WORKING GROUPS/ PILOT PROJECTS/COMMITTEES

Densification of ITRF

(Please see "Reference Frame Coordinator Report" – Section 2, Analyis Center Reports)

Report of the Tropospheric Working Group for 2002

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Weekly Combined Tropospheric Product and Densification

The quality and consistency of the IGS Final weekly combined tropospheric product (Gendt, 1996) has steadily improved during its more than 6 year history. The comparisons between the individual Analysis Center (AC) solutions and the IGS official combined solution are shown in Figure 1. All but one AC agree within 3 mm standard deviation since week 1180 (August 2002), for most ACs even at the 2 mm level. This corresponds to a quality of better than 0.5 mm in the precipitable water vapor.

The bias changes at individual ACs caused by changes in their analysis strategy are even smaller, and in total they are usually in the ±2 mm band. The only exception in the bias stability seen for ESA, where a pronounced seasonal effect can be observed, the origin of that is not clear. The consistency between the ACs having the smallest standard deviations agree best. It is during the last years even at the ±1 mm level. Those good ACs have the highest weight in the combination so that the expected bias changes in the combined solution are smaller than ±1 mm.

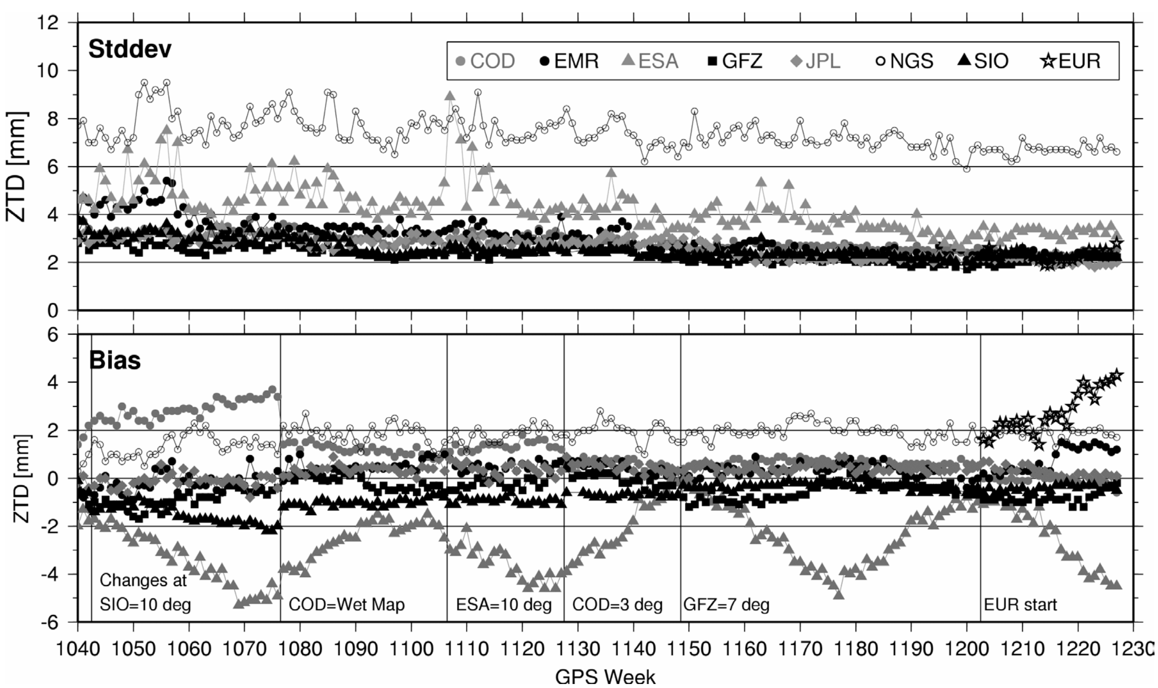

Figure 1. Standard deviation and bias in the neutral zenith total delay between the individual Analysis Center estimates and the IGS Combined Product. Mean values (over all sites) per week and per Analysis Center. (GPS Week 1042.6 = 2000.0)

In June 2001 the EUREF community has started a Pilot Experiment for the generation of tropospheric products. The solution is a combination of 15 individual EUREF ACs and comprises a European network of about 150 sites. After a short test phase in 2001 (Gendt 2002) an official EUREF (abbreviation: EUR) submission was included into the IGS combination starting in February 2002 (GPS week 1203). The standard deviation of the EUREF solution has the same level as seen for the best single IGS ACs. The bias seems to change with time, however, the time interval is yet too short for a final assessment. By this regional densification the number of sites included in the IGS Tropospheric Product has grown from 180 to 280.

During the last one and a half year also the number of collocated meteorological sensors have improved significantly (Figure 2). However, especially in the tropical region, where the water vapor in the atmosphere is most interesting to monitor, a need of additional sensors is obvious (Figure 3).

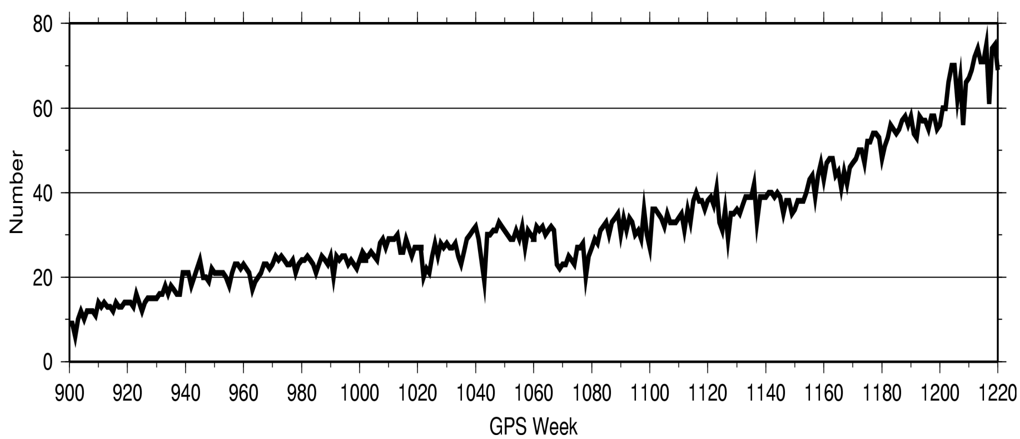

Figure 2. Number of sites with collocated meteorological sensors

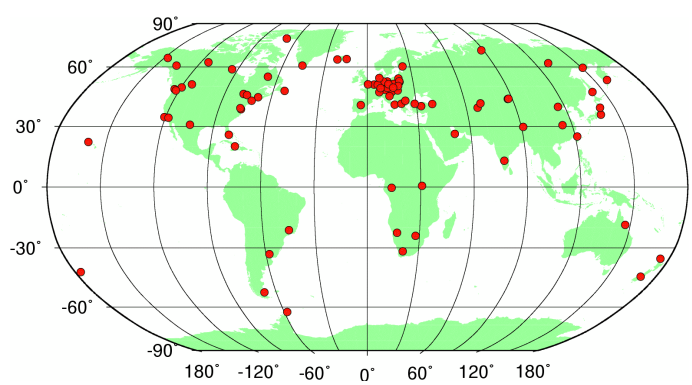

Figure 3. Network of collocated meteorological sensors

Near-Real-Time Product

After a Pilot Experiment starting in June 2001 the IGS is generating a near real-time (NRT) tropospheric product using the global hourly station network. Every three hours a product for the last 12 hours is combined by all individual submissions of up to 8 ACs. Some statistics for the contributing ACs are summarized in Table 1. The product is available with a delay of about 2.5 hours and comprises more than 140 stations (Figure 4). The consistency of the product is at the level of ±2 to 4 mm ZTD as already demonstrated in 2001 (see Gendt, 2002).

