IGS

ANALYSIS CENTERS

CODE IGS Analysis Center Technical Report 2002

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Introduction

CODE, the Center for Orbit Determination in Europe, is a joint venture of the following four institutions:

- the Federal Office of Topography (swisstopo), Wabern, Switzerland,
- the Federal Agency of Cartography and Geodesy (BKG), Frankfurt, Germany,
- the Institut Géographique National (IGN), Paris, France, and
- the Astronomical Institute of the University of Berne (AIUB), Berne, Switzerland.

CODE is located at the AIUB. All solutions and results are produced with the latest development version of the Bernese GPS Software [Hugentobler et al., 2001].

This report covers the time period from January through December 2002. It focuses on major changes taken place in the routine processing during this period and shows new developments and products generated at CODE. The processing strategies used in previous years are described in earlier CODE annual reports [Rothacher et al., 1995, 1996, 1997, 1998, 1999, Hugentobler et al., 2000, 2001].

A wide variety of GPS solutions are computed at CODE. Tables 1 and 2 give an overview of the products which are made available through anonymous ftp. In addition, a regional analysis considering about 50 stations of a sub-network of a European permanent network are processed on a daily basis. Weekly coordinate solutions in SINEX format are regularly delivered to EUREF (European Reference Frame, Subcommission of IAG Commission X).

In 2002, no real ultra-rapid orbits were computed at CODE. The solutions delivered to the IGS by CODE were pure predictions on the basis of our daily rapid orbit solutions (i.e., NRT hourly data is not yet considered). Nevertheless the quality of the orbits is entirely competitive with other AC orbit products. The orbits are delivered to the IGS for comparison and are excluded from the IGS ultra rapid orbit combination process but still treated for comparison purposes. The computation of ultra-rapid solutions based on hourly observation data is foreseen for 2003.

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Table 1: CODE products made available through anonymous ftp.

CODE rapid and predicted products available at ftp://ftp.unibe.ch/aiub/CODE	
CODwwwwd.EPH_R	Rapid orbits
CODwwwwd.EPH_P	24-hour orbit predictions
CODwwwwd.EPH_P2	48-hour orbit predictions
CODwwwwd.EPH_5D	5-day orbit predictions
CODwwwwd.ERP_R	Rapid ERPs belonging to the rapid orbits
CODwwwwd.ERP_P	Predicted ERPs belonging to the predicted orbits
CODwwwwd.ERP_P2	Predicted ERPs belonging to the 2-day predicted orbits
CODwwwwd.ERP_5D	Predicted ERPs belonging to the 5-day predicted orbits
CODwwwwd.CLK_R	Rapid clock product, 5-minute values, clock-RINEX format
CODwwwwd.TRO_R	Rapid troposphere product, SINEX format
CODGddd0.yyI	Rapid ionosphere product, IONEX format
COPGddd0.yyI	1-day or 2-day ionosphere predictions, IONEX format
CODwwwwd.ION_R	Rapid ionosphere product, Bernese format
CODwwwwd.ION_P	1-day ionosphere predictions, Bernese format
CODwwwwd.ION_P2	2-day ionosphere predictions, Bernese format
GLOwwwwd.EPH_5D	5-day GLONASS orbit predictions (based on broadcast info)
CGIMddd0.yyN_R	Improved Klobuchar-style coefficients, RINEX format
CGIMddd0.yyN_P	1-day predictions of improved Klobuchar-style coefficients
CGIMddd0.yyN_P2	2-day predictions of improved Klobuchar-style coefficients
P1C1.DCB	Moving 30-day P1-C1 DCB solution, Bernese format
P1P2.DCB	Moving 30-day P1-P2 DCB solution, Bernese format

Table 2: CODE products made available through anonymous ftp.

CODE final products available at ftp://ftp.unibe.ch/aiub/CODE/yyyy	
CODwwwwd.EPH.Z	Final orbits, our official IGS product
CODwwww7.ERP.Z	Final ERPs belonging to the final orbits, values for full week
CODwwwwd.TRO.Z	Final troposphere product, SINEX format
CODGddd0.ION.Z	Final ionosphere product, Bernese format
CGIMddd0.yyN.Z	Navigation messages containing improved Klobuchar-style ionosphere coefficients
CODwwww7.SNX.Z	Weekly SINEX product
CODwwww7.SUM.Z	Weekly summary files
COXwwwwd.EPH.Y	Precise GLONASS orbits (for GPS weeks 0990-1066)
COXwwww7.SUM.Z	Weekly summary files of GLONASS analysis
P1C1yymm.DCB.Z	Monthly P1-C1 DCB solutions, Bernese format
P1P2yymm.DCB.Z	Monthly P1-P2 DCB solutions, Bernese format

Changes in the Routine Processing

The major changes implemented in the CODE routine analysis within the year 2002 are listed in Table 3. For details we refer to the IGS analysis questionnaire of CODE available at the IGS CB.

Table 3: Modifications to the CODE processing strategy accomplished between January 2002 and December 2002 (and important changes in 2001).

Date	Doy/Year	Description of Change and Impact
23-Aug-01	231/01	Estimation of horizontal troposphere delay gradient parameters (one set per day and per station). Change of elevation cut-off angle from 10 deg to 3 deg.
20-Sep-01	252/02	Use of a modified single-layer ionosphere model mapping function (approximating the JPL extended slab model mapping function).
10-Oct-01	280/01	Increase of spatial resolution of global ionosphere maps from harmonic expansion 12x12 to 15x15.
09-Dec-01	338/01	Switch from IGS97 to IGS 2000 for the definition of the datum.
13-Jan-02	009/02	Implementation of effect of the Moon's penumbra on orbits.
13-Mar-02	069/02	Earth potential coefficients considered up to degree/order 12.
13-Mar-02	069/02	Start to provide receiver DCB information in IONEX format.
18-Mar-02	074/02	Revised ambiguity resolution strategy.
27-Mar-02	076/02	GIM results for the middle day of a 3-day solution are considered.
07-May-02	124/02	Start to distinguish between three receiver classes (P1/P2, C1/C2, C1/P2) in clock, ionosphere, and wide lane ambiguity resolution procedures. Consider "Trimble 4700" no longer as C1/C2 but as C1/P2 receiver.
08-May-02	123/02	Improved P1-C1 bias values are retrieved from an additional clock estimation step but are based on ambiguity-fixed double differences conforming with the Melbourne-Wübbena linear combination.
09-Jul-02	187/02	Maximum number of stations in final analysis increased from 120 to 150.
29-Oct-02	301/02	Network condition deactivated in rapid analysis. Datum definition done by constraining fiducial sites (3mm)
14-Nov-02	314/02	All orbit products are written in SP3c format.
15-Nov-02	307/02	All IONEX products with 13 2-hourly ionosphere maps. Piece-wise linear (instead of constant) functions are used for representation in the time domain.

Starting with GPS week 1143 the datum of the station coordinates is defined using IGS00, the IGS realization of ITRF2000. In order to further densify our solutions the maximum number of stations was increased from 120 to 150 for the final analysis starting with doy 187/2002. Starting with doy 301/2002, the datum for the rapid analysis is no longer defined by a no-net rotation constraint on the coordinates of fiducial sites but by constraining the fiducial sites with 3 mm. Important for assuring the quality of our products was the complete revision of the ambiguity resolution scheme in both, final and rapid analysis (see below).

Several improvements concern ionosphere products and differential code biases (P1-P2 as well as P1-C1). More details are given below. Since November 14, all orbit products (including intermediate precise orbit files) are written in the new SP3c format.

Refined Ambiguity Resolution

Resolving initial carrier phase ambiguities seems to be essential not only for determination of high quality station coordinates but also for orbital parameters. This is supported by Figure 1 in an impressive manner. During about three weeks of the end of 2001 (doy 290-312), ambiguity fixing as part of our rapid analysis was – by mistake – deactivated. The figure shows the smoothed weighted rms for each IGS AC rapid orbit solution with respect to the IGS-combined orbit product. The arrow indicates the significant increase of CODE's orbit rms for the ambiguity-float solution.

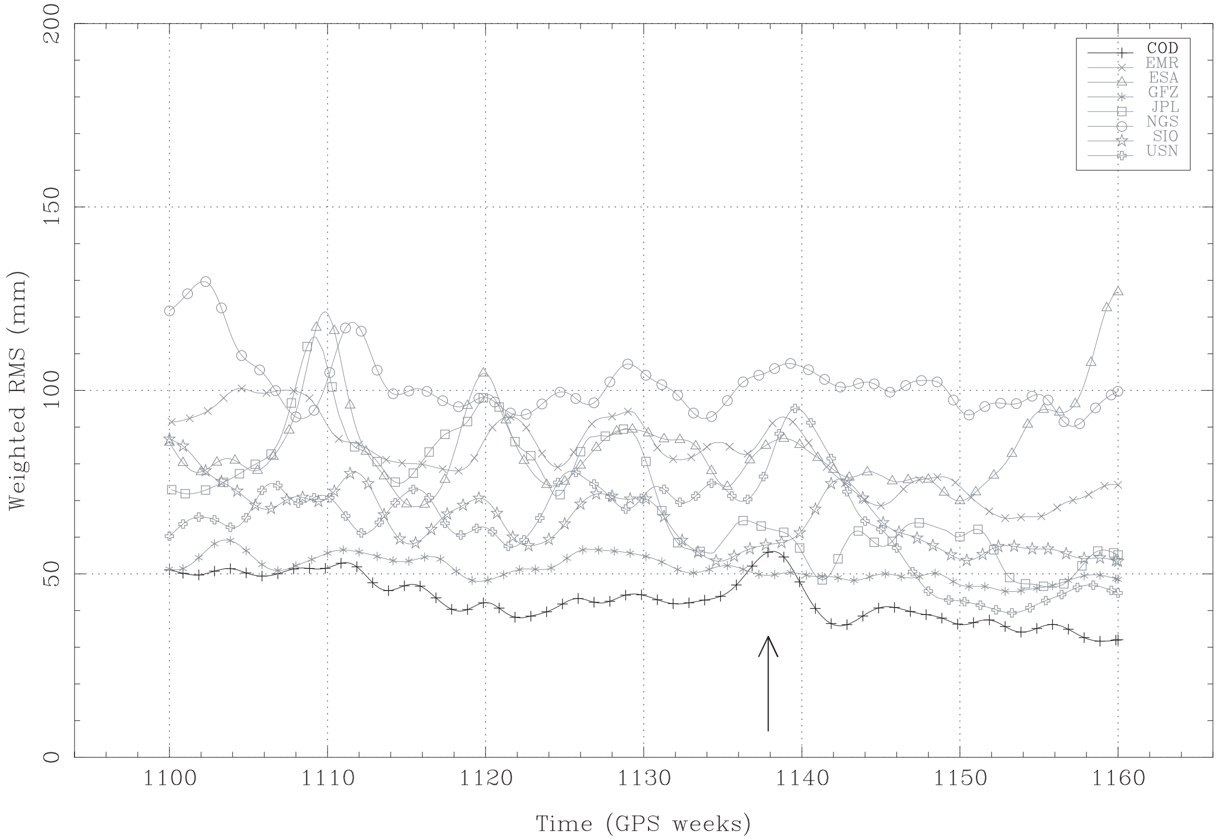

Figure 1: Smoothed weighted rms for each IGS Analysis Center rapid orbit solution with respect to the IGS-combined orbit product. The arrow indicates the period during which ambiguity resolution was by mistake deactivated at CODE.

Motivated by this unintentional experiment we reviewed our ambiguity resolution strategy for the final as well as for the rapid analysis. In March 2002 (doy 074) we activated a completely revised ambiguity resolution scheme for the final analysis. In a cascade of steps we attempt to fix ambiguities for baselines up to 6000 km length:

a) In a first step the widelane ambiguities are solved using the Melbourne-Wübbena strategy, followed by fixing of the corresponding narrowlane ambiguities. The procedure is applied in two iterations. In a boot-strapping step baselines up to 3000 km length are considered, in the final iteration baselines up to 6000 km length are processed.

b) In a second step, unresolved ambiguities on baselines up to a length of 2000 km are fixed using the quasi-ionosphere-free (QIF) strategy.
c) A subsequent step solves widelane and narrowlane ambiguities (relying on phase data only) up to a maximum baseline length of 200 km.
d) Finally, ambiguities on very short baselines (up to 20 km length) are resolved directly on the two carriers.

Assuming that the fraction of resolved (widelane) ambiguities on a specific baseline can be decomposed as the product of performance factors for the two receivers involved, quality indicators for the receivers in a network can be derived. Results show a broad range of such receiver or receiver type specific quality factors. Some receiver types may be found regularly at the upper end of the scale while others show a poor performance for widelane ambiguity resolution. A third class of receivers show a large range in quality factors for individual receivers of one and the same type. Due to the potential sensitivity of the results no rating of receiver types is provided here.

Estimation of Satellite and Receiver Clock Parameters

At CODE, a large number of IGS receivers is considered in the GPS clock estimation process. The final analysis is based on about 120 stations while the rapid analysis typically includes 90 stations. This can be achieved by doing the analysis in three global station clusters and subsequently combining the resulting satellite and receiver clock offsets. Effort was put into the algorithm to get an optimum distribution of stations in the different clusters. The clock offsets are aligned to GPS broadcast time and are referenced to that receiver clock that exhibits the smallest rms difference in a linear fit.

The clock zero-difference processing is based on the results from the double-difference analysis. Satellite orbits as well as determined station coordinates and troposphere parameters are considered fixed in the clock solution. Coordinates and troposphere parameters for additional stations are solved for in the zero-difference analysis.

Ionosphere

During winter 2001/2002 the solar activity passed its maximum. Mean vertical TEC values up to more than 60 TECU could be observed occasionally, one order of magnitude higher than the minimum mean value during solar activity minimum in 1996. When highest peaks were observed in the mean TEC, auroral phenomena could be observed even in Switzerland. To convert line-of-sight TEC into vertical TEC, a modified single-layer model mapping function approximating the JPL extended slab model mapping function is adopted since September, 2001.

Since doy 076/2002 (GPS week 1158) the CODE final GIM results correspond to the results for the middle day of a 3-day combination analysis solving for 37 times 256, or 9472 vertical TEC parameters and one common set of satellite and receiver DCB constants. In this way, discontinuities at day boundaries can be minimized. Furthermore, a time-invariant quality level is achieved. This model change was announced in IGS Mail 3823.

Starting with doy 307/2002 (GPS week 1191), all provided CODE IONEX files include 13 VTEC maps. The first map refers to 00:00 UT, the last map to 24:00 UT (instead of 01:00 and 23:00 UT, respectively). The time spacing of the maps (snapshots) is still 2 hours. Due to the fact that each new daily file contains ionospheric information covering not only 22 but 24 hours, data interpolation becomes more user-friendly. This model change was announced in IGS Mail 4162.

Determination of Differential Code Bias Values

As part of the ionosphere parameter estimation process, P1-P2 DCB values are determined for all active GPS satellites and for about 200 IGS stations. The daily repeatability of these parameters is of the order of 0.1 ns. Monthly P1-P2 DCB solutions are available as of October 1997. In order to ensure that the precise clock information is fully consistent to P1/P2 code measurements, P1-C1 code biases are accounted for as of GPS week 1057. Although the size of P1-C1 bias values is approximately three times smaller than that of P1-P2 values, these biases are still significantly detectable. Based on ambiguity-fixed double differences conforming with the Melbourne-Wübbena linear combination we are doing a kind of "finishing" of the P1-C1 bias retrievals coming from the undifferenced analysis. These P1-C1 bias values, provided since doy 123/2002, have a day-to-day repeatability of the order of 30 picoseconds.

Starting with doy 069/2002, receiver DCB information is provided in CODE IONEX data.

To verify the tracking technology for the different receivers a procedure was developed which safely identifies the receiver class. The procedure is based on the differing code bias corrections for appropriate linear combinations of the carriers and provides reliable results even based on GPS tracking data of a single day. In several cases the tracking technology for new receivers could be determined and were afterwards confirmed by the receiver manufacturers. A file containing the tracking types for the receivers commonly used within the IGS is maintained and made available at http://www.aiub.unibe.ch/ download/BSWUSER/GEN/ RECEIVER.

More details on CODE's DCBs and ionosphere products may be found on our ionosphere-dedicated web site http://www.aiub.unibe.ch/ionosphere.

GPS Satellites in Moon's Penumbra

GPS satellites periodically pass through the penumbra of the Moon. Eclipsing phases may occur when the angular distance between the Moon and the Sun is less than about 4.5 degrees which is the case close to the New Moon phases in the vicinity of the nodes of the lunar orbit with respect to the ecliptic plane. As a consequence, eclipses occur two times per year for four (in rare cases only three) successive New Moons. The Moon's penumbra sweeps the GPS satellite constellation in about 17 hours. On average, 9 satellites are affected by the shadow. It is worth mentioning that up to 20 eclipses on a single day could be observed since 1997. The mean duration of the partial eclipses is 45 minutes; durations of up to 2.5 hours may occur in exceptional cases. In the last seven years only three total eclipses of GPS satellites by the Moon occurred and lasted for up to 50 seconds.

Until January 13, 2002, our software did not take into account the Moon's penumbra for the computation of the radiation pressure acting on the satellites. The accuracy of the GPS satellite orbits, however, reached a level where this effect could no longer be neglected. Experiments showed that the orbit rms difference for satellites passing through partial eclipse may reach 10 cm, an unacceptable large value in view of the accuracy reached by the IGS orbits. Starting with doy 009/2002, all CODE products are based on the improved orbit model.

Kinematic and Dynamic Orbit Determination for Low Earth Satellites

The AIUB is participating in the IGS LEO Pilot Project. In the context of the Ph.D. thesis of Heike Bock a set of programs were developed allowing for an efficient and robust kinematic and reduced-dynamic orbit determination for LEOs based on GPS tracking data. The procedure is based on a precise point positioning generating positions from code observations and position differences from phase differences from one epoch to the next. The phase epoch-differences eliminate the phase ambiguities allowing for an efficient epochwise processing. Positions and position differences are combined to high precision positions in a second step.

GPS orbits are introduced as fixed while high rate clock corrections (30 sec) are generated by combining clock corrections derived from code with clock correction differences from one epoch to the next derived from phase, both based on observations of the IGS tracking network. With the POD procedure an orbit accuracy of about one decimeter can be reached. The limited accuracy is due to neglected correlations between epoch differences. The built-in data screening algorithms makes the procedure, however, very robust and allows for a quick check of the data quality for a LEO and the rapid generation of a good a priori orbit for a procedure providing an orbit accuracy in the centimeter range. The procedure was successfully tested using observations from CHAMP and SAC-C [Bock et al., 2000].

In a follow-up Ph.D. work by Adrian Jäggi the focus is put on the rigorous GPS data processing for spaceborne GPS receivers as well as on the improvement of dynamic orbit models and stochastic orbit parameterization.

First tests for a combined processing of GPS ground tracking and LEO receiver data using double differenced observations were performed to approach the question on the impact of a combined processing [Hugentobler et al., 2002b]. The fast motion of a LEO and the correspondingly large number of ambiguity parameters required (typically 800 per day) causes an increase of the computation effort for the inclusion of a single LEO which is much higher than for an additional ground station. Simulations show, as expected, an impact in particular on the geocenter coordinates.

Tests using tracking data from JASON-1 orbiting at a higher altitude than CHAMP are foreseen for 2003. In addition the inclusion of GPS tracking data originating from LEO satellites is intended for the generation of global ionosphere maps. CHAMP orbits at a sufficiently low altitude to be sensitive to about 2/3 of the impact of the ionosphere as seen by a ground station for tracking data acquired above the local horizon.

Outlook

In the near future, developments are foreseen in various fields eventually resulting in a further increased accuracy of the products generated by CODE for the IGS. Significant effort is expected in regard to the switch to absolute antenna phase patterns for the GPS satellite constellation and the IGS ground receivers. A thorough investigation on the impact of this step on orbits and terrestrial frame is intended.

Studies of GLONASS orbits as well as of the data availability within the IGLOS tracking network are underway. As soon as the global data from combined receivers is available rapidly enough, a fully combined processing of GPS and GLONASS orbits is foreseen. It is planned to start delivering "real" ultra rapid orbits based on hourly RINEX data. High-rate (30-second) GPS satellite clock corrections based on a phase consistent interpolation of our 5-minutes clocks may be expected as final as well as rapid products.

Further improvements in the LEO data processing will be made, including studies on combined processing of ground receiver and LEO tracking data. LEO observations are intended to be included for the generation of global ionosphere maps.

References

Bock, H., U. Hugentobler, T. A. Springer, G. Beutler (2002), Efficient Precise Orbit Determination of LEO Satellites using GPS, Adv. Space Res., 30(2), pp. 295-300.

Dach, R., T. Schildknecht, T. Springer, G. Dudle, L. Prost (2002), Continuous Time Transfer Using GPS Carrier Phase, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, 49(11), 1480-1490.

Hugentobler, U., T. Springer, S. Schaer, G. Beutler, H. Bock, R. Dach, D. Ineichen, L. Mervart, M. Rothacher, U. Wild, A. Wiget, E. Brockmann, G. Weber, H. Habrich, C. Boucher (2000), CODE IGS Analysis Center Technical Report 1999, in IGS 1999 Technical Reports, edited by K. Gowey et al., IGS Central Bureau, JPL, Pasadena.

Hugentobler, U., S. Schaer, T. Springer, G. Beutler, H. Bock, R. Dach, D. Ineichen, L. Mervart, M. Rothacher, U. Wild, A. Wiget, E. Brockmann, G. Weber, H. Habrich, C. Boucher (2002), CODE IGS Analysis Center Technical Report 2000, in IGS 2000 Technical Reports, edited by K. Gowey et al., IGS Central Bureau, JPL, Pasadena.

Hugentobler, U., S. Schaer, P. Fridez (Eds.) (2001), Bernese GPS Software, Version 4.2, Astronomical Institute, University of Berne.

Hugentobler, U., D. Ineichen, G. Beutler (2002a), GPS Satellites: Radiation Pressure, Attitude and Resonance, Adv. Space Res., 31(8), pp. 1917-1926.

Hugentobler, U., G. Beutler (2002b), Strategies for Precise Orbit Determination for Low Earth orbiters Using the GPS, to appear in Earth Gravity Field from Space – From Sensors to Earth Sciences, G. Beutler, M. Drinkwater, R. Rummel, R. von Steiger (Eds.), Space Science Reviews, Kluwer Academic Publishers.

Rothacher, M., G. Beutler, E. Brockmann, L. Mervart, R. Weber, U. Wild, A. Wiget, H. Seeger, S. Botton, C. Boucher (1995), Annual Report 1994 of the CODE Processing Center of the IGS, in IGS 1994 Annual Report, edited by J. F. Zumberge et al., pp. 139-162, IGS Central Bureau, JPL, Pasadena, CA.

Rothacher, M., G. Beutler, E. Brockmann, L. Mervart, S. Schaer, T. A. Springer, U. Wild, A. Wiget, H. Seeger, C. Boucher (1996), Annual Report 1995 of the CODE Processing Center of the IGS, in IGS 1995 Annual Report, edited by J. F. Zumberge et al., pp. 151-174, IGS Central Bureau, JPL, Pasadena, CA.

Rothacher, M., T. A. Springer, S. Schaer, G. Beutler, E. Brockmann, U. Wild, A. Wiget, C. Boucher, S. Botton, H. Seeger, (1997), Annual Report 1996 of the CODE Processing Center of the IGS, in IGS 1996 Annual Report, edited by J. F. Zumberge et al., pp. 201-219, IGS Central Bureau, JPL, Pasadena, CA.

Rothacher, M., T. A. Springer, S. Schaer, G. Beutler, D. Ineichen, U. Wild, A. Wiget, C. Boucher, S. Botton, H. Seeger, (1998), Annual Report 1997 of the CODE Processing Center of the IGS, in IGS 1997 Technical Reports, edited by I. Mueller et al., pp. 73-87, IGS Central Bureau, JPL, Pasadena, CA.

Rothacher, M., T. A. Springer, G. Beutler, R. Dach, U. Hugentobler, D. Ineichen, S. Schaer, U. Wild, A. Wiget, E. Brockmann, C. Boucher, E. Reinhart, H. Habrich (1999), Annual Report 1998 of the CODE Processing Center of the IGS, in IGS 1998 Technical Reports, edited by K. Gowey et al., pp. 61-73, IGS Central Bureau, JPL.

The ESA/ESOC IGS Analysis Centre Annual Report 2002

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Introduction

This Report gives an overview of the ESOC Analysis Centre activities and a presentation of the IGS activities at ESOC during the year 2002.

This year the ESOC AC activities have continued uninterrupted and have consolidated with the timely delivery of all the products part of the IGS and participation in several of the IGS Working Groups and Pilot Projects. There have been no major changes to the routine processing during 2002, only some small changes to the processing strategies as outlined and described below.

Currently ESOC's GPS-TDAF (Tracking and data Analysis Facility) handles automatically the ESA ground receiver network, the IGS network data retrieval and storage and all of the routine daily and weekly data processing of the different IGS products. The system is capable of performing autonomous operations for up to five days. Information is available on the website: http://nng.esoc.esa.de/gps/gps.html

Changes and Activities in 2002

These have been the changes to IGS activities at ESOC during 2002:

Jan 2002 *GLONASS processing*: Changed terrestrial reference frame to ITRF2000, based on the IGS2000.SNX file generated by the IGS for the core stations, together with the use of the GPS fixed orbits which had been switched to ITRF2000 a few months back.

May 2002 *Ultra-Rapid processing*: Switched processing to use only RINEX data for 48 hours, no fixed positions from previous sp3 files were further used.

Nov 2002 *IGS processing*: switched all orbit submissions to the SP3c format to comply with the new IGS standard.

Dec 2002 *IGS processing*: Changed the processing during satellite eclipses from excluding the data during eclipse periods and introducing a manoeuvre at the eclipse exit to <u>leaving all the data in</u> and <u>not</u> including a manoeuvre at the eclipse exit.

