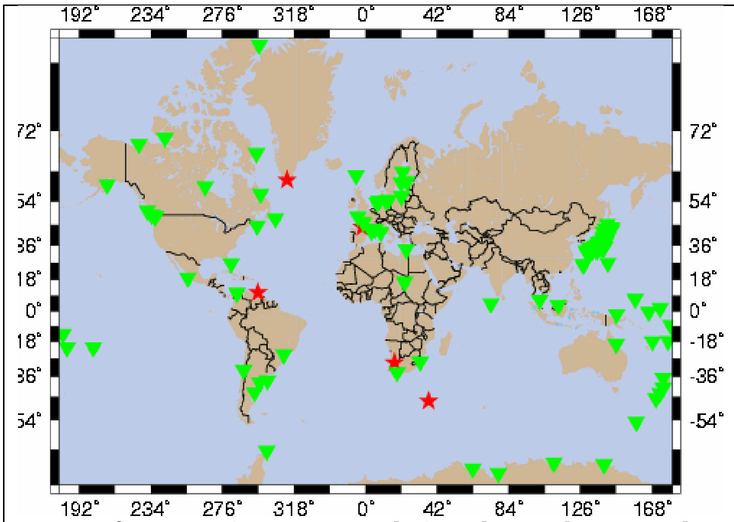
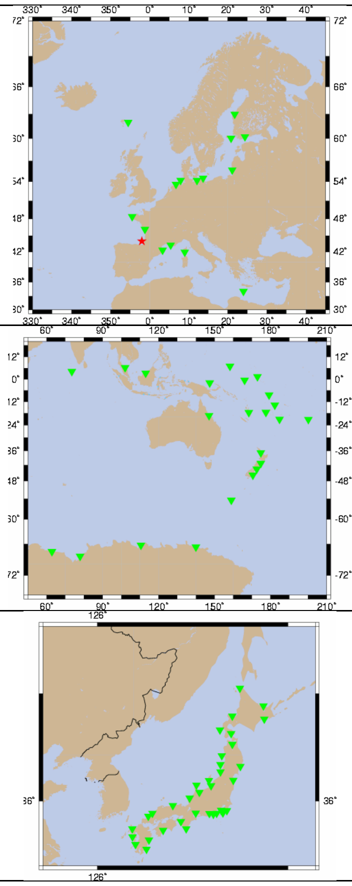
Status of TIGA, December 2006

TIGA Observing Stations (network)

According to a tide gauge survey and constant update by Guy Wöppelmann (University La Rochelle, France), about 280 stations are known to have a GPS station within 10 km distance; about 100 stations have GPS within 500m. In the beginning only a few stations participated, now the network increased to more than 100 TIGA stations (TOS). This is a real step forward, since for the first time a source is available for users which hold the information about the ties between GPS and tide gauge benchmarks.





Map of TOS (green triangles) where the complete information is available. Red stars are proposed, but not yet installed. Also the situation around the Indian Ocean will improve due to UNESCO/IOC efforts to install an Indian Ocean Tsunami Warning System.

TIGA Analysis Centers

Currently six TIGA analysis centers have committed themselves to process TIGA stations. This is done on a best-effort basis. Only EUREF is providing a short-latency solution on a regular basis. However, there has been a very good progress in the forward processing and, especially in the backward processing of GPS data. The processing effort can be seen from the table, details are given in the center sections (01.DEC-2006).

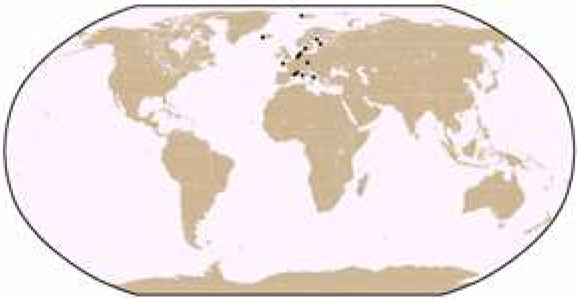
	First Week	Last Week
Geoscience Australia	0782	1295
Canberra, Tasmania, ANU Univ.	0938	1199
DGFI	1054	1393
EUREF	1021	1397
GFZ	1112	1251
University La Rochelle	0887	1341

Deutsches Geodätisches Forschungsinstitut (DGFI)

Within the TIGA project DGFI provides weekly solutions of a GPS network including 54 stations (22 of them at tide gauges) around the Atlantic Ocean. The data analysis is performed using the Bernese GPS Software 5.0. In October 2005 DGFI started the reprocessing of the data applying absolute instead of relative phase center corrections to ensure consistent station position time series and reliable station heights and velocities. For the time span between GPS week 1054 and 1330 one week per month was recomputed; then forward the processing is been carried out for each week. Since November 2006 DGFI uses the set of absolute phase center corrections adopted by the IGS.

