Agenzia Spaziale Italiana

BOOK OF ABSTRACTS

European VLBI Group for Geodesy and Astrometry (EVGA)

Palazzo Viceconte, Matera (6-11 April 2025)

1.1 Session 1.1

Technology

Abstract 15

SANTA MARIA RAEGE STATION OVERVIEW AND DEVELOPMENTS

Oral

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The Atlantic Network of Geodynamic and Space Stations (RAEGE) is a collaborative Spanish-Portuguese initiative aimed at constructing, installing, and operating four fundamental geodetic stations: two in Spain (Yebes and Gran Canaria) and two in the Azores (Santa Maria and Flores). These facilities contribute to the advancement of geodetic research and the enhancement of geophysical and astronomical observation networks.

The Santa Maria RAEGE station on Santa Maria Island in the Azores plays a pivotal role in this network. Fully integrated into the VGOS network since October 2023, the station routinely participates in VGOS observing sessions. Operational since May 2021, the station has a 13.2m VGOS radio telescope, “Colombo”, equipped with a broadband receiver developed at Yebes laboratories. In addition, the station hosts two permanent GNSS receivers and a gravimetry room housing an iGRAV-051 superconductive gravimeter, a seismograph (Centaur-3/Trillium 120PA), and a SILEX accelerometer. Local ties for geodetic calibration were built in November 2024.

The RAEGE project also aims to emphasize capacity building and data analysis, fostering collaboration between IGN, the Yebes and Santa Maria observatories, and the University of Alicante. A dedicated data analysis group was established in 2021 to enhance the quality and utility of geodetic products derived from the network’s observations.

In addition to supporting geodetic and geophysical research, the Santa Maria station actively contributes to academic initiatives. Current projects include a master’s thesis focused on designing a tunable downconverter and a doctoral thesis exploring advanced radio astronomy techniques. The focus of the master student is to design a tunable downconverter capable of observing any frequency between 4 and 14 GHz with several bandwidths, while performing the necessary adjustments via software, thus enhancing the hardware setup for radio astronomy observations. The doctoral research investigates in detail the capabilities of the radio telescope of the RAEGE Santa Maria station, with the

goal of implementing a monitoring campaign of nearby active galactic nuclei (AGN).

This presentation will provide an updated overview of the Santa Maria RAEGE station, highlighting its infrastructure, technical upgrades, operational activities, scientific contributions to geodesy, and involvement in academic and collaborative projects under the RAEGE framework.

Technology

Abstract 24

THE HARTEBEESTHOEK TERRESTRIAL LASER SCANNING PROJECT -- CONCEPT AND FIRST RESULTS

Oral

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In May 2024, gravitational deformation measurements were performed at the 26 m and 15 m radio telescopes of the South African Radio Astronomy Observatory at Hartebeesthoek (HARTRAO and HART15M) in cooperation of SARAO, TU M¨unchen and TU Wien. The method of choice was to use a terrestrial laser scanner (TLS) mounted underneath the sub-reflector with a two-axis gimbal hinge to keep the scanner in a vertical position at all telescope tilts. For a full gravitational VLBI delay model, the 26 m HARTRAO telescope with polar mount was pointed at about 80 different Hour Angle/Declination positions for the TLS to perform its scans of the main reflector and the sub-reflector. Here, we present the necessary steps of preparation, the measurements themselves, and first results.

Observations

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VLBI ACTIVITIES AT MATERA SPACE GEODESY CENTER

Oral

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Matera VLBI station is located at the Italian Space Agency's 'Centro di Geodesia Spaziale G. Colombo' (CGS) near Matera, in Italy. The CGS came into operation in 1983 when the Satellite Laser Ranging SAO-1 System was installed at CGS.
In May 1990, the CGS extended its capabilities to Very Long Baseline Interferometry (VLBI), installing a 20m dish radio telescope. Input frequencies are in S Band (2210−2450 MHz) and in X Band (8180−8980 MHz). The Data Acquisition Terminal is a standard Mark V system.
In 2021 implementation of a new VLBI system started. The Matera VLBI Global Observing System (MATVGOS) system, that is compliant with the new standards recommended by the International VLBI Service for Geodesy and Astrometry (IVS), is under the acceptance phase by the Italian Space Agency and should become fully operational in the second half of the current year.
The aim of this article is to describe the operational activities carried out by the Matera Center through the system based on the 20-meter antenna and the main characteristics of the MATVGOS system currently being completed.

1.2 Session 1.2

Technology

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BROADBAND RECEIVER DEVELOPMENTS FOR VGOS RADIOTELESCOPES AT YEBES OBSERVATORY

Oral

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The Yebes Observatory, a department of the Spanish National Geographic Institute (IGN-Spain), has a distinguished history spanning over 35 years in the development of advanced radio astronomy receivers, including those tailored for Very Long Baseline Interferometry (VLBI). Since 2015, Yebes is a Technological Development Center within the International VLBI Service for Geodesy and Astrometry (IVS).

This presentation highlights recent advancements in receiver technology achieved at the Yebes Observatory, emphasizing the design and construction of three cutting-edge broad-band receivers for the VLBI Global Observing System (VGOS) operating across the 2-14 GHz frequency range. Among these receivers, one has been specifically developed for the Matera VGOS station in Italy, equipping it to join the VGOS core network shortly. The presentation will cover the key stages of design, development, integration, and testing, following the whole signal chain from the front-end to the backend.

Technology

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THE POTENTIAL OF SYSTEM MONITORING

Oral

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Monitoring of health states and workflows becomes increasingly important when we consider the complex, combined systems of a telescope and even telescope networks. Fast error detection and identification leads to better quality of observations. Therefore, system monitoring is essential to monitor VLBI telescopes, complete observatories, and whole networks. The talk presents the new developments made at Wettzell observatory using ZABBIX 7.0.

Observations

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CONNECTING GEODETIC VLBI TELESCOPE GENERATIONS AT THE NY-ÅLESUND GEODETIC EARTH OBSERVATORY THROUGH SHORT-BASELINE INTERFEROMETRY – FINAL RESULTS

Oral

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The transition of geodetic Very Long Baseline Interferometry (VLBI) from legacy S/X telescopes to the modern VLBI Global Observing System (VGOS) necessitates careful integration of the new network with existing infrastructure. This presentation will showcase the final results of the NYTIE campaign, conducted at the Ny-Ålesund Geodetic Earth Observatory, where the decommissioning of the legacy S/X telescope NYALES20 was preceded by an extensive short-baseline interferometry campaign to the new VGOS telescopes NYALE13S and NYALE13N.

Comparing VLBI results with surveying campaign using total station and GNSS, we find very good agreement in the horizontal components, at the 2-mm level, and slightly less good agreement in the vertical component (up to 8 mm).

We find that dedicated measurements, such as NYTIE, give significantly improved results compared to the use of regular IVS-R1 and IVS-R4 sessions for obtaining local-tie information. We assess advantages and limitations for group- and phase-delay results, and we note a significant offset (up to 11 and 23 mm for NYALE13S and NYALE13N, resp.) between the two, also found in the ONTIE project.

Lastly, we present our lessons learned from this project with the aim of encouraging other observatories that also host telescopes of both generations to undertake VLBI local-tie measurements.

1.3 Session 1.3

Technology

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RADIO FREQUENCY COMPATIBILITY OF VGOS AND DORIS STATIONS

Oral

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In the framework of the Global Geodetic Observing System (GGOS), the co-location of space and satellite geodetic techniques is strongly promoted to achieve GGOS goal of a network of stations with 1 mm in accuracy and 0.1 mm/yr in stability. The last realization of ITRF2020 has only a number of 10 local ties between VLBI and DORIS stations, so there is a high demand for increasing number of VLBI and DORIS co-located stations.
The installation of a DORIS beacon at a VGOS site seems difficult without affecting radio astronomical measurements, in fact the VLBI systems are designed to receive extremely faint cosmic signals down to -110 dBm, whereas the DORIS beacon emits signals at a frequency of at 401.25 MHz and 2,036 MHz with 40 dBm output power. While the lower frequency is outside the frequency range of a VGOS system (2GHz-14GHz), the higher frequency is in the lower S-band. It is therefore highly recommended to evaluate each radio telescope site before installing a DORIS system in its vicinity.
We present compatibility studies carried out with Pycraf (open source software) to investigate on different types of exclusion zones for some individual European VGOS observatories taking into account also the path propagation loss, the effective antenna gains and available free digital terrain models. Identification of sites for possible installation of new DORIS stations in the vicinity of VGOS radio telescopes are also considered.

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A REPORT ON NEW VGOS FREQUENCY SEQUENCES TEST OBSERVATIONS

Oral

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The IVS VGOS Technical Committee (IVS VTC) discussed several times on how to maximize the benefits of VGOS for geodesy and astrometry. Unused potential for improvement was identified in (a) increasing the synthesized bandwidth per VGOS observing band from 480 MHz to 1024 MHz, and (b) distributing the four VGOS frequency bands between 3 and 14 GHz instead of only up to 10.6 GHz as is currently the case. In order to demonstrate the feasibility and possible benefits by using that potential, a series of fringe tests and test sessions were carried out in late 2024, and further tests are planned for early 2025. The results of these tests are expected to provide important input to the efforts of the IVS to anchor the observed frequency channels in the ITU Radio Regulations, so that in the future more consideration could be given to VGOS radio telescopes with regard to unwanted radio radiation. To this end, the optimum VGOS frequency configurations are being sought, as they are to be used in the long term. On behalf of the group members, who carried out these tests, we will report on the performance of these sessions and present preliminary results and recommendations for suitable frequency setups, if possible.

Observations

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STATUS OF THE SPECTRUM MANAGEMENT FOR VGOS

Oral

Hase H.*

BKG ~ Wettzell ~ Germany

Spectrum Management for VGOS is crucial to avoid decreasing data quality and quantity. The expansion of telecommunication networks increases the number of transmitters on ground and in space dramatically over the next years. In order to be recognized as an essential service for society, geodetic VLBI needs protection as a passive technique realized in a global network of VGOS radio telescopes. It is important to achieve an Agenda Item on Geodetic VLBI at the World Radio Conference 2030. Activities to achieve that started 5 years ago, but there is still a longer way to go. We will show what has been achieved so far and what the upcoming activities in spectrum management will be.

1.4 Session 1.4

Technology

Abstract 60

RECENT STATUS OF THE SHANGHAI CORRELATOR

Oral

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The Shanghai VLBI Correlator is hosted and operated by the Shanghai Astronomical Observatory (SHAO), Chinese Academy of Sciences (CAS). It is one of the correlator in IVS, dedicating to astronomical and geodetic data correlation. Our data products are mainly generated from those legacy S/X and VGOS sessions coordinated by the IVS, CVN observations, as well as EAVN K-band geodetic sessions. I will summarize the recent status of the Shanghai VLBI Correlator, including technical aspects of the DiFX cluster and its performance, team members and activities. Highlights include VGOS correlations, mixed-mode correlations and the fringe tests for CHIANGMAI 13-m radio telescope.

Observations

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THE RAEGE CORRELATOR AT YEBES OBSERVATORY: DESCRIPTION AND STATUS

Oral

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In this report, we describe the RAEGE correlator placed at Yebes Observatory. The RAEGE network envisaged four stations across the Iberian peninsula, the Canary Islands and the Azores in Portugal. RAEGYEB and RAEGSMAR, the first two stations of the RAEGE project, are already contributing to VGOS observations. The third station in the network, located in the Canary Islands, is about to become a reality. Installed at the Yebes Observatory, the software correlator will allow the observations of the network to be processed, as well as to serve as another contribution to the IVS. An Intensive campaign between the two operational antennas together with other stations has been established. Since 2021, we have been operating a small cluster to train staff in the correlation process using DiFX and post-processing tools for geodetic applications such as HOPS, nuSOLVE, CALC/SOLVE, etc. During this period we processed about 100 experiments from various projects, including EU-VGOS and intensive sessions, most of them involving three stations. This allowed us to dimension the new HPC so that we could estimate an observation time per correlation time factor of less than 1.

