IN SEARCH OF AUTONOMOUS REGULATORY PROCESSES
IN THE GLOBAL ATMOSPHERE
Rethinking the model of the Earth's greenhouse
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ABSTRACT

The most important features of the tropospheric greenhouse effect are called to mind while remembering that nowhere is there a static equilibrium state in the troposphere, not at any latitude, at any time of the day or year

Nevertheless over a diurnal cycle of 24 hours a dynamic balance between incoming and outgoing energy at the surface can be identified theoretically. We suggest with reference to current complexity theory that this condition acts as an attractor which induces a temporarily attracting cycle that is maintained by autonomous regulation of three major and interactive energy carriers: (a) the solar radiation, (b) the infrared radiation field in the troposphere maintained by continuous re-emission and re-absorption of infrared radiation that is strongly generated from the surface, and (c) the continuous exchange of heat by winds and ocean currents among the climate zones and the exchange of sensible and latent heat between surface and troposphere by convection. These processes (under c) are together described as the 'wind-water effect'.

We have developed an algorithm to quantify the conditions of this attractor taking into account the sea and land surface temperatures at three different latitudes. This has been done for four different days of the year: March 22, June 21, September 21 and December 21.

If only the mentioned energy carriers (a) and (b) were active, this numerical approach would lead to extreme and highly unrealistic surface temperatures, far above what is being observed at 30º and 60º N in spring and summer. From this can be concluded that at the current state of the IR radiation field of the troposphere, mainly caused by water vapour, H_2O plays a dual role in the maintenance of local surface temperature. On one hand water is responsible for the holding of heat due to its property of absorbing infrared radiation; on the other it counteracts this property by its phase transition liquid ↔ vapour near the surface. At a specific latitude with opacity above a specific value, any further increase in opacity would limit the surface temperature rise to nil. This has an important consequence for the current model of climate variability as postulated by Working group I ('the scientific base') of the Intergovernmental Panel on Climate Change (IPCC) of the UN.

As is well known, the IPCC attributes a major role to CO_2 gas in the functioning of the Earth's greenhouse.

Mainstream climatology deserves rethinking with respect to the neglect of autonomous regulatory mechanisms at work in the global troposphere.

PART I. THEORETICAL CONSIDERATIONS

1. Introduction on the goal of the exercise: in search for regulatory mechanisms

For the last 150 years a rise in the global average temperature of 0.8 ºC has been reported. This coincides with a gradual increase of the CO_2 concentration in the troposphere over this whole period and is expected to hinder escape of infrared radiation (IR) from the surface to space. According to a current hypothesis (see section 25) which is based on the application of physical laws to IR radiation passing through an air column, this hindrance should result in a rise of the surface temperature.

Doubts arise about a strict correlation between temperature and gradual CO_2 concentration rise *in situ* based on a number of arguments. To mention a few: among the IR active molecules in the troposphere, water vapour, liquid water and ice containing clouds are major constituents while CO_2 is but a minor one. On decennial and geological time scales there is seldom a close correlation between temperature and change in CO_2 concentration. Thirdly, the so-called general Global Circulation Models (GCM) which were originally developed for weather forecasting, failed to simulate the observed temperature stability over the last two decades, especially when used for longer projections.

Consequently one should be motivated to investigate the possibility that a theoretically potential effect of CO_2 on temperature may *in situ* be largely undone by the action of regulatory mechanisms that have not been adequately recognized. The contribution increased CO_2 concentration makes to the optical density of the troposphere is nevertheless an interesting phenomenon to examine other dynamic atmospheric processes.

2. A revised conceptual model

This exercise should be read in the spirit of the subtitle of a well-known popular book[1] on current complexity theory: "Discovering simplicity in a complex world". In addition another principle, taught by Arons should be adhered to, namely his advise on how to approach new concepts:

> "... a scientific concept involves an idea first and a name afterwards, and understanding does not reside in the technical terms themselves" (Arnold B. Arons (1997). "Marks of scientific literacy").[2]

Current trends in research into climate variability relate strongly to the complicated technical terms applied to the action of mass-heat transports (e.g. described by the Navier-Stokes equations), combined with theoretical effects of radiation transfer processes as described by the Schwarzschild (1904) equation and Einstein's theory (1924) on the distinction of spontaneous and forced absorption and emission processes in the atmosphere.

The glass greenhouse is used as a simplified model to explain the influence of the composition of the troposphere on the surface temperature. Like most metaphors, it is useful but also partly misleading. All that a 'real' greenhouse has in common with the Earth´s

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1 Jack Cohen, and Ian Stewart (1994). *The collapse of chaos: discovering simplicity in a complex world* (London etc.: Viking).

2 In: *Teaching introductory physics* (New York: John Wiley and Sons), pp. 345-46. people.westminstercollege.edu/faculty/pconwell/teaching/mark_of_sci_literacy.pdf

atmosphere is that the radiative heat received from the Sun during the day is conserved in both. The greenhouse in the garden is holding heat because it is an enclosure in which cooling by upward convection is prevented. If overheating by the sun is to be prevented, windows in the roof are opened to induce convection. The Earth's greenhouse is an open system in which convection is the rule rather than the exception that is during a wind still period.

In the convective processes, however, temperature regulation resides in another common feature. When a gardener expects overheating he could paint the roof of the greenhouse white in order to increase reflection. Cloud cover plays a comparable role spontaneously in the troposphere.

Convective cooling of the surface may take place by two processes: (a) by the removal of sensible heat (SH) carried by the upward wind flow, and (b) by the removal of latent heat (LH) as water evaporates at the surface. With the upward induced flow, the wet air moves to higher altitude with lower temperature and pressure. When the dew point is reached water will condense, the latent heat is liberated and cloud formation may be induced. This in turn would increase the reflection of the sunlight and shield the surface from warming. What the gardener performs by hand in the greenhouse, takes place in the troposphere greenhouse by autonomous regulation.

There is another important difference between the closed garden and the Earth's open greenhouse. The latter cannot be considered as a single 'house' but consists of multiple entities. These compartments may be described as the major climate zones that are operational at the same time under different conditions, but are coupled in a way comparable with communicating (water) vessels.

Another important feature must be kept in mind when rethinking of the conceptual model of the Earth's greenhouse in this paper: the terminology. When we speak of an expected effect *in situ* which is deduced from theoretical calculations or laboratory experiments, the prefix 'potential' will be added, or should assumed. It is important to recognize that the atmosphere is a complex open thermodynamic system, subject to many interactive forces. A static equilibrium state as in a closed system will never occur at any place at any time, hour, day or year. It will be argued however that we can nevertheless recognize potential dynamic balances over time periods (especially during a diurnal cycle). These 'calculated' balances act as stable states that in complexity theory are called attractors. These predicted conditions may not take place because counteracting repellors may undo the stable state. The combined action of attractors and repellors may result in non-periodic behaviour called an attracting cycle with maximum and minimum borders.

At the current state of our 'rethinking' we reduce initially the arising complexity by focusing on the *in situ* action of three major forces involved in maintaining the surface temperature of the Earth: local insolation, optical density of the troposphere and the heat transports caused by the hydrological cycle on the water planet. These theoretical considerations are followed (part III) by numerical simulations of the expected progression of these three forces over a diurnal cycle, taking into account some indisputable observations of the real planet but necessarily including some educated guesses.

Based on the conclusions from these simulations, it will be suggested that given the current optical density of the atmosphere, the global 'Earth's greenhouse' acts as a cooling entity rather than a warming one. How to arrive at this proposition requires in the first place a review of generally accepted meteorological and physical principles that govern climate variability and stability. Readers who are familiar with climate studies may consider this as superfluous. However, as this working paper is also addressed to natural scientists less familiar with the discipline, we hope to raise their interest in current disputes relating to actions called for in response to the Earth's greenhouse effect. For fifty years large amounts of public money have been spent on related research.

3. The unique properties of the water planet: the major climate zones acting as communicating vessels

Here it is enough to briefly review the origin of the complexity of the Earth's 'greenhouse'. The planet spins around its Sun in 365 days and around its own inclined axis in 24 hours. The combination of the two phenomena leads to four seasons of three months duration and a daily diurnal cycle of 24 hours with different duration of day and night depending on the latitude and the day of the year.

The theoretical effect of the two phenomena on the atmospheric processes has been studied for more than two centuries and has largely been supported by observations.

The next figure shows what are generally accepted as the major horizontal wind flows over the surface and the vertical cycles (cells) that provide for heat exchange among the major climate zones.

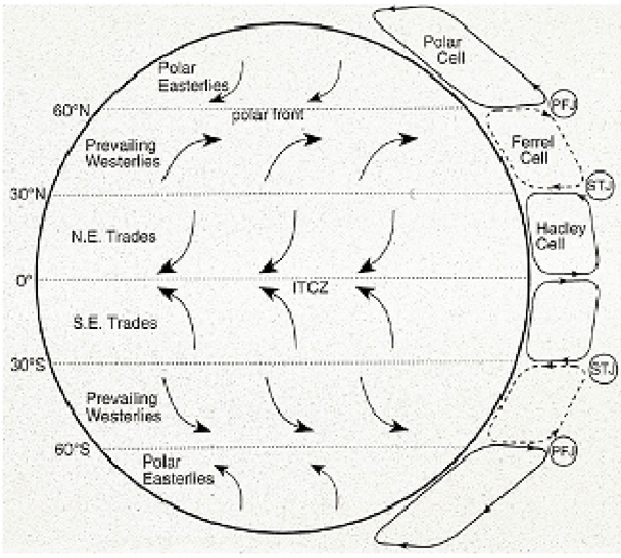

Figure 1. Horizontal and vertical winds.

The quantitative exchange of heat by ocean currents between climate zones is probably more important than that by winds. 70 percent of the Earth's surface is covered by oceans and water has a much higher specific heat capacity than air. Therefore a global average condition will largely be determined by the physical interactions between atmosphere and ocean surfaces.

	Density kg m^{-3}	Heat capacity J kg^{-1} K^{-1}	Heat capacity J m^{-3} K^{-1}
Soil inorganic	2600	733	$1.9*10^6$
Soil organic	1300	1921	$2.5*10^6$
Water	1000	4182	$4.2*10^6$
Air	1.2	1004	$1.2*10^3$

Table I. Heat capacity of earth materials (Hartmann 1994).[3]

For particular latitudes heat in the oceans is transported from east to west, and the reverse, in a capricious way. But a net transport from equator pole wards has been well identified.

4. The global average annual energy balance.

In 1997 Kiehl & Trenberth[4] presented an average global annual energy balance that has given much guidance to current thought on the origin of the 'greenhouse effect'. Figure 2 presents an update by Wild at al, 2013. The essence of these schemes is that a strong long wavelength IR (LWIR), so-called back-radiation to the surfaces from the troposphere (342 W/m^2), is thought to be necessary to maintain the average current annual global balance temperature at the surface. It is almost twice as high as the average solar energy coming to the surface (161 W/m^2). Another remarkable feature is that the contribution made by upward convection to the cooling of the surface (20 W/m^2) is estimated to be low.

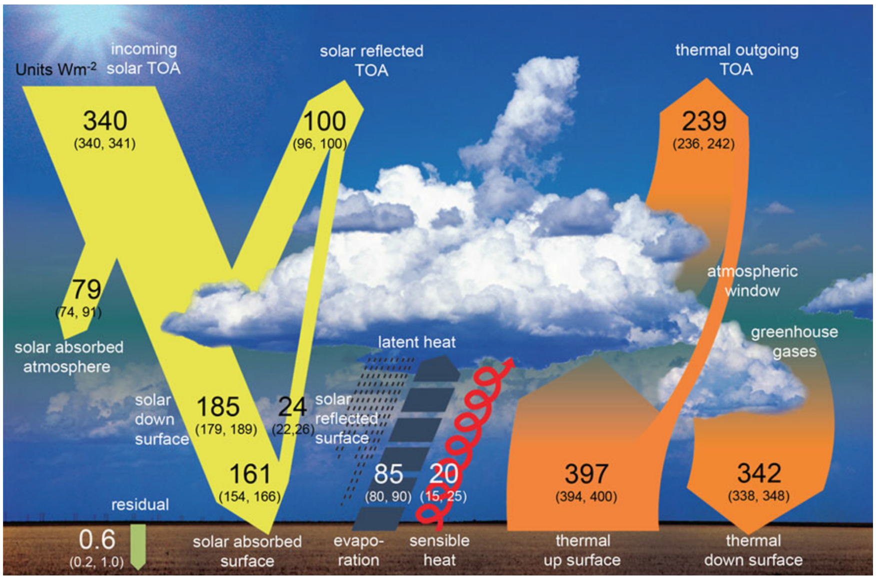

Figure 2. The global annual energy balance according to Wild et al. 2013[5]

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[3] Dennis L. Hartmann (1994). *Global physical climatology* (San Diego, Calif., [etc.]: Academic Press), pp. 85

[4] J.T. Kiehl, & K.E. Trenberth (1997). "Earth's annual global mean energy budget." *Bulletin of the American Meteorological Society* 78(2), pp. 197-208.

[5] Martin Wild, Doris Folini , Christoph Schär, Norman Loeb, Ellsworth G. Dutton, and Gert König-Langlo (2013). "The global energy balance from a surface perspective." *Climate Dynamics* 40 (11-12), pp. 3107–3134. DOI 10.1007/s00382-012-1569-8

Several authors have disputed the concept that the so-called back-radiation should contribute to the warming of the surface. Their arguments, mainly made on websites, have so far not been convincing to most current mainstream climatologists. These disputes will be elaborated on in part IV and concern the fundamental physics of how the IR wavelengths that are generated in the troposphere interact with a water or solid surface.

In this working paper we accept in principle the data presented in the Wild scheme but avoid the dispute on the effect of the back-radiation for the time being with the suggestion that for the energy balance at the surface, it is the fraction from the surface IR source that passed unhindered through the troposphere (named the atmospheric window) that is of primary interest. According to the Wild scheme the global average opacity factor is f = 342/397 = 0.861. Consequently the size of the atmospheric window amounts to (1-f), that is of the order of magnitude of 60-80 W/m^2.

5. Energy flows from the surface at a particular location and time

When considering average global balances over long periods as presented in figure 2 not much insight is given about how the major and interactive energy carriers changing over time at the surface (over the seasons and the diurnal cycles)

Three major processes need to be kept in mind:

(a) the solar radiation reaching the surface,

(b) the infrared radiation field in the troposphere that is maintained by continuous re-emission and re-absorption of IR that is primarily induced by radiation from the surface, and

(c) the continuous exchange of heat between surface and troposphere and by winds and ocean currents among the climate zones or between smaller neighbouring areas.

The last urges especially to consider primarily the most import energy transfer processes at a particular location, e.g. at different latitudes at different days of the year. Their properties are briefly summarized below and consist of multiple interactions with consequences for a locally maintained surface temperature.

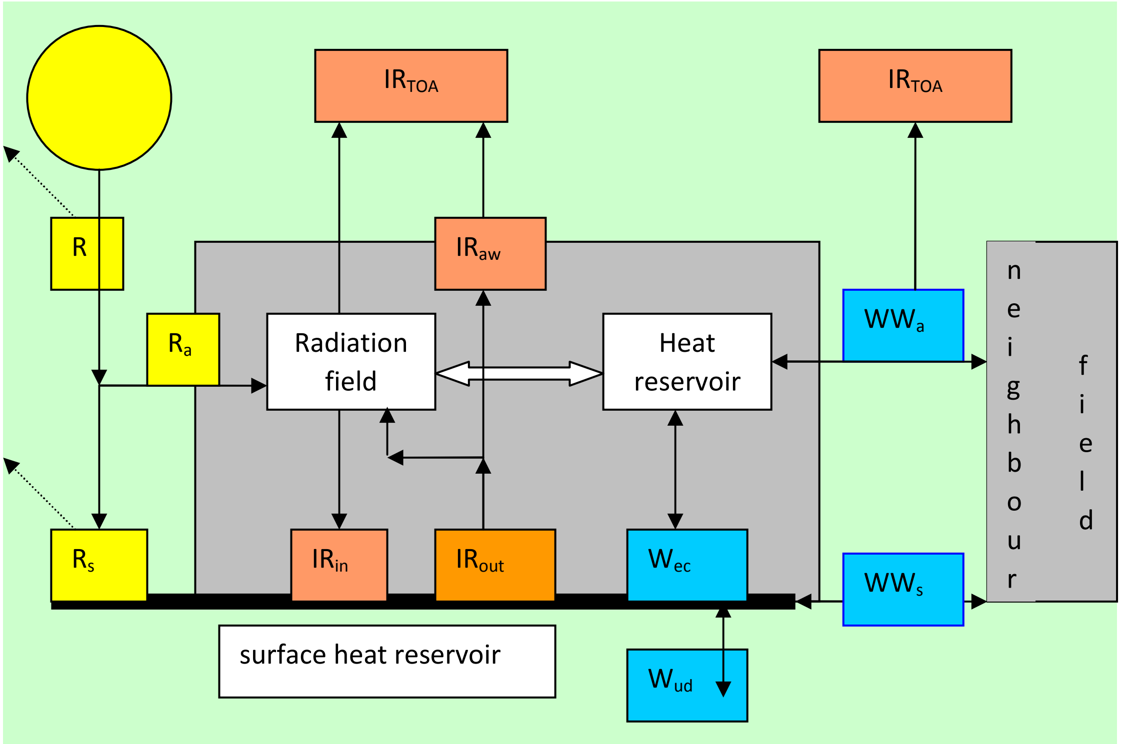

Figure 3. Energy flows from and to the surface through the troposphere at a particular location during a short time interval on a particular day.

In this working paper attention is focused on the description of the processes taking place at the Earth's surface, and the elements that lead to its ever changing skin temperature during the hours of the day. Processes occurring in the troposphere deserve attention as far as they have an influence on this surface skin temperature. It is mainly the lower troposphere that produces an effect on the surface skin temperature, whereas the upper part, near the top of the atmosphere (TOA), has the function to emit (radiation) energy to space from the system as a whole, the combined effect of the interactive atmosphere and surface. A fraction of the radiation that originates from the surface, (IR_{out}) that is not absorbed by IR active molecules passes unhindered to space and is called the atmospheric window (IR_{aw}).

The system has two heat reservoirs, the airborne and the surface one. Their specific heat capacities differ strongly (see table I). Moreover, the heat capacity of the boundary layer of ocean and land differ more than a factor ten. These heat capacities determine strongly the heat hold in the boundary layers over time and therewith the change of temperature during a diurnal cycle. In the ocean surface the difference between maximum and minimum temperature is of the order of magnitude < 1 ºC. On solid soil it can differ from 10 to 20 ºC.

The troposphere heat reservoir shows a temperature gradient that depends at each altitude on gravity, the distribution of molecules, density and surface temperature. It has a temperature lapse rate caused by adiabatic expansion with altitude.

