26th European VLBI Group for Geodesy and Astronomy Working Meeting

11-15 June 2023
Bad Kötzting
Germany

Information and book of abstracts

2023-06-03

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EVGA2023 information

Scientific Organizing Committee (SOC)

- Simone Bernhart (Reichert GmbH/BKG/MPIfR Bonn, DE)
- Sigrid Böhm (Technische Universität Wien, AU)
- Susana Garcia-Espada (Kartverket, NO)
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- Daniela Thaller (BKG Frankfurt, DE)
- Vincenza Tornatore (Politecnico di Milano, IT)
- Nataliya Zubko (Maanmittauslaitos, FI)

Local Organizing Committee (LOC)

- Eva Schroth (LOC chair)
- Torben Schüler (LOC co-chair)
- Alexander Neidhardt
- Christian Plötz
- Thomas Klügel

Series of events during the EVGA2023

Date	Time	Event
11 June	18:00−21:00	EVGA2023 Icebreaker and registration
12 June	08:45−17:45	EVGA2023-day-1
	18:00−20:00	VTC meeting
13 June	09:00−18:00	EVGA2023-day-2
	18:00−23:59	EVGA2023 conference dinner
14 June	09:00−19:00	EVGA2023-day-3 and excursions
15 June	09:00−18:00	IVS Analysis Workshop and splinter meetings

The conference venue is Hotel-Gasthof zur Post, Herrenstraße 10, DE-93444 Bad Kötzting.

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RAEGE capabilities: a simulation study

E. Azcue, M. Karbon, S. Belda, V. Puente, M. Moreira

Abstract

RAEGE (Red Atlántica de Estaciones Geodinámicas y Espaciales / Rede Atlântica de Estações Geodinâmicas e Espaciais) is a project resulting from the cooperation between the National Geographic Institute of Spain (IGN Spain) and the Government of Azores. It is aimed to set up four multi-technique stations: two in Spain (Yebes and Gran Canaria) and two in Azores (Flores and Santa Maria). These stations will stablish a Iberatlantic Very Long Baseline Interferometry VLBI observing network meeting the international requirements needed for VGOS. Currently the VGOS-antennas at Yebes and Santa Maria are operational, the other two are in the planning stage.

The RAEGE project focuses not only on the instrumentation and on operating the observations and stations, but also on developing analysis capabilities. With this objective a cooperation between IGN Spain, Azores Government and the University of Alicante was born for exploding the geodetic observations of the RAEGE observatories for geodetic and geodynamic purposes.

The key feature of this network is its distribution over three tectonic plates (Eurasian, African and North American), which will augment the estimates of the movements between the plates, both in direction and speed and thus improve the TRF (Terrestrial Reference Frame). Major improvements are expected for constraining the rotational component of the African plate, where we have currently only one VLBI station in South Africa and a very sparse network of about 30 IGS-GNSS antennas over the entire continent.

Within this study we want to explore the capabilities of the RAEGE-network in "stand-alone" mode, i.e. wich accuracies can be reached with this network in terms of EOP and station position accuracies, and in a second step we evaluate the performance when expanding the network with additional VGOS-antennas of the IVS network.

Presentation type: oral

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The compatibility of DORIS with VGOS

M. Bautista-Durán, J.S. Ferreira, S. Garcia, H. Hase, J. Kallunki, M. Lindqvist, J.A. López-Pérez, W. Madkour, W. Probst, L.M. Tangen, V. Tornatore, B. Winkel

Abstract

The most precise global geodetic reference frame, the International Terrestrial Reference Frame (ITRF), is based on four space geodesy techniques: Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS) and the Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) System. All four techniques complement each other with their observations for the terrestrial reference frames, because of the individual advantage: VLBI is unique for the Earth orientation parameters and the tie of ITRF to the International Celestial Reference Frame (ICRF), SLR is strong in the determination of the centre of mass of the planet Earth and of the scale in the ITRF, GNSS is good for densification of global networks and of orientation and DORIS technique is unique in the most homogeneous global network of reference sites. In order to combine these advantages in a synergetic way, a co-location of these techniques in geodetic observatories is an objective for progress in global geodesy.

The question of how the desired co-location of DORIS at a VLBI site (or vice-versa) can be achieved is under permanent discussion. 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 2,036 MHz with 40 dBm output power. There is a potential for coupling between DORIS emissions and the VLBI receiving chain generating spurious signals. A risk of overloading or even damaging the VLBI low noise amplifiers (LNA) is possible. Even if in VLBI the same frequency is not being observed, in the worst case the LNA of the VLBI receiver could be saturated by DORIS transmission leading to useless VLBI observations.

Meanwhile, several geodetic observatories collected measurements, made studies, and even co-located active DORIS beacons. The CRAF-VGOS group presents a compatibility study in pycraf with simulations of exclusion zones for DORIS with respect to VGOS radio telescopes. It collates site-specific experiences and may be helpful for future decisions on how to co-locate both techniques at new sites.

Presentation type: poster

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The VGOS High Road: From Inception and Prototyping to Operations to Maturation and Beyond

D. Behrend, C. Ruszczyk, P. Elosegui, A. Neidhardt

Abstract

Legacy S/X has been the production system of the IVS since the inception of the service. VGOS was declared operational in 2020 after a visionary journey that involved designing, prototyping, and demonstrating the feasibility of the new observing system to generate high-quality geodetic products. And a fledgling VGOS network of between 8 and 10 stations has been contributing IVS products operationally ever since. That VGOS network had further increased by the end of 2022 to 12 stations, and counting. Currently, the VGOS observing program encompasses the 24-hour VGOS-OPS and VGOS-RD session series; further, a weekdaily VGOS Intensive series has been established (with other VGOS Intensives being set up). In addition to the network, VGOS correlation capabilities have also expanded to try to keep pace with the increased VGOS correlation load, morphing into a multi-center distributed correlator. In this poster, we will provide a status overview of the infrastructure realization efforts of the VGOS station network and the correlation centers as well as plans for a bright VGOS future.

Presentation type: poster

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Earth orientation parameters estimated from recent Australian mixed-mode and Southern Intensive sessions

S. Böhm, L. McCallum

Abstract

In principle, we can use geodetic Very Long Baseline Interferometry (VLBI) measurements to calculate all types of Earth orientation parameters (EOP), namely celestial pole offsets, polar motion, and UT1-UTC. However, the sensitivity toward the single EOP and the resulting accuracy strongly depends on the network extension, the session duration, and the recording rate. We can expect high-quality estimates from sessions with a well-distributed observation network designed for EOP determination, such as the R1 and R4 sessions. On the other hand, it takes quite a long time from the actual observation to the delivery of the analysis results.

The 24-h sessions observed within the Australian mixed-mode program (AUA/AUM) do not provide a globally extended network of stations. Still, they involve the future potential to deliver results with a short latency. Under this aspect, we investigate the possibilities to determine different sets of or single EOP from the AUA and AUM sessions observed since 2020. The networks usually comprise the Australian stations (Ho, Hb, Ke, Yg) and the telescopes in South Africa (Ht) and New Zealand (Ww). Due to the spatial limitation of that constellation, the estimation of the complete set of EOP is not always favorable. Therefore, different analysis schemes are tested, including treating the 24-h sessions similarly to Intensive sessions. A subset of the telescopes (Hb, Yg, Ht) have been or are involved in observing the so-called Southern Intensive sessions since 2020. In addition to the results of the 24-h sessions, we present the UT1-UTC estimates derived from the latest Southern Intensives (2022, 2023).

Presentation type: oral

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Imaging ICRF3 sources at 0.2 mas resolution with the European VLBI Network at K band

P. Charlot, M. E. Gomez, R. M. Campbell, A. Collioud, A. Keimpema, M. Kettenis

Abstract

We report on the results of imaging ICRF sources at K band (22 GHz) from observations conducted on the European VLBI Network (EVN). These data were acquired as part of the JUMPING JIVE project with the primary goal of measuring the geodetic positions of non-geodetic EVN antennas (i.e. antennas not equipped with the proper dual-frequency S/X (2.3/8.4 GHz) receivers traditionally used for geodesy). To this end, two experiments have been carried out, in June 2018 and October 2020. The EVN includes long East-West and North-South baselines (from Europe to Asia and from Europe to South Africa) along with baselines of shorter and intermediate lengths within Europe, making it a prime network for imaging. In all, 17 EVN telescopes have the capability to observe at K band, allowing for a resolution of 0.2 mas. The vast majority of these telescopes participated in our geodetic experiments. The network for the October 2020 experiment was further augmented with the four e-MERLIN out-stations (in the UK) and the 26 m antenna in Hobart (Australia), thus forming a large array of 22 stations. Scheduling was accomplished by using sub-netting to optimize the sky coverage at each telescope, as in standard geodesy experiments. In this scheme, a minimum of four stations per sub-net was also ensured to provide useful closure quantities for imaging. A total of 125 different sources belonging to the third realization of the International Celestial Reference Frame (ICRF3) were observed in these experiments, two-thirds of which are defining sources. The resulting images may be used to further assess the source compactness – and hence their astrometric suitability – at a frequency and a resolution higher than probed by the standard S/X observations that formed the basis for selecting the ICRF3 defining sources. Future plans include engaging additional such observations, focusing at first on the rest of the ICRF3 defining sources visible by the network, and then going to weaker sources, taking advantage of the large antennas that are comprised in the EVN.

Presentation type: oral

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Bonn Correlator Status

Y. K. Choi, S. Bernhart, H. Rottmann, J. Wagner

Abstract

We report on the status of the Bonn Correlation Center focusing on geodesy.

The Bonn Distributed FX (DiFX) correlator is operated jointly by the Max Planck Institute for Radio Astronomy (MPIfR) in Bonn and the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG). Various versions of DiFX software are used to correlate from IVS S/X legacy sessions to VGOS observations. As one of the IVS correlators we correlate Intensive series (INT3), R1 series as well as OHIG and T2 series for IVS S/X Legacy sessions and VGOS 24-hour sessions. Since October 2021, we upgraded to a commercial 10 Gbps link (NetCologne) for e-VLBI.

In this talk, as well as technical aspects of the cluster and its performance, we summarize our duties as one of the IVS correlators and recent progress.

Presentation type: oral

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Data Identifiers and Metadata for the IVS

G. Coetzer, Y. Takagi, K. Elger

Abstract

In 2000, the International DOI Foundation (IDF) introduced Digital Object Identifiers (DOIs) for unambiguous identification and linking of online articles. Four years later, the first DOI for digital datasets was registered. Since then, millions of DOIs have been minted by customers of Registration Agencies (RAs). A DOI is permanent and can therefore always be used to locate the data object to which it refers. One of the key values of a DOI is that it stays the same, even if the Uniform Resource Locator (URL) of the object to which it is attributed changes. The user can thus always find the data by using the DOI, as long as altered metadata are updated with a new URL.

The International VLBI Service for Geodesy and Astrometry (IVS) is committed to providing quality data and products in support of geodetic, geophysical and astrometric research and operational activities through good Research Data Management (RDM) practices. The use of DOIs can contribute significantly to making data and products generated by the IVS community Findable, Accessible, Interoperable and Reusable (FAIR). An exploratory study to determine best practices for attributing DOIs to datasets and products of the IVS community has been initiated. Here we present feedback on progress with this study, highlighting past and current challenges and providing recommendations.

