ΑΣΤΡΟΝΟΜΙΑ.— **Atmospheric Pressure Variations of the Martian Atmosphere,** *by Constantin J. Macris and Basil C. Petropoulos**.

Ἀνεκοινώθη ὑπὸ τοῦ Ἀκαδημαϊκοῦ κ. Ι. Ξανθάκη.

ABSTRACT

We have used the computed Franck - Condon factors and the data of pressure and temperature near the surface, secured by Mariners 4, 6 and 7 flights, to calculate the pressure and the temperature function to altitude into the atmosphere of Mars.

The Chamberlain's model and the programme of Pitts, based on the hydrostatic model, have been used for these calculations. The constructed curves of temperature vs altitude, change inclination at 15 km and 100 km. The constructed curve of the logP vs altitude change inclination at 15 km, 60 km, 100 km, and 140 km. By used of the above results we have separated vertically the atmosphere of Mars in five zones. 1) 0 - 15 km, 2) 15 - 60 km, 3) 60 - 100 km, 4) 100 - 140 km, 5) 140 km and upper.

We can see that the clouds and the bluish haze that Mariners have observed, correspond at the same altitudes where the temperature and the pressure change inclination. Indeed the calculated temperatures and pressures at the altitudes at 15 and 100 km, where the temperature and pressure change inclination, are not very different from the pressures and temperatures of solidification of CO_2. We can concluded that possible clouds of solidificatet CO_2 can be appear at these altitudes. At 60 km. Mariners have observed one bluish haze. The composition of this bluish haze can be attributed at the formation of $CO_2CO_2^+$ in the Mars atmosphere. The pressure and the temperature into the Mars atmosphere have been calculated for a percent content 50% $CO_2CO_2^+$ and 50% CO_2.

It appear that if the bluish haze is composed from $CO_2CO_2^+$, her altitude will change with solar activity.

We have also studied the chemical reactions that take place in the

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* ΚΩΝΣΤ. Ι. ΜΑΚΡΗ καὶ ΒΑΣΙΛ. Χ. ΠΕΤΡΟΠΟΥΛΟΥ, **Αἱ μεταβολαὶ τῆς ἀτμοσφαιρικῆς πιέσεως τῆς Ἀριανῆς ἀτμοσφαίρας.** Research Center for Astronomy and Applied Mathematics, Academy of Athens.

Mars atmosphere in connection with the calculated pressures and temperatures and have proposed a model of the structure for the Mars atmosphere.

1. INTRODUCTION

In a previous paper (Macris - Petropoulos, 1973) we studied the variation of the temperature of atmosphere of the planet Mars in connection with altitude.

By use of the same computer programme and the data of Mariners 4, 6, and 7, we have calculated the variation of the temperature and pressure from the surface of the planet to its higher atmosphere as a function of altitude.

For this calculation we have used Chamberlain's model (1961) which we generalized, taking into account all the possibilities of dissociation of the CO_2 of the martian atmosphere.

We have made two working hypotheses.

1) That the CO of the martian atmosphere is due to the action of the components of the solar flux, taking into account all the possibilities of dissociation of the CO_2 molecule, as well as all possible electronic transitions.

2) That the data supplied by Mariners 6 and 7 can be used to calculate the abundance of the molecules as a function of the altitude for different vibrational states.

We have used the Franck - Condon factors, calculated by Petropoulos (1968) and Botter - Petropoulos (1973) and the spectroscopic data supplied by Mariners 6 and 7, in order to obtain theoretically the abundance of CO according to the altitude in the atmosphere of Mars. For the calculation of the variations of the temperature and of the pressure of the martian atmosphere in connection with altitude, we have accepted the different possible chemical compositions of the martian atmosphere shown in Table I, and used the hydrostatic model and the Pitts (1968) programme. The data of surface pressure and surface tempereture, which have been used in this calculation are those produced by Mariners 6 and 7 and are shown in Table II.

2. VARIATIONS OF THE TEMPERATURE AND OF THE PRESSURE IN CONNECTION WITH ALTITUDE

The variation of temperature in connection with altitude, in the atmosphere of Mars, shows by Figure 1. It is remarkable that all the curves of the variation of the temperature in connection with altitude (curves 1 - 4) of Figure 1 change inclination at an altitude of 15 km and 100 km (Figure 1). It is interesting to note that this result is the same for all the chemical compositions of Table I and all data of Table II. The temperature remains constant at all altitudes about 100 km.

TABLE I

Chemical composition of the atmosphere of Mars.

	CO_2	CO	A	O	O_3
1	100 %				
2	99 %	1 %			
3	95.9 %	0.1 %		3 %	1 %
4	99.7 %	0.3 %			
5	98 %	2 %			
6	64.7 %	2 %	33.3 %		
7	64 %	2 %	30 %	3 %	1 %

TABLE II

Atmospheric parameters on Mars from Mariners 6 and 7 (Hogan, 1972 and Kliore et al., 1969).

	Surface Temperature (°K)	Surface Pressure (mb)	Longitude	Latitude
Mariner 6, entry	254 ± 7	6.07 ± 0.31	355° E	4° N
Mariner 6, exit	152 ± 5	8.51 ± 0.48	184° E	79° N
Mariner 7, entry	221 ± 8	4.95 ± 0.24	30° E	58° N
Mariner 7, exit	209 ± 6	8 02 ± 0.45	24° E	38° N

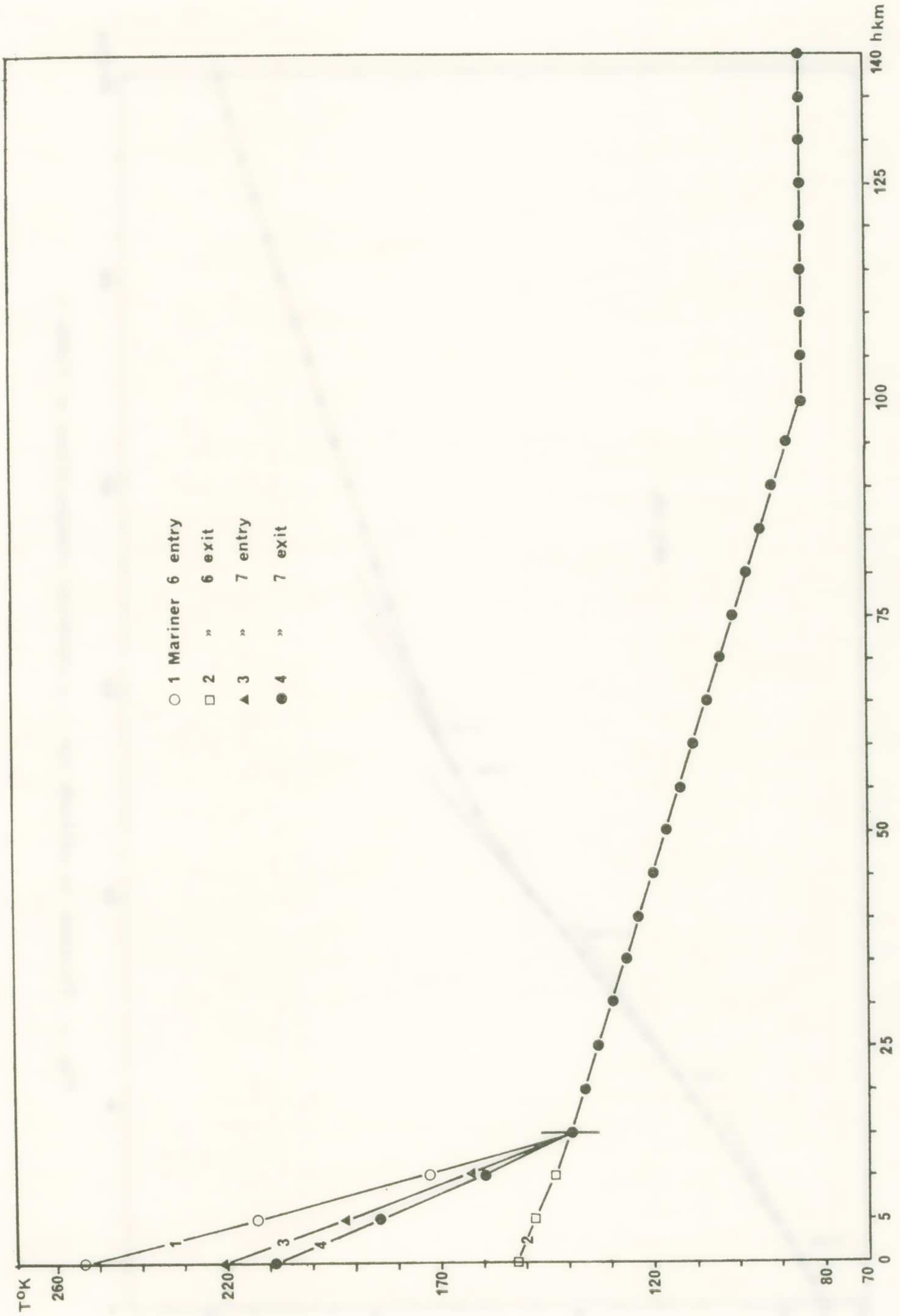

Fig. 1. Temperature vs altitude for Mariners 6 and 7 (entry and exit).

