WHAT SURFACE TEMPERATURE IS YOUR MODEL REALLY PREDICTING?

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SUMMARY

The whole anthropogenic global warming (AGW) argument falls apart when we ask the rather simple question: ***What surface temperature is your model really predicting?*** Most large scale climate models still use radiative forcing to predict changes in surface temperature. The original radiative forcing derivation, by Manabe and Wetherald in 1967 clearly defined an 'equilibrium surface' that interacted with an 'equilibrium surface flux' to produce an 'equilibrium surface temperature'.[1] However, the Earth's surface is never in thermal equilibrium so radiative forcing is, by definition, based on invalid assumptions. The surface temperature is set by the dynamic energy flux balance at the surface. When real surface temperatures are calculated using the thermal properties of the surface material and measured values of the surface energy flux terms, the small change in downward LWIR flux from a 100 ppm increase in atmospheric CO_2 has no measurable effect on the surface temperature. The whole AGW argument disappears.

Now, the meteorological surface temperature (MSAT) has indeed shown an increase over last 50 years or so, but this has nothing to do with the ground surface temperature or CO_2. The MSAT is the temperature of the air in an enclosure at eye level, 1.5 to 2 m above the ground. To make their models appear to work, the modelers have switched from the ground surface temperature to the MSAT without changing their 'equilibrium' predictions. The minimum MSAT is usually a measure of the bulk air temperature of the local weather system as it passes by the weather station. The maximum MSAT is just a measure of the temperature of the warm air that is circulated by convection from the ground as it is heated by the sun during the day. Since 75% of the Earth's surface is ocean, most of the weather systems are formed over the oceans. The bulk air temperature of the weather system is therefore set by the ocean surface temperatures along the approach path of the local weather systems. The 'hockey stick' temperature increase is just the part of the ocean surface temperature that shows up in the MSAT. There was a convenient coincidence between the increase in ocean surface temperatures and the increase in CO_2 concentration that has now ended.

However, instead of simply shouting 'fraud' and trading insults we can make good use of the ocean temperature signal. It provides a baseline temperature reference that can be used to probe urban heat island effects and look for anomalies in the weather station record. Once we understand which surface temperature we are dealing with we can make quantitative predictions of both the ground temperature and the MSAT. This provides us with a way forward. We no longer have to hide the decline. We simply require that our climate models predict it – quantitatively.

INTRODUCTION

The surface temperature that we need for atmospheric radiative transfer calculations is the ground temperature. This means the temperature of the ground under our bare feet. The temperature used in the climate record is the meteorological surface air temperature (MSAT). This is the temperature of the air in an enclosure placed at eye level 1.5 to 2 m above the ground.

[2,3] There is no simple or obvious relationship between the ground temperature and the MSAT. The ground temperature is set by the dynamic energy balance of the surface heating and cooling fluxes coupled into a solid surface layer at least 1 m thick with well defined thermal properties. The daily surface flux can vary between +1000 and -100 $W.m^{-2}$ over a period of less than 12 hours. When the 1.7 $W.m^{-2}$ 'clear sky' increase in LWIR flux from a 100 ppm increase in atmospheric CO_2 concentration is added to this variable daily flux, it can cause no detectable change in ground temperature or the resulting MSAT. Over a 24 hour period, the 1.7 $W.m^{-2}$ increase in LWIR flux produces a cumulative flux of 0.15 $MJ.m^{-2}$. The heat capacity of a cubic meter of soil is approximately 1.5 MJ and the heat capacity of a 10 km high tropospheric air column with an area of 1 m^2 is approximately 8 MJ. In many regions of the world, the bulk air temperature of the prevailing weather systems is set by the ocean surface temperatures along the approach path. The minimum MSAT record should therefore contain information on the ocean surface temperatures. When the proper distinction between ground and MSAT is made, the whole global warming argument disappears.

This article is divided into two parts. In Part I, the surface energy transfer is considered in detail. Measured flux data from a S. California micrometeorological station are provided as an example to show how the various flux terms interact to set the ground temperature. This clearly demonstrates that there can be no CO_2 'signature' in the MSAT record. In Part II, the long term averages of selected weather station data in both California and the UK are investigated for ocean influences. The minimum MSAT data for the California weather stations is compared to the Pacific Decadal Oscillation, (PDO) and the minimum MSAT data for the UK is compared to the local Atlantic Multidecadal Oscillation (AMO).[4] In both cases there is a very well defined ocean signal. It is shown that the ocean surface temperature index can be used as a reference to investigate urban heat island effects and identify potential anomalies in the station records. When the surface energy transfer and the ocean signature analyses are combined, it becomes possible to develop quantitative simulation techniques to analyze the MSAT record

PART I: DYNAMIC ENERGY BALANCE AND GROUND SURFACE TEMERPATURE

The AGW argument starts from the empirical assumption that an increase in atmospheric CO_2 concentration of 100 ppm must cause an increase in 'surface temperature'. It is then assumed, without any justification that the observed increase in the 'global average' meteorological surface air temperature (MSAT) of 1 C has been caused by CO_2. The totally unrelated increases in atmospheric CO_2 concentration and MSAT are then plotted and scaled to overlap on the so called 'hockey stick' curve. Independent and reliable radiative transfer calculations show that a 100 ppm increase in atmospheric CO_2 concentration produces an increase of ~1.7 $W.m^{-2}$ in the downward atmospheric LWIR flux. This number is obtained using the spectroscopic constants of CO_2 available from the HITRAN database. [5] However, instead of looking quantitatively for cause and effect by analyzing the surface energy transfer, an empirical 'radiative forcing constant', λ, is then defined as

$$\lambda = 0.66\ C/(W.m^{-2}) \qquad (1)$$

This is just 1/1.7. The LWIR flux has now been converted into an empirical 'radiative forcing constant' that no longer has any physical meaning. This 'constant' has been 'hard wired' into the large scale global circulation models and used to 'predict' the rise in 'surface temperature'.

The surface temperature must rise as the CO_2 concentration is increased. This is just the 'hockey stick' feeding back on itself. The 'radiative forcing constant' for CO_2 is then extended to generate the empirical 'radaitive forcing constants' for other IR active molecules and aerosols. The increase in atmospheric concentration of these molecules is converted into an increase in downward LWIR flux. Using these additional empirical 'radiative forcing constants', the 'surface temperature' magically rises even faster in the greenhouse land that exists only inside these computer models. This is nothing more than climate astrology.[6] There are two fundamental errors in the AGW argument. The first is the radiative forcing assumption that long term averages of dynamic climate variables can be analyzed as though they are in equilibrium. The second is the assumption that the meteorological surface air temperature (MSAT) can be substituted for the ground surface temperature.

In order to understand the errors in the AGW argument, it is necessary to examine the energy transfer processes that set the surface temperature for a real surface with well defined thermal properties. These are illustrated in Figure 1. During the day, the sun heats the ground and the excess heat is coupled into the air through a combination of convection, evaporation and LWIR absorption. The net transfer of energy from the ground to the air by convection is termed the sensible heat flux. The IR absorption of a portion of the LWIR surface emission by the atmosphere is part of a more complex LWIR exchange process that depends on the surface temperature, the thermal gradient near the surface and the H_2O concentration (absolute humidity). In addition to LWIR exchange, latent heat effects due to water evaporation, condensation and precipitation also contribute to the surface energy transfer. Freezing and thawing must also be considered at lower temperatures. The evaporative transfer of energy from the ground to the air is termed the latent heat flux. Water evaporation removes heat from the ground and adds water vapor to the air. The warm air heated by the surface rises and mixes with the cooler air above. This vertical air flow is a complex turbulent mixing process involving eddy currents over a wide range of length scales. In addition, some of the solar flux is reflected at the surface and does not contribute to the surface heating. As the surface is heated by the solar flux, the resulting thermal gradient conducts heat below the surface. There is both a daily and a seasonal warming and cooling of the ground that has to be included as part of the surface energy transfer. A small fraction of the solar flux may also be absorbed by plants and used for photosynthesis. As the warm air rises, it cools and the water vapor condenses, usually at altitudes above 1 km to form clouds with the release of the latent heat of evaporation. The latent heat that is released then adds to the convection. These energy transfer processes are dynamic. The flux terms are always changing with time and the surface temperature is set by the instantaneous flux balance at the surface. There is no equilibrium value that the system can ever reach.

