Geodetic research at IRA-INAF: recent results between a golden past and a gloomy future

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Abstract. Medicina (Northern Italy) and Noto (Sicily) 32 m, AZ-EL, VLBI radio telescopes are managed by the Institute of Radioastronomy and funded by the National Institute of Astrophysics. They have been successfully performing geodetic observations since the end of the 80s. Nowadays, geodetic research is no longer an IRA institutional research activity. The finalization of the 64 m Sardinia Radio Telescope is foreseen for the second half of 2010 and, in INAF's perspectives, it will replace the two older VLBI antennas. Unfortunately, it is not meant to operate at S/X geodetic frequencies. If, on the operational side, the Italian observing activity in geodetic VLBI will shortly experience a dramatic cut (the two 32 m antennas will most probably be dismissed by the end of 2011), on the research side, IRA geodetic activity is quickly coming to an end. We focus here on the role of the two telescopes during these two decades: their importance in the Mediterranean region and within the International VLBI geodetic network. We review the most important activities carried out so far and present the most recent solutions obtained with CALC/SOLVE regarding crustal deformation.

Keywords. VLBI, Radio telescope, Medicina, Noto, SRT

1 Introduction

The Italian Consiglio Nazionale delle Ricerche (CNR) started the Italian VLBI project in mid 1970s, appointing its branch Istituto di Radioastronomia (IRA) to design a national VLBI network by planning the construction of three identical VLBI radio telescopes in different parts of Italy. The main purpose was to develop radioastronomic as well as geodetic research ensuring, at the same time, an extension of the geodetic VLBI network for geodynamics applications in the Mediterranean region. A lack of available funding led to a major reconsideration of the project: it was eventually modified withdrawing the construction of the radio telescope in Sardinia.

Medicina and Noto radio telescopes were regularly built and completed during the 80s. The first geodetic observation took place in January 1987 in Medicina (Tomasi et al., 1988) while Noto's geodetic observations began in June 1989 (Tomasi, 1993). Ever since, both telescopes have actively participated in the observations of the international VLBI network; in particular, the geodetic activities are nowadays coordinated by the International VLBI Service (see Schlueter and Behrend 2007), which has been greatly contributing in widely and uniformly promoting the scientific as well as the technological development of VLBI technique.

In the early 90s the Italian VLBI increased its potential when a geodetic 22 m VLBI telescope started its operation in Matera. Furthermore, in the same decade, the construction of the Sardinia radio Telescope (SRT) was reconsidered (Setti, 2006). By the end of 1997 IRA submitted to the Ministry of Research a first detailed executive program that was accepted, in its definitive form, only a couple of years later, in May 1999. SRT is designed as an Azimuth-Elevation (AZ-EL) 64 m dish whose technical characteristics can be found in Olmi and Grueff (2006); it should be completed and operative in the second half of 2010. Up to 2004, the Noto and Medicina observatories were funded by CNR for the specific purpose of performing astronomic and geodetic research. In 2005, after a re-organization of the Italian public research system, IRA was joined to INAF, an institution that unifies the astronomical observatories locally distributed on the Italian territory and three former CNR Institutes. INAF's aims and scopes are strictly related to astronomic research and, as a result, geodetic research is considered out of the institutional activity. This statement was explicitly made by INAF's President T. Maccacaro in October 2008. Despite the efforts made in recent years, we are now facing a gloomy future for the geodetic research within IRA and a total lack of perspective. If, as a matter of fact, geodetic activities have been officially dismissed without a serious process of evaluation of the opportunities offered by the Italian geodetic VLBI infrastructure within the national and the international contexts, on the other hand, the minutes of the latest meetings of INAF's Scientific Committee depict a very uncertain future for the astronomical use of the two telescopes, too. Their operability will be reconsidered once SRT will be fully functional and it is widely agreed that SRT should replace the two VLBI telescopes within the observing activity of the astronomical VLBI networks.