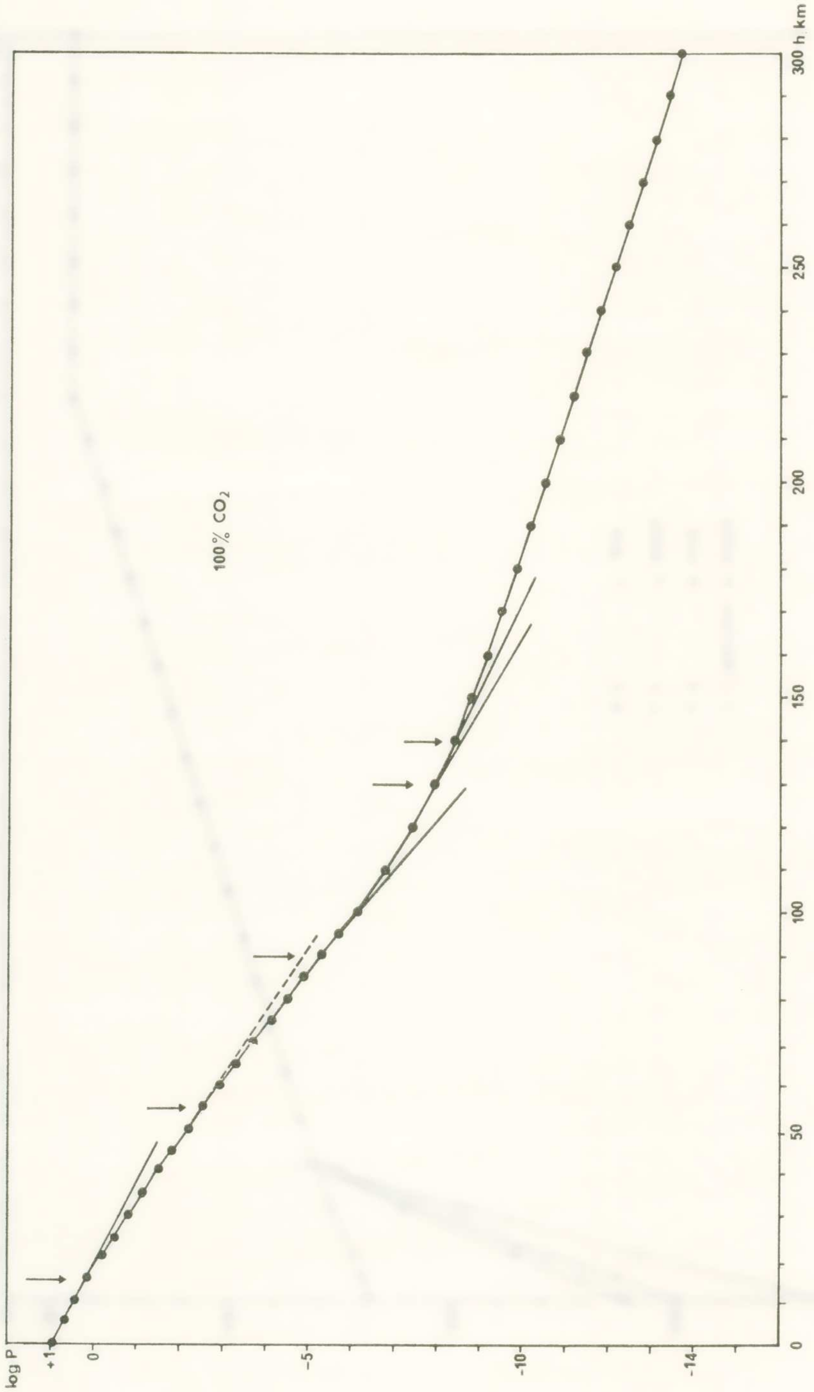

Fig. 2. Pressure vs altitude for 1 - 5 chemical compositions of Table I.

TABLE III

Pressure vs alditude calculated for the Mars atmosphere.

