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MID-LATITUDE ROCKET OBSERVATIONS OF THE ALTITUDE PROFILE OF THE O_2 ($a\ ^1\Delta_g$ - $X\ ^3\Sigma_g^-$) TRANSITION

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GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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On November 19, 1968, a Nike-Apache was launched from Wallops Island, Va. at a launch elevation angle of 83°. The firing took place at 1:30 Pm local time, EST. The azimuthal launch angle was 100° from magnetic north while the sun lay at an azimuthal angle of 260° and a zenith angle of 57°. One of the experiments on board the payload was an infra-red radiometer designed to detect radiation from the O_2 $(a^1\Delta_g - X^3\Sigma_g^-)$ transition centered at 1.268μ.

The radiometer consisted of an uncolled PbS detector with a matching blackened PbS detector which was used as a load resistor in a voltage divider configuration in order to compensate for temperature drifts in the light sensitive detector (Welker, Jean and Jones, W. H.). Radiation was chopped by a wheel rotating at 75 cps which was located in front of the single optical system which consists of an f/1.0 lens. The chopper wheel was composed of two semi-circular interference filters mounted on a wheel rim and axle. One interference filter was centered at 1.268μ with a 100 Å half width for the transmission profile; the other filter was centered at 1.23μ with a 100 Å half width for the transmission profile and this second filter was to represent the background radiation. The radiometer was designed to detect radiation in the 0.5 to 10.0 Megarayleigh range and was mounted in the payload so that it looked out of the side of the rocket in a direction perpendicular to the cylindrical axis of the rocket.

Unfortunately, the tracking radar failed and the altitude determination could not be made directly as is usually the case. Rocket trajectory estimates were made using loss of telemetry signal, Faraday rotation data, trajectory calculations based on procedures developed in the Mercury Program which are based on actual rocket and payload configurations and launch tower angles used, and finally, the ionograms taken just prior to launch and immediately after impact. Trajectory data is judged accurate to within 2 km.

