NASA CR-147517

ESTIMATION OF DAILY MEAN AIR TEMPERATURE FROM SATELLITE DERIVED RADIOMETRIC DATA

Job Order 92-105

(NASA-CR-147517) ESTIMATION OF DAILY MEAN AIR TEMPERATURE FROM SATELLITE DERIVED RADIOMETRIC DATA (Lockheed Electronics Co.) 75 p HC $4.50 CSCL 04B G3/47

N76-21840

Unclas 25425

Prepared By

Lockheed Electronics Company, Inc.
Aerospace Systems Division
Houston, Texas

Contract NAS 9-12200

For

HEALTH APPLICATIONS OFFICE
LIFE SCIENCES DIRECTORATE

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

January 1976

LEC-7852

TECHNICAL REPORT INDEX/ABSTRACT

(See instructions on reverse side.)

1. TITLE AND SUBTITLE OF DOCUMENT

ESTIMATION OF DAILY MEAN AIR TEMPERATURE FROM SATELLITE DERIVED RADIOMETRIC DATA

2. JSC NO.

3. CONTRACTOR/ORGANIZATION NAME Lockheed Electronics Co., Inc.	4. CONTRACT OR GRANT NO. NAS 9-12200
5. CONTRACTOR/ORIGINATOR DOCUMENT NO. LEC-7852	6. PUBLICATION DATE (THIS ISSUE) January 1976
7. SECURITY CLASSIFICATION Unclassified	8. OPR (OFFICE OF PRIMARY RESPONSIBILITY) C. M. Barnes
9. LIMITATIONS GOVERNMENT HAS UNLIMITED RIGHTS [X] YES [ ] NO IF NO, STATE LIMITATIONS AND AUTHORITY N/A	10. AUTHOR(S) D. Phinney
11. DOCUMENT CONTRACT REFERENCES	12. HARDWARE CONFIGURATION
WORK BREAKDOWN STRUCTURE NO. N/A	SYSTEM N/A
CONTRACT EXHIBIT NO. N/A	SUBSYSTEM N/A
DRL NO. AND REVISION N/A	MAJOR EQUIPMENT GROUP N/A
DRL LINE ITEM NO. N/A	

13. ABSTRACT

The Screwworm Eradication Data System (SEDS) at JSC utilizes satellite derived estimates of daily mean air temperature (DMAT) to monitor the effect of temperature on screwworm populations. The performance of the SEDS screwworm growth potential predictions depends in large part upon the accuracy of the DMAT estimates.

14. SUBJECT TERMS

Radiometric data	Life Sciences	
Regression Coefficients	Bioengineering	
NOAA Satellite		

JSC-10920

ESTIMATION OF DAILY MEAN AIR TEMPERATURE FROM SATELLITE DERIVED RADIOMETRIC DATA

Job Order 92-105

PREPARED BY

Dale Phinney
Lockheed Electronics Company, Inc.

APPROVED BY

LEC

Frank C. Forsberg, Manager
Life Sciences Applications
Department

NASA

Charles M. Barnes, Manager
Health Applications Office

Prepared By

Lockheed Electronics Company, Inc.

For

Bioengineering Systems Division

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS

January 1976

LEC-7852

CONTENTS

TABLES

FIGURES

ABBREVIATIONS, ACRONYMS AND SYMBOLS

ALT	Elevation in meters
ANOVA	Analysis of Variance
DMAT	Daily mean air temperature
DMATK	Daily mean air temperature in degrees Kelvin
K	Filter constant set to .125
TMET	Ground truth control station's observed mean air temperature
NOAA	National Oceanic and Atmospheric Administration
SEDS	Screwworm Eradication Data System
TSDK	Day radiometric temperature in degrees Kelvin
TSNK	Night radiometric temperature in degrees Kelvin
A_1, B_1, C_1	Multiple regression coefficients
ΔT	Temperature difference
°K	Degree Kelvin

1. INTRODUCTION

The Screwworm Eradication Data System (SEDS) at the Johnson Space Center, Houston, Texas utilizes satellite derived estimates of daily mean air temperature (DMAT) to monitor the effect of temperature on screwworm populations. A set of coefficients derived from multiple linear regression studies is used to convert radiometric data obtained by the National Oceanic and Atmospheric Administration (NOAA) satellite into estimates of daily mean air temperature. The performance of the SEDS screwworm growth potential predictions depends in large part upon the accuracy of the DMAT estimates.

1.1 PURPOSE

This technical memorandum evaluates the temperature accuracies obtained by SEDS production processor using spring data (March 29 through June 27, 1975).

1.2 BACKGROUND

Depending upon the amount of cloud-free data obtained from the twice daily satellite coverage, four basic methods are used to calculate DMAT. An accurate evaluation of SEDS performance requires an understanding of these methods.

The first three methods of calculating DMAT use current radiometric data. The cases are as follows:

- Case 1 - Both night and day radiometric data usable

  $DMATK = A_o + A_1*TSNK + A_2*TSDK + A_3*ALT$

- Case 2 - Only day radiometric data usable

  $DMATK = B_o + B_1*TSDK + B_2*ALT$

- Case 3 - Only night radiometric data usable

  $DMATK = C_o + C_1*TSNK + C_2*ALT$

Where the symbols are defined as follows:

DMATK - Daily mean air temperature in degrees Kelvin

TSDK - Day radiometric temperature in degrees Kelvin

TSNK - Night radiometric temperature in degrees Kelvin

ALT - Elevation in meters

A_i, B_i, C_i - Multiple regression coefficients

Usable data is radiometric data which has survived all cloud detection tests. When no radiometric data is available, DMAT is estimated using ground data and a temperature difference field.

The ground truth fill-in utilizes a network of surface meteorological stations. Each point in the SEDS image is assigned to the "zone of influence" of a surface station. These zones are shown in figure 1. The size and shape of each zone is determined primarily by the density of the surface network.

A temperature difference (ΔT) field for each zone is derived from days on which good quality radiometric data was available. The ΔT field represents the difference between the ground truth control station's observed surface temperature and the radiometrically derived DMAT estimate for each point. When radiometric data is unavailable at a point, the DMAT estimate is made by adding the point's control station's observed surface temperature to the point's ΔT value. This may be written for point (x,y) as

$$DMAT_{(x,y)} = TMET + \Delta T_{(x,y)}$$

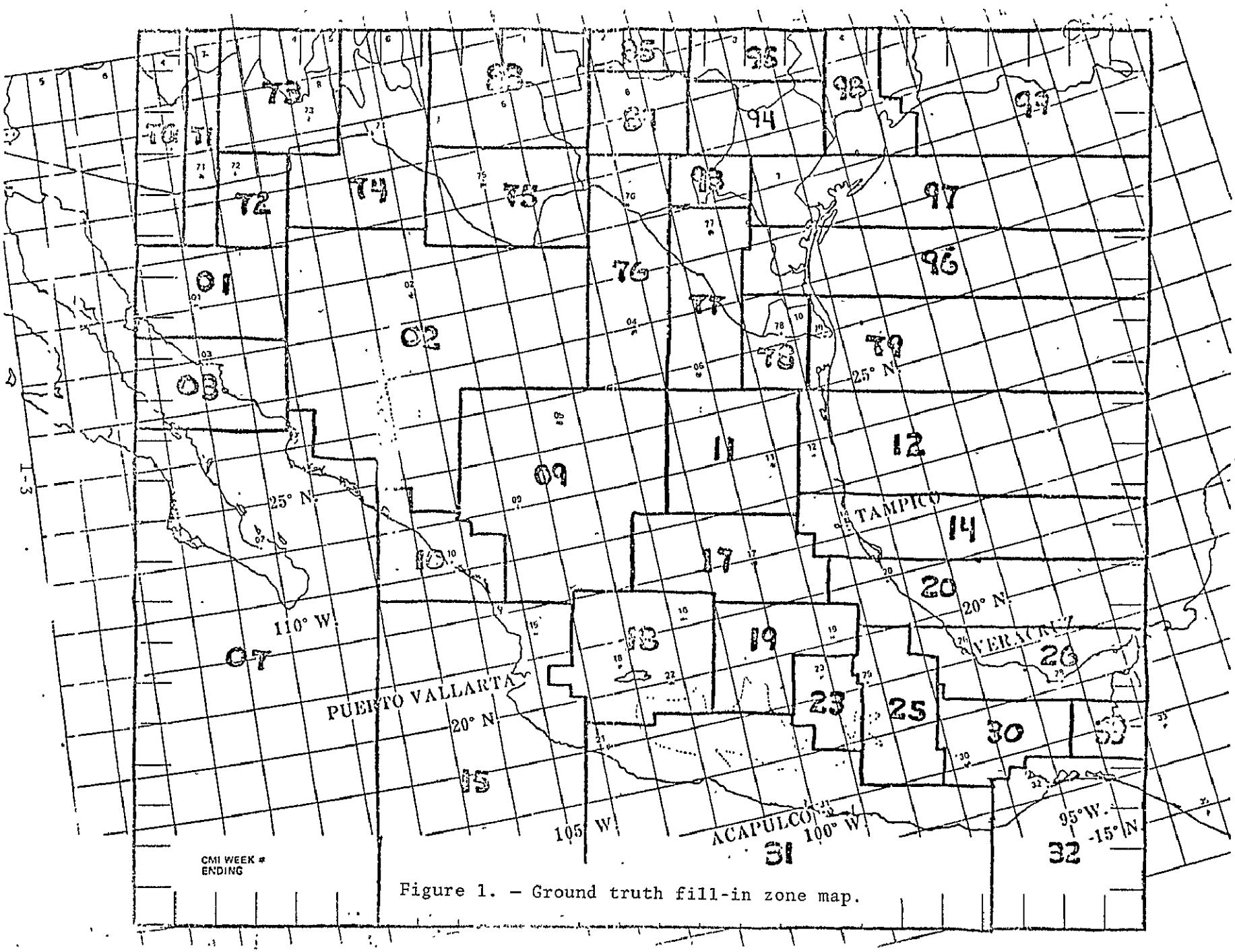

Figure 1. – Ground truth fill-in zone map.

where TMET - The ground truth control station's surface observed mean air temperature

$\Delta T_{(x,y)}$ - The temperature difference field value at the point (x,y).

When a DMAT estimate is made from radiometric data, the ΔT field is updated. To prevent rapid fluctuation in the ΔT field, a low pass filter is used. The update may be written

$$\Delta T_{(x,y)} = K(DMAT_{(x,y)} - TMET) + (1-K)\Delta T(-1)_{(x,y)}$$

where K - The filter constant which has been set to .125

$\Delta T(-1)_{(x,y)}$ - The temperature difference field from the previous day for the point (x,y).

