PMD Analysis Center Report for 2011

Vincenza Tornatore, Letizia Cannizzaro

Abstract

This report gives an overview of the "Politecnico di Milano" (PMD) VLBI Analysis Center activities during 2011 and briefly outlines the plans for 2012. The PMD AC processes IVS EUROPE sessions for baseline length variation computation and determination of time series coordinates of VLBI antennas. The AC performs also research and software development aimed to improve time series analysis. This work was developed within the context of comparison of VLBI and GPS (Global Positioning System) techniques and with respect to the geophysical models available in the European area. Another important task concerns the observational part; in particular several tests have been carried out to demonstrate the possibility of detecting GNSS satellite signals using the VLBI technique.

1. General Infomation

During 2011 the PMD AC did not significantly change its principal characteristics, e.g., the hardware and software components, location, sponsorship agency and staff described in the 2010 report. Three of the main fields of interest to PMD during 2011 are briefly highlighted in this report. They can be summarized here:

- Space co-location (VLBI—GNSS)
- Processing of EUROPE VLBI sessions
- Establishing procedures for VLBI and GPS time series analysis.

The current status of these activities, the principal results achieved, and foreseen further developments for next year are described in the following.

2. Space Co-location (VLBI—GNSS)

Many efforts dedicated to continue the observation activity of GNSS signals started already in 2009 [1]. International cooperation with other universities and research centers with similar interests was strongly supported. Thanks to the availability of different instruments, software, and interdisciplinary capabilities, several tests were performed to establish procedures for making possible the observation of GNSS signals with VLBI antennas. This is a very challenging task, since the use of the same optics (including gravitational and thermal deformations), electronics, and processing pipelines as for natural radio sources, observed with the VLBI technique, ensures the cross-calibration of two frames. GLONASS (GLObal NAvigation Satellite System) data observed during an experiment in 2010 with the Medicina and Onsala VLBI antennas were processed with two different correlation software packages, giving promising results; see [2] for more details on the experiment. The plans of PMD in this field are to continue with observing tests, using more than two stations, longer observing time intervals, and different designs that can foresee the use of natural calibrators near the satellite orbits for effectively reducing the contribution of uncalibrated errors in VLBI delay measurements such as station clock offsets, instrumental errors, and effects due to signal propagation in the ionosphere and the troposphere.

3. Processing of EUROPE VLBI Sessions

All the European sessions available since 1990 through the end of 2010 have been processed under the same modeling conditions and analogous parameterizations. The software used was VieVS (Vienna VLBI Software) [3] developed by the members of the VLBI group of the Institute of Geodesy and Geophysics (IGG), Vienna University of Technology (TU Wien) under the Matlab programming language. The configuration of the European geodetic VLBI network, that started with a core of six radio telescopes observing with an average of six sessions per year, reaches today a number of fourteen participating radio telescopes observing as regularly as possible with the same duty cycle. European site coordinates and baseline lengths with respective variance-covariance matrices have been estimated with VieVS to study their temporal evolution. The adjustments were performed both using single session and global approaches. Analyses of different solutions are in progress. In 2012, we plan to investigate in more detail the obtained results and to study also the influence of different datum definitions on European network parameter estimations.

4. Establishing Procedures for Time Series Analysis

In the framework of algorithm development for improving time series analysis of VLBI data and comparing them with GPS results, the goal was to develop tools that were common as much as possible to both techniques. Some members of the group working at the 'Surveying Section' of DIIAR gained a lot of experience on the Continuous GPS (CGPS) time series analysis field in the last years. This experience was considered as a starting point to develop/adapt such algorithms to VLBI time series analysis. It is well known that GPS solutions are daily or weekly solutions, generally quite regular for any GPS station; in contrast, VLBI solutions are usually carried out not as frequently. Then it often happens that, due to hardware or software problems at a VLBI station, this station will not take part in all the planned. European sessions. In particular the work at PMD during 2011 was devoted to refining tools for CGPS coordinate time series analysis for geodynamic applications. In the last two decades the issues of CGPS time series analysis for geophysical applications were of great interest among the scientific community; different approaches have been developed, and several works have been published by different authors, e.g., [4], [5], [6]. The PMD DIIAR team faced the issue of GPS time series analysis in the context of the Seismic Information System for Monitoring and Alert Project (S.I.S.M.A. project) which was a three-year pilot project funded by the Italian Space Agency (ASI) starting in February 2007 [7], [8] with the aim to integrate Earth Observation data: SAR (Synthetic Aperture Radar) and GPS techniques and new advanced methods in seismological and geophysical data analysis for time-dependent seismic hazard assessment. The procedure implemented at PMD estimates a certain number of parameters by least squares adjustment. The most interesting parameters, from the geophysical point of view, are the velocity displacements and their errors. As scientific literature proved, the observations are temporally correlated and the adopted method estimates the proper deterministic and stochastic models. Here we briefly illustrate the analysis procedure that can be divided into five steps.

