KTU-GEOD Analysis Center Report

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Abstract This report summarizes the activities of the KTU-GEOD Analysis Center (AC) in 2021 and 2022 and outlines the planned activities for 2023 and 2024. Our specific interests and focused subjects for 2021 and 2022 were as follows: (1) analyzing precision criteria of the radio sources in the daily IVS sessions, (2) monitoring the changing precision of radio sources realizing the Celestial Reference Frame in continuous VLBI campaigns, (3) investigating the sensitivity levels of VLBI stations in the CONT14 campaign by combination with GNSS, evaluation of daily CONT17 sessions with the Potsdam Open Source Radio Interferometry Tool (PORT), (4) estimating station velocities of the European IGS and VLBI sites, and (5) estimating the amplitudes and Greenwich phase-lags of the principal semidiurnal and the diurnal tides of the ocean tide loading displacements at the worldwide distributed 37 VLBI stations.

1 General Information

The IVS [1, 2] 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, Kocaeli University, and Gümüşhane University support the activities of the KTU-GEOD AC through analyzing the VLBI observations as well as interpreting the geodetic and geodynamic parameters.

2 Staff at KTU-GEOD Contributing to the IVS Analysis Center

Members who contributed to the KTU-GEOD AC research in 2021 and 2022 are listed in Table 1 (in alphabetical order) by their main focus of research and working location [3, 4, 5, 6].

Table 1 Staff of the KTU-GEOD Analysis Center.

Name	Working Location	Main Focus of Research
Emine Tanır Kayıkçı	Karadeniz Technical Univ., Dept. of Geomatics Eng., Trabzon, Turkey	responsible person from 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
Özge Karaaslan	Gümüşhane Univer., Dept. of Geomatics Eng., Gümüşhane, Turkey	data analysis
Pakize Küreç Nehbit	Kocaeli Univ., Dept. of Geomatics Eng., Kocaeli, Turkey	data analysis

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

KTU-GEOD Analysis Center

IVS 2021+2022 Biennial Report

Fig. 1 Members of the KTU-GEOD AC at the Turkish National Geodesy Commission Scientific Meeting held in November 2022, Gebze Technical University.

3 Current Status and Activities

3.1 Analyzing Precision Criteria of the Radio Sources in the Daily IVS Sessions

The quality criteria of a geodetic network are determined by the precision criteria computed from the co-factor matrix of the unknown parameters. In two-dimensional networks—and the celestial reference frame realized by extragalactic radio sources can be considered as such—the Helmert mean error ellipse consists of three parameters which are the semi-major and semi-minor axes of the error ellipse and the direction of the semi-major axis. In a well-designed geodetic network, the error ellipses should have homogeneous structures. In other words, the semi-axes of the error ellipses for all radio sources should be similar. In this study, daily CONT17 sessions were evaluated with The Potsdam Open Source Radio Interferometry Tool (PORT) and the parameters of the Helmert mean error ellipses were computed for the radio sources for each session (Figure 2). The results are also compared with the number of observations and the angular position of the radio sources. The results of this study show how the precision criteria are affected depending on the angular position of the radio sources [7].

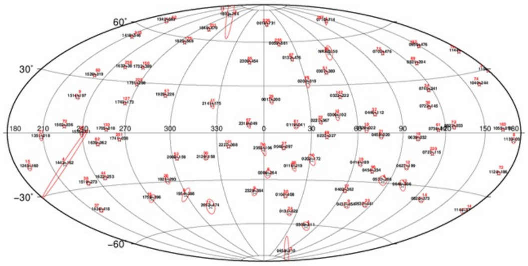

Fig. 2 Error ellipses and the number of observations to the radio sources in the $17DEC08XB$ session of CONT17.

3.2 Monitoring the Changing Precision of Radio Sources Realizing the Celestial Reference Frame in Continuous VLBI Campaigns

The changing precision of radio sources realizing the Celestial Reference Frame (CRF) in continuous VLBI campaigns was analyzed by different precision criteria. The quality of a geodetic network is classically determined by the precision criteria obtained from the co-factor matrix of the unknown parameters. The Helmert mean error ellipse, which is one of the precision criteria, consists of semi-major axis, semi-minor axis, and the direction of the semi-major axis. In a well-designed geodetic network, it is expected that the error ellipses should have homogeneous structures. In this study, the CONT17 sessions, having a Legacy-1 observation network, were evaluated with PORT. Parameters of the Helmert mean error ellipses of the radio sources were computed in each session of the CONT17. The relationship between the Helmert mean error ellipse parameters and the angular positions and the observation numbers of each radio source has been investigated.

