# Is there a greenhouse effect?

Michael Schnell, Hermann Harde

## Abstract

The question, if greenhouse gases are contributing to global warming only by their mere existence divides climate skeptics into two groups, one which fundamentally recognizes an influence of infrared-active gases on our climate, while the other group denies such an impact and thus has doubts about the existence of an atmospheric greenhouse effect. This leads to great uncertainty and to the further question, which theory is the right one. With a new experimental concept we show that infrared-active gases directly affect the radiative exchange between bodies of different temperatures and even increase the temperature of a warmer, constantly heated body. Various control experiments show that other possible explanations can be ruled out.

## 1. Introduction

The term greenhouse effect leads to the imagination that this effect can be demonstrated with a simple model consisting of a closed housing filled with $CO_2$ and irradiated with a lamp. As early as 1909, however, Robert Wood [1] had discovered that a greenhouse only heats up because it prevents heated air from rising and escaping from the housing. In later years Wood's experiment was repeated several times and his thesis was confirmed (A. Watts, 2011 [2]; N. S. Nahle, 2011 [3]; J.-E. Solheim, 2017 [4]).
Hoimar von Ditfurth was able to achieve a particularly high temperature increase in a spectacular self-experiment (H. v. Ditfurth, 1978 [5]). A reconsideration of this experiment showed that the observed increase in temperature is due to a stratification effect that, similar to multiple glazing of windows, causes very good thermal insulation (M. Schnell, 2020 [6]). Such stratification occurs when concentrated $CO_2$ is filled into a device from the bottom side. If the $CO_2$ is evenly mixed with the air in the vessel as in the atmosphere, there is minimal or no air heating. With these greenhouse experiments, the greenhouse effect can principally not be verified, which requires a new approach.

It is undisputed that $CO_2$ is an infrared (IR) active gas and can absorb and re-emit thermal radiation, which has been proven by a large number of IR spectral studies. These data are also available for the public as HITRAN database [7]. But climate scientists still intensely dispute, whether and to what extent the temperature of the Earth is influenced by $CO_2$ (H. Harde, 2014 [8]; H. Harde, 2017 [9]). The first part of this question, if a colder greenhouse gas can also contribute to a temperature increase of a warmer, heated body, will be clarified by a new experimental investigation.

First of all, we have to be aware that energy can have different forms and is transported in the atmosphere by a number of different mechanisms. These include vertical and horizontal air currents, evaporation, condensation and freezing of water, heat conduction of the air, but also heat radiation (IR radiation). The greenhouse effect only affects the last case, the exchange of thermal radiation from the Earth's surface with different layers of the atmosphere and its IR-active components. These IR-active components of the atmosphere can be greenhouse gases, aerosols or clouds.

## 2. Experimental Set-Up

For our studies we use an experimental set-up, which consists of two plates in a closed housing, one plate heated to 30 °C, the other cooled to -1.8 °C. The plates have a distance of 1.11 m to each other, and the vessel can be filled with different gases to study the radiation transfer between the plates in the presence of the greenhouse gases. In contrast to the above-mentioned greenhouse experiments, no irradiation with a light source from the visible to the mid infrared is used, but heat radiation is investigated, which in this way also occurs on Earth and in the atmosphere. Heat flows, which are not part of the radiation exchange must be prevented or minimized by appropriate measures.

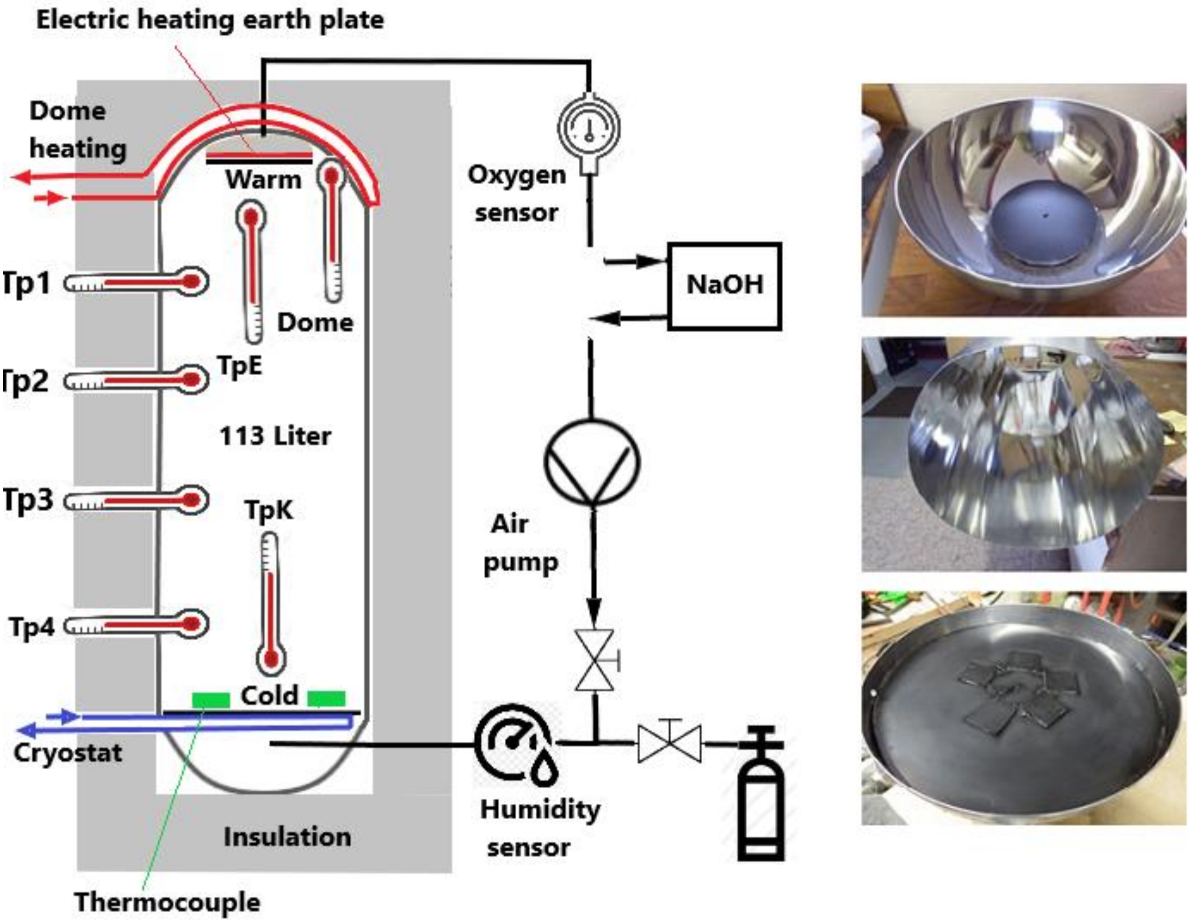

Fig. 1: Left: Schematic structure of the experiment.
Right: Earth plate in the dome, connecting pipe and cold plate.

Fig. 1 shows the schematic structure of the apparatus and the most important components. Their vertical installation, with the warm plate in the top position, creates a stable layer of air, which per se prevents vertical air movement (heat flow through convection - cold air does not rise).
A possible energy transport by means of water vapor (latent heat) can be excluded, since either dried air or argon is used as gas filling (see appendix).

