FOUND - A Missing (Climate) Link.

Introduction:

I have been considering how real world processes would have to work given that we observe a cooler stratosphere when we observe a warming troposphere.

That observation has been used by some to try and support anthropogenic global warming (AGW) fears even though we know so little about the upper layers of the atmosphere that nothing can be determined for certain about it's detailed mechanics at present. That field of endeavour, and climatology in general, is rife with speculation that reaches our media almost daily, presented as fact rather than supposition.

For an example of the currently confused state of the science relating to the stratosphere one need only note the fate of this page from the self appointed AGW guru site of Realclimate:

http://www.realclimate.org/index.php/archives/2004/12/why-does-the-stratosphere-cool-when-the-troposphere-warms/

If they can make such a hash of it I see no reason why I should not make my own modest efforts to understand it all.

The idea proposed by AGW supporters is that increased greenhouse gases hold heat energy in the troposphere for longer and so deprive the stratosphere of some of the energy supply that would normally pass through it thereby making it cooler.

However please see the latest position here:

http://www.jstage.jst.go.jp/article/sola/5/0/53/_pdf

"The evidence for the cooling trend in the stratosphere may need to be revisited. This study presents evidence that the stratosphere has been slightly warming since 1996."

As we all know CO_2 in the air has been continuing to increase so a shift to stratospheric warming appears to suggest that the AGW fears may already be falsified.

I need to split this article into two sections. The first dealing with the regime of energy transfer from surface to stratosphere where convection and the hydrological cycle are dominant. The second dealing with the regime of energy transfer from stratosphere to space where upward radiation of energy is dominant.

As will be seen in the second section, recent observations show that the rate of energy transfer from upper atmosphere to space is affected by solar influences.

I hope to demonstrate that all observed climate variations can be accounted for by solar and ocean variability interacting at the stratosphere via variations in the rates of energy flow into the stratosphere from below and out of the stratosphere to space.

The missing link of the title is the behaviour of the stratosphere in acting as the region of competition between oceanic effects from below and solar effects from above.

It is the successful resolution of that conflict over the past 4 billion years that explains the stability that has led to human existence.

A - From Surface to Stratosphere

Discussion points:

In my previous articles and especially here:

Greenhouse Gases Can Cause Cooling !

where I discussed the so called ocean skin effect I pointed out that evaporation creates a reversal of the energy flow 1mm below the surface. That 1mm depth is the ocean skin. The effect of evaporation is to accelerate energy from ocean to air despite the existence of a contrary force (conduction) that would normally be expected to send energy downward.

The bulk of the ocean is warmest towards the top due to stronger solar input as one approaches the top. On that basis one would expect energy to flow downward by conduction but it does not because the power of evaporation from the top pulls energy upward continually.

In relation to the bulk of the troposphere, (the lowest region of the atmosphere between the land and ocean surfaces and the highest clouds), it is important to note that the most significant process for energy transfer upwards is the hydrological cycle that encompasses evaporation, condensation and convection.

When the speed of the hydrological cycle speeds up, more energy in the form of latent heat, tied up in water vapour is propelled upward by wind and convection towards the tropopause (from now on I will just use TP), the boundary between troposphere and stratosphere.

At the TP the temperature gradient abruptly reverses. From surface upwards the air gets quickly cooler with height but at the TP there is a layer of air warmer and drier than the air below it. The rising air from the surface, often laden with water droplets in the form of clouds is brought to a sudden halt by the warmer layer above.

The sharpness of the boundary can be seen in the flat tops of thunderclouds as they are suddenly constrained from further upward progress.

I propose that at the TP there is a region akin to the ocean skin namely a ‘tropospheric skin’ effect.

After all, air and water both have fluid characteristics. It matters not that one is a gas and the other a liquid. We are just dealing here with flows of energy in fluids and trying to make sense of observations.

The tropospheric skin effect would be a mirror image of the ocean skin effect being both reversed and inverted as regards the temperature profile.

