Climate Change: Driven by the Ocean not Human Activity

by

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Abstract

This paper discusses how the variation in the global ocean's Meridional Overturning Circulation (MOC) resulting from changes in the Atlantic Thermohaline Circulation (THC) and deep water Surrounding Antarctica Subsidence (SAS) can be the primary cause of climate change. (MOC = THC + SAS) is the likely cause of most of the global warming that has been observed since the start of the industrial revolution (~1850) and for the more recent global warming that has occurred since the mid-1970s. Changes of the MOC since 1995 are hypothesized to have lead to the cessation of global warming since 1998 and to the beginning of a weak global cooling that has occurred since 2001. This weak cooling is projected to go on for the next couple of decades.

Recent GCM global warming scenarios assume that a slightly stronger hydrologic cycle (due to the increase in CO_2) will cause additional upper-level tropospheric water vapor and cloudiness. Such vapor-cloudiness increases are assumed to allow the small initial warming due to increased CO_2 to be unrealistically multiplied 2-4 or more times. This is where most of the global warming from the GCMs comes from – not the warming resulting from the CO_2 increase by itself but the large extra warming due to the assumed increase of upper tropospheric water vapor and cloudiness. As CO_2 increases, it does not follow that the net global upper-level water vapor and cloudiness will increase significantly. Observations of upper tropospheric water vapor over the last 3-4 decades from the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data and the International Satellite Cloud Climatology Project (ISCCP) data show that upper tropospheric water vapor appears to undergo a small decrease while Outgoing Longwave Radiation (OLR) undergoes a small increase. This is opposite to what has been programmed into the GCMs. The predicted global warming due to a doubling of CO_2 has been erroneously exaggerated by the GCMs due to this water vapor feedback.

CO_2 increases without positive water vapor feedback could only have been responsible for about 0.1-0.2^{o}C of the 0.6-0.7^{o}C global mean surface temperature warming that has been observed since the early 20th century. Assuming a doubling of CO_2 by the late 21st century (assuming no positive water vapor feedback), we should likely expect to see no more than about 0.3-0.5^{o}C global surface warming and certainly not the 2-5^{o}C warming that has been projected by the GCMs.

1. INTRODUCTION

There are about 20 different General Circulation Model (GCM) groups around the world that have been conducting extensive numerical modeling simulations of the likely changes in global mean temperature that should be expected to occur from a doubling of atmospheric carbon dioxide (CO_2). Carbon dioxide has so far risen about 33 percent (to 385 ppm) over its pre-industrial values and about 15 percent during the last 30 years. It is expected that there will be a doubling of atmospheric CO_2 by the latter part of the 21st century. Most of these GCM simulations indicate that there will be a 2-5^{o}C (4-9^{o}F) increase in global mean temperature by the time this doubling takes place. Such large warming as obtained by the GCMs would cause great changes to human society. These large warming scenarios are highly unlikely, however. The GCMs greatly exaggerate the potential warming that will occur. These exaggerations are due to:

1. GCMs assume that an increase in atmospheric CO_2 will cause weak global warming and an increase in global precipitation that will lead to a large increase in upper-level water vapor and cloudiness. They simulate that this increase in water vapor and cloudiness will block large amounts of infrared radiation emitted to space. New observations by satellite and reanalysis data, however, do not support these GCM assumptions. The global warming that has occurred since the mid-1970s has been associated with a modest decrease of global upper tropospheric water vapor and an increase of Outgoing Longwave Radiation (OLR). These measurements contradict model predictions.

2. GCMs do not currently accurately model the globe's deep-water ocean circulation. Accurately modeling the global ocean's deep circulation is fundamental to any realistic understanding of global temperature change, as this circulation appears to be the primary control of global surface temperature. The global warming we have seen since the mid-1970s and over the last 100 years is likely largely due to reductions in the rate of global ocean deep water circulation (or the MOC) which is viewed as being driven by global ocean salinity variations. CO_2 changes play no role in these ocean changes.

The most basic AGW question appears to be how we would expect upper level water vapor changes to respond to increases of CO_2. The GCMs program a very large (and in my view, quite unrealistic) upper level water vapor increase as a response to CO_2 doubling. This is a consequence of the GCM's faulty sub-grid convective parameterization schemes and the strict interpretation of the Clausius-Clapeyron (CC) equation to upper level temperature changes which dictate that water vapor increase with temperature increase. Observations indicate that this is not occurring. The cumulus convective schemes employed by the GCMs develop unrealistic high amounts of water vapor which block too much OLR and cause artificial warming which is 2-4 times greater than the warming that would result from the CO_2 blockage of OLR by itself.

Observations and other theoretical analysis indicate that little or no upper level water vapor increase will occur with a doubling of CO_2. If this is true then the CO_2 induced global temperature increases will be only a quarter or a third as much as the GCMs currently indicate.

All the various data sets (Figure 1) that I and some of my colleagues have been working with indicate that upper level water vapor (near the radiation emission level) should not necessarily rise with increases of CO_2 and global temperatures. Rather than rise, there appears to be a tendency for a slight upper tropospheric decrease in water vapor as upper level temperature and CO_2 have increased. This would allow about as much water vapor induced OLR to space after CO_2 amounts have increased as they had before. Little water vapor induced warming should result. There are good theoretical arguments for this being the case. [This does not mean that lower tropospheric water vapor and net precipitable water content will not slightly rise as CO_2 amounts double.]

Thunderstorms and cumulonimbus (Cb) activity are the primary mechanisms to bring mass into the global upper troposphere. Such deep convective activity is highly concentrated at any one time to only about 2-3 percent of the global area. The mass that goes up in the deep convective clouds is then advected outward from the convective areas to the environment and sinks in response to the upper tropospheric radiational cooling, cirrus evaporation cooling, and the need for mass balance (Fig 2).

The vertical gradient of saturation vapor pressure in the upper troposphere is very large. Upper level subsidence requires that upper level water vapor and RH values remain low. There appears to be no way a few percent increase in deep convection with CO_2 doubling could raise upper level water vapor amounts enough to significantly reduce OLR beyond the reduction of OLR by the increased CO_2 by itself.

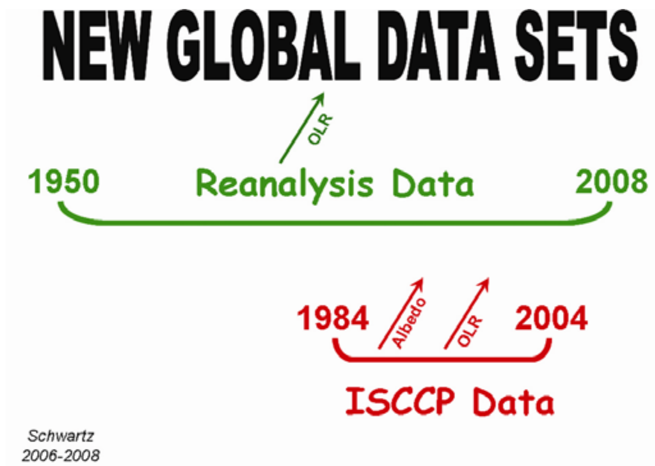

Figure 1. Data sources utilized in this study. NCEP/NCAR Reanalysis data (1950-2008) of wind, thermodynamics and OLR derived radiation, and data from the International Satellite Cloud Climatology Project (ISCCP) for the period of 1984-2004 which contain a variety of radiation components are examined.

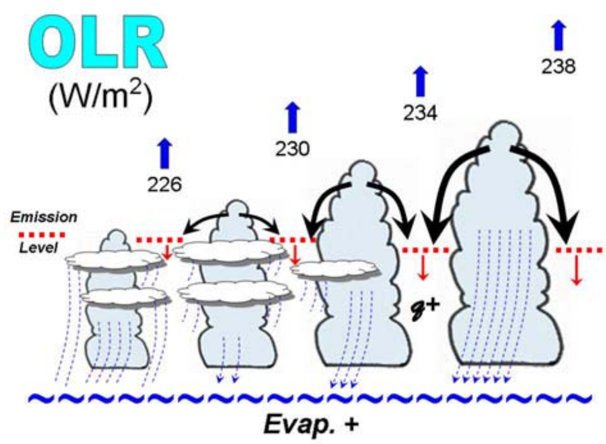

Figure 2. Idealized portrayal of how deeper and more intense cumulonimbus (Cb) convection can lead to progressively more return flow dry subsidence. Enhanced upper level subsidence acts to reduce upper layer water vapor, and enhanced OLR.

2. GCM MODELING PROBLEMS

Skillful initial-value numerical GCM climate prediction will likely never be possible. This is due to the overly complex nature of the global atmosphere/ocean/land system and the inability of numerical models to realistically represent and forecast the full range of this physical complexity.

