http://en.wikipedia.org/wiki/File:ModtranRadiativeForcingDoubleCO2.png

http://en.wikipedia.org/wiki/Radiative_forcing

Emission of Radiation from the Earth

By Colin Davidson, November 2012

Introduction

This paper examines the spectrum of out-going radiation from the Earth[1] – not just from the Surface, but from the planet plus its atmosphere.

Particular attention is paid to the main CO_2 absorption frequencies. It turns out that for the major part of that frequency band:

a. There can be very little additional absorption of Surface-radiated energy, as this band is already mostly opaque, and,

b. Radiation to Space in this band from CO_2, is mostly coming from molecules very high in the atmosphere, above the Tropopause (ie in the Stratosphere), and therefore,

c. An increase of CO_2 can be expected to have mostly a net cooling effect in this band[2].

The Earth Viewed in the Infra-Red from Space

Figure 1 shows an infra-red spectrum gathered by a satellite looking down towards the Earth from around 20km. This spectrum shows the intensity of emission plotted against frequency (wavenumber[3]). The energy depicted is mostly radiated from the surface of the Earth, which is almost a perfect blackbody and radiates radio waves in the infra-red frequency band. The imperfections in the shape of the spectrum are caused by the 20km of atmosphere through which the infra-red waves have travelled.

In general this spectrum follows the classical shape postulated by Wien[4]. The dotted lines on the plot are the levels which would be emitted by theoretically perfect black bodies at the indicated temperatures. The temperature of the Surface of the planet can be inferred from

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[1] In this paper the main locations are used as proper nouns, so have initial capitals. These locations are: Earth, Space, Surface, Tropopause, Troposphere, Stratosphere.

[2] The temperature gradient is positive or zero in the Stratosphere. An increase in concentration means an increase in the average height of emission. The increased height means an increased temperature and therefore an increased intensity of emission. Because more energy is being exported from the planet, the planet must cool down to restore the energy balance with the sun.

[3] Wavenumber is in units of cm^{-1}. It is the frequency divided by the speed of light, or 1/wavelength in cm.

[4] http://en.wikipedia.org/wiki/Wien's_displacement_law

frequencies where the atmosphere has not been absorbing emissions, for example the Wavenumber 900-1000 region, and is about 296°K (23°C)

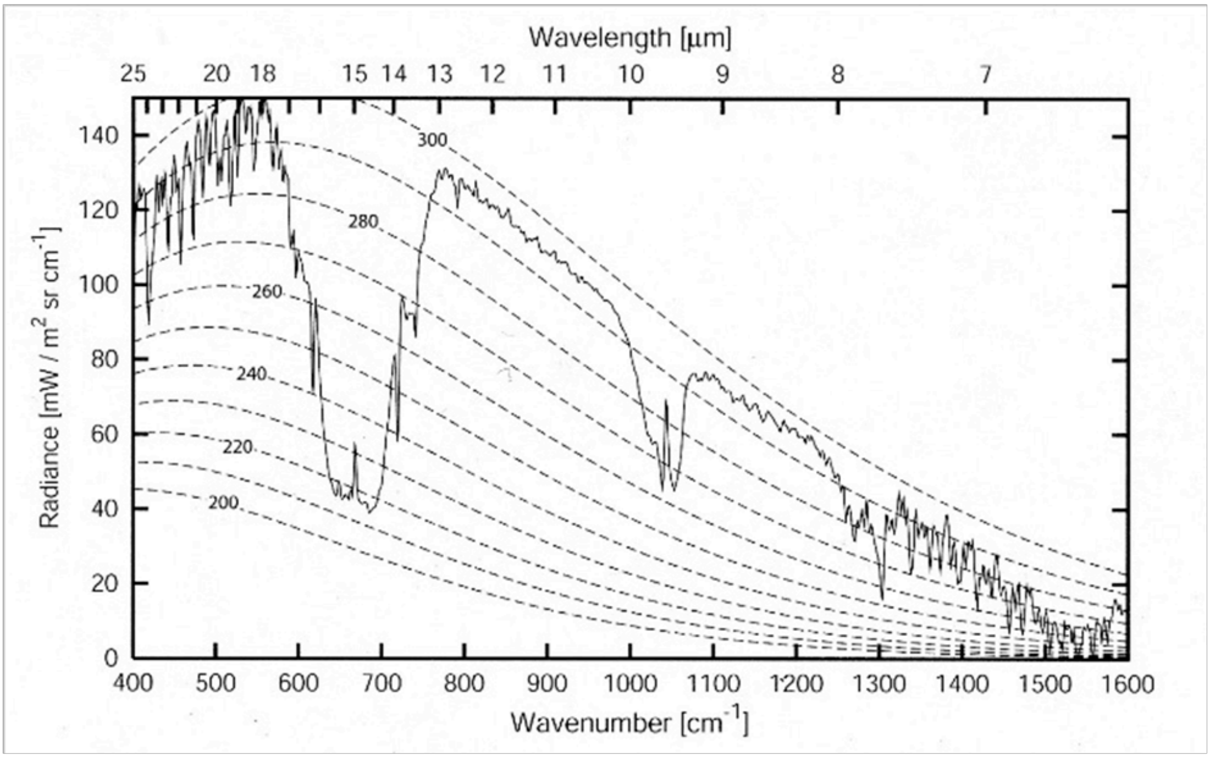

Figure 1. Infra-Red Spectrum of emissions from Earth viewed from a satellite above Iraq in 1974.[5]

