Title: Bursting the Atmosphere: what happens when rain falls up? 12/16/09

Summary: Global warming, though potentially devastating to our planet, may turn out to be a nearly temperature-neutral process dominated by physical changes in, and loss of planetary ice, snow and water, rather than a significant rise in atmospheric warmth.

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OVERVIEW

The phrase global warming may be as controversial as the event it portends: increased atmospheric temperature due to greenhouse gas effect. In fact, this phrase may be a misnomer as the event could manifest without any significant rise in temperature. The Earth contains three major heat sinks - solid water, liquid water and the atmosphere - which allow trapped solar energy to alter the planet's composition without raising its temperature. The short-term consequences of this phenomena might seem encouraging, but the long-term outcome could destroy the planet's water cycle creating a one-way process that ejects water into free space. The author presents a novel analysis of global warming using the *ideal gas law* and suggests *global phase change* as a more appropriate name for this event.

## INTRODUCTION

The End. Not the end of a story, a life or even a species. The end of it all. The end of the world as we know it, everything we know about it and every living thing on it. Throughout the ages, from Nostradamus to Edgar Cacye, pundits and prophets have postulated this catastrophic event with, as of yet, little end result. Although few doubt The End will happen one day - even astronomy predicts Earth's far-off doom in the final expansive death throws of our Sun - there is little consensus on the exact whens, hows and whys of this terminus. For while a singular ending may be easy to explain - the death of one person, the destruction of one city, the extinction of one species - The End of everything is a bit more complex. Why even the lowly cockroach would likely survive our own nuclear autocide, making weapons of mass destruction - chemical, biological or atomic - incapable of ushering in The End. No, The End would appear to exist only on the Hollywood extreme of this spectrum: massive asteroids, solar red giants, and black holes. Yet, is it possible that The End will not be all that complex? Could it be much simpler than galactic terrorism, nuclear reactions or even calculus? In the end, might The End not lie in something mundane as the *ideal gas law*? This is the question I would like to raise, and I will begin by phrasing it in terms of global warming.

## BACKGROUND

Global warming appears to be real, and its existence is an underlying premise of this paper. As to who started it - man or nature - that will not be addressed here. For important as it is to know a problem's cause in seeking a solution, I wish to only examine one possible consequence of doing nothing. I raise this consequence not as a guarantee of what will happen, but as a question, an impetus to inquiry, and an act of consciousness-raising. For if it could happen, it would be a shame to let it happen solely because it quietly advanced upon us while we remained unaware.

Another premise of this paper is the impact of global warming on the various components of the Earth's solid heat sink system. The major components of this system include the Arctic, Antarctic and Greenland ice caps. The minor components include all other glacial systems around our planet and, to a lesser degree, mountainous snow ranges. In addition, all of these large and small components are reinforced and replenished by seasonal snow fall. If we could re-morph Earth into a planet-sized glass of ice tea, then the land would be the glass, the oceans and seas would be the tea, and this gigantic solid heat sink system would be large ice cubes floating about keeping everything cool. By absorbing the latent energy of phase change, this system's components transform from a solid to liquid state and offset the solar heat that is trapped in our planetary glass by greenhouse gases. This is the same process which occurs when the smaller ice cubes in your drink fight off the temperature-destabilizing energy from your hand and the surrounding air. This produces one of the most astounding paradoxes of global warming.

Today, many nay-sayers point to the indisputable fact that the planet's temperature has only risen slightly, some claiming less than a degree on any scale you choose. If global warming did exist, shouldn't we be melting in our boots by now? And if we're not, then why worry? Look back to your last glass of ice tea for the answer. Someone hands you the familiar drink. You hold it cold in your hand. You drink in its cooling effects. Yet, if you hold it too long, drink too slow, what then happens? Over time, too much time, your ice cubes fail. They melt. They have absorbed all the energy they can possibly endure and are gone to phase change, leaving your tea abandoned to the inevitable: warming up. Our planet's solid heat sinks are also melting. They are exhausting themselves against the advance of global warming.

So, is that it? We accept global warming. We accept that global warming will sooner or later melt away all of Earth's ice and snow. We accept that when these frozen behemoths have all liquified there will be no effective counterweight against the pending thermo-metric rise. The End? No, for while global warming and loss of our solid heat sinks premise this paper, their manifestations only herald the end of stage one in this proposition: the loss of our first bulkhead against bursting the atmosphere. There are three stages toward bursting the atmosphere:

Stage 1 - melt the planet's solid heat sinks

Stage 2 - expand the atmosphere

Stage 3 - rain falls up

We have just seen the rationale behind stage one. Stage two is simply an extension of this same process once the planet's solid heat sinks are gone. But in this middle stage we need another savior, another way of counteracting the unforgiving rise in temperature portended by global warming. So, it is here in stage two that we turn to the next victim of greenhouse gases: our atmosphere.

