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Recent Discoveries in Atmospheric Physics and their Consequences on Climate Mitigation

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Abstract

After reviewing the respective science history from Newton to Planck, the two novel and recently published detection methods are reported which have been developed and mathematically modeled by the author. Their results are basically questioning the conventional theory, particularly the greenhouse theory, providing a better understanding of atmospheric processes and delivering practical clues for mitigating the climate.The first method concerns the measurement of temperature enhancement of gases irradiated by infrared light, while the second method allows the direct determination of the solar absorption coefficients of coloured opaque materials. In both cases, the irradiated material is warmed up to a steady limiting temperature where the intensity of the absorbed light is equal to the intensity of the emitted radiation or heat. An eminent theoretical finding of the author was delivered by the evidence that the intensity of the thermal emission of gases is proportional to the collisional frequency of the gas particles. Based on this assumption, and verified by measurements at two distinct locations differing in their altitudes and thus in their respective atmospheric pressures, a direct dependence of the atmospheric counter-radiation intensity on the pressure and on the square root of the absolute temperature could be found. This physical law explains the paradox that the temperatures on mountains are generally lower than those in lowlands, in spite of the higher solar radiation intensity on mountains. Moreover, it clearly proves that atmospheric trace gases such as carbon-dioxide do not have any influence on the climate.

As a consequence, the only possibility for mitigating the climate is to reduce the solar absorptivity of the Earth surface, particularly in cities. This would be possible by lightening-up of surfaces, particularly of roofs and of pavements, and by reducing the macro-roughness resulting from high-rises. White, light-brown or straw-yellow colours have to be favored.

Historical Review of Measuring Methods Regarding the Greenhouse Theory

The starting point of this investigation was the generally accepted greenhouse theory assuming that the recent climate change would be predominantly due to the growing content of the so-called greenhouse gases in the atmosphere, particularly of carbon dioxide. This theory traces back to the comparison of the Earth atmosphere with the glass of a hot house, made by M. Fourier 1827 [1], first promoted by Tyndall 1861/1863 [2, 3], and later by Arrhenius 1896/1901 [4, 5].

The herewith implied question of the IR (infrared) radiation and of its interaction with matter, particularly with gases, is one of the most delicate problems in physics being connected with the question of the nature of light. It goes back to the beginning of natural science, and has been investigated over a long period of time, starting with Newton's discovery of the light spectrum in 1672, followed by Huygens' wave propagation principle in 1678, and resulting in Planck's quantum law in 1900 about the black-body radiation [6], Einstein's relation about the photo-effect in 1905 [7], Bohr's atom model in 1913 [8], and De Broglie's electronic wave hypothesis in 1924 which lead to the modern quantum mechanics. During this wide period of time, the comprehension of matter has considerably changed, too. And insofar as heat and temperature are affected, further physical scopes are involved, in particular thermodynamics and the kinetic gas theory. With regard to IR-radiation, it is important to distinguish between near IR (λ = 0.8-3 µm), emitted at high temperatures (> 1000 K), and medium IR (λ = 3-50 µm) occurring at lower temperatures as true heat radiation.

While the relevant literature is rich in theory, it is poor in basic empirical investigations and experiments, at least concerning thermal and thus other than spectroscopic measurements. So it is astonishing that the commonly alleged light-adsorption law of Bouguer, Lambert [9] and Beer [10] traces back to work published in the years 1729, 1760 and 1852 - hence at times where electric light was not available, and artificial light had to be delivered by candles or by oil lamps. Photometers used at that time - like those of Rumford or of Ritchie - utilized the fact that when comparing the intensities of two light sources which are cast abreast on a white surface, they decrease reciprocally to the square of the difference in distance. A lot of materials, which are readily available nowadays, were not

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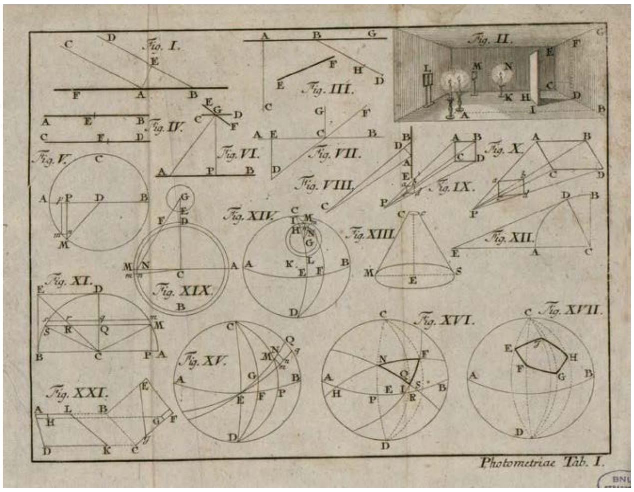

Figure 1: Table I in Lambert's "Photometria" (1760) [9].

known then, particularly synthetic materials. Moreover, the early work, written in Latin, French, English or German, was usually quite extensive, laboured and hardly comprehensible. The "Photometria" of Lambert e.g., written in Latin and published in 1760 [9], comprises 547 pages, 1243 paragraphs, 40 experiments, 52 theorems and 107 figures see e.g. table I in (Figure 1).

Hence, for better understanding the historical progress concerning the state of knowledge and the relevant measurement methods, first of all the milestones will be listed up which have been reached from Newton to Planck. Not only the results and applied methods will be considered, but also the materials and instruments available at that time, due to the technical progress. Thereby, besides spectroscopic investigations concerning light absorption, also light emission phenomena will be taken into account, as well as the thermal conduction measurements in gases. Subsequently, some prominent features will be described more detailed, likewise discussing their deficiencies from the present point of view. Finally, the recent foreign work will be reviewed insofar it exhibits novel experimental approaches:

Isaac Newton, 1672: "New Theory about Light and Colors": The light-spectrum

Christiaan Huygens, 1678: "Traité de la Lumière": The wavy character of light

Pierre Bouger, 1729: "Essai d'optique sur la graduation de la lumière"

Jean-Henri Lambert, 1760: "Photometria": Contribution to the absorbance law for light (Figure 1)

William Herschel, 1800: Discovery of the infrared radiation

Wilhelm Ritter, 1801: Discovery of the ultraviolet radiation

Thomas Young, ca. 1802: Determination of wave-lengths, three-colour-theory

John Dalton, 1808: Colour blindness, law of multiple proportions, atom hypothesis

Joseph Fraunhofer, 1814: Discovery of single lines in the spectrum of sunlight

P.L. Dulong/A.T Petit, 1817: Besides the formulation of the law about the heat capacity of solid elements, measurements about the heat transfer of gases and in vacuum were made, too (Figure 2)

August Beer, 1852: Measurement of the red-light absorbance in coloured fluids

Kirchhoff/Bunsen, 1858: Development of the spectral analysis

John Tyndall, 1861: "On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction." (Figure 3)

Thomas A. Edison, 1879: Invention of the electric light bulb based on a carbon filament

M. J. Stefan, 1879: The formulation of the temperature-dependence-law for the energetic radiative intensity including the assumption of a back-radiation, based on the empirical data of Dulong/Petit

Ludwig Boltzmann, 1884: Delivered the theoretical foundation of Stefan's law on the basis of the electromagnetic light theory

S.P. Langley, 1884: Spectroscopic investigations of the light absorption by the Earth's atmosphere

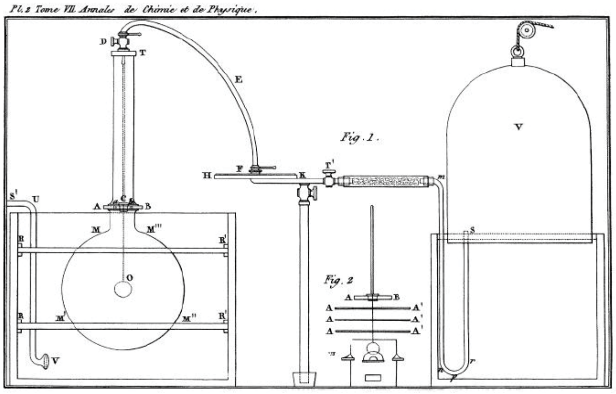

Figure 2: Equipment of Dulong/Petit (1817) [11].

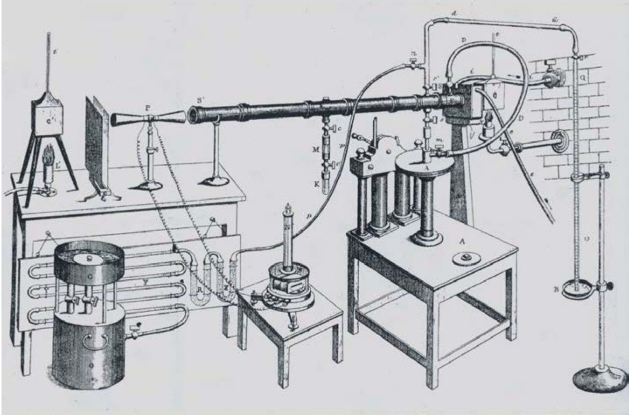

Figure 3: The preferred apparatus of Tyndall (1861) [2].

