The Arctic ice melting confirms the new theory

Ernani Sartori

ABSTRACT

The new theory shows that the global and the Arctic atmospheres behave as an open atmosphere (few clouds) or as a 'closed' atmosphere (fully cloudy), which explains the Arctic ice melting. Within the closed atmosphere the solar radiation, wind and evaporation are reduced while the water and air temperatures and the humidity increase. Real data confirm these effects for the planet and for the Arctic. Many authors did not understand these apparent inconsistencies, but this paper solves many intriguing problems, and provides solutions that led the present author to discover the new hydrological cycle. Some human activities increase the formation of clouds and precipitation or of droughts. The sun is not the only heat source for the atmosphere. Several real data confirm that clouds have increased over decades globally and at the Arctic. These intensifications also confirm the operation of the new hydrological cycle and of the Sartori theory. Many real data show that while the Arctic ice has melted, the cloud cover has pushed the temperatures up above freezing and has raised them by 2–3 °C compared to cloudless skies as well as acting to warm the Arctic for most of the annual cycles.

Key words | Arctic ice, atmosphere, climate, clouds, evaporation, hydrological cycle

Ernani Sartori
Universidade Federal da Paraíba,
João Pessoa PB,
Brazil
E-mail: *e.solar@hotmail.com*

INTRODUCTION

The Arctic/Greenland ice melting has been a great concern for the world and particularly for researchers, some of whom have attempted to determine why the ice is melting. Kobashi *et al.* (2015), for example, reasoned that the sun's activity controls Greenland's temperature. However, the sun makes the temperatures go up and down on the whole planet and not only in the Arctic. The sun also does not have full control of the temperatures because there are several local factors that influence them, such as the urban heat islands as well as the different conditions between the Amazon and the Sahara. New in this context is the fact that the sun is not the only heat source for the atmosphere, as demonstrated physically and mathematically by Sartori (2015) and in the present article. Some other works also tried to find explanations for the problem. Among these is the work by Hanna *et al.* (2016), who linked this melting to high pressures over Greenland; Hanna *et al.* (2014), who attributed it to a 'heat dome' due to warm winds over Greenland; Keegan *et al.* (2014), who linked the Greenland ice melting with fires in Europe; and Straneo *et al.* (2011), who connected the issue to heat which is transported to Greenland glaciers.

However, not one of these attempts is accompanied by a reference parameter; that is, by a correct, consistent, coherent and valid theory that gives support and direction to the empirical results. One or more of these works may have some reason, but in isolation and without the help of a true theory they cannot guarantee a solution, because due to the extremely vast, specific, variable, random, isolated and complex nature of the atmospheric behaviors these specific works cannot provide a direct, firm, rapid, clear and decisive relationship among them. Thus, a solution or final conclusion on even a single event may require infinite time and effort and cannot be found.

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In order to advance for the benefit of humankind, science needs all types of contributions for clarifying the complexities of nature. Thus, parallel to these experimental developments there is the knowledge on the physical principles that compose the Earth's atmospheric behaviors and guides us more rapidly, firmly and objectively to the proper and coherent directions and solutions. Through the first principles we can verify the validation, application, importance and coherence of the vast and confused real data without losing the correct direction and excess of time and efforts. They lead us on the proper line.

Physical principles make a car run, a building stand up, a rocket rise and can explain true atmospheric behaviors. However, they must also be checked with the corresponding experimental data to verify their validations, applications and accuracies. The present author uses theoretical works to compare and validate them with experimental data, such as by Sartori (1987, 1989, 1991, 1996, 2000, 2006, 2012, 2015), where good agreements were also obtained.

In the same way, this is also done in the present work, where the corresponding theoretical principles are seen to be valid globally and also for the Arctic/Greenland conditions. This theory is clearly, consistently, substantially and coherently explained and confirmed by extensive experimental data as well. Close agreements between these physical principles and measurements by satellites and on land have been obtained through works from different sources such as by NSIDC (2017), NASA (2016), NOAA (2016, 2017); Sun & Groisman (2000), Angell *et al.* (1984), Hansen *et al.* (2001), Henderson-Sellers (1986), Jones & Henderson-Sellers (1992), Jacobson & Kaufman (2006), Pryor *et al.* (2009), Schneider & Hook (2010), Van Tricht *et al.* (2016), Intrieri *et al.* (2002), Bennartz *et al.* (2013), Eastman (2009), Wang *et al.* (2012), Jun *et al.* (2016) and many others.

BASIC PRINCIPLES OF THE SARTORI THEORY

The Sartori theory is essentially constituted by an open and a closed evaporator that represents and explains the thermal behaviors of an open and a 'closed' atmosphere, depending on the closing conditions by clouds as well as by the direct influences of heat and mass emissions from certain human activities on both the open and 'closed' atmospheres.

In order to better understand how an open and 'closed' Earth's atmosphere behaves thermally, it is important and informative to make brief descriptions of the thermal behaviors of the human-made open and closed evaporators, whose physical principles are the same and are valid for the open and 'closed' atmospheres. Sartori (1996) analyzed the thermal behaviors of the open and closed evaporators in depth, significantly contributing to the present understanding.

The human-made open evaporator

The general literature considers that the air temperature depends or is consequent solely from the radiation exchange between the atmosphere and the Earth's surface due to the action of some gases. However, this is an incorrect consideration because it does not include water and, besides radiation, the planet's surface naturally transfers heat by evaporation, convection and conduction, and mass by evaporation to the atmosphere, the modes of which warm and humidify the environment in every instance and at every place where there is water. Thus, these heats cannot be neglected. Since the Earth's surface is composed mostly of water, including vegetation and humid soils, we could say that roughly about 90% of the planet's surface releases heat and mass by evaporation and only about 10% constituted by deserts and constructions do not emit such heat and mass. Thus, all of this heat and mass from such a vast body of water substantially affects the atmospheric balances and consequently the air temperature, as well as the natural cycles, and thus cause other effects, too. We could say that this is a planet of evaporation, and even where there is not water the radiation is not the sole heat transfer mode because there are also the convection and conduction heat transfer rates that influence the atmospheric heat balance and other conditions. Ahead in this paper we will see calculations that show the order of magnitudes of these heat transfer rates. Now, let us see the basic principles of the open evaporator and of the open atmosphere. Further information on these subjects is found in Sartori (1996, 2012, 2015).

The basic thermal operation of the open evaporator (free water surface) is as follows. After the water layer of the open evaporator is heated by the solar radiation (after various absorptions and reflections), it loses heat by evaporation, infrared radiation, forced or free convection and conduction, and mass by evaporation, and thus heats the environment as well as affects the natural cycles. Radiation and convection from the atmosphere can also affect the water temperature and the processes of heat and mass transfer. Since this water layer is exposed directly to the free air, it is submitted directly to the wind (V), humidity (RH), air temperature (t_a) and atmospheric pressure (P) and thus loses heat directly to the environment. The heat and mass exchanges occur between the water and air temperatures, except the radiation heat loss from the water layer that may occur in two ways: (a) when the sky is clear the radiation is exchanged with the sky temperature which is up to 20 °C lower than the ambient air temperature and this happens through the atmospheric 'window' that exists in the range of frequencies from 8 to 13 μm; (b) when the sky is overcast, the clouds close this window and make the sky temperature to be equal to or to approach the ambient air temperature. The water temperature is the final result of all heat gains and losses by the water layer and also depends on the physical characteristics of the system. Therefore, there are more 'forcings' for the ambient warming than only the radiation. If the heat transfer processes by evaporation, convection and conduction are not taken into account, the energy balance for the evaporator does not match. The heat released per square meter by evaporation corresponds to about 60% of the total heat transfer released, which obviously cannot be neglected. This heat is also much greater than the corresponding radiation transfer from the surface to the atmosphere (Sartori 1996, 2000). All of these influences are considered only in the Sartori mathematical models and corresponding equations for evaporation.

Figure 1 shows a representation of the open evaporator and its thermal processes.

The natural open atmosphere

The thermal operation of the open evaporator built on Earth is the same or very similar to the thermal behavior of natural free water surfaces working under an open (no cloud cover or with a few clouds) atmosphere. Repeating the prior information, the basic thermal operation of free water surfaces under an open atmosphere is as follows. After the water layer of the free water surface is heated by the solar radiation (after various absorptions and reflections), it loses heat by evaporation, IR radiation, forced or free convection and conduction, and mass by evaporation, and thus heats the environment and affects the natural cycles. Radiation and convection from the atmosphere can also affect the water temperature and the processes of heat and mass transfer. Since this water layer is exposed directly to the free air, it is submitted directly to the wind (V), humidity (RH), air temperature (t_a) and atmospheric pressure (P) and thus loses heat directly to the environment. The heat and mass exchanges occur between the water and air temperatures, except that the radiation heat loss from the water layer in clear sky happens to the sky temperature. Therefore, there are more forcings for the ambient warming than only the radiation. The water temperature is the final result of all heat gains and losses by the water layer and also depends on the physical characteristics of the systems. If the heat transfer processes by evaporation, convection and conduction are not taken into account, the energy balance for the atmosphere does not match.

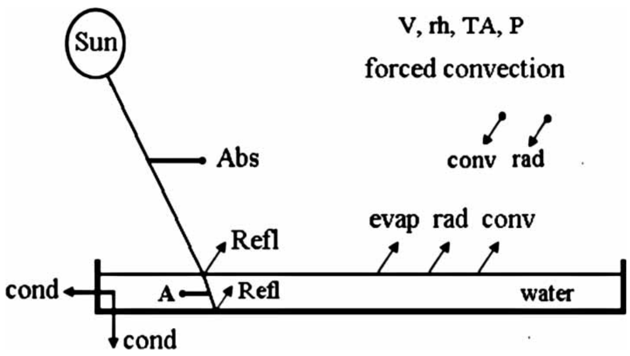

Figure 1 | Representation of an open evaporator. See its high similarity with the thermal behaviors of the open atmosphere (Figure 2).

Therefore, an open evaporator built by humans represents very well the heat exchanges and what occurs between the planet's surface and the atmosphere without cloud cover or with a few clouds, as shown schematically in Figure 2.

