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Earth's Thermal Switch the Driving Force behind Climate Change

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Abstract

There has been an accumulative amount of data demonstrating that our world is warming and climates are shifting, but the cause and source remains speculative. Thermodynamic laws, in conjunction with data analysis, demonstrate that the Earth heats and cools through long-term oscillations in underground heat flux, thus warming our world to a level greater than the sun alone can account for. To confirm the impacts of this event, an Earth Simulator was created to reproduce the heat flux at depths of 8 to 9.6 Meters. Acting as our planet's secondary heat source in this process, the sun, in conjunction with the axial tilt, increases the amount of energy upon the earth creating an "overturn" event of energy. This generates our planet's thermal switch shutting down and reversing energy flow into the Earth forcing upwelling heat to build and is a natural form of energy conservation. Recreating the overturn event in a controlled environment demonstrates how increased surface heat increases subterranean heat through energy exchange over time, and how human altered land increases heat flow warming our world. It allows us greater insight into the importance of water and how it both retains and moves heat within the system, and how the soil aids in retaining this energy by resisting the flow of water. Using time and depth as units of measure, a means to determine the yearly gain/loss per season can be obtained to assess yearly alterations. Soil temperature data can be measured and evaluated, and then alterations to our environment can be implemented to amplify cooling. Current policies and proposals set forth around the world to combat climate change are addressing the after- effects of this heat, not the source. Our world is a finite world and adaptation of the natural habitat has its limits that we have surpassed. Until we make serious changes in our lifestyles to adapt to the needs of our world, our current trends will continue to amplify.

Keywords: Climate change; Environment; Temperature; Solar energy

Introduction

The amount of data and analysis within this report is a small percentage of the entire research, much is withheld to reduce the length and to limit the data to what's necessary to understand our world's thermal switch. Although known for several years by these researchers, theories are determined by reproducing the event in a controlled environment. Our world is dynamic and the exchange of energy between the sun and the earth is the primary driving force for our world's energy budget. By researching, analyzing, and then recreating observed events beneath the surface we are able to identify and analyze the impact on our world's climates. For this reason, reproduction of this event is critical in order to fully understand this process that even at times surprised this research team.

Reproducing the Earth's thermal switch allows us to begin the assembly of a "Theory of Operation" for our world, and will become a tool for other researchers to build upon.

The primary emphasis of this study is how the earth heats to a level greater than the sun alone can account for. Research is focused on the solar energy and how our world reacts to this heat based upon its cycles and the exchange of energy beneath the surface soil. A model of our world called "The Earth Simulator" is created to simulate temperature flow between 8 to 9.6 meters beneath the surface. Recreating this event brought clarity into the unique relationship that exists between the soil and water and how it generates our world's heating, storage, and yearly heat flux that impacts surface climates over time. The Earth Simulator utilizes upper radiant heat, lower subterranean heat, water injection within a sealed container that is filled with soil. This is recorded, documented, and cross-referenced to actual Earth data.

In order to obtain conclusive results, Earth Science must adhere to the fundamental laws of Thermodynamics. This is necessary in order to obtain conclusive results. Some basic laws referred to are that heat can only flow from hot to cold and cannot flow from cold to hot without forcing or work; that heat cannot be created or destroyed; and that energy in the form of heat can be conserved but always seeks equilibrium.

Based upon these basic laws, a cycle occurs beneath the surface soils of land exposed above the water that is within a temperate region. This cycle acts as our planet's thermal switch. With a system that cycles, storage of heat is determined by time and can be identified by temperature deviations by depth.

Our planet's thermal switch was first identified in early research at the University of Minnesota Agricultural Experiment Station by Baker and Swan (1966). In the spring, when the surface temperatures exceed subterranean temperatures, there is a reversal in energy flow that the research team termed an "overturn". When this reverses again in the fall, they termed this a "reverse overturn". The functionality of the overturn event described is a thermal switch that activates based upon heat levels. Heat seeks equilibrium and Isaac Newton's "Law of Cooling" can only be altered by subjecting the primary heat, in this case the subterranean heat, to a heat source equal to, or greater than itself. This occurs every spring when the axial tilt alters the daylight hours that, due to the increased time, warms the surface temperatures to a level greater than the subterranean heat. Upwelling heat is shut down creating a charging event, along with the additional heat being added from the increased

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daylight hours from above. The outcome is energy conservation for a season [1,2].

Activation of the thermal switch in the spring coincides with the spring bloom. Vegetation now exchanges energy through the water inducting heat into the soils and at night through transpiration accelerates heat discharge. During the day, the vegetation and thatch supplies surface cover that maintains a cool environment. When the energy reverses in the fall the leaves are shed and the convection cycle shuts down retaining heat. This is imperative for life that moves below ground in preparation for winter.

The farther one travels towards the equator, the greater the solar energy until impact on a region sustains continual overturn. This is where the average low temperatures stay above the average subterranean temperatures yearly. In these areas, predominantly near the coast and tropical regions, the vegetation remains green and doesn't cycle its leaves as in colder regions. By doing this, it sustains continual transpiration throughout the year, thus amplifying the discharging of heat.

In a system that charges and discharges with heat, when the charging rate increases greater than its discharge rate, an increase in temperature occurs over time. Since 1963, an average rate of nearly 0.05 degree Celsius per year had been recorded and verified by Baker, J.M. and Baker, D.G, (2002). Importantly, the amount of yearly alterations being researched are within this small parameter, an important fact that can be easily overlooked. Identifying the ground as storage is important in understanding the fluctuating heat cycles. Increased storage capacity increases temperature over time, while decreased storage decreases temperatures over time. What alter storage capacity is the charge rates that are based upon the length of time that the yearly charge to discharge rate occurs and the size of the area impacted.

Located at the University of Minnesota, St. Paul Campus, the Climate Observatory has a unique historical record dating back more than 50 years. Situated in the mid-latitude, at the center of the continental plate, and under continental climatic conditions, this location presents an ideal site for measuring long-term subterranean heat flux. The top soil is mowed and the area surrounding it remains predominantly farmland. On August 12, 2015, Minnesota State Climatologist Peter Boulay made relevant data available via written communication for analysis. Temperatures are recorded at depths of 1, 5, 10, 20, 40, 50, 60, 80, 100, 120, 160, 320, 480, 640, 800, 960, 1120 and 1280 cm depth since 1963. The 80 cm probe discontinued operation on December 20, 2009. From January 1, 2000 to November 12, 2015, data was available hourly with accuracy down to 0.01 degrees Celsius. Data for 1997 to 1999 was not available. Data was monthly from 1963 to 1996 with accuracy down to 0.1 degrees Celsius. Data needed to be filtered due to maintenance and/or repair for missing data, but these were minor. The website for the Observatory can be visited at (https://www.dnr.state.mn.us/climate/climate_monitor/climate_observatory.html).

As layers are discussed, these are only in reference to temperature differentiation based upon depth. The system as a whole can't be viewed as such. It needs to be viewed as a sealed mass with transitional regions and not isolated layers.

The solar energy upon the earth radiates downward no more than 20 cm (8 inches) in depth during the day at this location as shown in Figure 1. Depending upon land cover, the amount of energy will vary. By the end of the summer the heat is impacting regions up to 11.2 meters beneath the surface. How this occurs is the focus of this research.

On June 25th, 2000, at 0700 hours, the overturn occurred at the 480 cm level forcing the 620 cm region to begin to store energy. This is observed in the rising temperatures that follow in Figure 2. This overturn moves layer by layer and continues beyond the maximum depth of 12.8 meters. This generates multiple layers of heat mass, followed by cooling, in a form of pulses down into the territorial aquifers. This heat then disperses this energy throughout its mass when there is a positive heat flux. The territorial aquifers then reverberate this exchange of energy through the same overturn process into deeper regions, further slowing this process.

As the overturn occurs through the deeper layers of soil, the region that overturns will accelerate in heat proportionately to deeper regions. This is due to the regions above this layer being at a greater level of heat creating a lid. This forces the rising energy to build, along with the exponential force of downward heat. Depending upon the water tables, there may be several layers of energy being driven downwards through this overturn before diffusing into the regional aquifers. The average speed of this event is 6 feet per month, 72 feet per year. The level of heat

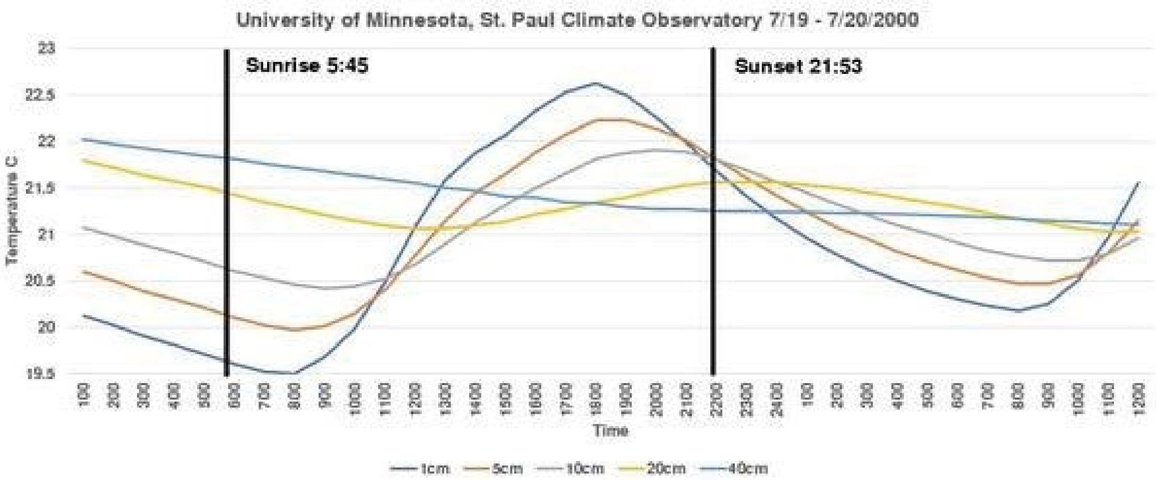

Figure 1: Daily heating over sod at the University of Minnesota, st. paul campus climate observatory.

is based upon the size of the area impacted and the amount of time the heating cycle is active. Primarily driven by the axial tilt, there are other factors such as the solar cycles, jet streams, precipitation, and other events such as large volcanic eruptions that influence our planets yearly overturn. Adding together all the underground temperatures during a given year from 160 cm to 1280 cm in depth, namely, eight data sets at intervals of 160 cm, the average yearly underground temperatures were calculated beginning in 1963. Using data retrieved from Twin Cities, Minnesota Department of Natural Resources, Minneapolis St. Paul Climate Data.

(https://www.dnr.state.mn.us/climate/twin_cities/listings.html), and the following graphic comparison was created. Figure 3 demonstrates the direct impact that the subterranean layers have on the surface temperatures. These two separate stations, with different teams, equipment, and records, are located 9.1 miles apart by road on separate sides of the Mississippi River. The 1997 to 1999 underground data was not available.

The temperatures above the surface are directly connected to the rising underground temperatures. The surface temperatures increase proportionately to the rising subterranean heat. Baker and Baker (2002) drew similar assessments. Additionally, one body (the atmosphere) cannot heat another body (the ground) to a temperature greater than itself, thus indicating that flow is moving from the ground up. This confirms the ground is heating the air and losing, on average, 4 degrees Fahrenheit between the ground and the thermometer on the surface due to the heat loss associated with the atmosphere. This provides the temperature threshold needed to be achieved in the simulation.

For further confirmation, data was obtained from Swan Lake Research Farm, United States Department of Agriculture, Soil Management Services Morris, MN (https://data.nal.usda.gov/dataset/swan-lake-research-farm-weather-station-ltar-umrb-morris-minnesota/resource/67788151-22e2-40a3-8eba 79e584e4b341). Selected for its rural location and its historical recording two inches below bare soil, and the air temperature directly above it, data was analyzed to calculate ground inversions from 2000 to 2017. Because the ground is typically warmer than the air during the winter months, December through February were excluded. A ground inversion would cause warming of the surface soils and is typical in the spring as the ground and lakes thaw. The sun naturally increases daytime temperatures by heating the surface, so ground inversions are amplified and identified by reviewing nighttime low temperatures and is displayed in Figure 4.

When ground temperatures and nighttime air temperatures were analyzed, never in the month of August had the air temperature been greater than the ground temperature two inches below the surface. Only 1% of the time in July and September had a ground inversion

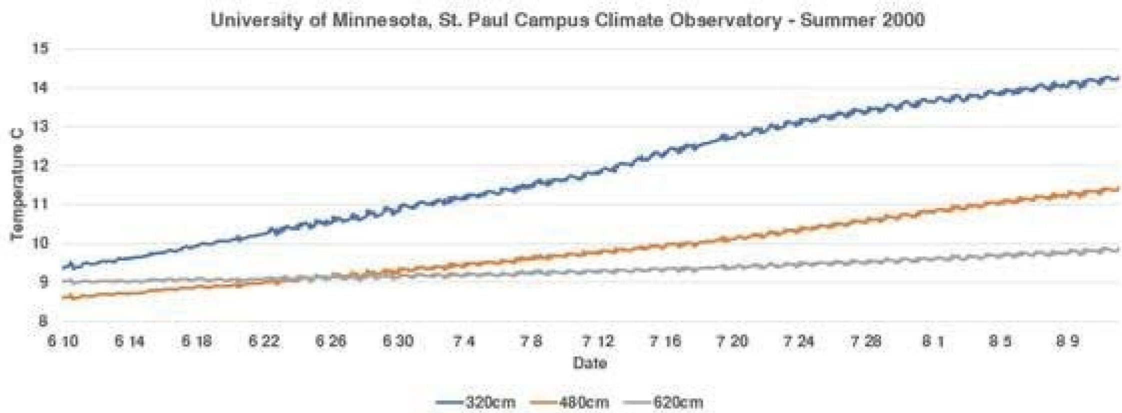

Figure 2: University of Minnesota, St. Paul Campus Climate Observatory 480 cm Overturn Event.

