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PEGASUS*Plus: A frame for GNSS Data Evaluation

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NavSat

2002

Satellite navigation and positioning world show



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Introduction

As part of the approval process for operations using new navigation systems, their performance needs to be evaluated. One step in this process is the analysis of real data gathered from data collection campaigns. These data processing activities require adequate tools to be developed and validated in order to obtain the required results.

As part of the activities of the EUROCONTROL GNSS Programme, the SBAS and GBAS Projects aim at the operational validation of the Space Based Augmentation Systems (SBAS) and Ground Based Augmentation Systems (GBAS) respectively.

To support both the SBAS and the GBAS projects and to provide them with adequate tools for their respective data evaluation campaigns, a dedicated Tools Development activity has been put in place within the GNSS Programme.

One of the major tools developed is known as PEGASUS*Plus. This tool is presently being used to analyse the performance of the European experimental SBAS known as the EGNOS System Test-Bed (ESTB). The tool is being used by the SBAS Project and has been delivered to various European partners who are using it for their data evaluations campaigns for both, static and dynamic measurement.



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Background

Global Navigation Satellite Systems (GNSS) are being introduced as foreseen in the EUROCONTROL Navigation Strategy for ECAC, which envisages a gradual transition towards the use of satellite navigation services until 2015. The initial step, up to 2005, will exploit the potential of the Global Positioning System (GPS) in a first generation GNSS (GNSS-1) providing a navigation service for all phases of flight down to and including Category I (CAT-1) precision approach and landing capability. This will be followed by a growing use of GNSS through to 2010 by which time a fully integrated GNSS of the second generation (in particular encompassing Galileo) should be available. Within the context of GNSS-1, the GNSS Programme is concerned with the introduction of two principal augmentations to GPS, Space-Based Augmentation Systems (SBAS) and Ground-Based Augmentation Systems (GBAS). SBAS and GBAS are expected to be important components in the transition from ground-based to satellite-based navigation. In Europe, the SBAS is called the European Geostationary Navigation Overlay Service (EGNOS) whose development is being overseen by the European Tripartite Group, composed of the European Commission (EC), European Space Agency (ESA) and EUROCONTROL whose joint activities are outlined in the Tripartite Agreement.



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Background (2)

The GNSS Programme, in consultation with stakeholders, serves in particular as a co-ordination platform for all GNSS technical-, operational-, safety- and economic-related issues in the context of civil aviation.

For EGNOS, ESA will perform an extensive EGNOS Technical verification campaign, which will focus on the signal-in-space as seen by a network of independent reference stations. There is still a need to demonstrate compliance with the EGNOS Mission Requirements Document for Civil Aviation. Those additional operational validation activities are performed within the EUROCONTROL SBAS Project whose overall objectives are:

- To support the Member States in achieving operational approval for the use of GNSS-1.
- To encourage a harmonised approach to GNSS-1 operational approval throughout ECAC.
- To serve as a co-ordination platform for all issues related to SBAS.



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Background (3)

The related activities are supported and reviewed by a dedicated SBAS working group composed of European ATSPs, ESA and EUROCONTROL, which is monitored by the GNSS Programme Steering Group (PSG) on a regular basis and updated accordingly.

