ESA/ESOC IGS Activities

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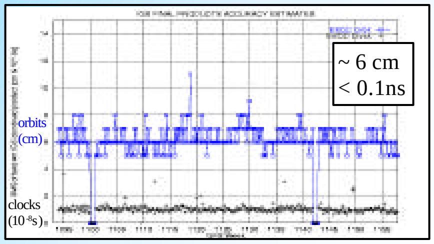
http://nng.esoc.esa.de/

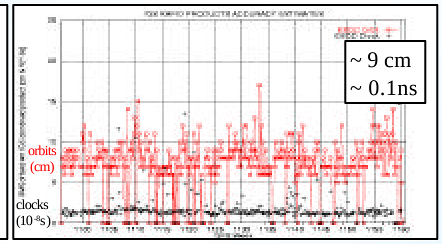
Orbit Processing Recent Changes

Date	Change
MAR 2001	*GPS processing:* Started Clock bias submissions with UltraRapid product. Estimated (24 hrs) + Predicted (24 hrs).
APR 2001	*GPS processing:* UltraRapid strategy changed from "2 step" fit (RINEX and then positions) to one step (RINEX and positions together).
MAY 2001	*GLONASS processing:* Raised the noise cutoff for GLONASS data to the same level as for GPS (from 30 to 50 cycles between phase and code measurements).
MAY 2001	*GLONASS processing:* using a 9 parameter solar radiation model.
JUNE 2001	*GPS processing:* For satellites in eclipse excluding 14 minutes of data at the exit of the eclipse (down from 30 minutes).
DEC 2001	*GPS processing :* changed to ITRF2000 based on the IGS2000.SNX station coordinate file.
JAN 2002	*GLONASS processing:* changed to the ITRF2000, and to a 3 day data arc per day.

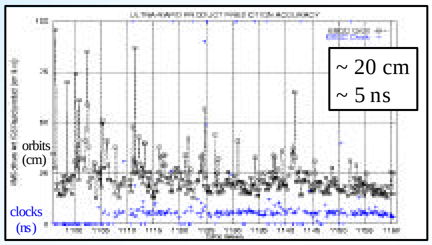
Final Product Comparisons



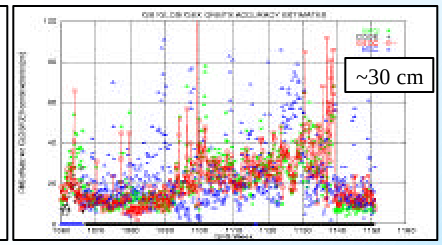
Rapid Product Comparisons



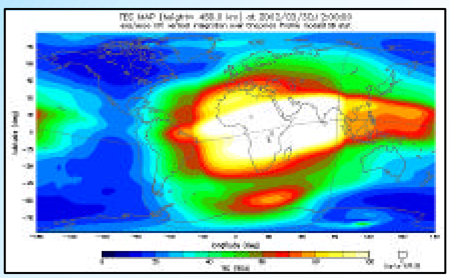
UltraRapid ***Predicted*** Part Comparisons



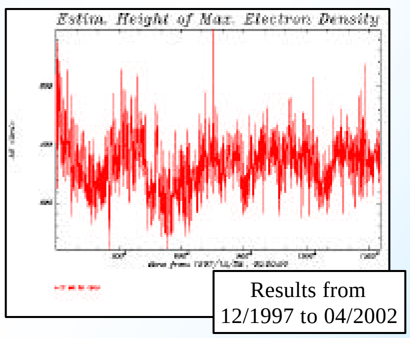
GLONASS Orbit Comparisons



Ionospheric Map 089/2002



Maximum Electron Density Height



Results from
12/1997 to 04/2002

Ionospheric Processing

❶ Basic Observables
- Carrier phase levelled to code
- 6 min. sampling rate / Elev. cutoff is 10 °
- The solar-magnetic frame used internally.

❷ Four runs per day with 24 hours of observation data from about 130 stations:

1st run: Nighttime data. For L1/L2 delay values.

Three more runs: Using 3-d Chapman Profile models. The height of maximum electron density h0 and a geometry parameter are treated in different ways for each run.

ESA GNSS Stations, Recent Changes

❶ Apr. 2001: Malindi (MALI) became an hourly station.

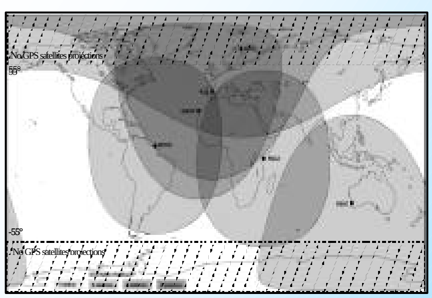
❷ Jan 2002: Kourou 1 (KOU1), a Topcon GPS/GLONASS receiver installed.

❸ Participated in two 1 Hz observation campaigns (Aug.1999 & Apr.2001)

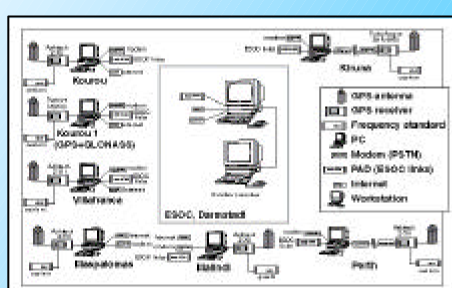
❹ All stations except KIRU now use the new TCP/IP data transfer.

In the near future two new stations in New Norcia (Australia), and Redu (Belgium).

ESA Stations Distribution
and Visibility (20° min. elev.)



ESA Stations Equipment and Connections



* ESA/ESOC LEO Pilot Project activities described in the "IGS LEO - CHAMP Orbit Campaign Status" poster of this session.

Use of the IGS ultra-rapid orbits in the COST–716 NRT campaign 2001

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♣ Introduction

The COST–716 (http://www.oso.chalmers.se/geo/cost716.html) was started in 1999 as the European action for the exploitation of ground based GPS for climate and numerical weather prediction applications. One of the main goals of COST–716 is to demonstrate that it is possible to use the GPS data for operational meteorology. The near real-time (NRT) demonstration campaign for the monitoring of the troposphere was started in February 2001 and the Geodetic observatory Pecný (GOP) has been operating as one of the GPS analysis centers. In this poster, we present the results of our NRT tropospheric monitoring in 2001 during this demonstration campaign. The analysis has been purely based on the use of IGS ultra-rapid orbit product, thus the overview of its 2001 performance is also given.

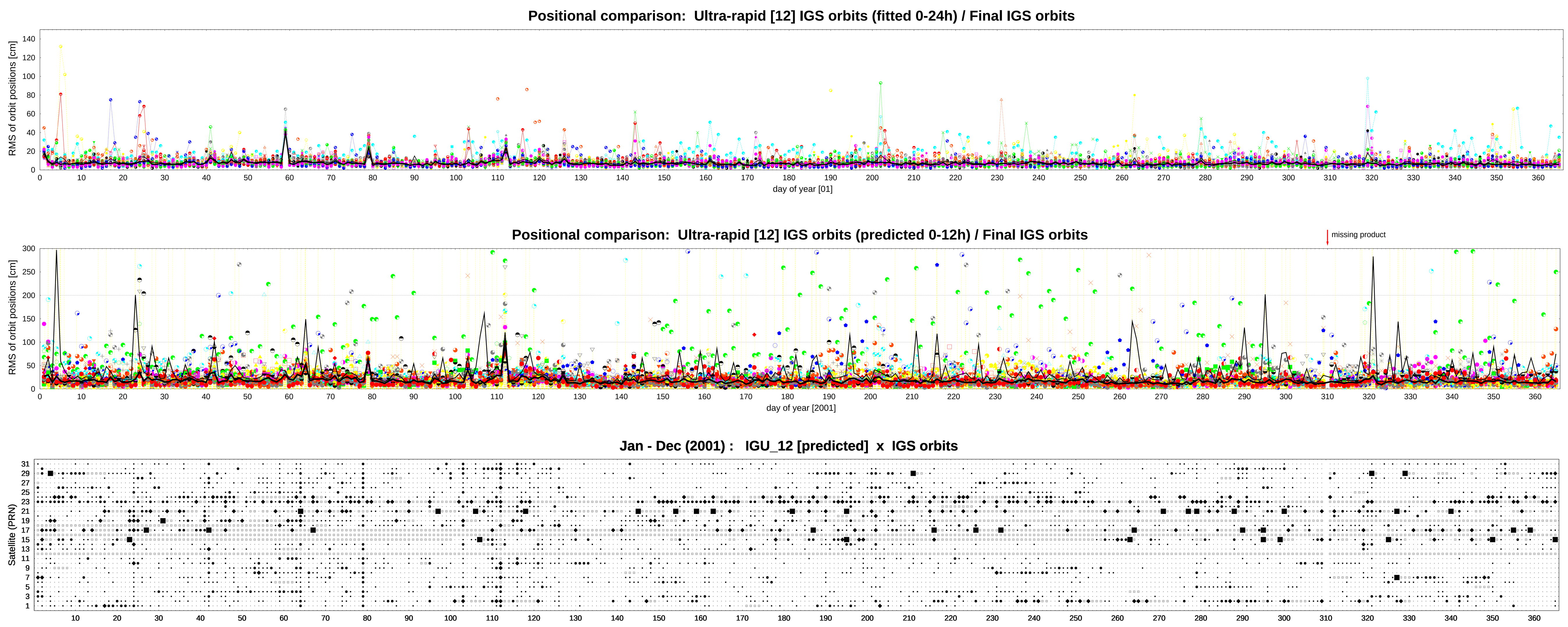

Fig. 1 : *Three plots display the differences of the IGS ultra-rapid orbits (fitted and predicted) compared to the IGS final orbits. The IGU_00 product results in the similar plots.*

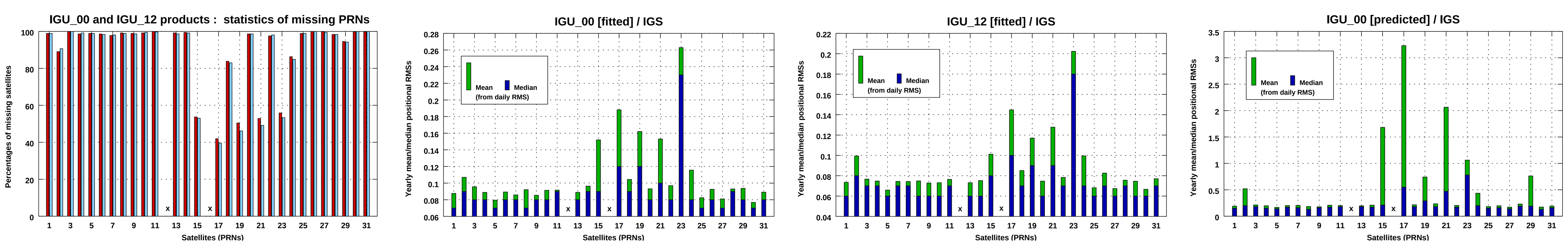

Fig. 2 : *The figure left shows the statistics of missing PRNs in the IGS ultra-rapid 2001 products (IGU_00: red, IGU_12: blue). The last four graphs displays the mean and median RMS during 2001 for all PRNs, for fitted and predicted parts of the IGU [00,12] orbits.*

♣ IGS ultra-rapid orbits (performance in 2001)

The IGS ultra-rapid orbits (IGU) have been available since March 2000, *(Springer and Hugentobler, 2001)*. At the beginning, the product suffered especially of the lack of data and the contribution of only a few analysis centers. Nevertheless, mostly six centers has delivered their contributions during 2001, and thanks to the effort of many operational centers, data centers and the coordination by the IGS, the IGU product has started to be very stable. This is obvious from the Fig. 1 showing the daily comparisons with respect to the IGS final orbits in 2001. From the comparison the quality can be characterized by the median RMS of about 8 cm and 18 cm, or the mean RMS values of 10 cm and 50 cm, for fitted and predicted part respectively. Labeling IGU_00 the moorning ultra-rapid product and IGU_12 the afternoon one, there was in total only a single missing IGU solution during 2001 – IGU_12: doy 310. While using the product in NRT, or checking a posteriori comparisons in Fig 1, we could identify about 2-4 further solutions hardly to be useable especially in its predicted parts – IGU_12: doys 059, 064, 079 and 112. The problem always dealt with the single IGU combination, thus it has been simply solved in our NRT analysis by the automatic prolonging the orbit arcs from previous IGU product.

The Figure 2 shows the quality of each satellite performance individually. We clearly see that only a few satellites suffered of modelling problems during the whole year 2001. The results presented in the following section proved that IGS ultra-rapid orbits reached in 2001 the stability sufficient for the operational NRT tropospheric monitoring.

♣ Results from COST–716 NRT tropospheric monitoring campaign

Tab. 1 : *ZTD comparisons*

	NRT × PP		
site	bias [mm]	sdev [mm]	#
ABYW	-0.3	5.4	3996
BEAU	-0.4	5.1	4246
BOGO	-0.1	4.7	3288
BOR1	-0.0	4.4	5171
BUCU	-0.7	5.9	4118
BZRG	-0.9	5.8	3999
CAGL	0.9	7.0	3050
CAMB	-0.8	5.3	4739
DELF	0.4	4.8	4472
DENT	-0.4	5.1	758
DOUR	-0.8	4.9	4574
DUNK	-1.1	5.3	5112
EIJS	-0.4	4.3	4479
GOPE	-0.8	5.2	4863
HELG	-0.4	5.3	5179
HERS	0.3	5.4	3613
HOFN	-0.6	5.7	3776
HURN	-0.4	5.3	4080
ISTA	-0.8	7.0	4041
KIRU	0.3	5.2	2079
LERW	-0.4	4.8	5168
MALL	-1.2	7.4	4813
MAR6	0.3	4.7	4958
MATE	-0.9	7.0	4244
ONSA	1.4	4.5	4985
ORID	-0.9	6.1	4157
OSJE	-0.8	5.1	4978
PENC	-0.1	4.8	4562
PERS	-1.1	5.1	3839
PFAN	-0.4	4.0	2757
POTS	0.7	4.1	5493
REYK	3.9	7.0	4982
SBGZ	-0.3	4.0	3166
TERS	0.0	4.4	4538
TORI	-0.6	5.8	3742
TUBO	-0.2	4.3	1732
UPAD	-0.4	5.2	4290
VALE	-0.6	7.5	4427
VENE	-0.0	5.1	4529
VIS0	0.4	4.6	5010
WROC	-0.7	4.6	3578
ZWEN	0.6	6.6	3605

Since the beginning of 1999, the GOP AC has been routinely analyzing a part of the EUREF Permanent GPS Network (EPN) for the NRT tropospheric monitoring. Our solutions have been processed using the Bernese GPS software *(Hugentobler et al.,2001)* and the double-differenced observation approach. From the beginning, various strategies of NRT analyses, especially concerning different orbit handling, were performed, e.g. *(Douša, 2001)*. High stability of the IGU product in the second half of 2000 allowed us to set up a procedure with orbit generally fixed for COST-716 NRT 2001 campaign. The NRT procedure of satellite checking based on residual checking *(Springer and Hugentobler, 2001)* was performed during the analyses in two steps: the first for total PRN exclusion (very bad cases only), the second for the PRN exclusion from individual baselines only (usually some cases for long baselines). The necessity of the first step was rather exceptional during 2001 (the satellites were already excluded in the combination).

The procedure of our NRT analysis has been running for every hour by estimating one tropospheric parameter (ZTD) per each hour. The procedure is based on hourly preprocessing followed by the stacking of last 12 normal equations. The coordinates are solved for the last 7 days before the final ZTD estimation where they are already kept fixed. The latency of the COST-716 NRT tropospheric product is required to be less then 1 hour 45 minutes, in our case it is usually about 1 hour. The network analysed in GOP AC for the COST-716 project consists of the EPN sites providing hourly GPS data. Preferred location is the central and eastern part of Europe, Fig 6. Additionally, we are also processing the GPS sites operated by the UK Met. Office and the sites from Belgium and Netherlands.

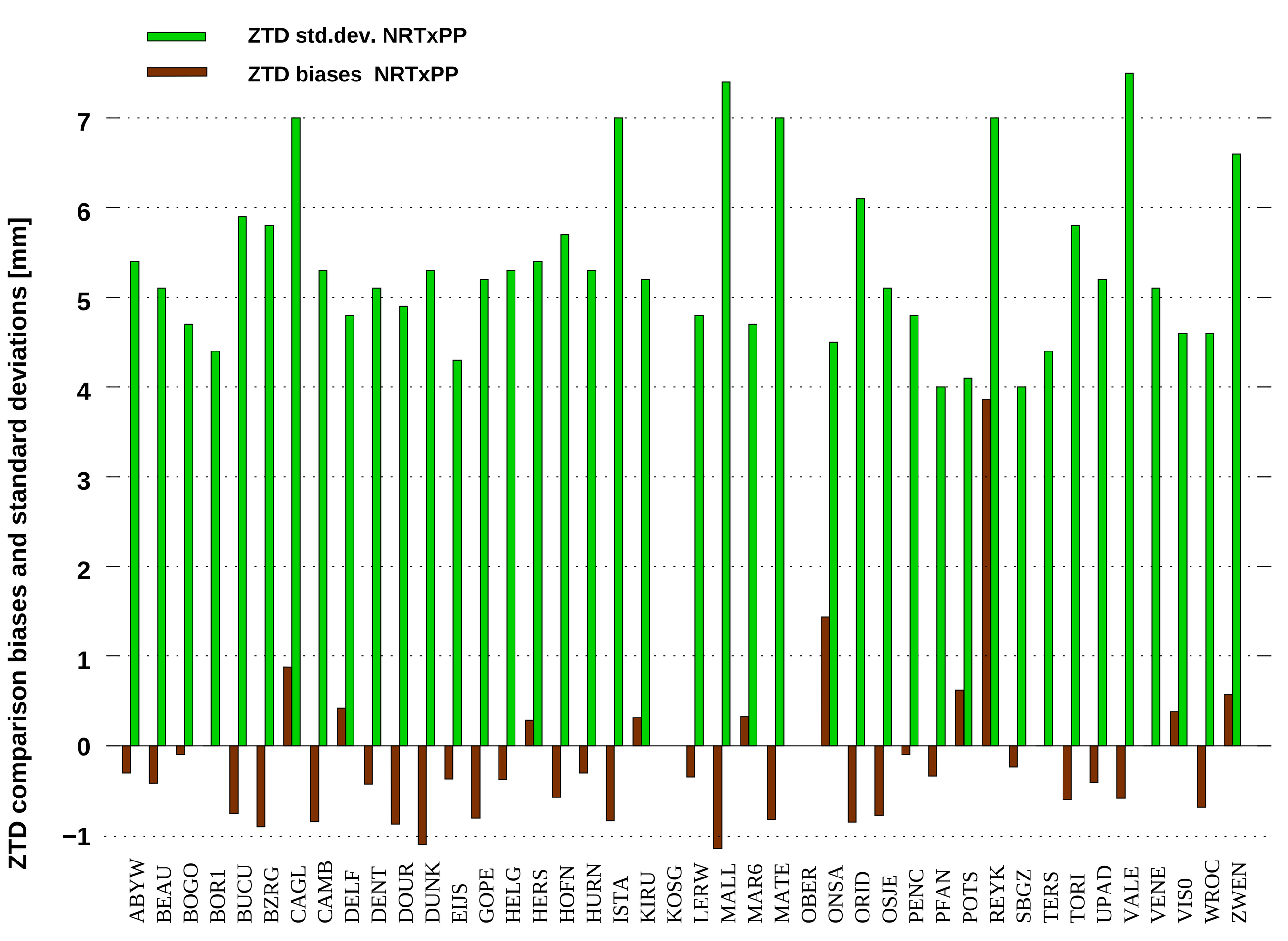

Fig. 3 : *The graph summarizes standard deviations and biases for the GOP NRT and PP ZTD comparisons.*

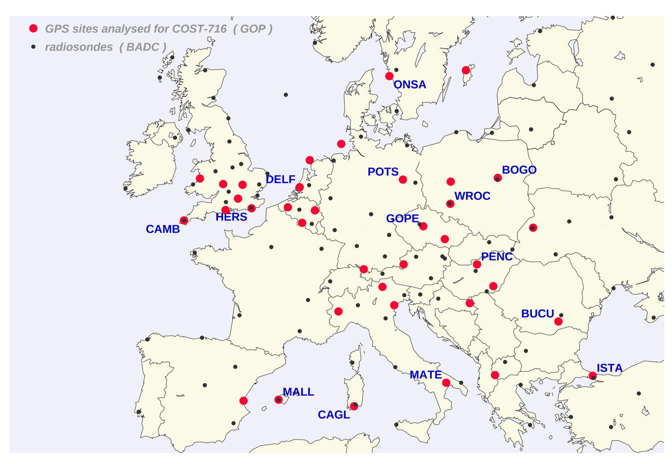

Fig. 4 : *The map of the core of European NRT network analysed by GOP in 2001.*

site	bias [mm]	sdev. [mm]	#
BOGO	0.8	1.2	228
BUCU	0.6	1.8	279
CAMB	0.9	1.3	666
DELF	-0.1	2.0	670
GOPE	0.5	1.6	788
HERS	0.5	1.6	257
ONSA	0.9	1.6	277
PENC	-0.4	1.9	350
POTS	-0.1	2.1	847
WROC	0.7	1.6	91

Fig. 5 : *PWV comparisons*

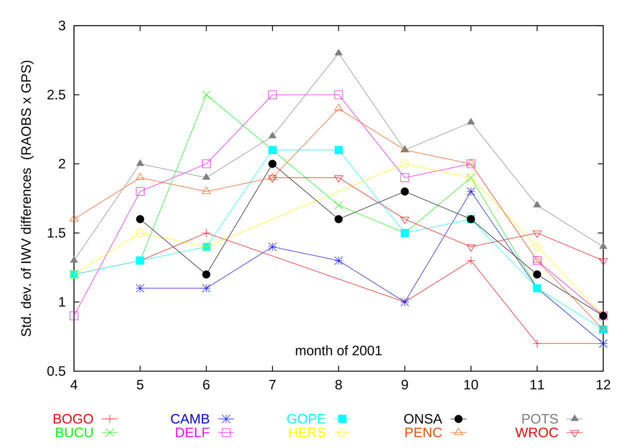

Fig. 6 : *The monthly comparisons of PWV from GPS and radiosondes.*

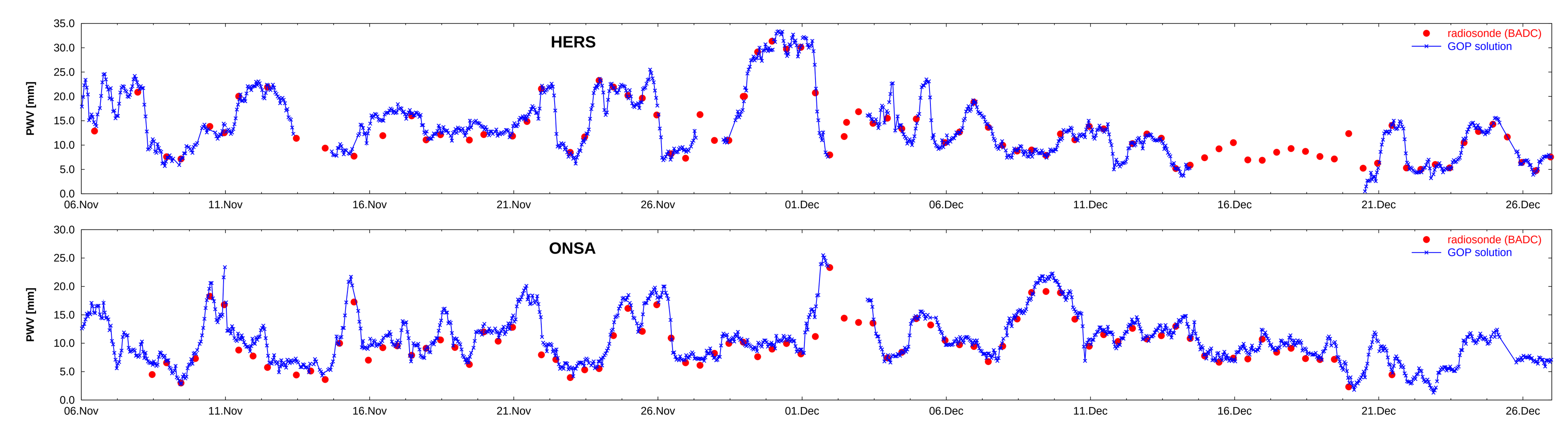

Fig. 7 : *Two examples of the PWV series estimated from a ground based GPS and from radiosonde profiles (sites ONSA, HERS).*

Besides the NRT solution, the GOP AC has routinely provided also the post-processed GPS solution (PP) in 2001. The PP solution is based on daily processing and made use of the IGS rapid orbits. Presented ZTD comparisons between our NRT and PP solutions thus represents the internal GPS quality (Table 1 and Fig 3) of two sligtly different approaches with different fixed orbits. In addition, for some sites of our network, there were close radiosonde sites to the GPS stations (considering up to 50km) – Fig 6 – and we could compare our ZTD NRT results (transformed by S. de Haan, for the COST-716 to the precipitable water vapor – PWV) with those PWV values integrated directly from the radiosonde observations. The monthly and total PWV comparison can be found in Fig. 6 as well as short example of PWV time-series for two sites, Fig. 7. Summarizing the results, we could find the typical standard deviations of 4-6mm in ZTDs, about 7 mm in ZTD for sites on margin of our network (baselines > 2000 km) and the standard deviation of 1.2–2.1 mm in the PWV values from preliminary comparisons with the independent technique (radiosondes).

