3. Radiative Forcing

The radiative forcing caused by a prescribed doubling of the pre-industrial (or present or any) CO_2 concentration is the imbalance in the Earth's radiation budget that is supposed to cause global warming. More CO_2 means more absorption of the infrared (IR) re-radiation which the Earth emits to space to compensate for the solar short wave irradiation. To restore the radiative equilibrium between warming and cooling, the average 15 °C ground which sends most of the thermal black body Planck emission directly to space, has to warm up slightly until the withheld energy – i.e. in our definition the increased back-radiation – is re-emitted.

The IPCC used the following definition, focusing on tropopause level conditions:

"The radiative forcing of the surface-troposphere system (due to a change, for example, in greenhouse gas concentration) is the change in net (solar plus longwave irradiance) in W/m² at the tropopause AFTER allowing the stratospheric temperatures to re-adjust to radiative equilibrium, but with surface and tropospheric temperature and state held fixed at the unperturbed values".

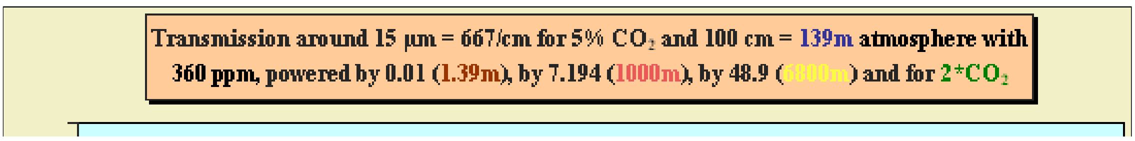
The often quoted additional absorption for CO_2 doubling within the troposphere is not the forcing itself, as formerly often (mis)understood by non-specialists, but it is the source of the (thermal) re-emission to ground which is based on the atmospheric energy equilibrium. This means, the re-emission at tropopause level plus the re-emission to ground (which causes the warming) is equal to the additionally absorbed energy.

Using HITRAN-1996 CO_2 transmission spectra from *Jack Barrett*, an Excel diagram (Fig. 3.1) was prepared for a range of 300 cm^-1 and 560 intervals. It shows the transmission, i.e. the intensity ratio **$T=I/I_0$** of an IR beam travelling from ground to the top of the troposphere, which would be a layer of 6800 m for ground pressure. T depends strongly on the wavenumber per cm (for example 15 µm means a wavenumber of 1/15*10^4=667/cm).

The data from HITRAN (high resolution transmission molecular absorption database by *L.S. Rothman et al.*) are extinctions **E=-log(T)** (or line intensities, linestrengths) given per CO_2 molecule for each individual peak wavenumber. The resolution is extremely precise, about 0.0005 cm^-1. To cope with the optical density, the molecular extinction is multiplied by the number of molecules (the troposphere contains about 4.1 kg CO_2/m²). HITRAN integrates the linestrengths for each interval, coping with the peak shape, pressure and temperature dependency – but the fact that nitrogen is not neutral with respect to the CO_2 IR absorption which may be doubled, is omitted by HITRAN **[*H. Hug*, CHEMKON 7, 6-14 (Jan 2000)]**.

The absorption is **A=1-T**. The residual area in Fig. 3.1 (difference between the yellow 1*CO_2 and green 2*CO_2 spectra) is the CO_2 doubling absorption. Integrated to 16.8 cm^-1, this is **6.4 W/m²** when multiplied with a medium Planck radiation of 0.38 W/m²/cm^-1 for 288 K in the range around 15 µm. The total absorption for 1*CO_2 amounts to 74 W/m². Whether and how much N_2 may effect the CO_2 residuals, is not yet cleared.

This absorbed energy depends very little on the layer thickness (optical density) and is thus not at all sensitive to the accuracy of absorption within the troposphere (which was here simply powered up according to the Lambert-Beer law, based on a 139 m equivalent probe, to show the layer characteristics). Let us assume the residual absorption for CO_2 doubling to be **7.4 W/m²** in total, coping with the missing part of the yellow and green spectra at the left and right side of the diagram – here considering as well the missing *hot bands* around 960 und 1064 cm^-1.



