magicGNSS: Precise GNSS Products Out of the Box

R. Píriz, A. Mozo, P. Navarro, D. Rodríguez, *GMV, Spain*

BIOGRAPHY

Ricardo Píriz has a Master of Science in Aerospace Engineering, from the Universidad Politécnica de Madrid, Spain. He is Product Manager within the GNSS Business Unit of GMV.

Álvaro Mozo has a Master of Science in Aeronautical Engineering, from the Universidad Politécnica de Madrid, Spain. He is Head of the GNSS Algorithms and Products Division within the GNSS Business Unit of GMV.

Pedro Navarro has a Bachelor of Science in Mathematics from the University of Murcia (Spain) and Postgraduate studies in Theoretical Physics at the University of Valencia (Spain). He is a Senior Engineer at GMV.

Daniel Rodríguez has a Masters of Science in Telecommunication Engineering from Polytechnic University of Catalonia, Spain. He is a Senior Engineer at GMV.

ABSTRACT

Today, an increasing number of users need high-quality GNSS products, such as precise satellite orbit and clock estimations and predictions, accurate receiver coordinates or tropospheric delays, for their applications (e.g., precise point positioning, GNSS augmentation services, weather services, etc). While there are a number of products and tools available for this purpose (e.g. IGS products, or different GPS processing SW packages developed by research institutions), these are sometimes not tailored to the specific user needs and often difficult to use and not developed according to industry quality standards.

GMV is a developer of high-technology solutions and products in several domains, including aerospace, defense, transport, IT and medicine. Over the last two decades, GMV has accumulated a vast expertise in the development of precise Orbit Determination and Time Synchronization (ODTS) algorithms and tools, especially in the GNSS field, through a number of activities. These activities include the development of Precise Orbit Determination SW packages for use in several satellite missions, the participation in the European GNSS programmes EGNOS and Galileo since their early stages, as well as a strong R&D activity to improve skills and foster innovation is this key area.

With all this background, GMV is in the process of developing *magicGNSS*, a suite of software and data products covering a wide range of GNSS user needs. *magicGNSS Beta* is already available online at magicgnss.gmv.com. This is a free-of-charge online service for registered users. At present it provides a fully-functional demo version of the Orbit Determination & Time Synchronization (ODTS) module processing past and current GPS data from a network of global IGS stations.

INTRODUCTION

magicGNSS is envisaged to be a suite of data and software products to support a wide variety of GNSS projects and objectives, including service volume simulations, core operational functions (such as orbit, clock, and ionosphere determination and prediction), receiver performance analysis, added-value services including integrity, local augmentation developments, and all related performance and accuracy analyses. The *magicGNSS* suite may be applied to projects related to GPS, Galileo, or Glonass, as well as their augmentation systems, both space-based (SBAS) and ground-based (GBAS).

For example the Service Volume Simulator (SVS) is a tool that allows the system analyst a rapid evaluation of navigation performances for different user applications in different environments (including urban canyons). SVS demonstrates the benefits to be gained with a combination of navigation systems and sensors to support feasibility and cost-benefit studies.

The IONO algorithm calculates the ionospheric electronic content using geometry-free dual-frequency data from a global network of GPS (and Galileo) stations. It can also extract the station and satellite inter-channel bias for a pair of separate frequencies. The ionospheric electronic density can be fitted to the NeQuick ionospheric model (version 2) which uses just 3 broadcast parameters for the single-frequency user.

The SBAS module provides SBAS performance assessment of the Signal-in-Space (SIS) from an existing SBAS or of a possible SBAS defined by a set of regional GPS stations. Friendly and easy-to-use, users can obtain a report of the overall SBAS performance in terms of precision, availability, continuity and integrity in both pseudo-range and position domains. SBAS module supports any SBAS with MOPS and SARPS compliant messages: WAAS, EGNOS, MSAS, etc. It also processes real GPS data in RINEX format.

Another module in the suite for the end user is the Receiver Performance Analysis (RXAN) software tool that implements receiver algorithms providing GNSS performance (GPS, Glonass and SBAS Systems) given the *true* position as entered by the user. It can process data from several receiver models, RINEX navigation and observation files, and SBAS messages, and provides standard performance and integrity information.

The first version of the suite is called *magicGNSS Beta* and it provides online near real-time GPS data processing using the Orbit Determination & Time Synchronization (ODTS) algorithm to generate precise orbits, clocks, tropo and station coordinates in a very friendly and easy way. *magicGNSS Beta* is a free-of-charge online service for registered users and can be accessed at the http://magicgnss.gmv.com web address.

OVERVIEW OF MAGICGNSS BETA

magicGNSS Beta (hereafter in this paper referred to as simply *magicGNSS*) is a web application whose address is magicgnss.gmv.com. Figure 1 shows the application's main page.

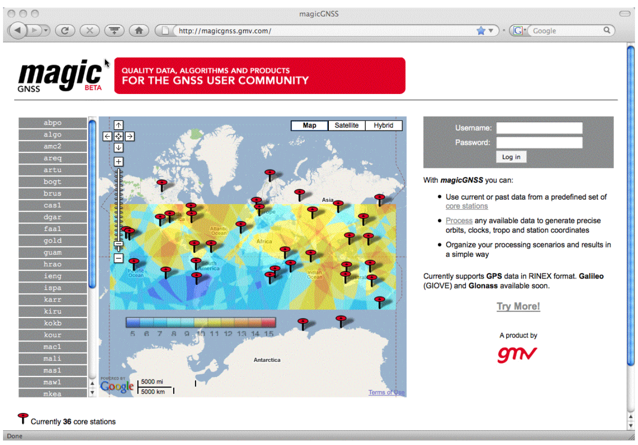

Figure 1: The *magicGNSS Beta* web site

The *magicGNSS* server maintains data from a selected subset of ground stations from IGS, the International GNSS Service [Ref. 1]. They are called *core stations* throughout the application. Core station data is available starting from July 1st 2008, to current time (with a latency of typically one hour).

