Balancing the Earth's Energy Budget

By

Stephen Wilde

Introduction:

I have previously described the Earth's energy system as being similar to a pair (ocean and air) of electrical resistors placed in series both being independently variable and one being hugely larger than the other.

That is all very well but I should go on to examine the practical implications of such an analogy by trying to describe the types of climatic changes it should be able to generate. One can then compare that which would be expected with real world events.

The first thing to say is that with electrical resistors the throughput of energy remains constant as long as the source of the energy remains stable. The amount of energy going into the first resistor will always be the same, as the amount of energy leaving the second resistor PLUS the heat energy generated by the delay in transmission.

Since the Earth is a globe the amount of energy radiated to space from the air includes the energy generated by the delay in transmission. That radiation to space always equals the solar input over time.

From satellite measurements we see that in relation to the Earth that is what happens. The amount of energy received from the sun is the same as the amount of energy radiated to space. However it seems logical that there must be minor temporary perturbations for reasons set out later in this article. It may be that our satellites are not yet sensitive enough to measure them.

The heat generated by a resister is not a product solely of the amount of energy running through it. Instead that heat is a consequence of the delay in the transmission of the energy caused by the resistor. The longer the delay the higher the temperature will be.

Relating that to the issue of global warming then of course one would initially assume that if the strength of the resistor effect of the air is increased by the presence of more greenhouse gases, then of course the heat generated within the planetary system increases.

This link describes the problem that this article seeks to address:

http://www.npr.org/templates/story/story.php?storyId=88520025

Complications:

1) There are two resistors, ocean and air.

2) They each vary in the strength of their resistance to the solar energy flow over time. In the case of the oceans, oceanic cycles cause the flow of energy to the air to speed up and slow down over periods of 30 years or so for each negative or positive phase. In the case of the air it is the circulation of the air that causes the energy flow to space to speed up or slow down but in that case it varies on a daily basis.

3) One resistor is massively greater than the other due to the huge density and volume of the oceans as compared to the air.

4) If the oceans are in a surface cooling (negative) mode they are net absorbers of solar energy and are releasing less energy to the air than is needed to replace the energy lost by the air to space. That is an increase in the resistor effect of the oceans and the main body of the oceans is normally warming unless solar input is so weak that it negates the warming effect of the negative mode.

5) If the oceans are in a surface warming (positive) mode they are net emitters of solar energy and are releasing more energy to the air than is needed to replace the energy lost to space by the air. That is a decrease in the resistor effect of the oceans and the main body of the oceans is normally cooling unless solar input is strong enough to offset the cooling effect of the positive mode. That may have been the case from 1975 to 2000.

Discussion points:

1) The net energy flow is always one way from sun, into oceans, to the air, then to space. Air cannot warm water, only the sun can do that (if we ignore geothermal sources).

Solar energy penetrates the oceans for 100 metres or more and is retained for long periods of time by the oceanic circulations involving the deepwater Thermohaline circulation working under the influence of density variations and the Earth's rotation.

Infra red radiation (IR) from the air, whether it be natural or from human CO2 cannot penetrate water so it just warms up surface water molecules and thereby enhances the rate of evaporation so that the energy from the IR returns to the air locked in water vapour without affecting ocean temperature at all. Indeed it seems plausible that because evaporation has a net cooling effect on the areas around the location where it occurs then more rapid evaporation from extra human CO2 could accelerate the energy flow from water to air and thus COOL the planet (something more to worry about).

When one perspires the skin feels cool. If any energy were left after evaporation the skin would keep warming albeit more slowly but clearly it does not. Just as the seas have their own energy source (the sun) the human body produces it's own energy from metabolic processes yet in the case of human skin the latent heat of evaporation is large enough and variable enough to maintain a constant outward flow of energy which maintains a stable body temperature despite intense IR from sunlight falling on the skin. I am not convinced that the ocean skin behaves any differently.

I have found some AGW proponents to be unaware (even disbelieving) of that characteristic of evaporation so here is independent corroboration:

Latent heat

From Wikipedia, the free encyclopaedia

In thermochemistry, **latent heat** is the amount of energy in the form of heat released or absorbed by a chemical substance during a change of state (i.e. solid, liquid, or gas), or a phase transition.

The term was introduced around 1750 by Joseph Black as derived from the Latin *latere*, to lie hidden. The term has now been replaced by "enthalpy of transformation".

