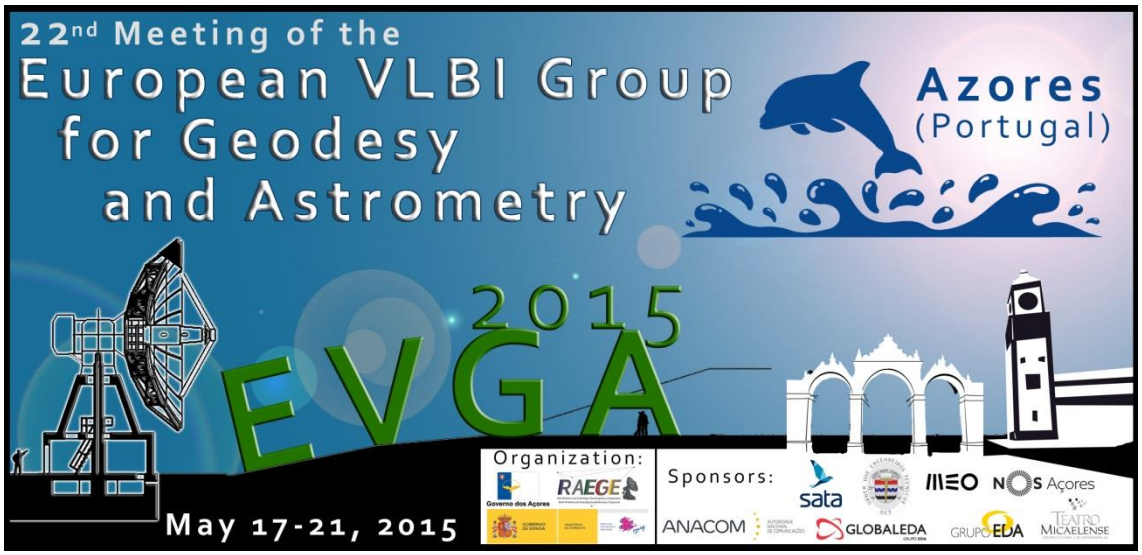

SCHEDULE OF EVENTS

Date	Time	Event	Location
May 17	20:00 – 22:00	Icebreaker reception*	Hotel Açores Atlântico
May 18	09:00 – 18:30	EVGA day 1*	Teatro Micaelense
May 19	08:45 – 18:30	EVGA day 2	Teatro Micaelense
May 19	20:00 – 23:00	EVGA dinner	Hotel Açores Atlântico
May 20	06:00 – 20:30	RAEGE inauguration	Santa María island
May 21	08:30 – 11:30	Analysis workshop	Laboratório Regional de Engenharia Civil (LREC);
May 21	16:30 – 20:30	RAEGE CACT meeting (closed)	Secretaria Regional do Turismo e Transportes (SRTT)
May 21	16:30 – 20:30	ICRF-3 meeting	Direção Regional das Obras Públicas e Comunicações (DROPC)
May 21	16:30 – 18:30	Asia-Oceania VLBI (AOV) group meeting	Biblioteca Pública e Arquivo Regional de Ponta Delgada
May 21	18:30 – 20:30	VTC meeting	Biblioteca Pública e Arquivo Regional de Ponta Delgada
May 22	09:00 – 17:00	IVS Board Meeting (closed)	Direção Regional das Obras Públicas e Comunicações (DROPC)

* Registration to EVGA2015 during icebreaker reception, and from 08:30h on May 18th.

Website: http://evga2015.raege.net/

European VLBI working group for Geodesy and Astrometry (EVGA)

Chair: **Rüdiger Haas (rudiger.haas@chalmers.se)**

Secretary: **Susana García-Espada (Susana.G.Espada@azores.gov.pt)**

EVGA 2015

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- Alessandra Bertarini (University of Bonn, Germany)
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- Johannes Böhm (Vienna University of Technology, Austria)
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- Francisco Colomer

EVGA 2015 SCIENTIFIC PROGRAM

MAY 18			**time**
Welcome		Eng.º Bruno Pacheco, President of the RAEGE Executive Committee, and Eng.º Vitor Fraga, Regional Secretary of Tourism and Transports of the Azores Government	09:00-09:15
Session-T1	**90 min**	Chair: Alessandra Bertarini	
Bill	Petrachenko	VGOS Operational Readiness	09:15-09:30
Kazuhiro	Takefuji	Broadband VLBI at 6GHz to 14GHz frequency between Kashima 34 m and Ishioka 13 m	09:30-09:45
José Antonio	López Fernández	Technological Developments for VGOS from IGN Yebes Observatory	09:45-10:00
Torben	Schüler	Results from the TWIN Commissioning Phase	10:00-10:15
Jamie	McCallum	Toward VGOS with the AuScope array	10:15-10:30
coffee		**10:30-11:00**	
Session-T2	**90 min**	Chair: José Antonio López-Fernández	
Pablo	de Vicente	The 13m Yebes antenna. Telescope control, commisioning and tests	11:00-11:15
Gino	Tuccari	DBBC3L - A full compliant VGOS backend	11:15-11:30
Evgeny	Nosov	Development of Multipurpose Digital Backend for "Quasar" network radio telescopes	11:30-11:45
Alexander	Neidhardt	Results from the test realization of a system monitoring for seamless auxiliary data	11:45-12:00

Walter	Alef	Expanding the Bonn Correlator for VGOS and summary of recent activities	12:00-12:15
Voytsekh	Ken	IAA VGOS GPU-based software correlator: current status and broadband processing	12:15-12:30
12:30-14:00		**Extended lunch and poster viewing**	
Session-O1	**75 min**	Chair: Hayo Hase	
Jesus	Gomez-Gonzalez	Status of the Spanish/Portuguese RAEGE project	14:00-14:15
Jim	Lovell	The southern hemisphere AUSTRAL program: A pathway to VGOS	14:15-14:30
Ryoji	Kawabata	GSI's regional stations and AOV activities	14:30-14:45
Yoshihiro	Fukuzaki	First geodetic result of Ishioka VGOS Station in Japan	14:45-15:00
Fengchun	Shu	On the role of Tianma radio telescope for improving celestial reference frames	15:00-15:15
coffee		**15:15-15:45**	
Session-O2	**75 min**	Chair: Rüdiger Haas	
Yuri	Bondarenko	Russian radio interferometer of new generation	15:45-16:00
Arthur	Niell	Status report on observations with the GGAO-Westford VGOS systems	16:00-16:15
Ludwig	Combrinck	Contributions of HartRAO to Space Geodesy, Astrometry and related disciplines	16:15-16:30
Matteo	Stagni	Geodetic Italian VLBI: first tests	16:30-16:45
Hayo	Hase	An Observation and Analysis Scenario for VGOS in 2020	16:45-17:00

break		**17:00-17:30** "strech-your-legs"	
Session-O3	**60 min**	Chair: Yuri S. Bondarenko	
John	Gipson	Practical Uses of VGOSDB format	17:30-17:45
Andreas	Hellerschmied	Scheduling VLBI observations to satellites with the Vienna VLBI Software (VieVS)	17:45-18:00
Rüdiger	Haas	GLONASS-VLBI: Onsala-Wettzell test observations	18:00-18:15
James M	Anderson	Software Development for D-VLBI Scheduling and Analysis of Spacecraft Observations	18:15-18:30
			END 18:30

MAY 19

INAUGURATION OF THE GEODETIC VLBI STATION IN **ZELENCHUKSKAYA** (RUSSIA)			08:45-09:30
Session-A1	**75 min**	Chair: Thomas Hobiger	
Kamil	Teke	GNSS zenith delays and gradients in the analysis of VLBI Intensive sessions	09:30-09:45
Benjamin	Mannel	Observing GNSS L-band signals: ionospheric corrections by co-located GNSS measurements	09:45-10:00
Younghee	Kwak	VLBI-like GNSS delays in the analysis of CONT11	10:00-10:15
Armin	Hofmeister	Influence of the horizontal resolution of numerical weather models on ray-traced delays for VLBI analysis	10:15-10:30
Sebastian	Halsig	Augmenting the stochastic model in VLBI data analysis by correlations from atmospheric turbulence models	10:30-10:45
coffee		**10:45-11:15**	

Session-A2	**105 min**	Chair: Johannes Böhm	
Robert	Heinkelmann	Atmospheric refractivity gradients from VLBI compared to those from GNSS, DORIS, WVR, and NWM	11:15-11:30
Benedikt	Soja	Subdaily station motions from Kalman filtering VLBI data	11:30-11:45
Tobias	Nilsson	Antenna axis offsets estimated in VLBI data analysis	11:45-12:00
Thomas	Artz	Numerical issues of VLBI data analysis	12:00-12:15
Axel	Nothnagel	Sophistication in UT1-Intensive Scheduling by Using Impact Factors - First Results of Field Tests	12:15-12:30
Daniel	MacMillan	The CONT campaigns as a precursor to VGOS observing	12:30-12:45
Thomas	Hobiger	CONT14 as a testbed for the combination of VLBI and GPS data on the observation level	12:45-13:00
13:00-14:15		**Extended lunch and poster viewing**	
Session-A3	**60 min**	Chair: Gèraldine Bourda	
David	Mayer	Earth Orientation Parameters for VLBA Calibrator Survey Sessions	14:15-14:30
David	Gordon	Revisiting the VLBA Calibrator Surveys, VCS-II	14:30-14:45
Christopher	Jacobs	ICRF-3: Status, Plans, and Multi-wavelength Progress towards the next generation ICRF	14:45-15:00
Andreas	Iddink	Assessment of CRF Solutions from Session-wise Normal Equation Systems	15:00-15:15
coffee		**15:15-15:45**	

Session-A4	**60 min**	Chair: Bill Petrachenko	
César	Gattano	Studying impacts of strategy choices concerning the Celestial Reference Frame on the estimates of nutation time series during geodesic VLBI Analysis	15:45-16:00
Patrick	Charlot	Reducing the impact of source structure on the celestial frame: modeling or mitigation strategies?	16:00-16:15
Lucia	Plank	On the estimation of a celestial reference frame in the presence of source structure	16:15-16:30
Arnaud	Collioud	Imaging the IYA09 VLBI super-session	16:30-16:45
break		**16:45-17:15** "strech-your-legs"	
Session-A5	**60 min**	Chair: Patrick Charlot	
Géraldine	Bourda	Aligning VLBI and Gaia Extragalactic Celestial Reference Frames	17:15-17:30
Minghui	Xu	Estimating the velocity of the Solar barycenter from VLBI observations	17:30-17:45
Guangli	Wang	The CVN Geodetic Observation and its Result	17:45-18:00
Wu	Jiang	Preliminary results of pulsar astrometry with CVN	18:00-18:15
Closure		Rüdiger Haas (EVGA Chair) Dr. Fausto Abreu, Regional Secretary of Sea, Science and Technology of the Azores Government	18:15-18:30
			END 18:30

EVGA 2015 POSTER CONTRIBUTIONS

Name	Surname	Title	Number
Remi	Rayet	QRFH Wideband Cryogenic Receivers	P1-01
Alina	Caddemi	Ultra Wide-Band HTS filter for new geodetic VLBI front-ends	P1-02
Alexander	Neidhardt	The new release of e-RemoteCtrl	P1-03
Christian	Plöt	The German Antarctic Receiving Station O''Higgins - upgrades of the VLBI-capabilities for future challenges	P1-04
Lucia	Plank	Hb-Ho: observations with the sibling telescopes in Hobart	P2-01
Jim	Lovell	The Asia-Oceania VLBI Group for Geodesy and Astrometry	P2-02
Minttu	Uunila	An experimental scanning of the Metsähovi radio telescope dish	P2-03
Caroline	Schönberger	The contribution of the Twin Telescopes at Onsala and Wettzell to the VGOS System	P2-04
Rüdiger	Haas	Contributions of the Onsala Space Observatory to the GGOS	P2-05
Huan	Zhou	Spacecraft VLBI Phase Referencing Tracking with the Chinese VLBI Network and Deep Space Network	P2-06
Beatriz	Córdoba	Local Tie works in Yebes Observatory	P2-07
Michael	Lösler	Coordinate Based Bundle Adjustment - Advanced Network Adjustment Model for Polar Measurement Systems.	P2-08
Tong	Ning	A GPS-based local-tie vector at the Onsala Space Observatory	P2-09
Marisa	Nickola	Determining HartRAO antenna reference point and axis offset parameters using VieVS	P2-10
Dirk	Behrend	Continuous VLBI Scheduling: The CONT14 Example	P2-11
Sergei	Bolotin	Implementation of VGOSDB format.	P2-12
Andreas	Hellerschmied	Current status and future plans for the Vienna VLBI Software (VieVS)	P2-13

John	Gipson	Minimization of the UT1 Formal Error through Minimization Algorithms	P3-01
Niko	Kareinen	Automated analysis of Kokee-Wettzell intensive sessions	P3-02
Benedikt	Soja	Applying Kalman filtering to investigate tropospheric effects in VLBI analysis	P3-03
Thomas	Hobiger	Combining VLBI and GPS for inter-continental frequency transfer	P3-04
Anastasiia	Girdiuk	Atmospheric tidal effects in Earth rotation observed by VLBI	P3-05
Minttu	Uunila	Baseline dependent weights in VieVS	P3-06
Tobias	Nilsson	Combination of common parameters for co-located VLBI antennas	P3-07
Volkmar	Thorandt	VLBI Analysis at BKG	P3-08
Linda	Messerschmitt	IVS Combination Center at BKG: Combination products and the IVS contribution to ITRF2014	P3-09
Julián Andrés	Mora Diaz	The GFZ global VLBI solution	P3-10
Maria	Karbon	CONT14 analyzed by a Kalman filter: a test case	P3-11
Vincenza	Tornatore	Comparison of VLBI and DORIS solutions in view of ITRF2014	P3-12
Ke	Xu	Status Report of VLBI Measuring System based on China Deep Space Network	P3-13
Dezhen	Xu	First determination of the locations of the Chinese Deep Space Stations -- JIAMUS66 and KASHI35 using Geodetic VLBI	P3-14
Dong	Zhang	dDOR Data Processing and Analysis in CE-3 Mission	P3-15
Aletha	de Witt	A Celestial Reference Frame at 22 GHz (K-band)	P3-16
Zheng	Weimin	CVN High Accuracy VLBI Phase-referencing Positioning experiment for Deep Space Probe	P3-17
Christopher	Jacobs	The X/Ka-band (8.4/32 GHz) Celestial Frame: Can it be more accurate than the ICRF2?	P3-18
Nataliya	Zubko	Source structure influence on GeoVLBI observations	P3-19
Karine	Le Bail	Observing Gaia transfer sources in R&D and RDV sessions	P3-20

ORAL PRESENTATIONS

VGOS Operational Readiness

Bill Petrachenko

The state of VGOS operational readiness will be discussed from the point of view of the IVS Techology Development Coordinator.

