EVLA Memo #217
The Distribution of Observed Azimuth and Elevation Angles for the Post-upgrade VLA

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1. Introduction

This is a companion memo to EVLA Memo 215 (Butler 2022), but for the post-upgrade VLA. At the time I wrote memo 215 I had thought that it would be extremely difficult to retrieve the necessary information for the post-upgrade VLA, but have since found a way to do so. The VLA Monitor and Control (M&C) archive has this information, in postgres files backed up on disk, and I can access those files to get the information. It is not quite as straightforward as for the pre-upgrade VLA, but with some effort the proper values can be retrieved and histograms constructed.

2. Retrieving the quantities from the M&C archive database backup files

The post-upgrade M&C archive records various quantities from the M&C system for the VLA. Roughly 18 months of data are kept in an active database which can be queried from the M&C archive query tool; beyond that data are kept in postgres (the particular database format used) backup files on disk. These files are created once per month, starting in January 2011. The quantities of interest for this study are under the device 'ACU' and in the monitor points: 'AZPos' (the azimuth); 'ElPos' (the elevation); and 'StowStat' (whether the antenna is stowed or not). The azimuth and elevation are stored for each antenna once per minute, while the stow status is only stored every 10 minutes. I note that there has been a problem identified with the way that the backup files are created – there is roughly 1.5 missing days at every month boundary. While unfortunate, that should not affect the results of the study (it's ~5% of the data).

Unlike the pre-upgrade values of azimuth and elevation, the values that come from the M&C archive backups are stored regardless of the status of the array, i.e., whether it is observing or not. The pre-upgrade values, which were retrieved from EXPORT data archive files, were only recorded when data was being correlated. Because of this, it is important to try to ascertain whether a given antenna is stowed or not – otherwise the distribution would be contaminated (and in fact dominated) by values at the stow azimuth (which can in principle be any value but in practice is one of a few) and elevation (either 88° or 92°). The first cut indicator of whether an antenna is stowed is in the 'StowStat' monitor point value, and azimuth and elevation values can be filtered when that value is set, but unfortunately the cadence is slow enough (10 minutes) that many values when the antennas are clearly stowed slip past this filter. In addition, I have found that the value of that particular monitor point does not always seem to be a proper indicator of stow status – either that or antennas are at the stow position and are not really 'stowed' (in the full system sense). To address this, I manually filtered out positions that seemed to clearly be stow positions (mostly by examination of the elevation).

I note that there is no easy way of determining whether the values of azimuth and elevation are occurring during science or test observing, similar to what was done in Memo 215 for the pre-upgrade VLA. It could be done with difficulty, but is beyond the scope of this document. So there is no evaluation of the difference here (similar to section 4.b of Memo 215). I also note that elevations are stored in the full range of values, i.e., there is no separate indicator of whether an antenna is over-the-top (OTT) or not, it is just there in the value of the elevation. Additionally, azimuth values are recorded in their full range, so wrap can be determined in the range where it is ambiguous (to the North); I have ignored that complication here and only present values normalized to the range $0°$ to $360°$ (so physical azimuth, not encoder azimuth).

As in Memo 215, the important quantity for each record in the postgres backup files is the product of the number of antennas times the integration time. In this case, I just count each record as one antenna for one minute. The distribution of the sum of that quantity over time gives an aggregate idea of where the VLA antennas pointed.

3. Data retrieval and filtering

A python script was written to pull the three monitor points of interest out of the postgres backup files. In total, 320714642 records were found, in the period from January 1, 2011 through January 31, 2022. Another python script was written to combine together the azimuth and elevation of a given antenna at a given time, and determine whether it was stowed or not (the first cut filter described above). A third python script was then written to do the manual stow position filtering. The final result is a CSV file with 141423301 records, containing antenna, MJD, azimuth, and elevation in each row. Table 1 shows the overall numbers from the data, broken into everything, and OTT only. What I call "Array Days" in Table 1 is just Antenna Days (which is the summed number of antennas times the integration time in units of days) divided by 27, so, if the full array was observing (all 27 antennas) this is how many days were accumulated. So, there is roughly 8.7 years of post-upgrade VLA observing contained in the resulting overall histograms.

Table 1. Total number of final records and antenna time used to calculate histograms.

