ngVLA Memo #73
Preliminary ngVLA Observing Band Availability Estimate

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Abstract

In order to do planning for possible observing with the ngVLA, it is useful to know what fraction of time might be available at the various bands as a function of time of year and time of day. I have used values measured by the Atmospheric Phase Interferometer (API) at the VLA during the period 1997-2015 to make a preliminary estimate of these fractions. I note that this is a preliminary estimate, to be refined with the addition of more data from the VLA site itself, as well as other potential locations for ngVLA antennas.

1. Introduction

For planning possible observing strategies in the early years of ngVLA (e.g., Wrobel & Murphy 2020), it is useful to know what fraction of the time it might be possible to observe with the various bands of ngVLA, as a function of time of year and time of day. The three main quantities that affect these fractions at ngVLA frequencies are atmospheric phase stability, atmospheric opacity, and surface wind speed. Ideally, we would have measurements of these three quantities at every site in the reference configuration of the ngVLA (Selina et al. 2019), over the past several decades (to sample across weather phenomena which may span many years or even decades, like El Niño or La Niña). We do not have that information available, and at most sites other than the VLA it does not exist. Even for the VLA site, we do not have a good measure of continuous atmospheric opacity, and while wind has been continuously measured, it is not presently available as a coherent collection of data (it could be retrieved from actual observing data archive files, and that is the focus of a separate current effort [Butler 2020], but it is not currently available. What we do have is a long time series of phase stability, as measured on the Atmospheric Phase Interferometer (API) at the VLA site (see Morris 2014 for a description of the current instrument, and Butler & Desai 1999 for the original instrument). While this is not exactly what we want, it is a reasonable proxy for at least the core and plains portions of the configurations, and for many of the longer baselines (those to the south and west). Note that we use only the API values to determine the fraction of VLA time available for high frequencies when we make a Call for Proposals for VLA time currently, and have found that even though we don't use the wind and opacity values along with it, it provides a reasonable guideline on how much time to approve for observing in those bands. Also note also that using API values is not appropriate for low frequencies, as the API is relatively insensitive to ionospheric fluctuations (though it operates at ~12 GHz), which can be significant for at least bands 1 and 2 of ngVLA.

2. Data

The API at the VLA measures phase continuously (at 1 second intervals) by observing a geostationary satellite near 12 GHz (Morris 2014) on a roughly E-W baseline of 300 m length. Since 2013, there are actually six different API baselines (four antennas), with various directions and baseline lengths, but the period covered by this data is not long enough for our purposes, so we use only data from the original E-W baseline. Every 10 minutes, these 1 second phase measurements are used to derive the quantities of the atmospheric structure function: rms phase; slope; and corner time (Butler & Desai 1999). Though all of these quantities are of interest when examining atmospheric stability, the rms phase is the primary quantity of interest, and the one I use in this study.

The API data used for this analysis runs from May 1, 1997, to May 1, 2015, for a total of 18 years. There are more recent data available (from May 1, 2015 to the present), and some older data (going back to 1994), but this is the data that is in good shape for this preliminary analysis, and should suffice.

3. Band rms phase cutoffs

I assume the required phase rms measured on the API is as we use now for frequencies covered by the VLA (bands 1-5 of ngVLA). For ngVLA band 6, I use a value of 3.0 degrees for frequencies below 95 GHz ("6 lower"), and 2.0 degrees for higher frequencies ("6 upper"). There is a slight problem with that latter value, in that it is getting close to the noise limit of the API, but fractions derived using that value can be considered to be lower bounds. Table 1 shows these API limits for the various ngVLA bands.

Table 1. API rms phase limits for the ngVLA bands assumed for this analysis.

ngVLA Band	Frequency Range (GHz)	API rms limit (deg)
1	1.2-3.5	∞
2	3.5-12.3	30
3	12.3-20.5	15
4	20.5-30.4	10
5	30.5-50.5	5
6 lower	70.0-95.0	3
6 upper	95.0-115.0	2

4. Results

Figures 1-3 show 10th, 50th, and 90th percentile rms phase values as a function of UTC hour, for each month. The expected trends are seen: winter is much better than summer, and nighttime is better than daytime. Using these data, along with the band cutoffs in Table 1, gives the fractional availability as a function of time of year and day. Table 2 summarizes the fractional availability averaged per month, and over the entire year.

Table 2. Fractional availability, in percent, by month and over the entire year for all of the bands.

Month	Band 2	Band 3	Band 4	Band 5	Band 6l	Band 6u
Jan	100	100	98	77	51	28
Feb	100	100	94	67	39	19
Mar	100	98	91	62	35	17
Apr	100	96	86	55	29	12
May	100	94	83	51	27	12
Jun	100	90	76	44	21	8
Jul	98	84	68	28	6	0
Aug	99	84	68	29	5	0
Sep	99	87	71	33	11	2
Oct	100	93	81	50	26	12
Nov	100	99	94	68	41	22
Dec	100	100	97	74	49	27
Year	100	94	84	53	28	13

The fractional availability data for each band, for each month and UTC hour, are shown in Appendix A. These more detailed data show that in winter, as much as 40% of time might be available for band 6 upper during nighttime, while during daytime only 5% or so might be available. In summer, there is virtually no available time for band 6 upper at any time of day, and for band 6 lower, there is no available time during daytime, and perhaps as much as 20% during nighttime.