Figure 1. The Medicina (Bologna) VLBI telescope: an AZ-EL 32 m steerable antenna mount whose twin telescope is located in Noto (Siracusa). In the foreground of the picture the IGS GPS antenna co-located with the VLBI telescope is visible.

2 IRA's contribution to geodetic research

Medicina and Noto telescopes are twin AZ-EL mount 32 m dish with non intersecting axis (the Medicina VLBI telescope is shown in Figure 1); according to the project's design, the offset between the fixed azimuth axis and the moving elevation axis is $O = 1.829$ m.

Since the beginning of their observing history, the two telescopes have performed both astronomic and geodetic observations. VLBI and single dish astronomic observations represent the larger amount of observing time for both telescopes. Medicina telescope participated in more than 360 geodetic experiments in the time span 1987–2008, thus performing observations in more than 16 VLBI geodetic sessions per year. The number of geodetic experiments performed at Noto observatory is lower: in the two decades 1989–2008 the telescope took part in 180 sessions, thus performing, on the average, 9 sessions per year.

The frequency operability spans the range 1.4–22 GHz for Medicina telescope and 0.3–43 GHz for Noto telescope. The two telescopes perform observations with receivers located in primary or Cassegrain focus. Insights on technical characteristics of the two telescopes can be found on the web page of IRA (`www.ira.inaf.it`). The primary reflectors are made by 240 aluminum panels supported by a reticular structure (see Figure 1). In order to counter the effect of gravity, Noto telescope's was upgraded with an active surface in 2001 (Orfei et al., 2004). The panels that form the primary reflector can be moved through electromechanical actuators. Each panel moves according to an elevation dependent correction model: values are listed in a file and represent the translations that must be applied to the panels for restoring the ideal parabolic shape of the primary mirror. A detailed survey of the primary reflectors of the two telescopes was performed in September 2005 using a laser scanner. The effect of gravity on the parabolic mirror was determined at six pointing elevations and the entire surface was scanned and was represented by point clouds containing more than 1.5 million points. A comprehensive discussion concerning the set up of the survey, the measuring approach and the collection of observations, data processing, data post processing, results and outcomes are reported in detail in Sarti et al. (2009).

Investigations on the effects of deformations on the travelling time of signals in the near-field of the Medicina radio telescope have been gathered by studies of different components being affected by changes in gravitation. A combination of terrestrial triangulation and trilateration, laser scanner and FEM analysis was applied in order to derive an elevation-dependent correction model for the signal path traveled by the incoming radio signal. Results are summarized in a paper by Sarti et al. (submitted) recently submitted to Journal of Geodesy and currently under review.

Both telescopes have a remarkable series of tie vector's surveys. Particularly, Medicina telescope was surveyed six times with terrestrial methods (2001, 2002, 2003, 2005, 2006 and 2007) and three times with GPS technique (2000, 2003, 2006) for the purpose of estimating the tie vector between the co-located VLBI and GPS reference points. With the same purpose, Noto telescope was surveyed in 2003 and 2005 with terrestrial methods and 2003 and 2006 with GPS technique. The surveying method is based on an indirect approach (Sarti and Angermann, 2005) that combines observations acquired on targets mounted on the telescope's structure and performed rotating the antenna in elevation and azimuth (Sarti et al., 2004).

The effects generated by the introduction in the ITRF-like computation of the redundant determinations of the Medicina tie vector were tested by (Abbondanza et al., in press) using CATREF (see Altamimi et al. 2002). The residuals originated by the combination of space geodetic solutions and both terrestrial- and GPS-derived tie vectors were evaluated and used to assess the consistency of each tie vector's realization and to determine their agreement with the space geodetic observations. These residuals are potentially capable of highlighting biases that might be related to the performance of each co-located space geodetic instrument. If, on one hand, the residuals simply highlight a disagreement for a specific co-location site, on the other hand, they are the starting point for a rigorous investigation on the wide variety of causes that might originate from technique specific problems. It should be noticed that the whole process of combination of frames is characterized by the unavoidable complication of reliably coupling measurements of different nature (space geodetic and terrestrial) related to different reference points (electronic and conventional points).

