The significance of the European VLBI network for the concept of EUREF

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Abstract

In this contribution, the European Geodetic VLBI network is presented in its function as a backbone for the definition and maintenance of the European Reference Frame. Some results from recent VLBI solutions are shown in terms of horizontal and vertical site motions. The importance of a long and homogeneous time series for the determination of reliable site velocities is pointed out.

1. Introduction

The European region benefits from a particularly high concentration of relatively large and sensitive radio telescopes. For both the radio astronomers and the geodesists this situation has offered the possibility to exploit the VLBI technique to its fullest extent and precision. The moderate size of the network with baseline lengths ranging from a few hundred to a few thousand kilometers lends favourable conditions to achieve a very high accuracy in geodetic point positioning. For VLBI in particular, the good simultaneous visibility among all stations of the network provides an optimal geometrical configuration for both horizontal and vertical control.

The objectives of regular geodetic VLBI campaigns covering a long period of time are focussed on the changes of point positions rather than on the positions themselves. Due to its extragalactic reference and its self-calibrating measurement concept, the VLBI technique has proven to be the most reliable tool for the monitoring of small sub-millimeter per year tectonic motions.

2. The European Geodetic VLBI Network

In Europe, after an initial phase of observing sessions in the frame of the NASA Crustal Dynamics Project (CDP) in the late eighties, the funding for regular operations was secured from the European Commission under the 2nd Framework Programme "Science". In this first phase under the title "European VLBI for Crustal Dynamics" the work has been concentrated on the measurement of horizontal crustal motions which were expected to show up in the data of a time series rather soon, i.e. within three or four years. The continuation and expansion of the project has been accepted by the European Commission under the 4th Framework Programme "Training and Mobility of Researchers (TMR)", enabling a second phase of funding of geodetic VLBI observations in Europe. This second phase stresses the determination of vertical site motions, which are much more difficult to detect. Together with the already existing series of observations, the entire project will include an EC-funded observation time span of nearly 10 years (CAMPBELL 1988, CAMPBELL & NOTHNAGEL 2000).

The results of the observing program are of high importance for the monitoring of land uplift and subsidence, sea level changes, glaciology and other vertical motion applications and are hoped to contribute to the evaluation of global climatic changes and other environmental effects.

At present, the European Network consists of 10 stations (Fig. 1), six of which have an observing record longer than 7 years. In October 1994 the new 20m antenna established by the Norwegian Mapping Agency at Ny Ålesund on the arctic archipelago of Spitsbergen has begun to take part routinely in the European VLBI experiments. The 15m antenna of the Instituto Geografico Nacional at Yebes, about 80km east of Madrid, has been equipped for geodetic VLBI and made its first experiments in 1996. With the help of NASA the station of Simeiz in Crimea (Ukraine) has been enabled to take part in several of the European geodetic sessions. Moreover, the astronomical radio observatoy of Effelsberg (Germany) has been making its 100m antenna available for the geodetic campaigns at a level of one 24h-session per year.

In the second phase of the EU funding scheme, the TMR-network comprises eight participants from six different countries. In addition, several institutions and groups that are not explicitly part of the TMR program are taking part in the observing programs nonetheless, such as Yebes, Effelsberg and the station in Crimea.

The observations are being taken care of by the participating observatories using their own staff. The scheduling, sending out of tapes and the correlation is accomplished by the Bonn VLBI-group of the Geodetic Institute. The geodetic analysis is shared by all participants in this project, using the different available software packages, and contributing further developments needed to obtain the optimal accuracy in the results.

Between January 1990 and December 1999 a total of 52 observing sessions in slightly varying configurations have been carried out. On average, six purely European sessions have been observed each year.

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Fig. 1

Fig. 1: The European VLBI network

Of course, most of the European stations are also active in different global VLBI campaigns and in this way the European network has been intimately tied to the global VLBI frame.

3. Data Analysis and Results

A most important feature of geodetic VLBI analysis compared to GPS is the capability to handle the entire set of observed data from all stations and all epochs in one combined adjustment. In this way, after each model improvement and software refinement a complete recomputation using all available data can be performed in a reasonable time (usually one day). Moreover, different processing options can be easily tested and evaluated as to their effect on the global solution.

In the frame of the European VLBI Project, the data are being analysed by several of the participating groups and the results are compared and discussed at regular intervals (see e.g. BÖRGER 1999). Most of the groups are using the CALC/-SOLVE analysis software developed at the NASA GSFC (MA et al. 1992), but the strategies and the amount of data used in the solution are left to the discretion of each team.

A preferred analysis strategy for the European Network is one that has the benefit of showing the baseline and site coordinate evolution with time. It consists of a combined adjustment of all sessions, but station coordinates are estimated independently for all epochs in relation to one station held fixed at a given reference epoch (for more details see e.g. NOTHNAGEL & CAMPBELL 1993). In this case, of course, the Earth Orientation Parameters have to be taken from an external source, e.g. from a global VLBI solution. Thus the inherent stability of the global solution is used to orient the regional network in space (the translations are inhibited by fixing one station). With a conservative estimate for the orientational stability of 0.3 mas (1 cm at one Earth radius) over short as well as longer time scales, we may put an upper bound on the influence of the reference system on a baseline vector of 1000 km length at 1.5mm. This would mean for example, that the entire network from Sicily to Spitsbergen or Madrid to Crimea could be tilted after 10 years by at most 5mm, i.e. 0.5mm/y as a system related long term site velocity. On the other hand, there could be short term variations of up to ±2.5mm/y, posing a limit to what space techniques can presently achieve from edge to edge on networks of European scale.

