CORE Operation Center 2015 & 2016 Biennial Report

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Abstract This report gives a synopsis of the activities of the CORE Operation Center from January 2015 to December 2016. The report forecasts activities planned for the year 2017.

1 Changes to the CORE Operation Center's Program

The Earth orientation parameter goal of the IVS program is to attain precision at least as good as 3.5 μs for UT1 and 100 μas for pole position.

The IVS program, which started in 2002, used the Mark IV recording mode for each session. The IVS program began using the Mark 5 recording mode in mid-2003. By the end of 2007, all stations had been upgraded to Mark 5. Due to the efficient Mark 5 correlator, the program continues to be dependent on station time and media. The following are the network configurations for the sessions for which the CORE Operation Center was responsible in 2015 and 2016:

- IVS-R1 (2015): 52 sessions, scheduled weekly and mainly on Mondays, seven to 14 station networks
- RV (2015): Six sessions, scheduled evenly throughout the year, 13 to 15 station networks
- IVS-R&D (2015): ten sessions, scheduled monthly, six to 11 station networks
- IVS-R1 (2016): 52 sessions, scheduled weekly, seven to 14 station networks
- RV (2016): Six sessions, scheduled evenly throughout the year, 14 to 15 station networks
- IVS-R&D (2016): 13 sessions, scheduled monthly, four to 12 station networks

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CORE Operation Center

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2 IVS Sessions from January 2015 to December 2016

This section describes the purpose of the IVS sessions for which the CORE Operation Center is responsible.

- IVS-R1: During the period of January 2015 through December 2016, the IVS-R1s were scheduled weekly with seven to 14 station networks. During that time, 20 different stations participated in the IVS-R1 network, but there were only seven stations that participated in at least half of the scheduled sessions during 2015 and 2016—Wettzell (52, 52), Ny-Ålesund (48, 45), Katherine (43, 39), Yarragadee (42, 42), Tsukuba (41, 49), Sejong (36, 38), and Fortaleza (32, 41).
  The purpose of the IVS-R1 sessions is to provide weekly EOP results on a timely basis. These sessions provide continuity with the previous CORE series. The "R" stands for rapid turnaround because the stations, correlators, and analysts have a commitment to make the time delay from the end of data recording to the analysis results as short as possible. Participating stations are requested to ship disks to the correlator as rapidly as possible or to transfer the data electronically to the correlator using e-VLBI. The "1" indicates that the sessions are mainly on Mondays. The time delay goal is a maximum of 15 days from the end of data

Table 1 Median (first line) and variability (second line) of EOP formal uncertainties.

Session Type	Num	X-pole (μas)	Y-pole (μas)	UT1 (μs)	DPSI (μas)	DEPS (μas)
R1	52,52,49	43,34,39	44,40,41	2.2,2.1,2.2	82,60,75	32,26,28
		12,10,15	10,6,10	0.6,0.3,0.7	30,26,33	13,11,13
R4	49,50,51	45,36,44	45,40,45	2.3,2.1,2.3	90,70,100	37,27,40
		20,12,20	19,8,14	1.0,0.4,1.0	50,32,45	19,12,20
RV	6	39,38,41	40,41,40	2.1,2.6,2.1	63,77,66	25,30,30
		4,4,5	3,2,6	0.3,0.4,0.3	6,5,19	5,3,5
CONT11	15	27	28	1.3	39	16
		0.7	0.7	0.1	3	1
CONT14	15	28	30	1.4	40	14
		0.7	0.3	0	3	1

For the R1s, R4s, and RVs the values are for 2016, 2015, and 2014 in that order. The number of sessions listed are the number in our operational solution.

recording to the end of correlation. Forty-two percent of the IVS-R1 sessions were completed in 15 or fewer days during 2015. The remaining 58% were completed in 16 to 41 days [16 days (seven), 17 days (five), 18 days (one), 20 days (four), 21 days (two), and 22 days (five), with the remaining six sessions being processed in the range of 25 through 41 days]. During 2016 the percentage of R1 sessions being processed within 15 days increased from 42% to 85%. There were only eight sessions that were completed in 16 to 21 days.

- RV: There are six bi-monthly coordinated astrometric/geodetic experiments each year that use the full ten-station VLBA plus up to five geodetic stations. These sessions are being coordinated by the geodetic VLBI programs of three agencies: 1. USNO performs repeated imaging and correction for source structure; 2. NASA analyzes this data to determine a high accuracy terrestrial reference frame, and 3. NRAO uses these sessions to provide a service to users who require high quality positions for a small number of sources. NASA (the CORE Operation Center) prepares the schedules for the RDV sessions.
- R&D: The purpose of the ten R&D sessions in 2015, as decided by the IVS Observing Program Committee (OPC), was to vet sources for GAIA proposal (RD1501, RD1502, RD1503, RD1504, RD1508, and RD1509) and observe the Chang'E-3 Lander with VLBI (RD1505, RD1506, RD1507, and RD1510).
  The purpose of the R&D sessions in 2016, as decided by the OPC, was to vet sources for GAIA proposal (RD1602, RD1605, RD1606, RD1607, RD1611, and RD1612), observe the Chang'E-3 Lander (RD1601, RD1604, RD1609, and RD1613), evaluate a new strategy for scheduling the INT1 sessions (RD1608 and RD1610), and test the theoretical model for gravitational delay of propagation of light through the field of the Sun. Three extra R&Ds were added during 2016 to ensure that approved proposals were supported.

