Critique of the Climate Change Debate and the Impact of Energy Consumption on the Instrumental Temperature Record

by

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A Thesis Presented for the Degree of Master of Science in Energy Systems and the Environment

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University of Strathclyde
September 2004

Acknowledgements

I would like to thank Professor Joe Clarke for supervising my project. I also wish to express my thanks to the British tax payer, lecturers and staff of the Engineering Department, my family and my wonderful colleagues that accompanied me on the Energy Systems and Environment course.

Abstract

The purpose of this thesis is to highlight the aspects of scientific and engineering uncertainty that are inherent within the climate change debate. Particular attention is given to the instrumental global mean surface temperature record (GMTR) because it provides the foundational evidence that supports the establishment of the global warming phenomenon, and because it is heavily criticised as being subject to bias from the urban environment.

The widely held consensus is that observed warming in the GMTR of 0.6K (not observed in satellite data) is due to additional radiative forcing (1.4 W/m^2) from the build up of anthropogenic emissions of CO2 in the atmosphere. This thesis shows that the heat from energy consumption in urban centres can have radiative forcings that are regionally, nationally and locally comparable and even greater than that of CO_2. It is argued that energy consumption combined with other urban biases has the potential to influence the GMTR to a higher degree than the IPCC currently accept.

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Chapter 1: Introduction

The IPCC define that the term “Climate change” refers to: “a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.” (IPCC, TAR Appendices).

Global warming, as observed in the instrumental global mean temperature record, can therefore be referred to as ‘climate change’ because it is a statistical variation in the mean, persisting for an extended period. Also under the terms of this definition the cause of climate change may be natural or anthropogenic.

However, the UN Framework Convention on Climate Change (UNFCCC), in its Article 1, defines “climate change” as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods”. They therefore draw a distinction between “climate change” attributable to human activities altering the atmospheric composition, and “climate variability” attributable to natural causes (IPCC, TAR Appendices).

The media and the general public’s perception is that global warming is happening here and now, as a direct and unilateral consequence of increasing carbon dioxide emissions. The main justification of this declaration is the correlation between an apparent increase in the instrumental global mean temperature and increasing CO_2 levels from the combustion of fossil fuels. However, on exploration of the mass of evidence and considerable uncertainties in the climate change debate, the widely held conclusion is less compelling.

The significant, scientific and engineering uncertainties that exist in the climate change debate can be grouped into three areas: 1) the climate system and its mechanisms; 2) climate modelling and scenario development; and 3) the temperature record reconstruction. Some examples of the various uncertainties from each area, respectively, include: a poor understanding of the influence that solar variability and atmospheric water vapour concentration has on climate; climate models are not able to accommodate multiple climate parameters; the instrumental global mean surface temperature record is not globally representative and the individual data from urban centres is subject to thermal influences from the built environment.

The Intergovernmetal Panel on Climate Change (IPCC) is regarded as the World leading body of knowledge on climate change. It was established by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP) in 1988 to: a) assess available scientific information on climate change, b) assess the environmental and socio-economic impacts of climate change, and c) formulate response strategies. The IPCC Third Assessment Report (TAR), the most recent publication, was published in 2001, and is regarded as being representative of the present level of scientific understanding. Reference is made to the IPCC's TAR throughout this thesis.

The climate system and its mechanisms

This area is concerned with the underlying principles that govern the Earth's climate. It is a complex topic that is mostly out-with the scope of this thesis. One key issue is addressed in the present work: the concept of radiative forcing, which is the means by which modelers represent the temperature elevating effect of CO_2 atmospheric absorption.

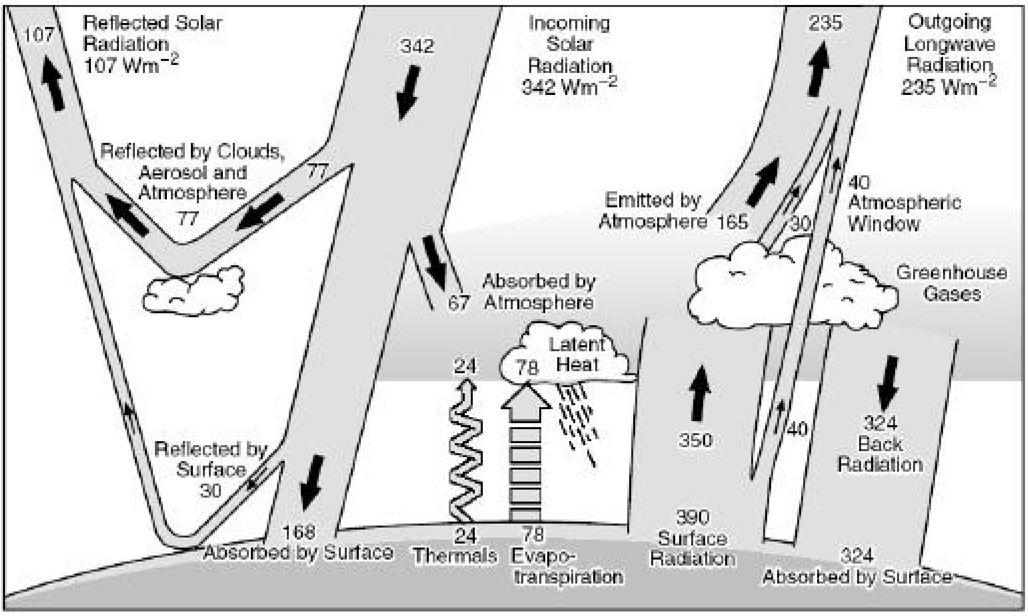

Figure 1: *The Earth's annual and global mean energy balance* (IPCC 2001a, Chapter-01, p90). This diagram shows the distribution paths that incoming solar radiation undergoes on interaction with the surface and the atmosphere. Of the incoming solar radiation, 49% (168 Wm^{-2}) is absorbed by the surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal infrared radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. An increase in atmospheric concentration of CO_2 reduces the escape potential of long wave radiation, trapping heat in the atmosphere. This heat is thus regarded as an additional/positive radiative forcing.

Climate modelling and scenario development

Climate modelling is the major tool used by climate change investigators to predict the future of Earth's climate system, and in particular the global temperature trend. While these models attempt to recreate the climate system as accurately as possible, they are nevertheless simplified representations of climate, with high levels of uncertainty. In this thesis, a detailed understanding of climate modelling uncertainties is not pursued; rather the impact of the major quantified uncertainties are.

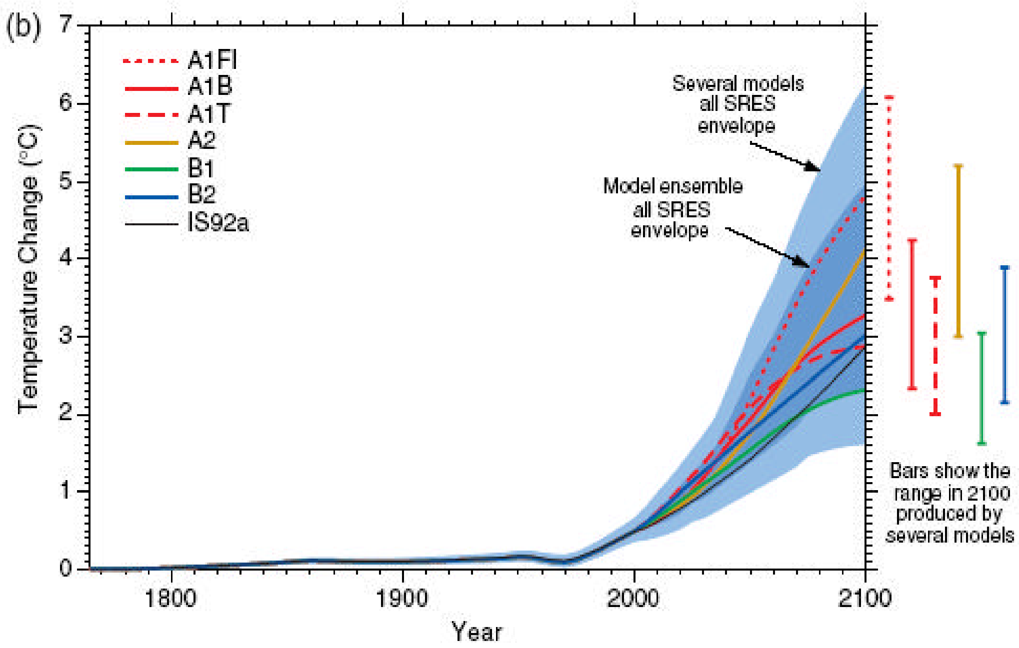

Figure 2: *Simple model results* (IPCC 2001a, Chapter-09, p554). Temperature projections for the next 100 years based on the various emissions scenarios.

