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NEW STUDIES OF VENUS

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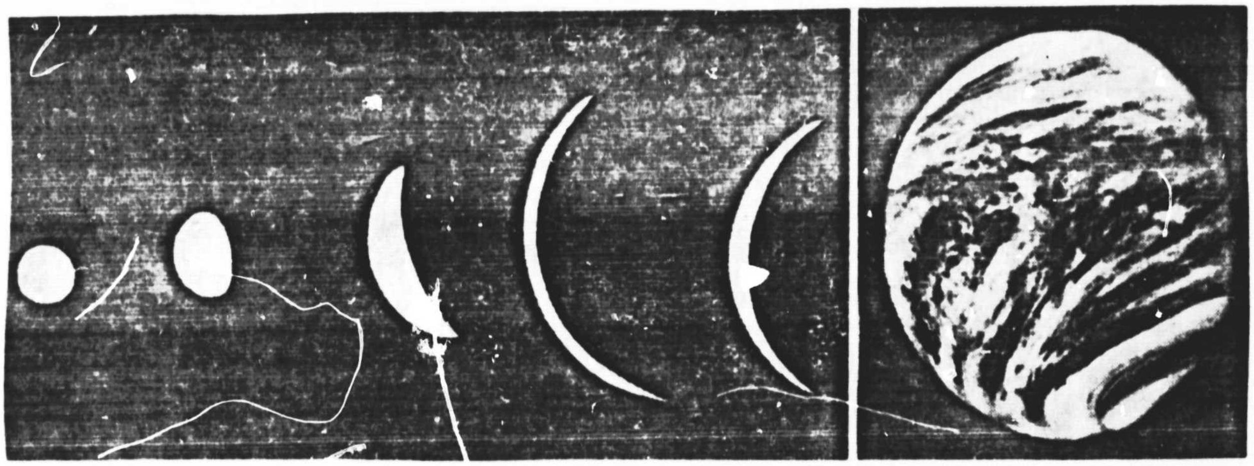
[Article by L. V. Ksanfomaliti, doctor of physicomathematical sciences]

[Text] Two Soviet space vehicles, Venera 11 and Venera 12, investigated the atmosphere of Venus anew in 1978. Seven Soviet vehicles had previously probed the planet's atmosphere. The first American experiment on direct probing of the Venusian atmosphere from the Pioneer Venus vehicles was also conducted in 1978.

The New Expeditions

The preparation of the experiments on the Soviet and the American vehicles proceeded independently. However, the scientific objectives of the researchers dictated the performance of like experiments. Both the Soviet and the American vehicles were outfitted with equipment for chemical analysis of the atmosphere--mass spectrometers and gas chromatographs. This problem was resolved by large groups of researchers, headed here by V. G. Istomin and L. M. Mukhin, and, in the case of the Americans, by G. Hoffman and V. Oyama and their associates. The chemical analysis of cloud particles was conducted on the Venera spacecraft only, by means of X-ray fluorescence. Yu. A. Surkov headed the experiment. Cloud layer structure and the physical properties of cloud particles were analyzed by nephelometers--instruments which measure the turbidity of a medium. M. Ya. Marov headed up the Soviet experiment, and B. Regent (US) and J. Blamont (France) the American experiment. A special device for studying aerosol particle size was installed on Pioneer Venus. R. Hollenberg and D. Hunton supervised the experiment. During launching, the Pioneer Venus probes measured solar radiation and scattered and intrinsic radiation of the atmosphere and surface. The work was directed by M. Tomasco. Similar apparatus was used on the Venera series in 1972 and 1975; but in 1978, Soviet scientists employed a much more complex scanning spectrophotometer covering the 4000-12000 Å range. V. I. Moroz directed the experiment. Venera 11 and 12 alone were equipped with instruments for recording possible storms on Venus and for analyzing the electrical activity of its atmosphere. These investigations were directed by the author. Scientific experiments were also performed in the course of the vehicles' orbital travel. Thus, the arsenal of science available to the Soviet and American probes was considerably greater than on the earlier Venera spacecraft, which, nevertheless, did obtain important information (ZEMLYA I VSELENNAYA No 1, 1969, pp 10-19; No 3, 1971, pp 42-47; No 1, 1974, pp 33-37; No 3, 1976, pp 3-15.--Ed.).

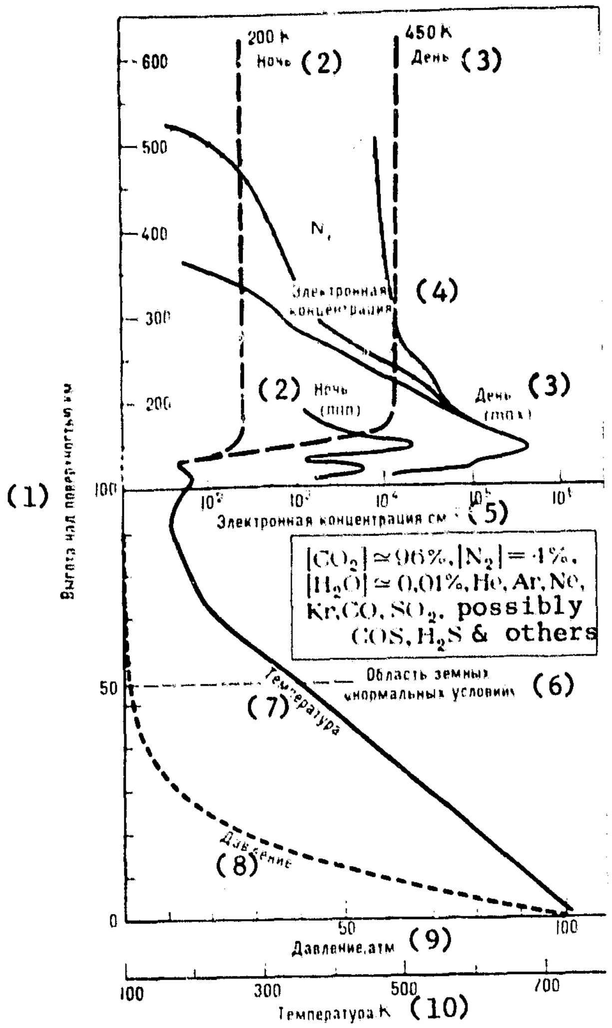


The phases of Venus as seen by telescope, and the planet's image in ultraviolet obtained by Mariner 10 in 1974.

