METEOROLOGICAL RESULTS FROM MULTISPECTRAL PHOTOMETRY IN AIRGLOW BANDS BY THE OGO-4 SATELLITE

GUENTER WARNECKE
EDITH I. REED
WALTER B. FOWLER
EARL R. KREINS
LEWIS J. ALLISON
JACQUES E. BLAMONT

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GODDARD SPACE FLIGHT CENTER
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Guenter Warnecke*
Planetary Radiations Branch
Goddard Space Flight Center

Edith I. Reed
Astrophysics Branch
Goddard Space Flight Center

Walter B. Fowler
Astrophysics Branch
Goddard Space Flight Center

Earl R. Kreins, Major, USAF**·
USAF Environmental Technical Applications Center
Washington, D. C.

Lewis J. Allison
Planetary Radiations Branch .
Goddard Space Flight Center

Jaques E. Blamont
Centre National de la Recherche Scientifique
Paris, France

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*On leave from Freie Universität Berlin, Germany, as a National Academy of Sciences - National
Research Council Senior Postdoctoral Resident Research Associate with the National Aeronautics
and Space Administration
**Air Weather Service member temporarily attached to Goddard Space Flight Center

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ABSTRACT

The presence or absence of clouds, an indication of cloud top heights,
and variations of surface albedo have been correlated with observations made
at several different wavelengths in the visible spectrum. These were made at
night, with and without moonlight, by an airglow photometer aboard the OGO-4
satellite during August 1967 through January 1968. The wavelength regions
studied were approximately 50A bands centered at 3914A, 5577A, 5893A, 6225A,
and 6300A, and in the energy range of 10^{-7} to 10^{-3} ergs $cm^{-2}sec^{-1}$ A^{-1} $ster^{-1}$.
It was found that observations at 3914A outside the auroral zone were strongly
influenced by light returned through Rayleigh and Mie scattering in the lower
atmosphere and the presence of high clouds, but were only slightly sensitive to
changes in surface albedo. At longer wavelengths, Rayleigh and Mie scattering
become less important and variations in surface albedo and presence of low
clouds are readily apparent.

The radiance measurements in one of the longer wavelengths in conjunction
with the ratio between this longer wavelength radiance and that at a shorter
wavelength make it possible to determine cloud amount and cloud top heights

from the multi-channel photometric measurements. Measured ratios between radiances at 5577A and 3914A varied from 1.0 for scattered low clouds over ocean, to 2.7 for opaque high clouds, both in moonlight. Respective changes without moonlight were from 4.0 to 8.5. This technique has a high potential for meteorological applications in providing cloud information on the night side of the earth.

METEOROLOGICAL RESULTS FROM MULTISPECTRAL

PHOTOMETRY IN AIRGLOW BANDS

BY THE OGO-4 SATELLITE

1. INTRODUCTION

From August 1967 through January 1968, an airglow photometer aboard a
Polar Orbiting Geophysical Observatory (OGO-4) observed the night side of the
earth in a number of different wavelengths in the visible spectrum. It was flown
for the purpose of studying airglow, a luminescence of the atmosphere dimly visible
to the naked eye. Besides the light from the airglow, three photometers unavoidably
also observed the light emitted by various other natural and artificial sources,
such as aurora and city street lights, and in addition, the moonlight, starlight,
and zodiacal light, reflected from the cloud covered earth. A careful study was
made of these nighttime observations to determine their usefulness in detecting
the presence and absence of clouds, cloud top heights, and surface albedo.

Hitherto, satellite observations of the nightside for meteorological pur-
poses have used only infrared techniques, although the Mercury and Gemini
astronauts were able to discern clouds under no-moon conditions (Dunkleman,
1968). The cloud mapping by Nimbus High Resolution Infrared Radiometer
(HRIR) measurements was a decisive step in the development of a meteorological
observation system from space. Although infrared measurements can be used
to infer cloud top altitudes from the derived cloud top temperatures, measure-
ments in the visible part of the spectrum also should, at least theoretically
provide both cloud coverage and cloud top heights. Suomi and Parent (1968) sug-
gested the evaluation of cloud pictures taken in three different spectral regions

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of the visible by the ATS-III Multi-Color Spin Scan Cloud Camera to derive cloud top heights at least near the terminator. The OGO-4 airglow experiment with its high sensitivity and much narrower spectral bandwidth provided, however, data which allow one to explore the possibilities of deriving cloud coverage and cloud top altitude information from multi-spectral measurements in the visible, even under nighttime conditions, from satellite altitudes.

2. THE AIRGLOW EXPERIMENT

The OGO-4 Main Body Airglow Photometer was a multi-channel instrument which observed in the nadir direction with an aperture of 10 degrees. This corresponds to a field of view at the surface of the earth of between 71 km at the perigee of 408 km to 159 km at the apogee of 908 km. Radiances between 10^{-7} and 10^{-3} erg cm^{-2} sec^{-1} A^{-1}ster^{-1} could be measured with a relative accuracy generally better than 20%. The absolute accuracy is comparable and is based on photometer calibration prior to launch. Preliminary checks show that the variations in sensitivity after launch were small and were neglected for the purposes of this paper. The cycle of measurements was eight seconds, corresponding to approximately 0.5° latitude of spacecraft motion. A brief description of the instrument is given by Reed and Blamont (1967).

The five filters at visible wavelengths were each approximately 50A in bandwidth and were centered at wavelengths of particular significance for airglow studies. They are as follows, ranging from the blue end of the spectrum to the red:

3914A The second positive system of N_2^+ characteristic of aurora. Outside of the auroral regions weak Herzberg and Chamberlain bands are within the bandwidth of this filter.

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5577A   The forbidden green line of atomic oxygen.

5893A   The yellow sodium doublet at 5890A and 5896A.

6225A   For background determination. OH emissions in this interval are

  sometimes quite strong.

6300A   One of the forbidden red lines of atomic oxygen.

These emissions all originate at altitudes ranging from 60 to 1000 km.

3.   THE METEOROLOGICAL SIGNIFICANCE OF THE EXPERIMENT

3.1 Theoretical considerations

Looking directly toward the earth at nighttime in the described portions of

the visible spectral region, radiation from the following sources will be detected:

airglow $A(\lambda)$, reflected airglow $\alpha(\lambda) A(\lambda)$, aurora $P(\lambda)$, reflected aurora $\alpha(\lambda)$

$P(\lambda)$, reflected moonlight $\alpha(\lambda) M(\lambda)$, reflected starlight $\alpha(\lambda) S(\lambda)$, and re-

flected zodiacal light $\alpha(\lambda) Z(\lambda)$. The spectral albedo, $\alpha(\lambda)$, is the radiant reflec-

tance of a lambert surface which gives a radiance identical to that measured.