Presentation type: poster

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The K-band (24 GHz) Celestial Reference Frame: Current Status and Roadmap

A. de Witt, D. Gordon, C. Jacobs, H. Krásná, C. García-Miró, M Johnson, J. McCallum, T. Jung, J. Hodgson

Abstract

The current K-band (24 GHz) celestial reference frame (CRF) consists of 1038 relatively uniformly distributed sources—comparable to the number of regularly observed S/X sources—constructed from just more than 2 million observations (of which 99.5% are from VLBA sessions supported through the USNO's 50% timeshare allocation), a much smaller number compared to the 17.6 million observations used to realise the frame at the lower frequencies. For sources overlapping with the S/X-band frame the median precision of the K-band CRF is 47 μas in right ascension, comparable to the 46 μas of the S/X-band frame, while the median precision in declination is 80 μas for K-band and 58 μas for S/X-band. Looking to the future, the K-band CRF collaboration is developing a roadmap to continually improve the quality of our observations. In order to improve the accuracy of the K-band CRF we are pursuing: (1) improved sensitivity through higher data rates (4 to 8 Gbps) and larger apertures (e.g. the addition of the 40m Yebes telescope in Spain and 50m LMT in Mexico); (2) improved analysis e.g. improved ionospheric calibrations, elevation-dependant weighting, and source structure corrections) and (3) improved geometry by extending our network e.g. the recently started collaborations with Yebes, Spain and the Korean VLBI Network which are expected to improve declination accuracy. We will present the details of such improvements and an estimate of the impact of each improvement.

Presentation type: oral

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Imaging, modelfitting and source structure corrections for the K-band (24 GHz) Celestial Reference Frame

A. de Witt, C. Jacobs, M. Bietenholz, D. Gordon, M. Nickola, L. Hunt, M Johnson, H. Krásná, N. Mwiya

Abstract

The K-band VLBA celestial reference frame program that is supported through the USNO's 50% timeshare allocation, has so far provided high-resolution VLBI images for more than 730 AGN sources at up to 87 epochs. A detailed analysis of the images has allowed us to determine several quantities that provide useful indicators of the quality of each image and the suitability of each source as a calibrator or reference source. In addition, modelfitting has allowed us to determine for each image the angular size and radial extent of the brightest and second brightest component and the position angle between them as well as estimates of the overall extent and direction of the source structure. While VLBI images of CRF sources show that in general they appear more compact at K-band (24 GHz) than at X-band (8.4 GHz), they can still exhibit measurable extended emission at K-band. We started a project to apply structure corrections directly to the data during the analysis process using updated models of the source structure. This is possible because of readily available VLBI images from our dedicated K-band CRF observing campaigns to map and monitor the source structure. We will present an overview of our image analysis and plans to investigate the impact of source structure using all available K-band CRF sources.

Presentation type: poster

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Indian space geodesy project “SaptaRishi”: Current status and outlook

S. Dhar, N. Mammadaliyev, S. Glaser, R. Heinkelmann, H. Schuh, A. Tiwari, A. Laha, B. Nagarajan, O. Dikshit

Abstract

Project “SaptaRishi” is initiated by the National Centre for Geodesy (NCG) established at the Indian Institute of Technology, Kanpur to set up the modern space geodetic infrastructure in the country. The proposed plan of the project is to establish VLBI twin telescopes with SLR and DORIS space geodetic techniques at the existing IGS site to form a core site, and to equip the other two SLR sites with VLBI and GNSS infrastructure. In addition, the project proposes to refurbish existing communication antennas at Arvi, Pune for use in geodesy and astronomical applications. This work presents the past, present, and future status of the project and its detailed science plan. In addition to that, it presents the simulation studies about the impact of adding the VLBI antennas to the global terrestrial reference frame by showing Helmert transformation parameters and precision of geodetic parameters. Furthermore, the u-v coverage of some radio sources from the southern hemisphere of the celestial reference frame is examined in observing networks with and without the proposed antennas. The proposed VLBI stations are also scheduled and simulated to observe the NAVIC (Navigation with Indian Constellation) satellites along with quasars to assess their potential contribution to the Indian satellite navigation system. Overall, the current work aims to publicize the explicit objectives and development of India’s space geodesy project.

Presentation type: oral

Sujata Dhar[1,2], Nijat Mammadaliyev[1,3], Susanne Glaser[1], Robert Heinkelmann[1], Harald Schuh[1,3], Ashutosh Tiwari[4], Arnab Laha[2], Balasubramanian Nagarajan[2], Onkar Dikshit[2]
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Eliminating the Wiggle in the Wobble

C. Dieck

Abstract

Previous analysis of the MK-VLBA:PIETOWN Intensive series observed by the US Naval Observatory has demonstrated a periodic signal in the UT1−UTC estimate residuals with respect to multiple reference series. The same analysis also suggested that the periodic signal may be present in the UT1−UTC residuals of the IVS KOKEE:WETTZELL Intensive series. Following the discontinuation of the MK-VLBA:PIETOWN series, the periodic signal is shown to be present in the HN-VLBA:MK-VLBA series which replaced it, though with a smaller amplitude. Investigation into the characteristics of the periodic signals, combined with a review of the parameterization of the USNO VLBI Analysis Center's Intensive solution, indicates that the lack of including the celestial pole offset Earth orientation parameters is the root cause of the periodic signal. Building on theoretical and simulation studies regarding the impact of incorrect orientation of the celestial pole, this empirical study conclusively shows that celestial pole offsets are required to be added to the precession-nutation model, even when estimating UT1−UTC with Intensive sessions. Additionally, because of the increased sensitivity of the MK-VLBA:PIETOWN geometry to errors in a priori model values, this study demonstrates the value of such a series through its ability to validate the models.

Presentation type: oral

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On the use of water vapour radiometry for assessment of wet delay estimates from space geodetic techniques

G. Elgered, T. Ning

Abstract

During the development of the Mark III VLBI system in the seventies, water vapour radiometers (WVR) were envisaged to provide independent observations of the signal propagation delay due to water vapour along the line of sight. The standard design of the WVR is to measure the atmospheric emission at two frequencies, close to and further away from the centre of the water vapour emission line at 22.2 GHz. These measurements are used to estimate two unknowns, the amount of water vapour, or the wet delay, and the amount of liquid water, along the line of sight. The main drawback of using a WVR is that the retrieval algorithm requires that any drops of liquid water in the sensed volume of air are much smaller than the wavelength observed by the WVR, i.e. approximately 1 cm. The algorithm therefore more or less breaks down during rain, meaning that the instrument cannot be relied on for 100 % of time, unless it never rains on, or close to, the site. The method generally used to avoid using WVR data with poor accuracy is to ignore observations obtained during rain and when the inferred liquid water content is above a specific threshold. However, there are a couple of difficulties with these procedures. (i) There may be rain drops in the sensed atmospheric volume in spite of the fact that no drops are detected at the ground on the site; (ii) there may still be drops of water on the WVR instrument, such as on the protective covers of the horn antennas and the mirrors many minutes after the rain has stopped; (iii) a low density of large drops may result in a smaller liquid water content than many small drops.

We have used WVR data from 2022 together, with rain observations, to study the retrieval accuracy by comparing them to wet delay estimates from the GNSS station ONSA. We search for general rules of thumb searching for periods when WVR and GNSS data offer the best agreement in the equivalent zenith wet delay, given the rain observations and the inferred liquid water content. The first preliminary results, that will be updated for the presentation, are summarised as follows. First all rain periods were deleted from the WVR data as well as all observations resulting in a equivalent zenith liquid water content (LWC) larger than 0.7 mm. For each 5 min period having more than 30 WVR observations, spread over different directions on the sky, the equivalent zenith we delay (ZWD) and linear horizontal gradients were estimated. This resulted in 86,162 data points, corresponding to a time coverage of 82 % of the year. After synchronising with the available GPS ZWD, there are 85,313 data points resulting in a mean bias (WVR−GPS) of 4.5 mm and a standard deviation of 5.2 mm. When ignoring all WVR estimates with a mean absolute value of LWC, over the 2 min period, larger than 0.05 mm, there are 60,869 data points (58 % of the year covered), and 60,180 remaining after after synchronising with GPS ZWD. Now, as expected, the agreement for the ZWD is improved. We get a mean bias 3.3 mm and a standard deviation 4.3 mm. We conclude that using WVR data for validation of ZWD estimates in space geodesy is a balance between data availability and data accuracy.

Presentation type: poster

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Radiometry performance of a VGOS receiver

G. Elgered, P. Forkman, R. Haas, E. Varenius

Abstract

With the introduction of the VLBI Global Observing System (VGOS) the parallel use of the VGOS receiver as radiometer in order to estimate the wet propagation delay was recognised as a future possibility. That is when observations can be carried out at higher frequencies, closer to the water vapour emission line at 22.2 GHz. An advantage of having the radiometer in the VLBI telescope, compared to the use of a stand-alone Water Vapour Radiometer (WVR), is that the radiometer will observe the same atmospheric volume that is causing the signal propagation delay.

We have assessed this method using simulations and arrived at the following two important conclusions: (1) the receiver's measurements of the sky brightness temperature is likely to be the main error source, rather than the algorithm error introduced when calculating the wet delay from the observed sky brightness temperatures; (2) the method requires an extension of the frequency range of the receiver well beyond 14 GHz in order to increase the sensitivity for water vapour. The radiometric measurements shall be made within a couple of GHz from the emission line at 22.2 GHz.

In spite of the fact that the present VGOS receivers observe at too low frequencies we find it meaningful to assess the radiometric stability of these receivers at the higher end of the frequency band. We have used one of the Onsala Twin Telescopes for this purpose, which is able to observe both polarizations in the frequency band 15.36–15.58 GHz. The system temperature has been observed at different elevation angles in order to separate the atmospheric sky brightness temperature and the receiver noise temperature. The observations are carried out during different atmospheric conditions and the estimated sky temperatures are compared to the observations done with one of our stand-alone WVRs. By using one-frequency algorithms we may also, during cloud-free conditions, compare the wet propagation delays using 20.7 GHz observations from the stand-alone WVR and 15 GHz observations from the VGOS receiver.

Presentation type: poster

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Enhancing the Bernese GNSS Software for multi-technique analysis at BKG - Focus on the VLBI implementation

C. Flohrer, A. Walenta, D. Thaller, C. Gattano, R. Dach, U. Hugentobler

Abstract

The Geodesy Group of the BKG (Federal Agency for Cartography and Geodesy) has been involved in IVS analysis and combination activities for many years. It successfully operates an IVS Analysis Center (using NASA's software packages νSolve and Calc/Solve) and the IVS combination centre (using the DFGI-TUM software package DOGS_CS). BKG also operates an ILRS analysis center and is a partner in the CODE consortium, which operates the IGS analysis center CODE at the AIUB (Astronomical Institute of the University of Bern). Both analysis centers are using the Bernese GNSS Software, which is developed by AIUB and continuously adapted to changing requirements and user needs.

Currently, BKG uses different software packages for different space-geodetic techniques. However, our focus is not only on the individual techniques, but also on the combination of the different observation techniques, in particular to improve the Earth rotation parameters. We would like to continue the multi-technique combined analysis using a single software package, namely the Bernese GNSS Software. Ultimately, this will allow us to combine GNSS, VLBI and SLR data not only at SINEX level, but also at the observation level in the near future. We present the current status of the Bernese GNSS Software enhancements for the analysis of VLBI data. We also compare the results of the VLBI data analysis derived from Calc/Solve with those derived from the Bernese GNSS Software. For the latter we use the unconstrained normal equations from Calc/Solve as input and discuss different options for constraining station and quasar coordinates.