All vehicles from Venera 4 to Venera 10 indicated the temperature and pressure at the surface of the planet (at a radius level of 6052 km) are very high--on the order of 750°K and 93 kg/cm^2. When the vehicle landed on high ground, the pressure and temperature proved to be lower. Venera 11 registered 727°K and 87 kg/cm^2 at the instant it landed.

The mass of Venus' atmosphere is great--some 100 times that of Earth's atmosphere, and it amounts to about 10^{-4} of the planet's total mass. (We would remind the reader that the total mass of the Earth's atmosphere is on the order of $5.3 \cdot 10^{21}$g, which is approximately 10^{-6} of the Earth's mass.) It wasn't long ago that Venus and Earth were held to be sister planets, if not twins. Actually, the mass of Venus is 0.815 of the mass of Earth and their respective densities are 5.24 and 5.52 g/cm^3; hence, it was presumed that the internal composition of the two planets must be similar. The quantity of solar energy absorbed by the planets is almost the same. Although Venus is closer to the sun, its clouds reflect a large portion of the solar radiation.

At the same time, studies indicated that Venus differs from Earth not only in its high surface pressure and temperature and the composition and mass of its atmosphere (all of these characteristics are interrelated). It has lately been possible to successfully measure by ground-based radar the true duration of Venusian diurnal cycles. Day and night on Venus last 59 Earth days each and its rotation period (the direction of it is opposite to Earth's rotation) amounts to 243 Earth days, exceeding the Venusian year (225 days).

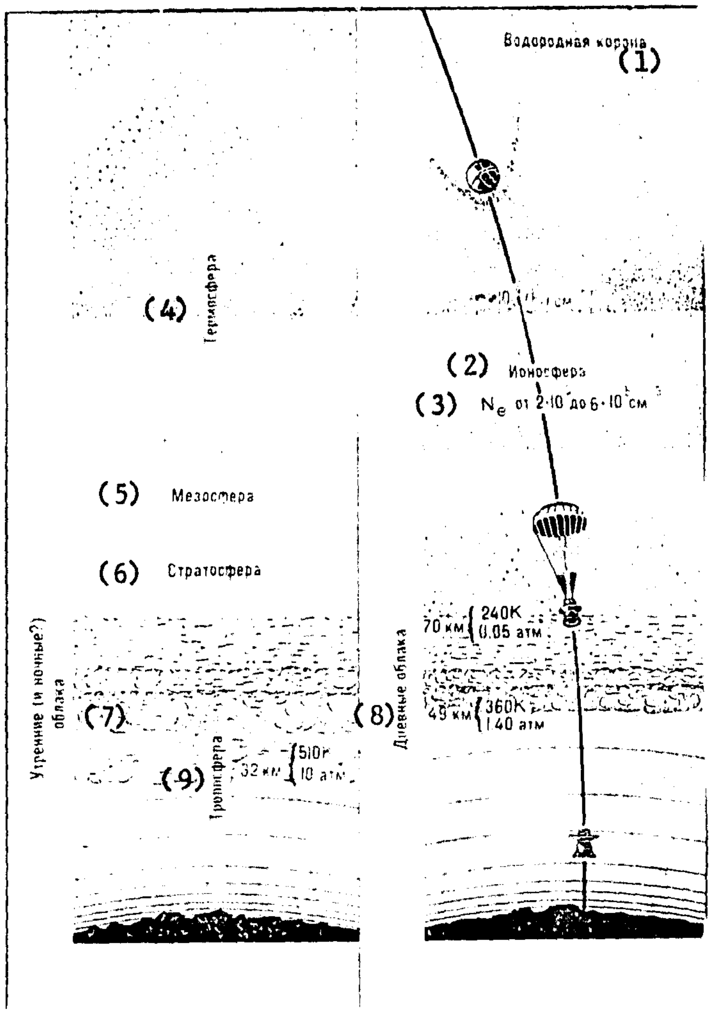


Vertical profiles of temperature, pressure and electron concentration in the atmosphere of Venus, with an indication of the chemical composition of the atmosphere.

Key:
1. Height above surface, km
2. Night
3. Day
4. Electron concentration
5. Electron concentration, cm^{-3}
6. Region of Earth's "normal conditions"
7. Temperature
8. Pressure
9. Pressure, atm
10. Temperature, °K

The Greenhouse Effect

The oceans of our planet contain a lot of water--$1.35 \cdot 10^{24}$g. Were Earth's temperature to rise enough for the oceans to evaporate, the pressure in our atmosphere would increase to 260 kg/cm^2 due to the water vapor. There can not be any oceans on Venus, certainly, for the surface temperature is so high that in deep valleys, in darkness, it is possible even to see the dark red glow of the hot surface. But then, this isn't surprising; there is almost no water vapor in the Venusian atmosphere. According to the data of V. I. Moroz, obtained by Venera 9 and Venera 10 in 1975, the relative content of water vapor by volume is about 10^{-4}. Measurements from Venera 11 and 12 showed an even lower figure: about $3 \cdot 10^{-5}$. The deficiency of water on Venus (or the abundance of it on Earth) is one of the planet's toughest puzzles, assuming that the protoplanetary matter from which Venus and Earth were formed had the same composition.