Appendix B shows data for each band, but instead of months, uses quarters, and times are converted to LST. So for each month, values are shifted in time by the difference between LST and UTC, then over the three months in each quarter, values for a given LST time are averaged. Note that to the accuracy needed here, LST ~ UTC + (month-1)*2 + 0.5.

References

Selina, R., and 37 others. System Reference Design Volume 1: System Design, ngVLA Document 020.10.20.00.00-0001-REP-B, 2019.

Butler, B.J. In preparation, 2020.

Butler, B., & K. Desai, Phase Fluctuations at the VLA Derived from One Year of Site Testing Interferometer Data, VLA Test Memo 222, 1999.

Morris, K., Atmospheric Phase Interferometer Instrument Description, EVLA Memo 181, 2014.

Wrobel, J., and E. Murphy. A Notional Reference Observing Program, ngVLA Document 020.10.15.05.10-0001-REP-B, 2020.

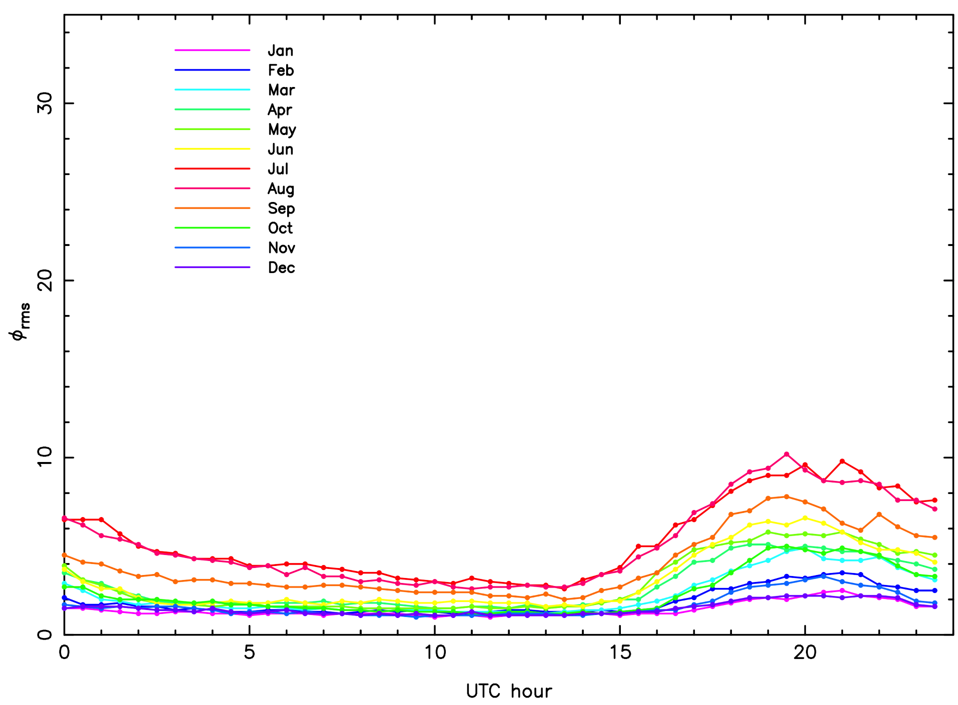

Figure 1. VLA site 10th percentile rms phase as a function of month and time of day, 1997-2015.

