Biennial Report (2015–2016) of PMD IVS Analysis Center

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Abstract The main activities carried out at PMD IVS Analysis Center during 2015 and 2016 are summarized in this report and plans for 2017 are briefly pointed out. Three main subjects were tackled during 2015 and 2016. One concerns the so-called space ties; in this framework a number of GNSS observation tests have been proposed, planned, and carried out with European VLBI antennas. A second investigation was dedicated to VLBI coordinate time series analysis and comparison with corresponding results from other space geodetic techniques involved in ITRF2014 computation. Finally, data processing of CONT campaigns have been carried out for studies on tropospheric parameter estimation from VLBI data and comparison with GNSS estimates at co-location sites.

1 General Information and Staff

The Department of Civil and Environmental Engineering (DICA) of the Polytechnic University of Milan hosts the Politecnico di Milano DICA (PMD) IVS Analysis Center (AC). Milan Polytechnic is the largest technical university in Italy with about 40,000 students. It offers undergraduate, graduate, and higher education courses in engineering, architecture, and design. The Milan Polytechnic has seven main campuses, two are in Milan city and five across Lombardy and Emilia Romagna. The majority of the research and teaching activities are located in the historical campus called Milano Leonardo. PMD AC is located at this campus, in particular it is supported by the Geodesy and Geomatics research area of DICA as far as hardware equipment, software licenses, and assistance are concerned. Members who cooperated with the activities of the PMD IVS Analysis Center in 2015 and 2016 are listed in Table 1.

Table 1 PMD IVS AC support staff in 2015 and 2016.

Name	Working Location	Contribution to PMD
Vincenza Tornatore	Politecnico di Milano, DICA, Geod.Geom.Area, Milano, ITALY.	Responsible person from AC, project coordinator
Giovanna Venuti	Politecnico di Milano, DICA, Geod.Geom.Area, Como, ITALY.	Troposphere
Cinzia Vajani	Politecnico di Milano, DICA, Geod.Geom.Area, Milano, ITALY.	Software maintenance
Lorenzo Rossi	Politecnico di Milano, DICA, Geod.Geom.Area, Como, ITALY.	Support for data processing

Staff member contributions and working locations (see [1] and [2]) are indicated in the table as well.

2 Current Status and Activities

The main topics investigated during 2015 and 2016 continued to be related to the improvement of reference frames stability, to satellite/space geodetic intertechnique comparisons, and to troposphere parameter esimation from VLBI and GNSS observations at co-

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PMD Analysis Center

IVS 2015+2016 Biennial Report

location sites. The scientific software used for data processing and analysis was updated to the last version available, and some home made algorithms were improved.

2.1 Planning and Realization of VLBI Observations of GNSS Satellites

The activities related to the planning and realization of GNSS satellite observations by the VLBI technique (that started some years ago, see, e.g., [17] and [18]), were carried out during the biennium 2015–2016. In particular in this period the experiments were devoted primarly to test the use of the DBBC3 [20] for the acquisistion of the strong satellite signal at Medicina VLBI station [3] and at the Sardinia Radio telescope (SRT) [4].

SRT is a large (64-m primary mirror with a 7.9 m secondary) radio telescope, fully steerable located in the province of Cagliari in Sardinia, inaugurated in 2013 (see Figure 1).

Fig. 1 A view of Sardinia Radio Telescope; credits by http://www.media.inaf.it/.

The use of the DBBC3 during VLBI observations of GNSS satellites has the advantage to automatically set the power attenuation on the very strong signal coming from the satellites. Then it also takes off the attenuation once the radio telescope receives the weak signal from celestial natural radio sources usually tracked during geodetic VLBI experiments.

One experiment was carried out on the 23 November 2015 on the single baseline between the VLBI stations Medicina and Wettzell. Three satellites for each constellation (GPS, GLONASS, GALILEO) were tracked, alternating satellite observations with natural radio source observations. The software used for scheduling GNSS and natural radio source observations was the VieVS satellite scheduling program [13], which is included as a module in the VieVS software [10]. First attempts of data correlation were successful, but the whole pipeline of the experiment data processing still needs to be completed.

