Space weather services for enhanced aviation

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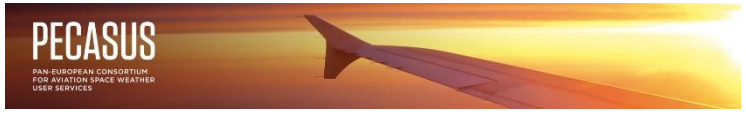
The Customer: ICAO

- International Civil Aviation Organization,
- 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

Figure: Wikipedia

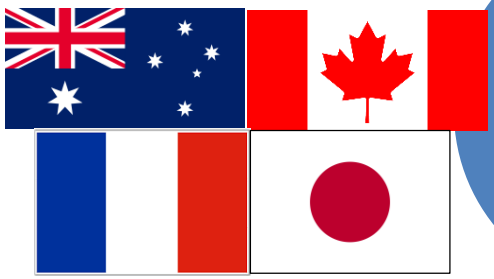
The three global space weather centers



PECASUS consortium

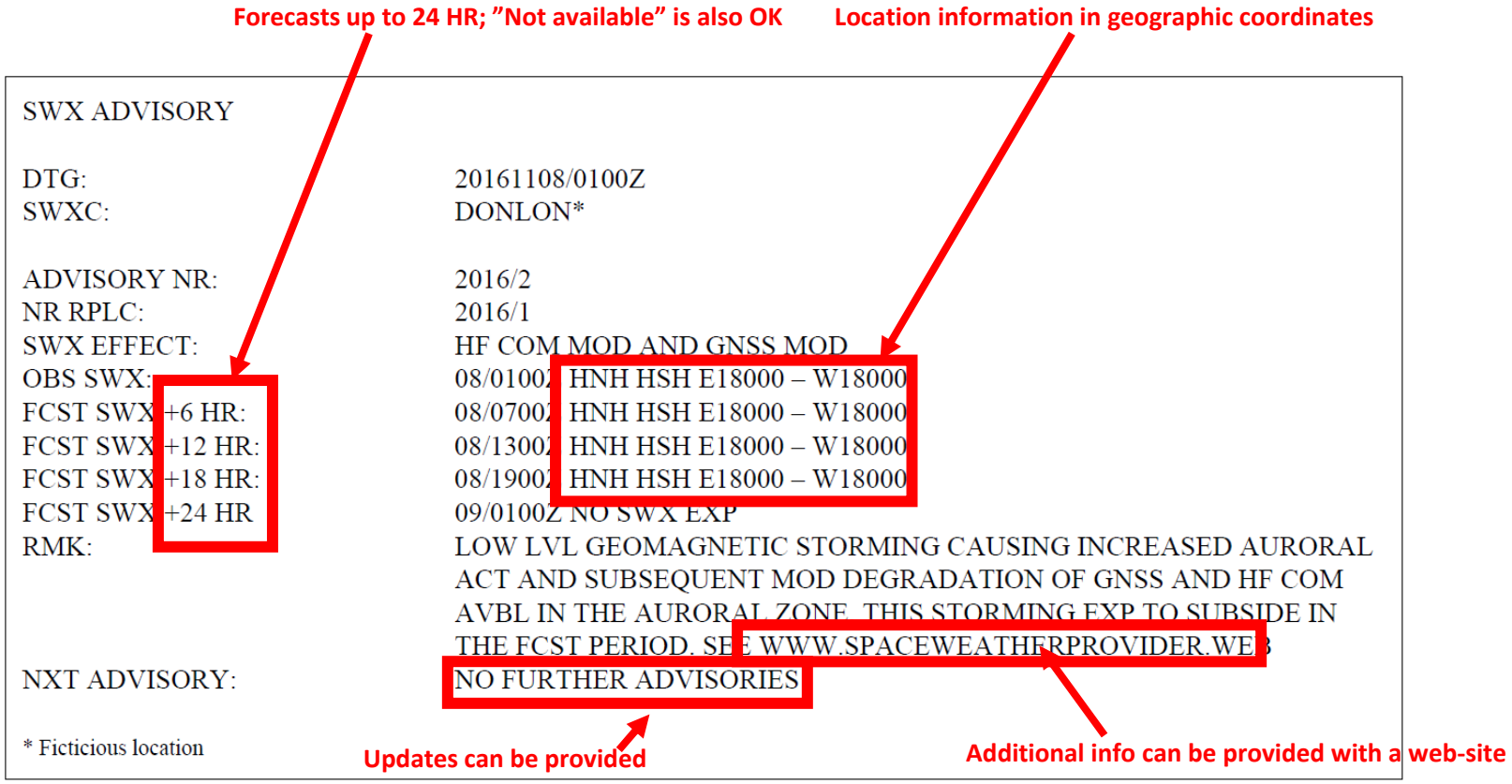
NOAA Space Weather Prediction Service

ACFJ consortium



- Two week shifts in the responsiblity of advisory validation and dissemination