The DMAT estimate based on the ΔT field is made for each point, but is used only when the radiometric data is cloudy or unavailable.

2. ANALYSIS OF MODEL

The basic model used to convert radiometric data to estimates of DMAT uses elevation as an independent variable. To test the need for elevation in the model, several regression studies were performed using SEDS data from the 28 September to 9 October time period. Each of the three methods of calculation described earlier were examined both with and without elevation as a variable. Additionally, the case where both radiometric passes produce usable data was examined to determine if the inclusion of latitude as variable was desirable. Summaries of these regression studies including the correlation matrix, coefficient of determination, standard error of estimates, analysis of variance, and tests of significance for the coefficients may be found in appendix A. These regressions were performed using data from the ground truth zone control stations shown in table I.

Using the results of these regressions, Analysis of Variance (ANOVA) was used to determine the significance of elevation and latitude as regression variables. Elevation was a highly significant variable for each method of calculation. The highest significance occurred for the day radiometric only usable and the lowest for both radiometric usable. Latitude was not a significant variable for this sample. The complete ANOVA's may be found in appendix B.

TABLE I. — GROUND TRUTH ZONE CONTROL STATIONS

STATION NAME	SEDS ID	LATITUDE	LONGITUDE	ELEVATION
Hermosillo	01	29:04	110:57	211 m
Chihuahua	02	28:38	106:04	1354 m
Guaymas	03	27:55	110:53	16 m
La Paz	07	29:04	110:20	10 m
Durango	09	24:01	104:40	1889 m
Mazatlan	10	23:12	106:25	3 m
Ciudad Victoria	11	23:44	99:08	321 m
Soto la Marina	12	23:46	98:12	25 m
Tampico	14	22:13	97:51	12 m
Tepic	15	21:30	104:53	915 m
Rio Verde	17	21:56	100:00	991 m
Guadalajara	18	20:36	103:23	1567 m
Pachuca	19	20:08	98:44	2426 m
Tuxpan	20	20:57	97:23	14 m
Mexico City	23	19:24	99:11	2298 m
Puebla	25	19:03	98:12	2162 m
Veracruz	26	19:09	96:07	13 m
Oaxaca	30	17:03	96:43	1500 m
Acapulco	31	16:50	99:55	82 m
Salina Cruz	32	16:10	95:12	70 m
Las Casas	33	16:44	92:38	2128 m
Tucson	70	32:07	110:56	2555 ft.
Fort Huachuca	71	31:35	110:20	4685 ft.
Douglas	72	31:27	109:36	4107 ft.
Deming	73	32:15	107:42	4324 ft.
El Paso	74	31:48	106:24	3916 ft.
Marfa	75	30:22	104:01	4858 ft.
Del Rio	76	29:22	100:55	1027 ft.
Cotulla	77	28:27	99:13	479 ft.
McAllen	78	26:11	98:14	112 ft.
Brownsville	79	25:54	97:26	20 ft.
Midland-Odessa	83	31:57	102:11	2851 ft.
San Angelo	84	31:22	100:30	1903 ft.
Abilene	85	32:25	99:41	1784 ft.
San Antonio	93	29:32	98:28	788 ft.
Austin	94	30:18	97:42	597 ft.
Waco	95	31:37	97:13	501 ft.
Corpus Christi	96	27:46	97:30	41 ft.
Victoria	97	28:51	96:55	104 ft.
Houston	98	29:58	95:12	96 ft.
Port Arthur	99	29:57	94:01	16 ft.

3. INTERPRETATION

The evaluation of the DMAT estimates requires an understanding of the multitude of factors which influence their quality. The mean air temperatures observed by the surface meteorological stations are used to verify the DMAT estimates. The underlying assumption is that these temperatures are correct. However, the quality of the stations used in SEDS varies. In general, the U.S. stations are of higher quality than many of the Mexican stations.

The U.S. stations are of two types. The so-called first order stations are mostly sited at airports. The stations are manned, calibrated, and observed by professional meteorologists. These stations are used as ground truth zone control stations and may be regarded as the best stations. A second group of U.S. stations are the cooperative stations. The observers at these stations are interested non-professionals, but the stations are sited and maintained by the U.S. National Weather Service. These stations also provide high quality data.

The Mexican stations are in some cases less useful than the U.S. stations. Many of these stations are run by a professional staff. However, the calibration and siting of the instruments are not always of the highest quality. The location of these stations is often in a town on the top of a building. Temperatures taken from these stations may not be as representative of the surrounding areas as might be desired.

The use of elevation as a variable in the DMAT estimates also produces lower quality data in Mexico. It has been shown that the relative quality of the elevation base map used in SEDS is poor in Mexico. Since this calculation depends mostly on the elevation variable, the effect is most pronounced in the DMAT estimates produced using day radiometric data only.

The initial guidelines for the spring evaluation indicated that the evaluation would be conducted in the U.S. only. Accordingly, the DMAT coefficients were derived using only U.S. and Mexican border stations. The resulting DMAT estimates for regions well away from the U.S.-Mexican border area should be handled with care. The higher elevations experienced in some parts of Mexico are outside the range of data over which the DMAT coefficients were calculated. This factor alone restricts the usefulness of many Mexican stations.

The spring evaluation data was calculated using only two sets of DMAT coefficients. The initial set was calculated using 15-29 March 1975 data. This set of coefficients was used until 5 June 1975 when a new set was introduced derived from 10-23 May 1975 data. This situation resulted because of the accelerated processing of this data and of the limited staff available for recalculation. Although extremely valuable, the resulting DMAT represents a system performing at less than its capabilities.

The emissivity base map used to correct the radiometric data was based on 15-29 March 1975 data. This map was not updated during the spring evaluation due to the limitations of time. By the end of the evaluation period, the applicability of this map was marginal, contributing to the slightly lower quality data.

The DMAT estimates derived from the ground truth fill-in utilizing the ΔT field must also be evaluated with care. The expectation would be that the error rate associated with DMAT estimates would increase with distance from the control stations. Thus, the best estimate of the performance of this technique would probably come from a network of stations that do not include the control stations.

4. EVALUATION AND RESULTS

The evaluation of the DMAT estimates depends upon the statistical comparison of surface observations of mean air temperature and of the satellite estimates. For review and clarification, a short discussion of common statistical measures of error may be found in appendix C.

Data was available for the 95 locations shown in table II. The geographical distribution of these stations is shown in figure 2; the ground truth zone control stations are indicated with a square.

Considering the information in the previous section, the data was stratified in a number of ways to enhance the understanding of SEDS performance. The following is a summary of this stratification:

- Overall SEDS Performance - The error of all stations without regard to method of calculation.
- Ground Truth Fill-in - The error associated with those DMAT estimates calculated using the ΔT field. These cases had no usable radiometric data.
- Both Radiometric Usable - The error associated with DMAT estimates calculated from both morning and night satellite passes.
- Night Radiometric Only - The error associated with DMAT estimates calculated from the night satellite pass; the corresponding morning pass was either missing or cloudy.
- Day Radiometric Only - The error associated with DMAT estimates calculated from the day satellite pass; the corresponding night data was either missing or cloudy.

TABLE II. – SEDS LOCATION LIST OF WEATHER STATIONS
(Begin approx. 14 Nov 75 - Spg Eval Phase II)

ID	NO./LTR	LATITU	LONGITU	ID	NO./LTR	LATITU	LONGITU	ID	NO./LTR	LATITU	LONGITU
SMMX											
01	160/HMO	29:04N	110:57W	14	548/TAM	22:13N	97:51W	24	680	19:26N	99:08W
02	225/CUU	28:38	106:04	15	[illegible]/TEP	21:30	104:53	25	685/PEB	19:[illegible]	98:12
03	255/GYM	27:55	110:53	16	[illegible] LEO	21:07	101:41	26	692/VER	19:[illegible]	[illegible]:07
05	382/TRC	25:32	103:27	17	581/RVS	21:56	100:00	28	741/CTZ	18:[illegible]	25
06	393/MTY	25:52	100:14	18	613/GDL	20:36	103:23	29	762/CHG	1[illegible]	:30
07	405/LAP	24:09	110:20	19	632/PCA	20:08	98:44	30	775/OAX	17:03	[illegible]:43
08	412/CUL	24:48	107:23	20	640/TUX	20:57	97:23	31	805/ACA	16:50	99:55
09	423/DGO	24:01	104:40	21	654/MZL	19:03	103:52	32	833/SCZ	16:10	95:12
10	458/MZT	23:12	106:25	22	662	19:59	102:19	33	845	16:44	92:38
11	491/CVM	23:44	99:08	23	679/MEX	19:24	99:11	35	903/TAP	14:54	92:15
12	499/SOT	23:46	98:12								
SAMX											
36	AGS/571	21:52N	102:18W	49	MLM/665	19:42N	101:11W	59	SRL/253	27:17N	112:15W
38	CEN/258	27:29	109:56	50	MTT/781	17:59	94:32	60	TCG/634	20:05	98:22
39	CJS/226	31:44	106:29	51	NAU/642	20:13	96:46	61	TGZ/843	16:45	93:06
41	IMA/658	19:14	103:44	52	NLD/286	27:30	99:30	62	TMN/541	22:00	98:46
42	IZT/830	16:32	95:10	53	NOG/080	31:14	110:59	63	UPN	19:24	102:02
43	JAL/687	19:31	96:54	55	PVR/601	20:37	105:14	65	VSA/743	17:59	92:55
46	LZC	17:59	102:13	57	REX	26:01	98:14	66	ZIH/758	17:38	101:34
47	MAM/399	25:52	97:31	58	SLP/539	22:09	100:58				
SMUS & SAUS											
67	290/MYF	32:49N	117:08W	75	MRF	30:22N	104:01W	93	253/SAT	29:32N	98:28W
68	IPL	32:50	115:34	76	261/DRT	29:22	100:55	94	254/AUS	30:18	97:42
69	280/YUM	32:40	114:36	77	COT	28:27	99:13	95	256/ACT	31:37	97:13
70	274/TUS	32:07	110:56	78	MFE	26:11	98:14	96	251/CRP	27:46	97:30
71	FHU	31:35	110:20	79	250/BRO	25:54	97:26	97	255/VCT	28:51	96:55
72	DUG	31:27	109:36	83	265/MAF	31:57	102:11	98	243/IAH	29:58	95:21
73	DMN	32:15	107:42	84	263/SJT	31:22	100:30	99	241/BPT	29:57	94:01
74	270/ELP	31:48	106:24	85	266/ABI	32:25	99:41				

ADDITIONAL TEXAS STATIONS (CO-OP)

ID	LATITU	LONGITU	NAME	ID	LATITU	LONGITU	NAME
00	31:11N	105:21W	Sierra Blanca	64	29:16N	97:45W	Nixon
04	31:54	103:55	Red Bluff Dam	80	29:43	96:32	Columbus
13	29:34	104:23	Presidio	81	29:12	96:17	El Campo
27	29:16	103:18	Chisos Basin	82	30:19	95:27	Conroe
34	30:12	103:14	Marathon	86	30:03	94:49	Liberty
37	30:09	102:24	Sanderson	87	31:06	97:21	Temple
40	30:53	102:18	Bakersfield	88	28:27	97:42	Beeville
44	30:09	101:07	Juno	89	27:30	99:28	Laredo
45	31:51	100:59	Sterling City	90	27:18	98:40	Hebbronville
48	31:43	98:59	Brownwood	91	26:56	97:48	Armstrong
54	30:44	99:13	Mason	92	26:12	97:40	Harlingen
56	28:42	100:29	Eagle Pass				

This sheet dated: Tue 7 Oct 75.

