

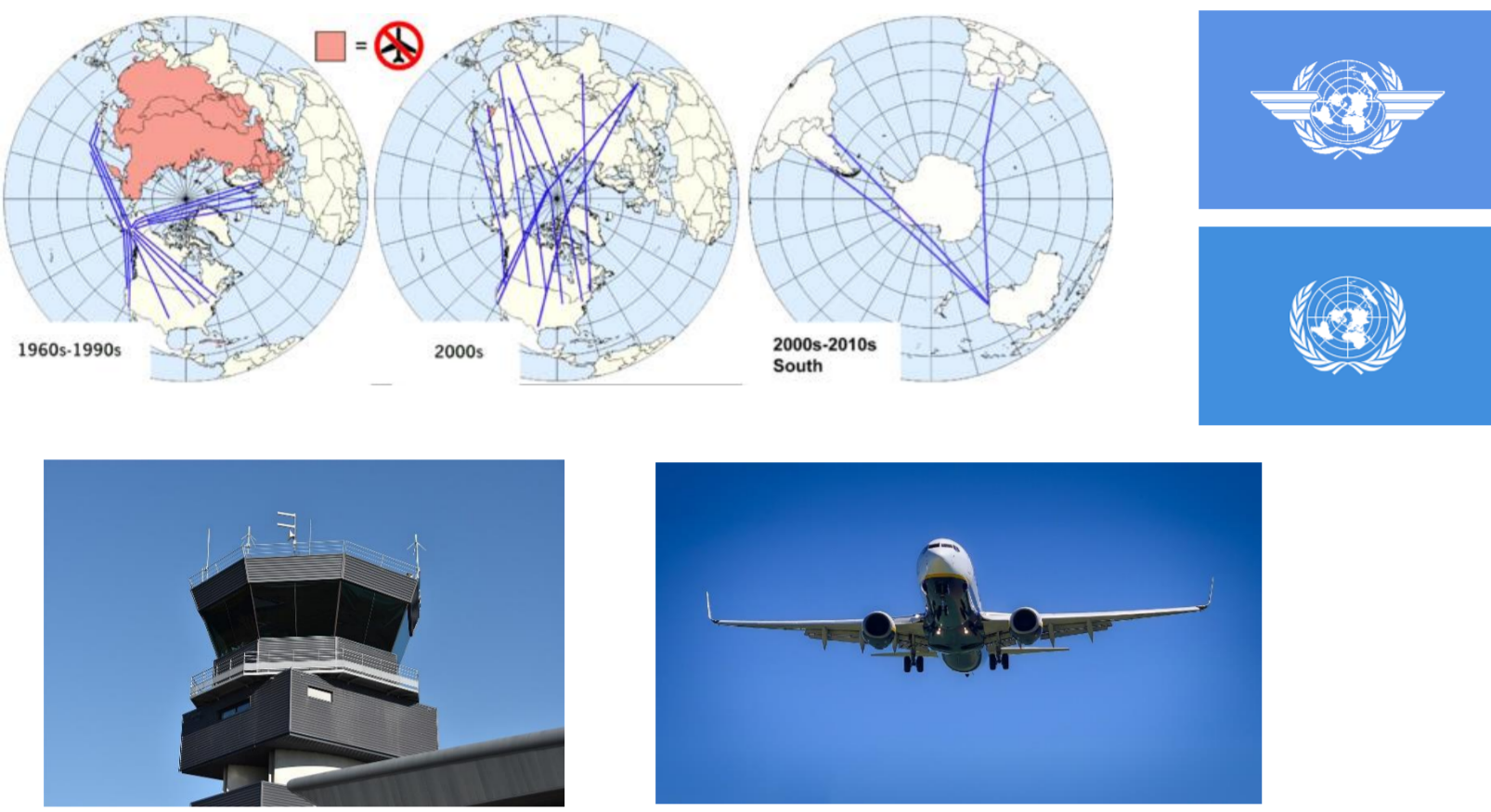
# PECASUS

## ICAO Designated Space Weather Service Network for Aviation

The customer and its interests

### International Civil Aviation Organization (ICAO)

- Works under UN and was established in 1944
- Develops principles and techniques for enhanced safety in civil aviation
- Close collaboration with WMO
- Wishes to integrate Space Weather (SWx) services to its regulations due to enhanced traffic across the polar caps



Figures: Wikipedia & Pixabay

The audit and assurance company PricewaterhouseCoopers and UK Met Office have conducted a cost-benefit analysis of the ESA SSA programme in 2016. The space weather part of this survey reveals that the aviation user domain is among the top three of areas getting largest economic benefit from space weather services. The survey also postulates that the cost of extreme space weather events for aviation will become almost two-fold (three-fold) by 2024 (2032) when compared to the cost estimate of 2016 (~6600 M€).

