

# Pre-operational Space Weather Services

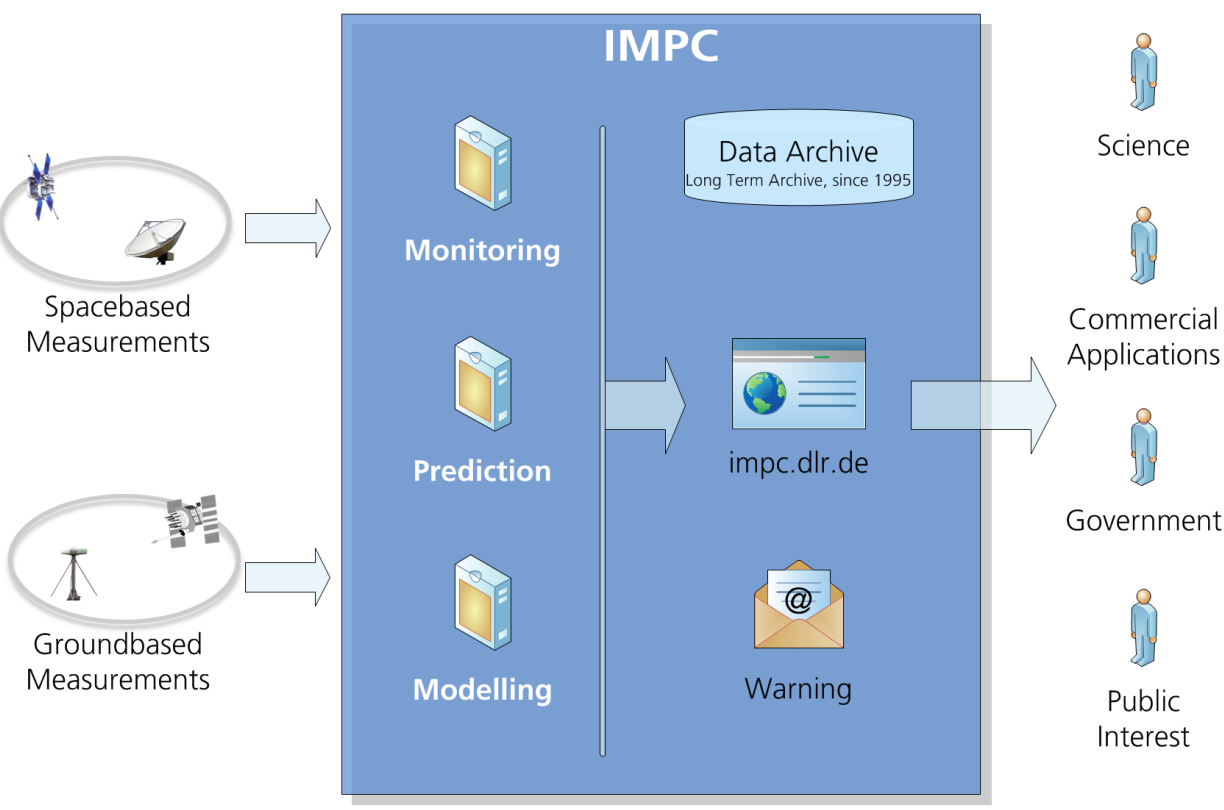