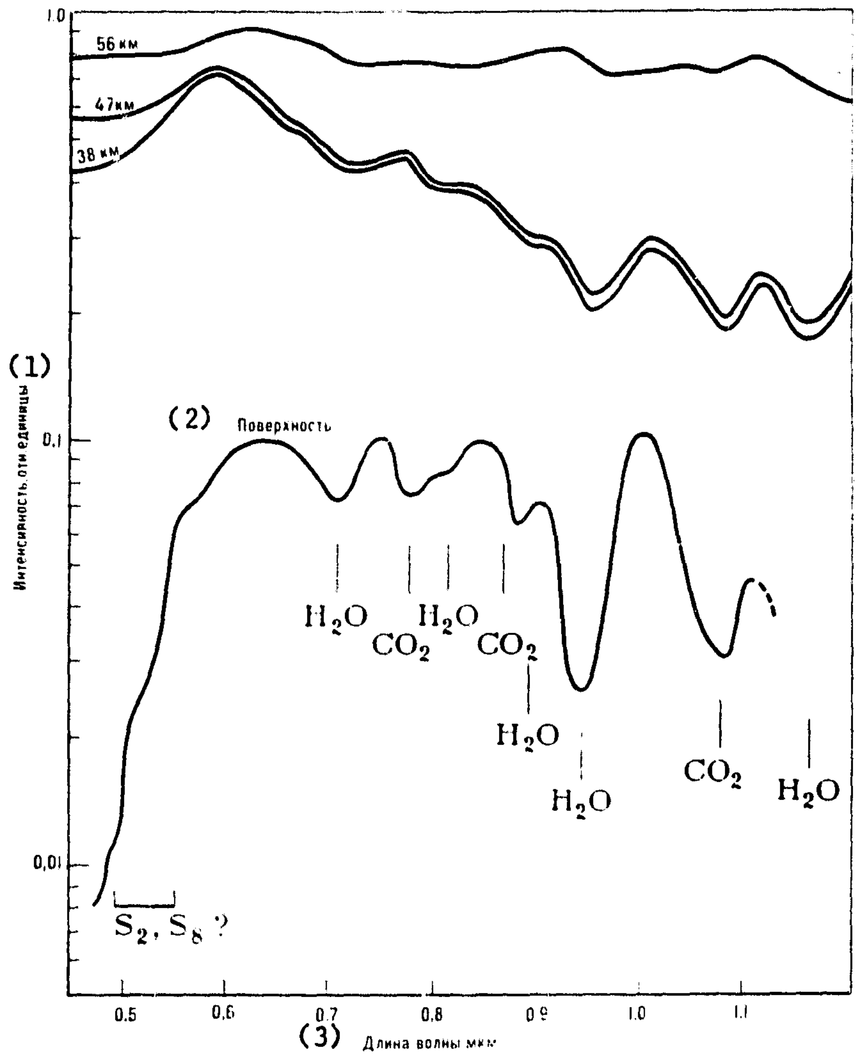


Structure of the Venusian atmosphere by day (left) and by night. The descent of a space vehicle in the atmosphere is depicted.

Key:
1. Hydrogen corona
2. Ionosphere
3. N_e from $2 \cdot 10^3$ to $6 \cdot 10^5$ cm^{-3}
4. Thermosphere
5. Mesosphere
6. Stratosphere
7. Morning (and nighttime?) clouds
8. Daytime clouds
9. Troposphere

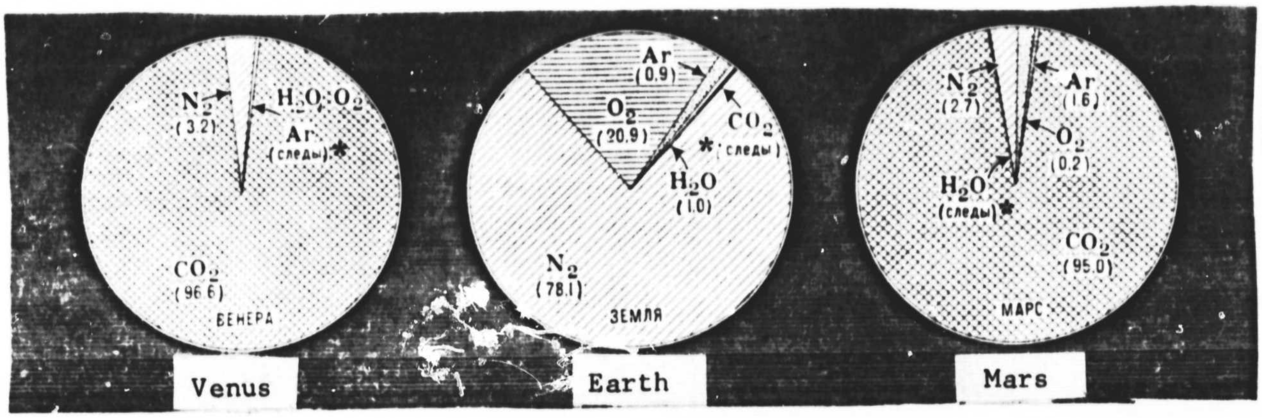
Scientists explain the heating up of the Venusian atmosphere via a greenhouse effect. The sun's rays penetrate rather deeply into the planet's atmosphere and are to some extent absorbed by the clouds and the gaseous medium. Several percent of the radiation reaches the surface and is absorbed. If the planet doesn't get hotter from day to day, it means that as much energy as is absorbed is radiated into space. As we know, the planet radiates in the long wave thermal range. Here, in the infrared region, carbon dioxide with a small amount of water vapor added is but slightly transparent. In order that an ample amount of radiation pass through a low-transparency medium, the source has to be quite intense. Consequently, the temperature of the surface and the lower layers of the atmosphere is high. And if there were more water vapor, the temperature would rise higher still.

A detailed analysis of the greenhouse effect requires careful spectral measurements over the entire depth of the atmosphere. Additionally, it is necessary to know the scattering angular characteristics--the luminosity of the scattering and absorbing media in all directions. Just such an experiment was con-



Scattered solar radiation spectra obtained at different levels during descent of Venera 11 and 12, and from the surface of Venus (bottom curve). Where Venera 11 landed the temperature reached 727°K and the pressure 87 kg/cm^2. Most of the bands in the spectrum belong to carbon dioxide and water vapor; the weak bands were identified with vapors of sulphur. Sulphur was detected in the atmosphere of Venus for the first time. Key: 1. Intensity, relative units; 2. Surface; 3. Wavelength, µm

ducted by Soviet scientists. Highly valuable information on the structure of the atmosphere was obtained. The lower boundary of the cloud layer lies at a height of 48-50 km. The clouds themselves attenuate the light by about 50%. Below the 48-km level, the light which reaches the surface is further weakened to a tenth of the cloud-attenuated intensity due to the atmosphere's high density. There is cause to assume that the extent of the clouds varies over the course of the Venusian day.



