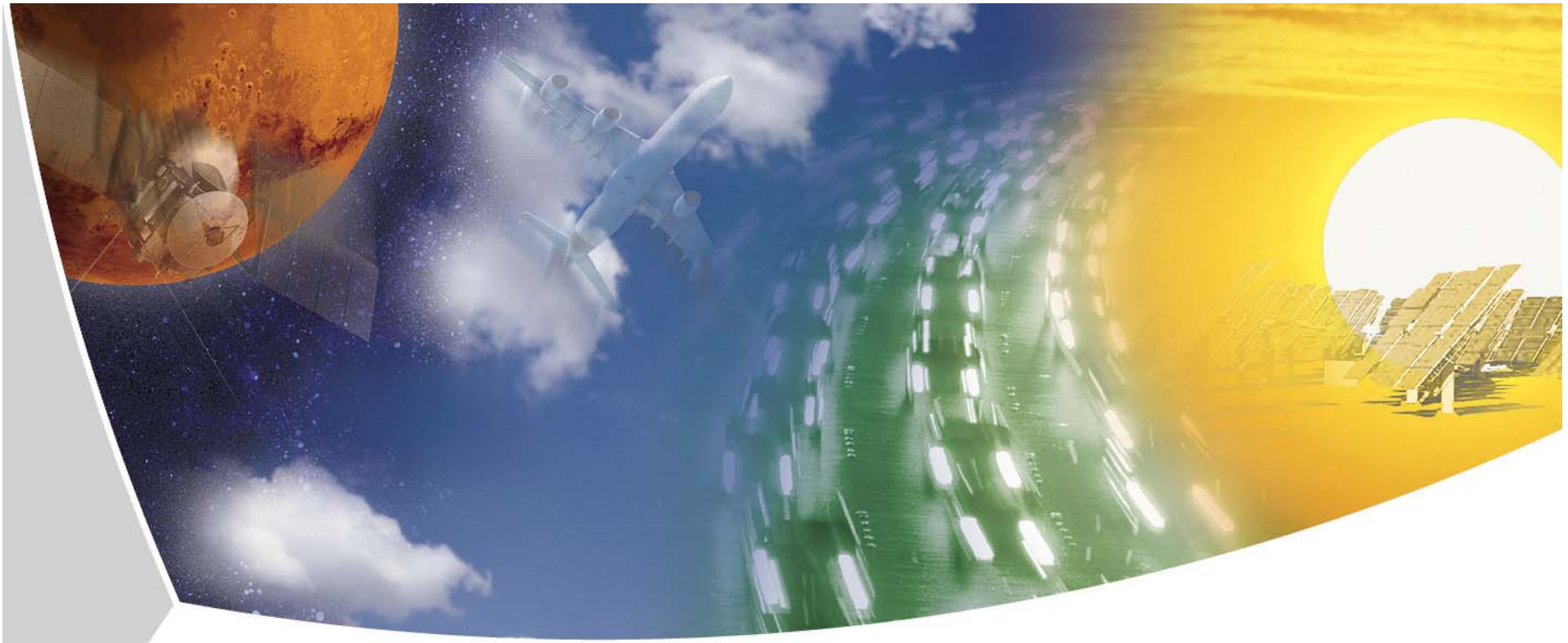

Operational Products of the Space Weather Application Center Ionosphere (SWACI) and capabilities of their use

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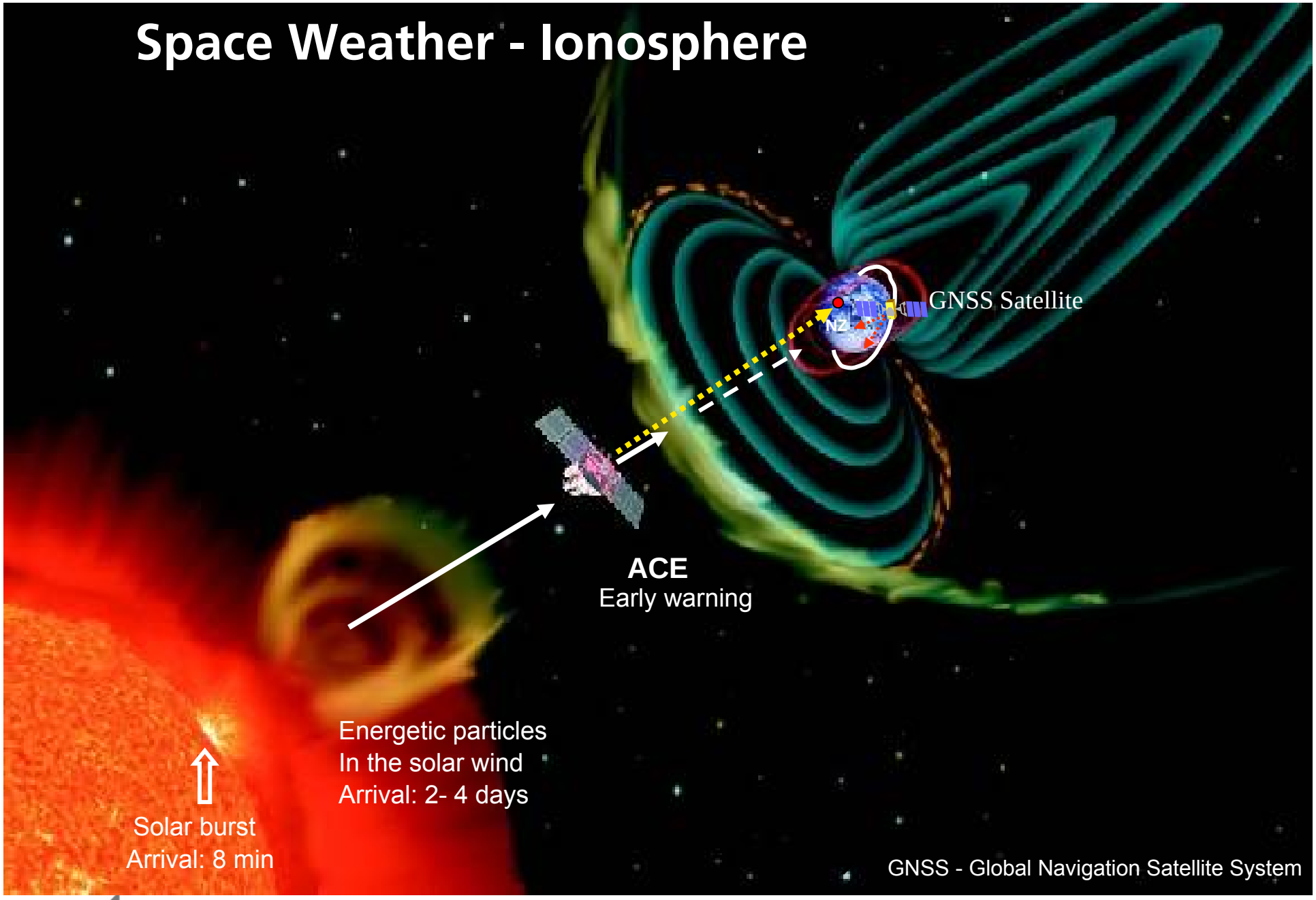
OUTLINE

