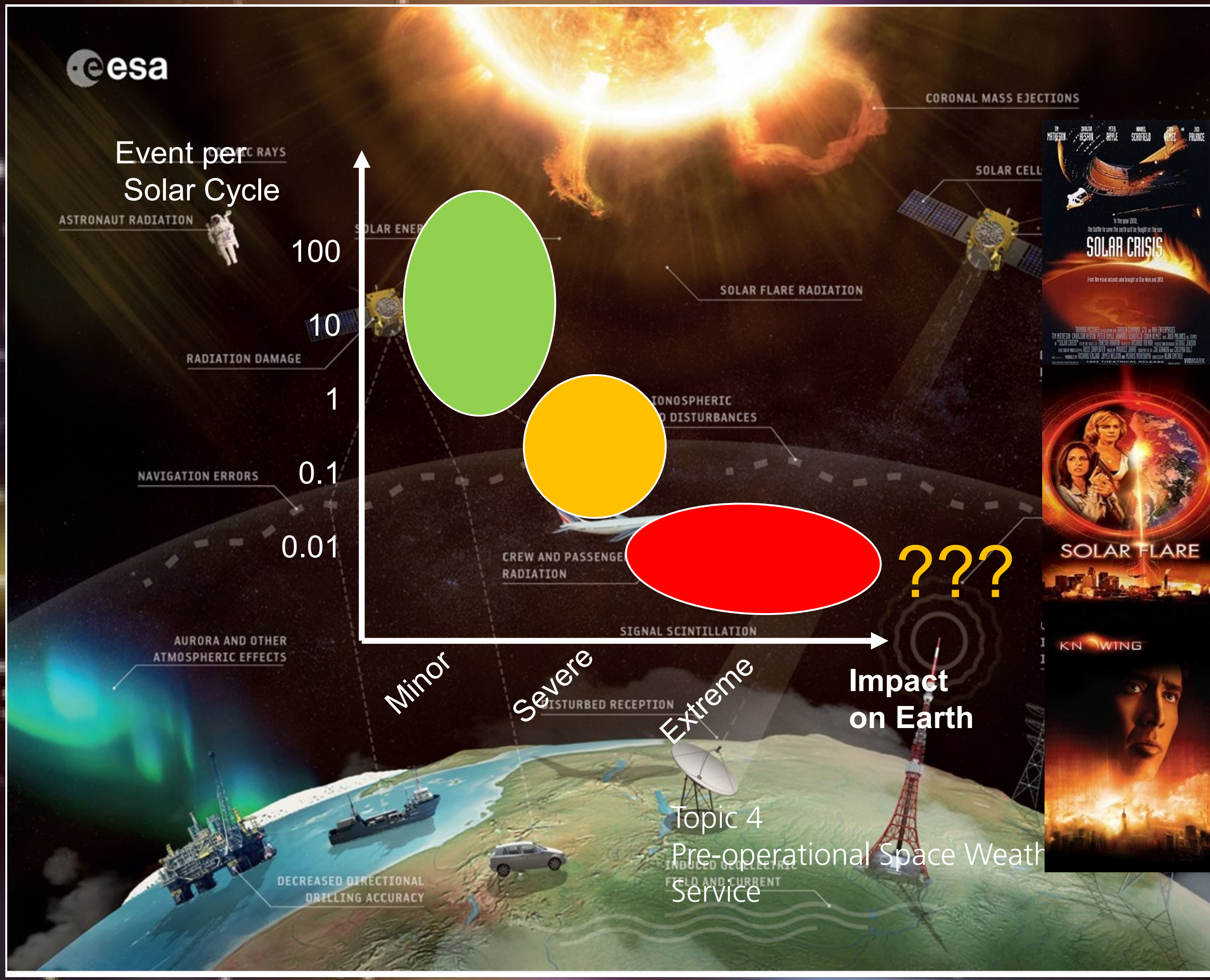
Motivation

Topic 3
Space Weather Events

Solar Flare
Arrival: 8 min
Duration: 1- 2 hours

Solar Radio Bursts
Arrival: 8 min
Duration: minutes to hours

Energetic particles / CMEs
Arrival: 2- 4 days
Duration: several days



Institute Vision

To establish and apply the scientific and technological capability to:

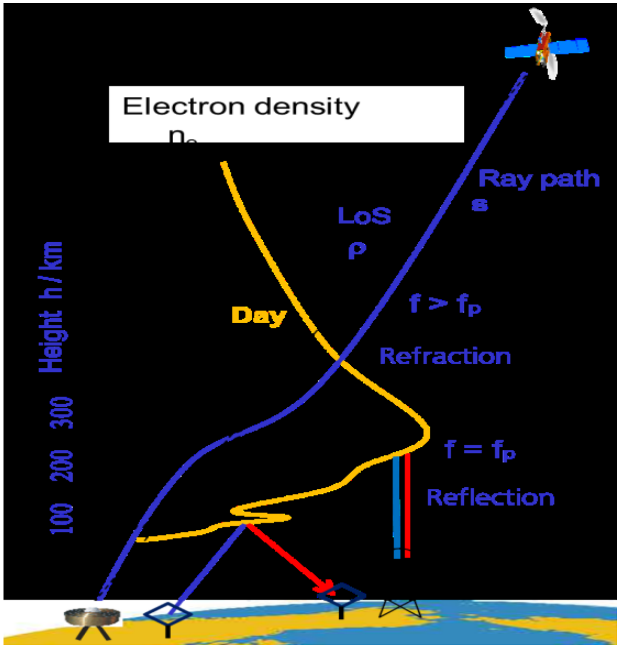
- Provide timely, accurate and reliable space environment observations
- Develop user relevant space weather products and forecasts
- Foster the resilience of critical technological infrastructures of our society by dedicated vulnerability assessments and space weather impact studies

Space Environment Observations

User Products and Forecasts

Safeguard Critical Infrastructures

Institute structure

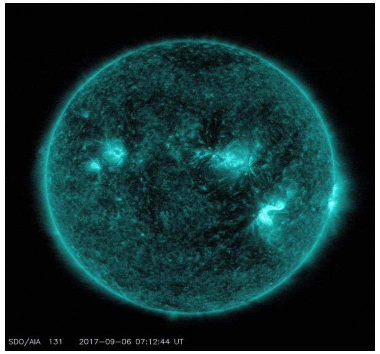


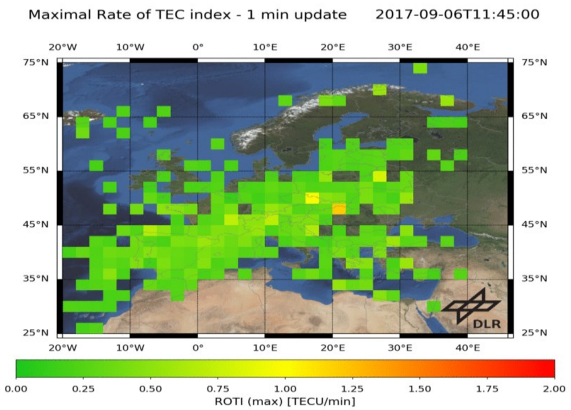
Institute for Solar-Terrestrial Physics

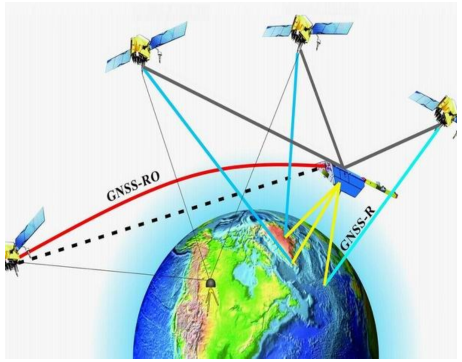
Administration

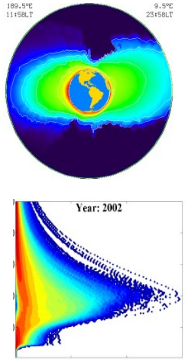
Space Weather Observations	Solar-Terrestrial Coupling Processes	Space Weather Impact
Space Based Observations	Terrestrial Atmospheric Coupling	Characterization and Prediction of Disturbances
Ground Based Observations	Solar Driven Coupling Processes	Space Weather Impact Studies
Data Fusion and Reconstruction	Physical Modelling	Preoperational Services and Validation

R2O and O2R









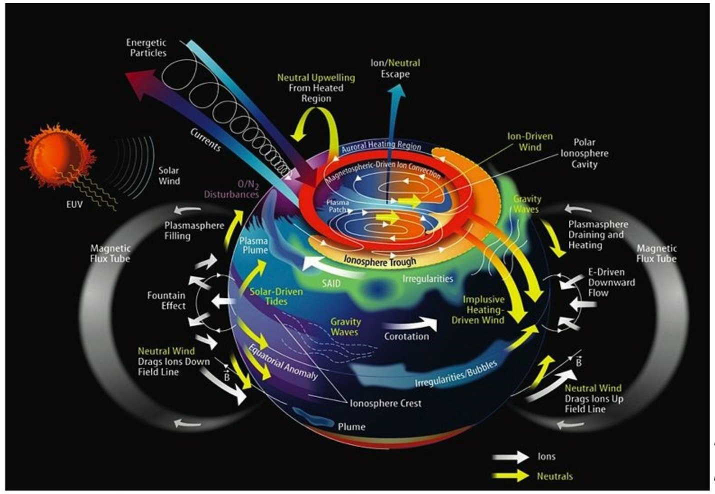
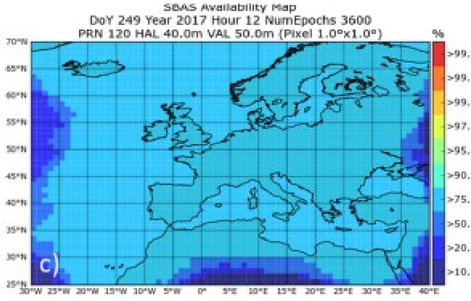
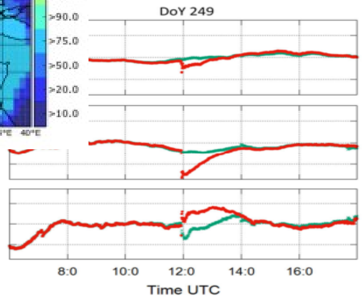


Image courtesy of J. Grebowsky, NASA Goddard Space Flight Center.





Space Weather Observations

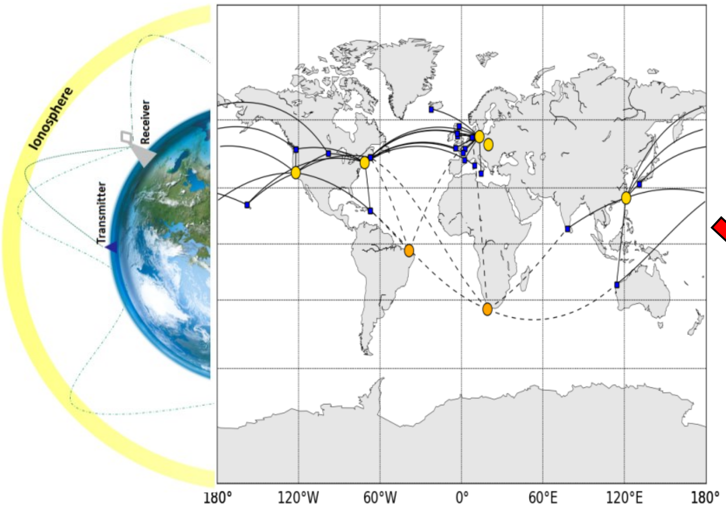
- Development/improvement of measurement techniques, methods and related algorithms for continuous ground and space based Space Weather monitoring.
- Data fusion and tomographic reconstructions of electron density and derivatives to create an appropriate data base for research and space weather services.

Ground Based Observations

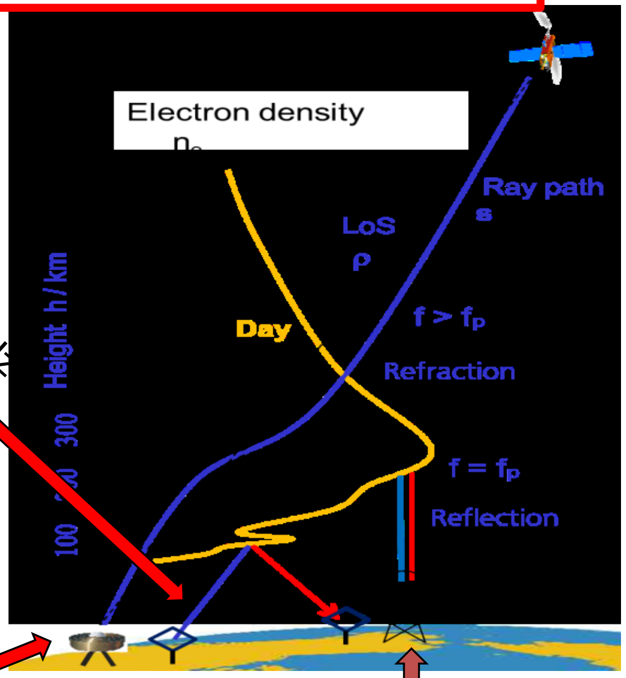
Our knowledge on the ionosphere is primarily from electromagnetic radio waves impacted by the ionospheric plasma.

GIFDS: Global Ionospheric Flare Detection System

- Reception of very Low Frequency (VLF) signals
- Detection of particle precipitation at high latitudes is important for transpolar flights



10-150 kHz

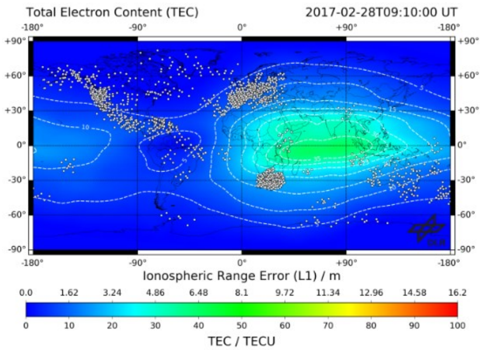


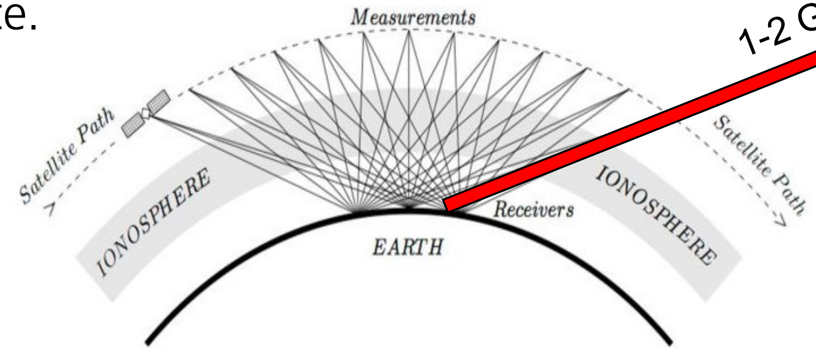
0,1- 30 MHz

Vertical sounding

GNSS TEC measurements are most important data source for research and space weather service.