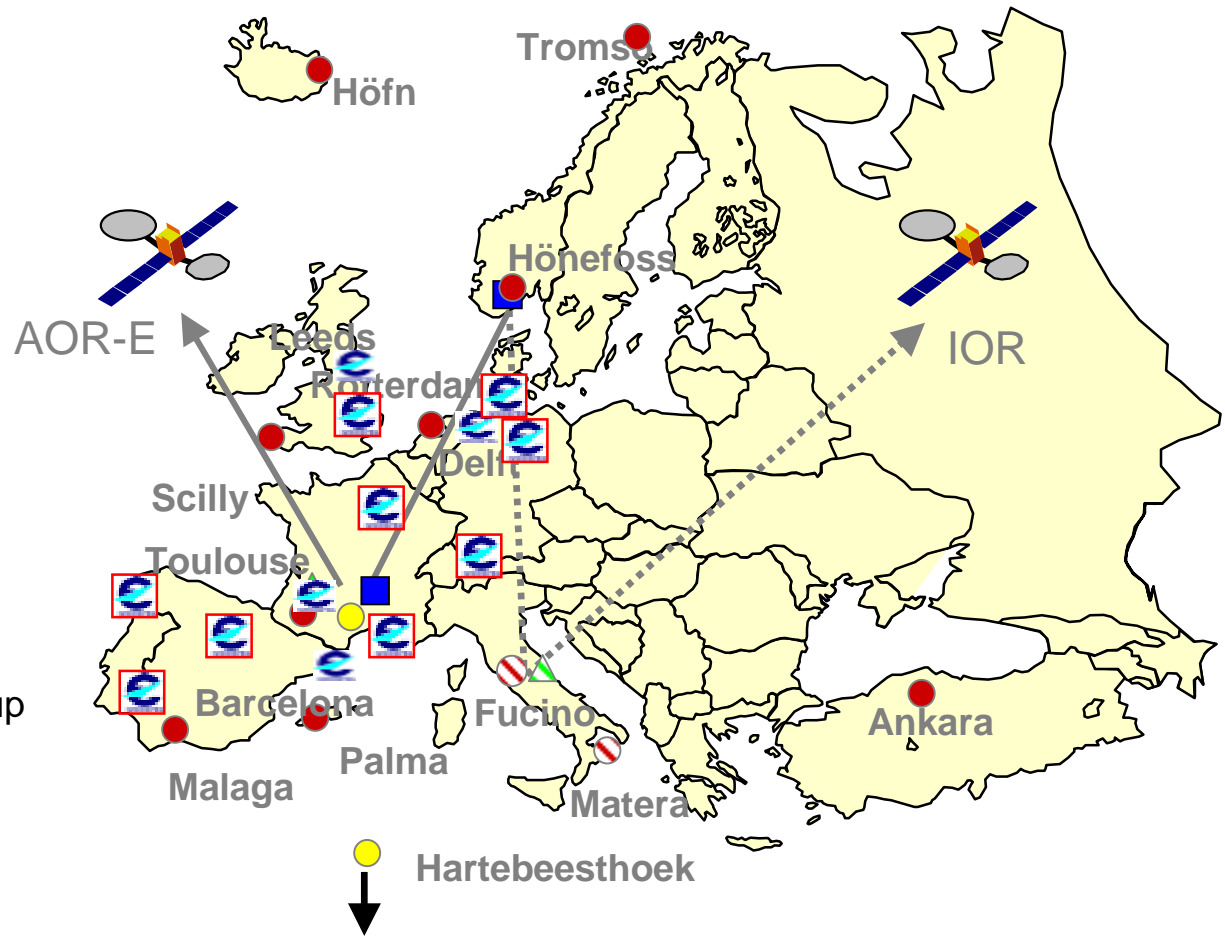
Within the scope of the operational validation related activities – that also encompass a support brought to the development of relevant guidance material for: the design of GNSS flight procedures; flight inspection criteria; the definition of aeronautical information services (AIS) required for the operational implementation of GNSS; and potential new ATC procedures – an extensive use is made of the EGNOS System Test Bed (ESTB) through early trials to be performed in preparation for the real operational validation involving a data collection network, composed of different sites all around Europe.



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ESTB and Data Collection Network

- ESTB reference station (RIMS)
 - EURIDIS reference station
 - ESTB processing facilities (CPF, MCC)
 - ▲ NLES
 - ESTB Data Collection NW
 - GNSS Operational Validation Working Group
- Kourou
● Canaries





Objective

Since the data evaluation is part of the usual process for the validation of a navigation system and this process is complex, the GNSS data evaluation needs a support of appropriate computer tools enabling the production of the relevant results. These tools should be able to evaluate EGNOS data, meeting a wide range of user requirements, be easily modifiable to meet changing requirements and at the same time should be easy to use in order to minimise the user effort.

The main objectives of a data evaluation tool are to to optimise the data evaluation process, to minimise the duplication of the effort and to avoid multiple format standards in this evaluation in order to facilitate data exchange. To obtain this result, it is preferable for one tool to be used as “standard” and widely used for the data analysis by the different users.

At the same time this tool should be validated against other developments in order to ensure validity of its algorithms and thus wide acceptance, not only amongst European users, but also in the global community.



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Methodology

Such a tool, named PEGASUS*Plus, has been developed and is continuously updated in the frame of the EUROCONTROL GNSS programme in order to allow the analysis of the performances of the EGNOS System Test-Bed (ESTB) by the SBAS Project.