It should be noticed, however, that the bidirectional reflectance of the earth

varies widely with the geometry of incident illumination and the albedo term is

an apparent albedo. The detected spectral radiance, $N(\lambda)$, can be repre-

sented by the following expression:

$$N(\lambda) = A(\lambda) + P(\lambda) + \alpha(\lambda) \ [\overline{A}(\lambda) + M(\lambda) + \overline{S}(\lambda) + \overline{Z}(\lambda) + \overline{P}(\lambda)], \qquad (1)$$

where λ is the wavelength and the bar indicates an observed radiance integrated

over the hemisphere. Average values for each of the components, as listed in

Table 1 (Roach, 1964), show that starlight and zodiacal light together are of the

Table 1

Typical radiances from nocturnal sources measured in 50A

spectral intervals (erg sec^{-1} cm^{-2} ster^{-1})

Source	3914 A	5577A	5890 A	6225 A	6300 A
$A(\lambda)$, continuum	3×10^{-6}	7×10^{-5}	1.2×10^{-5}	1.2×10^{-5}	3.0×10^{-5}
$M(\lambda)$, maximum	3×10^{-3}	6.9×10^{-3}	7.5×10^{-3}	6.6×10^{-3}	6.6×10^{-3}
$S(\lambda)$, $100s_{10}$ (vis)	3.6×10^{-6}	6.2×10^{-6}	5.9×10^{-6}	5.5×10^{-6}	5.4×10^{-6}
$Z(\lambda)$, $200s_{10}$ (vis)	7.3×10^{-6}	1.2×10^{-5}	1.2×10^{-5}	1.1×10^{-5}	1.1×10^{-5}
$P(\lambda)$	highly variable				

same order of magnitude as airglow, but moonlight generally exceeds all the

other components by up to several orders of magnitude.

In the case of no moonlight ($M = 0$) and outside the auroral zone ($P = 0$),

equation (1) reduces to

$$N(\lambda) = A(\lambda) + \alpha(\lambda) \ [\overline{A}(\lambda) + \overline{S}(\lambda) + \overline{Z}(\lambda)] . \qquad (2)$$

It can be seen that the variations in airglow which can be observed are limited

by the variations in albedo and the accuracy to which integrated radiances of

starlight and zodiacal light can be estimated. The expression can be further

simplified by noting that the integrated starlight, $\overline{S} (\lambda)$, and the integrated

zodiacal light, $\overline{Z} (\lambda)$, are nearly constant. Then we are left with only two vari-

ables,

$$N(\lambda) = f (A(\lambda), \ \alpha(\lambda)) .$$

Since along the orbit of a satellite or, generally, in any horizontal distribution, the horizontal variation of airglow will very likely be of a much larger scale than the changes of background albedo due to cloud patterns and structural differences on the earth surface, measurements of N (λ) in space and time will to a high degree reflect changes in albedo. Thus outside the auroral zone and even in the absence of moonlight it is possible to distinguish different reflectors, for example, to detect clouds.

In the case of moonlight, outside the auroral zone, equation (1) reduces to

$$N(\lambda) = A(\lambda) + \alpha(\lambda) \, [\overline{A}(\lambda) + M(\lambda, m, \nu) + \overline{S}(\lambda) + \overline{Z}(\lambda)] \, ,$$

where m is the moon phase, and ν is the lunar elevation angle. Considering the relatively small magnitude of all the other components if compared with the moonlight (Table 1), it follows that, except near new moon, the measured radiance is overwhelmingly controlled by reflected moonlight and therefore by the variations in background albedo.

The incident moonlight can be computed from the lunar phase and the effects of zenith angle vary slowly and in a predictable manner. N (λ) then becomes a measure of albedo, i.e.,

$$N(\lambda) = f(\alpha(\lambda)) \, .$$

This spectral albledo, $\alpha(\lambda)$, is a composite of the albedos of the surfaces within the field of view and includes the earth's surface, clouds, and the effects of scattering in the lower part of the atmosphere due to dust and atmospheric

molecules. Typical values of the reflectance of various natural surfaces are given in Table 2.

Table 2

Examples of reflectance values of some
natural surfaces at 5577 Å

Surface	Spectral Reflectance	Reference
Water surface	0.05	Krinov, 1947
Green grass	0.10	Kondratiev et al, 1963
Sand dunes	0.30	Krinov, 1947
Clay or limestone	0.62	Krinov, 1947
Cloud	0.72	Novoseltsev, 1964
Snow	0.75	Krinov, 1947
Snow	0.82	Kondratiev et al, 1962

Scattering and thin clouds have the dual effects of having an effective albedo and of reducing the transparency of the atmosphere. Plass and Kattawar (1968) indicate that the albedo of the atmosphere due to scattering alone at 4000A is between .18 and .60, depending upon the zenith angle of the source of light. Since only a portion of the light reaches the earth's surface, and only a portion of this is able to again reach the top of the atmosphere, the changes in surface albedo, for this short wavelength, have a relatively small effect on the observed spectral albedo. However, most of the scattering takes place near the earth's surface (half of the atmosphere is below 5 kilometers) and clouds at the higher levels are increasingly important in determining the observed albedo. By comparison at 7000A, scattering is less important; Plass and Kattawar indicate that the

albedo due to scattering from the atmosphere is between .04 and .36, the latter

value being for the source only 6 degrees above the horizon. Hence for the

longer wavelengths, the atmosphere is more nearly transparent and the earth's

surface and low clouds cannot be distinguished from the high clouds by the

observed albedo.

To make a quantitative estimate of the effect of the atmosphere, Figure 1

was constructed from the results of Plass and Kattawar (1968). This was done

by using the bidirectional reflectance which is a function of both the source and

observer angles. By the reciprocity theorem of Helmholtz, the source and re-

ceiver can be interchanged. Since we are interested only in the plane of incidence,

we can then use the data given by Plass and Kattawar to find the radiance which

should be received by an observer at zenith from a source at various elevation

angles. For the purposes of this computation the radiances of the source at

4000A and 7000A were assumed equal and the ratio received by the observer was

plotted for the various surface albedos. If there were no atmosphere, the radi-

ance received would be independent of the wavelength and equal to 1.0.