Small-Scale Problems. In order to integrate over the entire globe and many years into the future it is necessary that the GCMs have rather large grid spacing. This requires that the GCMs employ sub-grid scale cumulus parameterization schemes which can often be poor approximations of the complex real-world, non-linear, small-scale cumulus convective processes. An important deficiency in the global models is the large amount of compensating up-and-down motion occurring between grid spaces that cannot be explicitly resolved by the models (Figure 3). These poorly-resolved approximations of sub-grid scale processes are integrated by the models for hundreds of thousands of time steps into the future. This guarantees large errors. Realistic sub-grid scale parameterization schemes have yet to be developed. Most GCM modelers are unfamiliar with the detailed functioning of the hydrologic cycle. Their models assume that changes in lower and upper tropospheric water vapor occur simultaneously which the observations do not verify (Figure 4). Observations show, in fact, that as global warming has occurred since the mid-1970s that lower tropospheric water vapor has increased while upper tropospheric water vapor has decreased. This appears to be a result of there being somewhat more deep Cb convection and a higher rainfall efficiency when the globe is warmer than when it is colder. There are slightly more deep convective updrafts and compensating mass subsidence drying at upper levels during times when the globe is warmer.

Much research on the small scale parameterization of cumulus convection in terms of the large scale circulation patterns was done in the 1970s and 1980s without satisfactory resolution. The topic was too complex to be resolved during this period. To move forward the GCMs primarily ignored this difficult task. They chose not to get ‘down-in-the-trenches’ on such a complex topic. They accepted a few simple compromised schemes (with known problems) and went forward with their broader-scale modeling integrations assuming that their sub-grid schemes were ‘good enough’ or that the errors would average out in the end. This assumption is not valid.

There are many large and complicated variations as to how sub-grid scale cumulus parameterization should be accomplished with respect to differences in latitude, surface characteristics, season, and other conditions. There are no general sub-grid parameterization schemes that can perform this function within various regions and on long climate time-scales.

The net effect of the GCM’s sub-grid scale parameterization schemes is to underestimate sub-grid subsidence drying, and to unrealistically suppress OLR to space. It is thus not surprising that the GCMs produce so much global warming (~2 to 5^oC) for only a relatively small increase (3.7 $^W/_{m^2}$) of suppressed radiation to space for a doubling of CO_2.

It is expected that global rainfall will increase somewhat as human-induced greenhouse gases increase. This increased rainfall is expected to primarily manifest itself in increased and concentrated deep cumulus convection and increased rainfall efficiency in the normal areas where deep convection and rainfall are already occurring. This somewhat greater and more concentrated rainfall will not bring about global upper-level water vapor and cloud increase anywhere near as much as the GCM modelers have assumed. The diagram of Figure 5 gives the author’s concept of how the globe will handle a doubling of CO_2 by the end of the 21st century. We will not see a global warming of 2-5^oC as the GCM models indicate but rather a much more modest warming of about 0.3-0.5^oC.

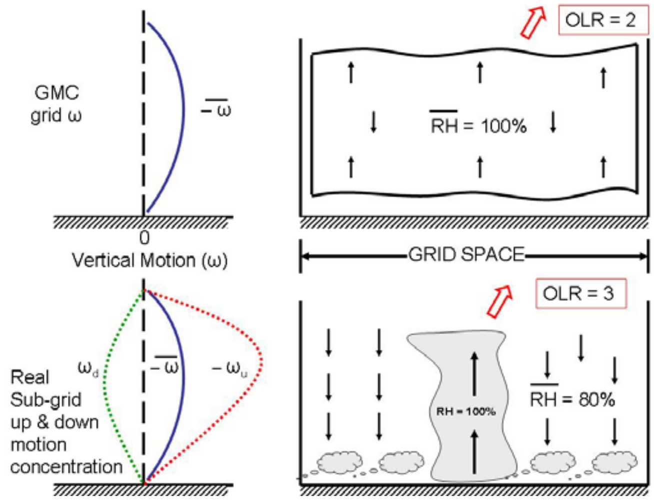

Figure 3. Idealized portrayal of how the grid size of the GCMs is too large to accommodate real sub-grid scale vertical motion. GCMs cannot resolve (top) the concentrated rain or the surrounding cloud downdrafts and subsidence within the scale of its grid space (bottom). The top and bottom diagrams contrast the mean vertical motion of the GCM (top) and the real up-and-down vertical motion of nature if deep convection is occurring within a grid space. Note that the unresolved vertical motion of the top diagram allows less OLR to escape to space.

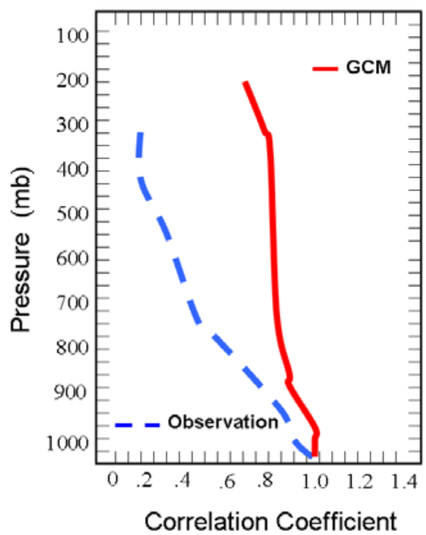

Figure 4. Comparison of correlation coefficient between upper and lower level tropospheric water vapor of the typical GCMs output (red) and that of the Rawinsonde-reanalysis observations (blue line). The GCM outputs are programmed to have a simultaneous moistening of the lower and upper tropospheric levels, but the observations of upper vs. lower troposphere moisture shows little correlation. This high correlation of the models causes them to artificially moisten the upper troposphere and block too much OLR to space. Adapted from Sun and Held 1996.

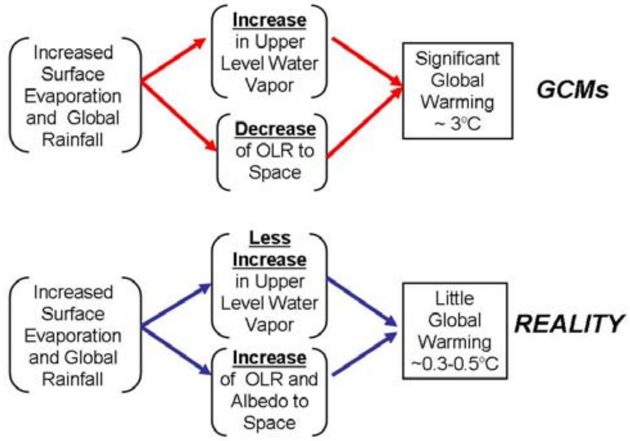

Figure 5. A view of the physical process differences between the global warming for a doubling of CO_2 from the GCMs (top) and hypothesized reality (bottom).

<u>Positive or Negative Water Vapor Feedback</u>? Most geophysical systems react to forced imbalances by developing responses which oppose and weaken the initial forced imbalance; hence, a negative feedback response. Recent GCM global warming scenarios go counter to the foregoing in hypothesizing a positive feedback response. Observations indicate that the specific humidity and relative humidity of the middle and upper troposphere have been going down over the last 4-5 decades (Figure 6). The assumed positive water vapor increase with temperature as programmed into the GCMs does occur however at the surface and the lower troposphere. But this simultaneous increase of temperature and water vapor is not found in the upper troposphere near the radiation emission level. It is not the total precipitable water which is most important (measurements show this goes up with temperature) but rather the amount of water vapor near the upper tropospheric emission level which is important. This more closely specifies the amount of OLR.

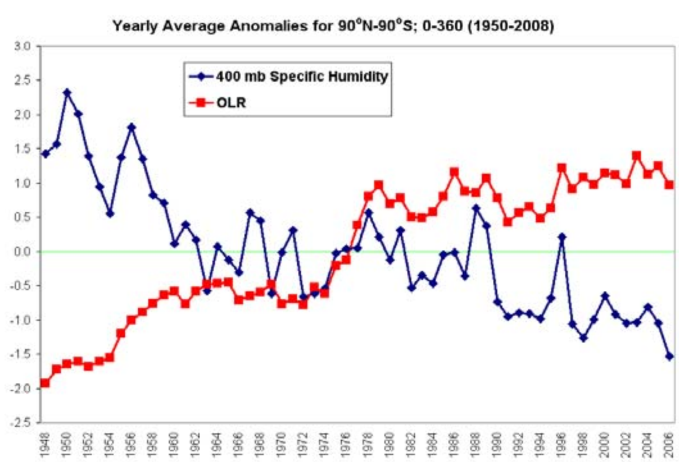

Figure 6. NCEP/NCAR reanalysis of standardized anomalies of 400 mb (~7.5 km altitude) water vapor content (i.e. specific humidity – in blue) and Outgoing Longwave Radiation (OLR) from 1950-2008. Note the downward trend in moisture and the upward trend in OLR.

Faulty Reasoning Behind Climate GCMs. A basic assumption error behind the GCMs has been the model builder's general belief in the physics of the National Academy of Science's (NAS) 1979 study – often referred to as *The Charney Report.* This report hypothesized that a doubling of atmospheric CO_2 would bring about a general warming of the globe's mean temperature between 1.5 – 4.5°C (or an average of ~ 3.0°C). This was based on the report's assumption that the relative humidity (RH) of the atmosphere should be expected to remain quasi-constant if the globe's temperature were to increase. The fundamental tenet of the Clausius-Clapeyron (CC) equation specifies that as the temperature of the air rises its ability to hold water vapor increases exponentially. If relative humidity (RH) were to remain constant as atmospheric temperature rose then the water vapor (q) amount in the atmosphere would accordingly rise (Figure 7 and Figure 8). Observations show that this is indeed a valid assumption for the lower tropospheric levels but does not observationally apply in the upper troposphere (300-400 mb) where water vapor and relative humidity have been observed to slightly decrease as the atmospheric temperatures rises. Lower RH and reduced water vapor content near the upper-atmosphere emission level act to increase the amount of OLR which will be emitted to space.