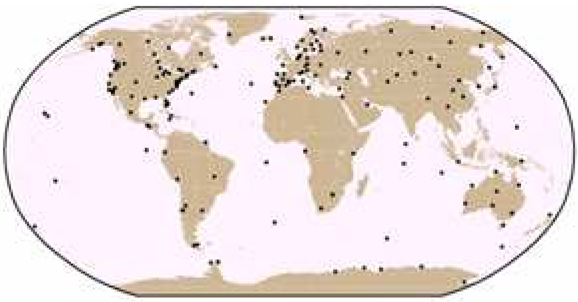
Today, altogether 139 weekly solutions are available. The solutions are provided in SINEX format via the TIGA archive at GFZ. The TIGA pro- and reprocessing will be continued with the hitherto strategy, indeed DGFI starts to process the omitted weekly solution.

EUREF



EUREF, through the BKG (Frankfurt, Germany) is providing a free network solution of the EUREF combination. The combination is computed with a latency of two weeks. For all European TOS stations coordinates are provided. Details on the processing strategy can be found at the EUREF web page. For TIGA, old solutions have been recovered from BKG's data achieve, thus SINEX files are available beginning GPS week 1021.

GeoForschungsZentrum Potsdam



Since 2001 TIGA effort at GFZ was founded by third party funding. Due to the project end and man-power restrictions GFZ has stopped the processing and reprocessing in March 2005. Till then, GFZ has reprocessed data back to GPS week 785 on daily basis with some gaps in 1997. Successful test have been made also to process data from 1994. The processing is done in the same way as by the GFZ analysis center. Processing is done in several clusters and a combination at normal equation level. Most of the available TOS are already processed in the routine AC operation, one cluster is (was) processed and combined with 460 days latency. Recently a new third-party funded project was started aiming also on TIGA. Processing will be continued as soon as GFZ has a trained operator.

In addition GFZ made some extensive testing on time series in order to find jumps in time series. A large number of station discontinuities were identified and fixed. This information will also be used during the combination.

Studies have been performed about the advantage of using atmospheric loading corrections for the combination of weekly files. Atmospheric loading corrections provided by the Sub-Bureau for

Loading (SBL) of the IERS as 6-hourly loading values and based on the numerical weather forecast models have been used.

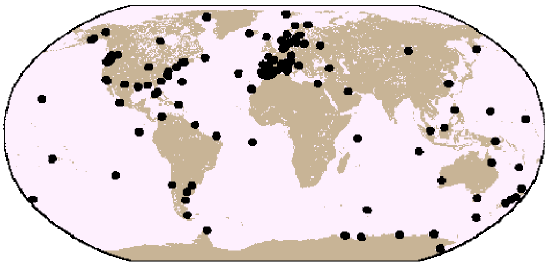
The group at GFZ has primarily investigated the effect of correcting atmospheric loading displacements to the daily estimated station coordinates by applying a daily mean correction. After applying this correction, the scatter of the position time series is decreased significantly. The critical issue is that correcting atmospheric loading displacements can affect the vertical rate estimates of a level of a few sub-millimeter/year. How to correct the loading displacements is still under discussion.

Although some funding was secured to continue the reprocessing for TIGA, the resources have not been available so far.

Geoscience Australia

Yet, no report available

University La Rochelle



The ULR analysis center consortium was established in 2002 to process GPS data from stations at or close to tide gauges. It contributes to the TIGA pilot project since October 2002 by providing weekly solutions with 460 days latency. The data analysis is performed using: (i) GAMIT software (King and Bock 2005) for processing on a free network approach the GPS measurements that are split into several global clusters, each with at most 50 stations and (ii) CATREF software (Altamimi et al. 2004) for combining the cluster solutions into daily solutions, and then into weekly solutions. Wöppelmann et al. (2004) present the rationale for the ULR analysis consortium and provide details on the initial processing strategy.