From Figure 1 it is to be noted that one of the limits to the usefulness of

multi-spectral photometry depends on the nature of the surface. If it is flat and

of high albedo (greater than about 0.5) then the observed albedo at either 4000 or

7000A depends only slightly on the presence or absence of an intervening

atmosphere. Hence high clouds can hardly be distinguished from low-lying sur-

faces which have a high albedo such as snow, sea ice, fog, or very low cloud

decks. But if the surface is uneven and the elevation angle of the light source is

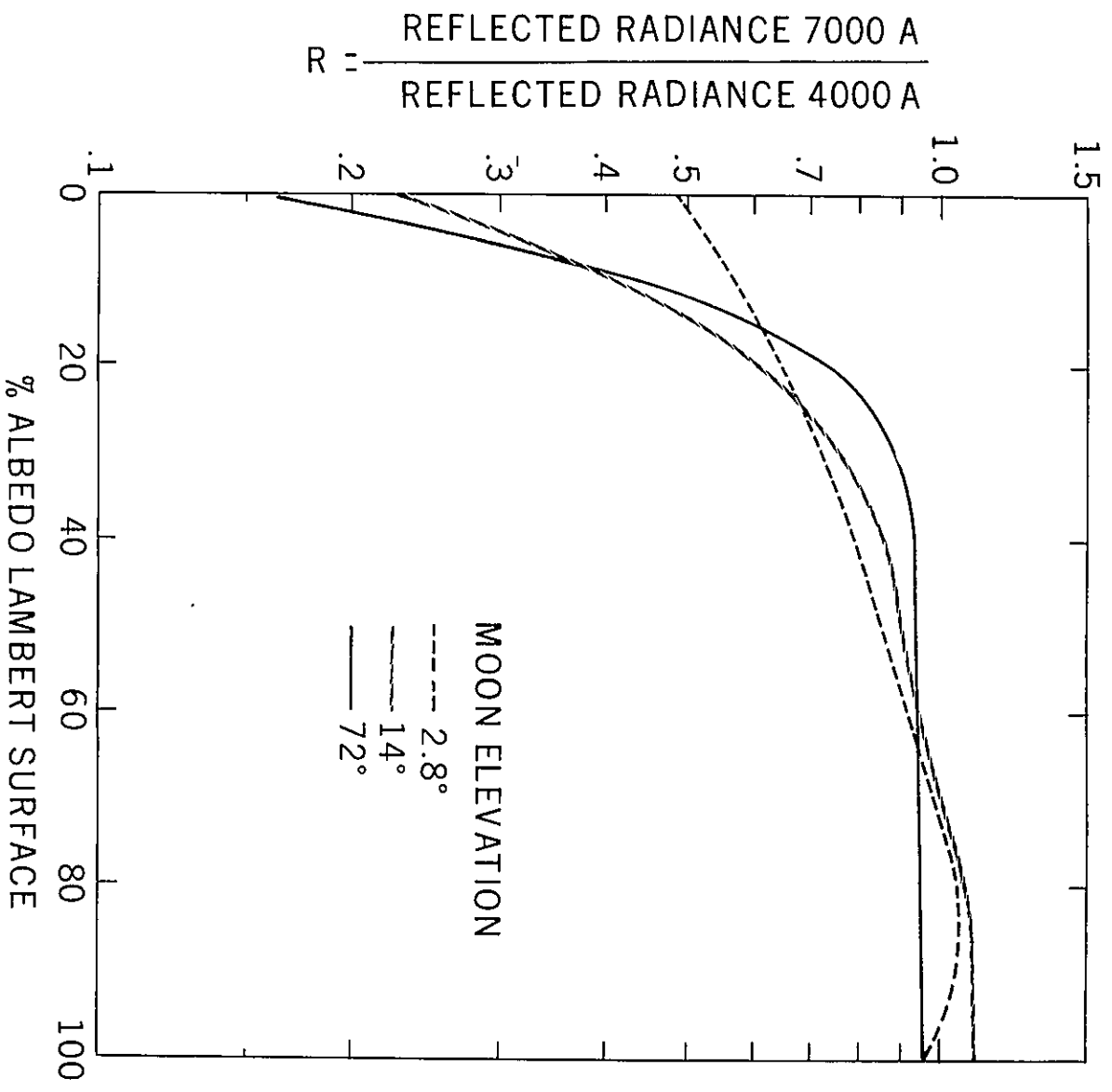such that a considerable portion of the surface is in shadow, then its effective

Figure 1—Effect of the intervening atmosphere on the spectral radiance observed from a satellite as a function of the albedo of the earth's surface. In the absence of the atmosphere, the color ratio is equal to 1.0 for all albedos.

albedo is lowered and the observed albedo does depend on the presence or absence of an intervening atmosphere. This makes it possible to estimate the height of cloud decks which have a non-uniform upper surface.

The data available confirm this, in that the arctic regions have a uniformly high observed albedo similar to that of the high cloud decks of the tropics. We did not find any observations, thus far, of low stratus clouds or ground fog that could be confirmed by surface observations.

From these theoretical considerations it can be concluded that at some lunar elevation angles multi-spectral measurements of the outgoing terrestrial and atmospheric spectral radiance in reflected visible light should provide two-parameter information on the nature of reflecting surfaces. Differences in albedo make it possible to distinguish, under clear skies, between different kinds of terrain, while color ratios, $R = N(\lambda_2)/N(\lambda_1)$, should provide a measure for height discrimination in the case of thick clouds. In the case of scattered or thin (partially transparent) clouds in the field of view of the photometer, the absolute value of the measured radiance as well as the color ratio will be reduced, and the measurement should fall between the clear-skies and overcast curves in a (N,R) space.

3.2 Experimental Results

Data from three OGO-4 orbits have been selected for this publication covering cases of new moon and full moon primarily over Africa, where a large variety of terrestrial and cloud conditions along the meridional satellite track could be expected, and also over oceanic regions, where the background is comparably homogeneous.

Data obtained over arctic regions, not presented herein, indicate that the albedo is high in all wavelengths, and the observed variations are generally less than 20%. However, by a more careful study than has been done so far, it may be possible to relate these variations to cloud cover over a snow or ice background.

3.2.1 No-moonlight Case

On orbit 507, 1 September 1967, OGO-4 on its near-midnight passage went southward along 21.9°E across the Mediterranean Sea, passed the North African coast near Marsa Susa, Libya, and flew over large sections of cloudfree Sahara Desert and finally passed over tropical cloud systems in Central Africa. Figure 2 is an ESSA-5 television view of this area about twelve hours later. It is a reasonable assumption that the cloud distribution in this photograph is fairly representative for the time of the OGO-4 overpass. The airglow measurements of three channels are reproduced in Figure 3.