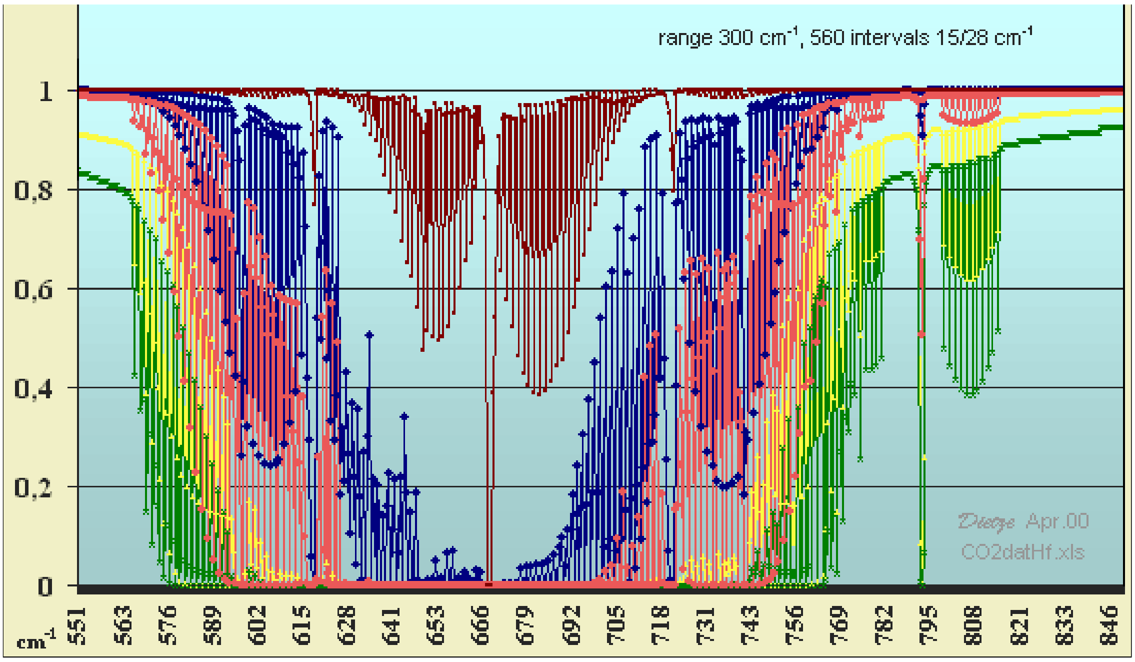
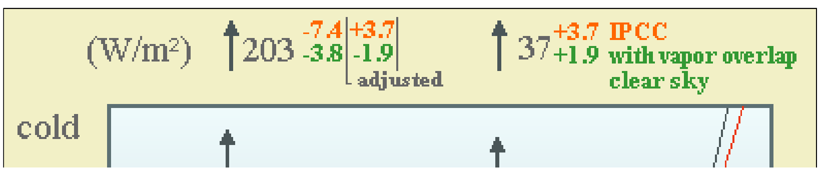


Fig. 3.1: HITRAN transmission diagram based on data for 5% CO_2 and 100 cm at ground pressure

The absorbed radiation is mostly thermalized and dissipated (acc. to *J. Barrett* and *H. Hug*). In thermal equilibrium this energy is re-radiated by atmospheric components as CO_2 (double density yields double emission for the same temperature) and partly by other GHGs – the latter only in case the temperature profile shifts, contradicting the IPCC definition. In this case convective and latent heat processes would become involved in additional vertical energy transport. All these have to end up in thermal re-emission at tropopause level, directed to both sides, space and ground. Whereas the lower atmosphere warms, the upper atmosphere is cooling (thus increasing the lapse rate) – here doubled CO_2 takes over a part of the emission from the other GHGs.

As all re-emission has to be considered as being bidirectional, we can assume in first approximation that half the total re-emission goes to space and half goes to ground. So we yield the new (by 15% reduced) IPCC TAR forcing of **3.7 W/m²**, as shown in Fig. 3.2. But the emission depends on the 4th power of the absolute temperature. So if we assume the bulk radiation temperature near ground (500m) as 285 K and in the upper troposphere (5500m) as 255 K, the upper emission should be only 64%. On the other hand we find very little water vapor in the upper troposphere, whereas the vapor near ground considerably absorbs the CO_2 emission. We have a mixture of up and down radiation, absorption and thermal re-emission, normally being evaluated using the Schwarzschild radiative transfer equation. Here we only consider the sum of re-radiation which is known. As the correct ratio of the two emissions cannot easily be determined, it seems reasonable to assume that the total emission is split about 1:1.