### Space weather impacts on aviation

- Radiation at flight altitudes
  - Flights across polar areas
  - Air crew: Accumulated doses
- Problems in Global Navigation Satellite Systems (GNSS) & SATCOM
  - Errors in positioning
  - Scintillation in the signal amplitude and phase
- Disturbances in HF communication
  - Anomalous propagation paths
  - Variations in the usable frequencies
- About SATCOM
  - ICAO has not given yet the thresholds for advisories
  - Data and voice drop out at frequencies < 2 GHz (L-band)
  - No big problems in S, C, Ku and Ka
  - SWx something to keep in mind when planning future automated ATM systems

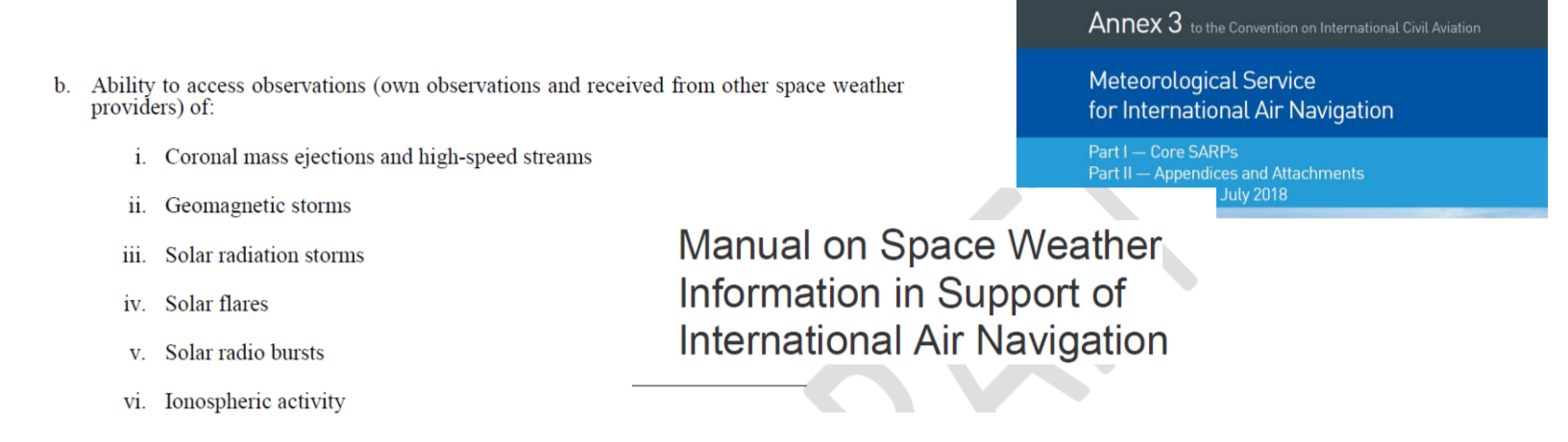


Figure: ESA/Proba2, EUMETSAT, STCE

GNSS	PARAMETERS	NOO	SEV
Longitude/ScatterIndex	54 (Eurasian/India)	175	100
Phase ScatterIndex	Aggregated (India)	174	107
Total Ionospheric Error (TIE)	TEC error	125	175
RADIATION	Effective dose (mSv)	20	80
HF COM			
Aviation Abnormal (AA)	0	1	1
Phase ScatterIndex (PCI)	0	1	1
Minimum Fadeout (MF)	Solar X-ray (1.8-8.0) (W10)	1137 (X3)	1137 (X3)
Phase ScatterIndex (PCI)	0%	50%	50%

### ICAO Documentation

- State letter dated 9 June 2017 with its Annex
- Annex 3 to the Convention of ICAO (Standards And Recommended Practises)
- Space Weather Manual (Doc 10100)



SWx information will be given as strictly formulated advisories

Forecasts up to 24 HR; "Not available" is also OK; Location information in geographic coordinates

