JRB-75-201-AA

USE OF SKYLAB EREP DATA IN A SEA SURFACE TEMPERATURE EXPERIMENT

Interim Report

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Prepared for

National Aeronautics and Space Administration
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FOREWORD

The research described herein, which was conducted by JRB Associates - a wholly owned subsidiary of Science Applications, Incorporated, was performed under NASA Contract NAS9-13277. This interim report covers the period from 1 September 1974 to 28 February 1975.

ABSTRACT

This report discusses the status of an experiment to utilize S191 spectrometer data acquired over ocean areas to access the ability of spaceborne infrared multispectral sensing to function as a means of providing improved estimates of sea-surface temperature over that obtainable with a single channel radiometric instrument. All data products from SL-2, -3 and -4 and all support data have been received and critiqued, and a plan for data analysis has been established. The details and rationale for the data analysis plan are presented. Also presented are preliminary results for two test sites.

Use of Skylab EREP Data in a Sea Surface Temperature Experiment

INTRODUCTION

NASA is planning to launch an ocean observation satellite in the near future (Nimbus G) which will contain a two-channel infrared radiometric instrument capable of measuring the sea surface temperature to an accuracy of $\pm$ 1 Kelvin. The initial design of the instrument has been postulated but the spectral response of each of the two channels has not been finalized. It is expected that the results of EREP will influence the spectral response selection. An experiment of particular relevance consists of acquiring S191 infrared spectrometer data ($\sim$ 6 to $\sim$ 15 μm) over ocean areas for which the atmospheric and sea surface conditions and temperatures are known. The measured data will be compared with theoretical predictions and postulated radiometric techniques for measuring sea surface temperatures will be tested. The results are expected to provide an important input to the final selection of the spectral response of each of the two radiometric channels. The status of this experiment is described herein.

EXPERIMENT SUMMARY AND DATA

The candidate test sites scheduled for analysis are given in Table 1. In a previous report (see quarterly report dated September 1974) two additional test sites were scheduled for analysis (i. e., SL-3 pass 16 and SL-3 pass 43). These were for coastal stratus test sites and have been eliminated from consideration because of data problems (see quarterly report dated September 1974 for further justification). For each test site the time, location, support data, and EREP data products received are noted. The present plan for analysis (and the status thereof) of the data for each test site is as follows:

Table 1.

Test Site Data Products

PASS DESCRIPTION	GMT	LATITUDE-LONGITUDE	GROUND TRUTH	NOAA SATELLITE DATA	RADIANCE TAPES	RADIANCE TABS	POST AUTOCAL	HOUSEKEEPING	COMMENTS
MISSION: SL-2 PASS: 5 DAY: 156 DATE: 5 June 73	START: 18:03:05 END: 18:03:35	START: 28N, 95W END: 27N, 94W	AIRBORNE PRT-5 SEA-SURFACE TEMPERATURE. AIRCRAFT-BORNE AIR TEMPERATURE AND DEW POINT DEPRESSION.	NONE AVAILABLE	√	√	√	√	NADIR SCAN. SCATTERED CUMULUS. LWIR RADIANCE DATA NOT AVAILABLE.
MISSION: SL-2 PASS: 8 DAY: 162 DATE: 11 June 73	START: 15:21:44 END: 15:23:03	START: 26N, 89W END: 23N, 85W	AIRBORNE PRT-5 SEA-SURFACE TEMPERATURE. AIRCRAFT-BORNE AIR TEMPERATURE AND DEW POINT DEPRESSION.	ITOS (#2991) VHRR VISIBLE/IR MAPS. ITOS (#2991) SR.	√	√	√	√	NADIR SCAN. SCATTERED CUMULUS.
MISSION: SL-3 PASS: 36 DAY: 255 DATE: 12 Sept. 73	START: 17:08:20 END: 17:09:33	TARGET LOCATION: 37N, 76W	BUCKET TEMPERATURE. NO AIR OR RADIOMETRIC SURFACE TRUTH.	NONE AVAILABLE	√	√	√	√	TRACKED TARGET. VERY HAZY.
MISSION: SL-3 PASS: 46 DAY: 260 DATE: 17 Sept. 73	START: 15:06:54 END: 15:07:00	TARGET LOCATION: 37N, 76W	BUCKET TEMPERATURE. NO AIR OR RADIOMETRIC SURFACE TRUTH.	ITOS (#4219) VHRR VISIBLE/IR MAPS. ITOS (#4219) SR AND VTPR.	√	√	√	√	TRACKED TARGET. SCATTERED CUMULUS
MISSION: SL-4 PASS: 78 DAY: 8 DATE: 8 Jan. 74	START: 16:29:03 END: 16:31:47	START: 19N, 86W END: 27N, 79W TARGET LOCATION: UNKNOWN	AIRBORNE PRT-5 SEA-SURFACE TEMPERATURE. BUCKET TEMPERATURE. RADIOSONDE.	ITOS (#5633) VHRR VISIBLE/IR MAPS. ITOS (#5633) SR AND VTPR.	√	√	√	√	TRACKED TARGET. DAC NOT TURNED ON SO GIMBAL ANGLES DURING DATA TAKE PERIOD ARE UNKNOWN: TARGET LOCATION NOT DETERMINABLE.
MISSION: SL-4 PASS: 79 DAY: 9 DATE: 9 Jan. 74	START: 15:50:23 END: 15:52:59	TARGET LOCATION: 32.5N, 66.3W	NO GROUND OR AIR TRUTH AVAILABLE	ITOS VHRR VISIBLE/IR MAPS	√	√	*	√	TRACKED TARGET. * NO POST AUTOCAL
MISSION: SL-4 PASS: 87 DAY: 21 DATE: 21 Jan. 74	START: 20:10:25 END: 20:13:19	TARGET LOCATION: 24.5N, 82.4W	AIRBORNE PRT-5 SEA-SURFACE TEMPERATURE. BUCKET TEMPERATURE.	ITOS (#5802) VHRR VISIBLE MAP. ITOS (#5802) VHRR IR, SR, AND VTPR.	√	√	√	√	TRACKED TARGET. FIELD-OF-VIEW APPEARED GREENISH-BLUE INDICATING BOTTOM REFLECTIONS.

