FORWARD SCATTERING AND BACKSCATTERING OF SOLAR RADIATION BY THE STRATOSPHERIC LIMB AFTER MOUNT ST. HELENS ERUPTION[1]

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Stratospheric limb-radiance profiles versus altitude of closest approach of the line of sight to the Earth's surface have been measured before and after the Mount St. Helens eruptions by means of photographs taken from a Sun-oriented balloon gondola floating above 35-km altitude over France. Preliminary data have been reported (Ackerman et al., 1980) for flights in October 1979 and in May and June 1980. The radiance integrated along the line of sight as in-situ radiance (R*) can be derived taking into account absorption by ozone and air. The onion-peeling inversion method has been used to derive the vertical-radiance (R*) profiles shown in figures 1 and 2 for June 5 and October 15, respectively. The values of R* have been determined in the solar azimuth, at respective solar elevation angles equal to 6° and 6.7°, and 180° from the solar azimuth at solar elevation angles respectively equal to 12° and 11.8°. The solar elevation angles have been chosen larger for the backscattering observation than for the forward-scattering observation in order to deal with as similar illumination conditions as possible despite the Earth's sphericity.

In the first approximation only direct-solar illumination of the stratosphere is considered. The scattering angles, θ, for one altitude are indicated. The backscattering radiances are represented by the dotted curves while the forward-scattering radiances are represented versus altitude by the dashed curves. The backscattering signal shows little structure versus altitude. Since it is mainly due to Rayleigh scattering, its subtraction from the forward signal leads to the solid curves representing the forward scattering almost solely due to the aerosols.

Evenually, figure 3 shows versus altitude the ratio between aerosol forward scattering in blue light (Wratten filter nr. 47) and in red light (Wratten filter nr. 25) deduced from simultaneously taken photographs in the previously described solar illumination conditions.

Several conclusions can be drawn from these preliminary data. On June 5, a large enhancement of forward aerosol scattering is observed below 16 kilometers showing a layered structure of the volcanic aerosol. The horizontal homogeneity is doubtful from the observations themselves so that backscattering and forward scattering can hardly be correlated even if the latter one shows an effect due to the volcano. On the other hand, on October 15, the volcanic aerosol below 18 km shows a great horizontal homogeneity. A comparison between back and forward signal indicates an increase of the forward to backscattering aerosol ratio with decreasing altitude indicating a change of optical properties of the aerosol with altitude. An aerosol peak appears at 23.5 km with horizontally inhomogeneous extensions up to 27 km. The color ratio shown in figure 3 indicates also a variation of optical properties versus altitude. Minima of the ratio are observed at 17 and at 23 km where layers have been frequently observed in red light in the background aerosol on the occasions of previous flights.

The aerosol enhancement on June 5 peaking at 15.5 km appears to have modified the limb radiance at higher altitudes. This represents an observational support to theories emphasizing the effect of aerosol layers on atmospheric-optical measurements relying on scattering of radiation such as ozone measurements performed by means of the "umkehr" and of the B.U.V. methods (DeLuisi, 1979, and DeLuisi et al., 1979).

Ramanathan and coworkers (1969) have already suggested that the "second umkehr effect" is due to aerosol scattering which is typically variable, present at all altitudes up to 35 km as observed by us and even at 50 km as observed by Giovane et al. (1976).

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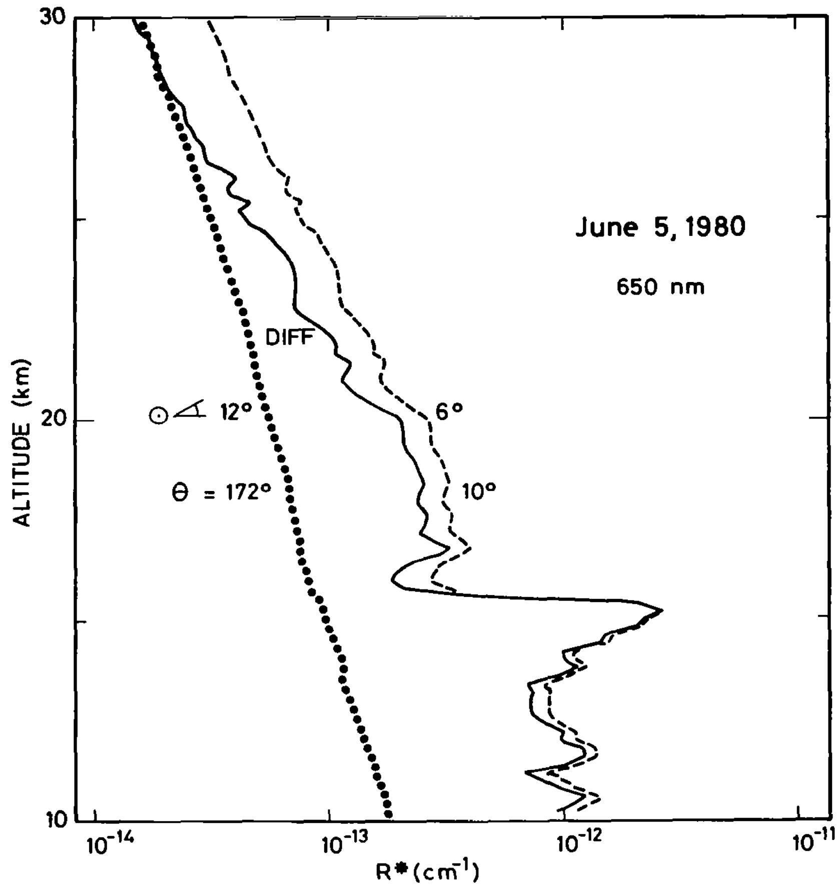

Figure 1. June 5, 1980, radiance per unit slant path and in units of solar radiance at the altitude of closest approach to the earth surface versus altitude. The observation conditions have been described by Ackerman et al. (1980). Solar elevation angles (⊙ ∢) are indicated as well as scattering angle, θ, for the direct-solar radiation. The dashed curve shows the near forward scattering, the dotted curve represents the near back-scattering and the solid curve corresponds to the difference between the two which means radiance almost solely due to the injection of volcanic material. The back signal is slightly increased at that altitude but no correlations with the forward signal are possible since the inspection of the photographs shows horizontal inhomogeneities in the layer.

