Experimental verification of the greenhouse effect

1. Communication: The mutual influence of clouds and greenhouse gases

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Abstract

A novel test set-up with which the greenhouse effect of the IR-active gases can be tested experimentally is presented. The IR radiation of these gases is measured against a much colder background. The experimental setup simulates the effects of greenhouse gases under a cloud layer and can therefore contribute to the discussion and understanding of the greenhouse effect. This first paper presents the design and basic characteristics of the equipment used and a test with propane as a powerful greenhouse gas. The focus is on the question of how two radiation sources of different temperature and topographical arrangement influence each other. The simple experimental concept is suitable to convey the effect of atmospheric greenhouse gases as well as the mitigation (relativization) of their greenhouse effect through clouds to a broader public.

1. Introduction

The first attempts at explaining the CO2 greenhouse effect were derived from IR absorption spectroscopy. In this measurement method, an IR light beam from a high energy density radiation source is passed through a cuvette filled with CO2, whereby an attenuation of its intensity is detected. The energy, absorbed by CO2 leads to a slight heating of the cuvette. If this method of measurement is applied to the Earth, the Earth's surface is the radiation source and the atmosphere is the cuvette with certain CO2 content.

In climate research, it is common to consider the atmosphere as a whole and to measure the atmospheric IR radiation with an emission spectrometer from a satellite (upwelling radiance, TOA = top of the atmosphere). However, when interpreting these spectra, it should not be forgotten that around 60% of the Earth's surface is covered by clouds or haze and that they cause the greatest uncertainty in climate modelling (1).

Clouds hinder the IR radiation of the earth through reflection, scattering, absorption and re-emission. In addition, energy flows can be influenced by phase transitions (latent heat), turbulences, airflows, and fall and upwind. A laboratory apparatus will not be able to simulate all these factors, but should contain at least two surfaces with different temperatures, for the Earth's surface and for a cloud layer. Simple devices that have been irradiated from the outside like a greenhouse do not meet this requirement. Transparent but closed rooms heat up when exposed to sunlight, because they mainly prevent the escape of heated indoor air (2), (3).

A cloud layer is usually colder than the Earth's surface and therefore can receive energy from the Earth through IR radiation, heat conduction, convection, and evapotranspiration. The new concept for the verification of the greenhouse effect is based on the energy transfer that occurs through IR radiation. The experimental apparatus contains as IR transmitter a warm surface and as IR receiver a cold surface with the same temperatures, which are also typical for earth and clouds. In this first paper, only the IR radiation from the cold to the warm surface is examined. Since this radiation direction contradicts the predominant energy transport from warm to cold, it is also referred to as counterradiation. The warm surface, called the earth plate, is influenced by this IR irradiation (counterradiation) and is the focus of the investigation. The apparatus simulates a surface of the Earth under clouds and can thus be regarded as a model of the near-earth atmosphere. If the tube is filled with IR-active gases, a possible greenhouse effect of these gases under natural conditions can be investigated.

An entirely different method for the experimental proof of the greenhouse effect is based on the construction of an IR spectrometer (4). Even the title "Absorption thermischer Strahlung durch atmosphärische Gase" reveals that not the IR radiation, but only the absorption of the greenhouse gases is studied which is characterized by a warming. This warming of CO2-containing air, observed in many experiments, was originally a "simple" explanation for the relatively high earth temperatures. However, this has largely changed. The realisation that most of the IR radiation into space is not from the Earth's surface, but from the atmosphere led to a new understanding of the heat fluxes. Today's climate models assume an IR radiation of 240 W/m^2 at the top of the atmosphere (TOA) (5). According to the IPCC, CO2 has influenced this radiation balance, which was called radiative forcing RF, an external force. The change of this radiative forcing dF was described by a logarithmic ratio of the CO2 concentration C (in ppm) to a pre-industrial concentration C_0 of 280 ppm.

Equation 1: CO2 radiative forcing: $dF = 5.35 \cdot \ln(C/C_0)$ W/m^2

According to the differential form of the Stefan-Boltzmann law ($dT = dS/S/4 \cdot T$) a temperature increase of 1.11 K per CO2 doubling (IPCC basic value = CO2 climate sensitivity) is calculated, however, without taking into account clouds, water vapor and feedback (6).

Equation 2: CO2 climate sensitivity: $dT = 5.35 \cdot \ln(2)/240/4 \cdot 288 = 1{,}11$ K

NASA satellites measured above the atmosphere (TOA) in addition to the IR radiation of 240 W/m^2 a solar reflection of 101 W/m^2 (= 30% of the 341 W/m^2 solar radiation, Albedo = 0.3). These values led to the hypothesis that an earth without an atmosphere would have a temperature of -18 °C (Figure 1 , A) and allegedly heated by greenhouse gases by 33 K to a temperature of + 15 °C[1]. A calculation with a flaw, but the bare Earth's surface has only an Albedo of 0.15 = 51 W/m^2 (7), (8), (9). The 30% reflection (spherical Albedo, measured by the satellite) is only achieved together with the clouds. The term "Earth without atmosphere" proves to be wrong and should be called "Earth with Clouds" correctly.