A second experiment was carried out on the 23 May 2016; participating VLBI stations were Medicina, SRT, and Onsala85 [5]. This test was planned as a multi-station, multi-frequency, and multi-constellation experiment. In this case we observed not only GPS, GLONASS, and GALILEO, but also the Chinese Beidou constellation, as it is shown on the skyplot of Medicina station in Figure 2. Some, still unresolved, problems were found during the correlation of the data from the Medicina VLBI station. Investigating the reasons and possible solutions of the problems are in progress.

2.2 Satellite/Space Geodetic Inter-technique Comparisons

We carried our investigations on time series of site coordinates belonging to the networks of the three microwave space-geodetic techniques: Global Navigation Satellite Systems (GNSS) [12], Very Long Baseline Interferometry (VLBI) [16], and Doppler Orbitography and Radio Positioning Integrated by Satellite (DORIS) [21].

Figure 3 shows the networks of sites belonging to all four satellite/space-geodetic techniques contributing to ITRF2014, Satellite Laser Ranging (SLR) [8] included, as of mid-2014. In preparation of the computation of the new realization of the International Terrestrial Reference Frame ITRF2014 [9] all ACs, belonging to individual satellite/space-geodetic services of the International Association of Geodesy (IAG)—the International DORIS Service (IDS), the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), and the International GNSS Service (IGS)—reprocessed data ac-

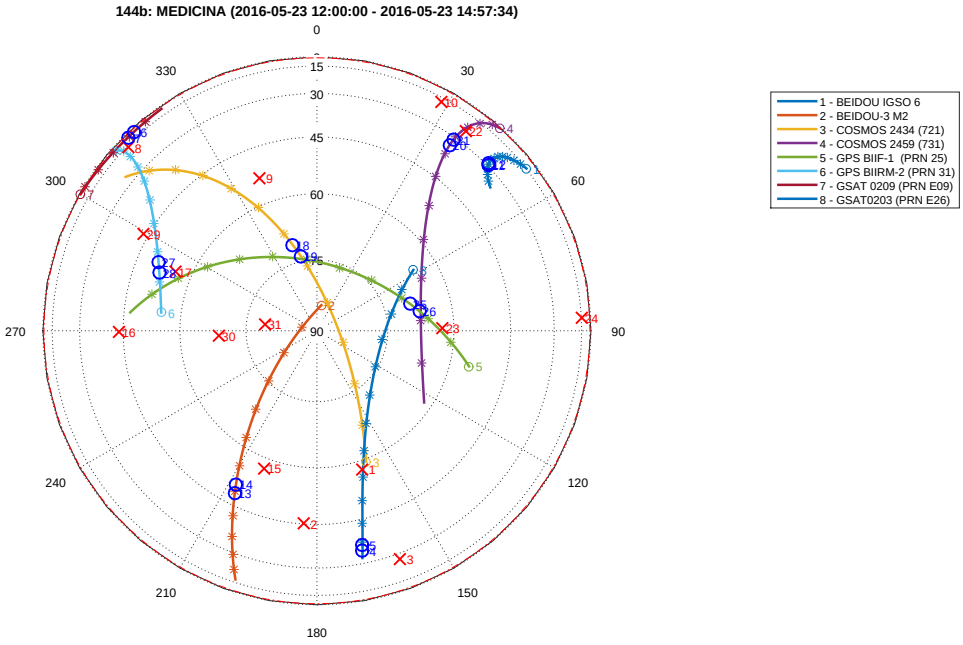

Fig. 2 Skyplot for one of the participating stations (Medicina) of the 23 May 2016 experiment; courtesy of A. Hellerschmied.

