GALILEO IONOSPHERE PREDICTION SERVICE (GIPS)

The objective of the Ionosphere Prediction Service (IPS) project is to design, develop and operate a web-based prototype platform to monitor and predict the behavior of the ionosphere and the potential effects of it on the performance of GNSS-based applications.

In fact, ionosphere effects are well known sources of disturbances on GNSS; in some cases the impact is so penalizing on man-made systems that it is better to anticipate upcoming disturbances so as to be able to put in place mitigation measures in a timely manner. Targeted users are typically GNSS-based applications sensitive to sudden degradation of performance, such as aviation, high accuracy (construction works, civil engineering), and synchronized networks (energy grids, banks, telecom).

In this sense, ionosphere now-casting and forecasting can contribute to the mitigation of the impact of significant space-weather related geophysical events on the final performance of the specific GNSS-based applications.

Contract Number: Call for Tenders No 434/PP/GRO/RCH/15/8381

Project Segment: Horizon 2020, Galileo Mission and Services evolution

Duration: 24 months

Budget: € 669 000

Project Partners: Telespazio (IT); Telespazio Vega (Germany); Nottingham Scientific Ltd (NSL, UK), The University of Nottingham (UK), the University of Rome Tor Vergata (Italy) and the Istituto Nazionale di Geofisica e Vulcanologia (INGV, Italy)

Project Coordinator:
Mr Filippo Rodriguez, Telespazio Italy (coordinator)

Filippo.Rodriguez@telespazio.com

Project Manager:
Mr Eric Guyader, European Commission
Eric.Guyader@ec.europa.eu

Background

The Ionosphere Prediction Service (IPS) is an initiative of the European Commission in the framework of the Galileo Programme.

IPS is a prototype of a service for the monitoring and prediction of the Ionosphere effects on the final GNSS user. The web-based IPS platform monitors and forecasts the solar and ionospheric activity and its well-known effect on GNSS signals and on the final performance of user applications. The predictions are delivered for both ionosphere-related parameters and GNSS performance indicators, over two geometric scales (the European region and globally) and three time scales (now-cast, 30 minutes and 24 hour ahead).

The project team is composed of Telespazio Italy (coordinator), Telespazio Vega Germany, Nottingham Scientific Ltd (NSL), The University of Nottingham, the University of Rome Tor Vergata and the Istituto Nazionale di Geofisica e di Vulcanologia (INGV).

Project objectives

- Design, develop and operate a service prototype platform
- Monitor the ionospheric behavior during the period
- Predict potential effects on the performances of GNSS based applications
- Translate the prediction and forecasting of the ionosphere into tangible results and user-devoted metrics.

The project is structured along two main activity streams: on the one hand the design, development, operation and maintenance of the web-based prototype; and on the other hand the scientific research activity at the base of all the implemented algorithms.

Results

The predictions are delivered for:

- solar flares and other solar related products;
- ionosphere-related products such as Total Electron Content
- high accuracy related products
- aviation-related GNSS products

The project allowed testing a capacity of prediction for the benefits of GNSS users. Several similar web-based platforms exist today, but they mostly deliver monitoring products rather than providing forecasting products, and they leave the final user construct its own prediction of impact. Moreover, most of the services do not provide products dedicated to users and operators of infrastructure but are more suited to scientific usage.

Another distinguishing characteristic of IPS is that it has been conceived as a centralized “federation” of different processing facilities; this means that all processors are located within the same stand-alone platform and synchronized to each other, allowing a greater capacity for expansion and replication in other places; this is a novelty as existing platform use distributed architectures amongst several laboratories, which is less practical to handle, evolve and replicate.

This potential to be tailored to regional scale is particularly innovative, as it may actually be better fitting the user who are more interested in monitoring a given areas (airport, surveyed field, etc) than the whole planet Earth; indeed the platform is built to deliver products at any scale, depending on the data that is ingested. Therefore it has a huge potential in the deployment for a local or regional usage.

One other key element of the project was the elaboration of retro-validation products, i.e. products showing immediately how the forecast compares to the reality. This is a central

element of the prototype never seen before in similar endeavours, and proves to be essential in assessing the goodness of the prediction. This ensures full transparency to the user in giving an indication of the quality of the predictions. This function is essential as it increases the confidence level in the products.

Interestingly, some EGNOS disruption events occurred during the period, the cause of which was not immediately identified. IPS was used to retrieve the ionosphere activity during the period, and could confirm *a posteriori* the absence of any critical ionosphere activity that could have caused the disruption. After a few days, it was confirmed that the disruption was caused by an internal anomaly. So IPS has also an interest in real-time monitoring of the ionosphere state, as it can be used later for eliminating hypothesis during investigations.

Many articles have been submitted during the project execution, and several conferences on the topics have been attended with active talks about the prototype. Further insight into the results are available in the project final report.

Impact

The project allowed developing novel approaches in both a scientific field (ionosphere and sun-earth interaction), and engineering (forecasting methods).

One of the greatest challenge of the development was the real-time requirement for delivering the predictions: it means real-time access to observation networks to collect the relevant data, real-time processing of this data and real time publishing of the result on the portal, while tolerating only a few minutes of latency to maintain the validity of the prediction. It required novel approaches (neural networks, high speed servers, real-time fluxes of input data, specific software techniques) to absorb huge quantities of data in reduced time frame.

The subject of space weather and ionosphere phenomena is also a topic that is difficult to bring to the attention of GNSS users who are not assumed to have any prior specialized knowledge of the mechanisms at stake. It was therefore key to design products and functions that are easily understandable by users; more importantly, it was critical to raise the confidence level of the user and gain his trust in the goodness of the predictions. Therefore, a great deal of pedagogy and ergonomics was put during the conception of the GUI and of the system design overall, to bring clarity and ease of use.

The prototype could be tested thoroughly; it will be further tested and improved within the European Commission, with the idea to be deployed eventually at the GNSS Service Center in Madrid, for the benefit of all GNSS users.

Any institutional initiatives in the field on operational space weather could also benefit from the operation of the service, e.g. through the collection and reuse of the prediction products generated by IPS, the comparison with their own prediction, or by feeding their own algorithms with additional observation and prediction data to improve the reliability of the forecast.

The original contribution of IPS are:

- The prototype is dedicated to GNSS users interested to run their applications and not only to scientific communities;
- It is fully suited for operational users thanks also to its high level of customization and alarms configurability;
- Most of IPS products provide forecast analysis, instead of now-cast analysis as almost all of the similar existing services actually do;
- It can provide in real time the “quality of the service” as an estimation of the forecasting goodness;
- The user has complete access to the repository of prediction products for further offline processing and time series analysis.

Disclaimer: IPS service prototype cannot be liable for the availability or quality of its products and the final user is the only responsible of their use and interpretation.