*(traces)

Charts showing content of principal gases in the lower atmosphere of Venus, Earth and Mars. (Illustration from SKY AND TELESCOPE Vol 57, No 2, 1979.) In the opinion of Soviet scientists, the presence of oxygen in the troposphere of Venus is doubtful. The nitrogen content shown here is somewhat lower than the results of the mass spectrometer measurements from Venera 11 and 12 (4%).

The spectra of scattered sunlight obtained from the surface of Venus have many characteristic bands belonging mainly to carbon dioxide and water vapor. Using laboratory measurements, V. I. Moroz succeeded in identifying several bands in the blue-green part of the spectrum with sulphur vapors.

The instruments of Venera 4 detected in 1967 that the Venusian atmosphere contains not less than 90% carbon dioxide. Further measurements increased this figure to 95%. Analysis of the minor components of the atmosphere on both Soviet and American spacecraft was to reveal the makeup of the remaining 4-5% of the Venusian atmosphere. All of the vehicles showed it to contain nitrogen (3.5-4%) and inert gases, primary among which is argon (about 0.01%), one tenth that amount of neon, and one two-hundredth of krypton (which only the Venera spacecraft detected). Helium was found--several thousand times more of it in the Venusian atmosphere than in Earth's. And chlorine, sulphur, sulphur dioxide and a number of other compounds were also detected.

The isotopic composition of argon on Venus was a scientific sensation. Argon comprises 1% of Earth's atmosphere. Of that percentage, 0.996 is argon-40 (formed in radioactive decay of potassium-40 contained in the crust), 0.003 is argon-36 and 0.0006 is argon-38. The last two isotopes probably arrived here with protoplanetary matter when the planet was forming. If the conditions of Earth's and Venus' formation were similar, it is remarkable that argon's isotopic composition in the Venusian atmosphere has turned out differently: the amount of argon-40 there is about the same as the amount of argon-36 and argon-38 combined. Is this, like the water deficiency, related to peculiarities in the planets' formation which are unknown to us?

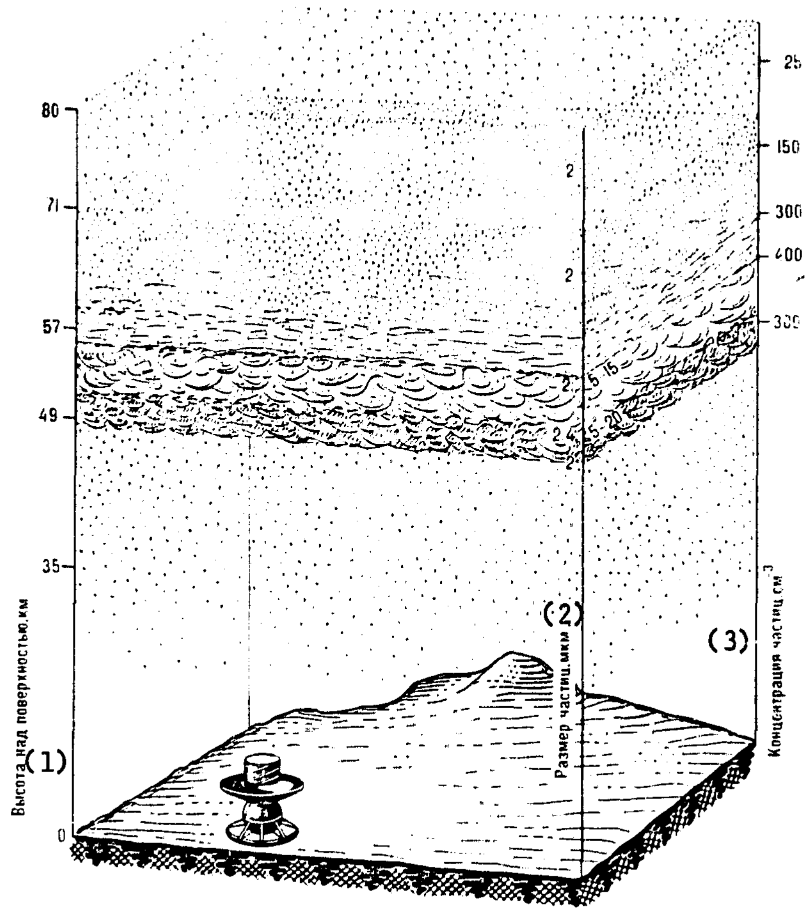


Diagram showing the structure of the daylight cloud layer of Venus. Key: 1. Height above surface, km; 2. Particle size, um; 3. Particle concentration, cm^{-3}

Clouds of Fog

The clouds of Venus are located at heights of 48-72 km. In essence, they are not clouds but a medium density fog in which the range of visibility (there is such a meteorological concept) amounts to several kilometers.

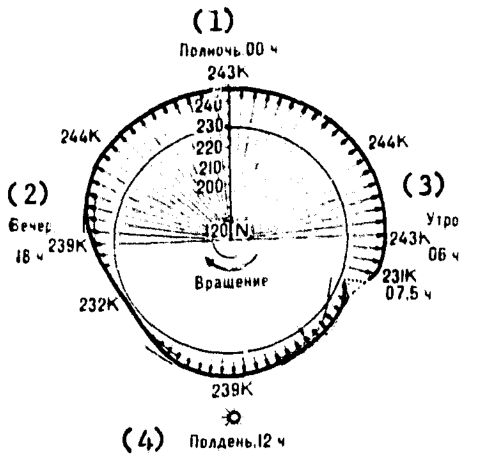
The hypothesis of a sulphuric acid composition of the clouds, proposed in 1972 by G. Sill and in 1973 by L. and E. Young, husband and wife (US), quickly gained popularity (ZEMLYA I VSELENNAYA No 3, 1976, pp 3-15.--Ed.). The particles' index of refraction, close to 1.44, and their liquid state at 233°K were known from ground-based polarimetric and radiometric observations. These properties of the particles were easily explained within the framework of the following model: the particles are extremely fine drops of 75-percent H_2SO_4, measuring about 2 μm; and all the drops, the concentration of which averages about 300 cm^{-3}, are of approximately the same size. One must pay attention to this strange feature. The drops in Earth clouds, in fact, gradually enlarge and their range of sizes expands. This occurs under the action of condensation and as the result of consolidation--coagulation and coalescence. Coagulation leads to consolidation as a result of thermal (Brownian) motion of the particles, and coalescence, as a result of the particles' falling at different speeds in Earth's gravitational field. It was clear that the approximately uniform sizes of the particles in the upper layer of the Venusian clouds point to something important.