Routine Activities

ESOC participates in the IGS as an Analysis Centre providing the following routine products either to the Analysis Centre coordinator or to the IGS Global Data Centre CDDIS:

- Final GPS Orbits plus clock biases
- Final GLONASS Orbits plus clock biases
- Rapid GPS Orbits plus clock biases
- Twice Daily Ultra-Rapid GPS Orbits plus clock biases
- Daily Rapid EOP file
- Daily Ultra-Rapid EOP file
- Weekly final EOP file
- Weekly final processing summaries
- Weekly free network solution in SINEX format
- Daily final tropospheric files
- Daily final ionospheric files in IONEX format
- Weekly combined IGS ionosphere IONEX files; ESOC is the IGS Ionosphere Associate Combination Center (IACC)
- Daily rapid RINEX clock files with 5 minutes sampling
- Daily final RINEX clock files with 5 minutes sampling

Processing Method

The ESOC GNSS precise orbit determination processes for all the cases are based on a batch least squares estimation solution of RINEX IGS station data using various numbers and distributions of stations based on availability, past performance and processing time available. The average numbers of stations used for each of the processes at ESOC are as follows:

- Final GPS POD: 52 stations
- Final GLONASS POD: 27 to 30 stations
- Rapid GPS POD: 40 to 45 stations
- Ultra-Rapid GPS POD: 30 to 35 stations

The estimation method for all the POD activities uses an in-house estimation program, BAHN, currently in version 7 and which can handle most types of data for satellite POD activities (ranges, range rates, SLR, Doris, Prare, altimetry, GNSS observables in undifferenced, and double- differenced modes). The quantities estimated by the program are variable depending on the focus of the run. For the IGS submissions the quantities estimated are:

- The station coordinates,
- The satellite state vectors,
- The solar radiation pressure extended force model parameters,
- Cycle-per-revolution empirical accelerations,
- The undifferenced carrier phase ambiguities for the ionospheric-free linear combination,
- The GPS-GLONASS receiver biases (for the GLONASS processing only),
- The Earth rotation parameters: *x* and *y* pole position and rates and Length of Day,

- The tropospheric zenith delay for every station every 2 hours,
- Station and satellite clock biases, estimated as time-dependent parameters (one value for every observation epoch).

More information on our routine GPS and GLONASS processing, processing description, model usage, result plots, etc can be found at:

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http://nng.esoc.esa.de/
http://igscb.jpl.nasa.gov/igscb/center/analysis/esa.acn
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Ultra-Rapid Processing

The processing has changed minimally by removing the sp3 orbits as pseudo-observations. In the past the Ultra-Rapid has used a number of days of fixed orbits as pseudo-observations before the RINEX data arc. This practice would stabilise the orbit solutions when there were few stations available with current data. At this time the hourly data availability is such that for the Ultra-rapid processing there is always more than enough RINEX data to produce very good estimated orbits and thus to predict the orbits into the future with a high degree of accuracy.

Eclipse Data Processing

During satellite eclipses the ESA/ESOC processing used to exclude the data and estimate a manoeuvre at the eclipse exit. The exclusion of the data over the eclipse period was done to simplify the estimator calculations in fitting the data. The eclipse manoeuvre was included to try and absorb some of the unmodelled behaviour when the satellites reacquire the sun. These two strategies made the ESOC solution both incomplete and discontinuous. Incomplete since we cannot calculate clock biases when no data is processed so none where included in the clock solution for around one hour (Figure 1). The orbit solution was also subject to discontinuities, which appeared as large peak differences when comparing to other orbit solutions.

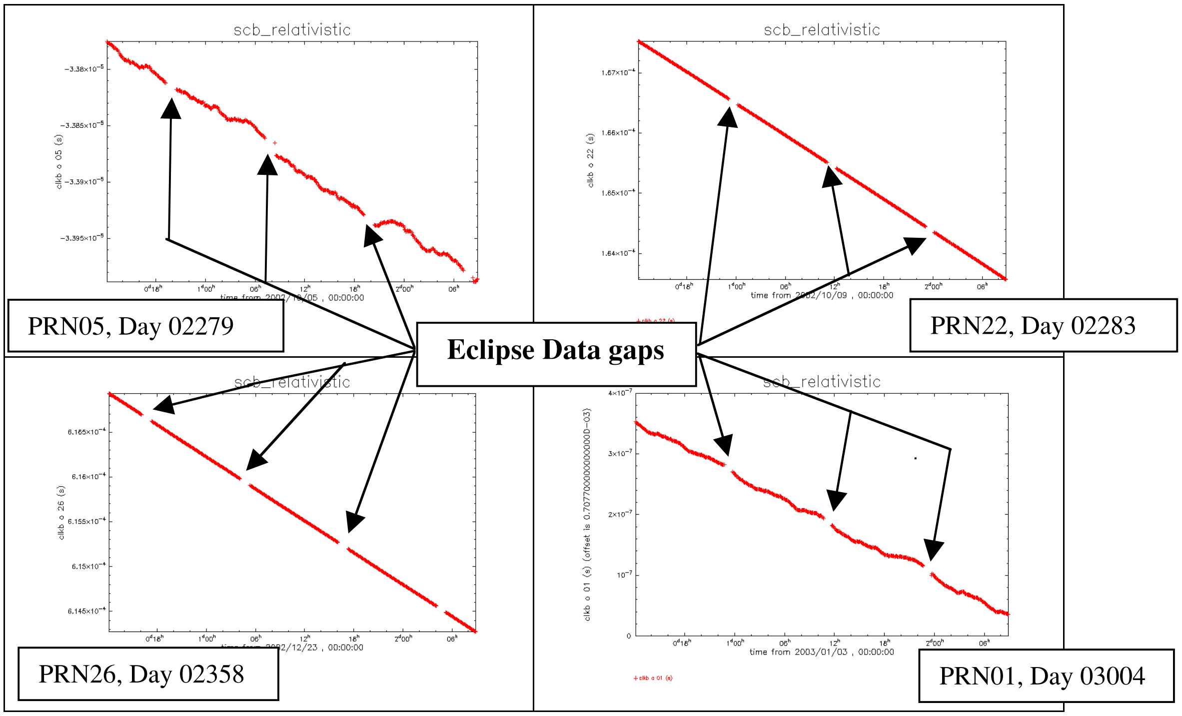

Figure 1: Clock bias values showing data gaps due to eclipse data exclusions.

Towards the end of 2002 and early 2003 the new strategy of including all the data all the time and NOT including eclipse manoeuvres was tested, validated and implemented.

GLONASS Processing

GLONASS processing at ESOC has continued during 2002 as it had done during 2001.

A change implemented during 2002 in the GLONASS processing has been to switch to the ITRF2000 as had been done for all the other IGS operations a few months earlier.

During 2002 the processing continued using the complete 9-parameter Solar Radiation Pressure (SRP) model for the GLONASS satellites; this had been a change for testing purposes from the 5-parameter model used up to 2001 (Romero et al., 2002). The processing was stopped after the summer of 2002 due to manpower problems and was later resumed without loss during 2003.

Figure 2 shows the weighted orbit comparisons between the solutions from CODE, BKG, MCC (Mission Control Centre, Moscow) and ESOC versus the GLONASS combination up to the time of writing. CODE orbit contributions ceased during 2000. The ESOC weighted comparison to the combination has stabilised at an error level of around 10 to 15 cm.

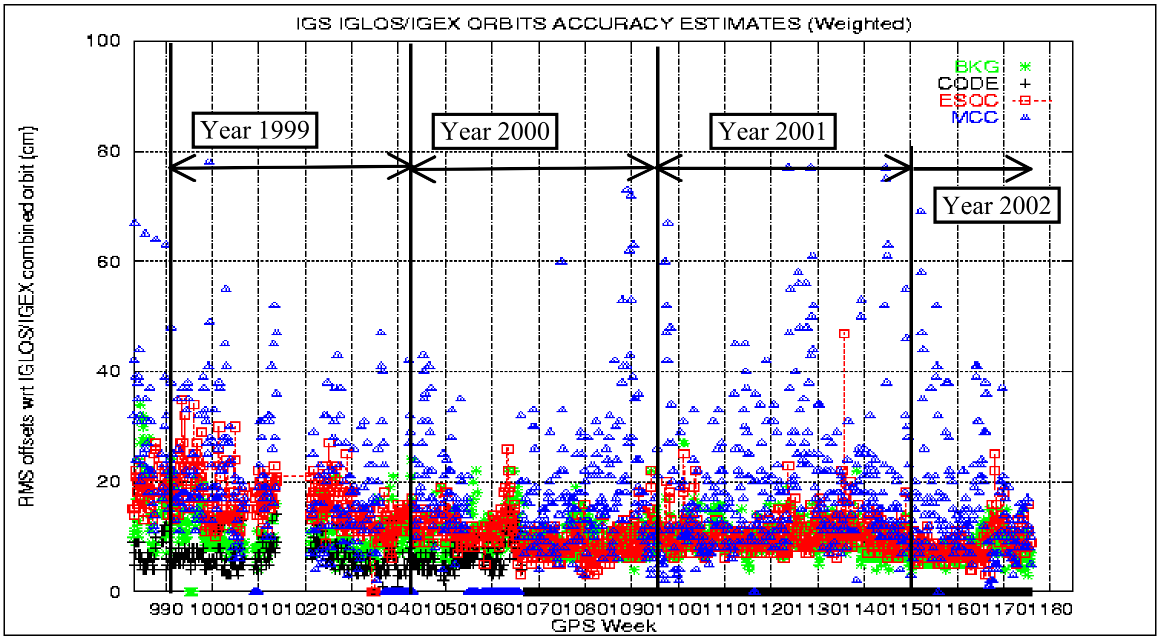

Figure 2: IGLOS/IGEX AC weighted orbit comparisons versus the combination.

Ionosphere Processing

Routine processing of ionospheric Total Electron Content (TEC) maps and satellite/receiver differential code biases (DCBs) continued during 2002.

The ionosphere processing in final mode continued with the rapid orbits. The number of ground stations used was increased to about 180. The daily routine ionosphere processing in 2002 was as follows:

1) A nighttime TEC data fit is made to obtain a set of reference DCB values for that day. The nighttime TEC itself is absorbed in this fit with low degree and order spherical harmonic. In the other fits 2) - 4) these DCBs are then introduced as constraints.
2) A Chapman profile model is fitted to the TEC data of that day, where the layer of maximum electron density N0 and its height h0 are estimated as surface functions of geomagnetic latitude and local time. h0 is restricted to have values within a predefined range only, currently 350 km =< h0 =< 450 km or 400 km =< h0 =< 450 km. This run is the official ESOC contribution to the IGS Ionosphere Working Group to be part of the combination.
3) A Chapman profile model is fitted to the TEC data, where h0 is estimated as a global constant. This run is made for test reasons and theoretical studies.
4) A Chapman profile model is fitted to the TEC data, where h0 is kept fixed as global constant at a height of 450 km, and the influence of the solar zenith angle is not accounted for. This run is made for test reasons and theoretical studies.

Beyond the routine processing of our own TEC maps, ESOC has also chaired the IGS Ionosphere Working Group (Iono_WG) from 1998 to 2002, before transfer of the chairmanship to Dr. M. Hernandez Parajes. As part of these activities, ESOC was responsible for the weekly comparisons of Iono_WG products as IGS Ionosphere Associate Combination Centre.

LEO Activities

The activities of the ESOC Analysis Centre for the IGS LEO Pilot Project over 2002 have concentrated on implementing LEO processing capability in the available POD systems, using the data from CHAMP. Because ESOC also coordinates the Pilot Project itself, please refer to the Chapters on the LEO Pilot Project for more information, or consult the igsleo website at nng.esoc.esa.de/igsleo.html

Future Activities

ESOC Analysis Centre will remain active during the next year; continue the regular contributions to the IGS orbit and clock products, troposphere, ionosphere, station network solutions and EOPs. In the area of LEO POD significant efforts are underway to completely redesign the LEO calculations. All the processes will be streamlined further and the GPS-TDAF will be improved for more efficient and independent operations, paying particular attention to the GLONASS processing to make it more efficient and to reconsider the processing of GPS and GLONASS orbits together.

References

Feltens, J., 2001 IGS Activities in the Area of the Ionosphere, *IGS 2001 Technical Report*, 2002.

Boomkamp, H., IGS LEO Pilot Project, *IGS 2001 Technical Report*, 2002.

Romero, I., Garcia, C., Kahle, R., Dow, J., Martin-Mur, T., Precise Orbits Determination of GLONASS Satellites at the European Space Agency, *Advances in Space Research*, Vol. 30, No. 2, pp. 281-287, 2002.

Dow, J.M., Feltens, J., Garcia, C., Romero, I., The ESA/ESOC IGS Analysis Centre, Annual Report 2000, *International GPS Service 2000 Technical Report*, JPL Publication 02-012, IGS Central Bureau eds., Pasadena CA, Jet Propulsion Laboratory, 2001.

Dow, J.M., Feltens, J., Garcia, C., Romero, I. Kahle R., The ESOC IGS Analysis Centre, *1999 IGS Technical Report*, IGS Central Bureau eds., Pasadena, CA, Jet Propulsion Laboratory, 2000.

Dow, J.M., Feltens, J., Garcia, C., Romero, I., The ESOC IGS Analysis Centre, *1998 IGS Technical Report*, R. Neilan, A. Moore, K. Gowey, eds., Pasadena CA, Jet Propulsion Laboratory, 1999.

Martin-Mur T., Dow, J.M., Feltens, J., Garcia, Bernedo P., The ESOC IGS Analysis Centre, *1997 IGS Technical Report*, I. Mueller, R. Neilan, K. Gowey, eds., Pasadena CA, Jet Propulsion Laboratory, 1998.

GFZ Analysis Center of IGS - Annual Report for 2002

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Summary

The changes introduced during 2002 and early 2003 are summarized in Table 1. They were focused on the improvement in the product quality and in the robustness of the analysis strategy.

Table 1. Changes in the analysis strategy

Week	Date	Description
1168	2002-05-30	Introduction of new single site data cleaning strategy
1172	2002-06-23	Use of UT1 instead of UT1R
1174	2002-07-07	Loosing the a-priori orbit sigma during its eliminations from the SNX-file (old: ~0.1 m resp. m/d new: ~ 1 m resp. m/d)
1179	2002-08-11	Extension of used IGS network to 150 stations via cluster strategy
1184	2002-09-19	Rapid products with concatenation of two days
1189	2002-10-20	Introduction of new sp3c-format
1202	2003-01-19	Introduction of ambiguity fixing into Rapid analysis
1214	2003-04-13	Enlargement of network (~50 station) for Rapid analysis

Data Cleaning

The data are cleaned iteratively by scanning the post-fit residuals from the network solution. The number of iterations needed for obtaining a clean data set depends heavily on the quality of the GPS data the procedure start with, as large cycle slips will bias the residuals in the network solution. To speed up the clean procedure a single station data clean strategy is implemented as described by Blewitt (1990) to flag and repair as many cycle slips as possible before starting the network analysis. It is well known that the method fails when the pseudo range observations are not good enough. This is unfortunately true for a number of stations as our network is extended to more than 150 sites. Rapid ionosphere changes can also lead to erroneously removal of good observations. To overcome those problems, we reduce the geometric effect from the ionosphere-free phase observation and fit the difference between satellites piece by piece for data without SA clock dithering. The rms and the residuals of the fitted observations give an additional quality index along with wide-lane and ionosphere change for making a decision on the observation quality. The new software has been introduced into our routine data processing since May 30, 2003. For non-SA data the remaining cycle slips detected in the later iterative procedure are in average no more than 4% of all the cycle slips over all the 150 stations and their values are rarely larger than 1 cycle in L1 wavelength. This is especially effective for our ultra-rapid and rapid processing where precise satellite clock information is not yet available for cleaning the data station by station using the precise point positioning technique as it is done for the Final analysis.

Rapid Products

Whereas the quality of the GFZ Final orbits has reached a level of 2 cm during 2001 the quality of the GFZ Rapid products with 5 to 6 cm has not improved significantly throughout the last years. Therefore efforts were made to utilize elements from the Final analysis also here. One orbit-stabilizing factor in the Final analysis is that three-day orbits are used to get the best orbit solution for the middle day, avoiding orbit problems at the day boundaries. For the Rapid orbit two days were concatenated and the second day is taken as the product. However, the most visible progress in the orbit quality was gained by the introduction of the ambiguity fixing (Fig. 1). This was feasible because the robustness of the ambiguity fixing was improved recently so that it could be introduced into the automated analysis for the Rapid products.

Additionally, the selected station set was enlarged from ~35 to ~50 so that the realization of the reference frame will be less effected by the available station data.

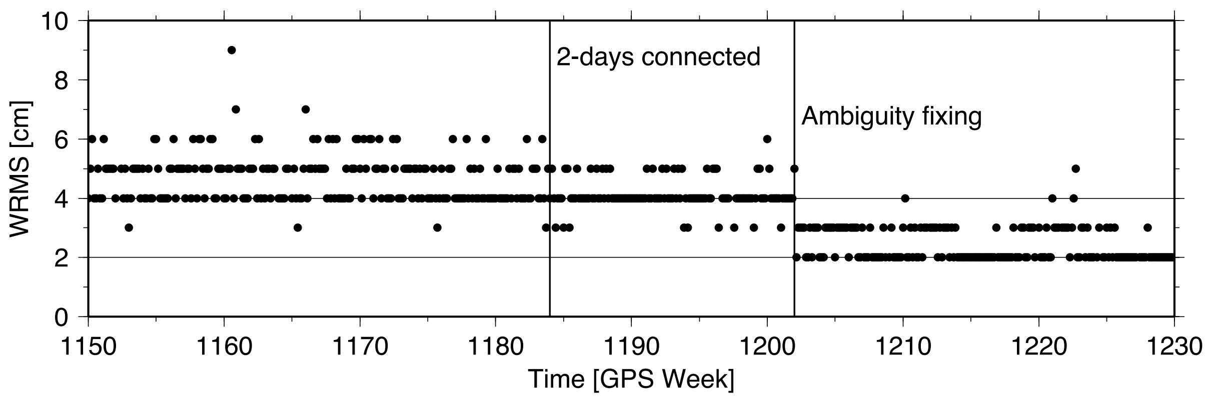

Fig. 1. Quality of the various GFZ satellite orbit products taken from the official combinations reports

Final Products

To extend our IGS final network, we process data in a cluster mode for saving computer time and overcoming computer memory limitation. We divided all the stations to be processed into several clusters. Each cluster includes no more than 80 stations. That is for the moment the most economic station number for EPOS running on our mainframe computer. A set of common stations is necessary to be included in each cluster as the reference network for connecting the clusters. Each cluster is processed independently similar to usual GFZ final data processing strategy by calling standard EPOS procedures. The cluster (named 'IGS base') for generating IGS orbit and clock is processed at first, so that its products can be used for cleaning the data of the other clusters by scanning precise point positioning residuals. Each cluster provides a normal equation with station coordinate, orbit and earth rotation parameters. Daily normal equations of several clusters are combined together to generate a daily normal equation with all station coordinate and unique orbit and earth rotation parameters for further processing. With this strategy we enlarged our IGS network to about 150 stations and integrated TIGA stations into our routine data processing effectively.

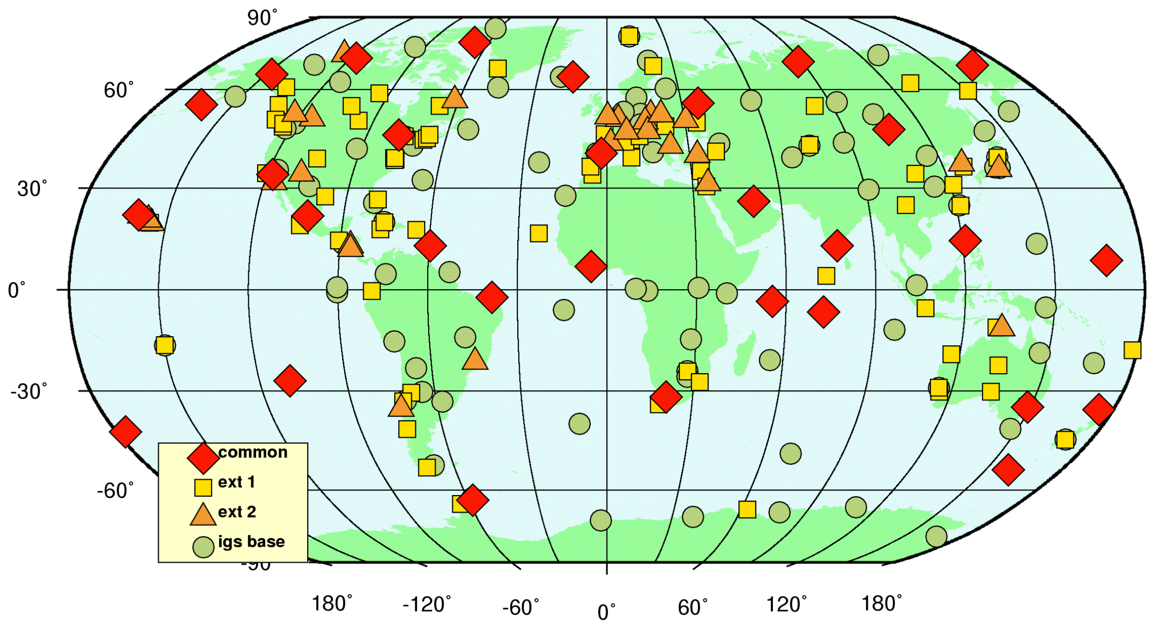

Fig. 2. IGS station distribution and cluster definition, common stations are included in all clusters

There are 4 clusters now in our routine data processing, the 'IGS base' cluster, one TIGA cluster and two IGS extended clusters (named 'ext1', 'ext2'). Figure 2 shows the station distribution of the IGS clusters (the TIGA cluster is shown in Fig.4). To produce a daily solution for IGS or TIGA by normal equation combination, the corresponding cluster solutions are chosen. To generate the IGS solution the clusters 'IGS base', 'ext1' and 'ext2' are combined and to get the TIGA solution the clusters 'IGS base', 'ext1' and TIGA are used. The common stations are included in all clusters.

We combine 3 daily solutions with appropriate orbit constraint at the day boundaries and output a 3-day normal equation for generating weekly products. The final IGS weekly SINEX solution is obtained by combing seven 3-day normal equations. Fixing the station coordinates and earth rotation parameters to the values in the weekly solution, we repeat the 3-day combination to get the consistent final orbit for each day. With station coordinate, ERP and orbit fixed to the value we got in the last step, we solve for clock again from observation to get the clock estimates submitted to IGS. For the moment, only the 'IGS base' cluster is used for final clock estimation.

The solution quality obtained by the new cluster strategy can be seen in Figure 3. The difference to the weekly combined IGS solution has slightly improved by about 1 mm for all components and is approaching ±1 mm and ±4 mm in the horizontal and vertical components respectively.

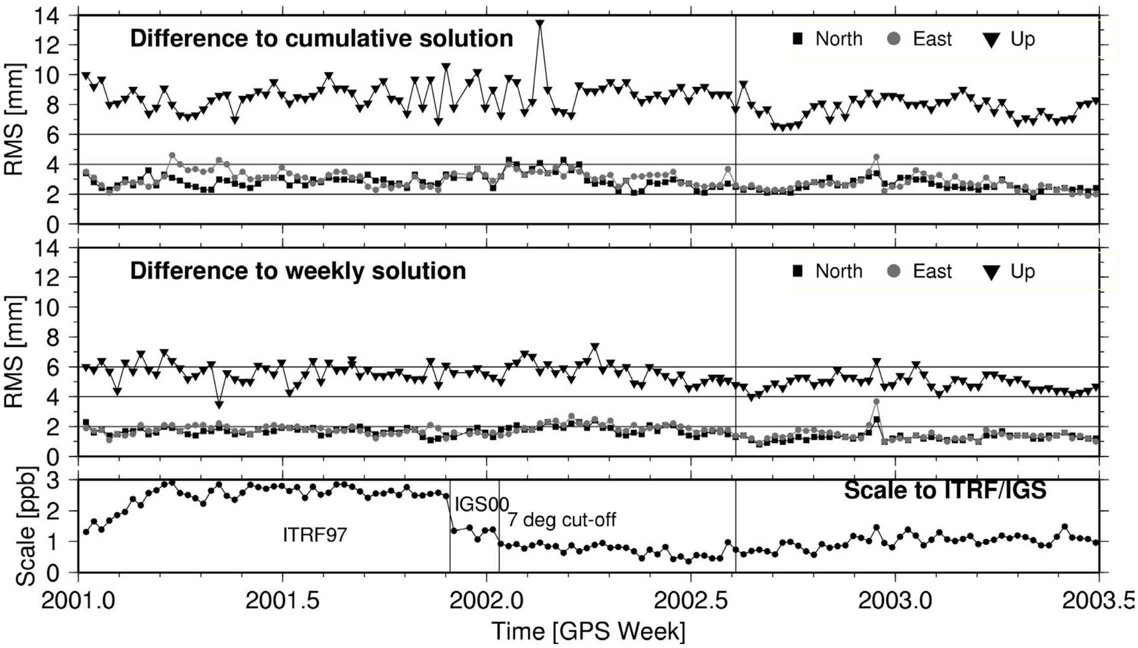

Fig. 3. Quality of GFZ station coordinate solutions extracted from the IGS SINEX combination reports. Since August 2002 the cluster solution strategy was introduced.

TIGA Data Processing

For the TIGA project, an additional cluster, the TIGA cluster, is defined and processed following the same cluster strategy mentioned above. There are about 80 stations for the moment and Figure 4 shows its distribution. The final TIGA solution comes from combining the TIGA cluster and two IGS clusters as already mentioned. To keep the data set as complete as possible, GPS raw data retrieval is carried out by scanning all TIGA related data centers before starting the job for a day.

At the moment, GFZ is operating three TIGA processing chains. The first chain, with 1-week latency and in parallel with the GFZ/IGS data processing, starts from 2002.0. The second chain, with 460-day latency starting from processing GPS week 1112, is dedicated to TIGA as a permanent routine service. The weekly SINEX solutions are available at ftp://ftp.gfz-potsdam.de/pub/transfer/kg_igs/igstiga/solutions/. The last chain, the backward processing planned to trace back to year 1994, is carried out with a 4-week time step to get a quick look of the time series. This chain started from processing the data of year 2001 and year 1997 is nearly finished now. For consistency, the IGS clusters are reprocessed with the state-of-the-art data processing technique.

To validate the results, the solutions are compared with official IGS solutions and other TIGA AC solutions routinely. Figure 5 gives the rms of the station coordinate differences between the official IGS and the GFZ TIGA weekly solutions (for about 200 weeks) and the number of common stations compared. From Figure 5, the coordinate consistency is ±1 to ±4 mm, and ±5 to ±10 mm in horizontal and vertical directions respectively.

Daily solutions are generated to obtain time series for estimating vertical velocities of TIGA stations. To improve the accuracy of velocity estimation, we are considering applying seasonal variation correction caused by mass loading redistribution derived from geophysical data.