Broadband VLBI at 6GHz to 14GHz frequency between Kashima 34 m and Ishioka 13 m

Kazuhiro Takefuji, NICT Tetsuro Kondo, NICT Hideki Ujihara, NICT Mamoru Sekido, NICT

We have been developing a broad-band system for Kashima 34 meter antenna. Currently broadband feed for 6.5 GHz to 15 GHz and broadband receivers, high-speed samplers (K6/OCTAD-G and ADS3000+) were developed and installed. The feasible broad-band VLBI sessions with Kashima 34 m and new VGOS-type Ishioka 13 m were carried out from end of 2014 to January 2015. The backend was made up two digital and analog parts. One is direct sampling system covered with 6GHz, 7GHz, 8GHz and 9GHz. The other was analog frequency converter for 10GHz and 13GHz. Both systems were set up for both antennas. We carried out intensive sessions for 6 to 14GHz (6-bands, 2048Msps, 1bit). Fringes from every six frequencies could be simultaneously obtained after software correlation with GICO3. Then acoherent phase connection over six frequencies was performed. An error of delay resolution function by the super bandwidth synthesis is estimated 0.1 ps. We will report more detail in presentation.

Technological Developments for VGOS from IGN Yebes Observatory

Jose Antonio López Fernández, Felix Tercero Martínez, José Antonio López Pérez, José Manuel Serna Puente, and Juan Daniel Gallego Puyol (IGN Spain)

Several technological development activities at IGN Yebes Observatory have been focused on different topics related to VGOS. Our low noise amplifiers can cover the S and X geodetic bands but also the 2-14 GHz band new ones (that yield average 7.5 K noise temperatures) for the broad band delay experiments. Our Tri-band receiver (S, X and Ka bands) is now installed at Yebes and Ishioka 13.2 radio telescopes. We are also working in our first broad band receiver which will cover the mentioned 2-14 GHz band.

Results from the TWIN Commissioning Phase

Torben Schüler (1), Gerhard Kronschnabl (1), Alexander Neidhardt (2), Christian Plötz (1), Alessandra Bertarini (3), Laura La Porta (3), Simone Bernhart (3), and Arno Müskens (3); (1) Geodetic Observatory Wettzell, (2) Technical University of Munich, (3) University of Bonn/MPIfR

The TWIN radio telescope pair at the Geodetic Observatory Wettzell features two identical antenna constructions reserved for geodetic VLBI within the International VLBI Service for Geodesy and Astrometry with slightly different receiving systems. The first telescope, TTW1, owns a tri-band feed horn in S-, X- and Ka-band with dual-polarization capabilities and a particularly broad usable X-band window from 6 to 10 GHz. This system entered its commissioning phase in 2014. First results are being presented here. The positioning performance evaluated over the 120 meters baseline between TTW1 and the existing 20 m RTW telescope is very satisfactory in X-band, whilst S-band suffers from increased radio frequency interference and likely requires additional measures to be taken. Corresponding correlation samples will be presented. Moreover, the status of the second telescope, TTW2, will be portrayed. A broadband feed (Eleven-Feed from 2 to 12 GHz) was successfully developed and delivered by the manufacturer to the Observatory. The results from a first quality analysis will be discussed. In summary, these results indicate a very suitable performance for this VGOS antenna. The integration of the feed is scheduled for mid of this year after the necessary, though unexpected, modifications of the feed cone have been completed.

Toward VGOS with the AuScope array

Jamie McCallum, Jim Lovell, Elizaveta Rastorgueva-Foi, Lucia Plank, and Stanislav Shabala (University of Tasmania)

The AuScope array consists of three fast-slewing 12m telescopes located across the Australian continent, currently equipped with uncooled S/X feeds. In mid-2015, a prototype broadband feed will be tested on the Hobart telescope with a view to installation on all three telescopes of the AuScope array in 2016 to make them fully compatible with the VGOS requirements. In preparation, we are developing calibration techniques, support for high data-rate recordings and the logistical challenges they provide, and expanding our correlation and analysis facilities. I will be presenting a short review of our efforts and the results to date.

The RAEGE 13m antenna in Yebes. Telescope control, commisioning and tests.

P. de Vicente, R. Bolaño, L. Barbas, A. Moreno, and A. Diaz (IGN Yebes, Spain)

The 13m antenna in Yebes Observatory (IGN, Spain) is the first element of the RAEGE network. During 2014 the control system has been debugged and the antenna has been characterized at S, X and Ka band. We will explain how the FS communicates with the antenna control system developed at our observatory and present the main results obtained from single dish observations like beam pattern, efficiency, pointing RMS, calibration determination and focus. A description of the tri-band receiver will also be provided. We will also show the RFI of the spectrum covered by the current receiver. We will present the first fringes detected in December 2014 between the Yebes 40m and the Yebes 13m antenna at X band, both using DBBCs and Mark5Bs. During the first months of 2015 the 13m is scheduled in tag along mode and we hope to present also the first results from these observations.

DBBC3L - A full compliant VGOS backend

G. Tuccari (INAF-Istituto di Radioastronomia, Noto, Italy and Max Planck Institute fuer Radioastronomie, Bonn, Germany), W. Alef, A. Bertarini, A. Felke, H. Rottmann, M. Wunderlich (Max Planck Institute fuer Radioastronomie, Bonn, Germany), S. Buttaccio, P. R. Platania (INAF-Istituto di Radioastronomia, Noto, Italy), S. Casey, M. Lindqvist (Onsala Space Observatory, Sweden)

The Radionet3 JRA project named DBBC3 is progressing as formally planned and going to a completion. The first three units are under realization for both astronomy and geodesy. Indeed the DBBC3L operating with a set of up eight full 4 GHz bandwidth IFs it is capable to cover the entire VGOS range 2-14 GHz in double polarization. The main parts of the system as VGOS backend will be shown with the performance, and an overview of its use for the new coming geodetic network will be pointed out.

Development of Multipurpose Digital Backend for “Quasar” network radio telescopes

Evgeny Nosov (IAA RAS)

Multipurpose Digital Backend (MDBE) is a system intended to replace the currently used backends of RT-32 radio telescopes of Quasar network. MDBE is compact, light weighted and can be easily placed inside the focal cabin of the antenna. MDBE digitizes up to 8 input signals with 512 MHz bandwidth or up to 4 signals with 1024 MHz bandwidth and processes the signals in FPGA. The system has several operational modes to perform all required types of observations. For VLBI observations, MDBE supports wideband channel mode, digital downconverters (DDC) mode and polyphase filter bank mode. The output data stream is packed into 10G Ethernet frames and transferred through fiber optic lines. MDBE supports VDIF data format for all VLBI observation modes. To ensure compatibility with existing data acquisition systems, the data in DDCs mode can also be packed in Mark5B data format. Besides VLBI observation modes, MDBE implements a spectrometer and a radiometric backend mode. The system implements a broad range of signal analysis features including PCAL extraction, 2-bits data statistics, input signals capture, power spectral density estimation and other. These features allow remote monitoring of the whole system condition and can greatly reduce down time due to faults. MDBE can replace a lot of equipment with one compact device and significantly reduce overall system complexity.

Results from the test realization of a system monitoring for seamless auxiliary data

Alexander Neidhardt, FESG; Jim Lovell, UTAS; Katharina Kirschbauer, THD; Ed Himwich, NASA/NVI; Jamie McCallum, UTAS; Christian Plötz, BKG; Jonathan Quick, HartRAO; Matthias Schönberger, BKG

During the analysis workshop following the 2014 IVS General Meeting in Shanghai, a new IVS Taskforce was formed to address the issue of seamless auxiliary data. The project has now progressed to the stage where a formal proposal has been prepared and first test realizations have been implemented at Wettzell. Underlying this development are definitions of the Monitoring and Control Infrastructure (MCI) in combination with the Wettzell System Monitoring (SysMon) hardware and software. We will present the design of this system and the first realizations, and an initial demonstration of the results.

Expanding the Bonn Correlator for VGOS and summary of recent activities

Walter Alef (1), Torben Schüler (2), Arno Mueskens (3), Axel Nothnagel (3), Alessandra Bertarini (3), Helge Rottmann (1), Laura La Porta (3), and Simone Bernhart (3); (1) Max-Planck-Institut f¨ur Radioastronomie Bonn, (2) Bundesamt für Kartographie und Geodesie/Wettzell, (3) Institut für Geodesie und Geoinformation Bonn

We will present the status of the Bonn Correlator Center with emphasis on the geodetic correlation. The correlator center has been operated jointly by the Max Planck Institute for Radio Astronomy in Bonn, the Bundesamt f”ur Kartographie und Geodäsie in Frankfurt with support from the Institute for Geodesy and Geoinformation in Bonn. Correlation has been done with the DiFX software correlator. We will give a brief summary of our experience with correlating the CONT14 session, the first CONT to be correlated with DiFX. We will also discuss our plans for upgrading/renewing the HPC cluster in preparation for the expected impact of the future VGOS observations on the available computing and playback resources.

IAA VGOS GPU-based software correlator: current status and broadband processing

Voytsekh Ken, Yana Kurdubova, Nadezda Mishina, Vladimir Mishin, Violet Shantyr, and Igor Surkis (IAA RAS)

The VGOS FX-type software correlator was designed in the IAA RAS. The correlator is able to process VDIF data from up to 6 stations simultaneously at a maximum rate of 16 Gb/s from each station. The main idea of the correlator design is the usage of Graphical Processing Units (GPUs) for fringe stopping, Fourier transformation, spectra multiplication and pcal extracting operations. The correlator hardware is based on a hybrid blade server cluster. Each blade server holds two Intel CPUs and two Tesla K20x GPUs. Usage of GPUs allows us to reduce the amount of blade servers required for such a high correlator performance. At present, the correlator cluster and the cooling system are almost assembled in the IAA. The cluster contains 4 compute racks with 8 cache and 40 blade servers, 80 TB data storage based on Panasas, and control servers. In order to test the six-station correlator in a maximal mode, an experiment was carried out with the following setup: 4 frequency channels each of 512 MHz bandwidth at 2 polarizations, 2-bit sampling. In each frequency channel 78 fringes were found. The first results of comparison of the DiFX correlator and the IAA VGOS correlator were obtained. The post-processing software and graphical user interface are close to be completed.

Status of the Spanish/Portuguese RAEGE project

Jesús Gómez-González, IGN Spain; Luis R. Santos, DRTC Azores; José Antonio López-Fernández, IGN-Yebes Spain; Francisco Colomer, IGN Spain

The Spanish/Portuguese RAEGE project (“Atlantic Network of Geodynamical and Space Stations”) is being deployed in Yebes (Spain) Santa Mara (Azores Islands). The status of the RAEGE project will be presented. Commissioning of the radio telescope at Yebes is ongoing, and the construction of the antenna in Santa Mara site is very advanced (its dedication expected on May 20 2015, just after EVGA). Site works for a new station in Tenerife (Canary Islands) have started.

The southern hemisphere AUSTRAL program: A pathway to VGOS

Jim Lovell (1), Jamie McCallum (1), Lucia Plank (1), Elizaveta Rastorgueva-Foi (1), Stas Shabala (1), David Mayer (2), Johannes Bohn (2), Jing Sun (3), Oleg Titov (4), Jonathan Quick (5), Stuart Weston (6), Cormac Reynolds (7), Alexander Neidhardt (8), Hayley Bignall (7), Sergei Gulyaev (6), Tim Natusch (6); (1) University of Tasmania, (2) Technical University of Vienna, (3) Shanghai Astronomical Observatory, (4) Geoscience Australia, (5) Hartebeesthoek Radio Astronomy Observatory, South Africa, (6) Auckland University of Technology, New Zealand (7) Curtin University, Australia, (8) Technical University of Munich

The AuScope VLBI array participated in 178 IVS sessions in 2014 and will observe in 235 sessions in 2015. Half of these are dedicated to the southern hemisphere AUSTRAL program together with antennas at Hartebeesthoek (South Africa) and Warkworth (New Zealand). AUSTRAL has three main streams: astrometry to monitor and enhance the southern hemisphere celestial reference frame; geodesy to improve the southern hemisphere terrestrial reference frame and the baseline time series; and four 15-day CONT-like sessions to densify the time series and investigate a range of observing strategies. The high observing rate is providing new insight into some of the challenges of a 24/7 VGOS observing program and is allowing us to trial new scheduling and observing strategies such as Dynamic Observing. All AUSTRAL sessions are being scheduled with VieVS, observations are carried out remotely using the eRemoteCtrl software, data are processed at the Curtin University AuScope correlator and analysis is carried out in Hobart. We will present some results from the AUSTRAL program to date and describe the steps we have taken and have planned to approach VGOS-like operations.

GSIs regional stations and AOV activities

Ryoji Kawabata and Takahiro Wakasugi (Geospatial Information Authority of Japan)

The Geospatial Information Authority of Japan (GSI) has been operating three VLBI telescopes, i.e. Tsukuba 32-m, Aira 10-m, and Chichijima 10-m telescopes. These stations have observed many IVS regular sessions including Japanese domestic sessions (JADE sessions). Some other Japanese stations have also participated in the JADE sessions. However, GSI determined to finish VLBI observation at Aira and Chichijima site by March 2015. Therefore there will be no JADE session from April 2015. Instead, GSI will devote their effort to the newly established Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) in operation, correlation, and analysis. Tsukuba 32-m and Ishioka 13m are going to observe six AOV sessions in 2015. We will report on the current status of GSIs regional stations and AOV activities for GSI.

First geodetic result of Ishioka VGOS Station in Japan

Yoshihiro Fukuzaki, Kojin Wada, Jiro Kuroda, Shinobu Kurihara, Ryoji Kawabata, and Takahiro Wakasugi (Geospatial Information Authority of Japan)

The Geospatial Information Authority of Japan (GSI) started a new project for constructing VGOS station (Ishioka Geodetic Observing Station) in Japan. The construction of the antenna (radio telescope) has been completed and the necessary equipment (Front-end, Back-end, H-maser, and so on) has also been delivered. New receiving systems have been developed for the new antenna. In order to achieve compatibility with legacy S/X-band receiving, tri-band feed system developed by Spanish IGN is employed. By installing the tri-band feed system on the new antenna, S/X-band experiment was carried out on Feb. 19th in Japanese domestic VLBI network including Tsukuba, Aira, Chichijima, Kashima-34m, Kashima-11m, Koganei, VERA-Mizusawa, and VERA-Ishigaki. In the presentation, the first geodetic result of the new antenna will be briefly reported.

