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COMPOSITION OF THE MID-LATITUDE WINTER MESOSPHERE AND LOWER THERMOSPHERE

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INTRODUCTION

Measurements of the atmospheric composition were obtained on 23 January 1976 at Wallops Island, Virginia as part of a coordinated effort to study properties of the winter mesosphere. The atmospheric species were measured using a liquid helium cryosorption pumped quadrupole mass spectrometer. The measurements were obtained over an altitude range from 78 to 122 km. Near the time of the launch of the mass spectrometer payload, a chemical trail was released to measure the dynamical properties of the mesosphere and lower thermosphere. Also, inflatable falling spheres obtained measurements of density and temperature from 40 to 90 km and other meteorological payloads were used to help characterize the temperature and density structure during this period. The measurements discussed here were made on a day of moderate to low radio wave absorption in the D-region following a period of several days of strong radio absorption which were identified as winter anomaly days by vertical incidence absorption measurements, partial wave reflection techniques and ionospheric sounder signatures.

While the ionospheric characteristics of anomalous winter absorption have been recognized and studied for many years, the physical processes,which probably involve the chemistry of the neutral atmosphere as modified by dynamical transport processes, are yet to be identified. Measurements made during campaigns by U.S. scientists and by West German scientists (1) during January 1976 should lead to an identification of those processes.

THE EXPERIMENT

The mass spectrometer used in this experiment is an improved version of an instrument described previously (2,3). The major differences include use of a liquid helium instead of a liquid nitrogen cryosorption pump, use of three ionization energies (80, 20 and 15 eV), extended dynamic range and improved accuracy by simultaneous collection of ion current on a grid and a secondary emission multiplier. Fig. 1 shows a sample spectrum at 88 km from the flight telemetry record for the case of 80 eV ionizing electrons. The lower energy (20 and 15 eV) modes are important in measuring certain of the species. For example, the 16 amu mass peak contribution of atomic oxygen would be difficult to detect below 100 km because of the larger contribution from dissociative ionization of O_2 in the 80 eV case, but is easily measured at 20 and 15 eV. Examination of the results of this and previous flights has shown that the 8 amu signal (O^{++}) at 80 eV gives the proper response to interpret the atomic oxygen, though with less signal and poorer accuracy due to poor knowledge of the cross-section for double ionization of atomic oxygen.

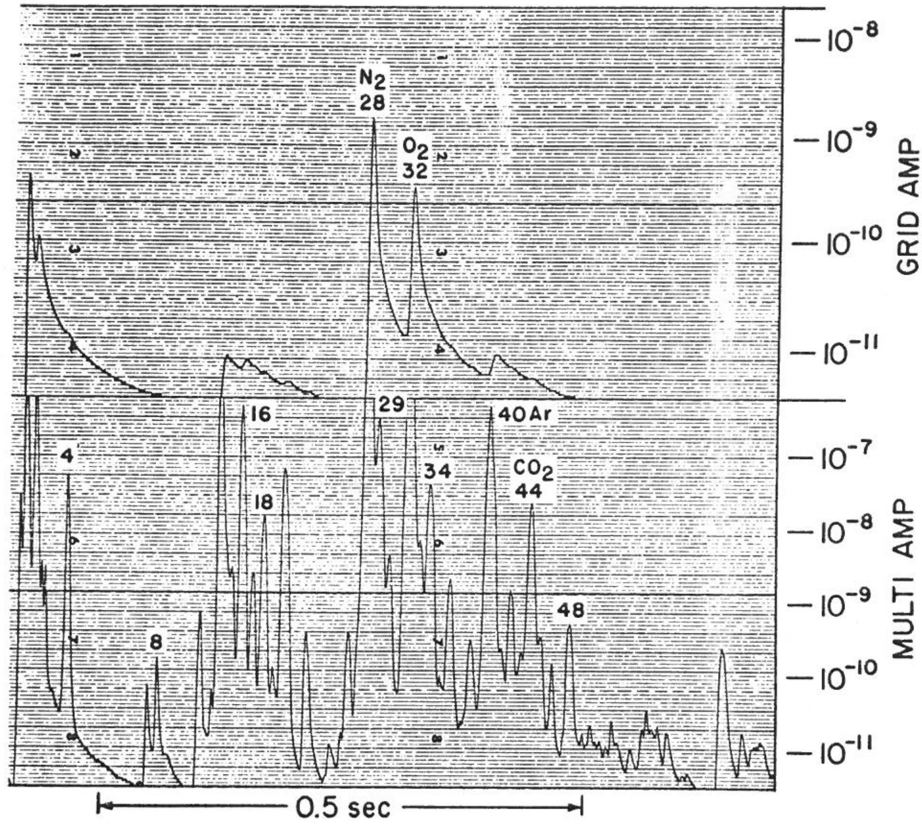


Fig. 1. Sample spectrum from the telemetry record near 88 km with some of the significant peaks identified.

MEASUREMENTS AND RESULTS

The profiles of the species $[N_2]$, $[O_2]$, $[O]$ and $[Ar]$ measured by the mass spectrometer are shown in Fig. 2. The atomic oxygen profile shown is from the 20 eV spectra measurements. The atomic oxygen density in the 105 to 110 km region was determined from the 80 eV spectra and the 20 eV profile was adjusted to that density. This procedure is necessary since laboratory measurements of the atomic oxygen ionization cross-section at 20 eV are not available.