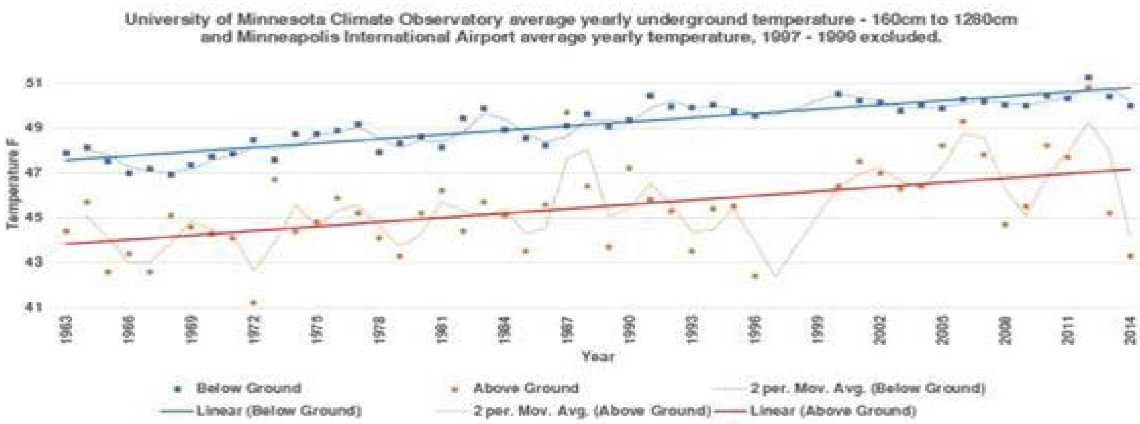

Figure 3: University of Minnesota, St. Paul Campus Climate Observatory, Overall Yearly Average Underground Temperature from 160 to 1280 cm in Depth and the Minneapolis International Airport Average Yearly Air Temperature, 1963 to 2014, 1997-1999 Excluded.

occurred. Heat flow at night was from the ground up and warming the thermometer 90.2% of the nights during these months. With months having 30 days there are 510 days in 17 years, and 527 for those with 31. Convection is used throughout the year for discharge of heat, but is amplified during the spring and summer bloom when transpiration is active. For this reason, this portion of the cycle is termed the convection cycle. During the winter, the transpiration is shut down and energy flow moves in the conventional way we have assumed, a constant flow from the subterranean to the surface which is termed the conduction cycle. To confirm the impacts that increased thermal mass has on surface temperatures, monthly differentiation in surface temperatures were analyzed. Consistency is vital for long-term analysis in determining alterations in surface temperatures. Altering locations or equipment can vary measurements. There were many variables in measurements and data collection since Daniel Fahrenheit invented the thermometer in 1724. This makes early temperature measurements and readings speculative. On August 10, 1868, the Army Surgeon General established the first set of guidelines for temperature measurements including specifics to the location and shelter used in taking measurements. The Minnesota Department of Natural Resources maintains records for a weather station located in Milan, Minnesota. This is a rural location noted for its long and stable record that was recommended by Peter Boulay for its consistency. An increase in subterranean heat will increase nighttime temperatures and delay the onset into winter. Figure 5 demonstrates the average nighttime low temperatures during September since 1894. Data can be accessed at

(https://www.dnr.state.mn.us/climate/historical/dailydata.html?sid=215400&sname=MILAN%201NW&sdate=por&edate=por).

Increased thermal mass will maintain its heat longer at night and require more time to discharge, thus resulting in increased nighttime temperatures. September is the month when cooling begins in preparation for fall and an increase in thermal mass would be identified by sustained heat. Since 2012, nighttime low temperatures have been reaching record levels. Figure 6 displays the 1963 to 1989 average yearly temperature increase by month when compared to the 2000 to 2018 average.

Increased thermal mass will require more time to discharge its heat in the fall and delay the onset into winter. This displays the yearly rate of rise that increased geothermal heat will produce. Without exception, all twelve stations examined across Minnesota demonstrated the greatest

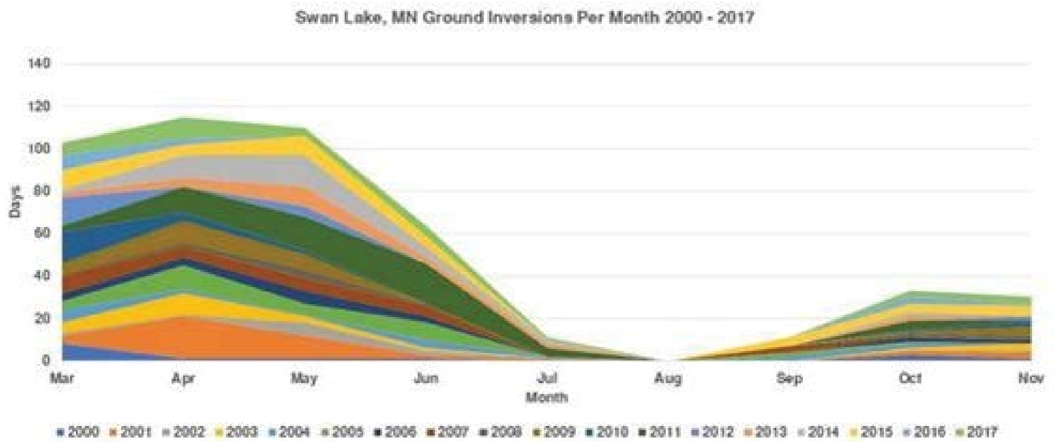

Figure 4: Total Number of Ground Inversions by Month over Bare Soil from 2000 - 2017. Data Compiled pfrom Swan Lake Research Farm.

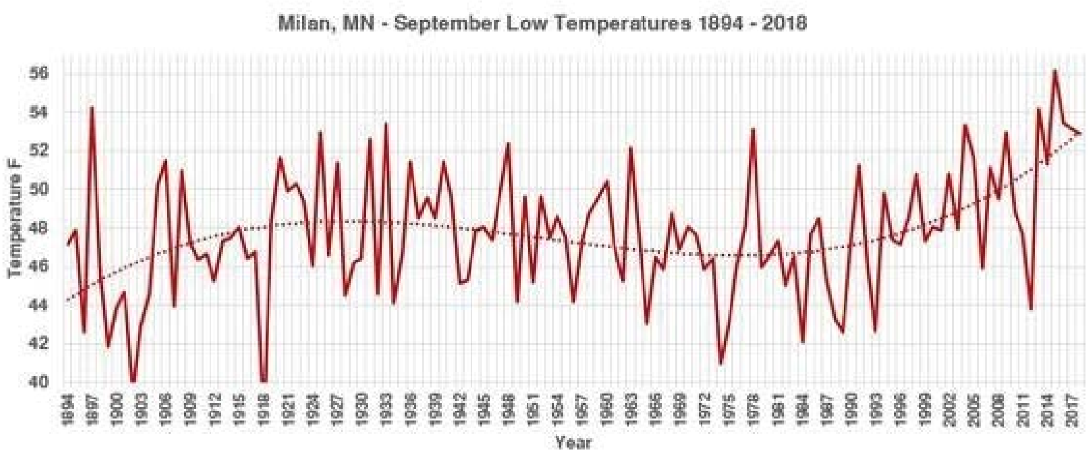

Figure 5: Milan, Minnesota September Low Temperature 1894 - 2018.

increase during the month of January while spring and summer demonstrated the lowest increase through August.

Warming temperatures require increased heat transfer. To confirm this, underground temperatures need to be compared between the natural environment of a forest and human altered land. Long-term historical temperature records in the natural environment are very limited, especially underground readings. In Northern Minnesota there is a location where data has been collected since 1961 at the USDA Forest Service, Northern Research Station, Marcell Experimental Forest. Temperature records were obtained via written communication on January 9, 2018 from Research Soil Scientist, Randy Kolka. The data is from 1961 to August of 2017 in various environments and down to a maximum depth of 2 meters. Records were taken once a week and two upland locations were recommended for comparison in this research. One location, termed "open upland," is kept groomed for the National Weather Service and the other is called "aspen upland"; these are displayed in Figure 7. The website can be accessed at https://www.nrs.fs.fed.us/ef/marcell/. The spring bloom arrives in the first part of May and ends mid-October. In the spring, prior to the bloom, we can see the temperature disparity begin and carry through the summer as the increased energy is radiated directly upon the surface soils with little to no resistance. In the fall, cleared land releases energy more rapidly and can be seen as the disparity narrows. The amount of gain exceeds this loss throughout the year resulting in increased thermal mass that slowly accumulates season by season. In one reading near the end of the year they reached equilibrium. This is the only exception for the year within this data bogs and fens also demonstrated an overturn. All open water that freezes experiences an overturn event when the surface becomes warmer than the deeper water in the summer. Overturn naturally occurs anywhere the surface warms to a temperature greater than the subterranean, depth and impact varies by region. This includes both land and open water, but what differs is open water overturns daily while open land generates an overturn yearly, and the impacts are vastly different. With convection, heat can move spontaneously towards the surface and will dissipate its energy into the surrounding waters. Once surfaced, it can readily exchange energy with the atmosphere. Due to their mass and depth, deep water equatorial regions were analyzed for long-term impact on deep water energy storage as a result of the daily overturn. Variations in geothermal heat distribution were picked up by deep water ocean buoys at depths beyond 100 meters. During the daytime, heat is generated upon the surface waters equally for the same amount of time per latitude. A series of buoys along the Pacific equatorial region with a long historical data base was analyzed for deviations by depth and is available through the National Data Buoy Center, National Oceanic Atmospheric Association. The site can be accessed at (https://www.ndbc.noaa.gov/). Figure 8 demonstrates the yearly average temperatures of the Pacific Ocean at a depth of 100 and 200 meters deep along the equator.

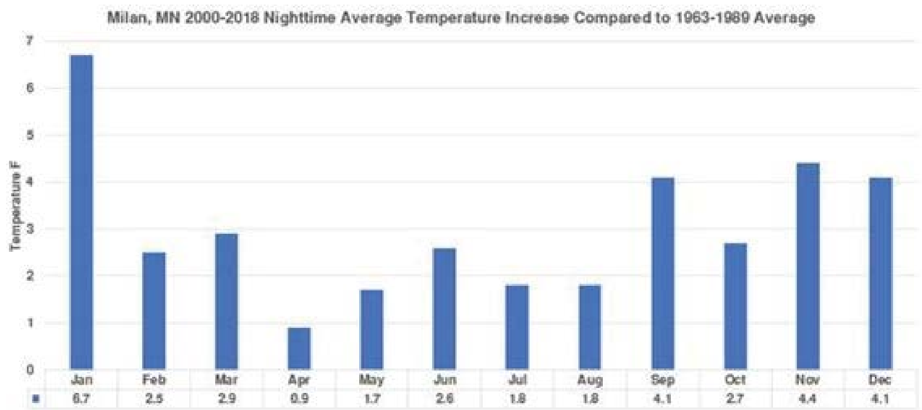

Figure 6: Milan, Minnesota Nighttime Temperature Differentiation Comparison of 1963 – 1989 Average Compared to 2000 to 2018 Average.

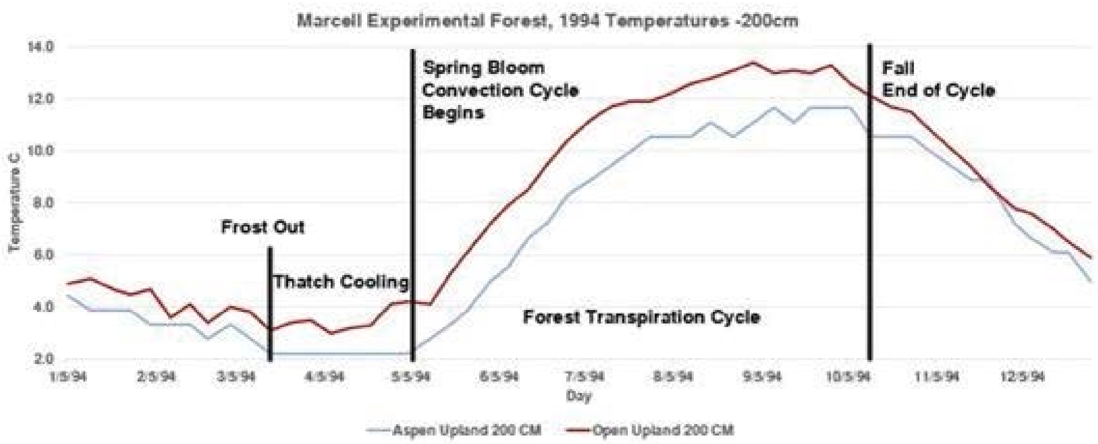

Figure 7: Marcell experimental forest temperature deviations between open upland sod cover and aspen upland forest, 200 cm beneath the surface, 1994.

The buoys in the chart match the buoys in the image that are marked one to eight. Buoys are subject to failure so calculations were based upon a complete year of data. Buoys one, four, five, seven and eight are for May 21, 2018 to May 21, 2019. Buoy two is data for 3/20/18 to 3/20/19, buoy three is 12/11/17 to 12/11/18, and buoy six is 2/6/17 to 2/6/18.

Along the equator the temperatures declined from west to east across the Pacific. The buoys near the North American coastal waters begin to rise slightly due to the proximity of the plate boundaries increasing geothermal heat near these regions. Extrapolating the data near the Australian Plate demonstrates an even greater increase in deep water temperature readings as the buoys near the Continental Plate. This is also a region known for having a high rate of volcanic activity, and deep water is no exception. The gravitational forces upon our world generate movement of water through the tides and carry this heat from west to east dissipating it out to sea. Because 200 meters is well beyond direct solar impact, this increased heat is a result of geothermal activity and the solar overturn upon the surface creating a lid on the latent heat rising and forces it to build daily. Over time, this creates the disparity in temperatures observed. If the sun alone provided the majority of incoming energy to heat the oceans, the temperatures would not display the variability they do.

Water, in liquid form, always seeks out its lowest point and is found deep beneath the soil due to the pressure increasing its boiling point. The critical point of water is 705 degrees Fahrenheit, so there is a maximum depth for water beneath the surface. Our world is wrapped with water, and land is everywhere, but in some locations the land protrudes above the surface waters. Some are small islands while others create the continental plates, but everywhere beneath the surface one finds water, just at various volumes and depths. This massive exchange of energy between the surface land masses and the oceans greatly amplifies the exchange of energy flow through the water resulting in the heating and cooling of the surrounding oceans along the shores far greater than the surface water can account for. The oceans then carry this energy out to sea and dissipate this heat using the tides and jet streams.