In order to understand the relative magnitudes of the various flux terms and their variation it is convenient to consider an example take from real weather station data. Figure 2 shows the net solar, net IR, sensible (convection) and latent heat fluxes for a Southern California AmeriFlux micrometeorological weather station operated by the University of California, Irvine. This station designated 'Grasslands' is located in Limestone Canyon Regional Park, east of Irvine.[7] The half hour average data for June 30 2008 are shown. At night, the sensible and latent heat flux terms are close to zero. The night time IR flux shows a cooling of ~-40 $W.m^{-2}$. (We follow the sign conventions of the reported data). During the day the net solar flux increases to a peak of ~900 $W.m^{-2}$. This sets up a convective (cooling) flux of ~400 $W.m^{-2}$. The daytime IR cooling flux increases to ~-200 $W.m^{-2}$.

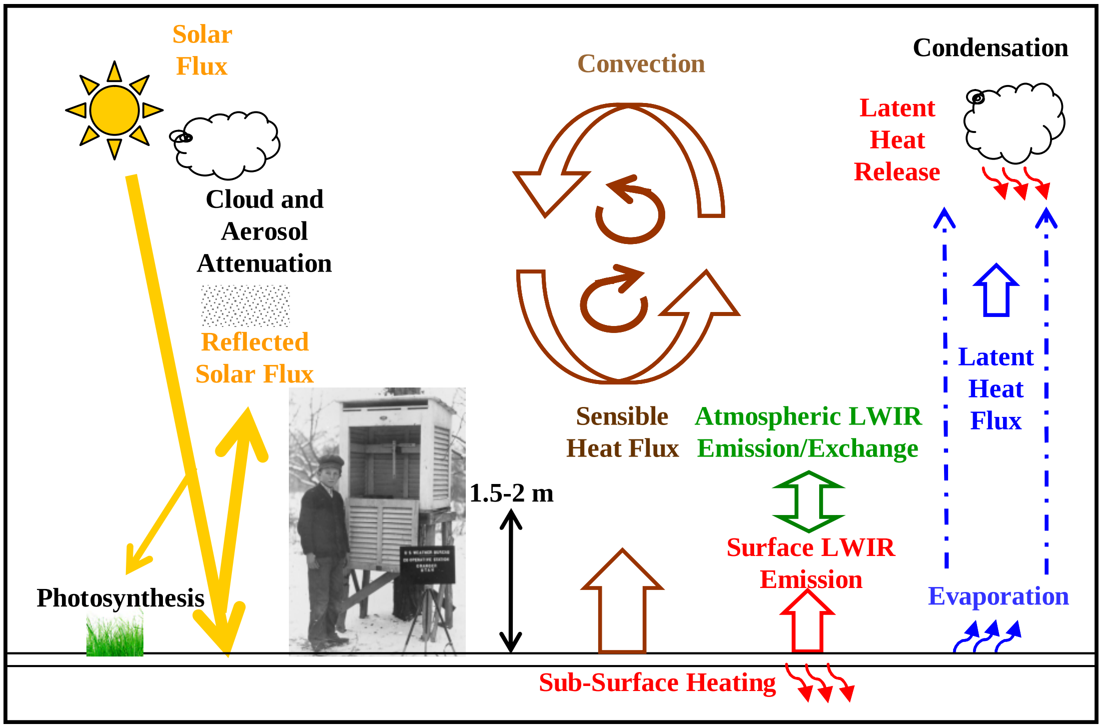

Figure 1: Surface energy transfer (schematic)

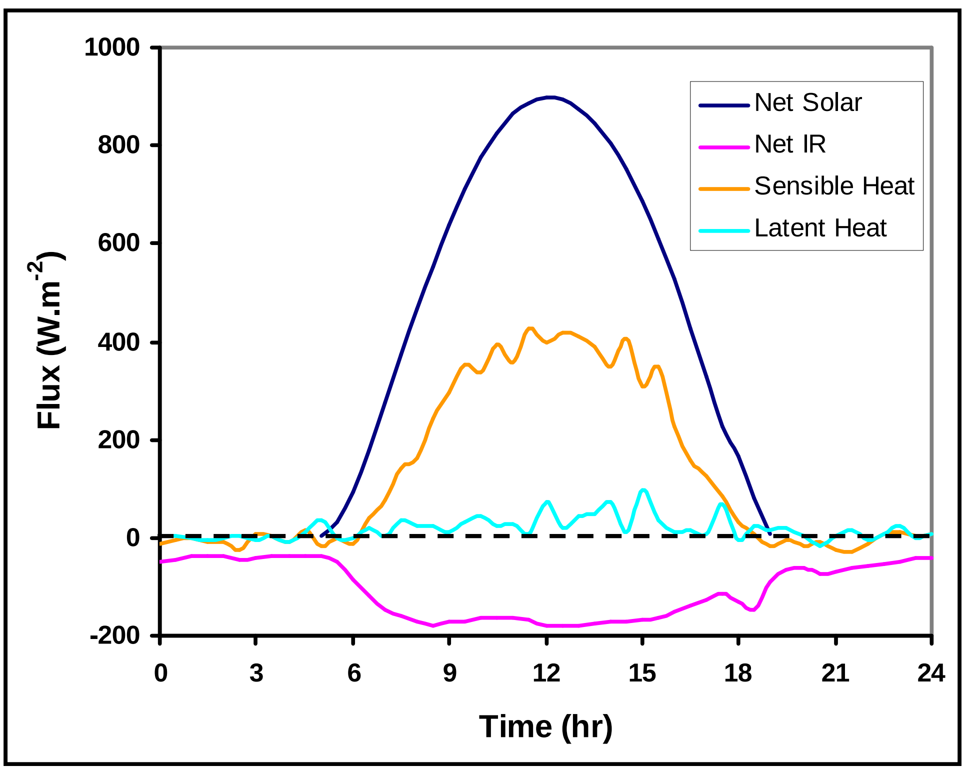

Figure 2: Flux data from the 'Grasslands' AmeriFlux micrometeorological station in S. California for July 30 th 2008.

It is also instructive to examine the cumulative flux terms for the day. The cumulative solar flux was 26.6 MJ.m^{-2}. The cumulative LWIR, sensible and latent heat fluxes were 9.4, 11.4 and 1.6 MJ.m^{-2} for a total of 22.4 MJ.m^{-2}. These measurements are made by separate point sensors located on a tower above the ground, so formal energy conservation is not to be expected. The night time LWIR cooling flux was approximately -40 W.m^{-2}. When this value is also used for the daytime flux through the atmospheric LWIR window, it places an upper limit of about 6 MJ.m^{-2} on the LWIR flux that is absorbed by the atmosphere. The balance, 3.4 MJ.m^{-2} is radiated directly to space through the LWIR transmission window. The rest of the surface energy, ~19 MJ ends up as sensible heat flux or convection. This assumes full condensation of the latent heat flux. At least 90% of the 6 MJ.m^{-2} of excess LWIR energy from the surface will be absorbed within the first km layer of air above the surface. This means that 17.4 MJ of surface energy is used to heat the air above the surface and induce convection. This is sufficient to heat a tropospheric air column 1 m^2 x 10 km by ~2 K, assuming a heat capacity of 8 MJ.K^{-1}. As the air rises through the atmosphere, some of the heat is used up as mechanical work to overcome the gravitational potential and the air cools. The remainder of the convective energy is released to radiate to space as LWIR radiation as the molecular linewidths narrow with altitude.[8] The cumulative energy transfer is illustrated in Figure 3.