The profiles of N_2, O_2 and Ar exhibit significant structure compared to the more normally observed monotonic shape. This structure appears to be wave-like with the largest feature in the 95 km region and amplitude decreasing toward monotonic at higher altitudes. The atomic oxygen profile is also highly structured; however, the structure is mostly uncorrelated to that in the other profiles. Cases showing both structured and smooth atomic oxygen profiles in the 80 to 110 km region have been previously reported (3). The unusual feature of this measurement is that the atomic oxygen peak density occurs at a very low altitude, near 85 km. The only other case of such a low altitude peak included in the summary of Offerman (4) is the high latitude photometer measurement of Dandekar (5). A low altitude atomic oxygen peak would be associated with a decrease in the mixing rate in the upper mesosphere. The calculations of mixing effects by Keneshea and Zimmerman (6) would result in a larger peak density and a lower peak altitude as the turbopause altitude is lowered and the eddy diffusion coefficient or mixing rate is decreased.

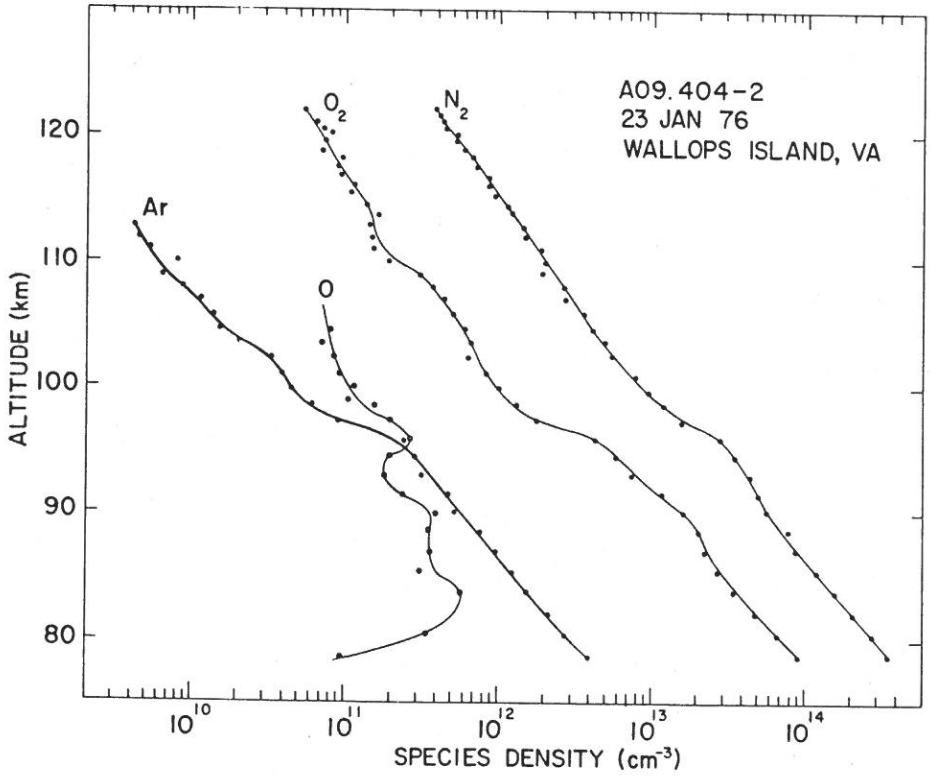
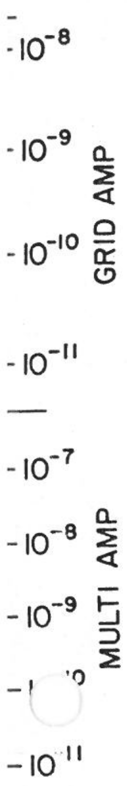


Fig. 2. Species profiles measured by the mass spectrometer on 23 January 1976.

In Fig. 3 the ratio of the Ar to N_2 density is shown. A significant separation from the mixing ratio at ground level is observed between 90 and 95 km. This represents the lowest altitude of argon separation that we have measured and is interpreted as representing a lower than normal turbopause altitude.



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The chemical release and inflatable sphere data which were obtained at the same time have been analyzed and show a lower than expected occurrence of turbulence in the mesosphere (7). All of these features (atomic oxygen profile, argon separation and stability analysis), are consistent with a lower than normal mixing rate. The wave structure observed in the major species profiles may even be associated with an increased transmission of wave energy through the mesosphere because of a decrease in dissipative forces active in turbulent regions. The extent to which these results may be more closely associated with the normal or recovery phase from anamolous conditions is unclear at the present time.

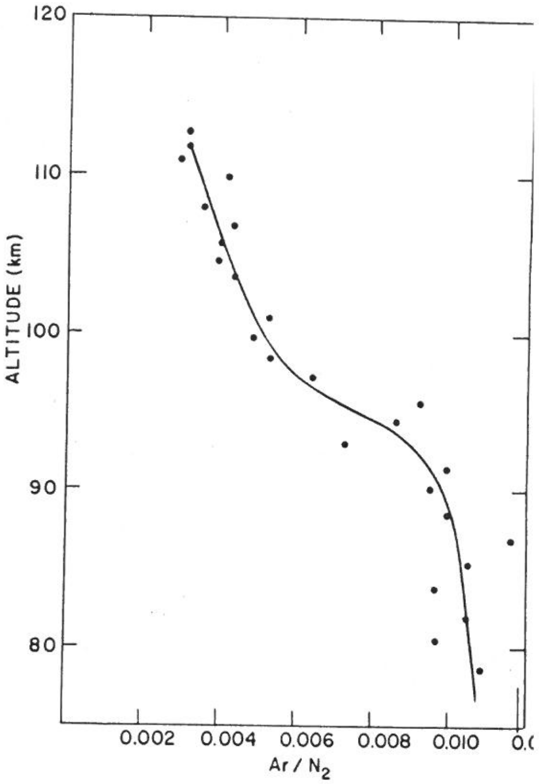

Fig. 3. Ratio of the measured argon nitrogen densities as a func of altitude.

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