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gLAB Upgrade with DGNSS data processing

Software User Manual for DGNSS processing

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1 INTRODUCTION

The GNSS-Lab Tool suite (gLAB) is an interactive educational multipurpose package to process and analyse GNSS data. The first release of this software package allows processing only GPS data, but it was prepared to incorporate future module updates, such as an expansion to Galileo and GLONASS systems, SBAS and differential processing.

With the current upgrade, gLAB is able to process DGNSS data for GPS positioning (DGPS), as well as being capable of reading and converting RTCM v2.x and RTCM v3.x to gLAB proprietary format and RINEX 2.11 or RINEX 3.00 standard correspondingly.

In the current version, these new functionalities are only available using command line. Future updates will be done to update the GUI.

1.1 DOCUMENT SCOPE AND PURPOSES

This document contains detailed information related to the new functionalities added to gLAB, including an explanation of the new parameters available, output message and usage examples through command line.

1.2 DOCUMENT OVERVIEW AND STRUCTURE

This document is split in sections, which describe:

- A list of all the new parameters for gLAB with their explanation.
- A description of the new output message in gLAB.
- gLAB usage examples through command line.

1.2.1 Applicable documents

The following documents refer to the applicable documents for the project.

AD-01 RTCM Standard 10403.1. “Differential GNSS Services – Version 3”. RTCM. SC-104. October 2006.

AD-02 RTCM 136-2001. “RTCM Recommended Standards for Differential GNSS Service”. RTCM. SC-104. August 2001

AD-03 GNSS Lab Software User Manual, gAGE/UPC, 2009.

1.2.2 Reference Documents

RD-1 RINEX 2.11/3.00 (ftp://cddis.gsfc.nasa.gov/reports/formats/).

1.2.3 Acronyms and Terms

AD	Applicable Document
DGNSS	Differential GNSS
DGPS	Differential GPS
DoY	Day of Year
ESA	European Space Agency
gAGE	Research Group of Astronomy and Geomatics
gLAB	GNSS-Lab tool
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IODE	Issue Of Data Ephemeris
PRC	Pseudo Range Correction
PRN	Pseudo Random Noise
RD	Reference Document
RINEX	Receiver Independent EXchange format
RRC	Range Rate correction
RTCM	Radio Technical Commission for Maritime
SOW	Statement Of Work
SPP	Standard Point Positioning
S/W	Software
TBC	To Be Confirmed
TBD	To Be Determined
TBW	To Be Written
TOW	Time of Week
UDRE	User Differential Range Error
UPC	Technical University of Catalonia
URA	User Range Accuracy

2 gLAB PARAMETERS

These are the new parameters added to gLAB for DGNSS processing. This list is included in the help message of gLAB (which is shown by executing the command ‘gLAB –help’):

2.1 INPUT PARAMETERS

-input:dgnss <file>	Sets the input RINEX observation file of the Reference Station for DGNSS
-input:rtcm <file>	Sets the input RTCM binary file, gLAB will automatically detect the RTCM version
-input:rtcm2 <file>	Sets the input RTCM v2.x binary file
-input:rtcm3 <file>	Sets the input RTCM v3.x binary file
-input:rtcm:initdate <date>	Sets the date when the record of the binary file RTCM began (YYYYMMDD), required when processing or converting RTCM v2.x and RTCM v3.x
-input:rtcm:inithour <hour>	Sets the hour in GPST, when the record of the binary file RTCM began (HH 24-hour format), required only when processing or converting RTCM v2.x
The use of any '-input:rtcm' without a '-input:obs' will result into converting the input RTCM to its corresponding output	

2.2 PREPROCESSING PARAMETERS

-pre:dgnss:excludeSmoothingConvergenceUser	Exclude satellites during the smoothing convergence in the User Station [default off]
--pre:dgnss:excludeSmoothingConvergenceUser	Do not exclude satellites during the smoothing convergence in the User Station
-pre:dgnss:excludeSmoothingConvergenceRef	Exclude satellites during the smoothing convergence in the Reference Station, it will be effective if at least one cycle-slip detector is activated [default on]
--pre:dgnss:excludeSmoothingConvergenceRef	Do not exclude satellites during the smoothing convergence in the Reference Station
-pre:dgnss:smoothmin <val>	Number of seconds of continuous code smoothing before steady-state operation [default 360]
-pre:setrecpos <val>	**<val> = RINEX** Set the user receiver a priori position as the one specified in the RINEX observation file [default] **<val> = SINEX** Set the user receiver a priori position to be read from a SINEX file (to be specified by the '-input:snx' parameter) **<val> = calculate** The user receiver a priori position will be calculated by the program, starting from (Earth’s radius,0,0). This is