Being a mirror image of the ocean skin effect, instead of weakening and reversing the downward conductive flow of energy in the ocean the tropospheric skin effect actually strengthens the inversion of the temperature gradient that starts at the TP.

Bear in mind that as air laden with water vapour rises upwards it progressively sheds that water vapour in the form of condensation into cloud droplets and when that happens the latent heat of condensation is released to the surrounding air at that level so that the air warms.

That warmer air within the troposphere at higher levels above the surface then radiates more energy upward and into the stratosphere.

At the TP any residual water droplets in the form of clouds evaporate when they hit the TP because the air there is warmer and can hold more water vapour. That is a cooling effect so one finds a thin cooler layer at the TP that is a mirror image of the cooler layer at the top of the oceans also caused by evaporation.

That cooler layer increases the temperature differential between surface and TP and so accelerates upward the energy in the air column below that had previously been released by the condensation process lower down.

The air just above the TP thus becomes even warmer and drier than it otherwise would be. The whole process is driven by the speed of the hydrological cycle. That speed is primarily dictated by the rate of evaporation from the ocean surfaces.

The temperature inversion that starts at the TP becomes stronger in direct relation to the speed of the hydrological cycle which is in turn forced by the temperature of the ocean surfaces, the consequent rate of evaporation and thus the rate of energy release from the oceans (and, as it happens, by greenhouse gases that also work to increase evaporation).

One might ask why the TP exists at all. My own idea on that (and I'm not sure whether others have previously proposed this) is that it represents the dividing line between two entirely separate and competing regimes of energy transfer.

From surface to TP the energy transfer is substantially via convection and the speed of the hydrological cycle that transfers huge volumes of latent heat upward at variable rates but releasing much of it via condensation on the way up. As the air moves upward the energy transfer method becomes increasingly in the form of upward radiation as the latent heat of condensation is progressively released.

The rate of energy flow to space then depends on the temperature differential between the top of the stratosphere and space.

I have previously proposed that the air has to perform two incompatible functions in order to ensure that variations in solar energy flow through the Earth system (induced by the oceans varying their rates of energy release) are cancelled out so that over time the energy received from the sun equals energy radiated to space.

I was aware that higher ocean temperatures and extra greenhouse gases in the air would both provoke increased evaporation and speed up the hydrological cycle.

That then speeds up energy flow to the TP ensuring that surface air temperatures do not diverge from sea surface temperatures.

I had a problem in then considering how that speeding up of energy transfer in the troposphere would be offset by changes in the air higher up. The stratosphere and the layers of atmosphere above it do not have air circulations so I needed a process that would vary the energy flow to space and ensure that over time energy in from the sun did not exceed energy lost to space.

It seemed to me that the failure of asteroid strikes, huge volcanic disruptions, vast changes in continental shapes and positions and substantial changes in the composition of the air and biosphere had never destabilised the system to the extent that we lost our liquid oceans.

Whatever has happened to the Earth over four billion years it has always bounced back to something similar to that which existed previously.

There had to be a fine and responsive balancing act going on somewhere and in my opinion it appears to involve the unique qualities of water and it's multiple phase changes with the enormous scope that they provide for variable energy transfer rates between ocean surface and TP.

Evidence in support:

We need to find some indication that at the TP there is a mirror image of the ocean skin effect.

In the ocean skin effect the topmost few microns are warmed up by infra-red radiation from the air. Beneath that there is then a cool layer about 1mm deep which is caused by the fact that evaporation pulls energy out of the water faster than it can be conducted up from below.

For a mirror image of that we need the very lowest portion of the troposphere to show anomalous cooling as a result of upward convection from the cooler layer below.

