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DIURNAL VARIATION OF OZONE AT HIGH ALTITUDES

By

Jagir S. Randhawa

ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO

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ABSTRACT

A rocket-borne ozonesonde (self-pumping type) has been developed which utilizes the chemiluminescent principle for the detection of ozone concentration in the atmosphere. This has been flown with the ARCAS rocket at Fort Greely (64N), Alaska, during the day as well as at night. The results show large diurnal variations in upper stratospheric ozone and agree with the observations made at White Sands Missile Range (32N) with different rocket-borne ozonesondes (Sampling chamber). Results of soundings made at White Sands Missile Range with the self-pumping type instrument are also presented. Ozone concentrations found with these rocket-borne ozonesondes show higher values of ozone in the upper stratosphere than that predicted by oxygen photochemical theory.

CONTENTS

INTRODUCTION

Knowledge of the vertical distribution of ozone, an important constituent of the earth's atmosphere, has been considerably increased during the last couple of years, especially from data obtained by balloon-borne ozonesondes [Hering and Borden, 1964, 1965]. The chemiluminescent-type ozonesonde developed by Regener [1960, 1964] and the bubbler-type electrochemical ozonesonde developed by Brewer and Milford [1960] are being used extensively for detailed measurements of the vertical distribution of ozone. Recently, a rocket-borne ozonesonde [Randhawa, 1966 a], a self-pumping type utilizing the chemiluminescent principle for ozone detection, has been developed and flown with the ARCAS rocket at White Sands Missile Range (32°N), New Mexico, as well as at other locations.

INSTRUMENT

The ozonesonde (Figure 1) is deployed from an ARCAS rocket vehicle above the stratopause level. The sample bottle empties itself as it is carried to low pressures of high altitudes. Flow into the bottle results from the differential pressure as the instrument descends on a 15-foot diameter radar reflective parachute. Ozone in the environment flows over the chemiluminescent detector (silica gel plus rhodamine B), and the photons produced by the destruction of ozone molecules are monitored by the photomultiplier tube. The output signal is transmitted on a carrier frequency of 1680 megacycles and received at the ground by AN/GMD-1 equipment [Clark and McCoy, 1965].

In order to measure ozone concentration, the flow rate of air into the detector must be known. This flow rate can be expressed as

$$\text{Flow rate} = \frac{V_i T_a}{P_a T_i}\left[\frac{dP_i}{dt} - P_i \frac{d \ln T_i}{dt}\right]$$

