Providing the GPS Navigation Bits (NBS) for LEO GNSS occultation processing in support of atmospheric measurements and research

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Abstract

This poster presents the work led by ESA/ESOC to develop an NBS standard and implement a data service to Eumetsat to support satellite occultation processing. The Navigation Bit Stream (NBS) is the sequence of bits corresponding to the navigation message; these bits contain the satellite's navigation message plus the constellation almanac. The information contained in this sequence of bits can be very useful for radio occultation processing at very low or even negative elevation angles. In the presented work **teqc** is used to extract the navigation bits from the receiver's binary files of a worldwide tracking network of existing CORS.

All the stations in view receive the same bit stream from each of the overhead satellites; therefore there is the high possibility of redundancy. It is considered useful to have a merged file (similar to the 'brdc' combined GNSS navigation message file). This is the reason why ESOC has defined a format that contains the most useful information from the output of **teqc** and that allows the possibility of combining messages from several receivers in a very compact way.

It is proposed that the IGS start accumulating the Navigation bits from multiple stations in the IGS network and that a long-term NBS data repository is developed by the IGS to support occultation processing for LEO satellites.

NBS Precursors

Instigated by the need for complete GPS navigation bit messages to process open-loop radio occultation data, GFZ established a L1-C/A navigation bit archive in June 2007. The data is collected by GFZ's network of ground station GPS receivers and distributed on a "best effort" basis. During the past seven years the total number of receivers feeding the archive has grown from five to more than 20 (see figure) leading to a significant improvement in median sub-frame multiplicity.

Since early 2011 three receivers from the Multi-GNSS Experiment (MGEX) network supplement the raw data records. The current configuration produces an almost complete image of the transmitted C/A code navigation bit data in daily batch processing mode.

A subset of GFZ navigation bit raw data is made available in near-real-time to ESA/ESOC in support of their NBS data service to Eumetsat.

GFZ's navigation bit data archive is open to the scientific community for post-processing applications and may be accessed through GFZ's Information System and Data Center at the URL http://isdc.gfz-potsdam.de.
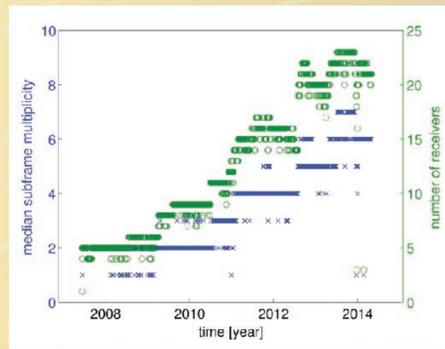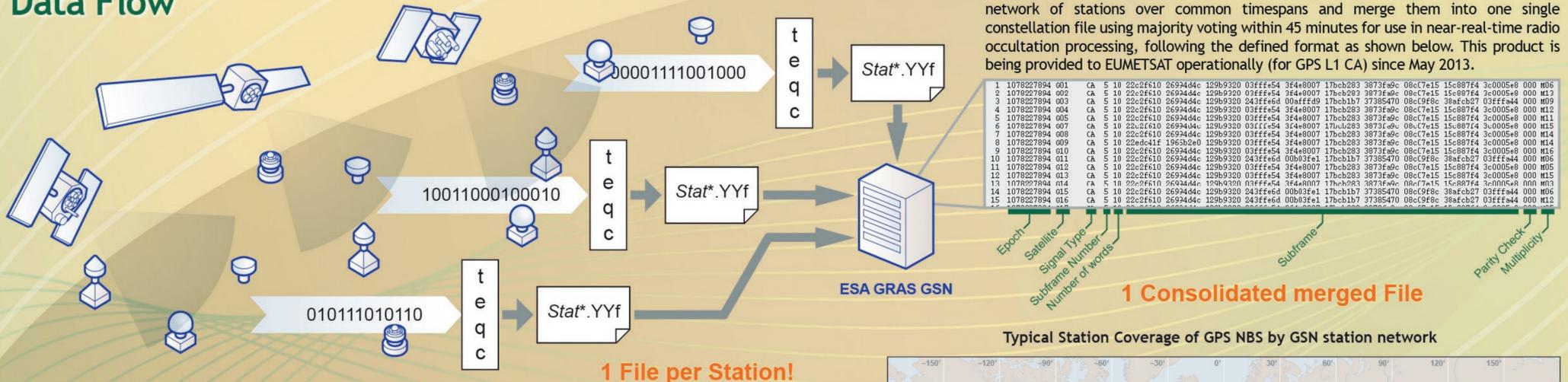

NBS Usage: GRAS Radio Ocultation Processing

Usually GPS receivers provide carrier phase measurements where the navigation bit data have been wiped off as part of the usual closed-loop tracking. Under low signal-to-noise (SNR) conditions, where closed loop algorithms don't work well any more, Radio Occultation (RO) receivers such as GRAS on-board Metop exploit open loop techniques where navigation bits are not automatically removed anymore. As a consequence, the raw carrier phase is chopped up with the navigation bits in open loop mode (see Fig. below, top). However with knowledge of externally acquired navigation bits sequences, navigation bits can be demodulated from the open loop data (see Fig. below, middle and bottom) and can be used in the usual RO processing algorithms in order to improve lower troposphere RO retrievals, especially in the tropics.
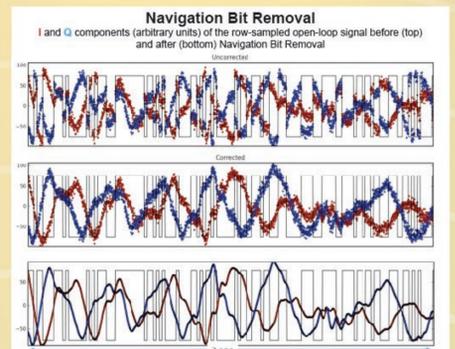
As navigation bit measurements can suffer from reception problems, GSN implements a strict quality control based on the simultaneous observation of the same navigation bit sequences by independent GPS ground receivers ("multiplicity"), aiming for global and continuous coverage with a 45 min maximum delivery window.