IRA participated in the IVS Pilot Project on Tropospheric Parameters estimated with VLBI since its very beginning. The initial phase started in July 2002 with a regular submission of wet and total zenith delays and horizontal gradients for all IVS-R1 and IVS-R4 sessions. The solutions produced by different Analysis Centers were checked and combined together in order to identify the best analysis and combination strategy. As this phase ended, there was the transition from Pilot Project to IVS Tropospheric Products (TROP) thus ensuring a regular provision of IVS official products. Because of the importance of long time series of data and in particular of water vapour content, we estimated and submitted to the combination center long-term tropospheric parameters analyzing all the available VLBI experiments in our catalogue (see Heinkelmann et al. 2007).

3 IRA's latest solution on crust deformation in the Mediterranean

As stated in Sect. 1, investigations of crust deformation by means of VLBI technique comprised a fundamental scientific motivation towards the development of the Italian VLBI infrastructure. In the 70s, VLBI was the most promising technique for monitoring global geodetic parameters. NASA's Crustal Dynamic Project (CDP) represented the first coordinated international effort aimed at *(i)* determining the motions of the major tectonic plates, *(ii)* understanding and measuring crustal kinematic and dynamics, *(iii)* relating crustal motion with earthquakes and active fault monitoring, *(iv)* detecting and understanding the possible relations between Earth Orientation Parameters (EOP) and geodynamics and geophysical phenomena. To this respect, up to the end of the 90s, IRA has regularly produced crustal deformation solutions with VLBI technique, with a particular emphasis on the deformation patterns regarding the Mediterranean area (see Tomasi et al. 1999).

The most recent solution performed at IRA comprises all the VLBI session stored at IRA from 1987 up to 2008. The velocity estimates for the three Italian VLBI sites are given in Table 1.

The dataset is formed by more than 1000 geodetic experiments that were analyzed with CALC/SOLVE Mark-5 software. Figure (2) shows the vectors representing the estimated vertical velocities computed for the European sites.

Table 1. Estimates of *(i)* Up component of the local velocity, *(ii)* global horizontal velocity (ITRF2005), *(iii)* horizontal velocity relative to Wettzell, whose values where fixed to those of ITRF2005 and *(iv)* azimuth of the vector representing the relative horizontal velocity.

	Medicina	**Noto**	**Matera**
Vertical velocity (mm/yr)	-2.3 ± 0.1	-1.2 ± 0.1	-0.3 ± 0.1
Absolute horizontal velocity (mm/yr)	28.1 ± 0.1	28.7 ± 0.1	29.8 ± 0.1
Relative horizontal velocity (mm/yr)	3.2 ± 0.1	4.4 ± 0.1	5.0 ± 0.1
Azimuth rel. hor. vel. (deg)	47 ± 1	22 ± 2	45 ± 4