Figure 4 shows the net LWIR and the latent heat fluxes on an enlarged scale. Almost all of the latent heat flux transport occurs during the day. The early morning LWIR flux before sunrise is close to -40 W.m^{-2}. However, in the evening after sunset, the LWIR flux decreases gradually from ~-80 W.m^{-2} to ~-40 W.m^{-2} over a period of about 5 hours. This is because the subsurface heat that accumulates in the ground during the day is released during the evening.

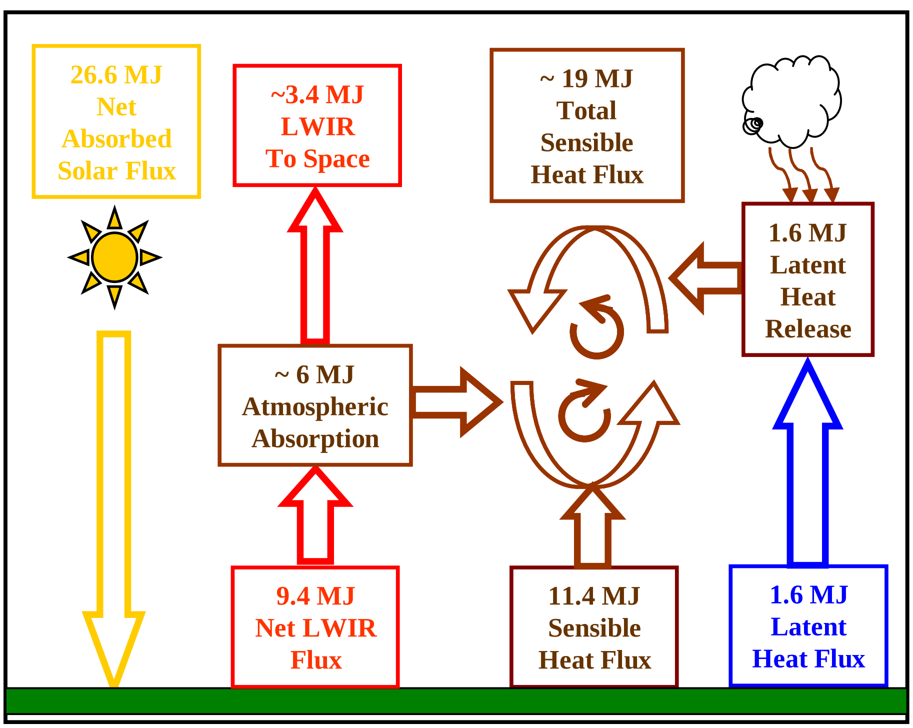

Figure 3: Approximate cumulative daily flux terms from Figure 2.

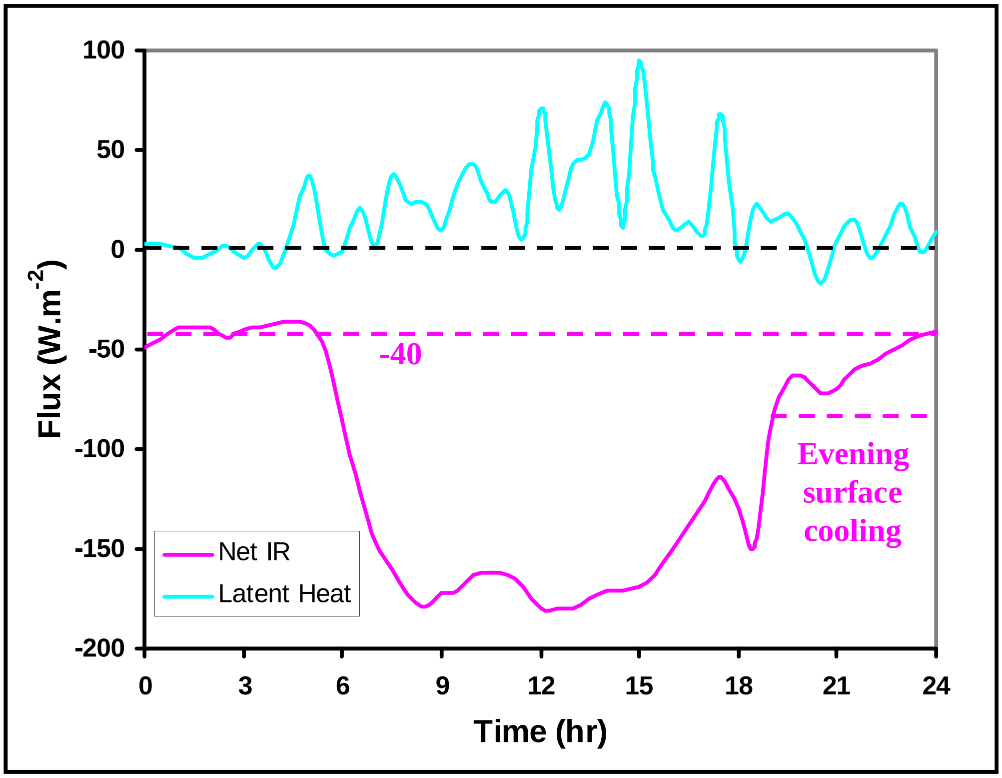

Figure 4: Net IR and latent heat fluxes from Figure 2, enlarged scale.

Conventional maximum and minimum MSATs were recorded at this site, but the surface ('skin') temperatures were obtained from satellite observations as 8 day averages. For the period of interest, the average minimum surface temperature was 18.6 C and the maximum was 44.4 C. The half hour average MSAT for June 30 is shown in Figure 5. The minimum MSAT temperature was 20.4 C. The maximum was 29.1 C. The minimum MSAT was similar to the minimum average surface temperature from the satellite data. However, the maximum satellite surface temperature was over 16 C higher than the MSAT maximum. This is because the MSAT is the air temperature recorded in an enclosure placed 1.5 to 2 m above the ground. The air is cooler than the surface because of convective mixing. Using the temperature and flux data available from the full 2008 data set, a model of the surface energy transfer was developed that simulated the surface temperature and the subsurface heat transfer. The calculated surface and subsurface temperatures and the total subsurface heat transfer are shown in Figure 6.

The model used a simple 2D finite element algorithm for the thermal conduction calculation with a flux balance at the surface to set the temperature of the surface layer. This is described in more detail in Reference 8. The time step was 30 minutes. The subsurface depth resolution was 1 cm. The calculated maximum surface temperature is in good agreement with the satellite average value. The subsurface temperatures show the characteristic hysteresis effects to be expected in this type of dynamic heat transfer as the variable surface heat load is conducted below ground. The change total heat flux coupled to the surface material during the 24 hour cycle is shown in Figure 6b. This diurnal flux change is over 2.5 MJ and the corresponding surface temperature change is almost 30 C. The total daily increase in downward LWIR flux from a 100 ppm increase in atmospheric CO_2 concentration over the last 200 years is only 0.15MJ. This can have no measurable effect on the ground surface temperature. Nor can it have any effect on the bulk temperature of an air column with a heat capacity of about 8 MJ.

