

CORE Operation Center 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 2023 to December 2024. The report forecasts activities planned for the year 2025.

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 μ s for UT1 and 100 μ 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 2023 and 2024:

- **IVS-R1 (2023):** 52 sessions, scheduled weekly and mainly on Mondays, six-to-14-station networks
- **VGOS-OPS (2023):** 24 sessions, scheduled bi-weekly on Wednesday or Thursday, five-to-10-station networks
- **VGOS-INT-A (2023):** 227 sessions, scheduled daily during the weekdays, mainly two-station networks

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IVS 2023+2024 Biennial Report

works, but eight sessions had three-to four-station networks

- **IVS-INT-00 (2023):** 97 sessions, scheduled at least once a week and twice when Kokee was in the R1 network, two-station networks
- **IVS-R1 (2024):** 53 sessions, scheduled weekly and mainly on Mondays, three-to-15-station networks
- **VGOS-OPS (2024):** 31 sessions, scheduled three times a month, mainly on Wednesdays, five-to-12-station networks
- **VGOS-INT-A (2024):** 227 sessions, scheduled daily during the weekdays, two-station networks
- **IVS-INT-00 (2024):** 123 sessions, scheduled at least once a week and other times when Kokee was in the network, two-station networks

2 IVS Sessions from January 2023 to December 2024

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

- **IVS-R1:** During 2023 and 2024, 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. The sessions had both S/X and VGOS stations (mixed-mode) participating. All of the sessions were recorded with a data rate of 512 Mbps.

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. Table 1 shows the processing latency for the R1 sessions.

Table 1 R1 and VGOS-OPS (VO) processing latency in 2023 and 2024. Columns 2 and 3 show the percentage of sessions for each session type and year that were processed within a certain number of days. The R1 2024 session values do not include one session that was processed by a different correlator and was completed in 98 days.

Session type	% Sessions	Latency range (days)
R1 (2023)	77.0% *	15 or fewer
	23.0%	16 to 27
R1 (2024)	85.0%	15 or fewer
	15.0%	16 to 21
VO (2023)	41.7%	30 or fewer
	25.0%	30+ to 40
	8.3%	40+ to 50
	12.5%	50+ to 60
VO (2024)	41.9%	30 or fewer
	22.6%	30+ to 40
	12.9%	40+ to 50
	12.9%	50+ to 60
	9.7%	67 to 162

* This decreased from 88% in 2022.

- VGOS-INT-A:** 227 sessions were scheduled during 2023 and 2024. The cadence increased to five sessions per week, observing on Monday through Friday. The main network was Kokee-12m and Wettzell-South during both years. But, near the end of November 2022, Wettzell-South went down for repairs, so Onsala-East replaced Wettzell-South in the VGOS-INT-A sessions starting mid-December 2022 through late March 2023. Other antennas were occasionally tagged along for special purposes during 2023: Onsala-West (five times) and the McDonald 12-m antenna (one time).
- IVS-INT-00:** The Midnight Intensive sessions continued to be scheduled during 2023 and 2024 with 97 sessions and 123 sessions, respectively. The Midnight Intensives were scheduled twice a week to run during an R1 (with Kokee as a participating station) and an R4 session because the station was staffed regularly during those periods. During 2024, the Midnight Intensives were scheduled when Kokee participated in a session.
- VGOS-OPS:** The sessions include VGOS stations that have been vetted by the Haystack Correlator. During 2023, the VGOS-OPS sessions observed simultaneously with another session that had Kokee in its network on Wednesdays or Thursdays with a start time of 18:00 UT. During 2024, the VGOS-OPS sessions were observed only on Wednesdays at 00:00 UT. The cadence was still three times a month. The cadence will not increase until most of the VGOS-OPS sessions can be processed consistently in 30 days or fewer at all six correlators: Bonn, Haystack, Vienna, Washington, Wettzell, and Shanghai. In 2023, 24 VGOS-OPS sessions were scheduled and 31 sessions were scheduled in 2024. Table 1 shows the processing latency for the VGOS-OPS sessions.