Open water offers no resistance in the movement of heat to the surface. Land that protrudes above the surface resists the flow of water and, in the resistance to flow, also resists the heat that is being carried by

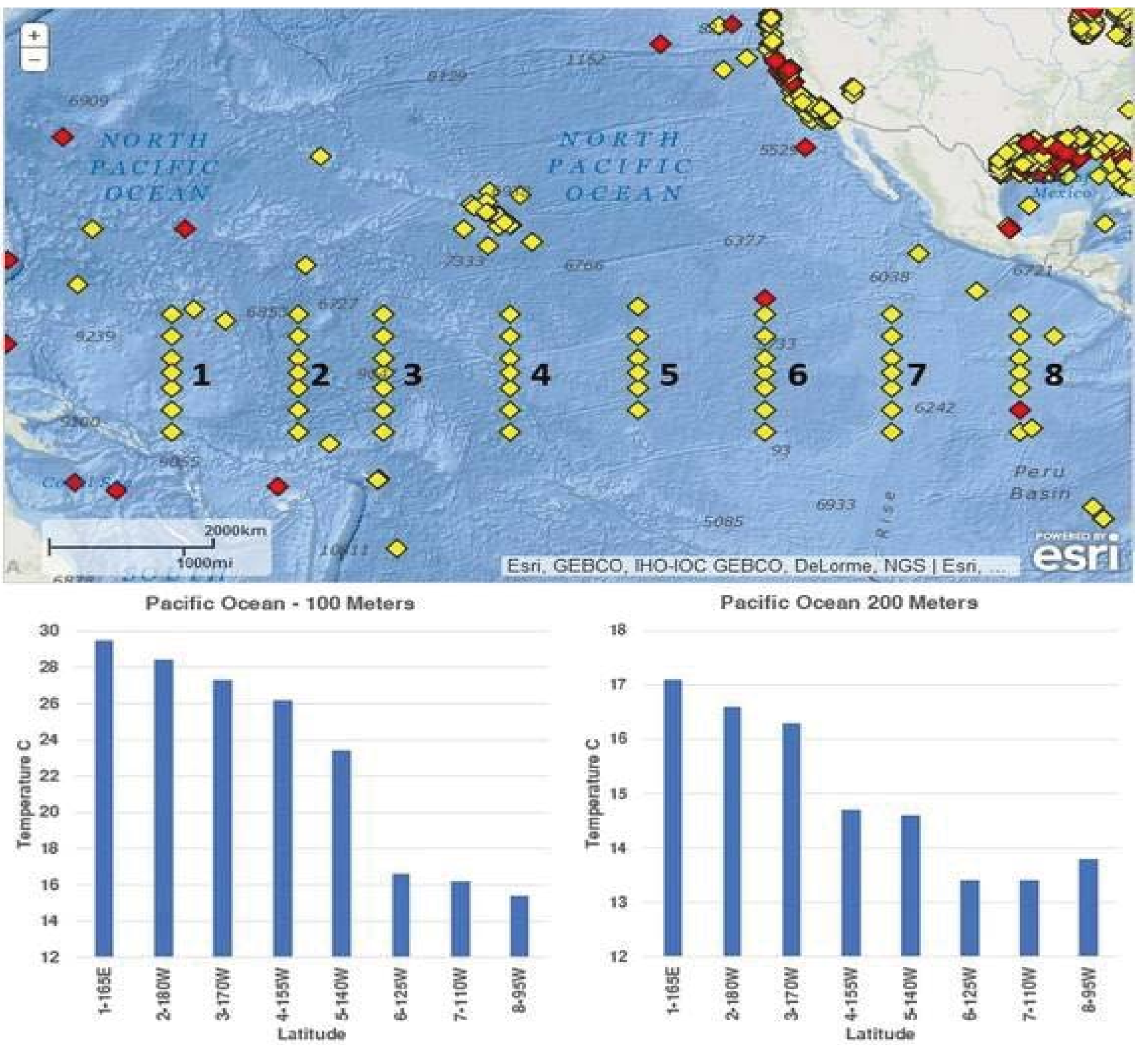

Figure 8: Pacific Ocean - equatorial yearly average temperatures 100 and 200 meters deep. Locations from 165e to 95w. National data buoy centre.

the water. This results in an inversion of heat compared to open water that gets colder as you travel deeper. Thermodynamic Laws indicate that resistance to heat flow must increase temperature. Like energy formulas that use resistance, the same needs to apply to the energy flow beneath the land masses. Experiments were conducted on the assumption of these basic means of heat transfer that our world uses [3,4].

Method

The location where the experiments were conducted was the basement the author's residence in St. Cloud, Minnesota. The environment is unheated and stable with the air temperature remaining within a variable of +/- one-degree daily. Local surface soil temperatures are frequently measured upwards of 140 degrees Fahrenheit, so this was the maximum heat potential used throughout the experiments.

The first experiments used damp soil without water injection within a well-insulated PVC pipe and the system failed to perform. Moving heat through soil dissipates water rapidly and resistance to heat flow increased as water declined. Attempting to force heat by increasing wattage only increased bulk heat, and the heat loss increased proportionately until it became too great to contain and the PVC began to melt. Ceramic, which is heated clay, has a very high resistance to heat flow. Clay is formed by sifting soil, hence, as compressed soil dries out and heats, there is increased resistance to energy flow. Water is necessary for the movement of heat indicating that surface temperatures rise due to the decline in surface water availability. To determine the relationship between the soil and water, preliminary tests of thermal capacity were conducted by heating soil, rock, water, and then combinations at various levels. This was accomplished by heating these to 140 degrees Fahrenheit and then recording the amount of time it would take to cool. The soil needed to be absent of water so it was heated in the oven overnight at 350 degrees Fahrenheit. It was then cooled and sifted to extract all the impurities. The rock was solid granite, so a hole was drilled into it and a probe inserted and sealed.

To ensure that equal proportions were applied, water was used to measure the displacement. The granite rock used in the experiments displaced 8-ounces of water, so this was the volume selected. Eight ounces of firmly packed soil displaced six ounces of water, a four to one ratio while unpacked soil was half this amount. A glass beaker was used that aided in visual observations and the temperature probes were mounted so they centered themselves within the center of beaker. The sidewalls generate cooling and alter the readings. Water was used for a base reference in all preliminary experiments. These experiments included a variety of combinations including temperatures, water ratios and water placement. Analyzing how heat is stored and moves underground and the relationship between the water and earth required several months of testing. These experiments produced some unexpected results that guided further tests. In order to better understand this dynamic cycle, a larger-scale assembly was needed that included water injection. An "Earth Simulator" was designed and created to simulate the heat flux observed at the 800 to 960 cm depth. (A material list and assembly instructions are available in the Appendix.) Subterranean heat, water injection, soil, and an external radiative heat source were used to simulate this event. The world has a constant flow of latent heat and an abundance of subterranean water, so this experiment only pertains to land exposed above the water in temperate regions while the sun, along with the axial tilt, is the primary driver we simulate.

Heat loss was a major issue encountered and cannot be stopped, only minimized. For this reason, an open top kiln with a sealed 12-inch diameter ceramic inlay was used. Two temperature probes were sealed in the sidewalls and two in the bottom to measure heat loss of the system. For cross comparisons to square meters in determining water flow and energy calculations, size comparisons were needed. A 12-inch round pot is 113 square inches, and one square meter is 1550 square inches. To compare calculations used in the experiment to earth data, 13.7 is the multiplier used to convert measurements to a square meter. Temperature gauges come in two parts, the digital remote and probe. Probes are not interchangeable between different manufacturers and once sealed into the Earth Simulator they cannot be replaced. Multiple temperature gauges were ordered and tested but those in the Appendix were used for the 5, 8, 11, and 14 inch depth. Temperature levels read down to 0.1 degree Fahrenheit while the remaining gauges, including the probe at the 2-inch depth, were equipped to read to a single degree Fahrenheit. For greater accuracy it is recommended that these gauges be equipped with those in the Material List in the Appendix, or superior. After constructing the frame, the temperature probes were calibrated by using water as a medium to verify accuracy. One probe used 0.2 degrees Fahrenheit cooler than the other three. Variations were in the probes and confirmed by interchanging the digital remotes. The 5-inch probe is for reference only and the other three were used for the 8, 11 and 14 inch depth due to their accuracy and consistency between them. The precision was surprisingly accurate, which is critical. As heat increased and decreased, movement remained constant between all four probes while the deviation remained constant. A heater blanket was initially tested but restricted the flow of water that is vital for the experiment, even if it is into the environment. For this reason, radiant heat is selected in order to control the surface soil temperatures. This is accomplished through low level heating and maintaining proper moisture. A 40-watt incandescent bulb was selected along with a directional shield for the best overall coverage of the area and to minimize loss. Using an IR camera, the optimum range for this level of energy placed the light source nine inches off the surface to best encompass the 12-inch opening. This was enough energy to raise the temperature probe two inches below the surface 6 degrees Fahrenheit [5].

The subterranean heater selected was a 25 watt, 120 volts (AC), flexible strip heater. A variable light switch was wired in series to the outlet to adjust the voltage for altering the heat levels. The open outlet was then used for voltage calibration and monitoring. Heat calculations were calibrated and recorded for reference and is displayed in Figure 9 in the Results. When 0.065 watts of power was applied to the heater blanket there was no sensation of heat. This was one of many estimates found when researching the level of energy rising upwards to the surface. A momentary touch provided more heat transfer into the heater than the heater was capable of producing and an IR camera demonstrated that a Samsung Cell phone sitting idle with Wi-Fi off and Bluetooth on was generating more heat. Based upon initial experiments, it was determined that the level of heat would need to be minimally 24 volts (AC) to initiate the kind of heat recorded when the frost is being driven out. To offset for heat loss, additional heat would be necessary by increasing the applied voltage. The minimum available on the dimmer switch of 32.7 volts (AC) was used. At 583 ohms the current flow is 0.056 amps or 1.8 watts. Converted to a square meter would be 24.7 watts. A 10-inch round piece of galvanized steel was cut out of a sheet of 20-gauge galvanized steel. Cutting several slits in the metal, it was then bent to resemble the blades of a fan to allow for the flow of heat and water without restriction. An image of this heater can be found in the Appendix. The heater was adhered to the bottom of the steel that is used for heat distribution. Enough sand was placed in the bottom to completely bury the heater by twisting the blades down into the sand. The system has no drainage so water flow needed to be calibrated

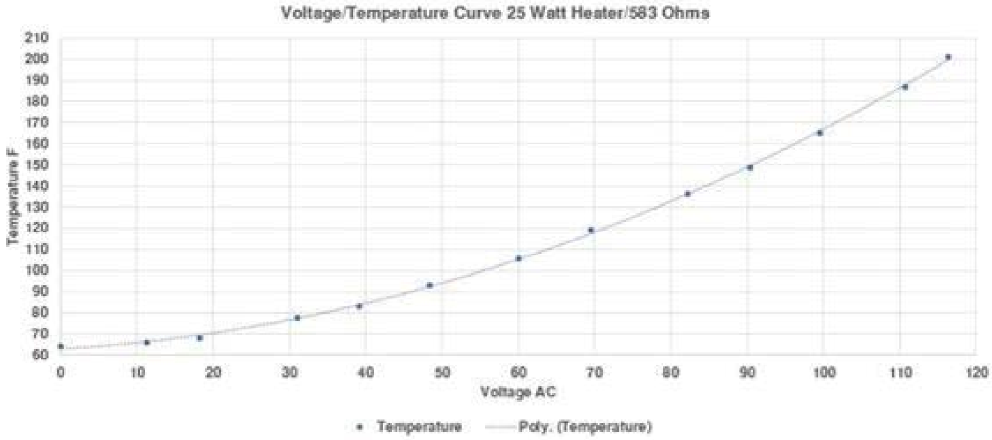

Figure 9: Heater blanket temperature according to voltage applied.

to avoid flooding. Looking to the frost line during the cold winters provided one set of results. The impact that the cold air has directly upon the soils over cleared land quickens the frost. Doing so, any water rising would freeze on contact and drive down further and faster in this environment giving a more accurate reading of rising vapor compared to soil under snowpack that can retain heat and prevent freezing. The Minnesota Department of Transportation gives historical frost depths by year that was used in determining the speed and depth of frost lines. Once the frost line passes 5 inches in depth, the frost line averages a half to one inch per day in the extreme cold. Moist soil will quicken the frost depth, while dry soil will build at a slower pace. By using the lowest rate gives us a measure of rising within dry soils and at ½-inch of frost per day converts to 3/8 inch of water. Next, a container of water was placed out on the barren soil and in the sun during the summer for 24 hours. The amount of water loss registered was also 3/8 inch.

The diameter is 12 inches and at 3/8 inch per day, the total daily amount needed is 23 ounces (0.68 liter). This was recorded at a drip rate of one drip every seven seconds and excess flow never occurred at this rate. Calibrating the drip system was unstable and at such a small rate any foreign object would cause obstruction. To ensure proper volume and avoid flooding the experiment the amount of water was restricted and added to the system on a daily schedule. Water drip should only be activated when the lower heat assembly is on to avoid water accumulation in the base. The amount of soil needed is 1.4 cubic feet, which is saturated with 2.6 gallons of water when firmly packed. The pot is tapered so the soil volume is slightly less, but with the sand a pebble rock, the water volume would be estimated within this range. To calibrate and ensure the water volume didn't flood the system, the soil is first well saturated and water injection shut-off. Subterranean heat is set to continuously flow at the minimum rate of 32.7 volts (AC) that provided 1.8 watts of power. The radiant heat of 40 watts was set for 12 hours on and off for ten days. The surface continued to demonstrate moisture until just after a week, and by the tenth day was relatively dry and shut down. If the loss is calculated at an estimated 1.8 gallons in 10 days, the volume is 23 ounces per day. The vaporization rate of the subterranean heated will vaporize four ounces of water per day while the heated soil and open air amplify the vaporization rate. If the soil is well saturated, it's best to operate with no more than four ounces of water for the first cycle and begin movement before maximizing flow. Gravity feed water injection was installed using a ¼-inch copper tubing and drilling a hole every four inches for two feet with a 3/32-inch bit and the end crimped. Using pebble rock, a layer was placed above the sand completely covering the heater region below. Making the copper line into a coil, it was placed into the chamber so the water could disperse throughout the system. Pebble rock was then poured in the chamber until the coil was completely covered. A thermos for the gravity feed water injection was placed on the ledge built for the light and connected to the copper tube. Blowing into the tube verified that the tube was clear. Room temperature tap water was then used for injection. After the shell was constructed and both the subterranean heater assembly and water tube was in place, it was filled with soil that was obtained from an excavated farm site for a new home located north of Mora, Minnesota. Soil in this region is classified as loam, a sandy clay mix with organic matter that is very fertile. Four, five-gallon buckets were collected for use. The soil was filtered for large rocks and debris and then allowed to air dry. It was then moistened to a constancy so that it could be formed by hand and packed. Probes were installed according to the instructions in the Appendix as filled.

In the final measurements, applied energy needed to be calculated. We needed to simulate the average yearly usable energy, not the surface energy from the sun that can peak well above these levels. A 40-watt light bulb with an estimated 25% loss would apply 30 watts upon the surface, and for 12 hours is 360-watt hours. Multiplied by 13.7 to convert to one square meter is 4.9-kilowatt hours per square meter. This was confirmed by the solar energy industry for monthly average energy at https://decisiondata.org/solar-by- state/minnesota/. A 50-watt bulb would generate 6,165-watt hours exceeding the average amount of energy in July with a 25% loss.

Recoding of the system temperature deviations over time was imperative for accuracy. For this reason, a time lapse recorder with two cameras were used for monitoring and recording. This made it possible for accurate review and confirmation. System recording is set at one image per second with one camera set to record the subterranean heat loss, the other monitoring the soil temperatures and surface area for visual observation. An initial power test demonstrated its ability to heat well beyond the 4 degrees Fahrenheit threshold needed. Running the subterranean heater at 70 volts (AC) and a 120-watt quartz light nine inches off the surface attained temperatures exceeding 75 degrees Fahrenheit and slowed. The system was shut down when the temperatures in the sidewalls exceeded 70 degrees Fahrenheit demonstrating a massive rise in bulk energy and increasing heat loss.