Table 1. Summary on Analysis Center contributions to NRT Trop Pilot Experiment

AC	Submission rate	No. stations	Delay[h]	Start of submission
CODE	12h	70	2:00	07/2003
EMR	3h	40	1:30	06/2001
GFZ	3h	50	1:15	06/2001
ESA	12h	40	2:00	07/2001
SIO	3h	40	2:30	08/2001
USNO	3h	35	1:30	09/2001
JPL	Real-time	60	0	11/2001
GOP*	3h	60	2:00	02/2002

* GOP- Geodetic Observatory Pecny, EUREF Analysis center

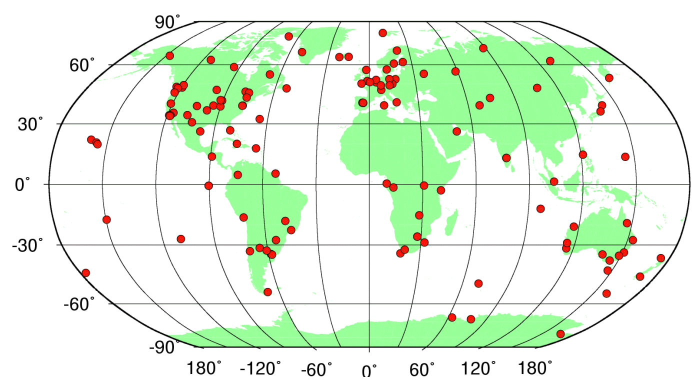

Figure 4. Network of stations with NRT tropospheric products

Summary

Progress was made since the last annual report in the densification of the Final product by inclusion of the high quality EUREF combined tropospheric product.

The NRT products were regularly generated with a high reliability (about 99% availability) since two years now.

The quality of the IGS combined products – both the Final and the NRT - corresponds to better than 1 mm in the water vapor content.

References

Gendt, G (1996): Comparison of IGS tropospheric estimates. Proceedings IGS Analysis Center Workshop, 19-21 March 1996 Silver Spring, Maryland USA, Eds. R E Neilan, P A Van Scoy, J F Zumberge, pp. 151-164

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IGS LEO Pilot Project

H. Boomkamp

Introduction

The IGS Low Earth Orbiter Pilot Project is concerned with the analysis of data from LEO satellites that are equipped with a GPS receiver. The LEO satellites employ GPS as a tracking system for their own mission objectives, while the IGS LEO Pilot Project aims at investigating possibilities to exploit this LEO GPS data for enhancing the IGS products. With the expected increase in LEO GPS satellites over the present decade, the possible ways of integrating this data in routine IGS processing must be considered with care.

Pilot Project Objectives and Implementation

During the course of 2002, the format and objectives of the IGS LEO Pilot Project have been consolidated, and were formalized in a Pilot Project charter. In parallel, the number of operational LEO GPS satellites has grown to six, although the only three satellites of which the data is now readily available are CHAMP, SAC-C and JASON. Of these three, CHAMP and JASON are receiving most attention from the scientific community although the more recent SAC-C data also appears to be in good shape. It is hoped that data from the two GRACE satellites and ICESAT will also be available in the near future.

The GPS datasets from just two or three LEO satellites would clearly have a hard time trying to influence the IGS products in any way, if their introduction would merely lead to an increase in the amount of tracking data. The IGS ground network is in fact growing much quicker than the constellation of LEO GPS satellites, and this will remain the case be for the years to come. What is of interest to IGS is therefore the analysis and exploitation of fundamental qualitative differences between LEO data and ground-based data. The principal objectives of the Pilot Project are to demonstrate whether such qualitative differences exist, and that they can be used to the benefit of the routine IGS products.

In support of this analysis, the Pilot Project charter proposes to maintain a list of fundamental differences between LEO data and ground-based data. These differences will then be investigated one by one, leading to a fairly complete view on what the LEO data may contribute to IGS. This aspect of the LEO charter is being implemented via the IGS LEO website, at http://nng.esoc.esa.de/gps/igsleo.html.

Four categories of differences are identified:

Differences in tracking geometry

The main benefit of the LEO data is expected from the rapidly changing geometry between LEO satellites and the GPS constellation, and the relative independence of the LEO satellites from models for earth rotation and reference frame. These are the areas in which LEO data has the greatest potential for improving the IGS products in some way.

Differences in signal propagation

The main benefit of LEO data would be the absence of tropospheric delays, and the significantly reduced ionosphere delays, but it is clear that these effects will always be small. The analysis of occultation data is not (yet) part of the LEO Pilot Project, but developments in this area are being followed with interest.

Differences in data flow

These differences are clearly significant, not just in terms of latency but also in terms of data distribution policies. Compared to ground-based data, LEO data will probably always have a more complicated trajectory from the receiver to the IGS analysis centers. Such issues mainly affect operational use of the data, which for the time being is not considered as a critical problem.

Differences in data processing

These differences must be carefully analyzed to ultimately make a cost/benefits assessment about the potential integration of LEO data in routine IGS processing. Processing of LEO data is still difficult; in fact, as will be discussed further below, current precision levels are not yet considered compatible with the ground based data. This additional burden on IGS analysis centers should be compensated by clear advantages.

Data Processing Precision

Before LEO data can hope to bring any improvement in an IGS product, a first requirement with regard to LEO GPS data must be to ensure data precision levels that are compatible with the precision of ground-based GPS data. Until now, this has been the main area of investigation in the IGS LEO Pilot Project.

In more concrete terms, the position of the antenna phase center of the LEO receiver is only as precise as the orbit and attitude determination of the LEO satellite. Both for CHAMP and for JASON precise orbit determination has achieved very high standards in recent times: estimated orbit errors are as low as 5 cm RMS for the best CHAMP orbits, and below 3 cm RMS for JASON. As good as this may be, the precision with which antenna phase centers of IGS ground stations are determined – as part of routine IGS processing - is assessed to be at the level of a few millimeters, which is an order of magnitude better. It is therefore optimistic to speak of compatible precision levels at this point in time.