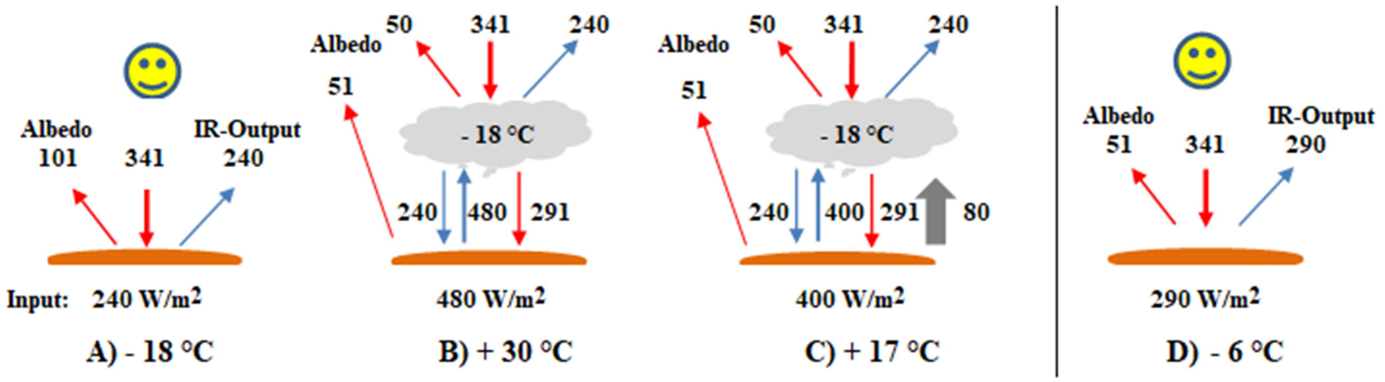

Figure 1: Energy balances (W/m^2) and Earth temperatures (°C): Solar radiation (red), IR radiation (blue), water evaporation (grey) with/without clouds; Albedo 101 (A - C) and 51 (D) W/m^2

With the help of the clouds, the Earth Albedo (Earth cooling) could be doubled from 51 to 101 W/m^2, reducing the earth input to 240 W/m^2 and giving - 18 ° C according to the calculation in footnote 1. If one already takes the "cold" side of the clouds into the radiation calculation, one should also consider their IR emissions, their warming side. A thought experiment (Figure 1, B + C) shows the dubiousness of trying to calculate an "earth with clouds, Albedo = 0.3". If one follows only the logic of a pure radiation exchange according to Figure 1 B, then an earth that is <u>completely</u> covered by clouds would have a temperature of 30 ° C (assuming that a cloud layer of -18 ° C permits IR radiation of 240 W/m^2, which emits it uniformly in all directions). This calculation is unrealistic because, as a pure radiation calculation, it ignores the energy flows that are involved in the formation of clouds. A realistic value for an "Earth with clouds" would be + 8 ° C if water evaporation and cloud coverage are considered[2].

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[1] In these energy balances, the earth temperature is calculated from the input energy; $T_p = (\text{Input} \cdot 10^8 / (5.67037 \cdot \varepsilon))^{0.25} + 273.15$ (Stefan-Boltzmann, ε = 1 as a simplified emissivity of the earth's surface).

[2] To determine a realistic temperature of an "Earth with clouds", one has to consider in addition to the radiation balances at least the water evaporation of 80 W/m2 (Figure 1 C, grey arrow). At 100% clouds covering then the earth temperatures would be + 17 °C. With a cloud cover of 60%, an "Earth with clouds" could have an approximate temperature of + 8 °C (40% A + 60% C).

The radiation calculations also reveal a surprise! Clouds have a similar radiation behavior as greenhouse gases (9). They allow around 85% of the sunlight to pass (15% are reflected, cloud albedo = 0.15; absorption should be neglected, red arrows), but not the IR light, which they scatter, absorb, emit much more strongly (blue arrows). Clouds and IR gases are collective components of the greenhouse effect with comparable but also different properties. IR gases only absorb certain wavelengths of the IR light, but they are distributed more evenly in the atmosphere. However, clouds that cover only part of the Earth can absorb all wavelengths of IR light as a black body. In contrast to IR gases, they also cause cooling of the Earth by reflecting the sun's rays, which makes their assessment so difficult.
The thought experiment shows that for an "Earth with clouds" (Figure 1, B + C) different, but above all, very high temperature values are obtained. The calculation according to Figure 1, A is a deliberate deception of the public, with the intention of attaching the greatest possible effect of 33 K to greenhouse gases.
An honest, unambiguous calculation with the "naked Earth" would have been quite possible, because it's Albedo = 0.15 (51 W/m^2) is known (9) and would have yielded a temperature range of - 3 ° C (ε = 0.96) to - 6 ° C (ε = 1, Figure 1, D). The actual, about 20 K higher earth temperature of + 15 ° C is the result of various influencing variables of a water planet with its clouds, greenhouse gases, water evaporations and currents of the atmosphere. The contribution of greenhouse gases to this temperature increase is still to be determined, but is definitely much smaller than 20 K[3].

Typically, the increase in CO2 is explained as a cause and not as a result of global warming. But if this is questioned, other interpretations arise. Cloud changes caused by cosmic events were also assumed to be the primary cause of temperature fluctuations (10). Also, a lower, man-made cloud cover (fine dust reduction by flue gas filter) could have caused a warming (11). In these cases, the increase in CO2 since 1750 could also be explained as a result of this global warming.