Important to mention that IPCC's forcing *for clear sky conditions* is meant for *well mixed* GHGs, i.e. without water vapor overlap **[*G. Myhre, J. Highwood, P. Shine, F. Stordal* in Geophs. Res. Letters 25, 2715-2718 (July 15, 1998)]**. IPCC argues that at tropopause level the water vapor density is negligible, which is true – but in reality the forcing stems from absorption and back-radiation within the *lower troposphere* near ground where we find the bulk of water vapor. As by vapor overlap here practically the low frequency part (i.e. about 50%) of the radiative forcing residual is cancelled (see below), we take **1.9 W/m²** as radiative forcing (Fig. 3.2).



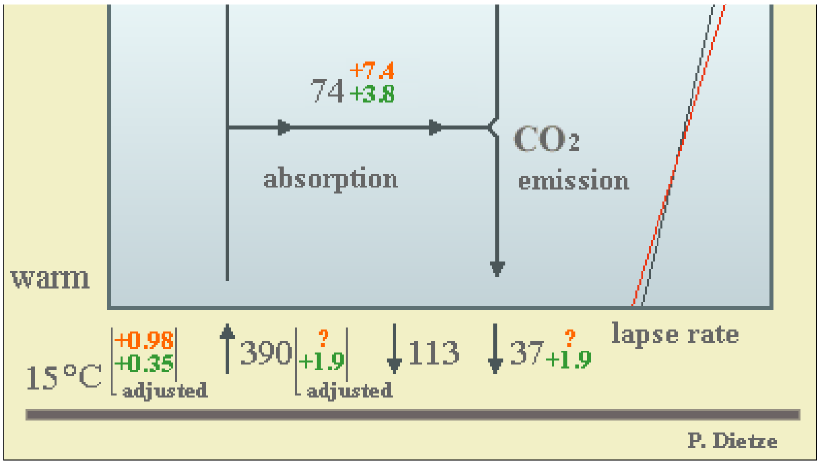


Fig. 3.2: Radiative fluxes and forcing for CO_2 doubling, atmospheric thermal equilibrium model

Now the IPCC errors become very obvious. Using the former forcing of 4.3 W/m² for tropopause level, application of the differential form of the Stefan-Boltzmann law **dT/T=1 /4·dS/S**, with S=240 W/m² and T=255 K, yielded a temperature increment of dT=1.14 K (which is now reduced to 0.98 K with 3.7 W/m²). The IPCC assumed that this increment that doesn't exist as the upper atmosphere is rather cooling, would be transmitted 1:1 down to the ground, based on a constant lapse rate. Because water vapor is a strong greenhouse gas, the IPCC then used a factor of 2.2 as the effect of water vapor feedback – neglecting that on the other hand vapor should also *reduce* the radiative CO_2 forcing – and thus obtained a warming of 2.5 °C for CO_2 doubling, the 'best guess' – so called by *T. Wigley* and *S. Raper* in a review paper **[Nature 357, 293-300 (1992)]**). *D. Rind* titled his article about the feedback approach "Just add Water Vapor" **[Science 281, 1152 (21 Aug 1998)].**

But as observations did not support the exaggerated warming, the IPCC assumed, the discrepancy was an effect of aerosol cooling while other effects (e.g. amplification of solar forcing) were considered to be insignificant. Their exaggerated aerosol cooling and the gain in parameter variability was ideal to maintain a far too high CO_2 climate sensitivity, thus compensating for missing solar forcing amplification and any other model discrepancies, just as required.

Of course, the argument exists that the amount of near ground moisture will increase with warming, and water vapor is a strong greenhouse gas. This argument depends on IPCC's questionable assumptions of total transfer of an unrealistic upper troposphere warming to the lower atmosphere, and a strong water vapor feedback. But here we have to consider a feedback damping because the more IR is absorbed around 15 µm by water vapor, the less remains for CO_2 to be absorbed in the same overlapping bands, and the water vapor absorbtion capability is mostly saturated in this region of the IR spectrum, though not in other parts. According to a mean ratio of 1.34 between clear sky and cloudy sky forcing **[Tab.1 and Tab.2 in *G. Myhre et al.* (1998), see above]** we can adapt our forcing of 1.9 W/m² to **1.4 W/m²** for cloudy sky condiditions. So at *ground level* and 288 K with 390 W/m², the radiative equilibrium warming of **0.35 K** in Fig. 3.2 has to be modified to **0.26 K**, any water vapor feedback not yet being included. We follow *R. Lindzen* who claims a considerably smaller feedback and we assume a factor of about 1.6 (half of IPCC's). The ground warming would increase to about **0.42 K**, a factor six less than IPCC's climate sensitivity.