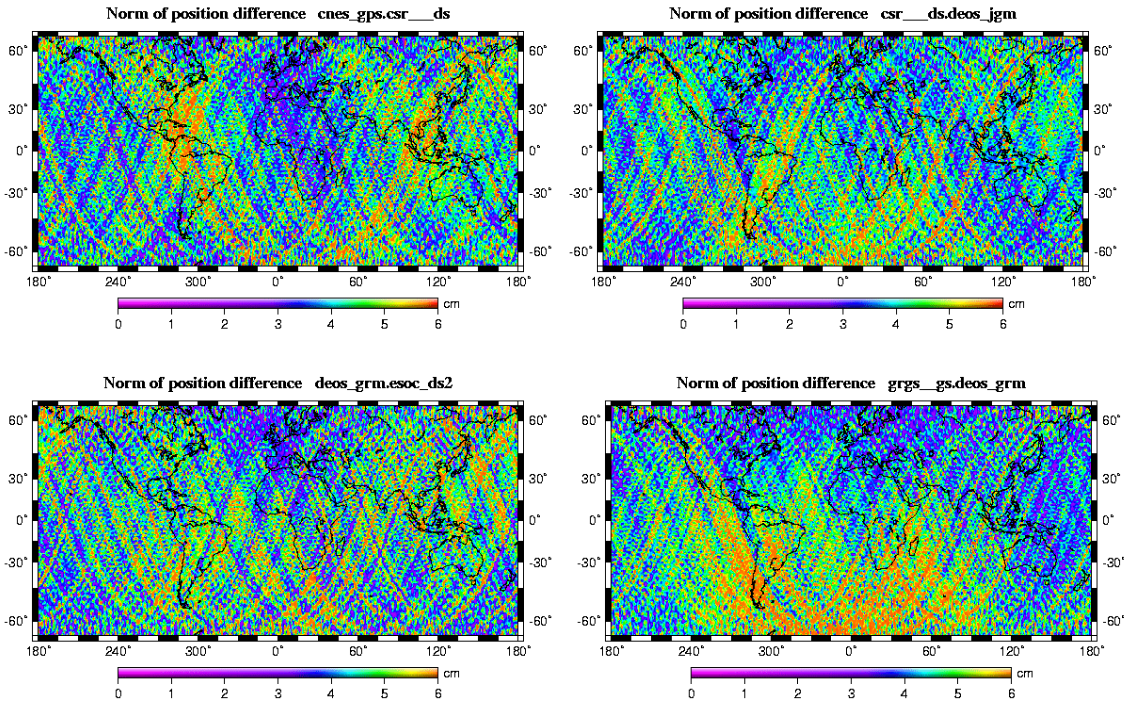

Figure 1a-d *: Examples of orbit comparisons from the JASON orbit campaign. Orbit differences between a large set of solutions form an important source of information on LEO POD quality.*

Because of its critical nature, the error mechanism that currently prevents integration of the less precise LEO data with ground-based GPS tracking data will be briefly summarized here. To reach the high precision levels of IGS products, a typical POD system for GPS - as performed routinely by the analysis centers - contains a variety of delicately balanced data editing algorithms. If a station produces tracking data that is notably of worse quality than the data from other stations, this data will either be rejected by the process, or it will be down-weighted to the point at which it no longer has any relevant influence on the output products. This second option allows for improvements e.g. of the station coordinates of the less precise station, without affecting the actual GPS orbits and clocks in a negative way. Such protection mechanisms are inevitable as long as the LEO data is referred to antenna positions that have an error level of several centimeters, and the result is that the influence of the LEO data on the output products is marginalized.

As a rule-of-thumb objective, the IGS LEO Pilot Project now aims at a LEO orbit precision level that is better than 1 cm RMS. This precision level cannot yet be confirmed for any of the available LEO satellites, but at the same time, there has been substantial progress both in LEO orbit determination itself, and in the way in which the orbit precision can be assessed with confidence. Major activities of the Pilot Project are the on-going Orbit Campaigns for CHAMP and more recently for JASON, which aim at supporting and analyzing POD improvements for these two satellites. The latest results can always be found on the IGS LEO website, referenced above. Some examples of results from these campaigns have been included as Figures 1, 2 and 3 in this Chapter.

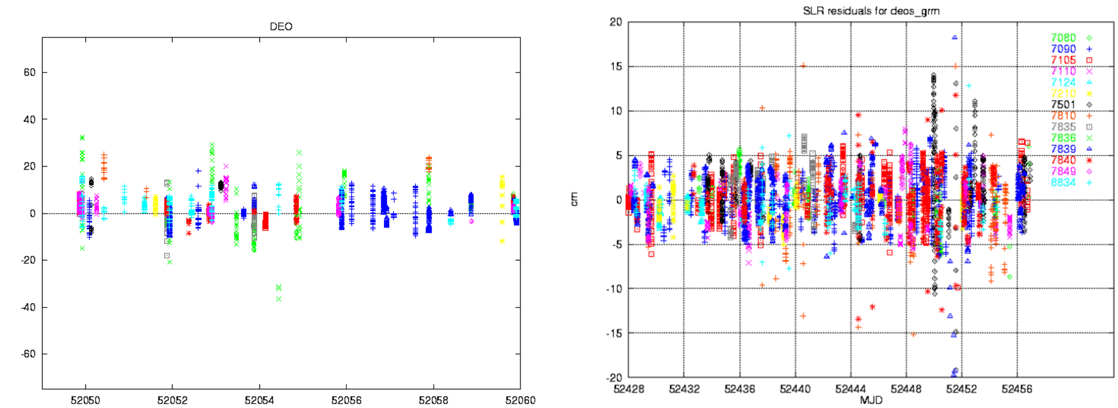

Figure 2a & b: Examples of SLR residuals from the IGS LEO orbit campaigns for CHAMP (left) and JASON (right). It is clear that the higher JASON orbit receives more SLR tracking.

High Rate Data and POD Capacity

Combined solutions of GPS and LEO satellites introduce another important technical problem, namely that of processing capacity, or POD performance. For LEO POD the tracking data rate must be much higher than for the GPS satellites, first because the LEO geometry changes more rapidly, and second because the dynamic models of the LEO contain signals of much shorter wavelengths than the dynamics of the GPS satellites. The LEO orbit model typically requires a relatively large number of estimated parameters, and therefore requires more densely spaced tracking data. This (GPS) data can only be processed if accurate clocks and phase ambiguities are available at the same high-rate, and this means that the basic GPS POD process will also have to cope with the same high data rate. As a result, various IGS centers notice that their POD systems are stretched to the limits of their capacity - or beyond - by the introduction of the LEO data.

On the one hand, these extreme demands on the POD systems have the negative consequence of slowing down the Pilot Project analysis, even prohibiting certain analysis that seems relevant. On the other hand, these new demands urge the centers to implement various improvements in their analysis systems, which can be seen as a first positive side-effect of the Pilot Project. Increased POD capacity is a matter of great interest to IGS as a whole, not just in support of LEO analysis, but also in support of other developments like (near-) real time processing or the handling of data from substantially larger ground station networks.

The two centers GFZ and JPL, who have had access to the CHAMP data since launch, produced high precision CHAMP orbits (around ~5cm RMS error) about 1.5 years later. The centers CODE and ESOC needed about the same time to implement CHAMP POD capability, illustrating the effort that is typically required to stabilize the POD systems for LEO GPS analysis. The fact that such analysis is now possible – which was not the case even two years ago - can be considered as important progress.

Table 1: Recent POD precision estimates for CHAMP

cm	1-way SLR	orbit error	sigma
DEOS	3.60	5.94	0.54
CSR	4.43	7.31	0.67
TUM	4.61	7.60	0.69
GFZ	4.81	7.93	0.72
JPL	5.31	8.75	0.80
GRGS	6.80	11.21	1.02
NCL	7.44	12.26	1.12
ASI	7.88	12.99	1.19
AIUB	13.56	22.36	2.04
CNES	13.58	22.39	2.04
ESA	16.83	27.74	2.53
UCAR	17.35	28.59	2.61
UNB	27.37	45.11	4.12

Table 2: Recent precision estimates for JASON

cm	1-way SLR	orbit RMS	sigma
csr__gds	1.700	3.656	0.606
gsfc_gs4	1.771	3.809	0.632
ncl___ds	1.844	3.966	0.658
jpl__gps	1.912	4.112	0.682
gsfc_dyn	1.973	4.243	0.704
gsfc_red	2.008	4.319	0.716
gsfc_gps	2.071	4.454	0.738
grgs__gs	2.257	4.854	0.805
esoc_ds2	2.386	5.132	0.851
esoc__ds	2.464	5.299	0.879
gsfc_rex	2.491	5.357	0.888
deos_grm	2.579	5.547	0.920
csr___ds	2.655	5.710	0.947
deos_jgm	2.669	5.740	0.952
cnes_poe	2.842	6.112	1.013
cnes_gps	2.890	6.215	1.031
asi__in2	5.138	11.050	1.832
asi__ext	9.039	19.440	3.223

Participation in Pilot Project Analysis

Initially, there were two groups of centers that expressed an interest in the LEO Pilot Project, namely centers with particular expertise in orbit determination for Low Earth Orbiters – who consider the GPS data as tracking data for the LEO itself – and centers with an interest in GPS product generation, i.e. the IGS analysis centers. The first group of centers was clearly the larger one, because outside the IGS there are very few centers that compute GPS orbits and clocks for research objectives. Nonetheless, with the consolidation of the Pilot Project charter and the concrete objectives that it formulates, it became clear that the main participation in the Pilot Project is expected to come from the second group of centers. In practice, not even all of the IGS Analysis Centers can participate in the analysis of the LEO data.