According to the Lambert-Beer law IR active molecules (e.g. H_2O and CO_2) absorb radiation energy (carried by photons) at particular wavelengths that bring them into a number of subsequent 'excited', quantum states. Re-emission takes place according to Planck's law. These processes of alternating absorption and re-emission produce locally a radiation field of photons. Its strength, however, is strongly dependent on the local temperature of the heat reservoir. A fraction of non IR active molecules (N_2 and O_2) will by frequent collisions (order of magnitude 10^{14}/sec) transfer kinetic energy to the IR active ones and bring them into a higher quantum state. The return process is also continuously in progress. Part of the IR active molecules in a particular quantum state do not fall back into a lower quantum state by the emission of a photon, but transfer the energy difference between two quantum states by collision to the non IR active molecules.

In this working paper little attention only will be given to these interactive dynamic processes in the radiation field, with one exception. When the balances of the radiative and heat transfer processes are being studied a Local Thermodynamic Equilibrium (LTE) is usually assumed at a particular altitude. In current views of the behaviour of an open thermodynamic system with a continuous through flow of energy, as is the case in the troposphere, this LTE is disputed This subject is elaborated on in PART IV section 31.

The radiation field locally emits in all directions with a net flow upwards and downwards. The upward flow results in the radiation energy that ultimately escapes at the TOA to space. The radiation field is directly fed by absorption of IR by the IR active molecules from two radiation sources: the solar energy R_a that is absorbed near the TOA and the radiation flow IR_{out} from the surface. This energy is temporarily stored in the quantum states of the IR active molecules with a lifetime of the order of magnitude of a second. The concurrent temperature rise increases the strength of the radiation field and thus its emission downwards and upwards.

A third important contributor to this temperature rise is the flow of sensible heat (SH) and latent heat (LH) from the surface (W_{ec}) . The carried LH on the water planet is the result of the evaporation of water at the surface with the rate dependent on the latter's temperature. The LH is liberated at a particular altitude with a particular temperature by condensation when the dew point is reached at a cooler altitude above the surface due to the adiabatic expansion. This contribution to the airborne heat reservoir has two effects on the radiation field: increased kinetic energy of a fraction of the gas mixture will by collisions bring IR active molecules into a higher quantum state and potentially increase their emissivity. In addition, this emissivity is ruled by the local air temperature according to Planck's law. The size of the fraction molecules that can bring an IR absorbing molecule into a higher quantum state is determined by the kinetic energy distribution over all molecules, the bell-shape Maxwell distribution that is average temperature determined.

Consequently, with increasing altitude, the fraction will decrease due to the decrease of temperature caused by the adiabatic expansion. Another result is that the intensity of the radiation field decreases with altitude.

The interaction of the energy exchange between the surface and the radiation field near the surface is complex, because the changing surface temperature and that of the airborne heat reservoir near the surface are mutually interdependent. Next to this we need to deal with an additional number of fluctuating energy carriers at the surface per m^2 with time and these can be comprised as follows:

(a) the up-going flux IR_{out} from the surface, a broad-spectrum emission from a black body,

(b) the return flux IR_{in} generated by the radiation field that comprises the specific wavelengths emitted by the IR active molecules in the low troposphere.

Thirdly,

(c) the combined mass/heat vertical flow W_{ec} upwards or downwards dependent on a number of changing conditions of the surface and the lower troposphere during a diurnal cycle.

Fourthly,

(d) the downward radiation flux from the sun R_s, the solar energy that reaches the surface (part of incoming radiation flux R from the sun is scattered back near the TOA by clouds and airborne particles from the surface also upwards).

And lastly

(e) an upward or downward heat flow from the surface (W_{ud}) to the heat reservoir below the surface.

Two more heat flows are presented in figure 3 that illustrates a local and not a global average condition as shown in figure 2: the WW_a near the TOA and the WW_s at the surface.

WW_a concerns the wind carried horizontal mass flow described in figure 1 as part of the Hadley and Polar cells. Its mass carries also clouds and IR active molecules, so during the movement over the globe it continues to emit IR to space. WW_s consists of two components, wind and ocean flows. On a global scale wind concerns e.g. the trade winds, westerlies and easterlies. The second component is the ocean flow that moves from the equator to the poles. It contributes to the maintaining of a particular surface temperature at higher latitudes over a relatively long time interval of a season besides an atmospheric contribution to that temperature.

Here attention is focused on the dynamic processes during the short time interval of a diurnal cycle at a restricted number of m^2, and then we need not reckon with these WW exchanges between locations. They become of importance, however, if we come to consider neighbouring areas with a short distance from each other. At the coast sea and land breezes will change direction during a diurnal cycle. The same is taking place in a hilly landscape with mountain and valley breezes.

This reductionist approach will bring the complex interactions of the energy carriers at the surface back to a rather simple mathematical model that is supported by observations *in situ*. This is also done because the description of the fluctuations in the energy carriers b – e is in itself complex. As long as it is possible to test the modelling continuously against observations a reductionist approach we consider this as legitimate. We aim at finding out how changes in parameters influence in particular the interactions of the wind and water (WW) effect with the radiative processes.

The simplified equation applied to describe the temperature profile of a diurnal cycle over a short time interval Δt reads:

$$\Delta T = \Delta t^*(R_s + IR_{in} - IR_{out} \pm W_{ec} \pm W_{ud})/Cm^2 \qquad [1]$$

in which Cm^2 is the heat capacity of the surface per m square. Further explanation is presented in the next section.

The net effect of the variety of processes on the maintained surface temperature is summarized as follows, taking notice of the global scheme presented in figure 2, but with a somewhat different appearance. The sole warming force is the solar energy reaching the surface (R_s), active only during day time. It changes by the hour, is dependent on the height of the sun in the sky at a particular day of the year at a particular latitude, but also on the duration of the day.

Cooling of the surface occurs mainly through the pathway: heat removal from the surface by W_{ec} contributes to the atmospheric heat reservoir and subsequently to the radiation to space by the radiation field. The energy flow directly going to space (IR_{ew}) from the surface is relatively small and if hindered by clouds decreases to almost zero.

The obvious mutual interaction of all the forces calls for an investigation first of the expected local autonomous regulatory processes before considering an effect of a single potential force, e.g. the increase of the CO_2 concentration in the atmosphere.

A very basic autonomous regulation process can be recognized already in the radiation law of Stefan-Boltzmann. If a body receives more radiation energy from an external source, e.g. the Earth's surface from the Sun, its potential temperature will rise, assuming no other forces like WW are active. With rising temperature, however, the emissivity of the body will also increase, resulting in a limitation of the rate of temperature rise. This is illustrated in figure 4.

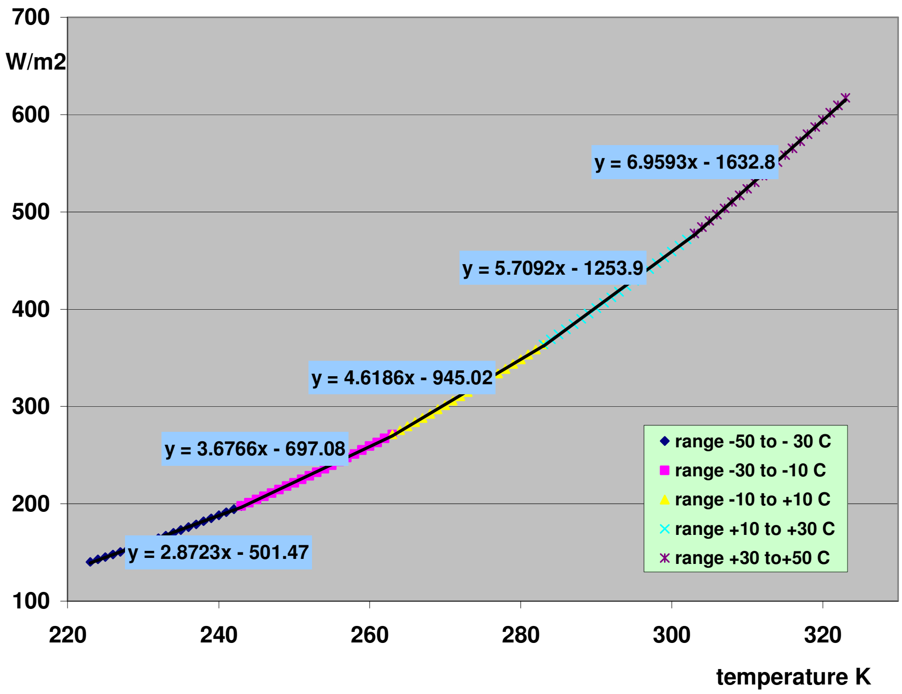

Figure 4. The reduction of the law of Stefan-Boltzmann, the emission of a body as a function of its temperature to the power 4, to a linear relationship over short temperature intervals.

Within the range of observed surface temperatures all over the globe the slope of W/m^2 versus ΔK varies from 2.87 to 6.96.

A second autonomous regulation process should be recognized on a local scale, that with increased insolation (R_s) the removal of heat from the surface by the flow W_{ec} will be enhanced and leads on the water planet to increased cloud formation that reduces the solar energy that can penetrate to the surface.

In this working paper a third potential regulation process is highlighted. It resides in the diurnal cycle: the striving for a dynamic balance between heat accumulating during day time at the surface and the removal of heat during the whole 24 hour period in which on the water planet the phase transitions of H_2O (liquid ↔ vapour) play a major role.

6. The non-equilibrium state at a particular hour of the day at the surface

The temperature change ΔT over the period Δt is strongly dependent on the specific heat capacity c_v of the surface per m^2 (Cm^2) that participates in the heat exchange with the atmosphere. The accumulating Joules in the heat reservoirs can be written as the product $Cm^2 . \Delta T$ in which the symbol Cm^2 stands for the specific heat capacity per m square and T is expressed in Kelvin

[1] reads in the unbalanced state during Δt:

$$\Delta T = \Delta t*(R_s + IR_{in} - IR_{out} \pm W_{ec} \pm W_{ud})/Cm^2$$

in which Δt in seconds and ΔT will have a positive or negative sign.

On day time R_s will have a positive sign and during the night it will be 0. IR_{in} and IR_{out} will always have a positive sign in this equation.

If $(R_s + IR_{in}) > (- IR_{out} \pm W_{ec} \pm W_{ud})$, [2]

then the surface temperature will rise, which will be the case if the insolation is sufficiently powerful during the most part of the day.

During the night, when $R_s = 0$, the temperature will fall or may stay constant if WW_{ec} has a positive sign and $IR_{in} = W_{ec} \pm W_{ud} - IR_{out}$. This is a particular situation observed in O'Neill, Nebraska in August 1953, when during day time the temperature rises to 40 ºC, but during the night between 22.00 and 06.00 h slows down caused by the release of latent heat by condensation of water at the surface at its dew point (Hartmann 1994, p. 96).

WW_{ec} gets a positive sign if during the night no heat is removed from the surface but returned to the surface by a downward air flow and at the surface the dew point is reached or passed and latent heat is liberated at the surface. O'Neill in Nebraska is located in a hilly environment and a downward wind is probably bringing latent heat from the lower troposphere that has been accumulating at the hill top during the day above the dew point. Attention is paid to this observation in section 16 which is used as an important reference in this working paper to test the legitimacy of the methods (Part II).

Equation [2] can be further simplified by expressing IR_{in} as a fraction f of IR_{out}, as already suggested in section 4, when the Wild global annual average budget was discussed. Factor f is then named the opacity factor of the troposphere, its total optical density that hinders the direct escape to space of radiation energy at the wavelengths of IR active molecules.

Secondly we can combine W_{ec} and W_{ud} to a single variable that counteracts the radiation effects named WW, although W_{ud} is not a particular 'wind' effect but a flow governed by a heat flow by conduction. W_{ud}, like W_{ec}, is a process that removes heat from, or adds it to, the surface, also counteracting the radiative processes. It plays a role during a diurnal cycle but the process (W_{ud}) is relatively slow and it may be neglected in some simulations if W_{ec} is strong. It should however be incorporated in the equation if W_{ec} becomes itself small, e.g. in a dry environment like a desert or cold troposphere

From observations we have some information on the relative effects of sensible heat (SH), latent heat (LH) removal from the solid soil surface (a W_{ec} flow) and by conduction to the underground (W_{ud}) as summarized in Hartmann (1994) page 107-109 at different conditions of the surface.

	Noon				Sunset		
Location	Rs	SH	LH	Wud	SH	LH	Wud
1	600	500	0	100	0	0	-100
2	500	220	250	250	-20	-20	-90
3	800	-10	810	10	-20	10	-10

Table II. Rough estimate of heat flows (W/m^2) from and to the surface (W/m^2), deduced from Hartmann's figures (Rs: the solar energy reaching the surface)

Location 1.[6] A dry lake in California, June 1950

Location 2.[7] Corn field in Wisconsin, September 1952

Location 3. Irrigated alfalfa field with dry wind from neighbour environment, Wisconsin, July 1956.

In our approach we will primarily focus attention on energy exchanges on the ocean's surface that covers 70 % of the Earth's surface and is expected to determine largely global average conditions. The exchange of energy on solid soil is of great interest because of large temperature fluctuations during a diurnal cycle which give more insight on the dynamics of the various processes..

With the implementation of the law of Stephan-Boltzmann equation [2] then reads:

$$\Delta T = 1800*(R_s - (1-f) *\varepsilon\sigma T_t^{\,4} \pm W_{ec} \pm W_{ud})/Cm^2 \qquad [3]$$

in which ΔT (in Kelvin) the temperature change over half an hour (1800 sec). T_t is the actual average temperature in Kelvin of the surface during this time period.

The search for autonomous regulatory mechanisms also needs to consider the value of W_{ec} (J/sec/m^2). This in a complex physical way is dependent on wind speed, pressure and the relative humidity of the air. And the latter will influence the opacity factor f. W_{ec} is also strongly dependent on the surface temperature in the period Δt.

Lastly the solar energy reaching the surface (R_s) depends on the hour of the day and the length of that day, as well as on the season at the given latitude. This is illustrated in figure 7 for four latitudes at a particular day.

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6 J.E. Vehrencamp (1953). "Experimental investigation of heat transfer at an air-Earth interface." *Eos: Transactions American Geophysical Union* 34 (1), 22-30

7 C.B. Tanner (1960). "Energy balance approach to evapotranspiration from crops." *Soil Science Society of America Journal* 24, 1-9.

7. The approach to describe the wind-water effects

For the regulation of the surface temperature over a short time interval (most of the time five days are followed) the value of W_{ec} is a most important factor to be considered. As already mentioned it is a direct function of the surface temperature but also strongly dependent on wind speed, air pressure and relative humidity near the surface. The physics is well understood but complex[8] [9] and strongly influenced if a laminar air flow changes into a turbulent one, as observed by many authors at different locations at different times of the day.[10] [11]

Nevertheless it is considered to be justified to introduce a general simplified mathematical formula with three parameters in our comparative studies to mimic the profile of an observed diurnal cycle under the condition that particular observations are respected (e.g. average, maximum and minimum temperature) and with the follow-up that the parameters are adjusted to simulate the diurnal cycle accurately.

$$W_{ec} = W_c(T^n/T_d -1) \qquad [4]$$

in which W_{ec} the wind-water effect, expressed in W/m^2 to be introduced in equation [3],

W_c is a 'constant' related to the speed of energy transfer ($Joules/m^2/sec$), determined by the wind speed and relative humidity, that may change every hour of the day and night. (As said, the value of W_c will change strongly if a laminar flow changes into a strong turbulent one if it is a regular component in a diurnal cycle as observed off the coast of several islands in the Pacific, but also occasionally over land.) W_c is expressed in W/m^2, that is to say in J/m^2 per second, the rate of removal of heat from the surface.

T is the surface temperature in C in each step of the application of equation [3], to be deduced from the temperature in K.

n is an exponent just above 1 that makes Wec not completely linearly dependent on T.

T_d a 'constant' in grades C that is determined by the dew point of water that *in situ* is determined by air pressure and relative humidity. If $T^n = T_d$, then W_{ec} becomes 0. With $T_n / T_d > 1$ heat is removed from the surface by evaporation. If $T^n / T_d < 1$ than heat is added to the surface from the troposphere by condensation. Further analysis of this simplified mathematical approach in the context of the development of a conceptual model is presented by P. van Toorn.[12] The prerequisite however at all times is that the simulation is not violating actual observations.

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8 D. Thoenes (2010), "The stabilising effect of the oceans on the climate." *Energy & Environment* 21 (4), 237.

9 Harold J. Blaauw, (2017) "Global Warming: sun and water." *Energy & Environment* 28 (4), 468-483. DOI: 10.1177/0958305X17695276.

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11 Roy J. Clark (For the time being personal communication.)

12 Peter van Toorn. "General mathematical background of attractor function." Presented on www.arthurrorsch.com, section comments.

8. The formulation of the heat flow from the surface to the boundary layer below

The simple equation can be applied

$dQ/dt = (T_s - T_u).\ S_c$ [5]

in which T_s the (skin) surface temperature, the T_u the temperature at a particular depth that participates during a diurnal cycle in the exchange of heat between the two, and S_c a heat conduction coefficient.

In the simulations of diurnal cycles we are obliged to make some educated guesses of the chosen values of T_u and S_c. There are data available but they may strongly vary for different locations. (See table II.) The ocean flows are capricious. On solid soil the conductivity is strongly dependent on structure (e.g. water content and vegetation). However, from the observations presented in table II a standard value for T_u and S_c can be deduced taking into account that in a wet area W_{ud} is approximately 20% of the SH and LH removal from the surface.

9. The dynamic equilibrium state at the surface over the full diurnal cycle

As mentioned, a stable equilibrium state with respect to temperature will never occur at any place or at any time. However, we can recognize a theoretical dynamic equilibrium state during a diurnal cycle with respect to temporarily held heat provided the amount absorbed at the surface during the day equals that lost during the night. Over a limited period this can be considered a locally variable ‘steady state’. We can find this theoretical equilibrium with our algorithm (see annex I) and simulate the development of a diurnal cycle provided we search for subsequent diurnal cycles with the same temperature at subsequent sun rises. Only then, if no other parameters change (e.g. interference by weather events), will maximum and minimum temperature in the subsequent cycles, as well the net accumulating heat during the cycles, be similar. The diurnal energy balance will be zero between subsequent sunrises. The situation is however somewhat complicated if we consider changes in heat flow relative to seasonal change, as will be explained in section 18.

As said, the question remains whether such a theoretical dynamic equilibrium state will be reached during a seasonal cycle. In terms of complexity theory we can name it an attractor or fixed point, a condition when all variables dX/dt = f(X,Y,Z), dY/dt = f(X,Y,Z) etc become zero. In equation (2) R_s has a life of its own, changing daily with the course of the seasonal cycle, so the attractor is continuously on the move. It may be named a ‘drifting’ attractor.

This aspect of an ever drifting attractor is elaborated on in section 18.

