Network Coordinator Report

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Abstract This report includes an assessment of the network performance in terms of lost observing time for calendar years 2015 and 2016. Compared to previous years, the observing time loss has significantly increased, mainly due to broadband testing, long delays in repairs, and bad weather. Overall, the observing time loss was about 18% in 2015 and 21% in 2016. Despite higher statistics, the network performance was for the most part very good. The most significant identified cause of loss in 2015 was the scheduled broadband testing at Westford, which accounted for 91 station days being missed or 4% of total loss. The data loss of 2016 was dominated by maintenance and broadband testing accounting for 192 station days or 10% of total loss. RFI in S-band continues to be a significant source of data loss. A table of relative incidence of problems with various subsystems is presented. The report also presents analyses on station SEFDs and antenna slewing models using the 2015–2016 data set.

1 Network Performance

The network performance for the actual observing time is about the same as previous years. The apparent increase from previous years is due to our way of reporting statistics. We included stations that did not observe and were not included in correlation reports, resulting in an additional loss of 5% in 2015 and 10% in 2016. Broadband testing and antennas being down for repairs or maintenance accounted for most of this increase in data loss. RFI in S-band continues to be an important source of loss given that correlators dropped over 2.5% of recorded channels. Bad weather affected stations in many ways. Many hours were lost by antennas being stowed due to high winds or typhoons. Bad weather added unexpected delays to the maintenance of antennas and equipment. Some antennas were also damaged during storms. Antenna problems accounted for 9.3% of loss in 2016 due to long delays in delivering unique parts. Recording system problems were rare, and less than 1% of data were lost, mainly due to bad modules. Overall, operator performance was very good including reacting quickly to problems. Some problems due to operators happened, mainly at stations observing few geodetic experiments.

This network performance report is based on correlator and analysis reports from all 24-hour experiments correlated as of February 15, 2017. Experiments correlated at the VLBA were also included when data analysis reports provided relevant information on reasons for data loss. The 2015 data set is almost complete, because 227 of the 235 observed experiments, 97%, have been correlated. The average number of stations per experiment is 9.0 in 2015. The list of non-correlated experiments included four R&D, three CRDs, and one T2. The 2015 data set includes 1,288,881 dual frequency observations. About 75% of these observations were successfully correlated, and over 70% of them were used in the final IVS Analysis Reports. As of the date of submission of this report, only 166 of the 192 observed experiments, 86%, were correlated for 2016. The average number of stations per experiment is 10.7 in 2016. A total of 26 T2, R&D, OHG, CRDS, APSG, AOV, AUA, AUG, and HOB experiments were not correlated yet. The 2016 data set includes 1,046,001 dual

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frequency observations. About 76% of these observations were successfully correlated and over 70% of them were used in the final IVS Analysis Reports. Table 1 summarizes the data set used for the 2015–2016 network performance report. The data in parentheses represent the station days processed by the correlators. These values are used to compute loss in actual observing time.

Table 1 Data sets used for the 2015–2016 network performance report.

Year	Experiments	Station days	Obs	Correlated	Used
2015	227	2048 (1945)	1288881	75%	70%
2016	166	1775 (1593)	1046001	76%	70%

An important point to understand is that the network performance is expressed in terms of lost observing time. This is straightforward in cases where the loss occurred because operations were interrupted or missed. However, in other cases, it is more complicated to calculate. To handle this, a non-observing time loss is typically converted into an equivalent lost observing time by expressing it as an approximate equivalent number of recorded bits lost. As an example, a warm receiver will greatly reduce the sensitivity of a telescope. The resulting performance will be in some sense equivalent to the station having a cold receiver but observing for (typically) only one-third of the nominal time and therefore recording the equivalent of only one-third of the expected bits. In a similar fashion, poor pointing can be converted into an equivalent lost sensitivity and then equivalent fraction of lost bits. Poor recordings are simply expressed as the fraction of total recorded bits lost.

Using correlator reports, an attempt was made to determine how much observing time was lost at each station and why. This was not always straightforward to do. Sometimes the correlator notes do not indicate that a station had a particular problem, while the quality code summary indicates a significant loss. Reconstructing which station or stations had problems—and why—in these circumstances does not always yield accurate results. Another problem was that it is hard to determine how much RFI affected the data, unless one or more channels were removed and that eliminated the problem. It can also be difficult to distinguish between BBC and RFI problems. For individual station days, the results should probably not be assumed to be accurate at better than the 5% level.