The temperature record reconstruction

The reconstruction of Earth's past temperature profile lies at the heart of the climate change debate. Most important of which is the instrumental temperature record for the past 100 years (see figure 3). Understanding how it was created and thus what it actually represents is of crucial importance. There are a number of engineering and scientific uncertainties that must be addressed in respect to: what data was used; what are the methods of its constructio n; and how it is interpreted.

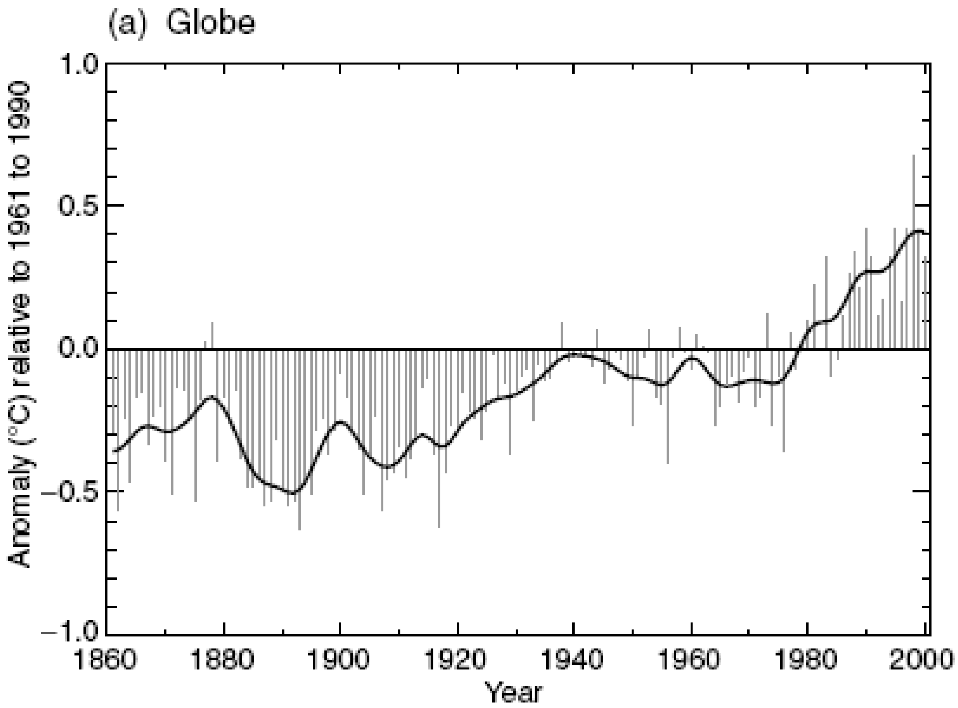

Figure 3: *Annual anomalies of global average land-surface air temperature (?C), 1861 to 2000, relative to 1961 to 1990 values* (IPCC 2001a, Chapter-02, p107).

1.1 Objectives

This thesis has the following objectives:

1. To construct a synopsis of the uncertainties associated with the climate change debate, and in particular with the instrumental global mean temperature record (GMTR).
2. To decompose the global mean temperature record and identify inherent ambiguities.
3. To put forward an alternative interpretation of the observed warming in the GMTR based on an analysis of the radiative forcing associated with heat flux associated with increasing energy consumption in the major industrial centres.

Chapter 2: Uncertainties in the understanding of the climate system

2.1 Introduction

The climate system is a complex 'machine' that reacts to variations in inputs (parameters). These reactions are determined by the physical laws of nature, and the present state of the climate system. Time plays an especially important role: on the one hand it helps reveal natural climatic rhythms, but on the other hand it works with the climate system to mask/delay the effects of input (parameter) variation. The interaction of the various inputs with each other and with the system as a whole (or regionally) provides an additional and significant degree of complexity and uncertainty. See appendix for IPCC definition of climate system.

The present level of understanding of the climate system is vast and the IPCC's scientific report is testament to this fact. However, there still remains doubt over the importance of many climate parameters (and their variation) and their affect on climate variability and climate change. A number of these parameters are described below.

2.2.1 Solar Variability

Solar output is now recognised as being variable over annual/decadal periods, where the Total Solar Irradiance can vary by 0.08% (or 1.1 Wm^{-2}) between minimum and maximum of the 11year solar cycle (IPCC 2001a, Chapter 06, p380). Svensmark has shown that a more active cosmic ray flux, which is inversely related to solar activity, can cause an increase in total cloud cover and thus cause climatic cooling (IPCC 2001a, Chapter 06, p384). The IPCC claim that the mechanisms for amplification of solar forcing are not well established and that there is insufficient evidence to confirm cloud cover response to solar flux. The IPCC attribute a value of + 0.3 W/m^2 to solar activity (see figure.4). However, there remains a number of scientists (e.g. Baliunas and Soon 1999) that support evidence and conjecture of a stronger correlation; and call for more investigation into solar variability and climate response.

2.2.2 Water Vapour

Water vapour is responsible for about 88% of infrared absorption in the range of 4 - 60?m (Clarke 2003). The IPCC state that the total atmospheric water vapour has increased several per cent per decade over many regions of the Northern Hemisphere since the early 1970s (IPCC 2001a, Chapter 02, p103). It is also well established that the atmospheric concentration of water vapour varies strongly with temperature. For example, as atmospheric temperature decreases so does the water content, which results in a reduction in the infrared opacity, thus high latitudes and high altitudes are more efficient at venting solar radiation (Elssaesser, J. 1993). The IPCC have been criticised for not taking proper account of the role of water vapour. In their defence, this is in part due to the complexity of the interactions and feedbacks within the troposphere, and the complications its inclusion causes within models. The following is a quote from a prominent NASA scientist:

"The role of water vapour in the climate system has resisted definitive empirical evaluation, because of the poor state of water vapour measurements and the fact that the tropospheric temperature change has been small in the past 20 years; ozone depletion has also complicated the problem (Hansen 2002)."

Water vapour in the troposphere and surface is not considered by the IPCC to be a forcing agent (like CO_2) but more accurately? a feedback variable. This is because their climate modelling requires all parameters to be held fixed, except for the concerned parameter (eg CO_2 concentration). Any changes that do occur in the climate model can then be attributed to anthropogenic (CO_2) or natural (volcanic) perturbations, and not to any secondary effects (IPCC 2001a, Chapter 06, p405-406, paragraphs F-H). The IPCC also considered any changes in the condensed liquid and solid phases of water (ie, clouds) as part of climate feedback. The only instances where water vapour is classed as a forcing agent is with H_2O derived from the oxidation of CH_4 in the stratosphere, and aircraft and fossil fuels (which are negligible sources). If the feedback effects of water vapour on temperature were removed the remaining warming from the minor greenhouse gases would only be a few tenths of a degree (Baliunas and Soon 1999).

2.2.3 Other Uncertain Parameters

There are a host of other climate parameters, which have been assigned varying radiative forcing magnitudes, all of which have high levels of uncertainty in respect to the level of scientific understanding associated with them. These are displayed in the IPCC table in figure.4. Even though the IPCC admit that there is a great deal of parameters with very low scientific understanding, they remain adamant that the greenhouse gas concentrations provide the largest radiative forcing.

2.3 Radiative Forcing

The IPCC define 'radiative forcing', in the context of climate change, as changes in the radiation balance of the surface troposphere system imposed by external factors, with no changes in stratospheric dynamics, without any surface and tropospheric feedbacks in operation (i.e. no secondary effects induced because of changes in tropospheric motion or its thermodynamic state), and with no dynamically-induced changes in the amount and distribution of atmospheric water (vapour, liquid and solid forms). They also define 'global mean' forcing as the globally and annually averaged estimate of the forcing (IPCC 2001a, Chapter 06, p353).

It is unclear to what extent the factors identified by the IPCC influence the global and regional climate. In particular, the *magnitude* of the radiative forcing associated with each factor is poorly resolved; even determining with confidence the *sign* of the forcing is in doubt with respect to certain factors.

It is accepted that individual radiative forcings can be added together to produce a net forcing. The additivity concept may hold true for a small number of agents. However, it is the IPCC's view that it not possible to say, with absolute certainty, that linear additivity will hold for the complete set of agents (IPCC 2001a, Chapter 06, p396).