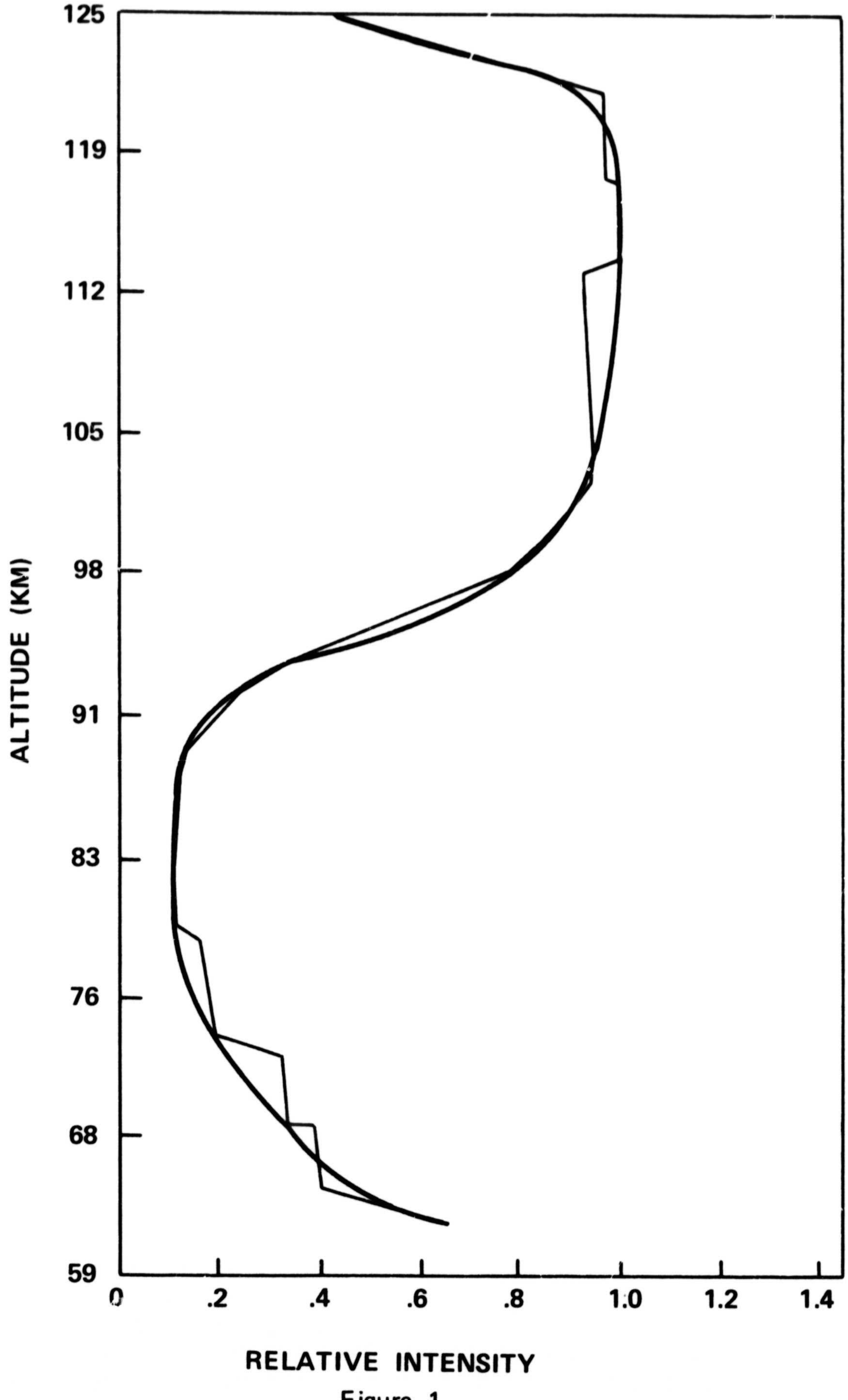
The viewing direction of the radiometer was unusual for radiometer of this type. Most radiometers are mounted in the mose of the rocket payload and look forward along the cylindrical axis of the rocket. Since the radiometer was pointed out the side in a direction perpendicular to the cylindrical axis of the rocket, more stringent requirements were placed on the frequency modulation functional characteristics of the radiometer. This radiometer accompanied a number of other experiments on the payload and space considerations alone dictated this viewing configuration. If the instrumental obstacles in the construction of the radiometer can be overcome, this unusual viewing direction presents some advantages. For example, in this flight, the side viewing configuration necessitated obtaining a reading every fifth of a kilometer which is a fine altitude resolution. Also, for regions of low radiation extinction, a layer of gases of a dimension of a few kilometers altitude which is emitting radiation would be more easily detected by side viewing direction.

