Current Status and Future Plans at the Natural Resources Canada (NRCan) Analysis Centre

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Abstract

As an IGS Analysis Center (AC), NRCan has generated since the beginning of the IGS, GPS core products such as GPS satellite orbits, GPS satellite and station clocks, earth rotation parameters and station positions. NRCan has also been involved in the production and promotion of GPS Real-Time (RT) and Near Real-Time (NRT) products and services for more than 10 years. NRCan has more recently begun producing both rapid and final GLONASS orbits and clocks, and is currently working on the development of ultra rapid GLONASS orbits and clocks. Key products and services, like 1Hz GPS station data, 30 second GNSS station data, and GNSS Precise Point Positioning (PPP) continue to be refined and available to the global GNSS community.

This presentation will summarize the current status of NRCan's core GNSS products as well as our NRT data, products, and services. It will also show NRCan's planned contribution and analysis strategy for the upcoming IGS repro2 campaign, initial results of NRCan's recently developed GLONASS ultra rapid products, as well as a description of NRCan's planned contribution to the final IGS ionospheric TEC grid.

1. NRCan Participation in the IGS

The NRCan Analysis Center (NRCan-AC) has been contributing GPS products to the International GNSS Service since the early days of the IAG service. The NRCan-AC has also participated in the 1st full reanalysis (repro1) of GPS data collected within the IGS since 1994. Plans are now underway to begin a 2nd full reanalysis (repro2) and the NRCan-AC once again plans to participate. The NRCan-AC has also recently begun contributing GLONASS products to the IGS. The day-to-day operations of the analysis center are performed by staff at the Geodetic Survey Division in the Natural Resources department of the Canadian federal government. The NRCan-GSD is responsible for the maintenance of the national horizontal, vertical and gravitational data as well as providing the means of accessing these data.

In addition to routinely generating all core IGS products, NRCan is also chairing both the IGS Real Time Working Group (RTWG) and the RTCM/RINEX Working Group. NRCan also contributes over 40 stations to the IGS network through the GSD Canadian Active Control System (GSD-CACS), the Geological Survey of Canada's Western Canada Deformation Array (GSC-WCDA) and GSD's Regional Active Control System (GSD-RACS). The current NRCan station contribution to the IGS is shown in figure 1.1. NRCan has also been involved in the past as both the Analysis Centre Coordinator and the Reference Frame Coordinator. Table 1.1 summarizes NRCan's current IGS activities within the IGS.

IGS Activities	Representative
NRCan Analysis Centre	Yves Mireault and Brian Donahue
Chair of the Real Time Working Group	Mark Caissy
Chair of the Real Time Pilot Project	Mark Caissy
Chair of the IGS/RTCM RINEX Working Group	Ken MacLeod

