GR2 Reprocessing from CNES/CLS IGS Analysis Center: specificities and results

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Introduction

We present in this contribution the main aspects of the reprocessing efforts done at the CNES/CLS Analysis Center. We processed 15 years of GPS and 5 years of GLONASS data together on a daily basis with a network of up to 230 stations.
In these solutions we gave a particular attention to the standards and we followed the IGS REPRO2 recommendations. An exception concerns the use of a time variable gravity field. We show the statistical results of our GR2 processing such as ambiguities fixing success rate, orbit residuals, orbit comparisons and one example of station position time series. We focus on the main specificities of our processing and its implementation (zero-difference ambiguity resolution). The main events or discontinuities in the solutions results are discussed.

Standards, Models And Processing Strategy

We do process daily solutions for GNSS. We fix the undifferenced ambiguities after May 2000 (the details of the method is described in Loyer et al., 2012). We present in the following tables the standards and models used for our ITRF2013 processing (in red the main changes).

Software	GINS/DYNAMO
Reference System	Earth reference system & station coordinates from IGb08(GNSS); Celestial reference system from inertial J2000; Polar motion & UT1 from IERS C04 08; Precession/nutation from IERS 2010 using NRO origin.
Displacement of reference points	Solid Earth tidal displacement and solid pole tide displacement from IERS2010 Conventions; Ocean loading from FES2012 Tidal atmospheric loading from S1/S2 Ray & Ponte (2003) ; No Non tidal atmospheric loading is used.
Gravity	Gravity field (time varying) : EIGEN-6S2 up to degree 95 including time variable terms up to degree 12 (bias & drift per yr from 2002 to 2012, periodic 18.6, 1, 0.5yrs); Solid Earth tides and Earth pole tide from IERS2010 conventions; Ocean tides up to degree 50 (12 for GNSS) from FES 2012 (32 principal waves, + 60 admittance waves); Atmospheric gravity up to degree 12 from 3hr ERA-interim / ECMWF; Non tidal oceanic gravity up to degree 12 from TUGO R12; Atmospheric tides are considered through the ECMWF atmospheric data; Ocean pole tide up to degree 12 from Desai 2002; Third bodies : Sun, Moon, Mars, Venus, Jupiter, Saturn, Uranus and Neptune (ephemeris : DE421-JPL).
Troposphere	Troposphere from GPT2/VMF1 Model; One zenith delay (per 2h for GNSS; wet tropo scale factor adjusted) + one daily tropospheric gradient per station in North & East directions are used for troposphere correction.
Relativity	Schwarzschild model + Lense-Thirring + geodetic precession

Satellite Attitude laws	Kouba's model according to IGS recommendations
Block-specific satellite thrusting due to signal transmission	GPS: applied (IGS REPRO2 standards) GLONASS: none
Radiation Pressure model	Box&Wings model limited to solar panels scaled by one adjusted scale factor
Earth radiation	Computed from albedo and IR mean grids values on the solar panels.
Additional empirical acceleration terms	Estimated acceleration (1/per day) : Y-Bias ; Periodic terms in X-direction and D-direction ; 1 set of stochastic pulses per eclipses For GPS Blocks IIA no periodic terms in the D-direction to suppress correlation with LOD.
Estimated measurements parameters	Undiferenced iono-free observations (2nd order ionospheric contribution corrected using IGS/COD TEC maps) with ambiguities fixed (when possible) for GPS. 1 clock parameter per satellite & receiver. Inter System biaises between constellations. 1 tropospheric zenital tropospheric delay per 1 hour; 1 gradient set (N/E) per day

