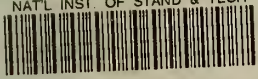


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# Technical Note

No. 206-4

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## 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

## *Technical Note . 206-4*

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  
Boulder, Colorado

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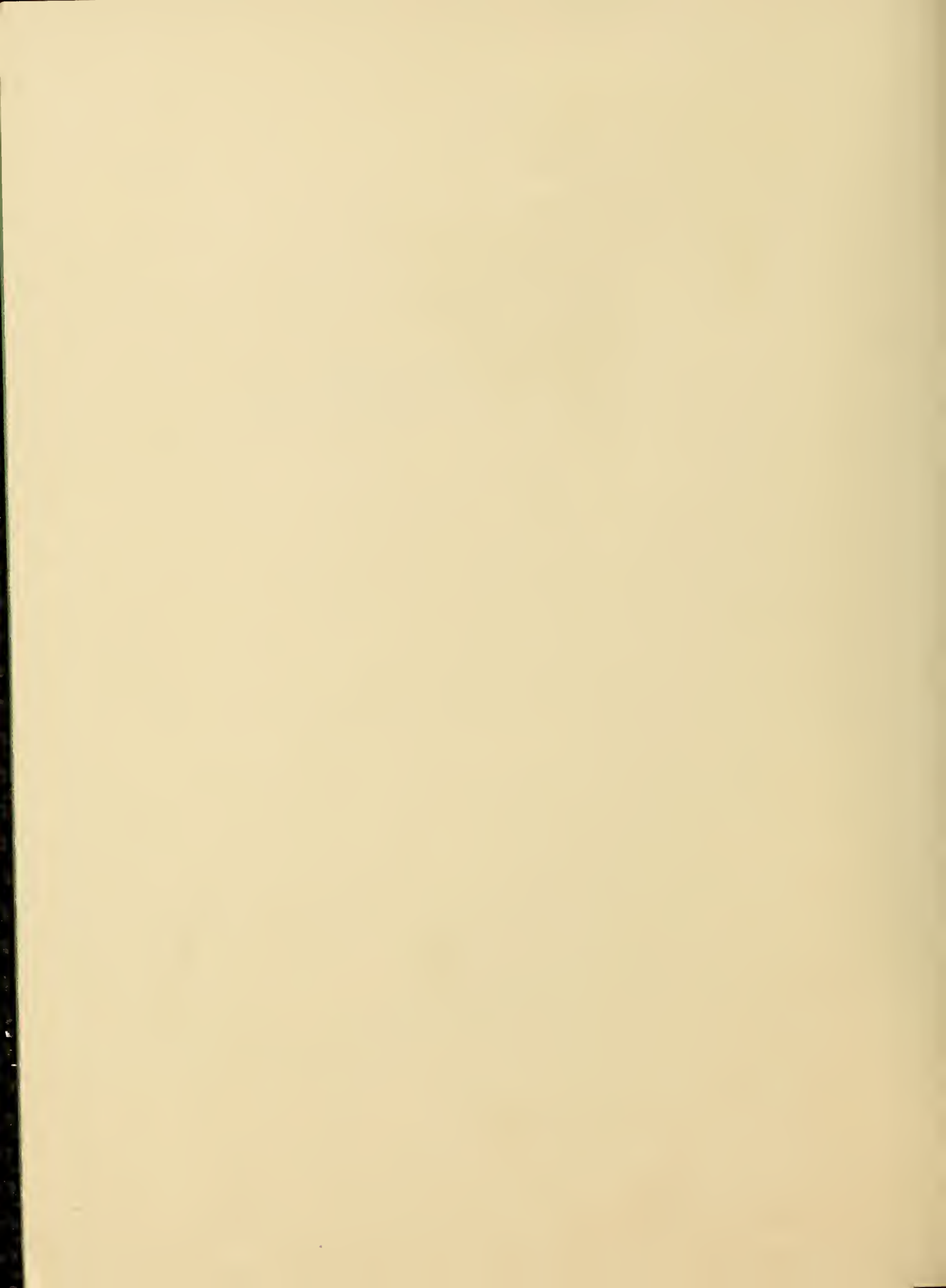
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## CONTENTS

	Page
Abstract . . . . .	1
1. Introduction . . . . .	1
2. Data Analyses . . . . .	1
3. Diurnal Phase Variations . . . . .	2
3.1 Seasonal Variation in Diurnal Phase Changes . . . . .	2
3.2 Variation of Phase with Amount of Illuminated Path . . . . .	2
3.3 Sunrise . . . . .	2
3.4 Sunset . . . . .	3
4. Phase Stability . . . . .	3
5. Acknowledgment . . . . .	4
6. References . . . . .	5
Figures . . . . .	6
Tables . . . . .	10



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  $20^\circ$  and a maximum in March. The apparent 12 month component has an amplitude of about  $22^\circ$  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  $90^\circ$  and  $97^\circ$ .

#### 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  $97^\circ$ . 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  $10^{\circ}$  without any seasonal trend being apparent. When the path is dark, the day-to-day standard deviations vary between about  $20^{\circ}$  and  $45^{\circ}$ , but tend to be higher in the winter. For this path, a change in phase of  $1^{\circ}$  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