- Introduction
- Space Weather Application Center-Ionosphere
- Ionosphere monitoring and derived products
  - Space based techniques
  - Ground based techniques
- Selected service products & their use
- Summary

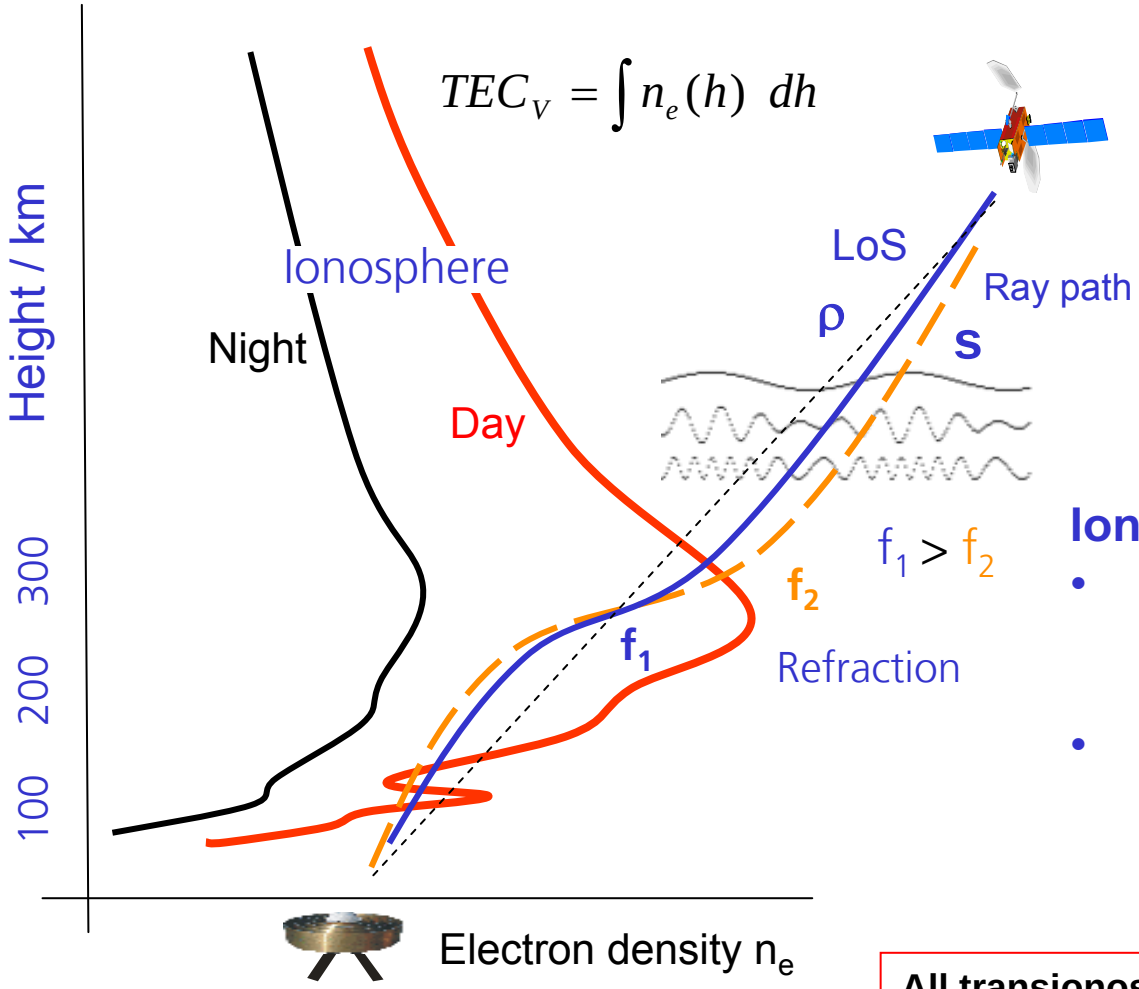
Space Weather - Ionosphere

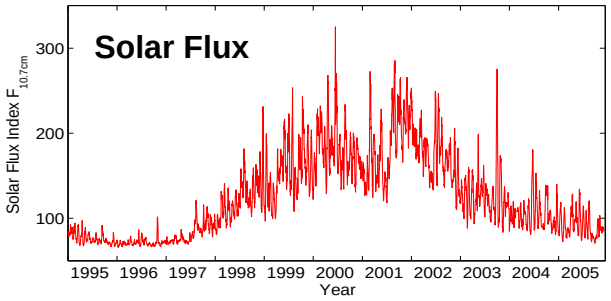


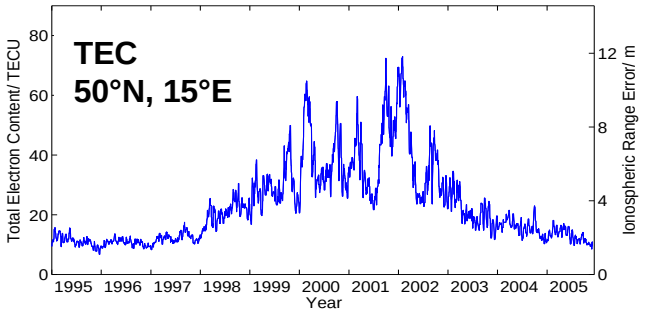
GNSS - Global Navigation Satellite System

Transionospheric Radio Wave Propagation

Electron density n_e & Total Electron Content (TEC)
are closely related to the solar irradiance







Ionosphere causes

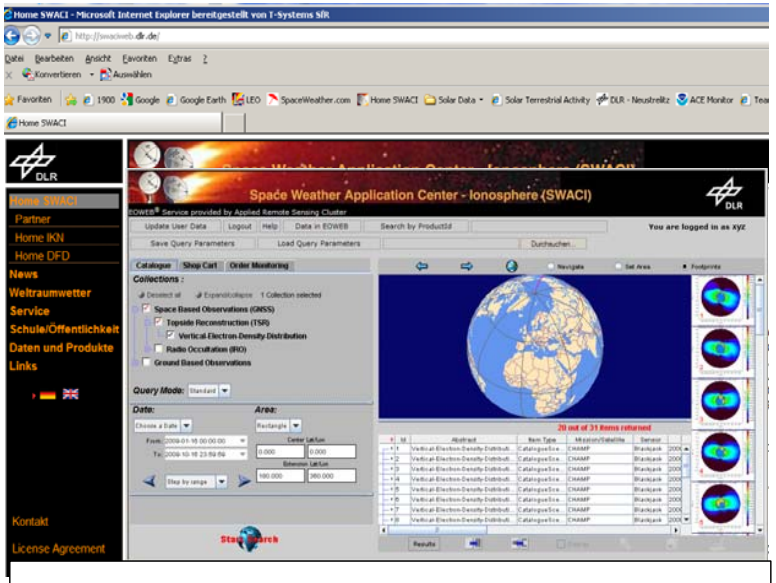
- **Regular effects**
  - signal delay, range errors
  - rotation of polarisation plane
- **Irregular effects**
  - Radio scintillations,
  - Defocussing of radar images
  - Hazardous misleading information