The solar fraction analysis sensitivity (see above) is by a factor three less than IPCC's 2.5 K. If we would assume a factor 2.2 for water vapor feedback, our doubling sensitivity would become **0.57 K**, still 33% less than the solar fraction analysis figure. These values do not require an assumption of enforced aerosol cooling because they provide better agreement with observations than IPCC's 'best guess' sensitivity.

As most of the absorption for CO_2 doubling occurs near ground – a doubling test for 139 m already yielded 6.5 W/m² (88% of 7.4 W/m²) – the water vapor overlap should mostly cancel the left residual (and btw. some fraction of the right one as well). *H. Fischer* has shown this in a graph of a position paper of the German Meteorological Society (DMG), which advocates the greenhouse effect. The "residuals" are the differences in transmission between 1*CO_2 and 2*CO_2 (Fig. 3.3). We can estimate the cm^-1 area of the right residual (the left was cancelled because the water vapor transmission is very small here) and multiply with the associated Planck radiation per cm^-1. The radiative clear sky forcing represented by this DMG residual is **1.7 W/m²** only, of which 0.3 W/m² stems from the hot band around 960 cm^-1. So our **1.9 W/m²** forcing in Fig. 3.2 is likely. *H. Fischer* used HITRAN data and apart from water vapor overlap he coped with other greenhouse gases and with thermal CO_2 emission depending on atmosphere temperatures.