References: **Hugentobler U., Schaer, S. and Fridez, P. (2001),** *Bernese GPS Software Version 4.2, Astronomical Institute, University of Berne, Berne, Switzerland.*

Douša, J. (2001), *The Impact of Ultra-Rapid Orbits on Precipitable Water Vapor Estimation using Ground GPS Network Estimation Phys. and Chem. of the Earth, Part A, 26/6-8.*

Springer, T.A. and Hugentobler U. (2001), *Ultra-rapid products – quality dependence on network performance, Phys. and Chem. of the Earth, Part A, 26/6-8.*

Acknowledgements: *The radiosondes data were provided by the British Atmospheric Data Center (BADC), the conversion of ZTD to PWV was done by Siebren de Haan (KNMI, the Netherlands). This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic (OC 716.001) and Grant Agency of the Czech Republic (103/00/P028)*

CTU

Study of different analyzing schemes for the ultra-rapid orbit determination using the Bernese GPS software

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♣ Motivation

The Bernese GPS software (BSW) *(Hugentobler et al., 2001)* is a package for processing GPS data in batch mode. With version 4.0 the BSW provides a tool for the stacking of normal equation (NEQ) allowing to minimize redundant raw data re-processing. The CODE rapid orbit product is based on this method using the advantage of generating 3-day arcs by combination of three daily NEQs pre-processed individually. Nevertheless, with today's requests for near real-time (NRT) analyzing capabilities, also the orbits should be computed in a subdaily cycle. There is, therefore, a high priority on setting up a strategy optimized between a fully data re-processing (correct) approach (Fig. 1a) and a fully stacking (efficient) approach (Fig. 1c) with the pre-processing interval (and NEQs) reduced to the update cycle. This was a primary motivation for the work presented in this poster besides of setting up a general procedure for an ultra-rapid processing with the Bernese GPS software and adapting the source-code accordingly for version 5.0.

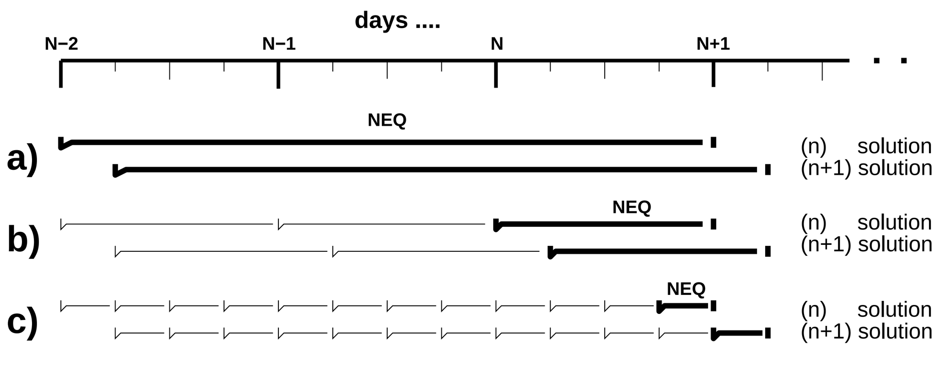

Fig. 1: The variants of a final 3-day solution generated using a different data pre-processing interval and NEQ combination technique (6-hours updating cycle): a) fully 3-day batch processing, no stacking, b) combined strategy, c) no-redundant pre-processing, fully stacking procedure.

♣ Variants of Analysis Strategy

To study the optimum approach for generating ultra-rapid orbits five variants of the same processing strategy have been set up using pre-processing intervals ranging from 2 to 24 hours, see Table 1. The general scheme of the processing was designed as close as possible to the current CODE rapid solution. We had to respect the specific aspects of the subdaily analysis using the hourly GPS data and we had to unify the setup for all 2H, ..., 24H solutions! In addition, the common strategy was simplified in order to separate the influence from ambiguity fixing, applying stochastic orbit parameters, and estimating ERPs.

The GOP NRT solution (last line of the table) *(Douša, 2001)* was routinely provided in Jan-Apr/2001 using an adapted version of BSW V4.2 and a 3 hours updating cycle. Although the strategy is different from the tested variants, we include this solution for comparison purposes.

An automatic arc splitting procedure, referred to in the last column of Table 1, is applied in the case of problems with long-arc modeling. The CODE arc splitting procedure is based on checking of residuals from fitting the positions of two consecutive precise (SP3) orbit files into a single orbit arc. The procedure adopted for the tests is checking the differences between long-arc orbits (e.g. 3 days) and the respective short-arc orbits (e.g. 6×12 hours). For the GOP product, the new satellite arc splitting procedure was performed for the tests only.

Variant	final arcs	pre-processing	# NEQs	data files	amb. fixing	ERPs	stoch. orbit	# sites	arc splitting procedure
	[days]	[hours]		[hours]					
24H	3	24	3	1	no	no	no	51	differences
12H	3	12	6	1	no	no	no	51	differences
6H	3	6	12	1	no	no	no	51	differences
4H	3	4	18	1	no	no	no	51	differences
2H	3	2	36	1	no	no	no	51	differences
CODE	3	24	3	24	yes	yes	yes	120	residuals
GOP	2	6	8	1	no	yes	no	43	(differences)

Tab. 1: Table summarizes the setup for the tested variants, CODE rapid, and GOP NRT orbit products.

♣ Benchmark Data Set

Hourly RINEX observation files for the benchmark tests were downloaded from the IGS data centers for 18 days in the year 2001 (doys 052-069). Three satellites (PRN 6, PRN13 and PRN 18) were manoeuvered during this time period, but the events were considered as a priori unknown and identified by the processing. Except for PRN 15 (status: unhealthy) the orbits of all available satellites were determined.

♣ Comparison

The comparisons of all tested variants are based on two criteria: 1) on the efficiency expressed in the processing time and 2) on the accuracy of the fitted and predicted arcs of the orbits. The accuracy was derived from the residuals of a 3-parameter Helmert transformation between the inertial satellite positions compared to the IGS final orbits. The rotation parameters of the transformation were estimated to eliminate the effect of slightly different ERP parameters. The fitted part was compared for the entire day of the arcs, the predicted part was divided into four subintervals (0-6h, 6-12h, 12-18h, 18-24h predictions). The subdaily solutions were updated several times per day, for the comparisons, however, only the last solution of the day was evaluated. To estimate the impact of the tested variants on all the orbits, no satellites were excluded from the comparison except those actually manoeuvered. The final IGS orbits, as the best available solution, were used as a 'ground truth' for the comparisons. Nevertheless, the IGS orbits of individual satellites incidentally show inconsistencies between consecutive days as may be seen in Fig. 5. This may affect our comparisons, especially for the predicted part.

For the first two days a lower orbit accuracy for the tested variants is expected because of the initialization of the processing - only observations from one resp. two days were used instead of three days.

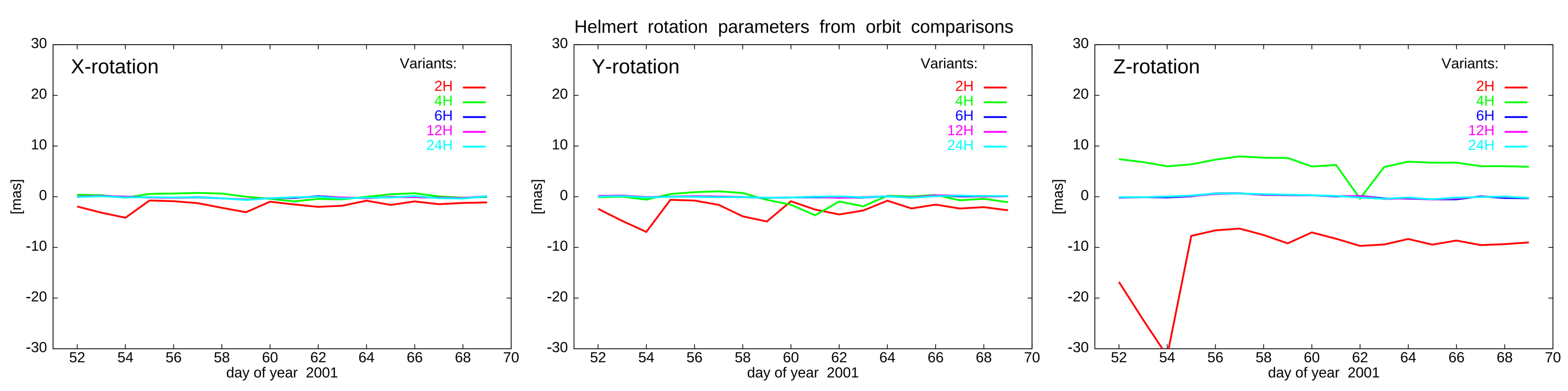

Fig. 4: Helmert rotations estimated from the comparison of five tested orbit solutions with respect to the IGS final orbits.

♣ Results

A) Figure 2 and Figs 7-9, 12-13 clearly indicate that the variant 6H (6-hours pre-processing, stacking of 12 NEQs) is a reasonable compromise among all other tested variants listed in Table 1.

The solutions based on shorter NEQs (2H, 4H) are too unstable for the pre-processing due to the ambiguity estimation, Fig. 3. Some arcs have been biased in the along-track component which caused the additional Z-rotations in the Helmert comparisons (see Fig. 4). As a consequence, the accuracy for all orbits in the 2H and 4H solutions was decreased, Figs 7-9, 12-13. The efficiency of the two shortest variants is even not higher since the number of parameters (troposphere zenith delays, ambiguities) is not much reduced.

The solutions from the longer pre-processing variants (12H, 24H) took in general 1,5 to 2,5 times more processing-time while an accuracy equivalent to that of the 6H solution was achieved.

The first day of the comparisons demonstrate the lower accuracy for the case where the long-arc makes use of one day of data only.

B) The new automatic procedure for long-arc splitting was successfully set up and tested. It does not require any a priori information and usually stops with introducing necessary arc-splittings over the 3-day orbit solution after 2-4 iterations, Fig. 10. The procedure is efficient and general enough to accomplish the tasks for a subdaily orbit product with arbitrary update rate.

C) Comparing the CODE rapid orbits with the most similar variant 24H (Figs. 7-9, 12-13) we could check our tested strategies against the strategy adopted in the CODE rapid service. The main differences of these strategies are summarized in Table 1. In addition, Fig. 11 shows the expected impact on the orbit accuracy by extending the prediction interval.

D) The routine results for the GOP NRT orbits are very close to the results achieved by the 6H variant, see Figs. 6 and 12, 13.

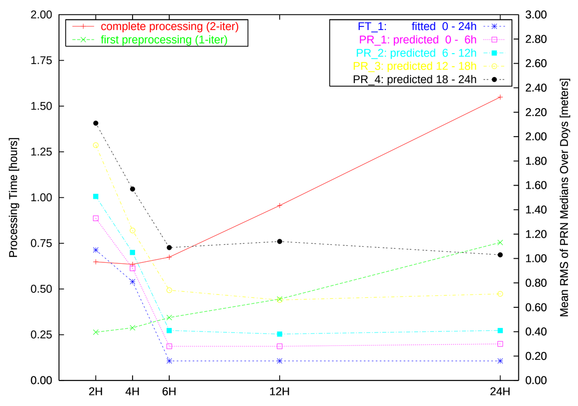

Fig. 2: The x-axis corresponds to the data pre-processing and NEQ lengths (variant ident.). The y-axis shows the processing time for two analysis steps. The y2-axis gives the mean RMS of the comparison of the resulting orbits with the IGS final orbits.

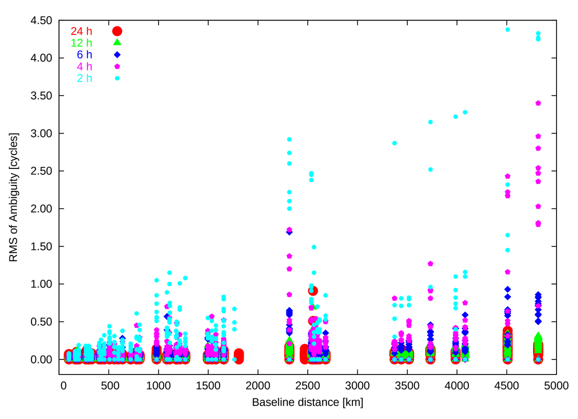

Fig. 3: RMS values of baseline-wise estimated ambiguities for the strategies 2H, ..., 24H as a function of baseline length. Extremely high RMS in the 2H and 4H solutions might be the main reason for the problems in modeling of the arcs for some PRNs.

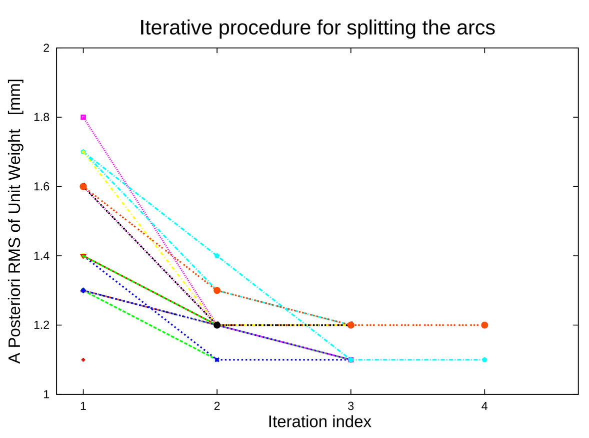

Fig. 10: The figure demonstrates the improvement of the orbit solution for badly modeled PRNs with the number of iterations (x-axis) for automatic long-arc splitting.

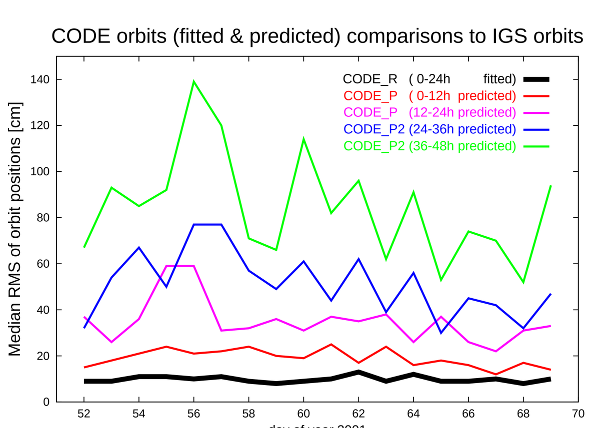

Fig. 11: The median RMS of CODE fitted and predicted orbits (CODE_R, CODE_P, CODE_P2) characterizes the decrease of orbit accuracy when extending the prediction interval by a multiple of 12 hours.

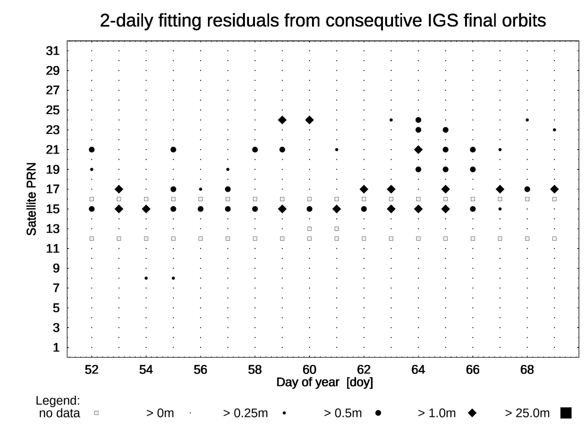

Fig. 5: Consistency of fitting two consecutive IGS final SP3 files with a single 2-day arc.

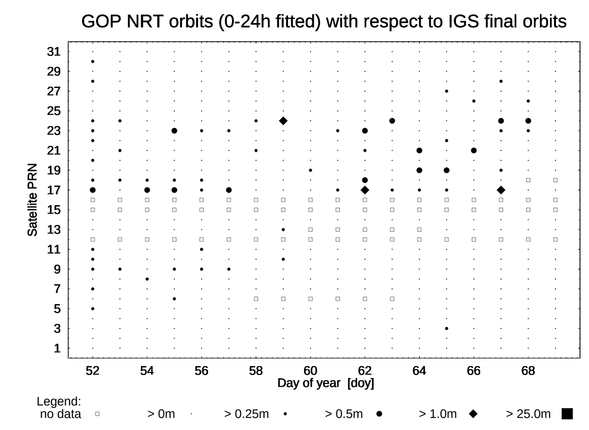

Fig. 6: Comparison of fitted orbits (0-24h) for GOP NRT orbits.

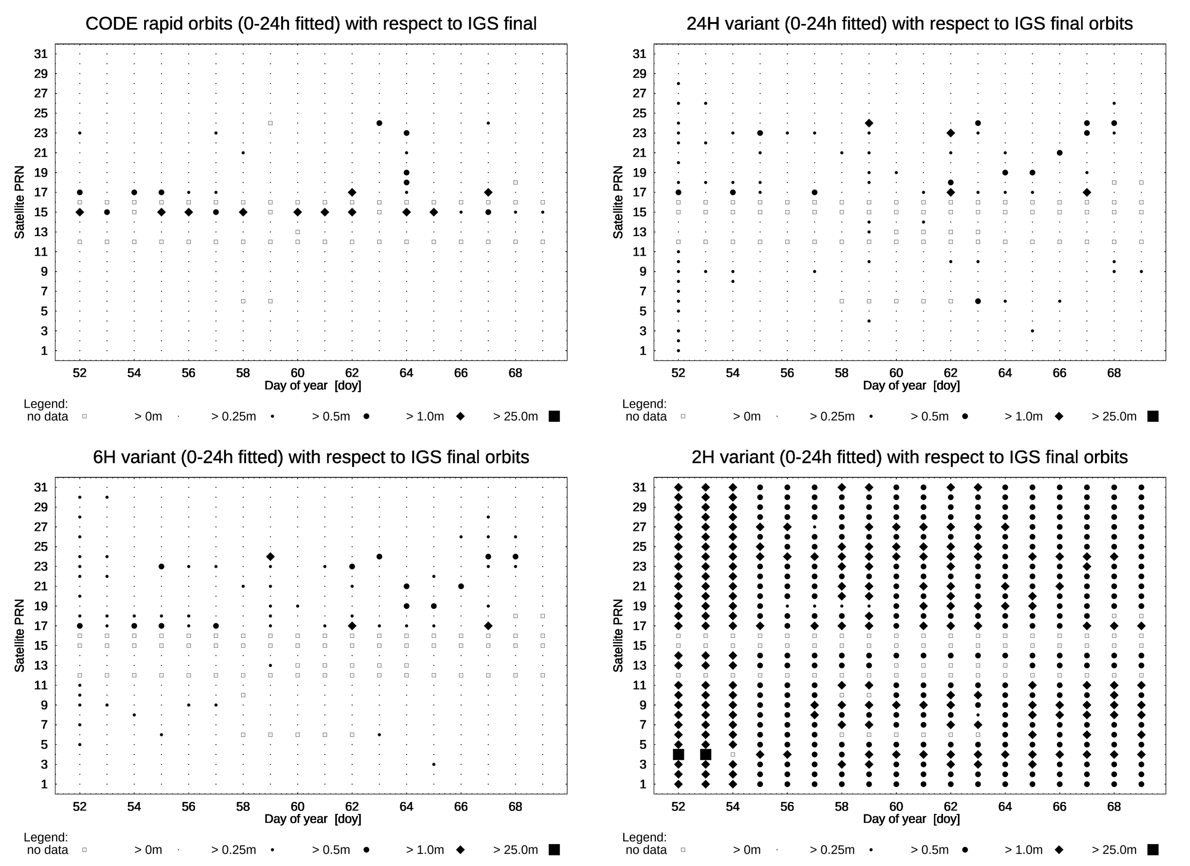

Fig. 7: Comparison of the fitted orbit parts (0-24h): CODE_R (rapid) orbits and the variants 24H, 6H and 2H with respect to the IGS final orbits ordered in accuracy bins.