Heat conduction, both through the vessel wall or along the gas phase, cannot be prevented, but it can be minimized. The warm plate (Earth plate) is located in a hemispheric cover (dome - Fig. 1), which is wrapped with a vinyl tube on the outside. Water at a constant temperature of 29.6 ° C flows through this hose. Because of the low temperature difference of 0.4 K between the dome and the earth plate, there is only little heat conduction in this area.

**The constant dome temperature is essential for this investigation and is achieved by constant electrical heating of the water for the dome heating.**

The high temperature of the dome guarantees good thermal insulation of the earth plate, but is also an orientation aid for the evaluation of the experiments. The dome has a polished stainless steel surface, which makes it largely insensitive to thermal radiation. A possible warming of the black earth plate after adding greenhouse gases can then be visually recognized by the increasing distance to the dome temperature (Fig. 2 and following).

From the outset, the earth plate has the highest temperature in the test set-up (0.4 K higher than the dome and significantly higher than all other parts of the apparatus and also higher than the sample gases. This results in a small, unavoidable heat flow from the earth plate mainly to the dome but also to the vessel wall and the cold plate. If the earth plate is heating up, also the heat loss increases. Without this loss an even higher temperature rise caused by the greenhouse gases can be expected. Thus, the heat flow to the dome could be reduced by increasing the dome temperature during an experiment parallel to the temperature of the earth plate. However, for the actual investigation we avoid such tracing in order to categorically rule out any suspicion of manipulation.

The heat conduction of the gases between the warm and cold plate is inherently very low, as gases are poor heat conductors. Nevertheless, still some influence of the different thermal conductivities of air and the sample gases could be possible. This is a serious argument that can be refuted by control experiments with noble gases.

The methodology of the experiments is based on the successful investigation of the "Ditfurth experiment", which is characterized by a high level of transparency (M. Schnell, 2020 [6]). It is not a single temperature registration, according to the motto "eat or die", but rather a long observation phase with more than seventy temperature data which are displayed in the diagrams on a time axis from left to right.

The first 90 minutes before adding a sample gas show that the earth plate is in thermal equilibrium. The electrical heating of the earth plate reflects the heat loss by thermal radiation and thermal conduction (input = output). The earth plate has a constant temperature of 30.0 ° C. The display accuracy is ± 0.13 K, which is the limit of detection (LOD). The greenhouse effect is considered to be verified, if a significant temperature increase $\Delta Tp_E$ >> LOD is registered during an experiment, i.e. a multiple of the LOD value.

After 90 minutes of equilibration of the air-filled apparatus, the sample gases are let in with a flow rate of 1 l/min via an inlet at the bottom side of the apparatus. Then the inside air is recycled for some shorter period by an aquarium pump sucking out the gas from an upper outlet and refilling it back at the lower inlet (at the dead space below the cold plate - Fig. 1). As a result of this recycling the sample gases are displaced from the dead space and clearly positioned between the warm and cold plate. Adding and recycling the sample gases are the only external interventions during an experiment. From now on only the data of the sensors are recorded.

## 3. Effect of the sample gases at constant heating of the earth plate

### 3.1 The $CO_2$ experiment

A measurement with $CO_2$ as sample gas at a concentration of 15.4 vol.-% in dry air is shown in Fig. 2a. *For comparison: at this concentration and a distance between the plates of 1.1 m, this corresponds* *roughly to an absorption and emission that can be expected from 100 ppm $CO_2$ (without other greenhouse gases) over the propagation path in the atmosphere.*

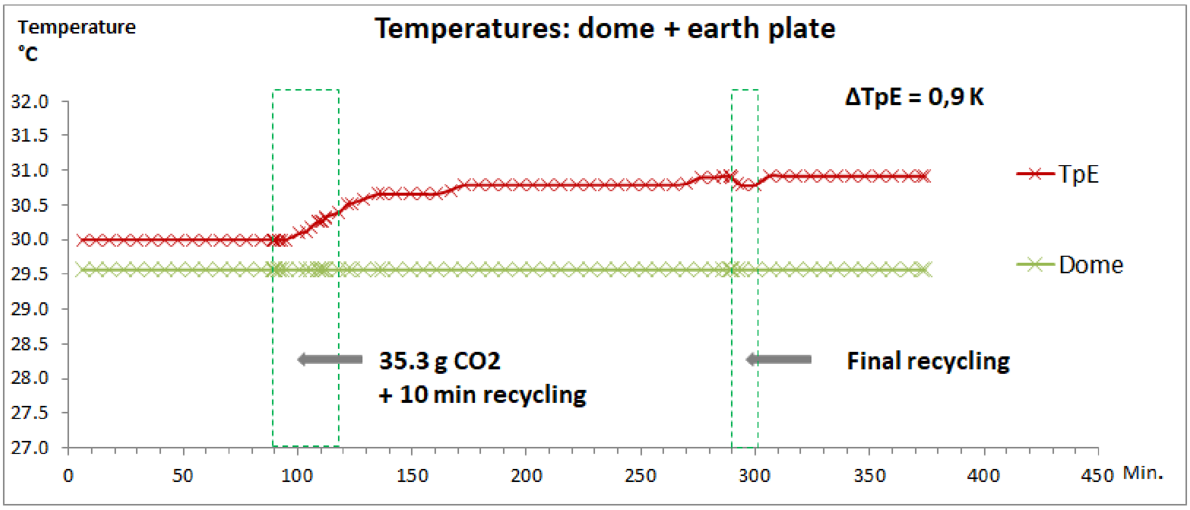

Fig. 2a: $CO_2$ experiment No. 30: Final concentration 15.4 vol.-% $CO_2$

Directly after filling and recycling $CO_2$ the temperature of the gas at sensor Tp4 is aboud 12 ° C, after all 18 K colder than the earth plate (see Fig. 2b). Nevertheless, the distant earth plate reacts only a few minutes after entering $CO_2$ with a significant temperature increase. The $CO_2$ layer slowly expands through diffusion in the entire apparatus, with ever warmer regions being reached. The earth plate reacts to this with a continuous rise in temperature, which reaches a maximum of $\Delta Tp_E$ = 0.9 K after 290 minutes. Even another 10-minute final recycling does not change this value.

At this point we remind, when the Ditfurth experiment was checked, a final recycling was a "knockout" criterion. The original increase in temperature disappeared when pumping and homogenizing the gas mixture, and the Ditfurth experiment could be exposed as fake (M. Schnell, 2020 [6]).

Obviously the new experimental concept cannot be compared with the many “greenhouse experiments” of the Ditfurth type. Also serious differences show up for the gas temperatures between the plates. Over the entire recording time the sensors display a constant temperature and a stable gradient from 27.3 ° C at Tp1 to 12.6 ° C at Tp4. Additional $CO_2$ does not cause any significant temperature changes at these measuring points (Fig. 2b).