GEOMETR. ALTITUDE	P = 6.07mb. MARINER 6 (Entry) 100% CO_2	P = 8.51mb. MARINER 6 (Exit) 100% CO_2	P = 4.95mb. MARINER 7 (Entry) 100% CO_2	P = 8.02mb. MARINER 7 (Exit) 100% CO_2	P = 4.95mb. MARINER 7 (Entry) 95.9% CO_2 0.1% CO 3.0% O 1.0% O_3	P = 8.02mb. MARINER 7 (Exit) 95.9% CO_2 0.1% CO 3.0% O 1.0% O_3	P = 4.95mb. MARINER 7 (Entry) 64.7% CO_2 2.0% CO 33.3% A	P = 8.02mb. MARINER 7 (Exit) 64.7% CO_2 2.0% CO 33.3% A	P = 4.95mb. MARINER 7 (Entry) 50% CO_2 50% $CO_2CO_2^+$	P = 8.02mb. MARINER 7 (Exit) 50% CO_2 50% $CO_2CO_2^+$
0	6.07	8.51	4.95	8.02	4.95	8.02	4.95	8.02	4.95	8.02
5	3.97	4.39	3.06	4.84	3.08	4.88	3.11	4.92	2.52	3.94
10	2.37	2.23	1.75	2.72	1.77	2.76	1.80	2.79	1.27	1.94
15	1.24	1.11	$9.04x10^{-1}$	1.40	$9.16x10^{-1}$	1.42	$9.29x10^{-1}$	1.44	$6.30x10^{-1}$	$9.60x10^{-1}$
20	$6.07x10^{-1}$	$5.44x10^{-1}$	$4.43x10^{-1}$	$6.84x10^{-1}$	$4.49x10^{-1}$	$6.94x10^{-1}$	$4.55x10^{-1}$	$7.04x10^{-1}$	$3.09x10^{-1}$	$4.70x10^{-1}$
25	$2.94x10^{-1}$	$2.62x10^{-1}$	$2.14x10^{-1}$	$3.30x10^{-1}$	$2.17x10^{-1}$	$3.35x10^{-1}$	$2.20x10^{-1}$	$3.40x10^{-1}$	$1.49x10^{-1}$	$2.27x10^{-1}$
30	$1.40x10^{-1}$	$1.25x10^{-1}$	$1.02x10^{-1}$	$1.57x10^{-1}$	$1.03x10^{-1}$	$1.59x10^{-1}$	$1.04x10^{-1}$	$1.62x10^{-1}$	$7.09x10^{-2}$	$1.08x10^{-1}$
35	$6.53x10^{-2}$	$5.83x10^{-2}$	$4.75x10^{-2}$	$7.34x10^{-2}$	$4.81x10^{-2}$	$7.44x10^{-2}$	$4.88x10^{-2}$	$7.55x10^{-2}$	$3.31x10^{-2}$	$5.04x10^{-2}$
40	$3.00x10^{-2}$	$2.68x10^{-2}$	$2.18x10^{-2}$	$3.37x10^{-2}$	$2.21x10^{-2}$	$3.42x10^{-2}$	$2.24x10^{-2}$	$3.47x10^{-2}$	$1.52x10^{-2}$	$2.32x10^{-2}$
45	$1.35x10^{-2}$	$1.21x10^{-2}$	$9.85x10^{-3}$	$1.52x10^{-2}$	$9.98x10^{-3}$	$1.54x10^{-2}$	$1.01x10^{-2}$	$1.57x10^{-2}$	$6.87x10^{-3}$	$1.05x10^{-2}$
50	$5.99x10^{-3}$	$5.35x10^{-3}$	$4.36x10^{-3}$	$6.74x10^{-3}$	$4.42x10^{-3}$	$6.83x10^{-3}$	$4.48x10^{-3}$	$6.93x10^{-3}$	$3.04x10^{-3}$	$4.63x10^{-3}$
55	$2.60x10^{-3}$	$2.32x10^{-3}$	$1.89x10^{-3}$	$2.92x10^{-3}$	$1.92x10^{-3}$	$2.96x10^{-3}$	$1.94x10^{-3}$	$3.01x10^{-3}$	$1.32x10^{-3}$	$2.01x10^{-3}$
60	$1.10x10^{-3}$	$9.86x10^{-4}$	$8.03x10^{-4}$	$1.24x10^{-3}$	$8.14x10^{-4}$	$1.26x10^{-3}$	$8.26x10^{-4}$	$1.28x10^{-3}$	$5.60x10^{-4}$	$8.53x10^{-4}$
65	$4.59x10^{-4}$	$4.10x10^{-4}$	$3.34x10^{-4}$	$5.16x10^{-4}$	$3.38x10^{-4}$	$5.23x10^{-4}$	$3.43x10^{-4}$	$5.31x10^{-4}$	$2.33x10^{-4}$	$3.54x10^{-4}$
70	$1.86x10^{-4}$	$1.66x10^{-4}$	$1.35x10^{-4}$	$2.09x10^{-4}$	$1.37x10^{-4}$	$2.12x10^{-4}$	$1.39x10^{-4}$	$2.15x10^{-4}$	$9.44x10^{-5}$	$1.44x10^{-4}$
75	$7.42x10^{-5}$	$6.63x10^{-5}$	$5.40x10^{-5}$	$8.34x10^{-5}$	$5.47x10^{-5}$	$8.46x10^{-5}$	$5.55x10^{-5}$	$8.58x10^{-5}$	$3.77x10^{-5}$	$5.73x10^{-5}$
80	$2.93x10^{-5}$	$2.61x10^{-5}$	$2.13x10^{-5}$	$3.29x10^{-5}$	$2.16x10^{-5}$	$3.34x10^{-5}$	$2.19x10^{-5}$	$3.39x10^{-5}$	$1.49x10^{-5}$	$2.26x10^{-5}$
85	$1.14x10^{-5}$	$1.02x10^{-5}$	$8.30x10^{-6}$	$1.28x10^{-5}$	$8.42x10^{-6}$	$1.30x10^{-5}$	$8.53x10^{-6}$	$1.32x10^{-5}$	$5.79x10^{-6}$	$8.82x10^{-6}$
90	$4.40x10^{-6}$	$3.93x10^{-6}$	$3.20x10^{-6}$	$4.94x10^{-6}$	$3.24x10^{-6}$	$5.01x10^{-6}$	$3.29x10^{-6}$	$5.08x10^{-6}$	$2.23x10^{-6}$	$3.39x10^{-6}$
95	$1.71x10^{-6}$	$1.53x10^{-6}$	$1.25x10^{-6}$	$1.93x10^{-6}$	$1.26x10^{-6}$	$1.95x10^{-6}$	$1.28x10^{-6}$	$1.98x10^{-6}$	$8.69x10^{-7}$	$1.32x10^{-6}$
100	$6.95x10^{-7}$	$6.20x10^{-7}$	$5.05x10^{-7}$	$7.81x10^{-7}$	$5.12x10^{-7}$	$7.92x10^{-7}$	$5.19x10^{-7}$	$8.03x10^{-7}$	$3.52x10^{-7}$	$5.36x10^{-7}$
110	$1.38x10^{-7}$	$1.23x10^{-7}$	$1.00x10^{-7}$	$1.55x10^{-7}$	$1.02x10^{-7}$	$1.57x10^{-7}$	$1.03x10^{-7}$	$1.60x10^{-7}$	$7.00x10^{-8}$	$1.07x10^{-7}$
120	$3.46x10^{-8}$	$3.09x10^{-8}$	$2.52x10^{-8}$	$3.89x10^{-8}$	$2.55x10^{-8}$	$3.94x10^{-8}$	$2.59x10^{-8}$	$4.00x10^{-8}$	$1.75x10^{-8}$	$2.67x10^{-8}$
130	$1.02x10^{-8}$	$9.13x10^{-9}$	$7.43x10^{-9}$	$1.15x10^{-8}$	$7.53x10^{-9}$	$1.16x10^{-8}$	$7.64x10^{-9}$	$1.18x10^{-8}$	$5.18x10^{-9}$	$7.89x10^{-9}$
140	$3.55x10^{-9}$	$3.17x10^{-9}$	$2.58x10^{-9}$	$3.99x10^{-9}$	$2.62x10^{-9}$	$4.05x10^{-9}$	$2.65x10^{-9}$	$4.11x10^{-9}$	$1.80x10^{-9}$	$2.74x10^{-9}$
150	$1.45x10^{-9}$	$1.29x10^{-9}$	$1.05x10^{-9}$	$1.63x10^{-9}$	$1.07x10^{-9}$	$1.65x10^{-9}$	$1.08x10^{-9}$	$1.67x10^{-9}$	$7.34x10^{-10}$	$1.12x10^{-9}$
160	$6.41x10^{-10}$	$5.73x10^{-10}$	$4.67x10^{-10}$	$7.21x10^{-10}$	$4.73x10^{-10}$	$7.31x10^{-10}$	$4.80x10^{-10}$	$7.42x10^{-10}$	$3.52x10^{-10}$	$4.95x10^{-10}$
170	$2.88x10^{-10}$	$2.57x10^{-10}$	$2.10x10^{-10}$	$3.24x10^{-10}$	$2.12x10^{-10}$	$3.29x10^{-10}$	$2.15x10^{-10}$	$3.33x10^{-10}$	$1.46x10^{-10}$	$2.23x10^{-10}$
180	$1.31x10^{-10}$	$1.17x10^{-10}$	$9.54x10^{-11}$	$1.47x10^{-10}$	$9.67x10^{-11}$	$1.49x10^{-10}$	$9.80x10^{-11}$	$1.52x10^{-10}$	$6.65x10^{-11}$	$1.01x10^{-10}$
190	$6.04x10^{-11}$	$5.40x10^{-11}$	$4.39x10^{-11}$	$6.79x10^{-11}$	$4.45x10^{-11}$	$6.89x10^{-11}$	$4.52x10^{-11}$	$6.99x10^{-11}$	$3.06x10^{-11}$	$4.67x10^{-11}$
200	$2.82x10^{-11}$	$2.52x10^{-11}$	$2.05x10^{-11}$	$3.17x10^{-11}$	$2.08x10^{-11}$	$3.21x10^{-11}$	$2.11x10^{-11}$	$3.26x10^{-11}$	$1.43x10^{-11}$	$2.18x10^{-11}$
210	$1.32x10^{-11}$	$1.18x10^{-11}$	$9.63x10^{-12}$	$1.49x10^{-11}$	$9.76x10^{-12}$	$1.51x10^{-11}$	$9.90x10^{-12}$	$1.53x10^{-11}$	$6.72x10^{-12}$	$1.02x10^{-11}$
220	$6.25x10^{-12}$	$5.58x10^{-12}$	$4.55x10^{-12}$	$7.03x10^{-12}$	$4.61x10^{-12}$	$7.13x10^{-12}$	$4.67x10^{-12}$	$7.23x10^{-12}$	$3.17x10^{-12}$	$4.83x10^{-12}$
230	$2.96x10^{-12}$	$2.65x10^{-12}$	$2.16x10^{-12}$	$3.33x10^{-12}$	$2.19x10^{-12}$	$3.38x10^{-12}$	$2.22x10^{-12}$	$3.43x10^{-12}$	$1.50x10^{-12}$	$2.29x10^{-12}$
240	$1.41x10^{-12}$	$1.26x10^{-12}$	$1.03x10^{-12}$	$1.59x10^{-12}$	$1.04x10^{-12}$	$1.61x10^{-12}$	$1.05x10^{-12}$	$1.63x10^{-12}$	$7.16x10^{-13}$	$1.09x10^{-12}$
250	$6.74x10^{-13}$	$6.02x10^{-13}$	$4.91x10^{-13}$	$7.58x10^{-13}$	$4.97x10^{-13}$	$7.69x10^{-13}$	$5.04x10^{-13}$	$7.80x10^{-13}$	$3.42x10^{-13}$	$5.21x10^{-13}$
260	$3.24x10^{-13}$	$2.89x10^{-13}$	$2.36x10^{-13}$	$3.64x10^{-13}$	$2.39x10^{-13}$	$3.69x10^{-13}$	$2.42x10^{-13}$	$3.74x10^{-13}$	$1.64x10^{-13}$	$2.50x10^{-13}$
270	$1.56x10^{-13}$	$1.39x10^{-13}$	$1.13x10^{-13}$	$1.75x10^{-13}$	$1.15x10^{-13}$	$1.78x10^{-13}$	$1.17x10^{-13}$	$1.80x10^{-13}$	$7.91x10^{-14}$	$1.20x10^{-13}$
280	$7.54x10^{-14}$	$6.74x10^{-14}$	$5.49x10^{-14}$	$8.48x10^{-14}$	$5.69x10^{-14}$	$8.60x10^{-14}$	$5.64x10^{-14}$	$8.73x10^{-14}$	$3.83x10^{-14}$	$5.83x10^{-14}$
290	$3.67x10^{-14}$	$3.27x10^{-14}$	$2.67x10^{-14}$	$4.12x10^{-14}$	$2.70x10^{-14}$	$4.18x10^{-14}$	$2.74x10^{-14}$	$4.24x10^{-14}$	$1.86x10^{-14}$	$2.83x10^{-14}$
300	$1.79x10^{-14}$	$1.60x10^{-14}$	$1.30x10^{-14}$	$2.01x10^{-14}$	$1.32x10^{-14}$	$2.04x10^{-14}$	$1.34x10^{-14}$	$2.07x10^{-14}$	$9.07x10^{-15}$	$1.38x10^{-14}$

The variation of the pressure (logP) in connection with altitude has been calculated on the basis of the surface temperature and the surface pressure, measurements made by Mariners 6 and 7 upon entry into the martian atmosphere, as well as upon exit from this atmosphere and are shown in Figure 2. These curves are constructed by use of the results of the computer. Comparison of pressure vs altitude shown in Table III.