When considering the individual strengths of radiative forcing agents, the IPCC is faced with a lack of quantitative information, which results in no uniform method of statistical analysis. The IPCC therefore adopts a qualitative approach to radiative forcing uncertainty, termed 'Level of Scientific Understanding'. In this approach, factors of concern are rated with a confidence level, based on little more than consensual opinion (IPCC 2001a, Chapter 06). This non-statistical assessment approach has been heavily criticised by the climate change critics and other concerned parties (Schneider and Moss 2002). They point out that the adoption of these qualitative ratings by policy makers and environmentalists, to bolster their position, is a serious concern.

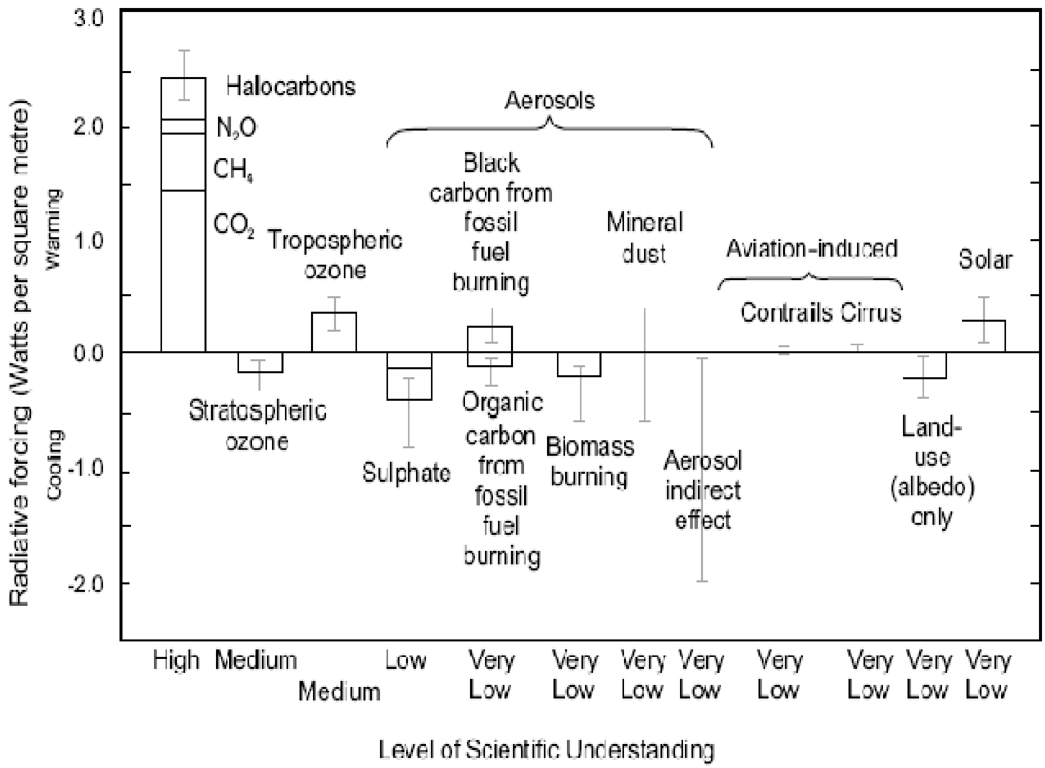

Figure 4: *Global, annual mean radiative forcings (W/m^2) due to a number of agents for the period from pre-industrial (1750) to present* (IPCC 2001a, Chapter 06, p392). This chart compares the relative radiative forcings of various climate parameters, with the parameters assigned a level of scientific understanding that is not statistically supported.

2.4 Summary

The following uncertainties in the climate system inputs and system mechanisms are the main sources of uncertainty in the climate change debate to date (they are all recognised and addressed by the IPCC): land-use change, solar forcing, cosmic rays and clouds, differential warming rate between surface and troposphere, and water vapour.

There are, in fact, additional dynamic attributes of the climate system, which offer further uncertainty, and more radically, a different perspective on the possible reason for global temperature trends. These however, are not considered or mentioned by the IPCC in their 'Third Assessment Report'. They include: heat transfer by deep convective clouds; and heat (or the equivalent radiative forcing) from urban energy consumption.

It is clear that the level of understanding of the climate system is extensive, with knowledge of many individual system components. However, understanding and modelling the capabilities of the complete system, including its inputs, component interactions and feedback mechanisms has yet to be achieved to high levels of certainty.

Chapter 3: Climate Modelling and Projections

3.1 Climate Modelling

Climate modelling is at present potentially unrestricted by computer power. However, having considered the uncertainties and knowledge gaps in climate science (section 2), it is possible to understand where many of the limitations in climate modelling arise from. It is fair and logical to therefore state that a limited understanding of the climate system has a direct influence upon the accuracy of Global Climate Models (GCM). One of the major problems? *modelling the direct effects that each of the many parameters has on the climate*? is considered by the IPCC to be "now quite feasible". However, the magnitude of this problem is multiplied when the individual forcings are combined together, and then further complicated when the indirect effects (feedbacks) of parameter variation are considered.

As climate science develops, so the models are adapted and revised. In regard to its models, the IPCC has recently been criticised for not explaining the failings and shortcomings of their initial models and increasing the number of parameters in subsequent models, thus creating more complexity and uncertainty. These criticisms are reflected in the continual readjustment of the IPCC's global temperature projections. IPCC's estimates of global warming magnitudes, based on GCMs, have consistently been revised downwards, with each new publication. Their "best estimate" for the coming century in 1990 was 3.3?C; in 1992 2.8°C; in 1996 2°C (Freitas 2002).

Another major criticism of the IPCC's models is derived from their non-quantitative attitude to the uncertainty associated with the radiative forcing parameters (see section 2.2). It is clear to all that these uncertainties should impinge in some way upon the accuracy of their climate models. However, the IPCC Summary Report for Policy Makers (IPCC 2001, SPM) boldly claimed a high level of confidence in their projected changes in climate. This is most worrying as the SPM is an 'end of the line' political document that uses descriptive language:

"Problems in the simulation of clouds and upper tropospheric humidity, however, remain worrisome because the associated processes account for most of the uncertainty in climate model simulations of anthropogenic change." (IPCC 2001a, Chapter 8, p486).

Accounting for the other major uncertainties such as: aerosols, land-use change, ocean thermal circulation and solar variability, is currently restricting the credibility of climate projection models.

3.2 Differences between model outputs and actual observations

There are a number of major discrepancies between IPCC model predictions and observations as given by the instrumental global surface temperature record and satellite data.

1. GCMs predict that polar regions should warm faster than equatorial and low latitude regions. However, the IPCC declare that the largest recent warming is in the winter extra-tropical Northern Hemisphere (IPCC 2001a, Chapter 2, p101).

2. GCMs predict a temperature increase in the lower troposphere. The observed trend from satellite and balloon data indicates that the lower troposphere is not warming as fast as the surface (IPCC 2001a, Chapter 2, p102). Freitas 2002 suggests that warming of the troposphere is an essential component of greenhouse gas induced warming, and the fact that this is not observed is direct evidence against the IPCC global warming hypothesis.

3. GCMs predict a steady increase in the global surface temperature as atmospheric CO_2 concentrations increase. However, the combined weather station temperature change displays obvious deviation away from a steady state (see figure 3). In fact it shows a fall between 1940 - 75, which the IPCC claim is non-significant.

4. The models predict that the northern hemisphere should warm more slowly than the southern hemisphere due to the fact that most aerosols are produced there. This has roughly been the case with the Northern hemisphere, which has demonstrated cooling during the period 1946 to 1975, while the Southern hemisphere displayed warming.

However, the recent warming from 1976 to 2000 was largely synchronous, which goes against the predictions of the models (IPCC 2001a, chapter 02, p101).

5. GCMs are unable to explain why most of the warming observed in the combined weather station record occurs at night and in winter (see diagram (a) of figure 5). Figure.5 shows clearly that the greatest warming trends occurred in the months of December, January and February. The IPCC claim that some of these regional trends are due to atmospheric circulation changes, and are also sensitive to changes in record length (IPCC 2002a, Chapter 2, p117). This point is developed further in Chapter 5.