The results here should not be viewed as an absolute evaluation of the quality of each station's performance. As mentioned above, the results themselves are only approximate. In addition, some problems such as weather and power failures are beyond the control of the station. Instead the results should be viewed in aggregate as an overall evaluation of what percentage of the observing time the network is collecting data successfully. Development of the overall result is organized around individual station performance, but the results for individual stations do not necessarily reflect the quality of operations at that station.

Because stations typically observe with more than one other station at a time, the average lost observing time per station is not equal to the overall average loss of VLBI data. Under some simplifying assumptions, the average loss of VLBI data is roughly twice the average loss of station observing time. This approximation is described in the Network Coordinator's section of the IVS 2001 Annual Report. The 2015–2016 results (Table 3) do not agree with this rough approximation. When reporting losses on single baseline, single frequency (S or X) observations, the correlators use stations included in the schedule file only.

The estimated ratios are affected by the high number of stations that were not included in the correlator reports for 2015 and 2016. For a better comparison with the previous year, corrected values are being used. The corrected statistics removed the non-correlated station days from the overall observing time. As shown in Table 2, using corrected statistics, the overall observing time loss is reduced to about 14% in 2015 and 12% in 2016. These corrected numbers are more in agreement with the 25%-24% non-correlated data. This corrected time loss shows the importance of quickly informing the IVS Coordinating Center when a station cannot participate in an experiment. In such a situation, a schedule is generated without the missing station. If these stations have been used to generate schedules, the successfully correlated data would have been less than 65% instead of the reported 75% and 76% for 2015 and 2016 respectively.

For 2015–2016, the actual percentage of dual frequency data that was not included by the analysts was approximately 30%. This is even larger (by approximately 5%) than the single baseline observations reported lost by the correlator. It is expected that this

Table 2 Major sources of losses for 2015–2016.

Year	Loss	Antenna	Miscellaneous	RFI
2015	18.2%	3.6%	4.7%	1.6%
2015 (corr)	13.8%	2.3%	1.3%	1.7%
2016	21.2%	9.2%	5.2%	2.3%
2016 (corr)	11.8%	3.2%	0.9%	2.5%

Table 3 Lost observing time. The percentage applies to a subset of the 1999–2000 experiments. Percentages for 2010 and 2011 are omitted but should be 10-20%.

Year	Percentage
1999-2000*	11.8
2001	11.6
2002	12.2
2003	14.4
2004	12.5
2005	14.4
2006	13.6
2007	11.4
2008	15.1
2009	21.5
2012	12.3
2013	16.2
2014	11.9
2015	18.2
2016	21.2

number should be higher both because of the dual frequency nature of the final observable and the fact that analysts use additional criteria beyond what is discussed here to decide when to exclude observations. However, it means in effect that only about 70% of the observations we attempted to collect were useful. This number is lower than previous years. This could be explained by baselines that were deselected because too many channels were dropped due to RFI. In addition, most of the WETTZELL-WETTZ13N observations were successfully correlated, but analysts rejected most of the data from that baseline. The rejection of this baseline accounted for about 5% of unused data for experiments that included these two stations at the same time.

Table 3 shows higher observing time loss for 2015–2016 when compared to previous years. As previously discussed, the 2015–2016 observing time loss was highly affected by broadband testing and by delays in repairing antennas or masers. Because these problems were known in advance, more than 103 station days in 2015 and 192 in 2016 were not included in schedules, thereby not affecting the correlation percentage. When removing these station days from the assessment, the corrected observing losses (Table 2) are comparable with previous years.

An assessment of each station's performance is not provided in this report. While individual station information was presented in some previous years, this practice seemed to be counter-productive. Although many caveats were provided to discourage people from assigning too much significance to the results, there was feedback that suggested that the results were being over-interpreted. Additionally, some stations reported that their funding could be placed in jeopardy if their performance appeared bad, even if it was for reasons beyond their control. Last and least, there seemed to be some interest in attempting to "game" the analysis methods to apparently improve individual station results. Consequently, only summary results are presented here. Detailed results are presented to the IVS Directing Board. Each station can receive its own results by contacting the Network Coordinator (Ed.Himwich@nasa.gov).