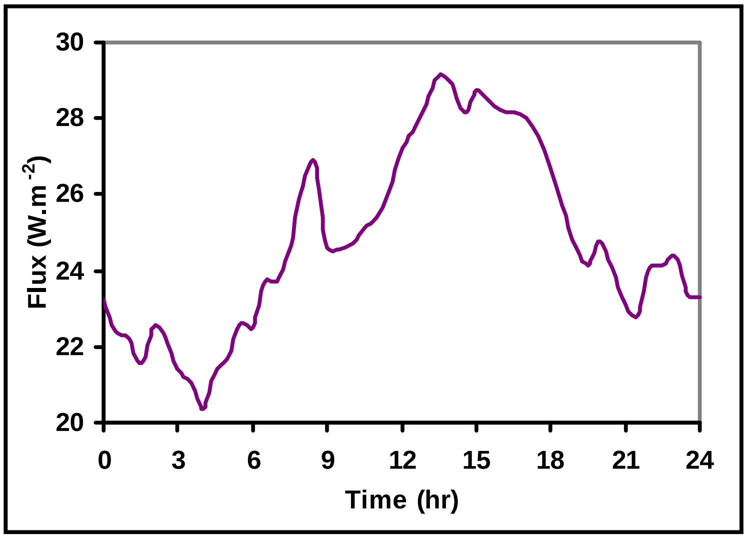

Figure 5: Half hour average MSAT for June 30 th 2008 for the Grasslands site.

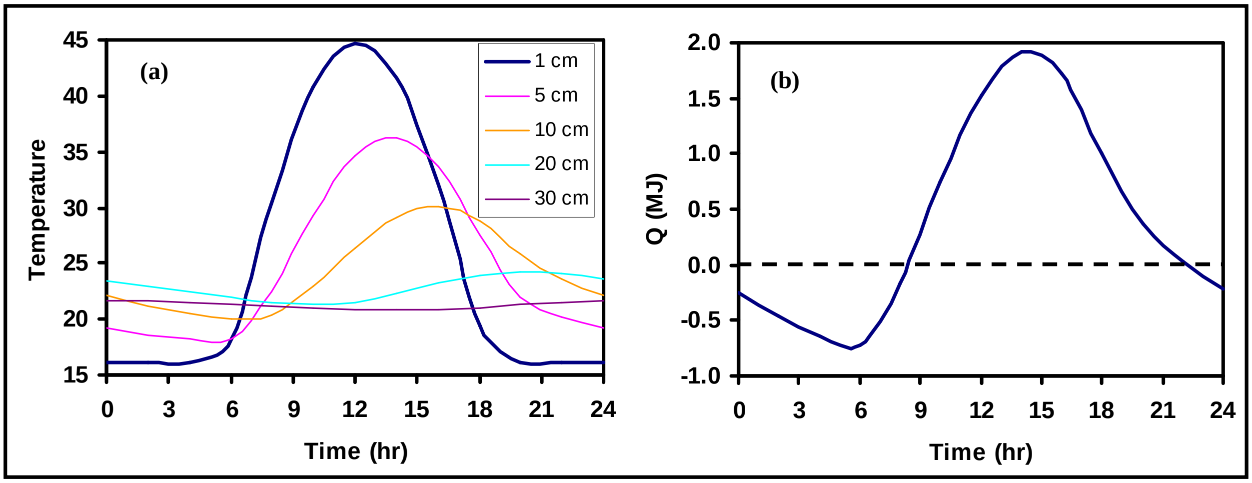

Figure 6: a) Calculated surface and subsurface temperatures and b) Total subsurface heat transfer for June 30 th 2008 for the Grasslands site.

PART II: OCEAN SURFACE TEMERPATURES AND THE MINIMUM MSAT

It is clear from the discussion of surface temperature in Part I that there can be no CO_2 signature in the long term MSAT record. The minimum MSAT is an approximate indicator of the bulk surface air temperature of the local weather system. The daily increase in temperature from minimum to maximum is an indicator of the solar surface heat load that is coupled by convection to the surface air layer. Since 75% of the Earth is ocean, most weather systems are formed over the ocean. Any long term change in the MSAT record may be expected to contain information on the change ocean surface temperatures along the path of the prevailing weather systems. This effect may be studied by comparing the minimum MSAT record of a selected weather station to the appropriate ocean surface temperature record. For the State of California, and neighboring regions, the appropriate reference is the Pacific Decadal Oscillation, PDO and for the UK and surrounding regions, the appropriate reference is the local Atlantic Multidecadal Oscillation, AMO.

Figure 7 shows the 5 year rolling average of the PDO from 1904. The data were downloaded from the University of Washington website.[9] The long term trend line for the full data set is almost flat. This was obtained using the linear trend line algorithm in Excel™. However, over shorter time periods, a significant slope, positive or negative may be derived from the data. The California weather station data was downloaded from the Western Region Climate Center website and used 'as received'.[10] The data for Pierce College was downloaded from the college website.[11] Figure 8 shows the minimum MSAT for Los Angeles Civic Center, five year rolling average from 1925 to 2005. The PDO from Figure 7 is also shown over the same time period. The linear trend lines for both data sets from 1925 to 2005 are also shown. The minimum MSAT data for the LA Civic Center shows the characteristic 'signature' of the PDO superimposed on an upward sloping baseline. The difference in slope between the PDO and the weather station data, 0.022 $C.yr^{-1}$ is an approximate indicator of the urban heat island effect for Los Angeles.

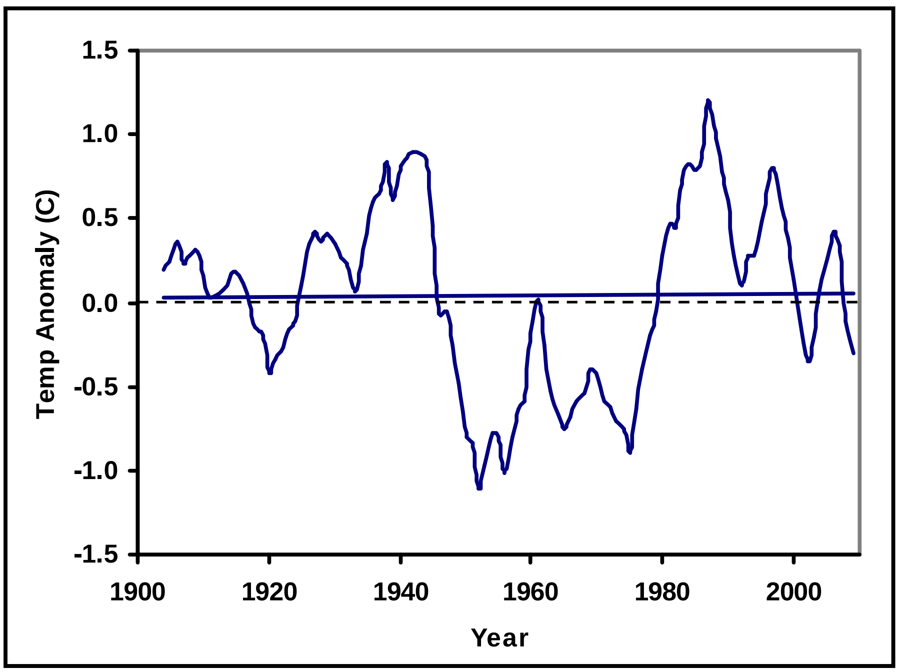

Figure 7: Pacific Decadal Oscillation (PDO), five year rolling average from 1904.