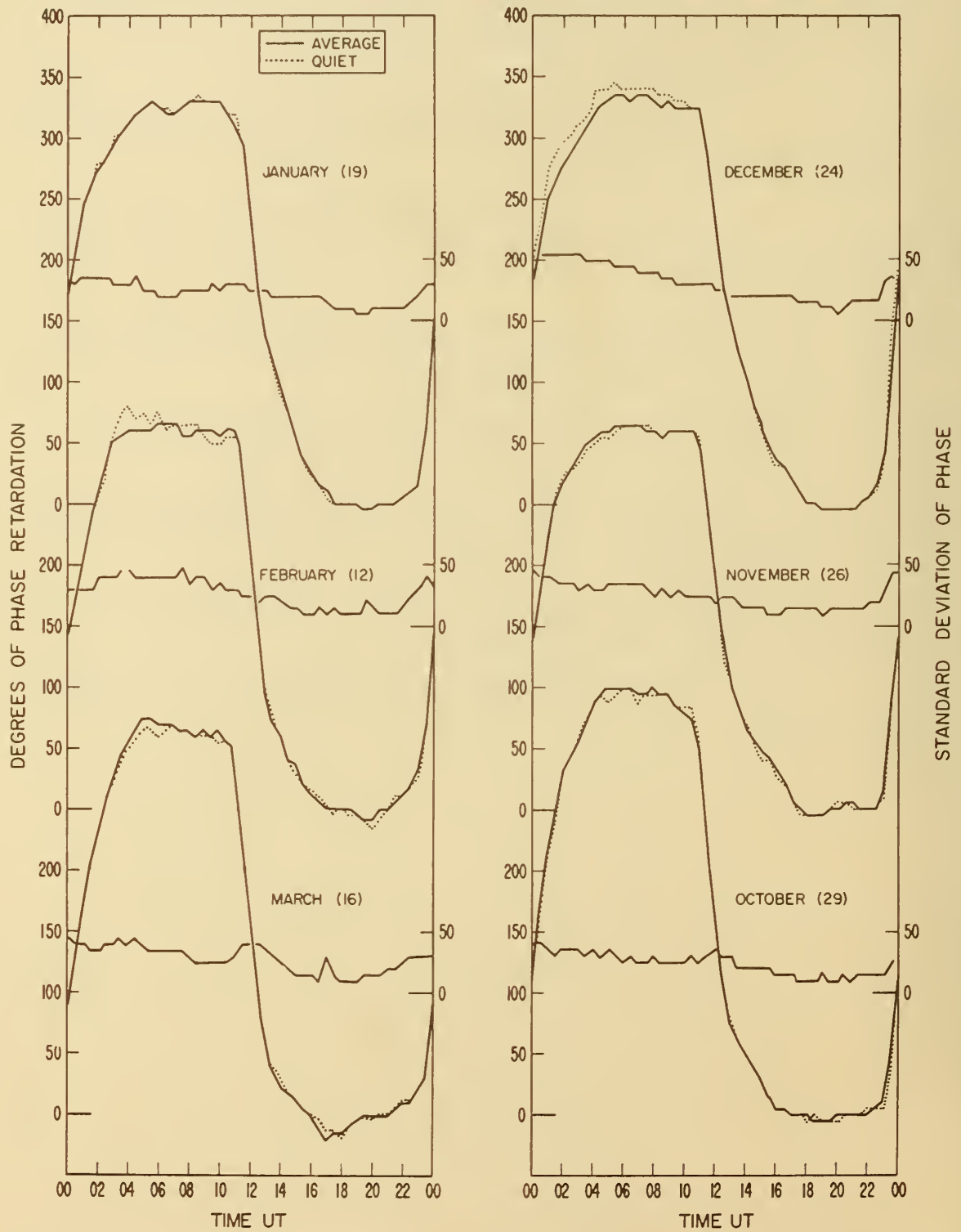


Figure 1. Mean phase variations and standard deviations in degrees for January - March and October - December 1962.

