25th European VLBI Group for Geodesy and Astronomy Working Meeting

14-18 March 2021
Cyberspace

Information and book of abstracts

2021-03-03

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EVGA2021 information

Scientific Organizing Committee (SOC)

- Simone Bernhart (Reichert GmbH/BKG/MPIfR Bonn)
- Sigrid Böhm (Technische Universität Wien)
- Susana Garcia-Espada (Kartverket)
- Anastasiia Girdiuk (BKG Frankfurt)
- Rüdiger Haas (Chalmers University of Technology)
- Karine Le Bail (Chalmers University of Technology)
- Nataliya Zubko (Finnish Geospatial Research Institute)

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- Periklis-Konstantinos Diamantidis (Chalmers University of Technology)
- Susana Garcia-Espada (Kartverket)
- Rüdiger Haas (Chalmers University of Technology)
- Karine Le Bail (Chalmers University of Technology)

Series of events during the EVGA2021

Date	Time	Event
14 March	UT 16:00-18:00	Icebreaker party
15 March	UT 10:50-17:00	EVGA2021-day-1
16 March	UT 11:00-17:00	EVGA2021-day-2
17 March	UT 11:00-17:00	EVGA2021-day-3
18 March	UT 11:00-14:45	EVGA2021-day-4
18 March	UT 14:45-18:30	IVS Analysis Workshop

All events will be in Cyberspace, i.e. virtually, and the corresponding information to access the virtual events will be provided via email to the participants. Interested persons not presenting themselves at the EVGA2021, but still interested in attending the oral presentations, are asked to get in to contact with the VOC via email to receive further instructions.

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2020-03-14	**Icebreaker party - online**	UT 16:00-18:00

2020-03-15

Haas	**Welcome and Introduction**	UT 10:50-11:00
Session-01	**Chairperson: Rüdiger Haas**	
McCallum J	A wideband observing mode for the AuScope array	UT 11:00-11:15
Tangen	Current status at Ny-Ålesund Geodetic Earth Observatory	UT 11:15-11:30
Lopez-Perez	The current status of RAEGE	UT 11:30-11:45
Lopez-Perez	Preamplifier module for VGOS and legacy S/X observations compatibility in the presence of RFI signals	UT 11:45-12:00
	break - shake your legs	UT 12:00-12:15
Session-02	**Chairperson: Nataliya Zubko**	
Gomez-Molina	New Designs in VGOS Frontends in Yebes Observatory	UT 12:15-12:30
Tuccari	The BRAND EVN receiver and the new DBBC4 backend	UT 12:30-12:45
Plötz	Advances in automatized schedule generation at the VLBI operation center DACH and introduction of the VLBI correlation center at Wettzell	UT 12:45-13:00
Schartner	Automated VLBI scheduling utilizing Artificial Intelligence based parameter optimization	UT 13:00-13:15
	break - shake your legs	UT 13:15-13:30
Session-03	**Chairperson: Karine Le Bail**	
Ricci	A geodetic VLBI experiment with the dissemination of a clock via coherent optical fibre link	UT 13:30-13:45
Jaron	EU-VGOS activities in Vienna	UT 13:45-14:00
Barrett	A first look at mixed VGOS-S/X correlation and post-processing	UT 14:00-14:15
Ruszczyk	Experience from S/X–VGOS mixed-mode observations	UT 14:15-14:30
	break - shake your legs	UT 14:30-14:45
Poster and movie session and discussions		UT 14:45-17:00

2020-03-16

Session-04	**Chairperson: Sigrid Böhm**	
McCallum L	Australian mixed-mode sessions	UT 11:00-11:15
Takagi	A superconductor filter installed in the broadband feed of Ishioka VLBI station	UT 11:15-11:30
Gruber	Simulation of VGOS observations at the raw data level with VieRDS	UT 11:30-11:45
Varenius	ONTIE: Short-baseline interferometry at Onsala Space Observatory	UT 11:45-12:00
	break - shake your legs	UT 12:00-12:15
Session-05	**Chairperson: Nataliya Zubko**	
Kern	VLBI Intensive sessions: the selection of baselines for UT1 estimation	UT 12:15-12:30
Kurdubov	Approaches of optimal scheduling of UT1 geodetic VLBI sessions	UT 12:30-12:45
Malkin	On the selection of prospective sources for ICRF extension	UT 12:45-13:00
de Witt	Improving the S/X Celestial Reference Frame in the South: A Status Update	UT 13:00-13:15
	break - shake your legs	UT 13:15-13:30
Session-06	**Chairperson: Sigrid Böhm**	
Gomez	Determination of the geodetic position of non-geodetic EVN antennas	UT 13:30-13:45
Hase	Spectrum Management for the VGOS	UT 13:45-14:00
Behrend	New Ingest Software at IVS Data Centers	UT 14:00-14:15
Jacobs	X/Ka Network Enhanced by Misasa, Japan's 54-meter antenna	UT 14:15-14:30
	break - shake your legs	UT 14:30-14:45
Poster and movie session and discussions		UT 14:45-17:00

2020-03-17

Session-07	**Chairperson: Karine Le Bail**	
Salarpour	An empirical review of structure index characteristics for geodetic VLBI observations	UT 11:00-11:15
Kurdubov	The source structure as main error source in Russian intensive sessions	UT 11:15-11:30
Kareinen	Mitigating the effect of extended source structure in geodetic VLBI by re-weighting observations using baseline-to-jet orientation	UT 11:30-11:45
Lösler	On the impact of the coordinate representation onto the estimates in least-squares adjustment	UT 11:45-12:00
	break - shake your legs	UT 12:00-12:15
Session-08	**Chairperson: Susana Garcia-Espada**	
Wang	VLBI Processing in the PANDA Software	UT 12:15-12:30
Flohrer	VLBI enhancement of the Bernese GNSS Software for multi-technique analysis at BKG	UT 12:30-12:45
Hellmers	Combined IVS contribution to the ITRF2020	UT 12:45-13:00
Girdiuk	Intensives and 24-hour session data reprocessing for BKG AC 2020a solutions	UT 13:00-13:15
	break - shake your legs	UT 13:15-13:30
Session-09	**Chairperson: Anastasiia Girdiuk**	
Balidakis	On the Origin of Clock Breaks Detected in Geodetic VLBI Data	UT 13:30-13:45
Krasna	Baseline-dependent clock offsets in VLBI analysis	UT 13:45-14:00
Nilsson	Evaluation of the results from the VGOS sessions	UT 14:00-14:15
Gipson	Review of Operational VGOS Sessions in 2020	UT 14:15-14:30
	break - shake your legs	UT 14:30-14:45
Poster and movie session and discussions		UT 14:45-17:00

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Session-10	**Chairperson: Susana Garcia-Espada**	
Xu S	The K Band Geodesy with the East Asian VLBI Network	UT 11:00-11:15
Zubko	Ionosphere comparison study of VGOS and Total Electron Content global maps	UT 11:15-11:30
Negusini	A Broadband VLBI experiment with transportable stations between Japan and Italy with a new observation scheme using closure delay relation	UT 11:30-11:45
Teke	Ocean tide loading displacements from VLBI and the long term ocean tide variability	UT 11:45-12:00
	break - shake your legs	UT 12:00-12:15
Session-11	**Chairperson: Anastasiia Girdiuk**	
Puente	Consistency of VLBI estimates in the CONT17 campaign	UT 12:15-12:30
Diamantidis	Inter- and intra-technique combination on the observation level between VLBI and GPS - a study case for CONT17	UT 12:30-12:45
Lengert	Combination of GNSS and VLBI data for consistent estimation of Earth Rotation Parameters	UT 12:45-13:00
Haas	VGOS Intensives Ishioka-Onsala	UT 13:00-13:15
	break - shake your legs	UT 13:15-13:30
Session-12	**Chairperson: Rüdiger Haas**	
de Witt	K-band Imaging of 732 ICRF3 sources	UT 13:30-13:45
Xu M	Imaging VGOS observations and the effects of source structure	UT 13:45-14:00
Hunt	Update on VLBA Imaging of ICRF3 Sources	UT 14:00-14:15
Le Bail	Source flux-density monitoring in the VGOS era	UT 14:15-14:30

Haas	**Closing remarks - good bye**	UT 14:30-14:45

Gipson	**IVS Analysis Workshop 2021**	UT 14:45-18:30

POSTERS		
Zubko	Status of the VGOS project at the Metsähovi Geodetic Research Station	P-01
Chuan	AuScope VLBI Dynamic Observing	P-02
Nickola	HartRAO weather data	P-03
Nurul Huda	Measuring the impact of Indonesian antennae to Earth Orientation Parameter estimation	P-04
Anderson	Effects of Source Weighting in Geodetic VLBI Analysis	P-05
Anderson	The Potsdam Open Source Radio Interferometry Tool (PORT)	P-06
Basu	Source structure and position stability of celestial reference frame sources in the Deep South	P-07
Elgered	Small scale atmospheric variations sensed with very short baseline interferometry (VSBI) and microwave radiometry	P-08
Kirkvik	First results from the new station NYALE13S	P-09
Liu	Comparison of tropospheric zenith wet delay from VLBI and GNSS Time Series	P-10
Mammadaliyev	Precise orbit determination with VLBI to satellites: a simulation study	P-11
Mironova	Combination of IVS Intensive sessions using SINCOM software	P-12
Mironova	Improving of the covariance functions of the clock and troposphere parameters	P-13
Nothnagel	Reference epochs in VLBI estimations of clock parameters	P-14
Raut	Assessment of sub-daily Earth Rotation Parameters from VLBI with GNSS during the CONT17 campaign	P-15
Seitz	First VLBI-only TRF/CRF solution based on DGFI-TUM data for ITRF2020	P-16
Soja	The New IVS Associate Analysis Center at ETH Zurich	P-17
Xu M	Impacts of source structure as seen from the Gaia and VLBI comparison	P-18

MOVIES		
Neidhardt	Data Unlimited – The IVS Seamless Auxiliary Data Archive at the Wettzell observatory	M-01
Neidhardt	Autonomous Observations at the Wettzell observatory	M-02
Jaradat	10 years of AuScope VLBI	M-03
Titov	A jump in the VLBI position of the radio galaxy J1147+3501	M-04

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The Potsdam Open Source Radio Interferometry Tool (PORT)

PORT Team at GFZ (J. Anderson, K. Balidakis, G. Beyerle, S. Glaser, S. Lunz, R. Heinkelmann, F. Bamahry, S. Dhar, O. S. Jenie, C. Kitpracha, N. Mammadaliyev, S. Modiri, S. Raut, J. Wang, H. Schuh)

Abstract The Potsdam Open Source Radio Interferometry Tool (PORT) is the VLBI analysis software developed and maintained at the GFZ German Research Centre for Geosciences. PORT development started at GFZ in August 2018 with the initial import of the existing VieVS@GFZ code base (Nilsson et al., 2015) into the distributed version-control system "Git". As the name implies, VieVS@GFZ originated from VieVS, which has now independently evolved into the Vienna VLBI and Satellite Software (Böhm et al., 2018) and branched off from VieVS in 2012. Similar to its predecessor, PORT is focused on the timely processing of VLBI sessions as well as post-processing activities supporting the generation of celestial and terrestrial reference frames; notably, GFZ's contribution to ITRF2020 is produced by PORT. In addition, PORT provides a framework for research and development projects within the VLBI working group at GFZ and is part of the educational tool set used in training and promotion of young researchers.

In a typical analysis run, PORT estimates EOPs, radio source and station positions, as well as tropospheric parameters. Observational data input stored in vgosDB or legacy NGS data format is supported. A refined graphical interface allows the user to manually insert clock breaks and to flag outlier data points. Weighting of group/phase delays, amplitudes and position constraints can be applied to stations, radio sources and baselines on an individual basis. Parameters are estimated either with a Kalman filter approach or on the basis of a conventional least squares adjustment. Results are displayed on screen, written to disk for later usage (e.g. as input to global solutions) and the corresponding normal equations are stored in PORT-specific and SINEX data formats.

Current PORT development activities focus on both, consolidation of the legacy code base and revision of its design, code structure and implementation in order to improve robustness, modularity, readability, and thus maintainability. The source code repository is organized in four Git branches with more than 0.5 Mio. lines of code, about half of which is written in the MATLAB®, the other in the Python programming language. PORT is developed under open source licenses and will be made available to the VLBI user community (see `www.gfz-potsdam.de/en/section/space-geodetic-techniques/topics/geodetic-and-astrometric-vlbi/`).

References:
Böhm et al. (2018): Vienna VLBI and Satellite Software (VieVS) for Geodesy and Astrometry, Publications of the Astronomical Society of the Pacific, 130:044503, doi: 10.1088/1538-3873/aaa22b
Nilsson et al. (2015): Application of Kalman filtering in VLBI data analysis, Earth, Planets and Space, 67:136, doi: 10.1186/s40623-015-0307-y

Session-3: Analysis

Presentation type: poster

J. Anderson[1,2], K. Balidakis[1], F. Bamahry[1,2], G. Beyerle[1], S. Dhar[1], S. Glaser[1], R. Heinkelmann[1], O. S. Jenie[1], C. Kitpracha[1,2], S. Lunz[1], N. Mammadaliyev[1], S. Modiri[1], S. Raut[1,2], H. Schuh[1,2], J. Wang[1,2]
(1) Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Telegrafenberg, D-14473 Potsdam, Germany
(2) Technische Universität Berlin, Institute of Geodesy and Geoinformation Science, Chair of Satellite Geodesy, Kaiserin-Augusta-Allee 104-106, D-10553 Berlin, Germany
Corresponding author: `georg.beyerle@gfz-potsdam.de`

Effects of Source Weighting in Geodetic VLBI Analysis

J.M. Anderson, S. Lunz, R. Heinkelmann, H. Schuh, M.H. Xu

Abstract Quasar source structure is known to be a significant component of residual errors in geodetic VLBI data analysis. As the radio source structure is unique to each quasar, is frequency-dependent and time-variable, and as the structure "seen" by the interferometer is baseline length- and orientation-dependent, different quasars contribute different amounts of structure errors to different baselines at different times. As part of the Extension of the coordinate parameterization of radio sources observed by VLBI (ECORAS-2) project, we are investigating methods to detect, mitigate, and correct for source structure effects in geodetic VLBI. We have modified the Potsdam Open Source Radio Interferometry Tool (PORT) software package for analysis of geodetic data at the GFZ German Research Centre for Geosciences to enable various methods of weighting observational data in order to account for various error terms that we allow to be station-, baseline-, and source-dependent. Error terms that are added on top of the measurement errors are determined by an iterative solution which automatically optimizes the error terms of individual objects such that the residual χ^2 values (that is, χ^2 corrected for the number of degrees of freedom) for each object approach unity. This process downweights observations of quasars with large residual errors and increases the relative weighting of quasars showing the least source structure. Reductions in the post-fit weighted root mean square (WRMS) residual values of up to 40 % are not uncommon as a result. In this contribution we present the results of baseline length repeatability tests using source-dependent weighting to repeatability tests without source-dependent weighting in order to evaluate how well this technique can improve geodetic parameters of interest.