Table 1.1: Current NRCan Participation in the IGS

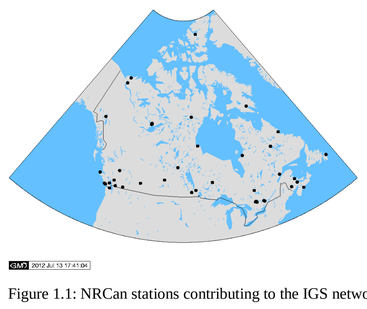


Figure 1.1: NRCan stations contributing to the IGS network

2. NRCan GPS and GLONASS Products

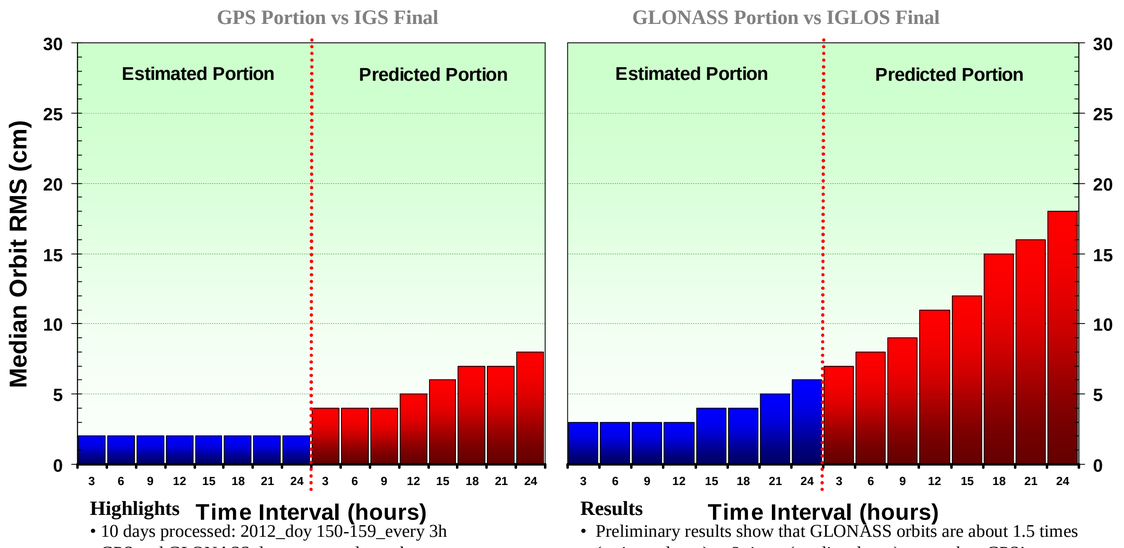
This section summarizes the different characteristics of the current NRCan GPS and GLONASS core products. Some or our products, like the GPS Finals, Rapids and Ultra-Rapids, have been running for several years. In 2011, we added to our family of products daily Rapid and weekly Final GPS+GLONASS solutions as well. We are currently working on Ultra-Rapid GPS+GLONASS solutions. Highlights are given in the table below.

Type	Product Characteristics
Final (weekly)	➢ **GPS only** • Since 1994 • Use of JPL's GIPSY-OASIS II v6.1.2 • Orbits, 30-sec clocks, ERP and SINEX • Weekly submission for IGS Final combination ➢ **GPS+GLONASS** • Since 2011-Sep-11 • Use of Bernese 5.0 • Orbits, 30-sec clocks and ERP • Weekly submission for IGLOS Final combination • For the time being, station XYZ are constrained as in our Rapid solutions
Rapid (daily)	➢ **GPS+GLONASS** • Since 2011-May-22 (GPS-only solutions, using GIPSY, started in 1994 and was stopped on 2011-May-21) • Use of Bernese 5.0 • Orbits, 30-sec clocks and ERP • Daily submission for IGR combination
Ultra-Rapid (hourly)	➢ **GPS only** • Since early 2000 • Use of Bernese 5.0 • Orbits, 30-sec clocks and ERP **(every hour!)** • Submission for IGU combination (4x daily) ➢ **GPS+GLONASS** • In development … • Use of Bernese 5.0 • Working on Orbit/ERP solutions for now (see beside for some preliminary Ultra-Rapid GNSS orbit results) • Clock development during fall 2012…

Table 2.1: Summary of NRCan GPS and GLONASS core products

NRCan Ultra-Rapid GPS+GLONASS Preliminary Results

NRCan-GSD is currently working on a strategy to produce GNSS hourly orbit products. The method is very similar to the current implementation of our GPS only Ultra-Rapid strategy already described in Mireault et al. (2008). The processing of both GPS and GLONASS data is done the same way as in our Rapid GNSS solutions. The development is nearly completed and parallel testing will soon begin. GNSS clock estimation development will most likely start in the fall of 2012. Full implementation of Ultra-Rapid GNSS orbits and clocks should be available by early 2013. One major draw back of producing GNSS products is the increase in processing time which will probably prevent us from delivering both orbit and clock hourly products. An optimized strategy will be needed! Nevertheless, a longer update interval and/or a longer delay may result from the addition of the GLONASS constellation.



Highlights
- 10 days processed: 2012_doy 150-159_every 3h
- GPS and GLONASS data processed together
- 3 clusters (~35-40 stations each)
- Ambiguity resolution for GPS only!

Results
- Preliminary results show that GLONASS orbits are about 1.5 times (estimated part) to 2 times (predicted part) worse than GPS!

3. NRCan Participation in IGS repro2 - Plans and Preliminary Results

Beginning in mid-2012 the NRCan-AC will start re-estimating the core IGS products for the years 1994 to 2012. This 2nd IGS reprocessing campaign will be called repro2 and the NRCan-AC products will be named em2. The plan for repro2 is for all ACs to estimate the products in a consistent way using the latest models and methodology. Table 3.1 summarizes the em2 solution characteristics. The plan for repro2 at NRCan is to begin estimating solutions in mid 2012 and to process at a rate of ~ 2 years/month. This will allow for the completion of the project by the end of 2013.

