Regenerate Earth

How hydrological processes naturally regulate and cool Earth's climate

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For the past 4 billion years water has governed some 95% of the heat dynamics and thus climate of the blue planet via a range of sequential and interacting hydrological processes and influences.

These processes helped Earth to sustain relatively stable temperatures some 33oC above physical background levels and liquid water in its oceans. This enabled life to evolve 3.8 billion years ago and survive, despite marked fluctuations in CO2 levels and its far smaller greenhouse component effect.

The microbial formation of the Earth's soil carbon sponge, its hydrology and the extension of plants over 29% of the planet' s land surface from 420 million years ago further enhanced this hydrological regulation and buffering of the Earth's climate, including its cooling over the recent millions of years, despite the natural progressive intensification of our sun and incident solar radiation.

Our degradation of these terrestrial bio-systems over the past 10,000 but particularly past 100 years has grossly altered these hydrological processes and the natural heat dynamics, cooling and climate of regions; as well as oxidised soil carbon sinks, as evidenced in the abnormal increase in CO2 levels.

Our disruption of these hydrological processes is accelerating dangerous hydrological climate risks that threaten many regions in the next decades. We can not now prevent of mitigate these by any level of CO2 emissions reduction or draw down. As in nature we can however safely and naturally avoid and buffer these risks by restoring the natural hydrological cooling processes and balances.

Given that we are abnormally warming the planet by an average of 3 watts per square meter, or less than 1% of the incident solar radiation, our imperative is to safely cool it by this 3w/m2, urgently.

The following outlines how we can do this practically and in time if we restore natural hydrological processes that our current land management practices have impaired. As different elements of this sequence of these 10 natural processes may be more relevant in different regions, this must be considered in designing optimal practical rehydration and cooling strategies for a particular region.

The 10 natural hydrological processes that govern the heat dynamics and cooling of our climate.

1. The Cooling effect of latent heat fluxes.

For water to evaporate from water surfaces or be transpired by plants it needs to be transformed from its liquid to its gaseous state as water vapour. This requires large quantities of heat energy that needs to be sourced from that surface and is transferred as latent heat with the vapour into the air, thereby cooling those surfaces.

Some 24% or 80 w/m2 of the 342 w/m2 of incident solar heat continually received on average at the top of the troposphere is currently transferred from the Earth's surface into the air this way. While the transfer from ocean evaporation may not have been grossly altered by us, we have grossly impaired these cooling latent heat fluxes by our destruction of over half the Earth's former natural vegetation that had a much higher transpiring leaf surface area than the oceans and the creation of some 5 billion hectares of man-made desert and wasteland over 40% of the land surface.

We have further impaired these cooling latent heat fluxes by our degradation of the Earth's soil via the oxidation of carbon from them which collapses their structure, capacity to infiltrate and retain rain and thus ability to sustain water for the longevity of transpiration by the residual vegetation.

Conversely we can rapidly and significantly enhance these latent heat fluxes and their cooling effects by simply regenerating these soil carbon sponges to restore their rainfall retention and supply capacity and thus the longevity of green growth with its cooling latent heat transfers to the air.

In the medium term regenerating the area of green growth via re-forestation action can also help.

Given we need to cool the Earth by some 3 w/m2, this should be theoretically achievable if we increase these latent heat fluxes or the longevity of green growth by some 4-5%. However this is also influenced by subsequent processes in this heat dynamic that also need to be considered.

2. The formation of warming, dimming and aridifying humid hazes.

As the water vapour that has been evaporated and transpired into the air cools, both at night and at higher altitudes it will re-condense on very small aerosol particles to form liquid micro-droplets or hazes, mists and fogs. As it condenses the latent heat used to sustain it as vapour is released. This will warm the surrounding air from which some of it may re-radiate up and back out to space.

When the sun comes out these liquid haze micro-droplets will then directly absorb solar radiation and again evaporate to form humid air masses containing up to 5% water by weight. This cycle of releasing and reabsorbing heat will continue daily while they remain in the air, continually warming that air as well as reducing the solar energy reaching the surface, as evidenced by global dimming.