MISSION: SL-2
PASS: 5
DAY: 156
DATE: 5 June 73

The long wavelength detector temperatures were high during EREP passes 1 through 5 and valid long wavelength responsivities could not be calculated. Consequently, LWIR radiance data are not available for this pass. Therefore, these data cannot be analyzed.

MISSION: SL-2
PASS: 8
DAY: 162
DATE: 11 June 73

The data for this EREP pass is quite comprehensive; surface and air truth plus NOAA satellite support data. The major uncertainty, as indicated by the data acquisition camera (DAC), is possible contamination of the S191 field-of-view by clouds. The processing and analysis plan is to check the instrument calibration and correct the data for responsivity drift errors if necessary. Subsequently predictions and measurement results will be compared. Errors larger than measurement and calibrational uncertainties will be attributed to clouds and the corresponding data will be rejected. This analysis is planned for the next quarter.

MISSION: SL-3
PASS: 36
DAY: 255
DATE: 12 Sept 73

The data for this pass have marginal utility because the surface and air truth data are minimal. No air or radiometric surface truth are available, only bucket temperatures. Also, no satellite data are available. Air

truth data may be obtainable from local weather stations, but would likely not be coordinated closely in time. Because of time and funding limitations these data will not be processed initially, pending the results of data analysis for other more promising missions.

MISSION: SL-3
PASS: 46
DAY: 260
DATE: 17 Sept 73

These data are similar in potential utility as those for pass 36. Ground truth data consists of bucket temperatures only. The data have a further problem in that the field-of-view was probably contaminated by clouds (as indicated by the DAC). As for pass 36, these data will not be processed initially, pending the results of other analyses.

MISSION: SL-4
PASS: 78
DAY: 8
DATE: 8 Jan 74

The data for this pass, by design, are the most comprehensive of all EREP passes. The ground and air truth data consists of radiometric surface temperatures, bucket temperatures, and radiosonde data. Additional support data include ITOS D-G scanning radiometric data and temperature and humidity profiles from the VTPR. A comprehensive analysis of these data should provide more information relative to the satisfaction of experimental objectives than any other EREP pass. The effort will basically include examining the data for responsivity drift errors and correcting them if necessary, and then comparing measurement results with analytical predictions. The first stages of this analysis have been completed and the results are given in the Data Analysis Section.

MISSION: SL-4
PASS: 79
DAY: 09
DATE: 9 Jan 74

The data for this mission were acquired by tracking a water surface area near Bermuda. The area was totally cloud free and from the DAC appeared to occur at a time of high visibility. Unfortunately no ground or air truth data are available for the test site area. Consequently, these data appear to have little utility in satisfying experimental objectives and will, therefore, not be analyzed further.