When assembled and operated, one becomes quickly aware of the system's ability to retain heat and its resistance to cooling. What takes hours to warm, can take days to cool. Ice or snow will be needed to amplify cooling, or a great deal of patience between tests. To bring the system down to equilibrium with the ambient air temperature it would be emptied down past the 5-inch probe, filled with snow, covered, and left for several days to cool. When cooling it is not necessary to attain equilibrium, but to be sure the probes reach temperatures at or just below room temperature and no positive heat retained that can alter the results. Once heat flow begins the system adjusts rapidly. When refilled it can sustain much of this water used to cool the system, as it was in the final run in the simulation. For this reason, water injection should be limited until heated. As long as the soil remains moist, results remain constant. With it fully prepared and cooled down, an independent control was performed on both the subterranean and radiant heat. This is to identify the impacts of heat based upon the energy applied individually. After complete the final simulation began and ran for three full cycles. The first cycle warmed the system, the second and third cycle matched indicating that equilibrium had been reached and the system was shut down. It was then analyzed and cross compared to actual Earth data The Earth Simulator duplicates farm fields in the early spring with radiant heat upon barren soil. For this reason, farm fields and the natural forests were measured and recorded for analysis to compare the impact of conversion. Additional measurements include sod and pavement measurements. These measurements were then analyzed and compared to the Earth Simulator.

Results

Numerous experiments had been generated before attempting to simulate the Earth, but four influenced the direction of this research and the formulation of tests for the Earth Simulator. In order to understand the thermal capacity of various conditions, heating soil, water and rock to 140 degrees Fahrenheit and then measuring the time it takes to move from 120 down to 80 degrees was monitored and recorded.

In this first experiment the following was recorded and then calculated using water as a base: loose dry soil was 48% efficient, dry packed soil was 73%, 3 ounces of heated water under lightly packed soil was 97% efficient, and the granite rock was 134%. Increasing water, even a small amount under the soil, amplified thermal capacitance rapidly. The next experiment was then generated with the same heating method using the granite rock, but with it submerged in room temperature water and recorded. What took three hours and 14 minutes to cool now cooled in eight minutes. Because the rock is in direct contact with the water, the same experiment was generated, but this time with the granite rock encased in a surgical glove sealing it from having contact with the water. This would demonstrate the ability of water to move energy through a confined aquifer. The experiment resulted in the exact same rapid loss, eight minutes. This clearly indicated that in order for subterranean heat to rise in latent heat, the subterranean water temperatures would need to rise.

In the next experiment water and soil was heated to 140 degrees Fahrenheit. One beaker was filled with 8 ounces of water, one with 3 ounces of water with soil packed on top to the 8-ounce mark, and the last one was soil with 3 ounces of water poured in from the top. The amount of time it took the three to cool from 120 degrees Fahrenheit to 80 degrees was recorded. The water took 73:19 and the surface-soaked soil was 53:25. The heated soil over heated water retained its heat for 68:19. Thermal capacity increases due to the resistance in the soils restricting the flow of water to the surface. Water expels energy rapidly once in contact with the atmosphere, but while sustained below the surface its ability to retain heat amplifies. The increase in temperature gradients measured beneath the surface soils that increases with depth is not a measure of heat flow, but a measure of the thermal increase due to the soil resisting the flow of water that is moving the heat that results in an inversion compared to open water.

In the last experiment the soil was heated to 120 degrees Fahrenheit. Three 16-ounce glasses were filled with 4.5 ounces of water each with different temperatures, one was 120 degrees Fahrenheit, one room temperature at 74, and the other was 42 degrees. The soil was filled to the 14-ounce mark and lightly packed as to not force the water to the surface. The ones with room temperature and hot water slowly equalized in temperature but the one with cold water demonstrated an unexpected result, the water flowed up to the surface and saturated the surface soil. Because a temperature probe was penetrating the surface, and the water flowed from this point first and saturated the surface, a second glass was filled without a probe. The surface soil became fully saturated again, just the probe allowed easier access to vent. What appeared to violate the laws was actually conforming to the laws. As the surface soil cools the surface contracts and seals the energy in beneath the surface. This in turn creates a negative pressure. With the subterranean being cooler, the heat is naturally driven downwards and in exchange, water flows up and the energy is released. This experiment was reproduced multiple times and was found to be dependent upon the heat of the surface soil and water availability. The flow is then amplified by the disparity between the ambient air temperature and the subterranean water temperature. Although the soil temperatures are sustained by the water, the water temperature is regulated by the soils [6,7].

Subterranean heater

Before operating the subterranean heat, measurements are taken directly on the heater blanket to prevent overheating. This is a rating of its maximum heat at the source while attached to the heat sink. Figure 9 demonstrates the heat curve produced by the heater based upon the level of voltage applied.

Isolating energy to the subterranean heater, an initial control was conducted. The subterranean heater was operated for 24 hours and 23 ounces of water injected from the drip system. The dimmer switch supplied 32.7 volts (AC) to the heater, 1.8 watts. Figure 10 displays the heat gradients by layer.

Ambient air temperature started out at 57 degrees Fahrenheit. A cold front came in and temperatures slowly declined. After returning home late that afternoon I was bringing in supplies and the doorway opens into the basement and the cold air descended cooling the air. A coincidence that provided a positive result. The temperature probe 2 and 5 inches below the surface responded to the decrease in ambient air temperature. Maximum heat rise recorded was 0.6 degrees Fahrenheit with any single probe below two inches and stabilized. The bulk energy slowly built beneath the surface to a maximum of 57.4 degrees Fahrenheit and stabilized but on the surface, like our world, the air temperature was the predominant force.

Radiant heat control: Isolating energy to the radiant heat, a control of the systems was generated. The light was a 40-watt incandescent light nine inches off the surface with a directional shield. This was operated continuously for 24 hours and recorded. Results are displayed in Figure 11.

The probe two inches below the surface reached maximum

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temperature in 12 hours after radiant heat was applied. This maximum heat potential also coincides with the increased sunlight hours in the spring as summer approaches, and declines in the fall with the approach of winter. The 8-inch probe registered a maximum temperature of 59.6 degrees Fahrenheit, and the 11-inch probe registered 59.5 and stabilized, more than double the subterranean heat control temperatures. The soil temperatures increased proportionately, the upper probe heating first and then slowly descends while the regions closest to the source increased the greatest.

Although the upper region attained its maximum heat in 12 hours, flow didn't stop and capacity continued to rise. In Figure 12, the sidewall of the system demonstrated heat loss after 21 hours. This is through six inches of mortar and one inch of ceramic demonstrating the level of bulk energy that was building under a very small amount of heat.

After 12 hours into the radiant heat being applied, the probe at 14 inches moved up to 58.1 degrees Fahrenheit and radiant heating continued for another 12 hours and then shut down (this is demonstrated by the vertical line in Figure 13). The heat continued to increase for two hours and retained a level above 58.1 degrees Fahrenheit for a total of 57 hours. Heat loss through the bottom and side walls amplifies this heat loss.

As the soil cools the surface begins to contract sealing the heat in and is evident in the discharge rate of the deeper probes. Like a check valve, the unit absorbed heat readily, but resists discharge. Due to this resistance in the soils, the radiant heat applied produced an overturn event demonstrating its ability to retain and move heat independently and is displayed in Figure 14.

Radiant heat is adding energy to this cycle and its ability to increase the latent heat, but to attain this level of heat required 24 hours of continually applied energy. The temperature levels and amplitude could not be duplicated with radiant heat alone. The 8 and 11-inch probes demonstrated an increase from 58 degrees Fahrenheit ambient temperature to a maximum of 59.9 after 24 hours.

Simulation: In the final simulation the heat applied remained unchanged. Radiant heat reached a maximum surface temperature of 74 degrees Fahrenheit. The ambient air temperature was 58 degrees

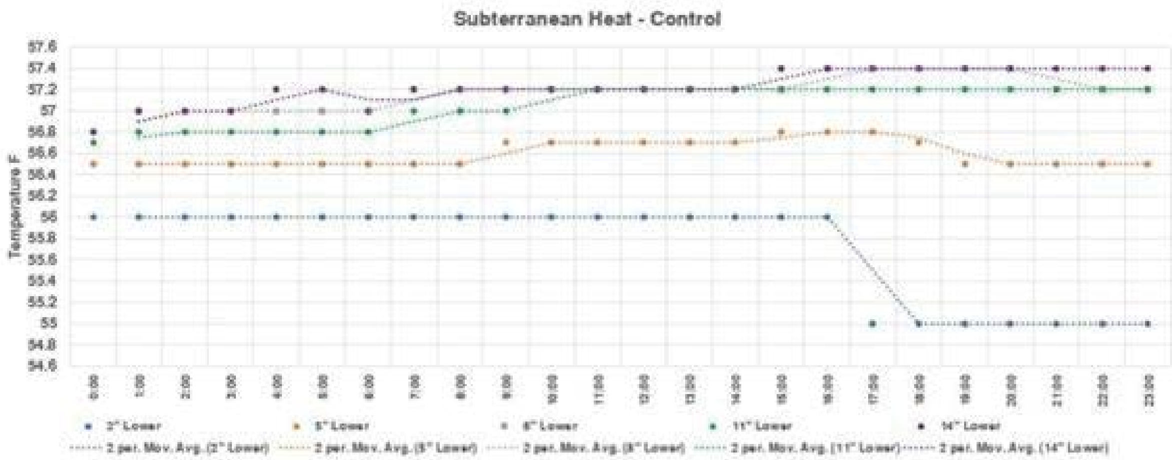

Figure 10: Subterranean Heat Control for 24 hours on 32.7VAC, 1.8 watts and Water Injec.

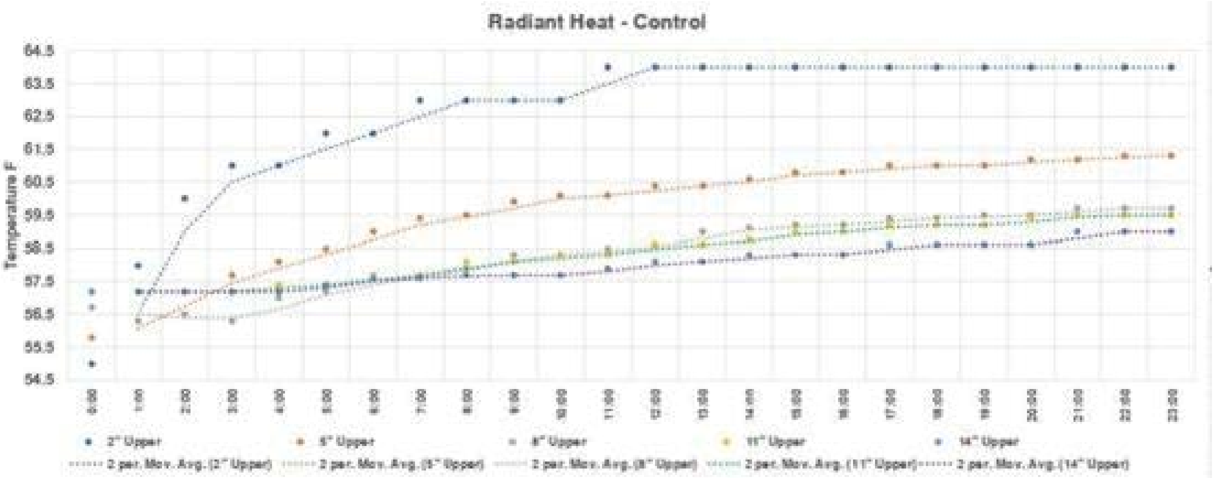

Figure 11: Radiant Heat Applied for 24 hours, 40-watt Incandescent Bulb 9" off the Surface.

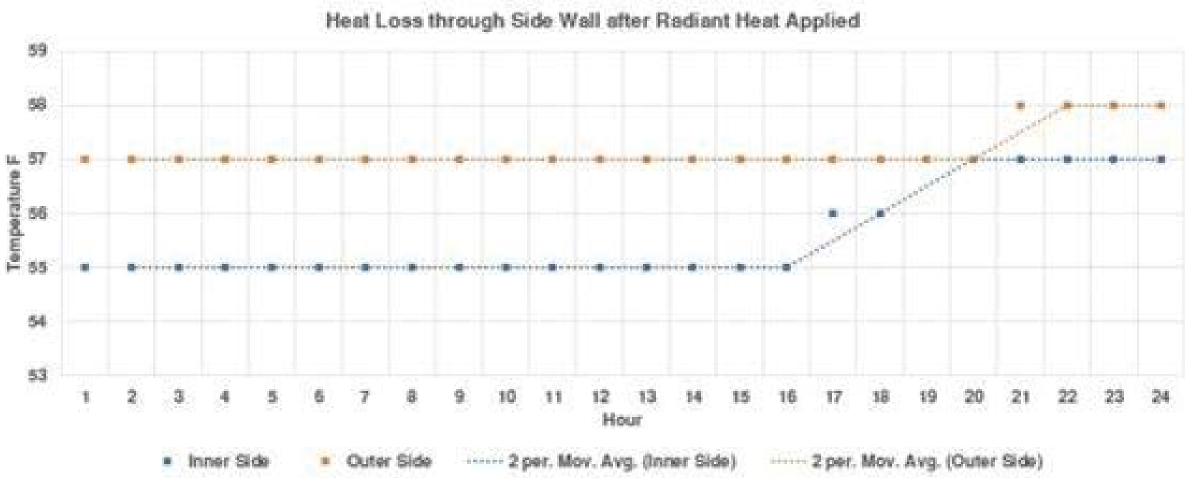

Figure 12: Heat loss through the side wall, six inches of mortar and one-inch ceramic wall.

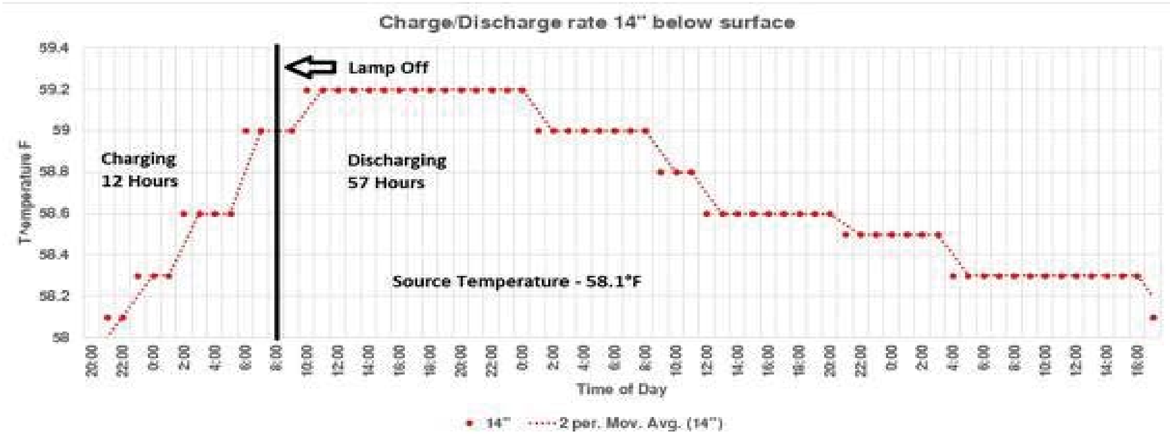

Figure 13: Charge/discharge rate of radiant heat 14 inches deep.