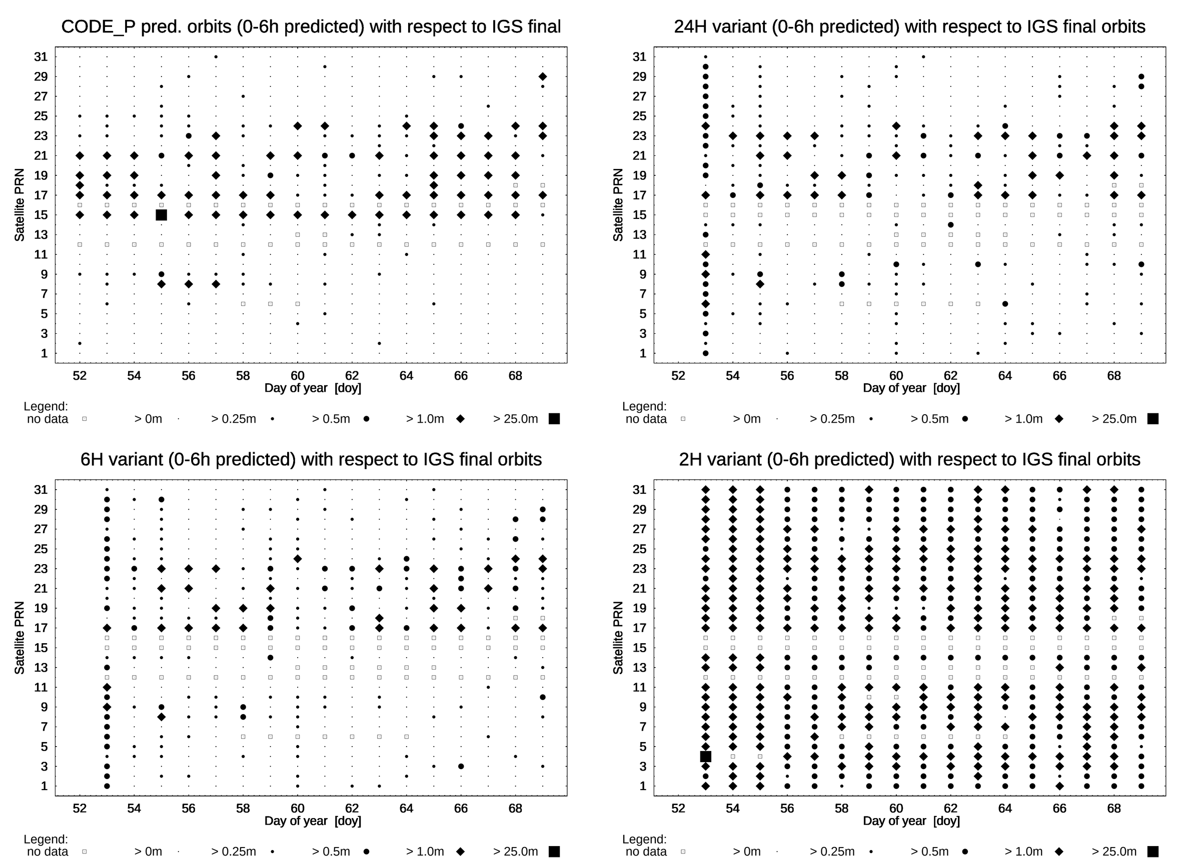

Fig. 8: Comparison of predicted orbit parts (0-6h): CODE_P (1 day predicted) orbits and the variants 24H, 6H and 2H with respect to the IGS final orbits ordered in accuracy bins.

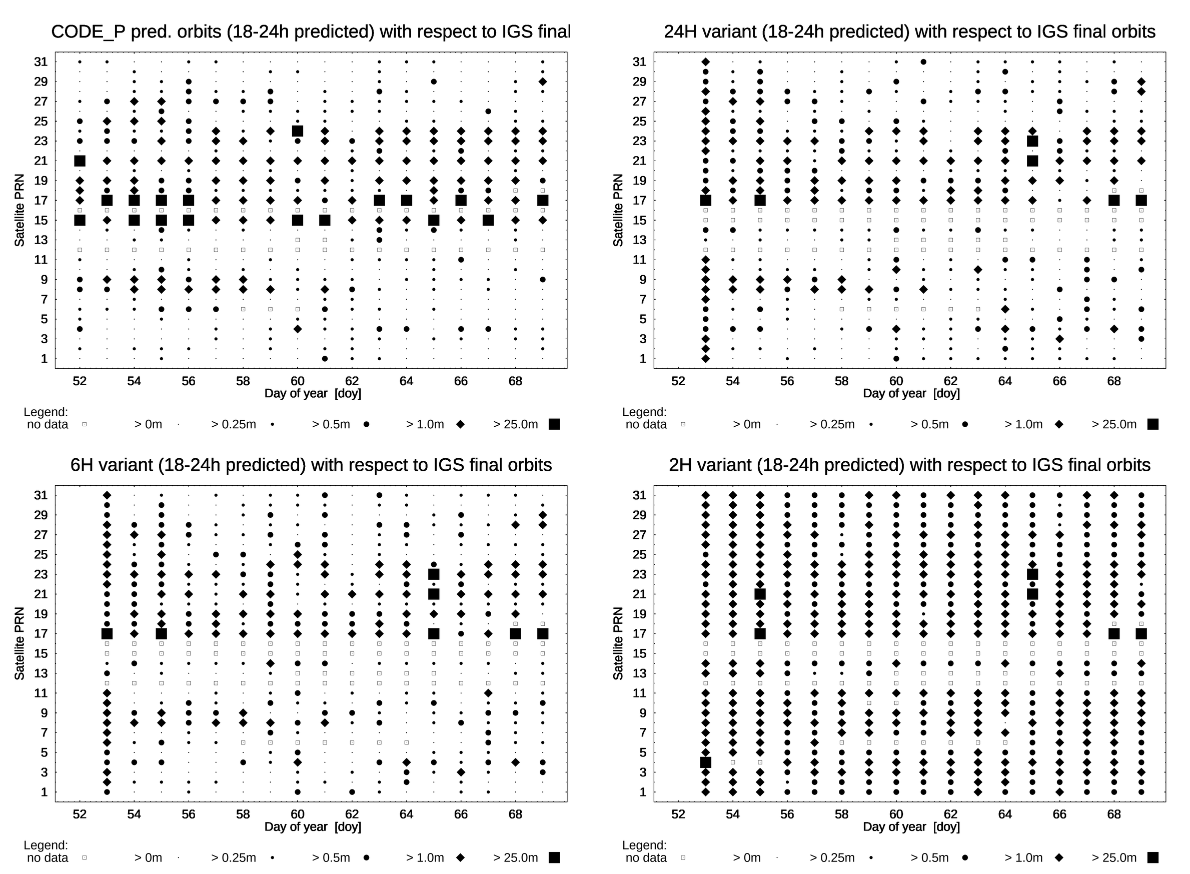

Fig. 9: Comparison of predicted orbit parts (18-24h): CODE_P (1 day predicted) orbits and the variants 24H, 6H and 2H with respect to IGS final orbits ordered in accuracy bins.

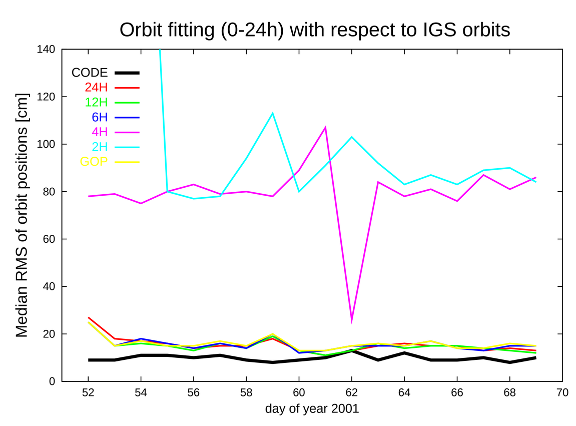

Fig. 12: Median RMS values of the last fitted day (0-24h) for all different solutions, for CODE rapid, and for GOP NRT orbits.

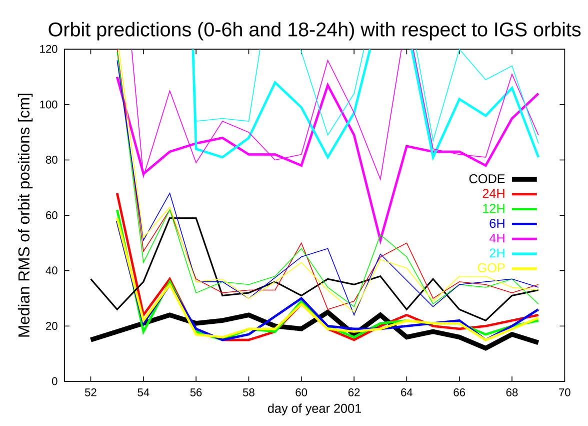

Fig. 13: Median RMS values of predicted parts (0-6h, 18-24h) for all different solutions, for CODE rapid, and for GOP NRT orbits.

Acknowledgement. *This project was supported by the Swiss National Science Foundation (20-57168.99) and by the Ministry of Education, Youth and Sports of the Czech Republic (OC 716.001, LN00A005).*

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Global NRT solution by the Geodetic Observatory Pecný AC

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♣ Motivation

The activity of the Geodetic Observatory Pecný (GOP) AC in the field of the NRT processing has started already in 1999. The main priority was given in the operational monitoring of the troposphere. Such analysis is rather dependent on the quality of the orbits and the GPS geometry. In the beginning, we have used the CODE predicted orbits with its partial relaxation prior to the other variants, e.g. *Douša 2001*.

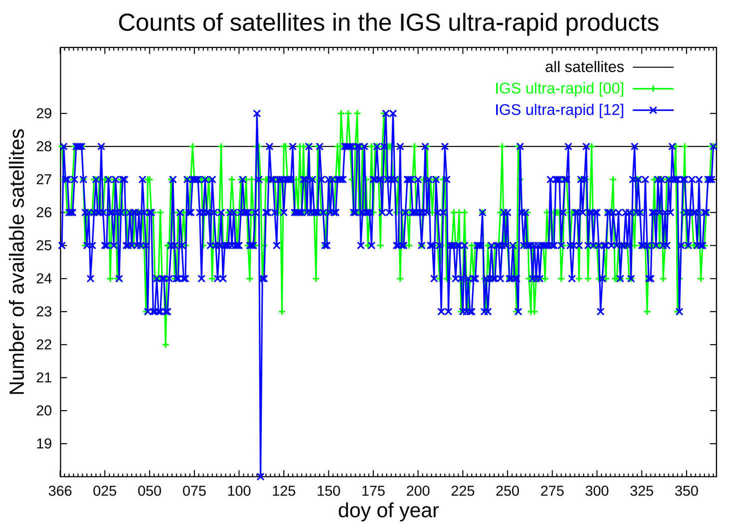

Fig. 1 : *The numbers of satellites in IGU product (2001).*

Thanks to the IGS's effort in the coordination and, of course, thanks to all the responsible contributing institutes, high quality NRT orbits (ultra-rapid, IGU) has been available since March 2000 *(Springer and Hugentobler, 2001)*. For the COST–716 NRT demonstration campaign 2001 (`http://www.knmi.nl/samenw/cost716/`), the GOP purely used 'fixed' IGU-orbits for routine analysis of the network of 46 GPS sites in Europe, *(Douša, 2002)*. Although the IGU product proved to be very stable for the activity of troposphere monitoring, some slight improvements can be still expected. Let assume two reasons:

1) satellites missing in the IGU product (up to six – Fig. 1) weaken the GPS geometry (this is more or less significant in the troposphere estimation),

2) using a prediction necessarily up to 15 hours, the IGU orbit errors of some satellites can reach up the meters (exceptionally even tens of meters).

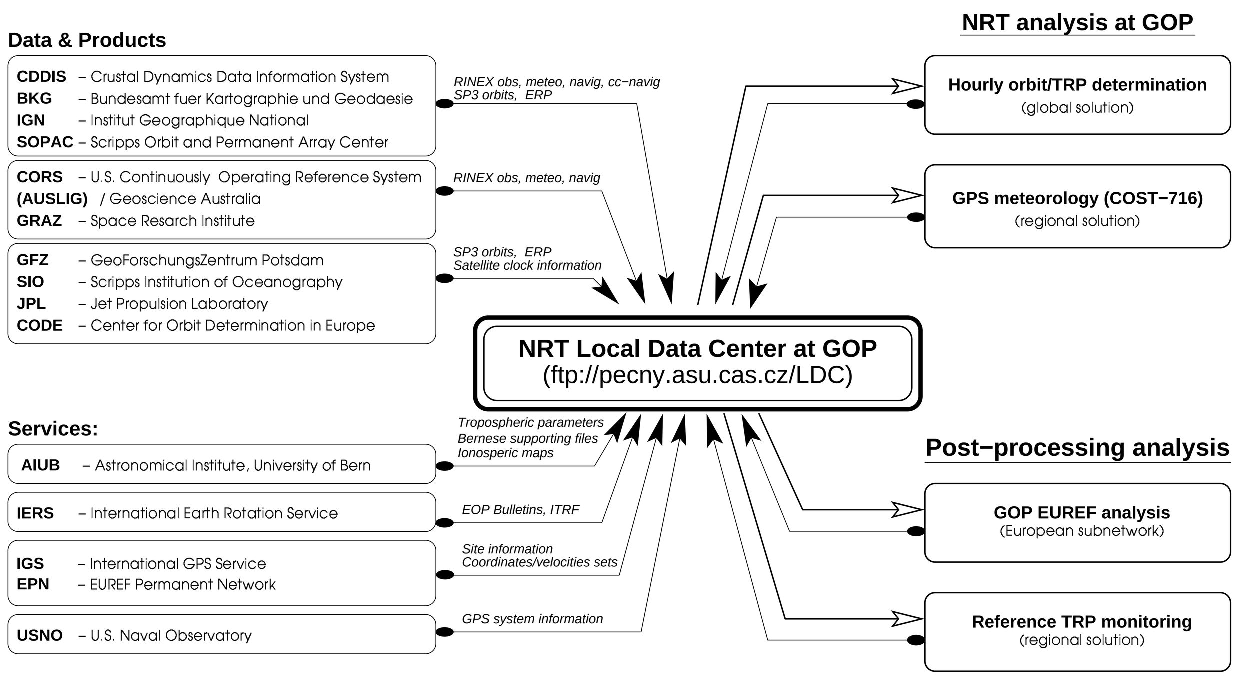

Fig. 3 : *The scheme of the GOP near real-time data center flows.*

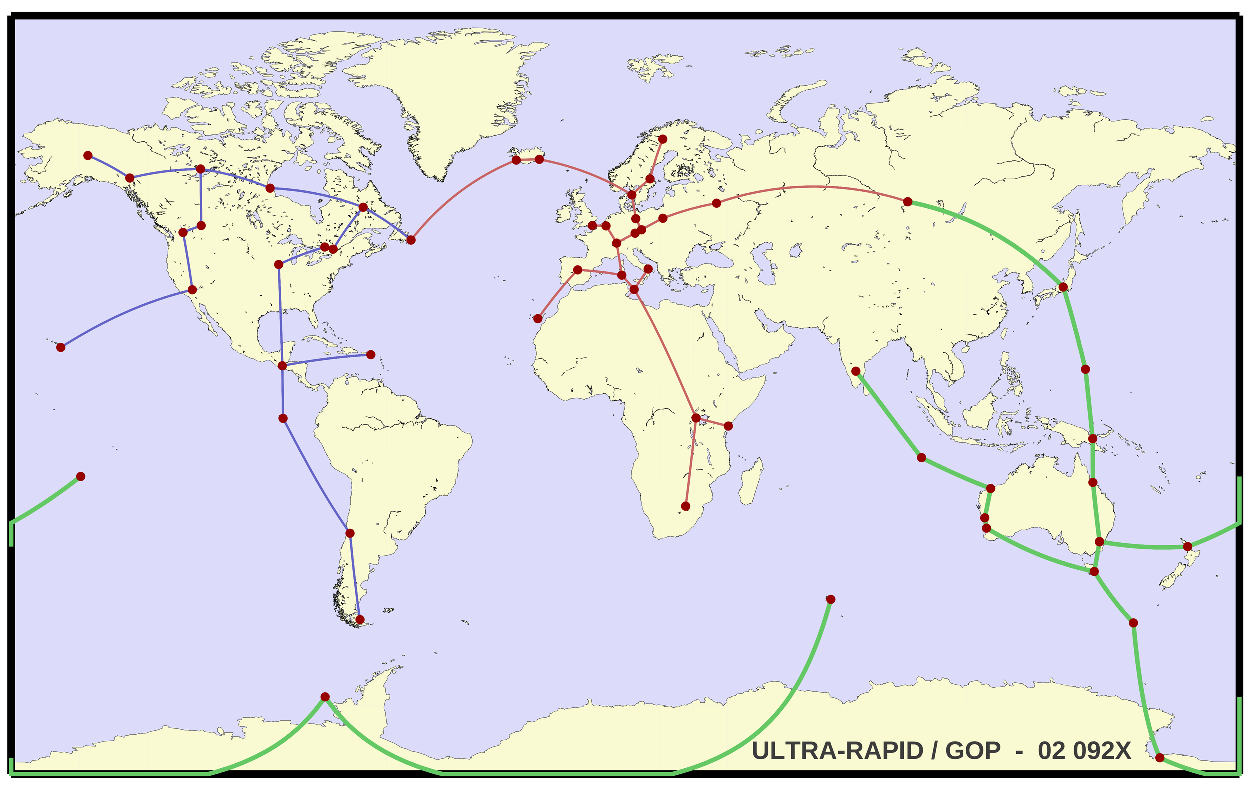

Fig. 4 : *Global NRT network for GOP orbit determination (analysed using three cluster).*

♣ Introduction

Based on above motivation, the GOP AC actually processes also a NRT solution devoted to the correct global orbit determination. We still consider worthwhile to contribute into the common service while sharing the effort better than applying any individual regional orbit relaxation. Thus, beside the other routine GPS analyses (e.g. Fig. 3) our global activity was started at the end of 2000. Only since Oct 30, 2001 the analyses has been running continuously. The processing is performed with the Bernese GPS software (BSW, *Hugentobler et al., 2001*). From the beginning, the adopted version 4.2 of the BSW was applied, while in the second half of 2001, the new (preparing) version 5.0 was introduced to our routine global NRT solution. Together with the significant changes between the BSW version 4.2 and 5.0, especially concerning the new libraries and MENU system, our script structure has been completely rewritten and further efficiently prepared even for the possible Bernese Processing Engine update.

♣ Processing system

Our system of the global NRT analysis is mostly based on the effective procedure of stacking the normal equations (NEQs). The special experiment *(Douša and Hugentobler, 2002)* proved that optimal strategy consists in 6 hours data pre-processing and saving the NEQs. These pre-processing steps are analysed in 2-3 clusters, Fig 4, thus they are combined into the unique global subsolution as well. Finally, the orbit determination is purely an act of applying the sequential NEQ combination technique on the set of relevant subsolutions.

Our analysis scheme is sketched in Fig. 2. Starting from Jan 1, 2002, the whole processing cycle, and thus the GOP NRT orbits, are updated in 3 hours period. The GPS observations from approx. 70 global sites are downloaded through the GOP NRT data center (Fig. 3). The center mirrors relevant resources for data, products and information useful in all our routine analyses. The latency of our global NRT products are about 2 hours, since we are waiting for the GPS data until 50 minutes and the total time for our routine run is approx. 60-80 minutes (dual 600MHz, Linux PC).

The orbits are generating using a 3-day arcs, updated 8 times per day. After 2 processing iterations, the final orbits are checked for the arc-overlaps consistency with the previous two solutions and any exceeding orbits are automatically excluded.

♣ Tropospheric parameters

site	bias [mm]	sdev. [mm]	#	site	bias [mm]	sdev. [mm]	#
ALGO	4.4	3.4	*542*	MKEA	1.9	4.7	*212*
AUCK	1.8	5.0	*183*	MSKU	1.8	4.3	*356*
BRUS	2.1	2.1	*420*	NKLG	0.8	4.9	*294*
CHUR	1.5	2.6	*572*	NLIB	7.9	7.2	*213*
COCO	4.3	5.9	*183*	NRC1	1.4	2.3	*185*
CRO1	2.9	7.1	*245*	ONSA	2.1	2.1	*358*
DRAO	3.5	2.9	*559*	PERT	5.5	3.7	*372*
FAIR	2.6	4.0	*452*	POTS	2.7	2.5	*599*
GOLD	2.3	2.1	*430*	PRDS	2.2	2.1	*368*
GUAM	2.9	4.6	*162*	REYK	2.1	2.5	*526*
HARB	0.3	2.4	*392*	RIOG	-2.8	6.2	*227*
HOFN	6.0	3.5	*580*	SANT	4.4	6.8	*245*
HRAO	1.7	4.3	*217*	SCH2	-1.5	2.1	*373*
IISC	-2.6	5.3	*184*	STJO	0.6	3.3	*405*
KERG	2.0	5.7	*309*	TIDB	4.7	3.9	*393*
KIRU	-0.5	2.4	*367*	TOW2	-1.4	3.0	*170*
KOUR	1.6	6.6	*190*	USUD	3.1	4.5	*196*
LAE1	2.8	5.5	*286*	VILL	0.4	2.3	*417*
MALI	1.6	6.5	*288*	WHIT	0.3	2.0	*393*
MAS1	2.5	4.2	*241*	WTZR	3.2	2.6	*592*
MATE	2.2	3.5	*488*	YAR2	-1.5	2.6	*393*
MBAR	2.6	4.5	*231*	YELL	3.7	2.6	*555*
MCM4	2.7	3.0	*447*	ZWEN	2.4	3.0	*528*

Fig. 6 : *ZTD comparisons*

Besides the orbits, also the NRT tropospheric parameters are estimated in our NRT solution - setting up one parameter per hour. The final GOP orbits are kept fixed in this solution. The processing consists in the combination of last two 6 hours special NEQ sets. From Feb 21, 2002 our NRT tropospheric product is regularly uploaded for the combination in GFZ. After some initial problems, the GOP NRT tropospheric solution has been stabilized. The simple consistency checking with the combined NRT product shows generally good agreement, as demonstrated in Table 6.

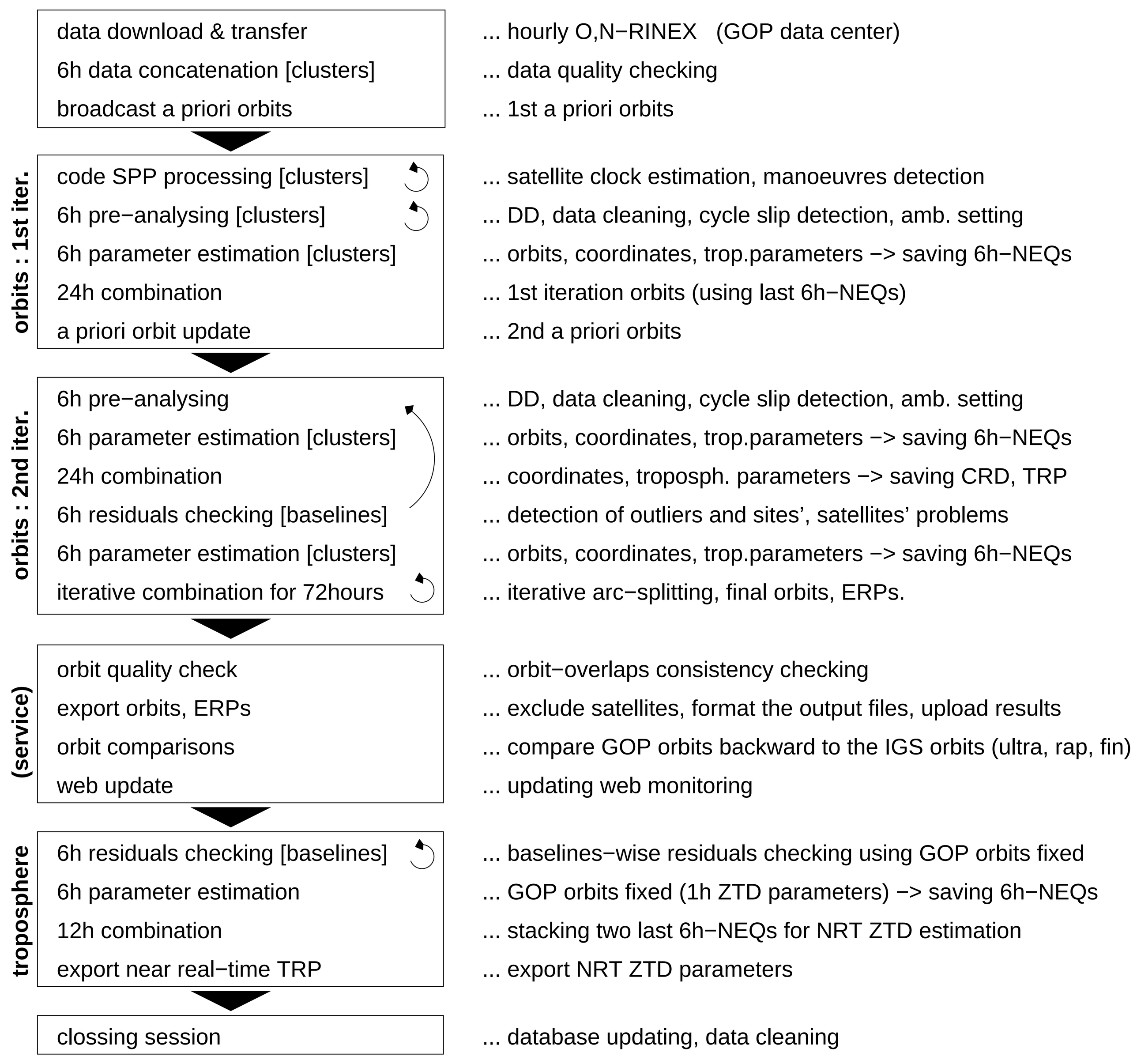

Fig. 2 : *The scheme of the GOP global NRT analysis for the orbit and tropospheric estimation.*

♣ GOP orbits' performance

Usually only a few satellites are missing in our orbit product. Mostly it is a lower number than by the IGU product, Fig. 5. Are the additional satellites in GOP product of a sufficient quality ? During the period of 5 months (Nov 1, 2001 – March 2, 2002), the performance of the GOP orbit is rather variant, but shows the significant improvements from the start of 2001, and later on from the beginning of March (i.e. for last 30 days), Fig. 7. The reasons can be identified with some additional improvements implemented in our solution concerning the careful network reconfiguration, optimized site checking method, setting up an alternative internet connection to avoid any data gaps and even some others.