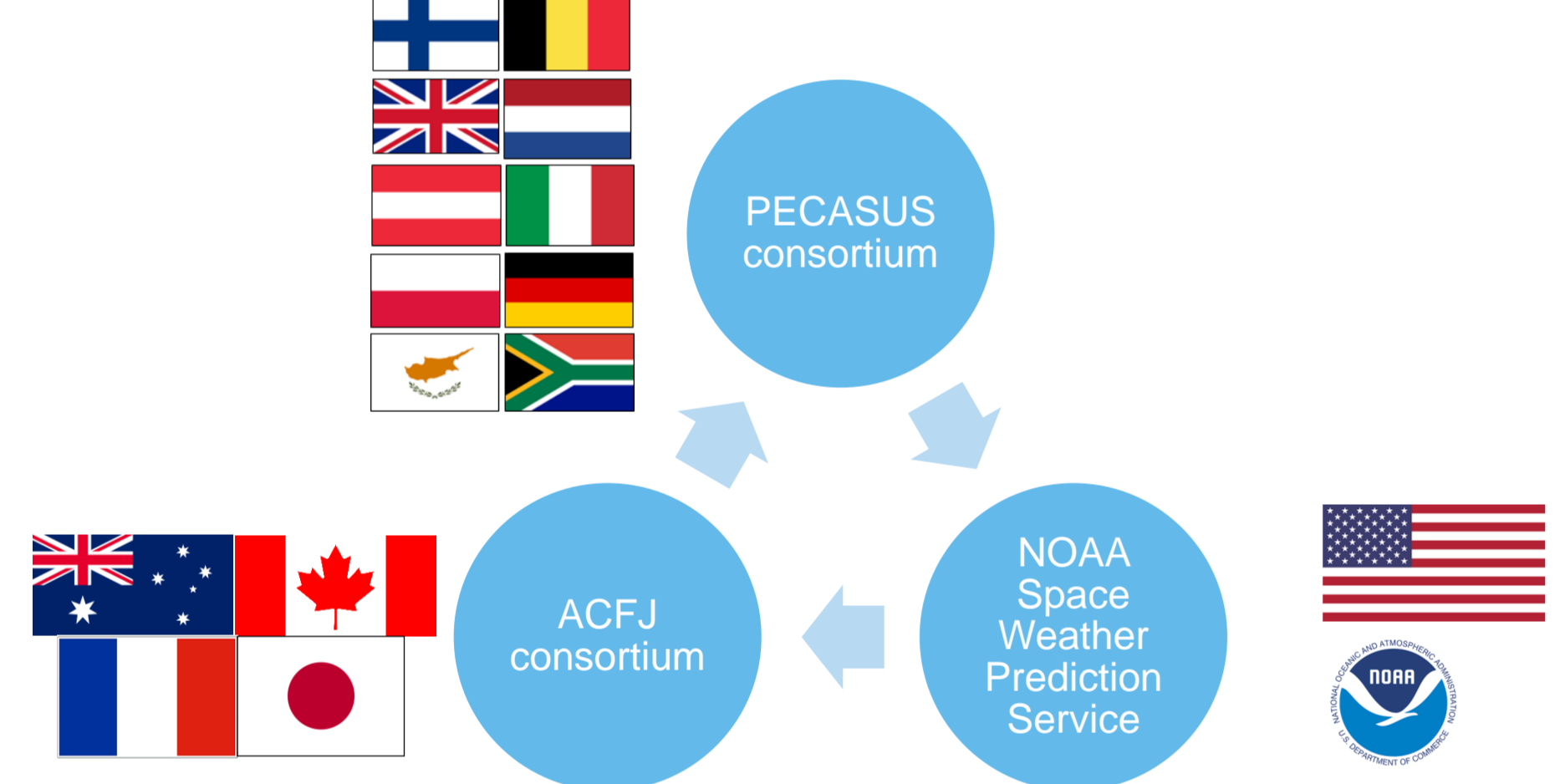
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SWX ADVISORY
DTG: 20161108 0100Z
SWXC: PECASUS
ADVISORY NR: 20162
NR RPLC: 20161
SWX EFFECT: HF COM AMB AND GNSS MOD
OBS SWX: 08:0100 HNH HSH E18000 - W18000
FCST SWX -6 HR: 08:0700 HNH HSH E18000 - W18000
FCST SWX -12 HR: 08:1300 HNH HSH E18000 - W18000
FCST SWX -18 HR: 08:1900 HNH HSH E18000 - W18000
FCST SWX -24 HR: 09:0100 SWX SWX E18000 - W18000
RMK: LOW LVL GEOMAGNETIC STORMING CAUSING INCREASED AURORAL ACT AND SUBSEQUENT MOD DEGRADATION OF GNSS AND HF COM AVBL IN THE AURORAL ZONE. THIS STORMING EXP TO SUBSIDE IN THE FCST PERIOD. SE WWW.SPACEWEATHERPROVIDER.WE
NO FURTHER ADVISORIES
    
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Updates can be provided; Additional info can be provided with a web-site

