Adv. Space Res. Vol.3, No.1, pp.95-98, 1983
Printed in Great Britain.
0273-1177/83/010095-04$03.00/0

PROPERTIES OF THE NEUTRAL DENSITY AND COMPOSITION IN THE THERMOSPHERE

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ABSTRACT

Measurements of the density and composition of the thermosphere between 150 and 500 km, which were obtained by the S3-1 satellite, have been compared with the Jacchia and MSIS models. The measurements of the densities of O, N_2, N and Ar show some differences from the current models which should be considered during the preparation of the next CIRA model. The Ar measurements are particularly useful in examining the response of the neutral atmosphere to geomagnetic heating. These results are useful in establishing the appropriate lower boundary conditions for modeling of the thermosphere.

INTRODUCTION

The enclosed ion source mass spectrometer on the S3-1 satellite obtained measurements of O, N_2, N and Ar in the altitude range of 150 to 500 km [1,2]. The measurements provide an opportunity to test model predictions of the composition in the thermosphere. The models which are most used in the scientific community today are the MSIS model [3] and the Jacchia 77 model [4] which have been based on a large number of previous mass spectrometer experiments and other techniques.

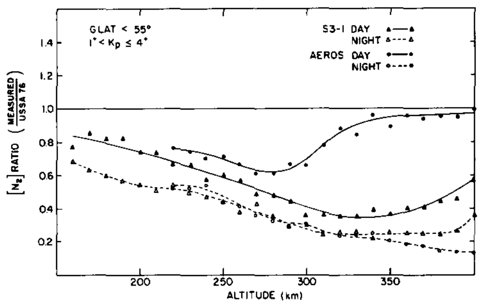
The S3-1 measurements represent the conditions for low solar flux during the 1974-75 period. A set of measurements during the period when the satellite perigee precesses from mid-northern latitudes on the dayside (11 hours) across the northern polar region to mid-latitudes on the nightside (22 hours) has been used for comparison with models. The argon measurements have been given special attention because these provide a sensitive test of the heating and dynamics in the lower thermosphere. During the same period of time, Nov. 1974 through Feb. 1975, data were obtained by the neutral and ion mass spectrometer experiment on the AEROS-B satellite [5]. A comparison of the S3-1 and AEROS-B results has shown good agreement between the mass spectrometer measurements. The local time coverage for the AEROS-B satellite was near 1600 hours on the dayside and 0400 hours on the nightside. Comparisons to the models show the results from the AEROS-B to illustrate the local time dependence and to extend the altitude range of the argon results.

The procedure used for the analysis was to calculate the value of the Jacchia 77 and MSIS model appropriate for the geophysical conditions and location of each measurement point. The ratio of the measurement to the model value was then formed. The ratios were collected by 10 km altitude bins and were subdivided by three ranges of K_p, by two divisions of geomagnetic latitude and by day or night measurement periods. For each of the data bins thus formed, the mean and standard deviation was calculated. The bins contained a few tens to a few hundreds of measurements. It will only be possible in this brief paper to show a few of the comparisons which have been made using the results.

RESULTS

Figure 1 shows comparisons of the measured N_2 at middle latitudes with the model values. Each point shown represents the calculated mean and the lines are intended to assist in following the trend. In Fig. 1a, the comparison with the USSA 76 model is shown for the S3-1 and AEROS-B satellites. Comparison with an invariable model profile such as this is useful for examining the atmospheric variations which may or may not be properly considered when comparing to other models. The AEROS-B and the S3-1 results show excellent agreement for the nightside measurements. The difference in the dayside measurements is due to the local time difference, 1100 hours for S3-1 and 1600 hours for the AEROS-B. The late afternoon increase in the N_2 density at higher altitudes is demonstrated, and it is interesting to note that the local time dependence is much smaller below 280 km. In Fig. 1b, the ratio of the measured S3-1 values to the Jacchia 77 model is shown together with the magnitude of the standard deviation of the mean for the middle range of K_p. The increase in the size of the standard

(a)