The values of pressure (Table III) for each level of altitude show very little difference from the same values of pressure, calculated in basis of a chemical composition 100% CO_2, and the data of the surface pressure and surface temperature measured by Mariners 6 and 7. The constructed curves are homologous. In the scale of Figure 2 these curves coincide.

The altitudes in the martian atmosphere where the inclination of logP changes on account of different chemical compositions are given in Table IV. These altitudes are 15 km, 60 km, 100 km, 130 km and 140 km. If we take into account all the variations of ΔlogP/Δh we can separate the martian atmosphere according to altitude into 4 zones (Table IV). Above an altitude of 140 km the variation of logP is regular in connection with the altitude.

TABLE IV

Zones of the Martian atmosphere according to the variation of the logP inclination.

Zone	Altitude (km)	Altitude of variation of ΔlogP/Δh
I	0 - 15	15*
II	15 - 60	60
III	60 - 100	100
IV	100 - 140	130, 140

* For the entry of Mariner 6 this altitude is 10 km.

3. STUDY OF THE PRESSURE'S CURVES

If we compare the curves of variation of the temperature (Figure 1) with the curves of variation of the pressure (Figure 2), we see that at the two altitudes where the inclination of the temperature changes 15 and 100 km there is a correspondance change, in the inclination of logP, however the curves of logP have in addition three further altitudes, where the inclination of the curves changes, one at 60 km the others at 130 and 140 km altitude. These five altitudes of change of the inclination of the Figure 2 separate the martian atmosphere into the four zones of Table IV.

The first variation of $\Delta \log P/\Delta h$ is apparent at an altitude of 15 km. At this altitude the temperature that we have calculated is $139.4^{\circ}K \pm 7^{\circ}$ and the average pressure, calculated on the basis of all the data of surface pressure and surface temperature measured by Mariners 6 and 7 is 1.26 ± 0.3 mb. But the values of pressure calculated in this work (Table III) vary from 0.96 to 1.44 mb, because the data obtained from Mariners 6 and 7 was acquired in different seasons for different periods of time and for different latitudes.

If we take into account the above average value of pressure 1.26 ± 0.3 mb (0.95 Mm Hg), at the temperature of $135.5^{0}C$ the CO_2 ought to be solidified (Handbook of Chemistry, 1973) Taking into account the margin of error in Mariners measurements and comparing the above values of pressure and temperature of solidification of CO_2, with those for the martian atmosphere which we have calculated, and given we can conclude that over an altitude of 15 km above the surface of Mars, it is very probable that at least CO_2 is solidified, possibly in crystal form. Thus at the altitude of 15 km we have one inhomogenity. This first zone of inhomogenity of the atmosphere of Mars has also been observed by Mariner 9 at the same altitude. It is probable that this layer is composed of crystals of CO_2 and other particles of the martian atmosphere. This layer coincides also in altitude with the cloudy zone of yellow dust observed recently (Kliore, 1973), and with the astronomical observations of Antoniadi (1930) and others (Capen, 1974).

The second altitude of change of $\Delta \log P/\Delta h$ (Figure 2) is at 60 km and here is created the second zone (Table IV). Mariner 9 also observed a bluish layer (Kondrat'yev and al., 1974) at an altitude of 60 km that is similar to terrestrial haze. This bluish layer had previously been optically observed by astronomers, but its composition was unknown. No satisfactory explanation of the nature of the blue haze and its clearings exists. A number of theories have been advanced since 1950, but all seem to have weaknesses.

1) The water ice crystal theory was proposed by Schatzman (1952).

2) Carbon dioxide-ice crystal theory was proposed by Hess (1950).

3) Meteoritic dust of microscopic size was suggested by Link (1950) and Kviz (1961).

4) Carbon smoke theory advanced by Rosen (1953).

5) Urey and Brewer (1957) attempted to explain the blue haze in terms of fluorescence of ions such as CO_2^+, CO^+, N_2^+. But N_2^+ spectrum has not yet been observed by Mariners in the atmosphere of Mars.

If the last theory is correct, the existence of $CO_2CO_2^+$ molecules in this bluish haze is also possible.

Another variation of $\Delta \log P / \Delta h$ can also be observed in Figure 2 at the altitude of 100 km and creates a new zone from 60 - 100 km (Table IV).

Above 100 km, we can find two further altitudes, of change of the inclination of logP. The first is at the altitude of 130 km and the second at the altitude of 140 km, consequently a final zone in Table IV can be created, between 100 and 140 km.

4. ORIGIN OF THE ZONES

From the study of the curves of pressure in the martian atmosphere, we will try to find the causes of the formation of the four zones of Table IV. Figure 3 shows the altitudes of the zones in the atmosphere of Mars. The formation of these zones can be attributed to the following causes.

The first zone, that is the lower atmosphere, as we have said above, is formed by a powder of different molecules CO_2, H_2O (in small quantities), SiO_2 (Kondrat'yev and Bunakova, 1974) and by other different molecules, H_2S and others (Beer, 1971) that have been also found in the spectrum of the atmosphere of Mars. These particles create one cloudly

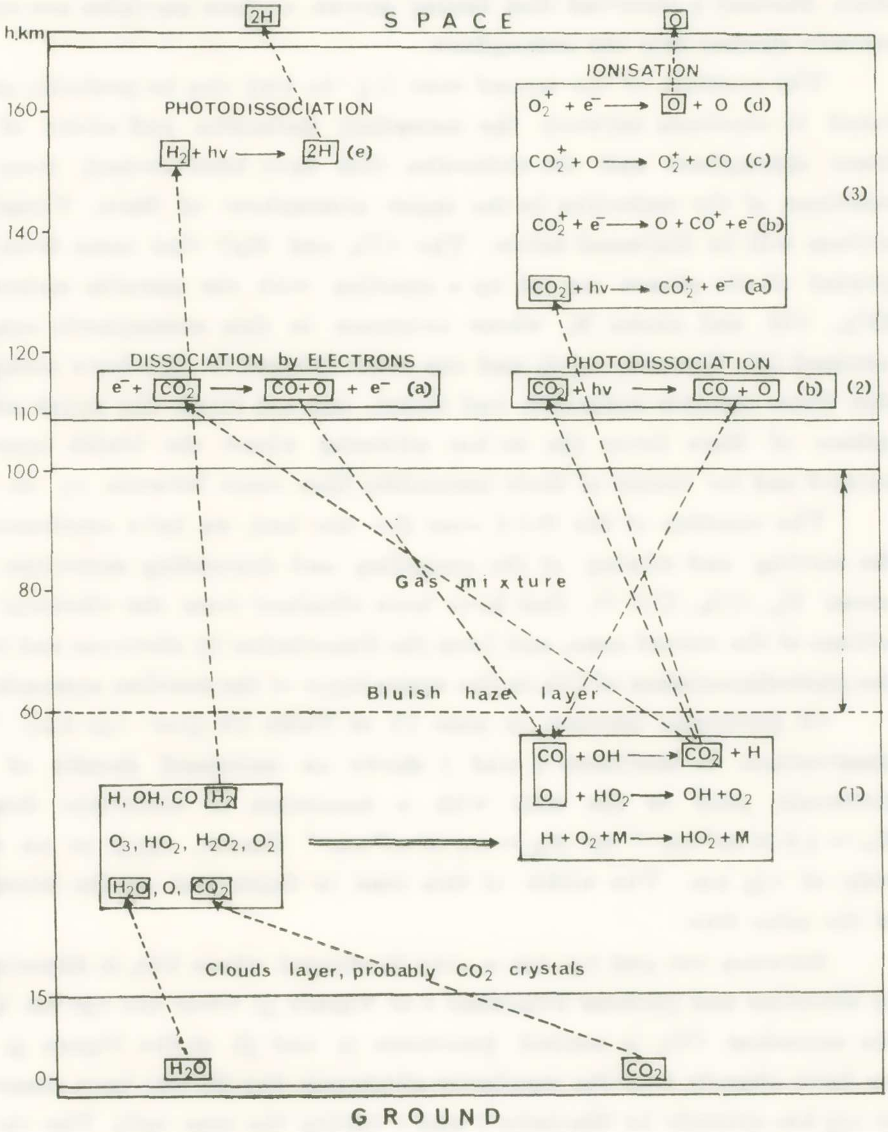

Fig. 3. Chemical reactions and altitudes of the zones, calculated by Macris - Petropoulos in the Mars atmosphere.

zone where crystals of CO_2 are probably present above the 15 km altitude. The molecules of the first zone are furnished by the ground of Mars. Mariner 9 observed that during storms, surface particles are continuously ejected into the atmosphere.