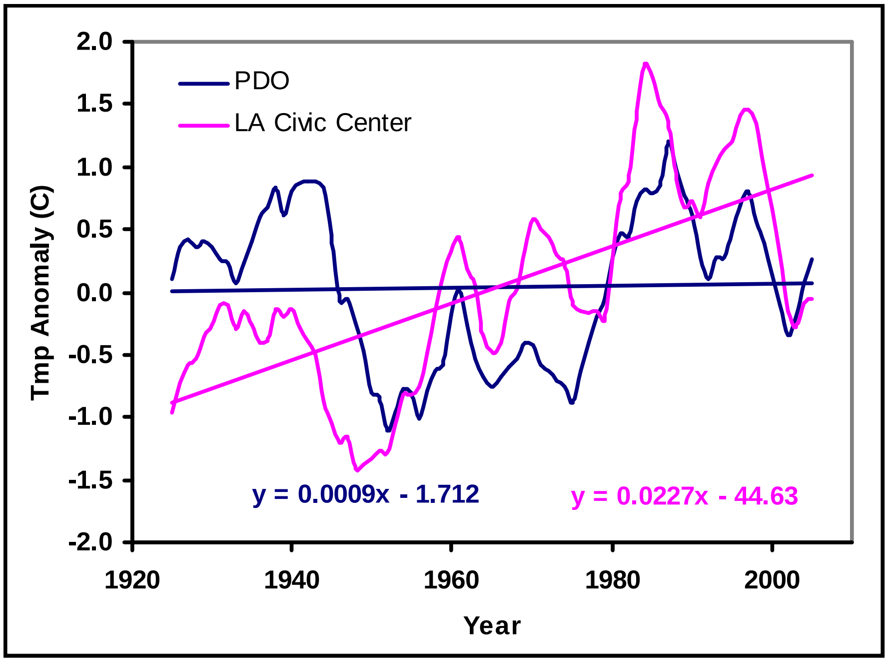

Figure 8: Minimum MSAT temperature, 5 year rolling average, for the LA Civic Center from 1925 to 2005. The PDO and the trend lines over the same time period are also shown.

Figure 9 shows the minimum MSAT for Los Angeles Airport, LAX, from 1950 to 2008 with the PDO and trend lines over the same time period. In this case, the slope of the station data is close to that of the PDO. The slope difference is 0.005 C.yr^{-1}. LAX is located on the coast, approximately 25 km west of the Civic Center. The effect of the marine layer and onshore flow at LAX significantly reduce the urban heat island effect compared to the Los Angeles Civic Center.

Figure 10 shows the minimum MSAT for Nevada City, from 1935 to 2009, again with the PDO reference and trend lines. This station is located about 100 km NE of Sacramento. It should be a 'rural' station with a small urban heat island effect. Inspection of the data reveals a temperature rise of over 3 C between 1978 and 1990. This is probably caused by a change in station location. The temperature trends on either side of this anomaly are 0.06 and 0.05 C.yr^{-1}. These are still high for a 'rural' station, indicating that further investigation is needed.

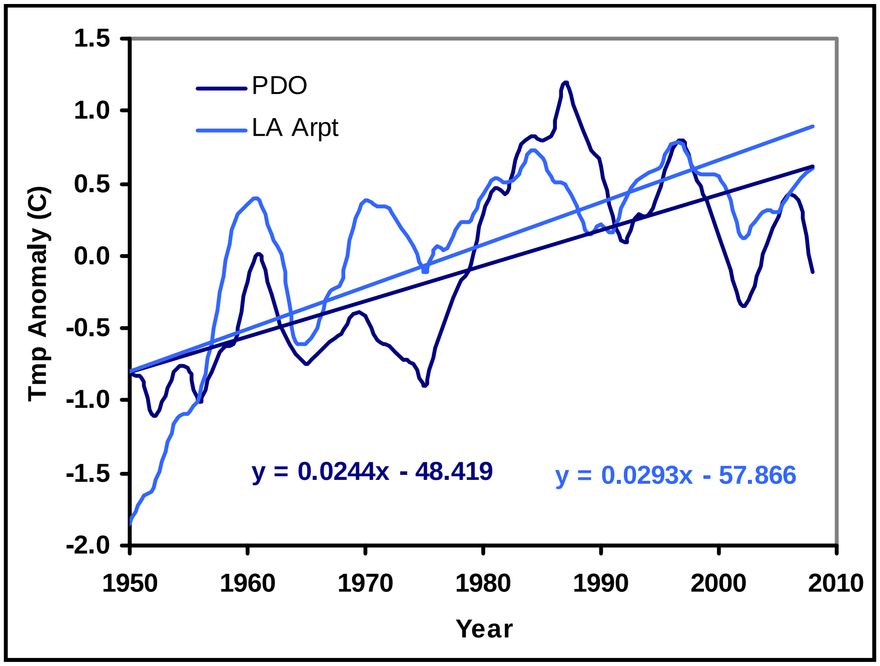

Figure 9: Minimum MSAT temperature, 5 year rolling average, for LA Airport from 1950 to 2008. The PDO and the trend lines over the same time period are also shown.

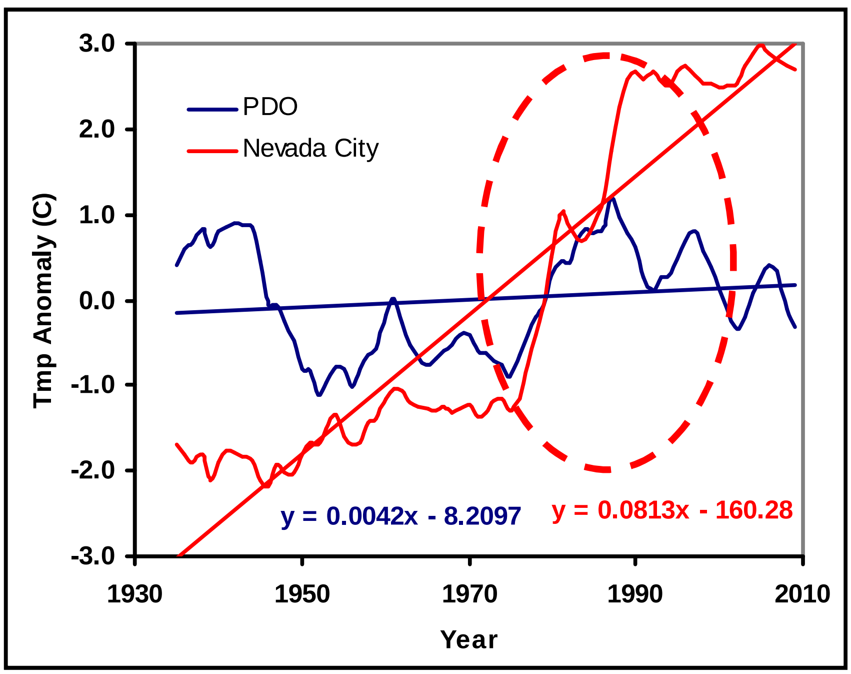

Figure 10: Minimum MSAT temperature, 5 year rolling average, for Nevada City from 1935 to 2009. The PDO and the trend lines over the same time period are also shown. The circled temperature anomaly was probably caused by a station relocation.

The minimum MSAT trend data for LA Civic Center, LAX and Nevada City are examples of a general technique that compares the minimum MSAT data to a reference set of ocean surface temperatures along the approach path of the prevailing weather systems. While care is needed in the interpretation of such data, the difference in slope between the ocean reference and the station data is a measure of the local urban heat island effect on the station. In addition, obvious discrepancies such as steps or unexpected peaks in the station data can be used to flag data anomalies for further investigation. Using this technique, a total of 34 California weather stations were analyzed. Stations with a minimum record duration of 50 years were selected to be representative of the full geographical and climate extent of California. The linear trend data are plotted in Figure 11. The stations were divided into four groups. The first group was 'coastal' which included 10 coastal weather stations from Crescent City to San Diego. The second group was 'rural' which included 9 stations with warming trends below 0.01 $C.yr^{-1}$. These were mainly located in rural areas. The third group was 'urban' which included 14 stations with warming trends above 0.01 $C.yr^{-1}$. The fourth group was 'anomalous' where visual inspection of the station data indicated obvious discrepancies associated for example with changes in location, that require further investigation. In most cases, the anomaly only impacted part of the data set and the rest of the data could be processed normally with a reduced time scale. Numbers after the station name indicate truncated, reprocessed data sets.