where

V_i = Bottle volume

T_i = Air temperature inside the bottle

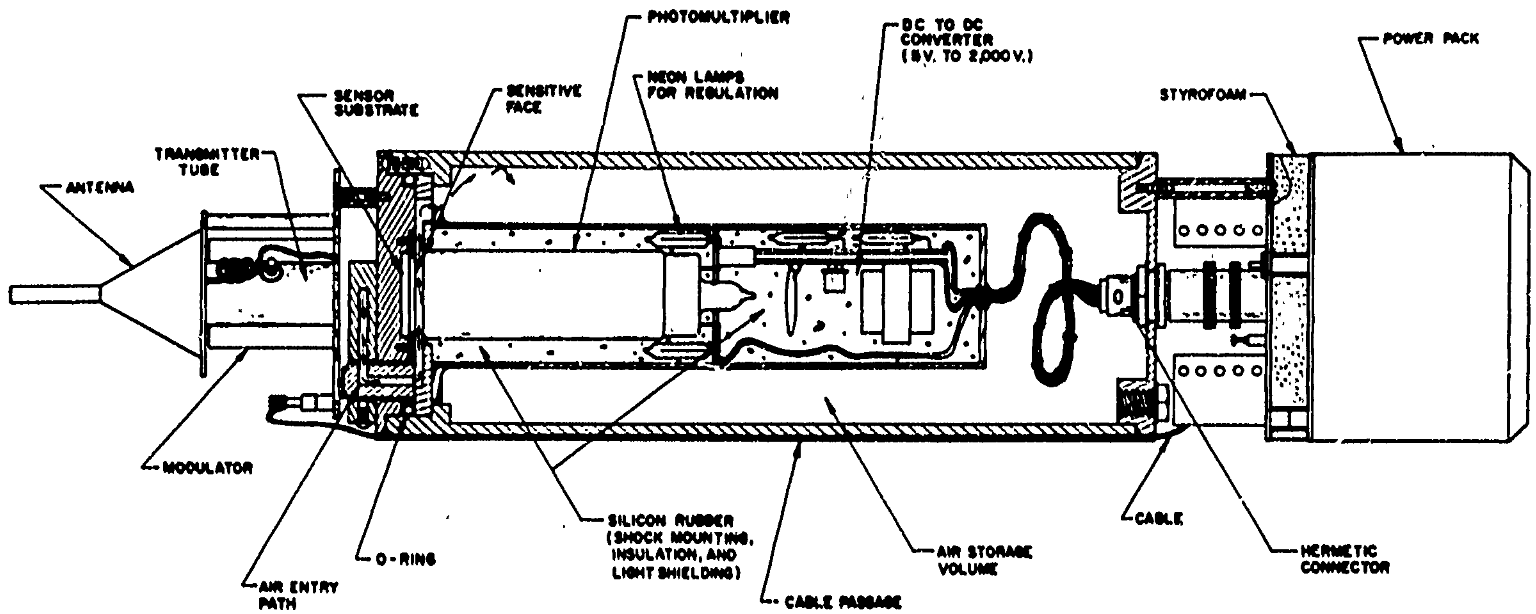

FIGURE 1. Schematic Diagram of Rocket-Borne Ozonesonde.

P_i = Pressure inside the bottle

T_a = Ambient external temperature

P_a = Ambient external pressure

t = Time

The above equation is derived from the equation of state for an ideal gas $Pv = nRT$.

The ozonesonde is calibrated before launch by the use of an ozone generator [Regener, 1964]; ozonized air of known concentration and flow rate is injected into the bottle, and sensitivity is set in the proper range.

DISCUSSION

This self-pumping rocket-borne ozonesonde has been flown at White Sands Missile Range (32°N), New Mexico, as well as at Fort Greely (64°N), Alaska. The firings at White Sands Missile Range were made during May, June and September 1966, and the firings at Fort Greely were in July and August 1966. The results of these firings are shown in Figs. 2 - 6. In all cases, the ozonesondes were deployed at or about 60 km altitude, and ozone concentration was measured down to approximately 10 km. The signal at the lower end of the descent gets very weak due to the very small flow rate of ozone over the detector. This is partly due to the slow fall rate (of the order of 4 meters/second) of the ozonesonde. All firings were made during daytime except the one on 10 August 1966, which was made more than two hours after sunset. All these observations have been in agreement with the measurements of total ozone by Dobson's spectrophotometer at the proper latitude and season.

RESULTS

The ozone profile obtained from the ozonesondes shows quite a change from day to day as well as from day to night. For example, the profile made in May 1966 (Fig. 2) shows one standard peak at about 25 km altitude, whereas the June observation

