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ON EXPLAINING THE F-REGION SEASONAL ANOMALY IN TERMS OF COMPOSITION CHANGES IN THE LOWER ATMOSPHERE

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In a recent paper, Chandra and Stubbe (1971) have shown that the depression in N_mF_2 usually observed in the midlatitude ionosphere during geomagnetic storms arises mainly from the decrease in $[O]/[N_2]$ in the lower atmosphere. By solving a system of coupled time dependent ionospheric and atmospheric equations, it was shown that a decrease in $[O]/[N_2]$ in the region around 120 km results in an increase of the neutral gas temperature and a depletion of the O^+ layer. Earlier, a similar conclusion was arrived at by Chandra and Herman (1969) from the steady state solutions of the equations for electrons, ions and the neutral gas.

Duncan (1969) has drawn attention to the fact that the behavior of the ionosphere during geomagnetic storms is very similar to that of the summer months. He argues that the F-region seasonal anomaly should be interpreted as an anomalous decrease in N_mF_2 in the summer months rather than an anomalous increase in the winter months. The decrease in N_mF_2 during geomagnetic storms and during summer months may, therefore, be the manifestation of the same phenomenon. They may both result from composition changes in the lower atmosphere or, more specifically, from the decrease in $[O]/[N_2]$ in the altitude region of 100-120 km. Such an idea is extremely attractive and has found considerable support in recent years (Strobel and McElroy, 1970; Evans and Cox, 1970; Cox and Evans 1970). We refrained from making a similar suggestion on the ground that it presents difficulties in explaining the behavior of the neutral atmosphere in summer and winter months. As we pointed out in our earlier papers, the ionospheric and atmospheric problems cannot be separated from each other because of the strong coupling between them. Any change in the relative concentrations of O and N_2 in the lower atmosphere generates a complex chain of events which not only affects the ionospheric parameters, but the atmospheric parameters as well. The purpose of this paper is to discuss specifically the effect of this change on the seasonal behavior of the neutral atmosphere.

Figures 1 and 2 show the diurnal variations of the exospheric temperature and the neutral density at 300 km for the summer and winter conditions. The numerical results are based on the solutions of the energy balance equation using the dynamic diffusion model of the neutral atmosphere (Chandra and Stubbe 1970). The two cases A and B shown in these figures differ only with respect to their values of [O], $[O_2]$ and $[N_2]$ at the lower boundary which is taken to the 120 km. Their values at 120 km for 1800 hours local time are shown in the following table (the values at 1800 hours are identical to the diurnal averages):

	A	B
$[O_2]$	$1.13 \times 10^{11}/cm^3$	$1.69 \times 10^{11}/cm^3$
$[N_2]$	$6.00 \times 10^{11}/cm^3$	$9.00 \times 10^{11}/cm^3$
[O]	$6.76 \times 10^{10}/cm^3$	$5.00 \times 10^{10}/cm$
$[O]/[N_2]$	0.11	.055

The other parameters used in the calculations of Fig. 1 and 2 are exactly the same as given in Chandra and Stubbe (1971). Thus the two cases A and B differ mainly with respect to their values $[O]/[N_2]$ at the lower boundary which are .11 and .055 respectively. They are identical to the cases Q and D2 of the magnetic storm paper (Chandra and Stubbe, 1971), where they described quiet and magnetically disturbed conditions, respectively. We note from Figs. 1 and 2 that the temperature and the density differences between summer and winter conditions are quite large even when the boundary conditions are the same in the two seasons (case A or case B). Typically, the summer temperatures are a factor of 2 higher than the corresponding winter temperatures. The model temperatures inferred from satellite drag measurements do not show such large variations from winter to summer (see for example the COSPAR International Reference Atmosphere 1965) and hence are in basic disagreement with these results. The assumption that the ratio $[O]/[N_2]$ in summer is decreased compared to its winter values may appear plausible to explain the seasonal anomaly in the ionosphere (Strobel and McElroy, 1970) but it makes the situation in the neutral atmosphere even worse (compare curve A of winter with the curve B of the summer). In order to decrease the temperature difference in the two seasons we need to effect a change in the neutral composition in the opposite direction i.e. we should decrease $[O]/[N_2]$ in the winter months, because the neutral gas heat loss is proportional to [O] (Bates, 1951). This makes the problem of explaining the seasonal anomaly in the F-region even more difficult.