Once all the ice and snow has melted, we will have lost the largest solid heat sinks on our planet. However, we will still retain two substantial fortifications against pending doom: a liquid heat sink system and a gaseous heat sink system. The liquid type consists of our rivers, lakes, seas and oceans while the gaseous one is our atmosphere. Yet, why would global warming impact our atmosphere ahead of our large bodies of water? Because, gases can react much quicker to a rapid accumulation of solar heat energy: they will expand long before water reaches its boiling point. It is here that the *ideal gas law* comes into play. Through $pV = nRT$, this law outlines the relationship between pressure ($p$), volume ($V$), the amount of gas present ($n$ - measured in moles), the gas constant ($R$ - about 8.31 joules / kelvin • mole), and temperature ($T$). This eloquent equation demonstrates that temperature is directly related to both pressure and volume, which means that a rise in temperature must be accompanied by a rise in either pressure, volume, or both.

The *ideal gas law* is another premise of this paper, and by it I assume that, just as the planet's solid heat sinks will follow the physics of phase change in stage one, our atmosphere will abide by the *ideal gas law* during stage two. Once Earth's frozen water vanishes and there is no longer any significant ice or snow left to absorb the increasing amounts of solar energy that are continually being trapped by greenhouse gases, the temperature of the atmosphere will want to rise. But will it? No, not significantly, for the planet's atmosphere is not contained within a hard shell as is a scuba diving tank's. Instead, it resembles a balloon whose plastic skin pulls inward like gravity while the constrained gases push outward, allowing for an increase in volume in response to increased internal pressure. Unlike a balloon, however, and though it currently just glazes the Earths' surface as a thin veneer, our atmosphere's outer boundaries are potentially endless as they extend upward toward outer space. In stage two this will be our temporary saving grace.

Given the *ideal gas law*, as the temperature of atmospheric gas rises slightly, so too will its pressure. However, as with a balloon, since our atmosphere is not constrained by a hard outer shell, this slight rise in pressure will cause a slight rise in volume. In other words, in the absence of the planet's solid heat sinks, for each slight rise in temperature that global warming induces in stage two, there will be a slight expansion of our atmosphere. Though this will be accompanied by an increase in the number and severity of storms and tidal surges we experience at ground level, this permanent expansion will counteract the preceding rises in both pressure and temperature, reducing both back to their original or near-original states. To better understand this, let's return to our hand-held toy.

The balloon example uses your muscle energy of exhalation to increase the amount of enclosed gas which then increases the internal pressure to expand the volume. In stage two, the solar energy trapped by global warming's greenhouse gases (which replaces your muscle energy and exhalation) will increase atmospheric temperature which then increases atmospheric pressure to expand its volume. In the former example, muscle energy and exhalation increased pressure to increase volume, while on the larger scale trapped solar energy heats the atmospheric gas to raise its temperature and pressure so there will be a rise in volume. In both cases, energy starting in one form - muscle or solar - produces an increase in pressure which then results in an expansion of volume.

Ultimately, the energy of global warming will pass through both temperature and pressure to produce increased atmospheric volume, allowing pressure and temperature to vacillate within narrow ranges (as your breathing vacillates between inhalation and exhalation while blowing up the balloon). This expansion will do two important things. First, as previously mentioned, each minute step in the expansion process will relieve and reverse the upward momentum on both pressure and temperature. Second, stage two will not only keep the atmosphere's apparent temperature relatively constant, it will also provide an outlet for our planet's liquid heat sink systems and its land masses to both cool themselves by radiating their absorbed solar heat into the atmosphere. This cast off energy will feed into the gaseous temperature-pressure-volume cycle, accelerating the process of atmospheric expansion, while at the same time cooling our large bodies of water so as to prevent them from reaching their boiling points.

As greenhouse gases continue to trap more solar energy, this process will be repeated over and over, slowing blowing up our atmosphere just like a balloon. By this repetitive, pumping action - increasing temperature raising the pressure that expands the volume which decreases the pressure that lowers the temperature - progressive global warming will continue to befuddle us with little significant, overall rise in atmospheric warmth. But whereas in stage one this thermo-metric homeostasis will be paid for by the visible, phase-changing extinction of our solid heat sinks, the price in stage two will be practically invisible: a slow, pump-like, outward expansion of our atmosphere. And this brings us to stage three.