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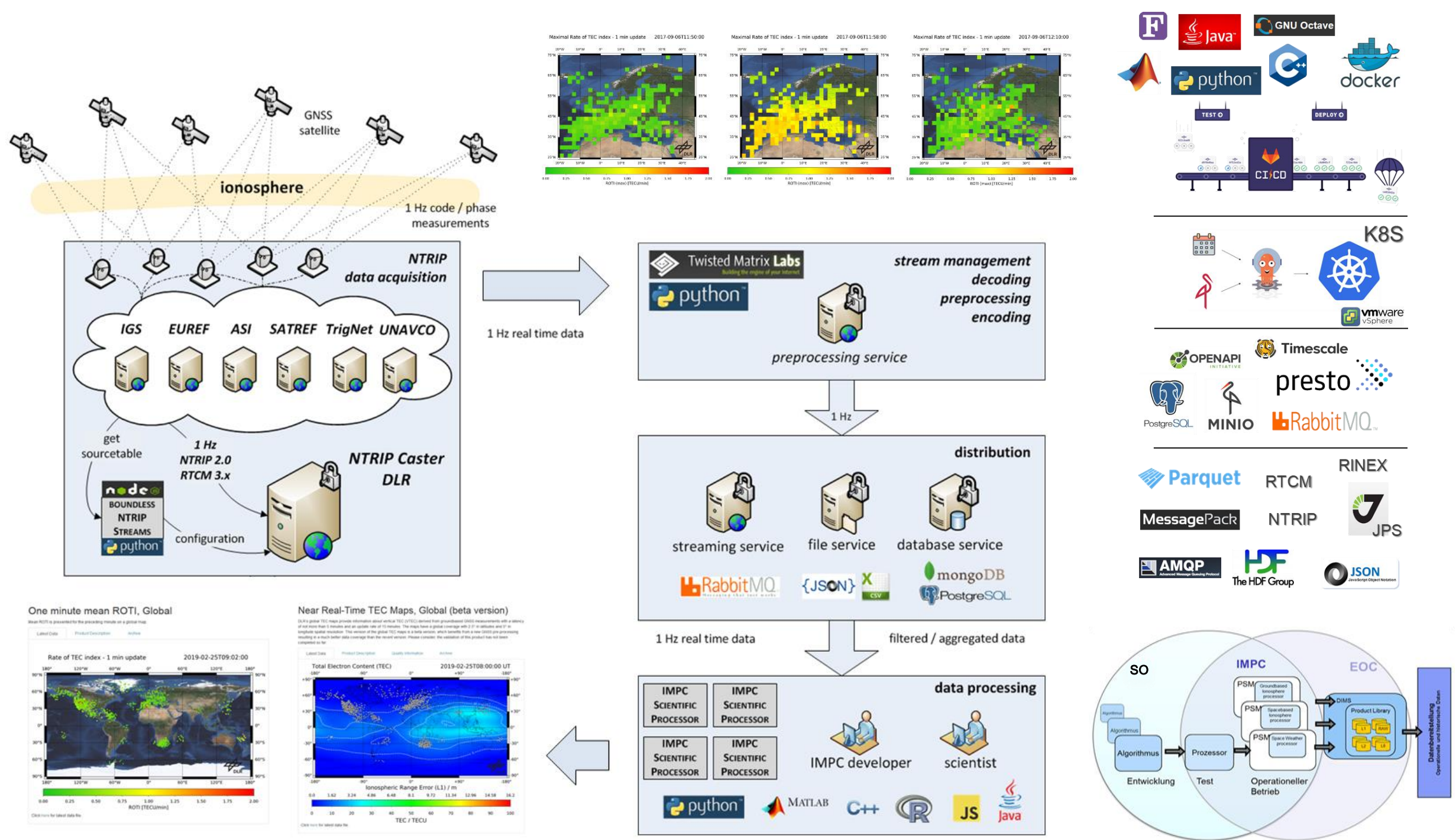
## Introduction