Two latent heats (or enthalpies) are typically described: latent heat of fusion (melting, and latent heat of vaporization (boiling). The names describe the direction of heat flow from one phase to the next: solid → liquid → gas.

The change is endothermic, i.e. the system absorbs energy, when the change is from solid to liquid to gas. It is exothermic (the process releases energy) when it is in the opposite direction. For example, in the atmosphere, when a molecule of water evaporates from the surface of any body of water, *energy* is transported by the water molecule into a lower temperature air parcel that contains more water vapour than its surroundings.

Because energy is needed to overcome the molecular forces of attraction between water particles, the process of transition from a parcel of water to a parcel of vapour requires the input of energy causing a drop in temperature in its surroundings.

If the water vapour condenses back to a liquid or solid phase onto a surface, the latent energy absorbed during evaporation is released as sensible heat onto the surface. The large value of the enthalpy of condensation of water vapour is the reason that steam is a far more effective heating medium than boiling water, and is more hazardous

My comments:

As stated above the change in state requires the addition of new energy over and above the energy required to provoke the change in state.

That is the latent heat of evaporation and it is very large

Evaporation goes on whether or not additional energy is added to a water molecule, because of the different densities of water and air. Adding extra energy from IR or anything else just accelerates a process that is going on already.

Latent heat of evaporation has to come from somewhere and it is extracted from the surroundings i.e. from nearby molecules of water or air.

Even if one were to find that after all there is a net warming of ocean surface by extra human induced IR then it would be truly miniscule in proportion to natural energy flows and would take many millennia to have a measurable effect. We can see the huge changes in the energy budget of the air provoked by large or persistent El Nino or La Nina events in the Pacific. The effect of any human enhancement of down welling IR in the air via an ocean skin effect would only be felt as a very slightly warmer El Nino phase peak and a very slightly less cool La Nina phase trough.

2) Remember that in the case of a globe such as the Earth, energy coming from the sun has to match energy radiating to space over time.

What happens if the oceans independently of the air introduce a discontinuity in the ocean/air energy flow by switching from surface warming to surface cooling mode or as is more likely in the real world keeps switching one way or the other at varying rates and on varying scales and at varying times with different cycles in every ocean?

Note that what we are considering here is not any change in the current (solar input) but merely changes in the speed of transmission across two resistors of hugely different sizes.

Thus faster transmission means a lower temperature of the resistors and slower transmission means a higher temperature of the resistors

Oceanic Surface Warming mode:

a) The sea/air interface:

The oceanic resistor effect weakens allowing faster energy flow into the air. The air has to respond by adjusting it's own resistor effect to match the increased speed of energy flow from the oceans. It does so by changing the weather systems. The equatorial air masses expand forcing the weather systems towards the poles allowing faster emission of energy to the upper air but leaving average surface air temperatures matching the sea surface temperatures.

b) The air/space interface:

The flow of energy from air to space cannot exceed the energy flow from the sun significantly or for long. What goes up must come down so the air carrying the pulse of energy from the equatorial air masses having led to a surge of energy into the upper air soon has to descend again without yet having released all the excess energy to space and it does so nearer the poles. That process slows down the transmission of energy to space to keep the energy departing from exceeding the energy coming in from the sun.

So, although there might still an excess of energy coming from the ocean surface (pushed into the upper air by the latitudinal movement of the weather systems) there is also a mechanism (provided by the vertical movement of the weather systems) for slowing the speed of transmission of that excess energy to space so that it does not significantly or for long upset the balance between solar energy reaching the planet and energy departing into space.

Throughout the process the speed of energy throughput is what has changed both in oceans and air. Just as with an electrical resistor the inevitable result of the faster throughput is a cooler system overall but the fact is that it is exclusively the main body of the oceans that has cooled and the air has actually warmed.

Oceanic Surface Cooling Mode:

a) The sea/air interface:

The oceanic resistor effect strengthens thereby reducing energy flow into the air. The air has to respond by matching it's own resistor effect to the decreased speed of energy flow from the oceans. It does so by changing the weather systems. The equatorial air masses contract allowing the weather systems to move closer to the equator reducing the rate of emission of energy to the upper air to try to keep sea surface temperatures matching surface air temperatures.

b) The air/space interface:

The flow of energy from air to space cannot be less than the energy flow from the sun significantly or for long so the air has to deal with the reduced energy flow from the seas somehow. The reduced energy from the contracting equatorial air masses leads to a reduction of energy flowing into the upper air. In doing so it allows the polar high pressure systems to expand. Cooler dryer air surges towards the equator to pick up more energy from more ocean surfaces to reduce or eliminate the deficit that had developed between solar energy reaching the planet and energy departing the planet.