Session-3: Analysis

Presentation type: poster

J.M. Anderson[1,2], S. Lunz[2], R. Heinkelmann[2], Harald Schuh[2,1], and Minghui Xu[3,4,1]
(1) Technische Universität Berlin, Institut für Geodäsie und Geoinformationstechnik, Fakultät VI, Sekr. KAI 2-2, Kaiserin-Augusta-Allee 104-106, D-10553 Berlin, Germany
(2) GFZ German Research Centre for Geosciences, Telegrafenberg, D-14473 Potsdam, Germany
(3) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, FI-02540 Kylmälä, Finland
(4) Aalto University Department of Electronics and Nanoengineering, PL 15500, FI-00076 Aalto, Finland
Corresponding author: anderson@tu-berlin.de

On the Origin of Clock Breaks Detected in Geodetic VLBI Data Analysis

K. Balidakis, J.M. Anderson, L. McCallum, J. McCallum, J. Wang, R. Heinkelmann, H. Schuh

Abstract Events where the phase-locked loop between the frequency synthesizer and the signal emitted by the cavity of the active hydrogen maser is suspended, are labeled as clock breaks in VLBI literature. A plausible explanation might be that the frequency standards stability is affected by changes in meteorological conditions or local magnetic fields. In geodetic VLBI data analysis, clock breaks appear as jumps of variable magnitude in the stations' group delay residuals, and are usually treated by introducing a new polynomial after the clock break occurrence. Since the size of a clock break can range between nanosecond fractions (e.g., Yg@R1863) to several hundred nanoseconds (e.g., Wz@R1863), the detection thereof cannot be carried out automatically with a uniform accuracy, given a noise level. In the presence of unaccounted effects such as source structure, detecting sub-nanosecond clock breaks often requires visual inspection. The latter is, as of early 2020, one of the main obstacles hindering automation at the analysis center level. Analyzing the entirety of non-intensive VLBI sessions carried out in the framework of IVS reveals that there are more than 2700 events that manifest as clock breaks. In this contribution we demonstrate that what in the residuals may appear as a clock break in most cases can be traced back to erroneous instrumental calibration (spurious or ambiguous cable delays and unstable phase calibration tones), or incorrect auxiliary data (e.g., pressure jump Nt@R1920). For instance, while analyzing a large number of 24-hour sessions where Yarragadee participates, we found that two 0.7 nanosecond large clock breaks occur at almost the same time, 09:00 and 20:00 local time, in 70% of the cases. This issue is attributed to phase calibration group delay jumps that coincide with phase calibration amplitude reductions. This suggests that most clock-break-like features could potentially be prevented with improved calibration data and a well-established feedback loop between observation and analysis

Session-3: Analysis

Presentation type: oral

Kyriakos Balidakis[1], James M. Anderson[1,2], Lucia McCallum[3], Jamie McCallum[3], Jungang Wang[1,2], Robert Heinkelmann[1], Harald Schuh[1,2]

(1) GFZ German Research Centre for Geosciences, Geodesy, Telegrafenberg A17, 14473 Potsdam, Germany

(2) Technische Universität Berlin, Chair of Satellite Geodesy, Kaiserin-Augusta-Allee 104-106, 10553 Berlin, Germany

(3) University of Tasmania, Hobart, Australia

Corresponding author: kyriakos.balidakis@gfz-potsdam.de

Contact addresses: kyriakos.balidakis@gfz-potsdam.de, anderson@tu-berlin.de, lucia.mccallum@utas.edu.au, Jamie.McCallum@utas.edu.au, jgwang@gfz-potsdam.de, rob@gfz-potsdam.de, schuh@gfz-potsdam.de

A first look at mixed VGOS-S/X correlation and post-processing

J. Barrett, R. Cappallo, B. Corey, P. Elosegui, D. Mondal, A. Niell, C. Ruszcysck, M. Titus

Abstract The processing of geodetic VLBI experiments involving both S/X and VGOS stations is highly desirable for a multitude of reasons. Beyond the express purpose of obtaining geodetic ties between existing S/X stations and the rapidly expanding network of VGOS stations, a period of overlap and integration between the two systems is beneficial in order to help preserve reference frame continuity during the transition from the S/X to VGOS network, as well as to provide an opportunity to study any systematic differences between the two. Therefore, it is important to correlate and fringe-fit data collected contemporaneously by both S/X and VGOS stations to obtain delay observables on mixed baselines. A brief overview of one possible implementation of this process will be presented, describing correlation (including the use of the DiFX zoom-bands feature) along with the peculiarities of data handling on mixed S/X-VGOS baselines during post-processing with *fourfit*. Some results from the mixed-mode sessions RD2005 and RD2006 will be presented, and future prospects will be discussed.

Session-1: Technology

Presentation type: oral

J. Barrett[1], R. Cappallo[1], B. Corey[1], P. Elosegui[1], D. Mondal[1], A. Niell[1], C. Ruszcysck[1], M. Titus[1]
(1) MIT Haystack Observatory, 99 Millstone Rd, Westford, MA, USA
Corresponding author: barrettj@mit.edu

Source structure and position stability of celestial reference frame sources in the Deep South

S. Basu, A. de Witt, C. Gattano

Abstract Very long baseline interferometric (VLBI) observations in the Southern Hemisphere have always been more difficult than in the north, and in the past, there have been no dedicated imaging observations of celestial reference frame (CRF) sources at declinations below $\sim 45^\circ$ south. In 2013, we started an imaging campaign to map, monitor and study the structure of southern CRF sources using data from routine astrometric observations in the south. These observations are coordinated through the IVS as part of the Celestial Reference Frame (CRF) and Celestial Reference Frame Deep South (CRDS) sessions. In 2018, we increased the data rate (and thus sensitivity) of the CRF and CRDS sessions to allow for more and weaker sources to be observed. We also optimised the scheduling for improved uv-coverage for imaging. To date, we have imaged 164 sources from 10 CRDS sessions. For 110 of these sources, we produced the first-ever high-resolution images at both 2.3 and 8.4 GHz. We now have multi-epoch images for 96 sources allowing us to study the structural variability over time. We present the most recent results from our imaging campaign, in particular from recent CRDS that included for the first time also the O'Higgins antenna in Antarctica. We also present an analysis of the source astrometric positions estimated from the CRDS sessions in the prospect of assessing the link between individual astrometric variation and structure changes.

Session-3: Analysis

Presentation type: Poster

Sayan Basu[1], Aletha de Witt[1], Cesar Gattano[2]
(1) South African Radio Astronomy Observatory (SARAO), Hartebeesthoek, Farm 502 Q Hartebeesthoek, Broederstroom Road, Krugersdorp, South Africa
(2) Astronomical Institute of the University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland
Corresponding author: sayan@hartrao.ac.za

New Ingest Software at IVS Data Centers

D. Behrend, M. Bérubé, C. Hesse, J. Woo, A. Girdiuk, M. Goltz, J. Gipson, C. Barache

Abstract About 1.5 years ago, personnel from the CDDIS and the Goddard VLBI Group started efforts to rework the data ingest at the IVS data centers. Unlike the original monolithic software, it was decided to take a more modular approach for the new software suite. As at the CDDIS the ingest of VLBI data and products had to be integrated into a larger suite that supports all geodetic techniques, it was not feasible to create a software suite that could be ported in its entirety to the other data centers (at BKG and OPAR). However, pieces could be extracted as building blocks for a second suite that basically replicates the features of the CDDIS software at BKG and OPAR. Hence, the Goddard VLBI Group worked with staff from all three data centers to implement the new ingest process in a consistent fashion.

The new software suites are written in Python3. In addition to the filename check, which was already done with the original software, the new ingest software added a validation step (QC) into the processing chain. That means that every data type is validated prior to be added to the data repository. If a submitted file fails the name check or the validation check, it is being rejected. The validation routines and the accompanying data description files (DDFs) form the modular pieces that are exchanged between the data centers. In this presentation we will provide a brief summary of the history of the ingest process, an outline of the IVS data center structure, and an overview of the features of the new ingest software.

Session-2: Observations

Presentation type: oral

Dirk Behrend[1], Mario Bérubé[1], Cody Hesse[2], Justine Woo[3], Anastasiia Girdiuk[4], Markus Goltz[4], John Gipson[1], Christophe Barache[5]
(1) NVI, Inc./NASA Goddard Space Flight Center, 7257 Hanover Parkway, Suite D, Greenbelt, MD 20770, USA
(2) Chalmers University of Technology, Chalmersplatsen 4, SE-412 96 Göteborg, Sweden
(3) SSAI/NASA Goddard Space Flight Center, 10210 Greenbelt Rd, Lanham, MD 20706, USA
(4) Federal Agency for Cartography and Geodesy (BKG), Richard-Strauss-Allee 11, D-60598 Frankfurt a.M., Germany
(5) Observatoire de Paris – SYRTE, 61 Avenue de l'Observatoire, F-75014 Paris, France
Corresponding author: dirk.behrend@nasa.gov

AuScope VLBI Dynamic Observing

L. Chin Chuan, L. McCallum, J. McCallum, G. Molera Calvés, T. McCarthy

Abstract The AuScope VLBI network actively participates in the IVS sessions and is dedicated to achieving compatibility with the future way of geodetic observation: VGOS. However, the realization of VGOS is significantly limited by the current operational model, which relies heavily on manual inputs from the schedulers and operators. The dynamic observing programme aims to introduce more automation into the AuScope VLBI observation process and improving the observations with feed-back loop. In terms of improved feed-back, the performance of the stations and the flux densities of sources on the Australian network are determined automatically to improve the agreement between the observed and the scheduled signal-to-noise ratios (SNRs). On the technical side, the current applications of this programme are advanced semi-automated operations for small AuScope observing routines such as regular fringe checks and mixed mode observations.

Session-2: Observations

Presentation type: poster

Lim Chin Chuan[1], Lucia McCallum[1], Jamie McCallum[1], Guifré Molera Calvés[1], Tiege McCarthy[1]
(1) School of Natural Sciences, University of Tasmania, Private Bag 37, Hobart 7001, Australia
Corresponding author: chinchuan.lim@utas.edu.au

Improving the S/X Celestial Reference Frame in the South: A Status Update

A. de Witt, S. Basu, P. Charlot, D. Gordon, C. Jacobs, M. Johnson, H. Krásná, K. Le Bail, F. Shu, O. Titov, M. Schartner

Abstract Catalogs of positions of compact extra-galactic radio sources, including the ICRF3, are generally weaker in the south by factors of 2 or more in both density and precision. In 2018 we started a campaign to improve the S/X celestial reference frame in the South by upgrading and improving existing IVS astrometric observing programmes. Our efforts were mainly focused on the Celestial Reference Frame (CRF) and Celestial Reference Frame Deep South (CRDS) sessions, which are dedicated astrometric observing programmes of sources at mid-and southern declinations. In particular, the data rate of the CRF and CRDS sessions were increased from 256 Mbps to 1 Gbps and the pool of sources were increased by a factor of two. The scheduling was also optimised to allow for simultaneous astrometric and imaging observations, and the CRF network were revised for improved uv-coverage. We provide details of our efforts, to date, to improve both the density and precision of the southern CRF, as well as our efforts to map and monitor the sources to quantify non-point-like structure and measure jet directions. We also discuss planned changes and upgrades, noting that the Australian 12-m telescopes are transitioning to broadband and will not be available for S/X astrometric observing in future. We also present the ideas and role of the newly-established IVS-CRF committee to improve the celestial reference frame in the south

Session-2: Observations

Presentation type: presentation

Aletha de Witt[1], Sayan Basu[1], Patrick Charlot[2], David Gordon[3], Chris Jacobs[4], Megan Johnson[3], Hana Krásná[5,6], Karine Le Bail[7], Fengchun Shu[8], Oleg Titov[9], Matthias Schartner[10]
(1) SARAO, South Africa
(2) University of Bordeaux, France
(3) USNO, United States
(4) NASA/JPL, United States
(5) Tu Wien, Austria
(6) Astronomical Institute of the Czech Academy of Sciences, Czech Republic
(7) OSO/Chalmers University of Technology, Sweden
(8) SHAO, China
(9) Geoscience, Australia
(10) ETH Zurich, Switzerland
Corresponding author: alet@hartrao.ac.za

K-band Imaging of 732 ICRF3 sources

A. de Witt, C. Jacobs, D. Gordon, M. Nickola, A. Bertarini

Abstract We present an overview of K-band (24 GHz) images of 732 compact extragalactic radio sources with sub-milliarcsecond (sub-mas) resolution based on radio interferometric observations made with the Very Long Baseline Array (VLBA) of ten telescopes during 29 day-long sessions spanning from 2015 to 2018 using a data rate of 2048 Mbps. Many of these sources are imaged for the first time at frequencies above X-band (8 GHz) with sub-mas resolution. The K-band images provide the following source properties: the source flux density and size, the sources compactness and radial extent, and the jet direction. The vast majority of sources are imaged at multiple epochs providing insights into the temporal behavior of the sources. The use of K-band was motivated by the opportunity to access more compact intrinsic source morphology as well as to leverage the factor of three improvement in interferometer resolution relative to the historically standard S/X-band (2.3/8.4 GHz) used for much reference frame and calibrator work. Lastly, as most of the sources imaged here are in the K-band component of the 3rd International Celestial Reference Frame (ICRF-3), these images serve characterize the objects used in that IAU standard.

Session-3: Analysis

Presentation type: oral

Aletha de Witt[1], , Chris Jacobs[2], David Gordon[3], Marisa Nickola[1], Alessandra Bertarini[4]

(1) SARAO, South Africa
(2) Jet Propulsion Laboratory, California Institute of Technology/NASA, United States
(3) USNO, United States
(4) DLR, Germany
Corresponding author: alet@hartrao.ac.za

Inter- and intra-technique combination on the observation level between VLBI and GPS - a study case for CONT17

P.-K. Diamantidis, G. Kłopotek, R. Haas

Abstract Combination of different space-geodetic techniques at co-location sites can be achieved via the common estimation of shared parameters of interest such as station clocks or tropospheric delays and gradients. Such an approach should, in principle, lead to more precise station position estimates and also positively impact earth orientation parameters (EOP). The combination of different networks of the same space-geodetic technique such as distinct networks of the Very Long Baseline Interferometry (VLBI) system, can be achieved for instance via the common estimation of EOP. The augmented geometric coverage should in turn lead to the improved EOP estimates.
In this contribution we investigate both inter- and intra-technique combination schemes based on the combination on the observation level (COL) conducted with the c5++ analysis software. More specifically, we perform COL based on the CONT17 VLBI dataset, using the so-called Legacy-1 (L1) network as our reference solution. We first augment L1 with co-located Global Positioning System (GPS) observations via the common troposphere model and assess how station position repeatabilities and frame-defining parameters are impacted due to this combined (L1&GPS) approach. Next we combine two different interferometric networks, namely L1 with the so-called Legacy-2 (L2) network via common EOP. The impact on EOP of both combination schemes (GPS&L1 and L1&L2) is examined, and the underlying consequences that common troposphere and EOP bring, are also discussed.

Session-3: Analysis

Presentation type: oral

Periklis-Konstantinos Diamantidis[1], Grzegorz Kłopotek[2], Rüdiger Haas[1]

(1) Department of Space, Earth and Environment, Chalmers University of Technology, Sweden
(2) Department of Civil, Environmental and Geomatic Engineering, Institute of Geodesy and Photogrammetry, ETH Zürich
Corresponding author: periklis.diamantidis@chalmers.se

Small scale atmospheric variations sensed with very short baseline interferometry (VSBI) and microwave radiometry

G. Elgered and R. Haas

Abstract Three telescopes at the Onsala Space Observatory are regularly used in geodetic VLBI experiments: the 20 m radome enclosed telescope and the twin telescopes. The distance between the twin telescopes (OE and OW) is approximately 75 m and they are in turn approximately 470 m and 540 m southwest of the 20 m telescope (ON), respectively. A series of local interferometer experiments has been carried out with these three telescopes during 2019 and 2020. In these experiments differential equivalent zenith wet delays (ZWD) have been estimated for the twin telescopes relative to the 20 m telescope.

The location of the Onsala telescopes close to the coast line suggests that there may occasionally be significant local horizontal gradients in the atmospheric water vapour content. By significant we mean larger than the formal errors of the estimated differential ZWD. In our study these formal errors vary from 0.2 mm to 3.5 mm with a mean value of 0.5 mm. This shall be compared with the mean of value of the absolute differential ZWD which is 0.5 mm, indicating that any atmospheric signals may be too small to be detected. Nevertheless, given that horizontal gradients estimated by collocated GNSS stations and a Water Vapour Radiometer (WVR) can reach a size of several millimetres an assumed scale height of the horizontal gradients of 1 km predicts that the differential ZWD over a 500 m distance may be a couple of millimetres. Therefore, we find it meaningful to compare horizontal gradients from the WVR with the differential ZWD between the OTT telescopes and the 20 m telescope.

We find, as expected, that both the differential ZWD between the 20 m telescope and the OTT telescopes and the gradients estimated from the WVR are slightly larger during the warmer season when there is a higher water vapour content in the atmosphere. In spite of that there are insignificant correlations between the WVR gradient and the differential ZWD for the entire dataset. A major question is if it is reasonable to estimate any differential ZWD between the 20 m telescope and the OTT telescopes. These estimates may also absorb other errors in the observations and thereby hiding the possibility to identify their origin. A consequence is that when there is a large difference between the WVR gradient and the differential ZWD this calls for detailed studies in order to identify and eliminate problems that may not be related to the atmosphere.

