

IGS Reference Frame Maintenance

R. Ferland, G. Gendt, T. Schoene

This presentation will review recent Reference Frame related activities and propose some short to medium term improvements. The recent activities will include results from the weekly SINEX combination and details of the upgrade of the IGS realization (Igb00) of the ITRF. The combination strategy will be reviewed, with emphasis on potential weaknesses.

The reported results of weekly SINEX combination will include station coordinates/velocity, scale, ERP's and apparent geocenter. Large discontinuities in station coordinates time series are currently accounted for, small discontinuities are more difficult to reliably and quickly flag; suggestions will be made.

Aspects of realizing the RF using IGS orbits and clocks will also be discussed. For specific projects, significant subsets of the data may have to be reprocessed, primarily to improve the height component; details will be discussed.

Environmental Issues and Monumentation

Y. Bock

The presentation will discuss a host of non-tectonic site motions that influence the accuracy and precision of the reference frame, for example, monumentation, seasonal effects, ground-water effects and post-glacial rebound.

Current Challenges of Monitoring Station Height with GPS

D. Dong, M. Heflin

With the rapid development of the continuous GPS global network and analysis models, the GPS derived station height time series are able to detect the vertical deformation information on secular, seasonal and short time scales. To further improve the accuracy of the station height solutions, the following five challenges must be studied and be resolved:

- (1) Known and unknown systematic errors exist in current GPS analysis, in particular the satellite elevation angle dependent systematic errors.
- (2) Many estimated parameters in current GPS analysis are highly correlated in vertical direction. A small phase perturbation causes big variations in estimated station heights.
- (3) Reference frame is not well constrained in vertical variations of site coordinates, in particular on seasonal time scales.

(4) There is no single dominant contributor for the vertical deformation, so that multiple contributors must be considered together to interpret the observed station height variations. (5) Vertical deformation has good "memory" on historical events, such as past deglaciation, big earthquakes. Historical events must be taken into account to interpret the observed station height variations.

I will address these challenges in the workshop.

IERS Rigorous Inter-Technique Combination Implications to IGS

M. Rothacher, D. Thaller, R. Schmid, P. Steigenberger

In Spring 2004 the IERS Combination Pilot Project (CPP) will start. This CPP should be a major step towards more consistent, routinely generated IERS products. "Weekly" SINEX solutions made available by the various Technique Services -- e.g. by the IGS -- and containing site coordinates, EOPs, and, possibly, quasar coordinates (VLBI), shall be rigorously and routinely combined into consistent weekly IERS products (SINEX files).

The major goal of the CPP will be to study and develop optimum strategies for a rigorous combination (including weighting schemes, datum definition, use of local ties, handling of systematic biases, ...) to ensure consistent and highly accurate IERS weekly solutions. The new products resulting from these combination procedures are expected to replace a considerable part of the present IERS products in the future, if the IERS CPP proves to be successful.

For the IGS, the implications of these developments are three-fold:

First, because systematic effects in the IGS (and other) solutions may torpedo the inter-technique combination, these effects have to be reduced to the extent possible. Systematic effects are clearly present in, e.g., LOD (and nutation rate) estimates from GPS, geocenter and site coordinates and troposphere zenith estimates (due to antenna phase center problems and multipath).

Secondly, to obtain consistent weekly IGS SINEX solutions over ten years or more for the realization of improved ITRF realizations, the IGS Analysis Centers (ACs) -- or other groups -- should get ready to periodically re-process the global GPS network. Each time, new modeling standards will be adopted, such a re-processing will be necessary to ensure consistency with other space techniques. In addition, changes in site equipment leading to jumps in the coordinate time series will have to be monitored in detail.

Finally, the IGS should continue to improve its products and make them (even) more consistent. If the idea of a rigorous combination is persistently pursued, also orbits or troposphere zenith delays, as examples, should eventually be rigorously combined between IGS ACs and between space techniques. Considerable inconsistencies still exist between these parameters from different IGS ACs and different techniques.

Detection and Handling of EPN Station Irregularities

C. Bruyninx, G. Carpentier, F. Roosbeek, A. Kenyeres

The stations of the EUREF Permanent Network (EPN) are primarily used for maintaining the European Terrestrial Reference Frame (ETRS89). Not only the quality of the ETRS89 realisation, but also its proper use by the National Mapping Agencies, is strongly dependent on the detection and proper handling of irregularities in the station coordinates. We will discuss how, within the EPN, station performance is monitored with the goal to detect irregularities in the station coordinates. Once these irregularities are detected it is also important how this information is passed to the user community. We will describe how this is presently handled within the EPN.

Contribution to EUREF of the ASI (Agenzia Spaziale Italiana) Matera Space Geodesy Center “G. Colombo” (CGS)

C. Ferraro, A. Nardi, G. Bianco, F. Vespe

Within the space geodesy analysis activities performed at ASI-CGS, a predominant role is played by the geodetic research and products devoted to the Terrestrial Reference Frame realization: global and regional geodetic products, based on the three space geodesy techniques hosted by CGS (SLR, VLBI, GPS) are regularly submitted to the geodetic international organizations (IERS, ILRS, IVS, IGS). In particular, ASI CGS has been contributing to EUREF since 1996, starting with weekly coordinate solutions of a network of seven permanent GPS receivers, distributed in Italy, Spain and Germany. Since then, the contribution has been growing in the years both in terms of number of analysed sites (twenty-two up to now) and of data products; moreover, following the evolution of the EUREF objectives, at present ASI-CGS submits regularly not only coordinates but also tropospheric zenith delays.

ASI-CGS is actively participating to two EUREF special projects: "EUREF Permanent Network Time series monitoring" and "Troposphere Parameter Estimation". A general overview on the activities developed in seven years of collaboration have been described in this work.

