

# Molar Mass Version of the Ideal Gas Law Points to a Very Low Climate Sensitivity

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**Abstract:** It has always been complicated mathematically, to calculate the average near surface atmospheric temperature on planetary bodies with a thick atmosphere. Usually, the Stefan Boltzmann (S-B) black body law is used to provide the effective temperature, then debate arises about the size or relevance of additional factors, including the ‘greenhouse effect’. Presented here is a simple and reliable method of accurately calculating the average near surface atmospheric temperature on planetary bodies which possess a surface atmospheric pressure of over 10kPa. This method requires a gas constant and the knowledge of only three gas parameters; the average near-surface atmospheric pressure, the average near surface atmospheric density and the average mean molar mass of the near-surface atmosphere. The formula used is the molar version of the ideal gas law. It is here demonstrated that the information contained in just these three gas parameters alone is an extremely accurate predictor of atmospheric temperatures on planets with atmospheres >10kPa. This indicates that all information on the effective plus the residual near-surface atmospheric temperature on planetary bodies with thick atmospheres, is automatically ‘baked-in’ to the three mentioned gas parameters. Given this, it is shown that no one gas has an anomalous effect on atmospheric temperatures that is significantly more than any other gas. In short; there can be no 33°C ‘greenhouse effect’ on Earth, or any significant ‘greenhouse effect’ on any other planetary body with an atmosphere of >10kPa. Instead, it is a postulate of this hypothesis that the residual temperature difference of 33°C between the S-B effective temperature and the measured near-surface temperature is actually caused by adiabatic auto-compression.

**Keywords:** Climate Sensitivity, Climate Change, Global Warming, Venus Temperature, Greenhouse Effect, Temperatures of Planetary Atmospheres, Earth Temperature, Auto-Compression

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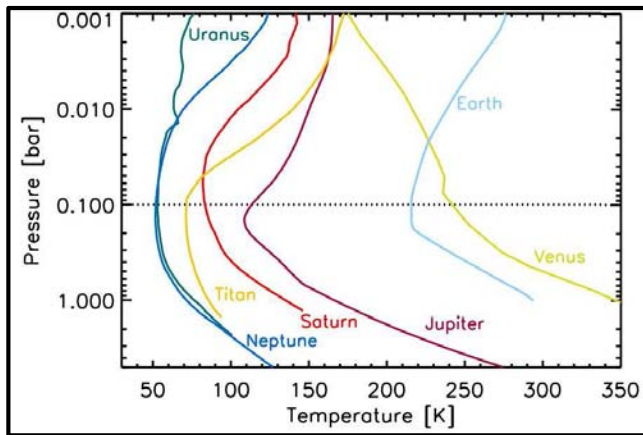
## 1. Introduction

It is known that planetary bodies which have thick atmospheres, naturally set up a rising temperature gradient in that part of the atmosphere which is higher than a pressure of 10kPa, (0.1 bar) until that bodies’ surface is reached [1] (Figure 1). Less well known is that this rising temperature gradient continues even below the surface [2]. It is postulated that in this denser part of the atmosphere, (on Earth, the troposphere) convection and adiabatic auto-compression effects rule over radiative or ‘greenhouse’ effects in the determination of atmospheric temperatures and thermal gradients. However, higher up in the atmosphere, once the atmospheric pressure drops below 10kPa (0.1 bar) then radiative effects dominate. This is because the atmosphere there is too thin to initiate convection or any warming due to

auto-compression. Although the term ‘auto-compression’ may be unfamiliar to some, this can be seen as simply an engineering term for what meteorologists call the ‘lapse rate’ and astronomers call the ‘Kelvin-Helmholtz’ contraction. Under the latter, the contraction of a large inter-stellar molecular gas cloud under gravity, achieves such high temperatures that nuclear fusion initiates, and a star is born [3].