Checking the differences between the GOP NRT and IGS rapid orbits during the last 30 days (the most stable period) gives the mean RMS of the GOP orbits of about 10-15 cm for the fitted position and for the 6 hour predicted part about 20-25 cm, see Fig. 5. The comparison performed between IGU and GOP products for the last 3 months (starting on Jan 1, 2002) is characterized by the values only slightly higher: 13-17 cm for fitted part and 20-32 cm for predicted part (6 hours).

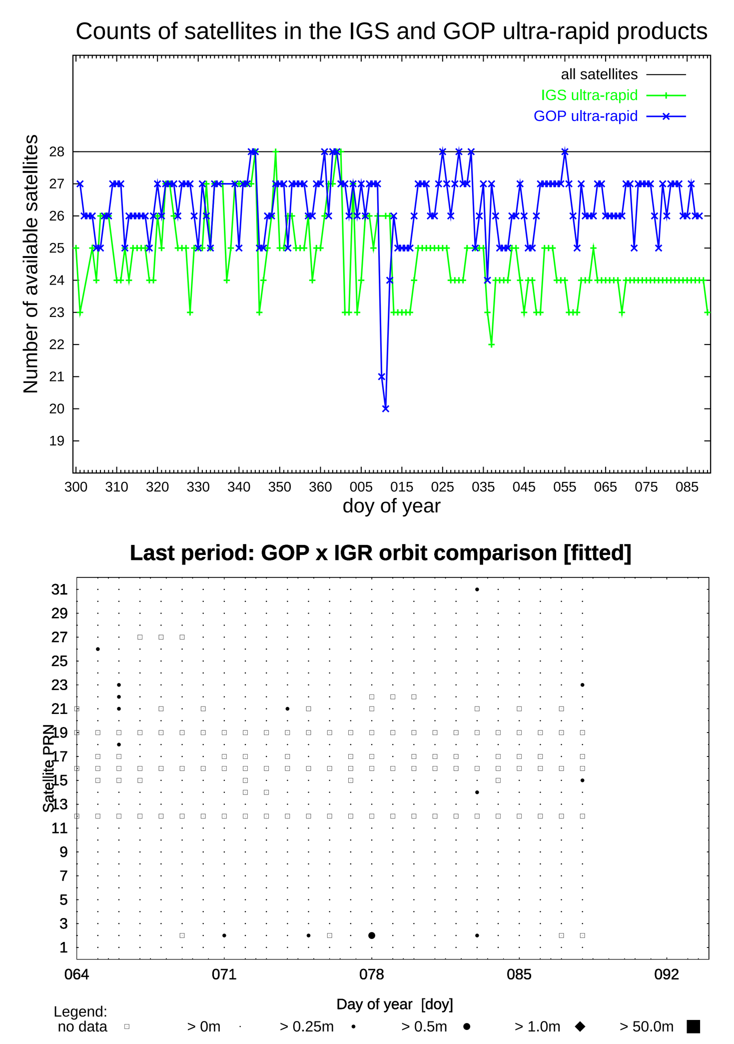

Fig. 5 : *Upper plot shows the numbers of satellites in the GOP and the IGU products. The bottom plot then affirms that GOP fitted orbits are in the last month of high quality for all available satellites. The evaluation here is to the IGS rapid product.*

Acknowledgements:

The author would like to thank for the possibility of sharing the experience with the Bernese GPS group as well as the opportunity to take advantage of preparing Bernese software version 5.0. Special thanks are given to Urs Hugentobler for the work on the NRT orbit determination and to Leoš Mervart for the hard work on the new version 5.0, for ADDNEQ2 combination program extensively used in our solution and for a new MENU system.

This project was supported by Grant Agency of the Czech Republic (103/00/P028) and by the Ministry of Education, Youth and Sports of the Czech Republic (LN00A005).

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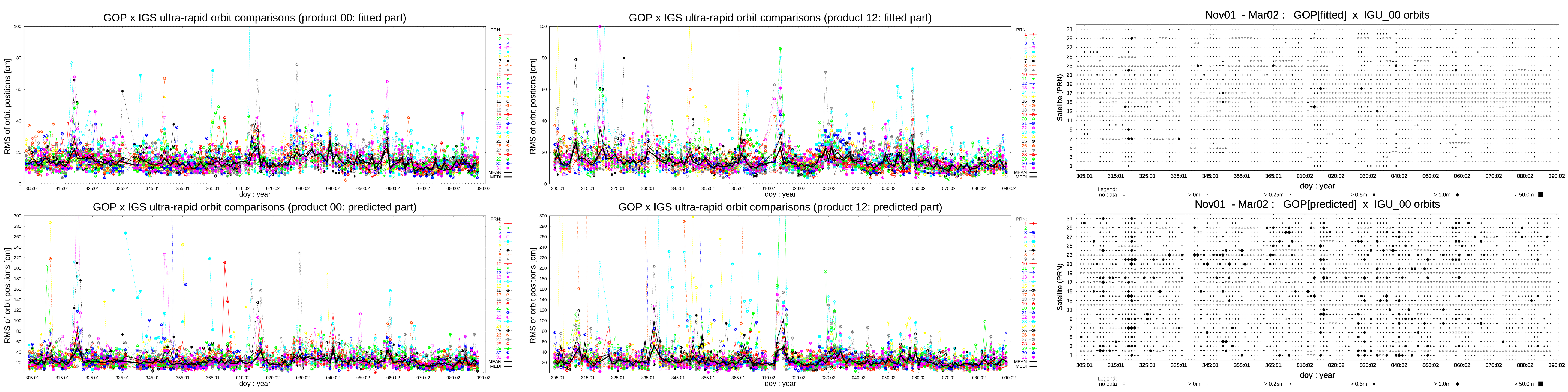

Fig. 7 : *The graphs display the positional differences (twice a day – 00, 12) of the GOP NRT orbits with respect to the IGS ultra-rapid orbits. The upper row plots the differences from the fitted parts (0-24 hours), the lower row for the predicted parts (0-6 hour). Two figures at the right show the quality of the individual satellite orbits sorted in 5 accuracy bins. Missing columns mostly point out the epochs with the lack of the data, which occured before the secondary (alternative) internet connection was established in February 2002.*

CTU

Geoscience Australia Activities Related to the International GPS Service (IGS)

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The International GPS Service (IGS) and Geoscience Australia continue to have a strong relationship. Geoscience Australia (formerly the Australian Surveying and Land Information Group, AUSLIG) currently provides data from 15 permanently tracking GPS stations to the IGS, these stations are known as the Australian Regional GPS Network (ARGN). Future development of the ARGN will focus on the availability of near real time data and the augmentation of precise clocks and meteorological equipment at selected stations. Additionally Geoscience Australia has been an IGS Regional Network Associate Analysis Centre (RNAAC), contributing an Australian regional GPS solution, for almost six years. Apart from these contributions to the IGS, NMD is currently making use of IGS products, including precise GPS trajectories, Earth Orientation Parameters (EOP) and station coordinates and velocities in the delivery of an Internet based precise GPS processing service (AUSPOS) widely used by both the Australian and International GPS communities. In this poster Geoscience Australia's IGS related activities are reviewed.

1. The Australian Regional GPS Network (ARGN)

The ARGN consists of 15 continuous GPS reference stations on geologically stable observing pillars. Each ARGN site typically consists of: AOA SNR-8100 and/or Ashtech ZXII3 GPS receiver (a spare receiver is kept at most sites); Dorne Margolin T choke ring antenna; Low-loss heliax antenna cable, with in-line amplifier where the cable length is more than 60 metres; PC running Linux operating system and in-house developed software; Uninterruptable Power Supply (UPS); GPS Power Controller (GPC) which allows remote control of the GPS power; Multiplexer, configured to allow remote access and control of most site equipment; Dual modems & phone lines and Internet wherever possible.; and External, high accuracy clock (at selected sites).

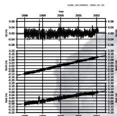
Local stability of the observing pillars is periodically monitored by accurate local surveys to nearby (20 m) deep-driven reference marks. Data is automatically retrieved on an hourly basis. At the end of each UT day, the data is automatically concatenated, converted to RINEX format and quality checked using TEQC. The results of the quality checking are graphically presented at **http://www.auslig.gov.au/geodesy/argn/argnqual.htm**. The data is submitted to IGS within 30 minutes of the end of the UT day. The data is also freely available from Geoscience Australia's anonymous FTP or via a data selection form at **http://www.auslig.gov.au/geodesy/argn/argndata.htm**. Operational status is automatically monitored and "alarm" email are automatically generated for exceptional events. Interested users may subscribe to the ARGN Email list that notifies any outages or unusual events **http://www.auslig.gov.au/geodesy/argn/argnmail.htm**.

Current developments of the ARGN include; Rapid data (hourly, within 10 minutes) is now available from selected sites; High rate data (1-5 sec) will also be implemented for sites with suitable communication links; Meteorological data will be supplied at selected sites; and GPS steered Rubidium clocks are being tested for use.

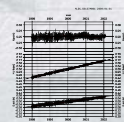
Geoscience Australia is also Regional Data for the IGS.

ARGN Overview. Near real time data refers to a 30 second RINEX product available 1 hour after observation. Coordinates are ITRF2000 @ 1/1/2000 on the GRS80 ellipsoid

Station	Id	Receiver	Communication	Near Real Time	Met. Equipped	GLONASS	Clock	Latitude (DMS)			Longitude (DMS)			Height(m)
Alice Springs, Australia	ALIC	Turbo Rogue	Dial Up	-	-	-	Internal	-23	-40	-12.4311	133	53	7.8577	603.2896
Casey, Antarctica	CAS1	Turbo Rogue	Internet	-	-	-	Internal	-66	-17	-0.0932	110	31	10.9415	22.4703
Ceduna, Australia	CEDU	Turbo Rogue	Dial Up	-	-	-	Internal	-31	-52	-0.0017	133	48	35.3852	144.7722
Cocos Island, Australia	COCO	Turbo Rogue	Internet	Yes	-	-	Internal	-12	-11	-18.0561	96	50	2.285	-35.2501
Darwin, Australia	DARW	Ashtech ZXII3	Dial Up	-	-	Yes	Internal	-12	-50	-37.3436	131	7	57.8579	125.1512
Davis, Antarctica	DAV1	Turbo Rogue	Internet	Yes	-	Yes	Rubidium (planned)	-68	-34	-38.3625	77	58	21.4068	44.4217
Jabiru, Australia	JAB1	Ashtech ZXII	Dial Up	.	.	.	Internal	-12	-39	-31.8665	132	53	38.0274	74.1514
Hobart, Australia	HOB2	Turbo Rogue	Internet	Yes	-	-	Hydrogen Maser	-42	-48	-16.9711	147	26	19.4418	41.0829
Karratha, Australia	KARR	Turbo Rogue	Dial Up	Yes	-	-	Internal	-20	-58	-53.1554	117	5	49.8841	109.1777
Macquarie Island, Australia	MAC1	Turbo Rogue	Internet	Yes	-	-	Internal	-54	-29	-58.3127	158	56	8.9988	-6.7634
Mawson, Antarctica	MAW1	Turbo Rogue	Internet	-	-	-	Internal	-67	-36	-17.1596	62	52	14.5761	59.1501
Mount Stromlo, Antarctica	STR1	Turbo Rogue	Internet	Yes	-	Yes	Internal	-35	-18	-55.9256	149	0	36.1868	799.9655
Tidbinbilla, Australia	TID1	Turbo Rogue	Internet	-	-	-	Hydrogen Maser	-35	-23	-57.1421	148	58	47.9915	665.3609
Townsville, Australia	TOW2	Turbo Rogue	Internet	Yes	Planned	-	Rubidium (planned)	-19	-16	-9.4137	147	3	20.4744	88.1595
Yarragadee, Australia	YAR2	Turbo Rogue	Dial Up	Yes	-	Yes	Caesium	-29	-2	-47.6027	115	20	49.1123	241.2882



Karratha (KARR)



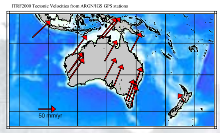
A number of ARGN sites are co-located with other fundamental geodetic facilities. At co-located sites, the facilities are rigorously connected by accurate terrestrial surveys. The results of these terrestrial surveys have been included in the ITRF2000. Results of all terrestrial surveys are available in SINEX format at **ftp://ftp.auslig.gov.au/sgac/sinex/ties/**

Site	SLR	VLBI	GLONASS	DORIS	Absolute Gravity	Tide Gauge
Stromlo	✓		✓	✓	✓	
Yarragadee	✓		✓	✓	✓	
Tidbinbilla		✓			✓	
Hobart		✓			✓	
Darwin			✓			
Townsville					✓	✓
Davis			✓			✓
Mawson						✓
Casey						✓
Macquarie Is.						✓

2. The Geoscience Australia Regional Network Associate Analysis Centre (RNAAC)

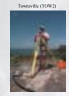
Geoscience Australia participates in the IGS as an RNAAC by processing all IGS stations in the Australian Regional GPS Network (ARGN). The weekly combined SINEX result files are submitted to the Crustal Dynamics Data Information System (CDDIS) as Geoscience Australia's role as an IGS type 2 Associate Analysis Centre. Data processing is undertaken using the Bernese GPS Processing Software version 4.2. Daily solutions are computed using the following strategy: L3 double differenced phase observable; No resolution of integer ambiguities; Elevation cut-off angle of 10° with elevation dependant weighting; Estimation of tropospheric zenith delay parameters at 2 hourly intervals; IGS antenna phase centre variation model applied; IGS final orbits and EOPs held fixed; Station coordinates for a single station constrained (either TID2 or YAR1). Seven daily solutions are combined at the normal equation level to obtain the weekly solution output in SINEX format submitted to the CDDIS. The Geoscience Australia RNAAC weekly SINEX solution files are included in the Type 2 GNAAC combination generated by the Massachusetts Institute of Technology (MIT) GNAAC Polyhedron solution. A regularly updated analysis report can be found at **http://www.auslig.gov.au/geodesy/sgc/gps/.**

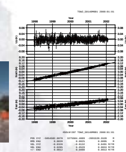
ITRF2000 Tectonic Velocities from ARGN/IGS GPS stations



Alice Springs (ALIC)

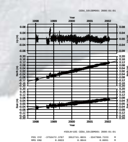
Townsville (TOW2)

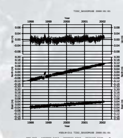




In 1992 GPS observations were completed on eight geologically stable marks at sites across Australia, these marks form the Australian Fiducial Network (AFN). Additional GPS observations were also carried out at a number of existing geodetic survey stations across Australia. In 1993 and 1994 these were supplemented by further observations and results in a network of about 70 GPS sites with a nominal 500 km spacing across Australia and is known as the Australian National Network (ANN). GPS observations at both the AFN and ANN sites were combined in a single regional GPS solution in terms of the International Terrestrial Reference Frame 1992 (ITRF92) and the resulting coordinates were mapped to a common epoch of 1994.0. The positions of both the AFN and ANN sites were used to define the Geocentric Datum of Australia (GDA). The positions of both the AFN and ANN sites were used to constrain a re-adjustment of the Australian geodetic networks. GDA94 is officially regarded as the Australian national datum.

Ceduna (CEDU)





Tidbinbilla (TID2)

3. The Geoscience Australia Online GPS Processing Service (AUSPOS)

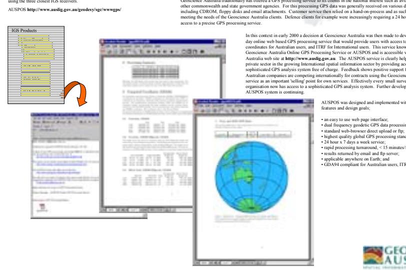
Geoscience Australia's Online GPS Processing Service (AUSPOS) provides users with the facility to submit via the Internet, dual frequency geodetic quality GPS RINEX data observed in a 'static' mode and receive rapid turn-around precise coordinates. The service is free and provides both ITRF and GDA94 coordinates.

This Internet service takes advantage of both the International GPS Service (IGS) analysis product range and the IGS GPS network and works with GPS data collected anywhere on Earth. AUSPOS processes user data differentially using the three closest IGS receivers.

AUSPOS **http://www.auslig.gov.au/geodesy/sgc/wwwgps/**

As high precision global geodetic GPS technology has evolved, processing and analysis software has become more sophisticated and in general more automated. This development has now seen the implementation of Internet based geodetic GPS processing services by various International groups. In Australia these International GPS Processing Services were being widely used by the geodetic GPS community. It was at this time that the potential for user confusion between the International Terrestrial Reference Frame (ITRF), as provided by these International GPS processing services and the Australian national datum, GDA94 was recognised. Since GDA94 was based on the ITRF92 at a fixed epoch of 1994 the latest ITRF coordinates produced were becoming substantially offset. This difference is due largely to the tectonic motion of the Australian plate. Coordinate differences between GDA94 and the ITRF are at this time approximately 0.5 metres in magnitude.

Geoscience Australia traditionally has offered a GPS processing service to its clients in the national interest such as aviation, defence and other commonwealth and state government agencies. For this processing GPS data was generally received on various digital media, including CDROM, floppy disks and email attachments. Customer service then relied on a hand-on-process and as such was not necessarily meeting the needs of the Geoscience Australia clients. Defence clients for example were increasingly requiring a 24 hour x 7 day a week access to a precise GPS processing service.



In this context in early 2000 a decision at Geoscience Australia was then made to develop a 24-hour a day online web based GPS processing service that would provide users with access to GDA94 based coordinates for Australian users, and ITRF for International users. This service known as the Geoscience Australia Online GPS Processing Service or AUSPOS and is accessible via the Geoscience Australia web site at **http://www.auslig.gov.au**. The AUSPOS service is clearly helping the Australian private sector in the growing International spatial information sector by providing access to a sophisticated GPS analysis system free of charge. Feedback shows positive support for the service and Australian companies are competing internationally for contracts using the Geoscience Australia service as an important 'selling' point for own services. Effectively every small survey/GPS organisation now has access to a sophisticated GPS analysis system. Further development of the AUSPOS system is continuing.

AUSPOS was designed and implemented with the following features and design goals;

- an easy to use web page interface;
- dual frequency geodetic GPS data processing capability;
- standard web-browser direct upload or ftp;
- highest quality global GPS processing standards;
- 24-hour x 7 days a week service;
- rapid processing turnaround, < 15 minutes/file;
- results returned by email and ftp server;
- applicable anywhere on Earth; and
- GDA94 compliant for Australian users, ITRF elsewhere.

The AUSPOS Overview

Feature/function	Description
Observations	RINEX dual frequency GPS code and carrier phase. User GPS navigation data is not required.
Data quantity	Minimum of 1 hour, recommended minimum of 6 hours
Multiple files submission	Maximum of 7 user files per submission
Compression	UNIX, ZIP, Hatanaka formats only
Orbit and Earth Orientation	IGS precise, ultra-rapid, rapid, final
Observations used	Double difference carrier phase
Reference frame	IGS-SSC (nominally ITRF2000 at present), GDA94 for Australia
Geoid	Heights above the geoid are supplied within Australia using AUSGeoid98 (Johnston and Featherstone, 1998).
# IGS stations used	3
Results quality	<10mm horizontal <20mm vertical with 6 hours of data
Antenna phase centre	IGS or NGS models
Report delivery	Email and anonymous ftp
Report format	ADOBE PDF

Developments in Absolute Field Calibration of GPS Antennas and Absolute Site Dependent Multipath

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1. Introduction

Antenna phase variations (PCV) and multipath (MP) are site dependent errors on GPS stations, which can have a magnitude of several centimeters. Neglecting these errors can cause severe problems in ambiguity resolution, but also for estimation of distance dependent errors (e.g. troposphere) and coordinates.

Geo++® and IfE have developed an operational procedure to determine the absolute PCV of an antenna in a field calibration completely independent from any multipath effects. Subsequently, it is now possible to separate between PCV and MP error components. Currently, a procedure is under investigation, which gives absolute carrier phase multipath and can be used for absolute site multipath calibration.

