THE APERIODIC DIURNAL RANGE OF TEMPERATURE OVER THE NORTH ATLANTIC OCEAN

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ABSTRACT

Frequency distributions of aperiodic diurnal ranges of temperatures at 9 of the North Atlantic Ocean Vessel Stations are examined. It is found that the means, disperions, and asymmetries of these distributions are largest in winter and smallest in summer. It is also found that the aperiodic diurnal range exceeds the periodic diurnal range on virtually all winter days and on the great majority of summer days.

1. Introduction

If the temperature is measured at several observation hours over a number of days, an average temperature can be computed for each of the observation hours. When these average temperatures are plotted against time and joined by a smooth curve, one obtains a representation of the periodic daily variation of temperature. After Hann [3], the range of temperatures on the above defined curve is called the "periodic diurnal range of temperature."

The author has discussed the periodic diurnal range of temperature (PDRT) at 9 of the North Atlantic Ocean Vessel Stations (OVS) in a previous paper [7]. It was shown that a knowledge of the PDRT provides considerable insight into the local vertical heat balance. However, as will be shown below, the PDRT at the OVS are very poor measures of the diurnal variations of temperature which actually occur at these stations. From the point of view of human comfort, frequency distributions of "aperiodic diurnal ranges of temperature" (hereafter, ADRT) provide far more information concerning diurnal variations of temperature than do values of PDRT. The ADRT is defined [3] as the difference between the maximum and minimum temperatures for a given day.

Many authors have discussed monthly and annual means of ADRT for various regions (for examples, see [1; 2; 3; 6; 9]). On the other hand, frequency distributions of ADRT have been greatly neglected in the climatological literature. There do exist, however, at least two previous sets of frequency distributions of ADRT for marine areas. Jacobs and Clarke [5] give a frequency distribution of ADRT which covers the entire final voyage of the "Carnegie." Howe [4] presents frequency distributions of ADRT for the North Atlantic OVS for the months of February and August.

The purpose of this paper is to discuss the annual variation of frequency distributions of ADRT at the North Atlantic OVS in somewhat more detail than that given by Howe [4].

It is important to note that the OVS records do not contain true maximum and minimum temperatures (as recorded, for instance, by a thermograph or by maximum and minimum thermometers). The terms "maximum" or "minimum" temperature, as applied to the OVS data, denote the highest or the lowest of the eight daily temperature observations (starting with the observation following local midnight). The chances that the true maximum or minimum temperature will occur at one of the eight 3-hourly observations are slim. Hence, when the procedure described above is followed, the maximum temperature is underestimated and the minimum temperature is overestimated. The ADRT is, therefore, also underestimated.

It should also be noted that the term "aperiodic diurnal range of temperature" as applied to the difference between daily maximum and minimum temperatures is a misnomer. This quantity is dependent on both periodic and aperiodic variations of temperature. A full discussion of this topic is found in [7].

The OVS included in this study are listed, together with their latitudes and longitudes, in table 1. Their locations are illustrated by fig. 1. The period of study is given by table 2, and table 3 gives, for each month at each OVS, the number of days during the study period for which complete records of eight 3-hourly "on station" observations are available.

2. Discussion of data

Frequency distributions of ADRT for each of 6 bimonthly periods[2] were compiled for each OVS.

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[2] These bimonthly periods are: January and February (J-F), March and April (M-A), May and June (M-J), July and August (J-A), September and October (S-O), and November and December (N-D).