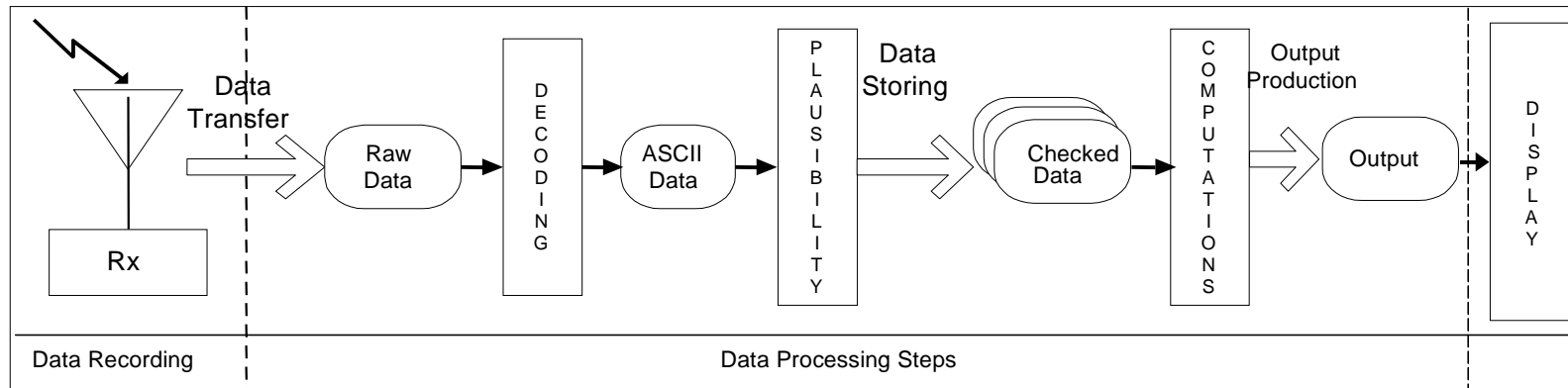
The PEGASUS*Plus tool allows the analysis of raw GNSS and SBAS data streams for the experimental augmentation system known as the ESTB using only algorithms contained in the published standards. This tool is being used by the SBAS Project and delivered to the various European partners who are using it for their data evaluations campaigns, both for static and dynamic measurements.

Tools, used by the FAA, ESA and the universities in the ESTB Data Collection Network, are utilised constantly to validate the quality of the PEGASUS*Plus results.

PEGASUS*Plus is also planned to be used for GBAS data evaluation in the near future.

Data processing sequence

Each data evaluation campaign can be separated into three major parts, the recording, the data processing part and the display and interpretation of the results. The following figure presents the organisation of a typical data evaluation campaign.





Data processing sequence parts

- > The data **recording part** is specific for each user and depends on the hardware installation.
- > The data **processing part** is more general and can be divided in four steps:
 - > **Decoding step:** as the recorded data vary from one receiver to another the format of the data has to be harmonised. This step is needed to transform the data in standard format ready to be used for the analysis.
 - > **Checking step:** The plausibility-checking step verifies that the data to be used for the further steps are synchronised and plausible. This checking is a direct way to ensure that the recording process runs properly, allowing at the same time the exclusion of irrelevant or incomplete data from the processing sequence. A manual intervention ensures no relevant events is excluded.
 - > **Data storing step:** The data used as input for the computations and the visualisation is stored in files on the computer file system.
 - > **Computation and results production step:** After the decoding and checking of the data, different types of analyses can be performed - analysis of special events, statistical analysis, running of algorithms to perform additional computations, display of the results.



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PEGASUS*Plus

PEGASUS*Plus

PEGASUS*Plus is a fully automated tool allowing the processing of data collected in-flight and on the ground with the European Satellite Test-Bed (ESTB) and giving the possibility of easy access to the graphical presentation of the results.

Structure of PEGASUS*Plus

The tool is composed of two main elements - a main frame programme and several data processing modules.

- > The frame is the main component, providing access to all processing parameters and containing a link to a data processing scheduler, that allows an easy organisation of the data processing tasks and the full automation of the computation processes.
- > The modules are the computation components in the tool and include the necessary algorithms for the data processing and the display of the results.



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PEGASUS*Plus main frame

In order to facilitate the processing and the access to the data, the tool uses a main frame controlling the entire process.

The main frame offers the possibility to organise the processing defining data processing jobs, composed of a sequence of predefined tasks called scenarios and associated predefined parameters to each of the scenarios. The tasks correspond to the integrated modules and a possibility to run a user defined program is implemented in the tool.

The main PEGASUS*Plus frame contains a graphical user interface allowing the access to every functionality of the tool and displaying the status of the data processing.

The top left part allows the definition and configuration of the processing sequences called scenarios and the determination of the parameters defining processing details. Scenarios and associated parameters are then transferred to the scheduler for processing.

The lower part of the window allows the monitoring of processing activities, opening a detailed history and status window on demand.

In addition, individual modules can be started manually.



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PEGASUS*Plus main frame and process monitoring window

The screenshot displays the Pegasus Plus Version 1.2 main frame and the Batch Processor Monitor window. The main frame includes a 'Start Scenario' section with fields for Scenario, Parameters, Input file, Job name, and Description. The 'Start Standalone Program' section contains icons for Converter, Plausibility Check, WinGPSAll, Truth Reference, and MFile Runner. The Batch Processor Monitor window shows a table of job execution details.