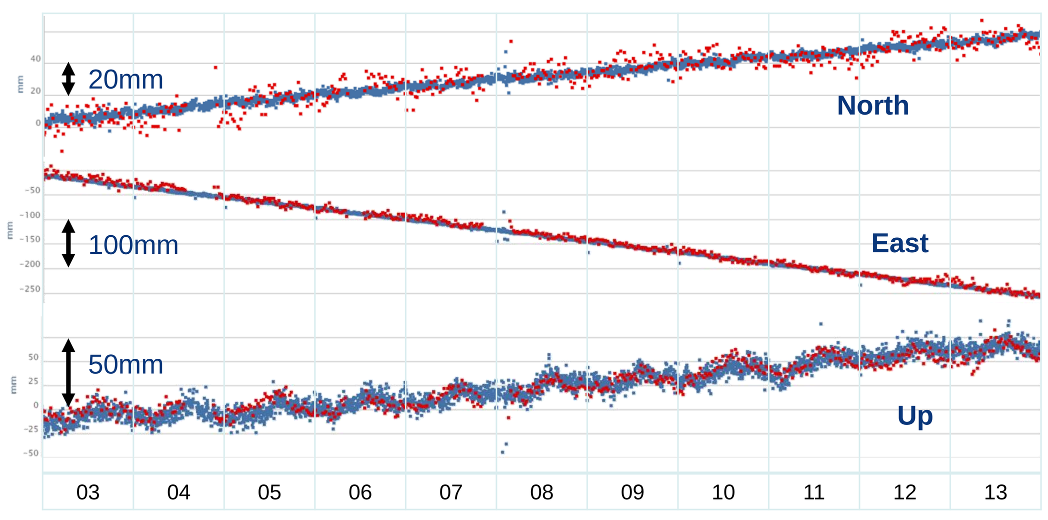
Station position time series for a collocated site

GRGS is implementing on its web site (http://grgs.obs-mip.fr/) new tools to browse station coordinates time series provided by the GRGS Analysis Centers. The objective is to display and compare position time evolutions of DORIS, GPS, SLR and VLBI sites. The tools proposed by this web service are:

- a network viewer, called Mapshup, (see http://mapshup.info) to select sites,
- a plot tool based on the Highcharts/Highstock libraries (see http://highcharts.com) to display time series.

They have been first developed by CLS on behalf of CNES for the International DORIS Service (IDS) (http://ids-doris.org/plottool/). The plot tool contains utilities for selecting charts to plot, displaying time series, editing data, exporting plot appearance, specifying scaling, downloading data, plots and graph statistics in several formats. It is equipped with statistic tools for the calculation of mean, slope and weighted rms with respect to the slope (Weighted Relative Standard Deviation).
Several series can be viewed and compared on the same graph. Additional data can also be displayed, such as station or satellite events for DORIS, available on the IDS website (http://ids-doris.org/system/doris-stations-events.html). The interactive global map visualizes the networks of the DORIS, GPS, SLR, VLBI sites analyzed by the GRGS Analysis Centers. It also helps in easily selecting sites stations for the time series plot tools, and getting access to site information.

Example of the obtained station position time series over ten years for the collocated stations DORIS & GNSS at Thule on the west coast of Greenland (distance between the two sites is of ~61m). As seen by these two individual techniques this site has an impressive vertical motion related to the melting of the adjacent ice shield.



north

Series	WRSD	Fitted slope
THU3 gr214dp01	1.65mm	4.84+/-0.01mm/year
THUB lca14wd40	5.9mm	4.99+/-0.08mm/year

east

Series	WRSD	Fitted slope
THU3 gr214dp01	1.66mm	-22.39+/-0.01mm/year
THUB lca14wd40	5.37mm	-22.63+/-0.07mm/year

up

Series	WRSD	Fitted slope
THU3 gr214dp01	8.1mm	7.68+/-0.04mm/year
THUB lca14wd40	9.04mm	6.9+/-0.12mm/year