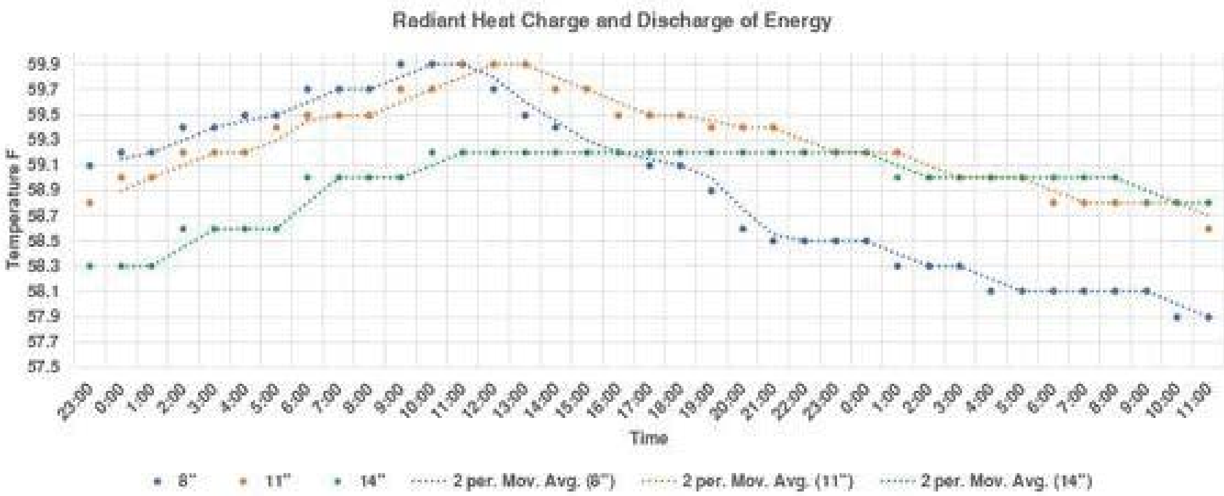

Figure 14: Radiant heating and cooling demonstrating overturn.

Fahrenheit. Soil was well saturated from cooling so four ounces of water was added twice to compensate for the subterranean heat. The first cycle increased the temperature and stabilized while the second cycle maximized the systems heat potential. The third cycle duplicated the second cycle with no increase. The system was then shut down meeting its maximum potential and analyzed. Figure 15 is the graph formulated from the experiment along with the year 2000 underground temperatures between 800 cm and 960 cm depth.

Temperature just greater than four degrees Fahrenheit above the ambient air temperature was reached demonstrating the amount of energy necessary to sustain this level of heat at this depth. When combined, the energy sustained temperatures greater than 61.7 degrees Fahrenheit for the 8-inch probe and 62.2 for the 11-inch probe. A maximum of 63.1 degrees Fahrenheit was reached for the 11-inch probe, and 63.5 for the 8-inch probe.

The predominant heat is the radiant heat. Radiant heat in the control was operated for 24 hours and reached a maximum 59.6 degrees Fahrenheit at 8 inches. In contrast, attaining maximum temperature prior to the completion of the second cycle, less than 24 hours of applied radiant heat, the same probe registered 63.5 degrees Fahrenheit. After 24 hours of radiant heat applied, and 48 hours of the less dominant subterranean heat, the system retained a temperature of 61.7 degrees Fahrenheit. The low temperature was 2.1 degrees above the peak high temperature produced from the radiant heat control. The applied radiant heat, in conjunction with the accumulative subterranean heat, created an overturn of energy resulting in the storage of energy through the cycle. This is classified as energy conservation.

Cold water injection: To run the final experiment, the light was replaced with a 90-watt quartz light and operated until the temperature two inches beneath the surface was 84 degrees Fahrenheit and the temperature five inches beneath the surface obtained a reading of 71.4. The light was shut down but the subterranean heat continued and one and a half gallons of 35 degrees Fahrenheit water was added to the subterranean, 23 degrees less than the ambient air temperature. Over the next 12 hours there was a visible alteration as the surface soils became saturated. This was demonstrating an exchange in energy between the heated surface soil and the cold water injected that reflected and confirmed previous experiments.

Earth data comparisons: In comparing Earth data, we must have two sources: the natural and altered measurements. Although urban development consumes vast amounts of land, it's shadowed in comparison to the amount of farmland necessary to feed the people. The Earth Simulator is a mirror image of farmland in the spring, barren exposed soil. When solar energy is applied equally to an area, such as a farm field or roadway in the sun, the temperature variations fluctuate within an average of five degrees Fahrenheit in all locations, but varies greatly between them. All vegetation registers a decline in heat levels while in bloom and water is available.

In the springtime, when the sun has been shining and there has been no precipitation, variations in temperature measurements attain the greatest disparity. When snow is absent, and before the crops germinate enough to shade the surface, the raw soil is exposed to the sun causing a vast disparity in temperature measurements. For this reason, temperature measurements are taken this time of the year demonstrating this disparity.

On May 31, 2019 at 14:15, temperature measurements are taken between a forest and an adjacent farm field in Saint Cloud, Minnesota. This was the fourth day with sun and no precipitation. Measurements

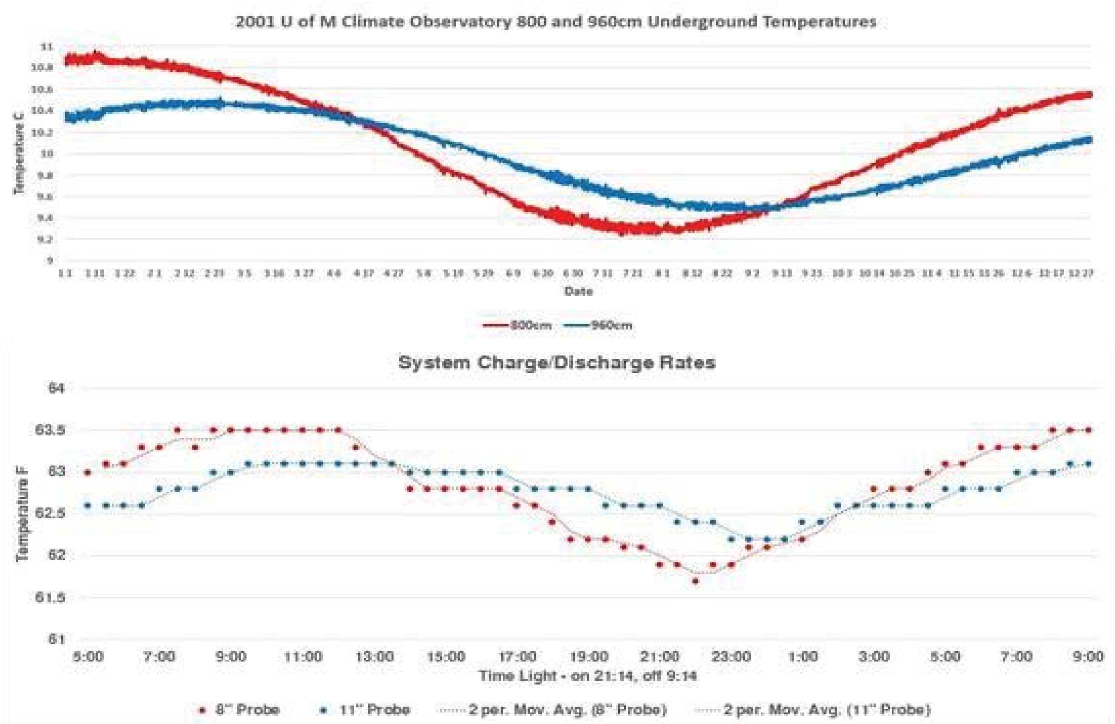

Figure 15: University of Minnesota, st. paul campus climate observatory, year 2000 and earth simulator overturn 24-hour.

were taken of the sod just outside of my home before departing. Surface soil temperature registered 92 degrees Fahrenheit and 72.1 four inches below the surface.

Using the same temperature probe for the air and below ground readings assured continuity within the measurements and an IR laser thermometer is used for measuring the surface temperatures. Temperature measurements are taken outside of the city limits of the air, surface, and four inches below ground within the same acre of land. It's a hazy day due to some wildfires but sunny, air temperature is 86.0 degrees Fahrenheit at chest height in the farm field and 83.3 degrees Fahrenheit in the forest. The blacktop road adjacent to the area being measured registered no greater than 115 degrees Fahrenheit. Farm field surface area selected was 116.2 degrees Fahrenheit and 80.8 degrees Fahrenheit below the surface. In contrast, the forest surface temperature absent of thatch was 75.4 degrees Fahrenheit and 56.5 degrees below ground. Under thatch and in the sun the surface temperature was 67.6 degrees Fahrenheit and 54.7. Thatch in the sunlight varied greatly by leaf reaching temperatures in the upper 80's. With the tree canopy and wind, the solar radiance upon the surface varies and is inconsistent resulting in lower temperatures than continually exposed thatch found in a yard or garden Although hazy, the energy was continually sustained and surface soil temperatures remained constant. Only when the radiant heat remains constant can accurate ratios of heat transfer be calculated. The low temperature in the morning was reported to be 53 degrees Fahrenheit. The surface of the farm field was 116 degrees Fahrenheit, an increase of 63 degrees. A temperature reading of 81 degrees Fahrenheit is registered four inches beneath the soil, 28 degrees increase in temperature levels. Open land forces the conduction of heat at a rate of 44% of the energy applied 4 inches beneath the soil, and 56% is being released into the surrounding environment. Forest without thatch increased surface temperature by 22 degrees Fahrenheit, and 4 degrees Fahrenheit below ground. The amount of energy being induced into the soil is 18%. With thatch, the increased surface temperature was 15 degrees Fahrenheit and 2 degrees Fahrenheit below ground. In contrast, although the surface of the thatch was warmer, its protective cover reduced the energy being induced down to 13%.

Based upon this daily data, the heat transfer rate of open farm land soil ranges from 26 to 31% greater than the forest. As a result, the air temperature over the farm land was 2.7 degrees Fahrenheit warmer within the same acre of land. Additionally, the temperature of the forest is going to increase above its natural levels due to the altered land amplifying induction, both above and below ground.

According to Isaac Newton, the ambient air temperatures will need to be less than 116.2 degrees Fahrenheit, but greater than 75.4 degrees Fahrenheit. This is directly proportionate to the amount of area between the two and the difference in temperatures between them. The high temperature reported in Saint Cloud for this day by the National Weather Service was 88 degrees Fahrenheit over groomed sod. This is a temperature loss of 4 degrees registered between the lawn measurements of 92-degrees Fahrenheit and the air temperature of 88. This coincides with the average yearly four-degree variable found between ground and air temperature readings.

Current heating indicates that the air temperature is greater than the soil in the forest while farmland was warmer than the air. Both battling for dominance, but with the length of the daytime hours, heating becomes predominant resulting in a warming forest. The forest is a surface buffer for heat transfer and to demonstrate this impact, another set of readings were taken a week later. On June 7, 2019, at 15:00, temperature measurements were taken in the same region. It was partly cloudy and the air temperature in the farm field was 87.6 degrees Fahrenheit. Surface temperature varied greatly based upon cloud cover ranging from 90 degrees Fahrenheit to just above 100. When sustained, it reached a temperature of 103.1 degrees Fahrenheit and 78.1 below ground when recorded. This is slightly less than the previous readings due to the increased cloud cover shading the surface from direct exposure. The four-inch probe was 2.9 degrees Fahrenheit cooler than the previous week and didn't alter with cloud cover.

The air temperature in the forest was 84.2 degrees Fahrenheit, 3.4 degrees less than the farm field and 1.1 degrees warmer than the previous week. Surface temperature under thatch was now 73.3 degrees Fahrenheit, a 5.7 degree increase from the previous week. Below ground registered 63.5 degrees Fahrenheit, an 8.8 degree increase from the previous weeks reading of 54.7. These readings demonstrate the slow methodical heat transfer that occurs through induction into the forest's biomass, but is being accelerated by the neighboring farm field.

Soil temperatures were taken on this same day of sod temperatures at 06:30 in the city of St. Cloud, MN. During the warmer months, equilibrium reaches its closest measurements just before sunrise. The surface soil was 63.6 degrees Fahrenheit and matched the air temperature, tree trunks, homes, even a vehicle sitting overnight were within one degree. The temperature four inches below ground was 70.4 degrees Fahrenheit. This level of heat beneath the sod in the early morning demonstrates the increased heat transfer that took place the prior day. This was 6.5 degrees Fahrenheit greater than the peak day time temperatures register in the forest.

Driveways, streets and sidewalks demonstrated a distinctive increased in surface temperatures. By obstructing the flow of water to the surface that facilitates cooling that even barren soil or dirt roads allow at night, heat is retained. This was demonstrated by the massive amount of transpiration evident by the water available within the lawns and gardens. As a result, the temperature levels registered three to five degrees warmer.

These temperature readings between environments are typical for this time of the year and as the crops develop and shade more land and the roots deepen, the disparity declines. In contrast, as the summer continues and precipitation declines, lawns and open land dry out and increase in temperature. The temperature differentiation between the environments underground demonstrates an increased heat transfer rate when a biomass is removed. This is due to the direct exposure to the solar energy resulting in forced radiant conduction into the soil.

Current experimentation into the application of this process into crop production started in late June. Using two cucumbers, one in a garden and one in the Earth Simulator without the heater, comparisons are being made. The Earth Simulator has the bottom open to avoid flooding, but is firmly packed with soil to resist discharge. On July 15, 2019, at 12:40, inspection of the cucumber demonstrated stress as the leaves were wilting. As the plant increases in size the demand for water increases. Watering had increased to 1-gallon of refrigerated water in the early morning, and another at sundown. The leaves were measuring 94 to 98 degrees Fahrenheit and the soil was 82 degrees 4 inches beneath the surface. One gallon of refrigerated water was added at 42 degrees Fahrenheit through injection beneath the roots. When measurements were taken an hour later the leaves had reduced to 88 degrees Fahrenheit and the soil increased to 86 degrees. Surface soil remained dry indicating that the water injection targeted into the plant. Targeting injection decreases water demand by greatly reducing surface evaporation experienced through typical irrigation and trickling methods in use. Because the plant is sealed and the temperatures amplify evaporation, it creates a negative pressure and is demonstrated by wilting. By injecting cold water below the roots, the roots are naturally drawn down to the water and act as receptors drawing in the cool water and in exchange, moves the heat down. This has been demonstrated multiple times during the daylight hours as the plant and soils heat. This demonstrates the heat transfer of vegetation through convection resulting in mass induction of a biomass. This disparity in temperatures amplifies convection and in turn amplifies growth, production, and cooling.