After Manual of Space Weather Information in Support of Air Navigation

## The service providers



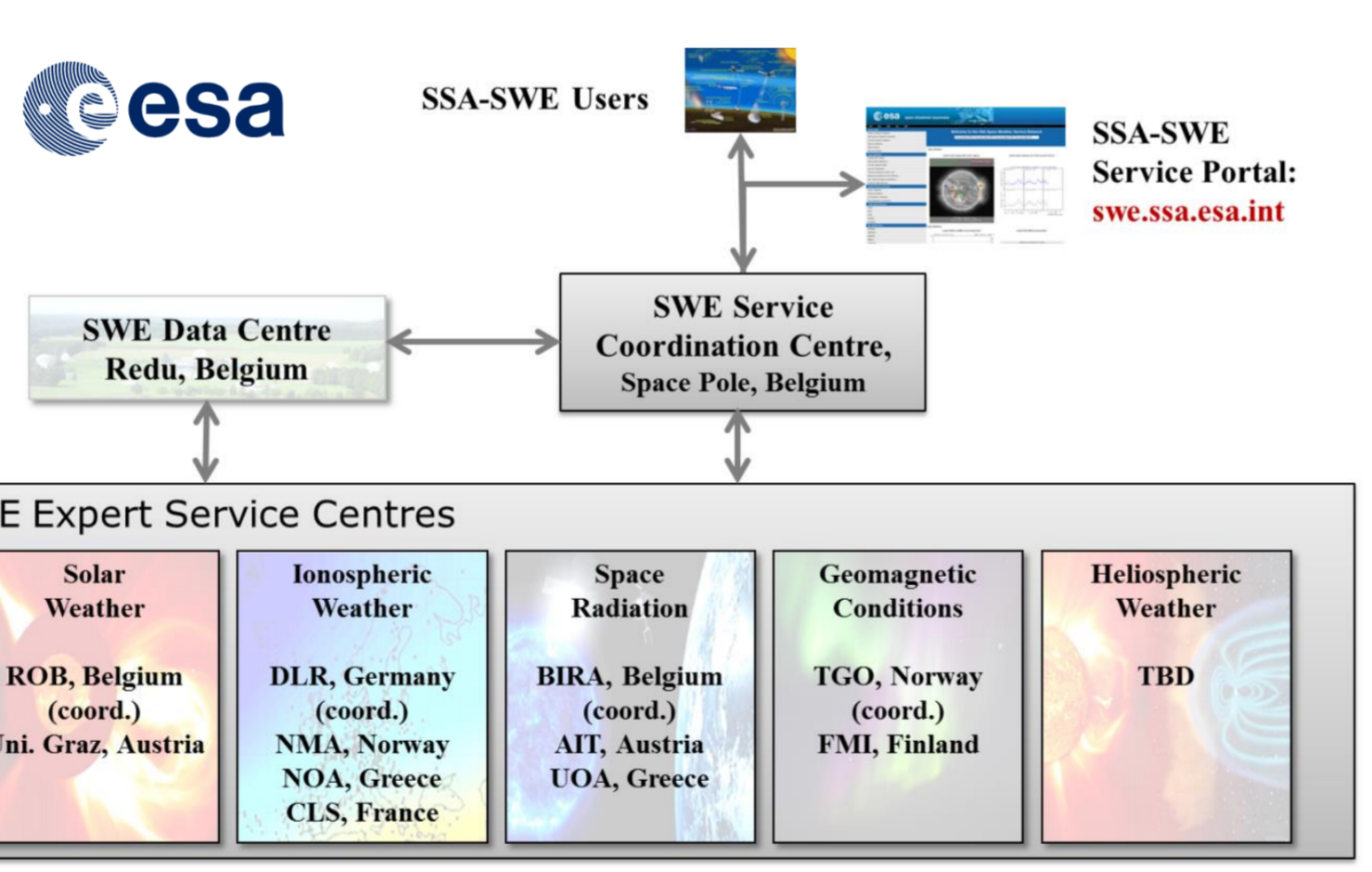
ICAO has selected three providers for global services.

Work for consolidated services among the three centers started in Dec 2018

The centers have agreed to have two week shifts in the responsibility of advisory validation and dissemination

All centers will monitor space weather continuously.

Official operations have started on Nov 7, 2019.