Studies were carried out to investigate the best strategy to implement the terrestrial reference frame and to align the station position solutions at the millimeter level (Wöppelmann et al. 2006a). The results led to an extension of the GPS stations processed at ULR to include the 92 IGb00 reference frame stations of the IGS (IGSSTATION-352, Ferland 2005). The ULR processing infrastructure is now coping with a network of up to 223 GPS stations. In parallel, major advances were made in absolute antenna phase centre corrections for both GPS satellites and receivers (e.g. Ge et al. 2005, Gendt 2005). Both the network extension and the new antenna model corrections encouraged ULR to reprocess backwards the GPS data. The reprocessing started in January 2006. Weekly SINEX solutions with the new strategy have satisfactorily been processed from 1999.0 up to 2005.7 (GPS weeks 0992 to 1341), replacing the former solutions which covered the period 1997.0 to 2004.0 (GPS weeks 0887 to 1250). The new strategy also includes the troposphere GMF mapping function from Boehm et al. (2006), as well as the atmospheric pressure loading corrections from Tregoning and van Dam (2005).

In addition ULR has carried out analyses to assess the quality of its solutions, and to construct coherent time series of station positions. An exercise of combining tide gauge and GPS results was undertaken for the World Climate Research Program workshop on “Understanding Sea-level Rise and Variability” which took place in June 2006, in Paris (Wöppelmann et al, 2006b). The idea was to reproduce Douglas (2001) and Peltier (2001) analysis by using GPS land motion estimates instead of the glacio-isostatic adjustment (GIA) corrections to derive GPS-corrected tide gauge trends. The results were quite encouraging. They showed that GPS corrections reduce the dispersion of sea-level trends, either regionally and globally, compared to GIA corrections. A detailed analysis was carried out to publish this findings, and a paper was then submitted to a peer reviewed journal (Wöppelmann et al. 2006c).

The reprocessing of 6.7 years of GPS data took 8 months with the computer facilities currently available at ULR. Solutions are being investigated to enhance the computing facilities in order to reduce the GPS processing time. This is a key technical issue for future backwards reprocessing of the entire GPS data set that is now available, when new models are available or new strategies are devised.

References cited here (external, ULR team are at the end):

Altamimi, Z., Sillard, P., Boucher C., 2004. CATREF software: Combination and analysis of terrestrial reference frames. LAREG Technical Note SP08, Institut Géographique National, Paris, France.

Boehm, J., Niell, A., Tregoning, P., Schuh, H., 2006. Global mapping function (GMF): a new empirical mapping function based on numerical weather model data. Geophys. Res. Lett., 33, L07304, doi:10.1029/2005GL025546.

Douglas, B.C., 2001. Sea level change in the era of the recording tide gauge. In *Sea Level Rise: History and Conseque*nces, Int. Geophys. Ser., vol.75, edited by B. Douglas, M. Kearney, and S. Leatherman, chap.3, Academic, San Diego, pp. 37-64.

Ferland, R., 2005. IGb00 review - GOUG - YAKT. IGSSTATION-352 of Dec. 31, 2005, available at http://igscb.jpl.nasa.gov/mail/igsstation/2005/msg00035.html

Ge M., G. Gendt, G. Dick, F.P. Zhang and C. Reigber (2005). Impact of GPS satellite antenna offsets on scale changes in global network solutions. Geophysical Research Letters, 32, L06310, doi: 10.1029/2004GL022224.

Gendt, G., 2005. Switch the absolute antenna model within the IGS. IGSMAIL-5272 of Dec. 19, 2005, available at http://igscb.jpl.nasa.gov/mail/igsmail/2005/msg00193.html

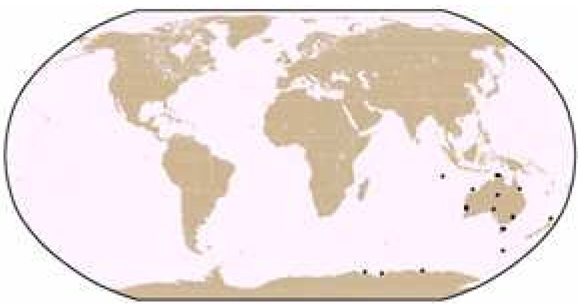
King, R.W., Bock, Y., 2005. Documentation for the GAMIT GPS Analysis Software. Release 10.2, Mass. Institute of Technology and Scripps Institution of Oceanography.

Peltier, W.R., 2001. Global glacial isostatic adjustment and modern instrumental records of relative sea level history. In *Sea Level Rise: History and Conseque*nces, Int. Geophys. Ser., vol.75, edited by B. Douglas, M. Kearney, and S. Leatherman, chap.3, Academic, San Diego, pp. 65-95.