Presentation type: oral

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Status at Ny-Ålesund Geodetic Earth Observatory

S. Garcia-Espada, R. Bolano Gonzalez, L.M. Tangen, T. Gasmoe, A. Meldahl, G. Grinde, P.E. Opseth

Abstract

The current status of the Ny-Ålesund Geodetic Earth Observatory will be presented. Special focus will be placed on the status of the VGOS twin telescopes (Ns, Nn) operations and of the legacy 20-meter antenna (Ny) to be dismantled during autumn 2023.

Presentation type: oral

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Operational KOKEE12M–WETTZ13S VGOS Intensives

J. Gipson, K. Baver, F. Lemoine, M. Davis

Abstract

Since January of 2021 the GSFC VLBI group in collaboration with USNO scheduled and analyzed a series of intensives using the Kokee12M and Wettzell13M VGOS antennas. These intensives were scheduled to run simultaneously with the Kokee–Wettzell S/X intensives. In terms of several metrics (agreement with UT1 estimates from R1s/R4s and agreement with external series such as C04, USNO, or JPL), the VGOS intensives are as good as or better than the S/X intensives. These results were reported at the IVS 2022 General Meeting and are updated with more recent data. An obstacle towards using the VGOS intensives operationally is that the formal errors are unrealistically small with respect to the accuracy of the UT1 observation, which results in problems with integrating the VGOS intensives into the IERS Rapid Service / Prediction Center's (RS/PC) combined Earth Orientation Parameters (EOP) solution. We were able to solve this problem by replacing the formal errors of the VGOS intensives with the predicted scatter in UT1 estimates. This scatter is computed by a simulation program which adds noise to the delay, finds the resulting change in UT1, repeats this process many times, and calculates the RMS scatter of the UT1 estimates. Using the scatter instead of the formal error results in more realistic estimates of the error of the UT1 estimates. It also results in better agreement with the RS/PC UT1 estimates and the JPL series (both of which do not use VGOS data in their EOP combination). Based on these results, the RS/PC plans to begin using the VGOS intensives in its operational products in spring of 2023.

Presentation type: oral

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Investigating the datum parameters of new solutions by IVS AC DGFI-TUM

M. Glomsda, M. Seitz, M. Bloßfeld, D. Angermann

Abstract

In 2022 and at the beginning of 2023, the three latest realizations of the International Terrestrial Reference System (ITRS) became available: ITRF2020, JTRF2020, and DTRF2020. Among others, the data contribution by the International VLBI Service for Geodesy and Astrometry (IVS) to these reference frames contains new models for the gravitational deformation of six VLBI antennas. In particular, these models affect the estimated heights of the corresponding stations.

In 2023, the IVS Analysis Centers (ACs) reprocessed their session series from 1979 to the present. The respective series of the AC at DGFI-TUM is *dgf2023a*. The main changes w.r.t. the previous series *dgf2020a*, which served as input data for the ITRS 2020 realizations, are a) the usage of ITRF2020 as a priori reference frame, and b) the corrections for the gravitational deformation of another seven antennas. Thereby, the choice of stations used for the no-net-translation and no-net-rotation conditions is a crucial issue. Furthermore, the additional deformation models will likely influence the scale parameter of similarity transformations between VLBI single-session solutions and the ITRS realizations. Three of the corresponding seven antennas belong to the next generation VLBI Global Observing System (VGOS).

In this presentation, we examine the effects of the above mentioned novelties in solution *dgf2023a*. In particular, we take a look at the similarity transformations, i.e., the time series of datum parameters, and we put special emphasis on the scale parameter. Above all, a drift in the VLBI scale was observed for sessions after about 2013.75 during the computation of the ITRF2020. Not least to investigate this finding, we also apply the other two ITRS 2020 realizations, JTRF2020 and DTRF2020, as a priori reference frames.

Presentation type: oral

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Close-Range Photogrammetry for Antenna Deformation Measurements

A. Greiwe, R. Brechtken, M. Lösler, C. Eschelbach, G. Kronschnabl, C. Plötz, A. Neidhardt

Abstract

The knowledge of gravitational deformations at the receiving unit of VLBI antennas is one of the crucial components in achieving the GGOS accuracy goal of 1 mm in position on a global scale. Various geodetic methods for measuring the object geometry of the antenna's receiving unit are known such as terrestrial laser scanning (TLS) or close-range photogrammetry to cite but a few. The advantage of a photogrammetric approach compared to surface measurements by a single TLS station is the complete coverage of the surface by varying camera positions. Thus, surface points potentially shaded by structural elements are also captured. Moreover, for signalized markers and under optimal conditions, close-range photogrammetry achieves an accuracy of up to 5 µm + 5 µm m^{-1}.

Due to the high accuracy requirements, a photogrammetric approach was chosen for the deformation measurements of the legacy 20 m Radio Telescope Wettzell (RTW) for the first time. To realize a stable an reliable block geometry configuration, a remote controlled unmanned aerial vehicle (UAV) was used as sensor platform. Signalized markers mounted at the receiving unit of the RTW were measured in ten elevation positions to investigate elevation dependent deformations. In each elevation position, image data were captured at least twice to obtain redundant data sets. Up to four flights were performed in selected elevation positions using different camera systems. This contribution presents the results of the photogrammetric analysis of this extensive data material.

Keywords: Close-range photogrammetry, Gravitational deformation, Radio telescope, VLBI

Presentation type: oral

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Atmospheric parameters derived from VGOS sessions observed with the Onsala twin telescopes

R. Haas, G. Elgered, J. Johansson, T. Nilsson, T. Ning

Abstract

In order to improve the accuracy and precision of the estimated geodetic parameters by one order of magnitude compared to the so-called legacy S/X VLBI system, the International VLBI Service for Geodesy and Astrometry (IVS) developed the next generation VLBI system, called the VLBI Global Observing System (VGOS). VGOS is still in its build-up phase and by the end of 2022 the VGOS operational network had reached 10 globally distributed stations. These VGOS stations are equipped with fast-slewing radio telescopes, typically 12–13 m in diameter, with broad-band receiving devices of reasonably high sensitivity, and with digital backends with high sampling capability. Among those is the Onsala Space Observatory which is operationally active with its VGOS twin telescopes since 2019.

At least a factor of two in the number of observations per station is currently achieved within operational VGOS sessions (VO), compared to standard S/X legacy VLBI sessions. An even larger number of observations has successfully been achieved in dedicated VGOS Research and Development (R&D) sessions (VR) through minimizing the scan lengths.

Due to this large number of observations and their good local sky distribution, it becomes possible to resolve atmospheric parameters, e.g. zenith total delays and linear horizontal gradients, with high temporal resolution. We analyse VGOS sessions in both the VO- and the VR-series in order to assess the current ability of VGOS to sense small-scale, rapid variations in the signal propagation delay caused by the neutral atmosphere. The VGOS-derived results are compared to results from simultaneous observations with co-located instrumentation at Onsala, i.e. the ground-based microwave radiometer as well as receiving stations of signals from Global Navigation Satellite Systems (GNSS).

Presentation type: oral

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Characterization of the Atmospheric Turbulence using the Outputs of Assimilation Numerical Weather Models

N. Habana, L. Petrov

Abstract

We used the output of a high resolution numerical weather model, from the so called NASA Global Modeling and Assimilation Office Nature Run with a spatial resolution 7 km and time resolution 30 minutes for characterizing stochastic properties of the atmosphere. We have computed dense time series of slant path delay on a grid of elevations and azimuths for over 250 VLBI sites by directly integrating the propagation of radio waves through the heterogeneous atmosphere with the refractivity field computed from the output of the numerical weather model. We also computed time series of sample time and spatial covariance spatial covariance functions. We compared our results with the so called IVS turbulence model and found a gross deficiency of that model. The implications of our findings on analysis and simulation of VLBI geodetic data are discussed.

Presentation type: oral

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Study of Baseline Telemetry at NASA VGOS Sites

N. Habana, L. Petrov, L. Hilliard, D. Hudson, J. Dorman, K. Pazamickas, E. Terrazas, C. Coughlin

Abstract

Over the past year, we have been running up to 60 hour long single dish experiments at three VGOS stations, namely, Goddard Geophysics and Astronomy Observatory (GGAO) in Maryland, MacDonald Geological Observatory (MGO) in Texas, and Kokee Park Geophysical Observatory (KPGO) in Hawaii. Together with the VLBI data from VGOS sessions we have studied telemetry data, at the aforementioned sites dating as far back as 2019. We present the baseline telemetry at each antenna, along with the assessment of the levels of natural variability of the monitored parameters when antennas are perfoming normally. Specifically, the telemetry assess are the system temperature ($Tsys$), phase calibration phase and amplitude, and the antennas formatter minus GPS clock.

Presentation type: poster

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Obtaining Local-Tie Vectors from Short-Baseline Interferometry between legacy S/X and VGOS Telescopes

R. Handirk, E. Varenius, T. Nilsson, R. Haas, A. Meldahl, S. A. Grøslie Wennesland, T. Gasmoe, R. Bolaño González, S. Garcia-Espada

Abstract

With the VLBI Global Observing System (VGOS) being the next step in the development of geodetic VLBI, it is necessary to connect the new VGOS network to the existing legacy S/X telescopes. Specifically designed short-baseline interferometry sessions aim to obtain local-tie vectors between these telescope generations at observatories that have both legacy S/X and new generation VGOS telescopes.

At the Onsala Space Observatory (OSO), this is being done by sessions referred to as ONTIE, including the VGOS Onsala twin telescopes ONSA13SW and ONSA13NE and the legacy antenna ONSALA60. First results were published in 2021. Since then, more sessions have been carried out, with different frequency set-ups and session durations.

Similarly, since 2020, short-baseline interferometry sessions referred to as NYTIE have been performed at Ny-Ålesund, involving the VGOS telescope NYALE13S and the legacy S/X antenna NYALES20, but results have not been published yet.

Previous interesting and still unresolved findings of the ONTIE sessions include unexpected offsets in the results of group and phase delay analyses, jumps in the coordinates of the twin telescopes, and apparent seasonal signatures that might be an artifact of unmodelled thermal expansion of the telescopes that are left in the data.

We analyse the NYTIE sessions in order to compare the group and phase delay results of the ONTIE and NYTIE time series. We also compare the differently dense time series to identify any seasonal signals that may be present.

Presentation type: oral

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Investigating software specific dependencies within the intra-technique VLBI combination

H. Hellmers, S. Modiri, S. Bachmann, D. Thaller, M. Bloßfeld, M. Seitz

Abstract The IVS Combination Centre generates and releases the combined VLBI products of the International VLBI Service for Geodesy and Astrometry (IVS). These solutions are generated session-wise by applying an intra-technique combination of the individual contributions delivered by multiple IVS Analysis Centres (AC). For the twice-per-week R1/R4 combination, there are eleven different ACs contributing pre-analysed 24-h VLBI observations consisting of datum free normal equations (NEQ) in SINEX file format. Station coordinates, source positions and full sets of Earth Orientation Parameters (EOP) are parameterized. As the same software packages are used by various ACs (e.g. CalcSolve by five ACs), the combined solution is in danger of being dominated by these contributions. The estimates of EOP and station coordinates could be affected then mainly by the software specific modelling. In this contribution we study the impact of such software dependencies on the final combined parameters. We investigate an enhanced weighting strategy for the individual contributions in order to better handle potential dependencies due to identical software packages. Thereby, software specific sub-combinations are carried out in the first step. Finally, the ultimate combination consists of the weighted individual contributions of each applied software. In order to assess the quality of the individual components of the combination the internal as well as the external comparisons of the estimated EOP are carried out. In this context, the combined solution as well as external time series (e.g., IERS Bulletin A) serve as reference.