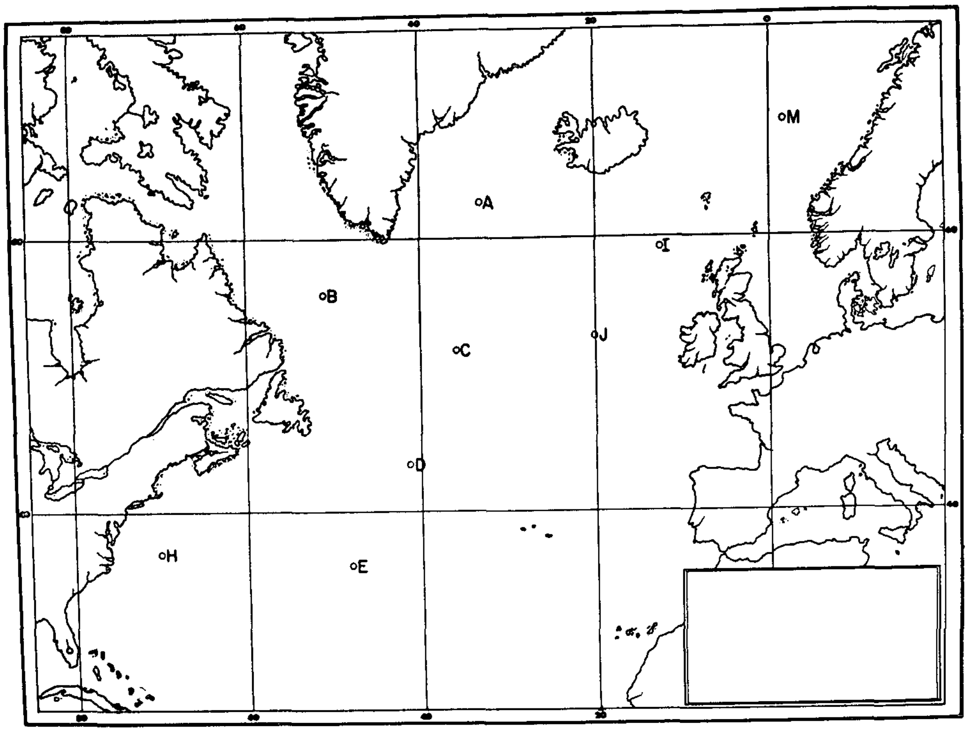

Fig. 1. Positions of the North Atlantic OVS.

Table 4 gives the means of these distributions. This table shows that, with the exception of station E, the mean ADRT at the OVS are clearly largest in the cold season and smallest in the warm season. This indicates that these ADRT are dominated by aperiodic temperature variations (as one would expect to be the case over the oceans (see [7])).

At station E, minimum-mean ADRT (3.7F) occurs in both the M-J and N-D periods. Also, the annual

Table 1. Positions of North Atlantic OVS.

Station	Latitude	Longitude
A	62.0N	33.0W
B	56.5N	51.0W
C	52.8N	35.5W
D	44.0N	41.0W
E	35.0N	48.0W
H	36.7N	69.6W
I*	59.3N	16.4W
J	52.5N	20.0W
M	66.0N	02.0E

* Station I is alternately operated from two positions, 59.0N–19.0W and 60.7N–13.7W. To make the records at station I comparable with those at the other OVS, an average position of 59.3N–16.4W was selected for this station. "On station" data for station I were then taken to be those observations made within a square, having sides of 210 n mi, centered on the average position.

Table 2. Period of study used in the analysis of diurnal variations of temperature.

Station	January through May	June	July through December
A	1950–1954	1950–1954	1949–1953
B	1950–1954	1950–1954	1949–1953
C	1950–1954	1950–1954	1949–1953
D	1950–1954	1950–1954	1948–1953
E	1950–1954	1950–1954	1949–1953
H	1950–1954	1950–1954	1949–1953
I	1951–1954	1950–1954	1950–1954
J	1951–1954	1950–1954	1950–1954
M	1951–1955	1950–1954	1950–1954

Table 3. Number of days for which complete records of eight 3-hourly "on station" temperature observations are available.

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
A	121	125	133	111	121	107	124	115	119	129	108	124
B	143	130	150	140	155	149	150	136	147	152	149	143
C	142	137	147	150	150	150	155	151	142	153	136	149
D	133	126	143	147	154	146	151	153	140	150	150	153
E	150	139	147	150	149	149	155	147	145	131	140	152
H	153	138	153	148	153	150	146	153	144	150	150	148
I	67	81	101	103	93	132	123	109	108	94	74	62
J	110	101	102	105	91	121	125	133	120	107	104	118
M	142	130	146	139	144	140	142	150	143	144	136	132

TABLE 4. Mean ADRT (F) at the North Atlantic OVS.