The algorithm that processes station data to generate products in *magicGNSS* is called ODTS, which stands for *Orbit Determination & Time Synchronization*. The basic ODTS input measurements are pseudorange (code) and phase L1-L2 dual-frequency iono-free combinations. The raw input code and phase measurements are decimated and used internally by ODTS at a typical rate of 5 minutes. ODTS is based on a batch least-squares algorithm that minimizes measurement residuals solving for orbits, satellite and station clock offsets, phase ambiguities, and station tropospheric zenith delays.

The ODTS process generates the products shown in Table 1. As far as possible the products follow the file formats endorsed by the IGS (see http://igscb.jpl.nasa.gov/components/formats.html).

Product	**Format**
ODTS Report	PDF
Estimated satellite orbits	SP3
Predicted satellite orbits	SP3
Estimated satellite clocks	clock RINEX
Predicted satellite clocks	clock RINEX
Estimated station clocks	clock RINEX
Estimated Zenith Tropo Delay	txt
Estimated Station Coordinates	SINEX
Estimated Solar Radiation Parameters	txt
Estimated Earth Rotation Parameters	erp

Table 1: The ODTS products

What accuracy can be expected from the *magicGNSS* products? Figure 2 shows a comparison between orbits and clocks estimated by ODTS and the final IGS products. The comparison has been done for a set of consecutive ODTS executions covering one week of data using data from 30 IGS stations.

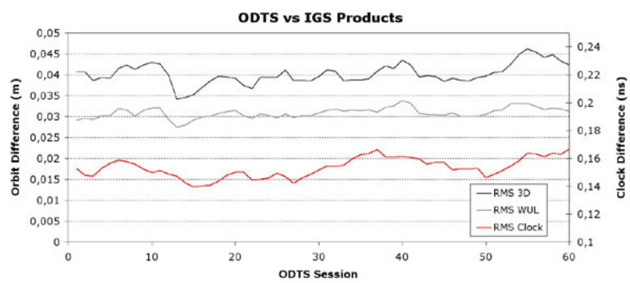

Figure 2: Comparison between ODTS vs IGS products

As can be seen from the figure the orbit RMS difference is at the level of 4 cm and the clock RMS difference is around 0.15 ns. This shows that ODTS products achieve a quality similar to that of the IGS products. This is of course assuming you use the full core station network, and data from all core stations is available.

INPUT DATA

As a general rule, the products generated by the ODTS process (orbits, clocks, tropospheric delay and station coordinates) are of a better quality if you use data from a high number of globally distributed stations. On the other hand, the higher the number of stations, the greater the computer time required to process their data on the server.

A station coverage map like the one shown on the *magicGNSS* web page (and in Figure 3) shows how well the network of stations is distributed to provide coverage for GNSS satellite tracking.

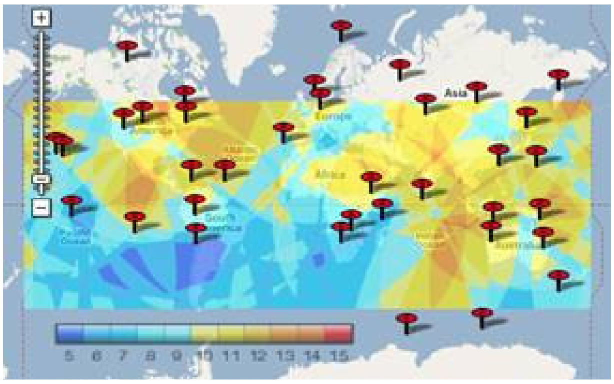

Figure 3: The coverage map of the core stations

On such a map, the color code indicates the number of stations in view of the satellite at the sub-satellite point and at the GPS height (20,200 km). The number of stations in view is also expressed as *Depth of Coverage* (DOC). The coverage, or DOC, map is truncated at ±55° latitude, which corresponds to the GPS orbit inclination towards the equator, and is then the maximum latitude for a GPS sub-satellite point. The DOC color scale ranges from the minimum to the maximum DOC (between ±55° latitude), for the selected network of stations.

The *magicGNSS* core stations guarantee at least a DOC=5 everywhere. For maximum product accuracy all core stations should be used in the ODTS process. For faster processing, but less accurate products, you can use a smaller station network in your scenario. As a rule-of-thumb, the smallest network of stations that can be reliably processed by ODTS should be one that provides at least a DOC=2 everywhere. This corresponds to a minimum network of around 13 stations distributed evenly worldwide.

The core station data is shared with the IGS Real Time Pilot Project in which GMV participates. Every hour, the latest data is downloaded from the IGS servers in RINEX format (15-minute files) and stored in the *magicGNSS* server. Thus the data latency is typically between 1 and 2 hours. This allows the user to monitor in near real-time the status of the station network and of the GPS constellation, for example to analyze the behavior of all atomic clocks (on-ground and in-space) with a delay of just a couple of hours.