For both the human-made and natural free water surfaces, the heat balance in steady-state (for simplicity) is given by the equation:

$$S = q_e + q_{su} + q_r + q_c + q_k \tag{1}$$

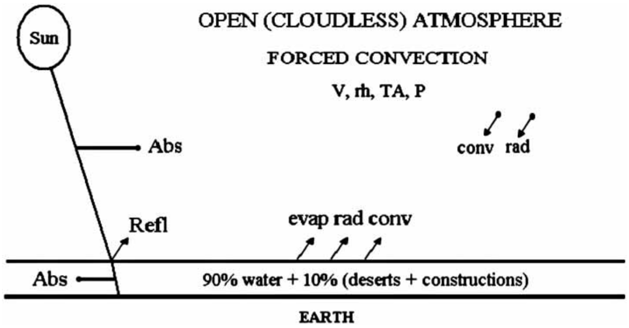

Figure 2 | Earth's surface and the atmosphere without cloud cover (open atmosphere). See the high similarity between Figures 1 and 2.

where S = solar radiation, W/m^2; q_e = heat loss by evaporation, W/m^2; q_{su} = heat loss by sublimation, W/m^2; q_r = heat loss by radiation, W/m^2; q_c = heat loss by convection, W/m^2; q_k = heat loss by conduction, W/m^2.

In a transient regime, Equation (1) becomes:

$$\alpha S = q_e + q_{su} + q_r + q_c + q_k + m.c.dt_w/d\theta \quad (2)$$

where α = solar absorptivity of water or land, fraction; $dt_w/d\theta$ = water temperature variation with time, °C; m = mass, kg; c = specific heat, kJ/kg °C.

Therefore, to consider only the radiation heat transfer is equivocated because this means to convert Equation (1) into Equation (3):

$$S = q_r \quad (3)$$

which obviously represents incorrectly and inaccurately the total heat exchange between the surface and the atmosphere, and consequently the warming of the atmosphere. The climate occurs within a few kilometers above the surface.

For both human-made and natural free water surfaces, the following Sartori equation for the evaporation rate for forced convection in fully turbulent air flow is recommended:

$$E = 0.0041V^{0.8}L^{-0.2}(P_w - \phi P_a)/P \quad (4)$$

where E = evaporation rate, kg/m^2s; V = wind velocity, m/s; L = surface length in the wind direction, m; P_a and P_w = partial pressures of the water vapor at the air and water temperatures, Pascal; P = atmospheric pressure, Pascal; ϕ = relative humidity, fraction.

Equation (4) is based on the boundary layer theory and on the Bowen–Sartori equation (Sartori 1987, 1989, 1996, 2000, 2012) and is recommended to be applied for all situations, that is, for large and small free water surfaces because the turbulent air flow normally occurs in forced convection in practical applications (see also Sartori 2006).

For calculating the evaporation rate from salt water the following equation (Sartori 1991) should be employed:

$$E = 0.0041V^{0.8}L^{-0.2}(P_s - \phi P_a)/P \quad (5)$$

where $P_s = P_w.X_m$ and $X_m = 1/(1 + 0.621[S/(100 - S)])$ being the salinity, $S = (m_{salt}/m_{water}) \times 100$.

The Sartori equations for laminar, mixed and fully turbulent air flows for evaporation are the only equations for evaporation that can calculate all the cases of mass transfer that can occur when a water surface is exposed to the air (Sartori 1987, 1996, 2000, 2003), that is, when:

(1) $t_w > t_a > t_d$ Higher evaporation
(2) $t_a > t_w > t_d$ Lower evaporation
(3) $t_w = t_a$ and $RH < 100\%$ Lower evaporation but higher than case 2
(4) $t_w = t_a$ and $RH = 100\%$ Zero evaporation
(5) $t_a > t_w < t_d$ Condensation = dew = 'negative' evaporation

where t_a = air temperature, °C; t_d = air dew point temperature, °C; t_w = water temperature, °C; RH = relative humidity.

In comparison to case 1, cases 2 and 3 also show the relevance of the air temperature increase on the evaporation decrease, as demonstrated physically and mathematically by Sartori (2012, 2015).

The amount of dew deposited on the water surface was also measured and a high accuracy with the Sartori equations was found (Sartori 1987). Equation (4) also proved to be the most accurate in comparison to extensive real data and among several famous empirical formulas (Sartori 2012). The Sartori equations for the evaporation and for the convection coefficient for forced air flow over flat surfaces (Sartori 2006) were obtained from theoretical principles and thus are the only ones that can be applied to general situations as well as to other planets' surfaces, needing only minor modifications. The corresponding empirical formulas obtained from experimental tests are not valid for other atmospheric compositions and conditions. To be applied to other atmospheric compositions, new empirical formulas must be obtained experimentally, just on the other planets' surfaces.

Now, let us compare the emissions of heat by evaporation and by radiation per square meter from the Earth's surface. Let us consider that the water and the land temperature of the planet is 25 °C, the air temperature is 20 °C, the wind velocity is 5 m/s and the relative humidity is 60%. Then, using Equation (4) we have:

$$E = 0.0041 \times 5^{0.8} \times 1(3,165.07 - 0.60 \times 2,335.81)/101,325$$
$$E = 0.00025861\ \mathrm{kg/m^2 s}.$$

To obtain the heat that this mass of water carries together we need to multiply it by the corresponding latent heat of vaporization, that is:

$$q_e = 0.00025861 \times 2,441.86 \times 1,000 = 631.49\ \mathrm{W/m^2}.$$

To obtain the heat emitted by radiation we should use the Stefan–Boltzmann Law:

$$q_r = \varepsilon\sigma[(T_w)^4 - (T_{sky})^4]\ [\mathrm{W/m^2}] \quad (6)$$

where ε = emissivity of surface, fraction; σ = Stefan–Boltzmann constant, $\mathrm{W/m^2\,K^4}$; T_a and T_w = air and water temperatures, K. So, for water surfaces:

$$q_r = 0.94 \times 5.670 \times 10^{-8}[(298.15)^4 - (273.15)^4]$$
$$q_r = 124.5\ \mathrm{W/m^2}$$

This value is only about 20% of the evaporation heat loss shown above.

The radiation emission occurs from the Earth's land and water surfaces while the evaporation occurs only from the water surfaces, and thus the heat by evaporation had to be multiplied by 0.90 (according to this author's evaluation for evaporating surfaces). However, since the vegetation and the animals evaporate through all of their leaves, trunks, branches and sides, and thus increase the area of evaporation, this heat should be much higher than the one obtained above, but let us keep it as is. So, with these conditions, the heat emitted by evaporation per square meter of the planet is about five times greater than the heat emitted by radiation from the same area. However, when the sky is overcast the emitted heat by radiation becomes only 27.5 $\mathrm{W/m^2}$ and thus the above relation becomes 23 times greater.

From the surface to the air, heat is also released by convection. Considering that the Earth's surface is flat, this heat for forced convection in turbulent flow is calculated through the Sartori equation for the convection coefficient over flat surfaces (Sartori 2006), which is also based on the boundary layer theory:

$$h_c = 5.74V^{0.8}L^{-0.2} \quad (7)$$

where h_c = convection coefficient, $\mathrm{W/m^2\,K}$; V = wind velocity, m/s; L = surface length in the wind direction, m. Equation (7) proved to be the most accurate among lots of known empirical formulas by the excellent work by Kaplani & Kaplanis (2014) and by Sartori (2014), and then:

$$q_c = 5.74 \times 5^{0.8} \times 1(25 - 20) = 104.00\ \mathrm{W/m^2}$$

As can be seen, this value is comparable to the one obtained for the radiation heat loss when the sky is clear and is much greater when the sky is overcast.

This heat by convection added to 631.49 $\mathrm{W/m^2}$ gives 735.49 $\mathrm{W/m^2}$, which is 26.7 times greater than the heat emitted by radiation when the sky is fully covered by clouds.

The mathematical demonstrations above serve to show the relevance of the heat by evaporation and by convection on the determination of the air temperature.

The human-made closed evaporator

The thermal processes of the closed evaporator (solar still) are essentially the same as those of the open evaporator; however, due to the transparent glass or plastic cover, there are some differences that determine great changes. In-depth physical and mathematical descriptions of the thermal behaviors of the open and closed evaporators and atmospheres are found in Sartori (1996, 2012, 2015).

The main physical processes that take place in the apparatus are described below, which will lead us to understand the 'closed' atmosphere that is affecting the planet and the Arctic ice. Part of the solar radiation that reaches the glass is reflected back by this transparent cover and another part is absorbed by the glass. The part that is transmitted to the inner side of the solar still suffers reflections at the water surface and at the still bottom. A part of the solar radiation is absorbed by the water layer and by the still bottom. Due to these absorptions, the water and the glass cover heat up. From then on, the water starts to evaporate more water than without this energy supply, and then the water vapor rises, reaches the cover (which is cooled by the wind), condenses (whenever the inside dew point temperature is higher than the cover temperature), and then the liquid water (precipitable water) goes down the cover as pure water, which is collected by troughs and recipients. The heat and mass exchanges within the system occur between the water and cover temperatures. The water layer loses heat by evaporation, by IR radiation, by free convection and by conduction (this one through the sides of the system), and also loses mass by evaporation, and thus heats and humidifies the solar still inner air and the glass cover. After conduction through the glass or plastic sheets, the transparent cover's external face loses heat by IR radiation and by forced convection (due to the wind) while this cover's internal face gains heat by evaporation, by IR radiation and by free convection from below. The outside forced convection is converted into the free convection inside the system due to the solid cover that blocks the wind circulation, and thus the heat removal inside is much less than that which occurs outside in forced convection, and the heat and humidity increase inside. This makes a large difference in terms of warming and of thermal behaviors, and due to the absorption of solar radiation by the transparent cover, the solar radiation that arrives at the inner side of the solar still is lower than that which exists at its external side and on the water of the open evaporator. However, even so the internal temperatures of the solar still become much higher than those of the water of the open evaporator.

Due to the reflected radiation by the glass to the water, plus the reflected radiation by the water to the glass, plus the emitted radiation by the glass to the water, plus the radiation emitted by the water to the glass, plus the heat released by evaporation and by convection from the water, a greenhouse effect is created inside the apparatus, i.e. an accumulation of energy occurs and thus there is a consequent increase of the internal temperatures. Figure 3 shows a representation of the closed evaporator and its main thermal processes.

