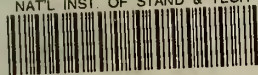


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Technical Note

No. 206-4

THE NORMAL PHASE VARIATIONS OF THE 18 kc/s SIGNALS FROM NBA OBSERVED AT COLLEGE, ALASKA

J. H. CRARY AND A. C. MURPHY

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NATIONAL BUREAU OF STANDARDS

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ISSUED September 30, 1965

THE NORMAL PHASE VARIATIONS OF THE 18 kc/s SIGNALS FROM NBA OBSERVED AT COLLEGE, ALASKA

J. H. Crary and A. C. Murphy
Central Radio Propagation Laboratory
National Bureau of Standards
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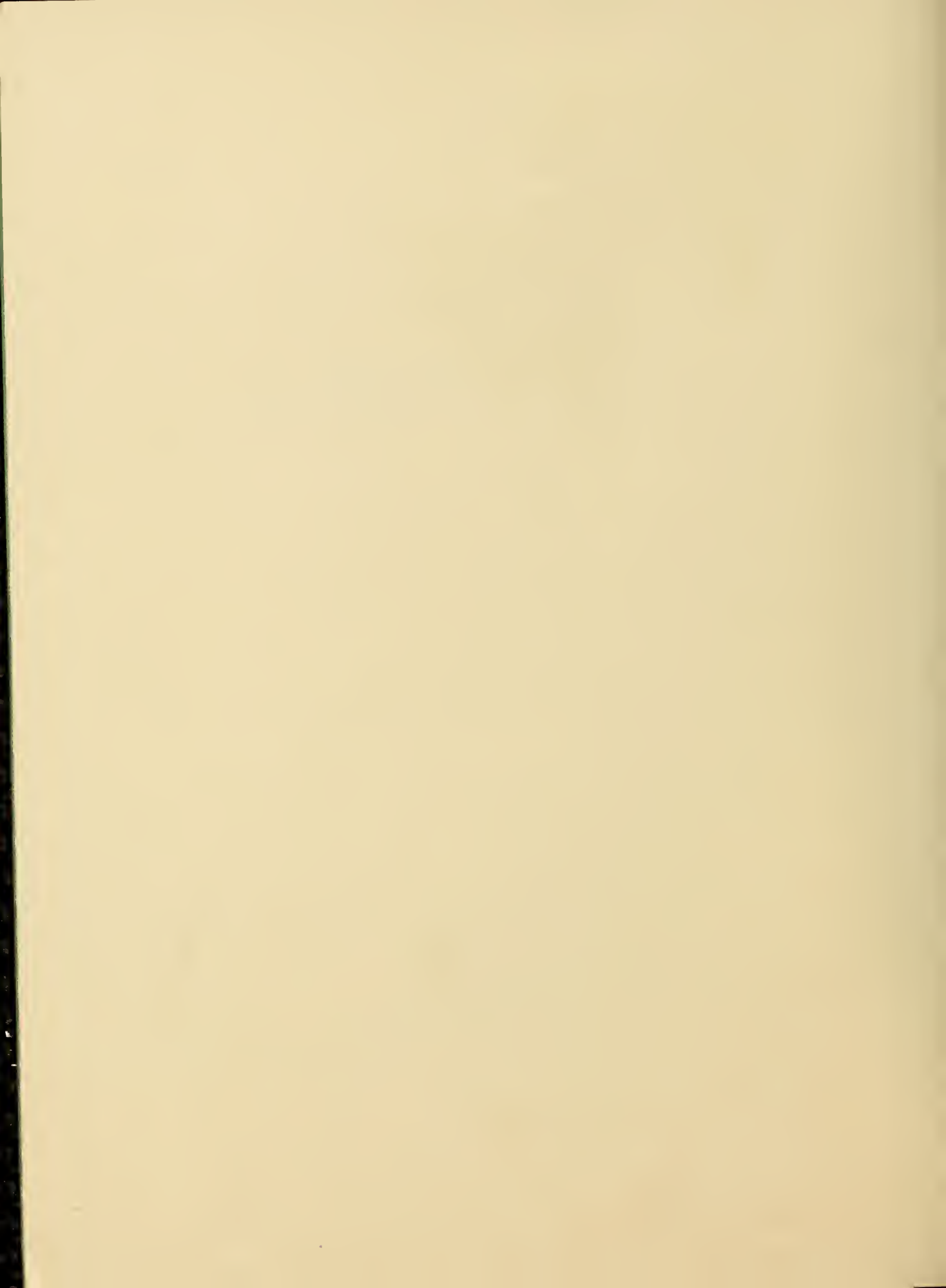
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The Normal Phase Variations of the 18 kc/s Signals
from NBA Observed at College, Alaska, U.S.A.

J. H. Crary and A. C. Murphy

Observations of the normal phase variations of the 18 kc/s signals radiated from the Canal Zone and received in College, Alaska, U.S.A., are given in the form of monthly averages and standard deviations at five minute intervals. The relations between the diurnal phase variations and the diurnal variation in the length of sunlit path are shown. The calculated mean diurnal change in effective height of reflection is 16 km. Values of the short term phase differences are also given.

Key Words: VLF, phase, normal, diurnal, Panama-Alaska.

1. Introduction

This is the fourth of a series of reports, each of which summarizes the normal (or undisturbed) behavior of the phase of signals from various VLF transmitters as observed at particular receiving sites. This report deals with the reception at College, Alaska (lat. N $64^{\circ} 51' 36''$, long. W $147^{\circ} 33' 48''$), of 18 kc/s transmissions of NBA in the Canal Zone (lat. N $09^{\circ} 03' 15''$, long. W $079^{\circ} 38' 53''$), a path length of 8054 km.

The earlier three reports in this series deal with the reception of NBA at Frankfurt, Germany [Brady et al., 1963], Maui, Hawaii [Brady et al., 1964a], and Boulder, Colorado [Brady et al., 1964b].

It is the purpose of these reports merely to present the reduced phase data, with a minimum of discussion. The data in these reports will be used in subsequent papers, each of which will deal with a specific aspect of the data on all the paths.

2. Data Analyses

All the phase data used in these reports have been taken, reduced, and presented in a uniform manner as described in the first of the series [Brady et al., 1963]. Thus tables 1-12 contain monthly phase averages (AVER) at 5 minute intervals, standard deviations (SDV), the number of observations (NO) used in obtaining these quantities, the quiet average (QAV), which is the average after values more than one standard deviation from AVER are discarded, and the number (NO) of values used in QAV. (A fuller description of these tables is given in the first note of this series).

3. Diurnal Phase Variations

The monthly mean diurnal phase changes and standard deviations for 1962, taken from tables 1-12, are plotted in figures 1 and 2. The average diurnal phase change for 1962 is 320 degrees. According to the mode theory of VLF propagation [Wait, 1962], a phase change of this magnitude corresponds to a change in the effective height of the ionosphere along the whole path of 16 km (assuming that the ionosphere is sharply bounded and that the mean of the daytime and nighttime heights is 80 km).