Using this knowledge, an exacting yet simple method is introduced, which enables the average near-surface atmospheric temperature of any planetary body with an atmospheric pressure of over 10kPa, to become easily and quickly calculated. A molar version of the ideal gas law is utilized (formulas 5 and 6), which consists of a gas constant and three basic atmospheric parameters; the average near-surface atmospheric pressure, the average near-surface

atmospheric density and the mean molar mass of the near-surface (or on Earth, the tropospheric) atmosphere.



**Figure 1.** A thermal gradient appears in all planetary atmospheres >10kPa (0.1 bar) [1].

This formula proves itself here, to be not only more accurate than any other method heretofore used, but is far simpler to calculate. It requires no input from parameters previously thought to be essential; solar insolation, albedo, greenhouse gas content, ocean circulation and cloud cover among many others. The reason these are not required, is because they are already automatically ‘baked-in’ to the three gas parameters mentioned. Note: although *terms* for insolation intensity and auto-compression are not used in the formula, these two are still what *virtually determine* the average near-surface planetary atmospheric temperature.

### 1.1. Venus Is the Planet Which Is Hard to Explain

There has always been difficulty in explaining, or in formulating a simple method to satisfactorily explain or calculate the very high surface atmospheric temperature of the planet Venus using conventional mathematical means or by employing the greenhouse gas hypothesis. Here, the molar mass version of the ideal gas law, will be used to simply and accurately determine the surface temperature of this planet, by using just three variable gas parameters and one fixed gas constant.

### 1.2. Molar Mass Version of Ideal Gas Law Calculates Planetary Surface Temperatures

The ideal gas law may be used to more accurately determine surface temperatures of planets with thick atmospheres than the S-B black body law [4], if a density term is added; and if kg/m<sup>3</sup> is used for density instead of gms/m<sup>3</sup>, the volume term V may be dropped. This formula then may be known as the molar mass version of the ideal gas law.

The ideal gas law is;

$$PV = nRT \quad (1)$$

Convert to molar mass;

$$PV = m/M.RT \quad (2)$$

Convert to density;

$$PM/RT = m/V = \rho \quad (3)$$

Drop the volume, find for density;

$$\rho = P/(R.T/M) \quad (4)$$

$$\text{Find for temperature; } T = \frac{P}{(R \times \frac{\rho}{M})} \quad (5)$$

V = volume

m = mass

n = number of moles

T = near-surface atmospheric temperature in Kelvin

P = near-surface atmospheric pressure in kPa

R = gas constant (m<sup>3</sup>, kPa, kelvin<sup>-1</sup>, mol<sup>-1</sup>) = 8.314

$\rho$  = near-surface atmospheric density in kg/m<sup>3</sup>

M = near-surface atmospheric mean molar mass gm/mol<sup>-1</sup>)

Alternatively, the molar mass version of the ideal gas law can be written thus;

$$T = PM/R\rho \quad (6)$$

## 2. Methodology Involves Calculating Average Near-Surface Temperature of Planets

Formula 5 is here used throughout:

Using the properties of Venus, [5]

$$T = \frac{9200}{(8.314 \times \frac{65}{43.45})}$$

Venus calculated surface temperature = 739.7K

Using the properties of Earth from Wiki, [6]

$$T = \frac{101.3}{(8.314 \times \frac{1.225}{28.97})}$$

Earth calculated surface temperature = 288.14K

Venus is calculated at 739.7K, which is given by NASA as ~740K. Earth is calculated at 288K, currently its quoted by NASA [7] at 288K. It will be noted that the average temperature of the surface of Titan was measured by the Voyager 1, and by the Huygens lander [8] and was probably used as an input to find the surface density; (the independently-measured surface density on Titan could not be found in the literature). The 94K will therefore come out of the below formula, since it is a rearrangement of formula 1. This could be seen as a circular argument. However, it is unlikely that if and when the density of Titan is directly measured, for instance by the use of a dasymeter, it will be significantly different from the 5.25kg/m<sup>3</sup> stated here.