Comparisons among the thermal behaviors of the open and closed evaporators

Sartori (1996) studied in depth the thermal behaviors of an open and a closed evaporator and then for the present study we can use and apply the following basic information. Figures 4 and 5 show representing temperatures attained by a closed and an open evaporator, respectively, both devices

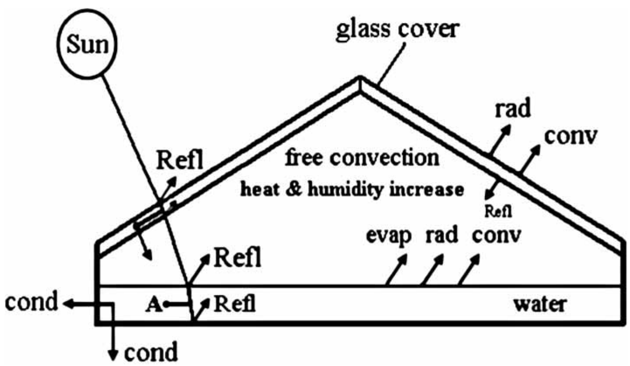

Figure 3 | Closed evaporator (solar still).

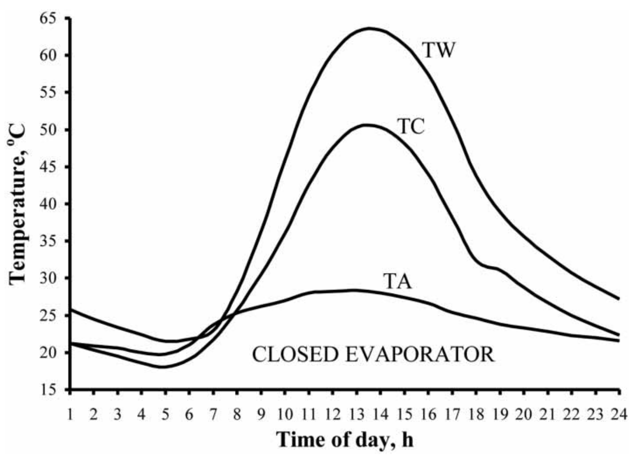

Figure 4 | Temperatures of water (TW) and cover (TC) of the closed evaporator and of the air (TA).

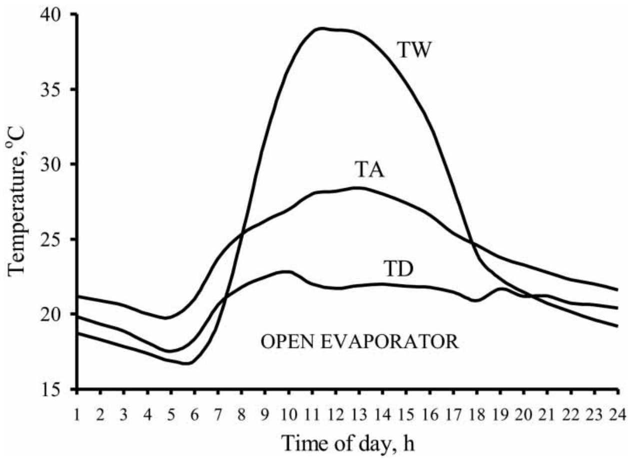

Figure 5 | Water (TW) temperature of the open evaporator together with the air (TA) and the dew point (TD) temperatures.

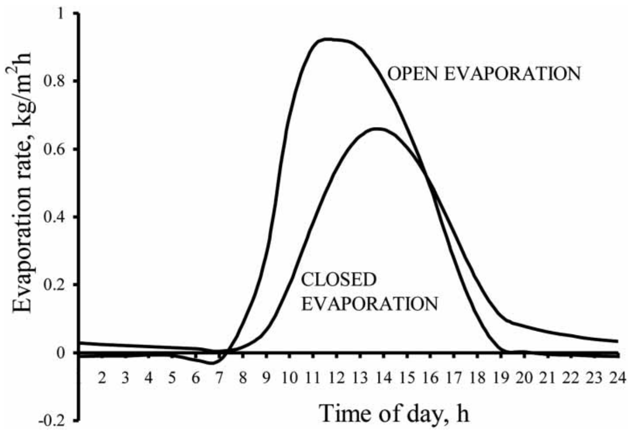

Figure 6 | Evaporation rates from the open and closed evaporators.

being of the same size and construction characteristics as well as submitted to the same daily environmental conditions.

It can be seen that the closed evaporator attains much higher temperatures than those that are reached by the water layer of the open evaporator, although the closed evaporator receives less solar energy. This reduced energy is due to the influence of the glass cover. For typical values of the glass cover solar reflectivity $\rho = 0.08$ and its solar absorptivity $\alpha = 0.05$, the transmitted solar energy became $\tau = 0.87$, and then the solar radiation that reached the water of the closed system was 13% lower. The higher temperatures are due to the accumulation of energy, as explained above, and also due to the higher removal of heat by the wind over the open evaporator. The cover substantially reduces the removal of heat from below (it traps the energy) because it blocks the wind from passing over the water layer and thus also causes free convection inside the greenhouse. Equivalent effects occur with cloud covers.

It is also very important to note that although the evaporation is a strong function of the water temperature, the evaporation in the closed evaporator (where the greenhouse effect takes place), is much lower than the one produced by the open evaporator, contrarily to what is normally expected. Figure 6 shows such a difference.

This is explained as follows. The open evaporator suffers direct influence from the wind flowing over its water surface and then normally works under forced convection (higher heat and mass loss). Meanwhile, the closed evaporator has a solid cover that blocks the wind and thus the free convection (lower heat and mass loss) takes place; that is, causing a higher accumulation of energy. It can be seen in Figures 4 and 5 that even at night hours the water temperatures of the closed system are much higher than those of the open evaporator. This is due to the energy accumulated during the daytime and to the lesser heat loss during the nighttime. It can be seen that the cover temperatures are much higher than the air temperature, even at night hours. This is due to the heat received from below (evaporation, radiation, convection), due to the solar radiation absorbed by the glass cover, and due to the daytime energy accumulated in the system. This night effect is also highly important for explaining the cloud cover influence on the air warming and on the Arctic ice melting.

The lower evaporation rates by the closed evaporator also have other causes. The more the water vapor within the closed evaporator, the more the condensed (precipitable) water, but the higher the saturation condition, the higher the air pressure and slower the evaporation. Also, the effect of the wind directly over the open evaporator dissipates the heat and mass much more, and more rapidly than occurs in the closed evaporator, and thus removes more water vapor and heat. Over the open evaporator there is also a much lower humidity than that within the closed one and this allows a greater withdrawal of water vapor, thus causing higher heat and mass transfer by evaporation. Moreover, inside the closed evaporator, saturation is reached, which does not allow faster evaporation. High air temperatures (TA) and high humidity reduce the evaporation. Therefore, there are combinations of various factors that make the temperatures of the closed evaporator higher and its evaporation lower, such as occurs with natural 'closed' environments.

In Figure 6 we can also see a time lag of about 2 h between the evaporation of the open and closed evaporators. This is due to the higher thermal inertia of the closed system caused by the cover and higher water vapor concentration influences. Covers and high water vapor concentration delay and reduce the evaporation. This effect also occurs in the open and 'closed' atmospheres, because when there are cloud covers and high air humidity the evaporation (from the skin, for example) becomes very small and much slower making people feel warm and uncomfortable. Also, when the wind velocity outside the closed evaporator is low, the cover temperature (TC) becomes higher and since the evaporation is directly proportional to the difference (TW–TC), the closed evaporation also reduces.

The current literature considers that the air is warmed only by the radiation heat exchanges that occur between the Earth's surface and the environment. However, as shown in this topic and in the rest of this paper, it is important to highlight that the cover and the inner air of the solar still are heated by the evaporation, radiation and convection heats released by the water layer; that is, not only by the solar/IR radiation. Since in nature all the physical processes are the same and only their amounts change, this heating process also occurs with the open and 'closed' atmospheres.

Showing additional accuracies of these physical and mathematical developments, in Figure 6 we can also see a 'negative evaporation' or condensation (dew) in some hours of the night and the morning. Figure 5 clarifies this. We can see that in these hours the dew point temperature is always higher than the water temperature, and this is the cause of the condensation of the humid air onto the water or onto any other surface. These temperatures and condensation were also observed experimentally, including the visual observations of the dew onto the sides of the open evaporator while its increasing water level was being measured (Sartori 1987).

Figures 7 and 8 present the hourly heat transfer rates per square meter by evaporation, radiation, convection and conduction from the water layers of the closed and open evaporators, respectively.

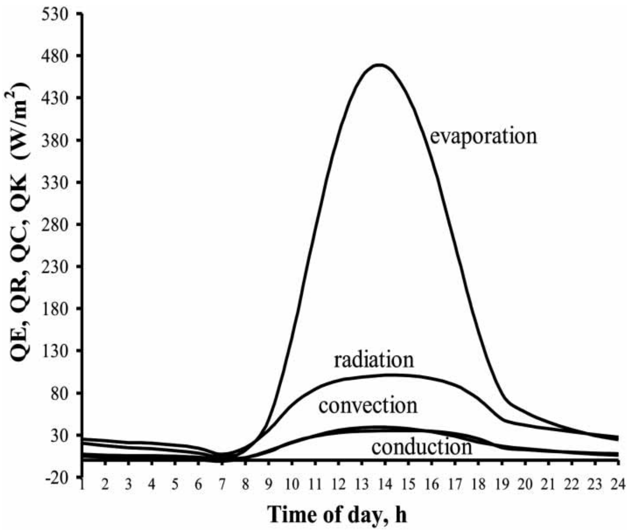

Figure 7 | Hourly heat transfer rates by evaporation, radiation, convection and conduction of the closed evaporator.

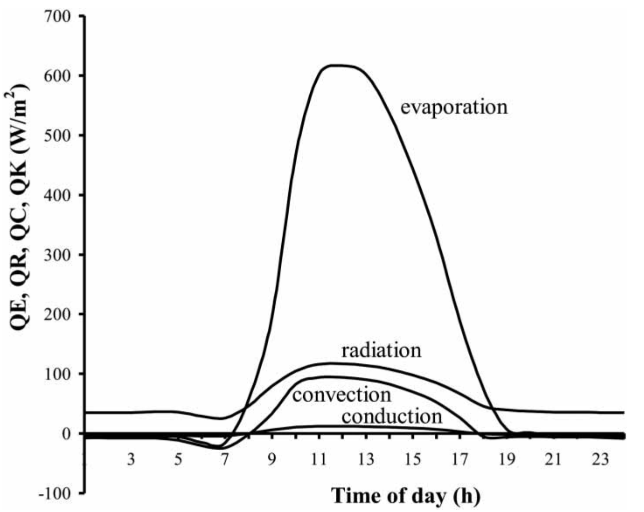

Figure 8 | Hourly heat transfer rates by evaporation, radiation, convection and conduction of the open evaporator.