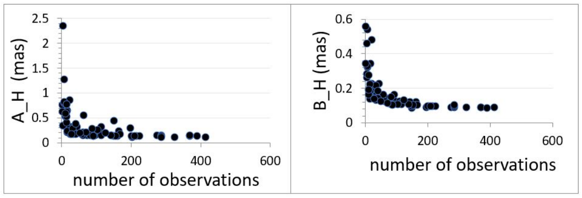

Fig. 3 Comparing the number of observations with the semi-major (A_H) and the semi-minor (B_H) axes (Figure drawn by Susanne Lunz).

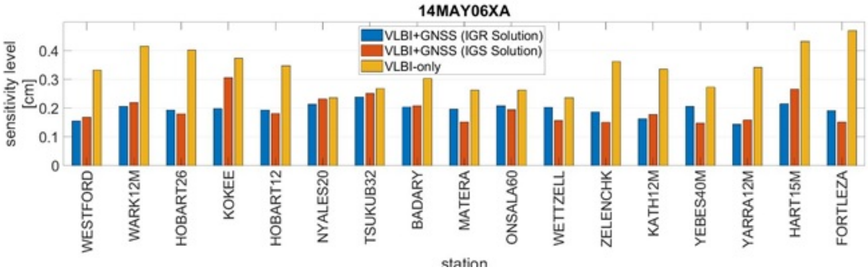

Fig. 4 Comparing the sensitivity levels of the VLBI antennas with combined VLBI and GNSS in session 14MAY06XA of CONT14.

Accordingly, it was seen that values of the semi-axis are directly related to the number of observations of the radio sources (Figure 3) [8].

3.3 Improving the Sensitivity Levels Generated from Hypothesis Testing by Combining VLBI with GNSS Data

The individual space-geodetic techniques have different advantages and disadvantages. For instance, the global observing network of VLBI consists of much fewer stations with a poorer distribution than GNSS. The sensitivity level of any geodetic network provides information on the detection capacity of observing stations based on undetectable gross errors in a geodetic network solution. Furthermore, sensitivity can be understood as the minimum value of the undetectable gross errors by hypothesis testing. The location of the station in the network and the total weight of observations contribute to the sensitivity levels thereof. The total observation number of a radio source and the quality of the observations are also critical for the sensitivity levels of the radio sources. Besides these criteria, a radio source having a larger structure index has a larger sensitivity level.

In this study, it is investigated whether the sensitivity levels of VLBI stations in the CONT14 campaign improve by combination with GNSS. The combination was performed on the normal equation level using 153 GNSS stations in total, 17 VLBI radio telescopes, and local ties at five co-located stations which are ONSA-ONSALA60, NYA1-NYALES20, ZECK-ZELENCHK, MATE-MATERA, and HOB2-HOBART26 during the CONT14 campaign spanning 15 days. To evaluate the observations of GNSS and VLBI, the software of EPOS8 and VieVS@GFZ (G2018.7, GFZ, Potsdam, Germany) were used respectively. In the VLBI-only solution, FORTLEZA shows the poorest sensitivity level compared to the other VLBI radio telescopes (Figure 4). As a result of the GNSS combination, it can be seen that the sensitivity levels of FORTLEZA improved by about 60% in all sessions of CONT14. It can be concluded that VLBI stations, which are poorly controlled by the other radio telescopes in the network, can be supported by the other space-geodetic techniques to improve the overall quality of the solution [9].

3.4 Estimating Station Velocities of the European IGS and VLBI Sites

We formed two networks (Network #1, Network #2) over European continent covering IGS (International GNSS Service) stations to review the effect of the increase in the number of stations on the velocity estimation in the analysis. Network #1 contains 12 stations, while Network #2 contains 41 stations. The common GNSS stations in Network #1 and Network #2 are: CRAO (Ukraine), MADR (Spain), MATE (Italy), MEDI (Italy), METS (Finland), NOT1 (Italy), ONS1 (Sweden), SVTL (Russian Federation), TIT2 (Germany), WTZR (Germany), YEBE (Spain), and ZECK (Russian Federation). The velocities of these stations were compared according to the density in the network.

The observations performed for three years at IGS stations and during the GNSS campaign measurements of 2017, 2018, and 2019 were used as input data. Coordinates of the geodetic points were calculated in the ITRF2014 reference frame using the Bernese 5.2