Station	J-F	M-A	M-J	J-A	S-O	N-D	Annual range
A	4.9	4.4	3.6	3.1	3.6	3.9	1.8
B	5.9	4.2	3.5	3.4	3.5	4.5	2.5
C	5.7	4.2	3.7	3.3	3.9	4.7	2.4
D	7.8	6.5	4.8	4.8	5.7	6.6	3.0
E	4.0	4.1	3.7	3.9	4.0	3.7	0.4
H	7.1	6.4	4.5	4.2	4.3	6.2	2.9
I	4.3	3.8	2.7	2.4	3.3	4.1	1.9
J	4.0	3.5	2.5	2.9	3.3	4.2	1.7
M	4.3	4.1	2.8	2.4	2.9	3.6	1.9

range of mean bimonthly ADRT at E is only 0.4F. The next smallest annual range of mean ADRT, 1.7F at station J, is over 4 times greater than that at E. The modesty and irregular form of the annual variation of mean ADRT at station E indicate a situation in which the aperiodic tendency to produce largest mean ADRT in winter is nearly balanced by the periodic tendency to produce largest mean ADRT in summer. The uniqueness of the annual variation at station E is probably an effect of the location of this station with respect to the North Atlantic subtropical anticyclone. Mean pressure charts [8] show station E to be within the circulation of the subtropical high cell during all months. The fairly steady conditions, usually associated with anticyclonically dominated weather, should be reflected in the temperature regime as relatively few aperiodic variations of temperature. Coupled with this, periodic variations of temperature at station E are greater than at the other stations (see [7]).

TABLE 5. Percentage of days having ADRT greater than or equal to PDRT.

Station	J-F	M-A	M-J	J-A	S-O	N-D
A	99	96	96	89	97	99.6
B	100	95	86	92	98	100
C	100	97	94	93	98	99
D	100	98	93	88	99	99
E	96	91	79	67	88	95
H	99	97	87	84	97	100
I	97	95	87	88	96	99
J	95	90	86	91	99	99
M	100	100	96	94	99	100

Table 5 gives the percentage of days on which ADRT is equal to or greater than PDRT. Values of PDRT were taken from [7]. This table clearly indicates that PDRT is a very poor estimate of the actual diurnal ranges of temperature. ADRT exceeds PDRT on at least 95 per cent of the days in the N-D and J-F bimonthly periods. With the approach of the warm season, aperiodic temperature variations decrease in frequency and intensity; PDRT, on the other hand, increases. This sequence of events is reflected in table 5 as a decrease, from winter to summer, of the percentage of days on which ADRT exceeds PDRT. However, even in the warm season, with the exception of station E, the percentage of such days is nowhere less than 84.

Fig. 2 gives a pictorial representation of the frequency distributions in the J-F and J-A periods. In J-F, the modes are located well below the midpoints of the observed ranges of ADRT. As a result, the distributions show a pronounced skewness to the right. The dispersion of the distributions shows considerable variation from station to station. It appears to be greatest at stations D and H and least at station E. The curves for the summer bimonthly period show less asymmetry and dispersion than do the winter curves. This is a result of the steadier conditions and weaker temperature gradients which are characteristic of the warm season. Such a situation should produce fewer days of strong advection and hence fewer days with large ADRT. This is reflected in the frequency curve as a recession of the right-hand tail with the approach of the warm season.

To facilitate considerations of the annual variations of these frequency distributions, the medians (R_{50}), 25 per cent points (R_{25})[3] and 75 per cent points (R_{75}) were computed for each of the distributions (tables 6, 7, and 8). Graphs, with bimonthly period as abscissa and ADRT as ordinate, were then constructed to show the annual courses of mean ADRT ($\bar{R}$), R_{25}, R_{50}, and R_{75} at each OVS. These graphs (fig. 3) give the

[3] The ξ per cent point of a frequency distribution is that value of the variate which is exceeded by 100-ξ per cent of the observations.