The channel centered at 3914 A does not show any significant response to surface features like the Mediterranean coast with its remarkable change in albedo between the dark ocean and the bright desert which is very prominent in the satellite television picture. South of 16°N, however, a pronounced increase in the 3914A radiance coincides with an extended tropical cloud system of variable density and cloud top altitudes. Over these clouds the radiance increased by an average factor of 2.0 from the clear zone. At longer wavelengths, 6225 A and 5577 A, the coastline is indicated by increases in radiance by 1.8 and 1.5, respectively, and both the channels show continuously high values over the desert areas. A further increase by factors of 2.6 and 2.9, respectively, was observed over the tropical cloud systems previously mentioned.

ESSA-5
PHOTOGRAPH
1 SEP 1967
13 GMT
ORBIT 1699

OGO-4

40N — 40N
30 — 30
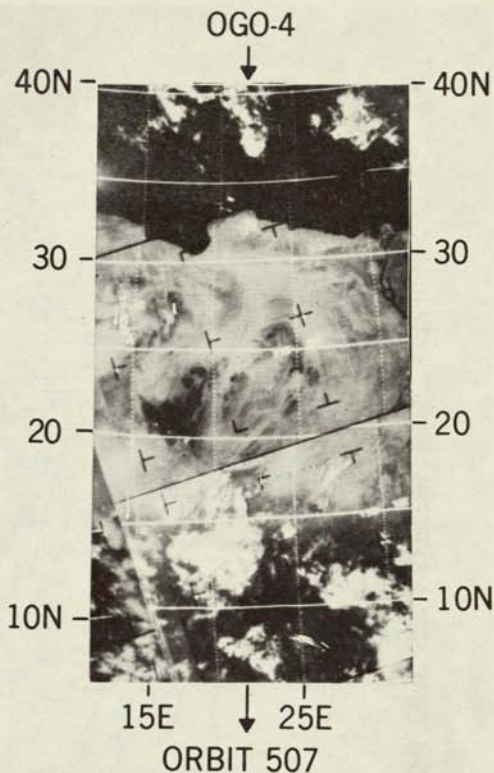20 — 20
10N — 10N

15E 25E
ORBIT 507

Figure 2—Path of OGO-4 orbit 507 (indicated by arrows) superimposed on photographs from
the ESSA-5 satellite. Latitude and longitude are indicated at the edges of the picture.
These photographs were made about 12 hours after the OGO-4 data presented in Figure 3.
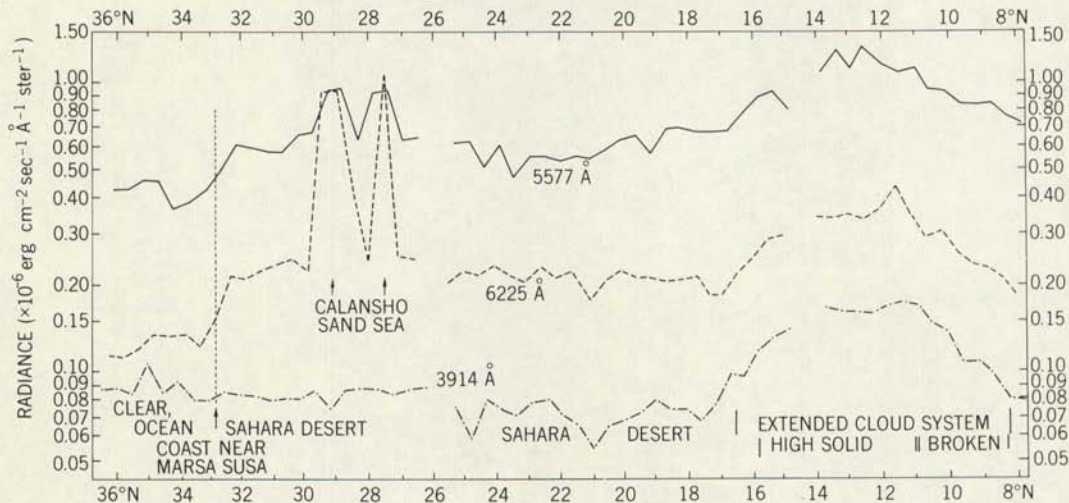
Figure 3—Observed radiance as a function of geographic latitude.

This example clearly show that without illumination by moonlight the combined intensities of reflected airglow, reflected starlight and reflected zodiacal light are sufficient for a unique differentiation between clear and cloudy regions; they do significantly show terrestrial features like brightness differences between sea and desert land. The different response of the three channels to surface features (coast line) and clouds obviously makes possible, even under the most unfavorable condition of the absence of moonlight to discriminate cloudy and clear areas.

An originally mysterious singularity in the airglow measurements shown in Figure 3 occurred between 27° and 30°N in the area of the Calansho Sand Sea, where two very strong peaks in the radiance recorded in the 6225A channel were observed. The fact of no noticable concurrent variation in the 3914A channel suggests a surface phenomenon. It appears that the photometer sensed the incandescent outdoor lights and burning of excess natural gas in the oil fields newly exploited in this area.

3.2.2 Moonlight Cases

On 20 August 1967 OGO-4 on orbit 331 passed along 26°E southward over Africa under near full moon. Moon elevations increased from 13° at 40°N to 27° at 5°S. The ESSA-5 photograph taken 12 hours later and reproduced in Figure 4 shows again clear skies over large parts of the Mediterranean Sea and the North African deserts. Between 20°N and the equator, clouds of various horizontal and presumably different vertical extent were beneath the subsatellite track.
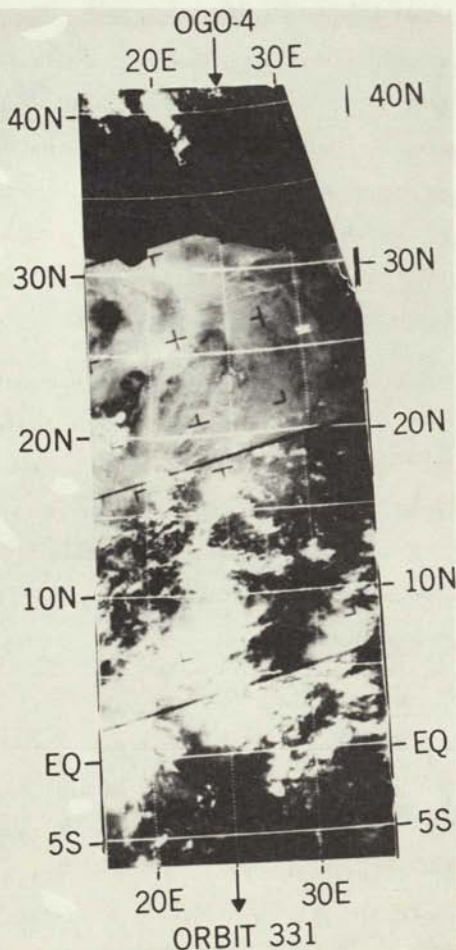
13

Figure 4—Path of OGO-4 orbit 331. These photographs were made about 12 hours after the OGO-4 data presented in Figures 5 and 6.