Calculate for Titan, data [9];

$$T = \frac{146.7}{(8.314 \times \frac{5.25}{28.0})}$$

Titan calculated surface temperature = 93.6K  
Calculate for Earth's South Pole, data [10];

$$T = \frac{68.13}{(8.314 \times \frac{1.06}{28.97})}$$

South Pole average calculated temperature = 224K (-49°C)  
Calculate for Mars [7];

$$T = \frac{0.6}{(8.314 \times \frac{0.02}{43.34})}$$

Mars calculated surface temperature = 156K

The average temperature on Mars is 218K; as suspected from other work [1] this method is inaccurate for Mars, due to the very low atmospheric pressure. It is only in atmospheres with a pressure of over 10kPa (0.1bar) that strong convection and a troposphere/tropopause is formed, and its associated temperature gradient. Mars is included to demonstrate the validity of the >10kPa rule. Now the gas giants will be assessed; these planets do not have a defined surface like the terrestrials have, so here they are given a 'surface' by using the Earth's surface pressure of 101.3kPa (1 atm) as a level to use for this calculation.

Calculate for Jupiter [7];

$$T = \frac{101.3}{(8.314 \times \frac{0.16}{2.2})}$$

Jupiter calculated temperature at 1atm of pressure = 167K  
Calculate for Saturn [7];

$$T = \frac{101.3}{(8.314 \times \frac{0.19}{2.07})}$$

Saturn calculated temperature at 1atm of pressure = 132.8K

Calculate for Uranus [7];

$$T = \frac{101.3}{(8.314 \times \frac{0.420}{2.64})}$$

Uranus calculated temperature at 1atm of pressure = 76.6K  
Calculate for Neptune [7];

$$T = \frac{101.3}{(8.314 \times \frac{0.450}{2.53})} \quad T = \frac{101.3}{(8.314 \times \frac{0.450}{2.69})}$$

In the case of Neptune, NASA gave two values for mean molar mass; 2.53 and 2.69, this necessitated two separate calculations to give a high and a low of calculated temperatures. Neptune's calculated temperature at 1atm of pressure = 68.5K to 72.8K. The temperature on Neptune at 1atm of pressure is 72K; this lies quite between the two calculated temperatures.

**Table 1.** Comparison of calculated and actual average surface temperatures.

Planetary body	Calculated temperature Kelvin	Actual temperature Kelvin	Error
Venus	739.7	740	0.04%
Earth	288.14	288	0.00%
South Pole of Earth	224	224.5	0.20%
Titan	93.6	94	0.42%
Mars (low pressure)	156	218	28.44%
Jupiter	167	165	1.20%
Saturn	132.8	134	0.89%
Uranus	76.6	76	0.79%
Neptune	68.5 to 72.8	72	0.00%

## 2.1. Analysis About the Postulates and Hypothesis Being Presented Herein

If this simple relationship between surface atmospheric density, pressure and molar mass is an accurate method of predicting surface temperatures on bodies with a thick atmosphere, it will necessarily be informative about what actually determines these planetary surface temperatures, and will have important implications for climate sensitivity.

In short, the hypothesis being put forward here, is that in the case of Earth, solar insolation provides the 'first' 255 Kelvin – in accordance with the black body law [11]. Then adiabatic auto-compression provides the 'other' 33 Kelvin, to arrive at the known and measured average global temperature of 288 Kelvin. The 'other' 33 Kelvin cannot be provided by

the greenhouse effect, because if it was, the molar mass version of the ideal gas law could not then work to accurately calculate planetary temperatures, as it clearly does here.

Temperature in a gas is a measure of the average kinetic energy of the particles in the gas. When atmospheric gas pressure exceeds 10kPa, a temperature gradient is set up from that pressure level, [1] down to the planetary surface (this thermal gradient continues even below the surface, if there is for example, a mine shaft). It is postulated here, that the cause of this thermal gradient is adiabatic auto-compression [2].

The origins of this effect go back to James Maxwell, who, in his 1872 book 'Theory of Heat' [12] demonstrated that the formation of the thermal gradient from the tropopause downwards is assisted by convection and more particularly, the increasing atmospheric pressure, which itself is a result of

a combination of the Earth's gravitational field, and the atmospheric density.

*"In the convective equilibrium of temperature, the absolute temperature is proportional to the pressure."* [12].

