der was found to be excellent from a comparison of the z_1 and z_2 sensor data, which agreed to better than 0.1 cm/sec^2 (0.3 km radius) throughout the descent.

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7. The radius of Venus in the vicinity of the large probe landing site has been measured by ground-based radar and reported to be 6049.5 ± 0.5 km, near the mean planetary radius according to present data [D. B. Campbell, R. B. Dyce, R. P. Ingalls, G. H. Pettengill, I. I. Shapiro, *Science* **175**, 514 (1972)].
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17. At pressures above 10 bars, longitudinal temperature contrasts should be less than 1 K because of thermal inertia relative to solar heating rates (*9*). Hence the temperature contrasts in Fig. 4 above 10 bars are thought to be associated with the meridional direction. A balance in the meridional direction between the centrifugal force due to the mean zonal wind and the meridional pressure gradient, combined with the hydrostatic equation, gives
$$2\bar{u}\frac{d\bar{u}}{dz'}\text{ctn}\,\theta = \frac{R\,\partial\bar{T}}{H\,\partial\theta}$$
where $\bar{u}$ is the mean zonal wind, θ is colatitude, R is the gas constant for CO_2, H is a typical pressure scale height, $\bar{T}$ is the zonally averaged temperature, and $z' = -H \ln p$, where p is pressure A $d\bar{u}/dz'$ of 50 m/sec per 30 km would give meridional temperature gradients sufficient to create temperature differences of several degrees. Zonal wind profiles measured by Veneras 8, 9, and 10 are consistent with the boundaries of such regions being in the vicinity of 10 and 30 bars and possibly also near 1.5 bars [M. Ya. Marov, V. W. Avduevsky, V. V. Kerzhanovich, M. K. Rozhdestvensky, N. F. Borodin, O. L. Ryabov, *J. Atmos. Sci.* **30**, 1210 (1973); M. V. Keldysh, paper presented at the 19th COSPAR meeting, Philadelphia, 14 to 19 June 1976]. Figure 4 implies that temperature increases with latitude away from the equator up to some latitude, but then decreases toward the poles. Such temperature profiles have been seen in a numerical solution of the Venus circulation [R. E. Young and J. B. Pollack, *J. Atmos. Sci.* **34**, 1315 (1977)] when the mean zonal velocity has a latitudinal profile similar to that implied from the Mariner 10 ultraviolet observations, namely increasing away from the equator up to ≈ 45° latitude and then decreasing to zero at the poles [V. Suomi, *NASA Spec. Publ. SP-382* (1974)].
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Preliminary Results of the Pioneer Venus Nephelometer Experiment

Abstract. *Preliminary results of the nephelometer experiments conducted aboard the large sounder, day, north, and night probes of the Pioneer Venus mission are presented. The vertical structures of the Venus clouds observed simultaneously at each of the four locations from altitudes of from 63 kilometers to the surface are compared, and similarities and differences are noted. Tentative results from attempting to use the data from the nephelometer and cloud particle size spectrometer on the sounder probe to identify the indices of refraction of cloud particles in various regions of the Venus clouds are reported. Finally the nephelometer readings for the day probe during impact on the surface of Venus are presented.*

A backscattering nephelometer instrument (*1*) was included in the experiments complement of each of the four Pioneer Venus probes (*2*). The objective of the nephelometer experiment (designated LN on the large sounder probe and SN on the other probes) was to investigate simultaneously the vertical structure of the clouds of Venus at four widely separated locations. A secondary objective was to attempt to vertically document the source of atmospheric ultraviolet absorption in the atmosphere. Each of the nephelometer instruments functioned, and data were recorded from the time the instrument was deployed (window cover opening) at altitudes of about 65 km until probe impact on the surface of the planet, or, in the case of the day probe, until 64 minutes after impact. Although data pertinent to both of these objectives were obtained during the mission, only the data applicable to the first have been analyzed and presented here.