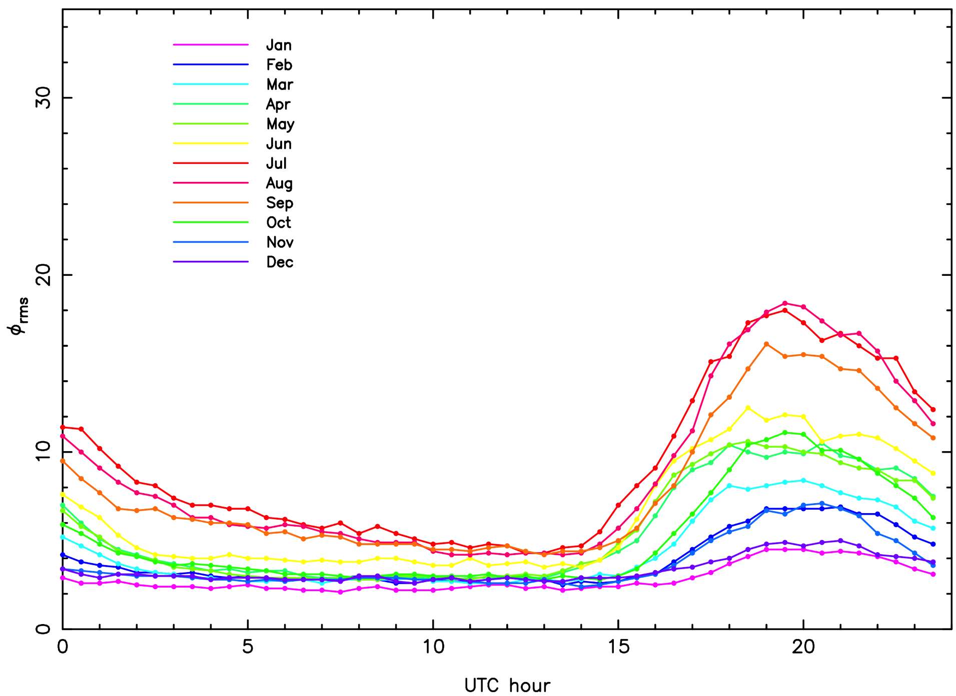

Figure 2. VLA site 50th percentile (median) rms phase as a function of month and time of day, 1997-2015.

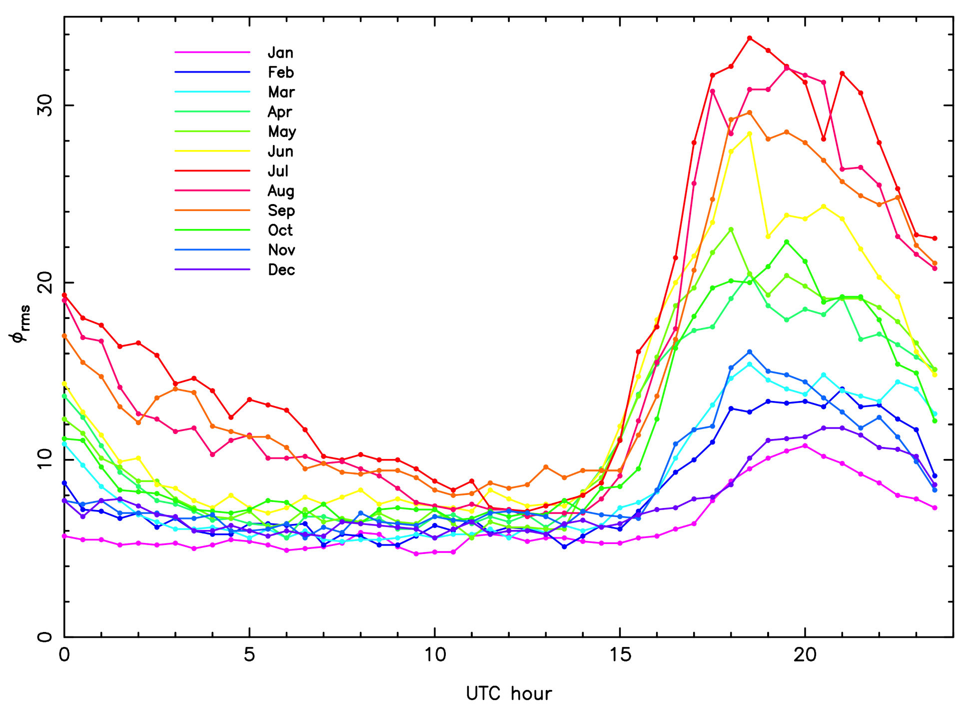

Figure 3. VLA site 90th percentile rms phase as a function of month and time of day, 1997-201

Appendix A

Fraction of available observing time per band per month; each month shown separately. Columns are: UTC hour; band 2 fractional availability; band 3 fractional availability; band 4 fractional availability; band 5 fractional availability; band 6 lower fractional availability; band 6 upper fractional availability. All fractions are shown in percent. Band 1 is not included because it is effectively available 100% of the time, barring RFI and ionospheric fluctuations.

January

```
 0.5, 100.0, 100.0, 100.0, 74.0, 46.0, 22.0
 1.5, 100.0, 100.0, 100.0, 78.0, 48.0, 25.0
 2.5, 100.0, 100.0, 100.0, 82.0, 56.0, 30.0
 3.5, 100.0, 100.0, 100.0, 83.0, 56.0, 32.0
 4.5, 100.0, 100.0, 100.0, 82.0, 58.0, 33.0
 5.5, 100.0, 100.0, 100.0, 83.0, 62.0, 35.0
 6.5, 100.0, 100.0, 100.0, 85.0, 62.0, 35.0
 7.5, 100.0, 100.0, 100.0, 85.0, 64.0, 40.0
 8.5, 100.0, 100.0, 100.0, 85.0, 62.0, 40.0
 9.5, 100.0, 100.0, 100.0, 85.0, 63.0, 40.0
10.5, 100.0, 100.0, 100.0, 85.0, 63.0, 40.0
11.5, 100.0, 100.0, 100.0, 85.0, 63.0, 40.0
12.5, 100.0, 100.0, 100.0, 85.0, 64.0, 37.0
13.5, 100.0, 100.0, 100.0, 85.0, 65.0, 42.0
14.5, 100.0, 100.0, 100.0, 84.0, 60.0, 40.0
15.5, 100.0, 100.0, 100.0, 81.0, 58.0, 33.0
16.5, 100.0, 100.0, 100.0, 76.0, 51.0, 30.0
17.5, 100.0, 100.0, 94.0, 70.0, 42.0, 20.0
18.5, 100.0, 100.0, 93.0, 61.0, 30.0, 12.0
19.5, 100.0, 100.0, 91.0, 56.0, 25.0, 10.0
20.5, 100.0, 100.0, 89.0, 56.0, 26.0, 6.0
21.5, 100.0, 100.0, 89.0, 56.0, 24.0, 7.0
22.5, 100.0, 100.0, 92.0, 61.0, 30.0, 10.0
23.5, 100.0, 100.0, 100.0, 72.0, 40.0, 20.0
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February