The creation of the second zone (15 - 60 km) can be probably attributed to reactions between the ascendant molecules and atoms of the lower atmosphere and the molecules that have been formed, from the reactions of the molecules in the upper atmosphere of Mars. These reactions will be discussed below. The CO_2 and H_2O that came from the ground of the planet can set up a reaction with the unstable molecules HO_2, OH and atoms H, whose existence in this atmospheric zone is assumed (Mc Connell, 1973), and can react CO and O. We have accepted that these instable molecules and atoms, can not reach the upper atmosphere of Mars (over the 60 km altitude) where the bluish layer is formed and for reason of their instability they react between 15 - 60 km.

The reaction of the third zone (60 - 100 km), we have attributed to the moving and mixing of the ascending and descending molecules and atoms H_2, CO_2, CO, O, that have been obtained from the chemical reactions of the second zone, and from the dissociation by electrons and from the photodissociation of CO_2 in the upper layer of the martian atmosphere.

Of particular interest is zone IV of Table IV (100 - 140 km). The observations of Mariners 6 and 7 shows an increased density of the electronic peak in the zone with a maximum of electronic density $N_m = 1.6 \times 10^5\ cm^{-3}$ or $N_m = 1.7 \times 10^5\ cm^{-3}$ (Bauer, 1973) at an altitude of 135 km. The width of this zone is dependent on the intensity of the solar flux.

Between 100 and 130 km a zone is created where CO_2 is dissociated by electrons and photons (reactions 2 of Figure 3). Over the 130 km level the ascendant CO_2 is ionised (reactions 3a and 3b of the Figure 3). As we have already told the maximum electronic density has been observed at 135 km altitude by Mariners 6 and 7 during the year 1969. The curves of pressure (Figures 2) that we have calculated and the variation of the inclination of logP distinctly show the creation of this zone.

Above the 140 km level the chemical reactions 3c, 3d, 3e are possible. From these reactions, O and H can be produced and ejected in space (Mc Elroy, 1972).

The molecules CO and O that have been created by the reactions 2a and 2b between 100 - 120 km max. descend to the lower atmosphere and recombine via the series of reactions (1) that give CO_2. These reactions close the cycle of production of CO_2 in the martian atmosphere. Mc Elroy and Donahue (1972) accepted that most of the O was transported to the lower atmosphere. This transfer of CO to the lower atmosphere is also in concurrence with the fact that the abundance of CO that we calculated in a preceding work (Macris, Petropoulos, 1973) increases in inverse ratio to the altitude as the altitude decreases.

The quantity of CO that exists between 15 - 60 km, can be explained by the descent of CO from the upper to the lower atmosphere. In the reactions (1) of Figure 3 we have admited (Ajello, 1973) that, very probably, there exists a catalyst (molecule M), that comes from the ground of the planet and may be A, H_2S or some other molecule.

For this reason we have calculated the variation of the pressure in correlation with the altitude taking into account, Table I, a high percentage of A (30 - 33.3 %) (Anderson and al. 1972, Mc Connell 1973). The form of the variation of the curves in correlation with the altitude does not present a great difference from the curves that we have constructed with the other chemical compositions of Table I. The change of the inclination of these curves of logP are at the same altitude in both. That mean that Argon if in fact it does exist in the martian atmosphere, does not react with the other molecules but because it is an inert gas can act only as a catalyst.

We have said above that the fluorescence theory (Urey and Brewer, 1957) can explain the bluish haze, on the assumption that CO_2^+ ions exist in the martian atmosphere. The ion CO_2^+ exists also in the spectrum of the upper atmosphere of Mars (Mc Connell, 1973).

On the assumption that in the martian atmosphere the $CO_2CO_2^+$ molecule can be composed (50 % $CO_2CO_2^+$ and 50 % CO_2) we have calculated the curves of variation of the pressure in correlation with the altitude (Figure 4) and we have observed one first variation of $\Delta \log P/\Delta h$ at the altitude of 60 km. We can find the variation of $\Delta \log P/\Delta h$, as we have said, in all the curves at 60 km altitude and we have deduced this variation from the presence of a bluish haze layer in the martian atmosphere. Two other variations of $\Delta \log P/\Delta h$ are shown in Figure 4 at the

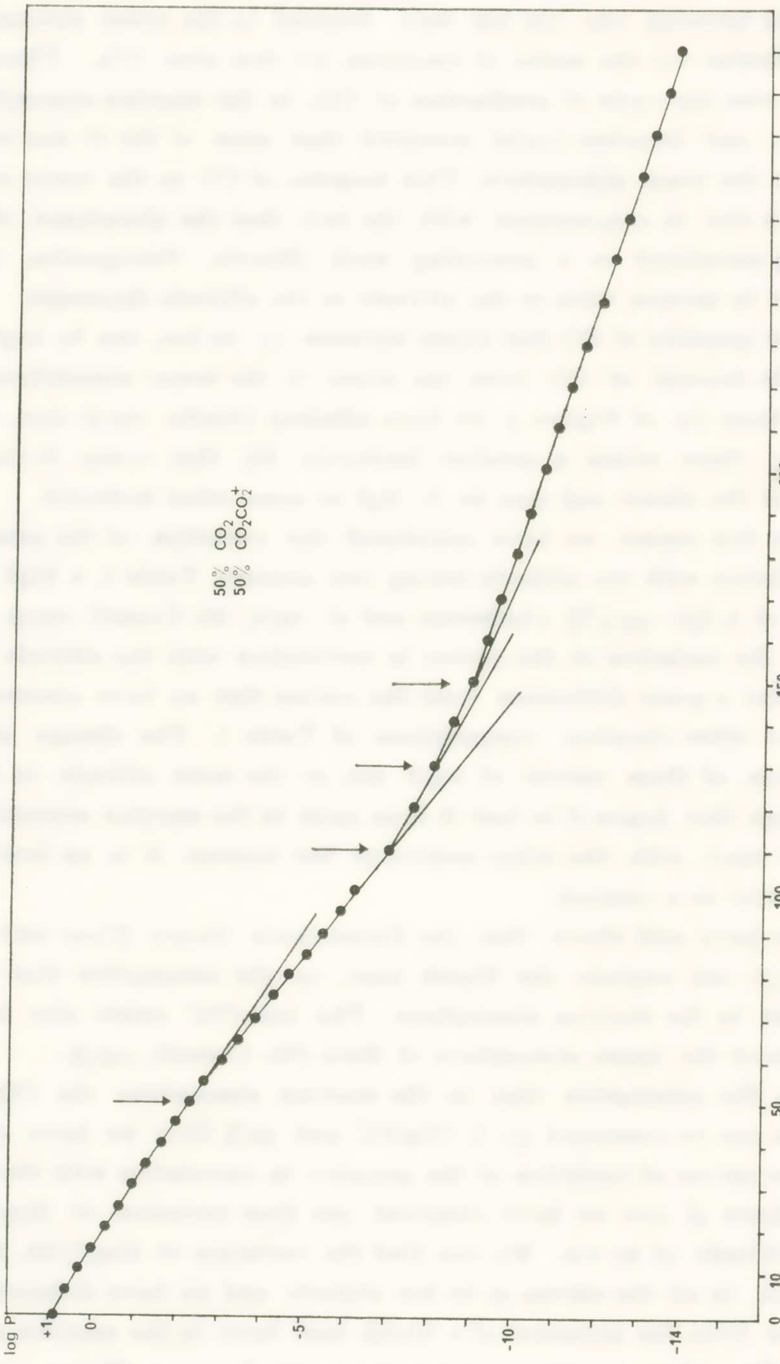

Fig. 4: Pressure vs altitude for the chemical composition 50 % CO_2 and 50 % $CO_2CO_2^+$.

altitudes of 110 km and 130 km and are further weak variation at 150 km altitude. The maximum of electronic concentration measured is at 135 km altitude above the surface of the planet Mars. But the assumption of the existence of $CO_2CO_2^+$, moves the above maximum to the altitude of 110-130 km (Figure 4). From this result we can conclude that either this molecule does not exist in the martian atmosphere or a percentage 50% is excessive. The percentage of $CO_2CO_2^+$ in the atmosphere of Mars is correlated with the augmentation of solar activity and increases if solar activity increases, because the reactions of dissociation (reactions 2 of Figure 3) grow.

