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METEOROLOGICAL SATELLITE LABORATORY
REPORT NO 34

An Investigation of Degradation Errors in TIROS IV Scanning Radiometer Data and the Determination of Correction Factors

WASHINGTON, D. C.
OCTOBER 1965

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METEOROLOGICAL SATELLITE LABORATORY

REPORT NO. 34

AN INVESTIGATION OF DEGRADATION ERRORS IN TIROS IV SCANNING RADIOMETER DATA AND THE DETERMINATION OF CORRECTION FACTORS.

by

P. Krishna Rao, Elford G. Astling, and Francis J. Winninghoff

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AN INVESTIGATION OF DEGRADATION ERRORS IN TIROS IV SCANNING RADIOMETER DATA AND THE DETERMINATION OF CORRECTION FACTORS

ABSTRACT

The degradation errors in the TIROS IV scanning radiometer data of reflected solar radiation (channel 3) and emitted long-wave radiation (Channel 2) are discussed and correction factors are derived. For the reflected solar radiation measurements, a correction factor was obtained by comparisons with aircraft albedo measurements under cloudless conditions. The results for channel 3 are compared with balloon-flight measurements and other studies. For the channel 2 data, the correction factor was obtained from a comparison of daily average values of outgoing long-wave radiation with the average value on the first day after launch. Variations in the daily averages of outgoing long-wave radiation for the area bounded by 55°N and 55°S latitudes are compared with variations in the average values at individual points. The correction factors obtained for both channels give reasonable results when applied to individual grid points, but when the corrected values are summarized over the entire field of data they yield quasi-global averages which appear to be too low if radiative equilibrium is assumed.

I. INTRODUCTION

The calibration levels on channel 2 and 3 of the medium resolution scanning radiometer aboard TIROS IV have appeared to decrease with time. The channel 3 measurements of reflected solar radiation from the earth (0.2 to 6.0 microns) displayed a marked decrease by a factor between one-fourth and one-half the initial calibration level and the channel 2 measurements in the atmospheric window region (7.5 to 13.5 microns) decreased by approximately one-tenth the initial level. Unfortunately, causes for the degradation have not been established.

Since there was no on-board calibration for the scanning radiometer, some indirect techniques have been employed to obtain correction factors for the degradation [8,9]. These techniques necessarily have involved many assumptions and the resulting corrections have been subject to some question. For example, correction factors for channel 3 data, presented in the TIROS IV Radiation Data Catalog and Users' Manual [8] were derived from a comparison between balloon-borne radiometer and satellite measurements made simultaneously. A re-examination of the balloon-borne radiometer data reveals that not only was the comparison in error, but also the balloon-borne radiometer calibration level was incorrect (Bartman, personal communication).

II. TIROS IV RADIATION DATA

The data from channels 2 and 3 of TIROS IV, which are discussed in this report, were in the form of daily composite values. These are average values of outgoing long-wave radiation and albedo obtained within a one-day sequence of orbital passes and in 5 degree latitude-longitude areas. The averages were printed out on a Mercator projection at 5 degree latitude-longitude intervals between latitudes 55°N and 55°S. The actual observation times for the daily composite maps covered a considerable portion of a 24-hour period since the orbital track shifted westward with time due to the rotation of the earth. Data poleward of 30°N and 30°S were obtained from as many as four successive orbital passes at intervals of 1 1/2 to 2 hours. In lower latitudes data were usually derived from one orbital pass. In order to improve the data reliability, only single open mode scans were used [1]. Measurements made at nadir angles of view greater than 58 degrees were deleted to insure that no part of the sensor's field of view was directed to space. In addition only grid points with data populations greater than 20 and greater than 10 were used for channels 2 and 3 respectively. The lesser restriction was placed on the channel 3 data because it was limited to daylight regions.

The albedo values were obtained from channel 3 measurements by assuming the reflecting and scattering properties of the atmosphere and the earth's surface are isotropic. This assumption could produce some error in the albedo values in view of the recent study of anisotropic properties of clouds found from TIROS IV measurements of reflected solar radiation [6]. Such differences were found to be large for measurements made at very low solar zenith angles. As a result, the angular dependence in the TIROS measurements, together with the low signal-to-noise ratio found for low solar zenith angles, causes the channel 3 data to be sensitive to large errors at these angles. After making several tests it was found that these effects were largely overcome by eliminating all channel 3 measurements for solar zenith angles greater than 60 degrees. Consequently, this restriction, together with the satellite nadir angle cut-off at 58 degrees, will bias the data toward lower scattering angles and, hence, bias the albedo measurements toward slightly lower values.

The channel 2 measurements (7.5 to 13.5 microns) were converted to total outgoing long-wave radiative flux by a theoretical and empirical method developed by Wark et al. [10]. Statistical limb-darkening corrections based on TIROS III and a few orbits from TIROS IV were applied in order to increase the areal coverage and to obtain more reliable data for measurements made at large nadir angles.

III. DEGRADATION CORRECTIONS FOR CHANNEL 3 DATA

The albedo measurements obtained from the channel 3 scanning radiometer on TIROS IV have generally appeared to be too low. Evidence of this can be found in figures 1 and 2 which are graphs of the maximum and minimum albedo measurements obtained from the composite maps for each day. The maximum albedos were generally over cloudy regions and the minumum albedos generally over clear oceanic areas. It can be seen in figure 1 that several maximum albedos in February exceed 50 percent while in the following months the average values drop gradually to 40 percent. Monthly averages of the maximum albedos (fig. 1) decreased by approximately 4 percent from February to March and by less than 3 percent from March to April. Thereafter, they remain nearly constant. In figure 2, the degradation is not as evident. The marked decrease in the minumum albedos during the second week in February is primarily due to data coverage being limited to cloudy areas and cannot be attributed to degradation alone.

A comparison of the albedos shown in figures 1 and 2 with those found from other sources indicates that the TIROS IV measurements are much too low for high albedos and are in near agreement for low albedos. The maximum values (fig. 1), which are primarily over cloudy areas, appear to be 10 to 20 percent lower than average cloud albedos found from other studies. Roach [4,5] has made a large number of aircraft measurements over different types of clouds and obtained mean albedo values of 56 percent for overcast conditions. A similar value of 50 percent has been estimated by Fritz [2] for the average cloud albedo for the entire earth. On the other hand minimum albedos shown in figure 2 appear to be only about 2 percent lower than minimum albedos measured over the earth's surface by other methods. Minimum values near 5 percent over sea surface areas have been obtained by Roach [4,5] from aircraft measurements. Hence, the degradation in the channel 3 measurements appears to be proportional to the albedo.