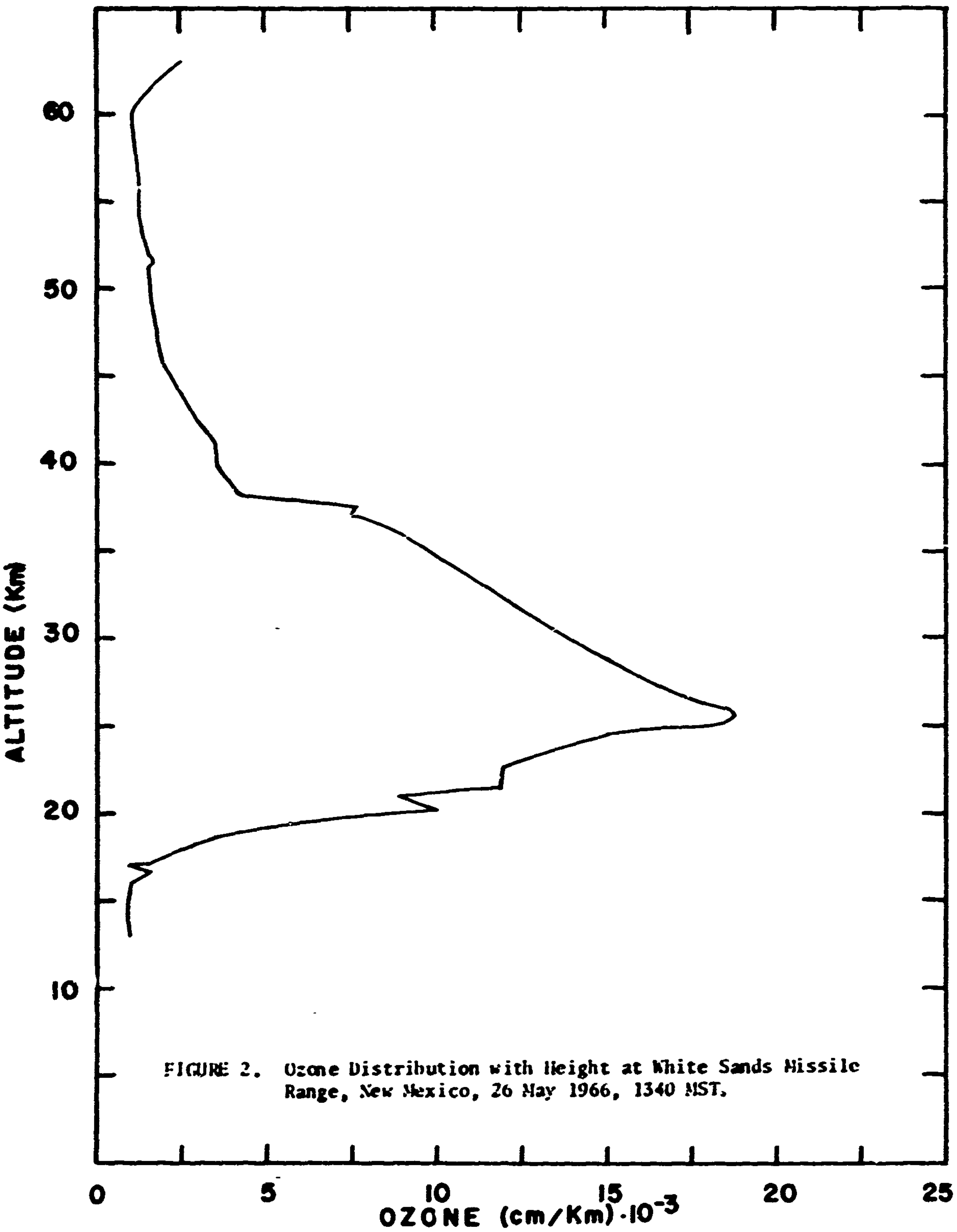

FIGURE 2. Ozone Distribution with Height at White Sands Missile Range, New Mexico, 26 May 1966, 1340 MST.