It can be seen in Figures 7 and 8 that in both systems the evaporation is the major heat loss and is much greater than the other three modes together. It can also be seen that the heat losses by radiation and convection of each system are comparable with one another, as also calculated in this paper. Within the closed evaporator, this difference is higher because the free convection produces lower heat transfer.

It is very important to note that the heat losses from both systems explain and define why the Arctic ice is melting. The radiation heat loss from the water layer of the closed evaporator for that representing day was 1,205.23 W/m^2, while the radiation heat loss from the water layer of the open evaporator was 1,431.47 W/m^2. The reason for this higher heat loss is that the radiation from the open evaporator is emitted to the sky temperature; that is, clear sky, while the radiation from the water layer of the closed evaporator is emitted to the cover temperature, which is much higher than the sky temperature. The heat losses by convection and evaporation follow the same line. The heat loss by convection from the water layer of the closed evaporator was 393.55 W/m^2 while the heat loss by convection from the open evaporator was 627.30 W/m^2. The heat loss by evaporation of the closed evaporator was 3,212.00 W/m^2, while the heat loss by evaporation from the open evaporator was 4,122.23 W/m^2. This means that the free water surface in open atmosphere loses more heat and thus its water layer remains with lower temperatures, as is also seen in Figures 4 and 5, while the water layer of the closed evaporator loses less heat and therefore more heat remains within the greenhouse. An ice sheet under a full cloud cover presents the same behavior; that is, loses less heat and within the greenhouse formed by the full cloud cover there remains more heat and the necessary heat that can melt the ice. The ice is formed in a freezer when the corresponding water loses (i.e. the equipment removes) the higher and necessary heat to make its temperature reach 0 °C; otherwise, with less heat removal, the ice is not produced. As can be seen, all of the physical principles of the Sartori theory match.

Cooper (1970) carried out simulations with a solar still working with salinities from 0% up to 30%. With zero salt, the maximum TC was 50.6 °C and with 30% salt, the maximum TC was 47.4 °C. The TC (and the solar still inner air temperatures) decreased because the total heat emitted by evaporation, radiation and convection reduced from 381.40 to 334.08 W/m^2 due to the deposition of salts that whiten the solar still basin, which then absorbs less solar radiation and thus releases less heat. Since all of the simulations were carried out with the same value of solar radiation, the same amount of it was absorbed by the glass cover in all cases, which means that the amount of energy that comes from below changes the cover and the air temperatures. Sartori (1991) obtained equivalent results for an open evaporator. These behaviors also occur in the atmosphere; that is, the evaporation, radiation, convection, conduction and sublimation heat transfer modes from the wet and dry surfaces of the Earth influence the air temperature, that is, not only the transmitted and absorbed solar radiation by the humid and dry air of the atmosphere and of the cloud covers do this. Since the planet's surface is mostly wet and emits heat by evaporation from water surfaces, vegetation, humid soils and animals, the heat loss from the total surface area of the globe without certain human activities is mainly by evaporation, which substantially influences the air temperature and other atmospheric behaviors.

The 'closed' atmosphere

A 'closed' atmosphere occurs when the sky is fully covered by clouds.

The operation of the 'closed' atmosphere is very similar to the operation of the closed evaporator. In the same way as a transparent cover, cloud covers reflect, absorb, reduce, transmit and trap thermal energy and then help to create a greenhouse effect. Also, such as the glass and due to their more solid and closing conditions, cloud covers can substantially reduce the wind velocity. Sartori (2012, 2015) discovered and demonstrated that cloud covers have the physical property of reducing the wind, the characteristic or physical property of which is not owned by any gas. The water from oceans, rivers, lakes, seas, glaciers, vegetation and humid soils evaporates (from glaciers it also sublimates), rises, reaches the upper and cooled layers of the atmosphere, condenses (whenever the air dew point temperature is higher than the air dry bulb temperature), forms clouds and precipitates as rain, snow or hail. The Earth's surface loses heat by evaporation, radiation, convection, conduction, and sublimation, and mass by evaporation and sublimation, and thus heats and humidifies the environment. Under a full cloud cover, the Earth's surface emits radiation to the air temperature, in contrast to the emission of radiation to the sky temperature in clear skies. This means that the environment closed by clouds loses less heat than if there were no clouds, that is, accumulates more energy and consequently can increase its air temperature. After convection and conduction processes through the clouds, the cloud cover loses heat by IR radiation and by forced convection to the outer space while the cloud cover's lower face gains heat by evaporation, by IR radiation and by free or forced convection from below. The thermal processes that take place in this system are the same as those that occur in the closed evaporator, as can be seen schematically in Figure 9. In nature, all the physical processes are the same, only their amounts change.

Any solid cover, such as the one on a pot, keeps heat and humidity below and humans live under cloud covers which are more solid than water and gases. That is, in both the closed evaporator as in the 'closed' atmosphere by a full cloud cover, especially a transparent one without openings and colors, the air tends to become airless, warm and humid. Such conditions 'melt' the people and can melt the ice.

The literature normally considers that clouds have the capacity of solely cooling the environment. This is valid for isolated clouds but not always for full cloud covers because these have the capacity to 'close' the environment (clouds are more solid than water and thus than any gas). Comparing the Sahara with the Amazon, we can see that the temperatures in the Sahara range from about –5 to 60 °C while in the cloudy Amazon the temperatures during the year range from about 26 to 38 °C. Thus, due to these less oscillating temperatures, the presence of energy storage processes by the water vapor and cloud cover in the Amazonian region is clear. Cloud covers work by storing and retaining the energy received for a longer time, as demonstrated for the closed evaporator. Cities surrounded by mountains are much warmer than others because the air and its water vapor remain stagnant and this works as a cover that traps the heat and humidity, such as within a pot, causing a weak removal of heat and humidity from the skin. This warming effect also occurs within closed stadiums. Since the Arctic is also mountainous, the combination of mountains and cloud covers may be creating such pots and contributing to the ice melting.

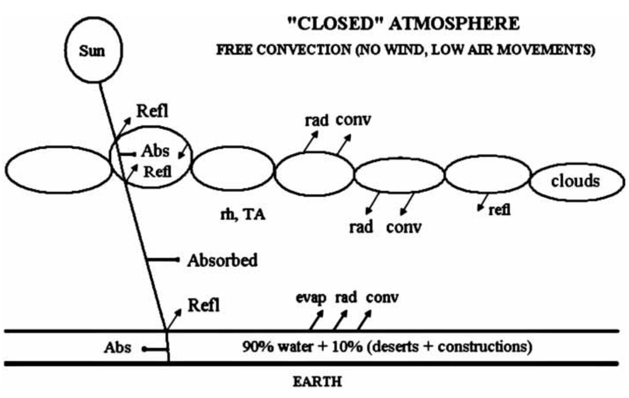

Figure 9 | 'Closed' (totally cloudy) atmosphere.

McIlhattan (2015) states that clouds are the largest regulators of radiation and that 'thick, bright clouds reflect energy from the Sun during the day, causing the Earth's surface to be cooler than on a cloudless day. High, thin clouds allow energy from the Sun to reach the surface while trapping heat emitted by the planet, thus acting as a blanket and causing the surface to be warmer than on a cloudless day.' These statements correspond to the general understanding by the current literature on the subject, but are not completely valid. First, as already demonstrated by Sartori (2012, 2015) and in the present paper, the cooling/warming processes are not determined or do not depend solely on radiation, because the atmosphere does not work only with radiation and cloud covers do not trap only radiant energy. The natural heats by evaporation, convection and conduction from the surface as well as these same ones from some human activities, plus the corresponding latent heat, also heat the environment and are stored by cloud covers. The sun is no longer the only heat source for the atmosphere and the amount of heat held in the air is no longer dependent only on the sun's energy. The climate and the planet do not work only with radiation and with an almost unique greenhouse effect due to a certain gas, contrarily to that which has been reported up to now by the global warming area. Second, reflectivity is a physical property that depends on surface colors and conditions, not on thicknesses or volumes, and thus we can have thick clouds reflecting less than thin clouds. We can also have thick clouds trapping much energy, warming the environment and making it airless. Third, even with a certain reflectivity, the greenhouse formed by a cloud cover can increase the temperatures; that is, the reflectivity alone does not determine the cooling/warming processes, and also because the summation of the heats by evaporation, convection and conduction emitted by the surface is higher than the corresponding radiation value, as can also be seen in Figures 7 and 8. Fourth, the trapping, warming and airless effects caused by a cloud cover also depend on its closing conditions. The closing reduces the wind as well as the removal of heat and thus increases the internal energy and thus warms the environment. It is correctly believed by such researchers that 'at night, with no incoming solar radiation, clouds trap heat and warm the surface'. As already explained and seen in Figures 4 and 5, the temperatures of the closed evaporator (closed atmosphere) at night are much higher than the ones of the open evaporator (open atmosphere) and of the ambient air temperatures.

Inside an igloo, the outside temperatures of about −50 °C are converted into about +16 °C due to the solid cover (independent of the substance) that converts the outdoor forced convection (strong winds and high heat loss by bodies) into the free convection inside (tiny air movements and low heat loss by bodies) and also due to the addition of sensible heat (radiation, convection, by bodies) and latent heat (sweat, respiration, speaking) to the inner air. However, the warm and humid air from the lungs melts the ice.

Inside a car exposed to the sun and with the windows closed, a greenhouse effect is created, which increases the inner warming, but if there is water inside, the corresponding air temperature is determined through the heat and mass balances as shown in Equations (1) and (2) and not through the solar/thermal radiation only (Equation (3)). Moreover, inside this car, the air humidity increases and thus the warming due to the thermal sensation also increases. Even on rainy days, the temperature inside a car with the windows closed becomes higher and more airless than outdoors (mainly due to latent heat) and this is why the water vapor condenses onto the windows, or more specifically, this occurs when the inside air dew point temperature is higher than the windows' temperature.