A curve of the backscatter cross section recorded as a function of altitude above the surface of Venus during the descent of the sounder probe is shown in Fig. 1. The data reported for this probe (and also that for the high-altitude phases of early descent for the other probes) contain gaps as a result of a delay caused by the effort required for reprocessing and reconstituting data tapes from the receiver stations. These data will be available later. The altitude scales shown in each of the figures are only crudely known at the time of this report, but will be modified as improved trajectory data become available. Typical signals obtained were greater than 20 data elements (granular elements), whereas average noise was a fraction of one such unit. Thus, even many of the minor fluctuations shown in the data are believed to be real. Because below about 45 km the signals from each probe tended to be small, usually below the limit of instrument sensitivity [which confirmed the results of Marov *et al.* (*3*) that the clouds have a well-defined lower boundary overlying a relatively particulate-free atmosphere down to the surface], the data below about 45 km have not been plotted on this curve or on corresponding curves for the data from other probes. These will be discussed in subsequent reports. The magnitudes of the main cloud signals measured were also similar to those of Marov *et al.* (*3*).

The structure within the clouds is characterized by four distinct regions (Fig. 1). Region A, beginning at about 46.1 km, is made of narrow stratified layers (one 50 m, the other 200 m thick). Region B (maybe the only region that could really be called a "cloud") extends from about 47.4 to 49.4 km and is characterized by a strong maximum. Region C (about 49.4 to 56.0 km) is smooth over much of its extent. Region D (about 56.0 to above 62 km) is less smooth, and is considered different from region C by consideration of the large probe cloud particle size spectrometer (LCPS) data. The data from the highest altitude reported here are still far from the top of the cloud system.

The sparser data currently available from each of the other three probes are plotted in Fig. 2. The altitude intervals

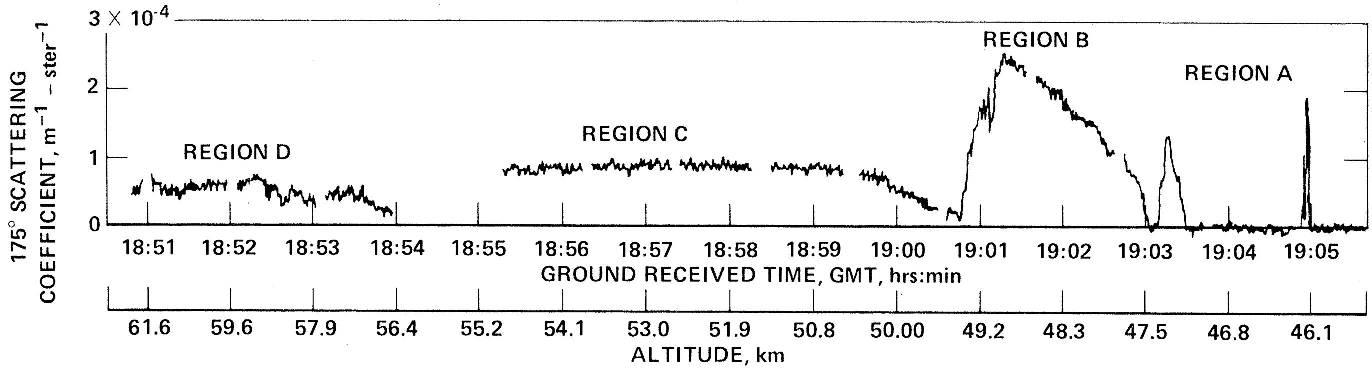


Fig. 1. Variation of the 175° angular scattering coefficient with ground received time (*GMT*) for the sounder probe nephelometer. Altitude markings in this figure and in Figs. 2 and 3 are only crudely known at the time of publication but will be available later.

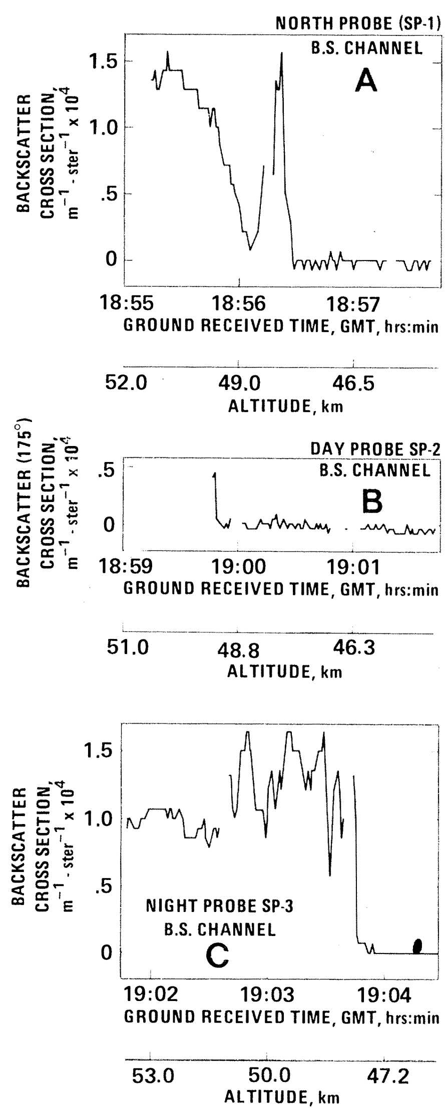
over which data are integrated for these probes are larger than those for the sounder probe since these free-falling probes descended through the cloud regions more rapidly than the sounder probe, which descended on a parachute. Nevertheless the general cloud features and variations in cloud features are apparent in these data.