3 Analysis of the CORE Operation Center’s IVS Sessions

This section analyzes the 2023 and 2024 performance of the session types scheduled by the CORE Operation Center: the IVS-R1 (“R1”), VGOS-OPS (“VO”), VGOS-INT-A, and IVS-INT-00 (“Midnight Intensive”) sessions. Analysis of the IVS-R4 (“R4”) sessions scheduled by USNO is also included for comparison to the R1 sessions. The results in Tables 2 and 3 were derived from the most recent GSFC EOP series, gsf2023a, which was based on the terrestrial reference frame of the GSFC 2023a quarterly Calc/Solve solution. The solution reference frame was constrained to be consistent with ITRF2014 and ICRF3.

Table 2 gives the median Earth Orientation Parameter (EOP) formal uncertainties during 2023 and 2024 for the R1 and R4 operational series. Results are also shown for the VGOS-OPS (VO) 24-hour sessions that were observed during those years. To provide a sense

Table 2 Median uncertainties and variability of R1, R4, and VGOS-OPS (VO) EOP formal uncertainties for 2023 and 2024. The median uncertainties are shown in line 1. The RMS variabilities of the uncertainties are shown in line 2. In each case, 2023 and 2024 values are shown separated by a comma and in chronological order. UT1 represents UT1–UTC.

	Num Sessions	X-pole (μs)	Y-pole (μs)	UT1 (μs)	X nutation (μs)	Y nutation (μs)
R1	51, 53	44.0, 52.0	45.0, 52.0	3.0, 3.6	34.0, 39.0	34.0, 39.0
		13.3, 26.0	9.4, 90.7	0.8, 4.7	13.5, 22.8	11.3, 22.3
R4	52, 52	48.0, 50.5	49.5, 55.0	3.0, 3.3	40.0, 39.5	41.0, 41.5
		17.6, 21.4	10.4, 21.2	0.7, 1.5	11.1, 19.1	13.1, 20.2
VO	21, 31	47.0, 42.0	43.0, 40.0	2.2, 2.3	30.0, 25.0	29.0, 24.0
		12.6, 6.9	6.3, 5.6	0.6, 0.4	11.0, 6.9	11.0, 7.3

Table 3 Offset and WRMS differences (2023 and 2024) relative to the IGS Finals Combined Series (April 16, 2025 download). Values are for the 2023 and then the 2024 R1, R4, and VGOS-OPS (VO) series. For the R1 and the R4 series, the values in parentheses are for the entire series since 2002.

	Num Sessions	X-pole		Y-pole		LOD	
		Offset (μs)	WRMS (μs)	Offset (μs)	WRMS (μs)	Offset ($\mu\text{s}/\text{d}$)	WRMS ($\mu\text{s}/\text{d}$)
R1	51, 53 (1181)	−143, −199 (−44)	93, 134 (96)	67, 61 (19)	60, 152 (87)	−5.3, 3.6 (0.7)	20.2, 21.9 (15.0)
R4	52, 52 (1182)	−126, −135 (−53)	176, 90 (111)	71, 47 (21)	90, 85 (93)	3.1, −7.2 (0.4)	17.1, 15.7 (16.5)
VO	21, 31	12, 44	148, 187	−74, −95	172, 176	6.4, 4.5	6.4, 12.8

of the variability of the uncertainties, the standard deviation of the uncertainties is also shown.

In Table 2, the R1 and R4 2023 and 2024 median values are comparable, although the 2024 values tend to be larger. The R1 and R4 2023 and 2024 median values are higher than the 2021 and 2022 values, with the greatest increase coming from the 2024 values. The R1 and R4 2023 and 2024 variability values are generally comparable. The R1 and R4 2023 variability is generally comparable to the 2021 and 2022 variability, but the 2024 variability is higher than the variability for the three previous years. We have not tried to determine why the 2024 median values and variability are higher than in previous years. But the R1 2024 Y-pole variability is reduced from 90.7 μs to 17.5 μs if two outliers with values of 206 μs and 698 μs are removed. This is much more in line with the other variability values.

In Table 2, the VGOS-OPS 2024 median values are lower than the 2023 median values for all parameters except UT1–UTC, and the VGOS 2024 variability is lower than the 2023 variability for all five parameters. The VGOS-OPS 2023 and 2024 median values are generally higher than the 2021 and 2022 median values, but the 2023 and 2024 variability values are

generally lower than the 2021 and 2022 variability values.