It turned out later that the composition of Venus' clouds is more complex than had been assumed. It appears that there are present there larger, solid particles, few in number, probably particles of sulphur. Nephelometric measurements performed on Venera 9, 10, 11 and 12 and on Pioneer Venus spacecraft, and also a study of particle-size range by Pioneer Venus instruments showed that there are solid aerosols measuring 5-15 μm, together with the fine drops at heights of 51-55 km. At 48-51 km the particles' composition and sizes are even more complicated. Drops measuring 1-2, 4 and 5-15 μm are found there. Below 48 km, in daylight, very thin (50-300 m) bands of clouds consisting of only the finest particles were noted. It is assumed that the large particles have already thawed and evaporated at 48 km. The temperature in this region of the atmosphere is close to 370°K, but pressure is about 1.5 kg/cm^2. Still lower, down to 32 km, fine particles are present in the atmosphere in small quantity.

At 32 km there is a puzzling boundary in the Venusian atmosphere, below which are found such compounds of sulphur as COS and H_2S and allotropes of sulphur; but above it--SO_2. An hypothesis has been voiced that oxidation processes are here replaced by reduction. It is interesting that, early in the morning (Venusian local time) Venera 8 observed a lower cloud limit right at 32 km.

How a sulphuric acid aerosol is formed from the gaseous components is still not entirely clear. We were able to obtain some information on the origin of the aerosol medium from a radiometric experiment conducted on Venera 9 and 10 in 1975-1976. All of the thermal radiation of Venus which escapes into space is formed in the upper part of its cloud layer, the temperature of which is near 240°K. It was established that the night side of Venus has a brightness temperature* 12° higher than the evening temperature and 6° higher than the temperature of the daylight side of the planet. A minimum temperature of 232°K was observed at 16 hrs. The temperature is higher at noon, 239°K, and reaches 244°K at night. Calculations indicated that this strange pattern of brightness temperature can not be explained by one shift of the boundary of the upper part of the cloud layer. Most likely these changes are connected with photochemical processes of sulphuric acid particle formation in the Venusian stratosphere--the supracloud part of the atmosphere situated at heights of 70-90 km. No doubts are raised that the production and destruction of the clouds' aerosol particles is in dynamic equilibrium with the ambient medium. As already noted, the particle sizes in Venusian clouds are surprisingly uniform, in contrast to Earth clouds. This means that we are looking at a layer of recently formed particles; otherwise, their uniformity would be

*) The brightness temperature of an object is the temperature of a blackbody which has, in the given spectral range, the same brightness as the object being studied.



Distribution of brightness temperatures in the equatorial belt of Venus according to data from Venera 9 and 10. Radiation comes from the upper part of the clouds located at a height of 65-70 km. The intensity of the thermal radiation corresponds to the length of the arrows. The nighttime side of the planet is hotter than the daytime side.

Key:
1. Midnight, 00 hrs
2. Evening, 18 hrs
3. Morning, 06 hrs
4. Noon, 12 hrs

upset in the process of particle consolidation. Since we are observing the outermost part of the cloud cover, the inference is that these particles are falling from somewhere above, where they are originating. But what does this sulphuric acid "rain" originate from?

It was shown recently that, under the action of solar ultraviolet rays, the photochemical transformations of gaseous compounds of sulphur in the supra-cloud atmosphere where there is a small quantity of water vapor should lead, in the final analysis, to the occurrence of sulphuric acid droplets. The process of the formation of this "rain", which drops onto the clouds, is very slow. In an entire Venusian day 25 droplets with a diameter of 1.5 μm are formed in 1 cm^3 of atmosphere; but that number of droplets provides satisfactory explanation for the observed variations of the brightness temperature.

This course of reasoning has led the author to an hypothesis which can be simply stated in the following way. The stratosphere of Venus is transparent in the morning, but there is a considerable amount of particles in it by noon as a result of the photochemical processes. Since the temperature of the stratosphere is lower than the temperature in the radiating layer of clouds, the thermal radiation from below is noticeably weakened by this medium. The greatest concentration of particles is reached at 16 hrs local time, which explains the evening minimum of brightness temperatures. At night, when the photochemical processes are not active, the sky becomes transparent again and the brightness temperature rises to maximum value. In this way, the temperatures being measured are linked to the production and composition of the aerosol particles. It stands to reason that local inconsistencies and, possibly, even years-long fluctuations in the intensity of these processes may be observed. The Pioneer Venus orbital spacecraft registered an exten-

Contrast ultraviolet details of the cloud layer of Venus. Television picture from Venera 9.

sive cold region with a temperature of 215°K at the planet's north pole, whereas the brightness temperature of the surrounding region was 240°K. In 1975-1976 Venera 9 and 10 gave an average temperature for the planet of 240.3°K, on the basis of which the planet's radiometric albedo was computed at 0.79.

It is interesting that many characteristics of Venus--the distribution of its thermal radiation, for instance--are not entirely constant. There is a notable variation of contrast of the dark bands observed under ultraviolet rays on the disk of Venus. Sometimes the bands are quite clearly visible, as in the television pictures from Venera 9 and Mariner 10. But it is occasionally impossible to make out any details, as was the case at the very beginning of operation of the Pioneer Venus spacecraft. The origin of the contrast bands and their ability to last for 10 Earth days or more are not fully understood. It is not ruled out that both dark and light features are situated at the same heights and are associated with local transfer of some gaseous component or other, SO_2 for example, from the troposphere.