The GCMs which test the influence of CO_2 increases have accepted the hypothesized NAS – Charney Report (1979) scenario. Some of the GCM modelers such as the early NASA-GISS (Hansen 1988) model have even gone further than the Clausius-Clapeyron equation would specify for water vapor increasing with temperature. Hansen's early GISS model assumed that a doubling of CO_2 would cause the upper tropospheric RH not just to stay constant but to actually increase. His assumed upper tropospheric increase of water vapor (q) for a doubling of CO_2 led to a water vapor increase (Δq) in the upper troposphere of as much as an extremely unlikely 50 percent. These large vapor increases caused Hansen to require that his model have a tropical (30°N-30°S) upper tropospheric warming for a doubling of CO_2 of as much as 7°C (Figure 10). A 7°C warming at the upper level emission level is equivalent to a 23 W/m^2 enhancement of OLR for a doubling of CO_2 forcing of only 3.7 W/m^2. No wonder Hansen got such high values of global warming for a doubling of CO_2. This logically followed from his extremely high and unrealistic water vapor assumptions.

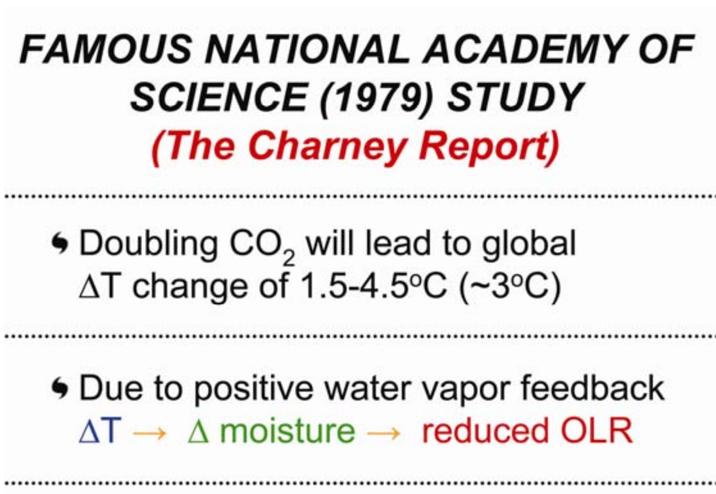

Figure 7. The very influential NAS report of 1979 which deduced that any warming of the globe would occur with near constant relative humidity (RH). Global warming consequently is thought to cause an increase in atmospheric water vapor (q) and a decrease in OLR. This assumption appears valid in the lower troposphere but not for the upper troposphere. Although temperature increase may cause precipitable water to increase in the troposphere, it does not mean that upper tropospheric water vapor will necessarily increase.

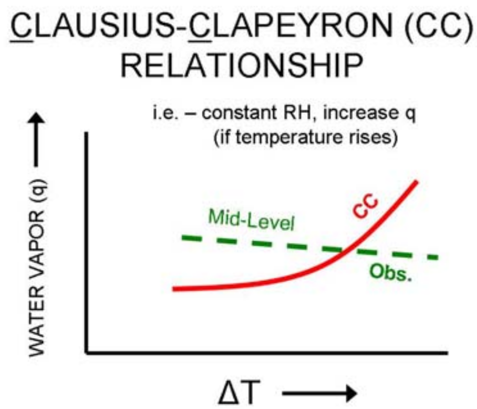

Figure 8. Clausius-Clapeyron (CC) relationship showing the required increase of water vapor as temperature increases at constant RH – red line. The observations of upper tropospheric water vapor – green dashed line – do not follow this theoretical relationship. This is likely a result of a warmer climate causing more deep convection and more return flow subsidence (as shown in Figure 2).

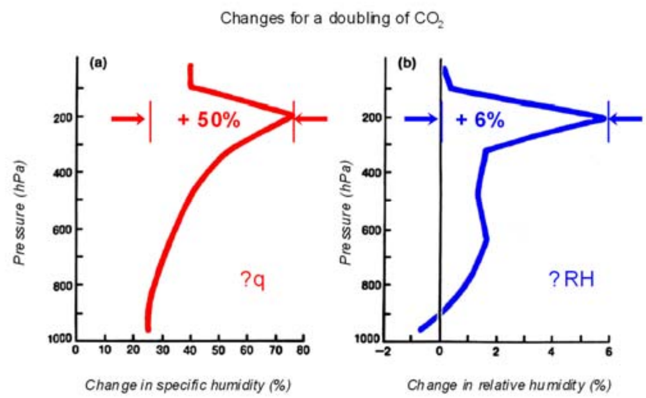

Figure 9. James Hansen's early GISS model showing his assumed increases in specific humidity (q) and RH for a doubling of CO_2. Such water vapor assumptions are completely unrealistic, especially for conditions in the upper troposphere where water vapor typically increases less.

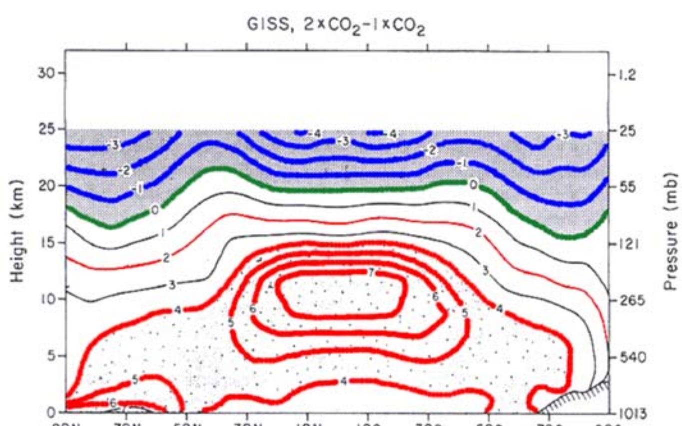

Figure 10. North-South vertical-cross section showing Hansen's early GCM's model change in temperature (^oC) that would accompany a doubling of atmospheric CO_2. There is no way a doubling of CO_2 and an extra 3.7 $^W/_{m^2}$ blockage of OLR to space could lead to such extreme upper tropospheric temperature rises. These large temperature increases occurred because of Hansen's unrealistic upper level water vapor assumptions.

In order to obtain the global balance of incoming and outgoing radiation for his assumed high values of upper tropospheric water vapor it was necessary for Hansen to unrealistically raise his model's upper tropospheric temperatures to obtain the amounts of OLR (or σT^4) to space that would accomplish net radiation balance. It is amazing that Hansen's high water vapor increase and massively high upper tropospheric temperature rise assumptions for a doubling of CO_2 were not immediately challenged.

It was these large amounts of warming resulting from his model's gross over-estimate of water vapor which Hansen presented to a US Senate Committee hearing at the request of then Senator Al Gore during the hot summer of 1988. The media and much of the general public accepted it all. The environmentalists salivated. Hansen had secured his place in the sun. History will reverse such adulation when his warming predictions are inevitable proven to be wrong.

Not only have Hansen's extreme and unrealistically high values of upper tropospheric moisture and temperature changes (for a doubling of CO_2) not been challenged, they were instead closely emulated by most of the other prominent early GCM groups of NOAA-GFDL (Figure 11), NCAR (Figure 12) and the British Met Service (Figure 13). They all followed suit and incorporated unrealistically high amounts of upper tropospheric water vapor and, as a result, obtained unrealistically high values of global upper and surface temperature just as Hansen had. The fact that most of the (assumed independent) GCMs produced similar warming results were used as verification of each model's results. But this was untrue. All the modelers were wrong in the same direction and in the same way.

Although the more recent GCM runs of Hansen's GISS model and the more recent, GFDL, NCAR and UKMET models have been improved, they are still fundamentally flawed. I expect the current set of GCM modelers will say I am referring to older model runs that are now obsolete. This argument does not hold however. If the more recent year models are superior to the older ones, then we would be seeing a revision downward of their warming estimates. But their newer models give much the same magnitude of warming as their older ones.

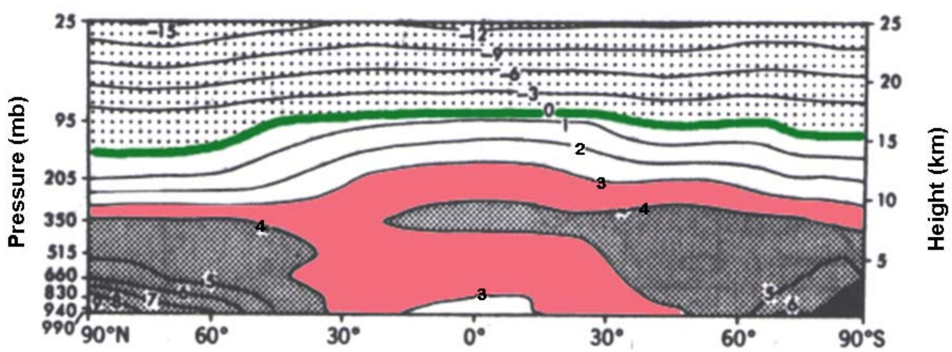

Figure 11. Same as Figure 10 but for the NOAA-GFDL GCM.