Discussion and Summary

Convection is the predominant means of heat transfer our world uses above, upon and below the surface soils. Heat conduction from the core is very low creating an extremely large temperature gradient beneath the surface and as a result, convection becomes very strong. The Earth Simulator recreated this and temperatures amplified. This temperature gradient is maintained by the water that is continually fed from heat below and a yearly charge/discharge event from above, hence creating a large buffer for the surface environment. Buffers are not fixed and increase or decrease if the heat transfer rates alter.

Heat loss and gain throughout the summer varies greatly and is dependent upon the surface environment. Because heat cannot be created or destroyed, heat gain can be identified knowing the storage of a system. Heat gain increases when discharge is restricted or input is amplified, while heat loss is amplified by increased discharge or decreased input. As the Earth Simulator demonstrates, this increases subterranean temperatures over time and impacts surface temperatures.

Simulating the energy flow in 24 hours and comparing this to a yearly cycle of the Earth is clearly an unequal comparison. What takes the Earth 17 days to move this heat is being generated in one day, but mass explains this. The simulator utilizes a very small amount of mass, but Isaac Newton's Law indicates that given enough time, equilibrium will occur if the heat applied remains constant. If the mass increased 100 times the amount used in the experiment, and heat loss remained constant, the same temperature increase will be sustained given enough time. Attaining and sustaining a four-degree Fahrenheit increase in the experiment will equalize in any given volume over enough time but keeping in mind that we must adjust for heat loss that is not associated with our world.

With the Earth Simulator, direct radiant energy upon the surface soil is used to generate heat just beneath this region. In doing so, we are also simulating altered farm land in the spring and can draw some assessments based upon the results. Although the solar energy is far greater, when resistance is constant in the soils, heat transfer and temperature alter proportionately with time determining the amount of change. The light bearing down is not uniform maintaining greater heat towards the center but near the edge there is some heat loss registering as low as 67 degrees Fahrenheit. Additionally, there is heat loss through the bottom and sides. In contrast, the Earth is sealed with no sides or bottom, thus remaining 100% efficient. The only outlet is through the surface, and water is the predominant means of transmission.

Using the data from the final run of the Earth Simulator, energy ratios are analyzed. Taking the lowest surface temperature of 67 degrees Fahrenheit to include surface heat loss, less the air temperature of 58 degrees, gives us a total gain of 9 degrees. Subtracting the surface temperature of 67 degrees Fahrenheit from the five-inch probe of 63.5 is a net gain of 3.5 degrees, or a 5.5 degrees loss. Net gain is 39% of the applied energy while 61% of this heat is lost into the surrounding environment. Actual earth data was calculated at 44% at 4 inches in depth supporting these measurements. With 40 watts applied, a 25% initial loss reduces the energy to 30 watts. With 39% efficiency this reduces this to 11.7-watts of usable energy into the system at five inches. The total amount of energy per cycle is estimated at 140.4-watt hours for 12 hours of applied radiant heat five inches beneath the surface.

To offset for heat loss, it's estimated that subterranean voltage would need to be reduced to 24 volts (AC) reducing the current draw down to 0.04 amps and producing 1 watt, 24- watt hours of energy. This is a 6 to 1 ratio of energy. For every watt of energy rising, there is 6 watts of energy being transferred into the system from the solar radiance. If we calculate any additional heat loss from the radiant heat, the energy ratio continues to decline to achieve the four-degree increase necessary. If the subterranean heat was reduced by any marginal factor, the Earth Simulator would not be able to achieve the four-degree increase needed without greatly intensifying the radiant heat, and in doing so greatly alters the amplitude of the overturn. We must also note that much of this heat that we term "core heat" is stored energy re-radiated back to the surface due to this cycle.

The final run in the Earth Simulator demonstrated that when cooling begins the surface soils contract and seals the heat in. This creates a negative pressure amplifying the movement of water towards the surface and in exchange, the heat moves down. Due to these findings, data analysis was reviewed once again for the summer months when nighttime temperatures exceed subterranean temperatures. What was assumed to be natural daytime heating was actually nighttime cooling when heat transfer occurred via the water. Figure 16 demonstrates this heat transfer between the surface and 320 cm deep. This has been universally measured in all years available from 2000 to 2015 and this graph can be duplicated using any year. This confirms the findings in the preliminary experiments and the Earth Simulator demonstrating the energy flow beneath the surface.

There was an identifiable dip in temperatures every evening as cool water was moving up through this layer, and in exchange warms 0.6 degrees Celsius this week. The first dip on the left was the nighttime of June 25th, and disruption occurs on July 1. Looking at surface weather, on the evening of June 30th, a cold front came in and there was 0.51 inches of precipitation. Nighttime temperatures were averaging above 70 degrees Fahrenheit every night and then dropped to 53 degrees Fahrenheit on July 1st and slowly began to warm and increased to 58 degrees on July 2nd. This can be identified in the underground temperature data 3.2 meters below the surface clearly indicating energy transfer. Although warming slowed, it did not stop due to the latent energy continuing to rise. Unable to penetrate the region above due to the heat levels being greater creating a lid, it's forced to accumulate and continues to slowly build without the increased energy exchange. This demonstrates the daily convectional energy transfer.

This process occurs when the Earth's thermal switch activates in the spring, but becomes amplified during this period of time due to increased nighttime temperatures. Figure 2 demonstrates this oscillation over a longer time frame and is picked up on multiple probes. Each dip is a night, and a decline in oscillation indicates a cold front and/or precipitation. Quantity and depth of exchange is dependent upon the disparity of temperatures, surface precipitation, and both subterranean water Temperature and availability. This confirms that these experiments apply to our world and how this energy flow moves below ground. This demonstrates how a biomass, such as a forest or prairie, attains its water necessary when there is not enough precipitation for its daily needs.

Radiant energy transfer means: The sun is our major energy source and radiates energy upon the earth using three natural forms of radiative energy transfer: convective, conductive, and thermal mass induction. This radiative transfer also creates a secondary heating effect known as an overturn that activates our planet's thermal switch. Humans create a fourth means of measurable heat transfer known as forced radiative conduction.

Convective transfer: This is the major form of heating with a world predominantly consisting of open water. Open water can transmit energy rapidly with the atmosphere and are vents for subterranean heat. These are open energy systems that use convection to move heat towards the surface until maximum density is reached at 3.98 degrees Celsius (39.16 degrees Fahrenheit). When maximum density is reached, heat is still driven to the surface but is diffused faster than its ability to gain and ice is formed. Unless its volume exceeds its maximum density, such as a deep ocean volcanic eruption, it will remain until the axial tilt allows the solar radiance more time to heat the body of water. By creating an overturn event on a body of water, energy during the day is trapped beneath the surface and is forced to build. Over time, this energy will increase in bulk heat and can be picked up on temperature deviations at depths beyond the impact of the sun. Figure 17 displays the disparity in bulk energy beneath the surface of the Western Pacific Ocean along the same longitude retrieved from the National Data Buoy Center, National Oceanic Atmospheric Association at (https://www.ndbc.noaa.gov/).

This demonstrates the differentiation of the bulk energy between eight degrees north and south in August and is a consistent pattern. August is a time when solar energy is peaking in the north compared to the south, but the southern Pacific is measurably warmer than the north down to 300 meters. With convection, bulk energy in the upper regions is a measurement of retained heat. Calculating energy in this volume of water is determined by the energy needed to heat and maintain this mass of water to the temperature differentiations measured. This would obtain an estimated amount of geothermal heat differentiation between these two locations. The buoys with the maximum deep temperature readings are those closest to the Australian Plate and demonstrate the heat discharge and is a region known for volcanic activity. Although the sun does not directly heat this region, it's because of the sun and the daily overturn of energy that forces this to occur over time.

Conductive transfer: This occurs over open land and rock absent of vegetation and is found predominantly in the deserts and mountains. The energy exchange in sand is rapid and can both build and release energy rapidly acting as an insulator from the earth and rock below. Regions like shorelines or river ways also have conductive transfer but also have massive water exchange on or near the surface that aids in

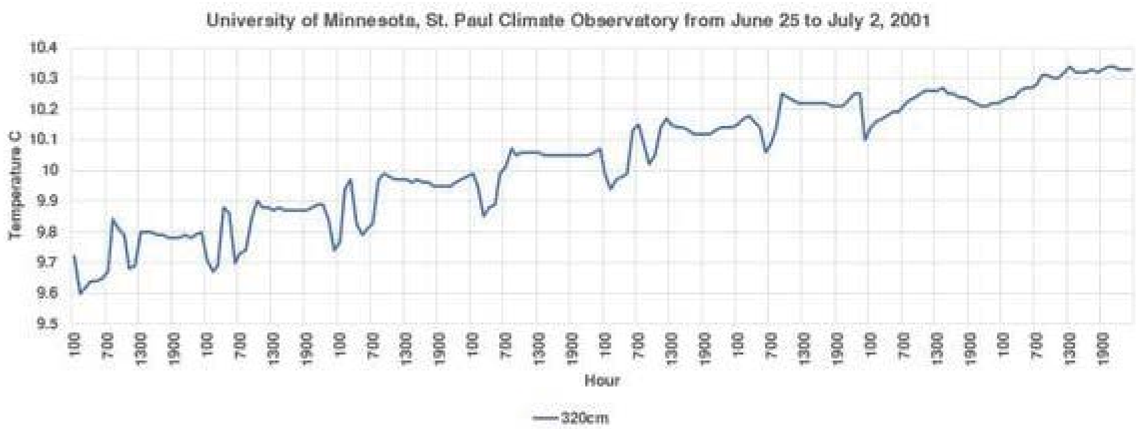

Figure 16: University of Minnesota, St. Paul Campus Climate Observatory 320 cm Temperature from June 25 to July 2, 2001 Hourly Temperatures.

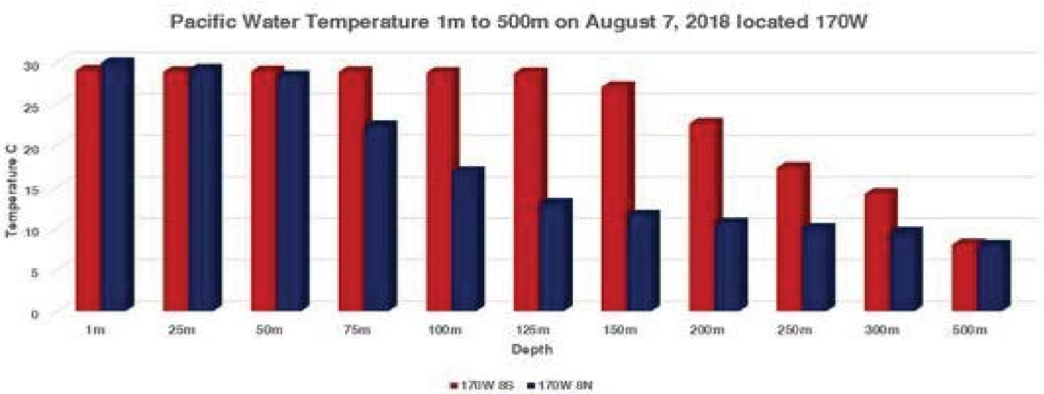

Figure 17: Pacific Ocean Temperatures 1 to 500 meters Beneath the Surface, 8N to 8S at 170W on August 7, 2018. data retrieved from the national data buoy center.

the rapid release of energy. Mountain regions remain cool due to their elevation and are also greatly impacted by snow during the winters and dew during the summers minimizing heat gain.

Thermal mass induction: This is the process of heating found over the majority of the Earth's land surface. This includes the forests, prairies, savannahs and jungles. The sun's radiant energy upon the biomass and through convection, conduction, and the ambient air temperature under pressure from the atmosphere slowly warms the surface soils. As the surface soils slowly increase during the summer months, this warmth builds in depth increasing surface temperatures through mass transfer.

The increased daylight hours amplify energy flow creating an overturn in the spring by reversing directional flow. The latent heat rising is shut down and energy below ground begins to build. This period of time also corresponds to the spring bloom that naturally shades the surface and accelerates heat flow through transpiration at night increasing heat loss through amplified convection. In the fall, the leaves shed and the convection cycle ends resulting in a slow decline in surface temperatures. The Earth needs to store energy for life that moves below ground so shutting down the convection cycle is imperative. When spring comes about, but before the spring bloom, the leaves act as ground insulation when absent of snow to protect the surface and maintain moisture. As the temperatures warm, decay increases and fuels the vegetation by accelerating carbon dioxide concentrations.

When measurements are taken in the surface soils of the forests and prairies there is a negative or zero temperature gain. The atmospheric temperatures exceed surface soil temperatures during the day. This indicates that these regions are maintaining a cooler environment, not warming it. In regions where ground temperatures are less than the air temperature, air pressure is a force multiplier of the ambient air temperature that induces heat into the biomass slowly inducting heat into the ground. When the sun shines down upon the surface, the surface of the thatch remains warmer than the ambient air temperature protecting the surface soil below and maintaining a cool damp environment isolating the atmospheric impact upon the surface soils to nighttime or periods of precipitation. This protective cover and slow induction of heat is our planet's protective layer that prevents overcharging prior to the spring bloom and maintains warmth in the fall before snow cover.

Forced radiative conduction: This is how humans alter the planet's climates and is a unique form of heat transfer. Even after fires or washouts of land, vegetation quickly takes root and a battle for sunlight continues throughout the summer months. When humans alter the land, the solar energy is able to radiate down directly upon the surface and forces the soils to heat at an increased rate. As this heat mass increases beneath the surface for longer periods of time and drives to greater depths, there is a slow increase in heat that transmits down into the territorial aquifers. In order for these to heat, all regions below this region will also need to slowly heat increasing temperatures over time. Due to their mass, the amount of increase has averaged 0.05 degrees Celsius per year for the 40-year long term analysis available increasing temperatures by two degrees Celsius or 3.6 degrees Fahrenheit from 1963 to 2014.

In regions where the ground temperature is greater than the ambient air temperature, pressure acts as a force multiplier moving heat away from the Earth and generates the buoyancy effect. On a hot sunny day, the temperature differentiation between the surface of an open farm field and the air temperature have been recorded upwards of 45 degrees Fahrenheit in Central Minnesota in the spring. Any heating of the surface or within the atmosphere that is greater than the ambient air temperature of its surroundings, is forced upwards from its source due to the pressure of the surrounding ambient air temperature. The opposite is also true, pressure will force colder air downwards from its source but the ambient air temperature is the determining factor.