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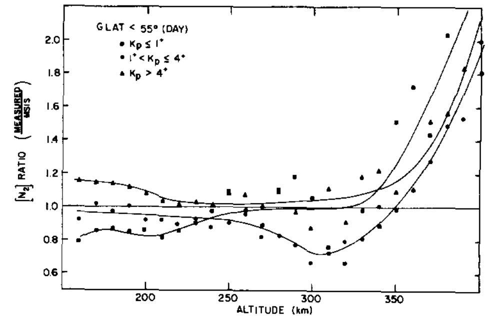

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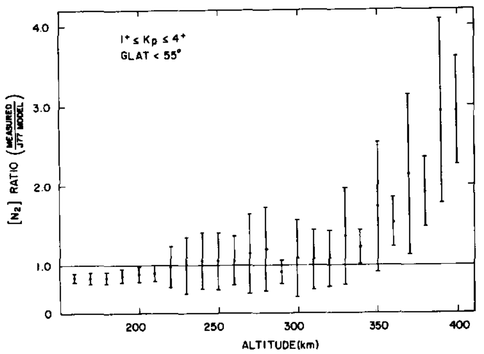


Fig. 1. Mean values of N_2 measurements compared to USSA76, Jacchia77 and MSIS models.

deviation with altitude primarily reflects the larger variability of the atmosphere at higher altitudes. The increase of the ratio above 350 km was observed in both the S3-1 and AEROS-B data relative to both the Jacchia 77 and the MSIS models, see Fig. 1c. This increase is significant and probably is due to the severe flattening of the model temperature profiles as they asymptotically approach the exospheric temperature value. Fig. 1c shows the comparison of the S3-1 results with the MSIS model. A stronger K_p dependence is observed below 200 km than is indicated by the model. In the case of the comparisons with the Jacchia 77 model, the same is also true, but to a lesser magnitude.

Figure 2 shows the mean values of atomic oxygen compared to the Jacchia 77 model. While the middle and high K_p values lie within about ± 20% of the model, it is noted that the quiet geomagnetic conditions indicate significantly lower density for altitudes between 200 and 400 km. The K_p dependence in the measurement ratio to the Jacchia 77 model is obviously not properly included in the model. When the measured values are compared to the USSA 76, independent of K_p, the variation with K_p is found to be significantly smaller than that dependence included in the model. For example, at 250 km, the percent difference between the $K_p<1^+$ and $K_p>4^+$ from Figure 2 is 35%, whereas in the case where the same data are compared or when they are compared to the USSA 76 model, the percent difference is 22% on the nightside and 3% on the dayside. The conclusion is that the Jacchia 77 model contains a stronger K_p dependence for the atomic oxygen than would be justified. This conclusion can be also reached by examining the AEROS-B data. The MSIS model is better regarding this point in that its dependence on K_p for atomic oxygen is much weaker. This better dependence for the MSIS model may be expected due to the stronger reliance on mass spectrometer data in its formulation. However, the MSIS model does not account for the weak anticorrelation which exists between the atomic oxygen density and K_p which the Jacchia 77 model overcorrects.

The results of the comparison of the Ar measurements to the Jacchia 77 model are shown in Figure 3. Reasonable agreement has been found between the S3-1 and the AEROS-B satellite results. From these results it is obvious that the modeled argon is significantly different from that measured. The fact that argon is significantly heavier than the mean molecular weight means that its scale height is a sensitive measure for the temperature structure and dynamical processes of the upper atmosphere. Thus argon measurements provide a good "thermometer" for the thermosphere. The altitude variation observed could be reconciled with a significantly steeper gradient in the effective model temperature profile in the lower thermosphere. The dependence included in the Jacchia 77 model for K_p variations has accounted for the majority of the argon and molecular nitrogen variation, however, the magnitude of the modeled effect should be larger.

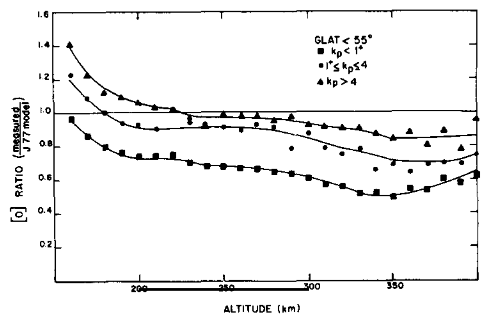


Fig. 2. Mean values of O measurements compared to the Jacchia77 model.