The spectrum has many chunks missing, due to interference by the atmosphere in the passage of radiation from the Earth's Surface to Space. Most of the selective attenuation in the 400-600cm^{-1} portion is due to water vapour. The large missing chunk from 630-710cm^{-1} is due to CO_2, the feature at 1000 – 1100cm^{-1} is due to ozone, and from 1250cm^{-1} is due to methane and water vapour. In the unseen portion of the spectrum below 400cm^{-1} there is considerable water vapour attenuation.

[5] http://www.barrettbellamyclimate.com/page19.htm "This is an emission spectrum of a part of the Earth taken by satellite and it shows most of the main features of the spectra of the greenhouse gases. The units of radiance are milliwatts per square metre per steradian per reciprocal centimetre! The spectrum was recorded in 1974 and the machinery on board the satellite was not capable of recording radiance below 400 cm^{-1}." The source of the spectrum is not given.

Emission and Absorption

Gases which **absorb** also **emit** radiation. What we see in the spectrum is therefore a complex sum of :

a. Emitted Surface radiation some of which is absorbed by the overlying atmospheric gases, and,

b. Emissions from the gases in the atmosphere, some of which is absorbed by the overlying gases.

Emission is proportional to the number of molecules per unit volume (the "*number density*") and temperature. Absorption is proportional to the *number density;* temperature has little effect on the strength of absorption.

Although many authors state that the radiance temperature is the average of the temperature at which emission occurred, this is not a correct interpretation of the evidence. For example, the radiance temperature at the base of the CO_2 absorption band (say at around $650cm^{-1}$) is about 218^oK, but it is incorrect to ascribe that as being the average emission temperature. The situation is far more complex than that.

For any portion of the spectrum we have to decide where the emissions are coming from, and the relative strengths of emission and absorption by the atmosphere, before we can make any statement about the source of the emitted photons.

The CO_2 Absorption Band at 630-710cm^{-1}

At first glance, the spectrum has a large chunk removed in this band, and often this is interpreted as the Surface radiation being absorbed by CO_2. This is incorrect. In this band, the Surface radiation is ***entirely extinguished*** by absorption, mostly within 100 metres of the ground. What we see in this band is entirely radiation from the ***upper*** portions of the atmosphere.

This is clearly seen in Figure 2.

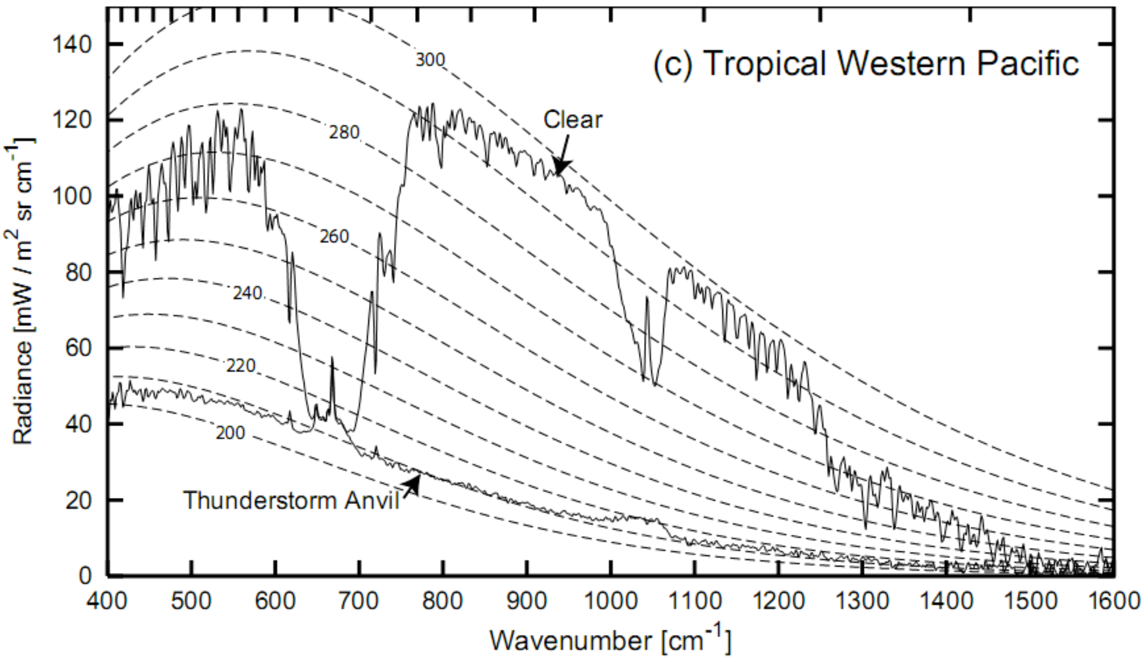

Figure 2: Two spectra superimposed on each other. The spectra were obtained by a satellite looking towards the ground. The top spectrum was obtained in clear conditions; the lower spectrum was taken when a thunderstorm was in progress.[6]