All transionospheric radio systems operating at frequencies < 10 GHz are **affected**

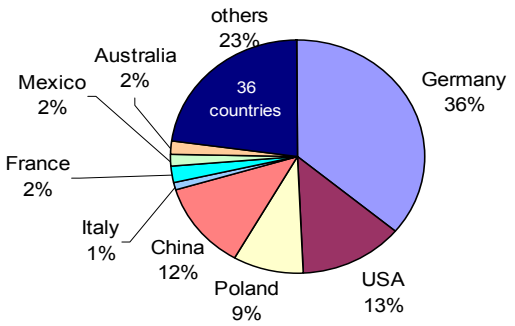
Space weather Application Center Ionosphere (SWACI)

- The **Space Weather Application Center - Ionosphere** (SWACI) is a joint project of the Institute of Communications and Navigation and the German Remote Data Center of DLR.
- The project is essentially supported by the German State Government of Mecklenburg-Vorpommern, will be finished in March 2011.
- SWACI data base is mostly related to ground and space based GNSS measurements.
- Data in particular suited to characterize ionospheric conditions along transionospheric radio links.
- SWACI information shall support operators and users of transionospheric radio systems in communication, navigation and remote sensing.

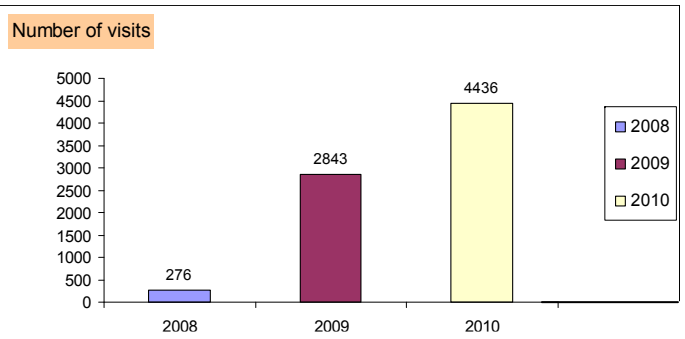
http://swaciweb.dlr.de

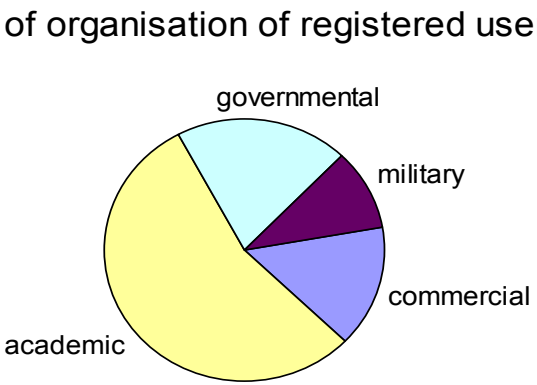


Worldwide access, e.g in October 2010



SWACI service architecture





User

operational products

MONITOR

AFFECTS

SWENET

NOAA

SWACI Portal

http://swaciweb.dlr.de

one-stop-shopping

EOWEB-Catalogue

historical products

DIMS

PSM

Groundbased

PSM

Spacebased

PSM

Space Weather processor

Input data

Product Library

L1

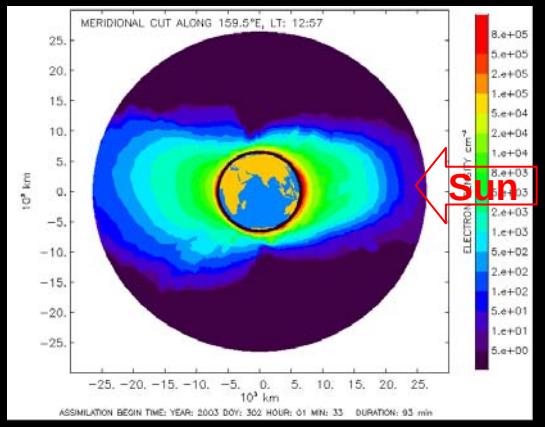
RAW

L2

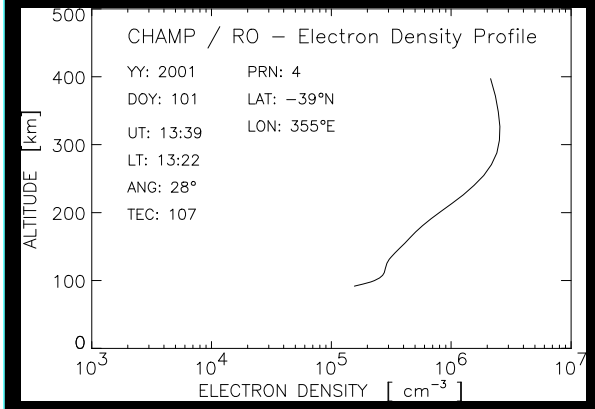
L0

http://swaciweb.dlr.de

Space Based Monitoring of the Ionosphere



GNNS Satellit



Okkultation (1Hz)

Navigation (0.1 Hz)