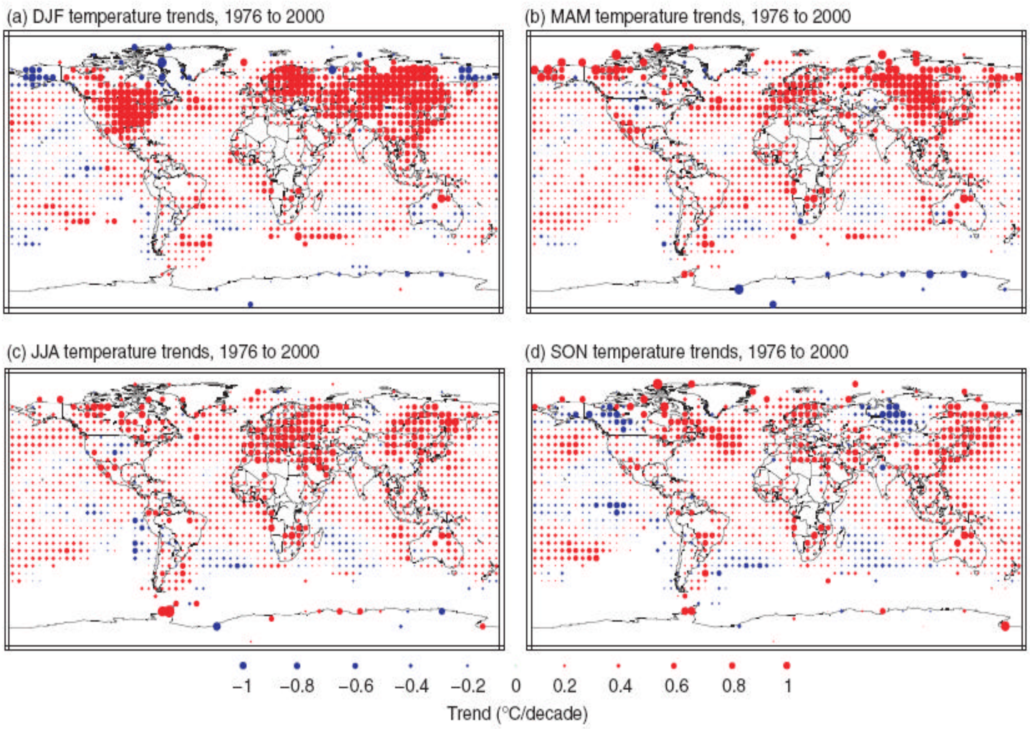

Figure 5: *Seasonal surface temperature trends for the period 1976 to 2000 (?C/decade)* (IPCC 2001a, chapter 02, p117)**.** The red, blue and green circles indicate areas with positive trends, negative trends and little or no trend respectively. The size of each circle reflects the size of the trend that it represents. The greatest warming occurs in the Northern hemisphere in the winter months.

3.3 Model Projections

Climate models are also used to project possible future climate conditions (global temperature, humidity, wind etc), but their true intentions are to assess the impact that anthropogenic forcings (green house gas emissions) have on these conditions. These projections rely on the simple climate models, e.g. Atmosphere-Ocean General Circulation Model (AOGCM) that are used to recreate climate, but with the level of greenhouse gas concentrations in the models altered on the basis of future emissions scenarios.

3.3.1 Scenarios

The latest 2001 report by the IPCC, introduced a new section entitled Special Report on Emissions Scenarios (SRES), in which they detail a number of potential future emissions scenarios that are ultimately used in climate projection modelling. "What constitutes a viable scenario of future climate has evolved along with our understanding of the climate system and how this understanding might develop in the future."

There are forty scenarios in total, but these are in fact based on variations of six main scenarios. The scenarios consider a number of variables: rate of population growth, rate of economic growth, energy consumption, technological advancements (energy efficiency), and degree of cultural amalgamation; all of which are geared to generate a picture of global emissions. Although having created these scenarios with the intention of applying them all to climate modelling, the IPCC was able only to apply two *draft* families of scenarios to AOGCM modelling due to Third Assessment Report time constraints.

Further they only consider the variables that they are confident about, namely greenhouse gas concentrations. The fact that most AOGCM simulations do not include forcings due to land-use change, mineral dust, black carbon, changes in solar flux and volcanic aerosol concentrations (IPCC, 2001a, Chapter 9, p527) means that these issues are not accounted for in the scenarios.

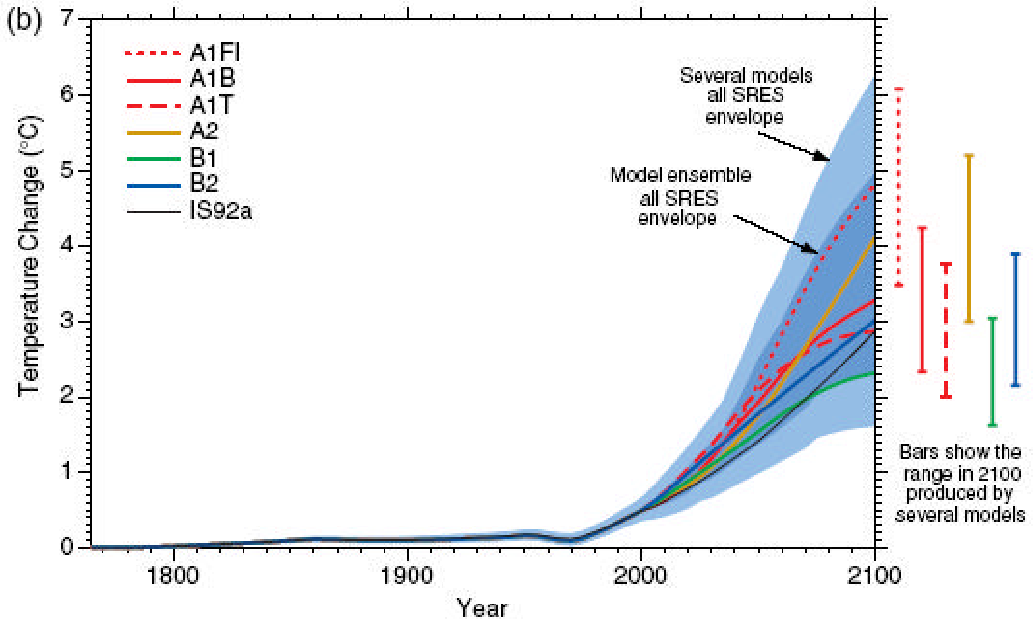

Figure 6: *Simple model results* (IPCC 2001a, chapter 09, p554). This shows the temperatures associated with the estimated radiative forcings that are derived from emissions levels in the SRES marker scenarios.

3.3.2 Discussion

The SRES scenarios do not include additional government climate initiatives. This means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change (UNFCCC) or the emissions targets of the Kyoto Protocol. However, government policies that are not related directly to climate change but can influence emissions are regarded as greenhouse gas emission drivers (IPCC 2001a, Chapter 9, p531). Given the global recognition of the Kyoto Protocol, is it acceptable that the Kyoto emissions targets are not included in any of the SRES scenarios. This brings in to question the effectiveness of proposed Kyoto Protocol.

An important feature of climate modelling is the role CO_2 and the other greenhouse gases play in affecting the complex global climate system as expressed by the global mean temperature. In order to simplify these models, the various other well-mixed greenhouse gases (CH_4, NOx etc) are converted to an "equivalent" CO_2 concentration, i.e. the CO_2 concentration that gives a radiative forcing equal to the sum of the forcings for the individual greenhouse gases. This means, for example, that when the IPCC talk about CO_2 increasing by 1%/year (compound) in their projections, they actually mean CO_2 and all the other gases combined are increasing by 1%/year. Throughout much of Chapter 9 of the IPCC report the term "CO_2" has this meaning.

This has an effect of forcing AOGCM (scenario) experiments to consider stabilisation of CO_2 concentrations as a stabilisation of both CO_2 and the other gases, effectively assuming that concentrations of other gases are stabilised immediately. To allow for ongoing increases in other greenhouse gases, the assumed levels of CO_2 would need to fall to obtain the same climate change impact. For example, in the IS92a scenario, other trace gases contribute 1.3 Wm^2 to the radiative forcing by 2100. If the emissions of these gases were to continue to increase as in the IS92a scenario, then CO_2 levels would have to be reduced by about 95ppm to maintain the same level of climate change in these experiments (IPCC 2001a, Chapter 9, p558).

