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TEMPERATURE DISTRIBUTIONS IN ASPHALTIC CONCRETE PAVEMENTS

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ABSTRACT

The straight-line relationship between temperatures at a given depth and the surface temperatures combined with 5-day average air temperatures appears to be as valid for upper New York state and Arizona as for Maryland. The main differences were in the annual ranges and annual mean temperatures. The concept for estimating pavement temperature distributions appears to be valid and may be used with confidence for estimating pavement temperatures at all latitudes and longitudes.

INTRODUCTION

Asphalts are susceptible to temperature change. In a like manner, the structural responses of bituminous concrete pavement systems to traffic loadings vary with temperature fluctuations. Surface deflection (or rebound) is a readily measurable response of a pavement system to an applied load. To improve correlations between loads and deflections, adjustment of measured deflections to an equivalent deflection at a common (or base) temperature offers hope of reducing the effect of the temperature variable. Under normal conditions of obtaining surface deflection measurements, only the surface temperature at the time of measurement can be conveniently determined. Previous analyses indicated that the long-term influences on pavement temperature were reasonably accounted for by a 5-day air-temperature history. Accordingly, a technique *(1)* for adjusting pavement deflection measurements to a reference, mean pavement temperature was developed. Mean pavement temperatures were estimated from the measured pavement surface temperature at the time of the deflection measurement and the mean daily air temperatures for the previous 5 days as an indication of the air-temperature history. This method was simplified by the Asphalt Institute and incorporated into their manual on pavement rehabilitation *(2)*.

The method of estimating pavement temperatures at depths raised several questions:

1. What is the effect upon the accuracy of the temperature estimating system of such variables as altitude, latitude, longitude, and solar exposure?
2. Does the straight-line relationship *(1)* developed using Maryland data *(3)* hold true for data from other locations?
3. If other data sets are combined with the Maryland data, does the accuracy of the estimate increase?
4. Can graphs developed from the Maryland data set be used with confidence for other locations?

Answers to the above questions required the acquisition and analysis of additional data sets. Professors Arthur Straub *(4)* of Clarkson College in upper New York state and Rudolph Jimenez *(5)* of the University of Arizona at Tucson supplied data sets for this analysis. Their cooperation is greatly appreciated.

ANALYSES AND RESULTS

The New York and Arizona data sets were analyzed separately using the same computer program *(1)* used to analyze the Maryland data set. The analyses indicated that a straight-line relationship was equally valid for all data sets; however, the equations were not identical (see Table 1). The major differences between the data sets were in the annual temperature ranges and the annual mean temperatures. Inspection of the data and least-squares fits showed that, for a given hour, depth, and surface temperature plus 5-day average air-temperature history, there could be an apparent difference in temperatures of as much as 5 to 10 F (2.8 to 5.6 C) in the upper (extrapolated) ranges (see Figure 1). Closer inspection showed that, when the equation was solved for temperatures within the temperature range for the respective sites, the discrepancies were minimal and generally within the limits of scatter of the Maryland data set.

The scatter (standard error of estimate) for the New York and Arizona data sets was generally less than the scatter for the Maryland data for corresponding depths. However, the number of observations were considerably less. Figure 2 shows the data for 1300 hours and a 4-inch (102-mm) depth. Slight rotational and horizontal shifts were observed in the New York and Arizona data compared to the Maryland data.

From the standpoint of longitudes, the New York site was eight clock minutes earlier or ahead of the Maryland site; the Arizona site was 16 clock minutes later or behind the equivalent Maryland clock time. To adjust for these longitudinal effects, New York and Arizona clock times were determined for the appropriate Maryland sun times. Interpolated pavement temperatures for those adjusted clock times were plotted. Figure 3 shows the same data as in Figure 2 but adjusted for longitudinal differences. A threefold net effect of the longitudinal adjustment could be noted:

1. The rotational shifts in the fitted straight lines were less.
2. The horizontal shifts between the data sets were less.
3. Longitudinal adjustments for depths from the surface down to the 2-inch (51-mm) depth were very slight and are likely to be unnecessary. Longitudinal adjustments appear to begin to be significant for depths equal to and greater than 4 inches (102 mm).

The net result of adjustments for longitude was a closer grouping of the data which then fell within the outer limits of the Maryland data. The increased number of observations within the same limits has the statistical result of a reduced standard error of estimate and an increased correlation coefficient.

The question, "Could the scatter of pavement temperature data be reduced if the data were analyzed on the basis of daytime exposure to solar radiation?" was investigated. Analyses were made for sunrise, midmorning, midday, midafternoon, and sunset. Letting SR = sunrise clock time and SS = sunset clock time, obtained from tables prepared by the Nautical Almanac Office, US Naval Observatory, Washington, D.C.,

Sunrise = SR,

Midmorning = SR + 0.25 (SS - SR),

Midday = SR + 0.50 (SS - SR),

Midafternoon = SR + 0.75 (SS - SR), and

Sunset = SS.