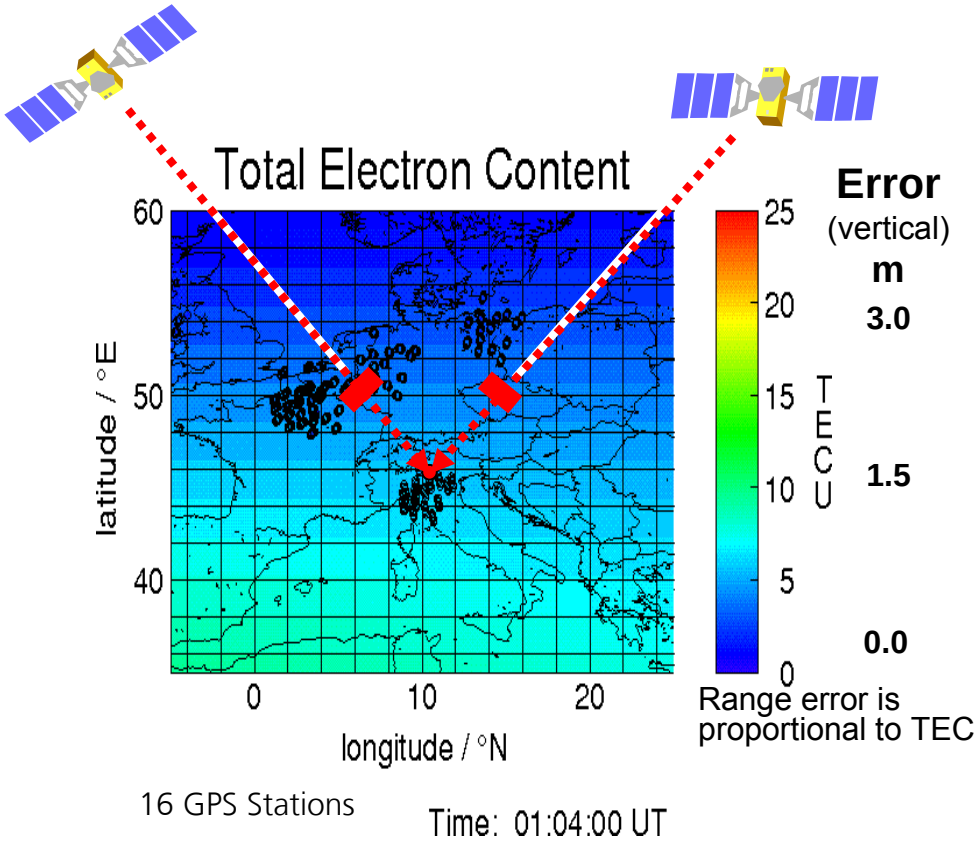
LEO Orbit

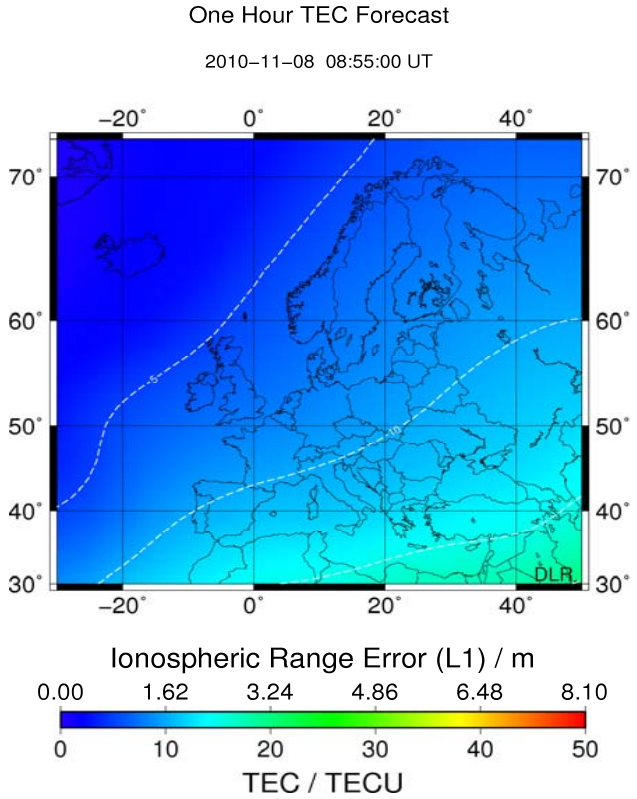
CHAMP, GRACE

TerraSAR-X

Tandem-X, SWARM

Ionosphere weather service: Now- & Forecast

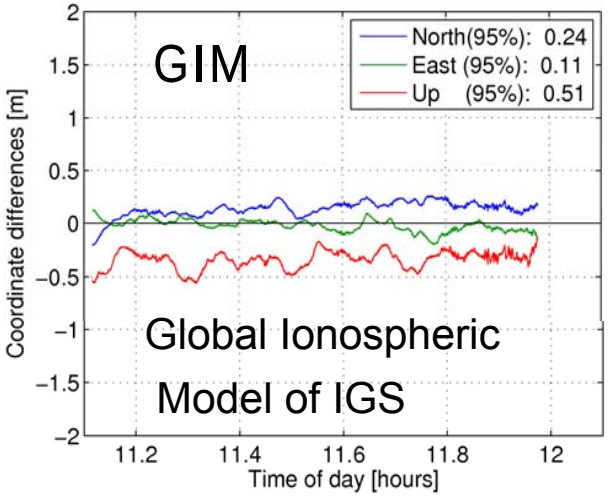


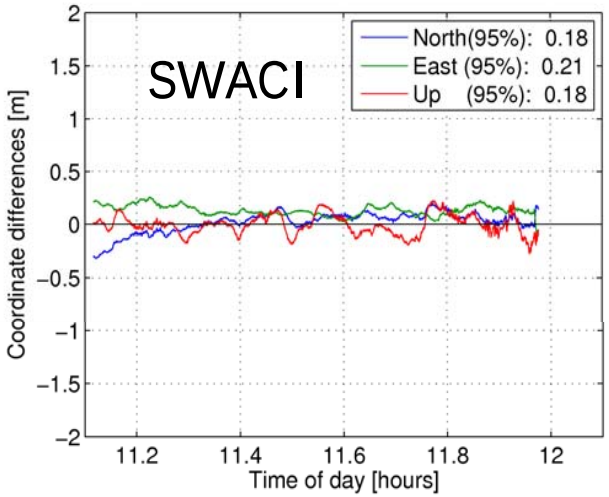


- Near real time ground based GNSS* measurements enable the computation of high resoultion TEC maps over certain areas (e.g. Europe, Japan, USA)
- Maps enable the correction of single frequency GNSS measurements
- Ionosphere is the biggest error source in single frequency applications.
- Model assisted reconstruction enables TEC forecast 1 hour ahead

*GNSS- Global Navigation Satellite System

Use of SWACI TEC maps for the **Single-Frequency Precise Point Positioning** Experiment of the TU Delft in Mai 2005





Requirements:

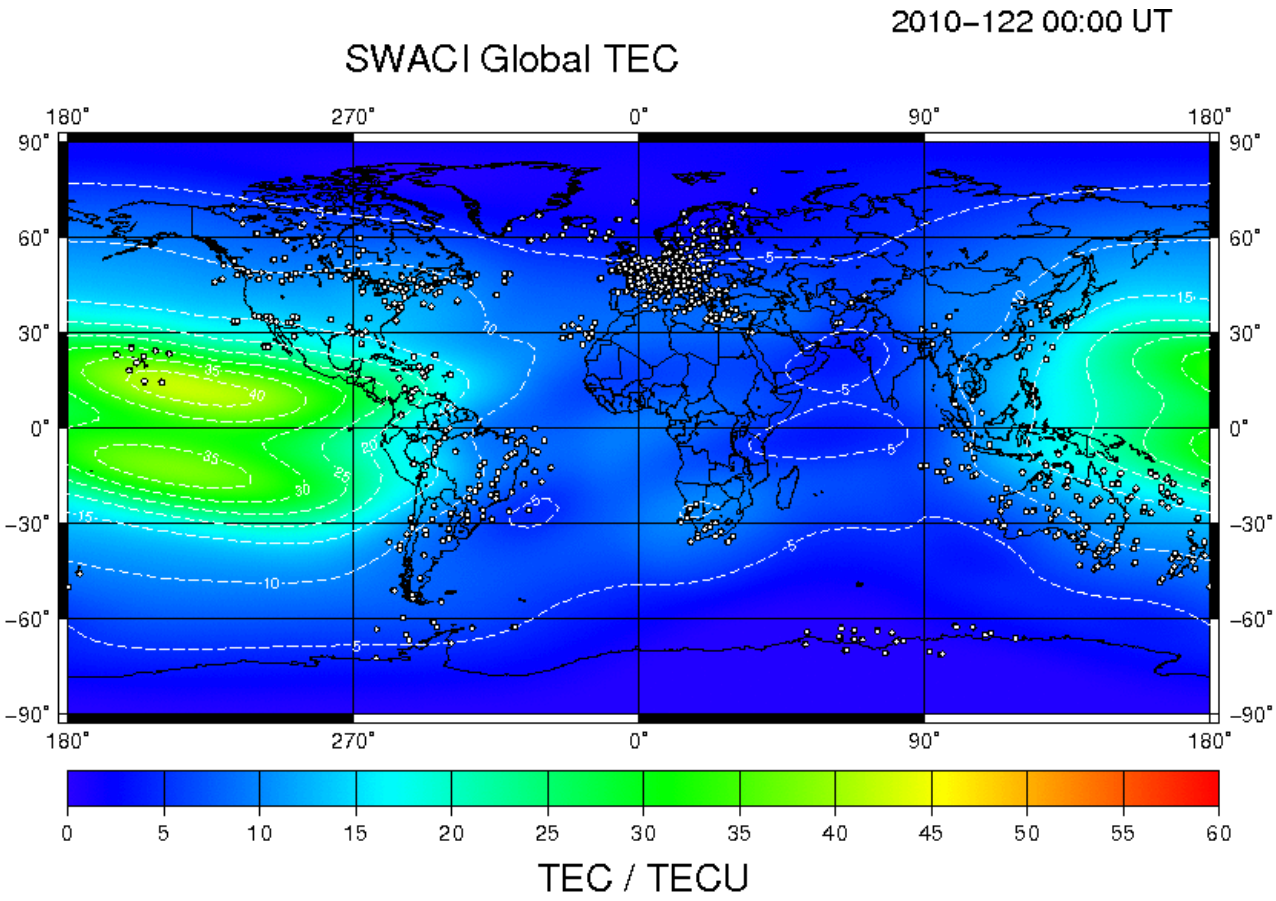
- Good accuracy of TEC
- Sufficient spatial and temporal resolution

Results of the Experiment:

- SWACI correction enables vertical positioning accuracy in dm range,
- SWACI can be improved by covering a larger region.

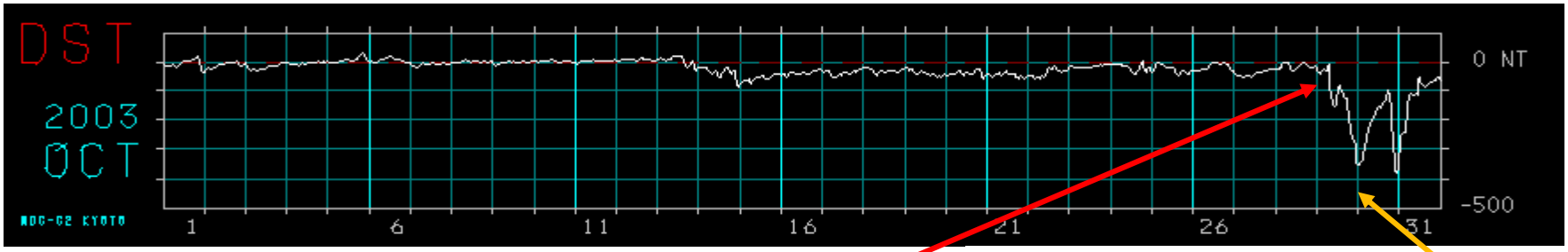
A.Q. Le, C.C.J.M. Tiberius, H. van der Marel, N. Jakowski (2008), Use of Global and Regional Ionosphere Maps for Single-Frequency Precise Point Positioning, International Association of Geodesy Symposia / Vol. 133, 2008 doi: 10.1007/978-3-540-85426-5_87, 759-769

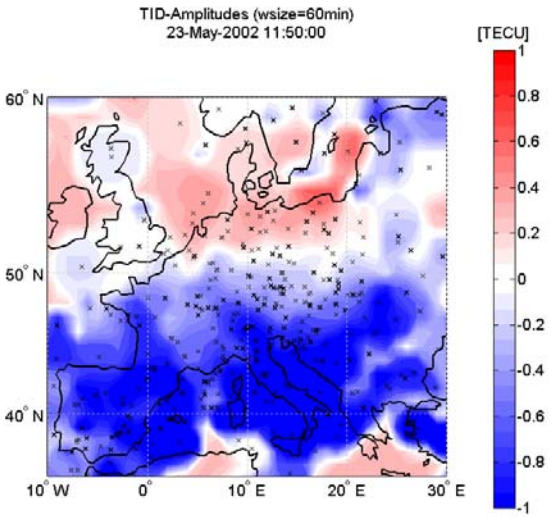
Global TEC monitoring

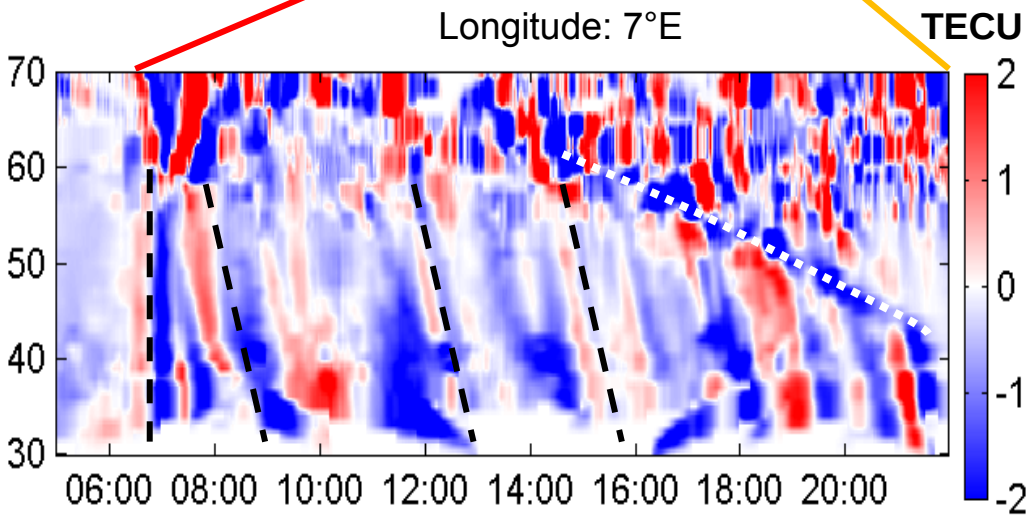


- Since July 2010 global TEC maps are routinely produced in DLR. Maps are available via SWACI every 5 min and therefore fulfil requirements of single frequency users.
- Data base is provided by the **Real Time Pilot Project** of the International GNSS Service (**IGS**).
- Global TEC model has been developed to act as background model for data assimilation