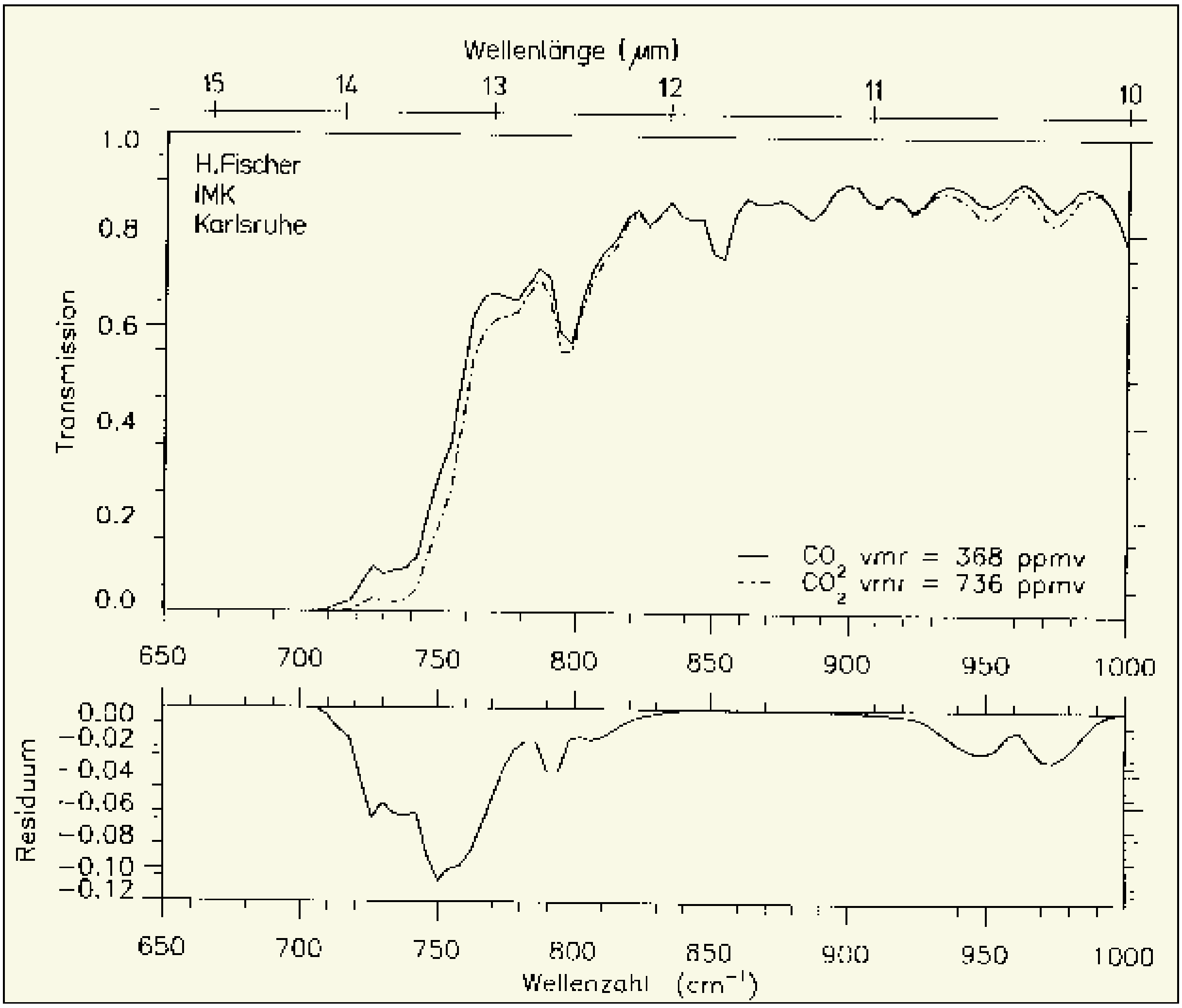


Fig. 3.3: German DMG residual (*H. Fischer*, IMK Karlsruhe 1999)

IPCC authors so far refused to disclose details about the modelling assumptions and computation of their core parameter, demanding us to believe in their results – which is an unprecedented offence against rules in public funded science, and the TAR again follows this line. A graph about radiative forcing of the 1994 IPCC report is shown in Fig. 3.4. As the left residual is not cancelled, here obviously water vapor overlap has hardly been considered, contrary to the statement in the note on p.174 and the approach of *H. Fischer*. Each residual area in W/m² from net irradiance at tropopause level roughly matches the one in Fig. 3.3 when logarithmically adapted to CO_2 doubling, though IPCC claims having even coped with cloud effects. *R.D. Cess et al.* state in "Uncertainies in CO2 Radiative Forcing in Atmospheric GCMs" **[Science 262, 1252 (19 Nov 1993)]** "The forcing is substantially reduced through radiative overlap of the CO_2 absorption bands by the absorption of water vapor" and "Clouds also reduce the forcing".

Surprisingly the IPCC residuals (Fig. 3.4c) come together at 15 μm, whereas in Fig. 3.3 they would be about 70 cm^-1 apart from each other. The IPCC residuals were calculated with radiative transfer equations, using the standard narrow band code of *P. Shine* 1991 – both not been published by IPCC and obviously available within the 'community' only. Residuals show a broad gap inbetween when only absorption is considered. Coping with thermal emission, they are shifted towards the 15 µm center – the more, if only a fractional layer (e.g. upper troposphere) is evaluated. Their area (which is important) only changes little. More details see at Estimation of the Radiative Forcing for CO2 doubling and discussion.