On the role of Tianma radio telescope for improving celestial reference frames

Fengchun Shu, Jinqing Wang, Wu Jiang, Guangli Wang, and Zhiqiang Shen (Shanghai Astronomical Observatory)

The Tianma 65-m radio telescope, located in Shanghai and approximately 6 km west of the station Seshan25, has been operated by Shanghai Astronomical Observatory since its inauguration in 2012. Tianma65 can be used as a single-dish or a powerful VLBI element for a variety of research on radio astronomy, geodesy as well as space science. Equipped with S/X dual band receiver and CDAS (Chinese VLBI Data Acquisition System), Tianma65 has been operational in CVN (Chinese VLBI Network) and then IVS sessions since 2013. It will be also equipped with X/Ka dual band receiver by the end of 2015. By taking advantage of its high sensitivity, Tianma65 is able to improve detection of astrometric sources and increase the total number of observations in one session, which is of importance for connection of radio-optical frames and densification of the ICRF. We will briefly describe the characteristics of this new antenna, introduce its performance on antenna measurements and fringe tests, present current observational status and discuss the future observations optimized for improving celestial reference frames.

Russian radio interferometer of new generation

Yuri Bondarenko, Alexander Ipatov, Dmitry Ivanov, Gennady Ilin, Valery Olifirov, Vyacheslav Mardyshkin, Igor Surkis, Leonid Fedotov, Iskandar Gayazov, and Viktor Stemkovsky (Institute of Applied Astronomy RAS)

The radio interferometer of new generation, created in the Institute of Applied Astronomy at the stations of “Quasar” VLBI network is considered. Currently this new radio interferometer consists of two antennas with a mirror diameter of 13.2 m installed at the “Badary” and “Zelenchukskaya” observatories. All installation works of the antenna systems were carried out by the end of 2014. Antenna control system and subreflector were successfully tested. Tri-band Receiving System was installed on the antennas of the radio interferometer. The first observations of calibration radio sources were carried out at the “Badary” observatory. Processing and analysis of newly obtained data showed that the radio interferometer of new generation allows to operate as a part of the International and European VLBI networks and having an accuracy of 3 mm for pole coordinates, 100 microsecond of arc for the nutation and precession angles and no more than 10 s for the Universal Time determination, that meets all requirements of the VGOS program.

Status report on observations with the GGAO-Westford VGOS systems

Arthur Niell, MIT Haystack Observatory

The GGAO12M and Westford antennas have been instrumented with the majority of the components needed for VGOS broadband observations. The primary missing component is the Cable Delay Calibration System at each site. Nevertheless, a series of six bi-weekly one-hour sessions was begun in January to evaluate the performance of the systems and to develop the operational procedures, from scheduling through single-baseline parameter estimation, that are needed to accommodate the new four-band data acquisition. The important recent developments in the broadband signal chain for both antennas are the upgrade to the RDBE-G (3.0) for the digital backend and the switch to a single Mark6 for recording at, currently, 8 Gigabits per second, from the four RDBEs. The digitized data are encoded as complex samples in VDIF. Three sessions have been observed and correlated (as of Mar 1), and processing of the first session has been completed through parameter estimation. While the early sessions will be controlled by a combination of the Field System for the antenna motion and scripts for the RDBEs and Mark6, by the end of the series it is expected that the sessions will be run almost fully by the Field System.

Contributions of HartRAO to Space Geodesy, Astrometry and related disciplines

Ludwig Combrinck, Roelf Botha, Philip Mey, Alet de Wit, and Jonathan Quick (Hartebeesthoek Radio Astronomy Observatory)

The Hartebeesthoek Radio Astronomy Observatory (HartRAO), located in South Africa, has been active for several decades in the various fields of space geodesy and astrometry. Within the framework of the VLBI Global Observing System (VGOS, HartRAO has commenced with a project to install a VGOS antenna, which will supplement the existing 26-m and 15-m antennas. We have added geophysical instruments on site and are expanding our activities on Marion Island, Gough Island and Antarctica. In support of the African VLBI Network (AVN), we are part of an international team that will provide training, equipment upgrade and new installations in Africa in support of the AVN and Square Kilometre Array (SKA). We will also increase our support for the RadioAstron VLBI satellite, by including ground control and data downlink capacity. Here we report on progress to date and sketch our plans for the next 3 years.

Geodetic Italian VLBI: first tests

Matteo Stagni and Monia Negusini (IRA-INAF, Italy)

First experiments of the Italian VLBI correlated in Bologna have involved the Medicina, Noto and Matera antennas. Although the scientific validity of these tests are yet to be proven, these tests have served as a benchmark to verify a full, in-house, correlation pipeline, from the scheduling through the software correlation using DiFX to finally generating a geodetic data base. A future inclusion of the Sardinia Radio Telescope, when geodetic receivers will be installed, will enhance the capability to plan ad hoc observations to strengthen the VITA network to become a basis for the definition of the national datum.

Options for VGOS observations and analysis in 2020

Hayo Hase, Dirk Behrend, Axel Nothnagel, Harald Schuh

With the VGOS program, the IVS continues to improve its service. In the coming years a modern network of very fast radio telescopes will become available in addition to the existing legacy network of VLBI observing stations. The projection of the ambitious VGOS plans and the potential of the existing legacy stations lead to a new vision on how the VLBI infrastructure may be used in 2020. In order to take advantage of the new possibilities that the increased data volumes constitute, a new scenario for scheduling, observing, and analyzing VLBI data may shift the VLBI operations from being session-based to continuous observations. Depending on possible upgrades of data transfer and correlation infrastructure, we anticipate to move from an analysis session-by-session to other scenarios which depend on latency requirement. One such scenario is a continuously running analysis, where new observations are added one by one to filter solutions as soon as they pour out of a continuous transfer and correlation process. Another concept is to identify stations with high transfer capabilities forming a network which provides data for low latency EOP results before the complete network is processed and analyzed for less stringent requirements like TRF or CRF results.

Practical Uses of VGOSDB format

John Gipson, NASA GSFC/NVI Inc.

I discuss how the vgosDB format makes it possible to easily answer questions which are difficult or impossible using Mark3DB or NGS. Examples include: What are the effects of not-applying cable-calibration at some station? Why do two Mark3 databases produced by different institutions give different answers? What causes the apparent differences we see between multi-tone and single-tone processing of the same database? All of these examples highlight the flexibility and use of the vgosDB format.

Scheduling VLBI observations to satellites with the Vienna VLBI Software (VieVS)

Andreas Hellerschmied (1), Johannes Böhm (1), Rüdiger Haas (2), Jan Kodet (3), Alexander Neidhardt (3), Lucia Plank (4); (1) Technische Universität Wien, (2) Chalmers University of Technology, Onsala Space Observatory, (3) Technische Universität München, Geodetic Observatory Wettzell, (4) University of Tasmania

The observation of satellites with the VLBI technique is an interesting approach, providing a variety of new possibilities. Promising applications can be found, among others, in the field of inter-technique frame ties. Although several test observations to GNSS satellites have been carried out in recent years, this approach is still far away from being applied routinely. Difficulties already start during observation planning, with the standard scheduling software not being prepared to include satellites as observation targets. The new satellite scheduling module of the Vienna VLBI Software (VieVS) for the planning of satellite observations with VLBI antennas offers a solution to this. It allows the user to prepare schedules for selected satellites, which are simultaneously visible from a chosen station network. The schedule files are created in the current VEX format and provide the possibility to conduct actual satellite observations with standard VLBI antennas, e.g. those of the IVS network. By applying these schedules the antennas can be controlled directly by using sequences of discrete celestial coordinates. Specific modifications in the antenna control intended for satellite tracking are not required in this case. Several experiments with observations to GLONASS satellites were carried out on the baseline Onsala Wettzell in January 2014 based on schedules generated with VieVS. The correlations of the recorded data showed, that the observations and therefore the scheduling with VieVS were successful. The next step is to extend the new software to enable the creation of combined schedules with observations to satellites and to quasars in one session. The development of convenient scheduling software in the form of the new VieVS module is important to promote further research and development in this field of VLBI.

GLONASS-VLBI: Onsala-Wettzell test observations

Rüdiger Haas (1), Thomas Hobiger (1), Andreas Hellerschmied (2), Alexander Neidhardt (3), Jan Kodet (3); (1) Chalmers University of Technology, Earth and Space Sciences, Space Geodesy and Geodynamics, Onsala, Sweden, (2) Vienna University of Technology, Institute of Geodesy and Geophysics, Vienna (Austria), (3) Technical University Munich, Geodetic Observatory Wettzell (Germany)

During the last years several experimental Very Long Baseline Interferometry (VLBI) sessions have been conducted to observe Global Navigation Satellite System (GNSS) signals with VLBI. Since GNSS satellites usually transmit signals in L-band, radio telescopes with corresponding receiving equipment are necessary to do these observations. Most telescopes involved in the astronomical European VLBI Network (EVN) have L-band capability, but usually telescopes contributing to geodetic observations within the International VLBI Service for Geodesy and Astrometry (IVS) do not. Therefore, special equipment was developed at Wettzell to allow L-band observations via the existing Wettzell S-band receiving system (Kodet et al., 2013). This new equipment was tested in early 2013 during an experiment together with the 25 m telescope at Onsala. One GLONASS satellite was observed on the baseline Onsala-Wettzell for about 1 hour on January 28, 2013. The observed data were correlated at Onsala with the DiFX correlator (Deller et al., 2007) that is widely used in the geodetic VLBI community and fringes were successfully found (Haas et al., 2014). The RMS-scatter of the derived group and phase delays were 1.4 ns and 8.8 ps, respectively, for integration times of 30 s (Haas et al., 2014). In 2013/2014 a satellite scheduling module was written for the Vienna VLBI Software (VieVS) (Hellerschmied et al., 2014). Using this scheduling software, several GLONASS-VLBI tests were planned for the baseline Onsala-Wettzell, this time with observations of several GLONASS satellites. The observations were performed in early 2014 and several hours of data were recorded. The data were correlated at Onsala with DiFX and fringes were successfully found. In this presentation we give an overview on the 2014 test observations, the data correlation, and preliminary results.

Software Development for D-VLBI Scheduling and Analysis of Spacecraft Observations

James M. Anderson (1), Li Liu (1), Robert Heinkelmann (1), Harald Schuh (2,1), Kyriakos Balidakis (1), Susanne Glaser (2), Maria Karbon (1), Cuixian Lu (1), Julián Andrés Mora-Diaz (1), Tobias Nilsson (1), Virginia Raposo-Pulido (1), and Benedikt Soja (1); (1) Deutsches GeoForschungsZentrum GFZ, (2) Technische Universität Berlin

We aim to demonstrate the potential of differential-VLBI (D-VLBI, known as phase referencing in the astronomical community) for the establishment of frame ties to spacecraft and Solar System dynamical reference frames with the international terrestrial reference frame (ITRF) and the international celestial reference frame (ICRF). By largely canceling common instrumental, atmospheric, and delay model error sources, D-VLBI observations enable precise relative astrometric measurements of space probe positions and velocities. As part of projects at the GFZ to assess the current capabilities of D-VLBI for making frame ties between dynamical systems and the ICRF, we are developing software to aid in the scheduling and analysis of D-VLBI observations of spacecraft. In contrast to astronomical phase referencing observations where the target and calibrator sources have fixed positions common to all telescopes, observations of nearby spacecraft, including GNSS, low Earth orbit (LEO), Lunar, and Lagrangian point (such as Gaia) spacecraft, must deal with rapid angular motion of the spacecraft and geocentric parallax effects. Thus, different telescopes often require different calibrator targets, the target to calibrator separation changes with time and telescope, and multiple calibrator targets are required as the target moves across the sky. We present an overview of the challenges faced by D-VLBI for nearby space missions and the status of our software developments to aid in calibrator source selection, the design of the scheduling sequence for D-VLBI observations of nearby spacecraft, and the calibration of the resulting observations for multiple calibrator and target geometries.

GNSS zenith delays and gradients in the analysis of VLBI Intensive sessions

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Very Long Baseline Interferometry (VLBI) is the only space geodetic technique which is sensitive to Universal Time (UT1). VLBI Intensive sessions of the International VLBI Service for Geodesy and Astrometry (IVS) are observed for the rapid production of UT1. However, the accuracy achieved with those sessions is still below what could be expected from formal uncertainties of the estimates and one of the reasons is the inappropriate modeling of azimuthal asymmetries of the troposphere delays, because usually no gradients are modeled or estimated. To overcome that deficiency, we introduced troposphere zenith delays and horizontal total gradients estimated from the observations of Global Navigation Satellite Systems (GNSS) i.e. the solutions of the Center for Orbit Determination in Europe (CODE) and the International GNSS Service (IGS) in the analysis of VLBI Intensive sessions carried out in 2013. We compared our results with the length of day (LOD) estimates of a CODE solution of GNSS observations. We get the best agreement of LOD in standard deviation of differences between the solution with zenith wet delays and gradients from CODE and LOD from CODE for XK Intensive sessions. The improvement of agreement compared to the standard IVS solution is largest for XK sessions with gradients from IGS and CODE and for XU sessions with gradients from IGS. The improvement is as large as 6 microseconds. We do not see any additional significant improvement of LOD agreement when external zenith wet delays are introduced.

Observing GNSS L-band signals: ionospheric corrections by co-located GNSS measurements

Benjamin Männel and Markus Rothacher (ETH Zurich)

As an alternative and complement to ground-based co-location of the space geodetic techniques, the use of co-location in space is gaining more and more interest. As a result of dedicated hardware developments in the last years it became possible for a few VLBI telescopes to track the GLONASS L1 signal. This opens up the possibility to analyze observations of GLONASS satellites simultaneously tracked by VLBI, GNSS and SLR at co-located fundamental sites. Also comparisons between single-technique solutions and combined estimations of common parameters are feasible. We will present a method, named L4R approach, to correct the ionospheric delay for a single-frequency VLBI satellite observation using the co-located GNSS phase measurement to the same satellite. We will discuss our method in detail concerning network effects (baseline lengths), different GNSS (GPS and GLONASS) and the possibility to resolve the GNSS phase ambiguities. For validation purposes we tested our method by using GNSS and VLBI data from 2013. In a first step we applied the GNSS-based ionospheric delay corrections to an L1 GNSS processing and compared the residuals and station coordinate repeatibilities against a dual-frequency solution. In a second step we compared ionospheric delay corrections derived by VLBI observations (R1 and R4 sessions) against our GNSS-based ionospheric delay corrections. Based on the insights obtained from these studies we will highlight the potential applications and limits of the L4R approach.