- Global coverage
- Multi-frequency, multi-GNSS
- Good horizontal resolution





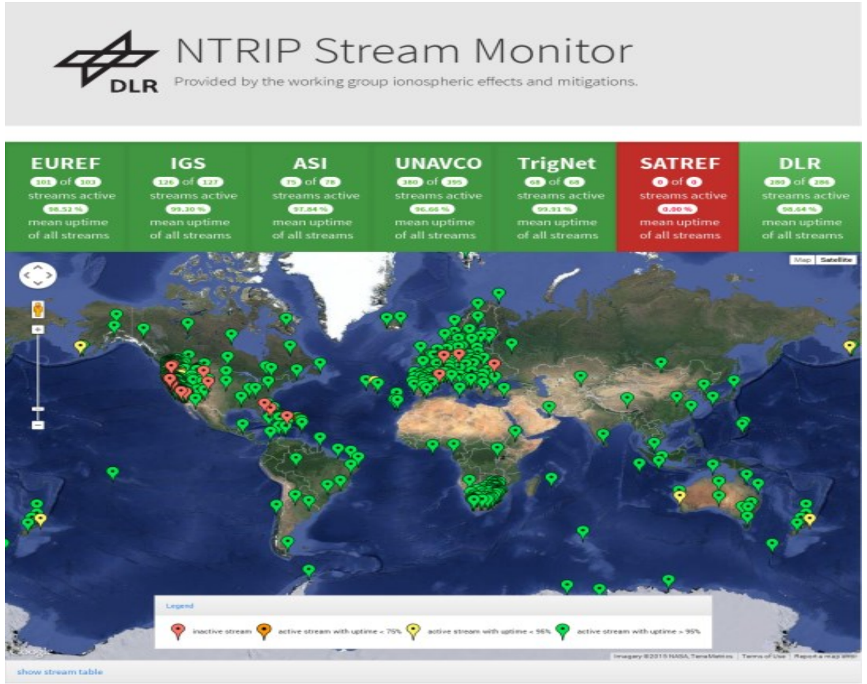
1-2 GHz

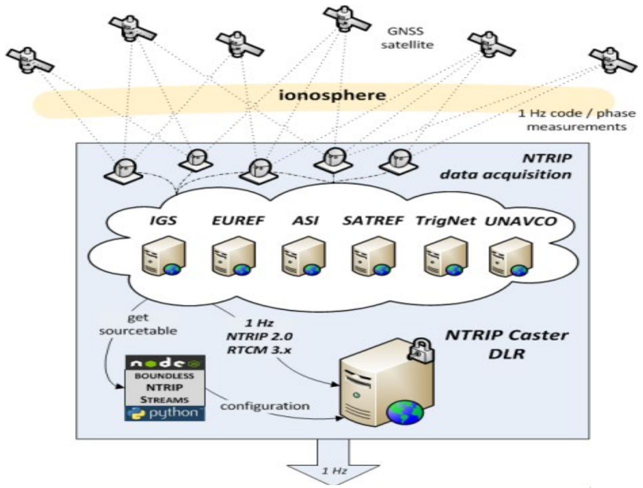
- Ionosonde stations provide information on the vertical electron density distribution.
- Good vertical resolution and complementary to GNSS based sounding

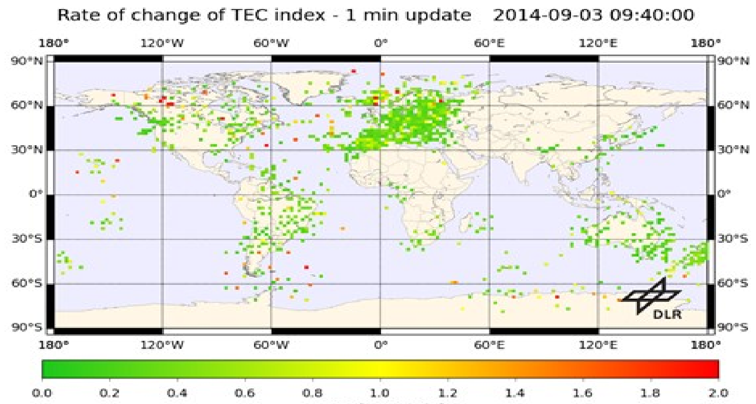
GNSS: Global Navigation Satellite Systems

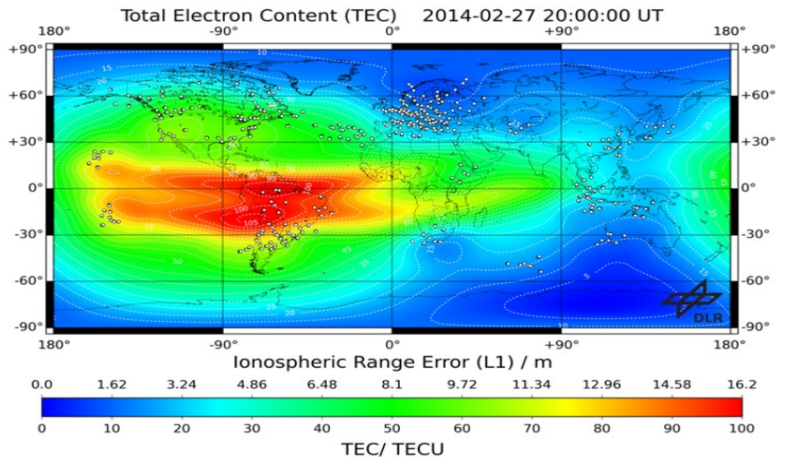
GNSS data from ground based reference networks (1-2 GHz, 1 Hz data rate)

- Allows characterization the actual state of the ionosphere in near real-time
- Data base over Europe since 1995 allows modelling of seasonal and solar cycle dependence
- The system automatically processes and distributes high rate GNSS data (1Hz) of several hundred GNSS receivers from GNSS-reference networks worldwide (IGS, EUREF, UNAVCO, ASI, TrigNet)





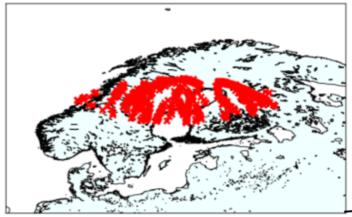


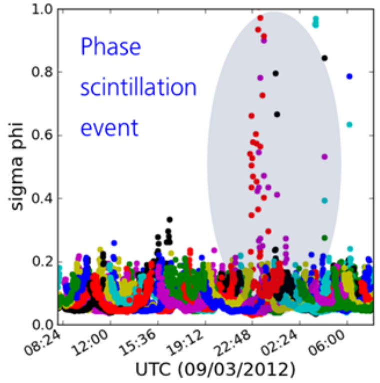


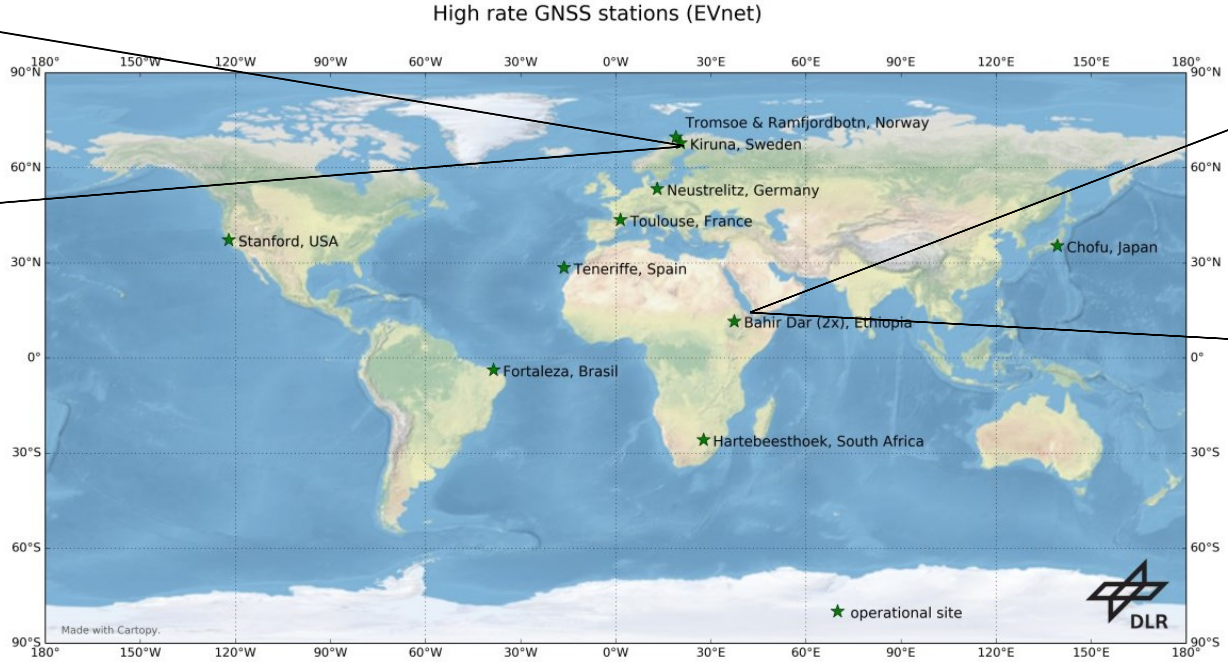
Experimentation and Verification Network (EVNet)

DLR operates its own **high rate GNSS receiver network** (20 -100 Hz) for scintillation measurement from high latitudes down to equatorial regions.

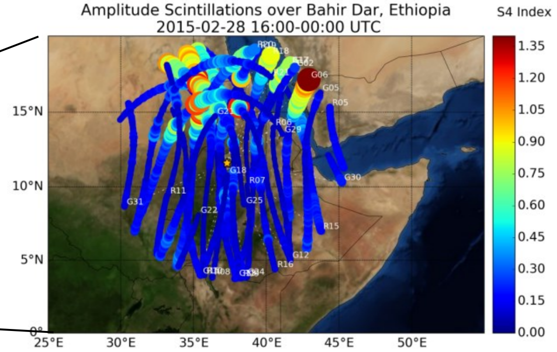
Kiruna / Sweden

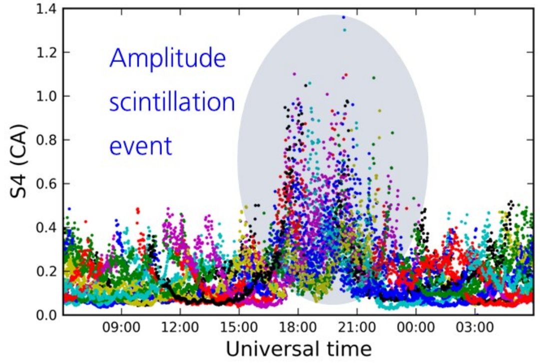






Bahir Dar/ Ethiopia





Problems

- Scintillation data very sparse
- No forecasting
- Receiver influence

Solutions

- Modelling
- Usage of proxies like ROTI
- Data-grabber / record and replay

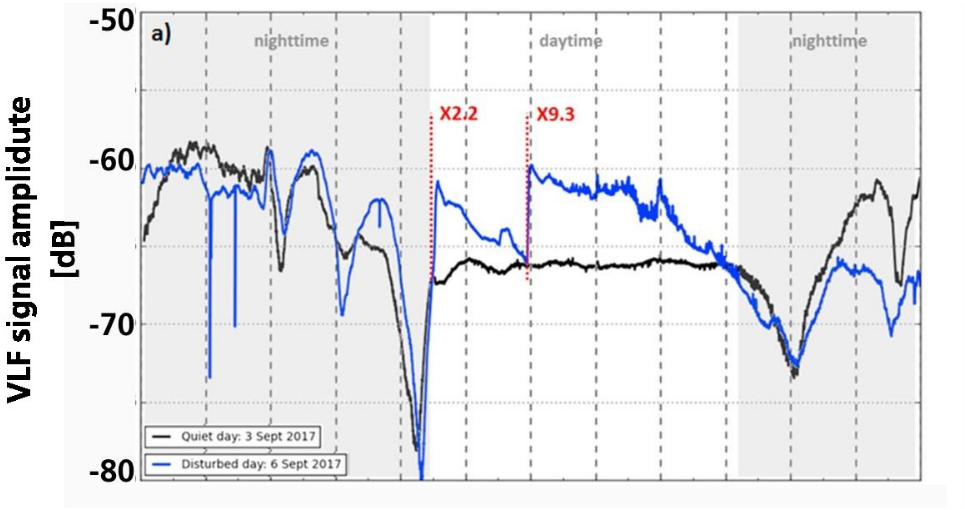
GIFDS: Global Ionospheric Flare Detection System (VLF System, 10 – 300 kHz)