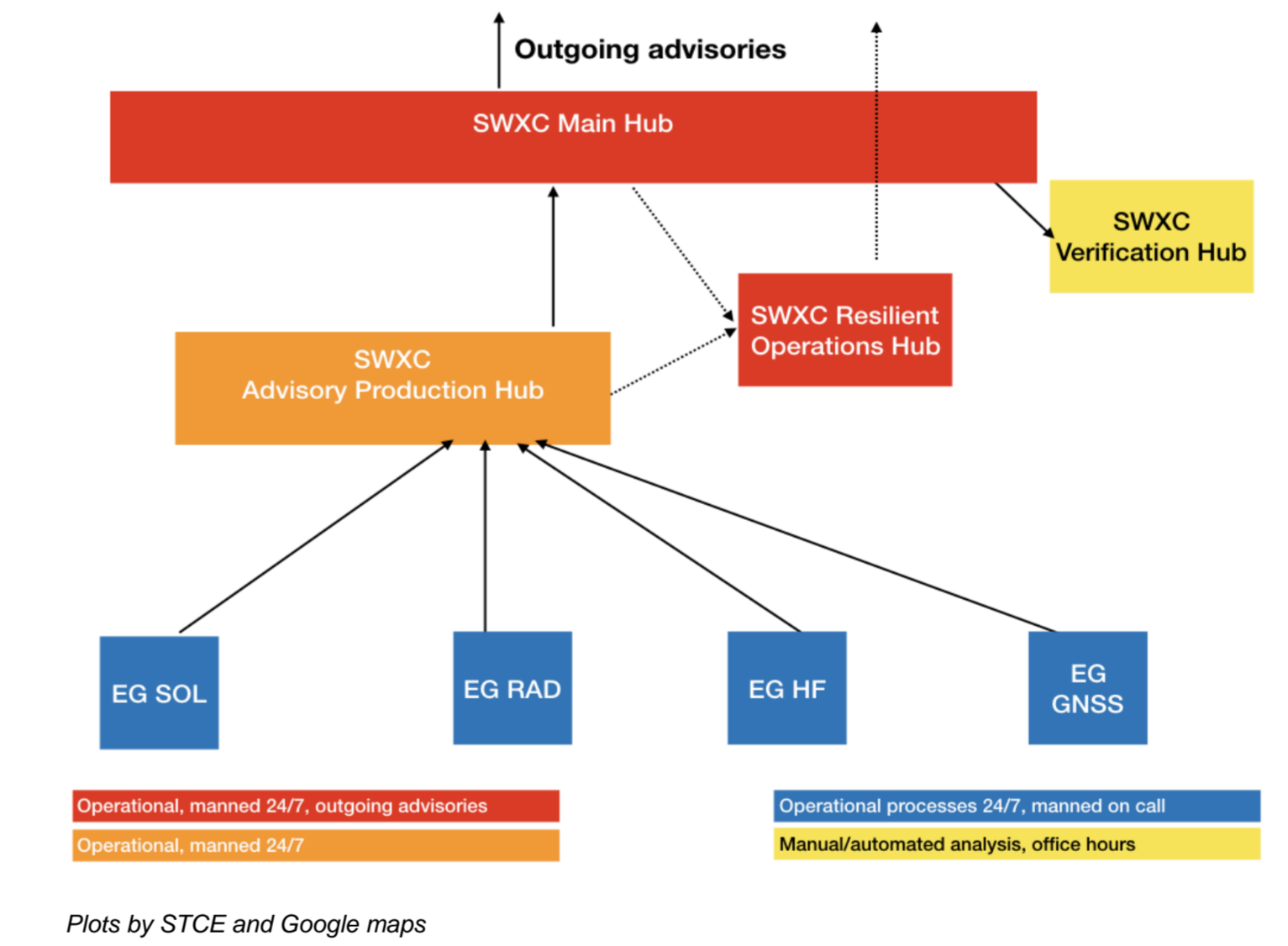


## PECASUS approach

(Left) The ICAO member countries contributing to PECASUS.  
 (Bottom) The dashboard that the PECASUS duty officers use to monitor prevailing space weather conditions.

The PECASUS service is based on seamless and committed collaboration by ten ICAO member countries.

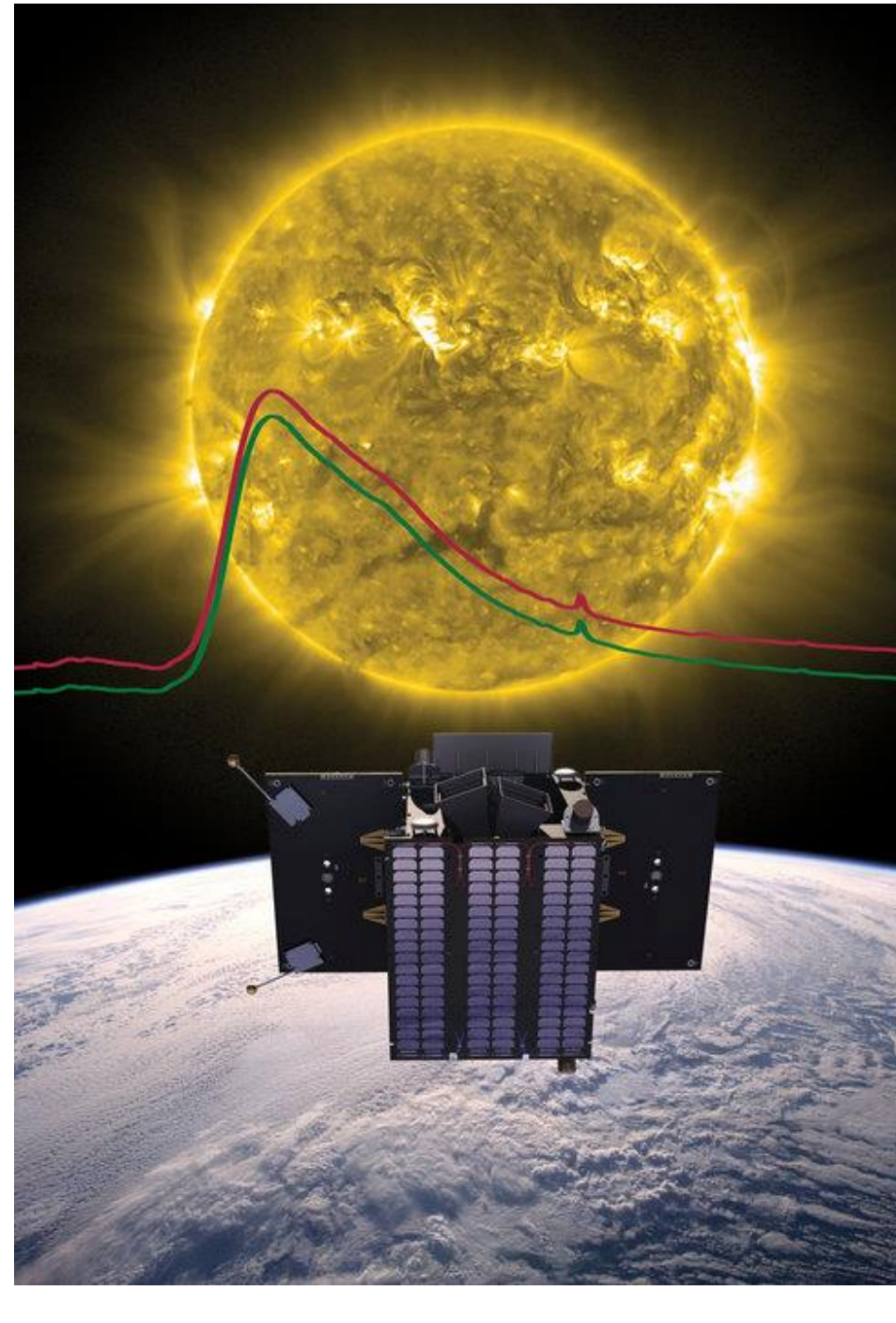
- The Finnish Meteorological Institute leads the consortium and takes care of final advisory validation and dissemination in the ICAO environment.
- The Solar Terrestrial Centre of Excellence (Belgium) composes the content of advisories.
- UK Met Office ensures resilient operations of the system.
- Input for the advisories is provided by the Expert Groups on Solar activity, Radiation, HF communication and GNSS (c.f. the list of institutes at the bottom in this poster).