Parameter	NRCan repro2 (em2)
Software	JPL's GIPSY-OASIS II v6.1.2
Satellite System	GPS Only
Observations	UD Iono-free phase and range
Elev Cutoff	10 degrees
Daily Arc	24h
Subdaily EOPs	IERS2010
2nd order Iono	Applied
Earth Albedo	Applied
SRP Model	GSPM-2010
Terrestrial Ref Frame	IGS08
Antenna Calibrations	igs08.atx (Offset and PCVs)
Tropo Mapping Function	GMF
Satellite Z-offset	Estimated
Tidal Models	IERS2010
Gravity Field	EGM 2008
Yaw Rates	Nominal + Estimate
SINEX Solution	1-day

Table 3.1: NRCan repro2 (em2) Processing Strategy

Product	NRCan repro2 (em2)
Satellite Ephemerides	Daily 15 min (sp3c)
Satellite Clocks	Daily 15 min (sp3c)
Satellite Clocks	Daily 30 sec (clock RINEX)
Station Clocks	Daily 5 min (clock RINEX)
Earth Rotation Parameters	Daily (SINEX & IERS erp)
Station Coordinates	Daily (SINEX)
Satellite PC Z-offset	Daily (SINEX)

Table 3.2: NRCan repro2 (em2) product delivery

NRCan Repro2 (em2) Preliminary Results

NRCan's repro2 strategy was implemented and tested on 7 months of daily solutions in 2000 (GPS weeks 1065 – 1094). The results have been compared against both the IG1 and EM1 solutions and are shown in figure 3.1 below.

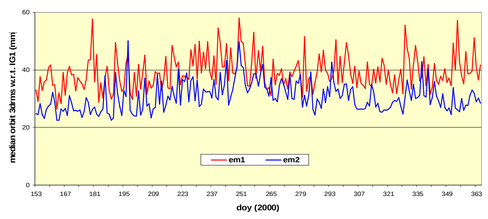


Figure 3.1: Daily median 3drms for the em2 and em1 orbit solutions with respect to the IG1 (IGS repro1) products.

	Em1	Em2	Improvement
Mean 3drms (mm)	47.5	39.7	16%
Median 3drms (mm)	39.2	30.6	22%

Table 3.3: NRCan repro1 and preliminary repro2 orbit comparison with respect to IG1 orbits.

In order to test the new NRCan repro2 strategy against other IGS08 solutions it was also run for 3 weeks in June 2012 (GPS weeks 1690 – 1692) . The results have been compared against both the IGS and NRCan production solutions and are summarized below.

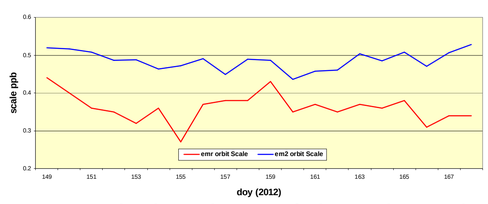


Figure 3.2: Daily Helmert scale parameter for the em2 and emr AC orbit solutions, with respect to the IGS Final products

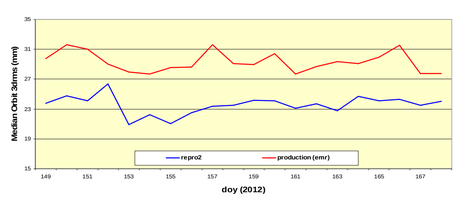


Figure 3.3: Daily median 3drms for the em2 and emr AC orbit solutions, with respect to the IGS Final products

4. Planned NRCan Final Ionosphere TEC Grid

Contribution to the final IGS ionospheric TEC grid is planned. In addition to our current process of producing a regional TEC grid using spherical cap harmonic analysis (Ghoddousi-Fard et al. [2011]), a process is also running to map vertical TEC using spherical harmonic expansion on a global geomagnetic reference frame. The process can be initialized by a global grid derived from International Reference Ionosphere (IRI2007). Vertical TEC values are estimated on a single layer model from GPS interfrequency, phase-smoothed, geometry-free pseudorange measurements corrected for satellite and receiver differential code biases.
The planned global daily TEC grid generation for contribution to the IGS products will complement our near-real-time global TEC grid generation currently under preliminary test. Figure 4.1 shows a summary of steps taken in the current preliminary test process for near-real-time global TEC generation.

As an example, estimated near-real-time vertical TEC at ionospheric pierce points (IPPs) from RT-IGS stations on May 04, 2012 at 18 UTC, as well as generated spherical harmonic grid and comparison with IGS rapid vertical TEC grid (igr) are shown in Figure 4.2.