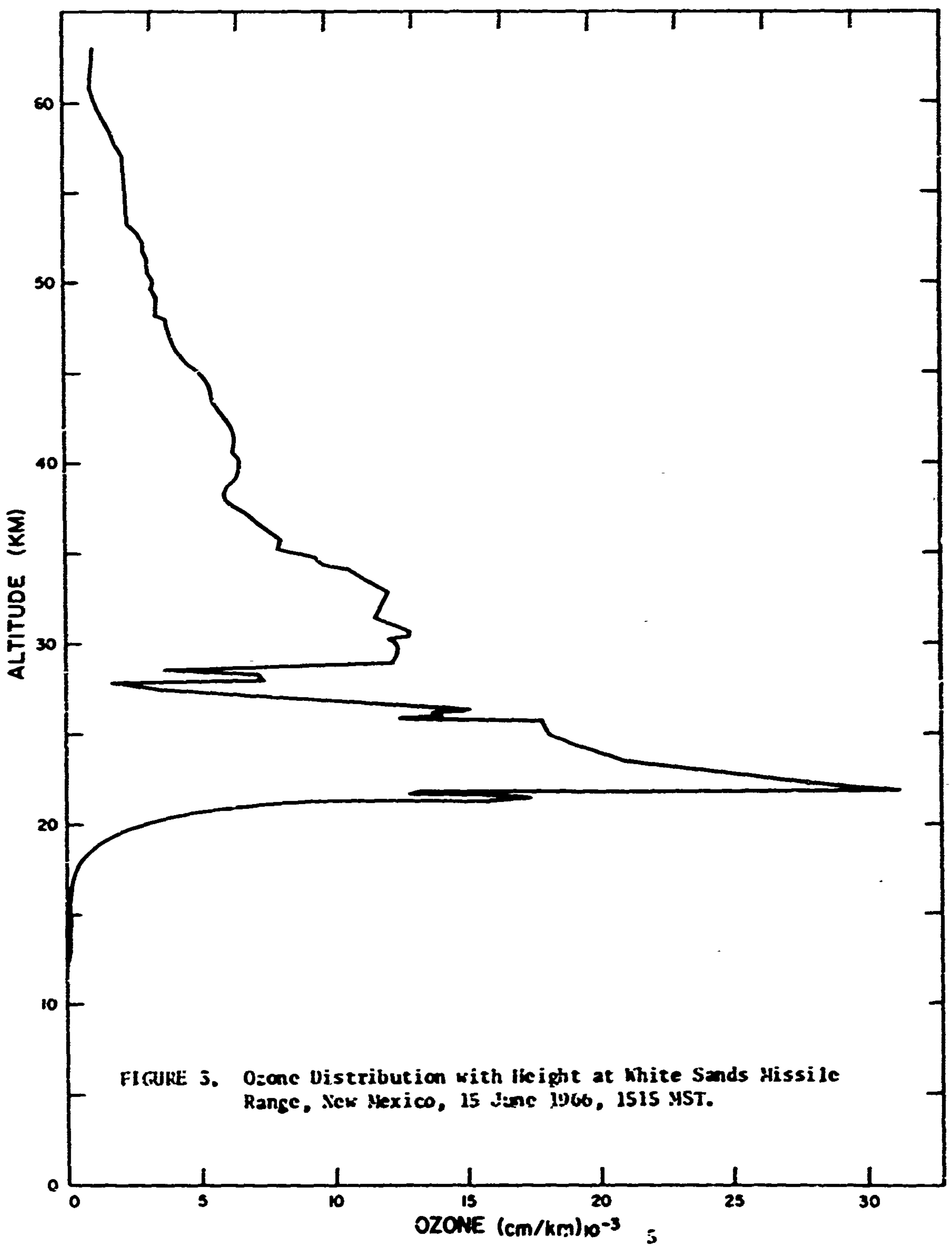

FIGURE 5. Ozone Distribution with Height at White Sands Missile Range, New Mexico, 15 June 1966, 1515 MST.