One interesting feature of *magicGNSS* is the automatic download and processing of the *Notice Advisory to NAVSTAR Users* (NANUs) issued by the U.S. Coast Guard Navigation Center (www.navcen.uscg.gov). This allows to maintain a database where unhealthy or unusable satellites are identified at any time. These satellites are automatically removed from the ODTS processing, which greatly increases the robustness of the algorithm and the quality of the resulting products.

Earth Rotation Parameters (ERPs) are also automatically downloaded from the International Earth Rotation Service (IERS) server, in such a way that the ODTS always uses the latest IERS estimations and predictions. By default ODTS uses the values published by the IERS, but it is also possible to estimate ERPs within the ODTS process.

For all the core stations, a priori coordinates from the International Terrestrial Reference Frame (ITRF) or IGS solutions are kept in the *magicGNSS* database. The user has the possibility to refine the a priori coordinates within the ODTS estimation process.

THE ODTS ALGORITHM

The ODTS software is based on a batch least-squares algorithm that processes stations data files in RINEX format, solving for orbits, satellite and station clock offsets, phase ambiguities, station tropospheric zenith delays, and station coordinates.

Dual-frequency measurements from the two GPS carriers (L1 and L2 frequencies) are processed in ODTS in order to remove the ionospheric delay. This is done at pre-processing level. The tropospheric delay is removed as part of the estimation process, modeled as a zenith delay for each station using a mapping function to account for the measurement elevation. Station tropospheric zenith delays are estimated as constant values every two hours. Pseudorange (code) and phase measurements are used in ODTS. The code measurements are smoothed using the phase by means of a Hatch filter. This reduces the level of noise/error of the code from typically one meter in the raw code to around 30 cm or less in the smoothed code.

This technique reduces the level of error in the satellite and station clock estimations.

Within ODTS, the satellite and Earth dynamics are based on high-fidelity models that follow IERS recommendations. Modeled forces include a full Earth gravity model, Sun, Moon and planetary attractions, solid Earth tides, and Solar Radiation Pressure (SRP), including eclipses. Earth Rotation Parameters (ERPs) are downloaded from the IERS server, but they can also be estimated by ODTS itself. A priori station coordinate values come from ITRF or IGS solutions, and they can be refined within the ODTS process.

The orbit fit is based on the estimation of the initial state vector (position and velocity) and 5 empirical Solar Radiation Pressure (SRP) parameters. The satellite orbits can be propagated (predicted) into the future time using the estimated parameters and the ODTS internal dynamic model.

Satellite and station clock offsets are estimated with respect to a reference clock, normally provided by one of the stations. Clocks are calculated as snapshot values, i.e., as instantaneous values at the measurement time stamp. Thus, clocks are estimated at the same rate as the internal measurements used by the ODTS (typically every 5 minutes). These estimated snapshot values are adjusted to a linear model that can be extrapolated into the future for clock prediction.

A particular aspect of the ODTS software is the usage of an empirical Solar Radiation Pressure (SRP) model for all GPS satellites. Figure 4 shows the reference frame used for the empirical SRP model.

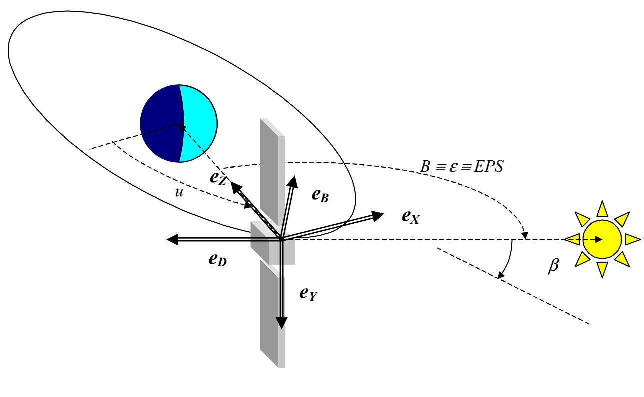

Figure 4: Reference frame for the radiation model

In this frame the *Y* axis is oriented along the solar panels rotation axis, the *D* axis is oriented in the direction from the Sun to the satellite, and the *B* axis completes a right-handed frame. The major component of the solar radiation force is clearly in the *D* direction, since the solar panels are permanently oriented perpendicular to the Sun.

D_0, Y_0, B_0, B_C, B_S are empirical coefficients estimated in the ODTS process along the 3 reference frame directions. The D_0 coefficient is equivalent to the classical C_R radiation pressure coefficient for a cannonball model. The Y_0 coefficient is the well-known GPS "Y-bias", which represents the component of the force along the solar array. The B_0, B_C, B_S coefficients capture the continuous and one-revolution (sine and cosine) effects on the direction perpendicular to the Sun direction. D_0 is non-dimensional and the rest of coefficients are measured in units of acceleration.

This empirical radiation model simplifies the satellite dynamics and requires no a-priori information about the satellite geometrical and reflectivity properties, just approximate mass and area values are needed. The estimation of the 5 empirical SRP coefficients, together with the 6 components of the satellite initial state vectors (position and velocity), i.e. 11 dynamic parameters in total, allows orbit estimation accuracies well below the decimeter. No other empirical accelerations are used.

A TOUR OF MAGICGNSS

This section describes a typical *magicGNSS* session on the web. The screenshots have been extracted from the video tour available for download on the *magicGNSS* main web page. The username *johnsmith* is used as an example of new user. Figure 5 shows how the web page looks like when *johnsmith* logs in for the first time.