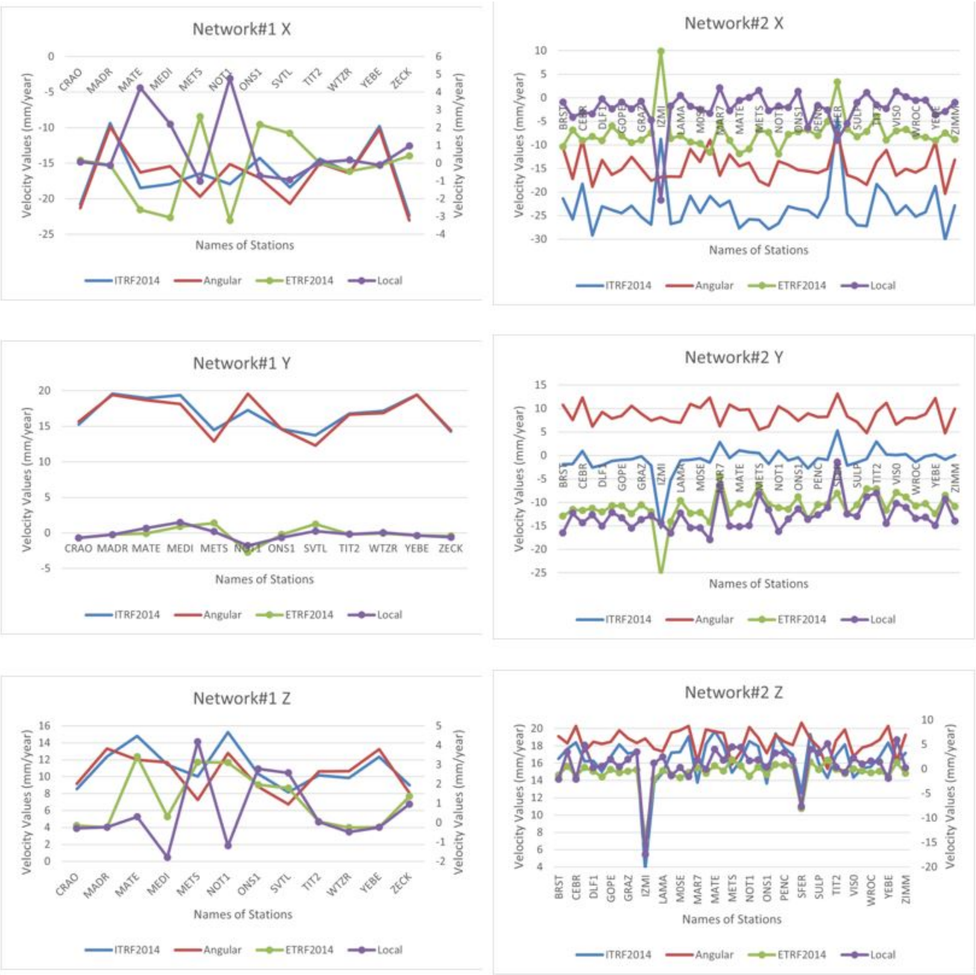

Fig. 5 ITRF2014 velocities, ETRF2014 velocities, local velocities, and the calculated angular velocities at IGS stations for Network #1 and Network #2.

GNSS Software. ITRF2014 velocity values obtained from Bernese 5.2 GNSS Software analyses were converted to ETRF2014 velocity values. ETRF velocities are obtained as a result of analyses made from stations across Europe, minus the crustal movements. Then, the calculation of the velocities, called angular velocity and local velocity (velocities on the surface of the earth), was performed. These velocities were compared with velocities obtained from the Bernese 5.2 GNSS Software and with the velocities obtained by coding (Figure 5).

Calculated angular velocities are expected to be compatible with ITRF2014 velocities, and calculated local velocities will be compatible with the ETRF2014 velocities. Although we achieved an agreement in the other stations at the level of ±1 mm, it was not seen at the IZMI IGS station in Network #2. We can interpret this situation as ITRF2014 velocities are found higher due to the discrete and incomplete data of the IZMI IGS station [10].

3.5 The Principle Diurnal and Semidiurnal Tides of the Ocean Loading Displacements from VLBI

In this study, the amplitudes and Greenwich phase-lags of the principal semidiurnal tides and the diurnal tides of the ocean tide loading displacements were estimated at the worldwide distributed 37 VLBI stations. The analysis of the daily IVS sessions, covering 36 years of geodetic VLBI observations from 1984 to 2020, was done using Vienna VLBI and Satellite Software (VieVS, [11]). Long-term variations are detected in the semidiurnal and diurnal tidal coefficients, i.e., the amplitudes and the Greenwich phase-lags from the sequential solutions of the Kalman filter [12].

4 Future Plans

In 2023 and 2024, our group will be working on (1) estimating the velocities using the VLBI observables of the Network #1 stations co-located with GNSS stations, and comparing the results with those derived from GNSS, (2) quality assessment of the VLBI stations, (3) estimating the in-phase and quadrature components of the phasor vectors of the semidiurnal and the diurnal prograde polar motion caused by the ocean tides and the libration as well as the semidiurnal retrograde polar motion using a Kalman Filter (KF). In this KF estimation, the state vector will be updated for each IVS daily session. The CIP coordinates in TRF at, e.g., 30 minutes intervals derived from the analysis of the IVS daily sessions will be considered as the measurements along with their fully occupied covariance matrices. To suppress the retrograde polar motion at tidal diurnal frequencies to zero, a new type of constraint will be imposed, i.e., different to those introduced in, e.g., [13] and [14].

Acknowledgements

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