Assuming the 1/3 relativization of the greenhouse effect through clouds (chapter 6), 7 K could be the temperature increase of the greenhouse gases. This value would also fit footnote 1 (8 ° C + 7 K = + 15 ° C).

[3] Assuming the 1/3 relativization of the greenhouse effect through clouds (chapter 6), 7 K could be the temperature increase of the greenhouse gases. This value would also fit footnote 2 (8 ° C + 7 K = + 15 ° C).

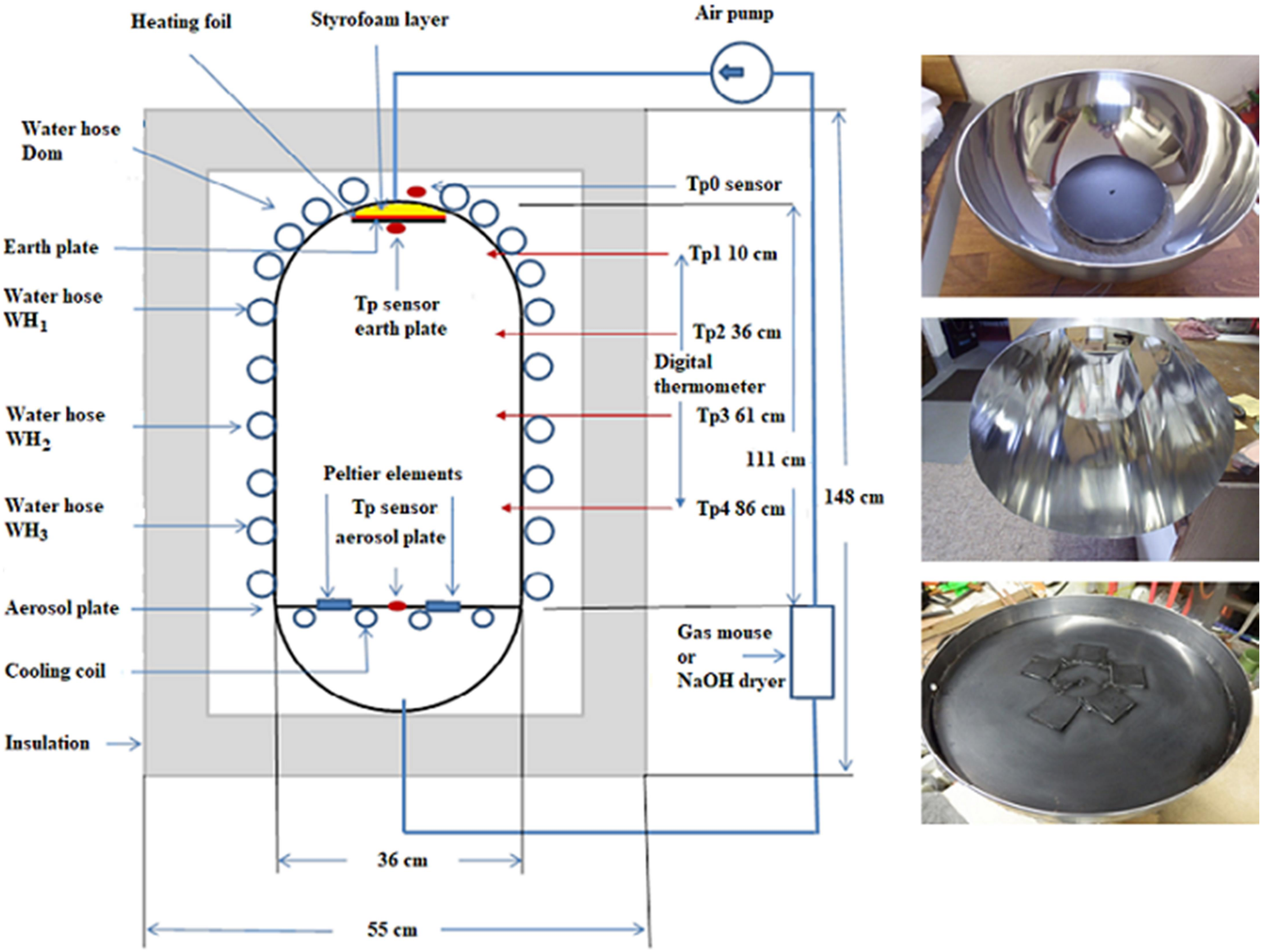

Figure 2: Left: Schematic setup of the experiment; Right from top to bottom: earth plate, aluminium tube and aerosol plate

2. Description of the experimental setup

The equipment used consists of a vertical aluminium tube with a volume of 107 litres and two dome-like ends (Figure 2). In it are two 1.11 m distant plates of different temperature. The top plate (earth plate) is both IR transmitter and receiver of an IR irradiation (counterradiation) and is controlled by an electric heating foil to constant 16.1 ° C. During a test, the electrical power required for a constant temperature of the earth plate is recorded.

The lower plate (aerosol plate) can be cooled down to -20 ° C by means of an integrated cooling coil and an external cooling unit. This plate is the receiver of the IR radiation at the end of the tube and at the same time simulates the IR radiation of clouds/aerosols. On it are 5 Peltier elements that register the IR transmission. Both plates have a temperature sensor whose values are forwarded to a computer via an A/D converter.