	especially useful when processing moving receivers (trajectories) or when the approximate receiver position is not known. With this option activated, the differential fields of the OUTPUT message will be zero **<val> = calculateRINEX** The user receiver a priori position will be calculated by the program, but the initial coordinate, instead of being (Earth's radius,0,0), it will be the one read in the RINEX observation header **<val> = calculateUSER** <x> <y> <z> The user receiver a priori position will be calculated by the program, but the initial coordinate, instead of being (Earth's radius,0,0), it will be the one given by user in this parameter **<val> = <x> <y> <z>** Specify the user receiver a priori position in meters Sample: '-pre:setrecpos 4789032.7143 176594.9690 4195013.2268'
-pre:setrecpos <val>	**<val> = RTCMbaseline** The user receiver a priori position will be calculated by the program as in option 'calculate', but the results solution will be compared with the RTCM antenna position to print the differential fields, which is the baseline vector from user to reference station in the OUTPUT message

2.3 MODELLING PARAMETERS

-model:dgnss:sigmainflation	The sigma is inflated during the smoother convergence [default on]
--model:dgnss:sigmainflation	Do not use the sigma inflation during the smoother convergence
-model:dgnss:maxage <val>	Set the maximum age value in seconds to stop applying DGNSS corrections [default 31]

Sigma inflation: during the transient period until the smoother converges, the measurement noise sigma is inflated according to the next equation:

$$Sigma\ inflation = \frac{f(n)}{f(Nstdy)} sigma$$

If (n < N) $f(n) = \sqrt{\frac{1}{n}}$

If (n >= N) $f(n) = \sqrt{\frac{1}{(2\,N-1)}\left(1+\frac{N-1}{N}\right)^{2\,(n-N)+1}}$

where: *n*: number of processed samples *N*: number of samples of the smoothing window *Nstdy*: number of samples when reaching the steady state: in gLAB, *Nstdy* = (int)(3.6 * N) For instance, with 1 second sampling rate and N = 100, the stationary state (*Nstdy*) is assumed to be reached after 360 seconds

2.4 FILTER PARAMETERS

-filter:dgnss:maxgdop <val>	Set the GDOP threshold (in metres) which will make gLAB switch from DGNSS to SPP [default 30.0]

2.5 OUTPUT PARAMETERS

-output:rinex <file>	Sets the RINEX output file name
-output:rinexversion <val>	**<val> = 2** Generates a RINEX v2.11 from the binary file RTCM v3.x **<val> = 3** Generates a RINEX v3.00 from the binary file RTCM v3.x [default]
-output:corrections <file>	Sets the ASCII Plain Text output file name for the corrections
-output:antenna <file>	Sets the ASCII Plain Text output file name for the antenna information
In case of not setting '-output:rinex', '-output:corrections' and/or '-output:antenna' gLAB will set automatically a name for the output file[s]. These previous options are effective only if an RTCM file is converted. Therefore, they will not output anything when processing an RTCM file	

2.6 VERBOSE PARAMETERS

-print:dgnss	Print DGNSS global information (only for DGNSS) [default off]
-print:dgnssunused	Print messages from discarded satellites due to GDOP switch (from DGNSS to SPP) [default off] An asterisk '*' will be added at the end of the first field to indicate that it is a discarded measurement

2.7 DIVERGENCE-FREE

The single frequency code (R_1) and carrier (Φ_1) measurements can be written in a simplified form as

$$R_1 = r + I_1 + \varepsilon_1$$
$$\Phi_1 = r - I_1 + B_1 + \epsilon_1$$

where r includes all non-dispersive terms such as geometric range, satellite and receiver clock offset and tropospheric delay. I_1 represents the frequency dependent terms as the ionosphere and instrumentals delays. B_1 is the carrier phase ambiguity term, which is constant along continuous carrier phase arcs. ε_1 and ϵ_1 account for the code and carrier thermal noise and multipath.