The performance of radio systems used in space-based communications, navigation and remote sensing can be strongly impaired by ionospheric disturbances. The accuracy and reliability of the affected communications and navigation systems can be improved by using pre-operational services such as provided by the **Ionosphere Monitoring and Prediction Center (IMPC)** which is being developed by the working group “Pre-operational Services” in the department “Space Weather Impact” and operated by the Earth Observation Center (EOC). IMPC provides near real-time information and data services on the current state of the ionosphere, as well as related forecasts and warnings generated by well-established products and facilities on regional and global scale.



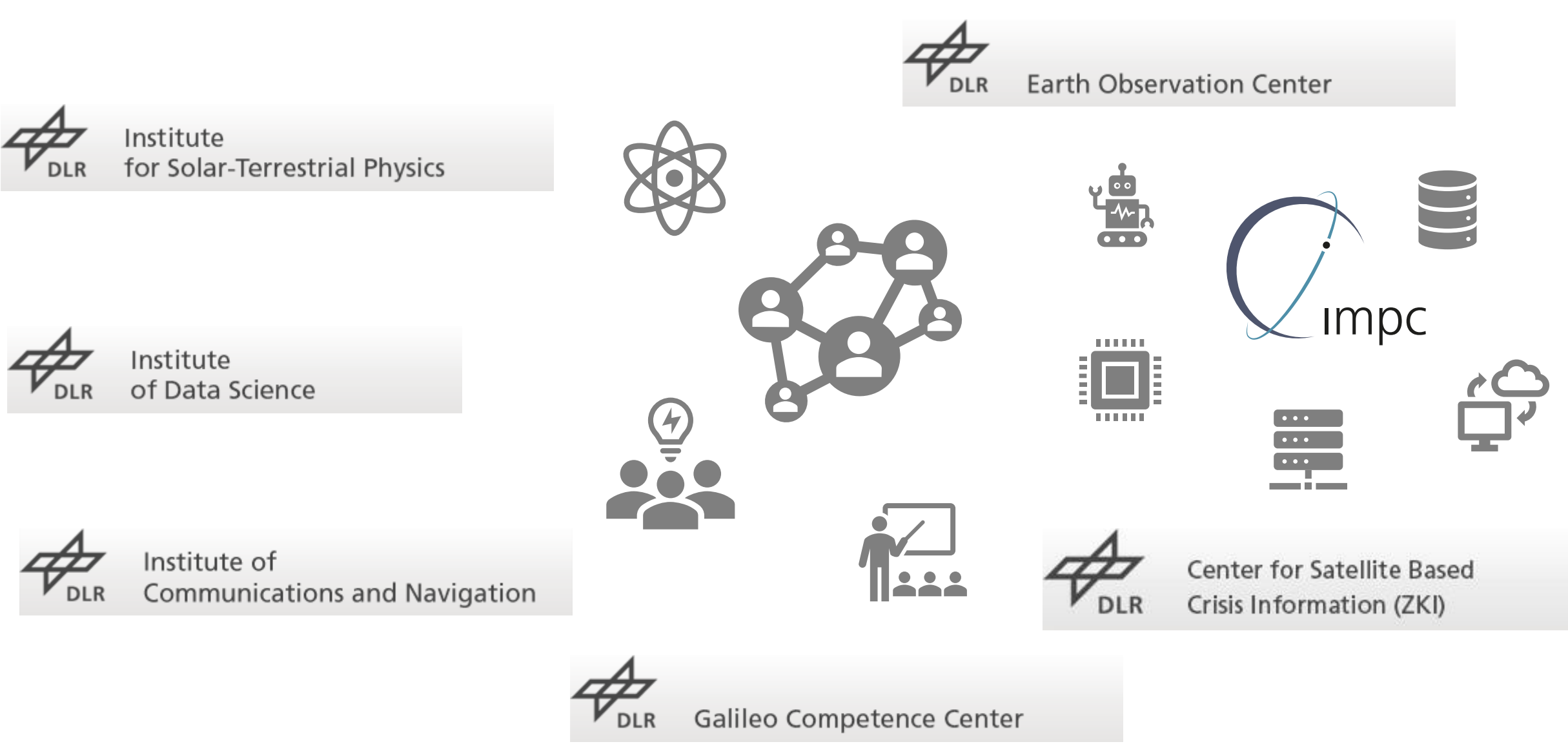
## Service Infrastructure

The development and continuous operation of efficient infrastructures based on excellent research, established standards and modern open source data processing and container technologies is the basic prerequisite for the operation of highly available and value-adding space weather services. This allows a wide range of products to be computed and delivered on time with very high cadence and very low latency, and ultimately to support internal and global research activities in space weather science and related applications.



