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*Original Paper*

# The Venusian Insolation Atmospheric Topside Thermal Heating Pool

Philip Mulholland[1*] & Stephen Paul Rathbone Wilde[2]

[1] Mulholland Geoscience, Edinburgh, UK

[2] Private Researcher, Wirral, UK

[*] Philip Mulholland, Mulholland Geoscience, Edinburgh, UK

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***Abstract***

*A 1 metre increment modelled pressure profile is used to study the troposphere of Venus from the surface to the lower stratosphere. Using a troposphere model lapse rate profile as the constraint on cooling by vertically convecting air, the modelled height of the tropopause convection limit is a close match to the level of the observed static atmosphere height for the 250 Kelvin freezing point level of 75% by weight of concentrated sulphuric acid, the primary condensing volatile in the Venusian atmosphere. This relationship suggests that the observed albedo of Venus is a response to and not a cause of planetary atmospheric solar radiant forcing.*

*Using the thermal lapse rate for the troposphere of Venus in its top-down mode of application, the depth below the tropopause that solar irradiance is able to achieve effective heating of the Venusian atmosphere is established. This radiant quenching depth delineates a pool of upper tropospheric air that both captures and responds to solar radiant forcing. Consequently, this top of the troposphere insolation forcing induces a process of full troposphere adiabatic convective overturn and delivers solar heated air to the ground via the action of forced air descent in the twin polar vortices of Venus.*

***Keywords***

*Venus atmosphere, Boyle's law, spherical shells, thermal heating pool, adiabatic convection*

## 1. Introduction

Close proximity observations of the planet Venus by the NASA Mariner 10 space probe in 1974 have shown that its upper atmosphere displays a set of cloud bands that are part of a global atmospheric circulation system, which connects the solar zenith point of maximum solar radiant forcing to both polar vortices of the planet (Figure 1).

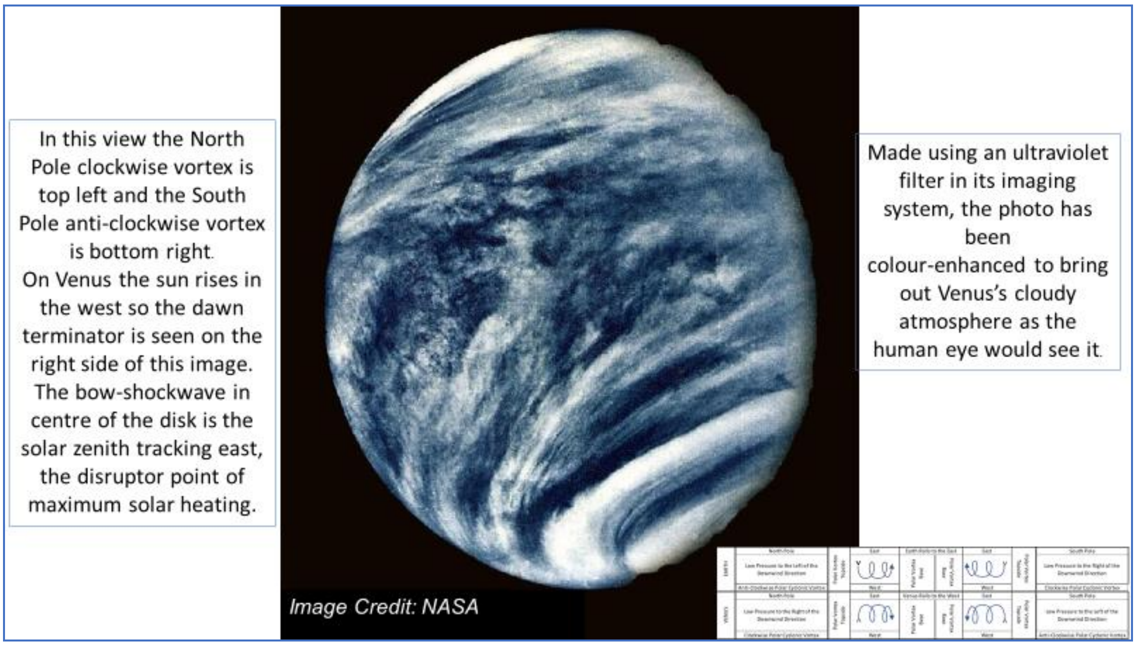


**Figure 1. NASA 1974 Mariner 10's Portrait of Venus**

This paper develops the results of the application of the Dynamic-Atmosphere Energy-Transport ((DAET) mathematical model to a study of the climate of Venus (Mulholland & Wilde, 2020) and addresses the following two issues:

1) That the intensity of the dim sunlight is too weak to fully energise the surface of the planet Venus at the base of a 63.4 km thick troposphere.

2) Consequently, the temperature at the base of the atmosphere of 699 Kelvin (426$^{O}$C) (Singh, 2019, pp. 1-5) has a value that far exceeds the effective solar radiative thermodynamic temperature of the surface insolation received by Venus (Table 1).

**Table 1. Venus Lit Hemisphere Illumination Interception Geometry**

| Illumination Intensity versus Solar Elevation | | | | | | | |
|---|---|---|---|---|---|---|---|
| Location | Latitude (Degrees) | Elevation Angle (Degrees) | Sine Angle | Solar Power Intensity ($W/m^2$) | Effective Flame Temperature (Kelvin) | Quenching Limit Height (Km) | Air Pressure (hPa) |
| North Pole | 90.00 | 0 | 0.00000000 | 0.00 | | | |
| Z1: Heating Limit | 86.43 | 3.57 | 0.06226276 | 37.25 | 160.10 | 110.000 | |
| Z1: | 85 | 5 | 0.08715574 | 52.15 | 174.14 | 88.092 | 0.37 |
| Z1: | 80 | 10 | 0.17364818 | 103.89 | 206.89 | 76.617 | 5.84 |
| Z1: | 75 | 15 | 0.25881905 | 154.85 | 228.60 | 70.502 | 20.89 |
| Z1: | 70 | 20 | 0.34202014 | 204.63 | 245.10 | 64.669 | 64.11 |
| Z1: | 65 | 25 | 0.42261826 | 252.85 | 258.41 | 61.065 | 123.05 |
| Z5: Hemisphere Average Flux | 60 | 30 | 0.50000000 | 299.15 | 269.51 | 58.461 | 192.90 |
| Z1: | 55 | 35 | 0.57357644 | 343.17 | 278.92 | 56.454 | 269.32 |
| Z1: | 50 | 40 | 0.64278761 | 384.58 | 286.97 | 54.850 | 348.82 |
| Z1: | 45 | 45 | 0.70710678 | 423.06 | 293.90 | 53.540 | 428.56 |
| Z1: | 40 | 50 | 0.76604444 | 458.32 | 299.84 | 52.461 | 505.92 |
| Z1: | 35 | 55 | 0.81915204 | 490.10 | 304.91 | 51.570 | 578.81 |
| Z1: | 30 | 60 | 0.86602540 | 518.14 | 309.18 | 50.839 | 645.33 |
| Z1: | 25 | 65 | 0.90630779 | 542.24 | 312.71 | 50.247 | 703.99 |
| Z1: | 20 | 70 | 0.93969262 | 562.22 | 315.55 | 49.798 | 751.53 |
| Z1: | 15 | 75 | 0.96592583 | 577.91 | 317.73 | 49.474 | 787.52 |
| Z1: | 10 | 80 | 0.98480775 | 589.21 | 319.27 | 49.244 | 813.95 |
| Z1: | 5 | 85 | 0.99619470 | 596.02 | 320.19 | 49.107 | 830.05 |
| Z1: Equator | 0 | 90 | 1 | 598.30 | 320.50 | 49.061 | 835.52 |