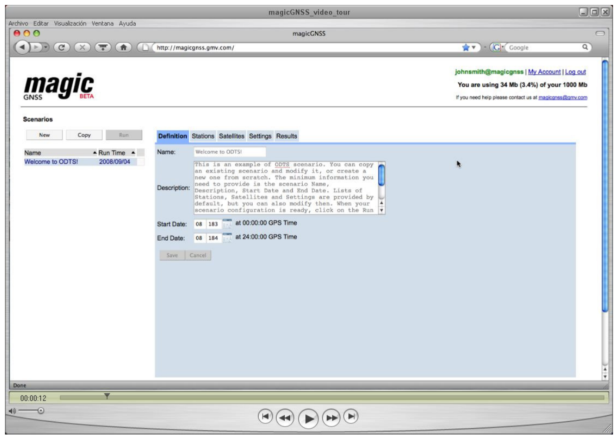

Figure 5: A new user logging in for the first time

The concept of *scenario* is fundamental within *magicGNSS*. A scenario is simply an interval of time for which station data is to be processed and results generated. A scenario is mainly defined by its Start Date and its End Date. Scenarios are listed on the left side of the page. A sample scenario called "Welcome to ODTS!" is provided as a typical example. This scenario cannot be deleted. Of course the user can create new scenarios (using the *New* button) or copy existing ones (using the *Copy* button).

In the following we show how to create and run (i.e., process) a new scenario. We click on the *New* button and go to the *Definition* tab where we enter the scenario Name ("Example 1" in this case), optionally a Description (blank), the Start Date and the End Date. This is shown in Figure 6.

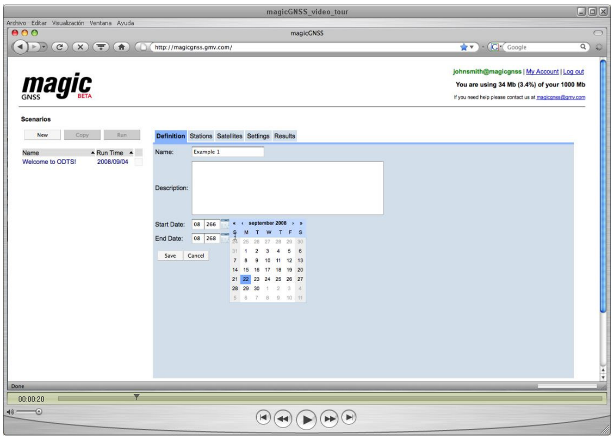

Figure 6: Definition of a new scenario

By default yesterday is selected as Start Date and today is selected as End Date (both relative to GPS Time, which is currently ahead of UTC by 14 seconds). In this way the user can process very easily the latest data available. Dates can be entered as year (yy) and day-of-year (doy) but a calendar is also available to select days in a more common way. Of course the user can select any other dates between July 1st 2008 and today. The minimum duration of a scenario is one day and the maximum one is currently two days.

We click now on the Save button and the new scenario "Example 1" is stored on the left-side Scenario list, as shown in Figure 7.

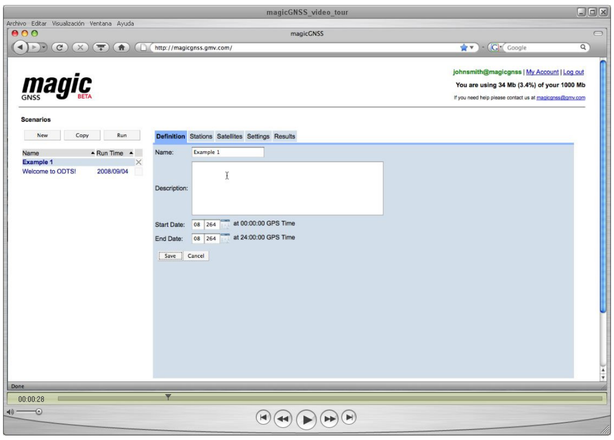

Figure 7: A new scenario called "Example 1"

On the Scenario list, scenarios can have three states:

1. Scenarios that have already been run (processed) appear in normal typeface and their Run Time is shown (as for example "Welcome to ODTS!" in Figure 7.)
2. Scenarios that have been created but have not been run yet appear in bold typeface and with no Run Time (as for example "Example 1" in Figure 7.)
3. A scenario that is currently running is shown in bold red typeface (see below). For a given user, there can be only one scenario running at any time, it is not possible to run several of them at the same time.

Any scenario (already run or to be run) can be deleted at any time by clicking on the delete icon ( ) to the right of the scenario Run Time. The "Welcome to ODTS!" scenario cannot be deleted.

If an scenario has been already run, you cannot run it again, but you can make a copy of it (see below) and run the new one.

We could now run the "Example 1" scenario we have just created. The Stations, Satellites and Settings tabs contain default values that do not actually need to be modified by the user for a successful run. However in this example we are going to see how the Stations, Satellites and Settings tabs look like and to make some modifications on them. The Stations tab is shown in Figure 8.