Type	$N_{records}$	Antenna Days	Array Days
All	141423301	85673	3173
OTT	2848491	912	34

4. Results

From all of the data, I form histograms of azimuth and elevation, with a single constraint: should I account for OTT explicitly, or just use physical elevation? I calculate the histograms with 1° bins, then Hanning smooth them (so effectively 2° width). Then I normalize them to the largest bin in the histogram.

Figures 1-3 show the resulting histograms for azimuth and elevation. Figure 1 displays physical azimuth, Figure 2 displays physical elevation (ignoring OTT), and Figure 3 displays encoder elevation (including OTT). The distributions of azimuth and elevation are quite similar to those found for the pre-upgrade VLA and shown in Memo 215. For azimuth: a broad hump at 180°, a sharp peak at 0° from system observations of the North Celestial Pole (NCP), and two sharp peaks near azimuth 60° and 300° (due to the sources tracked by system or operations observations). For elevation, a broad distribution peaked near 55°, with a small peak near 28° and little observing at very high and very low elevations.

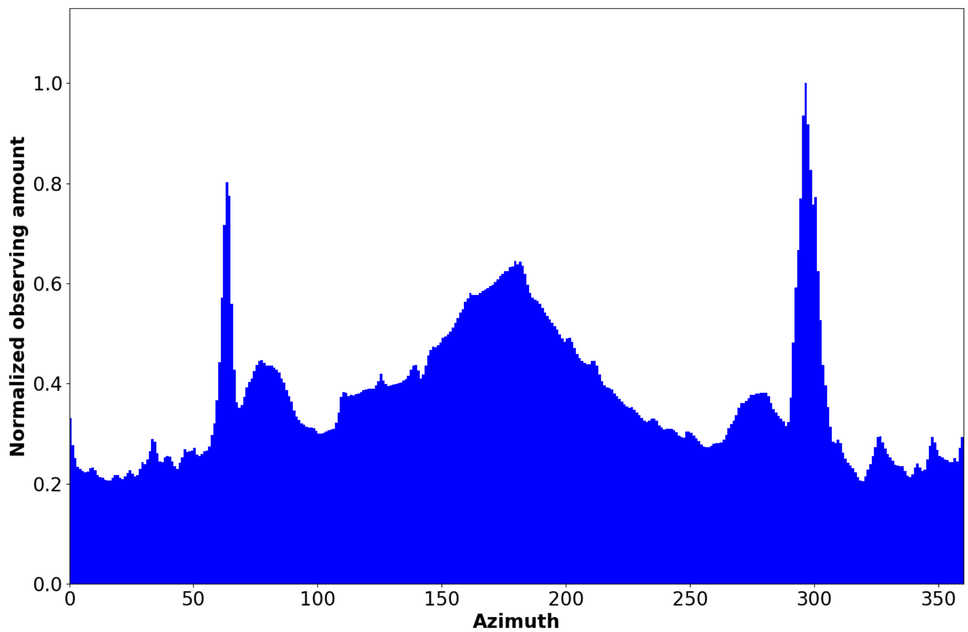

Figure 1. The distribution of azimuth of VLA observations in the period 2011-2022 for all observations. Sharp peaks are seen at 0°, 60°, *and* 300° *from system observations, and a broad hump centered at* 180° *from observing southern sources.*

