The Use of the IGS/EUREF Permanent Network For EUREF Densification Campaigns

W.GURTNER
Astronomisches Institut, University of Bern, Switzerland, gurtner@aiub.unibe.ch,
C. BOUCHER
lnstitut Géographique National, ENSG/LAREG, France, boucher@ensg.ign.fr
C. BRUYNINX
Royal Observatory of Belgium, Belgium, C.Bruyninx@oma.be
H. V. D. MAREL
Delft University of Technology, Fac. of Geodetic Eng., Netherlands, vdMarel@Geo.TUDelft.nl

1. Introduction

First guidelines about how to use IGS products for EUREF Densifications have been presented by W. GURTNER at the 1993 EUREF Symposium in Warsaw (GURTNER 1993). The basic principle consisted of performing all GPS computations in the ITRF-yy system, which the precise IGS orbits were based upon. Given ETRS89 coordinates of fixed sites had to be corrected for site velocities (reference epoch 1989.0 -> epoch of observation) and transformed into ITRF-yy by using the published transformation parameters (BOUCHER, 1993). Resulting coordinates primarily referred to ITRF-yy of the epoch of observation. In order to get them in ETRS89 the inverse transformation had to be applied and, if ETRS89 velocities were known or assumed to be known, they could be moved to the reference epoch 1989.0.
Resolution 2 of the Budapest Symposium recommended to process GPS campaigns to be incorporated into EUREF in two stages:

1. Using the IGS orbits and IGS fiducials in ITRF at the epoch of observations
2. Transforming the results into the European Terrestrial Reference System ETRS89 restricting in fact the "fixed" sites to be selected from IGS stations only.

In order to make full use of the established IGS network and its EUREF densification in Europe the guidelines have to be modified, especially taking into account the new possibilities of combining partial solutions using available variance-covariance matrices given in the SINEX format.

2. Reference System and Frame for Computations

IGS orbits have been computed by the IGS Analysis Centers based on a certain set of tracking stations fixed or strongly constrained to an ITRF-yy realisation coordinated by the IGS. As the ETRS89 reference system is rotating with respect to ITRS by about 3 cm per year in Europe the two systems are slowly drifting apart, too much to be neglected. Generating orbits in the drifting ETRS89 is not practical; therefore all high-precision large-scale computations have to be performed in the ITRS.
As the latest realisations (after-about ITRF93) do agree among each other on the centimeter level for most permanent sites in Europe it is in fact not important anymore that densifications are based on the identical ITRF-yy realization as the orbit generation, i.e. that for densifications the latest and best realizations can be used!
All ITRF coordinates to be used as constraints or fixed values have to be shifted into the mean epoch of observation of the campaign by applying the ITRF velocities. The estimation of the actual accuracy of these coordinates has to take into account the variance/covariance information of the velocities, as well.

3. Processing Strategies

Depending on the availability of partial solutions or combinations of local, regional or global permanent networks three different strategies can be formulated:

3.1 Use of individual fiducial sites

This strategy corresponds to the one formulated in 1993 with the exception that now not only permanent IGS tracking sites can be used but in fact all permanent sites in Europe the coordinates of which are included in an ITRF- yy solution and are known (at the epoch of observation) to better than 1 cm.
A number of fiducial sites (e.g. 3 to 4, distributed in and around the network to be processed) are included into the processing either through their original tracking data available at the respective data centers or by running own receivers on well-known excentric markers on these tracking sites.
The resulting coordinates referring to ITRF-yy (at the epoch of observation) are then transformed into ETRS89 through the published transformation parameters. If ETRS89 velocities are known the coordinates can also be moved into the ETRS89 reference epoch (1 989.0).
Steps:

1. Define the GPS campaign including data of 3-4 surrounding sites of the IGS/EUREF Permanent Network the coordinates of which are known in ITRF-yy to better than 1 cm at the epoch of observation.
2. Process the campaign, strongly constraining or fixing the ITRF-yy coordinates of the IGS/EUREF sites.
3. Transform the resulting coordinates into ETRS89 using the published transformation parameters. Move the new sites into the reference epoch of E. TRS89, provided the velocities are known.

3.2 Use of Solutions of the EUREF Permanent GPS Network

As there may be an important time lag between the start of operation of new EUREF permanent sites and their inclusion into an ITRF-yy solution such stations cannot be used (with strategy 3. 1) to anchor the GPS campaign in ITRF for a certain time.
However, as soon as there are SINEX solutions available from the EUREF Permanent Network processing, they can be combined (including the variance/covariance information) with the loosely constrained solution of the GPS campaign, provided the data of a certain number of the (new and/or older) permanent sites have also been included into the campaign network. The EUREF solution should at least cover the whole duration of the GPS campaign.
The EUREF solution will always contain enough permanent sites that can be strongly constrained or fixed to the appropriate ITRF-yy coordinates in the combination process.
Weekly EUREF solutions are available as SINEX files at CODE, at the EUREF Data Center (IFAG) in the EUREF Permanent Network information system (ORB, Brussels).
Steps:

1. Define OPS campaign including data of 3-4 surrounding sites of the EUREF Permanent Network
2. Process the campaign, generate a loosely constrained solution in SINEX format
3. Get a SINEX solution of the EUREF Permanent Net- work covering at least the campaign period
4. Combine the two solutions, constrain or fix the ITRF-yy coordinates of those sites known to better than one cm at the epoch of observation.
5. Transform the resulting coordinates into ETRS89 using the published transformation parameters. Move the new sites into the reference epoch of ETRS89, provided the velocities are known.

3.3 Use of Solutions of a Local Permanent Network

In order to further decrease the necessary network size of the GPS, campaign one could also combine the loosely constrained campaign solution with a solution of a Local Permanent Network plus a

solution of the EUREF Permanent Network, provided the data of a certain number (3-4) of the Local Permanent Network have been included into the campaign network and the solution of the Local Permanent Network contains enough sites (3-4) of the EUREF Permanent Network. High-quality sites contained in the ITRF-yy list are then fixed or strongly constrained to the ITRF-yy values at the epoch of observation.
Steps:

1. Define the GPS campaign including data of 3-4 surrounding sites of the Local Permanent Network
2. Process the campaign, generate a loosely constrained solution in SINEX format
3. Get a SINEX solution of the Local Permanent Network covering at least the campaign period
4. Get a SINEX solution of the EUREF Permanent Net- work covering at least the campaign period
5. Combine the three solutions, constrain or fix the ITRF- yy coordinates of those sites known to bester than one cm at the epoch of observation
6. Transform the resulting coordinates into ETRS89 using the published transformation parameters. Move the new sites into the reference epoch of ETRS89, provided the velocities are known.

3.4 Pre-constrained EUREF SINEX Solutions

Weekly or monthly EUREF SINEX solutions could also be specially prepared for the (campaign wise) densification purposes with respect to the reference frame fixing, where all the high-quality European reference stations are con- strained to the latest ITRF-yy values (at the mean epoch of the solution).
Step 4) of 3.2 and step 5) of 3.4 could then be done without having to explicitly constraining or fixing the reference stations. One advantage is that the decision, which sites to constrain does not have to be taken by the campaign analyst.