Technology

Abstract 52

TOWARDS VLBI WITH ESA'S GENESIS SATELLITE

Oral

Haas R.*

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The European Space Agency (ESA) plans to launch in 2028 the Genesis satellite. This mission is meant to contribute to the improvement of the International Terrestrial Reference Frame (ITRF) by combining the four space geodetic techniques Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS), Satellite Laser Ranging (SLR) and Doppler Orbitography and Radio Positioning Integrated by Satellite (DORIS) on one single spacecraft orbiting Earth. ESA has set up a Genesis Science Exploitation Team (GSET) to work on the goals of the mission. GSET involves four technique-specific working groups (WGs), one each for VLBI, GNSS, SLR and DORIS, as well as one working group for the ITRF and combinations. The technique-specific WGs have the task to advise and support ESA for all aspects of the Genesis mission. They also should assist in calibration, processing and validation of Genesis data, and exchange information with the international community. Currently, WG-3 (VLBI) focusses mainly on the VLBI transmitter that is planned for Genesis. Important aspect are the compatibility with the normal operations of the International VLBI Service for Geodesy and Astrometry (IVS) and the IVS product generation. Other important aspects such as optimal scheduling, end-to-end simulations, and eventually test observations of Genesis, will be addressed at a later stage. This presentation is on behalf of ESA GSET WG-3 (VLBI) and gives an overview on the current status of the work performed in the working group.

1.5 Session 1.5

Observations

Abstract 50

VLBI OBSERVATIONS TO GNSS SATELLITES USING THE AUSTRALIAN VGOS ARRAY

Oral

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One of the major deficiencies in the realization of the ITRF stems from the combination of the four space geodetic techniques that are contributing: VLBI, GNSS, SLR, and DORIS. Set for launch in 2028, geodesy's flagship mission GENESIS aims to improve the accuracy and stability of future realizations of the ITRF. However, VLBI observations to satellites are not standard and are not performed routinely yet. In the past, observations were limited to specific telescopes and setups. At the moment, most geodetic VLBI antennas of the IVS are not capable of observing currently available satellite signals. This makes testing difficult, although developments of such observations are urgently needed. In this work, we present the newly accessible L-band capability of the Australian VGOS telescopes. A series of test observations demonstrates geodetic VLBI observations to GNSS satellites with a continental-wide telescope array on a routine basis in the style of the IVS. We successfully conducted observations to satellites of the GPS, Galileo and BeiDou constellations in the frequency range from 1.2-1.6 GHz using the standard VGOS equipment. Observations of GNSS signals at L-band with the 12-m antennas Hb (Hobart), Ke (Katherine) and Yg (Yarragadee) are a valuable opportunity for testing and preparing the VLBI component of the GENESIS mission. In addition, such observations could realize the first-ever inter-technique ties between VLBI and GNSS in the Australian region. We describe the experimental setup, signal chain and key developments enabling these observations. The results include total delay measurements in L1, L2 and L5 band, reduced observations and ionospheric delay estimates from VLBI data, validated against observations of the co-located GNSS antennas.

Observations

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OBSERVATION OF CHANG'E 5 ORBITER WITH SHANGHAI AND URUMQI VGOS ANTENNAS

Oral

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In China, VGOS observatories have been constructed to carry out radio source observation and data processing on a regular basis. Nevertheless, they have not yet to be utilized for observation of artificial satellites or deep-space probes. This work presents the first tracking observation experiment conducted with the VGOS antennas to monitor the Chang'e 5 orbiter. We explored the data processing methodology of the VGOS observation satellite and provides an initial assessment of the fringe-fitting and data analysis. The VGOS satellite observation fringes have been obtained. The P/N0 of satellite signal has been subjected to analysis, the results of which demonstrated that the measured and theoretical values remained consistent. The data analysis has yielded the absolute value of the delay residuals less than 10 ns, with the median delay error of less than 0.30 ns at 30 s integration. The developed data processing chain can serve as the foundation for future VGOS observation Earth-orbiting satellite experiments, hopefully engaging in space co-location satellite mission, to construction of the Terrestrial Reference Frame (TRF).

Observations

Abstract 58

INVALUABLE LUNAR-BASED INTERFEROMETRY ENABLED BY ESA'S NOVAMOON MISSION

Oral

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Moon exploration has emerged as a global strategic priority in space exploration, with highly ambitious governmental and commercial missions over the coming decades. ESA is actively taking part in this new era of lunar activities through its involvement in major lunar programmes and has planned several missions to the Moon in the next decade. Among them, ESA is developing Argonaut, an innovative lander designed to provide Europe with autonomous access to the Moon's surface to support human exploration and foster lunar science. The first Argonaut mission (called ArgoNET) is scheduled for launch in 2031. ArgoNET will have a navigation payload called NovaMoon, a lunar differential positioning and selenodetic station including a VLBI transmitter co-located with a Lunar Laser Ranging (LLR) retroreflector, a Moonlight LCNS receiver and a TT&C transponder with direct-to-Earth ranging capabilities.

This co-location is key to improve the accuracy of lunar reference frames, because, for the first time, it enables a multi-technique approach to their realization with clear advantages in terms of bias estimation and complementarity of observational principles. In addition, the availability of a VLBI transmitter on the lunar surface is expected to strengthen the links between the lunar, terrestrial and celestial frames, to improve the characterization of Moon tidal deformations and Moon interior, and to contribute to enhancing the accuracy of lunar Digital Elevation Models (DEMs).

This presentation provides an overview of NovaMoon, highlighting the key role of the VLBI transmitter and of the receiving ground stations on Earth to ensure the achievement of the mission objectives. Furthermore, it will elaborate on the realization of the anticipated synergies between NovaMoon and the other ESA lunar missions and programmes as well as its scientific benefits.

This presentation seeks to actively involve researchers and experts in the early phases of preparation, fostering collaboration and collective input to ensure a successful development and exploitation of the VLBI payload and maximizing the scientific return.

1.6 Session 1.6

Observations

Abstract 22

FLUX MONITORING AT VGOS FREQUENCIES WITH THE ONSALA TWIN TELESCOPES

Oral

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The VLBI Global Observing System (VGOS) for geodesy and astrometry has been in operation for several years. However, many of the sources of the International Celestial Reference Frame (ICRF3) still have poorly known radio flux densities in the currently observed VGOS frequency bands. To improve the efficiency of observation scheduling, an accurate flux density catalog is urgently needed. We present the results of flux monitoring experiments performed with the Onsala Twin Telescopes (OTT) on a rather regular basis since June 2021. The telescopes have a diameter of 13.2 m and are located at Onsala, Sweden, forming an interferometer with a baseline of 75 m distance. We present time series of flux density in the standard VGOS bands that are used so-far for the VGOS Operational (VO) sessions, i.e. 3.0–3.5 GHz, 5.2–5.7 GHz, 6.3–6.8 GHz and 10.2–10.7 GHz, for over 140 sources, most of which are defining sources of the ICRF3. The first set of flux monitoring experiments, conducted between June and December 2021, were a pilot study focusing on seven radio sources from the standard VGOS catalog and three calibrators (3C147, 3C286 and 3C295). Each source was observed for one minute. Later experiments extended the source list to all ICRF3 defining sources, of which approximately 200 are visible from Onsala. Each source was observed in three one-minute scans distributed over an experiment duration of 20-26 hours. The scan length proved too short for the weaker sources, and was therefore increased to two minutes for the affected sources starting from November 2024. The data was correlated using the software correlator DiFX. In addition to these dedicated flux monitoring experiments with the OTT, we also analysed OTT data from several VO sessions. These VO observations have been calibrated by adding calibrator scans with the OTT to the end of the VO-schedules. All data were analyzed using Common Astronomy Software Applications (CASA). Due to local radio frequency interference at Onsala, few radio sources have reliable flux density values in the lowest VO-band (3.0–3.5 GHz). Also VO-band-2 (5.2–5.7 GHz) is somewhat affected by disturbing interference. Most sources are found to be variable over time. We estimate an uncertainty of 5 % for our flux density results. In the future, we plan to extend the method to include other stations, allowing to obtain flux densities for longer baselines as well.

Analysis

Abstract 9

EFFECTIVE FREQUENCIES AND IONOSPHERE CALIBRATION OF LEGACY S/X DATA

Oral

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Over the past, the computation of ionosphere calibrations for legacy S/X band observations and especially the derivation of effective frequencies has undergone various changes. The reason is that the bandwidths of individual channels/sub-bands have increased as storage and transmission capacity improved. Furthermore, the handling of corrupt channels was refined. While trying to reproduce the ionosphere calibration entries in vgosDB files, we discovered that during the transition from Mark3 databases to vgosDB files some sessions were handled inconsistently. In this presentation, IVS Analysis Centers are being made aware of the developments over time and the inconsistencies in vgosDB files. Fortunately, incorrect ionosphere calibrations in most cases behave indulgent as triangle closures are maintained. This leads to an absorption of the inconsistencies in relative clock offsets. In any case, a recommendation is given to re-compute effective frequencies and ionosphere calibrations always with up to date formulations and not to rely on vgosDB entries alone.

Analysis

Abstract 2

SYSTEMATIC ERRORS IN VGOS DIFFERENTIAL IONOSPHERIC TOTAL ELECTRON CONTENT

Oral

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The ionosphere introduces an additional delay in radio signal propagation, which in VLBI is characterized by the differential total electron content (dTEC) for each baseline. To correct the ionospheric effect on the delay, dTEC is estimated during the fringe-fitting of VGOS data. Comparing VGOS dTEC with dTEC extracted from Global Ionospheric Maps (GIMs) reveals a systematic offset in VGOS dTEC. We investigated the cause of this systematic error and found that manual corrections of the residual phases during fringe fitting affect the dTEC offset. Here, we present our latest results on this issue.

1.7 Session 1.7

Observations

Abstract 40

ENHANCING GEODETIC PRECISION IN THE EAST ASIAN VLBI NETWORK WITH K-BAND OBSERVATIONS

Oral

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Achieving microarcsecond-level astrometry with a Very Long Baseline Interferometry (VLBI) array requires station coordinates with millimeter-level accuracy. However, most Japanese and Korean radio telescopes within the East Asian VLBI Network (EAVN) have yet to achieve this precision. This limitation stems from their limited participation in global geodetic VLBI observations, primarily due to the absence or suboptimal performance of S/X band (2.3/8.4 GHz) receivers.

To overcome this challenge, we initiated regular geodetic observations at K-band (22 GHz) to directly measure the positions of non-geodetic EAVN stations relative to highly accurate reference stations. By combining approximately 10 EAVN geodetic observations conducted between 2019 and 2024 with thousands of archival geodetic sessions, we successfully determined the coordinates of core EAVN stations with millimeter-level precision.

This advancement enables the EAVN to meet the requirements for microarcsecond-level astrometry, positioning it to operate independently or in collaboration with the global VLBI community.

In this presentation, we will highlight the data sets, analysis results, and plans to extend these efforts across multiple frequencies.

Analysis

Abstract 68

EVIDENCE FOR THE NEED TO USE CORRECTIONS FOR PLANETARY NUTATIONS IN THE MODELLING OF CELESTIAL POLE OFFSETS

Oral

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The need to improve Earth rotation theories and models in a consistent and accurate way is now widely recognised and has been urged by recent IAG and IAU resolutions. Several researchers and groups at different institutions have been working on this problem using quite different approaches, either from a theoretical or a computational perspective. One possible source of the loss of accuracy of the celestial pole offsets can be due to the mismodeling of the planetary component of the IAU2000 nutation series. Indeed, this component is actually part of a rigid-Earth solution, namely SK1997, and does not include the Oppolzer terms, which are significantly affected by the Earth's non-rigidity. Therefore, the amplitudes of the planetary terms cannot be re-tuned at all by recalculating the basic Earth parameters used in the MHB2000 theory, as has been done in some recent research with the amplitudes of the lunisolar terms.