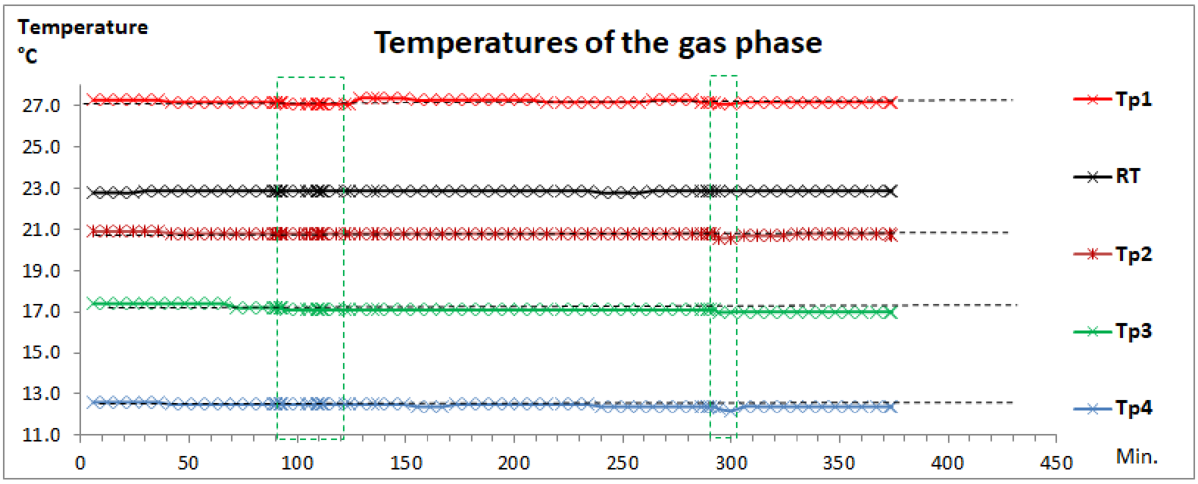

Fig. 2b: $CO_2$ experiment: Temperature data of the sensors.

The constant temperatures of the gas phase should not be overestimated, as the dome temperature was intentionally kept constant in order to avoid any accusations of a manipulation.

If the dome temperature would have been retraced at a constant temperature difference to the earth plate, the temperatures of the neighboring air layers would also slightly increase. However, this is a different story and the subject of the ongoing experimental investigation concerning the climate sensitivity of $CO_2$.

## Response of the thermocouples

According to the Seebeck effect an electrical voltage is generated in a circuit, which consists of two different electrical conductors, when two contact points of this circuit have different temperatures. Five thermocouples, which were stuck on the cold plate, are affected by the temperature of the cold plate on their rear side and by the heat flows in the vessel on their top side. These elements are connected in series and their voltage is registered as Th by a sensitive voltmeter.

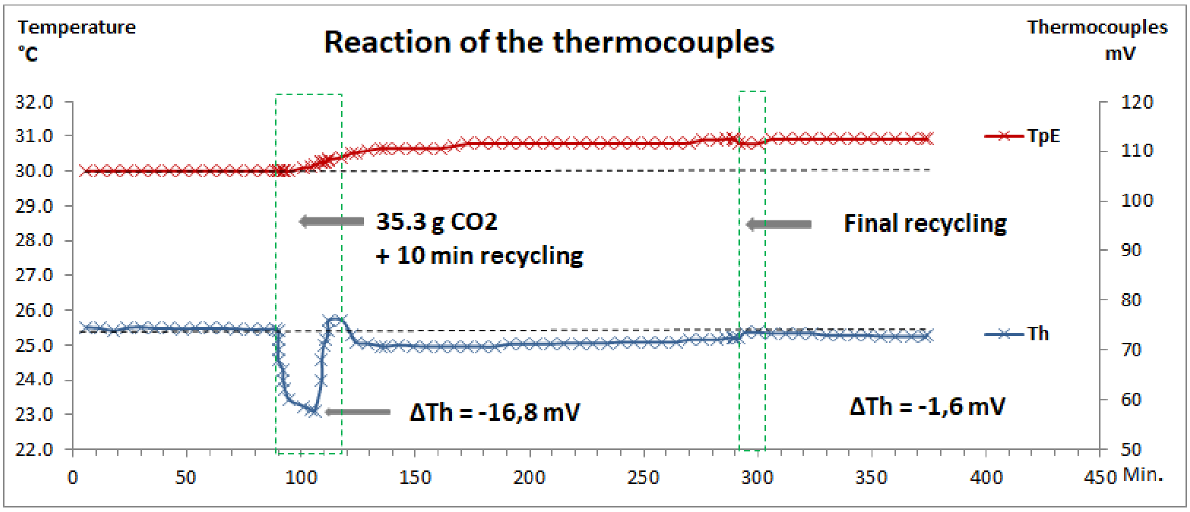

Fig. 2c: Temperature rise of the earth plate (red) and response of the thermocouples while filling and diffusion of $CO_2$ (blue, right ordinate).

When letting $CO_2$ in, in the first few minutes a "$CO_2$ lake" is evolving above the cold plate, which due to a lower thermal conductivity of $CO_2$ causes a stratification effect (M. Schnell, 2020 [6]), and as a result, the cold plate receives less heat from the warmer vessel. The top side of the thermocouples cools down and the initial voltage of Th = 74.6 mV decreases by ΔTh = -16.8 mV. When recycling the gas, the $CO_2$ layer is slightly raised and warmer air lapses around the thermocouples, causing the voltage to rise briefly to Th = 76 mV. After pumping is finished, again a slight stratification builds up, and the voltage drops to Th = 70.7 mV. In the further course of diffusion the $CO_2$ and the interior air are evenly mixed, which eliminates the stratification effect and the voltage of the thermocouples Th slowly approaches the initial value of Th = 74.6 mV (Fig. 2c). The final difference of ΔTh = -1.6 mV apparently is due to the lower heat conduction of a 15% $CO_2$-air mixture.

The response of the thermocouples shows that the charging with heavy gases and their subsequent diffusion can well be traced and thus also be documented. We will find a similar response later on with argon as buffer gas.

## 3.2 The propane experiment

Propane is a much stronger greenhouse gas than $CO_2$. With only 13% of the $CO_2$ amount (4.5 g propane vs. 35.3 g $CO_2$ or 2 vol.-% propane vs. 15.4 vol.-% $CO_2$), an almost equal temperature increase of $\Delta Tp_E$ = 0.8 K is observed (Fig. 3a).

The experiment was carried out with argon as buffer gas in order to examine the influence of heat conduction on the response of the thermocouples. Argon has a lower thermal conductivity than air (0.018 vs. 0.026 W/(m·K)) but a slightly higher value than propane (0.015 W/(m·K)). As a result, charging with a propane/argon mixture only causes a small decline in the voltage of the thermocouples (ΔTh = -4.6 mV), which again returns to the initial value when recycling the gas.

