Observations of Large-scale Frame Deformations and Related Effects

T. Herring

In this talk we concentrate on the characteristics of "local" frame realizations and the relationship between these realizations and global-based frame realization. For local networks such as the Southern California Integrated GPS Networks (SCIGN), the local realization yields horizontal position repeatability of ~0.5 mm and vertical repeatability of ~3 mm. As the size of the region used to realize the frame expands, these repeatabilities increase to 2 and 6 mm. This paper examines the changes in the character of the frame realizations as network size is increased and some of the processes, such as atmospheric and water loading, that affect frame realization.

Relationships Between Mass Redistribution, Station Position, Geocenter, and Earth Rotation: Results from IGS GNAAC Analysis

G. Blewitt

Redistribution of mass on the Earth's surface causes changes in the Earth's geometrical shape, gravity field, and orientation in space (the "three pillars of geodesy"), each of which are fundamental considerations for global reference frame definition. On seasonal to several-year time scales, surface mass redistribution is believed to dominate changes in Earth's shape, as measured by stations coordinates of the IGS network. Dynamic models connect this change in Earth's shape to variations in the geocenter (net movement of the solid Earth relative to the center of mass of the whole Earth system), and to Earth rotation. The IGS network provides a unique opportunity to investigate these relationships, due to the density of stations as compared to other techniques, and due to the high precision of the station coordinate time series. Here we present results of various investigations that probe these interactions using station coordinate time series from the Newcastle IGS Global Network Analysis Center. Based on these promising new results, we discuss how the quality of IGS data might impact geodetic science on the global scale. Specifically, we address how global geodetic science provides guidance on where IGS components might be improved to enhance the science return. Key issues include station density, station distribution, monument stability, station configuration stability, station metadata, and data analysis stability in time.

Tests of IGS Reference Frame Stability

Z. Altamimi, J. Ray

We examine the long-term stability of the IGS terrestrial reference frame through times series combination of the IGS weekly combined SINEX solutions. In order to define the combined frame under minimum constraints condition, we used different sets of stations, but still globally distributed, extracted from IGb00 reference set. Using this approach, we try to assess the behavior and stability over time of the origin, scale and orientation as well as Earth Rotation Parameters, by comparing the different realizations while varying the number and distribution of reference stations.

The Effect of the Second Order GPS Ionospheric Correction on Receiver Positions

S. Kedar, G. Hajj, B. Wilson, M. Heflin

The Global Positioning System (GPS) transmits two frequencies, allowing users to correct for the first-order ionospheric signal group delay (or phase advance) of 1-50 m. The second-order ionospheric term, caused by the Faraday rotation effect induced by the Earth magnetic field, is about 1000 times smaller and usually ignored. In this study, we implement the 2nd-order correction suggested by Bassiri and Hajj [1993] and investigate its effect on GPS-inferred station positions. The correction causes a latitude dependent 0.1-0.5 cm southward shift to the position, which is roughly proportional to the integrated electron density above the receiver, and has strong diurnal, seasonal and decadal signatures. By analyzing a three-year time series of equatorial station positions obtained without the 2nd-order correction, a strong semi-annual north-south oscillation is observed, the origin of which has not been hitherto explained. We verify that this apparent oscillation can be largely removed once the 2nd-order correction is applied.

Improving IGS Timescale Stability and Tracking of UTC

K. Senior, J. Ray

Currently the International GPS Service (IGS) timescales are aligned to the international timescale UTC by slowly steering (roughly consistent with a 30-40 d time constant) to observations of GPS time, which is itself steered to UTC via the UTC(USNO) realization. The instability of the IGS timescales has been determined to better than 2 parts in 1015 at 1 d, whereas the instability of GPS time is at least 10 times poorer. It is likely that due to its larger instability, steering to GPS time limits the stability of the IGS timescales for periods longer than a few days.

A new method (the topic of another paper at this conference) extends to geodetic systems the timing calibration from systems colocated at timing laboratories that contribute to UTC. These colocated geodetic systems and local UTC(k) realizations can have much better stabilities than GPS time. Using the empirical instrumental calibration biases together with predictions of UTC(k) offsets, suitable colocated geodetic clock data can provide a higher-quality and robust link of the IGS timescales to UTC. We discuss the techniques used to predict offsets of UTC(k) between monthly Circular T reports and assess the stability and overall quality of the IGS timescales as steered using these differentially calibrated systems instead of GPS time.

CERGOP-2/Environment

P. Pesec

CERGOP-2/Environment is a project, partially financed by EU under the 5th FP. It comprises the efforts of 13 countries in Central Europe to extend and update the monitoring network CEGRN, covering about 15 % of Europe, for geodynamical research, hazard mitigation and near real time data access. The project started April 2003 and will last for three years.