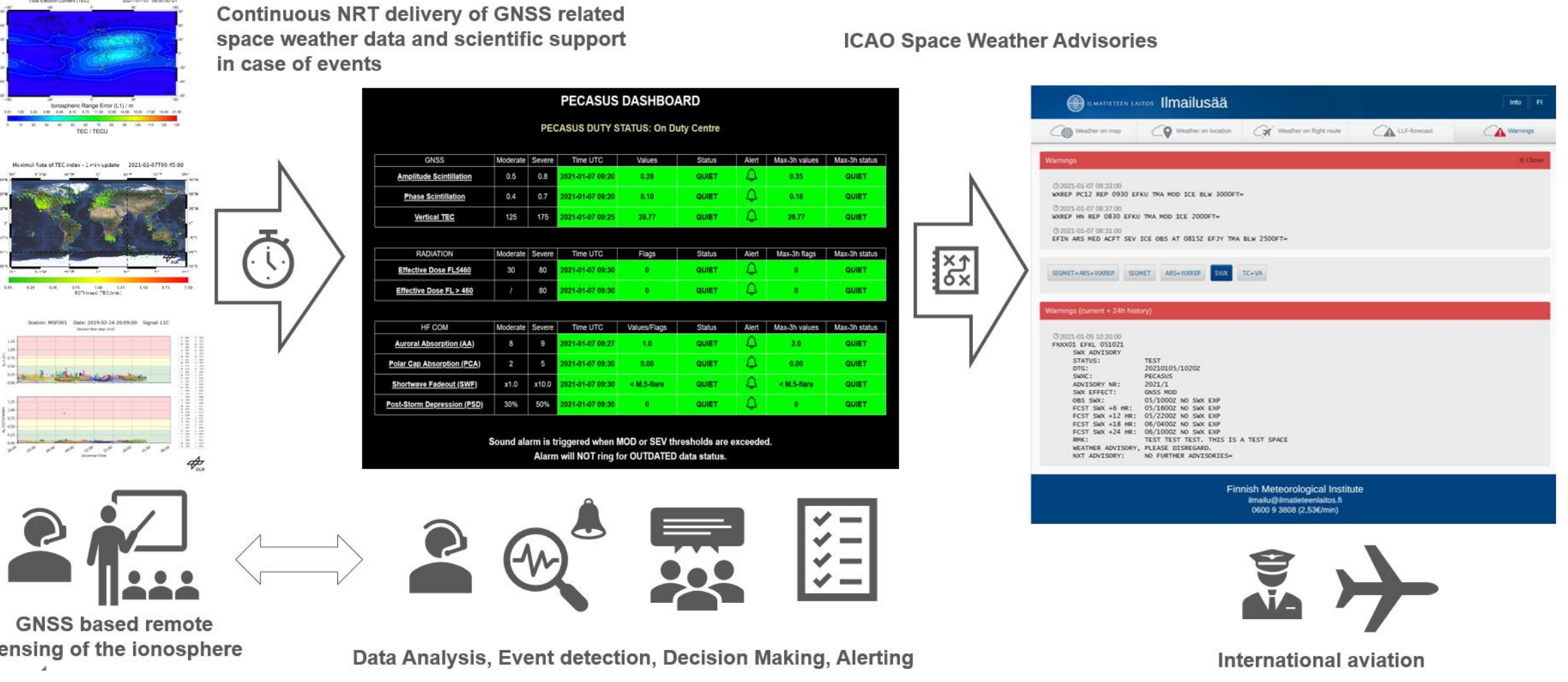
The real-time GNSS processing system developed at SO-WWE-PS and operated at EOC simultaneously processes hundreds of 1 Hz GNSS data streams to provide key ionospheric parameters such as TEC, ROTI and DIX in near real-time.