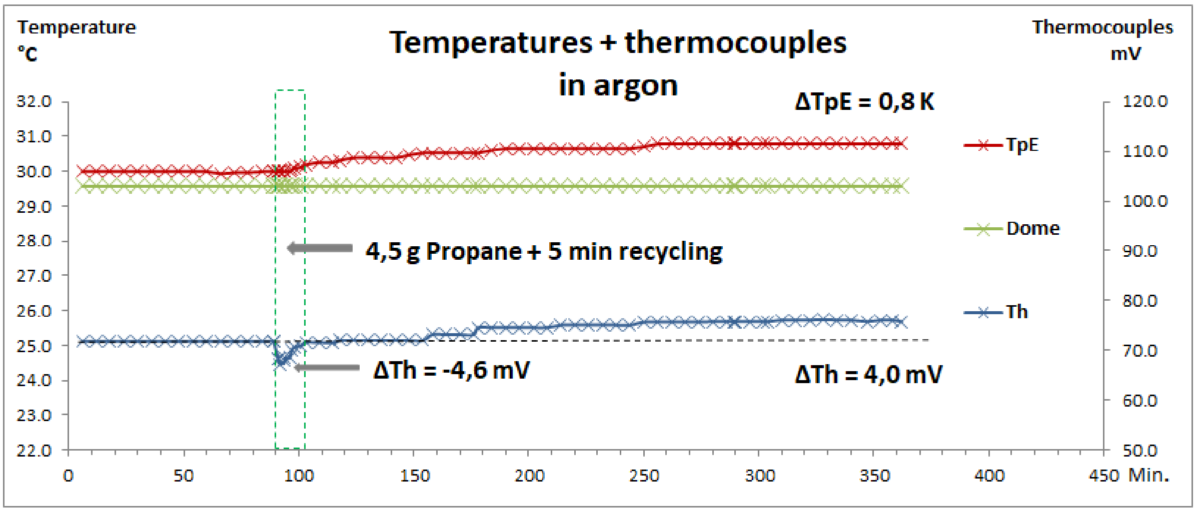

Fig. 3a: Propane experiment no. 6: Final concentration 2.0 vol.-% of propane.

During diffusion of propane, however, the voltage of the thermocouples Th continues to rise and finally is even 4.3 mV higher than the initial value, although with propane the heat conduction between vessel walls and the cold plate is further slightly reduced and thus, a lower voltage would be expected. This increase in Th is explained by an increased IR radiation of the earth plate, which meanwhile was heating up, and additionally by propane both emitting towards the cold plate, since a greenhouse gas not only absorbs thermal radiation but also emits it again dependent on its temperature. At the same time, the gas mixture slightly cools down (see Fig. 3b).

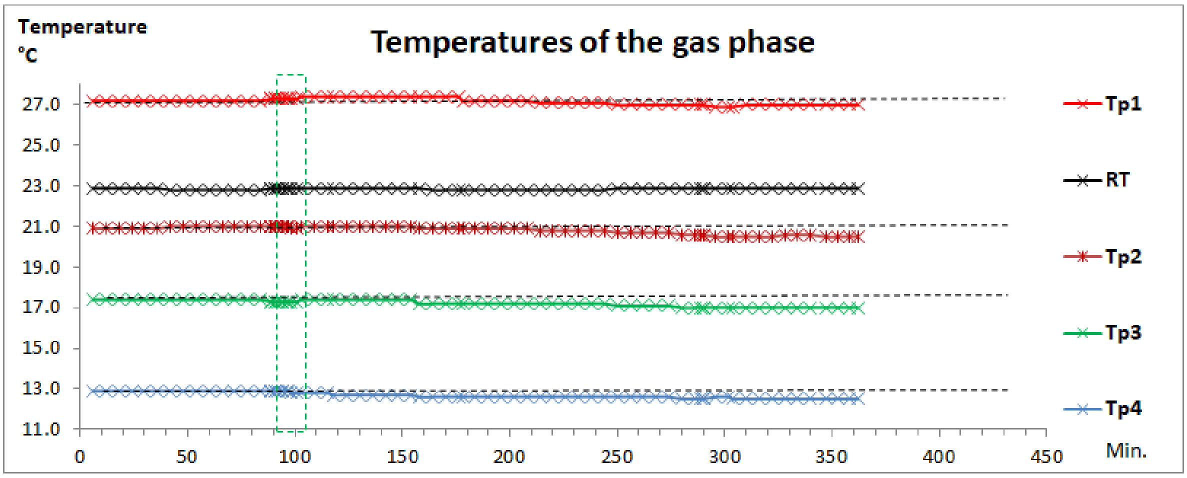

Fig. 3b: Propane experiment: Temperature data of the sensors.

To avoid any misunderstanding, this additional detection of the radiation and the cooling of the gas phase are primarily phenomena of the laboratory experiments. They are affected by the set-up and should only be understood as further evidence of the greenhouse effect.

Such energy flows do not exist in the atmosphere. The temperatures of the troposphere are mainly determined by the pressure gradient of the atmosphere (adiabatic temperature change of air parcels) and weather phenomena. If and to what extent greenhouse gases have an influence on the temperature of the troposphere is controversially discussed and cannot be decided by simple laboratory experiments.

### 3.3 The Freon Experiment

The Freon experiment (Fig. 4a and 4b) shows similar results compared to propane for both the temperatures and thermocouples. The very small amount of Freon 134a, which at 0.13 vol.-% already generates a temperature increase of about 1.2 K, is remarkable.

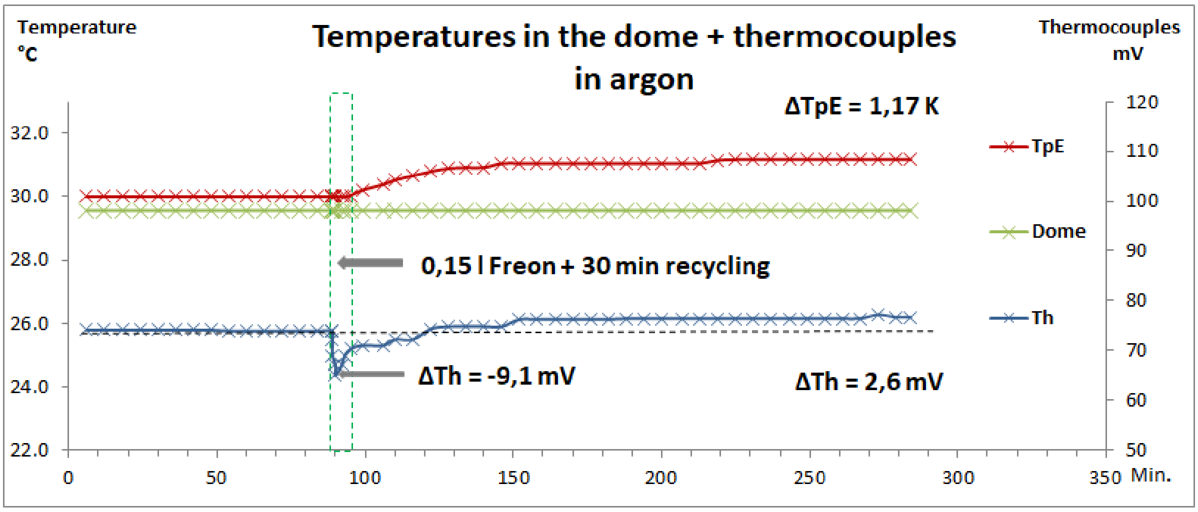

Fig. 4a: Freon experiment No. 13: Final concentration 0.13 vol.-% of Freon 134a

The thermal conductivity of gas mixtures with low concentrations is calculated in good approximation using the mole fraction. Any observable changes of the mechanical heat flux cannot be expected at this low Freon concentration.