To know what happens when a transparent cover is replaced by an opaque one, see Sartori (2012). While it rains, the enthalpy of the rain cools the air, but after the end of the rain this enthalpy stops cooling and then the air under a full cloud cover may become airless, and a warming sensation may prevail. The Antarctic and the Arctic are considered deserts, because the precipitation in those places range from only about 50 to 150 mm/year.

The above behaviors and effects also occur with cloud covers. Clouds are more solid than water (clouds are formed by fine solid particles such as dust, pollution, chemicals, from forests, marines, biologics, etc. in addition to water) and form 'solid' covers. The presence of clouds and water vapor also increases the mass in the atmospheric system and thus creates a higher thermal inertia and a time lag in relation to that of a cloudless or dry atmosphere, thus reducing the evaporation, as occurs in the closed evaporator.

When the air temperature is higher, the evaporation from free water surfaces under a cloud cover or not becomes lower because the evaporation is directly proportional to the difference (TW–TA). Further physical and mathematical demonstrations regarding this effect are shown in Sartori (2012, 2015).

The descriptions above show how open and closed environments of any kind really behave and this is another demonstration as to why any considered amount of solar/thermal radiation and values of temperatures are not sufficient to guarantee independently higher or lower warming, cooling and evaporation rates, mainly when the greenhouse effect produced by a cloud cover is involved.

Therefore, sometimes or somewhere the planet behaves as a large open evaporator and sometimes or somewhere as a large closed evaporator, depending on the cloudiness conditions, that can affect the wind, the warming and the humidity conditions with consequences for the environment and for the people.

The direct influences of certain human activities on the climate

This section briefly discusses how certain human activities can generate clouds, modify natural cycles and thus influence the climate, directly. Further information about these causes and effects is found in Sartori (2012, 2015).

Up to now, literature on the natural water cycle has always stated that Precipitation = Evaporation, but this equation is incomplete and thus we should include the sublimation mass and therefore we have Precipitation = Evaporation + Sublimation. Furthermore, if a drop of water is thrown into the atmosphere this equation must be modified to:

$$\text{Precipitation} = \text{Evaporation} + \text{Sublimation} + \text{One drop} \quad (8)$$

Of course, one drop does not matter, but the billions of fossil fuel and nuclear power plants, industries, vehicles, burnings, wildfires, etc. throw into the atmosphere at least millions of tons of water and aerosols, and much heat in every instance around the world and faster and more irregularly than natural processes can. These are just the factors that form clouds and affect hydrological and other natural cycles and thus the climate. The IPCC considers that 99.99% of water vapor has natural origins and thus no one deindustrialization could change the amount of this gas in the atmosphere. The new water cycle shows that the issue is not to change completely, but modify something partially. The atmosphere is not a monolithic block where only one factor at one side can be the cause of all phenomena and consequences at the other side. On the contrary, the atmosphere is gaseous, whose physical processes have multiple causes, variations and consequences. Such human activities humidify the planet, produce more clouds (or fewer clouds when the saturation limits of clouds for solid particles are reached; see Sartori 2012), more precipitation (or less precipitation) and more floods in irregular amounts, times and places. The strong heats and masses emitted directly by such human sources also cause atmospheric instability, being that storms, tornadoes and hurricanes occur only when the atmosphere is unstable.

Besides the heat and mass transfer modes seen in Equations (1) and (2), the great amounts of heat and mass released directly by certain human activities also directly and irregularly influence the heat and mass balances of the atmosphere and then Equation (1) for the heat balance converts into:

$$S + H = q_e + q_{su} + q_r + q_c + q_k + q_L \tag{9}$$

where H = heat generated at or added to the surface by human activities, W/m^2; q_L = latent heat loss from the surface due to the steam, W/m^2.

This energy added to or generated at the Earth's surface comes from the energy contained in the subsoil coal, oil, gas, uranium, etc., which is converted into heat by certain human activities and is released to the atmosphere by radiation, convection and latent heat. The heat released by volcanoes occurs by evaporation, radiation, convection, conduction and latent heat, being all of the modes already included in Equation (9).

To illustrate, let us see the following numerical example that considers only the latent heat and the corresponding mass of water thrown into the atmosphere by certain human activities. The water consumption by a coal-fired power plant of 600 MW is about 3.5 L/kWh or 35,000 L/min or still more; that is, this is the approximate amount of water that such a plant consumes (i.e. the water lost to the air, not the one that is 'recycled' by these plants) from rivers and lakes. The corresponding latent heat released can be easily calculated. The mass of water that only one of these plants throws into the air is obtained as:

$$\begin{aligned} m &= 3.5\ \text{L/kWh} \times 600.000\ \text{kWh} = 2,100,000\ \text{L/h} \\ &= 50,400,000\ \text{L/d}. \end{aligned}$$

A nuclear power plant releases about 70% more water than a fossil fuel power plant.

Now, calculating the latent heat for this case we obtain:

$$\begin{aligned} q_L &= \text{mL} = 583.33\ \text{kg/s} \times 2,261\ \text{kJ/kg} \times 1,000 \\ &= 1,318,909,130\ \text{W} \end{aligned}$$

that is, only one of such power plants can emit to the atmosphere 2.2 times its own nominal power solely in latent heat. Moreover, if we concentrate such emitted energy in one square meter, this energy will be equal to 1,318,909,130 W/m^2, or 1,884,156 times the solar radiation of 700 W/m^2, which is a high solar energy value, or can heat 1.884.156 m^2 of air with the equivalent energy of 700 W on each square meter.

Therefore, because of this strong heat added by human activities, we verify that the sun is not the only heat source for the atmosphere and thus not the only generator of temperature differences and thus of winds. Since the tons of gases released by the fossil fuel power plants can reach 1,000–2,000 °C, these temperatures can generate strong winds.

For those who thought that humans do not have the capacity to influence the climate, these are good measures and clarifying calculations, for the first time in the world, and since the latent heat that leaves the lungs is able to melt igloo ice, this powerful and concentrated latent heat from certain human activities, plus the corresponding heat by radiation and convection and combined with cloud covers, may melt the ice.

If so much heat multiplied by so many heat sources is released into the air in every instant around the world, obviously the local and regional air is heated and thermometers in the vicinities register such increases and then the average temperature and other atmospheric behaviors are affected. Such impacts are due to certain direct human actions and not indirect ones due to some gases and their greenhouse effects. Extra heat generates clouds, rain, strong temperature differences and thus strong winds, sporadically. So, certain human actions can in fact alter the heat and mass balances of the atmosphere and as a result alter its humidity, temperature and natural behaviors, directly. Therefore, as we can see again and mathematically, the heat lost from the Earth's surface is not due solely to radiation.

We can also evidence, corroborate and prove that the mass balance of the atmosphere is affected by these human sources by analyzing the natural hydrological cycle. The equation for the natural hydrological cycle for a layer of the atmosphere (Sartori 2012) is:

$$dM_{w,a}/d\theta = dM_{ev}/d\theta + dM_{su}/d\theta - dM_p/d\theta \quad (10)$$

or

Variation of the water vapor in the atmosphere
= variation of evaporation + variation of sublimation
– variation of precipitation

That is, the natural hydrological cycle and everything in the atmosphere depend on variations, not on fixed or absolute values, and they vary in time and space.

It was reported that in the last decades the amounts of clouds and precipitation increased in various parts of the world (e.g. Europe, Russia, USA, India, Venezuela), while the evaporation decreased (e.g. Brutsaert & Parlange 1998). Since in the natural hydrological cycle the formation of clouds and precipitation is considered to depend solely on evaporation and is in equilibrium with this natural emission of water vapor, the apparent inconsistency in these reactions of the nature led some authors to name such incomprehension as 'the evaporation paradox', saying that more precipitation is not conciliatory with less evaporation. Brutsaert & Parlange (1998) found a 'solution' that does not have physical meaning and Roderick & Farquhar (2002) found a 'solution' that violates the first law of thermodynamics. The above descriptions for the closed and open evaporator thermal behaviors, plus those by Sartori (2012), truly unveil such supposed inconsistency and solve physically and mathematically such a 'paradox' while leading the present author to discover the new hydrological cycle (Sartori 2012).

These registered increases of clouds around the world also, in reality, eliminate the water 'feedback' empirical concept that abolishes the influence of the water vapor in the atmosphere and in the corresponding greenhouse effect. Such a concept justifies saying that the water vapor lasts only about 8–10 days in the atmosphere because it generates clouds and precipitation and this process happens again and again indefinitely. If the water vapor only remained for about 8–10 days in the atmosphere, there would not be increases of clouds in various parts of the world over decades, among other reasons, as demonstrated by Sartori (2012, 2015) and in the present paper. Moreover, in such a way, the atmosphere of the whole planet would remain completely dry, with zero water vapor after 8–10 days, but it is obvious that this is not the reality, and it is not only in clouds that there is water vapor in the atmosphere; on the contrary, the most part of it is not in clouds.

Furthermore, for the resulting water vapor in the atmosphere to be zero, the evaporation or sublimation that occurs in every instant from all the water surfaces of the planet (oceans, seas, rivers, lakes, glaciers, vegetation, humid soils, animals), which do not cease anyway, would have to stop completely. The precipitation and its infiltration in the ground had to be total and immediate in a way to zero out the water vapor in the atmosphere, but this also does not happen. Or, even if the variation of precipitation was equal to the variation of the evaporation and the sublimation at any instant (10 kg–10 kg, for example), the resulting water vapor in the atmosphere would not be zero. For example: 100 kg (former balance) + 10 kg (evaporation and sublimation)–20 kg (precipitation) = 90 kg (new balance).

Moreover, through the equation of the new hydrological cycle for a layer of the atmosphere (Sartori 2012), we can see that there is another factor that does not allow the water vapor in the atmosphere to be zero:

$$dM_{w,a}/d\theta = dM_{ev}/d\theta + dM_{su}/d\theta + dM_h/d\theta - dM_p/d\theta$$

or

Variation of the water vapor in the atmosphere
= variation of evaporation + variation of sublimation
+ variation of water vapor emitted by human activities
− variation of precipitation

That is, besides evaporation and sublimation, water vapor also rises due to certain human activities, and they vary, too. With the new water cycle, the above numerical example becomes: 100 kg (former balance) + 10 kg (evaporation and sublimation), +10 kg (human activities) – 20 kg (precipitation) = 100 kg (new balance), and even in deserts the air humidity is of the order of 10–12%. Gases do not have the physical property to create water or clouds.