At its base Venus has a dense atmosphere with a value of 69.69 $kg/m^3$ (Table 2), while this is far less than the density of liquid water (1,000 $kg/m^3$), the oceans of Earth do provide a model as to how the topside of a planetary atmosphere can be heated. On Earth the photic zone is that shallow part of the ocean (typically less than 200 m water depth) where sunlight energy is absorbed and the water is heated.

On Venus the average post-albedo insolation received by the lit hemisphere is 299 $W/m^2$, which equates to a thermodynamic temperature of 269.5 Kelvin (-3.6$^{O}$C) (Figure 2). This average intensity will apparently provide heating for only the upper 5 km of the troposphere at heights above 58.4 Km, where the lapse rate reduced air temperature is below the 269.5 Kelvin value (Figure 3).

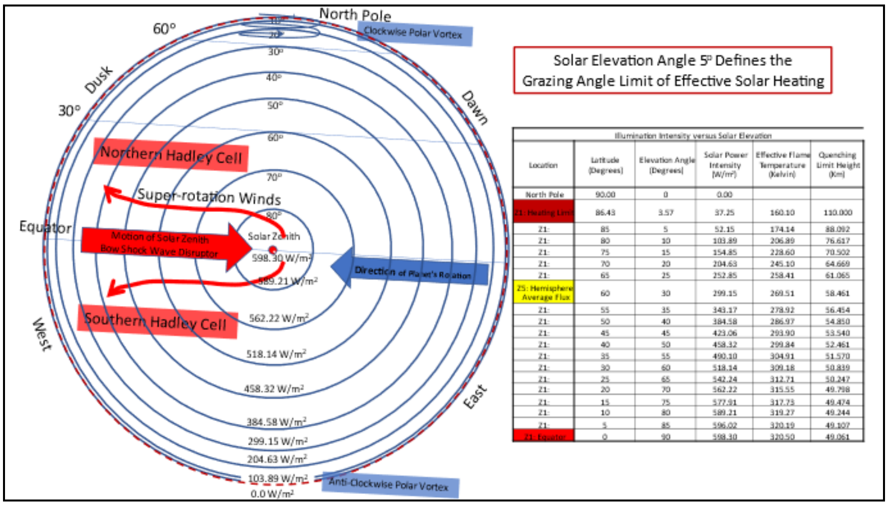


**Figure 2. Venus Lit Hemisphere Illumination Interception Geometry**

At depths in the atmosphere below this average insolation level the average energy contained in the sunlight is less than the ambient temperature of the surrounding air, so no heating is apparently possible. However, and perhaps more importantly the local intensity of the insolation at solar zenith has sufficient power to heat the Venus atmosphere down to a level of 49 km, in a column that is 14.4 km thick (Figure 3).

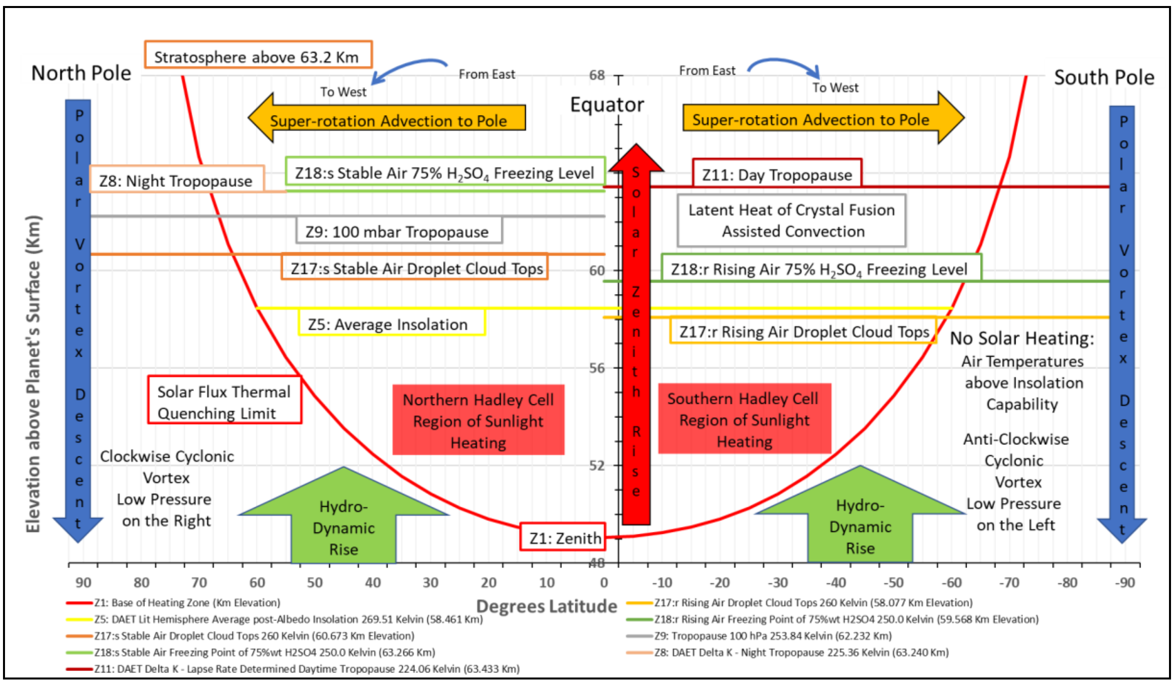


**Figure 3. Venus Atmospheric Solar Radiant Thermal Heating Pool**

It is this concentration of energy at the solar zenith, heating the upper air that creates the bow-wave disruptor observed in the centre of the blue disk, as the thermal impact of the solar zenith travels around the planet (Figure 1).

The energy imparted by the sun into that zenith induced bow-wave powers the circulatory system of the upper atmosphere (Limaye, 2010). So, just like the sun heats the top of the Earth's oceans, the sun clearly heats the top of the Venus atmosphere. However, unlike water in the Earth's oceans the heated topside atmosphere of Venus is a compressible gas held at high elevation in a gravity field. This has clear implications for the process of surface heating by full troposphere mass-motion solar forced convection overturn of a compressible gas in the presence of a gravity field.

In order to study this circulation process using the DAET climate model a pressure profile model for the Venus troposphere at 1 metre increments has been created. This calculation has been applied from the surface to the lower stratosphere, a modelled vertical height of 100 kilometres (Mulholland & Wilde, 2021).