Correction Factor Determined from Aircraft Observations

In order to obtain a correction factor which would be applicable to a wide range of albedos, comparisons were made with reliable aircraft albedo measurements for two markedly different parts of the earth under cloudless conditions. The lowest values in figure 2 were compared with Roach's [4,5] sea surface measurements and values obtained from TIROS and by Roach were also compared over the cloudless Sahara Desert region. Albedos over cloudy regions were not considered at this stage because of the difficulty in estimating cloud amounts and albedo variations with cloud type. A correction for the channel 3 albedo measurements was obtained from the two comparisons by assuming the following linear relationship

$$A = aA_s + b \qquad (1)$$

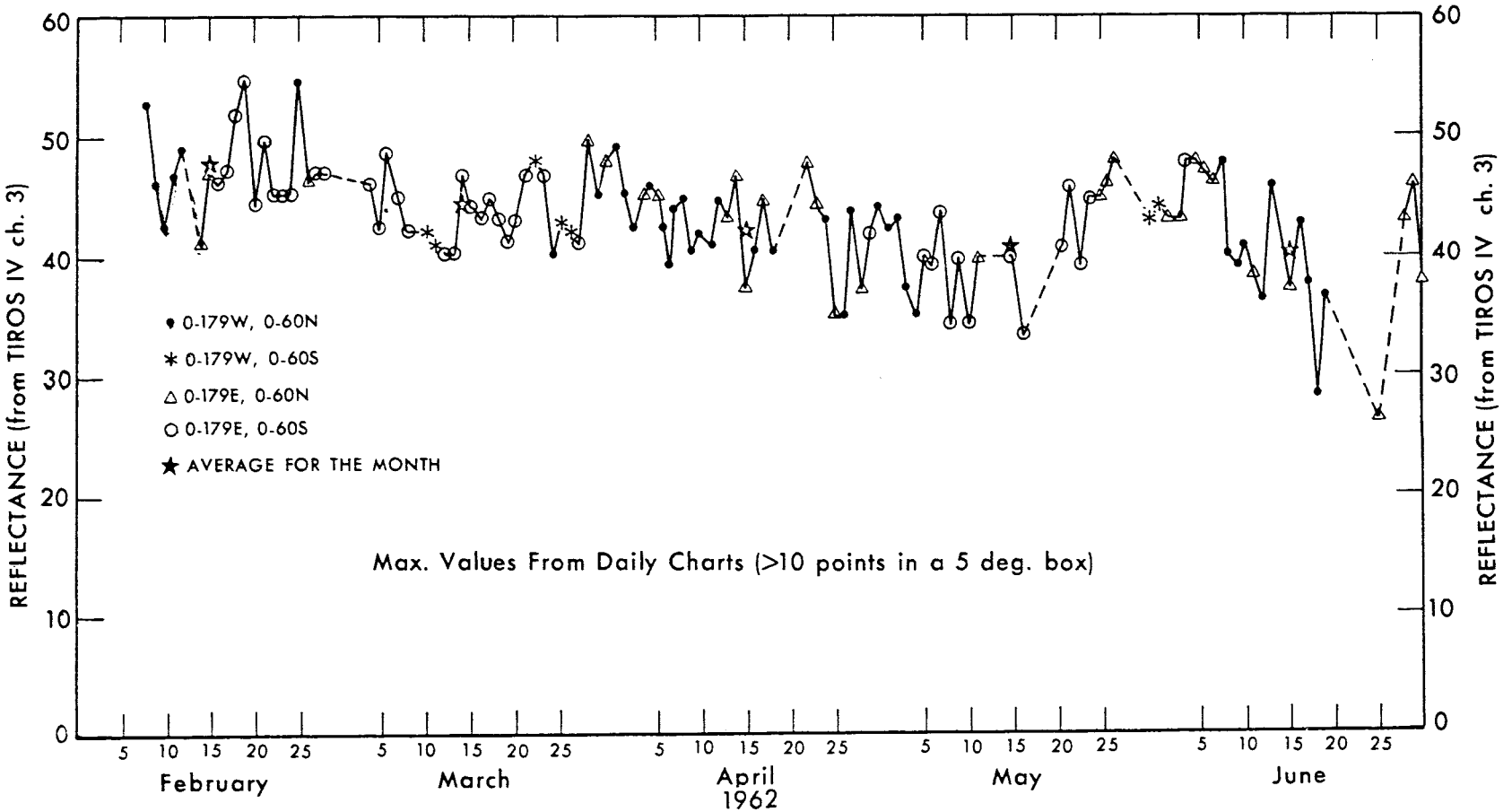

Figure 1. Maximum values of albedo from daily composite maps of TIROS IV, channel 3 data. Dashed lines indicate periods with missing data. Units are in percent.

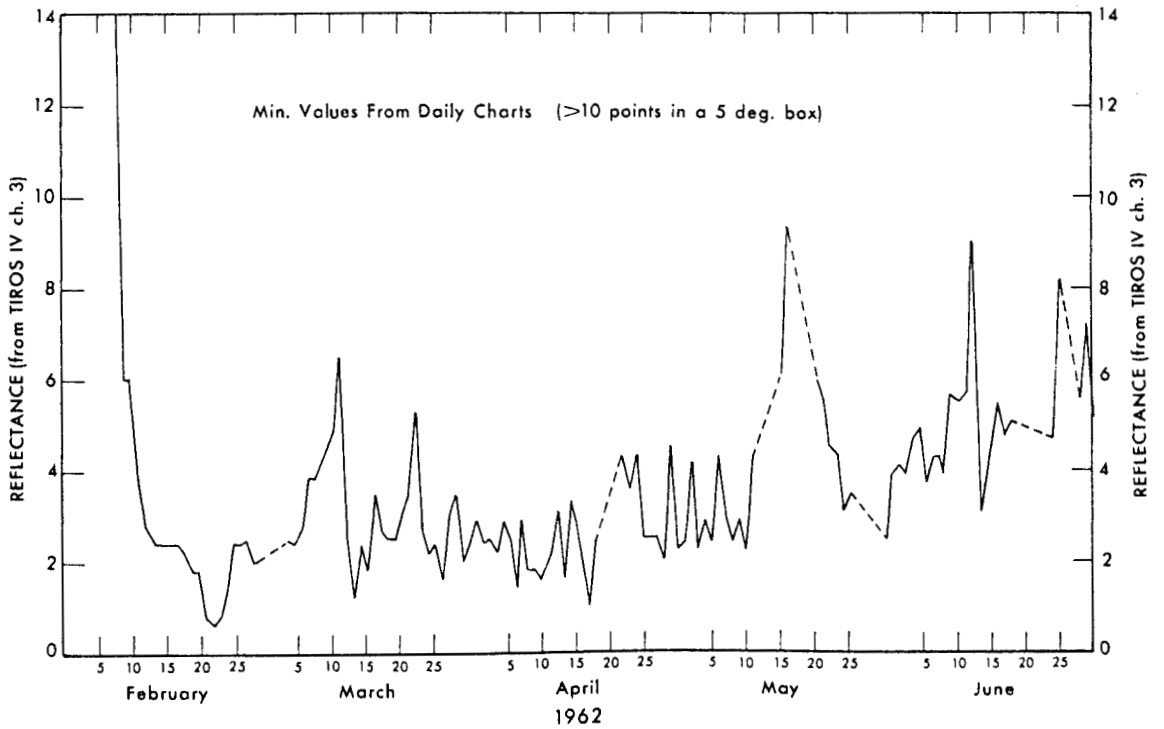

Figure 2. Minimum values of albedo from daily composite maps of TIROS IV, channel 3 data. Dashed lines indicate periods with missing data. Units are in percent.

were A is the true albedo (from aircraft measurements), A_s is the TIROS IV measurement, and a and b are constants.

In the comparison of albedos over the Sahara Desert, an average value of 32 percent was obtained from the aircraft measurements, while an albedo of 28 percent was obtained by averaging the TIROS IV channel 3 measurements during cloudless periods. In the comparison of low albedos over oceans, Roach's average value was 5 percent while the average satellite measurement was 2.7 percent. The satellite measurement was obtained by averaging the albedos given in figure 2 for the period between February 19 and May 11 except for the high values on March 10 and 22. This period was chosen because the measurements were over oceanic regions and appeared to be stable during the period. Substituting these two sets of values into equation (1) the constants a and b were found to be 1.33 and 1.41 respectively. Thus, equation (1) becomes

$$A = 1.33\ A_s + 1.41 \qquad (2)$$

One can check the applicability of equation (2) by applying it to the maximum albedo values given in figure 1. Substituting these values of A_s into equation (2), an average albedo for the period between February 19 and May 11 becomes 58 percent. This value is in good agreement with overall average albedo values over cloudy regions obtained by Roach (56 percent, [4,5])and in fair agreement with Fritz's average estimated value for clouds (50 percent, [2]). Thus, this equation appears to be a useful first approximation for the correction of the TIROS IV albedo measurements.