```
 0.5, 100.0, 100.0, 94.0, 63.0, 30.0, 12.0
 1.5, 100.0, 100.0, 97.0, 69.0, 36.0, 15.0
 2.5, 100.0, 100.0, 100.0, 76.0, 42.0, 20.0
 3.5, 100.0, 100.0, 100.0, 78.0, 45.0, 22.0
 4.5, 100.0, 100.0, 100.0, 81.0, 50.0, 23.0
 5.5, 100.0, 100.0, 100.0, 80.0, 52.0, 27.0
 6.5, 100.0, 100.0, 100.0, 82.0, 55.0, 27.0
 7.5, 100.0, 100.0, 100.0, 83.0, 53.0, 30.0
 8.5, 100.0, 100.0, 100.0, 83.0, 54.0, 27.0
 9.5, 100.0, 100.0, 100.0, 83.0, 58.0, 30.0
10.5, 100.0, 100.0, 100.0, 82.0, 57.0, 32.0
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12.5, 100.0, 100.0, 100.0, 83.0, 55.0, 30.0
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13.5, 100.0, 100.0, 100.0, 85.0, 58.0, 32.0
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16.5, 100.0, 100.0, 93.0, 65.0, 32.0, 12.0
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20.5, 100.0, 95.0, 75.0, 33.0, 9.0, 0.0
21.5, 100.0, 98.0, 76.0, 35.0, 7.0, 0.0
22.5, 100.0, 98.0, 82.0, 40.0, 15.0, 2.0
23.5, 100.0, 100.0, 88.0, 50.0, 20.0, 6.0
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March