The hot and cold surfaces are housed in an aluminium tube, the wall of which becomes a third, unwanted radiant surface. The atmosphere has no equivalent for this area. The first task was to understand the influence of this wall, before the measurements of the IR gas radiations could be started. Looking from the earth plate, the wall of the aluminium tube is a foreground emitter and the cold aerosol plate is a cloud layer that produces background radiation.

The wall of the tube and the upper dome are wrapped with hoses supplied by two independent thermostats with constant water temperature. The earth plate is thus in a heat zone of similar temperatures, which minimizes the physical heat flow from the earth plate to their environment. The temperature of the interior of the tube is measured every 25 cm, starting with Tp_1 in the upper dome, with four digital penetration thermometers (Tp_1 -Tp_4) and is manually logged. In this area, from top to bottom, a negative temperature gradient of about 1 °C is formed. This prevents convection of the internal air in the vertical apparatus.

Figure 3: Heating foil under the earth-plate; Thermal insulation upper dome and sidewall; Hoses for Thermostats

3. The radiation behaviour of all the surfaces involved

The interior of the experimental apparatus contains three surfaces, earth plate, sidewall and aerosol plate, which can emit IR rays. In principle, every point of these surfaces emits IR radiation at a solid angle of 0 - 180 °[4]. All three surfaces exchange IR-rays (photons) with each other, whereby energy is transferred.

Fehler! Verweisquelle konnte nicht gefunden werden. shows the irradiation of the earth plate by the aerosol plate, where the earth plate and the wall are always at the same temperature. The aerosol plate is a background emitter with the IR emission M_B. Its photons can reach the earth plate directly or through (multiple) reflection on the mirrored wall surfaces. However, part of the background emission M_B is absorbed by the wall (dashed line) and does not reach the earth plate. The aerosol plate only contributes part of its emission M_B to the irradiation of the earth plate. This fraction is called effective background radiation E_B.

In Figure 4 A, the aerosol plate (blue) is colder than the wall ($Tp_B < Tp_F$). The IR emission of the wall E_F (red arrow) is greater than the absorbed energy from the aerosol plate (blue dash arrow). The wall here is a foreground emitter (letter "F") and must be additionally heated from the outside (wall heating Q_F, energy for the foreground) to compensate for the energy loss[5].

In Figure 4 B, all three surfaces have the same temperature. According to the Kirchhoff law the absorbed photons from the aerosol plate (red) and the emitted photons of the wall E_F are equal. The irradiation of the earth plate by the aerosol plate is not hindered de facto (adiabatic radiation transport). The wall needs no energy supply, it is energetically neutral.

[4] The IR-emission of these surfaces is hereinafter referred to as "M" and the irradiation as "E".

[5] The energy flow of the wall heaters Q_F was not determined.

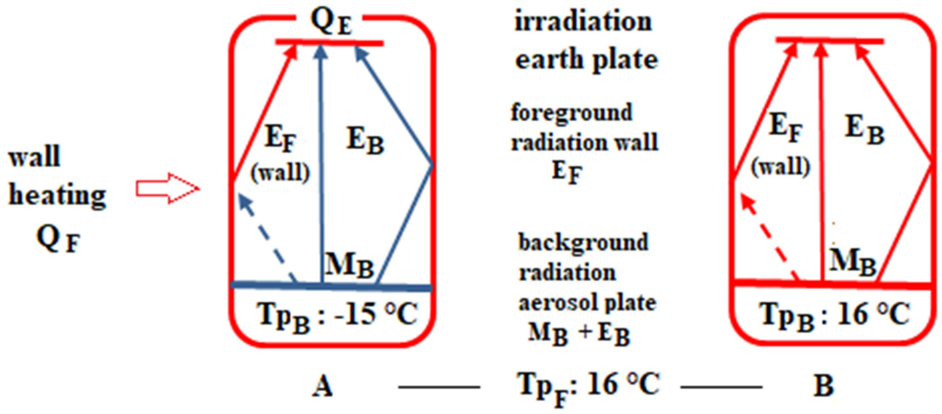

Figure 4: Irradiation of the earth plate by the aerosol plate: A: $Tp_B < Tp_F$; B: $Tp_B = Tp_F$

The energy balance of the earth plate is to be determined. Each solid (and liquid) body with a temperature > 0 K emits IR rays, which can be calculated according to Stefan-Boltzmann. The IR emission of the earth plate (M_E) is associated with a loss of energy. For a constant temperature, the earth plate has to be supplied with the same amount of energy that it lost through its IR emission. The energy is supplied by irradiation E_C ("C" = counterradiation = sum of the radiations of wall $E_{F(wall)}$ and aerosol plate E_B) and heating of the earth plate Q_E (Equation 3).

Equation 3: Energy balance of the earth plate: $M_E = E_C + Q_E$; $E_C = E_{F(wall)} + E_B$; $M_E = E_{F(wall)} + E_B + Q_E$

4. The effective background radiation of the aerosol plate E_B

The irradiation of the earth plate through the aerosol plate is to be investigated by a cooling experiment (response experiment).

Experiment Description: The temperature of the two thermostats and the cooling unit for the aerosol plate were set at 16 °C. The earth plate showed a temperature (Tp_E) of 16.09 °C. The electric heating Q_E (indicator of the counter-radiation) and the electrical voltage of the Peltier elements U_B (indicator of outgoing radiation of the tube) were almost zero. The temperature of the cooling unit was then lowered to-24 °C in five steps, whereby the temperature of the aerosol plate Tp_B decreased to -19.58 °C. The heating Q_E had to be increased continuously to ensure a constant temperature of the earth plate Tp_E (Tab 1).

