would tend to oxidize pyrite to magnetite at all altitudes, using its S to build up the deficit of atmospheric COS. This argument is specious. Fegley et al. argue from only one reaction and three species abundances in the Venus atmosphere, while [2] used an energy-minimization procedure that effectively considers all possible reactions simultaneously. Klose et al. [2] used as input the bulk elemental composition of the atmosphere, not the abundances of selected gas species in it. They determined the total equilibrium system, including concentrations of gas species in the atmosphere as well as surface minerals. Klose et al. found, as Fegley et al. say, that the equilibrium abundance of COS is greater than the concentration the Venus atmosphere appears to contain (~15 ppm vs. ~0.25 ppm). Apparently kinetic barriers prevent COS from attaining its equilibrium concentration at ground level. Thus the Venus system is not completely at equilibrium. One can debate how badly the system is out of equilibrium, but the nonequilibrium abundance of the minor species COS in the atmosphere by no means requires that the surface mineralogy is completely out of equilibrium; and to be in equilibrium with the atmosphere's concentration of SO_2, ~185 ppm, at the f_{O2} cited above, the mountaintop mineral assemblage must contain pyrite.

Fegley et al. [4] suggest that primary perovskite ($CaTiO_3$) in the rock might be responsible for low-emissivity mountaintops on Venus, since this mineral has a particularly high dielectric constant. They note the occurrence of perovskite in (relatively rare) SiO_2-undersaturated igneous rocks on Earth, but do not examine its thermodynamic stability in more typical basalts, or in Venus basalts having the compositions reported by Soviet landers. In fact, perovskite is not a stable primary mineral at crystallization temperatures in these expected Venus rock types: instead Ti appears as rutile, and most Ca as diopside and anorthite.

With time, the weathering reactions discussed by [2] work deeper and deeper into surface rock on Venus. The timescale of weathering—the time needed to weather rock to a depth sufficient to control the radiothermal emissivity measured by PVO and Magellan—is not known, but is expected to be long. Water is an essential ingredient of terrestrial weathering, and its near absence on Venus must greatly retard the process. To some extent this effect is offset by the much higher temperatures on Venus, but in spite of this it may take tens or even hundreds of millions of years to weather a high-altitude surface to a high-dielectric assemblage.

This is comparable to the timescales of other important processes on Venus, and an interplay between weathering and (e.g.) volcanism and tectonism is to be expected. In other words, it may be possible to use the presence or absence of weathering effects to distinguish between relatively young features on Venus and older landforms.

Volcanism: Klose et al. [2] and Robinson and Wood [5] have drawn attention to large and small flow units high on the volcanos Maat, Sapas, Ozza, and Theia Mons that display relatively high emissivities. They conclude these units are too young to have had time to weather to the high-dielectric pyritic state. This criterion, if confirmed, provides a crude basis for establishing a chronology of volcanism.

Tectonism: Klose et al. [2] and Pathare [6] have explored the complex relationship between altitude (a) and emissivity exhibited by Maxwell Montes. An a/e scatter plot of measurements made over the broad Maxwell landmass shows a well-defined band at e ~ 0.4, which presumably reflects the presence locally of completely weathered surface material; but there is also a broad scatter of points to higher values of e (<~0.6) in the diagram. Pathare [6] found these latter data points are provided by a belt of mountainous terrain (latitude ~67°, longitude 350°–05°) that defines the northern edge of the Maxwell Montes low-emissivity zone. Pathare [6] attributed the less-than-minimal emissivities in this belt to incomplete weathering, and concluded that this belt was uplifted more recently than other parts of Maxwell. The emissivity increases, and presumably the time of uplift decreases, westward along the belt.

The Magellan emissivity records contain other information of interest. For example, [5] found that some small volcanic domes and clusters of domes near plains level display anomalously low emissivity. At these altitudes, according to the model of [2], magnetite should be the stable Fe mineral, and weathered surface material should not have high-dielectric properties. Robinson and Wood [5] attributed this phenomenon to continued seepage of volcanic gas through the soil covering these domes, and showed that an admixture of only ~0.02% of sulfurous gas of the type emitted by the Kilauea volcano on Earth, with normal Venus atmospheric gas in the pores of the soil, would stabilize pyrite in the soil at plains altitude. They noted a correlation between the presence of apparently unweathered volcanic flows at the summits of volcanos, and nearby low-emissivity domes; both should be manifestations of recent volcanic activity.