Two options remain: perform a direct empirical fit of a certain set of leading terms or improve the theory to include realistic non-rigidity effects. After our revisit of the theory in Ferrándiz et al. (2018), the first path seemed more convenient for a first test with observational data, despite the high number of terms of planetary origin with very close periods and small amplitudes in the rigid-earth approach, considering the lack of an alternative theoretical solution useful to verify our initial analytical solution. The hypothesis of the influence of planetary terms on the unexplained CPO variance was shown to be realistic by directly fitting the amplitudes of a small number of nutation periods of strictly planetary origin that could be reasonably well separated by analysing the series of VLBI observations. The results provided significant fits, and the WRMS was successfully reduced by amounts comparable to those achieved with the lunisolar amplitude rescaling. This proved that it was worth taking a further step, i.e. continuing the theoretical developments to derive analytical expressions for the amplitudes of the non-rigid Earth planetary nutations.

In this presentation we show preliminary results considering the analytical formulae for such planetary amplitudes for a two-layer Earth model, including dissipation effects at the core-mantle boundary and anelasticity, obtained from a Hamiltonian method. Their performance is evaluated using several series of VLBI observations, with satisfactory results, and is placed in the general context of the improvement of the precession and nutation models sought by the JWG on Consistent Improvement of the Earth Rotation Theory.

Analysis

Abstract 38

SEARCHING FOR EVIDENCE OF FREE INNER CORE NUTATION IN VLBI DATA

Oral

Belda S.*[3], Karbon M.[3], Azcue E.[1], Escapa A.[2], Del Nido Herranz L.D.[3], Pérez Esteban C.[1], Ferrándiz J.M.[3]

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Free Core Nutation (FCN) and Free Inner Core Nutation (FICN) are distinct but related rotational phenomena of the Earth, governed by the interaction between its fluid outer core and solid inner core. These nutational modes reflect the complex internal dynamics of Earth's structure, offering critical insights into the coupling mechanisms within the Earth's core. Several attempts to discover the FICN signal through Very Long Baseline Interferometry (VLBI) nutation series failed during last years. One of the possible reasons behind this is that the IAU 2000A nutation model of Mathews et al. (2002) is not perfect. Therefore, one expects the VLBI-estimated offset of IAU 2000A to contain a non-negligible signal arising from unmodeled or mismodeled tidal terms (e.g., at 18.6-year or semi-annual periods) or other geophysical contributions including the atmosphere.

This study focuses on the development of an advanced nutation model to estimate rigorous FCN models for making progress in the search for FICN using high-precision VLBI data. This research also examines different nutation offsets released by various IVS operational centers, allowing for a detailed analysis of the nutational signals. By analyzing several decades of VLBI observations, we identify and isolate the FCN to investigate the FICN modes. This research will enhance our understanding of the Earth's internal structure and highlights the critical role of VLBI in improving nutation modeling for geophysical and planetary studies.

2.1 Session 2.1

Analysis

Abstract 57

VLBI-SCALE OF THE ITRF2020-U2023

Oral

Le Bail K.*[1], Ishigaki M.[2], Nilsson T.[3], Haas R.[1]

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Zuheir Altamimi officially introduced the ITRF2020-u2023 at the AGU24 conference in Washington DC on Monday 9 December 2024. This marks the first update of the ITRF2020, showcasing a novel approach to annual updates of the International Terrestrial Reference Frames (ITRF) without requiring global reprocessing from the four space-geodetic Technique Centers.

The update integrates the original ITRF2020 combined solution, which includes data up to December 2020, with an additional three years of observations (January 2021 to December 2023) for the inter-technique combination. For VLBI specifically, the IVS Combination Center supplied the ITRS Center with three years of new data, derived from the combined contributions of 12 IVS Analysis Centers using seven different analysis packages. This involved the analysis of nearly 700 sessions. Notably, these three years of data were independently analyzed by the respective Analysis Centers.

Regarding the VLBI scale in the IVS contribution to ITRF2020-u2023, the scale drift exhibits distinct behavior over different periods. The drift from 2013.75 to 2021.00 differs significantly from the drift observed between 2021.00 and 2024.00. While modeling the uplift of NYALES20 and accounting for station events improved the positive drift during the earlier period, it had no effect on the drift observed over the past three years. To understand these differences, the IVS Combination Center's contribution to ITRF2020-u2023 is carefully compared with the initial ITRF2020 contribution. Additionally, the OSO Analysis Center contribution is examined under various analytical configurations. The primary objective of this study is to assess the strengths and limitations of this innovative approach to updating the ITRF.

Analysis

Abstract 8

THE VLBI SCALE DRIFT: CURRENT STATUS AND REMAINING CHALLENGES

Oral

Kern L.*, Krásná H., Nothnagel A., Böhm S., Böhm J.

TU Wien ~ Vienna ~ Austria

Since the release of the International Terrestrial Reference Frame ITRF2020, significant efforts have been made to understand the positive scale drift observed in Very Long Baseline Interferometry (VLBI) solutions after epoch 2013.75 and its abrupt stop after 2021.0. Recent studies have demonstrated that introducing additional discontinuity intervals for the station NYALES20 (Svalbard, Norway), originating from the co-located Global Navigation Satellite Systems (GNSS) stations NYAL and NYA1, reduces this trend. Following these findings, the ITRF2020 update (ITRF2020-u2023) incorporates two additional discontinuity intervals for NYALES20. But can these adjustments fully capture the station's complex motion and reduce the VLBI scale drift?

In this study, we assess the effectiveness of the ITRF2020-u2023 modifications concerning NYALES20's station movement model in mitigating the VLBI scale drift and investigate the abrupt stop of the drift after 2021.0. Furthermore, we analyze the influence of non-tidal loading models on the time series of VLBI scale factors. Our findings provide insight into the current status of the VLBI scale and potential suggestions for further refinements.

Analysis

Abstract 19

DTRF2020_U2023: THE UPDATE OF DTRF2020

Oral

Seitz M.*, Bloßfeld M., Rudenko S., Zeitlhöfler J., Angermann D.

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To update the ITRS 2020 realizations based on observations from the geodetic space techniques VLBI, SLR, GNSS and DORIS until the end of 2020, the Technique Centers (TCs) have provided extension series for the three years 2021-2023 that are as consistent as possible with the previous input data series. Thus, in addition to the new series adopting the ITRF2020 scale, the IGS provided a second series consistent to the repro3 series which provides an independent GNSS scale based on Galileo satellite z-PCO calibrations. Since the DTRF2020 scale is realized based on VLBI and GNSS observations, a consistent extension of the IGS series is extremely important to consistently update DTRF2020.

In addition, the GGFC has provided extensions to the previous non-tidal load (NTL) station displacement time series as well as time series for new stations to be used in the DTRF2020 update to reduce non-linear station movements.

We update the DTRF2020 using the provided extension time series and NTL input data until 2023. We analyzed the extended time series of station position, datum parameters (origin and scale), and earth orientation parameters, introduced additional discontinuities, and accounted for postseismic deformation of stations affected by earthquakes.

We present the DTRF2020 update solution (i.e., DTRF2020-u2023) and discuss the consistency of the first and extension series with special attention to VLBI. In addition, we discuss the results of comparisons of the updates computed by the three ITRS combination centers, reflecting the internal accuracy achieved by today's ITRS realizations.

2.2 Session 2.2

Analysis

Abstract 23

THE JPL 2025A TERRESTRIAL AND CELESTIAL REFERENCE FRAMES

Oral

Jacobs C.*

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The JPL 2025a Terrestrial and Celestial Reference frames are based upon
20 years of X/Ka-band VLBI data from NASA's Deep Space Network, 11 years from ESA"s Deep Space Network and 5 years of JAXA's Deep Space network.
This paper will discuss the unique challenge of construction global reference frames with only single-baseline data. In particular, we will look at the challenges of tying to the ITRF-2020 using station that have little overlap with other VLBI networks. We will present evidence for the accuracy of these frames and the prospects for improving them going forward.

Analysis

Abstract 45

EVALUATION OF TERRESTRIAL AND CELESTIAL REFERENCE FRAMES ESTIMATED FROM VGOS DATA

Oral

Nilsson T.*[1], Haas R.[2], Le Bail K.[2]

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The next generation VLBI system for Geodesy and Astrometry, VGOS, has been observing regularly since the beginning of 2019. VGOS 24 h sessions have been performed on bi-weekly or weekly basis with a network of VGOS stations that increased in number from 7 to 14 during these years. Thus, there are now six years of data available from VGOS, which should be enough to estimate relatively stable and reliable reference frames. In this work we perform a global solution with the ASCOT software, using all available data from the 24 h VGOS sessions. The intention is to estimate a VGOS Terrestrial Reference Frame (TRF) and a VGOS Celestial Reference frame (CRF). These frames are then compared to the ITRF2020 and the ICRF3, respectively. We also compare to our own TRF and CRF solutions estimated with ASCOT using more than 40 years of legacy S/X VLBI data. The results provide information on the strengths and weaknesses of VGOS when estimating reference frames, as well as on how much the radio source positions differ between the VGOS and S/X frequencies.

Analysis

Abstract 11

VGOS CRF: CELESTIAL REFERENCE FRAME FROM THE VLBI GLOBAL OBSERVING SYSTEM UNTIL 2024

Oral

Krásná H.*[1], Jacobs C.[2], Schartner M.[3], Charlot P.[4]

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We present a celestial reference frame (CRF) from Very Long Baseline Interferometry (VLBI) Global Observing System (VGOS) including data until December 2023. The VGOS CRF is built with 1.39 million group delays observed in 155 multi-baseline 24-hour sessions with a fixed frequency distribution. It includes 418 radio sources, where 172 sources (41%) are introduced in only four research and development (VR) sessions alone (VR2302 introduced 88 new sources, VR2201 34, and VR2206 with VR2304 added 25 each). There are 37 most observed sources that were observed more than 10,000 times in the analyzed VGOS dataset.

In the global adjustment, the no-net-rotation condition was imposed with respect to 71 ICRF3 defining sources with more than 1,000 observations in the current VGOS CRF. In addition—because of the lack of observations in the southern hemisphere—a constraint for a zero slope in declination difference with respect to ICRF3-SX was applied. The presented VGOS CRF has excellent source position precision: the median formal error from the least-squares adjustment is 30 μas for right ascension and 47 μas for declination.

We evaluate the VGOS CRF by fixing the celestial reference frame in the geodetic analysis of the VGOS single sessions and examine the time series of estimated station positions, baseline lengths and Earth orientation parameters. When fixing the VGOS CRF instead of ICRF3-SX, an improvement in baseline length repeatability larger than 1 mm is achieved on the majority of baselines longer than 8,000 km. Furthermore, the EOP study reveals a lower wrms of all five EOP with respect to IERS 20C04 of about 10–15%.

2.3 Session 2.3

Analysis

Abstract 12

A GLOBAL TROPOSPHERE MODEL FOR VLBI SIMULATIONS

Oral

Schartner M.*, Soja B.

ETH Zurich ~ Zurich ~ Switzerland

VLBI simulation studies play an important role in various applications, including optimizing station network designs, exploring innovative concepts, advancing technological developments, and testing observation strategies. Realistic simulations are crucial for informed decision-making and must account for various error sources such as measurement noise, clock drift, and atmospheric effects. Accurate simulation of tropospheric effects, particularly incorporating spatio-temporal correlations, is essential in this context.