By consequence, the LEO Pilot Project may appear to have a much lower profile than was anticipated at its start, but that does not make it less relevant to IGS – on the contrary. The fact that at present only about five centers in the world are actually considered capable of analyzing LEO GPS data for the purpose of enhancing IGS products, implies that these (IGS) centers carry the full responsibility for this analysis.

Recent Focus and Future Developments

The Pilot Project wants to demonstrate potential benefits of LEO data in two stages, first at the level of individual centers – a center is expected to demonstrate that the LEO data contributes to its IGS products in a positive way – and then at the level of IGS combination solutions. Even though overall LEO orbit precision is still considered inadequate, four IGS analysis centers are now approaching a status of satisfactory LEO data processing. The first illustrations of LEO contributions to GPS data processing are expected in the very near future.

In parallel, some effort is invested in the subject of combination solutions for the LEO orbits. It is hoped that this may bring down the LEO orbit error to levels below 1 cm. Some of this analysis is being reported via the IGS LEO website, which is also recommended for any further information on the Pilot Project.

Conclusions

The Pilot Project analysis to be performed has been defined quite clearly and is made concrete via various analysis topics that are proposed on the website. The problems associated with GPS-based LEO POD are being addressed by various centers, not just the limited number of IGS analysis centers mentioned above. Processing systems are being improved and their capacity is being augmented, so that LEO GPS processing is already less of a challenge than in the early days of CHAMP data.

Progress in the Pilot Project is slow, but steady. Given the limited resources that can be dedicated to this work, and the complexity of the involved analysis, the developments in LEO GPS are satisfactory. Various general improvements in data processing are being achieved at the IGS analysis centers, merely because the demands for LEO processing require such improvements. This must be seen as a useful first contribution of the Pilot Project to the IGS.

International GLONASS Service – Pilot Project

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Abstract

The International GLONASS Service Pilot Project (IGLOS-PP) provided GLONASS observations and precise orbits from a tracking network of over 40 stations and three Analysis Centers for all of 2002. The International Laser Ranging Service (ILRS) also continued to observe three GLONASS satellites during the year. A new Russian launch of three satellites at the end of the year raised the number of available satellites to 10. After keeping the GLONASS data separate from the GPS data in the IGS for the first two years of the project, revisions were made to the IGS Site Logs, Analysis Center software and archival procedures at the Global Data Centers such that the IGLOS tracking data could be merged with the other IGS tracking data in routine operations. The accomplishment of this was a significant milestone.

GLONASS Constellation Status

On 25 December 2002, Russia launched three new GLONASS satellites into orbit plane 3 (slots 21, 22 and 23). This brought the total number of operational (healthy) satellites to 10. These satellites are the older series satellites (not GLONASS-M) and have SLR reflectors identical to the ones on the two operational satellites launched in December 2001 (132 corner cubes in panel). For most of 2002, there were 6-7 operational satellites.

Tracking Network

In coordination with the IGS GPS stations, all IGLOS stations were requested to submit new site log forms to become "official" IGS stations. These new site logs were designed to accommodate global navigation satellites in general, rather than just GPS, and to allow the full integration of dual GPS/GLONASS stations into the IGS. Only dual-frequency receivers capable of tracking at least four GLONASS satellites simultaneously were sanctioned as official IGS stations. As of December 2002, the IGLOS tracking network consisted of 46 stations, although six of these still lacked revised site logs. All the operational stations use either Ashtech or Javad Positioning

Systems receivers. The GLONASS data are now merged with the GPS data at the IGS Global Data Centers. Table 1 lists the IGLOS stations and their locations, receiver types, and sponsoring organizations.

The ILRS has provided continuous support for SLR tracking of three GLONASS satellites. In 2001, one GLONASS satellite in each of the three orbit planes was tracked (plane 1/slot 7, plane 2/slot 15, plane 3/slot 24). During 2002, the targeted satellites were changed to slots 3 and 6 of plane 1, along with slot 24 of plane 3.

Precise Orbit Computation

BKG and ESA produced precise orbits from the receiver network tracking data for all the operational GLONASS satellites. The Russian Mission Control Center (MCC) computes precise orbits based on the SLR observations alone. These individual orbits are combined in a weighted average computation by the IGLOS Analysis Center coordinator to produce the final IGLOS precise orbits. SLR orbit accuracies are probably at the 10-20 centimeter level, while the combined precise receiver-based orbit accuracies are about at the 20-centimeter level (see Figure 1). GLONASS orbit comparisons done at the Natural Environment Research Council (U.K.) have indicated that some long-term systematic biases may be present in the GLONASS receiver-based orbits compared to the SLR orbits.