MISSION: SL-4
PASS: 87
DAY: 21
DATE: 21 Jan 74

As for the data for EREP pass 78, these data are fairly comprehensive. The ground truth consists of both PRT-5 radiometric temperatures and bucket temperatures. Although no radiosonde data are available temperature and humidity data are available from the vertical temperature profile radiometer (VTPR) aboard ITOS. The analysis plan is to check for responsivity drift errors and make corresponding corrections to the data if necessary. Subsequently, analytical predictions and measurement data will be compared and interpreted. Analysis of these data has not yet begun.

DATA ANALYSIS

The main thrust of the analysis to be performed for this study is verification of existing analytical radiative transfer models. The verification procedure will involve inputting measured values of sea-surface temperature, air temperature and humidity into atmospheric radiance models and

calculating the spectral radiance one would expect at the entrance aperature of the S191 spectrometer. These calculated radiances will then be compared with measured values and any discrepancies resolved. Calculated and measured radiances are compared for the Monroe Reservoir, Salem, Illinois (EREP data acquisition on 6 June 1973) in Figure 1. Observe that the general agreement is good, and probably within experimental and analytical predictive uncertainties, with the exception of the spectral region from approximately 8 to 11 μm. Here the predicted values are consistently higher than measured values. This difference may be caused by measurement error, improper treatments in the predictive model, or both. Since such discrepancies can have a significant impact upon spaceborne earth-surface observations, a major remaining task will be to determine if such differences are consistently observed for other test sights and, if so, to identify the basis for such differences.

The Florida Keys test site, EREP pass 78 (data acquisition on 8 January 1974), has been the major subject of analysis thus far because of the comprehensive nature of the support data, which provides for a more definitive analysis. The support data include:

1) PRT-5 sea-surface temperatures acquired at an altitude of 1500 feet.

2) Bucket temperatures.

3) Radiosonde data giving temperature and humidity data to the 300 mb pressure level.

4) ITOS Vertical Temperature Profile Radiometer (VTPR) data giving temperature and humidity data to the 400 mb pressure level.

5) ITOS Very High Resolution Radiometer (VHRR) data giving upwelling radiance at 0.5 km spatial resolution between 10.5 and 12.5 μm.

The initial step in the analysis was to check for responsivity drift errors. This was achieved by computing the average spectral radiance