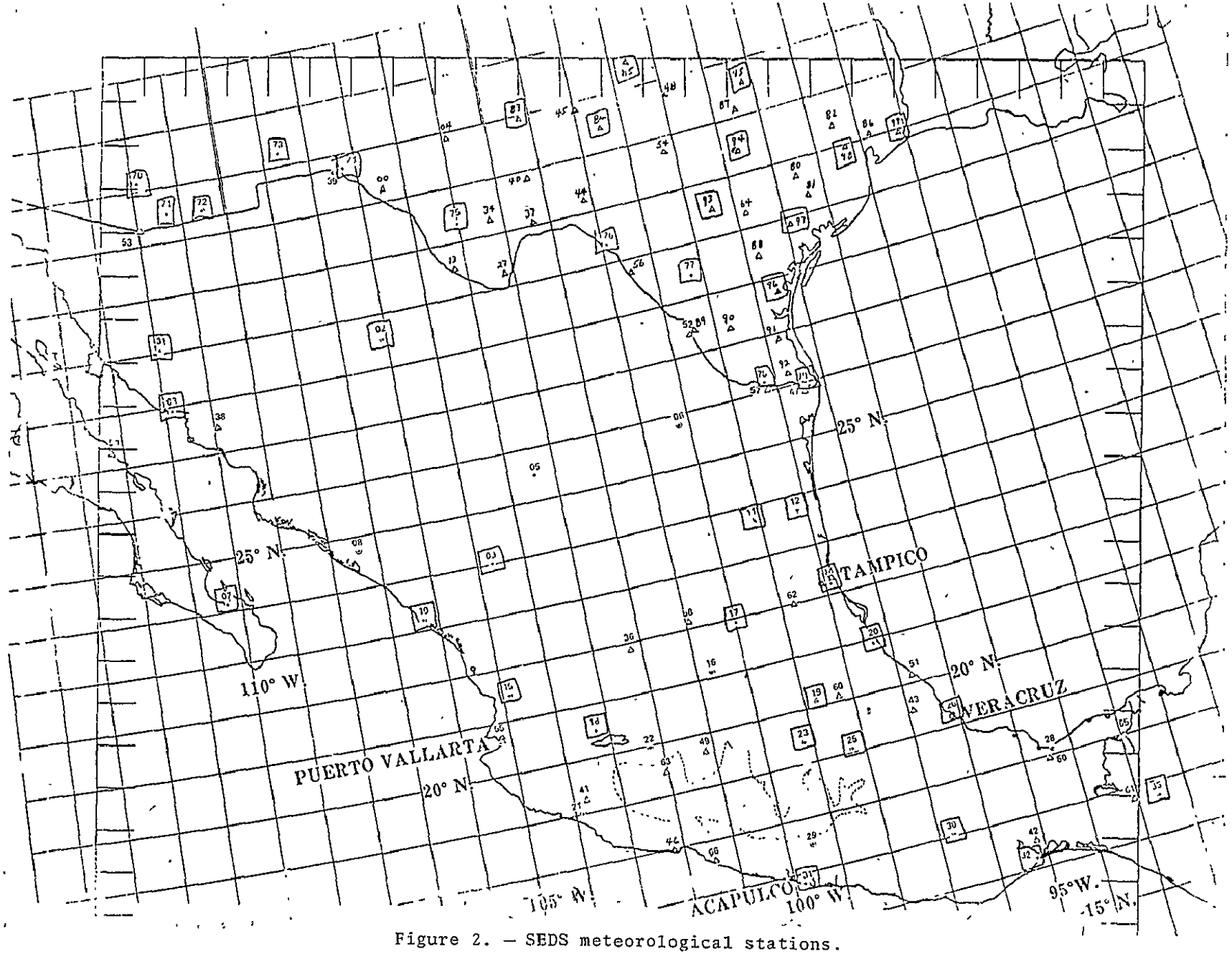

Figure 2. — SEDS meteorological stations.

Each of these major data groupings was further divided as follows:

- U.S. Stations - The error associated with DMAT estimates calculated for U.S. stations only.
- Mexican Stations - The error associated with DMAT estimates calculated for Mexican stations only.
- Ground Truth Control Stations Only - The error associated with DMAT estimates calculated for the ground truth zone control stations.
- Non-Control Stations - The error associated with DMAT estimates calculated for stations other than the ground truth control stations.

Those cases calculated from the ΔT field were further stratified as follows:

- U.S. Non-Control Stations - The error associated with DMAT estimates calculated for U.S. stations other than the ground truth zone control stations.
- Mexican Non-Control Stations - The error associated with DMAT estimates calculated for Mexican stations other than the ground truth zone control stations.

The standard error associated with each of these stratifications for the 29 March to 13 June SEDS data may be seen in table III. This table clearly demonstrates the variation in calculated error rate depending upon the stratification. The complete week by week analysis may be found in appendix D.

Based on these data and the limitations discussed in the previous section, four stratifications were selected which seem to

TABLE III. – STRATIFIED STANDARD ERROR FOR SPRING EVALUATION

	29 MAR 4 APR	5 APR 11 APR	12 APR 18 APR	19 APR 25 APR	26 APR 2 MAY	3 MAY 9 MAY	10 MAY 16 MAY	17 MAY 23 MAY	24 MAY 30 MAY	31 MAY 6 JUNE	7 JUNE 13 JUNE
OVERALL	4.74	3.93	3.53	3.94	3.92	4.39	3.69	4.30	4.08	4.038	3.018
GT ONLY											
Overall	3.98	3.00	3.13	3.03	3.06	2.93	3.59	3.31	3.52	3.64	3.12
U.S.	3.90	2.36	2.50	2.58	2.44	2.39	3.05	2.34	2.70	2.24	2.43
Mexican	3.41	2.68	2.85	2.95	3.26	3.34	3.47	3.60	3.63	3.41	2.83
Control	1.82	1.92	2.38	2.44	2.28	2.47	2.95	2.68	3.40	3.41	2.59
Non Control	5.22	3.78	3.76	3.53	3.64	3.24	4.09	3.81	3.63	3.85	3.48
U.S. Non	5.58	3.08	3.26	2.98	3.01	2.23	3.37	2.45	2.77	1.97	3.05
Mexican Non	4.10	3.09	3.27	3.56	3.78	3.44	3.97	4.28	3.84	3.82	3.37
TSD & TSN											
Overall	4.66	3.48	--	3.66	3.25	3.92	2.74	3.77	3.18	3.67	2.51
U.S.	(3.42)	(3.71)	--	4.67	2.85	2.77	2.58	3.52	2.48	3.08	2.46
Mexican	3.09	3.46	--	3.16	3.21	4.02	2.86	3.89	3.78	4.46	2.59
Control	(3.73)	4.21	--	3.03	3.46	4.60	2.35	3.97	2.86	3.67	2.27
Non Control	5.14	2.69	--	4.14	3.06	3.12	2.99	(3.54)	3.35	3.66	2.77
TSN ONLY											
Overall	4.79	4.60	2.65	3.57	4.07	4.88	3.95	5.08	4.46	4.44	2.38
U.S.	5.23	4.20	2.75	3.88	4.74	4.37	4.04	(5.16)	4.16	3.13	2.62
Mexican	3.59	4.75	2.61	3.32	3.56	5.31	3.56	4.98	4.79	4.38	2.12
Control	3.74	4.83	2.44	3.56	4.54	4.75	3.55	(3.94)	4.96	3.53	2.37
Non Control	5.78	4.13	2.86	3.62	3.43	5.06	4.41	5.47	3.94	5.02	2.30
TSD ONLY											
Overall	6.04	4.56	4.84	5.22	5.54	5.19	3.97	5.07	4.80	3.38	3.00
U.S.	4.88	4.53	4.38	5.52	6.18	5.24	3.18	4.75	4.35	2.46	2.92
Mexican	5.12	3.90	4.41	4.31	4.29	4.85	4.42	4.99	4.71	4.21	2.80
Control	5.46	4.17	4.44	5.11	5.97	5.42	4.18	5.23	5.12	4.18	2.51
Non Control	6.53	4.91	5.26	5.35	4.93	4.94	3.72	4.92	4.48	2.60	3.34

( ) indicates sample size less than 25.

most fairly reflect the capabilities of the SEDS DMAT estimates. The following groupings reflect this analysis:

- Ground Truth Fill-in - The U.S. non-control stations
- Both Radiometric Usable - All U.S. stations
- Day Radiometric Only - All U.S. stations
- Night Radiometric Only - All U.S. stations.

The DMAT performance as measured by the standard error of estimate for these four cases may be seen in figures 3 through 6. The best results were obtained when both radiometric passes were usable. Average performance in this case was near 2.5°C as measured by the standard error of estimate. The average performance for the night and day radiometric data only was near 3.9° and 4.5°C, respectively. The performance of the ground truth fill-in was excellent with an average standard error near 2.75°C.

Overall, the results of the spring evaluation were encouraging. The study has demonstrated that the design goal of 3.0°C error is obtainable. Under closely monitored conditions, a DMAT standard error of 2.5°C should be expected.

