3.4.3 International VLBI Service (IVS)

IVS Organization and Activities

During 2014, 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:

Event	*Location*	*Date*
8th IVS General Meeting	Shanghai, China	March 2–7, 2014
15th IVS Analysis Workshop	Shanghai, China	March 7, 2014
31st IVS Directing Board meeting	SHAO, Shanghai, China	March 8, 2014
32nd IVS Directing Board meeting	GSI, Tsukuba, Japan	October 27, 2014
3rd International VLBI Technology Workshop	Groningen, The Netherlands	November 10–13, 2014

- In the summer of 2014 the IVS published the 2013 Annual Report. Furthermore, three IVS newsletters were published in April, August and December to keep the community informed about IVS activities.
- In March 2014 the Asia-Oceania VLBI Group for Geodesy and Astrometry (AOV) was founded. It is a group which fosters VLBI activities on a regional basis, similar to the European VLBI Group for Geodesy and Astrometry (EVGA).

Network Stations and Observing Sessions

A total of 248 geodetic/astrometric 24-hour sessions were observed during the year 2014. The number of observing sessions coordinated by IVS was about ~4.7 days per week, a significant increase over previous years attributable to the increase of the number of regional AUSTRAL sessions and the observation days of the CONT14 campaign. The major observing programs during 2014 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 Tsukuba (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 Tsukuba (Japan).

IVS-T2 Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with 15–17

stations per session. Seven of these sessions were observed to monitor the TRF with all IVS stations. On November 11, 2014, the 100th session of this series was observed. Fig. 1 depicts the distribution of the sessions and the increase in the number of telescopes participating.

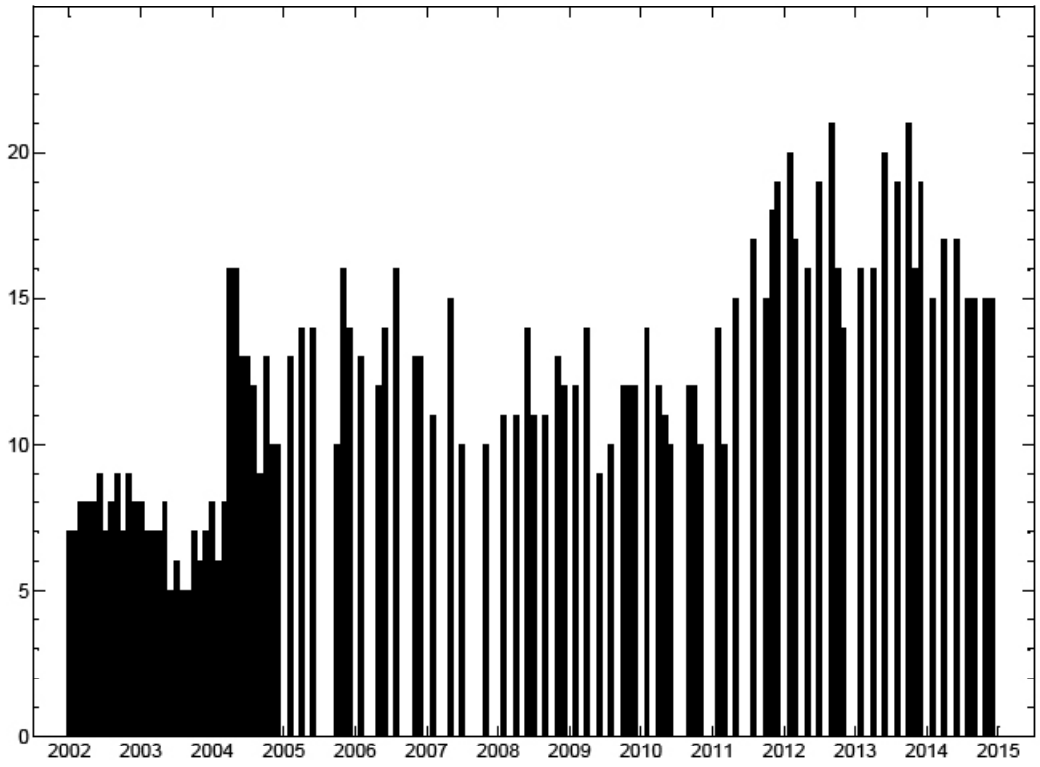

Fig. 1: Number of telescopes participating in the IVS-T2 sessions over the course of time.

IVS-CRF The Celestial Reference Frame (CRF) sessions, coordinated by the U.S. Naval 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 2014.

VLBA The Very Long Baseline Array (VLBA), operated by the National Radio Astronomy Observatory (NRAO), continued to allocate six observing days for astrometry/geodesy. These sessions included the 10 VLBA stations plus up to 6 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 sessions in 2014.

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 2014 six OHIG sessions were observed.

APSG The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2014.