For the purposes of this report, the stations were divided into two categories: **large N**: those that were included in 24 or more network experiments among those analyzed here and **small N**: those less than 24. The distinction between these two groups was made on the assumption that the results would be more meaningful for the stations with more experiments. Due to the high number of non-correlated station days, this analysis uses corrected statistics for 2015-2016 as shown in Table 4.

The average observing time loss from the large N group was much smaller than the average from the small N group, 12% versus 30% in 2015 and 10% versus 28% in 2016. The large N group accounts for more than 90% of the station days, so the large N group is dominant in determining the overall performance.

There are 23 and 22 stations in the large N group for 2015 and 2016 respectively. This is a significant increase from the 17 stations in this category in 2014. From the 2015 large N group, 11 stations observed in 49 or more experiments, and ten successfully collected data for approximately 92% or more of their expected observing time. The 2016 large N group had 12 stations that observed in 49 or more experiments, and nine collected 92% or more of their expected observing time.

Only one station from the 2015 large N group collected less than 70% of the scheduled data. No stations from the 2016 large N group collected less than 70% of the scheduled time. This is an improvement from previous years.

There are 23 and 21 stations in the small N group of 2015 and 2016 respectively. The range of lost observing time for stations in this category was 0%—100%. The median loss was approximately 25% in 2015 and 27% in 2016, a little worse than 2014 with 22%.

Table 4 Group analysis for 2015–2016. The average column shows the average lost observing time. The median column shows the median lost observing time. The 92% column shows the number of stations that observed in 49 or more experiments and successfully collected data for approximately 92% or more of their expected observing time.

	Large N				Small N		
Year	**Count**	**Average**	**Median**	**92%**	**Count**	**Average**	**Median**
2015	23	12.5%	11.7%	10	23	30.0%	24.9%
2016	22	10.8%	9.7%	9	21	27.7%	27.2%

The losses were also analyzed by sub-system for each station. Individual stations can contact the Network Coordinator (Ed.Himwich@nasa.gov) for the sub-system breakdown (and overall loss) for their station. A summary of the losses by sub-system (category) for the entire network is presented in Table 5. This table includes results since 2003 sorted by decreasing loss in 2016.

The categories in Table 5 are rather broad and require some explanation, which is given below.

Antenna This category includes all antenna problems, including mis-pointing, antenna control computer failures, non-operation due to wind through 2013, and mechanical breakdowns of the antenna. It also includes scheduled antenna maintenance. Wind stows were moved to Miscellaneous for 2014.

Clock This category includes situations in which correlation was impossible because the clock offset either was not provided or was wrong, leading to “no fringes”. Maser problems and coherence problems that could be attributed to the Maser are also included in this category. For example, the phase instabilities reported for Kokee in previous year were included in this category. DBBC clock errors are included in this category.

Miscellaneous This category includes problems that do not fit into other categories, mostly problems beyond the control of the stations, such as power (only prior to 2012), (non-wind) weather through 2013, wind stows (moved here from the Antenna category starting in 2014), cables, scheduling conflicts at the stations, and errors in the observing schedule provided by the Operation Centers. For 2006 and 2007, this category also includes errors due to tape operations at the stations that were forced to use tape because either they did not have a disk recording system or they did not have enough media. All tape operations have since ceased. This category is dominated by weather and scheduling conflict issues. Westford VGOS testing, 28 station days, has been assigned to Miscellaneous for the year, 2014.

Operations This category includes all operational errors, such as DRUDG-ing the wrong schedule, starting late because of shift problems, operator (as opposed to equipment) problems changing recording media, and other problems.

Power This category includes data lost due to power failures at the sites. Prior to 2012, losses due to power failures were included in the Miscellaneous category.

Rack This category includes all failures that could be attributed to the rack (DAS), including the formatter and BBCs. There is some difficulty in distinguishing BBC and RFI problems in the correlator reports, so some losses are probably mis-assigned between the Rack category and the RFI category.

Receiver This category includes all problems related to the receiver, including outright failure, loss of sensitivity because the cryogenics failed, design problems that impact the sensitivity, LO failure, and loss of coherence that was due to LO problems. In addition, for lack of a more clearly accurate choice, loss of sensitivity due to upper X-band Tsys and roll-off problems are assigned to this category.