VLBI-like GNSS delays in the analysis of CONT11

Younghee Kwak, Vienna University of Technology; Johannes Böhm, Vienna University of Technology; Thomas Hobiger, Chalmers University of Technology; Lucia Plank, University of Tasmania

During CONT11, VLBI and GNSS antennas were connected to the identical clocks at seven sites, which means that clock parameters can be also regarded as common parameters at those sites besides troposphere parameters. We build VLBI-like GNSS delays between the ranges from two stations to a satellite by using post-processed range measurements from a precise point positioning (PPP) GPS solution with the c5++ software and analyze those delays together with VLBI observations with the Vienna VLBI Software (VieVS). We estimate station coordinates, Earth orientation parameters and common parameters at the sites, i.e. zenith wet delays and clocks. We compare the combined solutions with single technique solutions and discuss the impact of the combination at the observation level with respect to those parameters.

Influence of the horizontal resolution of numerical weather models on ray-traced delays for VLBI analysis

Armin Hofmeister, Daniel Landskron, and Johannes Böhm (Technische Universität Wien)

Ray-traced delays offer the opportunity of an alternative way to correct the influences of the troposphere on observations of space geodetic applications such as Very Long Baseline Interferometry (VLBI). Compared to the standard approach, where the slant delays for the tropospheric correction are determined via estimated zenith delays and the application of mapping functions, the ray-tracing approach estimates the slant delays directly for the actual ray paths of the observations. In order to determine the actual ray paths and the slant delays of the observations, the ray-tracing method requires information about the troposphere in terms of refractivity values. These can be derived from meteorological data provided by a numerical weather model (NWM). Because the NWM builds the data base for ray-tracing, the selection of an appropriate NWM is of major concern. In this respect also the chosen horizontal resolution of the NWM may have significant impact on the resulting ray-traced slant delays. This aspect shall be investigated. In order to assess the effect of the horizontal resolution of the NWM on the ray-traced delays, we use our new ray-tracing program RADIATE to determine the delays. As meteorological data input we utilize a NWM from the European Centre for Medium-Range Weather Forecasts (ECMWF) with different horizontal resolutions, e.g. 0.125 deg x 0.125 deg and 1 deg x 1 deg. As observational data input we use the CONT11 campaign of the International VLBI Service for Geodesy and Astrometry (IVS) covering 15 days of continuous VLBI observations. In the first step we compare the estimated ray-traced delays derived from the same NWM with different horizontal resolutions in order to see the direct effect on them. In the next step we investigate the impact of the different horizontal resolutions of the NWM on the VLBI analysis. Therefore we apply the ray-traced slant delays in VLBI analysis to assess the effect in terms of baseline length repeatability.

Augmenting the stochastic model in VLBI data analysis by correlations from atmospheric turbulence models

Sebastian Halsig, Thomas Artz, Andreas Iddink, and Axel Nothnagel (IGG, University of Bonn)

Dynamic processes in the neutral atmosphere contribute considerably to the VLBI error budget. In particular, micro-scale fluctuations in refractivity lead to elevation-dependent uncertainties and induce physical correlations between the observations. However, up to now such physical correlations are disregarded in the stochastic model of geodetic VLBI data analysis. In fact, in operational data analysis of the IVS only the uncertainties from the VLBI correlation process are used. Thus, the formal errors of e.g., station coordinates or Earth orientation parameters, are too optimistic. In this study, the standard stochastic model is augmented by correlations induced by atmospheric turbulence. Thus, dependencies of the observations in time and space are introduced. To model atmospheric turbulences, we follow the principles of the widely accepted Kolmogorov turbulence theory. For this purpose, several atmospheric turbulence models were adapted and modified for geodetic VLBI data analysis, which differ primarily in the parametrization and combination of spatial and temporal correlations as well as the parametrization of the wind direction and its magnitude. The different approaches are applied to the continuous VLBI campaign 2014 (CONT14) in order to validate the new stochastic model and to investigate the performance of the different approaches.

Atmospheric refractivity gradients from VLBI compared to those from GNSS, DORIS, WVR, and NWM

Robert Heinkelmann, Galina Dick, Tobias Nilsson, Benedikt Soja, Florian Zus, Jens Wickert, and Harald Schuh

There is a long tradition of incorporating geodetic atmospheric parameters into meteorological and climatological models. A prominent example is the operational assimilation of GNSS based zenith delays into numerical weather models (NWM) to improve global and regional weather forecasts. GFZ is one of the leading institutions in atmosphere sounding using GNSS and has been contributing since more than 15 years within various meteorological and geodetic research projects to these developments. GFZ is also in charge of the IVS (International VLBI Service for Geodesy and Astrometry) troposphere products that currently include total and wet zenith delays. These are used for routine comparisons, e.g., by the IGS (IGS Troposphere Working Group) and by EUREF. Within the EU COST Action GNSS4SWEC (GNSS for monitoring Severe Weather Events and Climate) one focus lies on the provision of atmospheric refractivity gradients to add information on the horizontal distribution of the atmospheric parameters compared to the zenith delays. Data from the CONT14 campaign were used as a test case for the comparison of atmospheric gradients and their corresponding formal errors obtained by VLBI with the following techniques: GNSS, DORIS, water vapor radiometer (WVR), and three different solutions obtained from the weather models NCEP and ECMWF. We summarize initial results of our investigations to determine VLBI based atmospheric gradients and to provide estimations on their precision. Our investigations demonstrate that the VLBI technique shows great potential for obtaining accurate atmospheric gradients. In particular, w.r.t. the upcoming VGOS (VLBI Global Observing System) we expect to deliver atmospheric gradients from VLBI with very good accuracy and high temporal resolution.

Subdaily station motions from Kalman filtering VLBI data

Benedikt Soja (1), Maria Karbon (1), Tobias Nilsson (1), Kyriakos Balidakis (1), Susanne Glaser (2), Li Liu (1), Zhiguo Deng (1), Robert Heinkelmann (1), Harald Schuh (1); (1) GFZ German Research Centre for Geosciences, (2) Technische Universit¨at Berlin

Station coordinates are one of the most important parameters in geodetic VLBI analysis as they are necessary for global terrestrial reference system realization. It is common that the coordinates are estimated as a constant offset per session. However, subdaily changes in position occur, most notably due to tides and loading effects. While the majority of the geophysical signals can be removed by applying state-of-the-art models, some seem to remain due to deficiencies of the models. We have used the Kalman filter in the GFZ version of the Vienna VLBI Software (VieVS@GFZ) to estimate subdaily station coordinate time series. The state in the Kalman filter is updated for every VLBI observation, resulting in a temporal resolution of just a few minutes. Several models for tidal and non-tidal ocean and atmosphere loading, and combinations thereof have been applied to investigate the extent of the subdaily motion reduction. The residual coordinate variations may be due to shortcomings of the geophysical models, correlations of the station coordinates with other parameters, and other unmodeled effects. In order to test whether some part of the motions are specific to the VLBI technique, the coordinates have been compared to ones from a geophysically consistent GNSS solution derived at GFZ. Finally, empirical models of the subdaily motions of various stations, e.g. containing diurnal and semidiurnal signals, have been estimated based on the coordinate time series derived from Kalman filtering. Tests regarding the significance of the model parameters and the impact on coordinate and baseline length repeatabilities have been performed as well.

Antenna axis offsets estimated in VLBI data analysis

Tobias Nilsson,Maria Karbon, Julián Mora-Diaz, Virginia Raposo-Pulido, Benedikt Soja, Robert Heinkelmann, and Harald Schuh (GFZ German Research Centre for Geosciences)

The reference point of a VLBI antenna is defined as the intersection of the two axes of rotation. However, for many VLBI telescopes these two axes do not intersect, but have an offset relative to each other. These axis offsets amount to several meters for some telescopes. Since the axis offsets affect the derived results they have to be corrected in the VLBI data analysis. There are two ways of obtaining the axis offset: either by measuring it in a local survey or estimating it in a VLBI global solution. In this work we investigate with which precision the axis offsets can be obtained from the VLBI data analysis. This is done by estimating axis offsets in global solutions and comparing them with the results of local surveys. We also study the impact of several analysis options, like the modeling of the atmospheric delays and loading effects, on the axis offset estimates. In addition, we investigate how well changes in the axis offsets, caused by e.g. antenna repairs, can be detected.

Numerical issues of VLBI data analysis

Thomas Artz, Sebastian Halsig, Andreas Iddink, and Axel Nothnagel (University of Bonn)

In recent years, the VLBI Global Observing System (VGOS) has been developed. The advent of VGOS, will lead to increasing observational precisions and new opportunities for the determination of geophysical or technical process parameters. However, numerical issues of data analysis also play an important role for the quality of the derived parameters. Thus, conditioning as well as stability of the solution have to be investigated. While conditioning refers to numerical problems and it has no connection to the solution strategy, numerical stability refers to the algorithms which are used. Thus, a numerically stable algorithm does not amplify the errors of the observations. In this paper, a linearized least squares adjustment on the basis of a Gauss-Markov-Model is used to estimate the VLBI parameters. It is essential to note that the involved matrices are not only affected by the design of the measurement process, but also by the characteristics of the functional description and, thus, even more by the numerical characteristics of the equation system. For VLBI, the equation system of the least squares adjustment is typically ill-conditioned. Thus, errors of the observations are amplified during the adjustment process. This paper focuses on the impact of numerical conditioning. We present methods to reveal the relationship between numerical characteristics of the normal equation matrix and parameter types as well as network properties and the presence of data gaps. Furthermore, we show the impact of the algorithm which is used to solve the equation system on the estimated parameters.

Sophistication in UT1-Intensive Scheduling by Using Impact Factors - First Results of Field Tests

Axel Nothnagel, Judith Leek, and Thomas Artz (IGG University of Bonn)

Scheduling of geodetic VLBI observations can be done with different optimization targets. At IGG, we have developed a method using impact factors. It sequentially selects those observations which achieve the biggest influence at that instance on the parameters to be estimated. Test computations have shown that using the impact on all parameters is superior to looking only at the target parameter UT1-UTC. A good test bed for validating the approach are UT1 Intensive sessions with their limited number of observations where the failure of a single high-leverage observation may have a large adverse effect on the UT1 result. Starting in late 2014 a number of INT2 sessions between Tsukuba and Wettzell were observed with these schedules. We present the results of these sessions and discuss their characteristics.

The CONT campaigns as a precursor to VGOS observing

Daniel MacMillan; NVI, Inc. at Goddard Space Flight Center

The IVS continuous (CONT) VLBI campaigns have been designed to demonstrate the highest accuracy that geodetic VLBI is capable over two-week periods of continuous observing. Scale and EOP obtained from the CONT sessions are significantly better than from the operational R1 and R4 sessions. In addition, the performance of the CONT campaigns has improved since CONT02 (October 2002). Both the wrms agreement in polar motion compared to IGS finals and the wrms of scale over the respective two-week CONT periods have improved by factors of 2-3 in CONT14 (May 2014) compared with CONT02. We investigate the factors that contribute to the superior performance of the CONTs: larger station networks, use of an identical network of stations over the observing period, and better station performance. We perform simulations to compare the performance of the most recent CONT networks with future VGOS observing, where a large global network of 20-30 stations observes continuously.

CONT14 as a testbed for the combination of VLBI and GPS data on the observation level

Thomas Hobiger and Rüdiger Haas (Chalmers University of Technology, Onsala Space Observatory)

Co-located instruments at space geodetic observatories allow us to take benefit from sharing infrastructure at the site and make it possible to combine solutions from different techniques. Local ties relate between the reference points of the individual space geodetic techniques, but one can also take advantage from the close proximity of instruments and estimate troposphere parameters in site-wise models rather than parameterizing these unknowns for each technique separately. In order to realize such an approach, a suitable model for the nuisance parameters as well as proper weighting of the observations from the individual techniques are necessary. These aspects and the application of such an analysis strategy to VLBI and GPS data are being studied with the multi-technique space geodetic analysis software c5++. In doing so, variance component estimation (VCE) helps us to give proper weights to the observations from the individual techniques. In order to demonstrate the effectiveness of the concept of combination on the observation level, we are evaluating and comparing single- and multi-technique solutions from CONT14. Based on the experience gained from this exercise, we will suggest potential improvements for coming CONT sessions and discuss the necessary steps for rigorous combination on the observation level in general.

Earth Orientation Parameters for VLBA Calibrator Survey Sessions

D. Mayer, H. Krasna, and J. Böhm (Technische Universität Wien)

About two thirds of the sources in the ICRF-2 catalogue are estimated from VLBA Calibrator Survey (VCS) sessions. These sessions were carried out from 1994 to 2007 by a network of ten radio telescopes in North America with the densification of the celestial reference frame as the primary goal. A total of twenty-four VCS sessions, each with duration of 24 h, were observed in six campaigns. Coordinates estimated from these sessions have up to five times worse precision when compared to non-VCS sources from the ICRF catalogue, which is to a great extent due to the limited number of observations. In the analysis of VCS sessions Earth Orientation Parameters (EOP) were estimated alongside source coordinates and other parameters. This, however, is not ideal, since the network is regional (only North American telescopes) and, therefore, not suitable for EOP estimation. We examine the effect of EOP estimation on source coordinates from VCS sessions. This is done by comparing solutions with EOP estimated in the analysis with solutions where EOP are fixed to IERS C0408 combined series. Furthermore, we recommend strategies on how to reduce the effect of EOP uncertainties on the source estimates.

Revisiting the VLBA Calibrator Surveys, VCS-II

David Gordon; NVI Inc/NASA GSFC. VCS-II Team.

ICRF2 had 2 classes of sources. The first class was composed of sources observed in regular Mark3/Mark4/RDV VLBI geodesy and astrometry sessions over nearly 30 years. The second class was mostly composed of weaker sources observed in only one or a few specialized VLBA sessions called the “VLBA Calibrator Surveys” (VCS), whose primary purpose was to vastly increase the pool of calibrator sources available for phase-referencing VLBI. The VCS sources composed 2/3 of the ICRF2 sources, but they had formal errors approximately 5 times greater, on average, than the other 1/3. In order to reduce this 2 class distinction, the VCS-II team was formed to re-observe these sources for ICRF3 and to improve their usefulness as phase-referencing calibrators. We report here on the re-observations of 2100 of these sources in 7 VLBA sessions in 2014 and 2015. The new observations were made at 2 GBits/sec versus 128 MBits/sec for the original VCS sessions, and thus are considerably more sensitive. Some 1813 “old” VCS sources have been re-observed with formal errors improving by an average factor of 3.6 in RA and Dec. And 274 “new” sources (not detected in the original VCS analysis) have now also been detected. Mapping of these sources is also being performed and we anticipate being able to compute structure indices for them as well.