After clock times for these five points in time were determined for each day, pavement temperatures were interpolated, recorded, plotted, and analyzed. The results are summarized in Table 2. The scatter of data was reduced for the sunrise, midmorning, and sunset times but was increased for midday and midafternoon. The wider variations at midday and midafternoon appear to be caused by summer afternoon showers and variable cloud covers. While this last analysis was of interest and needed to be investigated, the system is very awkward to use, does not provide better accuracy, and is not recommended for general use; but it does lend credence to the original system.

DISCUSSION AND IMPLEMENTATION

Air temperature history appears to adequately account for differences in latitude and altitude. Adjustments can be made for differences in longitude by interpolating between hourly graphs, which can be prepared from data given in Table 1. If the purpose of estimating pavement temperatures is to determine the magnitude of the asphaltic tensile strain, longitudinal adjustments may well be worth the effort. If the objective is to adjust deflection data *(1, 2)*, such refinements may not be justified. The Asphalt Institute *(2)* has proposed the use of one graph for estimating temperatures at various depths to calculate an average pavement temperature which can be used to adjust measured deflections to equivalent deflections at a "standard" temperature. Such a use of one temperature distribution graph will produce greater discrepancies than those caused by not adjusting for longitude. Furthermore, the choice of adjustment curves for deflection measurements will have a more pronounced effect than making no adjustment for longitude or exposure to solar radiation. Therefore, the set of equations based upon Maryland data *(1)* may be used with confidence for other latitudes and longitudes.

SUMMARY

1. The addition of a 5-day, average air-temperature history to the surface temperature results in a straight-line correlation with temperature at a given depth. This relationship appears to be equally valid for data sets recorded in upper New York state, Maryland, and Arizona.

2. The equations originally developed from the Maryland data set appear to be reasonably accurate for other locations.

3. The effects of changes in latitude are accounted for in the air-temperature history. The net result is a shift up or down the temperature scale, reflecting the annual temperature range at a particular site.

4. The data from Maryland, New York, and Arizona combined into one data set resulted in slightly more scatter than the Maryland set alone.

5. Adjusting the New York and Arizona data to equivalent Maryland times (longitudinal adjustment) reduced the scatter and slightly improved the accuracy.

6. Analyzing all data sets in terms of daytime exposure to solar radiation also resulted in a straight-line correlation between surface temperature plus air-temperature history and temperature at a given depth. The accuracy was improved over the Maryland graphs for the sunrise, midmorning, and sunset times but worsened for the midday and midafternoon times.

7. Analysis of the data on the basis of daytime exposure to solar radiation was a nice exercise which validated the method of analysis used for the Maryland graphs but which is too cumbersome to use as a practical method.

8. Graphs derived from the Maryland data are recommended for use in other latitudes and longitudes. More accurate results may be obtained if the clock time at any site is adjusted to a longitude within that time zone that is equivalent to the College Park, Maryland, longitude of 76° 56' within the Eastern Standard Time zone.

REFERENCES

1. H. F. Southgate and R. C. Deen, *Temperature Distribution within Asphalt Pavements and Its Relationship to Pavement Deflection,* **Record 291**, Highway Research Board, 1969, pp. 116-131.
2. *Asphalt Overlays and Pavement Rehabilitation,* **Manual Series No. 17 (MS-17)**, The Asphalt Institute, First Edition, 1969.
3. B. F. Kallas, *Asphalt Pavement Temperatures,* **Record 150**, Highway Research Board, 1966, pp. 1-11.
4. A. L. Straub, H. N. Schenck, Jr. and F. E. Przybycien, *Bituminous Pavement Temperature Related to Climate,* **Record 256**, Highway Research Board, 1968, pp. 53-77.
5. T. N. Rumney, and R. A. Jimenez, *Pavement Temperatures in the Southwest,* **Record 361**, Highway Research Board, 1971, pp. 1-13.