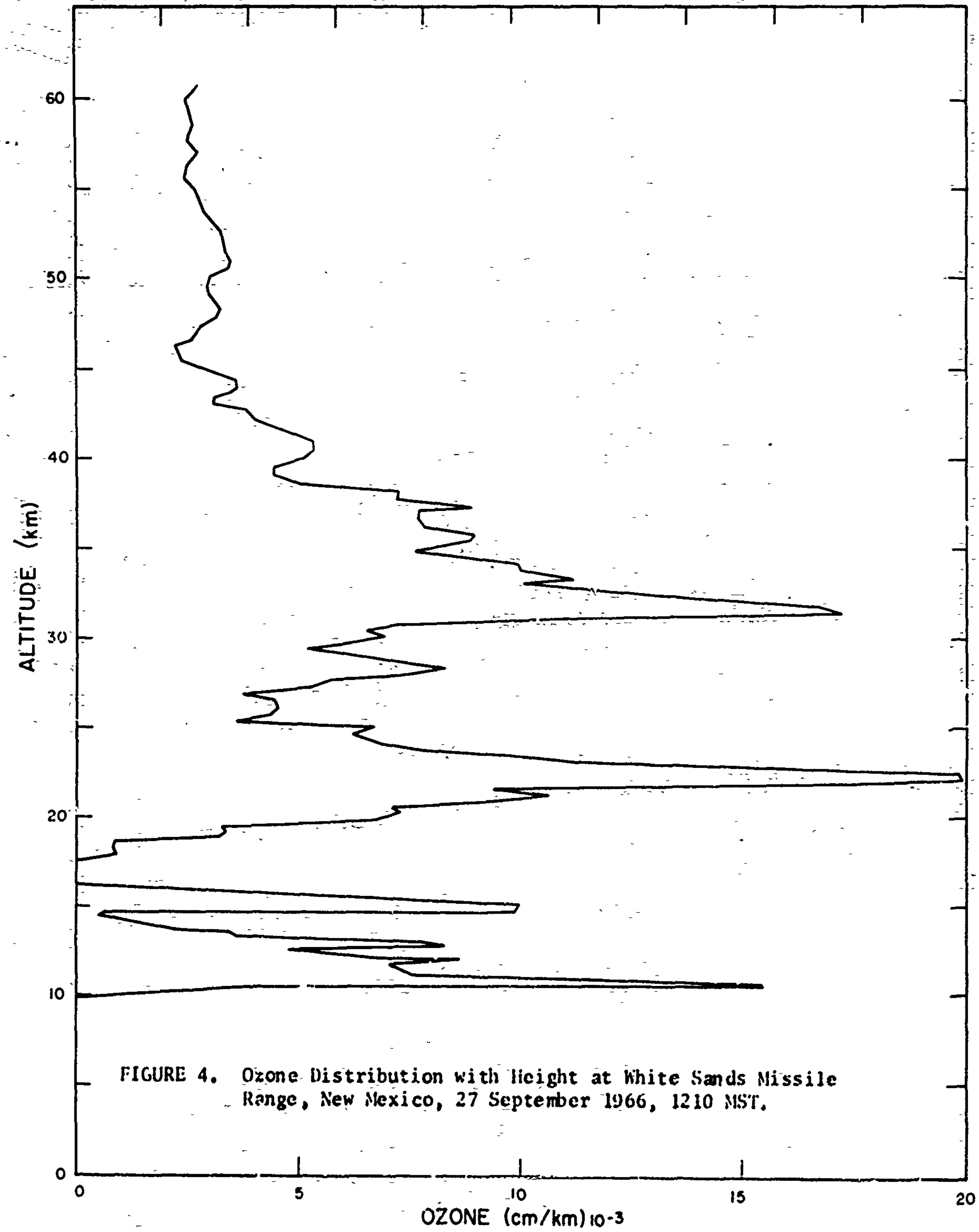

FIGURE 4. Ozone Distribution with Height at White Sands Missile Range, New Mexico, 27 September 1966, 1210 MST.

