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EQUATORIAL THERMOSPHERIC COMPOSITION AND ITS VARIATIONS

G. P. Newton, D. T. Pelz, and W. T. Kasprzak

ABSTRACT

The neutral atmospheric composition experiment on the San Marco - 3 satellite has measured the composition of the equatorial atmosphere from 29 April to 29 November 1971. Preliminary results on the diurnal variation of atmospheric composition from 19 May to 30 June at 225 km. altitude are presented. The diurnal variation of helium is seen to reach its maximum near 0800 hours and its minimum in the late afternoon in contrast to the behavior of molecular nitrogen and argon. The atomic oxygen densities show smaller variations than the other gases. The mass densities calculated from the composition data agree well with those determined from the in-situ drag force measurements and from orbital decay measurements.

The Italian satellite San Marco - 3 was launched into a three degree inclination orbit on 24 April 1971 with initial perigee and apogee of 213 and 713 km. respectively. The satellite carried the Italian air density experiment (ADE) and two Goddard Space Flight Center instruments; the neutral atmospheric temperature experiment (NATE) and the neutral atmospheric composition experiment (NACE). The satellite was spin stabilized with the spin axis maintained nearly normal to the orbit plane, and the spin period varied between six and ten seconds during the seven months of orbital life. Data were obtained from all experiments during the interval from approximately 29 April through re-entry of the satellite on 29 November 1971, and the structure parameters of the neutral equatorial atmosphere were measured over five complete cycles of local solar time.

This paper presents preliminary results from the NACE covering nearly 19 hours of local time of the diurnal cycle obtained during the time 19 May through 30 June (limited by the current status of data processing). The results are considered preliminary for three reasons. First, only 16 satellite interrogation intervals have been used which represents less than 20% of the data for this cycle. Second, no corrections have been made for physical-chemical effects (such as CO_2 and CO). These physical and chemical corrections are expected to be small however, because of the agreement of the mass density from the NACE with those of the ADE and orbital decay techniques. Third, no adjustments have been made to the data for solar and geomagnetic activity effects.

The NACE mass spectrometer analyzer was a double focusing instrument of the Mattauch design and was a modification of that flown on Explorers 17 and 32 [1]. The ion source was of the gold plated, dual filament, enclosed variety. The thermalization chamber for the atmospheric particles, which entered through a knife edge orifice, was gold plated stainless steel. The experiment system allowed essentially simultaneous monitoring of five masses (4, 16, 28, 32, 40). The instrumentation could be tuned on command and measurements of masses 14, 18, and 44 were obtained periodically throughout the satellite lifetime.

Figure 1 shows the atmospheric densities of atomic oxygen, molecular nitrogen, helium and argon measured near perigee on 20 May 1971. The total mass density calculated from the composition is compared with the mass densities determined from the ADE [2] and orbital decay [3] on this same data pass. The agreement between the three density data sets is representative of all passes examined to date. It is interesting to note that the NACE densities are slightly larger than the other densities.

The atomic oxygen densities for this paper were determined from the measured source densities at mass 32 by assuming: all atomic oxygen which enters the antechamber immediately recombines to form molecular oxygen; no molecular or atomic oxygen are permanently lost on the interior surfaces; there is no molecular oxygen in the atmosphere.

Figure 2 shows the atmospheric densities measured at 225 km. altitude versus local time. The data have not been adjusted for the solar activity index, $F_{10.7}$, and geomagnetic index, A_p, which are also shown in the figure. Although the activity adjustments will influence the diurnal variation amplitudes shown in Figure 2, the nearly inverse behavior of helium compared to that of molecular nitrogen and argon is noteworthy. The maximum in the helium variation appears to occur near 0800 hours with the minimum in the late afternoon. The oxygen densities show only small variations, but these may be influenced by solar activity. The agreement of the three mass density data sets is again good.