3.4 Summary

Global Climate Modelling is a tool that is continually evolving as more is understood about the climate system. However, as yet, there is no single model which can accurately reproduce past climate or predict future climate locally, let alone globally. Presently the IPCC utilise a number of different model results in order to acquire the best estimate of the global climate. Until the uncertainties associated with the climate parameters are resolved at least to higher levels of confidence and scientific understanding, those that have examined the body of evidence will remain sceptical towards climate models. Yet what is most alarming is the language used in the summary for policy makers, which presents a different picture of confidence in the models. This point is highlighted by Freitas (2002, p313):

"There is nothing wrong with GCM modellers, they do the best job they are able to. The problem is, that too many people believe in the unreliable predictions. This problem is thus not scientific, it is political."

Chapter 4: The 'Global Mean Temperature Record' (GMTR) over the last 100 years

4.1 Introduction

The GMTR plays a central role in the climate change debate and is heavily relied upon by the IPCC and other proponents of climate change. It is therefore crucial to understand: *how* the temperature record for the past century has been created, *what* it shows, and to understand the uncertainties associated with it.

The IPCC reviewed, and quotes from, three main databases of land-surface air temperature (IPCC 2001a, Chapter 2, p105), they are:

1. U.S. National Aeronautic and Space Administration's Goddard Institute for Space Studies (GISS);
2. Climatic Research Unit (CRU) from the University of East Anglia in Britain;
3. The Global Historical Climate Network (GHCN) run by the United States National Oceanographic and Atmospheric Administration (NOAA).

4.2 How the GMTR was constructed

The global mean surface temperature, which extends back over the last century, has involved the collation of thousands of thermometer readings from around the globe. The process from which the global mean is derived begins with selection of appropriate recording stations. The data from urban areas is then corrected for 'urbanisation' effects. The globe is then divided into 5°x5° latitude/longitude boxes. The weighted average of the monthly mean temperatures of the chosen stations within the grid-box is calculated. This average is then compared against a 1961–1990 reference period; the final figure obtained is a temperature anomaly for that grid-box for any particular month. The weighted hemispheric and global annual average anomaly is then determined from that monthly data. Boxes that have no data are left blank. They are not estimated from neighbouring boxes (Daly 2000). The IPCC in their 2001 Third Assessment Report do not detail the process of how the global mean temperature is derived.

4.3 Points of concern regarding the global mean temperature record data

There are many points raised questioning both the validity of much of the individual data used, and the methods used to derive the global mean. There are also doubts as to the plausibility of the IPCC's interpretation of the global mean trend over the past century, and especially over the last three decades. These will be detailed in the following chapter. As a result there are doubts as to the authority of the mean global temperature trend as being a true representation of the global climate. IPCC statements such as: "There is a discernable human influence on climate" and "Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gases" are bold and misleading. The IPCC acknowledge some of the uncertainties raised by some authors and do make attempts to defend the GMTR, but they still submit little insight into the uncertainties and derivation of the global mean.

Few stations with a long and uninterrupted record

One of the concerns is with the deficient number of recording stations and the consistency of data production over the last century. This arises from station redundancies, especially in rural areas. Two thirds of recording stations, many of which were rural, have been discontinued from around 1975 (Freitas 2002). This roughly coincides with the introduction of satellite recording systems and also with the growth of airport recording stations and urban growth in general. The resultant affect on the temperature record, from the presence of broken data streams, is to introduce statistical weaknesses arising from either the forced exclusion of data entirely, or from the amalgamation of data.

"Accordingly to Gray (2000), the GMTR does not represent a single continuous temperature record, or an average of continuous records. It represents a compilation of very many individual land and sea-surface temperature records, for different places and periods; each influenced by methods and times of measurement and by elevation and location".

Uneven spatial sampling

The map of figure 7 shows the distribution of temperature recording stations around the globe. It is apparent, that the majority of these stations are in the northern hemisphere and, in particular, within the continents of Europe and North America. This uneven spatial sampling among the continents and also between land and sea, contributes to averaging biases and ultimately contamination of the GMTR.

Data subject to high uncertainty

Uncertainty in the instrumental surface temperature data is thought to develop from a number of sources. Firstly, inconsistencies in the positioning of recorders in the local environment can affect the temperature. For example, there is no requirement on the distance that the equipment should be from buildings or roads; there is no control on surrounding vegetation; and the height of the equipment above the ground can vary between 1.25 and 2 meters (Gray 2000a).

The process of deriving a global average subjects the original station data to increasing inaccuracy. The process involves the following steps:

1. Generate monthly mean for each station (A) = mean of a mean of a variation;
2. 5x5 Grid mean (B) = mean of all (A) in grid;
3. Generate monthly Grid Anomaly mean (C) = (B) minus reference period mean;
4. Global mean (D) = average of all (C)

It is also a well-known fact in science that the act/presence of measuring/observing something will have an influence on the object being measured and thus affect the result. This leads to the second and related aspect of uncertainty, which has been recognised as causing a real affect on temperature data.

Most stations are in urban areas

Figure 7 shows that the majority of recoding stations are in the USA, Europe and Russia. The fact that there is a high density of stations within these particular land areas is ultimately due to the high levels of: urbanisation, social infrastructure and social stability.

One would expect recordings from these areas to provide consistently recorded, continuous and accurate data. While continuity and recording consistency are fairly well achieved, there is a major problem with the accuracy of urban data. This is referred to as the 'urban heat island effect', where recorded data is influenced by localised warming due to asphalt and concrete replacing grass and trees. In particular, the man-made surfaces absorb and retain solar radiation during the day and release it at night. The IPCC acknowledge the effect and attribute a 0.05?C increase up to 1990 in the global temperature records (IPCC 2001a, Chapter 2, p106). They claim that the temperature data used has been corrected for urbanisation effects; and that because the urban effects are substantially exceeded by the total warming, the presence of the urban heat effect is negligible. However, many studies and commentators (Gray 2000a, Freitas 2002) claim that the urban effect is more significant than the IPCC's estimate, and that the temperature record is more contaminated than previously recognised.

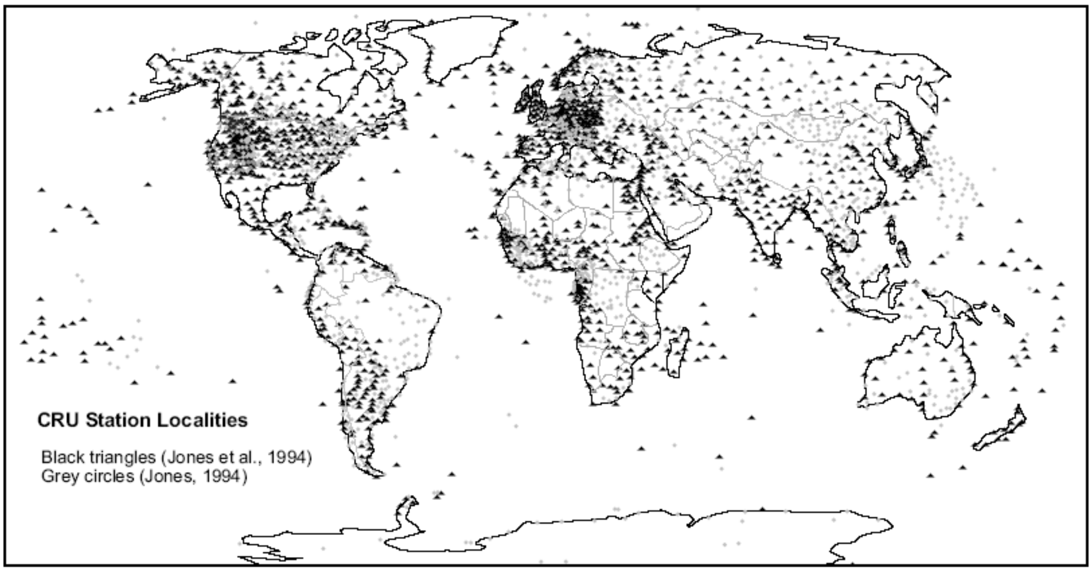

Figure 7: *Location of climate monitoring stations that make up the Jones (CRU) surface data used by the IPCC* (Freitas 2002).

Comments on IPCC's comments on Urbanisation effects

In their brief handling of the urban heat island effect (UHI), the IPCC admit that the urban heat effect is well known to raise urban night-time temperatures and thus produce a decrease in the diurnal temperature range (DTR). They also admit that there is evidence of a *relatively strong* correlation between increased cloud cover and a decreasing DTR (IPCC 2001a, Chapter 2, p106). From these two *relatively equal* lines of evidence they go in favour of the latter. In saying so they manage to extrapolate the point and bring in to question the credibility of the urban heat effect in terms of its influence on the mean global temperature record.