ICRF-3: Status, Plans, and Multi-wavelength Progress towards the next generation ICRF

Christopher Jacobs, JPL ICRF-3 working group

The ICRF-3: Status, Plans, and Progress on the next generation Celestial Reference Frame. C.S. Jacobs, JPL and the ICRF-3 working group ICRF-3 seeks to improve the highly successful ICRF-2. Our goals are to improve the precision, spatial and frequency coverage relative to the ICRF-2 by 2018. This date is driven by the desire to create radio frames that are ready for comparison with the Gaia optical frame. Several specific actions are underway. S/X-band re-observation of 2200 VLBA Calibrator Survey sources is reducing the factor of 5 deficit in precision compared to the rest of the ICRF-2. S/X-band southern precision improvements are underway with observations using southern antennas such as the AuScope and HartRAO. We also seek to improve radio frequency coverage with X/Ka and K-band work. An X/Ka frame of 660 sources now has full sky coverage and improved southern accuracy both aided by an Argentinian station. A K-band team has data over the south polar cap to complete full sky coverage and VLBA observations are approved to increase the number of sources to over 500. On the analysis front, combination techniques are being researched both of VLBI frames and of multiple data types. Consistency of the CRF with the TRF and EOP is another area of concern. Comparison of various celestial frame solutions is underway in order to identify and correct systematic errors. Most notable is a 100 as zonal shift between ICRF2 and ICRF3 candidates in the south from declination 0 to -30 degrees. Finally, work is underway to identify and pinpoint sources bright enough in both radio and optical to allow for a robust frame tie between VLBI and Gaia optical frames.

Assessment of CRF Solutions from Session-wise Normal Equation Systems

Andreas Iddink, Thomas Artz, Sebastian Halsig, and Axel Nothnagel (IGG University of Bonn)

The International Celestial Reference Frame (ICRF) is one of the fundamental products of the International VLBI Service for Geodesy and Astrometry (IVS). Until now, two realizations were computed and the next one is under construction. Today, some of the IVS Analysis Centers routinely produce solutions as session-wise normal equation systems also including radio source positions. For this reason, a rigorous combination using datum-free normal equation systems is also feasible for the ICRF. At the same time, the methodology permits the combination of single session X/S-band analysis results with that of Ka/X- band to provide an enhanced frequency coverage. However, various peculiarities have to be considered for the final CRF determination. In this presentation, we analyze various combined CRF catalogs from input of different analysis centers solely based on the official SINEX files submitted to the IVS. The combination process differs by the considered time spans as well as by the included session types and network geometries. The individual catalogs are compared and validated among themselves as well as to the ICRF2 by means of Helmert transformations. The quality is also assessed by looking at the resulting time series of Earth orientation parameters. In this context, the impact of the additional data, which became available after the ICRF2 was published, is examined and discussed as well.

Studying impacts of strategy choices concerning the Celestial Reference Frame on the estimates of nutation time series during geodesic VLBI Analysis

César Gattano, Sébastien Lambert, and Christian Bizouard (Observatoire de Paris, SYRTE)

Very Large Baseline Interferometry (VLBI) is the only technique which permits to determine Earth’s precession-nutation at submilliarcsecond accuracy. With its 35 years of observations, at the rate of 2 observing sessions a week during the last decade, it allows to estimate nutation over periods from 14 days to 20 years. But VLBI data analysis is of such a complexity that there are as much different nutation time series that there are analysis center working on it. So, it is worthful to investigate the nature of these differences in relation with the choices in the analysis strategy. Differences between the operational nutation time series are considered as composed of a signal and a noise, determined by mean of wavelets and Allan variance analysis. We try to explain them by the choices made on the Celestial Reference Frame. In particular, the ICRF2 catalog is perturbed by introducing random shifts on all the 3414 sources, and we investigate the consequences on nutation.

Reducing the impact of source structure on the celestial frame: modeling or mitigation strategies?

Patrick Charlot and Arnaud Collioud (Laboratoire d'Astrophysique de Bordeaux)

As the accuracy of VLBI observations increases, source structure is expected to become an ever-growing limitation in further improving the quality of the celestial reference frame. Very few sources are found to be fully point-like on VLBI scales, requiring modeling or mitigation strategies to reduce the effects caused by such structures. Incorporating structure modeling in the astrometric and geodetic VLBI data analysis requires availability of VLBI images on a recurrent basis since the source morphology often varies with time. Additionally, one should have the ability to properly align these images over time and frequency since these have no absolute sky coordinates due to the self-calibration procedure used to produce such images. Alternately, one may develop mitigation strategies to reduce the effects of such structures in the determination of the celestial frame. A possibility is to use the so-called structure indices, now available for more than 1000 sources from the Bordeaux VLBI Image Database (BVID), as a filter for scheduling only the most suitable sources at a given epoch. Such a filter is also worthwhile to properly select defining sources when a new realization of the celestial frame is built. This paper reviews all source structure material available to deal with the issue as best as we can in the framework of the upcoming ICRF3 realization.

On the estimation of a celestial reference frame in the presence of source structure

Lucia Plank (1), Stas Shabala (1), Jamie McCallum (1), Hana Krásná (2), Liza Rastorgueva-Foi (1), Bill Petrachenko (3); (1) University of Tasmania, (2) Technische Universität Wien, (3) Natural Resources Canada

The presence of source structure has long been identified as a non-zero contribution to the group delay measured by VLBI. It has also been shown that the positions of sources with high structure show larger variability or even systematic apparent motion. Using simulations of the IVS rapid session schedules, we investigate the effects of simple two-component sources on globally estimated source positions. We find that sources with nominal structure indices 2, 3, and 4 can all cause systematic displacements of source positions at the level of tens to hundreds of microarcseconds, clearly above todays level of source position uncertainties. In a thorough simulation study we compare multiple source models with only slightly changed parameters, namely the relative brightness of the two components and their separation. We then investigate the characteristics of the effects, i.e. that the source position is apparently moved along the jet axis of the source, which is the line between the two components of the source model. Finally we present an idea how to account for this dislocation in the analysis when estimating a celestial reference frame.

Imaging the IYA09 VLBI super-session

Arnaud Collioud and Patrick Charlot (Laboratoire d'Astrophysique de Bordeaux)

In the framework of the International Year of Astronomy (IYA2009), the IVS organized a dedicated 24-hour astrometric VLBI session with a large network of radio telescopes in order to observe as many of the 295 ICRF2 defining sources as possible. This "super-session" took place on the 18th of November 2009. In all, 35 radio telescopes observed 243 sources, which made the IYA09 session the largest VLBI session ever conducted. Although the session was primary targeted to astrometry, the observations are also useful to produce VLBI images of the sources due to the large network of telescopes that participated. In this paper, we present results of such imaging, including details about the data path and procedures. Overall, 228 sources were successfully imaged at X-band and 230 at S-band, corresponding to more than 90% of the scheduled sources. Taking an additional step, we derived structure indices from the resulting IYA09 images in order to assess the astrometric suitability of the sources. By studying the distribution of the structure indices, we discuss the relevance of the "ICRF2-defining" status for these sources.

Aligning VLBI and Gaia Extragalactic Celestial Reference Frames

Géraldine Bourda, Patrick Charlot, and Arnaud Collioud (Laboratoire d'Astrophysique de Bordeaux)

By 2020, two extragalactic celestial reference frames will coexist: the VLBI frame currently adopted by the IAU as the fundamental one and the Gaia frame determined from direct optical observations of quasars by this satellite. Aligning them with the highest accuracy will be important for consistency between optical and radio positions of any celestial targets. In this paper, we will discuss the selection of the VLBI-Gaia transfer sources, present the various initiatives to reach this goal, review the status of the projects and draw plans for the future.

Estimating the velocity of the Solar barycenter from VLBI observations

Minghui Xu (1,2), James M. Anderson (2), Robert Heinkelmann (2), Harald Schuh (2), Guangli Wang (1); (1) Shanghai Astronomical Observatory, (2) GeoForschungsZentrum GFZ

The property of time independence of the International Celestial Reference Frame (ICRF) requires a careful contemplation especially for the aim of establishing and using the ICRF at the microarcseconds level. The proper motion of radio source, which has been ignored in geodetic VLBI, is actually caused by the relative motion of the observed object and the observer. The motion field of radio sources with respect to the Cosmic Microwave Background (CMB) may be regarded as random over the sky, but the motion of the barycenter with respect to the CMB is identical for all the observed objects. Therefore, proper motions caused by the motion of barycenter should be systematic variations. Based on the current value of this motion from astrophysical research, around 400 km/s, the magnitude of this systematical variation would be 1 microarcsecond per year for a radio source with redshift of 0.02. We investigate the possibility to estimate the velocity of the Solar barycenter by simulation using the ICRF2 catalog with redshifts, a priori values for the velocity and the acceleration of the Solar barycenter, and a random motion field of radio sources. We present the result of the estimation of the Solar velocity from VLBI data, and investigate the determination of the velocity from the Gaia data.

The CVN Geodetic Observation and its Result

Guangli Wang, Fengchun Shu, Minghui Xu, Zhibin Zhang, Shuangjing Xu (Shanghai Astronomical Observatory)

The China VLBI Network, CVN, has been developed to consist of five antennas, Seshan 25m, Urumq 25m, Kunming 30m, Miyun 50m and Tianma 65m. Since the year of 2006, more than 20 geodetic domestic observations have been carried out. In this report the observation and data result will be presented.

Preliminary results of pulsar astrometry with CVN

Wu Jiang, Zhiqiang Shen, Fengchun Shu, Zhen Yan, and Li Guo (Shanghai Astronomical Observatory)

We will report a set of phase-referencing observations of pulsars with Chinese VLBI network (CVN). The stations located at Shanghai, Kunming and Urumqi took part in these observations. A DiFX correlator installed at Shanghai was used to perform the correlation with the pulsar gating technique. The preliminary results of a multi epoch positioning on millisecond pulsar B1937+21 and an S/X dual frequency band trial on B0329+54 will be presented in details.

POSTER CONTRIBUTIONS

QRFH Wideband Cryogenic Receivers

Remi Rayet, Steve Rawson, and Thomas Bonhoure(Callisto)

Callisto has over 20 years' experience producing cryogenic Low Noise Amplifiers for satellite ground stations. Callisto has produced more than 50 cryogenic receivers for worldwide renowned customers such as the European Space Agency (ESA), the Indian Space Agency (ISRO), the French Space Agency (CNES), the BKG (Wettzell Observatory) and several other institutional or private operators. Callisto has two wideband cryogenic receivers optimized for VLBI applications and using the Caltech designed QRFH feed: the "Compact" QRFH cryogenic receiver and the "Ultra" QRFH cryogenic receiver. Both versions feature state-of-the-art cryogenic technologies with different aims: uninterrupted operation with no service required for the compact version, and simplified cryocooler service for the ultra version.

Ultra Wide-Band HTS filter for new geodetic VLBI front-ends

Alina Caddemi, D.I.C.I.E.A.M.A. Dept., University of Messina, Italy; Emanuele Cardillo, D.I.C.I.E.A.M.A. Dept., University of Messina, Italy; Gino Tuccari, Italian National Astrophysical Institute Radio Astronomy Institute, Italy; and Max Planck Institute für Radioastronomie, Bonn, Germany

Nowadays for geodetic VLBI a very large bandwidth extending from S-band to low Ku-band is exploited for several reasons. Among those, it provides options for selecting RF observation channels free of interference. This critical task must be accomplished by the feed system and a key component thereof is the bandpass filter placed ahead of the LNA since it must outperform according to the following issues: a) Extremely large bandpass from 2 to 14 GHz, b) In-band very low-losses, c) Capability of implementing high rejection sub-bands (notches) to eliminate interfering signals. In the scientific literature of the last decade, different approaches have been proposed for the design and realization of high performance ultra wide band (UWB) planar filters for telecommunication application in the unlicensed FCC 3.1-10.6 GHz radio communication range. In our case, the fractional band is even more demanding since it reaches the top value of 150% which is not commonly found in advanced electronics. We here present the design procedure for such UWB filter for modern geodetic VLBI based on flexible approach which allows for including an in-band notch at a given frequency.

The new release of e-RemoteCtrl

Alexander Neidhardt, FESG; Jim Lovell, UTAS; Jamie McCallum, UTAS; Ed Himwich, NASA/NVI

A new release of the telescope control software e-RemoteCtrl, which is designed to run VLBI observations remotely, has been realized during a development and research stay at the University of Tasmania. The software was released early this year and includes new features, bug fixes and optimizations as a result of feedback from the AuScope operators, from tests at Hartebeesthoek, and from user experience at Wettzell. The poster describes the new features and gives additional information about the software.

The German Antarctic Receiving Station O"Higgins - upgrades of the VLBI-capabilities for future challenges

Christian Plötz, BKG; Alexander Neidhardt, FESG; Thomas Klügel, BKG; Torben Schüler, BKG; colleagues from the DLR

The German Antarctic Receiving Station (GARS) O'Higgins started in the early 1990th with regular VLBI operations. Because of its remote position on the Antarctic Peninsula, the VLBI observation was mostly restricted to the Antarctic summer month. New equipment, a continuous operation by the German Aerospace Center (DLR), and new realizations of observation schedules may open the door for regular observations over the whole year. The poster shows the upgrades carried out in hard- and software and discusses ideas to realize more regular observations in a planned test phase.