10. Summary

The suggested rethinking presented here differs in several respects from current mainstream opinion regarding the responses of the Earth to the open greenhouse effect. We differ in the emphasis that is given to the innate two properties of H_2O as expressed in the hydrological cycle: It hinders the radiation energy flow from surface to space, but also stimulates heat transfer from surface to the top of the troposphere, where the actual emission of radiation energy to space takes place. Also, surface flows redistribute heat over the major climate zones. We therefore urge investigation of the different dynamic behaviour of these compartments rather than starting from global annual averages. While the global average data provided by Wild et al. 2013 are important for comparisons, they do not give insight into the contribution made by the exchange of heat between climate zones in order to maintain local temperatures at particular days of the year.

In addition we propose several other departures from current practice in the atmospheric sciences, most of which have their starting point in molecular physics. Our 'rethinking' is largely based on approaches in physical process technology. In consequence, there is a strong emphasis on the principles of regulation phenomena, that are expected to be self-evidently present in complex interactions among a variety of energy carriers. From this follows a focus on current advances in complexity theory.

It should also be noted that throughout this working paper skin temperature (see figure 5) is adopted as a base for surface temperature, not the meteorological surface temperature standard, measured at 1.50 m above the surface. The physical base for this approach is that the surface skin itself is an important borderline in the temperature lapse rate from thermosphere to 10 km below the surface. See figure 5.

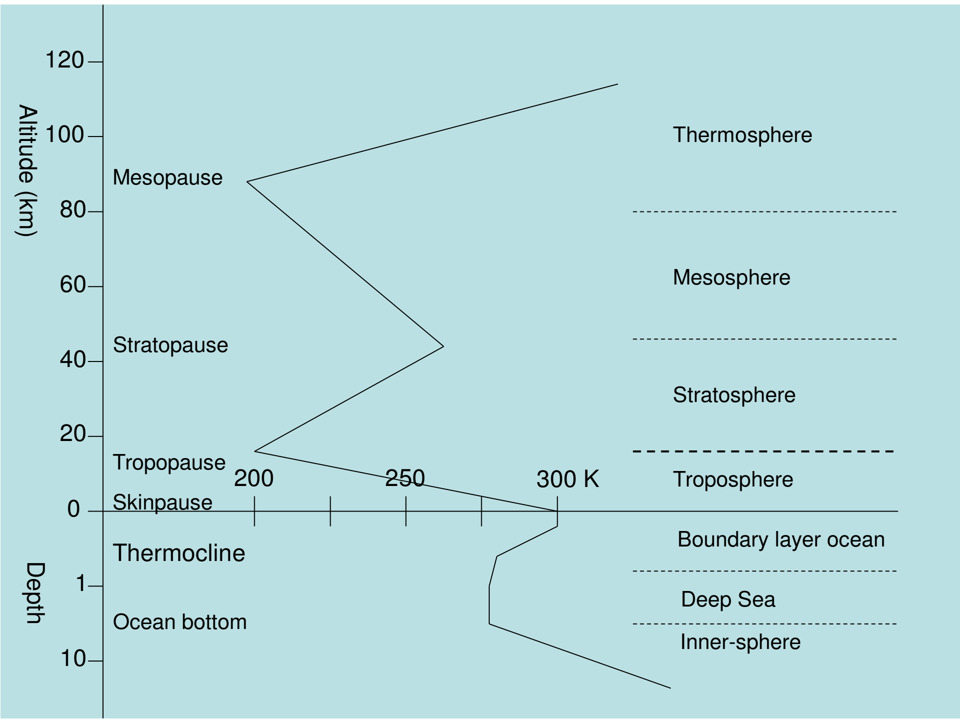

Figure 5. The temperature lapse rate from thermosphere to inner sphere with abrupt changes at 'pauses', thermocline in the ocean and at its bottom.

In this line of thought the surface border can be named the skin pause. From several observations it is clear that the temperature difference between this skin pause and the measured meteorological surface temperature can be several degrees C, caused by weather conditions near the surface. So-called inversions can occur between the two. Night frost at the surface is a well-known phenomenon in moderate climate zones beyond winter.

PART II. MATERIALS AND METHODS

11. Introduction

In this working paper we deal with a conceptual model that underlies the understanding of the principles of energy exchange mechanisms. In principle it is argued that energy transfer simulation models are produced based on observations that help to understand those physical mechanisms that are active *in situ*. Then, when a simulation corresponds well with observation, we need to think what physical principles underlie the values of the introduced parameters f, W_c T_d and n in equations [3] and [4] and in [5] T_u and S_c. And then, in the case of non-linear dynamic and open thermodynamic systems with an entropy sink, we raise the question whether the established principles deduced from closed systems work out similarly as in the open one. This procedure is general practice among modellers who alternate in considering physical principles with developed mathematical formulations. In many publications on climate variability this is apparently not the general practice, which may be ascribed to insufficient appreciation that we are dealing with the open thermodynamic system of the atmosphere.

The variation of the surface temperature over a diurnal cycle is strongly dependent on the specific heat capacity per m^2 of the surface, that is to say the depth that participates in the radiation out at the surface. This depth will change over time, in the soil by conduction, in the ocean by both conduction and exchange of heat by convection if there is an important downward or upward flow. The effect of these processes is in equation [5] comprised in the variable W_{ud}.

In section 16 and 17 some results are presented using the described methods to legitimate their use by the comparison of a particular simulation of a diurnal cycle with a local observation of its temperature profile

12. Data on sea (skin) temperatures

For daily, seasonal global averaging the sea surface temperature (STT) is most important because 70 % of the surface is covered by ocean. The values used are deduced from data provided in the textbooks by Hartmann (1994) and Sarmiento & Gruber (2006).

day	81	172	264	355
0º N	28.4	28.3	28.4	28.3
30º N	23.3	26.3	23.3	18.5
60º N	4.1	14.1	4.1	2.0
85º N	0.0	0.0	0.0	0.0

Table III. Surface (skin) temperature (C) at four days of the year at four latitudes in the oceans.

The contour lines of the ocean temperature on the real planet are however very capricious, obviously due to the (also) variable sea currents over degrees of latitude. Consequently for the ‘model’ Earth some educated guesses have to be made. At a later stage the consequences of the variability of the figures in table III may be considered. And this in relationship to the contribution of land areas.

For the temperature at 85° N a constant value of 0 ºC is adopted on the assumption that the water temperature will be in an equilibrium state with floating and melting ice. On land this is a meaningless value.

If we adopt an ocean surface layer of 3 m that participates directly in the exchange of heat with the atmosphere during a diurnal cycle, the heat capacity of the surface is estimated as $1.5*10^7$ J/m^2/C.

13. Data on land (skin) temperatures

In soil the transport of heat is only caused by conduction. Solar energy does not penetrate below the surface. From observations at O'Neill, Nebraska, it is deduced that during a diurnal cycle a few centimeters contribute. In our simulation studies a heat capacity of the soil of $7*10^5$ J/m^2/C is adopted, deduced from the right hand column in table I.

If simulations are in poor agreement with observations *in situ,* then a revision of the adopted value for the heat capacity is one of the first parameters that must be considered. If far reaching conclusions are reached on the importance of a particular (small) effect, e.g. the CO_2 concentration in the atmosphere, these should be subject to a sensitivity test of all adopted parameters, such as W_c , T_d and n.

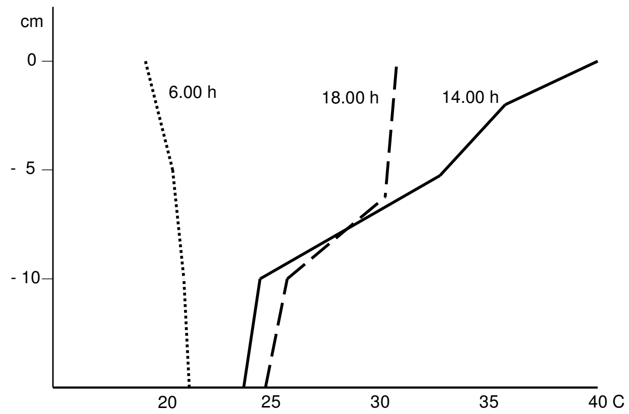

Figure 6. Temperature profile in the soil over a diurnal cycle, O'Neill, Nebraska, August 1953. Calculated diffusion rate in the boundary layer 2.5 to 6 times 10^{-7} m^2 sec^{-1} [13]

The conduction process expressed in variable W_{ud} progresses relatively slowly compared to other variables during a diurnal cycle, but it becomes of importance with respect to conservation of heat (or 'cold') surfaces over longer periods such as the seasons.

In general, the adopted observed values for surface temperature changes to be used in the simulations can be a guideline only because they are strongly dependent on occasionally changing weather conditions that have an influence on the rate (W_c) of exchange of heat

[13] **P**artly redrawn from the figure presented in the handbook by Hartmann (1994) based on a report by Lettau et al.

between atmosphere and surface. By variation of the value of W_c the simulations can however also mimic this capricious behaviour.

14. Data on insolation

In table IV is presented the diurnal average over a whole diurnal cycle of the sunlight received and absorbed at the surface for five latitudes at four different days of the year.

	22 march	21 june	21 sep	21 dec	annual
day	81	172	264	355	average
0º N	283.532	252	283.532	252.036	267.785
30º N	232.127	318.929	232.127	112.608	223.947
60º N	97.6945	289.883	97.6945	1.69692	121.742
85º N	1.58336	258.693	1.58336	0	65.4649
average	173.588	258.212	219.338	180.335	

Table IV. Daily average of insolation (W/m^2) for the major locations and days of the year used in the simulation studies (global average 169.73).

The next figure illustrates how during a diurnal cycle the intensity of the insolation varies during a particular day.

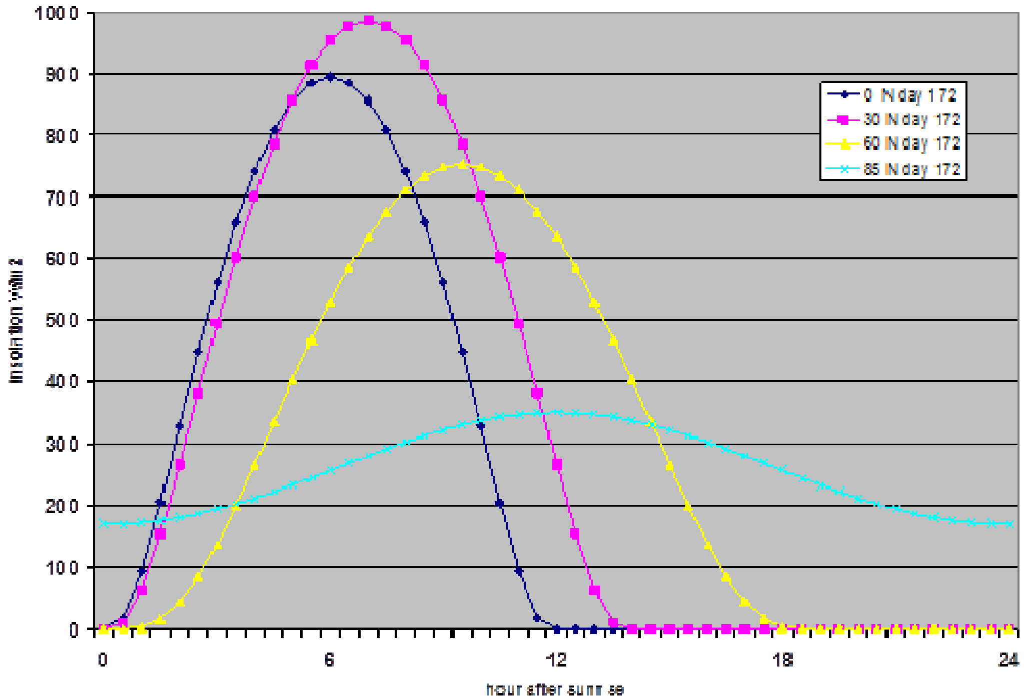

Figure 7. Insolation on four different latitudes on June 21.

Note the long lasting day (24 h) at 85° N during the Northern hemisphere summer.[14] Table II illustrates the statement made in section 2 that the planet's climate (condition) cannot be interpreted as the result of a single large greenhouse. Instead it consists of a multi-fold of these entities that are all operational at the same time, with different averages of diurnal insolation. (See the columns of table IV.)

15. Used parameters for IR emission

As we are especially dealing with the situation at the earth surface, it suffices to consider it as emitting according to the law of Stefan-Boltzmann: $IR_{out} = \varepsilon\sigma T^4$ with T expressed in Kelvin, with the Stefan-Boltzmann constant ($5.67*10^{-8}$ W m^{-2} K^{-4}) and ε the emissivity factor, 'black body' constant.

Most of our simulations deal with emissions from a water or solid surface and our main approach is to compare the effect of the three energy carriers at different situations and at different locations, for four days of the year, with an ε average value of 0.8985.

As mentioned in sections 4 and 5, the net radiation from the surface that reaches the top of the atmosphere (TOA) passes through the atmospheric window and is considered as a fraction (1-f) of the emission from the surface. (From the Wild scheme a global average value of 0.861 was deduced (section 4).) In addition to this average two special conditions will be considered: clear sky and strong cloud cover. For a clear sky f = 0.68 is applied. As clouds too emit almost as a black body and intercept most wave lengths, they will reduce the opacity factor seriously and a value of f = 0.95 is applied.

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14 Data provided by Roy Clark, data set 2 with reflection correction

16. The application of the simulation model to a real case: Nebraska, August 1953

The observations at O'Neill, Nebraska are of particular interest because they provide as well data in the troposphere up to 1500 meter (see figure 8) as in the boundary layer at the 'skin' between -1 and -20 cm depth. See figure 5 from Hartmann 1994, p. 86 and p. 96.

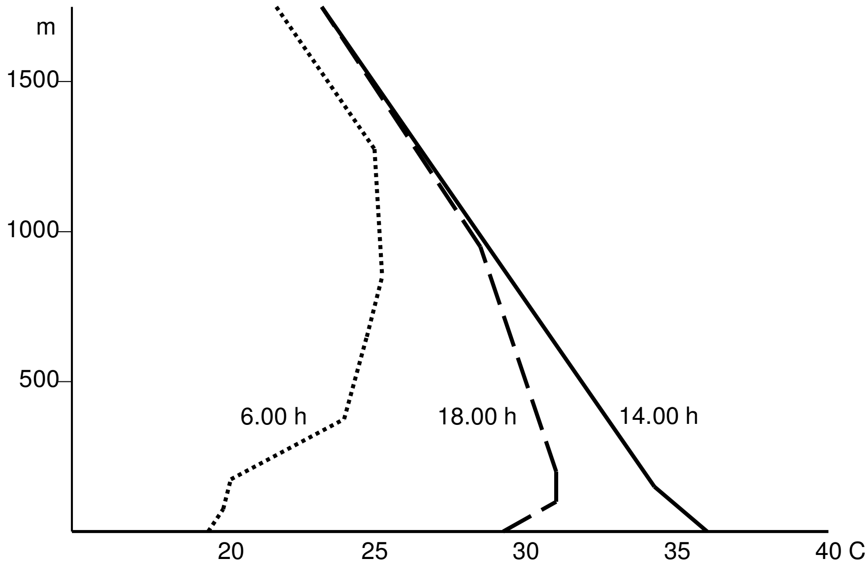


Figure 8. Temperature profile of the atmosphere O'Neill, Nebraska during a diurnal cycle.

It is a clear and very hot day on August 13. The insolation period, the daylight period, is 14 hours. At 2.00 hours after noon in the skin 42 ºC is observed and above it 36 ºC. During the night a very strong inversion occurs in the troposphere that is ascribed to a strong upward turbulent flow starting in the afternoon and removes heat efficiently from the surface. Then, during the night, cooling progresses because of IR emitted from the skin. The dew point T_d is just above the minimum temperature, because at nightfall the cooling decelerates due to the condensation of water at the surface and hence the release of latent heat that counteracts the radiative cooling.

Below (figure 9), our simulation of this diurnal cycle is shown in order to legitimate the very simplified approach used here to describe energy flows with only a few parameters (see equations [3] and [4] in section 6). The treatment of flows with complicated partial differential equations is thus avoided.

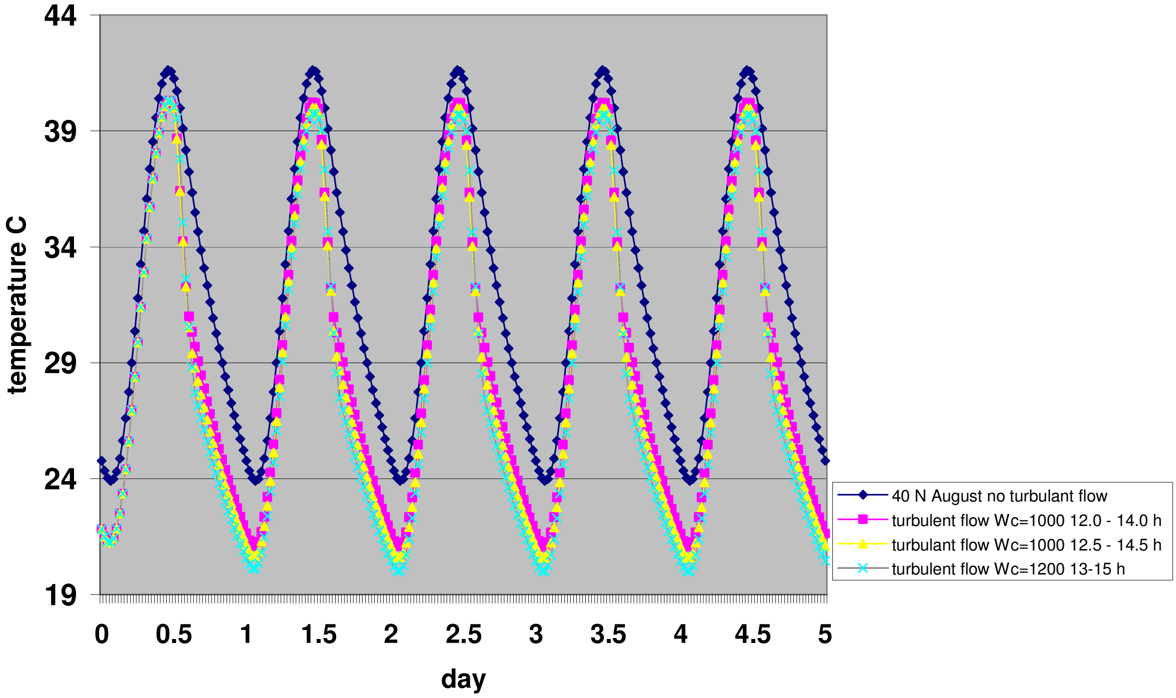


Figure 9. Step by step parameterization of the constant W_c .