TABLE 6. 50 per cent points (F) of the frequency distribution of ADRT.

Station	J-F	M-A	M-J	J-A	S-O	N-D
A	4.5	4.3	3.2	3.0	3.4	3.5
B	4.9	3.8	3.2	3.3	3.2	4.0
C	5.4	3.7	3.4	3.1	3.6	4.2
D	6.8	5.8	4.4	4.2	5.1	6.2
E	3.8	3.9	3.5	3.5	3.8	3.4
H	6.2	5.7	4.1	3.9	3.8	5.4
I	3.7	3.4	2.4	2.2	3.0	3.7
J	3.4	3.1	2.4	2.8	3.0	3.7
M	3.8	3.8	2.7	2.3	2.6	3.2

TABLE 7. 25 per cent points (F) of the frequency distributions of ADRT.

Station	J-F	M-A	M-J	J-A	S-O	N-D
A	3.1	2.9	2.2	2.1	2.3	2.3
B	3.4	2.4	2.1	2.3	2.3	2.7
C	3.4	2.6	2.5	2.2	2.8	3.1
D	4.3	3.5	3.2	2.9	3.6	3.7
E	2.7	2.9	2.6	2.6	2.8	2.6
H	4.1	3.8	2.9	2.8	2.7	3.7
I	2.2	2.1	1.7	1.5	1.9	2.3
J	2.2	1.9	1.6	1.9	1.9	2.3
M	2.5	2.4	1.8	1.6	1.7	2.0