Tregoning, P., van Dam, T., 2005. Atmospheric pressure loading corrections applied to GPS data at the observation level. Geophy. Res. Lett., 32, L22310, doi:10.1029/2005GL024104.

http://adsc.gfz-potsdam.de/tiga/TAC/ulr_tac.info

Universities of Canberra, Tasmania and ANU



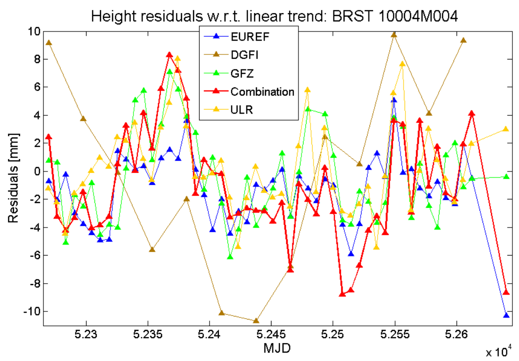
These three Universities have been the first providing an extensive set of SINEX files for a network with a focus on Australia and the Australian stations in Antarctica. The solution covers GPS week 938 till 1199 (261 weeks). Processing was done with GAMIT, and the combination to weekly solutions was done with GLOBK. A reanalysis of global TIGA data from 2000 onwards is currently underway, incorporating many new models that have been added to the GAMIT software (King and Bock, 2006) recently. These include absolute satellite and antenna phase centre variations and offsets, the Vienna Mapping Function-1 (Boehm et al., 2006), atmospheric pressure loading at the observation level (Tregoning and van Dam, 2005), the full IERS 2003 formulation for the solid Earth tide (Watson et al., 2006) and improved modelling of the a priori zenith hydrostatic delay (Tregoning and Herring, 2006). Investigations during 2006 have shown that each of these changes in modelling affect the precision and, in particular, annual and semi-annual periodic variations seen in height time series.

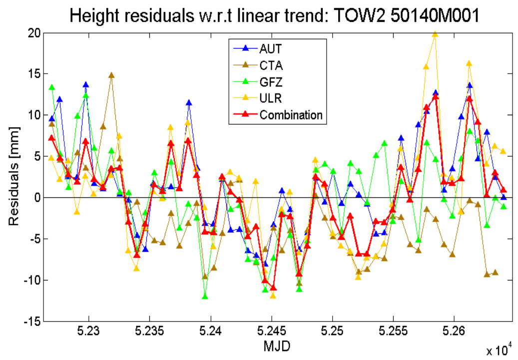
Updates to the previous SINEX file submissions made by the CTA Analysis Centre will be provided in December 2006 for inclusion in subsequent TIGA combinations. No funding is provided to any of the three universities to support the analysis activities of TIGA and the research is done on an opportunity basis only.

References:
The impact of solid Earth tide models on GPS time series analysis, C. Watson, P. Tregoning, R. Coleman *Geophys. Res. Lett.*, 33(8), L08306, 10.1029/2005GL025538, 2006.
Impact of a priori zenith hydrostatic delay errors on GPS estimates of station heights and zenith total delays, Tregoning, P. and T. A. Herring, *Geophys. Res. Lett., in press*, 2006.
The GMF: A new empirical mapping function based on numerical weather model data, Boehm, J., A. E. Niell, P. Tregoning, H. Schuh *Geophys. Res. Lett.*, 33(7), L07703, doi:10.1029/2005GL025546, 2006.
Boehm, J., B. Werl, and H. Schuh (2006), Troposphere mapping functions for GPS and very long baseline interferometry from European Centre for Medium-Range Weather Forecasts operational analysis data, *J. Geophys. Res.*, 111, B02406, doi:10.1029/2005JB003629.