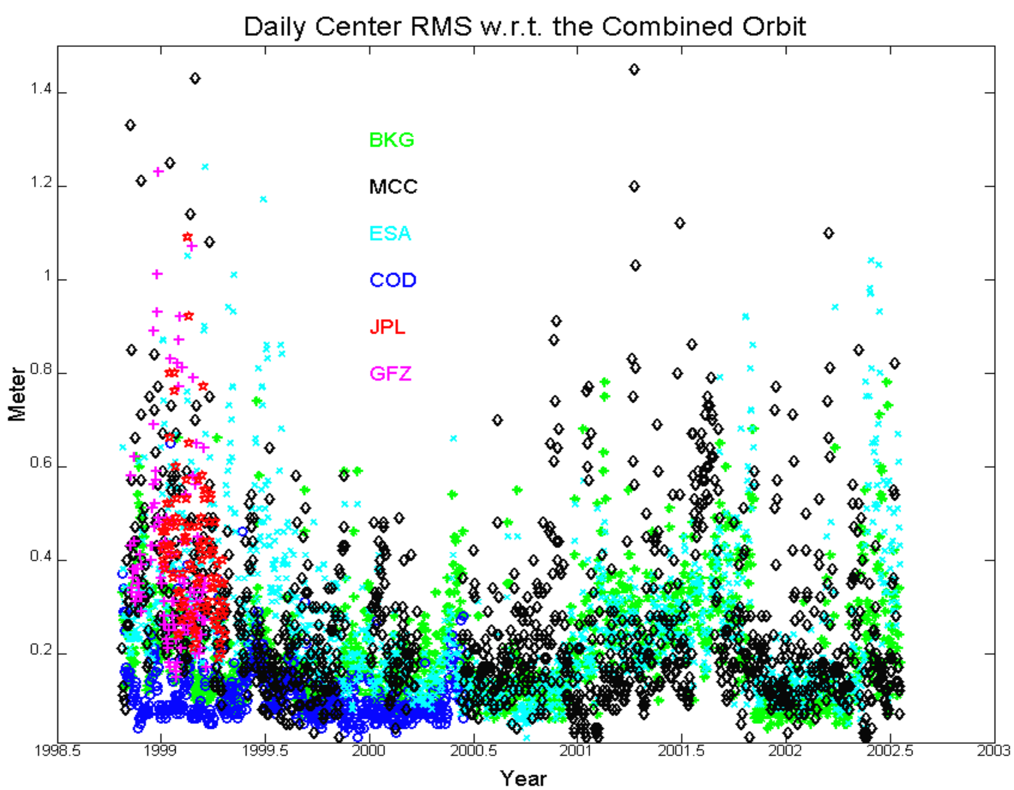

Figure 1

GLONASS Data and Product Usage

All receiver tracking data, including the satellite broadcast messages, and the precise orbit products are stored and retrievable at the IGS Global Data Center at NASA GSFC. Over an 11-month period from January to November 2002, 9,475 orbit products were downloaded from the Data Center. Two-thirds or more of these probably relate to the actual production of the precise orbits by the Analysis Centers in Austria, Germany and Russia, but at least 1,560 downloads are attributable to other users of the data products. These figures do not include downloads of the actual tracking data. It is not clear at this time what applications these products are being used for. This is definitely of interest and will be pursued in the coming year.

Summary

The number of active GLONASS satellites increased from 6 satellites in 2000 up to 10 satellites in March 2003. In the frame of IGLOS-PP precise GLONASS orbits are calculated by various Analysis Centers in regular (weekly) intervals. The accuracy of these orbits is about +/- 0.2 –0.3 m. Besides satellite clock offsets to GPS-time as well as station coordinates are provided.

Up to now the IGLOS products serve groups dealing with GNSS Time Transfer, all kinds of surveying using combined receivers (e.g. improving the situation in urban canyons with a lack of visible GPS satellites), and atmosphere monitoring for climate studies. A more rapid submissions of tracking data and a more frequent generation of products (compared to the current long latency) will certainly allow for a couple of new applications. Therefore the participants of the IGS Workshop in Ottawa 2002 passed a recommendations which asks all IGS-AC’s to intensify their ability to process data from combined GPS/GLONASS tracking sites.

There is an ongoing need to continue and to increase the tracking of GLONASS satellites by ILRS. GLONASS satellites observed by two independent space techniques realize a valuable kind of collocation in space. Moreover IGLOS-PP demonstrates the extensibility of IGS to accommodate other microwave systems (GLONASS, GALILEO).

Table 1. IGLOS Pilot Project - GLONASS Receiver Tracking Stations (Dec 02)

SITE NAME	SITE ID	LOCATION	COUNTRY	LAT. (deg)	LONG. (deg)	RECEIVER TYPE	CLOCK TYPE	SPONSORING ORGANIZATION
Crary	CRAR	McMurdo Station	Antarctica	-77.85	166.67	JPS Legacy	Internal	U.S. Geological Survey (USGS)
Davis	DAVR	Davis	Antarctica	-68.58	77.97	Ashtech Z18	Internal	Geoscience Australia
O'Higgins	OHIZ	O'Higgins	Antarctica	-63.32	-57.9	Ashtech Z18	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
AU053	YARR	Dongara (Yaragadee)	Australia	-29.05	115.35	Ashtech Z18	Internal	Geoscience Australia
Brisbane	SUNM	Brisbane	Australia	-27.48	153.04	JPS Legacy		Dept. of Natural Resources, Queensland
Darwin AU014	DARR	Darwin	Australia	-12.84	131.13	JPS Legacy	Internal	Geoscience Australia
Mt. Stromlo	STR2?	Canberra	Australia	-35.32	149.01	JPS Legacy	Internal	Geoscience Australia
Mattersburg	MTBG	Mattersburg	Austria	47.73	16.40	JPS Legacy	Internal	University of Technology, Vienna
UNB, Fredericton	UNB1	Fredericton	Canada	45.57	-66.38	JPS Legacy	Internal	U. of New Brunswick
Concepcion-TIGO	CONZ	Concepcion	Chile	-36.84	-73.03	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Lhasa	LHAZ	Lhasa	China	29.66	91.10	Ashtech Z18	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Pecny (Ondrejov)	GOPE	Ondrejov	Czech Rep.	49.91	14.79	Ashtech Z18	Internal	Research Inst. of Geodesy, Topography & Cartography
Metsahovi	METZ	Kirkkonummi	Finland	60.22	24.40	JPS Eurocard	Ext. Quartz	Finnish Geodetic Institute
Dresden	DREJ	Dresden	Germany	51.01	13.43	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Frankfurt/Main	FFMJ	Frankfurt/Main	Germany	50.09	8.66	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Leipzig	LEIJ	Leipzig	Germany	51.35	12.37	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
DLR IKN Neustrelitz	NTZ1	Neustrelitz	Germany	53.33	13.07	JPS Legacy	Rubidium	German Aerospace Centre (DLR)
Helgoland Island	HELJ	Helgoland Island	Germany	54.17	7.89	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Huegelheim	HUEG	Huegelheim	Germany	47.83	7.60	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Titz (Jackerath)	TITZ	Titz	Germany	51.04	6.43	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Wettzell	WTZJ	Koetzting	Germany	49.14	12.88	JPS Legacy	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Wettzell	WTZZ	Koetzting	Germany	49.13	12.87	Ashtech Z18	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Thule Airbase	THU2	Thule Airbase	Greenland	76.54	68.82	Ashtech Z18	Rubidium	Kort & Matrikelstyrelsen (KMS)
Reykjavik	REYZ	Reykjavik	Iceland	64.14	-21.96	Ashtech Z18	Internal	Bundesamt fuer Kartographie und Geodaesie (BKG)
Cagliari	CAGZ	Capoterra	Italy	39.14	8.97	JPS Eurocard	Cesium	Universita' di Calgliari
Ferrara	UNFE	Ferrara	Italy	44.83	11.59	Ashtech Z18	Internal	Agenzia Spatiale Italiana
Matera	MAT1	Matera	Italy	40.60	16.70	Ashtech Z18	H-maser	Telespazio S.p.A.
Mitaka A	MTKA	Tokyo	Japan	35.68	139.57	Ashtech Z18	Internal	Electronic Navigation Research Inst.
Delft	DLFT	Delft	Netherlands	51.99	4.39	JPS Legacy	Internal	Delft University of Technology
Gjovik	GJOV	Gjovik	Norway	60.79	10.68	Ashtech Z18		University College of Gjovik
Borowa Gora	BOGI	Borowa Gora	Poland	52.48	21.04	JPS Eurocard	Internal	Institute of Geodesy & Cartography
Wroclaw	WROC	Wroclaw	Poland	51.11	17.06	Ashtech Z18	Rubidium	Agricultural University of Wroclaw
Irkutsk	IRKJ	Irkutsk	Russia	52.22	104.25	JPS Legacy	H-maser	Inst. of Metrology for Time & Space (IMVP GP VNIIFTRI)
Khabarovsk	KHAJ	Khabarovsk	Russia	48.52	135.03	JPS Legacy	H-maser	Inst. of Metrology for Time & Space (IMVP GP VNIIFTRI)
Mendeleevo	MDVJ	Mendeleevo	Russia	56.03	37.50	JPS Legacy	H-maser	Inst. of Metrology for Time & Space (IMVP GP VNIIFTRI)
Novosibirsk	NOVJ	Novossibirsk	Russia	55.03	82.90	JPS Legacy	H-maser	Inst. of Metrology for Time & Space (IMVP GP VNIIFTRI)