Navigation Bit Removal
I and Q components (arbitrary units) of the row-sampled open-loop signal before (top) and after (bottom) Navigation Bit Removal

Data Flow

1 File per Station!

ESA/ESOC has developed a tool to read the **teqc** navigation bit stream files from a network of stations over common timespans and merge them into one single constellation file using majority voting within 45 minutes for use in near-real-time radio occultation processing, following the defined format as shown below. This product is being provided to EUMETSAT operationally (for GPS L1 CA) since May 2013.

1 Consolidated merged File

ESA GRAS GSN

Typical Station Coverage of GPS NBS by GSN station network

99.97% OK
3 station depth, 1.0 deg cutoff

NBS Frames Station Coverage Depth
0   3   6   9   12   15   18   21

Extracting the NBS

In this activity UNAVCO's software **teqc** is used to extract the NBS from certain receiver binary formats that record the full 300 bit CA navigation bits. The table below shows the NBS extraction capabilities of **teqc** using the "+raw_nav" option for which the extraction and correct reporting of the 300-bit NAV for GPS L1CA is well tested.

| Brand	Correct and tested	Preliminarily available	Future
Topcon	300-bit NBS for GPS L1CA		
Javad	300-bit NBS for GPS L1CA	GPS L2C and L5 (300-bit NAV or CNAV)	GPS L1C
Trimble	300-bit NBS for GPS L1CA	GPS L2C and L5 (600-bit CNAV+FEC) GLONASS SA	Galileo FNAV, INAV, CNAV, GNAV Beidou B1I QZSS B1I
Septentrio	300-bit NBS for GPS L1CA	GPS L2C and L5 (300-bit NAV or CNAV) GLONASS SA SBAS L1CA and L5 Galileo FNAV, INAV, CNAV, GNAV Beidou B1I QZSS L1CA, L2C, L5 (300-bit NAV or CNAV)	

Technical discussions with the manufacturers are vital to ensure that we have a correct understanding of what is being presented in their respective formats for raw navigation bits.

Conclusions

A new activity in gathering and storing the Navigation Bit Streams has been presented. The approach uses a majority voting approach from 3 or more stations using the NBS as decoded by **teqc** from receiver binary files. The stations used belong to a dedicated network "GSN" setup by ESOC and its partners to provide GPS products to EUMETSAT for support of their Metop satellite's on-board navigation and radio-occultation GPS receiver. The NBS service has been operational since May 2013 providing +99% of near-real-time products with +99% of NBS frames as agreed with 3 or more stations.
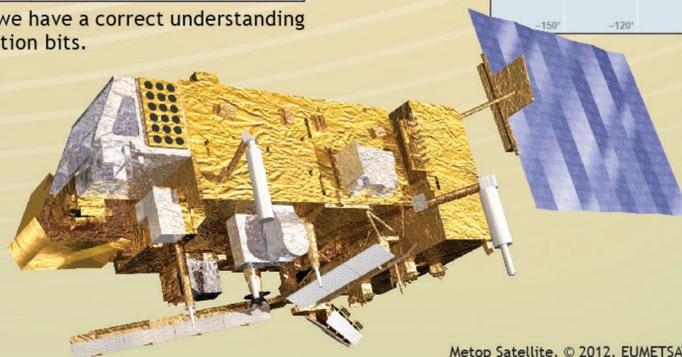
Metop Satellite, © 2012, EUMETSAT
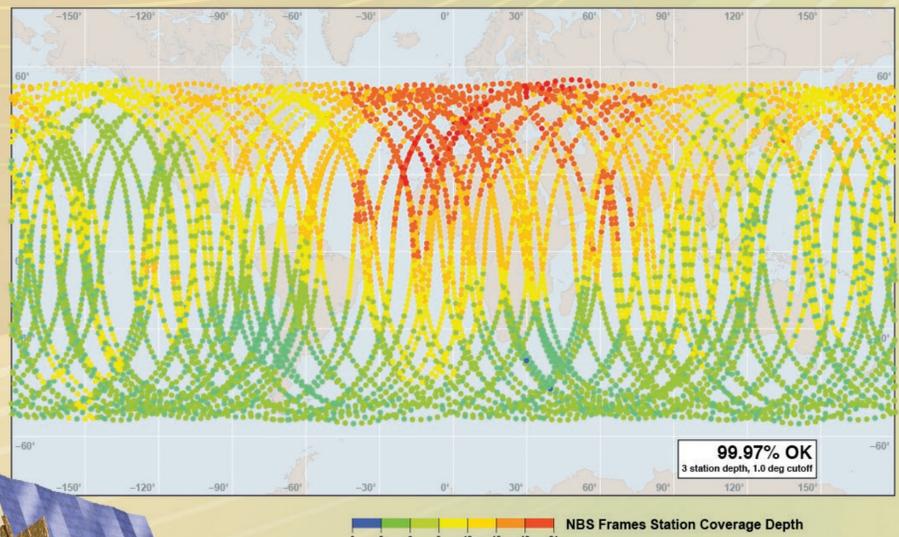
IGS proposal

The consortium presenting this poster proposes to the IGS that it activates a significant number of stations from the IGS network to provide NBS files to the Data Centers. In a dedicated effort the consortium members will support the Data Centers in the creation of merged NBS files so that a global, public, complete and fully redundant NBS repository is created to support GNSS RO and Reflectometry research and applications.