

CORE Operation Center 2021–2022 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 2021 to December 2022. The report forecasts activities planned for the year 2023.

- VGOS-INT-A (2022): 181 sessions, scheduled for most weekdays, two-station networks;
- IVS-INT-00 (2022): 64 sessions, generally scheduled twice a week, two-station networks;
- VGOS-O (2022): 42 sessions, scheduled weekly during the first three quarters, then bi-weekly during the fourth quarter, five- to 10-station networks.

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 $3.5 \mu\text{s}$ for UT1 and $100 \mu\text{s}$ 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 2021 and 2022:

- IVS-R1 (2021): 52 sessions, scheduled weekly and mainly on Mondays, five to 14 station networks;
- VGOS-INT-A (2021): 123 sessions, initially scheduled once to twice weekly, later scheduled up to five times weekly, two-station networks;
- IVS-R1 (2022): 52 sessions, scheduled weekly and mainly on Mondays, six- to 14-station networks;

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IVS 2021+2022 Biennial Report

2 IVS Sessions from January 2021 to December 2022

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

- **IVS-R1:** 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 goal is that the time delay is at most 15 days from the end of data recording to the end of correlation. Eighty-two percent of the IVS-R1 sessions were completed in 15 or fewer days during 2021. The remaining 18% were completed in 16 to 22 days. During 2022, the percentage of R1 sessions being processed within 15 days increased from 82% to 88%. The processing times of the remaining 12% ranged from 17 to 23 days.

During 2021, the IVS-R1 sessions were scheduled the same way as in 2020 with the extended 15-station network for half of the R1 sessions and with a data rate of 512 Mbps. The other half had fewer than 15 stations with a data rate of 256 Mbps. The two types of sessions were scheduled randomly throughout the year. Twenty-one different stations participated in the IVS-R1 network, and 13 stations participated in at least 26 of the 52 sessions. This was an increase from 2019 where 12 stations participated in at least half of the scheduled sessions.

After evaluating the sessions during 2020 and 2021 with the new scheduling scheme, the OPC (with analysis provided by the Coordinating Center) decided to change the scheduling scheme because some of the regular R1 sessions had poorer performance, which was attributed mostly to the network size and geometry of those sessions. During 2022, all the R1 sessions were planned with mostly a network size of 11 to 12 stations to provide reasonable robustness against quality falloff in the event of station dropouts. About six sessions had a network larger than 12 stations. All of the sessions were recorded with a data rate of 512 Mbps.

- **VGOS-INT-A:** VGOS-INT-A observing began in 2021. 123 sessions were scheduled during 2021. The cadence started at one session per week in January 2021, increased to two sessions per week in February 2021, and reached Monday through Friday observing by the start of December 2021. 181 sessions were scheduled during 2022. The network was Kokee-12m and Wettzell-South during both years. The number of sessions increased during 2022 because the Washington Correlator staff learned how to process the VGOS Intensive sessions more efficiently during 2021 and was able to process more sessions during 2022. Near the end of November 2022, Wettzell-South went down for repairs. Onsala-East replaced Wettzell-South in the VGOS-INT-A sessions from mid-December 2022 through late March 2023.
- **IVS-INT-00:** It was decided in January 2022 to add two additional legacy S/X Intensive sessions each week to gain experience with the operational impact of Intensives with a 00:00 UT midpoint. The two Midnight Intensive sessions were scheduled on Mondays and Thursdays at 23:30 UT after normal operations returned at Kokee and Wettzell. The Midnight Intensives were scheduled twice a week

starting March 14, 2022 when Kokee participated in an R1 session. The Midnight Intensive sessions were scheduled to run during an R1 (with Kokee as a participating station) and an R4 session because the station was staffed regularly during those periods.

- **VGOS-OPS:** The sessions include VGOS stations that have been vetted by the Haystack Correlator. The VGOS Operations sessions were scheduled by Haystack personnel until mid-May 2022. The CORE Operation Center took over the scheduling duty with VO2146, which was observed on May 26, 2022. These sessions run simultaneously with the R4 sessions on Thursdays for the most part. The VGOS-OPS sessions were observed with a weekly cadence until November 2022. The cadence changed to once every two weeks to give the correlators a chance to catch up on the backlog of sessions to be processed. During 2022, the VGOS-OPS sessions were processed by five correlators: Haystack, Bonn, Vienna, Washington, and Shanghai. Another evaluation of the cadence will be done in March 2023.

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

The results in Tables 1 and 2 were derived from the most recent GSFC EOP series, which was based on the terrestrial reference frame of the GSFC 2020a quarterly Calc/Solve solution. The solution reference frame

Table 1 Median uncertainties and variability of EOP formal uncertainties for 2021 and 2022. The median uncertainties are shown for 2021 and 2022 in that order. The RMS variabilities of the uncertainties are given on the second lines. For the VGOS sessions, the variabilities after removing one to three large outliers are given in the third line.

	Num	X-pole (μ as)	Y-pole (μ as)	UT1 (μ s)	X nutation (μ as)	Y nutation (μ as)
R1	52, 52	46, 42 14, 6	39, 37 15, 8	2.6, 2.7 1.4, 0.4	31, 26 14, 5	32, 26 12, 6
R4	52, 52	46, 43 14, 11	44, 42 10, 12	2.8, 2.9 0.8, 0.6	36, 29 11, 11	35, 30 13, 11
VG	25, 36	41, 38 27, 24 8, 12	36, 38 14, 23 5, 7	2.0, 2.0 0.6, 1.2 0.3, 0.6	22, 27 7, 16 6, 9	23, 26 9, 14 5, 10

Table 2 Offset and WRMS differences (2021 and 2022) relative to the IGS Finals Combined Series. Values are for the 2021 and then the 2022 R1, R4, and VG series. For the R1 and the R4 series, the values in parentheses are for the entire series since 2002.