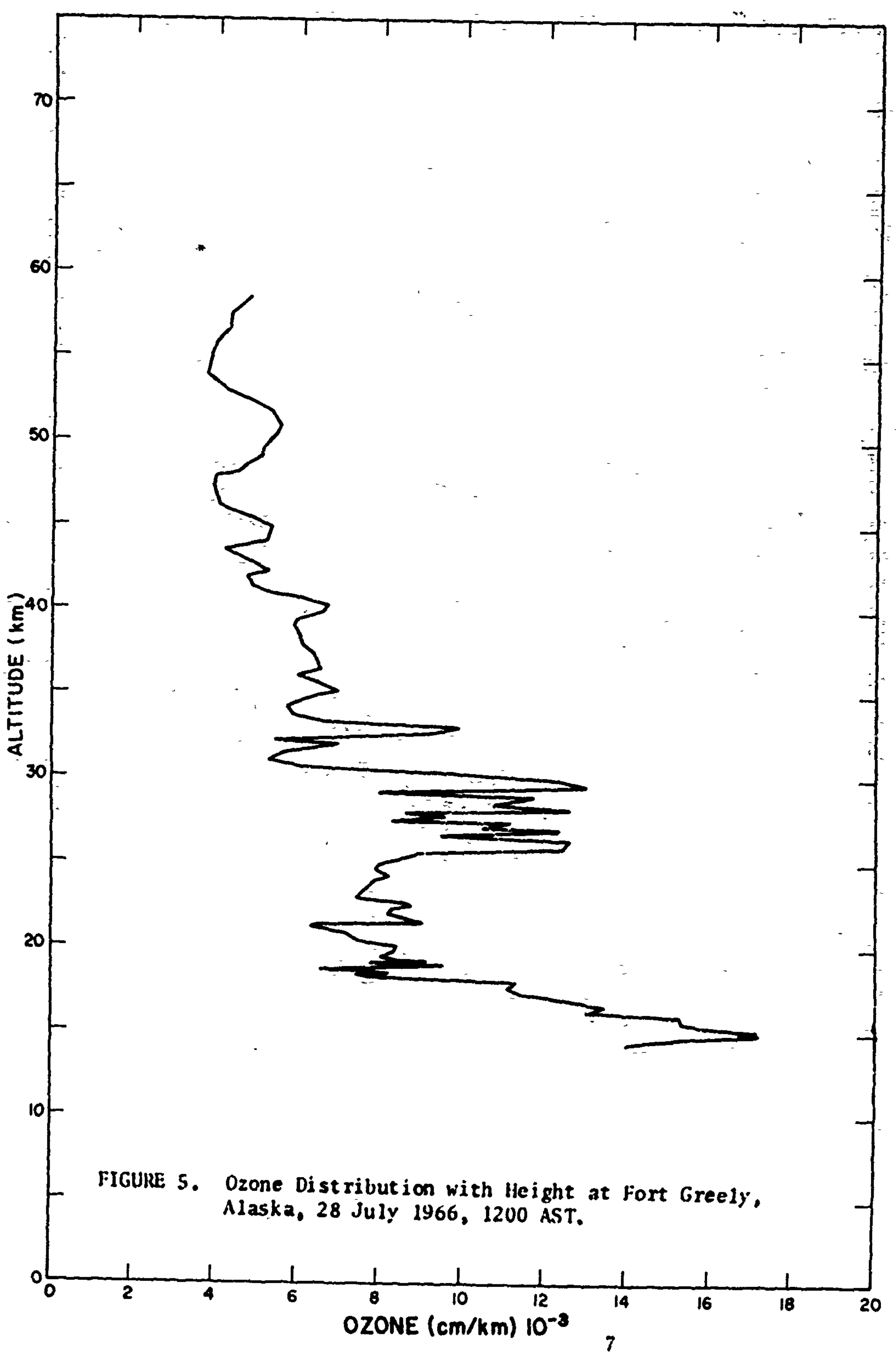

FIGURE 5. Ozone Distribution with Height at Fort Greely, Alaska, 28 July 1966, 1200 AST.