The increased levels of these persistent humid hazes over many regions often now absorb and retain up to 20% or 60 w/m2 , contributing to the abnormal warming of the atmosphere and the planet.

We have grossly and directly increased the level and warming effects of these hazes via our emission of vast quantities of microscopic aerosols particles into the air to form haze micro-nuclei. While there are many natural sources of haze micro-nuclei such as organic volatiles from algae, trees and fine dusts we now emit many billions of tonnes of extra dust, carbon, particulates, pollutants and poly aromatic hydrocarbon molecules into the air that form warming pollutant humid hazes.

As the haze micro-droplets are far too small to fall out of the air under gravity they persist, creating major humid heat and bronchial health risks but also aridifying the regions below them. By persisting they also ensure that very high relative humidity levels occur daily as soon as they are re-evaporated to water vapour, which is the dominant gas in the greenhouse effect as discussed subsequently.

3. Surface albedo effects and the heating of soils.

When the solar radiation that has not been absorbed by the liquid humid haze micro-droplets reaches the Earth's surface it is either reflected back into the air and out to space or absorbed by that surface. The albedo effect measures the level of this reflection. White reflective surfaces such as clean snow may reflect 90% of the incident 300+ w/m2 whereas dark surfaces such as bare soils,may reflect less than 10% of this incident heat.

The level of ground cover, be it by suspended leaves, pastures or litter will also influence how well that surface is insulated and protected from warming by the solar radiation that was not reflected.

Similarly the organic matter and thus moisture content of the soil will also influence the ability of soils to absorb heat and the degree to which its temperature will rise as a consequence.

Thus soils that are well protected and insulated mostly cant absorb enough solar heat to get warmer than 20 oC. By contrast bare, dry, dark unprotected soils in full tropical sunlight will often have very low albedo levels and absorb most of the incident heat and warm up to over 50 and even 70 oC.

4. The re-radiation of infra red heat from vegetation and soil surfaces.

Whereas the incident solar radiation that is reflected or absorbed is mostly of short wavelengths when it is absorbed it is re-radiated from that body or surface as infra red heat of long wavelengths. The amount of infra red heat re-radiated from any black body radiator is governed by physics and is related to the fourth power of the temperature of that body as defined by the Stefan Boltzman Law.

As such hot bodies or soils re-radiate exponentially more heat from them than cooler bodies or soils.

How much infra red heat is being re-radiated from the Earth's surface is fundamental as it is the key determinant and driver of both the natural and our enhanced abnormal greenhouse effect.

As such hot exposed bare soils at up to 70oC will re-radiate vastly more heat and generate a far higher greenhouse effect than the identical adjacent protected, insulated moist soil at 20 oC will.

Effectively we can turn down the greenhouse effect dramatically and rapidly by simply keeping soils protected, moist and cool irrespective of the level of greenhouse gas molecules in the air able to absorb that re-radiated infra red heat and then re-radiate back to earth in the greenhouse effect.

Given that we govern the level of bare soil exposure and desiccation and thus its temperature via our land management, our land management is a primary determinant of our abnormal greenhouse warming, its dangerous hydrological extremes and impacts but also our means to limit such impacts.

5. How we can safely turn down our abnormal greenhouse effect, warming and climate extremes.

Three key variable govern the greenhouse effect; the amount of heat being re-radiated by the Earth and the numbers of water vapour and CO2 molecules in the air to absorb it, before their saturation.

As indicated above we can simply practically and rapidly turn down the amount of heat being re- radiated to safely minimize its abnormal warming effects. As outlined in the points #6 and #7 we can also beneficially remove the additional 50,000 ppm of water vapour from the air as a result of the persistent humid hazes. Seasonally and regionally this now constitutes up to 80% of our abnormal greenhouse effect.

Provided we returned both of these dominant greenhouse determinants to their natural buffered states the slightly enhanced greenhouse warming (0.2-0.3oC) from the fact that CO2 levels have risen abnormally to some 410 ppm over 250 years is not dangerous, acute and can be readily offset via the dominant re-radiation and water vapour variables.