The first step in the simulation of the temperature profile during a diurnal cycle is to assume a dynamic equilibrium state over the entire cycle as explained in section 9. Average, maximum and minimum temperature in the subsequent cycles will be similar and the net accumulating heat during the cycles must be zero. (Provided other parameters also remain the same e.g. interference by weather events), Various values of W_c are applied to produce a profile of changing values of W_{ec} with time (and temperature) by trial-and-error in the SDC algorithm until the dynamic balance is reached with an outcome for maximum and minimum temperature that approaches observation. (The O'Neill observations do not comprise values for W_{ec}. We know from other observations (see table II) that in order to be realistic, W_{ec} should be in the range of 500 W/m^2 at noon and -100 W/m^2 after sunset, with an average of 150-200 W/m^2.)

When this matching method is applied and turbulent flow neglected, the result obtained for a dynamic equilibrium state is presented by the black curve in figure 9. However, this does not fit observation: the maximum and minimum temperature are 2 ºC too high.

To obtain a temperature profile that fits the observations better, a turbulent flow of two hours duration is then introduced in the SDC algorithm. With the condition W_c = 1200 W/m^2 for 2.00 hours, the simulation closely approaches the observations mentioned above.

Figure 10 illustrates the effect of this strong turbulent flow on heat removal (W_{ec}) half-hourly during the diurnal cycle.

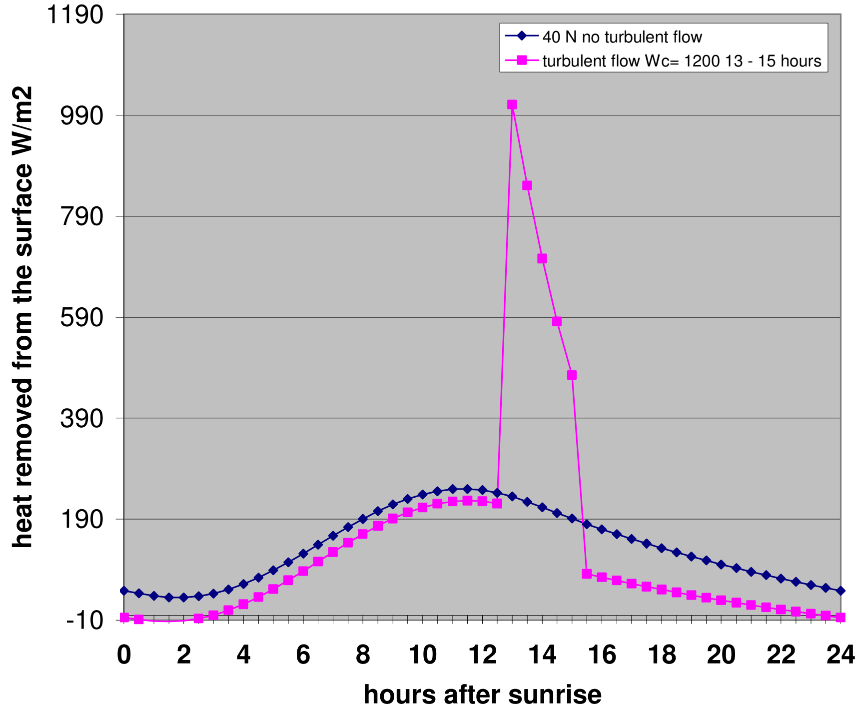


Figure 10. Comparison of the heat removal from the surface, with and without a turbulent flow, O'Neill, Nebraska, August 1953.

This boost of heat removal from the surface during the first half hour of strong turbulent flow is followed by its rapid decrease in spite of continued turbulent flow for another 1.5 hours. This is caused by the enhanced decrease of the surface temperature during and after the boost that limits heat loss by IR emission.

In order to investigate the relative effect of phenomena other than a turbulent flow on the attractor, we continue to apply our simulation method. This is considered justified because the simulation is matched with a number of real (local) observations as presented above.

17. Preliminary investigation of the effect of a small narrowing of the atmospheric window

One such an influence on narrowing the atmospheric window is the effect of an increase in CO_2 concentration in the troposphere. We approach this from the theoretical point of view, asking how a small change in the opacity factor f (see sections 5 and 6) from 0.68 to 0.69 (nearly clear sky) may influence the diurnal temperature profile in the O'Neill case. The change of f = +0.01 corresponds with a theoretical value of 4-5 W/m^2 increase of 'back-radiation' from the radiative field in the troposphere as estimated by several authors for the effect of a doubling of the CO_2 concentration. The results are collected in figures 11 and 12.

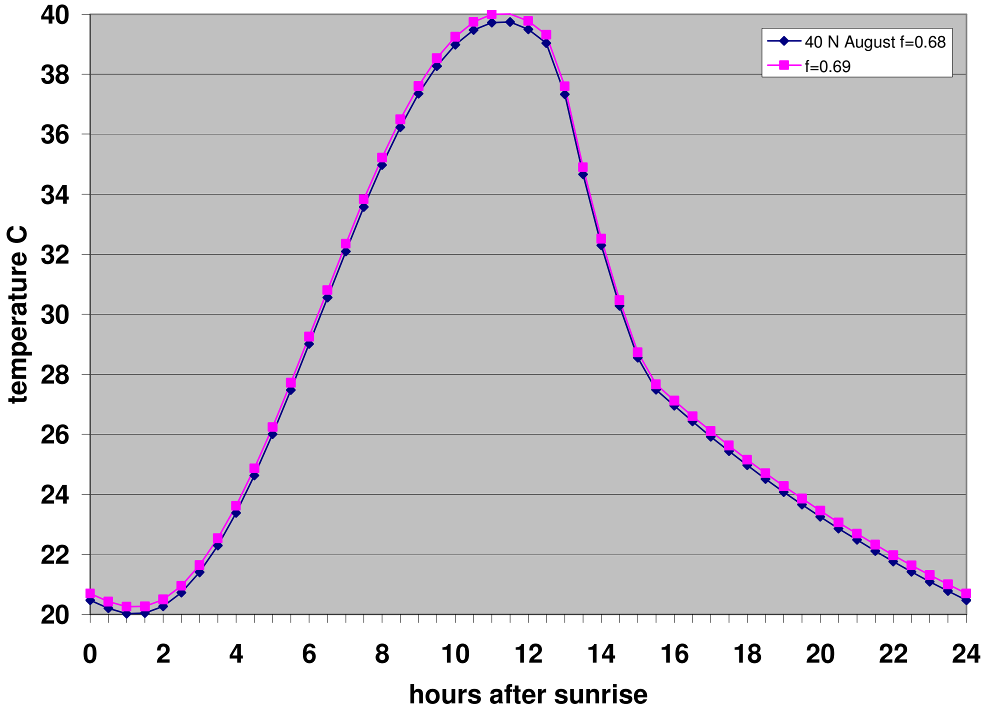


Figure 11. The theoretical effect of a small change in optical density of the troposphere on the temperature profile during a diurnal cycle.

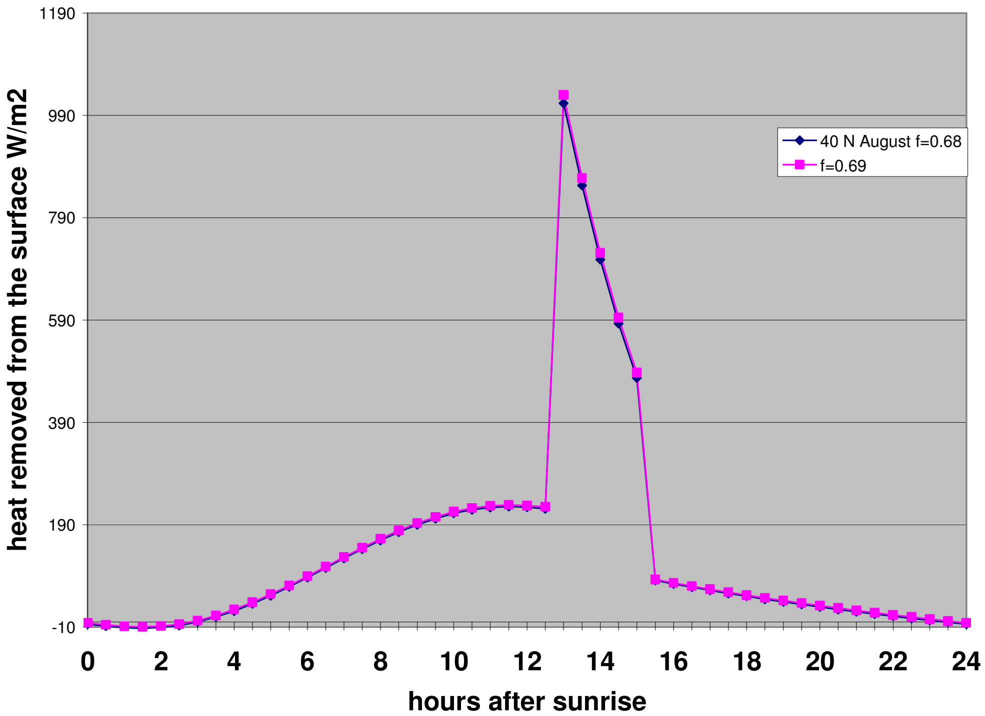


Figure 12. The calculated heat removal from the surface during a diurnal cycle with a short period of turbulent flow and a small increase in the optical density of the troposphere.

From the graphs a small but significant effect of increase of the opacity factor f can be deduced considering the actual calculated values as shown in table V.

	f = 0.68	f = 0.69	Δ
T balance	-5.8E-07	1.5E-05	1.6E-05
J accu	-0.3943	10.1146	10.5089
T aver	27.9948	28.222	0.22721
Tmax	39.7334	40.0076	0.27428
Tmin	20.0291	20.2556	0.22645
WW aver	143.8	147.599	3.7993
WW max	1013.83	1029.88	16.042
WW min	-12.216	-9.4845	2.7316

Table V. The effect of a small increase in opacity factor f on the average temperature and the heat removed from the surface (W_{ec} W/m^2) during a diurnal cycle

(T balance: the temperature difference between two subsequent sunrises. J accu: the accumulated or lost heat from the surface over the whole diurnal cycle, mJ/m^2).

With an increase in the f factor, the potential average temperature increases by 0.23 ºC. But the simulation model suggests that this temperature rise is accompanied by increased heat removal from the surface by W_{ec}, which in turn limits the potential temperature rise.

Why this result of our simulation differs from the conclusions in the IPCC reports (>1.5 ºC) will be briefly elaborated on in part IV. Here we note that the origin is ascribed to a different interpretation of the behaviour of the hydrological cycle at the (skin) surface.

We will return to the Nebraska case in more detail in Part III after having reported results of simulation studies under 12 other conditions at various latitudes on various days of the year

18. Reconsideration of the theoretical effect of the attractor during a diurnal cycle

The simulation studies of the behaviour of the three major energy carriers – insolation, the IR radiative field in the troposphere and the wind-water (WW) phenomena, and their mutual interference were started with the objective to find an autonomous regulatory mechanism. This leads unavoidably to the consideration of equilibrium states. From observations as well as theoretical considerations, it is clear these states will never occur at any particular time in the very dynamic interactive system of the three major energy carriers. Nevertheless, a dynamic energy balance can be defined over a period of a diurnal cycle that becomes zero if at two subsequent sunrises the temperature has the same value. Then energy gain at the surface by day equals the loss by night. In terms of complexity theory, the trajectory the variables follow over the diurnal cycle is identified as what has been named an attracting cycle around a fixed point, the attractor itself.

As expressed in equation [3], the observed amplitude of the oscillation of the temperature around the average temperature of the diurnal cycle is strongly dependent on the heat capacity of the surface. The amplitude is large, see figure 13, the black and blue curve for a land surface with a low heat capacity, ($7*10^5$ J/m2), which was the actual situation in O'Neill, Nebraska in August 1953.

This graph also illustrates a case (yellow and grey line) of a surface with a high surface heat capacity, $1.5*10^7/m^2$, here called a pseudo Nebraska situation.

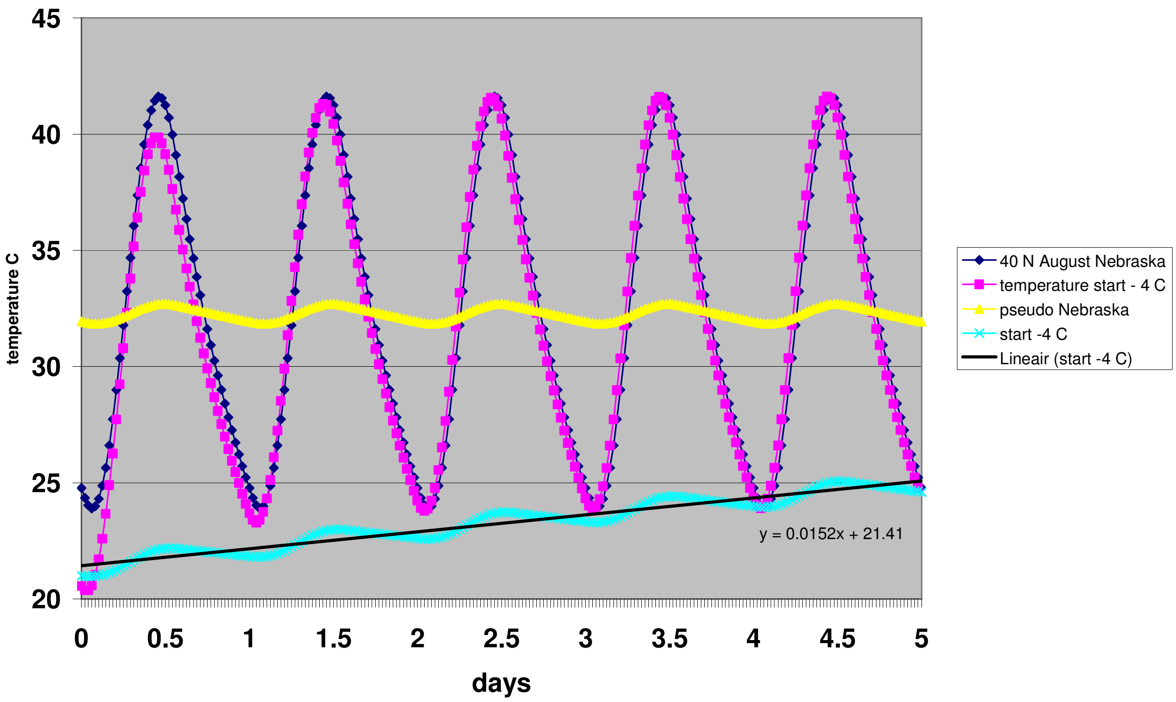


Figure 13. Drift of dynamic equilibrium states with different heat capacities of the surface.

More differences between the trajectories of surface temperature with different surface heat capacities need to be identified.

> "The surface energy balance determines the amount of energy flux available to evaporate surface water and to raise or lower the temperature of the surface. Surface processes also play an important role in determining the overall energy balance of the planet. [..] Understanding the energy budget of the surface is a necessary part of understanding climate." (Hartmann 1994, p. 81.)

Here we focus attention (figure 13) on the rate a dynamic diurnal cycle equilibrium state will be reached if it occurs at a particular sunrise outside of the range of the temperature trajectory of the next five days.

For the two cases presented above – a low and high heat capacity – an out of range temperature of 4 ºC is chosen below the average temperature. For the case of low heat capacity see the blue line in figure 13. In a diurnal cycle on land the attractor is apparently powerful enough to force the situation into the new diurnal equilibrium state within a few days (if no other weather events are interfering).

If a similar out-of-range temperature is chosen for the ocean, it would take a very long time before the theoretically calculated diurnal dynamic equilibrium state is reached. We even wonder whether in the ocean, at any given latitude or day of the year, the dynamic equilibrium state is ever reached during the progression of the seasons. In this respect we note that over seasonal changes at 30 and 60 degrees latitude, ocean temperatures differ by more than 4 ºC (see table III).

PART III. RESULTS OF NUMERICAL SIMULATIONS OF THE DIURNAL CYCLE

19. Introduction

The strength of the greenhouse effect is usually indicated by calculating the total global annual influx from the sun in the absence of an IR absorbing atmosphere. The temperature of this bare earth would be -15 ºC. The current global average is +17 ºC. Hence the greenhouse effect amounts to +32 ºC ; in its absence the Earth would be an 'ice-ball'.

We argue against this because presenting the phenomenon in this way has several shortcomings. Outside the equatorial zone alternating warming and cooling periods are unevenly distributed across the globe. When considering the dynamics of these warming and cooling processes, a different picture emerges than produced by the ice-ball, which is based on the averaging of global insolation.

In the next section 20 the comparison is made between a bare Earth surface and one associated with a radiation field. The Earth's surface is studied on the basis of observed phenomena at the current prevailing optical density of the troposphere. This leads to the conclusion that due to the functioning of the hydrological cycle from March 22 to September 21 in the Northern Hemisphere the present greenhouse acts as a cooling rather than a warming mechanism.

In section 21 the effect of a small narrowing of the atmospheric window that can be expected from an increase of the CO_2 concentration in the troposphere is investigated.

For the sake of clarity we first summarize the paradigm that led to the formulation of our rethinking of the current conceptual framework.

A greenhouse, of whatever kind, is an entity characterized as a closed system for mass flows and accumulates heat. However, in an open thermodynamic system temperature will not continue to rise because the radiation fluxes vary during the diurnal cycle, An average temperature will be established in the Earth system, with incoming radiation energy during the day equaling the outgoing and ongoing IR flux during the night. It has to be recognized that the largest IR out flux occurs has already occurred during the day time when surface temperature is increasing.

This is an autonomous regulatory mechanism already enshrined in the Stefan-Boltzmann law (see figure 4). In section 21 we show that it is not sufficient to adjust the temperature to observed values for the various latitudes and days of the year. Another regulatory mechanism needs to be considered and is described as the dynamic diurnal equilibrium state.

Below, we continue to ask why regulatory mechanisms are not considered to be the fundamental basis for the interpretation of observations in current climate research, e.g. by working group I of the IPCC.