Station network / Data / Satellites used

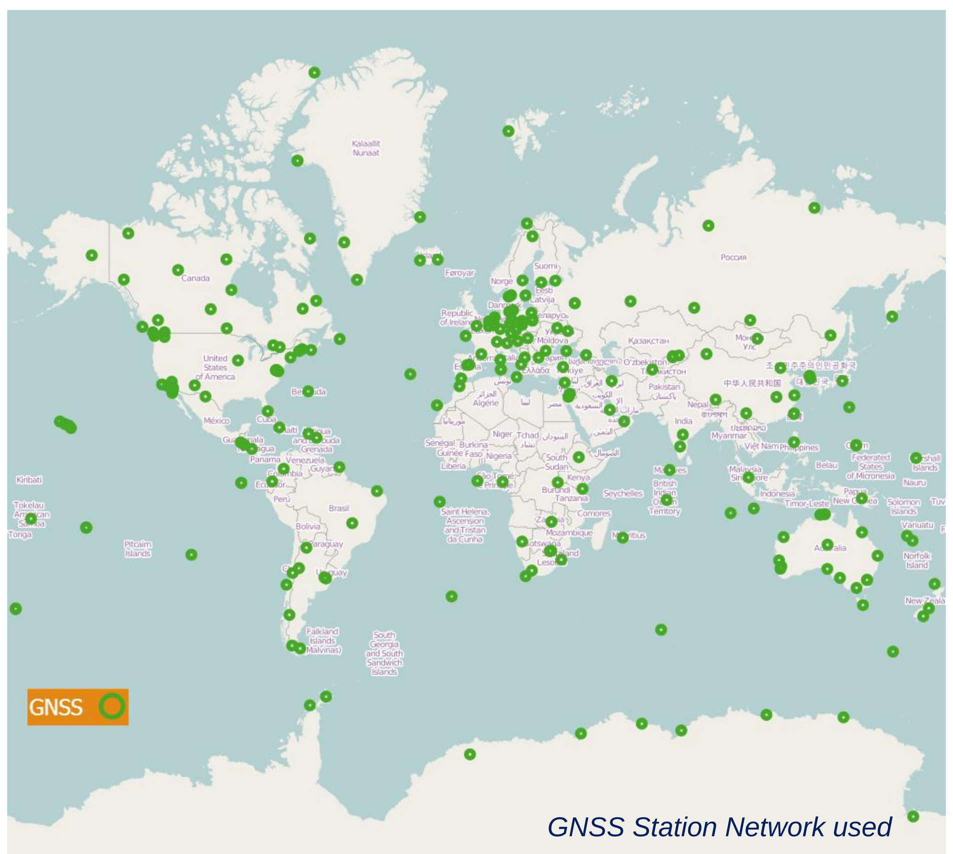
The complete network represent up to 275 stations distributed all around the globe.

The GNSS network is a compromise between processing capabilities and data availabilities.

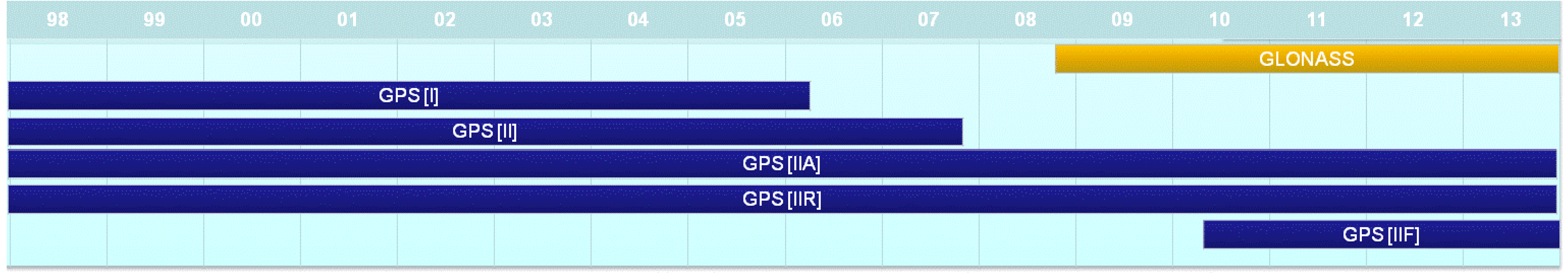
We made a choice by considering the longest time series, the collocated sites, and in the last period the hybrid GPS+GLONASS receivers.

We processed 15 years of GNSS data (GPS and GLONASS after mi-2008) from the IGS (International GNSS Service) tracking network.

The different satellites or satellites families used in our processing represent between 23 to 55 GNSS satellites (depending on the period considered).