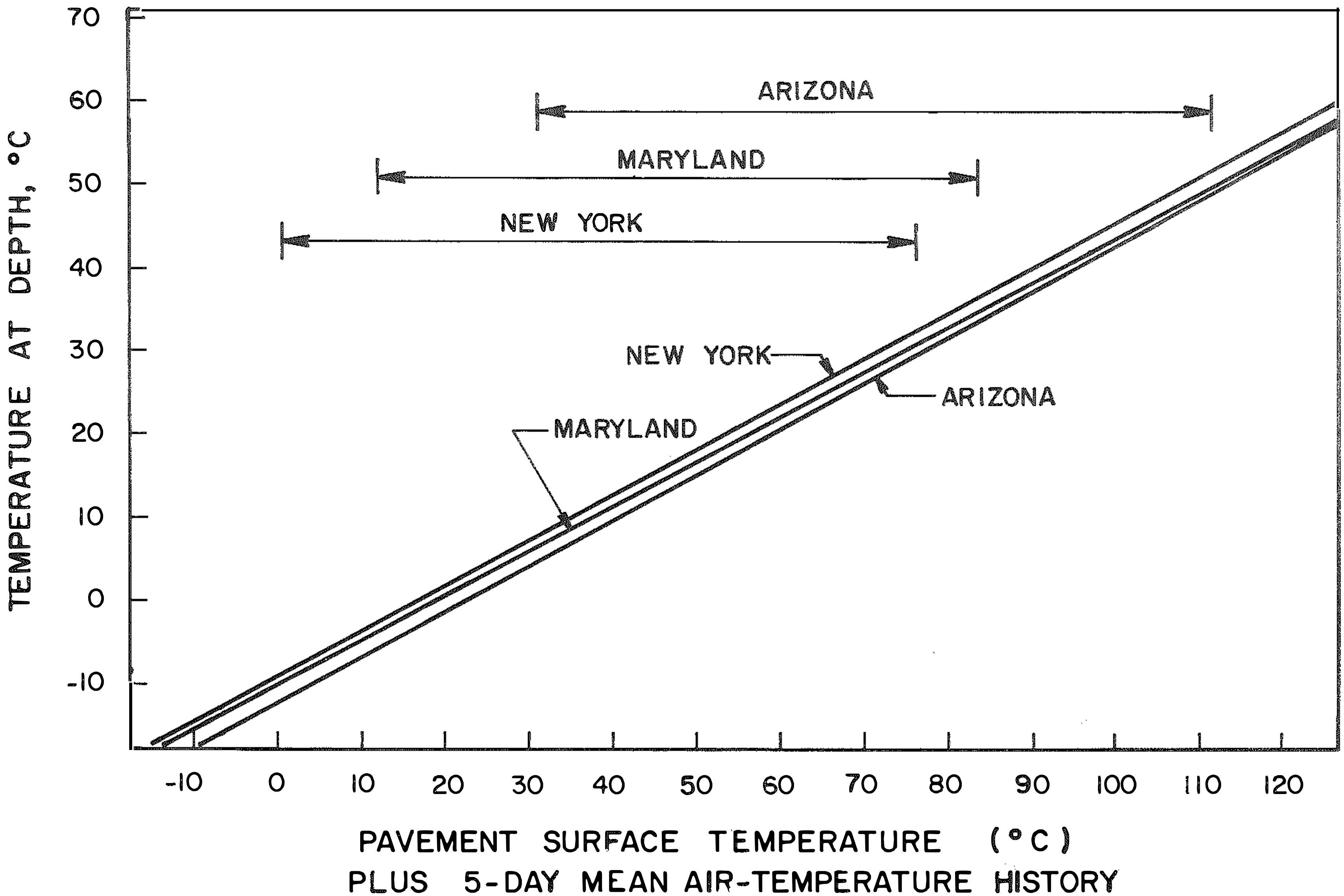

Figure 1. Temperature at 2-inch (51-mm) Depth at 1100 Hours.

