THE LASER RADAR ABOVE 30 KILOMETRES

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ABSTRACT

This is a short 'state of the art' report on laser radar observations of the atmosphere at heights greater than 30 km.

1. INTRODUCTION

Much of the work so far reported on applications of the laser radar technique has been concerned with the troposphere and lower stratosphere. This is due in part to the general interest in this region and in part to the fact that comparatively modest equipment can be used. A number of groups have, however, been applying the technique to the region between 30 km and 140 km. This work is being done with two principal aims: (i) the measurement of atmospheric density and scale height, (ii) the observation of dust between the heights of 60 km and 140 km.

The first work of this nature was reported from M.I.T. by Fiocco and Smullin (1963) who claimed to have observed dust layers at various levels between 70 and 140 km. Subsequently McCormick *et al*,(1966) working at Maryland reported similar results. These early measurements are now generally considered unreliable as they are based on radar returns containing spurious signals, which have been largely eliminated in later work. These spurious signals were due to fluorescence from the laser and enhanced noise from the photomultiplier detector (Sandford,1967; Clemesha, Kent and Wright, 1967). Later results from a number of workers are reviewed below.

2. MEASUREMENTS BELOW 70 KILOMETRES

Some recent results for the region between 30 km and 70 km are shown in figure 1. Here results from Kingston, Jamaica (Kent, Clemesha and Wright,1967), Maryland, U.S.A. (McCormick *et al*, 1967, Silverberg and Poultney,

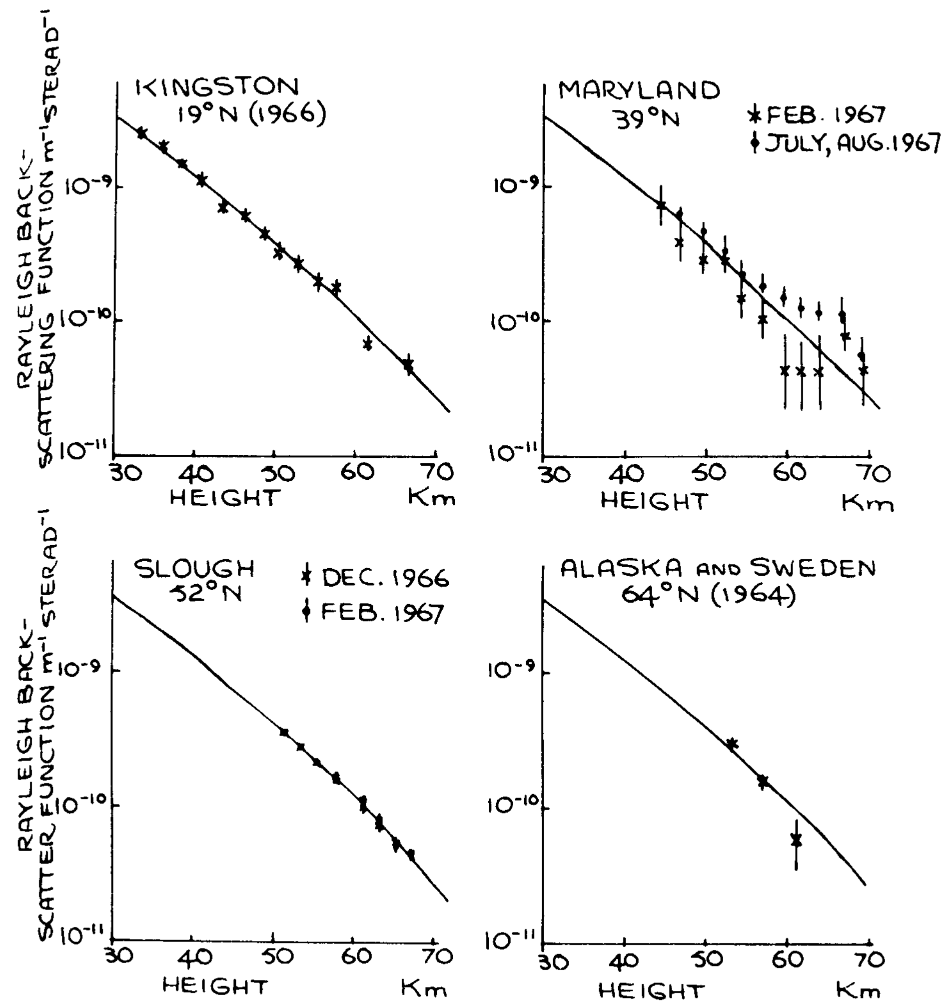

FIG.1. RECENT MEASUREMENTS OF THE RAYLEIGH BACK-SCATTER FUNCTION BETWEEN 30 AND 70 KILOMETRES.

