PMD IVS Analysis Center 2019–2020 Report

Vincenza Tornatore

Abstract The activities related to geodetic VLBI carried out at the IVS AC PMD during 2019 and 2020 were focused on different topics that are detailed below. As in previous years, routine computations of European baselines and tropospheric parameters were carried out. Comparisons of algorithms to detect jumps in time series were also performed in the framework of COST Action ES1206. The collaboration with the CRAF Committee has increased to defend the legacy S/X and VGOS frequency bands from external threats. And new collaborations and research under COST (DAMOCLES) and JRP GeoMetre projects have started. Visits and collaborations with other IVS ACs have also been organized and realized.

1 General Information

At the PMD IVS Analysis Center, hosted by the Politecnico di Milano DICA (see Figure 1), there were no significant changes compared to the previous two-year period (2017–2018) as regards to the location, the promoting agency, and the staff.

Politecnico di Milano, Department of Civil and Environmental Engineering (DICA), Geodesy and Geomatic Area

PMD Analysis Center

IVS 2019+2020 Biennial Report

Fig. 1 Politecnico di Milano Building 3, where the AC PMD is hosted.

2 Activities during the Past Two Years

2.1 Spectrum Protection for VGOS

During 2019 and 2020, we continued working on the issue related to spectrum managment at legacy S/X and VGOS antennas [1]. These studies were developed also under the framework of and in collaboration with the Committee on Radio Astronomy Frequencies of the of European Science Foundation (CRAF) [6] that coordinates activities to keep the frequency bands used by radio astronomy and space sciences free from interference. Geodetic and astrometric VLBI is a passive spatial technique; in the last years, its bands of interest were getting crowded by interferences caused by both terrestrial and space-borne private services [2]. Due to the increasing number of active terrestrial and space-borne private services that broadcast artificial signals it is becoming more and more difficult to protect observations from radio interference.

Fig. 2 Visit of the Meerkat telescope during the Fifth IUCAF Spectrum Management School for Radio Astronomy (Photo credit: Tasso Tzioumis).

One of the most dangerous threats to VGOS are the satellite systems Starlink and OneWeb downlink transmissions in the frequency range 10.7–12.75 GHz. In this range only the narrow band 10.6–10.7 GHz is allocated and protected by the radio astronomy service (RAS). On this matter technical studies at ECC project team SE40 have proposed several mitigation measures to protect the RAS band in Europe. Filtering requirements for the transmitters, constraints on power amplifier design, specified filtering, and deactivation of some channels when a satellite is in visibility of the telescopes were described in the ECC report 271 [8].

Under the initiative of the "Dark and Quiet Skies for Science and Society" event, radio astronomy representatives from around the world recommended solutions for the negative impacts expected (see Figure 3). The event was organized by the United Nations Office for Outer Space Affairs (UNOOSA) and the government of Spain, jointly with the International Astronomical Union (IAU). After the meeting, a report [9] was prepared and will be presented to the Committee on the Peaceful Uses of Outer Space (COPUOS).

For the recognition of the VLBI Global Observing System (VGOS) services by the International Telecommunications Union (ITU) [10], *questions* to the Radiocommunications sector (ITU-R) Working Party 7D of RAS have been submitted. VGOS as a new global infrastructure makes passive use in four sub-bands of the spectrum in the range of 2–14 GHz to meet the targeted accuracy goals. A recognition of VGOS applications by the ITU should allow certain level of coordination with the satellite constellation agency for the overlapping frequency bands.

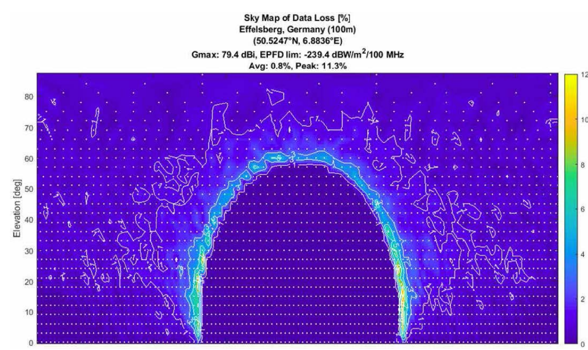

Fig. 3 Effelsberg sky map of data loss at 10.6–10.7 GHz (credit: ECC report 271).

The Scientific Committee on Frequency Allocations for Radio Astronomy and Space Scienc (IUCAF) and the South African Radio Astronomy Observatory (SARAO), together with CRAF and RadioNet organized the Fifth IUCAF Spectrum Management School for Radio Astronomy in Stellenbosch, South Africa, on March 2–6, 2020 [7]. An optional visit to the MeerKAT Telescope was organized for school participants (see Figure 2) where people at Meerkat are shown.