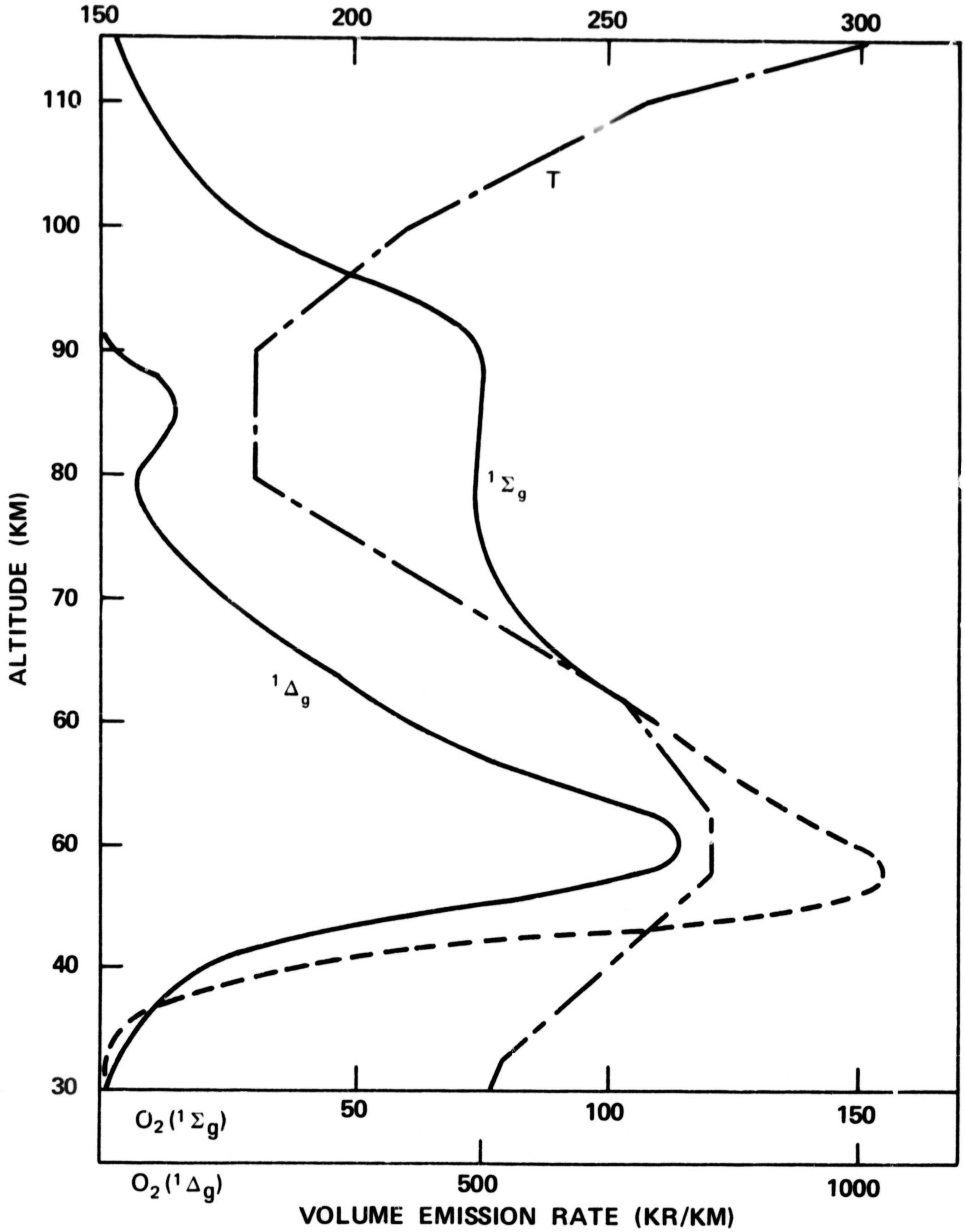
The rocket climbed at a rate of roughly 1 km/sec and spun at a rate of 5 cps. Therefore, the time taken for one spin of 360° was 200 millisecond and a spin occurred every fifth of a kilometer. During the flight, the radiometer looked in the direction of the sun, recorded a saturation signal, and recovered within its expected response time of 50 milliseconds or within 90° of the 360° spin angular rotation. In the remaining 150 milliseconds of the spin period, the radiometer responded to radiation signal lovels of the magnitude expected from the oxygen molecules in the atmosphere in the transition $O_2\left(a^1\Delta_g - X^3\Sigma_g^-\right)$.

A solar aspect sensor was located immediately above the infra-red radiometer viewing port and allowed an accurate determination of the point in the spin rotation of the rocket at which the radiometer saw the maximum solar signal. It also indicated the solar aspect angle between the normal to the radiometer viewing port and the solar direction. The rapid rotation of the spinning rocket producing first a viewing of the saturation signal in the sun's direction and then a recovery to the oxygen molecules emission radiance level effected a signal modulation with frequency which degraded the gain of the radiometer by factors of 2 to 4 times that of the original gain setting. This situation prevented an absolute determination of the magnitude of the signal irradiance.

As shown in Figure 1, the data begins in 50 km region where the maximum oxygen emissions has just passed its peak value. The second layer of radiation signal occurs in the 90 to 125 km region and is a thicker layer than would be expected under the atmospheric conditions which prevailed. At a considerable greater altitude but still short of apoge, the radiometer data became the irregular and it could be readily determined that the saturation signal produced initially by looking in the sun's direction remained for 20 or so milliseconds after the rocket spin had carried the radiometer and solar aspect sensor away from their more direct look at the sun. This siutation was even more exagerated on the downleg and thus prevented a cross-check on the upleg data in the 125 through 75 km region. A similar condition was similated in the laboratory on a duplicate radiometer and when the saturation signal remained on too long, signal level magnitudes of the response time of the radiometer. Below 75 km on the downleg, the spin became irregular and shortly thereafter, tumbling occurred. Data below 50 km on the ascent leg was unreliable because the rocket had not yet achieved the spinning, slowly coning characteristic motion which it maintained through the remainder of the upleg, through apoge, and down to 75 km.