Comparison with a Balloon-Borne TIROS Radiometer

On June 2, 1962, a balloon carrying a five channel radiometer, similar to the one on TIROS IV, was launched over South Dakota. The purpose of the balloon flight was to compare the balloon-borne radiometer measurements with corresponding TIROS IV measurements.

After the balloon was released it rose above 100,000 ft. and drifted towards the northwest (fig. 3). Overcast cloud conditions prevailed over South Dakota for the duration of the balloon flight, except for scattered to broken cloud conditions over the north-central portion of the state. One can see the large-scale cloud orientation from the TIROS IV albedo measurements shown in figure 3. Stationary features present on the surface weather map and continuous overcast conditions reported from hourly observations at Sioux Falls, Rapid City, and Huron, allows one to assume that the cloudiness remained virtually the same throughout the period (fig. 4). Assuming furthermore, that the cloud albedo changed little during the day, the data from both the TIROS IV and balloon radiometers can be compared.

The time of the satellite passage over South Dakota was 2143 GMT. For the comparison, mean hourly values centered at 43 minutes past the hour were computed from the balloon measurements. It was found that the balloon-borne radiometer was reading consistently higher than the TIROS IV radiometer, except near the end of the balloon flight where the balloon passed over scattered and broken clouds (fig. 5). The average ratio between the two sets of observations was found to be 1.2. This ratio is in agreement with an investigation made by Bartman of the University of Michigan (personal communication) for the same data. It should be noted that this ratio is in disagreement with the value of 1.84 obtained by NASA for these same data [8].

Recently, there have been some doubts about the calibration of the channel 3 radiometer carried on the balloon flight over South Dakota. According to Bartman (personal communication) a post-flight calibration indicated the balloon values should be increased by a

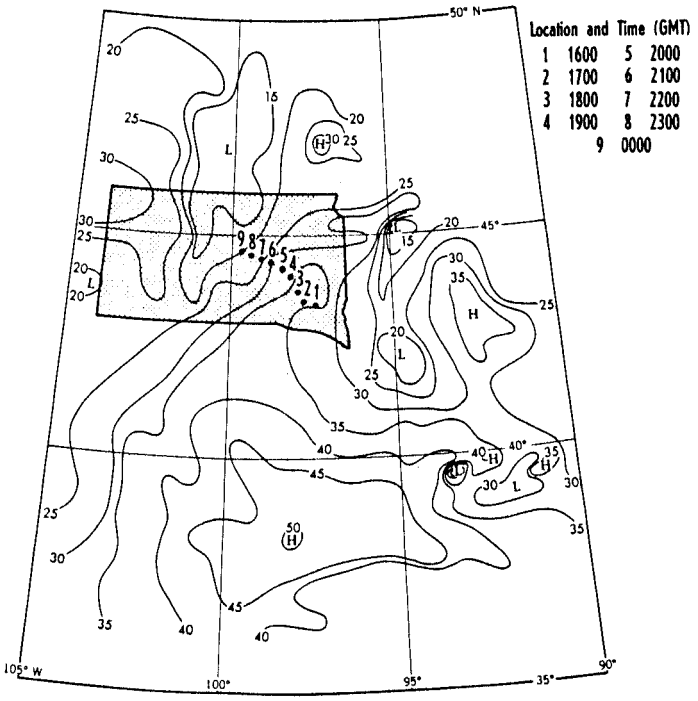

Figure 3. TIROS IV, channel 3 albedo measurements for orbit 1642, 2143 GMT, with isopleths drawn at 5 percent intervals. Hourly positions of the balloon from 1600 to 2400 GMT are indicated by the dots numbered from 1 to 9.

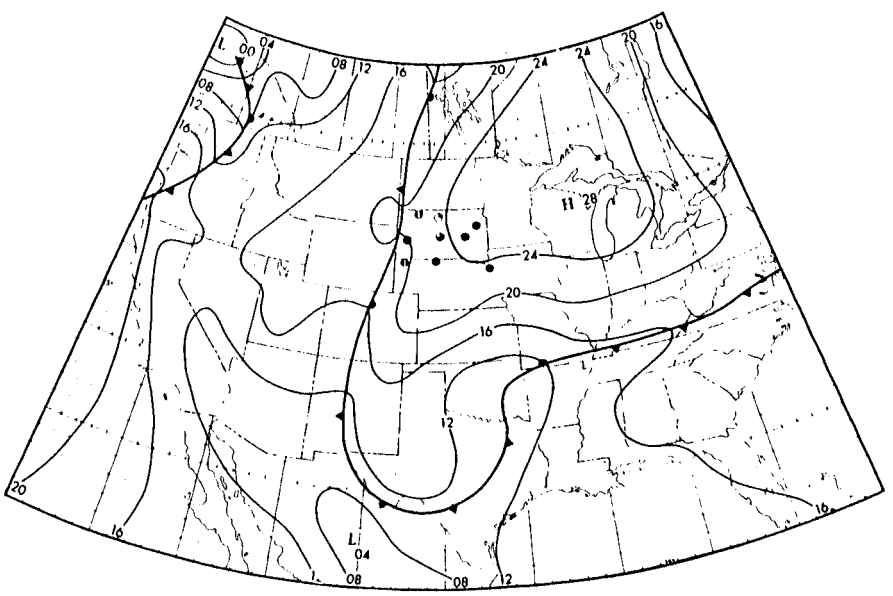

Figure 4. Surface chart for 1800 GMT June 2, 1965. Cloud amounts in the South Dakota area are indicated by synoptic cloud symbols.