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

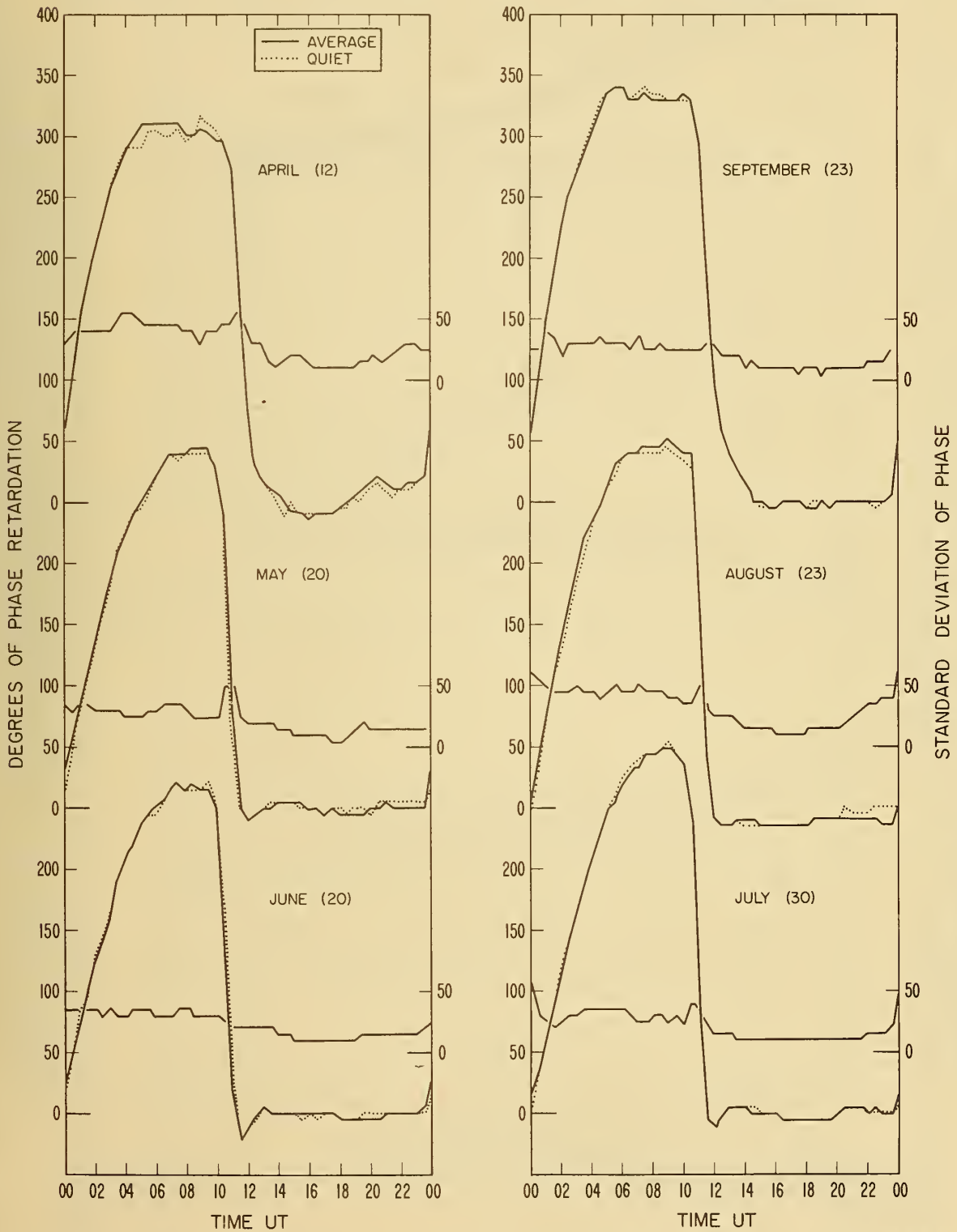


Figure 2. Mean phase variations and standard deviations in degrees for April-June and July-September 1962.

DIURNAL VARIATION AND PERCENTAGE OF DARKNESS ON NBA - COLLEGE PATH

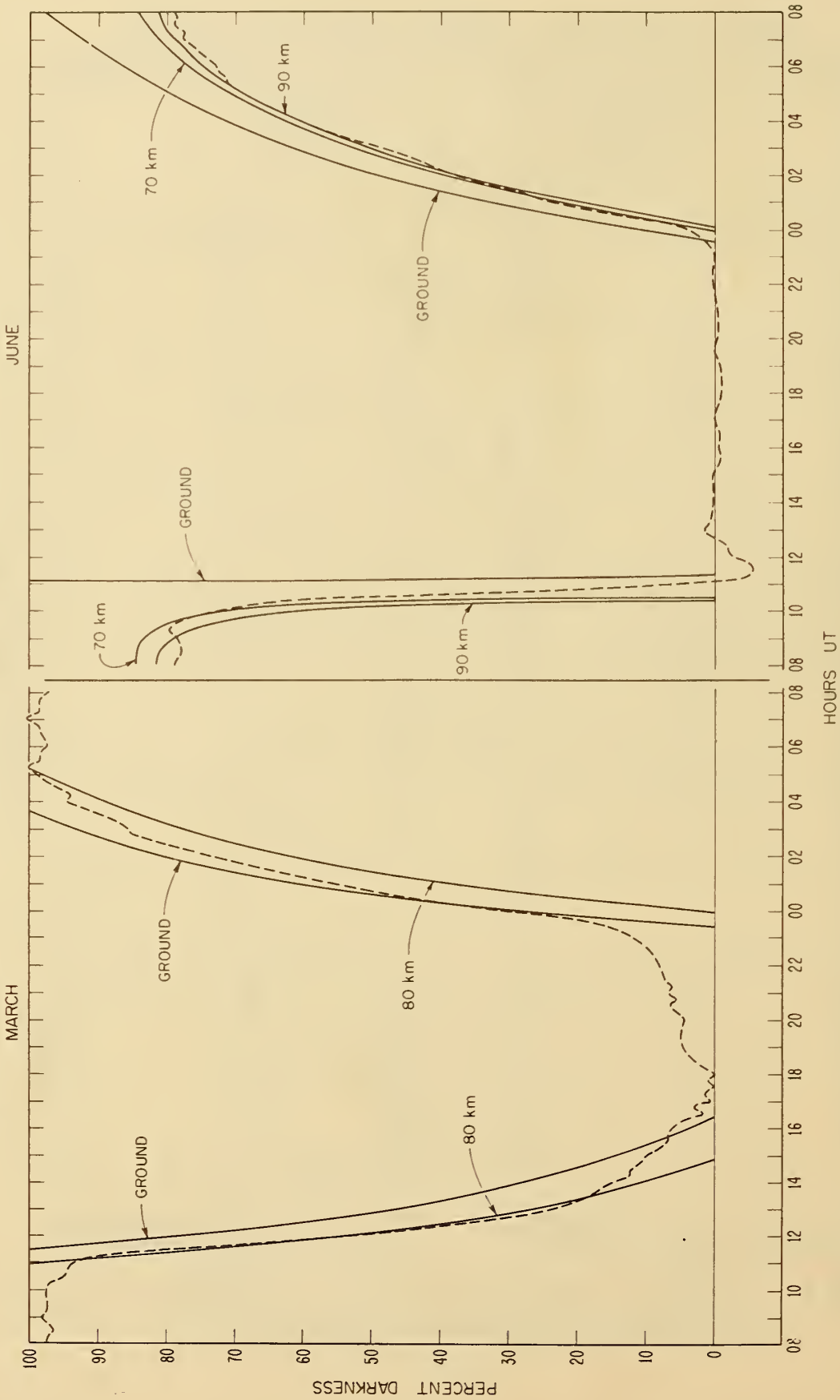


Figure 3. Diurnal phase variation (dotted) and percentage of darkness (solid lines) on path for March and June 1962. (Note: The ordinate also gives the percentage of the diurnal phase variation which has occurred.)