- All centers will monitor space weather continuously.

SWx information will be given as strictly formulated advisories



Manual of Space Weather Information in Support of Air Navigation (Draft)

Space weather impact areas of interest for civil 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

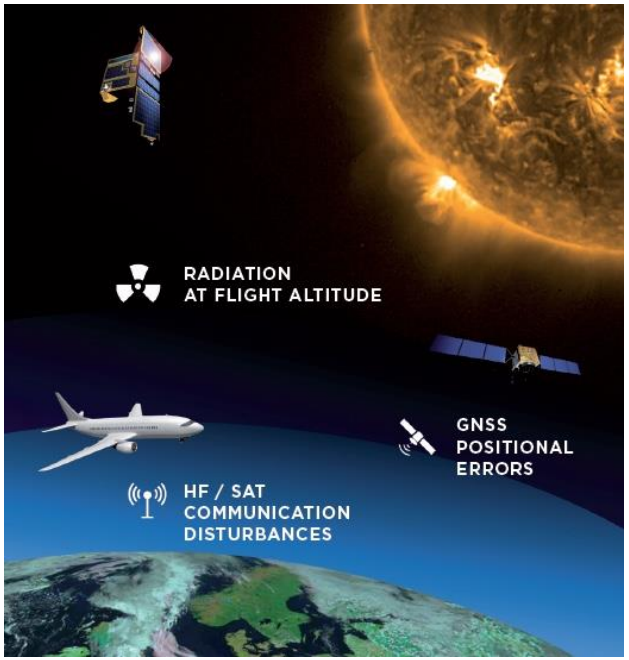
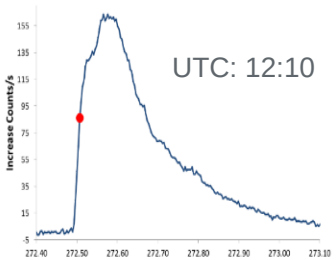


Figure: ESA/Proba-2, EUMETSAT, STCE

AVIDOS Sample Maps for Historical GLE42, Sep. 28th, 1989

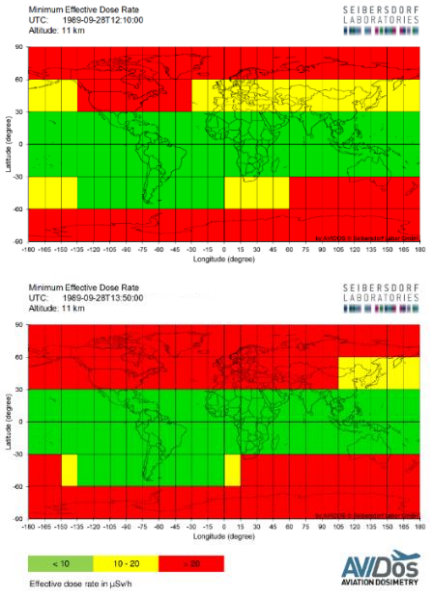
Minute INPUT-Data

Neutron Monitor (Oulu)