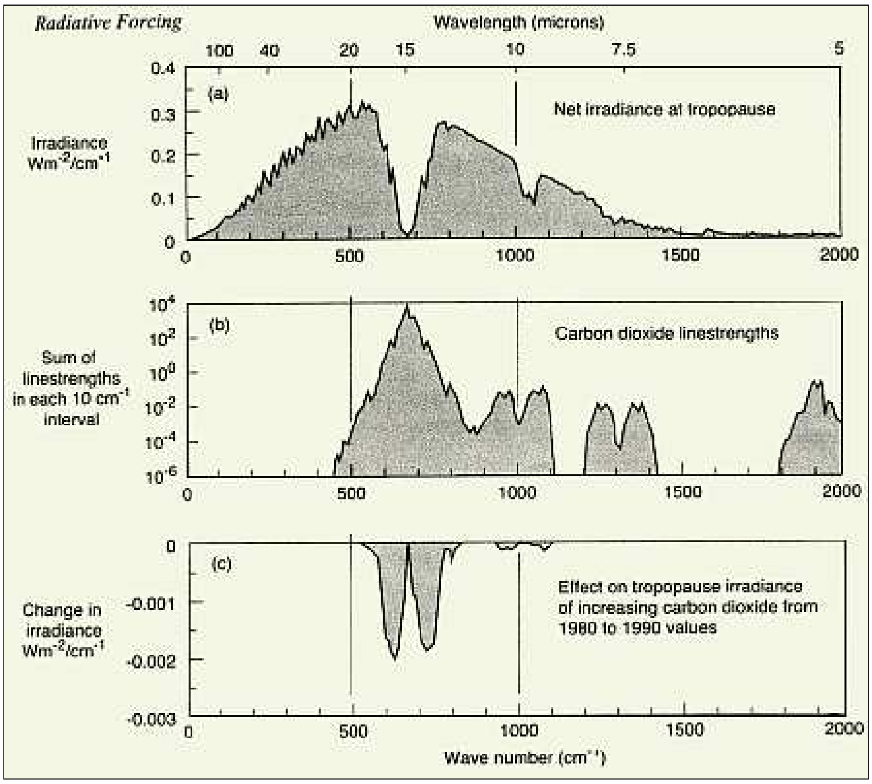
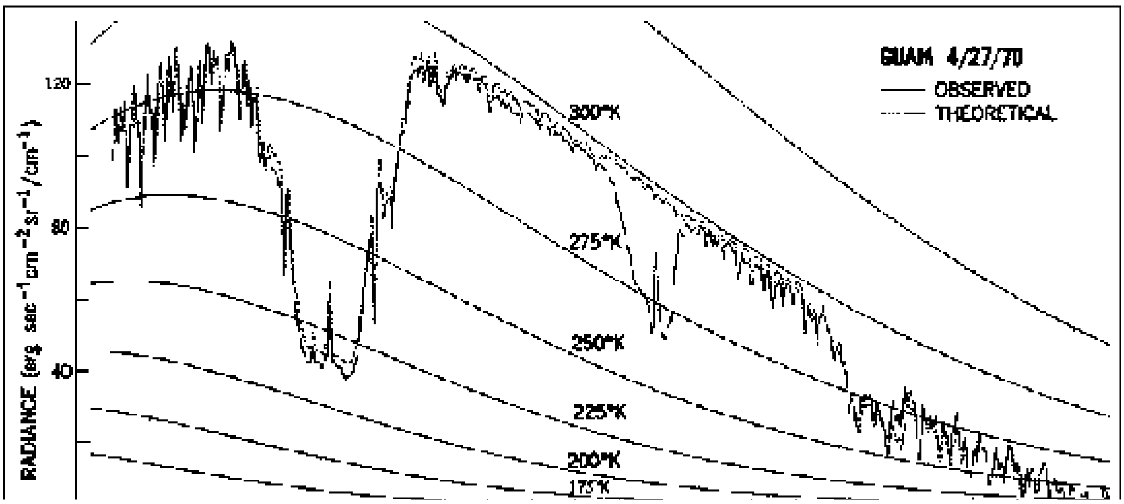


Fig. 3.4: IPCC 1994 p.175 radiative forcing figure 4.1

In Fig. 3.4a IPCC did not correctly model the emission characteristic to be seen in satellite measurements (Fig. 3.5) which does not show a zero emission at the bottom of the funnel around 15 µm, but a thermal emission of about 120 mW/m²/cm^-1 (the steradian-related value of 38 erg/(sec cm²) has to be multiplied by p though one would expect it to be 2p for one direction). This left out emission, being about 4 W/m² for the 1⋅CO_2 base case, results in a too high radiative forcing as it causes an increased part of the radiative energy being withheld at tropopause level in case of CO_2 doubling. The satellite clear sky measurements taken above Guam in 1970, with added theoretical black body emission curves, clarly show the water vapor impact below 575 cm^-1, a thermal tropopause CO_2 emission peak from the bottom of the absorption funnel at 667 cm^-1, the ozone absorption around 1050 cm^-1 and the methane and then water vapor absorption beyond 1250 cm^-1.



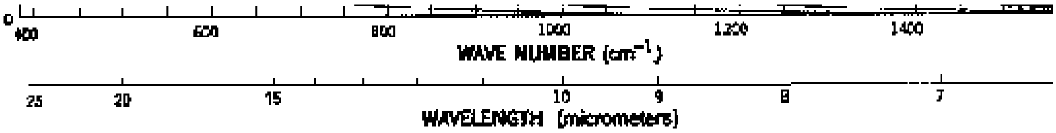


Fig. 3. Comparison of observed and theoretical radiances for a clear atmosphere near Guam at 15.1°N and 215.3°W, on April 27, 1970.