Recorder This category includes problems associated with data recording systems. Starting with 2006, no problems associated with tape operations are included in this category.

RFI This category includes all losses directly attributable to interference, including all cases of amplitude variations in individual channels, particularly at S-band. There is some difficulty

Table 5 Percentages of observing time lost by sub-system. Percentages for 2010 and 2011 were not calculated.

Sub-System	2016	2015	2014	2013	2012	2009	2008	2007	2006	2005	2004	2003
Antenna	43.4	20.0	14.8	39.6	18.1	29.4	19.2	34.6	19.0	24.4	32.9	17.8
Miscellaneous	24.3	25.8	35.1	9.4	6.9	15.3	12.8	7.6	18.0	8.0	8.0	6.0
RFI	10.7	8.6	13.2	6.4	11.8	5.9	14.8	10.4	11.6	6.2	5.0	9.3
Unknown	4.9	6.3	1.3	5.7	14.2	14.2	17.7	14.9	4.0	3.3	10.1	12.6
Rack	3.0	12.8	12.0	19.5	21.8	6.6	8.7	11.4	16.3	5.1	6.8	5.0
Receiver	2.8	10.1	13.9	7.7	11.7	18.6	13.8	14.9	20.8	24.2	18.0	25.2
Clock	2.5	0.9	0.2	3.5	1.8	1.9	0.5	0.3	4.9	14.5	0.5	3.4
Operations	2.3	5.9	4.1	2.5	2.0	1.2	2.3	0.0	2.0	4.7	6.1	3.6
Recorder	2.2	6.6	4.1	3.3	5.7	2.9	4.1	4.6	3.3	8.9	11.1	10.9
Power	1.9	1.2	0.4	2.1								
Shipping	1.6	1.3	0.0	0.9	3.6	4.0	5.4	1.0	0.0	0.2	1.4	6.1
Software	0.4	0.7	0.17	1.0	0.3	0.1	0.1	0.4	0.1	0.5	0.1	0.1

in distinguishing BBC and RFI problems in the correlator reports, so some losses are probably mis-assigned between the Rack category and the RFI category.

Shipping This category includes all observing time lost because the media were lost in shipping or held up in customs or because problems with electronic transfer prevented the data from being correlated with the rest of the experiment's data.

Software This category includes all instances of software problems causing observing time to be lost. This includes crashes of the Field System, crashes of the local station software, and errors in files generated by DRUDG.

Unknown This category is a special category for cases where the correlator did not state the cause of the loss and it was not possible to determine the cause with a reasonable amount of effort.

Some detailed comments on the most significant issues for this year's data loss are given below.

- The two largest source of data loss for 2015-2016 are Antenna and Miscellaneous. The Antenna subsystem is mainly due to repairs at antennas that were delayed by months waiting for replacement parts. The high values of Miscellaneous are highly affected by broadband testing at a few stations and maser maintenance at Katherine and Yarragadee.
- RFI due to commercial systems continues to be an important factor of data loss, mostly in S-band. Hobart26, Sejong, Matera, and Zelenchukskaya are losing over 10% of their data to RFI. Fortaleza is still affected by RFI with an average loss of 8%.
- The proportion of losses attributed to Unknown, 4.9% in 2015 and 6.3% in 2016, have increased from 2014. Lack of communication (no logs, no emails) in some occasions made it difficult to categorize the loss.

Overall, while the network operated well for the most part, there are a few notable issues (in alphabetical order of station), for stations that lost more than 120 total observing hours regardless of the number of scheduled experiments for 2015–2016.

- Fortaleza had a significant cryogenic problem that was fixed in mid 2015 by replacing its compressor. Affected by RFI.
- Hart15m replaced an antenna motor gear box assembly damaged during a storm.
- Hobart12 broadband testing occurred in 2016. Multiple wind stows.
- Hobart26 was affected by RFI. Conflict with LBA. Antenna and rack failure.
- Katherine12 had DBBC and maser issues. Some wind stows.
- Kokee replaced an antenna azimuth bearing in 2016.
- Matera continued to have serious RFI.
- Medicina had required antenna maintenance and recorder issues as well as RFI.
- Ny-Ålesund had antenna azimuth gear box problems. Affected by bad weather.
- Sejong had serious RFI issues. Some non-detections due to equipment failure.
- Seshan had antenna maintenance.
- Svetloe had antenna maintenance and repairs.