Traditionally, tropospheric simulations rely on Kolmogorov turbulence theory combined with the frozen flow assumption. These simulations are parameterized using the refractive index structure constant (Cn), alongside auxiliary parameters like wind velocity and troposphere height. Although Cn values can be derived from GNSS observations, most existing studies assume a generalized average troposphere, independent of specific locations or seasonal variations. Only a few incorporate simplistic, location-based conditions, often through a basic latitude-based interpolation. Furthermore, reliance on GNSS data limits the ability to test potential network extensions where such observations are unavailable.

This work advances tropospheric simulations by developing a global, three-dimensional (latitude, longitude, time) Cn model. The model is based on Zenith Wet Delay (ZWD) estimates from 21,000 GNSS stations (2000-2023) and meteorological data from the ERA5 reanalysis model, including specific humidity across 11 pressure levels (300 to 1000 hPa) and wind velocity. It is also adaptable for short-term prediction scenarios using HRES weather forecasts, making it suitable for operational applications.

The proposed model manages to capture both spatial and temporal patterns adequately, resulting in more realistic simulations. Additionally, it can be used to derive global monthly average estimates on a 0.25° x 0.25° grid, offering a practical and sufficiently accurate solution for most simulation studies. The model's performance is further validated through comparisons with real VLBI observations, demonstrating significant improvements in simulation accuracy.

Analysis

Abstract 17

IMPACT OF ATMOSPHERIC TURBULENCE ON VGOS TELESCOPE LOCATION IN INDIA

Oral

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Very Long Baseline Interferometry (VLBI) is the only space geodetic technique capable of accurately determining the complete set of Earth Orientation Parameters (EOP), including polar motion, UT1−UTC, and celestial pole offsets. Atmospheric turbulence, quantified by the refractive index structure constant (Cn), is a significant source of error in geodetic VLBI, so it is essential to consider this factor when selecting optimal telescope locations.

This study identifies 14 potential VLBI station locations across India, co-located with existing GPS stations and distributed homogeneously, to simulate their suitability for the VLBI Global Observing System (VGOS) telescope. Using zenith wet delay variances derived from GPS data over a 24-hour period, station-specific Cn values are calculated and incorporated into multiple scheduling simulations via VieSched++. These simulations evaluate the precision of EOP estimation in configurations that reflect current and future VGOS networks. The results indicate that the southern stations are optimal for polar motion and celestial pole offsets, while the eastern stations are most effective for UT1−UTC estimation.

Comparisons with utilizing an average Cn value (1.80 × 10^−7 m^−1/3) highlight the critical impact of station-specific Cn values on determining optimal telescope locations, particularly for networks with fewer stations. Stations with a Cn value higher than 2.60 × 10^−7 m^−1/3 impacts the UT1−UTC precision, and the precision of CPO and PM estimation degrades when the Cn value exceeds 3.00 × 10^−7 m^−1/3. Moreover, the study reveals that, despite a station being geometrically well-positioned, a high Cn value can make it unfavorable. This research underscores the importance of integrating station-specific atmospheric turbulence parameters in the planning of VGOS telescope networks to improve EOP precision.

Analysis

Abstract 54

MICROWAVE RADIOMETER OBSERVATIONS FOR VGOS DATA PROCESSING

Oral

Haas R.*, Feng P., Elgered G.

Chalmers University of Technology, Onsala Space Observatory ~ Onsala ~ Sweden

Since mid 2023, the Onsala Space Observatory is operating a new modern microwave radiometer, Greta, which is a commercial product of type HATPRO-G5. It is co-located with the other microwave radiometer, Konrad, which has been developed and built at Onsala. Konrad has been in operation since 2000 and is usually operated in so-called sky-mapping mode. The data of complete sky-scanning sequence are then analyzed together, providing zenith wet delay and wet horizontal gradient results with a temporal resolution of 5 minutes. In addition to operating in a similar sky-mapping mode, the new radiometer Greta has been operated synchronized with VGOS observations during several VGOS 24 h sessions from the year 2023 to 2024. This means that Greta was performing measurements of the local atmosphere in the same direction as the VGOS telescopes at Onsala, thus providing slant wet delay measurements for each individual VGOS observation. Together with the slant hydrostatic delays, calculated from ground pressure measurements, the possibility to avoid estimating the delays due to the neutral atmosphere exists and will be evaluated. We present first results of using these slant delays as external a priori information in the VGOS data analysis.

2.4 Session 2.4

Analysis

Abstract 31

CHARACTERISTICS OF DIFFERENT VLBI SESSION TYPES IN THE VIEW OF EARTH ORIENTATION PARAMETER DETERMINATION

Oral

Kehm A.*, Bachmann S., Klemm L., Modiri S., Thaller D.

Federal Agency for Cartography and Geodesy (BKG) ~ Frankfurt am Main ~ Germany

VLBI is the unique space-geodetic technique sensitive to the full set of Earth Orientation Parameters (EOP), i.e., polar motion offsets and rates, UT1–UTC, the length-of-day (LOD) and the nutation offsets. Classically, the Rapid (R1/R4) sessions, scheduled twice a week, are the main contributor to EOP determination as they are processed with highest priority (leading to comparably low latencies). Additionally, Intensive sessions scheduled daily are processed to determine the UT1–UTC offset at short latencies.
However, also other VLBI session types (mainly 24-hour sessions) are regularly observed and processed, but typically with longer latencies, and those sessions are not regularly combined yet. As most of these sessions also have the potential to deliver good EOP estimates, their inclusion into the combination would lead to a densification of the VLBI contribution to combined EOP series. Very recently, the IERS product centers for EOPs emphasized that such a combined IVS contribution would be very valuable to improve the accuracy and reliability of the Earth rotation products according to the user requirements.
This study aims to define a set of criteria to evaluate VLBI sessions with respect to their suitability for EOP determination. These sessions include, but are not limited to, 24-hour sessions with globally well-distributed networks which were initially scheduled for other purposes like the determination of the Terrestrial Reference Frame (TRF) but are also sensitive to EOPs. Besides the distribution of the stations in a geographical sense, the selection criteria also include investigation of the sensitivity of the observations to the parameters estimated within individual sessions and of correlations between these parameters.
The different characteristics of the various VLBI session types could lead to systematic differences in the EOP estimates. We thus will investigate the resulting EOPs in view of systematics and will set up a procedure to regularly monitor the consistency between the different session types. We outline the combination strategy being developed to enable such a flexible combination of pre-selected VLBI session setups for dedicated studies and also on an operational basis, whereby the routines are based on the current operational combination scenario of the BKG/DGFI-TUM IVS Combination Centre.

Analysis

Abstract 33

EVALUATING THE CONSISTENCY AND RELIABILITY OF DUT1 ESTIMATES FROM VLBI INTENSIVE SESSIONS

Oral

Modiri S.*, Thaller D., Klemm L., Engelhardt G., Goltz M., Schade C., Kehm A.

Federal Agency for Cartography and Geodesy (BKG) ~ Frankfurt am Main ~ Germany

At the BKG VLBI Analysis Center, we focus on the continuous analysis of dUT1 estimates derived from various Intensive session types, including legacy and VGOS observations. This study aims to investigate the consistency and reliability of these dUT1 estimates, with particular attention to differences in performance across session types and potential long-term trends in the data.

Our analysis leverages the comprehensive dataset processed at BKG, examining session-specific characteristics, biases, and variability to identify potential systematic effects. By comparing legacy and VGOS sessions, we aim to highlight the evolution of observing strategies and their implications for dUT1 estimation quality. The outcomes of this work will contribute to ongoing efforts to optimize VLBI observation schedules and refine analysis strategies for high-precision Earth Orientation Parameters.

This investigation builds on the routine activities at the Analysis Center and serves as a foundation for improving the robustness and consistency of operational VLBI products.

Analysis

Abstract 44

ENHANCING REGULARITY AND ACCURACY OF VLBI EOP PRODUCTS

Oral

Klemm L., Thaller D.*, Flohrer C., Modiri S., Bachmann S., Kehm A.

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This study focuses on the development of a daily VLBI time series of Earth Orientation Parameters (EOP) with improved accuracy and regularity by combining data from various VLBI sessions at the normal equation level. The combined approach addresses the limitations of the existing IVS EOP products, the EOP-S and EOP-I series, which are currently estimated and published separately for 24-hour geodetic VLBI sessions and 1-hour Intensive sessions.

While the EOP-S series is characterized by high accuracy due to the observation of global networks over 24 hours, its temporal resolution is irregular and non-daily. In contrast, the EOP-I series provides daily EOP values but also has irregular temporal resolution, as it is estimated at mid-session epochs that vary depending on the type of Intensive session. Furthermore, the short observation periods of one-hour result in lower dUT1 estimation accuracy compared to the EOP-S product. By combining data from these session types, this study aims to reduce these limitations to achieve a daily and more consistent EOP series with improved accuracy.

The presentation will detail the methodology used for the combination, including session selection and the data handling process. Challenges such as data gaps, inconsistencies, and systematic effects are addressed. The results demonstrate significant improvements in both the temporal regularity and the accuracy of the resulting EOP series, enabling better comparability with other EOP products and providing robust input for EOP prediction algorithms. This work highlights the potential of intra-technique combination to enhance the quality and usability of VLBI-based geodetic products.

3.1 Session 3.1

Analysis

Abstract 26

MITIGATING SOURCE STRUCTURE ON THE VISIBILITY LEVEL

Oral

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Source structure is one of the remaining unmodelled systematic errors in geodetic and astrometric VLBI. Our aim is to mitigate the impact of an extended structure at an early point in the processing chain, such that observables appear as if they had been obtained by observation of point sources. We have developed a tool to remove structure phases directly from the DiFX correlator output. Here we describe our method and present results from its application to observational VGOS data.

Analysis

Abstract 65

VARIATIONS IN THE QUAD-BAND SOURCE POSITIONS FROM VGOS OBSERVATIONS

Oral

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The new generation geodetic very-long-baseline interferometry (VLBI) system, named VLBI Global Observing System (VGOS), has started to make regular observations of active galactic nuclei (AGNs) to measure station positions of globally distributed antennas and Earth Orientation Parameters since 2019. It is currently understood that it is the astrophysics of the AGNs that limits the accuracy of the geodetic products from VGOS data --- the AGNs are all resolved to have angular structure on the milli-arcsecond scales that is varying with both time and frequency. Based on the existing VGOS data, dedicated geodetic solutions were made to detect source position variations over the time span from Dec. 2017 to Jun. 2024. We categorized the different types of variations and studied the potential factors causing such variations with insights from radio images. The differences between the quad-band and S/X band positions are also compared, which led to the conclusion that a quad-band position catalog is mandatory for processing routine quad-band observations. The results presented in this study will provide a reference to evaluate the improvement that can be obtained by modeling source structure in VGOS observations, which is the major research topic in the ERC project Astrogeodesy funded in 2023. In the presentation, we will also present the outlook of the plan related to this research topic.

Analysis

Abstract 74

SOURCE STRUCTURE INFORMED SCHEDULING FOR VGOS INTENSIVE SESSIONS

Oral

Wolfs R.*[1], Haas R.[1], Le Bail K.[1], Xu M.H.[3], Schartner M.[2]

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One of the major remaining error sources for VGOS is the angular structure of the observed radio sources, which typically show a featureless compact core and elongated extended jet components. Previous research has tried to mitigate the impact of source structure in the analysis stage by using source structure models and by weighting the observations accordingly. In this study we investigate a strategy that takes the source structure already into account during the scheduling of the observations. Astronomical observations of a large sample of radio sources have shown that the apparent movement of the radio source emission of a source is primarily along the jet direction. Therefore, a constraint between the source jet direction angle and the projected baseline orientation angle can be introduced during scheduling, which actively avoids the observations with these two directions in (or close to) parallel. This constraint should limit the apparent movement of the radio source emission along the jet direction as observed by the baseline. To test such a scheduling approach, the VGOS-INT-C observing program was established. To assess the effectiveness of the VGOS-INT-C scheduling method, the sessions can be compared with the state-of-the-art scheduled VGOS-INT-B sessions. The VGOS-INT-B sessions use the same baseline and source catalogue as the VGOS-INT-C sessions, and are scheduled on the same day and in close temporal vicinity to the VGOS-INT-C sessions. We present the analysis of 3 years of VGOS-INT-B and VGOS-INT-C data. We look at estimated UT1-UTC values and the thereof derived LOD values, and at the statistics from the session fits. The estimated Earth Rotation Parameters are compared to external data sets from IGS, CODE, IERS, and USNO. We also briefly show results of the combination on the observation level with GNSS for both sessions.