Two equations of state are used to achieve this objective, these are the Pressure, Volume, Temperature (PVT) version of Boyle's law, and the application of Newton's gravity law of spherical shells, used to calculate the reduction in strength of the gravity field as the height above the surface of Venus increases. For the purpose of this study a set of four linked predictive lapse rate equations based on published data has been created (Justus & Braun, 2007). These equations are used as the fundamental temperature control of the tropospheric pressure profile. The temperature data that controls these equations is calibrated to a surface datum global average temperature for Venus of 699 Kelvin (Singh, 2019, pp. 1-5).

## 2. Method

The spreadsheet analysis of the pressure profile of the Venusian atmosphere presented here is built on the following Baseline Parameters (Williams, 2023):

1) The surface pressure measured in Pascal.
2) The surface temperature measured in Kelvin.
3) The Molecular Weight of the Venus atmosphere measured in g/mole.
4) The surface gravity of Venus measured in $m/s^2$.
5) The planetary mass of Venus in kg.
6) The mean radius of Venus in metres.

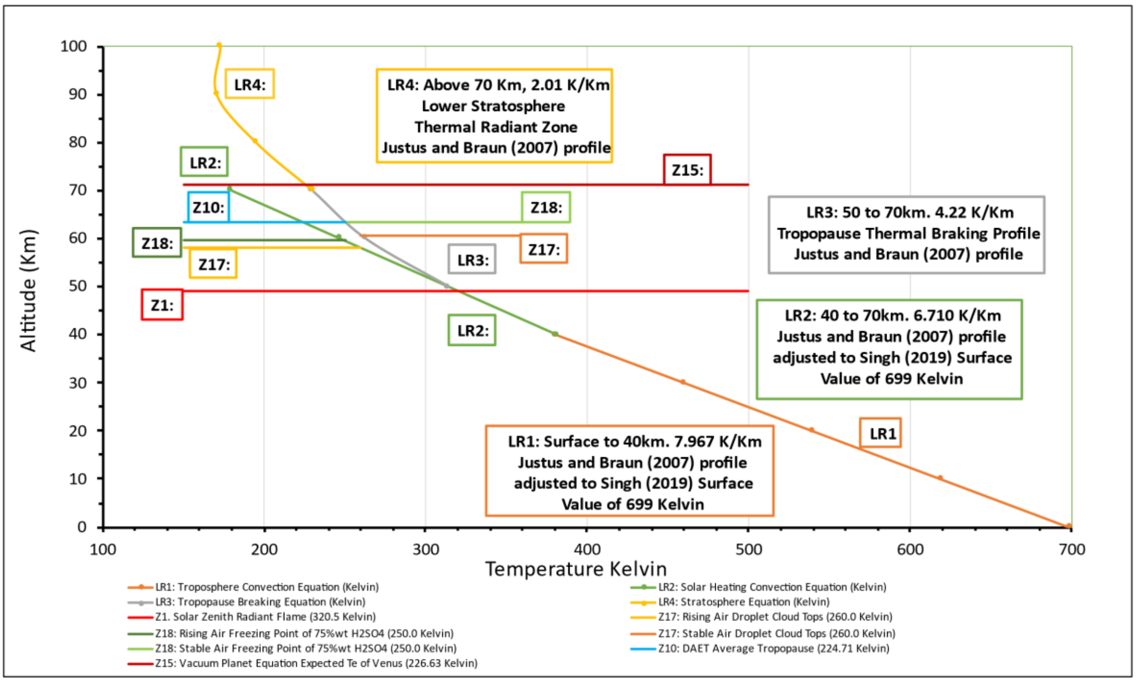


**Figure 4. Venusian Atmosphere: Temperature versus Altitude**

7) A set of four predictive temperature Lapse Rate equations for the atmosphere of Venus based on published data (Justus & Braun, 2007) measured in K/m and corrected to a surface datum value of 699 Kelvin (Singh, 2019, pp. 1-5) (Figure 4).

8) Using the two physical relationships of Boyle's gas law, and Newton's spherical shell gravity law, a pressure profile is created for the atmosphere, applying the predictive lapse rate equations as temperature control over the relevant height intervals (Figure 5).

The predictive lapse rate equations used in the pressure profile model are listed in Table 2.

**Table 2. Predictive Lapse Rate Equations**

| Item | Height (m) | Predictive Temperature Lapse Rate Equation | Temperature (Kelvin) | Pressure (hPa) | Density ρ ($kg/m^3$) |
|---|---|---|---|---|---|
| LR1: Lapse Rate: Start of Troposphere Equation | 0 | =-7.967*I2/1000+699 | 699.000 | 93,219.00 | 69.69140601 |
| LR1: Lapse Rate Tie Point: End of Troposphere Equation | 39,220 | =-7.967*I39222/1000+699 | 386.534 | 3,001.63 | 4.058083903 |
| LR2: Lapse Rate Tie Point: Start of Solar Heating Convection Equation | 39,221 | = -6.71*I39223/1000 + 649.7 | 386.527 | 3,001.27 | 4.057677378 |
| LR2: Lapse Rate Tie Point: End of Solar Heating Convection Equation | 50,000 | = -6.71*I50002/1000 + 649.7 | 314.200 | 729.81 | 1.213822584 |
| LR2: Lapse Rate Tie Point: Start of Tropopause Convection Overshoot Equation | 50,000 | = -6.71*I50002/1000 + 649.7 | 314.200 | 729.81 | 1.213822584 |
| LR2: Lapse Rate: End of Tropopause Convection Overshoot Equation | 70,000 | = -6.71*C20032/1000 + 649.7 | 180.000 | 16.67 | 0.048388192 |
| LR3: Lapse Rate Tie Point: Start of Tropopause Breaking Equation | 50,001 | = 0.092*(I50003/1000)^2 - 15.26*I50003/1000 + 847.2 | 314.194 | 729.70 | 1.213669421 |
| LR3: Lapse Rate Tie Point: End of Tropopause Breaking Equation | 70,477 | = 0.092*(I70479/1000)^2 - 15.26*I70479/1000 + 847.2 | 228.686 | 20.99 | 0.04796827 |
| LR4: Lapse Rate Tie Point: Start of Stratosphere Equation | 70,478 | =( 0.0027*(I70480/1000)^3 - 0.5809*(I70480/1000)^2 + 38.611* (I70480/1000)- 537.31)+(-0.0146*(I70480/1000)^2 + 1.594*(I70480/1000) - 54.84) | 228.683 | 20.99 | 0.047959369 |
| LR4: Lapse Rate: End of Stratosphere Equation | 100,000 | =( 0.0027*(I100002/1000)^3 - 0.5809*(I100002/1000)^2 + 38.611* (I100002/1000)- 537.31)+(-0.0146*(I100002/1000)^2 + 1.594*(I100002/1000) - 54.84) | 173.350 | 0.01588 | 4.78577E-05 |

The datum parameters used for the pressure profile analysis are listed in Table 3.