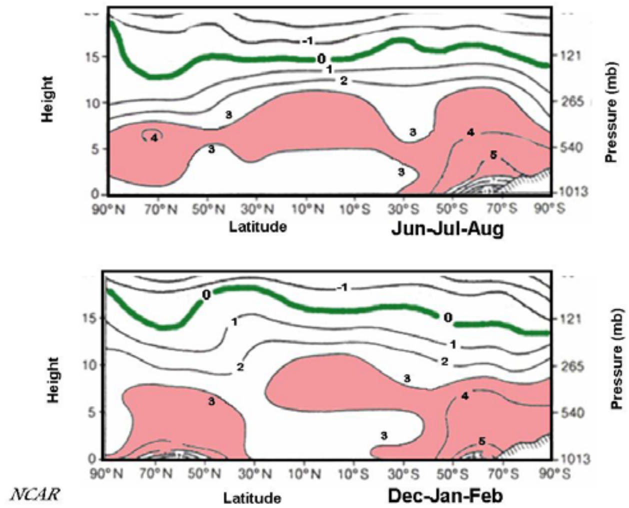

Figure 12. Same as Figure 10 but for the NCAR's GCM.

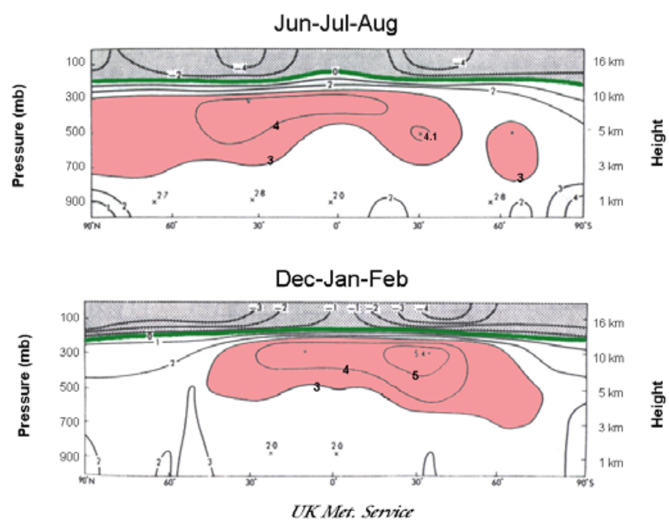

Figure 13. Same as Figure 10 but for the UKMET GCM.

3. IMPOSSIBILITY OF SKILLFUL GCM CLIMATE PREDICTION

Skillful initial-value numerical weather forecasts currently cannot be made for more than about two weeks into the future. This is because any imperfect representations of the highly non-linear parameters of the atmosphere-ocean system tend to quickly degrade (the so-called butterfly effect) into unrealistic flow states upon integration of longer than a week or two. Skillful short-range prediction is possible because there tends to be conservation in the initial value momentum-pressure fields which can be skillfully extrapolated or advected for a week or two into the future. But after 1-2 weeks, one must deal with the far more complex variation of the moisture and energy fields. Model results soon decay into chaos.

If skillful GCM forecasts were possible for a longer period of a season to a few years, we would be eager to track their skill. Currently, GCMs do not make official seasonal or annual forecasts. They dare not issue these forecasts because they know they are not skillful and would quickly lose their credibility if they gave real time forecasts that could actually be verified. How can we trust GCM climate forecasts 50 and 100 years into the future (that cannot be verified in our lifetime) when these same models are not able to demonstrate shorter range forecast skill?

4. GLOBAL WARMING DUE TO NATURAL PROCESSES

The global warming that has been observed since the mid-1970s and over the past century should not automatically be blamed on human-produced greenhouse gases. There is an alternate physical mechanism which I propose below. This alternate mechanism is related to the globe's deep ocean circulation (Figure 14 and 15). A weaker Atlantic Ocean Thermohaline Circulation (THC) and weaker Surrounding Antarctic Subsidence (SAS) or Meridional Overturning Circulation (MOC = THC + SAS) for the period of a decade or a decade-and-a-half can bring about a gradual global upper ocean warming. When a weaker MOC occurs, the Southern Hemisphere tropical oceans upwell less cold water into the thermocline, and there is generally less global rainfall. With a lag of 5-10 years a modest globe warming ensues. When the opposite occurs (MOC stronger than normal) there is more deep cold water upwelling into the tropical Southern Hemisphere oceans, somewhat more global rainfall, and (again with a 5-10 year lag) a gradual global cooling occurs.

I judge the THC and MOC to have been generally weaker over the last century and especially over the period from the late-1960s to the mid-1990s. It is this weaker MOC and not the increase in global CO_2 that was the primary cause of the recent global warming we have observed. The globe typically reaches its highest or lowest average temperature about 10-years following the onset of a weak or a strong MOC. We have recently been very close to the maximum global warming period following the onset of a strong MOC circulation in 1995. Continued global warming should not be expected. We should begin entering a weak global cooling period similar to what occurred between the mid-1940s and mid-1970s. Observations indicate that we have in fact entered a global cooling period which began in 2001. We should expect this weak cooling to continue for another couple of decades.

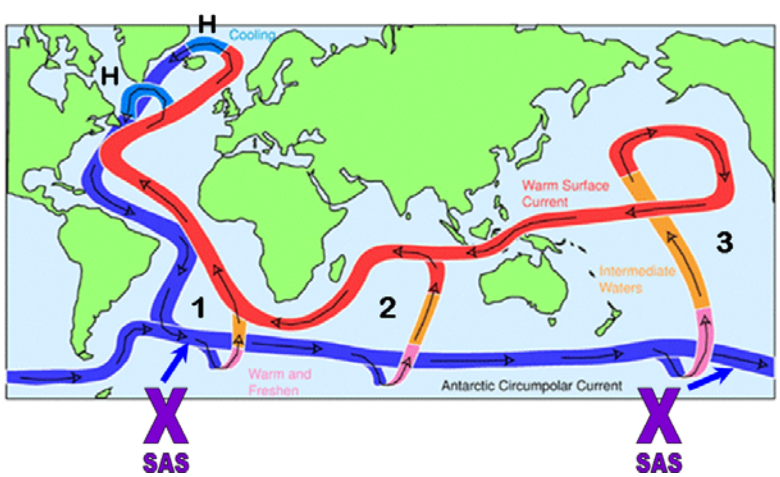

Figure 14. Idealized portrayal of the deep water Global Ocean Conveyor Belt (often referred to as the MOC) showing the typical locations in the Southern Hemisphere where upwelling occurs into the upper ocean thermocline and mixed layer (areas 1, 2, and 3) that is required to balance THC subsidence (H areas). Surrounding Antarctic Subsidence (SAS) is shown by X's. The MOC = (THC + SAS). Estimates are that the mass of the North Atlantic deep water subsidence is about twice the mass as the ocean subsidence around Antarctica. Over multi-decadal periods THC ans SAS are positively related to each other. Figure adapted from John Marshall, of MIT.

Figures 16-22 show how stronger deep water subsidence in the North Atlantic (THC+) and surrounding Antarctica (SAS+) or positive MOC can lead to more cold water upwelling in the Southern Hemisphere tropical ocean and result in upper ocean cooling.

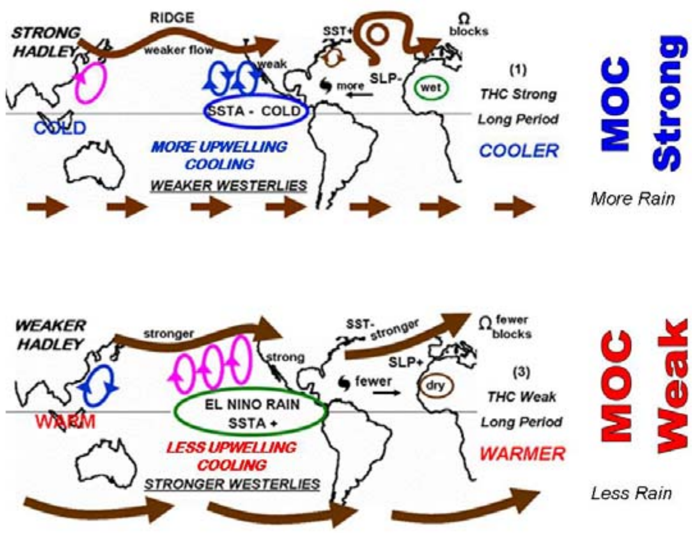

Figure 15. The top diagram shows the typical global wind patterns when the MOC has been strong for a long period and cold water upwelling in the Southern Hemisphere has been greater than the long period average. This leads to global temperatures becoming gradually cooler than average and more global rainfall (top diagram). The bottom diagram shows the typical global wind patterns when the MOC have been weaker than average for a long period and there has been reduced cold water upwelling in the Southern Hemisphere. The globe becomes gradually warmer during these periods and global rainfall is reduced. The top diagram shows characteristics of the conditions which existed during the modest global cooling period between the mid-1940s and the mid-1970s. The bottom diagram is characteristic of the conditions during the warming period of the mid-1970s to around 2000.