With two frequency measurements, the ionospheric term can be removed from a combination of the two frequencies carriers. Thus, neglecting the carrier noise and multipath ϵ_1 and ϵ_2 in front to the code ϵ_1, the divergence-free combination results:

$$R_1 - \Phi_1 - 2\,\frac{\Phi_1 - \Phi_2}{\left(\frac{f_1}{f_2}\right)^2 - 1}$$

The divergence-free combination has been implemented in gLAB and it can be used to smooth the code with the instruction '-pre:smoothMeas 1 DF'.

With the aim to show how to set the divergence-free, it is presented a configuration file. Notice that all the new commands implemented for DGNSS processing are highlighted in bold.

```
###################################################
#
#     gLAB - Version: 4.0.0
#     This is a self-generated configuration file.
#     Created at: 09:00 on 16/12/2016
#
###################################################


###################################################
#     INPUT section
###################################################

-input:obs ebre3140.15o
-input:nav brdc3140.15n
-input:dgnss EBRE3140.16n

###################################################
#     PREPROCESS section
###################################################

-pre:setrecpos RTCMbaseline
-pre:dec 0
-pre:elevation 5
--pre:eclipse
-pre:cs:li
-pre:cs:bw
--pre:cs:l1c1
-pre:cs:lli
-pre:smooth 100
-pre:smoothMeas 1 DF
--pre:dgnss:excludeSmoothingConvergenceRef

###################################################
#     MODELLING section
###################################################

-model:dcb:p1p2 RINEX
-model:dcb:p1c1 flexible
-model:satellitehealth
-model:satclocks
-model:satmovinflight
-model:earthrotinflight
--model:satphasecenter
-model:relclock
-model:iono Klobuchar
-model:trop:nominal UNB3
-model:trop:mapping Simple
--model:windup
--model:solidtides
--model:relpath
--model:recphasecenter
--model:arp
-model:dgnss:maxage 31
-model:dgnss:sigmainflation
```

```
####################################################
#     FILTER section
####################################################

-filter:SigmaIono
--filter:trop
-filter:nav kinematic
--filter:backward
-filter:phi:dr 0
-filter:q:dr 1e8
-filter:p0:dr 1e8
-filter:phi:clk 0
-filter:q:clk 9e10
-filter:p0:clk 9e10
-filter:fixedweight 1 1
-filter:meas pseudorange
-filter:select 1 C1C
-filter:dgnss:maxgdop 30

####################################################
#     OUTPUT section
####################################################

-output:file gLAB.out
-print:info
-print:cycleslips
-print:input
-print:model
-print:satellites
-print:prefit
-print:postfit
-print:filter
-print:output
-print:dgnss
-print:dgnssunused
--print:satdiff
--print:satstat
--print:satstattot
--print:meas

####################################################
#     End of self-generated parameters
####################################################
```

3 gLAB OUTPUT MESSAGE

Here is the description for the new output message in gLAB for DGNSS processing. This list is included in the help message of gLAB (which is shown by executing the command 'gLAB –messages'):

3.1 DGNSS MESSAGE

DGNSS corrections breakdown. It is shown when a model can be fully computed using DGNSS corrections for GPS C1C measurement.

#	FIELD	DESCRIPTION	UNITS
1	DGNSS	Fixed word indicating the data stored.	-
2	Year	Year number (4 digits).	Years
3	DoY	Day of Year (3 digits).	Days
4	Seconds of day	Seconds elapsed since the beginning of the day.	Seconds
5	GNSS system	Satellite constellation (GPS, GAL, GLO or GEO).	-
6	PRN	Satellite identifier.	-
7	PRC	Pseudorange correction to be applied to the satellite.	Metres
8	RRC	Range rate correction to be applied to the satellite.	Metres
9	RRC time	Seconds elapsed since the reception of the RRC correction.	Seconds
10	Delta PRC	Delta of PRC to be applied in case of change in case of a change in ephemeris.	Metres
11	Delta RRC	Delta of RRC to be applied in case of change in case of a change in ephemeris.	Metres
12	Delta RRC time	Seconds elapsed since the reception of the delta RRC correction.	Seconds
13	Total sigma	Sigma of the total residual error associated to the satellite Sigma of the total residual error = sigma of the UDRE + sigma degradation + sigma air	Metres
14	Sigma UDRE	Sigma of the UDRE (User Differential Range Error).	Metres
15	Sigma degradation	Sigma degradation consists of the URA (User Range Accuracy) degradation factor (we assume epsURA = 1 cm/s), and the satellite elevation. It only applies for RTCM v3.x Sigma degradation = (epsURA · dt) / tan(satellite elevation)	Metres
16	Sigma air	Sigma air consists of the sigma multipath, the sigma to noise GPS (we assume 0.25 m) and the sigma inflation (equal to 1 if deactivated) Sigma degradation = (sigma multipath + sigma to noise GPS) * sigma inflation	Metres
17	Sigma multipath	Sigma multipath = 0.0625 / tan(elev) / tan(elev)	Metres
18	Sigma inflation	Sigma inflation during the convergence of the smoothing	-