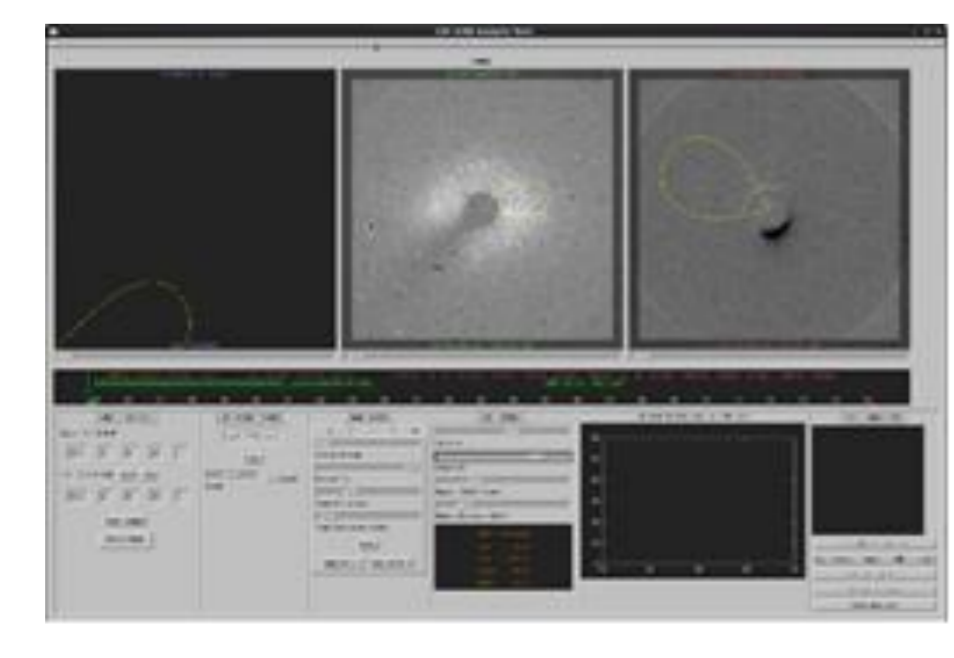
Plots by STCE and Google maps

## Examples of PECASUS products

### EG SOL



ESA's Proba-2 satellite monitors the solar corona in EUV wavelengths, providing images of coronal mass ejections (CME).



CAT tool used to calculate speed, direction and hence, estimated arrival time of incident CME.