Hb-Ho: observations with the sibling telescopes in Hobart

Lucia Plank, University of Tasmania; Jamie McCallum, University of Tasmania; Jim Lovell, University of Tasmania; David Mayer, Technische Universität Wien; Johannes Böhm, Technische Universität Wien

With the transition to VGOS, co-located radio telescopes will be common at many sites. This can be as a sibling telescope, when a VGOS antenna is built next to a legacy one or as the concept of a twin telescope, with two identical VGOS antennas. Besides a number of new observing possibilities in a network, such a configuration also allows the investigation of local effects or antenna-specific systematics. This is for example the measurement of the local baseline with VLBI and the subsequent comparison with the local tie as determined with classical surveying. The comparison of redundant observations to other antennas can be used as independent verification and identify systematic delays specific to each antenna. Lastly, co-location offers new possibilities in analysis, by combining common parameters like station positions, tropospheric conditions or clock modeling. In 2014, the two telescopes in Hobart, (12m-Hb, 26m-Ho) observed several common sessions. Besides Cont14, we also performed four dedicated twin sessions, some of them also including the antenna pair in Hartebeesthoek (15m-Ht, 26m-Hh). We report on differences we found in redundant observations, compare common parameters, determine the local baseline and its variations, and report on newly applied scheduling and analysis strategies.

The Asia-Oceania VLBI Group for Geodesy and Astrometry

Jim Lovell, University of Tasmania; Rioji Kawabata, Geospatial Information Authority of Japan; Shinobu Kurihara, Geospatial Information Authority of Japan; Fengchun Shu, Shanghai Astronomical Observatory; Jungho Cho, Korea Astronomy and Space Science Institute

The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) is a recently-formed organization of scientists supporting geodetic and astrometric VLBI in the Asia-Oceania region and is a sub-group of the IVS. The purpose of the AOV is to foster and encourage closer collaboration in the science, technology and education aspects of VLBI in the region. There is a focus on the challenges that are particular to the region, which is highly dynamic in geophysics and climate with a large number of destructive earthquakes, tsunamis, typhoons and cyclones. Many countries in Asia-Oceania will experience the effects of climate change much sooner or to a greater degree than other regions, due to more frequent extreme weather events and rising sea levels for example. In order to better understand the risks and reduce the effects of these phenomena, the AOV has an important role to play through measurement of tectonic plate motions, atmospheric variations and determination of the Geodetic Reference Frame for the region. We will present a brief history of the formation of the AOV, describe its aims, outline our initial observing program and plans for the future.

Baseline dependent weights in VieVS

M. Uunila, Aalto University Metsähovi Radio Observatory; J. Gipson, NVI Inc., NASA Goddard Space Flight Center; H. Krásná, Vienna University of Technology

It is well known that in processing VLBI data chi_2 is usually larger than 1, typically in the range of 4-8. This results from either too small measurement errors or of mismodeling the data. By re-weighting the data, by increasing the errors of the observation, we can make chi_2 sim1. In Solves operational solutions baseline dependent weights are always applied. VieVS uses a constant weight, i.e., global weighting. In order to use baseline dependent weights in VieVS we run the least-squares adjustment a second time after calculating the re-weights for each baseline in an observation. Baseline weighting reduces UT1 adjustment significantly. Discrepancy between VieVS and Solve is also reduced.

Contributions of the Onsala Space Observatory to the GGOS

Rüdiger Haas, Gunnar Elgered, Thomas Hobiger, Hans-Georg Scherneck; Chalmers University of Technology, Department of Earth and Space Sciences, Onsala Space Observatory (Sweden)

The Onsala Space Observatory is the fundamental geodetic station of Sweden and operates several geodetic and geophysical infrastructures that contribute to the GGOS. Onsala is the European observatory with the longest history in VLBI. Already 1968 Onsala was involved in VLBI observations. Since 1979 the 20 m telescope is used for VLBI, and currently about 4050 sessions per year are observed in the programs of the IVS. Onsala also participated in all CONT campaigns. In 2011 we received funding for twin telescopes at Onsala, to be part of the VGOS network. A contract to purchase the new telescopes has been signed in late 2014 and we expect that they will become operational in 2016/2017. In parallel to the VLBI activities, the observatory operates other instrumentation for geosciences, in particular receivers for GNSS, and ground-based microwave radiometers. There are several monuments used for GNSS measurements, and Onsala is actively contributing to the IGS. Recently a GNSS array consisting of six new GNSS monuments has been installed. Also several microwave radiometers are operated for tropospheric measurements. A superconducting gravimeter is operated at the observatory since 2009 in a dedicated gravity laboratory which is also hosting visiting absolute gravimeters, and in 2011 a seismometer station has been installed that is part of the Swedish National Seismic Network. Since 2010 we operate a so-called GNSS-R tide gauge. Additional equipment comprises several pressure-sensor based tide gauges, and since the autumn of 2013 a pneumatic tide gauge that is operated together with SHMI. In cooperation with SMHI, a multi-sensor installation, including also a radar-based tide-gauge, has been installed during 2014.

Spacecraft VLBI Phase Referencing Tracking with the Chinese VLBI Network and Deep Space Network

Huan Zhou, DeZhen Xu, HaiTao Li, and GuangLiang Dong (Beijing Institute of Tracking and Telecommunications Technology)

VLBI phase referencing widely used for quasar observation can also be applied to track spacecraft. It can provide a much more accurate angular location of the spacecraft in the plane-of-sky than conventional VLBI tracking methods. However, a large number of antennas are usually required. Our work focuses on the feasibility analysis of spacecraft VLBI phase referencing tracking with the Chinese VLBI Network (CVN) and Deep Space Network (CDSN). The CVN is made up of 5 telescopes located at Beijing, Shanghai, Kunming and Urumqi. The CDSN is still under construction. Two deep space stations, the Kashi 35m and the Jiamusi 66m, just come into service. Another one in Argentina will work two years later. Because at least one of the deep space stations should keep tracking the spacecraft for data transmission and offering ranging and Doppler measurements, only 5 or 6 antennas are now available for VLBI phase referencing observation, which is not enough to determine the spacecraft position without ambiguities during a short interval. To solve this problem, a novel observation scheme is proposed. Simulations using the measurement data from the Cassini Saturn probe and some

preliminary results from the tracking experiments conducted with Chinas first lunar rover are presented, which demonstrates the validity of the new scheme and renders a new high-accuracy application of the worldwide VLBI antennas in future deep space exploration.

Local–tie works in IGN Yebes Observatory

Beatriz Córdoba (IGN-Yebes), Javier López-Ramasco (IGN-Yebes). Susana García-Espada (IGN-RAEGE St María)

An important requirement to convert the RAEGE station in Yebes (Spain) into a Fundamental Geodetic Station is to accurately relate the different geodetic techniques, what is known as the Local Tie. We have investigated the possibility to measure the invariant reference point (IRP) of the 13-m radio telescope. In our case, there is a big advantage since the measurements can be performed inside the telescope cabin with a robotic total station, located on a central pillar built inside the radio telescope tower. The methodology used is based in the adjustment from measurements points on the radio telescope frame of circles in 3D constrictions, taken with a robotic total station, installed on a tripod with an optical plummet placed on the marked centered screw of this central pillar. A network of 24 monuments (concrete pillars) has also been built in the area of Yebes Observatory in order to relate the measurements taken by our two VLBI radio telescopes (40-m and 13-m) and two GNSS antennas (IGS code “YEBE”, on the roof of the office building, and “YEB1”, on the roof of the gravimeter building).

Coordinate Based Bundle Adjustment Advanced Network Adjustment Model for Polar Measurement Systems

Michael Lösler (1), Cornelia Eschelbach (1), and Rüdiger Haas (2); (1) Frankfurt University of Applied Sciences - Laboratory for Industrial Metrology, (2) Chalmers University of Technology, Onsala Space Observatory

To fulfil the requirements on local-ties formulated by GGOS, high precision instruments and rigorous uncertainty propagation are necessary. To evaluate the results of e. g. high performance total stations or laser trackers, the accuracy-limiting parameters of the measurement process have to be quantified and projected onto an uncertainty model. Using the generally and interdisciplinary accepted Guide to the Expression of Uncertainty in Measurement (GUM) a transparent and traceable stochastic model can be derived. A Cartesian coordinate based bundle adjustment is suggested, to integrate the local measurements into a global context, avoiding gravitational influences. The included comprehensive uncertainty model is based on a specific geometric model of a polar measurement system and takes instrument specific and target dependent error parameters into account.

A GPS-based local-tie vector at the Onsala Space Observatory

Tong Ning, Rüdiger Haas, Gunnar Elgered; Chalmers University of Technology, Department of Earth and Space Sciences, Onsala Space Observatory (Sweden)

So-called local-tie vectors at geodetic co-location stations are important pieces of information for the international terrestrial reference frame (ITRF). The Onsala Space Observatory is a co-location station contributing to the ITRF and operates equipment for geodetic Very Long Baseline Interferometry (VLBI) and Global Navigation Satellite System (GNSS) observations since several decades. The local-tie vector between the reference points of the instruments used at Onsala for VLBI and GNSS was previously observed several times by classical geodetic measurement techniques. In the summer of 2013 two gimbal-mounted GNSS-antennas were installed on the radio telescope, one on each side of the telescope dish, and several 24 hour long measurement campaigns were performed. Five semi-kinematic and four kinematic campaigns were conducted during July to September 2013. For the semi-kinematic campaigns, the telescope was pointed to different azimuth and elevation directions, spending up to 30 minutes at one position. The kinematic campaigns were conducted during normal

geodetic VLBI-sessions where the telescope is continuously in motion and either tracking radio sources (slow motion) or slewing to new targets (fast motion). The GPS-data recorded with 1 Hz sampling during these campaigns were analyzed together with data from the ONSA site with a in-house developed software applying the double-difference analysis strategy with ambiguity-resolution. Phase-centre variation corrections were calculated for the rotated GNSS-antennas and applied in the data analysis. The resulting positions of the two GNSS-antennas on the telescope were used to determine its reference point and axis offset. Doing so, the so-called local-tie vector between the reference point of the telescope used for geodetic VLBI and the ONSA GNSS-monument was determined directly in the geocentric GPS-based reference frame. The results from the nine campaigns show standard deviations of 2.1 mm, 0.8 mm and 2.6 mm for the X, Y-, and Z-axis respectively. The disagreement with respect to the coordinate differences calculated from the ITRF2008 coordinates of the reference points at epoch 2013 are 0.8 mm, 0.2 mm and 8.5 mm for the X-, Y- and Z-components. The result for the axis offset has a standard deviation of 2.9 mm and differs by 0.5 mm from the results derived from classical geodetic measurements in 2002 and 2008.

Determining HartRAO antenna reference point and axis offset parameters using VieVS

Marisa Nickola (1), Alet de Witt (1), Hana Krásná (2), Ludwig Combrinck (1), Johannes Böhm (2); (1) HartRAO, (2) TU Wien

The 15-m and 26-m radio telescopes at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) regularly participate in astrometric and geodetic VLBI sessions. The HartRAO 15-m telescope officially joined geodetic VLBI operations in 2013. In 2008 the HartRAO 26-m telescope suffered a critical bearing failure and only returned to operations in 2010 after it was repaired. Post-repair position time series solutions indicated no noticeable shift in the position. In 2014 the antenna axis offset for both the 15-m and 26-m were estimated using the Vienna VLBI Software (VieVS). A large discrepancy was found to exist between previously determined values of the antenna axis offset of the 26-m telescope (from ground surveys as well as from VLBI analysis before the bearing failure) and the VieVS determined values. Possible reasons for this discrepancy are being investigated. Further sessions have been included in the analysis and the VieVS obtained values of the antenna axis offset will also be compared to the local tie survey that was done in 2014. We are also looking at possible seasonal variations in both the antenna axis offset of the telescopes and, for sessions in which both HartRAO telescopes participated, also the baseline length between the two telescopes. A possible displacement of the antennas that may have occurred due to an earthquake in the vicinity of HartRAO during 2014 is also being investigated. We report here on the most recent results from our analysis.

Continuous VLBI Scheduling: The CONT14 Example

Dirk Behrend, NVI, Inc

One of the main goals of the Continuous VLBI Campaign 2014 (CONT14) was to collect VLBI observations over a time period of 15 days without interruptions. In order to achieve this observational continuity some aspects of the standard, session-wise scheduling procedure had to be modified. These modifications mostly pertained to the day boundaries but also to the foreseen station check times of one or two hour lengths. The driving factor was the retention and continuation of the cable wrap across boundaries, which is not taken into account with session-wise schedule writing. Carrying forward the cable wrap information for each station had to be implemented into SKED and the script file controlling SKED, respectively. Further, as CONT14 was still organized as individual days, three-minute gaps were incorporated at the end of each observing day so that each station was able to change schedules before continuing with observing the subsequent day. In this presentation, we will elaborate on some of these continuous scheduling aspects.

Implementation of VGOSDB format

Sergei Bolotin, Karen Baver, John Gipson, David Gordon, and Daniel MacMillan (NVI, Inc./NASA GSFC)

The IVS Working Group 4 developed the new format to store and exchange data obtained from geodetic VLBI observations. The new data format, VgosDb, will replace existing Mk4 databases this year. At the GSFC NASA we work on software that will implement VgosDb format and will be used routinely to convert correlator output to the new data storage format. On this poster we present general characteristics of the software, its current status and our plans for future development.

Current status and future plans for the Vienna VLBI Software (VieVS)

Andreas Hellerschmied, Johannes B”ohm, Sigrid Böhm, Anastasiia Girdiuk, Armin Hofmeister, Hana Krásná, Younghee Kwak, Daniel Landskron, Matthias Madzak, David Mayer, Jamie McCallum (2), Lucia Plank (2), Stas Shabala (2), Jing Sun (3), Caroline Schönberger (1), and Kamil Teke (4); (1) Technische Universität Wien, Austria; (2) University of Tasmania, Hobart, Australia; (3) Shanghai Astronomical Observatory, Shanghai, China; (4) Hacettepe University, Turkey

The Vienna VLBI Software (VieVS) is state-of-the-art VLBI analysis software, developed and maintained since 2008 by the VLBI group at Technische Universität Wien (TU Wien), with important contributions from other groups worldwide. VieVS is designed for the analysis of geodetic VLBI observation data, as well as for scheduling and simulation of various VLBI sessions. The current release (VieVS 2.2) was enhanced with a source structure simulator and provides revised capabilities for scheduling and global long-term solutions. VieVS comes with a graphical user interface and is written in MATLAB, which promotes convenient handling and coding and, hence, simplifies the entry into VLBI analysis for students. Furthermore, we maintain a VieVS-Wiki at vievswiki.geo.tuwien.ac.at. Current developments concentrate on upgrading VieVS for the possibility to use ray-traced delays for all VLBI observations and on refining the source structure simulations. We also work on an advanced treatment of sibling and twin telescopes in VieVS. Furthermore, it is planned to add scheduling functions for VLBI observations to satellites in the next release.

Minimization of the UT1 Formal Error through Minimization Algorithms

John Gipson, NVI, Inc. Karen Baver, NVI, Inc.