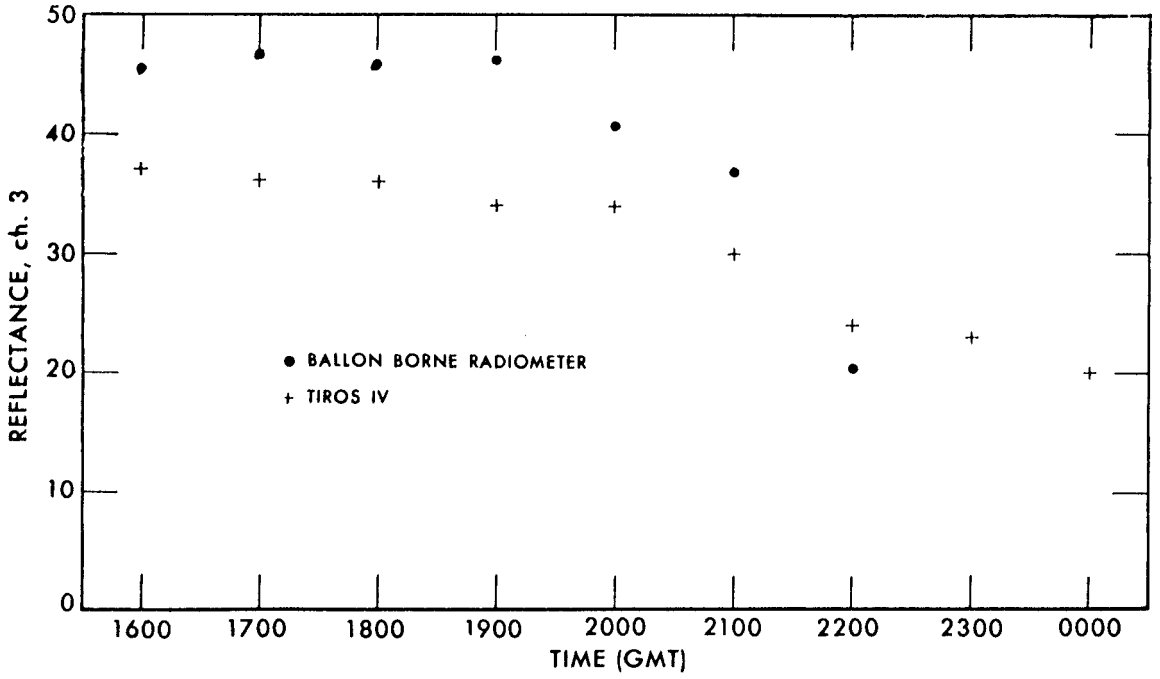

Figure 5. Comparison of channel 3 measurements from TIROS IV with hourly average albedo measurements obtained from the balloon-borne channel 3 radiometer.

factor of 1.2. Under such conditions the correction factor for the channel 3 radiometer on TIROS IV becomes 1.2 x 1.2 = 1.44. Although there are many uncertainties involved with the balloon-borne measurements, the correction factor from this comparison is rather close to that obtained with aircraft measurements (Roach [4,5]).

Comparison with Other Studies

Other investigators have attempted to derive correction factors for the degradation in the channel 3 data from TIROS IV. Staff members of the Aeronomy and Meteorology Division of NASA [8] obtained a correction factor of 1.84 presumably based on the same balloon-borne radiometer comparison just discussed. Such a correction factor appears to be reasonable when it is used to estimate the quasi-global albedo. An average albedo of 30 percent was found for the area bounded by 55°N and 55°S as compared to 33 percent estimated by London [3] for the same latitude zone. However, when this correction is applied to the average albedos for 5 degree grid intervals, the albedos appear to be too large. For example, one can see from the maximum albedos shown in figure 1 that some would exceed 95 percent and many would be greater than 90 percent.

In another study an attempt was made to determine the channel 3 degradation from albedo measurements made by a low resolution hemispheric radiometer on TIROS IV [9]. The comparison of these two radiometers presented several problems, particularly the restriction of scanning radiometer measurements to low scattering angles and the uncertainty of the hemispheric radiometer's spectral response. With scanning radiometer measurements limited to low nadir angles and low solar zenith angles,the channel 3 measurements are made at predominantly low scattering angles. Preliminary studies indicate that the solar radiation reflected from clouds is anisotropic with greater reflectivities at higher scattering angles [6]. As a result, the scanning radiometer data were biased to low albedos and may partially explain the high correction factor. In the second case, some laboratory measurements of the spectral response of an anodized aluminum sensor (similar to the hemispheric sensor aboard TIROS IV) were made after TIROS IV was launched [7]. Results have shown the sensor's spectral response to be dependent on the anodizing process of the aluminum and suggests some uncertainty in the hemispheric radiometer's spectral response. How this problem may change the correction factor of 2.0 or more, which was determined in [9], is uncertain.

IV. DEGRADATION CORRECTIONS FOR CHANNEL 2 DATA

A study of the degradation of the channel 2 radiation data from TIROS IV was carried out for the purpose of obtaining a correction factor which can be applied to the outgoing long-wave flux measurements. The degradation problem was examined from several different aspects. From daily composite maps, average values over the entire map were computed and compared with changes in the radiation values at several individual grid points on the composite maps. For measurements made at one grid point in the equatorial Pacific Ocean, a comparison was made with theoretical calculations. In addition, diurnal variations of outgoing long-wave radiation over land areas were estimated in order to determine their contribution to spatial and temporal variations. Results from these data were then considered in deriving a correction factor for the channel 2 degradation.

Daily Averages from Composite Maps

Results of the computations of the daily averages of outgoing radiation over the entire map are presented graphically in figure 6 (upper curve). One can see from figure 6 that variations in the averages from one day to the next amount to as much as 5 percent. An examination of the data for periods with large day-to-day variations reveals that variations in the data coverage are important. For example, the high radiation value found on March 23 (fig. 6) results from the data being limited predominantly to geographical areas of high outgoing radiation - warm desert regions over Africa and Australia and cloudless regions over the eastern tropical Pacific. For March 22 and 24 the longitudinal coverage was much greater; consequently, the daily average radiation values were lower.

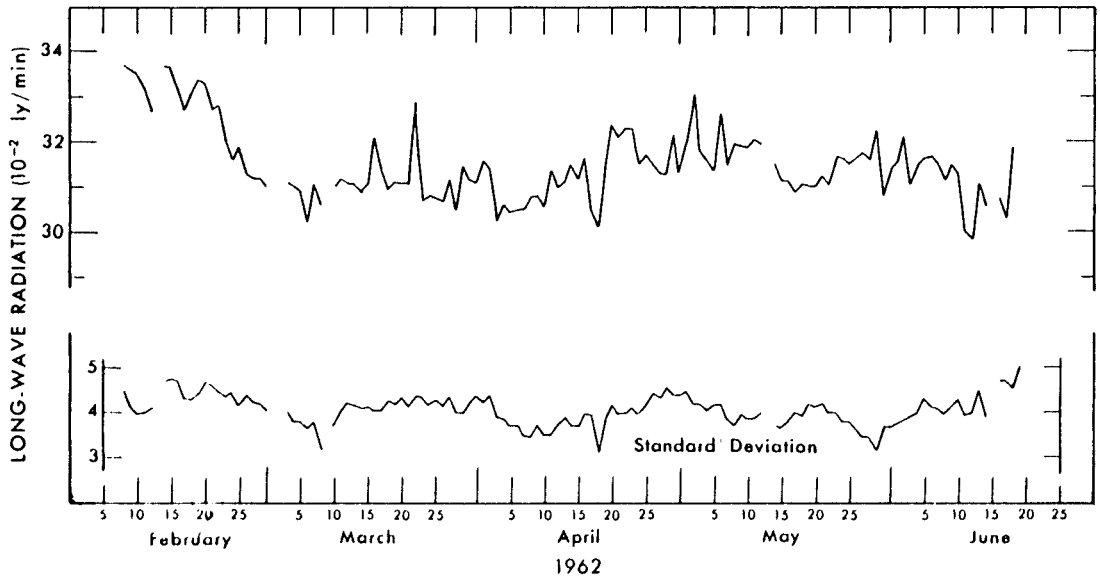

Figure 6. Daily averages and standard deviations over the entire composite maps of outgoing long-wave radiation from TIROS IV, channel 2 data.

Although there is a considerable variation in the averages from one day to the next, a definite decrease with time is apparent. The average value for the first day after launch was .336 ly./min. with values on the following days decreasing until the last week of February. Beyond this time the averages appeared to level off at approximately .310 ly./min. until the middle of April when they appeared to increase slightly. In general, the daily averages shown in figure 6 are in agreement with the degradation found in the quasi-global averages calculated by NASA [8] for the same data. It is unlikely that this initial decrease is due to any spatial change in the data coverage because the geographical areas sampled remained the same throughout the five month period of data. However, it is possible that the seasonal variations and local time of observation may have had an effect on the changes in the radiation values. This points out the need for examining the radiation values at individual points and will be discussed in the next section.