20. The potential temperature of the surface in the absence and the presence of a greenhouse effect

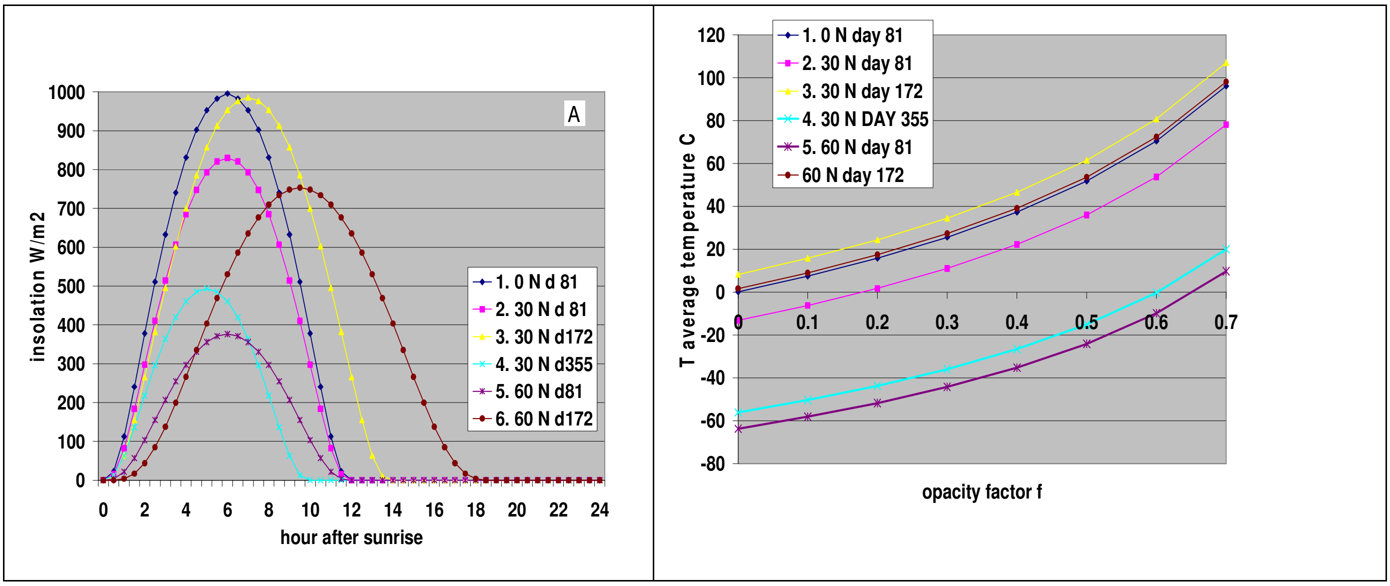


Figure 14. Left: Insolation. Right: Theoretical ocean surface temperature as a function of the optical density in the absence of a wind-water effect.

The average temperature at each location indicated in figure 14 is first calculated with the SDC algorithm for the condition prevailing at a dynamic equilibrium state as reached over a diurnal cycle. Next the potential temperature with increasing opacity factor f from 0 (the 'bare Earth') to 0.7 is considered (see right hand figure 14); the current condition just above the value for clear sky. This, namely, under the theoretical condition that the optical density of the troposphere alone determines the surface temperature, that no WW effects are interfering and that the sunlight reaching the surface during day time stays the same. This is of course an absurd assumption given the role H_2O plays in the Earth's greenhouse. With temperature rise, its phase transition liquid → vapour will increasingly remove heat from the surface. This initial neglect of a cooling process is used to demonstrate the contribution of the hydrological cycle to the greenhouse effect. We see in the right hand graph 14 the function T=F(f) as a gradually rising exponential one, that can be described as a polynomial to the power 3.

For three conditions in figures 14 and 15 given a (theoretical) value for f=0.4 during spring and summer, the surface temperature would rise above observed ones, and at f=0.7 would even reach the boiling point of water. Yet the oceans are not boiling. This is a first indication of the importance of a cooling mechanism in the greenhouse effect. Also during winter none of three locations would freeze in the absence of a greenhouse effect.

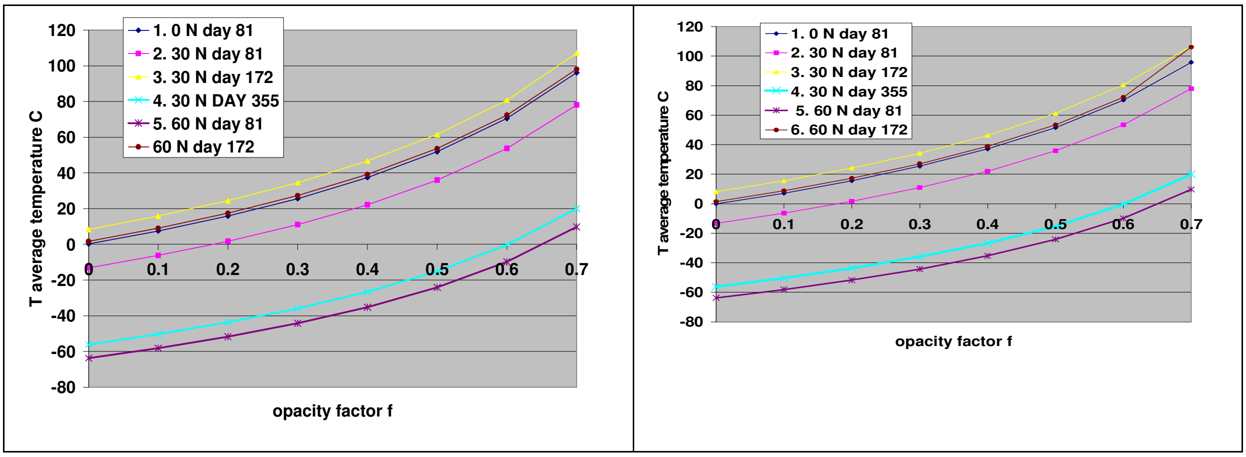


Figure 15. Theoretical surface temperature as a function of the optical density in the absence of a WW effect. Left hand: ocean. Right hand: land.

In figure 15 a comparison is presented between the behaviour of ocean and land. A small difference follows from this presentation of the data. The small difference of 0.2 ºC can be explained by the difference that emerges from observations of the large difference of the temperature amplitude during the diurnal cycle of sea and soil surfaces (see e.g. figure 13).

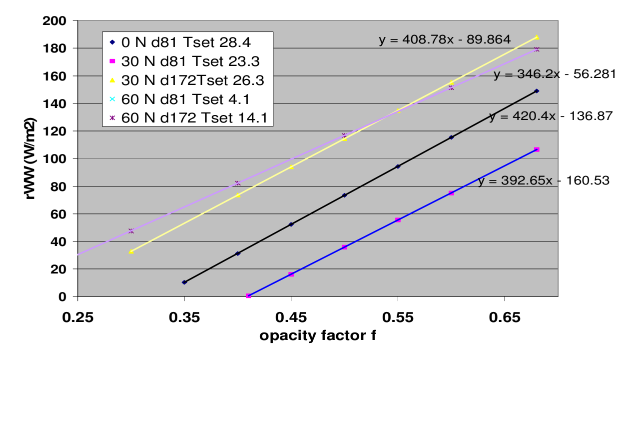
The next step in the interpretation of these calculations is to suggest that to explain a locally observed temperature – e.g. 30º N day 172 (June 21) is 26.3 ºC – would **NOT** require an optical density factor of 0.7, a value of f=0.3 would suffice. Then the question necessarily follows: **if** the optical density rises further from f=0.3 to 0.7, what would prevent the observed temperature of 26.3 ºC from rising to the absurd value of 105 ºC?

We therefore introduce a new term rWW (required WW effect, W/m^2) to compensate for a potential temperature rise above an observed value that may be caused by a potential increased optical density.

Rather than a variable, the value of rWW is a parameter associated with a particular observed surface temperature (see table III) at a particular location on a particular day.

To clarify the approach to explain with calculated values of rWW why absurd temperatures are not reached at the current optical density f=0.68 (for clear sky) in June at 30º N day 172 we focus again on the calculation that a f=0.3 would suffice to reach the observed temperature (26.3 ºC). We will show below there is a linear relationship between a 'must' for rWW increase per unit f to compensate for a potential temperature caused by the increasing optical density factor f to 0.7.

An increase of rWW0.68 to a value $rWW_{0.70}$ is also imperative. If not, there should be a reason why the indicated theoretical general trend over the range of f 0.4 → 0.7 is not continued.



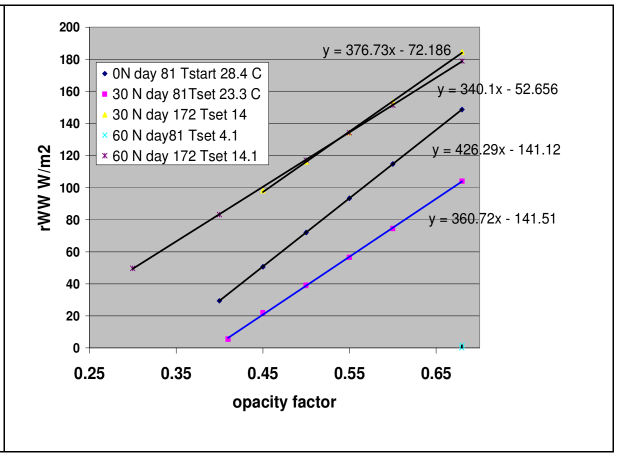


Figure 16. The required WW effect (rWW) to compensate for a temperature rise with a potential rise of the optical density per unit f. Left: Ocean (high surface heat capacity). Right: Soil (low surface heat capacity).

The slope of the curve ΔrWW/Δf is slightly dependent on the observed local surface temperature, indicated in the graphs as the Tset.

A theoretical physical explanation for the remarkable linearity of the function rWW = F(f) was recently presented by Koll & Cronin (2018)][15]

21. Simulations of conditions with clear sky and a small narrowing of the atmospheric window

Based on theoretical calculations, several investigators have estimated the narrowing of the atmospheric window by CO_2 doubling to 3-4 W/m^2. In the current terminology of mainstream climatology, this is called the 'back-radiation' from the lower troposphere.

Here, this corresponds to an increase of the opacity factor f from 0.68 to 0.69 at clear sky.

Below, to begin with, the effect on the surface temperature is described on the ocean for 60º N on day 172 (July 21), when the sun is high in the sky and the day length is 18 hours. Average insolation is 290 W/m^2 with a maximum of 753 W/m^2

[15] D.D.B. Koll, & T.W. Cronin (2018) . "Earth's outgoing longwave radiation linear due to H2O greenhouse effect." http://www.pnas.org/content/early/2018/09/24/1809868115. Supporting information to this article is to be found online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1809868115/-/DCSupplemental

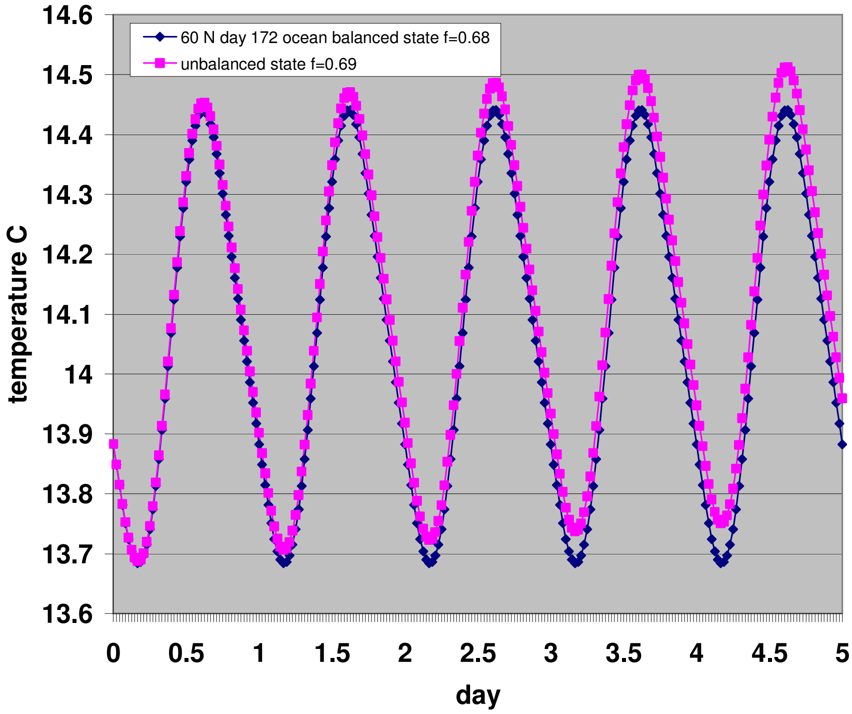


Figure 17. The initial effect of an increase of the optical density factor f 0.68 → 0.69 on the ocean surface temperature.

If we assume that the opacity factor jumps from one day to the other +0.01 unit, then the system is on the ocean for some time in an unbalanced diurnal state (due to the high surface heat capacity). See the blue curve in figure 17. Maximum temperature rises over 5 days by 0.03 ℃.

According to our paradigm on the linear relationship between WW effect and the opacity factor this temperature rise will be accompanied by enhanced latent heat removal from the surface. See the blue curve in the next figure 18.

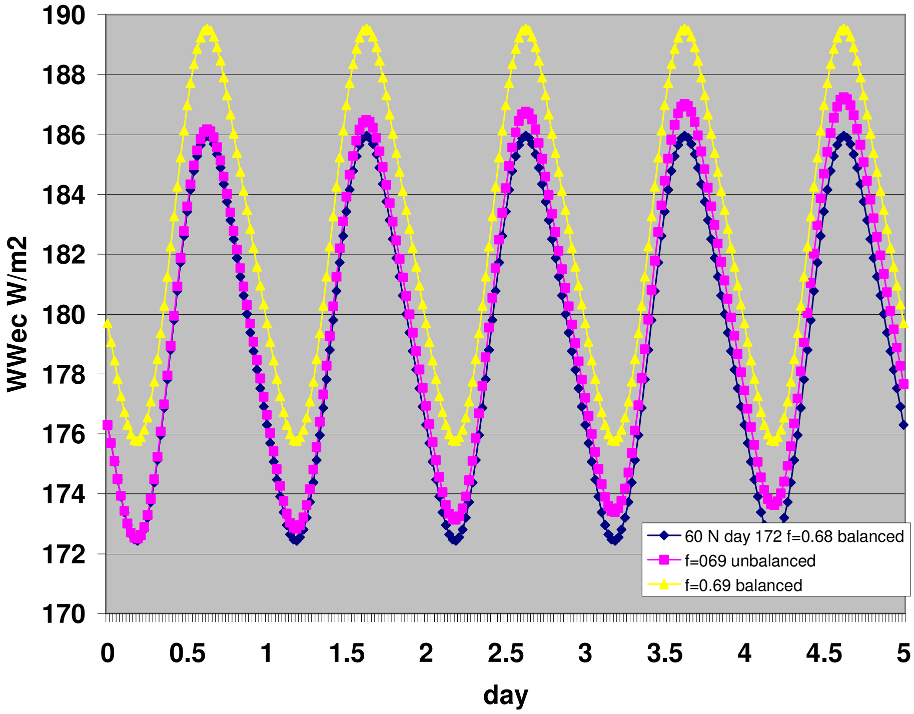


Figure 18. Accompanying increase of removal of heat (WW_{ec}) from the surface with increasing f 0.68 → 0.69.

At first hand the ultimate diurnal equilibrium state with this counteracting force cannot be forecast with the current algorithm with limited time span. For now we jump to the conclusion that the hydrological thermostat will be able to bring the diurnal temperature profile back to that of f=0.68. Then the accompanying required WW effect can be calculated. See figure 19.

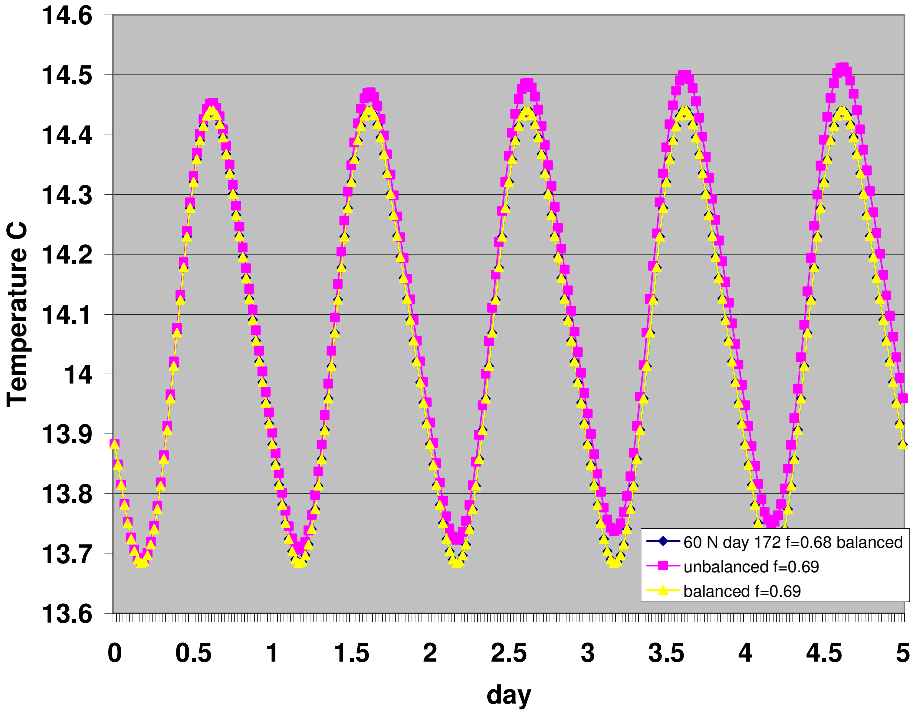


Figure 19. Return to a balanced temperature profile from f=0.69 to the one at f=0.68 with an active attractor.

This profile is represented by the yellow curve for f=0.69 which covers the black profile for f=0.68.

The next figure 20 depicts the state phase-diagram for the two conditions f=0.68 and f=0.69.

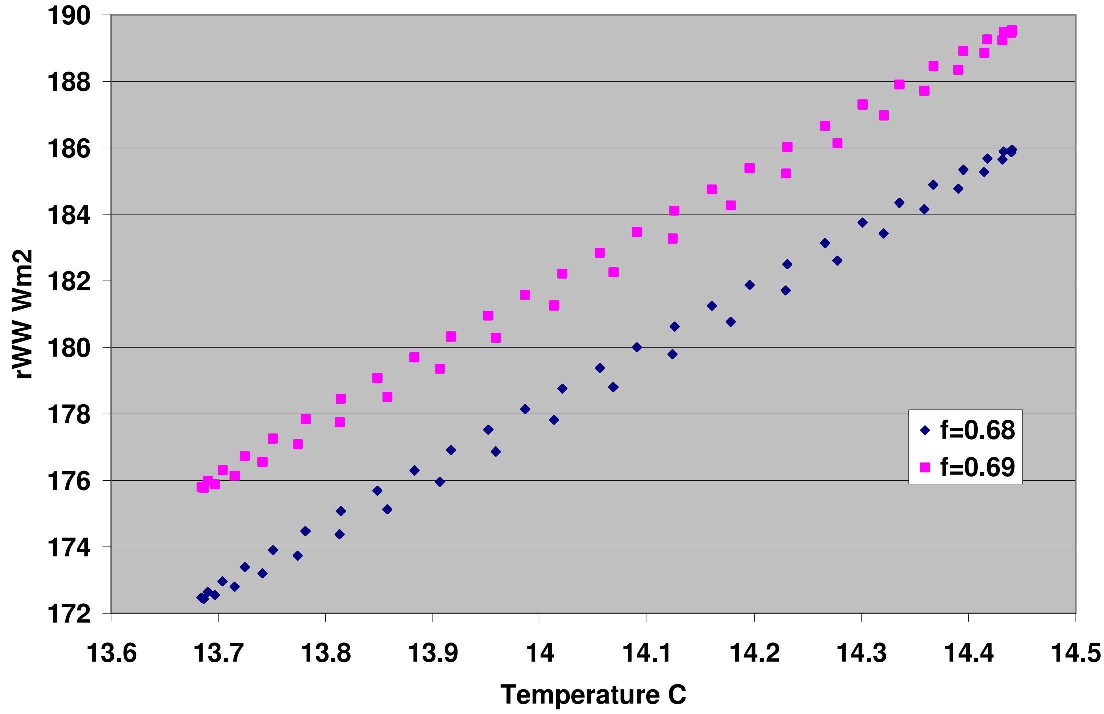


Figure 20. The attractor cycles for f=0.68 and 0.69 with the same minimum and maximum temperatures. (State-phase diagram for ocean.)