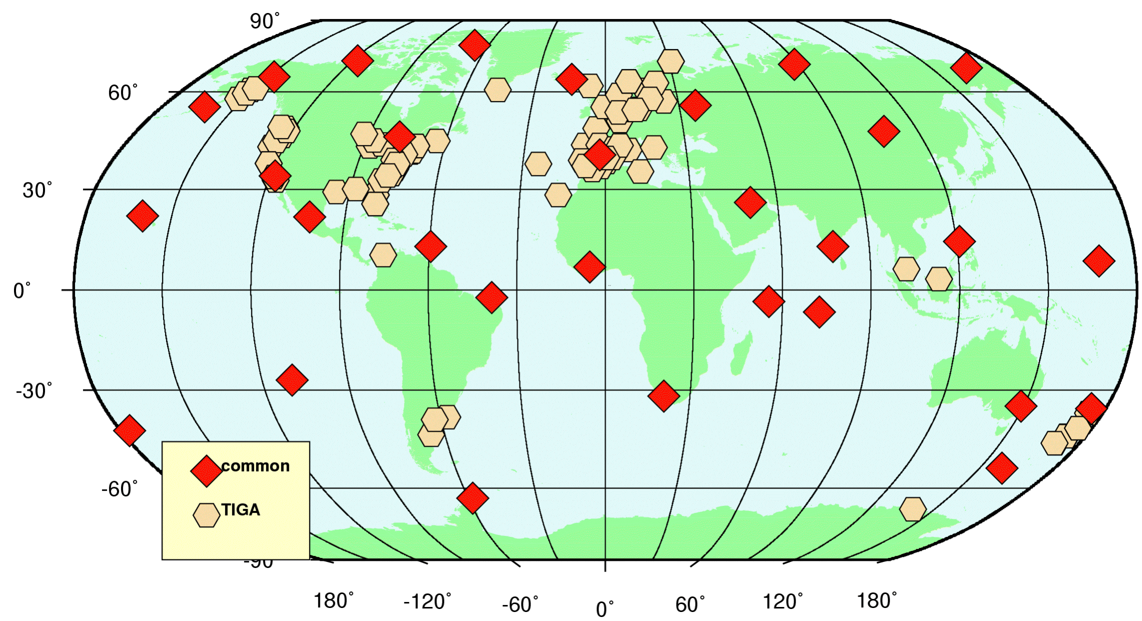

Fig. 4. Geographic distribution of TIGA stations

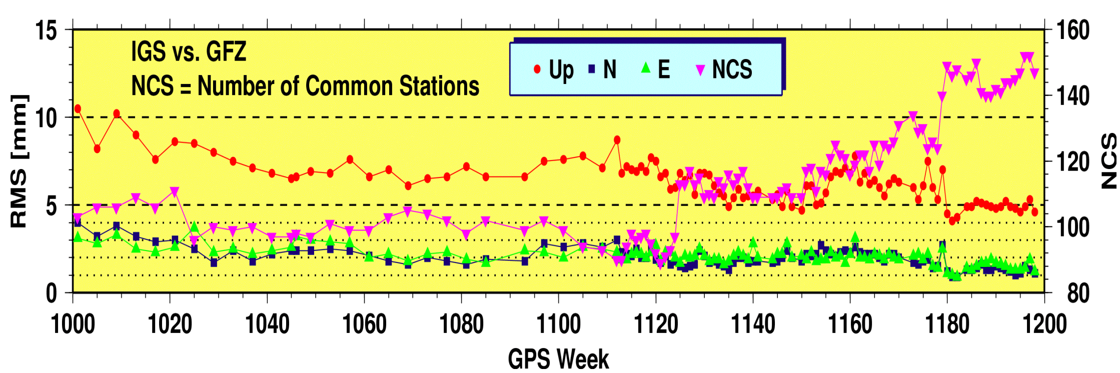

Fig. 5. Comparison between the GFZ/TIGA and the official IGS weekly solutions

References

Gendt, G (2002): GFZ Analysis Center of IGS - Annual Report for 2001, in "IGS 2001 Technical Reports", in press

Blewitt G.(1990) An automatic editing algorithm for GPS data, Geophysical Research Letter, Vol. 17 no 3 199-202

JPL IGS Analysis Center Report, 2001-2003

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Summary

Three GPS orbit and clock products are currently provided by JPL for consideration by the IGS. Each differs in its latency and quality, with later results being more accurate. Results are typically available in both IGS and GIPSY formats via anonymous ftp. Current performance based on comparisons with the IGS final products is summarized in Table 1. Orbit performance was determined by computing the 3D RMS difference between each JPL product and the IGS final orbits based on 15 minute estimates from the sp3 files. Clock performance was computed as the RMS difference after subtracting a linear trend based on 15 minute estimates from the sp3 files.

Table 1: Product Quality

Products	Delivery	Orbit	Clock
Final-Flinn	Weekly	5.2 cm	5.8 cm
Rapid	Daily	7.4 cm	6.2 cm
Real-Time	Every 15 minutes	17.7 cm	14.6 cm

Recent Improvements

Strategy improvements are listed in Table 2. Preparation for a new GIPSY release resulted in 80 station tracking capability, use of RCS (revision control system) for configuration control, an upgrade to Red Hat 9 (RH9), use of the gcc 3.2.2 compiler, and a new version of qfront. These improvements have led to our longest period of 4-cm orbit overlaps ever as shown in Figure 1.

Table 2: Strategy Updates

Action	Date
new qfront which calls clockprep, PvsCA, and teqc	09/14/03
RH9, RCS, gcc 3.2.2	08/10/03
Increase from 60 to 80 sites	04/20/03
Create sp3c files	02/16/03
Extra digit in sp3 files	10/20/02
Use USN1 and AMC2 reference clocks without alignment	09/23/02

Table 2: Strategy Updates (cont'd)

Action	Date
Ocean loading upgrade - FES02 [1]	07/23/02
Extra digit in jpl.txt files	07/14/02
New hi-rate clock process	06/17/02
Extra digit in eci files	05/27/02
Increase Flinn tracking network from 42 to 60 sites	04/07/02
Ocean loading upgrade - FES99 [2]	03/03/02
New ITRF2000 nominal coordinate database	01/09/02
Expand Flinn high rate clocks from 27 to 30 hours	01/20/02
ITRF2000 / IGS00 reference frame	12/02/01
IERS2000 tidal models	08/29/01
Tighten edit window to 2 m and 2 cm for range and phase	05/06/01

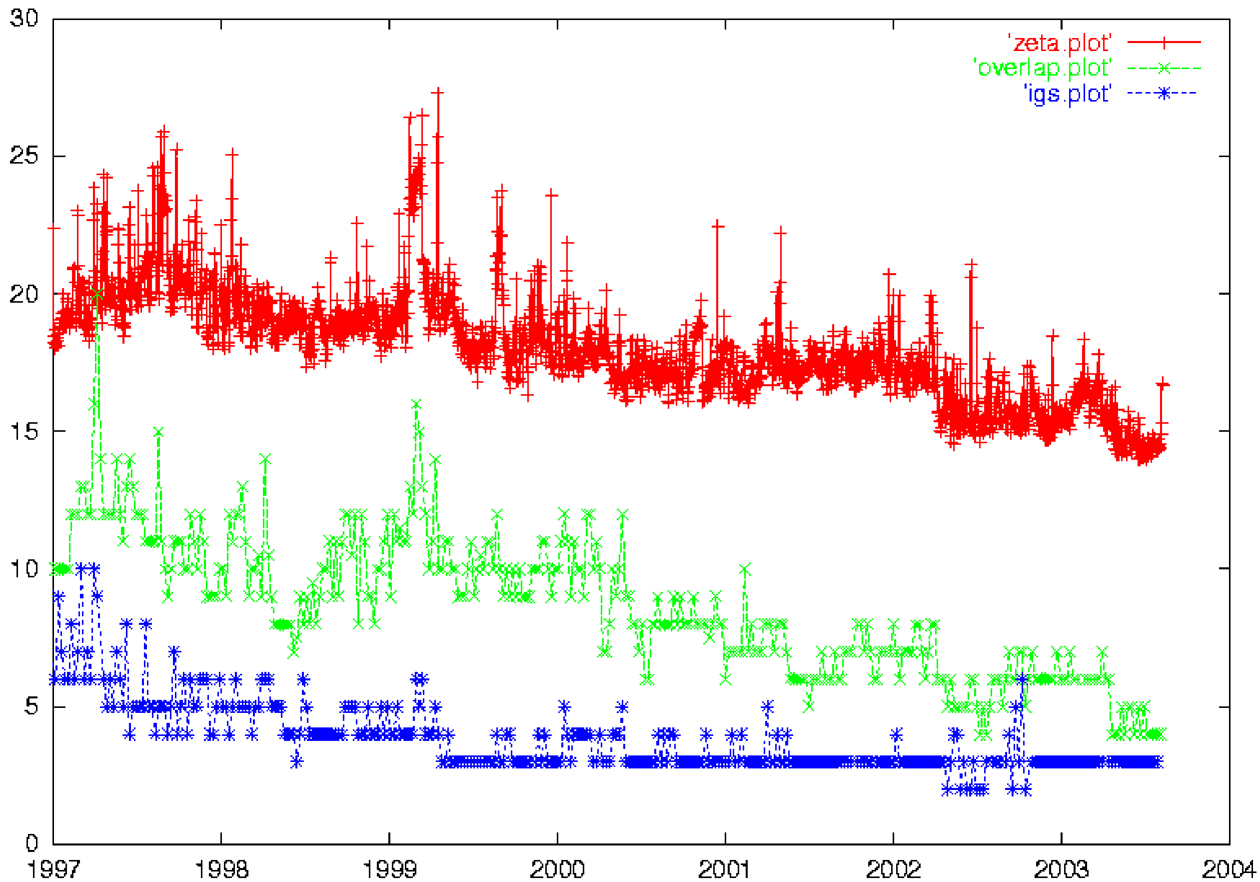

Figure1: Performance Metrics

Figure 1 shows the three main metrics used for monitoring performance; (1) zeta in hundreds of km is representative of the site distribution density, (2) three-dimensional orbit overlaps from day to day in cm, and (3) one-dimensional IGS orbit comparisons in cm. All metrics have improved over time. There is a significant correlation between tracking site distribution and orbit quality.

Flinn orbits and clocks are used in the analysis of data from NASA (and other) flight projects, including the ocean altimetry mission JASON and the gravity mission GRACE. Flinn orbits and clocks are also used to compute point positions for hundreds of terrestrial GPS sites around the world. Figure 2 shows the growth of point positioning over time from roughly 20 sites per day in 1991 to more than 600 sites per day in 2003. JPL currently computes time series for the IGS, SCIGN, CORS, NBAR, and PANGA networks. These time series provide insight into global plate motion, post-glacial rebound, seasonal loading, co- and post-seismic deformation due to earthquakes, and interseismic strain accumulation related to seismic hazards in active boundary zones such as Southern California. The current global velocity field is illustrated in Figure 3.

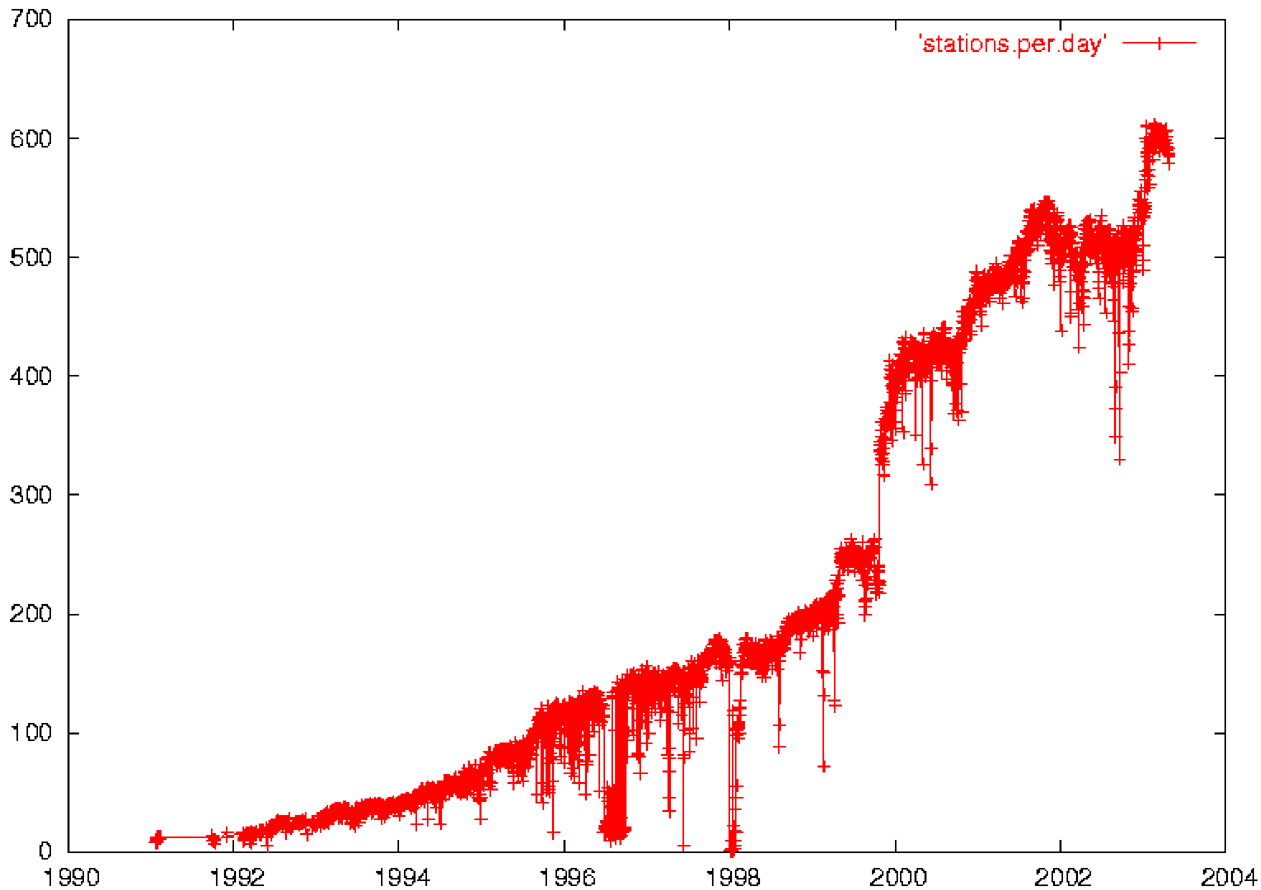

Figure 2: Point Positions Per Day

Products

Various products are made available via ftp and http as listed in Table 3. There are three major orbit and clock products. Orbit estimates can be found in the IGS format .sp3 and .yaw files as well as in the GIPSY format .eci, .yaw or .yaw_rates, and .shad or .shadow_events files. Clock information can be found in the IGS format .clk and .sp3 files and in the GIPSY format .gps_clock and .tdpc files. Tropospheric estimates can be found in the IGS format .tro files.

Earth orientation information is contained in the IGS format .erp files and the GIPSY format TPNML and tpeo.nml files. Post-processing based on Flinn products is used to derive our final time series of polar motion, length of day, geocenter, scale, and site position [3].

Table 3: Product Files

Real-Time Products

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ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/15min
jpl12322.clk.Z
jpl12322.sp3.Z
jpl12322.tro.Z
jpl12322.yaw.Z
2003-08-19.TPNML.Z
2003-08-19.eci.Z
2003-08-19.gps_clocks.Z
2003-08-19.shadow_events.Z
2003-08-19.yaw_rates.Z

Rapid Products

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ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/RapidService/orbits
jpl12321.clk.Z
jpl12321.erp
jpl12321.sp3.Z
jpl12321.sp3c.Z
jpl12321_pred.sp3.Z
jpl12321_pred_pc.sp3.Z
2003-08-18.DONE
2003-08-18.PREDICT
2003-08-18.TPNML.Z
2003-08-18.TPNML.predict.Z
2003-08-18.eci.Z
2003-08-18.eci.predict.Z
2003-08-18.eci.predict.edited.Z
2003-08-18.frame
2003-08-18.gps_clocks.Z
2003-08-18.shadow_events.Z
2003-08-18.yaw_rates.Z

Table 3: Product Files (cont'd)

Final-Flinn Products

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ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/jpligsac/1230
jpl12300.clk.Z
jpl12300.sp3.Z
jpl12300.sp3c.Z
jpl12300.tro.Z
jpl12300.yaw.Z
jpl12307.erp.Z
jpl12307.snx.Z
jpl12307.sum.Z

ftp://sideshow.jpl.nasa.gov/pub/gipsy_products/2003/orbits
2003-08-09.eci.Z
2003-08-09_nf.eci.Z
2003-08-09.tdpc.Z
2003-08-09_nf.tdpc.Z
2003-08-09tpeo.nml.Z
2003-08-09tpeo_nf.nml.Z
2003-08-09.frame
2003-08-09.shad.Z

Time Series

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http://sideshow.jpl.nasa.gov/mbh/series.html - web page with links to tables, plots, and ftp areas

ftp://sideshow.jpl.nasa.gov/pub/mbh/point - IGS, SCIGN, CORS, NBAR, and PANGA
ftp://sideshow.jpl.nasa.gov/pub/mbh/filtered - ambiguity resolved, regionally filtered SCIGN
ftp://sideshow.jpl.nasa.gov/pub/mbh/stacov - ambiguity resolved SCIGN stacov files

Time series are given as three ASCII files SITE.lat, SITE.lon, and SITE.rad containing the time in years, estimate in cm, sigma in cm, site, component, and date. Stacov files contain X, Y, Z estimates in m, sigmas in m, and correlations.

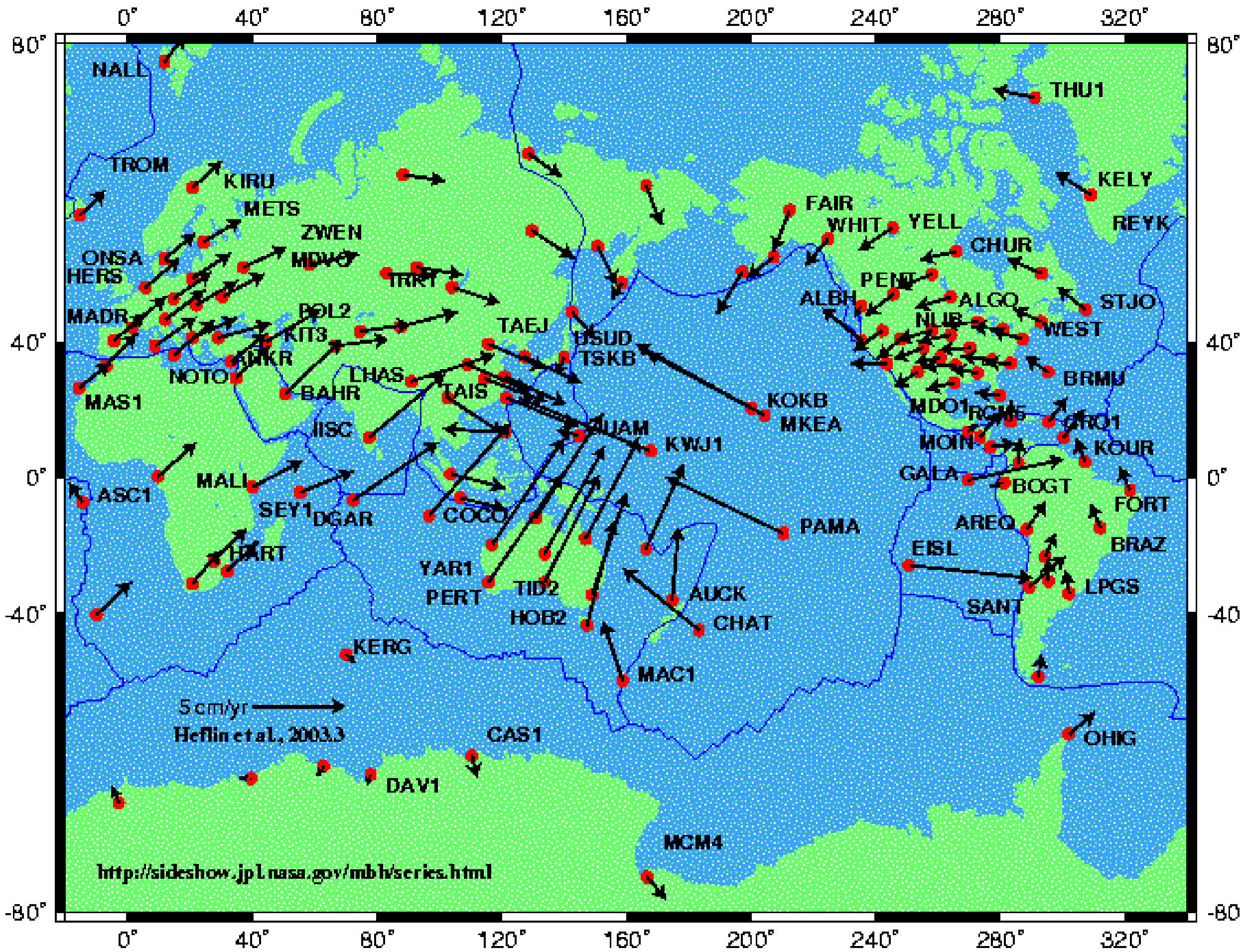

Figure 3: Global GPS Velocity Field

Acknowledgment

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References

FES2002--A new version of the FES tidal solution series
Le Provost, C., F. Lyard, F. Lefevre and L. Roblou, *Abstract Volume, Jason-1 Science Working Team Meeting,* Biarritz, France, 2002.

A global tide finite element solution assimilating tide gauge and altimetric information, FES99
Lefevre, F., F. Lyard, C. Le Provost, and E. J. O. Schrama, *Journal of atmospheric and oceanic technology,* 19 (9), 1345-1356, 2002.

Comparison of a GPS-defined global reference frame with ITRF2000
Heflin, M., D. Argus, D. Jefferson, F. Webb, and J. Zumberge, *GPS Solutions,* Volume 6, No. 1-2, pp. 72, 2002.

GPS Orbit and Earth Orientation Parameter Production at NOAA for 2002

National Geodetic Survey
National Ocean Service
National Oceanic and Atmospheric Administration
Silver Spring, MD USA

Spatial References System Division
William G. Kass, Robert L. Dulaney III, Robert B. Leonard Jr.

Geosciences Research Division
Gerald L. Mader, William H. Dillinger, Jim Ray, Stephen Hilla

Introduction

The GPS orbit and Earth Orientation Parameter (EOP) solutions submitted to the IGS by the National Geodetic Survey (NGS) are a joint effort between the Spacial Reference System Division (SRSD) and the Geosciences Research Division (GRD). The GRD is responsible for the development of the processing software and techniques while the SRSD is responsible for the operational production. SRSD and GRD are both activities within NGS which is part of the National Ocean Service (NOS) of NOAA (National Oceanic and Atmospheric Administration). A detailed description of the techniques and models can be found in the Analysis Strategy Summary located at http://www.ngs.noaa.gov/GPS/noaa_acn.html .

Station Network

Figure 1 shows a typical set of baselines used for forming double differences and for connecting the stations in the tracking network. NGS used an average of 60-70 tracking stations which are submitted to the IGS for the GPS orbit and EOP production. This list is not static but changes occasionally to include new stations that offer a more favorable geometry or new geographical coverage. If new stations are added in a region where the tracking network density is greater or redundant, other stations are dropped thereby keeping the total number at less than or equal to 70. This number appears adequate to provide overall tracking network stability that is relatively insensitive to daily tracking site drop outs within the global network. Included tracking sites are listed in the weekly summary available at the Crustal Dynamics Data Information System (CDDIS) at ftp://cddisa.gsfc.nasa.gov .

Software Changes

A few minor software enhancements were made during 2002. PAGES/GPSCOM, both developed at NGS, remain the software tools used for orbit production. During 2002, additional options were added to PAGES to allow for weighting by satellite and elevation angle; these options continue to be tested. Changes made to the preprocessing programs resulted in improved cycle slip fixing and the ability to reject data sets where the receiver had a runaway channel. Since the beginning of 2000, NGS has modelled deformations driven by ocean tidal loading using the Schwiderski model (Schwiderski 1983). On December 2, 2001 NGS, along with the other Analysis Centers, switched from the IGS97 reference frame to the IGS realization of the ITRF2000 reference frame (IGS00). Beginning with GPS week 1194 (November 24,2002) NGS began sending its final product to the IGS in the new SP3-c format.

Product Evaluation

Figure 2 shows the daily RMS differences between the NGS and IGS final ephemerides for the year 2002 after a "best fit" seven parameter transformation has been applied to the NGS ephemerides. It also shows the values of the associated seven parameter transformations. The subplots are: (left column, top to bottom) RMS of fit in meters, X translation in meters, Y translation in meters, Z translation in meters; (right column, top to bottom) scale in parts per billion, X rotation in milliarcseconds, Y rotation in milliarcseconds, and Z rotation in milliarcseconds. All available GPS satellites were included and universally the outlying points seen in the RMS subplot are caused by a single poorly estimated satellite within a day. Figure 3 shows the daily RMS differences between the NGS and IGS rapid ephemerides. The subplots are defined in the same way as Figure 2. On average over all 2002, NGS EOP match the National Earth Orientation Service Bulletin A values at: X pole -0.181 +/- 0.221 milliarcseconds and Y pole 0.143 +/- 0.209 milliarcseconds. The NGS software only uses double difference carrier phase as an observable and does not attempt to recover a UT1 time series.