In this figure the 630-710cm^{-1} region is most interesting. As with light, infra-red frequencies do not penetrate clouds. The cloud has extinguished the surface radiation, and what we see over most of the spectrum is the black-body radiation from the top of the cloud, which is at about 210^{o}K[7]. But in the CO_2 absorption band, the emission strength is ***unchanged***, the only explanation being that in this part of the spectrum all the emissions are coming from well above the top of the cloud.

The top of the cloud is at around 14km. (In tropical latitudes, the atmospheric temperature is about 210^{o}K at 14km[8].) So the emissions in the CO_2 band are all coming from above 14km. This situation is shown in the next diagram.

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[6]Source: "A First Course in Atmospheric Radiation", Grant W. Petty, 2nd edition, Figure 8.3(c).

[7] This is deduced from the 800-900 cm^{-1} band, where the emission strength closely follows the 210^{o}K theoretical blackbody curve (dotted line).

[8] This can be seen in Figures 6 and 8. A vertical line through -63^{o}C intersects the temperature profile for Guam at around 14km.

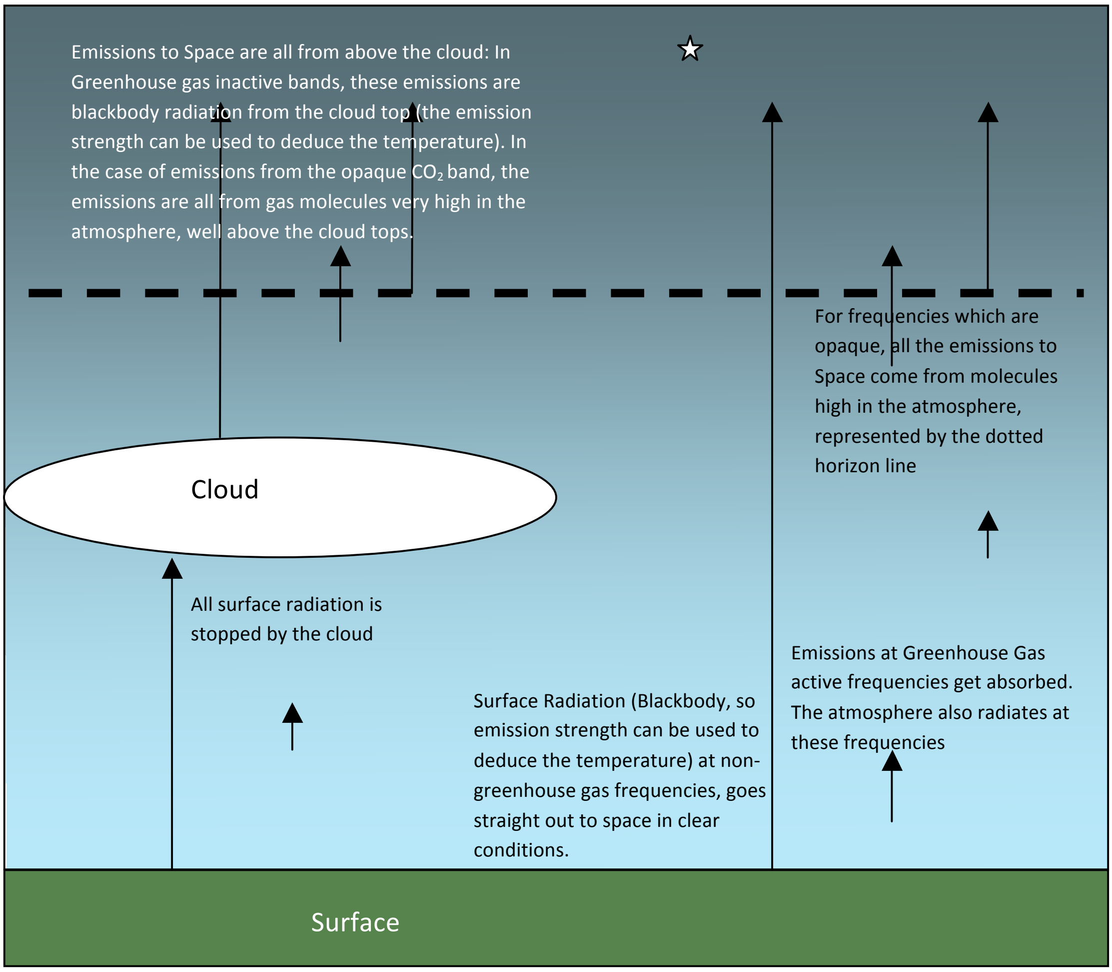

Figure 3: The spectra in Figure 2 can only be explained if emissions in the 630-710 cm^{-1} band are coming from molecules in the atmosphere above the top of the cloud.