Figure 5 shows the radiance measurements of three of the photometer channels along the subsatellite track indicated on the ESSA-5 picture. Near 32°N where the satellite crossed the North African coast near Sidi Baran, Egypt, the 3914 A channel did not show any significant response to the drastic change in surface albedo and stayed almost constant across the Sahara Desert to 19°N. In the 5577 A and 6225 A channels the coast is marked by a rapid increase of radiance in both channels; the width of the transition zone corresponds to the field of view of the photometer. The peak values over the central desert are above the level measured over the clear ocean by factors of 2.1 for 5577 A and 3.3 for 6225 A. Of particular interest are the little peaks observed when passing over the Island of Crete which has a higher albedo than the surrounding water. The absolute values, however, do not reach those over the continent because the island at no time filled the field of view of the photometer.

An interesting fact demonstrating the sensitivity of the photometers is that the measured radiances immediately south of the North African coast and also near 23.5°N were considerably lower than over the surrounding desert regions. As can be seen from Figure 4, the desert north of 30°N actually exhibits a lower albedo due to darker sands. Around 23.5°N the satellite passes over the Gilf Kebir Plateau which consists of lithosols including brown, chestnut, and reddish colors and which even bears some mountain vegetation, both in contrast to the surrounding bare and bright desert sands. In the ESSA-5 photograph this plateau shows some cloudiness in the center which is of orographic origin and will certainly be dissipated during the evening hours. The drop in radiance certainly does not reflect the true albedo change because the plateau did not fill the field of view of the photometer.
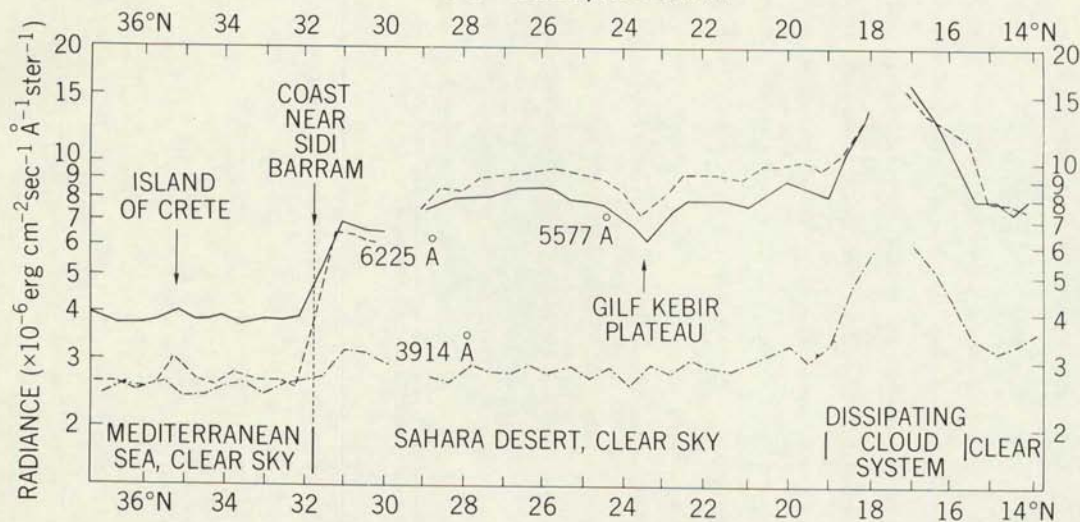
Figure 5—Observed radiance as a function of geographic latitude over the northern part of the region shown in Figure 4.

From 16° to 19°N high values in all three wavelength regions indicate the existence of high-reaching cloud systems which is confirmed by the ESSA-5 daytime photograph. Around 15°N the break in the cloud system, as shown in the television picture, is noticable in the photometer data near the Darfur Mountain where the apparent albedo is equal to that over the northern Sahara Desert (see Figure 6 which is the southward continuation of Figure 5). The cloud system detected south of 14°N and verified by the daytime photograph seems to increase in height toward the south as can be judged from the steady increase of the radiances measured in all three channels. The sharp southern boundary of the tropical cloudiness observed 12 hours later close to the equator (Figure 4) can be located near 3°N in the OGO-4 data. This difference is quite acceptable if one considers the structure of the tropical cloud systems exhibited in Figure 4 and taking in account the time difference between both the observations.

In the clear region between 2°N and 2°S the radiance measurements in the 5577A and 6225A channels show about 20% to 40% lower values than farther north over the clear desert, while the 3914A channel shows the same values as before. This indicates the photometer response to the lower albedo over the tropical rain forest of the Congo Basin in comparison with the brighter Sahara Desert.

Over the tropical cloud system the recorded radiances were higher by factors of 4.2, 6.7, and 8.5 in the 3914A, 5577A and 6225A channels, respectively, compared with the low values over the Mediterranean Sea. Only a small part of this change is due to the change in lunar elevation angle, which was not taken into account in the presented figures.
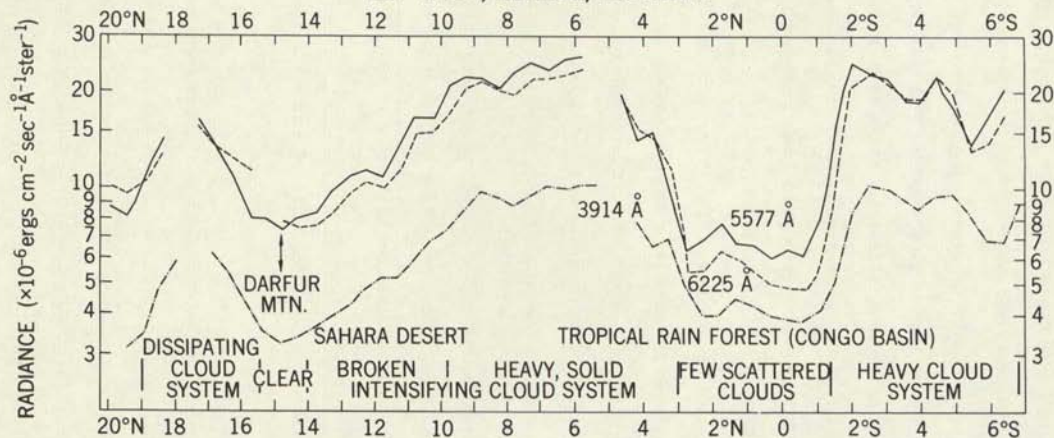
Figure 6—Observed radiance as a function of geographic latitude over the southern part of the region shown in Figure 4.