There is a further weak attempt to belittle the urban heat island effect. The IPCC state that the lower rate of temperature increase observed in the lower troposphere (satellite) compared to at the surface (instrumental) is a global phenomena, which they argue is due to the tropical and sub tropical oceans, rather than to urban heating. They then argue that because the difference between trends in the Northern hemisphere (where urban heat island effects are most apparent) is not significant, this means the UHI effect is not significant. They do however, acknowledge that the UHI effect is significant at the local level but that it is not representative of larger areas (IPCC 2001a, Chapter 2, p106).

Finally, the IPCC go on to claim that borehole temperatures, recession of the glaciers, and changes in marine temperature (all of which are not influenced by urbanisation), support instrumental estimates of surface warming over the last century (IPCC 2001a, Chapter 6, p106). However, they then go on to say (p132) that "borehole data are probably most useful for climate reconstructions over the *last five centuries*".

4.4 What the instrumental temperature record shows

The global mean temperature record from 1860 to 2000 shows a relative increase of about 0.3 to 0.6?C over the century (see figure 8a). However, since 1860 there have been obvious periods of growth, decline and stability. The two periods of significant warming were 1910-1945 and 1976-2000. The period in between (1946-1975) displayed no warming but instead a slight cooling. These trends are consistent (within a tight range) among all four of the data sets, see figure 8b.

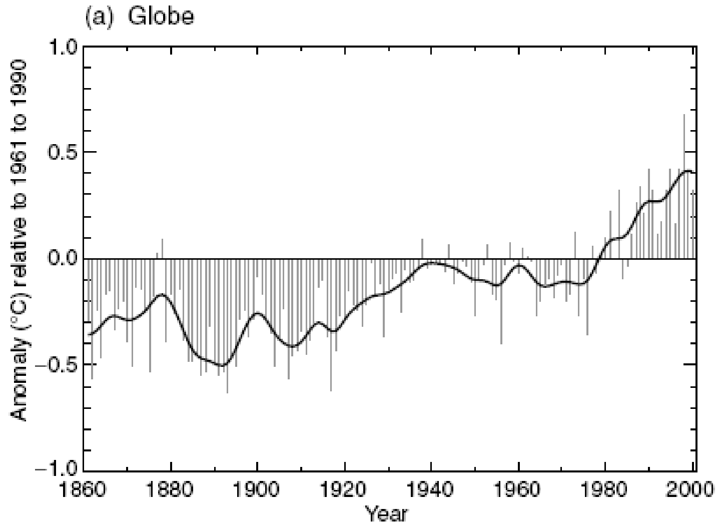

Figure 8a: *CRU Annual anomalies of global average land-surface air temperature (?C), 1861 to 2000, relative to 1961 to 1990 values* (IPCC 2001a, Chapter 2, p107).

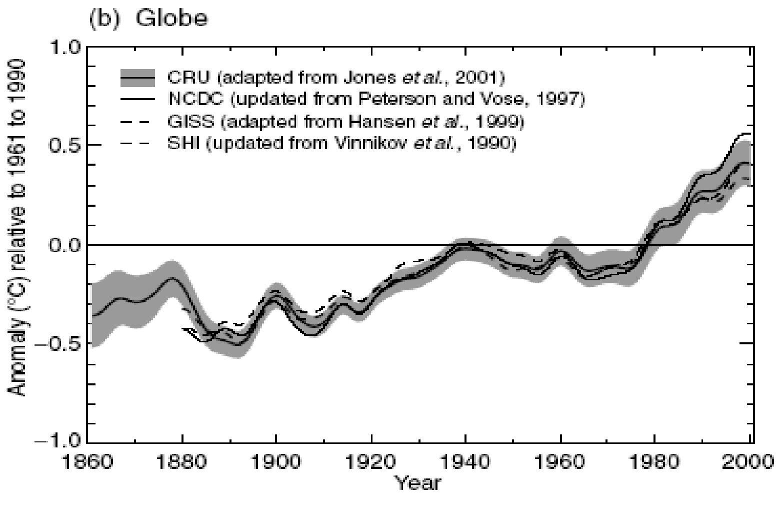

Figure 8b: *Trend comparison among the four sets of annual anomalies of global temperature* (IPCC 2001a, Chapter 2, p107).

4.5 Explaining the Trend

It is clear from the surface temperature record data that the global mean temperature appears to have increased over the last century and at a greater rate in the recent decades. However, what is not so clear is the underling uncertainties and biases that are inherent in the data that supports these trends. It is important to appreciate both the weaknesses of the graph and the limitations in climate system understanding before interpretations as to the causes of the trends are formulated. The IPCC have adopted the trends but have failed to give adequate mention to the supporting information; they simply state that anthropogenic related emissions of CO_2 is the primary cause of the global mean temperature increase. The assertions made by the IPCC are plausible but at the same time challengeable.

1946 to 1975 Cooling

A number of commentators have pointed out that the period 1946 to 1975, which displayed minor global surface cooling, was interestingly a time when global atmospheric CO_2 concentrations were rapidly increasing (Freitas 2002). It could be claimed that this is evidence contrary to the anthropogenic green house gas theory. Then again, this feature could also be a consequence of delayed climate response.

Atmospheric CO_2 Concentrations

The IPCC claim that the 1990s were the hottest years on record, and that the 0.6?C warming over the century can in part be attributed to CO_2 emissions from the burning of fossil fuels. The actual atmospheric concentration of CO_2 that can be attributed to humans is an order of magnitude smaller than the natural CO_2 fluxes (Schloerer 1996). For instance, the atmosphere acts as a sink to 750 GtC (1990 levels), with anthropogenic emissions totalling 7.1 GtC/year, and natural balanced fluxes in and out of the atmosphere totalling 120 GtC/year. It is also known that only half of the fossil fuel derived CO_2 remains in the atmosphere, the rest being absorbed by the oceans and land vegetation (IPCC 2001a, Chapter 3, p187). Since pre-industrial times atmospheric CO_2 concentration has increased from 280ppm to 367ppm (in 1999). This equates to an increase of ~30%. However, relative to the entire composition of the atmosphere, CO_2

has still remained at about 0.03% (see figure 9). The global warming proponents remain adamant that such a minor change has resulted in a significant impact on temperature.

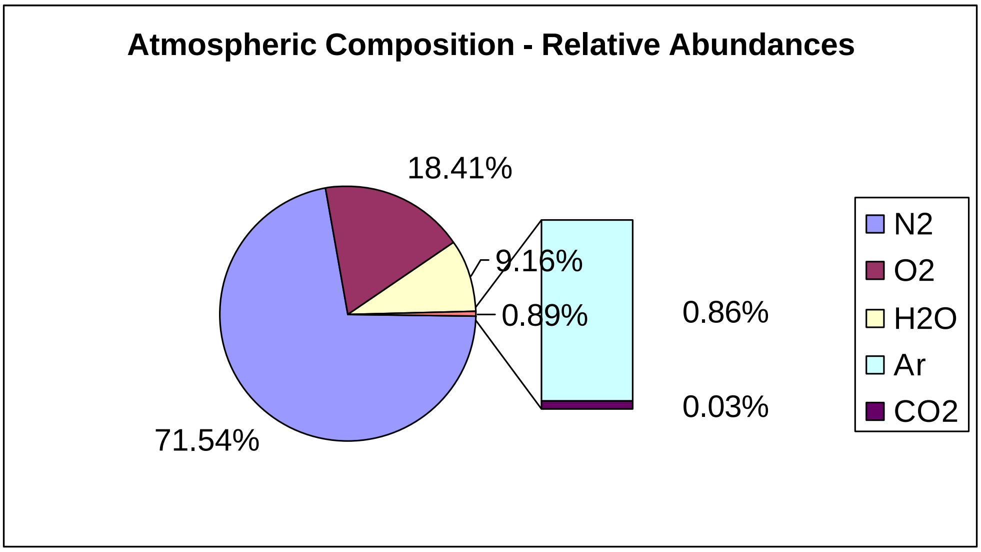

Figure 9: *Relative abundances of the major atmospheric gases.*

The introduction of satellite data

NASA satellites carrying Microwave Sounder Units have recorded truly-global temperatures (stratosphere and lower troposphere) since 1978. Their findings were that lower atmosphere temperatures have fluctuated within a 0.4?C band, and that there is no significant temperature trend (warming or cooling) for the lower troposphere (see figure 10). This is in direct contrast to the surface temperature record over the same period and contrary to model projections. Satellite data has also highlighted cooling of the stratosphere and lower troposphere (southern hemisphere) over the same period (see figure 11). Balloon measurements of the troposphere have verified the satellite findings.