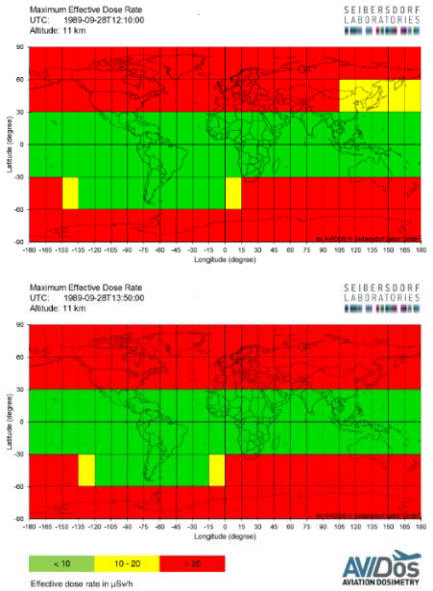


Global OUTPUT-Data - every 5 minutes

Minimum expected dose rate



Maximum expected dose rate



RAD	Moderate	Severe
Effective radiation dose (microS/hour)	30	80

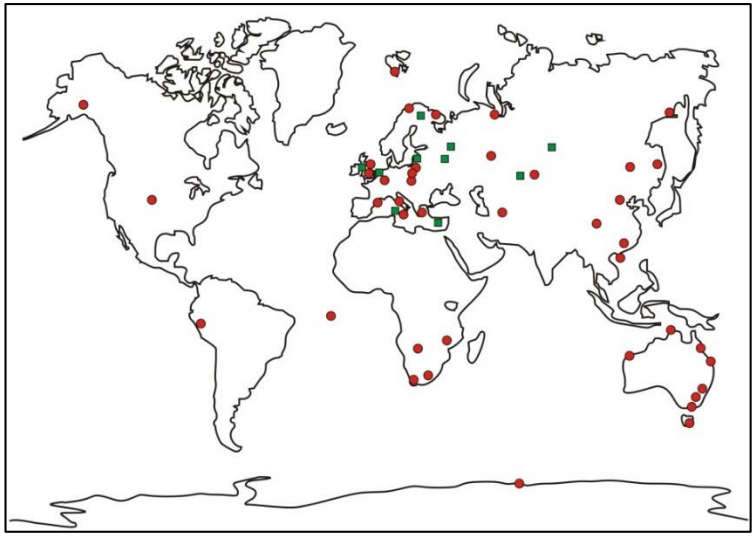
HF service

HF	Moderate	Severe
Kp-index	8	9
dB from 30 MHz riometer data	2	5
X-ray flux (0.1-0.8 nm) (W/m^2)	$1x10^{-4}$ (X1)	$1x10^{-3}$ (X10)
MUF depression	30%	50%