Table 1: Response experiment (# 145) without IR gases

Tp_E °C	Tp_B °C	Tp_1 °C	Tp_2 °C	Tp_3 °C	Tp_4 °C	Q_E W/m^2	U_B mV
16,09	15,89	15,90	15,90	15,85	15,70	0,13	-0,25
16,09	1,08	15,55	15,55	15,50	15,10	55,01	47,80
16,09	-5,83	15,50	15,40	15,40	14,80	77,83	69,55
16,09	-9,99	15,40	15,30	15,20	14,70	91,75	81,60
16,09	-15,03	15,25	15,20	15,10	14,50	107,02	95,75
16,09	-19,58	15,20	15,10	15,05	14,30	120,88	108,25

Tp_E, Tp_B = Temperatures of earth, aerosol plate and wall thermometers Tp_1 to Tp_4

Q_E = Heating the earth plate, U_B = voltage generated by the Peltier elements on the aerosol plate

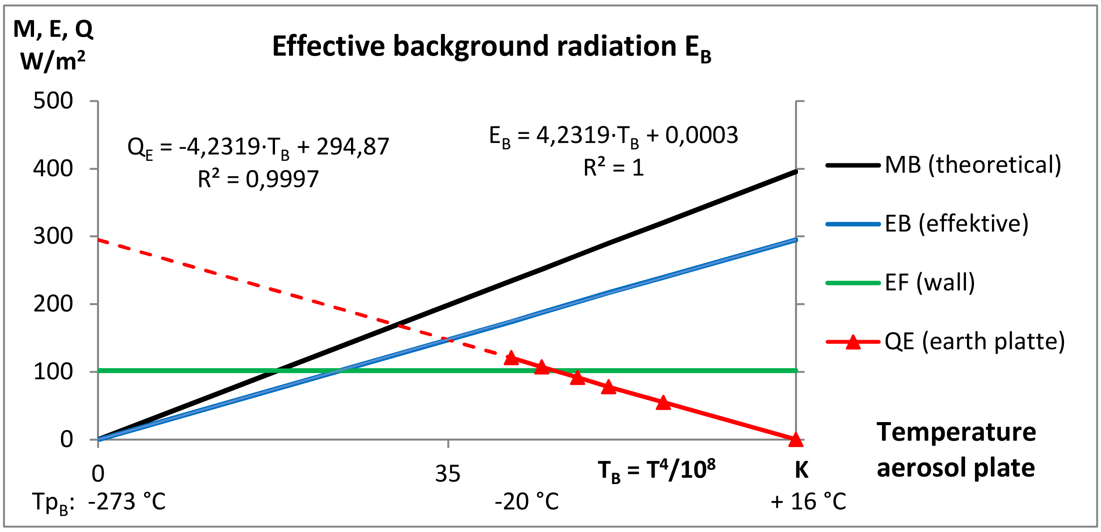

Figure 5: Determination of the effective background radiation of the aerosol plate E_B (blue line)

Evaluation (Figure 5**):** The temperature of the aerosol plate is plotted as an X-axis in the form of $T^4/10^8$.[6] The theoretical IR emission of the aerosol plate M_B (black line) is calculated according to the Stefan-Boltzmann law (ε = 1). When cooling the aerosol plate from Tp_B = + 16 to -20 ° C, the electric heating $Q_E(T_B)$ was increased five times (red line). Should the aerosol plate be further cooled (red dashed line), the required heating of the earth plate Q_E could be calculated from the trend line $Q_E = -4.2319 \cdot T_B + 294.87$. At T_B = 0 K (absolute zero point), the heating Q_E would be 295 W/m^2. Since at this temperature the aerosol plate does not generate IR radiation, Equation 3 can now be converted into Equation 5 and the foreground radiation of the wall E_F is calculated to 102.0 W/m^2 (green line). The IR emission of the earth plate M_E is 397 W/m^2 (Stefan-Boltzmann).

Equation 4: Radiation of the wall E_F (T_B = 0):

$$M_E = E_F + Q_E(T_B{=}0)$$
$$E_F = M_E - Q_E(T_B{=}0)$$
$$E_F = 396.87 - 294.87 = 102.0\ \mathrm{W/m^2}$$

The effective background radiation of the aerosol plate $E_B(T_B)$ (blue line) is calculated according to equation 6 from the slope of the trend line dQ_E/dT_B.

Equation 5: Effective background radiation $E_B(T_B)$:

$$M_E = E_B(T_B) + E_F + Q_E(T_B)$$
$$E_B(T_B) = M_E - E_F - Q_E(T_B)$$
$$E_B(T_B) = dQ_E/dT_B \cdot T_B$$

From the theoretical emission of the aerosol plate M_B, the earth plate receives only a certain amount of E_B (the effective background radiation), since some of the photons are absorbed by the wall (black vs. blue line). However, the experiment also shows that the earth plate receives energy E_B from the aerosol plate, although the latter has a lower temperature $Tp_B < Tp_E$. The irradiation of the earth plate by the aerosol plate is not a violation of the second law of thermodynamics, since ultimately the total heat flow continues to always flow from the warm earth plate to the cold aerosol plate, which can be seen by heating or cooling of both plates.