Fig. 3.5: Satellite spectrum (*Kunde,* 1974)

For a long time we had a controversial discussion about discrepancies between satellite MSU measurements (about 1-5 km height, indicating hardly any warming trend), and ground station readings, see as well http://www.john-daly.com/graytemp/surf-msu.htm#Dietze1. Using IPCC's flexible aerosols, *Ben Santer, Tom Wigley et al.* tried to model-experiment away and downplay this problem **[Science 287, 1227-1232 (18 Feb 2000), see as well *D.E. Parker* on p.1216]**. The warming effect from radiative CO_2 forcing occurs mostly near ground. So the GCMs which assume a parallel shift of the troposphere temperature profile (as e.g. *J.F.B. Mitchell* and *Sir John Houghton* formerly stated), instead of coping with an increased lapse rate (see Fig. 3.2), erroneously assume a well and fastly mixed troposphere.

Even the 1st TAR draft Ch.6 p.6, line 52-54 still said that surface and troposphere are closely coupled, the thermal structure being determined by a nominal lapse rate, all thus behaving as a single thermodynamical system. Because of the increasing lapse rate satellites measure a mix of cooling and warming and thus can principally not replicate the ground temperature trend.

Actually, if we apply proper physics, i.e. cooling of the upper troposphere for increasing CO_2, and we use IPCC's constant lapse rate, the ground should indeed be cooling (!) instead of warming. This demonstrates one of the most absurd errors of IPCC.

H. Volz found an essential error source in ground temperatures when calculating that the energy used in Germany, being radiated off across the area of the country acc. to Stefan-Boltzmann, would already cause an average temperature increment of 0.7 °C (!). This increment remains rather constant as well as our energy demand and does hardly increase with the CO_2 concentration. So this can neither be allocated to the CO_2 increment nor be subject to future CO_2 projections. An energy related ground bias may occur as the number of stations in developed and energy intensive countries is quite large. It is not known to what degree such effects have been corrected by IPCC.

4. Conclusions

The estimation of radiative forcing done here, shows that IPCC's CO_2 climate sensitivity has indeed to be reduced considerably, just resulting in a rather harmless (if not beneficial) warming till 2100. The corrections applied (as well as those for IPCC's seriously flawed carbon cycle model), would completely turn over all simulation results presented in the TAR.

The temperature trend of ground readings (especially because of unreliable ocean surface measurements) should not be (mis)used as a "proof" for the correctness of the highly erroneous CO_2 sensitivity parameter on which the IPCC model results are based on. A considerable part of the observed ground warming has to be allocated to amplification of solar forcing (via cloud coverage), as well as to urban heating and forest clearing (i.e. reduction of evaporation).

Within this century a reduction of emissions is indeed not at all necessary, as in 2090 most of the usable fossil fuel (estimated as 1300 GtC) will be depleted and the CO_2 concentration will not even be 550 ppm. When fossil reserves become rare, technology can be expected turning to bulk power production from fusion reactors and thorium breeders anyway. The latter alone will be able to supply mankind with the presently used amount of energy from oil and gas for 10.000 years.

A calculation of *Tom Wigley* (NCAR) **[Geophs. Res. Lett. 25, 2285-2288 (1998)]** shows that for compliance of developed nations with Kyoto, the temperature effect till 2050 will be only 0.07 °C. As IPCC uses a far too high climate sensitivity, **the realistic effect should be about 0.02 °C only**. Energy and CO_2 taxing within the EU will yield a contribution for temperature reduction of **0.002 °C only**. Contrary to the serious economic impacts, the temperature effects of claimed emission reductions are absolutely negligible. So the international bureaucratic activism to enforce Kyoto seems rather useless and ridiculous. The planned emissions trading requires the installation of a harmful eco-fascist repression bureaucracy, CO_2 counsils to allocate emission grants and limits to individual industries and carbon taxes to curb the folks. The permit to burn a ton of coal beyond the limits may cost 150 US$, four to five times the price for importing a ton of coal. Reporting and controlling facilities and drastic punishments are required as well – being already planned in most details (see the Greenbook of the EU commission) – and the WTO will trade-sanction governments that do not comply with the CO_2 restrictions.