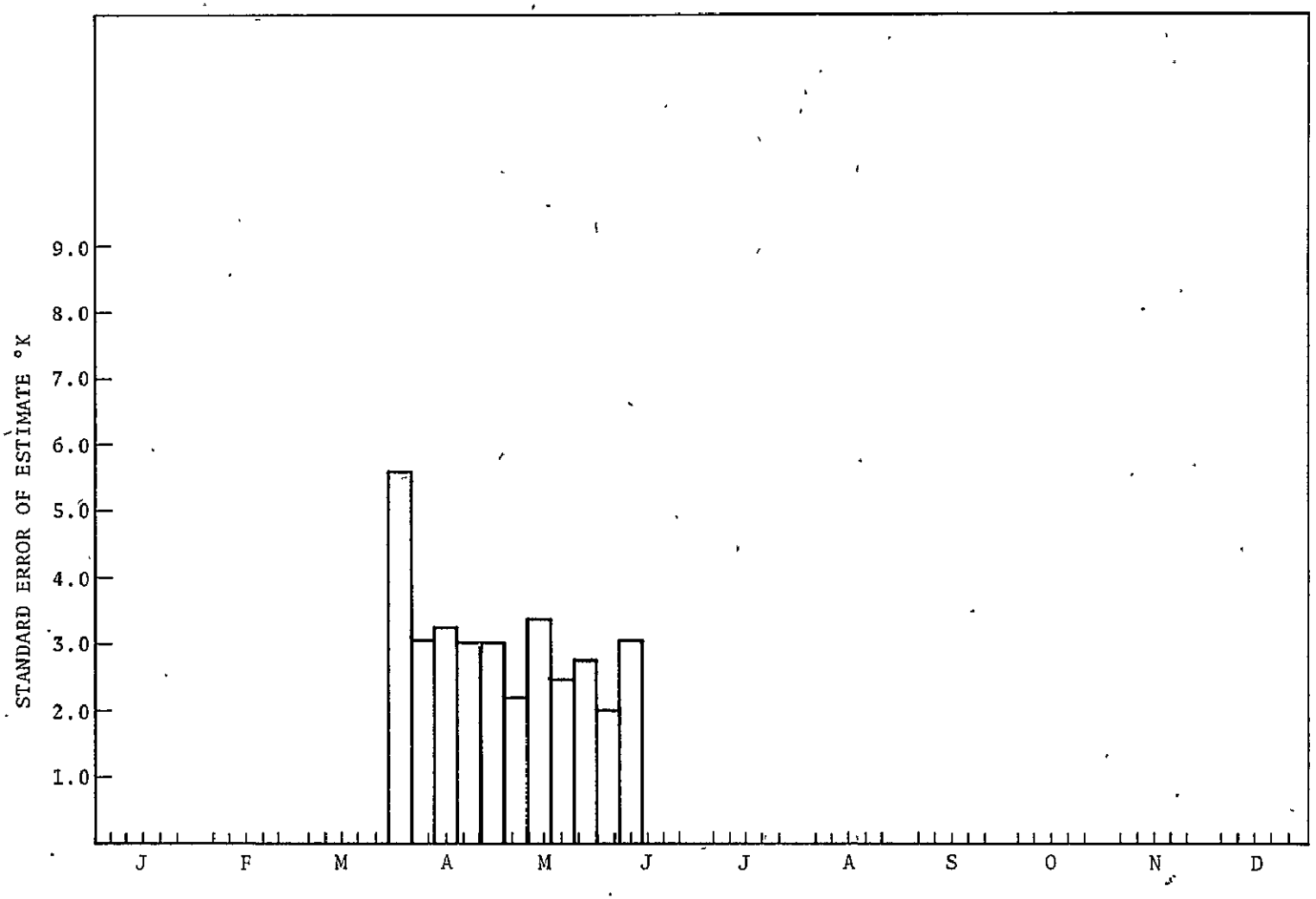

Figure 3. — Standard error for U.S. stations not used as control stations when DMAT was calculated using the ΔT field.

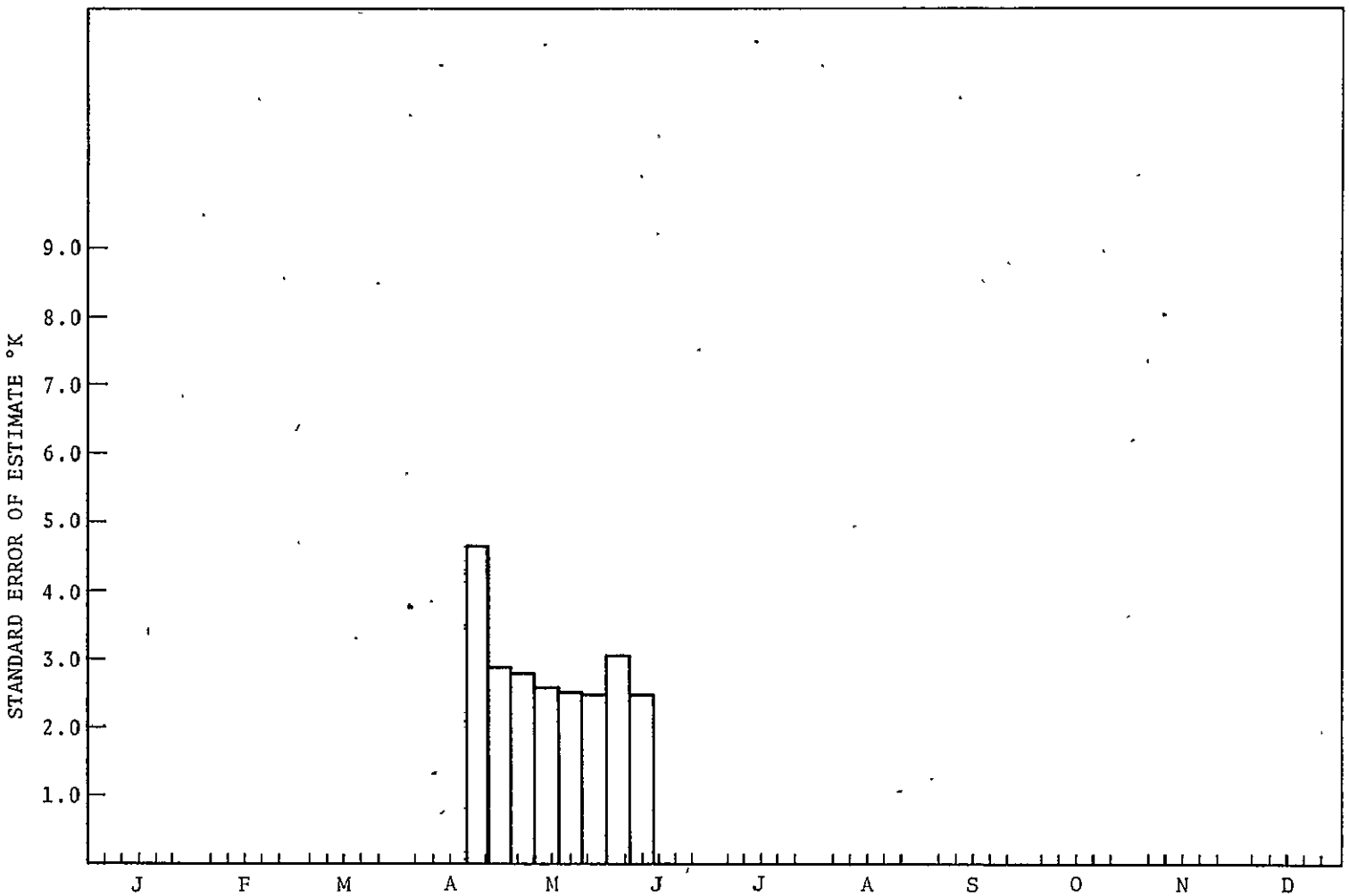

Figure 4. — Standard error for all U.S. stations when DMAT was calculated using both radiometric passes.

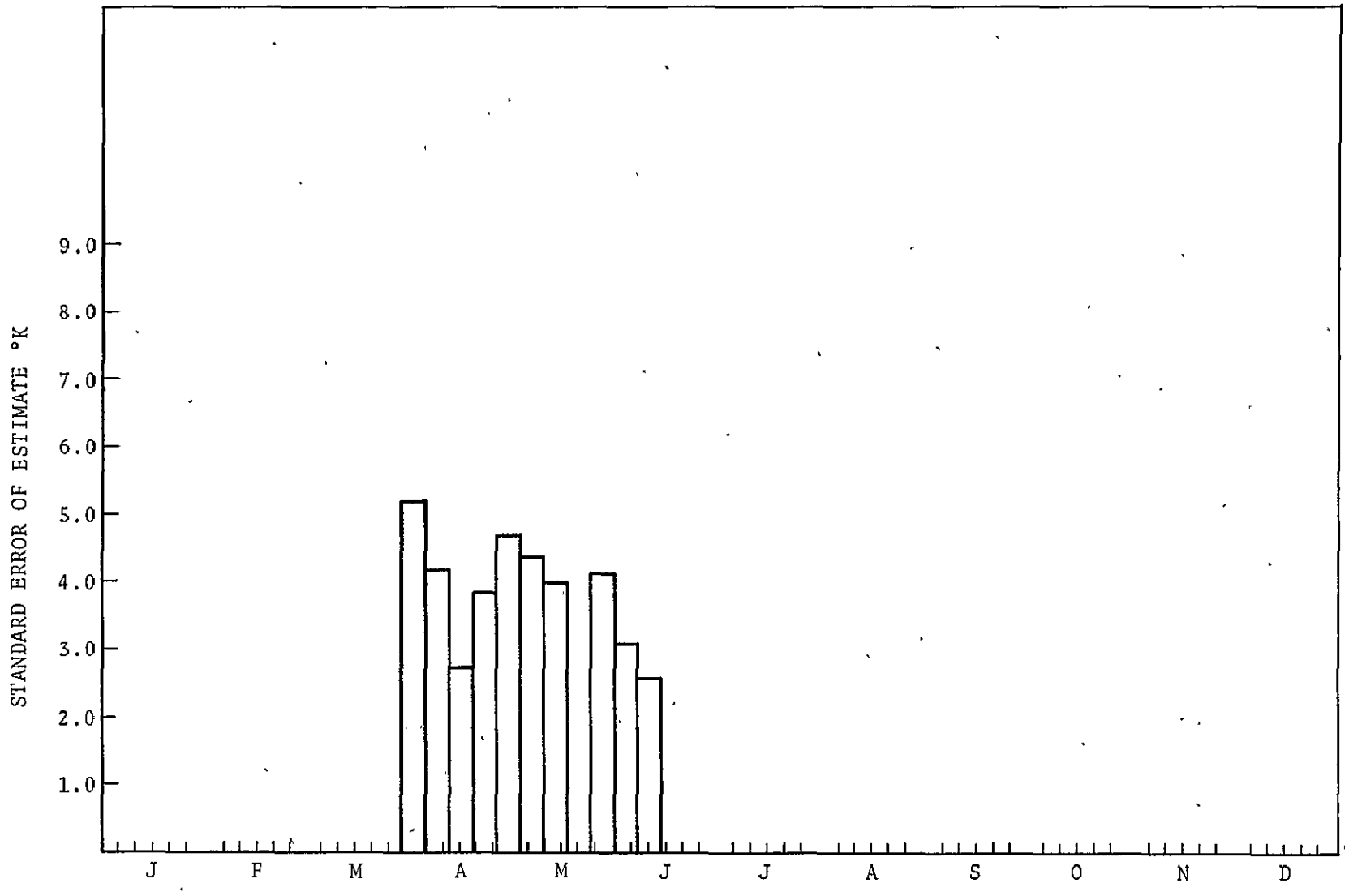

Figure 5. – Standard error for all U.S. stations when DMAT was calculated using night radiometric data only.