4 gLAB USAGE EXAMPLES

Usage examples to run gLAB with DGNSS data processing:

Convert a RTCM v2.x to an ASCII Plain Text

Linux/Cygwin:

```
./gLAB_linux -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08
```

Windows:

```
gLAB.exe -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08
```

Convert a RTCM v2.x to an ASCII Plain Text, setting the output name

Linux/Cygwin:

```
./gLAB_linux -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 -output:corrections ebre3140.15corr.asc -output:antenna ebre3140.15ant.asc
```

Windows:

```
gLAB.exe -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 -output:corrections ebre3140.15corr.asc -output:antenna ebre3140.15ant.asc
```

Convert a RTCM v3.x to a RINEX file (default v3.00)

Linux/Cygwin:

```
./gLAB_linux -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110
```

Windows:

```
gLAB.exe -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110
```

Convert a RTCM v3.x to a RINEX v2.11 file

Linux/Cygwin:

```
./gLAB_linux -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110 -output:rinexversion 2
```

Windows:

```
gLAB.exe -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110 -output:rinexversion 2
```

Convert a RTCM v3.x to a RINEX v3.00 file, setting the output file name

Linux/Cygwin:

```
./gLAB_linux -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110 -output:rinexversion 3 -output:rinex EBRE3140.15o
```

Windows:

```
gLAB.exe -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110 -output:rinexversion 3 -output:rinex EBRE3140.15o
```

Convert an input RTCM binary file, gLAB will automatically detect the RTCM version

Linux/Cygwin:

```
./gLAB_linux -input:rtcm ebre3140.15rtcm -input:rtcm:initdate 20151110 -input:inithour 08
```

Windows:

```
gLAB.exe -input:rtcm ebre3140.15rtcm -input:rtcm:initdate 20151110 -output:rinexversion 3 -input:inithour 08
```

Process DGNSS corrections through two RINEX files

Linux/Cygwin:

```
./gLAB_linux -input:obs ebre3140.15o -input:nav brdc3140.15n -input:dgnss EBRE3140.15o > outputfile.txt
```

Windows:

```
gLAB.exe -input:obs ebre3140.15o -input:nav brdc3140.15n -input:dgnss EBRE3140.15o > outputfile.txt
```

Process DGNSS corrections through two RINEX files

Linux/Cygwin:

```
./gLAB_linux -input:obs ebre3140.15o -input:nav brdc3140.15n -input:dgnss EBRE3140.15o > outputfile.txt
```

Windows:

```
gLAB.exe -input:obs ebre3140.15o -input:nav brdc3140.15n -input:dgnss EBRE3140.15o > outputfile.txt
```

Process DGNSS corrections through a binary RTCM v2.x file

Linux/Cygwin:

```
./gLAB_linux -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 > outputfile.txt
```

Windows:

```
gLAB.exe -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 > outputfile.txt
```

Process DGNSS corrections through a binary RTCM v3.x file

Linux/Cygwin:

```
./gLAB_linux -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm3 ebre3140.15rtcm3 -input:rtcm:initdate 20151110 > outputfile.txt
```

Windows:

```
gLAB.exe -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm2 ebre3140.15rtcm2 -input:rtcm:initdate 20151110 > outputfile.txt
```

Process DGNSS corrections through an input RTCM binary file, gLAB will automatically detect the RTCM version

Linux/Cygwin:

```
./gLAB_linux -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm ebre3140.15rtcm -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 > outputfile.txt
```

Windows:

```
gLAB.exe -input:obs ebre3140.15o -input:nav brdc3140.15n -input:rtcm ebre3140.15rtcm -input:rtcm:initdate 20151110 -input:rtcm:inithour 08 > outputfile.txt
```

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