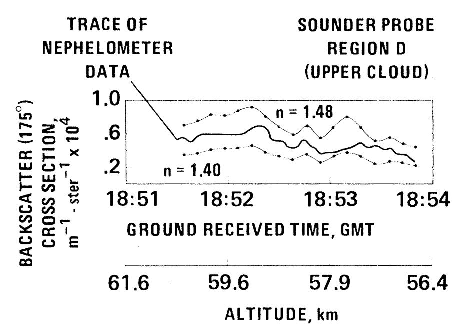
The data from the north probe, which entered on the nightside of the planet at high latitudes, show the same gross characteristics as those from the sounder probe. The magnitude of the signal received from the tentatively identified C region is roughly the same as that seen by the sounder probe. Regions B and C are apparent, although the relative magnitudes and shapes of the regions indicate that the detailed composition or distribution of particle size may be substantially changed from those observed by the sounder probe. In particular, the relative magnitudes and shape of region B with respect to region C hint at the absence of the upper part of region B as seen by the sounder probe. This region is characterized for the sounder probe by the presence of large (> 5 μm in diameter) particles (*4*). The presence of region A is also hinted by the change of inflection on the low-altitude boundary of region B, although its presence is not clearly delineated as it was for the sounder probe. The sharp, lower altitude boundary of the cloud is, however, evident.

High-altitude data received at the time of this report for the day probe start only 4 seconds or 200 m above the lower boundary of the cloud layer, which is apparent at about 49 km for this probe; the general lack of backscatter signal was again manifested all the way to the surface. This probe did survive impact and transmitted reports during impact and for approximately 60 minutes after impact.

Available data for the night probe again showed the same gross overall features as the sounder probe for the lower cloud. The separation between regions B and C is distinctive, and the relative magnitude of the signal in region C agrees fairly well with that obtained on the sounder probe. In region B, the relative magnitude is less than that for the sounder probe and the shape is much more jagged, again hinting at the absence of as much large-particle scattering near the top of this region and perhaps more large-particle scattering near its base. Region A, below the base of region B is about the same magnitude as seen by the sounder probe and is again not as clearly separated from region B, appearing to be bifurcated before merging with region B.

Pending further verification from the





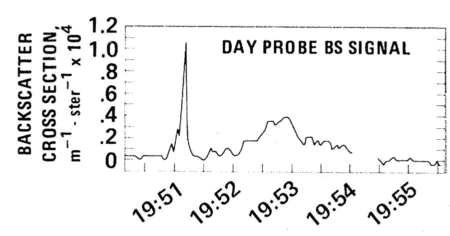


Fig. 2 (left). Variation of the 175° angular scattering coefficient with ground received time (*GMT*) for nephelometers from the (A) north probe, (B) day probe, and (C) night probe. Fig. 3 (top right). Comparison of signals measured by the sounder probe nephelometer in region D (upper cloud region), with values calculated according to the particle size distribution measured simultaneously by the sounder probe cloud particle size spectrometer, and under the assumptions of spherical particles and no absorption, and by varying the assumed index of refraction for the particles. Fig. 4 (bottom right). Day probe nephelometer signals obtained during the period of probe impact on the surface of Venus.

delayed data for the small probes, it appears that region C is a planetary feature, whereas regions tentatively identified as A and B may differ from one location to another. No data on region D is, as yet, available for the small probes.

A consideration of the sounder probe nephelometer response at a given altitude and comparison with the particle size distribution measured by the LCPS experiment at the same altitude makes possible best-fit analyses for the indices of refraction of the particles at those altitudes, assuming that the particles have very little or no absorption at 900 μm and that they are spherical or that the shape factor is known (*5*). The assumption of low absorption is supported by the results of the solar net flux radiometer (LSFR) experiment (*6*), and supporting evidence for the sphericity or lack of sphericity for the particles, especially for large particles, is obtained from the LCPS experiment. These data support the hypothesis that the particles are spherical in all of the regions except possibly region C. The comparisons and analyses have yielded the following results.