## Cooperation at DLR



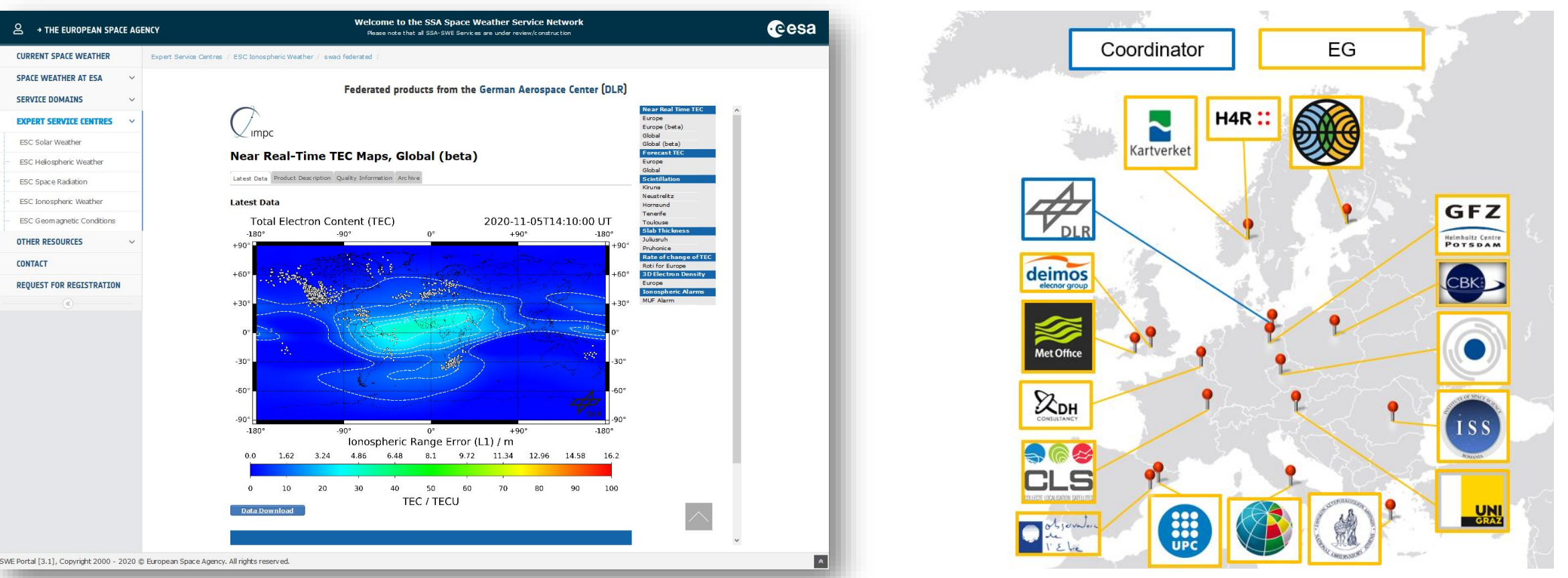
## Global and European Services

The Pan-European Consortium for Aviation Space Weather User Services (**PECASUS**) is lead by the Finnish Meteorological Institute (FMI) and advises pilots in case Space Weather (SWX) causes a moderate or severe impact on the radiation at flight level, satellite navigation or long distance radio communication. DLR leads the developments of the GNSS domain (DLR, INGV, SRC, STCE, FMI).



Based on continuous and robust data processing pipelines DLR continuously delivers near real time products (TEC and ROTI maps, scintillation indices) to generate space weather advisories for aviation and provides scientific and technical support on pre-operational level.

