CORE Operation Center 2019–2020 Report

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Abstract This report gives a synopsis of the activities of the Continuous Observation of the Rotation of the Earth (CORE) Operation Center from January 2019 to December 2020. The report forecasts activities planned for the year 2021.

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 were upgraded to Mark 5. Due to the efficient Mark 5 correlator, the program continues to be dependent on station availability and media storage. The following are the network configurations for the sessions for which the CORE Operation Center was responsible in 2019 and 2020:

- IVS-R1 (2019): 53 sessions, scheduled weekly and mainly on Mondays, five to 12 station networks
- RV (2019): Six sessions, scheduled evenly throughout the year, 14 station networks
- IVS-R&D (2019): Ten sessions, scheduled monthly, six to nine station networks

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IVS 2019+2020 Biennial Report

- IVS-R1 (2020): 52 sessions, scheduled weekly and mainly on Mondays, four to 14 station networks
- RV (2020): Six sessions, scheduled evenly throughout the year, 13 to 14 station networks
- IVS-R&D (2020): Ten sessions, scheduled monthly, five to 16 station networks

2 IVS Sessions from January 2019 to December 2020

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

- IVS-R1: During the period of January 2019 through December 2019, the IVS-R1s were scheduled weekly with five to 12 station networks. The last two sessions of 2019 only had five stations because the sessions were scheduled during the holiday season and most of the stations were not available. Seventeen different stations participated in the IVS-R1 network, and 12 stations participated in at least 26 of the 52 sessions. This was a decrease from 2017–2018 when 14 stations participated in at least half of the scheduled sessions.
  During 2020 the IVS-R1 sessions were scheduled differently. John Gipson proposed that we strive for the same level of accuracy as CONT17, for half of the IVS-R1 sessions, over an extended period of time. The Observing Program Committee (OPC) approved the scheduling of a series of 14 station sessions with a bi-weekly cadence using the same observing setup as CONT17. These 14 station IVS-R1 networks were scheduled with the CONT17 data rate of 512 Mbps. The other 26 sessions were

scheduled with networks with fewer than 14 stations and with a 256 Mbps data rate. Unfortunately, due to station problems, mainly due to the COVID-19 pandemic, many of the 14 station networks lost several stations.

Starting with R1704 in 2015 and continuing through the end of 2019, the IVS-R1 sessions were observed with two different frequency sequences: 256 Mbps for the odd sessions and 512 Mbps for the even sessions. This scheduling scheme was changed during 2020 because of the 14 station network sessions. Many of the European VLBI Network (EVN) stations participated in the 14 station IVS-R1 sessions. Therefore, these sessions had to be scheduled during non-EVN periods. There are three EVN periods every year: late February to mid-March, late May to mid-June, and mid-October to early November. The monthly e-VLBI sessions as well as the Global mm-VLBI Array (GMVA) sessions had to be avoided as well. As a result, there is no pattern to which sessions observed with a 256 Mbps or 512 Mbps data rate.

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 recording to the end of correlation. Sixty-four percent of the IVS-R1 sessions were completed in 15 or fewer days during 2019. The remaining 36% were completed in 16 to 24 days [16 days (nine), 17 days (three), 19 days (one), and 20–24 days (six)]. During 2020, the percentage of R1 sessions being processed within 15 days increased from 64% to 86.5%. The remaining 13.5% ranged from 16 to 17 days [16 days (six) and 17 days (one)]. The largest delay in 2019 was 24 days, but in 2020 the largest delay was 17 days.

- RV: There are six bi-monthly coordinated astrometric/geodetic experiments each year that use the full ten station VLBA plus up to seven geodetic stations. These sessions are coordinated by the geodetic VLBI programs of three agencies: 1) USNO performs imaging and correction for source structure; 2) NASA analyzes RDV 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 2019, as decided by the IVS OPC, was to vet Gaia transfer sources. The purpose of the R&D sessions in 2020, as decided by the OPC, was to vet Gaia transfer sources for seven sessions and to observe mixed-mode sessions (mixed S/X and VGOS network) for three of the sessions (RD2005, RD2006, and RD2007) with the primary purpose to tie the S/X and VGOS frames together.

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

Table 1 provides the median Earth Orientation Parameter (EOP) formal errors for the R1, R4, and RDV sessions observed in 2019 and 2020. The standard deviation of the formal errors for each case is also shown to give an indication of the variability of the formal errors.

Median R1 formal uncertainties in 2020 did not differ significantly from those in 2019 (5–15% depending on the component). The variability of the uncertainties was significant, but this was largely due to large outliers corresponding to sessions with small networks. Similarly, the R4 formal uncertainties from 2019 were not significantly different from those in 2020 (7–17%). RDV median formal uncertainties were better in 2020 versus 2019 by about 20%. One of the RDV sessions in 2019 had a network only consisting of the ten VLBA stations with no additional IVS geodetic stations, which had the effect of roughly doubling the formal EOP uncertainties. Table 1 also shows the median uncertainties and RMS variabilities for each session series after removing large outliers.