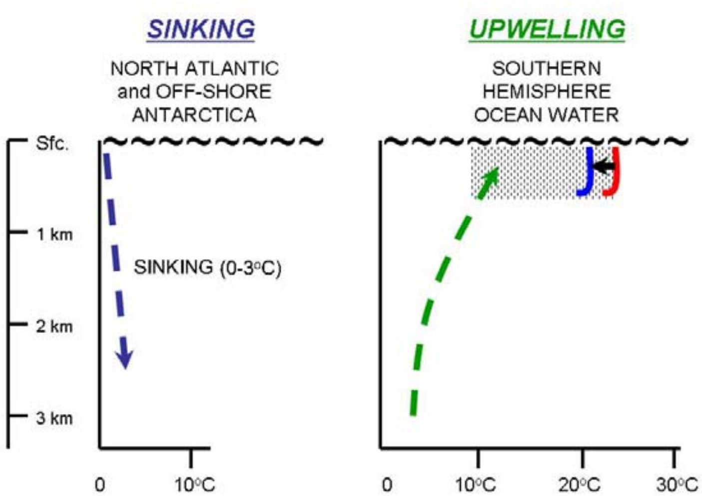

Figure 16. Illustratation of how cold water subsidence in polar regions and compensating upwelling in the Southern Hemisphere tropics could lead to upper ocean cooling.

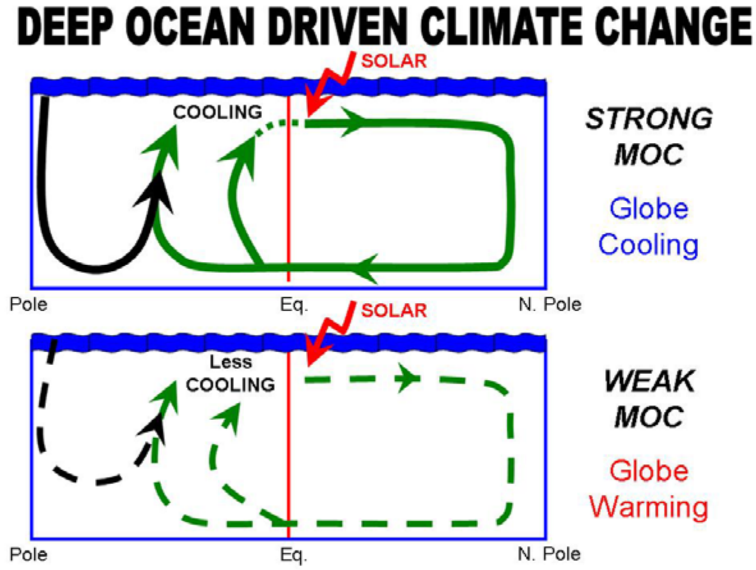

Figure 17. Idealized North-South graphical illustration of a strong (top) and weak (bottom) MOC. It is hypothesized that these differences in MOC strength are caused by salinity variations.

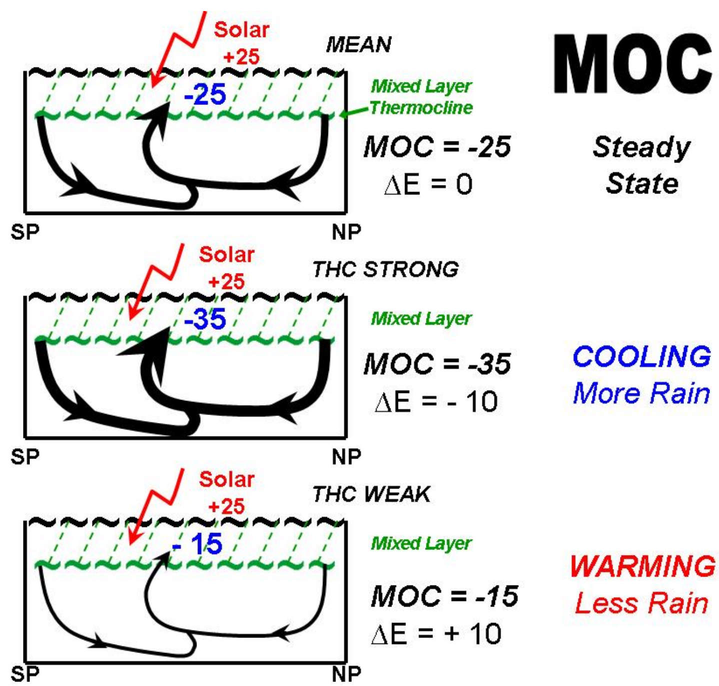

Figure 18. Hypothesized global MOC induced upper ocean energy budget for steady (top), cooling (middle) and warming (bottom) global conditions. Observations indicate that the globe has somewhat more rainfall when the MOC is strong than when it is weak. MOC units in Sverdrups (10^{12} gm/s). ΔE gives upper ocean energy changes. There is theoretical and observational evidence that north and south polar subsidence is related to each other over longer multi-decadal time periods.

Figure 19. The MOC is thought to be a combination of the THC and SAS.

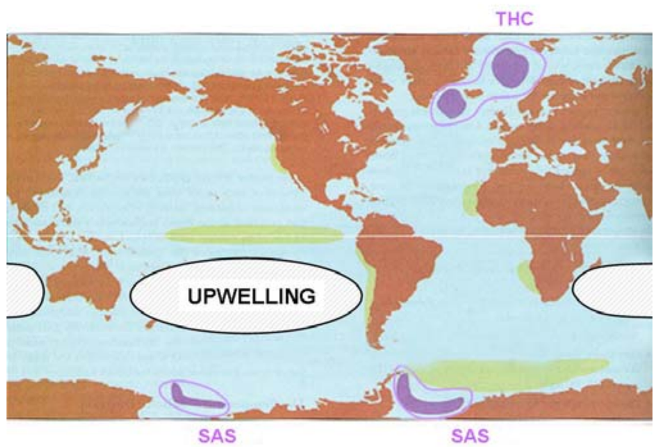

Figure 20. Areas of THC and SAS deep water formation and typical areas of corresponding upwelling.

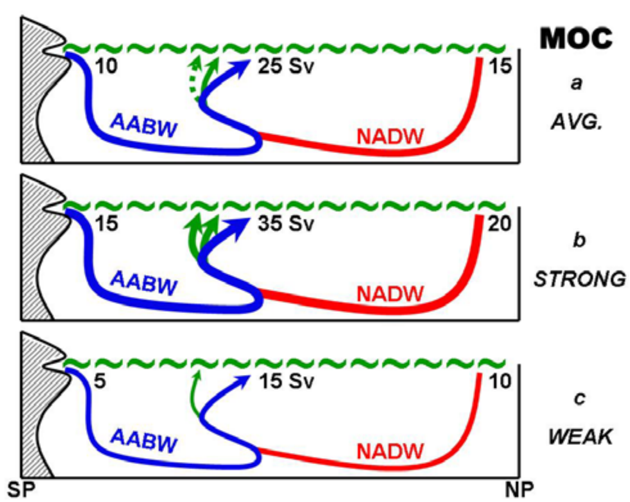

Figure 21. Idealized portrayal of the typical strength of the THC characterized by North Atlantic deep water formation (NADW) and Antarctica bottom water (AABW) in Sverdrups. The top diagram is for average conditions, the center is for strong MOC conditions and the bottom is for weak MOC conditions. It has been diagnosed that NADW (or THC) is typically about 1½ to 2 times stronger than AABW (or SAS). And there is evidence that on long time scales they tend to be of similar sign.

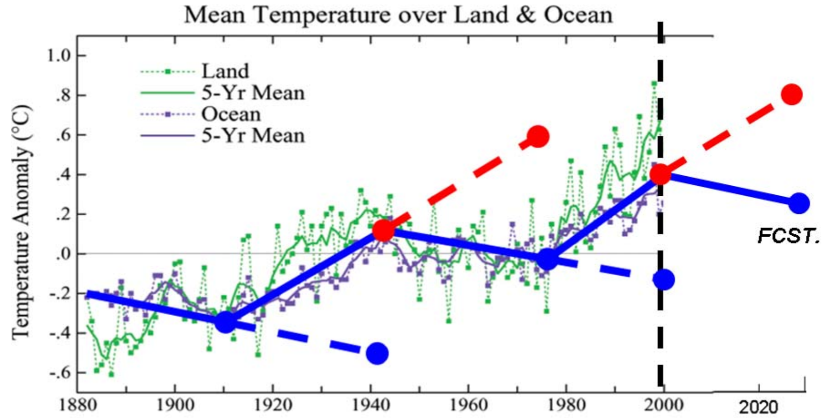

Figure 22. Illustration of how much error one would have made by extrapolating a cooling or warming curve beyond 30-35 years. The recent 1975-2000 warming trend should not be expected to continue. We have seen weak global cooling since 2001. I estimate global temperature by 2030 will be somewhat below the value of today's global temperature.