**Table 3. Datum Values**

| Datum Values | | | |
|---|---|---|---|
| | Surface Pressure | 92 | Atmospheres |
| Control used at L2 | Surface Pressure | 9,321,900 | Pascal |
| | Area | 1 | Square metre |
| | Force | 9,321,900 | Newton |
| Used in Column T | Universal Gravitational Constant | 6.67430E-11 | $m^3.kg^{-1}.s^{-2}$ |
| | Boltzmann constant | 1.38065E-23 | J/K |
| | Avagadro constant | 6.02214E+23 | $mol^{-1}$ |
| Varied in Column T | Venus Gravity | 8.87039 | $m/s^2$ |
| Used at U2 | Atmospheric Mass | 1,050,901 | Kg |
| Used in Column M | Molecular Weight | 43.45 | g/mol |
| Used at M2 | Surface Density | 69.691 | $Kg/m^3$ |
| Notional QC Check | Total "Thickness" (Scale Height) | 15,079 | m |
| Control used at J2 | Surface Temperature | 699 | Kelvin |
| | STP Temperature | 273.15 | Kelvin |
| | STP Temperature | 0 | Celsius |
| Used in Column J | LR1: Lapse Rate (Troposphere) | Predictive Equation | K/m |
| Used in Column J | LR2: Lapse Rate (Tropopause) | Predictive Equation | K/m |
| Used in Column J | LR3: Lapse Rate (Stratosphere) | Predictive Equation | K/m |
| | Z9: Pressure Tropopause | 100 | hPa or mbar |
| | Z9: Tropopause 100 hPa | 62.232 | Km |
| | Z9: Tropopause 100 hPa | 253.84 | Kelvin |
| Key Pad | | | |
| Air Properties | Earth STP | Venus | Units |
| Pressure | 101,325 | 9,321,900 | Pascal |
| Pressure | 1,013 | 93,219 | hPa or mbar |
| Temperature | 273.15 | 699 | Kelvin |
| Temperature | 0 | 425.85 | Celsius |
| Volume | 22,414 | 623.458 | $cm^3$ |
| Density | 1.939 | 69.691 | $Kg/m^3$ |
| Lapse Rate | Convection Troposphere | 7.270 | K/km |

## 3. Result

In order to verify the DAET climate model of Venus, the model was first calibrated against the new surface datum temperature of 699 Kelvin (Singh, 2019, pp. 1-5). This process was achieved by reducing the energy intensity flux partition ratio to an atmosphere retained percentage of 98.071%, down from the previously published value of 99.1138% (Mulholland & Wilde, 2020, pp. 20-35). This adjustment is in line with the modelling concept that the average global surface temperature of a planet is a function of the energy flux partition ratio between the retained atmospheric energy in the troposphere, and the radiant energy loss to space from the stratosphere (Table 4).

**Table 4. Adiabatic Model of Venus showing Internal Energy Recycling for Both Hemispheres**

| Venus Insolation Adiabatic Model Partition Parameters 1.0929% Loss : 98.9071% Retained | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cycle | Space Incoming Captured Radiation (W/m²) | Lit Ground Received Energy (W/m²) | Lit Side Radiant Partition is 1.0929% (W/m²) | Sun Lit Air Partition is 98.9071% (W/m²) | Dark Side Radiant Partition is 1.0929% (W/m²) | Dark Night Air Partition is 98.9071% (W/m²) | Space Outgoing Radiation Balance (W/m²) |
| | Partition Ratio Target Temperature 699 Kelvin (425.85°C) | | 1.0929% | 98.9071% | 1.0929% | 98.9071% | |
| 0 | 299.1495 | | | | | | |
| 1 | 299.1495 | 299.1495 | 3.269451845 | 295.8800482 | 3.233719493 | 292.6463287 | 6.50317134 |
| 2 | 299.1495 | 591.7958 | 6.46782951 | 585.3279992 | 6.397141586 | 578.9308576 | 12.8649711 |
| 3 | 299.1495 | 878.0803576 | 9.596678067 | 868.4836795 | 9.491794466 | 858.991885 | 19.0884725 |
| 4 | 299.1495 | 1158.141385 | 12.657509 | 1145.483876 | 12.5191731 | 1132.964703 | 25.1766821 |
| 5 | 299.1495 | 1432.114203 | 15.65180093 | 1416.462402 | 15.48073994 | 1400.981662 | 31.1325409 |
| 53995 | 299.1495 | 13761.0435 | 150.396604 | 13610.64685 | 148.752896 | 13461.89395 | 299.1495 |
| 53996 | 299.1495 | 13761.04345 | 150.396604 | 13610.64685 | 148.752896 | 13461.89395 | 299.1495 |
| 53997 | 299.1495 | 13761.04345 | 150.396604 | 13610.64685 | 148.752896 | 13461.89395 | 299.1495 |
| 53998 | 299.1495 | 13761.04345 | 150.396604 | 13610.64685 | 148.752896 | 13461.89395 | 299.1495 |
| 53999 | 299.1495 | 13761.04345 | 150.396604 | 13610.64685 | 148.752896 | 13461.89395 | 299.1495 |
| 54000 | 299.15 | 13,761.04 | 150.40 | 13,610.65 | 148.75 | 13,461.89 | 149.57 |
| S-B | 5.67E-08 | 5.67E-08 | 5.67E-08 | 5.67E-08 | 5.67E-08 | 5.67E-08 | 5.67E-08 |
| Kelvin | 269.5 | 701.9 | 226.9 | 700.0 | 226.3 | 698.0 | 226.631 |
| Zone | Z5: | Z2: | Z16: | Z4: | Z12: | Z7: | Z14: |
| | Statistic | Mean Radiant Exit Temp | Mean Air Temp | Lit-side | Dark-side | Global | |
| | Kelvin | 226.63 | 699.00 | W/m² | W/m² | W/m² | |
| | Zone | Z13: | **Z6:** | 13761.04 | 13610.65 | 27371.69 | |
| | Thermal Enhancement (Kelvin) | Atmospheric Model | | Tropopause | Lapse rate | Tropopause | |
| | | Zone | Delta K | Kelvin | K/Km | Km | |
| | | Z11: Lit Tropopause | 474.9 | 224.06 | 7.270 | 65.329 | |
| | 472.4 | Z10: Mean Tropopause | 474.3 | 224.71 | 7.270 | 65.240 | |
| | | Z8: Night Tropopause | 473.6 | 225.36 | 7.270 | 65.150 | |

The key results from the Boyle's Law Pressure Model Analysis for the atmosphere of Venus (Mulholland & Wilde, 2021) are listed in Table 5 and displayed in Figure 5.

These results include the following:

1) The average post-albedo irradiance for the lit hemisphere of Venus is 299 W/m$^2$, this intensity (Table 1, Z5) converts to a thermodynamic temperature of 269.5 Kelvin (-3.6$^{O}$C). This temperature occurs at an altitude of 58.46 Km and a pressure of 192.9 hPa. By geometry the average intensity value of 299 W/m$^2$ also occurs at a solar elevation angle of 30$^o$ (Figure 2).