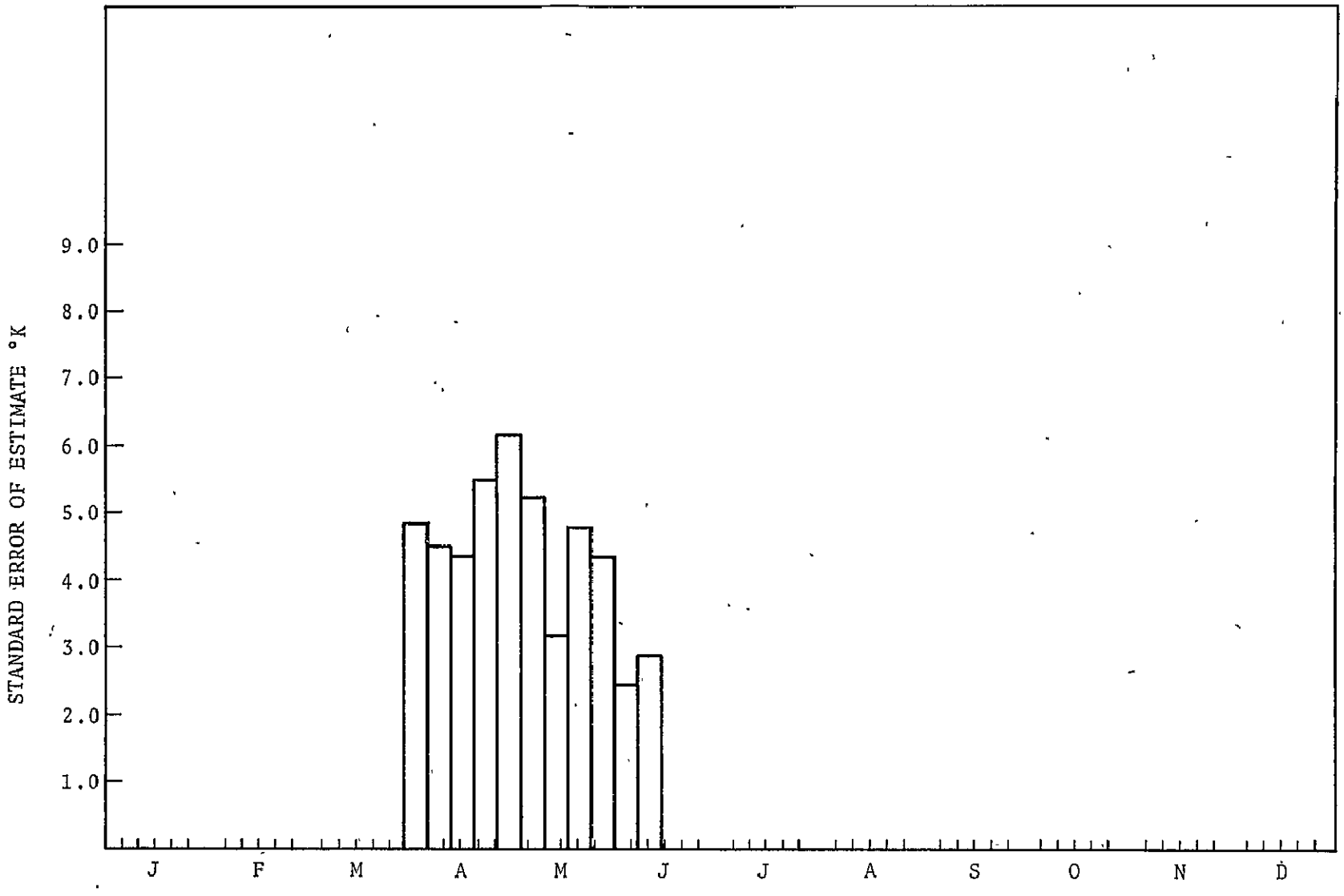

Figure 6. – Standard error for all U.S. stations when DMAT was calculated using day radiometric data only.

APPENDIX A
SUMMARIES OF REGRESSION ANALYSES

Sept 28 - Oct 9, 1975

Model: Day Radiometric Only Usable With Altitude

Correlation Matrix

		ALT	TSDK	TT		
		1	2	3	4	Y
ALT	1	1.00000	-.14662	-.76616		
TSDK	2		1.00000	.26951		
TT	3			1.00000		
	4					
	Y					

R = .77961 Adjusted for degree of freedom.
SEE = 2.51465
(1.36 degree improvement over without altitude.)

ANOVA

	DF	SS	MS	F	
Reg	2	1737.394	868.697	137.376	
Res	174	1100.288	6.323		
Total	176	2837.683			

REG. COEFFICIENTS

VAR		COEF	SE	SIG	
ALT	1	-.00432	.00027	-15.561	
TSDK	2	.19497	.05792	3.366	
	3				
	4				
Intercept	0	238.406	17.707		

Sept 28 - Oct 9, 1975

Model: Day Radiometric Only Usable Without Altitude

Correlation Matrix

		TSDK	TT			
		1	2	3	4	Y
TSDK	1	1.00000	.27140			
TT	2		1.00000			
	3					
	4					
	Y					

R = .26146 Adjust for degrees of freedom
SEE = 3.87548

ANOVA

	DF	SS	MS	F	
Reg	1	209.008	209.008	13.916	
Res	175	2628.398	15.019		
Total	176	2837.407			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
TSDK	1	.32982	.00000	3.29820	
	2				
	3				
	4				
Intercept	0	194.16179	26.980		

Sept 28 - Oct. 9, 1975

Model: Night Radiometric. Only Usable Without Altitude

Correlation Matrix

		TSNK	TT			
		1	2	3	4	Y
TSNK	1	1.00000	.55443			
TT	2		1.00000			
	3					
	4					
	Y					

R = .54887 Adjusted for degrees of freedom
SEE = 3.30179

ANOVA

	DF	SS	MS	F	
Reg	1	546.747	546.747	50.152	
Res	113	1231.912	10.902		
Total	114	1778.629			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
TSNK	1	.43868	.06194	7.08178	
	2				
	3				
	4				
Intercept	0	164.69238	18.24930		

Sept 28 - Oct 9, 1975

Model: Night Radiometric Only Usable With Altitude

Correlation Matrix

		ALT	TSNK	TT		
		1	2	3	4	Y
ALT	1	1.00000	-.52671	-.80899		
TSNK	2		1.00000	.68779		
TT	3			1.00000		
	4					
	Y					

R = .86269 Adjusted for sample size

SEE = 1.88298

(1.447 degree improvement over without altitude)

ANOVA

	DF	SS	MS	F	
Reg	2	1143.217	571.608	100.76	
Res	112	635.352	5.673		
Total	114	1778.569			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
ALT	1	-.00321	.00030	-10.495	
TSNK	2	.29647	.04822	6.148	
	3				
	4				

Intercept 0 208.891 14.351

Sept 28 - Oct 9, 1975

Model: Both Radiometric Usable With Altitude

Correlation Matrix

		ALT	TSD	TSN	TT	
		1	2	3	4	Y
ALT	1	1.00000	-.02327	-.57758	-.78842	
TSD	2		1.00000	.11872	.07281	
TSN	3			1.00000	.76998	
TT	4				1.00000	
	Y					

R = .87211 Ajusted for sample size

SEE = 1.761

(.578 degree improvement over without altitude)

ANOVA

	DF	SS	MS	F	
Reg	3	748.185	249.395	80.420	
Res	72	223.284	3.101		
Total	75	971.469			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
ALT	1	-.00268	.00036	-7.4446	
TSD	2	.00559	.06583	.0849	
TSN	3	.41897	.06204	6.75319	
Intercept	0	170.2778	25.522		

Sept 28 - Oct 9, 1975

Model: Both Radiometric Usable With Altitude/Latitude

Correlation Matrix

		ALT	TSDK	TSNK	LAT	TT
		1	2	3	4	Y
ALT	1	1.00000	-.02327	-.57758	.10955	-.78842
TSDK	2		1.00000	.11872	.33524	.07281
TSNK	3			1.00000	-.34847	.76998
LAT	4				1.00000	-.26093
TT	Y					1.00000

R = .87165 Adjusted for degree of freedom
SEE = 1.76395

ANOVA

	DF	SS	MS	F	
Reg	4	750.550	187.637	60.304	
Res	71	220.920	3.111		
Total	75	971.469			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
ALT	1	-.00272	.00036	-7.47720	
TSDK	2	.03181	.07248	.43889	
TSNK	3	.39361	.06861	5.73663	
LAT	4	-.05785	.06637	-.87170	
Intercept	0	171.33666	25.59383		

Sept 28 - Oct 9, 1975

Model: Both Radiometric Usable Without Altitude

Correlation Matrix

		TSDK	TSNK	TT		
		1	2	3	4	Y
TSDK	1	1.00000	.11872	.08178		
TSNK	2		1.00000	.76650		
TT	3			1.00000		
	4					
	Y					

R = .75915 Adjusted for sample size

SEE = 2.33891

ANOVA

	DF	SS	MS	F	
Reg	2	569.05	284.526	52.010	
Res	73	399.350	5.470		
Total	75	968.401			

REG. COEFFICIENTS

	VAR	COEF	SE	SIG	
TSDK	1	-.01078	.08730	-.12350	
TSNK	2	.68125	.06717	10.14084	
	3				
	4				
Intercept	0	95.60826	31.31418		

APPENDIX B
SUMMARIES OF ANALYSES OF VARIANCE

ANOVA.- Day Radiometric Only Usable 28 September to 9 October 1975 - Significance of Elevation