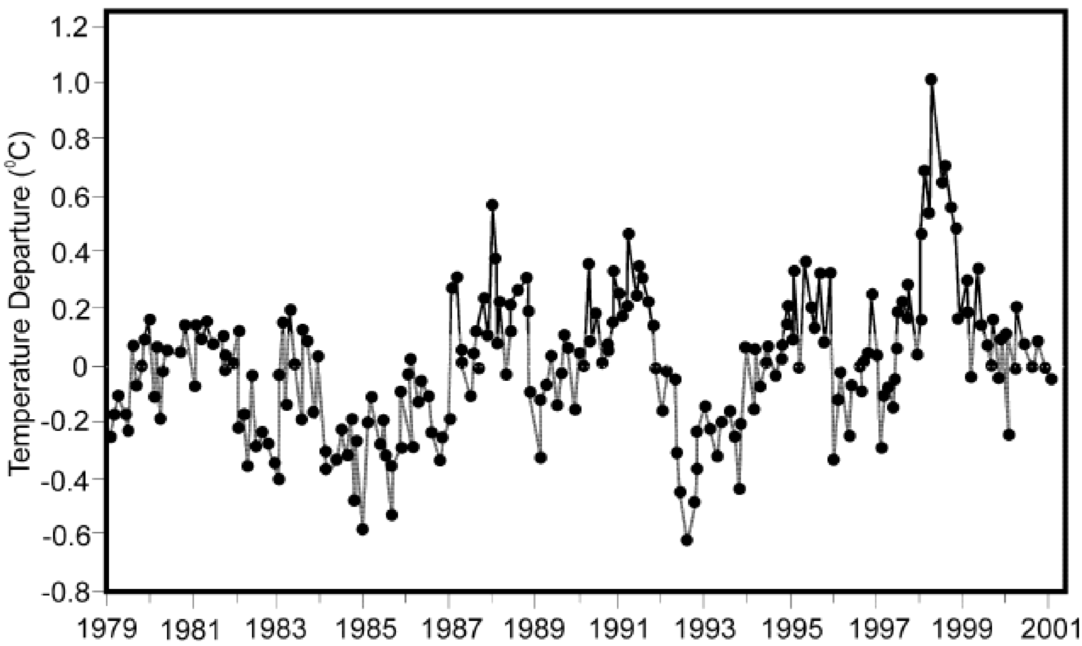

Figure 10 *Satellite global temperature data for the period 1979-2001 for the Northern hemisphere* (Freitas 2002). The satellite data does not show the degree of warming that the surface data does over the same period. The large peak for 1998 is the effect of the El-Nino event.

Even though the surface and the lower troposphere are different atmospheric zones, the IPCC models predict that they should act as though they are directly coupled, where warming at the surface should be mirrored with warming of the lower troposphere. The IPCC partly attribute this modelling discrepancy to a lack of knowledge of the vertical distribution of radiative forcing agents (IPCC 2001a, Chapter 8, p512). Recent research claims to have resolved the observed difference between the lower troposphere and the surface. The IPCC is also eager to highlight the errors associated with satellite data, such as from orbit drift (-0.11°C/decade) and instrument response (+ 0.04?C) (IPCC 2001a, Chapter 2, p120). Others argue that this observation highlights a lack of scientific understanding of the climate system and the limited capability of the climate models.

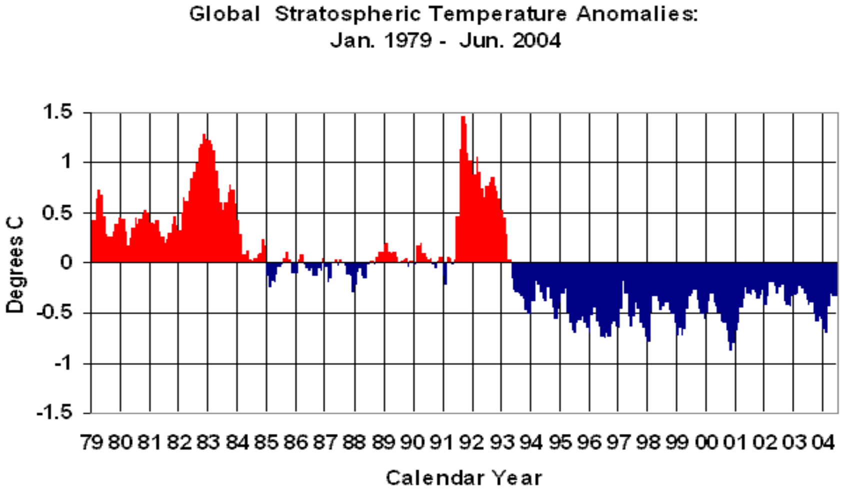

Figure 11: *Global Stratospheric Temperature Anomalies: Jan. 1979 - Jun 2004* (NASA, ref no.3).

Interestingly, prior to 1979, when satellite temperature measurements began, the surface record showed no temperature increase since 1940. Combine this observation with the results of no significant change from satellite data, and this could be taken to indicate that global temperatures have not increased significantly for 60 years.

As urban areas account for 1% of the global surface area, and the majority of recording stations are in urban areas, the mean global surface temperature record is in effect more an average of the local urban environment than the globe. Satellite data is not restricted in this manner and is therefore a truly global record.

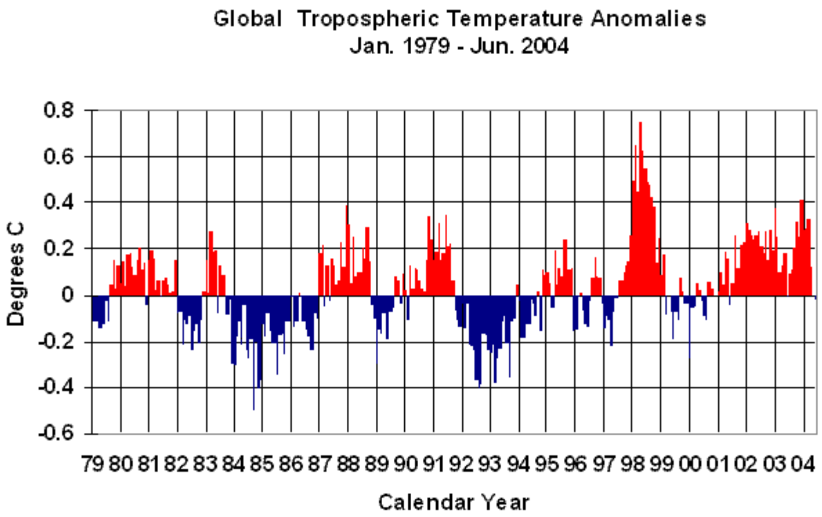

Figure 12: *Global Tropospheric Temperature Anomalies: Jan.1979 - Jun. 2004* (NASA, ref. No.3)

4.7 Summary

The question is whether all or part of this warming can be linked to increases in greenhouse gases or to other factors linked to climate variability and change. For example, the warming may simply reflect changes in atmospheric transmissivity from volcanic dust or other sources of atmospheric aerosols ? natural or anthropogenic; solar variability; or the additional heat from energy consumption, associated with the growth of towns and cities (urban heat island effect).

The second section of this thesis will attempt to show that the energy released in the form of heat by the combustion of fossil fuels, in the neighbourhood of urban areas, may in fact be responsible for the observed trend in the global mean temperature record; providing an alternative to the considerable consensus that increased greenhouse gas concentration is the principal cause.

Chapter 5: Global Warming: A Local Phenomena?

5.1 Introduction

The preceding chapters identified the uncertainties and biases associated with the global mean surface temperature record; pointing out, for example, that the uneven distribution of recording stations across the globe results in an unrepresentative measure of global mean temperature. It also highlighted the real influence that the urban environment has on the instrumental surface temperature record ? in the form of the 'urban heat island effect' (UHI). In particular, the influence of daytime-retention and night time release of solar thermal radiation. There is, however, an additional contributor to the UHI effect; a feature that has not yet been mentioned by the IPCC in their handling of the UHI, but which has been discussed by a some researchers (Gray 2000b) and will be considered further in this section.