3.1 Seasonal Variation in Diurnal Phase Change

The mean diurnal phase change for each month is listed in table 13. Fourier analysis of these monthly means suggests that there may be small periodic variations having periods of 6 and 12 months. The apparent 6 months component has an amplitude of about 20° and a maximum in March. The apparent 12 month component has an amplitude of about 22° but a maximum in December. Because of the scatter in the monthly means, these periodic components are probably not significant. However, if they should prove to be significant, they represent peak-to-peak variations in the diurnal height change of about 1.0 km and 1.1 km, respectively.

3.2 Variation of Phase with Amount of Illuminated Path

The monthly average phase variation shown in figures 1 and 2 shows typical superficial dependence on the length of path which is in daylight [Crombie et al., 1958; Pierce, 1957]. A detailed examination of this relationship is given by plotting the diurnal phase changes at sunrise and sunset, together with variation in the length of illuminated path (at appropriate heights) at these times. This has been done in figures 3 and 4, which show the sunrise and sunset variations for March and June and for September and December, respectively, for 1962. The figures have been drawn so that the full diurnal phase variation fits the full "percent darkness" scale in each case.

The calculations of the length of illuminated path were made in the way described by Brady and Crombie [1964], and Crary [1965]. It is assumed in these calculations that the screening height of the earth's atmosphere is 30 km. Sunrise or sunset at the heights of 0 and 80 km are thus equivalent to solar zenith angles of 90° and 97° .

3.3 Sunrise

Figures 3 and 4 show that the smoothed sunrise phase change follows fairly closely the percentage of the path in darkness. In most cases the sunrise phase change started when the solar zenith angle was about 97° . More variability occurred in June, however, as shown in figure 3.

3.4 Sunset

Figures 3 and 4 also show that the dependence of the sunset phase change on the length of illuminated path is much weaker than at sunrise. In particular, the figures show quite clearly that during several hours before ground sunset at the eastern end of the path, a small phase retardation, typically ten percent of the total diurnal change, often occurs. This is most pronounced in March but also occurs to some extent in December. Then at ground sunset there is a further major phase retardation which generally follows fairly closely the variation in the percentage of path in darkness. When about 70% of the path has become dark the rate of change decreases considerably and in some cases it takes as long as four hours after ground sunset before normal nighttime phase value is attained.

4. Phase Stability

It was pointed out in the first paper of this series that both day-to-day phase stabilities and the phase variations over periods of time up to an hour or so were of interest. Typical values for the NBA-Frankfurt path were given in that paper.

The day-to-day deviations of phase observed over this path are given at 5 minute intervals for each month of 1962 in tables 1-12, and are also plotted in figures 1 and 2. During the hours when the path is completely daylit, the day-to-day standard deviations have an average value of about 10° without any seasonal trend being apparent. When the path is dark, the day-to-day standard deviations vary between about 20° and 45° , but tend to be higher in the winter. For this path, a change in phase of 1° corresponds to a calculated change in the effective height of the ionosphere of 0.051 km. Thus the observed phase differences noted above are equivalent to height changes of about 0.5 km during the day if it is assumed that the fluctuations are entirely due to the ionosphere. The nighttime values range between 1.0 and 2.3 km.

The method of obtaining the short term phase variations has been described in the first of this series [Brady et al., 1963]. Table 14 contains the rms phase difference calculated in this way for intervals of 10-90 minutes (T). The data are given for both daytime and nighttime conditions during February, April, June, August, October and December of 1962. As noted in the other papers of this series, the rms phase differences increase as the time interval T increases, particularly when T is small. There is a tendency for the magnitude of the fluctuations to be greater at night than during the day when T is small. The table suggests that this is true for all the tabulated intervals T only during the summer months. During the rest of the year a cross over from greater night values to greater day values tends to occur for values of T between 10 and 60 minutes. This behavior is different than that found in the previously reported observations in this series.

5. Acknowledgment

The observations at College, Alaska, were obtained by Dr. H.F. Bates and Mr. Paul Albee of the Geophysical Institute of the University of Alaska. The work was supported under contract CST-7338 of the National Bureau of Standard from the Advanced Research Projects Agency, Washington, D. C., under order No. 183, which also supported the work at NBS.

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NBA (18 kc/s. BALBOA, PANAMA) TO COLLEGE, ALASKA
 AVERAGE PHASE FOR JANUARY - MARCH AND OCTOBER - DECEMBER 1962