Absolute PCV Field Calibration

Absolute PCV Corrections for Antennas

Absolute PCV Field Calibration:

- antenna is inclined and rotated around a nominal mean phase center
- PCVs from subsequent observations are free of MP (short−time observations)
- spherical harmonics used to model PCV

Characteristics:

- independent from geography and local site
- not affected by reference antenna
- elevation and azimuth dependent PCV
- high precision and repeatability
- duration of calibration is some hours

- pre−requisite for Absolute Multipath Calibration

2. Absolute Multipath Calibration/Basic Concepts

verification of Absolute Multipath Calibration using two robots and one antenna/site to be MP calibrated

1st: separate MP:

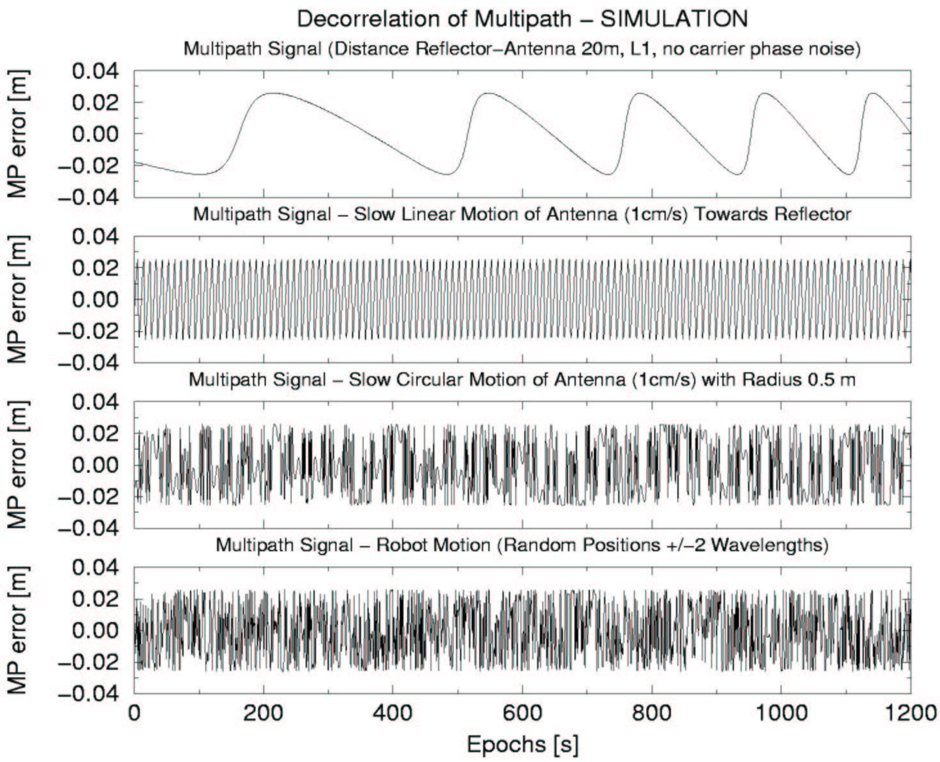
- separation of PCV and MP by applying absolute antenna PCV correction

2nd: separate Absolute MP:

- "decorrelation" of MP through fast and pseudo−random movements of antenna by a robot
- multipath is "randomized" or "noisified" through fast movements within a radius of two wavelengths

Simulation showing the decorrelation of MP through movements of an antenna:

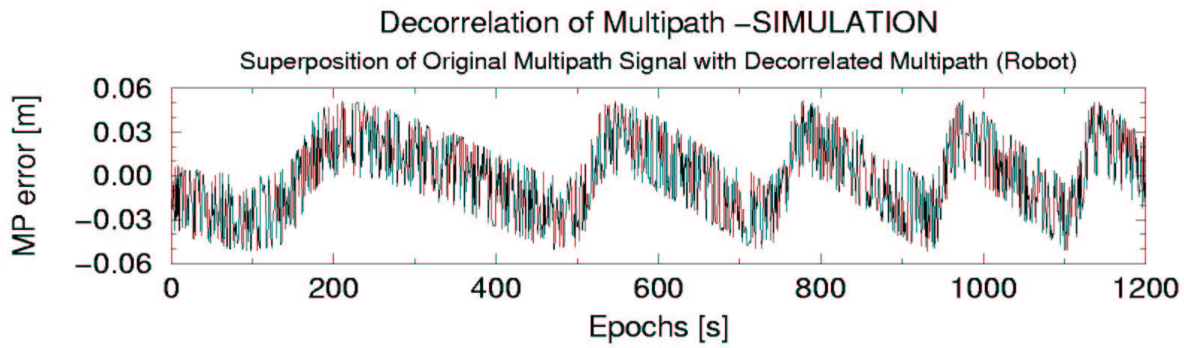
- static multipath
- multipath from small linear motion towards reflector (1 cm/s)
- multipath from slow circular motion (1 cm/s, 0.5 m radius)
- multipath from actual pseudo−random motion of robot (random positions within +/− two wavelengths)



decorrelation of MP with simulated data

Simulation of single difference between moving and static antenna:

- superposition of original static multipath and decorrelated multipath of moving robot
- low−pass filtering gives static multipath of one single station (absolute)

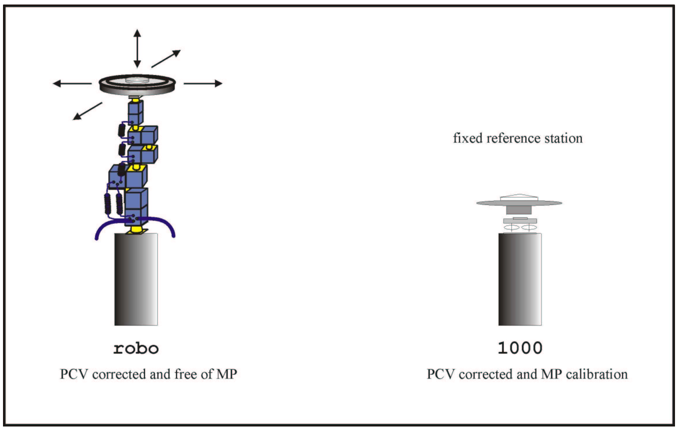


simulation of observation difference between moving and static station

3. Measurement Procedure and Multipath Adjustment/Representation

Measurement:

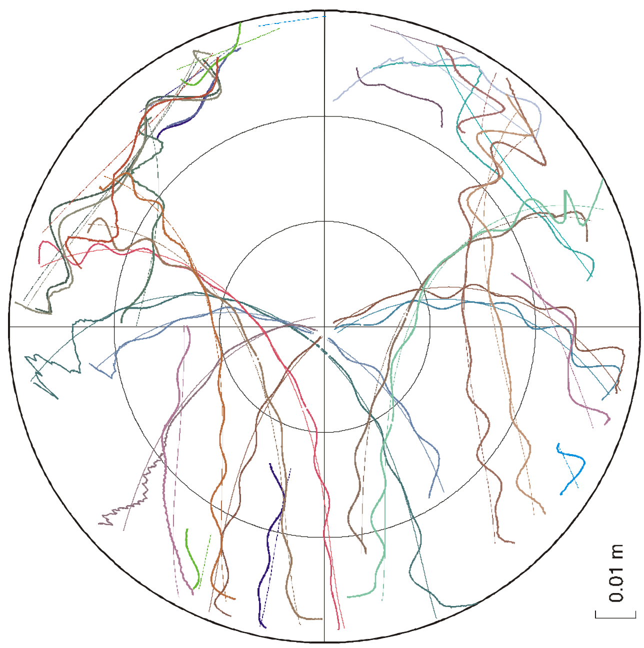
- station of interest is observed in static mode with associated antenna mount and antenna (in situ)
- robot with moving antenna is temporary reference station during calibration
- PCV are corrected for both antennas
- observations on the robot are corrected by the eccentricity vector to a nominal fixed point
- continuous pseudo−random motion within +/− two wavelength around fixed point in all directions
- over short distance single differences between antennas on the robot and on static station contain systematic MP of the static station and "noisified" MP of robot station



moving antenna on robot (decorrelated MP) and static antenna (MP calibrated)

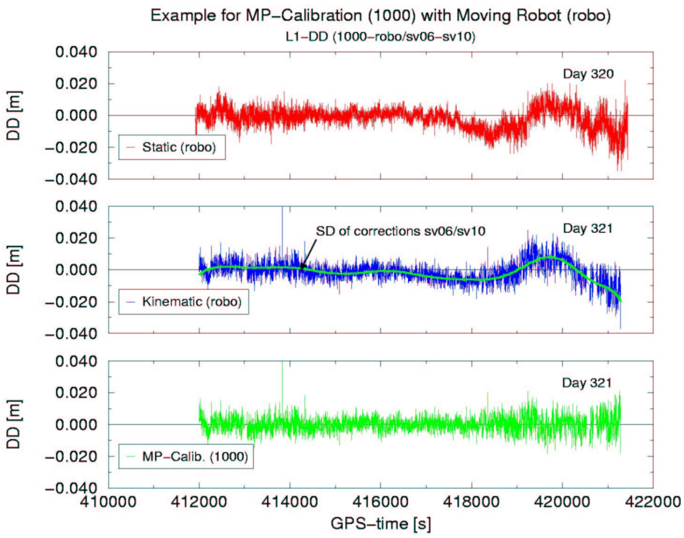
Adjustment/Representation:

- modeling of MP corrections using azimuth and elevation
- currently adjustment using spherical harmonics (limitation)
- currently storage of corrections using the Geo++ antenna file format, which utilizes the correction in the same way as PCV corrections



MP corrections shown in a sky plot

4. First Results after Applying MP Corrections



original DD of two stations, decorrelated stations and superimposed correction; corrected DD

Analysis of Double Differences (DD):

- example of absolute multipath
- original DD of two static stations
- uncorrected DD with absolute multipath signal from one station and „noisified“ MP from moving robot station; actually low−pass filtered MP correction superimposed
- corrected DD without multipath signal

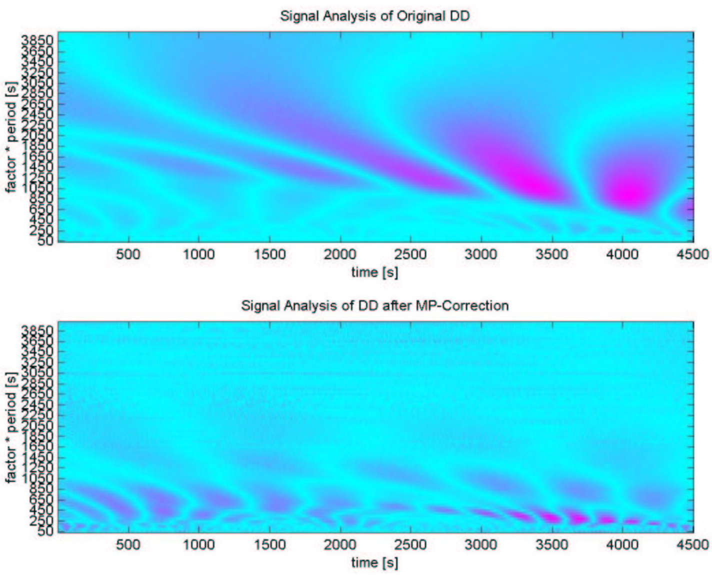
Selected DD with standard deviation:

- before and after correction
- moving average of 60 s

- reduction of noise in DD in both cases

satellites		*02−11*	*03−19*	*06−10*	*19−31*
uncorrected s [mm]	(1)	6.9	6.9	6.7	8.2
corrected s [mm]	(2)	5.2	5.6	5.2	7.2
reduction (1)/(2) [%]	(3)	24.6	18.8	22.4	12.2
moving average (60 s) of DD s [mm]	(4)	2.1	2.5	1.9	3.2
reduction (1)/(4) [%]	(5)	69.1	63.8	71.6	61.0

selected DD with standard deviation

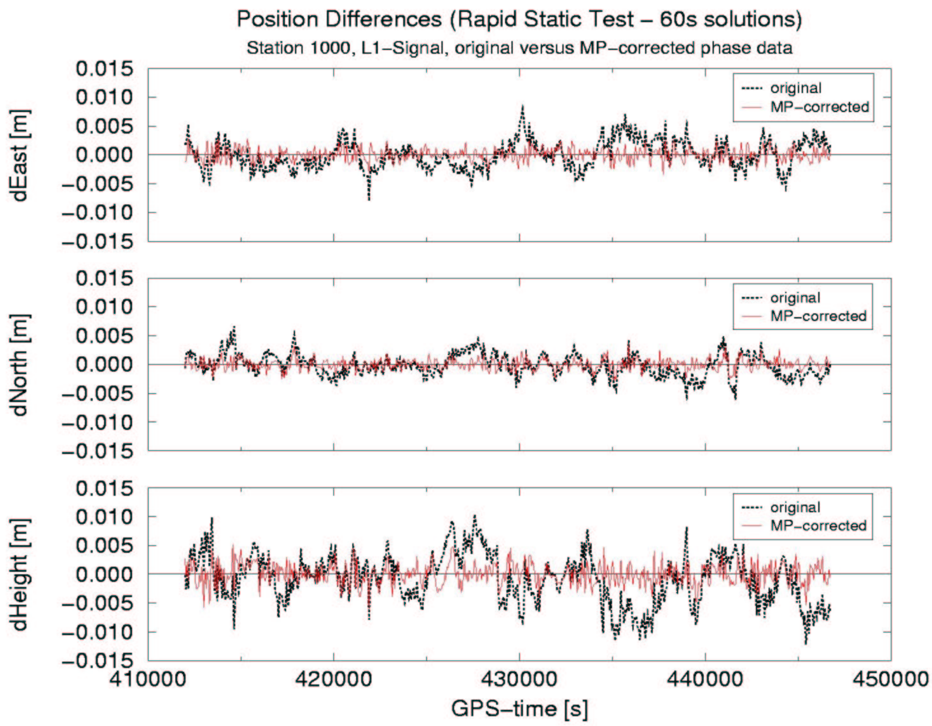


different relative color scale for graphs, which makes amplitudes not directly comparable

Wavelet Analysis of DD:

- verification of MP reduction
- low frequencies are reduced
- high frequencies remain

Analysis of Coordinates:



time series of 60 s−L1 coordinate estimations

Comparison of short−term coordinate estimation:

- reference station is antenna on robot
- MP corrected for static antenna
- 60 s blocks used for L1 coordinate estimation
- differences to known position

- reduction of noise for estimated coordinates

component		*north*	*east*	*height*
uncorrected s [mm]	(1)	2.44	1.93	4.29
corrected s [mm]	(2)	1.10	0.99	1.87
reduction (1)/(2) [%]	(3)	54.9	48.7	56.4

Outlook:

Hard− and software will be improved to enable faster and more effective measurements. Alternative models are investigated to substitute the spherical harmonics and to consider variation of multipath under changing environmental conditions (e.g. humidity on reflectors, SV orbit, snow). The absolute calibration of station dependent GPS error components will lead to improved global, regional and local reference station and RTK network services (e.g. IGS, SAPOS) as well as for precise GPS applications.

Acknowledgment:

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The presented results are based on Böder, V., F. Menge, G. Seeber, G. Wübbena, M. Schmitz (2001). How to Deal With Station Dependent Errors − New Developments of the Absolute Calibration of PCV and Phase−Multipath With a Precise Robot. Proceedings of International Technical Meeting, *ION GPS−01*, Salt Lake City, Utah, USA.

Recent Results and Activities of the
IGS ANALYSIS CENTER at JPL

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IGS Network, Data, and Analysis Center Workshop
Ottawa, ON Canada
April 8-12, 2002

JPL FLINN PROCESSING SPECIFICATIONS

Automatic Startup via UNIX "cron":
ζ=1800 km OR delay=4 days

No. Satellites	**27**
No. Stations	**42**
Data Arc	**30 hrs**
Decimation	**5 min**

GIPSY/OASIS II

HP-Linux x4000
i686 / 1.7 GHz

Processing Time	**4.75* hrs**
Disk Space	**1.4 Gb**

***<4 hrs on i686 / 2.0 GHz**

JPL IGS ANALYSIS CENTER PRODUCTS: FINAL (FLINN)

ftp://sideshow.jpl.nasa.gov/pub/jpligsac

FILE	CONTENTS
wwww/jplwwww[0-6].clk.Z	daily precise clocks
wwww/jplwwww[0-6].sp3.Z	daily precise orbits
wwww/jplwwww[0-6].tro.Z	daily tropospheres
wwww/jplwwww[0-6].yaw.Z	daily yaw-rates for eclipsing satellites
wwww/jplwwww7.erp.Z	weekly Earth orientation parameters
wwww/jplwwww7.snx.Z	weekly station coordinates
wwww/jplwwww7.sum.Z	weekly narrative summary
hirate/JPLwwww[0-6].sp3.Z	daily high-rate (30-sec) precise orbits and clocks
YYYY.eng.Z, YYYY_p.eng.Z	global and ppp engineering data for year YYYY
ytd.eng, ytd_p.eng	global and ppp engineering data, year-to-date

JPL IGS ANALYSIS CENTER PRODUCTS: RAPID (Quick-Look)

ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/RapidService/orbits

FILE	CONTENTS
jplwwww[0-6].clk.Z	daily rapid clocks
jplwwww[0-6].sp3.Z	daily rapid orbits (and clocks)
jplwwww[0-6]_pred.sp3.Z	daily predicted orbits
jplwwww[0-6].erp.Z	daily Earth orientation parameters

JPL IGS ANALYSIS CENTER PRODUCTS: ULTRA-RAPID

ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/UltraRapid

FILE	CONTENTS
jpuwwww[0-6].erp	daily Earth orientation parameters
jpuwwww[0-6]sp3.Z	daily fitted orbits, clocks; predicted orbits
jpuwwww[0-6].sum	daily post-fit residuals and overlaps summary

JPL IGS ANALYSIS CENTER PRODUCTS: 15-MIN (Real-Time)

ftp://sideshow.jpl.nasa.gov/pub/15min

FILE	CONTENTS
jplwwww[0-6].clk.Z	daily "real-time" clocks
jplwwww[0-6].sp3.Z	daily "real-time" orbits
jplwwww[0-6].tro.Z	daily "real-time" tropospheres
jplwwww[0-6].yaw.Z	daily "real-time" yaw-rates for eclipsing satellites

MAJOR STRATEGY CHANGES: 2000

- APPLY P1-CA BIASES FOR CROSS-CORRELATING RECEIVERS (00APR02)
- SWITCH FROM ITRF97 TO IGS97 (00JUN04)
- USE USNO, NRC1, PIE1, ALGO, PENT, FAIR AS REFERENCE CLOCK CANDIDATES (00JUL30)
- USE RECOMPUTED ASHTECH-BASED P1-C1 BIASES (00AUG27)
- USE BENCHMARK-BASED P1-C1 BIASES (00OCT15)
- USE RAY '95 SUB-DAILY EARTH ORIENTATION MODEL (00NOV12)

MAJOR STRATEGY CHANGES: 2001

- **USE RECOMPUTED ASHTECH-BASED P1-C1 BIASES (01FEB18)**

- **USE MULTI-PLATFORM (HP-UX, SunOS, Linux) "daily" SCRIPT (01APR01)**

- **ADJUST PARAMETER APRIORI TOLERANCES (01MAY06):**

```
UT1-UTCRATE      100 sec/day -> 3 ms/day
X,Y POLERATE      50 mas/day -> 5 mas/day
P-CODE OUTLIER     5 m       -> 2 m
PHASE OUTLIER    2.5 cm      -> 2 cm
```

- **SWITCH FROM IGS97 TO IGS00, USE IERS-2000 STANDARDS AND TIDE MODELS (01DEC02)**

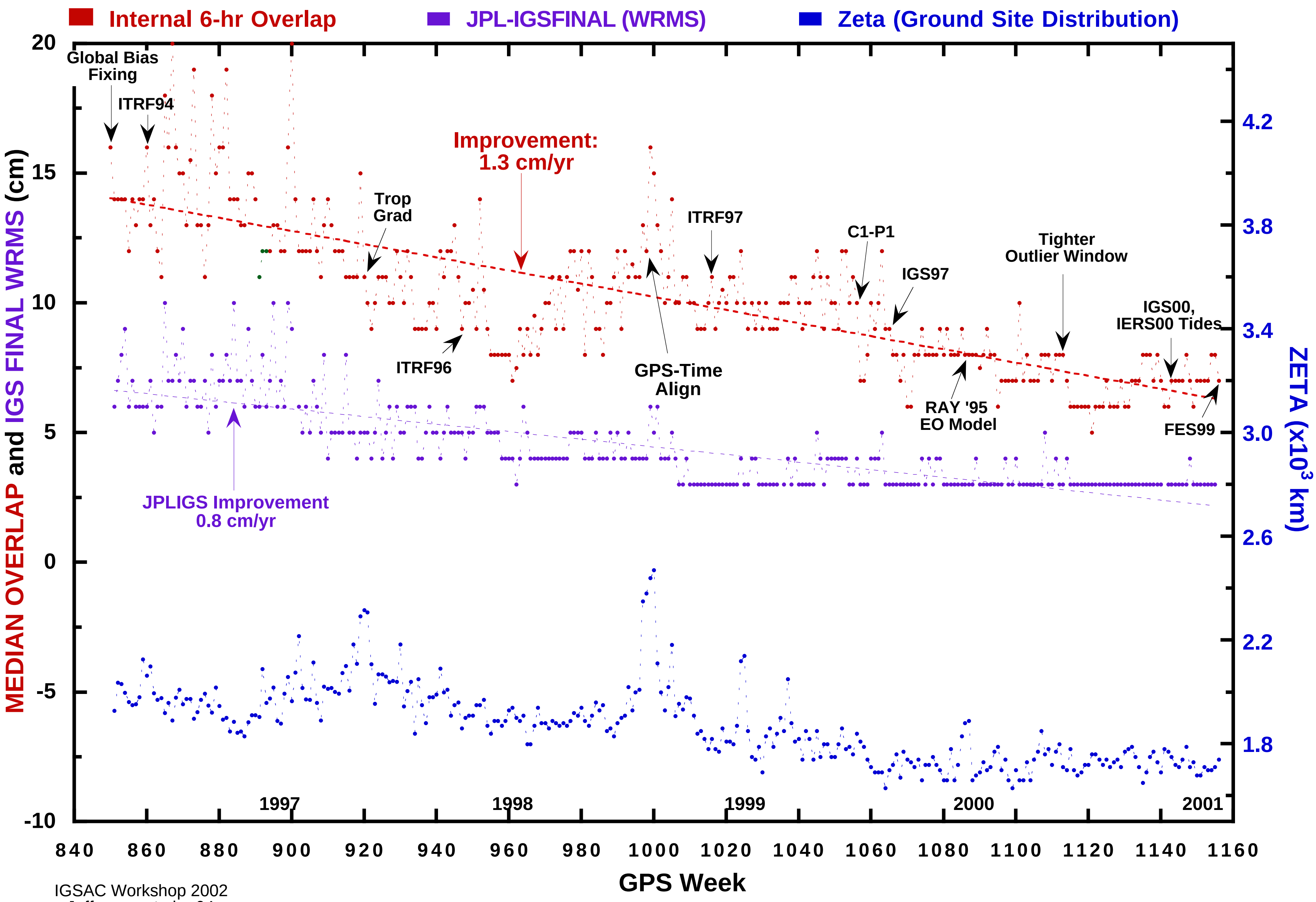
MAJOR STRATEGY CHANGES: 2002

- **HIGH-RATE CLOCKS SPAN 30 HOURS (02JAN20)**
- **OCEAN LOADING MODELS: (02MAR03)**
  - **- 5-min ocean function (Pavlis & Saleh '01)**
  - **- FES99 (short period)**
  - **- Self-consistent Equilibrium (long period)**

Future Plans

- **Upgrade FLINN from 42 to 60 stations:**
  Overlaps 7 cm ==> 5 cm
  Zeta 1733 km ==> 1547 km

MEDIAN ORBIT REPEATABILITY and STATION DISTRIBUTION



IGSAC Workshop 2002
Jefferson, et al. - 04

RECENT JPLIGS AC PRODUCT QUALITY: ORBITS and STATION COORDINATES (January, 2002)

Products	Delivery	3D Orbit (cm)	Positions (mm) N	E	V	# Stations	Zeta (km)
Final-Flinn	Weekly	6	3	5	8	42	1726
Quick-Look	Daily	9	5	8	11	35	2237 (32)
Ultra-Rapid	Twice per day	21	13	25	27	30* (*35 beg. Feb '02)	2815
"Real-Time"	Every 15 min	27	10	21	30	35	2405

IGS LEO - CHAMP Orbit Campaign Status

Henno Boomkamp, John Dow, ESA/ESOC

http://nng.esoc.esa.de/gps/campaign.html

Introduction

The CHAMP Orbit Comparison Campaign started in October 2001 and will continue as long as new orbit solutions are contributed, or while updates to existing solutions are made.