### EG RAD

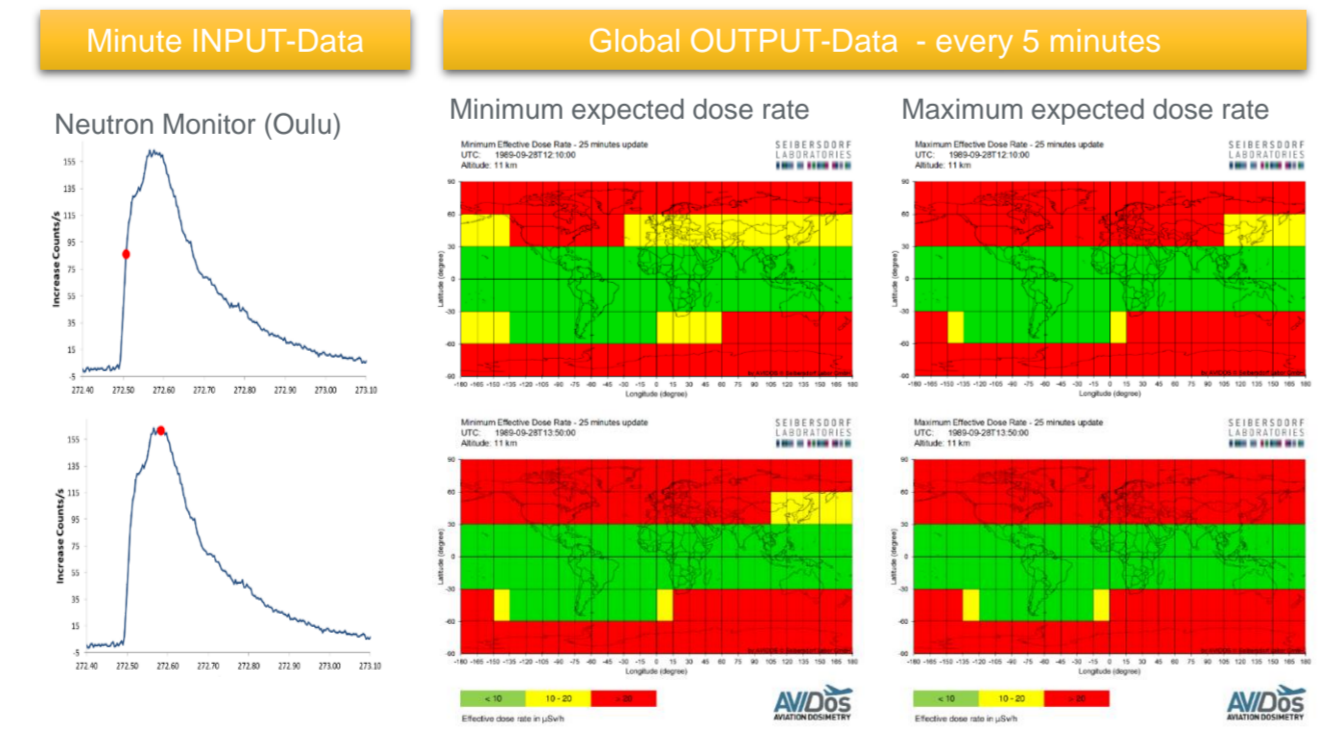
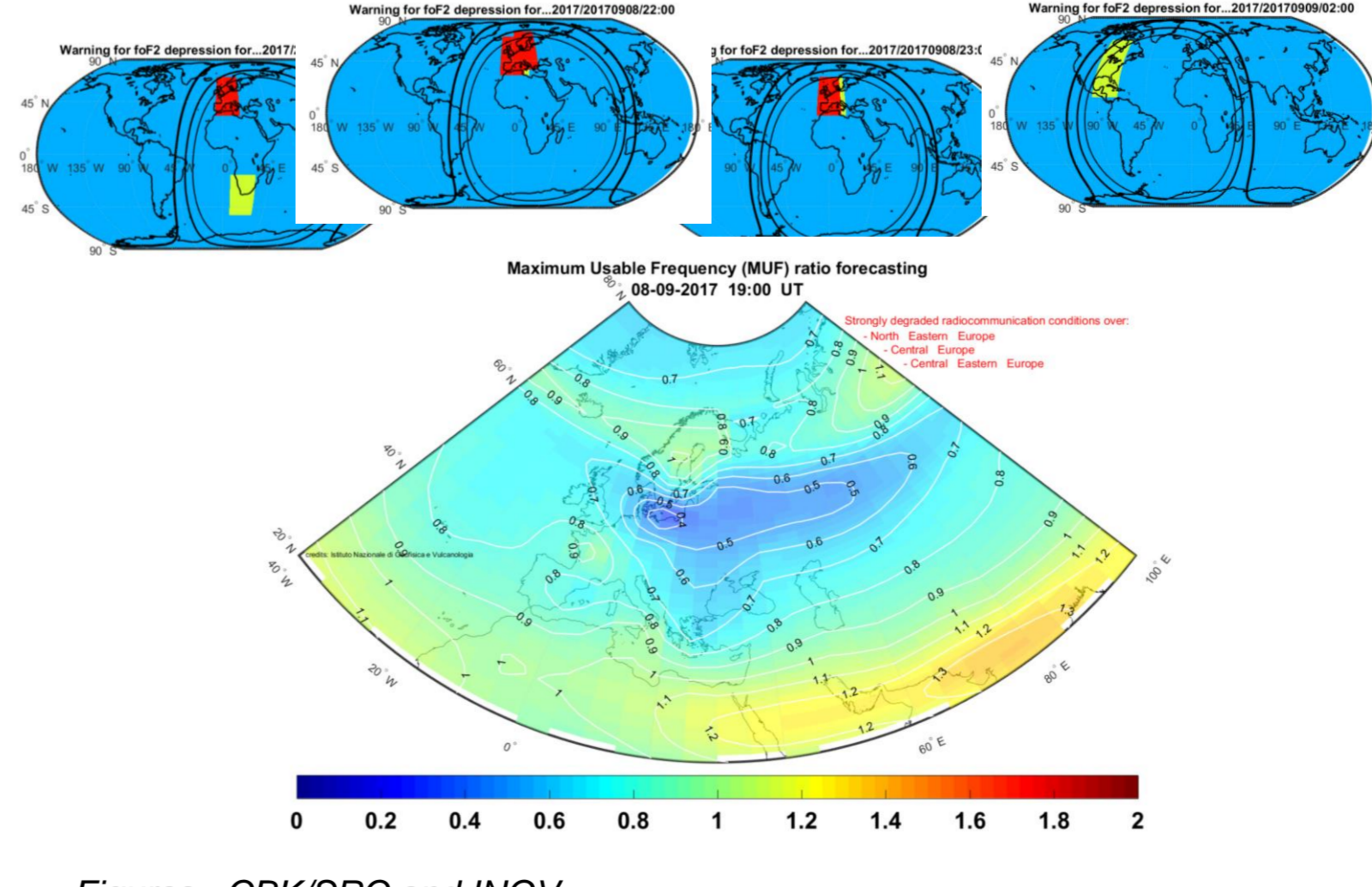