This is what the new hydrological cycle establishes and represents; that is, yes, there are human interferences on natural cycles and thus on the climate, but mainly direct ones and not due to a greenhouse effect and not as has been reported up to now.

REAL DATA CONFIRM THE SARTORI THEORY

Data for the planet

In recent decades (e.g. Brutsaert & Parlange 1998), the amount of clouds and precipitation increased in various parts of the world while evaporation decreased. Knowing only the principles of the natural hydrological cycle, these authors and others stated that less evaporation is not conciliatory with more precipitation and called this apparent inconsistency the 'evaporation paradox', which lack of true solution led Sartori (2012) to discover the new hydrological cycle.

Other increases of clouds using databases have been reported by Sun & Groisman (2000) for the Soviet Union, by Angell *et al.* (1984) for the United States, by Henderson-Sellers (1986) for Europe, and by Jones & Henderson-Sellers (1992) for Australia.

These increases of clouds over decades around the planet also confirm the equivocation of the water 'feedback' concept. They also confirm the real operation of the new hydrological cycle; that is, while the evaporation supposed to be the only water source for the formation of clouds has decreased in the world, human activities have increased the water vapor in the atmosphere and caused the formation of more clouds.

Figure 10 (NOAA 2017) shows a recent image of the Earth almost completely covered by clouds. It can be seen that the Earth is really very cloudy and the photo also confirms the findings by several works that experimentally verified such a cloudy condition of the planet.

Additionally, in recent decades many other atmospheric effects confirm the behaviors of the closed evaporator. Satellite data by Jacobson & Kaufman (2006) showing that wind speeds have decreased globally associated with the cloud cover and aerosols' increase are another confirmation of the physical principles demonstrated in this paper. Such data for February and August from 2002 to 2004 over California present a real indication of the wind speed decrease associated with the cloud cover increase, showing that the average near-surface wind speed over land in August decreased from 4.2 m/s (when the aerosol optical depth was low) to 3.5 m/s (when aerosol readings were high).

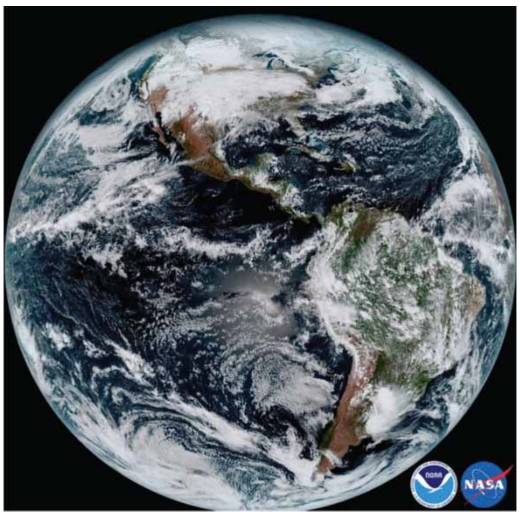

Figure 10 | Image by the satellite GOES-16 from NOAA/NASA about 36,000 km from Earth on January 15, 2017 (NOAA 2017).

The trend for February was similar, with a decrease in the wind speed from 7.5 m/s for lower aerosol counts to 6.5 m/s for higher aerosol counts. According to the authors, aerosol particles may also explain the reduction in the Asian seasonal monsoon and China's 'disappearing winds'. From 1974 to 1994 the wind speed in Southeast China dropped by 24% when aerosol optical depths increased from low to high levels. The authors also state that observed reduced wind speeds in Europe may also be due to the increase of cloud cover by aerosols. These results are also corroborated by Wang *et al.* (2009), who compiled a decades-long database of aerosols measurements over land and found that clear sky visibility decreased over land globally from 1973 to 2007, indicative of an increase of particulates and darkness in the air over the world's continents. The study by Pryor *et al.* (2009), based on measurements on the Earth's surface, show that the average and peak winds have decreased 10% or more per decade from 1973 to 2005, especially in the Midwest and the East of the USA. Pryor *et al.* (2009) did not understand why winds have decreased, but in the present paper all of these issues are really solved and with true physical meanings. Due to its denser and more solid conditions, the cloud cover closes the openings and thus decreases the winds. Alexander *et al.* (2006) show that the 20th century became wetter and with increasing precipitation and Groisman *et al.* (2005) show that almost all of the planet became wetter in recent decades. The data presented here also correspond to other confirmations of the working principles of the Earth's atmosphere, as demonstrated in this paper.

Measurements confirming the reduction of surface solar radiation in the USA and worldwide in recent decades show that this radiation declined 19 W/m^2 or 10% in the United States from the 1960s to the 1980s and 7 W/m^2 or 4% in other regions of the globe in three decades (Liepert 2002). Other satellite measurements (Zender *et al.* 1997) have also indicated that cloudy atmospheres absorb 50% more radiation than predicted, which harmonizes with the findings by Liepert (2002), and also with Hansen *et al.*'s (2001) results, who observed an increase in air temperature for the USA. All of these results represent confirmations that the cloud amounts are increasing and getting thicker. This ARM-ARESE study also found no evidence for enhanced absorption of radiation in clear skies and found strong evidence for enhanced radiation absorption in cloudy skies. Liepert (2002) and other researchers (e.g. Roderick & Farquhar 2002) did not understand why reductions in surface solar radiation and evaporation have been simultaneous with an observed increase in air temperature, cloudiness and precipitation in various parts of the world for the last decades. This paper solves all of these issues correctly. As demonstrated above under 'Basic principles of the Sartori theory', even with less solar radiation than for the open evaporator the temperatures of the greenhouse formed by the closed evaporator are much higher and the evaporation much lower than the ones for the open evaporator. All of these effects are in close agreement with the theoretical principles demonstrated by the present author.

The work by Schneider & Hook (2010) completes and confirms the demonstrations of this paper on the correct working principles of the atmosphere through their findings that water temperatures of 167 large lakes worldwide increased since 1985. Using satellite data, they found an average warming of 0.45 °C per decade, with some lakes warming as much as 1.0 °C per decade. The warming trends were mainly observed in Europe, North America, Siberia, Mongolia, China, and in the Southern Hemisphere. The satellites' temperature trends also agreed with trends measured by nine buoys at the Great Lakes. The authors also report that the satellites' measurements were in agreement with independent surface air temperature data from NASA's Goddard Institute.

All of these data by several works from different places in the world also reveal that the Earth is changing from an open to a more 'closed' condition by clouds. The reasons for such increases of clouds can also explain why more clouds have existed over the Arctic/Greenland, too.

Data for the Arctic

Recently, many different sources have independently presented data from measurements by satellites and on land about the Arctic ice melting. These data clearly agree and confirm the thermal behaviors of the open and closed evaporators that explain, represent and evidence the Earth's surface and the atmospheric thermal behaviors of the open and 'closed' atmospheres. Figure 11 (NSIDC 2017)

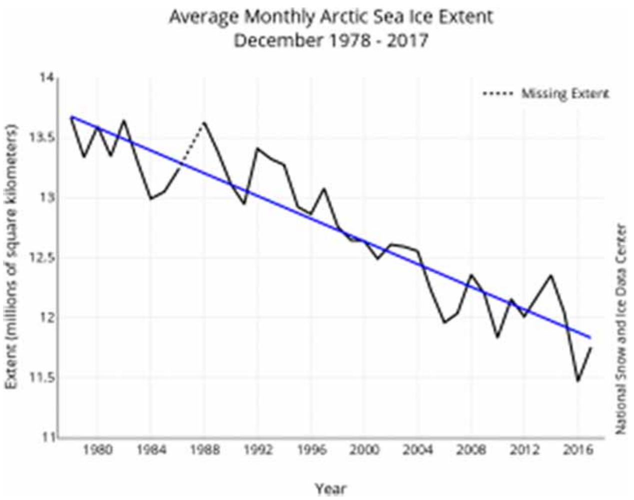

Figure 11 | Arctic sea ice extent (NSIDC 2017).

presents the Arctic sea ice extent, indicating the melting that occurred from January 1979 to January 2017.

Figure 12 (NOAA 2016) shows the percentage of clouds that has covered the Arctic region from 1980 to 2005.

We can clearly see in both figures that while the ice melting increased, the percentage of clouds has also increased and is very high, confirming the warming (accumulation of heat) produced by the closing of any cover, as explained above under 'Basic principles of the Sartori theory'. We can also see that both graphs seem to be only a single one with one of them inverted, so enormous is the coincidence of the events. We can also see that the inclination of the average curves is the same, needing only to superimpose one graph onto another. Furthermore, observing the variations of clouds and melting that compose the averages of each graph, we see that they follow almost the same profile and oscillations.

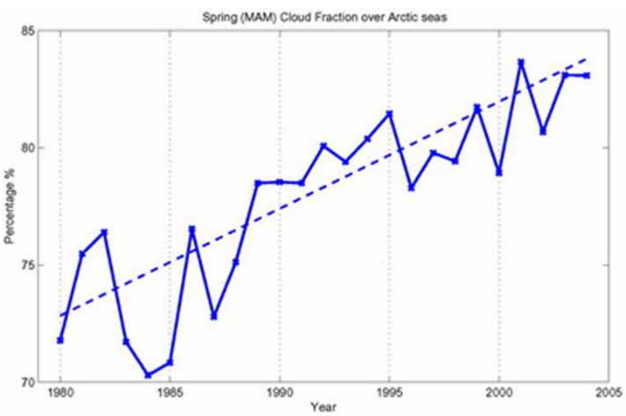

Figure 12 | Increase of clouds over the Arctic (NOAA 2016).

Van Tricht *et al.* (2016) show that clouds are raising the temperature of the Arctic/Greenland ice sheet by 2–3 °C compared to cloudless skies and accounting for as much as 30% of the ice sheet melt. This is an extraordinary confirmation of the Sartori theory through the closed evaporator and the 'closed' atmosphere thermal behaviors. Intrieri *et al.* (2002) firmly substantiate these evidences by finding experimentally that 'clouds act to warm the Arctic surface for most of the annual cycles with a brief period of cooling in the middle of summer'. Bennartz *et al.* (2013) said that low-level clouds were instrumental in pushing the temperatures up above freezing over large parts of the Greenland ice sheet. These authors also found that thin, low-lying clouds allowed the sun's rays to pass through and warm the surface of the ice, while at the same time trapping heat near the surface of the ice sheet. Bennartz *et al.* (2013) also show that this type of cloud is common over both Greenland and across the Arctic. Weather Spark (2016) also corroborates, saying that, 'The median cloud cover [over Greenland] is 87% [mostly cloudy] and does not vary substantially over the course of the year.' This percentage of clouds is also in close agreement with the data shown in Figure 12 for recent years. Eastman (2009) shows that the annual average of total cloud cover in the Arctic is up to 90% during a great part of the year. Eastman (2009) and Eastman & Warren (2010) present a series of graphs showing that the total cloud cover has increased since the 1970s in all seasons. These numbers are also in agreement with the abovementioned percentages. Eastman (2009) also states that clear sky scenes are not common in the Arctic. Eastman (2009) also says that during low ice years the total cloud cover appears to be greater throughout the year. Van Tricht *et al.* (2016) also show that the ice melts during the daytime while at night when the sky is overcast the temperature remains too high and only some of the water refreezes.