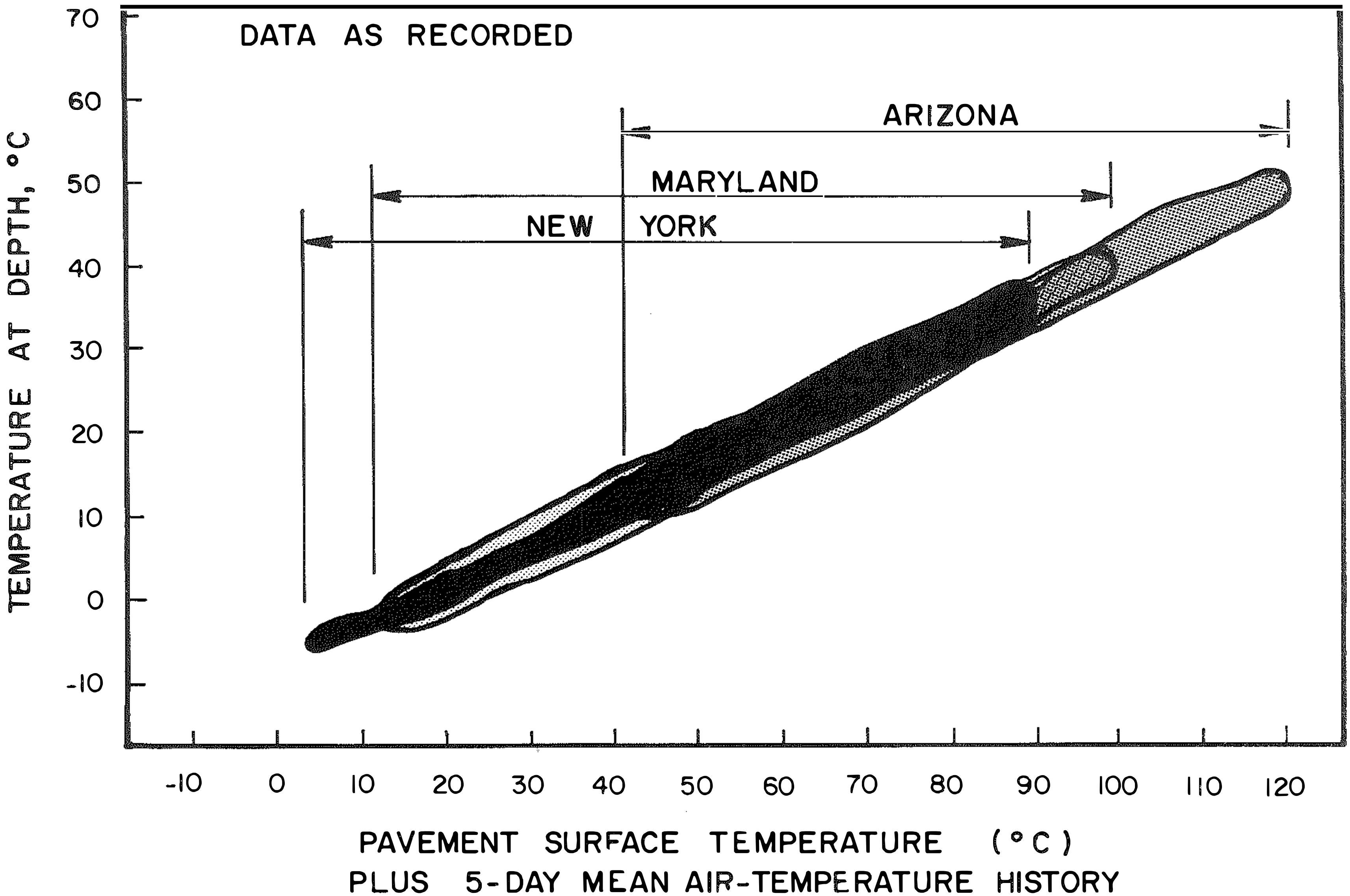

Figure 2. Temperatures as Recorded at 4-inch (102-mm) Depth, 1300 Hours.