GFZ Potsdam & UKMO

Riometers in Finland and Sweden

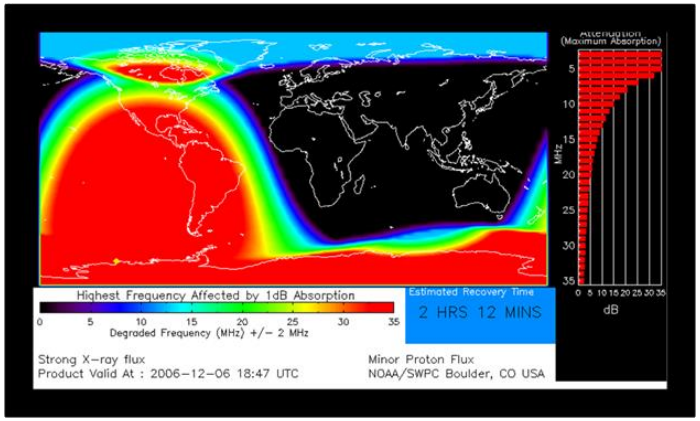
GOES from NOAA

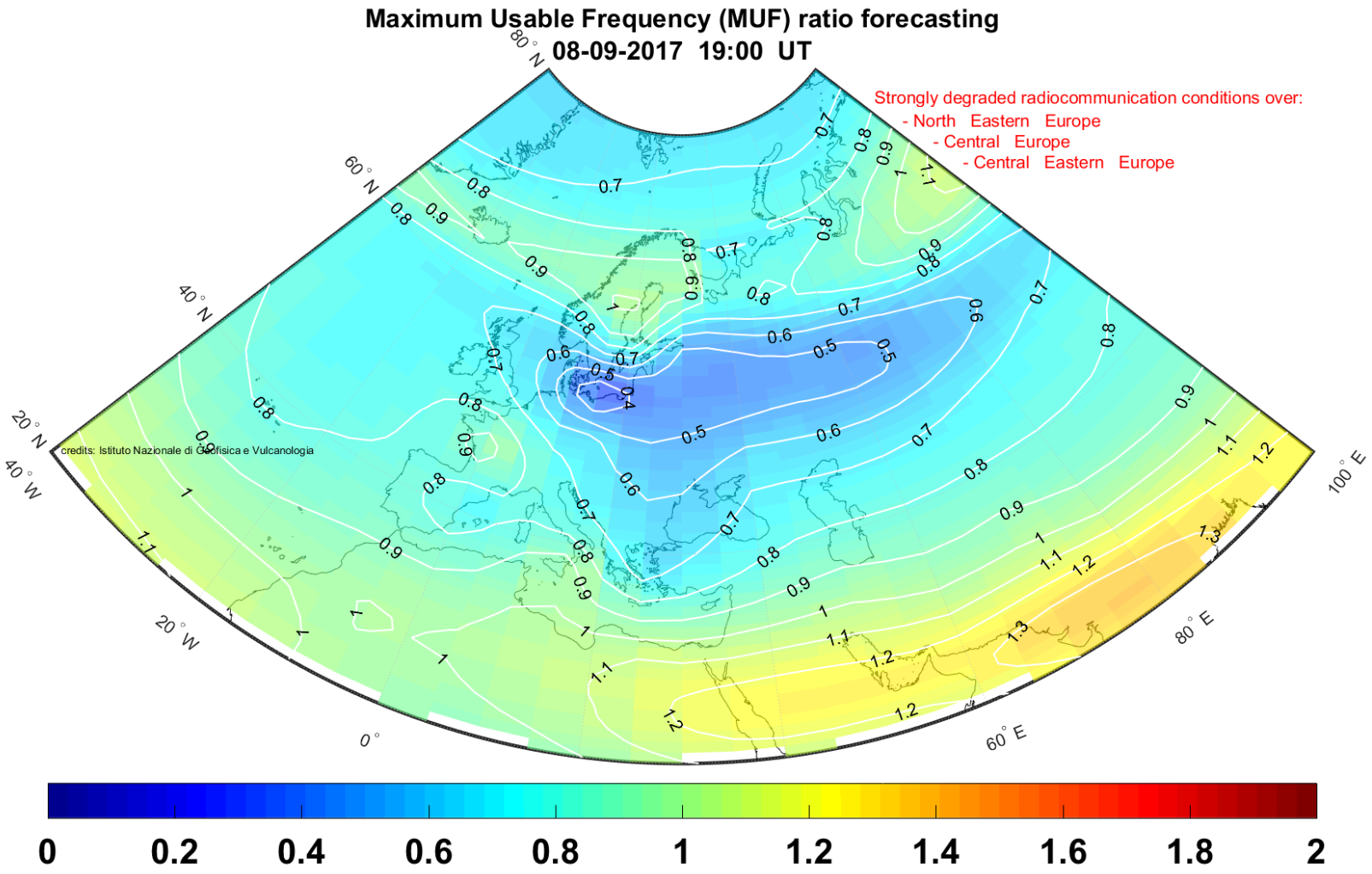


Network of ionosonde stations will be used to create the MUF depression maps

Reference level median of previous 30 days

D-RAP model