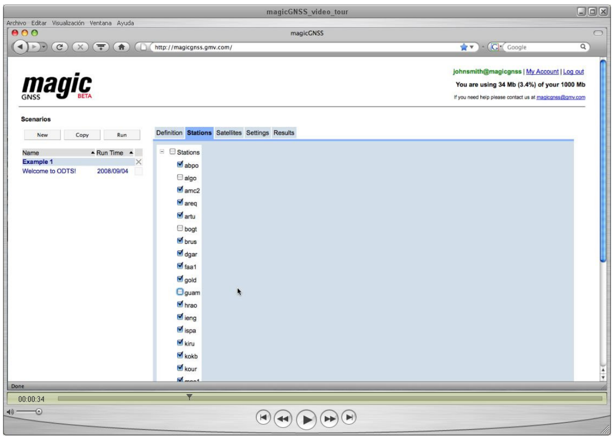

Figure 8: The Stations tab

The Stations tab shows all the core stations available. By default they are all selected. On the example in Figure 8 three of them have been deselected by the user. As explained above, if too many stations are deselected the ODTS process is likely to fail. In the near future a map will be implemented on the Stations tab to see the geographical location of the stations and their coverage.

We now click on the *Save* button below and move on to the Satellites tab shown in Figure 9.

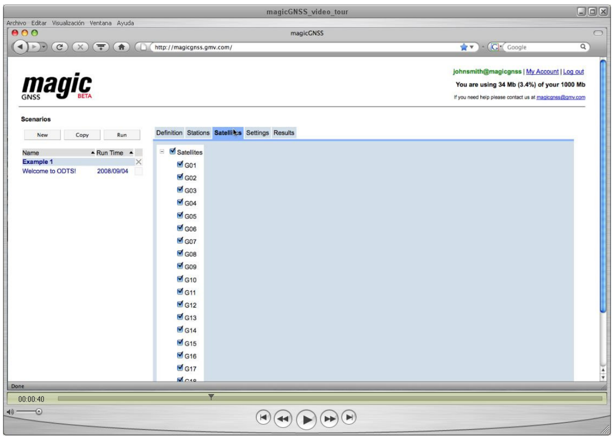

Figure 9: The Satellites tab

The Satellites tab shows all the GPS satellites available, sorted by PRN number. By default they are all selected. It is recommended not to deselect any satellite unless you know beforehand that a particular satellite is not behaving well. This is not really necessary because the application takes care of NANUs and problematic satellites are automatically discarded before the ODTS processing starts.

The Settings tab is shown in Figure 10.

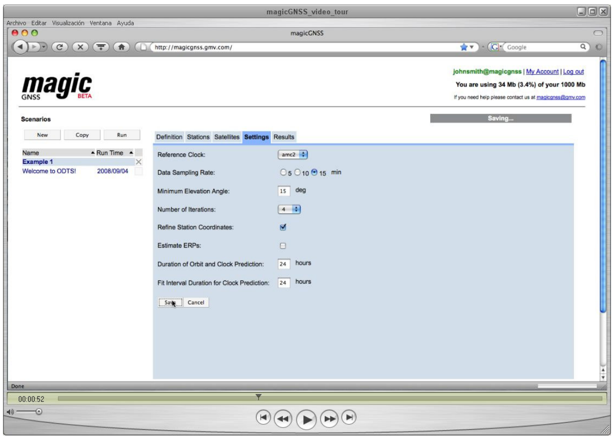

Figure 10: The Settings tab

The following Settings can be currently modified by the user:

1. Reference Clock: one core station must be selected as reference clock for all the clock estimations in ODTS (satellites and stations); by default the `uns3` station at USNO, Washington, is selected. If the chosen station does not provide enough data for the current scenario, the application might automatically select a different core station giving better data availability.
2. Data Sampling Rate: this is the rate to which the raw input measurements (code and phase) are decimated and used internally by the ODTS. The output estimated clocks (satellites and stations) will be given at this sampling rate too. Increasing the Data Sampling Rate reduces the processing time but also reduces the resolution on the estimated clocks. By default 5 min is selected.
3. Minimum Elevation Angle: the ODTS discards measurements below this elevation angle at the station. By default 15 deg is selected. The measurement error/noise is typically higher at low elevations (mainly because of multipath), therefore choosing a higher Minimum Elevation Angle allows for "cleaner" measurements (and therefore smaller code and phase residuals) at the cost of less data availability overall. Some parameters can be slightly affected by systematic multipath errors at low elevations, for example the estimated station coordinates.
4. Number of Iterations: this is the number of iterations to be done by the ODTS least-squares process. By default 4 is selected. Experience shows that typically after 4 iterations the ODTS has converged and that beyond that the solution virtually does not change anymore. If you want to be absolutely sure that the ODTS reaches an optimal solution from a mathematical point of view, you can increase the Number of Iterations to 6 or 7, a maximum of 10 is allowed. Of course the higher the Number of Iterations the longer the time needed by ODTS process to finish.
5. Refine Station Coordinates: if this checkbox is selected the ODTS algorithm will re-estimate the a priori station coordinates stored in the database. Internally the coordinate estimation is constrained so that station coordinate values do not move arbitrarily. By default the Refine Station Coordinates option is selected.
6. Estimate ERPs: if this checkbox is selected the ODTS algorithm will estimate the Earth Rotation Parameters instead of taking the IERS values. By default the Estimate ERPs option is deselected. In general it is not a good idea to estimate station coordinates and ERPs at the same time, since the global terrestrial reference frame defined by the stations is largely correlated with the ERPs.
7. Duration of Orbit and Clock Prediction: this is simply the duration of the predicted orbit and clock files generated by ODTS (see Table 1). By default one day is selected. Predictions start at the end of the End Date selected for the scenario.
8. Fit Interval Duration for Clock Prediction: estimated clock values are adjusted to a linear model that can be extrapolated into the future for clock prediction. This setting defines the duration of the adjust interval, counting backwards from the end of the End

Date selected for the scenario. By default one day is selected. The clock fit to the linear model is done using a simple least-squares scheme.