Table 1 (cont'd). IGLOS Pilot Project - GLONASS Receiver Tracking Stations (Dec 02)

SITE NAME	SITE ID	LOCATION	COUNTRY	LAT. (deg)	LONG. (deg)	RECEIVER TYPE	CLOCK TYPE	SPONSORING ORGANIZATION
SP Boras	SPT0	Boras	Sweden	57.71	12.89	JPS Legacy	Cesium	National Land Survey
Kiruna	KR0G	Kiruna	Sweden	67.88	21.06	Ashtech Z18	Internal	National Land Survey
Maartsbo	MR6G	Maartsbo	Sweden	60.60	17.26	JPS Legacy	Internal	National Land Survey
Onsala	OS0G	Onsala	Sweden	57.40	11.93	JPS Legacy	H-maser	Onsala Space Observatory, Chalmers
Visby	VS0G	Visby	Sweden	57.65	18.37	Ashtech Z18	Internal	National Land Survey
Zimmerwald GPS97	ZIMZ	Zimmerwald	Switzerland	46.88	7.47	Ashtech Z18	Internal	Swiss Fed. Office of Topography
Zimmerwald GPS87E	ZIMJ	Zimmerwald	Switzerland	46.88	7.47	JPS Legacy	Internal	University of Berne (CODE)
Herstmonceux	HERP	Hailsham	United Kingdom	50.87	0.34	Ashtech Z18	GPS/DFS	NERC Space Geodesy Facility
Greenbelt	GODZ	Greenbelt	United States	39.02	-76.83	Ashtech Z18	H-maser	NASA Goddard Space Flight Center
Woodinville	DWH1	Woodinville	United States	47.77	-122.08	JPS Legacy	Cesium	Hogarth, Douglas

TIGA - Tide Gauge Benchmark Monitoring Pilot Project

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Introduction

The TIGA Pilot Project was initiated in response to the demanding need for highly precise height coordinates and their changes with time at tide gauge benchmarks. TIGA was formally established during the 16th IGS Governing Board Meeting in Nice (April 2001).

For the first time it is not the intention of the IGS to provide results with a very low latency, but to have as many stations included as possible. The primary products of the Pilot Project are time series of coordinates for analyzing vertical motions of Tide Gauges (TG) and Tide Gauge Benchmarks (TGBM). All products will be made public to support and encourage other applications, e.g. sea level studies. In particular, the products of the service will facilitate the distinction between absolute and relative sea level changes by accounting for the vertical uplift of the station, and are, therefore, an important contribution to climate change studies. The service may further contribute to the calibration of satellite altimeters and other oceanographic activities. The pilot project will operate for a period of three years, from 2001 to 2003. After this period the IGS Governing Board will evaluate the project and decide whether or not this activity should become a regular IGS service function.

The goals of the TIGA-PP are identified as follows:

1. Establish, maintain and expand a global Continuous GPS at Tide Gauges (CGPS@TG) network
   - Select a set of GPS-equipped tide gauges with a long and reliable history practicable for both sea level change studies and satellite altimeter calibrations.
   - Apply IGS network operation standards.
   - Promote the establishment of more continuously operating GPS stations in particular in the southern hemisphere.
   - Promote the establishment of links to other sites, which may contribute to vertical motion determination, e.g., VLBI, SLR, DORIS and/or absolute gravity stations.
   - Develop recommendations for a minimum technical standard of the whole tide gauge system to be included into the Pilot Study, e.g., sensor types, the nature of the leveling program, and metadata documentation.

2. Contribute to the procedures in which IGS realizes a global reference frame in order to improve its utility for global vertical geodesy. This may involve reprocessing a significant subset of the (past and present) IGS global tracking data set.

3. Compute precise station coordinates and velocities for the CGPS@TG stations using a processing stream that runs months behind real-time in order to include the largest possible

number of stations. This effort will incorporate all previously collected GPS data at each CGPS@TG station. Later on the combined solution will have a maximum latency of one year.

4. Establish a secondary processing stream with much reduced latency in order to support operational activities that cannot tolerate large processing delays.

5. Monitor the stability of the network.

The progress of the project and other related information is maintained at the WEB site http://op.gfz-potsdam.de/tiga/.

Major Steps in 2001

An initial meeting was held during the APSG Sea Level Workshop in Hawaii (April 2001). A wide range of experts attended this meeting from the tide gauge as well the GPS community. A very intensive discussion took place aiming at the goals and deliverables of TIGA. Participants agreed on two main points. The first is that the completeness of data has a much higher priority than the latency of the processing stream. At second, only CGPS@TG's will be considered in a final solution for which all information, including the tide gauge data and the leveling data between the different benchmarks, is freely available to the scientific community.

Consequently, a Call for Participation was drafted and issued in June 2001. In total 23 Letter of Intent arrived, while finally 15 proposals were submitted. Proposals are covering all components of TIGA. These components are in particular TIGA Observing Stations (TOS), TIGA Data Center (TDC, 6 proposals), TIGA Analysis Centers (TAC, 8 proposals), and TIGA Associate Analysis Centers (TAAC, 2 proposals). By end of 2001 the review of the proposals was completed and a Letter of Acceptance was sent out.

TIGA Components

TIGA Observing stations (TOS) are primarily, but not exclusively, existing IGS, EUREF or NAREF stations. Some national agencies are providing GPS data not previously part of the IGS. Due to the higher latency of the processing also data from remote stations can be included into the routine analysis. A site information log for TOS was developed displaying necessary additionally information for each tide gauge. This log sheet supplements the standard IGS log. A plot of current TIGA Observing Stations is given in the figure attached (Figure 1). TOS forms are available at the TIGA web page.

TIGA Analysis Centers (TAC) will process data in different chains. The primary chain will have a latency of 460 days, which allows also the very remote stations, e.g. from Antarctica, to provide their data. A secondary chain will provide solutions with a very short latency to support operational aspects. In addition a few processing centers have agreed to re-compute a selected subset of the IGS and other network data (including a retro-processing of IGS station data for CGPS@TG) for an improved long-term stability of the reference frame since the inception of the IGS.