The idea of a thermal gradient naturally forming in any column of gas in a gravitational field was first proposed in the 1860's by Loschmidt [13]. At the time, Maxwell thought that this idea violated the second law of thermodynamics, yet as has been shown here, derivations of Maxwell's own ideal gas law is an excellent predictor of temperatures – when the atmosphere is thick enough to be compressed by a gravitational field. The controversy between Loschmidt on one side, with Maxwell and Boltzmann on the other, raged for some time and was finally experimentally tested in 2007, with the results published by Graeff [14]. Graeff's experiments concluded that a gravitationally-induced temperature gradient does spontaneously develop in sealed columns of both air and water – the bottom of the column being warmer than the top. The theoretical amounts of warming according to Graeff should be 0.07K/m and 0.04K/m respectively. Graeff's experimental apparatus reported 0.07K/m and 0.05K/m – so basically confirming Loschmidt's predictions. The thermal gradient appeared, despite the reverse gradient being prevalent in the immediate environment of the experiment. Loschmidt originally has said that the second law of thermodynamics needed to be re-stated to include the effects of gravitational fields on fluids.

The adiabatic auto-compression hypothesis enunciated herein, states that convection/pressure/lapse rate effects dominate over radiative effects in regions of all planetary atmospheres >0.1 bar and a temperature gradient is naturally formed. In effect, gravity forms a density and a temperature gradient; pressure is a corollary.

## 2.2. Auto-compression Is Known and Used Daily in Mining

Auto-compression is well known in underground mining, and is used by ventilation engineers to calculate how hot the mine air will get, so that they know how much cooling air to provide at each level. The effect of auto-compression can be calculated by the following:

$$P_e = P_s \exp(gH/RT)$$

Where;

$P_e$  = absolute pressure at end of column (kPa)

$P_s$  = absolute pressure at start of column (kPa)

$g$  = acceleration due to gravity ( $m/s^2$ )

$H$  = vertical depth (m)

As can be seen, this effect primarily relies on pressure and gravity, which will be different for each planetary body.

## 2.3. Mechanism Is Adiabatic

Note that we are examining an adiabatic process, and when a gas parcel expands adiabatically, as it does when rising in a gravitational field, it does positive work – and the kinetic

energy drops and so the temperature drops. However, when a gas parcel is compressed, as it is when it descends in a gravitational field, then it does negative work, and its kinetic energy rises and so its temperature goes up. Why does the kinetic energy of the gas rise when descending? It's because some of its potential energy is converted to enthalpy, so producing an increase in pressure, specific internal energy and hence, temperature in accordance with the following equation;

$$H = PV + U$$

Where;

$H$  = enthalpy (J/kg)

$P$  = pressure (Pa)

$V$  = specific volume ( $m^3$ )

$U$  = specific internal energy (kinetic energy)

## 2.4. Discussion on Maxwell vs Arrhenius and the 'Greenhouse Effect'

Work in this area of gas physics was detailed in the 19<sup>th</sup> century. However, there is a strong difference between the work and the views of the researchers Maxwell and Arrhenius. Maxwell's work shows that temperatures in the lower troposphere of Earth are primarily determined by convection and the atmospheric mass/pressure/gravity relationship. Arrhenius's later work [15] completely ignored this and determined that temperatures in the lower troposphere of Earth are caused by the radiative effects of greenhouse gases. There have been papers critical of Arrhenius's radiative effects ideas since 1909 [16]. Who is correct is critical to the present, since if Arrhenius is correct, then there should be concern about CO<sub>2</sub> emissions; if Loschmidt's version of Maxwell's work is correct, then more CO<sub>2</sub> will have no measurable effect on tropospheric atmospheric temperatures.