Look what I found here:

http://www.atmos-chem-phys-discuss.net/4/7615/2004/acpd-4-7615-2004-print.pdf

Abstract

We investigate the impact of convection on the thermal structure of the Tropical Tropopause Layer (TTL). We use temperature profiles measured by the Atmospheric Infrared Sounder (AIRS) onboard the Aqua satellite, and the time evolution of local convection determined by the National Centers for Environmental Protection/ Aviation Weather Center (NCEP/ AWS) half-hourly infrared global geostationary composite. The observations demonstrate that the TTL is cooled by convection, in agreement with previous observations and model simulations. By using a global data set, we are able to investigate the variations in this convective cooling by season and region. The estimated cooling rate during active convection is 7.5 _9 K/ day. While we cannot unambiguously identify the cause of this cooling, our analysis suggests that radiative cooling is likely not an explanation .

I propose that what has been observed is an anomalous cooling caused by the effect of evaporation just at the TP precisely analogous to a reversed ocean skin effect that is caused by evaporation at the ocean surface.

The very thin warmer layer (or less cool layer) at the top of the ocean skin is caused substantially by the impact of Infra-red radiation before it cools the rest of the ocean skin via evaporation and it’s associated evaporative cooling. In this case energy is drawn from the oceans by the evaporative process faster than it would otherwise have been released. More infra-red causes more evaporation that increases the evaporative cooling of the ocean skin. The AGW ocean skin theory proposes that more evaporation from extra infra-red would result in less evaporative cooling. That must be wrong. More evaporation must cause more evaporative cooling, not less.

The very thin cooler layer (or less warm layer) at the base of the TP is caused by cooler, upwardly convected air offloading it’s residual water droplets via evaporation resulting in associated evaporative cooling. In this situation energy is pumped upward into the stratosphere faster than would otherwise have been the case due to the acceleration upwards of the energy transfer caused by that evaporative cooling and consequent increased temperature gradient towards the top of the troposphere.

Significance:

What we see then is a two stage pumping process. First, evaporation pulls energy from the oceans, then it accelerates that energy into the stratosphere. The speed of the pump is directly related to the speed of the hydrological cycle because that affects the size of the temperature gradient from surface to TP. The faster the hydrological cycle the more cloud droplets reach the TP and the more evaporative cooling occurs.

Now if the change in the rate of evaporation at the ocean surface is provoked by a change in the rate at which the oceans release energy (due to internal ocean changes) then the temperature of the troposphere will change for so long as the oceans release energy into the troposphere faster than the hydrological cycle can remove it to the stratosphere. Usually, that is, until the next stage in the oceanic cycle when the rate of energy release changes again.

When oceans release more energy thus warming the air, the height of the TP (the boundary between the two different energy transfer systems) increases until a new balance is set between the energy flow from the oceans and the energy flow upwards and into the stratosphere.

As I have said in my previous articles, air cannot warm water significantly and I do not accept the effect attributed to the ocean skin by anthropogenic climate change proponents. Instead the sea surfaces control surface air temperatures and so any extra energy reaching the air from either ocean surface temperature changes or more greenhouse gases is accelerated upwards by increased evaporation and a faster hydrological cycle and that is achieved by a latitudinal shift in the tropospheric air circulation systems.

As regards changes in greenhouse gases their only effects will be a miniscule latitudinal shift in the air circulation systems and a miniscule increase in the height of the TP. Wholly insignificant in relation to what the oceans can do as a matter of routine.

There can be no temperature change at the surface because the oceans always dictate the surface air temperatures and the greenhouse gases cannot affect them.

Note that I am speaking in global terms here. There will be local and regional temperature effects from urban heat islands and land use changes especially in continental interiors but the seas and the variable speed of the hydrological cycle will always remove those effects without any effect on global temperature equilibrium.

The system works equally well to deal with greenhouse gas forcing because both ocean surface warming and greenhouse gas warming cause an increase in evaporation and so can both be dealt with similarly by a change in the speed of the hydrological cycle mediated at lower levels by a latitudinal shift in the air circulation systems and at the upper levels by a change in the height of the TP.

In graphical terms I would expect that if one draws the temperature profile from ocean to air and then turns it upside down and reverses it at the TP then this description should be capable of being confirmed or rebutted by careful observation and measurement at the TP.