Name	Description	Status	Start Date	End Date
pec		Finished	06/27/2002 16:07:19	06/27/2002 16:07:19
Converter		Finished	06/27/2002 16:07:19	06/27/2002 16:07:19
WinGPSAll		Finished	06/27/2002 16:07:19	06/27/2002 16:07:19
WinGPSAll		Finished	06/27/2002 16:39:56	06/27/2002 16:39:56
WinGPSAll		Finished	06/27/2002 16:39:56	06/27/2002 16:39:56
test		Finished	07/23/2002 09:30:28	07/23/2002 09:30:28
mfs		Finished	07/23/2002 13:14:25	07/23/2002 13:14:25
navsat_sample	test data process	Running	09/09/2002 10:06:54	
Converter		Running	09/09/2002 10:06:54	
Converter		Running	09/09/2002 10:06:54	
WinGPSAll		Waiting		



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Modules in PEGASUS*Plus (1)

Convertor: This module translates original binary or ASCII receiver data into a specific generic format used by PEGASUS*Plus to perform the position solution computations. This module uses input from different GNSS and ESTB receivers and transforms the recorded data into readable ASCII format.

At the moment four receivers are implemented: NovAtel WAAS/Millennium, NovAtel OEM4, DSNP Aquarius 5000 and Septentrio PolaRx-1. A possibility to plug in new receivers in the module is implemented and allows the external development of new receiver data drivers.

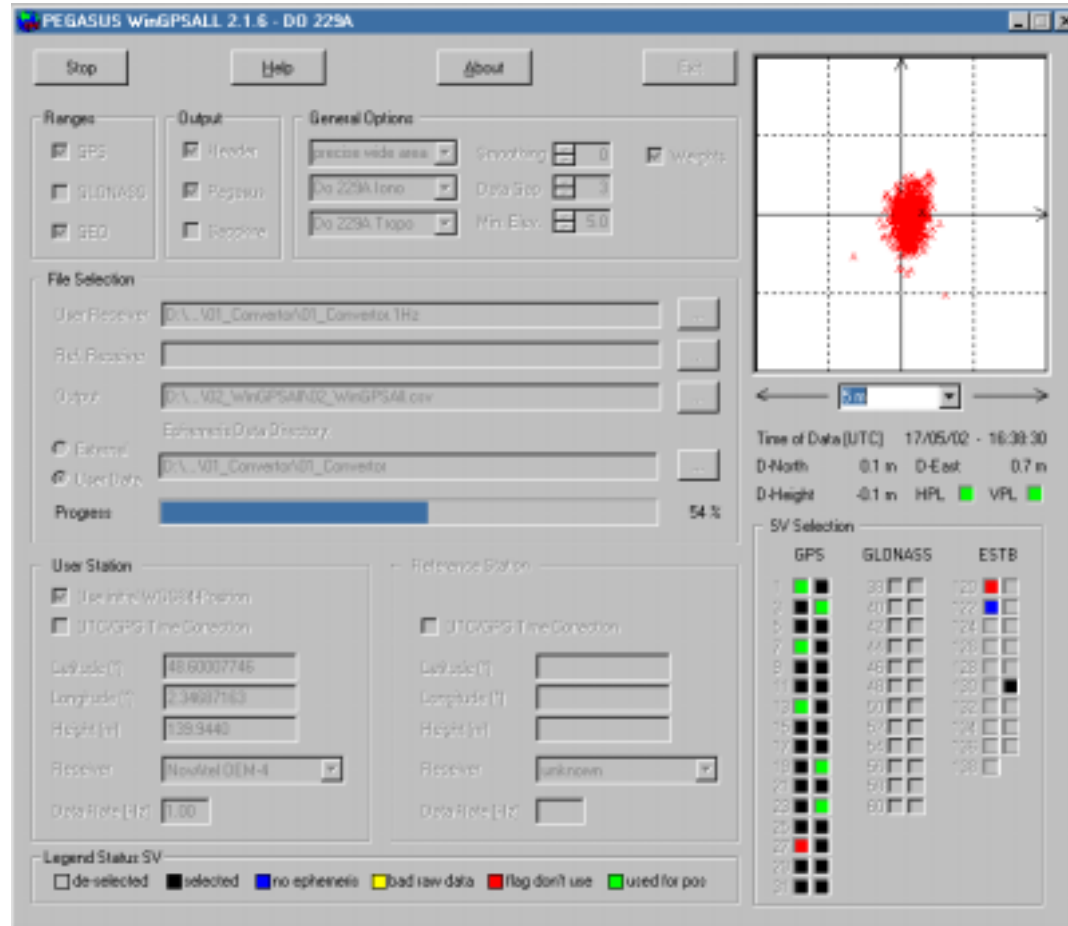
WinGPSAll: This module uses GNSS range measurements and satellite ephemeris in order to calculate a position solution and the protection levels according to RTCA DO229A. If the ESTB correction data is available, position corrections can be applied as well.