Yearly heating/Cooling calculations: During the winter energy can flow freely between the subterranean and the surface but is limited to the resistance in the soils. Resistance is a primary variable of heat that impacts temperatures as Joseph Fourier's Analytical Theory of Heat demonstrates. This flow of heat between these two bodies, the atmosphere and subterranean, are determined by Isaac Newton's Law of Cooling that determines energy flow. The rate of exchange is based upon the temperature differentiations between the two, the resistance between the two bodies, the size of the area and the amount of time. Time is a primary element in calculating energy fluctuations in a system that cycles. The only way to stop the Law of Cooling is to present a heat source equal to, or greater than the source. This is where the amount of sunlight upon the surface due to the axial tilt is the determining factor.

Increase in temperature gradients cannot be used to calculate energy flow of a system that cycles and uses convection as its primary means of transfer. The heat flux between the atmosphere and subterranean is constantly altering and changing. The sun alters on its own cycles, the Earth on seasonal and daily cycles, and even impacts that can alter energy flow in a matter of minutes with precipitation. Instead of looking at scientific heating equations for heat flow, it's necessary to use conventional means of energy conservation that uses time as an interval when reverse engineering an unknown system that cycles. Unknown meaning "we don't have the blue prints on the system design". Because energy is always rising in a system that uses convection, bulk energy and time is used to formulate heat gain/loss in this kind of system.

Using the overturn event as a time variable will attain the amount of overcharging that's occurring. This will result in increased surface temperatures over time. The opposite is also true, greater discharge rates over time will result in decreased surface temperatures.

After 2009, the temperature fluctuations began to oscillate severely altering the precision of the overturn events. As a result, the years from 2000 to 2009 were isolated and analyzed. Determining the average yearly depth of the solar energy can be ascertained by the depth where the charge and discharge time balance. Figure 18 displays the hours of gain/loss from the summer of 2000 through the winter season of 2008/09.

From 2000 to the 2008/2009-winter season, the average depth where balance occurred was at 640 cm. Above this range there is amplified heat gain from the solar radiance requiring additional discharge time. The regions at 800 cm and below are regions where additional heating or cooling occurs impacting long-term climates. This region is not seasonal, it's cumulative, so the yearly average is the amount of positive energy adding to the subterranean every year. For this period of time, the yearly average charge rate was just more than 12 days per year greater than cooling, and 10 of those days the energy is so great it extends down to 960 cm. If we calculate that a seasonal charge rate is six months, then it would only take 15 years to add an additional year's heat to the subterranean. The regions below 800 cm were added together by year demonstrating the total increase time in hours and is displayed in Figure 19.

The Earth's seasonal cycle differentiates from our calendar and occurs in April and October at 160cm, thus overlapping years. Hours can be based upon the summer of that year with the preceding winter, or the winter that follows. The graph selected was winter that preceded the summer for that given year. Without data available for 1999, the year 2000 could not be calculated and begins with the year 2001. When the heat cycle is greater than the cooling cycle, the Earth retains energy and increases in temperature. Both 2003 and 2005 displayed a decline in hourly charging that released more energy than it conserved. This would result in a brief period of subterranean cooling and can be seen in Figure 20.

When there is an increase in hours retained, there is also a slow methodical rise in subterranean temperatures that goes beyond the depths of these probes. The greatest increase during this period was the 2005 to 2006 year when there was an overall increase of just 0.22 degrees Celsius for the year. Because it's cumulative, the total increase above 9.5 degrees Celsius (50-year average) was 4.17 degrees Celsius (7.5 degrees Fahrenheit) above normal. This region is increasing at an average rate of only 0.05 degrees Celsius per year or 0.35 degrees Celsius for this period of time on average. This indicates that the majority of this energy is exchanging with the bedrock and deeper regional aquifers. This pattern will continue to slowly increase subterranean heat until the discharge rate becomes greater than its charge rate.

To condense, view a yearly cycle as 72 feet of soil with energy flow moving down. To have 36 feet of cooling and 36 feet of heat would balance the system. To have 42 feet of heating and 30 feet of cooling will result in warming, and 42 feet of cooling and 30 feet of heating will end up with permafrost over time. Time is the variable that's a slow and methodical yearly cycle creating a buffer for stabilization of the surface environments.

According to the laws, as pressure rises in a sealed system, temperatures will rise. Increasing the temperature of the territorial waters will build and force the lower regions to increase in temperatures through this same overturn of energy. The deep aquifers will exchange energy via the water with the now warmer territorial waters. In doing so, heat will move down increasing vapor pressure and explains the fluctuations being registered in the underground probes. This has, over recent years, been observed as massive subterranean oscillations in temperature readings. Figure 21 displays the final data set available in 2015 at 1280 cm in depth compared to 2001. What appears to be a potentially faulty probe is confirmed in the data of adjacent probes. The timing of these pulses of energy correspond to the pulsing of other probes that only water can provide at these depths. This demonstrates the vapor pressure and increasing thermal mass that has, and continues to increase over time through exchange.

Accelerated heat will amplify when equilibrium is reached between the territorial waters and the lower regional aquifers. Until

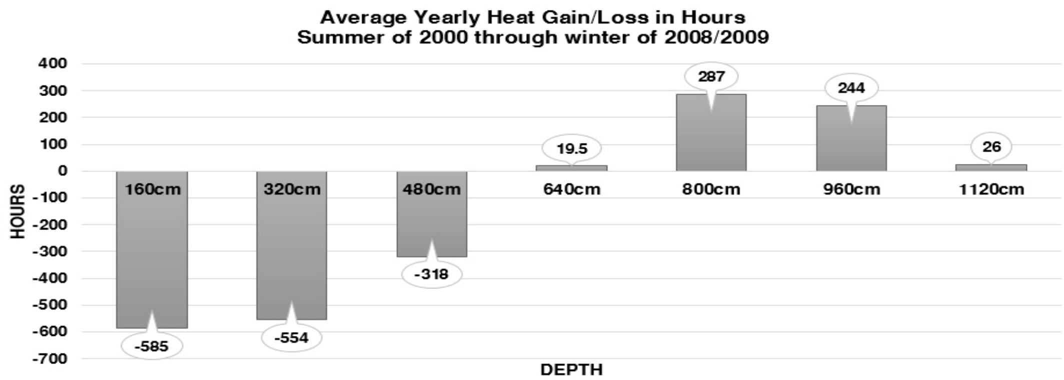

Figure 18: University of Minnesota, St. Paul Campus Climate Observatory Yearly Gain/Loss in Hourly Overturn

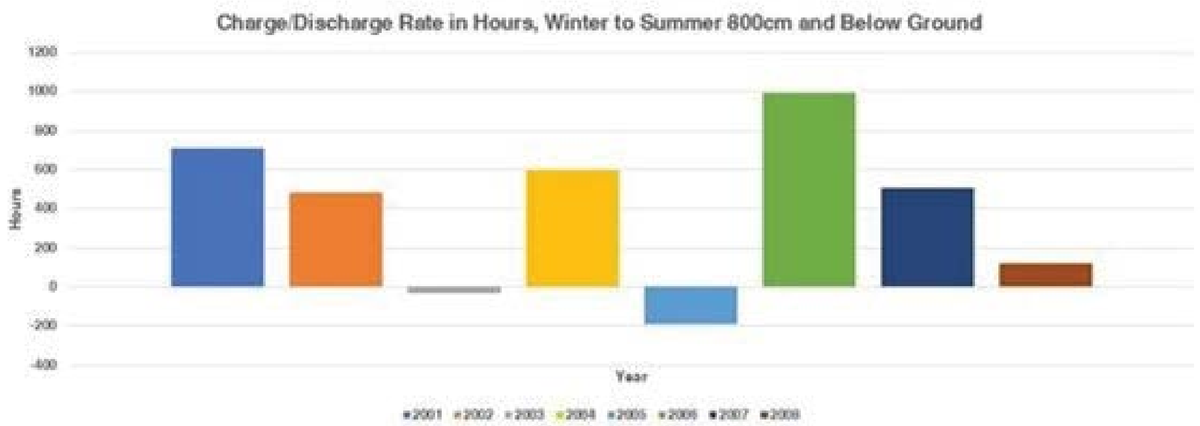

Figure 19: University of Minnesota, St. Paul Campus Climate Observatory 2001 summer to 2008/09 Winter Underground Temperature and Number of Hours the Energy Charge Rate Greater/Less than Charge Rate.

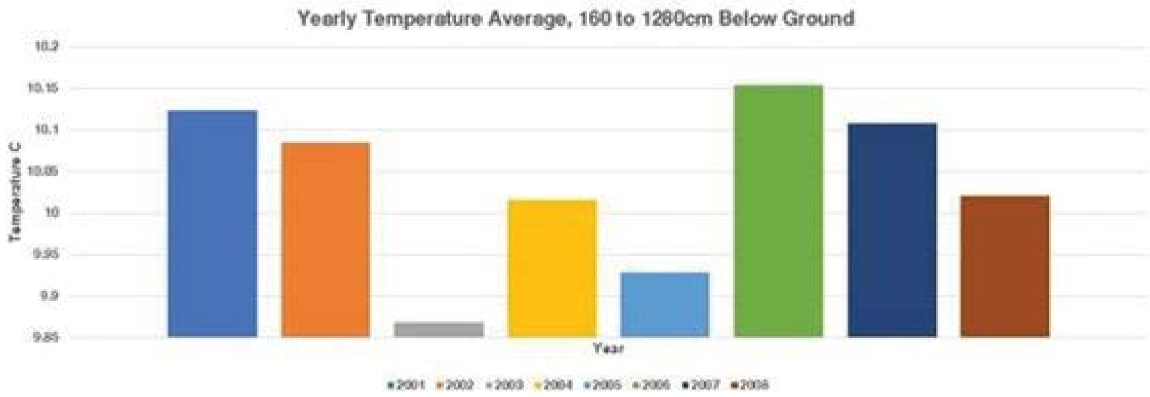

Figure 20: University of Minnesota, St. Paul campus climate observatory average below ground yearly temperatures from depths of 1.6 to 12.8 meters in depth.

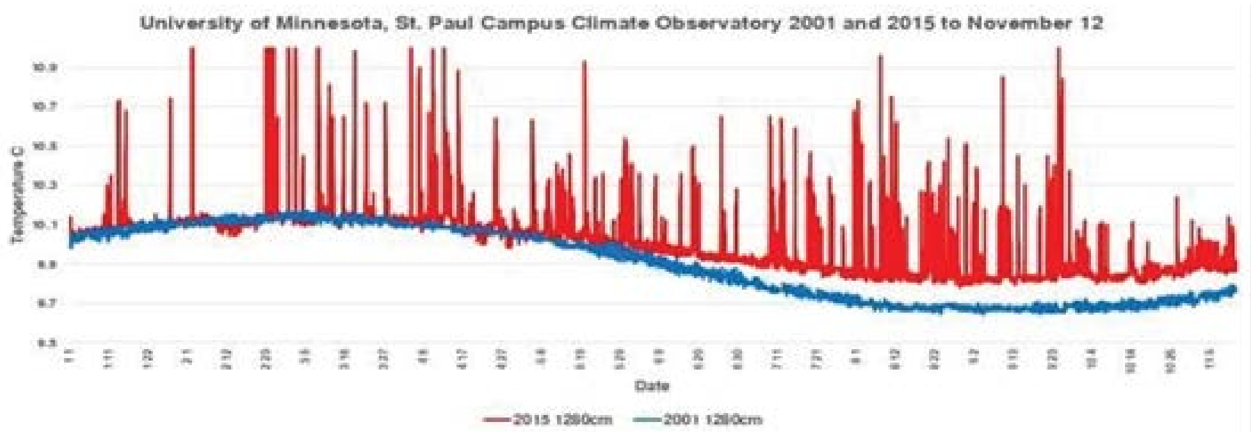

Figure 21: University of Minnesota, St. Paul Campus Climate Observatory 1280 cm deep, 2001 and 2015 ending November 12.

2012, cooling was associated with the surges in the deeper probes. In 2013, the cooling associated with the surging heat was now warmer than previously norms indicating that equilibrium had been reached between the upper and lower regional aquifers.

Conclusion

In order to determine human caused climate change, we must first assess a world without humans. Since the late 1800's, temperatures have been taken based upon a set of guidelines that conform to human altered land (Boulay, P. 2005). Initiated by the Army Surgeon General for justifiable reasons, taking just one reading in a system as large as our world has been detrimental to the study of Earth Science. Had temperatures been taken in various environments, we would have realized the impact that altered land would have had upon our surface temperatures and climates long ago. Buildings use multiple temperature sensors in various environments to monitor and control a buildings temperature, and we need to adapt to this same strategy for our world.

Historically, subterranean heat and how it works has been virtually disregarded by science. Although research has increased over recent years, it continues to be viewed with skepticism. When land is converted to human habitat and exposed to the incoming solar radiance, forced conduction takes place and the heat transfer rates increase. As this experiment reveals, this forced conduction amplifies heat gain and retains subterranean heat proportionately greater than its ability to dissipate it. Over time, this stored energy increases subterranean heat that results in rising surface temperatures and has become termed "climate change".

Our world is warming due to increased subterranean heat gain that can now be duplicated. There is a means to measuring human impact on our environment by land type and a means to measuring current, daily and yearly heat gain or loss by region. The importance of these findings and this knowledge is imperative for our world today. Research and resources need to be invested in facilities for analyzing subterranean earth and ocean data with the accuracy, hourly recordings, and depths necessary for that region similar to the Climate Observatory. Additional locations are needed in the natural environment such as the forests, prairies and jungles that are imperative for cross comparisons.

Understanding the source of our heat and how it works is just the beginning to understanding how and what we need to change. Massive projects to alter our current trends are necessary to both increase retainage and facilitate water flow. Cold water subterranean injection demonstrates a very positive new approach to irrigation. Altering our current methods can conserve water, amplify growth, and accelerate cooling through targeted injection. Application of the Earth Simulator into the production of a cucumber has been initiated with some very positive results demonstrating increased growth and production without conventional watering.

Altering crop selections using perennial crops and wet crops such as rice can amplify cooling. Replanting our forests and prairies is imperative, even down to small scale gardens and boulevards. An average adult tree needs a 30-foot diameter, so using a 30-foot spacing a tree should be planted wherever possible. Highways and boulevards should be planted with natural vegetative growth, prairie grass, and different grains to aid during times of shortage. Rather than mowing, when necessary, it would be best to use a control burn. Water is our world's natural coolant and infiltration is a necessary part of the cycle. Draining the water away from the fields and extracting underground water will gradually amplify heat over time. By channeling water to deep holding ponds and using the deep cold water for irrigation injection, infiltration would be amplified while increased yields would offset for the loss of land needed for holding ponds.