Decrease of solar activity, can be correlated with the augmentation of the reactions of ionization (reactions 3a and 3b of Figure 3) account the measurements of Mariner 4, moreover in a minimum of solar activity (1965) (Michaux, 1967) gave a surface temperature 210°K and a surface pressure 8 mb. The surface pressure and the surface temperature recorded by Mariner 4 are the same as the values that were given by Mariner 7 - exit (Table II). Consequently if we compute the pressure with data of Mariner 7 (209°K and 8.02 mb) it is as if we compute the same value with data of Mariner 4, and Figure 4 can be considered to give the maximum of electronic concentration in the minimum of solar activity. The above result is also in agreement with Mariner's 4 measurements of electronic concentration $N_m = 9 \pm 1 \times 10^4 \text{cm}^{-3}$ of the altitude of 120 km over the surface of Mars. We can then conclude that the reactions of ionization, increase the percentage of ion CO_2^+ and consequently, these may be a high percentage of molecule $CO_2CO_2^+$ in the composition of the martian atmosphere.

5. CONCLUSIONS

In this work we have calculated the meteorological curves (pressure and temperature) of the martian atmosphere as a function of the altitude. We have used for this calculation the measurements of the pressure and the temperature at the surface that were taken by Mariners 6 and 7. The results of these calculations are also valid for the similar surface pressures and surface temperatures, that were measured by Mariner 4. The surface pressures and surface temperatures, that have been recently measured by Mariner 9 in different latitudes and longitudes of the planet Mars and for different seasons (Woiceshyn, 1974) show notable differences. In our nextwork we will complete the calculation of the meteorological parameters by use of the measurements of Mariner 9.

The results of the calculation that we have done in this work, are valid if the hydrostatic model is valid for the martian atmosphere. This model can be used for vertical sections of the martian atmosphere on the assumption that this atmosphere is homogeneous.

In the atmosphere of Mars Mariner 9 observed a yellow dust and a bluish haze at an altitude of 60 km and also white and blue clouds at different altitudes of the lower atmosphere.

A study of the curves of pressure and temperature in correlation with the altitude shows that variations of the inclination of logP and T at 15 km and 60 km can be explained by the presence of inhomogeneities at these altitudes. These variations of the inclination are apparent in all the curves of pressure and we accept that their origin is not seasonal or local, but is a general condition of the martian atmosphere. It can readily be comprehensible that all these zones (I - IV) of Table IV can alter in width and that such alteration depends on the season and the longitude and latitude, where the various Mariners made their measurements of the surface pressure and the surface temperature.

The white and blue clouds are local and seasonal phenomena as observation has shown. The white clouds can be created over the poles, where the temperature is low. Dollfus (1956, 1957, 1961) accepted that these clouds resemble the terrestrial ice crystal clouds or fogs. Mariner 9 data indicate the existence of water vapour above the south polar cap. The spectroscopical observations of these clouds that have been made by Mariners 6, 7 and 9 indicate that water vapour rotational spectra are present. It is consequently probable that the white clouds are composed of water. But in this work we have ignored the presence of water in the chemical composition shown in Table I. The blues clouds that frequently appear along with white clouds and mists, may be observed at higher altitudes. Wilson (1958, 1959) estimates their elevation at 15 and 25 km with a possible maximum of 100 km. As we have said at the altitude of 15 km crystals of CO_2, may appear and these crystals may be the origin of the formation of CO_2.

Over 100 km we have found that the temperature is constant

(85°K or −188°C). The calculated pressure at 100 km, for a chemical composition 100% CO_2 of the martian atmosphere is between 5.05×10^{-7} mb (Mariner 7, entry) and 7.92×10^{-7} mb (Mariner 7, exit) as is shown in Table II. Below the pressure of 7.92×10^{-7} mb (5.86×10^{-4} μ Hg) and the temperature −188° C it is possible to have CO_2 in solid state until at an altitude of 100 km, the solid CO_2 may create local blue clouds. If we change the data of the chemical composition of the martian atmosphere and are admit 100% - 98% CO_2 and 0% - 2% CO, which is the maximum limit of the abundance of CO (Macris - Petropoulos, 1973) the pressures do not change (Table III). The quantity of CO is not due simply to photodissociation and dissociation by electrons, but probably to dissociation by protons. The quantity of CO in the martian atmosphere depends of the intensity of the solar flux and consequently of the solar activity, that changes with time. The pressures (Table III) that we have calculated show that the percentage of CO (maximum 2%) calculated on the basis of the measured intensity of the solar flux (Hinteregger, 1970) does not change the width of the zones of Table IV. But if we accept the presence of O and O_3 (chemical composition 3 of Table I) then the pressures, in comparison with those of columns 1 and 2 of Table III, are augmented by 1.4%. This augmentation of the pressure can facilitate the solidification of CO_2 at the altitude of 15 km and at the altitude of 10 km. But the concentration of O produced by the reactions of Figure 3 depends on the solar flux and is higher if the intensity of the solar flux increases. Then if the blue clouds have their origin in the solidification of CO_2, the concentration of CO_2 solid depends on the intensity of the solar flux and consequently on the solar activity.

If we assume that Argon can also exist in the martian atmosphere at a level of 33.3% (chemical composition 6 of Table I) the pressures that we have calculated (Table III) are higher by 3% than those that we have calculated with 100% - 98% CO_2 and consequently the solidification of CO_2 is probable. If we make the assumption that A, O, O_3, exist in the chemical composition of the martian atmosphere (chemical composition 7 of Table I) the pressures (Table III) increase by about 4% in comparison with the pressures calculated with 100% CO_2. All curves of variation of logP that we have calculated with the chemical compositions of Table I are parallels and we can see that the altitudes of variation of $\Delta \log P/\Delta h$ are the same.

We have said that spectroscopic studies of the martian atmosphere have shown the existence of the molecule CO_2^+. If we make the assumption that $CO_2CO_2^+$ is produced by this molecule and we accept 50% $CO_2CO_2^+$ with 50% CO_2 the calculated values of pressures (Table III, columns 9 and 10) increase by about 31%. Consequently the presence of $CO_2CO_2^+$ makes the solidification of CO_2 difficult and this fact, results in the inverted phenomenon of the augmentation of the concentration of O. Thus the solidification of CO_2 in the atmosphere of Mars is dificult and the result is the creation of a bluish haze, such as Mariners have observed at the altitude of 60 km.

To calculate values of pressures and to separate the atmosphere of Mars into zones we have used only some of the measurements that Mariners 4, 6 and 7 have recorded.

In following works we will take into account the measurements of Mariner 9 and the future measurements of Vikings. It will be possible with these results to check whether or not the proposed distribution of the zones (Table IV) is correct. Then it may be possible to find correlations between these zones and the variation of solar activity or the interaction between the atmosphere of Mars and its surface.

ΠΕΡΙΛΗΨΙΣ

Διὰ τὸν ὑπολογισμὸν τῆς θερμοκρασίας καὶ τῆς πιέσεως, συναρτήσει τοῦ ὕψους, ἐντὸς τῆς ἀτμοσφαίρας τοῦ Ἄρεως ἐχρησιμοποιήθησαν οἱ ὑπολογισθέντες παράγοντες Franck - Condon καὶ αἱ ὑπὸ τῶν Mariners 4, 6, 7 μετρηθεῖσαι θερμοκρασίαι καὶ πιέσεις ἐπὶ τῆς ἐπιφανείας τοῦ πλανήτου.

Διὰ τοὺς ὑπολογισμοὺς ἐχρησιμοποιήθη τὸ πρότυπον Chamberlain, καθὼς καὶ τὸ πρόγραμμα Pitts, τὸ ὁποῖον βασίζεται ἐπὶ τοῦ ὑδροστατικοῦ προτύπου.

Αἱ κατασκευασθεῖσαι καμπύλαι θερμοκρασίας μεταβάλλουν τὴν κλίσιν αὐτῶν εἰς τὰ ὕψη τῶν 15, 60, 100 καὶ 140 χιλιομέτρων.

Βάσει τῶν ἀνωτέρω εὑρεθέντων, ἠδυνήθημεν νὰ διαιρέσωμεν καθέτως τὴν ἀτμόσφαιραν τοῦ Ἄρεως εἰς πέντε ζώνας: 1) ἀπὸ 0 - 15 χιλιομ., 2) ἀπὸ 15 - 60 χιλιομ., 3) ἀπὸ 60 - 100 χιλιομ., 4) ἀπὸ 100 - 140 χιλιομ. καὶ 5) ἀπὸ 140 χιλιομ. καὶ ἄνω. Οὕτω διεπιστώθη ὅτι τὰ νέφη καὶ ἡ ὁμίχλη, τὴν ὁποίαν παρετήρησαν οἱ διάφοροι Mariners, ἀντιστοιχοῦν εἰς τὰ αὐτὰ ὕψη, εἰς τὰ ὁποῖα παρετηρήθη μεταβολὴ τῆς κλίσεως τῶν καμπυλῶν θερμοκρασίας καὶ τοῦ λογP.