From the foregoing discussion it is clear that the basic problem in the seasonal behavior of the neutral atmosphere is to understand why the exospheric temperatures in summer and winter are about equal. At any given time of day, the heat production in summer is much larger than in winter. Moreover, a day in summer is much longer than in winter. Therefore, it is evident that solutions of the heat conduction equation yield temperatures which are substantially higher in summer than in winter, equal composition provided. These theoretical results are incompatible with experimental evidence. It is possible to influence the theoretically obtained temperatures by changing the composition in the lower thermosphere. In order to reduce the summer temperatures and increase the winter temperatures, one has to assume considerably larger $[O]/[N_2]$ ratios in summer than in winter. As we saw above, just the opposite change is required for explaining the seasonal anomaly in the ionosphere. In other words: by explaining the seasonal anomaly in the neutral atmosphere in terms of appropriate composition changes in the lower thermosphere, one deteriorates the situation in the ionospheric behavior and vice versa.

Acknowledgement

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Figure Captions

Figure 1: The diurnal variations of the exospheric neutral temperatures for the summer and winter conditions. Curves A and B refer to different boundary conditions as discussed in the text.

Figure 2: The diurnal variation of the neutral density at 300 km for the summer and winter conditions. Curves A and B refer to different boundary conditions as discussed in the text.

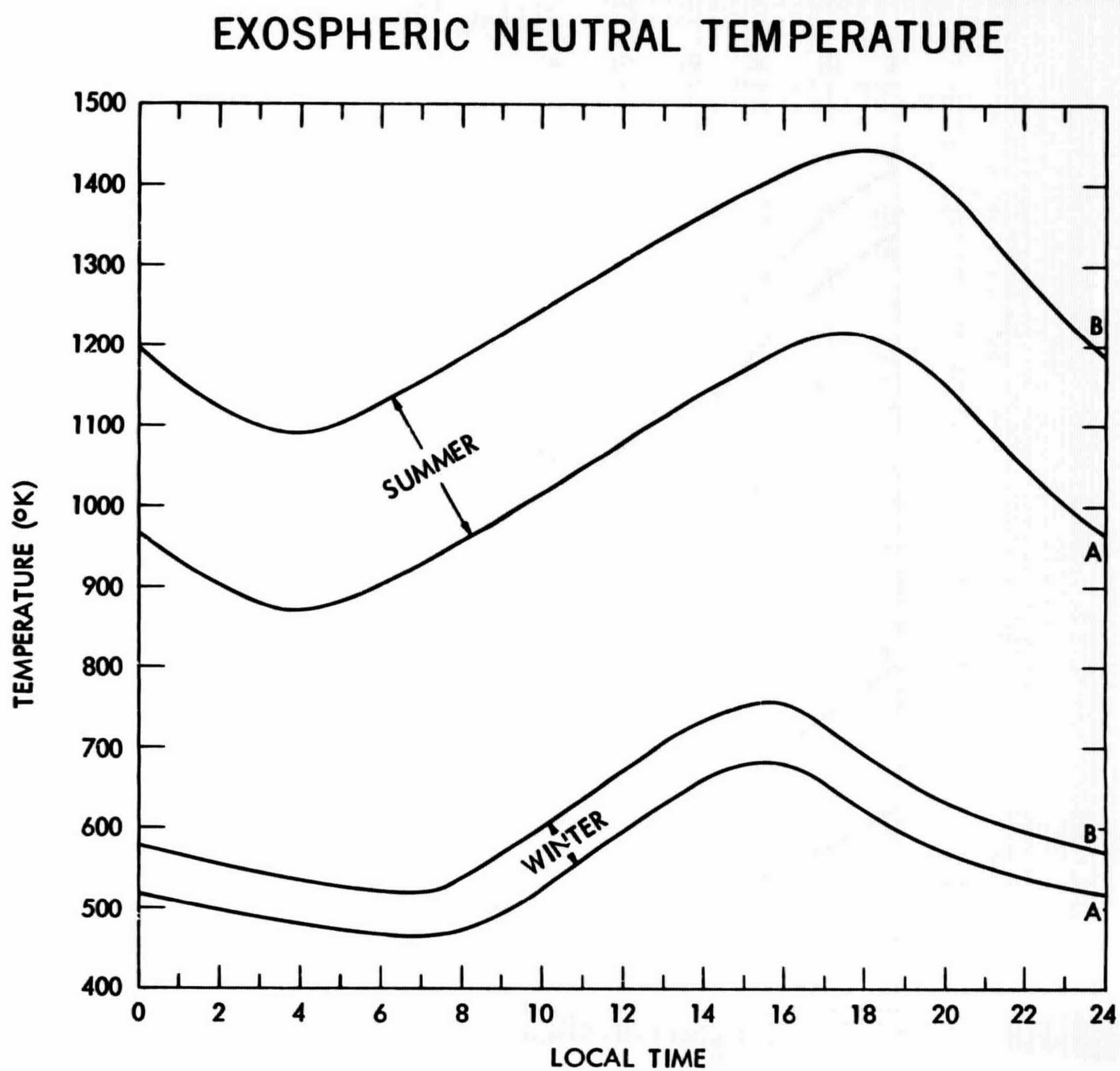
EXOSPHERIC NEUTRAL TEMPERATURE
TEMPERATURE (°K)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
0
2
4
6
8
10
12
14
16
18
20
22
24
LOCAL TIME
SUMMER
WINTER
B
A
B
A

