Radiation Components of the Energy Budget for Bomex

By

Stephen K. Cox

Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

Colorado State University

Department of Atmospheric Science

Paper No. 208

RADIATION COMPONENTS OF THE ENERGY BUDGET FOR BOMEX

by

Stephen K. Cox

This report was prepared with support from

Environmental Sciences and Services Administration

Grant E 22-55-70(G)

Final Report

Department of Atmospheric Science
Colorado State University
Fort Collins, Colorado

September 1973

Atmospheric Science Paper No. 208

ABSTRACT

A technique to derive large scale radiation divergence patterns by combining direct measurements of radiation, satellite cloud data, surface cloud observations and radiosonde observations is presented.

The technique is applied to the three BOMEX time periods selected for the core experiment analysis and the resulting radiation divergence values for the BOMEX array are given in tabular form.

TABLE OF CONTENTS

FIGURE LEGENDS

I. INTRODUCTION

The Barbados Oceanographic and Meteorological Experiment (BOMEX) was carried out in the western Atlantic Ocean in the period 1 May - 31 July 1969 (Holland 1972, Holland and Rasmussen 1972). One of the prime objectives of this observational program was to determine the vertical and horizontal fluxes of mass, momentum, water and energy in a fixed volume of the tropical atmosphere.

The tabulations of data and the results shown later in this report are the contributions to the energy budget by the radiative components. This paper describes the techniques used to derive the estimates of the shortwave (.3-3 μm) heating and longwave (3 μm - 100 μm) cooling of atmospheric layers. Production of a meaningful short time (∿24 hours) average values of shortwave heating or longwave cooling is complicated by the relatively few direct observations of the radiative components for such a large volume. Infrared irradiance was observed at three ships and the island Barbados; Suomi-Kuhn balloon borne net radiation sondes [Suomi and Kuhn (1958)] were used to measure the individual upward and downward infrared irradiances as a function of height. The frequency of these observations was once per day. These data are summarized by Kuhn and Stearns (1971). The net infrared irradiance at the surface was measured by ships <u>Rainier</u>, <u>Discoverer</u>, and <u>Rockaway</u>, (Figure 1) using a ventilated net radiometer and upward- and downward-looking shortwave pyranometers. Measurements of shortwave heating were obtained from aircraft equipped with pyranometers, however, these observations were made on only twelve days and sampled relatively small areas. Table 1 lists the aircraft missions by the NOAA Research Flight Facility and NCAR during the BOMEX experiment.

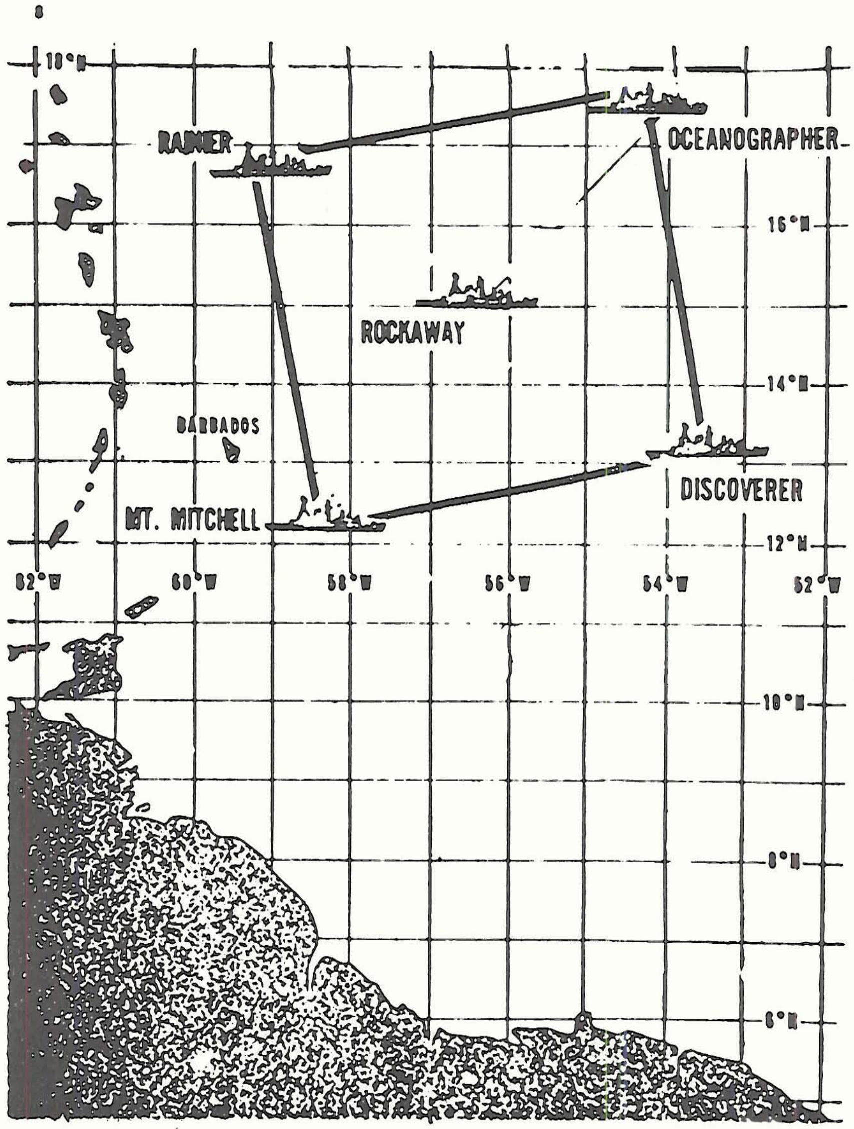


Figure 1. - Fixed ship array during Periods I, II, and III.

TABLE 1

DATE	AIRCRAFT	FLIGHT NUMBER
23 May 1969	NCAR	25
2 June 1969	NCAR	34
3 June 1969	NCAR	35
5 June 1969	NCAR	36
6 June 1969	NCAR	37
8 June 1969	NCAR	39
9 June 1969	NCAR	40
10 June 1969	NCAR	41
12 June 1969	NCAR	42
26 June 1969	NCAR	49
28 June 1969	RFF	
1 July 1969	RFF (2)	
2 July 1969	NCAR	55
2 July 1969	RFF	
2 July 1969	RFF (2)	
3 July 1969	NCAR	56
6 July 1969	NCAR	57
8 July 1969	NCAR	Cal.
9 July 1969	NCAR	61
10 July 1969	RFF	
11 July 1969	NCAR	62
12 July 1969	RFF	
12 July 1969	RFF (2)	
13 July 1969	NCAR	63
14 July 1969	RFF	
18 July 1969	NCAR	67
18 July 1969	RFF	
18 July 1969	RFF (2)	
18 July 1969	RFF (3)	
23 July 1969	RFF	
23 July 1969	RFF (2)	
23 July 1969	RFF (3)	
25 July 1969	NCAR	73

II. STRATEGY

From the direct observations of radiation mentioned above and other peripheral data, estimates of the radiation components for the volume defined by the BOMEX array, and the surface to 400 mb. layer were constructed. It is immediately apparent from the sparsity of direct radiation observations in both space and time that one cannot rely only upon the measurements of the radiation parameters. Cox (1969) and Cox et al (1970) recognized that such a mismatch between climatologically oriented data gathering systems and shorter time and space scale studies of weather phenomena was inevitable. The proposed solution was a method which used an independent variable observed on a time and space scale compatible with the requirements of the study. Such a strategy has been adopted in this study.

The independent variable selected for use in this study is the satellite cloud photograph. In the tropics, where air mass characteristics are relatively uniform, clouds are the primary modulator of both short and longwave radiation. For longwave radiation, clouds may even change the sign of the divergence, causing infrared warming of significantly deep layers of the troposphere (Cox 1969).

That clouds, and not variations in temperature and moisture, are primarily responsible for variations of radiative heating in a tropical atmosphere is clearly shown in Figure 2. Figure 2 is a comparison of the root square deviation (RMS) of computations of infrared cooling made from BOMEX rawinsonde temperature and moisture profiles collected during the period 31 May - 9 June, 1969 and radiationsonde observations of infrared cooling during the same period. The RMS deviation for the calculated case, which contains no clouds, is as much as a factor of