Figure 23 shows variations of the THC as measured by the North Atlantic sea surface temperature anomalies (SSTA) since 1870. Strong THC conditions occur when the North Atlantic SSTAs are positive due to poleward advection of warm ocean water. This occurs primarily when there are higher than average Atlantic salinity conditions as shown in Figure 24. Figure 25 contrasts strong and weak THC conditions. The top diagram of Figure 26 shows global SSTA conditions during strong THC conditions. The bottom diagram of Figure 26 shows THC variations over the last 150 years and how, with a lag of about 10 years, global surface temperature increases when THC conditions are weaker than average and decreases when THC conditions are stronger than average.

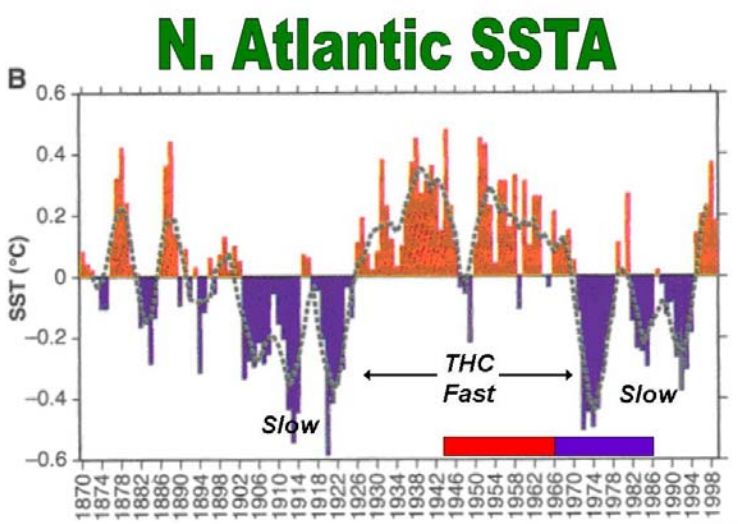

Figure 23. North Atlantic (50-65°N; 50-20°W) sea surface temperature anomalies (SSTA) from 1870-2000. Warmer temperature anomalies correspond to stronger than average THC conditions, and colder SST anomalies correspond to weaker than average THC conditions.

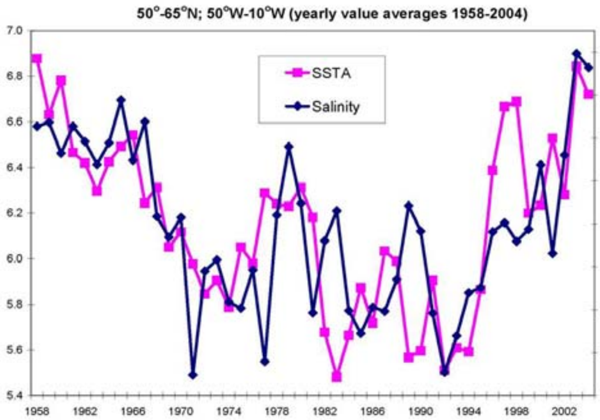

Figure 24. The close association between North Atlantic SSTA and observations of upper ocean salinity.

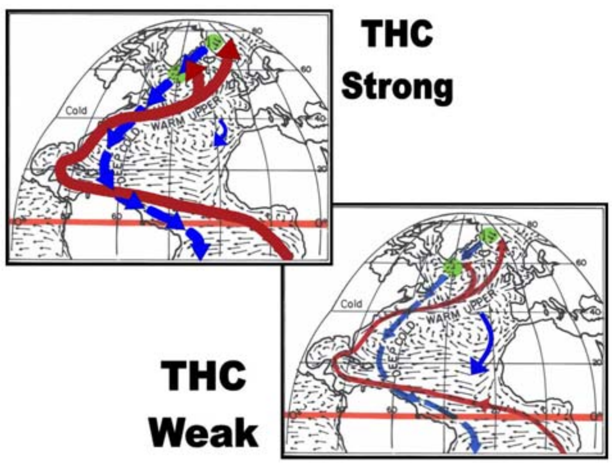

Figure 25. Portrayal of strong and weak THC conditions.

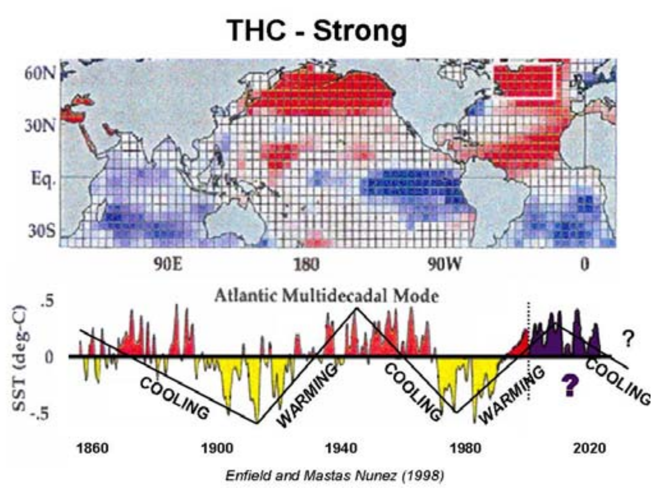

Figure 26. Illustration of typical global SSTA conditions during positive THC conditions (top) and the variation of THC strength over the last 150 years (bottom). With a lag of about 10 years, strong THC conditions lead to global cooling and weak THC conditions to global warming. Figure adapted from Goldenberg et al. (2001).

5. MERIDIONAL OVERTURNING CIRCULATION (MOC) INFLUENCE ON GLOBAL RAINFALL

Global tropospheric and ocean energy budget analysis in rainy situations indicate that during periods of a positive MOC there is in general about 3-5 percent more evaporation and rainfall as during those periods when the MOC is weaker than average. This 3-5 percent global evaporation difference is equivalent to 4-7 W/m^2 global surface ocean energy difference.

Following a lag of 5-10 years global surface temperatures undergo cooling during times of stronger than average MOC conditions and warming during times of weaker than average MOC conditions. This is because:

1. More ocean evaporation occurs during positive than negative MOC conditions. Extra energy is expended by the upper ocean to accomplish higher evaporation rates. More global evaporation requires the earth's surface to expense more energy to turn each gram of water into a gram of water vapor (~ 290 W/m^2).
2. More upwelling of colder water in the Southern Hemisphere tropical oceans during positive MOC periods gradually brings about more upper-ocean cooling (estimated 2-4 W/m^2 averages over the globe).

The extra evaporation from the oceans during positive MOC conditions causes extra tropospheric condensation warming and rainfall. Some of this extra rainfall occurs in enhanced deep Cb convection with its associated extra upper tropospheric subsidence drying. The more rainfall from deep convection, the more general IR loss to space.

From a global perspective, the observations indicate that variations in rainfall induced condensation warming within the troposphere are largely compensated by enhanced OLR. The troposphere cannot store energy like the ocean. Any excess or deficit of tropospheric energy gain-loss is compensated for by enhanced or reduced energy gain or loss to space or by changes in surface evaporation. Thus, the troposphere is, in general, a slave of the energy going into or coming out of the earth's surface. The more energy coming into the troposphere from the surface, the more energy that will be lost to space through enhanced radiation.

Figure 27 gives an idealized picture of this concept. Global surface temperature is strongly influenced by the amount of global surface evaporation which occurs and this evaporation is controlled by the strength of the MOC.

More evaporation occurs during strong MOC periods because:

1. More warm ocean water is advected into the high latitudes which causes the ocean minus surface air temperature and the saturated ocean minus the surface air water vapor gradient to be very large.

2. Mid-latitude westerly surface winds are stronger during weaker MOC periods. During these periods, Ekman-forced equatorial advection of cold ocean water under Ekman-forced poleward moving warm surface air causes a reduction of ocean to air gradients of water vapor and therefore less evaporation is possible than during periods of strong MOC conditions.

3. During strong MOC conditions, there is more advection of higher latitude cold air over warmer tropical water. This enhances surface evaporation in comparison to times of weak MOC conditions.

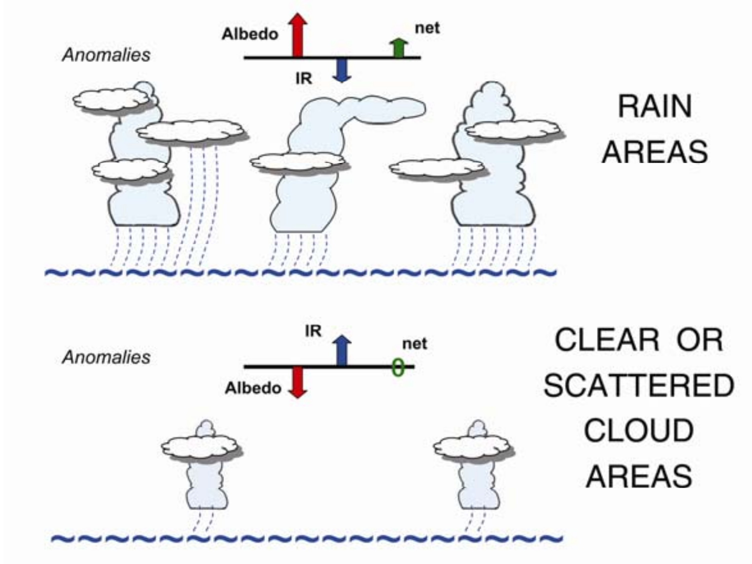

Figure 27. Idealized deviational changes of IR and albedo for rainy and cloudy areas (top) versus clear and scattered cloud areas (bottom).