In any case, ocean buffer and lag effects dictate that it may take centuries of even negative carbon emissions due to major draw down levels to return CO_2 levels and its minor green house effect back to natural pre industrial levels.

As discussed in Regenerate Earth and #10 below, urgent action will be needed to draw down up to 20 billion tonnes of carbon per annum from the air as negative emissions so as to regenerate the Earth's soil carbon sponge and restore these natural hydrological cooling and safe climate buffering processes, not simply to reduce emissions or return CO_2 to 300 ppm or some nominal level.

6. The natural conversion of the warming humid hazes into cooling, high albedo clouds.

As outlined in #3 and #5 above much of our abnormal warming has resulted from the warming effect of the enhanced humid hazes micro-droplets which warm the air directly by absorbing incident solar heat while in the liquid phase, and then by absorbing re-radiated infra red heat from the earth via the greenhouse effect while in the gaseous phase, resulting from the initial solar heat absorption.

We need to reduce and remove these humid haze micro-droplets if we are to cool the climate. This is difficult as the micro-droplets are charged and repel each other thereby persisting in the lower air. Our vastly increased emission of pollutant micro-nuclei has also contributed to their increased levels and persistence as has our impairment of their natural removal processes.

We need to better understand and restore these natural removal processes and how to help them.

As the haze micro-droplets are charged and dispersed, we need processes that can overcome this charge repulsion to coalesce them. Three forms of natural precipitation nuclei can do this via their variable hygroscopic coalescence ability. These are; ice crystals, certain salts and particular bacteria.

Most effective are the bacteria which contain highly hygroscopic organic solutes that can coalesce up to a million haze micro-droplets into larger cloud droplets and then dense high albedo clouds.

By coalescing these haze micro-droplets into dense clouds that cover 50% of the planet at any time these hygroscopic precipitation nuclei can rapidly convert the warming humid hazes into high albedo clouds. These can reflect up to 70%, and on average 33%, of the incident solar radiation back out to space to cool the earth by an average of 120 w/m2.

Given we need to cool the climate by 3 w/m2, a 2% increase in cloud albedo reflectance could readily offset our abnormal warming effect.

These two opposing but balanced hydrological warming and cooling effects is the lower atmosphere readily explains how nature could have regulated much of the heat dynamics and balance on Earth for the past billions of years and avoided Earth having a runaway greenhouse effect as on Venus.

Significantly this balance is regulated by the microbial production of two different types of haze micro-nuclei and the highly hygroscopic precipitation nuclei that coalesce and remove these hazes.

Science to date has failed to recognize these dual opposing nuclei and their hydrological processes and effects and assumed that they all operate by increasing water retention in the air as on Venus.

7. The natural nucleation and enhancement of rainfall.

These highly hygroscopic bacterial precipitation nuclei can not only coalesce the haze micro-droplets into the larger cloud droplets but also coalesce cloud droplets into raindrops, that are large and stable enough to fall out of the air under gravity. In this way the water that was transpired by plants from the Earth's soil carbon sponge in #1 can be returned as rain to again recharge that sponge and sustain this natural hydrological cycle and regulation of the Earth's heat dynamics and cooling.

The extension and reliability of this rainfall and hydrological cycling enabled microbial life, soils and vegetation to naturally establish across all of the ice free land on Earth following the last ice age. While we have degraded over 5 billion hectares or 40% of this into man- made desert and wasteland over the past 10,000 years, most of these arid wastelands still have river of humid air with 2-5% moisture contents continually flowing over them.

Many arid regions are blanketed by persistent humid heat hazes in summer that are often also highly polluted and threaten the health of people living under them from heat stresses. While there is adequate water in the air to regenerate such regions and re-establish their hydrological cycles, by removing the vegetation that naturally produced the hygroscopic bacterial precipitation nuclei we turned these regions into deserts. We can only regenerate them by restoring these nuclei processes.

More seriously and urgent we are currently aridifying large areas of our degraded but still vegetated global landscape via these same processes; resulting in an increase in persistent aridifying and warming humid hazes and the systemic decline in their nucleation to remove them via rainfalls. Vast regions and populations are and will increasingly be threatened by this systemic decline in rainfalls. Options exist to reverse this naturally and in time but only by recognizing these risks and processes.