Presentation type: oral

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Twin Telescope Tests: Tying Goldstone Antennas at the mm level

C.S. Jacobs

Abstract

Each of NASA"s three Deep Space Network (DSN) sites has multiple large antennas capable of acquiring VLBI data. The long range plan is to have four 34-meter antennas at each site. At present Goldstone has three; with another under construction. These antennas offer the opportunity to do connected element interferometry (CEI) over the few hundred meter baselines within each complex. Given that all antennas within a site are of nominally the same structural design, are run off the same clock, observe through almost the same atmosphere, and are subject to almost the same geophysics, doing CEI experiments is an excellent way to probe the limits of VLBI accuracy and expose station specific systematic errors. This paper will report on results from the Goldstone California complex over 2016 to 2023 which achieved a per pass baseline precision of about 0.2 mm horizontal and 1 mm in the vertical. There is evidence for 1 mm level systematics. Based on this data we will discuss the implications for whether the IAG's goal of 1mm station stability in VLBI geodesy is possible for large DSN antennas.

Presentation type: oral

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The X/Ka 2023a Celestial Frame

C.S. Jacobs, S. Horiuchi, D. Firre, Y. Murata, H. Takeuchi, T. Uchimura, K. Numata

Abstract

The X/Ka-band (8.4/32 GHz) Celestial Reference Frame became one component of the ICRF-3 in 2018. In the five years since, the X/Ka data set has increased by about 75% as well as adding the much needed north-south geometry from Japan to Australia. The latest solutions have median formal precisions of 44 μas in $\alpha \cos\delta$ and 65 μas in δ. The large spherical harmonics distortions seen in the ICRF3-XKa are greatly reduced with the Z-dipole term reduced from 314 μas to statistical insignificance and with the quadrupole 2,0 magnetic term reduced to ~ 100 μas. Noting that the X/Ka frame is derived from a limited geometry of only five observing sites, we discuss the susceptibility of this frame to geometric distortion. Finally, we discuss the prospects for future improvements.

Presentation type: poster

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The Australian VGOS Observing Program

A. Jaradat, G. Molera Calvés, T. McCarthy, J. McCallum

Abstract

This presentation provides an update on the transition of the AuScope Very Long Baseline Interferometry (VLBI) array to the VGOS mode, which aims to achieve millimetre precision. The Australian VGOS observing program (AUV) was launched in 2021 to conduct VGOS experiments on the HOBART12-KATH12M baseline, with a fortnightly cadence and 12-hour duration. The scheduling strategy is continuously improved, and the scan duration has been optimised to balance the number of scans with the total data volume and the SNR.

In this presentation, I will detail the feedback obtained from the observations, including the sensitivities of the baseline and stations across different frequency bands, the identification and mitigation of radio frequency interference (RFI), and the corresponding frequency setup. The baseline length repeatability is the primary metric to assess the measurement precision. Overall, progress towards achieving millimetre-level precision with VGOS is highlighted, along with the ongoing efforts to optimise the observation strategy and improve the results.

Presentation type: oral

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Cross-polarization bandpasses of VGOS antennas

F. Jaron, I. Martí-Vidal, M. Schartner, J. González-García, L. Petrov, J. Gruber, J. Böhm

Abstract

VGOS antennas observe in dual linear polarization mode. To obtain the maximum signal-to-noise ratio, the correlator visibilities have to be combined to Stokes I for fringe-fitting. For this processing step it is essential to calibrate the complex gain differences between the two linear feeds of each antenna. With the aim of better understanding the cross-polarization gains of VGOS antennas, we carried out an R&D session with a network of six antennas. The data allow us to measure the cross-bandpasses with high quality and to explore their temporal evolution over the six hours of the session. Here we present our results and discuss possible implications for future calibration strategies.

Presentation type: oral

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Exploring different methods to describe source position variations.

M. Karbon, S. Belda, A. Escapa and J.M. Ferrándiz

Abstract

The positions of the radio sources in the ICRF3 catalog, representing the newest realization of the Celestial Reference Frame (CRF), are given as a time invariant coordinate pair. However, systematic changes of source positions at different spacial and temporal scales are well documented. Failing to acknowledge such source behavior might lead to a deterioration in the quality of the frame, and thus in all derived variables, e.g. the orientation parameters of the Earth (EOP). One approach to overcome these shortcomings is the parametrization of source positions, similar to what is applied to the positions of the station.

We present several feasible approaches to parameterize all the source positions observed within the IVS data archive, based on linear or cubic parameterisation, Kalman filtering and machine learning. We produce celestial reference frames based thereon, together with a list of consistent defining sources. We compare the resulting frames with the conventional ICRF3 as well as the Gaia frame to uncover eventual deformations and their origin. Further we examine the resulting EOP and station positions and give an evaluation of the precision and accuracy of the parameters as well as the parameterisation method.

Presentation type: oral

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VLBI signals transmitted from Earth orbiting satellites

Ö. Karatekin, H. Sert, V. Dehant, B. Ritter, H. Vasseur, U. Hugentobler

Abstract

Creating an absolute space-tie where all the geodetic methods are onboard is the key for an improved and stable terrestrial reference frame as well as with various scientific applications. Such satellite concepts like GRASP and E-GRASP are already proposed to achieve an accurate and stable terrestrial reference frame. One of the most crucial and novel aspect of such concepts is the VLBI transmitter (VT) which will emit quasar-like signals to be observed by the VLBI ground stations. VT can directly link the terrestrial and celestial reference frames and bring the unique features of VLBI technique to an Earth orbiting satellite. In the context of call for future Galileo payloads a novel VT has been under development by a consortium led by Antwerp Space with the participation of Royal Observatory of Belgium. The VT instrument is designed to transmit simultaneously upto 4 wideband signals within 2 to 14 GHz with a power spectral flux density of less than few Jansky (10^{-26} W/m^2/Hz per hertz) at the surface of the Earth, in order to enable observations by VLBI ground stations and be in compatible with legacy and GGOS VLBI stations.

Recently, ESA FutureNAV programme includes one component to implement the GENESIS mission, consisting of the colocation, for the first time ever, of the four space-based geodetic techniques (GNSS, VLBI, SLR and DORIS) aboard a single well-calibrated satellite establishing precise and stable ties between the key geodetic techniques. This will result in a unique dynamic space geodetic observatory, which combined with the measurements of geodetic collocation techniques stations on Earth, shall allow contributing to a significant improvement of the International Terrestrial Reference Frame (ITRF).

Here we present the progress on ongoing ESA study for VT on future Galileo and perspectives of VT on GENESIS mission.

Presentation type: poster

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Mitigating the effect of source structure in geodetic VLBI using closure delays and baseline-to-jet orientation

N. Kareinen, N. Zubko, T. Savolainen, M.H. Xu, M. Poutanen

Abstract

The radio sources observed with geodetic Very Long Baseline Interferometry (VLBI) should ideally be strong and point-like. However, especially with VLBI Global Observing System (VGOS) observations and improved observing capacity most of the celestial sources exhibit finite structure. Radio source structure has been identified as a major source of error for VGOS, as well as also affecting the legacy VLBI observations. The extended structure causes an additional delay to the observables which, if not modelled or accounted for, will affect the estimated geodetic parameters. We investigate mitigating the impact of source structure by re-weighting the observations by parameterizing the source structure component in terms of closure delays and baseline-to-jet orientation. The re-weighting scheme was implemented in the Vienna VLBI Software (VieVS). In this work, we focus on the CONT17 S/X Legacy observations. The performance of the extended stochastic model is assessed by analysing the CONT17 sessions using different weighting schemes and comparing them to the respective reference solutions. Closure delays and jet position angles were estimated for the observed sources, from which source structure-based noise terms are calculated for each observation. The effects of the re-weighting are evaluated by inspecting the session fit statistics, source-wise residuals, and geodetic parameters. This relatively simple approach consistently improves the session fit by on average 5.5% with moderate variation from session to session.

Presentation type: poster

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Neglected issues of terrestrial datum definition in VLBI

L. Kern, H. Krásná, A. Nothnagel, J. Böhm, M. Madzak

Abstract

Very Long Baseline Interferometry (VLBI) observations describe the relative relationship between the stations within the observing network, resulting in a precise three-dimensional point cloud at a specific epoch. A geodetic datum describes the absolute location, orientation and scale of this point cloud with respect to a target frame by introducing certain conditions. This additional information ensures that the normal equations are regular, invertible and therefore solvable.

Today, the ”no-net-translation (NNT) and no-net-rotation (NNR)” approach is widely used. In this case, a condition matrix is formed to map a set of coordinates (and velocities) onto a conventional system, not allowing any net translation or rotations. Another widely used approach is ”Helmert rendering”, in which the Helmert parameters of the transformation are added to the system and are forced to be zero. This results in the determination of coordinates that deviate from the reference frame in a way such that the sum of the translations and the rotations with respect to the reference frame is zero. In both cases, the datum-free normal matrix is regularized with a datum matrix which needs to belong to the same family as that of a spectral decomposition into an Eigenvector system. A permitted alternative is scaling of the datum matrix so that the length of each column is one. In this presentation, we explain the background and discuss the implications of proper scaling and approximations.

Presentation type: oral

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Combined Earth Rotation Parameters based on homogenous VLBI and GNSS data: A closer look at today's VLBI Intensives

L. Klemm, D. Thaller, C. Flohrer, A. Walenta, D. Ullrich, H. Hellmers

Abstract

We present BKG´s current activities related to combined data processing of different space-geodetic techniques. The primary goal of the combined analyses is the improvement of the consistency between the techniques through common parameters, mainly Earth Rotation Parameters (ERP), and thereby to improve also the resulting ERP. In previous studies, we have investigated different combination approaches using VLBI and GNSS data and generated ERP series with latencies of about 1-2 or 14 days, depending on the input data we used. In this way, we achieved a significant improvement in accuracy, especially for the dUT1 series, compared to the individual technique-specific solutions. The processing is based on homogenized datum-free normal equations (provided via SINEX files), which allow a rigorous combination on the normal equation level instead of the observation level.

Our main objective is to generate an ERP product that is characterized by a continuous, daily and regular resolution and the shortest possible latency, especially for the highly variable dUT1. The requirement for achieving these characteristics is the daily and rapid availability of the input data, especially of the VLBI Intensive sessions. We noticed that the series of daily SINEX files of the legacy (S/X) VLBI Intensive campaigns had some gaps in the past. The reasons for this are manifold and can be found throughout the entire VLBI processing chain, i.e., from observation to analysis. However, in the last two years, an increasing number of VGOS Intensive campaigns has been conducted in addition to the legacy Intensives. As a result, the Intensive series is nowadays almost without gaps and there are even more than one Intensive sessions (up to 6) available per day. In our recent studies, we compare the VGOS and legacy Intensives data in terms of their latency and the quality of the resulting dUT1 estimates and integrate them into our combination process. We present also the challenges of extending the combination with the new VGOS data. Its incorporation will eventually pave the way for establishing an operational ERP product at BKG.

Presentation type: poster

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The benefits of the Australian mixed-mode program (2018 - 2023) for the celestial reference frame at S/X-band

H. Krásná, L. McCallum, T. McCarthy

Abstract

The current realization of the International Celestial Reference Frame at 8.4 GHz, the ICRF3-SX, is computed from Very Long Baseline Interferometry measurements starting in 1979 until March 2018. The concentration of the majority of VLBI telescopes in the Northern Hemisphere reflects itself in the unequal distribution of observations to radio sources over declination which causes the ICRF3-SX to be weaker in the south. One of the current VLBI observing programs active in the Southern Hemisphere is the Australian mixed-mode program (AUM) which started to be organized in July 2018.