Thus, all three of the above processes act to bring about generally greater amounts of ocean evaporation (and thus ocean cooling) during periods of high MOC conditions than during periods of low MOC conditions.

The global warming that has been experienced over the last century (~0.7^oC) has been primarily due to a slowdown in the MOC from what was experienced in the 19th century and during the period of the Little Ice Age. The 30-35 year periods of up-and-down global temperature change over the last century are due to shorter multi-decadal variations of the MOC. There is typically a 5-10 year lag before one is able to detect a noticeable globe surface temperature change from the initial onset of a stronger to weaker MOC or vice-versa.

The CO_2 increases that have been experienced with the globe's growing industrialization over the last century could have accounted for only about 15-20 percent of the warming that has been observed. The expected doubling of CO_2 from the pre-industrial background state by the end of the 21st century should by itself be expected to increase global temperature by no more than about 0.3-0.5^oC. It will be possible for humankind to adjust to this degree of warming.
The MOC could either enhance the late 21st century CO_2-induced warming or act to cancel it out. It would not be wise to engage in expensive national and international efforts to reduce CO_2 for the purpose of preventing global warming when nature through its MOC variations is holding the trump cards which can overwhelm anything CO_2 increases can accomplish. AGW advocates of CO_2 reduction strategies do not understand the physics of global climate change. Humankind would suffer severe economic hardships to follow the path advocated by the AGW advocates. There is very little humans can do to effect climate change. We must, as we have in the past, adjust to it.

6. PAST AND FUTURE GLOBAL TEMPERATURE CHANGES

We are seeing glaciers receding and arctic ice melting because we have been in a general warming period over the last century and particularly over the last quarter century period (from the mid-1970s to 2000). The generally increased global temperature we have witnessed over this warming period should, of course, be expected to bring about a degree of sea ice and glacier melting. The overall northern hemisphere middle-latitude winter wind patterns of most of this warming period (i.e., a positive North Atlantic Oscillation – positive Pacific North America pattern) caused warming in Alaska, northwest Canada, reduced snow in the European Alps, and general global glacial retreat. This is to be expected from such a weak THC or MOC flow regime. Similar warming conditions occurred from 1910 to the early 1940s. The Arctic Ocean and Greenland experienced a similar melting in the late 1930s and early 1940s as has recently been occurring in these areas. These are natural back-and-forth shifts in multi-decadal climate. But this recent warming pattern has now begun to reverse itself to a cooler pattern. Historically, multi-decadal cooling and warming trends such as we have seen over the last century typically do not maintain themselves for much more than 3-4 decades.

I judge our recent global ocean circulation conditions from the mid-1970s to the late 1990s to have been similar to that of the period of 1910-1945 when the globe had shown a large warming. There was concern in the early 1940s as to whether this 1910-1940 global warming would continue. It did not. A weak global cooling began from the mid-1940s and lasted until the mid-1970s. I predict this is what we will see in the next few decades. Since 2001 there has been a weak cooling.

The globe has been gradually coming out of the Little Ice Age since about 1850. The author views this long period change to be a result of a multi-century slow-down in the Atlantic THC and the MOC due to a general lowering of Atlantic upper ocean salinity. CO_2 increases are judged to have played only a very small role in the temperature rises that have been observed since we came out of the Little Ice Age.

Century Scale Perspective. It is hypothesized that on sub-orbital time scales (where solar activity does not significantly vary by time and place), such as the last 1000 years or so, that the primary force driving global climate change has been an internal one – namely, the long period multi-century and multi-decadal variations of the MOC as driven by global salinity variations on these time-scales.

I surmise that the medieval warm period was a result of a multi-century slowdown of the MOC in a similar fashion to the apparent slowdown of the MOC in the 20th century when we have had similar warming. I diagnose the Little Ice Age to have been a period of the MOC being stronger than average. Figure 28 portrays my suggested explanation for the global temperature changes we have seen over the last 130 years. I believe these temperature changes to be a combination of a 20th century general slowdown in the MOC together with various approximately 30-year multi-decadal speed-ups and slow-downs of the MOC. The top curve of this figure fits reasonably well with what we have seen for the global temperature curve over the last 130 years. Figure 29 gives an idealized portrayal of the THC (or MOC) being stronger in the 19th century as compared to the 20th century. It is to be expected that a weaker 20th century THC (or MOC) is associated with a warmer globe. There is some evidence (Figure 30) that the salinity contents of the upper ocean were higher in the 19th century then they were in the 20th century.

A paper by Broecker *et al*., 1999 (*Science*, 286, pp 1132-1135) titled “The Possible 20th Century Slowdown of Southern Ocean Deep Water Formation” states:

> *…A major reduction in Southern Ocean deep water production during the 20th century (from high rates during the Little Ice Age) is occurring.*

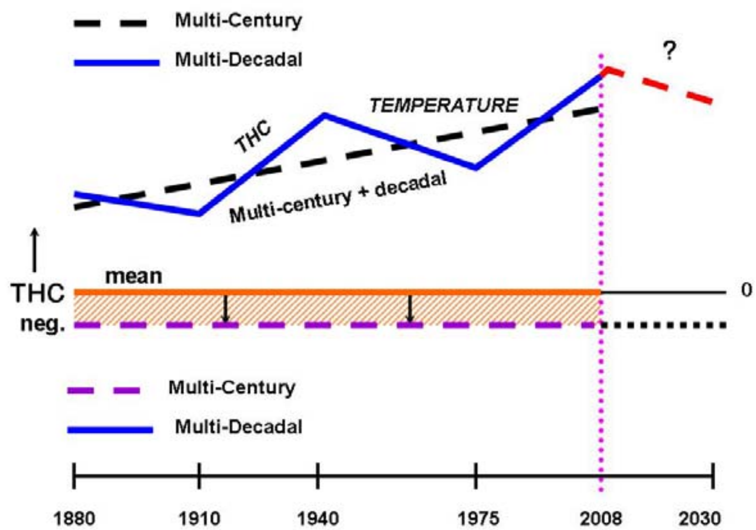

Figure 28. Idealized portrayal of how a combination of weak and strong multi-decadal variations in THC in combination with a century-scale long weak THC (or MOC) could well explain the long term up-and-down trend in global temperature over the last 130 years.

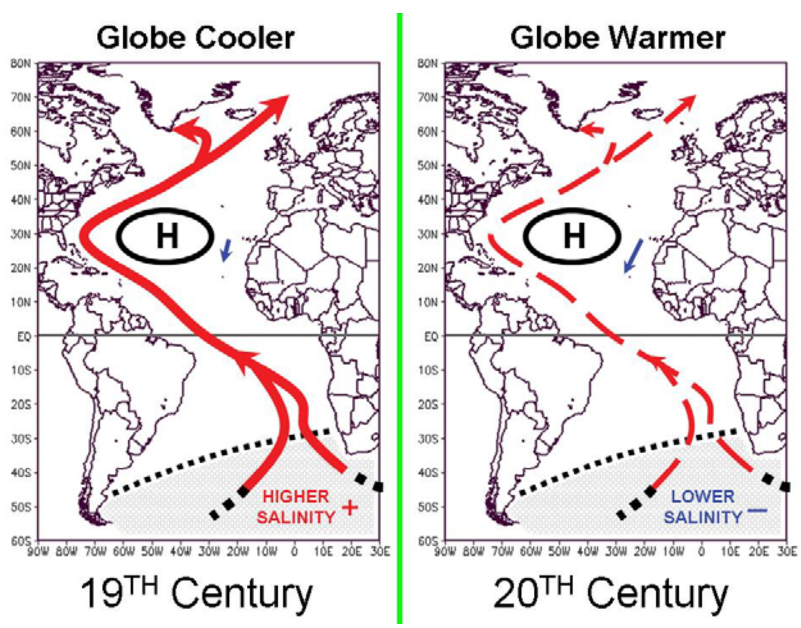

Figure 29. Idealized illustration of how the strength of the THC was likely stronger in the 19th century than it has been through most of the 20th century. These differences are hypothesized to be due to century-scale salinity variations.

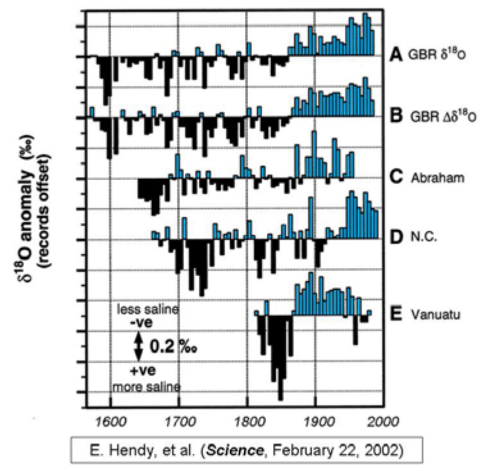

Figure 30. Inferred long period south Pacific salinity data indicating that 20th century upper ocean salinity may indeed have been lower than in prior conditions.