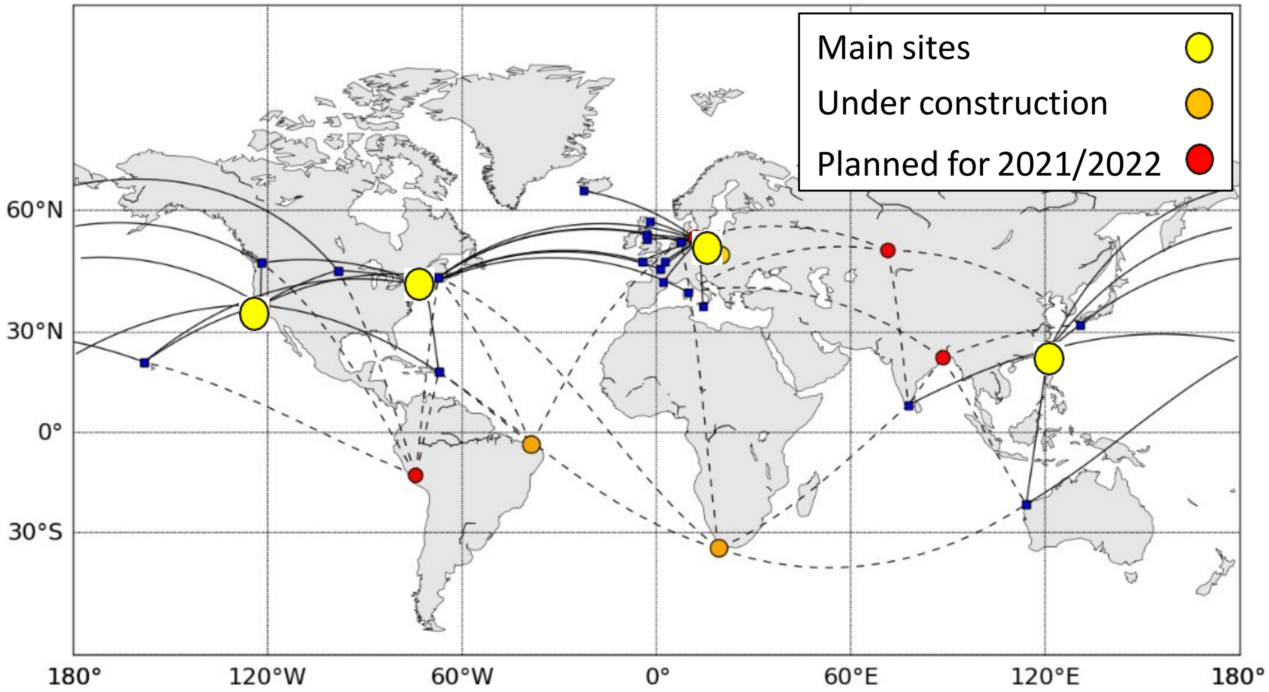
Installation of a global VLF network

- Laptop → Industrial PC (Linux)
- Software Defined Radio (SDR)
- 10 MHz rubidium oscillator
- MiniWhip-antenna

Data

- 1Hz amplitude and phase measurements of various VLF transmitters (possible spectrum from 10 – 300 kHz)

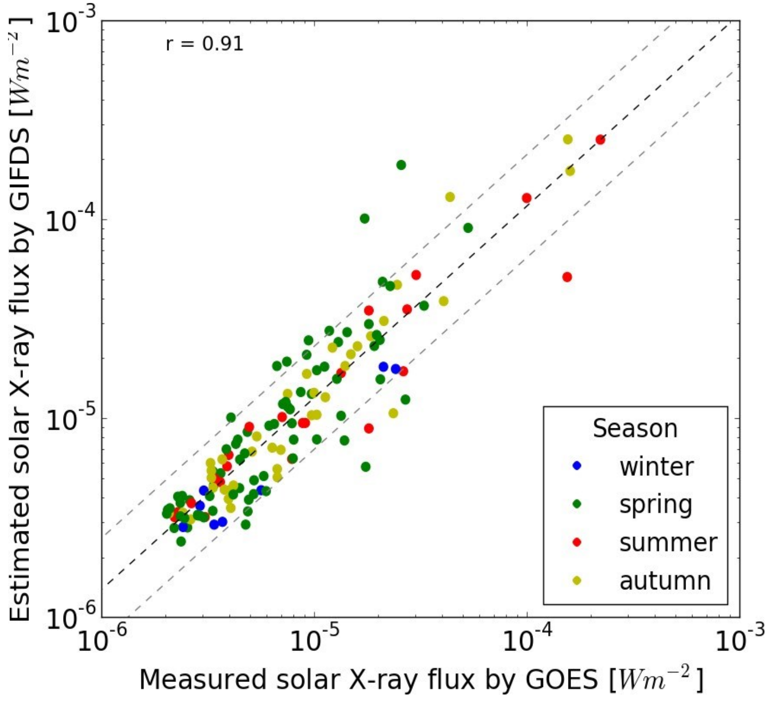




D. Wenzel, N. Jakowski, J. Berdermann, Chr. Mayer, C. Valladares, B. Heber, "Global Ionospheric Flare Detection System (GIFDS)", Journal of Atmospheric and Solar-Terrestrial Physics (2016), pp. 233-242 DOI information: 10.1016/j.jastp.2015.12.011.

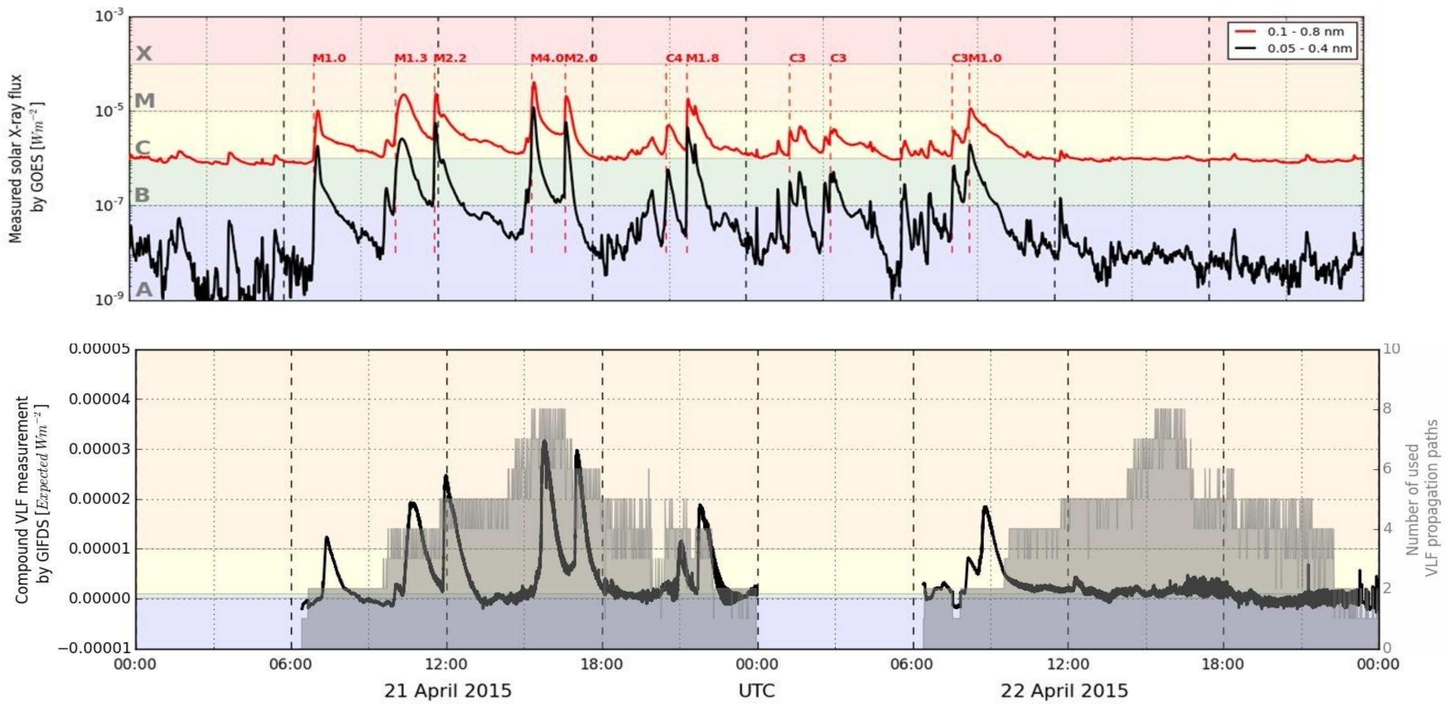
GIFDS: Global Ionospheric Flare Detection System

Strong corelation with GOES measurements (r=0.91):



Date	GOES Time [UTC]	GOES Size	GIFDS Time [UTC]	GIFDS Size
21-04-15	07:11:00	M1.0	07:12:00	$1.2 \cdot 10^{-5}$
	10:20:00	M1.3	10:22:00	$1.9 \cdot 10^{-5}$
	11:52:00	M2.2	11:52:30	$2.4 \cdot 10^{-5}$
	15:38:00	**M4.0**	**15:38:10**	$\mathbf{3.2 \cdot 10^{-5}}$
	16:58:00	M2.0	16:58:30	$2.9 \cdot 10^{-5}$
	20:53:00	C4.9	20:56:00	$1.1 \cdot 10^{-5}$
	21:42:00	M1.8	21:43:00	$1.9 \cdot 10^{-5}$
22-04-15	08:01:00	C3.8	08:04:00	$8.1 \cdot 10^{-6}$
	08:40:00	M1.0	08:41:00	$1.8 \cdot 10^{-5}$

Aim for continuous and operational information of lower dayside ionosphere via VLF setup in mid-latidudes



Real Time Solar Flare Analysis for GNSS users (combination of VLF and GNSS)

Solar flares at EUV and X-ray wave lengths can lead to a considerably increased plasma density in the ionosphere.

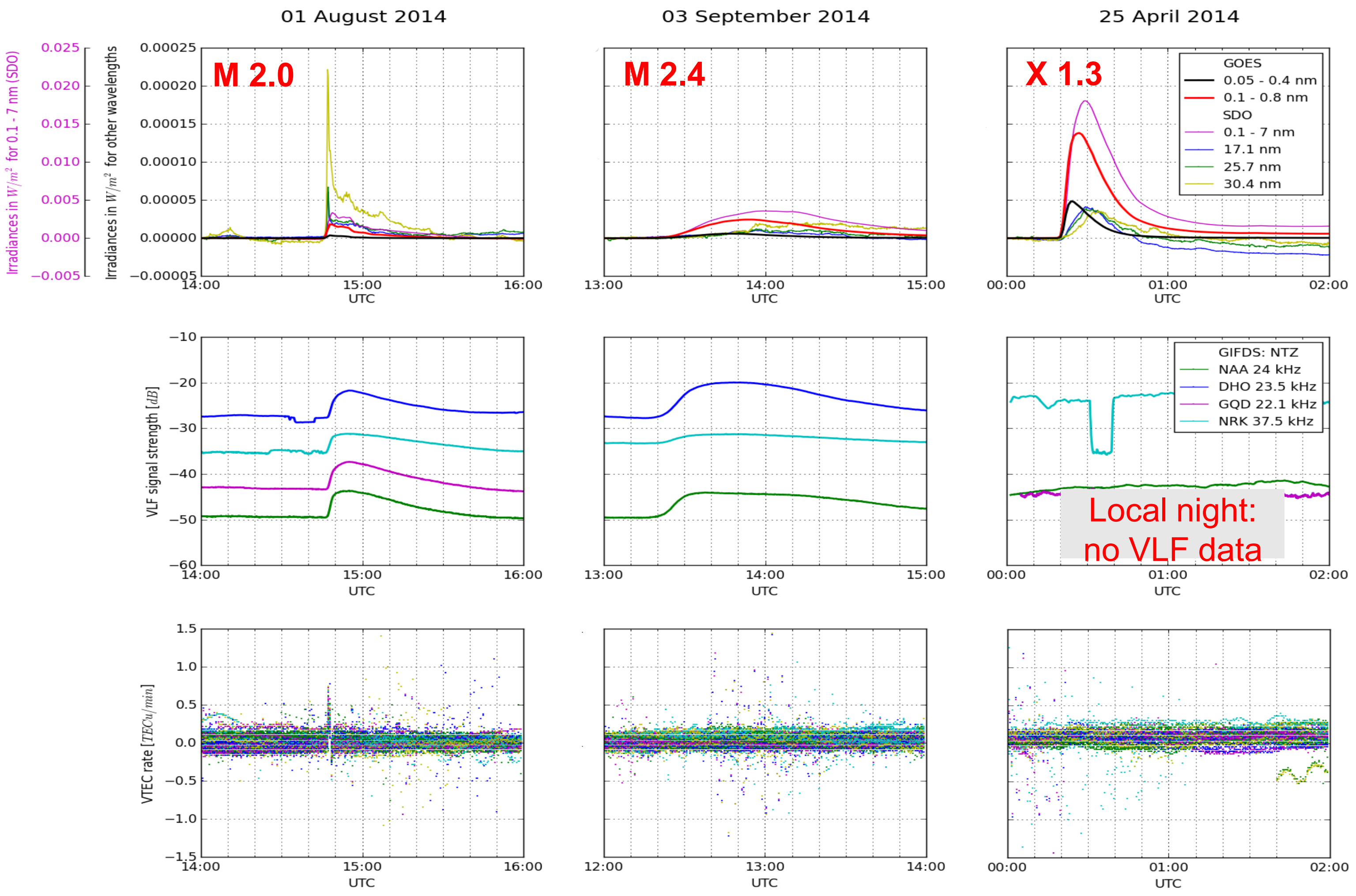
Need to distinguish between X-ray and EUV flare component:

- X-ray (red) primarily affects HF
- EUV (yellow) mainly influences GNSS

X-ray scales have only limited information for GNSS users

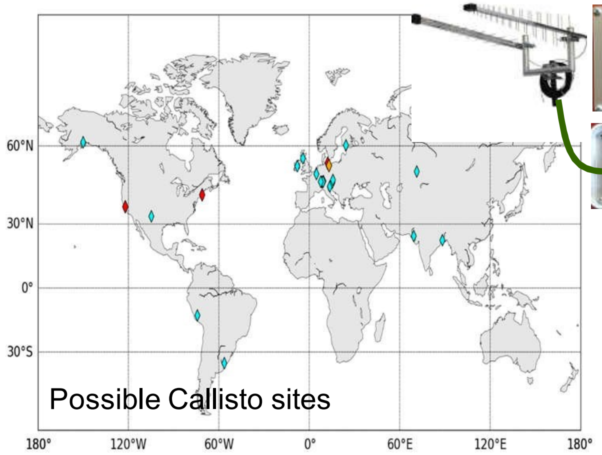
- Even strong X-ray flare may have weak EUV component (see X 1.3 on the right)
- False alarms are possible