A few words about the Venusian sky. How does it look from the surface of the planet? By day the sky is bright with a red-orange hue. According to data from the Venera series spacecraft, the sun is indistinguishable through the cloud layer. There is some basis to assume that the optical mass of the clouds lessens near midday. But clearing to the extent that the solar disk might be visible from the surface of the planet is not very likely.

Electrical Discharges Over Venus

Although assumptions have been voiced, there has been no information thus far about the occurrence of storms on other planets. For example, there was an attempt to explain flashes of radioemission from Jupiter as monstrous lightning flashes in its atmosphere. But the energy of those discharges had to be improbably high in order for radiowaves from them to reach Earth and yield a perceptible signal.

Venusian radioemission was discovered about 25 years ago. It originates from the planet's highly heated atmosphere and surface (ZEMLYA I VSELENNAYA No 2, 1966, pp 14-19.--Ed.) and has nothing to do with electrical discharges. As knowledge grew concerning the composition of the atmosphere, the question arose: How are certain of its minor components formed? It can be hypothesized, for example, that their production stems from electrical discharges. We know that ozone, oxides of nitrogen and other compounds are formed in Earth's troposphere under the effect of lightning.

A strange phenomenon, long recorded by astronomers, is well known: The nighttime side of Venus is sometimes slightly aglow. The planet has no natural satellites so the light can relate only to the planet itself. In 1954, N. A. Kozyrev was able even to obtain a spectrogram of the light. Then in 1975, in an experiment conducted by V. A. Krasnopol'skiy, instruments aboard Venera 9 and 10 detected yet another type of illumination of the night side of the planet. But it proved too weak to be seen from Earth. And then a half-way fantastic hypothesis was suggested: The light comes from lightning flashes in the planet's atmosphere. According to calculations, however, there has to be a very great amount of lightning for such illumination to be visible from Earth. To the point, the energy released in a lightning flash above the Earth averages 10^{15}-10^{16} ergs. About 100 lightning flashes per second are observed over all of Earth. If there are a thousand times more of them on Venus the light can infact be seen from Earth. But does lightning occur on Venus?

A miniature radio receiver-spectrum analyzer for long waves and very long waves was installed on Venera 11 and 12 to record electrical discharges. It possessed high sensitivity and a broad dynamic range since the experiment was set up blind, without data of any kind to go on. In the early morning of 21 December 1978 Venera 12 descended in the planet's atmosphere. Nine minutes after the instrument was activated came the first group of pulses from about 100 discharges and, eight minutes later, a second group. Were it not for the infrequency of the pulses, it could be said that the signal resembled the discharges of a distant thunderstorm on Earth. As the spacecraft dropped closer to the surface, the amplitude of the recorded radio noise began to diminish; and, after the landing, it fell off to the level of receiver noise. Inasmuch as weak discharges could also be produced as a result of the craft's electrizing through its movement at 10 m/s in the atmosphere, the observed phenomenon might have been, as they said in the old days, an artifact. But in the 32nd minute after the landing a large group of pulses was registered--the only one in the entire 110 minutes of the instrument's operation on the fiery surface of Venus.

On the morning of 25 December Venera 11 decended along the same path into practically the same region of the planet. The phenomena it registered

