Journal of Atmospheric and Terrestrial Physics, 1972, Vol. 34, pp. 593–599. Pergamon Press. Printed in Northern Ireland

Response of the neutral particle upper atmosphere to the solar eclipse of 7 March 1970

J. J. HORVATH
University of Michigan, Ann Arbor, Michigan 48105, U.S.A.

and

J. S. THEON
Goddard Space Flight Center, Greenbelt, Maryland 20771, U.S.A.

(*Received* 24 *November* 1971)

Abstract—A series of five pitot probes were launched from Wallops Island, Va. (38°N) in conjunction with the solar eclipse, 7 March 1970. Three soundings were programmed to occur at 40, 80 and 100 per cent obscuration of the Sun (at 100 km) during a 42-min period. The remaining two soundings were made 24 hr before and after the eclipse. The five soundings yielded neutral particle pressure, temperature, and density profiles over the altitude regime 30–125 km. Below 95 km the three density profiles resulting from the eclipse day launches had an average deviation of less than 1·5 per cent. Above 95 km density changes of up to 20 per cent were observed. Such changes in density are comparable in magnitude to those normally observed over a period of several hours. On 10 March 1971, three additional pitot probes were launched from Wallops Island, Va. at times identical to those of the 1970 eclipse day. Comparison of the two sets of data should provide for a more objective analysis regarding atmospheric response to solar input.

INTRODUCTION

PRIOR to 1970, only one set of rocket soundings of the neutral atmosphere above 30 km during a solar eclipse had taken place (BALLARD *et al.*, 1969). These data indicated rather large temperature variations at the stratopause and in the lower mesosphere over the several hour period spanning the eclipse. The data presented here resulted from the launch of eight pitot probe payloads. Three payloads were expended within a 42-min period on 7 March 1970 from Wallops Island during the actual solar eclipse event. An additional set of three payloads was launched, again from Wallops Island, on 10 March 1971 at identical times corresponding to the eclipse launches. These two sets of launches are referred to as the eclipse series and the control series respectively. Two additional soundings, which were conducted at approximately ±24 hr from the eclipse event, were intended to monitor the conditions before and after the eclipse. The unexpectedly large day-to-day variability reduced the value of these two soundings for background comparison, necessitating the March 1971 series for this purpose. The significance of the 'control' series lies not in a direct comparison of the absolute values of the control profiles with the eclipse profiles, but rather to demonstrate that the short term variability of the upper atmosphere over Wallops Island in March is similar in both the control series during which the solar heating changed gradually, and the eclipse series during which the solar heating changed abruptly.

EXPERIMENTAL TECHNIQUE

A brief description of the pitot probe technique of upper atmosphere observation should be given. It is an aerodynamic technique which utilizes the continuous measurement of the impact or stagnation pressure on an ascending rocket payload moving at supersonic speeds. Using theory appropriate to the unique flow regimes encountered, compressible fluid theory in the continuum region and a modified thermal transpiration interpretation in the free molecular flow region, a continuous undisturbed neutral particle density profile can be obtained between 30 and 125 km (HORVATH *et al.*, 1962). The absolute accuracy of the derived mass density profile is on the order of ±2 per cent up to 70 km, ±3 per cent between 70 and 85 km, ±4 per cent between 85 and 100 km. Discussion of absolute errors above 100 km requires the treading of very thin ice. For the purpose of these data only relative variations are important. Assuming, then, that the major possible error sources above 100 km, composition and horizontal winds, are constant in time over the 42 min observational period, the error is a function of sensor repeatability. Under this assumption, the assigned relative accuracy between observations within a series increases monotonically from ±4 per cent at 100 km to ±10 per cent at 125 km.

Once the density profile has been determined, a temperature profile can be derived by downward integration of the hydrostatic equation.

OBSERVATIONS

The experimental objective was to determine the local neutral atmospheric response to a sudden removal of solar radiation. As luck would have it, not only did the solar eclipse take place, but very high levels of geomagnetic activity were occurring over the same time interval.