Global surface temperature changes of the last century-and-a half appear to be largely controlled by global rates of surface evaporation as specified by the bulk formula [Evaporation $\propto C_E V(T_s - T_a)(q_a)$] where C_E is a turbulent evaporation constant and V is sea surface wind speed at 10 m, T_s is the saturated specific humidity at the ocean temperature and q_a is the vapor pressure of the air. Substituting realistic values for the variables gives values of tropical evaporation of about 0.4 cm/d and for the whole globe something a little less than 0.3 cm/d.

When surface evaporation (and rainfall) rates are larger than average the global upper ocean tends to cool more than usual because of the extra energy that must be expended to change more liquid water to atmospheric water vapor (~ 290 Wm^{-2} per gm). Much of the resulting extra condensation heating from the rainfall that occurs in the troposphere is then radiated to space as enhanced combination of changes in IR and albedo. By contrast, when tropical and/or global rates of evaporation and rainfall are reduced the upper ocean expends less energy to change liquid water to vapor and as a result the globe begins a gradual warming process (Figure 31).

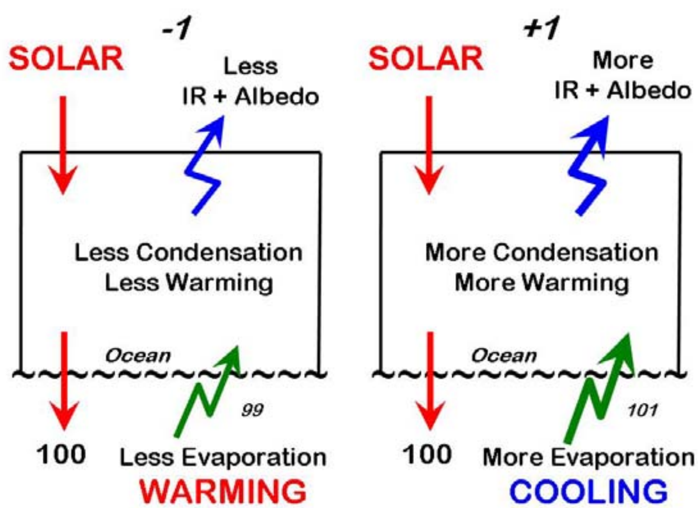

Figure 31. Idealized portrayal of the theory of natural multi-decadal climate change. Warming occurs when evaporation is reduced (left). Cooling when evaporation is enhanced (right).

7. EVIDENCE FOR HYPOTHESIS

Global analysis since the mid-20th century indicates that the rate of global precipitation is a function of the strength of the Atlantic Ocean multi-decadal thermohaline circulation (THC) and/or the Atlantic multi-decadal oscillation (AMO). THC and AMO are different terms for the same Atlantic Ocean circulation which functions on a back and forth time scale of about 60-80 years. When this Atlantic Ocean THC or AMO circulation is stronger than average, the ocean expends more of their energy in evaporation (Figure 9). A stronger THC induces more global meridional circulation and in the net causes somewhat more sea minus air temperature gradient and evaporation. When the THC is weaker than average we have more low level zonal wind circulation, sea minus air temperature is reduced and there is less evaporation. Enhanced evaporation induces (with a lag of 5-8 years) the beginning of a weak but noticeable global average cooling period. This cooling typically continues for 25-35 years until the THC circulation weakens (due to Atlantic salinity decrease). When this happens a new multi-decadal weak THC phase commences and with a similar lag of 5-10 years brings about a gradual global warming due to reduced global evaporation. For instance, during the period from the early 1940s to the early 1970s, and since 1998 the globe has been undergoing a weak cooling. These cooling periods are well associated with our diagnosis of the THC (or AMO) being stronger than average and with enhanced global rainfall. By contrast, in the period from the early 1970s to the late 1990s, global rainfall rates were reduced and the globe underwent a multi-decadal warming period of over a quarter century (Figures 32 and 33). These multi-decadal changes in the THC which bring about global temperature changes are a result of oceanic salinity variations not at all related to increases in CO_2.

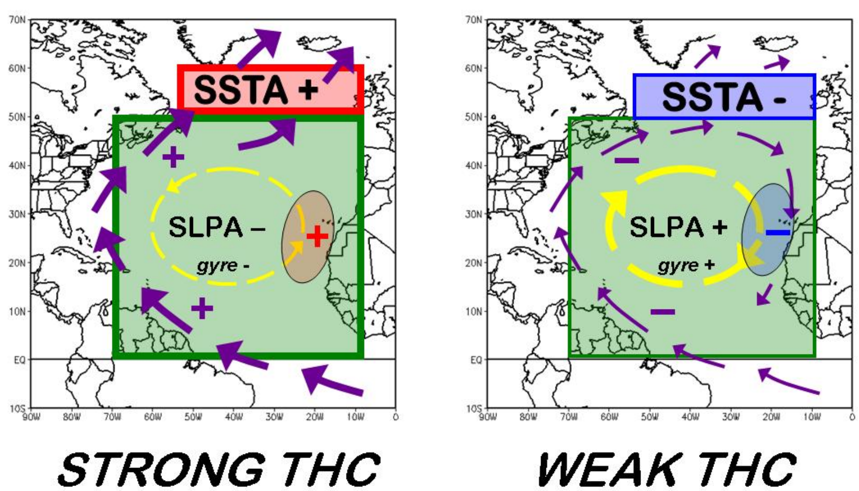

Figure 32. Idealized portrayal of general conditions during a strong (left) thermohaline circulation and a weak (right) and a weak thermohaline circulation.

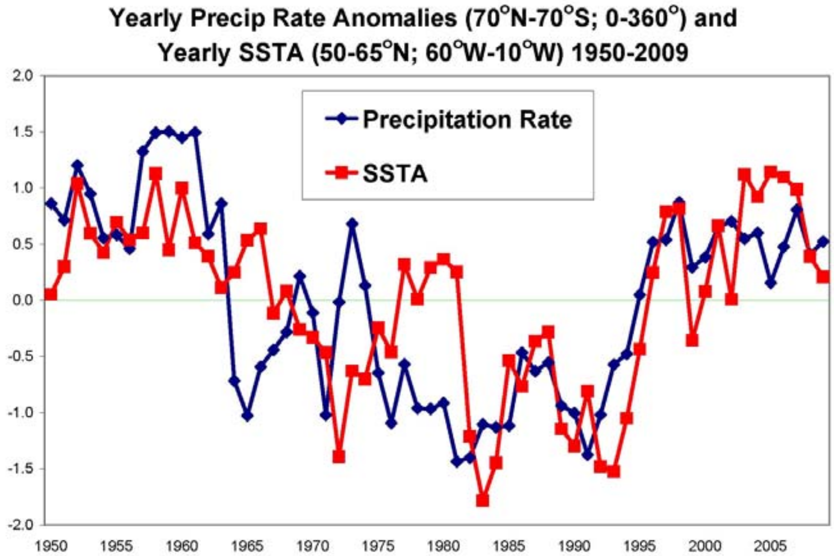

Figure 33. Portrayal of the close association between global precipitation and North Atlantic sea surface temperature anomaly (SSTA) – values portrayed in standard deviation (σ).

8. SUMMARY DISCUSSION

I believe this deep ocean circulation hypothesis offers the best explanation for the global temperature changes of the last century. I have not been a fan of variations in solar and sunspot activity, cosmic rays, dust, ozone, volcanic activity, etc. as being adequate explanations for the global temperature changes that have been observed over the last century. One of the primary reasons that the CO_2 warming hypothesis has been accepted by so many people for so long is that there has not been an appealing alternate hypothesis to CO_2 increase to explain the 20th century warming. I suggest this salt-driven ocean Meridional Overturning Circulation (MOC) provides a much more believable and much more realistic explanation of the temperature changes that have occurred than does CO_2 increases.

I have been studying weather and climate for over 50 years and have been making real-time seasonal hurricane forecasts for a quarter-century. I and many of my colleagues with similar experience have been dismayed at the untrue and exaggerated media hype about impending catastrophic global warming that has been so prominently discussed since the hot summer of 1988. We decry this alarmism. We do not believe we are in climate crisis! There are many other more serious national and global problems that need to be confronted.

Implementation of the proposed international treaties restricting future greenhouse gas emissions by as much as 20 percent (by 2020) and 80 percent (by 2050) of current emissions would lead to a large slowdown in the world's economic development and, at the same time, have little or no significant impact on the globe's future temperature. Such policies should be rejected.

About the Author

William M. Gray, Ph.D. has worked in the observational and theoretical aspects of meteorological research for more than 50 years. He has been with the Department of Atmospheric Science at Colorado State University since 1961. He has specialized in the global aspects of tropical cyclones for his entire professional career. Current areas of research include: 1) tropical cyclone structure, movement and intensity change; 2) seasonal hurricane prediction; 3) tropical and meso-scale rain systems; 4) ENSO variability and 5) climate change and global warming research. He pioneered Atlantic basin seasonal hurricane forecasts which he has been issuing for the last 26 years. He is a recipient of the Neil Frank Award from the National Hurricane Conference and the Banner I. Miller and Jule Charney Awards from the American Meteorological Society. He is the author or coauthor of more than 80 published papers and over 60 extensive research reports. He has supervised the successful graduations of 50 MS degree students and 20 Ph.D. degree students.

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