The result of the slower throughput is a warmer system overall but it is exclusively the main body of the oceans that has warmed and the air has actually cooled.

To summarise:

The ocean cycles disturb the flow of energy through the entire system and seek to upset the balance between energy in from the sun and energy out to space.

The air has to balance those perturbations whilst at the same time obeying the rule that the ocean sea surface temperature always (on average) matches the surface air temperature.

The latitudinal movement of the weather systems manipulates the sea/air energy flow so that sea surface temperatures match surface air temperatures.

The vertical movement of the weather systems manipulates the air/space energy flow so that energy in from the sun matches energy out into space.

3) Remember the one way energy flow from sun into oceans to atmosphere to space?

It is significant for the following reason.

In the oceanic warming mode the normal outward flow is simply being enhanced a little by warming changes on the ocean surface.

In the cooling mode something more happens. First the supply of energy to the air is reduced but then when the equatorial air masses contract the polar air floods towards the equator and being dryer than equatorial air it increases the flow of energy from ocean to air by increased evaporation in an attempt to limit the cooling process in the air alone and thereby drawing energy from the oceans faster to compensate for the deficit lost to space. However that just further cools the ocean surfaces to extend and intensify the period of cooling of the air.

Thus, generally, cooling spells become established more quickly and it takes longer to recover from them. Warming is like walking up a hill but cooling is like running down a hill.

I should mention here that, in the ice core records, warming to a peak is fast and cooling then takes place relatively slowly. At this stage I have to assume that climate changes forced by whatever creates ice ages (probably astronomical events) are different from climate changes caused by oceanic forcing.

4) Relevance to the issue of human influence.

Extra greenhouse gases from human sources will increase the resistor effect of the air alone. However for AGW theory to work those gases have to also change the resistor effect of the oceans because the oceans dictate the air temperatures. An attempt has been made to overcome that constraint for AGW theory via an idea involving the ocean skin but I do not find that convincing on times scales of less than a thousand years or as a significant influence in the face of natural ocean variability.

Increasing the resistor effect of the air alone will result in the surface air temperature trying to diverge from the sea surface temperature.

The oceanic resistor effect cannot strengthen to match the increased resistor effect of the air because the thermal inertia of the ocean is far too large. The air is feeble, easily influenced and fast changing compared to the oceans. Evaporation, upward radiation, convection and conduction all increase in response to increased energy in the air from extra greenhouses gases and so prevent ocean warming.

The resistor effect of the air has to keep matching that of the ocean. The reason it has to do so is because the energy entering the system from the sun always matches the energy leaving to space over time. In effect the oceans push energy into the air during a warming phase (holding it back during a cooling phase) and space pulls energy from the air during a cooling phase (holding back from accepting it during a warming phase) with the air via the weather systems having to adjust to maintain the balance.

The only way the air can resolve an imbalance caused by an increase or decrease in greenhouse gases is to use the latitudinal mobility of the weather systems to cancel out the changing effect of the greenhouse gases and restore equilibrium between the surface air and ocean surface temperatures.

Thus greenhouse gases slow down the energy transmission through the air but the movement of the weather systems speeds it up again. Extra or even reduced greenhouse gases are thus prevented from affecting the equilibrium between sea surface and surface air temperatures. The process occurs constantly as the global humidity of the air varies during warming or cooling spells since water vapour is the main greenhouse gas.

All the above assumes a constant solar input. The ocean cycles and air circulation only affect the speed, not quantity, of energy transmission through the system so that the energy input from the sun to the ocean always matches the energy output from the air to space. When energy transmission is faster there is less energy stored in the oceans and when it is slower more energy is stored in the oceans. The air is simply a ‘buffer’, smoothing out the effects of variations in the speed of energy transmission created by the ocean cycles

If the solar input does change then the equilibrium temperature of the whole system will change as regards both ocean and air.

Often, solar changes will be offset by ocean cycles resulting in reduced changes in air temperatures but sometimes the solar changes will be amplified by the ocean cycles depending how many of the ocean cycles are in phase with the solar changes and for how long. It seems likely that the amplification effect on air temperatures from the oceans can be many multiples of any effect from changes in solar output.