Figures 1 and 2 show the density profiles resulting from the two series. For convenience, the data are plotted as the ratio of the measured density to the value given in the 1962 U.S. Standard Atmosphere (DUBIN *et al.*, 1962). Below 90 km the standard deviation in the three density profiles for either series was less than ±2 per cent, or within the expected error flags of the measurement. The eclipse series continued to show very little variation all the way to 97 km while the control soundings (Fig. 2) indicate greater variability in the region 80–97 km. Above 97 km, reasonably large variations were observed in both sets of measurements. Note that at about 111 km an apparent 30 per cent decrease in density occurred in 27 min during the eclipse. Figure 3 shows a comparison between the eclipse and control series in terms of the standard deviations of density. As noted previously, the deviations below 90 km for each series are of the same order of magnitude, ±2 per cent and generally appear to be in phase. Note, especially, the large deviation of 6–7 per cent at 84–85 km in both series, while the absolute error in density at 85 km is not expected to be greater than ±3–4 per cent.

Between 90 and 100 km, the control series exhibits larger deviations than the eclipse series. Above 100 km, however, the eclipse density data include very large deviations. Again, at 111 km the 30 per cent density decrease that occurred in 27 min is reflected by a standard deviation of ±14·5 per cent.

Figures 4 and 5 show the temperature comparison for both 7 March 1970 and 10 March 1971. Below 105 km the small scale structure in each set of observations is very similar. Both contain wavelike variations with amplitudes on the order of 5°K, and vertical wavelengths between 2 and 10 km. Computation

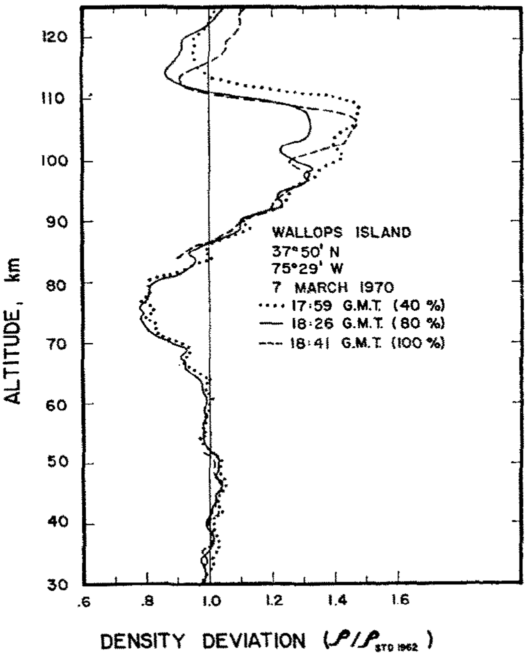

Fig. 1. Density profiles observed from Wallops Island on 7 March 1970 (eclipse day). The missing data between 52–84 km in the 1841 GMT profile resulted from a payload malfunction. Density is plotted as a ratio to the 1962 U.S. Standard Atmosphere value for convenience.

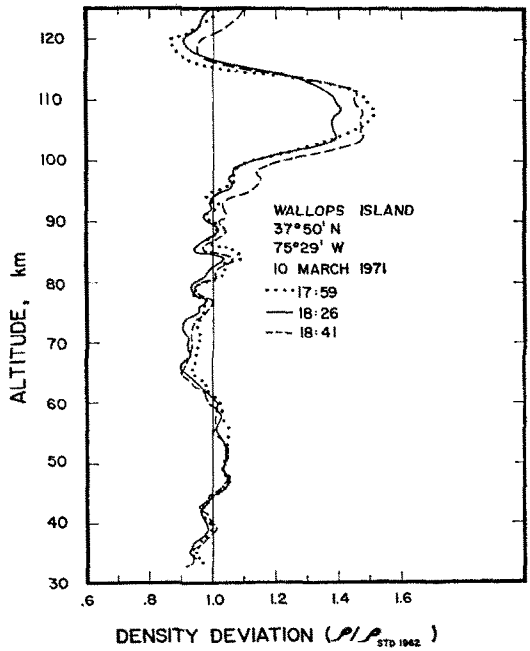

Fig. 2. Density profiles observed from Wallops Island on 10 March 1971 (control day). Density is plotted as a ratio to the 1962 U.S. Standard Atmosphere value for convenience.