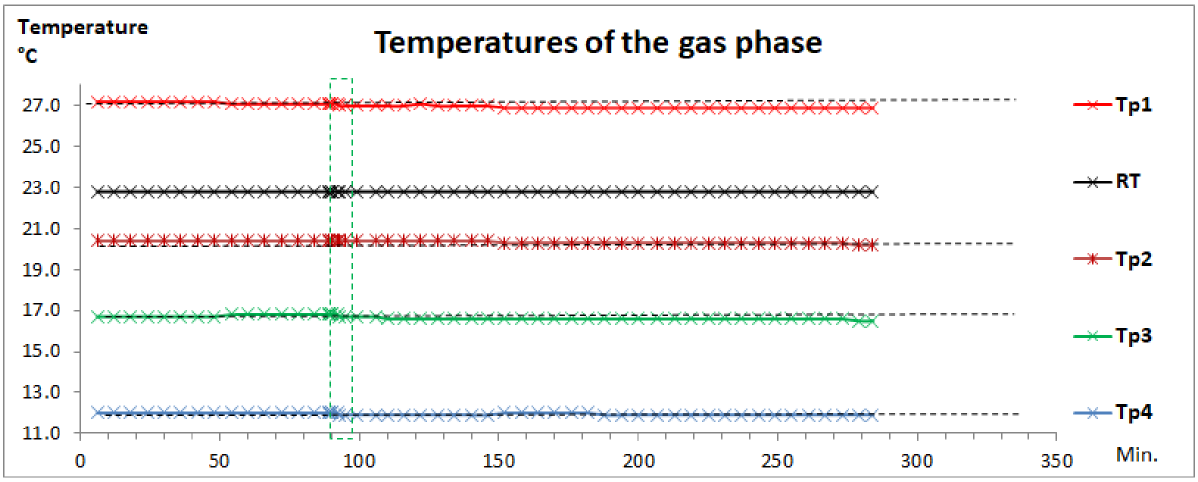

Fig. 4b: Freon experiment: Temperature data from the sensors.

### 3.4 The Argon control experiment

Adding argon as sample gas to the vessel, which is filled with dry air, has no measurable influence on the temperatures of the earth plate and the air. The fact that argon was let in at all, can be seen from the temporary drop in the voltage of the thermocouples ΔTh = -11.5 mV (Fig. 5a). When charging with argon a layer forms, which considerably reduces the heat conduction above the thermocouples through a stratification effect. Recycling and diffusion of argon removes this stratification, and the voltage of the thermocouples Th almost again reaches the initial value (see Fig. 5b) as already observed with $CO_2$ (Fig. 2c). This proves the voltage drop ΔTh to be caused by a stratification effect, when heavier gases are charged.

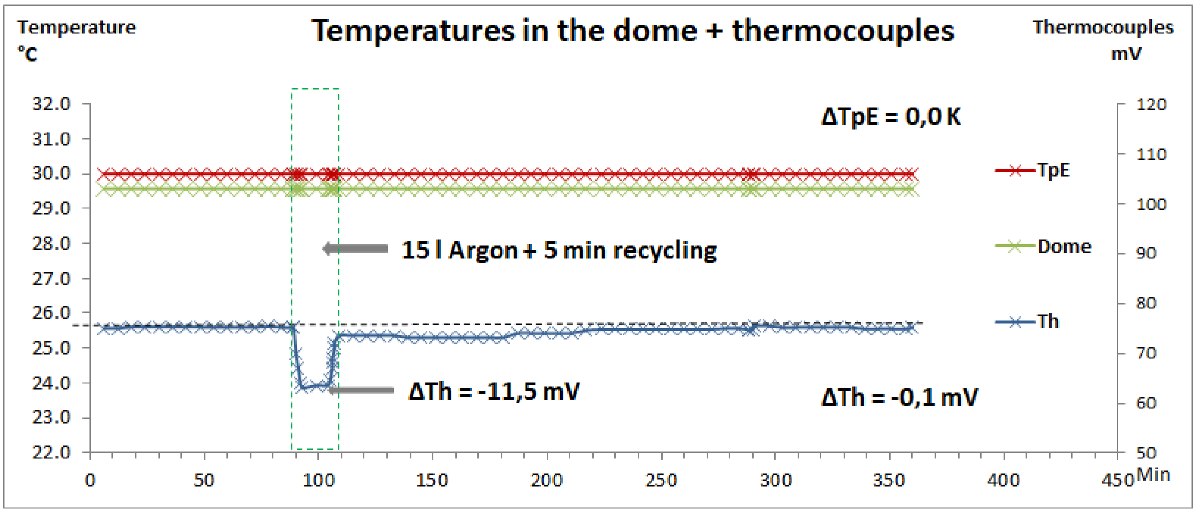

Fig. 5a: Argon control experiment No. 6: Final concentration 13 vol.-% of argon.

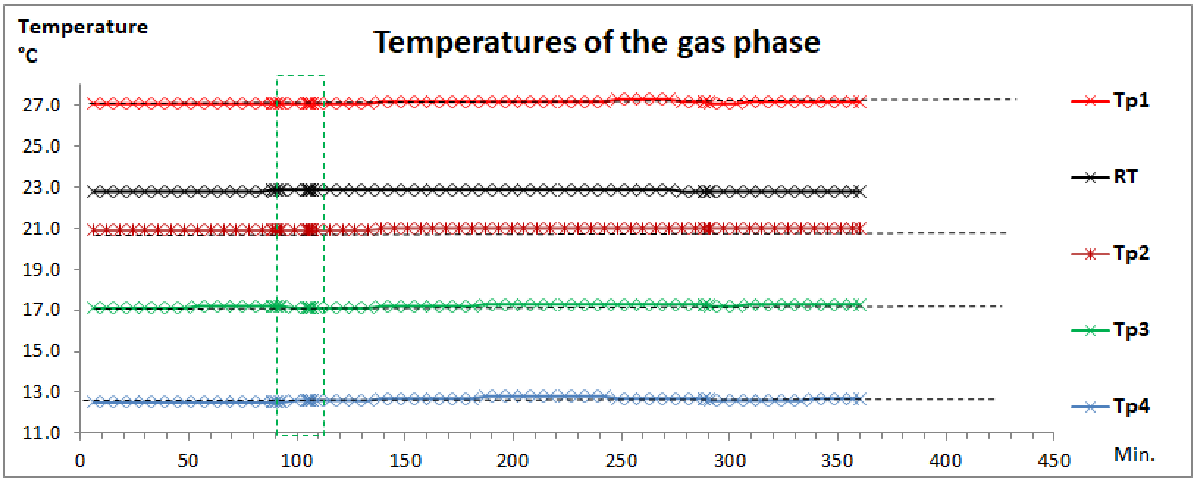

Fig. 5b: Argon control experiment: Temperature data of the sensors.

### 3.5 The Helium control experiment

Since helium is lighter than air, it is let in from above, just below the earth plate. Any recycling is not necessary, as there is no dead space around the earth plate.

Helium has a much higher thermal conductivity than air (0.157 vs. 0.026 W/(m·K)), but the temperature of the earth plate still holds the initial value, even after 350 minutes (Fig. 6). This is a further clear indication that heat conduction of the gases has no impact on the measurements and can be excluded as a possible explanation of the temperature increases described above in the presence of greenhouse gases.

Only when helium is filled in there is a slight temperature drop in TpE, when the cold helium flux passes the earth plate.