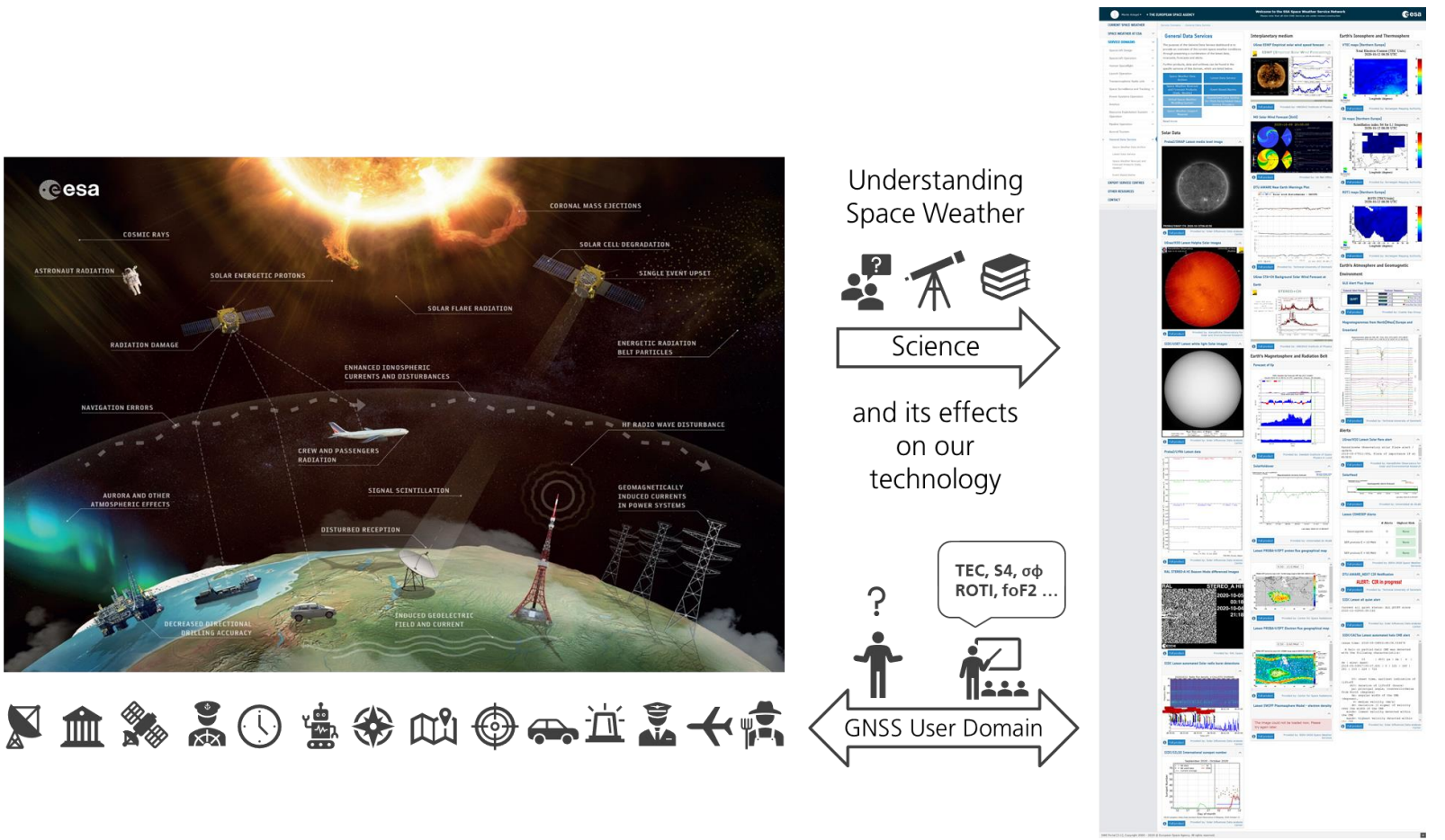
Furthermore, within the Space Weather segment of the **ESA Space Safety Programme (S2P)** the working group is coordinating and developing the **Expert Service Center Ionospheric Weather (I-ESC)** and is pre-operationally providing and developing ionospheric key parameters e.g. TEC, ROTI, scintillation indices S4 and sigma phi, slab thickness and MUF750 alarms.



The I-ESC provides, implements and supports the Ionospheric and upper Atmosphere Weather products and capabilities of the ESA Space Weather Service network, including the observation, monitoring, interpretation, modelling and forecasting of Ionospheric and upper Atmosphere Weather conditions.

## Conclusion / Outlook

In order to reduce the impact of space weather related disturbances on the performance of ground-based and space-based radio systems and its applications, early warnings and predictions of expected ionospheric and geomagnetic disturbances are derived from solar, geomagnetic and ionospheric data. The Institute of Solar-Terrestrial Physics and the Earth Observation Center at DLR develop and operate the IMPC to process Space Weather related observations in near real-time and to provide ionospheric and geomagnetic forecasts. IMPC provides a unique set of pre-operational services for the acquisition, processing and provision of space weather related products and services based on the latest space weather research to meet the broad range of requirements from science, industry and the public.



### References:

Kriegel, Martin und Berdermann, Jens (2021) Ionosphere Monitoring and Prediction Center. In: 2020 European Navigation Conference, ENC 2020. 2020 European Navigation Conference (ENC), 23.-24. Nov. 2020, Dresden, Germany. DOI: 10.23919/ENC48637.2020.9317443. ISBN 978-394497627-3.

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