The input data for the module should contain GNSS and ESTB data in a specific format defined by the standards of the PEGASUS*Plus project (Convertor output files). The output data file of the module contains position and time solution data, protection levels and position errors. Standalone and local area differential positioning are possible, as are various choices of ionospheric and tropospheric correction models.



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WinGPSAll interface - Module in PEGASUS*Plus



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Modules in PEGASUS*Plus(2)

Plausibility Check: This module performs a number of user defined checks on the data to detect any anomalies. The module uses user definable rules on the output data from the other modules in the tool in order to evaluate the data for plausibility. The user defined rules can be used to define relationships for particular parameters and relationships between individual parameters contained in one data file.

Truth Reference: This module determines the position error using mobile position data and external reference data. During the processing, in order to determine the error, the mobile and reference data are synchronised exactly if possible, otherwise an interpolation algorithm is used.

The input data necessary for this module is the mobile position data and the reference data. The output contains the calculated error.



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Modules in PEGASUS*Plus(3)

MFile Runner: The purpose of the MFile Runner is to produce graphs and displays of the PEGASUS*Plus data independently from other programs in order to evaluate the current performance of ESTB in a standardised way.

Scripts from the scientific tool MATLAB are used to produce graphics. In order to be used by users without MATLAB installation this module uses as a base compiled MATLAB scripts and is able to display results.

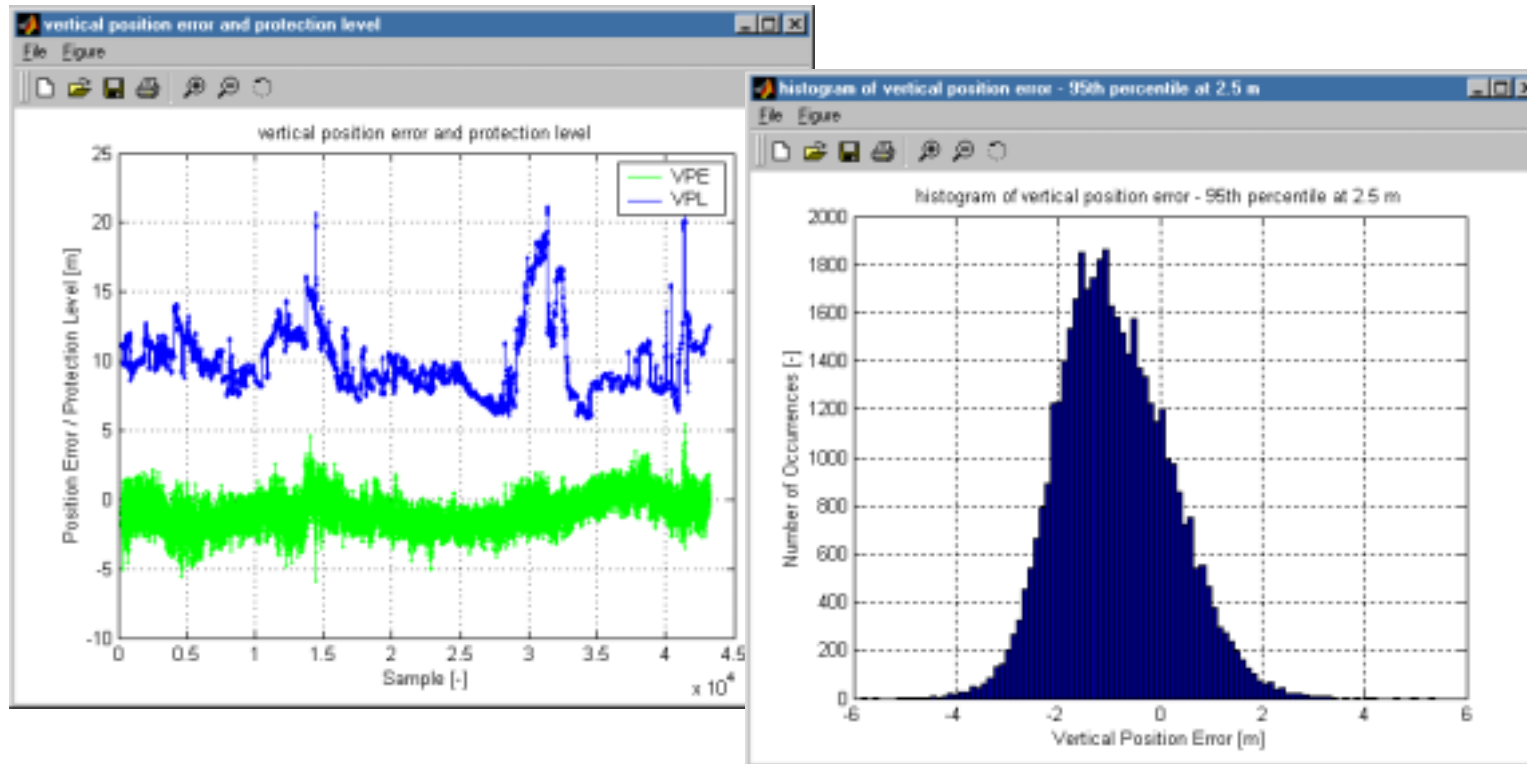
The analysed data can be ESTB message type data or position solution and protection level data.