In this presentation, we show the benefits of the AUM for the celestial reference frame and also discuss its current limitations. We concentrate particularly on a block of dedicated 24-hour sessions scheduled between August 2022 and April 2023 (AUM49-72) which were prepared with the aim to observe target sources in the south, that have a low number of observations in ICRF3-SX. The individual sessions were scheduled for currently available VLBI telescopes (Hb, Ke, Yg for the first block, then also including Ho and Ww in the second block in 2023). In terms of scheduling, the sessions were scheduled geodetically, i.e. aiming for a high number of scans. In each session, five target sources were observed in 4-5 scans of 10 minutes duration. This setup still ensures about 25 scans/hr/station, which is seen as a foundation even for good geodetic results.

Presentation type: oral

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VGOS for AGGO

Christian Kristukat[1], Hayo Hase[1], Federíco Salguero[2], Martín García[2], Augusto Cassino[2], Mauricio Gende[2]

Abstract

We report on the intention of the Bundesamt für Geodäsie und Kartographie (BKG) for the instalation of a VGOS antenna at the Argentinian German Geodetic Observatory (AGGO) at La Plata, Argentina. By integrating a VGOS antenna, and being a candidate for the installation of a DORIS beacon, AGGO aims at becoming a full GGOS site. We are currently in an early project phase during which we analyze the special conditions of the site and their impact on the project planing and the technical specifications of the antenna. AGGO is located between two metropolian areas and near an international airport, therefore special attention must be paid to the design of the feed in order to minimize the impact of surrounding radiation while assuring compatibility with the VGOS standard, which is still under discussion. Due to our location, many of the long-baseline observations have to be done at low elevation angles. The horizon mask at the site is defined by the surrounding trees which are whithin a natural reserve and their removal is almost impossible due to local regulations. Therefore the antenna will need a rather massive and high base. As AGGO is a joint endavor between BKG and CONICET the administrative and legal aspects of the project are rather challenging. The project planning phase should be terminated until end of 2024. The first observation is expected to happen around 2030.

Presentation type: oral

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Performance and technical equipment for the VGOS radio telescope TTW1 (Wn)

G. Kronschnabl, F. Kroner, A. Neidhardt, C. Plötz

Abstract

The VGOS radio telescope TTW1 (Wn) was over 9 years (2013 to 2023) involved within most of the VLBI observation programs of the IVS. The radio telescope was equipped with the so-called Triband feed, which was able to receive radio signals at S/X and Ka-Band. Now it is intended to introduce Wn as a second VGOS radio telescope at the GOW. We will represent the performance of the QRFH feed together with some new installed hardware.

Presentation type: poster

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Comparison between VLBI and other space geodetic techniques for determining Earth orientation parameters

A. Laha, J. Böhm, S. Böhm, O. Dikshit, B. Nagarajan

Abstract

Very Long Baseline Interferometry (VLBI) is the only space geodetic technique capable of providing the complete set of Earth Orientation Parameters (EOP) required for the accurate transformation between celestial and terrestrial reference frames. This study aims to generate long EOP time series (2001-2022) with the Vienna VLBI and Satellite Software (VieVS) with various parameters and settings, such as the representations of EOP with piecewise linear offsets, estimation time intervals, and the handling of station and source constraints. As part of the study, different space geodetic techniques will be compared and combined at the solution level to analyse and produce a single time series of the EOP and Length of Day (LOD). The study will focus on the comparison of EOP obtained from VGOS sessions and S/X sessions.

Presentation type: poster

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Exploring reasons for the ITRF2020 VLBI scale drift

K. Le Bail, T. Nilsson, R. Haas, M. Mouyen

Abstract

Since the release of the new realisation of the International Terrestrial Reference System, the ITRF2020, one of the focuses of the IVS community is to understand the cause of the drift in the VLBI scale factor time series detected by the ITRF team after 2013.75.

This work is an update on the investigations we presented at the 2022 REFAG meeting in October. We consider the OSO contribution to ITRF2020, submitted to the IVS Combination Center, and calculate the scale factors w.r.t. ITRF2020, w.r.t. DTRF2020 and w.r.t. JTRF2020. We compare these three terrestrial reference frames and identify discrepancies. We are interested in comparing station position modelling between VLBI stations and GNSS stations at the same sites, both in terms of discontinuities and post-seismic deformation models. We show how different geophysical modelling affect the VLBI scale.

Presentation type: oral

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Update on the VGOS-INT-S Program between MACGO12M and WETTZ13S

F.G. Lemoine, C. Plötz, M. Schartner, A. Walenta, L. Petrov, E. Terrazas

Abstract

We present a status of the VLBI Intensive program VGOS-INT-S observed between McDonald Observatory (*MACGO12M*) and Wettzell (*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 of developing a new baseline for UT1 determination, testing new scheduling strategies, and working to automate the data transfer and the data analysis pipeline. Two goals of the program were to observe sources with a more SNR-targeted strategy, and to rapidly switch between high- and low- elevation scans to enable an improved determination of delays caused by the neutral atmosphere. Since the program inception, we have successfully observed 25 Intensive sessions, observing once per week, when both VGOS stations were available. The performance in early 2022 achieved a $\sigma_{UTC-UTC}$ of 3.1 μs, but later the performance degraded due to different technical issues. We report on VGOS-INT-S performance after a hiatus in observations from November 2022 to March 2023. We also discuss the comparison of delays determined from the VGOS data with those from nearby GNSS stations at Wettzell and McDonald. We conclude with a perspective on future plans for the observing program.

Presentation type: poster

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On the consideration of frequency-dependent illumination functions in modelling signal path variations

M. Lösler, G. Kronschnabl, C. Plötz, A. Neidhardt, C. Eschelbach

Abstract

Investigations on the deformation behaviour of the receiving unit of large radio telescopes used for Very Long Baseline Interferometry (VLBI) indicate several elevation-dependent deformation patterns. These include, for instance, elevation-dependent deformations of the main reflector dish, variations in the position of the sub-reflector or the main reflector, or tilts of the sub-reflector. The deformation of the receiving unit yields signal path variations and, if unconsidered, distorts the vertical station position and, hence, the scale of the obtained global geodetic reference frame. Signal path variations result from a weighted combination of the overlapping deformation patterns. The corresponding weights are obtained by the intrinsic illumination function of the radio telescope. The gain of the feed horn and, thus, the illumination of the aperture depends on the frequency. In contrast to legacy radio telescopes, which observe in X-band at about 8.4 GHz, the new generation of radio telescopes participating in the VLBI Global Observing System (VGOS) is designed for broadband reception between 2 GHz and 14 GHz having corresponding illumination functions. This contribution investigates the impact of frequency-dependent illumination functions on signal path variations for the first time. For that purpose, several data-sets obtained from different feed-horns are analysed, and the impact on the signal path variations is studied.

Keywords: Illumination function, Radio telescope, Signal path variation, Deformation, VLBI, VGOS

Presentation type: oral

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Exploring the Efficacy of Space-Tie Vectors for SLR and VLBI Combination

N. Mammadaliyev, S. Glaser, P. Schreiner, K. H. Neumayer, R. König, H. Schuh

Abstract

One of the most important goals of space geodesy is the provision of a global terrestrial reference frame (TRF) that satisfies the Global Geodetic Observing System objectives. Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) are fundamental space-geodetic techniques that play a crucial role in the establishment and maintenance of the global terrestrial reference frame. Each technique has its individual strengths and weaknesses; hence, a rigorous combination of the techniques is essential for the generation of highly accurate and stable TRFs. Nowadays, the exchange of the strengths of the different techniques involved in the realization of the reference systems is mostly established through the utilization of local-tie vectors. However, the deficiency of reliable and accurate local-tie vectors can adversely affect the accuracy and precision of the reference frame. Therefore, this study aims to explore the potential of space-tie vectors as an alternative for local-tie vectors and to assess their effectiveness as well as to investigate the viability of utilizing space-tie vectors in combining SLR and VLBI techniques. Satellites located at six different orbits were used as a platform for the space-tie vectors, allowing for the combination of SLR and VLBI through space-ties over a period of seven years. Using the simulated observations, unconstrained normal equations (NEQ) were formulated for both techniques including the initial state elements of the orbits, the positions and velocities of the stations, and the Earth Orientation Parameters (EOP). Afterwards, the common parameters in the NEQ are stacked and inverted by imposing only no-net rotation (NNR) conditions through one of the techniques to obtain a unified global solution. The efficacy of the space-tie vectors in the combination of SLR and VLBI in terms of the ability to transfer datum information among the techniques was evaluated by the Helmert Transformation parameters of single-technique and combined solutions of the SLR and VLBI station networks. Furthermore, the corrections and formal errors of estimated parameters, such as EOP, were assessed. The study showcases that besides the datum information, the strength of the techniques can be effectively exchanged via the space-tie.

Presentation type: poster

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The Australia - Japan VGOS observation

S. Matsumoto, L. McCallum, J. McCallum, A. Jaradat, M. Ishigaki, H. Yoshifuji, T. Kobayashi

Abstract

The VLBI Global Observing System (VGOS) which has been promoted by International VLBI Service for Geodesy and Astronomy (IVS) is the new observation system designed to achieve higher accuracy by using the smaller and faster slewing antenna and observing across a broadband frequency range. The final goal of VGOS is continuous measurement of station position and EOP with initial results available in less than 24 hours. However, at the moment, it takes a lot of time to get the results because of the large amount of the data.

We started the VGOS mode observations for EOP determination between Ishioka (Japan), Hobart and Katherine (Australia) called AUJ (Australia - Japan) session. These three stations have smaller and faster slewing antennas and are equipped with broadband receivers. The AUJ observation aims to determine the EOPs in less turnaround time, enabled through short sessions on a small station network with reasonable data connections. We performed eight sessions scheduled for 3 hours in the same time range of R1 sessions in 2022.

In this presentation, we will show the EOP results from the AUJ observations and the comparison with the R1 sessions and discuss future plans for these observations.

Presentation type: poster

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The AuScope Array - Recent developments

J. McCallum, L. McCallum, T. McCarthy, O. Titov

Abstract

The AuScope array of three 12m telescopes spanning the Australian continent will be completing the transition to VGOS-compatible systems this year, replacing the last S/X system at Yarragadee. The changeover from S/X to VGOS has been slow and the removal of the stations from the S/X network has had implications for the legacy network in the Southern hemisphere while Hobart12 has only recently joined regular IVS-VGOS experiments. In this presentation we discuss some of the recent developments aimed at supporting the AuScope array operations in the VGOS era, including the Australian mixed-mode strategy, hardware developments, correlation capacity improvements and plans for connecting the remote stations with high speed internet.

Presentation type: oral

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The Australian mixed-mode stations in a nutshell

L. McCallum, J. McCallum, T. McCarthy, L. Chin Chuan

Abstract

The Australian stations in Katherine (Ke) and Hobart (Hb) have been upgraded to VGOS sites and have joined the VGOS sessions in 2022. Yet they have also re-joined the R1 and R4 sessions in legacy S/X mode. How is this possible? The answer is the Australian mixed-mode operation: through a special hardware setup as well as some tweaks in the recording and processing, those VGOS stations can observe in legacy S/X mode. This mixed-mode operation significantly strengthens the IVS network in the south, allowing us to maintain a busy observing schedule and generate a dense station coordinate time series. In this poster, we present the Australian mixed-mode operations in a nutshell, including easily understandable illustrations and diagrams to demonstrate to a wide audience how this special observing mode works. This contribution also contains an overview of the past and current mixed-mode sessions, together with some performance stats and results.