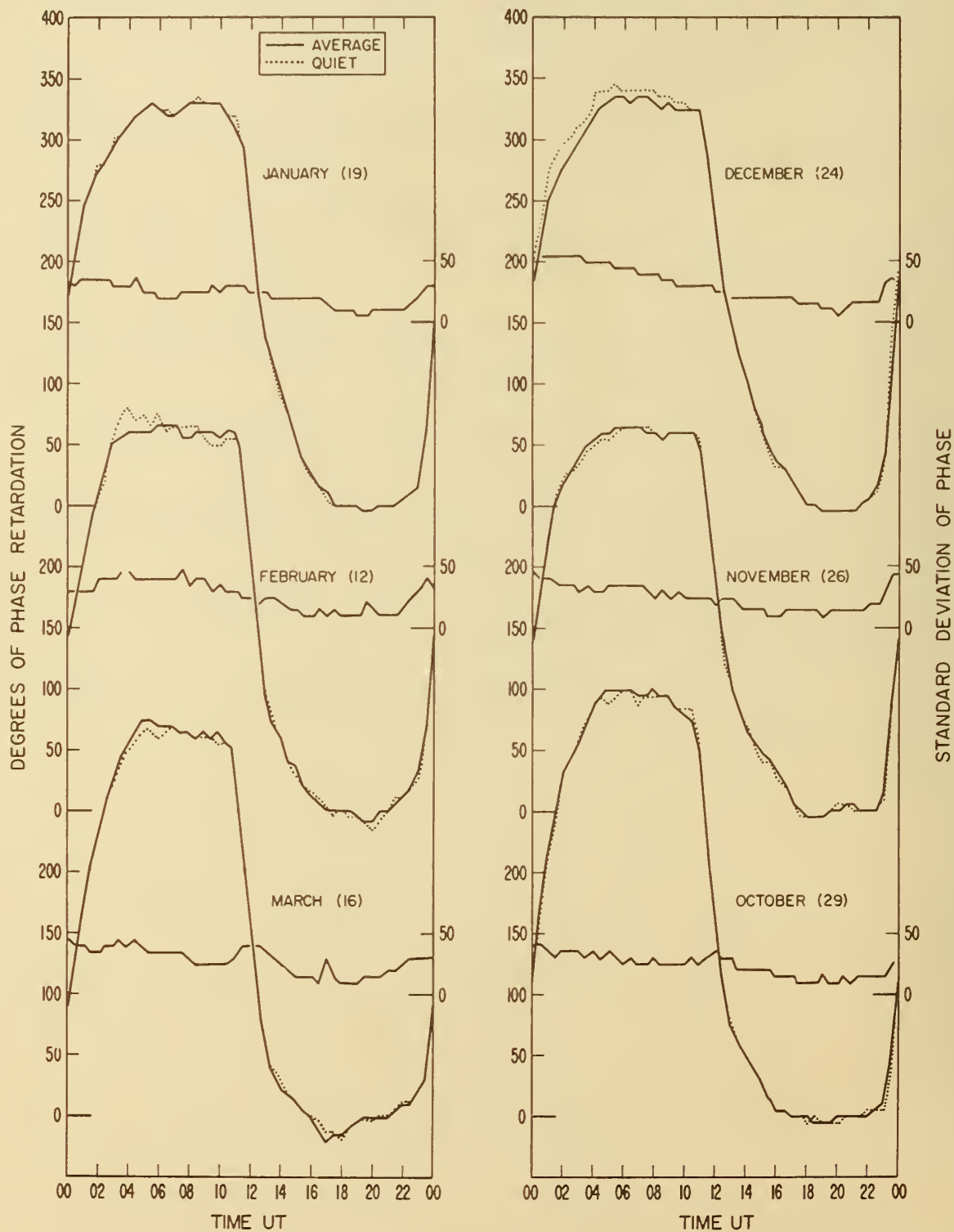


Figure 1. Mean phase variations and standard deviations in degrees for January - March and October - December 1962.

NBA (18 kc/s, BALBOA, PANAMA) TO COLLEGE, ALASKA
 AVERAGE PHASE FOR APRIL-JUNE AND JULY-SEPTEMBER 1962

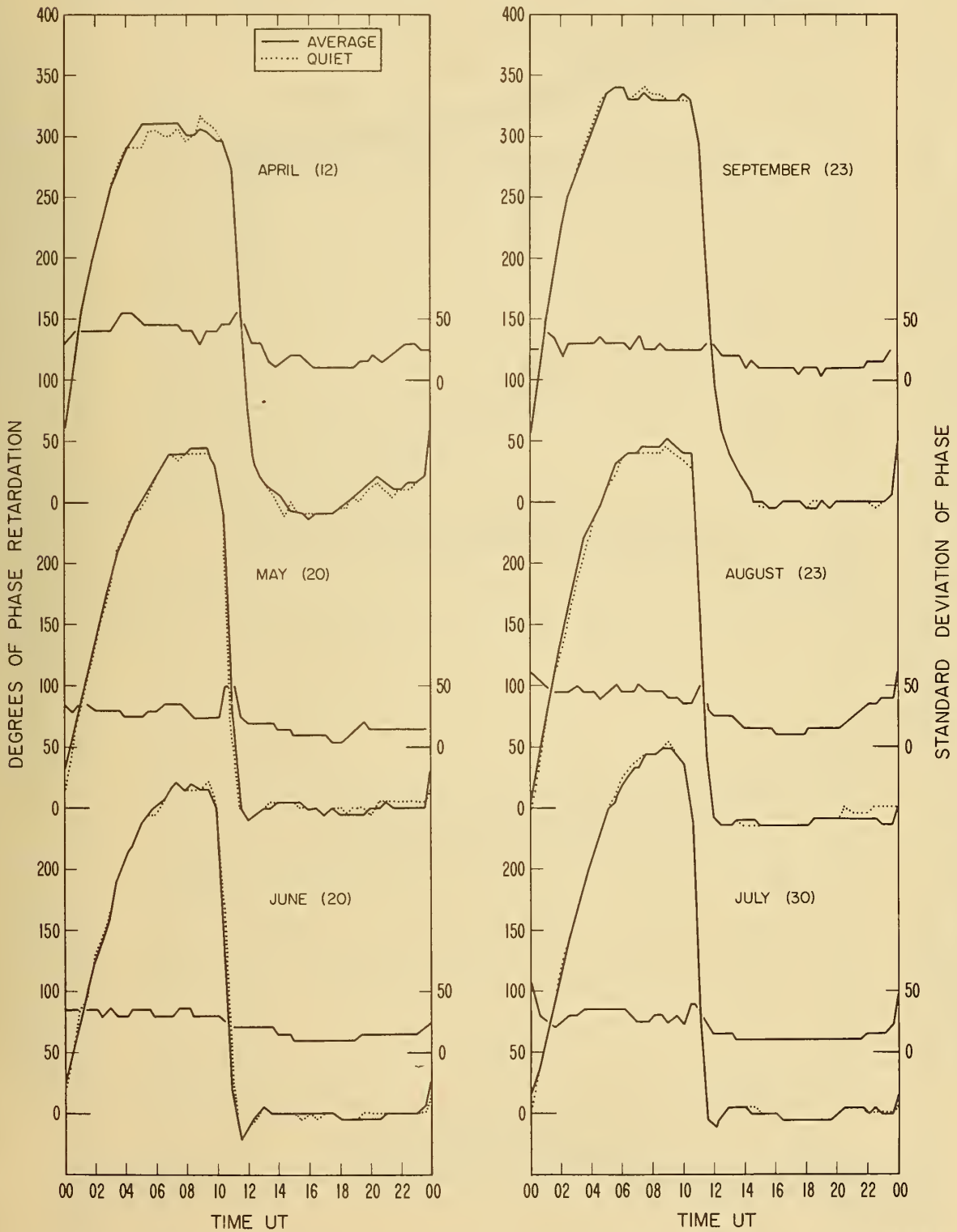


Figure 2. Mean phase variations and standard deviations in degrees for April-June and July-September 1962.