We are now ready to run the new "Example 1" scenario. We click on the Run button, the ODTS process starts on the server, and the new scenario becomes "red" as shown in Figure 11.

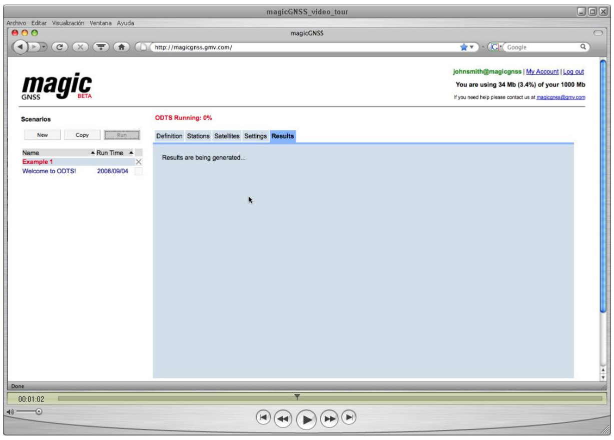

Figure 11: The new scenario is running

A red progress banner also pops up at the top of the page showing the text "ODTS Running:" and the percentage of the process currently completed. The Results tab shows now this message: "Results are being generated…" At this point you cannot run any other scenario and you cannot stop the one currently running, but you can continue to do things in the meantime as explained hereafter.

The web technology behind *magicGNSS* is based on AJAX. This technology allows to communicate with the server in an asynchronous way to update different parts of the web page without having to refresh the whole page. This results in more responsive and dynamic web applications, allowing for example to create/copy/delete scenarios while the ODTS is running and the progress banner is being updated. Figure 12 shows an example of this where, while "Example 1" is running, *johnsmith* has created a new scenario ("Example 2"), copied an existing one ("Copy of Example 1"), and is just deleting this one.

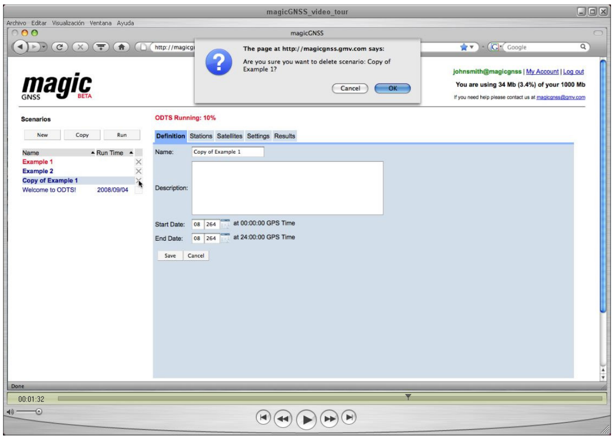

Figure 12: A responsive and dynamic web application

Finally, once the ODTS process has finished, the "Example 1" scenario turns from bold red to normal typeface with the Run Time attached to it. The Results tab shows now the message "Results successfully generated." By clicking on the *Download Results* button shown in Figure 13 the user downloads a ZIP file containing the 10 product files described in Table 1.

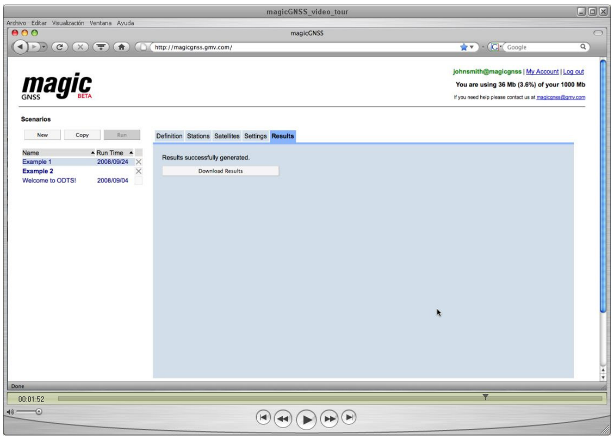

Figure 13: Results are ready to be downloaded

The most relevant of the products is the ODTS Report in PDF format that is described in the next section. This report allows a very complete diagnosis and understanding of the ODTS process and its results.

Each user scenario takes some disk space on the server, mainly because of the ZIP file containing the results (a few Megabytes). The ZIP file is kept within each scenario, and the user can download the results at any future time as long as the scenario is not deleted. Since the disk quota given by default to the user is quite generous (1 Gigabyte), there is no real need to delete scenarios.

For the user convenience, scenarios can be sorted by Name and by Run Time, in ascending or descending order, by clicking on the ▲ and ▼ arrows. By default the scenarios are sorted by ascending Run Time order in such a way that new and recent scenarios always appear on top.

THE ODTS REPORT

This section describes the ODTS Report in PDF format, which is the most notorious ODTS product. The report has been designed to be self-explanatory, and a full example is available for download on the *magicGNSS* main web page for the interested reader.