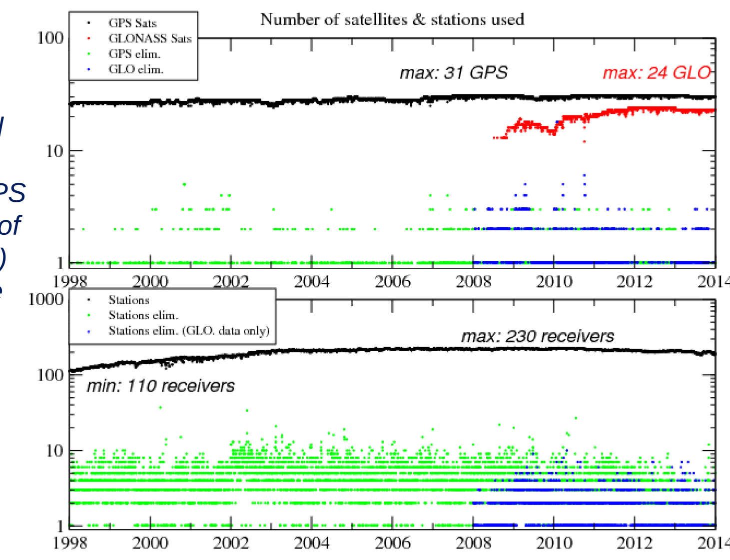


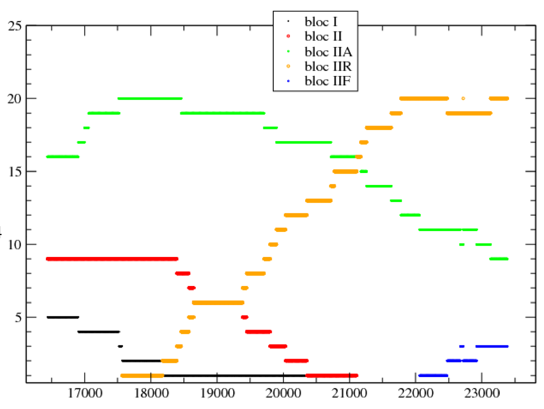
GNSS Station Network used



Satellites used in our processing (blue = GPS satellites ; orange =GLONASS satellites)

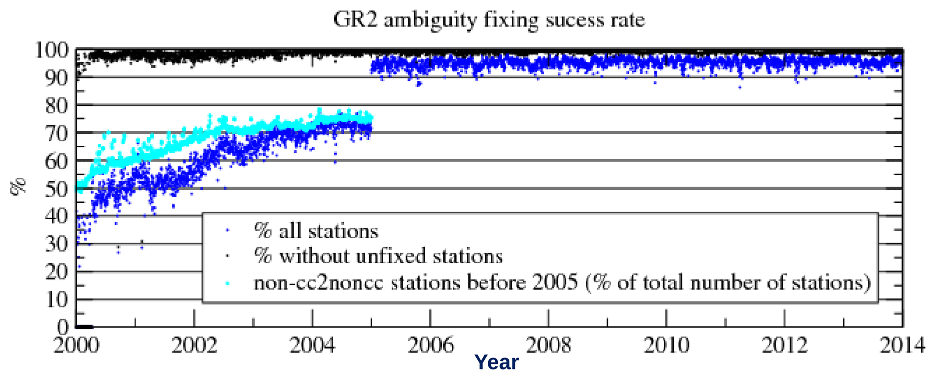
Number of GNSS satellites and receivers used in our contribution to ITRF2013 processing. The maximum number of satellites is 31 for GPS and 24 for GLONASS. The minimum number of receivers is 110 (at the beginning of the period) and the maximum number is 230. We can see also the number of satellites removed in the processing. On the right graph the satellite number by block is given.