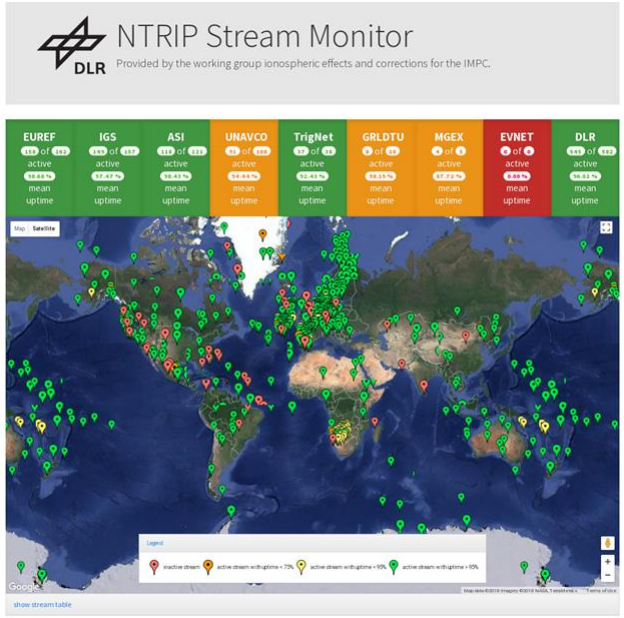


Plot: INGV, Italy

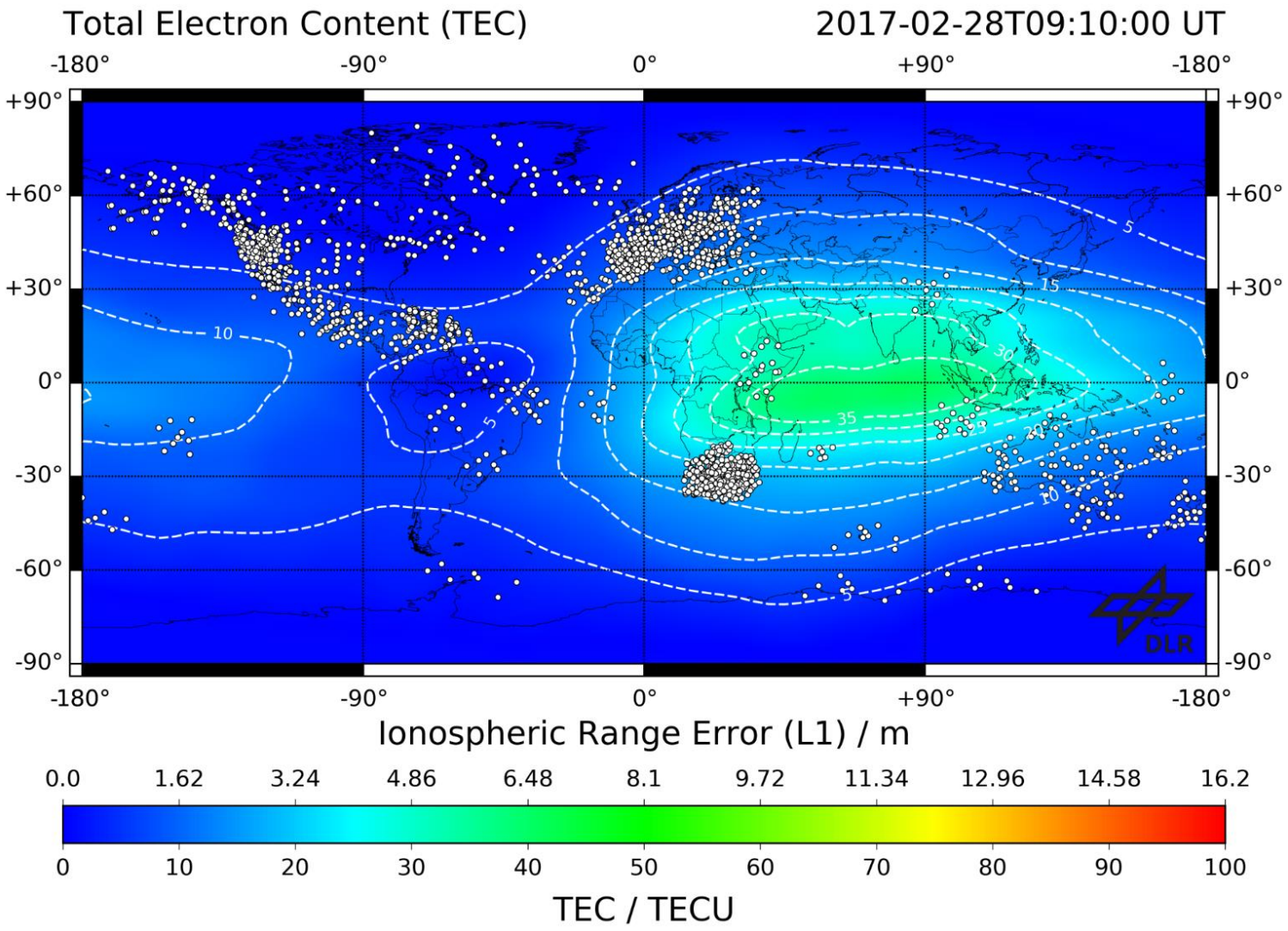
GNSS service

GNSS	Moderate	Severe
Amplitude Scintillation (S4) (dimensionless)	0.5	0.8
Phase Scintillation (Sigma-Phi) (radian)	0.4	0.7
Total Electron Content (TEC) (TEC Units)	125	175