Propagation of TIDs during ionospheric storms

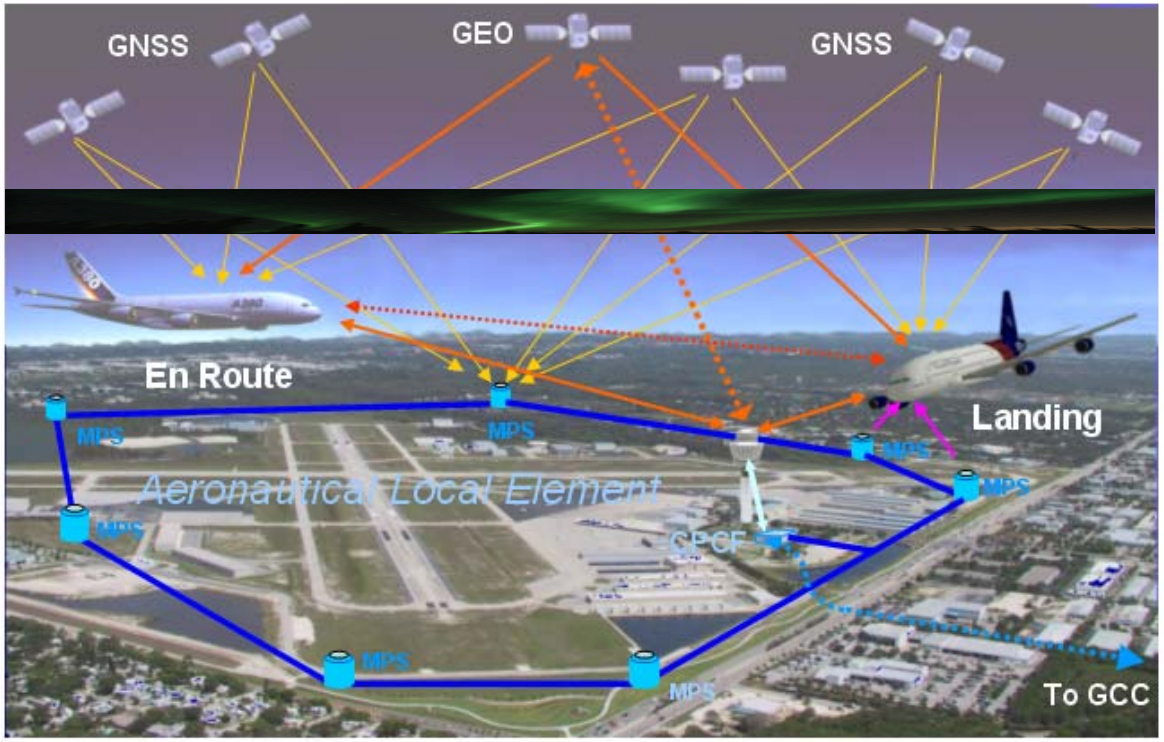


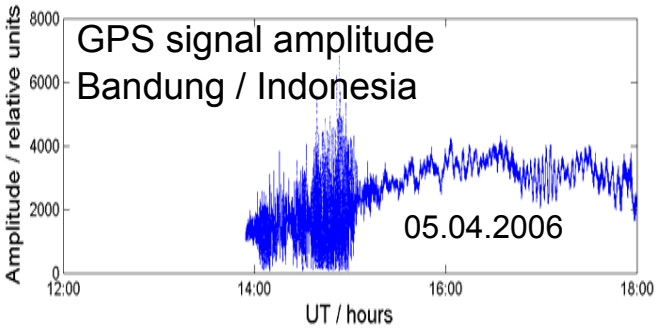


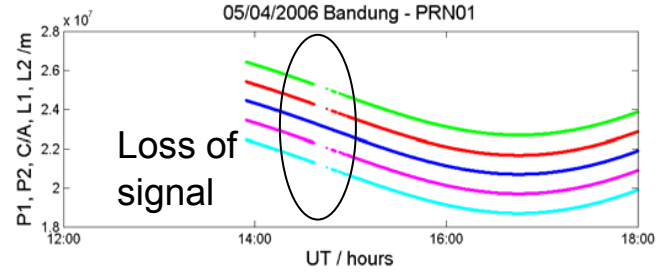


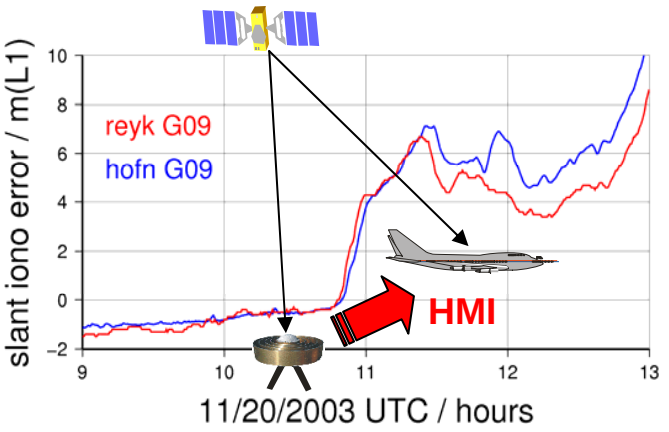
- Immediate propagation of the perturbation at the onset (electric field)
- Wavelike propagation of disturbances during the main phase of the storm on 29 October 2003 (speeds up to ≈ 1000 m/s)
- High latitude disturbance zone (northward of the trough) moves also equatorward (speed ≈ 70 m/s)