3.2 Session 3.2

Analysis

Abstract 4

NEW GRAVITATIONAL DEFORMATION MODEL OF THE HOBART26 VLBI TELESCOPE

Oral

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Gravitational deformation of VLBI telescopes causes systematic delays in the measurements. This is acceptable, if the characteristic of such deformation is known and a corresponding model is available during the analysis. The Hobart 26 telescope has been active in the IVS since the late 1980s, yet a model for its gravitational deformation has not been available until now.

In this contribution, we present the project of measuring the Hobart26 telescope by close-range photogrammetry using a drone. An international team of experts in photogrammetry, telescope surveying and VLBI combined forces for this project, making it a prime example of collaboration within the IVS.

We consider sharing our process of planning the project with the community equally important as the actual results. The measurements were of high quality and the deformation of the receiving unit was modelled using an innovative approach with Zernike polynomials. The model for the signal path variations is now available. With delay corrections of less than 2mm, the Hobart 26 radio telescope turns out to be surprisingly stable.

Analysis

Abstract 43

IMPACT OF THE INCLINATION OF GENESIS ON THE VLBI TERRESTRIAL REFERENCE FRAME

Oral

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TU Wien ~ Vienna ~ Austria

The Genesis mission of the European Space Agency (ESA) has been approved and is scheduled for launch in 2028. The satellite will serve as a dynamic space observatory, being equipped with the instruments of all four space-geodetic techniques referenced to each other with high precision. A unique feature of Genesis is a dedicated Very Long Baseline Interferometry (VLBI) transmitter, which allows the connection of geodetic VLBI stations to the instruments of the satellite techniques. One of the main objectives of the Genesis mission is the improvement of the Terrestrial Reference Frame (TRF), in terms of accuracy and stability.
The satellite is currently planned to operate in a polar orbit with an inclination of 97° and an altitude of 6000 km. However, there are discussions about reducing the inclination of Genesis to 60°. This raises the question of which inclination would be more suitable, considering factors such as observational coverage and the accuracy of the TRF determination.

This simulation study investigates the determination of a TRF based on VLBI observations to Genesis only for two different theoretical satellite orbits of Genesis, with inclination angles of 97° and 60°. To this end, a Genesis TRF is derived using 24-hour VLBI sessions on a weekly basis, encompassing observations to Genesis and quasars, scheduled over a two-year period. These investigations are conducted for a network comprising currently operational VGOS stations and an extended version of this network incorporating potential future VGOS stations.

In this setup, the station coordinates are estimated solely from Genesis observations, allowing for the determination of these coordinates within the Genesis frame. This approach enables the comparison between the station coordinates in the dynamic Genesis frame and in the kinematic quasar frame, thereby providing information on a frame tie between these frames on a per-station basis.

Analysis

Abstract 21

SIGNALS IN STATION POSITIONS REVEALED BY VGOS

Oral

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Over the past decade, the IVS has expended considerable effort to bring its infrastructure into the modern age under the aegis of VGOS (VLBI global observing system), with the aim of meeting the objectives set out by GGOS. The key features of VGOS include smaller, faster antennas, which facilitate better sky coverage, and broad-band receivers observing between 2-14 GHz to achieve an enhanced signal-to-noise ratio. A further innovation of VGOS is the deployment of twin telescopes, i.e. two VGOS antennas at the same location, separated only by dozens of metres; currently, three pairs are operational. In addition, the vast majority of VGOS antennas are co-located with a legacy antenna.

The outcomes of the initial years of VGOS observations are unparalleled in their precision, particularly with respect to the station positions. However, this has also exposed previously unidentified or overlooked systematics, signals obscured by noise, or signals that remained unmodeled as they were deemed too insignificant to warrant attention.

The present study focuses on the station positions of VGOS antennas and their residuals, comparing them to their twins and to the respective legacy antennas. The impact and origin of previously unseen signals is discussed, and possible methods to model and/or mitigate them to reach the highest possible accuracy are explored.

Analysis

Abstract 16

GEODETIC K-BAND VLBI OBSERVATIONS FOR THE CLOCK COMPARISON

Oral

Negusini M.*[1], Jung T.[2], Clivati C.[3], Heo M.[4], Cho B.[5], Ricci R.[1], Stagni M.[1], Bortolotti C.[1], Maccaferri G.[1], Perini F.[1], Roma M.[1], Xu S.[2], Byun D.[2], Je D.[2], Pizzocaro M.[3], Calonico D.[3], Cantoni E.[3], Cerretto G.[3], Condio S.[3], Costanzo G.[3], Donadello S.[3], Goti I.[3], Gozzelino M.[3], Mura A.[3], Levi F.[3], Risaro M.[3], Kim H.[4], Lee W.[4], Park C.Y.[4], Yu D.[4], Rhee J.H.[4], Lee Y.K.[4], Yi S.O.[6], Yoon H.[6], De Vicente Abad P.[7], González J.[7], Garcia Miró C.[7]

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We performed a clock comparison between Italy and Korea using geodetic 24-h K-band VLBI observations. The comparison involved H-masers used in Medicina and Sejong radio telescopes. The same clocks were simultaneously compared by a satellite link and by high-precision optical clocks maintained at National Metrology Institutes, Korea Research Institute of Standards and Science (KRISS) in Korea and Istituto Nazionale di Ricerca Metrologica (INRIM) in Italy, and delivered to the VLBI antennas via noise-compensated fiber links. We estimated the clock rate from VLBI data and these values were subsequently compared with clock differences derived by GPS Precise Point Positioning (PPP) and by local optical clocks. Results were in agreement at the level of 10−15 s/s. This result is a first confirmation that standard geodetic VLBI campaigns could be a viable approach to conduct intercontinental clocks comparisons, now possible only via satellite links. This experiment was a pilot test in view of the installation of new-generation, high-frequency, wideband receivers on the involved telescopes. K/Q/W band geodetic observations will allow an improvement in the accuracy of the resulting group delays and a better estimation of the clock parameters of the stations, contributing to progress in the redefinition of the second.

P.01 Poster

Analysis

Abstract 66

A VGOS CRF FULLY CONSISTENT WITH THE S/X FRAMES – PRELIMINARY RESULTS

Poster

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The development of the Very Long Baseline Interferometry (VLBI) Global Observing System (VGOS) is expected to enhance the accuracy of delay estimates obtained from VLBI observable in fulfillment of the challenging demands referred to as GGOS (Global Geodetic Observing System) goals. A high-precision VGOS celestial reference frame (CRF) is essential for achieving these goals. Besides K-band and X/Ka-band products, the current realization of ICRS (International Celestial Reference System), ICRF3, includes VLBI observations from the S/X IEEE frequency bands of legacy VLBI observations until March 2018. Based on 6366 S/X-band and 280 VGOS sessions of IVS (International VLBI Service of Geodesy and Astrometry), we present a preliminary VGOS CRF that is fully consistent with S/X CRF, TRF and EOP (Earth Orientation Parameters). Consistency is achieved by applying local ties between VGOS and S/X VLBI stations, using NNR+NNT constraints for S/X station coordinates and NNR constraints for S/X radio source coordinates. The full set of five EOP parameters is defined and estimated identically for both types of VLBI observations, VGOS and S/X, through global ties. Furthermore, we will present a comparison to the consistent realization of data and geodetic parameters obtained from S/X and VGOS observations alone. Concluding, several global solutions determined for S/X and VGOS with different sets of datum will be discussed and quantitatively compared in our presentation.

Analysis

Abstract 72

AN ASSESSMENT OF THE IONOSPHERIC TOTAL ELECTRON CONTENT ESTIMATED FROM VGOS

Poster

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In the new VGOS system, the ionospheric delay is handled in a new way. Instead of removing it in the data analysis using an ionospheric free combination of two frequencies, as done for the legacy S/X system, the ionospheric total electron content (TEC) is estimated fringe-fitting along with the group delays and delay rates. This means that the group delays from VGOS are free from ionospheric delays. Nevertheless, it is still interesting to study the ionospheric TEC estimated by VGOS. Firstly, to evaluate if VGOS can be useful for studying the ionosphere. Secondly, because the quality of the VGOS TEC estimates are related to the quality of the other parameters estimated in the fringe-fitting, like the group delays.

In this work the TEC from VGOS is investigated. This is done by first estimating station-wise timeseries of vertical TEC (VTEC) and TEC gradients for the VGOS stations. These are then compared to VTEC estimated from co-located GNSS receivers, from co-located legacy VLBI telescopes, and Global Ionospheric Models (GIM). The VGOS sessions from 2019-2025 are used in this study. This provides an interesting period for ionospheric studies, since it begins when the ionospheric activity is low, and ends at a solar maxima with high ionospheric activity.

Analysis

Abstract 14

ASSESSING THE IMPACT OF UPDATED ERPS ON FCN MODELING USING VLBI OBSERVATIONS

Poster

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Current theoretical nutation models do not account for the variations caused by the Free Core Nutation (FCN). Consequently, the impact of this free-oscillation mode of the Earth must be derived from the residuals obtained through VLBI (Very Long Baseline Interferometry) observations. VLBI is capable of deriving all Earth Orientation Parameters (EOPs) from 24-hour sessions. The Earth Rotation Parameters (ERPs) used as a priori data may influence the accuracy of FCN modeling, and addressing this potential impact is the focus of this study. Utilizing the IERS 20 C04 series as a priori EOP data, this study implements the following methodology:

First, VLBI sessions spanning 2013 to 2023 are processed and adjusted using a standard approach, producing time series of Celestial Pole Offsets (CPO), referred to as the “standard series”. The Earth Rotation Parameter residuals estimated from the standard processing are added to the IERS a priori values, generating an updated set of ERPs. These updated ERPs are fixed and used as inputs for a new processing, obtaining new CPO series, the so-called “modified series”.

The differences observed between the standard and modified residual series are significant, prompting the question of whether the updated ERPs exert a notable influence on FCN modeling.

To explore this, we follow the empirical approach proposed by Belda et al. (2016) and implement an FCN model. The objective is to analyze and compare the resulting models from both series, aiming to assess the impact of ERP refinement on FCN representation. This investigation seeks to quantify the relevance of these modifications and their potential to enhance the accuracy of nutation models.

Analysis

Abstract 70

ASSESSING VLBI OBSERVATION SNR FOR THE GENESIS SATELLITE

Poster

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[1] Royal Observatory of Belgium ~ Brussels ~ Belgium, [2] ETH Zurich ~ Zurich ~ Switzerland, [3] Chalmers University of Technology ~ Gothenburg ~ Sweden

The received power flux density on a VLBI telescope is a crucial parameter influencing the signal-to-noise ratio (SNR) of correlated signals between the baseline stations in VLBI. In traditional VLBI observations of quasars, the incoming radio signals arrive at ground stations with approximately the same power, resulting in uniform received power flux densities for identical telescopes. However, in the case of a VLBI transmitter (VT) onboard an Earth-orbiting satellite, the received signal power varies across different ground stations due to the geometrical configurations between the satellite and each station.

In this study, we analyze the received power flux densities at VLBI Global Observing System (VGOS) telescopes for signals transmitted from the Genesis satellite using simulations. We examine how the flux densities differ across various baselines that contribute to the observations and assess the variations in flux density for different baselines over the course of a one-day simulation of the Genesis satellite's by considering different antenna radiation patterns.