Over the whole trajectory a WW effect + 4 W/m^2 suffices to produce both diurnal equilibrium states.

Next we come to consider the situation on land with a much lower heat capacity of the surface. See figure 21.

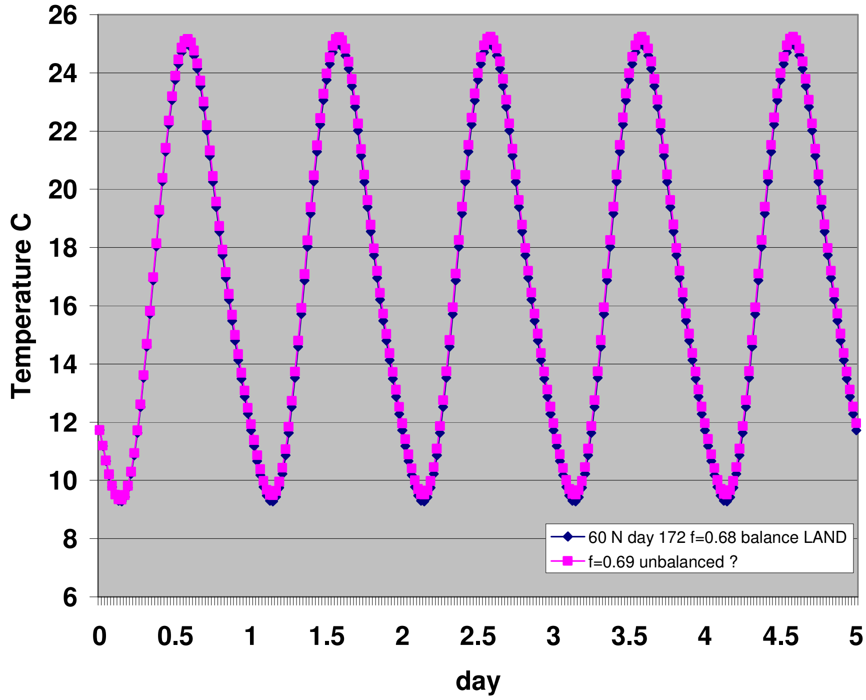


Figure 21. The initial effect of an increase of the optical density factor f 0.68 → 0.69 on the land surface temperature.

Again we assume that the opacity factor jumps from one day to the other +0.01 unit. Then the system remains briefly in an unbalanced diurnal state (due to the lower surface heat capacity than that of the ocean surface). See the blue curve in figure 22. Over five days the temperature rises to a higher value, although the graph suggests that it stays nearer to the equilibrium state of f=0.68, which is due to the scale used. (Temperature amplitude over a diurnal cycle is much larger over land than over ocean.)

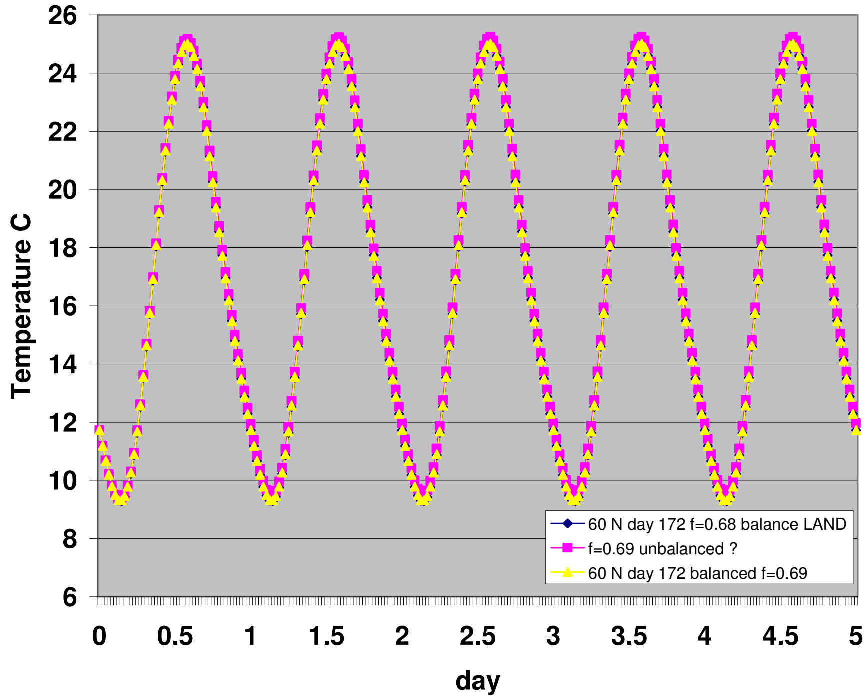


Figure 22. Return to a balanced land temperature profile from f=0.69 to the one at f=0.68 with an active attractor.

Again, we start from the assumption that the hydrological thermostat will be able to bring the diurnal temperature profile back to that of f=0.68.Which is illustrated in figure 22. The yellow curve for f=0.68 covers the black one for 0.69 perfectly.

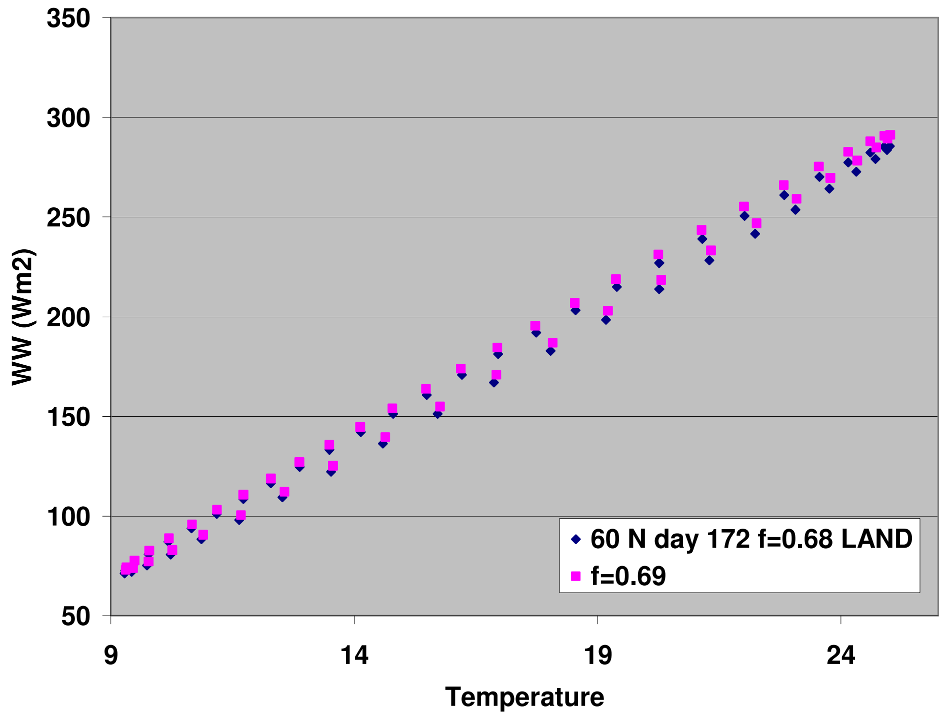


Figure 23. The attractor cycles for f=0.68 and 0.69 with the same minimum and maximum temperatures. (State-phase diagram for land.)

By night the established required WW effect to arrive at the attracting trajectory cycle is much lower then at noon. The amplitude for land is 105 W/m^2, whereas for the ocean (figure 20) it is only 13 W/m^2. This is of course due to the large difference in surface heat capacity and temperature amplitude. The average values over the diurnal cycle are not that much different.

In table VI the actual data are presented for the ocean and land surfaces, but now expressed in average values for WW and temperature.

		1	2	3	4
	60º N day 172 ocean	rWW	T aver	ΔrWW	ΔT
1	Balanced state f=0.68	179.1813	14.0618		
2	unbalanced state f=0.69	180.4417	14.1326	1.2604	0.07071
3	balanced state f=0.69	182.6407	14.0619	3.4594	7E-05
	60º N day 172 land				
4	Balanced state f=0.68	174.58	16.85		
5	unbalanced state f=0.69	177.81	17.09	3.23	0.24
6	balanced state f=0.69	178.16	16.86	3.58	0.01

Table VI. The collected numerical results from the diurnal cycle simulation for latitude 60º N on June 21 with increased f =+0.01 unit.

(The T average value for land is chosen a few degrees higher than for ocean as is expected for the difference between a continental and maritime climate.)

Column 1 presents the **average** WW value (W/m^2) required to bring the system to the temperatures given in column 2 in balanced and unbalanced dynamic states.

Column 2: The average temperature deduced from the temperature profile during the diurnal cycle.

Column 3. The increase of the required WW effect to bring the temperatures to the values in column 2; based on the arguments and calculations presented in section 19.

Column 4. The potential increase of the temperature in the unbalanced and balanced state at f=0.69 compared with the balanced state at f=0.68.

Note that the required WW effect to bring temperatures back to original values is of the same order of magnitude of the radiation flux to the surface calculated by several authors for a doubling of the CO_2

The presented case for 60º N day 172 is not an exceptionally rare one. Tables VII and VIII show the numerical results for twelve more conditions (at 2 latitudes on three days in the year on the ocean and on land. (With respect to insolation the condition on day 81 is the same as on day 264.)

land		1	2	3	4
60º N day 81		rWW	T aver	ΔrWW	ΔT
1	Balanced state f=0.68	2.633835	3.305077		
2	unbalanced state f=0.69	5.300306	3.613796	2.666471	0.308719
3	balanced state f=0.69	5.748148	3.202876	0.447842	-0.1022
30º N day 172					
1	Balanced state f=0.68	186.9473	26.76345		
2	unbalanced state f=0.69	198.8318	26.90399	11.8845	0.14054
3	balanced state f=0.69	195.2017	27	8.2544	0
30º N day 81					
1	Balanced state f=0.68	106.283	23.29417		
2	unbalanced state f=0.69	110.0246	23.41014	3.7416	0.11597
3	balanced state f=0.69	113.7778	23	7.4948	0
0º N day 172					
1	Balanced state f=0.68	116.9295	28.54605		
2	unbalanced state f=0.69	120.4333	28.95197	3.5038	0.40592
3	balanced state f=0.69	121.1614	28.54062	4.2319	-0.00543

Table VII. The collected numerical results from the diurnal cycle simulations on land for latitudes 0º, 30º and 60º N on March 22, June 21 and September 21.

ocean		1	2	3	4
60º N day 81		rWW	T aver	ΔrWW	ΔT
1	Balanced state f=0.68	2.2354	3.624998		
2	unbalanced state f=0.69	2.4956	3.6979	0.2602	0.072902
3	balanced state f=0.69	5.2184	3.6252	2.983	0.000202
30º N day 172					
1	Balanced state f=0.68	188.1073	26.3		
2	unbalanced state f=0.69	190.2718	26.37261	2.1645	0.07261
3	balanced state f=0.69	192.1953	26.30011	4.088	0.00011
30º N day 81					
1	Balanced state f=0.68	106.4716	23.30002		
2	unbalanced state f=0.69	108.6599	23.63679	2.1883	0.336774
3	balanced state f=0.69	110.3982	23.30009	3.9266	7E-05
0º N day 172					
1	Balanced state f=0.68	117.418	28.44915		
2	unbalanced state f=0.69	118.6662	28.53915	1.2482	0.09
3	balanced state f=0.69	121.6247	28.44918	4.2067	3E-05

Table VIII. The collected numerical results from the diurnal cycle simulations on ocean for latitudes 0º, 30º and 60º N on March 22, June 21 and September 21.

The current main stream model (IPCC) suggests a necessary rise of the surface temperature >1 ºC when the atmospheric window narrows. What is based on a so-called positive feedback mechanism and in contrast with the model presented here. In part IV section 29 ‘The effect of the downward IR flux’ and section 30 ‘The removal of heat by wind-water effects’ this discrepancy elaborates this contrast. The model based on the effect of the attracting trajectory during the diurnal cycle suggests, that with a jump of the opacity factor the system may be for a short time out of balance and temperature increases slightly (<0.34 ºC) but after some time it may be reduced to 0.

22. The effect of cloud formation during a diurnal cycle on future cycles

Capricious weather events involve the temporary disturbance of the dynamic diurnal equilibrium state, as described by a trajectory cycle. Among these events are the great variation of cloud covers intercepting radiation fluxes. The results of simulation of cloud coverage for short time intervals are presented in figure 24 on land at 30º N on day 172 (June 21)

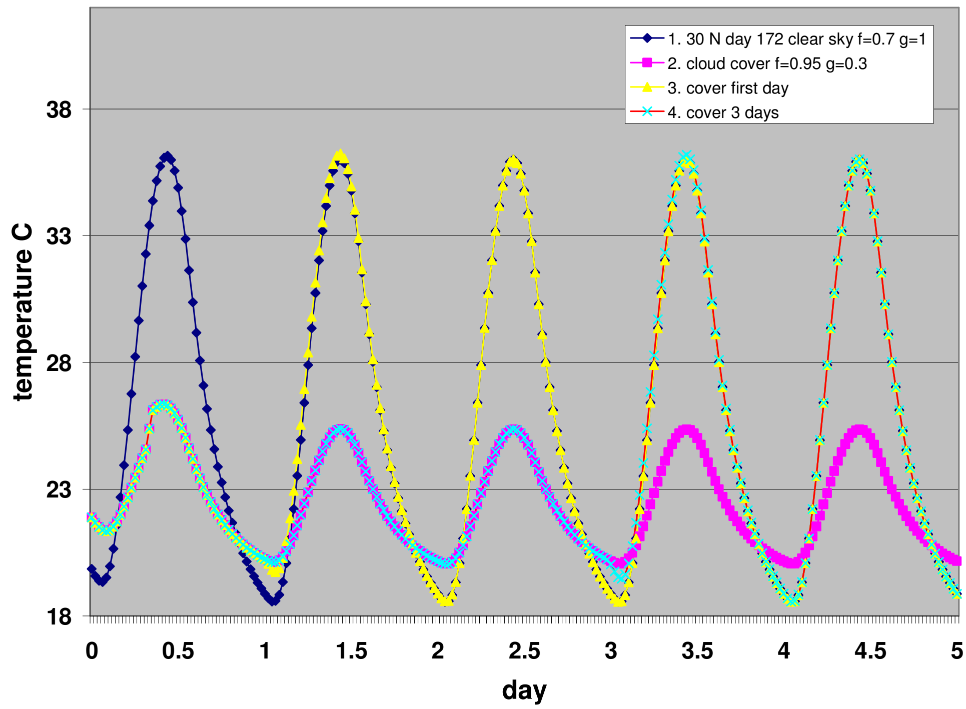


Figure 24. The effect of a change in occasionally occurring cloud cover on subsequent days with clear sky.

Line 1, the black curve, represents the theoretical diurnal temperature profile with an almost clear sky.

Line 2, the blue curve, represents the temperature profile of a cloud cover already in existence for many days and persisting for five more subsequent cycles.

Solar insulation is reduced to a factor g=0.3, that is 30% of the insolation that reaches the surface. The atmospheric window is closed for almost all IR wavelengths emitted from the surface, so an opacity factor f=0.95 is used. These values are here arbitrarily chosen for an extreme effect. Cloud covers take many forms.

The effect of the extreme condition is obvious. Maximum temperature is reduced because less solar energy reaches the surface than at clear sky. The minimum temperature rises because less radiation (energy) can escape from the surface at night. The atmospheric window is reduced to an extremely low value and more heat is retained at the surface.

Line 3, the yellow curve, represents the case of a cloud cover in existence during previous days that persists for one day longer only. Hence, when the sky later clears, the system will return within two days to its clear-sky profile, demonstrating the power that is built into the diurnal cycle itself for re-establishing a dynamic equilibrium state.

The effect is once more illustrated by the grey curve 4, when within the time period of five days the cloud cover persists for the three first days and within the next two the clear sky temperature profile is restored.

Cloud cover change may be accompanied by other meteorological events, such as stronger turbulent flows, caused by e.g a storm. Their combined action is illustrated in figure 25 if these events persist one day only.

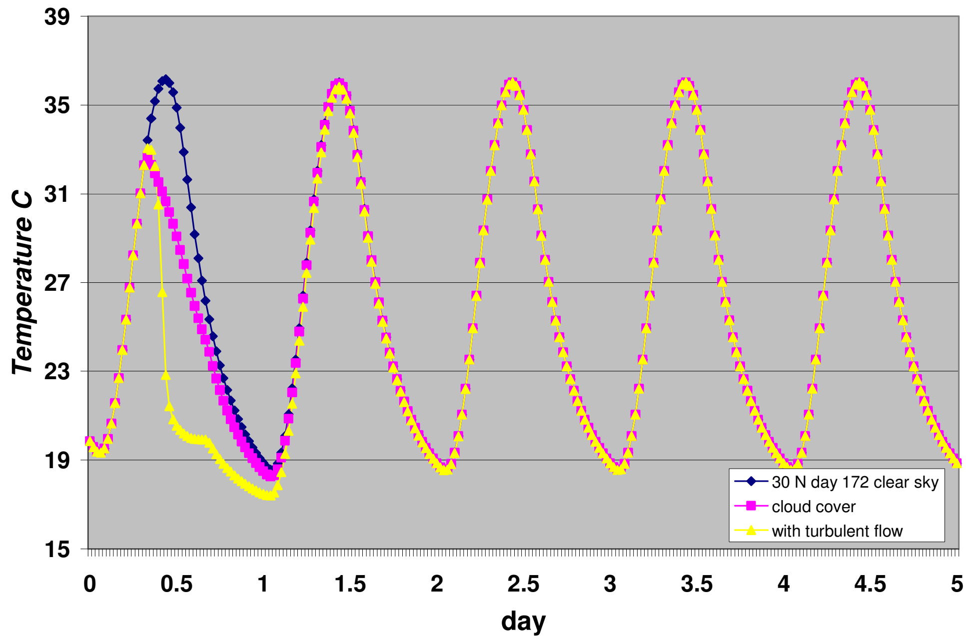


Figure 25. The combined action of cloud cover change and turbulent flow during one day on land.