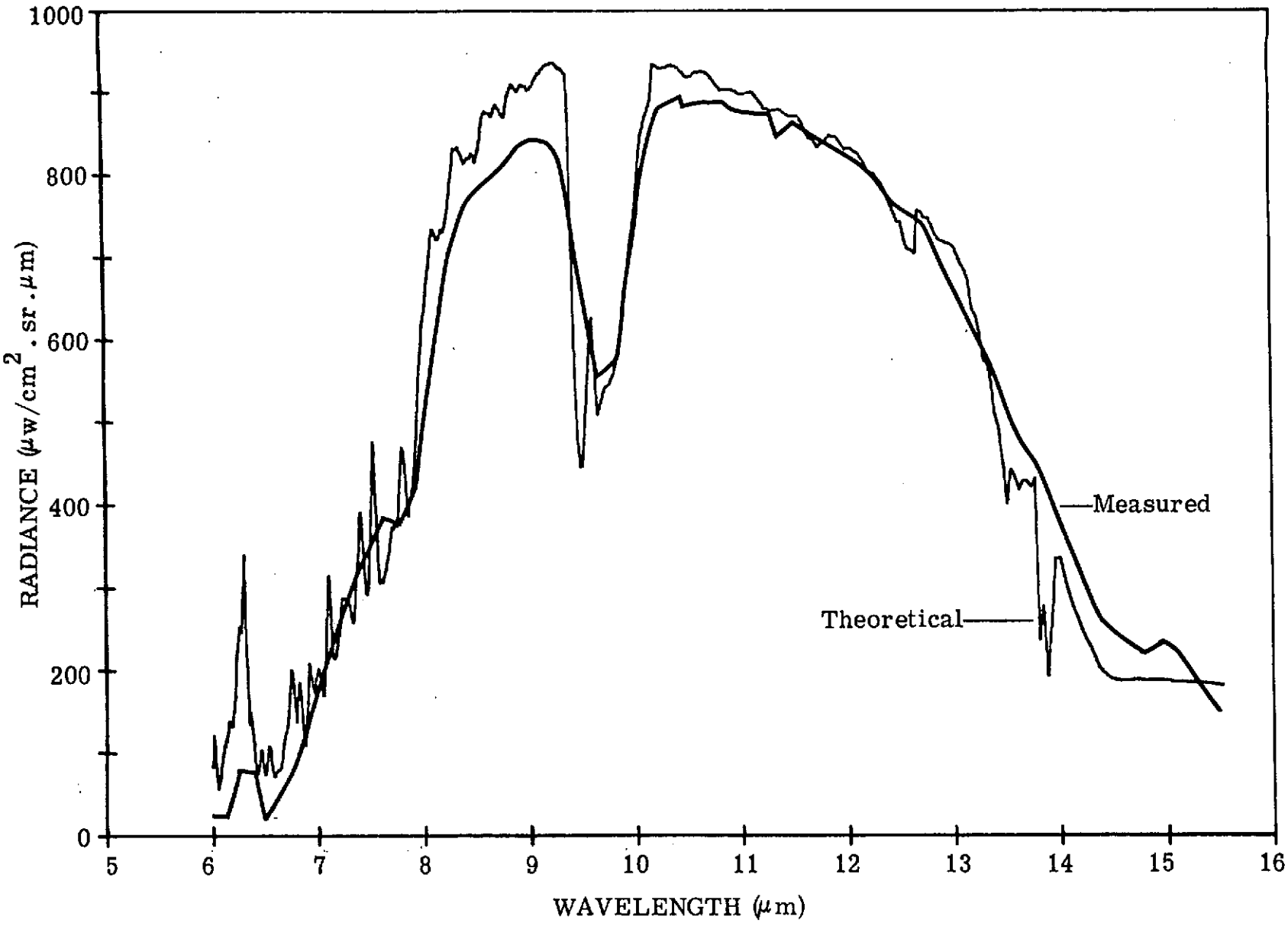

Figure 1. Comparison of Measured and Predicted Spectral Radiance for the Monroe Reservoir, Salem, Illinois, on 6 June 1973. Water Surface Temperature = 298 K.

for 30 sequential scans of the ambient calibration source and comparing the results with a blackbody radiance spectrum evaluated at the temperature of the ambient calibration source, as determined from the housekeeping data. The result is shown in Figure 2. The calibration source temperature at the time of the post autocal sequence was determined to be 291.67 Kelvins. The best fit blackbody curve for the post autocal radiance was determined to be 290.81 Kelvins, 0.86 degrees less. The lapsed time between the pre-pass calibration and the post-pass autocal was 1 hour and 30 minutes and data acquisition occurred 30 minutes after pre-pass calibration. Assuming the total difference is caused by a linear responsivity drift, the correction required is only approximately 0.3 Kelvins. In the context of the present experiment this is a negligible amount.

The next step in the analysis was to prepare the support data for calculation of the radiance at the entrance aperture of the S191. The radiosonde and VTPR data were processed and analyzed and a representative model atmosphere was constructed. The temperature and humidity profiles are shown in Figures 3 and 4, respectively. The actual radiosonde and VTPR data are given in Tables 2 and 3, respectively. The PRT-5 radiometric sea-surface temperatures and the bucket temperatures were obtained by NOAA and are shown in Figure 5. The difference between radiometric and bucket temperatures is not known at the present time.

The remaining step in the analysis is to use the model atmosphere data, and the sea-surface temperature data, and calculate the spectral radiance at the entrance aperture of the S191 for comparison with measured data. This effort is currently in progress.

FUTURE PLANS

The planned effort for the remaining quarter is primarily to perform a comprehensive analysis on the data from EREP passes 78 and 87, and