Observations

Abstract 5

AUSCOPE VLBI PROJECT – STATUS AND NEWS 2025

Poster

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The AuScope VLBI project covers Australia's IVS observations, with telescopes in Hobart (12m and 26m), Katherine and Yarragadee.
In this contribution we give an update of our activities, covering the technical situation of the telescopes and hardware, observing campaigns, scientific developments, as well as status and outlook of funding and personnel.

Analysis

Abstract 39

BAYESIAN MODELLING FOR FLUX DENSITY AND SEFD ESTIMATION WITH SINGLE-BASELINE VGOS OBSERVATION

Poster

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Estimating system equivalent flux density (SEFD) and source flux density is critical in the calibration and analysis of Very Long Baseline Interferometry (VLBI) observations. The VLBI Global Observing System (VGOS) employs a broadband observing system with fast-slewing telescopes, enabling high temporal and spectral resolution. However, station calibration presents significant challenges due to the complexities introduced by the broadband system and the limitations of the noise calibration unit, particularly at higher frequencies. Furthermore, flux estimation is complicated by the dynamic variability of radio sources, frequency-dependent differences in signal behaviour, and the time-sensitive nature of observing conditions. These challenges necessitate advanced methods to ensure reliable and accurate calibration and analysis.

To address these challenges, we developed a Bayesian model to estimate flux density and SEFD using single-baseline VGOS observations. The model incorporates a hierarchical structure with random walk priors to capture temporal variations in flux density and its spectral indices. A gamma likelihood function is utilised, offering a more accurate representation of the statistical behaviour of signal-to-noise ratio (SNR) data compared to traditional least-squares methods, which assume Gaussian error distributions. Unlike Gaussian-based approaches that rely on symmetric error assumptions and may produce negative values, the gamma likelihood effectively models the positive, skewed nature of SNR data, resulting in more reliable parameter estimates. Additionally, the VGOS frequency range was segmented into two bands (3–6.5 GHz and 6.5–13.5 GHz), with each band parameterised by its own spectral index (α) to account for distinct spectral characteristics.

The results confirm the reliability of the Bayesian approach. The estimated flux densities are in good agreement with the SKED catalogue, and the SEFD values derived by the model correspond closely to those obtained from calibration sessions conducted within a proximate time frame. Furthermore, the model estimates the spectral indices (α) of the observed sources.

This study highlights the advantages of Bayesian modelling for VGOS session calibration and flux density estimation, which in turn enhances scheduling efficiency. The approach is scalable to larger VGOS networks, enabling more precise estimations. By accurately

characterising SNR noise properties, the gamma likelihood significantly improves station calibration. This methodology also provides a foundation for future investigations into source variability and spectral properties within the VGOS system.

Analysis

Abstract 32

CHARACTERIZING SHORT-TERM VARIABILITY IN VGOS GROUP DELAY OBSERVABLES

Poster

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To achieve high-precision geodetic and astrometric measurements using VGOS, the operational design involves observing each radio source in single scans as short as 7 seconds. Therefore, it is essential to investigate the stability of group delay observables on short time scales (from one second to half a minute), focusing on instrumental effects and potential systematic errors introduced, for instance, by atmospheric turbulence.
The project presented in this poster aims to perform a time-series analysis of the VGOS group delay to characterize its short-term variability. We use data from the ER2201 observations, where a network of six VGOS antennas continuously observed the same target, 4C39.25, for six hours. The high flux density of this source allows us to determine group delays with one-second cadence, providing a unique opportunity to investigate the origins of short-term variations in group delay observables and offering significant potential for characterizing tropospheric effects on radio signals.

Technology

Abstract 63

CHARACTERIZING THE ONSALA TWIN TELESCOPES USING MICROWAVE HOLOGRAPHY

Poster

Vijayaraghavan M., Handirk R.*, Le Bail K., Haas R., Hovey G.

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In addition to geodetic VLBI observations, recently the Onsala Twin Telescopes (OTT) have also been used for assessing the impact of Radio Frequency Interference (RFI) from Low Earth Orbit (LEO) satellite constellations on modern arrays like the SKA. To calibrate and compute the total power from the satellite constellations, it is required to accurately know the beam of the telescope. This spawned a series of microwave holography measurements. Holography is an interferometric technique, whereby signals between a stationary reference antenna are cross-correlated with a scanning antenna under test. This process utilizes the Fourier relation between the aperture distribution and the complex far-field pattern of the antenna under test.

We present recent results from dual polarized beam holography of both the OTT carried out with a Geostationary satellite at approximately 25 deg elevation as the source. Through the recent measurements, we obtain both co- and cross-pol beams for the OTT at 11 GHz. From refined calibration methods, we find an efficiency of 45%, and a rms ray path length of less than 3 mm, compared to an upper limit of 10 mm that we obtained from previous measurements. We plan to continue these measurements at multiple VGOS operating frequencies, and at different elevations using astronomical sources and identify strategies to optimize the aperture efficiency.

Technology

Abstract 27

DBBC4 - A VERY WIDE BANDWIDTH VLBI ENVIRONMENT VGOS SUITABLE

Poster

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The development of the newer version of the VLBI digital front- and back-end system belonging to the DBBC systems' family is under way as a work-package of the EU-funded RadioBlocks Project. This instrument dedicated to increase the VLBI observation capabilities in terms of bandwidth and output data rate involves a number of relevant novelties ranging from the full 32 GHz digitized input band in a number of up to 8 RF/IFs per system, to a fast recording system, and is including for the first time in a VLBI system a first implementation of a hardware AI processor.
The DBBC4 can be implemented as a distributed system of elements to be positioned in different parts of the radio-telescope site, in contrast to the more traditional way of in a single box. Distributed elements which can operate also stand-alone are: DiFrEndVGOS covering the entire VGOS range 2 − 14 GHz with a single sampler in double polarization, DiFrEnd28 with full 28 GHz bandwidth, DiFrEnd4T with 6 GHz bandwidth in the range 0 − 33 GHz. The first one can also be used in conjunction with the DBBC3 to digitize the full VGOS band and replace any analogue frequency conversion. All the distributed elements can have backend functionality being able to produce channelized VDIF output packets to be recorded or to be sent through fiber to the correlator.
The progress of the DBBC4 development is reported together with a comprehensive description.

Observations

Abstract 41

DEVELOPMENT OF THE OPERATIONAL VGOS OBSERVING PROGRAM

Poster

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The S/X VLBI network has been the production system of the IVS since the Service's inception in 1999. In 2020, after a visionary journey from designing to prototyping to system rollout, the next-generation, broadband VLBI system called VGOS (VLBI Global Observing System) was declared operational and a (geographically) limited VGOS network of some eight (northern-hemisphere) stations started to contribute operationally to IVS products. That VGOS network has increased to 14 more globally distributed stations, and it continues to grow with further stations planning to join in 2025. The current operational VGOS observing program includes two 24-hour session series (known as VGOS-OPS and VGOS-RD) for EOP determination and a 1-hour (Intensive), weekdaily series (VGOS-INT-A) for dUT1 determination. Further VGOS Intensive series are being validated. Beyond the network buildout activities, other infrastructure components of the VLBI processing chain have been developed further (e.g., VGOS correlation and post-processing, VGOS analysis). In this presentation, we summarize the VGOS station network development and the evolution of the observational program as well as outline current limitations and risks.

Technology

Abstract 67

GRAVITATIONAL DEFORMATION MEASUREMENT OF 20 M RADIO TELESCOPE ON SVALBARD

Poster

Hedekvist P.O.[1], Rieck C.[1], Jarlemark P.[1], Spetz J.[1], Garcia Espada S.*[2]

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With the ongoing development and improvements of Very Long Baseline Interferometry (VLBI) for Geodesy, with precision aiming to better than 1 mm, the participating radio telescopes must be characterized with respect to gravitational deformation. The resulting correction coefficients will be connected to the elevation angle at the observation, and can be implemented even on historical data from previous measurements. Thus the benefits of scanning old telescopes, even on the rim of decommissioning, are still substantial. One of the busiest telescopes in Geodetic VLBI have been the 20 m radio telescope in Ny Ålesund on Svalbard. During 2020, we scanned this telescope using high performance, commercially available distance and 3D scanning equipment and calculated a correction table for the deformation. The measurements indicate that the telescope dish is stable with correction coeffients below 1.5 mm when changed from 0° – 90° elevation angle. The data from this study has been included in the newest International Terrestrial Reference Frame, IRTF2020.

Analysis

Abstract 7

GSI GLOBAL SOLUTIONS OF VLBI OBSERVATION DATA

Poster

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GSI has been involved in international VLBI observations in cooperation with International VLBI Service for Geodesy and Astrometry (IVS) to contribute to construction of the Global Geodetic Reference Frame and to determine the reference point in Japan. In global analysis, various parameters e.g. station positions, velocities, and the earth orientation parameters (EOPs) are estimated using long-term global VLBI database. GSI has conducted global analysis and released the results on the webpage since 2002.
In the latest analysis in GSI, we used more than 7,000 VLBI sessions' database from 1980 to 2024. We will show the results of the latest analysis and give a status report on improving our methods to obtain more accurate results of station coordinates and EOPs.

Analysis

Abstract 25

HYBRID MODELLING OF CORRECTIONS FOR GEOPHYSICAL AND UNMODELLED EFFECTS IN VLBI DATA ANALYSIS

Poster

Singh S.*[1], Böhm J.[2], Krásná H.[2], Böhm S.[2], Balasubramanian N.[1], Dikshit O.[1]

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Very Long Baseline Interferometry (VLBI) is essential for geodetic and astrometric applications, providing high-precision measurements of Earth's rotation, crustal deformation, and reference frame realization. However, systematic errors from geophysical effects, such as non-tidal loading (NTL), as well as unmodelled residuals in VLBI data analysis, introduce uncertainties in VLBI-derived station positions. Traditionally, these effects have been addressed using geophysical models based on established physical laws and equations, but their limited accuracy has prevented their full integration into the International Terrestrial Reference Frame (ITRF). Additionally, certain unmodelled effects in VLBI observations remain unexplained by any existing traditional geophysical model.

This study explores the potential of combining traditional geophysical models with machine learning (ML) techniques to improve corrections for geophysical and unmodelled effects in VLBI data analysis. While traditional geophysical models provide a theoretical foundation, ML has the capability to identify complex, nonlinear relationships that traditional methods may overlook. By integrating these approaches, this study aims to assess whether a hybrid model can improve the characterization of NTL effects over the traditional geophysical models. The findings of this research will help evaluate the feasibility of using data-driven methods to complement conventional geophysical correction models in VLBI.

Analysis

Abstract 53

INFLUENCE OF VLBI NETWORK GEOMETRY ON THE ESTIMATION OF EARTH ORIENTATION PARAMETERS

Poster

Del Nido Herranz L.D.*[1], Belda S.[1], Karbon M.[1], Azcue E.[2]

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The accuracy and reliability of Earth Orientation Parameters (EOP) are significantly influenced by the geometric configuration of the Very Long Baseline Interferometry (VLBI) network. This astronomical technique employs a global network of radio telescopes to collect data. The distribution of VLBI antennas affects the triangulation process used to determine the positions of celestial sources, which is integral to the calculation of EOP. An optimal geometry yields more accurate and reliable EOP results, which are essential for many scientific applications.

This study examines the impact of different VLBI networks on EOP estimation, using data collected during several Continuous VLBI Campaigns (CONT) and designing alternative networks by removing various antennas and/or baselines from the original configuration. The results of this analysis aim to contribute to the refinement of EOP and the achievement of the stringent GGOS accuracy targets (i.e., a frame with accuracy at epoch of 1 mm or better and a stability of 0.1 mm/y).