AUSTRAL In 2014, 73 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.

JADE The JApanese Dynamic Earth observation by VLBI (JADE) had five sessions during 2014. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

IVS-R&D Twelve research and development sessions were observed in 2014. The goals of the 2014 R&D sessions included the testing of the observing mode for the Continuous VLBI Campaign 2014 (CONT14), the observation of link sources between Gaia and the ICRF2, and the observation of the Chang'E-3 lander with VLBI.

CONT14 The continuous VLBI campaign CONT14 was observed May 6–20, 2014, and involved 17 stations worldwide. The data were correlated at the Bonn correlator.

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) and the correlator at the Geospatial Information Authority of Japan (GSI) in Tsukuba continued their efficient processing of the data recorded for the IVS. The majority of the 24 hour sessions were processed by the Bonn and Washington correlators. The Bonn correlator used the DiFX software correlator and processed, e.g., the R1, EURO, T2, Int3, and OHIG sessions. The Washington correlator used the Mark IV hardware correlator until October 2014 for processing, e.g., the R4, Int1, and CRF sessions. They then transitioned to using the DiFX software correlator. The Haystack correlator processed R&D sessions and some T2 sessions. The Int2 and JADE 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).

IVS Operational Data Analysis and Combination

The 15th IVS Analysis Workshop was held in Shanghai, China on March 7, 2014. In this workshop, the coordination of IVS routine data analysis was discussed as well as a number of individual items concerning geodetic and astrometric data analysis in the framework of the IVS. An outcome of the workshop was the request that all software packages used for IVS add the abilities to 1) estimate Earth rotation parameters (ERP) as piece-wise linear functions and 2) set the epochs of the estimates to full integer hours. The time frame for adding these abilities was set with the end of 2014.

The Combination Center at BKG/DGFI continued to perform the combination of session-based results from the individual IVS Analysis Centers on an operational basis. The combination strategy is based on the combination of normal equations; it is an adaptation of the combination process developed by IGG Bonn.

An initial set of VLBI SINEX files for the ITRF generation was submitted to the IERS ITRS Center at the beginning of December 2014. Ten IVS Analysis Centers had contributed their SINEX files to create the combined solution. One of the main tasks in 2014 was to gather the SINEX contributions and to make sure that all contributions meet the IVS analysis specifications for ITRF contributions. In the course of the year, it turned out that the ITRF could be extended by another year, including sessions until the end of 2014 (instead of 2013 as foreseen in the original ITRF call for participation). With this change, an additional IVS Analysis Center agreed to contribute.

Technology Development

The main focus of IVS technology development over the past year has been to achieve operational readiness for broadband observing as part of the VBLI Global Observing System (VGOS). This includes not only the development and proliferation of broadband systems but also the development of software and processes to enable efficient, and eventually automatic, operation of the VGOS stations and correlators. Already, a number of fully compliant (or nearly compliant) VGOS antennas have been constructed (many of these having already achieved first light and first fringes) with several more expected to come on line in the next year or two. The challenge is to ensure that signal chains are available for these antennas; that operating modes of the various systems are VGOS compliant, interoperable, and sufficiently robust against RFI; and that systems can be controlled and thoroughly monitored remotely.

Automation and remote control are very important aspects of VGOS. With the expectation of 24/7 operations and a sharp rise

Table 1: Progress in the build-out of the VGOS network as of December 2014.

Station	Recent milestone	Broadband readiness
GGAO	Test observations	now on fast RT
Westford	Test observations	now on legacy RT
Wettzell	Receiver tests	early 2015
Yebes	First fringes on X-band	late 2015
Noto	Receiver under construction	end 2015 on legacy RT
Ishioka	First fringes	end 2016 (initial S/X/Ka)
Santa Maria	RT constructed at site	2016
Badary	RT constructed at site	2015 (S/X/Ka)
Zelenchukskaya	RT constructed at site	2015 (S/X/Ka)
Kokee Park	RT being assembled at factory	2016
AuScope	Funding for upgrade secured	2016 on fast RTs
Tenerife	RT assembled at factory	2017
Ny Ålesund	Civil construction underway	2018

in the number of observations per day, it is necessary (in order to keep operating costs at a reasonable level) to make all processes (including schedule generation, station operation, correlation, fringe processing, and analysis) as automated as possible. A necessary step to achieve automation and remote control is to have a language to concisely and completely describe the instrumentation, operating modes and schedule for a session. This has been the role of the VEX language over the past decades. However, with the advent of VGOS and the new broadband systems, instrumentation and operating modes, which had not been conceived of when the original version of VEX was developed, now need to be handled. As a result, over the past few years, a new version of VEX, called VEX2, has been developed. VEX2 was completed this year; it went through a brief period of community consultation; and it is now being used to write software to control instrumentation and processes in the complete VGOS operational chain.

Dirk Behrend, Axel Nothnagel