What do atmospheric measurements actually show? Measurements [17] of the effects of more CO<sub>2</sub> in the atmosphere appear to strongly support Maxwell. At pressures above 0.1 bar, "the extra CO<sub>2</sub> merely replaces water vapour" and little difference is seen in temperatures – but at pressures below 0.1 bar more CO<sub>2</sub> is measured to cause strong cooling. One of the main problems with the Arrhenius view, appears to be that convection is virtually ignored as a mode of heat transfer; but later work shows that only 11% of heat transfer in the troposphere is actually carried by radiation [18]. A recent paper has supported the Arrhenius view somewhat by quantifying a forcing due to increased atmospheric CO<sub>2</sub> [19]. But there remains a lack of any paper in the literature, which quantifies any warming attributable to increasing atmospheric CO<sub>2</sub> concentrations.

## 2.5. Discussion on the Implications for Climate Sensitivity

The reporting of climate sensitivity in the literature has been steadily reducing for decades, with many recent papers pointing to a very low sensitivity, of much less than 1°C; [20, 21, 22]. A careful reading of these papers, (for example the

most recent one) clearly indicates that the 0.6°C cited, is in fact an absolute maximum. This present work, if not invalidated by subsequent work, clearly points to a climate sensitivity so low that it would not be possible to measure it in the real atmosphere. This work leads directly to the conclusion that a small change in any single atmospheric gas, such as a doubling of the carbon dioxide level, (CO<sub>2</sub>) from the 'pre-industrial' 0.03% to 0.06% can have no measurable positive or negative effect on atmospheric temperatures.

## 2.6. The Accuracy and Implications of Formulas 5 and 6

It is apparent that this simple formula calculates the 'surface' temperatures of many planetary bodies in our Solar System accurately (Figure 2). Specifically, those which have

atmospheres thick enough to form a troposphere (i.e. possessing an atmospheric pressure of over 10kPa or 0.1bar). These are; Venus, Earth, Jupiter, Saturn, Titan, Uranus and Neptune. All calculated temperatures are within 1.2% of the NASA reported 'surface' temperature (except for Mars, which is excluded because it has a much lower atmospheric pressure than 10kPa). This accuracy is achieved without using the S-B black body law, or the need to include terms for such parameters as TSI levels, albedo, clouds, greenhouse effect or, for that matter, adiabatic auto-compression. All that is required to be able to accurately calculate the average near-surface atmospheric temperature, is the relevant gas constant and the knowledge of three variable gas parameters.

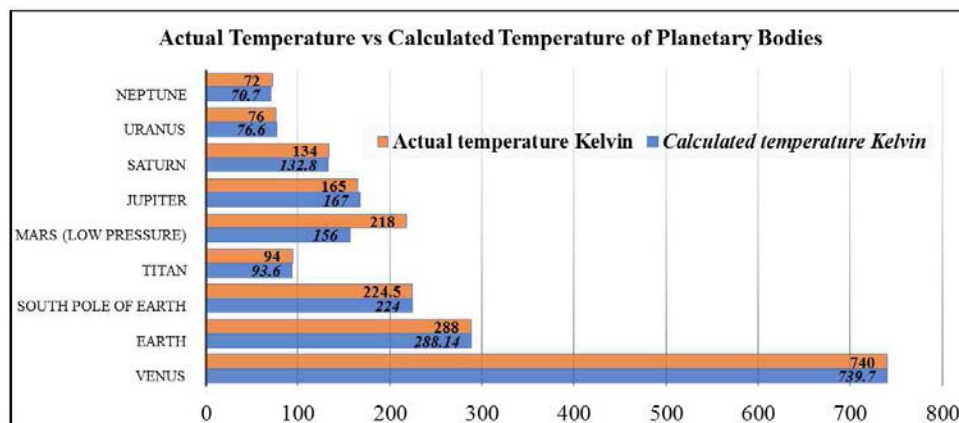


Figure 2. Actual temperature vs calculated temperature of 8 planetary bodies and the South Pole.

Some reflection upon the simplicity and accuracy of these results, will bring an unbiased person to the obvious implications of this work. These are that the residual (residual being the difference between S-B law results and actual) near-surface atmospheric temperatures on planetary bodies with thick atmospheres cannot be mainly determined by the 'greenhouse effect', but instead most likely by an effect from fluid dynamics, namely; adiabatic auto-compression. Another implication leads directly to the conclusion that the climate sensitivity to, for example, a doubling of the atmospheric carbon dioxide concentration has to be operating instantaneously, and also must be extremely low. Under this scenario, the climate sensitivity to CO<sub>2</sub> cannot be very different to the addition of a similar quantity of any other gas.