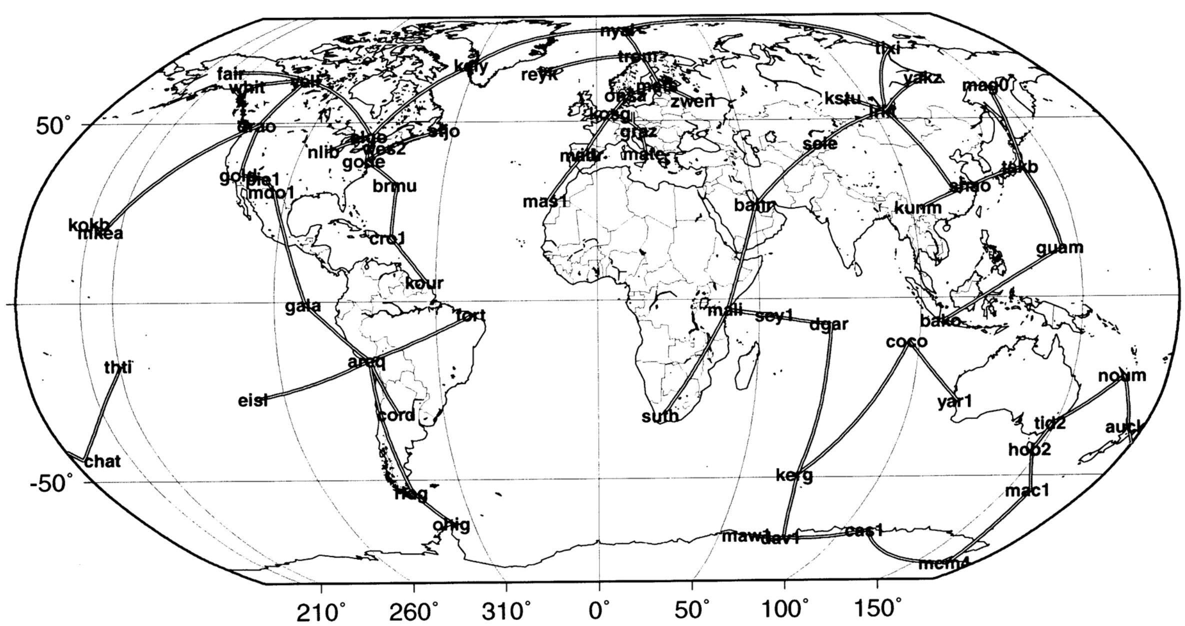

Figure 1.

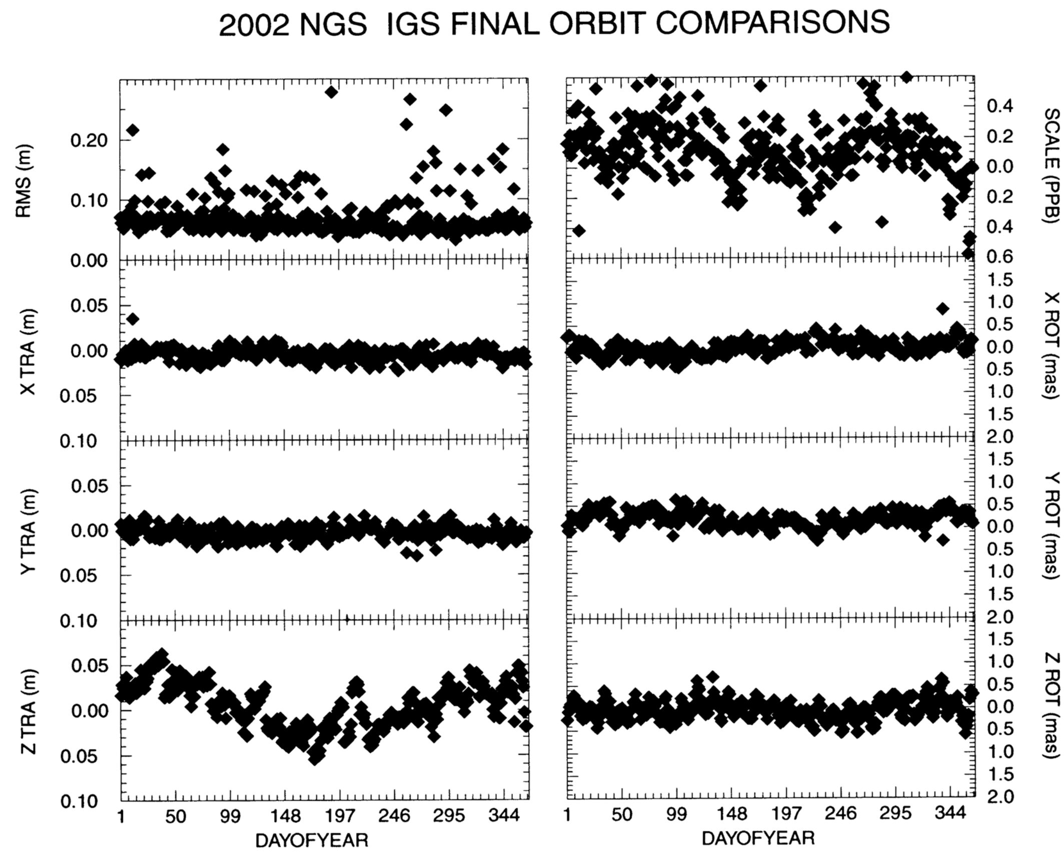
2002 NGS IGS FINAL ORBIT COMPARISONS
RMS (m)
X TRA (m)
Y TRA (m)
Z TRA (m)
SCALE (PPB)
X ROT (mas)
Y ROT (mas)
Z ROT (mas)
DAYOFYEAR
DAYOFYEAR

Figure 2

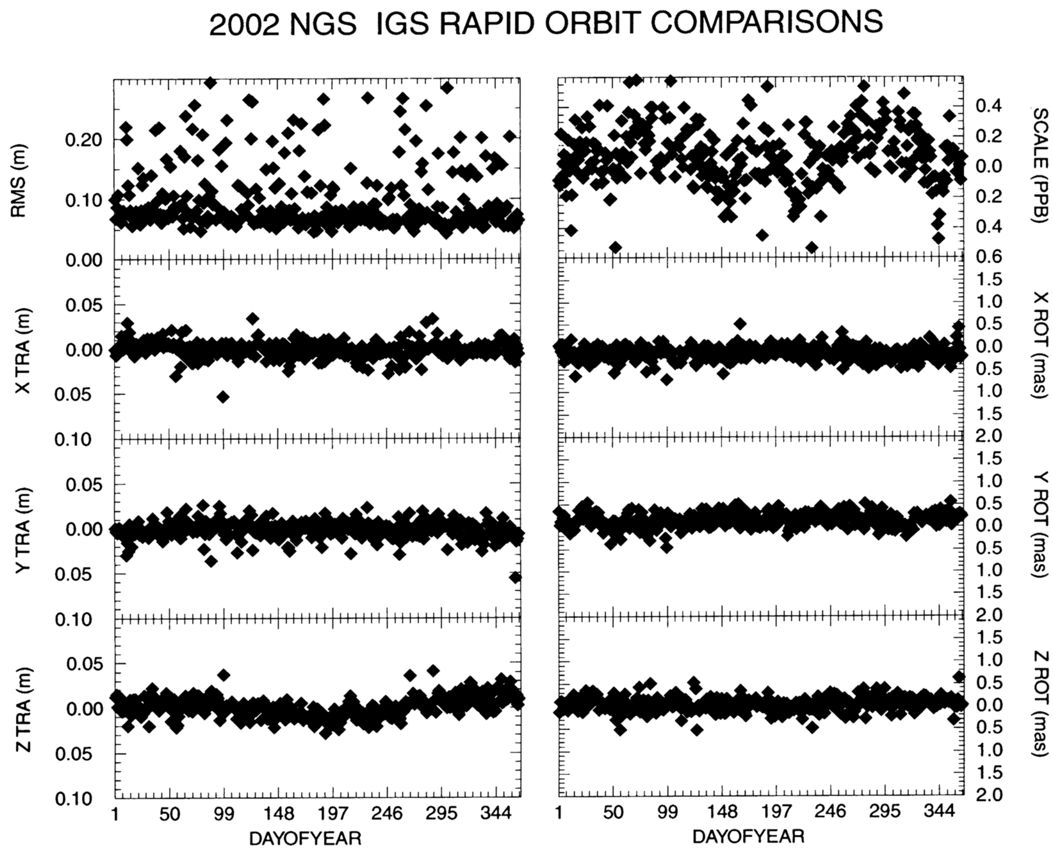

Figure 3

Orbit Products

I. Constrained Precise GPS Orbit: Up to 51 constrained IGS fiducial tracking sites in the IGS97, epoch 1997.0 reference frame
available - 3 to 6 days from date of observation
contact - http://www.navcen.uscg.mil/gps/precise/default.htm
accuracy - approximately 5-10 centimeters

II. Minimally Constrained Precise GPS Orbit: A consistent minimally constrained weekly solution in the IGS97, epoch 1997.0 reference frame
available - 4 to 10 days from date of observation
contact - ftp://gracie.grdl.noaa.gov/dist/cignet/Ngsorbits
accuracy - approximately 6-8centimeters

III. Rapid GPS Orbit: Up to 50 constrained IGS fiducial tracking sites in the IGS97, epoch 1997.0 reference frame

available - 16 hours from last observation
contact - ftp://www.ngs.noaa.gov/cors/orbits/rapid
accuracy - approximately 7-10 centimeters

IV. Ultra-Rapid GPS Orbit: A constrained estimated/predicted solution
in the IGS97, epoch 1997.0 reference frame
will be available - within 2 to 3 hours from last observation
contact - under development
accuracy - approximately 20-60 centimeters

V. Earth Rotational Parameters: Rapid and precise polar motion values
available - 16 hours from date of last observation
recipient - Bureau International de L'Heure (BIH)
United States Naval Observatory(USNO)
International GPS Service (IGS)
accuracy - approximately 0.25 milli-arcseconds

VI. Troposheric estimates for the zenith path delay
available - 4 to 10 days from date of observation
recipient - GeoForschungsZentrum, Potsdam, Germany
International GPS Service (IGS)

References

Schwiderski, E., 1983, “Atlas of Ocean Tidal Charts and Maps, Part I: The Semidiurnal Principal Lunar Tide M2", Marine Geodesy, 6, 219-256.

NRCan IGS Analysis Center Report for 2002

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Ottawa, Canada

During 2002 in addition to its continued contribution of GPS products to the IGS, NRCan had the pleasant task of organizing and hosting the first combined Network, Data and Analysis Center IGS Workshop. In 2002 NRCan was also able to improve the quality of its Rapid and Final orbit estimation. The pages that follow document the major changes to the strategies and software use by NRCan to generate the various products contributed to the IGS.

NRCan Final and Rapid Products

In 2002 NRCan continued to estimate Rapid and Final products using JPL's GIPSY-OASIS version 2.6 software as described in ftp://igscb.jpl.nasa.gov/igscb/center/analysis/emr.can. Table 1 lists several changes made to the NRCan strategy based on IGS recommendations. Table 1 also lists modifications made in order to improve the consistency and reliability of the Rapid and Final solutions.

Table 1: Final/Rapid Processing Strategies Modifications

GPS Week	Modification
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 set of <P1-C1> bias values (v3.0) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.
1165	Implementation of Rapid station clock estimation using precise point positioning (fixing emr rapid orbits and clocks) to augment our Rapid station clock solution. This strategy allows for estimation, and contribution to the IGS Rapid Timescale Product (IGRT) of station clock values for all IGS stations with stable frequency standards.
1167	Implementation of Final station clock estimation using precise point positioning (fixing emr final orbits and clocks) to augment our Final station clock solution. This strategy allows for estimation, and contribution to the IGS Final Timescale (IGST) of station clock values for all IGS stations with stable frequency standards.

1167	Implementation of ambiguity fixed solution for both Rapid and Final products.
1190	Re-aligned NRCan Final UT1-UTC value to VLBI derived value (Bulletin A) on day 0 and then resumed NRCan's normal daily estimation procedure for UT1-UTC.
1191	Re-aligned NRCan Rapid UT1-UTC value to VLBI derived value (Bulletin A) on day 3 and then resumed NRCan's normal daily estimation procedure for UT1-UTC.
1195	Adoption of new sp3c orbit format.
1197	Adoption of new set of <P1-C1> bias values (v3.2) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.

Ambiguity Resolution

During 2002 ambiguity resolution was implemented for both the Rapid and Final product estimation. Ambiguity resolution was implemented for the NRCan Final products estimation starting with GPS week 1167 day 0 and for the Rapid estimation starting with GPS week 1167 day 3. Improvements made by JPL in GIPSY-OASIS v2.6 as well as improved hardware implemented by NRCan in late 2001 finally made ambiguity fixing feasible. Under the current hardware and software configuration, ambiguity fixing increases the processing time by 1-2 hours for a Rapid solution and 2-3 hours for a Final solution. However the Rapid solution was contributed to the IGR combination more than 95% of the days in 2002 compared to only 79% in 2001 due to improved pre-processing techniques used for data screening. Resolving ambiguities significantly improved the consistency of the Rapid and Final solutions with respect to IGS. Figure 1 shows the Rapid orbit daily rms with respect to the IGR combination. Figure 2 shows the Final orbit rms with respect to the IGS combination. Developments are underway to further increase the consistency of NRCan Rapid and Final products in 2003.

NRCan Ultra Rapid Products

Processing Strategy and Changes

In 2002, NRCan continued the development and delivery of its Ultra Rapid Products (EMU). The most important improvement in 2002 was the introduction of the Ultra Rapid satellite clocks starting on October 31. Our Ultra Rapid overall strategy has not changed. Orbits and Earth Rotation Parameters (ERP) are still estimated first followed by the estimation of satellite clocks. For the satellite clocks, GPS data for the last 24 hours are gathered and processed at a 15-minute rate. Only 30 to 33 stations can be process due to CPU time limitation. Station selection is mostly based on the longest time span. EMU orbits and ERPs are held fixed and station coordinates (IGS2000) are constrained to their apriori standard deviation. Finally, satellite and station clocks along with hourly station TZDs and real ambiguities are estimated. The 24-hr estimated satellite clocks are then fitted and propagated using the following function:

$$CLK_{PRN} = A_{PRN} + B_{PRN}\Delta t + C_{PRN} SIN\left(D_{PRN}\Delta t + E_{PRN}\right) \quad (1)$$

where: A_{PRN} is the offset
B_{PRN} is the drift
C_{PRN} is the amplitude
D_{PRN} is the frequency fixed at $\frac{1}{12hr}$ for all PRN
E_{PRN} is the phase shift
Δt is the time

Equation (1) is then used to generate the 24-hr satellite clock predictions needed. The major changes to our Ultra Rapid processing strategy in 2002 are listed in Table 2. The reader is referred to previous IGS Technical Reports for more details on the processing strategy used.

Table 2. Modifications to NRCan Ultra Rapid processing strategy in 2002.

Date	Doy	Description of Changes
Apr. 24, 2002	114	Use of 10 degree elevation cutoff angle.
May 06, 2002	126	Use of 5 degree elevation cutoff angle.
Jun. 14, 2002	165	Station selection improved. It now uses some QC values such as the hourly number of observations and gaps.
Jul. 4, 2002	185	Inclusion of marginal satellites.
Oct. 31, 2002	304	First Ultra Rapid clock submission.
Dec. 1, 2002	335	Adoption of new sp3c orbit format.
Dec. 20, 2002	354	Adoption of new set of <P1-C1> bias values (v3.2) to transform cross-correlated pseudorange observations into synthesized non cross-correlated.

Results

This section shows the comparison of NRCan Ultra Rapid orbits, clocks and ERP products (EMU) with respect to the IGS Ultra Rapid (IGU). Six graphics are presented covering year 2002. Figure 3 shows the orbit RMS, Median RMS and Weighted RMS (WRMS) with respect to IGU (estimated and predicted portions not separated). Spikes can still be seen in the orbit RMS and WRMS plots. This indicates that NRCan (and other ACs at times) had problems modeling some satellite orbits and acknowledging it. Figure 4 shows the clock RMS with respect to IGU over a 48-hour period (i.e., estimated and predicted portions not separated). The graphic basically shows the overall quality of the predicted clocks since their precision is much worse than the precision of the estimated clocks. The quality of the estimated part is of the order of 0.2 to 0.4 ns (not shown here). Two spikes can be noticed on November 27 and December 22. The first one is not real since one AC's clock solution had a reference clock jump not acknowledged in the Ultra Rapid Combination resulting in high clock RMS for all ACs. The second one is real and was related to some processing problems with PRN26. Figures 5 and 6 show the Translations, the Rotations and Scale for EMU with respect to IGU. Figures 7 and 8 show the pole (Xp, Yp, Xp_{rate}, Yp_{rate}) and LOD comparisons with respect to IGU for both the estimated and predicted portions of EMU respectively.

Future Work (Ultra-Rapid)

In the near future, we will investigate the feasibility of estimating satellite orbits and clocks every hour instead of every 3 hours. If possible, we would also like to implement the estimation of satellite clock corrections every 5 minutes instead of 15 minutes. This would greatly benefit the Precise Point Positioning (PPP) users. It's also our intention to at least try to acknowledge badly behaving satellites that are not presently detected as they can cause serious problems to some users.

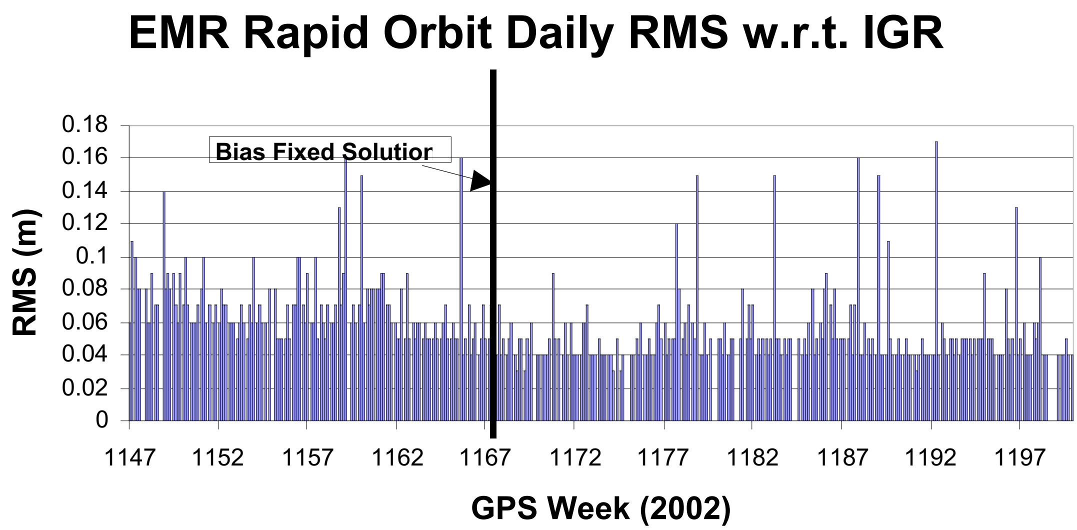

Figure 1: NRCan (EMR) Rapid orbit daily RMS w.r.t. IGR for year 2002

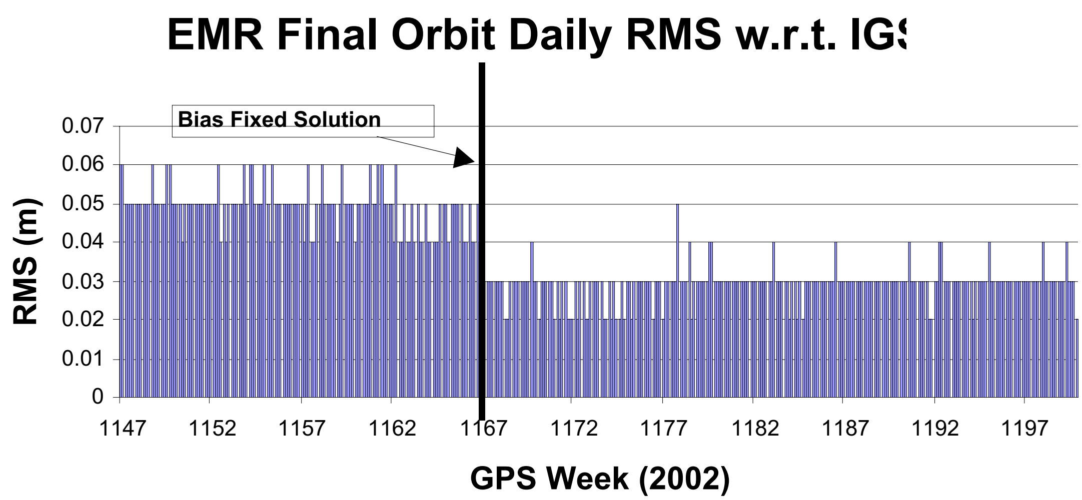

Figure 2: NRCan (EMR) Final orbit daily RMS w.r.t. IGS for year 2002

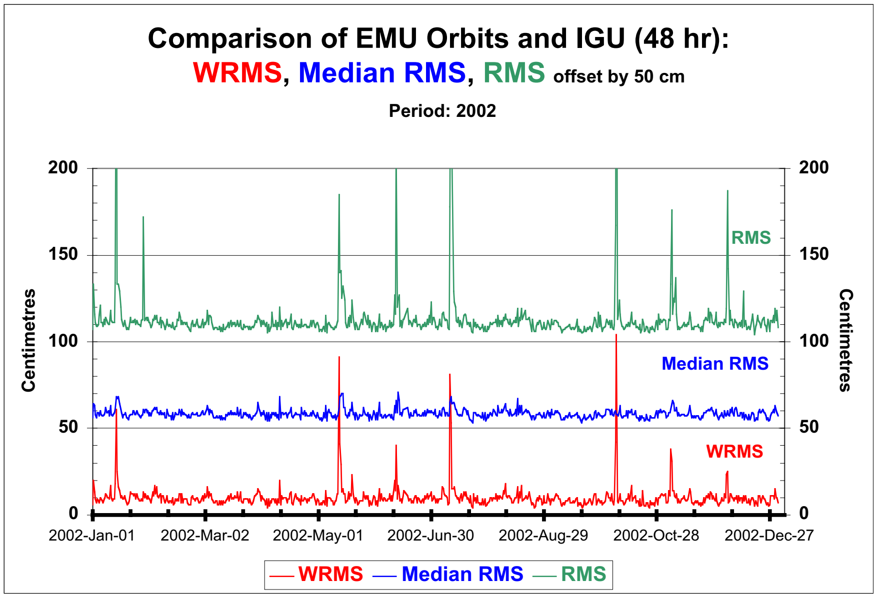

Figure 3: Comparison of EMU Orbits and IGU for 2002 (48-hour Orbit): **WRMS**, **Median RMS** and **RMS**, each offset by 50 cm.

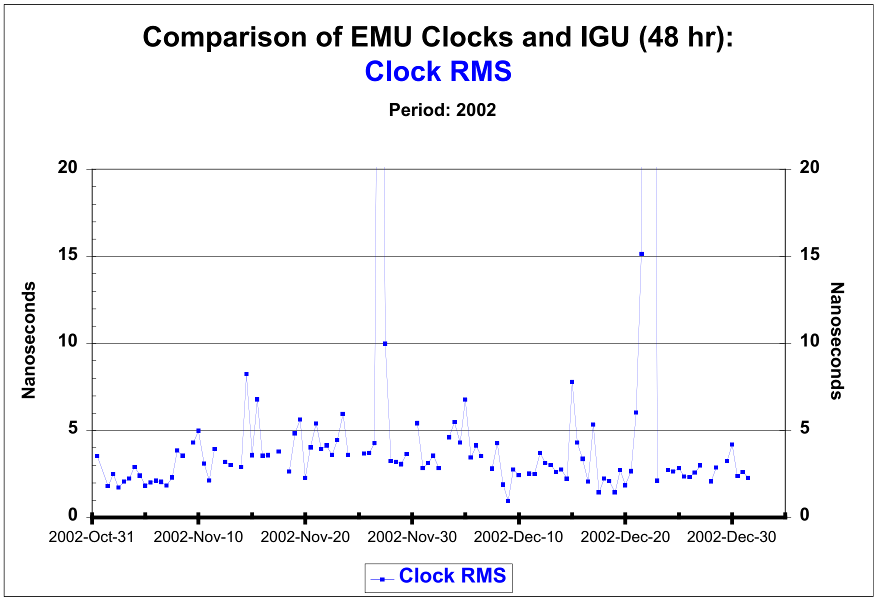

Figure 4: Comparison of EMU Clocks and IGU for 2002 (48-hour Clocks): **RMS**.

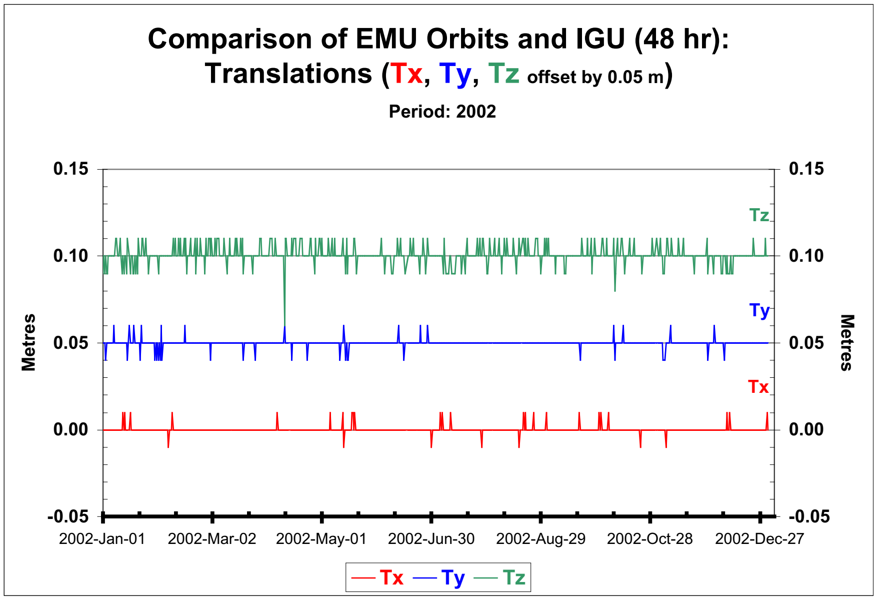

Figure 5: Comparison of EMU Orbits and IGU for 2002 (48-hour Orbit): **Translations Tx, Ty** and **Tz**, each offset by 0.05 m.

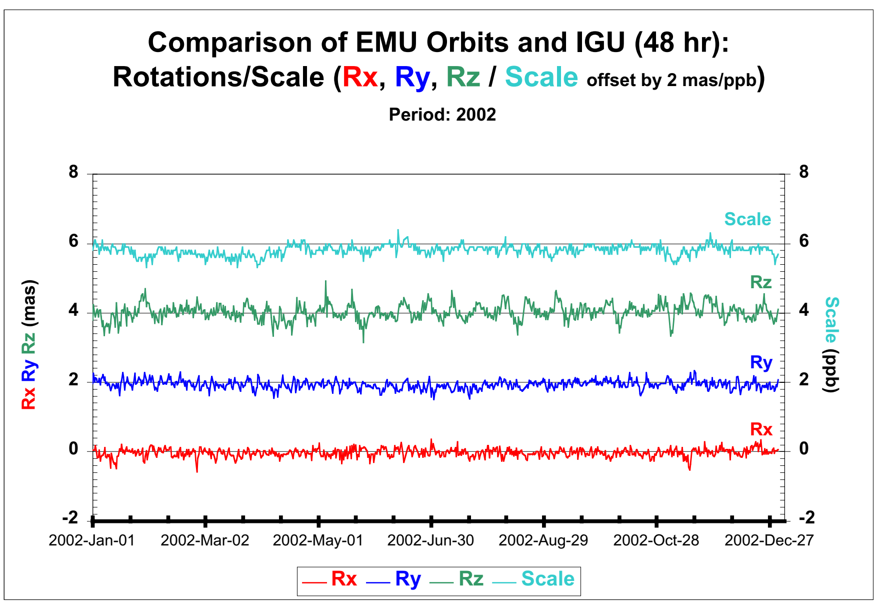

Figure 6: Comparison of EMU Orbits and IGU for 2002 (48-hour Orbit): **Rotations Rx, Ry**, **Rz** and **Scale** each offset by **2 mas**, **2 mas**, **2 mas** and **2 ppb** respectively.