Scintillation measurement stations

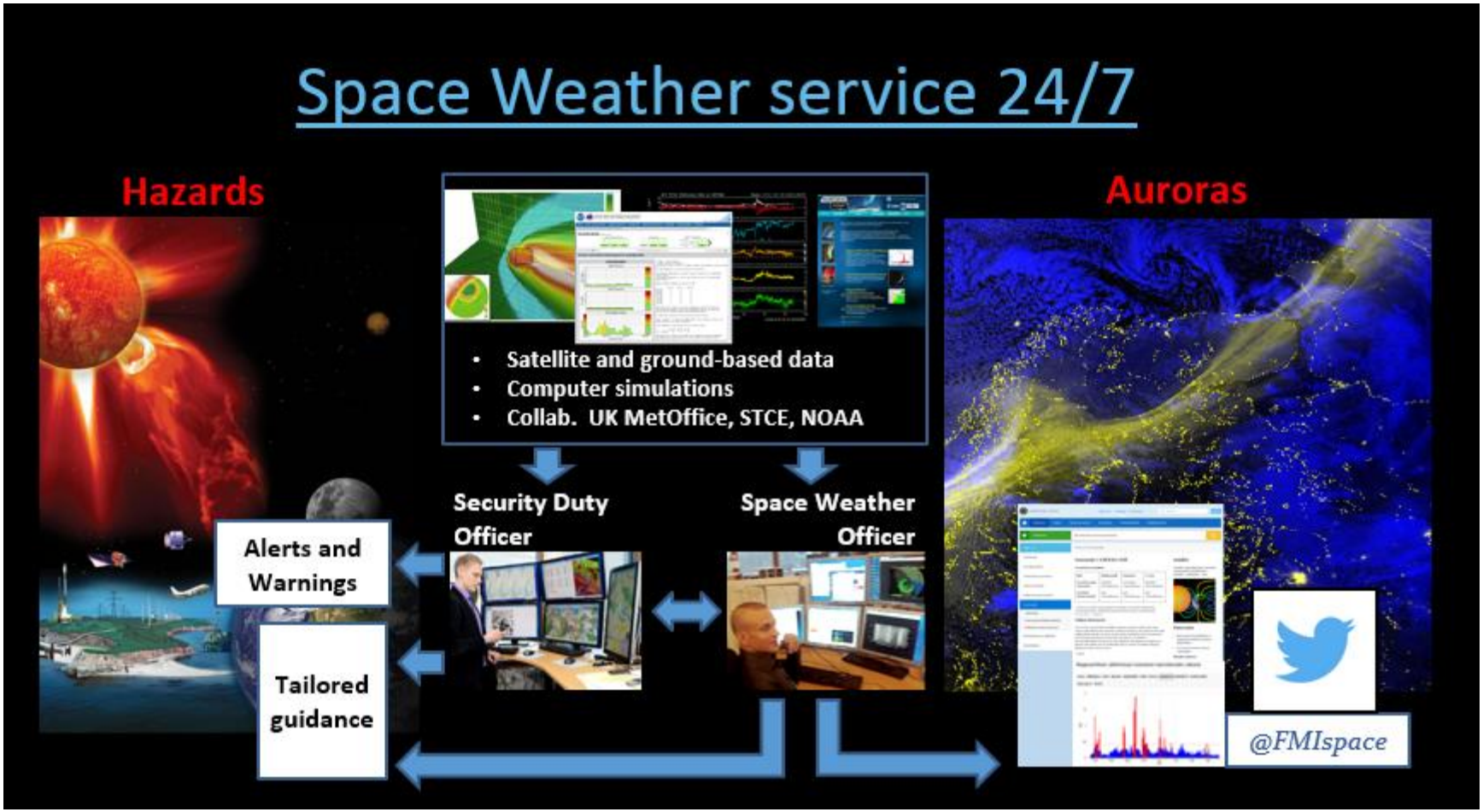


GNSS receivers (1Hz)