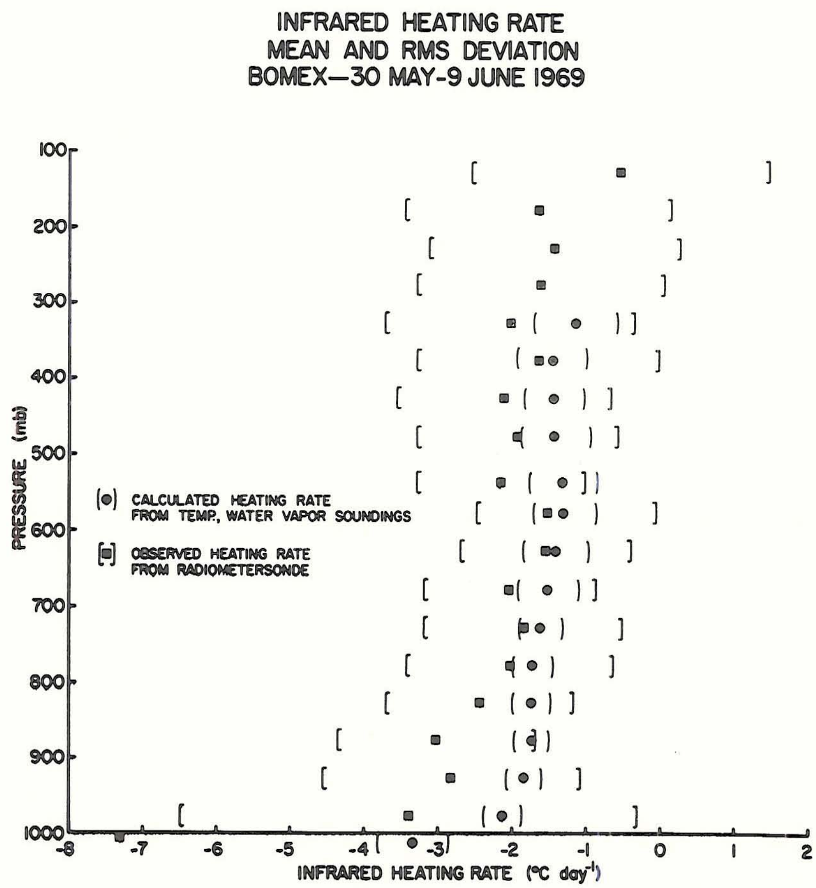


Figure 2. - Comparison of observed and calculated infrared heating rate values for the BOMEX period 30 May - 9 June 1969.

five less than the RMS deviation for the observed cases. The RMS error of the radiometersonde instrument has been given by Johnson and Kuhn (1966) as less than 0.25° C day^{-1}. Therefore, the dominance of clouds in modulating the radiative heating structure of the tropical atmosphere is readily apparent.

Satellite data coverage of the BOMEX data was the best yet attained during any large meteorological field experiment. ESSA and vidicon cameras gave one picture per day each. ATS III with its spin-scan camera gave virtually continuous daytime coverage interrupted only by scheduled ATS satellite communications functions. The NIMBUS III satellite was also available during this period. The most useful experiments from NIMBUS III for our purposes were High Resolution Infrared Radiometer (HRIR), Medium Resolution Infrared Radiometer (MRIS), Satellite Infrared Spectrometer (SIRS) and Infrared Interferometer - Spectrometer (IRIS).

Conventional data utilized in this study were rawinsonde data and surface observations of sky cover.

III. TECHNIQUE

A key component in this study is the determination of the dependence of the divergence of long and shortwave net irradiances on clouds. Figure 3 illustrates schematically the input and desired product of this work. This section describes the technique used to transform the input data into the desired product.

A. Infrared Cooling

All radiationsonde data given by Kuhn and Stearns (1971) were subjected to the following procedure in order to detect the cloud structure at the time of ascent.

1. The change of the upward and downward infrared irradiances as a function of height for each radiationsonde ascent were compared to the divergence calculated for a saturated water vapor atmosphere. If the observed divergence exceeded the calculated by an amount greater than the instrument error (.007 ly min^{-1}) (Kuhn and Johnson 1966), the layer was defined as cloudy. This procedure is described in more detail by Cox (1969b).

2. The accompanying relative humidity profile for each radiationsonde ascent was examined. A threshold of $rh \geq .85$ was selected as evidence of cloud.

3. Surface observations of sky cover were examined; ship precipitation records were also consulted.

4. Gridded satellite photographs of the area before sunset or after sunrise and also HRIR grid print maps from the nighttime NIMBUS III satellite were consulted for evidence of cloud.

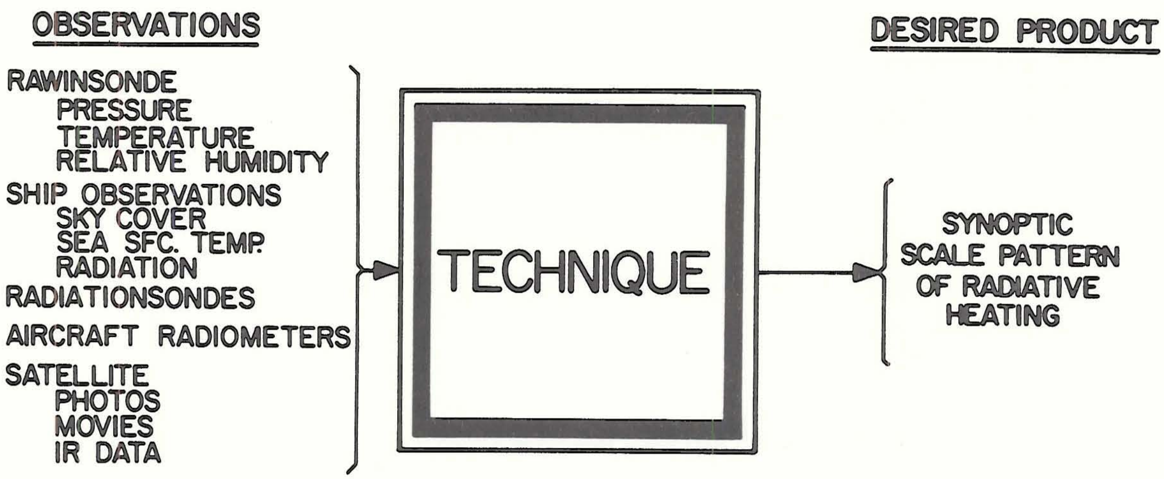


Figure 3. - Schematic representation of technique development problem.

Whenever three of the four above criteria were met, the sounding was put into the appropriate category (Table 2) depending on the cloud altitude; if there were no detectable clouds, the sounding was placed in category III.

TABLE 2

CODE	CATEGORY	PRESSURE AT CLOUD ALTITUDE
I	Low	$P \geq 750$
II	High	$P < 400$
III	Clear	

After categorizing each sounding as explained above, all soundings in a given category were averaged and a simple arithmetic mean cooling rate for each 50 mb. layer was computed. The resulting mean cooling rate profiles are shown in Figure 4.

The physical explanation for the curve representing clear conditions in Figure 4 showing significantly less cooling than the high cloud case, is that the high cloud cases were also often contaminated with scattered or broken clouds in the trade wind layer. The clear condition, by definition, excluded any such contamination and the resulting profile shows less cooling in the 1000-900 mb. layer.

B. Shortwave Heating

Analagous to the infrared cooling, model shortwave heating profiles were constructed for specific cloud conditions. The results of Roach (1961) were used to estimate the clear shortwave warming distribution with respect to height. These values were then biased by approximately 6% for pressure levels $\geq$ 600 mb. in order to agree with the results of Cox et al (1973). The in-cloud shortwave heating estimates were derived using the method described by Korb and Möller (1962). Figure 5 shows the profiles of shortwave heating used.

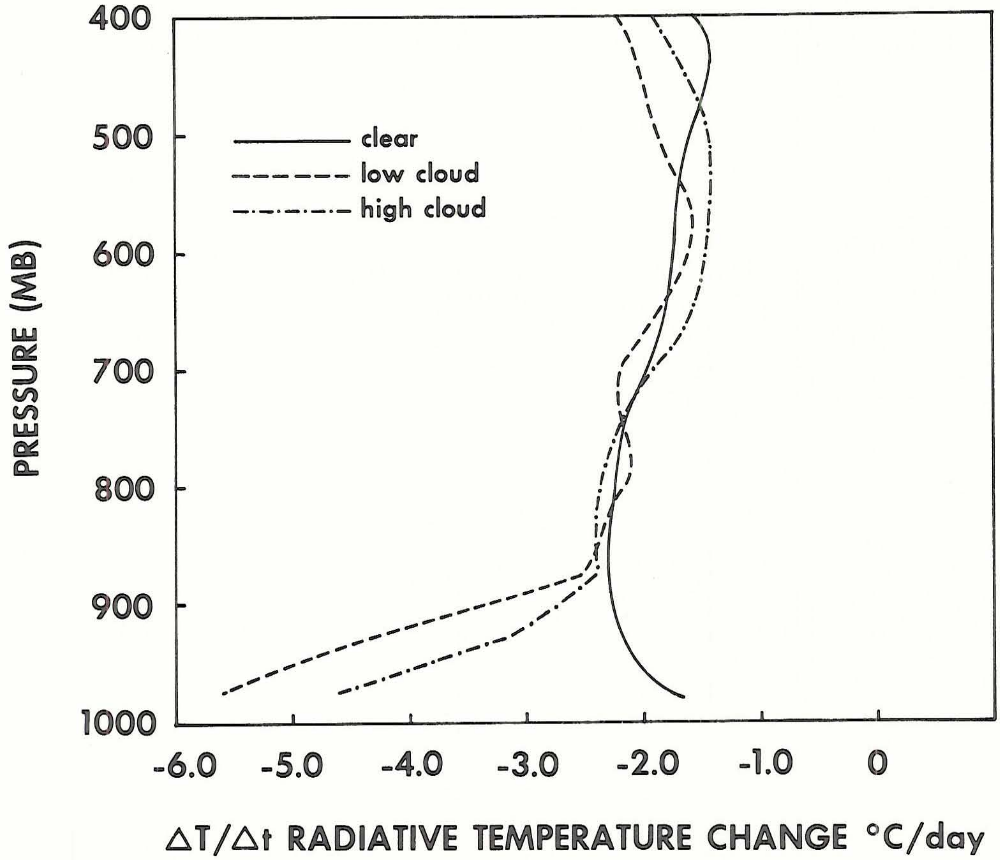


Figure 4. - Composite infrared radiative temperature change profiles for the three cloud conditions, clear, high cloud, and low cloud.