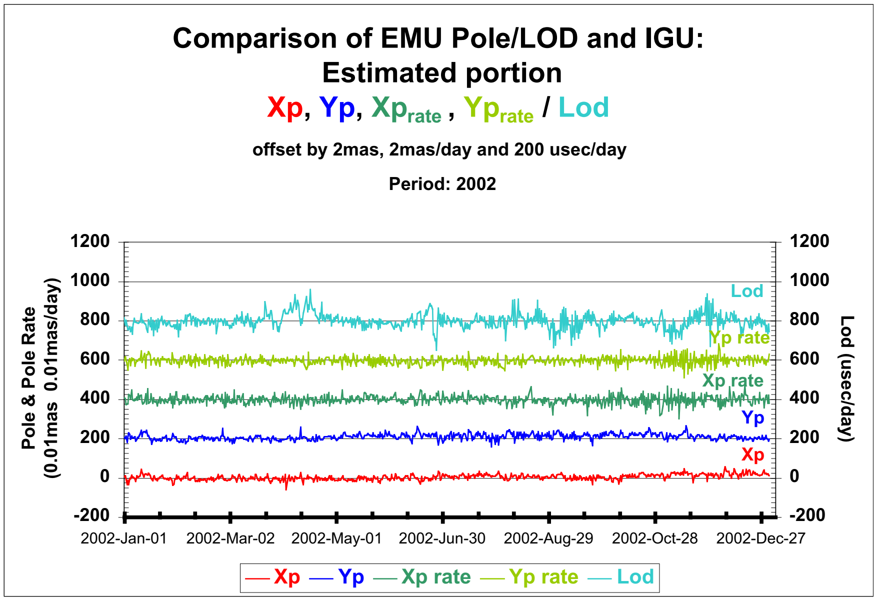

Figure 7: Comparison of EMU Estimated Pole/LOD and IGU for 2002: **Xp**, **Yp**, **Xp$_{rate}$**, **Yp$_{rate}$** and Lod, each offset by **2 mas**, **2 mas**, **2 mas/day**, **2 mas/day** and **200 usec/day** respectively.

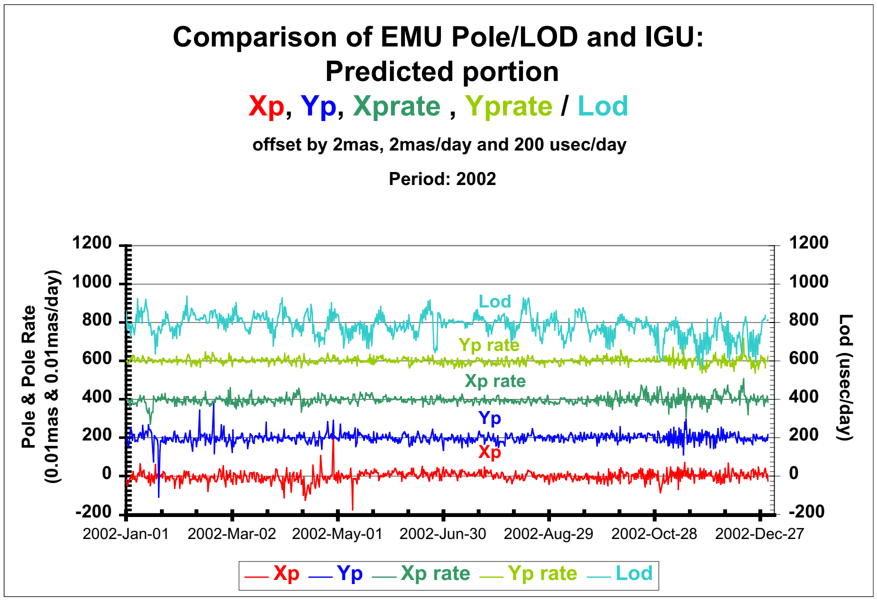

Figure 8: Comparison of EMU Predicted Pole/LOD and IGU for 2002: **Xp**, **Yp**, **Xp$_{rate}$** , **Yp$_{rate}$** and **Lod**, each offset by **2 mas**, **2 mas**, **2 mas/day**, **2 mas/day** and **200 usec/day** respectively.

SOPAC 2002 IGS Analysis Center Report

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Introduction

The Scripps Orbit and Permanent Array Center (SOPAC) at the Scripps Institution of Oceanography (SIO) has been producing precise satellite orbits, Earth Orientation Parameters, and station positions since 1991 when the Permanent GPS Geodetic Array (PGGA) project was initiated in southern California. SOPAC has been an analysis center from the inception of IGS.

This report covers the activities between 2000 and 2002, and will focus on SOPAC's GPS analysis strategy, changes in the software/procedure, and a review of some of the results.

Products Submitted and Served

SOPAC provides both processed products as well as observation data products (see companion SOPAC global data center report) accessible through anonymous ftp at (ftp://garner.ucsd.edu) and http (http://garner.ucsd.edu/), with explanatory information on our webpage (http://sopac.ucsd.edu/).

There are four types of processed products that SOPAC contributes to IGS at three latency levels. The products are summarized in Figure 1 and Table 1.

Analysis Procedure

SOPAC "final" solutions are based on daily sessions in distributed mode, that is, we divide the global network into sub-networks. During the period 2000-2002, three sub-networks were used (see Network Configuration below). Once the daily solutions are produced for a given GPS week, the loosely constrained solutions are fed into a weekly combination analysis, in which the orbits, EOP, and site positions are tied to a designated reference frame by constraining the positions of a group of selected core sites.

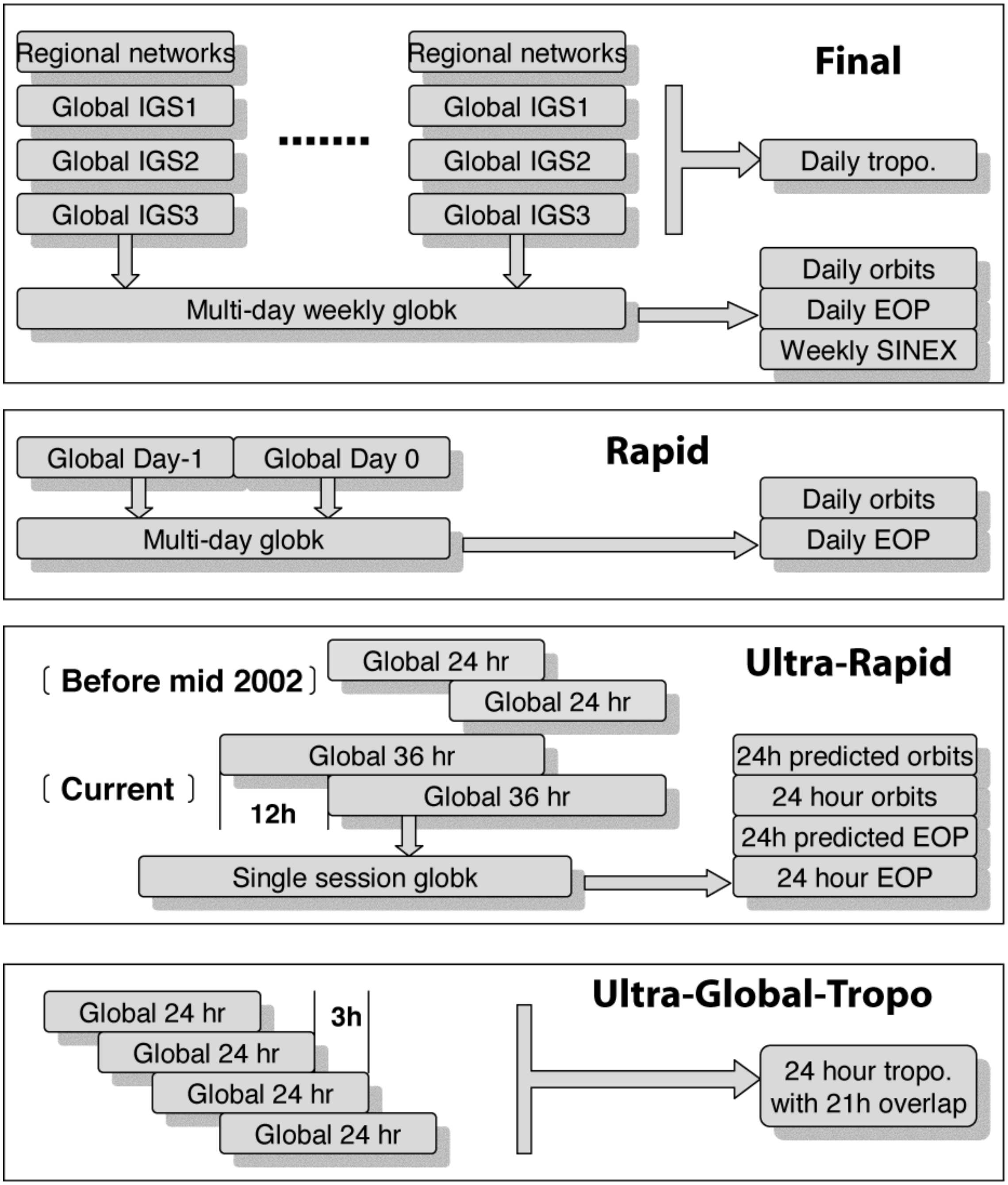

Figure 1. Flow chart for SOPAC final, rapid, ultra rapid processing and products.

SOPAC "rapid" solutions are based on multi-day solutions, that is, current day and previous day. The original two sub-network scheme, maximum 26 sites each, has been replaced by single network, up to 36 sites, since late 1999. This change was based on the evaluation of the orbit /EOP performance and the consideration of processing efficiency.

After the introduction of IGS ultra rapid products from GPS week 1075, SOPAC has contributed its 00h and 12h hourly orbit solutions. This process is based on a single 24-hour session using data from a single network of up to 38 sites.

SOPAC also contributes to the IGS near real-time global tropospheric delay product using a sliding window scheme. 24-hour session data from 40+ selected sites are processed every 3 hours with a latency of about 2 hours.

The main processing engines are GAMIT [*King and Bock*, 2002] and GLOBK [*Herring*, 2002].

The related software version changes and the applied model parameter changes for the above solutions are summarized in Table 2. More detailed processing parameters, models applied [*McCarthy*, 1992, 1996; *Beutler et al*., 1994; *Springer et al*., 1998; *Bar-Sever*, 1996; *Dong and Bock*, 1989; *Niell*, 1996, *Wu et al*., 1993] and processing strategies remained unchanged and have been reported in a previous SOPAC annual AC report [*Fang et al*., 1998]. The ocean loading model used is based on the *Scherneck* [1991] model.

Since all products are defined with respect to the global reference frame, the choice of core sites and the constraints on their positions and velocities play an important role in data processing. The constraint histories for final and rapid solutions can be found on the SOPAC webpage.

Network Configuration

For SOPAC final solutions, the global sites are grouped into 3 sub-networks: IGS1, IGS2, and IGS3, of 50+ sites each (Figure 2). IGS3 mainly includes the IGS defined core stations. Since there is a high concentration of global stations in Europe, some of the 'global' stations are grouped into SOPAC's EURO regional sub-network. Figures 1-3 show the basic network configurations for IGS1, IGS2, and IGS3. The sites in the maps include all sites processed within 2000 and 2002 time frame. Since the sites in each network have been adjusted from time to time, the detailed history of site inclusion and exclusion can be found in the constraint history plots.

Reprocessing of IGS Products

SOPAC has completed the reprocessing of its entire data holdings (starting in 1991) including both global and regional networks [*Nikolaidis*, 2002; *Bock et al*., 2003]. We now have a consistently analyzed data set and all SOPAC data products are referenced to ITRF2000 [*Altamimi et al*., 2002]. Web-based interfaces have been developed to facilitate users access to the IGS products and their derivatives. See, for example, http://sopac.ucsd.edu/cgi-bin/refinedJavaTimeSeries.cgi; http://sopac.ucsd.edu/processing/coordinates/).

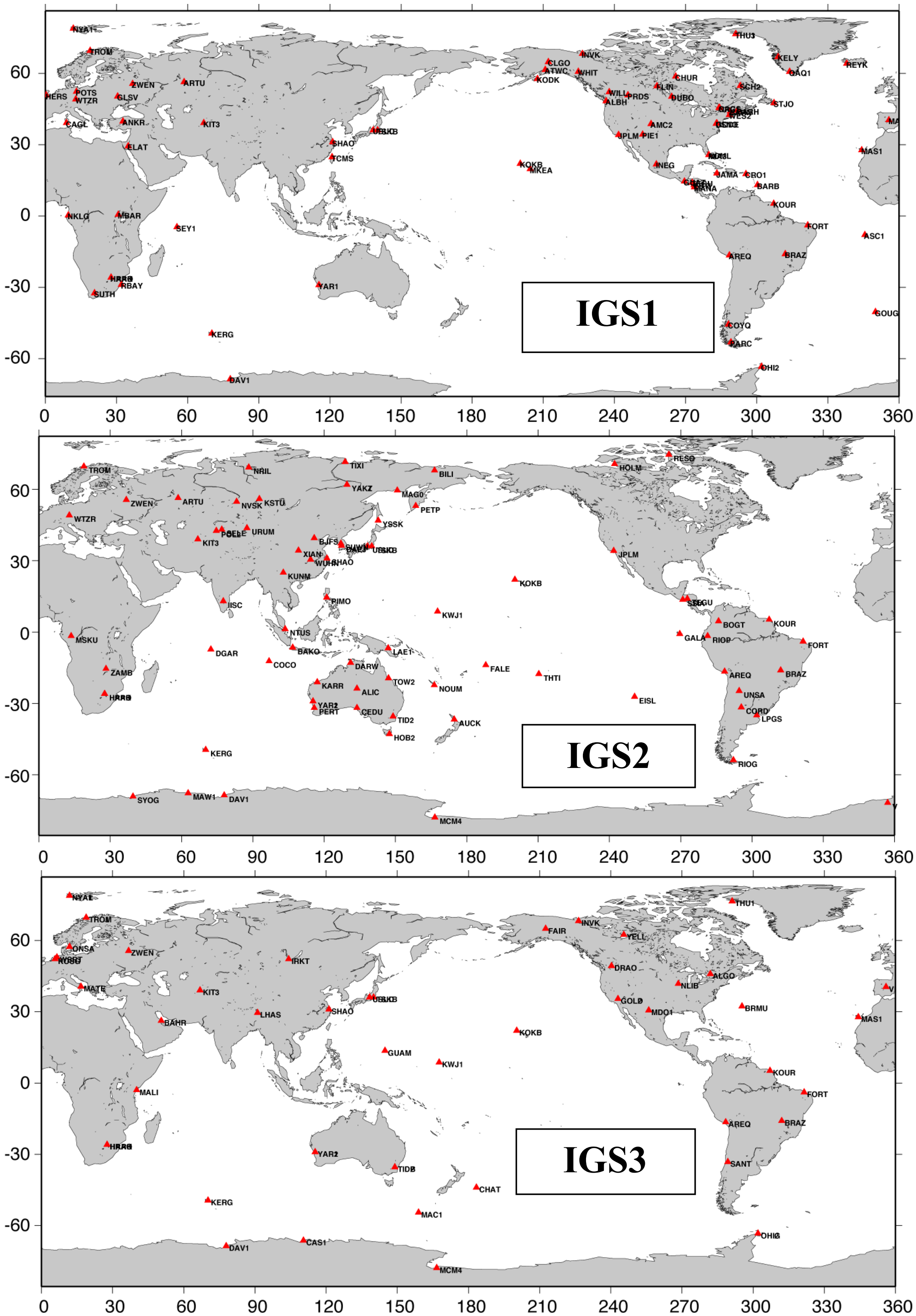

Figure 2. Site distribution of sub-networks for SOPAC final solutions (2000-2002).

Table 1. SOPAC IGS products (2000-2002)

Type of Product	**Latency**	**File Format**	*Description*
Final Products	4-8 days	siowwwwn.sp3	Daily precise orbits
		siowwww7.erp	Weekly EOP (pole, UT1-UTC, LOD)
		siowwww7.snx	Weekly SINEX files
		siowwwwn.tro	Hourly tropospheric delay updated daily
		siowwww7.sum	Weekly processing summary
Rapid Products	18 hours	sirwwwwn.sp3	Daily rapid orbit solutions
		sirwwwwn.erp	Daily rapid EOP solutions
Ultra Rapid Products	2 hours	siuwwwwn.sp3 *siuwwwwn_hh.sp3	24 hr estimated + 24 hr predicted orbits
		siuwwwwn.erp *siuwwwwn_hh.erp	24 hr estimated + 24 hr predicted EOP
		siowwwwn_hh.tro	Hourly tropospheric delay updated ever three hour

Latency is defined as the time period from product delivery to the end time of the observation session used in the data processing.
* new naming convention after the product update frequency changed from daily to every 12 hour.

Table 2. Reference frame, tidal model applied, and software version change history for SOPAC products (2000-2002)

	Reference frame		Pole tide/Ocean tide		GAMIT version		GLOBK version	
Final	2000 001	Itrf97	2000 001	No/No	2000 001	9.93	2000 001	5.05
					2000 122	9.92	2000 122	5.03
					2000 170	9.93	2000 170	5.04
			2000 331	Yes/Yes	2000 331	9.94	2000 331	5.05
	2001 302	Itrf00						
	2001 340	Itrf00U						
					2001 364	9.95		
							2002 055	5.06
Rapid/ Ultra Rapid	2000 001	Itrf97	2000 001	No/No	2000 001	9.93	2000 001	5.05
					2001 004	9.94		
	2001 345	Itrf00U						
					2001 363	9.95		
			2002 008	Yes/Yes				
							2002 035	5.06

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References

Altamimi, Z., P. Sillard, and C. Boucher, ITRF2000: A new release of the International Terrestrial Reference Frame for earth science applications, *J. Geophys. Res., 107*(B10), 2214, doi:10.1029/2001JB000561, 2002.

Bar-Sever, Y. E., A new module for GPS yaw attitude, in Proc. IGS Workshop: Special Topics and New Directions, edit. G. Gendt and G. Dick, pp. 128-140, GeoForschungsZentrum, Potsdam, 1996.

Beutler, G., E. Brockmann, W. Gurtner, U. Hugentobler, L. Mervart, and M. Rothacher, Extended Orbit Modeling Techniques at the CODE Processing Center of the International GPS Service for Geodynamics (IGS): Theory and Initial Results, Manuscripta Geodaetica, 19, 367-386, 1994.

Bock, Y., L. Prawirodirdjo, J. F. Genrich, C. W. Stevens, R. McCaffrey, C. Subarya, S. S. O. Puntodewo, E. Calais, Crustal Motion in Indonesia from Global Positioning System Measurements, *J. Geophys. Res*., 108 (B8), 2367, doi:10.129/2001JB000324, 2003.

Dong, D., and Y. Bock, Global Positioning System network analysis with phase ambiguity resolution applied to crustal deformation studies in California, Journal of Geophysical Research, 94, 3949-3966, 1989.

Herring, T. A., GLOBK: Global Kalman filter VLBI and GPS analysis program Version 4.17, Internal Memorandum, Massachusetts Institute of Technology, Cambridge, 2002.

Fang, P., M. van Domselaar, and Y. Bock, Scripps Orbit and Permanent Array Center 1997 Analysis Center report, IGS 1997 Technical Reports, ed. I. Mueller, K. Gowey, R. Neilan, Jet Propulsion Laboratory, 1998.

King, R. W., and Y. Bock, Documentation of the GAMIT GPS Analysis Software version 9.72, Mass. Inst. of Technol., Cambridge, 2002.

McCarthy, D. D. (ed.) (1992). IERS Standards (1992). IERS Technical Note 13, Observatoire de Paris, July 1992.

McCarthy, D. D. (ed.) (1996). IERS Conventions (1996). IERS Technical Note 21, Observatoire de Paris, July 1996.

Niell, A. E., Global mapping functions for the atmospheric delay, J. Geophys. Res., 101, 3227-3246, 1996.

Nikolaidis, R., Observation of geodetic and seismic deformation with the Global Positioning System, PhD Dissertation, Scripps Inst. of Oceanography, University of California San Diego, 2002.

Scherneck, H-G., A parameterized solid earth tide model and ocean tide loading effects for global geodetic baseline measurements, Geophys. J. Int., 106, 677-694, 1991.

Springer, T. A., G. Beutler, and M. Rothacher, A new solar radiation pressure model for the GPS satellites, IGS Analysis Center Workshop, Darmstadt, 9-11 February 1998.

Wu, J. T., S. C. Wu, G. A. Hajj, W. I. Bertiger, S. M. Lichten, Effects of antenna orientation on GPS carrier phase. Manuscripta Geodaetica 18, 1993, 91-98, 1993.

USNO IGS Associate Analysis Center Annual Report for 2002

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Summary

USNO contributed rapid, ultra-rapid and tropospheric products to the IGS during 2002. The development of a new way to assign weights to satellite orbits, combining the orbits produced from different approaches, and the introduction of multiple data arc processing to the estimated part of the ultra-rapid solutions were major activities during 2002. The acquisition of a new HP Unix workstation allowed USNO to upgrade to GIPSY/OASIS 2.6, and increase the number of sites processed in both the rapid and ultra-rapid solutions.

Changes to Routine Analysis

Table 1 shows the changes to USNO's routine analysis in 2002. The basic strategy remained unchanged for the rapid solutions. The most important changes to the rapid solution strategy were made to the post-processing scripts. Comparisons between the USNO rapid solutions and the preceeding IGS ultra-rapid combinations provide the accuracy codes for the sp3 orbit files. In addition, the orbit files from two computers which use slightly different approaches, and different versions of GIPSY/OASIS, were merged using the accuracy codes to indicate appropriate weights. Our use of GIPSY/OASIS 2.5 has a tendency to produce poor orbits for one or two satellites per solution with no indication of a problem in the formal errors. The satellites with poor orbits were not necessarily the same on the two computers. Therefore, merging orbits using appropriate weights could, and did, mitigate this problem. GIPSY/OASIS 2.6 is a much improved product and produces far fewer poor orbits.

The initial strategy used for the estimated part of the ultra-rapid solutions was merely a scaled-down version of the strategy used for the rapid solutions. In 2002, one computer was switched to multiple data arc processing. This approach achieves greater speed by processing data in three-hour arcs, thus permitting USNO to increase the number of sites used from 27 to 34. The strategy used on the new HP Unix was to process a single solution with more sites rather than two sequential solutions with fewer sites.

Slabinski's modification of the CODE radiation force model continues to be used for the predicted part of the ultra-rapid orbits. A satellite's parameter values which are used in the model are adjusted, as required, so that the model predictions match the observed secular perturbations to the GPS orbit. Orbit prediction is difficult for certain older "problem" satellites because of an attitude control thruster firing every ~2 days which causes large deviations in the satellite position from the predicted values. These "problem" satellites have been given very low weight so that the typical 30 m RMS prediction error following a thruster firing makes a negligible contribution to the weighted RMS ultra-rapid prediction error. Efforts to move the

Ultra-rapid prediction software to the new workstation were frustrated by a FORTRAN compiler error that was not uncovered until year's end.

Table 2 lists the products that were submitted to the IGS in 2002. For more details regarding the computational strategy see the USNO Analysis Strategy Summary at ftp://igscb.jpl.nasa.gov/igscb/center/analysis/usno.acn.

Table 1: Changes to rapid and ultra-rapid solutions.

2002-01-03	Implemented the use of comparisons of USNO orbits with IGS ultra-rapid combined orbits to set accuracy codes for rapid solutions. Implemented the mergers of sp3 rapid orbit and Earth orientation parameter files from two different computers.
2002-01-16	"Problem" satellites PRN 15, 17, 21, 23, and 29 were automatically assigned very low weight in ultra-rapid orbit files.
2002-01-20	Implemented new <P1-C1> pseudorange bias values.
2002-02-08	The GIPSY program spx2eci was modified to include sub-daily terms in the Earth orientation parameters when transforming IGS determined Earth-fixed positions to inertial space for use in a trajectory fit for ultra-rapid predictions.
2002-02-13	Updated cc2noncc routine.
2002-03-28	Added 15 more sites for clock solutions using precise-point positioning.

Table 1: Changes to rapid and ultra-rapid solutions (Cont'd)

2002-03-14	Implemented the use of comparisons of USNO orbits with IGS ultra-rapid combined orbits to set accuracy codes for ultra-rapid solutions. Implemented the merging of sp3 ultra-rapid orbit and Earth orientation parameter files from two different computers.
2002-06-26	First submission of multiple data arc processing results in the estimated part of the ultra-rapid solutions.
2002-06-18	Full implentation of the use of secure shell for the transmission of ultra-rapid solutions to the IGS.
2002-09-07	First submission of rapid solution which contained results from the new workstation utilizing GIPSY/OASIS 2.6 and 40 sites per solution.
2002-10-02	First submission of an ultra-rapid solution whose estimated part contained results from the new workstation utilizing GIPSY/OASIS 2.6 and 40 sites per solution.
2002-12-01	Began submission of version 'c' of sp3 orbit files to the IGS.

Table 2: USNO products provided to the IGS for GPS week/day wwww/d.

