The effect of Earth's atmospheric structure on global warming

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The purpose of this report is to explain how the structure of Earth's atmosphere tends to buffer the effect of added CO_2 on climate. This is a phenomenon that deserves more detailed analysis in the climate literature than it has seen.

Earth's temperature results from a balance between heating by sunlight and cooling by the emission of infrared radiation (IR) to space. IR emitted by Earth's surface within the CO_2 absorption band is absorbed strongly enough to prevent its direct transmission to space. Rather it is absorbed and re-emitted until reaching a sufficient altitude that escape becomes possible. That altitude may be in the troposphere, stratosphere, or mesosphere depending on the absorption coefficient value.

Figure 1 plots the absorption coefficient spectrum of CO_2 (in red color) overlaid with Earth's emission spectrum calculated assuming a CO_2 concentration of 389 parts per million by volume.[1] The absorption coefficient exhibits a range of values at each small wavelength interval for reasons connected with the quantum mechanics of molecular rotation, vibration and motion. It also varies slightly with ambient pressure and temperature. The emission spectrum is closely similar to that measured in 1972 over the Mediterranean in NASA's Nimbus 4 experiments.[2]

For a given absorption coefficient and atmospheric CO_2 content, emission to space will occur in the vicinity of an elevation at which the mass of CO_2 per unit area in the atmosphere above that elevation equals the reciprocal of the absorption coefficient. For vertical emission the atmospheric pressure at that point satisfies the following equation:

$$1/\alpha = p(atm)\cdot 14.7\cdot 360x10^{-6}\cdot 44/29\cdot 1550/2.2 = 5.66\cdot p(atm)\ kg/m^2$$

In this equation the term 14.7 converts pressure from atmospheres to pounds per square inch, the CO_2 concentration is taken equal to 360 parts per million by volume, the term 44/29 converts the CO_2 content from volume to mass fraction, and the final term, 1550/2.2 converts from pounds/square inch to kg per square meter.

Figure 2 plots temperature and pressure vs elevation for the U.S. 1976 Standard Atmosphere[3]. It illustrates, in order of increasing elevation, the temperature and pressure of the troposphere, stratosphere, and mesosphere. The dashed curve shows the average Earth temperature structure given by Plass[4] in his 1956 publication on warming of Earth by the atmosphere's CO_2. It suggests that the Standard Atmosphere is a reasonable model for Earth's average.

Values for the standard atmosphere elevation, pressure, and temperature where vertically-directed CO_2 emissions to space arise in the three atmospheric regions are given in Table 1. The range of absorption coefficient values for emission from the three regions is also given in the table and is marked out by the red dashed lines in Figure 1.

Table 1

Characteristics of the standard atmosphere from which Earth emits infrared radiation to space.

Region of Atmosphere	Elevation Km	Temperature Range, K	Pressure atm.	Absorption Coeff. m^2/kg
Troposphere	0 – 18	288 - 210	1 to 0.07	< 2.4
Stratosphere	18 – 50	210 - 270	0.07 to 0.0008	2.4 to 220
Mesosphere	> 50	< 270	< 0.0008	> 220

Longer path lengths, smaller pressure values and greater elevation values would apply for non-vertical emission to space. While there is substantial non-vertical emission it will cause relatively small changes in the region of the atmosphere from which such emissions to space arise because the pressure of the atmosphere decreases rapidly with elevation.

The equation shows that if the CO_2 concentration goes up, the pressure for emission to space will go down. The intensity of IR emission by any substance increases with its temperature. Therefore, the temperature and magnitude of IR emission will go down in the troposphere and mesosphere with increasing CO_2 content and go up in the stratosphere. This is how Earth's atmosphere tends to buffer the effect of added CO_2 on climate. Although Figure 1 shows that substantial emission occurs in the stratosphere, according to published climate science calculations the total effect is a net warming of the Earth. The buffering effect only makes warming much less than it would otherwise be.

Climate science would benefit from a publication of accurate calculations for IR emissions to space from the three atmospheric regions. Such results would make clear and undeniable the existence and magnitude of the driving force for climate change. Results would be for well-defined conditions and independently verifiable, e.g., if done for the standard atmosphere with fixed earth and atmosphere temperatures, pressures and CO_2 content varied from zero to 1000 ppmv. While such changes in the atmosphere influence climate, climate changes are more difficult to predict. It is the driving force for climate change, the influence of CO_2 on IR emission to space, that can be and needs to be more clearly and widely understood and accepted.

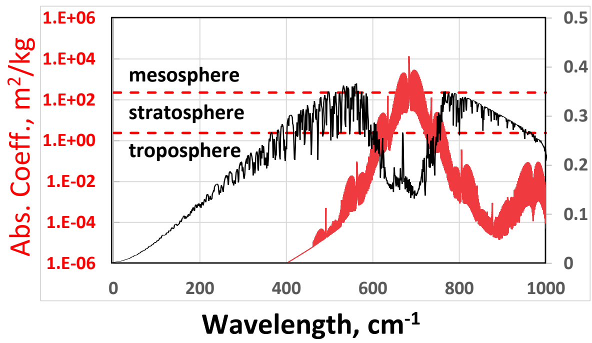

Figure 1. Calculated Earth emission (black) and CO_2 absorption coefficient (red) spectra.[2]

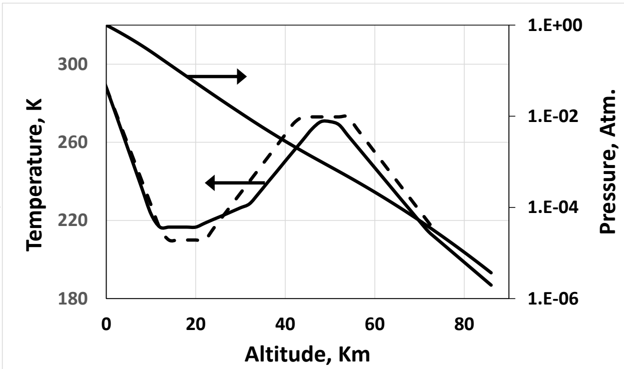

Figure 2. U.S. 1976 Standard Atmosphere.[3] The dashed temperature curve is from Plass.[4]

References

1. W. Zhong and J.D. Haigh, “The Greenhouse Effect and Carbon Dioxide,” Weather 68(4), pp. 100-105 (2013).

2. R.A. Hanel and B.J. Conrath, “Thermal Emission Spectrum of The Earth and Atmosphere Obtained From the NIMBUS 4 Michelson Interferometer Experiment,” NASA Report X-620-70-244, June 1970. Nature 228, pp, 143-145 (1970).

3. https://www.engineeringtoolbox.com/standard-atmosphere-d_604.html

4. G.N. Plass, “The Influence of the 15 μm Carbon-dioxide Band on the Atmospheric Infra-red Cooling Rate”, (1956). See: D. Archer and R. Peirrehumbert, “The Warming Papers: The Scientific Foundation for the Climate Change Forecast,” pp. 81-91, Wiley-Blackwell (2011).