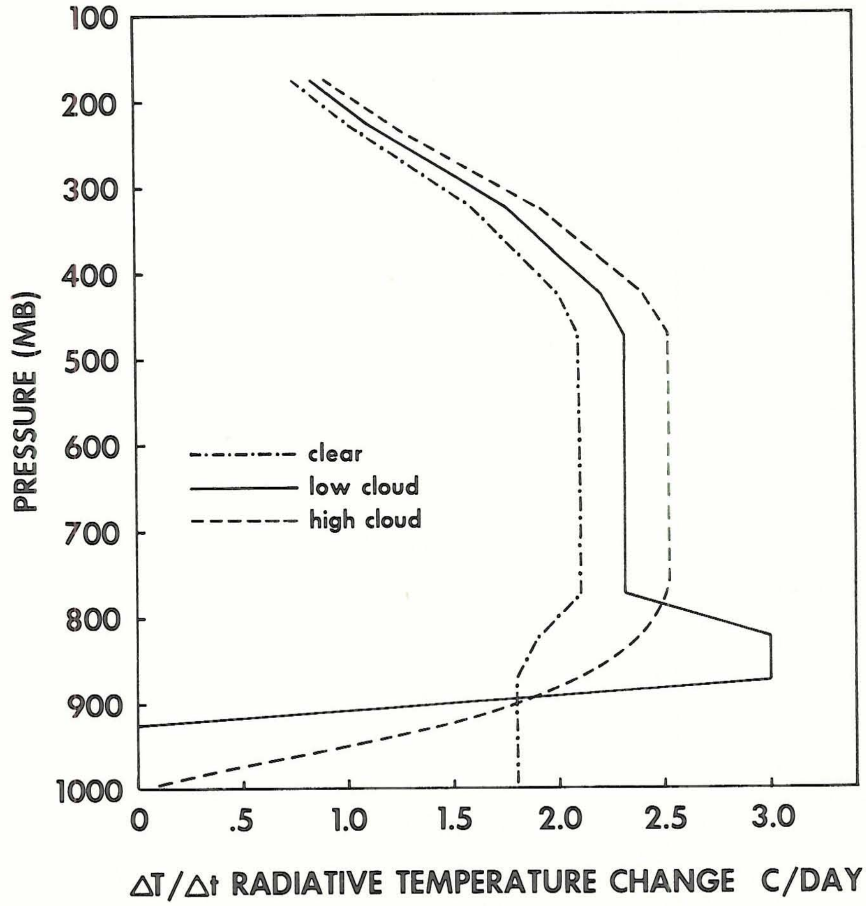


Figure 5. - Composite daily integrated shortwave heating profiles for the three cloud conditions, clear, high cloud and low cloud.

C. Areal Distribution of Sky Cover

Satellite observations of clouds inherently contain several problems. Those most acutely affecting our problem are the resolution limit of satellite images, dependence on solar geometry cloud appearance and cloud height determination. We shall discuss these three problem areas in sequence.

The ATS III satellite spin-scan camera has a nominal resolution at the sub-satellite point of 2.2 nautical miles. Since the horizontal extent of many maritime trade cumulus clouds is less than 2.2 n.m., these clouds do not appear as distinct white spots on satellite images but instead, tend to raise the mean brightness level of the area. If one establishes as a criterion for clouds a distinct "white spot", he will tend to underestimate the cloud amount. However, if one selects a scheme which recognized relatively large areas of slightly enhanced mean brightness as being cloud cover, the amount of cloud cover will be over-estimated. In this study, only clearly distinguished "white spots" were interpreted from satellite images as clouds. As a result, the cloud amounts deduced from the satellite data were consistently and significantly lower than the surface reports. While one must not overlook the possibility that the surface estimates are too large (Young, 1967) the limiting definition of cloud stated above is primarily responsible for the underestimate in this study.

Figures 6 and 7 show a comparison of surface-observed cloud cover taken from ship reports in BOMEX and the satellite-deduced cloud cover for the same times. These data are from a three month period, May, June, and July 1969. Since the satellite data offer the only temporally continuous and spatially complete representation of cloud data for the BOMEX array, a linear correction factor depicted by the dashed line was adopted to normalize the satellite-deduced cloud cover to surface

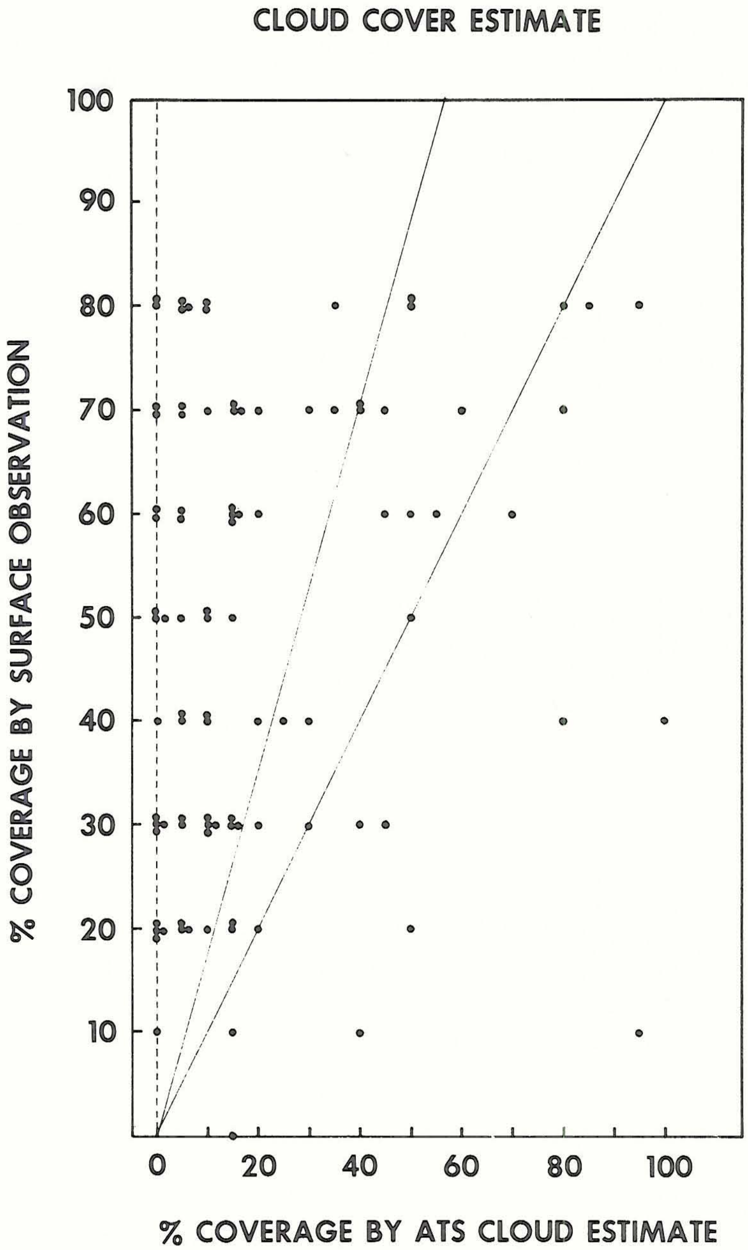


Figure 6. - Comparison of surface cloud cover estimate and satellite cloud cover determination for 0900 LST.

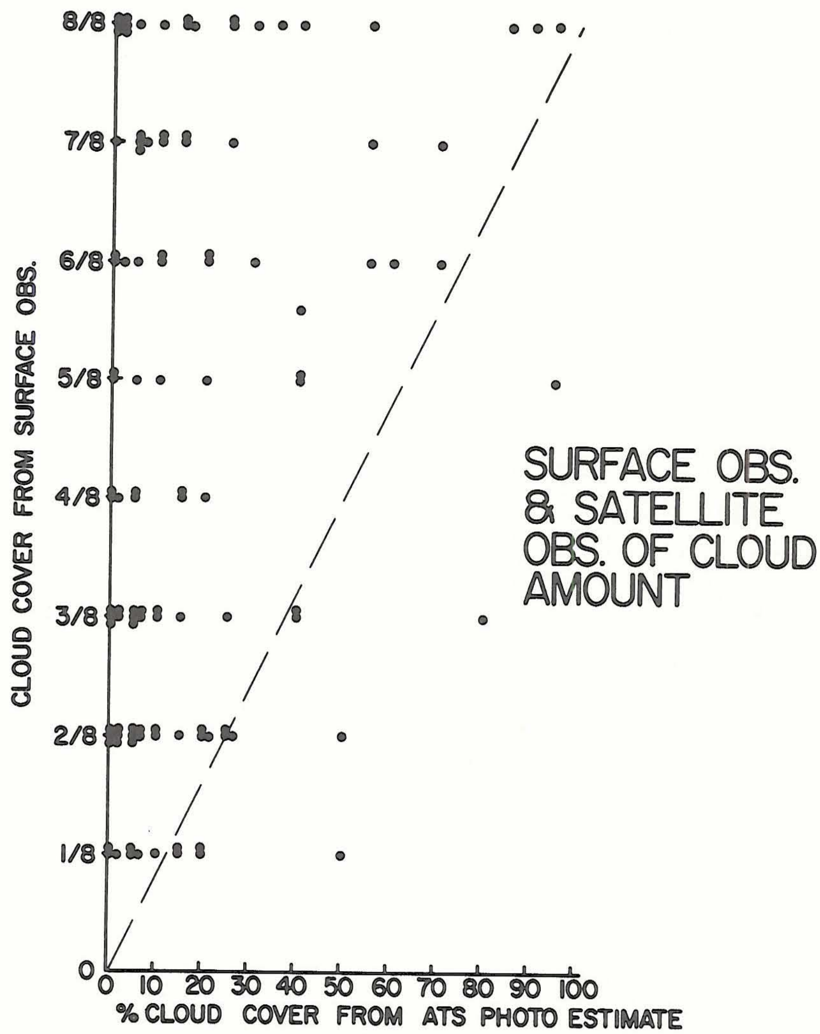


Figure 7. - Comparison of surface cloud cover estimate and satellite cloud cover determination for 1200 LST.