The ODTS Report cover page contains the scenario Definition, including username, scenario Name, Start Date, End Date, and Run Time. An example is shown in Figure 14.


magicGNSS ODTS REPORT

magic GNSS BETA

A product by

gmv

ODTS REPORT

Username: johnsmith
Scenario: Example
Start Date: 2008/09/15 00:00:00 (08259)
End Date: 2008/09/16 24:00:00 (08260)
Run Time: 2008/09/23 16:59:30 UTC

All times are GPS Time unless otherwise stated

QUALITY DATA, ALGORITHMS AND PRODUCTS FOR THE GNSS USER COMMUNITY

magicgnss.gmv.com
www.gmv.com

© GMV Aerospace and Defence, S.A., 2008 1

Figure 14: ODTS Report cover page

The ODTS Report is structured in three main sections:

1. Configuration Summary: this is just a printout of the scenario configuration as defined by the user on the web application, including List of Stations, List of Satellites, and Settings.
2. Processing Summary: a summary of the least-squares iterative estimation process, including total number of measurements and estimated parameters, code and phase residuals on each ODTS iteration, map of non-rejected stations and their corresponding DOC (see example in Figure 15), number of used and rejected measurements per station and per satellite, code and phase residuals per station (see example in Figure 16) and satellite, and information about satellites in eclipse (see example in Figure 17).

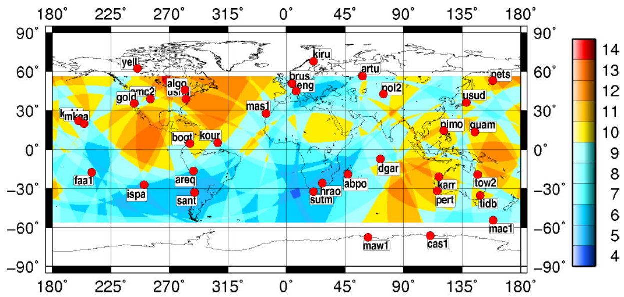

Figure 15: Example of DOC map

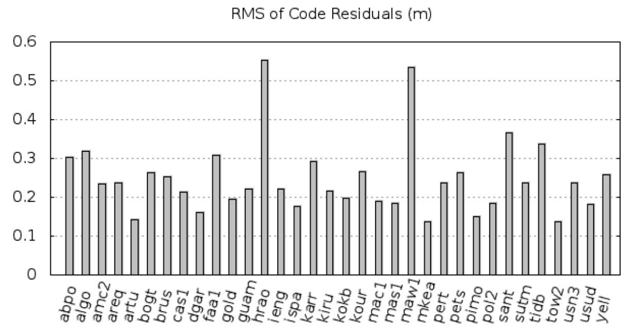

Figure 16: Code residuals per station

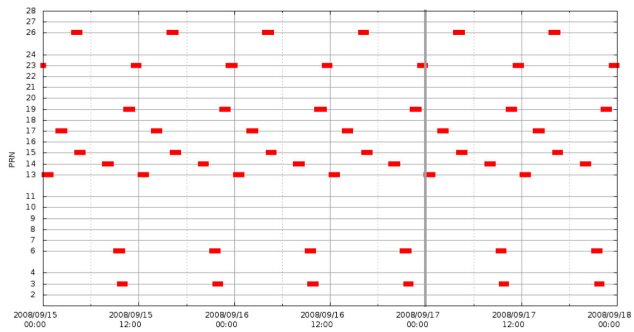

Figure 17: Satellites in eclipse

3. Products Summary: this is the main section in the ODTS report, describing in a graphical way the products that have been generated, including Zenith Tropospheric Delay plots per station (see example in Figure 18), estimated Solar Radiation Pressure (SRP) coefficients for all GPS satellites (see example in Figure 19), satellite clock offset evolution plots with respect to the reference clock after removing a parabola (see example in Figure 20), satellite clock

stability plots in terms of Allan Deviation [Ref. 2] (see example in Figure 21), station clock offset evolution plots (see example in Figure 22), station clock stability plots (see example in Figure 23), and difference between a priori and refined station coordinates, if applicable (see example in Figure 24).