Figure 3 shows the same NACE data as Figure 2 but with the addition of model atmosphere results calculated for the average activity conditions of the data interval. The OGO-6 model [4], determined from composition data near 450 km. altitude, used static, diffusive equilibrium equations to generate results at 225 km. altitude. It is interesting to note that the OGO-6 results show the maximum of the diurnal variation of helium to occur at 1000 hours at 450 km. altitude while the San Marco results show the maximum at 0800 hours at 225 km. altitude. This suggests that the time of maximum of the diurnal variation of helium may shift to earlier times at lower altitudes in the thermosphere. The Jacchia 1970 [5] and 1971 [6] models apparently under-estimate the argon content of the equatorial thermosphere. However, the Jacchia 70 model represents the San Marco data for molecular nitrogen and argon better than the 71 model. Until activity effects are accounted for in detail and a larger data base provided, it is not possible to determine which model is more accurate for atomic oxygen or mass density because of the small differences between the two models at this altitude.

It can be concluded: that helium in the lower thermosphere is showing a diurnal variation maximum at 0800 hours local time which is hours earlier than the diurnal maximum time of the heavier gases molecular nitrogen and argon; that there is good agreement between total mass densities measured by the NACE, ADE and orbital decay; and that the Jacchia 1970 model is a better representation of the molecular nitrogen and argon densities in the equatorial thermosphere at 225 km. altitude than is the Jacchia 1971 model.

ACKNOWLEDGEMENTS

This experiment was possible because of the dedicated contributions of a large number of people. We would particularly like to acknowledge the major part in the NACE development contributed by H. B. Benton, T. D. Clem and B. L. Johnson.

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[4] A. E. Hedin, H. G. Mayr, C. A. Reber, G. R. Carignan, and N. W. Spencer, Space Research, this volume, (1972).

[5] L. G. Jacchia, Smithsonian Astrophysical Observatory Special Report 313, (1970).

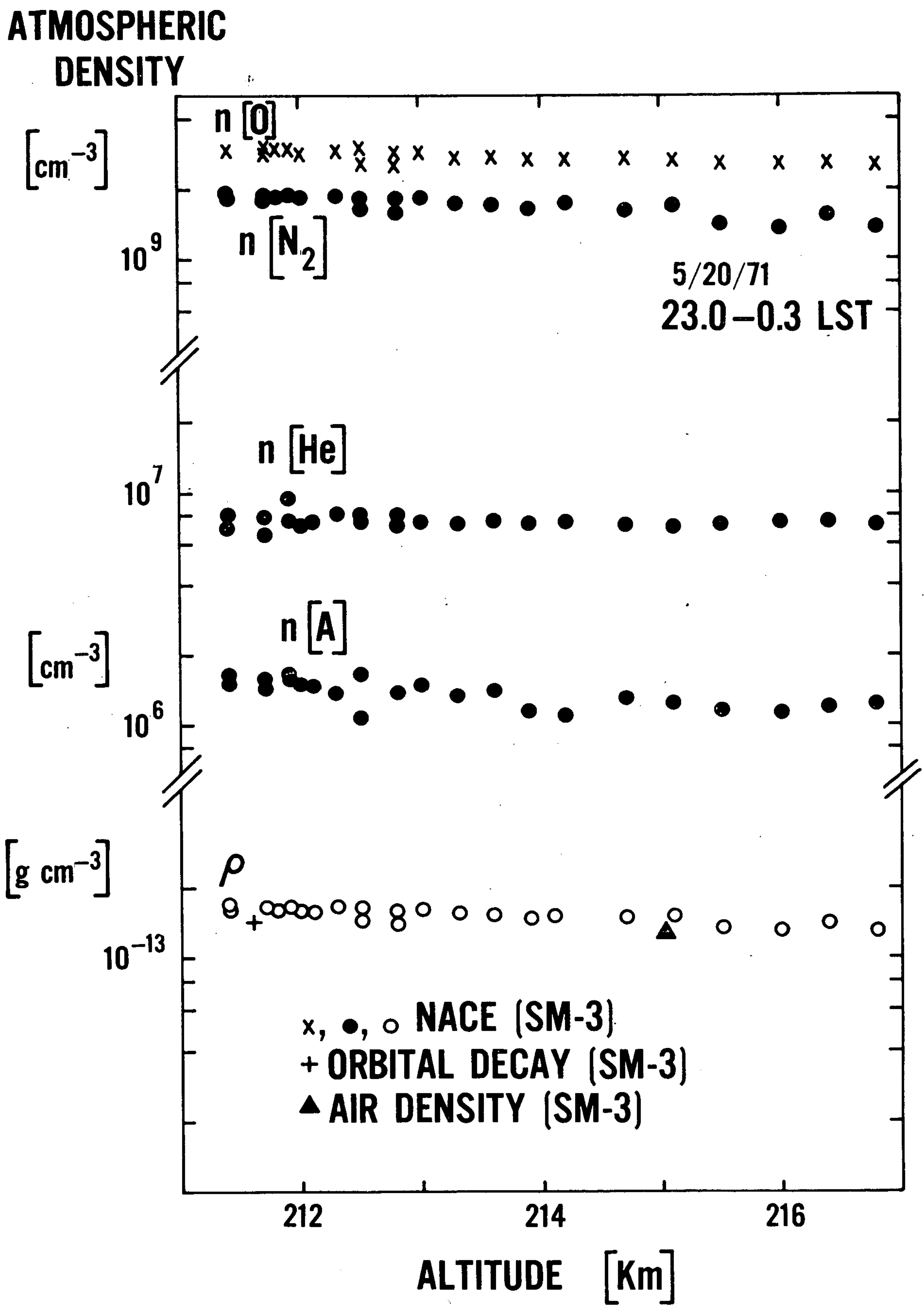
[6] L. G. Jacchia, Smithsonian Astrophysical Observatory Special Report 332, (1971).