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 0.5, 100.0, 100.0, 93.0, 54.0, 17.0, 5.0
 1.5, 100.0, 100.0, 98.0, 65.0, 29.0, 12.0
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 4.5, 100.0, 100.0, 100.0, 81.0, 50.0, 22.0
 5.5, 100.0, 100.0, 100.0, 83.0, 52.0, 25.0
 6.5, 100.0, 100.0, 100.0, 82.0, 55.0, 27.0
 7.5, 100.0, 100.0, 100.0, 84.0, 52.0, 30.0
 8.5, 100.0, 100.0, 100.0, 84.0, 55.0, 27.0
 9.5, 100.0, 100.0, 100.0, 86.0, 57.0, 27.0
10.5, 100.0, 100.0, 100.0, 84.0, 57.0, 30.0
11.5, 100.0, 100.0, 100.0, 84.0, 58.0, 33.0
12.5, 100.0, 100.0, 100.0, 83.0, 60.0, 33.0
13.5, 100.0, 100.0, 100.0, 84.0, 60.0, 33.0
14.5, 100.0, 100.0, 100.0, 80.0, 50.0, 30.0
15.5, 100.0, 100.0, 99.0, 70.0, 43.0, 22.0
16.5, 100.0, 100.0, 87.0, 52.0, 28.0, 10.0
17.5, 100.0, 94.0, 75.0, 35.0, 12.0, 1.0
18.5, 100.0, 91.0, 68.0, 25.0, 3.0, 0.0
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21.5, 100.0, 92.0, 70.0, 20.0, 1.0, 0.0
22.5, 100.0, 94.0, 75.0, 25.0, 3.0, 0.0
23.5, 100.0, 99.0, 81.0, 36.0, 9.0, 0.0
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April

```
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 6.5, 100.0, 100.0, 100.0, 81.0, 50.0, 20.0
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 8.5, 100.0, 100.0, 100.0, 80.0, 52.0, 23.0
 9.5, 100.0, 100.0, 100.0, 80.0, 52.0, 27.0
10.5, 100.0, 100.0, 100.0, 80.0, 51.0, 23.0
11.5, 100.0, 100.0, 100.0, 78.0, 52.0, 27.0
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14.5, 100.0, 100.0, 97.0, 66.0, 38.0, 18.0
15.5, 100.0, 100.0, 87.0, 53.0, 26.0, 12.0
16.5, 100.0, 90.0, 71.0, 33.0, 12.0, 1.0
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21.5, 100.0, 86.0, 56.0, 13.0, 0.0, 0.0
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23.5, 100.0, 96.0, 73.0, 26.0, 1.0, 0.0
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23.5, 100.0, 92.0, 72.0, 18.0, 0.0, 0.0
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 7.5, 100.0, 100.0, 96.0, 68.0, 32.0, 14.0
 8.5, 100.0, 100.0, 96.0, 69.0, 34.0, 14.0
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11.5, 100.0, 100.0, 96.0, 72.0, 40.0, 17.0
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21.5, 100.0, 71.0, 43.0, 6.0, 0.0, 0.0
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July

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4.5, 100.0, 100.0, 84.0, 28.0, 3.0, 0.0
5.5, 100.0, 99.0, 83.0, 33.0, 1.0, 0.0
6.5, 100.0, 100.0, 86.0, 38.0, 4.0, 0.0
7.5, 100.0, 100.0, 90.0, 39.0, 9.0, 0.0
8.5, 100.0, 100.0, 93.0, 47.0, 5.0, 0.0
9.5, 100.0, 100.0, 96.0, 53.0, 12.0, 0.0
10.5, 100.0, 100.0, 100.0, 60.0, 14.0, 0.0
11.5, 100.0, 100.0, 100.0, 64.0, 18.0, 2.0
12.5, 100.0, 100.0, 100.0, 70.0, 23.0, 2.0
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16.5, 100.0, 81.0, 60.0, 16.0, 0.0, 0.0
17.5, 95.0, 64.0, 39.0, 4.0, 0.0, 0.0
18.5, 90.0, 50.0, 23.0, 0.0, 0.0, 0.0
19.5, 90.0, 43.0, 20.0, 0.0, 0.0, 0.0
20.5, 93.0, 45.0, 18.0, 0.0, 0.0, 0.0
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23.5, 100.0, 70.0, 37.0, 0.0, 0.0, 0.0

August

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1.5, 100.0, 92.0, 70.0, 11.0, 0.0, 0.0
2.5, 100.0, 94.0, 80.0, 19.0, 0.0, 0.0
3.5, 100.0, 100.0, 81.0, 23.0, 0.0, 0.0
4.5, 100.0, 100.0, 86.0, 26.0, 0.0, 0.0
5.5, 100.0, 100.0, 88.0, 34.0, 1.0, 0.0
6.5, 100.0, 100.0, 87.0, 40.0, 2.0, 0.0
7.5, 100.0, 100.0, 92.0, 44.0, 5.0, 0.0
8.5, 100.0, 100.0, 90.0, 52.0, 8.0, 0.0
9.5, 100.0, 100.0, 99.0, 58.0, 15.0, 0.0
10.5, 100.0, 100.0, 100.0, 62.0, 15.0, 0.0

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11.5, 100.0, 100.0, 100.0, 70.0, 17.0, 0.0
12.5, 100.0, 100.0, 100.0, 68.0, 20.0, 1.0
13.5, 100.0, 100.0, 100.0, 71.0, 23.0, 0.0
14.5, 100.0, 100.0, 100.0, 62.0, 12.0, 0.0
15.5, 100.0, 100.0, 85.0, 32.0, 1.0, 0.0
16.5, 100.0, 84.0, 58.0, 11.0, 0.0, 0.0
17.5, 97.0, 62.0, 35.0, 1.0, 0.0, 0.0
18.5, 94.0, 46.0, 17.0, 0.0, 0.0, 0.0
19.5, 89.0, 37.0, 15.0, 0.0, 0.0, 0.0
20.5, 93.0, 40.0, 13.0, 0.0, 0.0, 0.0
21.5, 100.0, 46.0, 16.0, 0.0, 0.0, 0.0
22.5, 100.0, 58.0, 21.0, 0.0, 0.0, 0.0
23.5, 100.0, 74.0, 37.0, 0.0, 0.0, 0.0
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September

```
 0.5, 100.0, 88.0, 63.0, 18.0, 1.0, 0.0
 1.5, 100.0, 94.0, 78.0, 26.0, 3.0, 0.0
 2.5, 100.0, 96.0, 78.0, 32.0, 7.0, 0.0
 3.5, 100.0, 98.0, 83.0, 37.0, 10.0, 0.0
 4.5, 100.0, 100.0, 87.0, 40.0, 12.0, 1.0
 5.5, 100.0, 100.0, 87.0, 45.0, 13.0, 0.0
 6.5, 100.0, 100.0, 92.0, 49.0, 16.0, 0.0
 7.5, 100.0, 100.0, 95.0, 52.0, 17.0, 1.0
 8.5, 100.0, 100.0, 93.0, 55.0, 19.0, 4.0
 9.5, 100.0, 100.0, 95.0, 57.0, 24.0, 7.0
10.5, 100.0, 100.0, 100.0, 60.0, 24.0, 7.0
11.5, 100.0, 100.0, 100.0, 61.0, 27.0, 8.0
12.5, 100.0, 100.0, 96.0, 60.0, 27.0, 10.0
13.5, 100.0, 100.0, 91.0, 60.0, 30.0, 10.0
14.5, 100.0, 100.0, 94.0, 58.0, 22.0, 7.0
15.5, 100.0, 100.0, 86.0, 43.0, 14.0, 1.0
16.5, 100.0, 86.0, 68.0, 21.0, 5.0, 0.0
17.5, 100.0, 68.0, 42.0, 8.0, 0.0, 0.0
18.5, 92.0, 56.0, 29.0, 3.0, 0.0, 0.0
19.5, 93.0, 49.0, 24.0, 1.0, 0.0, 0.0
20.5, 96.0, 48.0, 24.0, 1.0, 0.0, 0.0
21.5, 96.0, 53.0, 27.0, 2.0, 0.0, 0.0
22.5, 99.0, 63.0, 35.0, 4.0, 0.0, 0.0
23.5, 100.0, 77.0, 44.0, 9.0, 0.0, 0.0
```

October