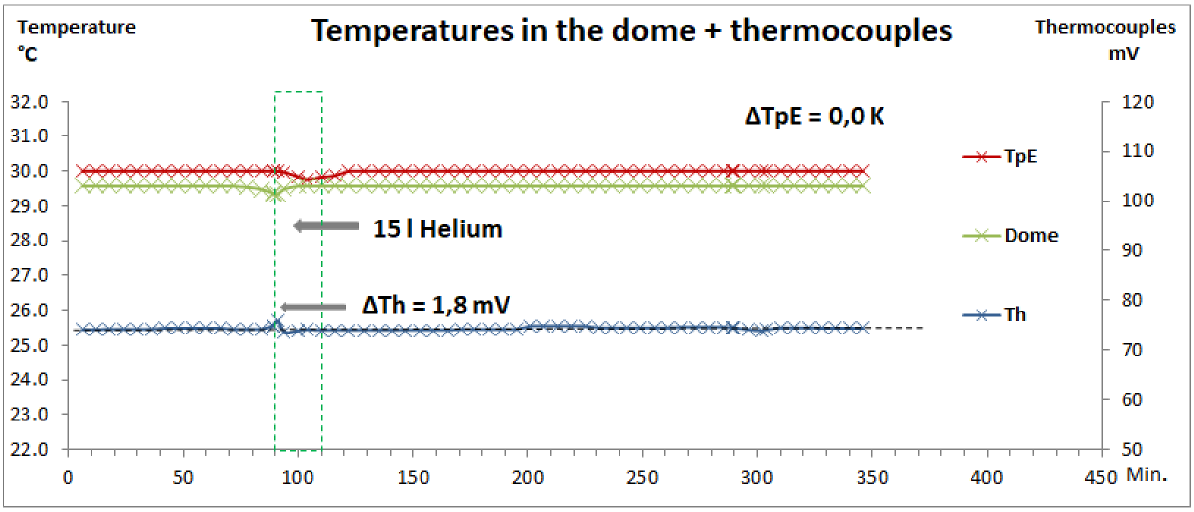

Fig. 6: Helium experiment no. 3: Final concentration 13 vol.-% of helium.

The thermocouples, which show no reaction in this experiment, are remarkable. As helium is charged from above, far from the thermocouples, these sensors only come into contact with the noble gas after complete diffusion. Therefore, there is no stratification effect and even the 13% helium-air mixture at the end of the experiment is not noticed by the thermocouples.

## 4. Freon measurement with constant temperature of the earth plate

Up to the 235th minute, this Freon experiment, No. 15, looks like a repetition of experiment No. 13 (see Figs. 7a to 7c). But there is a difference: the cold plate is about 10 K colder than in the previous experiment. Despite the lower temperature of the cold plate ($Tp_K$ = -11.4 °C vs. -1.8 ° C), the temperature increase $\Delta Tp_E$ of the earth plate is 0.55 K larger than in experiment 13 ($\Delta Tp_E$ = 1.69 K vs. $\Delta Tp_E$ = 1.17 K). This apparently paradoxical relationship was already mentioned earlier (M. Schnell, [10]). The temperature of the cold plate in so far plays an important role, as with declining difference between the greenhouse gases and this plate the radiation of the molecules is stronger superimposed by the background radiation of the plate (similar to the background radiation caused by clouds in the atmosphere, see also H. Harde [9]), and at identical temperatures no further warming of the earth plate by the gas can be expected.

After the maximum temperature increase $\Delta Tp_E$ (max) has been registered, the electric heating is gradually reduced until the earth plate again has the initial temperature of 30 °C. Freon turns out to be an especially good thermal insulator. The low concentration of 0.13 vol.-% Freon (0.15 l) means that the heating of the earth plate can be reduced by about 11% from 169.9 W/$m^2$ to 151.2 W/$m^2$. This insulation effect, however, is not caused by the heat conduction but by the radiation exchange (see Section 5). In this context we remind at the argon control experiment (Section 3.4), which showed no insulation effect despite a 10-fold amount of argon (15 l).

This experiment convincingly proves that the thermal radiation emanating from Freon is absorbed by the earth plate as so-called back-radiation, and that under the given experimental conditions (concentration of the gas, temperature, "viewed" solid angle) this leads to a correspondingly lower heating output of around 19 W/$m^2$.