Source	Degrees Freedom	Sum Squares	Mean Square	F
TSD,ALT	2	1737.394		
TSD	1	209.008		
ALT/TSD	1	1528.386	1528.386	241.72*
Residual	174	1100.288	6.323	
Total	176	2837.683		

*Significant at the .99 level

ANOVA.-Night Radiometric Only Usable 28 September to 9 October 1975 - Significance of Elevation

Source	Degrees Freedom	Sum Squares	Mean Square	F
TSN,ALT	2	1143.217		
TSN	1	546.747		
ALT/TSN	1	596.470	596.470	105.14*
Residual	112	635.352	5.673	
Total	114	1778.569		

*Significant at the .99 level

ANOVA.-Both Radiometric Data Usable 28 September to 9 October 1975 -
Significance of Elevation

Source	Degrees Freedom	Sum Squares	Mean Square	F
TSD,TSN,ALT	3	748.185		
TSD,TSN	2	569.050		
ALT/TSD,TSN	1	179.135	179.135	57.76*
Residual	72	223.284	3.101	
Total	75	971.469		

*Significant at the .99 level

ANOVA.-Both Radiometric Usable 28 September to 9 October -

Significance of Latitude

Source	Degrees Freedom	Sum Squares	Mean Squares	F
TSD,TSN,ALT,LAT	4	750.550		
TSD,TSN,ALT	3	748.185		
LAT/TSD,TSN,ALT	1	2.365	2.365	.76*
Residual	71	220.920	3.111	
Total	75	971.469		

*not significant

APPENDIX C
STATISTICAL MEASURES OF ERROR

STATISTICAL MEASURES OF ERROR

The nomenclature used when discussing error statistics is often confusing. The following definitions of commonly used terms may prove useful in clarifying the situation.

The error of estimate is the difference between the actual and the predicted value. SEDS uses multiple regression equations to predict values of daily mean air temperature from satellite observed radiometric data. The actual daily mean air temperature is observed on the surface at standard metorological stations. The error of estimate for daily mean air temperature may be written:

$$\varepsilon = TTK - DMATK$$

where

ε - The error of estimate

TTK - The surface observed daily mean air temperature in degrees Kelvin

DMATK - The SEDS estimate of daily mean air temperature in degrees Kelvin

The mean error represents a systematic variation of the sample from the true value. When SEDS is operating perfectly, the mean or bias error will be equal to zero. The mean error of estimate may be written:

$$\bar{\varepsilon} = \left(\sum_{i=1}^{n} \varepsilon_i \right) / n$$

where $\bar{\varepsilon}$ - The mean error of estimate

n - The sample size

The standard error of estimate is the standard deviation of the errors of estimate. The standard error, S, may be written:

$$S = \sqrt{\left(\sum_{i=1}^{n} \left(\varepsilon_i - \bar{\varepsilon}\right)^2\right) / (n - 1)}$$

In the past, root mean square (rms) error and standard error have been used as if they were the same. However, this is not true. The rms error may be written

$$RMS = \sqrt{\left(\sum_{i=1}^{n} \left(\varepsilon_i\right)^2\right) / (n - 1)}$$

Thus, the rms and standard error are equal only when the mean error is zero. All errors reported during SEDS development and evaluation have been standard errors.

Assuming that the errors are normally distributed approximately 67 percent of the errors will lie within $\pm$ one standard error of the mean error and 95 percent within $\pm$ two standard errors.

APPENDIX D
DETAILED WEEKLY ANALYSIS OF MODEL PERFORMANCE

29 MARCH – 4 APRIL 1975

OVERALL SEDS PERFORMANCE FROM 3-29-75 TO 4- 4-75
MISSING DATA = 90
BIAS ERROR = .471
RMS ERROR = 4.740
SAMPLE SIZE = 575

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = .283
RMS ERROR = 3.975
SAMPLE SIZE = 291

U.S. STATIONS ONLY
BIAS ERROR = -1.816
RMS ERROR = 3.952
SAMPLE SIZE = 164

MEXICAN STATIONS ONLY
BIAS ERROR = 1.961
RMS ERROR = 3.412
SAMPLE SIZE = 127

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = -.051
RMS ERROR = 1.821
SAMPLE SIZE = 140

NON-CONTROL STATIONS ONLY
BIAS ERROR = .593
RMS ERROR = 5.223
SAMPLE SIZE = 151

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = -1.290
RMS ERROR = 5.582
SAMPLE SIZE = 75

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.451
RMS ERROR = 4.095
SAMPLE SIZE = 76

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = .663
RMS ERROR = 4.661
SAMPLE SIZE = 53

U.S. STATIONS ONLY
BIAS ERROR = -3.665
RMS ERROR = 3.420
SAMPLE SIZE = 20

23 MARCH - 4 APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 3.286
RMS ERROR = 3.091
SAMPLE SIZE = 33

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.425
RMS ERROR = 3.731
SAMPLE SIZE = 20

NON-CONTROL STATIONS ONLY
BIAS ERROR = .202
RMS ERROR = 5.143
SAMPLE SIZE = 33

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.343
RMS ERROR = 4.788
SAMPLE SIZE = 94

U.S. STATIONS ONLY
BIAS ERROR = -1.626
RMS ERROR = 5.228
SAMPLE SIZE = 34

MEXICAN STATIONS ONLY
BIAS ERROR = 3.025
RMS ERROR = 3.590
SAMPLE SIZE = 60

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.646
RMS ERROR = 3.735
SAMPLE SIZE = 50

NON-CONTROL STATIONS ONLY
BIAS ERROR = .999
RMS ERROR = 5.784
SAMPLE SIZE = 44

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = .198
RMS ERROR = 6.038
SAMPLE SIZE = 137

U.S. STATIONS ONLY
BIAS ERROR = -4.360
RMS ERROR = 4.883
SAMPLE SIZE = 48

```
MEXICAN STATIONS ONLY
 BIAS ERROR =   2.656
 RMS ERROR =   5.116
 SAMPLE SIZE =    89

GROUND TRUTH CONTROL STATIONS ONLY
 BIAS ERROR =    .107
 RMS ERROR =   5.459
 SAMPLE SIZE =    63

NON-CONTROL STATIONS ONLY
 BIAS ERROR =    .275
 RMS ERROR =   6.527
 SAMPLE SIZE =    74
```

OVERALL SEDS PERFORMANCE FROM 4-12-75 TO 4-18-75
MISSING DATA = 111
BIAS ERROR = .734
RMS ERROR = 3.528
SAMPLE SIZE = 554

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = .459
RMS ERROR = 3.133
SAMPLE SIZE = 376

U.S. STATIONS ONLY
BIAS ERROR = -1.136
RMS ERROR = 2.500
SAMPLE SIZE = 192

MEXICAN STATIONS ONLY
BIAS ERROR = 2.124
RMS ERROR = 2.853
SAMPLE SIZE = 184

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .549
RMS ERROR = 2.375
SAMPLE SIZE = 190

NON-CONTROL STATIONS ONLY
BIAS ERROR = .367
RMS ERROR = 3.756
SAMPLE SIZE = 186

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = -1.590
RMS ERROR = 3.257
SAMPLE SIZE = 89

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.162
RMS ERROR = 3.270
SAMPLE SIZE = 97

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = .000
RMS ERROR = .000
SAMPLE SIZE = 0

U.S. STATIONS ONLY
BIAS ERROR = .000
RMS ERROR = .000
SAMPLE SIZE = 0

18 APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = .000
RMS ERROR = .000
SAMPLE SIZE = 0

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .000
RMS ERROR = .000
SAMPLE SIZE = 0

NON-CONTROL STATIONS ONLY
BIAS ERROR = .000
RMS ERROR = .000
SAMPLE SIZE = 0

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = .784
RMS ERROR = 2.652
SAMPLE SIZE = 64

U.S. STATIONS ONLY
BIAS ERROR = .745
RMS ERROR = 2.750
SAMPLE SIZE = 28

MEXICAN STATIONS ONLY
BIAS ERROR = .814
RMS ERROR = 2.612
SAMPLE SIZE = 36

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .767
RMS ERROR = 2.442
SAMPLE SIZE = 30

NON-CONTROL STATIONS ONLY
BIAS ERROR = .799
RMS ERROR = 2.861
SAMPLE SIZE = 34

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.612
RMS ERROR = 4.836
SAMPLE SIZE = 114

U.S. STATIONS ONLY
BIAS ERROR = -.704
RMS ERROR = 4.382
SAMPLE SIZE = 50

12-13 APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 3.422
RMS ERROR = 4.407
SAMPLE SIZE = 64

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.562
RMS ERROR = 4.435
SAMPLE SIZE = 58

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.643
RMS ERROR = 5.259
SAMPLE SIZE = 56

8-11 APRIL 1975

OVERALL SEDS PERFORMANCE FROM 4- 5-75 TO 4- 9-75
MISSING DATA = 117
BIAS ERROR = 1.253
RMS ERROR = 3.931
SAMPLE SIZE = 548

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = -.060
RMS ERROR = 3.000
SAMPLE SIZE = 323

U.S. STATIONS ONLY
BIAS ERROR = -1.306
RMS ERROR = 2.363
SAMPLE SIZE = 210

MEXICAN STATIONS ONLY
BIAS ERROR = 2.254
RMS ERROR = 2.675
SAMPLE SIZE = 113

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = -.103
RMS ERROR = 1.918
SAMPLE SIZE = 160

NON-CONTROL STATIONS ONLY
BIAS ERROR = -.019
RMS ERROR = 3.779
SAMPLE SIZE = 163

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = -1.718
RMS ERROR = 3.076
SAMPLE SIZE = 102

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.821
RMS ERROR = 3.086
SAMPLE SIZE = 61

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 2.478
RMS ERROR = 3.483
SAMPLE SIZE = 58

U.S. STATIONS ONLY
BIAS ERROR = .495
RMS ERROR = 3.710
SAMPLE SIZE = 4

5-11 APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 2.625
RMS ERROR = 3.457
SAMPLE SIZE = 54

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.670
RMS ERROR = 4.213
SAMPLE SIZE = 28

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.299
RMS ERROR = 2.694
SAMPLE SIZE = 30

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.005
RMS ERROR = 4.596
SAMPLE SIZE = 77

U.S. STATIONS ONLY
BIAS ERROR = 1.886
RMS ERROR = 4.203
SAMPLE SIZE = 34

MEXICAN STATIONS ONLY
BIAS ERROR = 3.890
RMS ERROR = 4.746
SAMPLE SIZE = 43

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.149
RMS ERROR = 4.834
SAMPLE SIZE = 42