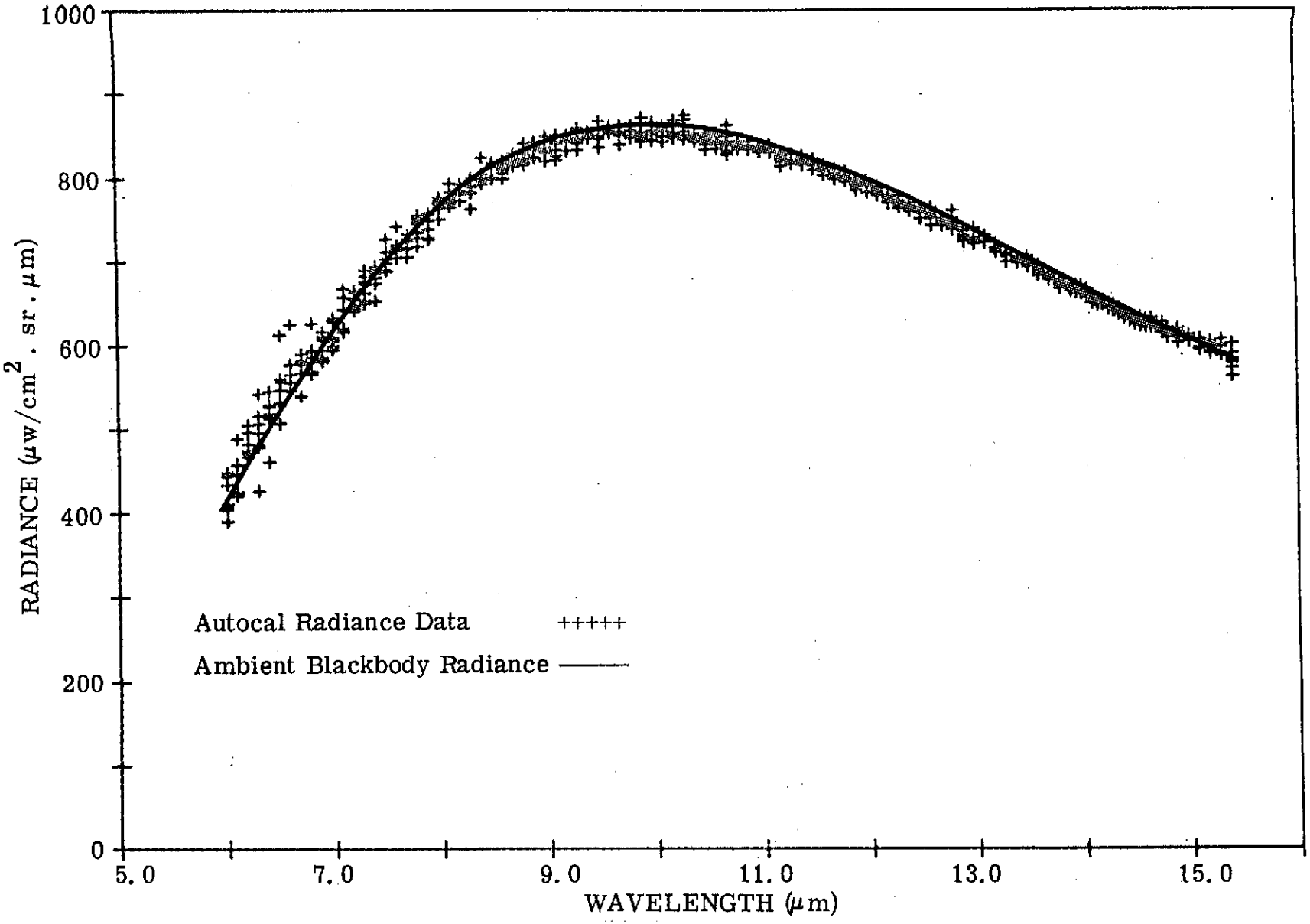

Figure 2. Comparison of Autocal Radiance Data with Ambient Blackbody Radiance for a Blackbody Temperature of 291.67 Kelvins.