EXPERIMENTAL RESULTS.

FITTED STANDARD ATMOSPHERES.

1967), Alaska and Sweden (Fiocco and Grams, 1966) are presented in the same diagram for the purpose of comparison. Note that in each case these results have been fitted to a calculated curve for a standard atmosphere. Absolute measurements are not available because of the difficulty involved in an absolute calibration of the laser radar. It may be seen that the height variation of the experimentally observed scattering function matches the predicted variation in all cases with the exception of the summer results from Maryland, which possibly indicate the presence of particulate material above 60 km. In the absence of particulate material the scattering function is directly proportional to atmospheric density.

The accuracy of the measurements is limited by the very weak signals received from great heights. These signals are measured by photon counting techniques and contain a statistical uncertainty when the number of photons counted is small. The most accurate results have been published by Sandford, 1967 and Kent,Clemesha and Wright, 1968. The latter workers state (Kent, Clemesha and Wright, 1968) that they can measure the scale height precisely enough to obtain temperatures with an error of $\pm 5^{\circ}C$ at 30 km increasing to $\pm 25^{\circ}C$ at 50 km. Our present knowledge of the behaviour of the atmosphere between 30 km and 90 km is very poor and hence data of this sort of accuracy are just good enough for the technique to provide new information on seasonal, and perhaps diurnal variations in density and temperature. With regard to diurnal variations it must be remembered that day time sky brightness limits the maximum height to which measurements can be made to about 30 to 40 km, high altitude measurements can only be made at night.

So far no routine measurements of this nature appear to have been made over a sufficient period of time to provide new information. This is partly due to equipment difficulties at this early stage in the development of the technique.

The measurements which we in Kingston have made have in fact been part of a feasibility study for a much more powerful radar which is presently (May 1968) about to go into operation. This system should give ±10% accuracy for density measurements at 100 km, improving to ±2% at heights of 70 km and below. We hope that these measurements will fill a considerable gap in our present knowledge of the 30 km to 100 km region.

There does exist one problem in respect of the atmospheric density measurements. The determination of density from the laser radar return assumes that the scattering is entirely due to atmospheric molecules. There is some evidence (see for example Volz and Goody, 1962) for the existence of dust particles at all heights up to 70 km. If the scattering from dust is more than a small fraction of the molecular scattering there will result errors in the computed densities. So far the laser radar measurements do not indicate the presence of dust between 30 and 60 km, although the stratospheric aerosol layer is observed (Fiocco and Grams, 1964). One way to resolve this problem would be to make near simultaneous observations on different frequencies (to date all published results have been based on work using the 0.6943 micron ruby laser wavelength).

3. MEASUREMENTS ABOVE 70 KILOMETRES

Some results of laser radar returns from above 70 km are shown in figure 2. These results are from the same workers as those shown in figure 1. By far the most accurate date are from Slough, showing meaningful measurements

