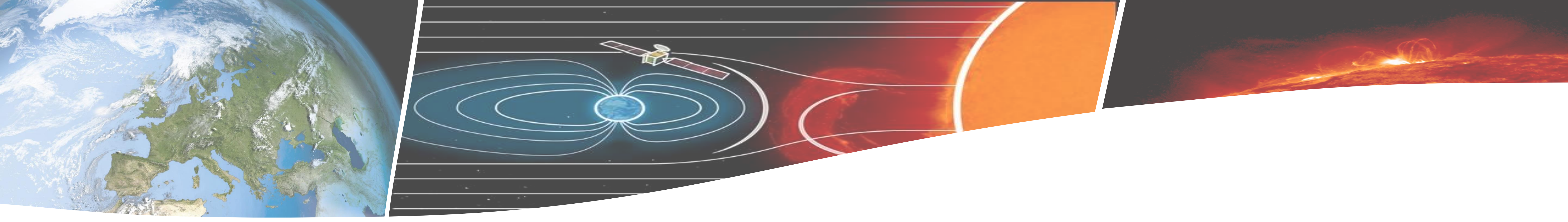

Development of a Performance Indicator Application to help identify Space Weather Impacts on GNSS

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Motivation / Introduction

In the context of the ESA Space Weather Service Network, the development of Global Navigation Satellite System (GNSS) performance indicators is considered essential to address the increasing end-user demand for space weather information in the navigation domain. A targeted analysis of space weather-related perturbations of technical systems and services in the field of satellite-based navigation has been done to fulfill the requirements in different user domains and related applications. The goal of the P3-SWE-XLII: Space Weather Impact on GNSS Performance Application Development (SWIGPAD) project is to design and develop an application that provides GNSS performance indicators on the basis of existing data supplied by various European research institutes through the ESA Space Weather Service Portal (available at https://swe.ssa.esa.int), tailored to representative use cases developed together with industry and government experts in specific user workshops. The SWIGPAD application provides users access to information on current and expected impacts of space weather on positioning at their particular location. It also presents end users in the various GNSS application domains a numerical and graphical representation of the estimate of position uncertainty based on recent ionospheric conditions, as well as its evolution over time.

Indicator Definition

The user groups identified for this project follow the definitions provided by the ESA Space Weather Service Network within the service domain Transionospheric Radio Link (available at https://swe.ssa.esa.int/web/guest/tio_dashboard) following the SSA Customer Requirements Document. [1]

The services requirements were derived from direct input of expert-users from industry and government. Most of the users expressed their interest in being able to use the service via a graphical user interface, which presents the data in numerical and in visual form including time series charts, as well as being able to get the data in an automated manner using a machine readable interface. Both near-real-time and archived space weather information are considered valuable by most user groups. While forecasts of up to 24 hours would be welcome in several user domains, forecasts with a shorter lead time (8 minutes to 12 hours) are also considered useful. The most interesting space weather parameters vary greatly between groups. The S4, σϕ, ROTI, TEC, and Kp parameters received higher weighting factors in many user groups.

Each of the above products is represented by its own performance indicator, while the GNSS performance indicator itself is computed by aggregating these. The aggregation method, in turn, depends on the respective use case. Depending on the position requested by the user, local products are preferred for the calculation, but global products are also used in case no local product is available.

To compute the TEC performance indicator, at least one of the data sources is required. These are the European or global IMPC Total Electron Content (TEC) maps, RTIM Vertical Total Electron Content (VTEC) maps for Northern Europe or the Swarm Total Electron Content (TEC) and Rate of TEC (ROT).

To process the ROTI-based performance indicator, one of IMPC Rate of change of TEC index (ROTI) maps for Europe, RTIM ROTI maps for Northern Europe, or RTIM ROTI@Ground maps for Fennoscandia is required.

Additionally, an indicator based on the positioning error is computed. This indicator is derived from the modelled probability of the positioning error, which was determined on the basis of ROTI according to [2].

For the calculation of the σϕ and S4 performance indicators, at least one of the local scintillation indices S4 and σϕ for Kiruna, Neustrelitz, Svalbard, Laguna, or Toulouse provided by IMPC must be available; however, for the σϕ indicator, the RTIM σϕ maps for Northern Europe are also eligible.

Finally, to calculate the Kp performance indicator, one of the following products is needed: BGS Global activity indices nowcasts (Kp), GFZ Kp index nowcast or archive, or IRF Forecast of Kp.