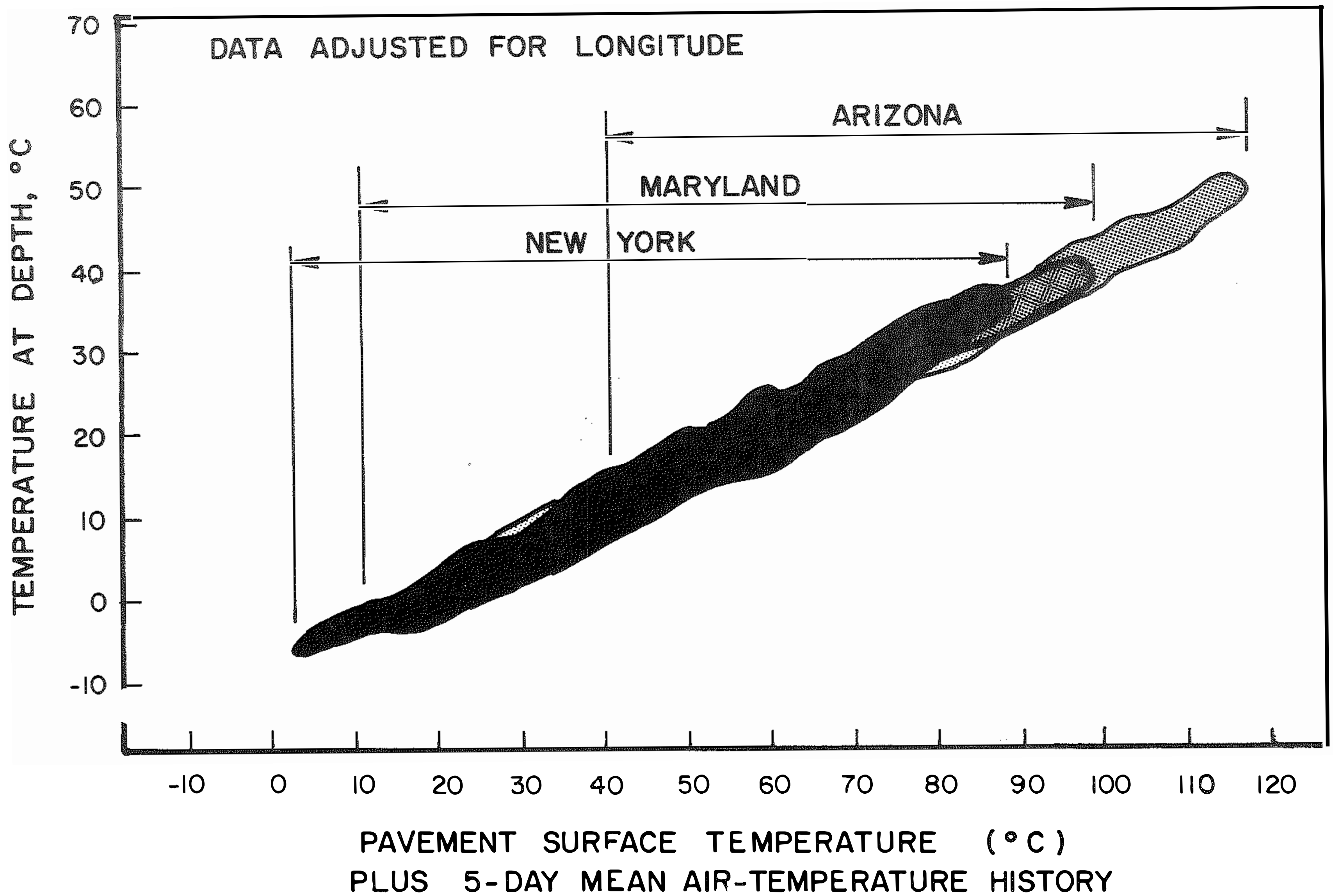

Figure 3. Temperatures at 4-inch (102-mm) Depth, 1300 Hours, Adjusted to an Equivalent Maryland Longitude.

TABLE 1

TEMPERATURE DISTRIBUTIONS[a] IN ASPHALTIC CONCRETE PAVEMENTS AS A FUNCTION OF TIME

[a]X = surface temperature plus 5-day average air-temperature history
Y = temperature at depth

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	NUMBER OF DATA POINTS IN ANALYSES: 316 — COLLEGE PARK, MARYLAND	254 — CLARKSON COLLEGE, NEW YORK	160 — UNIV OF ARIZ TUCSON, ARIZONA	730 — COMBINED DATA SETS	728 — LONGITUDINALLY ADJUSTED DATA
2	5.1	Constant A	-3.6	-0.5	-1.9	-2.2	-2.3
		Coefficient B	0.533	0.520	0.525	0.527	0.527
		Correlation Coefficient R	0.985	0.985	0.995	0.988	0.988
		Standard Error of Estimate	3.0	2.8	2.0	2.9	3.0
4	10.2	Constant A	-1.4	0.3	2.3	0.0	0.5
		Coefficient B	0.528	0.523	0.504	0.520	0.516
		Correlation Coefficient R	0.987	0.986	0.994	0.989	0.990
		Standard Error of Estimate	2.8	2.8	2.0	2.7	2.7
6	15.2	Constant A	0.3	1.0	5.2	1.5	1.7
		Coefficient B	0.531	0.530	0.497	0.523	0.519
		Correlation Coefficient R	0.988	0.986	0.994	0.990	0.989
		Standard Error of Estimate	2.7	2.8	1.9	2.7	2.7
8	20.3	Constant A	1.6	1.4	7.9	2.5	2.9
		Coefficient B	0.535	0.537	0.494	0.529	0.523
		Correlation Coefficient R	0.987	0.986	0.994	0.989	0.990
		Standard Error of Estimate	2.9	2.9	2.0	2.8	2.7
10	25.4	Constant A	2.7	2.0	10.5	3.4	3.8
		Coefficient B	0.536	0.540	0.489	0.532	0.526
		Correlation Coefficient R	0.985	0.985	0.992	0.987	0.988
		Standard Error of Estimate	3.1	2.9	2.2	3.0	2.9
12	30.5	Constant A	4.3	3.8	11.3	5.1	5.5
		Coefficient B	0.532	0.532	0.486	0.526	0.520
		Correlation Coefficient R	0.983	0.982	0.992	0.985	0.986
		Standard Error of Estimate	3.3	3.2	2.2	3.2	3.1

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS	LONGITUDINALLY ADJUSTED DATA
		NUMBER OF DATA POINTS IN ANALYSES	316	253	196	765	762
2	5.1	Constant A	-3.5	-1.1	-6.4	-1.8	-2.1
		Coefficient B	0.532	0.531	0.540	0.522	0.527
		Correlation Coefficient R	0.987	0.984	0.995	0.988	0.988
		Standard Error of Estimate	3.1	3.3	2.2	3.3	3.3
4	10.2	Constant A	-2.2	1.3	-4.2	0.0	0.2
		Coefficient B	0.501	0.489	0.502	0.485	0.486
		Correlation Coefficient R	0.978	0.979	0.991	0.982	0.984
		Standard Error of Estimate	3.8	3.5	2.8	3.7	3.6
6	15.2	Constant A	-1.0	3.0	-1.9	1.2	1.2
		Coefficient B	0.488	0.467	0.485	0.472	0.473
		Correlation Coefficient R	0.970	0.968	0.988	0.977	0.978
		Standard Error of Estimate	4.3	4.3	3.0	4.1	4.1
8	20.3	Constant A	0.2	3.8	0.6	2.2	2.8
		Coefficient B	0.484	0.462	0.474	0.468	0.464
		Correlation Coefficient R	0.967	0.962	0.987	0.975	0.976
		Standard Error of Estimate	4.5	4.6	3.1	4.2	4.2
10	25.4	Constant A	1.4	4.2	3.1	3.5	3.9
		Coefficient B	0.482	0.465	0.463	0.465	0.463
		Correlation Coefficient R	0.966	0.963	0.985	0.975	0.975
		Standard Error of Estimate	4.6	4.5	3.2	4.3	4.3
12	30.5	Constant A	2.8	5.8	4.7	4.9	5.4
		Coefficient B	0.479	0.456	0.457	0.460	0.457
		Correlation Coefficient R	0.965	0.960	0.986	0.974	0.974
		Standard Error of Estimate	4.6	4.7	3.1	4.3	4.3