Num	X-pole		Y-pole		LOD	
	Offset (μas)	WRMS (μas)	Offset (μas)	WRMS (μas)	Offset (μs/d)	WRMS (μs/d)
R1 52, 52 (1077)	-161, -215 (-119)	92, 126 (97)	34, 125 (29.2)	85, 60 (84)	1.6, -0.5 (0.3)	13.6, 12.8 (14.7)
R4 52, 52 (1078)	-175, -230 (-113)	90, 91 (108)	17, 78 (27)	98, 96 (95)	0.2, 0.7 (0.3)	14.3, 13.7 (16.4)
VG 25, 36	-47, -23	95, 83	-11, -34	135, 97	7.7, -1.3	14.7, 10.9

was constrained to be consistent with ITRF2014 and ICRF3.

Table 1 gives the median Earth Orientation Parameter (EOP) formal uncertainties during 2021 and 2022 for the two operational series R1 and R4. Results are also shown for the VGOS 24-hour sessions that were observed from January 7, 2021 until October 26, 2022. To provide a sense of the variability of the uncertainties, the standard deviation of the uncertainties is shown. Removing one to three large outliers from the VGOS uncertainties reduced these significantly. The R1 and R4 uncertainties are close to those for the preceding two years, 2019–2020.

Table 2 provides the EOP biases and WRMS differences of the R1, R4, and VGOS 24-hour series relative to the IGS Finals series. The X-pole bias offsets from Table 2 in 2021 and 2022 are consistent between the R1 and R4 series, most likely due to a bias between the VLBI and GNSS reference frames. The Y-pole biases are less consistent, but they are probably also due to reference frame biases. The inconsistencies of the VGOS biases with respect to the R1 and R4 biases are most likely caused by the biases between the VGOS station reference frame and the S/X frame. The R1 X-pole WRMS difference in 2022 of 126 μas is due to several large outlier residuals. If the five residuals that are larger than 5-sigma (200 μas) are removed, then this WRMS is reduced to 99 μas, which is more consistent with the WRMS for 2021. The Calc/Solve session analysis for these sessions does not show any obvious reason for the outliers.

Table 3 Intensive EOP median formal uncertainty (σ) and RMS variability.

	Num	UT1 (μs)	
		σ	RMS
Midnight (2022)	60	9.1	5.7
VGOS (2021)	118	14.5	3.8
VGOS (2022)	170	11.7	3.0

GSFC scheduled two additional Intensive series during 2021 and 2022. Sixty midnight Intensives were observed in 2022 with the Kokee–Wetzell baseline from March 17 until December 21. 288 VGOS Intensive sessions were observed with the Wetzell-South and the Kokee-12m antennas during 2021 and 2022. Table 3 provides more details.

4 The CORE Operation Center Staff

Table 4 lists the key technical personnel and their responsibilities so that people reading this report will know whom to contact about their particular questions.

Table 4 Key technical staff of the CORE Operation Center.

Name	Responsibility	Agency
Karen Bayer	CORE OC analysis and preparation of VGOS-INT-A observing schedules	NVI, Inc.
Dirk Behrend	Organizer of CORE program	NVI, Inc.
Mario Bérubé	Software engineer for the Web site	NVI, Inc.
John Gipson	SKED program support and development	NVI, Inc.
Lawrence Hilliard	Procurement of materials necessary for CORE operations (through April 2023)	NASA GSFC
Ed Himwich	Principal Scientist and Field System maintenance	NVI, Inc.
Derek Hudson	Procurement of materials necessary for CORE operations (starting in May 2023)	NASA GSFC
Dan MacMillan	CORE OC analysis	NVI, Inc.
Katie Pazamickas	Maser maintenance	Peraton
Jay Redmond	Receiver maintenance	Peraton
Cynthia Thomas	Coordination of master observing schedule and preparation of most observing schedules	NVI, Inc.

5 Planned Activities during 2023

The CORE Operation Center will continue to be responsible for the following IVS sessions during 2023:

- The IVS-R1 sessions will be observed weekly and recorded in Mark 5 mode. The eight- to 14-station sessions will be scheduled for 52 sessions with the 512 Mbps data rate. The sessions will have both S/X and VGOS stations (mixed-mode) participating. There were two mixed-mode test sessions scheduled during 2022. The last of the two sessions was successfully correlated within 15 days.
- The VGOS-OPS sessions will be observed every other week for the first quarter of the year. The cadence will be re-evaluated during March 2023 to determine if the cadence can return to weekly.
- The determining factor will be that correlators process the VGOS-OPS sessions within 30 days. The cadence will remain two-weekly until the VGOS-OPS sessions can be completed within 30 calendar days.
- The VGOS-INT-A sessions will continue to be scheduled Monday through Friday every week, with Kokee-12m and Wettzell-South. Onsala-East will be the backup station for Wettzell-South.
- The IVS-INT-00 sessions (Midnight Intensives) will continue to be scheduled with the Kokee-Wettzell baseline. The sessions will be observed on the Mondays when Kokee is a participating station in the R1 sessions and on the Thursdays when Kokee participates in the R4 sessions.