GCA TECHNICAL REPORT NO. 63-7-N

RECENT CONTRIBUTIONS TO THE KNOWLEDGE OF ATMOSPHERIC STRUCTURE AND COMPOSITION OBTAINED FROM DIRECT PROBING EXPERIMENTS

H. E. La GOW R. A. MINZNER

CONTRACT NO. NASw-394

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GODDARD SPACE FLIGHT CENTER

WASHINGTON 25, D. C.

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GEOPHYSICS CORPORATION OF AMERICA BEDFORD, MASSACHUSETTS

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SECTION 1

INTRODUCTION

The more significant aspects of the recent contributions reviewed include the following: (1) The average atmospheric temperature and mass density in the isothermal region above 200 to 300 km are both lower than corresponding values observed during the IGY, and both properties have significant short-term temporal variations; (2) The 70 - 100 kilometer temperature profile through the mesopause has been accurately measured for the first time; (3) The base of the altitude region of atomic oxygen dominance (where atomic oxygen comprises 50% or more of the total atmosphere) has been observed to be much lower than that generally assumed immediately after the IGY; (4) Helium has been recognized as being the dominant atmospheric constituent for a limited altitude region between the region of atomic oxygen dominance and the region of hydrogen dominance; (5) Winds are being measured synoptically up to 70 km altitude; (6) A 1962 U. S. Standard Atmosphere to 700 km altitude has been issued; it reflects the new temperature and density data but was prepared too soon to utilize the new O_2 dissociation information.

SECTION 2

TEMPERATURE, PRESSURE AND DENSITY

Two significant direct-probing satellite experiments serve to corroborate independently the satellite-drag densities reported separately by Jacchia (1963). These are ionization-gauge observations (McIsaac et al. 1962), and microphone-gauge observations (Sharp et al. 1962). The latter indicated a 4:1 diurnal variation in density at 550 km for Wallops Island latitudes and was in agreement with simultaneous satellite-drag results.

A rocket-grenade, sound-velocity experiment (Stroud et al. 1960) has detected large seasonal variations in temperature at Fort Churchill up to the temperature minimum at 80 mm altitude, and unpublished results of the same experiment show winter conditions above Wallops Island to be similar to simultaneously observed Fort Churchill conditions. Temperature and the related pressure- and density-altitude profiles were observed at Fort Churchill by the pitot-static-tube method (Ainsworth et al. 1961). Ainsworth's detailed and very accurate data provided a degree of fine structure in temperature from 30 to 110 km altitude not previously available. (Nordberg and Stroud 1961) measuring November temperatures to about 80 km over Guam found little difference from the average White Sands values. A simple and relatively inexpensive rocket-sonde system has provided synoptic observations of temperatures up to about 48 km altitude (Joint Sci. Adv. Group to Met. Rocket Net. 1961).

High-altitude temperatures have also been inferred from measurements of the following:

(a) Electron temperatures in certain altitude regions where thermal equilibrium is believed to exist in the quiet ionosphere, (Brace _et al._ 1962), (Serbu _et al._ 1961), Spencer _et al._ 1962).

(b) The altitude rate of decrease of natural log of electron number densities (Bauer 1962) above the F_2 maximum.

(c) The temperature of molecular and atomic ions (Nagy _et al._ 1962); (Bauer & Bourdeau 1962); and

(d) Spectral observations of emission lines from sodium vapor ejected into the upper atmosphere (Blamont 1962). (Blamont 1962) shows temperature above Wallops Island at altitudes from 210 to 420 km to be isothermal at $950 \pm 100^{\circ}$K.

The results of all the above measurements generally have been to confirm the existence of an isothermal region above about 300 km with a varying temperature which depends on time of day and upon other conditions.

SECTION 3

COMPOSITION

Rocket measurements of atmospheric composition have been performed by means of neutral-particle as well as charged-particle mass spectrometers, and ultraviolet monochromators. Composition has also been inferred from observations of electron and ion densities.

From measurement of the neutral particle ratio A/N_2 Meadows and Townsend (1960) showed diffusive separation to occur in the 100 to 120 km region.

Johnson and Holmes (1960) and Johnson (1961), and Taylor and Brinton (1961) reporting on ion composition from radio frequency mass spectrometer observations over Fort Churchill and Wallops Island respectively all report major ion constituents to be 16^+, 30^+, and 32^+ AMU, while ions of atomic mass 14^+, 18^+, and 28^+ were detected as minor constituents.