Πράγματι αἱ μεταβολαὶ τῆς κλίσεως τῶν καμπυλῶν θερμοκρασίας καὶ λογP εἰς τὰ ὕψη τῶν 15 καὶ 100 χιλιομέτρων ἀντιστοιχοῦν εἰς θερμοκρασίας καὶ πιέσεις, αἱ ὁποῖαι δὲν διαφέρουν πολὺ ἐκείνων στερεοποιήσεως τοῦ CO_2. Συνεπῶς εἶναι λίαν πιθανὸν εἰς τὰ ἀνωτέρω ὕψη νὰ ἔχωμεν δημιουργίαν νεφῶν λόγῳ στερεοποιήσεως τοῦ CO_2.

Εἰς τὸ ὕψος τῶν 60 χιλιομ., ἔνθα αἱ καμπύλαι τοῦ λογP ἐμφανίζουν μεταβολὴν κλίσεως, οἱ Mariners παρετήρησαν μίαν κυανῆν ὁμίχλην, ἀποδιδομένην εἰς τὴν παρασκευὴν τοῦ συμπλόκου μορίου $CO_2CO_2^+$. Ἡ μεταβολὴ τῆς θερμοκρασίας καὶ τῆς πιέσεως ἐντὸς τῆς ἀτμοσφαίρας τοῦ Ἄρεως, συναρτήσει τοῦ ὕψους, ὑπελογίσθη ὑπὸ χημικὴν σύνθεσιν: 50% $CO_2CO_2^+$ καὶ 50% CO_2, διὰ διαφορετικὰς θερμοκρασίας καὶ πιέσεις ἐπιφανείας, ἀντιστοιχούσας εἰς διαφορετικὰς χρονικὰς περιόδους τῆς ἡλιακῆς δραστηριότητος. Οὕτω συνάγεται ὅτι ἡ κυανῆ ὁμίχλη, ἐφ᾽ ὅσον ἔχει τὴν ἀνωτέρω σύνθεσιν τὸ πάχος αὐτῆς, ἐξαρτᾶται ἐκ τῆς ἡλιακῆς δραστηριότητος.

Βάσει τῶν ἀνωτέρω ἀποτελεσμάτων προτείνομεν ἓν πρότυπον, τὸ ὁποῖον παριστᾷ τὴν δομὴν τῆς ἀτμοσφαίρας τοῦ Ἄρεως, στηρίζεται δὲ εἰς τὰς χημικὰς ἀντιδράσεις ἐν συνδυασμῷ μὲ τὰς ὑπολογισθείσας θερμοκρασίας καὶ πιέσεις, αἱ ὁποῖαι λαμβάνουν χώραν ἐντὸς αὐτῆς.

Εἰς νεωτέραν ἐργασίαν θὰ χρησιμοποιήσωμεν τὰς μετρήσεις θερμοκρασίας καὶ πιέσεως ἐπιφανείας, αἱ ὁποῖαι ἐξετελέσθησαν ὑπὸ τοῦ Mariner 9 εἰς διάφορα ἀρεογραφικὰ μήκη καὶ πλάτη καὶ εἰς διαφόρους ἐποχάς, διὰ τὸν ὑπολογισμὸν τῶν μετεωρολογικῶν παραμέτρων, συναρτήσει τοῦ ὕψους.

REFERENCES

J. M. Ajello, J. Geoph. Res., **18** (1973), 4279.

D. M. Anderson - K. Biermann - L. E. Orgel - J. Oro - T. Owen - G. P. Shulman - III, P. Toulmin and H. C. Urey, Icarus, **16** (1972), 111.

E. M. Antoniadi, La Planète Mars, Hermann, Paris, 1930.

S. J. Bauer, Physics of Planetary Ionospheres, Springer-Verlag, 1973.

R. Beer - R. H. Norton and J. V. Martonchik, Icarus, **15** (1971), 1.

R. Botter and B. Petropoulos, Solar Activity and Related Interplanetary and Terrestrial Phenomena, Proc. of the First Europ. Astron. Meeting (Athens, Sept. 4-9, 1972), Vol. 1, 134, Ed. J. Xanthakis, Berlin, Springer-Verlag, 1973.

C. F. Capen, Icarus, **22** (1974), 345.

J. W. Chamberlain, Physics of the Aurora and Airglow, Acad. Press. New York 1961, p. 582.

A. Dollfus, La Météorologie, nº 42 (1956), p. 81.

———, Ann. d'Astrophysique, Supplement, nº 4 (1957), p. 70.

———, Proc. Lunar and Planetary Exploration Colloquium, Vol. 2, nº 3, North American Aviation, Inc., Aug. 15 (1961), p. 33.

Handbook of Chemistry, Amer. Inst. of Physics, Ed. D. E. Gray, sec. edition, 1973.

S. L. Hess, J. Meteorol., **7** (1950), 1.

H. E. Hinteregger, Ann. Geophysique, **26** (1970), 547.

J. S. Hogan, NASA TN D - 6683, 1972.

A. Kliore - G. Fjeldbo - B. L. Seidel and S. I. Rasool, Science, **166** (1969), 1393.

A. Kliore, J. Geophys. Res. **78** (1973), 4337.

K. Ya. Kondrat'yev and A. M. Bunakova, NASA TT F - 816, 1974.

Z. Kviz, Bull. Astron. Inst. Czech., **12** (1961), 150.

F. Link, Bull. Astron. Inst. Czech., **2** (1950), 1.

J. C. McConnell, Astroph. and Space Sci. Library, **35** (1973), 309, Ed. B. M. McCormac.

C. J. Macris and B. C. Petropoulos, Solar Activity and Related Interplanetary and Terrestrial Phenomena, Proc. of the First Europ. Astron. Meeting (Athens, Sept. 4 - 9, 1972), Vol. 1, 140, Ed. J. Xanthakis, Berlin, Springer-Verlag, 1973.

M. B. McElroy, Science, **175** (1972), 443.

M. B. McElroy and T. M. Donahue, Science, **177** (1972), 986.

C. M. Michaux, NASA SP - 3030, 1967.

B. C. Petropoulos, Comptes Rendus, Acad. Sci. France, **266** (1968), 276.

C. E. Pitts, NASA TN D - 4292, 1968.

B. Rosen, Ann. d'Astrophysique, **16** (1953), 288.

E. Schatzman, Comptes Rendus, Acad. Sci. France, **223** (1952), 692.

H. C. Urey and A. W. Brewer, Proc. Roy. Astron. Soc. London, **241** (1957), 37.

A. G. Wilson, Rand. Corp. Paper nº P - 1509, Oct. 6, p. 7, 1958.

———, Proc. Lunar and Planetary Exploretin Coloquium, Vol. 1, nº 4, North American Aviation, Inc., Jan. 12, 1959.

P. M. Woiceshyn, Icarus, **22** (1974), 325.

Ὁ Ἀκαδημαϊκὸς κ. **Ι. Ξανθάκης**, παρουσιάζων τὴν ἀνωτέρω ἀνακοίνωσιν, εἶπε τὰ ἑξῆς:

Εἰς τὴν παροῦσαν ἐργασίαν οἱ κύριοι Μακρῆς καὶ Πετρόπουλος μελετοῦν ἓν πρότυπον τῆς ἀτμοσφαίρας τοῦ Ἄρεως, ἀναφερόμενον εἰς τὴν μεταβολὴν τῆς θερμοκρασίας καὶ πιέσεως μετὰ τοῦ ὕψους ἐντὸς τῆς ἀτμοσφαίρας τοῦ πλανήτου. Τὸ πρότυπον τοῦτο στηρίζεται εἰς τὰς κάτωθι δύο ὑποθέσεις:

1) Ὅτι ἡ παρουσία τοῦ μονοξειδίου τοῦ ἄνθρακος ἐντὸς τῆς Ἀρειανῆς ἀτμοσφαίρας ὀφείλεται εἰς τὴν δρᾶσιν τῆς ἡλιακῆς ροῆς. Ἔλαβον ἐπίσης ὑπ᾽ ὄψιν, διὰ τὰς διαφόρους ἠλεκτρονικὰς καταστάσεις τοῦ μορίου τοῦ διοξειδείου τοῦ ἄνθρακος, ὅλας τὰς δυνατότητας διασπάσεως αὐτοῦ.