FIGURE 1

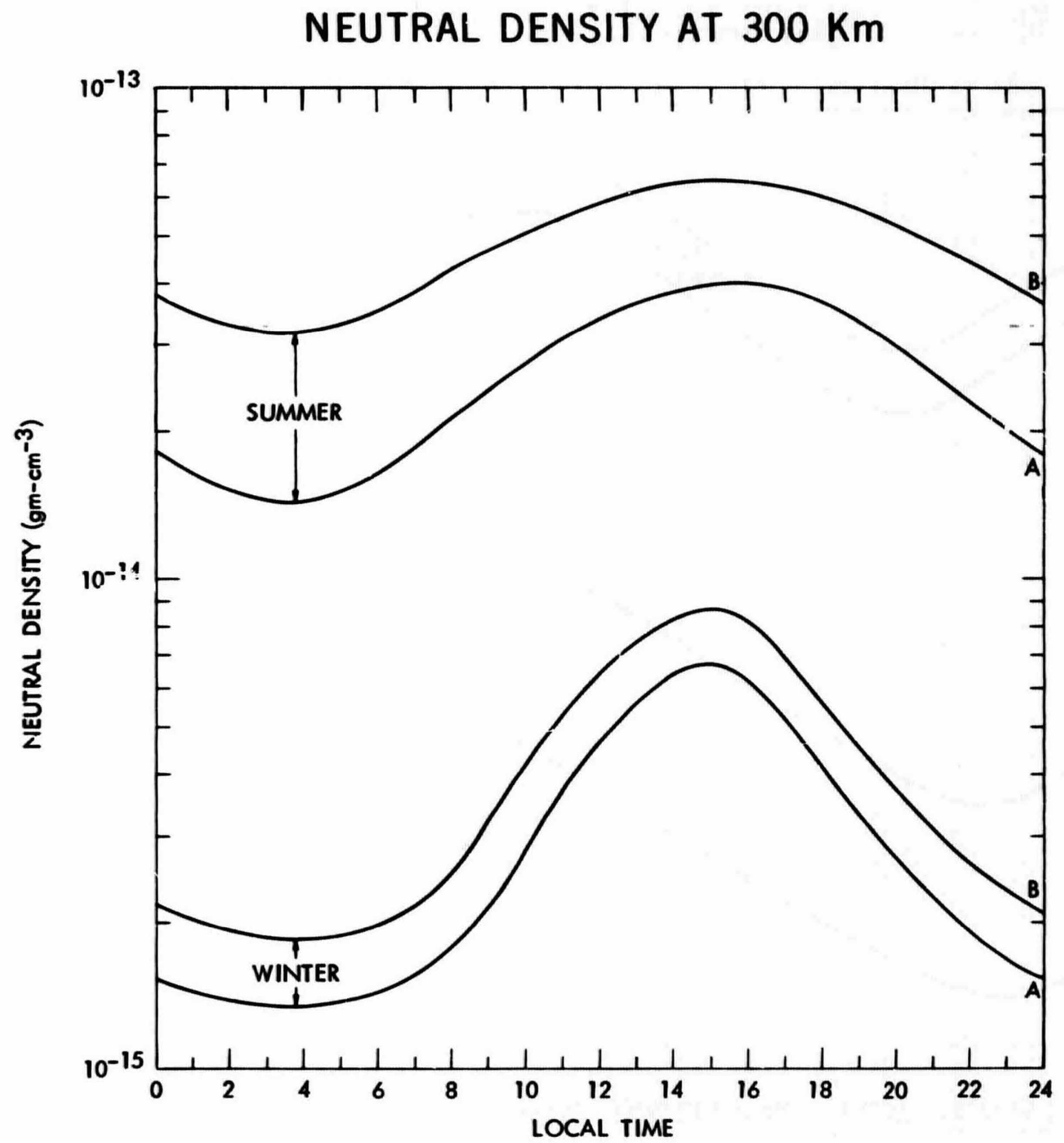
NEUTRAL DENSITY AT 300 Km
NEUTRAL DENSITY (gm-cm^-3)
10^-13
10^-14
10^-15
SUMMER
WINTER
A
B
0
2
4
6
8
10
12
14
16
18
20
22
24
LOCAL TIME

FIGURE 2