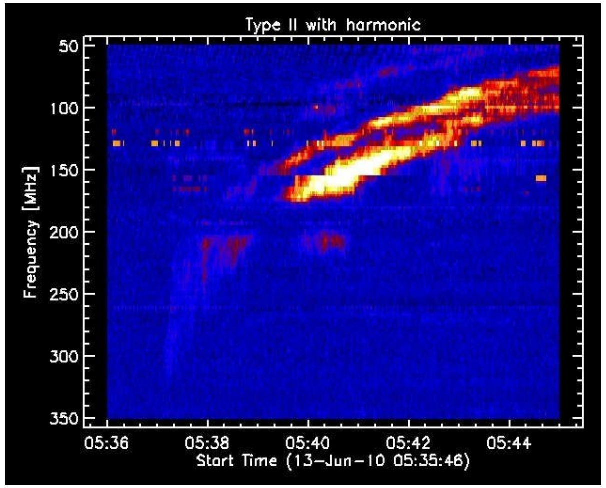
Combination of GIFDS and TEC rate information shall help to derive user-specific warnings of flares



CALLISTO Network

- The network is used to monitor solar radio burst and radio frequency interference in several frequency ranges (45 - 870 MHz, 1 - 1.6 GHz)
- Possibility to warn GNSS users of the radio burst effects





◆ <u>Under construction:</u>

Neustrelitz

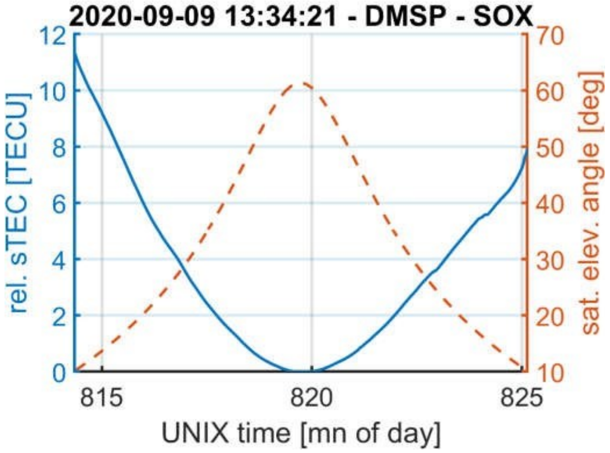
◆ <u>Planned for 2021/2022:</u>

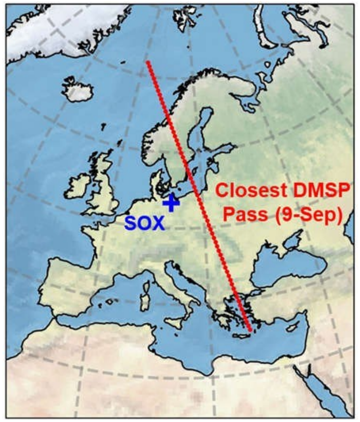
Rostock, Boston, Stanford

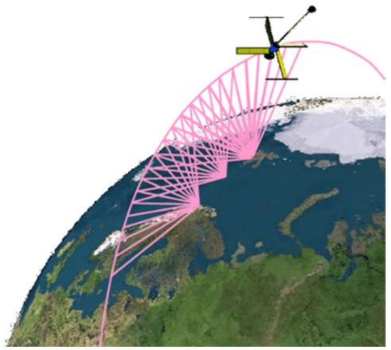
CALLISTO: Compound Astronomical Low frequency Low cost Instrument for Spectroscopy and Transportable

Beacon receiver Network

- Receive dual frequency signals (150 & 400 MHz) from LEO transmitters and the signals can be used for ionospheric TEC estimation
- The **geometry and high spatial resolution** make the radio beacon data very attractive for **regional tomography** of the ionosphere and detection of Travelling Ionospheric Disturbances (TID).







Helium Lidar

- Construction of a resonance fluorescence lidar (collaboration with DLR IPA)
- Resonance fluorescence scattering from metastable helium atoms to measure temperature and vertical wind profiles at altitudes of 200 -1000 km
- Investigation of coupling processes between ionosphere/plasmasphere and thermosphere

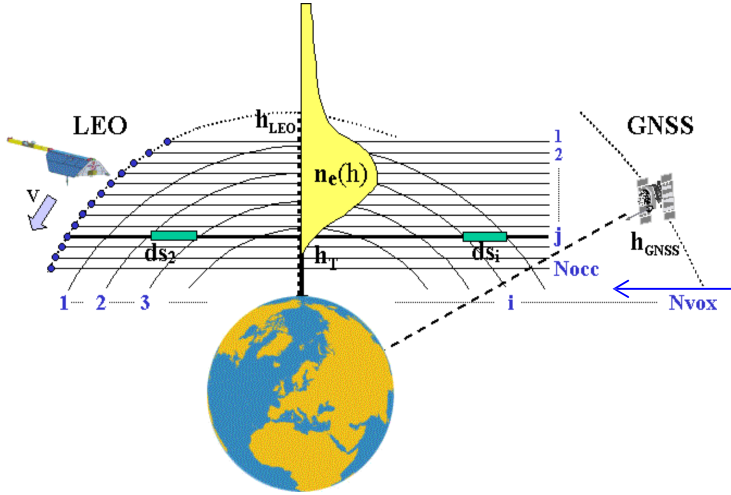
All Sky Imager

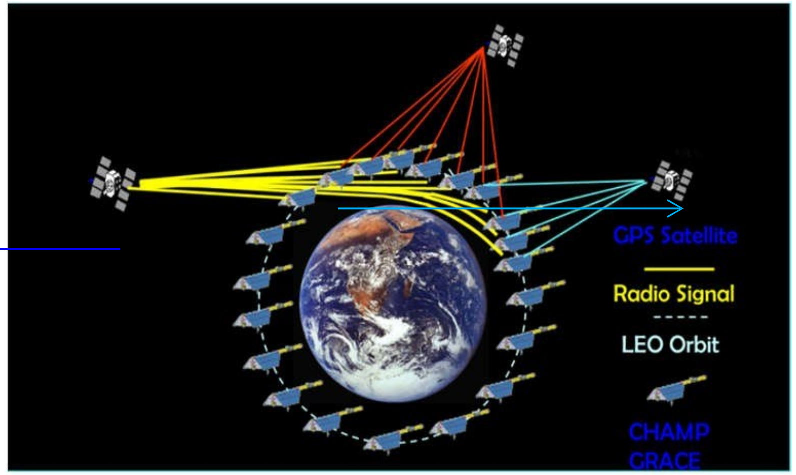
- Instrument installation done
- Currently test phase
- TID monitoring

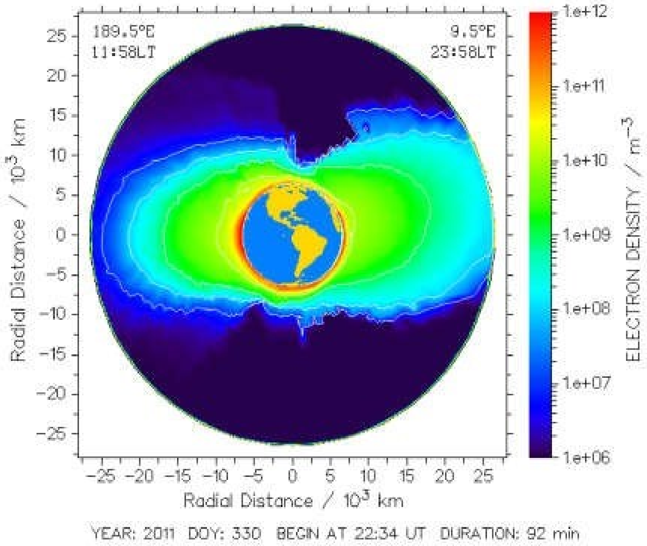
EISCAT

- Affiliate member since 2020
- First experiments conducted
- Strong involvement in EISCAT 3D envisaged

Space Based Observations





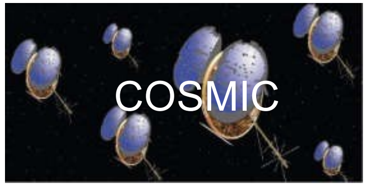


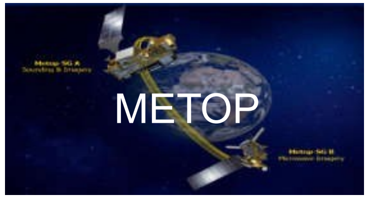
GNSS radio occultation data allow the reconstruction of the **electron density distribution** below the satellite orbit.

GNSS measurements on board LEO satellite are very useful for monitoring the ionosphere

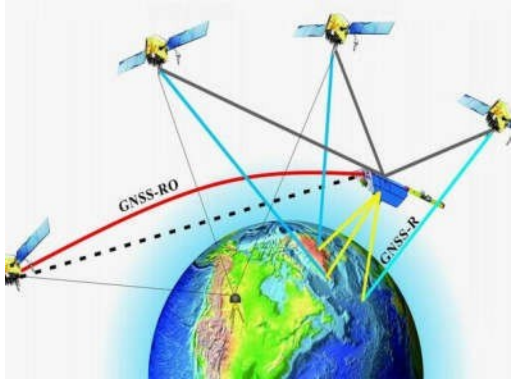
Navigation data enable reconstruction of the **3D electron density distribution** of the topside ionosphere/plasmasphere **over the satellite orbit**

GNSS: Global Navigation Satellite Systems
LEO: Low Earth Orbit (< 2000 km)



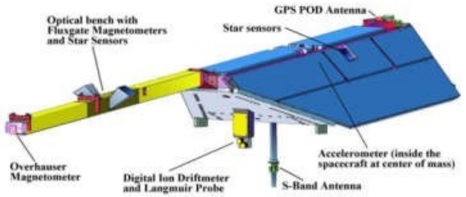


Space Based Observations

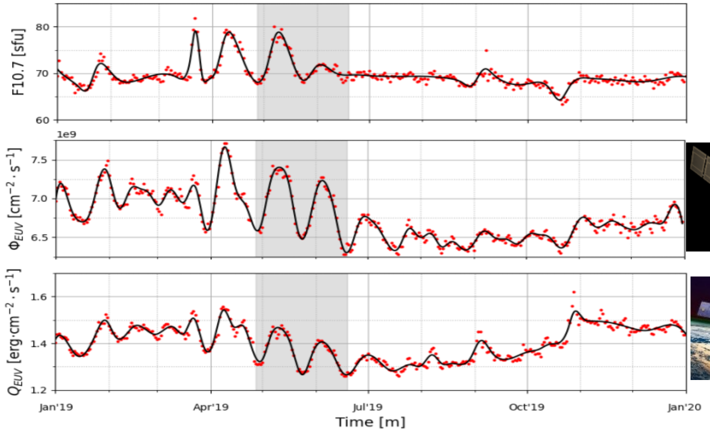


in situ measurements of electron density (e.g. Langmuir probe aboard CHAMP, …), temperature, wind, thermosphere composition (e.g. TIMED, ICON, GOLD, …) and solar irradiance

CHAMP



- **GNSS reflectometry** is a new field of research. The GNSS signal is **reflected from the Earth's surface** and passes through the ionosphere twice before being received.

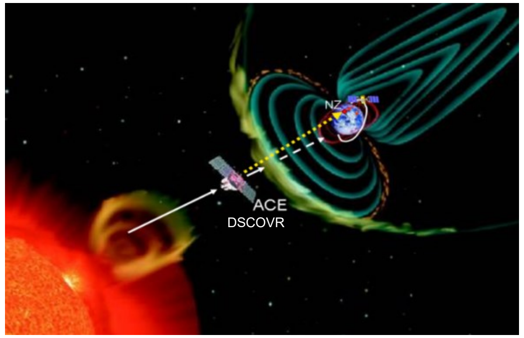


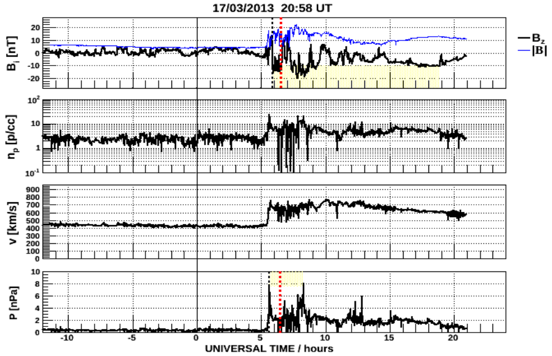
SOHO

GOLD

Erik Schmölter, Jens Berdermann, Mihail Codrescu, The delayed ionospheric response to the 27-day solar rotation period analyzed with GOLD and IGS TEC data, JGR Space Physics, 2021, Volume 126 Issue 2
https://doi.org/10.1029/2020JA028861

DLR is a **member of the Real Time Solar Wind (RTSW) observation network** involved in the data transfer and the analysis of NASA's Advanced Composition Explorer (ACE) and the Deep Space Climate Observatory (DSCOVR) satellite



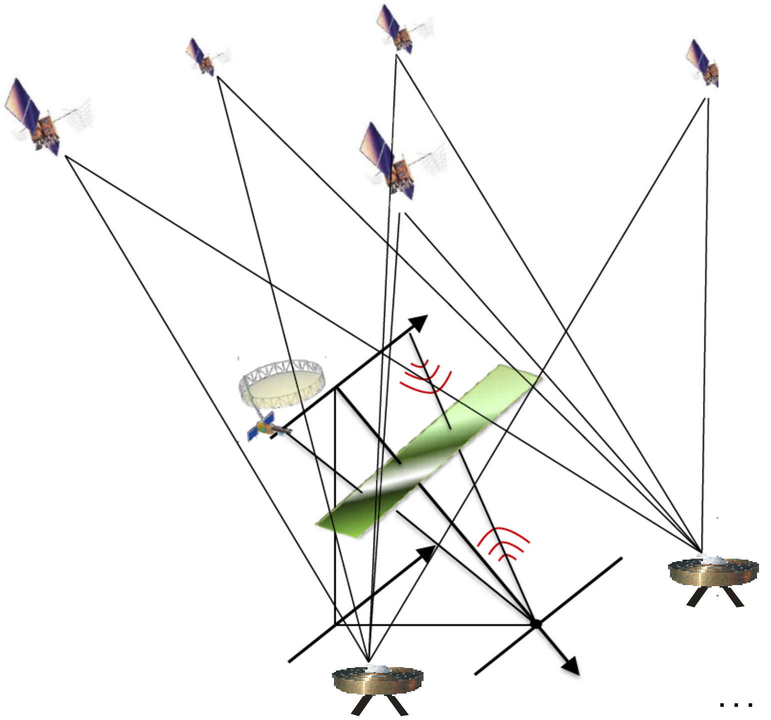


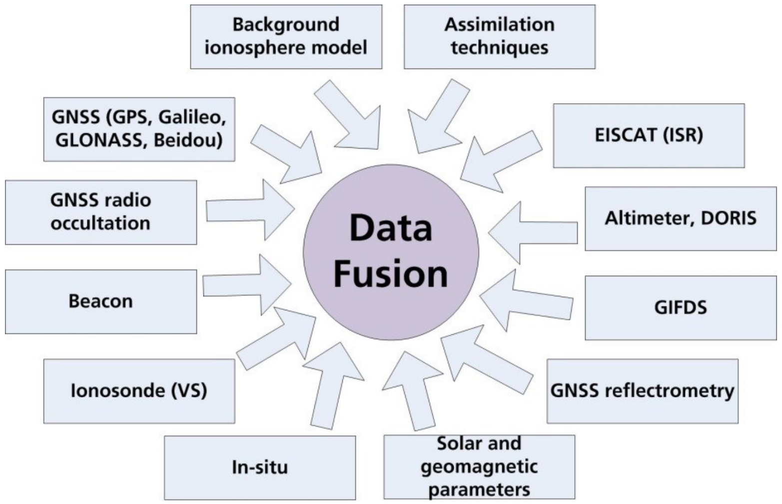
➔ **Reliable Space Weather information and forecasts at the earliest opportunity**