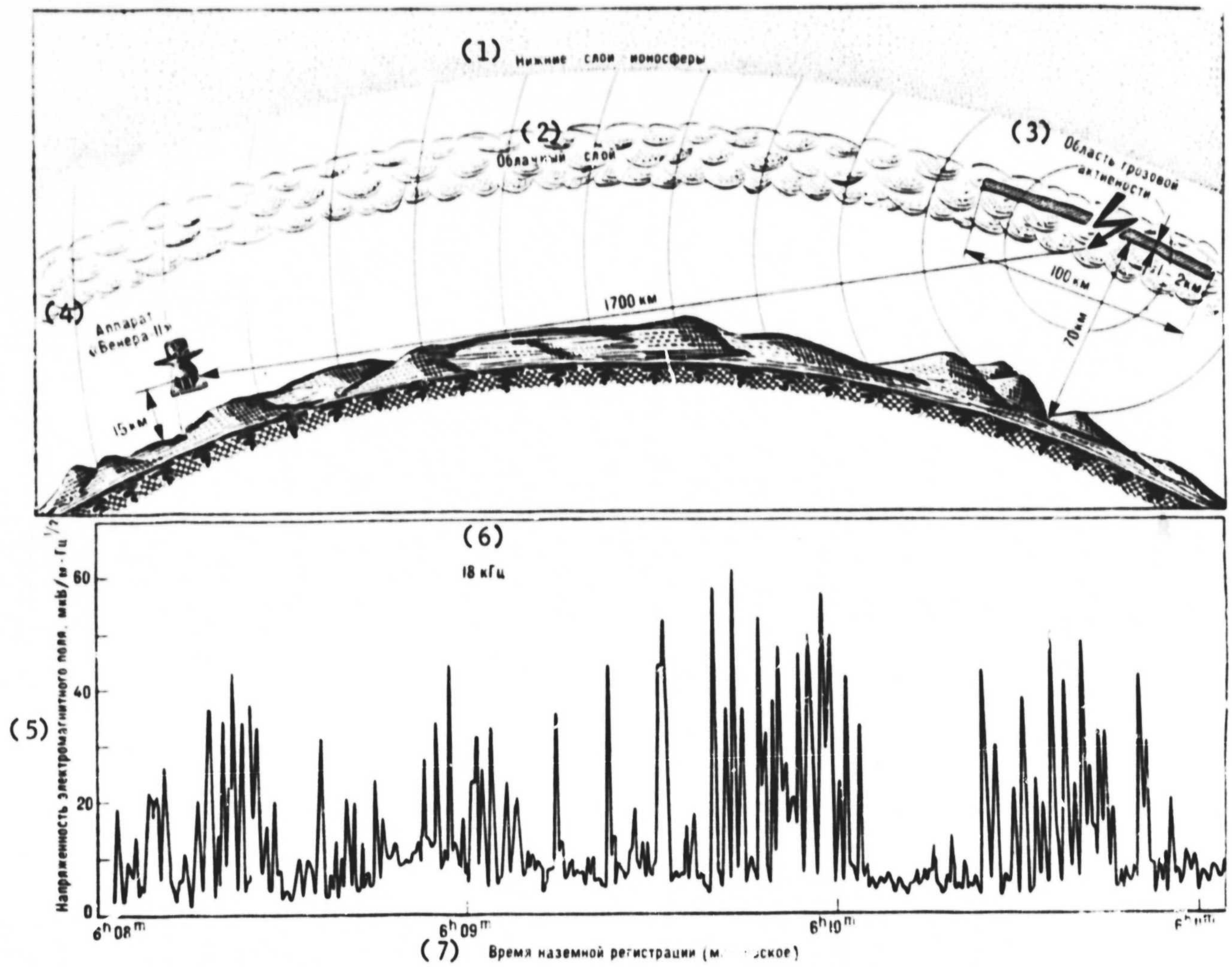


Diagram of Venera's recording of radio noise from a storm cloud in the Venusian atmosphere. The lower illustration is the radio noise recording at 18 kHz. Key: 1. Lower layers of the ionosphere; 2. Cloud layer; 3. Region of thunderstorm activity; 4. The Venera 11 spacecraft; 5. Electromagnetic field strength, $\mu V/m \cdot Hz^{1/2}$; 6. 18 kHz; 7. Time of ground-based recording (Moscow)

were vastly different. That day a very strong electrical storm was detected with 20-30 heavy discharges each second. The storm abated after several minutes, but the next one was waiting. The frequency of the discharges far exceeded the typical figure for Earth's storms. If it is possible to compare the characteristics of the electromagnetic field strength of discharges on Venus and on Earth then the source of the radio noise had to be thousands of kilometers away from the Venera 11.

It was soon possible to show that the low frequency radio noise is connected with electrical processes occurring in the atmosphere. The atmospheric noises which were the first radio signals picked up by A. S. Popov's radio receiver on Earth, also exist on Venus!

Since the "Storm" experiment (the name given the search for electrical discharges from Venera 11 and 12) was being conducted for the first time, processing the results of it entailed considerable difficulty. There were recorded, actually, several thousand short pulses from discharges grouped into individual surges of radio noise in the 10-100-kHz range. Given these recordings, how do you figure out the nature of the event itself? The key proved to be a group of surges recurring at periods of 50-60 seconds. Since the spacecraft was rotating slowly during its descent and the receiving antenna was directional, the periodicity could be explained by the thereby occurring modulation of radio noise from a source having small angular dimensions. A comparison of the period of the surges with the spacecraft's rate of rotation confirmed that hypothesis which then enabled finding the source's angular size (about 5°).

The energy of the discharges was then calculated from the measured electromagnetic field strength. The calculations were performed for different variants of source location. The electromagnetic field strength which was detected best matches the situation when a source having energy typical of Earth lightning (10^{15} ergs) is 1700 km distant from the spacecraft. But is the reception of radio signals from a source that far away possible on Venus? Radioengineering here on Earth skilfully employs the ionosphere-surface waveguide channel for the reception of signals from distant stations. The rather dense ionosphere on Venus' daylight side should, it would seem, also facilitate the long-range propagation of VLF radio waves. In addition, Venera 11 and 12 recorded a deep drop-off of electromagnetic field strength at the surface of the planet, which may be caused by some kind of radiowave absorption mechanism. Hence, we were looking at only a direct wave, when reception of an emission depends only on the height of the receiver and the source of the emission. Since, at the moment the radio noise was recorded, the vehicle was at 15 km altitude, a source 1600 km away would be visible if its altitude were 70 km (the cloud layer!). The source would quickly disappear beyond the radio horizon because the vehicle was descending at a rate of 1 km/min. The recorded data confirmed this. The source of the radio noise was a region stretching some 100 km horizontally and about 1-2 km top to bottom, situated at a height of 60-70 km. So thunderstorms have a local character on Venus, too (that's the way it was in any event on 21 and 25 December 1978).

But what about the light on the night side of the planet. The frequency of the discharges in the observed Venusian storm front is hundreds of times higher than on Earth. Therefore, in periods of elevated thunderstorm activity on Venus, when there are storms covering a large area, it is the author's opinion that the night light can be attributed to lightning!