Session-3: Analysis

Presentation type: poster

Gunnar Elgered, Rüdiger Haas
Chalmers University of Technology, Space, Earth and Environment, Space Geodesy and Geodynamics, Onsala, Sweden
Corresponding author: gunnar.elgered@chalmers.se

VLBI enhancement of the Bernese GNSS Software for multi-technique analysis at BKG

C. Flohrer, D. König, D. Thaller, C. Gattano, U. Meyer, R. Dach, U. Hugentobler

Abstract For many years the geodesy group at BKG (Federal Agency for Cartography and Geodesy) participates in IVS analyses and combination activities. It successfully operates an IVS analysis center and the IVS combination center. On the other hand BKG also contributes to ILRS and IGS activities. It runs an ILRS analysis center and is partner of the CODE consortia, which runs the IGS analyses center CODE at the AIUB (Astronomical Institute of the University of Bern). AIUB is also the home of the Bernese GNSS Software, where it is developed and enhanced, continuously adapting to changing requirements and user needs. By this, the software is in use for global GNSS analysis at CODE since the beginning of the IGS, and it is in use for global SLR analysis at BKG's ILRS analysis center since 2010. Therewith BKG has gained a long-standing experience in the analysis of the three geodetic techniques VLBI, SLR and GNSS. However, our focus is not only on the individual techniques but on the combination of the various observation techniques, in particular for the improvement of Earth rotation parameters. We would like to continue the multi-technique combined analysis using the Bernese GNSS Software and bring the efforts from earlier studies to operational implementations. We recently started an effort for the enhancement of the Bernese GNSS Software to enable also VLBI processing capabilities. Thus we could use the Bernese GNSS Software for the processing of all three space-geodetique techniques in the near future. Eventually it will allow us to combine GNSS, VLBI and SLR data not only on SINEX level, but on the observation level. We would like to present the current software development activities to enhance the Bernese GNSS Software for the analysis of VLBI data. We will discuss the advantages but also challenges to enable a consistent processing of GNSS, VLBI and SLR data within a single software package. Finally we will give an outlook on BKG's combination activities with its focus on Earth rotation.

Session-3: Analysis

Presentation type: oral

Claudia Flohrer[1], Daniel König[1], Daniela Thaller[1], Cesar Gattano[2], Ulrich Meyer[2], Rolf Dach[2], Urs Hugentobler[3],
(1) Federal Agency for Cartography and Geodesy (BKG), Department Geodesy, Frankfurt am Main, Germany
(2) Astronomical Institute of the University of Bern, Bern, Switzerland
(3) Institute for Astronomical and Physical Geodesy, Technical University of Munich, Munich, Germany
Corresponding author: claudia.flohrer@bkg.bund.de

Review of Operational VGOS Sessions in 2020

J. Gipson, S. Bolotin, K. Baver, D. Behrend, F. Lemoine, P. Elosegui, C. Ruszczyk

Abstract In 2020, the IVS observed for a second year an operational 24-hr VGOS session series (VGOS-O) at a bi-weekly cadence. The total number of sessions amounts to 24 for the full year; the network size was between 8 and 9 stations. In February 2020, we began an Intensive-type VGOS session series (VGOS-V2) of one-hour observing designed to measure UT1. There were a total of 21 VGOS-V2 sessions that were scheduled in the weeks when there was no 24-hr VGOS session and ran concurrently with the legacy S/X INT1 sessions. The VGOS-V2 sessions generally included the KOKEE12M–WETTZ13S baseline with GGAO12M, MACGO12M, and WESTFORD being tagged along or scheduled in depending on their availability. There were a total of 21 VGOS-V2 sessions. For both VGOS-O and VGOS-V2 sessions we discuss the scheduling, correlation, and analysis. We contrast the 24-hr VGOS sessions with 24-h S/X sessions of similar size. For the VGOS-V2 sessions we compare UT1 estimates with those obtained from the corresponding S/X Intensives.

Session 2: Observations

Presentation type: oral

John Gipson[1], Sergei Bolotin[1], Karen Baver[1], Dirk Behrend[1], Frank Lemoine[2], Pedro Elosegui[3], Chet Ruszczyk[3]
(1) NVI, Inc./NASA Goddard Space Flight Center, 7257 Hanover Parkway, Suite D, Greenbelt, MD 20770, USA
(2) NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD 20771, USA
(3) MIT Haystack Observatory, 99 Millstone Rd, Westford, MA 01886, USA
Corresponding author: john.m.gipson@nasa.gov

Intensives and 24-hour session data reprocessing for BKG AC 2020a solutions

A. Girdiuk, G. Engelhardt, D. Ullrich, D. Thaller, H. Hellmers

Abstract We present the newest BKG series of intensives and 24-hour VLBI session solutions. The data reprocessing includes almost all sessions since 1984 up to now. 24-hour session parameterization is aligned with ITRF2020 requirements. The differences from the previous BKG 2014 solution are new mean pole tide model, new recommendation for the high-frequency Earth Rotation variations – the tide corrections derived from TPXO8-based model, galactic aberration and corrections for the gravitational deformation of VLBI antennas. The a priori station positions are set to the ITRF2014 with corresponding post-seismic deformation corrections. For a few stations which are not included in the ITRF2014, the combined VTRF2020b built by the IVS Combination Center and the internal BKG solution are chosen. Among the others a priori station positions for new VGOS stations are adjusted internally as well. The source positions are aligned with the last realization of the celestial reference frame ICRF3. Applied models and reductions are updated for 1-hour solution correspondingly. This results in new 24-hour session series of consistently estimated EOPs, station coordinates and troposphere parameters. While intensives allow for routine dUT1 estimation only, they are also observed on long baselines as most of 24-hour sessions. The growing number of intensive sessions observed on 3-4 stations facilitate to collect at least twice as much observations and, thus, more accurate dUT1 estimates. This data reprocessing is focused on the quality and consistency of the obtained geodetic products. In particular, we are interested in the consistency between dUT1 estimates derived from intensives and 24-hour sessions. This work is aimed to pinpoint challenges and feasibility of the united analysis of intensives and 24-hour experiments.

Session-3: Analysis

Presentation type: oral

Anastasiia Girdiuk[1], Gerald Engelhardt[1], Dieter Ullrich[1], Daniela Thaller[1], Hendrik Hellmers[1]
(1) Unit G 1 - General Issues, Combination of Space Techniques, Federal Agency for Cartography and Geodesy (BKG), Richard-Strauss-Allee 11, 60598 Frankfurt am Main, Germany
Corresponding author: anastasiia.girdiuk@bkg.bund.de

New Designs in VGOS Frontends in Yebes Observatory

G. Gómez-Molina, O. García-Pérez, F. Tercero

Abstract The Yebes Observatory has designed and built five VGOS compliant receivers (2-14 GHz bandwidth) for their own radio-telescopes and for other European IVS partners under contract or agreement since 2015. This first generation of receivers uses a Quad-Ridged Flared Horn (QRFH) as a feed, which provides measured reflection coefficient lower than -10 dB in almost all the band, and up to -6 dB in the worst frequency sub-bands. The estimated aperture efficiency of the radio-telescope with this feed is in the range between 55-70% along its bandwidth. The cryostat, which has been designed and replicated for five receivers with minimum changes in the interfaces with the radio-telescopes, is based on a Sumitomo cold head which has proved its reliability in all the sites it has been installed. However, the dewar dimensions are a bit bulky in comparison with the size of the components that are lodged inside. Regarding the signal amplification stage of the receiver, in this first generation different single-ended and balanced hybrid configurations have been tested. Although such receivers are successfully working in their respective sites, we consider that there is still room for some improvements in the receiver design.
A second generation of this receiver is going to be built in Yebes Observatory with a new design of the feed and the cryostat. The new feed design improves the reflection coefficient below -10 dB across the whole bandwidth and a more similar response is expected between both polarizations compared to the previous design. The signal amplification stage uses a balanced hybrid configuration in these new receivers, to reduce the reflections between the LNAs and the feed. In addition, the new cryostat design improves the receiver weight and the boresight vision line of the feed. Three of these new receivers are scheduled for the 2021-2022 period.
This paper summarizes the first-generation receivers built until now and shows the improvements on the new second-generation design.

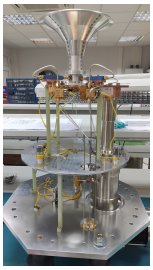

Fig. 1 Picture of first-generation VGOS receiver

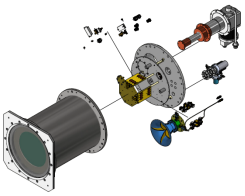

Fig. 2 Design of second-generation VGOS receiver

Session-1: Technology

Presentation type: oral

Gabriel Gómez-Molina[1], Oscar García-Pérez[1], Félix Tercero[1]
(1) Observatorio de Yebes, Instituto Geográfico Nacional (IGN), 19141 Yebes (Spain)
Corresponding author: ggomez@oan.es

Determination of the geodetic position of non-geodetic EVN antennas

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

Abstract One of the goals of the EC Horizon 2020 project JUMPING JIVE is to establish a geodetic path at the European VLBI Network (EVN) correlator at JIVE (SFXC). This was successfully developed by 2018, and since then we have conducted two EVN geodetic-type experiments at K-band, EC065 and EC076. These exercise all aspects of this newly-implemented geodetic path to export the data in mark4 format and post-process that using standard geodetic analysis tools. The two experiments were carried out in 2018 and 2020, and involved both geodetic and non-geodetic EVN antennas, including Sardinia, Torun, and the Jodrell Mark2 telescope. e-MERLIN antennas and KVN stations successfully joined in the latter observation. The main goal was to obtain precise geodetic coordinates for the non-geodetic antennas. The project will also consider the results from similar experiments conducted previously, going back to 2000, to allow estimation of the velocity of the non-geodetic antennas. This contribution will discuss the current state of the project.

Session-2: Observation

Presentation type: oral

Maria Eugenia Gomez[1]*, Patrick Charlot[1], Robert M. Campbell[2], Mark Kettenis[2], Aard Keimpema[2]
(1) Laboratoire d'Astrophysique de Bordeaux, Pessac, France
(2) Joint Institute for VLBI-ERIC, Dwingeloo, The Netherlands
Corresponding author: megomez@fcaglp.unlp.edu.ar

* currently at Faculty of Astronomical and Geophysical Sciences (UNLP) and CONICET-Argentina

Simulation of VGOS observations at the raw data level with VieRDS

J. Gruber, J. Böhm, A. Nothnagel, F. Jaron

Abstract Broadband observations of the VGOS system reveal new systematic influences within the interferometric magnitudes and phases that must be taken into account in the VLBI processing chain. These include, for example, the characteristic frequency response of the station or the nonlinear group delay contribution due to the ionosphere. Especially the correlation and fringe fitting analysis stages are affected by these systematics. In this talk, we present a novel software realization, called VieRDS, that simulates broadband VLBI observations at the raw data level. The approach is in contrast to existing simulation software packages that simulate at the group delay level. This presentation focuses on simulating the characteristic station frequency response of real VGOS telescopes and simulating the telescopes' phase calibration signal. The simulation of a dispersive group delay for a VGOS broadband frequency setup will also be shown and analyzed in the VLBI processing chain. Simulation of the source structure effect and dual linear polarization is discussed as an outlook.

Session-2: Observations

Presentation type: oral

Jakob Gruber[1], Johannes Böhm[1], Axel Nothnagel[1], Frederic Jaron[1]
(1) Technische Universität Wien (TU Wien), Department of Geodesy and Geoinformation, Wiedner Hauptstraße 8-10, 1040 Vienna, Austria
Corresponding author: jakob.franz.gruber@geo.tuwien.ac.at

VGOS Intensives Ishioka-Onsala

R. Haas, E. Varenius, P.-K. Diamantidis, S. Matsumoto, M. Schartner, and Tobias Nilsson

Abstract In the end of 2019 the International VLBI Service for Geodesy and Astrometry (IVS) decided to start a new and so-far experimental VGOS-Intensive series, called VGOS-B, involving Ishioka (Japan) and Onsala (Sweden). Both sites operate modern VGOS stations with 13.2 m diameter radio telescopes, i.e. ISHIOKA (IS) in Japan, and ONSA13NE (OE) and ONSA13SW (OW) in Sweden. In total 12 VGOS-B sessions were observed between December 2019 and February 2020, one every week, in parallel and simultaneously to legacy S/X INT1 Intensive sessions that involve the stations KOKEE (KK) on Hawaii and WETTZELL (WZ) in Germany. These 1-hour long VGOS-B sessions were scheduled rather conservatively, with 30 s scans length and not optimized for a maximum number of observations. They consist of more than fifty radio source observations, resulting in about 1.6 TB of raw data that are collected at each station. The scheduling of the VGOS-B sessions was done using VieSched++ and the subsequent steps (correlation, fringe-fitting, database creation) were carried out at the Onsala Space Observatory using DIFX and HOPS. The resulting VGOS databases were analysed with several VLBI analysis software packages, involving nuSolve, c5++ and ASCOT. In this presentation, we give an overview on the VGOS-B series, present our experiences, and discuss the obtained results. The derived UT1-UTC results are compared to corresponding results from standard legacy S/X Intensive sessions, as well to the final values of the International Earth Rotation and Reference Frame Service (IERS), provided in IERS Bulletin B. The VGOS-B series achieve 3-4 times lower formal uncertainties for the UT1-UTC results than standard legacy S/X INT series. Furthermore, the root mean square (RMS) agreement with respect to the IERS Bulletin B is slightly smaller for the VGOS-B results than for the INT1 results.

Session-3: Analysis

Presentation type: oral

Rüdiger Haas1, Eskil Varenius1, Periklis-Konstantinos Diamantidis1, Saho Matsumoto2, M. Schartner3, T. Nilsson4
(1) Chalmers University of Technology, Space, Earth and Environment, Space Geodesy and Geodynamics, Onsala, Sweden
(2) Geospatial Information Authority of Japan
(3) ETH Zürich, Institute of Geodesy and Photogrammetry, Zürich, Switzerland
(4) Lantmäteriet – The Swedish mapping, cadastral and land registration authority, Geodetic Infrastructure, Gävle, Sweden
Corresponding author: rudiger.haas@chalmers.se

Spectrum Management for the VGOS

H. Hase, J. A. López-Pérez, M. Bautista-Durán, J. Kallunki, P. Kupiszewski, V. Tornatore, W. Madkour, M. Lindqvist, B. Winkel

Abstract The VGOS-Group in the Committee of Radio Astronomy Frequencies (CRAF) started several initiatives to spread awareness of the need for protection of VGOS-observation sites against existent or future interferer to VGOS-observations. This talk will inform about the current status on:

- ITU-registration of VGOS-sites
- RAS-bands and active services vs. VGOS-subbands
- VGOS-observation configuration, legal issues
- draft questions to ITU-R
- draft report on geodetic radio astronomy
- draft IAU resolution

It is important to continue different VGOS channel distributions soon, in order to freeze in some moment a definite VGOS-frequency setup which may enter into a regulation process.

Session-*1*/2/3: *Technology*/Observations/Analysis

Presentation type: *oral* / poster / movie

Hayo Hase[1], José A. López-Pérez[2], Marta Bautista-Durán[3], Juha Kallunki[4], Piotr Kupiszewski[5], Vincenza Tornatore[6], Waleed Madkour[7], Michael Lindqvist[8], Benjamin Winkel[9]
(1) Bundesamt für Kartographie und Geodäsie, Geodätisches Observatorium Wettzell - AGGO, Sackenrieder Str. 25, 93444 Bad Kötzting, Germany
(2) Yebes Observatory, Instituto Geográfico Nacional, Cerro de la Palera sn, Yebes, E-19141 Guadalajara, Spain
(3) Universidad de Alcalá de Henares, Madrid, Spain
(4) Aalto University, Metsähovi Radio Observatory, Metsähovintie 114, 02540 Kylmälä, Finland
(5) Kartverket, Hönefoss, Norway
(6) Politecnico di Milano, Department of Civil and Environmental Engineering (DICA) - Geodesy and Geomatic Area, Piazza Leonardo da Vinci 32, 20133 Milan, Italy
(7) JIVE, Dwingeloo, The Netherlands
(8) Chalmers University Göteborg, Onsala Space Center, Onsala, Sweden
(9) Max-Planck-Institut für Radioastronomie, Bonn, Germany
Corresponding author: hayo.hase@bkg.bund.de

Combined IVS contribution to the ITRF2020

H. Hellmers, S. Bachmann, D. Thaller, M. Bloßfeld, M. Seitz, J. Gipson

Abstract The ITRF2020 will be the next official solution of the International Terrestrial Reference Frame and the successor of the currently used frame, i.e., ITRF2014. Based on an inter-technique combination of all four space geodetic techniques VLBI, GNSS, SLR and DORIS, contributions from different international institutions lead to the global ITRF2020 solution. In this context, the IVS Combination Centre operated by the Federal Agency for Cartography and Geodesy (BKG, Germany) in close cooperation with the Deutsches Geodätisches Forschungsinstitut (DGFI-TUM, Germany) generates the final contribution of the International VLBI Service for Geodesy and Astrometry (IVS). Thereby, an intra-technique combination utilizing the individual contributions of multiple Analysis Centres (AC) is applied.
The contribution of IVS data for ITRF2020 differs from ITRF2014 in several important aspects, e.g. updated geophysical and astronomical models, as well as gravitational deformation corrections for particular VLBI antennas. For the contribution to the upcoming ITRF2020 solution, sessions containing 24h VLBI observations from 1979 until the end of 2020 are processed by 10 to 12 ACs and submitted to the IVS Combination Centre. We discuss the criteria for inclusion in the list of selected sessions.
The required SINEX format includes datum-free normal equations containing station coordinates and source positions as well as full sets of Earth Orientation Parameters (EOP). For ensuring a consistently combined solution, time series of EOPs, source positions and station coordinates as well as a VLBI-only Terrestrial Reference Frame (VTRF) and a Celestial Reference Frame (CRF) were generated and further investigated.
One possibility to assess the quality of the IVS contribution to the ITRF2020 solution is to carry out internal as well as external comparisons of the estimated EOP. Thereby, estimates of the individual ACs as well as external time series (e.g. IERS C04, Bulletin A, JPL-Comb2018) serve as a reference. The evaluation of the contributions by the ACs, the combination procedure and the results of the combined solution for station coordinates, source positions and EOPs will be presented.