- Urumqi had antenna maintenance and problems with media delivery.
- Warkworth had antenna elevation problems.
- Westford lost all scheduled experiments due to VGOS testing.
- Yarragadee had maser maintenance.

2 SEFD

When preparing schedules, it is important to have a good knowledge of the stations' SEFDs to compute the observation time for obtaining the expected SNR for each scan. These SEFD values were usually provided by stations to be included in the scheduling catalog.

After each experiment, the analysts compute effective SEFDs for each station using SNRANAL. The software, developed by John Gipson and maintained by Dan MacMillan, uses normalized SNR values determined at the time of correlation to compute S and X SEFDs for a specific experiment. Stations should look at the SNR summary file by using the specific link on every experiment Web page. These values are also published in the performance matrix page of each experiment. For example, the 2016 station performance for all stations can be found at https://lupus.gsfc.nasa.gov/sess/sesshtml/2016/station-perf16.html.

R1 and R4 SEFD results for 2015–2016 were used to compute average SEFDs for 30 stations. See Figure 1 for an example of results. The difficulty was to detect bad experiments that could bias the results. Data from stations observing with a warm receiver or having tracking problems were rejected from the analysis.

The computed SEFDs were compared with published values and flagged when differences were more than 20%. Of the 30 stations, eight stations have better SEFDs for X-band, and three for S-band, than published. On the other hand, 13 stations have higher SEFDs in X-band and nine in S-band.

For the moment, the software is mainly used as a tool to detect performance issues at stations, but two stations were updated to reflect the significant improvements in computed SEFD values. Further analyses are still needed, because many stations have large variations in SEFD values as shown in Figure 1.

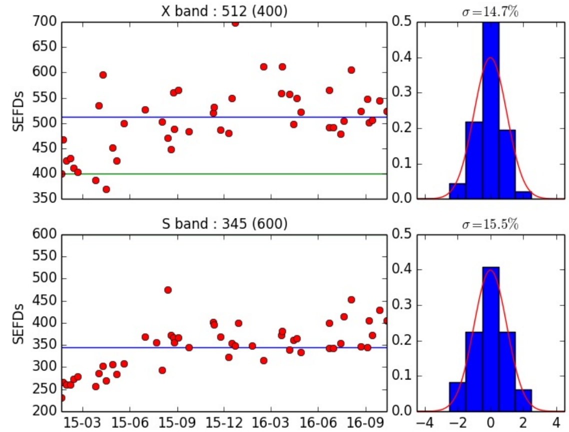

Fig. 1 SEFD example.

3 Antenna Slewing Models

Station log files are essential in analyzing station performance after each experiment. It was noticed that many stations had constant error messages showing they were still slewing at the beginning of PREOB or recording. Logs were showing that antennas could be late by more than 20 seconds in the normal operational mode.

The observing schedule uses a simple slewing model, a rate and offset for each axis, to determine when the antenna will arrive at the next source. If these models are wrong, the antenna does not arrive in time or waits longer than it needs to. Having precise slewing models is essential for optimum schedules. The rate represents the slewing speed in degrees per second of the antenna when at full speed. The offset is a constant value that includes the time to initiate the change of source, the time to reach maximum speed, and the time to slow down and lock on the source.

Some stations have turned on FLAGR in their FS so that antenna source acquisition information is available in their logs. Using this information, along with antenna and source positions, it is possible to estimate a slewing rate and an offset for azimuth and elevation.

Starting and arriving times were extracted from the 2015–2016 logs for 19 stations. The distances to travel in azimuth and elevation were generated by SKED. The new models were computed using a least square fit. The software to do this analysis for Azimuth/Elevation antennas was initially developed by the 2016 NVI interns — Lina Olandersson, Erik Thorsell, and Simon Strandberg. Mario Bérubé included statistical analysis to improve data selection.

See Figure 2 as an example of a computed versus a published slewing model for azimuth. In this case, the antenna is slower than expected by four deg/sec with a constant offset of nine seconds. The original model had no offset. Of the 19 stations analyzed, nine were moving slightly faster than scheduled. Stations with significant changes will be updated in the catalog in early 2017.