DIURNAL VARIATION AND PERCENTAGE OF DARKNESS ON NBA - COLLEGE PATH

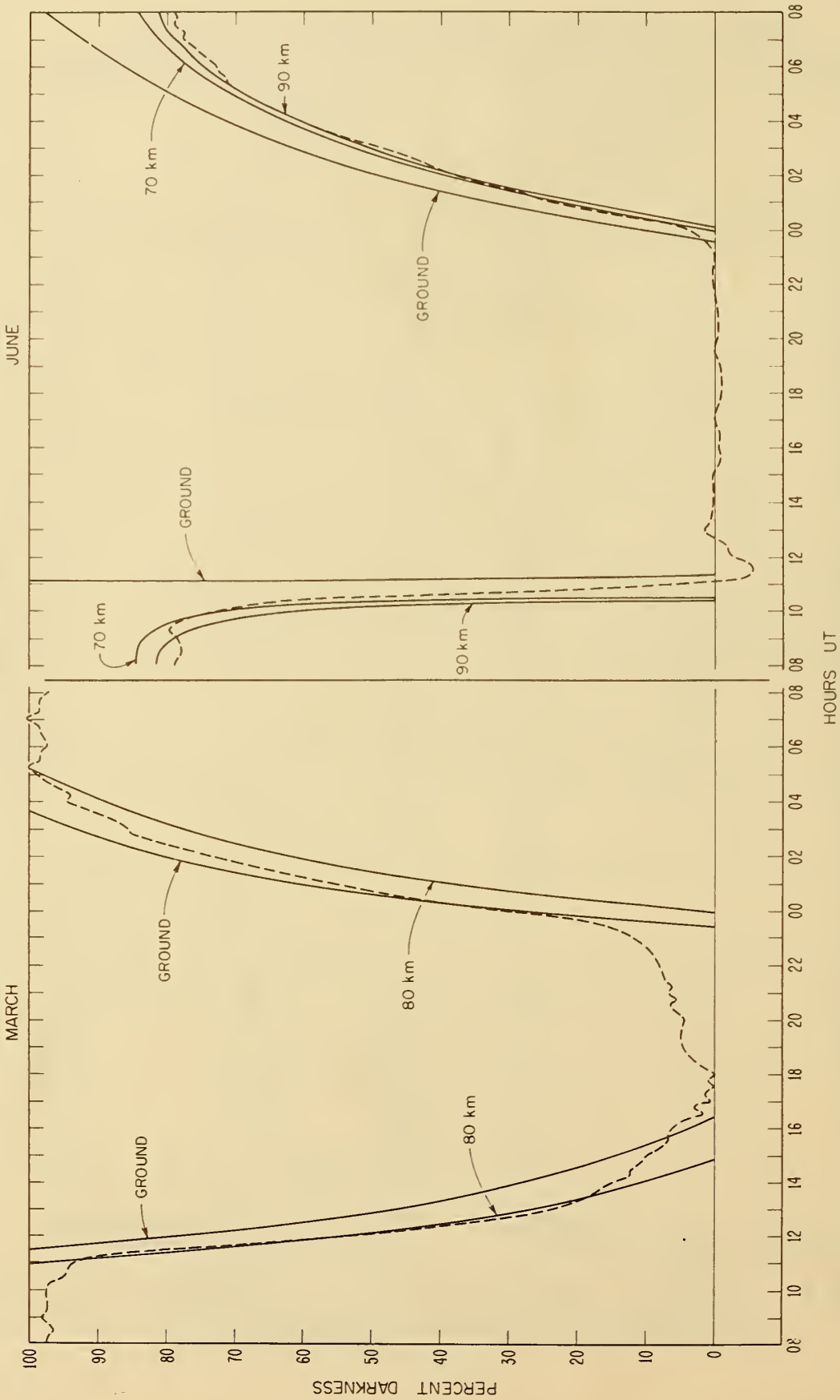


Figure 3. Diurnal phase variation (dotted) and percentage of darkness (solid lines) on path for March and June 1962. (Note: The ordinate also gives the percentage of the diurnal phase variation which has occurred.)

DIURNAL VARIATION AND PERCENTAGE OF DARKNESS ON NBA - COLLEGE PATH

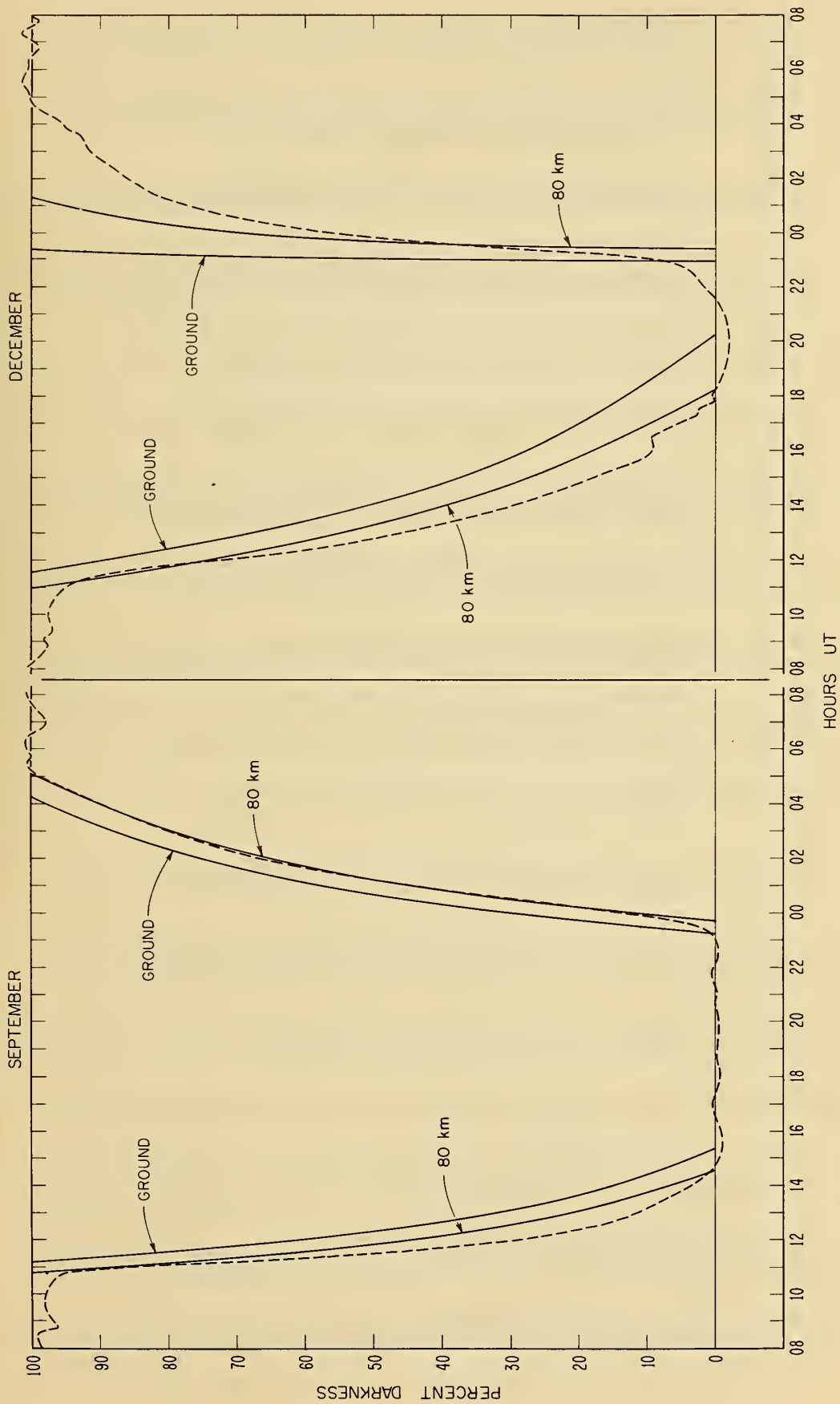


Figure 4. Diurnal phase variation (dotted) and percentage of darkness (solid lines) on path for September and December 1962. (Note: The ordinate also gives the percentage of the diurnal phase variation which has occurred.)