2) The post-albedo solar zenith irradiance for Venus is 598.3 W/m$^2$, this maximum possible intensity (Figure 3, Z1) converts to a thermodynamic temperature of 320.5 Kelvin (47.3$^O$C). This temperature occurs at an altitude of 49.06 Km and a pressure of 835.5 hPa (Table 5).

**Table 5. Predicted Pressures**

| Item | Height (m) | Predictive Temperature Lapse Rate Equation | Temperature (Kelvin) | Pressure (hPa) | Density ρ (kg/m$^3$) | PE =mgh (Joules) |
|---|---|---|---|---|---|---|
| Z6: Mean Air Temperature (699 Kelvin) | 0 | =-7.967*I2/1000+699 | 699.000 | 93,219 | 69.69140601 | 0 |
| Z1: Solar Zenith (albedo applied) | 49,061 | = -6.71*I49063/1000 + 649.7 | 320.501 | 835.52 | 1.362326292 | 583,372 |
| Z5: Space Incoming Captured Radiation (W/m$^2$) | 58,461 | = 0.092*(I59315/1000)^2 - 15.26*I59315/1000 + 847.2 | 269.512 | 192.90 | 0.374026892 | 190,285 |
| Z8: Night Tropopause | 63,240 | = -6.71*I63242/1000 + 649.7 | 225.360 | 76.31 | 0.176958051 | 97,234 |
| Z9: Tropopause Ceiling 100 hPa, 235.84 Kelvin, 62.232 Km | 62,232 | = 0.092*(I62234/1000)^2 - 15.26*I62234/1000 + 847.2 | 253.839 | 100 | 0.205873161 | 111,356 |
| Z10: Mean Tropopause | 63,337 | = -6.71*C13369/1000 + 649.7 | 224.709 | 74.83 | 0.174025191 | 95,766 |
| Z11: Lit Tropopause | 63,433 | = -6.71*C13465/1000 + 649.7 | 224.065 | 73.39 | 0.171162378 | 94,331 |
| Z12: Dark Side Radiant Partition is 1.0929% (W/m$^2$) | 71,156 | =( 0.0027*(I71158/1000)^3 - 0.5809*(I71158/1000)^2 + 38.611* (I71158/1000)- 537.31)+(-0.0146*(I71158/1000)^2 + 1.594*(I71158/1000) - 54.84) | 226.299 | 18.33 | 0.042334801 | 26,106 |
| Z13: Mean Radiant Exit Temperature (Kelvin) | 71,062 | =( 0.0027*(I71064/1000)^3 - 0.5809*(I71064/1000)^2 + 38.611* (I71064/1000)- 537.31)+(-0.0146*(I71064/1000)^2 + 1.594*(I71064/1000) - 54.84) | 226.631 | 18.68 | 0.043076419 | 26,529 |
| Z14: Space Outgoing Radiation Balance (W/m$^2$) | 71,062 | =( 0.0027*(I71064/1000)^3 - 0.5809*(I71064/1000)^2 + 38.611* (I71064/1000)- 537.31)+(-0.0146*(I71064/1000)^2 + 1.594*(I71064/1000) - 54.84) | 226.631 | 18.68 | 0.043076419 | 26,529 |
| Z15: Vacuum Planet Equation Expected $T_e$ of Venus (226.627 Kelvin) | 71,063 | =( 0.0027*(I71065/1000)^3 - 0.5809*(I71065/1000)^2 + 38.611* (I71065/1000)- 537.31)+(-0.0146*(I71065/1000)^2 + 1.594*(I71065/1000) - 54.84) | 226.627 | 18.68 | 0.043068467 | 26,525 |
| Z16: Lit Side Radiant Partition is 1.0929% (W/m$^2$) | 70,985 | =( 0.0027*(I70987/1000)^3 - 0.5809*(I70987/1000)^2 + 38.611* (I70987/1000)- 537.31)+(-0.0146*(I70987/1000)^2 + 1.594*(I70987/1000) - 54.84) | 226.902 | 18.97 | 0.043692829 | 26,880 |
| Z17:r Rising Air Droplet Cloud Tops (260 Kelvin) | 58,077 | = -6.71*C9600/1000 + 649.7 | 260.003 | 201.35 | 0.404689223 | 204,558 |
| Z17:s Stable Air Droplet Cloud Tops (260 Kelvin) | 60,673 | = 0.092*(I60675/1000)^2 - 15.26*I60675/1000 + 847.2 | 260.002 | 131.82 | 0.264950232 | 139,792 |
| Z18:r Rising Air Latent Heat Freezing Point of 75%wt $H_2SO_4$ (250.0 Kelvin) | 59,568 | = -6.71*C9600/1000 + 649.7 | 249.999 | 154.26 | 0.322448865 | 167,091 |
| Z18:s Stable Air Freezing Point of 75%wt $H_2SO_4$ (250.0 Kelvin) | 63,266 | = 0.092*(I63268/1000)^2 - 15.26*I63268/1000 + 847.2 | 249.999 | 82.97 | 0.173424014 | 95,331 |