2) Ὅτι τὰ δοθέντα στοιχεῖα ὑπὸ τῶν διαστημοπλοίων Mariners 6, 7 δύνανται νὰ χρησιμοποιηθοῦν διὰ τὸν ὑπολογισμὸν τῆς ἀφθονίας τῶν μορίων τοῦ μονοξειδίου καὶ διοξειδίου τοῦ ἄνθρακος συναρτήσει τοῦ ὕψους διὰ τὰς διαφόρους δυνητικὰς μεταστάσεις.

Διὰ τὸν ὑπολογισμὸν τῶν μεταβολῶν τῶν δύο αὐτῶν παραμέτρων μετὰ τοῦ ὕψους οἱ δύο ἐρευνηταὶ ἐδέχθησαν διαφόρους χημικὰς συνθέσεις τῆς Ἀρειανῆς ἀτμοσφαίρας καὶ ὑπὸ τὴν ὑπόθεσιν ὅτι ἰσχύει τὸ ὑδροστατικὸν πρότυπον εἰς τὴν ἀτμοσφαῖραν τοῦ πλανήτου ὑπελόγισαν τὰς μεταβολὰς θερμοκρασίας καὶ πιέσεως χρησιμοποιήσαντες εἰς τοὺς ἠλεκτρονικοὺς ὑπολογιστὰς τὸ πρόγραμμα τοῦ Pitts.

Ἐπὶ τῇ βάσει τῶν ἀνωτέρω ὑποθέσεων καὶ δεδομένων οἱ κύριοι Μακρῆς καὶ Πετρόπουλος εὗρον ὅτι αἱ καμπύλαι μεταβολῆς τῆς θερμοκρασίας μετὰ τοῦ ὕψους παρουσιάζουν μεταβολὴν τῆς κλίσεως αὐτῶν δι᾽ ὅλας τὰς μετρήσεις τῶν Mariners 6, 7, εἰς τὰ ὕψη τῶν 15 καὶ 100 km. Πέραν τῶν 100 km ἡ θερμοκρασία παραμένει σταθερὰ ὑφ᾽ οἱανδήποτε χημικὴν σύνθεσιν τῆς ἀτμοσφαίρας τοῦ Ἄρεως.

Ὅσον ἀφορᾷ τὰς μεταβολὰς τῆς πιέσεως, αἱ ἀντίστοιχοι καμπύλαι τοῦ logP διὰ τὰς διαφόρους ὑποτεθείσας χημικὰς συνθέσεις εἶναι παράλληλοι μεταξύ των. Πλὴν ὅμως δεικνύουν μεταβολὰς τῆς κλίσεώς των εἰς τέσσαρα σημεῖα ἀντιστοιχοῦντα εἰς τὰ ὕψη τῶν 15, 60, 100, 140 km.

Ἐπὶ τῇ βάσει τῶν παρατηρουμένων μεταβολῶν κλίσεως τῆς πιέσεως, οἱ ἐν λόγῳ ἐρευνηταὶ προτείνουν τὴν διαίρεσιν τῆς ἀτμοσφαίρας τοῦ Ἄρεως εἰς τέσσαρας ζώνας ἀπὸ 0 - 15 km, ἀπὸ 15 - 60 km, ἀπὸ 60 - 100 km καὶ ἀπὸ 100 - 140 km. Ὑπεράνω τῶν 140 km, ὁ λογάριθμος πιέσεως φαίνεται νὰ μεταβάλλεται ὁμαλῶς μετὰ τοῦ ὕψους. Τὴν διαίρεσιν ταύτην τῆς ἀτμοσφαίρας τοῦ πλανήτου εἰς τὰς ἀνωτέρω τέσσαρας στοιβάδας οἱ κύριοι Μακρῆς καὶ Πετρόπουλος ἀποδίδουν εἰς διαφόρους αἰτίας.

Οὕτως ἡ πρώτη ζώνη ἀπὸ τῆς ἐπιφανείας τοῦ ἐδάφους μέχρι τοῦ ὕψους τῶν 15 km δημιουργεῖται κατ᾽ αὐτοὺς ἀπὸ ἕνα μῖγμα κόνεως καὶ διαφόρων μορίων ὡς τοῦ διοξειδίου τοῦ ἄνθρακος ὑπὸ ἀερίαν ἢ κρυσταλλικὴν μορφήν, τοῦ ὕδατος, ἐλαχίστου εἰς ποσότητα, τοῦ διοξειδίου τοῦ πυριτίου, τοῦ ὑδροθείου καὶ ἄλλων.

Ἡ δευτέρα ζώνη ἀπὸ 15 - 60 km δημιουργεῖται λόγῳ μιᾶς σειρᾶς ἀντιδράσεων μεταξὺ μορίων καὶ ἀτόμων, τὰ ὁποῖα προέρχονται εἴτε ἀπὸ τὴν κατωτέραν ἀτμοσφαῖραν εἴτε ἀπὸ ἀντιδράσεις, αἱ ὁποῖαι λαμβάνουν χώραν εἰς τὴν ἰονόσφαιραν τοῦ πλανήτου.

Ἡ δημιουργία τῆς τρίτης ζώνης μεταξὺ 60 - 100 km ἀποδίδεται εἰς μετακινήσεις καὶ μίξιν ἀνερχομένων μορίων καὶ ἀτόμων ὑδρογόνου, διοξειδίου τοῦ ἄνθρακος, μονοξειδίου τοῦ ἄνθρακος καὶ ὀξυγόνου, ἅτινα προέρχονται ἀπὸ τὰς χημικὰς ἀντιδράσεις ποὺ λαμβάνουν χώραν εἰς τὴν δευτέραν ζώνην, καθὼς καὶ ἀπὸ τὴν διάσπασιν τῶν ἀνωτέρω μορίων ἐκ βομβαρδισμοῦ ὑπὸ τῶν ἠλεκτρονίων τῆς ἡλιακῆς ροῆς, καθὼς καὶ ἀπὸ τὴν φωτοδιάσπασιν τοῦ διοξειδίου τοῦ ἄνθρακος εἰς τὰ ἀνώτερα στρώματα τῆς Ἀρειανῆς ἀτμοσφαίρας.

Τέλος ἡ δημιουργία τῆς τετάρτης ζώνης, τῆς κυμαινομένης μεταξὺ 100 - 140 km ἀποδίδεται εἰς τὴν αὔξησιν τῆς ἠλεκτρονικῆς πυκνότητος, ἥτις ἐμετρήθη ἀπὸ τὰ διαστημόπλοια Mariners 4, 6, καὶ 7. Πράγματι ἐκ τῶν μετρήσεων τῶν διαστημοπλοίων τούτων διαπιστοῦται ἕνα μέγιστον τῆς ἠλεκτρονικῆς πυκνότητος εἰς τὸ ὕψος τῶν 135 km ποὺ λαμβάνει χώραν κατὰ τὸ μέγιστον τῆς ἡλιακῆς δραστηριότητος, καθὼς καὶ ἓν ἕτερον μέγιστον εἰς τὸ ὕψος τῶν 115 km, ποὺ λαμβάνει χώραν κατὰ τὸ ἐλάχιστον τῆς ἡλιακῆς δραστηριότητος.

Τὰ ἀνωτέρω πειραματικὰ δεδομένα ἀποδεικνύουν ὅτι τὰ ὅρια τῶν τεσσάρων ἀτμοσφαιρικῶν στοιβάδων πιθανῶς νὰ μεταβάλλωνται ἐκ τῆς ἐπιδράσεως ἀφ᾽ ἑνὸς μὲν τῆς ἡλιακῆς δραστηριότητος ἀφ᾽ ἑτέρου δὲ ἐκ τῆς ἀλληλεπιδράσεως μεταξὺ ἐπιφανείας καὶ ἀτμοσφαίρας τοῦ πλανήτου.

Τέλος οἱ κύριοι Μακρῆς καὶ Πετρόπουλος συνεχίζοντες τὰς ἐρεύνας ταύτας εἰς τὸ Κέντρον Ἐρευνῶν Ἀστρονομίας καὶ Ἐφηρμοσμένων Μαθηματικῶν προτίθενται νὰ τὰς ἐπεκτείνουν ἐπὶ τῇ βάσει τῶν νεωτέρων δεδομένων τοῦ διαστημοπλοίου Mariner 9, καθὼς καὶ ἐκείνων τὰ ὁποῖα σκοπεύουν νὰ λάβουν ἐκ τῶν διαστημοπλοίων Vikings, τὰ ὁποῖα ἐξετοξεύθησαν κατὰ τὸ παρελθὸν ἔτος καὶ ἀναμένεται κατὰ τὸ τρέχον ἔτος νὰ προσεδαφισθοῦν εἰς τὴν ἐπιφάνειαν τοῦ Ἄρεως.