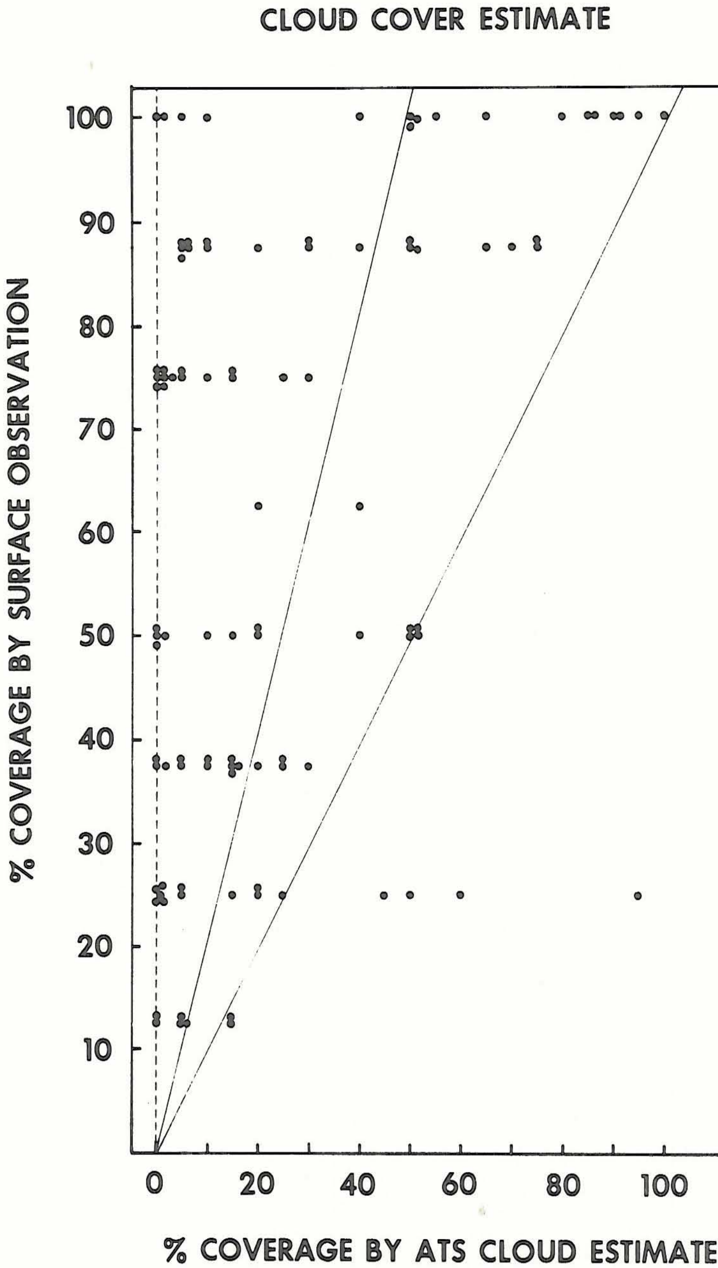


Figure 8. - Comparison of surface cloud cover estimate and satellite cloud cover determination for 1500 LST.

observations. Actual cloud cover was assumed to be the product of the satellite-deduced cover and the correction factor F_c. If this product were to exceed 1.0, the cloud amount was set equal to 1.0.

The appearance of a cloud on a satellite image is strongly dependent upon the sun-cloud-satellite geometry. This is due to the angular dependence of the cloud reflectivity. Acknowledgement of this uncertainty led to the decision not to use the magnitudes of the cloud brightness as an indication of either cloud type or cloud height. This effect also accounts for the differences between the dashed, normalization lines on Figures

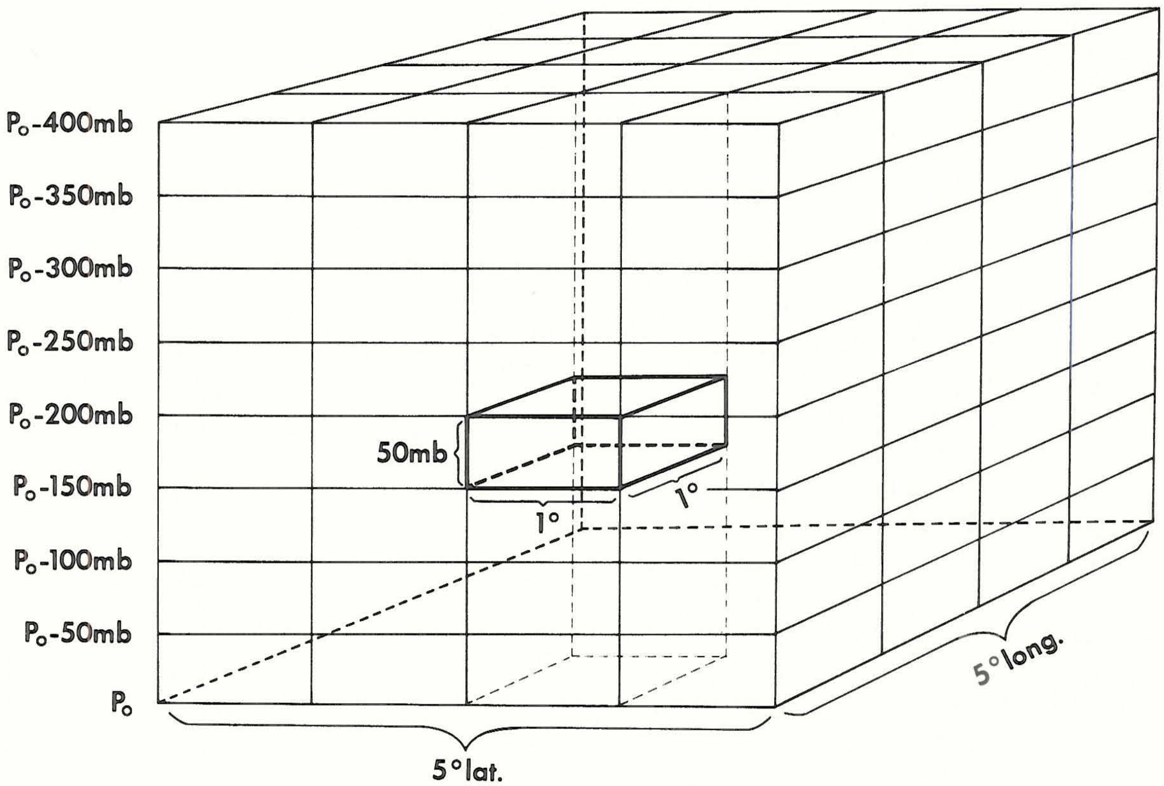
In the absence of infrared satellite observations, the problem of deducing cloud height from satellite data becomes qualitative and often the result of indirect reasoning using parameters such as brightness, movement, proximity to other clouds and the synoptic pressure analysis. Instead of relying on indirect reasoning, ship observations of low and total cloud cover were averaged for each ship over a three hour period centered on the time of the satellite photograph.

$$L = \frac{1}{3} \sum \frac{\text{(hourly ship observations of low cloud amount)}}{\text{(hourly ship observations of total cloud amount)}} \qquad (1)$$

A partitioning factor, L, defined by Equation (1) was used to partition the clouds into low and high categories. Since this technique was intended to apply to undisturbed weather conditions, low clouds and high clouds were assumed to be the dominant cloud features affecting the radiative energy exchanges. This average vertical partitioning of clouds was then applied to the corrected areal cloud cover deduced from the ATS photographs in the proximity of the appropriate ships.

The BOMEX array was divided into sixteen subareas of equal size (Figure 8). For each of these subareas, the amount of cloud was estimated from ATS satellite photos three times each day. Nimbus III HRIR data were used when available for a single nighttime cloud determination. After adjusting the satellite-observed cloud amounts and partitioning the amount as a function of height as explained above, models of radiative convergence and divergence (Figure 3) were combined proportionate to the cloud amount of a given height regime. The profiles used have a maximum vertical resolution of 50 mb. Fortunately, BOMEX objectives were principally to study "undisturbed weather" so the periods of interest did not contain complex cloud patterns.