The primary purpose of the IVS-INT01 sessions is the estimation of UT1. Improving the accuracy and the precision of the UT1 estimates is an important goal in the scheduling of these sessions. We previously investigated reducing the UT1 formal error through the use of the Sked scheduling program (e.g., by using new source catalogs or by changing Sked parameters). Now we are trying a new approach — using minimization algorithms to find the hypothetical observation set that minimizes UT1. We report on our progress and on the application of our work to evaluating actual and possible Intensive schedules.

Automated analysis of Kokee-Wettzell intensive sessions

Niko Kareinen, Thomas Hobiger, and Rüdiger Haas (Earth and Space Sciences, Onsala Space Observatory, Onsala)

We present results from an automated analysis of IVS intensive sessions, carried out between 2001-2015 on the Kokee-Wettzell baseline. The analysis is based on the version 1 X- and S-band databases in Mark3 format, which means that ambiguity resolution and ionosphere correction need to be done within the automated analysis chain. We use the C5++ VLBI analysis software and process all available databases using several different analysis configurations and investigate the impact of a priori information on ambiguity resolution success rate and obtained UT1-UTC estimates. We also assess whether external information, i.e. cable delay and weather data extracted from the station log files, is required in order to obtain highly accurate UT1-UTC products. This will allow us to conclude whether the availability of external information is crucial for real-time analysis of intensive sessions, or if empirical models can be applied without a significant degradation of the target parameters.

Applying Kalman filtering to investigate tropospheric effects in VLBI analysis

Benedikt Soja (1), Tobias Nilsson (1), Maria Karbon (1), Kyriakos Balidakis (1), Cuixian Lu (1), James Anderson (1), Susanne Glaser (2), Li Liu (1), Julián Mora-Diaz (2), Virginia Raposo-Pulido (1), Minghui Xu (1), Robert Heinkelmann (1), and Harald Schuh (1); (1) GFZ German Research Centre for Geosciences, (2) Technische Universität Berlin

Today, the troposphere is the most important error source in VLBI analysis. As the rapid variations of water vapor cannot be modeled with sufficient accuracy, it is necessary to estimate the resulting delays in the analysis process. Due to the turbulent nature of the atmosphere, parameters like zenith wet delays (ZWD) are best approximated stochastically. For this purpose, we have implemented a Kalman filter into the GFZ version of the Vienna VLBI Software (VieVS@GFZ). The state-based approach of the Kalman filter allows for a more realistic modeling of stochastic parameters compared to the deterministic approach of an ordinary least-squares adjustment. The VLBI data analyzed for this study comprises the CONT campaigns between 2002 and 2014. First, ZWD noise parameters (the power spectral densities of the driving white noise processes) of all individual stations participating in the CONT campaigns were estimated and analyzed. It followed that the behavior of ZWD could be described reasonably well using random walk processes. By tuning the ZWD process noise depending on the individual stations and campaigns, a Kalman filter solution was created which performed better, in terms of baseline length repeatabilities, than one using average noise parameters by up to 3%. The repeatabilities with respect to a least-squares solution could be improved by more than 10%. By comparing both the Kalman filter and least-squares solutions to ZWD time series from water vapor radiometers, it was found that the stochastic approach of the Kalman filter lead to a better agreement by more than 6% in terms of RMS.

Combining VLBI and GPS for inter-continental frequency transfer

Thomas Hobiger (1), Carsten Rieck (2), Rüdiger Haas (1), and Yasuhiro Koyama (3); (1) Onsala Space Observatory, Chalmers University of Technology, (2) SP, (3) NICT

For decades the Global Positioning System (GPS) has been the only space geodetic technique routinely used for inter-continental frequency transfer applications. In the past VLB) has also been considered for this purpose and the method's capabilities were studied several times. However, compared to GPS current VLBI technology only provides few observations per hour, thus limiting its potential to improve frequency comparisons. We therefore investigate the effect of combining VLBI and GPSI on the observation level in order to draw the maximum benefit from the strength of each individual technique. As a test-bed for our study we use the CONT11

campaign observed in 2011. First we review the frequency transfer performance that can be achieved with independent technique-specific analyses. With this analysis approach both techniques, GPS and VLBI, show similar frequency link instabilities at the level of 1e-14 to 1e-15 (MDEV) on inter-continental baselines for averaging times of one day. We also perform a combined analysis of VLBI and GPS data on the observation level and demonstrate that our combination approach leads to small but consistent improvements for frequency transfer of up to 10%, in particular for averaging periods longer than 3000 s. We discuss the implications of these findings and present our ideas about how VLBI can contribute to international frequency transfer tasks.

Atmospheric tidal effects in Earth rotation observed by VLBI

Anastasiia Girdiuk, Michael Schindelegger, Matthias Madzak, and Johannes Böhm (TU Wien)

In this study, we assess the contribution of diurnal (S1) and semi-diurnal (S2) atmospheric tides to variations in Earth rotation by analyzing geodetic Very Long Baseline Interferometry (VLBI) observations. Particular emphasis is placed on the dependency of S1 and S2 estimates on varying settings in the a priori delay model. We use hourly Earth rotation parameters (ERP) of polar motion and UT1 as determined with the Vienna VLBI Software (VieVS) from 25 years of VLBI observations and we adjust diurnal and semi-diurnal amplitudes to the hourly ERP estimates after disregarding the effect of high-frequency ocean tides. Prograde and retrograde polar motion coefficients are obtained for several solutions differing in processing strategies (with/without thermal deformation, different analysis windows, selections of a priori ERP models and celestial pole offsets) and we compare the corresponding harmonics against those derived from atmospheric and non-tidal oceanic angular momentum estimates.

Baseline dependent weights in VieVS

M. Uunila, Aalto University Metsähovi Radio Observatory; J. Gipson, NVI Inc., NASA Goddard Space Flight Center; H. Krásná, Vienna University of Technology

It is well known that in processing VLBI data chi2 is usually larger than 1, typically in the range of 4-8. This results from either too small measurement errors or of mismodeling the data. By re-weighting the data, by increasing the errors of the observation, we can make chi2 sim1. In Solves operational solutions baseline dependent weights are always applied. VieVS uses a constant weight, i.e., global weighting. In order to use baseline dependent weights in VieVS we run the least-squares adjustment a second time after calculating the re-weights for each baseline in an observation. Baseline weighting reduces UT1 adjustment significantly. Discrepancy between VieVS and Solve is also reduced.

Combination of common parameters for co-located VLBI antennas

Tobias Nilsson (1), Robert Heinkelmann (1), Susanne Glaser (2), Benedikt Soja (1), Maria Karbon (1), and Harald Schuh (1); (1) GFZ German Research Centre for Geosciences, (2) TU Berlin

There exist VLBI stations equipped with more than one antenna and several more are planned. With the upcoming VGOS there will be various new twin telescopes. When analyzing observations from VLBI sessions containing co-located antennas it is possible to combine the station coordinates and tropospheric parameters in the VLBI data analysis, and if the antennas are connected to the same atomic clock it is possible to estimate common clock parameters as well. This should theoretically lead to more precise results. In this work we investigate the possibility of combining common parameters for the co-located antennas with a special emphasis on the clock parameters. To do this we use data from the CONT14 campaign, where two co-located antennas observed at the Hobart station. We also carry out simulations of a future VGOS network of about 20 stations containing several twin telescopes. In the simulations we consider different cases for the clocks, i.e. that the clocks are truly identical or that there are small systematic or random differences between them caused by e.g. uncalibrated cable delays.

VLBI Analysis at BKG

Volkmar Thorandt, Gerald Engelhardt, and Dieter Ullrich (BKG, Germany)

The VLBI group of the Federal Agency for Cartography and Geodesy (BKG) in Leipzig is part of the jointly operated IVS Analysis Center of BKG and the Institute for Geodesy and Geoinformation of the University of Bonn (IGGB). BKG is responsible for regular submissions of time series of Earth Orientation Parameters (EOP) and tropospheric parameters, the generation of daily SINEX (Solution INdependent EXchange format) files for 24-hours sessions and Intensive VLBI sessions, quarterly updated solutions to produce terrestrial and celestial reference frame realizations (TRF, CRF), and generating Intensive schedules (mainly Tsukuba-Wettzell). Additionally, the BKG Analysis Center has generated input in the form of daily SINEX files for the ITRF2014 VLBI combination solution. The data processing steps are explained and also some activities in the technologies of data analysis are pointed out.

IVS Combination Center at BKG: Combination products and the IVS contribution to ITRF2014

Linda Messerschmitt, Sabine Bachmann, and Daniela Thaller; (Federal Agency for Cartography and Geodesy, Germany)

The IVS Combination Center is the central location for consolidating analysed VLBI data. This data is combined in a rapid and a quarterly operational mode. Every submission of the Analysis Centers has to be synchronized and prepared for the combination. The process comprises a quality control with format checking and detection of outliers for each contribution. Recently, two additional Analysis Centers (ACs) CGS (Centro di Geodesia Spaziale, Italy) and GFZ (German Research Centre for Geosciences, Germany) are under review for the operational rapid and quarterly combination. Including both ACs increases the number of operational contributions to eight institutions. The final combination products are estimated Earth Orientation Parameters (EOP), station coordinates, and a terrestrial reference frame (VTRF). The Earth Orientation Parameters are released as official IVS products. In March 2013 a call for participation for the next ITRF was sent out to the IERS Technique Services. For the IVS combined solution, a total number of eleven Analysis Centers prepared their contributions for the time span 1979 to the end of 2014. The files have to meet the IVS specifications to be included into the combined solution. The contributions in form of datum-free normal equations are provided in SINEX format containing station coordinates and EOPs, so that long-term series systematic changes and errors can be identified. The series are created by using the orbit and geodetic parameter estimation software (DOGS-CS) of the German Geodetic Research Institute/Technical University of Munich. The computation of the combined IVS contribution, in form of stacked normal equations, to the upcoming ITRF2014 was successfully finished in February 2015. The results of the operational as well as the ITRF analysis will be presented in our poster.

The GFZ global VLBI solution

Julián Andrés Mora-Diaz, Maria Karbon, Virginia Raposo-Pulido, Tobias Nilsson, Robert Heinkelmann, James Anderson, Kyriakos Balidakis, Susanne Glaser, Li Liu, Cuixian Lu, Benedikt Soja, and Harald Schuh (GFZ, Germany)

We have successfully performed the GFZ VLBI time series solution that will be part of the IVS input to ITRF2014, we will now present the GFZ VLBI global solution. In the present study, we show the first version of the global solution and we describe the different steps for its completion as well as the statistics of the results. The solution provides the GFZ VLBI Terrestrial Reference Frame (GFZ-VTRF), which was estimated with the GFZ version of the Vienna VLBI Software VieVS using data from 1979 through 2013 (5700 sessions). The solution was determined following the IERS Conventions (2010). For a reliable global solution preliminary analysis concerning the selection of datum stations, detection of station discontinuities, and outliers elimination were done. Furthermore, this research provides an outlook towards future improvements, for example the realization of the GFZ Celestial Reference Frame, and expected applications.

CONT14 analyzed by a Kalman filter: a test case

Maria Karbon, Benedikt Soja, Tobias Nilsson, Robert Heinkelmann, and Harald Schuh (Geo-ForschungsZentrum Potsdam)

In this work we investigate the performance of a Kalman filter within very long baseline interferometry (VLBI) data analysis. Our test case is the continuous VLBI campaign CONT14, observed from May 6th until May 20th 2014. We compare daily and hourly Earth orientation parameter (EOP) estimated by using the least squares method (LSM) with the results provided by various specifications of the Kalman filter. For external validation, hourly GNSS data are used. Our filter offers two main processing modes, one for near real-time processing, where the filter is run only forwards, and one for post-processing, where the data is filtered twice, forward and backward, followed by a smoothing algorithm. The latter is more precise than the first, since all the information contained in the data is used to improve the prediction.The drawback is the longer processing time, making it inapplicable for near real-time applications. Additionally, the filter includes a forecast tool, where EOP are predicted on the basis of angular momentum functions (AMF) of the atmosphere and the oceans. This tool not only forecasts EOP but also helps bridging gaps in the VLBI data and thus stabilizes the results. We assess the performance of the filter settings concerning internal precision (i.e., relative to each other and to the LSM solution), external accuracy (e.g., GNSS), and near real-time applicability (processing speed, memory consumption, and availability of the necessary external data like AMF).The performance of an adaptive Kalman filter will be tested as well because various authors suggest its use especially for EOP determination. So far our tests have not shown significant impact on the results.

Comparison of VLBI and DORIS solutions in view of ITRF2014

Vincenza Tornatore, Politecnico di Milano; Emine Tanir Kayikcci, Karadeniz Tech. Univ.

A new determination of the materialization of the International Terrestrial Reference System, ITRF2014, is upcoming. Several Analysis Centers, belonging to International Services of the four geodetic satellite/space techniques contributing to ITRF, performed a complete reprocessing of all data available till the end of 2014. In this framework, within this study we have focused our analysis on time series of coordinates and baselines related to VLBI and DORIS sites, with particular attention to co-located sites. We first investigated on different approaches available in literature for time series analysis. For example the automatic research of discontinuities, velocity changes, periodic functions and outliers of unknown reason, for epochs not associated with any events, e.g., events from the list of earthquakes or station information file. Noise characteristics of time series of both techniques have been inquired. The presence of temporal correlations and their impact on estimation of position and velocity precision has been checked. Finally to detect permanent station periodic behaviors, some methods for frequency analysis have also been studied considering for example that VLBI time series are not equally spaced in time. Discussion of results is presented, in order to better understand the origin of revealed signals.

Status Report of VLBI Measuring System based on China Deep Space Network

Ke Xu, Gongyou Wu, Xiaojuan Ou, Dong Zhang, Jia Wang (China State Key Laboratory of Astronautic Dynamics)

As an effective measuring method of deep space exploration, VLBI is not only widely used in geodesy and astronomy, but also used in spacecraft navigation currently. China is establishing deep space network (CDSN), which combines the existing China VLBI Network and will form a more precise, complete observation network. The current development status of CDSN is introduced in this paper, then the instruments of observation system is discussed, which include the digital base band converter (DBBC) and the correlator. The DBBC is compatible with MARK5B and RDEF. The correlator adopts parallel computing processing, which can be achieved on the DOD/DOR DOD/DOR observation modes of data processing. In recent years, CDSN participated in the international and domestic observation missions, including Venus Express and ChangE-3 mission in 2013, which data processing results are shown here.