Farther south, the OGO-4 measurements responded to another tropical cloud system which was confirmed by satellite photographs not included in Figure 4.

As a second case, an observation over the South Pacific Ocean on 20 August 1967 was selected. The moon was nearly full and at an almost constant elevation of about 27 degrees. The analysis of the photometer measurements are shown in Figure 8; the corresponding daytime cloud photographs were taken from the ATS-1 satellite seven hours later (Figure 7) and from the ESSA-5 satellite (Figure 9) twelve hours prior to the OGO-4.

A narrow band of high clouds was overflown between 5° and 10°S, as indicated by the strong response in all three photometer channels. Clear skies seem to prevail between 11° and 17°S in accordance with Figure 7. South of 18°S extended cloud systems were overflown which can be identified as middle altitude cloud decks from the ESSA-5 pictures in Figure 9. These photographs were taken near sunset, i.e. under a very low solar elevation angle, thus lower clouds appear darker under the dimmer illumination than higher clouds, and differences can easily be distinguished, particularly between 25° and 30°S where higher cloud build-ups are very pronounced in the television photograph. The photometer measurements also responded to these cloud build-ups as shown by the recorded higher radiances in all three channels. A cloud break at 31° to 32°S, suggested by the drop in all three photometer measurements can be identified in the satellite photographs as a pre-frontal cloud break along a cold front that had just passed New Zealand. In the post-frontal area of cellular cold air mass convection, south of 37°S, the spectral radiances resumed the same values observed over the medium high cloud systems 15 to 20 degrees to the north.
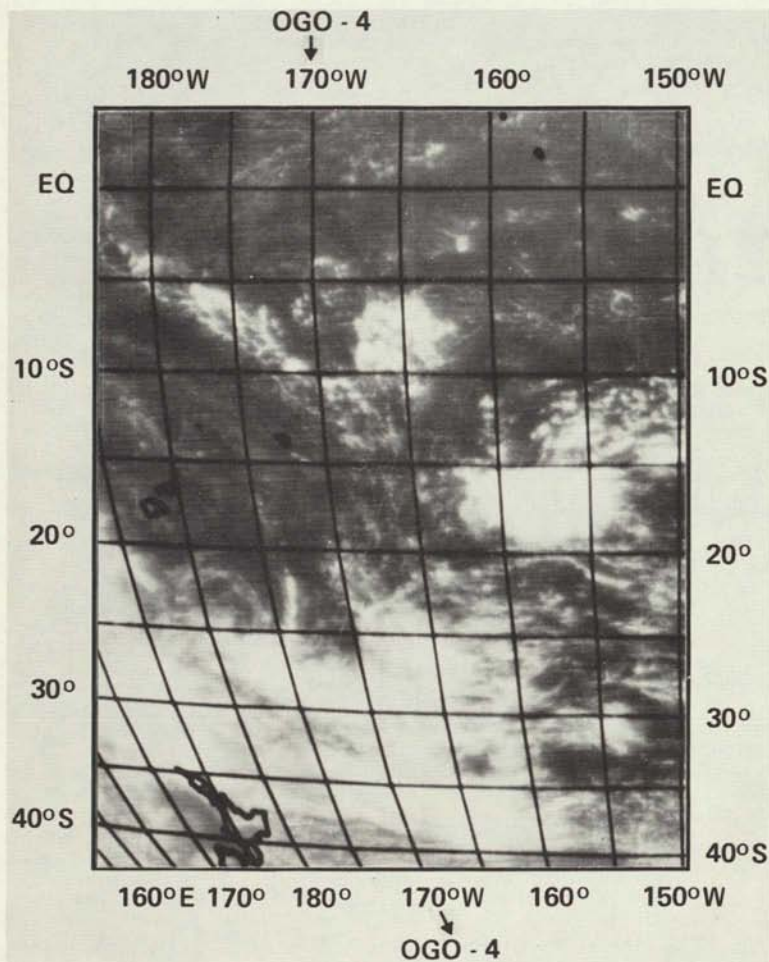
Figure 7—Path of OGO-4 orbit 339 superimposed on an ATS-1 satellite photograph of a portion of the Pacific Ocean taken about seven hours after the OGO-4 data presented in Figure 8.
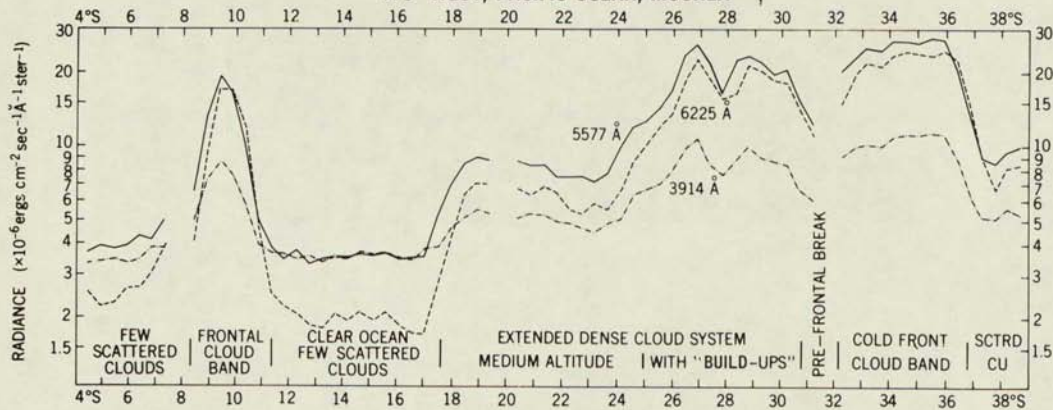
Figure 8—Observed radiance as a function of geographic latitude over the regions picture in Figures 7 and 9.