FIGURE CAPTIONS

Figure 1. Atmospheric Composition and Mass Density Measured Near Perigee by the NACE and a Comparison With Mass Densities Measured by the ADE and Orbital Decay.

Figure 2. Atmospheric Compositions and Mass Densities at 225 km. Altitude Measured by the NACE and Mass Densities Measured by the ADE and Orbital Decay. The Solar Activity Index $F_{10.7}$ and Daily Geomagnetic Activity Index correspond to the Day on Which the NACE Measurements Were Made.

Figure 3. The OGO-6, Jacchia 1970 and 1971 Models Compared With the NACE Data of Figure 2.



ATMOSPHERIC DENSITY
[cm⁻³]
n [O]
n [N₂]
10⁹
5/20/71
23.0–0.3 LST
n [He]
10⁷
n [A]
[cm⁻³]
10⁶
[g cm⁻³]
ρ
10⁻¹³
x, ●, ○ NACE (SM-3)
+ ORBITAL DECAY (SM-3)
▲ AIR DENSITY (SM-3)
212
214
216
ALTITUDE [Km]

FIGURE 1

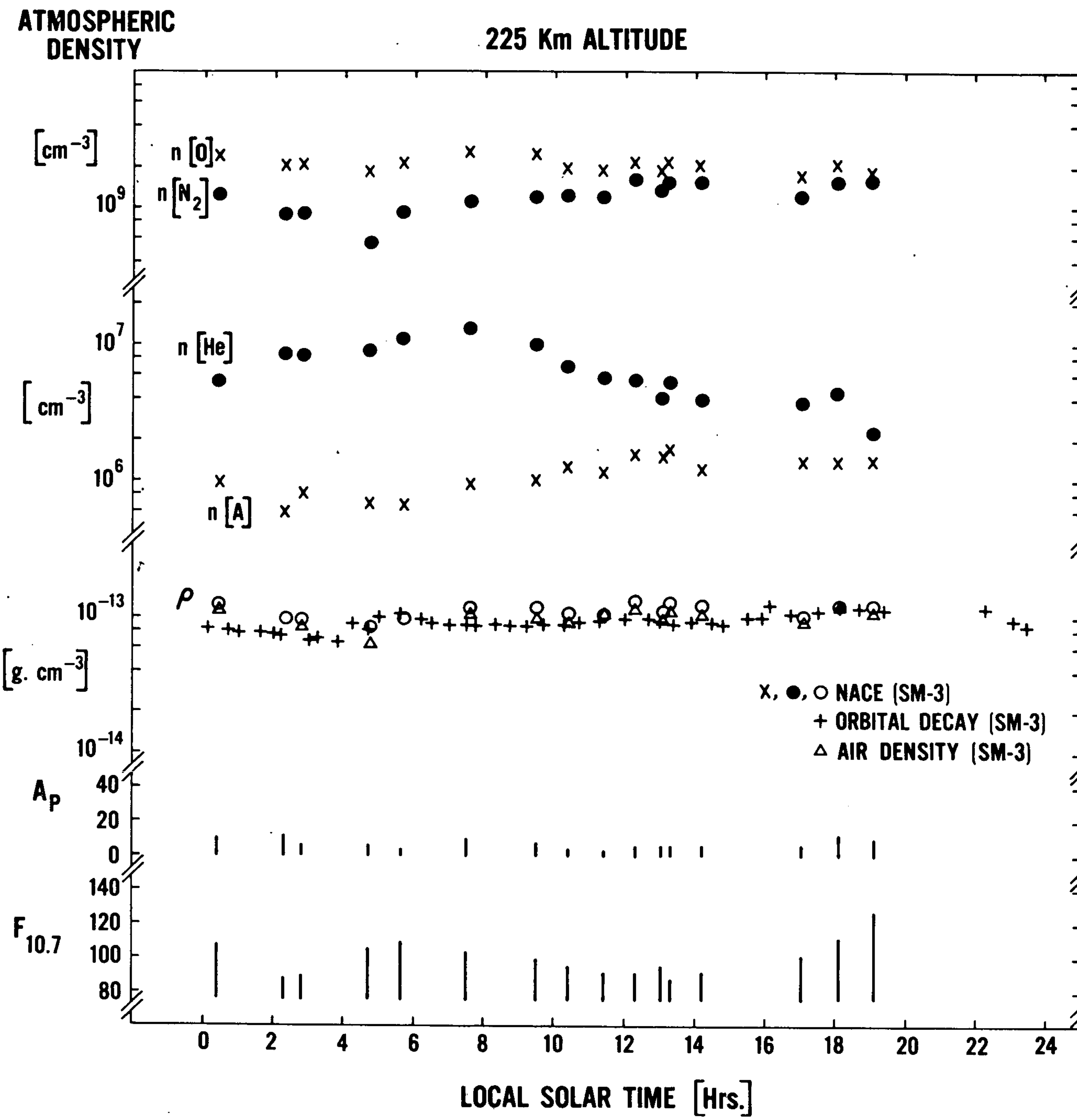
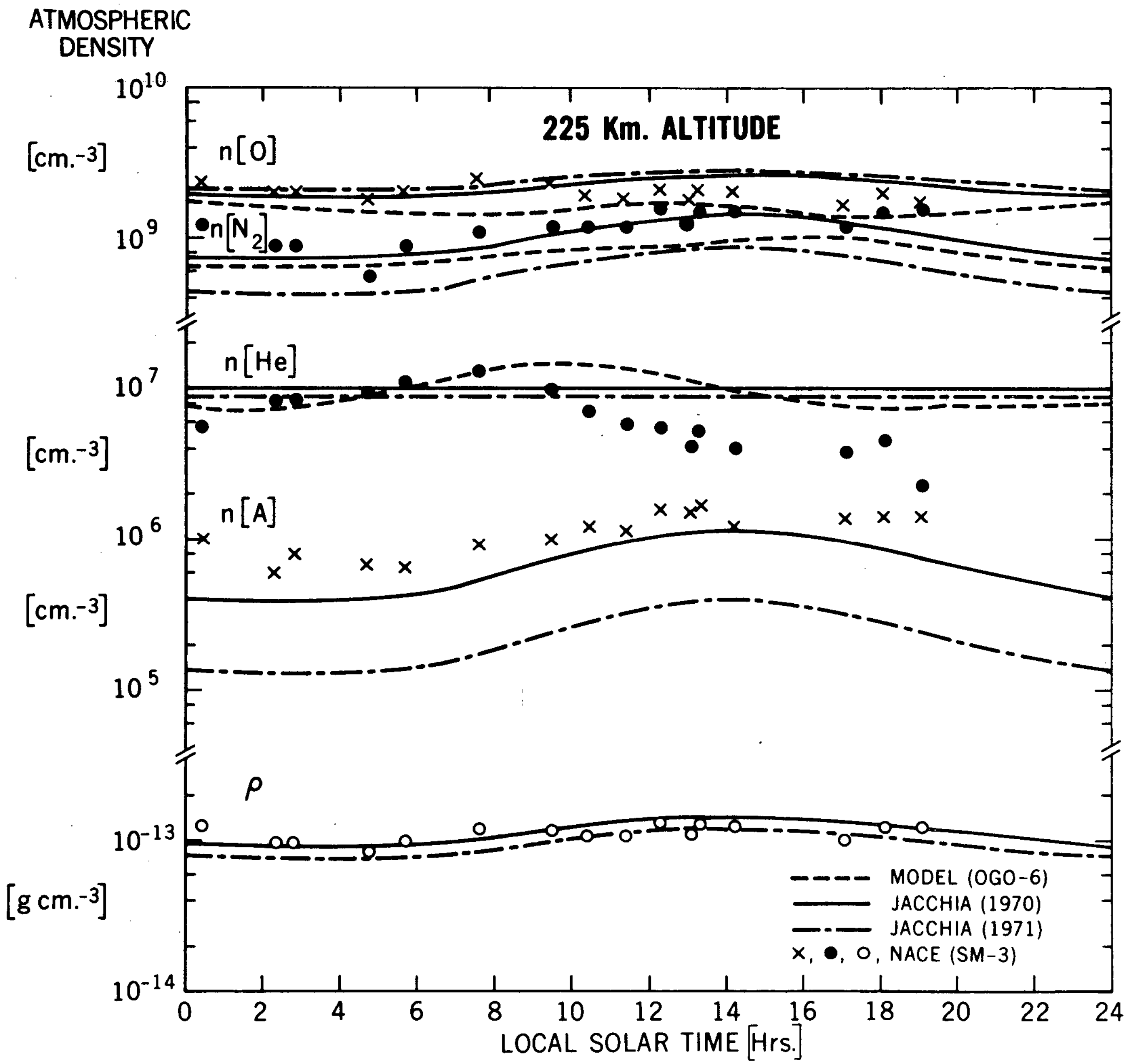

ATMOSPHERIC DENSITY
225 Km ALTITUDE
[cm^{-3}]
n [O] x
n [N$_2$]
10^9
10^7
n [He]
[cm^{-3}]
10^6
n [A]
ρ
10^{-13}
[g. cm^{-3}]
10^{-14}
x, ●, ○ NACE (SM-3)
+ ORBITAL DECAY (SM-3)
△ AIR DENSITY (SM-3)
A_P
40
20
0
140
$F_{10.7}$
120
100
80
0
2
4
6
8
10
12
14
16
18
20
22
24
LOCAL SOLAR TIME [Hrs.]

FIGURE 2



ATMOSPHERIC DENSITY
225 Km. ALTITUDE
10^{10}
[cm.-3]
n[O]
$n[N_2]$
10^9
n[He]
10^7
[cm.-3]
n[A]
10^6
[cm.-3]
10^5
ρ
10^{-13}
[g cm.-3]
10^{-14}
MODEL (OGO-6)
JACCHIA (1970)
JACCHIA (1971)
×, ●, ○, NACE (SM-3)
0 2 4 6 8 10 12 14 16 18 20 22 24
LOCAL SOLAR TIME [Hrs.]

8

FIGURE 3