Session-3: Analysis

Presentation type: oral

Hendrik Hellmers[1], Sabine Bachmann[1], Daniela Thaller[1], Mathis Bloßfeld[2], Manuela Seitz[2], John Gipson[3]
(1) Federal Agency for Cartography and Geodesy (BKG), Department Geodesy, Frankfurt am Main, Germany
(2) Deutsches Geodätisches Forschungsinstitut, TU München, München, Germany
(3) Goddard Space Flight Center - NASA
Corresponding author: hendrik.hellmers@bkg.bund.de

Update on VLBA Imaging of ICRF3 Sources

L. Hunt, P. Cigan, D. .Gordon, M. Johnson, J. Spitzak

Abstract We have developed a new calibration and imaging pipeline that is fully automated using the Common Astronomy Software Applications (CASA) package. CASA allows for a more technical calibration and imaging script that produces results comparable to, or better than the traditional calibration and imaging scripts used to image data using AIPS and Difmap. We plan to make these images available through the new Fundamental Reference Image Data Archive (FRIDA). FRIDA will be public later this year and will replace the Radio Reference Frame Image Database. With FRIDA you will be able to search for sources by name, position or realization of the ICRF amongst other search criteria. You will see the source image and information that can help assess image quality, and you will have the ability to download a fits image, a fits file showing the clean components, the calibrated UV-fits data, and a log containing the imaging and self-calibration steps. In this talk we will outline the steps that went in to calibrating and imaging the data, discuss some statistical properties of the sample, and give an updated preview of FRIDA.

Session-3: Analysis

Presentation type: oral

Lucas Hunt[1,2], Phil Cigan[1,3], David Gordon[1,3], Megan Johnson[1], John Spitzak[2]
(1) United States Naval Observatory, 3450 Massachusetts Ave NW, Washington, DC 20392, USA
(2) Computational Physics, Inc., 8001 Braddock Road, Suite 210, Springfield, VA 22151-2110
(3) George Mason University, 4400 University Dr, Fairfax, VA 22030
Corresponding author: lucas.r.hunt.ctr@mail.mil

X/Ka Network Enhanced by Misasa, Japan's 54-meter antenna

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

Abstract The Japan Aerospace Exploration Agency (JAXA) is finishing a new 54-meter antenna at Misasa, Japan for tracking spacecraft which will replace the Usuda 64-m. It will operate at X-band (8.4 GHz) and Ka-band (32 GHz). As part of ongoing joint support of deep space missions amongst JAXA, ESA, and NASA, we are developing a united multi-agency effort to improve the X/Ka celestial reference frame as well as a unified X/Ka terrestrial frame to be shared by the three agencies. The Misasa 54-m antenna enhances X/Ka sensitivity by virtue of having an aperture area 2.5 times larger than the NASA and ESA antennas in the network. Misasa improves the network geometry by providing four new baselines including the first direct north-south baseline (Japan-Australia) in the X/Ka VLBI network which will provide optimal geometry for improving declinations. The X/Ka component of the ICRF-3 has almost a factor of two lower precision in declination than in RA. Also, the X/Ka frame has systematic distortions vs. declination which may be partially modeled as Z-dipole and quadrupole 2,0 spherical harmonics. VLBI measurements with the Misasa 54-m are expected to reduce both the random error limiting precision and the systematic distortions vs. declination limiting accuracy. This paper will describe the new 54-m antenna and present the first Ka-band VLBI results on baselines to the Misasa 54-m.

Session-2: Observations

Presentation type: oral

Christopher S. Jacobs[1], Yasuhiro Murata[2], Hiroshi Takeuchi[2], Shinji Horiuchi[3], Daniel Firre[4], Sami Asmar[1], Takahashi Uchimura[2], Kenji Numata[2]
(1) Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA
(2) JAXA, Chuou-ku, Yoshinodai 3-1-1,Sagamihara Kanagawa, 252-5210, Japan,
(3) CSIRO Astronomy and Space Science, Canberra Deep Space Communication Complex, Tidbinbilla, ACT, Australia
(4) European Space Agency, Robert Bosch Str. 5, 64293 Darmstadt, Germany
Corresponding author: Chris.Jacobs@jpl.nasa.gov

10 years of AuScope VLBI

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

Abstract The AuScope VLBI array, comprising 12m telescopes in Hobart, Katherine and Yarragadee, has been participating in IVS observations since 2011, marking its ten year anniversary.
Originally filling a gap in the global network, triggering change in scheduling and recording speeds and being amongst the busiest telescopes in the IVS over the past years, the AuScope array has made an impact for global VLBI observations.
This contribution covers 10 years of AuScope VLBI data. Concentrating on Australian stations and baselines, we highlight the achievements of our first decade: after only a short time series was used for ITRF2014, we can now measure station velocities reliably, well in agreement with GNSS. Furthermore, intra-plate tectonics could be measured to sub-mm accuracy.
Besides the overall results of the long time series, we will discuss some systematics in the data, which could be linked to operational deficiencies at the telescopes themselves.

Session-3: Analysis

Presentation type: movie

Ahmad Jaradat[1], Lucia McCallum[1], Guifré Molera Calvés[1], Jamie McCallum[1], Tiege McCarthy[1].
School of Natural Sciences, University of Tasmania, Private Bag 37, 7001 Hobart, Australia.
Corresponding author: Ahmad.Jaradat@utas.edu.au

EU-VGOS activities in Vienna

F. Jaron, J. Gruber, M. Schartner, J. Böhm, B. Soja

Abstract The EU-VGOS collaboration carries out observational sessions with a network of European VGOS antennas on a regular basis. Part of these experiments are correlated at TU Wien. Using the infrastructure of the Vienna Scientific Cluster we are able to efficiently receive VGOS data from stations and to process these data from correlation to database creation. This is a report on the correlation and fringe-fitting of EU-VGOS experiments with particularly short scan durations. Performance of calibration algorithms will be discussed. Results about the quality of geodetic observables will be presented.

Session-1: Technology

Presentation type: oral

Frédéric Jaron[1], Jakob Gruber[1], Matthias Schartner[2], Johannes Böhm[1], Benedikt Soja[2]
(1) Department of Geodesy and Geoinformation, Technische Universität Wien, Wiedner Hauptstraße 8-10, A-1040 Wien, Austria
(2) Institute of Geodesy and Photogrammetry, ETH Zürich, Robert-Gnehm-Weg 15, CH-8093 Zürich, Switzerland

Mitigating the effect of extended source structure in geodetic VLBI by re-weighting observations using baseline-to-jet orientation

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

Abstract The VLBI Global Observing System (VGOS) has been expanded by multiple radio telescopes globally in recent years and is being used in conjunction with the legacy network. In VLBI, the electromagnetic radiation from extra-galactic radio sources is observed by two or more globally distributed telescopes. Before the signal reaches the telescopes it propagates through the atmosphere. This causes delay errors in the observed signals. Along with these atmospheric errors, the radio source structure is expected to be a major contributor to the VGOS error budget. An ideal geodetic source is a point-like and strong radio source. However, most of them exhibit finite structure. We focus on sources having an elongated structure due to the alignment of their relativistic jets with respect to the observing baseline. Typically the effect of source structure has been classified by so-called structure indices derived from the median structural delay. To mitigate this effect to the observations and derived geodetic parameters we model the source structure in terms of jet orientation relative to the observing baseline. We have developed a simple-to-implement weighting scheme to re-weight the observations based on available jet direction angles. We focus on CONT17 legacy sessions and also compare these results to some VGOS sessions. The effects of re-weighting are evaluated with respect to the session fit statistics and estimated geodetic parameters.

Session-3: Analysis

Presentation type: oral

Niko Kareinen[1], Nataliya Zubko[1], Tuomas Savolainen[2,3,4], Minghui Xu[2,3,5], Markku Poutanen[1]
(1) Finnish Geospatial Research Institute (FGI), National Land Survey of Finland Geodeetinrinne 2, FI-02430, Masala, Finland
(2) Aalto University Department of Electronics and Nanoengineering, PL 15500, FI-00076 Aalto, Finland
(3) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, 02540 Kylmälä, Finland
(4) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
(5) Institute of Geodesy and Geoinformation Science, Technische Universität Berlin, Straße des 17. Juni 135, 10623, Berlin, Germany
Corresponding author: niko.kareinen@nls.fi

VLBI Intensive sessions: the selection of baselines for UT1 estimation

L. Kern, M. Schartner, B. Soja, A. Nothnagel, J. Böhm

Abstract VLBI Intensives are one hour single baseline sessions dedicated to derive the parameter UT1-UTC with a short latency. Thus far, the optimal geometry was understood to include a long east-west extension to ensure an accurate estimation of UT1-UTC. In this presentation, we show that the selection of baselines for VLBI Intensives is not as simple as that.
In the case of this study, Monte-Carlo simulations for a global 10° grid of artificial station locations were performed and the suitability of the individual baselines based on the formal error of dUT1 was analysed. Concerning the global grid, the antennas were located at latitudes of -80° to 80° and longitudes of 0° to 180° and are assumed to have the same properties as the WETTZ13S telescope. Nine of 323 stations are selected as reference stations, which are all located at longitude 0° on the northern hemisphere. Based on monthly schedules, 2898 possible baselines between the reference stations and other artificial stations are individually investigated over one year to minimize potential seasonal variations. Therefore, it is possible to derive a global picture of the suitability of baselines for dUT1 estimation.
The findings show optimal geometries concerning VLBI Intensive sessions, which confirm that the IVS-INT1 baseline is among the best ones available. Moreover, we show that certain north-south baselines are also sensitive to dUT1 depending on their orientation with respect to the Earth rotation axis. Furthermore, we highlight that east-west baselines located on the equator are not suitable for the estimation of dUT1. Additionally, it has been shown that extremely long baselines are problematic due to the highly restricted mutual visibility.

Session-2: Observations

Presentation type: oral

Lisa Kern[1], Matthias Schartner[2], Benedikt Soja[2], Axel Nothnagel[1], Johannes Böhm[1]
(1) Institute of Geodesy and Geophysics, TU Wien, Wiedner Hauptstrasse 8, AT-1040 Vienna, Austria
(2) Institute of Geodesy and Photogrammetry, ETH Zürich, Robert-Gnehm-Weg 15, CH-8093 Zurich, Switzerland
Corresponding author: lisa.kern@tuwien.ac.at

First results from the new station NYALE13S

A-S. Kirkvik

Abstract In February 2020 the new VLBI station NYALE13S made its first successful 24 hour session. The station is equipped with a tri-band receiver and will participate in R1 and R4 sessions together with NYALES20 before NYALES20 is dismanteled and NYALE13S is equipped with a broadband receiver. The goal is to have at least one and a half year of parallel observations. The purpose of the legacy observations is to be able to transfer the long timeseries from NYALES20 to the new station NYALE13S and compare the results with the local tie measurements. The length of the NYALES20-NYALE13S baseline is approximately 1.5 kilometers and these parallel observations will be very useful for connecting future VGOS observations with the legacy network. Some early analysis resulsts from the observations gathered so far will be presented. The number of available observations is significantly less than scheduled due to problems with the equipment both at the new and old station. The results are therefore very preliminary and hopefully more sessions with be observed in the near future.

Session-3: Analysis

Presentation type: Poster

Ann-Silje Kirkvik[1]
(1) Norwegian Mapping Authority Kartverksveien 21, 3511 Hønefoss, Norway
Corresponding author: ann-silje.kirkvik@kartverket.no

Baseline-dependent clock offsets in VLBI analysis

H. Krásná, F. Jaron, J. Gruber, J. Böhm, A. Nothnagel

Abstract The primary goal of the geodetic Very Long Baseline Interferometry technique is to provide highly accurate terrestrial and celestial reference frames with Earth orientation parameters. In compliance with the concept of VLBI, additional parameters have to be estimated such as relative clock offsets and their variations at the stations with respect to a reference clock in the observing network. Reality shows that in many cases significant offsets appear in the observed group delays for individual baselines which have to be compensated for by estimating the so-called baseline-dependent clock offsets (BCOs). We investigate various aspects of BCOs including their impact on the estimates of geodetically important parameters. We choose a systematic approach for the empirical tests and investigate some of the theory behind BCO estimation. For the case study, we choose both legacy networks of the CONT17 campaign. We conclude that it is essential to estimate BCOs for baselines where an offset in the observed delay appears. Further we show, that estimation of the BCOs at baselines without any significant offset does not harm the geodetic solution under the condition that there are enough observations at the telescopes with good sky coverage which allows for decorrelation of station dependent parameters.

Session-3: Analysis

Presentation type: oral

Hana Krásná[1,2], Frédéric Jaron[1], Jakob Gruber[1], Johannes Böhm[1], Axel Nothnagel[1]
(1) Technische Universität Wien (TU Wien), Department of Geodesy and Geoinformation, Vienna, Austria
(2) Astronomical Institute, Czech Academy of Sciences, Prague, Czech Republic
Corresponding author: hana.krasna@geo.tuwien.ac.at

The source structure as main error source in Russian VLBI intensive sessions.

S. Kurdubov, S. Mironova, E. Skurikhina

Abstract The IAA RAS performing Russian national intensive sessions 3-4 times per day in order to estimate the UT1-UTC differences. Point of interest in this presentation is the discrepance between formal errors of UT1 estimation of individual sessions (5-10us) and scatter of the differences with IERS finals (20-35us). We consider different aproaches for this effect as instrumental one, intraday UT1 variations, stations and radio source coordinate errors. It will shown that the variations of radio source positions or changing of observed sources give us maxim effect on the UT1 vs finals differences.

Session-3: Analysis

Presentation type: oral

Sergei Kurdubov[1], Svetlana Mironova[1], Elena Skurikhina[1]
(1) Institute of Applied Astronomy Russian Academy of Sciences nab Kutuzova, 10, Saint-Petersburg, Russia
Corresponding author: kurdubov@iaaras.ru

Approaches of optimal scheduling of UT1 geodetic VLBI sessions

S. Kurdubov, A. Kudelkin, A. Melnikov

Abstract One of the main goal of the geodetic VLBI is the estimation of the UT1 − UTC correction (ΔUT1). The important factor of accurate ΔUT1 estimation is the scheduling strategy of the VLBI observations. In this presentation we discuss the approaches of sky coverage and covariance matrix optimization strategy. The matrix optimization strategy are less used due to the lack of stability againist tropospheric fluctuations, but if we can use external tropospheric calibration it is possible to obtain the several times improvement in the accuracy of UT1 estimations. We propose new improved algorithms for the covariance matrix optimization strategy in the case of intensive sessions. The numerical simulations were performed in order to compare proposed algorithms with the implemented in the existing VLBI scheduling software.

Session-2: Observations

Presentation type: oral

Sergei Kurdubov[1], Alexei Kudelkin[1], Alexei Melnikov[1]
(1) Institute of Applied Astronomy Russian Academy of Sciences nab Kutuzova, 10, Saint-Petersburg, Russia
Corresponding author: kurdubov@iaaras.ru

Source flux-density monitoring in the VGOS era

K. Le Bail, E. Varenius and R. Haas,

Abstract Source flux density is used to prepare optimal schedules of geodetic VLBI sessions in scheduling software packages such as Sked and VieSched++. It enters in the determination of the scan length to reach the signal-to-noise target to ensure successful source detection. We present a comparison of different available catalogs, and summarise the main current issues; lack of broad-band data, lack of southern sources, and calibration uncertainties and errors. We also present the first preliminary series of short-baseline (75 m) VGOS flux-density monitoring carried out in recent months using the Onsala twin telescopes.

