3.4.3 International VLBI Service for Geodesy and Astrometry (IVS)

IVS Organization and Activities

During 2018, the IVS continued to fulfill its role as a service within the IAG and IAU by providing necessary products for the maintenance of global reference frames: TRF, CRF, and EOP. Some highlights of the IVS organization and activities were:

- Several IVS Analysis Centers (ACs) in cooperation with the International Astronomical Union (IAU) Working Group on the third realization of the International Celestial Reference Frame (ICRF3) prepared CRF solutions as input to ICRF3. The new frame was adopted at the IAU General Assembly in Vienna, Austria on August 30, 2018 under Resolution B2. ICRF3 contains positions of more than 4500 extragalactic radio sources at three frequencies and became the Fundamental Astrometric Reference Frame on 01 January 2019.
- The IVS continued an observing program to determine the alignment of the next radio frame (ICRF3) with the future *Gaia* optical frame by observing ICRF–*Gaia* transfer sources.
- Following a call for proposals in July 2018, the Board approved the creation of an IVS Office for Outreach and Communications (OOC) at the MIT Haystack Observatory (lead: Nancy Kotary) at the end of 2018. The OOC will promote awareness and understanding of geodesy's unique and vital role in science and society to the larger scientific community, decision makers, and the general public.
- The Ny-Ålesund Twin Telescopes were inaugurated on June 6, 2018 as part of the Tenth IVS General Meeting, which was held in Longyearbyen, Svalbard, Norway. The meeting attracted 100 participants from around the world.
- The IVS published three IVS Newsletters in April, August and December, keeping the community informed about IVS activities.

Table 1: *IVS meetings in 2018. The AOV is a regional subgroup of the IVS organizing institutions that are active in geodetic and astrometric VLBI in Asia-Oceania.*

Event	Location	Date
10th IVS General Meeting	Longyearbyen, Norway	June 3–7, 2018
19th IVS Analysis Workshop	Longyearbyen, Norway	June 8, 2018
39th IVS Directing Board meeting	Longyearbyen, Norway	June 9, 2018
3rd General Meeting of the AOV	Canberra, Australia	November 9–10, 2018
7th Int'l VLBI Technology Workshop	Krabi, Thailand	November 12–15, 2018

Network Stations and observing sessions

A total of 190 geodetic/astrometric 24-hour sessions were observed during the year 2018 using the legacy S/X system. That translates to about ∼3.6 observing days per week that were coordinated by the IVS to determine operational products including EOP. Further, there were 366 1-hour Intensive sessions observed for the determination of UT1–UTC. Lastly, twenty-four 24-hour VGOS sessions were observed to establish the processing chain of the new VLBI system. The major observing programs during 2018 were:

IVS-R1, IVS-R4 Weekly (Mondays and Thursdays) 24-hour, rapid turnaround measurements of EOP. Databases were available no later than 15 days after each session. The NASA Goddard Space Flight Center (R1) and the U.S. Naval Observatory (R4) coordinated these sessions.

Intensive Daily 1-hour UT1 Intensive measurements were made on five days (Monday through Friday, Int1) on the baseline Wettzell (Germany) to Kokee Park (Hawaii, USA), on weekend days (Saturday and Sunday, Int2) on the baseline Wettzell (Germany) to Ishioka (Japan), and on Monday mornings (Int3) in the middle of the 36-hour gap between the Int1 and Int2 Intensive series on the network Wettzell (Germany), Ny-Ålesund (Norway), and Ishioka (Japan). For the Int3, Wettzell was employing their 20-m legacy antenna and repeatedly also the 13-m VGOS antenna (70% of the Int3s).

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with 14–16 stations per session. Seven of these sessions were observed to monitor the TRF with all IVS stations.

IVS-CRF The Celestial Reference Frame (CRF) sessions, coordinated by the Hartebeesthoek Radio Astronomy Observatory, provide astrometric observations that are required for improving the current CRF and for extending the CRF by observing 'new' sources. Twelve sessions were observed for the maintenance of the CRF in 2018.

VLBA The Very Long Baseline Array (VLBA), operated by the Long Baseline Observatory (LBO), allocated six observing days for astrometry/geodesy. These sessions included the 10 VLBA stations plus up to four geodetic stations, providing state-of-the-art astrometry as well as information for mapping ICRF sources.

Europe The European geodetic network, coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, continued with six ses-

sions in 2018.