Presentation type: poster

Closing the Gap: A Redesigned Prediction Package for Enhanced Accuracy of EOP Prediction using Single Space Geodetic Techniques

S. Modiri, D. Thaller, L. Klemm, D. König, H. Hellmers, S. Bachmann, C. Flohrer, A. Walenta, S. Belda

Abstract

Real-time Earth orientation parameters (EOP) are necessary for many space geodetic applications such as satellite navigation, tracking interplanetary spacecraft, and weather forecasting. Although modern high-precision space geodetic techniques such as Very Long Baseline Interferometry (VLBI), Global Navigation Satellite Systems (GNSS), and Satellite Laser Ranging (SLR) allow for the best possible estimation of EOP in terms of accuracy, data processing complexities and latency in the product availability remain an issue. As a result, it is of great scientific and practical importance to be able to accurately predict EOP. However, the existing methods are limited in their ability to predict EOP for a few days in the future. This requires overcoming two significant challenges: selecting the appropriate input data and selecting the most appropriate prediction method. A number of new methods or combinations of existing approaches are currently being explored as part of the "Second EOP Prediction Comparison Campaign (EOP-PCC)" organized by IAG and IERS as a coordinated effort to improve the accuracy of EOP predictions. In this study, we propose a redesigned prediction package containing input data and a prediction method in order to bridge the gap between observation and final estimate. We aim to increase the accuracy of predicted EOP and extend the prediction time span beyond the current few days. Our presentation will outline our contribution to the EOP-PCC and demonstrate the EOP products derived from analyzing the data of single space geodetic techniques at BKG. Following this, we will apply our prediction algorithm to both, i.e., the official IERS EOP series as well as our BKG single-technique analysis products for VLBI and SLR. In this study, we will combine the deterministic and stochastic methods to predict the EOP, and we will compare the results with those obtained in other studies. Furthermore, we will present our findings with regard to the ability to obtain real-time EOP prediction based on the usage of single space geodetic techniques.

Presentation type: poster

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Assessing the consistency of the conventional reference frames (terrestrial and celestial) and their impact on estimated EOP using VLBI-based data

M. Moreira, E. Azcue, M. Karbon, S. Belda, V. Puente, R. Heinkelmann, D. Gordon, J. Ferrándiz

Abstract

The conventional International Terrestrial Reference Frame (ITRF) is based on the combination of solutions from several space geodetic techniques, including observations until the end of 2020, and incorporates updated data and models. In contrast, the Celestial Reference Frame (CRF) is a VLBI-only solution based on data until 2015. These differing approaches could potentially lead to a gradual loss of consistency among EOP series. The recent release of ITRF2020 presents an opportunity to investigate this issue further.

This study empirically evaluates the consistency among different terrestrial reference frames (TRF) and the newest celestial reference frame (i.e. ICRF3), and EOP using historical Very Long Baseline Interferometry (VLBI) data from 1984 to 2022. Different TRFs are used as alternative settings in the analysis, including ITRF2020, VTRF2020, DTRF2020 and ITRF2014. Additionally, Helmert transformations are computed to determine the extent to which any observed behavior can be attributed to orientation differences of the TRFs. The results evidence the robustness of the different analyzed products, but more effort needs to be made to achieve the stringent goals for the ITRF realization in terms of accuracy (1 mm) and precision (0.1 mm/year).

Presentation type: oral

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New features in the IVS Seamless Auxiliary Data Archive (IVS SADA)

A. Neidhardt, S. Seidl

Abstract

Auxiliary and meta data can be collected and offered seamlessly with the IVS Seamless Auxiliary Data Archive (IVS SADA). Some antennas supported the data injection and especially with the Wettzell antennas it is possible to test new features. The presentation explains the functional principle of the IVS SADA and shows new features and possibilities.

Presentation type: oral

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RFI monitoring using mark5access spectra and Python programs

A. Neidhardt, A. Rozerin

Abstract

RFI monitoring is always an essential task. We made some experiments to monitor spectral power levels using the ”mark5access” spectra data from each scan in combination with Python code to generate waterfall plots. It is a straight forward method to present basic RFI information on-the-fly during or directly after a session.

Presentation type: poster

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Improved modelling for future VLBI contributions to ITRF

T. Nilsson, K. Le Bail, R. Haas

Abstract

The latest realization of the International Terrestrial Reference System, ITRF2020, was released in April 2022. When evaluating this terrestrial reference frame (TRF) , it was found that the scales from VLBI and SRL are in good agreement between 1998 and 2013.75, the difference is about 0.15 ppb. However, after 2013.75 the scale of VLBI seems to drift away. The reason for this is not yet understood.

One reason could be related to the models used in the VLBI data analysis, for example the models used to correct for the geophysical loading as well as for the thermal and gravitational deformations of the telescopes. In this contribution, we investigate what impact such models can have on the VLBI scale. In VLBI analysis done for ITRF2020, gravitational deformation models were applied for six telescopes. Since then, gravitational deformation models for another seven telescopes have become available. We investigate how applying those additional models affect the VLBI scale. To assess the impact of thermal deformation on the scale we analyse in the VLBI data both with and without thermal deformation corrections. For calculating the thermal deformations we test using both in situ temperature measurements as well as temperature from numerical weather models.

Presentation type: oral

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On VLBI errors

L. Petrov

Abstract

A rigorous assessment of measurement errors in many fields of science is no less important than the measurement value. Space geodesy is one of these fields. I will discuss activities which we need to undertake in order to obtain realistic errors of VLBI data products and to run simulations that will provide predicted errors close to that we report in data analysis and close to real errors. This includes antenna calibration, development of a realistic stochastic measurement model, and performing data analysis according to that stochastic model. I will present early results of our efforts to reach realism in assessment of VLBI errors.

Presentation type: oral

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Wide-band phase calibration system

L. Petrov, Lynn Miles

Abstract

The original phase calibration system designed in 1970s injects short pulses with a repetition rate of 1, 5, or 10 MHz. The spectrum of phase calibration signal consists of a rail of narrow-band peaks ($\Delta f < 1$ Hz). That design has a fundamental flaw: the response of a VLBI system to the narrow-band phase calibration signals is fundamentally different than the response of the data analysis chain to the wide-band signal from active galactic nuclea. Since the phase calibration unit is fed with the the same Hydrogen maser as other parts of VLBI hardware, it is highly susceptible internal radio interferences that affects only the calibrating signal, but virtually does not affect the signal to be calibrated. The miscalibrated phase response of the VLBI signal chain is one of the major sources of VLBI errors.

To overcome this flaw, we are developing a new system that injects the wide-band analogue noise generated from a pseudo-random digital sequence with a known key. Cross-correlation of the recorded calibration signal against its replica will allow us to compute the phase/amplitude response of a system to the broad-band signal. We will present the current status of the project.

Presentation type: poster

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VLBI correlator Wettzell - One year of experience as IVS correlator

C. Plötz, W. Probst, R. Wildenauer, B. Fischaleck, A. Neidhardt, M. Seegerer, T. Schüler

Abstract

The Geodetic Observatory Wettzell (GOW) in Germany was enhanced with a VLBI correlation facility. In December 2020, a high performance cluster (HPC-) based DiFX VLBI correlator replaced obsolete small hardware, also providing the performance to properly handle VGOS observations. Since late 2021 the VLBI correlator at Wettzell is acknowledged as an official IVS correlation component, contributing to the IVS correlation resources. Since then a special focus was laid on serving a timely deltaUT1 estimation with a dedicated IVS VGOS Intensive observation program between McDonald Observatory (MGO) and Wettzell. Additionally, since December 2022 regular IVS VGOS 24h session are assigned to the Wettzell correlator. An upgrade of the storage capacity and the internet data rate to 10 Gbps was done to handle to the increased amount of data of these 24h VGOS sessions. Experiences while establishing the correlation facility will be given.

Presentation type: oral

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Simulations of a VLBI transmitter on next-generation GNSS

S. Raut, S. Glaser, N. Mammadaliyev, P. Schreiner, K.H. Neumayer, H. Schuh

Abstract

This study investigates the impact of a Very Long Baseline Interferometry (VLBI) transmitter placed on next-generation Global Navigation Satellite Systems (NextGNSS) on geodetic products in a simulated environment. Here, the VLBI network observes the radio signals emitted from a VLBI transmitter on one medium-Earth orbit (MEO) satellite and extra-galactic radio sources (f.i. quasars). This research work consists of different VLBI networks (legacy, VGOS, and future VGOS stations) to study their impact on estimating orbit using precise orbit determination, Terrestrial Reference Frame (TRF), and Earth Rotation Parameters (ERPs) for an initial period of ten days. The network with future VGOS stations will comprise currently operational stations and stations upcoming in the next ten years. We also examine the effect of different simulated noise levels in the group delays on the TRF and ERPs. Furthermore, the study discusses the impact of the number of quasar and satellite observations on UT1-UTC estimation. Initial results show that the imposition of the No-Net Translation (NNT) condition on station positions is not required, as satellite observations provide access to the frame origin.

Presentation type: oral

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Intercontinental optical clock comparison using the geodetic VLBI technique in K-band

R. Ricci, M. Negusini, F. Perini, C. Bortolotti, M. Roma, G. Maccaferri, M. Stagni, C. Clivati, D. Calonico, M. Pizzocaro, M.-S. Heo, W.-K. Lee, C.Y. Park, D.-H. Yu, H. Kim, S.O. Yi, B. Cho, T. Jung, D.-Y. Byun, D.-H. Je, S. Xu, H. Yoon

Abstract

Comparing distant atomic clocks is very important for international timekeeping, global positioning and tests of fundamental physics. Optical clocks are most technologically advanced devices for frequency generation with a stability of 10^{-18}. In the near future they could be used in the redefinition of the SI second replacing the Cesium fountains. Optical fiber link networks allow the most performing optical clocks to be compared on distances up to two thousand kilometers, but for longer distances clock comparisons are limited by the performances of satellite frequency transfer techniques. In this presentation we show the use of high-frequency geodetic VLBI as an alternative technique for long distance frequency transfer. A K-band 24-h experiment involving six antennas between Europe and Korea was carried out in order to estimate the clock rate between the H-masers of Medicina and Sejong stations. These masers were connected and calibrated against two Ytterbium lattice optical clocks in INRiM (Italy) and KRISS (Korea). The fractional frequency difference between the optical clocks was thus evaluated.

Presentation type: oral

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Present state and future outlook for Mark6's

C. Ruszczyk, J. Barrett, P. Elosegui

Abstract

We will present an overview of the present state of the Mark6 and the next generation of Mark6 system capabilities. We will start with what is currently stable, notable hardware issues, and new features being added for end stations and correlators. This will be followed by a description of the next version of the Mark6 recording system, dubbed Mark6+, and what can be expected from it. We will give and overview of the new hardware, features and the path forward with the new system as well as its capabilities and where it fits in with the present VGOS end-to-end network.

Presentation type: oral

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Active mitigation of spaceborne radio frequency interference

M. Schartner, L. Wunderlin, N. Habana, L. Petrov, L.M. Hilliard, B. Soja

Abstract

The proliferation of spaceborne radio frequency interference (RFI) is threatening the operation of VLBI. In particular, mega-constellations, such as Starlink, OneWeb, and Amazon Kuiper, pose a significant threat since some of these satellites will emit signals in the upper-frequency range of the VLBI Global Observing System (VGOS). The power of these signals may saturate the amplifiers of VLBI antennas, causing nonlinearities within the observations. Furthermore, some future InSAR satellites, such as the NISAR mission, might emit signals strong enough to permanently damage the highly sensitive VLBI hardware.