There is a layer in the atmosphere called the tropopause. It is a the thin boundary between the troposphere - the atmosphere's lowest layer where our daily weather occurs - and the stratosphere where high altitude weather balloons fly. On average the tropopause lies about 6 to 8 miles above the Earth's surface, though its exact height can range between 5 and 11 miles depending upon latitude, temperature and season. The importance of the tropopause, however, is not its elevation, but what happens there. For it is in the tropopause that gaseous water reaches its maximal height before phase changing back into either its liquid or solid forms. Because of this, the stratosphere and all other atmospheric layers above it are virtually absent of water and, therefore, not part of our planet's water cycle. But the tropopause is a critical part of that cycle. It is the final safety net where water vapors are re-constituted into denser forms that gravity can pull back down to Earth's surface as rain, sleet, snow or hail. So far, given a relatively stable atmosphere, the tropopause functions well in preserving this water cycle. But what happens in an expanding atmosphere as presumed in stage two?

The tropopause will be affected by several important consequences that occur during stage two. First, as atmospheric volume increases, there will be a corresponding rise in the air's saturation point which means it will have an increased capacity to hold more water vapor: a powerful greenhouse gas in and of itself. In other words, increased volume will decrease the relative amount of humidity (there will be a greater volume of space in which to distribute the water vapors) allowing further absorption of gaseous water by evaporation from Earth's land, lakes, rivers, seas and oceans. Like an enlarging sponge, the atmosphere will draw up more water vapor as it expands during stage two, complimenting the aforementioned heat radiation by further cooling both the land and the liquid heat sink system. While this will also increase the total cloud canopy available to deflect solar energy away from the planet, it is unlikely to decrease overall global warming since the larger canopy will now be distributed over a proportionately larger area as the atmosphere expands outward (consider the increasing surface area of a balloon as it expands). Thus, proceeding unchecked, this expansion-absorption process might even counteract, or to some extent reverse the effects of rising sea levels caused by stage one's destruction of the planet's solid heat sink system.

Another significant consequence of stage two atmospheric expansion will be the elevation of the atmosphere's many layers. While the dimensions of these layers have been fairly constant over the relatively short time period that we have been able to measure them, in an expanding atmosphere they will likely rise in height. It is beyond this paper to predict the many complex interactions and alterations that will occur during this process, so another premise will be introduced: for the purpose of this discussion, as the atmosphere expands, its layers will retain their relative scales of position, size, composition and function with respect to each other and the atmosphere as a whole. This includes the assumption that no new layers will appear and no current layers will vanish. Thus, the troposphere will be presumed to continue being the lowest layer of our atmosphere, with the tropopause a proportionately thin barrier between it and the growing stratosphere above, and so on. They will all, however, swell in absolute size and, therefore, rise in height and volume during stage two. As each layer enlarges, it will push those above it further out into space, increasing both the surface area of boundaries between individual layers as well as the atmosphere's overall total height.

On the surface, stage two expansion seems to be a good idea as it appears to provide a safety valve against rising temperature due to the increasing amounts of solar heat being entrapped by greenhouse gases. Once absorbed at the Earth's surface, this energy can be radiated from land or water surfaces into the atmosphere so that the heat ultimately produces an atmospheric expansion where volume rises instead of temperature. Even elevations in sea levels may be ameliorated to some degree by the increased capacity of the enlarged atmosphere to absorb more water vapor, possibly yielding a more robust water cycle that can distribute rain over larger areas of our planet. Unfortunately, a particularly dark cloud looms on this horizon. It is located about 620 miles (1,000 km) above the Earth's surface where we currently enter the exosphere, and it is here that stage three begins.

The exosphere is the uppermost layer and limit of our atmosphere. It is the space where man-made satellites orbit the Earth. It begins at approximately 620 miles above the planet's surface, though its actual height can vary with latitude, temperature and season, just like the tropopause. It is from here that atmospheric atoms and molecules escape into free space. Though there is still enough gravity to recapture particles in this layer - even satellites fall back to Earth if they don't maintain sufficient orbit velocity to overcome gravitational pull - minute particles can fall prey to other dominating forces in the exosphere. Most prominent of these counter-gravity factors is solar wind.