Daily Averages at Individual Points

In order to see if the degradation found in figure 6 was biased due to temporal and spatial variations, daily averages from eight grid points on the daily composite maps were considered - five over oceans and three over land. All the cases were selected from low latitudes because the data can be identified with a single orbit and, hence, a specific time. Radiation values for each of the oceanic cases were plotted with respect to the day on which the measurement was made and each of the land cases was plotted with respect to local time. The results are presented in figures 7 and 8.

Two oceanic cases were selected over the Indian Ocean at 20°S, 60°E, and 20°S, 100°E. For both of these cases large day-to-day fluctuations appeared (fig. 7a, and b). Changes of more than 40 percent occurred during the period of February 21 to 28 and April 3 to 5 for the point in the western Indian Ocean. These are apparently due to changes in cloudiness associated with storms passing through the area during the two periods. Although daily radiation values changed significantly from day-to-day, it is difficult to detect any degradation from one month to the next. Some decrease from February to March followed by an increase from April to May appeared in the monthly averages. The decrease may be related to a seasonal shift toward the equator in the broad subtropical belt of high radiation values from February to April followed by an intensification in the higher latitudes later in May. This was evident on monthly charts of outgoing long-wave radiation for this period as discussed by Winston [11]. A similar pattern exists for the other point located in the eastern Indian Ocean. Because of the large variations and the seasonal changes it is difficult to draw any conclusions about degradation from these two points.

The other three oceanic cases were selected over the Pacific Ocean at 15°S, 150°W; 15°N, 170°E; and 10°S, 130°W. The daily values of outward flux at 15°S, 150°W (fig. 7c) were the only ones which appeared to increase with time. The monthly average in February was .345 ly./min. and increased to .360 ly./min. in June. An examination of the monthly charts of outgoing radiation revealed that the increase was due to an extensive area of low radiation values associated with the subtropical convergence zone in the South Pacific which shifted poleward and was replaced by high values of radiation in the dry clear equatorial zone.

It should be noted that large day-to-day fluctuations exist at 15°S, 150°W. Radiation values vary by the same amount found in the Indian Ocean cases. These fluctuations are attributed to the location of the grid point in an area of large gradients of radiation values between extensive clear and cloudy areas. It is reasonable to expect that large fluctuations appearing in figure 7c are a result of minor horizontal displacements of these areas of large gradients and movements of weather disturbances along them. Thus, the seasonal effects and day-to-day fluctuations at these oceanic grid points illustrate the need for selecting an area with negligible seasonal changes and uniform radiating surface characteristics for investigating the variations due to degradation.

Decreases in the daily averages of outgoing radiation were evident for the other points in the Pacific (fig. 7d, and e). These two cases are located in the center of a relatively clear equatorial dry zone, particularly the one at 10°S, 130°W. High radiation values with minor fluctuations in the daily averages as found in figure 7e are evidence

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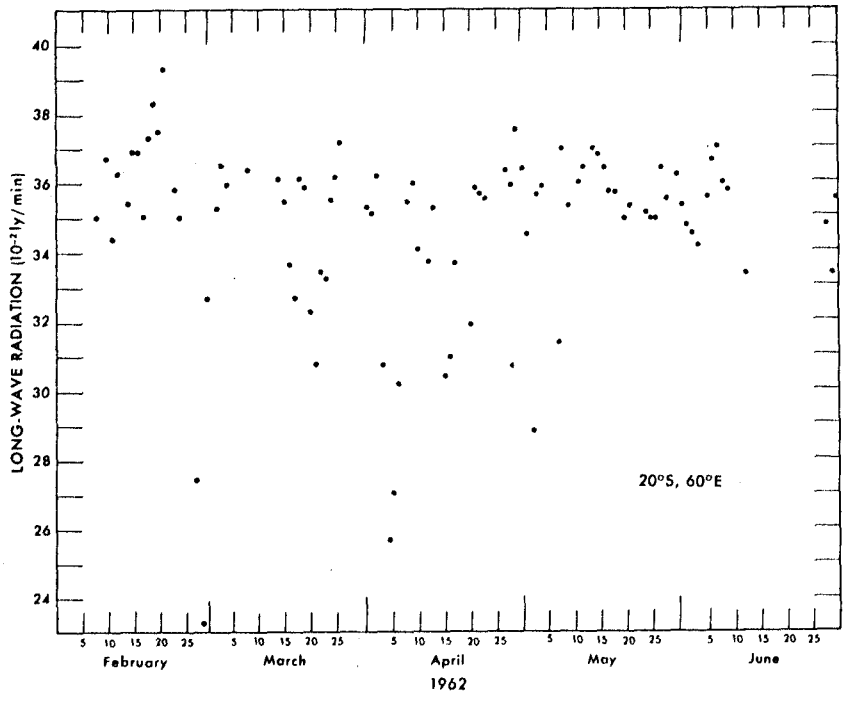


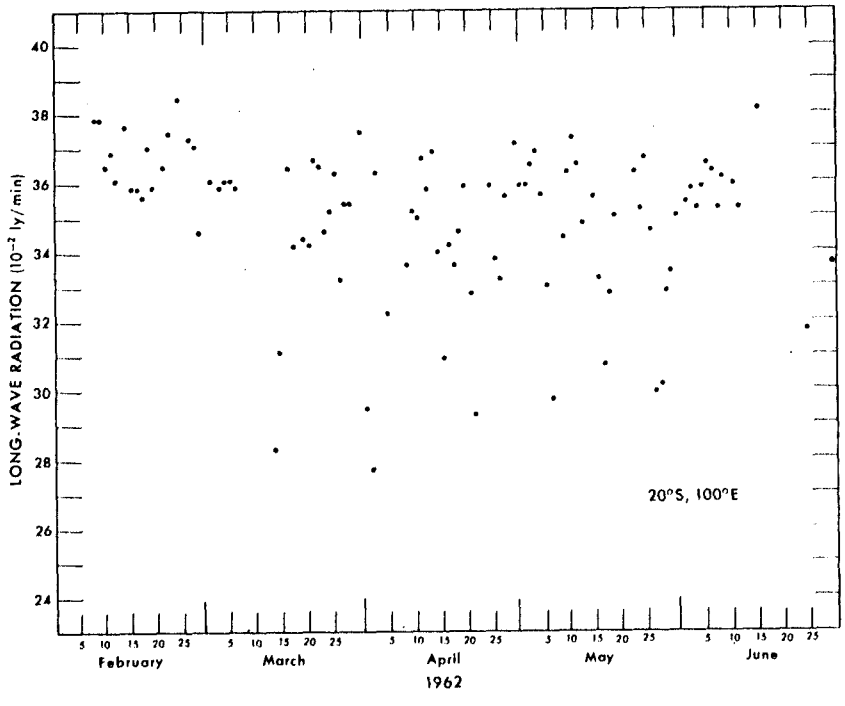
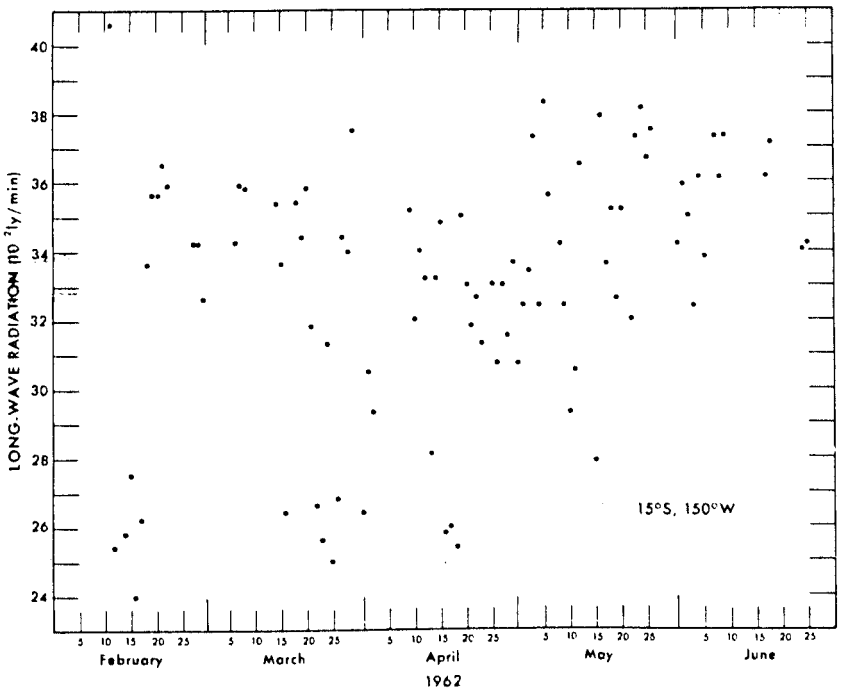