It is in the nature of the "response experiments" that the reverse direction of radiation, the IR irradiation of the **aerosol plate**, cannot be evaluated. The gradual cooling of the aerosol plate overlays irradiations and mechanical heat fluxes (diffusion and heat conduction) and is only displayed as sum U_B by the Peltier elements on the aerosol plate. The irradiation of the aerosol plate can be determined, however, if the emissivities of greenhouse gases at constant temperatures of all surfaces involved are determined. This should be reported separately.

[6] The term $T^4/10^8$ is taken from the Stefan-Boltzmann equation, which produces a linear function between radiation and temperature in Kelvin (T = Tp_B + 273.15) with the increase 5.670367 ($\sigma \cdot 10^8$).

5. The effective background radiation E_B in the presence of propane

In order to investigate the collective IR radiation of clouds and near-Earth IR gases, two response experiments in the presence of 1.3 and 60% by volume propane (IR-active model gas) were performed (Figure 6). In the presence of propane, the necessary heating of the earth plate Q_E decreases (red lines). From the trend lines Q_E, as described in chapter 4, the foreground radiations E_F (green lines, according to Equation 4) and the effective background radiations of the aerosol plate E_B (blue lines, according to Equation 5) are obtained.

Increasing the propane concentration causes opposing changes. On the one hand, the foreground radiation E_F increases from 130 to 272 W/m² (green lines)[7], and on the other hand, the effective background radiation of the aerosol plate dE_B/dT_B decreases from 3.88 to 1.81 (blue lines). Propane absorbs the photons of the aerosol plate (background radiation) and replaces them with its own IR emissions. The actual influence of the aerosol plate (blue line) on the heating of the earth plate Q_E decreases, although its actual emittance M_B (black line) is unchanged. From the perspective of the earth plate, the background radiation is obscured by the foreground radiation of the propane[8].

This phenomenon is the reason that the IPCC believes that the contribution of clouds to the near-Earth greenhouse effect is only 30 W/m² and that the actual, almost ten times higher background radiation of the clouds M_B was overlooked (9). Ultimately, it has meant that the mitigating effect of background radiation on the greenhouse effect has not been explored.

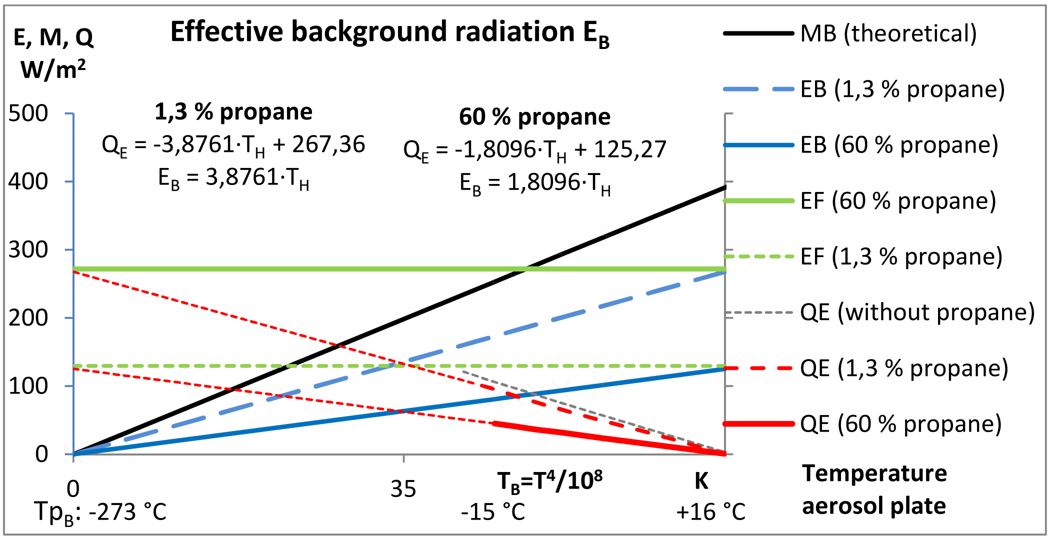

Figure 6: Reduction of the effective background radiation of the aerosol plate E_B by propane

Table 2: Response experiment (# 212) in 1.3 vol.-% propane

Tp_E °C	Tp_B °C	Tp_1 °C	Tp_2 °C	Tp_3 °C	Tp_4 °C	Q_E W/m²	U_B mV
16,09	15,20	16,10	16,10	16,10	16,50	0,00	2,90
16,09	7,06	15,90	15,85	15,85	15,80	28,87	32,50
16,09	-0,36	15,70	15,75	15,60	15,50	51,68	58,90
16,09	-7,41	15,60	15,65	15,40	15,20	72,75	82,90
16,09	-11,06	15,50	15,60	15,30	15,15	83,89	95,15
16,09	-15,32	15,45	15,45	15,30	14,95	96,88	107,95

[7] $E_{F\ 1,3\,\%}$ = 130 W/m² = 397 (M_E) -267 (Q_E(0 K)); $E_{F\ 60\,\%}$ = 272 W/m² = 397 (M_E) -125 (Q_E(0 K))

[8] The same applies to the non-visible aerosols, which are also background emitters.