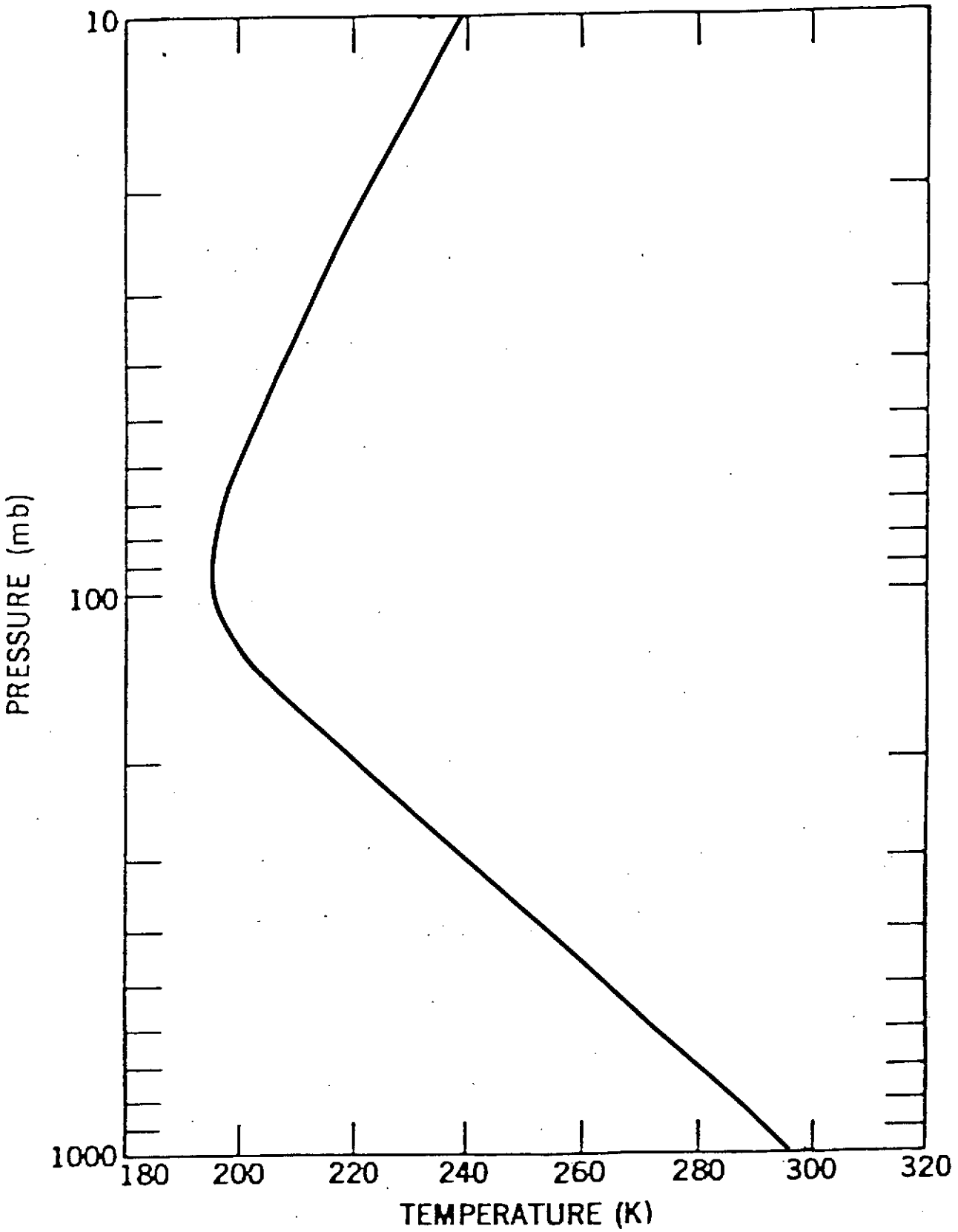

Figure 3. Atmospheric Temperature for Key West on 8 Jan 74.