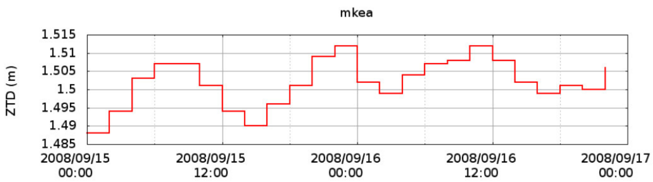

Figure 18: Example of Zenith Tropospheric Delay plot

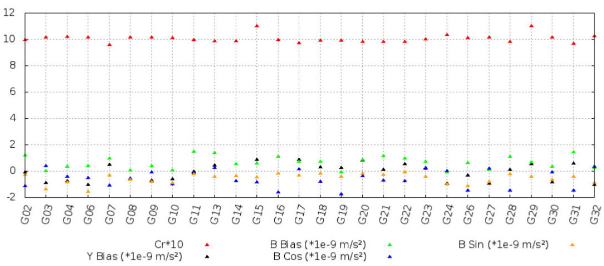

Figure 19: Solar Radiation Pressure (SRP) coefficients

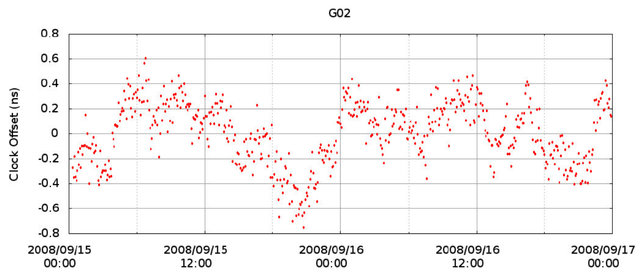

Figure 20: Satellite clock offset evolution

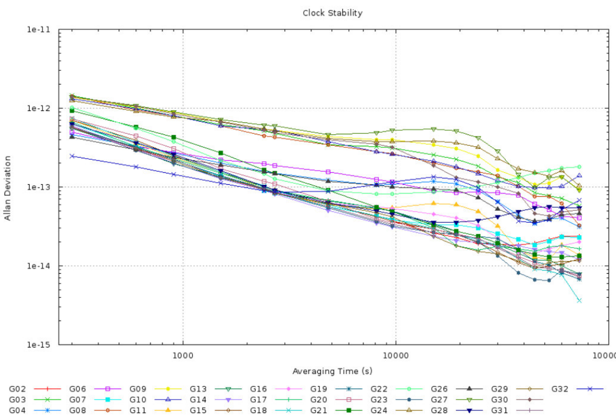

Figure 21: Allan Deviation plot for satellite clocks

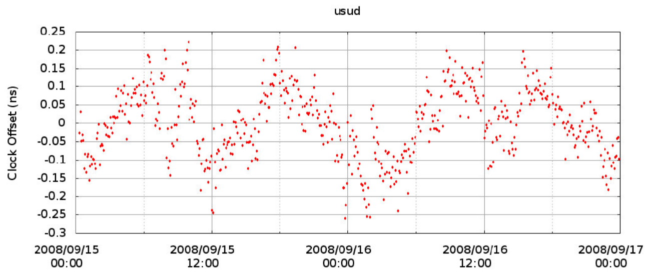

Figure 22: Station clock offset evolution

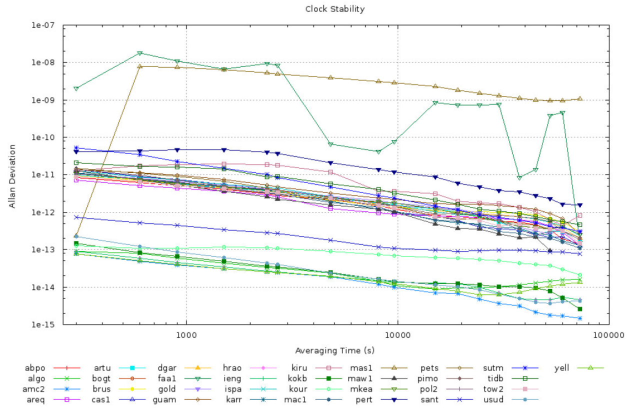

Figure 23: Allan Deviation plot for station clocks

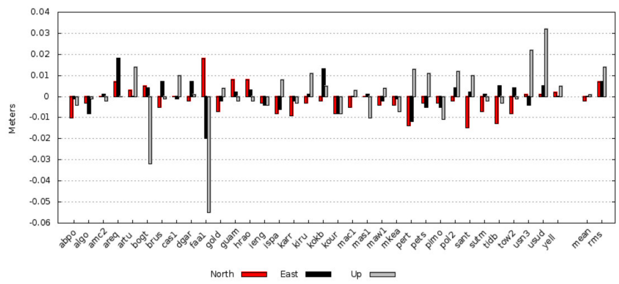

Figure 24: A priori vs refined coordinates

CONCLUSIONS AND FUTURE WORK

magicGNSS Beta is available now online at magicgnss.gmv.com featuring the ODTS algorithm (Orbit Determination & Time Synchronization) using GPS data. At the moment data availability is limited to a pre-defined network of core stations from IGS, but we envisage the implementation of user data upload in RINEX format in the near future. This would allow mixing data from any user station (or stations) with the existing core stations in an ODTS solution.

Two experimental Galileo satellites called GIOVE-A and GIOVE-B have been launched by the European Space

Agency (ESA). GIOVE-B carries the first-ever Passive Hydrogen Maser (PHM) atomic clock in space. GMV participates in the so-called GIOVE Mission to characterize the GIOVE-A and –B orbits and clocks and to generate the navigation message to be broadcast by the satellites. A network of 13 stations worldwide distributed permanently tracks the GIOVE satellites (and also the GPS satellites, since they are dual stations). The experience gained by GMV in the frame of the GIOVE Mission would make the implementation of GIOVE data and processing within *magicGNSS* quite straightforward. This would allow for example monitoring the GIOVE-B PHM stability in near-real time in a very simple way for anyone having a *magicGNSS* account.

The implementation of Glonass data processing in ODTS is also foreseen, using data from dual GPS/Glonass stations from IGS. Some key issues like the estimation of an inter-system bias per station and the usage of a generic (empirical) radiation model for the satellites have been already addressed and successfully solved in the frame of the GIOVE Mission. This will simplify the implementation of Glonass in *magicGNSS*.

Finally, as indicated in the Abstract and Introduction of this paper, ODTS is just the first product of the *magicGNSS* suite. More data, algorithms and services will become gradually available.

ACKNOWLEDGMENTS

We greatly appreciate the efforts done by IGS, the International GNSS Service [Ref. 1], to generate high quality data and products and make them available to the GNSS community in a timely and reliable way.

REFERENCES

1. J.M. Dow, R.E. Neilan, G. Gendt, *The International GPS Service (IGS): Celebrating the 10th Anniversary and Looking to the Next Decade*, Adv. Space Res. 36 vol. 36, no. 3, pp. 320-326, 2005. doi:10.1016/j.asr.2005.05.125

2. D. W. Allan, *Time and Frequency (Time-Domain) Characterization, Estimation, and Prediction of Precision Clocks and Oscillators*, IEEE Trans. UFFC, vol. 34, pp. 647-654, Nov. 1987.