Figure 9 is an illustration of the surface to 900 mb. net radiative heating rate for June 6, 1969 as it was derived from the above techniques. The radiative heating rate contours have been displaced northward from their actual position over the BOMEX array so that the cloud pattern is not obscurred.



BOMEX RADIATION GRID

Figure 9. - Spatial grid used in determining cloud cover distribution.

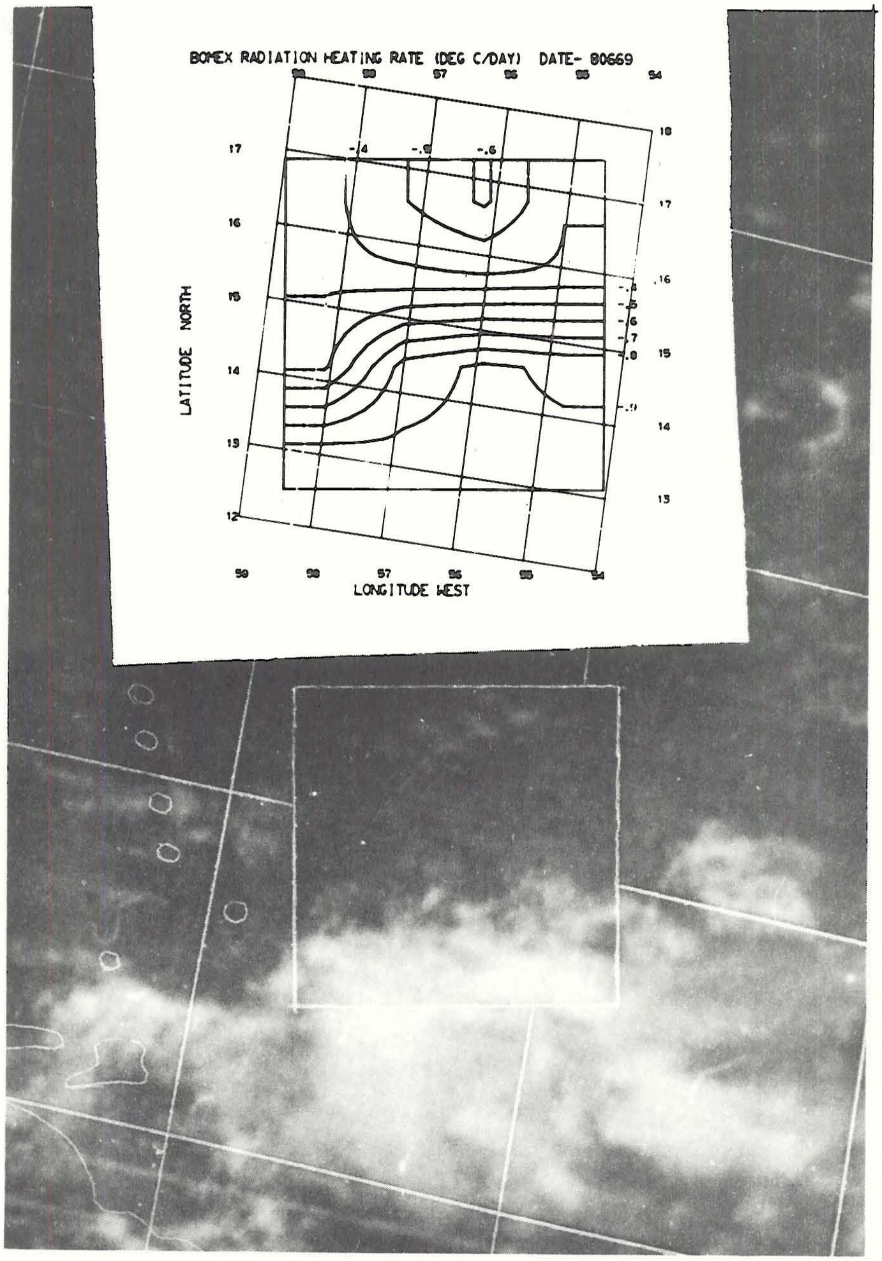


Figure 10. - Illustration of radiative heating rate depictions derived for BOMEX array superimposed on a satellite photograph of the BOMEX array.

IV. RADIATIVE HEATING DATA TABULATIONS

This section presents the mean radiative heating for 50 mb. layers for the entire BOMEX array. Similar values are available for each of the sixteen subareas within the array; the values in the following tables are simple arithmetic means of the subarea values for each time.

Radiative heating determinations were made three times per day: at approximately 0900 LST, 1200 LST and 1500 LST. Comparison of available night HRIR/MRIR cloud cover determinations with day time cloud cover showed no advantage to making a separate nighttime infrared cooling determination. The nighttime value of infrared cooling was, therefore, assumed to be the same as the mean of the daytime values.

DATE: May 31, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1015	965	915	865	815	765	715	665	615	565	515	465	415
0900 LST													
IR Cooling Deg C/day	-3.54	-2.99	-2.59	-2.25	-1.71	-2.21	-1.81	-1.77	-1.72	-1.61	-1.74	-1.61	-1.86
SW Warming Deg C/HR	.02	.02	.04	.04	.05	.06	.06	.06	.06	.06	.06	.06	.06
1200 LST													
IR Cooling Deg C/day	-3.62	-3.08	-.260	-2.24	-1.69	-2.24	-1.84	-1.79	-1.72	-1.61	-1.78	-1.61	-1.88
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
1500 LST													
IR cooling Deg C/day	-3.80	-3.21	-2.60	-2.24	-1.72	-2.27	-1.88	-1.79	-1.72	-1.60	-1.82	-1.63	-1.90
SW Warming Deg C/HR	.03	.03	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.08
DAY AVG													
IR Cooling Deg C/day	-3.65	-3.09	-2.59	-2.24	-1.71	-2.24	-1.84	-1.78	-1.72	-1.61	-1.78	-1.62	-1.88
SW Warming Deg c/day	.28	.29	.71	.73	.81	.84	.84	.84	.84	.85	.85	.83	.77
TOTAL SW + IR Deg C/day	-3.37	-2.80	-1.88	-1.52	-.90	-1.40	-1.00	-.94	-.88	-.76	-.93	-.79	-1.11

DATE: June 1, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1013	963	913	863	813	763	713	663	613	563	513	463	413
0900 LST IR Cooling Deg C/day	-3.60	-3.07	-2.59	-2.24	-1.70	-2.24	-1.83	-1.78	-1.72	-1.61	-1.77	-1.61	-1.88
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
1200 LST IR Cooling Deg C/day	-3.05	-2.87	-2.66	-2.19	-1.48	-2.24	-1.82	-1.87	-1.72	-1.65	-1.75	-1.50	-1.85
SW Warming Deg C/HR	.03	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
1500 LST IR Cooling Deg C/day	-3.69	-2.96	-2.55	-2.28	-1.82	-2.18	-1.78	-1.71	-1.73	-1.60	-1.70	-1.66	-1.85
SW Warming Deg C/HR	.03	.03	.05	.05	.10	.10	.10	.10	.10	.10	.10	.09	.08
DAY AVG IR Cooling Deg C/day	-3.45	-2.97	-2.60	-2.24	-1.67	-2.22	-1.81	-1.79	-1.72	-1.62	-1.74	-1.59	-1.86
SW Warming Deg C/day	.30	.31	.61	.62	.82	.84	.84	.85	.85	.85	.85	.83	.77
TOTAL SW + IR Deg C/day	-3.15	-2.66	-1.99	-1.62	-.85	-1.38	-.97	-.94	-.88	-.77	-.89	-.76	-1.09

DATE: June 2, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1013	963	913	863	813	763	713	663	613	563	513	463	413
0900 LST IR Cooling Deg C/day	-3.26	-2.95	-2.63	-2.21	-1.57	-2.24	-1.82	-1.84	-1.72	-1.64	-1.76	-1.55	-1.86
SW Warming Deg C/HR	.02	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
1200 LST IR Cooling Deg C/day	-3.22	-3.00	-2.66	-2.19	-1.51	-2.27	-1.85	-1.87	-1.72	-1.64	-1.79	-1.52	-1.87
SW Warming Deg C/HR	.02	.03	.06	.06	.05	.06	.06	.06	.06	.06	.06	.06	.05
1500 LST IR Cooling Deg C/day	-3.56	-3.14	-2.63	-2.22	-1.62	-2.28	-1.87	-1.83	-1.72	-1.62	-1.81	-1.59	-1.89
SW Warming Deg C/HR	.04	.04	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.08
DAY AVG IR Cooling Deg C/day	-3.35	-3.03	-2.64	-2.21	-1.56	-2.26	-1.85	-1.84	-1.72	-1.63	-1.79	-1.55	-1.88
SW Warming Deg C/day	.35	.36	.80	.82	.79	.82	.82	.82	.83	.83	.83	.81	.75
TOTAL SW + IR Dec C/day	-3.00	-2.67	-1.84	-1.39	-.77	-1.44	-1.03	-1.02	-.89	-.80	-.95	-.74	-1.12