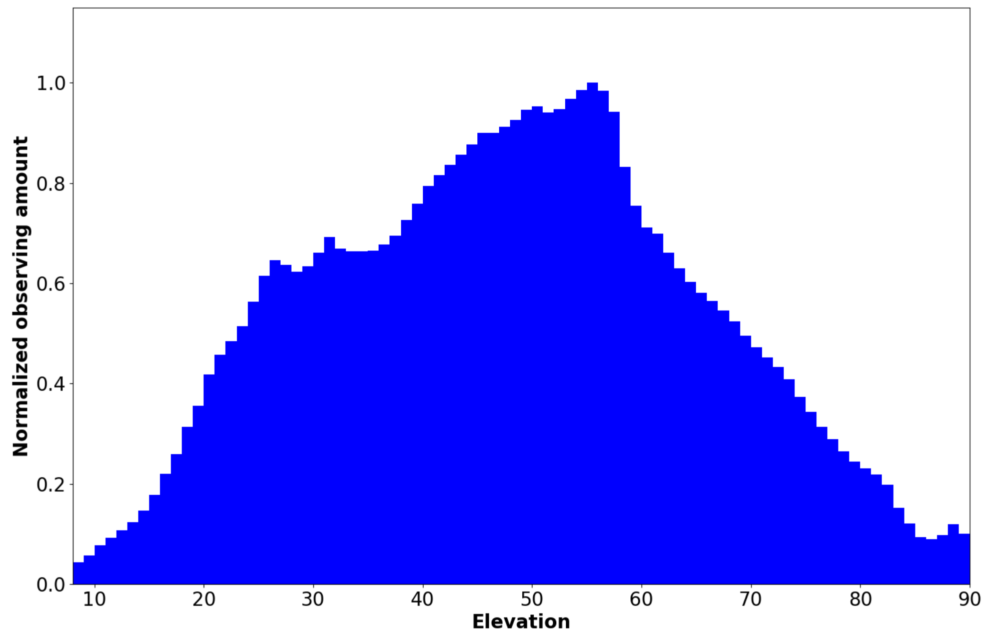

Figure 2. As Figure 1 but for elevation, ignoring OTT.

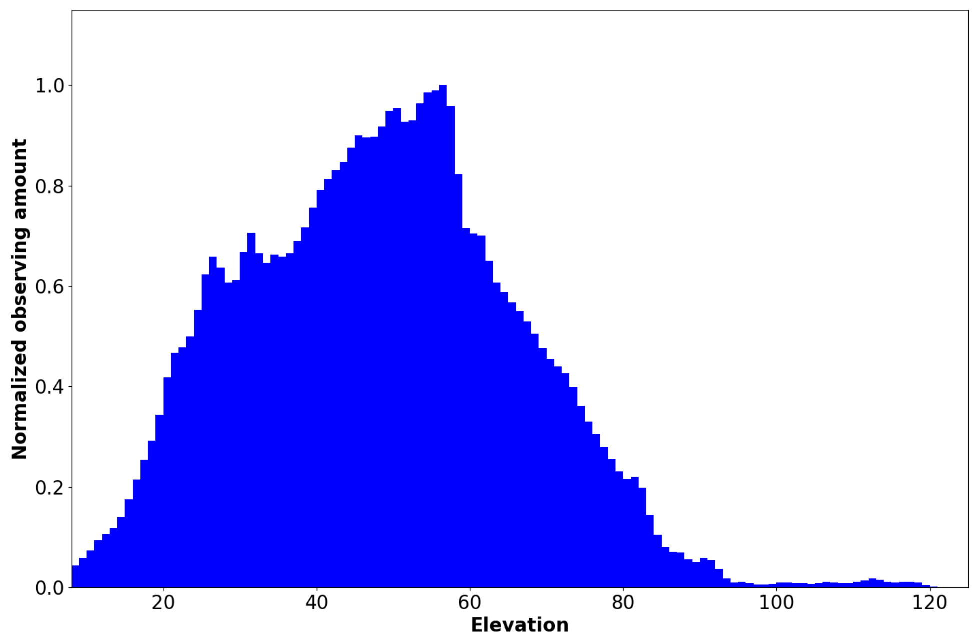

Figure 3. As Figure 2, but including OTT elevations (so encoder elevation instead of physical elevation).

5. Conclusions

The post-upgrade antenna azimuth and elevation distributions are very similar to those for the pre-upgrade VLA described in Memo 215. Perhaps that should not be surprising, as much of the science is similar, and system and operations observing has inherited many of the pre-upgrade practices and sources. I had expected the azimuth peaks at 60° and 300° to be reduced from the pre-upgrade distributions since there are a few more sources used regularly in the system and operations observations, and perhaps they are, but only slightly at best. As noted in Memo 215, if ngVLA wishes to avoid these sharp peaks in azimuth, sources from a broader range of declinations should probably be chosen for regular system and operations observations. It will not be possible to entirely get rid of them, however – it's the nature of an az/el telescope to observe rising and setting sources and those have a constrained azimuth range (at least at lower elevations). But it can be ameliorated partly by judicious choice of sources for system and operations observations.

Acknowledgements

As with Memo 215, this work was prompted by a question from Robert Laing. The help of Daniel Lyons was critical in extracting the monitor point values from the M&C archive postgres backup files.

References

Butler, B., The Distribution of Observed Azimuth and Elevation Angles for the Pre-upgrade VLA, EVLA Memo #215, 2022.