We all have a heat signature associated with our existence that amplifies heat gain and alters our planets climates so we all need to take personal responsibility for our current situation without blame. Responsibility does not lay with the governments alone and taxing it won't resolve it. As a result, the greatest responsibility lay with each and every individual by working within their communities to promote change. With millions of children in school, programs can be established for the germination and planting of various vegetation with subsequent coordination with cities and residents to replant their communities. This would create a tremendous long-term impact without any form of taxation. This is just one idea of many, but communities need to decide this on their own as regions vary greatly depending upon land usage and natural eco-systems. The Earth wants to grow and is demonstrated every year as we battle against the growth mowing and paving it to our desired state.

Current policies around the world addressing climate change are not addressing the root cause, and in failing to do so will achieve little to no impact. When a forest is cut down for a solar panel farm, we amplify heating in our attempt to reverse current trends. We live within a finite world and we fail to understand the impacts that our existence has, and the stress we place upon our world. Our existence, over time and through mass numbers, forces climates to change. Until humanity decides to make changes to adapt for the needs of our world, our current climate trends will continue to accelerate and we are destined to repeat the progression of past civilizations towards self-destruction.

Earth Simulator

Lower subterranean heater assembly: Using 24-gauge galvanized steel cut a 10-inch diameter circle. Peel off and with the adhesive tape attach the heater blanket in the center of the steel. Cut slits in the steel making sure not to cut the heater blanket. Bend the blades all in one direction to facilitate flow of heat and water vapor to avoid trapping heat or water below as shown in Figure 22.

Using a standard 2 prong, 110 volt (AC) plug in cord, solder the heater wires to the cord. Stager the wire leads in length and using 2 shrink tubes cut them long enough to cover the entire connection and place them over the wires. Make sure they are large enough to completely cover the connection after soldered. Solder the connections and then place the shrink tubes over the connection and using heat, shrink the tubes one at a time, smaller to larger until completely sealed. Tape up each lead independently with no less than 3 wraps, and then wrap the entire assembly as one lead. Although this connection will not be in water it will be in a very damp environment, be sure this connection is well taped and sealed.

Water drip system assembly

Using the ¼" copper tubing crimp one end closed. Using a 3/32" drill bit, drill a hole every 4 inches for the first 2 feet. Using a bender create a spiral that will lay in the bottom for distribution of water from the gravity feed system as shown Figure 23. Connect the other end to the ¼" tubing and using an adapter, adapt it down to support the aquarium air control valve that will be used to control the water flow. Using the adaptors, connect the thermos for the water supply tank. Be sure everything is clean and free of dust as the control valve can plug easily. Do not use more than 23 oz per day in the system, and apply only when operating the subterranean heat.

System assembly

Cut the 2"x 4" boards to the following lengths:

3 – 25; 6 – 28; 10 – 21; 4 – 20; 2 – 54; 1 – 31 ¼.

Using basic framing methods build a 28"x 28" frame using 2 x 4 construction with a center support for the bottom shown in Figure 24. Using ½" plywood make a floor for the base and attach it. If using half

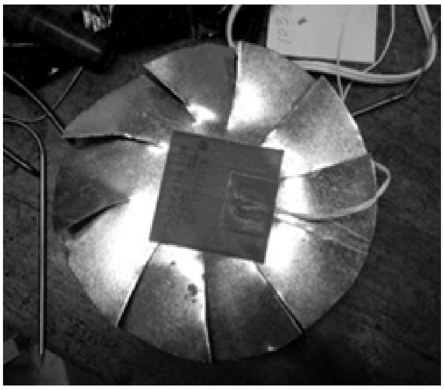

Figure 22: Subterranean heat assembly.

Figure 23: Water coil.

sheets (2' width) cut and use the center support for the seam. Due to heat loss detected in the lower region, it would be recommended to use the plaster/sand mix to fill this compartment. Seal the bottom with plastic and cover with ½" plywood. Attach the 4 wheels and mark one side as front. Using the same method build the 2 side walls, front and back wall as shown in Figure 25. Using ½" plywood cut and screw the plywood to the inside walls.

Build the frame for the front and back shown in Figures 26 and 27. Using a saw cut a shallow slot on the bottom along the outer edge of the front assembly for the outer-side temperature probe to feed. Cut two slots on the bottom of the front assembly as show for the inner side wall and lower bottom probe to feed. With duct tape mount one temperature probe to the base in the center and the other temporarily tape six inches below the top and feed these two probes through the slots. Using duct sealant fill the slots and mount the front wall assembly. With duct tape mount a temperature probe on the inside plywood, mid height for the outer-side temperature probe and route through the cut slot. Use duct sealant to fill the slot and install the front assembly. Assemble all four walls onto the base. Insulate all walls with R13 insulation or greater. Wrap all the walls with plastic and staple in place and then install the exterior plywood. Take extra precaution around the temperature probe feeds when attaching the plywood. When complete, line the inside with plastic.

The pot used has a hole in the bottom for water drainage. Place a temperature probe at the bottom and use a piece of wood or cardboard to temporarily seal the bottom and using quick set cement pour a layer of cement over the bottom no more than an inch thick to seal the hole and temperature probe in place.

When mixing the plaster and water, there is a limited amount of time before it will begin to set rapidly. Using water and plaster, mix until all the lumps are removed, and still easily pourable. Begin to add sand until consistency begins to thicken, but remains liquid enough to pour.

Using plaster begin to fill the bottom of the shell and insert the trash can into position so that it rises just above the side walls and allow it to set. Be sure to mount the inner-side wall temperature probe onto the trash can opposing the outer probe and attach with duct tape before filling See Figure 28.

Using plaster begin to fill the bottom of the trash can and lay the ceramic pot in so that it rises above the surface ¾" and allow it to set. Excess plaster can be used to fill in the outer shell. When set, mix up enough plaster to fill the entire unit to the top.

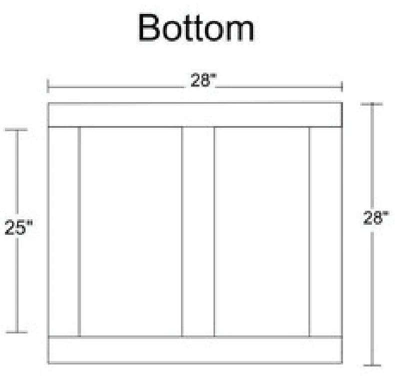

Figure 24: Bottom.

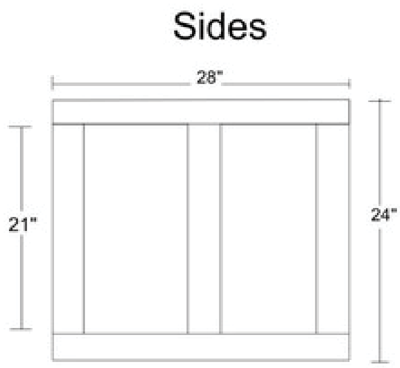

Figure 25: Sides.

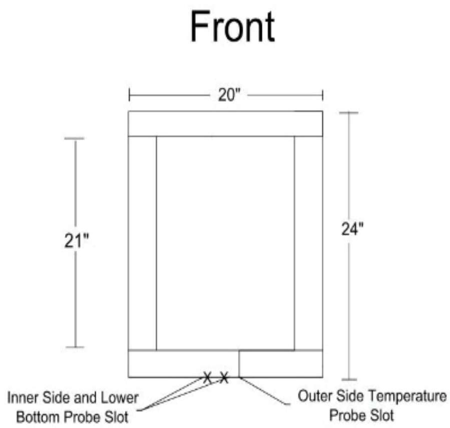

Figure 26: Front assembly.

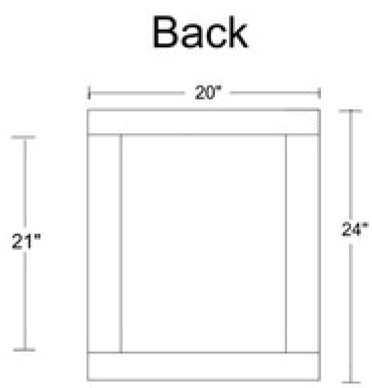

Figure 27: Back Assembly.

Figures 29 and 30 display the layers of assembly. Begin filling the pot with one inch of sand and then twist the lower heater unit into the sand, and then add just enough sand to completely cover the heater. Pour in an inch of pebble rock and lay in the water coil, and then cover the coil completely with pebble rock. Using a straight edge on the top begin filling and packing the unit by layer with moist soil, moist enough to be able to form the soil by hand. Measure and place each probe into the system as you fill it firmly packing the system as you layer it with

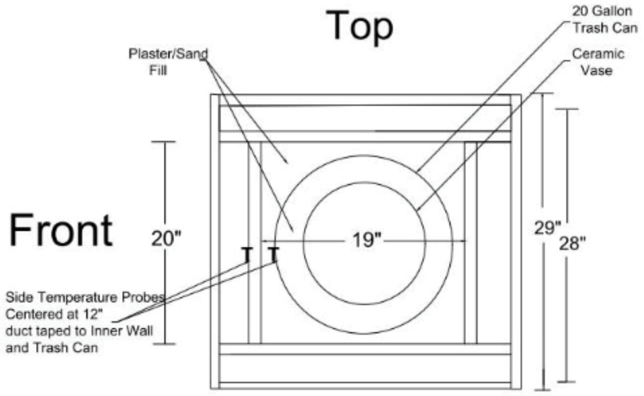

Figure 28: Image from above with side temperature probes.

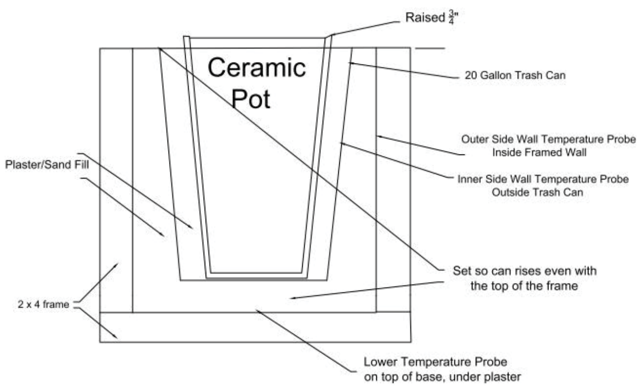

Figure 29: Side view.

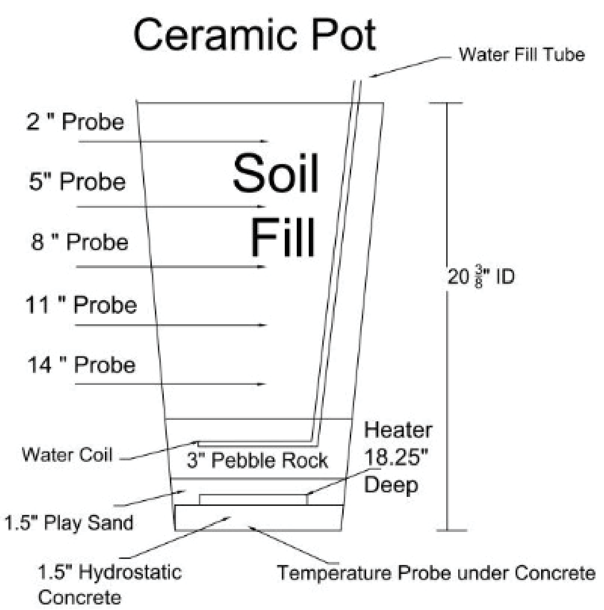

Figure 30: Layers.

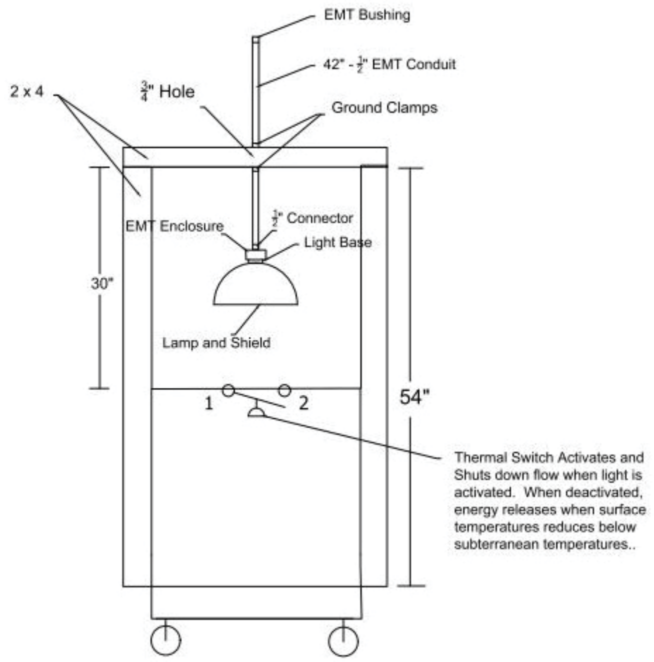

Figure 31: Light assembly.

soil. Route all the wiring up to the area towards the front of the system where the temperature gauges will be placed.

To save on time and continual monitoring and recording of the system, time lapse recording was used to ensure continuous monitoring and playback for review.

Light assembly

The light assembly uses a ½" conduit that can adjust vertically using two grounding clamps to hold it in place and is shown in Figure 31. For the light to remain on center it is recommended to use a drill press for precise alignment of the center hole. Using 2"x 4" lumber, build a frame to support the light as shown in the following image. The 31 ¼" – 2" x 4" piece is for this upper cross bracket that may vary slightly. This is for further experiments being able to vary the radiant heat upon the soil while remaining open to the surrounding environment.

Using the double box, wire in the variable switch in series to the outlet cord so that you can adjust the voltage to the outlet. Plug it in and test the outlet to assure that the voltage varies accordingly with the switch. A small piece of plywood was cut and mounted onto the top of the light assembly to support the thermos for the gravity feed water injection.

Acknowledgements

We would like to thank those who provided insight, information and expertise that greatly assisted this research. Although they may not agree with all of the interpretations or conclusions of this paper, there assistance was extremely valuable.

Although no longer with us, Donald Baker, whose dedication, desire and inquisitiveness into acquiring knowledge is something I admire and reflect in my life. Needing to know the impacts of the frost line and how it works, he was driven to bury temperature probes as deep as he did back in the 1960's, because he just wanted to know.

Peter Boulay, Climatologist for the State of Minnesota who provided the data available from the University of Minnesota, St. Paul Campus Climate Observatory. His insight and information that he provided, as well as direction, was extremely valuable to this research and is greatly appreciated.

Randy Kolka, Research Soil Scientist for the USDA located in the Marcell Experimental Forest, provided the historical forestry data necessary for cross comparisons. This data, along with his insight and direction, was highly beneficial to this study.

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