667cm^{-1} is the most active CO_2 frequency. Surface emissions at this frequency are virtually extinguished within 5 metres[9] of the ground, and the emissions to Space are coming from very high in the atmosphere, probably from above 30km.

On the other hand, in the 1000-1100 cm^{-1} region, only a small bump indicates emission by ozone above the cloud top. My interpretation of what is happening here is that emission in this portion of the spectrum is mostly from the ground, that Stratospheric ozone removes a portion of that radiation, but only adds a very small fraction to the outgoing radiation.

The detail of the CO_2 emission lines is shown in Figure 3:

[9] John Nicol, "Climate Change (A Fundamental Analysis of the Greenhouse Effect)" www.middlebury.net/nicol-08.doc Figure 6

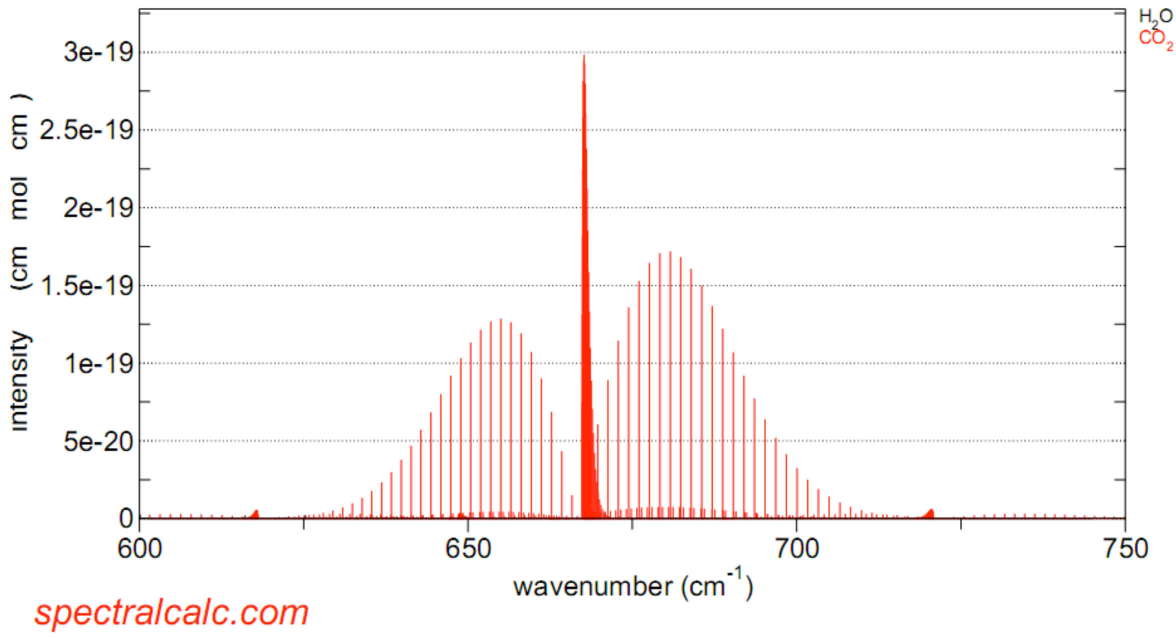

Figure 4. Theoretical Emission Spectrum for CO_2. Note the very strong lines at 667cm^{-1}. Cold gases do not emit radiation in a continuous spectrum like a blackbody, but at preferred frequencies. The CO_2 molecule has a resonant vibration mode at 667cm^{-1}. Due to quantum effects (these are responsible for the evenly spaced spikes) the molecules may emit at slightly different frequencies from the central one, the probabilities (intensities) are as shown.

The emission (and absorption) by cold gases is done at preferred frequencies (known as "lines"). Calculation suggests that:

a. There is complete absorption of Surface Emissions in the gaps between the lines from about 630-710cm^{-1}.

b. In the 630-710 cm^{-1} band, apart from the 667 cm^{-1} spike, the floor is relatively flat. This is likely due to the wide bandwidth of the measuring device.

c. Emissions from the 630-710cm^{-1} band are mostly from the Stratosphere.

Confirmation of the last conclusion comes from examination of spectra from different locations (Figure 5). The emission level in the 630-710cm^{-1} band is slightly higher in the temperate latitudes than it is in the Tropics. Since the composition and pressures in the atmosphere are very similar in both locations, this increased emission in temperate areas must mean that emissions are coming from a height where the atmosphere is warmer than it is in the tropics.