Table 3: Response experiment (# 156) in 60 vol.-% propane

Tp_E °C	Tp_B °C	Tp_1 °C	Tp_2 °C	Tp_3 °C	Tp_4 °C	Q_E W/m^2	U_B mV
16,09	15,46	16,10	16,00	16,00	15,90	0,00	1,20
16,09	0,51	15,90	15,70	15,45	14,95	23,31	62,65
16,09	-5,03	15,85	15,65	15,30	14,60	31,69	86,55
16,09	-8,50	15,70	15,60	15,30	14,35	36,29	100,20
16,09	-11,58	15,65	15,55	15,20	14,20	40,60	112,30
16,09	-14,67	15,60	15,35	15,10	14,10	44,93	124,35

6. The relativization of propane radiation

The collective irradiation of the earth plate E_C from now three radiation sources (wall, propane and aerosol plate) results from the sum of the two foreground emitters ($E_{F(Wall)}$ and $E_{F(Propane)}$) and the effective background radiation the aerosol plate $E_B(T_B)$ (Equation 7).

Equation 6: Irradiation of the earth plate E_C: $E_C = E_{F(Wall)} + E_{F(Propane)} + E_B(T_B)$

Due to the additional foreground radiation of the propane $E_{F(propane)}$, the irradiation of the earth plate E_C increases (Figure 7, red lines), which reduces the radiation cooling of the earth plate P_E (the difference between its IR emission M_E and its IR irradiation E_C) (Equation 7).

Equation 7: Radiant cooling P_E: $P_E = M_E - E_C$

Substituting M_E in Equation 7 by the expression EG + QE (from Equation 3) results in Equation 8.

Equation 8: $P_E = E_G + Q_E - E_G$; => $P_E = Q_E$

The correspondence of radiation cooling PE and heat input QE is a fundamental principle for a state of equilibrium of a warm surface emitting IR radiation. At equilibrium, a surface can only loss as much energy through IR radiation, as it has gained by other means ($P_E = Q_E$). If the radiation cooling P_E decreases, as in the case of the propane experiments, the heat input Q_E must be adequately reduced for a constant temperature of the earth plate.
If, however, one assumes a constant heat input Q_E by solar radiation in the real Earth, a stronger irradiation of the earth's surface E_C (by greenhouse gases) would first reduce P_E. The Earth would have to heat up to restore the equality of P_E and Q_E according to Equation 7 through an increase in the Earth's radiance M_E[9].
The propane experiment thus proved that IR-active gases increase the irradiation of the Earth's surface E_C and in principle have a greenhouse effect that influences the radiant cooling P_E.

[9] Provided further relevant cooling processes such as earth and cloud albedo, water evaporation or convection have remained constant.

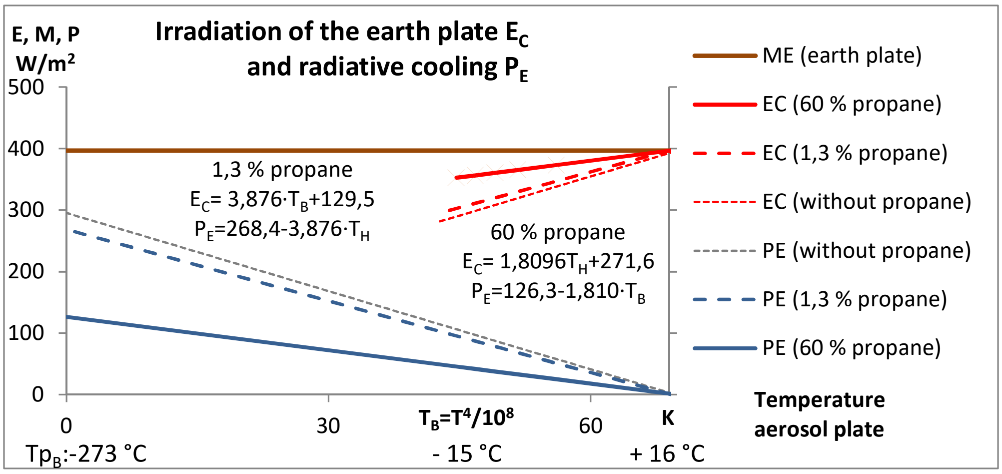

Figure 7: Reduction of radiant cooling P_E by propane

Figure 7 shows that radiative cooling P_E depends on both the propane concentration and the temperature of the aerosol plate. This results in a relativization (weakening) of the propane greenhouse effect, if the temperature of the aerosol plate T_B is considered.

At the aerosol plate temperature T_B = 0 K, the radiation cooling P_E is influenced only by the propane and its concentration. The distance between the blue lines and the grey line (P_E without propane) marks at this temperature the maximum theoretical greenhouse effect of the propane. As the temperature of the aerosol plate T_B increases, the real propane greenhouse effect decreases (the distances between the lines decrease). At Tp_B = 16 ° C, the radiant cooling P_E is zero in all experiments, regardless of whether or not propane is present. Earth and aerosol plates have the same temperature here, and the energy absorbed and emitted by propane is the same (adiabatic radiation transport, see also Figure 4, B).