The Surface of the Planet

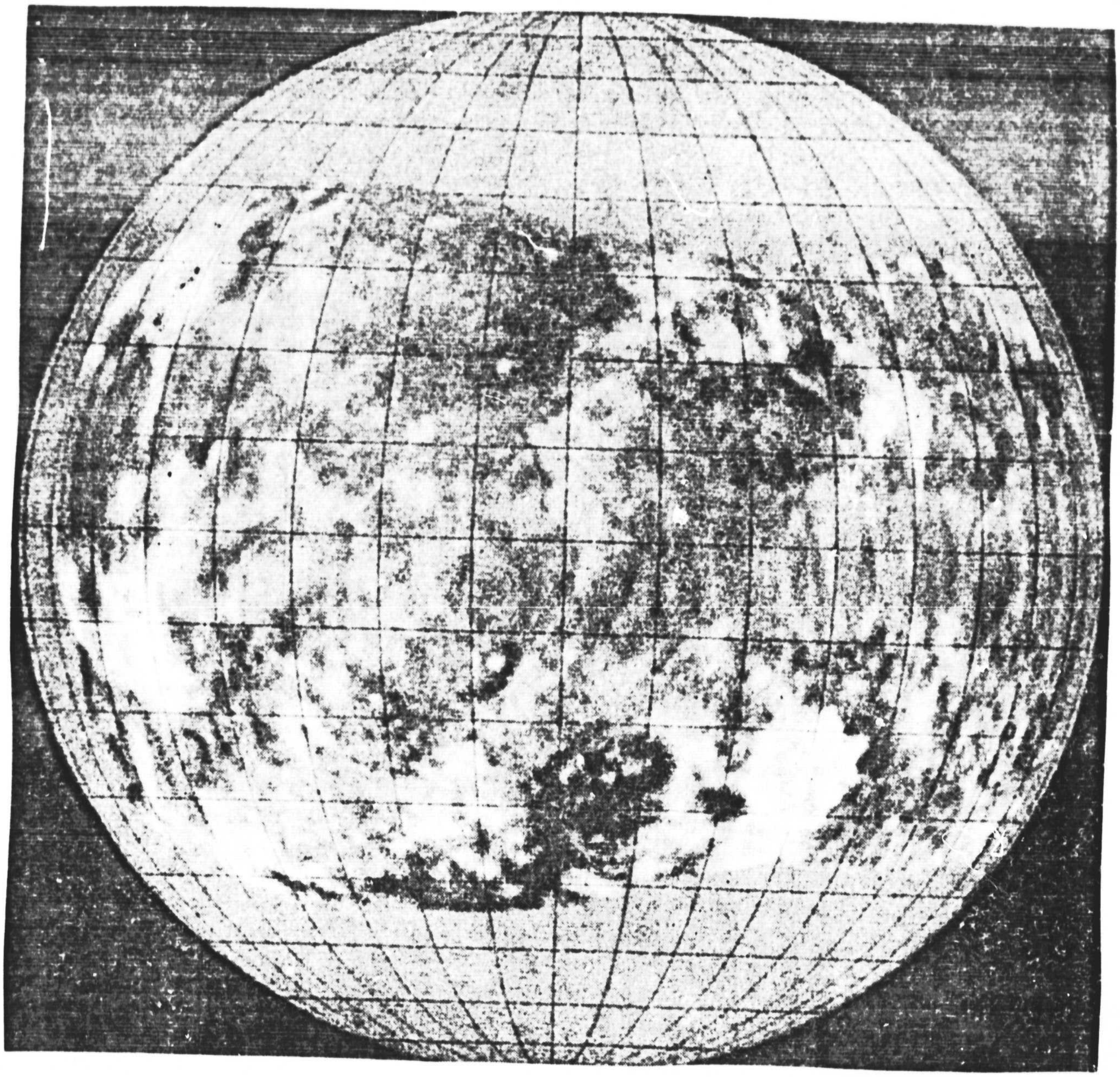
According to radar data there are not less than three long mountain ranges on the surface of Venus. We recall that Venera 9 descended to a mountainside strewn with large rocks in 1975. The scene which they viewed enabled the scientists to draw a conclusion about the planet's crustal tectonic activity, for these rocks can not be very old formations. Notwithstanding the constancy of the physical conditions on the planet's surface where the diurnal temperature varies no more than a degree and there is no precipitation (what kind of showers can you have at 460°C!), the relief is broken up over a long period of time nonetheless. Dust as dark as soot covers the surface of the planet. At the moment Venera 9 landed a fogging of the atmosphere was noted for several minutes: the dust was stirred up and was rising into the "air". The same thing was observed when the Pioneer Venus probe landed in 1978. According to data from the Venera probes the structure of the ground is more or less characteristic of basalt.

Thanks to progress in radar equipment and very complex machine processing of the radar coverage of Venus, American scientists succeeded in obtaining a radio map of a considerable portion of one hemisphere of the planet. The map shows the distribution of the planetary surface's radio reflection, the value of which is related to surface irregularities and to differences in the dielectric permeability and conductivity of the ground (ZEMLYA I VSELENNAYA No 1, 1977 pp 24-27.--Ed.). It is possible to adapt the same radar method for the production of hypsometric--elevation--charts. The vertical resolution on such charts amounts to hundreds of meters.

In some regions of Venus craters of comparatively regular form resembling meteorite craters have been detected. The existence of craters on Venus' surface evokes a great many questions. First of all, a meteoric body should slow down and vaporize in the dense atmosphere. It was demonstrated recently that meteoric objects with a mass of $2 \cdot 10^{11}$g could get through Venus' atmosphere. But there are very few such objects. Most of the meteorite craters could have been formed on Venus in a remote time when the mass of its atmosphere was substantially less. As is known, the craters on our moon and on Mercury almost never are disturbed; on Mars, with its rarefied atmosphere, the deterioration process goes on very slowly. On Earth, though, you have to look for meteorite craters hard and fast: they deteriorate quickly from the effects of water, wind and temperature changes. For the Venusian relief to have been preserved from ancient times would require that there be some kind of special conditions there. It is entirely possible that the craters on Venus are of volcanic origin.

Radioastronomers have found on Venus a deep, narrow valley between two elevated areas, and a large area resembling the lunar maria. It appears to be a depression rimmed by a rugged mountainous wall. Such a formation, suggest D. Campbell and his colleagues (US), indicates the Venusian relief and tectonic activity are young. We recall that, according to data from surveying of the planet's surface by the beam of the main radio transmitter on Venera 9 and 10, there are drops in elevation reaching 6 km.

On Venus, probably, as on Earth, Mars, the moon (and, likely, on Mercury), there are continents and seas, the latter having less density and crustal thickness. Geologists affirm that, on the basis of information already obtained, Venus can be termed a very active planet. Some of them suggest that



Radio map of Venus hemisphere presented at inferior conjunction. The map was produced by R. Goldstein's group (US) employing mathematical processing of ground-based radar signals.

Large rocks scattered on the slope of a Venusian mountain. Venera 9 came down at this point on 22 October 1975.

the interior and crust of Venus have evolved stronger than Earth's. Interestingly, if the chemical makeup of the two planets were identical, the average density of Venus would be 5.34 instead of 5.24 g/cm^3. As regards density of the Venusian surface rock (1.8-1.9 g/cm^3), it is very close to the density of the surface rock on Earth.

Every planet is a world with its own physical conditions, its own features and its own evolution. New data on the planets becomes part of the fundamental information of science. But the value of space research on the planets is not limited to that alone. The study of other planets makes it possible to better understand Earth's evolution, and the processes which go on within the Earth, its oceans and its atmosphere.