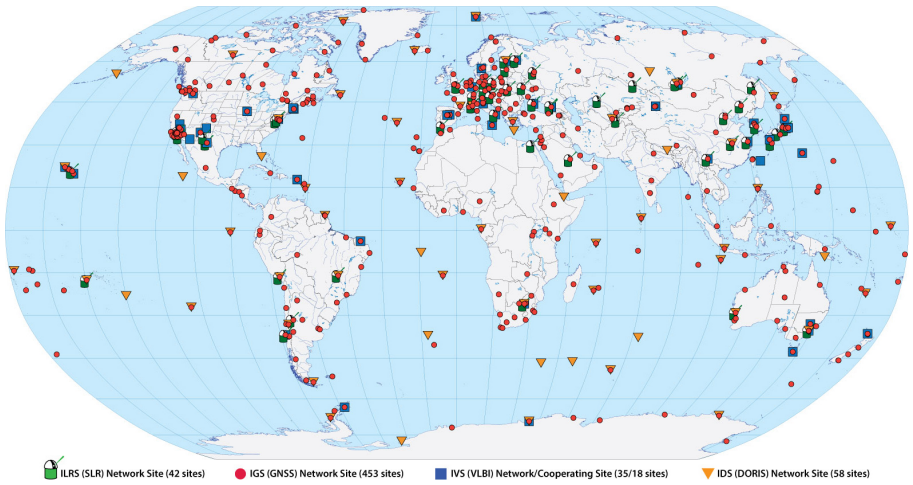

Fig. 3 The networks supporting the ILRS, IGS, IVS, and IDS; from [14].

cording to common guidelines and improved models conforming with the IERS Conventions 2010 [15] and updates posted at [6].

We based our studies on the site positions extracted from combined reprocessed input time series submitted for ITRF2014 computation by IVS, IDS, and IGS official Combination Centers (CCs). We used a novel approach to study time series that is described in detail in [19]. The analysis consists of three main steps: detection and removal of documented and undocu-

mented discontinuities, modeling of the long-term signal (constraining the system dynamic in order to obtain cyclostationary residuals), residuals harmonic analysis by a non-linear least squares algorithm. Frequencies and amplitudes of the residual signals and their percentage of incidence were estimated. Two classes of residual signals related to seasonal and tidal effects were detected for all the three techniques. At the co-location sites (running regularly VLBI, GNSS, and DORIS observations) we estimated also velocities and their standard deviations (STD) obtaining a good agreement among the three techniques both in the horizontal (1.0 mm/yr mean STD) and in the vertical (0.7 mm/yr mean STD) component. Some sites show larger STDs, mainly due to lack of data, different data spans, or noisy observations.

This work was carried out in collaboration with KTU-GEOD Analysis Center (Karadeniz Technical University) and Department of Architecture and Design (DAD) of Polytechnic University of Turin.

2.3 Estimation of Atmospheric Parameters using VLBI and GNSS Data

During 2015 and 2016 the scientific software for VLBI and GNSS data processing was updated to the last version delivered by the universities developing and maintaining the software: the Department of Geodesy and Geoinformation of Vienna University of Technology and the Astronomical Institute of the University of Bern, respectively. The releases now running are the 2.3 for VieVS [7] and the 5.2 for Bernese software [11]. After a period of testing of the new software versions, CONT campaigns were processed using VieVS 2.3. At the VLBI stations co-located with GNSS permanent stations, we are going to process GNSS data too to estimate troposphere parameters using the Bernese 5.2. This work was developed in cooperation with the IVS AC-VIE at Vienna University of Technology (TU Wien). Analysis and comparisons of the results need to be completed.

Some tests, in collaboration with the IVS KTU AC, were carried out to analyze GNSS time series of ZTD (Zenith Tropospheric Delay) and IWV (Integrated Water Vapour) estimates.

3 Future Plans

The plans of PMD IVS Analysis Center for the 2017 and 2018 biennium concern the continuation of studies and experiments on the problem of co-location in space and on ground of the space-geodetic techniques VLBI and GNSS.

The studies and comparisons of the results from the three microwave space/satellite geodetic techniques (VLBI, GNSS, and DORIS) will be extended also to the SLR technique.

Studies on troposphere parameter estimation from VLBI and GNSS will also be continued and some investigations on ionosphere parameters are planned too.

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