Table 4

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 4 1962

UT	AVER	SDV	NO	QAV	NO	MIN	MAX
00	446.	316.	12	449.	6	418.	493.
01	401.	350.	11	351.	6	416.	493.
02	321.	442.	11	389.	8	413.	493.
03	295.	438.	11	255.	8	413.	493.
04	231.	466.	11	222.	7	413.	493.
05	206.	457.	11	222.	7	413.	493.
06	193.	447.	11	222.	7	413.	493.
07	188.	443.	11	222.	7	413.	493.
08	192.	443.	11	222.	7	413.	493.
09	188.	439.	11	222.	7	413.	493.
10	195.	432.	11	222.	7	413.	493.
11	203.	418.	11	222.	7	413.	493.
12	207.	433.	11	222.	7	413.	493.
13	247.	455.	11	222.	7	413.	493.
14	375.	451.	11	222.	7	413.	493.
15	497.	432.	11	222.	7	413.	493.
16	497.	422.	11	222.	7	413.	493.
17	513.	416.	11	222.	7	413.	493.
18	510.	410.	11	222.	7	413.	493.
19	503.	411.	11	222.	7	413.	493.
20	497.	411.	11	222.	7	413.	493.
21	487.	425.	11	222.	7	413.	493.
22	484.	425.	11	222.	7	413.	493.
23	485.	424.	11	222.	7	413.	493.

Table 6

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 6 1962

UT	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23														
AVER	525.	554.	581.	598.	642.	688.	706.	723.	743.	750.	767.	768.	769.	769.	766.	749.	621.	490.	498.	504.	503.	502.	501.	500.	501.	499.	496.	497.	494.	500.	501.	500.	503.	504.				
SDV	37.	34.	34.	33.	32.	32.	34.	34.	34.	31.	32.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	16.			
QAV	16.	15.	12.	13.	16.	15.	16.	13.	13.	14.	15.	15.	14.	15.	14.	13.	15.	15.	18.	18.	18.	12.	11.	11.	11.	11.	11.	12.	13.	12.	11.	12.	11.	12.	11.	12.	12.	
NO	16	15	12	13	16	15	16	13	13	14	15	15	14	15	14	13	15	15	18	18	18	12	11	11	11	11	12	13	12	11	12	11	12	11	12	12		
MIN	518.	557.	615.	650.	697.	727.	740.	746.	758.	768.	766.	770.	772.	782.	796.	492.	490.	500.	502.	502.	502.	502.	501.	500.	501.	501.	497.	497.	498.	499.	499.	501.	501.	501.	506.	506.		
MAX	524.	569.	633.	657.	699.	712.	744.	751.	767.	766.	775.	778.	788.	488.	489.	490.	500.	500.	500.	500.	500.	500.	499.	500.	499.	499.	499.	499.	499.	500.	500.	500.	500.	500.	500.	500.		
MIN	0	19	20	20	20	20	20	20	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	
MAX	36.	35.	34.	33.	32.	32.	33.	33.	32.	33.	33.	33.	32.	29.	29.	21.	22.	20.	20.	20.	18.	18.	13.	11.	9.	9.	10.	8.	9.	13.	14.	15.	15.	16.	17.	19.	19.	
MIN	15	14	12	14	17	16	14	14	16	16	15	15	15	15	14	14	14	14	14	14	18	18	12	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
MAX	542.	576.	615.	637.	657.	698.	731.	748.	763.	769.	768.	770.	768.	754.	486.	486.	503.	503.	502.	502.	501.	501.	501.	500.	500.	499.	497.	496.	498.	499.	499.	501.	501.	502.	504.	507.	507.	
MIN	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
MAX	15	13	12	16	17	14	15	14	16	14	15	16	15	15	14	14	14	14	14	14	18	18	12	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
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MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
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MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.	501.	500.	502.	498.	497.	497.	497.	496.	497.	500.	501.	503.	504.		
MIN	37.	34.	34.	33.	32.	32.	34.	34.	31.	32.	33.	36.	35.	30.	28.	28.	29.	20.	22.	20.	21.	19.	17.	19.	19.	10.	9.	8.	9.	13.	15.	14.	15.	16.	17.	19.	19.	
MAX	527.	561.	585.	603.	645.	691.	724.	735.	744.	751.	758.	769.	769.	768.	767.	739.	602.	482.	499.	502.	503.	502.	502.</															

Table 7

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 7 1962

UT	AVER	SDV	AVERAGE	ON PATH	5	MIN	+10	MIN	+15	MIN	+20	MIN	+25	MIN
00	517.	55.	31	516.	35	31	512.	25	519.	19	21	517.	19	21
01	534.	29.	31	541.	24	31	573.	22	577.	20	23	582.	20	23
02	560.	24.	30	575.	22	30	630.	21	636.	20	23	646.	20	23
03	622.	25.	31	627.	22	31	657.	20	657.	20	23	670.	20	23
04	666.	32.	31	670.	23	31	691.	20	691.	20	23	709.	20	23
05	711.	36.	31	713.	30	31	716.	18	723.	19	20	727.	19	20
06	731.	33.	31	734.	33	31	752.	17	754.	18	20	756.	18	20
07	756.	36.	31	755.	34	30	771.	16	773.	19	20	776.	19	20
08	769.	33.	30	771.	32	30	776.	16	778.	18	20	781.	18	20
09	782.	32.	30	787.	31	30	788.	16	790.	18	20	795.	18	20
10	796.	26.	30	799.	28	30	799.	16	799.	18	20	799.	18	20
11	802.	29.	30	802.	27	30	802.	16	802.	18	20	802.	18	20
12	803.	29.	30	804.	27	30	804.	16	804.	18	20	804.	18	20
13	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
14	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
15	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
16	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
17	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
18	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
19	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
20	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
21	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
22	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20
23	805.	28.	30	805.	27	30	805.	16	805.	18	20	805.	18	20