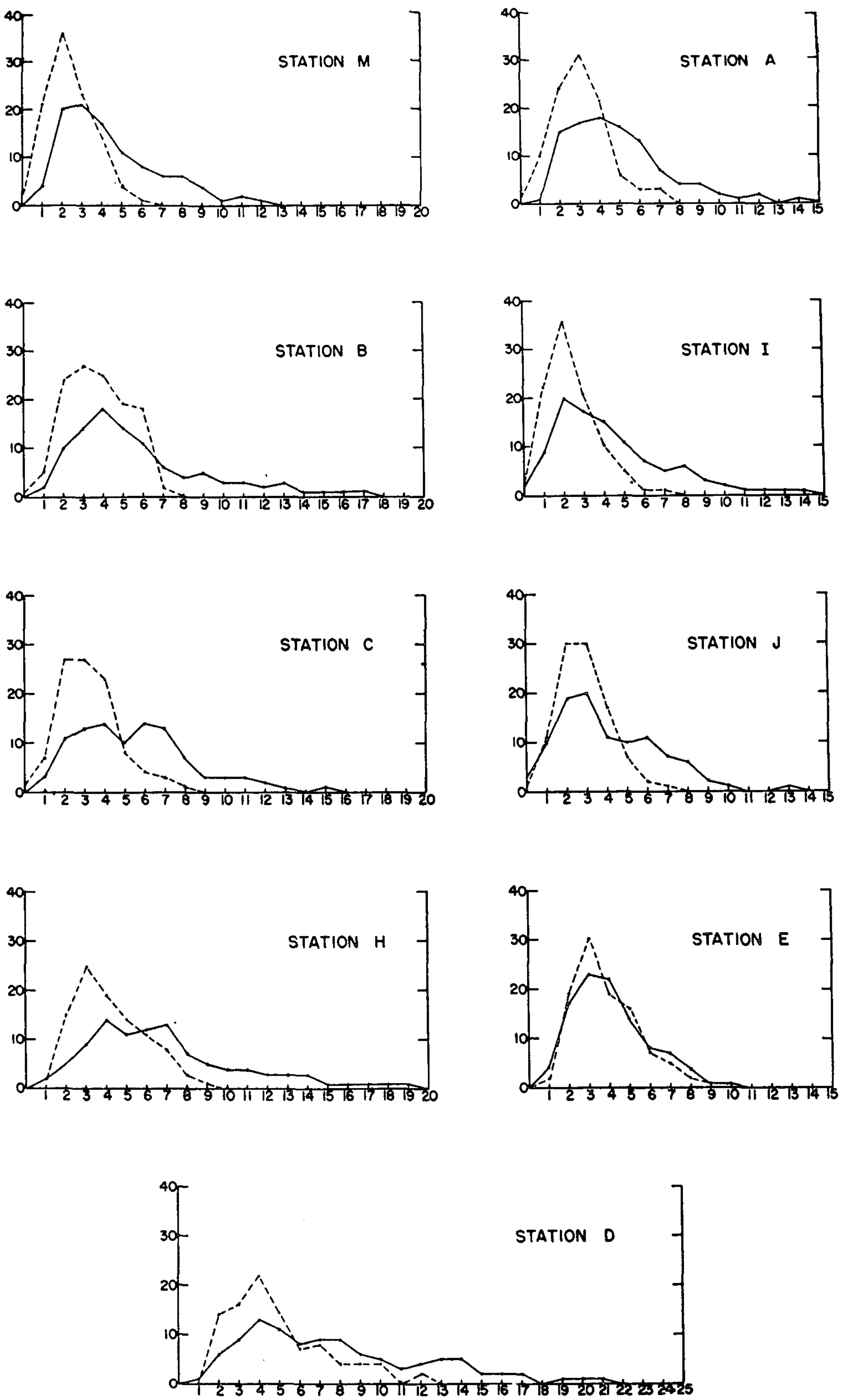

FIG. 2. Frequency curves of ADRT for the January and February bimonthly period (solid lines) and for the July and August bimonthly period (dashed lines). Ordinates are percentage frequency. Abscissas are ADRT in degrees F.