The black curve depicts the clear sky condition if it persists; the blue line does so if the cloud cover is not accompanied by a strong turbulent flow. This results in a decrease of the maximum temperature by 3 °C . With the additional occurrence of strong turbulent flow, the drop of the surface temperature is strongly accelerated and the minimum temperature at night is also lowered.

If on the next day both meteorological events did not persist, the clear sky temperature profile is quickly restored. The powerful attractor manifests itself as well as in the case of one occasional weather event.

23. Summary

Diurnal cycle simulations in both the absence and presence of a wind-water (WW) effect indicate a linear relationship between increased optical density and the required WW effect in order to maintain a particular observed surface temperature at the various latitudes considered at particular days of the year.

A physical explanation for the remarkable linearity of the function rWW = F(f) was recently put forward by Koll & Cronin (2018). This led to the suggestion that the inherent property of the phase transition liquid ↔ vapour of H_2O over a large range of an optical density change will completely counteract its property to narrow the atmospheric window for IR absorption to cause a temperature rise at the surface. This leads, however, to a potential warming of the gas mixture in the troposphere. If the proposed autonomous regulation that resides in the diurnal dynamic equilibrium state is accepted, it is expected that the hydrological cycle will continue its cooling function at the surface whatever cause of potential temperature rise at the surface, e.g. by increase of CO_2 concentration in the troposphere.

The slight warming observed by weather balloon observations and satellites above the skin pause during a century may be due to the concurrent rise of the CO_2, but this is not necessarily so. See section 33.

If CO_2 concentration change has an influence, it would affect the slope of the temperature lapse rate up to the altitude where emission takes place to space. At this height both the atmospheric heat reservoir and hence the strength of the radiation field will have increased (see figure 3).

This suggests that this process functions also as an autonomous regulatory mechanism limiting the skin surface temperature rise. (A note on this effect is in preparation by Roy C. Clark).

The critical reader is invited to weigh the arguments to encourage a 'rethinking' of the functioning of the Earth's greenhouse, which can be expected to be controlled by autonomous regulatory mechanisms, in contrast to proposed mechanisms in current mainstream climatology.

If we present the above summary with less circumstantial reservations, then the discussion can focus on the following straightforward statements:

1. Autonomous regulatory mechanisms in the atmosphere have been ignored.
2. The diurnal cycle contains a strong attracting dynamic equilibrium state.
3. Capricious weather changes mask this.
4. Between 22 March and 21 September (between 0 and 60 degrees North) at current optical density the surface temperature would rise strongly above observed values.
5. At the current optical density of the atmosphere this is undone by upward air convection and water evaporation at the Earth's surface.
6. A linear relationship can be identified between increasing optical density and increasing heat transport from the surface.
7. This leads to the suggestion that an increase of the surface temperature will be canceled by the water thermostat.
8. In turn, this requires a reassessment of major assumptions on which the current greenhouse gas theory is based.
9. Point 2 and 4 are in this summing-up of regulatory mechanisms that seem to have escaped attention so far.

PART IV. DISCUSSION AND FURTHER CONSIDERATIONS

24. Introduction

In the next section (25) first the current model used in mainstream climatology for the greenhouse effect is summarized. This is followed in section 26 by the 'rethinking'. This is done by giving more weight to autonomous regulatory mechanisms than are applied in the model adopted by the mainstream climatologists. Sections 27-32 summarize the major shortcomings as seen by critical scientists, e.g. in the application of physical principles *in situ* from which the IPCC model was constructed.

25. The basis of the current concept of the Earth's greenhouse effect[16]

The existence of the greenhouse effect was postulated by Joseph Fourier in 1824. Supportive arguments and the evidence were further strengthened by Claude Pouillet in 1827 and 1838, and supported by experimental observations made by John Tyndall in 1859, who measured the radiative properties of specific greenhouse gases.

The Earth system radiates IR wavelengths at its TOA to space, an energy carrier that originates from what is received from the sun. 1/3 of this thermal solar radiation is absorbed by the atmosphere and warms it, and 2/3 of it reaches the surface. The atmosphere also gains heat by sensible and latent heat fluxes from the surface and radiates energy both upwards and downwards; the part radiated downwards (named back-radiation) is absorbed by the surface of Earth. This leads to a higher equilibrium temperature than if the atmosphere were absent.

The atmosphere near the surface is largely opaque to thermal radiation (with exceptions for "window" bands), and most heat loss from the surface is by sensible heat and latent heat transport. Radiative energy losses become increasingly important higher in the atmosphere, largely because of the decreasing concentration of water vapour, an important greenhouse gas.

Earth's surface, if warmed to a temperature around 255 K, radiates considerably (its) long-wave (length), infrared heat in the range of 4–100 µm. At these wavelengths, greenhouse gases that are largely transparent to incoming solar radiation are absorbent to surface IR radiation. Each layer of atmosphere containing greenhouse gases absorbs some of the heat being radiated upwards from lower layers. Re-radiation takes place in all directions both upwards and downwards. A rising concentration of the greenhouse gases increases the amount of absorption and re-radiation, and therefore further warms the air layers and ultimately the surface below.

At the same distance from the Sun as Earth, an ideal black body would have a temperature of about 5.3 °C. However, because the Earth reflects about 30% of the incoming sunlight, this idealized planet's effective temperature, emitting the same amount of radiation, would be about −18 °C. The surface temperature of this hypothetical planet would be 33 °C below Earth's actual surface temperature of approximately 17 °C.

[16] Based on Wikipedia, *s.v.* Greenhouse effect (https://en.wikipedia.org/wiki/Greenhouse_effect), the way it is brought to the attention of the general public, and on IPCC AR5 WG1 reports (https://en.wikipedia.org/wiki/IPCC_Fifth_Assessment_Report) on the 'scientific base', with summaries for political decisionmakers (SPM).

The IR absorbing and emitting CO_2 is produced by fossil fuel burning and many other activities, including cement production, animal husbandry and tropical deforestation. Measurements of CO_2 from the Mauna Loa observatory and elsewhere show that concentrations have increased from about 313 parts per million (ppm) in 1960 to about 389 ppm in 2010, and reached the 400 ppm in 2013.

This increase is largely attributed to fossil fuel burning and it is labelled the anthropogenic component in the greenhouse effect (AGW). It contributes significantly to the optical density of the atmosphere and hence to back-radiation and the rise of the surface temperature.

An important issue in the current theory is the recognition that there are several substances other than CO_2 contributing to the Earth's atmosphere, with consequences for the intensity of the back-radiation to the surface. These so-called 'climate forcings' act largely independently and must be summed up.

Water vapour is recognized as the most important greenhouse gas. Its concentration is determined by the evaporation rate from the water planet's surface at a particular temperature.

With increasing surface temperature the humidity of the lower troposphere also rises and hence its back-radiation capacity to the surface. CO_2 increases this back-radiation, and therefore the surface temperature, independently. As the concentration of water vapour increases in the lower troposphere, the greenhouse effect of water vapour is also enhanced. This so-called positive feedback mechanism is caused by the interaction of CO_2 and H_2O molecules: the effect of increasing CO_2 is not limited to its own produced increase of back-radiation and hence to any potential rise of the surface temperature, but should be expanded to include the increased contribution of water vapour to back-radiation.

The interaction of climate forcings is included in Global Circulation Models (GCMs), based on fundamental physics. They are now applied to climate projections, but were originally designed for weather forecasting. That these models of 20 years ago did not forecast the current stabilization of the global average temperature, is attributed to unexpected weather events, but does not challenge the theoretical influence of CO_2 on climate change according to the IPCC model.

26. The concept that autonomous regulatory mechanisms in the troposphere rule the state of the Earth's greenhouse

Three major, very strongly interactive energy carriers determine the surface (skin) temperature of the planet:

(a) the solar radiation that reaches the surface

(b) the infrared radiation field in the troposphere that is maintained by continuous re-emission and re-absorption of IR radiation strongly generated from the surface itself

(c) the continuous exchange of heat by winds and ocean currents among the climate zones and the exchange of sensible and latent heat between surface and troposphere by convection. (Together these processes are called the 'wind-water effect'.)

Because of the varying strengths of the insolation at particular hours, the system is highly dynamic, with the result that a static equilibrium at the surface among the energy carriers is never reached.

Over a period of a diurnal cycle however a dynamic balance can be identified provided that at two subsequent sunrises the surface temperature is the same. This theoretical dynamic balance originates from the expected phenomenon that the amount of heat received and accumulated by day, when the sun is in the sky, is equal to the amount released from the surface during the night, when there is no insolation.

This dynamic balance has the character of an attracting cycle during a diurnal period. This attractor drifts day by day and over the seasons.

An autonomous regulatory system arises from two properties of H_2O with counteracting effect:

(i) Water vapour and water condensed into clouds are the major IR absorbing components in the troposphere. They narrow the atmospheric window and ensure that heat is trapped and keep the surface at an elevated temperature compared to the situation where H_2O molecules are absent

(ii) Fluid H_2O at the surface evaporates and hence cools it by the removal of latent heat.

The net effect of these two forces – built into the properties of the same molecule – depends primarily on the local surface temperature at a particular hour during the diurnal cycle and is at that hour seldom zero. The overall net effect over a diurnal cycle differs with latitude and day of the year because of different surface temperatures, primarily caused by different and varying daily average insolation.
At the current high opacity of the troposphere, when the energy carriers (a) and (b) were active only, the surface temperature during summer at most latitudes would rise far above those observed. It is the third energy carrier (c) that prevents an extreme high surface temperature.

Theoretically, there is a linear relationship between required action of the WW effects (c) and the opacity of the troposphere to maintain a particular surface temperature under the condition that the dynamic diurnal equilibrium state is approached. These WW effects strongly limit the potential effect of the contribution to the opacity of the troposphere to the surface temperature by other components, e.g. CO_2.

Occasionally and temporarily occurring weather events – wind changes caused by moving cyclones and anticyclones and change of cloud cover – can strongly influence local surface temperature by redistribution of heat over areas. As long as these events are restricted to short periods of some weeks, and over years do not occur at the same period in a season, they mask temporarily the strive for reaching a dynamic balance during a diurnal cycle. Established long term flows such as persistent ocean currents, the horizontal trade winds, polar westerlies and easterlies, vertical circulations in the Hadley and Polar cells are all permanent parts of the autonomous regulatory mechanisms that are ruled by the attractor of the dynamic diurnal balance at particular locations and days of the year.

27. Diverging opinions among scientists

The two approaches summarized in the sections 25 and 26 may appear complementary rather than conflicting. However, reconsideration of the first has been encouraged by a considerable number of scientists, who have suggested that the current mainstream view of how the Earth's greenhouse functions contains several shortcomings. And this even not directly in relationship to the approach presented in section 26. According to these critics these shortcomings have led to the development of a theory that is inconsistent with observations, e.g. it does not establish correlation between a small increase of the optical density of the troposphere and the temperature rise that can be expected from increased CO_2 concentration.

Below the objections of critical scientists are summarized concerning particular elements in the current greenhouse model.

The argument that since CO_2 is only a minor component in the composition of the atmosphere and hence does not influence the climate system, is also an unwarranted conclusion. An expected limited effect of CO_2 should be subject to further investigation. Its concentration rise is an established fact and from the scientific points of view a useful tool for the study of climate variability.

28. The application of the 'scientific method' to the atmospheric sciences

> 'The scientific method is an empirical method of knowledge acquisition which has characterized the development of natural science since at least the 17th century. It involves careful observation, which includes rigorous *scepticism* about what is observed, given that cognitive assumptions about how the world works influence how one interprets a percept. It involves formulating hypotheses, via induction, based on such observations; experimental and measurement-based testing of deductions drawn from the hypotheses; and refinement (or elimination) of the hypotheses based on the experimental findings. These are principles of the scientific method, as opposed to a definitive series of steps applicable to all scientific enterprises.'[17]

Many critical scientists have noticed shortcomings in the work of lead authors of the IPCC working group 1 with respect to scepticism what is observed and about 'how the world works and how one interprets a percept'. And even stronger objections have been raised about how the interpretations are transmitted by 'summaries for policymakers' (SPMs) to the public and the media.

Behind these SPMs is of course that is the task of IPCC to produce an analysis of human impacts on climate, not climate changes in general, and to suggest solutions to policymakers.

29. The effect of the downward IR radiation flux (generated in the atmospheric radiation field) on the surface temperature

In popular presentations it is frequently stated that the back-radiation produced by CO_2 is warming the Earth's surface. However, this is unlikely on purely physical grounds. CO_2 is in itself not an energy source, but merely captures radiation energy emitted from the surface, initially accompanied by its cooling.

Secondly, the emitted wavelengths of CO_2 do not penetrate more then 0.01 mm into a surface.. The 'skin pause' should be seen as the lowest layer of the atmospheric radiation field. It behaves similar to any other layer, with two differences: it emits over a broad spectrum and only upwards. The result is a net emission of radiation energy upwards. In this working paper

[17] Wikipedia, *s.v.* Scientific method (https://en.wikipedia.org/wiki/Scientific_method). Gives references to many authors going back to Newton [1726 (3rd ed.)]. *Philosophiæ Naturalis Principia Mathematica* (https://en.wikipedia.org/wiki/Philosophi%C3%A6_Naturalis_Principia_Mathematica).

this is indicated through the use of the opacity factor f <1, with the definition that radiation downwards is a fraction of that emitted upwards from the surface.

30. The removal of heat from, and the addition of heat to the surface by sensible and latent heat flows and by wind-water effects

This is a major issue for atmospheric scientists, because the model postulated by the IPCC contains the pertinent assumption that with increasing CO_2, the lower troposphere temperature will increase, as well as the humidity of the air, and thus the potential of the vapour layer will enforce the downward photon flux from the radiation field. This is called the positive feedback due to increasing CO_2 concentration.

This mechanism would be of importance if we were dealing with a motionless air column. Also humidity is not determined only by the air temperature, but also to a large degree by surface winds, denoted in this working paper by the parameter W_c in equation [4].

The alternative explanation for what happens at the surface reads: two forces bring the air near the surface unto upward motion: (a) warmed air will expand and rise, and (b) increasing water vapour content decreases the specific density of the air.

This upward flow of air parcels as carriers of heat removed from the surface to the TOA will increase their emission height, and decrease the downward emission of the radiation field.

These processes are interactive and complex and not easy to grasp, in particular because the origin of turbulent air flows is still difficult to understand given the air parcels continuously moving both upwards and downwards. The example presented in section 16 (Nebraska, August 1953) shows how powerful a short-lived turbulent flow can be to regulate the temperature over a diurnal cycle.

31. The application of Global Circulation Models (GCMs) to forecast climate changes

These models were originally developed for weather forecasting and have already a long history.[18] Great advances have been made thanks to the use of supercomputers which can store large data sets and work at a data handling speed that permits weather predictions before weather changes have actually taken place. A reliable forecast is now possible about five days in advance, and if wrong, can be explained by the occurrence of an occasional weather event. These explanations are essential because they constitute the scientific prerequisite for the use of models based on observations with objective to improve the models.

The use of these GCMs in climate change predictions is, however, a subject of dispute when considering the long term. When studying complex systems the processes are usually described by sets related partial differential equations which in themselves are insoluble, hence an algorithm with an iterative approach is applied.

A change in variables is calculated over a short time interval Δt, then the outcome of the calculation over that period is used as input for the variables in the next time interval. The accuracy and reliability of the outcome is strongly dependent on the chosen brevity of the time interval. If the interval is too long, a danger arises that the results of the models become too far removed from reality in the sequential steps of the iterative algorithm.

[18] David E. Randall, ed. (2000). *General circulation model development: past, present and future*. San Diego: Academic Press.

With the application of algorithms for weather forecasting to climate change, the use of the time interval is crucial. For weather forecasting an interval of one hour is apparently sufficient to make prediction for five days. But what is one to choose as time interval for climate change predictions covering decades? From this perspective the application of a GSM to the latter seems too ambitious.

Also a contributor[19] to the Randall volume (2000) has pointed out, that previously developed GCMs overlook basic theoretical thermodynamic principles and insights that arise from the occurrence of an entropy sink in an open thermodynamic system with a continuous energy flow through it. D.R. Johnson is one of the few researchers who continues to apply this knowledge to open thermodynamic systems.

In his more recent writings (2004, 2007) Johnson[20] [21] expressed his confidence that it will be possible to improve GSMs for weather forecasting and even for describing the causes of a particular climate state at a particular moment. This is also the approach recommended in this working paper, with the added proviso that the dynamic equilibrium state of the diurnal cycle opens the possibility to investigate the ever drifting attractor.

32. The dual interpretation of occasionally occurring weather events

Occasional weather events too are phenomena that act as disturbing agents on the trajectory of the attracting cycle during a diurnal cycle. In section 16, the Nebraska case was cited as an example of a short turbulent air flow. The influence of occasionally occurring weather events deserves further study.

A current interpretation is that increasing CO_2 concentration could explain changes in these events. A somewhat different view is that the events are part of the autonomous regulatory mechanism that keeps the skin surface temperature between particular borders. The two views are not mutually exclusive. Statistical analysis of the frequency and intensity of e.g. storms has also been subject to criticism even in the contributions to IPCC WG1 reports,[22] and may have been exaggerated. It may well be that an increased CO_2 concentration, in addition to other natural processes, has contributed to a slight rise of the temperature in the lower troposphere and that this may have affected weather conditions. However, if this CO_2 effect on temperature is as small as suggested from our simulations in part III, then two adjoining pieces of the jigsaw puzzle are going to fit: in addition, also the occurrence of extreme weather events was exaggerated.

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19 Donald R. Johnson (in Randall c.s., 2000). "Entropy, the Lorenz energy cycle, and climate," p. 659-720.

20 Donald R. Johnson (2008). Entropy as a property and process in understanding and modeling weather and climate; retrospection and introspection (Presentation at the 4th Hybrid Modeling Workshop) (https://www.esrl.noaa.gov/outreach/events/hybridmodeling08/presentations/Johnson_HybridPresentation.pdf

21 U.S. Department of Energy. Office of Scientific and Technical Information (2007). *Modeling and analysis of global and regional hydrologic processes and appropriate conservation of moist entropy* (technical report). (https://www.osti.gov/biblio/908633) DOI: 10.2172/908633.

22 IPCC SREX 2012 on extreme weather events. Quote from chapter 4: "There is medium evidence and high agreement that long-term trends in normalized losses have not been attributed to natural or anthropogenic climate change." Rather remarkably the summary for policymakers states: "There is evidence that some extremes have changed as a result of anthropogenic influences, including increases in atmospheric concentrations of greenhouse gases."