Table 9

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 9 1962

UT	AVER	SDV	AVERAGE ON PATH	QAV	NO	SDV	AVERAGE ON PATH	QAV	NO	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX		
00	549.	23.	21	548.	114	558.	23	547.	114	566.	12	567.	12	574.	19	574.	19	574.	19	574.	19	574.	19	574.	19	574.	19
01	601.	38.	23	601.	149	607.	38	601.	149	615.	13	627.	13	627.	19	627.	19	627.	19	627.	19	627.	19	627.	19	627.	19
02	692.	34.	23	692.	182	698.	34	692.	182	700.	11	709.	11	709.	23	709.	23	709.	23	709.	23	709.	23	709.	23	709.	23
03	727.	28.	24	727.	169	733.	28	727.	169	730.	10	741.	10	741.	22	741.	22	741.	22	741.	22	741.	22	741.	22	741.	22
04	769.	30.	22	769.	177	775.	30	769.	177	780.	9	787.	9	787.	22	787.	22	787.	22	787.	22	787.	22	787.	22	787.	22
05	804.	33.	23	804.	165	808.	33	804.	165	815.	8	824.	8	824.	23	824.	23	824.	23	824.	23	824.	23	824.	23	824.	23
06	836.	29.	23	836.	183	838.	29	836.	183	843.	7	849.	7	849.	23	849.	23	849.	23	849.	23	849.	23	849.	23	849.	23
07	839.	27.	23	839.	165	842.	27	839.	165	843.	6	847.	6	847.	23	847.	23	847.	23	847.	23	847.	23	847.	23	847.	23
08	829.	26.	23	829.	142	833.	26	829.	142	835.	5	839.	5	839.	23	839.	23	839.	23	839.	23	839.	23	839.	23	839.	23
09	830.	28.	23	830.	136	833.	28	830.	136	837.	4	841.	4	841.	23	841.	23	841.	23	841.	23	841.	23	841.	23	841.	23
10	824.	24.	23	824.	111	828.	24	824.	111	830.	3	833.	3	833.	23	833.	23	833.	23	833.	23	833.	23	833.	23	833.	23
11	825.	25.	23	825.	111	828.	25	825.	111	830.	2	833.	2	833.	23	833.	23	833.	23	833.	23	833.	23	833.	23	833.	23
12	601.	30.	22	601.	116	608.	30	601.	116	617.	1	627.	1	627.	23	627.	23	627.	23	627.	23	627.	23	627.	23	627.	23
13	560.	22.	23	560.	147	568.	22	560.	147	569.	0	579.	0	579.	23	579.	23	579.	23	579.	23	579.	23	579.	23	579.	23
14	527.	18.	19	527.	122	535.	18	527.	122	535.	0	543.	0	543.	19	543.	19	543.	19	543.	19	543.	19	543.	19	543.	19
15	503.	15.	19	503.	122	511.	15	503.	122	512.	0	520.	0	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19
16	497.	12.	19	497.	143	502.	12	497.	143	510.	0	517.	0	517.	19	517.	19	517.	19	517.	19	517.	19	517.	19	517.	19
17	496.	10.	18	496.	133	498.	10	496.	133	503.	0	509.	0	509.	18	509.	18	509.	18	509.	18	509.	18	509.	18	509.	18
18	498.	7.	18	498.	133	499.	7	498.	133	501.	0	507.	0	507.	18	507.	18	507.	18	507.	18	507.	18	507.	18	507.	18
19	499.	8.	18	499.	123	498.	8	499.	123	501.	0	507.	0	507.	18	507.	18	507.	18	507.	18	507.	18	507.	18	507.	18
20	498.	10.	19	498.	133	503.	10	498.	133	509.	0	517.	0	517.	19	517.	19	517.	19	517.	19	517.	19	517.	19	517.	19
21	503.	11.	20	503.	137	502.	11	503.	137	509.	0	517.	0	517.	20	517.	20	517.	20	517.	20	517.	20	517.	20	517.	20
22	502.	11.	23	502.	116	501.	11	502.	116	508.	0	515.	0	515.	23	515.	23	515.	23	515.	23	515.	23	515.	23	515.	23
23	507.	17.	24	507.	111	504.	17	507.	111	512.	0	520.	0	520.	23	520.	23	520.	23	520.	23	520.	23	520.	23	520.	23

Table 10

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 10 1962

UT	AVER	SDV	NO	QAV	NO	MIN	+10	MIN	+15	MIN	+20	MIN	+25	MIN
00	620	39	21	615	17	631	40	640	40	645	40	657	40	659
01	672	36	17	674	18	688	38	728	38	745	38	759	37	739
02	751	35	19	750	19	760	39	784	33	763	36	779	33	776
03	796	35	21	796	22	798	33	800	32	802	32	806	33	808
04	803	34	18	803	19	812	33	814	32	816	32	818	33	819
05	838	34	22	838	21	842	33	844	33	845	33	844	33	842
06	847	34	18	847	18	849	33	846	34	843	33	847	33	844
07	849	31	22	849	22	850	30	848	30	846	29	849	28	846
08	850	28	29	850	29	848	29	848	29	847	29	849	28	846
09	846	28	29	846	29	848	29	848	29	847	29	849	28	846
10	847	28	29	847	29	845	28	844	28	843	28	847	28	844
11	847	28	29	847	29	844	28	844	28	843	28	847	28	844
12	847	28	29	847	29	845	28	844	28	843	28	847	28	844
13	847	28	29	847	29	845	28	844	28	843	28	847	28	844
14	847	28	29	847	29	845	28	844	28	843	28	847	28	844
15	847	28	29	847	29	845	28	844	28	843	28	847	28	844
16	847	28	29	847	29	845	28	844	28	843	28	847	28	844
17	847	28	29	847	29	845	28	844	28	843	28	847	28	844
18	847	28	29	847	29	845	28	844	28	843	28	847	28	844
19	847	28	29	847	29	845	28	844	28	843	28	847	28	844
20	847	28	29	847	29	845	28	844	28	843	28	847	28	844
21	847	28	29	847	29	845	28	844	28	843	28	847	28	844
22	847	28	29	847	29	845	28	844	28	843	28	847	28	844
23	847	28	29	847	29	845	28	844	28	843	28	847	28	844

Table 11

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 11 1962

UT	AVER	SDV	NO	QAV	NO	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
00	639.	44.	27	643.	17	662.	17	662.	17	662.	17	662.	17	662.	17	662.	17	662.	17	662.	17
01	686.	30.	27	693.	18	707.	18	707.	18	707.	18	707.	18	707.	18	707.	18	707.	18	707.	18
02	725.	38.	25	728.	19	742.	19	742.	19	742.	19	742.	19	742.	19	742.	19	742.	19	742.	19
03	780.	36.	25	779.	19	783.	19	783.	19	783.	19	783.	19	783.	19	783.	19	783.	19	783.	19
04	800.	32.	26	797.	21	804.	21	804.	21	804.	21	804.	21	804.	21	804.	21	804.	21	804.	21
05	811.	32.	26	803.	20	809.	20	809.	20	809.	20	809.	20	809.	20	809.	20	809.	20	809.	20
06	816.	36.	26	804.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20
07	816.	35.	26	808.	20	814.	20	814.	20	814.	20	814.	20	814.	20	814.	20	814.	20	814.	20
08	817.	35.	26	818.	20	824.	20	824.	20	824.	20	824.	20	824.	20	824.	20	824.	20	824.	20
09	813.	34.	26	816.	21	822.	21	822.	21	822.	21	822.	21	822.	21	822.	21	822.	21	822.	21
10	810.	32.	25	807.	19	813.	19	813.	19	813.	19	813.	19	813.	19	813.	19	813.	19	813.	19
11	811.	32.	25	809.	19	815.	19	815.	19	815.	19	815.	19	815.	19	815.	19	815.	19	815.	19
12	830.	25.	25	812.	20	818.	20	818.	20	818.	20	818.	20	818.	20	818.	20	818.	20	818.	20
13	601.	22.	25	803.	17	809.	17	809.	17	809.	17	809.	17	809.	17	809.	17	809.	17	809.	17
14	581.	24.	25	739.	17	745.	17	745.	17	745.	17	745.	17	745.	17	745.	17	745.	17	745.	17
15	566.	20.	20	688.	16	694.	16	694.	16	694.	16	694.	16	694.	16	694.	16	694.	16	694.	16
16	540.	15.	20	620.	14	626.	14	626.	14	626.	14	626.	14	626.	14	626.	14	626.	14	626.	14
17	520.	11.	20	570.	13	576.	13	576.	13	576.	13	576.	13	576.	13	576.	13	576.	13	576.	13
18	499.	11.	21	553.	13	559.	13	559.	13	559.	13	559.	13	559.	13	559.	13	559.	13	559.	13
19	495.	11.	21	547.	13	553.	13	553.	13	553.	13	553.	13	553.	13	553.	13	553.	13	553.	13
20	503.	13.	22	497.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13
21	499.	14.	22	495.	13	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13
22	501.	11.	22	497.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13	503.	13
23	516.	12.	22	518.	14	524.	14	524.	14	524.	14	524.	14	524.	14	524.	14	524.	14	524.	14