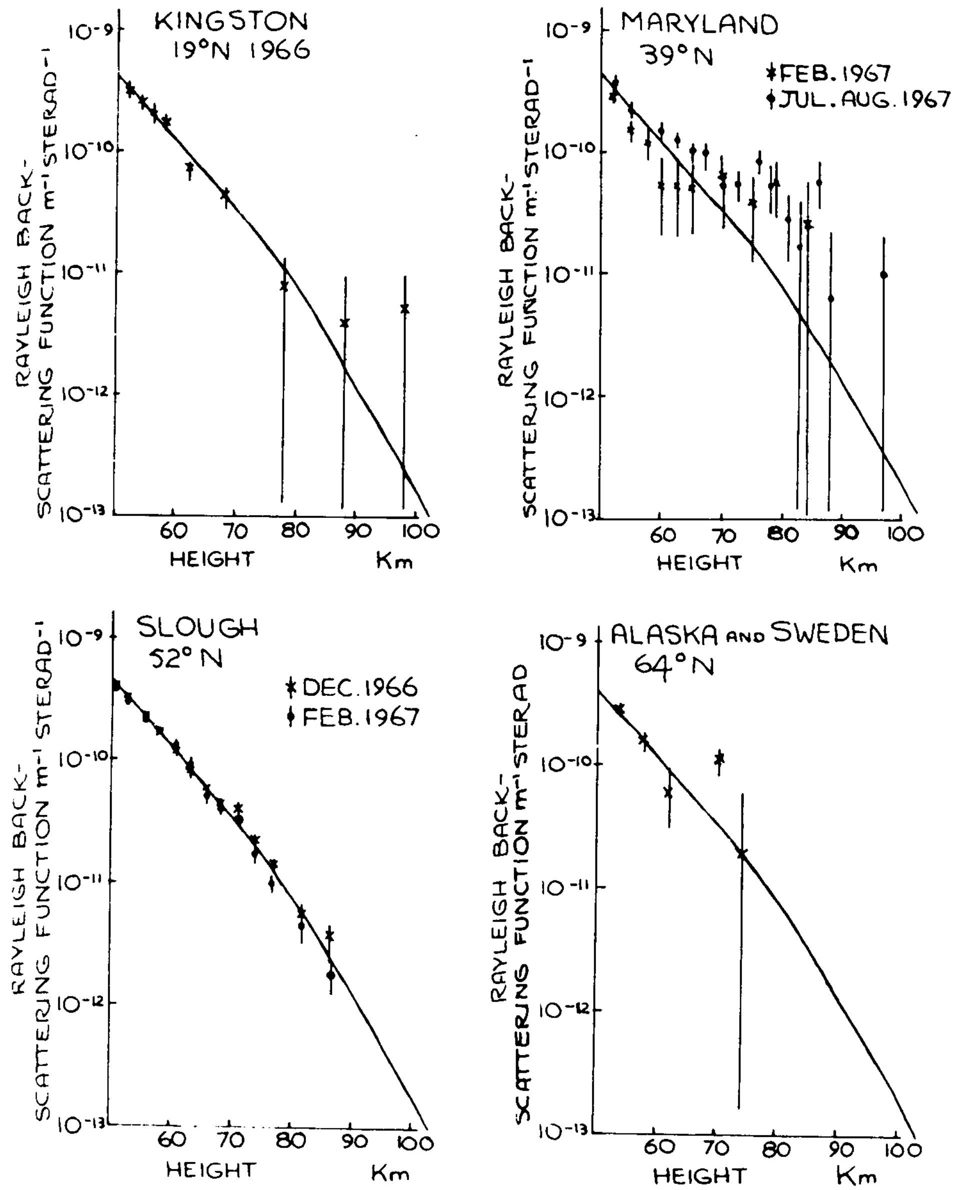

FIG. 2. RECENT MEASUREMENTS OF SCATTERING ABOVE 50 KILOMETRES.

EXPERIMENTAL RESULTS.
STANDARD ATMOSPHERES.

up to 85 km. Both Maryland and the M.I.T. group (Alaska and Sweden) claim that their results show scattering which is significantly in excess of the expected molecular scatter at certain heights. This enhancement is interpreted as being the result of dust particles in the atmosphere at these heights. Slough sees a slight enhancement near to 70 km on some occasions. At Kingston we observe no echoes significantly in excess of the predicted molecular return.

At the present time there is some controversy as to whether or not the excessive scattering from this region is genuine. The importance of the problem lies not only in the intrinsic significance of dust particles at this height, but also in the effect of dust on attempts to derive atmospheric densities from the observed scattering cross-sections. It has been pointed out (see for example Fiocco and Grams, 1964) that the entry of meteoric particles into the atmosphere could explain the existence of the dust, and that the height of observation is close to the mesopause, where noctilucent clouds are observed. On the other hand it is rather disturbing that the most accurate measurements (Sandford,1967) show the least enhancement. The basic problem is simply that the dust is observed at heights where the laser return is very weak, and hence most likely to be contaminated by an undetected noise source, as was certainly the case with early measurements. The final solution to this problem must await the advent of more powerful radars.

4. CONCLUSIONS

1. Present high sensitivity laser radars are capable, if used on a routine basis, of providing new information on molecular density and temperature in the height range 30 km to 60 km. The presence of the stratospheric aerosol precludes the possibility of measuring molecular density below this height in a simple experiment.

2. An increase in sensitivity by 2 to 3 orders of magnitude over radars currently in use would enable density measurements to be made rapidly and conveniently at heights from 30 km to 100 km, provided the atmosphere is not contaminated by dust. At least one group is currently building a radar with this sensitivity.

3. There is controversial evidence for the existence of aerosols in the 60 km to 90 km height range.

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