IVS-OHIG The purpose of the IVS-OHIG (Southern Terrestrial Reference Frame) sessions is to tie together optimally the sites in the southern hemisphere. In 2018 six OHIG sessions were observed.

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2018.

AUSTRAL In 2018, 23 Austral sessions were observed. The purpose is to determine the station coordinates and their evolution in the Australia (AuScope) and New Zealand geodetic VLBI network.

AOV The Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) had 12 sessions during 2018.

IVS-R&D Ten research and development sessions were observed in 2018. The main goal of the 2018 R&D sessions was the observation of link sources between *Gaia* and the ICRF2.

Correlators

The correlator at Haystack Observatory (USA), the correlator at the U.S. Naval Observatory in Washington (USA), the BKG/MPIfR correlator at the Max Planck Institute for Radio Astronomy in Bonn (Germany), the correlator at the Shanghai Astronomical Observatory (China), and the correlator at the Geospatial Information Authority of Japan (GSI) in Tsukuba efficiently processed the data recorded for the IVS. The majority of the 24-hour sessions were processed by the Bonn and Washington correlators. Both correlators used the DiFX software correlator; while the Bonn correlator processed the R1, EURO, T2, Int3, and OHIG sessions, the Washington correlator was responsible for the R4, Int1, and CRF deep south sessions. The Shanghai correlator analyzed CRF, APSG, and AOV sessions. The Haystack correlator processed R&D sessions and some T2 sessions. The Int2 sessions were processed at the Tsukuba correlator.

Data Centers

The IVS Data Centers continued to receive databases throughout the year and made them available for analysis within one day of correlation. The Data Centers also continued to receive solutions from Analysis Centers. All data and results holdings are mirrored several times per day among the three primary IVS Data Centers at BKG (Germany), Paris Observatory (France), and Goddard Space Flight Center (USA).

Data Analysis

The IVS began the transition from the legacy MK3 database format to the new vgosDB format in 2017. The original deadline of 30 September 2017 was postponed because a few analysis packages were not able to support the new format. The transition was essentially complete by 31 May 2018.

IVS Working Group 8 on Galactic Aberration successfully completed its charter to investigate the effects of galactic aberration and to make a recommendation to the IVS. Galactic aberration is due to the rotation of the solar system about the galactic center and leads to an apparent change in source position over time. The magnitude and direction of the effect depends on the source coordinates with respect to galactic center, and it is a dipole pattern. The VLBI determined constant is 5.8 μas/yr, which is relatively close to estimates of 4.8–5.4 μas/yr that can be derived from independent galactic astronomy measurements of proper motions and parallaxes of galactic masers. Although this effect is small, it is non-negligible given the 40-year timespan of VLBI measurements. The coordinates for ICRF3 include the effect of galactic aberration.

The CONT17 data (28 November to 12 December 2017) was correlated and made available to the IVS community. CONT17 involved two independent legacy S/X networks of 14 stations, and an independent 6-station VGOS network. This allows independent checks of the precision and consistency of VLBI measurements of EOP. Preparations are under way for a special issue devoted to CONT17 in Journal of Geodesy.

Several IVS Analysis Centers participated in the work of the IERS Working Group on Diurnal and Semi-diurnal EOP variation. Ten different models (including the current IERS model) of HF-EOP were used in VLBI analysis and different measures of goodness, such as baseline length repeatability or session fit, were evaluated. Some of the models were derived using altimetry-based models of ocean heights and currents, while others were purely empirical.

Technology Development

The main focus of the IVS technology development was placed on the build-out of the next-generation VLBI system (VLBI Global Observing System, VGOS) network and achieving operational readiness with the various installations of the signal chain realizations. Over the next several years a number of new VGOS stations will come online. Operational readiness for the existing VGOS stations was worked on in a series of test sessions of initially 1-, 2-, and 6-hour lengths in 2015/16 and then extended to 24-hour sessions from the second half of 2016 onward. These tests uncovered a number of smaller and larger issues of high-level, low-level, and transient nature that were successively ironed out or identified and actively being worked on. Since 01 January 2019 the currently available six-station VGOS network was operating in a stable

way, so that the session results could be made available on the IVS Data Center for general use. Aside from increasing the VGOS network size in the next couple of years, the focus of the VGOS effort will be on the data transport and correlation parts of the processing chain. Here the use of cloud services and distributed correlation to deal with the large amount of data are aspects that will be investigated.

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