ESSA-5 PHOTOGRAPH 20 AUG 1967 ORBIT 1541 02 GMT ORBIT 1542 04 GMT

OGO-4

175W · 165W

10S · 10S
20S · 20S
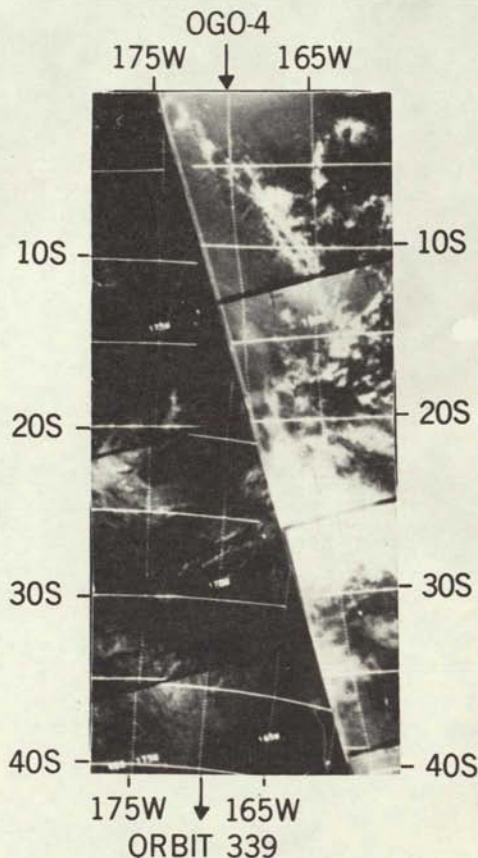30S · 30S
40S · 40S

175W · 165W

ORBIT 339

Figure 9—Path of OGO-4 orbit 339. These photographs were made about 12 hours
prior to data presented in Figure 8.

From these moonlight cases it can be concluded that because of the much stronger light source, albedo differences could be detected with even a better degree of separation than without moonlight. The behavior of different spectral intervals with regard to reflector altitude is very obvious and will be discussed in more detail in the next section.

3.2.3 Discrimination of Reflector Characteristics and Cloud Top Altitude by Color Ratio Differentiation

From the theoretical considerations and the discussion of the results in the foregoing sections it was suggestive to investigate in more detail the potential of multi-spectral photometric measurements for the derivation of cloud amount and altitude. OGO-4 moonlit orbits 331 and 339 on 20 August 1967 and orbit 507 without moonlight on 1 September 1967 over the Mediterranean Sea and Africa were selected for this purpose. Ratios between spectral radiances in different spectral intervals were computed for the data. Results of the 5577A/3914A ratio selected for a number of points of known nature of target were summarized and analyzed in Figures 10 and 11. The fact that the photometer channels are interrogated in sequence and therefore the measurements were not exactly for the same target was considered as insignificant because of more than 95% overlap of the field of view between the 5577A and 3914A channels.

Under clear sky conditions and in the moonlight case (Figure 10), the ratios of 5577A to 3914A radiance ranged from 1.0 to 3.0 from the dark ocean, over tropical rain forest, grass land to bright Sahara desert. The same range of ratios was covered by scattered or thin cloudiness over these same kinds of terrain, although the spectral radiances of the 5577A channel were higher,

RADIANCE OF EARTH AT 3914Å AND 5577Å OBSERVED BY
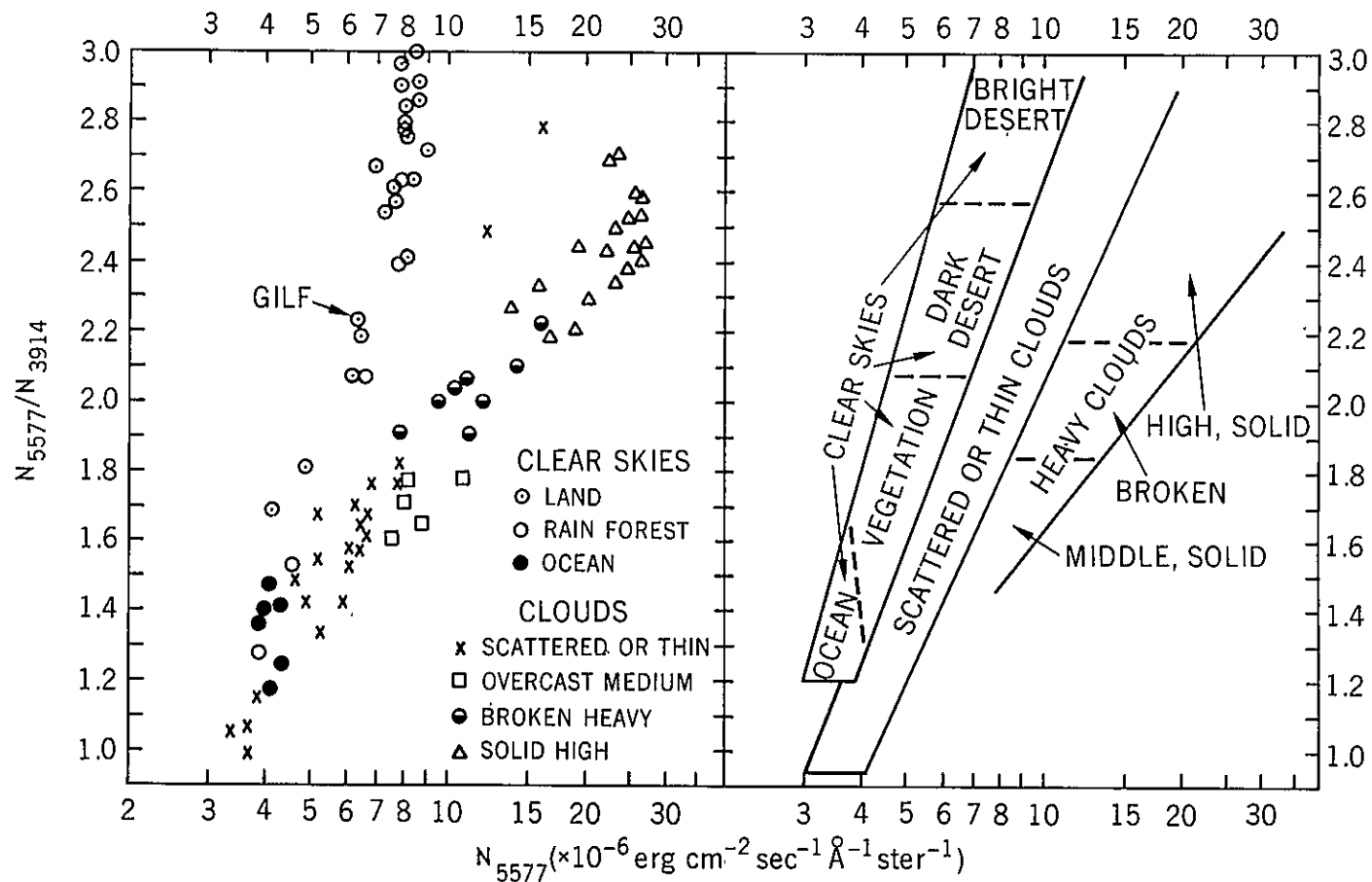# OGO-4, MOONLIT ORBITS 331 AND 339   20 AUG 1967