File Name	Frequency	Contents
usnwwwwd.sp3	daily	Estimated GPS satellite positions and clock corrections at 15 minute intervals
usnwwwwd.erp	daily	Estimated Earth orientation parameters
usnwwwwd.clk	daily	Estimated satellite and receiver clock corrections at 5 minute intervals
usuwwwwd.sp3	twice daily	Estimated GPS satellite positions and clock corrections for 24 hours + predicted satellite positions and clock corrections for 24 hours at 15 minute intervals
usuwwwwd.erp	twice daily	Estimated and predicted values of Earth orientation parameters
usuwwwwd.zpd	every three hours	Estimated total zenith tropospheric delay at 30 minute intervals

Performance

Statistics for the USNO rapid orbit and clock solutions are shown in Table 3. The mean and median for the daily values of the weighted root mean square (WRMS), median (MEDI) and clock root mean square (CLK RMS) taken from the IGS Rapid Combinations are given. In addition, the mean and median for the number of receiver clocks per solution, and the number of days that submissions were successfully made are listed. The numbers of receiver clocks per solution for 2001 are reckoned from the introduction of precise-point positioning to augment the number of receiver clocks per rapid solution. The average number of receiver clocks is 69.4 with a median of 75. The values in Table 3 shown significant improvement in all statistics.

Table 3: Rapid solution statistics.

		GPS Orbits WRMS (cm)	GPS Orbits MEDI (cm)	Satellite CLK RMS (ns)	Number of clocks per solution	Number of days submitted
2001	mean	6.9	4.8	0.100	69.4	347
	median	6	5	0.10	75	
2002	mean	3.7	3.6	0.075	91.2	358
	median	4	4	0.07	98	

Statistics for the USNO ultra-rapid orbit and clock solutions are shown in Table 4. The mean and median for the daily values of the weighted root mean square (WRMS), median (MEDI) and clock root mean square (CLK RMS) taken from the IGS ultra-rapid orbit comparisons are given.

In addition, the numbers of successful twice-daily submissions are listed. Note that the satellite clock statistics refer to the prediction performance, not observations of the clocks. The values in Table 4 show significant improvement from 2001 to 2002 in the quality of the orbit solutions, particularly in the WRMS.

Table 4: Ultra-rapid solution statistics.

		GPS Orbits WRMS (cm)	GPS Orbits MEDI (cm)	Satellite CLK RMS (ns)	Number of twice-daily submissions
2001	mean	45.1	18.9	5.356	641
	median	31	17	4.88	
2002	mean	21.1	13.8	5.196	650
	median	15	13	4.63	

A S S O C I A T E   A N A L Y S I S

C E N T E R S

IGS

GLOBAL NETWORK ASSOCIATE ANALYSIS CENTERS

The Newcastle GNAAC Annual Report for 2001-2002

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The GNAAC at University of Newcastle continued activities with submissions of weekly G-network and P-network SINEX files. The analysis procedure outlined previously (Davis & Blewitt, 2000; Nurutdinov et al., 2000) remained unchanged throughout the years 2001-2002. The IGS97 realization of ITRF97 has been used to constrain the solutions for GPS weeks 1065-1142. Starting with GPS week 1143 it has been replaced with IGS00 realization of ITRF2000. Combined solutions for Earth Rotation Parameters (X_p, Y_p, LOD) have been produced starting with week 1159.

G-network Results

A-network SINEX data from all seven global analysis centres (COD, EMR, ESA, GFZ, JPL, NGS, SIO) were processed. The appearance of a station in a minimum of three solutions defines a global station for inclusion in the combined NCL G-network (Figure 1). Any remaining stations and RNAAC (AUS, EUR, GSI, SIR) stations (Figure 2) are defined as regional stations and are included in the P-network along with global stations. During 2002 an average of 116 global and 84 regional stations appeared in the weekly P-network what is higher than during 2001 (103 global and 75 regional stations) and 2000 (100 and 60 respectively).

The loose G-network solution (GNET) is estimated from block of normal equations composed of each de-constrained A-network. The corresponding covariance matrix is augmented to remove Helmert rotation parameter constraints. This solution is constrained later to the CORE network, consisting of 51 stations of IGS97 or 54 stations of IGS00, for the months Jan-Nov 2001 or Dec 2001-Dec 2002 respectively.

Figure 3 shows the weighted RMS of residuals for each weekly A-network solution after Helmert transformation to the weekly loose G-network solution. Values for weighted RMS are in the region 2-9 mm describing repeatability of the G-network estimates.

Figures 4 through 7 show the translational parameters for 7-parameter Helmert transformation from deconstrained AC and GNET solutions to CORE network.

The effect of introducing of IGS00 realisation of ITRF2000 in December 2001 instead of IGS-97 realisation of ITRF-97 used before is seen clearly from Figure 9. Mean values of the scale parameter of the Helmert transformation from AC solutions to the IGS CORE network became 1.5-4 times smaller.

P-network Results

The creation of the P-network is based on the G-network and the weekly input R-SINEXes from the RNAACs. A minimum of three global and one regional stations is required for inclusion of a solution in the P-network. In the “attachment” method of network combination the G-network is not allowed to be perturbed by the R-networks. Figure 8 shows of the RMS residuals of station coordinates after 7-parameter Helmert transformation of the deconstrained R-network to the G-network.

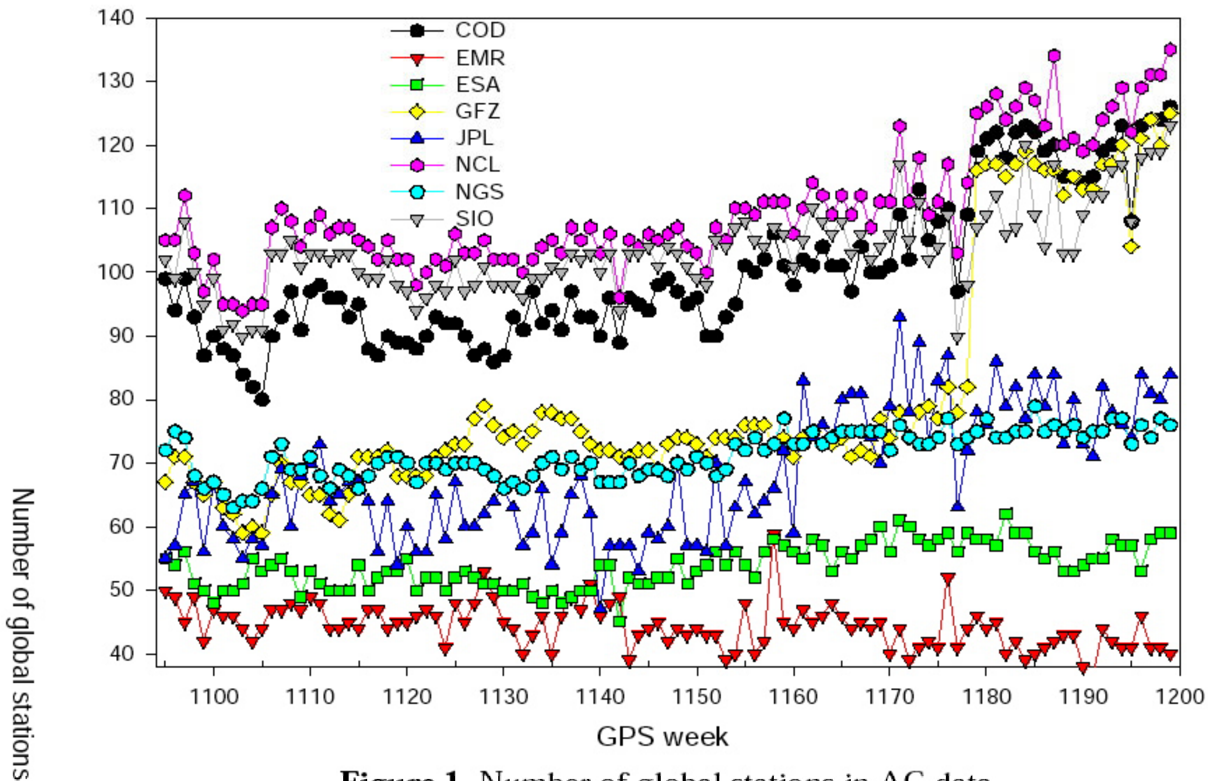

Figure 1. Number of global stations in AC data

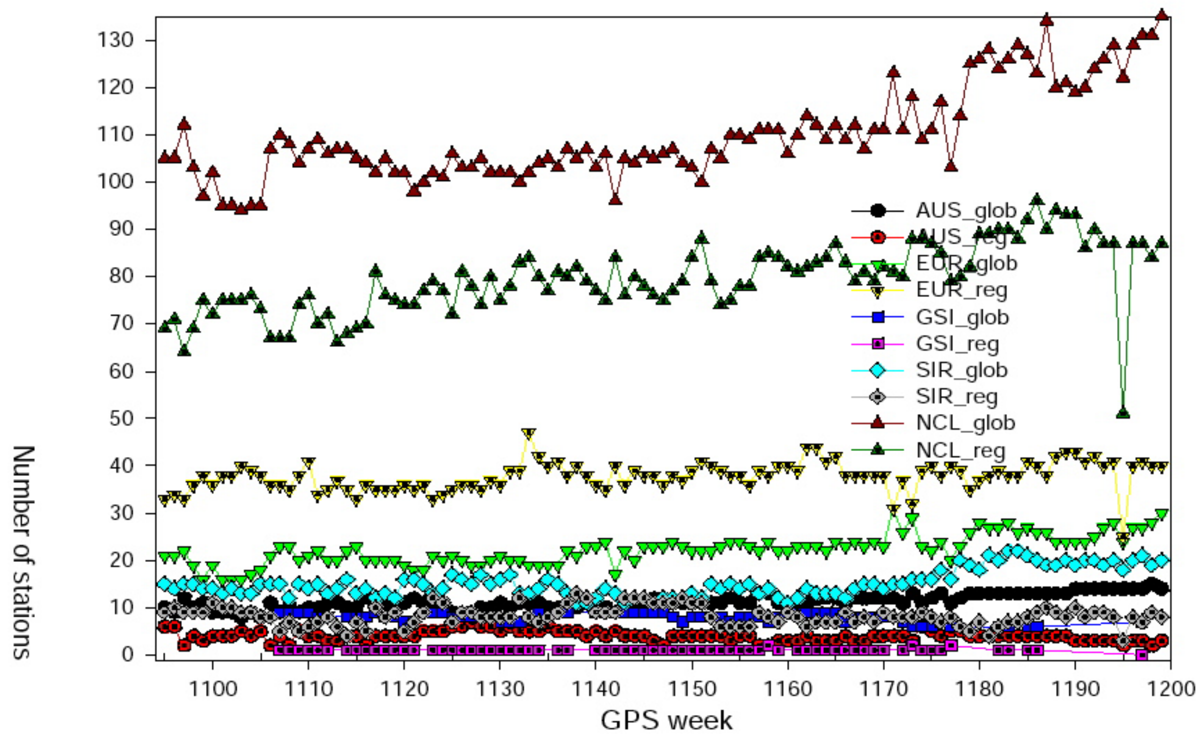

Figure 2. Number of global and regional stations in RNAAC and P-network solutions

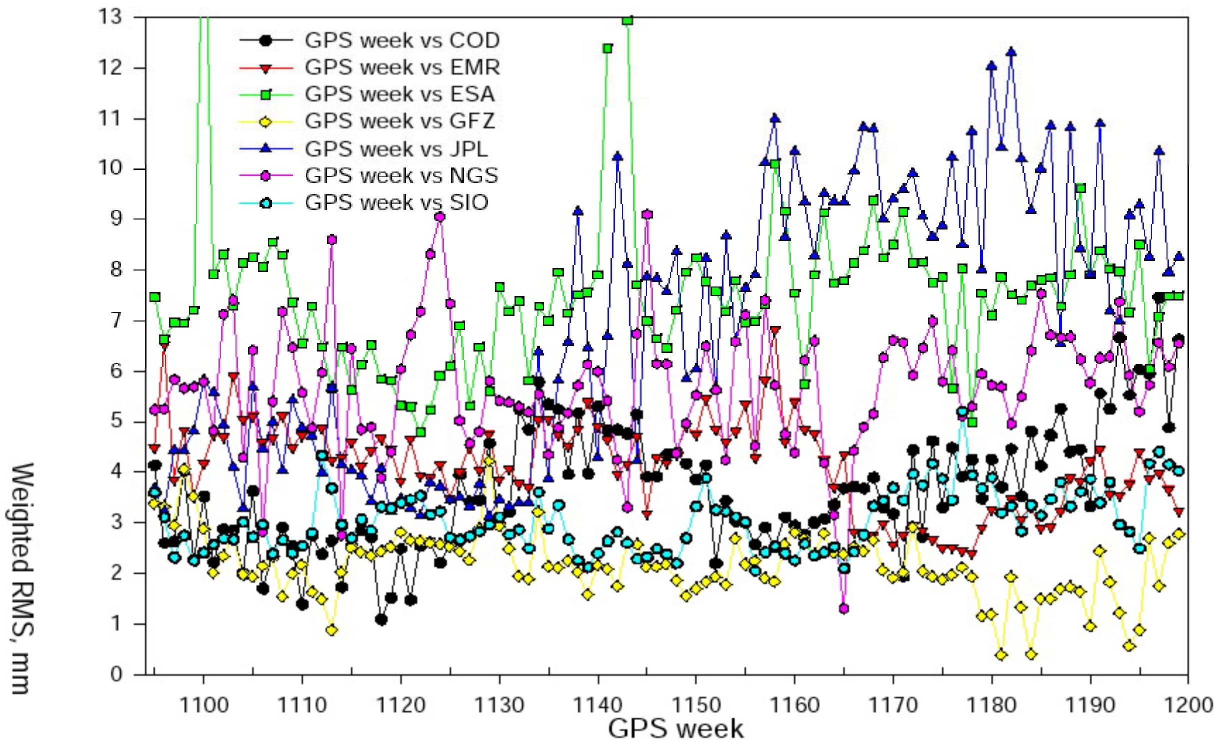

Figure 3. Weighted RMS of residuals for AC network transformation to loose NCL G-network

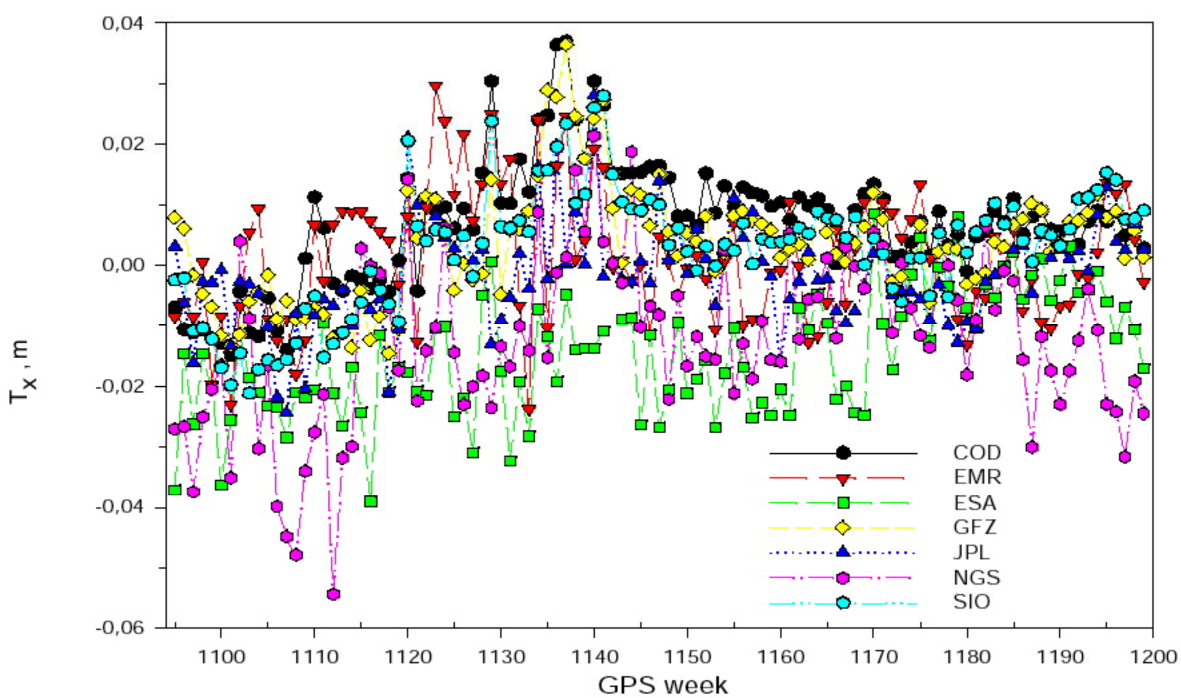

Figure 4. Time series of T_x transformation parameter for the ACs to ITRF

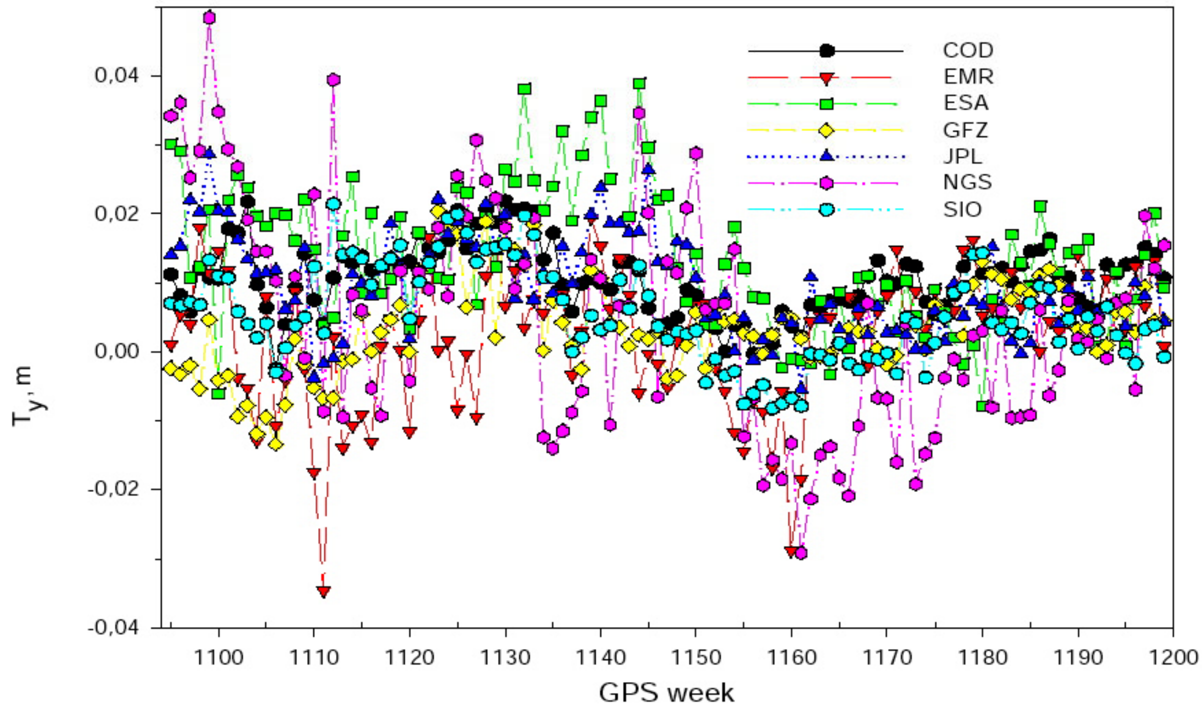

Figure 5. Time series of T_y transformation parameter for the ACs to ITRF

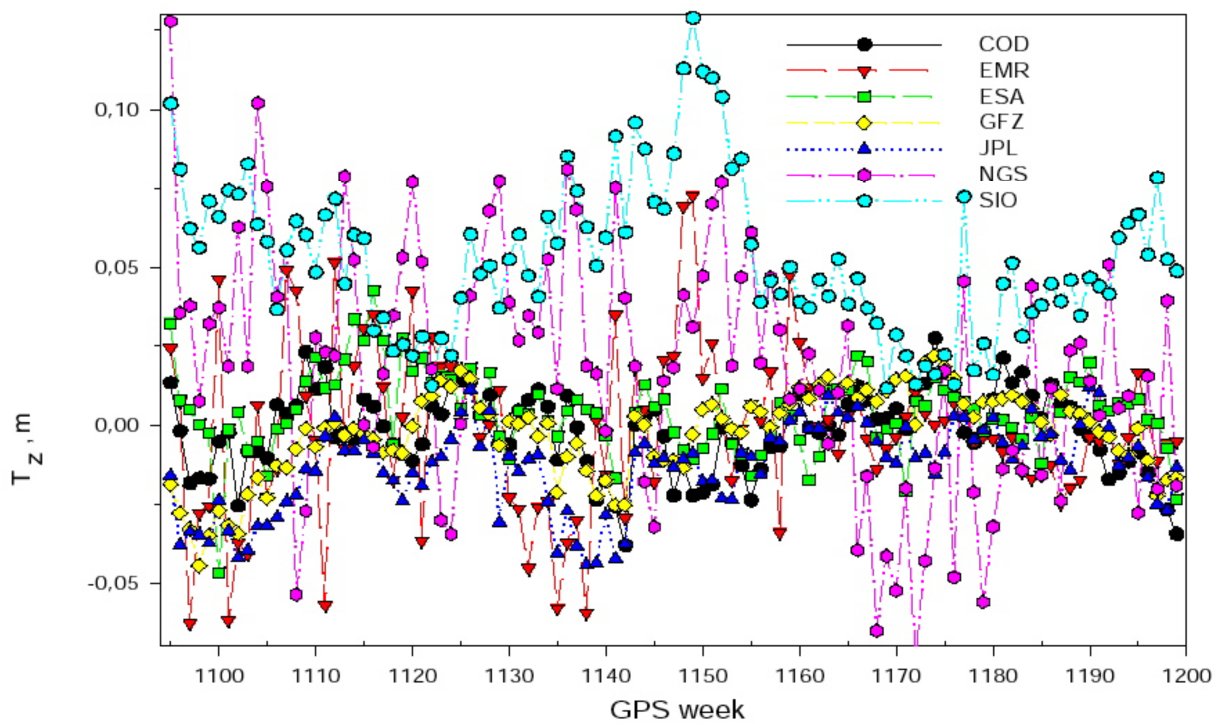

Figure 6. Time series of T_z transformation parameter for the ACs to ITRF

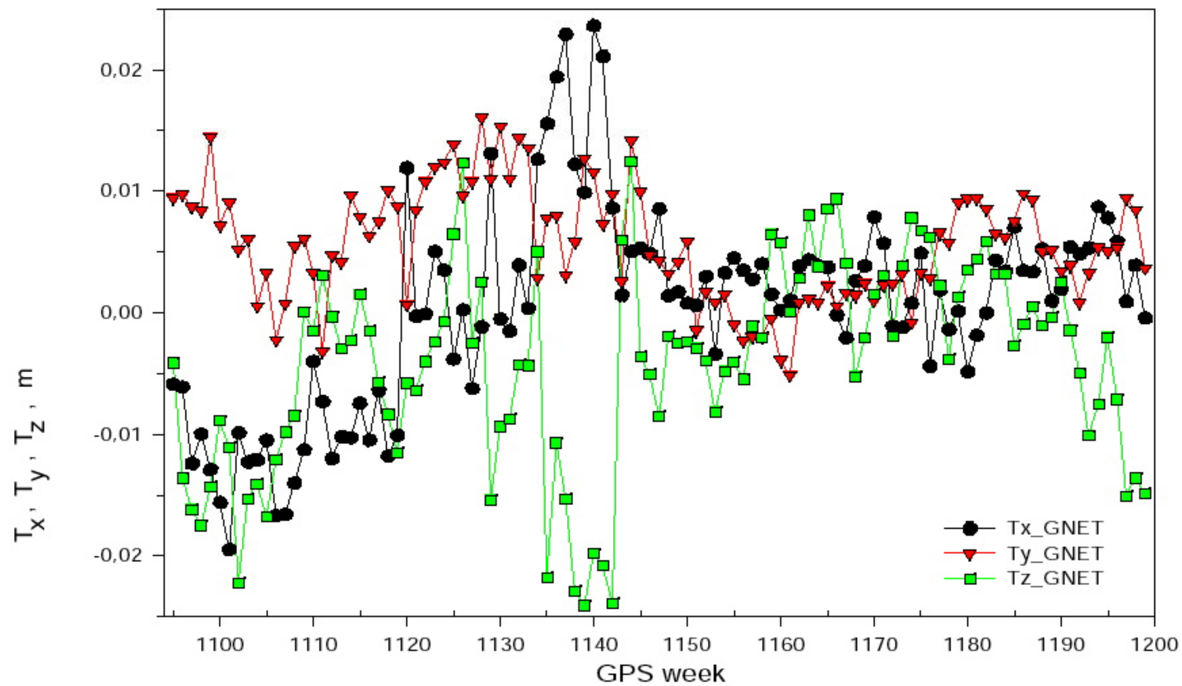

Figure 7. Time series of T_x , T_y , T_z transformation parameters for the NCL GNET to IGS

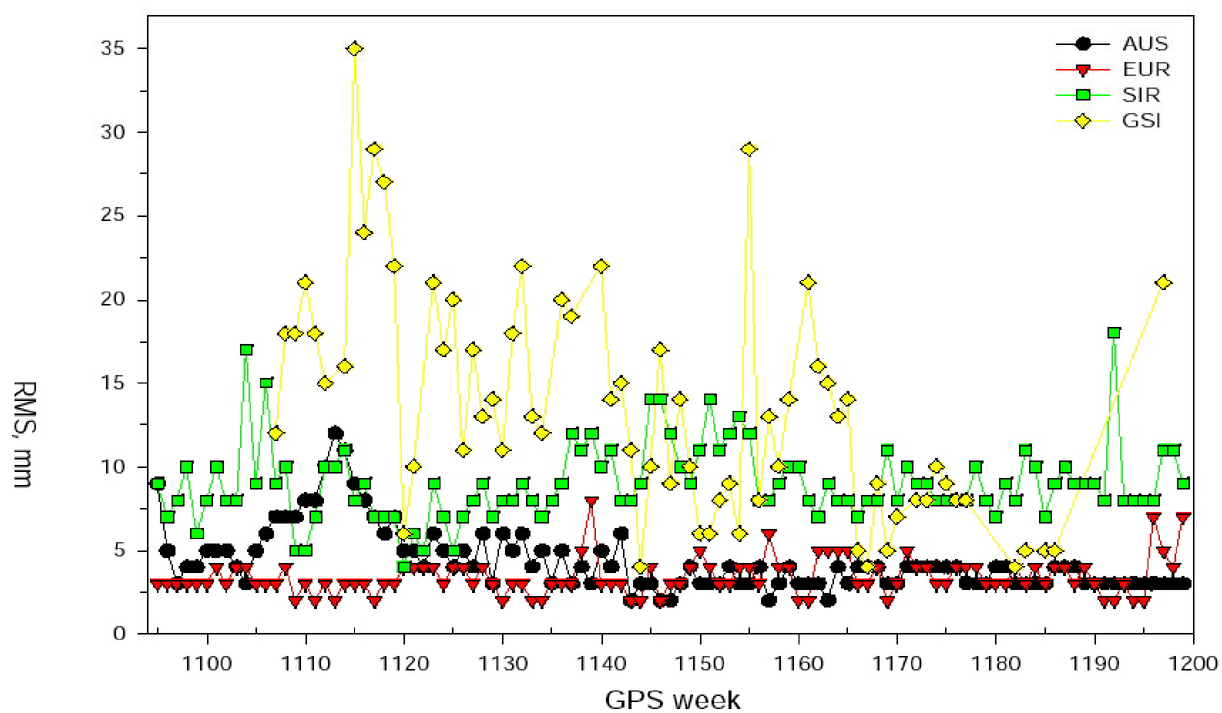

Figure 8. RMS of residuals for RNAAC R-network transformation to loose NCL G-network

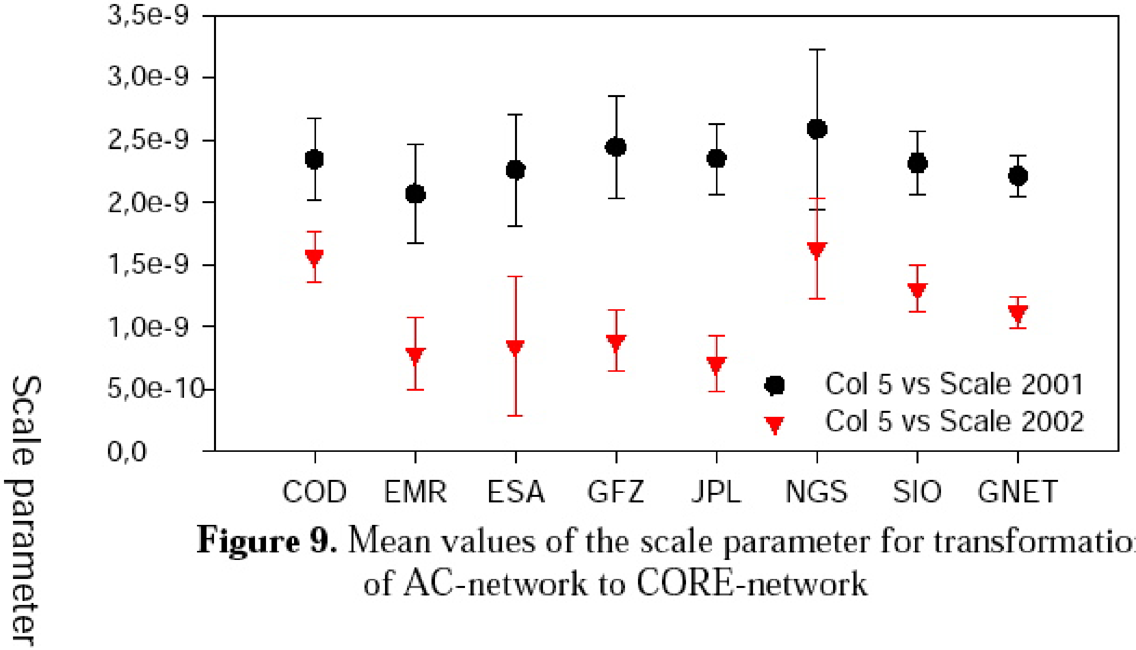

Figure 9. Mean values of the scale parameter for transformation of AC-network to CORE-network

Other Activity

NCL GNAAC P-sinex solutions over a five-year interval have been used to detect seasonal variations of station coordinates and geocentre position (Blewitt *et al.*, 2001a, 2001b). Contribution of seasonal interhemispheric (degree 1) mass transfer to variation in global mean sea level and nonsteric static ocean topography has been calculated, using published GPS results for seasonal degree-1 surface loading from the global IGS network (Blewitt & Clarke, 2003).

