Calculation of the surface temperature of Venus with a convective-adiabatic model

Dr.-Ing. Bernd Fleischmann,info@klima-wahrheiten.de , www.klima-wahrheiten.de, 16.12.2024

According to NASA the intensity of solar radiation on the orbit of Venus has a value of S_{max} = 2601 W/m² (https://nssdc.gsfc.nasa.gov/planetary/factsheet/venusfact.html). The closed cloud cover, the dense atmosphere and the high cloud speeds of more than 350 km/h ensure that the surface temperatures are very even. The variation is only a few per cent, compared to ±22 % on Earth. For Venus we can therefore apply the simplification that they are equal in latitude and longitude in order to arrive at a good approximation for the surface temperature. We therefore distribute the incoming solar radiation evenly over Venus (i.e. we have to divide by 4, the ratio of the spherical surface and the projected disc) and subtract the part that is reflected or absorbed by the clouds. The albedo (reflection) is 77 % according to the NASA factsheet. The absorption above the clouds is dominated by sulphur dioxide and the absorption band of carbon dioxide at 2.8 µm. I have assumed a value of 1 % for this. This is half as much as has been measured for the Earth, where ozone is the dominant absorber, which is absent on Venus. 98 % of the radiation is absorbed in the clouds (http://clivebest.com/blog/?p=4048). This gives us an effective absorbed intensity I_{eff} of

$$I_{eff} = S_{max}\,(1 - 0.77)\cdot(1 - 0.01)\cdot 0.98 / 4 = 145\ \mathrm{W/m^2}$$

With the radiation law by Stefan and Boltzmann

$$I = \varepsilon\,\sigma^{\,T(4)},$$

the simplification for the emissivity ε = 1 and the radiation constant σ = $5.67\cdot10^{8}$ W/(m²K⁴) we obtain

$$T_1 = (I_{eff}/(\varepsilon\,\sigma\,))^{1/4} = 225\ \mathrm{K}$$

What temperature is that now? Not the one on the ground, of course, because the solar radiation doesn't reach it due to the closed cloud cover. T_1 is the temperature at the top of the clouds. This is where the solar radiation is absorbed. The clouds emit infrared radiation according to their temperature. Absorbed and emitted energy are in equilibrium in the long term, otherwise Venus would constantly heat up or cool down. The effective cloud top is at an altitude of 65 km to 70 km and the atmospheric pressure, which depends somewhat on the latitude (distance from Venus' equator), is p_1 = 0.15 bar at this altitude. This is the mean value of various measurements and models (Taylor et al., 2009; Titov al., 2018, Limaye et al., 2017; Robinson and Catling, 2012). The atmospheric pressure on the surface of Venus is p_0 = 92 bar, almost 100 times higher than on Earth.

At a temperature of 225 K (-48 °C), the sulphuric acid that makes up the clouds is frozen. It is sulphuric acid crystals, at least in the upper 5 km of the clouds. Lower down in the atmosphere, we are dealing with droplets and sulphuric acid rain. In order to apply the adiabatic law, we still need the heat capacity ratio γ of the Venusian atmospheric gases. With 96.5 % CO_2 and 3.5 % N_2, this results in a value of γ = 1.3. In order to take phase transitions in the atmosphere (condensation, vaporisation, freezing, melting) into account, we use a correction factor k with the value 0.8 for the exponent, as NASA has been doing for 60 years. (Robinson and Catling, An Analytic Radiative-Convective Model for Planetary Atmospheres, 2012):

$$T_1 / T_0 = (p_1 / p_0)^{\,k(\gamma-1)/\gamma}$$

Now we have everything we need to calculate **T_0, the temperature on the surface of Venus.** The result is

T_0 = 736 K = 463 °C

NASA measured an average surface temperature of 464 °C for Venus, i.e. only 1 °C more (NASA factsheet).

That was a fairly simple calculation with the convective-adiabatic model and also quite correct, even if the result benefits from the fact that a few simplifications compensate for each other.

Convective equilibrium prevails in the atmosphere of Venus and the temperature changes adiabatically with altitude. If there were an additional greenhouse effect due to back-radiation from carbon dioxide molecules, the temperature gradient and the temperature at the surface would be much higher than the measured values.

In 1960, NASA physicist and Pulitzer Prize winner Carl Sagan also attempted to calculate the temperature of Venus using the adiabatic equation of Poisson. Because the thickness of the Venusian atmosphere and the pressure on the surface were incorrectly estimated at the time, he arrived at a temperature that was too low. He therefore postulated a "runaway greenhouse effect" due to carbon dioxide (NASA Technical Report No. 32-34, The Radiation Balance of Venus, 1960) to explain the discrepancy between the adiabatic calculation and the observed temperature.

If Sagan had had knowledge of the actual temperature and pressure conditions on Venus at that time, the postulate of the "runaway greenhouse effect", which many still believe in today, would not exist.

It is also instructive to calculate the temperature of Venus with a composition of the atmosphere as we have it on Earth, i.e. essentially nitrogen and oxygen plus 1 % argon, which results in an effective γ_{EA} (EA = Earth's atmosphere) of 1.402. We take the same correction factor k = 0.8 (this means that the atmosphere is slightly drier than on Earth on average). Because nitrogen and oxygen molecules are considerably lighter than carbon dioxide molecules, we take this into account (average molar mass of the Earth's atmosphere: 28.79 g/mol, Venus: 43.45 g/mol). This results in a pressure on the ground of p_{0EA} = 61 bar instead of the previous 92 bar. We leave the albedo and the solar intensity the same and insert the values into the known formula:

$$T_1 / T_{0EA} = (p_1 / p_{0EA})^{k(\gamma_{EA}-1)/\gamma_{EA}}$$

Result: T_{0EA} = 892 K = 619 °C

If the Venusian atmosphere were composed like the Earth's atmosphere, i.e. nitrogen and oxygen instead of carbon dioxide, its surface temperature would be more than 150 °C higher!

And what temperature do the greenhouse theorists calculate for Venus? I am not aware of any plausible and reasonably correct calculation using greenhouse theory (radiative equilibrium) . You only read the usual, hackneyed phrases, e.g. from Professors Schellnhuber and Rahmstorf: *"The temperature on Venus is a boiling hot 460 degrees. The reason for this is an extreme greenhouse effect: the atmosphere of Venus consists of 96 per cent carbon dioxide."* (https://www.bpb.de/shop/zeitschriften/apuz/30101/klimawandel-einige-fakten/?p=all). That's it. They don't even attempt a calculation. Or they have tried, failed and are covering it up.

Professors Schellnhuber and Rahmstorf, the figureheads of German climate research and media dissemination, have thus demonstrated their lack of understanding of the physics of planetary atmospheres and their ignorance of the current literature.