A. Schleiermacher, 1888: Development of a basic method for measuring the heat conductivity of gases and the heat transfer in vacuum (see below)

Wilhelm Wien, 1896: Law for the spectral shift of the black-body radiation

Lummer/Pringsheim, 1899: Instrumental perfection of the radiation measurements (Figure 4)

Max Planck, 1900: Quantum theory about the energy dispersion in the black-body radiation spectrum

Nearly all of the hitherto known measuring methods which were carried out with gases and/or in the vacuum trace back to ancient work made in the 19th century. They shall be shortly discussed although solely medium infrared radiation is involved, i.e. thermal radiation occurring at comparatively low temperatures ($\lambda > 3$ µm, cf. Planck's distribution law, (Figure 5).

The method of Dulong and Petit [11] allows the measurement of heat spreading in the presence of gases as well as in vacuum, the latter one being due to heat radiation. As drafted in figure 2, in the centre of a spherical vessel MM'M''M''' a ball O is positioned which is previously warmed-up to an elevated temperature while the spherical vessel is surrounded by a further vessel filled with ice-water and thus keeping the wall of the spherical vessel constantly at 0°C. After the start of the experiment, the central ball gradually cools down with a decreasing rate till radiation equilibrium is reached. As a central ball, the bottom of an Hg-thermometer was used, in some cases being coated with silver. The spherical vessel was made from copper, allowing an evacuation and thus determining heat spreading in the vacuum. The starting temperature ranged up to 260°C allowing the study of quite large temperature gaps. The eminent advantage of this method is the absence of any lateral walls along the radiation or heat conduction path, which may disturb the energetic conditions.

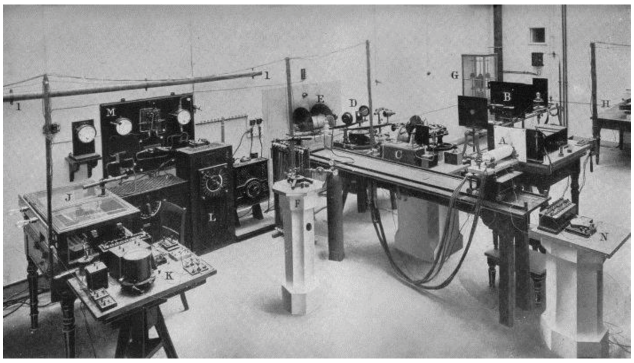

Figure 4: Equipment of Lummer and Pringsheim (1899) [26].

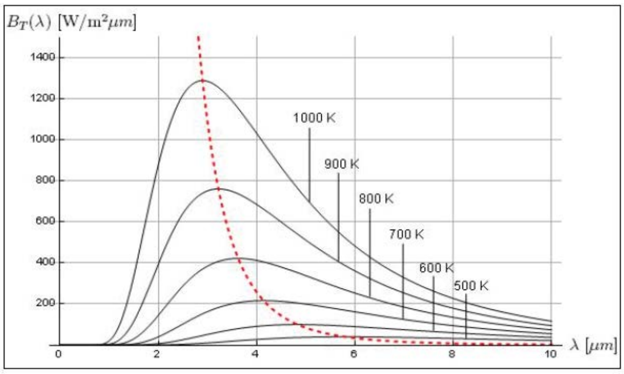

Figure 5: Specific spectral radiation BT(λ) of a black body at different temperatures, the red dotted line describing the respective intensity maxima (according to Planck's law).

Thereby, the author's original interpretation of the results is less important than the one given by Stefan [12] delivering the well-known Stefan's law, later being theoretically founded by Boltzmann [13]. It is given by the generally-known formula for the radiant flux P

$P = a \cdot \sigma\left(T_1^4 - T_2^4\right)$ wherein σ = Stefan-Boltzmann constant = $5.67 \cdot 10^{-8}$ Wm^{-2}K^{-4}, a = area

In Stefan's paper the relation is not given in this form but it also exhibits some ambiguities with respect to units impeding the feasibility of comparing the values. Moreover, it should be noted that the basic experiments of Dulong and Petit were made in a closed system encased in solid materials. Nevertheless, this formulation - particularly the fourth power of the absolute temperature T - represents a milestone in understanding radiation processes.

The method of Schleiermacher [14] for determining the heat conductivity of gases is in a certain way related to the method of Dulong and Petit since it operates with a heated central body and an encircling form, too. However, the central body is not a ball but a rod or a wire, and the encircling form is not a hollow sphere but a (glass) tube, implying a cylindrical and not a spherical topology. Moreover, the coaxial wire - being from platinum - is not cooling down during the process but held at a constant temperature by applying an electric current leading to a steady state. The encircling tube is hold at a certain temperature, too, due to an outer vessel filled with ice-water or with boiling water, while the temperature of the central wire is calculated as a result of the current strength and the electrical resistance. In spite of its old age (1888), the work of Schleiermacher is still of special interest allowing to study the respective basic impacts. In particular, the pressure-independency of the thermal conductivity of gases is noteworthy. Subsequent work was made by Weber [15], Guildner [16], and Wiegleb [17]. Due to these empirical results, especially concerning the thermal conductivity, the kinetic gas theory, developed by Meyer, Maxwell and Boltzmann, could be verified.

The Irish physicist John Tyndall was the first one who delivered empirical data for underpinning the hypothesis that carbon-dioxide would be the cause for an atmospheric warming-up inducing what we call now a »greenhouse effect«. He found that special gases (which he called «olefiant» gases), not least carbon-dioxide, absorbed thermal radiation whereas other gases, in particular nitrogen and oxygen, were inactive.

Moreover, he found non-linear pressure dependences of the absorbance. His preferred apparatus, first published in 1861 and drafted in Figure 3, consisted of a long tube from brass (polished inside, length 4 feet = 122 cm, diameter 2.4 inches = 6 cm) which he filled with various gases at different pressures but which also could be evacuate admitting measurements under vacuum. The ends of the tube were capped with slabs of rock salt crystal (sodium chloride), a substance known to be highly transparent to heat radiation. Leslie cubes were used as radiation sources. They consisted of cubic vessels from copper, coated with lampblack and filled with boiling water. One Leslie cube served as an emitter, the other as a reference. The emitted radiation traversed the gas containing tube before entering one cone of a differential thermopile. Radiation from a second, opposite Leslie cube passed through a screen and entered another cone. The common apex of the two cones, containing a differential thermopile junction, was connected to a galvanometer which measured small voltage differences. The intensity of the two sources of radiation (i.e. of the two Leslie cubes) entering the two cones could be compared by measuring the deflection of the galvanometer which is proportional to the temperature difference across the thermopile. Different gases in the tube, as well as different gas pressures, caused varying amounts of deflection of the galvanometer needle.

The kind of the radiation sources - namely of Leslie cubes - implied, due to the comparatively low temperature of the heat source, the emission of medium-wave IR light (wavelength λ = 3-50 μm) which is relevant to the thermal heat radiation of the Earth surface. Tyndall could not know this, because at that time Wien's distribution law - and even less Planck's radiation law - was not known. Besides of some systematic faults, Tyndall's consideration exhibits some theoretical faults which may be excused by the fact that he had made pioneer work, and that then the knowledge about radiation was quite poor. It is amazing that he speaks of «water atoms», and that he obviously did not know the absorption law of Bouguer-Lambert-Beer. Instead of this, he calculated on the base of - inversely proportional – absorption units leading to completely false results with respect to the atmosphere.

Forty years later, a similar apparatus was used by Sven Arrhenius, focusing the carbon-dioxide adsorption of infrared radiation, and pronouncedly propagating the greenhouse model [4, 5]. He applied a 50 cm long iron tube but two different IR-sources, namely - besides a Leslie-cube at 100°C - a hollow body from smutted copper that was chilled down to -80°C by a mixture of dry ice and ether. He varied the pressure but within such a high range that no significant deviation from linearity appeared.

At the same time, Knut Ångström (son of the well-known Anders Jonas Ångström) made IR-absorption measurements with carbon-dioxide using a two-chamber tube and varying the tube length as well as the carbon-dioxide concentration by adding air to distinct amounts. But since he used three different radiation sources delivering varying badly defined kinds of radiation - namely an Argand-lamp, a Bunsen-burner and a blackened platinum-spiral heated up to 300°C -, his results are difficult to interpret, and thus of limited interest [18, 19].

In a way, Tyndall's apparatus is similar to a modern infrared-spectroscope which nowadays is always used for analytical absorption measurements, and which yields for carbon-dioxide the spectrum shown in Figure 6. However, there is a principal difference insofar as spectroscopy is based on monochromatic radiation, i.e. solely a narrow range of the electromagnetic spectrum is used. Moreover, preferably visible light and liquids are affected, as it is notably apparent from the work of Beer [10] who studied the absorption of red light in coloured liquids using an oil-lamp as the light source and a dark-red coloured glass plate as a filter. Beer studied the intensity-loss as a function of the sample-thickness, varying the thickness between 1 and 2 dm. His empirical result may be written as

$I/I_0 = \mu^{-d}$ where μ = Beer's absorption coefficient, and d = thickness (normalized)

However, this formula doesn't match the formula which is given in modern textbooks, namely

$I/I_0 = e^{-\varepsilon \cdot c \cdot d}$ where ε = absorption coefficient, c = concentration.