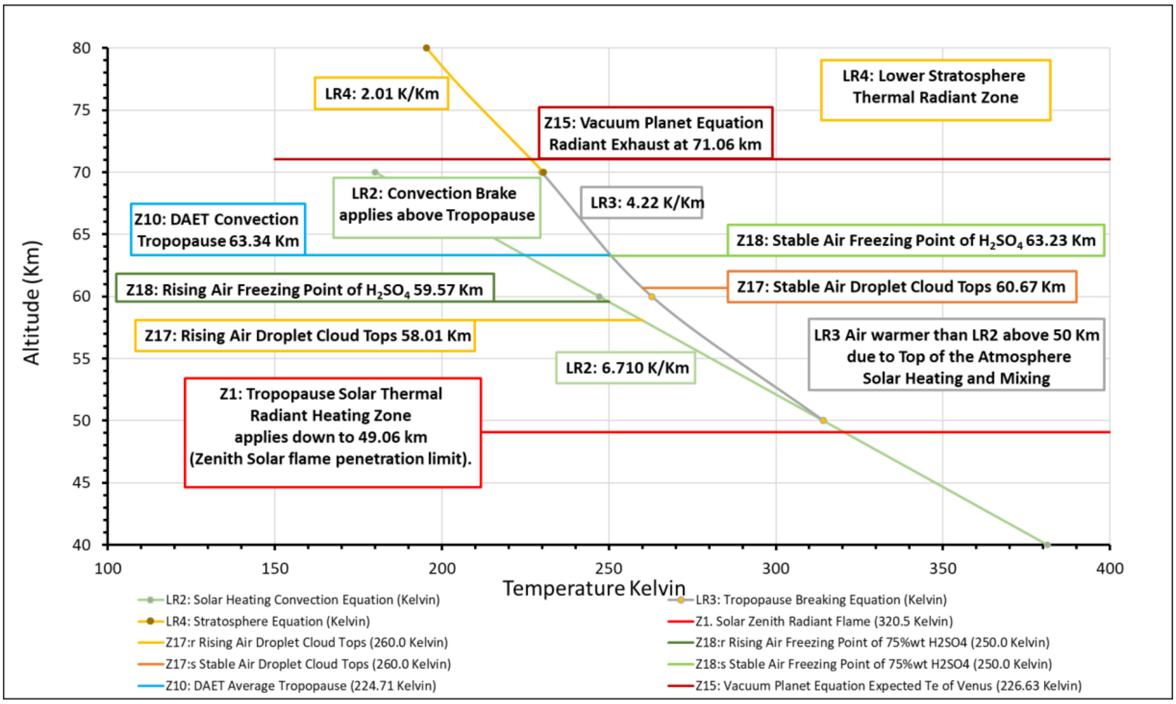


**Figure 5. Venusian Tropopause: Temperature versus Altitude**

3) The DAET adiabatic climate model of Venus predicts for the lit hemisphere a thermal emission intensity (Table 4, Z16) of 150.4 W/m$^2$ and a thermodynamic temperature of 226.9 Kelvin (minus 46.3$^O$C). This temperature occurs at an elevation of 70.99 Km and at a pressure of 19 hPa (Table 5).

4) The DAET adiabatic climate model of Venus also predicts for the dark hemisphere a thermal emission intensity (Table 4, Z12) of 148.75 W/m$^2$ and a thermodynamic temperature of 226.3 Kelvin (minus 46.8$^O$C). This temperature occurs at an elevation of 71.15 Km and at a pressure of 18.33 hPa (Table 5).

5) The modelled height of the Venusian droplet cloud planetary veil (Z17: s) occurs at an elevation of 60.67 Km and a temperature of 260 Kelvin (Young, 1973, pp. 564-582) with an associated pressure of 18.33 hPa (Table 5).

6) The measured freezing point of 75% wt $H_2SO_4$ (Z18:s) is 250 Kelvin (-23$^O$C) (Young, 1973, pp. 564-582). This temperature is found at a model altitude of 63.27 Km, and a pressure of 83 hPa (Table5). This near association between the stable air freezing point of concentrated sulphuric acid, the main condensing volatile in the Venus atmosphere, and the DAET modelled height of the convection tropopause warrants further study. Solid aerosol particles are efficient thermal emitters and can enhance atmospheric thermal radiation loss to space through the transparent lower Stratosphere (Figure 4).

*3.1 The Energy Consequence of Air Convection in a Gravity Field*

At the modelled convection tropopause of Venus, over 63.3 km above the planet's surface (Table 5, Z10), a cubic metre of Venusian air has a mass of 174 g and possesses a potential energy of 95.7 Kilojoules. All air mass held aloft in a gravity field contains a considerable quantity of potential energy. On descent to the surface this air will undergo adiabatic heating and consequent air temperature rise as it falls towards the planet's surface. In doing so it loses potential energy by the process of conversion to kinetic energy (Figure 6).

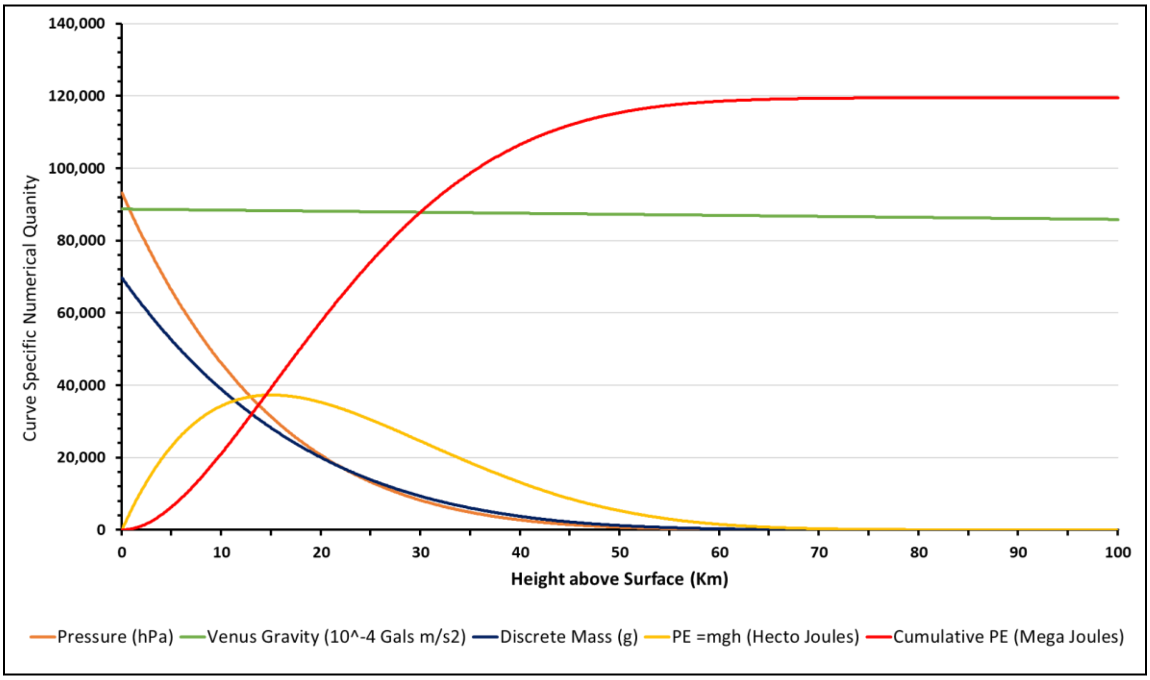


**Figure 6. Scaled Comparison Chart of Pressure, Gravity, Discrete Mass, Discrete Potential Energy (PE) and Cumulative PE Curves for Venus**

## 4. Discussion

On Venus the solar forced radiant heating of the upper troposphere at the zenith creates a process of pole-ward advection of heated air that feed the planet's polar vortices (Luz et al., 2011). Figure 2 shows how the upper atmosphere of the lit hemisphere of Venus intercepts the energy of the sunlight in a pattern of concentric rings of intensity centered around the zenith, the point at which the overhead sun provides the maximum flux that heats the atmosphere. When the sun heats the cold upper part of the Venusian atmosphere it will distort the lapse rate slope to the warm side. That forces the lapse rate profile downward. That compression then steepens the lapse rate slope lower down which causes convection to accelerate as a negative compensation mechanism.

As Venus slowly turns from east to west, the locus of the solar zenith tracks along the equator towards the east creating a point of disturbance in the upper air. This forms a bow shockwave disruptor dividing the equatorial flow of the zonal circulating winds which are forced apart and made to track towards higher latitudes (Figure 1).

Due to the conservation of angular momentum associated with the slow planetary rotation of Venus, these winds travel faster than the ground surface below them and are called super-rotation winds (Zasova et al., 2007). Eventually these circulating winds reach the planet's poles at a point on the rim of the lit hemisphere. Here the illumination intensity of the low angle sun within $5^{O}$ of the terminator does not have sufficient power to heat the tropospheric air. At the poles of Venus, the low power of the sunlight, combined with the angular momentum of the super-rotational winds creates a cyclonic vortex which drives the air down into the deep atmosphere below (Ignatiev et al., 2009).