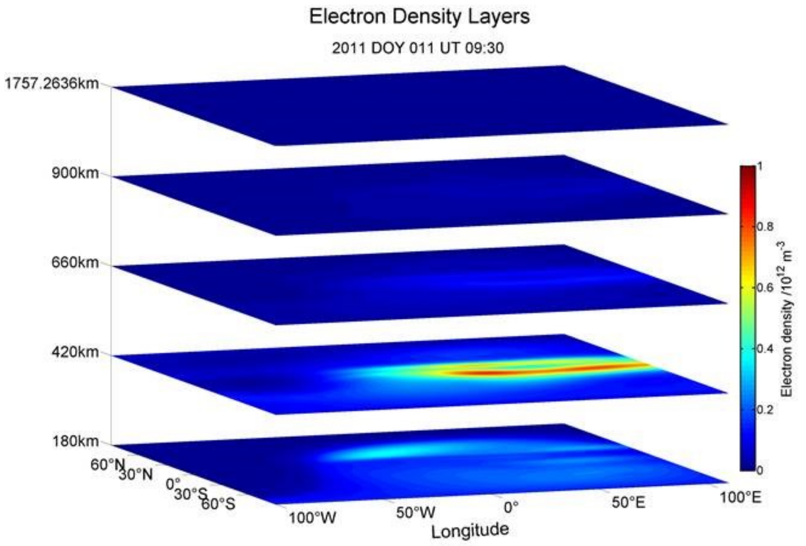
Data Fusion and Reconstruction

One goal is to generate **3D electron density reconstructions of the geo-plasma** environment with high temporal and spatial resolution by means of data fusion and reconstruction.

- Data originating from different sources need to be harmonized







… different area
… different altitude
… different sounding geometry

… different time resolution
… different latentcy
… different accuracy

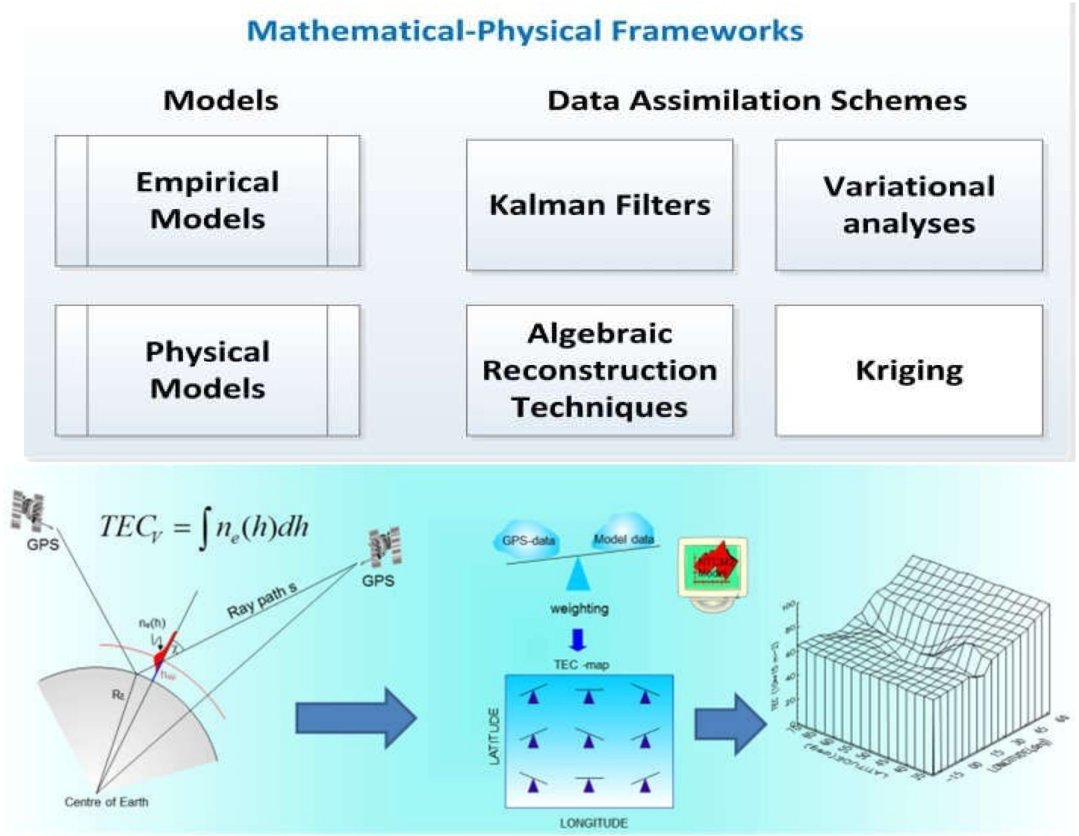
Data Fusion and Reconstruction

Data gaps can be filled by using background models.

- The development of fast and robust empirical 2D- and 3D- background models is one of the key tasks.

The institute is looking forward participating in **future satellite missions (e.g., CubeSat)** to enrich ionospheric database in collaboration with national and international partners.

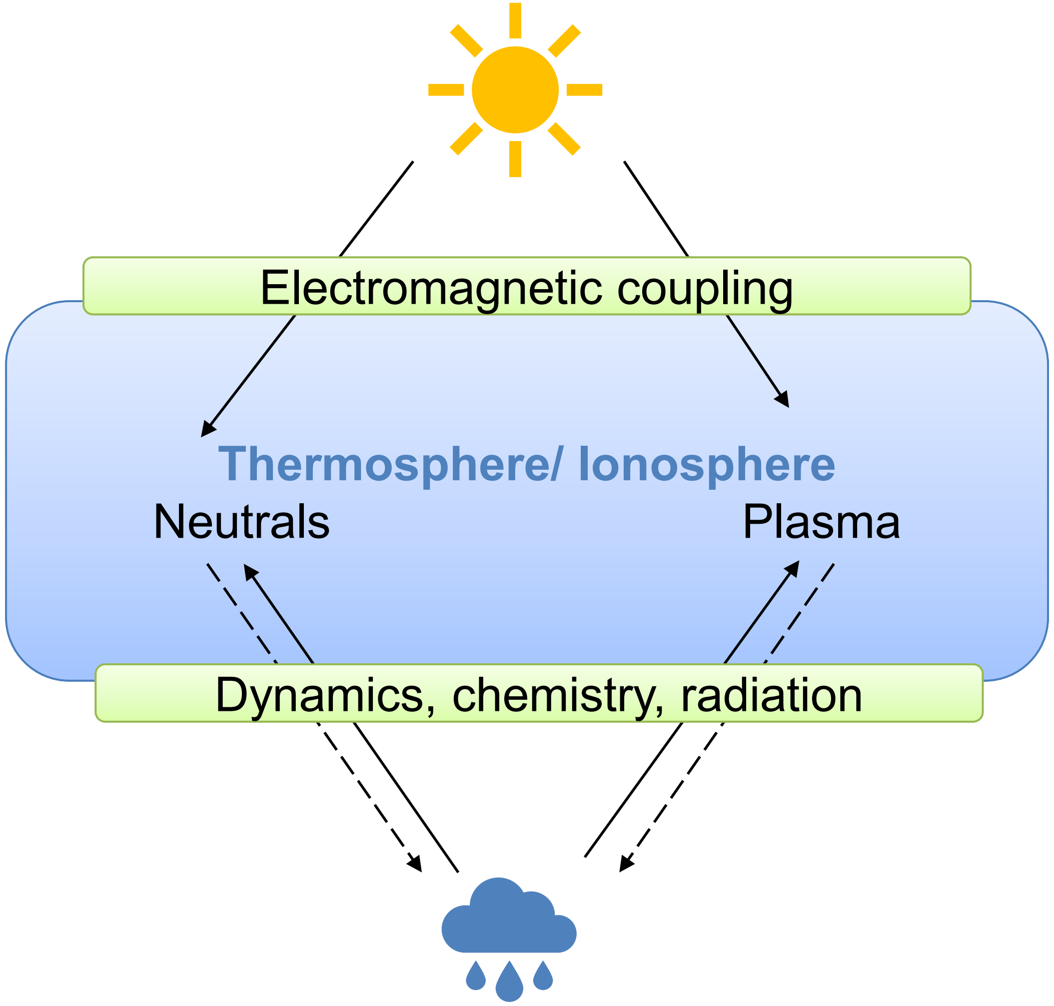
- Long term goal is to develop, test, fly and operate own instruments for space weather observations.

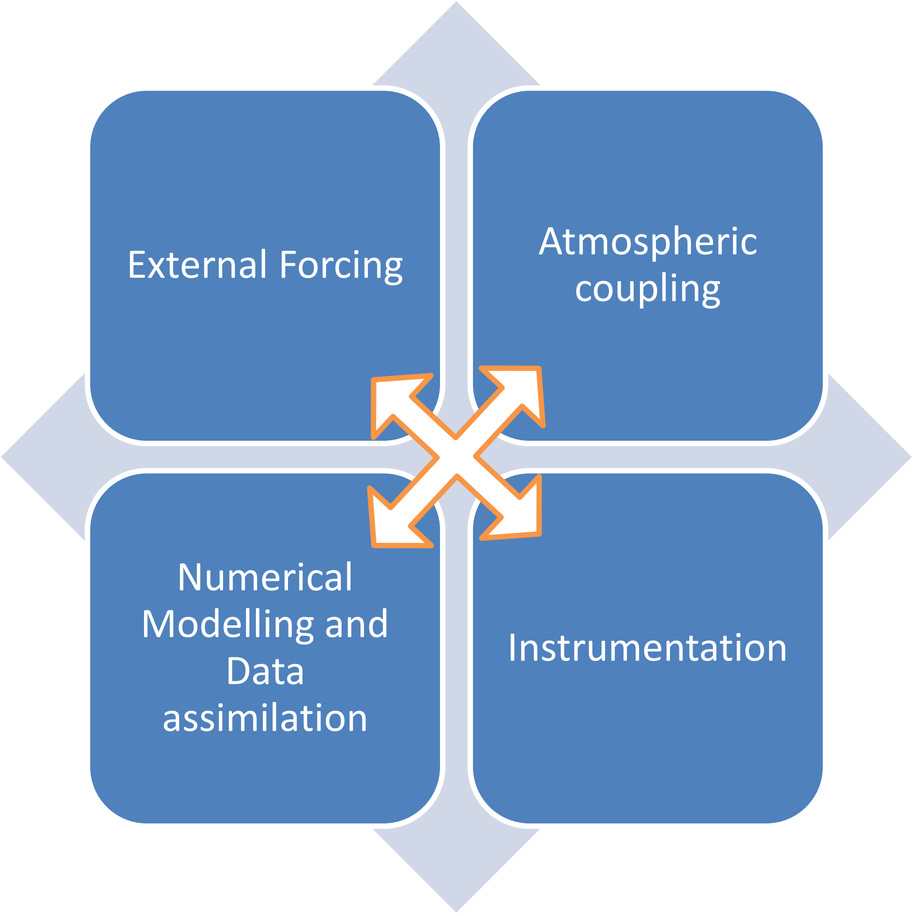


Solar-Terrestrial Coupling Processes

- Develop forecasts of the thermosphere-ionosphere based on a physical understanding of space weather
- Improve the understanding of electrodynamic processes in the thermosphere-ionosphere system