2.2 Break Detection in Time Series of Tropospheric Parameters

An investigation on the performance of different break detection methods has been carried out on three sets of benchmark datasets, each consisting of 120 daily time series (1995–2011) of integrated water vapor (IWV) differences between Global Navigation Satellite System (GNSS) data and the numerical weather prediction reanalysis (ERA-Interim) data. The number methods used for breack detection is eight: two of them are based on Maximum Likelihood (ML) multiple break principle,three on Standard Normal Homogeneity Test, one on Singular Spectrum Analysis (SSA), and two on non-parametric methods.

The benchmark was developed with the use of known climatic characteristics and earlier estimates of inhomogeneities of IWV data in 120 observing sites of GNSS data. The benchmark includes homogeneous and inhomogeneous sections with added breaks in the latter.

To assess the performances of break detection methods w.r.t. dataset characteristics, three different variants of the benchmark time series were produced. They have increasing complexity, but the mean break frequency (2.5 per time series) and break magnitude distribution is the same for each variant. "Easy" dataset includes annual and sub-annual cycles of the means, breaks, and white noise only. "Moderate" dataset includes easy dataset plus first order autoregressive process of the first order (noise model = AR(1)+WN). "Complex" dataset is composed by Moderate dataset with gaps (up to 20% of missing data) and non-climatic trends added.

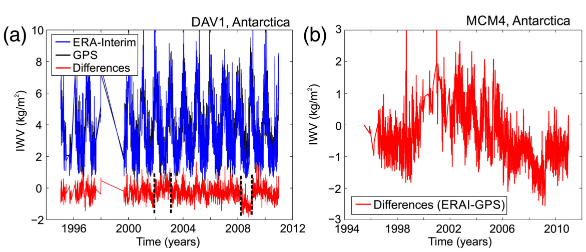

Fig. 4 Examples where break visual detection is (a) possible for DAV1 or (b) not possible for MCM4 (Credits to R. Van Malderen et al. 2020, Wiley's Open Access).

The purpose of "Complex" experiments is to examine the performance of break detection methods in a more realistic case when the reference series are not homogeneous. In Figure 4, examples for two Antarctic stations are shown in the first case, DAV1 station; a break is visible and also reported in the IGS site log, while for MCM4 visual detection of breaks is not possible.

The performance of different break detection methods and software was evaluated using skill scores, centered root mean square errors (CRMSE), and trend differences relative to the trends of the homogeneous series. We found that most methods underestimate the number of breaks and have a significant number of false detections. Trend bias improvement decreases with increasing complexity of the datasets. In most experiments the maximum likelihood multiple break method and Standard Normal Homogeneity Test method achieved the best results. All characteristics of this work, detailed results, and discussions can be found in the publication [3]. These studies have been carried out under COST Action ES1206 Advanced Global Navigation Satellite Systems tropospheric products for monitoring severe weather events and climate (GNSS4SWEC), sub-WG Data Homogenization.

3 Current Status

Under the COST ACTION CA17109 "Understanding and modeling compound climate and weather events (DAMOCLES)", PMD AC collaborates in WG2 "Stakeholder involvement and science-user interface" and in WG4 "New statistical approaches for model development and evaluation" since 2019. The main objectives of the project are to bring together climate scientists, impact modellers, statisticians, and stakeholders to better understand, describe, and project compound events, and it foresees a major breakthrough in future risk assessments. Compound events arise from the combination of physical processes; they can produce high-impact hazards [4]. The extent of their impact can not be foreseen considering only single processes but also their interactions. For example, it is not clear whether climate models can capture major changes in risk associated with compound events.

Another project where AC PMD is involved as a stakeholder is the JRP s-09 GeoMetre “Large-scale dimensional measurements for geodesy,” in particular for the WP3 “Local tie metrology at space-geodetic GGOS-CSs.” One of the objectives of the project is to investigate the determination of the SLR and VLBI reference points. They are, in fact, a metrological challenge because it is inaccessible and non-materialized. Indirect methods are normally used to estimate the reference points in a rigorous way, but their determination with high accuracy is still an issue. A modified approach that meets the demands on an automated and continued reference point determination of the Global Geodetic Observing System (GGOS) is presented in [5]. Different studies are ongoing for all the different WPs of the GeoMetre project.

Data processing of European VLBI experiemnts is regularly carried out to study both station coordinates and tropospheric parameters. Time series of different estimated parameters are under investigation also for comparison with results from other spatial techniques in particular with GNSS. The VieVs software normally used for parameter estimation was updated to present version 3.2. Members of the PMD AC participated in the VieVS Days held online as a webinar from September 14–15, 2020. The first day was devoted to the VLBI module of the Vienna VLBI and Satellite Software (VieVS) with lectures on single session analysis, multi-session analysis, and global solution analyzing R&D sessions. The focus moved to scheduling package VieSched++ on the second day. More information is available at [11] on VieVS VLBI V3.2 as well as VieSched++ V1.1. Capabilities to generate schedules and simulations ware explored using VieSched++ V1.1 software during the second day.