Analysis

Abstract 49

IVS COMBINATION CENTER: ITRF2020 UPDATE - FINAL RESULTS

Poster

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We will present the final results of the IVS contribution to the ITRF2020 Update. The original ITRF2020 covering the time span 1979 until 2020 was updated with three additional years, i.e., adding data from 2021 to 2023. For the first time, such an extension has been realized. The objective of such a procedure is to increase update cycles from 5-6 years to ideally only one year, in perspective.
Like the original ITRF2020 contribution, the update consists of a combined solution using the contributions of twelve different ACs. We will give an overview on the update process and show results of station coordinates, scale, and EOPs. Our special focus will be on the performance of VGOS sessions and the scale parameter and its evolution since the original ITRF2020.

Technology

Abstract 6

IVS WG 7 ON SATELLITE OBSERVATIONS WITH VLBI

Poster

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The IVS Working Group on Satellite Observations with VLBI (WG7) will study possibilities to observe Earth satellites with the VLBI ground network affiliated with the IVS. The main focus of this WG will be the Genesis mission, in particular how the IVS can support this mission through observations with its network. This covers technical issues, ensuring station compatibility to enable observations to Genesis as well as working towards an observing plan considering overall resources and regular IVS observing programs.
This WG further intends to be the contact point for other missions and applications in this area, such as GRITSS, potential VLBI transmitters on Galileo satellites, PRN-signal tracking with IVS telescopes, or others.
This contribution introduces its new members and outlines its ToRs, tasks and desired outcomes.

Observations

Abstract 73

LOCAL-TIE EXPERIMENTS OF CHINESE VLBI STATIONS

Poster

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This report is focused on local-tie experiments conducted using three co-located VLBI stations in China, namely Tianma and Sheshan in Shanghai, and Urumqi. Those VGOS antennas were tagged along with mixed-mode observations in regular S/X band sessions, followed by X-band only data correlation and post-correlation analysis. Furthermore, an attempt was made to determine the baseline vector between those co-located VLBI antennas through phase delay analysis.

Technology

Abstract 18

NEW ZEALAND GEODETIC VLBI - SPACEOPS NZ

Poster

Weston S.*

SpaceOps NZ Ltd ~ Auckland ~ New Zealand

A poster to introduce Space Operations New Zealand as the new operator of the Warkworth 12m IVS Station.

SpaceOps NZ is the trading name of Space Operations New Zealand Limited. It is a council-controlled trading organisation under the Local Government Act 2002, being a wholly-owned subsidiary of Southland Regional Development Agency Limited. In July 2023 Space Operations New Zealand Limited acquired the Warkworth Assets from the Auckland University of Technology, along with three of the staff. A interim service contract has been arranged with Land Information New Zealand (LINZ) to continue the Geodetic VLBI work with the Warkworth 12m antenna, while a new full service contract is negotiated. In addition Space Operations New Zealand Limited also provides antenna hosting at Awarua near Invercargill in South Island. Space Operations New Zealand Limited also provide Consulting and Low Earth Orbit Support.

Analysis

Abstract 56

ON THE ABSOLUTE SEA LEVEL AT THE SWEDISH WEST COAST ESTIMATED BY VLBI, GNSS, AND TIDE GAUGES

Poster

Elgered G., Haas R.*

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The telescopes used for geodesy VLBI at the Onsala Space Observatory are all located within a few hundred metres from the coast line, as are the GNSS stations. Therefore a collaboration begun with the Swedish Meteorological and Hydrological Institute (SMHI), responsible for the national observational network of sea level in Sweden, in order to install a tide gauge station at the observatory. This station has been operational since June 2015 and its characteristics were presented at the EVGA meeting in 2019. There is now an almost ten years long time series of relative sea level available, which nevertheless still is a bit short to combine with geodetic height data to assess the absolute sea level. However, the tide gauge station Ringhals, located 20~km south-south-east of Onsala has been operational since 1967 and useable VLBI data from Onsala exist since the autumn of 1980. This means that we have 44 years of simultaneous VLBI and tide gauge data. We use the existing simultaneous data (from 2014–2025) to asses the question of how representative the Ringhals tide gauge station is for the one at Onsala. Hourly values of the sea level are archived and open access available at SMHI. From 00 UT 24 June 2015 to 00 UT 28 December 2024 Onsala and Ringhals provide 83,307 and 82,817 data points, respectively. Before the comparison is done we select only data points that are acquired at the same minute resulting in 82,680 data points. This corresponds to 99.3 % of the total period. We find that the sea level trends at Onsala and Ringhals are 0.54 cm/year and 0.59 cm/year, respectively. These values are, however, not representative for a trend over a longer time period. The sea level trend for Ringhals using all the data from 1967 to 2024 is 0.05 cm/year. According to ITRF2020 is the uplift derived from VLBI data observed between 1980 and the end of 2020 with the Onsala S/X legacy telescope 0.29 cm/year. The corresponding uplift derived from GNSS observations with the ONSA station during 1994 to the end of 2020 is 0.27 cm/year according to ITRF2020. Assuming that the sea level measured at Ringhals, during the 57 years of operation, is representative also for Onsala, or that the uplift at Onsala is approximately equal to that at Ringhals, means that an overall linear trend of the regional absolute sea level has been approximately 0.33 cm/year.

Technology

Abstract 77

RECENT DEVELOPMENT AT THE ONSALA SPACE OBSERVATORY

Poster

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We present a short overview of recent developments
Text: at the Onsala Space Observatory. This includes for example the invar measurement systems installed on the Onsala Twin Telescopes in late 2023 and the so-called single-dish Tsys measurements performed with the OTT at zenith position. These Tsys measurements cover the entire VGOS frequency band from 3 to 15 GHz. We also address other quality control work at Onsala that is performed to ensure highest quality of the observational data.

Technology

Abstract 3

RECENT DEVELOPMENTS AT METSÄHOVI GEODETIC RESEARCH STATION

Poster

Kareinen N.*[1], Zubko N.[1], Eskelinen J.[2], Näränen J.[1], Koivula H.[1], Peltoniemi J.[1]

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VGOS telescope system at Metsähovi Geodetic Research Station (MGRS) is in the commissioning phase. The VGOS equipment and the backend have been relocated to the new main building. The integration work on the signal chain is ongoing. Testing has been performed with DBBC3 and FlexBuff together and the first test scans have been recorded on FlexBuff using jive5ab VLBI data recorder software. A new hydrogen maser was purchased and installed in a dedicated equipment room in a temperature controlled chamber built in-house and it is currently being tested. Securing operational and maintenance funding for MGRS marked a significant milestone for long-term operations of the station. An operational infrastructure team was formed and will be responsible in the future for the operations of the station. The contribution to IVS with VGOS telescope (Mf) will start after its commissioning is completed.

Analysis

Abstract 13

SCHEDULING AND SIMULATIONS FOR THE GENESIS MISSION

Poster

Schartner M.*, Soja B.

ETH Zurich ~ Zurich ~ Switzerland

The reduction of systematic errors in terrestrial reference frames (TRF) is crucial for numerous scientific and societal applications. To support this effort, the European Space Agency (ESA) plans to launch a dedicated space-geodetic mission, Genesis, in 2028. For the first time, VLBI will be required to observe and process satellite data, presenting both novel challenges and exciting opportunities.

In this work, we present preliminary studies supporting the Genesis mission, with a focus on scheduling and simulations. We investigate key aspects such as network visibility under different orbital parameters, specifically examining the impact of orbit altitude (ranging from 4000 to 9000 km) and inclination (ranging from 60 to 95 degrees). Our simulations show that while orbit altitude significantly affects visibility, lower inclinations allow the satellite to be observed slightly longer by at least two stations. Conversely, higher inclinations result in longer visibility with a larger network.

Additionally, we outline the current status and roadmap for essential VLBI software developments, aiming to foster discussions and potential collaborations within the community.

Analysis

Abstract 64

SIMULATING THE IMPACT OF NEW VLBI INTENSIVE BASELINES ON COMBINED UT1-UTC SOLUTIONS

Poster

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United States Naval Observatory ~ Washington, DC ~ United States of America

In the ongoing effort to improve Earth Orientation Parameter (EOP) estimates from the IERS Rapid Service/Prediction Center (RS/PC), we simulate the inclusion of potential VLBI contributions and measure changes to EOP estimates, especially UT1-UTC. Recent work has been focused on diversifying VLBI Intensive baselines that are included in the RS/PC combination in an effort to improve the robustness and reliability of the UT1-UTC solution. Care must be taken to study a new Analysis Center and/or baseline's impact before adding it to the combined solution, as to not unintentionally skew EOP estimates. Work is underway to redesign our Data Simulation (DataSim) package to evaluate the impact of a potential EOP contribution on historical EOP combined solutions. Here we show the inclusion of VLBA baseline Hn-Mk, and look at preliminary results of simulations of other potential S/X and VGOS baselines.

Analysis

Abstract 37

STABILITY ANALYSIS OF SOURCE COORDINATES FROM S/X AND VGOS STATION NETWORKS USING THE ARC LENGTH METHOD

Poster

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Most VLBI observing stations currently operate with the traditional S/X system, while newly established VLBI stations employ the modern broadband VGOS system. In early 2020, the IVS initiated regular observations using VGOS stations. In this poster, we examine the stability of source coordinates derived independently from observing sessions conducted since 2020, using both VGOS stations (VGOS-OPS network) and S/X stations (IVS-R1 and IVS-R4 networks). For each observing network, we generated time series of source coordinates and evaluated the arc length between pairs of radio sources for individual sessions. The arc length, being invariant to the Terrestrial and Celestial Reference Frames and Earth Orientation Parameters, provides a robust metric for our analysis. By analyzing variations in the arc lengths, we identified groups of stable and unstable sources. We then compared the results from the legacy S/X networks with those obtained using the VGOS system to assess differences in performance and reliability.

Technology

Abstract 62

STATUS AT NY-ÅLESUND GEODETIC EARTH OBSERVATORY

Poster

Garcia Espada S.*, Bolaño González R., Tangen L.M., Kirkvik A.

Norwegian Mapping Authority ~ Ny-Ålesund ~ Norway

Current status of the Ny-Ålesund Geodetic Earth Observatory will be presented. All efforts are focus on the VGOS VLBI twin telescopes (Nn, Ns) operations.
The SLR is planned to be operational end 2025. Then the observatory will be a so-called fundamental station co-locating VLBI, SLR, Doris and GNSS.

Observations

Abstract 34

STATUS OF THE VGOS-INT-S OBSERVING PROGRAM BETWEEN MCDONALD AND WETTZELL GEODETIC OBSERVATORIES

Poster

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We present an update of the VLBI Intensive program VGOS-INT-S observed between McDonald Observatory (MACGO12M) and the Wettzell Geodetic Obervatory (WETTZ13s) for the rapid determination of the Earth's rotation angle, expressed via UT1-UTC. The program was initiated in December 2021 with the goal to develop a new baseline for UT1-UTC observations, to test new scheduling strategies, and to automate the data transfer and the data analysis pipeline. A central goal was also to improve determination of delays caused by the neutral atmosphere, by rapidly switching between high- and low- elevation scans, but also to validate another geodetic baseline for routine determination of UT1-UTC. To maximize the number of scans in a session, we employed an SNR-based strategy to select suitable sources. Since the program inception in 2021, we have successfully observed 1-hr Intensive sessions, on a weekly basis, when both VGOS stations were available. Observations in the past year (2024) have included 24-hr sessions observed on a monthly basis coincident with the R1 sessions. These “24-hr Intensive sessions” were designed to alternate hourly between two observing strategies, one implementing the rapid switching between high and low elevation scans and one following a standard Intensive scheduling strategy. We report on the status of the correlation and analysis of these sessions. We discuss recent progress in automation of the correlation and visibility analysis at Wettzell and production of the vGOSdb’s for the sessions. We conclude with an overall perspective on the performance of the VGOS-INT-S sessions.