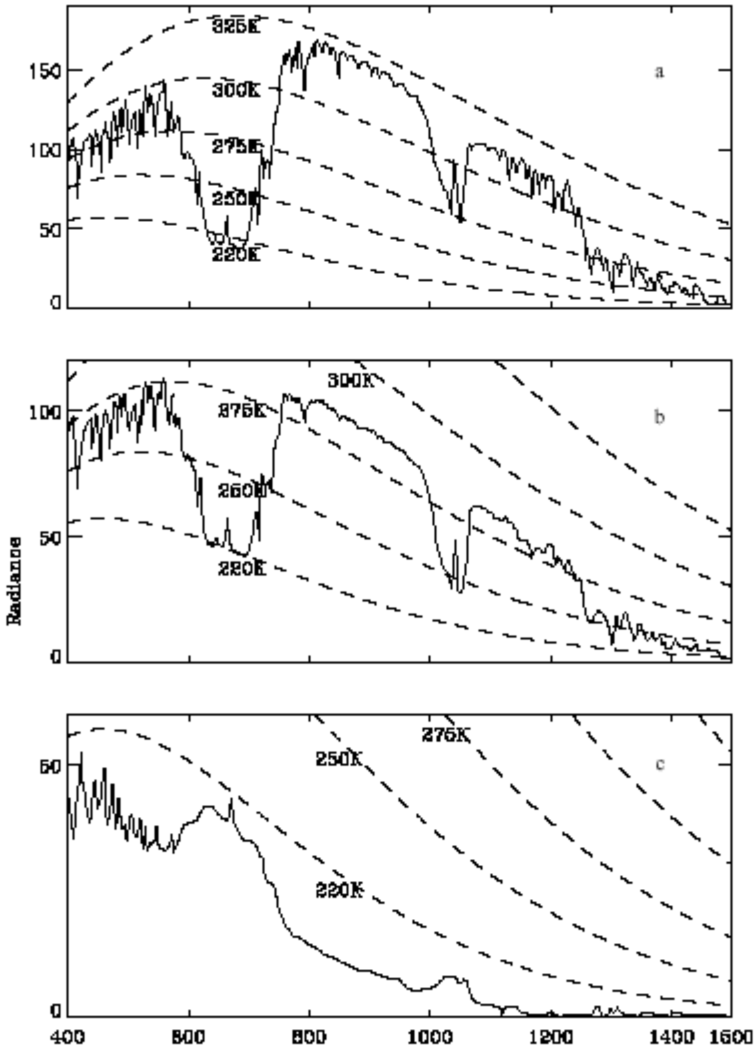

Figure 1.2 Thermal emission spectra of Earth measured by the IRIS Michelson interferometer instrument on the *Nimbus 4* spacecraft (see Endnote 4). Shown also are the radiances of blackbodies at several temperatures. (a) Sahara region; (b) Mediterranean; (c) Antarctic.

Figure 5 Comparison of Spectra[10] Note that the emission intensity at the bottom of the CO_2 emission region is lower from the Sahara than from the Mediterranean, even though the surface temperatures are much higher (judging by the 900-1000cm^{-1} band, 47^{o}C versus 15^{o}C).

Figure 6 compares typical weather balloon measurements from Guam and Istanbul[11]

[10] http://members.casema.nl/errenwijlens/co2/howmuch.htm That site does not acknowledge the original source, which is unknown.

[11] Weather Balloon measurements are plotted from data from http://weather.uwyo.edu/upperair/sounding.html