Figure 7a and b. Daily averages of outgoing long-wave radiation for 5 degree latitude-longitude areas centered at (a) 20°S, 60°E and (b) 20°S, 100°E



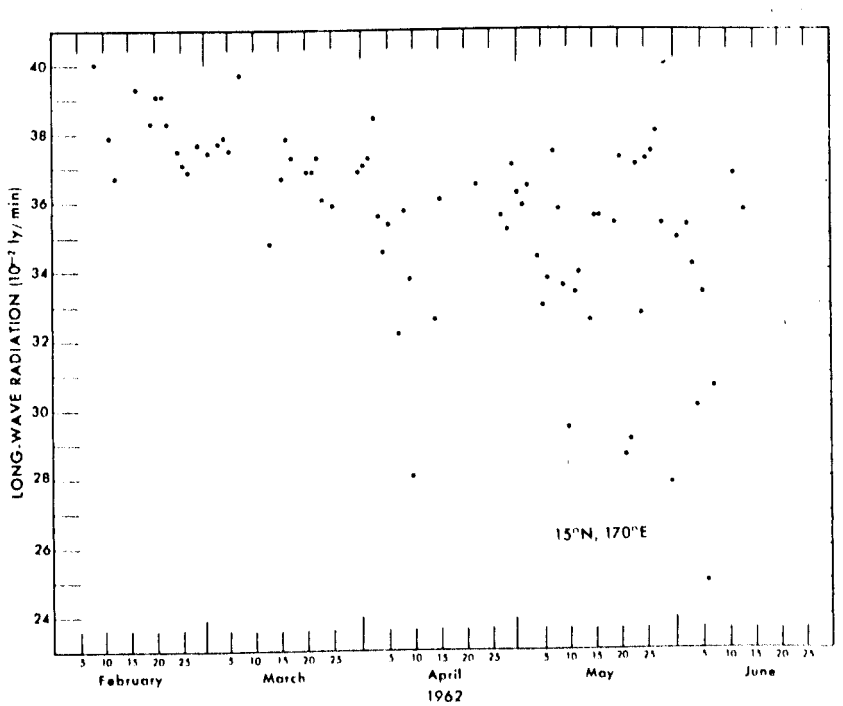


Figure 7c and d. Daily averages of outgoing long-wave radiation for 5 degree latitude-longitude areas centered at (c) 15°S, 150°W and (d) 15°N, 170°E.

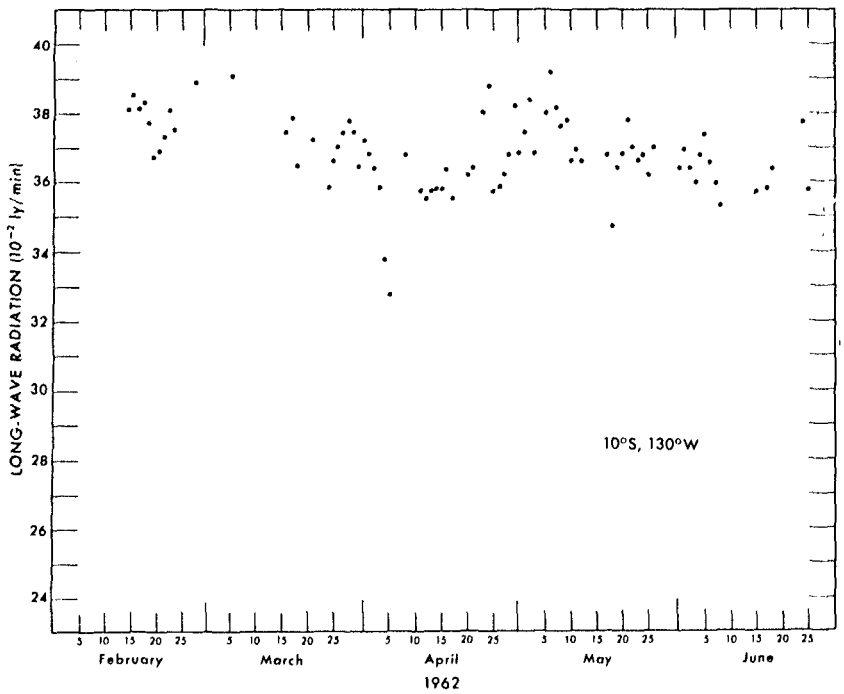


Figure 7e. Daily averages of outgoing long-wave radiation for 5 degree latitude-longitude areas centered at 10°S, 130°W.

of the predominance of days with relatively small amounts of cloudiness. With little variation in ocean temperatures, it appears that this area presents a reasonably uniform emitting surface for determining true degradation. The decrease in the maximum values of outgoing radiation of about 7 percent from February to June for this grid point corresponds favorably with the degradation appearing in the global averages (fig. 6).

The three land cases were selected from subtropical desert areas where diurnal changes are large and may contribute to changes in the daily averages for the entire composite maps. Two points were chosen over the Sahara Desert (15°N, 0°E and 15°N, 30°E) and one over Australia (20°S, 140°E). Since the longitudinal position of Africa is approximately 180° from Australia, observations over the respective regions were always made twelve hours apart from each other in local time. Daytime observations were made in February and late April over the Sahara Desert while nighttime observations were made over Australia. In March and May the areas of day and night observations were reversed. For each of the three cases, the TIROS period of observation extended over a four month period so that two samplings of a complete diurnal cycle were obtained.