8. The re-opening of night time re-radiation windows.

Up to 60% of our observed global warming to date has resulted from systemic increases in the night time minimum and mean temperatures relative to former cooler levels. This increase is associated with higher night time humidity levels and consistent with the increased, persistent humid hazes.

By contrast the previous natural rainfalls, often in the late afternoon and early evening, would have removed much of this humidity and these hazes from the air leaving clear starlit evening skies that would enable much of the heat that had been absorbed during the day to be re-radiated out to space, unobstructed by the water vapour blanket and it greenhouse warming effect. This night time re-radiation caused many, often tropical areas, having cooler night time temperatures than now.

While this rain would have removed much of the water vapour greenhouse effect it would not have altered the CO2 concentration or its greenhouse effect which would be the same day and night.

The fact that there is such a significant reduction in the greenhouse heat retention effect from removing just the water vapour greenhouse component but not the CO2 component effect, reinforces that water vapour is the dominant greenhouse gas and that we can reduce its warming effects via inducing its removal via rain so as to re-open these night time radiation windows.

We have no equivalent mechanism for reducing the much smaller CO2 greenhouse gas warming.

9. The restoration of biotic pump effects to restore rainfalls, rehydration and cooling.

The formation of the persistent enhanced humid hazes, their dual warming effects and the exponential increase in infra red heat being re-radiated from bare dry degraded lands exposed to solar radiation can all contribute to the creation of high pressure heat domes over such regions.

These high pressure heat domes invariably block the inflow of cooler moist air from marine or better watered regions that potentially could bring in some precipitation nuclei and rain. As such our degradation, aridification and desertification of prior moist regions can become self reinforcing.

Conversely the induction of rain in dry landscapes can aid plant growth, transpiration and surface cooling to create low pressure corridors and zones that can aid the inflow of such moist low pressure air and rain to help rehydrate and re-green these regions relative to nearby, similar arid areas.

These biotic pump, humid air inflow effects and zones may be seasonal or permanent and able to be induced via land management practices that optimize the regeneration of the soil carbon sponge, its water, infiltration, retention and thus the longevity of green growth and cooling in that zone.

Vast seasonal inflows of moisture from the oceans, such as in the Amazon and in different monsoons are influenced by these biotic pump effects and the aridity and management of the landscapes they flow over. As climates aridify and become less reliable and extreme, we should not take such humid air inflows at either a local or continental scale for granted. Instead we must regenerate and manage landscapes to optimize the effectiveness and reliability of such critical hydrological inputs.

10 Why regenerating the Earth's soil carbon sponge must be our key point of agency and action.

The above brief outline of the key hydrological processes that govern much of the hydration, heat dynamics and cooling of the blue planet reinforce how closely this sequence of natural processes are interconnected and sensitively balanced to regulate much of our regional and global climate.

They reinforce how directly and critical key microbial, vegetation and land management factors are in creating this hydrology, balancing these climate processes and effects and through these much of the productivity and resilience of the bio-systems we depend on fundamentally for our survival.

They also reinforce the critical reality that all of life, these bio-systems and our climate and its re-stabilization depends on and is governed by water. Water that is supplied from the Earth's soil carbon sponge and is returned to it via rain; to sustain a continuous efficient beneficial cycle.
Without that soil carbon sponge this hydrological cycle, our stable climate and bio-systems could not have evolved, continue to function or sustain as small fraction of the Earth's terrestrial productivity.

As such and as in nature in creating these bio-systems regenerating and protecting the Earth's soil carbon sponge is the key determinant to secure these natural processes, balances and outcomes.

Regenerating the Earth's soil carbon sponge is also the only point of agency we have through which to now repair our degradation and hope to secure our essential needs and future, hopefully in time.

We are responsible. To be so we must also be response able. We can be so practically and in time but only by regenerating the Earth's soil carbon sponge and through this the natural safe hydrological, climate and bio-systems outcomes essential in our existential self interest.