An online SINEX-checking facility to assist ACs in submitting SINEX files has been created at http://ucscgi2.ncl.ac.uk/~nkn3.

Summary and Outlook

The GNAAC at University of Newcastle continued to submit weekly G-network and P-network SINEX files to IGS. In the 2003, the Newcastle GNAAC continues to submit combined solutions to IGS. The TANYA software is developing further (Blewitt et al, 2000).

References

P. Davis, G. Blewitt, Methodology for global geodetic time series estimation: A new tool for geodynamics, J. Geophys. Res., Vol. 105, No. B5, pp. 11,083-11,100, 2000.

K. Nurutdinov, D. Lavallee, P. Clarke, G. Blewitt. The Newcastle GNAAC Annual Report for 1998-1999. Int. GPS Service for Geodyn. (IGS) 1999 Techn. Reports, 125-130, 2000.

G. Blewitt, P.J. Clarke, D. Lavallee and K. Nurutdinov. Degree one harmonic deformations weigh interhemispheric mass transport; a new method for determining geocenter variations. EOS Trans. AGU, 82(20), Spring Meeting supplement, S19, 2001a.

G. Blewitt, D. Lavallee, P. Clarke and K. Nurutdinov. A New Global Mode of Earth Deformation: Seasonal Cycle Detected. Science, Vol 294, pp.2342-2345, 2001b.

G. Blewitt, P. Clarke. Inversion of Earth's changing shape to weigh sea level in static equilibrium with surface mass redistribution. *J. Geophys. Res.*, 108 (B6), 2311 (doi:10.1029/2002JB002290), 2003.

G. Blewitt, D. Lavallee, P.J. Clarke, K. Nurutdinov, W.E. Holt, C. Kreemer, C.M. Meertens, W.S. Shiver and S. Stein. GPSVEL project: towards a dense global GPS velocity field. In 10th General Assembly of the WEGENER Project, extended abstracts book, Bulletin RAO 3/2000.

MIT T2 Associate Analysis Center Report 2001-2002

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Abstract
We discuss the analysis of the 2001-2002 combined solutions generated from the SINEX files submitted by the IGS analysis centers. We highlight the changes to the analysis procedures reported in previous annual reports. Analysis of our combined solutions shows mean fits to the up to 49, and on average 43, IGS reference sites in the P041 solution of 3.0 mm. For the G-SINEX combinations the median root-mean-square (RMS) repeatability in north, east, and height are 1.5, 1.6 and 5.4 mm, respectively for 256 sites. For the P-SINEX combinations, the median RMS repeatabilities are 1.6, 1.8, and 6,0 mm, respectively for 376 sites. The root mean square (RMS) scatter of the differences between daily pole position and IERS Bulletin A values is 0.08 milli-arc-seconds (mas) for both X- and Y-pole position. However, there are mean differences in Y-pole position of 0.39 mas (2001.0) and a rate of –0.09 mas/yr. The RMS scatters of the differences in polar motion rates are 0.09 mas/day for both components. For length-of-day (LOD), the RMS difference to Bulletin A is 0.023 milliseconds (ms).

Analysis Procedure Changes

As reported previously [*Herring*, 1996,1997, 2000], two analyses are performed each week. One of these analyses uses the IGS Analysis Center (AC) weekly A-SINEX files to generate a combined G-SINEX file, and the other uses the Regional Analysis Center (RAC) R-SINEX files combined with the G-SINEX file to generate weekly P-SINEX files. During 2001 and 2002, the G-SINEX files contain 256 sites that were used more than 10 times during the two years and 118 sites that were used at least 100 times. The corresponding values for the P-SINEX files are 376 and 118 sites, respectively. The G- and P-SINEX analyses are performed with 2 and 7 weeks delays.

The basic procedures we use are documented in the weekly summary files submitted with the combined SINEX files. During the 2001-2002 interval, we used the IGS realization of ITRF97 as given in IGS00P41_RS51. After GPS week 1125, we stopped using AREQ in the frame definition and variance factor calculations because of 0.5 m displacement of the site due to a nearby earthquake. After week 1110, we stopped applying a pole correction to the SIO SINEX files because they started to apply the correction in their weekly analyses. We continue to update the G- and R-SINEX files based on differences between the header information and the igs.snx file.

Deconstraining AC SINEX files

All of the IGS analysis centers now submit either loosely constrained SINEX files (JPL, SIO) or SINEX files with minimum constraints applied (EMR, GFZ, NGS, COD and ESA). For this latter group of analysis centers we add to their covariance matrix a rotational deconstraint with variance of $(10\ \mathrm{mas})^2$. This additional matrix is generated by computing the full covariance between station coordinates and Earth orientation parameters for rotations about each axis with $(10\ \text{mas})^2$ variance. The GFZ analysis center is applying constraints to the center of mass position. After week 1098, add a translation deconstraint matrix to this center's SINEX file so that the center of mass position of the combined SINEX file is not artificially constrained..

There are problems with desconstraining some the existing P-SINEX (regional SINEX) files. These analyses are performed with IGS orbits and earth orientation parameters fixed and usually have tight constraints on the sites from the G-SINEX files that are used to tie the regional networks to the global frame. For the EURREF SINEX files, the removal of the constraints applied does not appear to generate a loosely constrained solution (i.e., the standard deviations of the position estimates is still a few millimeters even after a nominal deconstraining to one meter. The regional SINEX files, after deconstraining them and re-aligning to one reference system still show discontinuities when there is a large change to the IGS system. We are sill investigating how to best account for these residual constraints. The net effect is that that P-SINEX files are not as useful as they could be in densifying the global reference system.

Earth Rotation Parameter Estimation

We carry forward into the SINEX combinations the estimates of Earth rotation parameters. In our combination we allocate elements in the Kalman filter state vector for the Earth orientation parameters (value and rate of change) for each day of the week centered at 12:00 UTC. The stochastic variations in these parameters are treated as a combination of a random walk (process variance 1 mas^2/day for pole position, and 0.066 ms^2/d of UT1) and integrated random walk (0.1 $\text{mas}^2/\text{day}^3$) for pole position and 0.007 ms^2/day^3 for UT1). The initial values at the start of the week are assumed to have variances of $(100\ \text{mas})^2$ for pole position, $(10\ \text{mas/day})^2$ for polar motion rate, $(6.7\ \text{ms})^2$ for UT1 and $(0.67\ \text{ms})^2$ for length of day. We ignore the values of UT1 given in the input SINEX files, i.e. the estimates of UT1 in our combined SINEX files are the IERS Bulletin A values at the start of week and integration of LOD for later days in the week.

We apply corrections to the submitted SINEX for some centers. For JPL, prior to January 1, 2000, we treat the input LOD as being regularized even through it is not given as LODR. For all dates, we reverse the sign of LOD since the submitted values appear to be the time derivative of UT1. For GFZ, we reverse the sign of UT1 since it appears to be given as UTC-UT1. (This latter change has little effect because we do not use the UT1 values).

Analysis Of Combined Solutions

Our analysis of 2001-2002 combined SINEX files examines the internal consistency of these combinations and their agreement with IGS97. In figure 1 we show for each weekly combination, the RMS agreement between the IGS977 reference sites. The list and number of sites used each week is given in weekly summary. This RMS is computed from the combination of the north, east, and height differences after a translation, rotation, and scale are removed from the weekly combination. In computing the RMS, the height is down-weighted by a factor of 3, i.e., we construct a weight matrix with the heights given one-tenth the weight of the horizontal components.

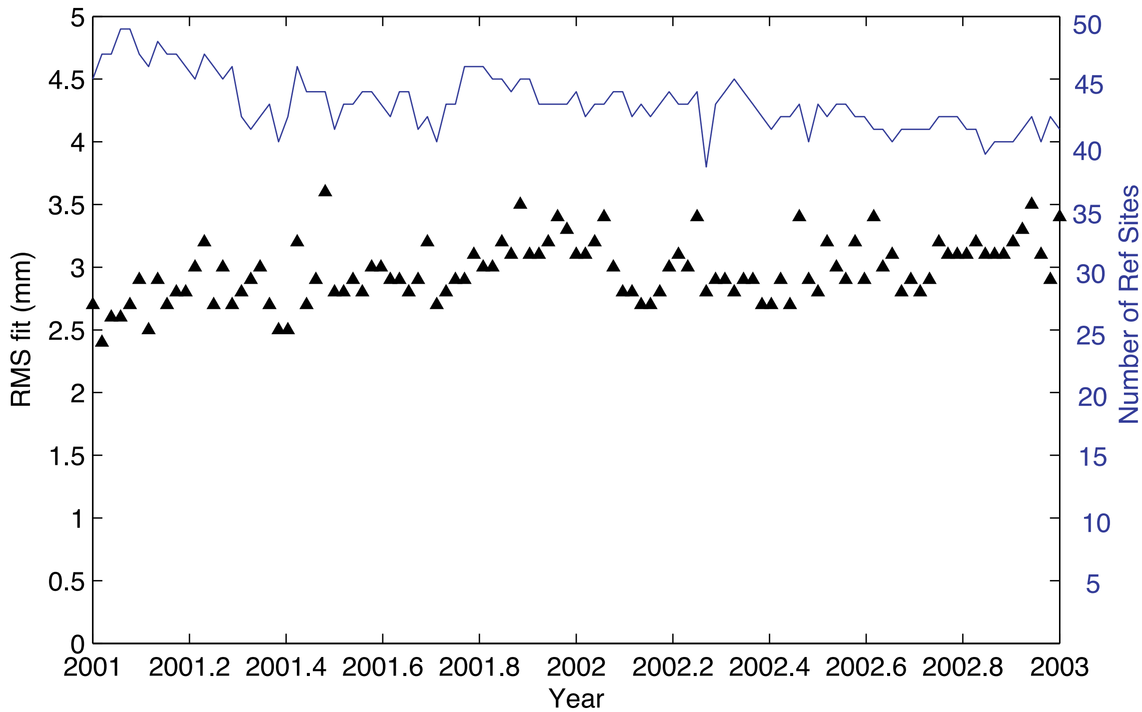

Figure 1: RMS fit of the weekly combinations to the up to 49 IGS97 reference sites. The mean RMS fit is 3.0 mm with a mean of 43 stations form the reference site list used.

In Figure 2 we show the differences in the pole position estimates between the MIT G-SINEX combination and IERS Bulletin A. The significant difference here is the offset and a mean rate of change between the Y-pole position and evolution given by the IGS97 station coordinate and velocity reference system and IERS Bulletin A. The LOD differences to Bulletin A do show any particular systematic behavior and have an RMS difference of 0.023 ms. The observed offset and drift in the Y-pole position presumably arises from differences in the IGS97 system site positions and velocities and those implicit in the IERS system.

In Figure 3, we show the positions of the sites in the G- and P-combinations. The time series of the position estimates can be found at http://www-gpsg.mit.edu/~fresh/MIT_IGS_AAC. The IGS weekly combination produced by Natural Resources Canada (NRCan) is updated weekly on this site. The time series from the other IGS centers shown are only updated occasionally. The statistics of the position residuals, after removal of linear trends, are given in Table 1. Analyses of the residuals do show offsets in the time series that are thought to arise from the residual effects of constraints on the solutions that cannot be completely removed. More detailed analysis of this problem is required at the moment.

We also make available Matlab based tools for the analysis of the IGS combined solution. These tools are available at http://www-gpsg.mit.edu/~tah/GGMatab. On the MIT IGS AAC web page a compressed tar file is available that contains the IGS weekly time series in a format suitable for use with these tools (http://www-gpsg.mit.edu/~tah/MIT_IGS_AAC/igsw/igsw.tar.Z)

Table 1: Distribution of the root mean square (RMS) scatters of the position estimates after removal of a linear trend for the North, East and Height components for the G- and P-SINEX combinations. Values shown are the RMS scatters below which either 50, 70 or 90% of the sites lie.

Component	G-SINEX Combination (256 sites)			P-SINEX Combination (359 sites)		
	50 % (mm)	70% (mm)	95%(mm)	50%)mm)	70% (mm)	90% (mm)
North	1.5	1.9	3.6	1.7	2.4	4.2
East	1.6	2.0	3.5	1.9	2.4	6.5
Height	5.4	6.5	10.6	6.0	7.7	13.8

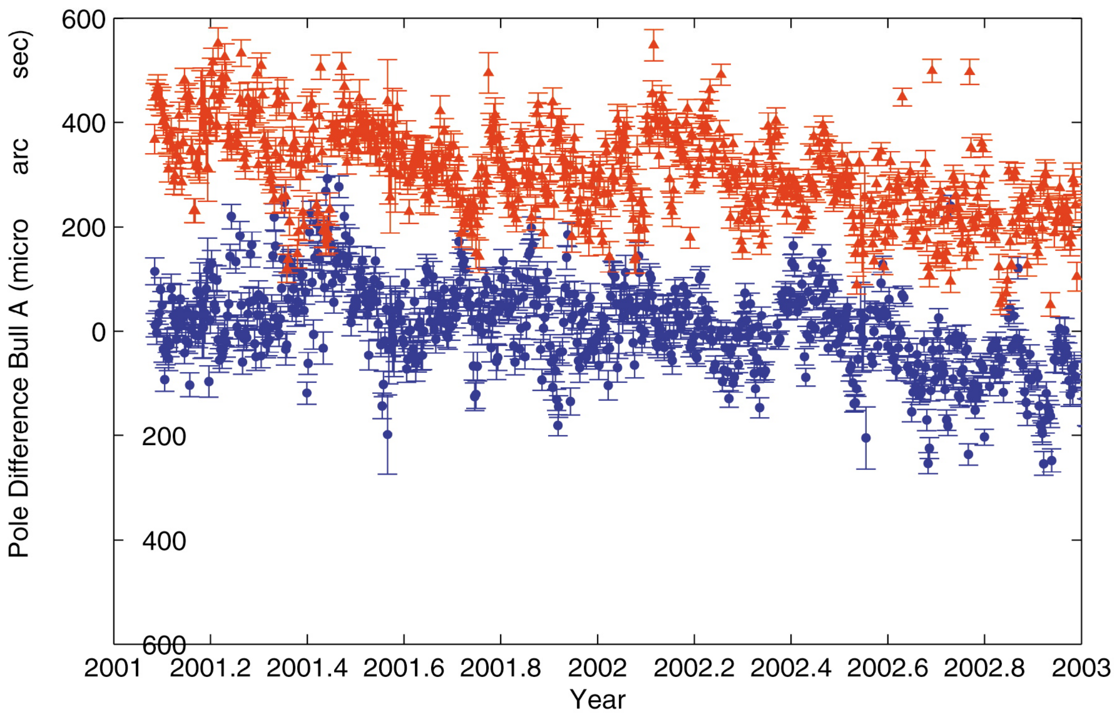

Figure 2: Differences between the X-pole (blue circles) and Y-pole (red triangles) position estimates from the MIT G_SINEX combination and IERS Bulletin A. The RMS differences after removal a mean X-pole offset of 0.003 mas and a Y-pole offset of 2001.0 and trend of 0.39 mas and –0.09 mas/yr are both 0,08 mas. The mean and RMS difference for LOD (not shown) are 0.008 ms and 0.023 ms.

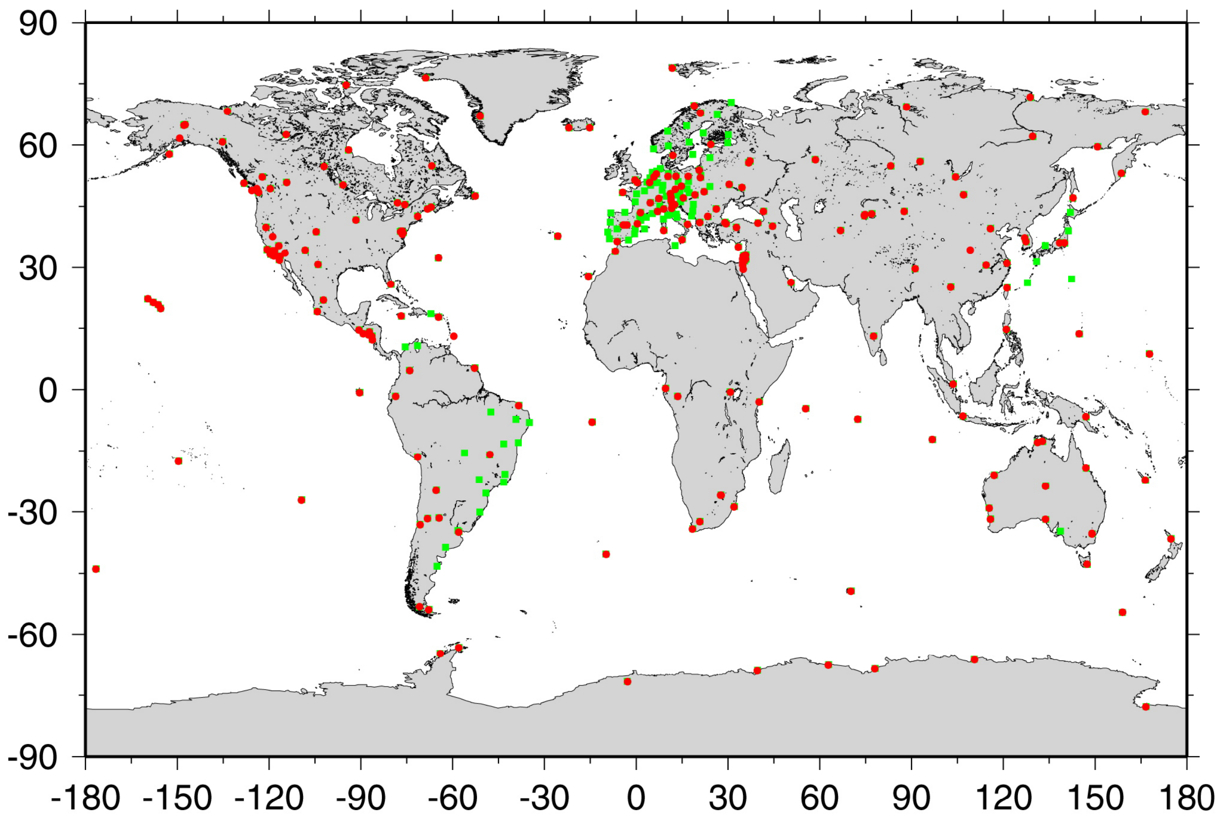

Figure 3: Global distribution of sites used more than 10 times between 2001 and 2002 in the G-SINEX (red circles) and P-SINEX (green squares) combinations. There are 246 sites in the G-SINEX files and 315 sites when the G- and P-SINEX files are combined.

References

Herring, T. A., MIT Global Network Associate Analysis Center Report, *International GPS Service for Geodynamics (IGS) 1995 Annual Report*, pp. 203-207, 1996.

Herring, T. A., MIT T2 Associate Analysis Center, *International GPS Service for Geodynamics (IGS) 1996 Annual Report*, pp. 255-267, 1997.

Herring, T. A., MIT T2 Associate Analysis Center 2000 *International GPS Service for Geodynamics (IGS).* http://www-gpsg.mit.edu/~tah/MIT_T2_Report_2000.pdf

IGS

REGIONAL NETWORK ASSOCIATE ANALYSIS CENTERS

The EUREF Permanent Network in 2002

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Introduction

The EUREF Permanent Network (EPN) consists of GPS tracking stations, data centers and analysis centers organized following a similar hierarchy as the IGS and based on voluntary contributions.

Growth of the Tracking Network

The EPN tracking network has continued to operate successfully during the year 2002, integrating 10 new stations in its network (see Figure 1):

AMMN*	Amman, Jordan			IGS		
BOGI	Borowa Gora, Poland	H		IGS	GL	M
LPAL	La Palma, Canarian Islands, Spain	H				
LROC	La Rochelle, France		TG	IGS		
PULA*	Pula, Croatia	H				
MORP	Morpeth, UK	H		IGS		
MIKL	Mykolaiv,Ukraine			IGS		
NYIR	Nyirbator, Hungary	H				
QAQ1	Qaqortoq, Greenland	H		IGS		M
SPT0	Boras, Sweden	H		IGS	GL	

With:

- H = Hourly data submission
- TG = ***Collocated with tide gauge***
- **IGS** = Included in the IGS network
- **GL** = GPS/GLONASS station
- **M** = Collocated with meteorological instrument
- ***** = Station is presently not active

The total number of EPN stations reached 137 at the end of 2002; about 58% of them deliver hourly data.

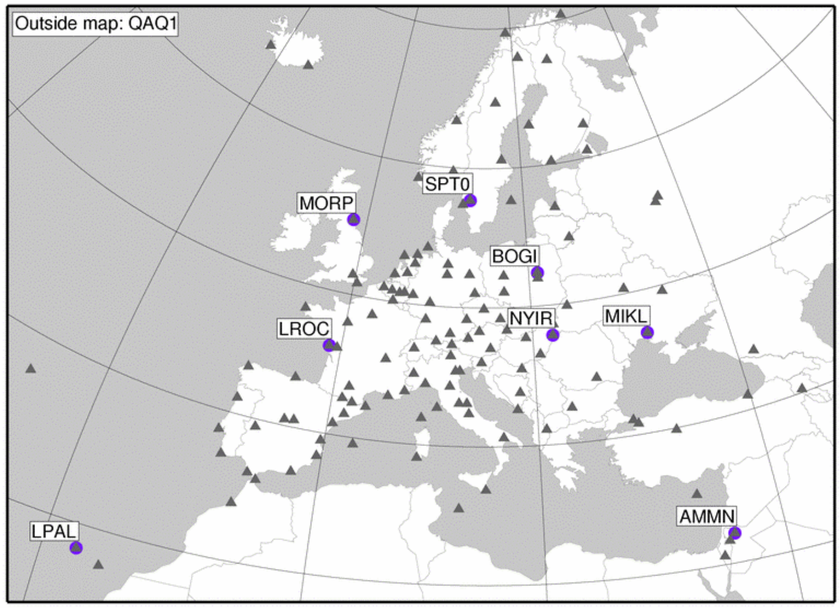

Figure 1: EPN tracking network (status Dec. 2002), stations denoted with circles joined the EPN in 2002.

Data Flow

During 2002 the problem of generating daily files from hourly ones was discussed. Daily files could be generated from hourly files to avoid the heavy traffic after midnight at the data centres. A minor problem is to avoid the sending of the same data twice. Comparing the size of a compressed RINEX file to other sources only the amount of 200 images or 50 MB a day will be saved. In 2003 some rules for creating daily files by concatenating hourly ones have been established.

There were some problems concerning the method of transfer by ftp. New ftp programs tend to transfer data in passive mode, which is sometimes rejected or restricted by the servers of the data centres. The reason is that both active and passive mode creates a security hole either in the uploading or receiving machine. Since anonymous ftp is the most comfortable and most general way to transfer data automatically one should stay to this method. However, during the next years a solution should be found which could replace the anonymous ftp and its use of lower port numbers. Because such a replacement affects the whole chain from the station managers over the data centres to the users downloading data, several platforms, like unices, Linux, Windows and Mac OS, have to be considered.