We will present our approach for an active mitigation strategy that modifies the current VLBI observing strategy to avoid observations in the direction of spaceborne RFI. However, active avoidance means additional constraints during the observation planning. We will present results of the investigation the impact of these constraints w.r.t. the precision of the geodetic parameters using simulations and compare it to a situation (1) with active avoidance, (2) without active avoidance, where affected observations are lost and simply removed from the simulations, and (3) without active avoidance and no spaceborne RFI being present. Our simulations are based on different VGOS networks and satellite mega-constellation expansion stages. We will discuss to which extent our approach can help to avoid spaceborne RFI but also highlight its limitations and necessary development steps towards operational use.

Finally, we will discuss the practical requirements of active mitigation of spaceborne RFI based on scheduling. Here, the accuracy of the orbit prediction seems to play a crucial role. With the current observation strategy of submitting a schedule seven days prior to observation, significant error margins must be applied to the satellite orbits. We will also present recent developments in storing and providing satellite orbit information in the form of two-line-elements (TLE) that will be used in the current scheduling pipelines.

Presentation type: oral

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First Experiences with the VLBI Quality Control System at Wettzell

T. Schueler, W. Probst, J. Konadl, C. Ploetz

Abstract

The Federal Agency for Cartography and Geodesy (BKG) introduced a Quality Management System in 2022. A certification process according to the international standard ISO 9001 followed in the same year. This was a motivation to extent the existing quality control system for the VLBI radio telescopes at the Observatory.

In addition to the system monitoring mechanisms in place, the systematic analysis of output files from correlation as well as geodetic analysis was introduced. The statistical analysis is carried out automatically. Moreover, a weekly quality review is conducted, following the established guidelines for information and feedback.

This contribution will review the quality control system, highlight the experiences gained throughout the last year regarding its effectiveness, and suggest improvements.

Presentation type: oral

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Efforts in Satellite VLBI at the University of Tasmania

D. Schunck, L. McCallum, G. Molera Calves

Abstract

Using the Very Long Baselines Interferometry (VLBI) technique to observe Earth-orbiting satellites is a topic of increasing interest for the establishment of frame ties. Future satellite missions are envisaged to be equipped with various instruments to strengthen the connection of the four space-geodetic techniques that contribute to the International Terrestrial Reference Frame (ITRF). However, no such satellite mission is currently in operation. In this work, we take into consideration the currently available infrastructure of radio telescopes around the world to simulate observations from antennas to GPS satellites to tie the VLBI frame and GPS satellite frame together. Conducting Monte Carlo simulations for 24-hour sessions, we develop possible observing strategies that are evaluated based on the precision of the estimated radio telescope positions in the GPS satellite frame. We also investigate the uncertainties in the estimated frame tie parameters based on a 7-parameter Helmert transformation. By observing quasars and GPS satellites with a realistic global network of stations within a 24 hour session, median station position accuracies of 7.5 mm can be achieved. The uncertainties of the frame tie parameters are on the order of a few millimeters. Additionally, the effect of ionospheric errors as well as orbit errors of the satellites is are investigated. This simulation study provides an understanding in the topic of building a frame tie using satellite-VLBI, and is the first of its kind in terms of global scheduling and the usage of a realistic station network. Besides this simulation study, we also present efforts in real VLBI observations to satellites. Using the AuScope telescopes, we perform observations to satellites to reveal efforts needed in the VLBI community to successfully support upcoming, dedicated satellite missions to realize a space tie.

Presentation type: oral

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An overview of Water Vapor Radiometers at the Geodetic Observatory Wettzell and the Argentinean German Geodetic Observatory

W. Schwarz, A. Böer, M. Brandl, C. Plötz

Abstract

Water vapor radiometers (WVR) have been in use for more than 20 years at the Geodetic Observatory Wettzell (GOW). An overview is given about the different water vapor radiometer generations and their main technical characteristics, as well as practical experiences of long-term operations. Furthermore, some details of the latest addition of the newest generation WVR at the GOW are provided. This model is also available at the Argentinean German Geodetic Observatory (AGGO) located at La Plata, Argentina.

Presentation type: poster

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Analysis of non-tidal loading deformation at VLBI sites

S. Singh, J. Böhm, H. Kràsnà, O. Dikshit, N. Balasubramanian

Abstract

Very Long Baseline Interferometry (VLBI) is one of the geodetic techniques which define the International Terrestrial Reference Frame (ITRF). It requires data from multiple antennas fixed at different locations on the Earth's surface. However, the accuracy of this technique is affected by the deformation of the Earth's crust by various geophysical effects, including plate tectonics, loading from solid Earth tide, atmospheric pressure, and water mass redistributions (over land and ocean).

This study aims to compare the non-tidal loading products retrieved from different loading services such as TU Wien, ESMGFZ, International Mass Loading Service, and Uni Strasbourg. Non-tidal loading refers to the deformation of the Earth's surface caused by mass redistributions within the Earth's system, such as changes in atmospheric pressure, groundwater, and ice-sheet melting. This deformation can cause positional shifts in the VLBI sites, affecting the accuracy of the VLBI measurements. To account for the non-tidal loading effects in VLBI analysis, geophysical models are used to estimate the displacement of VLBI stations.

We present the comparison of different non-tidal loading products from different loading services in Vienna VLBI and Satellite Software (VieVS) by analysing the variation in repeatability values of baseline length and Earth orientation parameters. This study will help to determine the accuracy of the different loading products and their impacts on VLBI analysis. Overall, the study highlights the importance of accurate geophysical models and loading products in VLBI analysis. The comparison and analysis of different loading products can help to identify the most accurate and reliable geophysical models for non-tidal loading for implementation in VieVS software.

Presentation type: oral

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Using a GNSS-radiotelescope interferometer to produce geodetic observables

J. Skeens, J. York, L. Petrov, K. Herrity, D. Munton, R. Ji-Cathriner

Abstract

We describe a unique interferometer utilizing a GNSS antenna and a radiotelescope that provides new opportunities for relating the GNSS and VLBI space geodesy techniques. A GNSS receiver providing raw baseband samples allows us to analyze emission from both celestial and GNSS sources through VLBI techniques including software correlation and fringe fitting. A recently collected dataset opens the possibility to production of high quality local tie vectors. A technique we have developed to produce a clock solution from simultaneous collection of GNSS observables also suggests that time transfer to VLBI stations is possible through GNSS-radiotelescope observations. We will discuss the potential applications of these developments and potential near-term advances from the technique.

Presentation type: oral

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Proposal to IVS: Extension of the ICRF Frame to L-Band for the Observation of GNSS Constellations in the Celestial Frame

Drazen Svehla

Abstract

We are proposing to observe GNSS satellites with VLBI in the celestial frame operationally. Terrestrial frame is fully determined basically only by the GNSS satellites and the celestial frame is based on the VLBI with AGNs. To combine those two fully independent frames, the only direct solution is to observe AGNs with VLBI in the L-band (L1 and L2 GPS frequencies). All other approaches to do that will introduce local ties and additional effects. This GNSS frequency band is internationally a metrology frequency band outside the interferences with huge LEO constellations of Cubesats operating in the S-band and in the X-band.

With the STE-QUEST mission proposal (Svehla et al., 2014), pre-selected (2009-2014) in ESA Cosmic Vision Programme, as well as with GRASP, eGRASP and GENESIS proposals and activities, there is only an indirect link via LEO or a similar orbit between GNSS satellites and AGNs in the celestial frame, and this is not going to be solved in order to get orbits of GNSS satellites directly connected with AGNs in the celestial frame. The only way to improve the accuracy of GNSS satellite orbits, and in this way terrestrial and celestial frame, is to observe GNSS satellites with VLBI relative to the AGNs.

LEO orbit is not very appropriate to significantly improve the orbit accuracy of GNSS satellites (gravity, albedo, SRP and thermal re-radiation effects for a very short LEO orbit revolution) and to be easily observed by all VLBI antennae on the ground. At higher orbit altitudes there are no active satellites placed in the inner Van Allen radiation belts $<$12000 km, in order to operate such a satellite actively over a longer period of time (like passive LAGEOS satellites or active GPS satellites placed at much higher orbit altitudes).

Related to the ICRF frame realization, positions or definitions of AGNs are ”bigger” in the L-band compared to the X-band, but there are lock-in amplifiers or the existing broadband VLBI receivers (VGOS) that can sample VLBI signal up to the X-band, and could cover the L-band simultaneously with the S-band and the X-band. Therefore, the overall cost for such a modification at a VLBI station has been significantly reduced over the years. It is expected that there will be an extension of the celestial frame to the higher frequencies like Q-band and V-band, mainly driven by NASA and ESA for the Delta-DOR technique, but the majority of VLBI stations could only focus on the lower frequency band that could be observed simultaneously in the L-band, S-band and X-band or even up to the Ka-band and used for the realization of reference frames. All GNSS frequencies in the L-band will stay internationally as a metrology frequency band in the future.

References:
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Presentation type: poster

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Status of Ishioka Geodetic Observing Station

Y. Takagi, M. Ishigaki, T. Nakakuki, H. Yoshifuji, M. Honda, K. Mori, Y. Sato

Abstract

The Ishioka 13-m telescope at the Ishioka Geodetic Observing Station (hereafter Ishioka station), operated by the Geospatial Information Authority of Japan, has participated in the IVS sessions since 2015. Currently, the Ishioka station is involved in VGOS observations for several months a year and in legacy S/X observations for the rest of the year by switching their respective receivers. The VGOS period, which was initially three months, was extended to six months in 2022.

We at the Ishioka station are actively involved in the following aspects: the issue of polarization, the installation of new recording systems and local-tie surveys. Firstly, we are now exploring measures that could help receive both VGOS and S/X bands by the broad-band receiver currently used for only VGOS observations. The measures will help us to eliminate the interruption period necessary to switch receivers. Since the problem of RFI in the S-band was fixed by installing the superconducting filters in the receiver, the remaining challenge is how to handle the polarization. This is because the polarization is different between VGOS and S/X observations. In addition to the method conducted by the IVS in which the correlator processes both linear and circular polarizations, we are investigating a way of converting linear polarizations to circular one at the recording system. Secondly, we are preparing to install a new sampler DBBC3 and a recording system FlexBuff. At the Ishioka station, ADS3000+ developed by NICT is currently used, but the issue is that new servers connectable to it are no longer available. We will begin adjusting the new systems after they arrive in March 2023 and will use them as soon as possible.

Thirdly, we are carrying out local-tie surveys regularly to estimate the local-tie vector between the reference points of the telescopes and the IGS GNSS station operated at the Ishioka station. The results of the 2018 and 2020 surveys were submitted to the IERS to contribute to the construction of ITRF2020. The surveys were also conducted in 2021 and 2022 and they are under calculation.

In this presentation, we will report the current status and near future prospects of the Ishioka Geodetic Observing Station.

Presentation type: poster

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How to deal with expanding telecommunication networks using spectrum of VLBI?

V. Tornatore, H. Hase

Abstract

New plans from telecommunication enterprises foresee the demand of wide sub-band allocations in the range of 1-100 GHz during the upcoming World Radio Conferences, which go beyond of the known expansion of spectrum use by 5G and large satellite constellations (starlink, OneWeb).

More than 50,000 satellites have been planned to be launched in the next decade by telecommunications industry to provide global connectivity, but satellite downlink signals can affect VGOS receivers. Furthermore there are indications that recent agreements among national administrations and satellite companies to coordinate protection zones around radio telescopes and VGOS stations, avoiding downlink satellite transmissions, have been rejected.

Installation of normal cell-phone base stations on communication satellites is also under discussion to connect normal smartphones to satellites to provide global connectivity.