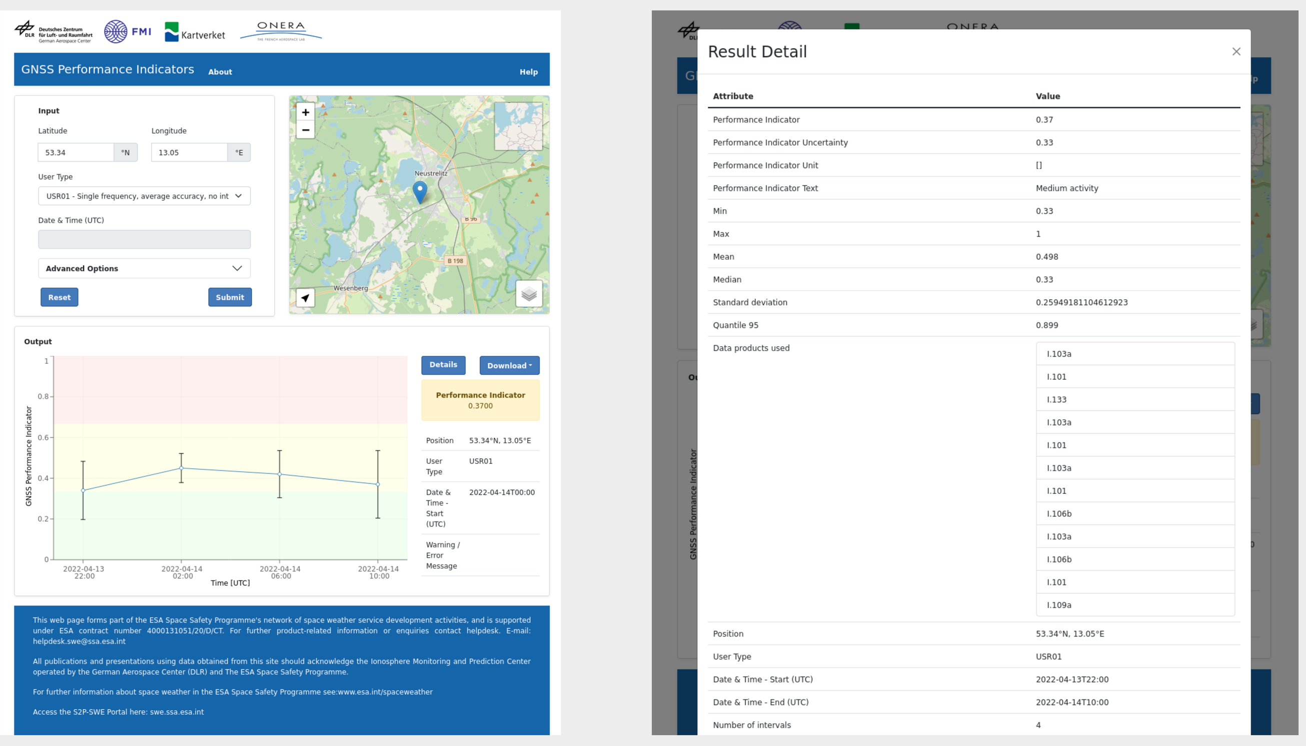
System Interfacing

To calculate the GNSS performance indicator, the eligible products are selected from the previously described list based on the location, time and use case provided by the user. For each product type, a specific indicator is calculated in the form of a numerical value, color-coded based on thresholds for each user group. The final performance indicator then results from the aggregation of the individual indicators, whereby the aggregation method again depends on the selected use case.

The central entry points for the user are a Graphical User Interface (GUI) and an HTTP Application Programming Interface (API).

The API handles messages in JSON format for input and output. It accepts user requests, validates the provided input parameters and communicates with the processing backend.

The GUI is a convenient tool that enables the user to work with the system in a very interactive way. It provides forms for the input parameters like time and use case as well as the user's location, which can be entered using an input form, an interactive map or optionally automations to fetch the position from the user's device. Additionally, the GUI offers a numerical representation of the performance indicator and a visualization in form of interactive time series charts presenting the timely evolution as well as a detailed view, which shows additional information like the products used for computation.



Screenshots of the Graphical User Interface showing the federated sites content.

Outlook / Conclusion

By now, the project has finished its implementation phase, by having successfully fulfilled all test case scenarios developed from the Customer Requirements Document. The test cases have been demonstrated to the ESA S2P team during the final acceptance test. It was successfully integrated into the ESA SSO system and made available on the ESA Space Weather Service Portal as a federated site under the provisions of IMPC with release 3.5 on October 11, 2022. A dedicated user test campaign following the deployment to the ESA Space Weather Service Portal has been organized to collect relevant feedback. Finally, the SWIGPAD performance indicator application will provide detailed information of the GNSS service performance for different applications and help mitigate Space Weather related disturbances on our modern security. Therefore, the SWIGPAD application will be an important tool to assess the space weather impact on the GNSS performance, which is especially important during the upcoming phase of increased solar activity with its expected maximum in 2025/2026.

References:

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