Safety of Life (SoL) application - aviation







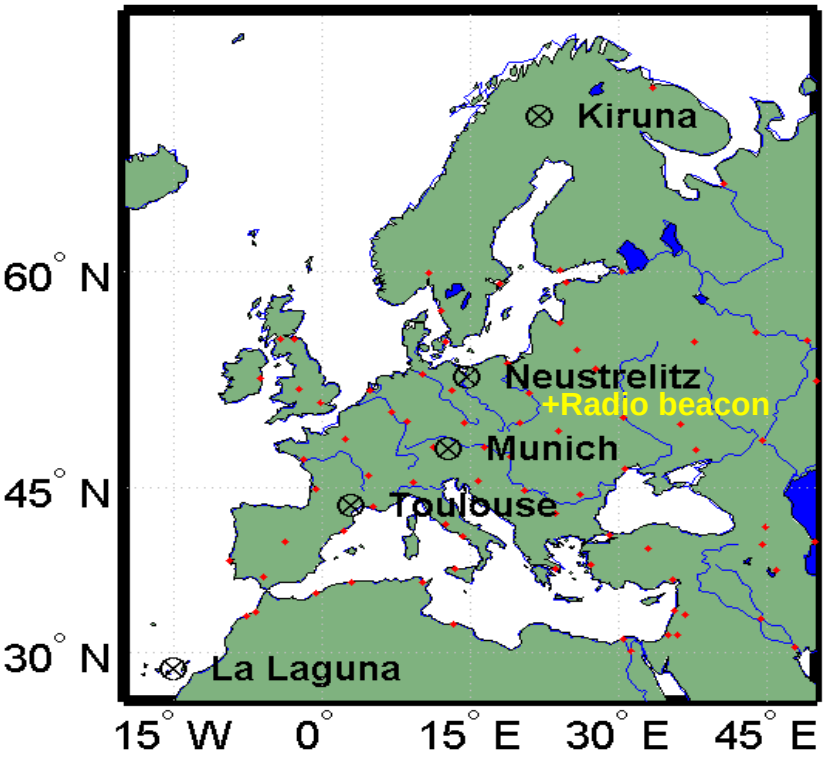


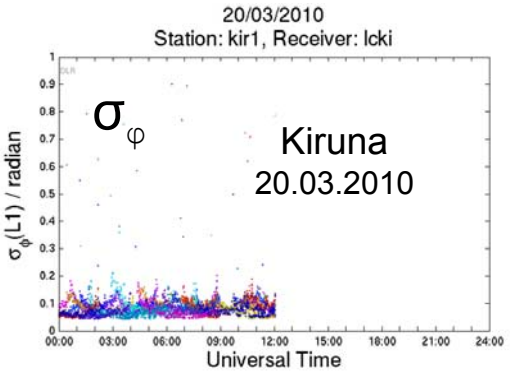
- Degradation of **accuracy, integrity, availability and continuity** of signals due to space weather effects in the ionosphere

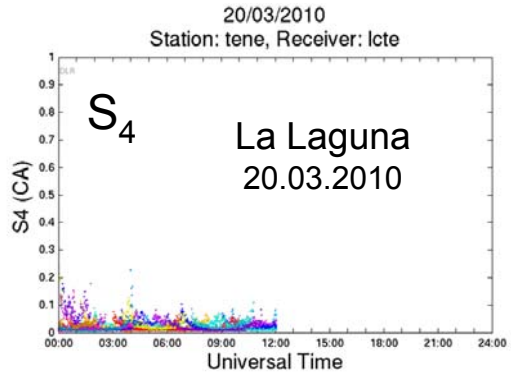
➡ Operational **detection and tracing** of ionospheric **perturbations** needed
Ionospheric "**Threat-Model**" required

HMI: Hazardous Misleading Information

GPS scintillation monitoring network of DLR







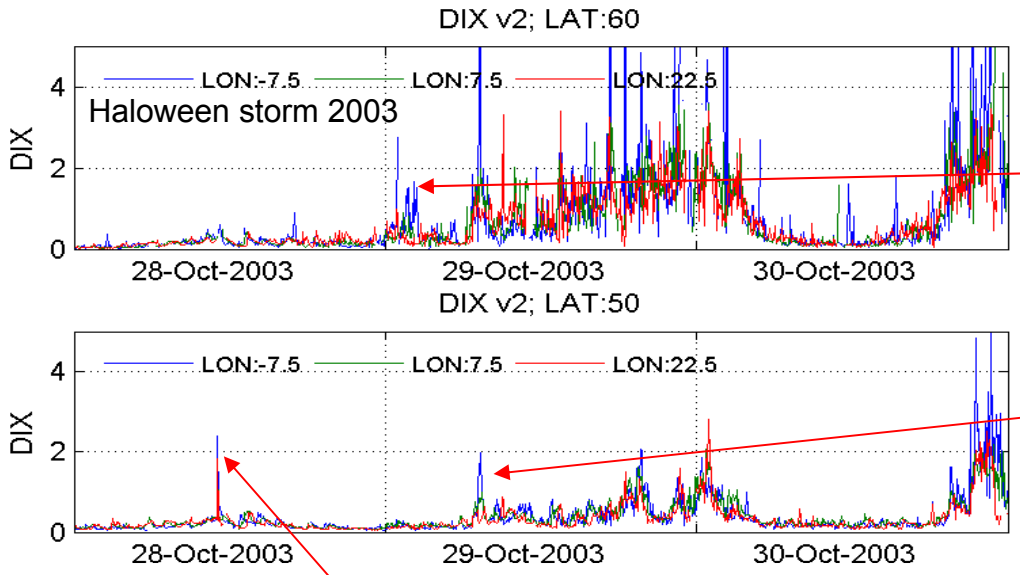
Update: 1 min

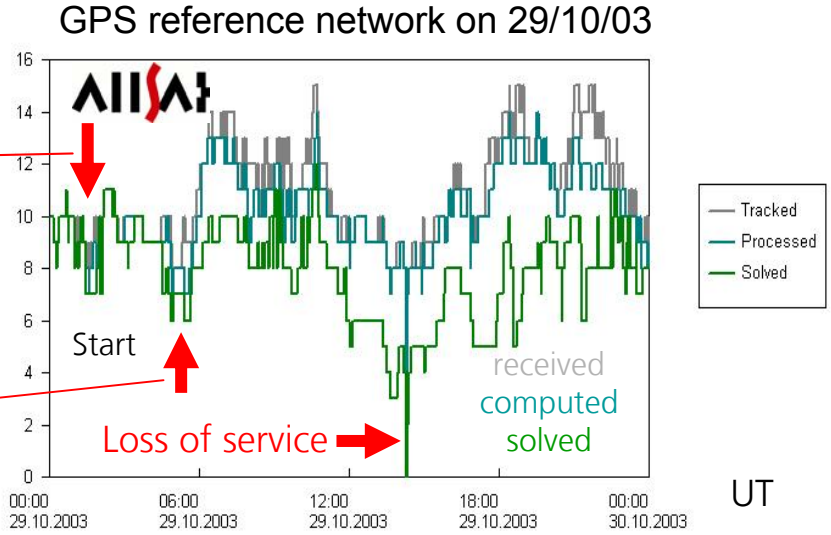
Remote access to all stations of the network (EVNet)

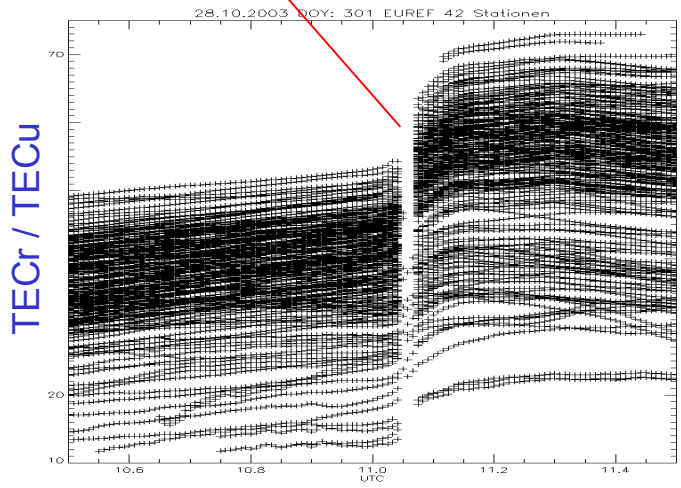
Data reduction on observation site by computing scintillation parameters

- DLR operates a network of high rate dual frequency GPS receivers (20-50 Hz) for scintillation monitoring.
- Network provides actual scintillation data for further distribution via SWACI.
- Extension of the network is planned towards North and South (Ethiopia), the network includes capabilities to receive Galileo signals.
- Network contributes to ESA project MONITOR.

