KTU-GEOD Analysis Center Report

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Abstract This report summarizes the activities of the KTU-GEOD Analysis Center (AC) in 2023 and 2024 and outlines the planned activities for 2025 and 2026. Our specific interests in 2023 and 2024 included: (1) improving the capacity of VLBI to detect station displacements through an inter-technique combination with GNSS and (2) estimating the diurnal and semi-diurnal Earth rotation variations due to ocean tides using IVS [1, 2] daily sessions carried out from January 1984 through May 2022.

1 General Information

The KTU-GEOD Analysis Center (AC) [3] is located at the Department of Geomatics Engineering, Karadeniz Technical University, Trabzon, Turkey. The Geomatics Engineering Departments at Hacettepe University and Kocaeli University support the activities of KTU-GEOD by analyzing VLBI observations as well as interpreting geodetic and geodynamic parameters.

2 Staff of the KTU-GEOD Analysis Center

Members who contributed to the KTU-GEOD AC research in 2023 and 2024 are listed in Table 1 together with their work location and research focus [3].

1. Karadeniz Technical University, Department of Geomatics Engineering
2. Hacettepe University, Department of Geomatics Engineering
3. Kocaeli University, Department of Geomatics Engineering

KTU-GEOD Analysis Center

IVS 2023+2024 Biennial Report

3 Current Status and Activities

3.1 *Sensitivity Levels of VLBI Solutions from a Combination with GNSS*

During 2023 and 2024, KTU-GEOD performed research work on the sensitivity levels of VLBI solutions

Fig. 1 Emine Tanır Kayıkçı (far left) presenting “Geodesy in Türkiye” at the Geodesy Capacity Development Workshop for Europe on Transitioning to a Modern Geospatial Reference System held by United Nations Global Geodetic Centre of Excellence on the United Nations Campus in Bonn, Germany, in February 2025 [4].

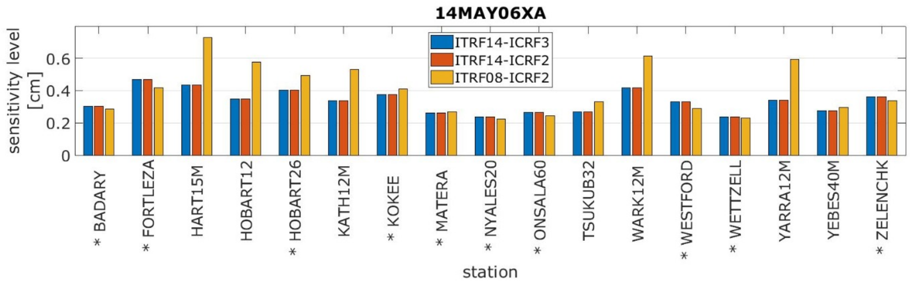

Fig. 2 Sensitivity levels of the VLBI stations depending on different reference frames obtained for session 14MAY06XA. Black stars indicate the common datum stations for both datums (ITRF2014 and ITRF2008) [14].

Table 1 Staff of the KTU-GEOD Analysis Center.

Name	Work Location	Main Focus of Research
Emine Tanır Kayıkçı	Karadeniz Technical Univ., Dept. of Geomatics Eng., Trabzon, Turkey.	responsible person for AC, parameter combination
Mualla Yalçınkaya	Karadeniz Technical Univ., Dept. of Geomatics Eng., Trabzon, Turkey.	data analysis
Haluk Konak	Kocaeli Univ., Dept. of Geomatics Eng., Kocaeli, Turkey.	data analysis
Kamil Teke	Hacettepe Univ., Dept. of Geomatics Eng., Ankara, Turkey.	data analysis
Pakize Küreç Nehbit	Kocaeli Univ., Dept. of Geomatics Eng., Kocaeli, Turkey.	data analysis

from a combination with GNSS [14]. The aim of the research work was: (1) to improve the detection capacity of the VLBI stations based on the undetectable gross errors through the inter-technique combination with GNSS using different scenarios and (2) to determine the effects of the standard deviations of the local ties on network quality. Within the study the effects of (1) the a priori coordinates, (2) the inter-technique combination on VLBI stations, and (3) the standard deviations of the local ties at co-location sites were researched based on sensitivity analyses.