Eastman & Warren (2010) correlated the Arctic cloud cover with the sea-ice extent and air temperatures of the region. In Figure 13 we can see the rising surface air temperatures of the Arctic since the 1970s, where the temperature increasing agrees with the aforementioned numbers for cloud covers.

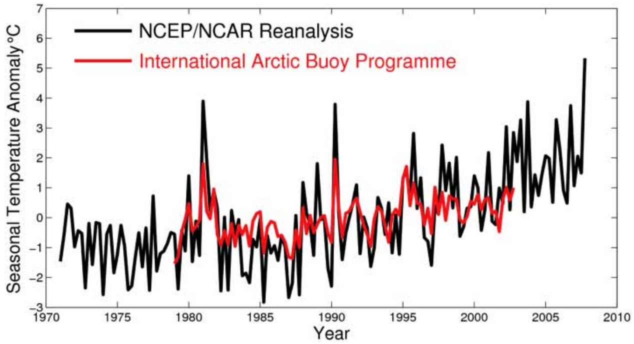

Figure 13 | Rising surface air temperatures in the Arctic (Eastman & Warren 2010).

Eastman & Warren (2010) stated that cloud changes of recent decades appear to enhance Arctic warming.

Figure 14 is in agreement with the referred series of graphs and with Figures 11–13 where we can see once again the close relationship between the Arctic ice extent declining and the increases of cloud cover and air temperatures.

Satellite observations over 1982–2004 (Wang *et al.* 2012) showed that the Arctic has warmed up and become cloudier. The authors report that the Arctic annual mean surface temperature has increased at a rate of 0.34 °C/decade. They also show that the Arctic sea ice has also declined substantially with decadal rates of −8, −5 and −15% in sea ice extent, thickness, and volume, respectively.

Using satellite observations and reanalyzed data, Jun *et al.* (2016) examined interannual variations of total cloud cover, near surface air temperature and sea ice cover during boreal winters (December–February) over the Arctic Ocean (North of 67° N) since the 1970s (Figure 15). This figure confirms once again that the cloud cover amount

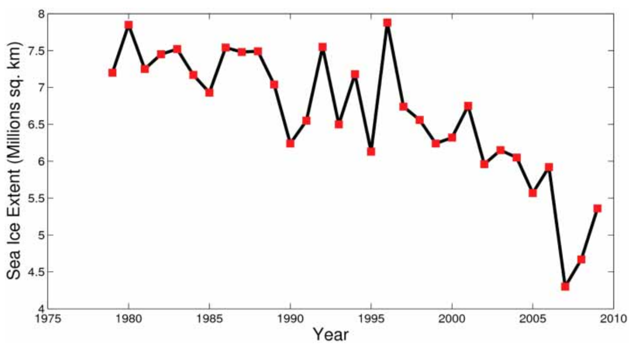

Figure 14 | Changes in Arctic sea ice extent since the 1970s (Eastman & Warren 2010).

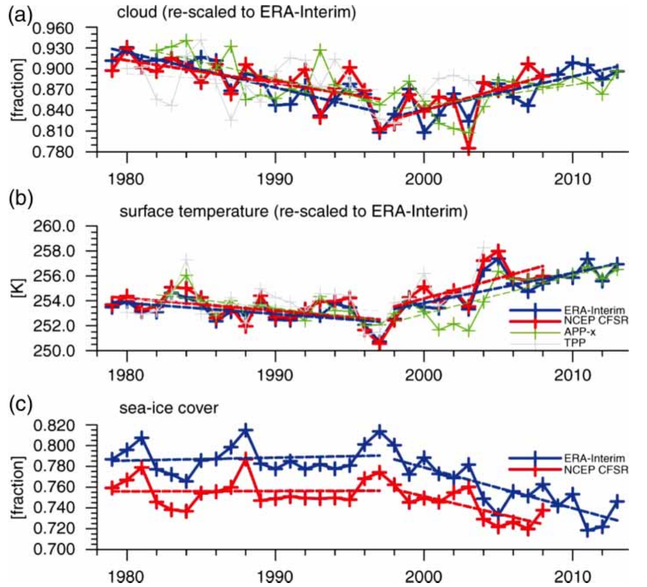

Figure 15 | Time series of (a) cloud cover amount, (b) near surface air temperature, (c) sea ice cover at the Arctic Ocean during winters (Jun *et al.* 2016).

is up to 90% and that the cloud cover, the near surface air temperature and the sea ice melting present coherent behaviors among them; that is, all of them increase and decrease consonantly, confirming other authors' experimental findings as well as verifying once more the described theoretical principles, and this time with the behaviors occurring in winters. A relative neutral behavior is noted for the sea ice fraction until the late 1990s. A small temperature decrease in the period was not sufficient to alter the sea ice concentration. This also means that there is no uniform global temperature and unique cause. The issues are specific and localized, but under the umbrella of the open or closed atmospheres.

Confirming low-speed winds, which is another of the closed evaporator behaviors, Greenland (2017) reports: 'Generally-speaking it is not that windy in Greenland. Many days are completely calm with calm seas and glassy fjords and lakes.' Weather and Climate (2016) verifies this low-speed wind showing, for example, that its average ranges from about 1.7 to 2.3 m/s. When there is a low wind speed below the cloud cover, this means that there is a low removal of heat and thus an accumulation of heat occurs and therefore this additional heat can melt the ice.

Other works (e.g. Palm *et al.* 2010; Cuzzone & Vavrus 2011) using satellite observations and reanalysis of data also show that the cloud cover has increased and its percentage over the Arctic is up to 90%, as well as showing the direct relationship between the Arctic cloud cover increase with the air temperature and the sea ice melting increases.

The internet is full of photos and videos showing that the Arctic region is very overcast, with great amounts of clouds. Among these sites are Dissolve (2017) and Alamy (2017). The latter shows a photo of real mountains with rings of clouds in East Greenland, creating the closed pots, evaporators and atmospheres demonstrated in this paper.

Eastman (2009) also observed that over the entire Arctic there is a substantial decreasing trend in precipitating clouds, but with a larger increase in low stratiform cloud cover. He argues that a possible cause for this could be changing aerosols within the Arctic atmosphere. Smokes, due to their heat, water and aerosols content, generate more clouds. Heat generates more clouds due to the same principle as when a warm water vapor (such as the one from the lungs) meets a surface (such as that of a window) and condenses when the dew point temperature is higher than the surface temperature or, in the case of clouds, when the dew point temperature is higher than the air dry bulb temperature. There are more fossil fuel and nuclear power plants, more industries, more vehicles and more burnings or wildfires in the neighbor countries of the Arctic/Greenland such as Europe, USA, Russia, and Canada. Water vapor, heat, smokes and aerosols travel through countries and continents and thus do not generate consequences only at their places of origin. Recently it was found that dust takes 5 days to go from East China to the Arctic (Huang *et al.* 2015).

The effects of aerosols are twofold: they can generate more clouds but they can also generate clouds saturated with particles and thus generate less precipitation and more droughts, as explained by Sartori (2012). The effects of particulate matter in clouds are also confirmed by the recent data by NASA (2016), seen in Figure 16, where we can see that smokes and their heats and particles caused by the recent intense wildfires in Canada are trapped in clouds. If such amounts of particulates are concentrated beyond the limits of saturation of clouds they cause less precipitation and more droughts.

Figure 16 also shows the rotating effect of the cloud. This author considers that this is due to the high amount of heat from the smokes that generate temperature

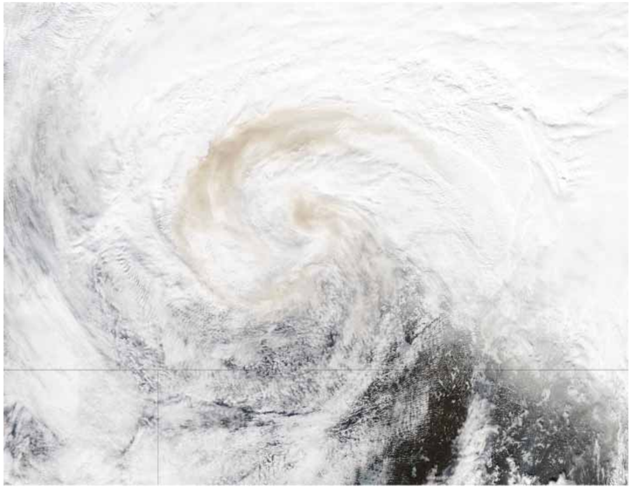

Figure 16 | Smoke and aerosols from Canadian wildfires trapped in clouds (NASA 2016).

differences within the clouds. Temperature differences are the cause and motors of air movements.

Dust also increases the darkening of the ice and thus increases the absorption of solar/thermal radiation and thus increases melting and evaporation.

Every physical principle of the theory matches with each other and with real data. All of the real data presented are *n*th proofs and confirmations that the planet and the Arctic ice melting behave according to the physical principles of the open and closed evaporators, depending on the closing conditions by clouds, as extensively demonstrated by the present author. These achievements and developments confirm the theory described in this paper.

DISCUSSION AND CONCLUSIONS

In this article a new theory is shown that demonstrates that the Earth's surface and the atmosphere behave as an open atmosphere (no clouds or with a few clouds) and/or as a 'closed' atmosphere (fully cloudy) corresponding to the operations of the open evaporator and of the closed evaporator (solar still), respectively, the physical principles of which also explain the Arctic/Greenland ice melting.

Cloud covers play the same role as that of the transparent one of the closed evaporator. Solid covers such as the 'solid' one constituted by clouds keep the qualitative thermal behaviors of the open evaporator or atmosphere, but modify the corresponding quantitative values.