In the current version of PEGASUS*Plus the following graphical displays are implemented: EGNOS message distribution, Fast and Slow correction analysis, Ionospheric analysis, Position error and protection levels analysis.

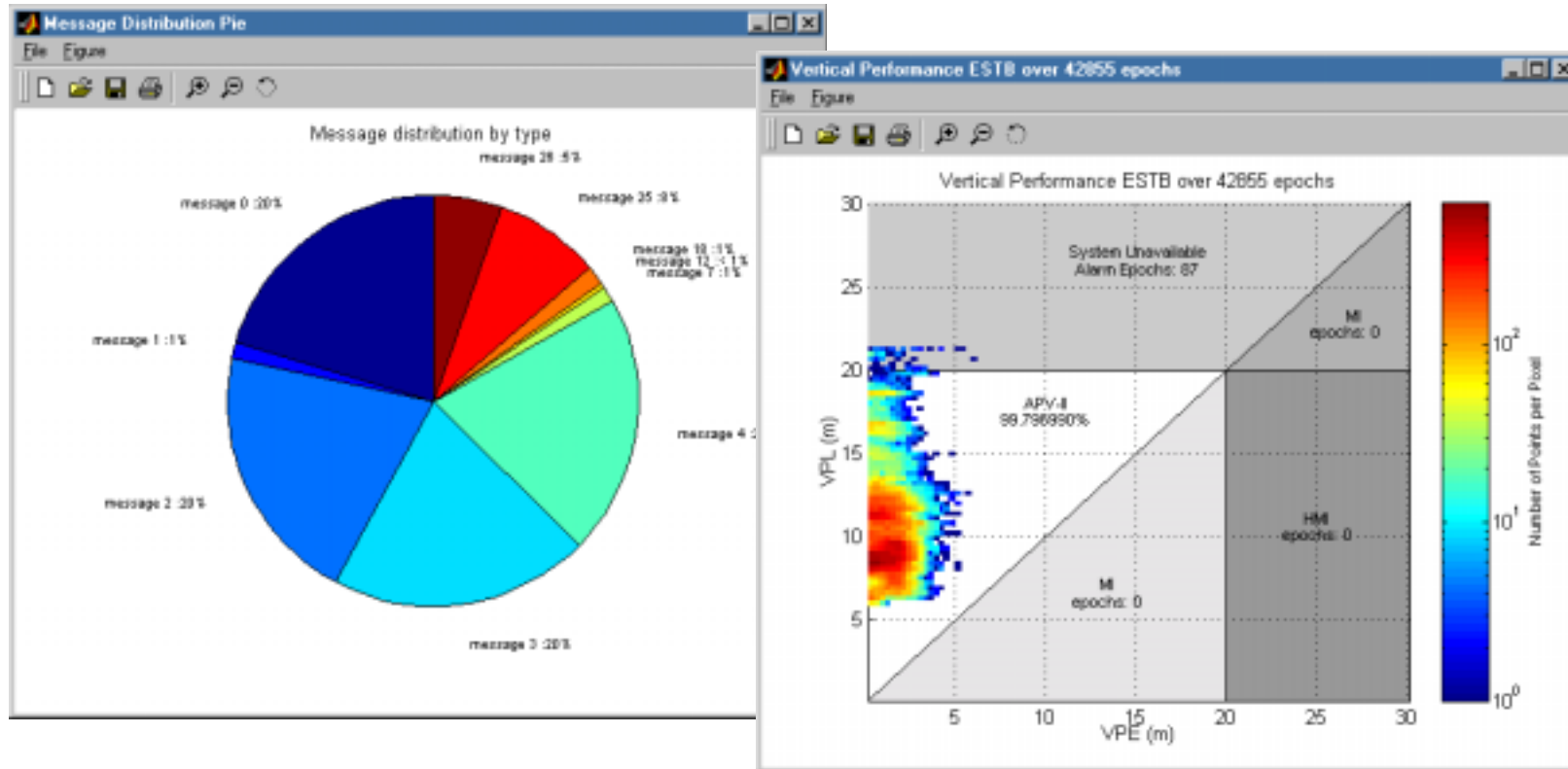


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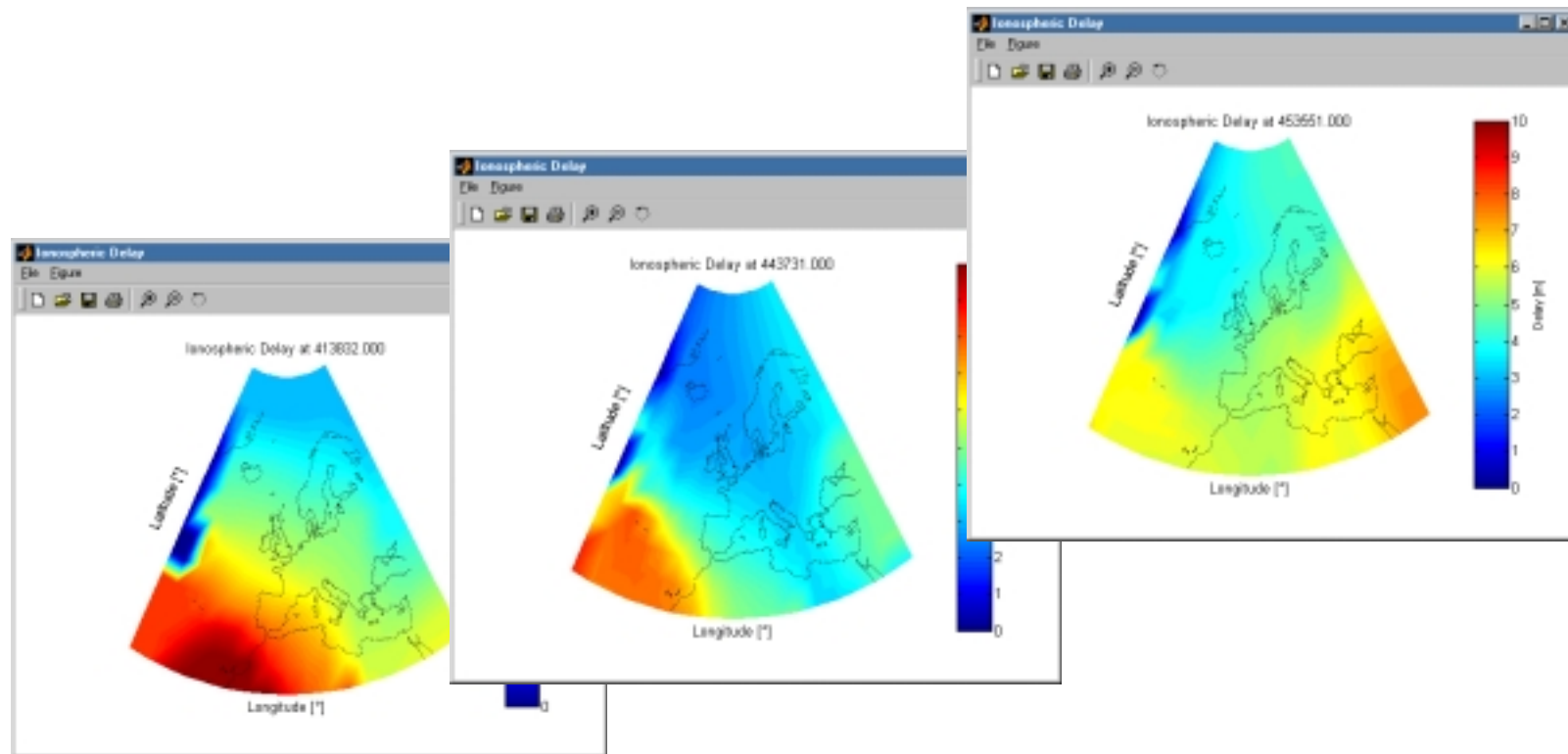
Position error and protection levels analysis