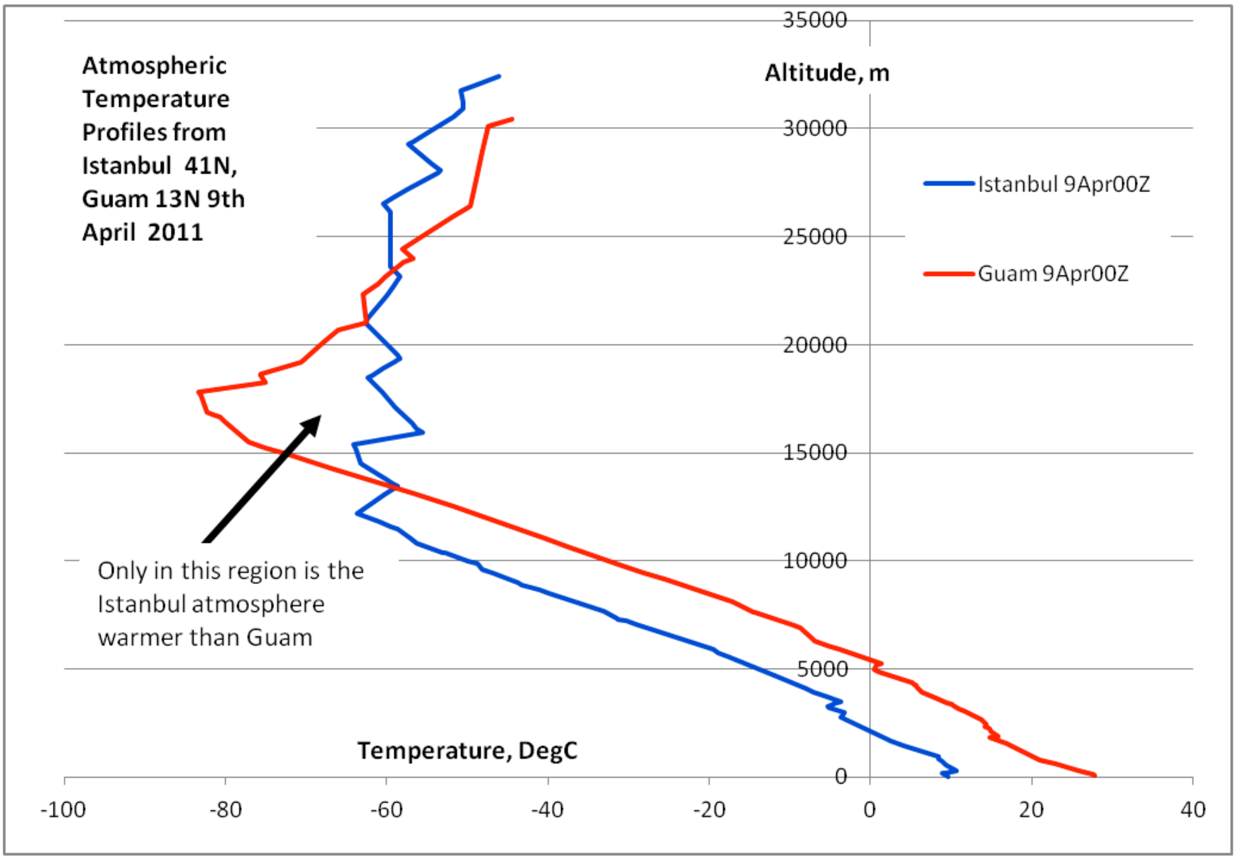

Figure 6: Comparison of Weather Balloon Measurements from above Istanbul and Guam. Such profiles are typical of temperate and tropical locations. Only at heights between about 15km and 20km is the temperate atmospheric temperature greater than in the tropics. (9Apr00Z is 0000 hours GMT on 9th April 2011).

The temperature is only warmer than the tropics in the temperate atmospheres above 14km.

The emissions in the 630-710cm^{-1} band are coming from CO_2 molecules well above 14km, ie above the Tropopause[12] for half the planet, and about the Tropopause for the other half.[13]

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[12] The Tropopause is the inflection point in the temperature profiles – for Istanbul in Figure 6 it is about 12km, for Guam about 17.5km. The region below the Tropopause is the Troposphere. The region above it is the Stratosphere which extends to around 45km. In the Troposphere the temperature gradient is negative, but in the Stratosphere it is neutral or positive, as depicted in Figure 6.

[13] This conclusion is supported by a comment made by DeWitt Payne on the "Science of Doom" mainstream scientific website: "Using MODTRAN and averaging transmittance over the range 630-710, at 280 ppmv CO2 the OD (*Optical Depth*) is 1.0 at about 16.6 km. Doubling the CO2 to 560 raises the altitude to 18.8 km." (comment on http://scienceofdoom.com/2011/09/02/radiative-forcing-and-the-surface-energy-balance/ at 1102, 4th December 2011) If emissions are as high as he claims, they are above the Tropopause (ie from the Stratosphere) over the whole planet.

Significance of Emissions from CO_2 Very High in the Atmosphere

The current greenhouse theory relies on the "Enhanced Greenhouse Effect". That hypothesis does not concern the *absorption* by the atmosphere of energy radiated by the Surface, but the *emission* of energy from the atmosphere to Space.

An increase in concentration of a Greenhouse Gas[14] increases both the absorption and the emission of photons.

In the opaque regions of the spectrum, increased concentration of a Greenhouse Gas obviously means increased absorption by overlying gas of photons emitted towards Space. So the average height of emission increases. Simple modelling suggests that this also occurs for the translucent regions.

In opaque cases, where emission is in the Troposphere (the region of the atmosphere where the temperature drops roughly uniformly with height), the increased average height of emission means a drop in the strength of emission due to the fall in temperature with height. This shortfall of energy export means that the planet as a whole has to heat up (the "Greenhouse Effect").