Schaefer (1961), (1962), using a massenfilter has reported values of O/O_2 ratio of 0.5 at 110 km, 1.2 at 120 km and 2 at 130 km altitude, and claims these results to be in general agreement with ultraviolet absorption results reported by Kupperian et al. (1960).

Hinteregger (1962) analyzing his extreme ultraviolet monochromator measurements reports atomic nitrogen to be a minor atmospheric constituent below 225 km altitude, and his data shows that atomic oxygen becomes the dominant atmospheric constituent above approximately 150 km altitude.

These results by Kupperian et al., Hinteregger, and Schaefer appear to confirm each other, and can be expected to markedly change the molecular weight and temperature-altitude profile of current model atmospheres.

Hanson and McKibbin (1961) have shown, from ion trap measurements of ion number density to 700 km, that above 350 km these data could represent mass 16^+ ions at a constant temperature of 1240°K. The predominance of O^+ in this altitude region was also derived from Explorer VIII data by Bourdeau et al. (1961).

Following the suggestion by Nicolet in April 1961, published in 1962, that a region of helium dominance between 750 and 1500 km could explain the Echo Satellite performance and that such an atmosphere could be demonstrated to exist on the basis of diffusive separation (Nicolet 1961), (Sauerman & Herzog 1961), various investigators began looking for helium specifically.

Ion density data to 5500 km (Hale 1961) were interpreted by Hanson (1962) as indicating the following: a predominance of O^+ ions up to 1200 km altitude, He^+ ions from 1200 to 3400 km, and H^+ ion (protons) above 3400 km. Bourdeau *et al.* (1962a), (1962b), substantiated the Hanson finding by obtaining a value of 1.3 $\pm$ .03 for He^+/O^+ at 1630 km by direct sampling techniques. Taylor *et al.* (1962) measuring H^+ and He^+ ions directly with an RF mass spectrometer found significant quantities of both ions from 400 to 940 km.

Bauer (1962 & 1962) suggests that the thickness of the helium ion belt varies with temperature from 2000 km at 1600^{o}K to about 200 km at 600^{o}K. This has been corroborated by recent experimental data being reported by Bourdeau (1962).

Unfortunately no direct measurements of neutral He and hydrogen have yet been made.

SECTION 4

WINDS

During the past three years winds have been measured synoptically for the first time to altitudes of 70 km (Joint Sci. Adv. Grp. to the Met. Rocket Net. 1961) by means of radar tracking of chaff, silvered balloons and parachutes (Rapp 1960), (Jenkins 1962) ejected from hundreds of small inexpensive rockets launched in coordinated series from several North American launch sites (Smith 1960, 1962), (Masterson et al. 1961) and (Keegan 1962). The data is centrally collected and distributed by the Meteorological Rocket Network Committee for analysis (Batten 1961), (Appleman 1962).

At higher altitudes up to about 200 km, wind measurements are not yet routine but have greatly increased in number. The several methods employed include rocket grenades (to altitudes of about 90 km) (Stroud et al. 1960), (Nordberg and Stroud 1961), tracking of rocket exhaust trails (to 140 km) (Woodbridge 1962), (Aufm Kampe et al. 1962), (Poctzchke H) and other especially formed vapor trails usually of alkali metals (Manring et al. 1961), and one pitot static tube experiment (Ainsworth et al. 1961).

Among the more significant developments has been the series of coordinated observations by the same method at various locations (GCA 1962) and by various methods at the same location (Nordberg and Smith 1962). Winds deduced from these data compare favorably (Manring et al. 1962). In November-December 1962 eight rocket-launch sites around the world were used for the launching of 23 high-altitude rockets with sodium-vapor and grenade payloads in a cooperative effort to establish global wind structure. Sound-grenade rockets were launched nearly simultaneously from Wallops Island, Fort Churchill, and Australia. Data from this operation is not yet available.

Although not enough data exists to construct circulation systems in the atmosphere above 70 km, the several experiments have measured other interesting though not completely understood phenomena. These include high and persistent wind shears in the region around 100 km altitude, wind velocities in excess of 100 meters per second above the shear region, and turbulence below this shear region (Blamont and Jager 1962), (Cote 1962). The circumpolar vortex characteristic of high latitude wintertime conditions has been observed to penetrate as far south as Wallops Island 38°N in February 1961 (Nordberg and Smith 1962).

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