DIURNAL VARIATION AND PERCENTAGE OF DARKNESS ON NBA - COLLEGE PATH

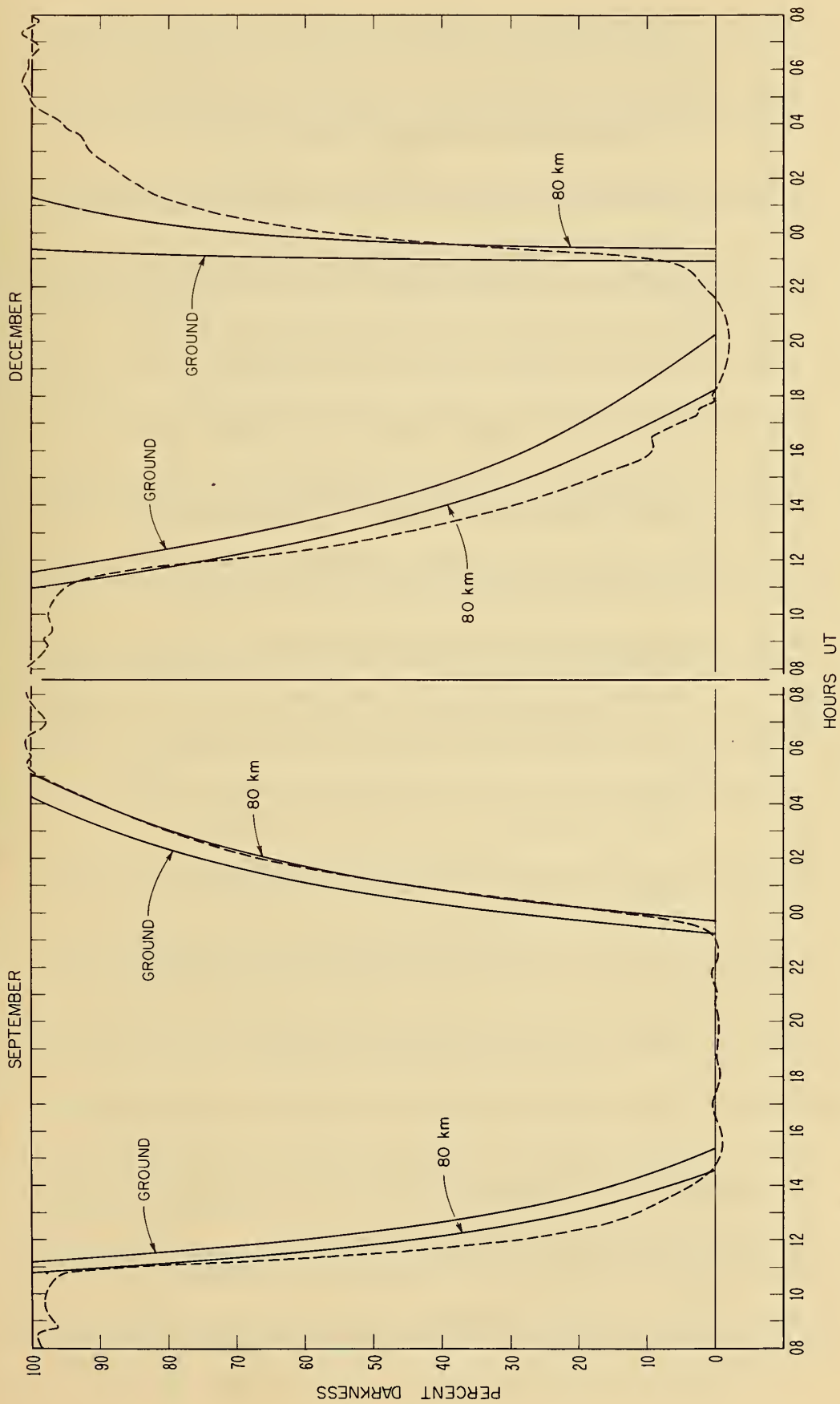


Figure 4. Diurnal phase variation (dotted) and percentage of darkness (solid lines) on path for September and December 1962. (Note: The ordinate also gives the percentage of the diurnal phase variation which has occurred.)

Table 1

UT	MONTHLY AVERAGE	SDV	NO	ON	PATH	2	2	FOR	MONTH	1	1962	MIN	MAX
00	338	330	18	NO	15	322	314	15	370	307	20	18	310
01	340	323	19	15	281	276	15	19	370	307	19	19	310
02	333	322	19	15	252	244	15	19	370	307	19	19	310
03	344	322	19	16	222	208	16	19	370	307	19	19	310
04	328	303	18	16	203	200	16	19	370	307	19	19	310
05	309	294	17	16	184	189	16	19	370	307	19	19	310
06	327	303	18	16	175	175	16	19	370	307	19	19	310
07	313	284	19	16	165	172	16	19	370	307	19	19	310
08	325	303	19	15	177	181	15	19	370	307	19	19	310
09	317	294	19	13	171	173	13	19	370	307	19	19	310
10	328	303	18	14	170	170	14	19	370	307	19	19	310
11	328	303	18	14	174	174	14	19	370	307	19	19	310
12	325	303	18	14	182	185	14	19	370	307	19	19	310
13	325	303	18	15	222	230	15	19	370	307	19	19	310
14	325	303	18	15	270	277	15	19	370	307	19	19	310
15	325	303	18	15	303	309	15	19	370	307	19	19	310
16	325	303	18	15	354	354	15	19	370	307	19	19	310
17	325	303	18	15	478	478	15	19	370	307	19	19	310
18	325	303	18	15	498	498	15	19	370	307	19	19	310
19	325	303	18	15	504	502	15	19	370	307	19	19	310
20	325	303	18	15	503	504	15	19	370	307	19	19	310
21	325	303	18	15	502	501	15	19	370	307	19	19	310
22	325	303	18	15	497	497	15	19	370	307	19	19	310
23	325	303	18	15	496	497	15	19	370	307	19	19	310