Table 12

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 12 1962

UT	AVER	SDV	NO	QAV	NO	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
00	698.	56.	24	704.	0	713.	20	710.	20	719.	20	725.	20	716.	20	755.	20	714.	20	759.	20
01	727.	56.	24	735.	20	742.	20	732.	20	751.	20	759.	20	744.	20	779.	20	744.	20	788.	20
02	777.	55.	24	780.	20	796.	20	774.	20	797.	20	799.	20	775.	20	807.	20	776.	20	806.	20
03	788.	55.	24	791.	20	804.	20	795.	20	808.	20	811.	20	792.	20	817.	20	796.	20	819.	20
04	806.	52.	24	808.	20	825.	20	802.	20	823.	20	825.	20	801.	20	835.	20	812.	20	832.	20
05	813.	48.	24	817.	20	835.	20	811.	20	841.	20	840.	20	812.	20	851.	20	822.	20	856.	20
06	834.	46.	24	831.	20	842.	20	832.	20	842.	20	841.	20	833.	20	840.	20	834.	20	844.	20
07	833.	45.	24	835.	20	842.	20	833.	20	843.	20	843.	20	833.	20	840.	20	833.	20	842.	20
08	833.	44.	24	833.	20	842.	20	833.	20	843.	20	843.	20	833.	20	840.	20	833.	20	842.	20
09	832.	42.	24	833.	20	842.	20	833.	20	843.	20	843.	20	833.	20	840.	20	833.	20	842.	20
10	822.	34.	24	822.	20	833.	20	822.	20	833.	20	833.	20	822.	20	833.	20	822.	20	833.	20
11	822.	30.	24	822.	20	833.	20	822.	20	833.	20	833.	20	822.	20	833.	20	822.	20	833.	20
12	822.	27.	24	822.	20	833.	20	822.	20	833.	20	833.	20	822.	20	833.	20	822.	20	833.	20
13	822.	27.	24	822.	20	833.	20	822.	20	833.	20	833.	20	822.	20	833.	20	822.	20	833.	20
14	604.	22.	19	604.	19	613.	19	604.	19	613.	19	604.	19	604.	19	613.	19	604.	19	613.	19
15	580.	20.	19	580.	19	592.	19	580.	19	592.	19	580.	19	580.	19	592.	19	580.	19	592.	19
16	546.	20.	19	546.	19	558.	19	546.	19	558.	19	546.	19	546.	19	558.	19	546.	19	558.	19
17	520.	20.	19	520.	19	532.	19	520.	19	532.	19	520.	19	520.	19	532.	19	520.	19	532.	19
18	502.	17.	18	502.	18	514.	18	502.	18	514.	18	502.	18	502.	18	514.	18	502.	18	514.	18
19	496.	17.	18	496.	18	508.	18	496.	18	508.	18	496.	18	496.	18	508.	18	496.	18	508.	18
20	493.	17.	18	493.	18	505.	18	493.	18	505.	18	493.	18	493.	18	505.	18	493.	18	505.	18
21	497.	13.	22	497.	22	509.	22	497.	22	509.	22	497.	22	497.	22	509.	22	497.	22	509.	22
22	503.	15.	22	503.	22	515.	22	503.	22	515.	22	503.	22	503.	22	515.	22	503.	22	515.	22
23	542.	37.	23	542.	23	554.	23	542.	23	554.	23	542.	23	542.	23	554.	23	542.	23	554.	23

Table 13

Monthly mean diurnal phase change
(NBA-College path)

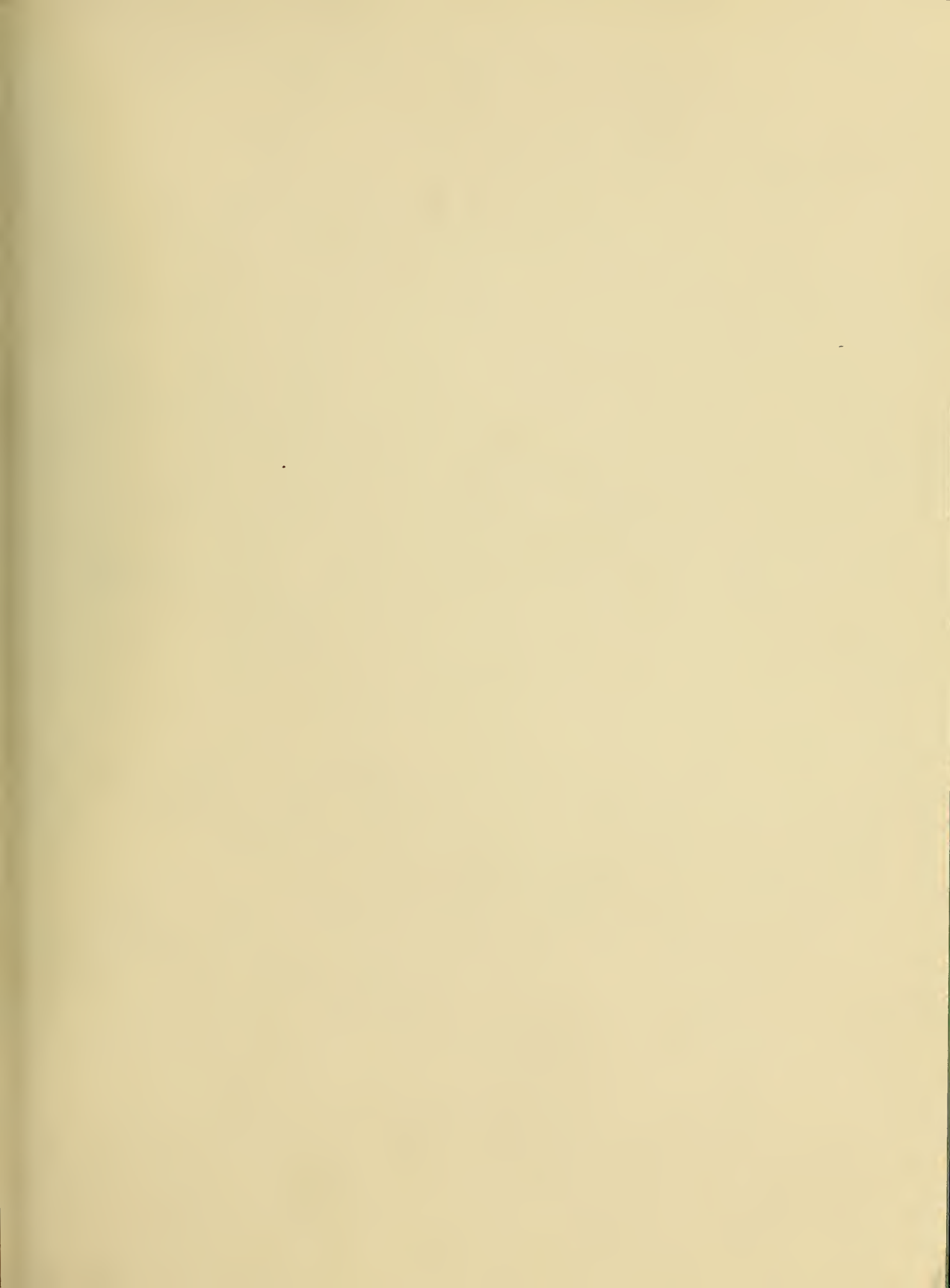
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1962	332	320	335	322	300	272	302	310	337	352	320	342
												degrees