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.033
RMS ERROR = 4.128
SAMPLE SIZE = 35

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.680
RMS ERROR = 4.557
SAMPLE SIZE = 90

U.S. STATIONS ONLY
BIAS ERROR = .358
RMS ERROR = 4.526
SAMPLE SIZE = 25

5-11 APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 4.958
RMS ERROR = 3.902
SAMPLE SIZE = 65

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.505
RMS ERROR = 4.170
SAMPLE SIZE = 42

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.834
RMS ERROR = 4.910
SAMPLE SIZE = 48

OVERALL SEDS PERFORMANCE FROM 4-19-75 TO 4-25-75
MISSING DATA = 118
BIAS ERROR = 1.784
RMS ERROR = 3.938
SAMPLE SIZE = 547

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = .717
RMS ERROR = 3.030
SAMPLE SIZE = 248

U.S. STATIONS ONLY
BIAS ERROR = -.345
RMS ERROR = 2.578
SAMPLE SIZE = 151

MEXICAN STATIONS ONLY
BIAS ERROR = 2.370
RMS ERROR = 2.950
SAMPLE SIZE = 97

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.053
RMS ERROR = 2.444
SAMPLE SIZE = 128

NON-CONTROL STATIONS ONLY
BIAS ERROR = .358
RMS ERROR = 3.526
SAMPLE SIZE = 120

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = -.802
RMS ERROR = 2.984
SAMPLE SIZE = 74

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.225
RMS ERROR = 3.557
SAMPLE SIZE = 46

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 3.307
RMS ERROR = 3.656
SAMPLE SIZE = 87

U.S. STATIONS ONLY
BIAS ERROR = 2.873
RMS ERROR = 4.671
SAMPLE SIZE = 26

APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 3.491
RMS ERROR = 3.155
SAMPLE SIZE = 61

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.851
RMS ERROR = 3.034
SAMPLE SIZE = 42

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.732
RMS ERROR = 4.144
SAMPLE SIZE = 45

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.353
RMS ERROR = 3.570
SAMPLE SIZE = 98

U.S. STATIONS ONLY
BIAS ERROR = 2.721
RMS ERROR = 3.877
SAMPLE SIZE = 39

MEXICAN STATIONS ONLY
BIAS ERROR = 3.771
RMS ERROR = 3.321
SAMPLE SIZE = 59

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.338
RMS ERROR = 3.563
SAMPLE SIZE = 53

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.370
RMS ERROR = 3.619
SAMPLE SIZE = 45

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.595
RMS ERROR = 5.223
SAMPLE SIZE = 114

U.S. STATIONS ONLY
BIAS ERROR = -.178
RMS ERROR = 5.525
SAMPLE SIZE = 56

[illegible] APRIL 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 3.306
RMS ERROR = 4.309
SAMPLE SIZE = 58

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.991
RMS ERROR = 5.109
SAMPLE SIZE = 56

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.212
RMS ERROR = 5.347
SAMPLE SIZE = 58

OVERALL SEDS PERFORMANCE FROM 4-26-75 TO 5- 2-75
MISSING DATA = 112
BIAS ERROR = 2.211
RMS ERROR = 3.919
SAMPLE SIZE = 553

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 1.812
RMS ERROR = 3.057
SAMPLE SIZE = 228

U.S. STATIONS ONLY
BIAS ERROR = .855
RMS ERROR = 2.445
SAMPLE SIZE = 153

MEXICAN STATIONS ONLY
BIAS ERROR = 3.766
RMS ERROR = 3.257
SAMPLE SIZE = 75

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.536
RMS ERROR = 2.281
SAMPLE SIZE = 112

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.089
RMS ERROR = 3.643
SAMPLE SIZE = 116

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = .912
RMS ERROR = 3.014
SAMPLE SIZE = 74

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.137
RMS ERROR = 3.776
SAMPLE SIZE = 42

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 1.342
RMS ERROR = 3.248
SAMPLE SIZE = 137

U.S. STATIONS ONLY
BIAS ERROR = .721
RMS ERROR = 2.853
SAMPLE SIZE = 43

26APR - 2MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 2.229
RMS ERROR = 3.214
SAMPLE SIZE = 64

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .951
RMS ERROR = 3.459
SAMPLE SIZE = 48

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.659
RMS ERROR = 3.058
SAMPLE SIZE = 59

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 2.511
RMS ERROR = 4.066
SAMPLE SIZE = 124

U.S. STATIONS ONLY
BIAS ERROR = 1.495
RMS ERROR = 4.735
SAMPLE SIZE = 44

MEXICAN STATIONS ONLY
BIAS ERROR = 3.079
RMS ERROR = 3.556
SAMPLE SIZE = 80

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.235
RMS ERROR = 4.543
SAMPLE SIZE = 67

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.835
RMS ERROR = 3.432
SAMPLE SIZE = 57

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.774
RMS ERROR = 5.536
SAMPLE SIZE = 94

U.S. STATIONS ONLY
BIAS ERROR = .279
RMS ERROR = 6.191
SAMPLE SIZE = 31

26 APRIL - 2 MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 5.493
RMS ERROR = 4.287
SAMPLE SIZE = 63

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.305
RMS ERROR = 5.967
SAMPLE SIZE = 53

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.380
RMS ERROR = 4.929
SAMPLE SIZE = 41

3-7 May 1975

OVERALL SEDS PERFORMANCE FROM 5- 3-75 TO 5- 9-75
MISSING DATA = 89
BIAS ERROR = 2.621
RMS ERROR = 4.389
SAMPLE SIZE = 576

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 1.567
RMS ERROR = 2.933
SAMPLE SIZE = 224

U.S. STATIONS ONLY
BIAS ERROR = .851
RMS ERROR = 2.391
SAMPLE SIZE = 137

MEXICAN STATIONS ONLY
BIAS ERROR = 2.695
RMS ERROR = 3.342
SAMPLE SIZE = 87

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.002
RMS ERROR = 2.467
SAMPLE SIZE = 111

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.123
RMS ERROR = 3.245
SAMPLE SIZE = 113

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = .692
RMS ERROR = 2.231
SAMPLE SIZE = 63

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.925
RMS ERROR = 3.438
SAMPLE SIZE = 50

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 1.486
RMS ERROR = 3.925
SAMPLE SIZE = 88

U.S. STATIONS ONLY
BIAS ERROR = -.620
RMS ERROR = 2.774
SAMPLE SIZE = 26

MEXICAN STATIONS ONLY
BIAS ERROR = 2.369
RMS ERROR = 4.017
SAMPLE SIZE = 62

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.846
RMS ERROR = 4.602
SAMPLE SIZE = 44

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.126
RMS ERROR = 3.119
SAMPLE SIZE = 44

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 2.516
RMS ERROR = 4.876
SAMPLE SIZE = 74

U.S. STATIONS ONLY
BIAS ERROR = 1.526
RMS ERROR = 4.373
SAMPLE SIZE = 49

MEXICAN STATIONS ONLY
BIAS ERROR = 4.456
RMS ERROR = 5.307
SAMPLE SIZE = 25

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.520
RMS ERROR = 4.752
SAMPLE SIZE = 37

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.512
RMS ERROR = 5.063
SAMPLE SIZE = 37

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 4.429
RMS ERROR = 5.192
SAMPLE SIZE = 190

U.S. STATIONS ONLY
BIAS ERROR = 1.945
RMS ERROR = 5.241
SAMPLE SIZE = 54

3-9 May 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 5.415
RMS ERROR = 4.849
SAMPLE SIZE = 136

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.810
RMS ERROR = 5.425
SAMPLE SIZE = 89

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.974
RMS ERROR = 4.942
SAMPLE SIZE = 101

10-16 May, 1975

OVERALL SEDS PERFORMANCE FROM 5-10-75 TO 5-16-75
MISSING DATA = 103
BIAS ERROR = 2.175
RMS ERROR = 3.692
SAMPLE SIZE = 562

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 3.017
RMS ERROR = 3.589
SAMPLE SIZE = 218

U.S. STATIONS ONLY
BIAS ERROR = 1.417
RMS ERROR = 3.052
SAMPLE SIZE = 98

MEXICAN STATIONS ONLY
BIAS ERROR = 4.323
RMS ERROR = 3.473
SAMPLE SIZE = 120

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.622
RMS ERROR = 2.953
SAMPLE SIZE = 107

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.397
RMS ERROR = 4.087
SAMPLE SIZE = 111

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.343
RMS ERROR = 3.370
SAMPLE SIZE = 44

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.746
RMS ERROR = 3.972
SAMPLE SIZE = 67

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = .834
RMS ERROR = 2.742
SAMPLE SIZE = 109

U.S. STATIONS ONLY
BIAS ERROR = .388
RMS ERROR = 2.578
SAMPLE SIZE = 60

10-16 MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 1.380
RMS ERROR = 2.863
SAMPLE SIZE = 49

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.011
RMS ERROR = 2.346
SAMPLE SIZE = 44

NON-CONTROL STATIONS ONLY
BIAS ERROR = .714
RMS ERROR = 2.993
SAMPLE SIZE = 65

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 2.442
RMS ERROR = 3.949
SAMPLE SIZE = 84

U.S. STATIONS ONLY
BIAS ERROR = .975
RMS ERROR = 4.044
SAMPLE SIZE = 35

MEXICAN STATIONS ONLY
BIAS ERROR = 3.490
RMS ERROR = 3.563
SAMPLE SIZE = 49

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.380
RMS ERROR = 3.551
SAMPLE SIZE = 45

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.636
RMS ERROR = 4.406
SAMPLE SIZE = 39

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.779
RMS ERROR = 3.971
SAMPLE SIZE = 151

U.S. STATIONS ONLY
BIAS ERROR = .860
RMS ERROR = 3.183
SAMPLE SIZE = 71

ID-16MA-1775

MEXICAN STATIONS ONLY
BIAS ERROR = 2.595
RMS ERROR = 4.419
SAMPLE SIZE = 80

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.569
RMS ERROR = 4.175
SAMPLE SIZE = 83

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.635
RMS ERROR = 3.721
SAMPLE SIZE = 68

17-23 May 1975

OVERALL SEDS PERFORMANCE FROM 5-17-75 TO 5-23-75
MISSING DATA = 79
BIAS ERROR = 13.433
RMS ERROR = 4.295
SAMPLE SIZE = 586

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 3.438
RMS ERROR = 3.309
SAMPLE SIZE = 261