Session-3: Analysis

Presentation type: oral

Karine Le Bail, Rüdiger Haas, Eskil Varenius
Chalmers University of Technology, Space, Earth and Environment, Space Geodesy and Geodynamics, Onsala, Sweden
Corresponding author: karine.lebail@chalmers.se

Combination of GNSS and VLBI data for consistent estimation of Earth Rotation Parameters

L. Lengert, C. Flohrer, A. Girdiuk, H. Hellmers, D. Thaller

Abstract We present the current activities of the Federal Agency for Cartography and Geodesy (BKG), towards a combined processing of VLBI and GNSS data. The main goal of the combined analyses of the two different space-geodetic techniques is the improvement of the consistency between the techniques through common parameters, i.e., mainly Earth Rotation Parameters (ERPs), but also station coordinates through local ties. Based on our previous combination studies using GNSS data and VLBI Intensive sessions on a daily and multi-day level, we generate a consistent, low-latency ERP time series with a regular daily resolution. Comparing the ERPs from the combined processing with the individual technique-specific ERPs, we achieved a significant accuracy improvement of the dUT1 time series and a slight accuracy improvement of the pole coordinates time series. In our recent studies, we extend the combination of GNSS and VLBI Intensive sessions by adding VLBI 24-hour R1 and R4 sessions, to exploit the combination benefit to its maximum extend. We analyse the impact of the combination on the global parameters of interest, i.e., mainly dUT1, polar motion and LOD, but also on station coordinates. BKG's primary interest is the combination of GNSS and VLBI data on the observation level. However, the current combination efforts are based on the normal equation level using technique-specific SINEX files as a starting point.

Session-3: Analysis

Presentation type: oral

Lisa Lengert[1], Claudia Flohrer[1], Anastasiia Girdiuk[1], Hendrik Hellmers[1], Daniela Thaller[1]
(1) Federal Agency for Cartography and Geodesy (BKG), Department Geodesy, Frankfurt am Main, Germany
Corresponding author: lisa.lengert@bkg.bund.de

Comparison of tropospheric zenith wet delay from VLBI and GNSS Time Series

V. Liu, M. Nordman, N. Zubko

Abstract In this study, we compared the agreement of tropospheric zenith wet delay (ZWD) seasonal variations derived from VLBI and GNSS observations at 5 AUSTRAL stations (WARK12M in New Zealand; HOBART26, KATH12M and YARRA12M in Australia; HART15M in South Africa) and 3 European stations (ONSALA60 in Sweden, WETTZELL in Germany and NYALES20 in Norway). We have analyzed time series of 8 years, starting in 2012 until the end of 2019. Results show that VLBI ZWD present clear seasonal variations which are specific for each station, in the tropics the variability is more pronounced than in mid-latitudes and polar regions. Furthermore, the VLBI ZWD also show a reasonably good agreement with seasonal fit model. When comparing zenith wet delays derived from co-located GNSS and VLBI stations at similar cut-off elevation angle (VLBI at 3.3° and GNSS at 3°), they agree quite well, which is proved by high correlation values. The correlation coefficients vary from 0.78 up to 0.95, except HOBART26 which has relatively small amount of observations, its correlation index of 0.6. Both the RMS differences and biases between the techniques are in mm level. As the ZWD directly affects the accuracy of the estimated Up component of the station's position, in the VLBI analysis, the wrms values of Up residuals were also computed. To investigate how the different cut-off elevation angles affect the estimated ZWD, data were analysed with a set of cut off angles (0°, 3.3°, 7° and 20°). The Up component wrms values of 8 stations at high cut-off elevation angles (20°) are between 1.15 cm and 1.97 cm, which are a few mm larger than that at low cut-off angles (0°, 3.3° and 7°). As expected, the higher the cut-off angle is applied, the larger the scatter presents in the Up component residuals at each station.

Session-3: Analysis

Presentation type: poster

Vicky Liu[1], Maaria Nordman[1,2], Nataliya Zubko[2]
(1) School of Engineering, Aalto University, Otakaari 4, 02150, Espoo, Finland
(2) Finnish Geospatial Research Institute (FGI), National Land Survey of Finland, Geodeetinrinne 2, FIN-02430 Masala, Finland
Corresponding author: vicky.liu@aalto.fi

On the impact of the coordinate representation onto the estimates in least-squares adjustment

M. Lösler, C. Eschelbach, C. Holst

Abstract In geodesy and metrology several coordinate representations are known. The most important representations are polar coordinates and Cartesian coordinates. The coordinate representations are rigorously convertible into each other. Such functional relations are well-known as the direct (first) and the inverse (second) geodetic problem. Instruments like e. g. total station, laser scanner, or laser tracker are polar measurement systems. It is common practise especially in surface analysis, e. g. deformation analysis of the VLBI main reflector, to initially convert the obtained polar coordinates into their Cartesian representations. Instead of the polar measurements, the converted Cartesian coordinates are introduced to the least-squares adjustment. In this investigation, the impact of the chosen coordinate representation onto the estimates is studied. It is shown that the adequate transformation of the functional model and the stochastic model of the least-squares adjustment is not sufficient to obtain identical estimates.

Session-2: Observations

Presentation type: oral

Michael Lösler[1], Cornelia Eschelbach[1], Christoph Holst[2]
(1) Frankfurt University of Applied Sciences,
Faculty 1: Architecture – Civil engineering – Geomatics,
Laboratory for Industrial Metrology,
Nibelungenplatz 1,
D-60318 Frankfurt am Main, Germany
(2) University of Bonn,
Institute of Geodesy and Geoinformation,
D-53115 Bonn, Germany
Corresponding author: michael.loesler@fb1.fra-uas.de

The current status of RAEGE

José A. López-Pérez, João S. Ferreira, Javier González-García, Carlos Albo-Castaño, Abel García-Castellano, P. de Vicente-Abad, José A. López-Fernández, Francisco W. Macedo, Luís R. Santos, Sara Pavão

Abstract When complete, the *Red Atlántica de Estaciones Geodinámicas y Espaciales* (RAEGE) will be composed of four VGOS radio-telescopes, two in Spain (Yebes and Gran Canaria) and two in Portugal (Santa María and Flores islands). The Yebes VGOS radio-telescope is fully operational and integrated in the VGOS core network. The Santa María VGOS radio-telescope is undergoing major maintenance operations. However, in November 2020 it performed joint observations of Bepi-Colombo at 8.4 and 32 GHz simultaneously, together with JPL/NASA Deep Space Network (DSN) antennas. More details on this experiment will be provided. The current status of all the four RAEGE radio-telescopes will be presented.

Session-1: Technology

Presentation type: oral

José A. López-Pérez[1], João S. Ferreira[2], Javier González-García[1], Carlos Albo-Castaño[1], Abel García-Castellano[1], P. de Vicente-Abad[1], José A. López-Fernández[1], Francisco W. Macedo[3], Luís R. Santos[3], Sara Pavão[3]
(1) Yebes Observatory, Instituto Geográfico Nacional, Cerro de la Palera s/n, Yebes, E-19141 Guadalajara, España
(2) Associação RAEGE Açores, Estação RAEGE de Santa María, Estrada dos Piquinhos s/n, 9580-324 Vila do Porto (Santa María - Azores, Portugal)
(3) Estrutura de Missão dos Açores para o Espaço, Rua do Mercado n. 21, 9500-326 Ponta Delgada (São Miguel - Açores, Portugal)
Corresponding author: ja.lopezperez@oan.es

Preamplifier module for VGOS and legacy S/X observations compatibility in the presence of RFI signals

José A. López-Pérez, M. Patino-Esteban, P. García-Carreño, José M. Serna-Puente, M. Bautista-Durán, A. Rivera-Lavado

Abstract It is well known that the initial 2 - 14 GHz bandwidth envisaged for VGOS has not been achieved due to the presence of RFI signals, particularly in S-band. In some VGOS receivers, either high-pass filters or band-splitting configuration have been implemented to deal with the reduction in dynamic range caused by RFI. On the one hand, high-pass filters usually start at 3 GHz and rejects the S-band from 2-3 GHz. This filtering impedes legacy S/X observations with VGOS receivers. On the other hand, the band is split in a low (2.1-5.6 GHz) and high ranges (3.6-14.1 GHz), but even in this case, the low range is affected by serious S-band RFI levels, at least in Yebes, that saturate the corresponding fiber-optic link and make legacy S/X observations impossible. A special configuration of the preamplifier module at the dewar's output is proposed, which will allow both VGOS and legacy S/X observations with a broad-band receiver in the presence of S-band RFI.

Session-1: Technology

Presentation type: oral

José A. López-Pérez[1], M. Patino-Esteban[1], P. García-Carreño[1], José M. Serna-Puente[1], M. Bautista-Durán[2], A. Rivera-Lavado[1]
(1) Yebes Observatory, Instituto Geográfico Nacional, Cerro de la Palera sn, Yebes, E-19141 Guadalajara, España
(2) Universidad de Alcalá de Henares, Madrid
Corresponding author: ja.lopezperez@oan.es

On the selection of prospective sources for ICRF extension

Z. Malkin

Abstract The International Celestial Reference Frame (ICRF) is the standard of the celestial reference frame recommended by the International Astronomical Union (IAU) for scientific researches and practical works in various fields. The third ICRF realization, ICRF3, approved by the IAU in 2018, is currently in use. It contains positions of 4588 sources. Although the number of sources in the ICRF catalog is continuously increased and the accuracy of their positions is continuously improved, the sky coverage by the ICRF sources, its density and uniformity are still not satisfactory. For this reason, various institutions are considering new observing programs aimed at improving the ICRF. The goal of this presentation is to discuss some new considerations for improving the source list for the next ICRF extension(s). Statistical analysis of the ICRF catalog allows us to identify less populated sky regions where new ICRF sources or additional observations of the current ICRF sources are most desirable to improve both the uniformity of the source distribution and the uniformity of the distribution of the position errors. Another part of this work work is to discuss including of additional sources with high redshift in the ICRF list These sources may be of interest for astrophysics. To select prospective new ICRF sources, the OCARS catalog is used. It includes more than 13 thousand sources with VLBI-based positions collected from the literature and the IVS data center. The number of sources in OCARS is about three times greater than in the ICRF3, which gives us an opportunity to select new ICRF sources that have already be tested and detected in various VLBI experiments.

Session-2: Observations

Presentation type: oral or poster

Zinovy Malkin
Pulkovo Observatory, 196140, St. Petersburg, Russia
Corresponding author: malkin@gaoran.ru, zmalkin@zmalkin.com

Precise orbit determination with VLBI to satellites: a simulation study

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

Abstract The project GGOS-SIM-2 focuses on the co-location of the four main space geodetic techniques in space to meet the goals of the Global Geodetic Observing System (GGOS) on global terrestrial reference frames (TRFs). It requires Precise Orbit Determination (POD) of all four techniques, DORIS, GNSS, SLR, and VLBI. However, POD with VLBI to satellites is not yet usual. In this study, the potential of POD with interferometric observations is explored based on simulated data in order to assess how well the space tie can be established involving VLBI. First, daily VLBI sessions are generated for the time span of seven years based on artificial schedules including quasar and satellite observations. Six different satellite orbits (three LEO and three MEO) and two different VLBI station networks (legacy and VGOS) are used to create various simulation scenarios. White noise and clock random errors as well as errors in the orbit modeling are considered to produce simulated observations. Then, precise satellite orbits are estimated together with the usual VLBI parameters and geocenter coordinates. Furthermore, the results are analyzed to assess the potential of the VLBI system to determine precise satellite orbits under various scenarios and to investigate the impact of VLBI to satellite observations on the estimated parameters.

Session-3: Analysis

Presentation type: poster

Nicat Mammadaliyev[1 2], Patrick Schreiner[2], Susanne Glaser[2], Karl Hans Neumayer[2], Rolf Koenig[2], Robert Heinkelmann[2], Harald Schuh[1 2]
(1) Technische Universitt Berlin, Chair of Satellite Geodesy, Strae des 17. Juni 135, 10623 Berlin, Germany
(2)Helmholtz Centre Potsdam, GFZ German Research Centre for Geosciences, Potsdam, Germany
Corresponding author: nicat@gfz-potsdam.de

A wideband observing mode for the AuScope array

J. McCallum,L. McCallum

Abstract With the upgrade of the Katherine radio telescope to a wideband system in late 2019, it became possible to make observations on a VGOS-baseline as part of the AuScope array together with the Hobart12 telescope. The wideband system installed at both Hobart12 and Katherine differs from the nominal VGOS design with only three 4-GHz bands (rather than four) spanning the 3-13.5 GHz frequency range, making fully compatible observations with the existing VGOS network difficult. However, it is possible to use the flexibility of the DBBC3 sampler in DDC mode to select an alternate configuration that allows for good dTEC and delay estimation. In this talk we outline the design of the new observing mode, the required post-processing steps and show some early results.

Session-1: Technology

Presentation type: oral

Jamie McCallum[1], Lucia McCallum[1]
(1) School of Natural Sciences, University of Tasmania, Private Bag 37, Hobart 7001, Australia
Corresponding author: Jamie.McCallum@utas.edu.au

Australian mixed-mode sessions

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

Abstract For the Australian AuScope VLBI stations (Hobart-Hb, Katherine-Ke, Yarragadee-Yg), the VGOS upgrade is a step-wise procedure: Hobart was upgraded in 2017, Katherine followed in 2019 and Yarragadee is scheduled to be upgraded once Hb and Ke successfully join the global VGOS observations. The reason for this is to maintain a viable contribution of AuScope to global VLBI. With Hb and Ke being equipped with the VGOS receivers and Yg still in legacy S/X configuration, the AuScope array is currently an inhomogeneous network, posing a challenge for its successful AUSTRAL observing program. A solution was found in mixed-mode observations. This means a (quasi-) standard S/X-configuration for Yg, paired with observations at Hb and Ke using the new VGOS receivers and back-ends. After previously reported test observations in 2018, we have been running a substantial mixed-mode observing program since. This has supported system integration and debugging.
Here we report on the technical details of our observations, lay out the post-processing procedures, and discuss the results. Our aim of this contribution is to show that mixed-mode sessions, as demonstrated with the Australian mixed-mode observations, is a viable technique that produces geodetically valuable results.

Session-2: Observations

Presentation type: oral

Lucia McCallum[1], Jamie McCallum[1], Lim Chin Chuan[1], Tiege McCarthy[1]
(1) School of Natural Sciences, University of Tasmania, Private Bag 37, Hobart 7001, Australia
Corresponding author: lucia.mccallum@utas.edu.au

Combination of IVS Intensive sessions using SINCOM software

S. Mironova, S. Kurdubov, I. Gayazov

Abstract The SINEX files of hourly VLBI sessions were combined in order to calculate the series of corrections to the Earth orientation parameter UT1-UTC. SINEX files provided by number of VLBI analysis centers (BKG, GSFC, USNO) as a result of processing of approximately 1000 VLBI Intensive sessions from the period from 2015 to 2020 were used for combination. The combination was made by SINCOM software, developed in the IAA RAS for the combination of SINEX files. Individual series of corrections to the UT1-UTC were made for each of the VLBI analysis centers separately. Combined series was calculated as a result of combining the individual series. The comparison of individual and combined series with the recommended series IERS EOP C04 and finals was made. The combined series has better consistency with recommended series than individual series.

Session-3: Analysis

Presentation type: poster

Svetlana Mironova[1], Sergei Kurdubov[1], Iskander Gayazov[1]

(1) Institute of Applied Astronomy of the Russian Academy of Sciences, Kutuzov embankment, 10, Saint Petersburg, Russian Federation
Corresponding author: mironova@iaaras.ru

Improving of the covariance functions of the clock and troposphere parameters

S. Mironova, S. Kurdubov

Abstract The QUASAR software is developed at the IAA RAS for VLBI data processing. The software uses the least square collocation technique for the estimation of the stochastic parameters: the clock and the troposphere. The aim of this work is to estimate the covariance functions of the stochastic signals of the clock and the troposphere from VLBI data processing. Covariance functions were calculated on hourly intervals and on daily intervals for further processing of hourly and daily VLBI sessions respectively. The parameters of the covariance function of the clocks of various VLBI stations were estimated. New covariance functions were used in VLBI data processing.