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS	LONGITUDINALLY ADJUSTED DATA
		NUMBER OF DATA POINTS IN ANALYSES	316	256	200	772	769
2	5.1	Constant A	-2.5	-2.4	-7.4	-1.4	-1.7
		Coefficient B	0.546	0.565	0.563	0.541	0.547
		Correlation Coefficient R	0.989	0.986	0.993	0.988	0.988
		Standard Error of Estimate	3.2	3.8	2.7	3.8	3.7
4	10.2	Constant A	0.1	1.1	-9.3	0.6	0.1
		Coefficient B	0.482	0.493	0.524	0.480	0.486
		Correlation Coefficient R	0.983	0.985	0.986	0.982	0.985
		Standard Error of Estimate	3.6	3.4	3.6	4.0	3.8
6	15.2	Constant A	1.7	3.8	-9.1	1.9	1.4
		Coefficient B	0.447	0.444	0.498	0.446	0.453
		Correlation Coefficient R	0.966	0.969	0.980	0.971	0.984
		Standard Error of Estimate	4.8	4.4	4.2	4.8	4.6
8	20.3	Constant A	2.8	5.3	-6.5	3.2	3.4
		Coefficient B	0.430	0.421	0.473	0.427	0.429
		Correlation Coefficient R	0.952	0.954	0.976	0.963	0.965
		Standard Error of Estimate	0.6	5.1	4.4	5.3	5.1
10	25.4	Constant A	4.0	6.0	-3.2	4.7	4.4
		Coefficient B	0.422	0.415	0.451	0.415	0.419
		Correlation Coefficient R	0.944	0.948	0.972	0.958	0.959
		Standard Error of Estimate	5.8	5.4	4.5	5.5	5.4
12	30.5	Constant A	5.5	7.8	-2.3	5.8	5.7
		Coefficient B	0.413	0.398	0.447	0.408	0.411
		Correlation Coefficient R	0.937	0.937	0.971	0.953	0.955
		Standard Error of Estimate	6.1	5.8	4.5	5.7	5.6

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	NUMBER OF DATA POINTS IN ANALYSES				
			316	256	197	769	768
			COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS	LONGITUDINALLY ADJUSTED DATA
2	5.1	Constant A	-2.7	-3.2	-5.6	-1.7	-2.1
		Coefficient B	0.574	0.595	0.580	0.569	0.576
		Correlation Coefficient R	0.986	0.984	0.992	0.987	0.987
		Standard Error of Estimate	4.0	4.4	3.1	4.3	4.3
4	10.2	Constant A	1.1	1.4	-7.1	1.1	0.4
		Coefficient B	0.501	0.514	0.539	0.503	0.511
		Correlation Coefficient R	0.987	0.988	0.987	0.986	0.989
		Standard Error of Estimate	3.5	3.4	3.6	3.8	3.5
6	15.2	Constant A	3.6	4.9	-7.4	3.0	2.1
		Coefficient B	0.451	0.452	0.508	0.457	0.467
		Correlation Coefficient R	0.976	0.977	0.983	0.979	0.981
		Standard Error of Estimate	4.2	4.1	3.9	4.4	4.2
8	20.3	Constant A	5.2	6.8	-6.9	4.4	4.1
		Coefficient B	0.422	0.417	0.484	0.428	0.433
		Correlation Coefficient R	0.962	0.961	0.979	0.969	0.972
		Standard Error of Estimate	5.1	5.0	4.1	5.0	4.7
10	25.4	Constant A	6.3	7.9	-5.7	5.6	4.8
		Coefficient B	0.406	0.400	0.466	0.410	0.418
		Correlation Coefficient R	0.950	0.952	0.974	0.961	0.963
		Standard Error of Estimate	5.6	5.3	4.4	5.4	5.3
12	30.5	Constant A	7.4	10.0	-4.5	6.4	6.0
		Coefficient B	0.392	0.375	0.457	0.399	0.405
		Correlation Coefficient R	0.937	0.935	0.973	0.953	0.956
		Standard Error of Estimate	6.2	5.9	4.5	5.8	5.6