3.1.1 Effects of a priori Coordinates

The datum and non-datum stations of ITRF2008 and ITRF2014 were applied in this study as provided. The results indicate that on average the sensitivity levels are smaller when applying the ITRF2014 datum as opposed to the ITRF2008 datum. As expected, taking the a priori values of celestial coordinates either from ICRF2 or from ICRF3 has no significant effect on the sensitivity of terrestrial stations (see Figure 2).

3.1.2 Effects of Inter-technique Combination

We investigated how the sensitivity levels of the VLBI stations changed in the inter-technique combination. The covariance matrices generated assuming statistical white noise for the VLBI and GNSS data were used to examine the theoretical improvements that could be expected in a combined solution. Figure 3 shows that the sensitivity levels of all stations decrease to around 2 mm or less through the combination except TSUKUB32 for session 14MAY08XA.

3.1.3 Impact of Standard Deviations of Local Ties

We investigated the effect of the selection of co-location sites on the sensitivity levels using four different scenarios (see Figure 4):

- For co-located sites with different standard deviations, the one with the maximal standard deviation was selected (*scenario 1*),
- The co-location sites having minimal standard deviations were selected (*scenario 2*),
- One of the five co-locations mentioned in the first scenario sites having the largest standard deviations was altered (*scenario 3*),
- Five co-location sites having smaller standard deviations among six co-location sites were selected (*scenario 4*).

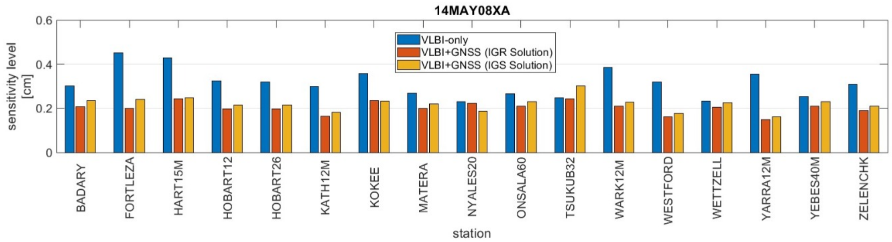

Fig. 3 Sensitivity levels for both VLBI-only and combined VLBI plus GNSS solutions for session 14MAY08XA [14].

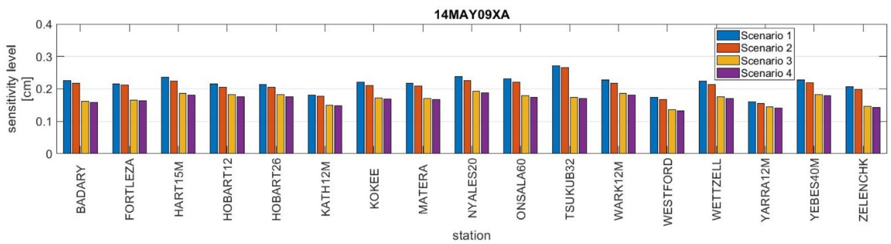

Fig. 4 Comparison of the sensitivity levels of the VLBI stations in the combined VLBI plus GNSS solution based on four scenarios for session 14MAY09XA [14].

Figure 4 shows that the sensitivity levels improve slightly when the local ties are selected for co-location sites with smaller standard deviations (e.g., *scenario 2* vs. *scenario 1*). When the estimated coordinates with *scenario 4* are compared with those determined before the combination, the x-, y-, and z- components have differences up to 2 cm.

The study shows (1) the importance of applying statistical constraints on the local ties used for the inter-technique combination to improve network quality and (2) the local ties having larger standard deviations than the other local ties affects the associated VLBI station more and other stations in the network less. Also the VLBI and GNSS inter-technique combined solutions result in improved VLBI station coordinates because the sensitivity levels are getting smaller and because the identification of gross errors improves. This implies that VLBI networks could be strengthened with a regional GNSS network with co-location sites.