The latter one, known as the Bouguer-Lambert-Beer law, is derived theoretically by integration, assuming that the differential intensity-loss is proportional to the present intensity which decreases insofar as the intensity decreases. However, with respect to gaseous IR-spectroscopy there is no empirical evidence for this widely used formula, cf. [20].

With respect to practical measurements, the general interest was more and more geared to spectroscopic methods for analytical applications, using artificial light sources and photo-detectors, the light usually being resolved by a prism in combination with a frame. However, in astronomy as well as in meteorology the direct analysis of natural light, in particular of solar light, plays still a certain part [21-23], whereby the measuring of the absolute intensities is much more needed here. But while the over-all intensity (given in Wm^{-2}) may be easily determined by temperature measurements at a blackened cavity - or by electronicainstruments (bolometers) gauged by such blackened cavities -, wave-specific measurements are much

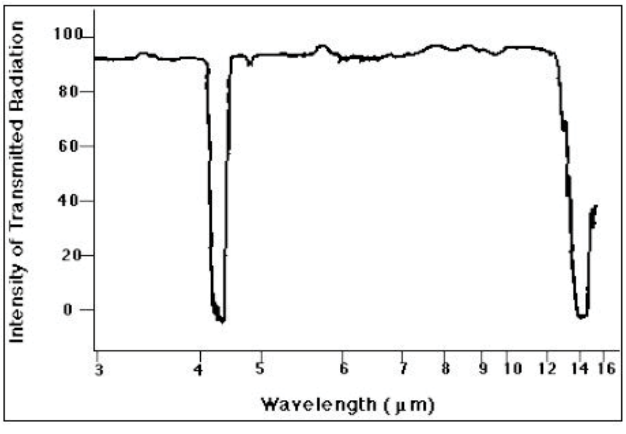

Figure 6: IR-spectrum of carbon-dioxide.

more delicate, particularly when infrared radiation is affected, since the medium for splitting the radiation may absorb parts of it leading to systematic measuring errors.

For the "spectro-bolometer" used by Langley [24] p. 130, e.g. interference due to the glass-prism may occur since glass absorbs IR-light. Even grating infrared spectrometers, e.g. the one described by Thompson et al. [25], may exhibit some intrinsic deficiencies since glassy materials such as glass-lenses and glass-prisms are necessary for focussing the beam, not least the ones of the telescope, and the complicated equipment of Lummer and Pringsheim [26], which are relevant for determining black-body radiation and shown in Figure 4, presages the difficulties which such measurements may encounter. When gases are concerned, the circumstances are even more complex, especially when they absorb only slightly, and when the absorption bandwidth is wide so that an absorption effect may be overlooked.

But beyond these difficulties, an essential aspect had been omitted in the above quoted literature, namely the fact that solely medium-IR had been regarded - and not near-IR as it occurs in direct and in reflected solar light. With respect to that, no investigation had been made - except one being reported in a previous paper of Knut Ångström [18]. Therein, he describes an apparatus consisting of two 40 cm long glass-tubes arranged side by side within a wider tube from wood, the latter one serving to the visual and thermal isolation, and exhibiting plates from fluorspar, on one end, and thermocouples on the opposite end. When one tube was filled with air, and the other with pure carbon-dioxide, and when the tubes were oriented perpendicularly to the sun beam, practically no temperature difference could be ascertained. That means: both gases either did not absorb any sunlight, or they absorbed it to the same extent. Since this result did not come to his expectations (and to the current opinion of that time), Ångström changed his focus subsequently regarding medium-IR, leading to his already alleged publication [19]. Apart from that, solely the intensity-loss of the incident light was measured, but not directly the warming-up of the embedded gas by measuring its temperature. That is a fatal deficiency because the intensity loss might be undetectable.

Since then, apparently no thermal measurements have been made with gases in the presence of IR-radiation, in particular of sunlight. In default of further published results, a diploma thesis of Sirtl will be alleged, originally written for didactic objectives but containing some interesting aspects [27]. Similarly to Tyndall's experiments, on one side of a horizontal tube, filled with a gas and laterally sealed by transparent foils, an IR-radiator was provided while on its opposite side a thermopile was positioned. Additionally, in the centre of the tube a temperature sensor was attached (Figure 7).

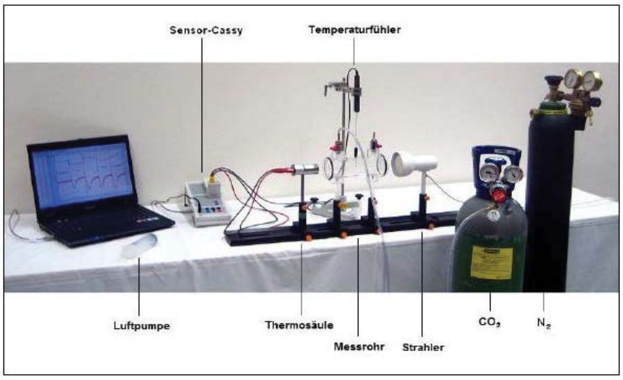

Figure 7: Preferred equipment of Sirtl [27].

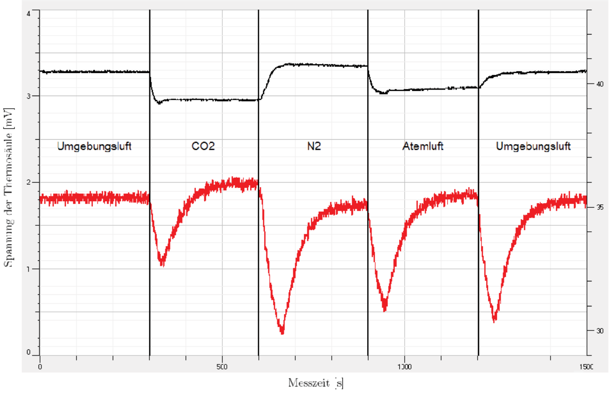

Figure 8: Temporal course at different media using a 60 W ceramic radiator [27].

Moreover, a tube from Plexiglas was used - instead of a metallic one -, and the variously applied radiators exhibited much higher temperatures than the Leslie cubes of Tyndall. In any case, obviously a limiting temperature was reached. But as exemplarily revealed in Figure 8, no significant differences appeared when different gases such as carbon-dioxide or surrounding air were used. When a 150 W infrared lamp was inserted, absolutely no effect could be detected. Certainly, this apparatus exhibits several deficiencies, such as the high IR-radiative absorbency of the Plexiglass-tube and its high thermal capacity. Hence these results are only of limited interest.

The actual public attention on the climate change and its theoretical conjunction with the increase of «greenhouse gases», in particular of carbon-dioxide, mainly traces back to the work of Gilbert N. Plass in the 1950s [28-34]. In contrast to the original authors, he relied on IR-spectroscopy which meanwhile had been established, especially in chemical analysis. However, he did not make own measurements, but he solely interpreted external data. A respective critical discussion is given in [20]. Over time, this theoretic construction was amplified, producing numerous theoretical publications and even text books [35-37], delivering various model predictions, and becoming a political - and thus very simplified - issue. It strictly excludes any other influences, in particular the one of the albedo, i.e. the solar reflection coefficient, which is a measure for the superficial warming up during a solar light exposure. Therefore, this item will later be discussed separately.

The common greenhouse theory, described e.g. in [38], may be shortly summarized as follows: The Earth surface, after being warmed up by incident solar light, radiates heat to the atmosphere which is warmed up the more the concentration of «greenhouse gases» such as CO_2 rises. Therefore, this theory also implies the warming-up of the ground by solar light. But this aspect is usually disregarded, assuming a temporary constant albedo of the Earth surface, which has obviously not been the case over the course of the last decades. All the more, exclusively the IR-spectroscopic results were taken into account which revealed that molecules with polar chemical bonds - such as the C=O bonds in CO_2 - absorb thermal radiation in the long IR-wave-range, while molecules with nonpolar chemical bonds - such as the main components of air N_2 and O_2 - are IR-inactive. This may be explained by atomic vibrations inside the molecules, induced by resonance with the radiation. However, in default of respective measurements, IR-spectroscopy did not deliver any empirical evidence that the absorbed radiation energy is quantitatively transformed into heat energy, for the temperature of a gas depends on the *inter*-molecular movement of its molecules which is not simply correlated to their *intra*-molecular vibrations. Thus it cannot be excluded that the absorbed radiation energy is re-emitted before being transformed into heat energy.

This would mean that in the absence of any «greenhouse gases» the temperature of the atmosphere would be extremely low, which is absurd. Moreover, it could not be satisfyingly explained why the incident solar light considerably loses intensity also in the short - IR-wave-range when it passes through the atmosphere, for in that range, CO_2 is IR-inactive. Even if this radiation amount is not easily detectable, a partial absorption of solar short IR by the atmosphere seems to be presumable. But in particular, our climate perception concerns the atmospheric conditions close to the Earth surface - and not through the entire atmosphere up to the stratosphere, as pretended the common greenhouse theory. Strictly speaking, a plausible explanation of the atmospheric behavior seems impossible when no further knowledge is available. Hence, the author's discovery of the thermal absorption behavior of gases delivers the information for basically explaining the atmospheric properties, getting along without these ominous «greenhouse gases», and delivering empiric evidence that any gas, also nitrogen and oxygen, is able to absorb IR-radiation.