Although there is no published profile for the $O_2\left(a^1\Delta_g - {}^3\Sigma_g^-\right)$ transition in the mid-latitude region for mid-November to which our data could be more closely related, we can question the meaning of our data in terms of what is known of other profiles. In the most recent discussion, (Evans, W.F.J. and Llewellyn, E.J., 1969), the point is made that in the fall season in a low latitude region, (Evans et al, 1968), the lower and upper regions of $O_2\left({}^1\Delta_g\right)$ emission begin to rise at 40 and 80 km respectively. See Figure 2.) Further, there is a correspondence between the lower level which begins at


125
119
112
105
98
91
83
76
68
59
ALTITUDE (KM)
0
.2
.4
.6
.8
1.0
1.2
1.4
RELATIVE INTENSITY
Figure 1



150
200
250
300
110
100
90
80
70
60
60
40
30
T
$^1\Sigma_g$
$^1\Delta_g$
ALTITUDE (KM)
$O_2(^1\Sigma_g)$
50
100
150
$O_2(^1\Delta_g)$
500
1000
VOLUME EMISSION RATE (KR/KM)

Figure 2

40 km and the increase in temperature observed in the same region since an increase in temperature due to absorption of ultraviolet energy by ozone would naturally occur in the production of $O_2\ (^1\Delta_g)$ from ozone decomposition.

Two other altitude profiles have been measured at high latitudes for summer conditions at Churchill, Manitoba. Both profiles show the lower region of high $O_2\ (^1\Delta_g)$ emission shifted upward in altitude by a few kilometers from the White Sands results. The upper altitude region of high $O_2\ (^1\Delta_g)$ emission of the Churchill results itself shows a great disparity in the thickness as well as an altitude variation from the morning and evening data. The evening peak has clear definition, is 8 or 9 km thick and begins at about 83 km. The late afternoon peak is poorly defined, some 17 to 18 km thick and begins at around 76 km. The White Sands results fall somewhere between these two extremes. (See Figure 3.)