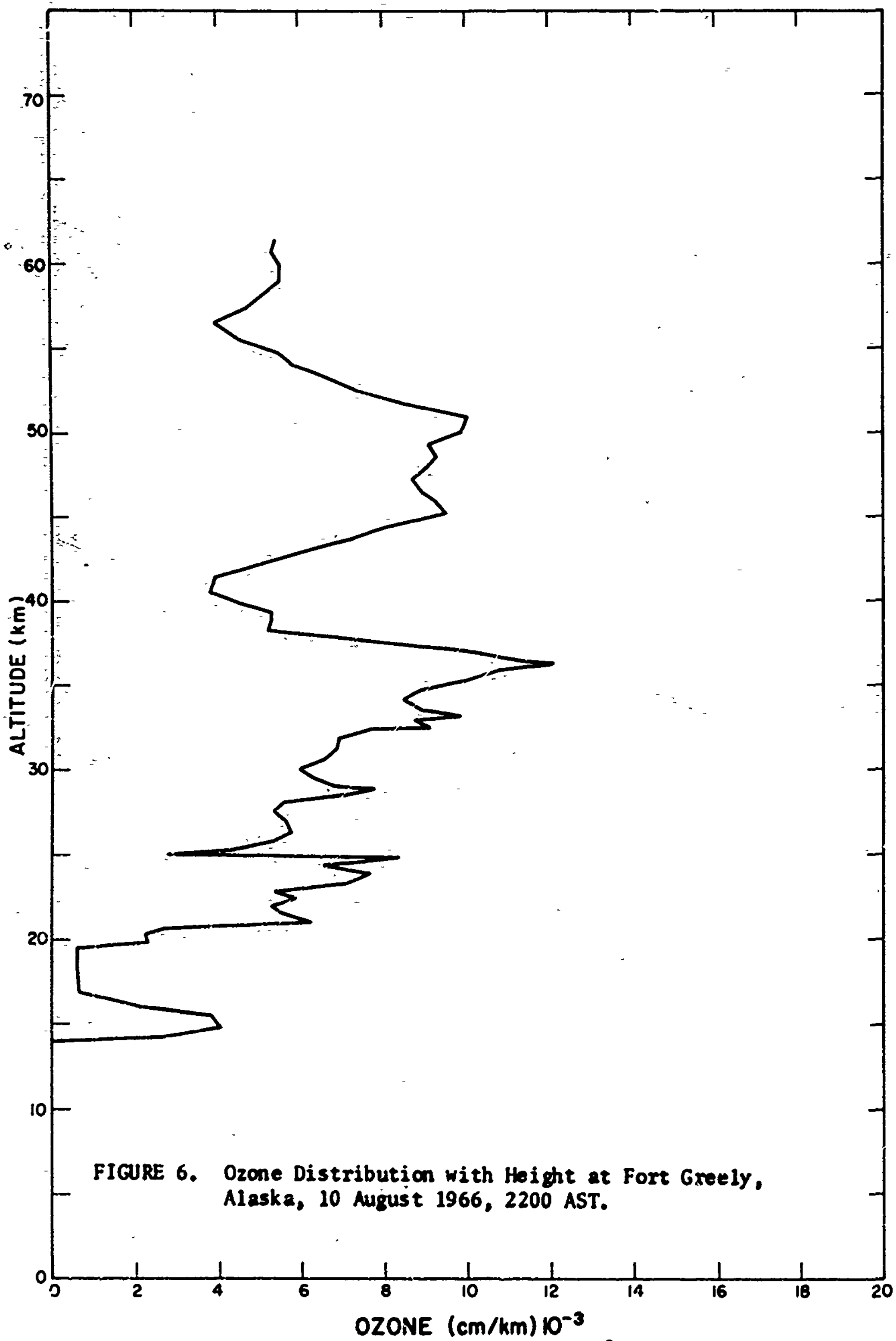

FIGURE 6. Ozone Distribution with Height at Fort Greely, Alaska, 10 August 1966, 2200 AST.

(Fig. 3) shows quite low concentrations between 25 and 30 km. There is quite a variation in the September observation (Fig. 4) over all altitudes. Fort Greely observations show considerable variation between day and night, especially above 35 km. The abrupt decrease of ozone in the lower altitudes on 10 August 1966 (Fig. 6) could be attributed to the large concentration of smoke at these altitudes since the whole forest around that area was on fire. The diurnal change in the ozone concentration above 35 km is in agreement with the observations made at White Sands Missile Range, New Mexico [Randhawa, 1966 b]. Rawcliffe and Elliott [1966] have calculated ozone concentration above 35 km from measurements of the earth's radiance and obtained values twice as large as that noted by Johnson [1952] and have quoted Barth to have obtained ozone concentration 25 times as great as Johnson's 1949 value. Mikirov [1965] has also measured high concentration of ozone at high altitudes and shows ozone concentration at 85 km to be 10^3 times greater at night than in daytime. The ozone concentrations obtained by these rocket-borne ozonesondes at high altitudes are an order of magnitude higher than that predicted by oxygen photochemical theory [Craig, 1950].

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13. ABSTRACT

A rocket-borne ozonesonde (self-pumping type) has been developed which utilizes the chemiluminescent principle for the detection of ozone concentration in the atmosphere. This has been flown with the ARCAS rocket at Fort Greely (64N), Alaska, during the day as well as at night. The results show large diurnal variations in upper stratospheric ozone and agree with the observations made at White Sands Missile Range (32N) with different rocket-borne ozonesondes (sampling chamber). Results of soundings made at White Sands Missile Range with the self-pumping type instrument are also presented. Ozone concentrations found with these rocket-borne ozonesondes show higher values of ozone in the upper stratosphere than that predicted by oxygen photochemical theory.

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