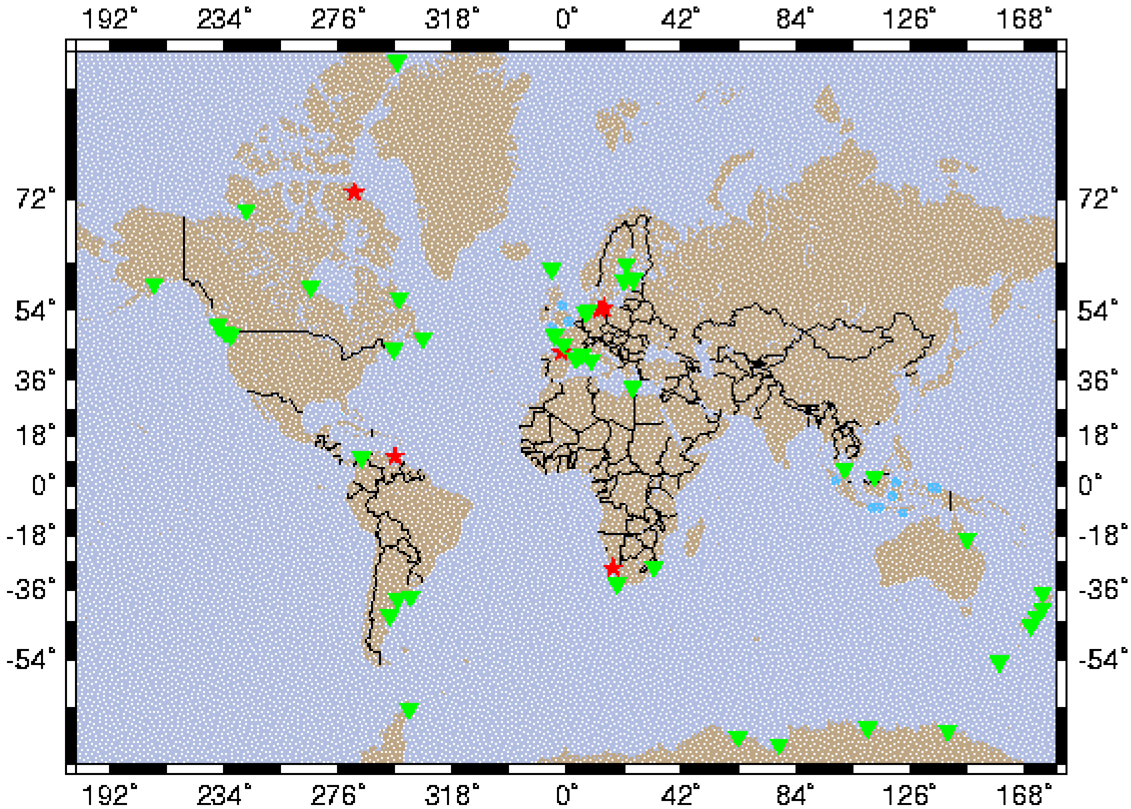

Figure 1: Overview about the current status of TOS stations (August 2003)
For few stations (triangles) all necessary information is available. In the near future, more stations will become available (dots). In response to the TIGA Call for Participation also new GPS stations will be installed near tide gauges (stars). For large areas either no CGPS@TG stations exist or the necessary information is not provided to TIGA.

TIGA Associate Analysis Centers (TAAC) will facilitate TIGA in two different ways. This ranges from the processing of a selected regional subset of CGPS@TG stations, while others will analyze the results of the TAC's in various ways, including comparisons to other space techniques or absolute gravity measurements.

As a new component, TIGA Data Center (TDC) will not only store and re-distribute GPS data, but also metadata. They will fulfill three functions:

1. Store GPS data sent by different media (FTP, computer tapes, CD-ROM, diskettes, etc.) with high and changing latency.
2. Store Metadata (e.g. leveling data, sketch maps of the TG) of any kind (e.g. computerized, handwritten, microfiches, etc.)
3. Establish links to Tide Gauge Data Centers for easy and convenient data access.

Activities in 2002

In the first half of 2002, the processing strategy for the analysis and re-analysis was discussed and some important TIGA components, like the TDC at the University La Rochelle, were established and tested. In August 2002 six TAC's started with the forward processing. It was agreed upon to allow a latency of data submission of 460 days. This primarily allows also very remote stations, like e.g. in Antarctica, to provide data in due time.

After an initial period a regular submission was established by three centers:
- EUREF
- GFZ, GeoForschungsZentrum Potsdam, Germany
- ULR, University La Rochelle/IGN, France

In addition, three more centers
- Geoscience Australia, Australia
- University of Canberra, University of Tasmania, Australian National University, Australia
- DGFI, Deutsches Geodätisches Forschungsinstitut, Germany

providesolutions with varying submission dates (Fig. 2 & 3). EUREF is providing a solution with short latency, while all other centers are processing and re-processing GPS data.

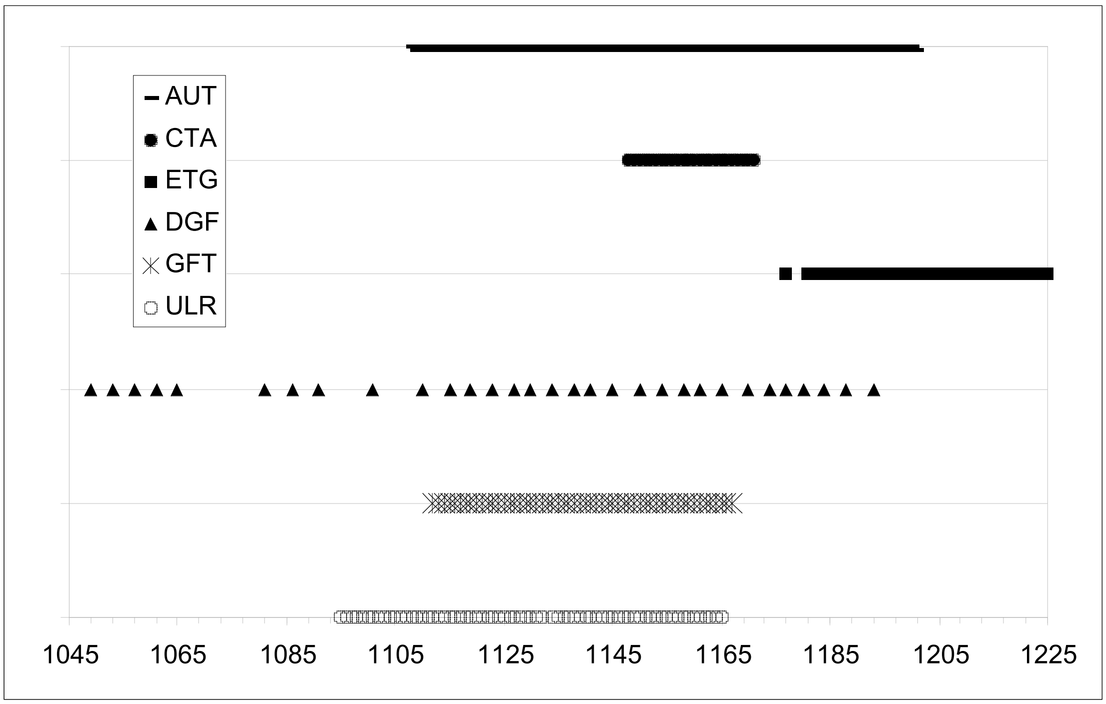

Figure 2: Weekly SINEX file availability at the TIGA FTP server.