Table 3 provides the EOP biases and WRMS differences of the R1, R4, and VGOS-OPS 24-hour series relative to the IGS Finals series. The R1 and R4 X-pole bias offsets are reasonably consistent, as are the R1 and R4 Y-pole bias offsets. The exception is the largest bias, the R1 2024 X-pole bias of −199 μs . The general consistency of the X-pole and Y-pole bias offsets is probably due to a bias between the VLBI and GNSS reference frames [1]. The VGOS-OPS X-pole biases are very different from the R1 and R4 X-pole biases, although the Y-pole biases and the LOD biases of the three series are more consistent. A possible explanation for the differences between the VGOS-OPS X-pole biases and the R1 and R4 X-pole biases is that there are biases between the S/X and VGOS station reference frames as mentioned in [1].

Outliers contributed to the large bias offsets and WRMS values in Table 3. For example, removal of two VGOS-OPS 2024 outliers greater than 300 μs decreased the VGOS-OPS 2024 X-pole WRMS, the largest WRMS, from 187 μs to 159 μs . But removal of four R1 2024 outliers greater than 300 μs had less of an effect on the R1 2024 X-pole bias, the largest bias, only decreasing the original bias from −199 μs

to $-186 \mu\text{s}$. We have not analyzed the outliers to try to identify their cause.

The CORE Operation Center scheduled two Intensive series during 2023 and 2024. 209 Midnight Intensive (IVS-INT-00) sessions were observed with the Kokee–Wetzell baseline. 424 VGOS-INT-A Intensive sessions were observed, generally with the Wetzell-South antenna and the Kokee-12m antenna. Table 4 breaks down the number of sessions by year, and it reports the median UT1–UTC formal uncertainties and the RMS of the uncertainties for each year and session type.

Table 4 2023 and 2024 IVS-INT-00 (Midnight) and VGOS-INT-A Intensive UT1–UTC median formal uncertainties (σ) and RMS variability of the uncertainties (μs).

	Num Sessions	UT1 (μs)	
		σ	RMS
Midnight (2023)	90	11.4	15.3
Midnight (2024)	119	9.0	8.6
VGOS-INT-A (2023)	217	10.6	11.1
VGOS-INT-A (2024)	207	10.9	3.3

4 The CORE Operations Staff

Table 5 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 2025

The CORE Operation Center will continue to be responsible for scheduling the following IVS sessions during 2025:

- 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.
- The VGOS-OPS sessions will be observed three times a month. The cadence will be re-evaluated

Table 5 Key technical staff of the CORE Operation Center.

Name	Responsibility	Agency
Karen Baver	Analysis and preparation of VGOS-INT-A schedules	NVI, Inc.
Dirk Behrend	Organizer of CORE program	NVI, Inc.
Mario Bérubé	Software engineer for the web site	NVI, Inc.
Sergei Bolotin	Analysis	NVI, Inc.
Jeffrey Dorman	Procurement of materials necessary for CORE operations	NASA/GSFC
John Gipson	SKED program support and development	NVI, Inc.
Ed Himwich	Principal Scientist and Field System maintenance	NVI, Inc.
Dan Hoak	Analysis	Haystack
Katie Pazamickas	Maser maintenance	Peraton
Jay Redmond	Receiver maintenance	Peraton
Cynthia Thomas	Coordination of master observing schedule and preparation of R1, IVS-INT-00, and VGOS-OPS observing schedules	NVI, Inc.

after the six correlators can process the data in 30 days or less.

- The VGOS-INT-A sessions will continue to be scheduled up to five times a week (Monday through Friday) with Kokee-12m and Wetzell-South. Wetzell-North will tagged along to the sessions starting in January 2025 until enough sessions (60) have been observed to verify that the Kokee-12m to Wetzell-North baseline is viable. This will allow Wetzell-North to be the backup station for Wetzell-South when Wetzell-South goes down for repairs during the middle of 2025.
- The IVS-INT-00 (Midnight) Intensives will continue to be scheduled with the Kokee–Wetzell baseline. The Midnight Intensives will be observed whenever Kokee participates in a 24-hour session.

References

1. Cynthia Thomas and Daniel MacMillan. “CORE Operation Center 2021–2022 Report”, in IVS 2021+2022 Biennial Report, pp. 119–122, edited by K. L. Armstrong, D. Behrend, and K. D. Baver, NASA/TP-20230014975, 2023.