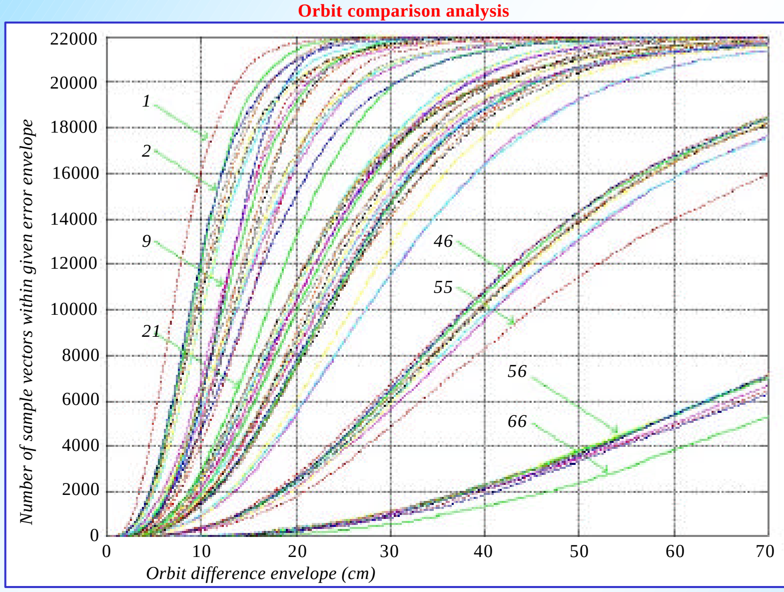
The objectives of the Campaign are to assess the current levels of POD precision for CHAMP, and to assist the Associate Analysis Centres in their efforts to improve LEO POD methods.

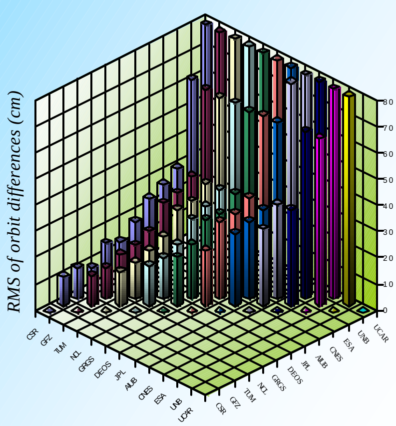
Participating Centres provide a POD solution for CHAMP, for the Campaign period from day 140 to 150 of the year 2001 (May 20 to 30).

At ESOC the pair-wise differences are computed for all solution pairs, and SLR residuals are computed for each input orbit. By combining the information from the orbit comparisons and from the SLR analysis, an estimate of the absolute orbit error in each solution can be derived.

Similar Campaigns are planned for the JASON and GRACE satellites as soon as their flight receiver data is released.

Orbit comparison analysis





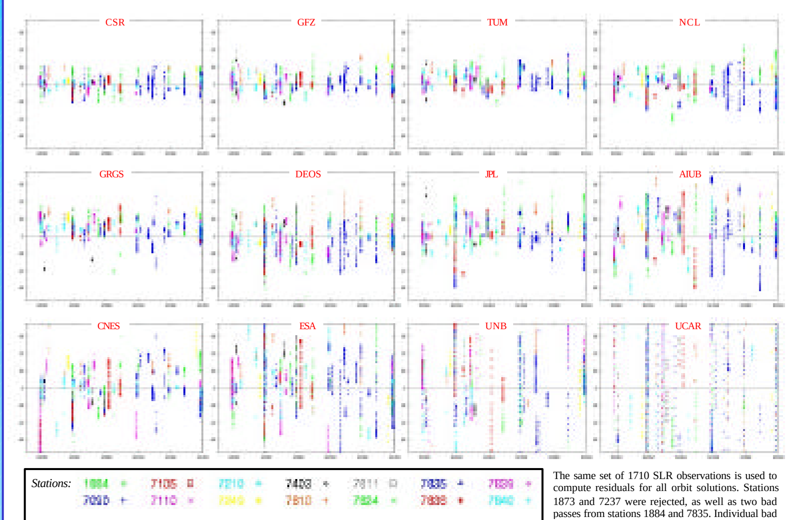
cm	CSR	GFZ	TUM	NCL	GRGS	DEOS	JPL	AIUB	CNES	ESA	UNB	UCAR
CSR	*	2	5	1	13	8	17	22	30	39	52	61
GFZ	10.94	*	3	4	9	10	15	24	27	38	48	57
TUM	11.82	11.52	*	6	7	14	18	25	26	37	46	58
NCL	9.14	11.60	12.94	*	11	12	16	23	29	40	49	59
GRGS	15.67	14.09	13.56	15.21	*	19	20	31	28	42	47	60
DEOS	13.64	14.80	15.71	15.57	18.40	*	21	34	36	43	50	56
JPL	18.23	17.52	18.39	17.77	20.53	21.20	*	32	35	41	51	63
AIUB	24.53	25.47	25.48	24.80	27.30	29.35	27.61	*	33	44	55	65
CNES	27.18	26.48	26.41	26.92	26.85	29.73	29.35	29.10	*	45	53	64
ESA	30.66	30.43	30.33	30.71	31.80	33.26	31.34	35.91	36.53	*	54	62
UNB	61.60	60.70	60.52	60.93	60.54	61.48	61.54	79.52	63.72	63.91	*	66
UCAR	152.36	151.60	151.56	151.97	151.97	151.24	152.80	154.50	153.08	152.63	162.44	*

Top triangle Location of the pair-wise comparison curve in the Figure
Bottom triangle RMS of orbit differences over the 22000 comparison points

Contributed orbit solutions

Centre	Summary of POD Method
AIUB	Reduced dynamics solution using positions and position differences from a kinematic solution as pseudo-observations. Parameters: 6 initial state, 15 dynamical parameters, stochastic pulses 3D every 10 minutes. Kinematic solution from pseudoranges and phase differences. GPS orbits and clocks fixed to CODE solutions.
CNES	Reduced dynamic solutions. Accelerometer data and attitude control events are not used. The measurements are zero-difference pseudorange measurements reconstructed from phase with adjusted ambiguities using the code (code smoothed with phase).
CSR	Dual frequency double-differenced pseudo-range and carrier phase. Dynamic solution (TEG4), GPS fixed to IGS final, CHAMP attitude GFZ. Parameters: CHAMP orbit: 6 initial states, drag coef 1.5 hour, 1-CPR along/cross-track 0.8 hours. Ambiguity parameters, tropospheric parameters, champ Z-offset parameter.
DEOS	Triple differenced phase data. Dynamic, using GEODYN - TEG4 gravity field. Empirical parameters included to compensate dynamic modelling deficiencies.
ESOC	Kinematic approach based on sequential filter GPSBET. Data: undifferenced pseudorange and phase data, using GPS orbits and clocks from ESOC contribution to IGS. Dynamic solutions under preparation.
GFZ	Third generation Rapid Science Orbits from March 2002. Dynamic orbit solution (EIGEN gravity field) from onboard GPS SST data only. No accelerometer data and no SLR data are incorporated. Attitude + thruster data is used. GPS orbits and clocks from a preparation run before the CHAMP POD - no IGS outputs used.
GRGS	Reduced dynamic solutions, GPS only (Range + Phase). Zero-difference observables, GPS satellite orbits fixed to IGS solution but GPS satellite clocks fixed to a priori computed values.
JPL	Undifferenced dual frequency pseudorange and carrier phase measurements. Method: First, dynamic orbit solution for estimating global perturbing force parameters, then reduced-dynamic filtering to estimate remaining perturbing accelerations as stochastic time series.
NCL	First, the initial conditions, drag, once-per-revs, phase biases and CHAMP clock are solved to produce a converged dynamic orbit. Then the once-per-revs and drag scale factors are held fixed and a stochastic empirical acceleration introduced to allow a kinematic element into the POD process.
TUM	Reduced-dynamic solution, double-difference carrier phase measurements (sampling 30 sec). CHAMP attitude, CODE GPS orbits/clocks. Several solutions submitted to the campaign; the most precise TUM solution (fine ambiguity resolution, 'boot-strap' method) is still incomplete due to large CPU load.
UCAR	Kinematic position and position differences using undifferenced pseudorange and time-differenced phase observations, followed by smoothing using a dynamic model. Enhancements in LEO POD software are expected in early 2002.
UNB	Point-positioning solution, phase connected. Platform independent GPS-only solution.

SLR residual analysis



SLR residuals (cm) per station and per orbit solution

The same set of 1710 SLR observations is used to compute residuals for all orbit solutions. Stations 1873 and 7237 were rejected, as well as two bad passes from stations 1884 and 7835. Individual bad measurements were rejected on the basis of a 1.5 sigma winodw around the three most precise orbits.

Orbit precision estimates

The RMS of SLR residuals from individual orbits can be used to construct a pair-wise RMS_{AB} from

$$RMS^2_{AB} = RMS^2_A + RMS^2_B.$$

This relation is valid as long as the solutions A and B are independent. In that case, the pair-wise RMS of orbit errors with respect to the true CHAMP orbit also follows from this relation. This pair-wise orbit error is given by the orbit comparison RMS.

The ratio between the pair-wise orbit error and the pair-wise SLR residuals turns out to be nearly constant. If the two least accurate solutions are disregarded, as well as solution pairs that are suspected to be dependent, an empirical relationship is found between SLR residuals and orbit error:

$$RMS(orbit) = (1.52 \pm 0.18)\ RMS(SLR)$$

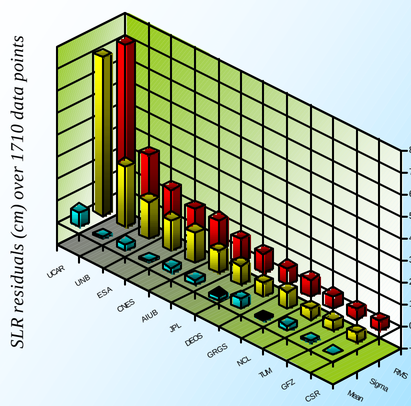
From elementary statistical analysis it follows that this same relation applies to the single orbit results. This provides estimates for the absolute orbit error in each contributed solution.

cm	CSR	GFZ	TUM	NCL	GRGS	DEOS	JPL	AIUB	CNES	ESA	UNB	UCAR
CSR	*	1.671	1.678	1.055	1.805	1.360	1.617	1.709	1.891	1.738	2.205	2.099
GFZ	6.55	*	1.582	1.309	1.587	1.452	1.534	1.760	1.827	1.716	2.168	2.087
TUM	7.05	7.28	*	1.401	1.466	1.493	1.570	1.733	1.794	1.692	2.152	2.087
NCL	8.66	8.86	9.23	*	1.444	1.334	1.393	1.595	1.730	1.649	2.133	2.087
GRGS	8.68	8.88	9.25	10.54	*	1.575	1.608	1.755	1.724	1.707	2.119	2.087
DEOS	10.03	10.20	10.52	11.67	11.68	*	1.546	1.796	1.817	1.724	2.119	2.072
JPL	11.27	11.42	11.72	12.75	12.77	13.72	*	1.611	1.711	1.570	2.089	2.088
AIUB	14.35	14.47	14.71	15.55	15.56	16.34	17.14	*	1.506	1.643	2.584	2.096
CNES	14.37	14.49	14.72	15.56	15.57	16.36	17.15	19.32	*	1.607	2.070	2.076
ESA	17.64	17.73	17.93	18.62	18.63	19.29	19.97	21.86	21.87	*	1.970	2.051
UNB	27.94	28.00	28.12	28.57	28.57	29.01	29.46	30.77	30.78	32.44	*	2.095
UCAR	72.59	72.61	72.66	72.83	72.83	73.01	73.19	73.72	73.73	74.43	77.52	*

Top triangle Pair-wise value (RMS of orbit error) / (RMS of SLR residuals)

Bottom triangle Pair-wise RMS of SLR residuals from $RMS^2_{AB} = RMS^2_A + RMS^2_B$

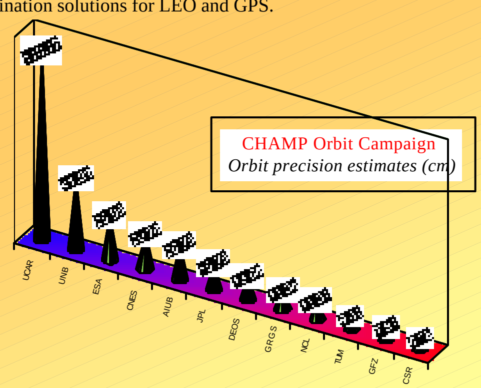
Grey values were excluded from the orbit error estimation process



Conclusions

The complementary information from orbit comparisons and SLR analysis makes it possible to estimate the absolute orbit error in the contributed solutions. As shown in the Table below, the most precise CHAMP orbits show orbit errors below 10 cm RMS. The GRACE mission can take direct advantage of the experience with CHAMP, while JASON is not expected to pose new POD problems due to its higher orbit. LEO POD based on GPS is reaching a precision level that allows for realistic combination solutions for LEO and GPS.

cm	Nr obs	Mean	Sigma	RMS	Estimated orbit error
CSR	1710	0.02	4.44	4.44	6.75
GFZ	1710	0.75	4.76	4.81	7.31
TUM	1710	2.55	4.84	5.47	8.31
NCL	1710	-0.61	7.41	7.44	11.31
GRGS	1710	4.09	6.20	7.46	11.34
DEOS	1710	-1.93	8.78	8.99	13.66
JPL	1710	2.39	10.08	10.36	15.75
AIUB	1710	2.69	13.39	13.65	20.75
CNES	1710	0.47	13.67	13.67	20.78
ESA	1710	2.75	16.86	17.07	25.95
UNB	1384	0.75	27.58	27.58	41.92
UCAR	1710	6.85	72.15	72.45	110.12



For further information please contact Henno.Boomkamp@esa.int, ESA / ESOC, Robert-Bosch-Strasse 5, D-64293 Darmstadt, Germany

Continental Plate Rotations Derived from International GPS Service Station Coordinates and Velocities, 1996-2002

***D. Hutchison*[1]**

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International GPS Service (IGS) Analysis Centres (ACs) currently compute daily precise station coordinates and Earth Rotation Parameters (ERPs). From these, weekly results are computed and forwarded to three Global Network Associate Analysis Centres (GNAACs) in an established ASCII format known as Solution Independent Exchange (**SINEX**). The GNAACs then combine these results on a weekly basis. On behalf of IGS, Natural Resources Canada (NRCan) combines all weekly SINEX files from the ACs to form a weekly and a cumulative solution and compares the results with those obtained by the GNAACs. Since GPS week 1143, all the solutions have been aligned to an IGS realization of **ITRF 2000**, the Year 2000 International Terrestrial Reference Frame (**IGS00**, 54 stations). The **weekly solution** contains estimates of station coordinates and ERPs pertaining to the GPS week, and the **cumulative solution** contains station coordinates and velocities at epoch Jan. 1, 1998. **IGS00** is a subset of the cumulative solution for GPS week 1131, itself aligned to **ITRF 2000**. Before GPS week 1143, NRCan's weekly and cumulative solutions were aligned to an IGS realization of **ITRF 2000**'s precursor, **ITRF97,** called **IGS97**. The latter is a 51-station subset of the cumulative solution for GPS week 1046 transformed to **ITRF97**.

Using the cumulative solution from any given week, we estimate rotation components (**Euler vectors**) of any continental plate represented and compare them statistically with results from published literature and two known plate motion models**: NNR NUVEL 1** and **NNR NUVEL 1A**. As of week 1162, some 215 stations and 19 plates are represented. Mean residual velocities are also computed with respect to each plate, thus providing net residual velocities over all stations with respect to both plate motion models.

Statistical tests from the cumulative solution for GPS week 1162 (labeled **IGS02P16** for the **16th** week of the year 20**02)** indicate that motions derived from IGS results for the Eurasian, Pacific and Australian Plates differ significantly from predictions of either model. (The Philippine, Cocos, Juan-de-Fuca, Scotia and Rivera Plates are not analyzed.) For Eastern and South-East Asia, some significant differences are shown to exist between station velocities observed from **IGS02P16** and those expected from the computed plate rotation for Eurasia (without China) derived from **IGS02P16**. The mean misfit between recorded horizontal velocities on plates with two or more stations and those predicted from appropriate Euler vectors for **IGS02P16** is approximately 1.5 mm/yr. Major plates such as North American, South American, Eurasian, Pacific, Australian and Caribbean show horizontal misfits of 1 mm/yr or less. Mean vertical misfit for **IGS02P16** is approximately 6 mm/yr.

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GPS·C

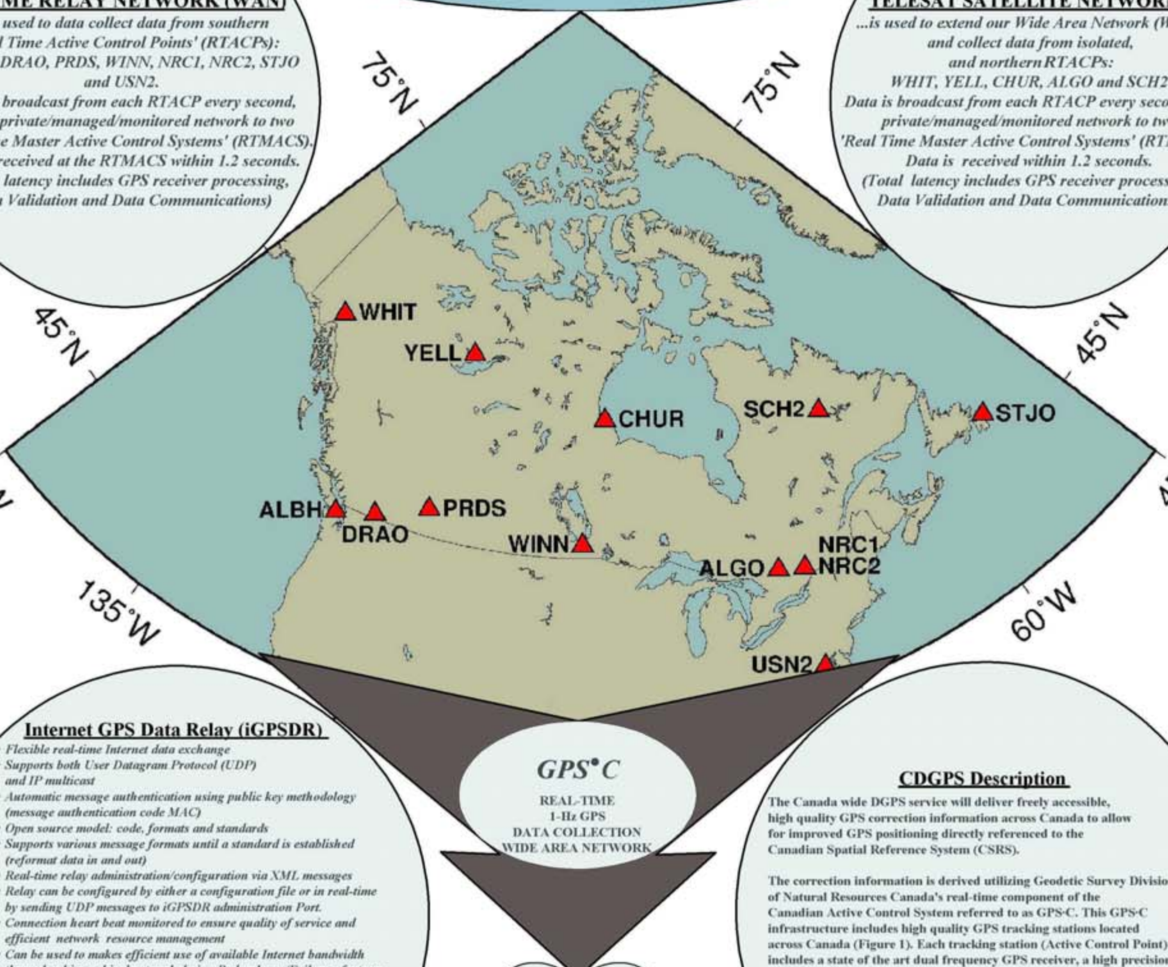
NRCan / Geodetic Survey Division

FRAME RELAY NETWORK (WAN)

...is used to data collect data from southern 'Real Time Active Control Points' (RTACPs): ALBH, DRAO, PRDS, WINN, NRC1, NRC2, STJO and USN2. Data is broadcast from each RTACP every second, via a aprivate/managed/monitored network to two 'Real Time Master Active Control Systems' (RTMACS). Data is received at the RTMACS within 1.2 seconds. (Total latency includes GPS receiver processing, Data Validation and Data Communications)

TELESAT SATELLITE NETWORK

...is used to extend our Wide Area Network (WAN) and collect data from isolated, and northern RTACPs: WHIT, YELL, CHUR, ALGO and SCH2 Data is broadcast from each RTACP every second, via private/managed/monitored network to two 'Real Time Master Active Control Systems' (RTMACS). Data is received within 1.2 seconds. (Total latency includes GPS receiver processing, Data Validation and Data Communications)



Internet GPS Data Relay (iGPSDR)

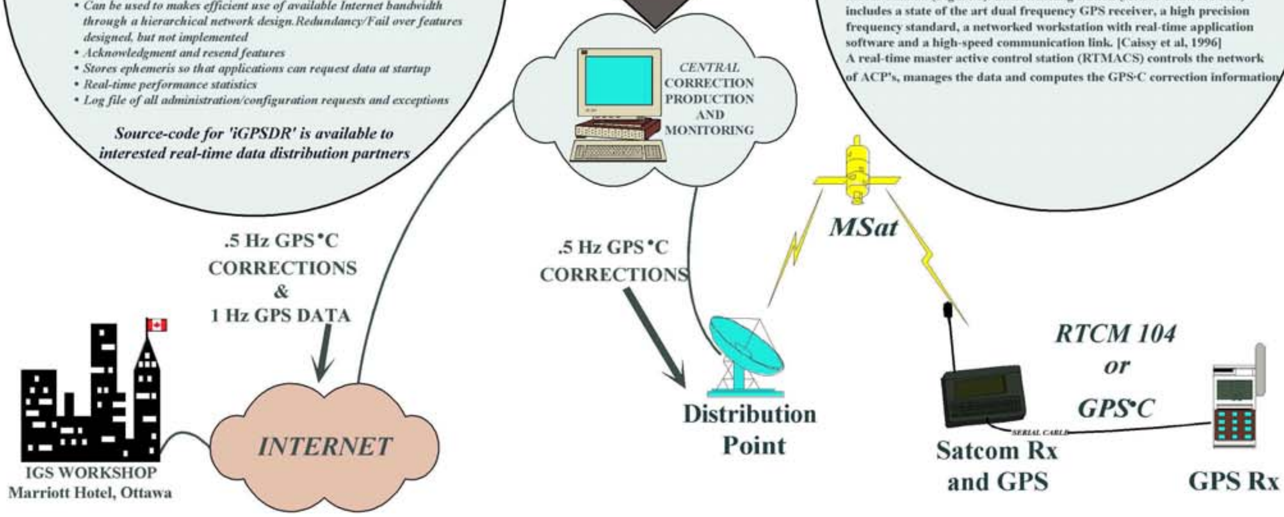
- *Flexible real-time Internet data exchange*
- *Supports both User Datagram Protocol (UDP) and IP multicast*
- *Automatic message authentication using public key methodology (message authentication code MAC)*
- *Open source model: code, formats and standards*
- *Supports various message formats until a standard is established (reformat data in and out)*
- *Real-time relay administration/configuration via XML messages*
- *Relay can be configured by either a configuration file or in real-time by sending UDP messages to iGPSDR administration Port.*
- *Connection heart beat monitored to ensure quality of service and efficient network resource management*
- *Can be used to makes efficient use of available Internet bandwidth through a hierarchical network design.Redundancy/Fail over features designed, but not implemented*
- *Acknowledgment and resend features*
- *Stores ephemeris so that applications can request data at startup*
- *Real-time performance statistics*
- *Log file of all administration/configuration requests and exceptions*

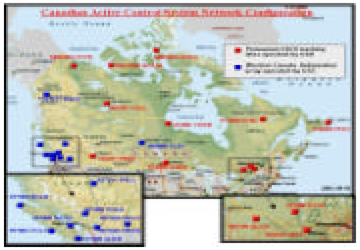
Source-code for 'iGPSDR' is available to interested real-time data distribution partners

CDGPS Description

The Canada wide DGPS service will deliver freely accessible, high quality GPS correction information across Canada to allow for improved GPS positioning directly referenced to the Canadian Spatial Reference System (CSRS).