Another interesting aspect of weathering and emissivity on Venus is the fact that the mineral reaction boundary separating pyrite (low-emissivity) from magnetite (high-emissivity), which presumably follows an isothermal surface in the Venus atmosphere, does not intersect all highlands at the same altitude. The observed "snowline" varies in altitude from ~2.5 km (Sapas Mons) to ~4.7 km (Maxwell). Curiously, the "snowline" altitude correlates well with the total height of the mountain; the "snowline" occurs at roughly half the peak height. This suggests that the thermal structure of the atmosphere is somehow modulated by topography on Venus, a concept that has not found favor with atmospheric scientists. An alternative explanation has not been forthcoming, and this phenomenon remains to be understood.

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FINITE AMPLITUDE GRAVITY WAVES IN THE VENUS ATMOSPHERE GENERATED BY SURFACE TOPOGRAPHY.

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A two-dimensional, fully nonlinear, nonhydrostatic, gravity wave model is used to study the evolution of gravity waves generated near the surface of Venus. The model extends from near the surface to well above the cloud layers. Waves are forced by applying a vertical wind at the bottom boundary. The boundary vertical wind is determined by the product of the horizontal wind and the gradient of the surface height. When wave amplitudes are small, the near-surface horizontal wind is the zonally averaged basic-state zonal wind, and the length scales of the forcing that results are characteristic of the surface height variation. When the forcing becomes larger and wave amplitudes affect the near-surface horizontal wind field, the forcing spectrum becomes more complicated, and a spectrum of waves is generated that is not a direct reflection of the spectrum of the surface height variation. Model spatial resolution required depends on the amplitude of forcing; for very nonlinear cases considered, vertical resolution was 250 m, and horizontal resolution was slightly greater than 1 km. For smaller forcing amplitudes, spatial resolution was much coarser, being 1 km in the vertical and about 10 km in the horizontal. Background static stability and mean wind are typical of those observed in the Venus atmosphere.

Computations to date have considered a periodic sinusoidally varying surface height. Such forcing is relevant to the situation in which surface topography consists of a series of ridges extending over a region largely compared to the dimensions of each individual ridge. Because of the particular variations with altitude of static stability and mean wind in the Venus atmosphere, an evanescent region exists between about 15 km altitude and just below the cloud layer for waves having horizontal wavelengths less than about 100 km. This means waves generated at the surface having short wavelengths do not propagate to cloud levels with significant amplitude. At longer wavelengths (> 100 km), waves easily reach cloud levels and above. With surface wind speeds of several m/s and surface slopes having values in the vicinity of 0.02 (not unreasonable values in the higher mountainous regions of Venus such as Aphrodite), wave amplitudes are large enough to cause considerable nonlinear effects. From the surface to cloud levels and above, wave spatial patterns are relatively complicated and the spectra exhibit much shorter wavelengths than typical of the surface height variation, the dominant wavelength being somewhat less than 100 km for a surface height wavelength of 400 km. For this same case, maximum vertical winds at middle cloud levels associated with the waves are typical of the 2–3 m/s vertical winds observed by the VEGA balloon as it overflew the Aphrodite region. Wave horizontal wind amplitude at middle cloud levels is about 10 m/s. To date, with reasonable values of the surface forcing, we have not been able to generate waves having sufficient amplitude to cause wave breaking. Wave-induced mean winds are largest near the surface, and can become comparable to the low-altitude background wind.

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MIDDLE ATMOSPHERE OF VENUS AND ITS CLOUDS: LATITUDE AND SOLAR TIME VARIATIONS.