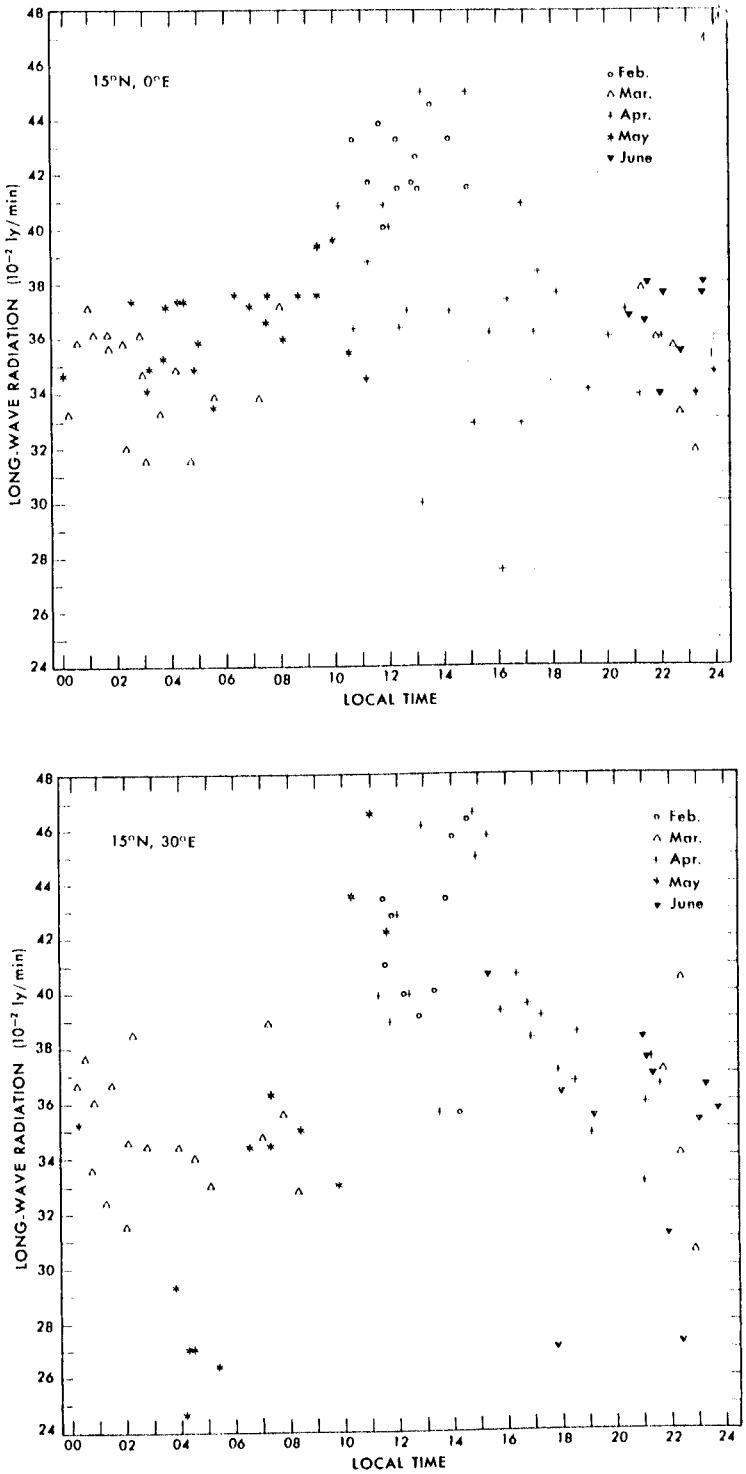


Figure 8. Outgoing long-wave radiation measurements as a function of local time for (a) 15°N, 0°E and (b) 15°N, 30°E.

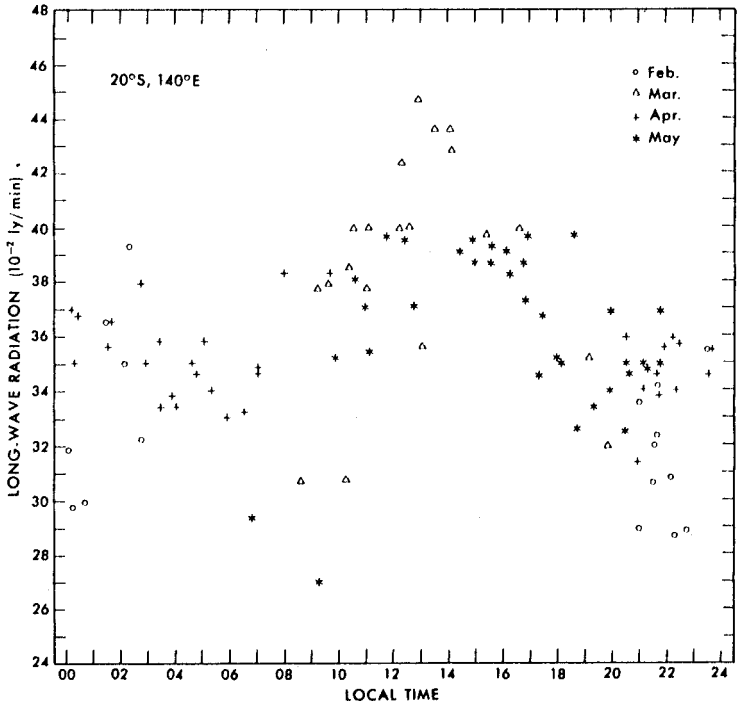


Figure 8c. Outgoing long-wave radiation measurements as a function of local time for 20°S, 140°E.

Graphs of the radiation values versus local time for the three land cases are given in figure 8. One can see that, as expected, daytime measurements were higher than nighttime measurements. Assuming maximum values for each local hour are representative of cloudless situations, day-night differences amount to about .080 to .100 ly./min. or more than 25 percent of the total outgoing flux.

If the diurnal variations shown in figure 8 occur over extensive desert areas in the subtropical latitudes, then diurnal effects may contribute to changes in the daily averages for the entire composite maps. To determine the significance of these diurnal effects two daily averages of outgoing long-wave radiation for an entire composite map were computed. In one case average nighttime values shown in figure 8a were used for the grid points over the subtropical desert areas in the Northern Hemisphere, and in the other case average daytime values shown in figure 8a were used. For all other grid points values were arbitrarily selected from the measurements made by TIROS IV on February 16, 1962.

From the two averages that were computed a difference of 3 percent of the average outward flux was found. Thus, one can see that the differences due to diurnal effects may be one-half of those due to degradation. Diurnal effects of this amount may explain the increase in

daily averages of long-wave radiation from the middle of April (night-time measurements over the subtropical desert areas) to the first week in May (daytime measurements) (fig. 6). It is doubtful that the diurnal effects contributed to the sudden decrease in February because a similar decrease was found at individual grid points over the Pacific Ocean.

From the radiation data shown in figure 8, some evidence of degradation is found in February with little change in the following months. At the two grid points over Africa (fig. 8a and b), one would expect the radiation values to increase from February to April due to the seasonal warming of approximately 10° K over the cloudless Sahara Desert. However, figures 8 a and b show that the satellite measurements obtained during the daytime hours of maximum solar heating in February are about the same as measurements made in the afternoon hours of April. This indicates that the satellite measurements degraded from February to April by an amount approximately equal and opposite to the seasonal trend. The lack of further degradation after the first month of satellite measurements is apparent at 20°S, 140°E (fig. 8c) where the maximum daytime values for March are considerably higher than in May. At this grid point, the decrease in outgoing long-wave radiation from March to April (cloudless months) corresponds with the seasonal cooling for this area. Changes opposite to the seasonal trend are found between 2000 and 0200 local time (figure 8c) where April and May values are greater than February values. However, the low values in February may be explained by the presence of clouds associated with the subtropical easterly circulation at 20°S, 140°E [11]. In the months following February, the outgoing long-wave radiation increases as the clouds shift equatorward.

Comparisons with Theoretical Calculations

A comparison of the TIROS IV long-wave measurements was made with those calculated from a theoretical method using radiosonde observations [10]. Because the time variations in the radiation measurements over the tropical Pacific Ocean appeared to be small, comparisons were made for the area over Canton Island where surface cloud reports and radiosonde data were available.