DATE: June 3, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1015	965	915	865	815	765	715	665	615	565	515	465	415
1606 LST IR Cooling Deg C/day	-2.84	-2.73	-2.66	-2.19	-1.46	-2.21	-1.78	-1.87	-1.72	-1.66	-1.71	-1.48	-1.83
SW Warming Deg C/HR	.05	.05	.07	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
2016 LST IR Cooling Deg C/day	-2.59	-2.61	-2.67	-2.18	-1.39	-2.19	-1.76	-1.90	-1.72	-1.68	-1.68	-1.44	-1.81
SW Warming Deg C/HR	.03	.03	.04	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
DAY AVG IR cooling Deg C/day	-2.71	02.67	-2.66	-2.19	-1.42	-2.20	-1.77	-1.88	-1.72	-1.67	-1.69	-1.46	-1.82
SW Warming Deg C/day	.49	.50	.71	.74	.86	.88	.89	.89	.89	.89	.89	.87	.79
TOTAL SW+IR Deg C/day	-2.22	-2.17	-1.95	-1.45	-.56	-1.32	-.88	-1.00	-.83	-.78	-.80	-.60	-1.03

DATE: June 4, 1969 BOMEX RADIATION EXPERIMENT

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1257 LST IR Cooling Deg C/day	-2.96	-2.80	-2.65	-2.20	-1.49	-2.22	-1.79	-1.86	-1.72	-1.66	-1.72	-1.50	-1.84
SW Warming Deg C/HR	.03	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
1556 LST IR Cooling Deg C/day	-3.40	-2.99	-2.62	-2.23	-1.62	-2.24	-1.83	-1.81	-1.72	-1.63	-1.76	-1.57	-1.87
SW Warming Deg C/HR	.04	.04	.08	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
2021 LST IR Cooling Deg C/day	-3.09	-2.84	-2.64	-2.21	-1.54	-2.22	-1.80	-1.84	-1.72	-1.65	-1.72	-1.52	-1.84
SW Warming Deg C/HR	.03	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-3.15	-2.87	-2.63	-2.21	-1.55	-2.22	-1.81	-1.84	-1.72	-1.64	-1.73	-1.53	-1.85
SW Warming Deg C/day	.37	.38	.69	.70	.80	.83	.83	.83	.83	.83	.84	.82	.76
TOTAL SW + IR Deg C/day	-2.78	-2.49	-1.94	-1.51	-.75	-1.40	-.98	-1.01	-.89	-.81	-.90	-.71	-1.09

DATE: June 5, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1255 LST													
IR Cooling Deg C/day	-4.52	-3.51	-2.53	-2.29	-1.95	-2.29	-1.92	-1.69	-1.73	-1.55	-1.87	-1.76	-1.94
SW Warming Deg C/HR	.01	.01	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
1607 LST													
IR Cooling Deg C/day	-4.57	-3.53	-2.53	-2.30	-1.97	-2.30	-1.92	-1.69	-1.73	-1.55	-1.87	-1.77	-1.94
SW Warming Deg C/HR	.02	.02	.08	.09	.10	.10	.10	.10	.10	.10	.10	.09	.08
DAY AVG													
IR Cooling Deg C/day	-4.55	-3.52	-2.53	-2.29	-1.96	-2.29	-1.92	-1.69	-1.73	-1.55	-1.87	-1.76	-1.94
SW Warming Deg C/HR	.16	.17	.84	.85	.91	.94	.94	.94	.94	.94	.94	.92	.84
TOTAL SW + IR' Deg C/day	-4.39	-3.35	-1.69	-1.45	-1.05	-1.36	-.99	-.75	-.79	-.61	-.93	-.85	-1.10

DATE: June 6, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1614 LST IR Cooling Deg C/day	-3.08	-2.87	-2.65	-2.20	-1.51	-2.23	-1.81	-1.86	-1.72	-1.65	-1.74	-1.51	-1.85
SW Warming Deg C/HR	.05	.05	.08	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
DAY AVG IR Cooling Deg C/day	-3.08	-2.87	-2.65	-2.20	-1.51	-2.23	-1.81	-1.86	-1.72	-1.65	-1.74	-1.51	-1.85
SW Warming Deg C/HR	.56	.56	.96	1.00	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	.94
TOTAL SW + IR Dec C/day	-2.51	-2.31	-1.68	-1.20	-.41	-1.13	-.71	-.76	-.62	-.55	-.64	-.47	-.91

DATE: June 7, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1259 LST IR Cooling Deg C/day	-2.18	-2.43	-2.71	-2.15	-1.26	-2.18	-1.73	-1.94	-1.72	-1.71	-1.64	-1.37	-1.79
SW Warming Deg C/HR	.04	.04	.04	.04	.05	.06	.06	.06	.06	.06	.06	.06	.05
1557 LST IR Cooling Deg C/day	-2.26	-2.51	-2.71	-2.15	-1.25	-2.20	-1.75	-1.95	-1.72	-1.71	-1.67	-1.37	-1.80
SW Warming Deg C/HR	.06	.06	.08	.08	.09	.09	.09	.09	.09	.09	.09	.08	.08
2022 LST IR Cooling Deg C/day	-1.83	-2.30	-2.74	-2.12	-1.13	-2.18	-1.72	-2.00	-1.72	-1.73	01.63	-1.30	-1.77
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-2.09	-2.41	-2.72	-2.14	-1.21	-2.18	-1.73	-1.96	-1.72	-1.72	-1.65	-1.35	-1.79
SW Warming Deg C/HR	.56	.58	.67	.69	.77	.79	.79	.80	.80	.80	.80	.79	.73
TOTAL SW + IR Deg C/day	-1.53	-1.83	-2.05	-1.45	-.45	-1.39	-.94	-1.17	-.92	-.92	-.84	-.56	-1.06

DATE: June 8, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1258 LST IR Cooling Deg C/day	-3.54	-3.08	-2.61	-2.23	-1.65	-2.26	-1.85	-1.81	-1.72	-1.62	-1.79	-1.59	-1.88
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
1601 LST IR Cooling Deg C/day	-3.42	-2.98	-2.61	-2.23	-1.64	-2.23	-1.82	-1.80	-1.72	-1.62	-1.75	-1.58	-1.86
SW Warming Deg C/HR	.04	.04	.07	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
2037 LST IR Cooling Deg C/day	-3.38	-3.04	-2.63	-2.21	-1.58	-2.26	-1.85	-1.84	-1.72	-1.63	-1.79	-1.56	-1.88
SW Warming Deg C/HR	.02	.03	.06	.06	.05	.06	.06	.06	.06	.06	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-3.45	-3.03	-2.62	-2.22	-1.62	-2.25	-1.84	-1.82	-1.72	-1.62	-1.77	-1.58	-1.87
SW Warming Deg C/day	.34	.35	.73	.75	.80	.83	.83	.83	.83	.84	.84	.82	.76
TOTAL SW + IR Deg C/day	-3.11	-2.68	-1.89	-1.48	-.82	-1.42	-1.01	-.98	-.89	-.79	-.93	-.76	-1.11

DATE : June 9, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1255 LST IR Cooling Deg C/day	-2.56	-2.66	-2.69	-2.16	-1.34	-2.22	-1.78	-1.93	-1.72	-1.68	-1.71	-1.42	-1.82
SW Warming Deg C/HR	.03	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
1555 LST IR Cooling Deg C/day	-2.30	-2.53	-2.71	-2.15	-1.26	-2.21	-1.76	-1.95	-1.72	-1.70	-1.68	-1.38	-1.81
SW Warming Deg C/HR	.06	.06	.08	.08	.09	.09	.09	.09	.09	.09	.09	.08	.08
2112 LST IR Cooling Deg C/day	-2.50	-2.61	-2.69	-2.17	-1.34	-2.21	-1.77	-1.92	-1.72	-1.69	-1.69	-1.42	-1.82
SW Warming Deg C/HR	.03	.03	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-2.45	-2.60	-2.70	-2.16	-1.31	-2.21	-1.77	-1.93	-1.72	-1.69	-1.69	-1.41	-1.82
SW Warming Deg C/day	.51	.53	.72	.74	.77	.80	.80	.80	.80	.81	.81	.79	.73
TOTAL SW + IR Deg C/day	-1.94	-2.07	-1.98	-1.42	-.54	-1.41	-.97	-1.13	-.91	-.89	-.89	-.62	-1.08

DATE: May 10, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1015	965	915	865	815	765	715	665	615	565	515	465	415
1553 LST IR Cooling Deg C/day	-4.10	-3.25	-2.54	-2.28	-1.88	-2.24	-1.86	-1.71	-1.73	-1.58	-1.79	-1.71	-1.90
SW Warming Deg C/HR	.02	.02	.07	.07	.10	.10	.10	.10	.10	.10	.10	.09	.08
2012 LST IR Cooling Deg C/day	-4.36	-3.30	-2.50	-2.32	-2.00	-2.22	-1.84	-1.65	-1.73	-1.56	-1.78	-1.76	-1.90
SW Warming Deg C/HR	.01	.01	.04	.04	.06	.06	.06	.06	.06	.06	.06	.06	.06
DAY AVG IR Cooling Deg C/day	-4.23	-3.28	-2.52	-2.30	-1.94	-2.23	-1.85	-1.68	-1.73	-1.57	-1.79	-1.74	-1.90
SW Warming Deg C/day	.21	.22	.66	.67	.92	.94	.94	.94	.94	.95	.95	.92	.84
TOTAL SW + IR Deg C/day	-4.02	-3.06	-1.86	-1.63	-1.02	-1.29	-.91	-.74	-.78	-.62	-.84	-.81	-1.05