Thus far I have only explained how the systems of energy transfer in the troposphere work to transfer energy from oceans to air and then stratosphere with a consequent warming of the stratosphere in parallel with warming of the troposphere. That is only half the story because we see that the stratosphere does not warm when the troposphere warms. Instead it cools and we now have to look at the effects of radiative energy transfers in the levels of the atmosphere above the top of the stratosphere to see why that can be so.

B – From Stratosphere To Space

As described in Part A an increased rate of energy flow from the oceans caused either by internal ocean changes or an increase in greenhouse gases causes an increased rate of energy transfer from surface to stratosphere via an energised hydrological cycle.

The tropopause (TP) rises and the strength of the temperature inversion within the stratosphere increases as energy accumulates within it.

In effect the excess energy coming from the ocean surfaces is transferred to the stratosphere at a speed that tries to maintain temperature equilibrium between sea surface and surface air.

Once the extra energy reaches the stratosphere the next stage depends on what the sun is doing, or more particularly the flow of energy from the sun. From the TP upward it is radiative energy transfers that dominate so we really need to know how they can vary.

At this point I need to refer to some recent empirical findings described here:

http://www.nasa.gov/topics/earth/features/AGU-SABER.html
"Sunspots unleash solar flares that create a ripple effect well beyond Earth. But when that energy flow does reach Earth the atmosphere reciprocates by ejecting radiation as a cooling effect to maintain the planet's energy balance. That cooling response creates the expansion and contraction of the upper atmosphere."

Now that is quite a surprise. The conventional wisdom is that increased solar activity in the form of sunspots and solar flares has a warming effect on the Earth but it seems that instead there is a cooling effect at least in the upper atmosphere.

So, clearly, increased energy flow from the oceans will add energy to the stratosphere but increased activity on the sun will remove energy from the stratosphere and the upper atmosphere above it.

The temperature of the stratosphere will therefore depend on the interaction between the two processes.

There would appear to be four potential scenarios.

i) More disturbed sun + warmer ocean surfaces = cooler stratosphere + warmer troposphere.

ii) Less disturbed sun + cooler ocean surfaces = warmer stratosphere + cooler troposphere.

iii) More disturbed sun + cooler ocean surfaces = cooler stratosphere + cooler troposphere.

iv) Less disturbed sun + warmer ocean surfaces = warmer stratosphere + warmer troposphere.

According to the link I posted before

http://www.jstage.jst.go.jp/article/sola/5/0/53/_pdf

It would appear that from about 1975 to 2000 we enjoyed scenario i) with a more disturbed sun and a run of powerful El Nino events.

At present we have scenario ii) with a quieter sun and a negative oceanic phase.

How it could work:

1) The reason for a cooling stratosphere at a time of a disturbed sun is unclear. The authors of the article are clearly puzzled. It is generally thought that it is the chemistry (including ozone and ultra violet radiation) and associated interactions within the upper atmosphere that govern temperatures by affecting the flows of energy between layers. There are no circulations in the upper atmosphere due to it's stable stratification.

2) I suggest an alternative mechanism. The article refers to ripples. That reminds me of ripples caused by wind across an ocean surface. The stronger the wind the larger the ripples and they can become large waves. The presence of waves increases the ocean surface area so that loss of energy to the air via evaporation and radiation increases. If a more disturbed flow of energy from the sun causes ripples or even waves in the boundaries between the layers of the upper atmosphere then it will provoke a larger surface area at each boundary and increase the rate of radiation to space.

3) That fits well with the four scenarios listed above and with observations.

4) Note that it is not the power of the solar energy flow that makes the difference. It is the extent to which it is disturbed. Thus one can theoretically achieve an enhanced loss of energy from stratosphere to space without any extra rate of energy coming from the sun. Just like the wind cooling effect on skin in a steady temperature.

5) That fits well with the most recent research of Judith Lean, Leif Svalgaard and others who are finding that the actual variation in the quantity of energy coming from the sun over centuries despite large variations in the number of sunspots and flares is infinitesimal compared to the climate effects actually observed.