Step 1: removal of outliers and known discontinuities (see, e.g., Figure 1) due to

- technical equipment changes (e.g., GPS antennas/receivers)
- discontinuities due, e.g., to non-straight alignment of Reference Frame parameters

- co-seismic effect

Step 2: linear and periodic parameter estimations by least squares adjustment
Step 3: KPSS test [9] on residuals for assessment of stationary behavior
Step 4: study of coordinate time series correlations

- stationary residuals: estimate of the Empirical Covariance Function
- non-stationary residuals: simplified White Noise + Flicker Noise model [5]

Step 5: linear and periodic parameter re-estimations by least squares adjustment, applying the correct stochastic model.

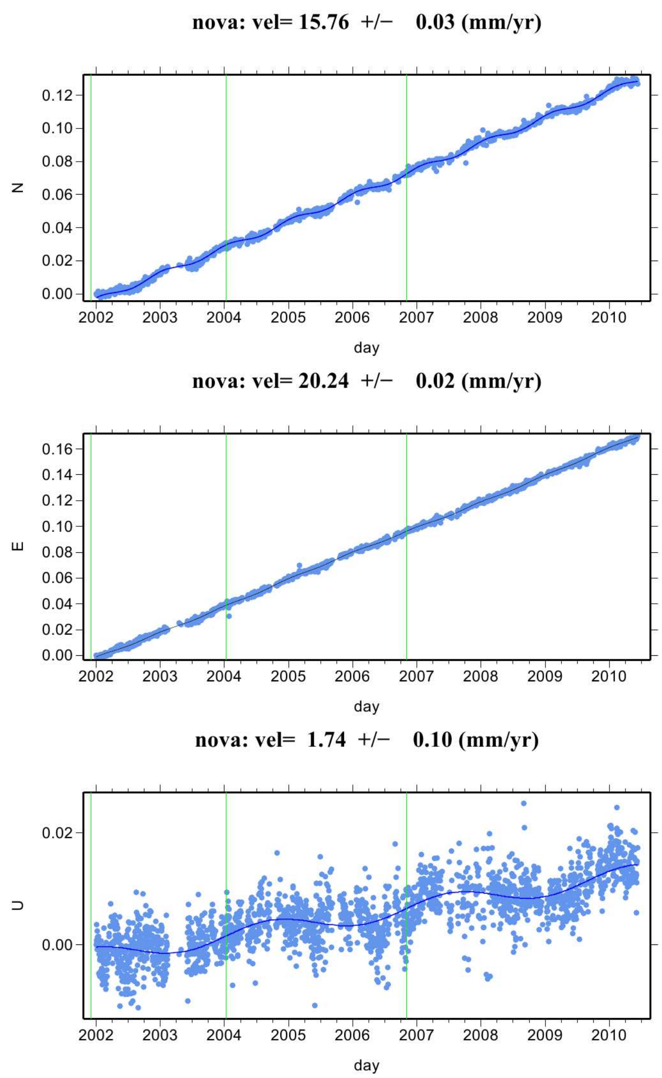

Figure 1. Coordinate time series for the GPS station of Novara.

The dots are North (mm), East (mm), and Up (mm) daily coordinate time series of the NOVA CGPS station (located in the town of Novara) and belonging to the Italian GPS fiducial network managed by the ASI – Italian Spatial Agency. Vertical lines represent the date of known discontinuities due to the Reference System and GPS antenna/receiver changes (the discontinuities have been removed in the figure). Continuous lines represent the final estimated deterministic models superimposed on the time series: the linear parameters stand for the velocity displacement of NOVA coordinate components.

The described procedure was applied to several Italian GPS stations. Due to the success of the method on GPS data which proved to have more reliable results, we plan for next year to adapt the developed algorithms from Fortran to the Matlab programming language and to VLBI time series studies. The final goal of such a task is to set up a statistical method common to both techniques, to reveal possible differences in estimated deformations of the European plate, and to compare the results with geophysical models.

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