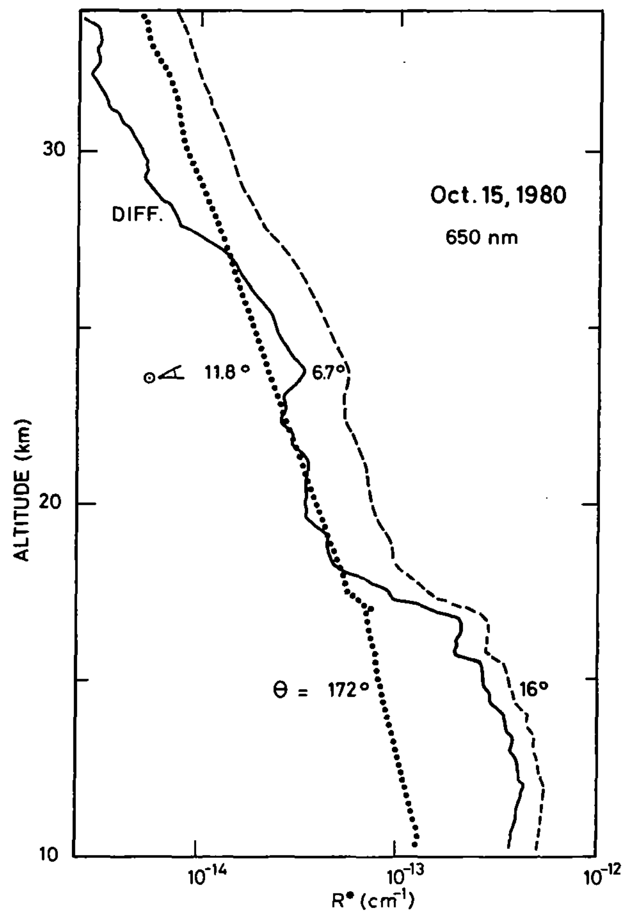

Figure 2. Identical as figure 1 but for October 15, 1980. After five months the injected material has spread horizontally so that layers not observed at 24-km altitude before the end of June over Europe (Reiter et al., 1980) are now visible over large horizontal extent. Some of it seems to extend up to 27-km altitude. A backscattering abrupt enhancement is observed below 17 km which in terms of lidar backscattering ratio would amount to R = 1.15. It should be noticed that the back signal at 30-km altitude almost exclusively due to Rayleigh scattering is in this case a factor of two lower than on June 5. In this latter case the 15.5-km strong aerosol layer leads to a large increase of atmospheric radiance at all altitudes above it.

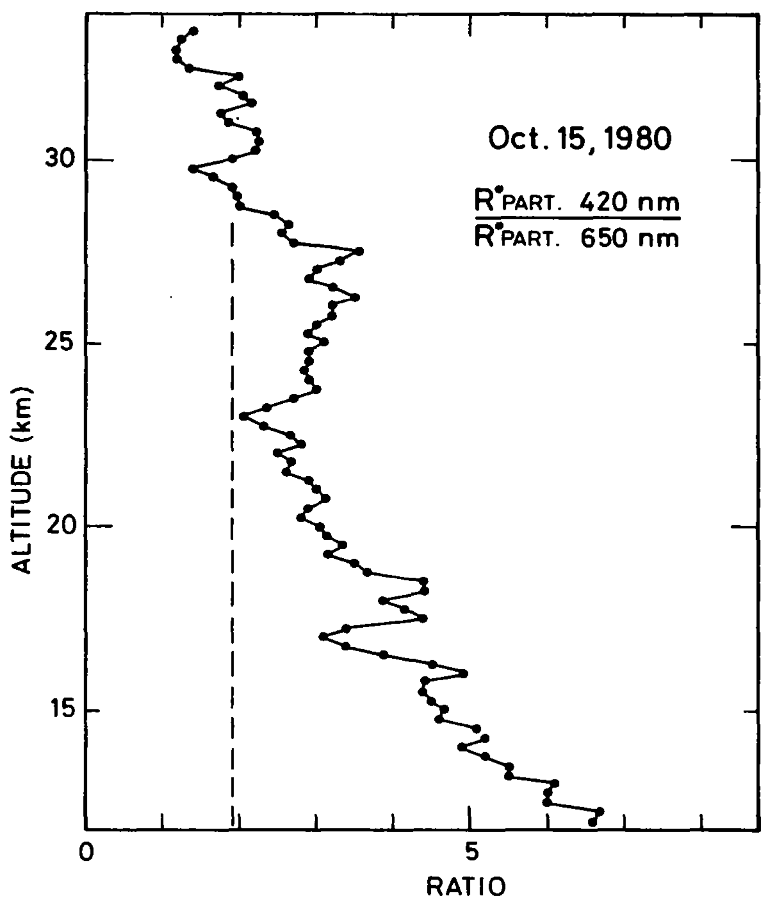

Figure 3. Ratio of in-situ radiance, R*, in blue light to radiances in red light. The radiance increase corresponding to decreasing wavelength is not the same at all altitudes showing a variation of the aerosol optical properties with altitude.