3 Current Analysis of the CORE Operation Center's IVS Sessions

Table 1 provides the median formal Earth Orientation Parameter (EOP) errors for the R1, R4, and RV for 2014, 2015, and 2016. To give an idea of how much variation there is, the standard deviation of the formal errors for each case is also shown. For comparison, the formal error statistics for the CONT11 and CONT14 are also given. The R1 session formal uncertainties were better in 2015 than in either 2014 or 2016. This is especially clear for polar motion and nutation, where uncertainties were 20-35% better than in 2014 and 2016. This is also reflected in the standard deviations of these errors, which are 30-60% less in 2015. It is most likely due to a more stable global network of stations during 2015.

The RV X-pole, Y-pole, and UT1 formal errors are comparable to the uncertainties of the R1 and R4 experiments. On the other hand, nutation uncertainties are significantly better. This is probably due to the fact that

RV sessions have a larger global network that is more stable from session to session. The formal uncertainties in 2016 were generally better than in 2014–2015.

For comparison, we also included the formal uncertainties for the CONT11 and CONT14 campaigns. These are significantly better than for any of the other networks. Median polar motion uncertainties are at or below 30 μas, and the UT1 uncertainties are only 1.2-1.3 μs or equivalently 18-20 μas.

Table 2 shows EOP biases and WRMS differences with respect to the IGS Finals series for the R1, R4, and RV series and the CONT11 and CONT14 series. To do this calculation, we used the latest operational GSFC EOP series based on the new GSFC 2016a quarterly solution. This solution used the new ITRF2014 reference frame model, which includes Earthquake site models for co-seismic offsets and post-seismic deformation. In doing this, we no longer estimated post-seismic station positions for TSUKUB32 and TIGOCONC. This has the effect of reducing formal uncertainties as well as allowing these stations to contribute fully to EOP estimation. We have found that this leads to better agreement between VLBI and IGS polar motion.

The WRMS differences were computed after removing a bias, but estimating rates does not affect the residual WRMS significantly. Both the R1 and R4 series have better WRMS agreement in X-pole, Y-pole, and LOD for 2015 than for the corresponding full series from 2000 to 2014. The WRMS agreement was clearly better in 2015 than in 2016. The X-pole biases (30-60 μas)and Y-pole biases (110-130 μas) of the R1 and R4 sessions relative to IGS are significant and are likely due to reference frame bias. The biases for the CONT and RV sessions are at a similar level, indicating an overall reference frame bias of the VLBI solution relative to the IGS frame.

In both 2015 and 2016, the WRMS agreement for polar motion was better than for the full period of RV observing since 2000. The RVs have the best agreement with IGS of all the series that have observed over the full period 2000–2014.

For comparison with the 2015–2016 operational R1 and R4 sessions discussed here, we included the statistics for the CONT11 and CONT14 campaigns. These sessions clearly have the best WRMS agreement with IGS. The X-Pole agreement with IGS for CONT14 is significantly better than for CONT11; otherwise, the WRMS differences are comparable. It is expected that the CONT networks will perform better than the operational R1 and R4 sessions because 1) the CONT sessions have better geometry and 2) the CONT networks are unchanged over the period of continuous observing.

4 The CORE Operations Staff

Table 3 lists the key technical personnel and their responsibilities so that everyone reading this report will know whom to contact about their particular question.

5 Planned Activities during 2017

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2017:

- The IVS-R1 sessions will be observed weekly and recorded in Mark 5 mode. There is a strong possibility that mixed mode will be observed and processed. Westford may be added to the network as a Mark 6 station.
- The IVS-R&D sessions will be observed ten times during the year.
- The RV sessions will be observed six times during the year.
- The CONT17 Campaign will be observed with three networks observing simultaneously. There will be a regular legacy station network observing with a frequency sequence of 512 Mbps, a VLBA plus a few legacy stations observing with a frequency sequence of 256 Mbps, and a broadband network. The broadband network will not observe for the full 15 days.

Table 2 Offset and WRMS differences (2016 and 2015) relative to the IGS Finals combined series.

		X-pole		Y-pole		Length Of Day (LOD)	
Session Type	Num	Offset (μas)	WRMS (μas)	Offset (μas)	WRMS (μas)	Offset (μs/d)	WRMS (μs/d)
R1	52,52(770)	40,56(10)	63,62(87)	114,116(136)	81,74(80)	0.4,-1.9(0.5)	13.1,16.0(16.3)
R4	49,50(761)	30,33(-19)	85,56(91)	135,132(141)	99,71(99)	4.7,-2.8(1.5)	18.2,13.4(17.5)
RV	6(102)	63,56(44)	77,111(86)	96,74(142)	68,80(73)	5.7,8.7(0.3)	12.2,9.5 (13.5)
CONT11	15	-10	26	107	29	7.1	5.7
CONT14	15	27	19	175	30	1.9	5.3

Values are for 2016 and then 2015 and in parentheses for the entire series (since 2000) for each session type.

Table 3 Key technical staff of the CORE Operations Center.

Name	Responsibility	Agency
Dirk Behrend	Organizer of CORE program	NVI, Inc./GSFC
Brian Corey	Analysis	Haystack
John Gipson	SKED program support and development	NVI, Inc./GSFC
Frank Gomez	Software engineer for the Web site	Raytheon/GSFC
David Gordon	Analysis	NVI, Inc./GSFC
Ed Himwich	Network Coordinator	NVI, Inc./GSFC
Dan MacMillan	Analysis	NVI, Inc./GSFC
Katie Pazamickas	Maser maintenance	Harris Corporation
Heidi Riesgo	Receiver maintenance	Harris Corporation
David Rubincam	Procurement of materials necessary for CORE operations	NASA/GSFC
Braulio Sanchez	Procurement of materials necessary for CORE operations	NASA/GSFC
Cynthia Thomas	Coordination of the Master Observing Schedule and preparation of observing schedules	NVI, Inc./GSFC