Table 2 shows EOP biases and WRMS differences with respect to the IGS Finals series for the R1, R4, and RDV series. To do this calculation, we used the latest operational GSFC EOP series based on the GSFC 2020a quarterly solution. This solution used

Table 1 Median and variability of EOP formal uncertainties for 2019 and 2020.

	Num	X-pole (µas)	Y-pole (µas)	UT1 (µs)	X nutation (µas)	Y nutation (µas)
R1	53(49), 52(51)	40 (40), 42(42)	38(37), 32(32)	2.8(2.6), 2.5(2.4)	31(30), 28(27)	31(30), 28(28)
		24(10), 21(13)	25(12), 20(16)	1.4 (0.9), 1.4(1.4)	20 (12), 19(13)	23(12), 19(13)
R4	52(46), 53(51)	43(41), 46(45)	42(37), 38 (36)	2.8(2.6), 2.9 (2.9)	36(32), 33 (30)	35(33), 35 (34)
		42(18), 28 (12)	25(18), 22 (9)	2.6(1.34), 1.1(0.5)	33(20), 26 (13)	27(18), 26 (12)
RDV	6(5), 6	62(55), 44	44(41), 34	2.9(2.5), 2.8	41(35), 26	38(33), 25
		15, 4	10, 3	4.3(0.4),0.3	40(13), 4	36(11), 4

Values are given for 2019 and 2020 in that order. The RMS variabilities are given on the second lines. The values in parentheses were computed by removing sessions with large outliers.

Table 2 Offset and WRMS differences (2019 and 2020) relative to the IGS Finals Combined Series.

		X-pole		Y-pole		LOD	
	Num	Offset (µas)	WRMS (µas)	Offset (µas)	WRMS (µas)	Offset (µs/d)	WRMS (µs/d)
R1	53, 52 (978)	−181, −114 (−110)	62, 76 (98)	17, −43 (23)	69, 61 (85)	−0.4, −0.2 (0.1)	14, 14 (18.4)
R4	52, 53 (978)	−176, −146(−118)	79, 76 (133)	5.3, −35 (24)	76, 73 (98)	−2.1, −1.0 (−0.1)	13, 14 (18.6)
RDV	6, 6 (126)	−214, −139 (−86)	82, 104 (123)	26, 12 (47)	52, 45 (73)	7.6, −0.9 (0.9)	9, 16 (14.5)

Values are for 2019 and then 2020 and in parentheses for the entire series (since 2000) for each session type.

the ITRF2014 earthquake site models for co-seismic offsets and post-seismic deformation. In doing this, we no longer needed to estimate post-seismic station positions for TSUKUB32 and TIGOCONC. This reduces the formal uncertainties as well as allowing these stations to contribute fully to EOP estimation. We 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. The R1 series has somewhat better WRMS agreement with IGS polar motion than the R4 series. The X-pole biases for all of the VLBI series (176 to 214 µas in 2019 and 114 to 146 µas in 2020) are significantly larger than expected from the formal EOP uncertainties and appear to be likely due to overall reference frame bias between the VLBI and IGS, because the biases are all at the same level. On the other hand, the Y-pole biases are much smaller.

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.

Table 3 Key technical staff of the CORE Operation Center.

Name	Responsibility	Agency
Dirk Behrend	Organizer of CORE program	NVI, Inc./GSFC
Brian Corey	Analysis	Haystack
Jay Redmond	Receiver maintenance	Peraton
John Gipson	SKED program support and development	NVI, Inc./GSFC
David Horsley	Software engineer for the Web site during 2019	NVI, Inc./GSFC
Mario Bérubé	Software engineer for the Web site during 2020	NVI, Inc./GSFC
David Gordon	Analysis	NVI, Inc./GSFC
Ed Himwich	Network Coordinator	NVI, Inc./GSFC
Dan MacMillan	Analysis	NVI, Inc./GSFC
Katie Pazamickas	Maser maintenance	Peraton
Lawrence Hilliard	Procurement of materials necessary for CORE operations	NASA/GSFC
Cynthia Thomas	Coordination of master observing schedule and preparation of observing schedules	NVI, Inc./GSFC

5 Planned Activities during 2021

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2021:

- The IVS-R1 sessions will be observed weekly and recorded in Mark 5 mode. The 14 station sessions will be scheduled again for 26 sessions with the 512 Mbps data rate.
- 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 analysis of the sessions will switch to USNO due to personnel changes.