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	432.	667
01	401.	350.	11	351.	6	326.	688
02	321.	422.	11	389.	8	340.	777
03	295.	339.	11	255.	8	407.	777
04	231.	466.	11	222.	7	455.	999
05	206.	557.	11	222.	7	520.	999
06	193.	577.	11	222.	9	424.	999
07	188.	447.	11	195.	9	444.	999
08	192.	443.	11	202.	9	444.	999
09	188.	439.	11	194.	9	411.	999
10	195.	391.	11	203.	9	333.	1100
11	203.	418.	11	197.	9	403.	1100
12	207.	383.	11	223.	9	445.	1100
13	247.	455.	11	245.	9	452.	1100
14	375.	328.	11	377.	9	322.	1100
15	497.	328.	11	497.	9	311.	1100
16	497.	116.	11	505.	9	113.	1100
17	513.	110.	11	509.	9	113.	1100
18	510.	112.	11	511.	9	110.	1100
19	503.	111.	11	505.	9	110.	1100
20	497.	113.	11	499.	9	110.	1100
21	487.	114.	11	494.	9	110.	1100
22	484.	112.	11	489.	9	110.	1100
23	485.	111.	11	484.	9	110.	1100







Table 8

MONTHLY AVERAGE ON PATH 2 2 FOR MONTH 8 1962

UT	AVER	SDV	NO	AV	NO	ON	PATH	2	2	FOR	MONTH	8	1962
00	500.	5.	23	501.	19	510.	58.	23	MIN	19	507.	547.	19
01	538.	5.	23	577.	16	584.	47.	23	MIN	16	581.	551.	16
02	604.	4.	23	630.	17	613.	46.	23	MIN	17	639.	589.	17
03	662.	4.	23	688.	18	675.	49.	23	MIN	18	696.	639.	18
04	721.	4.	23	732.	17	725.	48.	23	MIN	17	753.	696.	17
05	745.	4.	23	766.	19	753.	47.	23	MIN	19	777.	735.	19
06	780.	4.	24	791.	17	784.	46.	24	MIN	17	809.	777.	17
07	797.	4.	23	802.	16	792.	45.	23	MIN	16	829.	791.	16
08	796.	4.	24	809.	17	797.	45.	24	MIN	17	829.	792.	17
09	798.	4.	24	811.	18	796.	44.	24	MIN	18	830.	798.	18
10	792.	3.	24	809.	17	797.	43.	24	MIN	17	830.	798.	17
11	682.	3.	24	783.	16	792.	43.	24	MIN	16	820.	785.	16
12	591.	2.	24	652.	15	625.	35.	24	MIN	15	782.	785.	15
13	483.	2.	24	522.	15	482.	26.	24	MIN	15	625.	599.	15
14	488.	1.	20	490.	15	489.	26.	20	MIN	15	489.	488.	15
15	488.	1.	19	487.	15	489.	17.	19	MIN	15	487.	489.	15
16	485.	1.	19	487.	15	487.	17.	19	MIN	15	487.	489.	15
17	486.	1.	19	485.	14	485.	10.	19	MIN	14	486.	485.	14
18	487.	1.	19	486.	13	487.	10.	19	MIN	13	486.	485.	13
19	491.	1.	19	489.	11	489.	13.	19	MIN	11	492.	488.	11
20	490.	1.	20	491.	12	491.	15.	20	MIN	12	492.	489.	12
21	490.	2.	22	494.	14	493.	15.	22	MIN	14	493.	491.	14
22	490.	2.	22	495.	14	492.	16.	22	MIN	14	493.	491.	14
23	487.	3.	24	499.	13	487.	19.	24	MIN	13	499.	487.	13

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	23	21	548.	114	596.	15	596.	15	596.	15	596.	15	596.	15	596.	15	596.	15	596.	15
01	601.	23.	19	601.	114	23	19	601.	114	638.	17	638.	17	638.	17	638.	17	638.	17	638.	17	638.	17	638.	17
02	692.	34.	23	692.	114	34	23	692.	114	720.	19	720.	19	720.	19	720.	19	720.	19	720.	19	720.	19	720.	19
03	727.	28.	24	727.	114	28	24	727.	114	769.	20	769.	20	769.	20	769.	20	769.	20	769.	20	769.	20	769.	20
04	787.	30.	22	787.	114	30	22	787.	114	818.	17	818.	17	818.	17	818.	17	818.	17	818.	17	818.	17	818.	17
05	804.	33.	23	804.	114	33	23	804.	114	859.	19	859.	19	859.	19	859.	19	859.	19	859.	19	859.	19	859.	19
06	836.	29.	23	836.	114	29	23	836.	114	895.	18	895.	18	895.	18	895.	18	895.	18	895.	18	895.	18	895.	18
07	839.	28.	23	839.	114	28	23	839.	114	842.	16	842.	16	842.	16	842.	16	842.	16	842.	16	842.	16	842.	16
08	829.	26.	22	829.	114	26	22	829.	114	836.	15	836.	15	836.	15	836.	15	836.	15	836.	15	836.	15	836.	15
09	830.	28.	23	830.	114	28	23	830.	114	829.	14	829.	14	829.	14	829.	14	829.	14	829.	14	829.	14	829.	14
10	834.	24.	23	834.	114	24	23	834.	114	837.	15	837.	15	837.	15	837.	15	837.	15	837.	15	837.	15	837.	15
11	825.	25.	23	825.	114	25	23	825.	114	828.	14	828.	14	828.	14	828.	14	828.	14	828.	14	828.	14	828.	14
12	601.	30.	22	601.	114	30	22	601.	114	798.	17	798.	17	798.	17	798.	17	798.	17	798.	17	798.	17	798.	17
13	560.	18.	23	560.	114	18	23	560.	114	599.	13	599.	13	599.	13	599.	13	599.	13	599.	13	599.	13	599.	13
14	527.	18.	19	527.	114	18	19	527.	114	563.	16	563.	16	563.	16	563.	16	563.	16	563.	16	563.	16	563.	16
15	503.	15.	19	503.	114	15	19	503.	114	527.	14	527.	14	527.	14	527.	14	527.	14	527.	14	527.	14	527.	14
16	498.	12.	19	498.	114	12	19	498.	114	513.	12	513.	12	513.	12	513.	12	513.	12	513.	12	513.	12	513.	12
17	496.	10.	18	496.	114	10	18	496.	114	497.	12	497.	12	497.	12	497.	12	497.	12	497.	12	497.	12	497.	12
18	498.	7.	18	498.	114	7	18	498.	114	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11
19	499.	8.	18	499.	114	8	18	499.	114	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13	501.	13
20	498.	10.	19	498.	114	10	19	498.	114	499.	12	499.	12	499.	12	499.	12	499.	12	499.	12	499.	12	499.	12
21	503.	11.	20	503.	114	11	20	503.	114	509.	13	509.	13	509.	13	509.	13	509.	13	509.	13	509.	13	509.	13
22	502.	11.	23	502.	114	11	23	502.	114	509.	14	509.	14	509.	14	509.	14	509.	14	509.	14	509.	14	509.	14
23	507.	17.	24	507.	114	17	24	507.	114	501.	12	501.	12	501.	12	501.	12	501.	12	501.	12	501.	12	501.	12