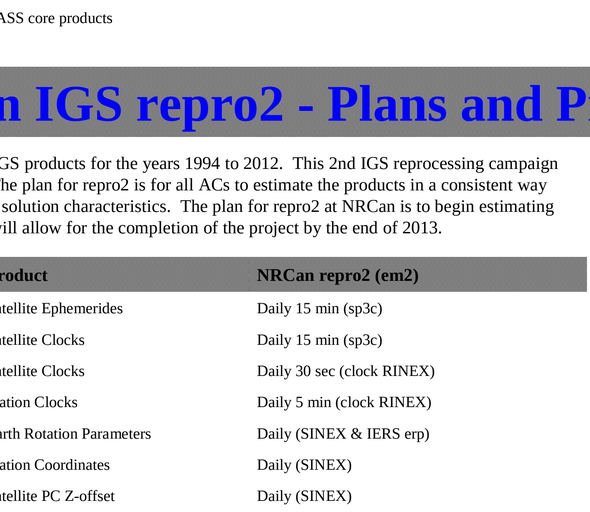


Figure 4.1- Flow diagram of preliminary test run for near-real-time global TEC map generation

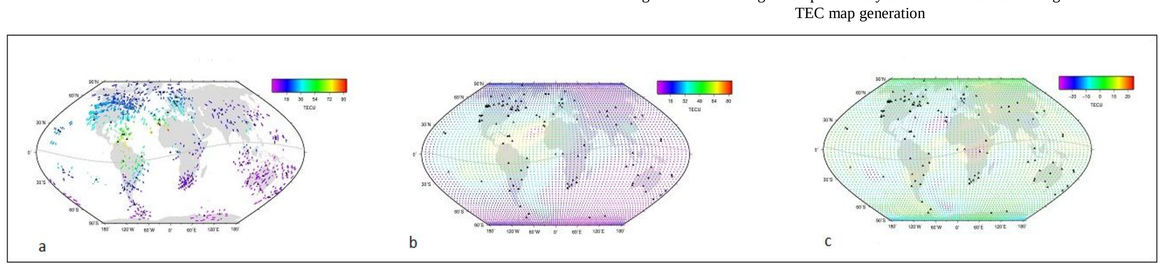


Figure 4.2- a) Near-real-time VTEC estimates at IPPs from RT-IGS stations; b) generated VTEC grid from spherical harmonic analysis; and c) comparison between rapid IGS global VTEC grid (igr) and the near-real-time spherical harmonic grid on May 04, 2012 at 18 UTC.

5. NRCan On-Line PPP GNSS Processing Service (CSRS-PPP)

NRCan uses IGS products in many of its IGS and Canadian Spatial Reference System (CSRS) activities. CSRS-PPP, NRCan web-based GNSS processing service, serves as a bridge between these two activities by providing an alternative to traditional ground control and RTK base stations to connect users to the de facto space reference system provided by the IGS products.

CSRS-PPP can be used to process both static and kinematic GNSS data (GLONASS starting on week 1650) in order to obtain ITRF or NAD83(CSRS) coordinates. Although CSRS-PPP was based entirely on IGS products when first launched in 2003, it now makes use of a mixture of IGS and NRCan (EMR) products. NRCan products, computed using data from the IGS global tracking network, are needed to provide a rapid access to 30 second GPS and GLONASS clock products.

Products Used for CSRS-PPP Processing http://www.geod.nrcan.gc.ca/products-produits/ppp_e.php

Orbits and Clocks
Hourly: EMR (GPS only)
Rapid: EMR (GPS and GLONASS)
Final: IGS (GPS only) and EMR (GLONASS only)

TEC Grid (for single frequency CSRS-PPP processing)
Hourly: EMR (to be implemented in near future)
Rapid and Final: IGS

Soon to be implemented
Processing of GPS data prior to GPS week 1460 will use IGS Repro 1 products

References

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[2] Mireault, Y., P. Tétreault, F. Lahaye, P. Héroux and J. Kouba. Online Precise Point Positioning, GPS World, Vol. 19, No. 9 (September 2008), pp. 59–64.
[3] Dach, R., U. Hugentobler, P. Fridez and M. Meindl. Bernese GPS Software Version 5.0, AIUB, Astronomical Institute, University of Bern, January 2007.
[4] Ghoddousi-Fard, R., P. Héroux, D. Danskin, and D. Boteler, Developing a GPS TEC mapping service over Canada, Space Weather, 9, S06D11, doi:10.1029/2010SW000621, 2011.

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