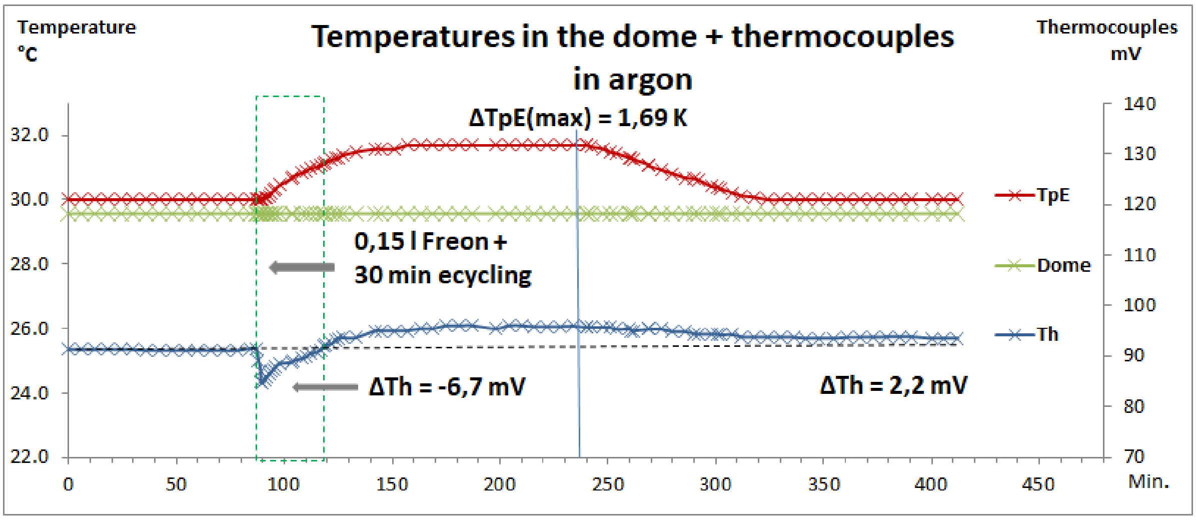

Fig. 7a: Freon experiment no. 15: Final concentration 0.13 vol.-% of Freon 134a

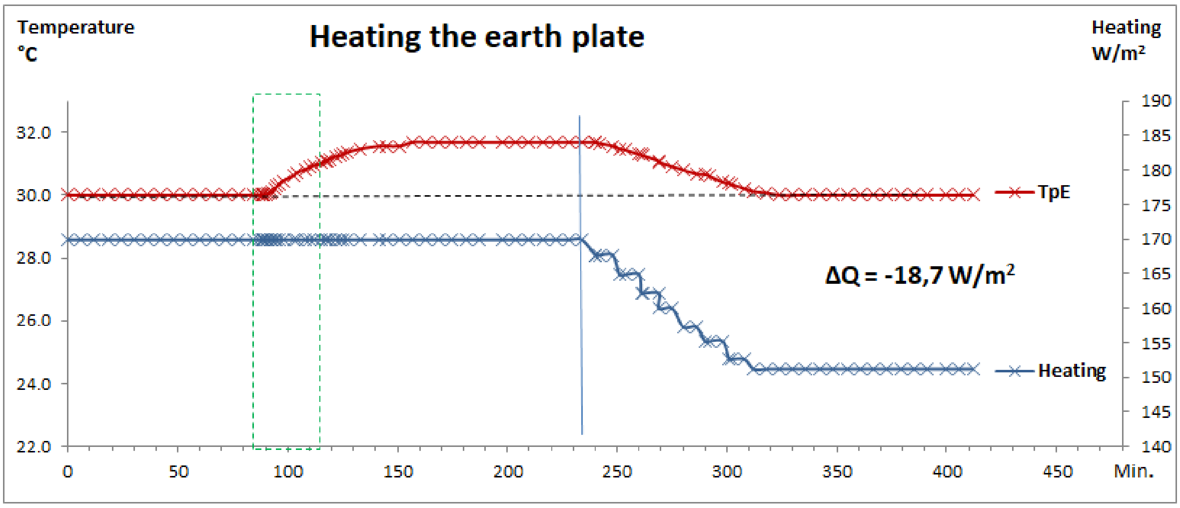

Fig. 7b: Evidence of the isolation effect of Freon 134a

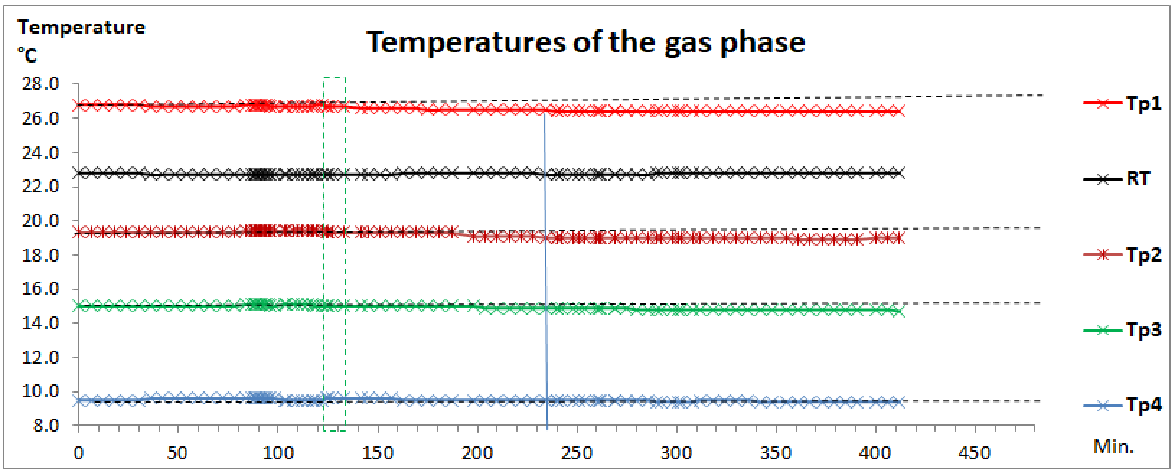

Fig. 7c: Freon insulation experiment: temperature data from the sensors.

## 5. Heating of the earth plate

This experiment is primarily about the question: "How does the temperature of the earth plate change if its heating is switched on with a delay?"

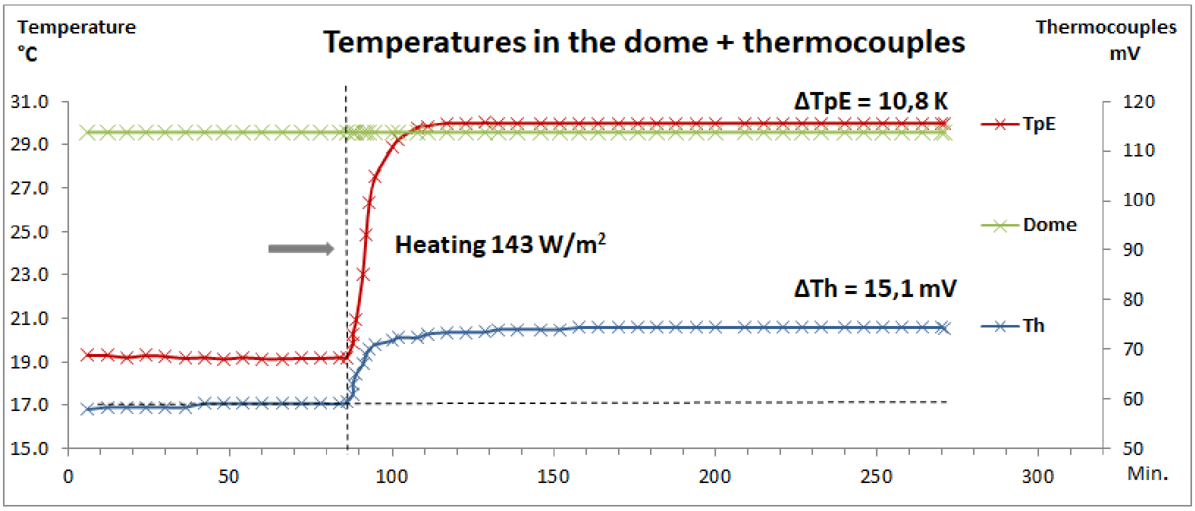

Fig. 8a: The heating of the earth plate is switched on at 86th minute.

The experiment begins with the same preparations as described before. In this case the cold plate is cooled to –1.8 °C, and the hose wrapping of the dome is supplied with 29.6 °C warm water. The first 86 minutes show that the earth plate is in thermal equilibrium and assumes a temperature of 19.2 °C, when its heating is still switched off (Fig. 8a). The earth plate is now 10.4 K colder than its immediate surroundings, the dome, which is at 29.6 °C thanks to its water heater. This is comparable to the cooling of bodies that are exposed to a cold sky, which in our latitudes is known as radiation frost.

This experiment is a further test to scrutinize, how far the temperature of the earth plate is mainly determined by the radiation exchange with the cold plate 1.11 m away.

This exchange describes the heat loss of a warm body in a cold environment. It is a loss that is caused solely by a mutual exchange of thermal radiation. When the heating is switched on, the temperature of the earth plate rises, and thus, its thermal radiation increases. The thermocouples react to this additional thermal radiation by an increasing voltage of ΔTh = 15.1 mV, synchronous with the temperature of the earth plate.

From this observation, the reaction of the thermocouples can be explained as:

- an increase of the voltage Th, caused by the thermal radiation from the earth plate, and
- a decrease in Th primarily determined by the lower heat conduction of heavier gases or a stratification effect.

The temperature of the unheated earth plate (19.2 °C) results from heat losses by radiation exchange with intensity *I*, mainly with the cold plate, and the heat supply Q from its warmer environment (dome).
When the heating is switched on, the temperature differences between the earth plate, dome and cold plate are changing, whereby the heat flow Q decreases and the radiation exchange *I* increases. A new equilibrium is established at the earth plate temperature of 30 ° C.

Assuming that the heat flow Q can be neglected at almost the same temperatures of the dome and the earth plate, the radiation exchange intensity can be calculated using the Stefan equation (Wikipedia [11]).