Session-3: Analysis

Presentation type: poster

Svetlana Mironova[1], Sergei Kurdubov[1]
(1) Institute of Applied Astronomy of the Russian Academy of Sciences, Kutuzov embankment, 10, Saint Petersburg, Russian Federation
Corresponding author: mironova@iaaras.ru

A Broadband VLBI experiment with transportable stations between Japan and Italy with a new observation scheme using closure delay relation

M. Negusini, M. Sekido, K. Takefuji, H. Ujihara, T. Kondo, N. Nemitz, M. Tsutsumi, H. Hachisu, E. Kawai, M. Pizzocaro, C. Clivati, F. Perini, G. Maccaferri, R. Ricci, C. Bortolotti, M. Roma, J. Leute, G. Petit, D. Calonico and T. Ido

Abstract A broadband VLBI system inspired by the concept of VGOS was developed by NICT and implemented in the Kashima 34 m antenna and in two transportable stations utilizing 2.4 m diameter antennas. The transportable stations were conceived as a tool for intercontinental frequency comparison but are equally useful for geodesy. In the procedure of node-hub style (NHS) VLBI, the closure delay relation provides a virtual delay observable between 'node' stations, thanks to joint observation with a large, high sensitivity 'hub' antenna. This overcomes the limited sensitivity of the small diameter node antennas, while error sources associated with large diameter antennas (e.g., gravitational deformations) are eliminated. This scheme does not result in an increased sensitivity to radio source structure if one side of the baseline triangle is kept short. We performed VLBI experiments utilizing this approach over 8700 km baselines among Medicina, Koganei, and Kashima, with the aim of comparing two remote optical clocks. We used the Vienna mapping function (VMF3) for atmospheric delay corrections including its anisotropic components. The performance of NHS VLBI scheme was evaluated to be comparable with IVS-R1/R4 via baseline length repeatability. The NHS VLBI scheme can be applied at VGOS observation stations, and it may become a tool for improving the global distribution of geodetic VLBI station and for co-location with other space geodetic techniques. Our measurements reveal signatures of structure effects in the correlation amplitude of several of the observed radio sources. Finally, this system demonstrates in intercontinental frequency comparison performance beyond satellite techniques and can potentially be used for future long-term stable international clock comparison that is fundamental to international timekeeping, global positioning and test of fundamental physics.

Session 3: Analysis

Presentation type: oral

Monia Negusini[1], Mamoru Sekido[2], Kazuhiro Takefuji[3], Hideki Ujihara[2], Tetsuro Kondo[2,4], Nils Nemitz[5], Masanori Tsutsumi[2], Hidekazu Hachisu[5], Eiji Kawai[2], Marco Pizzocaro[6], Cecilia Clivati[6], Federico Perini[1], Giuseppe Maccaferri[1], Roberto Ricci[1], Claudio Bortolotti[1], Mauro Roma[1], Julia Leute[7], Gérard Petit[7], Davide Calonico[6] and Tetsuya Ido[5]

(1) Istituto Nazionale di Astrofisica (INAF), Istituto di Radioastronomia (IRA), Bologna, Italy

(2) National Institute of Information and Communications Technology (NICT), Kashima Space Technology Center, Space-Time Standards Laboratory, Kashima, Japan

(3) JAXA Japan Aerospace Exploration Agency, Space Tracking and Communications Center, Saku, Japan

(4) Shanghai Astronomical Observatory, Chinese Academy of Sciences, Shanghai, China

(5) National Institute of Information and Communications Technology (NICT), Space-Time Standards Laboratory, Koganei, Japan

(6) Istituto Nazionale di Ricerca Metrologica, QN Metrologia quantistica e nanotecnologie, Torino, Italy

(7) Bureau International des Poids et Mesures, Time Section, Sevres, France

Corresponding author: negusini@ira.inaf.it

Data Unlimited – The IVS Seamless Auxiliary Data Archive at the Wettzell observatory

A. Neidhardt, S. Weston

Abstract During the Analysis Workshop of the IVS 2014 General Meeting in Shanghai, there was an idea put forward to collect and offer auxiliary data continuously. Auxiliary and meta data are usually recorded in log files which are created by the NASA Field System (FS) during and especially for the time of an observation session. Therefore, these data points - like meteorological values, clock offsets, cable calibrations, other calibration information, and so on - are just sporadically available from time to time between start and stop of an observation. But continuous data and especially auxiliary data become more and more important on the way to the accuracy of VGOS, because they help to improve data, correlation, and analysis quality. Therefore, the first seamless auxiliary data center started at the Wettzell observatory (https://vlbisysmon.evlbi.wettzell.de/zabbix). This presentation explains the technical background, the requirements at the stations, but also wants to encourage others to participate.

Session-2: Observations

Presentation type: movie

Alexander Neidhardt[1], Stuart Weston[2]
(1) FESG, TU of Munich, Germany
(2) Auckland University of Technology, New Zealand
Corresponding author: alexander.neidhardt@tum.de

Autonomous Observations at the Wettzell observatory

A. Neidhardt, Ch. Plötz, J. Eckl

Abstract The contribution shows completely autonomous observations with the 20m legacy telescope and the TWIN telescopes of the Wettzell observatory. It shows requirements, current workflows, and demonstrates benefits of unattended observations.

Session-2: Observations

Presentation type: movie

Alexander Neidhardt[1], Christian Plötz[2], Johann Eckl[2]
(1) FESG, TU of Munich, Germany
(2) BKG, Germany
Corresponding author: alexander.neidhardt@tum.de

HartRAO weather data

M. Nickola, A. de Witt, R. Botha, P. van Zyl

Abstract The meteorological sensors at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) provide in-situ measurements of barometric pressure, ambient temperature and relative humidity, which are of great importance in geodetic and astrometric VLBI processing as well as in the analysis of data from other space geodetic techniques and astronomical single-dish and VLBI data. The sensors utilised in conjunction with HartRAO 26-m and 15-m antenna observations, have not been calibrated or upgraded for at least 10 years. Also, a recent request by the IVS Network Coordinator for updated information regarding IVS station meteorological data, prompted this investigation. We investigate the quality of historical and current meteorological data from the HartRAO sensors, and its possible degradation over time, by comparison with long-term meteorological data provided by the MET4 of the IGS GNSS reference station HRAO, located in close proximity ($\sim$ 50 m away). Both these data sets are also compared to short-term data from a new MET4 test installation, used as a a calibrator. The planned installation of a full scientific-level meteorological sensor set and high-accuracy pressure sensors are also discussed.

Session-2: Observations

Presentation type: poster

Marisa Nickola[1,2], Alet de Wit[1], Roelf Botha[1], Pfesi van Zyl[1]
(1) Hartebeesthoek Radio Astronomy Observatory, PO Box 443, Krugersdorp 1740, South Africa
(2) University of Pretoria, Private Bag X20, Hatfield 0028, South Africa
Corresponding author: marisa@hartrao.ac.za

Evaluation of the results from the VGOS sessions

T. Nilsson, R. Haas, E. Varenius

Abstract Since the beginning of 2019, operational, bi-weekly VGOS sessions have been performed with up to nine VGOS antennas. Presently, more than 30 of these sessions have been correlated. Thus, there are now enough data available to do a proper evaluation of the results obtained from these sessions. In this work, we investigate the Earth Orientation Parameters (EOP) and the tropospheric parameters estimated from the VGOS sessions. The results are compared to those obtained from legacy S/X sessions. Since the VGOS sessions are currently always observed at the same time as a legacy VLBI session, this is always possible, and typically some of the VGOS antennas are co-located with an S/X antenna participating in the legacy VLBI session. External evaluation are done by comparing the results from VGOS and legacy VLBI with the results obtained from GNSS. Furthermore, the tropospheric parameters are also compared with those derived from numerical weather models, like ERA5. The results of this investigation will show how the current results from VGOS compare to that of legacy VLBI and to the accuracy goals of VGOS.

Session-3: Analysis

Presentation type: oral

Tobias Nilsson[1], Rüdiger Haas[2], Eskil Varenius[2]
(1) Lantmäteriet – The Swedish Mapping, Cadastral, and Land Registration Authority, Lantmäterigatan 2C, SE-801 82 Gävle, Sweden
(2) Chalmers University of Technology, Onsala Space Observatory, SE-439 92 Onsala, Sweden
Corresponding author: jan-tobias.nilsson@lm.se

Reference epochs in VLBI estimations of clock parameters

A. Nothnagel, H. Krásná

Abstract By default, the reference epoch of the relative clock offsets has always been the start of the sessions. If we consider a simple first order model for the relative clock parameters, i.e., just an offset and a rate, the formal errors of the parameters improve if the reference epoch is chosen to be at the middle of the session. In Altamimi et al. (2002), this is called the epoch of minimum variance. In a small study we have investigated whether this fact could be exploited in VLBI data analysis. For the CONT17a series of sessions, we ran solutions with the reference epochs of the clocks being the middle of the session and compared the results to those of standard solutions. We found that even for more sophisticated parameterizations of the clocks, i.e., with polynomials and piece-wise linear polygons, the formal errors of all clock parameters did improve significantly. Although the correlation matrices change as well, there, unfortunately, is no improvement for the formal errors of any other, (non-clock) parameter. At the same time, the condition numbers of the solutions did not change significantly either. We conclude that the effects of changing the reference epoch in VLBI estimations of clock parameters are confined to the clock parameter space alone.

Session-3: Analysis

Presentation type: Poster

Axel Nothnagel[1], Hana Krásná[1,2]
(1) Technische Universität Wien, Forschungsbereich Höhere Geodäsie (E120-04), Wiedner Hauptstrae 8 A-1040 Wien, Austria
(2) Astronomical Institute of the Czech Academy of Sciences, Prague, Czech Republic
Corresponding author: axel.nothnagel@tuwien.ac.at

Measuring the impact of Indonesian antennae to Earth Orientation Parameter estimation

I. Nurul Huda, T. Hidayat, and B. Dermawan

Abstract In the near future, two radio telescopes will be installed in the Indonesian region. Mount Timau in Timor Island (lat = -9.60°, long = 123.78°) will be the host of the new National Observatory and in the original proposal, a radio telescope envisaged to be integrated to the next VLBI generation was proposed. Meanwhile, a decommissioned telecommunication antenna in the city of Jatiluhur (lat = -6.52°, long = 107.41°) is currently being undertaken to be converted into a radio telescope. To develop the Indonesian VLBI campaign, and considering two antennae will be available in Jatiluhur and in Timau site, in this work we first undertake to study the possibility to use these telescopes for astrogeodetic purpose. Here we simulated the implication of these two future Indonesian antennae to the estimates of Earth orientation parameters. We simulated the 24-hour session by adding the Indonesian antennae to the two existing network configuration, which is R4 (R4934) and AOV (AOV049). Overall we found that the addition of Indonesian antennae to each network configuration decrease the reapeatability value of the Earth Orientation Parameter by about 20%.

Session-2: Observations

Presentation type: poster

Ibnu Nurul Huda, Taufiq Hidayat, and Budi Dermawan
Department of Astronomy and Bosscha Observatory, FMIPA, Institut Teknologi Bandung, Jalan Ganesha 10, Bandung 40132, Indonesia
Corresponding author: ibnu@as.itb.ac.id

Advances in automatized schedule generation at the VLBI operation center DACH and introduction of the VLBI correlation center at Wettzell

C. Plötz, M. Schartner, J.Böhm, T. Schüler, B. Soja

Abstract This presentation outlines two newly established VLBI components, the Operation Center DACH and a new VLBI correlation facility.
The Geodetic Observatory Wettzell (GOW), jointly operated by the Federal Agency for Cartography and Geodesy (BKG) and the Technical University of Munich (TUM), was accepted as an IVS Operation Center (OC) on November 19, 2019. This addition complements BKG's substantial contribution to the IVS and its continuous and long-term VLBI observation programs. Recently, the OC in cooperation with ETH Zürich (ETHZ) and TU Wien (TUW) added automated schedule generation to its capabilities. This cooperation within the institutions operates now under the unified Operation Center with the abbreviation DACH, unifying BKG, ETHZ and TUW. The assigned VLBI schedules for this operation center are generated with an innovative approach consisting of a Python framework (VieSched++ AUTO), which allows to fully automate the generation of highly optimized schedules with VieSched++. The complete workflow is designed to gather and evaluate all master files, calling the VieSched++ scheduling application and also upload the selected schedule files to the IVS data centers. Additionally, a new website at BKG shows the complete history of all scheduled sessions, including quality oriented parameters with graphical comparison of the last 10 sessions as a quick overview.
Furthermore, an outline of the new VLBI correlation facility at the Geodetic Observatory Wettzell will be presented. This includes technical specifications, milestones and timelines.

Session-2: Observations

Presentation type: oral

Christian Plötz[1], Matthias Schartner[2], Johannes Böhm[3], Torben Schüler[1], Benedikt Soja[2]
(1) Bundesamt für Kartographie und Geodäsie (BKG), Sackenrieder Str. 25, D-93444 Bad Kötzting, Germany
(2) Institute of Geodesy and Photogrammetry, ETH Zürich, Robert-Gnehm-Weg 15, CH-8093 Zürich, Switzerland
(3) Technische Universität Wien, Wiedner Hauptstraße/E120, A-1040 Wien, Austria

Consistency of VLBI estimates in the CONT17 campaign

V. Puente, E. Azcue, E. Martínez, M. Moreira, M. García

As part of its observing program, the International VLBI Service for Geodesy and Astrometry (IVS) arranges special observation campaigns of continuous Very Long Baseline Interferometry (VLBI) known as CONT campaigns. The last CONT campaign (CONT17) was carried out by the end of 2017 and consisted of three networks observing in parallel: two legacy S/X networks and a VGOS broadband network. This strategy brings an interesting opportunity for the comparison of VLBI estimates as result of the processing of the data acquired by the antennas of each network. The purpose of this contribution is to compare the consistency between the estimates of the different networks in order to gain insight into the influence of the geometry of the network and the observing technology on the geodetic products estimated through VLBI.

Session-3: Analysis

Presentation type: oral

Víctor Puente[1], Esther Azcue[1], Elena Martínez[2],Mariana Moreira[3], Marina García[1]
(1) National Geographic Institute of Spain, General Ibañez de Ibero 3, Madrid, Spain
(2) Observatory of Yebes - National Geographic Institute of Spain, Cerro de la Palera S/N Yebes, Spain
(3) RAEGE Santa Maria, Azores, Portugal

Assessment of sub-daily Earth Rotation Parameters from VLBI with GNSS during the CONT17 campaign

S. Raut, R. Heinkelmann, S. Modiri, C. Kitpracha, H. Schuh

Abstract Monitoring the Earth rotation variation is a fundamental topic for several fields and applications such as astronomical and geodetic reference systems, precise satellite orbit determination, and space navigation. Very Long Baseline Interferometry (VLBI) and Global Navigation Satellite Systems (GNSS) provide high accurate observation of sub-daily changes in Earth rotation, mainly caused by ocean tides, and smaller effects from the atmosphere interact the solid Earth.
In this work, we analyzed the sub-daily Earth Rotation Parameters (ERP) estimates from VLBI using VieVs@GFZ software during the CONT17 campaign. We chose the CONT17 campaign as it provides 15 days of continuous VLBI data from the two legacy networks i.e., IVS and VLBA, having different network geometry, and five days of new-generation VGOS sessions. We derived ERP by combining the two legacy networks at the normal equation level for better precision. We assessed the VLBI results with polar motion (PM) and length of day (LOD) estimated from the GNSS using EPOS software at GFZ at the hourly resolution. As GNSS only provides LOD estimates, we computed LOD from VLBI-derived UT1-UTC (dUT1) parameters. This is possible as LOD is the negative time-derivative of dUT1. Besides, we evaluated the VGOS performance with the legacy networks at the sub-daily resolution.
We do not estimate Celestial Pole Offsets (CPO) due to their correlation with sub-daily PM for the analysis. Our preliminary results show that sub-daily ERP from a combined legacy network shows better agreement with the GNSS and smaller formal errors than ERP from the individual legacy networks. The dUT1 estimates from the VGOS network show good agreement with the legacy networks.