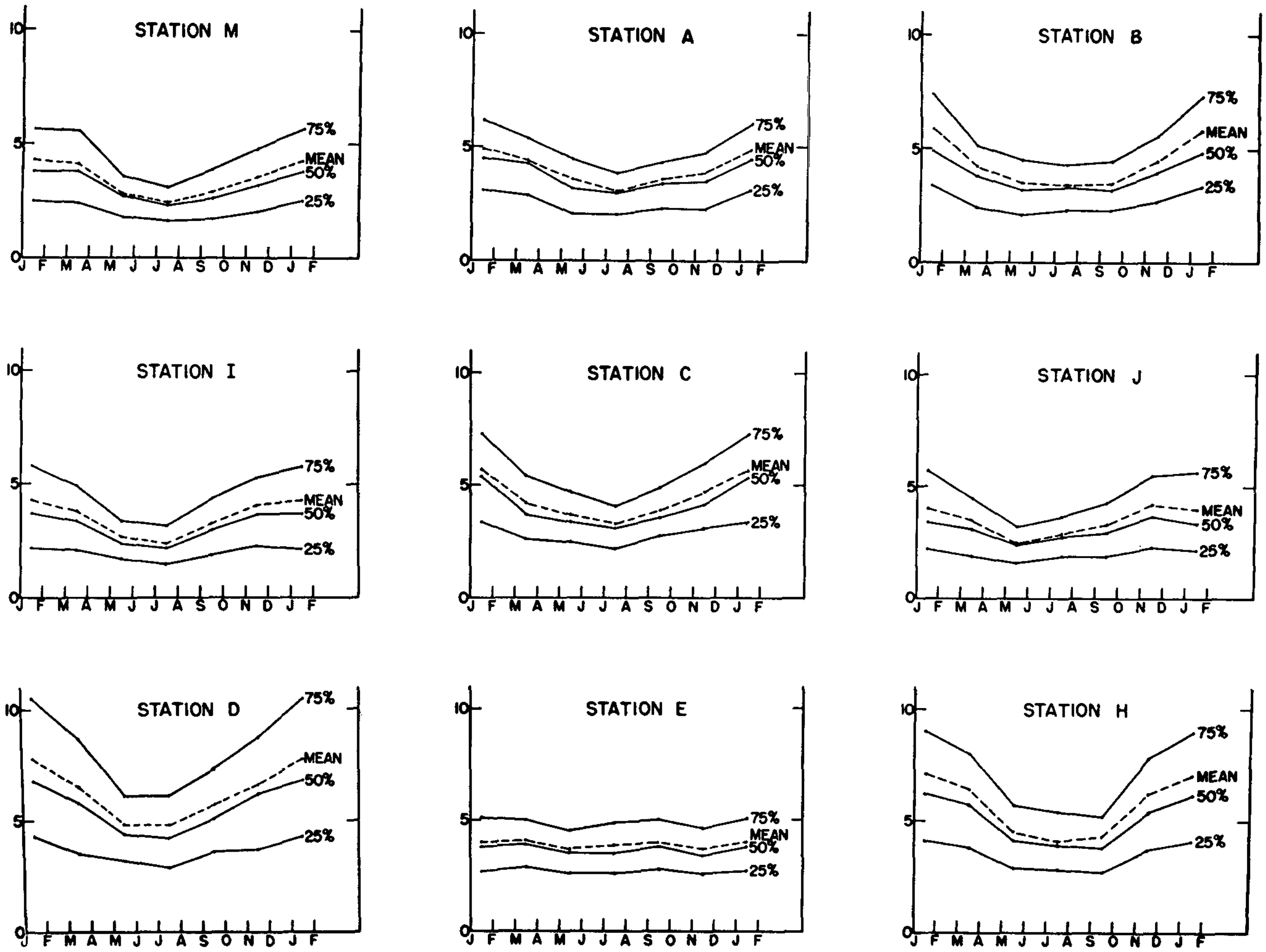

FIG. 3. Annual variations of the means, 25, 50, and 75 per cent points of the frequency distributions of ADRT. Ordinates are ADTR in degrees F. Abscissas are months of the year.

essential features of the annual variations of the frequency distributions. For purposes of analyzing fig. 3, a convenient measure of dispersion is given by $R_{75} - R_{25}$ (the interquartile range). $\bar{R} - R_{50}$ gives a rough-and-ready measure of asymmetry.

Fig. 3 indicates that the annual variations of R_{25}, R_{50}, and R_{75} at station E are quite small when compared to those at the other OVS. Again, this is probably a reflection of the unique physical conditions at E. The other OVS show well marked annual variations of $\bar{R}$, R_{25}, R_{50}, and R_{75}. Fig. 3 also shows, as was to be expected from fig. 2, a pronounced annual variation of interquartile range. Smallest values occur in the warm season and largest values in the cold season. A distinct tendency for largest values of $\bar{R} - R_{50}$ to occur in the cold season is also apparent from fig. 3.

TABLE 8. 75 per cent points (F) of the frequency distributions of ADRT.

Station	J-F	M-A	M-J	J-A	S-O	N-D
A	6.2	5.4	4.5	3.9	4.4	4.8
B	7.4	5.1	4.5	4.3	4.5	5.9
C	7.3	5.4	4.7	4.1	4.9	6.0
D	10.5	8.7	6.1	6.1	7.3	8.7
E	5.1	5.0	4.5	4.9	5.0	4.6
H	9.0	8.0	5.7	5.4	5.2	7.7
I	5.8	4.9	3.4	3.2	4.4	5.3
J	5.7	4.5	3.2	3.7	4.3	5.5
M	5.7	5.6	3.6	3.2	3.9	4.8

3. Summary

Frequency distributions of ADRT have been discussed for each of six bimonthly periods at nine of the North Atlantic OVS. It was found that the means, twenty-five, fifty, and seventy-five per cent points of these distributions have annual variations such that these quantities are largest in winter and smallest in summer. The dispersion and asymmetry of these distributions were also found to be largest in the cold season and smallest in the warm season. It was also found that ADRT exceeds PDRT on virtually all winter days and on the great majority of summer

days. Hence, PDRT is a very poor estimate of the actual diurnal ranges of temperature at these OVS.

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