U.S. STATIONS ONLY
BIAS ERROR = 4.161
RMS ERROR = 2.340
SAMPLE SIZE = 111

MEXICAN STATIONS ONLY
BIAS ERROR = 4.383
RMS ERROR = 3.599
SAMPLE SIZE = 150

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.204
RMS ERROR = 2.684
SAMPLE SIZE = 128

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.663
RMS ERROR = 3.813
SAMPLE SIZE = 133

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.528
RMS ERROR = 2.449
SAMPLE SIZE = 46

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.304
RMS ERROR = 4.282
SAMPLE SIZE = 85

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 1.830
RMS ERROR = 3.767
SAMPLE SIZE = 49

U.S. STATIONS ONLY
BIAS ERROR = 1.086
RMS ERROR = 3.518
SAMPLE SIZE = 18

17-23 MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 2.263
RMS ERROR = 3.894
SAMPLE SIZE = 31

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.444
RMS ERROR = 3.968
SAMPLE SIZE = 27

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.304
RMS ERROR = 3.537
SAMPLE SIZE = 22

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 2.713
RMS ERROR = 5.076
SAMPLE SIZE = 49

U.S. STATIONS ONLY
BIAS ERROR = 1.183
RMS ERROR = 5.162
SAMPLE SIZE = 14

MEXICAN STATIONS ONLY
BIAS ERROR = 3.325
RMS ERROR = 4.984
SAMPLE SIZE = 35

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .962
RMS ERROR = 3.940
SAMPLE SIZE = 20

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.920
RMS ERROR = 5.472
SAMPLE SIZE = 29

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.930
RMS ERROR = 5.074
SAMPLE SIZE = 227

U.S. STATIONS ONLY
BIAS ERROR = 2.593
RMS ERROR = 4.749
SAMPLE SIZE = 127

17-23 MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 5.628
RMS ERROR = 4.986
SAMPLE SIZE = 100.

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.469
RMS ERROR = 5.231
SAMPLE SIZE = 105

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.326
RMS ERROR = 4.922
SAMPLE SIZE = 122

24-30 MAY, 1975

OVERALL SEDS PERFORMANCE FROM 5-24-75 TO 5-30-75
MISSING DATA = 100
BIAS ERROR = 3.415
RMS ERROR = 4.077
SAMPLE SIZE = 565

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 3.737
RMS ERROR = 3.516
SAMPLE SIZE = 309

U.S. STATIONS ONLY
BIAS ERROR = 2.207
RMS ERROR = 2.695
SAMPLE SIZE = 132

MEXICAN STATIONS ONLY
BIAS ERROR = 4.878
RMS ERROR = 3.628
SAMPLE SIZE = 177

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.525
RMS ERROR = 3.399
SAMPLE SIZE = 155

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.950
RMS ERROR = 3.629
SAMPLE SIZE = 154

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.550
RMS ERROR = 2.771
SAMPLE SIZE = 60

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.844
RMS ERROR = 3.836
SAMPLE SIZE = 94

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = .720
RMS ERROR = 3.182
SAMPLE SIZE = 75

U.S. STATIONS ONLY
BIAS ERROR = -.028
RMS ERROR = 2.482
SAMPLE SIZE = 45

5 1-30 MAY 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 1.841
RMS ERROR = 3.785
SAMPLE SIZE = 30

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .007
RMS ERROR = 2.865
SAMPLE SIZE = 36

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.378
RMS ERROR = 3.352
SAMPLE SIZE = 39

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 2.391
RMS ERROR = 4.464
SAMPLE SIZE = 65

U.S. STATIONS ONLY
BIAS ERROR = 1.746
RMS ERROR = 4.164
SAMPLE SIZE = 38

MEXICAN STATIONS ONLY
BIAS ERROR = 3.299
RMS ERROR = 4.787
SAMPLE SIZE = 27

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.723
RMS ERROR = 4.959
SAMPLE SIZE = 31

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.000
RMS ERROR = 3.936
SAMPLE SIZE = 34

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 4.874
RMS ERROR = 4.801
SAMPLE SIZE = 116

U.S. STATIONS ONLY
BIAS ERROR = 3.192
RMS ERROR = 4.353
SAMPLE SIZE = 55

21-30 MAY . .5

MEXICAN STATIONS ONLY
 BIAS ERROR = 6.392
 RMS ERROR = 4.710
 SAMPLE SIZE = 61

GROUND TRUTH CONTROL STATIONS ONLY
 BIAS ERROR = 4.539
 RMS ERROR = 5.123
 SAMPLE SIZE = 58

NON-CONTROL STATIONS ONLY
 BIAS ERROR = 5.210
 RMS ERROR = 4.475
 SAMPLE SIZE = 58

31 MAY TO 6 JUNE 1975

OVERALL SEDS PERFORMANCE FROM 5-31-75 TO 6- 6-75
MISSING DATA = 75
BIAS ERROR = 2.496
RMS ERROR = 4.038
SAMPLE SIZE = 590

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 3.862
RMS ERROR = 3.640
SAMPLE SIZE = 289

U.S. STATIONS ONLY
BIAS ERROR = 1.070
RMS ERROR = 2.242
SAMPLE SIZE = 95

MEXICAN STATIONS ONLY
BIAS ERROR = 5.229
RMS ERROR = 3.407
SAMPLE SIZE = 194

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 3.572
RMS ERROR = 3.407
SAMPLE SIZE = 145

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.154
RMS ERROR = 3.851
SAMPLE SIZE = 144

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.272
RMS ERROR = 1.974
SAMPLE SIZE = 41

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 5.301
RMS ERROR = 3.820
SAMPLE SIZE = 103

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = .189
RMS ERROR = 3.667
SAMPLE SIZE = 117

U.S. STATIONS ONLY
BIAS ERROR = -.473
RMS ERROR = 3.081
SAMPLE SIZE = 83

31 May - 6 June 1975

MEXICAN STATIONS ONLY
BIAS ERROR = 1.805
RMS ERROR = 4.459
SAMPLE SIZE = 34

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = .555
RMS ERROR = 3.674
SAMPLE SIZE = 55

NON-CONTROL STATIONS ONLY
BIAS ERROR = -.135
RMS ERROR = 3.660
SAMPLE SIZE = 62

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.912
RMS ERROR = 4.443
SAMPLE SIZE = 109

U.S. STATIONS ONLY
BIAS ERROR = -.556
RMS ERROR = 3.129
SAMPLE SIZE = 48

MEXICAN STATIONS ONLY
BIAS ERROR = 3.854
RMS ERROR = 4.376
SAMPLE SIZE = 61

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 1.394
RMS ERROR = 3.527
SAMPLE SIZE = 47

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.304
RMS ERROR = 5.020
SAMPLE SIZE = 62

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 1.678
RMS ERROR = 3.384
SAMPLE SIZE = 75

U.S. STATIONS ONLY
BIAS ERROR = .730
RMS ERROR = 2.456
SAMPLE SIZE = 53

31 May - 6 June

MEXICAN STATIONS ONLY
BIAS ERROR = 3.962
RMS ERROR = 4.206
SAMPLE SIZE = 22

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.083
RMS ERROR = 4.185
SAMPLE SIZE = 33

NON-CONTROL STATIONS ONLY
BIAS ERROR = 1.360
RMS ERROR = 2.601
SAMPLE SIZE = 42

OVERALL SEDS PERFORMANCE FROM 6- 7-75 TO 6-13-75
MISSING DATA = 59
BIAS ERROR = 3.806
RMS ERROR = 3.018
SAMPLE SIZE = 606

GROUND TRUTH DATA ONLY

ALL STATIONS
BIAS ERROR = 4.553
RMS ERROR = 3.116
SAMPLE SIZE = 309

U.S. STATIONS ONLY
BIAS ERROR = 2.503
RMS ERROR = 2.432
SAMPLE SIZE = 115

MEXICAN STATIONS ONLY
BIAS ERROR = 5.769
RMS ERROR = 2.830
SAMPLE SIZE = 194

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 4.344
RMS ERROR = 2.591
SAMPLE SIZE = 139

NON-CONTROL STATIONS ONLY
BIAS ERROR = 4.725
RMS ERROR = 3.485
SAMPLE SIZE = 170

U.S. NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.948
RMS ERROR = 3.047
SAMPLE SIZE = 55

MEXICAN NON-CONTROL STATIONS ONLY
BIAS ERROR = 5.575
RMS ERROR = 3.370
SAMPLE SIZE = 115

BOTH RADIOMETRIC USABLE

ALL STATIONS
BIAS ERROR = 2.527
RMS ERROR = 2.511
SAMPLE SIZE = 66

U.S. STATIONS ONLY
BIAS ERROR = 2.250
RMS ERROR = 2.457
SAMPLE SIZE = 30

MEXICAN STATIONS ONLY
BIAS ERROR = 2.758
RMS ERROR = 2.566
SAMPLE SIZE = 36

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.360
RMS ERROR = 2.274
SAMPLE SIZE = 34

NON-CONTROL STATIONS ONLY
BIAS ERROR = 2.705
RMS ERROR = 2.766
SAMPLE SIZE = 32

NIGHT RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.087
RMS ERROR = 2.375
SAMPLE SIZE = 97

U.S. STATIONS ONLY
BIAS ERROR = 2.608
RMS ERROR = 2.623
SAMPLE SIZE = 42

MEXICAN STATIONS ONLY
BIAS ERROR = 3.453
RMS ERROR = 2.118
SAMPLE SIZE = 55

GROUND TRUTH CONTROL STATIONS ONLY
BIAS ERROR = 2.599
RMS ERROR = 2.371
SAMPLE SIZE = 49

NON-CONTROL STATIONS ONLY
BIAS ERROR = 3.585
RMS ERROR = 2.296
SAMPLE SIZE = 48

DAY RADIOMETRIC ONLY

ALL STATIONS
BIAS ERROR = 3.231
RMS ERROR = 2.996
SAMPLE SIZE = 134

U.S. STATIONS ONLY
BIAS ERROR = 2.647
RMS ERROR = 2.923
SAMPLE SIZE = 91

```
MEXICAN STATIONS ONLY
 BIAS ERROR =   4.467
 RMS ERROR =   2.796
 SAMPLE SIZE =    43

GROUND TRUTH CONTROL STATIONS ONLY
 BIAS ERROR =   3.297
 RMS ERROR =   2.507
 SAMPLE SIZE =    58

NON-CONTROL STATIONS ONLY
 BIAS FRROR =   3.180
 RMS ERROR =   3.338
 SAMPLE SIZE =    76
```