The Author's Own Thermic Gas Absorption Measurements

The measurement of warming-up of gases in the presence of thermal radiation entails considerable difficulties due to the interference between the walls of the probe-tube and the gas, since the walls exhibit a higher heat capacity than the enclosed gas, which may falsify the results. Even the glass-envelopes of the thermometers may disturb since they can absorb heat radiation.

Thus, for such measurements square tubes from 3 cm thick Styrofoam with comparatively large diameters (25 cm) were used which were covered at both ends with thin plastic foils [39]. Styrofoam does not only exhibit low heat capacity but also low heat conductivity which both are desirable for good isolators. For detecting the temperature-course along a tube, three thermometers were mounted at three positions (below, intermediate, and above). The tips of the thermometers were mirrored with aluminium foils to ensure a minimal measuring distortion. The test gas was supplied by a steel cylinder, exhibiting a reducing valve, and blown into the tube via a connecting pipe. The filling level was monitored by a hygrometer because initially the tube was filled with ambient moist air which then was filled with the dry test gas. The filling process lasted normally approx. one hour. The measuring tube was stepwise improved and finally mirrored with flimsy aluminium foils and sealed with adhesive foils (Figure 9).

The first measurements were made in sunlight using twin solar tubes (Figure 10), one filled with air, and the other filled with carbon-dioxide. Thereby the temperature rose in a few minutes to a limiting value, simultaneously at the three measuring points. Surprisingly, warming-up was in both cases nearly

Figure 9: Optimized solar tube, adjustable towards the sun [39].

Figure 10: Original twin tubes [39].

equal - namely approx. 10°C -, contrary to the expectation that solely carbon-dioxide should be warmed up. Already this tentative result delivered a striking hint that the greenhouse theory cannot be accurate. Furthermore, it gave the impetus to study this topic more profoundly, using artificial light which can be applied more precisely.

The most extensive investigations were made with a single Styrofoam tube and an IR-spot which was mounted above (Figure 11). Thereto, spots with different intensities were employed (50 W, 100 W, and 150 W), which are commercially available for terraria. Particularly the 150 W spot induced significantly larger temperature enhancements of the enclosed gases than solar light did. Thereby, variable effects - in particular the nature of the gas - could be studied more precisely. The disadvantage of this method arose from the fact that temperature gradients along the tube occurred, due to the spotty character of artificial light sources. However, this effect could be minimalized by optimizing the tube. Due to the higher temperature of the spot, the amount of shortwave IR-radiation was larger than it has to be expected for the (low temperature) heat radiation of the Earth surface, which is relevant for the greenhouse theory or for other respective atmospheric theories. But subsequent measurements using a hotplate, mounted at the lower end of the tube, yielded similar results for air and carbon-dioxide [20].

Due to the results obtained with IR-spots and different gases, essential knowledge about interaction between IR-light and gases could be gained. In any case, the irradiated gas was warmed up to an invariant limiting temperature where the absorbed radiation power was equal to the radiation power emitted by the gas. As obvious from the diagram in Fig. 4, on the one hand the finding of the experiment with solar tubes was confirmed that air warms up almost like pure carbon-dioxide, whereby humid air did not significantly differ from dry air. On the other hand it became apparent that noble gases absorb IR-radiation, too. This result was even more surprising than the similarity of air and carbon-dioxide. But it could theoretically be explained, as follows.

Figure 11: Heat radiation tube with an IR-spot [39].

Interpretation of the Results

As Figure 12 reveals, the warming-up rate (given by the initial slope) is independent of the type of gas, whereas the limiting temperatures depend on the type of gas. Since at any limiting temperature the absorbed radiation power is equal to the emitted radiation, the latter one, which is not directly measurable, may be determined by the former one, which is directly measurable.

In practice, the absorbed radiation power is not easily determinable because the local intensity of the irradiated IR-light is hard to assess, due to the intensity losses between the IR-spot and the upper end of the tube, as well as inside and along the tube. In order to bypass this difficulty, the limiting temperatures of the noble gases helium, neon and argon were compared, assuming proportionality between the limiting temperatures and the emission powers.

Apparently, there exists a correlation between the limiting temperatures - and thus of the emitted radiations - and the molar masses of the respective gases, whereby the emitted radiation increases when the molar mass increases.

However, when the molar masses of helium (= 4), neon (= 20), and argon (= 40) are compared with the respective limiting temperatures 314K, 324K, and 331K, it is obvious that besides the molar mass at least one further factor must be involved, since the ratio of the molar masses differs considerably from the ratio of the limiting temperatures. Therefore the question arises, which one could be this factor, and - moreover - whether the influence of this factor could be mathematically verified using physical agents.

The answer to this question could be found by applying the kinetic gas theory and by formulating the hypothesis that the thermic emission of gases is proportional to the collisional frequency *f* of the gas particles. Thereby, the size of the

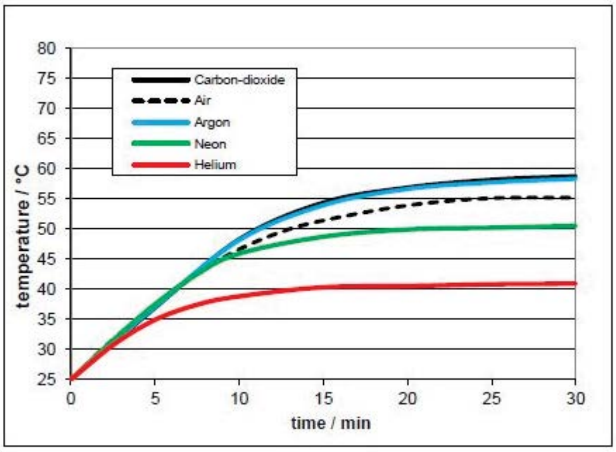

Figure 12: Temperature courses of different gases [39]; (150 W IR-spot, intermediate thermometer position).

particles-or rather their cross sectional area σ-acts a part, besides the gas pressure *p*. Overall, relation (1) turned out to be accurate:

$f \propto p \cdot \sigma \cdot \sqrt{T/M}$ (1) T = absolute temperature, M = molar mass

The comparison of the results obtained by using IR-spots, on the one hand, and sun light, on the other hand, yielded that the absorbed IR-radiation was short-wavy, supposedly approx. 1.9 µm. Subsequent experiments with a hot-plate positioned below the radiation tube (Figure 13), which entailed lower temperatures (<90°C) and therefore larger wave lengths, were less precise but delivered similar results [20]. However, at a larger distance pure CO_2 was even less warmed up than air (Figure 14).

Thus, this kind of absorption occurs over a relatively large wave-length range, in contrast to the hitherto known IR-spectroscopic measurements which deliver solely narrow absorption bands. Obviously, another kind of IR-absorption has herewith been discovered, characterized by a considerable warming-up of the irradiated gas, but not detectable with usual IR-spectrometers, whereas in the latter case, the absorbed IR-radiation is supposedly re-emitted, without having a warming-up effect. This novel kind of IR-absorption is supposedly not associated with vibrations of atom nuclei within molecules, but rather with vibrations of atomic electron shells.

The Interaction of Solar Light with Solid Opaque Bodies

One of the initial reasons for assuming an influence of the Earth surface on climate, at least on microclimate, was historically given by the phenomenon of the so called urban heat islands. Howard [40] was the first to provide evidence that air temperatures are often higher in the city of London than in its surrounding countryside. Nearly a century later, Vienna's heat island was described in great detail, among others by Schmidt [41]. After the Second World War, in 1961 Mitchell put forth the phenomenon of higher temperatures in cities [42]. However, at that time climate change had not yet attracted the attention of the public, and even less temperature increase in cities. Only in the 1990es the feasibility of mitigating the micro-climate in cities was considered. Thereby, the influence of surface colouring is obvious, whereby bright colours cause a minor warming-up in the presence of sunlight than dark ones.

Figure 13: Heat radiation tube with a hot-plate [20].

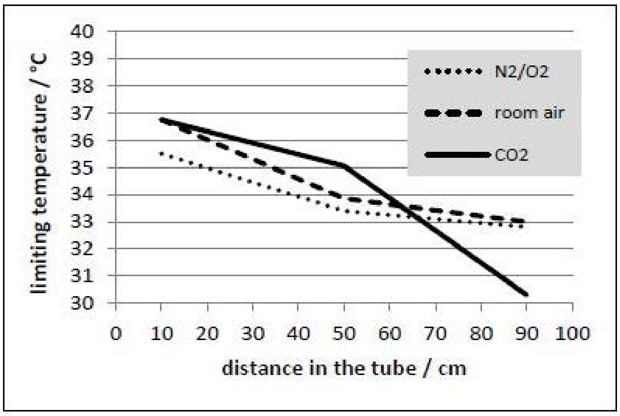

Figure 14: Temperature courses of air, a N_2/O_2 mixture (4:1), and of CO_2 in a heat radiation tube with a hot-plate [20].