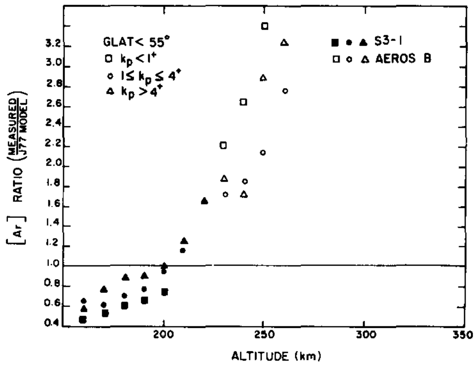
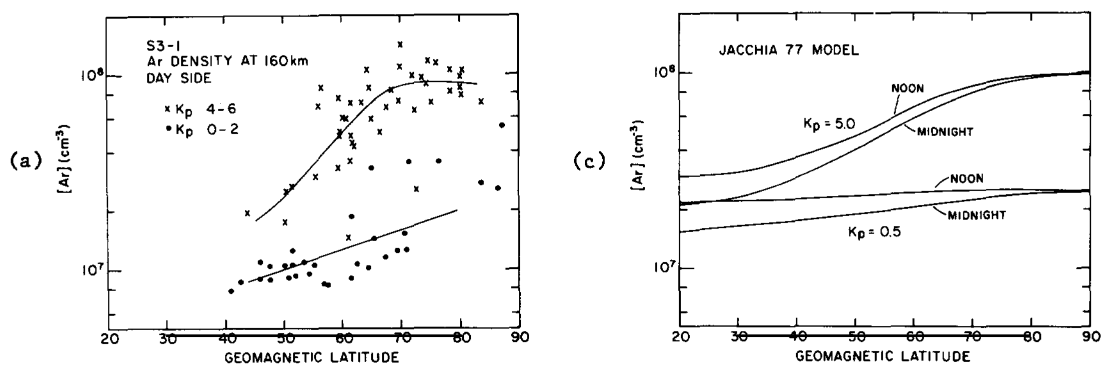


Fig. 3. Mean values of Ar measurements compared to the Jacchia77 model.

In Figure 4 the day and night measurements of argon for individual orbit crossings at 160 km are shown. Also the Jacchia 77 model of the argon variation is shown for comparison. The measurements subdivide well into two groupings by K_p but some scatter is evident. Most of the scatter is due to those periods where the 3-hour K_p index does not provide sufficient time resolution when the index is changing rapidly at the beginning or end of a geomagnetically disturbed period. There is an apparent asymmetry between the dayside and nightside response to the geomagnetically active periods. The K_p response of the Jacchia 77 model, which was primarily based on early analysis of the S3-1 results, does not show the same dependence as measured. However, the model does account for a significant proportion of the latitude and K_p variation. The most strongly heated region is apparently near the polar cusp, on the dayside near 70° geomagnetic latitude.



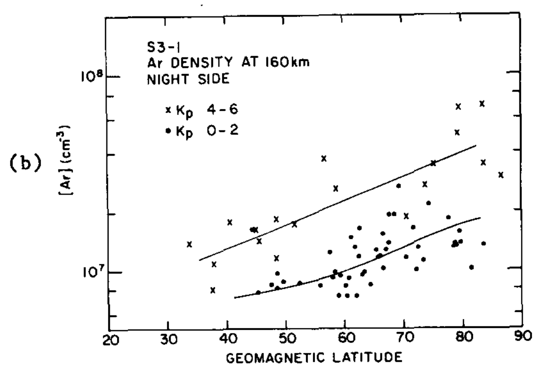


Fig. 4. Measurement of Ar at 160 km, subdivided into low and high K_p ranges and the Jacchia77 model.

In conclusion, several points have been presented which reflect on the differences between the current models and the measurements of the S3-1 and the AEROS-B satellites. The model parameters for the thermal structure and the K_p dependence of the atmosphere can be improved by examination of these composition dependencies. The low altitude argon measurements provide a unique data set for use in describing the properties of the lower thermosphere.

ACKNOWLEDGEMENTS

Helpful discussions with Drs. D. Krankowsky, K.S.W. Champion and J.W. Slowey are acknowledged. Part of this work was completed while one of us (C.R.P.) was visiting scientist at the Max-Planck-Institut für Kernphysik. This work has been sponsored in part by the Bundesministerium für Forschung und Technologie.

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