In particular, formula 5 (and 6) as presented here, totally rules out any possibility that a 33°C greenhouse effect of the type proposed by the IPCC in their reports [23] can exist in the real atmosphere. The reason is that the IPCC state in their reports that a 0.03% increase in atmospheric CO<sub>2</sub> (i.e. a doubling from pre-industrial levels) must result in a global temperature rise of ~3°C; (a range of 1.5°C to 4.5°C, which has hardly changed since 1990) [24]. This is the so-called 'climate sensitivity'. Anything like this magnitude of warming caused by such a small change in gas levels is completely ruled out by the molar mass version of the ideal gas law. i.e.;

Calculate for a doubling of CO<sub>2</sub> from the pre-industrial level of 0.03%;

$$T = \frac{101.33}{(8.314 \times \frac{1.226}{28.98})}$$

Calculated temperature after doubling of CO<sub>2</sub> to 0.06% ≈ 288.11K

Climate sensitivity to CO<sub>2</sub> is ≈ 288.14 - 288.11 ≈ - 0.03K

The change would in fact be extremely small and difficult to estimate exactly, but would be of the order -0.03°C. That is, a hundred times smaller than the 'likely' climate sensitivity of 3°C cited in the IPCC's reports, and also probably of the opposite sign. Even that small number would likely be a maximum change, since if fossil fuels are burned to create the emitted CO<sub>2</sub>, then atmospheric O<sub>2</sub> will also be consumed, reducing that gas in the atmosphere – and offsetting any temperature change generated by the extra CO<sub>2</sub>. This climate sensitivity is already so low that it would be impossible to detect or measure in the real atmosphere, even before any allowance is made for the consumption of atmospheric O<sub>2</sub>.

## 3. Conclusion

It has always been complicated mathematically, to calculate the average near surface atmospheric temperature

on planetary bodies with a thick atmosphere. Usually, the Stefan Boltzmann (S-B) black body law is used to provide the effective temperature, then debate arises about the size or relevance of additional factors such as the greenhouse effect. Here is presented a simple and reliable method of calculating the average near surface atmospheric temperature on planetary bodies which possess a surface atmospheric pressure of over 10kPa. This method requires knowledge of the gas constant and only three variable gas parameters; average near- surface atmospheric pressure, average near surface atmospheric density and the mean molar mass of the atmosphere.

The formula used is the molar mass version of the ideal gas law. It is here demonstrated that the information contained in just these three gas parameters alone is an extremely accurate predictor of average near-surface atmospheric temperatures, in atmospheres >10kPa. Therefore, all information on the effective plus the residual near-surface atmospheric temperature on planetary bodies with thick atmospheres; residual meaning the difference between the effective, (that predicted by S-B black body law), and the measured actuality, must be automatically 'baked-in' to the three mentioned gas parameters. This leads directly to the conclusion that a small change in any single atmospheric gas, not only has little effect on atmospheric temperatures, but has a very similar effect to the same percentage change in any other atmospheric gas. It is seen therefore, that no one gas particularly affects atmospheric temperatures over any other gas; so, there can be no significant 'greenhouse warming' caused by greenhouse gases on Earth, or for that matter on any other planetary body. Instead, it is proposed that the residual temperature difference of 33°C on Earth, and the tropospheric thermal gradient observed, are actually caused by adiabatic auto-compression.