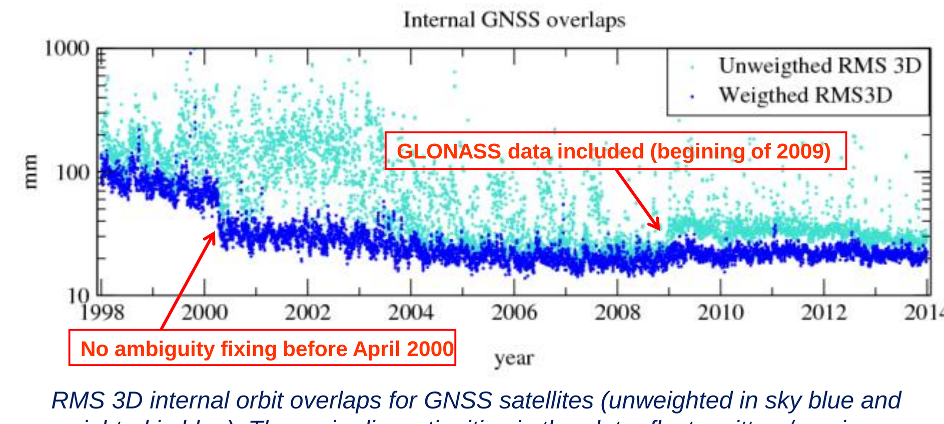


GR2 Processing Results & Products

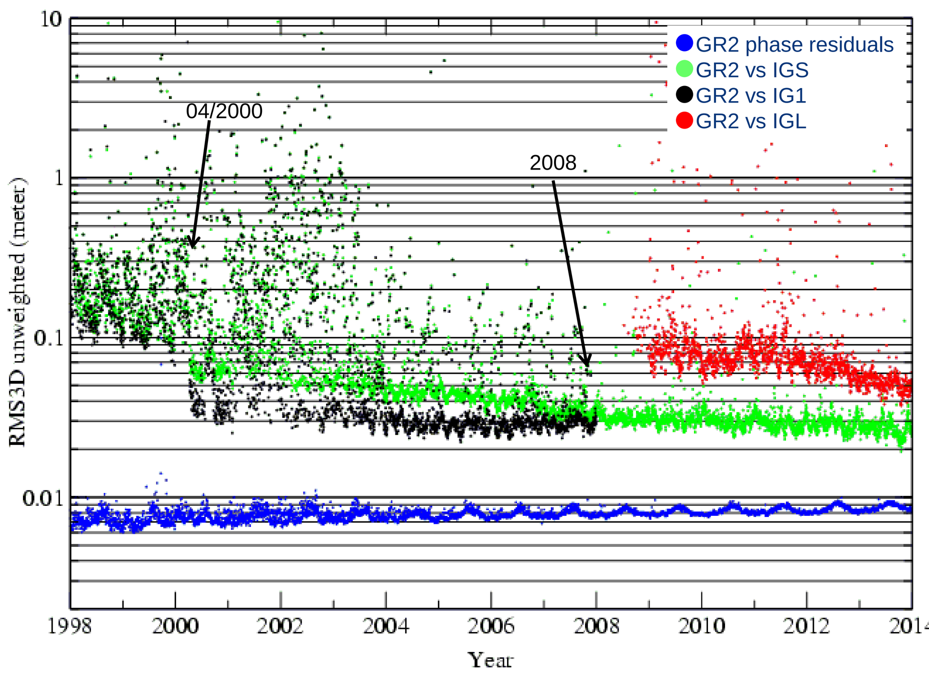
GR2 Processing Results:
We present here some results of GR2 processing results. First, the GR2 ambiguity fixing success rate. After, we give some results as orbits overlaps, orbit residuals and orbit comparisons to IGS which reflect the quality and the homogeneity of the results. These results are presented on the following plots:



*GR2 ambiguity fixing success rate. The fixation rate is very good from 2005 to the end of 2013. From 2000 to the end of 2004 we fix only the stations which do not require a code data correction with the program cc2noncc. This topic is discussed in the poster "**Wide-Lane ambiguity fixing anomalies observed in Repro2 solutions**" by F. Mercier et al. in the session PS03 - Bias and Calibration -.*