Thanks to the ERASMUS+ project a visit has been carried out at the KTU-GEOD Analysis Center (Karadeniz Technical University) by PMD AC. During the visit, common projects between the two IVS ACs were discussed in detail and lectures were given to the KTU graduate and MSc/PhD students (see Figure 5).

Fig. 5 Lectures at KTU during ERASMUS+ program, February 2020 (Photo credit: Prof. E. Tanır Kayıkci).

4 Future Plans

In 2021 and 2022, IVS AC PMD will be working on the optimal estimations of the tropospheric VLBI parameter and comparison with results from GNSS data. Studies on ionospheric effects will also be tackled. Under COST ACTION CA17109 (DAMOCLES), work will be carried out with the aim to extend the network of collaborations with international colleagues from different fields, e.g., climate, wheather predictions, impact modellers, statisticians, and also to strengthen collaborations with Italian Meteorological Offices/Services, e.g., military aviation, which takes care of the weather forecast in Italy. Contributions to the GeoMetre project will also be given for the improvement of local tie determinations in Italy.

Acknowledgements

We thank the Department of Civil and Environmental Engineering (DICA) of Politecnico di Milano University, in particular the Geodesy and Geomatics Area for hosting and supporting the IVS PMD AC activities.

We also thank the COST projects ACTION ES1206 and ACTION CA17109.

We acknowledge CRAF and IVS for their activities to defend VGOS frequencies.

We thank AC KTU and Karadeniz Technical University, Department of Geomatics Engineering for their kind hospitality and for research and teaching collaboration.

References

1. A. Niell, J. Barret, A. Burns, R. Cappallo, B. Corey, M. Derome, C. Eckert, P. Elosegui, R. McWhirter, M. Poirier, G. Rajagopalan, A. Rogers, C. Ruszczyk, J. SooHoo, M. Titus, A. Whitney, D. Behrend, S. Bolotin, J. Gipson, D. Gordon, E. Himwich, and B. Petrachenko, 2018, "Demonstration of the Broadband Very Long Baseline Interferometer System: A New Instrumentfor High-Precision Space Geodesy", Radio Science, 53(10), pages 1269–1291, https://doi.org/10.1029/2018RS006617
2. V. Tornatore, H. Hase, W. Benjamin, P. Bolli, "VGOS wideband reception and emerging competitor occupations of VLBI spectrum" In K. Armstrong, K. D. Baver and D. Behrend, editors, 10th IVS 2018 General Meeting Proceedings, Longyearbyen, Svalbard, 3-9 June 2018, pages 32–36, 2019, https://ivscc.gsfc.nasa.gov/publications/gm2018/08-tornatore_etal.pdf
3. R. Van Malderen, E. Pottiaux, A. Klos, P. Domonkos, M. Elias, T. Ning, O. Bock, J. Guijarro, F. Alshawaf, M. Hoseini, A. Quarello, E. Lebarbier, B. Chimani, V. Tornatore, S. Zengin Kazancı, J. Bogusz, "Homogenizing GPS Integrated Water Vapor Time Series: Benchmarking Break Detection Methods on Synthetic Data Sets", Earth and Space Science,7,e2020EA001121, pages 1–20, 2020, https://doi.org/10.1029/2020EA001121
4. D. Paprotny, M.I. Vousdoukas, O. Morales-Nápoles, et al., "Pan-European hydrodynamic models and their ability to identify compound floods" In Nat Hazards 101, pages 933–957, 2020 https://doi.org/10.1007/s11069-020-03902-3
5. M. Lösler, C. Eschelbach, S. Riepl, T. Schüler, "A Modified Approach for Process-Integrated Reference Point Determination" In R. Haas, S. García-Espada and J.A. López Fernández, editors, Proceedings of the 24th European VLBI Group for Geodesy and Astrometry Working Meeting, pages 172–176, 2019
6. URL 1: https://www.craf.eu/, Date of Access: February 2021.
7. URL 2: http://www.iucaf.org/sms2020/, Date of Access: February 2021.
8. URL 3: https://docdb.cept.org/document/1032, Date of Access: February 2021.
9. URL 4: https://www.iau.org/static/publications/dqskies-book-29-12-20.pdf Date of Access: February 2021.
10. URL 5: https://www.itu.int Date of Access: February 2021.
11. URL 6: https://vievswiki.geo.tuwien.ac.at/doku.php Date of Access: February 2021.