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## References

- [1] Robinson, T. D., & Catling, D. C. (2014). Common 0.1 [thinsp] bar tropopause in thick atmospheres set by pressure-dependent infrared transparency. *Nature Geoscience*, 7(1), 12-15.
- [2] McPherson, M. J. (2012). *Subsurface ventilation and environmental engineering*: Springer Science & Business Media.
- [3] Elmegreen, B. G., & Elmegreen, D. M. (1986). Do density waves trigger star formation? *The Astrophysical Journal*, 311, 554-562.
- [4] Stefan, J. (1879). On the relationship between thermal radiation and temperature. *Bulletin from the sessions of the Vienna Academy of Sciences (Vienna, 1879)*, 79, 391-428.
- [5] Zasova, L. V., Ignatiev, N., Khatuntsev, I., & Linkin, V. (2007). Structure of the Venus atmosphere. *Planetary and Space Science*, 55(12), 1712-1728.
- [6] Wikipedia, Properties of Earth's atmosphere, (2017). Accessed 14/11/2017. [https://en.wikipedia.org/wiki/Density\\_of\\_air](https://en.wikipedia.org/wiki/Density_of_air)
- [7] NASA fact sheet data on the planets, (2017). Accessed 14/11/2017 <https://nssdc.gsfc.nasa.gov/planetary/factsheet/>
- [8] Fulchignoni, M., Ferri, F., Angrilli, F., Ball, A. J., Bar-Nun, A., Barucci, M. A.,... & Coradini, M. (2005). In situ measurements of the physical characteristics of Titan's environment. *Nature*, 438(7069), 785-791.
- [9] Lindal, G. F., Wood, G., Hotz, H., Sweetnam, D., Eshleman, V., & Tyler, G. (1983). The atmosphere of Titan: An analysis of the Voyager 1 radio occultation measurements. *Icarus*, 53(2), 348-363.
- [10] IceCube Wise; Wis/Mad Uni. Accessed 13/11/2017 <http://icecube.wisc.edu/pole/weather>
- [11] NASA, black body curves Sun and Earth, (2017). Accessed 14/11/2017 [https://earthobservatory.nasa.gov/Features/ArcticReflector/Images/black\\_body\\_log\\_log\\_rt.gif](https://earthobservatory.nasa.gov/Features/ArcticReflector/Images/black_body_log_log_rt.gif)
- [12] Maxwell, J. C. (2012). *Theory of heat*: Courier Corporation.
- [13] Flamm, D. (1997). Four papers by Loschmidt on the state of thermal equilibrium *Pioneering Ideas for the Physical and Chemical Sciences* (pp. 199-202): Springer.
- [14] Graeff, R. W. (2007). Viewing The Controversy Loschmidt–Boltzmann/Maxwell Through Macroscopic Measurements Of The Temperature Gradients In Vertical Columns Of Water. *Preprint. Additional Results Are on the Web Page*.
- [15] Arrhenius, S. (1896). XXXI. On the influence of carbonic acid in the air upon the temperature of the ground. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 41(251), 237-276.
- [16] Wood, R. W. (1909). XXIV. Note on the Theory of the Greenhouse. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 17(98), 319-320.
- [17] Clough, S. A., Iacono, M. J., & Moncet, J. L. (1992). Line - by - line calculations of atmospheric fluxes and cooling rates: Application to water vapor. *Journal of Geophysical Research: Atmospheres*, 97(D14), 15761-15785.
- [18] Khilyuk, L. (2003). Global warming: are we confusing cause and effect? *Energy Sources*, 25(4), 357-370.
- [19] Feldman, D. R., Collins, W. D., Gero, P. J., Torn, M. S., Mlawer, E. J., & Shippert, T. R. (2015). Observational determination of surface radiative forcing by CO2 from 2000 to 2010. *Nature*, 519(7543), 339-343.
- [20] Harde, H. (2014). Advanced Two-Layer Climate Model for the Assessment of Global Warming by CO2.
- [21] Cederlöf, M. (2014). Using seasonal variations to estimate earth's response to radiative forcing.

- [22] Abbot, J., & Marohasy, J. (2017). The application of machine learning for evaluating anthropogenic versus natural climate change. *Geo Res J*, 14, 36-46.
- [23] Team, C. W., Pachauri, R., & Meyer, L. (2014). IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, 151.
- [24] Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., Church, J. A.,... Dubash, N. K. (2014). IPCC Fifth Assessment Synthesis Report-Climate Change 2014 Synthesis Report.