DATE: May 11, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1657 LST IR Cooling Deg C/day	-3.53	-2.92	-2.56	-2.27	-1.76	-2.18	-1.77	-1.74	-1.73	-1.61	-1.70	-1.63	-1.85
SW Warming Deg C/HR	.03	.03	.06	.06	.10	.10	.10	.10	.10	.10	.10	.09	.08
2017 LST IR Cooling Deg C/day	-4.34	-3.43	-2.55	-2.28	-1.90	-2.29	-1.91	-1.72	-1.72	-1.56	-1.85	-1.73	-1.93
SW Warming Deg C/HR	.01	.01	.05	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06
DAY AVG IR Cooling Deg C/day	-3.93	-3.17	-2.56	-2.27	-1.83	-2.23	-1.84	-1.73	-1.73	-1.59	-1.78	-1.68	-1.89
SW Warming Deg C/day	.28	.29	.66	.67	.91	.93	.93	.93	.93	.93	.94	.91	.83
TOTAL SW + IR Deg C/day	-3.65	-2.88	-1.90	-1.60	-.92	-1.31	-.91	-.80	-.79	-.65	-.84	-.77	-1.05

DATE: May 12, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1555 LST													
IR Cooling Deg C/day	-3.01	-2.83	-2.65	-2.20	-1.49	-2.23	-1.80	-1.86	-1.72	-1.65	-1.73	-1.51	-1.85
SW Warming Deg C/HR	.05	.05	.08	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
DAY AVG													
IR Cooling Deg C/day	-3.01	-2.83	-2.65	-2.20	-1.49	-2.23	-1.80	-1.86	-1.72	-1.65	-1.73	-1.51	-1.85
SW Warming Deg C/day	.58	.58	.94	.98	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	.94
TOTAL SW + IR Deg C/day	-2.43	-2.26	-1.71	-1.22	-.39	-1.13	-.70	-.76	-.62	-.55	-.63	-.46	-.90

DATE: May 13, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1600 LST IR Cooling Deg C/day	-3.30	-3.03	-2.65	-2.20	-1.53	-2.27	-1.86	-1.86	-1.72	-1.64	-1.79	-1.54	-1.88
SW Warming Deg C/HR	.04	.04	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.08
DAY AVG IR Cooling Deg C/day	-3.30	-3.03	-2.65	-2.20	-1.53	-2.27	-1.86	-1.86	-1.72	-1.64	-1.79	-1.54	-1.88
SW Warming Deg C/day	.54	.54	1.10	1.12	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.05	.94
TOTAL SW + IR Deg C/day	-2.76	-2.49	-1.55	-1.07	-.44	-1.17	-.76	-.76	-.62	-.54	-.70	-.49	-.94

DATE: June 22, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1251 LST													
IR Cooling Deg C/day	-2.27	-2.50	-2.71	-2.15	-1.27	-2.19	-1.75	-1.94	-1.72	-1.70	-1.66	-1.38	-1.80
SW Warming Deg C/HR	.03	.04	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.05
1606 LST													
IR Cooling Deg C/day	-2.07	-2.41	-2.72	-2.14	-1.21	-2.19	-1.73	-1.97	-1.72	-1.72	-1.65	-1.35	-1.79
SW Warming Deg C/HR	.07	.07	.08	.08	.09	.09	.09	.09	.09	.09	.09	.08	.08
2024 LST													
IR Cooling Deg C/day	-2.15	-2.44	-2.71	-2.15	-1.24	-2.19	-1.73	-1.95	-1.72	-1.71	-1.65	-1.36	-1.79
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.06	.06	.06	.06	.06	.05
DAY AVG													
IR Cooling Deg C/day	-2.16	-2.45	-2.71	-2.15	-1.24	-2.19	-1.74	-1.96	-1.72	-1.71	-1.65	-1.36	-1.79
SW Warming Deg C/day	.55	.57	.67	.69	.77	.79	.80	.80	.80	.80	.80	.79	.73
TOTAL SW + IR Deg C/day	-1.61	-1.87	-2.05	-1.46	-.47	-1.39	-.94	-1.16	-.92	-.91	-.85	-.58	-1.06

DATE: June 23, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1300 LST													
IR Cooling Deg C/day	-3.40	-2.98	-2.61	-2.23	-1.63	-2.23	-1.82	-1.81	-1.72	-1.63	-1.76	-1.58	-1.86
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
1551 LST													
IR Cooling Deg C/day	-2.84	-2.74	-2.66	-2.19	-1.46	-2.21	-1.78	-1.87	-1.72	-1.66	-1.71	-1.48	-1.83
SW Warming Deg C/HR	.05	.05	.07	.08	.09	.09	.09	.09	.09	.09	.09	.09	.08
2017 LST													
IR Cooling Deg C/day	-2.84	-2.70	-2.65	-2.20	-1.48	-2.19	-1.76	-1.86	-1.72	-1.66	-1.69	-1.49	-1.82
SW Warming Deg C/HR	.03	.03	.04	.04	.05	.06	.06	.06	.06	.06	.06	.06	.05
DAY AVG													
IR Cooling Deg C/day	-3.03	-2.80	-2.64	-2.21	-1.52	-2.21	-1.79	-1.85	-1.72	-1.65	-1.72	-1.52	-1.84
SW Warming Deg C/day	.41	.42	.66	.68	.79	.82	.82	.83	.83	.83	.83	.81	.75
TOTAL SW + IR Deg C/day	-2.62	-2.38	-1.98	-1.53	-.73	-1.39	-.97	-1.02	-.89	-.82	-.88	-.70	-1.09

DATE: June 24, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1251 LST IR Cooling Deg C/day	-2.05	-2.41	-2.73	-2.14	-1.19	-2.19	-1.73	-1.97	-1.72	-1.72	-1.65	-1.34	-1.79
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.06	.06	.06	.06	.05
1610 LST IR Cooling Deg C/day	-1.84	-2.32	-2.74	-2.12	-1.13	-2.18	-1.72	-2.00	-1.72	-1.73	-1.63	-1.31	-1.78
SW Warming Deg C/HR	.07	.07	.08	.08	.09	.09	.09	.09	.09	.09	.09	.08	.08
2042 LST IR Cooling Deg C/day	-1.79	-2.29	-2.75	-2.12	-1.12	-2.18	-1.72	-2.00	-1.72	-1.74	-1.63	-1.30	-1.77
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-1.89	-2.34	-2.74	-2.13	-1.15	-2.18	-1.72	-1.99	-1.72	-1.73	-1.64	-1.31	-1.78
SW Warming Deg C/day	.60	.63	.67	.70	.76	.79	.79	.79	.79	.79	.79	.78	.72
TOTAL SW + IR Deg C/day	-1.29	-1.71	-2.06	-1.43	-.39	-1.40	-.94	-1.20	-.93	-.94	-.84	-.54	-1.06

DATE: June 25, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
<u>1138 LST</u>													
IR Cooling Deg C/day	-1.93	-2.35	-2.74	-2.13	-1.16	-2.18	-1.73	-1.99	-1.72	-1.73	-1.64	-1.32	-1.78
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.06	.06	.06	.05
<u>1608 LST</u>													
IR Cooling Deg C/day	-1.72	-2.26	-2.75	-2.12	-1.10	-2.17	-1.71	-2.01	-1.72	-1.74	-1.62	-1.29	-1.77
SW Warming Deg C/HR	.07	.07	.07	.08	.09	.09	.09	.09	.09	.09	.09	.08	.07
<u>1957 LST</u>													
IR Cooling Deg C/day	-1.72	-2.26	-2.75	-2.12	-1.10	-2.17	-1.71	-2.01	-1.72	-1.74	-1.62	-1.29	-1.77
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05	.05
<u>DAY AVG</u>													
IR Cooling Deg C/day	-1.79	-2.29	-2.75	-2.12	-1.12	-2.18	-1.72	-2.00	-1.72	-1.74	-1.63	-1.30	-1.77
SW Warming Deg C/day	.62	.64	.67	.69	.76	.78	.78	.78	.79	.79	.79	.77	.72
TOTAL SW + IR Deg C/day	-1.17	-1.65	-2.08	-1.43	-.36	-1.39	-.93	-1.22	-.93	-.95	-.84	-.52	-1.06