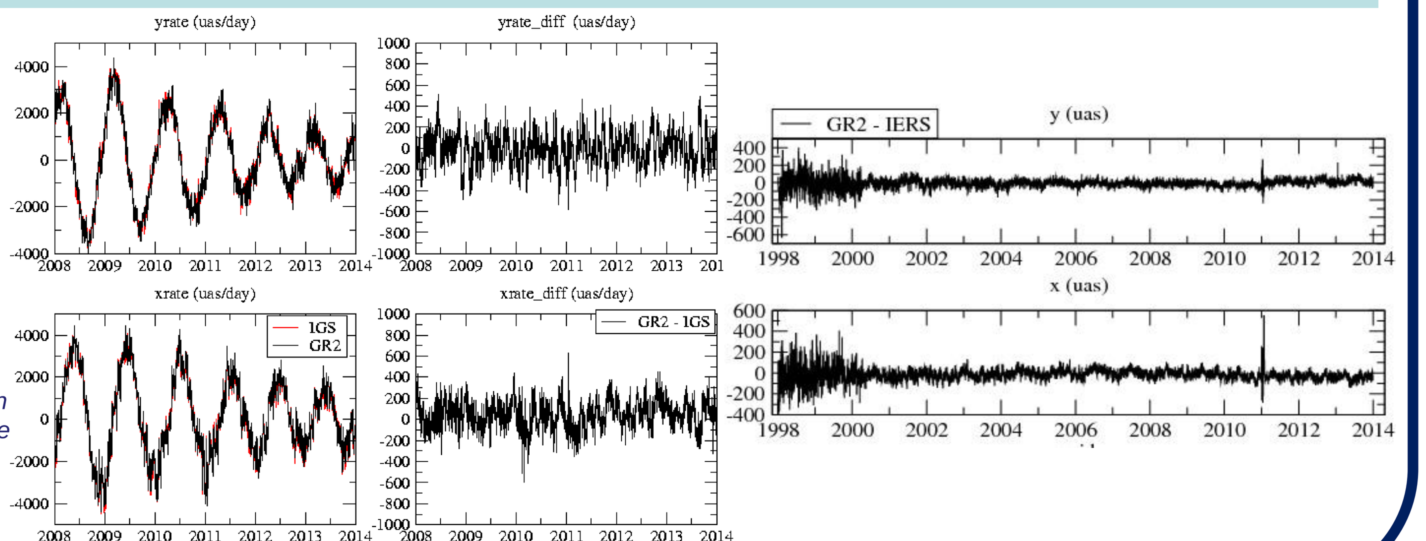
RMS 3D internal orbit overlaps for GNSS satellites (unweighted in sky blue and weighted in blue). The main discontinuities in the plot reflect emitters/receivers events, processing changes, or the number and types of satellites used. There are two main events, the beginning of ambiguity after April 2000 which allows to reduce the RMS3D. The second event is the inclusion of GLONASS data in 2009, the RMS3D is slightly higher because the mean RMS3D for GLONASS is 5 cm against 3 cm for GPS.



Phase measurement residuals and the RMS3D orbit comparisons to the IGS orbits on the overall ITRF2013 processing period.
The phase measurement residuals range between 8 and 10 mm (blue curve).
In green on the graph, GR2 orbits compared to the weekly IGS orbits. We can see a slight increase of the RMS3D comparison before 2008.
However, when we compare GR2 orbits to the REPRO1 IGS orbit (IG1, in black), the RMS3D is at the same level, about 3 cm. Indeed, the GR2 orbits are more consistent with the IG1 orbits which have been reprocessed for the ITRF2008.
The comparison for GLONASS orbits is illustrated by the red curve.
The discrepancy to the IGL orbits decreases with time.

GR2 Products:
The main products delivered to the IGS coordinators are the solutions for the EOP (Earth Orientation Parameters) and the stations coordinates parameters. They are computed on a 24h basis. We also provide to the International services the orbits (GNSS) and the clocks parameters (30 sec) that will allow users to perform homogeneous GNSS precise positioning over the last 15 years. Note that from April 2000 to the end of 2013 the GR2 products have an integer nature (allowing the integer fixing in a PPP mode, Loyer et al., 2012).
They are available at the IGS REPRO2 products area under the name *gr2*.
The following plots represent the GR2 and IGS pole rate and the EOP differences between GR2 and the IERS C04 series.

On the left figure, we can see the good agreement between the IGS pole rate and the GR2 pole rate. This result is also shown on the second graph which gives the differences between the both pole rates.
On the right, we can see the EOP differences between GR2 and the IERS C04 series. After April 2000, for the pole coordinates, the differences are very small except one peak in 2011. This peak is explained by an error in the IERS C04 series. Before April 2004, as the ambiguity fixing is not applied, the GR2 solution is less good and the differences to the IERS are larger.



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