Due to the transparent cover, within the closed evaporator the solar radiation is reduced and the external wind (forced convection) is converted into infinitesimal air movements; that is, free convection takes place, while the water and air temperatures and the concentration of water vapor increase considerably inside. The temperatures increase because there is a smaller and slower removal of heat and thus there is an accumulation of heat inside. Although being a strong function of the water temperature, the evaporation decreases substantially in comparison to the one by the open evaporator. This also means that a higher evaporation cannot be attributed to the water temperature alone when many other factors are involved. In this same way, a lower air temperature cannot be guaranteed to exist inside a closed system because the solar radiation is reduced due to the action of the transparent cover, such as the one formed by clouds.

Much data from measurements by satellites and on land and from several different and independent works confirm all of these theoretical principles for the planet as well as for the Arctic/Greenland situations.

In recent decades, the amount of clouds and precipitation have increased in various parts of the world while evaporation decreased (e.g. Brutsaert & Parlange 1998). Knowing the information of the natural hydrological cycle, Brutsaert & Parlange (1998) stated that more precipitation is not conciliatory with less evaporation and named this apparent inconsistency as the 'evaporation paradox'. These authors also found a 'solution' that does not have physical meaning while Roderick & Farquhar (2002) found a 'solution' that violates the first law of thermodynamics. The thermal operations of the closed and open evaporators, plus the knowledge on how direct influences of some human activities on the atmosphere occur, truly unveil such supposed inconsistency and solve such a 'paradox' physically and mathematically, which led the present author to discover the new hydrological cycle (Sartori 2012, 2015).

Up to now, the literature on the natural water cycle has held that Precipitation = Evaporation, but we should add the sublimation mass and thus we have Precipitation = Evaporation + Sublimation. Furthermore, if I throw a drop of water into the atmosphere this equation must be modified to:

$$\text{Precipitation} = \text{Evaporation} + \text{Sublimation} + \text{One drop}$$

This is what the new hydrological cycle establishes; that is, it is a consequence of certain direct human influences on the natural water cycle. One drop does not matter, but calculations presented in this paper show for the first time that the sun is not the only heat source for the atmosphere and thus not the only generator of temperature differences and of other consequences, including strong winds. Only one fossil fuel power plant of 600 MW throws more than 50 million liters of water and much heat and tons of particles into the atmosphere per day. The billions of fossil fuel and nuclear power plants, industries, vehicles, burnings, wildfires, etc. throw into the atmosphere at least millions of tons of water, aerosols and much heat in every instant around the world, and faster and more irregularly than natural processes can do. These are just the factors that generate clouds and affect the hydrological and other natural cycles and thus the climate. In this paper, both the natural and the new hydrological cycles are represented by mathematical equations, which make these understandings clearer. These physical and mathematical formulations had never been done before the present author.

Other increases of clouds around the world using databases were reported by Sun & Groisman (2000), Angell *et al.* (1984), Henderson-Sellers (1986), and Jones & Henderson-Sellers (1992), etc. All of these increases of clouds over decades around the planet also confirm the equivocation of the water 'feedback' concept. They also confirm the real operation of the new hydrological cycle; that is, while the evaporation supposed to be the only water source for the formation of clouds and precipitation has decreased, some human activities have directly increased the emissions that generate more clouds and precipitation. On the other hand, gases do not have the physical property or the capacity to create more water, more clouds and more precipitation.

In recent decades, many other atmospheric effects have been observed that confirm the behaviors of the closed evaporator. Satellite data by Jacobson & Kaufman (2006) show that wind speeds decreased globally associated with the cloud cover and aerosols increase. Pryor *et al.* (2009), based on measurements on the Earth's surface, show that the average and peak winds decreased 10% or more per decade from 1973 to 2005, especially in the USA. Wang *et al.* (2009) compiled a decades-long database of aerosols measurements and found that clear sky visibility has decreased over land globally from 1973 to 2007, indicative of an increase of particulate matter and darkness in the air over the world's continents. Pryor *et al.* (2009) did not understand why winds have decreased. The physical principles of the closed evaporator solve this issue, too. Alexander *et al.* (2006) show that the 20th century became wetter and with increasing precipitation and Groisman *et al.* (2005) show that almost all of the planet became wetter in recent decades.

Measurements confirming the reduction of surface solar radiation in the USA and worldwide in recent decades show that this radiation declined 19 W/m^2 or 10% in the United States from the 1960s to the 1980s and 7 W/m^2 or 4% in other regions of the globe in three decades (Liepert 2002). Other satellite measurements (Zender *et al.* 1997) also indicate that cloudy atmospheres absorb 50% more radiation than predicted, which harmonizes with the findings by Liepert (2002), and also with Hansen *et al.*'s (2001) results, which observed an increase in air temperature for the USA. This ARM-ARESE study also found no evidence for enhanced absorption of radiation in clear skies and found strong evidence for enhanced radiation absorption in cloudy skies. These results for clear and cloudy skies are also real indications that greenhouse gases such as CO_2, CH_4, N_2O do not play a key role in the absorption of radiation and thus in air warming (also confirming the analysis by Sartori 2015).

Liepert (2002) and other researchers (e.g. Roderick & Farquhar 2002) did not understand why reductions in surface solar radiation and evaporation have been simultaneous with an observed increase in air temperature, cloudiness and precipitation in various parts of the world for the last decades. All of these real effects confirm the theoretical principles demonstrated by the present author. This paper solves all of these issues correctly and with true physical meanings.

The work by Schneider & Hook (2010) completes and confirms the operation of the closed evaporator through their findings that water temperatures of 167 large lakes worldwide increased 0.45 °C per decade on average, with some lakes warming as much as 1.0 °C per decade, in Europe, North America, Siberia, Mongolia, China, and in the Southern Hemisphere, since 1985.

All of these real data also reveal that the Earth is changing from an open to a more 'closed' condition by clouds. Such increases of clouds can also explain why there are more clouds over the Arctic/Greenland, too. Recently, many different sources have independently presented data from measurements by satellites and on land about the Arctic ice melting, which clearly agree and confirm the behaviors of the open and closed evaporators that explain, represent and evidence the thermal behaviors of the open and 'closed' atmospheres.

We can clearly see in the data presented for the Arctic region that while the ice melting increases, the percentage of clouds also increases and is very high, confirming the warming due to the accumulation of heat produced by the closing effect of any transparent cover.

Other sources of data (Van Tricht *et al.* 2016) show that clouds are raising the temperature of the Arctic/Greenland ice sheet by 2–3 °C compared to cloudless skies and accounting for as much as 30% of the ice sheet melt. This is an extraordinary confirmation of the Sartori theory through the closed evaporator and the 'closed' atmosphere thermal behaviors. Intrieri *et al.* (2002) firmly substantiate these evidences by finding experimentally that 'clouds act to warm the Arctic surface for most of the annual cycles with a brief period of cooling in the middle of summer'. Bennartz *et al.* (2013) found that low-level clouds were instrumental in pushing the temperatures up above freezing over large parts of the Greenland ice sheet. These authors also found that thin, low-lying clouds allowed the sun's rays to pass through them and warm the surface of the ice, while at the same time trapping heat near the surface of the ice sheet. Bennartz *et al.* (2013) also show that this type of cloud is common over both Greenland and across the Arctic. Weather Spark (2016) also corroborates, saying that, 'The median cloud cover [over Greenland] is 87% (mostly cloudy) and does not vary substantially over the course of the year.' Several other sources of data (e.g. Eastman 2009; Eastman & Warren 2010; Palm *et al.* 2010; Cuzzone & Vavrus 2011; Jun *et al.* 2016; NOAA 2016) show that the cloud cover over the Arctic is really up to 90% during a great part of the year and has increased since the 1970s in all seasons, as well as showing the direct relationship among the Arctic cloud cover increase with the air temperature and sea ice melting increase. Eastman (2009) also states that during low ice years the total cloud cover appears to be greater throughout the year. Satellite observations over 1982–2004 (Wang *et al.* 2012) showed that the Arctic has warmed up, become cloudier, and the sea ice has declined substantially.

Van Tricht *et al.* (2016) also show that the ice melts during the daytime while at night when the sky is overcast the temperature remains too high and only some of the water refreezes. As explained in this paper and seen in Figures 4 and 5, the temperatures of the closed evaporator at night are much higher than the ones of the open evaporator and of the ambient air temperatures.

Confirming the low-speed winds, the site Greenland (2017) reports: 'Generally-speaking it is not that windy in Greenland. Many days are completely calm with calm seas and glassy fjords and lakes.' When there is a low wind speed below the cloud cover, this means that there is a low removal of heat and thus this additional heat can melt the ice.

Heat generates more clouds due to the same principle as when a warm water vapor (such as the one from the lungs) meets a surface (such as that of a window) and condenses (whenever the dew point temperature is higher than the surface temperature) or, in the case of clouds, condenses whenever the dew point temperature is higher than the air dry bulb temperature. There are more fossil fuel and nuclear power plants, more industries, more vehicles and more burnings or wildfires in the neighbor countries of the Arctic/Greenland. The water vapor, heat, smokes and aerosols generated by certain human activities are just the factors that create more clouds (or fewer clouds) and travel through continents and thus do not generate consequences only at their original places.

The effects of aerosols are twofold: they can generate more clouds but they can also generate clouds saturated with particles and thus generate less precipitation and more droughts, as explained in Sartori (2012). The effects of particulate matter in clouds are also confirmed by the recent data from NASA (2016), which show that smokes and their heats and particles were trapped in clouds caused by wildfires in Canada. If such amounts of aerosols are concentrated beyond the limit of saturation of clouds, they cause less precipitation and more droughts.

Several intriguing problems existent up to date in the literature have been solved consistently, coherently and with true physical meanings through the physical principles of the open and closed evaporators.

All of the thermal behaviors of the 'closed' atmosphere reproducing the thermal behaviors and physical principles of the closed evaporator have been substantially and strongly confirmed by real data about the Arctic ice melting and about the planet. Every physical principle of the new theory matches with the other ones and with the real data. All of the real data shown for the Arctic ice melting and for the planet are *n*th proofs and confirmations that the planet behaves according to the physical principles of the open and closed evaporators, depending on the closing conditions by clouds, as extensively demonstrated by the present author. All of these achievements and real proofs confirm the theory described in this paper.

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