```
 0.5, 100.0, 96.0, 80.0, 41.0, 16.0, 1.0
 1.5, 100.0, 100.0, 87.0, 51.0, 20.0, 7.0
 2.5, 100.0, 100.0, 90.0, 59.0, 27.0, 10.0
 3.5, 100.0, 100.0, 97.0, 60.0, 30.0, 10.0
 4.5, 100.0, 100.0, 97.0, 65.0, 32.0, 12.0
 5.5, 100.0, 100.0, 92.0, 64.0, 34.0, 14.0
 6.5, 100.0, 100.0, 93.0, 65.0, 38.0, 16.0
 7.5, 100.0, 100.0, 94.0, 66.0, 40.0, 20.0
 8.5, 100.0, 100.0, 95.0, 68.0, 40.0, 20.0
 9.5, 100.0, 100.0, 94.0, 70.0, 42.0, 23.0
```

```
10.5, 100.0, 100.0, 90.0, 69.0, 43.0, 25.0
11.5, 100.0, 100.0, 95.0, 71.0, 43.0, 24.0
12.5, 100.0, 100.0, 95.0, 72.0, 44.0, 25.0
13.5, 100.0, 100.0, 94.0, 73.0, 45.0, 25.0
14.5, 100.0, 100.0, 95.0, 68.0, 45.0, 24.0
15.5, 100.0, 100.0, 88.0, 61.0, 38.0, 18.0
16.5, 100.0, 90.0, 77.0, 44.0, 22.0, 10.0
17.5, 100.0, 82.0, 61.0, 26.0, 11.0, 2.0
18.5, 100.0, 74.0, 49.0, 15.0, 5.0, 1.0
19.5, 100.0, 69.0, 44.0, 11.0, 0.0, 0.0
20.5, 100.0, 73.0, 46.0, 12.0, 1.0, 0.0
21.5, 100.0, 76.0, 50.0, 14.0, 0.0, 0.0
22.5, 100.0, 84.0, 61.0, 19.0, 4.0, 0.0
23.5, 100.0, 92.0, 75.0, 29.0, 8.0, 0.0
```

November

```
 0.5, 100.0, 100.0, 100.0, 67.0, 37.0, 18.0
 1.5, 100.0, 100.0, 100.0, 72.0, 46.0, 20.0
 2.5, 100.0, 100.0, 98.0, 79.0, 47.0, 24.0
 3.5, 100.0, 100.0, 100.0, 78.0, 50.0, 27.0
 4.5, 100.0, 100.0, 100.0, 80.0, 50.0, 30.0
 5.5, 100.0, 100.0, 100.0, 81.0, 54.0, 32.0
 6.5, 100.0, 100.0, 100.0, 81.0, 53.0, 30.0
 7.5, 100.0, 100.0, 100.0, 77.0, 54.0, 32.0
 8.5, 100.0, 100.0, 100.0, 79.0, 53.0, 30.0
 9.5, 100.0, 100.0, 100.0, 80.0, 53.0, 32.0
10.5, 100.0, 100.0, 100.0, 81.0, 52.0, 32.0
11.5, 100.0, 100.0, 100.0, 78.0, 53.0, 32.0
12.5, 100.0, 100.0, 100.0, 78.0, 54.0, 32.0
13.5, 100.0, 100.0, 100.0, 81.0, 55.0, 33.0
14.5, 100.0, 100.0, 100.0, 81.0, 57.0, 35.0
15.5, 100.0, 100.0, 96.0, 74.0, 48.0, 30.0
16.5, 100.0, 100.0, 89.0, 65.0, 40.0, 22.0
17.5, 100.0, 96.0, 81.0, 52.0, 27.0, 13.0
18.5, 100.0, 97.0, 77.0, 40.0, 15.0, 6.0
19.5, 100.0, 93.0, 74.0, 33.0, 13.0, 4.0
20.5, 100.0, 95.0, 75.0, 34.0, 12.0, 1.0
21.5, 100.0, 93.0, 78.0, 39.0, 14.0, 1.0
22.5, 100.0, 100.0, 85.0, 48.0, 19.0, 4.0
23.5, 100.0, 100.0, 94.0, 62.0, 28.0, 11.0
```

December