The correction information is derived utilizing Geodetic Survey Division of Natural Resources Canada's real-time component of the Canadian Active Control System referred to as GPS·C. This GPS·C infrastructure includes high quality GPS tracking stations located across Canada (Figure 1). Each tracking station (Active Control Point) includes a state of the art dual frequency GPS receiver, a high precision frequency standard, a networked workstation with real-time application software and a high-speed communication link. [Caissy et al, 1996] A real-time master active control station (RTMACS) controls the network of ACP's, manages the data and computes the GPS·C correction information





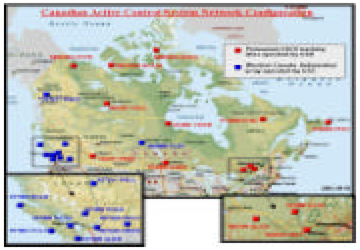
NRCan Analysis Centre Contributions to the IGS

B. Donahue, P. Héroux, C. Huot, D. Hutchison, J. Kouba, Y. Mireault and P. Tétreault
Geodetic Survey Division (GSD)

Natural Resources Canada
Ressources naturelles Canada

Abstract

As part of Natural Resources Canada (NRCan), the primary role of the Geodetic Survey Division (GSD) is to maintain, continuously improve, and facilitate efficient access to what is now known as the Canadian Spatial Reference System (CSRS). The CSRS serves as a reference for all positioning, mapping, charting, navigation, boundary demarcation, crustal deformation, and other georeferencing needs within Canada. While continuing to serve ongoing requirements for survey control, the growing demands of GPS users in particular have resulted in a new focus for the Division, a focus on supporting positioning from space. The Canadian Active Control System (CACS) was established during the 1990's to facilitate GPS user access to the CSRS. NRCan participation in IGS is an efficient way of providing for Canada a positioning and navigation infrastructure based on modern technologies and international standards. NRCan has been an IGS Analysis Center (EMR) since the 1992 initial IGS pilot phase. This poster lists some of NRCan current contributions to IGS and describes recent modifications, innovations as well as on-going and up-coming developments.



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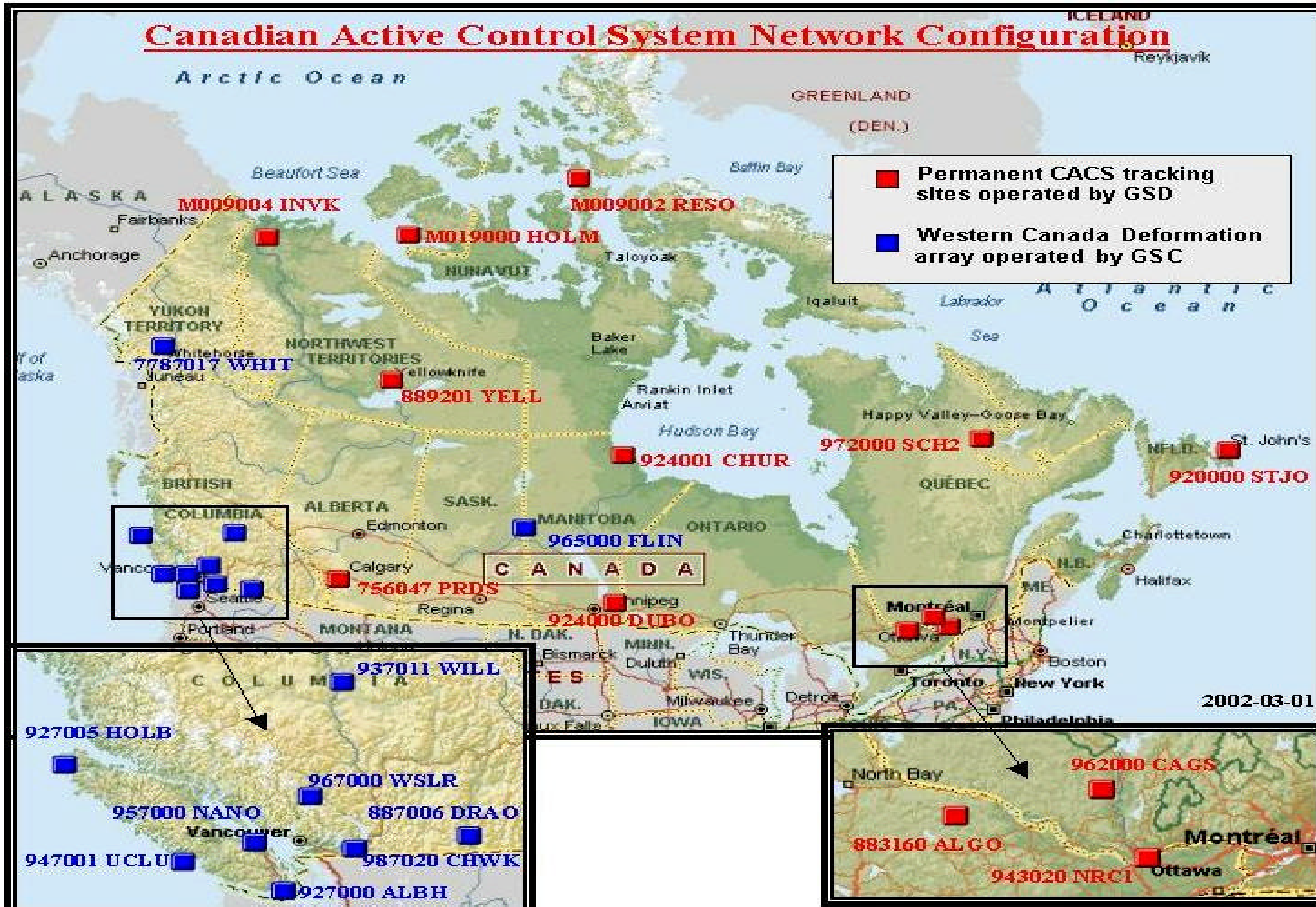

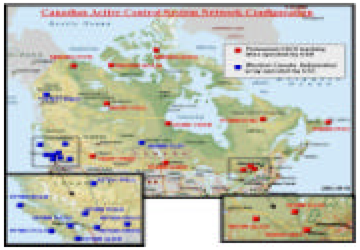

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1. NRCan Final and Rapid Products (EMR)

1.1 Final and Rapid Processing Strategy Modifications since GPS Week 1082

1090 Following implementation of precise point positioning (fixing igr orbits and clocks) to validate stations carrier phase and pseudorange observations for Final solution (GPS week 1070), station pseudorange observations can now be excluded from processing.

1097 Adoption of new set of <P1-C1> bias values (v2.0) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.

1100 Implementation of precise point positioning (fixing igu orbits and clocks) to validate stations carrier phase and pseudorange observations for Rapid solution. This procedure was discontinued after week 1110 due to problems arising from limitations in the accuracy of ultra-rapid clock estimations.

1106 Adoption of new set of <P1-C1> bias values (v2.1) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.

1121 Began applying sub-daily (12h/24h) ocean tides in the transformation from inertial to Earth-fixed coordinates (sp3) as recommended by IGS/IERS.

1139 Implementation of JPL's GIPSY-OASIS Version 2.6 software for Final solution (Figure 1a).

1142 Implementation of JPL's GIPSY-OASIS Version 2.6 software for Rapid solution (Figure 1b).

1143 Adoption of IGS00 (IGS realization of ITRF 2000) station coordinates and velocities.

1145 Re-aligned NRCan UT1-UTC value to VLBI derived value (Bulletin A) on day 0 and then resumed our normal daily estimation procedure for UT1-UTC.

1150 Adoption of new set of <P1-C1> bias values (v2.4) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.

1153 Adoption of new version of cc2noncc software (v3.0) for transforming cross-correlated pseudorange observations into synthesized non cross-correlated. Version 3.0 also includes C1, Y-codeless receivers in addition to cross-correlated receivers.

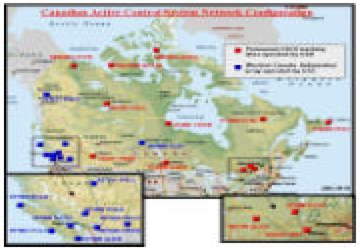

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Figure 1a

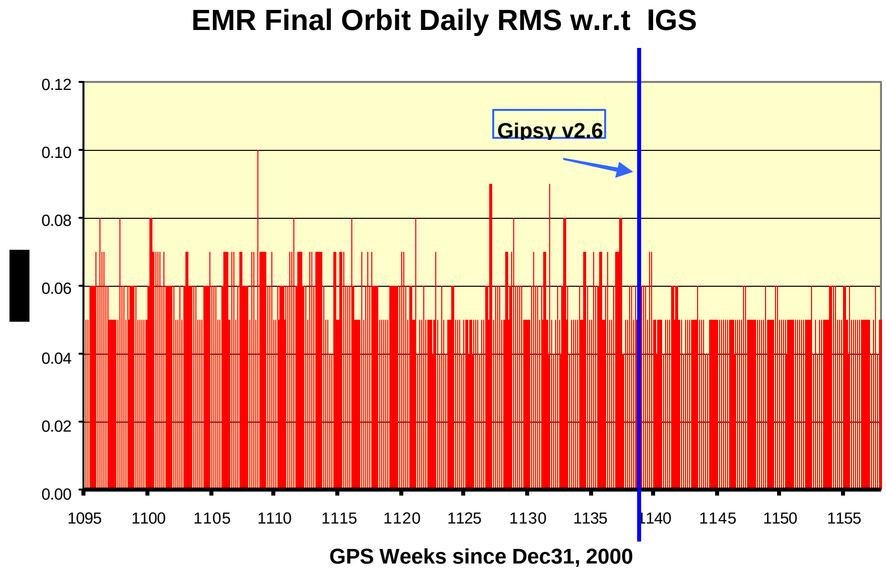
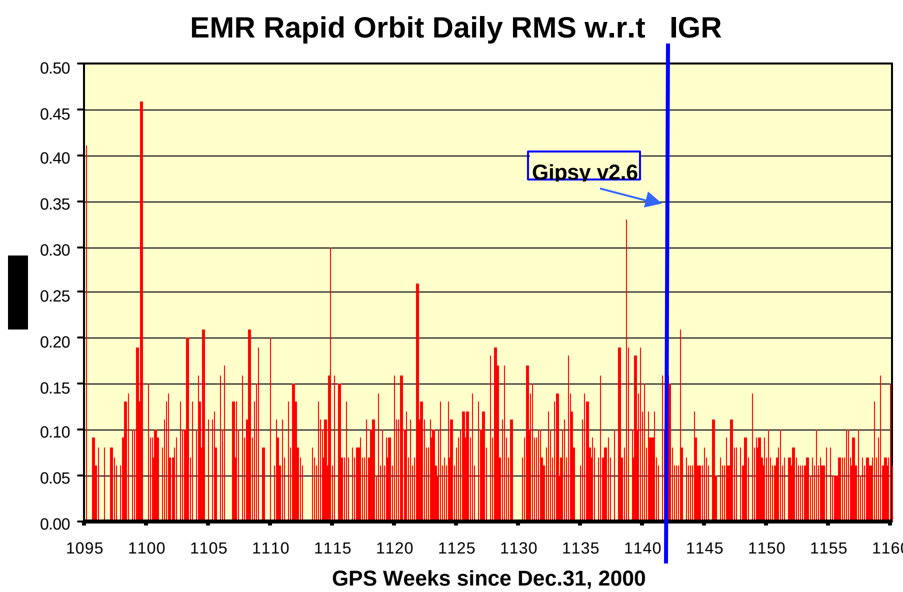
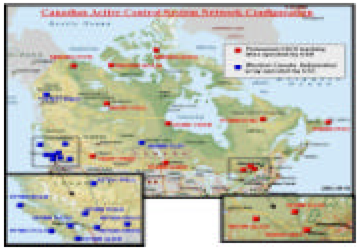


Figure 1b





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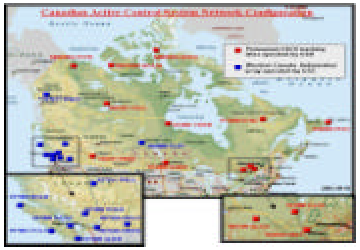
Geodetic Survey Division (GSD)

1.2 IGS97 to IGS00 Discontinuities in NRCan Rapid Products for GPS Week 1157

Solutions	RX(mas) -PMy	RY(mas) -PMx	RZ(mas) DUT1	Sc(ppb)	TX(cm)	TY(cm)	TZ(cm)
NRCan Orbits	0.020	0.034	-0.141		-0.059	-0.003	0.848
Sigma	0.021	0.029	0.027		0.045	0.098	0.165
NRCan EOP	0.010	0.022	-0.202				
Sigma	0.021	0.028	0.054				
NRCan Stations	-0.023	-0.037	-0.173	-0.957	-0.286	-0.276	2.648
Sigma	0.019	0.019	0.039	0.113	0.050	0.065	0.101
IGS Realization	-0.024	-0.004	-0.159	-1.451	-0.45	-0.24	2.60
Sigma	0.092	0.099	0.076	0.270	0.41	0.50	0.75

Note: NRCan results were estimated processing GPS week 1157 (March 10-16, 2002) using both IGS97 and IGS00 coordinates and velocities along with their associated sigmas. IGS results refer to epoch 02-Dec-2001 (GPS week 1143-0)



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Geodetic Survey Division (GSD)

2. NRCan Ultra Rapid Product (EMU)

2.1 Ultra Rapid General Information (EMU)

- Use of Bernese v4.2 (HP-UX 11.0)
- Fully automated

2.2 EMU History and Changes

- Mar 20, 2000:First EMU submission for IGU
- Dec 12, 2000: Started using an orbit fit (IGR, IGU, EMU)

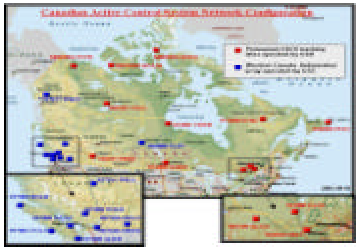
- Jan 15, 2001: Satellite de-weighting implemented
- June 2001: Started submission of 1hr TZD to G. Gendt

- Jul 12, 2001: Improved station selection
- Sep 15, 2001: Improved pole estimates

- Oct 18, 2001: Use of ADDNEQ2 from Bernese
- Dec 02, 2001: Adoption of IGS00

2.3 EMU Future Work

- Improve EMU's orbit estimated portion (1st 24 hrs)
- Estimate satellite clocks ??? (**Major CPU limitation !!!**)



NRCan Analysis Centre Contributions to the IGS

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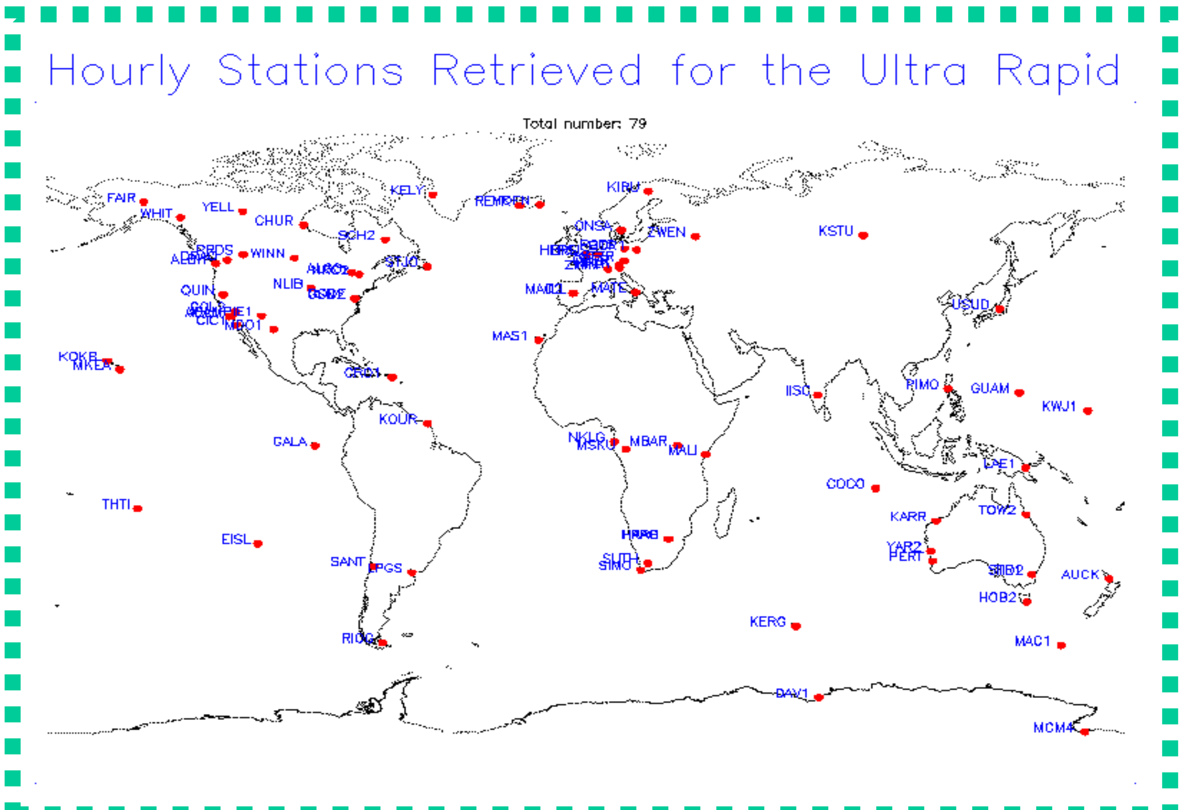
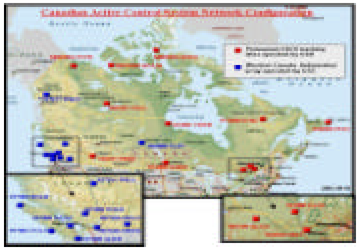
2.4 IGS Hourly Stations Used and Ftp'ed

- About 80 IGS hourly stations are ftp'ed regularly
- Only missing stations are retrieved from the following 4 Data Centres:
  CDDIS, SIO, BKG, AUSLIG

- About 35 stations are regularly processed
- 2-4 ftp's per hour are performed to each of the above Data Centre





2.5 EMU Processing Strategy

- Processing is done in 3 hr sessions, i.e. 0-3; 3-6; 6-9;… 21-24
- Processing time for one 3 hr session is about 50min (35 stations)

- Each 3 hr session is delayed by 1h to maximize the number of stations processed

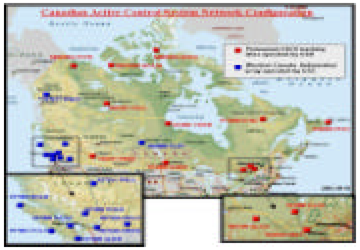
- Apriori orbits are the EMU solution from the previous 3 hr session. Other choices are: IGU and BRD
- Apriori ERP is the IERS Bulletin A

- **N**ormal **EQ**uation files (**NEQ**) are created for every 3 hr session
- Parameters estimated are orbits, station xyz, real ambiguities, ERP and TZD

- EMU orbits are produced in 2 steps:

  - A first EMU orbit is generated using at most sixteen (16) 3-hr NEQ files
  - A second and "final" EMU orbit is produced by fitting the IGS Rapid and/or Ultra Rapid orbits (already available) along with our first Ultra Rapid from step 1. Altogether, a minimum of 2 days and a maximum of 3 days worth of Rapid/Ultra Rapid orbit fitting are performed on a regular basis

- Each EMU orbit file contains orbit positions for 48 hrs: a 24 hr real or estimated portion followed by a 24 hr prediction portion.