Technology

Abstract 71

STATUS OF THE VLBI CAPABILITIES AT WETTZELL OBSERVATORY

Poster

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[1] Technical University of Munich, Geodetic Observatory Wettzell ~ Wettzell ~ Germany, [2] Bundesamt für Kartographie und Geodäsie, Geodätisches Observatorium Wettzell ~ Wettzell ~ Germany

This poster shows the current status of the VLBI systems at the Geodetic Observatory Wettzell. We will especially focus on VGOS techniques.

Analysis

Abstract 20

STRATEGIC PLACEMENT OF THIRD VGOS TELESCOPE IN INDIA FOR IMPROVED EOP ESTIMATION

Poster

Dwivedi A., Laha A.*, Dikshit O.

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Very Long Baseline Interferometry (VLBI) is the only space geodetic technique capable of directly observing Universal Time (UT1), along with determining all other Earth Orientation Parameters (EOP). This study explores improving EOP precision by identifying the optimal location for a third telescope within the Indian subcontinent, inspired by the Australian AuScope telescope configuration. Using Monte Carlo simulations with VieSched++ software, we evaluated the combined impact of multiple new stations, addressing a limitation in prior research that primarily focused on single-station evaluations. Our approach involves defining four reference networks, integrating legacy telescopes, global VGOS stations, and proposed VGOS stations. The Indian subcontinent is then divided into a 5 x 5 degree grid to identify potential locations for new VGOS telescopes, resulting in a total of 22 potential sites considered for this research. For each potential site, we sequentially add stations to the base reference network (Ref) and reference network incorporating two planned Indian telescopes (Ref-In), located in southern and north-eastern India. The analysis compares EOP repeatability values after including the third station with those of Ref and Ref-In networks. Results suggest that while adding a third station does not significantly improve EOP precision, however it strengthens network redundancy. The findings indicate that the optimal placement for the third station lies in the western or northern regions of India, depending on the reference network.

Technology

Abstract 35

THE CRUSTAL DYNAMICS DATA INFORMATION SYSTEM (CDDIS) – VLBI UPDATES FOR 2025

Poster

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The Crustal Dynamics Data Information System (CDDIS), established in 1982, is NASA's archive for space geodesy and geodynamics. Over decades, the CDDIS has grown and evolved alongside space geodesy communities, such as the DORIS, GNSS, SLR, and VLBI user communities. With this growth, the CDDIS has worked to ensure new updates and releases of data and products are made known to the general user community. Inquiries on the use of data and product have become more common from various agencies. This poster provides an overview of these items.

Technology

Abstract 10

THE CX/KA-BAND RECEIVER SYSTEM FOR GEODESY AND ASTROMETRY OF THE KOREAN VLBI NETWORK

Poster

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[1] KASI ~ Daejeon ~ Korea, Republic of, [2] With Wave ~ Yongin ~ Korea, Republic of

We have developed a new VLBI receiver, which enables to make simultaneous observations in C/X and Ka bands (C: 6.2~7.0 GHz, X: 8.0~8.8 GHz and Ka: 28~34 GHz). The primary motivations behind this development were that S-band is mostly excluded in observation due to severe condition of radio frequency interference (RFI) in Korea and we are planning to participate in the recent activities on multi-band Astrometry. The measured noise temperatures of the developed receiver system are around 40K at 6.2~7.0 GHz, 30K at 8.0~8.8 GHz, and 30K at 28~34 GHz, respectively. When measuring the receiver noise temperatures, the quasi-optical system was not included and it is likely possible that the total receiver noise temperatures go higher than the above measured values due to larger beam sizes at lower frequency band compared to mirrors in the quasi-optical system. Contrary to low-frequency VLBI receiver system of which the feedhorn is located directly at Cassegrain focal point or primary focus, the developed receiver system utilizes a quasi-optics through which beam waist sizes are changed to be appropriate at Cassegrain focal point of the Korean VLBI Network (KVN) radio telescope. Since the KVN antenna was designed for millimeter-wave VLBI observation, the antenna focal length is much longer than typical lower frequency VLBI antenna. It means that the feedhorn size for lower frequency observation using the KVN antenna must be extremely large. In order to avoid this feedhorn size problem, a quasi-optical system using two ellipsoidal mirrors was designed for the CX/Ka-band receiver system. Septum polarizers have been developed for dual-circular polarization observations. Directional couplers for phase-calibration noise injection are combined with the septum polarizer for CX/Ka-band. The developed receiver system with the quasi-optical system will be installed at Pyeongchang site, which is one of 4 sites of the KVN early this year. The second receiver system will be assembled until this year and it will be installed at Yonsei site of the KVN in the next year. These receivers will be used for geodetic and astrometric experimental campaign in collaboration with National Geographic Information Institute (NGII) in the following years. In addition, it is being planned that the developed CX/Ka-band receiver system will be made use of to conduct test observations of spacecraft tracking.

Analysis

Abstract 42

THE IMPORTANCE OF COMMUNICATION IN SCIENCE, WITH A FOCUS ON VLBI AND THE RAEGE PROJECT.

Poster

Azcue E.*[1], Moreira M.[2], Moura L.[2], García Esteban C.[1], Belda S.[3], Karbon M.[3]

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Effective communication in science is essential for bridging the gap between researchers and society. This is particularly true in geodesy, a field that not only advances our understanding of Earth's dynamic processes but also impacts everyday life through applications such as navigation, disaster monitoring, and climate studies. The Global Geodetic Observing System (GGOS) exemplifies this commitment by integrating global geodetic efforts and promoting the transmission of geodetic knowledge to society.

Very Long Baseline Interferometry (VLBI) rely on advanced technology and international collaboration to measure Earth's rotation, positions and other critical parameters. Projects such as The Atlantic Network of Geodynamic and Space Stations (RAEGE), a collaborative Spanish-Portuguese initiative aimed at constructing, installing, and operating four fundamental geodetic stations in Spain and Portugal (Azores), require substantial investment and societal engagement, emphasizing the need for effective communication strategies.

Engaging with the general public fosters understanding and appreciation of geodesy's contributions, helping to demystify its technical aspects and highlight its relevance. Simplified explanations and relatable applications build trust and support for projects like RAEGE. For local communities near observatories, outreach efforts—such as educational programs or open days—encourage coexistence, address concerns, and showcase mutual benefits.

Within the scientific community, clear communication ensures the dissemination of findings and fosters interdisciplinary collaboration. A key focus of communication efforts is inspiring the next generation of scientists to pursue careers in VLBI and geodesy. GGOS plays a pivotal role here by uniting geodetic initiatives and enhancing their visibility. Transparent and strategic communication also strengthens the case for sustained funding by demonstrating the scientific and societal impact of long-term projects. With these goals a GGOS affiliate, called GGOS IberAtlantic, was created to foster collaboration across the Iberian Peninsula and the Atlantic region to integrate regional geodetic observations into global systems and ensure their visibility and impact.

In this contribution the efforts in the RAEGE project to reach diverse audiences and bring science closer to the public through outreach initiatives are presented.

Analysis

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THE IMPORTANCE OF COMMUNICATION IN SCIENCE, WITH A FOCUS ON VLBI AND THE RAEGE PROJECT.

Poster

Azcue E.*[1], Moreira M.[2], Moura L.[2], Pérez Esteban C.[1], Belda S.[3], Karbon M.[3]

[1]National Geographic Institute of Spain ~ Madrid ~ Spain, [2]Estação RAEGE de Santa María, Associação RAEGE Açores ~ Santa María, Azores ~ Portugal, [3]UAVAC, Applied Mathematics Dept., University of Alicante ~ Alicante ~ Spain

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Observations

Abstract 76

TWELVE YEARS OF IVS R&D SESSIONS DEDICATED TO OBSERVATIONS OF ICRF-GAIA TRANSFER SOURCES

Poster

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On January 15, 2025, the European Space Agency's Gaia mission completed its final observations, marking the end of 10.5 years of mapping the sky. Over this period, Gaia successfully observed stars and other objects in the optical spectrum, including 1.6 million compact extragalactic sources.
In parallel, from July 2013 to June 2025, IVS Research & Development sessions focused on regularly observing a subset of these quasars at S- and X-band frequencies. These quasars, known as ICRF-Gaia transfer sources, were either previously unobserved or only sporadically observed by IVS S/X legacy telescopes, and are suitable for aligning the radio and optical celestial reference frames.
This poster showcases the achievements of this 12-year observational program, designed as the "Gaia alignment to ICRF." It presents the scheduling and source selection strategies and demonstrates how these long-term observations have strengthened the connection between the Gaia Celestial Reference Frame and the International Celestial Reference Frame (ICRF). The resulting dataset provides valuable opportunities to further investigate the stability of celestial reference frames and explore quasar properties across radio and optical wavelengths.

Analysis

Abstract 28

TYING TOGETHER LEGACY S/X AND VGOS NETWORKS USING COMBINED OBSERVATION STRATEGY

Poster

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A network of 20+ VLBI stations has been observing in the legacy S/X frequency bands for the last 40 years. More recently, since 2020, a growing network of more than eight broadband stations, known as VGOS, has been conducting observations about once weekly. The long-term goal is for VGOS to eventually replace the S/X observing program. Although the two networks currently coexist, they operate completely independently. To ensure a smooth transition to VGOS that preserves the long-term stability of S/X while providing geodetic products with enhanced accuracy, an integrated approach is essential. Significant efforts have been made to bridge the two networks by conducting simultaneous observations as a unified geodetic instrument, a strategy referred to as mixed-mode observing. Geodetic products derived from these mixed-mode sessions are expected to establish the much-needed global geodetic ties between the S/X and VGOS networks. Two mixed-mode sessions observed in 2020 were included in the ITRF2020 combination. Implementing mixed-mode observing requires extensive customizations, including adjustments in scheduling, correlation procedures, and geodetic data processing. In this presentation, we will describe the observed mixed-mode sessions, detailing scheduling strategies, correlation techniques, and geodetic processing methods used, as well as their implications for global geodetic reference frames such as the ITRF.

Analysis

Abstract 55

VLBI DATA ANALYSIS AT ESA/ESOC

Poster

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[1]PosiTim UG for ESA/ESOC ~ Darmstadt ~ Germany, [2]ESA/ESOC ~ Darmstadt ~ Germany

ESA's Navigation Support Office is responsible for providing the geodetic reference for ESA missions. The office has a long-established analysis capability of the data provided by the three geodetic satellite techniques that contribute to the realization of the International Terrestrial Reference Frame (ITRF), namely GNSS, SLR and DORIS. In the latest years, the Office has been developing its capability to process VLBI data. This endeavour has now reached a mature level, completing the Office's portfolio of space geodetic products contributing to the realization of the ITRF.

All space geodetic products published by the Navigation Support Office are generated with the ESA Precise Navigation System (EPNS) software, ensuring the highest possible consistency in the analysis and processing of the observations provided by the different techniques. Concerning VLBI, the software development targets current IVS modelling and parametrization standards. The latest software version is currently being run automatically on the ESA/ESOC infrastructure, processing R1, R4 and intensive S/X sessions as soon as the relevant vgosDB v4 archives are released on IVS data centres. The results of this analysis are then routinely monitored and ingested as input to the ESA Earth Rotation Parameter Service, together with ESA's results of the data processing of the other geodetic techniques. While the S/X sessions are routinely processed at operational level, the processing of the VGOS sessions is currently under testing. Upon completion of the planned software development, ESA products will be routinely submitted to IVS. A first batch of R1/R4 test solutions has already been submitted to and reviewed by the IVS Combination Center during the summer of 2023 with promising results.

This contribution will present ESA's VLBI processing setup, report on its status, future development, and publication plans, especially in the context of the upcoming GENESIS mission.

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