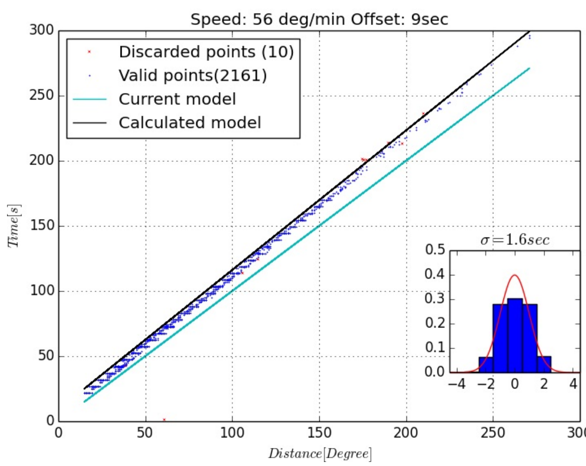

Fig. 2 Azimuth slewing model.

4 New Stations

There are prospects for new stations and antenna upgrades on several fronts. These include (in approximate order of how soon they will start regular observations):

- There are several antennas that started operational VGOS testing during the period of this report. These include: Ishioka (Japan), Kokee Park 12 m (USA), Wettzell South (Germany), and Yebes 13 m (Spain, part of RAEGE, see below).
- The three 12-m antennas that are part of the AuScope network (Australia) are being converted for VGOS use.
- In Sweden, the new twin 13-m telescopes at Onsala will start operational testing in the next year.
- In Norway, the new twin 13-m telescopes at Ny-Ålesund will start operational testing soon.
- In Spain/Portugal, the RAEGE (Atlantic Network of Geodynamical and Space Stations) project aims to establish a network of four fundamental geodetic stations, including radio telescopes that will fulfill the VGOS specifications: Yebes (1), Canary Islands (1), and Azores (2).
- In the USA, a new 12-m antenna was ordered for McDonald Geodetic Observatory (Texas) for VGOS observing.
- There is interest in India in building a network of four telescopes that would be useful for geodesy.
- Saudi Arabia is investigating having a combined geodetic observatory, which would presumably include a VLBI antenna.
- Colombia is investigating having a combined geodetic observatory, which would presumably include a VLBI antenna.
- An old ground station antenna in Peru is being converted for use in VLBI and may get some use for geodesy.
- Several old ground station antennas in Africa are being converted for use in VLBI as part of the African VLBI Network (AVN). It is not clear if these antennas will see any use for geodesy.

Many of these antennas will become available for use in the next few years. Efforts are being made to ensure that these antennas will be compatible with VGOS.

5 Network Coordination Activities

Network coordination during this period involved dealing with various network and data issues. These included:

- Reviewing all experiment “ops” messages, correlator reports, and analysis reports for problems and working with stations to resolve them.
- Responding to requests from stations for assistance.
- Identifying network station issues and working with the IVS Coordinating Center and the stations to resolve them. This year these included:
  - Encouraging timely delivery of log files, and
  - Validating DBBCs replacing existing systems.
- Participating in development of the new VEX2 schedule file standard.

- Providing catalog update information for station equipment and track lay-outs.
- Recognizing and reporting DBBC issues to station observing staff.
- Reviewing Mark 5 recording error checks for problems and informing correlator staff and station staff.
- Troubleshooting clock problems, including resolving the AuScope clock jump problem.
- Troubleshooting power supplies and identifying the correct parts for shipping.
- Troubleshooting video converters and organizing shipments to stations.
- Providing telescope pointing analysis and advice.
- Support, including software development, for the 12-m antennas at GSFC, KPGO, and the VGOS observing system operations.
- Support for TOW 2015.

6 Future Activities

Network coordination activities are expected to continue next year. The activities will largely be a continuation of the previous year's activities:

- Reviewing all experiment "ops" messages, correlator reports, and analysis reports for problems and working with stations to resolve them.
- Responding to requests from stations for assistance.
- Identifying Network Station issues and working with the IVS Coordinating Center and the stations to resolve them.
- Developing standard procedures for handling of station clocks for correlation.
- Updating Network Station configuration files.
- Organizing station registration with ITU.
- Improving Web presentation of IVS data and results.
- Providing support, including software development, for the 12-m antennas at GSFC, KPGO, MGO, and the VGOS observing system operations.
- Support for TOW 2017.
- Assisting with support for the CONT17 observing campaign.
- Other activities as needed.