Figure: Seibersdorf Laboratories

Radiation environment at aviation altitudes is controlled by galactic cosmic radiation and solar eruptions. In EG RAD radiation conditions are characterized with the AVIDOS tool and Solar Energetic Particles (SEP) alerts are generated with a set of forecast tools (COMSESP, HESPERIA, and UMASEP-500) to increase alertness of the duty officers.

### EG HF



Figures: CBK/SRC and INGV

Time and space variations of Maximum Usable Frequency are monitored with methodologies developed in SRC and INGV. The nowcasts use advanced kriging techniques and are based on both NRT ionospheric observations and monthly median conditions by empirical ionospheric models. FU and SANSa contribute to the service with their ionosonde data.

### EG GNSS

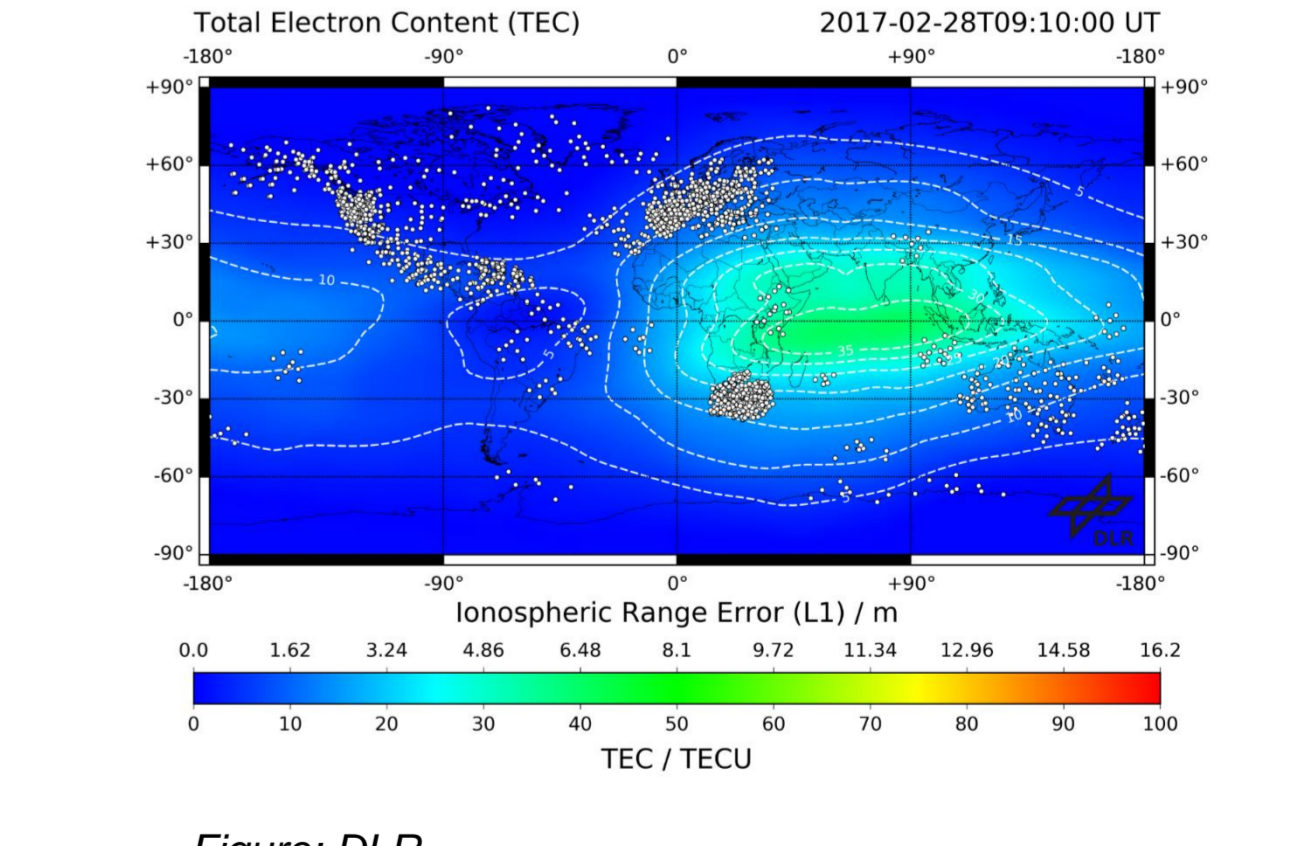


Figure: DLR

Global and European Total Electron Content nowcasts are provided with the GNSS receiver data processing routines used in DLR. GNSS input data is acquired and processed in real time from several global and regional GNSS receiver networks. Scintillation data are provided as joint effort of DLR and INGV.

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