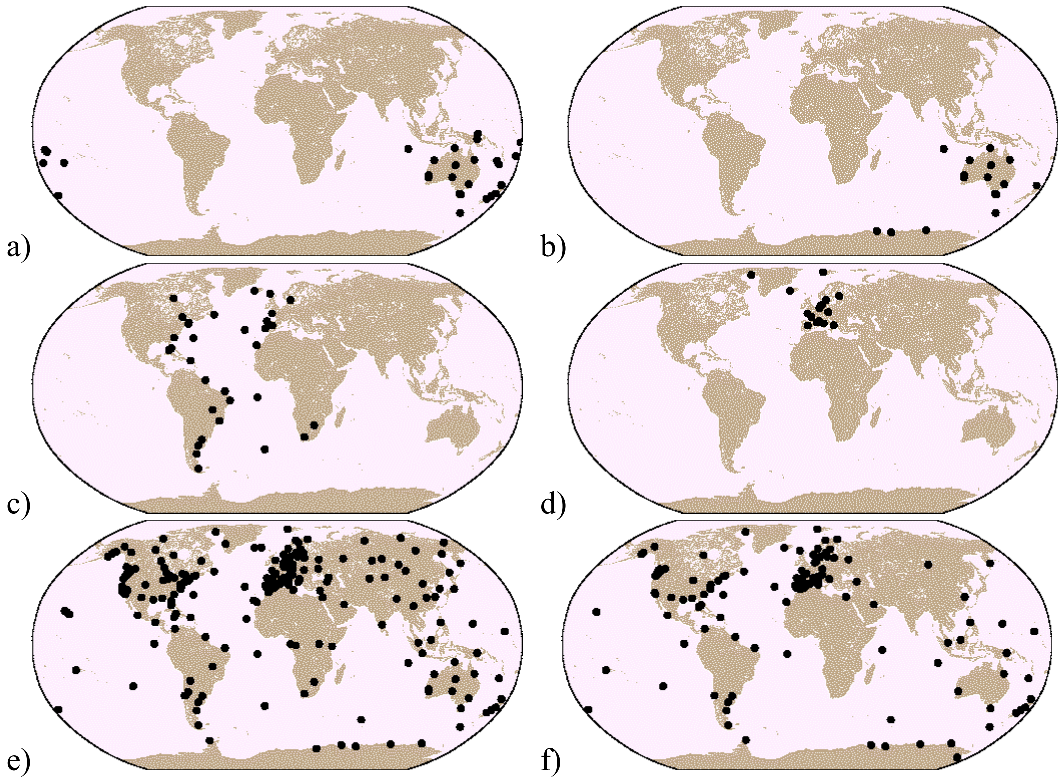

Figure 3: Station distribution for the individual SINEX solution for GPS week *1165* *for (a) Geoscience Australia, (b) University of Canberra, University of Tasmania, Australian National University, (c) Deutsches Geodätisches Forschungsinstitut, (d) EUREF (week 1181), (e) GeoForschungsZentrum Potsdam, and (f) University La Rochelle/IGN.*

Analysis of Center Solutions

Although a routine combination is not yet carried out, all individual solutions are compared by a Helmert transformation. The comparison between all solutions as well as with the IGS final solutions is used to detect inconsistencies, outliers or instabilities. However, the comparison shows an agreement in the 5 mm level for the horizontal components as well as 7 to 10mm for the vertical component. Selected Results are shown in Figure 4.

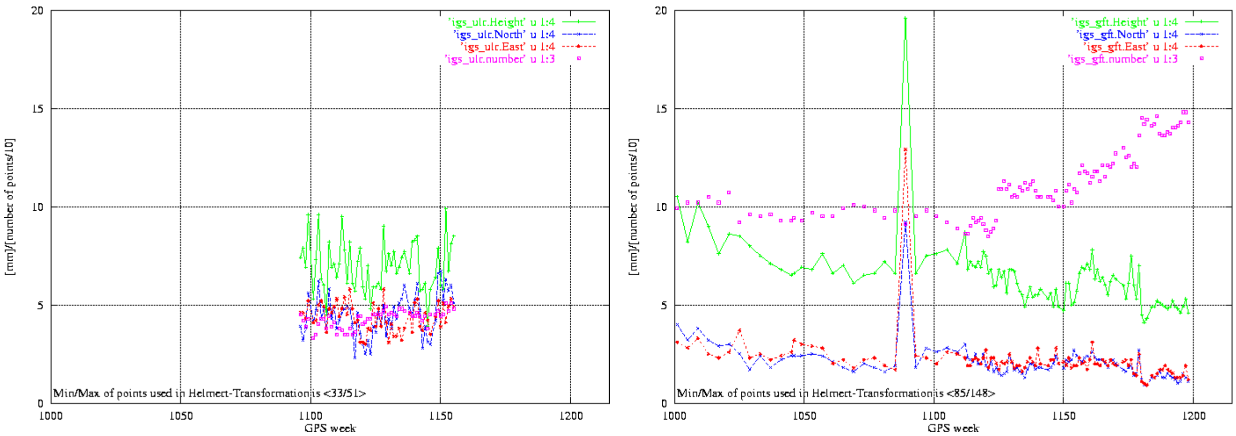

Figure 4: Comparison of individual TIGA solutions with the IGS combined solution (ULR solution (left hand side) and the GFZ solution (right hand side)). *The agreement for the ULR solution is 5 mm for the horizontal and 7 mm for the vertical component. For the GFZ solution the agreement is 3 mm for the horizontal and 10 mm around GPS week 1000 and 5 mm for the later data. This can be explained by the fact that for the later data the GFZ AC solution is part of the final IGS solution forms as well as of the GFZ TIGA solution.*

Future Tasks

By end of 2002 the processing chain was established by the TAC's. Starting with GPS week 1112 SINEX solutions are routinely provided and distributed via the TIGA FTP server. For the backward period SINEX files are provided without a strict timeline. Also by end of 2002 29 TOS stations are accepted for TIGA. However, the number is still growing. An important task for the future will be the constant effort for the establishment of more leveling ties to tide gauge benchmarks.

The main task for the future of TIGA is to establish capabilities for the analysis of the individual solutions and the combination in order to provide a final and verified TIGA product to the user community.

IGS Data Center Working Group Report

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At its 18th meeting held December 09, 2001 in San Francisco, the IGS Governing Board recommended the formation of a working group to focus on data center issues. This working group will tackle many of the problems facing the IGS data centers as well as develop new ideas to aid users both internal and external to the IGS. The direction of the IGS has changed since its start in 1992 and many new working groups, projects, data sets, and products have been created and incorporated into the service since that time. Therefore, this may be an appropriate time to revisit the requirements of data centers within the IGS.

The IGS Data Center Working Group (DCWG) will address issues relevant to effective operation of all IGS data centers, operational, regional, and global. Some of these issues include:

- effective data flow
- backup of the operational data flow
- security issues at data centers
- consistency of data holdings among data centers
- timely archive and dissemination of data as the IGS moves into a real-time mode for selected products

The charter of the IGS Data Center Working Group (DCWG) was approved at the IGS Governing Board meeting held in Ottawa in April 2002. Since that time, a web site was created (*http://cddisa.gsfc.nasa.gov/igsdc*) for the working group. This website contains the charter and list of members and has the capability to expand to include other components pertinent to the working group. In June 2002, an exploder (*igs-dcwg@igscb.jpl.nasa.gov*) was implemented at the IGS Central Bureau for the working group.

One area of interest for the DCWG is the GSAC, the GPS Seamless Archive Center initiative currently being supported by five of the six largest GPS archives within the U.S. (CDDIS, UNAVCO, SOPAC, SCEC, and NCEDC), and with intent to join expressed by NGS in the U.S., GSD in Canada, BKG (EUREF), and IGN. The GSAC working group, currently operating under UNAVCO auspices, would very much like to encourage participation in the GSAC by other GPS archives, particularly outside the U.S. DCWG members were given information about the GSAC and its documentation and were asked to run tests of the GSAC client software. In 2002, the CDDIS completed modifications to software permitting the data center to become an official GSAC wholesaler. The GSAC working group has asked the DCWG to encourage all IGS data centers to consider making the metadata from their archives accessible through the GSAC.

Plans for 2003 include the development of a data center requirements document that would be useful to any group wishing to join the IGS as a global or regional data center or an operational center. The working group will also develop procedures for identifying replacement data, methodologies for handling replacement data in all data centers, and ways to notify the user community of these data updates.