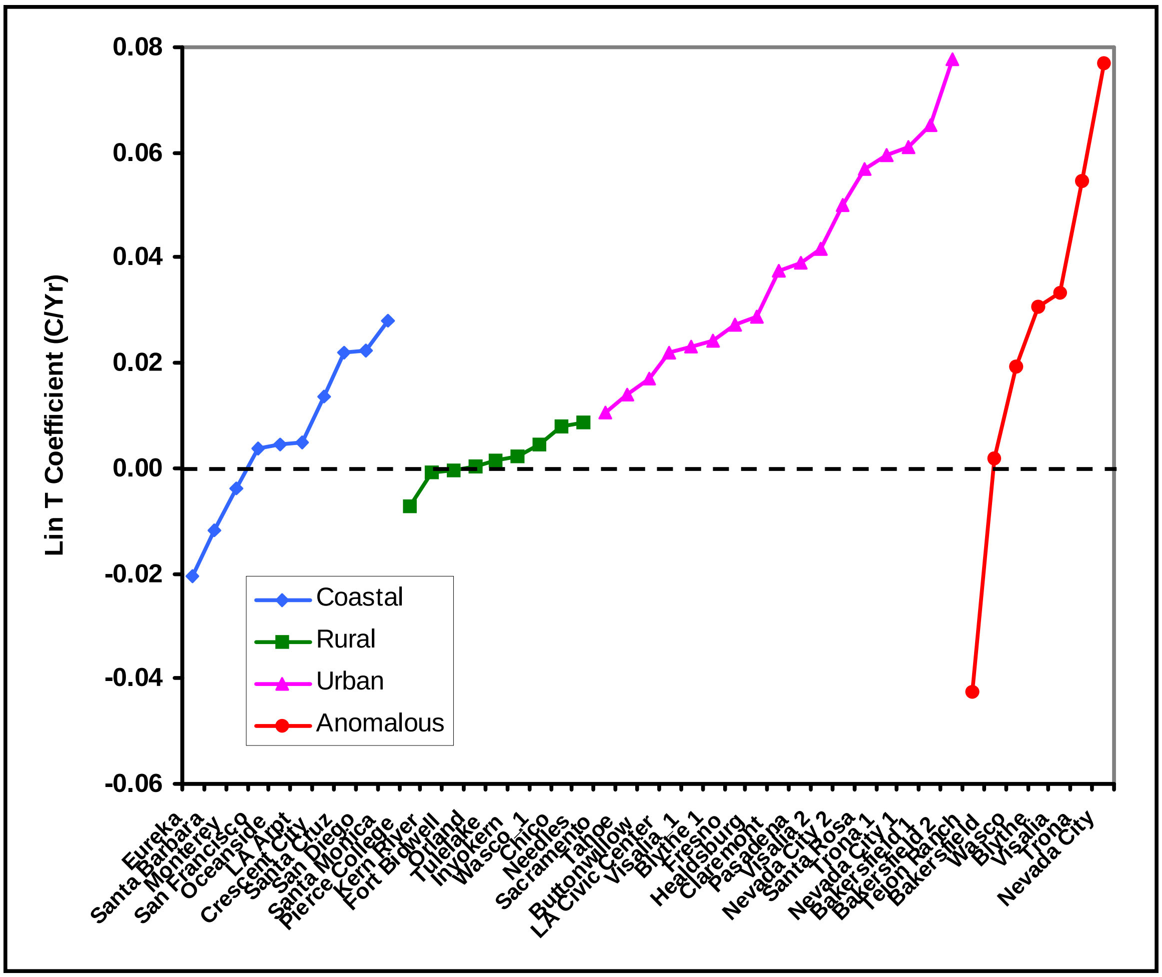

Figure 11: Linear warming trend data for the California weather stations. The stations were divided into four groups based on location and linear trend magnitude.

These results show that the climate of the State of California, as measured by the minimum MSAT weather station record is set mainly by the PDO. Superimposed on the PDO is an approximately linear urban heat island effect that depends on the local microclimate of the individual station and the influence of urban development on diurnal and seasonal subsurface heat storage. Each station has its own unique microclimate and local bias effects. The 'one size fits all' practice of averaging station data into 5° latitude and longitude 'boxes' overestimates climate change by adding urban heat island effects to the natural climate trends.

The analysis of the minimum MSAT record for the 34 California weather stations was extended to 33 UK weather stations using the local Atlantic Multi-decadal Oscillation as the ocean surface temperature reference. The weather station and AMO data were downloaded from the Hadley Center web site and used 'as received'.[11] The rolling 5 year average of the 45-50 N, 10-15 W; 45-50 N, 5-10 W and 50-55 N, 10-15 W 5 x 5 ° 'boxes' from the HadSST2 database was used as the local AMO reference. Figure 12 shows the five year rolling average of the AMO used in the UK station analysis. Figure 13 shows the linear trend analysis for Heathrow, which displayed the largest urban heat island effect in the UK station data. Figure 14 shows the linear trend data for the 33 stations. These were divided into three groups based on the magnitude of the linear trend. Group 1 contained four stations with slightly negative trends (-0.005 to 0.0 $C.yr^{-1}$). Group 2 contained 21 stations with trends between 0 and 0.01 $C.yr^{-1}$ equivalent to the 'rural' California stations. Group 3 contained the remaining 8 stations with trends above 0.01 $C.yr^{-1}$, equivalent to the California 'urban' stations.

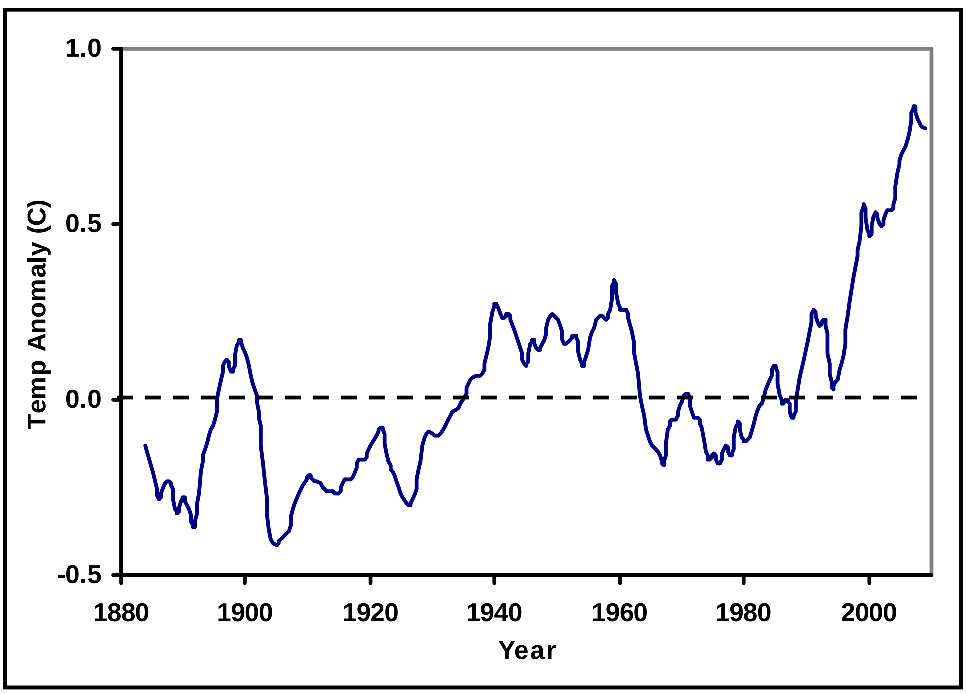

Figure 12: Local AMO reference, 5 year rolling average used in the analysis of the UK weather stations.