3.2 Estimating Diurnal and Semi-diurnal Earth Rotation Variations Caused by Ocean Tides

The in-phase and quadrature components of the phasor vectors of the semi-diurnal and the diurnal prograde polar motion caused by the ocean tides as well as the semi-diurnal retrograde polar motion along with UT1-UTC were estimated (after reducing libration) using VieVS [13]. The analyzed observations cover in total 4,610 daily sessions [1, 2] of the IVS (from January 1984 through May 2022) with at least five VLBI stations. Firstly, the CIP coordinates in TRF along with UT1-UTC were estimated at 30-minute intervals, i.e., 218,210 epochs of Earth rotation parameter (ERP: xp, yp, UT1-UTC) estimates along with their fully occupied covariance matrices. The parametrization of the session analysis is as follows. Troposphere zenith hydrostatic delays (ZHD) [6] were reduced from the observations a priori to the adjustment. Troposphere zenith wet delays (ZWD) were estimated as piecewise linear offsets (PLO) at 15-minute intervals (VMF3, [7], loose relative constraints as 0.7 ps^2/s). Troposphere gradients were estimated as PLO at 60-minute intervals ([8], C=0.0032, loose relative constraints as 2 mm/day). Clock errors were eliminated by fitting a quadratic polynomial plus estimating PLO at 15-minute intervals (loose relative constraints as 0.4 ps^2/s). Thermal deformations were calculated from the model of [9]. The displacements of the stations due to the Solid Earth tides, ocean tidal loading, TPXO72 [10], pole tide [11], and tidal and nontidal atmosphere loading [15] were calculated