Research Areas

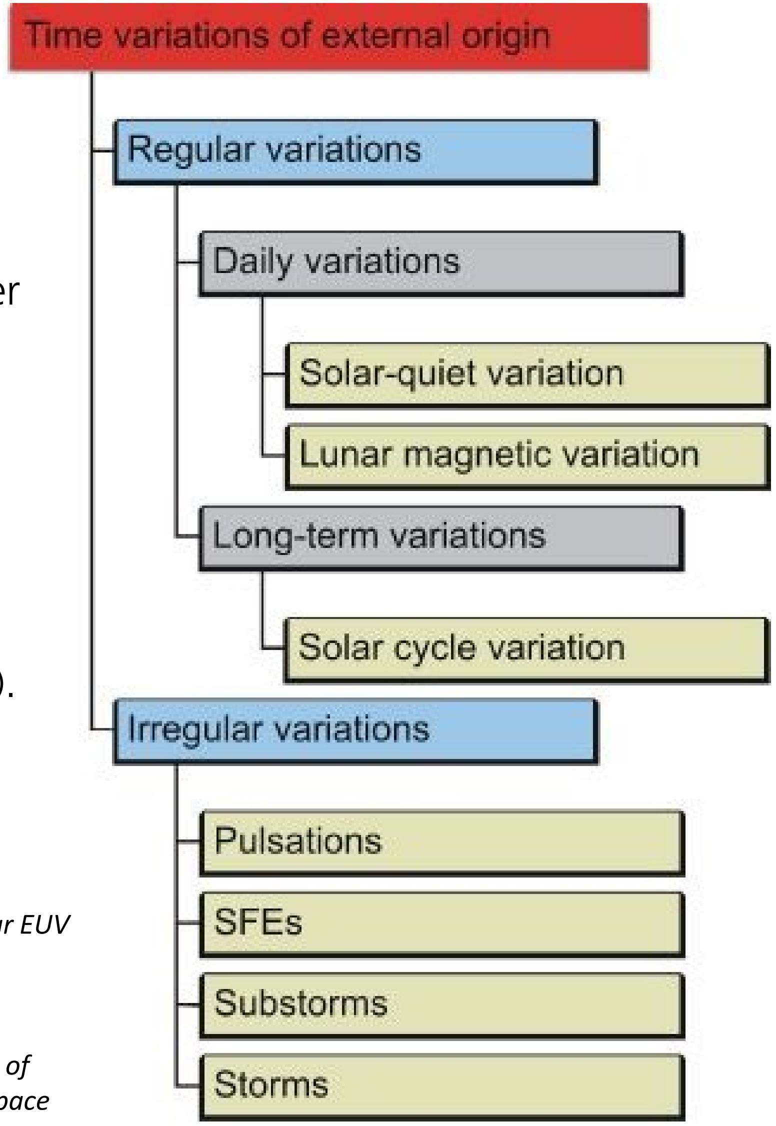




External forcing topics

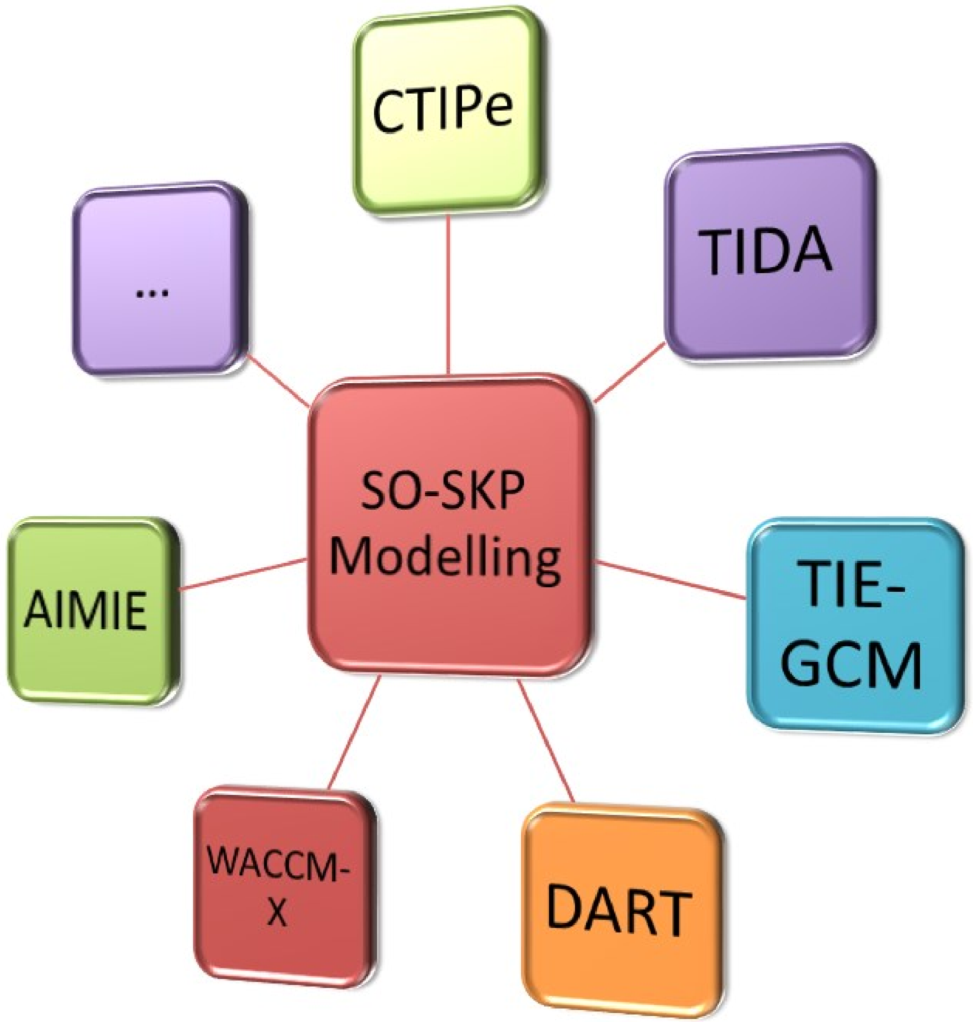
External forcing due to either natural solar/geomagnetic variations, or artificial ionosphere modifications.

- **Periodic forcing** studies:
  - impact of EUV variations due to solar rotation harmonics solar cycle impact on lower thermosphere/ionosphere and trends (E. Schmölter et al., 2020)
  - impact of solar activity on forecasting (T. Kodikara et al., 2021)
- **Irregular forcing** studies:
  - generation of TIDs due to geomagnetic storms (A. Ferreira et al., 2021)
  - formation of polar cap density anomalies during storms (D. Pokhotelov et al., 2021).
- **Artificial heating** of the auroral ionosphere with EISCAT HF facility
  - resulting plasma instabilities (H. Sato et al., 2021)



- *Erik Schmölter, Jens Berdermann, Norbert Jakowski, Christoph Jacobi, Spatial and seasonal effects on the delayed ionospheric response to solar EUV changes, Ann. Geophys., 38, 149-162, https://doi.org/10.5194/angeo-38-149-2020, 2020.*
- *Kodikara, Timothy und Zhang, Kefei und Pedatella, Nicholas und Borries, Claudia (2021) The Impact of Solar Activity on Forecasting the Upper Atmosphere via Assimilation of Electron Density Data. EGU General Assembly 2021 Virtual. doi: 10.5194/egusphere-egu21-10756.*
- *Ferreira, Arthur Amaral und Borries, Claudia und Xiong, Chao und Borges, Renato Alves und Mielich, J. und Kouba, Daniel (2020) Identification of potential precursors for the occurrence of Large-Scale Traveling Ionospheric Disturbances in a case study during September 2017. Journal of Space Weather and Space Climate, 10 (32), Seiten 1-17. EDP Sciences. doi: 10.1051/swsc/2020029. ISSN 2115-7251.*
- *Pokhotelov, Dimitry und Fernandez Gomez, Isabel und Borries, Claudia (2021) Polar cap plasma transport during geomagnetic superstorm. CEDAR 2021, 20.-25. Jun. 2021, Boulder, USA (online).*
- *Sato, Hiroatsu und Rietveld, Michael und Jakowski, Norbert (2021) GLONASS observation of artificial field-aligned plasma irregularities near magnetic zenith during EISCAT HF experiment. Geophysical Research Letters. Wiley. doi: 10.1029/2020GL091673. ISSN 0094-8276.*

Physical Modelling



Modelling

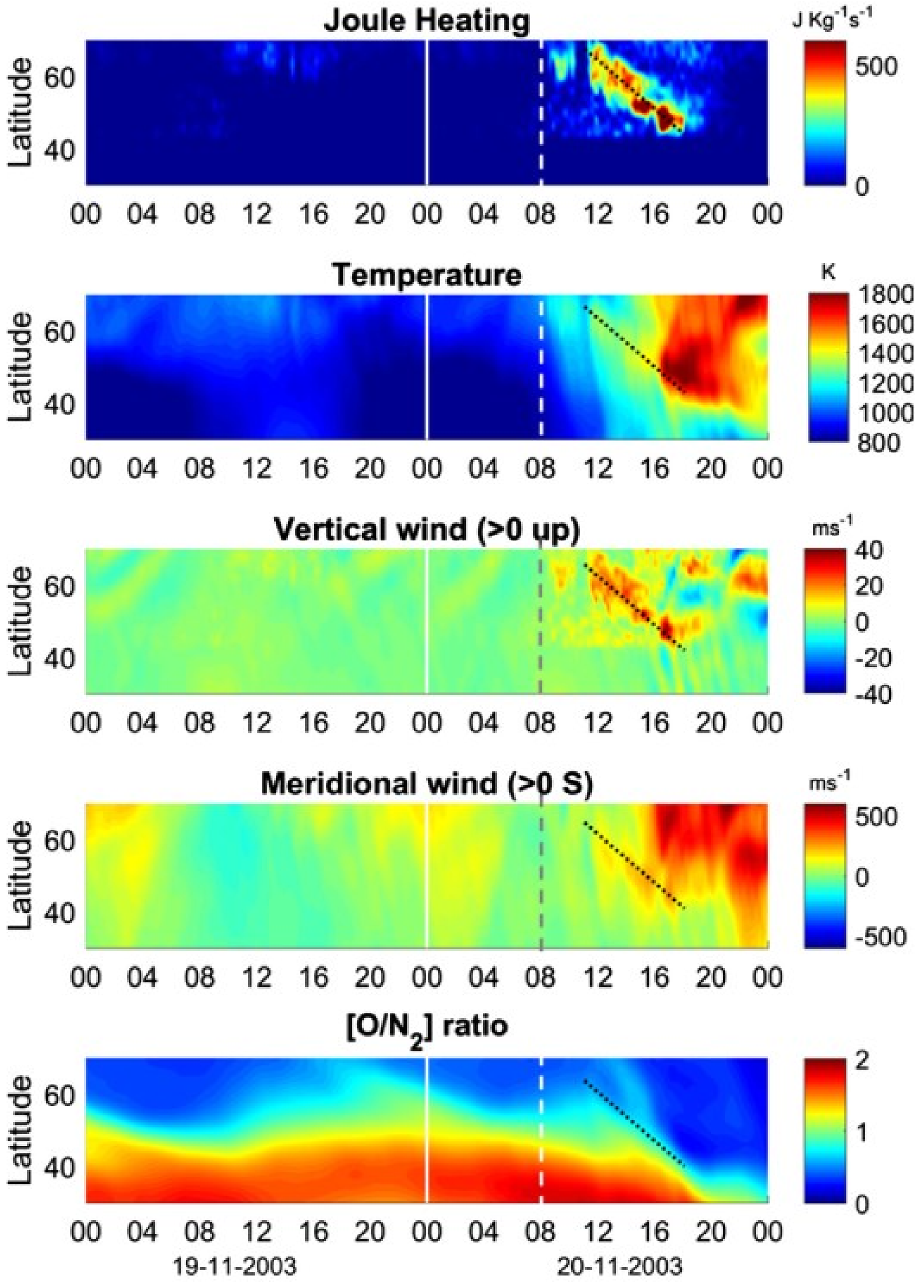
- Physics based/ numerical (TIEGCM and CTIPe)
- Validation and quantification of model quality
- Identification of potential improvements and implementation of improvements
- Real-time application of CTIPe in preparation
- Development of forecasts

Data Assimilation (TIEGCM-DART and CTIPe-TIDA)

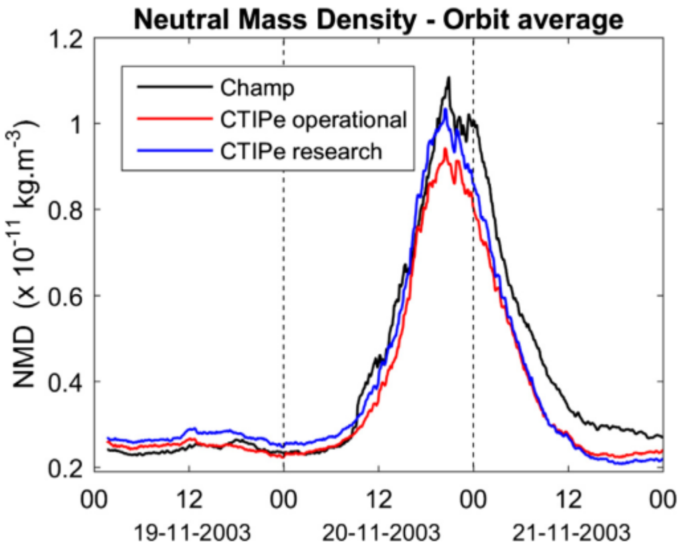
- Sparse data coverage in the thermosphere and ionosphere
- Comparison and analysis of existing models frameworks for data assimilation (DA)
- Future goal is real-time DA

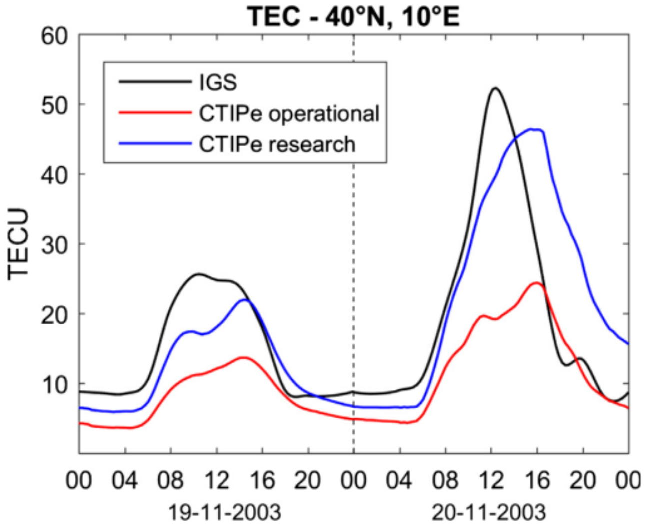
Physical Modelling

Storm dynamics at z = 400 km reproduced with CTIPe



Validation of CTIPe results with neutral density from CHAMP and TEC from IGS



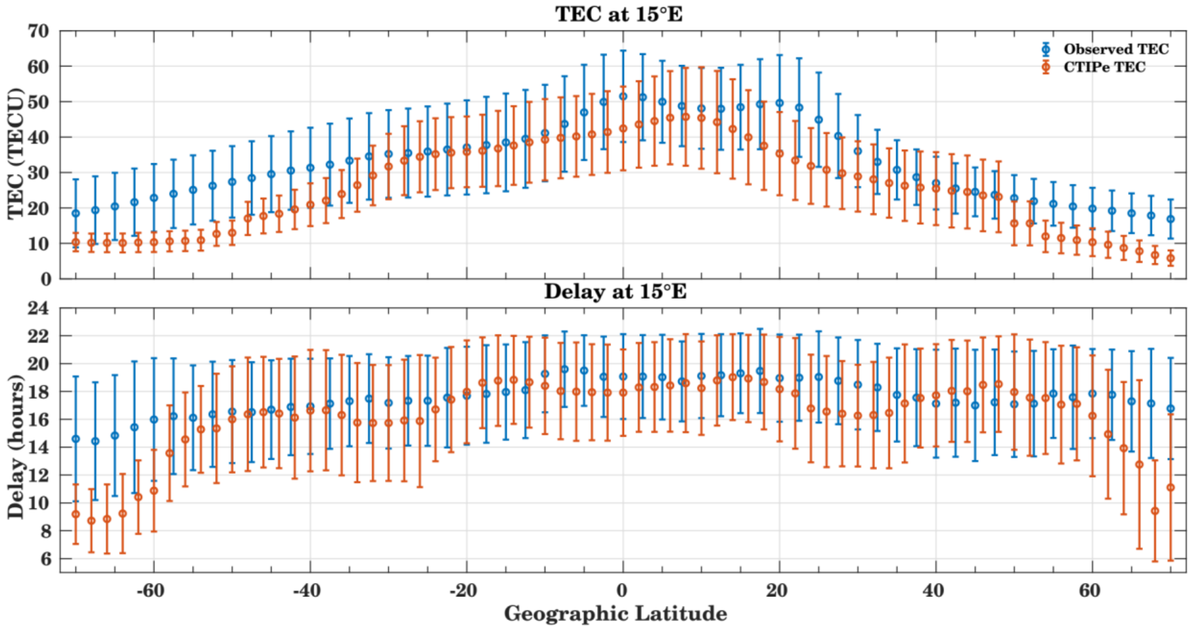


I. Fernandez-Gomez, M. Fedrizzi, M. V. Codrescu et al., On the difference between real-time and research simulations with CTIPe, Advances in Space Research, https://doi.org/10.1016/j.asr.2019.02.028