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	38	645	40	657	40	659
01	672	36	17	671	18	698	38	728	38	745	38	759	37	739
02	751	35	19	740	19	760	39	784	33	783	33	779	33	776
03	796	32	21	796	22	798	33	800	32	802	32	790	33	808
04	803	34	18	803	19	812	33	814	32	816	32	804	33	819
05	838	34	22	833	22	842	33	844	33	845	33	832	33	842
06	847	34	18	847	18	849	33	849	34	848	34	847	33	854
07	849	31	22	844	22	850	32	848	32	846	32	849	32	846
08	850	28	29	846	29	849	29	848	29	848	29	849	29	846
09	859	27	20	855	20	848	29	850	29	848	29	849	29	846
10	847	23	29	847	29	845	29	844	29	843	29	847	29	848
11	842	23	29	843	29	843	29	844	29	844	29	847	29	848
12	825	27	17	825	17	843	28	846	28	847	28	846	28	845
13	828	27	22	828	22	833	28	836	28	833	28	834	28	835
14	713	32	28	713	28	777	31	768	31	770	31	769	31	770
15	642	36	22	640	22	699	33	691	32	692	32	681	32	683
16	555	19	29	555	29	572	31	554	30	555	30	564	30	555
17	546	19	26	546	26	555	29	555	29	555	29	554	29	555
18	532	22	24	532	24	555	29	555	29	555	29	554	29	555
19	532	22	24	532	24	555	29	555	29	555	29	554	29	555
20	500	20	23	500	23	503	24	503	24	502	24	502	24	502
21	497	18	22	497	22	496	22	496	22	496	22	499	22	499
22	496	18	22	496	22	497	22	498	22	498	22	496	22	496
23	500	18	22	500	22	501	22	503	22	503	22	502	22	502
24	500	18	22	500	22	501	22	503	22	503	22	502	22	502
25	500	18	22	500	22	501	22	503	22	503	22	502	22	502
26	500	18	22	500	22	501	22	503	22	503	22	502	22	502
27	500	18	22	500	22	501	22	503	22	503	22	502	22	502
28	500	18	22	500	22	501	22	503	22	503	22	502	22	502
29	500	18	22	500	22	501	22	503	22	503	22	502	22	502
30	500	18	22	500	22	501	22	503	22	503	22	502	22	502

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
00	639.	44.	27	643.	17	692.	17	692.	17	692.	17	692.	17	692.	17	692.	17	692.	17
01	686.	30.	27	693.	18	730.	18	730.	18	730.	18	730.	18	730.	18	730.	18	730.	18
02	725.	38.	25	728.	19	773.	19	773.	19	773.	19	773.	19	773.	19	773.	19	773.	19
03	780.	36.	25	779.	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
05	811.	32.	26	803.	20	804.	20	804.	20	804.	20	804.	20	804.	20	804.	20	804.	20
06	816.	36.	26	804.	20	808.	20	808.	20	808.	20	808.	20	808.	20	808.	20	808.	20
07	816.	35.	26	818.	20	814.	20	814.	20	814.	20	814.	20	814.	20	814.	20	814.	20
08	813.	39.	26	816.	21	813.	21	813.	21	813.	21	813.	21	813.	21	813.	21	813.	21
09	810.	27.	25	807.	19	807.	19	807.	19	807.	19	807.	19	807.	19	807.	19	807.	19
10	811.	25.	26	812.	20	809.	20	809.	20	809.	20	809.	20	809.	20	809.	20	809.	20
11	830.	25.	25	803.	17	817.	17	817.	17	817.	17	817.	17	817.	17	817.	17	817.	17
12	880.	25.	25	888.	17	888.	17	888.	17	888.	17	888.	17	888.	17	888.	17	888.	17
13	601.	24.	25	622.	17	622.	17	622.	17	622.	17	622.	17	622.	17	622.	17	622.	17
14	581.	20.	20	570.	14	579.	14	579.	14	579.	14	579.	14	579.	14	579.	14	579.	14
15	556.	15.	20	553.	11	555.	11	555.	11	555.	11	555.	11	555.	11	555.	11	555.	11
16	540.	11.	20	532.	10	535.	10	535.	10	535.	10	535.	10	535.	10	535.	10	535.	10
17	520.	11.	21	519.	11	519.	11	519.	11	519.	11	519.	11	519.	11	519.	11	519.	11
18	498.	15.	21	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11	497.	11
19	495.	15.	21	495.	11	495.	11	495.	11	495.	11	495.	11	495.	11	495.	11	495.	11
20	503.	13.	22	503.	12	503.	12	503.	12	503.	12	503.	12	503.	12	503.	12	503.	12
21	499.	14.	24	501.	14	501.	14	501.	14	501.	14	501.	14	501.	14	501.	14	501.	14
22	501.	11.	27	502.	11	502.	11	502.	11	502.	11	502.	11	502.	11	502.	11	502.	11
23	518.	22.	25	518.	11	518.	11	518.	11	518.	11	518.	11	518.	11	518.	11	518.	11