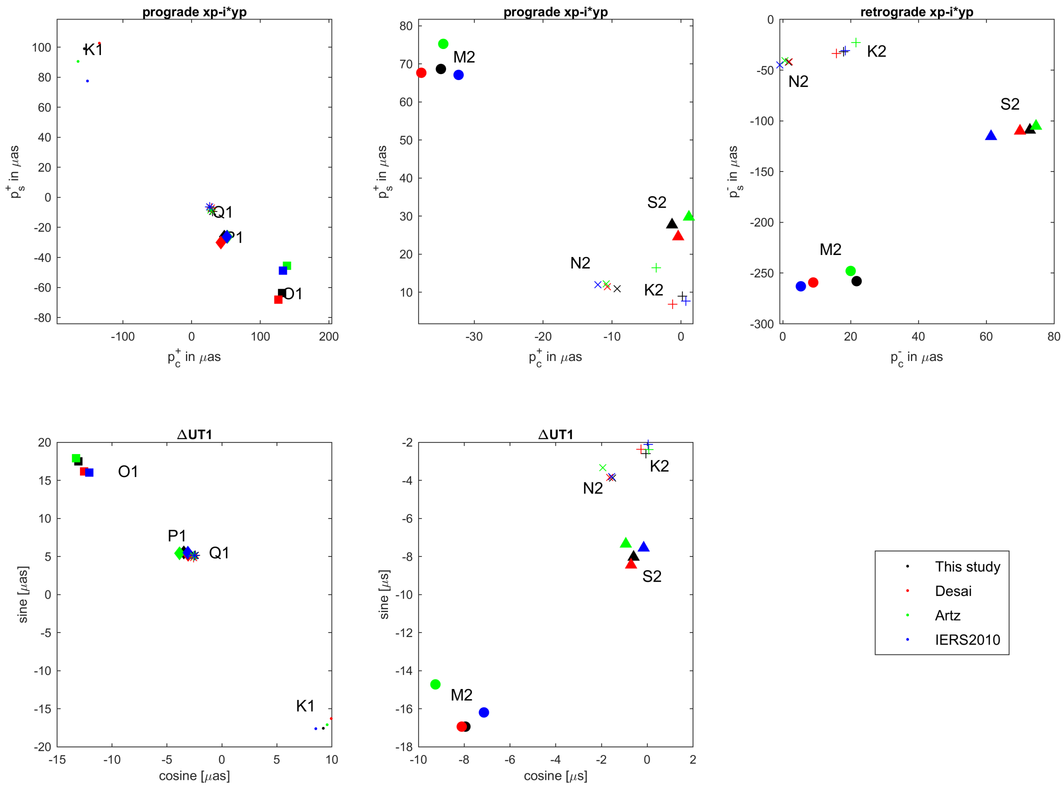

Fig. 5 Prograde and retrograde components of the polar motion phasor vectors along with the UT1-UTC harmonic function [11] coefficients caused by ocean tides derived from different solutions [11, 12, 23, 22]. "This study" in the plot refers to [12].

and added to the ITRF2014 [18] coordinates of the stations. Station coordinates were estimated as one offset per daily VLBI session providing the estimated TRF will have zero translation and zero rotation w.r.t. ITRF2014. Source coordinates were estimated as one offset per daily VLBI session providing the estimated CRF will have zero rotation w.r.t. ICRF3sx [19]. CIP coordinates in CRF were held as fixed to the *IAU*2000*A* [20] model values plus the CPO derived from the Lagrange interpolated *IERS* 14 *C*04 [21] series. ERP were estimated as PLO at 30-minute intervals (e.g., at 0:00, 0:30, 1:00, 1:30 UT) in addition to the *IERS* 14 *C*04 series plus a priori ERP model from [22] (loose relative constraints as 30 mas/day for PM as well as 2 ms/day for UT1-UTC). Finally, the in-phase and quadrature components of the phasor vectors of the semi-diurnal and the diurnal ERP were selected as the elements of the state vector which is updated daily with a Kalman filter (KF) of which observations are designated as ERP coordinates at 30-minute intervals along with their full covariance matrices. To suppress the retrograde polar motion at tidal diurnal frequencies to zero in the KF solution, a new type of constraint was imposed, i.e., different to those introduced in, e.g., [16] and [17]. The first results, e.g., see Figures 5 and 6, were presented at the scientific colloquium on "Recent Achievements and Future Perspectives in Geodesy" held in honor of Prof. Dr. Harald Schuh from 21–22 February 2024 at GFZ [12].

4 Future Plans

In 2025 and 2026, our group will be working on the tropospheric parameter precipitable water vapor, which will be monitored by the GNSS and VLBI techniques. The results will be compared between co-located GNSS, VLBI, and radiosonde stations considering the height differences between the antenna reference points of the receivers. In addition, the work

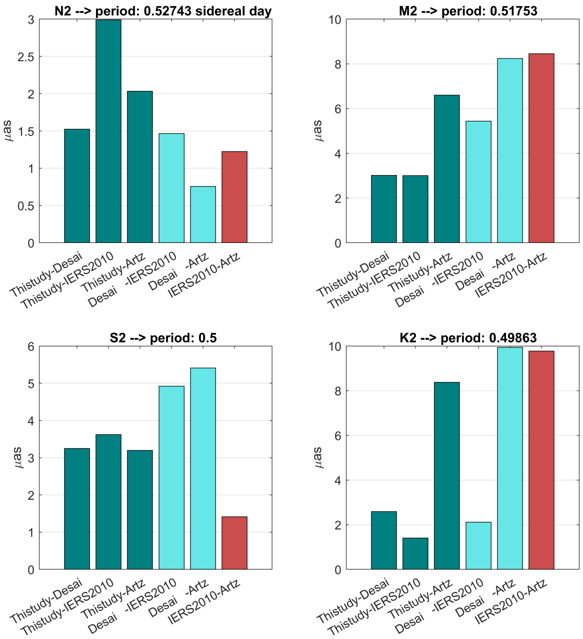

Fig. 6 The magnitudes of the prograde semi-diurnal polar motion phasor vector differences between the various solutions [11, 12, 23, 22]. "This study" in the plot refers to [12].

on high-frequency ERP variations due to ocean tides will be continued.

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