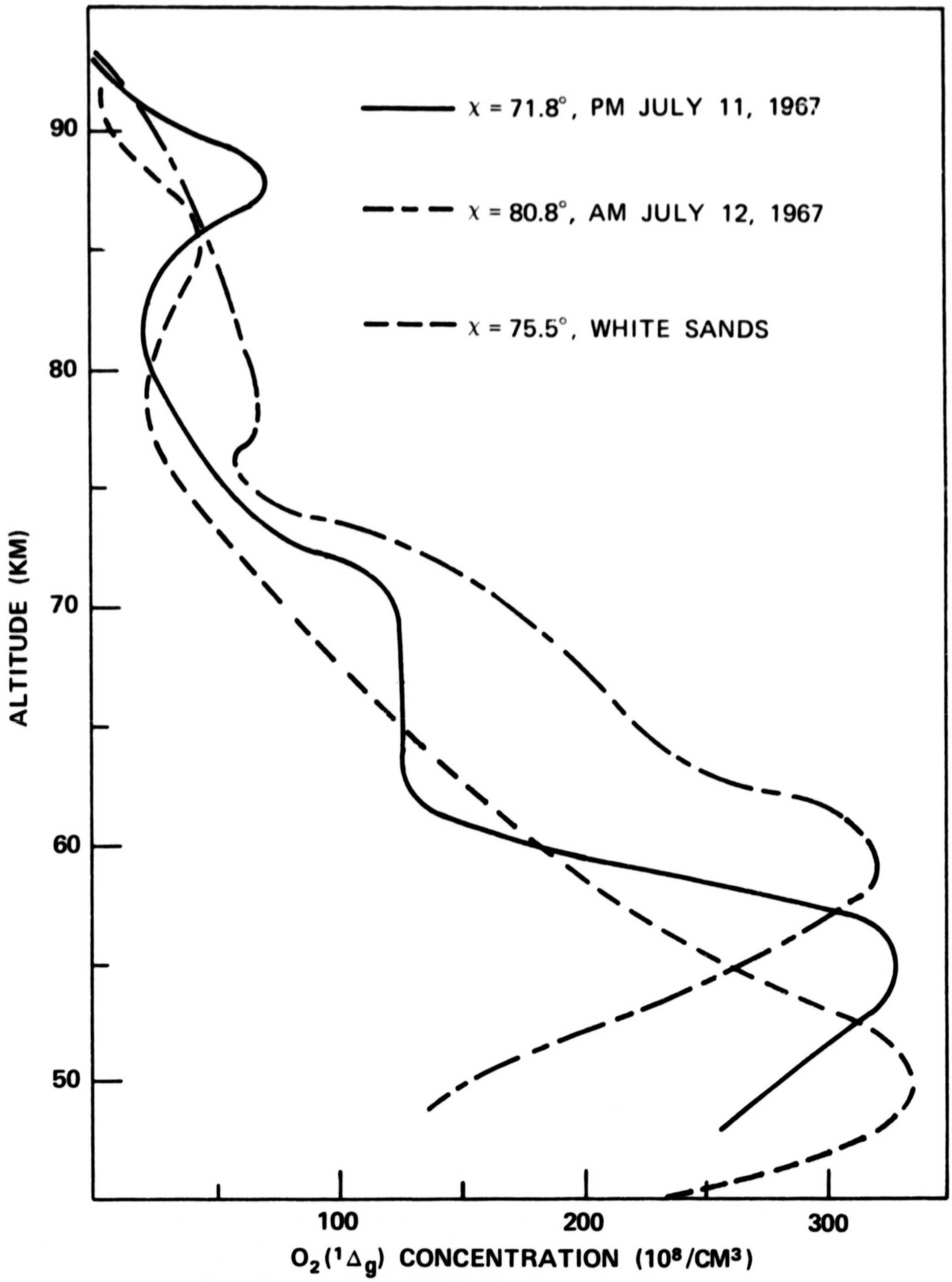
More recently, (Evans, W.F.J. and Llewellyn, E.J., 1969) quote unpublished data from H.C. Wood of altitude profiles under spring conditions again at high latitudes at Churchill, Manitoba. Again there is a great difference between morning and evening results and if anything, the upper emission layer is even thicker than the summer Churchill results, the thickness at evening being some 22 km. (See Figure 4.) As for calculations, most calculations show good agreement, loc. cit. Evans and Llewellyn, 1969, but they are for the lower altitude region of high $O_2\ (^1\Delta_g)$ emission and predicated on the ozone dependent reaction

$$O_3(^1A) + h\nu\ (2000Å < \lambda < 3100Å) \rightarrow O_2(^1\Delta_g) + O(^1D) \qquad (1)$$

These calculated profiles do not really explain the second layer of strong $O_2\ (^1\Delta_g)$ emission around 80 km where the reaction

$$O + O + M \rightarrow O_2\ (^1\Delta_g) + M \qquad (2)$$

is mentioned quite often, but this reaction does not completely explain away the upper layer loc. cit. Evans, Llewellyn Vallance Jones 1968. There is, however, one other argument which has been advanced by loc. cit. Evans and Llewellyn, 1969, which involves the photalysis reaction, equation 1. It claims that available evidence, though not conclusive, indicates the $O_2\ (^1\Delta_g)$ is produced by incoming solar radiation between 2660 and 3100A while $O_2(^1\Sigma_g^+)$ molecules are the result of radiation in the 2000 to 2600A range. An $O_2\ (^1\Sigma_g^+)$ profile is shown in figure 2 and the upper altitude region of high emission is some 40 km thick, which corresponds more closely to our own $O_2(^1\Delta_g)$ profile shape. If the conditions for absorption of the 2660 to 3100A wavelength range radiation should change, a thicker upper layer for the $O_2(^1\Delta_g)$ emission would be expected. Naturally, the way to test this possibility is to simultaneously monitor the $O_2(^1\Delta_g)$ and $O_2(^1\Sigma_g^+)$ emission altitude profiles in flight.