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	MIN	MAX	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	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20	710.	20				
01	727.	56.	24	735.	20	742.	20	732.	20	751.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20	732.	20		
02	777.	55.	24	780.	20	796.	20	772.	20	797.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20	772.	20		
03	788.	55.	24	791.	20	804.	20	792.	20	808.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20	792.	20		
04	806.	52.	24	809.	20	825.	20	801.	20	823.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20	801.	20		
05	813.	48.	24	817.	20	833.	20	811.	20	831.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20	811.	20		
06	834.	45.	24	838.	20	854.	20	834.	20	854.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20	834.	20		
07	833.	45.	24	837.	20	853.	20	833.	20	853.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20	833.	20		
08	832.	42.	24	834.	20	850.	20	832.	20	850.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20	832.	20		
09	822.	41.	24	828.	20	844.	20	828.	20	844.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20	828.	20
10	822.	34.	24	823.	20	839.	20	823.	20	839.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20
11	822.	30.	24	823.	20	839.	20	823.	20	839.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20
12	822.	30.	24	823.	20	839.	20	823.	20	839.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20
13	822.	27.	24	823.	20	839.	20	823.	20	839.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20	823.	20
14	604.	22.	19	610.	19	626.	19	604.	19	626.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19	604.	19
15	580.	20.	19	587.	19	603.	19	580.	19	603.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19	580.	19
16	546.	20.	19	554.	19	570.	19	546.	19	570.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19	546.	19
17	520.	20.	19	528.	19	544.	19	520.	19	544.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19	520.	19
18	502.	17.	17	510.	17	526.	17	502.	17	526.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17	502.	17
19	496.	17.	17	504.	17	520.	17	496.	17	520.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17	496.	17
20	493.	17.	17	501.	17	517.	17	493.	17	517.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17	493.	17
21	497.	13.	22	505.	13	521.	13	497.	13	521.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13	497.	13
22	503.	15.	22	511.	15	527.	15	503.	15	527.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15	503.	15
23	542.	30.	23	550.	30	566.	30	542.	30	566.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30	542.	30

Table 13

Monthly mean diurnal phase change  
(NBA-College path)

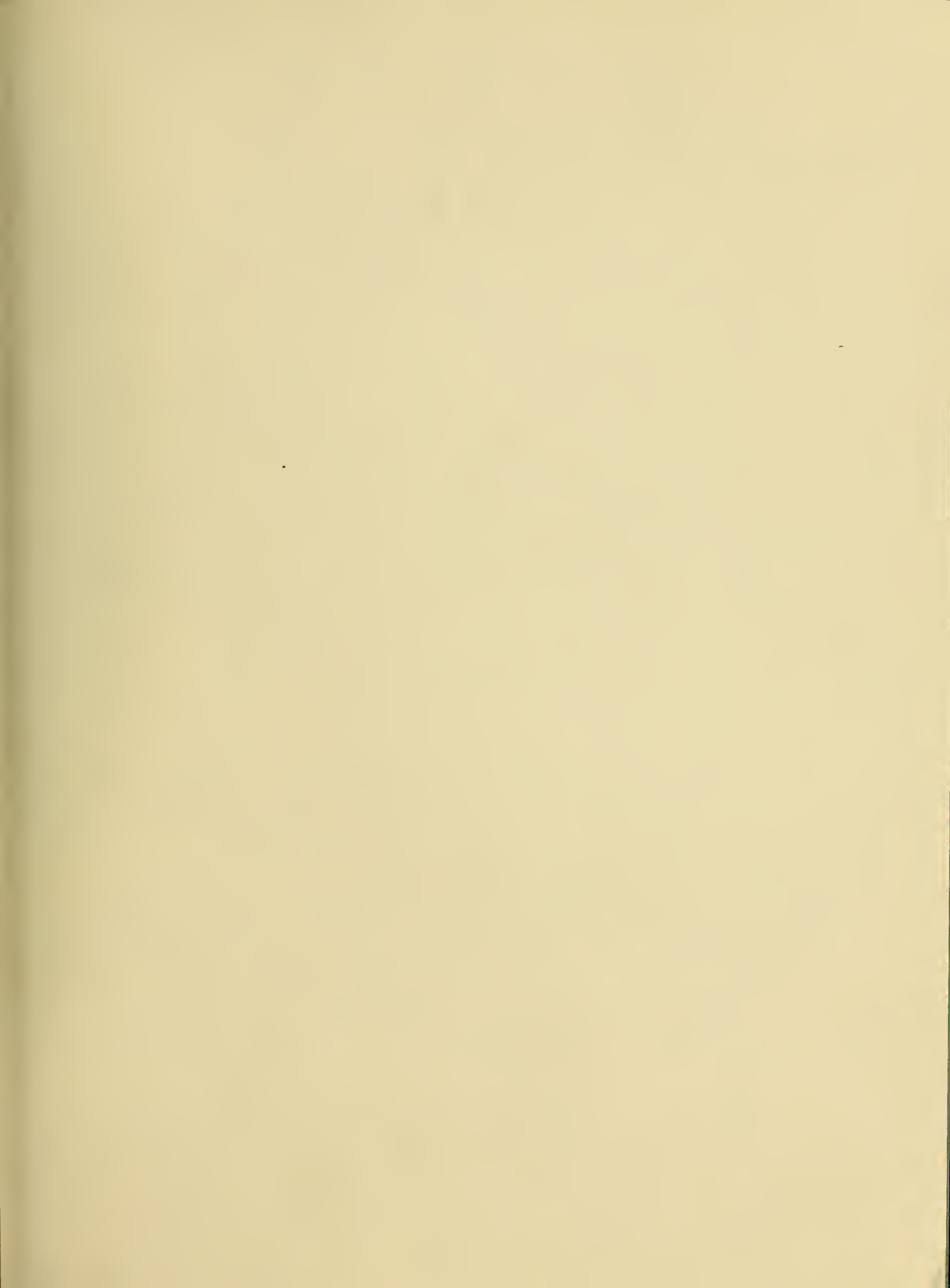
Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1962	332	320	335	322	300	272	302	310	337	352	320	342
												degrees