In region D, the curves of nephelometer reading and total particle concentration are similar, especially at the higher altitudes, which implies that the distribution function of particle sizes is relatively constant, as is also directly verified from the LCPS measurement. From our preflight calibration without renormalization, the nephelometer data can be derived directly from the measured particle size distribution by assuming spherical particles and an index of $n = 1.44$, in agreement with the properties of a 75 to 85 percent concentration of H_2SO_4. Figure 3 shows the sensitivity of the calculation to the choice of index of refraction. We conclude that in region D the particles are essentially composed of a concentrated solution of H_2SO_4.

In region C, our early calculations indicate that it is not possible to fit the nephelometer data with values of index greater than 1.40 for the larger particles (assuming sphericity) while retaining a value of $n = 1.44$ for the smaller particles and that our best fit occurs when we use a value of 1.33. We are not in a position, however, to definitively exclude high-index, irregularly shaped particles such as sulfur from this region, since such particles may well have backscattering cross sections much smaller than spheres of equal volume and refractive index.

In region B, again in accord with the results of the LCPS and LSFR measurements, we assume liquid (spherical) particles and conservative scattering; from the particle size distributions measured by the LCPS, we compute that in all parts of this region the nephelometer data cannot be fit by assuming an index as large as 1.44 for the large particles ($d > 5$ μm), and by assuming $n = 1.44$ for smaller particles. The largest value of index (under the assumption that the large particles are spherical), which provides rough agreement with our data, is $n = 1.37$. Further refinement of our calculations may change this value slightly. We tentatively conclude that in this region it is not necessary to invoke large sulfur particles in order to explain the data.

Region A appears to be composed of particles similar to those of region D with a slightly broader distribution. The very narrow peak appearing in the nephelometer data at an altitude of about 1500 m below the major structure of region A is evident in the data of both the nephelometer and cloud particle sampling experiment and is, again, apparently similar in its physical properties to region D. Nephelometer signals from region A may be explained by using the measured particle size distribution results from this region, corrected for the integration time differences between the LCPS and large probe nephelometer experiments, by assuming particles of $n = 1.44$ (H_2SO_4). Because of the similarity in particle size distributions between the lower portion of region B and region A, we infer that region A has been detached from region B by local weather.

Finally, we report the nephelometer signals observed during the impact of the day probe (Fig. 4). We have inferred that this probe landed in loosely compacted material so that a small amount of fine "dust" was ejected from the surface into the atmosphere in the vicinity of the probe. This dust subsequently settled out onto the surface over the next few minutes until the atmosphere in the vicinity of the probe was again free of particulate matter.

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Clouds of Venus: Particle Size Distribution Measurements

Abstract. *Data from the Pioneer Venus cloud particle size spectrometer experiment has revealed the Venus cloud system to be a complicated mixture of particles of various chemical composition distinguishable by their multimodal size distributions. The appearance, disappearance, growth, and decay of certain size modes has aided the preliminary identification of both sulfuric acid and free sulfur cloud regions. The discovery of large particles > 30 micrometers, significant particle mass loading, and size spectral features suggest that precipitation is likely produced; a peculiar aerosol structure beneath the lowest cloud layer could be residue from a recent shower.*

The cloud particle size spectrometer flown on the large sounder probe (hereafter LCPS) during the Pioneer Venus mission provided detailed microstructural data on the Venus cloud system. Aircraft-mounted particle-size spectrometers are currently widely used in terrestrial cloud physics, air-quality studies, and research programs involving the sizing of airborne particulates (*1*). However, this is the first time a particle size spectrometer has flown on a space mission.

The LCPS measured particle size and number density in the clouds and lower atmosphere of Venus as a function of altitude. The LCPS is an in situ measuring device capable of high-resolution measurements of particle size in the range of 0.5 to 500 μm. It makes single-particle measurements even at high concentrations (10^3 to 10^4 cm^{-3}) and is relatively insensitive to particle shape and orientation.

In the primary measurement, the shadows of laser-illuminated particles are imaged onto a linear photodiode array. The number of photodiode elements interrupted by each particle is counted as a specific size. Three different magnifica-