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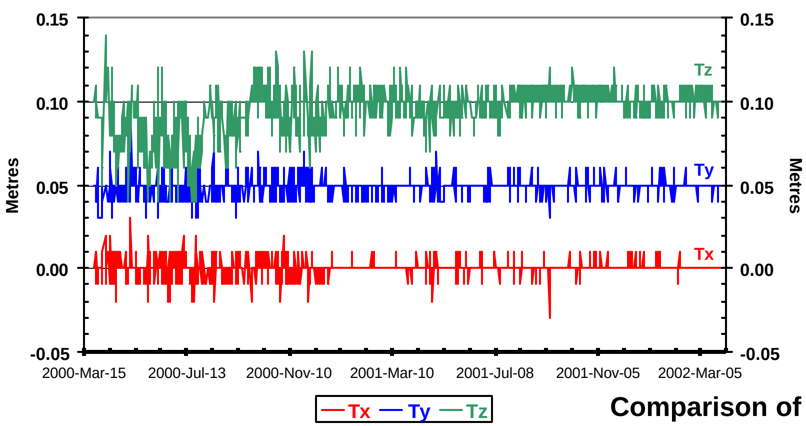
2.6 EMU Results with respect to IGU

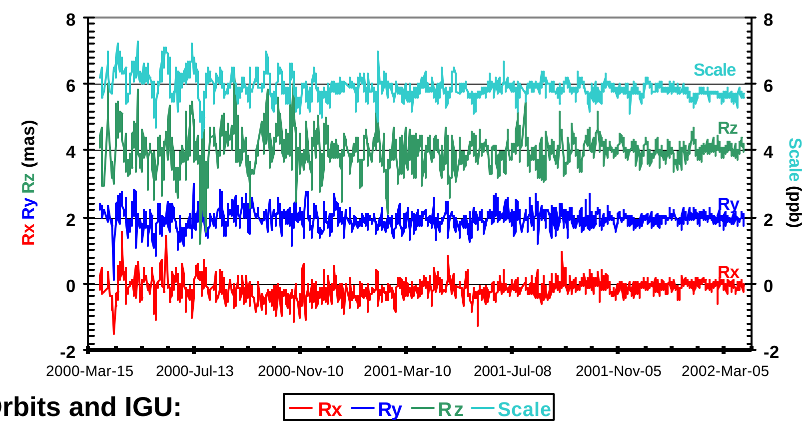
Comparison of EMU Orbits and IGU: Translations (Tx, Ty, Tz offset by 0.05 m)

Period: 2000-2002



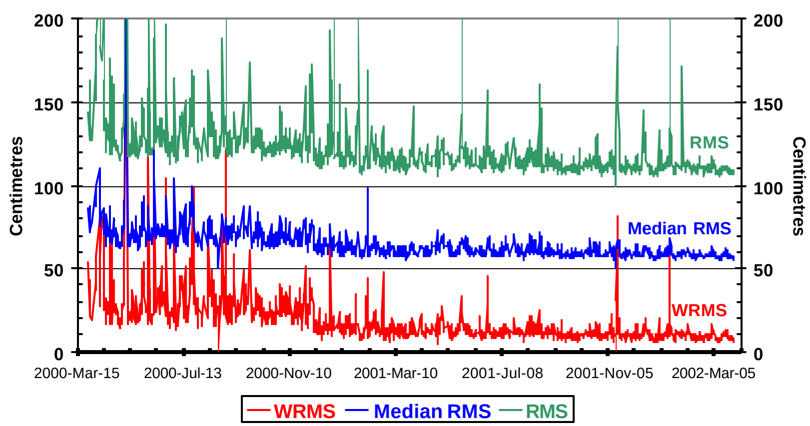
Comparison of EMU Orbits and IGU: Rotations/Scale (Rx, Ry, Rz / Scale offset by 2 mas/ppb)

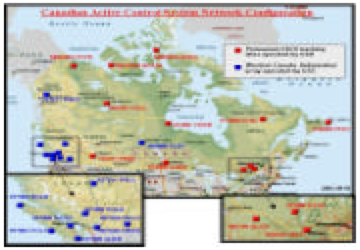
Period: 2000-2002



Comparison of EMU Orbits and IGU: WRMS, Median RMS, RMS offset by 50 cm

Period: 2000-2002





NRCan Analysis Centre Contributions to the IGS

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Natural Resources Canada
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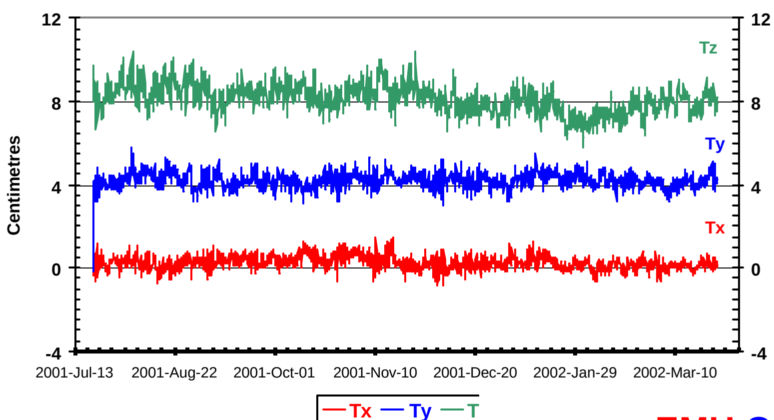
2.7 EMU Results with respect to IGR

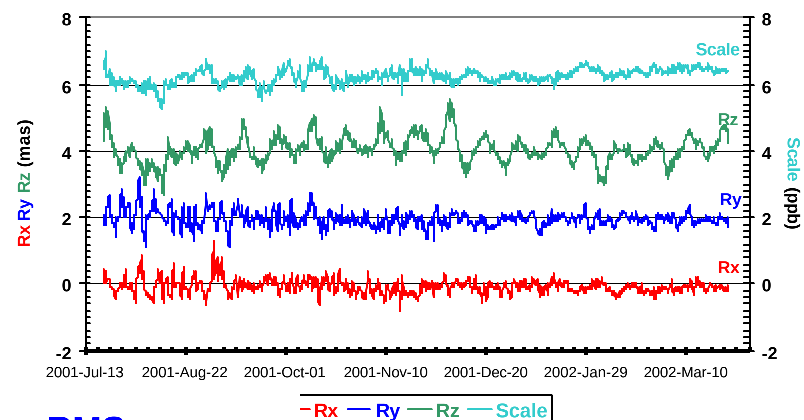
Comparison of EMU Orbits and IGR: Translations (Tx, Ty, Tz offset by 4 cm)

Period: 2001-May-20 to 2002-Mar-26



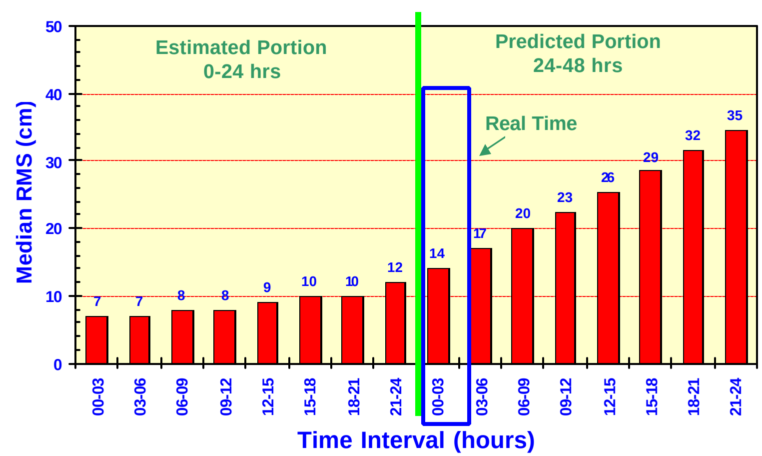
Comparison of EMU Orbits and IGR: Rotations/Scale (Rx, Ry, Rz / Scale offset by 2 mas/ppb)

Period: 2001-May-20 to 2002-Mar-26



EMU Orbit Median RMS

(Jan. 1 - Mar. 26, 2002)



A COMPARISON OF GPS RADIATION FORCE MODELS

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A poster paper presented at the
International GPS Service
"Toward Real Time Workshop"
2002 April 8-11
Ottawa, Ontario, Canada

Figures updated 2002 May 3 to include LM-IIR model predictions.

Abstract

The following models have been proposed to model the radiation force on GPS Block IIR satellites:

- The "CODE 1998" model reported by Springer(1998);
- JPL's GSPM_XYZ.1 model from Bar-Sever(1998a);
- The T30 model from Fliegel and Gallini(1996);
- The (Lockheed Martin Corp.) Block IIR model "LM-IIR" reported by Bar-Sever(1998b);
- CODE/VJS-01 model based on the author's recommended changes to some mathematical expressions in the CODE 1998 model.

We compare the secular perturbation rates predicted by the models, as a function of Sun angle from the orbit plane, with the observed values for a Block IIA and Block IIR spacecraft. The Block IIA comparison illustrates the accuracy of the CODE 1998 and the GSPM_XYZ.1 models in their intended application. The Block IIR comparison shows that the CODE/VJS-01 model gives the best accuracy of all models tested.

MODELS CONSIDERED

The following models have been proposed to model the radiation force (RF) on GPS Block IIR satellites:

- The "CODE 1998" model reported by Springer(1998);
- JPL's GSPM_XYZ.1 model from Bar-Sever(1998a);
- The T30 model from Fliegel and Gallini(1996);
- The (Lockheed Martin Corp.) Block IIR model "LM-IIR" reported by Bar-Sever(1998b);
- CODE/VJS-01 model.
  - Based on my recommended changes to some mathematical expressions in the CODE 1998 model.
  - Name emphasizes fact that much of Springer's CODE model is left intact.

- NOTE: Names are assigned here to some models ("CODE 1998", "LM-IIR") for ease of reference.
  - Investigators should assign names to models, not just call each new development the "New RF Model".

WHAT CONSTITUTES A MODEL?

- "Model" as used in this paper refers to a set of mathematical expressions (physical-model or empirical based) for computing GPS spacecraft acceleration due to radiation forces.
  - Usually a function of:
    - Satellite orbital longitude ($L - L_H$) relative to Sun projection on orbit plane and
    - Sun orbital latitude B_H (Sun geocentric angle from orbit plane).
  - "CODE model" here refers to such a RF model, not to a particular method of orbit determination.

- CODE 1998 model involves parameters whose numerical values are spacecraft or GPS-series dependent.
  - We recommend changed parameter values for certain spacecraft.
    - This is not a model change because computer implementation does not involve changing computer code.
    - Changed parameters can be input through a change to an input namelist or data file.
  - Our recommended changes to some CODE mathematical expressions constitute a new model because computer code must be changed.

EVALUATION OF MODELS BASED ON SECULAR PERTURBATIONS PRODUCED

- Necessary condition for a good model is that it closely match secular orbit perturbations produced by real satellite.
  - Secular perturbation accuracy is particularly important when predicting future satellite positions.

- We compare secular perturbations produced by various models with the observed secular perturbations to the GPS orbits.
  - This comparison method can be more instructive than the common evaluation approach of inserting a RF model in an orbit-determination computer program and noting which model gives smaller fitting-residuals or better prediction accuracy.
  - This method can isolate the deficiencies of a particular model and suggest simple modifications to improve accuracy.
    - We later illustrate this approach with our modifications to the CODE 1998 model.

ORBIT RESONANCE PARAMETERS

- For the nearly-circular GPS orbits, secular perturbations are produced by the constant and once-per-revolution terms in a Fourier expansion of the radiation force.

- For each model we deal with the acceleration components

  a_r = radial component (positive away from Earth),
  a_s = transverse (in-plane) component (positive in general direction of orbital motion), and
  a_w = orbit-normal component (positive in orbital angular momentum direction).

- For the Sun at a fixed orbital-latitude B_H, acceleration components may be numerically evaluated at closely-spaced (~1°) intervals. A Fourier analysis performed over the orbital longitude $(L - L_H)$ relative to Sun gives

$$a_r = C_r + R_c \cos(L - L_H) + R_s \sin(L - L_H) + \ldots \quad (1)$$
$$a_s = C_L + S_c \cos(L - L_H) + S_s \sin(L - L_H) + \ldots \quad (2)$$
$$a_w = C_w + W_c \cos(L - L_H) + W_s \sin(L - L_H) + \ldots \quad (3)$$

  - The expansion here only shows the constant terms C_x and the once-per-revolution terms whose cosine and sine amplitudes are R_c, R_s, S_c, S_s, W_c, and W_s.
  - It is useful to define the "equivalent along-track amplitudes"

$$E_c \equiv S_c + \frac{R_s}{2} \quad (4)$$

$$E_s \equiv S_s - \frac{R_c}{2} \quad . \quad (5)$$

- Secular perturbations to a circular orbit are proportional to the following "resonance parameters":

C_L = Constant along-track (transverse) acceleration;
- this acceleration results in a secular, along-track acceleration in the satellite position
- this acceleration is usually modelled via the "Y-bias" acceleration

E_c, E_s = Amplitude of the once-per-revolution cosine and sine terms in the equivalent along-track (transverse) acceleration;
- Secular perturbations to the orbit center position (eccentricity vector) are proportional to the E_c, E_s linear combinations.
- Observed secular perturbations allow one to determine E_c and E_s but not the R and S amplitudes separately.
- E_c=0 for an absorbing sphere.

W_c, W_s = Amplitude of the once-per-revolution cosine and sine terms in the acceleration component along the orbit-normal direction.
- These parameters give secular perturbations to the orbit normal direction in inertial space.

ASSUMPTIONS ON USE OF MODELS

- Models give acceleration a_{model} for the spacecraft in full sunlight at 1 AU from Sun.
  - Force goes to zero in Earth (and Moon) shadow.
  - Exception is LM-IIR model which includes a small body-fixed "constant thermal acceleration" $a_{thermal}$ which continues to act in Earth shadow.
  - Acceleration a_{RF} used in orbit integration is given by

$$\vec{a}_{RF} = f_{shadow}\left(\frac{1\,AU}{r_H}\right)^2 \vec{a}_{model} + \vec{a}_{thermal} \qquad (6)$$

  where the last term on the right only applies to the LM-IIR model,

  f_{shadow} = shadow factor
  =1 in full sunlight,
  =0 in Earth's umbral shadow,
  = value between 0 and 1 in penumbra, and

  r_H = spacecraft distance from Sun center (in AU).

- The models use nominal-attitude spacecraft axes in inertial space, that is, spacecraft axes with no yaw bias. The real spacecraft may always show a definite yaw bias, and that changes the observed radiation force. But models based on observation (especially the CODE models) express the observed radiation force in terms of acceleration components along nominal-attitude axes.

- LM-IIR model is evaluated here on assumption that Sun lies in spacecraft XZ plane at all times (EL=0 in tables) with +X axis pointing away from Sun.
  - Block IIR +X axis nominal pointing is opposite to direction for Block II and IIA spacecraft.

OBSERVED PERTURBATION RATES

- To obtain daily "observed" secular perturbation rates for a satellite, USNO uses JPL's GIPSY-OASIS II computer software to fit a continuous trajectory through previous several days of IGS Rapid orbit (position) data.
  - Ordinarily use a 6 day data span.
  - Use 4 day span for satellites in eclipse season.
  - If a thruster is detected within the data span, only use data after the firing.
  - This study only uses fits with a 4 day or longer data span giving a 3-dimensional root-mean-square fit of 0.5 m or less.

- Trajectory based on standard gravity model for Earth,
  - includes gravitational perturbations from Sun, Moon, and planets (Mercury through Saturn), tidal gravity, and
  - includes standard ocean tide variations in Earth orientation.

- Radiation force computed from CODE 1998 RF model with my parameter-value improvements and model-expression changes as they are developed.
  - Currently use the CODE/VJS-01 model.

- The fit also adds acceleration corrections a_s, a_w to the transverse and orbit-normal components of the RF acceleration from Eq.(6),

$$\Delta a_s = \Delta C_L + S_N \cos L + S_V \sin L \tag{7}$$
$$\Delta a_w = \Delta C_w + W_N \cos L + W_V \sin L \quad . \tag{8}$$

  - Assumption made that only significant force-modelling errors are in RF model.
  - These corrections allow for secular-perturbation-producing errors in RF model.

- Trajectory least-squares fit solves for satellite initial position and velocity vectors (6 parameters) plus the 6 parameters C $_L$C S_W S_N W_V W_N $_V$.
  - These particular acceleration corrections are used because they are already implemented in the GIPSY code.
  - These solved-for acceleration corrections are saved in a solution file along with the Sun direction (B_H and L_H values) at midfit.
  - For an assumed circular orbit in the actual orbit plane at the midfit time, "model" resonance parameter values ($C_L^{(model)}$, etc.) are computed for Sun at 1 AU using RF model (same expressions and parameter values) actually used in the trajectory fit.
  - These "a priori" values are also saved in the solution file.

- At a later time resonant parameter corrections from the file are converted to corrections at 1 AU and added to stored model parameter values to give "observed" resonance parameters. For example,

$$C_L^{(obs)} = C_L^{(model)} + \left(\frac{r_H}{1\ AU} \right)^2 \Delta C_L \qquad (9)$$

  - This gives the "observed" data points displayed on the graphs alongside the curves predicted by the various RF models.

METHOD OF CODE MODEL ADJUSTMENT

The CODE models give expressions for accelerations along five different axes. Outside of eclipse season for a satellite, the expression for each axis usually contributes to only one of the resonance parameters, as summarized in Table 1. Because of this one-to-one correspondence, if the model predictions seriously disagree with the observed values for one of the resonance parameters, the corresponding model-axis expression can be adjusted to improve the agreement with no impact on the agreement for the other resonance parameters. One first adjusts the spacecraft-specific parameter in the axis expression; only when no satisfactory fit results does one vary the other parameters or change the mathematical expression.

The exception is the nominal-attitude Y_{na} axis expression which affects both the C_L and W_s resonance parameters. This poses no problem since we find that adjusting the Y_{na} axis expression to improve agreement with the observed C_L values simultaneously improves the agreement with the observed W_s values.

Table 1 - Resonance Parameter Contributions from Each CODE Axis

CODE Expression	Resonance Parameter					
	C_L	E_c	E_s	W_c	W_s	C_w
D axis			yes	eclipse		yes
Z_{na} axis		yes				
Y_{na} axis	yes	eclipse			yes	
X_{na} axis	yes	eclipse	eclipse	yes	yes	eclipse
B axis			eclipse	yes		eclipse

eclipse = contributes during eclipse season only

The X_{na} axis expression contributes to the same resonance parameters as the Y_{na} and B axes expressions. Since the X_{na} axis expression involves only small terms and contributes to all the parameters, we have made no adjustments to this expression.

MODEL COMPARISON WITH DATA

We use the Block IIA SVN 30 (PRN 30) and Block IIR SVN 44 (PRN 28) satellites in the comparisons of RF model prediction with observation because these two satellites are in orbits that experience a very wide range of Sun angle B_H, of order ±75°. We include a Block IIA satellite in the comparisons because the CODE 1998 and GSPM_XYZ.1 models were developed for that series; we wish to show how well they work for that series.

Consult the author for a complete explanation of the figures.

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Springer, T. A., "CODE RPR Model", IGS Electronic Mail Message No. 1842 (Mar 25, 1998), available at Internet site http://igscb.jpl.nasa.gov/igscb/mail/igsmail/1842 . The equations in this reference contain some typographic errors: YC and BC should be YC2 and BC2; in each Zp and Xp equation line, every second "COS" should be "SIN" (Tim Springer, private communication, April 27, 1998).

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On-line Web GPS Processing using Bernese and IGS Products

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INTRODUCTION

We would like to highlight a new project which has been started in our Institute. This is a service which enables users to process automatically their own GPS data through our Internet Web site.
The user is requested to fill out the form (on the right) and send RINEX file to our computer. Then our system begins to start. It downloads all necessary things to make processing, process data and afterwards sends results back to the user.

The poster presents brief description of the service as well as some first tests performed using it.
However due to some technical problems it is not opened for users for now and it is still in testing mode.

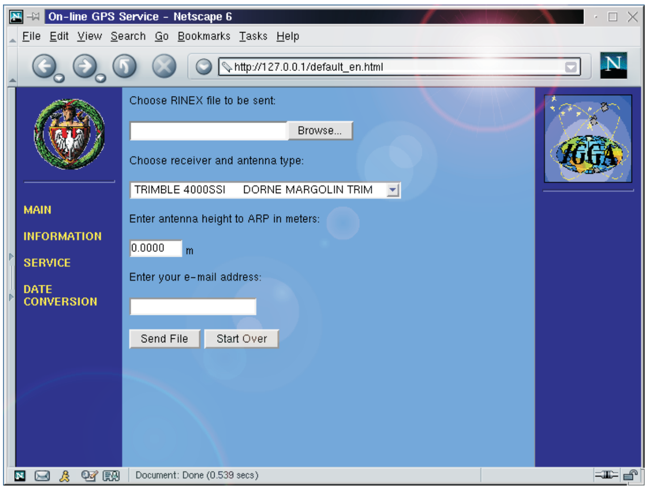
DESCRIPTION OF THE SERVICE

SOFTWARE:

It is based on Bernese 4.2 GPS Processing Software.
We do not use BPE and original panels (only main programs are used).
Script which controls automated processing, prepares all necessary input files and some others things have been written in Perl language.

STRATEGY:

- entire processing is carried out in network mode (star strategy with user station at the center)
- closest station is fixed/heavily constrained
- using Bulletin A Earth Orientation Parameters
- using the best available orbits at the time of request
- ambiguity resolution QIF
- tropospheric parameters are set up according to session length (session length is divided into 2 hours intervals whithin which one tropospheric parameter for each station is estimated, if the last (remainig) interval is longer than 1 hour then additional parameter is set up, if it is not, previous interval is increased by the remaining interval)



Appearence of the application form. User has to specify name of his (or her) RINEX file, type of the receiver and antenna, height of the antenna and e-mail address. The upload is performed using CGI script.

LIMITATIONS:

The services does not allow to process observations stemming from one frequency receivers.
Observations have to be performed within one UT day.
For now we do not make use of hourly data from IGS/EUREF sites. We use only daily files, therefore observations should be at least from previous day.
It is not possible to upload more than one file at once.

Identifying user file.
Is it RINEX?
Defining session (start, end)
Getting orbits
Single Point

Stations definition
Getting lists of stations from IfAG, CDDIS, LOX
Compute distances between user point and all stations specified in coordinate files
Finding 3 closest stations (min. dist. 100m, max. dist. 1000km) (no optimization with respect to shape of the network)
Download 3 stations

Checking downloaded files
Checking if the files have common epochs with user file
Checking if receiver and antenna types exist in PCV file

Processing
Process observations according to described strategy
Helmert transformation to reference frame

End
Checking if there are any errors which may have occured during processing
Making report file
Sending report file to user

Simplified scheme of service.

EXPERIMENTS

Scheme ot tested network

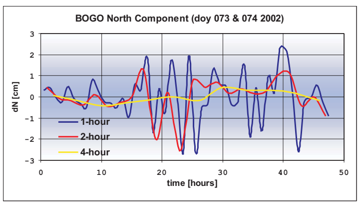
We have performed some tests to find out what would be expected accuracy of this service.

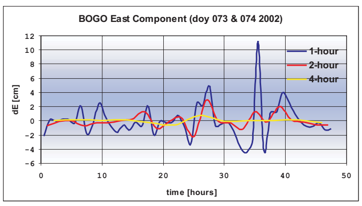
We chose four Polish stations: BOR1, JOZE, LAMA and BOGO and treated BOGO as station submited by the user.

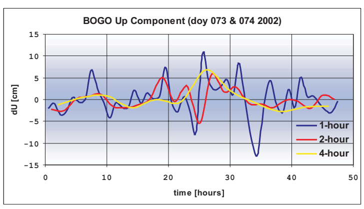
We expect that main users will be surveyors who will submit several hours observation files.
Therefore three different session lengths (but not very long) have been tested: 1, 2 and 4 hours sessions.

The figures on the right show changes of the components: north, east and up for 4 days (73, 74, 76, 78 of 2002) of the station BOGO.

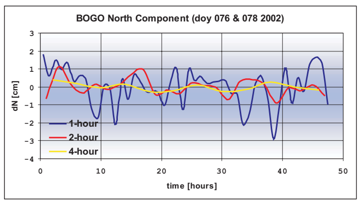
Days 073 and 074 were computed using CODE final orbits and days 076, 078 were computed using CODE rapid orbits.

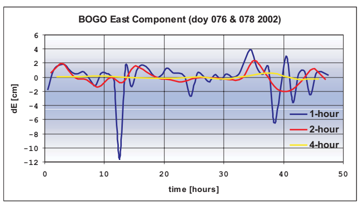


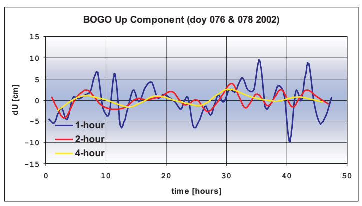




Variant 1: CODE final orbits, Bulletin A ERPs and ITRF2000 coordinates used.







Variant 2: CODE rapid orbits, Bulletin A ERPs and ITRF2000 coordinates used.

Two tables below show expected accuracy with respect to different session lengths.

Table below showsRMSs obtained from 1st variant for days 073 & 074

Interval	RMS [cm] North	East	Up
1h	1.2	2.6	4.1
2h	0.9	1.1	2.5
4h	0.3	0.3	2.5

Table below shows RMSs obtained from 2nd variant for days 076&078

Interval	RMS [cm] North	East	Up
1h	1.0	2.4	3.9
2h	0.5	1.0	1.9
4h	0.2	0.2	1.4

We do not recommend to send data below 1 hour length.

TO DO:

We would like to minimize list of limitations (the most important thing for us is to set up support for one frequency receivers).

Optimization with respect to shape of the network while defining permanent stations to process (not only distance).

And of course make it finally available for users.

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