In order to reduce the effects of synoptic changes between the time of the Canton Island observations and the time of the TIROS IV measurements and to account for the effect of clouds on the outgoing radiation, some restrictions were placed on the data. Only days in which surface observations reported no clouds or only one layer of low clouds and in which radiosonde observations were taken within three hours of a satellite pass were considered. Since the number of days meeting these criteria were relatively few, the previous restriction on data population for the 5 degree latitude-longitude average values was removed. Thus, for this comparison, satellite values with data populations less than 20 were included. Cloud top heights were estimated from the temperature and dew point temperature values in the soundings. For the sixteen cases that met the restrictions, two calculations were made in each case, one for completely clear sky conditions and one for completely overcast conditions. Then, an interpolation was made between the two in proportion to the amount of cloudiness.

For a comparison of calculated values with the corresponding satellite measurements some difficulty arises because the calculated values are representative for Canton Island while the satellite measurements are averaged over a 5 degree latitude-longitude square. Thus, the comparison is valid only when clouds are uniformly distributed over the entire square. From the analyzed daily composite long-wave radiation maps there were four days in which large gradients of radiation values appeared in the Canton Island area. For these days the calculated values adjusted for cloud amount are uncertain.

One can see from the results, which are given in Table I, that the adjusted calculated radiation values fluctuate considerably from February to June with no apparent decrease with time. In fact, days with highest values occurred in May and June. For the corresponding satellite measurements there is agreement with the calculated values on the first day after launch. Thereafter the satellite measurements decrease, with the ratios of the satellite measurements to the calculated values being around .88. The large differences present on February 16 and 18 are probably due to extensive cloudiness south of Canton Island but located within the 5 degree square. A sharp increase in cloudiness to the south of Canton Island was indicated by a strong gradient of radiation in the TIROS IV daily composite radiation maps. Although this data sample is very small, it tends to indicate that degradation occurred within February and possibly early March and leveled off in the following months.

Correction Factor

In the preceding discussion, the long-wave radiation measurements were found to degrade with time. A definite decrease in the data was apparent for radiation values obtained from averages over the entire composite map and from individual grid points. Day-to-day fluctuations in the daily composite map averages were attributed to spatial and temporal variations in the geographical areas sampled, while the general decrease which occurred in February and March was due to degradation.

To adjust the TIROS IV channel 2 measurements for degradation, a correction factor was derived. First, the standard deviations of the daily averages from the composite maps were computed to determine if the degradation correction should be an addition factor or a multiplying factor. The results of the computations indicated that there was some correlation between the radiation measurements and their variance (fig. 6). That is, large variances in the radiation measurements occur with high values of radiation. A linear regression equation computed for the variation of the standard deviation with time was found to be

$$\sigma = .0420 - .000023t \qquad (3)$$

where t is expressed as days after launch. Using equation (3) one finds that the ratio of the standard deviation on any day in the initial period to one occurring later is equivalent to the ratio of the average radiation values for the same times. Therefore, a multiplying factor for the degradation correction is a better approximation than an addition factor.

Table I. Comparison of outgoing long-wave radiative flux (ly./min.) from TIROS IV, channel 2 measurements with calculated values for an area over Canton Island.

Date	Satellite Measurement	Calculated Value Clear	Calculated Value Cloudy	Cloud Cover	Adjusted Calculated Value	
1962	F_s	F_t	F_c	(%)	F	F_s/F
Feb 8	.406	.414	.390	10	.412	.99
Feb 14	.370	.408	.384	25	.402	.92
Feb 16	.350	.413	.392	10	.411	.85+
Feb 18	.350	.411	.390	25	.406	.86+
Feb 23	.385	.414	.396	25	.410	.94*
Feb 25	.370	.414	.382	50	.398	.93*
Mar 20	.360	.425	.397	25	.418	.86*
Apr 1	.355	.412	.376	40	.399	.89
Apr 23	.345	.410	.377	50	.394	.88+
May 3	.360	.406	.383	25	.400	.90
May 7	.350	.404	.383	25	.399	.88+
May 25	.370	.428	.385	25	.417	.89
Jun 4	.365	.424	.394	25	.416	.88*
Jun 7	.365	.421	.387	25	.412	.88
Jun 12	.360	.431	.393	60	.407	.88*
Jun 28	.365	.420	.388	10	.417	.87

*** Cases with radiation data population less than 20**
+ Cases with large gradients of radiation in Canton Island area

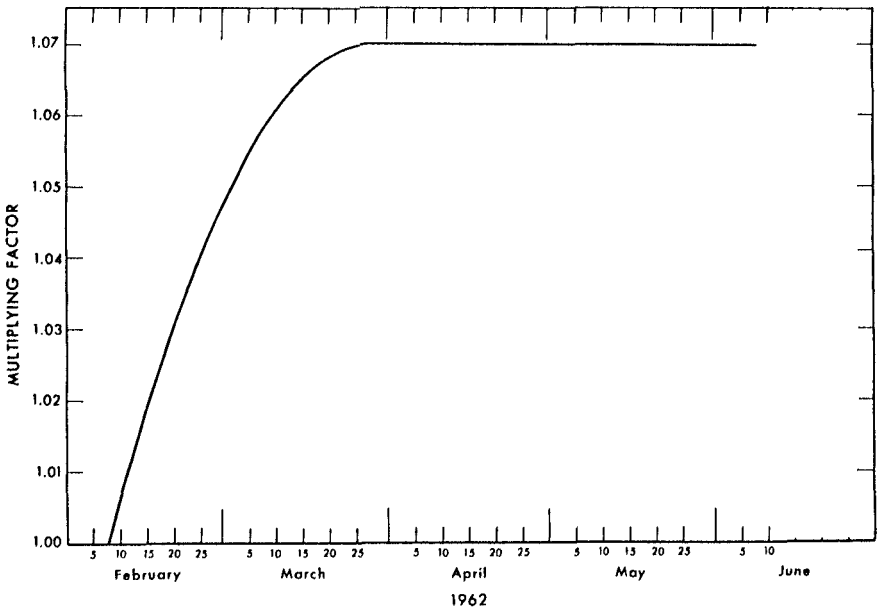


Figure 9. Correction factor for degradation of TIROS IV outgoing long-wave radiation measurements.

The second step was to determine the value of the multiplying factor to be used for the degradation correction. This was obtained by smoothing the daily average values shown in figure 6 (upper curve) and using the following ratio

$$C = R_I/R_s \tag{4}$$

where R_I is the daily average value from the composite map (.336 ly./min.) on the first day after launch and R_s is a smoothed daily average value for the day on which the correction factor is to be applied. To correct for degradation, for any given day the radiation value is multiplied by the corresponding value of C which is given in figure 9.

V. CONCLUSION

An attempt has been made to derive correction factors for channels 2 and 3 on TIROS IV. The results found from a comparison of the channel 3 measurements with aircraft albedo measurements indicate the satellite values should be corrected by a factor of approximately 1.33. This correction appears to give reasonable results when applied to individual grid points on the composite radiation maps, but seems to be too small to allow for balancing of the outgoing long-wave radiation when the grid points are summarized to obtain a quasi-global average albedo [12].

The correction factor for channel 2 was found by smoothing the daily averages of outgoing radiation and comparing them with measurements made on the first day after launch. A value of 1.07 was found for the channel 2 measurements made after March.

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