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The structure of the middle atmosphere of Venus and its upper clouds, derived from infrared spectrometry (from 250 to 1650 cm^{-1}) on Venera 15 [1–5] are discussed. Poleward increasing of temperature, monotonous on the average, at altitudes h >70 km changes to poleward decreasing at h <60 km. Temperature inversion at 85–95 km at low latitudes was observed as a half-day wave with two minima near 9:00 a.m. and 9:00 p.m., with a more pronounced morning feature. At high latitudes the inversion with temperature minimum near 64 km exists. There are several minima depending on solar time, but the most pronounced is one on the dayside, where the depth of inversion may reach more than 40 K (near 10:00 a.m.; we have no observations closer to noon). Another minimum is situated symmetrically on the nightside. Usually in the polar region the temperature inversion is situated deeper in the atmosphere (near 62 km). A jet at latitudes 50°–55°N divides Venus into two drastically different latitude zones: pretty homogeneous at 56–95-km zone <50° N with diffuse clouds and daily temperature variations near cloud tops about several degrees, and zone >55°N (where such dynamic structures as cold collar and hot dipole were observed) with dense low clouds (with the exceptions of the regions at 55°–80°N outside the cold collar).

We separate Venus into four latitudinal zones with approximate latitude boundaries, where the different IR-features were observed. They are characterized by different cloud scale height, H, and observed position of upper boundary of clouds (optical thickness is reached unit): h (1152) is for spectral region with maximal aerosol absorption coefficient (1152 cm^{-1}), and h (365) for the spectral region with minimal aerosol absorption coefficient (365 cm^{-1}). They are

1. l<55 – rather homogeneous, low and mid latitudes, with H_a = 3.5–4 km, and h (1152) = 67–69 km, and h (365) = 57–59 km.

2. 55 <l <75 – the most inhomogeneous latitudes as for aerosol, and for temperature. Two types of areas are found here: (1) cold collar, with $H_a \le 1$ km, h (1152) = 60–62 km, and h (365) = 58–60 km, and (2) inhomogeneous areas outside cold collar with $H_a \ge 4$–5 km, h (1152) = 70–72 km, and h (365) = 56–60 km.

3. 75 <l <85 – the hot dipole. The temperature is only several degrees higher in hot dipole than outside it near the upper boundary of the clouds at the same levels in the atmosphere. The clouds are situated lower and have larger scale height. For the hot dipole H_a = 1–1.5 km, h(1152) = 59–63 km, and h(365) = 56–58 km, and outside it, $H_a \le 1$ km, h (1152) = 63–64 km, and h (365) = 61–63 km.

4. l>85 – usually the clouds here have a very sharp upper boundary, with $H_a \le 0.5$ km, h (1152) = 62–64 km, and h (365) = 62–64 km.

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SO_2 IN THE MIDDLE ATMOSPHERE OF VENUS: IR MEASUREMENTS FROM VENERA 15 AND COMPARISON TO UV.

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Two sets of measurements of SO_2 bands in the Venus spectra are presented and compared: IR spectra obtained on the USSR Venera 15 orbiter [1–3] and UV spectra from the American Pioneer Venus orbiter and sounding rockets [4–6]. The 40-mbar level was chosen as a reference level for comparison. The UV data are referred to this level. There are three SO_2 bands in the infrared spectrum: at 519 cm^{-1}, 1150 cm^{-1}, and 1360 cm^{-1}. The levels of their formation in the atmosphere may differ significantly, more than 10 km. In principal, it allows us to obtain the vertical profile of SO_2 from 58 to 72 km, in the best case. So the IR data are sensitive to the 40-mbar level (maybe with exception of the cold collar). For low and mid latitudes, both data give a mixing ratio, f, of several tens of ppb and SO_2 scale height (H) of 1.5–2.5 km, which is in a good agreement with the photochemically predicted values [7]. This confirms that the photochemical processes dominate in the upper clouds at low and mid latitudes. Both data show an increase of abundance to several hundreds of ppb at high latitudes, but there are differences in scale-height latitudinal behavior. Decreases to 1 km are seen according to UV, but according to the IR the high latitudes of Venus are seen to be strongly inhomogeneous. Dynamic features with low position of