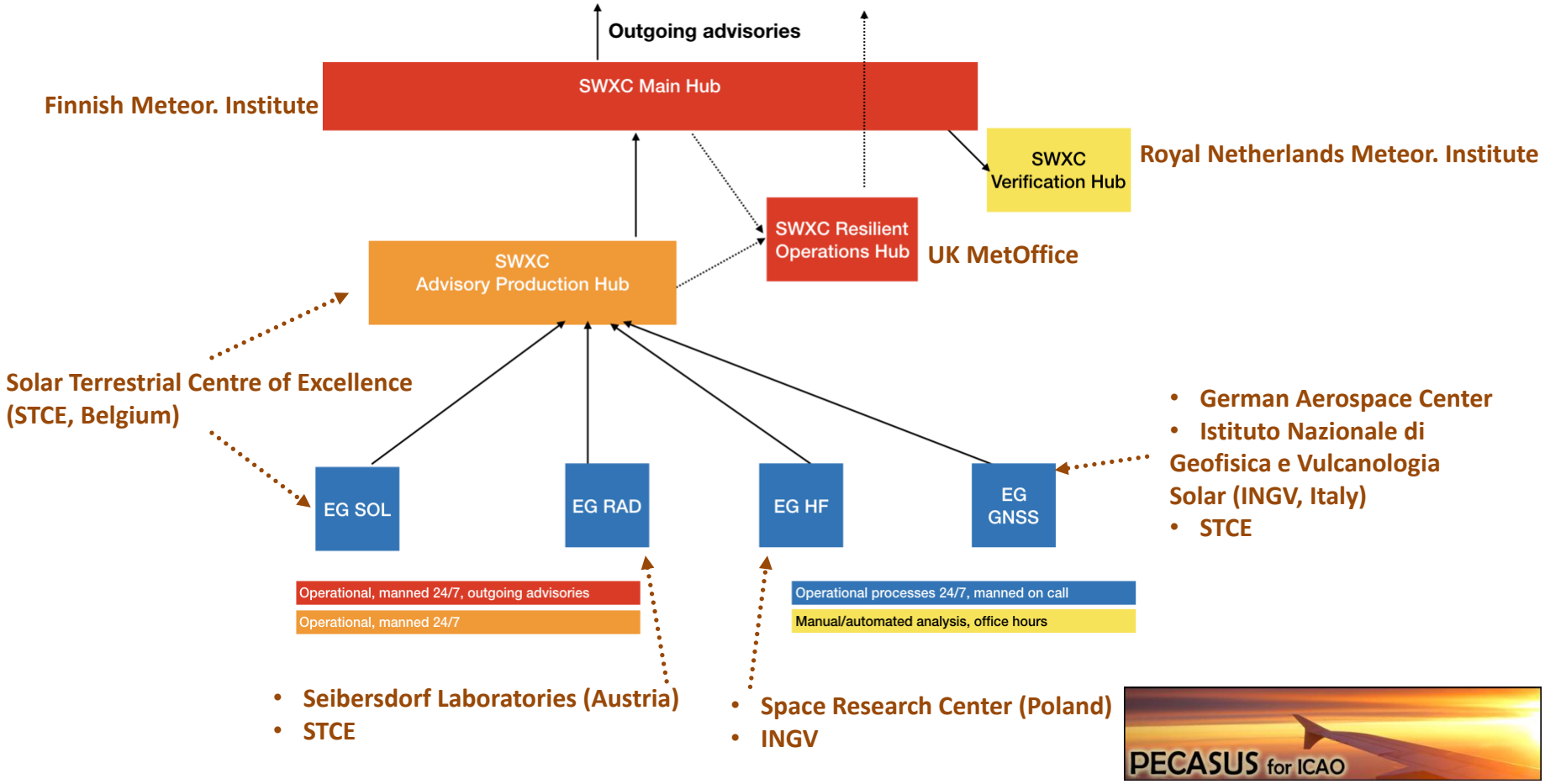


Plot: DLR, Germany

Space Weather service 24/7



The concept for operations



Future steps

- Official operations will start on Nov 7 2019
- Pilot phase (operations by own cost) → 2022 after that the cost of the services will be included to the aviation cost base.
- Regional SWXCs will be integrated at latest 2022
- ICAO will re-evaluate the number of centers in 2027
- Plans in Finland:
  - Collaboration between FMI and Defence Forces for dual-usage of the services
  - The routines and procedures developed for PECASUS will be used as the starting point for a national Space Situational Awareness system

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Thanks for your attention!

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