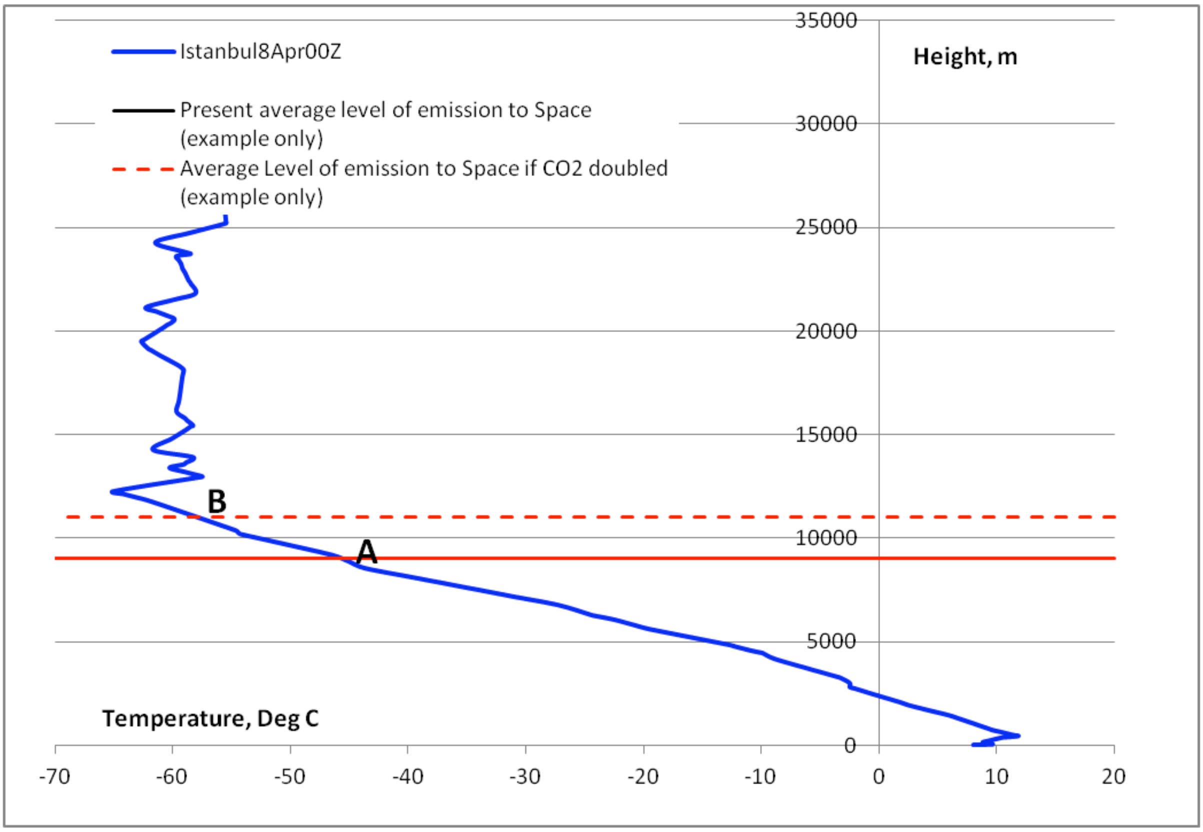

Figure 7: The "Enhanced Greenhouse Effect" . For an opaque frequency where the average height of emission is lower than the Tropopause, a doubling of CO_2 means the average height of emission is higher. This is colder (B is colder than A), so the intensity is less. This means that the planet is not exporting as much energy as before, so it has to heat up to restore the energy balance with the sun.

[14] ie a gas which emits and absorbs in the Infra-Red, eg Water Vapour (which is the most active), CO_2, O_3, CH_4

But in opaque cases where emission is above the Tropopause, in the Stratosphere, increased height of emission means either no change or an increase in temperature. In this case (ie for the whole 630-710 cm^{-1} band) the strength of emission either does not change, or increases. This surplus in energy export implies that the planet as a whole has to cool down.