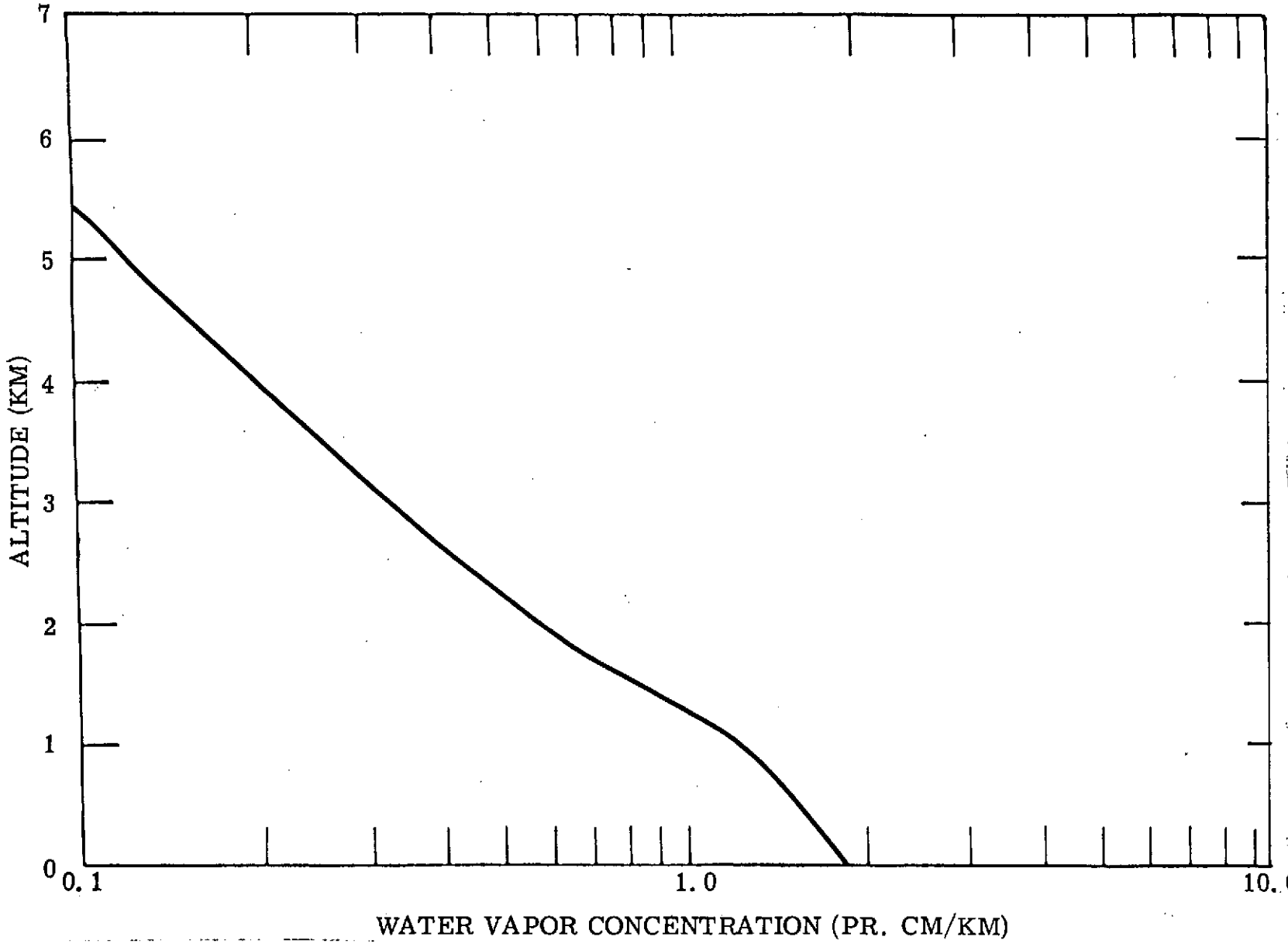

Figure 4. Water Vapor Concentration for Key West on 8 Jan 74.

Table 2.

Radiosonde Data for Key West on 8 Jan 74
Latitude = 24.6N Longitude = 81.7W

H(m)	P(mb)	T(K)	R.H.(%)
0.0	1021.0	298.0	79.0
83.2	1011.0	294.8	82.0
175.4	1000.0	296.2	85.0
1035.9	902.0	290.3	86.0
1342.8	869.0	289.1	63.0
1523.8	850.0	288.3	64.0
1935.9	808.0	286.0	66.0
2026.4	799.0	285.4	34.0
2138.2	788.0	284.4	72.0
2282.4	774.0	283.1	66.0
2641.5	740.0	281.5	72.0
2837.0	722.0	281.7	30.0
3081.5	700.0	281.0	31.0
3413.5	671.0	278.4	55.0
3781.5	640.0	276.5	42.0
4014.3	621.0	276.3	22.0
5216.6	530.0	266.9	21.0
5649.8	500.0	263.8	13.0
6104.6	470.0	255.8	10.0
7553.6	384.0	248.3	14.0
9250.4	300.0	234.1	14.0
10453.8	250.0	224.3	0.0
11159.3	224.0	222.9	0.0
11510.6	212.0	224.3	0.0
11882.5	200.0	222.9	0.0
13719.2	150.0	210.6	0.0
16309.7	100.0	196.1	0.0
18590.3	70.0	197.5	0.0
18966.6	66.0	198.0	0.0
19470.7	61.0	201.7	0.0
19793.3	58.0	200.5	0.0
20250.7	54.0	205.6	0.0
20744.2	50.0	205.4	0.0
21421.8	45.0	208.5	0.0
21714.9	43.0	215.1	0.0
24050.5	30.0	222.0	0.0
25791.3	23.0	226.9	0.0
26712.9	20.0	225.8	0.0
27789.6	17.0	225.2	0.0
28192.6	16.0	225.0	0.0
29326.3	13.5	229.3	0.0

Table 3.