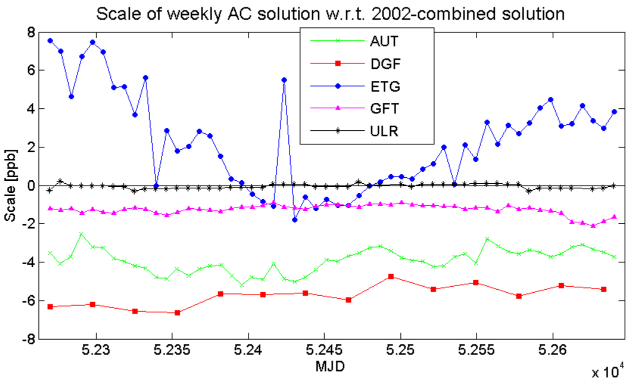
Combinations

GFZ announced to provide the resources to generate a combined solution. For this purpose, the Bernese GPS Software Version 5.0 is employed. Up to now, the procedure has been implemented and tested by using the available TIGA data for the year 2002. Looking at the repeatabilities of the station coordinates, the increase of the stability of the time-series due to the combination is visible. The combined solution for 2002 has an overall repeatability of 2.59 mm, 2.78 mm and 7.04 mm for the north, east and height component, respectively. The time-series of station heights are shown exemplarily for two sites (Brest/France, Townsville/Australia). The combined solution is opposed to the individual solutions of those analysis centers that included the appropriate site.





In order to derive reasonable and good station heights, a scale parameter was set up for the individual contributions, and the scale of the combined solution was fixed to ITRF2000. The scale parameters estimated for each weekly contribution with respect to the yearly combined solution of 2002 are shown in the figure below. Except for the EUREF contribution (=ETG), the time-series of scale parameters are very stable for each analysis center, so that it should be enough to estimate only one scale parameter per analysis center in a final multi-week / multi-year combined solution. The varying scale parameters in the EUREF contribution (more or less a yearly signal) might be caused by the fact that the area covered by the EUREF network is very small. Thus, all sites are influenced by similar seasonal effects so that the height variations are absorbed by the scale parameter in the estimation. But this behavior still has to be investigated in more detail.



The next step will be to generate weekly combined solutions for the whole time span where TIGA solutions are available. As long as not all analysis centers have switched to the absolute antenna phase center variations, the combined solution will be based on the "old" contributions using the relative antenna calibrations, because a mixture of both antenna models should be avoided. The combined solutions will be provided in weekly SINEX files and as coordinate time-series.

Chairman's activities

TIGA was presented with posters at different meetings, in particular IAG (Cairns), at the ESA/CNES workshop "15 years of Progress in Radar Altimetry" in Venice (March 2006). Parts of TIGA and the importance of the GPS control of tide gauges were also presented at a few Tsunami-related meetings.
At the WCRP workshop in Paris, results from TIGA processing have been presented.
Recently lectures at the IOC ODINAFRICA trainings course in Oostende (Belgium) have been given.

TIGA related or stipulated publications

Sanchez L., Krügel M.: The role of the TIGA project in the unification of classical height systems. International IAG/FIG Symposium on "Geodetic Reference Frames", GRF 2006, 9-14 October 2006 (Poster).
Wöppelmann G., M-N. Bouin, Z. Altamimi, L. Daniel and S. McLellan, 2004: Current GPS data analysis at CLDG for the IGS TIGA Pilot Project. Cahiers du Centre Européen de Géodynamique et de Séismologie, *The state of GPS vertical positioning precision : Separation of earth processes by space geodesy*, Ed. T. van Dam and O. Francis, Vol. 23, pp.149-154.
Wöppelmann G., M-N. Bouin and Z. Altamimi, accepted 2006a: Terrestrial reference frame implementation in global GPS analysis at TIGA ULR consortium. Physics and Chemistry of the Earth, submitted May 2005, accepted November 2006.
Wöppelmann G., B. Martin Miguez, M-N. Bouin and Z. Altamimi, 2006b: An exercise of combining tide gauge and GPS results. World Climate Research Program Workshop on *Understanding Sea-level Rise and Variability*, 6-9 June 2006, UNESCO/IOC, Paris, France
Wöppelmann G., B. Martin Miguez, M-N. Bouin and Z. Altamimi, submitted 2006c: A global sea-level trend estimate from GPS-corrected tide gauge records. Global and Planetary Change, submitted September 1, 2006.
Schoene, Tilo: "Linking GPS to Tide Gauges and Tide Gauge Benchmarks". World Climate Research Program Workshop on *Understanding Sea-level Rise and Variability*, 6-9 June 2006, UNESCO/IOC, Paris, France

Blewitt, G., Z. Altamimi, J. Davis, R. Gross, C. Kuo, F. Lemoine, R.Neilan, H.P. Plag, M. Rothacher, C.K. Shum, M.G. Sideris, T. Schöne, P. Tregoning, S. Zerbini: Geodetic Observations and Global Reference Frame Contributions to Understanding Sea Level Rise and Variability World Climate Research Program Workshop on *Understanding Sea-level Rise and Variability*, 6-9 June 2006, UNESCO/IOC, Paris, France