Table 14

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

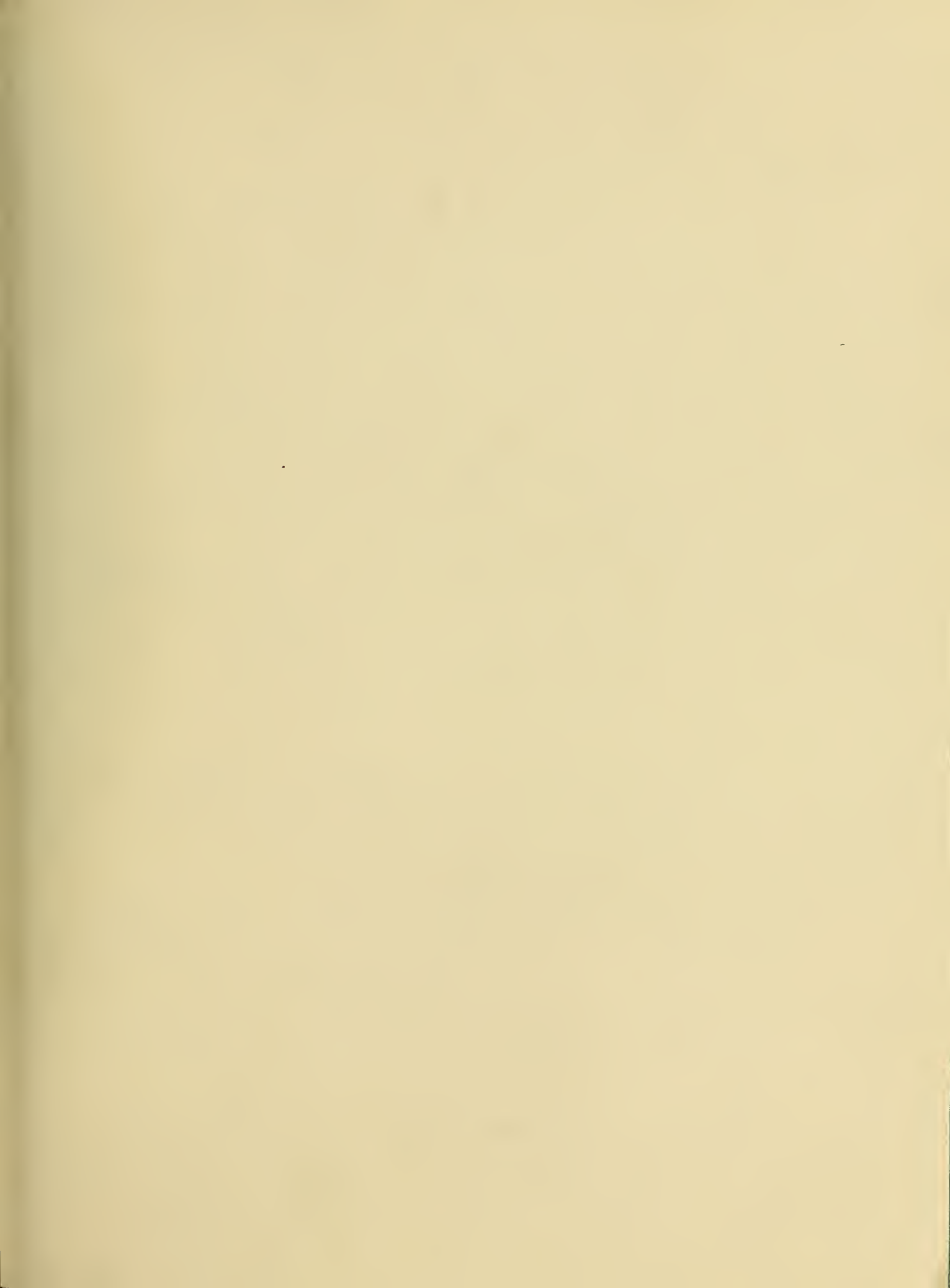
1962 Month	Time of Day	T										minutes
		10	20	30	40	50	60	70	80	90		
Feb.	Night	6.4	8.4	10.0	11.4	12.1	12.6	13.6	14.3	14.4	degrees	
"	Day	5.2	8.4	11.2	13.8	16.4	18.7	21.4	21.7	23.2	"	
Apr.	Night	7.4	12.2	15.6	18.8	20.6	20.2	19.0	17.5	17.4	"	
"	Day	5.9	10.4	14.0	17.1	19.6	22.0	24.4	27.1	29.0	"	
June	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	"	















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