VII. GEOPHYSICAL RESEARCH*

Academic and Research Staff

Prof. G. Fiocco
Dr. G. W. Grams
Dr. W. D. Halverson
J. B. Thompson

Graduate Students

S. J. Bless
J. B. DeWolf

A. OPTICAL RADAR OBSERVATIONS OF MESOSPHERIC AEROSOLS IN NORWAY DURING THE SUMMER 1966

In the summer of 1964, optical radar experiments were performed in Alaska and Sweden to observe the mesospheric aerosol content during noctilucent cloud (NLC) displays (see Fiocco and Grams[1]). These preliminary experiments provided measurements of the average scattering cross section of stratifications near 70 km. The presence of a layer at 70 km, well below the height commonly found for noctilucent clouds, was taken as an indication that measurable processes involving a wide range of mesospheric heights might be involved.

In order to acquire further evidence, a new series of experiments was carried out at Kjeller (60.0°N, 11.0°E) near Oslo, Norway, during the summer of 1966. The data obtained in these experiments also showed an increase in the 60-70 km signal with a maximum in the altitude interval 66-68 km; the enchanced signal was more evident for nights during which noctilucent clouds were present. The data are statistically relevant and point to an average backscattering optical thickness for the 2-km interval from 66-68 km of $(5.6 \pm 1.6) \times 10^{-6}$ during nights when NLC were visually observed and of $(2.8 \pm 1.5) \times 10^{-6}$ for nights when NLC were not visible. Since the optical thickness is equivalent to the product $HN\sigma$, where H is the thickness of a homogeneous layer containing N particles per unit volume with radar cross section σ, we estimate that such values are consistent with a particle density $N \sim 1\ cm^{-3}$ for aerosols of radius 0.1 μ and refractive index n = 1.5.

It should be possible to relate the presence of dust in the mesosphere to available sources and transport mechanisms. If the particles are very small, updrafts of relatively small amplitude could lift them from the lower stratosphere to equilibrium levels in the mesosphere. Murgatroyd and Singleton[2] have developed a model for the upper atmospheric circulation. Their vertical velocity profiles displayed a maximum of approximately 1 cm sec^{-1} at 65 km for mid-summer conditions at 60°N. Since the sedimentation velocity in a stationary atmosphere increases with height, equilibrium conditions may

*This work was supported by the National Aeronautics and Space Administration (Grants NGR-22-009-131 and NGR-22-009-114).

exist in the vicinity of this altitude; this vertical velocity profile, for example, would cause an accumulation of particles of 0.01 μ and 0.03 μ radius at altitudes of 69 km and 63 km, respectively. Such small particles could then act as condensation nuclei for ice-coated NLC particles. Also, settling particles with larger radii would be retarded considerably in their descent through this altitude region.

The model of Murgatroyd and Singleton also points, however, to the existence of very strong meridional winds (~5 $msec^{-1}$) for the mid-summer mesosphere. This agrees with analyses of meteor trail data[3] and data from the Meteorological Rocket Network.[4] Large-scale horizontal transport of particulate material could therefore be expected. Simple computations indicate that essentially all extraterrestrial dust particles having radii less than ~0.5 μ and impinging on the Earth's atmosphere at latitudes higher than 60°N would be expected to transit at altitudes between 60 km and 70 km on the 60°N parallel during summer. This model leads to an estimate of approximately 4000 tons/day for the total influx of extraterrestrial material on Earth, a meridional velocity of 10 $msec^{-1}$, and dielectric particles of radius between 0.05 μ and 0.5 μ and of refractive index n = 1.5.

It is also interesting to notice that the increase in cross section occurs at heights that are close to the exclusion limit for condensed water vapor in the upper atmosphere (Khvostikov,[5] MacDonald,[6] and Schilling[7]). It is conceivable that the temperature structure below the mesopause may lead to trapping of water substance in large amounts. This might provide a continuous source of water vapor for steady-state models of NLC formation such as have been postulated by Charlson.[8]

The records also indicate the presence of echoes at altitudes closer to the mesopause, which provide definite evidence for the observation of NLC. On 6-7 July visual observations indicated that a noctilucent cloud was approaching from a northerly direction and appeared to be directly overhead just before dawn. The optical radar observations showed a scattering layer with a definite wave structure having a vertical amplitude of ~2 km and a horizontal wavelength corresponding to a transit time of approximately 3 minutes. The average optical thickness of this layer was calculated to be 10^{-4} during the time that the noctilucent cloud was overhead.

The relative visibility of the stratifications found at 66-68 km and of those observed near 74 km during the short time interval on 6-7 July has also been considered. An optical thickness of 6×10^{-6} for the lower altitude interval exceeds that of a 2-km layer of the molecular atmosphere at that height by a factor of 4. If the particles are sufficiently small to remain suspended in this region, their scattering function might approach that of molecules, so that no marked enhancement of forward scattering would be expected for twilight illumination conditions. On the other hand, the backscattering cross section of the layer at 74 km was approximately 200 times greater than that of a 2-km layer at that height, and appeared to be geometrically thinner. Since

NLC particles are known to be large enough to scatter preferentially in the forward direction, the 74-km layer could be observed visually, because of its marked contrast with the sky background.

G. Fiocco

References

1. G. Fiocco and G. Grams, "Observations of the Upper Atmosphere by Optical Radar in Alaska and Sweden during the Summer 1964," Tellus 18, 34-38 (1966).
2. R. J. Murgatroyd and F. Singleton, "Possible Meridional Circulation in the Stratosphere and Mesophere," Quart. J. Roy. Meteorol. Soc. 87, 125-135 (1961).
3. A. Kochanski, "Circulation and Temperatures at 70-100 Kilometer Height," J. Geophys. Res. 68, 213-226 (1963).
4. W. L. Webb, Structure of the Stratosphere and Mesosphere (Academic Press, New York, 1966).
5. I. A. Khvostikov, "Noctilucent Clouds," Priroda 5, 49-59 (1952).
6. J. E. McDonald, "Atmospheric Exclusion Limits for Clouds of Water and Other Substances," J. Geophys. Res. 69, 3669-3672 (1964).
7. G. F. Schilling, "Forbidden Regions for the Formation of Clouds in a Planetary Atmosphere," J. Geophys. Res. 69, 3663-3667 (1964).
8. R. J. Charlson, "Noctilucent Clouds: A Steady-State Model," Quart. J. Roy. Meteorol. Soc. 91, 517-523, 1965.