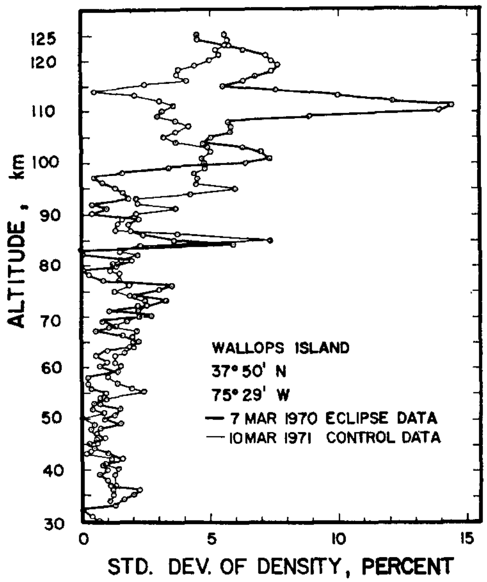

Fig. 3. The standard deviations of the observed density profiles as a function of altitude for the eclipse day (heavy curve) and the control day (light curve).

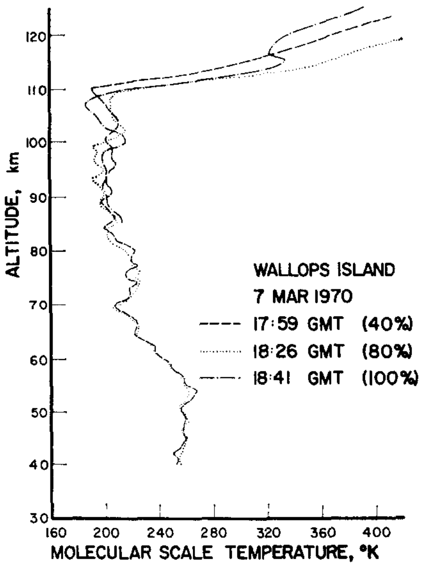

Fig. 4. Temperature profiles derived from the observed density profiles for the eclipse day.

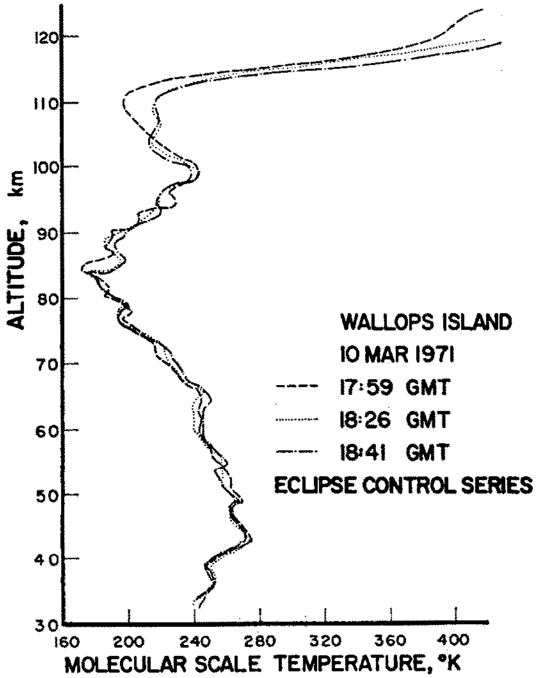

Fig. 5. Temperature profiles derived from the observed density profiles for the control day.

of mean temperature profiles for each series allows a comparison of standard deviations to be made between series. Below 80 km, the average standard deviation for both series is less than ±2·5°K, and increases to about ±3·5°K between 80 and 95 km. Between 95 and 105 km, the average standard deviation is ±4°K and ±7·7°K for the control and eclipse series respectively.