For describing this effect quantitatively, the term «albedo» has been widely used so far. It is derived from Latin meaning «whiteness», was introduced by Lambert [9], and is commonly assumed as the colour-dependent solar reflection coefficient, normally indicated by α. It is defined as the ratio between intensity of the light, which is reflected by a coloured surface, and the intensity of the incident solar light. Besides this process - occurring directly on the Earth surface und thus concerning the surface albedo -, the global interaction between the Earth and Outer Space may be considered, concerning the global albedo and affecting the over-all radiated emission. However, this term is much more complex since any atmospheric incidents are involved. So it cannot be expressed by a simple number. If this is nevertheless done - as it is often the case in climate modelling, e.g. in all the textbooks [35-37] and in [43] -, it is not correct.

However, already with the definition of the term (surface) «albedo» some ambiguities arise: for, strictly speaking and regarding its true meaning, the albedo value should not be an absolute one but a relative one, namely being related to a white surface. However, in the literature such a distinction is not made. Rather, the terms «albedo» and «solar reflection coefficient» are used as synonyms. Moreover, according to the citations in the publication of Coulson and Reynolds [44], one finds the further apparent synonyms «spectral reflectance»,

Figure 15: Commercially available albedometer.

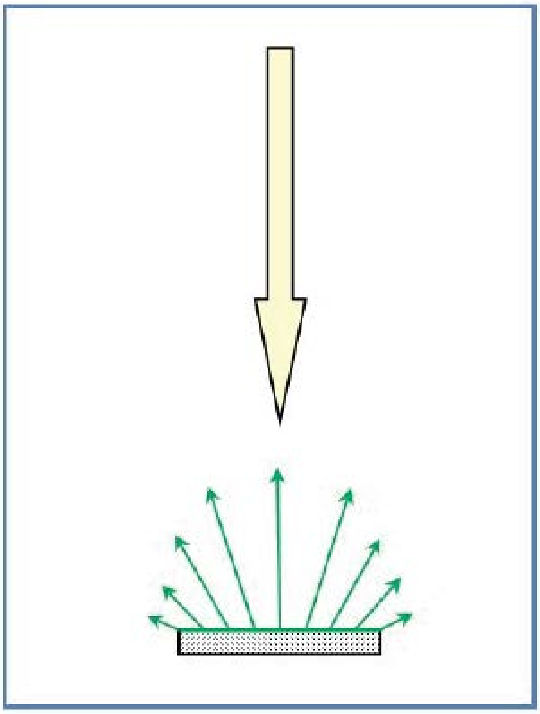

Figure 16: Scattering of reflected solar light on a coloured solid opaque plate.

«optical reflection», «reflection of direct radiation» and «reflectivity». Thus, in order to clarify the terms, it has been proposed to distinguish between the-absolute - solar reflection coefficient as and the - relative - albedo αs.

In order to determine the solar reflection coefficient of a certain solid area or plate, it immediately suggests itself to measure simultaneously the intensity of the incident solar light, on the one hand, and of the reflected light, on the other hand. That is indeed the case with the so-called albedometers, as exemplarily shown in Figure 15. Therein, the light intensity is measured by two diametrically opposed pyranometers, being approx. adapted to the electromagnetic spectrum of solar light extending from wavelength 300 to 3500 nm, where the range <380 nm matches UV (= ultraviolet) radiation, and the range >760 nm matches IR (= infrared) radiation. According to ASTM Standard E1918-06, a pyranometer operating in the range 280-2800 nm is recommended.

However, there is a fundamental problem which makes an absolute determination of the solar reflectance coefficient impossible. It results from the fact that the reflected solar light is - unlike mirrored one - scattered, thus its intensity depends on the distance (Figure 16). On the contrary, the intensity of the incident solar light does not depend on the distance. As a consequence, the albedometer readings depend on the distance, and thus they are not well defined. Hence, solely relative measurements are possible, preferably using a white surface as a standard. Thereto a simple light-meter, being the custom for photography, delivered satisfying results within field measurements.

In view of the fact that actually the absorbed solar energy is relevant for warming up the Earth surface - and not the reflected one -, it would suggest itself to determine the solar absorption coefficient bs which formally amounts to 1- a_s. Thereby, the warming-up of focussed materials should be measured, and not their thermal radiative emission. However, respective measurements on the object are difficult to perform since the boundary conditions cannot easily be influenced, allowing no well-defined characterization of the materials. Nevertheless, field measurements where nearly the only methods reported so far in literature.

Doulos et al. [45] and Synnefa et al. [46, 47] studied different building materials recording the mean hourly ambient temperature during the day as well as during the night and using sampling tiles with a normal size of 40 cm x 40 cm. The sampling tiles were placed on an especially modulated platform covering a surface of 40 m^2, but being not embedded within a heat-isolating material, and being not orientated in a well-defined direction. The selected sample materials consisted of several different construction materials, of different surface colour materials, and of different surface texture materials. The basic experimental equipment used for the implementation of the measurements consisted of an infrared camera to measure surface temperatures. Measurements were also performed by using contact thermometers in order to take into account minor errors associated with reflected infrared radiation and the non-complete knowledge of the material emissivity.

The optical and thermal criteria were both regarded but not separated, so the classification «cold materials» were vaguely characterized by a high reflectivity factor to the short-wave radiation and a high emissivity factor to the long-wave radiations. Within the study [46], an infrared camera was used in order to observe the temperature distribution on the surface of the samples as well as to depict the temperature differences between the samples, whilst within the study [47], the infrared emittance of the samples was also measured with the use of an «emissometer», while the spectral reflectance of the samples was measured using a UV/VIS/NIR spectro-photometer. Yet again, the reported results solely concern steady final states, and not temporal temperature courses, the boundary conditions being poorly defined.

Hagishima and Tanimoto [48] made field measurements for estimating the convective heat transfer coefficient at building surfaces, being defined as the quotient of the convection heat flux [Wm-2] and the temperature difference between air and surface. The material specificity was not studied, but mainly the dependence of wind velocity. Generally, the variation of the results was quite large.

Exact laboratory-like methods with well-defined boundary conditions have hardly been applied, yet. The only known seems that one described by Schwerdtfeger [49], using a simple apparatus consisting of aluminium disks being set into insulating Styrofoam-blocks and laterally equipped with Hg-thermometers. Since they are cooled by an electric blower during the solar insolation, the influence of air convection is maximized instead of minimized. Moreover, this method affects only limiting, i.e. stagnation conditions.

The Direct Determination of the Solar Absorption Coefficient and the Modelling of the Absorption Process at Coloured Plates

The novel method, in detail described in [50], enables the direct determination of colour dependent solar absorption coefficients βs under lab-like conditions by detecting the temporal course of coloured plates irradiated by solar light. It delivers quite precise results, but it interrelates with the character of the sunlight which depends on the solar altitude, the sea level of the measuring point, and the status of the atmosphere.

For this purpose, differently painted standardized plates are used (preferably 10 x 10 x 2 cm^3), equipped with thermometers, which are orientated perpendicularly to the solar radiation and continuously repositioned during the measurement period by hand. Preferably several measuring units are placed on a panel which allows the orientation towards the sun light by respective inclining (Figure 17). The plates are preferably made from aluminium, below and laterally isolated with Styrofoam, and above covered with thin PVC-foils serving as outer windows (Figure 18).

For comparison, other materials were used for the plates, too (wood, brick, and natural stones). Simultaneously, the intensity of the incident solar light (in W/m^2) must be measured with a suitable electronic instrument as a reference.

Such an experiment lasts preferably half an hour, whereby the temperature measurements are made every five minutes. During the whole process the sky must be cloudless. When the temperatures are plotted against time, a diagram of the type shown in Figure 19 is obtained. Together with the heat capacity of the plates (which may be calculated from their specific heat capacity found in literature) and the electronically measured radiation intensity of the sunlight, the graphically determined initial slopes of the curves yield the respective solar absorption coefficients β_s (Figure 20).

The solar reflection coefficients as = 1- β_s can easily be computed as the complement to the solar absorption coefficients. Moreover, the albedo values, here defined as the measured solar absorption coefficients relative to the measured absorption coefficient of white colour, can likewise be computed.

Figure 17: Panel with six measuring units [50].

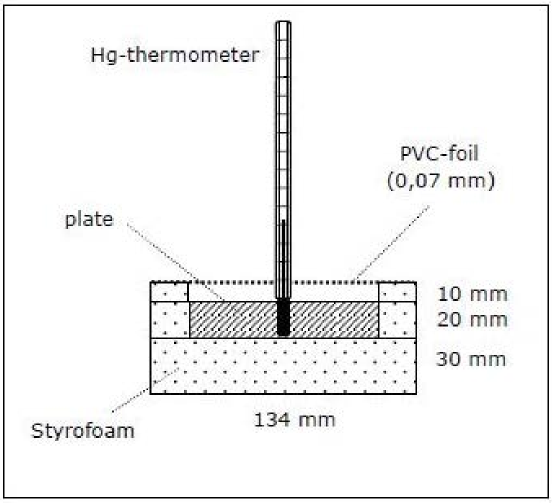

Figure 18: Coloured plate embedded into Styrofoam and covered with a transparent foil [50].