Session-3: Analysis

Presentation type: poster

Shrishail Raut[1,2], Robert Heinkelmann[2], Sadegh Modiri[1,2], Chaiyaporn Kitpracha[1,2], Harald Schuh[1,2]
(1) Chair of Satellite Geodesy, Technische Universität Berlin, Institute of Geodesy and Geoinformation Science, Faculty VI, Kaiserin-Augusta-Allee 104-106, Room KAI 2221, 10553 Berlin
(2) GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam
Corresponding author: raut@gfz-potsdam.de

A geodetic VLBI experiment with the dissemination of a common clock via coherent optical fibre link

R. Ricci, M. Negusini, F. Perini, D. Calonico, C. Clivati, A. Mura, F. Levi, M. Siciliani de Cumis, L. Santamaria Amato, G. Bianco, M. Roma, C. Bortolotti, G. Maccaferri, M. Stagni, R. Haas, B. Tercero

Abstract Atomic clock synchronization plays an important role in both radio astronomical and geodetic Very Long Baseline Interferometry, as time and frequency standards are provided by station clocks. National metrological institutes have recently started streaming (via optical fiber links) frequency references from ultra-stable clocks based on optical line transitions in Strontium/Ytterbium laser-cooled lattices. Optical lattice clocks are already two order of magnitude more stable than the radio station H-masers. In this talk we will describe how the Italian Link for Frequency and Time (LIFT) was used to carry out a series of European geodetic VLBI experiments in which the Medicina and Matera radio stations were connected to the same remote clock located at the Italian Metrological institute in Turin, via the LIFT link. In the foreseeable future a European VLBI network of radio stations could be connected via optical fiber links to a single very high-performance clock hosted by a European Metrological institute.

Session-1: Technology

Presentation type: oral

Roberto Ricci[1],2, Monia Negusini[1], Federico Perini[1], Davide Calonico[2],Cecilia Clivati[2], Alberto Mura[2], Filippo Levi[2], Mario Siciliani de Cumis[3], Luigi Santamaria Amato[3], Giuseppe Bianco[3], Mauro Roma[1], Claudio Bortolotti[1], Giuseppe Maccaferri[1], Matteo Stagni[1], Robert Ambrosini[1],Ruediger Haas[4], Belen Tercero[5]
(1) Istituto Nazionale di Astrofisica - Istituto di Radioastronomia (INAF- IRA), Bologna, Italy
(2) Istituto Nazionale di Ricerche Metrologiche (INRiM), Torino, Italy
(3) Agenzia Spaziale Italiana - Centro di Geodesia Spaziale (ASI-CGS), Matera, Italy
(4) Onsala Space Observatory (OSO), Chalmers University of Technology, Gothenburg, Sweden
(5) Yebes Observatory, National Geographic Institute (IGN), Yebes, Guadalajara, Spain
Corresponding author: ricci@ira.inaf.it

Experience from S/X–VGOS mixed-mode observations

C. Ruszczyk, P. Elosegui, M. Titus, D. Behrend, J. Gipson

Abstract Year 2020 was the culmination of a few earlier years of meticulous preparatory work for obtaining observations simultaneously with the legacy S/X and the VGOS networks as if they were a single, seamless network. The main goal of these so-called mixed-mode sessions is to determine the positions of the new VGOS stations in the terrestrial reference frame defined by the long-lived, stable legacy stations, thus effectively tying both networks together. Three mixed-mode sessions had been executed prior to 2020, each session adding one new small-step to the previous session to ensure technology development and advancement. Indeed, the first session involved a single VGOS station, Westford, participating in a standard R&D S/X observing network in tag-along mode in 2016. The second and third sessions involved the participation of two (add GGAO) and three (add KPGO) VGOS stations, respectively, in 2018, hence expanding from a station to a VGOS baseline and then a triangle, or closure. An important component of this progressive approach has been to identify, and where possible, solve software challenges and limitations, to then move forward with knowledge transfer to the IVS community. An ambitious plan was then launched in 2020 when, building on the success of the earlier sessions, a series of three mixed-mode sessions were run whereby the existing entire VGOS network of 8 stations joined in R&D-type 8-station S/X sessions, thus synthesizing a 16-station mixed-mode network. The main goal of these augmented sessions was to strengthen the network ties for the upcoming ITRF2020 realization. This presentation will focus on the goals of the original vision for the sessions, how the goals morphed to what became the reality, and the impact on the processing and software of these modifications; a lessons-learned perspective. We will conclude with what may a best way forward for 2021.

Session 1: Technology

Presentation type: oral

Chet Ruszczyk[1], Pedro Elosegui[1], Mike Titus[1], Dirk Behrend[2], John Gipson[2]
(1) MIT Haystack Observatory, 99 Millstone Rd, Westford, MA 01886, USA
(2) NVI, Inc./NASA Goddard Space Flight Center, 7257 Hanover Parkway, Suite D, Greenbelt, MD 20770, USA
Corresponding author: chester@mit.edu

An empirical review of structure index characteristics for geodetic VLBI observations

S. Salarpour, L. McCallum, S. Shabala, J. McCallum, L. Chin Chuan

Abstract It is known that the sources instabilities are linked to variations in their brightness distribution, causing so-called structure delays in VLBI observations. The Structure Index (SI) is often used as an indicator to select sources with a reasonable structure for astrometric and geodetic observations. We analyse 7990 images to study some characteristics of the SI in a large sample. We study SI variations over time, as well as the effect of various observing modes on SI values. Moreover, the median structure delay estimated in different VGOS observation networks is obtained, and the results are compared with nominal SI. We notice variations on the order of tenths to one SI unit.

Session-3: Analysis

Presentation type: oral

Simin Salarpour[1], Lucia McCallum[1], Stanislav Shabala[1], Jamie McCallum[1], Lim Chin Chuan[1]
(1) School of Natural Sciences, University of Tasmania, Private Bag 37, Hobart, TAS 7001, Australia
Corresponding author: simin.salarpour@utas.edu.au

Automated VLBI scheduling utilizing Artificial Intelligence based parameter optimization

M. Schartner, C. Plötz, B. Soja

Abstract Within this presentation, a new geodetic Very Long Baseline Interferometry (VLBI) scheduling approach inspired by evolutionary processes is presented. It mimics the biological idea of ”survival of the fittest” to iteratively explore the scheduling parameter space looking for the best solution. Therefore, the algorithm utilizes concepts such as selection, crossover and mutation. Based on Monte-Carlo simulations, it can be shown that the resulting schedules are of high quality. Moreover, since this approach automatically takes care of the schedule parameterization, it enables fully automated processing based on daily cronjobs.
Due to the high quality of the produced schedules and the reduced workload for the schedulers, the IVS observing programs AUA, INT2, INT3, INT9, OHG, T2 and VGOS-B are already using the new approach. For every observing program, a dedicated scientific goal was defined. Based on this goal, the evolutionary strategy optimizes the scheduling parameters to receive optimal results. This ensures a fully transparent workflow and removes human biases in scheduling.
We will briefly introduce the concept behind the new scheduling algorithm and present some comparisons to discuss the expected improvements. In the case of sessions with a difficult telescope network, an improvement in the precision of the geodetic parameters up to 15% could be identified, as well as an increase in the number of observations of up to 10% compared to classical scheduling approaches.

Session-2: Observations

Presentation type: oral

Matthias Schartner[1], Christian Plötz[2], Benedikt Soja[1]
(1) Institute of Geodesy and Photogrammetry, ETH Zürich, Robert-Gnehm-Weg 15, CH-8093 Zürich, Switzerland
(2) Bundesamt für Kartographie und Geodäsie (BKG), Sackenrieder Str. 25, D-93444 Bad Kötzting, Germany
Corresponding author: mschartner@ethz.ch

First VLBI-only TRF/CRF solution based on DGFI-TUM data for ITRF2020

M. Seitz, M. Glomsda, M. Bloßfeld, A. Kehm, M. Gerstl, D. Angermann

Abstract DGFI-TUM is an operational Analysis Center of the International VLBI Service for Geodesy and Astrometry (IVS). In this role, we reprocessed almost all VLBI sessions between 1979 and 2020 for the IVS contribution to the upcoming realization of the International Terrestrial Reference System (ITRS), the ITRF2020. The reprocessed solution contains all requested new geophysical models, including the latest realization of the International Celestial Reference System (ICRS), the ICRF3, as a priori input for the estimated quasar coordinates. Since DGFI-TUM is also an ITRS Combination Center of the International Earth Rotation and Reference Systems Service (IERS), we used our homogeneously reprocessed data to create a preliminary VLBI-only TRF/CRF solution, in which we consistently estimated station positions and velocities, Earth Orientation Parameters (EOP), and quasar positions. The latter will be a part of the ITRF for the first time ever. On this poster, we describe the input data, the selection criteria, as well as the results of our combination, which was performed at the normal equation level with our DGFI Orbit and Geodetic parameter estimation Software (DOGS). We also discuss the impact of recently observed sessions on the CRF.

Session 3: Analysis

Presentation type: poster

Manuela Seitz[1], Matthias Glomsda[1], Mathis Bloßfeld[1], Alexander Kehm[1], Michael Gerstl[1], Detlef Angermann[1]
(1) Deutsches Geodätisches Forschungsinstitut, Technische Universität München, Arcisstraße 21, Munich, Germany
Corresponding author: matthias.glomsda@tum.de

The New IVS Associate Analysis Center at ETH Zurich

B. Soja, M. Schartner, G. Kłopotek

Abstract At the end of 2020, a new IVS Associate Analysis Center was established at ETH Zurich (ETHZ). In the past, ETHZ has already been involved in research related to the combination of geodetic data sets, including VLBI observations. However, the newly established Chair of Space Geodesy at ETHZ has an even stronger focus on VLBI, with several of its members having experience in VLBI. For the first time, this allows ETHZ to contribute actively to IVS goals and products. In addition to analyzing specific VLBI data sets as called for by the Analysis Coordinator, ETHZ performs research-driven analyses of specific data sets, such as those related to the CONT campaigns, R1/R4 sessions, and the Intensives, with the aim of processing both legacy and VGOS observations.
ETHZ focuses on increasing the degree of automation of VLBI data analysis tasks. We believe that in this context, there is a lot of potential for strategies and methodologies based on artificial intelligence, including supervised and unsupervised machine learning. Increased automation will allow us to participate in demanding reprocessing efforts that smaller VLBI groups typically cannot undertake.
In this contribution, we will provide an overview of the activities and future plans of the IVS Associate Analysis Center at ETHZ, including the presentation of first analysis results, automation strategies and utilized tools. Additionally, we will showcase other analysis-related VLBI research that is pursued at ETHZ.

Session-3: Analysis

Presentation type: poster

Benedikt Soja[1], Matthias Schartner[1], Grzegorz Kłopotek[1],
(1) Institute of Geodesy and Photogrammetry, ETH Zürich, Robert-Gnehm-Weg 15, CH-8093 Zürich, Switzerland
Corresponding author: soja@ethz.ch

A superconductor filter installed in the broadband feed of Ishioka VLBI station

Yu Takagi, Haruka Ueshiba, Tomokazu Nakakuki, Saho Matsumoto, Kyonosuke Hayashi, Toru Yutsudo, Katsuhiro Mori, Tomokazu Kobayashi, Mamoru Sekido, Jamie McCallum, Fengchun Shu

Abstract At the Ishioka VLBI station, we installed a new superconductor filter in the broadband feed which was designed to suppress the strong RFI around S-band so that the Ishioka station can observe S-band and participate in legacy S/X sessions with the broadband feed. After the installation of the filter, we investigated the signal after passing through the filter using a spectrum analyzer and confirmed that the strong RFI was mitigated as expected. Then, we conducted some test VLBI observations with domestic and international stations. They were S/X sessions and we detected fringes in both S- and X-bands. In this talk, we will report the results of the signal investigation and the test observations.

Session-2: Observations

Presentation type: oral

Yu Takagi[1], Haruka Ueshiba[1], Tomokazu Nakakuki[1], Saho Matsumoto[1], Kyonosuke Hayashi[1], Toru Yutsudo[1], Katsuhiro Mori[1], Tomokazu Kobayashi[1], Mamoru Sekido[2], Jamie McCallum[3], Fengchun Shu[4]
(1) Geospatial Information Authority of Japan, 1 Kitasato, Tsukuba, Japan
(2) National Institute of Information and Communications Technology, Kashima, Japan
(3) University of Tasmania, Hobart, Australia
(4) Shanghai Astronomical Observatory, Shanghai, China
Corresponding author: takagi-y96pg@mlit.go.jp

Current status at Ny-Ålesund Geodetic Earth Observatory

L.M. Tangen, S. L'Orange, R. Bolaño González, S. Garcia-Espada, P. Kupiszewski, A. Meldahl, R. Kleiven, G. Grinde, H.C. Munthe Kaas

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

Session-1: Technology

Presentation type: oral

Leif Morten Tangen[1], Simon L'Orange[2], Rubén Bolaño González[2], Susana Garcia-Espada[2], Piotr Kupiszewski[2], Axel Meldahl[2], Robin Kleiven[1], Gro Grinde[1], Hans Christian Munthe Kaas[1]
(1) Norwegian Mapping Authority, P.O.Box 600 Sentrum, N-3507 Hønefoss, Norway
(2) Ny-Ålesund Geodetic Earth Observatory - Norwegian Mapping Authority P.O. Box 13, N-9173 Ny-Ålesund, Svalbard, Norway
Corresponding author: Leif.Morten.Tangen@kartverket.no

Ocean tide loading displacements from VLBI and the long term ocean tide variability

K. Teke

Abstract The principal semidiurnal tides: M_2, S_2, N_2, K_2, and the diurnal tides: K_1, O_1, P_1, Q_1, of the ocean tide loading displacements (OTLD) were estimated at the 37 VLBI stations from the analysis of the IVS daily sessions carried out from 1984 till 2020. Then, the VLBI observed OTLD were compared with those of the recent global ocean tide models (GOTM), among others, i.e. TPXO9-Atlas (Egbert and Erofeeva 2002), FES2014b (Carrére et al. 2016), and GOT4.10c (Ray 2013). The analyses were repeated 37 times across all the daily sessions, that is the same number of the stations considered in this study, with the only difference between the runs is that the 2 hourly piece-wise linear offset (PLO) coordinates of only one station were estimated in each run whereas the other stations' coordinates were fixed to their a priori values. Due to the high correlation between the troposphere delays and station coordinates at sub-daily intervals, the troposphere delays were reduced from the observations a priori to the adjustment. Through considering these 2 hourly PLO coordinates of the VLBI stations as observations, the principal semidiurnal and diurnal tides of OTLD were estimated i.e. VLBI OTLD model, using Kalman filter solution. The lunar only M_2 tide radial phasor vector differences between the VLBI OTLD model and the GOTM are found as the largest among all the principal tides, the VLBI sites, and the coordinate components. The root-mean-square misfits of the phasor vectors between the VLBI OTLD model and the GOTM are detected as the largest for the radial components over the coastal sites at the lunar M_2 (from 0.9 mm to 1.0 mm) and O_1 tides (0.4 mm – 0.5 mm), the solar S_2 tide (0.5 mm – 0.6 mm), and the luni-solar K_1 tide (0.4 mm – 0.5 mm). Long-term variations are detected in the semidiurnal and diurnal tidal coefficients, i.e. the amplitudes and the Greenwich phase-lags from the sequential solutions of the Kalman filter. These variations exhibit quasi-periodic behavior over decadal periods, more evident at the K_1 and O_1 tides at most of the coastal stations in radial components, with the values up to about 1.2 mm and 12 degrees in the amplitudes and the Greenwich phase-lags, respectively. For most of the coastal stations, the median formal errors of the Kalman filter sequential estimates of the radial amplitudes and the phase-lags of K_1 and O_1 tides are within 0.01-0.05 mm and 0.1-1 degrees, respectively.

Session-3: Analysis

Presentation type: oral

Kamil Teke
(1) Department of Geomatics Engineering, Hacettepe University, Beytepe Campus, Ankara, Turkey
Corresponding author: kteke@hacettepe.edu.tr

A jump in the VLBI position of the radio galaxy J1147+3501

O. Titov, S. Frey

Abstract The fundamental celestial reference frame is realized by regular VLBI observations of extragalactic radio sources. Compact radio-emitting active galactic nuclei also serve as reference points for relative positioning of other radio sources. For both purposes, the long-term positional stability of the reference objects is essential. VLBI absolute astrometric data indicate that the nucleus of the radio galaxy J1147+3501 (at redshift $z = 0.063$) apparently changed its position significantly, by about 20 milliarcsec some time between 1999 and 2017. Based on high-resolution VLBI images of the source obtained at multiple epochs, we suggest that this is a consequence of a drastic change in its brightness distribution.