Figure 10—A plot of the color ratio for 5577A and 3914A of the reflected moonlight as a function of the observed radiance at 5577A. The right half of the figure is an interpretation of this (N,R) space.

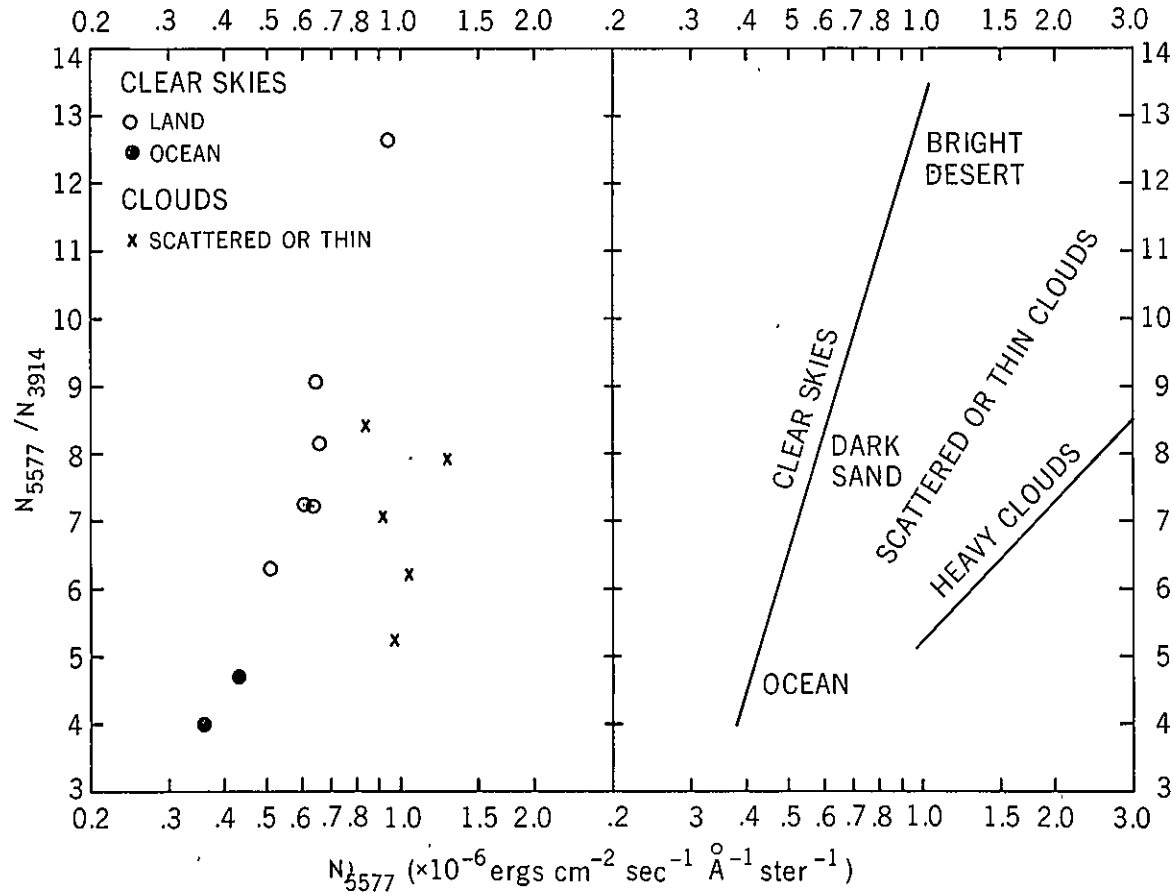## RADIANCE OF EARTH AT 3914A AND 5577A OBSERVED BY OGO-4, NIGHT, NO MOONLIGHT, ORBIT 507, 1 SEPT 1967

Figure 11—A plot of the color ratio in the absence of moonlight as a function of the observed radiance and the corresponding interpretation of this (N,R) space.

because of the cloud contribution, than under clear sky conditions. The increase of contribution in the 5577A channel is also true with gradually increasing cloud amount. Under overcast conditions, a clear distinction could be made between middle and high cloud tops. However, no low stratus overcast was contained in the selected data sample to allow comparisons with them.

In the no-moonlight case (Figure 11), the 5577A/3914A ratio was found to vary between 4 and 13 in the chosen sample. Although the number of different targets was small, the distribution of the data points within the (R,N) space appeared as organized as in the moonlight case (Figure 10). Therefore it seems to be evident that the photometric measurements in the visible airglow bands are capable, both with and without moonlight, of permitting the derivation of cloud amount and top altitude information, although the exact quantitative relationships have to be established by more extensive observations.

4. CONCLUSIONS

From this evaluation of OGO-4 photometric measurements for meteorological purposes it can be concluded:

1. the illumination of the nightside of the earth is sufficient, even in the absence of moonlight, to detect clouds and certain surface features under clear sky conditions;

2. the measurements are sufficiently sensitive to apply the technique of color discrimination in order to derive cloud amount and average cloud top altitude within the field of view.

For a meteorological application, some instrumental changes would be desirable, namely, the photometer should have a narrower field of view and a scanning device. Both requirements seem to be possible by present technology. An additional channel should be provided in a spectral interval containing only auroral emission (e.g. about 2970A), in order to detect and eliminate disturbed data.

The results presented in this report have been derived from a relatively small sample of data. However, it is believed that the results are qualitatively correct. Quantitative relationships between the three-dimensional cloud distribution and the multi-spectral photometric measurements have to be established statistically on the basis of a larger volume of data before this method would be quantitatively operational. It is hoped that a further study of the data over snow-covered regions will make it possible to interpret the observed variations in terms of surface ice or snow cover and clouds.

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