For E = 1 (emission exchange rate), $T_E$ = 303.15 K (30 °C) and $T_K$ = 271.35 K (1.8 °C), an intensity *I* is calculated for the radiation exchange with $\sigma_B$ as Boltzmann's constant:

$$I = \sigma_B \cdot E \cdot \left(T_E^4 - T_K^4\right) = 478{,}9 - 307{,}4 = 171{,}5\ W/m^2 \tag{1}$$

In fact, only an electrical heating power of 143 W/m$^2$ is required for the temperature of the earth plate of 30 °C, which is only 83% of the theoretical radiation exchange *I*. This is largely confirmed when the cold plate is cooled to -11.4 °C, then for a required heating power of 169.9 W/m$^2$, corresponding to 80% of the theoretical value. The performance determined in this way is a quality feature of the apparatus and shows how the apparatus reacts to the thermal radiation from the cold plate.

The deviation from the theoretical value is mainly caused by a second radiation exchange *I*‘ between the earth plate and the vessel walls. The tank has a higher temperature than the cold plate, which means that the earth plate loses less heat in this direction.

The measurements of the air temperature show, when switching the heating on, mainly the air near the earth plate at measuring point Tp1 is heating up (Fig. 8b).

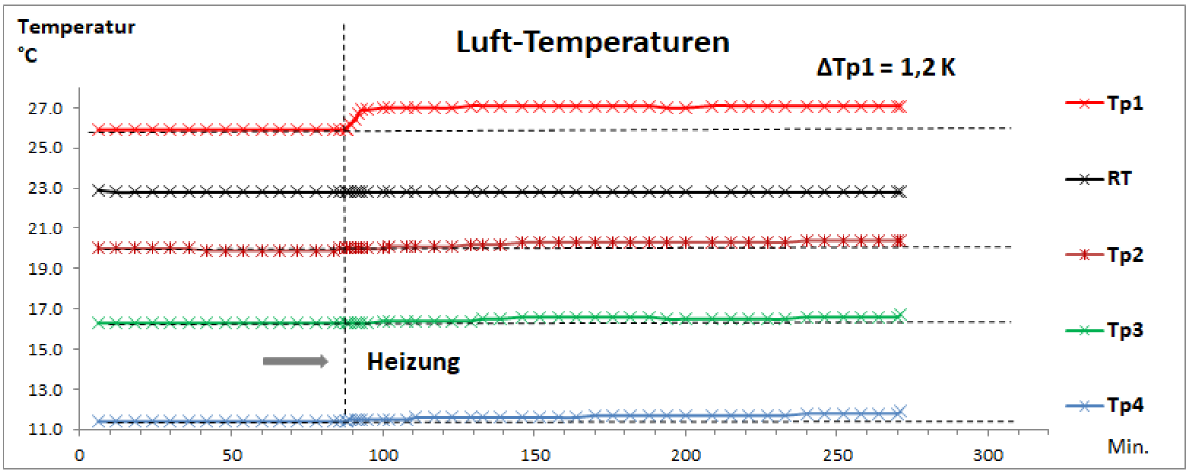

Fig. 8b: Changes in air temperature when switching on the heating

## 6. Conclusion

The experimental set-up can be described as a model that simulates the radiation exchange of the Earth's surface under a cloud layer. The selected temperatures including a temperature difference between the earth and cold plate can also be found on the Earth and in the atmosphere.
Other parameters such as solar radiation, the influence of water vapor, a pressure gradient, vertical and horizontal air currents, heat transport through latent heat and many weather phenomena are not considered in this experimental set-up. It is therefore not possible to derive or even predict any global temperatures of the Earth.

All the temperatures determined are only demonstrations, which show that greenhouse gases can generally contribute to warming of the Earth and that the greenhouse effect is physically possible.

The diagrams displayed are a smaller collection of about 50 experiments carried out. In all cases, without exception, the addition of an IR-active gas caused an increase in temperature of the earth plate, despite constant heating of this plate and a constant temperature of its immediate surrounding.
Objections raised against a greenhouse effect were largely taken into account in our investigations. So it could be clearly shown that a heated body, here the earth plate, warms up even in the presence of significantly colder greenhouse gases. It has also been demonstrated that the heating effect depends on both the gas temperature and the type of the gas. Even a very small concentration of an IR-active gas does not speak against the greenhouse effect, which can still have a significant impact due to the long propagation paths of radiation in the atmosphere.
The gas temperatures are lower than those of the earth plate and do not change or sooner drop slightly during an experiment. The warming of the earth plate cannot be explained by a heat flow from its surroundings.

Control experiments with the noble gases argon and helium show that the different thermal conductivities of these sample gases compared to air have no influence on the temperature of the earth plate.

The observed warming of the earth plate is the ability of greenhouse gases not only to absorb IR radiation, but also to re-emit radiation at the same wavelengths according to their temperatures. This further reinforces the already existing back-radiation from the cold plate. Thus, in agreement

with the Stefan equation, at constant temperature the energy transfer from the earth plate to the cold plate is reduced. This would result in an imbalance between input and output, but because of the conservation of energy the earth plate has to warm up in order to restore the balance of input and output at a higher temperature.
In simple terms, basically is the greenhouse effect a kind of "insulation effect" controlled by the radiation exchange (like our blanket, which keeps us nice and warm at night, except that we have a gas layer and we speak of heat radiation).

In further experiments this thermal radiation could also be detected and quantified for propane and Freon 134a.

A climate sensitivity cannot be derived from the experiments, as the temperature of the dome - the immediate surrounding of the earth plate - was kept constant. However, the observed temperature increase of 0.9 K at a comparatively high concentration of $CO_2$ already suggests that the IPCC claims about $CO_2$ being an extremely dangerous climate driver appear strongly exaggerated and cannot be confirmed by our measurements. The dispute about the $CO_2$ climate catastrophe will further go on, and eventually the controversial question is not whether, but how high is the $CO_2$ greenhouse effect. That is a different story and the subject of further experimental investigations.

## Acknowledgement

We would like to thank Ing. Ulrich Tengler for his support and for providing the Isotemp 1016S cryostat free of charge.

## Appendix

Test procedure: On the day before an experiment, a caustic soda cassette is connected between the pump and the oxygen sensor and the indoor air is recycled at 1.5 l/min for 4 hours, which removes water vapor and $CO_2$ (see Fig. 1). In the case of argon as gas filling, 300 liters of argon are filled from below into the apparatus that is opened at the top and removes the air.

At night, at 1:30 a.m., the cooling unit, dome heating and room thermostatic control are put into operation and after some delay the heating of the hot plate is switched on.
A digital laboratory power supply (KA3005D) in dc voltage mode with a resolution of 0.01 V is used for the electrical heating of the earth plate. The required heating power for the 219 $cm^2$ earth plate is multiplied by the factor 45.65 to convert to the heating of an area of 1 $m^2$.
Around 7:30 a.m., the computer-aided recording of the temperatures $Tp_E$, $Tp_K$ and of dome are sampled every minute. Every 6 minutes, an average value for the last 6 minutes is calculated and saved for an Excel table. All other data are manually collected at specified time intervals.
Over the first 90 minutes the constancy of all measured values within an accuracy of ± 0.13 K is demonstrated. Around 9:00 a.m., the sample gas is charged to the tank from bottom side and for a shorter period is the air sucked out at the dome with an aquarium pump and re-filled into the lower dead space. In the case of $CO_2$ and propane, the concentration of sample gases is determined by weighing the gas bottles. The volume of argon and helium is determined using a rotameter. A lockable gas mouse with a volume of 0.15 l is used for Freon 134a, which is connected between the air pump and the humidity sensor.

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