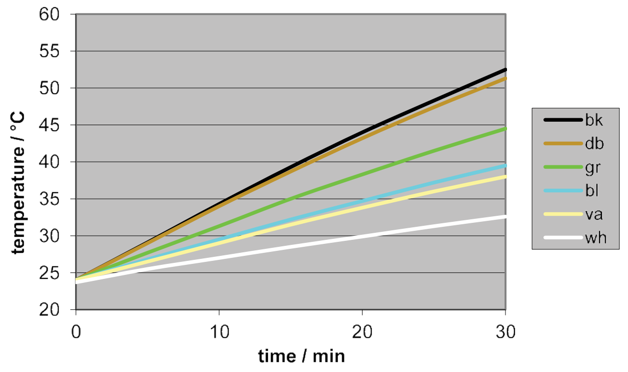

Figure 19: Warming-up of aluminium plates at 1040 Wm^{-2}, Glattbrugg 2013-09-04, φ = 36° [50]
Initial slopes [°/min]: wh 0.31 / va 0.52 / bl 0.58 / gr 0.77 / db 1.02 / bk 1.08
(wh = white, va = vanilla, bl = light blue, gr = light green, db = dark brown, bk = black).

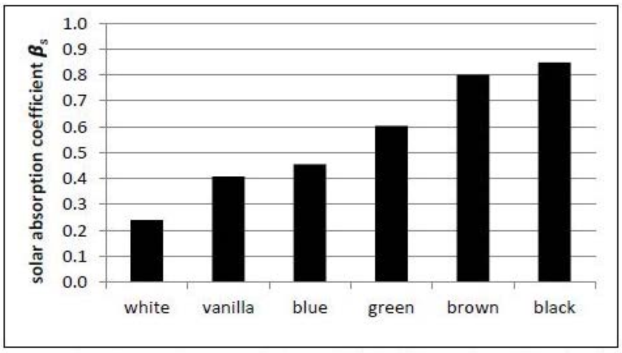

Figure 20: Solar absorption coefficients derived from the values in Figure 19.

When the measurements are continued, i.e. when the plates are irradiated for an extended period, the slopes of the time/temperature-curves begin to decrease since the plates emit or transfer heat to the atmosphere. This heat transfer increases proportionally to the temperature difference, till a limiting temperature is reached. At this moment, the emitted radiation power is proportional to the absorbed one. Thus there is an analogues effect as in the case of IR-radiation onto gases.

However, in this case it lasts much longer till the limiting temperature is reached, namely - for 20 mm thick aluminium plates - several hours. Since during such a long period of time the solar radiation varies too much, such long lasting measurements are practically not feasible. Therefore the question arose whether it could be possible to measure the cooling down behavior of the plates separately, and subsequently to mathematically combine the warming up process with the cooling down process. Such cooling-down measurements were carried out in a darkened room using the same isolated holders for the plates. They were preheated in an oven. Thereby, the cooling down rates turned out to be independent of the surface coloring of the plates and solely dependent on their thickness or the heat capacity, respectively.

Based on the measuring data, mathematic regularities could be found, which allowed extrapolation of the curves and modelling of the process. Thereby, the actual (absolute) temperature T of a plate is given by the equation (2), whereas the limiting temperature T_{lim} can be calculated according to equation (3):

$$T = T_{am} + \frac{\Phi \cdot \beta_s}{B}\left(1 - e^{-\frac{B\cdot a}{m\cdot c_m}t}\right) \tag{2}$$

$$T_{\mathrm{lim}} = T_{am} + \frac{\Phi \cdot \beta_s}{B} \tag{3}$$

T_{am} = ambient temperature [°K or °C] Φ = intensity of the solar radiation [Wm^{-2}]

β_s = solar absorption coefficient [dimensionless] B = heat transfer coefficient [$Wm^{-2}K^{-1}$]

a = surface area [m^2] m = mass [kg] c_m = specific heat capacity [$g^{-1}K^{-1}$] t = time [s]

Φ must be measured separately, preferably with an electronic instrument; β_s can be determined by the initial slope of the time/temperature-curve and the total heat capacity of the plate; whereas B can be determined by means of cooling-down experiments, as described in [50]. B is independent of the material, but dependent on the surrounding conditions. For the experiments with a thin PVC-foil as an outer window, the value of B was approx. 9 $Wm^{-2}K^{-1}$. In the absence of such an outer window, B was considerably larger.

Equation (2) enables to compute the time/temperature-curves for different coloured plates when the key-values are known, and when the boundary conditions are fulfilled. As obvious from Figure 21, the limiting temperatures solely depend on the colours of the plates, whereas the warming-up rate and therefore the length of time for reaching the limiting temperatures depend on the thickness of the plates. The principal correctness of this modelling method could be demonstrated by measurements with thinner aluminium plates (8 mm instead of 20 mm Figure 22) which were carried out four years later [51].

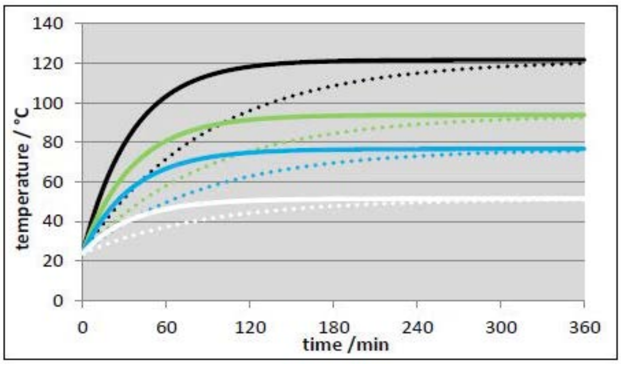

Figure 21: Modelled curves, according to equation (2) and Fig. [19]; continuous lines: 8 mm alu-plates / dashed lines: 20 mm alu-plates.

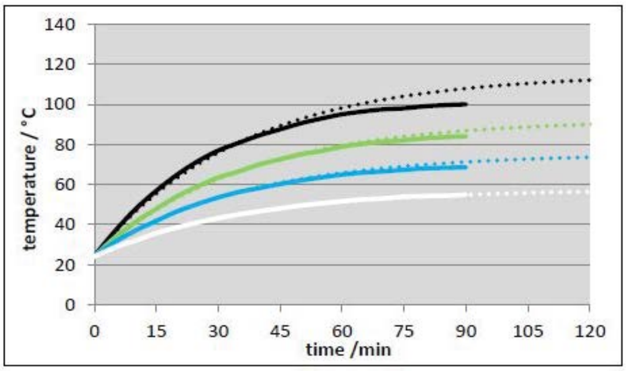

Figure 22: Comparison of measured curves (dashed lines, according to [51] G8b) and modelled curves (continuous lines), using 8 mm aluminium-plates.

The Altitude-Paradox of the Temperature

The assessment that the temperatures on mountains are generally higher than in lowlands is banal, but the attempt to explain this physically is not banal. Ordinarily, it is explained by the fact that the air is cooled down when it ascends upwards from a valley bottom. However, this argument seems not to be convincing at least for extensive upland plains, far away from inclines where air may ascend. All the more this phenomenon appears to be paradox since the intensity of the solar irradiation is larger on mountains than in lowlands, due to the partial absorption of several solar light-components such as UV-light, but even of IR-light (as reported in the second chapter), which may lead to warming-up of the atmosphere. Further evidence for solar light absorption by the atmosphere is the blue coloration of the sky, due to Raleigh Scattering, as well as the red sky in the morning and in the evening. Thereby, it appears reasonable to assume coherence between the atmospheric pressure and the absorption degree at the solar irradiation.

However, that is only half the truth. Much more important than this direct interference of the solar irradiation with the air is the indirect one via Earth surface, at least with respect to our climatic feeling. There the main part of the sunlight is absorbed and subsequently passed to the atmosphere, not only by thermal radiation but also by pure heat transfer. Thereby, this process is complicated by other influences such as wind or hydrological cycle implying vaporisation and condensation of water. To avoid - or at least minimize - such disturbing influences, the above-described method (referring to [50]) is optimal. This method is even necessary to make the below-described investigation which resolves the said paradox.

To understand the real coherences, a perception is required which principally takes up the conventional relation of Stefan/Boltzmann, but partly questions it. Thereby, the basic concept that - in the case of radiation equilibrium - the warming-up of a solar irradiated surface of a solid material is not only determined by the absorbed incident solar light, but also by a thermal counter radiation of the atmosphere. Likewise it can be stated that the heat energy of the absorbed solar radiation is equal to the difference between the emitted thermal radiation of the solid material and the counter radiation of the atmosphere. Thus the Stefan/Boltzmann law, applied on solar irradiated coloured plates, and regarding the equilibrium state, can be expressed with equation (4). Therein, «SOB» means «solid opaque body». As mentioned above, any solid opaque body behaves - with respect to radiative emission - like a «black body».

$$\beta_s \cdot \Phi_{sun} = \sigma(T^4_{SOB,\lim} - T^4_{atm}) \tag{4}$$

β_s = solar absorption coefficient, colour dependent

Φ_{sun} = intensity of the incident solar radiation

σ = Stefan/Boltzmann Constant

$T_{SOB,\lim}$ = absolute limiting temperature of the focussed SOB

$T_{SOB,\lim}$ = absolute temperature of the ambient atmosphere

While the temperature dependence of the SOB-term (usually called «black body radiation) is beyond discussion, its likewise application on the atmospheric radiation appears questionable even if the accordance to empiric values, based on model computation according to equation (3), is astonishing Figure 23. However, such an empiric verification-or falsification-would be delicate, requiring a lot of measurements on several locations. In particular, the big temperature dependencies, due to their fourth power, entail a principal difficulty to precisely determine the temperature of the ambient atmosphere. It cannot be excluded that there is a coincidence which cannot precisely be explained.