The solar wind is a stream of charged particles ejected from the upper atmosphere of our Sun on a regular basis. It consists mostly of electrons and protons which travel at high rates through space. Amongst other things, when they enter the ionosphere (a layer found below the exosphere) these particles create a visible aurora called Northern Lights. Higher up, however, they can randomly collide with atoms and molecules in the exosphere, knocking them in all directions including into free space. The energy transferred during such impacts can provide sufficient escape velocity required to overcome the remaining gravitational force in our uppermost atmospheric layer. Unfortunately, if this escape velocity is combined with an outward trajectory, there is little hope that particular atom or molecule will ever return to Earth.

Though 620 miles may seem like a great distance to us, on a planetary scale it is rather small. If the Earth were shrunk to the size of a basketball - about 9.5 inches in diameter - then the tropopause's current veneer-like position would lie about 1/1000 of an inch above the planet's surface. In turn, atmospheric expansion would only have to raise the tropopause about 4/5 of an inch above basketball-Earth's surface in order to reach the exosphere's precarious gravitational boundary. On this scale, the tropopause need rise less than one inch before the planet's water can be swept into outer space, thereby bursting the atmosphere. This brings us to the dilemma of stage three.

In a continually expanding atmosphere as proposed in stage two, it is only a matter of time before the tropopause reaches heights of 620 miles and beyond. Once that altitude has been achieved, the tropopause will continue to function as before - an assumed premise of this paper - however, will gravity still be able to retrieve its water vapor that has phase changed back into solid or liquid forms? Will these reconstituted particles continue to fall to Earth as rain, sleet, snow and hail, or will the solar winds begin to sweep them into free space? In other words, once the tropopause reaches heights where gravity is no longer the predominant factor, will rain fall up?

## RESULTS

This is the disturbing question being raised by this paper, for if rain falls up we will have broken our planet's water cycle. Over time, the invisible stage two expansion of our atmosphere will raise water particles beyond the effective grasp of Earth's gravitational field whereupon they will begin a one-way exodus. The tropopause will no longer be a safety net that - along with gravity - returns life-sustaining water to the planet's surface, but rather a staging platform from which to blindly eject water into free space. The implications of such a process are dire not only for our species, but for every living thing on Earth. We could, in essence, burst our atmosphere by creating a hole through which the most basic life-supporting element might escape forever.

Bursting the atmosphere is by no means a simple process. As proposed here it takes three discreet stages and there are many challengeable premises this paper defines to support their advent. In addition, there are uncountable micro- and macro-factors which could be of more critical importance even if these stages should come to pass. For example, if the atmosphere does expand as proposed in stage two, could the relative concentration of oxygen in the troposphere drop to critical levels? If so, breathing might become of greater concern long before thirst.

Finally, there is the question of time scale, for if this could happen, then how long will it take to happen? Obviously, even as proposed here, we have yet to complete stage one. Evolution of the entire bursting process could be measured in centuries or millennia. It would do us well, however, not to look away, for even millennia are mere seconds on a planetary time scale. Also, there is some evidence that this process may actually have begun. In a 2003 article titled *Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes* (Santer BD; Wehner MF, Wigley TML, et. al.; Science 25 July 2003: vol. 301. no. 5632, pp. 479 - 483) the authors conclude that "the height of the tropopause - the boundary between the stratosphere and troposphere - has increased by several hundred meters since 1979." In addition, they "attribute overall tropopause height changes to a combination of anthropogenic and natural external forcings, with the anthropogenic component predominating." In other words, these authors have found the tropopause to have risen unexpectedly, and that this elevation in height is mostly due to man-made factors (anthropogenic). While this is by no means conclusive evidence of the atmospheric bursting process, it does provide ample food-for-thought when considering whether or not we are in stage one. Also, as the aforementioned article suggests, it is possible that these stages may not be discreet one-after-the-other linear processes. Instead, they may overlap and occur to varying degrees simultaneously which, if true, could make the advent of stage three sooner rather than later.

SUMMARY

In conclusion, when I was born no one talked about the possibility of melting our polar ice caps. Today, fifty years later, it is common to find news articles suggesting that in summertime the Arctic might be ice-free as soon as 2030. Under such circumstances, just waiting to see what happens does not seem to be a prudent proposal. The End may be coming to a planet near us - too near us - in the not too distant future. Though its exact form and time frame are still up for grabs, this paper is not a call to worry. Rather, it is a call to study, for by opening this can of worms we may yet find a means to fish for our long-term survival. In the meantime, there are many uncertainties for which we need answers, including the concept of global warming itself. For if thermo-homeostatic atmospheric bursting is possible, then a more apt term for the underlying culprit might be global phase change. Either way, it will be our individual and collective responses to this challenge which will determine how we all fare in The End.