Physical Modelling

Delayed response of the ionosphere

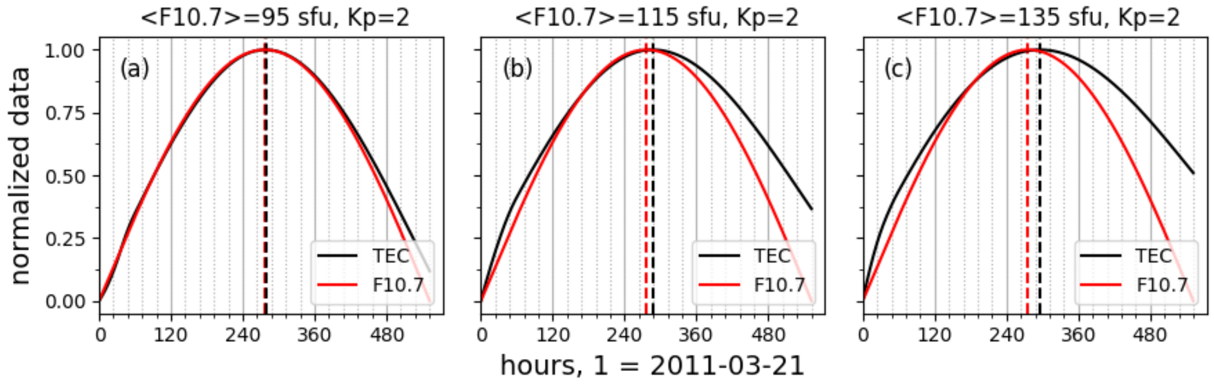
The **Coupled Thermosphere Ionosphere Plasmasphere Electrodynamics (CTIPe)** model simulated TEC are used to investigate the delayed ionospheric response against solar flux and its trend during the years 2011 to 2013.



The model can reproduce the measured ionospheric delay with about 18 h at mid-latitudes

Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) is used to describe the delayed ionospheric response to solar Extreme Ultraviolet (EUV)

- F10.7 is used in the model to present the solar activity.
- Investigate the influence of F10.7 changes on the delayed ionospheric response.
- The corresponding ionospheric delay is given by the difference between the maximum of F10.7 and TEC.



The increase of the ionospheric delay with increasing solar activity can be reproduced with the TIE-GCM model.

- *Rajesh Vaishnav, Erik Schmölter, Christoph Jacobi, Jens Berdermann and Mihail Codrescu, Ionospheric Response to Solar EUV Radiation Variations: Comparison based on CTIPe Model Simulations and Satellite Measurements, Ann. Geophys., 39, 341–355, 2021* https://doi.org/10.5194/angeo-39-341-2021
- *E. Schmölter, J. Berdermann, C. Jacobi and N. Jakowski, "Modeling Of The Delayed Ionospheric Response With The TIE-GCM Model," 2020 European Navigation Conference (ENC), Dresden, Germany, 2020, pp. 1-9, doi: 10.23919/ENC48637.2020.9317355.*

Space Weather Impact

Application oriented research to improve the knowledge about space weather interactions with human technological infrastructures.

Characterization and Prediction of Disturbances

Date: 2019-11-20, **Time**: 12:15:13 UT, **Estimated Arrival**: 2019-11-20 12:36:00 UT

P	64.0 nPa	Yellow Warning: P > 7.5 nPa	Red Warning: P > 50.0 nPa
v	1200.0 km/s	Yellow Warning: v > 800.0 km/s	Red Warning: v > 1000.0 km/s
B_z	-60.0 nT	Yellow Warning: B_z < -10.0 nT	Red Warning: B_z < -50.0 nT
n_p	70.0 p/cc	Yellow Warning: n_p < 40.0 p/cc	Red Warning: n_p < 60.0 p/cc

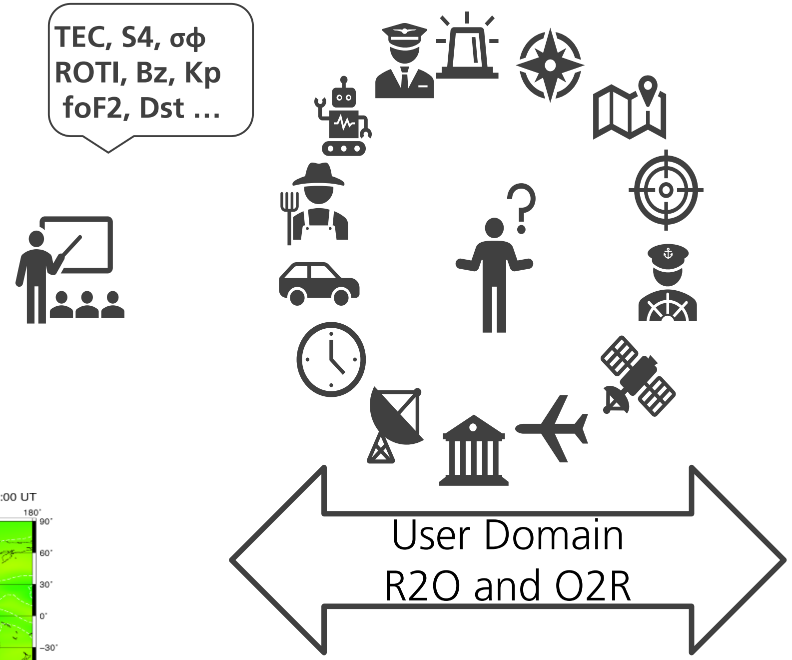
Show further information

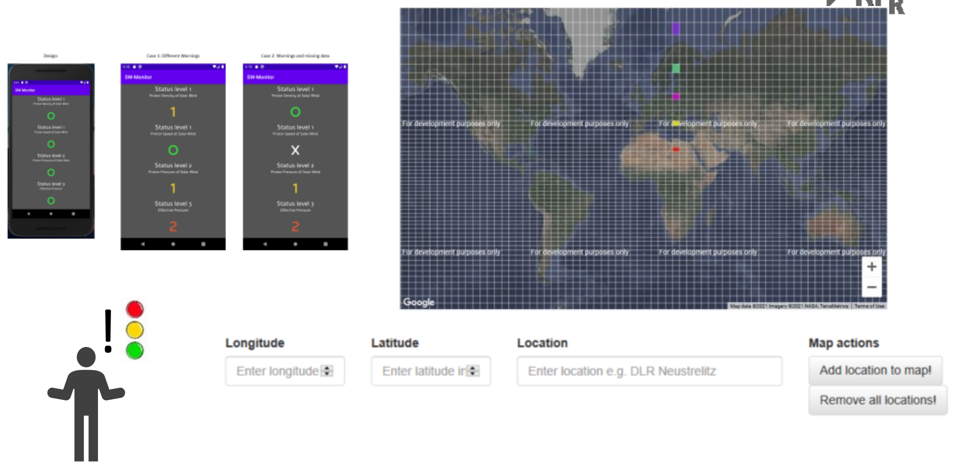
Date: 2019-11-20, **Time**: 12:14:59 UT, **Estimated Arrival**: 2019-11-20 12:42:00 UT

P	5.0 nPa	Yellow Warning: P > 7.5 nPa	Red Warning: P > 50.0 nPa
v	900.0 km/s	Yellow Warning: v > 800.0 km/s	Red Warning: v > 1000.0 km/s
B_z	-60.0 nT	Yellow Warning: B_z < -10.0 nT	Red Warning: B_z < -50.0 nT
n_p	10.0 p/cc	Yellow Warning: n_p < 40.0 p/cc	Red Warning: n_p < 60.0 p/cc

Show further information

TEC, S4, σϕ
ROTI, Bz, Kp
foF2, Dst …

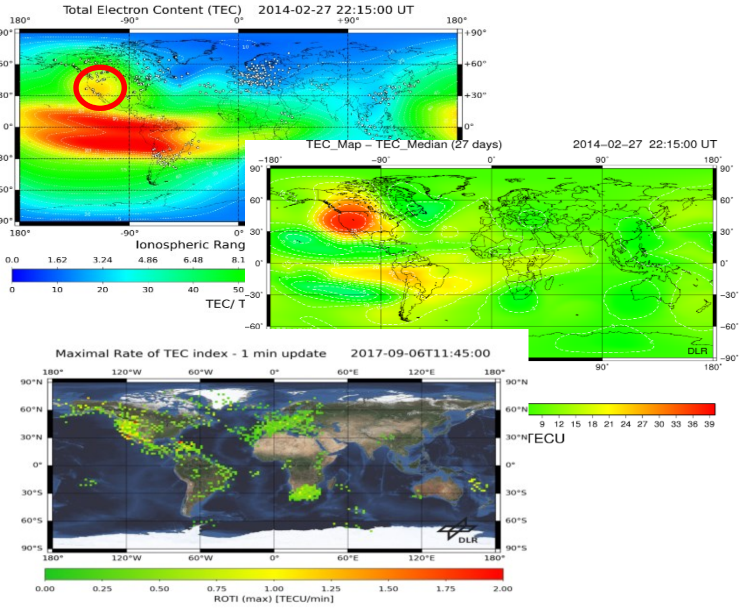




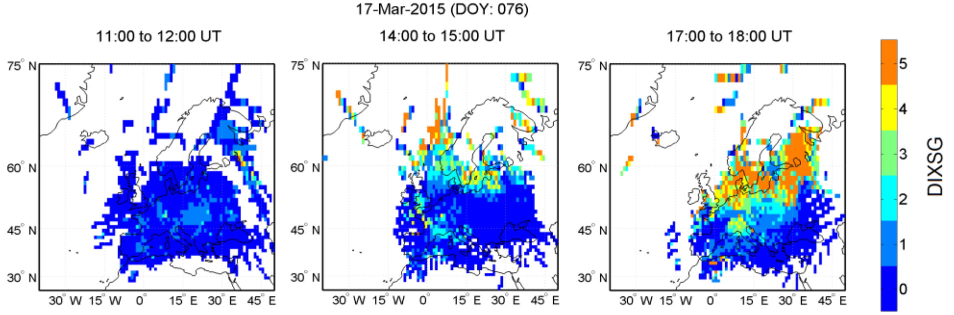
Which time period, time interval or GNSS frequency do you want to analyse?

Please specify the start and the end time of the time series according to your downloaded ESPAS data. You can also limit the data processing time by setting a time interval of interest. Select a GNSS frequency, if you are interested in the corresponding range error instead of TEC.

Start Time	End Time	Interval	GNSS Frequency
08/10/2017 00:00 UTC	16/10/2017 00:00 UTC	15 Minutes	Galileo E1



Important to develop methods and indices providing direct information on the performance of precise and safety-critical GNSS applications to the different user groups.



Publications

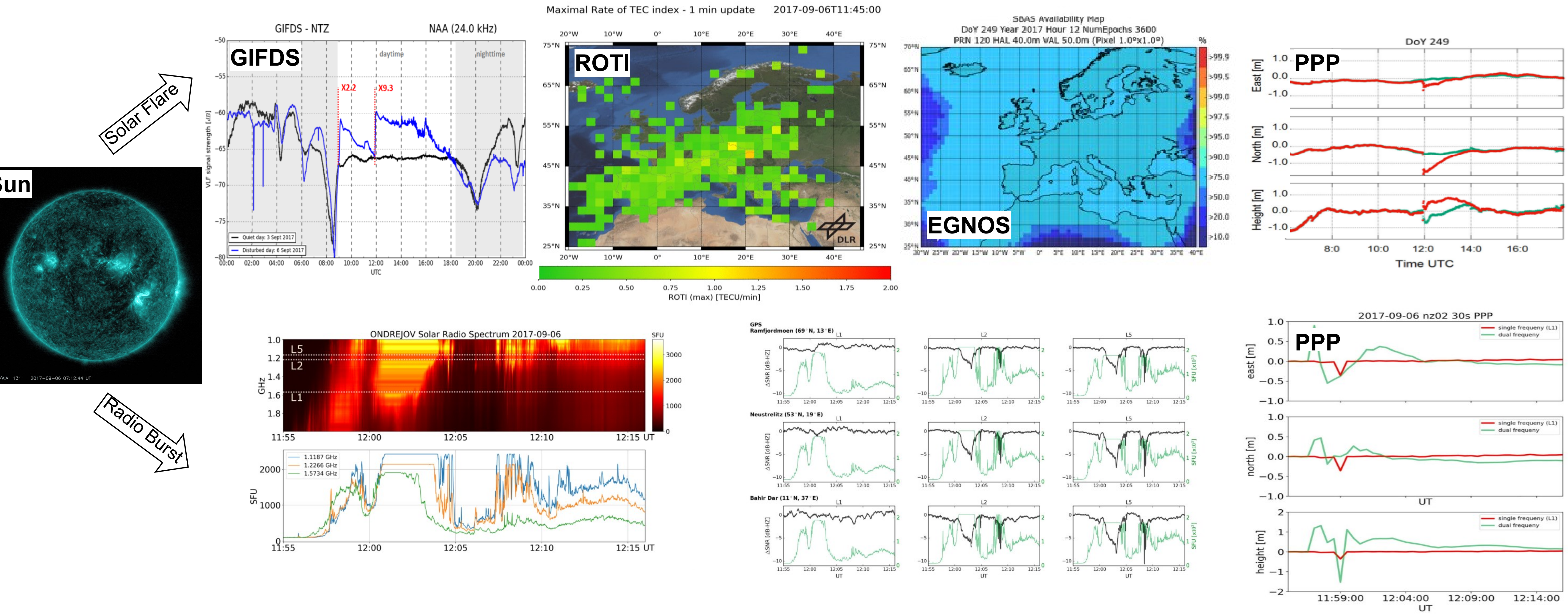
- *Wilken, V., Kriegel, M., Jakowski, N., Berdermann, J. , (2018), An ionospheric index suitable for estimating the degree of ionospheric perturbations, Space Weather Space Clim. 8 A19 (2018)*
- *Anna Belehaki, Sarah James, Mike Hapgood, Spiros Ventouras, Ivan Galkin, Antonis Lembesis, Ioanna Tsagouri, Anna Charisi, Luca Spogli, Jens Berdermann, Ingemar Häggström (2016) The ESPAS e-infrstructure: Access to data from ner-earth spacel, Advances in Space Research, Volume 58, Issue 7, 10/2016 (1177-1200)*