Table 4 shows this reduction (relativization) of the greenhouse effect[10] as factor F_{eff}, which was calculated from the ratio of the real to the theoretical greenhouse effect for both experiments. The effectiveness factor F_{eff} obviously does not depend on the concentration of propane (its greenhouse effect), but only on its temperature and background temperature. The real greenhouse effect of an IR-active gas is thus calculated from the radiation force RF (its theoretical value) by multiplying it by the F_{eff} factor.

Table 4: Reduction of the propane greenhouse effect as a function of the temperature of the aerosol plate Tp_B

Tp_B °C	-273	-80	-50	-30	-20	-10	± 0	+10	+16
F_{GE} (1,3 % propane)	1,00	0,80	0,64	0,49	0,41	0,31	0,20	0,07	0,00
F_{GE} (60 % propane)	1,00	0,80	0,64	0,50	0,41	0,31	0,20	0,08	0,00

The near-earth greenhouse effect depends (as in the propane experiment) on background radiation, namely the IR emission of the clouds. Clouds consist of water droplets or ice crystals, which due to their large surface come close to a black body and like the aerosol plate relativize the effect of the IR-active gases. This relativization of the greenhouse effect by clouds has not yet been considered by the IPCC. However, if clouds are taken into account, the real CO2 climate sensitivity is only approximately 0.35 K, about one third of the IPCC value of 1.11 K[11].

The relativization of the greenhouse effect also concerns the water vapor radiation and thus the controversial CO2-water feedback. In addition, as cloud coverage increases (due to increased water vapor in the atmosphere), the radiation from clouds increases, reducing the effectiveness factor F_{eff}.

[10] The relativization of the greenhouse effect results from the opposite change in foreground and background radiation if a greenhouse gas is added to or removed from an Earth with clouds (Chapter 5). Although the contribution of the greenhouse gas $E_{F(IR\ gas)}$ then increases/decreases, this effect is attenuated by an opposite change in the effective background radiation E_B (Equation 6).

[11] A detailed description of the CO2 radiation and the CO2 greenhouse effect will be given in the next paper.

But even when the sky is clear there is an unexpected weakening of the greenhouse effect. The energy for the propane IR-emission is supplied jointly by the background radiation M_B and the wall heating Q_F (Figure 4). Q_F is a hidden heat flow that was not quantified in the experiment and increases with decreasing temperature of the aerosol plate. However, it can be recognized by the temperature decrease of Tp_1 during cooling of the aerosol plate (Table 2 and Table 3). In the case of the earth, this heat flow Q_F means an increase in convection from the earth's surface to the ground-level IR gases, which cools the earth's surface.

That cloud reduces the near-Earth CO2 greenhouse effect is not new knowledge (1), (6), (12), (13), (14). Direct measurements of atmospheric counterradiation in the vicinity of Barrow, Alaska (71,325 N, 156,615 W) at different degrees of cloud cover also show this correlation (15).

The testing of the apparatus with propane shows that the experimental setup is suitable for determining the radiation capacity (emissivities) of greenhouse gases as well as their relativization (attenuation) by means of background radiation. The only exception is the water vapor radiation, which cannot be investigated with this apparatus, since water vapor would condense or freeze on the cold aerosol plate.

7. Summary

Clouds and greenhouse gases both contribute to the greenhouse effect of the atmosphere with similar but also different radiation properties. In the presence of clouds, there is an increase in the near-Earth counterradiation, but also overlays occur. On the one hand, the greenhouse gases cover most of the cloud radiation, but on the other hand, clouds relativize the effect of the IR-active gases. Decisive for the mitigation of the greenhouse effect of the IR-active gases are altitude (temperature) of the clouds and their optical density.

Model experiments with propane show that its actual, real greenhouse effect under clouds would amount to only about one third of its theoretical value. This relativization, which affects all greenhouse gases as well as the controversial CO2-water feedback, has not yet been considered by the IPCC, which means that its calculations and forecasts are too high and should be corrected.

The investigations served as test of a new apparatus that can quantify the radiation of atmospheric greenhouse gases as well as its relativization by clouds.

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9. Appendix

Equipment	Details	Equipment	Details
Earth plate	Aluminium Ø 16,7 cm, 219 cm2	Timer for cooling unit	ESCO ET10: Control chiller if brine Tp > 0 °C
Aerosol plate	Copper Ø 35,5 cm, 990 cm2	5 x Peltierelemente	TEC1-12706 12V, 60 W 40 X 40 X 3.8 mm
Aluminium tube	Made of 2 x aluminium sheets 1000 x 1000 x 0,8 mm	Voltmeter for Peltierelemente	Voltacraft VC 250
heating foil earth plate	12 V/DC, AC 14 W Ø 174 mm, self-adhesive	CO2 Monitor	ZG 106 until 3000 ppm CO2
Power supply heating earth plate	Korad KA3005D DC 30 V, 5 A	2 x thermostats	ESCO digital thermostat ES10

Equipment	Details	Equipment	Details
2 x temperature sensors earth- und aerosol plate	Infineon KTY 11-5: TO-92 Mini radial	3 x PVC tube	8 x 12 mm, 3 x 25 m
4 x inserting thermometer	IP54, TFA 30.1040: Tp_1 to Tp_4	Silicone tube	8 x 10 mm, 22 m
Cooling unit for brine	Cortina Unold 48806	Cooling coil for aersol plate	Copper 8 x 1 mm, 6 m
Power supply for heating brine	BaseTech: BT-305, 0-30 V	Propane	Kältegas R290

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