Concerning the conducted power levels of cell-phone base stations would have an impact on any radio astronomy observation. CRAF studies show that coordination zones of up to 100km radius would be required to continue with undisturbed VLBI observations. This demonstrates that the future of VLBI is at risk, if no actions are taken to protect VLBI-sites.

Another troubling clue comes from the contention of a big part (6425-7125 MHz) of the so called mid-band by international mobile telecommunication (IMT), 5G and RLAN (Wi-Fi) services in many European Countries. This would degrade sensitivity and accuracy of VGOS measurements in this band. In addition RA community is going to loose the long observed Methanol spectral line at 6650-6675.2 MHz, despite this line is protected by ITU-R Footnote 5.149. National licensing processes are necessary to protect radio astronomy facilities in this band.

Important achievements in increasing sensibility of scientific communities on the importance of geodetic VLBI and VGOS activities have been reached, but still urgent initiatives and strategies are necessary to gain proper protection of VGOS bands before they will be fully crowded by signal of telecommunications services. The situation raises the question what should be done?

Presentation type: poster

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Progress on the BRAND extreme-wideband receiver

G. Tuccari, W. Alef, S. Dornbusch, M. Wunderlich, R. Rottmann, A. Felke

Abstract

The BRAND prototype primary focus receiver with the very wide frequency range from 1.5 GHz to 15.5 GHz has been delayed due to the Covid-19 pandemic and unexpected technical problems with the so-called digital frontend. All the other components are ready. In the recent 12 months a breakthrough could be achieved with the digital frontend, a single board which receives up to 2×28 GHz RF signals, samples them and performs a first digital processing in up to four powerful FPGAs. We will report on the present status of the receiver.

Presentation type: oral

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DBBC4

G. Tuccari, H. Rottmann, W. Alef, S. Buttaccio, S. Dornbusch, A. Roy, M. Wunderlich

Abstract

The development of the newer version of the digital front- and backends belonging to the DBBC systems' family is fully active. This instrument involves a number of relevant novelties which can be of interest for the VLBI community. A description is presented about the general architecture with some details, pointing out in particular the elements relevant for the VGOS network. The current status of development is also reported.

Presentation type: oral

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Current status at BKG IVS-DC

A. Walenta, M. Goltz, D. Thaller

Abstract

Last year has brought several changes for IVS Data Center at BKG. By introducing the new software ingest for processing uploaded files, the unified file validation among the IVS Data Centers is enforced. The next significant steps in the routine operations have been related to our own service: discontinuity of FTP in favour of FTPS and HTTPS. We have arranged a personal account for every uploader on request and supported the old user ivsincoming during the protocol transition. At the end, user ivsincoming has been removed as well. Corresponding mapping of user accounts and uploads simplifies the data center maintenance. In particular, an automatic feedback loop is planned to improve our user support. Also, we monitor the uploads and downloads by the users on a daily basis in a straight forward manner. The related illustrations are available on our website. The security measures are exercised as required by our internal IT-. It means, that we provide proper supervision to secure sensitive data. Also, each incoming file is checked with a virus scanner, where the SWIN files are treated separately because of their large file size.

According to IVS regulations on the Data Centers, we keep our Data Centers in sync with the other IVS Data Centers by mirroring them as well as a consistency check to guarantee the data acquisition. Additionally, before activating new changes in the ingest software we perform a test with sample data. For these operations, we distribute the incoming files to a white and a black list, which are updated continuously.

Our server setup allows introducing software updates and tests without inflicting the productive environment. For instance, the last activities were regarding the validation of the EOP3.0 format from several ACs and proper acceptance of the new file name convention for the Level 2 Data Analysis in vgosDb format and SINEX files. These data comprise the major part of files uploaded to the Data Center, as a consequence, their validation impact the IVS Community at most. We will illustrate, how incoming data is validated at the example of EOP, SINEX and SWIN files, where the latter is slightly different.

Presentation type: poster

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The Level 1 Data: availability and benefits

A. Walenta, M. Goltz, D. Thaller, G. Engelhardt, D. Ullrich

Abstract

Since the last year the Level 1 Data or so-called SWIN files (as short for Swinburne) are available for the currently observed sessions. The SWIN data is the product of the the DiFX correlator and contains the visibility data. The source structure can be derived from the visibility data, which application is pointed out already to enhance the geodetic analysis and entails a potential to reach the higher geodetic products accuracy level. The exhaustive studies of the substantial for geodetic analysis amount of data were limited due to the absence of the SWIN data. The availability of the data at the IVS Data Centers is the first step to facilitate this goal. And with this contribution we aimed to encourage strongly the use of these data in the geodetic analysis.

We present here how to access the data at BKG Data Center. The other official IVS Data Center – CDDIS - stores the SWIN files. The disk space demand for the SWIN files, however, constitutes the challenge. Besides, the data transfer of the historical data stored at the Haystack correlator has been initiated from the “cold data storage” to the CDDIS. The total amount of these data reaches up to 60TB, where about a half of the data are available at the correlator in Bonn. Because of the technical demands, we are interested in the discernible use of these data. The SWIN files provide the potential to be exploited far beyond the geodetic IVS community, and the geodetic analysis is to benefit from it. Driving by these reasons we are aimed to reach out the relevant communities to announce and advertise the availability of the new data. The first activity in this direction is the meeting in Bologna, where a broad variety of the astrophysical researches is presented. Here we will share our experience in communicating with the community and learning their needs. The BKG Data Center team is eager to improve our services. Following our goals, we work on the support and facilitation of the barrier free data access, thus the feedback is essential to us.

Presentation type: oral

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Investigating the VLBI Scale w.r.t. different TRFs

J. Wang, S. Glaser, G. Beyerle, R. Heinkelmann, K. Balidakis, M. Ge, H. Schuh

Abstract

Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) are the two techniques that contribute to the scale realization of the current International Terrestrial Reference Frame (ITRF). The VLBI scale of ITRF2020 shows a drift after around 2014 (https://itrf.ign.fr/images/solutions/ itrf2020/vlbi-scale-mm.png), and thus the contribution of VLBI to ITRF2020 scale is not considered after this period. The reason for this abnormal scale behavior is not discovered yet. In principle, several effects could result in biases and drifts of the VLBI scale. For example, the modeling of station displacements and the VLBI theoretical delay, the distribution of network stations, and the processing strategies of data analysis and of intra- and inter-technique combinations. We present the scale investigations of the GFZ VLBI solutions with respect to different TRF realizations, including ITRF2014, ITRF2020, DTRF2014, and DTRF2020p and focus on the scale differences between these TRFs. In this study, the solutions are based on the official VLBI contribution of GFZ to ITRF2020, but we extended them by incorporating more recent sessions. Due to the large noise level of the VLBI session-wise scale estimates, we quantify the temporal variations of the scale using numerical fitting of scale time series within different time windows. In this way, we analyze both, the scale drift and the corresponding uncertainty. Furthermore, we look into other similarity transformation parameters, which could be correlated to the scale estimates as well. We carefully inspect specific stations with large discrepancies between different TRFs to identify their potential contribution to the scale anomaly. In our work, we demonstrate that the a priori TRF has only limited impact on the long-term scale estimates. Furthermore, we found that the impact of the mean pole model on the scale estimates is insignificant.

Presentation type: oral

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Absolute orientation of Galileo orbits from simulated VLBI and GNSS observations

H. Wolf, J. Böhm, U. Hugentobler

Abstract

Mounting a dedicated Very Long Baseline Interferometry (VLBI) transmitter on one or more Galileo satellites would expand space and science applications due to the possibility of observing these satellites with VLBI radio telescopes. The combination of VLBI observations to satellites and extragalactic radio sources enables to determine the satellite orbit in the terrestrial but also in the celestial reference frame as VLBI is uniquely capable to determine the Universal Time UT1.

This simulation study investigates the quality of estimating orbit arcs based on combined VLBI observations and GNSS measurements. The aim of this study is the estimation of the absolute orientation of the orbital plane, which is equated to the estimation of the right ascension of the ascending node RAAN. To achieve this, GNSS measurements from Bernese are introduced in VieVS as partial derivatives of the state vector of the satellite with respect to RAAN during the analysis process of a schedule including satellite and quasar observations. In VieVS these measurements are used for the final computation of the sensitivity of the time delay with respect to RAAN, which further enables the estimation of the right ascension of the ascending node from simulated VLBI observations. In addition, at a further stage, the results from VieVS and Bernese could be combined at the normal equation (NEQ) level using the module ADDNEQ2. This would allow to retrieve a fully consistent result for the orbital parameter RAAN based on VLBI and GNSS observations.

Presentation type: oral

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Imaging VGOS observations and source structure effect

Ming Hui Xu, Tuomas Savolainen, Robert Heinkelmann, Harald Schuh

Abstract

The new generation of geodetic VLBI, VLBI Global Observing System (VGOS), is now regularly observing to produce the best geodetic VLBI data ever, with a thermal noise level of about 3 ps. However, the systematic errors due to angular structure of the radio sources are becoming prominent in these high-precision VGOS observations. It is important to understand, study, and monitor these systematic errors with the aim to model them in geodetic data processing. Improvements have been made to derive structure images and Gaussian components at the four bands (3 – 14 GHz) directly from VGOS observations on a regular basis. The image alignment over both time and frequency has been understood as the major challenge in creating consistent structure models for VGOS observations. We used several methods to do image alignment and validate the results. We will report the progress and these challenges in modeling source structure effects.

Presentation type: oral

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VGOS dTEC assesment using TEC GIM maps

N. Zubko, M. Xu, N. Kareinen, T. Savolainen, M. Poutanen

Abstract

The ionosphere causes an extra delay in radio signal propagation, which in VLBI is characterised by the differential total electron content (dTEC) for each baseline. In broadband VGOS observation ionosphere has a dispersive effect on the signal delay along all bands. The multiband delay is solved by finding the non-dispersive part of the group delay and the dispersive part of the ionosphere with the maximisation criterion of the fringe amplitude. The non-corrected instrumental effects also can have dispersive characteristics that may be absorbed by the estimated dTEC. In this work, we perform an assessment of the VGOS dTEC using the Center for Orbit Determination in Europe global ionospheric maps (CODE GIM) that are based on modeling of the ionosphere TEC using GNSS observations. The results show that there is a systematic offset between VGOS and CODE GIM dTECs. The detected offsets or biases reveal the presence of the instrumental effect in VGOS dTEC data. Moreover, the dTEC is also affected by the radio source structure effect. We show how the impact of the source structure appears in VGOS dTEC.

Presentation type: oral

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Recent developments at Metsähovi Geodetic Research Station

N. Zubko, J. Eskelinen, J. Näränen, N. Kareinen, U. Kallio, H. Koivula, M. Poutanen, J. Peltoniemi

Abstract

VGOS telescope system at Metsähovi Geodetic Research Station is under the commissioning phase. Analysis of the thermal stability of the telescope steel pedestal revealed that additional insulation of the pedestal is required to avoid the effect of uneven temperature distribution and its rapid fluctuations due to solar radiation. At the end of 2022 the telescope pedestal was covered with an additional insulation shell that improved the pedestal temperature stability and thus the stability of the telescope reference point. To measure the telescope reference point and to perform local tie measurement two different techniques were applied, which are based on kinematic GNSS and terrestrial tachymetric monitoring measurements. A new office and instrumentation building has been constructed. VGOS equipment and the backend will be relocated to the new building this year. The integration work on the signal chain is ongoing. The IVS GeoVLBI observations performed in collaboration with Metsähovi Radioastronomical Observatory (Aalto University) with legacy telescope (Mh) since 2005 were terminated last year. The contribution to IVS with VGOS telescope (Mf) will start after its commissioning is completed.

Presentation type: poster

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