VTPR Data for Key West on 8 Jan 74
Latitude = 23.98N Longitude = 80.78W

P(mb)	T_{air}(K)	T_{dew}(K)	P_{H_2O}(mb)
1000	298.12	294.87	25.96
850	288.35	285.37	14.21
700	279.06	271.77	5.51
500	262.62	252.79	1.21
400	250.90	240.58	0.40
300	236.07	-	-
250	227.39	-	-
200	219.79	-	-
150	212.73	-	-
100	207.04	-	-
70	199.43	-	-
50	206.10	-	-
30	217.36	-	-
20	222.16	-	-
10	229.47	-	-

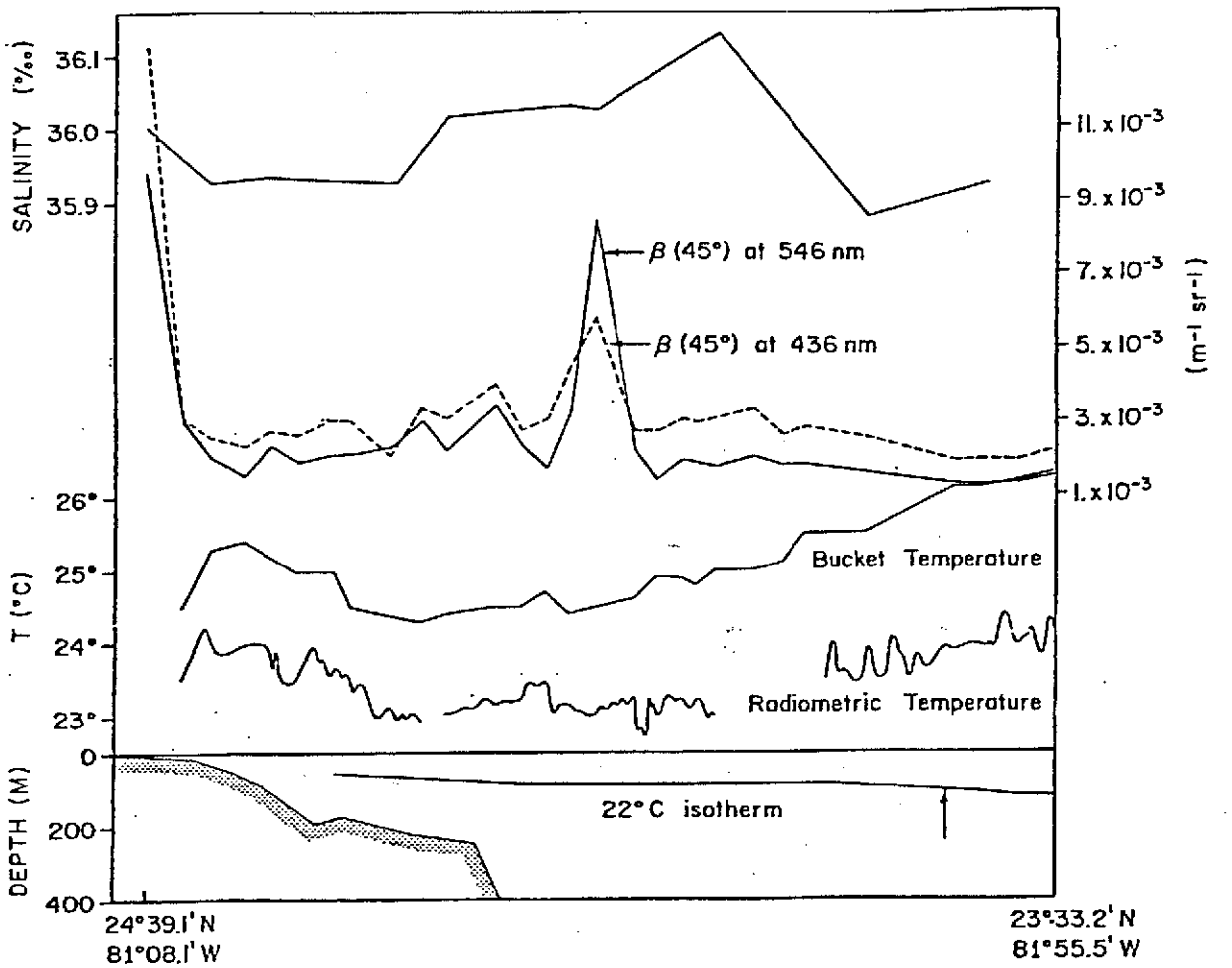

Figure 5. Sea Temperature Data from NOAA for Key West on 8 Jan 74.

analyze the data for other missions as time and funds permit. Passes 78 and 87 are the only passes for which; 1) the support data were of adequate scope and reliability to perform a definitive analysis, and 2) did not have possible field-of-view contamination by scattered cumulus. It is felt that the results of this effort will satisfy the experimental objectives to the extent possible from available EREP S191 data.