Under development: Disturbance Ionosphere Index (DIX)



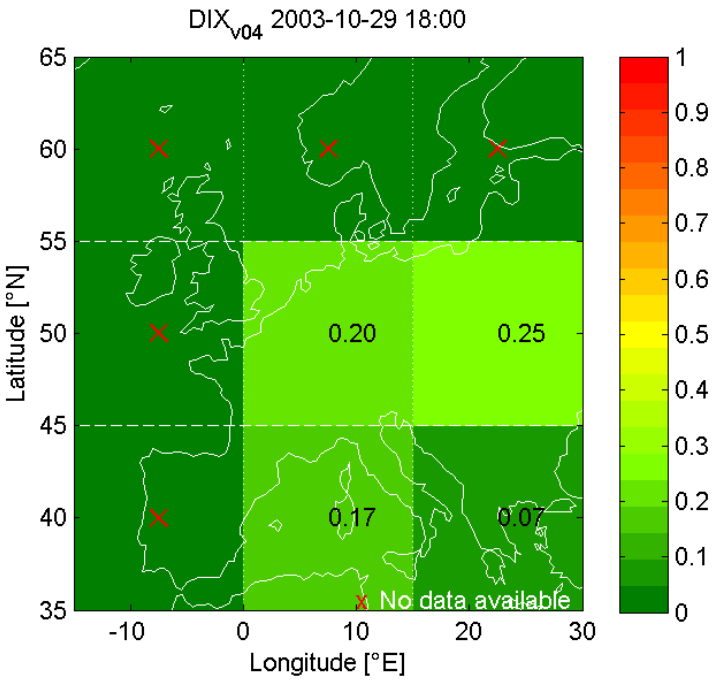


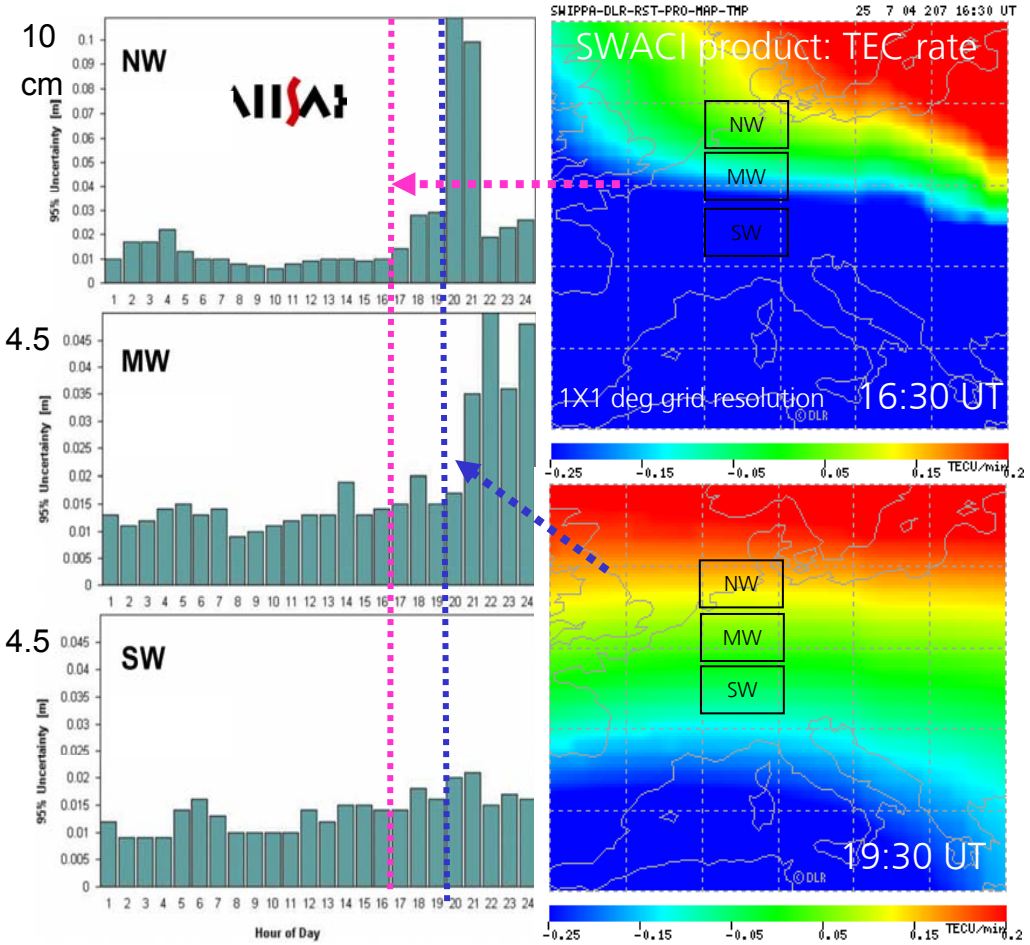


Universal Time / hours.

- The Disturbance Ionosphere Index (DIX) is based on GNSS measurements. DIX may be defined on local, regional and global scale depending on user needs.
- *The plot clearly indicates the flare on 28 October and strong spatial effects on subsequent days*
- It is planned to release regional DIX products via SWACI in January 2011

Use of DIX in precise positioning





- Perturbation degree is quantified by the regionalized Disturbance Ionosphere Index DIX
- The index can directly be used by customers to estimate the GNSS Performance
- Forecast of DIX is future task

Performance of the GPS reference network of Allsat GmbH, Hannover degrades during the ionospheric storm on 25 July 2004

Summary

- **Transionospheric radio systems in communication, navigation, positioning and remote sensing are principally impacted by the ionospheric plasma at operating frequencies < 10 GHz.**
- **SWACI operational service provides products such as:**
  - Regional and global TEC maps for ionospheric range error corrections in GNSS and remote sensing applications
  - Scintillation data along a meridional chain from high to low latitudes for detection of small scale irregularities
  - Disturbance Ionosphere Index (DIX) for detection of mid- to large scale perturbations (will be released in 2011)
  - Vertical electron density profiles from RO measurements
  - Topside reconstructions of the 3D electron density

Thank you for your attention !

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