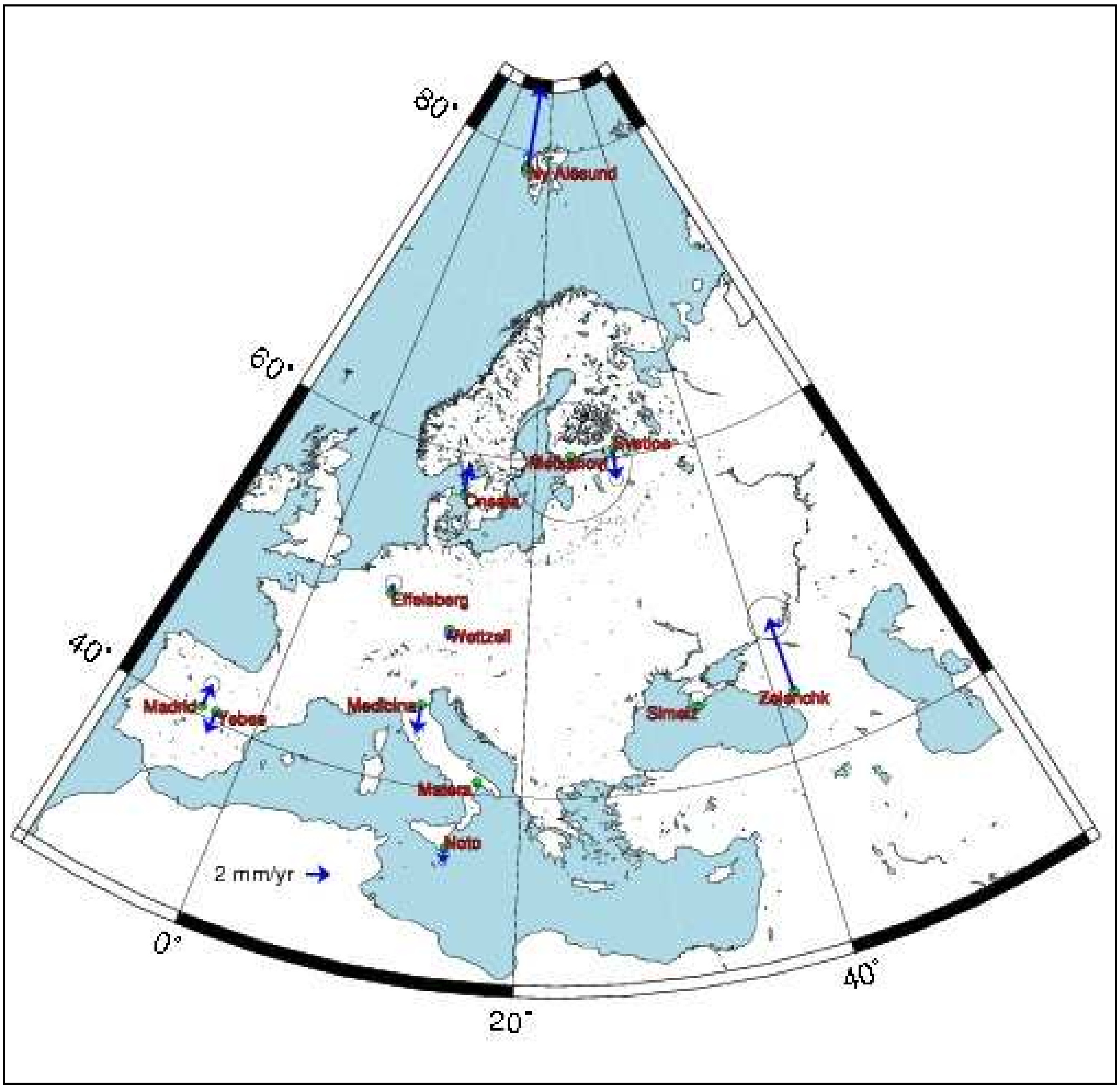

Figure 2. Representation of the Up component of the velocities for the European VLBI stations.

4 Conclusions

This paper briefly summarizes the present day situation of geodetic research at IRA and very shortly resumes its highlights and achievements. Since it was moved from CNR to INAF, IRA geodetic activity suffered from a sudden decay and is now facing a total lack of perspectives. The threat of an end in the operation of the two main Italian radioastronomical sites represent a miserable eventuality not only for geodesy and astronomy. The evolution of our planet is strictly connected to reliable long time series of records: they are fundamental in depicting and understanding complex phenomena which, to a varying extent, combine and contribute to the evolution of our planet Earth. In this respect, the sites of Medicina and Noto have accurately observed for more than two decades phenomena such as e.g. the evolution of the crust kinematic, the rotation of the Earth and its response to global phenomena, the presence and variability of water vapour in the atmosphere and have greatly contributed in boosting technological development as well as accuracy in the estimate of geodetic parameters.

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