3.4.3 International VLBI Service (IVS)

**IVS Organization and Activities**

During 2011, 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:

- The 20th European VLBI for Geodesy and Astrometry (EVGA) Working Meeting was held in Bonn (Germany) March 29–31, 2011.
- The 12th IVS Analysis Workshop was held in Bonn (Germany) on March 31, 2011.
- The spring 2011 IVS Directing Board meeting (IVS DB #25) was held on April 1st in Bonn (Germany). At this meeting Harald Schuh was elected chair of the IVS DB for another four years.
- The 6th IVS Technical Operations Workshop (TOW) was held at Haystack Observatory (USA), May 9–12, 2011.
- The continuous VLBI campaign 2011 (CONT11) was observed on September 15–29, 2011, including 13 participating stations.
- An IVS retreat was held on September 21–22, 2011, at Hohe Wand, Austria.
- The fall 2011 IVS Directing Board meeting (IVS DB #26) was held on September 23, 2011, at Hohe Wand, Austria.
- The 10th International e-VLBI Workshop was held on November 13–16, 2011, at Broederstroom, South Africa.
- In the summer of 2011 the IVS published the 2010 Annual Report. Furthermore, three IVS newsletters were published in April, August and December to keep the community informed about IVS activities.

**Network Stations**

The IVS network operated well for most of 2011. The average single station loss is estimated to have been in the range of 10–20%, similar to previous years. One of several positive developments was increased use of e-transfer with data from Ny-Ålesund, Fortaleza, AuScope, and Warkworth now being largely e-transferred. This speeds data transfer and reduces shipping costs. Another positive development was that Mark 5B recorders were installed at several stations improving correlator efficiency. A third development is that digital back-ends are starting to be used at more stations for operations. The DBBC developed by the EVN is being used at Hobart, Katherine, Yarragadee, and Warkworth. The Haystack/NRAO developed RDBE is nearing readiness for observations and is expected to start being used in 2012. There were a few notable issues with IVS antennas:
• On March 11, 2011, a major earthquake and Tsunami affected the east coast of Japan, impacting the VLBI stations at Tsukuba and Kashima. Also the VERA station at Mizusawa was affected and severely damaged.

• Several stations had problems with warm receivers.

• Noto was not operating due to a rail repair.

• The AuScope stations had some problems with recording devices.

• The use of the Chinese stations Seshan25 and Urumqi was restricted due to obligations in connection with the Cheng’E mission.

• The station Warkworth participated in one of the CONT11 sessions.

A total of 171 geodetic/astrometric 24-hour sessions were observed during the year 2011. The number of observing sessions coordinated by IVS was about ~3.3 days per week, similar to previous years. The major observing programs during 2011 were:

**IVS-R1, IVS-R4**

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

**Intensive**

Daily 1-hour UT1 Intensive measurements are 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).

Since Tsukuba was affected by the Tohoku earthquake in March 2011 and exhibited continued, post-seismic nonlinear motion, back-to-back Int2 sessions were organized where a Wettzell–Kokee Intensive was immediately followed by a Wettzell–Tsukuba Intensive. This program was continued until the Tsukuba motion could be properly modeled. Also, when possible, Seshan25 was added to the Int3 sessions.

**IVS-T2**

Bi-monthly sessions coordinated by the Institute of Geodesy and Geoinformation of the University of Bonn, Germany, with at least 12 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 U.S. Naval Observatory, provide astrometric observations that
are required for improving the current CRF and in extending the CRF by observing 'new' sources. Twelve sessions were observed for the maintenance of the ICRF in 2011.

**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 7 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 2011.

**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 2011 six OHIG sessions were observed.

**APSG**
The Asia-Pacific Space Geodynamics (APSG) program operated two sessions in 2011.

**AUSTRAL**
In 2011 two 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 eight sessions during 2011. These sessions included the dedicated 32-m dish at Tsukuba and are designed to monitor the domestic network within the ITRF.

**IVS-R&D**
Seven research and development sessions were observed in 2011. The goal of the 2011 R&D sessions was to test and validate the observing mode to be used during the CONT11 campaign.

**CONT11**
The continuous VLBI campaign CONT11 was observed September 15–29, 2011, and involved 13 stations worldwide. The data were correlated at the Washington 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 Radioastronomy in Bonn (Germany), and the correlator at the Geographical Survey Institute (GSI) in Tsukuba, Japan 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 still used the Mark IV hardware correlator and processed, e.g., the R4, Int1, and CONT11 sessions. The Haystack correlator processed RD sessions and some T2 sessions. The INT2 and JADE sessions were processed at the Tsukuba correlator that also processed the baseline Onsala–Tsukuba during the whole CONT11 campaign in ultra-rapid mode.

**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 combination process for the two IVS EOP series (rapid and quarterly solutions) has been continued exclusively on the basis of datum-free normal equations in SINEX format. In 2011, six IVS Analysis Centers (BKG, DGFI, GSFC, IAA, OPA, and USNO) contributed to the IVS combined products by providing input in the correct format. The rapid solutions contain only R1 and R4 sessions and new data points are added twice a week as soon as the SINEX files of at least five IVS Analysis Centers are available. The SINEX file submissions should not be later than 48 hours after the correlation is completed. A Web page is automatically updated which lists the timeliness of the latest submissions of the R1 and R4 sessions (see <http://ida.bkg.bund.de/IVS/data/timeliness_2.html>).

The results are reported in two EOP time series: the rapid solution file and the quarterly solution file, both in the IVS EOP Exchange format. Solution files are available in two forms: expressed with nutation offsets dX, dY referred to the IAU2006 precession-nutation model excluding free core nutation and with nutation offsets dPsi, dEps referred to the IAU200A precession-nutation model excluding free core nutation.

**CONT11**

The continuous VLBI campaign CONT11 was observed September 15–29, 2011 and involved 13 participating stations on six continents. The goals of CONT11 were to address the discrepancies seen between the theoretical models (ocean tidal and atmospheric) and the observations at the M2 and S1 frequencies as well as between long-term and short-term values of tidal amplitudes. The Tsukuba correlator processed the Onsala–Tsukuba baseline in ultra-rapid mode during the whole CONT11 campaign, thus producing dUT1 results during the ongoing campaign.
Technology Development

During 2011 progress continued towards the goal of a next-generation VLBI system, e-VLBI, and other technical aspects. Some important highlights were:

- The VLBI2010 prototyping work continued with, e.g., test of broadband feed horns and digital backends.
- The Mark 5C VLBI data system is now used routinely at 2 Gbps to a single 8-disk module and will enter service at 4 Gbps in early 2012.
- A 16 Gbps COTS-based Mark 6 system is under development at Haystack Observatory; a successful 16 Gbps VLBI experiment using an early Mark 6 development system was conducted in November 2011. The Mark 6 is projected to enter service in mid/late 2012.
- A number of VLBI2010 data-taking sessions between Westford and NASA/GSFC were undertaken during 2011. Most were recorded onto four Mark 5C units at each station using RDBE backend units as data sources, at an aggregate data rate of 8 Gbps/station. More of the processing of VLBI2010 data continues to be moved from the Mark 4 correlator to the DiFX correlator at Haystack Observatory.
- The DiFX software correlator was prepared for a 16-station VLBI2010 operational mode.

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