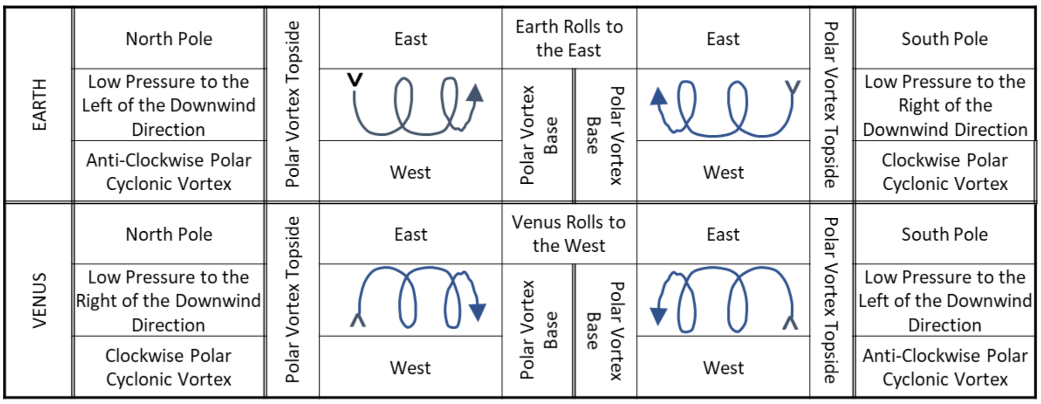


**Figure 7. Planetary Rotation and the Conservation of Angular Momentum**

This forced descent of the topside heated air, means that the compressible air undergoes adiabatic heating as it falls in the gravity field of Venus. The descending mass flow within the polar vortex provides a hydrodynamic piston drive that causes the planet's air to circulate vertically in a giant hemisphere encompassing Hadley cell (Figure 3). By this means the compressed air is heated as it falls and the apparent thermal limit set by insolation at the top of the atmosphere is easily surpassed (Lacis & Hansen, 1974).

Figure 3 shows the impact of upper atmosphere heating, the circulation system powered by the solar zenith constantly replenishes the forced descent vortex over both poles which heats the surfaces beneath. That energy then flows across the entire Venusian surface so that it can reach temperatures much higher than predicted by the Stefan-Boltzmann (S-B) radiation equation. The greater the mass of the Venus atmosphere the greater the system's efficiency, and the more heat that will be delivered to the surface by the air descent at the poles.

The piston-like hydrostatic circulation is fuelled by whatever energy is available from any source, but can never exceed the amount of energy required to balance the upward pressure gradient force with the downward force of gravity. The pattern of differing lapse rate slopes within the vertical plane is infinitely variable, but must always average out to the slope dictated by mass and gravity.

### *4.1 The Utility of the DAET Climate Model*

The key physical process that the DAET climate model describes is that mobile compressible fluids circulating within a gravity field over and above the surface of a rotating terrestrial planet, will at the same time capture, store and transport energy in various guises. Not all of these are thermal and so not all are subject to radiative loss. While energy can flow from cold to hot (e.g., the meteorological process of cooling rain falling onto the surface of a hot desert below), however heat being a directed dynamic process cannot flow from cold to hot (e.g., Unconfined rivers of water cannot flow uphill).

Mass motion is a process that generates a system lag because it is inherently slower than radiative processes. Convection is also a process that deals with albedo variations because convection just shifts to equalise these perturbations. There is still enough room for internal climate variability as the system lags somewhat in response to destabilising influences, but it always gets there quickly enough to retain the atmosphere in a dynamically stable state.

The Venus surface is at the temperature it is simply because that is the temperature needed to balance the mass of the atmospheric gases against gravity. It makes no difference what the source of that energy is. It is the same for stars in the cold of space and the gas planets far from the sun. Convection always settles at a level that keeps the gases suspended against the downward force of gravity. Until, in the case of stars, a fusion reaction starts whereupon convection adopts a new equilibrium.

It is by this mechanism of circulating mass motion of a compressible gas acted on by a gravity field, within the context of a rotating spherical planet that surface thermal enhancement is created, and which it is proposed here to call the Maxwell Mass Effect after the work of James Clerk Maxwell (Maxwell, 1868).

### 5. Conclusion: The Venus Heating Paradox Explained

In conclusion the matter of the high surface temperature of the planet Venus, and the paradox of the dim surface sunlight not being able to create this 699 Kelvin global average temperature will now be addressed.

The process of deep atmospheric convection throughout the whole 62.2 km (100 mbar limit) of the Venus troposphere means that sunlight heated air at the top of the atmosphere can and does deliver heat to the planet's surface. Instead of solar radiation, this process of energy delivery to the surface occurs by the mechanisms of full troposphere planetary rotation-forced mass-motion, the circulation of polar vortex descending air and heating by adiabatic auto compression.

The warming at the surface of Venus is from the mechanical process of convection, and any potential warming effect from downward radiation is neutralised by convective adjustments. Instead, descending air heats both itself and the surface beneath via reconversion of Potential Energy (PE) to Kinetic Energy (KE). The atmosphere is held aloft by potential energy which is not thermal energy. Heat cannot be amplified, but it can be stored in a non-kinetic form as potential energy so that it is not then sensed as temperature.

Potential energy is in effect a form of Latent Heat. This store of energy within mass is then returned again as temperature at a later time and critically at a lower elevation. So, as long as there is constant mass motion recycling to and fro between PE and KE as the air moves vertically within a gravity field, then the surface will receive kinetic energy from the descending air and be warmed.

To maintain long term hydrostatic equilibrium the total energy retained at the surface must be a dynamic equilibrium that is just right to support the weight of atmospheric gases against the downward force of gravity. It makes no difference whether the source of the necessary energy is from the sun, the surface, volcanic outbreaks, atmospheric opacity, particulate aerosols or anything else.

It is known that planetary atmospheres vary hugely in composition, and that the way the composition of an atmosphere is sorted into differing compositional layers will affect the vertical boundaries between those layers. Thus, a tropopause can vary in height somewhat depending on the various compositionally induced stratifications within a planet's atmosphere. However, if an atmosphere is to be retained by a planet, then the average lapse rate slope between surface and space must always net out to the slope specified by mass and gravity.

Convection always adjusts in order to balance energy into the system from space with energy out to space derived from the net combination of all energy transfer mechanisms between surface and atmosphere. If it were not so then the tiniest radiative imbalance would prevent the formation and retention of an atmosphere. It is known that atmospheres are ubiquitous and last for geological eons in the absence of catastrophe, so it must be that convection neutralises all "normal" radiative imbalances.

However, the DAET concept needs to apply to every scenario, whatever the density or opacity of an atmosphere the final outcome must be the same, and the cause will be a combination of heating of upper levels and heating of the surface with the proportions related to atmospheric opacity to radiation. It is a universal rule of meteorology that any temperature induced density variations in the vertical plane will lead to convective overturning in the entire depth of an atmosphere, with consequent heating of the surface.