Below 105 km, the temperature differences, observation to observation, are not large in either series. In addition, features in the small scale wave structure can, for the most part, be identified between observations within each series. Above 105 km, the temperature structure for both series is consistent in gross character. However, definite wavelike features in the temperature structure exist in the third launch of the eclipse series at about 112 km, and in the first launch of the control series at about 120 km. A wavelike structure was also observed near 110 km on the day following the eclipse series (Fig. 6).

CONCLUSIONS

Based upon the comparison of all the data acquired and presented here, the following conclusions were reached:

(1) There were no detected effects of neutral atmospheric response attributable solely to the solar eclipse and/or the disturbed condition of the geomagnetic activity below 97 km during the 42 min observation period.

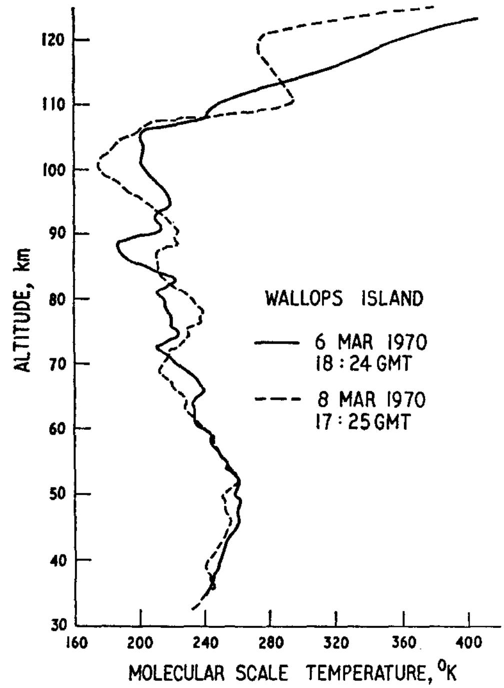

Fig. 6. Temperature profiles observed on 6 March 1970, 1824 GMT (full curve) and 8 March 1970, 1725 GMT (broken curve).

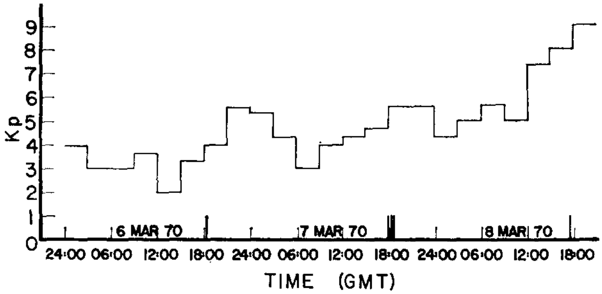

Fig. 7. Geomagnetic activity as a function of time on 6–8 March 1970.

(2) The evidence also indicates very little, if any, response of the neutral atmosphere between 97 km and 120 km due to the solar eclipse, since similar variations were observed in both series.

(3) The wave structure observed in the last measurement on eclipse day, and the more pronounced amplitude of a wavelike feature on 8 March 1970 might be related to the geomagnetic activity (see Fig. 7). However, it is more probable that the dynamic nature of that region of the atmosphere is such

that changes in temperature and/or density of the order observed normally occur.

REFERENCES

BALLARD H. N. *et al.*	1969	*J. geophys. Res.* **74**, 711.
DUBIN M., SISSENWINE N. and WEXLER H.	1962	*U.S. Standard Atmosphere.* U.S. Gov't Printing Office, Washington.
HORVATH J. J., SIMMONS R. W. and BRACE L. H.	1962	Univ. of Michigan Rept. NS 1, Ann Arbor.