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	NUMBER OF DATA POINTS IN ANALYSES: 316 COLLEGE PARK, MARYLAND	255 CLARKSON COLLEGE, NEW YORK	196 UNIV OF ARIZ TUCSON, ARIZONA	767 COMBINED DATA SETS	739 LONGITUDINALLY ADJUSTED DATA
2	5.1	Constant A	-2.7	-3.7	-0.2	-2.1	-2.8
		Coefficient B	0.595	0.613	0.577	0.593	0.600
		Correlation Coefficient R	0.985	0.982	0.991	0.986	0.985
		Standard Error of Estimate	4.4	5.0	3.1	4.5	4.6
4	10.2	Constant A	2.5	1.2	0.5	1.4	1.2
		Coefficient B	0.526	0.542	0.544	0.537	0.539
		Correlation Coefficient R	0.988	0.987	0.986	0.988	0.989
		Standard Error of Estimate	3.6	3.8	3.7	3.7	3.5
6	15.2	Constant A	5.8	4.9	0.0	3.8	3.4
		Coefficient B	0.474	0.482	0.519	0.491	0.496
		Correlation Coefficient R	0.987	0.984	0.982	0.986	0.986
		Standard Error of Estimate	3.4	3.6	4.1	3.7	3.7
8	20.3	Constant A	7.5	7.1	0.3	5.5	5.3
		Coefficient B	0.441	0.442	0.493	0.458	0.460
		Correlation Coefficient R	0.981	0.977	0.978	0.980	0.981
		Standard Error of Estimate	3.8	4.0	4.3	4.1	3.9
10	25.4	Constant A	8.5	8.5	1.7	6.6	6.4
		Coefficient B	0.420	0.416	0.468	0.434	0.437
		Correlation Coefficient R	0.972	0.970	0.973	0.974	0.973
		Standard Error of Estimate	4.3	4.4	4.5	4.5	4.5
12	30.5	Constant A	9.9	10.7	2.6	7.7	7.7
		Coefficient B	0.399	0.386	0.456	0.416	0.417
		Correlation Coefficient R	0.961	0.955	0.969	0.964	0.963
		Standard Error of Estimate	5.0	5.0	4.7	5.1	5.1

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	NUMBER OF DATA POINTS IN ANALYSES				
			316	256	74	646	615
			COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS	LONGITUDINALLY ADJUSTED DATA
2	5.1	Constant A	-5.0	-3.9	-2.7	-4.3	-4.7
		Coefficient B	0.619	0.621	0.603	0.618	0.619
		Correlation Coefficient R	0.984	0.979	0.989	0.982	0.982
		Standard Error of Estimate	4.6	5.2	2.9	4.8	4.9
4	10.2	Constant A	0.6	0.2	-0.8	0.1	0.3
		Coefficient B	0.570	0.577	0.594	0.577	0.574
		Correlation Coefficient R	0.985	0.983	0.984	0.984	0.985
		Standard Error of Estimate	4.1	4.3	3.3	4.2	4.0
6	15.2	Constant A	4.9	3.7	0.0	3.7	3.6
		Coefficient B	0.523	0.531	0.576	0.534	0.532
		Correlation Coefficient R	0.986	0.986	0.982	0.985	0.986
		Standard Error of Estimate	3.6	3.6	3.5	3.7	3.7
8	20.3	Constant A	7.4	6.0	0.5	5.9	5.9
		Coefficient B	0.488	0.492	0.557	0.500	0.498
		Correlation Coefficient R	0.986	0.987	0.980	0.985	0.986
		Standard Error of Estimate	3.3	3.2	3.6	3.5	3.4
10	25.4	Constant A	8.6	7.6	1.1	7.2	7.4
		Coefficient B	0.465	0.461	0.538	0.474	0.470
		Correlation Coefficient R	0.985	0.986	0.976	0.982	0.982
		Standard Error of Estimate	3.4	3.1	3.8	3.6	3.6
12	30.5	Constant A	10.2	9.8	2.7	9.0	9.0
		Coefficient B	0.439	0.429	0.518	0.448	0.444
		Correlation Coefficient R	0.979	0.980	0.974	0.975	0.976
		Standard Error of Estimate	3.7	3.5	3.8	4.0	4.0

TABLE 2

TEMPERATURE DISTRIBUTIONS[a] IN ASPHALTIC CONCRETE PAVEMENTS AS A FUNCTION OF DAYTIME EXPOSURE TO SOLAR RADIATION

[a]X = surface temperature plus 5-day average air-temperature history
Y = temperature at depth

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS
2	5.1	Constant A	-5.2	-0.7	-2.0	-3.1
		Coefficient B	0.561	0.532	0.534	0.547
		Correlation Coefficient R	0.988	0.982	0.993	0.985
		Standard Error of Estimate	2.8	3.1	2.2	3.0
4	10.2	Constant A	-2.8	-0.3	-0.2	-1.5
		Coefficient B	0.573	0.555	0.546	0.563
		Correlation Coefficient R	0.990	0.982	0.996	0.987
		Standard Error of Estimate	2.6	3.3	1.8	2.9
6	15.2	Constant A	-1.7	0.5	1.4	-0.5
		Coefficient B	0.579	0.565	0.554	0.571
		Correlation Coefficient R	0.988	0.981	0.995	0.986
		Standard Error of Estimate	2.9	3.5	1.8	3.1
8	20.3	Constant A	-0.3	1.4	3.3	0.6
		Coefficient B	0.585	0.565	0.557	0.576
		Correlation Coefficient R	0.987	0.980	0.994	0.985
		Standard Error of Estimate	3.1	3.6	2.1	3.2