In reality, the SOB is supplanted by the Earth surface, where limiting temperature conditions are normally not met. Thus equation (4) is usually not fulfilled solely for this reason. However, the most disturbing factor arises from the fact that the atmospheric temperature T_{atm} partly - but not entirely - depends on the surface temperature of the Earth, as well as on the solar radiation intensity Φ. Therefore, both respective temperatures are neither independent of one another nor strictly dependent. But such a mathematical relation is principally not acceptable. Rather an additional parameter should be involved which is widely independent of the temperature, preferably the atmospheric pressure.

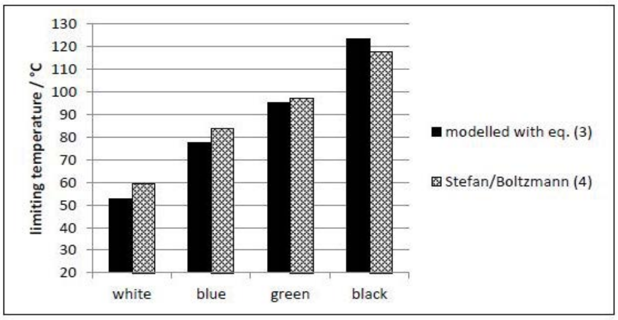

Figure 23: Exemplary comparison of calculated values according to equations (3) and (4) [51].

Based on the perception of infrared gas radiation, described in the previous chapters (referring to [39]) and expressed with formula (1), it suggested itself to assume an analogous approach for the counter radiation of the atmosphere since their main components nitrogen and oxygen are physically quite similar. As a consequence, the Stefan/Boltzmann relation (4) would be modified, yielding equation (5):

$$\beta_s \cdot \Phi_{sun} = \sigma \cdot T^4_{SOB,\lim} - A \cdot p_{atm} \cdot \sqrt{T_{atm}} \qquad (5)$$

Therein, A represents a constant which has to be evaluated empirically. It may be called atmospheric emission constant. In order to evaluate it, measurements of the limiting temperatures were made with differently coloured aluminium plates (white, light blue, light green, black), applying the above mentioned method. To attain sufficiently short exposition times, 8 mm thick plates were used; and to verify relation (5), measurements at two distinct locations were made, considerably differing in altitude and thus in atmospheric pressure [51].

The Evaluation of the Atmospheric Emission Constant A

As mentioned above, the measurements were made with the same equipment and materials as described in [49] but with thinner aluminium plates (8 mm instead of 20 mm) enabling shorter exposition times to reach the limiting temperatures (approx. 90 minutes). In order to vary the atmospheric pressure, two distinct locations were provided which considerably differed in altitude, namely Glattbrugg (near Zurich, Switzerland), 430 m above sea level, and the top of the Furka pass (also Switzerland), 2430 m above sea level, corresponding to the pressures 0.948 and 0.738 bar. The pressures were computed by means of the barometric height formula because the values given by the meteorological measuring stations are standardized to zero sea levels. A variation of the pressure at constant temperature is principally not possible since the latter one also depends on the altitude. At each location, two measurements were made within a period of a few days, using white, light-blue, light-green and black coloured plates. The resulting A-values are depicted in Figure 24. Using solely the results of the light-blue and the light-green coloured plates, the average value for A was 21.9 ± 1.2 $\mathrm{Wm^{-2}bar^{-1}K^{-0.5}}$.

Even if the experimental circumstances were not throughout perfect and precisely defined, the relatively high constancy of the factor A appears to have delivered empiric evidence for the correctness of the postulated equation (5). The herewith found relation represents insofar a considerable improvement of the original Stefan/Boltzmann equation (4), as the pressure emerges as the dominating factor for the counter radiation of the atmosphere, whereas the (absolute) temperature acts only a subsidiary part due to the low exponent 0.5 (instead of 4 in the case of the Stefan/Boltzmann relation). In fact, it can be considered as a natural law.

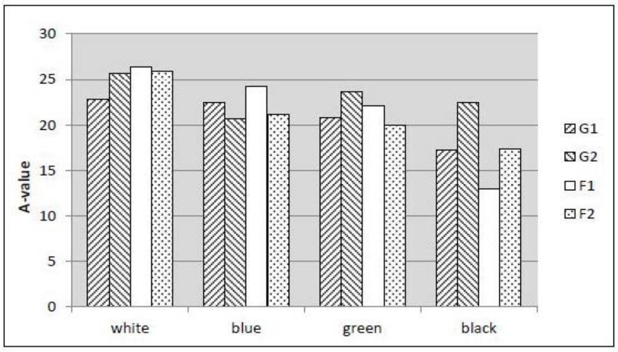

Figure 24: A-values from different measurements (G = Glattbrugg, F = Furka-Pass).

With regard to the micro-climate, the SOB temperature may be substituted by the surface temperature of the Earth. Moreover, this relation is presumably also valid when the limiting temperature condition is not fulfilled. As a consequence, the totally emitted thermal radiation Φ_{tot} by the Earth surface can be expressed with formula (6).

$$\Phi_{tot} = \sigma \cdot T^4_{Earth} - A \cdot p_{atm} \cdot \sqrt{T_{atm}} \qquad (6)$$

Therefore, the Earth emits overall more thermal radiation when the atmospheric pressure is lower. This leads to increased cooling - down and - at constant solar irradiation intensity and a constant solar absorption coefficient - to lower temperatures. It explains that temperatures on mountains are lower than those on lowlands, even if a precise modelling is not feasible due to additional effects influencing the atmospheric temperature. A scheme of the principal radiative influences at constant vertical solar irradiation is given in Figure 25. It clarifies the fact that «greenhouse gases» do not have the slightest influence on the climate. Rather it is impossible to influence the climate by manmade atmospheric intervention except by producing dust or smoke. However, measures regarding the Earth surface, particularly buildings in cities, represent the only possible means for influencing the climate.

Possible Measures for Mitigating the Climate particularly in Cities

At the end of the 1990s the feasibility of influencing microclimates mainly by improving the solar reflection of surfaces arose, particularly in cities. As reported in the review of Erell [52], additional influences such as surface geometry, wind convection and water transfer were taken into account.

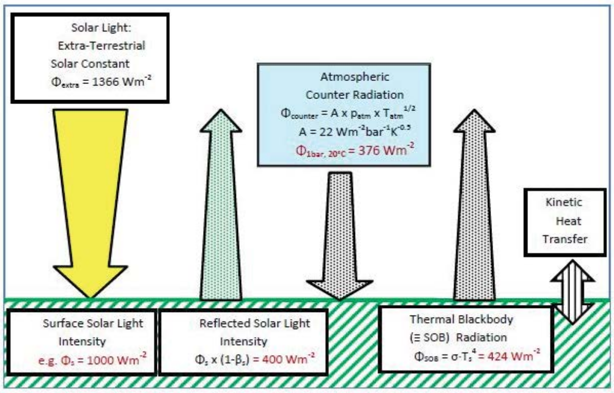

Figure 25: Radiation scheme at the Earth surface at vertical solar radiation (red numbers: arbitrary values).

However, at that time the greenhouse doctrine had already gained significant traction in the «scientific community», in the public and in politics, disregarding any other influences. In spite of its plausibility, the alternative albedo concept did not find an echo in the public. It would be beyond the scope of this study to analyse all the possible reasons for this reaction, including economic ones. Solely those concerning the scientific argumentation, which contributed to this failure, will be discussed. They are not least due to the lack of the here presented methods and results, and to the blind faith in a false theory.

Akbari, Pomerantz and their associates in the Lawrence Berkeley National Laboratory (CA, USA) were the most prominent apologists for this kind of measures, creating the term «cool roofs» [53-55]. Keeping in mind the alleged predominant influence of atmospheric CO_2, they abandoned the aspiration of influencing the microclimate. Instead, the cost savings of energy needed for air-conditioning came to the fore, and also the savings of CO_2 which would be entailed due to such energy savings. But apart from this, the model computation for buildings was erroneous, wrongly applying the Stefan/Boltzmann relation on the heat transfer between roofs or walls and the atmosphere, unaware of the regularities which were recently found by the author [50]. The final death-knell of the albedo approach was given by a global model simulation predicting only a minor climatic influence due to urban albedo enhancement [56,57]. However, such simulations cannot be taken seriously in view of the fact that all these models and their presumptions are obviously not correct.