DATE: June 26, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1016	966	916	866	816	766	716	666	616	566	516	466	416
1301 LST IR Cooling Deg C/day	-1.74	-2.27	-2.75	-2.12	-1.10	-2.18	-1.71	-2.01	-1.72	-1.74	-1.62	-1.29	-1.77
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.05	.06	.06	.05
1549 LST IR Cooling Deg C/day	-1.72	-2.26	-2.75	-2.12	-1.10	-2.17	-1.71	-2.01	-1.72	-1.74	-1.62	-1.29	-1.77
SW Warming Deg C/HR	.07	.07	.07	.08	.09	.09	.09	.09	.09	.09	.09	.08	.07
2022 LST IR Cooling Deg C/day	-1.94	-2.37	-2.74	-2.13	-1.16	-2.19	-1.73	-1.99	-1.72	-1.73	-1.64	-1.32	-1.78
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.06	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-1.80	-2.30	-2.75	-2.12	-1.12	-2.18	-1.72	-2.00	-1.72	-1.74	-1.63	-1.30	-1.77
SW Warming Deg C/day	.62	.64	.67	.70	.76	.78	.78	.78	.79	.79	.79	.77	.72
TOTAL SW + IR Deg C/day	-1.18	-1.66	-2.07	-1.42	-.36	-1.40	-.93	-1.22	-.93	-.95	-.84	-.52	-1.06

DATE: June 27, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1015	965	915	865	815	765	715	665	615	565	515	465	415
1254 LST IR Cooling Deg C/day	-3.53	-3.07	-2.61	-2.23	-1.65	-2.25	-1.85	-1.81	-1.72	-1.62	-1.78	-1.59	-1.88
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
2002 LST IR Cooling Deg C/day	-2.17	-2.46	-2.72	-2.14	-1.23	-2.19	-1.74	-1.96	-1.72	-1.71	-1.66	-1.36	-1.80
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.06	.06	.06	.06	.06	.05
DAY AVG IR Cooling Deg C/day	-2.85	-2.77	-2.66	-2.19	-1.44	-2.22	-1.79	-1.88	-1.72	-1.66	-1.72	-1.48	-1.84
SW Warming Deg C/day	.34	.37	.60	.61	.63	.67	.67	.68	.68	.68	.69	.69	.65
TOTAL SW + IR Deg C/day	-2.51	-2.40	-2.07	-1.58	-.81	-1.55	-1.12	-1.21	-1.04	-.98	-1.03	-.79	-1.19

DATE: June 28, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1015	965	915	865	815	765	715	665	615	565	515	465	415
1254 LST IR Cooling Deg C/day	-2.00	-2.39	-2.73	-2.13	-1.18	-2.19	-1.73	-1.98	-1.72	-1.72	-1.64	-1.33	-1.78
SW Warming Deg C/HR	.04	.04	.05	.05	.05	.05	.05	.05	.05	.06	.06	.06	.05
1549 LST IR Cooling Deg C/day	-2.22	-2.48	-2.71	-2.15	-1.25	-2.19	-1.75	-1.95	-1.72	-1.71	-1.66	-1.37	-1.80
SW Warming Deg C/HR	.06	.06	.08	.08	.09	.09	.09	.09	.09	.09	.09	.08	.08
2019 LST IR Cooling Deg C/day	-3.51	-3.01	-2.60	-2.24	-1.68	-2.23	-1.82	-1.79	-1.72	-1.62	-1.75	-1.60	-1.87
SW Warming Deg C/HR	.02	.02	.05	.05	.05	.06	.06	.06	.06	.06	.06	.06	.06
DAY AVG IR Cooling Deg C/day	-2.58	-2.62	-2.68	-2.17	-1.37	-2.20	-1.77	-1.91	-1.72	-1.68	-1.69	-1.43	-1.82
SW Warming Deg C/day	.49	.51	.68	.70	.78	.81	.81	.81	.81	.81	.82	.80	.74
TOTAL SW + IR Deg C/day	-2.08	-2.12	-2.00	-1.48	-.59	-1.40	-.96	-1.10	-.91	-.87	-.87	-.64	-1.08

DATE: June 29, 1969 BOMEX RADIATION DEPICTION

Pressure (mb)	1017	967	917	867	817	767	717	667	617	567	517	467	417
1256 LST IR Cooling Deg C/day	-3.83	-3.11	-2.56	-2.27	-1.81	-2.22	-1.82	-1.73	-1.73	-1.59	-1.76	-1.67	-1.88
SW Warming Deg C/HR	.02	.02	.04	.04	.06	.06	.06	.06	.06	.06	.06	.06	.06
1549 LST IR Cooling Deg C/day	-3.38	-2.85	-2.58	-2.26	-1.71	-2.18	-1.77	-1.76	-1.73	-1.62	-1.69	-1.60	-1.84
SW Warming Deg C/HR	.04	.04	.06	.06	.10	.10	.10	.10	.10	.10	.10	.09	.08
2014 LST IR Cooling Deg C/day	-3.61	-3.00	-2.57	-2.26	-1.75	-2.21	-1.80	-1.75	-1.73	-1.61	-1.73	-1.63	-1.86
SW Warming Deg C/HR	.02	.02	.04	.04	.05	.06	.06	.06	.06	.06	.06	.06	.06
DAY AVG IR Cooling Deg C/day	-3.61	-2.99	-2.57	-2.26	-1.76	-2.20	-1.80	-1.75	-1.73	-1.61	-1.73	-1.63	-1.86
SW Warming Deg C/day	.30	.31	.55	.57	.82	.85	.85	.85	.86	.86	.86	.84	.78
TOTAL SW + IR Deg C/day	-3.31	-2.68	-2.02	-1.70	-.93	-1.35	-.95	-.89	-.87	-.75	-.87	-.79	-1.08

REFERENCES

Cox, Stephen K., 1968: A radiation model in which the effects of clouds are simulated from moisture and temperature parameters. Annual Report on WBG-88, Department of Meteorology, University of Wisconsin, pp. 2-50.

Cox, Stephen K., 1969: Observations of infrared effective emissivities of cloud layers. Final Report, Radiation in the Free Atmosphere, ESSA Research Laboratories Grant E 22-113-68 (G), Department of Meteorology, University of Wisconsin, pp. 27, 37.

Cox, Stephen K., 1971: Infrared radiation models for the tropics. Proceedings of the Miami Workship on Remote Sensing, NOAA, Boulder, Colorado, pp. 161-178.

Cox, Stephen K., K. Hanson, T. Vonder Haar, and V. Suomi, 1968: Scientific objectives and data requirements for radiation studies during BOMEX. Studies in Atmospheric Energetics Based on Aerospace Probings, Annual Report, Department of Meteorology, University of Wisconsin, pp. 143-151.

Cox, Stephen,K., K. Hanson, T. Vonder Haar, and V. Suomi, 1973: Measurements of absorbed shortwave energy in a tropical atmosphere. Solar Energy, Vol. 14, pp. 169-173.

Holland, J., 1972: The BOMEX Sea-Air Interaction Program: background and results to date. NOAA Technical Memorandum ERL BOMAP-9, March.

Holland, J. Z., and E. M. Rasmussen, 1972: Measurements of the atmospheric mass, energy and momentum budgets over a 500 km. square of the tropical oceans. Preprint of an article to appear in the Monthly Weather Review.

Johnson, D., and P. Kuhn, 1966: Improved radiometersonde observations of atmospheric infrared irradiance. J.G.R., 71, pp. 367-373.

Kondratyev, K. Ya., 1971: Preliminary results of the first expedition under the program of the Complex Atmospheric Energetics experiment. (C aenex - 70). W.M.O. Bull., 20, pp. 160.

Korb, G., and F. Möller, 1962: Theoretical investigation on energy gain by absorption of solar radiation in clouds, Final Report on U. S. Army Signal Corp Contract No. DA-91-541-EUC-1612, 185 pages.

Kuhn, P., and L. Stearns, 1971: Radiative transfer observations and calculations during BOMEX, NOAA Technical Report ERL 203-APCL 19, 171 pages.

Roach, W., 1961: The absorption of solar radiation by water vapor and carbon dioxide in a cloudless atmosphere. Q.J.R.M.S., 87, pp.

Young, M. J., 1967: Variability in estimating total cloud cover from satellite pictures. J. of Appl. Meteor., 6, 3, pp. 573-579.

BIBLIOGRAPHIC DATA SHEET	1. Report No. CSU-ATSP-208	2.	3. Recipient's Accession No.
4. Title and Subtitle: Radiation Components of the Energy Budget for BOMEX			5. Report Date: September 1973
			6.
7. Author(s): Dr. Stephen K. Cox			8. Performing Organization Rept. No. CSU-ATSP-208
9. Performing Organization Name and Address: Department of Atmospheric Science, Colorado State University, Fort Collins, Colorado 80521			10. Project/Task/Work Unit No.
			11. Contract/Grant No. ESSA Grant E 22-55-70(G
12. Sponsoring Organization Name and Address: Environmental Sciences and Services Administration and Department of Atmospheric Science, C.S.U.			13. Type of Report & Period Covered: Final Contract Report
			14.

15. Supplementary Notes

16. Abstracts

A technique to derive large scale radiation divergence patterns by combining direct measurements of radiation, satellite cloud data, surface cloud observations and radiosonde observations is presented.

The technique is applied to the three BOMEX time periods selected for the core experiment analysis and the resulting radiation divergence values for the BOMEX array are given in tabular form.

17. Key Words and Document Analysis. 17a. Descriptors

BOMEX
Radiation Budget
Tropical Radiation
Radiation Measurements

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages
Unlimited Distribution	20. Security Class (This Page) UNCLASSIFIED	22. Price