Fig. 2

Fig. 2: Horizontal and vertical site motions from pure European VLBI data set (HAAS et al. 2000)

The baseline length repeatability obtained from the time series has proved to be the best indicator for the inherent accuracy of VLBI because it is essentially free from orientational errors of the reference system. For the European baselines we obtain a wrms of ±2.0mm + 0.8mm × b, where b is the baseline length in units of 1000km (HAAS et al. 1999). The horizontal coordinate wrms repeatabilities range from ±1.5 to ±5.7 (Ny Alesund north component) whereas the values for the vertical are about three times larger, i.e. ±8.0 to ±14.4mm.

Constraining the motion of Wettzell to its value in the NUVEL-1A-NNR frame, we have estimated the horizontal and vertical velocity vectors from the time evolution of the coordinates of each station with respect to Wettzell (HAAS et al. 1999). The results are shown in Fig. 2 and 3.

Fig. 3

The most prominent horizontal motions are concentrated on the Italian peninsula with the effect of the northward moving African plate on the Adriatic plate being obvious at Matera and partly also at Medicina, while Noto is probably more directly affected by the motion of Africa. A smaller but significant effect on horizontal motions in Scandinavia can be seen at Onsala and Ny Alesund.

In spite of the larger uncertainties of the vertical rates, some of these rates are beginning to show significant trends. However, the observed vertical motions still have to be interpreted with great care because of the large number of local effects that interfere with the more global picture (PLAG 1999). We expect that the time series will have to be extended over a period of at least ten years before any safe estimates can be obtained for the long term trends of vertical motion.

4. Significance of the European VLBI network for EUREF

The importance of VLBI as *the* space technique for providing a zero order reference system realization has been recognised from the early days of the establishment of a uniform and consistent European frame of point positions, the EUREF89. One instance is the series of mobile VLBI campaigns carried out in Europe in the years of 1989 until 1993 in order to densify the sparse net of fixed VLBI stations (SEEGER 1992, ZARRAOA et al. 1995). This big effort has been the result of a cooperation between NASA and several European survey institutions under the coordination of the Institut für Angewandte Geodäsie (IfAG) in Frankfurt, Germany (ZARRAOA et al. 1995). With the full deployment of GPS in the early nineties, however, it became clear that the task of densification would be solved in a perfectly satisfying and economic way by this system (if certain requirements concerning the observations and the data analysis were fulfilled).

At present, the 7 core stations of the European VLBI network (Onsala, Wettzell, Medicina, Matera, Noto, Madrid and Ny Alesund) have been tied to the European geodetic network by special local surveys that provide the eccentricities between the VLBI reference points and several other markers in and around the stations. At several of these sites, campaigns of remeasurement of these local ties are underway, to ascertain the stability of the telescopes as well as the local networks (NOTHNAGEL 1999, PLAG 1999). A substantial part of these data are contained in the different sections of the ITRF Reports (BOUCHER et al. 1999), with the effect that the European VLBI stations have become an intrinsic part of the ITRS realization.

A different aspect is introduced by the notion of temporal evolution of a network of points. Even if all other sources of point motion are under control, the fact that tectonic motions of the Earth´s crust are constantly deforming the global geodetic networks makes the constant monitoring of such networks an inevitable task. In this situation those measuring techniques that are by definition tied to inertial space should have the highest priority in taking care of this task.

The site velocities determined by VLBI in the global frame have shown to be most reliable in reproducing the motions of the major tectonic plates and have contributed significantly in the realization of an NNR frame (ARGUS, GORDON 1996). These VLBI derived site motions are part of the ITRF realizations by way of the global VLBI input to the combination solution.

Presently, the EUREF Permanent Network (EPN) is not explicitly delivering its own velocities because of the constraining of the EUREF-reference sites to the actual ITRF velocities (see e.g. BRUYNINX et al. 1997). However, by inspecting the time series of weekly solutions of the EPN, the quality of the GPS velocity estimates can be checked and compared with the long term VLBI values. This is of special interest for the GPS results at those VLBI sites that are not used as reference sites in the EUREF solutions (e.g. Medicina, Noto and Madrid).

5. Outlook

The European VLBI campaigns will be continued at a rate of several 24h-sessions per year. The regular global campaigns with the involvement of different European VLBI stations in different configurations are providing additional geometrical strength to the network. In view of the successful implementation of the newly developed MkIV data acquisition and correlation system we expect a sizable increase in measuring accuracy, which will eventually propagate through improved analysis software models to a higher accuracy in the results.

The importance of the VLBI contribution to EUREF and the EPN in particular will be determined by the following aspects:

- the European VLBI results are available to serve as a comparison standard in terms of colocated site eccentricities (local surveys), stability of the network with respect to scale and rotation, as well as velocities of the colocated VLBI/GPS sites.
- the VLBI time series allow the monitoring of systematic effects in the site velocities at the level of tropospheric effects, antenna effects and non-tectonic site motions
- the EUVN will profit from the long term geometrical stability of the VLBI network providing geometrical support for the vertical component and its temporal variation over large distances.

6. References

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