6) Applying all this to the period 1975 to 2000 I would suggest that increased rates of energy release from the oceans warmed the troposphere and the hydrological cycle speeded up to transfer the extra energy flowing through the air upwards to the stratosphere. At the same time the sun was at a historic high in activity but despite that it was not putting a sufficient quantity of extra energy into the system to cause the changes in energy transfer rates that were observed.

7) Instead it was disturbing the upper atmosphere, increasing the surface areas of the various layer boundaries and accelerating energy to space faster than it was being transported to the stratosphere by the hydrological cycle. The outcome being scenario i) above. The reverse now applies as per scenario ii).

Do the Oceans behave independently or not ?

We have never observed scenarios iii) and iv) so far as I know. Our ability to measure temperature changes accurately in the upper atmosphere did not arise until the satellite era so we do not know how the stratospheric temperature changes that accompanied tropospheric temperature changes altered in the past.

However, if scenarios iii) and iv) can occur from time to time then that could explain the rapidity of past climate changes. In particular I note that until 10,000 years ago there was a very unstable global climate with large shifts between cold and warm climates every 1,500 years or so as described here:

http://en.wikipedia.org/wiki/Bond_event

It would be consistent with my ideas if that instability occurred when sun and oceans were out of phase thus supplementing the effect of each other whereas for the past 10,000 years the sun and oceans have been in phase and thus offsetting the effects of each other.

Note that ‘in phase’ can be a confusing term in this context because warm ocean surfaces cause warming of the troposphere but a more active sun causes cooling of the stratosphere so ‘out of phase’ actually means when both sun and oceans are causing the same effect. That arises when either oceans surfaces are warmer AND the sun is LESS active OR when ocean surfaces are cooler AND the sun is MORE active (scenarios iii) and iv) above.

Scenarios iii) and iv) can only occur for any length of time if the ocean cycles vary independently of solar changes.

One difficulty in diagnosing the level of independent ocean variability is that day to day climate chaos and the interannual ENSO (El Nino Southern Oscillation) effects conspire to hide trends on timescales of less than the PDO (Pacific Decadal Oscillation) periodicity of about 30 years on average.

As far as we can see back to the Roman Warm Period the levels of solar activity have shown some (albeit imperfect) correlations with global air temperature changes. Some have tried to establish a correlation back to the Minoan Warm Period but due to the lack of contemporaneous records and sufficiently accurate proxies I doubt we could go any further.

Throughout all that time sun and ocean appear to have been approximately in phase (and thus offsetting each other) as far as we can tell. When the sun is more turbulent (and so cooling the stratosphere) the oceans are releasing energy faster to the tropospere and vice versa. However that coincidence appears somewhat unreliable and I discuss the implications of that in the next section.

I have suggested that the rate of energy loss to space depends more on the turbulence of the energy flow from the sun than the power of the energy flow.

At the same time the rate of energy flowing upward into the stratosphere depends mostly on oceanic rates of energy release.

Our climate is governed primarily by that balancing act.

The changes in the rate of energy release by the oceans seem to depend on the underlying water flows and whether from time to time more or less of the water warmed to a depth of 100 metres or so by solar input manages to get back to the surface to release energy to the air.

For 30 years at a time the oceans seem to increase or decrease their rates of energy release and there is some evidence for another underlying cycle of between 1000 and 1500 years.

So, for the time being at least, a more disturbed sun accompanies a positive (warming) ocean phase as for the period 1975 to 2000 and a less disturbed sun accompanies a negative (cooling) ocean phase as now. Interestingly the trend changed from a cooling stratosphere to a warming stratosphere in 1996 and in 2000 I noticed that the air circulation systems had shifted back towards the equator, probably due to the ocean phase in the Pacific starting to turn negative and reducing energy flow rates through the troposphere. So the sun and oceans remain in phase (offsetting each other's extremes) fortunately for us.