Session 3: Analysis

Presentation type: movie

Oleg Titov[1], Sándor Frey[2]
(1) Geoscience Australia, PO Box 378, Canberra 2601, Australia
(2) Konkoly Observatory, ELKH Research Centre for Astronomy and Earth Sciences, Konkoly Thege út 15-17, 1121 Budapest, Hungary
Corresponding author: frey.sandor@csfk.org

The BRAND EVN receiver and the new DBBC4 backend

G. Tuccari on behalf of the BRAND EVN Team

Abstract The BRAND wideband receiver is being developed with support from the European Union's Horizon 2020 research and innovation programme as a part of RadioNet. The project represents a big technological challenge in the entire signal chain from the feed section to the digital processing. Its continuous frequency range from 1.5 GHz to 15 GHz makes it a scientifically extremely interesting development for the EVN network and radio astronomy in general. It also covers the VGOS frequenciesand even extends them to lower and higher frequencies. It will allow to retrofit traditional prime focus antennas to become compatible with VGOS antennas in terms of frequency coverage, with a much greater output data rate. The new VLBI backend project "DBBC4" is well underway and in one of its versions will make use of the BRAND sampler device. This new backend is capable of a much wider input band of up to 256 GHz input and is planned to offer many new functionalities including burst mode and add-on recording. The DBBC4 is an autonomous backend and thus can be part of the BRAND receiver. Completion of the BRAND receiver has been severely delayed by the Covid19 pandemic. The present status of the BRAND project is reported with the goals achieved and items still under way. An overview of the DBBC4 is presented.

Session-1: Technology

Presentation type: oral

INAF Istituto di Radioastronomia and Max Planck Institute fr Radioastronomie[1] [2]
(1) INAF Istituto di Radioastronomia, via Gobetti 101, Bologna, Italy
(2) Max Planck Institut fr Radioastronomie, Auf dem Hgel 69, Bonn, Germany
Corresponding author: tuccari@mpifr-bonn.mpg.de

ONTIE: Short-baseline interferometry at Onsala Space Observatory

E. Varenius, R. Haas, T. Nilsson, and P.-K. Diamantidis

Abstract A growing number of geodetic VLBI stations participate in the VLBI Global Observing System (VGOS). Multiple sites operate both new VGOS telescopes and legacy S/X VLBI telescopes. At Onsala Space Observatory, Sweden, we operate two 13.2 m diameter VGOS radio telescopes, ONSA13NE (OE) and ONSA13SW (OW), as well as the 20 m legacy S/X telescope ONSALA60 (ON). Transitioning from the legacy system and providing continuity of the terrestrial and celestial reference frames necessitate establishing ties between S/X and VGOS telescopes. Since spring 2019, we have carried out more than 20 short-baseline (550 m) interferometric observations at X-band to establish local-tie vectors between ON, OE and OW. The obtained data were correlated at Onsala Space Observatory using DiFX, post-processed using HOPS and analysed with *v*Solve and *ASCOT*. In this presentation we given an overview of the observations, analysis, and results of these local-tie experiments. We investigate the impact of modeling e.g. gravitational deformation, and the possibility of using phase-delays to improve the precision. Finally, we present a comparison with preliminary results from two other methods: global mixed-mode observations and classical local-tie measurements.

Session-2: Observations

Presentation type: oral

Eskil Varenius1, Rüdiger Haas1, Tobias Nilsson2, Periklis-Konstantinos Diamantidis1

(1) Chalmers University of Technology, Space, Earth and Environment, Space Geodesy and Geodynamics, Onsala, Sweden
(2) Lantmäteriet – The Swedish mapping, cadastral and land registration authority, Geodetic Infrastructure, Gävle, Sweden
Corresponding author: rudiger.haas@chalmers.se

VLBI Processing in the PANDA Software

Jungang Wang, Kyriakos Balidakis, Maorong Ge, Robert Heinkelmann, Harald Schuh

Abstract For the consistent realization of the Terrestrial Reference System, the Celestial Reference System, and the Earth Orientation Parameters (EOPs) by multi-technique integrated processing on the observation level, the Positioning And Navigation Data Analyst (PANDA) software has been recently upgraded to process the Very Long Baseline Interferometry (VLBI) observations. The PANDA software has been widely used in high-precision GNSS data processing, and currently we have developed the VLBI module following the latest IERS Conventions and the consensus delay model. We will present the current status of the VLBI implementation and describe the adopted processing strategy. The CONT05–CONT17 campaigns are used to demonstrate the VLBI capability, with focus on both station coordinates and EOP. The achieved station coordinate precision is on millimeter level, that is, 2–3 mm horizontally and 6–8 mm vertically. Comparing to the IERS 14 C04 product, the EOP precision is about 80–100 μas on the polar motion components, around 10 μs on the UT1-UTC component, and around 45 μas on the celestial pole offsets. Further development plans will also be discussed.

Session-3: Analysis

Presentation type: Oral

Jungang Wang[1,2], Kyriakos Balidakis[2], Maorong Ge[1,2], Robert Heinkelmann[2], Harald Schuh[1,2]
(1) Technische Universität Berlin, Institut für Geodäsie und Geoinformationstechnik, Kaiserin-Augusta-Allee 104-106, 10553 Berlin, Germany
(2) GFZ German Research Centre for Geosciences, Space Geodetic Techniques, Telegrafenberg, 14473 Potsdam, Germany
Corresponding author: jgwang@gfz-potsdam.de

Imaging VGOS observations and the effects of source structure

M.H. Xu, T. Savolainen, N. Zubko, M. Poutanen, N Kareinen, S. Lunz, H. Schuh, G.L. Wang

Abstract We have successfully imaged VGOS observations using closure quantities, which allows the source structure to be derived even when amplitude calibration information is not available. The images at the four frequency bands, one per band, were obtained from the closure phases and the closure amplitudes of the actual VGOS data. The images allow us to make in-depth investigations of the effects of source structure in the broadband observables. We tested and validated our imaging process by comparison to the astronomical images from the MOJAVE data base as well as through simulations. The systematical errors in broadband observables can be well explained by the modeling results of structure effects. The alignment of the four images of each source, involving core shift, is demonstrated to be an important and challenging issue in mitigating the systematic and random errors induced by these effects. We will present the images and discuss the alignment in the talk.

Session-3: Analysis

Presentation type: oral

M.H. Xu[1,2,6], T. Savolainen[1,2,3], N. Zubko[4], M. Poutanen[4], N Kareinen[4], S. Lunz[5], H. Schuh[6,5], G.L. Wang[7]
(1) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, 02540 Kylmälä, Finland
(2) Aalto University Department of Electronics and Nanoengineering, PL15500, FI-00076 Aalto, Finland
(3) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
(4) Finnish Geospatial Research Institute, Geodeetinrinne 2, FIN-02430 Masala, Finland
(5) DeutschesGeoForschungsZentrum (GFZ), Potsdam, Telegrafenberg, 14473 Potsdam, Germany
(6) Institute of Geodesy and Geoinformation Science, Technische Universität Berlin, Straße des 17. Juni 135, 10623, Berlin, Germany
(7) Shanghai Astronomical Observatory, Chinese Academy of Sciences, No. 80 Nandan Road, 200030, Shanghai, P. R. China
Corresponding author: minghui.xu@aalto.fi

Impacts of source structure as seen from the Gaia and VLBI comparison

M.H. Xu, S. Lunz, J.M. Anderson, T. Savolainen, N. Zubko, H. Schuh

Abstract Celestial reference frame (CRF) sources commonly have angular structure at milliarcsecond (mas) scales at cm-wavelengths. Source structure is time and frequency dependent, and it is not modeled in the data analysis of building the CRFs. The source positions and their uncertainties in the third realization of the International Celestial Reference Frame (ICRF3) are determined from global least-square fitting of the 40 years of geodetic VLBI observations and are thus not able to characterize the impacts of the systematic position variations due to source structure. However, these impacts can be demonstrated by investigating the position differences between radio and optical. Based on the ICRF3 and Gaia Early Data Release 3 (EDR3), we made detailed examinations of the position differences by using the actual observable-based structure "indices" (log closure amplitude root-mean-square (CARMS)) and the images from Monitoring Of Jets in Active galactic nuclei with VLBA Experiments (MOJAVE) database. The study has found that the majority of the sources with statistically significant position offsets between the ICRF3 and Gaia EDR3 are associated with the sources having extended structure and the magnitudes of the position differences increase with CARMS. Using the available radio images to inspect the position differences, it suggests that for a significant fraction of sources the radio positions are dominated by the jet components and the optical positions are close to the radio cores. The separations between the jets and the cores are typically at sub-mas level but can be up to tens of mas for the CRF sources. The position variations due to source structure were estimated to be at the level of 0.2 mas or less from correcting source structure effects in a single VLBI session by Petrov & Kovalev (2017). However, the impacts of source structure on VLBI positions cannot be fully addressed in their study because structure and observing networks change over time; these changes lead to larger position shifts than structure effects based on images. The radio to optical offsets suggest that the true level of the impacts is substantially greater. The directions of the position differences are also investigated with respect to jet position angles for the MOJAVE sources, and the possibility of 180° offsets in the jet position angles determined from radio images is discussed.

Session-3: Analysis

Presentation type: poster

M.H. Xu[1,2,4], S. Lunz[3], J.M. Anderson[4,3], T. Savolainen[1,2], N. Zubko[5], H. Schuh[3,4]
(1) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, 02540 Kylmälä, Finland
(2) Aalto University Department of Electronics and Nanoengineering, PL15500, FI-00076 Aalto, Finland
(3) DeutschesGeoForschungsZentrum (GFZ), Potsdam, Telegrafenberg, 14473 Potsdam, Germany
(4) Technische Universität Berlin, Institut für Geodäsie und Geoinformationstechnik, Kaiserin-Augusta-Allee 104-106, 10553 Berlin, Germany
(5) Finnish Geospatial Research Institute, Geodeetinrinne 2, FIN-02430 Masala, Finland
Corresponding author: minghui.xu@aalto.fi

The K Band Geodesy with the East Asian VLBI Network

S. Xu, T. Jike, T. Jung, F. Shu, L. Cui, A. Melnikov, J. McCallum, S. Yi, B. Zhang, N. Sakai, X. He, H. Imai, N. Kawaguchi, D. Sakai, C. Oh, P. Jiang, M. Xu, G. Wang

Abstract The East Asian VLBI Network (EAVN) is an international collaborative array, which consists of radio telescopes in China, Japan and Korea. Since 2018, EAVN has invited proposals for open-use observations at C, K and Q-bands. For the high precision astrometry, EAVN Astrometry Working Group has been conducting K-band Geodetic observations by collaborating with several IVS stations (Russian "Quasar" network, Hobart and Sejong). Based on the first EAVN geodetic observation and the local tie measurement, the agreement of 2 cm (in terms of the ITRF) was achieved for Korean VLBI Network (KVN). Such experiments can also contribute to the ICRF at K-band.

Session-2: Observations

Presentation type: oral (or poster)

Shuangjing Xu[1,2], Takaaki Jike[3],Taehyun Jung[1], Fengchun Shu[2], Lang Cui[4], Alexey Melnikov[5], Jamie McCallum[6], Sang Oh Yi[7], Bo Zhang[2], Nobuyuki Sakai[1], Xuan He[2], Hiroshi Imai[8], Noriyuki Kawaguchi[3], Daisuke Sakai[3], Chungsik Oh[1], Pengfei Jiang[4], Minghui Xu[9], Guangli Wang[2]
(1) Korea Astronomy and Space Science Institute, 776 Daedeokdaero, Yuseong-gu, Daejeon 34055, Republic of Korea
(2) Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Road,Shanghai 200030, China
(3) Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, Osawa 2-21-1, Mitaka-shi, Tokyo 181-8588, Japan
(4) Xinjiang Astronomical Observatory, Chinese Academy of Sciences, 150 Science 1-Street, Urumqi, Xinjiang 830011, China
(5) Institute of Applied Astronomy RAS, 10 nab. Kutuzova, 191187 St. Petersburg, Russia
(6) University of Tasmania, Private Bag 37, Hobart, Tasmania 7001, Australia
(7) National Geographic Information Institute, Space Geodetic Observatory, Sejong, PO Box 30060, Republic of Korea
(8) Amanogawa Galaxy Astronomy Research Center, Graduate School of Science and Engineering, Kagoshima University, 1-21-35 Korimoto, Kagoshima 890-0065, Japan
(9) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, 02540 Kylmälä, Finland
Corresponding author: sjxu@kasi.re.kr

Status of the VGOS project at the Metsähovi Geodetic Research Station

N. Zubko, J. Eskelinen, N. Kareinen, U. Kallio, J. Näränen

Abstract The VGOS radio telescope at the Metsähovi Geodetic Research Station, Finland was constructed and commissioned in 2018-2019. It is equipped with a quad-ridge horn, 2.1-14 GHz broadband receiver manufactured by IGN Yebes Technology Development Center, Spain. The signal from the receiver is divided into low (2.1 - 4 GHz) and high (3.6 - 14.1 GHz) frequency bands transmitted to the backend via RF over fiber (RFoF) link.

The first light of the Metsähovi VGOS telescope was obtained in November 2019. During 2020 the receiver performance has been investigated together with RFI conditions at the site. Substantial RFI sources were observed in the 2-3GHz band, limiting its usability in observations. A real-time RFI monitoring system is under development.

A Flexbuff recording system development is in progress. Tests of the whole telescope system, as well as the integration of the signal chain components are planned for 2021. 10 Gb internet connection will be installed at the research station in 2021 for VGOS data transfer.

To improve the thermal insulation and consequently stability of the telescope's steel pedestal an additional insulation layer is planned to be added. This work is planned for 2021 together with the telescope manufacturer.

The telescope was included in new local tie measurements of the station area. Two GNSS antennas were attached to the edges of the main dish for reference point monitoring. The antennas are installed in gimbals that keep them vertical at all zenith angles. Automatic monitoring of VLBI telescope reference point from the network pillars were tested with robot tachymeter simultaneously with GNSS measurements. Final monitoring measurements with tachymeter for reference point determination is planned for 2021, also GNSS local tie measurements will continue.

Session-1: Technology

Presentation type: poster

Nataliya Zubko[1], Joona Eskelinen[1], Niko Kareinen[1], Ulla Kallio[1], Jyri Näränen[1]
(1) Finnish Geospatial Research Institute (FGI), National Land Survey of Finland, Geodeetinrinne 2, FIN-02430 Masala, Finland
Corresponding author: nataliya.zubko@nls.fi

Ionosphere comparison study of VGOS and Total Electron Content global maps

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

Abstract Total Electron Content (TEC) of the ionosphere is an important characteristic whose accurate estimation is needed in various application which are based on measurements in radio wave band. There is a number of Global TEC models designed to describe conditions of ionosphere. We have conducted a comparative study of the two selected TEC global maps with the results from the observations of the VLBI Global Observing System (VGOS). The estimated differential TEC (dTEC) from VGOS data has been improved considerably compared to the traditional geodetic S/X VLBI observations, the formal error of VGOS dTEC is of about 0.01 - 0.2 TECU. It can be used in evaluation of the TEC global maps, as well as an additional data source for the further improvement of the TEC map models.

We have compared VGOS ionosphere product with the dTEC calculated using global ionosphere TEC maps. For analysis, we selected two TEC global models, CODE GIM and Neustrelitz TEC Model Global (NTCM-GL). The comparison was performed for the VGOS observations made in 2019, when the solar activity was at about its minimum. The comparison shows a good agreement between VGOS dTEC and dTEC obtained using global TEC maps. However, it also reveals shortages of the global TEC models in some locations. The VGOS data can be considered as an additional information source and, hence, they can be used for the further improvement of the global TEC models.

Session-3: Analysis

Presentation type: oral

Nataliya Zubko[1], Minghui Xu[2,3,4], Niko Kareinen[1], Tuomas Savolainen[2,3,5], Markku Poutanen[1]
(1) Finnish Geospatial Research Institute (FGI), National Land Survey of Finland, Geodeetinrinne 2, FIN-02430 Masala, Finland
(2) Aalto University Department of Electronics and Nanoengineering, PL 15500, FI-00076 Aalto, Finland
(3) Aalto University Metsähovi Radio Observatory, Metsähovintie 114, FI-02540 Kylmälä, Finland
(4) Institute of Geodesy and Geoinformation Science, Technische Universität Berlin, Straße des 17. Juni 135, 10623, Berlin, Germany
(5) Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, 53121 Bonn, Germany
Corresponding author: nataliya.zubko@nls.fi

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We hope see you all in person again at EVGA2023!