33. The prospects of the application of a mathematically simplified approach for further conceptual development provided by the SDC algorithm (Simulation of the Diurnal Cycle)

In this working paper we dealt with only a limited number of aspects of interpreting observations. We adopted the paradigm that in the diurnal cycle resides an autonomous regulatory mechanism, ruling climate variability. We nevertheless hope that our reductionist approach will inspire further research into the underlying interactive physical forces that produce the relevant phenomena in the troposphere. The reader will note that our attention is limited to processes that are expected to overheating by the sun at the current optical density of the troposphere between March 21 and September 21 at latitudes 0, 30 and 60º N. With respect to the winter period we are dealing with the opposite of overheating: an additional heat source is required to prevent a local ice-ball situation. The likely source is the relatively warm ocean current that has previously conserved heat in the equatorial zone. To study the process of bottom-up warming requires physicists and the contribution of oceanographers in addition to that of atmospheric physicists.

If the concept that CO_2 concentration is the major controller of the skin surface and lower troposphere temperature at the current optical density of the troposphere is abandoned, then one still has to look for an explanation on why after the end of the last Little Ice Age 150 years ago, the temperature has gradually risen by 0.8 ºC. Many scientists from a variety of disciplines (e.g. astronomers and geologists) have already made suggestions, but most of these are still of a qualitative nature. The use of the simplified simulation approach is expected to provide a useful beginning for a more quantitative analysis. Attention then has to be focused on forces that change during the seasons: the drift of the attractor on an annual base.

Lastly, the application of the SDC algorithm and the concept behind it may encourage the discussion between applied mathematicians and scientists in other natural sciences concerning the usefulness of the reductionist methodology in climatology.

ACKNOWLEDGMENT

The help of Sonja Böhmer-Christansen (geographer, Hull university, United Kingdom) with the use of the English language is gratefully acknowledged.

This study is based on the result of many informal seminars held over the last 15 years in the Netherlands with the participation of independent critical scientists from many different disciplines, and occasionally mainstream climatologists.

Several of them also contributed to this working paper during its three years of preparation.

Annex I

THE DESCRIPTION OF THE SIMULATION PROGRAM FOR THE DIURNAL CYCLE (SDC).

(The Excel file is available on request.)

1. The principle of the iterative approach to describe the progress during a diurnal cycle

1.1 Graphical presentations

The development of five subsequent diurnal cycles is graphically presented as the surface (skin) temperature changing with time after a chosen start for the sunrise on a particular day of the year. See figure 1.

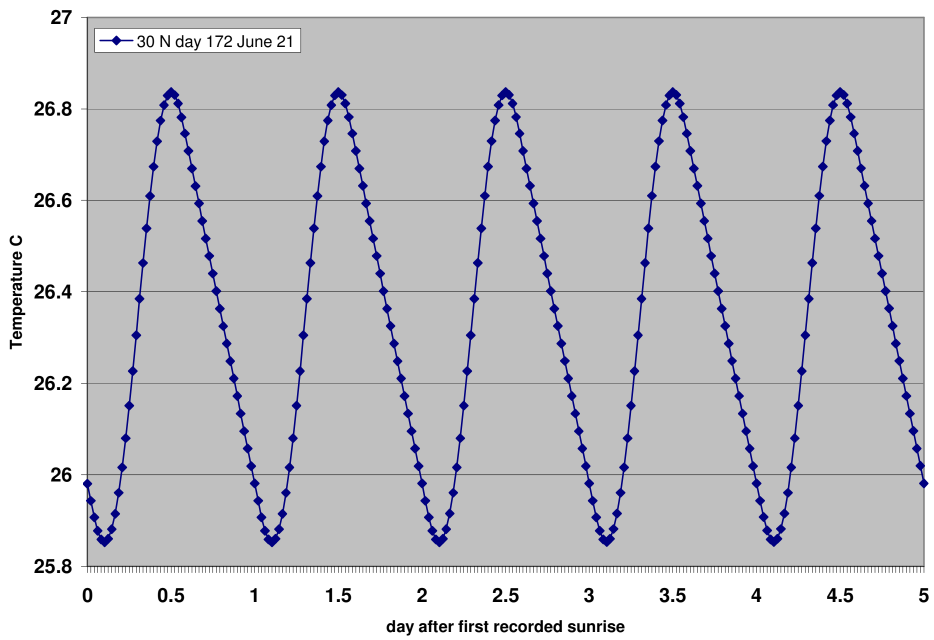

Figure 1. Surface temperature change with time in the ocean.

In the working paper sometimes also the local intensity of the insolation change is graphically depicted, see figure 2.

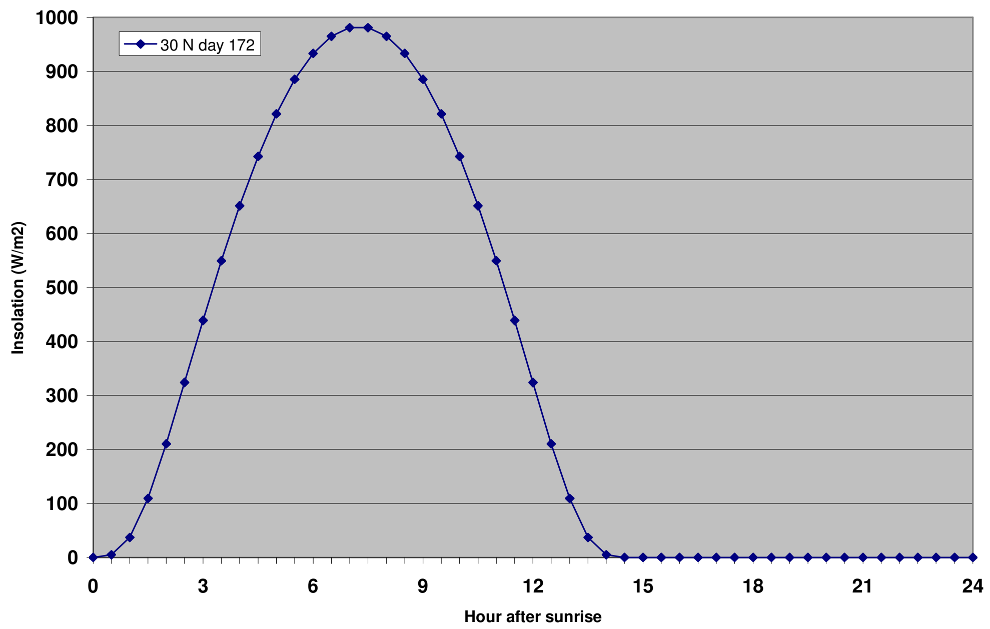

Figure 2 Insolation change with time over one diurnal cycle.

Where relevant, the accumulated heat over time at the surface is also described. .

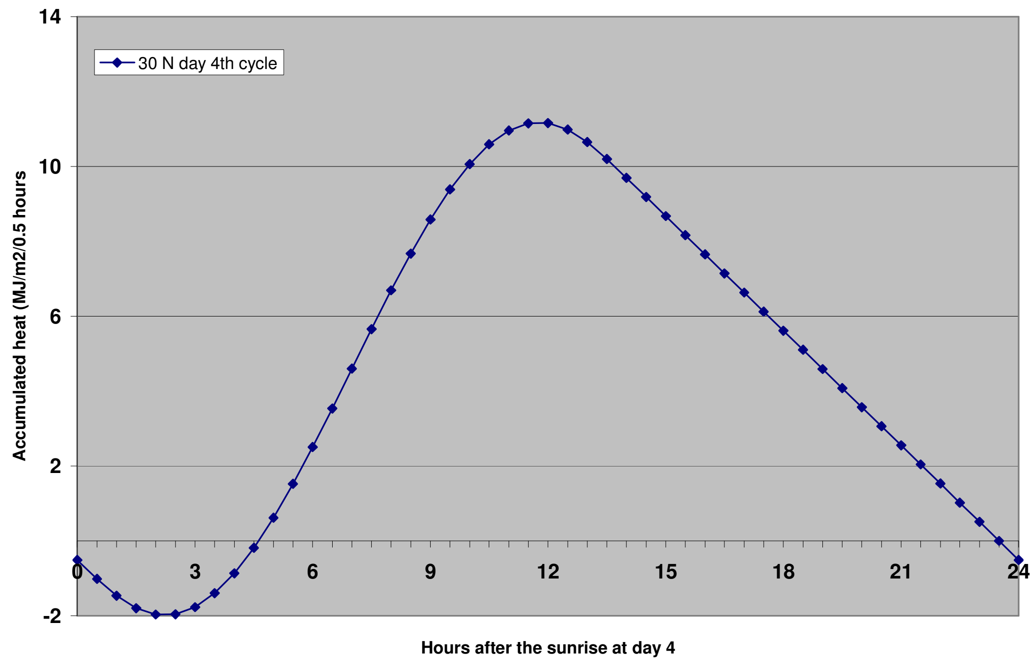

Figure 3 Accumulated heat after sunrise in the 4th diurnal cycle

1.2 The mathematical basis

Three major and interactive energy carriers influence the surface (skin) temperature:

(a) the solar radiation reaching the surface,

(b) the infrared radiation field in the troposphere that is maintained by continuous re-emission and re-absorption of IR that is strongly generated from the surface, and

(c) the continuous exchange of surface heat with the atmosphere and by winds and ocean currents among the climate zones.

The effect of these energy flows are comprised in a simple equation that describes the temperature change (ΔK) over a specific time interval (Δt)

$$\Delta K = 1800*(R_s - (1\text{-}f) *\varepsilon\sigma K_t^{\ 4} \pm WW)/Cm^2 \qquad [3]$$

in which ΔK is calculated over a period of half an hour and K_t the actual average temperature of the surface during this time period.

R_s is the solar energy (W/m^2) that is reaching the surface during this time interval.

The effect of the energy carrier (b), the removal of heat by IR radiation from the surface is calculated in the third term of [3] (1-f) *$\varepsilon\sigma K_t$ in which

f is called the opacity factor of the atmosphere and (1-f) the result thereof for the atmospheric window.

ε presents the albido of the surface and

σ the Boltzmann factor ($5.67*10^{-8}$).

The fourth term in [3] the effect of energy carrier (c) comprises the heat that is removed or added to the surface by the mentioned influences (exchange of heat of the surface with the atmosphere and by winds and ocean currents among the climate zones). The acronym WW stands for 'wind and water effects' .

The fifth term Cm^2 stands for the specific heat capacity per square meter of the surface that influences strongly the ultimate effect of the three major energy carriers a, b and c.

Carrier a, the insolation, changes with latitude, the day of the year and therewith with the length of the day time. It is the primary cause of the change of the surface temperature during a diurnal cycle. The data for each time interval of 0.5 hour were provided by Roy Clark.[i]

The reaction of carrier b and c on this initial energy flux is complex and these are also mutually dependent. These are expected to change during each considered time interval Δt and to describe these changes (insoluble) non-linear difference equations are required.

The general mathematical practice to illustrate this complex interaction of mutual dependent variables is to consider short time intervals for these : ΔX/Δt = f(X,Y,Z), ΔY/Δt=f((X,Y,Z) and ΔZ/Δt= f((X,Y,Z).

This iterative approach in the developed iterative algorithm reads as follows in its subsequent lines:

$K_{t=0}$ is an adopted value for the start of a first diurnal cycle.

$$\Delta K_{t=0} = \quad \Delta t*(R_s - (1\text{-}f) *\varepsilon\sigma K_t^{\ 4} \pm WW_t\ ) /Cm^2$$

$K_{t=1} = K_{t=0} + \Delta K_{t=0}$

$\Delta K_{t=1} = \quad \Delta t^{*}(R_s - (1\text{-}f) * \varepsilon\sigma K_t{}^4 \pm WW_t) / Cm^2$

$K_{t=2} = K_{t=1} + \Delta K_{t=1}$

Etcetera to the end of a diurnal cycle.

(In these formulae R_s also changes with each time interval.)

2. The domains of the program

The algorithm consists of a number of domains which are elaborated below.

2.1 The insolation

	A	B	C
	hour	days	insolation
line	first sunrise		over period
5	0	0	0
6	0.5	0.020833	10.15189
7	1	0.041667	63.70754
8	1.5	0.0625	155.1466
9	2	0.083333	265.9712
10	2.5	0.104167	382.1949

Column A: the hour of the day after sunrise.

Column B: the time course expressed as part of the diurnal cycle.

Colomn C: the insolation data (W/m^2) over 1800 sec, provided by Clark.

2.2 The constants used in calculations

	D	E	F	G	H	I	J
line	f	g	Wsur	Wc	n	Td	m
5	0.68	1	0	597.17	1	20	0
6	0.68	1	0	597.17	1	20	0
7	0.68	1	0	597.17	1	20	0
8	0.68	1	0	597.17	1	20	0
9	0.68	1	0	597.17	1	20	0
10	0.68	1	0	597.17	1	20	0

All constants can be changed for any half hour period (column A) in the iterative calculation to mimic a diurnal cycle.

Column D: the opacity factor f (=0.68 clear sky).

Column E: the fraction g of the sun light reaching the surface (=1 clear sky).

Column F: reserved for constant to be used for other heat flows from surface (e.g. conduction in the soil).

Column G: the constant for the rate of heat exchange between surface and troposphere (see column O).

Colum H and I: other constants in the formula in column O.

Column J: reserved for another constant to modify used formulae.

2.3 The calculation of the change of K_t to K_{t+1} with Δt

This is the heart of the iterative program.

	K	L	M	N	O	P	Q	R
line								
	Kn	R act	IR out	IR in	WWa	WWb	ΔQ/Δt	ΔK
5	298.930	0	406.7983	276.6229	177.059	0	-307.235	-0.03687
6	298.8931	10.15189	406.5977	276.4864	-0.9983	0	-118.961	-0.01428
7	298.8789	63.70754	406.52	276.4336	-0.9983	0	-65.3805	-0.00785
8	298.871	155.1466	406.4773	276.4046	-0.9983	0	26.07217	0.003129
9	298.8741	265.9712	406.4943	276.4161	-0.9983	0	136.8913	0.016427
10	298.8906	382.1949	406.5837	276.4769	-0.9983	0	253.0864	0.03037

Column K: the temperature (grades K) at the start of a period Δt.

In the first line 5 this is an arbitrary chosen value at the beginning of the algorithm. In the next line 6 Kn the value is the result of adding the calculated value ΔK over the period Δt (column R) to the previous value in line 5. (See next domain column N line 5.)

Column L: the value used for the insolation presented in column D. In this example these are values calculated for clear sky. With increasing cloud cover these values may be reduced by a factor g, column N.

Column M: the calculated value for the upward radiation from the surface from the temperature in column K.

Column N: the value of IR emission from the troposphere to the surface as calculated as a fraction f from the surface upward emission.

Colomn O: the calculated value of the exchange of heat between troposphere and surface with the (simplified) formula [4] Wec= Wc(T^n/Td-1).

Column P: a reserve column if other actors than 'wind and 'wate' contribute to exchange of heat of the surface with its bounderly layers, e.g. conduction in soil.

Column Q: the heat accumulated during the period Δt as the result from the data in column L (the insolation), M and N (the net IR radiation from the surface) and (the contributing WWa effect). Its bearing is elaborated on in section 14 of this working paper, the theoretical approach to describe the wind-water effects.

Finally, column R: the calculated temperature change over the period Δt by division of the value in column Q by the specific heat capacity of the surface.

2.4 The calculation of temperatures and heat accumulation over the periods Δt for graphical presentation

	T	U	V	W	Z	AA
line						
	Kn+1	Tn C	T(n+1) C	Tav C	J/m2	mJ/m2
5	298.89313	25.93	25.89313	25.91157	-553023	-0.55302
6	298.87886	25.89	25.87886	25.88599	-767153	-0.76715
7	298.87101	25.88	25.87101	25.87493	-884838	-0.88484
8	298.87414	25.87	25.87414	25.87258	-837908	-0.83791
9	298.89057	25.87	25.89057	25.88235	-591504	-0.5915
10	298.92094	25.89	25.92094	25.90575	-135948	-0.13595

Column T presents the temperature in grades K that are reached after each period Δt= 0.5 h as explained in the previous section.

Column U: the temperature in grades C at the beginning of period Δt (= column K – 273).

Column V: the temperature in grades C at the end of each period Δt, calculated from column T.

And lastly column W: the averages of the temperature during period Δt, calculated from column U and V that are used in graphical presentations (see figure 1).

Column Z line 5 is the accumulated (or lost) energy in the surface during each time interval Δt J/m^2 per 0.5 hours, and the next lines the amounts that is added in the next time intervals (see figure 3). The next column these values $*10^{-6}$.

2.5 The summary of the result of calculations over five diurnal cycles

	J	K	L	M	N	O	P	Q	R
line									
249	project	lat 30 N	day 172	f=0.68	g=1	ε=0.8985	heat cap	1.5*10^7	tday 14 h
250		Kn	R act	IR out	IR in	WWa	WWb	ΔQ/Δt	T C av
251	Average	299.3	318.9294	408.8191	277.997	188.1073	0	-4E-05	26.30001
252	max	299.7993	985.4376	411.5509	279.8546	203.0149	0	667.3193	26.79643
253	min	298.8071	0	406.1296	276.1681	173.3891	0	-331.522	25.80932
254	Mx-Mn	0.992215	985.4376	5.421284	3.686473	29.62582	0	998.841	0.987104
255	Tset	Td	n=	Tstart C	balanceT	J accu	Wc	IRout-IR in	m
256	26.3	20	1	25.93078	-2.3E-07	-3.49451	597.1653	130.8221	0

This domain above is shown at the bottom of each algorithm that has been used to simulate a particular observed diurnal cycle. The condition of the diurnal cycle are summarized in line 249

The next line (250) presents the indication of the terms involved as described in the previous sections.

The next lines present

251: the average value of the terms over the last (fifth) cycle

252: the calculated maximum value

253: the calculated minimum value

254: the amplitude, the difference between maximum and minimum values.

The line 256 is used when operating the program in search of the diurnal equilibrium state which was expected during the last studied cycle a stable temperature profile was expected to be established (e.g. as illustrated in figure 1).

This condition is realized when

(1) The temperature at sunrise in the last diurnal cycle equals almost the temperature at the end of that cycle. The difference between these temperatures is to be found in column N line 256.

(2) The average of ΔQ/Δt (column Q line 250) is almost zero.

(3) The figure for the accumulation of heat over the last cycle approaches 0 in column O line 256.

The search for these conditions is performed by trial and error by introducing in line 5 column K a value for the start temperature at the beginning of the algorithm and for the WW effect in line 5 column G.

3. The more sophisticated use of the algorithm

The program is capable of simulating any observed temperature profile, as well as values of maximum and minimum temperature changes during a sequence of five diurnal cycles by introduction in columns D to J at any given time interval different parameters. This approach is in particular useful to demonstrate the stability of the system if a parameter is changed during one cycle and the consequences of this change have to be demonstrated for the next cycle, that is to say the stability of the dynamic diurnal equilibrium state.

[end]