EUREF-IP Pilot Project - Real-time GNSS Data via Internet and Mobile IP Networks

Due to the increased capacity of the Internet, applications which transfer continuous data-streams by IP-packages, such as Internet Radio or Internet Video-on-Demand, have become well-established services. Growing mobile IP-Networks like GSM, GPRS, EDGE, or UMTS furthermore allow the mobile use of these real-time services. Compared to Multimedia applications, the bandwidth required for streaming GNSS data is relatively small. As a consequence, the global Internet can be used for the real-time collection and exchange of GNSS data, as well as for broadcasting derived differential products.

EUREF decided in June 2002 to set up and maintain a real-time GNSS infrastructure on the Internet using stations of its European GPS/GLONASS Permanent Network EPN. Although today's primary objective is to disseminate RTCM corrections over the Internet for precise differential positioning and navigation purposes (see *Resolution No. 3 of the EUREF symposium in Ponta Delgada, June 5 - 8, 2002*), various other applications are in sight like real-time orbit determination and ionosphere or troposphere parameter estimation.

A pilot project was established called EUREF-IP (IP for Internet Protocol). This real-time GNSS data service uses a new dissemination technique called "Networked Transport of RTCM via Internet Protocol" (Ntrip). Ntrip stands for an HTTP application-level protocol streaming GNSS data over the Internet. Currently about 110 data streams are available through EUREF-IP Ntrip Internet Broadcaster. Most of the stations generate pseudorange corrections (DGPS), other streams include carrier phase information (RTK) or raw measurement data. Seven real-time data streams are part of the EUREF-IP pilot project, the others are generated by various networks in Europe and US, among these about 15 European IGS stations. Currently no worldwide concept exists for GNSS Real-Time data dissemination. For the future it would be desirable to coordinate the efforts of EUREF-IP and IGS Real-Time Working Group.

The Broadcaster's Internet connection handles a maximum of 1000 users simultaneously. Some of the data streams are available for demonstration purposes and thus are accessible without authentication/authorization. For receiving protected data streams, the user needs a user-ID and a client password.

For receiving the real-time data the program "GNSS Internet Radio" is available for MS Windows, Windows CE and Linux operating systems. This client program is designed to run on a PC, Laptop or Pocket PC. It handles all communication through HTTP and transfers the received GNSS data to a serial or IP port supporting a networking software or DGPS/RTK application.

Further information at: http://www.epncb.oma.be/projects/euref_IP/euref_IP.html

Data Analysis

The EPN continued to apply the proven method of combining the EPN sub-network solutions as computed by Local Analysis Centres (LACs) into one official EPN solution. The Slovak University of Technology Bratislava, Slovakia (EPN abbreviation: SUT) joined the group of LACs at GPS week 1182 (September 2002) and increased the number of LACs to 16.

An IGS initiative of regional networks densifications has been presented at the IGS 2002 workshop in Ottawa, Canada. Various methods of datum definition for the densification of the global IGS polyhedron by regional networks were discussed. In order to contribute to this initiative, the EPN Analysis Coordinator (AC) started to generate two new EPN solutions.

- The first solution fixes all station coordinates of the weekly IGS global network solution and combines the IGS and the EPN networks only solving for the non-IGS stations of the EPN. The solution is generated routinely since GPS week 1136.

- The second test solution has been generated routinely since GPS week 1149 and combines the cumulative IGS global solution with a cumulative EPN solution following the datum definition strategy of the first test solution.

The EUREF TWG decided at a meeting in March 13 and 14, 2002 not to publish the results of these two test solutions as long as there is no clear recommendation for the datum definition by the IGS. It is important to save the users from too many different solutions, as was stressed at this meeting. However, the results of these solutions are available for scientific comparisons on request and they are used for internal consistency checks.

Since Dec. 2002, new guidelines for EPN Analysis Centres have been issued (http://www.epncb.oma.be/guidelines/guidelines_analysis_centres.html). Next to the general guidelines for the EPN AC's, they include information for new local analysis centres as well as an historical overview of all processing options.

Time Series Special Project

The basic aim of the Special Project is the monitoring of the EPN time series, in order to identify and eliminate the outliers and offsets present in the original EPN weekly combined solutions. Adding this information back to the original time series the estimated site velocities, especially for the height component can be substantially improved. The monitoring is based on the so-called *standard EPN time series* produced by C.Bruyninx and G.Carpentier at the EPN CB. These time series are used for the identification of time series inconsistencies related to equipment change at the sites. Then the found offsets are estimated in a separate run of the Bernese ADDNEQ program. The procedure is repeated offset-by-offset, where the previously estimated offset is introduced into the processing.

The retrospective analysis has been completed in 2002, than the offset and outlier database is being maintained periodically. Although the newly appearing offsets can be easily identified the reliable offset estimation can be done only with a few months delay. The main product of this work is the '*improved EPN time series'* published and periodically updated at the EPNCB website. The set of estimated offset values and outlier periods, which is collected in the Bernese format STACRUX.EPN file is being made also public and being published at the Time Series section of the EPNCB website October, 2003. Another product is a set of velocities, which are estimated by the Bernese ADDNEQ program based on the cumulative solution of the improved weekly EPN combined SINEX files. The estimated velocities are also published at the EPNCB. The height component velocities have been compared to VLBI and levelling solutions and gave good agreement.

Troposphere Special Project

The objective of the EPN Special Project "Troposphere Parameter Estimation" is the generation of a EUREF-troposphere product. A weekly combined troposphere solution for all sites included in the EUREF Permanent Network is computed. The Special Project started in June 2001 (GPS week 1110). Since GPS week 1143 all Local Analysis Centres have been participating. Besides some changes of processing options for the standardization of the analyses and improvement of the results in GPS week 1130, two changes have been introduced into the troposphere parameter estimation concerning the constraining of the weekly coordinate solution to ITRF and the fixing of the weekly coordinate solution during the final estimation of the daily troposphere parameters. These steps showed a significant reduction of the weekly mean biases between the combined solution and the individual solutions below 3-4 mm in Zenith Total Delay values.

Two institutions have been performing the combination of the individual solutions, GeoForschungsZentrum Potsdam and Bundesamt für Kartographie und Geodäsie, Frankfurt. The differences between the two solutions are below 0.2 mm in Zenith Total Delay for the mean bias with a standard deviation of ± 0.5-0.6 mm. More about the combination procedure and detailed results are presented in (Soehne and Weber, 2002).

Starting with GPS week 1203, the EUREF troposphere combination has been contributing to the IGS combination of Zenith Total Delay values. Since the IGS combination has a stringent timeliness a preliminary EUREF troposphere combination is calculated every week with all individual solutions arrived so far. The reason for the weekly mean bias of ~ 2-4 mm ZTD of the EPN solution is probably that the EPN solution is a regional solution whereas the other contributing solutions are global solutions (Soehne and Weber, 2003).

Network Coordination

Similar to the IGS, the EPN changed site log format on June 11, 2002. In addition, automated site log tests and submissions through e-mail have been introduced.

In 2002, the following items were added to the website of the EPN Central Bureau (http://www.epncb.oma.be/):

- Daily updated web-pages with an overview of metadata errors going back to mid 1998
- On-line papers related to the EPN activities (http://www.epncb.oma.be/papers.html)
- EPN coordinate time series expressed in the ITRS and ETRS89 (http://www.epncb.oma.be/series.html)

Due the growing number of IGS stations in Europe, the EPN TWG decided that from March 2002 on, IGS stations located in Europe, should separately apply to join the EPN (see http://www.epncb.oma.be/guidelines/procedures_becoming_station.html), instead of being automatically included in the EPN, as was done in the past.

References

Soehne, W., Weber, G. (2002): "EUREF Troposphere Combination at BKG – First Results and Improvements", Proceedings of the COST Action 716 Workshop "Exploitation of Ground-Based GPS for Meteorology", January 28-29, 2002, GeoForschungZentrum Potsdam

Soehne, W., Weber, G. (2003): "Progress and status of the EPN Special Project 'Troposphere Parameter Estimation'", Proceedings of the EUREF Workshop, June 04-07, 2003, Toledo (in press)

Geoscience Australia RNAAC – 2002 Annual Report

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Introduction

The RNAAC function of routinely processing all stations in the Australian Regional GPS Network (ARGN) continued during 2002. The weekly combined SINEX result files were submitted to the Crustal Dynamics Data Information System (CDDIS).

Station Network

The station network processed by the Geoscience Australia (GA) RNAAC as at December 2002 is shown in Figure 1. Fifteen of the nineteen stations in this network are operated by GA. The stations AUST, NNOR, PERT and TIDB are owned and operated by other agencies.

Commencing GPS week 1174 site NNOR was added to the solution. Commencing GPS week 1194 site MOBS was added to the solution.

Data Analysis and Results

The Bernese GPS Software version 4.2 (Hugentobler, Schaer and Fridez 2001) was used for the GPS data processing. Daily solutions were computed using the following strategy:

- L3 double differenced phase observable.
- No resolution of integer ambiguities.
- Elevation cut-off angle of 10°.
- Elevation dependent observation 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 TIDB or YAR2).

Seven daily solutions are combined at the normal equation level to obtain the weekly solution output in SINEX format submitted to the CDDIS. These solutions were tightly constrained to the station coordinates from the IGS00 realisation of ITRF2000 at the following IGS reference stations; CAS1, CEDU, DAV1, HOB2, MAC1, PERT, TIDB and YAR2.

The Geoscience Australia RNAAC weekly SINEX solution files were included in the GNAAC combination generated by the Massachusetts Institute of Technology (MIT) and the University of Newcastle upon Tyne Polyhedron solutions.

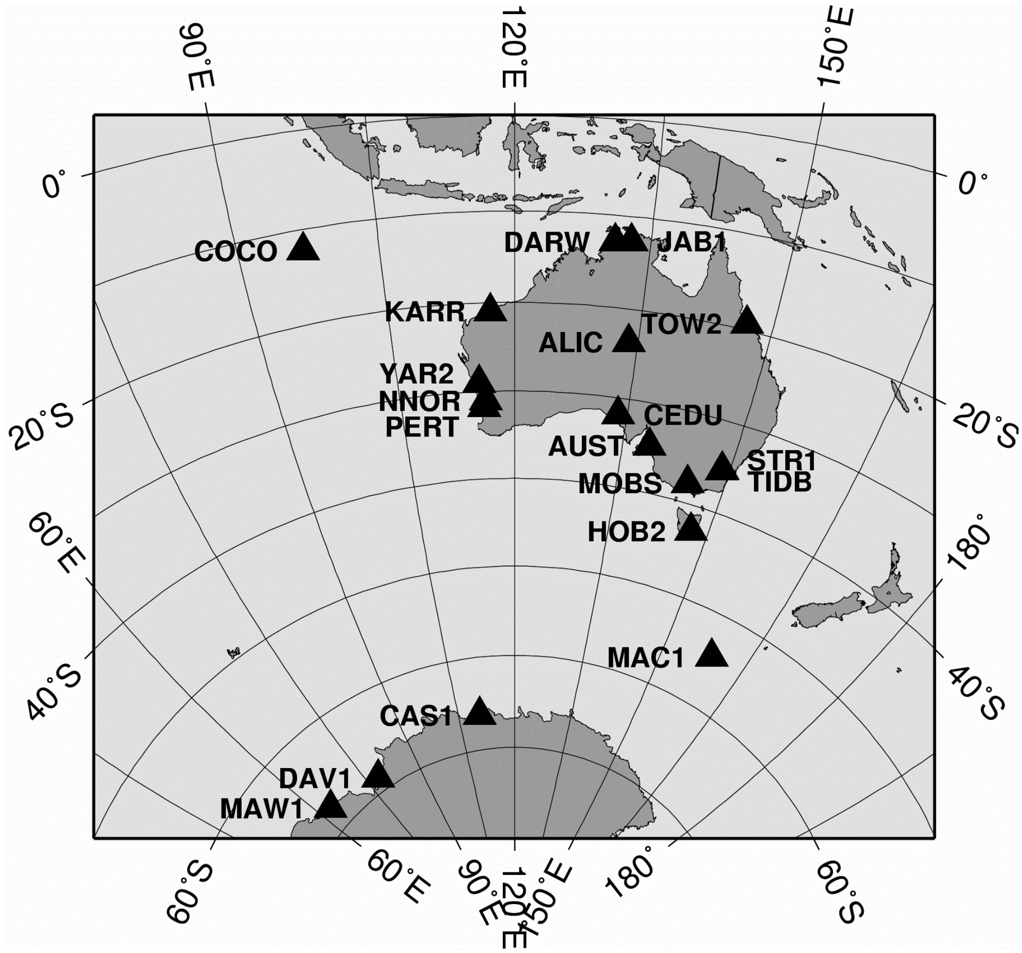

Figure 1. Geoscience Australia RNAAC station network as of 31 December 2002

Other GPS data processing and analysis activity at GA include:

- IGS GPS Tide Gauge Benchmark Monitoring Project as a type A analysis centre.
- The South Pacific Sea Level & Climate Monitoring Project.
- Asia Pacific Regional Geodetic Project (annual observation campaigns).
- Australian South West Seismic Zone monitoring project.
- South Australian Seismic Zone monitoring project.

References

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

GSI RNAAC Technical Report 2002

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Introduction and Overview

Since 1996, Geographical Survey Institute (GSI) has been contributing as a Regional Network Associate Analysis Center (RNAAC). The network for the GSI's analysis consists of 10 IGS global sites (Figure 1a) and 7 domestic GPS sites (Figure 1b).

Outline of Processing

Coordinates and covariance are generated in daily basis using GAMIT version 9.95 and they are combined with GLOBK version 5.04 to generate weekly solutions with loose constraint.

The specification of the analysis is as follows;
Final IGS orbits and Earth orientation parameters are applied.
Measurement elevation cut-off angle of 20 degrees
Data rate of 30 secs for single-day adjustments.
Tropospheric zenith delays are estimated every 3 hours.
Station coordinates estimated, applying a priori sigma of ~10m.

Since the 1145th week, we've input the data from YAR2 instead of YAR1 due to the trouble with YAR1 reported in IGS mail No. 3884.

Current State

The standard deviation of GSI RNAAC weekly solution is shown in Figure 2. The results of the latter half year seem to be stable.

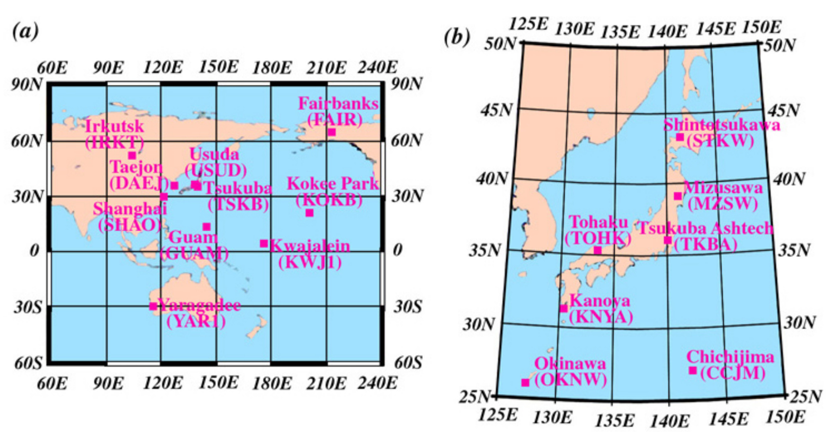

Figure 1. GPS observation sites for GSI RNAAC analysis
(a) IGS global sites (b) domestic sites

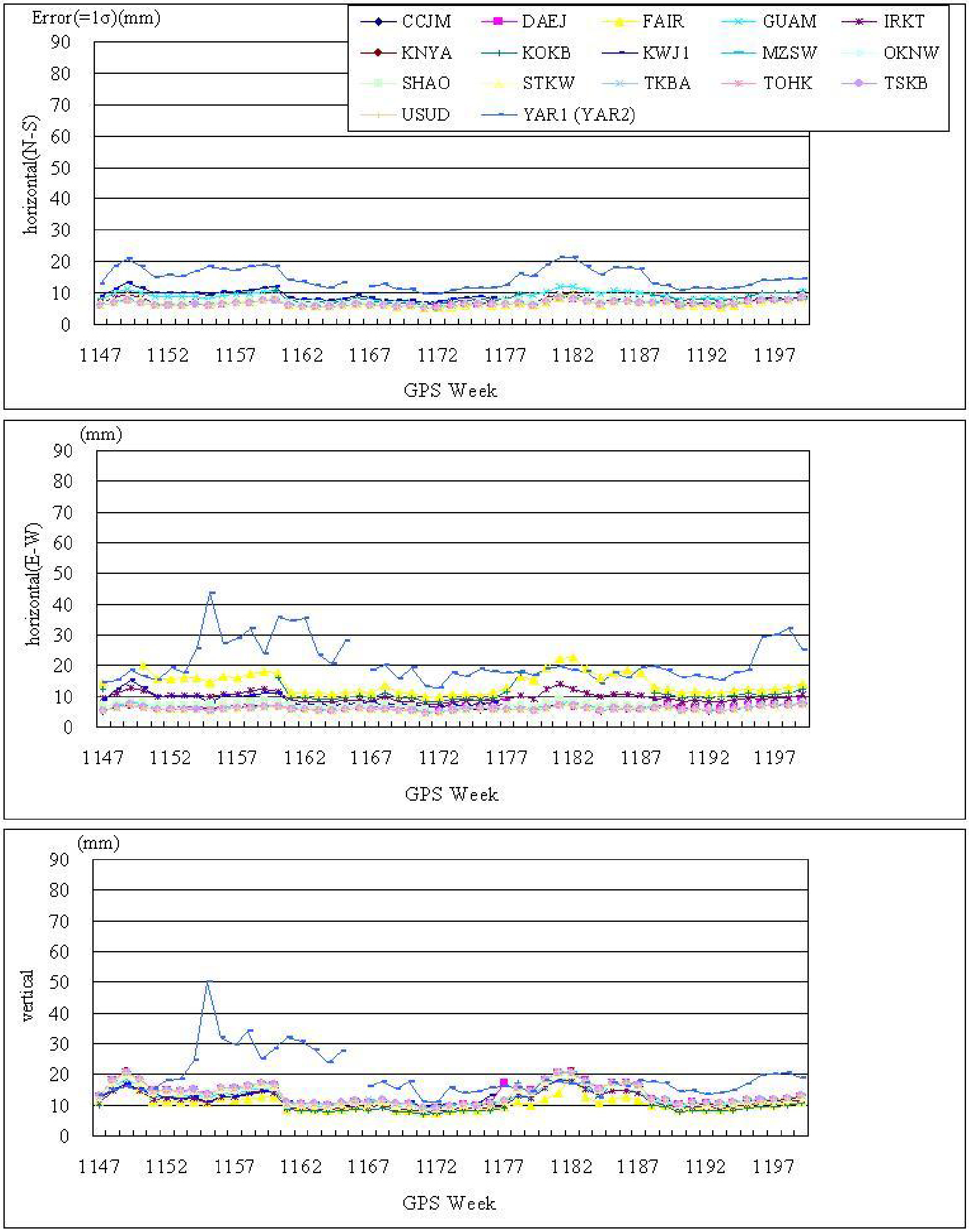

Figure 2.Standard Deviation of GSI RNAAC weekly solution

Annual Report 2002 of IGS RNAAC SIR

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Abstract

Changes in the RNAAC SIR station network and a new solution for coordinates and velocities are presented in this report. Additionally the impact of an earthquakes near Manzanillo (Mexico) on the weekly coordinate solutions and the velocity estimates are shown. The processing strategy is updated to include the influence of ocean loading.

Station Network

End of 2002 the network of IGS RNAAC SIR consisted of 62 GPS stations, 19 of them are regional stations (see fig.1). New global IGS stations are Key Biscayne (AOML)/USA, Ensenada (CIC1)/Mexico, Freetown (FREE)/West End (BHMA) on Bahamas, Santiago de Cuba (SCUB)/Cuba, and Concepcion (CONZ)/Chile, the GPS instrument of the German Transportable Integrated Geodetic Observatory (TIGO). New regional stations are Crato (CRAT)/Brasil, and Mar del Plata (MPLA)/Argentina.

Solutions

From GPS week 1156 onward the ocean loading effects are considered in the weekly solutions of IGS RNAAC SIR. At the International Symposium on recent Crustal Deformation in South America and surrounding areas (IAG), Oct. 21-25, 2002 in Santiago de Chile the new solution of coordinates and velocities was presented. Fig.1 shows this solution DGFI02P01 which covers the time period from June 30, 1996 to August 31, 2002. It is compared with ITRF2000 and the geophysical solution NNR NUVEL-1A. Again the solution is based on weekly SINEX files generated by the IGS RNAAC SIR. The velocities are given in figure 1 only for stations with more than one year of observations.

As already shown in the annual report for 2001, earthquakes are monitored in the region of the RNAAC SIR. An earthquake with significant displacements on the station Manzanillo (MANZ) was detected. The co-seismic and post-seismic displacements are shown in figures 2 and 3.

Conclusion

It becomes more and more clear that we have to consider seriously the proper modelling of episodic events like earthquakes which cause large displacements at the IGS RNAAC SIR stations as shown for the GPS sites San Salvador and Arequipa (see annual report 2001), and Manzanillo in 2002.

Including the effects of ocean loading has strengthened the daily solutions so that the repeatability from day to day processing is below one cm for the North and East components, and about one cm for the up component. The accuracy of the new velocity estimates of the solution DGFI02P01 increased due to more observation data, and for some more stations velocity estimates could be generated.

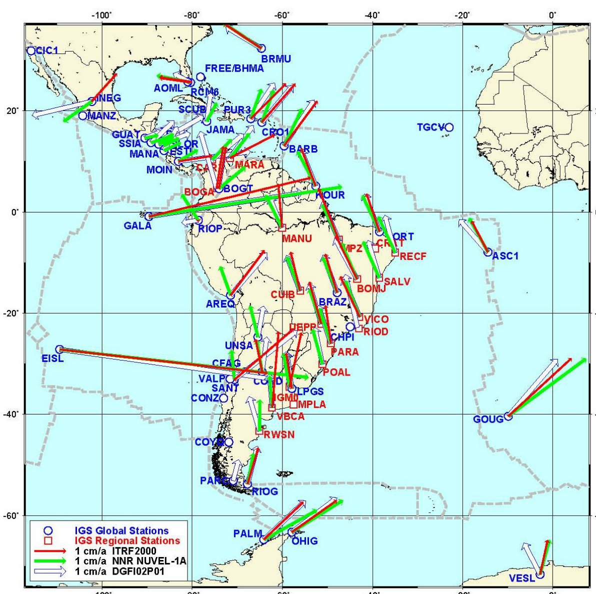

Figure1: IGS RNAAC SIR network and horizontal velocities of solution DGFI02P01 compared with ITRF2000 and NNR NUVEL-1A

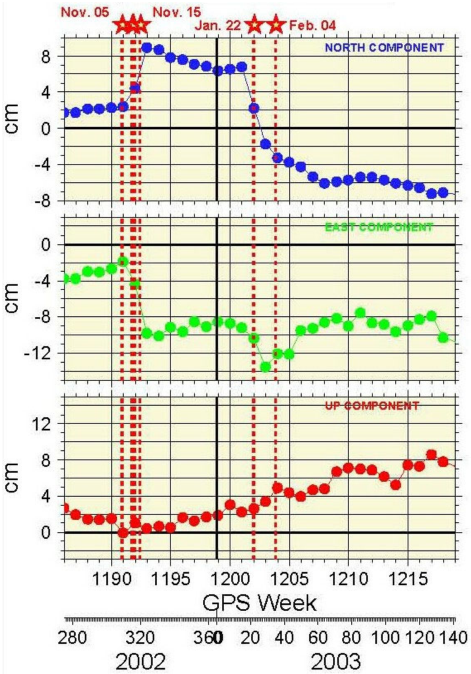

Fig.2 (above): Weekly variations of Station MANZ positions due to earthquakes near Manzanillo

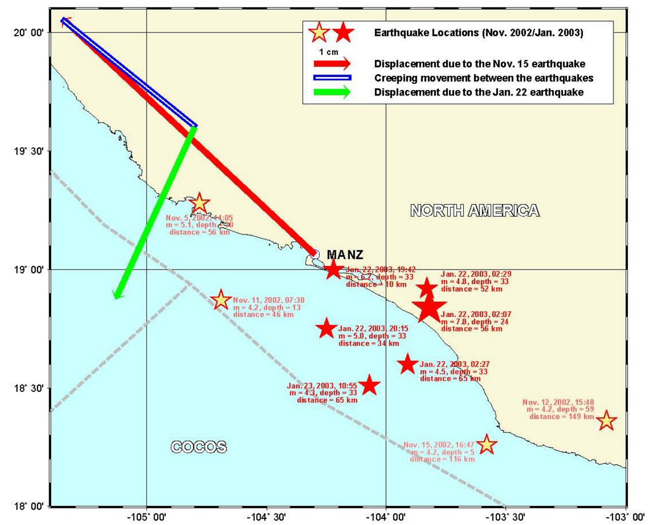

Fig.3 (above): Earthquake locations near Manzanillo and resulting displacements to site MANZ

References

ROTHACHER, M. and L. MERVART (eds.): Bernese GPS Software, Version 4.0, Astronomical Institute, University of Berne, 1996.

HUGENTOBLER, U., S. SCHAER, P. FRIDEZ (eds.): Bernese GPS Software, Version 4.2, Astronomical Institute, University of Berne, 2001.

SEEMUELLER, W. and H. DREWES: Annual Reports of RNAAC SIRGAS, IGS Technical Reports, IGS Central Bureau, Pasadena, CA: Jet Propulsion Laboratory, 1997, 1998, 1999, 2000.

SEEMUELLER, W., K. KANIUTH, H. DREWES: Velocity estimates of IGS RNAAC SIRGAS stations, In: H. DREWES, A. DODSON, L.P.S. FORTES, L. SANCHEZ, P. SANDOVAL (Eds.): Vertical Reference Systems, IAG Symposia, Volume 124, pp. 7-10, Springer, 2002.

KANIUTH, K., H. MUELLER, W. SEEMUELLER: Displacement of the space geodetic observatory Arequipa due to recent earthquakes, In: Zeitschrift fuer Vermessungswesen (127) 238-243, 2002.

USGS: United States Geological Service, National Eartquake Information Center (http://neic.usgs.gov/neis)