Projects

- *ESA SSA Project SWIGPAD (2020-2022) Development of GNSS Performance Indicators*
- *DLR-TM Project RICOPA (2018-2021) Regional ionosphere corrections for positioning applications*

Real time Observation and Analysis of Space Weather Events

Source | Observation | Impact



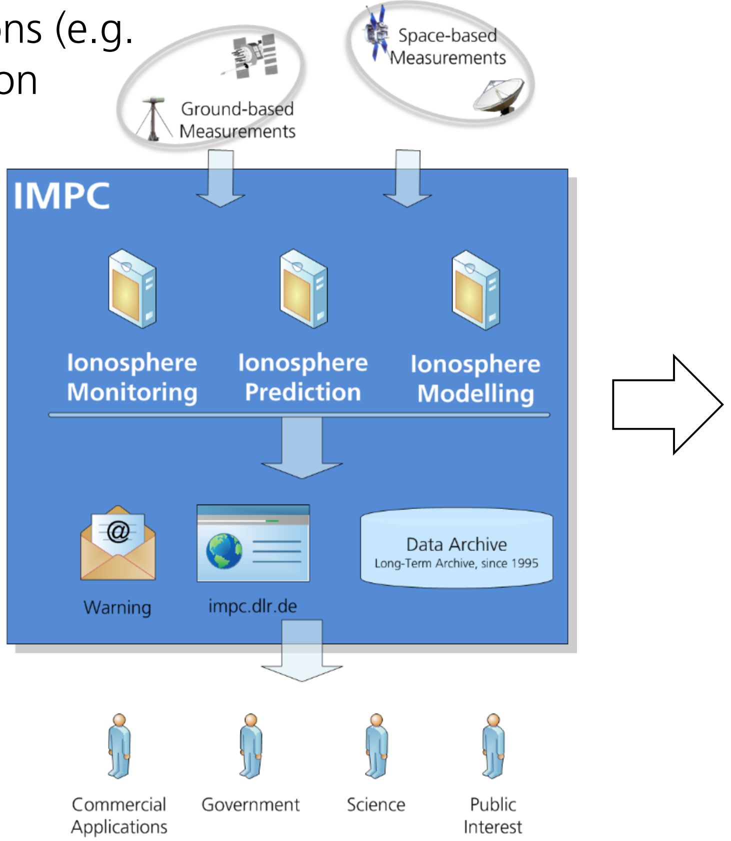
- *Berdermann, J., Kriegel, M., Banys, D., Heymann, F., Hoque, M. M., Wilken, V., et al.* ***(2018)****. Ionospheric response to the X9.3 Flare on 6 September 2017 and its implication for navigation services over Europe.* ***Space Weather, 16****.* https://doi.org/10.1029/2018SW001933
- *Sato, H. , Jakowski, N. , Berdermann , J. , Jiricka, K., Heßelbarth, A. , Banyś, D. , Wilken V.* ***(2018)****, Solar Radio Burst Events on 6 September 2017 and Its Impact on GNSS Signal Frequencies.* ***Space Weather, 16****. https://doi.org/10.1029/2018SW001933*

Pre-operational Services

Information about the ionospheric state can afford significant contributions to avoid safety-critical situations (e.g. air transport) or high costs by useless expeditions (e.g. surveys of offshore resource development or precision positioning).

The **Ionosphere Monitoring and Prediction Center (IMPC) of DLR contributes to the mitigation of ionospheric impacts** on technology with

- Near real-time ionosphere monitoring
- Prediction of ionospheric conditions
- Modelling the ionosphere
- Warning messages to users
- Data delivery services
- Education and public outreach



ESA SSA / ESA S2P

DLR SO is responsible for the coordination and service provision of the ESA Expert Service Center Ionospheric Weather.

PECASUS

A Global ICAO Space Weather Centers is operated by the PECASUS consortium since 07.11.2019, where DLR's role is to provide data and information for the GNSS user services.

Publications

- *Martin Kriegel, Jens Berdermann et al., Ionosphere Monitoring and Prediction Center, accepted paper in the European Navigation Conference 2020 procedings to be published at IEEE*
- *Berdermann et al. Ionospheric Monitoring and Prediction Center (IMPC)," Proceedings of the 27th International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS+ 2014), Tampa, Florida, September 2014, pp. 14-21*

Projects

- *EU H2020 Projects PITHIA-NRF (2021-2024) Development of an research Infrastructure to build a European distributed network integrating observing facilities, data processing tools and prediction models for ionospheric, thermospheric and plasmasphere research*
- *ESA S2P ESC Projects (2020-2022ff) Expert Service Center Ionosphere*
- *ICAO Project PECASUS Project (2019-2022) Pan-European Consortium for Aviation Space Weather User Services*

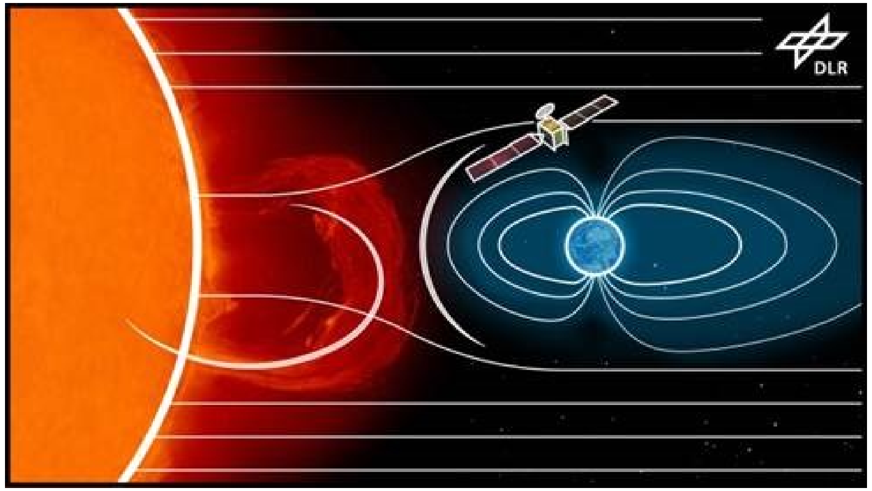
Research and development projects between DLR-SO and the University of Rostock

WG Dynamics of Molecular Systems

Interaction of UV and EUV radiation with planetary atmospheres, in particular on conditions in the Earth's upper atmosphere.

WG Physics of Surfaces and Interfaces

Charge transfer and distribution on surfaces to evaluate and mitigate space weather induced disturbances on technical systems in space.



DLR Institute for Solar-Terrestrial Physics

LEIBNIZ-INSTITUT FÜR ATMOSPHÄREN PHYSIK IAP

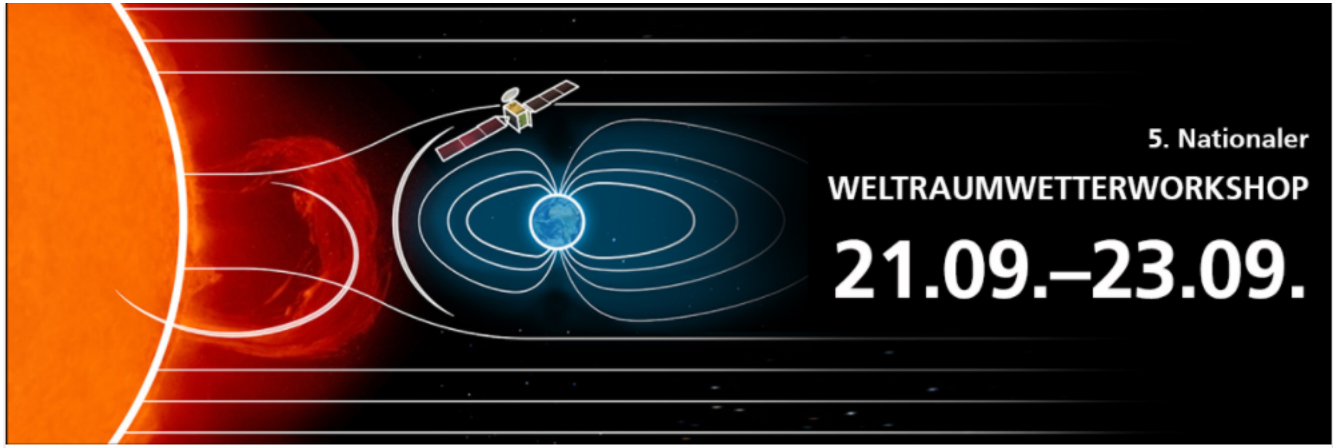
Lehrstuhl Atmosphärenphysik

Investigation of coupling processes between the ionospheric D-layer and the mesosphere using VLF and radar measurements.

WG Statistical Physics

Investigation of the interaction of exoplanets with the space weather conditions in their respective star system to study and evaluate extreme Space Weather events.

DLR Institute of Planetary Research



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Anmeldung

Die Teilnahme am virtuellen 5. Nationalen Weltraumwetter-Workshop ist nur nach einer Online Registrierung über diese Registrierungswebseite möglich. Die Registrierungswebseite wird über den DLR Rahmenvertragspartner BESL Eventagentur GmbH & Co. KG bereitgestellt.

Wir bitten Sie, die Felder des Anmeldeformulars vollständig und korrekt auszufüllen. Nach Abschluss des Registrierungsprozesses wird eine elektronische Anmeldebestätigung vom System generiert und automatisch an die angegebene E-Mail-Adresse gesendet.

Die Registrierung öffnet am 12. August 2021 und schließt am 13.September 2021.

Nach dem 13. September 2021 ist eine Anmeldung nur noch auf Anfrage möglich. Bitte senden Sie Ihre Anfrage per E-Mail an Antje.Scherdin@dlr.de

Teilnahmebedingungen

Mit Erhalt der Anmeldebestätigung, die zur Teilnahme am virtuellen 5. Nationalen Weltraumwetter-Workshop vom 21.-23.9.2021 berechtigt, erklären Sie sich mit den Teilnahmebedingungen einverstanden. Wenn Sie sich im Namen einer anderen Person anmelden, liegt es in Ihrer Verantwortung sicherzustellen, dass die teilnehmende Person diese Bedingungen kennt und sie akzeptiert. Indem Sie die Anmeldung im Namen einer anderen Person ausfüllen, garantieren Sie, dass Sie die teilnehmende Person auf diese Bedingungen aufmerksam gemacht haben und dass sie diese Bedingungen akzeptiert hat.

Download der Teilnahmebedingungen (PDF)

Gebühren

Es werden keine Teilnahmegebühren für die Teilnahme am virtuellen 5. Nationalen Weltraumwetter-Workshop vom 21.-23.9.2021 erhoben.

Stornierung

Eine Stornierung Ihrer Teilnahme senden Sie bitte per Email Antje.Scherdin@dlr.de

https://nwww2021.welcome-manager.de/

DLR

4th. National Space Weather Workshop at DLR Neustrelitz (2015)

Empfehlungen für die Stärkung nationaler Aktivitäten zum Thema Weltraumwetter

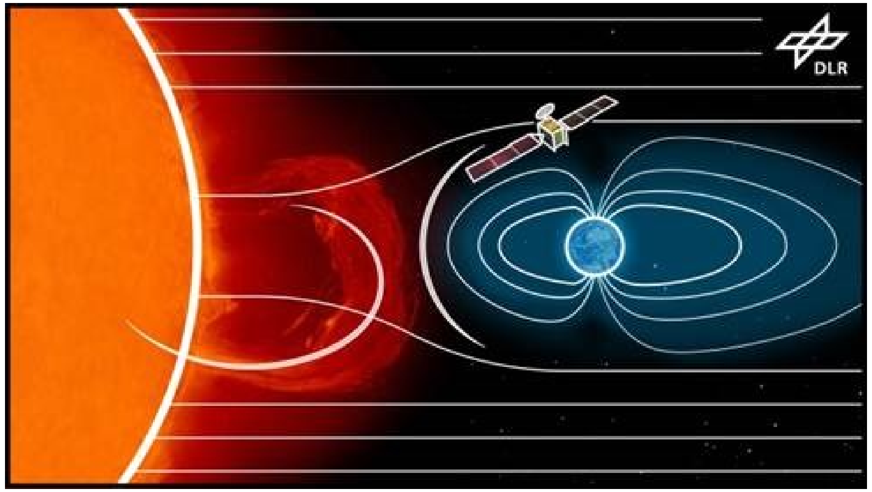
Erstellt von Teilnehmern des

4. Nationalen Weltraumwetterworkshops

vom 11-13 Mai 2015 am DLR Neustrelitz

Dr. Jens Berdermann, Deutsches Zentrum für Luft und Raumfahrt
Dr. Volker Bothmer, Universität Göttingen
Priv.-Doz. Dr. Klaus Börger, Weltraumlagezentrum
Dr. Barbara Görres, Zentrum für Geoinformationswesen der Bundeswehr
Prof. Bernd Heber, Christian-Albrechts-Universität Kiel
Dr. Norbert Jakowski, Deutsches Zentrum für Luft und Raumfahrt
Dr. Günther Reitz, Consultant Deutsches Zentrum für Luft und Raumfahrt
Prof. Claudia Stolle, Deutsches Geoforschungszentrum
Axel Wagner, Airbus Defence and Space

Thank you!



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