Discontinuities in the IGS Tracking Stations Coordinate Time Series

P. J. Mendes Cerveira, R. Weber

The present work represents an attempt to characterize IGS station coordinate time series under various aspects. We investigated the weekly SINEX coordinate time series of more than 300 globally distributed IGS GPS-sites submitted from eight different IGS Analysis Centres (ACs). These series cover a 4.5 years period ranging from August 1999 till February 2004. We have to note that the coordinate time

series contain numerous non-stationary or transitory characteristics: discontinuities, short time events or periodical signals which affect our analysis results. Nevertheless, these characteristics are an important part of the signal, but Fourier analysis is not suited to detecting them. Wavelet analysis, on the other hand, using a varying resolution in time, allows to use long time intervals where precise low-frequency information is needed, and shorter spans where we want high-frequency information. If we could find a systematic way to eliminate these discontinuities, the long term trends from the different IGS AC's coordinate series would probably agree much better and we would have a better idea of what the data are telling us about seasonal amplitudes.

The final purpose is to gain insight into surface loading processes on the Earth. Some evidence does suggest that we should look at the stations deformation indicated by spherical harmonics, and perceive to what extent this deformation equates to the same spherical harmonic of the load.

GPS Time Series and Sea Level

M. Poutanen, H. Koivula, M. Tervo, K. Kahma, M. Ollikainen, H. Virtanen

Time series of IGS, EUREF and FinnRef networks show in most cases a statistically significant periods both in station coordinates and inter-station distances. In regional networks the scale of the whole network is changed periodically and a secular trend of the scale can be seen. Loading caused by the variable sea level height of the Baltic Sea is also visible in the GPS time series of those GPS stations close to the shoreline. Weekly, daily and sub-daily GPS time series were analysed together with hourly tide gauge data of Finnish tide gauges.

We also performed a test to simulate the height variation of a GPS antenna. The purpose is to distinguish between the actual loading effect on the crust and the tropospheric path propagation error. Sea and atmospheric loading are the major contributors in the error budget when determining vertical motions. Our goal is to study the accuracy in determining the sea surface variability using the combined information of GPS and tide gauges. Our work will contribute to the IGS TIGA project.

Hafelekar GPS Permanent Station Seasonal Monitoring

G. Stangl, C. Haslinger, E. Cristea

From the beginnings at 1996 the Hafelekar (HFLK) IGS permanent GPS station shows a seasonal strong variation in its time series of coordinates, especially in the North and Up components. Starting from 2001 a few local GPS campaigns were performed seasonally with three auxiliary GPS stations in order to monitor this behavior. The three stations are situated at close distances from HFLK, to investigate if the movement is a local sliding of the platform where the GPS station is embedded, or to confirm a possible water basin theory.

Patscherkofel (PATK), another Austrian GPS permanent station situated 10 km apart, is stable in its lateral components and is used in the calculations forming a baseline with HFLK. Some other neighbor

permanent GPS stations are used to form a small network. It can be proved that the variation is a local phenomenon.

IGS Tide Gauge Benchmark Monitoring Pilot Project

T. Schoene

Sea level is a very sensitive parameter to natural and human-driven climate related changes and an important factor for the vulnerability of near coastal, densely populated areas. For more than a century tide gauges (TGs) have been the most important measuring devices for the sea level. Although new remote sensing techniques, like e.g. radar altimetry, have become available, TG measurements remain a valuable tool. The limiting factors for using TGs for sea level change studies are the globally uneven distribution of TG measurements and the stability of the TG benchmark (TGBM).

Historically tide gauges had either no ties to a height reference system or the tie was maintained by first order leveling only. With the broad use of GPS since the 1990th ties are more and more established either through repeated campaigns or more recently on a continuous basis. This gives the unique possibility to reference the sea level measurements to an absolute reference frame.

In 2001 the IGS established the Tide Gauge Benchmark Monitoring Pilot Project (TIGA-PP). The primary product of the service will be time series of coordinates for analyzing vertical motions of TGBMs. Different Analysis Centers are providing weekly solutions for selected GPS stations near TGs on a continuous basis. The pilot project was operated for the period 2001 to 2004, but is now continued for at least two years.

See also <http://op.gfz-potsdam.de/tiga>.

Processing, Combination and Time Series Analysis of Continuous GPS Data: A Test Study

M. E. Ayhan, C. Demir, A. Kilicoglu, A. Cingoz, B. Aktug, A. Kurt, H. Yildiz

Global Positioning System (GPS) is now being used routinely for mm-level horizontal and vertical positioning. Time series analysis based on daily estimates of positions is used for monitoring crustal movements and detecting periodical signals which may be caused from geophysical phenomena and/or other effects such as atmospheric loading, reference frame definition etc. that are not properly modeled during the post-processing. Combination of daily GPS solutions and forming a time series require a well defined reference frame consistent with IGS orbits and ITRF coordinates. To investigate suitable reference frame stabilization for daily time series, we used a 90-day GPS data from a test network of 34 stations formed within European Sea Level Service-Research and Infrastructure (ESEAS-RI) Project. The network stations are collocated at tide gauge stations located mostly on the coast of Western Europe. GPS data from this network were processed with GAMIT/GLOBK and the daily time series were examined using TSVIEW time series analysis software that allows us to search for periodical

signals and outliers. The reference frame was defined for each day using both a reliable set of 35 global IGS stations and 10 regional IGS stations in the vicinity of the area. The results of the analysis yielded that local stabilization of the reference frame using regional IGS stations gives better results than global stabilization. A two monthly periodic effect on the up component was detected, which might be caused by the influence of the hydrological loading dominating on the northern seas.