Message distribution and ESTB performance



Ionospheric delay





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Next release updates

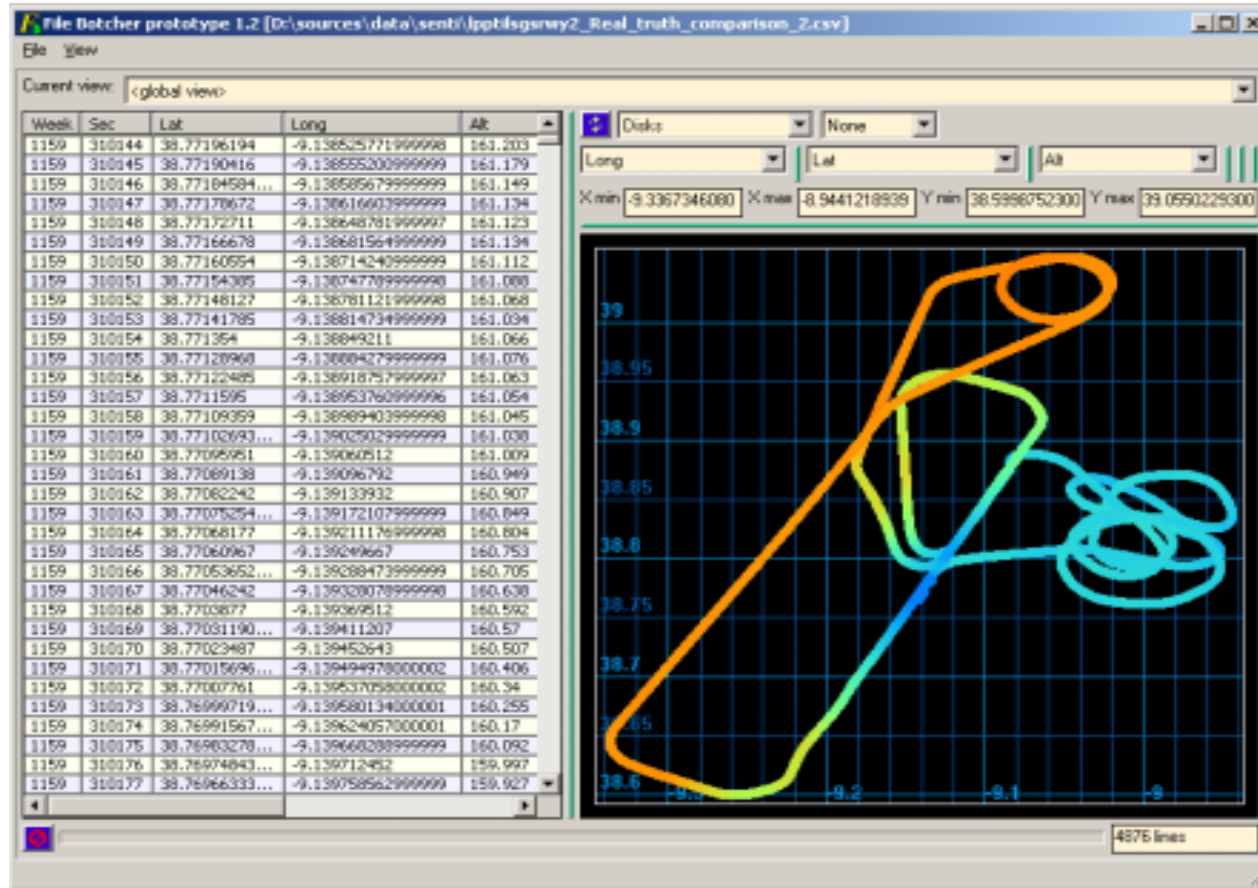
As users are processing larger amounts of data and the Signal-in Space standards continuously evolve, the PEGASUS*Plus tool will be improved in parallel. In the new release to be delivered at the end of this year, two major updates will be added :

- > File manager: A new functionality included in the frame that permits to easily manage, analyse and combine data from input files collected during long term recording campaigns. This manager will allow also to search for individual elements in large data files set and to execute predefined scenarios on them. An additional possibility to display data numerically and graphically will be included as a part of the file manager.
- > The conformance to the DO229B standard signal in space. This change is mandatory because the ESTB transmits data according to this standard since September 2002. The future versions of PEGASUS*Plus will continue to follow the signal in space changes.
- > Changes requested by system users as a part of the ongoing user support.



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File manager





Future extensions

The future versions of PEGASUS*Plus will support new GNSS data processing needs, and in particular GBAS activities.

To support the Operational Validation activities, the GBAS Project is developing a GBAS Modular Analysis and Research System (MARS) allowing to collect and evaluate relevant data and provide required results. MARS will be able to assist Air Traffic Service Providers to carry out site approval and obtain operational approval of a GBAS installation for supporting CAT-I precision approach conditions at an airport from their respective safety regulation authorities. In order to support MARS with PEGASUS*Plus, the following modules will be added :

- > New receivers in the Convertor module.
- > A module providing integrity prediction from satellites constellation analysis.
- > A Carrier phase processing module for automated generation of truth reference tracks.
- > An aircraft dynamics analysis module taking to account various offsets for multiple antennas.
- > An approach procedure display module providing an approach chart view .
- > Multi-path evaluation functionality using a specialised receiver.



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Conclusion.

PEGASUS*Plus is a widely used modular software package dedicated to GNSS validation activities.

- > The first PEGASUS*Plus objective was to provide an initial system for evaluating the quality of the SBAS Signal in Space provided by the EGNOS Test-Bed.
- > The second step is an evolution of PEGASUS*Plus towards a tool for the use in the operational validation of EGNOS.
- > In a third step, it will have to concentrate on GBAS system validation.
- > The next step could be to augment PEGASUS*Plus with new modules dedicated to Galileo validation.