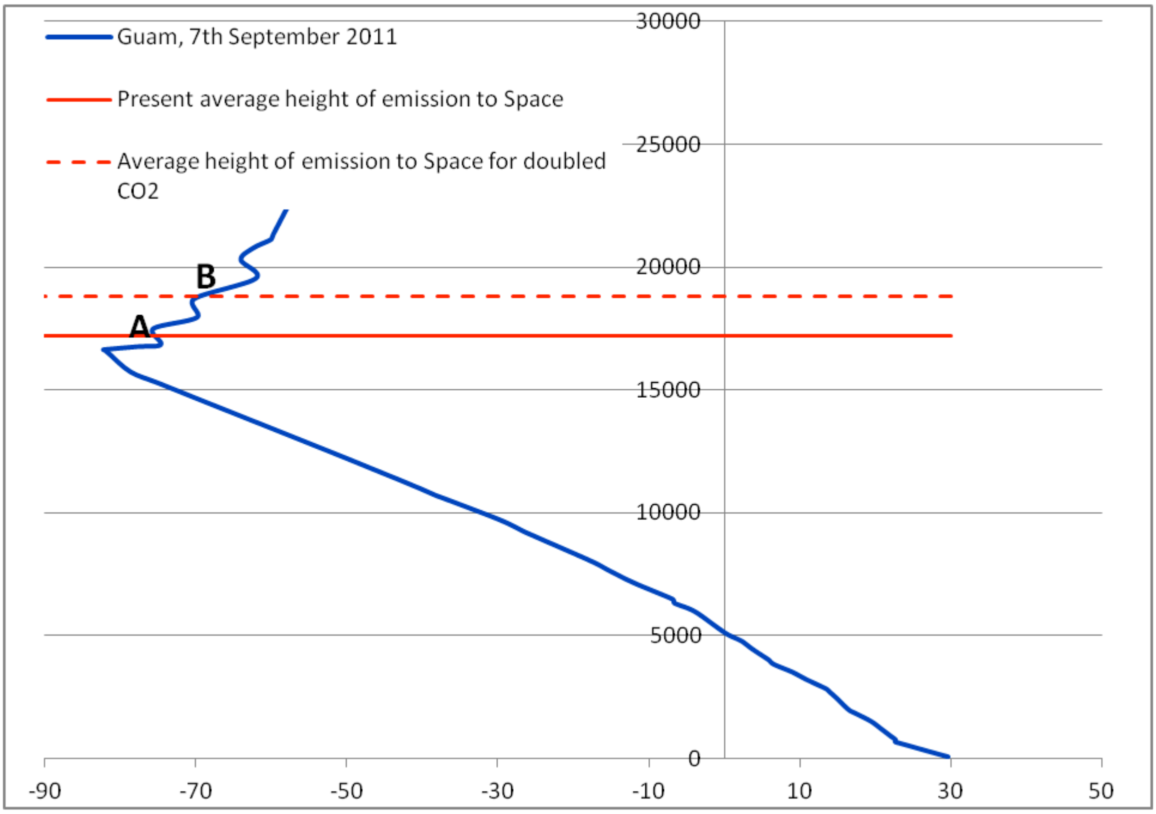

Figure 8 Atmospheric Profile above Guam, 13N, on 7th September 2011. The level at A, 17,200m, is the approximate average height from which photons are emitted to Space in the main CO_2 frequency band (Wavenumbers 630 through 710). The level at B, 18,800m, is the approximate average emission height from this band when CO_2 concentration is increased to 560ppm. Note that the emission temperatures are different: at 560ppm, emissions in this band would be stronger because of the higher temperature (-70°C instead of -75°C) and increased proportion of CO_2 molecules, despite the drop in pressure.

Conclusions

In the **most active region** of the CO_2 Infra Red absorption band (630-690 cm^{-1})[15], an increase in gas concentration implies:

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[15]Figure 2 suggests that the emissions in the 690-710 region are from near the cloud top. This portion of the spectrum is probably neutral to increases in CO_2 concentration.

a. No change in absorption of Surface infra-red emissions. As this is an opaque band, 100% of Surface emissions are already being extinguished.

b. An increase in infra-red emissions to Space. This increased emission from the Stratosphere implies a cooling of the Stratosphere, with a consequent change in the balance of emissions from each of the component Greenhouse Gases.

If one looks at Figure 3 and mentally removes this cooling band from the CO_2 spectrum there is not much left (Figure 9). Further from the centre is a neutral area, where a doubling of concentration will have no effect on planetary temperature. The remaining very weak portions of the CO_2 active band have to:

a. Overcome the cooling effects of the strong central part, and,

b. Generate significant additional heating to drive the very strong greenhouse effect claimed by some scientists.

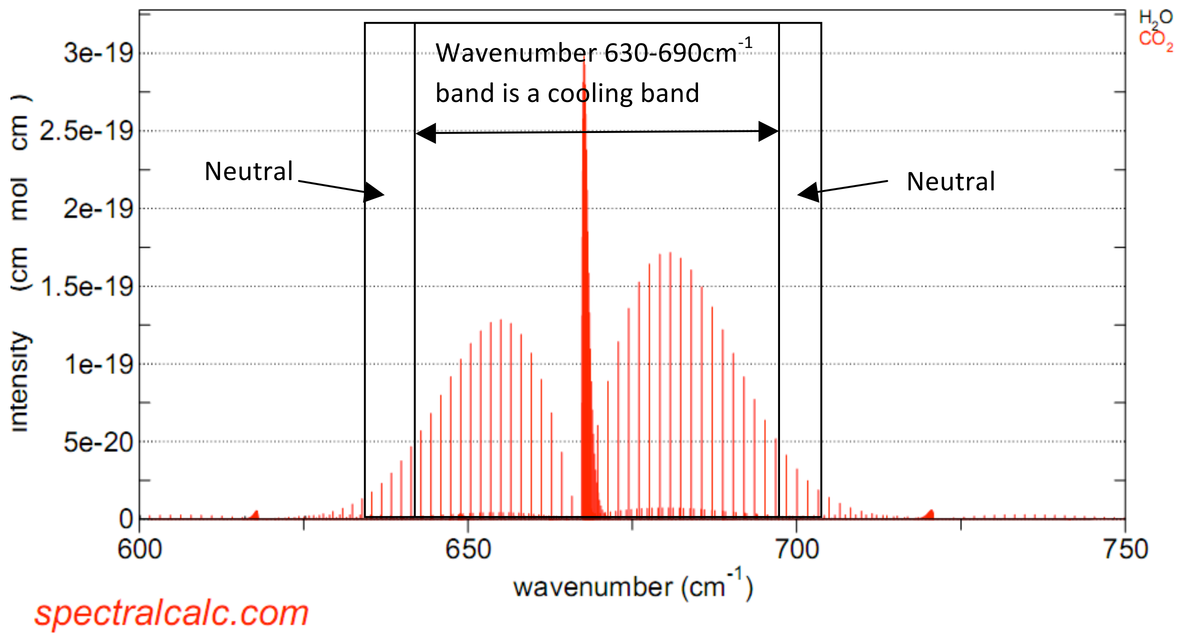

Figure 9: CO_2 emission/absorption spectrum, with indication of the band which would net cool the planet if CO_2 concentration is increased.