```
 0.5, 100.0, 100.0, 95.0, 71.0, 43.0, 20.0
 1.5, 100.0, 100.0, 99.0, 73.0, 45.0, 22.0
 2.5, 100.0, 100.0, 100.0, 80.0, 50.0, 25.0
 3.5, 100.0, 100.0, 100.0, 80.0, 53.0, 32.0
 4.5, 100.0, 100.0, 100.0, 81.0, 57.0, 33.0
 5.5, 100.0, 100.0, 100.0, 81.0, 52.0, 32.0
 6.5, 100.0, 100.0, 100.0, 82.0, 60.0, 35.0
 7.5, 100.0, 100.0, 100.0, 84.0, 57.0, 35.0
 8.5, 100.0, 100.0, 100.0, 83.0, 60.0, 33.0
```

```
 9.5, 100.0, 100.0, 100.0, 82.0, 60.0, 35.0
10.5, 100.0, 100.0, 100.0, 83.0, 60.0, 35.0
11.5, 100.0, 100.0, 100.0, 84.0, 60.0, 37.0
12.5, 100.0, 100.0, 100.0, 83.0, 62.0, 37.0
13.5, 100.0, 100.0, 100.0, 83.0, 60.0, 37.0
14.5, 100.0, 100.0, 100.0, 82.0, 60.0, 37.0
15.5, 100.0, 100.0, 100.0, 77.0, 54.0, 32.0
16.5, 100.0, 100.0, 95.0, 72.0, 47.0, 26.0
17.5, 100.0, 100.0, 96.0, 65.0, 40.0, 20.0
18.5, 100.0, 100.0, 90.0, 62.0, 30.0, 12.0
19.5, 100.0, 100.0, 87.0, 56.0, 25.0, 8.0
20.5, 100.0, 100.0, 87.0, 53.0, 27.0, 10.0
21.5, 100.0, 99.0, 86.0, 57.0, 26.0, 10.0
22.5, 100.0, 100.0, 90.0, 63.0, 33.0, 13.0
23.5, 100.0, 100.0, 94.0, 69.0, 42.0, 20.0
```

Appendix B

Fraction of available observing time per band per quarter; each quarter shown separately. Quarters are defined as: January-March; April-June; July-September; October-December. Columns are: LST hour; band 2 fractional availability; band 3 fractional availability; band 4 fractional availability; band 5 fractional availability; band 6 lower fractional availability; band 6 upper fractional availability. All fractions are shown in percent. Band 1 is not included because it is effectively available 100% of the time, barring RFI and ionospheric fluctuations.

First Quarter (Jan-Mar)

```
 0, 100.0,  96.0,  81.3,  43.0,  18.0,   7.7
 1, 100.0,  97.0,  84.3,  46.0,  21.3,   9.7
 2, 100.0,  98.3,  87.7,  52.3,  27.0,  11.7
 3, 100.0,  99.0,  90.3,  59.3,  31.7,  15.3
 4, 100.0, 100.0,  95.3,  66.3,  37.0,  17.0
 5, 100.0, 100.0,  99.0,  73.3,  43.3,  20.3
 6, 100.0, 100.0, 100.0,  79.7,  47.7,  24.3
 7, 100.0, 100.0, 100.0,  81.0,  51.3,  27.0
 8, 100.0, 100.0, 100.0,  81.3,  55.3,  29.7
 9, 100.0, 100.0, 100.0,  83.7,  56.7,  30.7
10, 100.0, 100.0, 100.0,  83.7,  56.7,  33.0
11, 100.0, 100.0, 100.0,  83.7,  57.3,  32.3
12, 100.0, 100.0, 100.0,  83.7,  57.7,  32.0
13, 100.0, 100.0, 100.0,  83.7,  58.0,  33.0
14, 100.0, 100.0, 100.0,  84.7,  57.7,  34.0
15, 100.0, 100.0, 100.0,  83.3,  59.0,  34.7
16, 100.0, 100.0, 100.0,  83.3,  58.0,  31.7
17, 100.0, 100.0,  99.0,  79.0,  52.3,  29.0
18, 100.0, 100.0,  97.0,  74.0,  46.0,  23.0
19, 100.0, 100.0,  94.3,  63.3,  32.3,  16.0
20, 100.0, 100.0,  89.0,  53.7,  25.7,  10.0
21, 100.0,  99.3,  83.0,  44.7,  17.3,   4.3
22, 100.0,  96.7,  78.0,  40.7,  14.7,   3.3
23, 100.0,  95.3,  80.3,  42.0,  16.3,   5.3
```

Second Quarter (Apr-Jun)