First determination of the locations of the Chinese Deep Space Stations: JIA-MUS66 and KASHI35 using Geodetic VLBI

Dezhen XU (1), Huan ZHOU (1), Guangliang DONG (1), Haitao LI (1), Guangli WANG (2), and Fengchun SHU (2); (1) Beijing Institute of Tracking and Telecommunications Technology, (2) Shanghai Astronomical Observatory

Accurate spacecraft navigation especially deep space navigation using radio metric measurements requires good knowledge of the locations of the ground stations. As a request of the Chinese Deep Space Exploration Missions in the coming future, the station locations of the two Chinese Deep Space Stations JIAMUS66 and KASHI35 (both put to use in late 2012), which are located in northeast and northwest China respectively, should be determined with high accuracy and tied into the international terrestrial reference frame (ITRF). Since both of the two stations have the ability of VLBI measurements, a 24-hour S/X dual-band geodetic VLBI experiment was conducted on Sep. 28, 2014, with the participation of the four Chinese VLBI telescopes (SESHAN25, URUMQI, BEIJING and KUMING). However, for this experiment, the data were recorded in the band 2200 2300 MHz (through 4 channels) and 8400 8500 MHz (also through 4 channels) at JIAMUS66 and KASHI35, which is a limitation of the VLBI backend available at the two Chinese Deep Space Stations. For the four Chinese VLBI telescopes with much wider-frequency range (300 MHz at S-band and 500 800 MHz at X-band), 2 more channels at S-band and 4 more channels at X-band were setup. More than 3000 delay observations were obtained at both S-band and X-band, and analysis of the observations yields good results in terms of formal errors. The locations of JIAMUS66 and KASHI35 are measured to a precision about 1 cm in the local north and east direction, and 3 5 cm in the local up direction, which validates the effectiveness of the design, data processing, and analysis of the experiment.

ΔDOR Data Processing and Analysis in CE-3 Mission

Dong Zhang, Gongyou Wu, Jia Wang, Ke Xu (China State Key Laboratory of Astronautic Dynamics)

Delta differential one way range ΔDOR is a higher precision measurement technology based on Very Long Baseline Interferometry (VLBI), which is widely used in deep space navigation. The ΔDOR principle and method of data processing are presented, and the result of the interferometry measurement data processing of CE-3 is shown in this paper. The residual delay and residual delay rate are obtained by correlation algorithm and bandwidth synthesis, and the accuracy with different integral time are compared and analyzed. When the residual delay rate is very small, the result with long integral time is better than the short integral time. The processing results of measured data show that the delay accuracy of ΔDOR is less than 1ns, which is better than the broadband telemetry signal.

CVN High Accuracy VLBI Phase-referencing Positioning experiment for Deep Space Probe

Zheng Weimin, Tong Fengxian , Liu Lei, Shu Fengchun (Shanghai Astronomical Observatory, Chinese Academy of Sciences)

Recent VLBI Phase-referencing positioning experiments show that CVN has the ability of absolute and relative positioning of deep space probe. The VLBI phase-referencing method can be divided into two categories, Phase-Referencing Imaging (PR-I) and Phase-Referencing Direct solver positioning (PR-D). They are both used for Chinese lunar explorer Chang'e-3 (CE-3) Lander and Rover relative positioning experiment. In astronomical observations, the PR-I method is often used, and the method of calculation of the uvw is used for extragalactic radio sources only. For a target that is near the Earth, the traditional prediction of uvw was not suitable. This paper develops a new method for near-field target uvw prediction. Based on the Chinese VLBI network (CVN), we used the phase-referencing method and together with the

near-field uvw calculation method to solve the relative position between CE-3 Lander and Rover. Compared with the visual localization results, the accuracy of the relative position obtained by the phase-referencing method was about 1 meter. The phase-referencing absolute positioning experiments results of MEX (Mars Express) spacecraft and Chang'e 5-T1 (precursor of Chinese Chang'e 5 lunar probe) are also presented.

A Celestial Reference Frame at 22 GHz (K-band)

Aletha de Witt, Hartebeesthoek Radio Astronomy Observatory; Alessandra Bertarini, Max Planck Institut fu r Radioastronomie; Chris Jacobs, Jet Propulsion Laboratory, California Institute of Technology/NASA; Jonathan Quick, Hartebeesthoek Radio Astronomy Observatory; Shinji Horiuchi, C.S.I.R.O/Canberra Deep Space Communications Complex; Jim Lovell, University of Tasmania; Jamie McCallum, University of Tasmania; Taehyun Jung, Korea Astronomy & Space Science Institute; Geraldine Bourda, University of Bordeaux; Patrick Charlot, University of Bordeaux

Relative to observations at the standard S/X observing bands, at higher radio frequencies sources that make up the international celestial reference frame are expected to exhibit more compact source morphology and the effect of core-shift is expected to be smaller. This reduction in astrophysical systematics should allow for a more well-defined and stable reference frame at higher frequencies, and also be advantageous in tying the VLBI reference frame to future optical reference frames such as Gaia. Astrometric and imaging observations by Lanyi et al. (2010) and Charlot et al. (2010) provided a foundation for the development of a reference frame at 22 GHz (K-band). However, the current K-band frame consists of only 279 sources with weak coverage in the southern hemisphere and several localised regions with no sources, especially near the ecliptic and galactic planes. We present an overview of our plans to improve the accuracy and coverage of the K-band celestial reference frame and present ongoing results from our observational efforts. Specifically, dedicated high-resolution imaging and astrometric observations are currently underway to complete sky coverage in the south using South Africa to Australia baselines and to improve the K-band celestial reference frame in the North using the VLBA to densify the spatial coverage of sources. Our goal is to achieve a frame of at least 500 sources.

The X/Ka-band (8.4/32 GHz) Celestial Frame: Can it be more accurate than the ICRF2?

Christopher S. Jacobs, JPL; Cristina Garcia-Miró, INTA/NASA; S. Horiuchi, CSIRO/NASA; Lawrence G. Snedeker, SaiTech/NASA; J.Eric Clark, JPL; Roberto Maddè, ESA; Matia Mercolino, ESA; Charles J. Naudet, JPL; Diego Pazos, Telespazio; Phil Pope, CSIRO/NASA; Ioana Sotuela, INTA/NASA; Leslie A. White, JPL

Observations at X/Ka-band are motivated by their ability to access more compact source morphology and reduced core shift relative to observations at the historically standard S/X-band. In addition, the factor of four increase in interferometer resolution at Ka-band should resolve out some wide binary black holes which are a topic of concern for AGN centroid stability. Given these motivations, an X/Ka-band (8.4/32 GHz) celestial reference frame has been constructed using a combined NASA and ESA Deep Space Network. In 110 observing sessions we detected 660 sources covering the full 24 hours of right ascension and the full range of declinations. The resulting XKa median precision is now comparable to the ICRF-2 precision thereby raising the question of which frame is more accurate. Comparison of about 530 X/Ka sources in common with the S/X-band (2.3/8.4 GHz) ICRF2 produced wRMS agreement of about 200 uas. There is evidence for systematic errors at the 100 uas level. Known errors include limited SNR, lack of phase calibration, troposphere mismodelling, and terrestrial frame distortions. Actions are underway to reduce all of these errors. In particular, a collaboration between NASA and the ESA deep space antenna in Malarge, Argentina is quickly reducing weaknesses in the southern hemisphere. By looking at the best observed sources, we probe the accuracy limits of current celestial frames in an effort to understand the advantages of each frame.

Source structure influence on GeoVLBI observations

Nataliya Zubko, Finnish Geospatial Research Institute; Elizaveta Rastorgueva-Foi, University of Tasmania; Lucia Plank, University of Tasmania

We present results on study of the source structure effect on the estimated GeoVLBI parameters. The extended source structures introduce an additional time delay component into the measured time delay and, thereby, it affects the estimated geodetic parameters. We study this impact for several defining radio sources, which were observed on a regular basis with GeoVLBI. Despite the fact that the defining sources are selected based on their stability, many of them have considerable extended structure. We select ten radio sources among the defining sources, which revealed noticeable variations in their extended structure over the time period 20002014. We analyze the GeoVLBI sessions when the selected radio sources were observed. We have investigated a capability to detect a source structure effect on the measured time delay for different baselines. Also we study EOP and evaluate source structure effect on the estimated parameters.

Observing Gaia transfer sources in R&D and RDV sessions

Karine LeBail, David Gordon, and John M. Gipson (NVI, Inc., at GSFC/NASA)

The ESA mission Gaia was successfully launched on December 19, 2013. For five years, it is expected to observe and map billion of objects, including 500 000 quasars. The team of the Observatory of Bordeaux identified 195 sources to link the Gaia-optical frame and the VLBI-radio frame. They submitted a proposal that was approved in 2012 to include these sources in the IVS monitoring program and observe them regularly. Over the 195 sources, sixty six were not sufficiently observed and forty were not part of the IVS monitoring program. We included the sources in the IVS monitoring program in two steps. First, we modified the observation target of all the sources to twelve successful sessions per year. Second, as the forty sources not initially in the IVS monitoring program were mostly weak, we specifically scheduled them in R&D and RDV sessions. Since the beginning of this effort in 2013, we are now able to see significant improvements in position uncertainties and we know better the flux values of the 195 transfer sources. We were also able to identify a set of sources too weak to be observed regularly in regular IVS sessions. This paper explains the strategy developed, shows the significant improvements, and discusses the next step, taking into account the updates on the mission.

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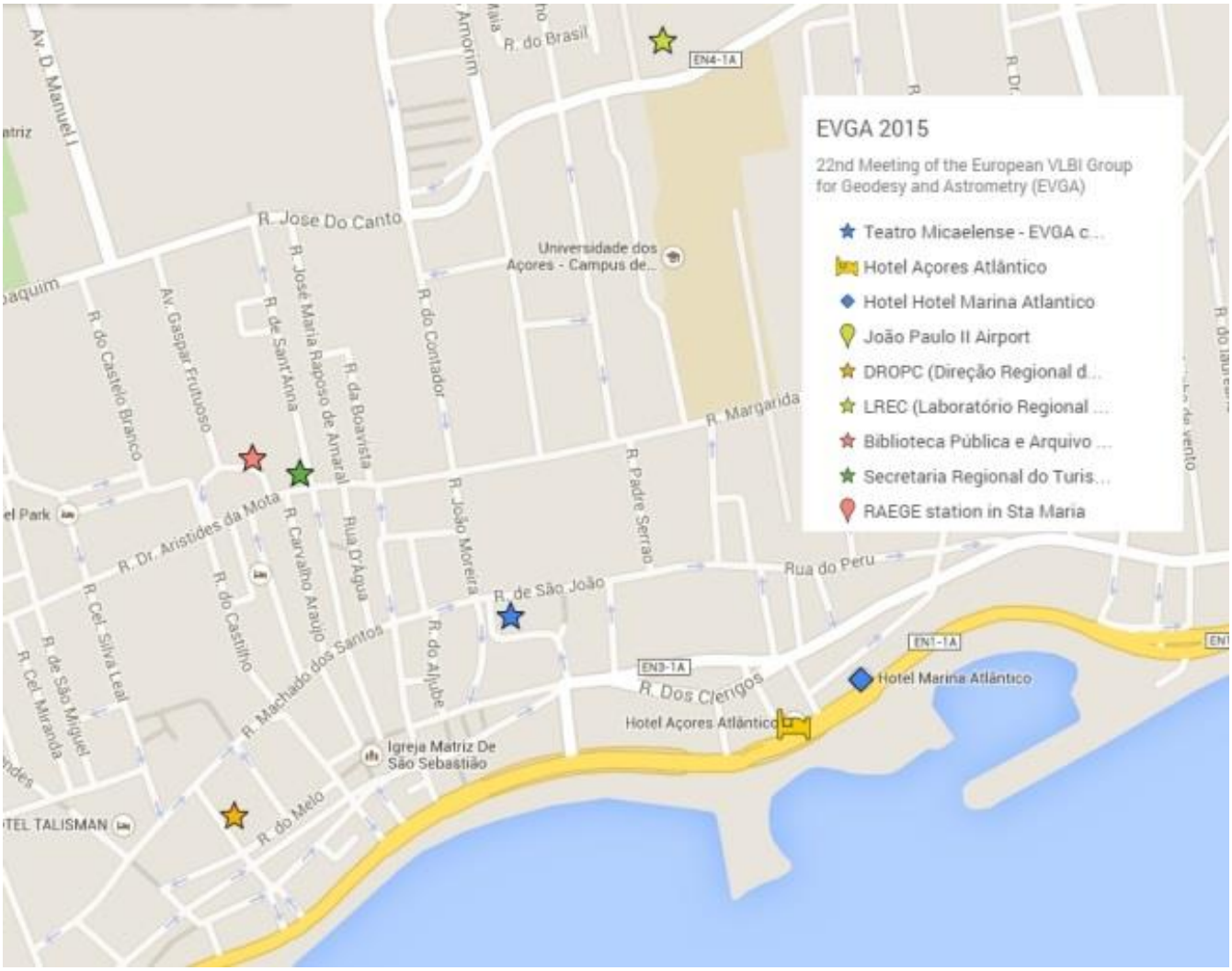
Location of EVGA2015 activities



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EVGA2015 Organization

Governo dos Açores

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NOS is a communications' company that was born from the fusion of ZON and Optimus, the two biggest enterprises of communications in Portugal. Because of that, NOS is a strong and responsible company, focused in the future and clearly committed to the excellency of its services, as well as to the customers' satisfaction. In order to provide a faster, safest and innovative service, NOS has joined, into one strong and integrated structure, all fixed and mobile communications, using the smartest and most advanced networks of our country.

EDA is a company operating in production, distribution and trading of electricity. Recognized by their customers for the efficiency and quality of the services provided, EDA plays a key role in the Azores development process, safeguarding the environmental and cultural heritage and electing as its strategic areas, telecommunications, information systems and electrical and mechanical maintenance. On what concerns to the electrical sectors, EDA's growing commitment is to renewable energies.

The main mission of Teatro Micaelense is to assure the providing of a public service within the field of cultural promotion, through the presentation, production and co-production of activities from the most diverse artistic strains. In parallel, Teatro Micaelense takes on its place as a privileged instrument for the development of the Meetings and Incentives sector in the Azores, allowing for the holding of conferences, business meetings and other social events.

The Technical Engineers Order – OET - is the representative association for the Technical Engineers, which are skilled professionals with a 1st cycle degree of an Engineering graduation or equivalent training. These professionals practice in the engineering area and have skills, technical and scientific knowledge and a high practical sense that enable them to perform on their expertise areas.