By now we succeeded the first annual period. The poster will summarize the works deployed by now on the basis of 17 work packages.

CODE High-rate GPS Satellite Clock Corrections

H. Bock, R. Dach, U. Hugentobler, S. Schaer, G. Beutler

CODE started to regularly generate 30-seconds phase consistent high rate satellite clock corrections. The product will soon be submitted to the IGS for the rapid and the final solution. The poster describes the procedure used to generate the high rate clock corrections based on the previously computed 5-min clocks and presents results from kinematic precise point positioning experiments used to validate the product.

Continuously Operating GPS Receivers at Thule, Greenland

S. A. Khan, F. B. Madsen, P. Knudsen

The National Survey and Cadastre - Denmark (KMS) is responsible for the geodetic definition of the reference network in Greenland. Permanent GPS play an important role in the monitoring and maintenance of the geodetic network. Furthermore, KMS supports the international GPS infrastructure and research by supporting IGS. In October 1998 KMS has established a permanent GPS station THU2 at Thule Airbase. Besides THU2 the old permanent station THU1 is also running. The Thule stations are important because they are two of the few northernmost stations in the IGS network. THU2 has been operating since March 1999, and it is now a high quality and high performance station contributing to the IGS Low-Earth Orbiters (LEO) network. Besides the GPS stations in Thule, KMS is also running a permanent GPS station SCOB in Scoresbysund, which was established in August 1997, and in October 2001 a permanent station QAQ1 was established in Qaqortoq. This station is registered at IGS. Furthermore, University of Colorado operate the IGS station Kellyville near Kangerlussuaq and a station in Kulusuk.

Reprocessing of the Global GPS Network: First Results

M. Rothacher, P. Steigenberger, R. Dietrich, M. Fritsche, A. Ruelke

During the time span of ten years since the official start of the IGS in 1994, considerable improvements in the processing strategies and modeling of global GPS solutions were achieved. Due to the changes at the individual IGS analysis centers during these years, the resulting time series of global geodetic parameters are very inhomogeneous and inconsistent and make a geophysical interpretation of long series difficult and questionable.

In view of these deficiencies, the Technical Universities of Munich and Dresden decided to perform a reprocessing of a global GPS network over the last ten years in a joint effort, implementing a processing scheme similar to the one used at the CODE Analysis Center of the IGS at the University of Berne. With powerful LINUX clusters available at both institutions, the processing of the entire 10-year data set should be possible, CPU-wise, in about two months.

After a careful selection of about 160 global stations (based primarily on long observation time, homogeneous global distribution, and collocation with other techniques and tide gauges) and extensive processing tests, a significant amount of the ten years was processed to allow a first assessment of the quality of the results and the benefits to be expected from the reprocessing effort.

This contribution will show, that a significant improvement can be achieved in orbit quality, repeatability of the station coordinates and the quality of the Earth rotation parameters. The new results are compared with the original CODE solutions as well as the official IGS solutions. Besides the general improvement, a wealth of interesting differences and effects can be detected in the comparisons of the time series.

Rigorous Combination of GPS and VLBI to Study Reference Frame Related Issues

M. Krügel, V. Tesmer, D. Angermann, D. Thaller, M. Rothacher, R. Schmid

The space geodetic observation techniques such as GPS, VLBI, SLR and DORIS contribute in a different and unique way to the realization of reference frames and to the determination of geodetic parameters (e.g. site positions, Earth orientation parameters, tropospheric parameters, gravity field coefficients). Today's accuracy of these parameters is mainly limited by technique- and/or solution-related systematic effects (biases), that are often poorly characterized or quantified. This can cause too optimistic accuracy expectations. Both, the different characteristics of the various space geodetic techniques in determining several parameters and the existing discrepancies between them, strongly require the development of rigorous combination methods.

This presentation focuses on the combination of GPS and VLBI solutions on the normal equation level. Due to a large number of common parameters, their combination provides a stabilization of the normal equations and possibly the identification of the origin of systematic differences between the two techniques. The International VLBI Service (IVS) has initialized an intensive 15-days VLBI campaign in October 2002 with eight participating stations, named CONT02, which provides a perfect data set for the combination with data of the global IGS network. The VLBI sessions were processed at DGFI using the OCCAM software, daily normal equations for a global IGS network were obtained with the Bernese GPS Software 5.0 at TU Munich. These free normal equations were generated taking much care to use identical models and the same parameterization of common parameters, i.e. coordinates, Earth orientation parameters, tropospheric zenith delays and gradients.