Table 14

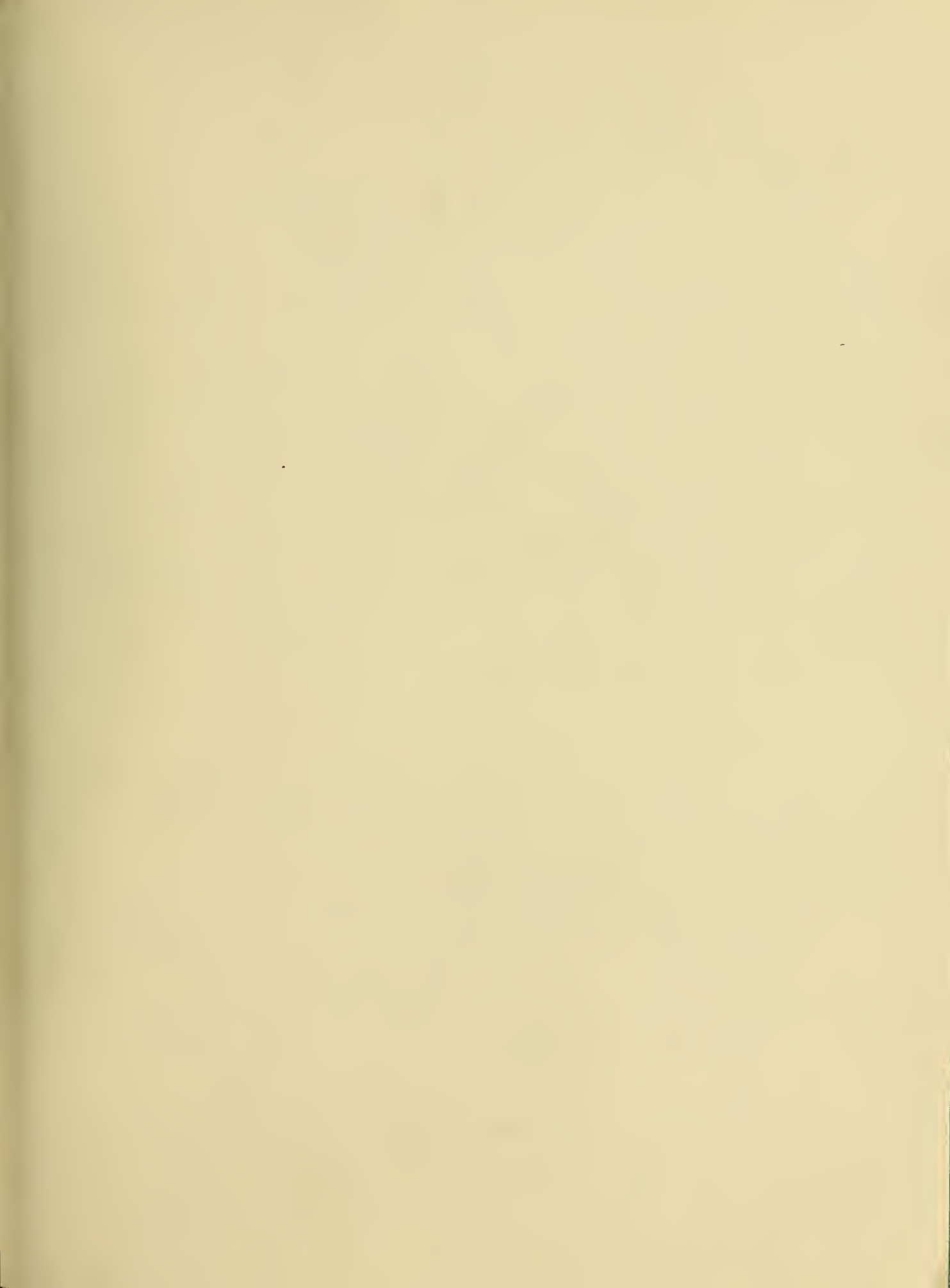
RMS phase difference between observations
separated by time T (NBA-College path)

1962 Month	Time of Day	T										minutes
		10	20	30	40	50	60	70	80	90		
Feb.	Night	6.4	8.4	10.0	11.4	12.1	12.6	13.6	14.3	14.4	degrees	
"	Day	5.2	8.4	11.2	13.8	16.4	18.7	21.4	21.7	23.2	"	
Apr.	Night	7.4	12.2	15.6	18.8	20.6	20.2	19.0	17.5	17.4	"	
"	Day	5.9	10.4	14.0	17.1	19.6	22.0	24.4	27.1	29.0	"	
June	Night	10.4	19.8	28.6	34.4	45.4	53.1	61.4	69.0	76.7	"	
"	Day	3.3	5.2	6.3	7.5	8.9	9.9	10.5	11.1	11.6	"	
Aug.	Night	11.7	16.5	20.7	24.2	28.5	30.6	32.3	35.9	38.8	"	
"	Day	2.6	3.8	5.8	6.5	7.6	8.8	9.8	10.9	11.9	"	
Oct.	Night	11.9	15.7	16.5	14.2	13.5	15.9	17.3	19.7	18.6	"	
"	Day	5.3	7.5	9.5	11.4	13.1	14.5	16.1	17.1	18.7	"	
Dec.	Night	9.7	13.7	17.1	18.7	20.1	21.1	22.3	23.4	24.0	"	
"	Day	6.2	10.8	13.7	17.2	20.0	22.7	25.3	27.9	30.7	"	













U.S. DEPARTMENT OF COMMERCE
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