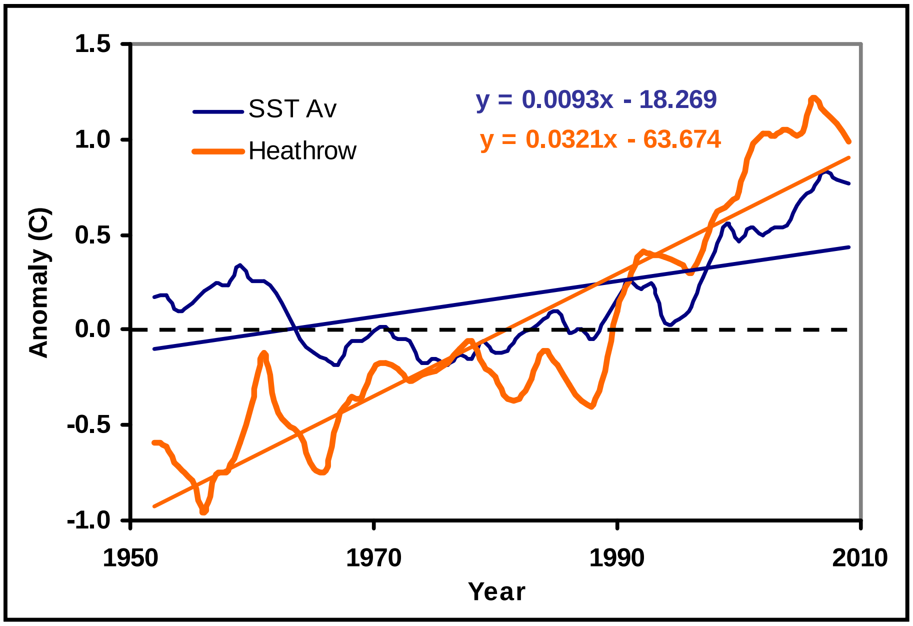

Figure 13: Linear trend analysis for Heathrow using the AMO as reference.

Overall, the linear trends for the UK stations showed lower urban heat island effects compared to the California stations. The UK linear trend range was from approximately -0.005 to +0.025 $C.yr^{-1}$. The California linear trend range was from approximately -0.02 to + 0.08 $C.yr^{-1}$ (excluding the anomalous station data). The urban heat island effect is a measure of the increase in heat stored in the ground (and structures) as a result of urban development. It depends on both the solar heating of the area and the changes in latent heat flux as a result of urban run off and vegetation loss. Since the UK receives less sunshine and more rainfall than most of California, the urban heat island effects are lower for the UK. The general climate trend for the UK is decreasing rainfall and increasing sunshine from N to S and W to E. This is reflected in the urban heat island trends. The higher trend values tend to be located in the SE. However, each station has its own microclimate that needs to be evaluated on a case by case basis. The concept of 5 x 5° 'boxes' of climate averages is not a very useful one and leads to overestimates of climate warming from local urban heat island effects.

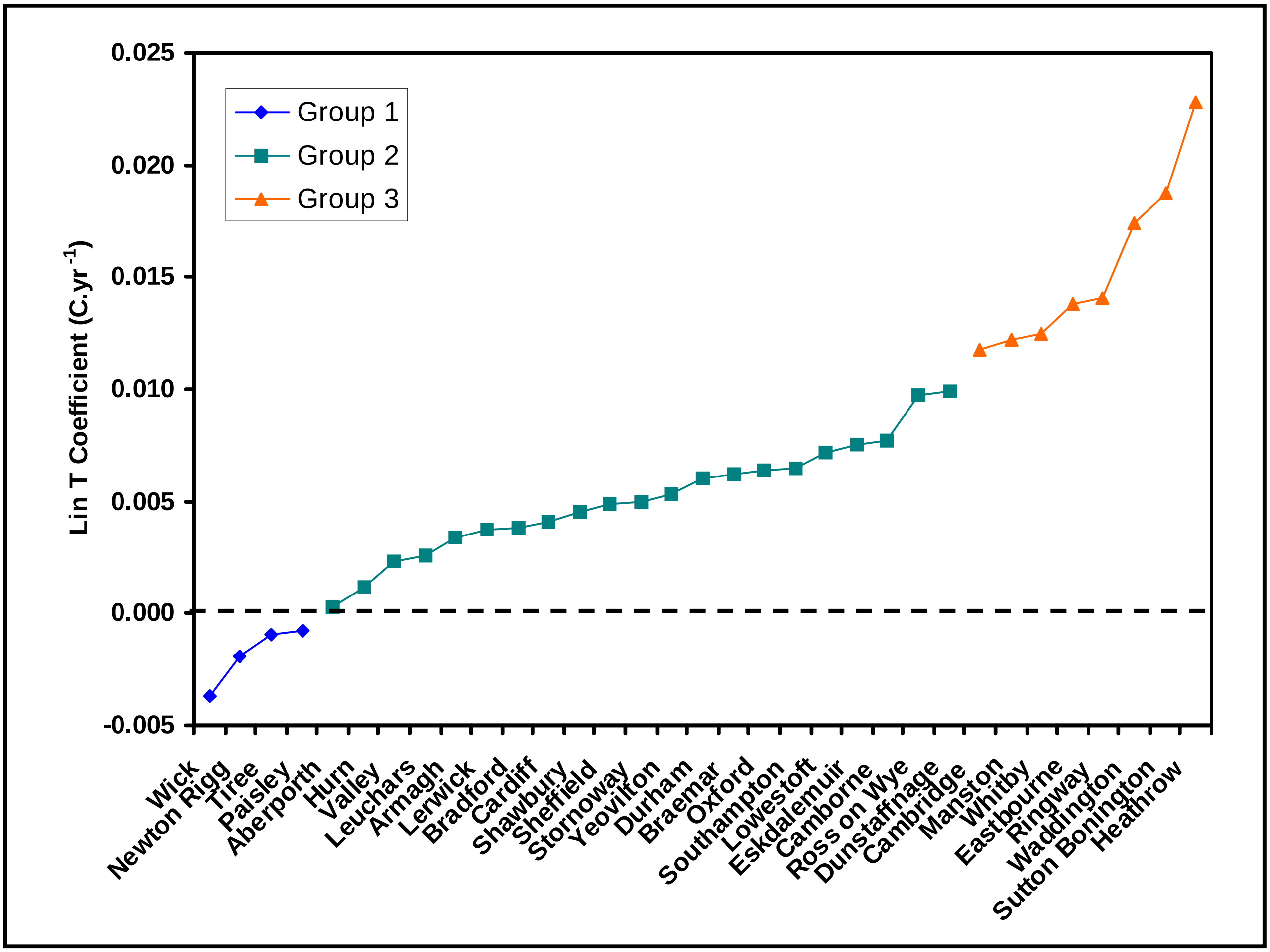

Figure 14 Linear warming trend data for the UK weather stations. The stations were divided into three groups based on linear trend magnitude.

It is also interesting to compare the ocean surface temperature trends to the 'predicted' change in 'surface temperature' using the 'radiative forcing constant' for CO_2. This is shown in Figure 15. The AMO (green), the PDO (blue) and their linear trends from 1960 are plotted along with the change in 'surface temperature' derived from the increase in downward CO_2 LWIR flux and the 'radiative forcing constant' for CO_2.[14] This is the red 'hockey stick' line in the figure. The light orange line is the average of the AMO and PDO trend lines. When this is offset by 0.243 C it overlaps very well with the hockey stick 'prediction. This should make it clear that the observed change in 'surface temperature' has nothing to do with CO_2, but is related to changes in ocean surface temperatures. While the data processing used to generate the 'hockey stick' has been deliberately concealed, it is not unreasonable to expect that the combination of urban heat island increases and temperature 'homogenization' or 'adjustment' would account for the observed offset.