SUNRISE

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS
2	5.1	Constant A	-3.1	-0.1	-6.0	-2.0
		Coefficient B	0.525	0.516	0.544	0.521
		Correlation Coefficient R	0.980	0.983	0.994	0.985
		Standard Error of Estimate	3.3	3.0	2.1	3.1
4	10.2	Constant A	-4.4	-0.8	-5.2	-1.6
		Coefficient B	0.541	0.525	0.530	0.518
		Correlation Coefficient R	0.983	0.983	0.992	0.983
		Standard Error of Estimate	3.2	3.1	2.4	3.3
6	15.2	Constant A	-5.2	-0.7	-4.3	-1.6
		Coefficient B	0.553	0.534	0.529	0.525
		Correlation Coefficient R	0.982	0.982	0.991	0.982
		Standard Error of Estimate	3.4	3.2	2.5	3.5
8	20.3	Constant A	-4.5	-0.3	-2.1	-0.9
		Coefficient B	0.562	0.537	0.526	0.531
		Correlation Coefficient R	0.984	0.983	0.990	0.984
		Standard Error of Estimate	3.3	3.1	2.6	3.4

MIDMORNING

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS
2	5.1	Constant A	-2.4	-2.7	-6.8	-1.3
		Coefficient B	0.548	0.571	0.563	0.543
		Correlation Coefficient R	0.986	0.984	0.993	0.986
		Standard Error of Estimate	3.7	4.0	2.8	4.0
4	10.2	Constant A	0.4	1.1	-9.9	0.4
		Coefficient B	0.482	0.493	0.531	0.484
		Correlation Coefficient R	0.982	0.984	0.988	0.983
		Standard Error of Estimate	3.7	3.5	3.5	4.0
6	15.2	Constant A	1.5	3.8	-9.7	1.7
		Coefficient B	0.451	0.448	0.506	0.451
		Correlation Coefficient R	0.970	0.972	0.981	0.973
		Standard Error of Estimate	4.5	4.2	4.1	4.7
8	20.3	Constant A	2.8	5.0	-6.1	3.4
		Coefficient B	0.434	0.427	0.473	0.429
		Correlation Coefficient R	0.957	0.960	0.977	0.965
		Standard Error of Estimate	5.2	4.8	4.3	5.1

MIDDAY

DEPTH (in.)	DEPTH (cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS
2	5.1	Constant A	-4.9	-4.5	-5.9	-3.4
		Coefficient B	0.603	0.618	0.599	0.595
		Correlation Coefficient R	0.984	0.981	0.992	0.984
		Standard Error of Estimate	4.6	5.1	3.0	4.7
4	10.2	Constant A	-1.4	-0.8	-8.4	-1.4
		Coefficient B	0.536	0.548	0.574	0.540
		Correlation Coefficient R	0.985	0.985	0.987	0.986
		Standard Error of Estimate	4.0	3.9	3.7	4.1
6	15.2	Constant A	0.7	2.7	-9.3	0.4
		Coefficient B	0.491	0.491	0.547	0.497
		Correlation Coefficient R	0.982	0.982	0.981	0.982
		Standard Error of Estimate	3.9	3.8	4.2	4.2
8	20.3	Constant A	2.9	4.8	-8.1	2.6
		Coefficient B	0.458	0.452	0.514	0.460
		Correlation Coefficient R	0.975	0.974	0.975	0.975
		Standard Error of Estimate	4.3	4.4	4.6	4.6

MIDAFTERNOON

DEPTH (in.)	(cm)	STATISTICAL PARAMETERS FOR Y = A + BX	COLLEGE PARK, MARYLAND	CLARKSON COLLEGE, NEW YORK	UNIV OF ARIZ TUCSON, ARIZONA	COMBINED DATA SETS
2	5.1	Constant A	-4.4	-2.6	-2.6	-3.4
		Coefficient B	0.613	0.607	0.596	0.607
		Correlation Coefficient R	0.979	0.972	0.987	0.977
		Standard Error of Estimate	4.7	5.3	2.8	4.8
4	10.2	Constant A	-2.4	-1.9	-5.7	-2.1
		Coefficient B	0.602	0.603	0.616	0.600
		Correlation Coefficient R	0.983	0.977	0.988	0.981
		Standard Error of Estimate	4.0	4.8	2.7	4.3
6	15.2	Constant A	-1.2	-0.1	-8.1	-1.0
		Coefficient B	0.578	0.576	0.622	0.578
		Correlation Coefficient R	0.985	0.981	0.986	0.983
		Standard Error of Estimate	3.7	4.1	3.0	3.9
8	20.3	Constant A	0.0	1.2	-9.7	0.2
		Coefficient B	0.557	0.548	0.614	0.555
		Correlation Coefficient R	0.987	0.984	0.983	0.985
		Standard Error of Estimate	3.3	3.6	3.2	3.5

SUNSET