The declining level of solar instability after the peak of cycle 23 led to the change in stratospheric trend in 1996 towards warming and that was followed a little later by a change in the rate at which the oceans emitted energy to the air which then caused the air circulation shift and the current slow cooling trend in the troposphere. Fitting perfectly with the ideas set out herein.

Someone has pointed out that the main oceanic cycle, the PDO, shifts every third solar cycle. Thus for three solar cycles the ocean surfaces will show net warming and for three solar cycles net cooling.

That does look like a linked rhythm with the ocean phases changing to a beat of three solar cycles as an imbalance (first one way and then the other) builds up and is then released. It's like a worn set of gears slipping twice and then engaging on every third revolution. Each successive shift moving the separate (and diverging) oceanic and solar underlying trends back towards equilibrium.

That would give the 'stepped' appearance of temperature changes throughout either a longer term warming or cooling period which we do actually observe as witness the changes in temperature trend during the 20th Century.

Indeed it may well be that we will still see more steps upward during the 21st Century if we have not yet reached the peak of the longer 1000 to 1500 year cycle.

That said the current quiet sun is making it look increasingly that we have now passed the peak.

Further thoughts:

If it be the case that solar and ocean effects can move out of phase as per scenarios iii) and iv) above and if they can do so for long periods of time then that could resolve the doubts entertained by some about whether orbital changes are sufficient on their own to induce ice ages.

We can see from the Bond events of more than 10,000 years ago that ice age conditions seem to occur when the global air temperatures swing more wildly whereas inter glacial periods seem to be much more stable.

It may well be that during inter glacial periods the solar and oceanic effects described above minimise extremes by offsetting one another.

When the oceans release energy to the air faster a more active sun is cooling the stratosphere to reduce overheating. When the oceans release energy to the air more slowly a less active sun is allowing the stratosphere to warm to reduce overcooling.

The more evenly balanced the two effects are then the warmer the global air temperatures can become because the winter cooling effects of the northern land masses are minimised. In this connection I think the current landmass distribution is critical in determining whether cooling occurs faster than warming when the solar and oceanic cycles start drifting away from offsetting one another and instead start supplementing one another.

The less balanced the solar and oceanic effects become the larger the climate swings and during the northern summers ice takes longer to melt with the current landmass distribution thus gradually skewing the global air temperatures even more towards overall cooling of the air and continents.

When both solar and oceanic effects combine to supplement each other on a regular basis the global air temperature swings become large enough to allow accumulations of ice in the northern landmasses to survive the summer melts over increasingly large areas.

I note that glacial periods have been much longer than inter glacial periods so I suspect that inter glacial periods can currently (given existing land mass distributions) only arise when the solar and oceanic effects are substantially (rather than just partially) offsetting one another.

Conclusion:

Rather a lot of hitherto unexplained observations can be accounted for once one realises that a more active sun can induce cooling of the upper atmosphere especially if the rate of energy release from the oceans is capable of varying independently from solar variability over extended periods of time.

The phasing of the two influences becomes critical for explaining the temperature changes observed in the troposphere.

It is even capable of explaining the timing of ice ages and the discrepancy between the size of changes in solar energy output and the consequent changes in climate.

The first indication we will get that the current interglacial is coming to an end will be an increasing frequency and duration of oceanic positive phases coinciding with a quiet sun and vice versa.

That will reintroduce the wild temperature swings associated with glacial epochs by causing simultaneous warming (or cooling) of both troposphere and stratosphere.

A slow rate of energy transfer from ocean to air during a negative ocean phase at the same time as a fast rate of energy loss to space during a period of active sun is the cold scenario that is most to be feared. In such a situation the air temperatures would drop fast and far.

A fast rate of energy transfer from ocean to air during a positive ocean phase at the same time as a slow rate of energy loss to space during a period of quiet sun would produce a warming effect dwarfing current concerns.

The different scale of global temperature variability between glaciations and inter glacial periods has to be accounted for somehow and I am not aware of any other plausible explanation.