Nevertheless, now and then articles such as [58] were published which report approaches considering the albedo aspect, but precise quantitative results with respect to the taken measures are not available. Instead, promising measures based on the author's method and results described in [50] were proposed [59-61]. They are summarized below:

1. The most important influence is due to the surface colouring. As obvious from Figure 20, (light) green is not advantageous for applications at buildings since it exhibits a comparatively high solar absorption coefficient. Certainly, it is true that the green colour of plants differs from the artificial green colour which was used in the experiments. It plays an important part in nature since the chlorophyll of the plants is needed for photosynthesis. However, a vegetative temperature regulation by water evaporation is required. Moreover, vegetated areas need maintenance. Hence planted «green roofs» do not significantly contribute to mitigate the micro-climate, especially when they solely contain lawns. In particular for roofs, rather a light-brown or straw-yellow colouring is preferred, as shown in Figure 26, while facades should preferably be white or at least less light than the roofs. For this purpose, normal weather-resistant colours may be used. As the example in Figure 27 reveals, such a colour design may indeed fulfil aesthetic criteria.
2. The colouring of pavements appears to be problematic since they are exposed to a high pollution and since the solar radiation absorption of the normally ensuing grey colour is considerably high, as recent additional measurements yielded (Figure 28). White colouring is out of question since it blinds too much. Light-brown

Figure 26: Crude red-brick (βs = 0.53) and painted one (light brown, βs = 0.30).

Figure 27: Guild-hall «zur Zimmerleuten», Zurich (recently restored).

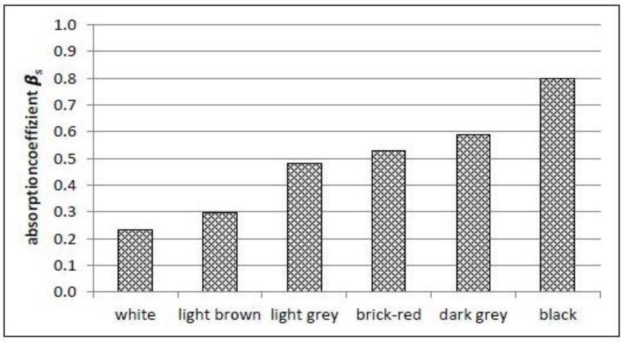

Figure 28: Comparison of solar absorption coefficients which are relevant for roofs, walls and pavements.

or straw-yellow would be optimal, also from aesthetic reasons, but it seems difficult to replace asphalt to an acceptable price. Moreover, a further aspect has to be regarded: the (micro-)climate does not solely concern the temperature just above the ground, i.e. the pavements, but the lowest atmospheric layer as a whole. Hence, the roof-level is of considerable importance even if a pedestrian does not directly feel it. Trees, parks and canopy roads provide shade and contribute to embellish the landscape, emphasizing the emotional component of the climate. However, they do not favour the albedo and thus the radiation budget of a city since their cooling effect is mainly due to evapotranspiration, while the part of energy consumption by photosynthesis is probably low but hard to estimate. In particular, it will not be possible to knock down buildings to a considerable extent, replacing them by trees. Thus the strategy must consist in lightening the cities but not in greening them.

3. However, the best colouring is of limited use when it is destroyed by weathering, as it is normally the case with tiled roofs (Figure 29). This may be prevented by a protecting layer, preferably by paint. At ancient roofs, this can be made afterwards, too, but then it needs a prior cleaning. Presumably, the weathering of tiles is fortified by acid rain due to a high CO_2-emission in the surroundings. This phenomenon should be a warning signal to the fact that CO_2 being emitted in large quantities as a result of fossil fuel combustion, combined with soot, fine dust and other waste gases, still represents a considerable source for environmental pollution implying hardly assessable consequences such as acidification of the oceans, presumably leading to a damage of the marine plankton.

4. A further relevant criterion concerns the construction materials since they influence the heating rate because of their heat capacity. Obviously, a high heating rate of walls engenders a high heating rate of the ambient atmosphere. It may be induced either by a dark surface colouring or by a low heat capacity of a wall. A well-insulated wall which exhibits a low heat capacity is solely warmed up at its outer layer since the heat cannot be dissipated within the wall. As a consequence, the ambient atmosphere is heated up while the interior of the house is not affected. For this climatic reason, house walls made from stone are better than those from wood which isolates well but exhibits a low heat capacity. Likewise, additional layers from artificial isolating materials should preferably be attached inside the house walls, and not outside. Moreover, glass facades and windows induce thermal traps, thus being unfavourable.

5. The building dimensions as well as the ambient ground influence radiation characteristics, too. Thereby, considerable radiative interactions between the ground and the facades are to be expected while flat roofs are independent of the other parts. By contrast, gable roofs may partly influence each other, due to the reflected light. In general it can be stated that the solar radiation absorbance of a building group is increased when its macro-roughness is increased, depending on the proportion between altitude and latitude of the buildings. Thus low houses inherently engender an inferior macro-roughness than high houses.

Figure 29: Roof with recently substituted bricks.

Figure 30: The skyline of Qatar.

Unfortunately, the worldwide trend for ever-growing black sky-scrapers and for ever-growing mega-cities, as exemplarily shown in Figure 30, is entirely acting against this philosophy. Thus the question arises, whether there are rather economic and prestigious reasons than technical ones that will impede effective climate mitigation.

Conclusions

Within the scope of empiric atmospheric sciences, recently two novel detection methods have been developed and mathematically modelled by the author. Their results are thoroughly questioning the conventional theory, particularly the greenhouse theory, providing a better understanding of atmospheric processes and delivering practical clues for mitigating the climate, even if - in view of the complex interdependencies - an adequate modelling of the worldwide climatic conditions seems to be impossible.

The first method concerns the measurement of temperature enhancement of gases irradiated by infrared light, while the second method allows the direct determination of the solar absorption coefficients of coloured opaque materials. In both cases, the irradiated material is warmed up to a steady limiting temperature where the intensity of the absorbed light is equal to the intensity of the emitted radiation or heat. However, in the first case (Figure 31) the warming-up rate is independent of the kind of gas, while the radiative emission rate depends on it. In the second case (Figure 32), the warming-up rate depends on the surface colour of the irradiated plate, while the thermal emission – or rather the heat transfer of the plate onto the surrounding atmosphere - is independent of the colour.

An eminent theoretical finding of the author was delivered by the evidence that the intensity of the thermal emission of gases is proportional to the collisional frequency of the gas particles (atoms or molecules). Based on this assumption, and verified by measurements at two distinct locations differing in their altitudes and thus in their respective atmospheric pressures, a direct dependence of the atmospheric counter-radiation intensity on the pressure and on the square root of the absolute temperature could be found. This physical law explains the paradox that the temperatures on mountains are generally lower than those in lowlands, in spite of the higher solar radiation intensity on mountains. Moreover, it clearly proves that atmospheric trace gases such as carbon-dioxide do not have any influence on the climate.

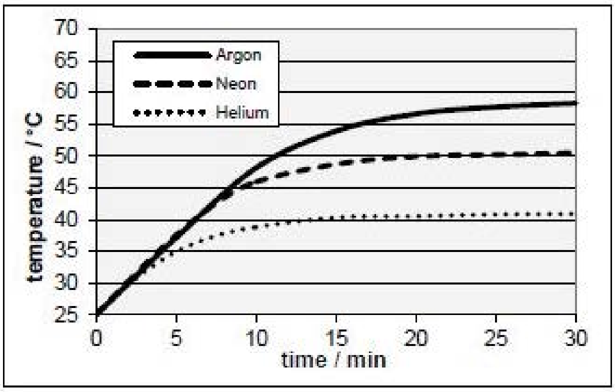

Figure 31: Comparison of the time/temperature curves of different gases irradiated by IR-light.

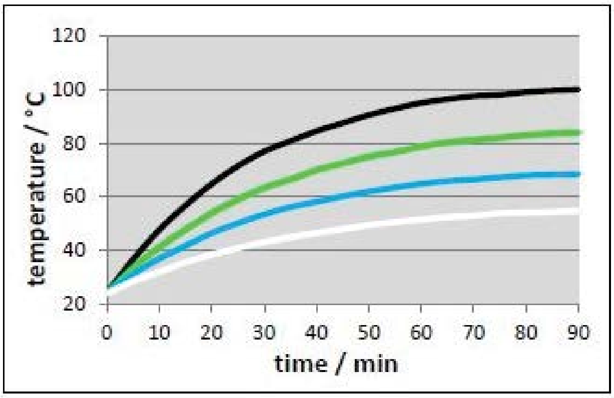

Figure 32: Comparison of time/temperature curves of distinctly coloured aluminium plates irradiated by solar light.

As a consequence, the only possibility for mitigating the climate is to reduce the solar absorptivity of the Earth surface, particularly in cities. This would be possible by lightening-up of surfaces, particularly of roofs and of pavements, and by reducing the macro-roughness resulting from high-rises. White, light-brown or straw-yellow colours have to be favored. Unfortunately, the worldwide trend for ever-growing black sky-scrapers and for ever-growing mega-cities is entirely acting against this philosophy. Thus the question arises, whether there are rather economic and prestigious reasons than technical ones that will impede effective climate mitigation.

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