```
 0, 100.0,  91.7,  75.3,  39.0,  17.7,   6.7
 1, 100.0,  88.0,  68.0,  27.7,   8.7,   2.7
 2, 100.0,  80.0,  55.7,  17.0,   3.3,   0.3
 3, 100.0,  78.0,  51.0,  12.3,   1.0,   0.0
 4, 100.0,  77.7,  49.3,  10.0,   0.0,   0.0
 5, 100.0,  78.7,  53.3,  10.7,   1.0,   0.0
 6, 100.0,  83.0,  58.0,  14.7,   2.3,   0.0
 7, 100.0,  86.3,  65.7,  22.0,   5.0,   0.0
 8, 100.0,  91.0,  73.3,  31.7,   9.3,   2.7
 9, 100.0,  93.7,  81.0,  42.3,  15.7,   4.7
10, 100.0,  95.7,  85.7,  50.7,  24.3,   8.0
11, 100.0,  97.7,  91.0,  57.7,  30.0,  11.0
```

12,	100.0,	99.0,	94.3,	66.7,	34.3,	13.7
13,	100.0,	100.0,	97.0,	71.7,	42.0,	16.7
14,	100.0,	100.0,	97.3,	73.3,	44.3,	18.0
15,	100.0,	100.0,	98.7,	75.3,	44.7,	21.0
16,	100.0,	100.0,	98.0,	74.3,	45.7,	19.7
17,	100.0,	100.0,	98.3,	75.7,	45.0,	20.7
18,	100.0,	100.0,	98.7,	78.0,	44.0,	20.0
19,	100.0,	100.0,	99.3,	78.0,	47.0,	20.7
20,	100.0,	100.0,	100.0,	77.0,	45.3,	21.0
21,	100.0,	100.0,	95.7,	71.0,	41.7,	19.0
22,	100.0,	98.7,	92.0,	65.0,	36.3,	16.3
23,	100.0,	95.7,	85.0,	53.0,	27.3,	11.0

Third Quarter (Jul-Sep)

0,	100.0,	100.0,	98.0,	60.7,	17.0,	1.0
1,	100.0,	100.0,	97.7,	65.0,	22.0,	2.0
2,	100.0,	100.0,	98.3,	65.0,	22.0,	3.0
3,	100.0,	100.0,	97.7,	57.0,	18.0,	2.0
4,	100.0,	97.0,	90.7,	50.7,	15.7,	3.7
5,	99.7,	90.0,	79.7,	37.7,	11.7,	2.7
6,	97.7,	83.7,	65.3,	26.3,	9.0,	3.3
7,	96.3,	71.3,	51.3,	17.7,	6.3,	1.3
8,	96.3,	63.3,	40.0,	9.7,	2.3,	0.0
9,	93.7,	55.7,	28.7,	4.0,	0.0,	0.0
10,	95.0,	50.3,	24.0,	2.0,	0.0,	0.0
11,	96.3,	52.7,	23.7,	0.3,	0.0,	0.0
12,	96.7,	58.0,	29.0,	1.3,	0.0,	0.0
13,	99.3,	65.7,	37.7,	3.0,	0.0,	0.0
14,	99.0,	74.7,	47.7,	7.7,	0.0,	0.0
15,	100.0,	83.0,	59.7,	12.3,	1.7,	0.0
16,	100.0,	91.7,	69.3,	19.0,	0.7,	0.0
17,	100.0,	96.0,	77.7,	24.0,	1.7,	0.0
18,	100.0,	97.7,	81.3,	29.3,	3.7,	0.0
19,	100.0,	99.7,	86.7,	35.3,	5.7,	0.0
20,	100.0,	100.0,	87.7,	40.7,	7.3,	0.0
21,	100.0,	100.0,	90.0,	43.7,	8.7,	0.0
22,	100.0,	100.0,	93.0,	51.7,	11.3,	0.3
23,	100.0,	100.0,	95.0,	56.3,	14.0,	1.3

Fourth Quarter (Oct-Dec)

0,	100.0,	100.0,	97.0,	74.0,	45.3,	23.7
1,	100.0,	100.0,	98.3,	75.3,	47.3,	26.7
2,	100.0,	100.0,	98.0,	76.0,	50.3,	26.7
3,	100.0,	100.0,	98.7,	75.3,	49.3,	28.0
4,	100.0,	100.0,	96.7,	76.3,	50.0,	29.0
5,	100.0,	100.0,	97.3,	77.7,	51.0,	31.0
6,	100.0,	100.0,	98.0,	78.7,	52.0,	31.0
7,	100.0,	100.0,	98.3,	77.7,	54.0,	30.7
8,	100.0,	100.0,	99.0,	77.7,	53.3,	32.0
9,	100.0,	100.0,	97.0,	76.3,	52.3,	28.7
10,	100.0,	99.3,	94.3,	73.0,	49.7,	28.0

11,	100.0,	95.0,	90.0,	66.0,	42.7,	23.3
12,	100.0,	92.0,	82.7,	57.3,	36.3,	21.3
13,	100.0,	88.7,	77.0,	50.0,	31.3,	17.7
14,	100.0,	87.7,	74.3,	44.0,	23.7,	11.7
15,	100.0,	89.3,	73.3,	39.7,	20.0,	9.3
16,	100.0,	90.0,	75.0,	38.0,	15.7,	6.0
17,	100.0,	93.7,	77.0,	39.0,	15.7,	4.7
18,	100.0,	97.3,	82.0,	45.3,	17.3,	4.0
19,	100.0,	100.0,	86.3,	52.7,	23.3,	8.0
20,	100.0,	100.0,	91.0,	61.0,	28.3,	10.3
21,	100.0,	100.0,	95.7,	65.3,	35.0,	16.7
22,	100.0,	100.0,	98.3,	70.0,	41.3,	18.0
23,	100.0,	100.0,	96.3,	72.7,	43.3,	20.0