When the energy present in a mass aloft is converted from PE (not thermal) to KE (thermal) by forced descent then that solves the problem of the apparent radiative limit. Radiation does not limit the mechanical transformation of energy between PE and KE in convection. Climate theorists who have been fixated on radiation miss this point. Potential energy is a form of latent heat. Kinetic energy (motive heat) is the direct consequence of the conversion of potential energy during the descending phase of convective overturning.

As the case of Venus proves insolation does not need to reach the surface to provoke planetwide deep convection. It is sufficient if insolation beneath the solar zenith creates density differentials at any point within the mass of an atmosphere. Convection can achieve that because radiative imbalances alter the lapse rate slope and the rate of convection changes in a negative response to this forcing (Wilde, 2012).

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## Appendix

**The Pressure Profile Calculation Method:**

Starting with the Gas Equation:

$P_1.V_1/T_1 = P_2 V_2/T_2$ Equation 1

Where:

$P_1$ Is the Initial Gas Pressure measured in Pascal.

$V_1$ Is the Initial Gas Volume measured in Litres.

$T_1$ Is the Initial Gas Temperature measured in Kelvin.

$P_2$ Is the Final Gas Pressure measured in Pascal.

$V_2$ Is the Final Gas Volume measured in Litres.

$T_2$ Is the Final Gas Temperature measured in Kelvin.

In the Troposphere as height above the surface increases, air pressure and air temperature both decrease. In the open atmosphere the air pressure decrease is a function of air mass and gravity, while the temperature decrease, the Lapse Rate, is a measured known parameter (Jenkins et al., Fig. 4., 1994). This then leaves the change in volume with height as the one variable to be calculated.

Equation 1 can be rearranged to give Volume in terms of Pressure and Temperature

$V_2 = P_1.V_1.T_2/T_1 /P_2$ Equation 2

The next issue to be resolved is to determine the rate of pressure reduction with height.

In a column of air, the pressure is a function of the overlying mass, so if that the atmosphere is modelled as a stack of one metre cubes of air, then for each one metre rise in height the mass of the overlying column will be less, and so this mass reduction will cause a pressure reduction which can be calculated.

Pressure is a force; it is defined as the product of mass times acceleration. In the atmosphere the acceleration acting on the air parcel at rest in the column is the planet's gravity at that level, and this can be determined by Newton's gravity law of spherical shells. The value of the surface gravity of a planet can be calculated by using the Universal Gravity Equation, and knowing the planet's mass and its average radius.

But a standard measured quantity of gas is also required.

To do this the process used by chemists to find the relationship between the mass in grams and the volume in litres ($dm^3$) at Standard Temperature and Pressure (STP) for one mole of gas has been adopted here.

At 273.15 Kelvin ($0^oC$) and 1013.25 hPa (mbar) the volume is 22.414 litres ($dm^3$) and so for air with a molecular weight of 43.45 g/mol (standard Venus atmospheric composition) the mass contained in molecular volume (22.414 $dm^3$) will be 43.45g.

**Phase 1: Building the Pressure Ladder for the Venus Atmosphere.**

Step 1: From knowledge of the surface pressure of the Venusian atmosphere and the value of the surface gravity of Venus, compute the total atmospheric mass in a column bearing down on 1 square metre of the planet's surface.

Using the equation of force F = m.a this equation can be restated as Pressure/Gravity = Mass

For Venus the equation of state is:

9,321,900/8.87039 = 1,050,990.969 kg (1,051 tonnes/sq metre).

Step 2: Compute the volume change for I mole of gas from STP at the Earth's surface to the ambient temperature and pressure conditions on the surface of Venus.

Using the constant Pressure Volume Temperature relationship of $P_1.V_1/T_1 = P_2.V_2/T_2$ this establishes the unknown $V_2$ (the volume of 1 mole of gas at the surface of Venus).

$V_2 = P_1.V_1.T_2/T_1 /P_2$

$V_2$ = 101,325 * 22.414 * 699 / 273.15/9,321,900 = 0.623 $Dm^3$ (Litres)

Step 3: Compute the density of the unit mole of compressed gas at the surface of Venus under ambient surface conditions.

Using the standard formula: Density = Molecular Weight/Volume

Surface Density = 43.45 / 0.623 = 69.691 $Kg/m^3$.

Step 4: Convert the Gas Density to Discrete Mass of Gas per Unit Metre Cube.

Discrete Mass = 69.691 Kg

Step 5: Establish the Mass of Gas in the Atmospheric Column lying above this Unit Cube.

Mass Bearing Down = Column Mass minus Unit Mass

Mass Bearing down at 1 metre elevation = 1,050,900.969 – 69.691 = 1,050,831.277 Kg.

There is now sufficient information to begin climbing the Pressure Ladder of the Venus Atmospheric Profile at Unit Steps of 1 metre increment.

**Phase 2: Climbing the Pressure Ladder of the Venus Atmosphere.**

Step 1: Compute the new $P_2$, The Base Pressure of the Overlying Column of Gas.

Using the standard equation of Force: F = m.a where **m** is the mass of the overlying column and **a** is the value of gravity at the surface of Venus.

$P_2$ = 1,050,831.277 * 8.87039 = 9,321,282 Pascal

Step 2: Compute the new value of $T_2$ one metre above the base surface temperature of Venus using the relevant predictive Tropospheric Lapse Rate equation in K/m and inputting the height value *h* where *h* is the full distance above the surface in metres.

$T_2$ = 699-7.967**h*/1000= 698.9920 Kelvin

Step 3: Compute the new value of $V_2$ at one metre elevation using the standard Pressure Volume Temperature relationship $V_2 = P_1.V_1.T_2/T_1/P_2$

$V_2$ = 9,321,900 * 623.458 * 698.9920/699.0000 / 9,321,282 = 623.492 $cm^3$

N.B. The Volume increase for $V_2$ is due to the reduction in Pressure $P_2$ (which increases volume) dominating over the reduction in Temperature $T_2$ (which decreases volume) in the equation for each step up the ladder.

Step 4: Compute the Density of the New Unit Cube of Gas.

Using the standard formula: Density = Molecular Weight/Volume

New Density = 43.45/623.492* 1,000 = 69.68758 $Kg/m^3$.

Step 5: Convert the New Gas Density to Discrete Mass of Gas per Unit Cube.

Discrete Mass = 69.688 Kg

Step 6: Subtract the Discrete Unit Cube Mass from the Column Mass at this level to give the overlying Column Mass Bearing down on this Unit Cube.

Overlying Mass = Current Column Mass minus Unit Mass

Bearing Down Mass = 1,050,831.277 – 69.688 = 1,050,761.590 Kg

Step 7: Use Newton's Gravity Law of Spherical Shells and set $M_2$ to be the unit mass to compute the reduced value of planetary gravity at this new increment of 1 metre elevation.

The required information to climb one step of the ladder and continue the calculation cycle is now known. The bearing down Mass at the top of the unit cube defines the Pressure at the base of the next unit cube above.

Step 8: Return to Step 1 and continue climbing the Pressure Ladder by 1 metre increments.