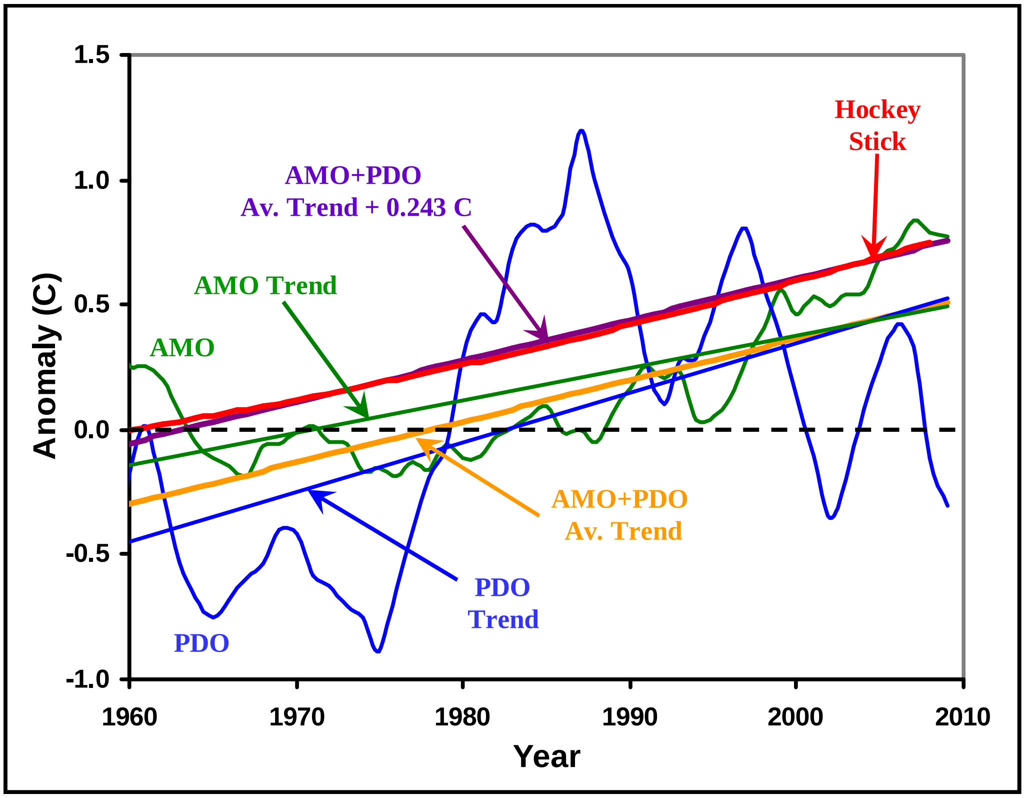

Figure 15: AMO and PDO and trend lines plotted from 1960. The hockey stick surface temperature prediction is also shown. When the average AMO+PDO trend line is offset by 0.24 C it almost overlaps the hockey stick prediction.

CONCLUSIONS

The energy transfer processes that set the ground surface temperature have been considered in detail. The increase in downward 'clear sky' LWIR flux from a 100 ppm increase in atmospheric CO_2 concentration is 1.7 W.m^{-2}. When this flux is added to a total surface flux that can vary from +1000 to –100 W.m^{-2} within a few hours, the CO_2 flux can have no measurable effect on the ground temperature or the resulting MSAT. The empirical assumption that a 100 ppm increase in CO_2 can produce a 1 C rise in 'equilibrium surface temperature' is based on a fundamental misinterpretation of the MSAT record. Such an increase in temperature is usually caused by a change in ocean surface temperature along the path of the prevailing weather systems. This has been clearly demonstrated by an analysis of the minimum MSAT record of weather stations in both California and the UK. A simple comparison of the long term trend in the minimum MSAT with the corresponding ocean surface temperature trend over the same time period allows the station urban heat island effect to be estimated. In addition, obvious peaks or steps in the station record that do not follow the expected trends can be flagged as anomalous and their cause investigated. The minimum MSAT trends in California are consistent with overall trends in the US surface temperature record that have been shown to follow the combined PDO and AMO temperature anomaly.[15] It is anticipated that this type of minimum MSAT analysis will have general applicability to other regions of the world where an ocean surface temperature signal may be found in the station record. Such analysis should help to identify and resolve issues related to temperature 'adjustments' that have been used to create spurious warming trends.[16]

Historically, the systematic recording of weather station data began in the 1850's following the development of the railroad and the telegraph. The temperature measurements were made using Six's thermometer. This is the origin of our recent climate record. It is really only within the last decade or so that the instrumentation and computerized data acquisition systems have become available that enable the measurement of the various energy fluxes that are needed to quantify the surface energy transfer. Unfortunately, the dogma of CO_2 induced global warming has become separated from its foundation in physics and moved into the realm of climate astrology. The process of predicting and preventing non-existent natural disasters caused by global warming has now evolved into the lucrative new business of environmental mythology.[17] The tools are now available, including both the instrumentation and the computer capabilities to quantitatively measure and simulate surface energy transfer and its role in setting the Earth's climate. This article has provides some simple examples of how these new tools can be applied quantitatively to the surface temperature record. It is hoped that this is a first step towards a quantitative reassessment of the full surface temperature record. There is significant evidence that the sun and the planets may play a much larger role in setting the Earth's climate than is currently accepted. However, our climate and the surrounding solar system are governed by the basic laws of physics. There is no longer any room for empirical speculation or astrological prediction in climate science. We must require quantitative prediction by climate models that have been independently validated using reliable experimental data.

REFERENCES

1. Manabe, S. and R. T. Wetherald, J. Atmos. Sci. **24** 241-249 (1967), 'Thermal equilibrium of the atmosphere with a given distribution of relative humidity'
2. Oke T. R., WMO/TD-No. 1250, '*Initial guidance to obtain representative meteorological observations at urban sites*', World Meteorological Association, 2006
3. Quayle, R. G., Easterlin, D. R., Karl, T. R. and Hughes, P. Y., Bull. Amer. Met. Soc., **72**(11) 1718-1723 (1991), 'Effects of recent thermometer changes in the cooperative station network'
4. http://scienceandpublicpolicy.org/originals/pacific_decadal.html Clark, R. 'California climate change is caused by the Pacific Decadal Oscillation, not by carbon dioxide'
5. Rothman, L. S. et al, (30 authors), J. Quant. Spectrosc. Rad. Trans., **96** 139-205 (2005), 'The HITRAN 2004 molecular spectroscopic database'
6. Hansen, J. et al, (45 authors), J. Geophys. Research, **110** D18104 pp1-45 (2005) 'Efficacy of climate forcings'
7. http://public.ornl.gov/ameriflux/index.html, AmeriFlux Network
8. Clark, R., Energy and Environment **21**(4) 171-200 (2010), 'A null hypothesis for CO_2'
9. http://jisao.washington.edu/pdo/PDO.latest, Pacific Decadal Index from 1900
10. http://www.wrcc.dri.edu/Climsum.html Western Region climate data
11. http://www.piercecollegeweather.com/ Pierce College weather station data
12. http://www.metoffice.gov.uk/climate/uk/stationdata/ UK Historical Climate Data

13. http://www.cru.uea.ac.uk/cru/data/temperature/ HadSST2 Sea Surface Temperature Database
14. http://scrippsco2.ucsd.edu/data/in_situ_co2/monthly_mlo.csv. Keeling curve data
15. D'Aleo, J Effects of AMO and PDO on temperatures Intellicast, May 2008. http://www.intellicast.com/Community/Content.aspx?a=127
16. D'Aleo, J. '*Progressive Enhancement of Global Temperature Trends*', Science and Public Policy Institute, July 2010. http://scienceandpublicpolicy.org/originals/progressive_enhancement.html
17. Alley R. B., et al, (51 authors), *IPCC, Summary for Policymakers, Climate Change 2007: The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment, eds: Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B. Tignor, M. and Miller, H. L., Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., 2007.