χ = 71.8°, PM JULY 11, 1967
χ = 80.8°, AM JULY 12, 1967
χ = 75.5°, WHITE SANDS
90
80
70
60
50
ALTITUDE (KM)
100
200
300
$O_2(^1\Delta_g)$ CONCENTRATION ($10^8/CM^3$)

Figure 3

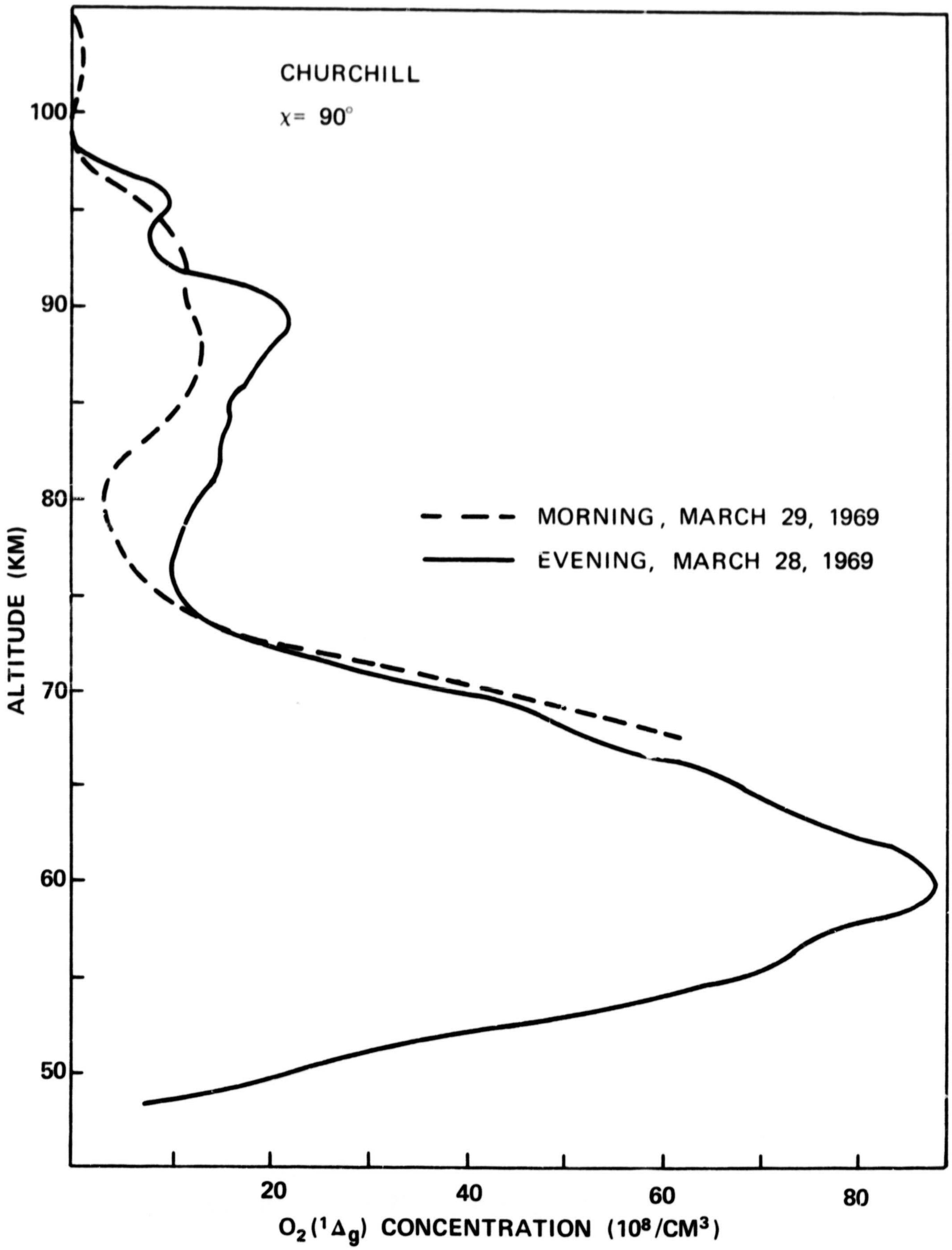

CHURCHILL
χ= 90°
MORNING, MARCH 29, 1969
EVENING, MARCH 28, 1969
100
90
80
70
60
50
ALTITUDE (KM)
20
40
60
80
O2(1Δg) CONCENTRATION (10^8/CM^3)

Figure 4

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