A key role within the combination of the two techniques plays the local tie information that connects both techniques. A major aspect was the selection of suitable local ties by applying various criteria. Important issues in this context are the analysis of systematic differences between the techniques and the interactions between local ties and the combined parameters. Future studies are necessary to understand the origin of remaining discrepancies between separately estimated parameters, i.e. in the scale, Earth orientation parameters and tropospheric zenith delays, before aiming at a rigorous combination of VLBI and GPS solutions. In the future also SLR solutions will be included into this rigorous combination to improve the realization of the geocentric terrestrial reference frame.

Seasonal Height Errors and the TRF

A. E. Niell

The simple seasonal model of the hydrostatic mapping function, NMFh, leaves fictitious position height errors at annual and semi-annual periods in addition to a random error.

Errors in both the geodetic estimates and in atmosphere delay estimates are largest at high latitudes and are smallest in the equatorial region. At mid-latitudes the annual term of the height error has an amplitude of approximately 5 mm for minimum elevation of 5 degrees, and the semi-annual error is about half that. The errors are smaller by a factor of about two for 7.5 degree minimum and by about six for a 15 degree minimum.

The sense of the error is generally to depress the height in northern hemisphere winter.

These errors can be significantly reduced by using atmosphere delay mapping functions based on a Numerical Weather Model.

Swedish Activities During 10 Years as a Data Provider and Customer of the IGS: Geophysical and Geodetic Applications

J. Johansson, H.-G. Scherneck, M. Lidberg, R. Haas, S. Bergstrand, L. Jivall

The land uplift processes in Fennoscandia have been subject to scientific research for morethan a century. The cause of this land uplift phenomenon is a glacial isostatic adjustment (GIA) process, which has its origin in the last ice age that culminated about 20 kyr ago.

In 1993, the Baseline Inferences for Fennoscandian Rebound Observations Sea Level and Tectonics (BIFROST) project was therefore started, with a primary goal to establish a new and useful 3D observable, able to constrain models of the GIA process in Fennoscandia. A network of permanently operating GPS receivers was established in Sweden and Finland with an inter-station distance of 100 to 200 km. In this study we have analysed GPS observations from August 1993 until June 2003. The analysis also includes data from the permanent networks in Norway, Denmark, and about 15 stations from the EUREF Permanent Network south of east of the Baltic Sea.

In this study we present results from different methods used to re-analyse the BIFROST data. The Precise Point Positioning technique (PPP) available for the GIPSY software have been applied, the elevation cut-off angle is lowered from 15(to 10(making especially the vertical component of the solution stronger, and we solve for the integer ambiguities. To be able to study possible software specific effects, we have performed an additional analysis using the GAMIT/GLOBK and Bernese software packages. A detail description of the different GPS processing results, analysis of the GPS time series, and comparisons with GIA model predictions are presented. Common for all analyses methods is the extensive use of IGS data, IGS precise orbits and clocks, and the use and comparison with the ITRF and IGS reference frames.

The Impact of Auto- and Cross-correlations in Daily Solution Time Series of GPS Permanent Stations

R. Barzaghi, A. Borghi, M. Crespi, F. Giannone, G. Pietrantonio, F. Riguzzi

The correct estimation of GPS-derived coordinate and velocity precisions is of fundamental importance when GPS permanent stations are used to realize and maintain a reference system and to infer geodynamical interpretations. Despite of the fact that several authors evidenced temporal correlations in the GPS coordinate time series of the daily solutions, in the standard processing procedures for GPS permanent networks weekly solutions and site velocities are estimated by adjusting daily solutions without taking into account the temporal correlations themselves. This fact leads to an overestimation of parameter precisions when daily solutions are least squares adjusted in order to estimate "public" weekly solutions and site velocities. In the present work, analyzing the time series of 4 Italian GPS permanent stations belonging to the IGS global network, we found, as expected, that temporal correlations are not negligible at all. Without analyzing, for the moment, their causes, we just tried to introduce these correlations (in terms of both autocovariances and cross-covariances) in the solution of our small "pilot" GPS network with the aim of discovering how weekly solution and velocity precisions change when a more correct stochastic model is used. In this respect we implemented a new software in C language (KINADGPS) for velocity and weekly solution estimations taking into account temporal covariances; to evaluate the impact of such covariances, the software also performs the standard adjustment, where daily solutions are assumed as temporally uncorrelated and the stochastic model is represented by a block diagonal covariance matrix (each block representing the covariance matrix of one daily solution).

At present KINADGPS performs just a single station-adjustment, considering auto and cross-covariances among the coordinates of one station at once; anyway we have also estimated the empirical cross-covariance functions among coordinates of different stations with the aim to investigate, in the next future, the impact of correlations in multibase solutions, what requires a deep investigation on the cross-covariance functions modelling from the empirical data.