This second and often overlooked aspect of the UHI effect is the addition of heat to the urban environment from the consumption of energy. This is an altogether significant anthropogenic activity yet, strangely, it receives little attention and scrutiny. This chapter proposes that the recent increase in the global mean surface temperature could in fact be an illusion created by local urban heat biases from energy consumption corrupting the urban temperature recordings, rather than (or in addition to) greenhouse gas forcings.

5.2 Anthropogenic Sources of Heat

The primary source of heat as a direct result of human activities (electrical power generation and consumption, motor travel etc) comes from the combustion of the fossil fuels ? natural gas, coal, petroleum, oil and biomass. There are also additional sources of heat which are associated with the various modes of non-combustive electricity generation (nuclear, hydro and various renewables), i.e. end user consumption and conversion of electrical energy to heat. Urban areas are the epicentres of consumption of these fuels and electrical energy.

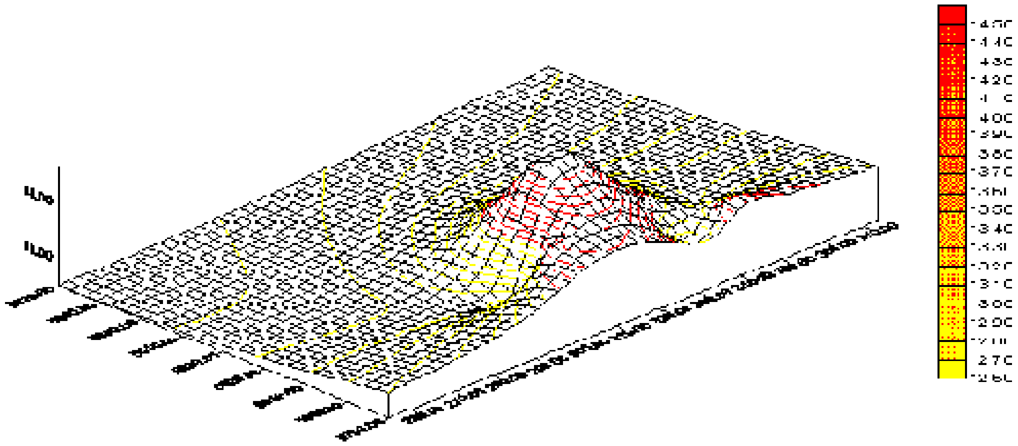

Figure 13: *UHI anomaly over Melbourne city* (Morris, J). 1985-94 Summer Mean Minimum Potential Temperature contours of Melbourne city, Australia. The UHI anomaly is calculated by subtracting local airport average temperatures from city average temperatures. The maximum (peak contours) is over the Central Business District.

Figure13 shows the thermal signature of the UHI effect over the city of Melbourne, Australia. This is a significant phenomenon when one considers that the majority of temperature recording stations are located within similar urban areas and zones of influence. The following sections attempt to quantify the UHI effect in terms of the *radiative forcing* of heat from energy consumption: globally, hemispherically, regionally and locally.

5.3 Global Energy Consumption

The combined global consumption of primary energy in 2002, in the form of fossil fuels (coal, oil, and natural gas), stands at 411 quadrillion (10^{15}) BTU (Energy Information Association 2003). The historical consumption trend for the last 20 years can be seen in figure 14. It clearly shows that global energy consumption has increased linearly over the 20 year period, with 2002 consumption levels almost double (44% increase) the 1980 figure of 284 quadrillion BTU.

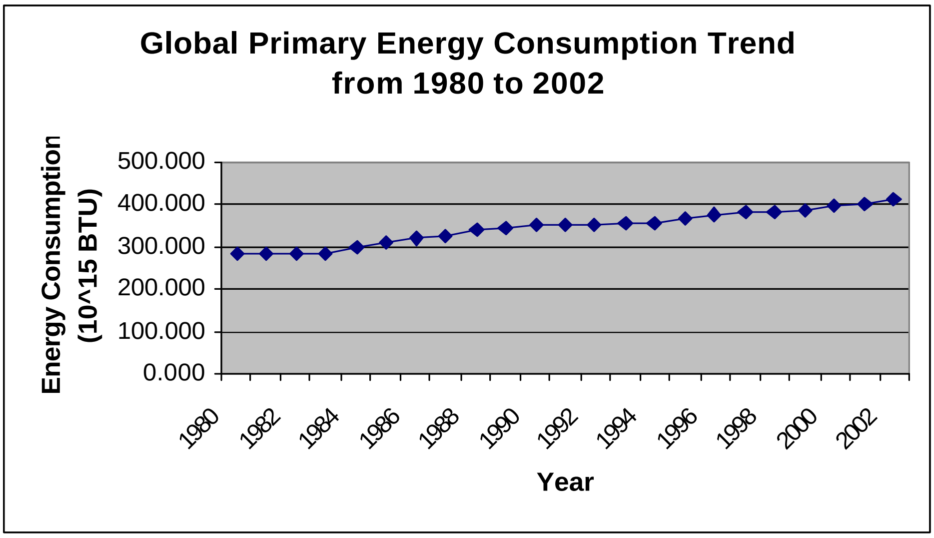

Figure 14: *Global primary energy consumption trend from 1980 -2002.*

These figures can be broken down into their hemispheric components producing figures for the Northern and Southern hemispheres. Figure 15 shows that the majority (~93%) of primaryenergy is consumed in the Northern Hemisphere. It is also clear that this north to south ratio has remained constant since 1980.

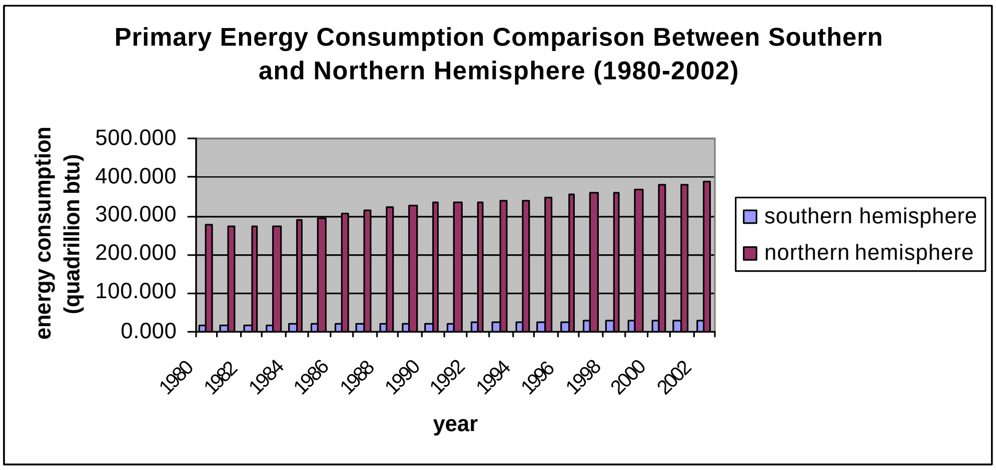

Figure 15: *Energy consumption comparison between Northern and Southern hemispheres.*

5.4 Radiate Forcing of Global Energy Consumption

The heat produced from the burning of fossil fuels and electricity consumption can be expressed in the form of a radiative forcing (Wm^{-2}). This is an expression of power density per unit area and it represents an externally imposed perturbation in the radiative energy budget of the Earth's Climate system (IPCC 2001a, Chapter 6, p353). By viewing energy consumption in this manner allows one to draw comparisons with the radiative forcings associated with climate parameters such as CO_2 concentration.

5.4.1 Converting Energy Consumption (Heat) in to a Radiative Forcing

This conversion is achieved by first converting the heat energy expressed in British Thermal Units (BTU) into an electrical energy equivalent (kWh). This is then converted to an expression of Power (W) by dividing by the number of hours in a year (8760). The final step involves dividing the Power value by the Area (m^2). The Area value in the case of a 'global' radiative forcing is taken as the surface area of the Earth; the hemispheric RF uses half the global surface area; and in order to derive the radiative forcing of a particular 'country' one would use the surface area of that country.

5.5 Results from Calculations

The raw energy data used for this study was derived from published global energy statistics given on the Energy Information Association's website (EIA 2003).

Figure 16 shows that for a single year the radiative forcing due to world energy consumption is roughly 0.09 W/m^2 (calculations consider entire surface area of the Earth). For the Northern and Southern hemisphere it is 0.18 W/m^2 and 0.01 W/m^2 respectively. If all urbanised surface area is considered, which represents only 1% of global surface area, then the RF from world energy consumption, for a single year, would be a massive 143 W/m^2.

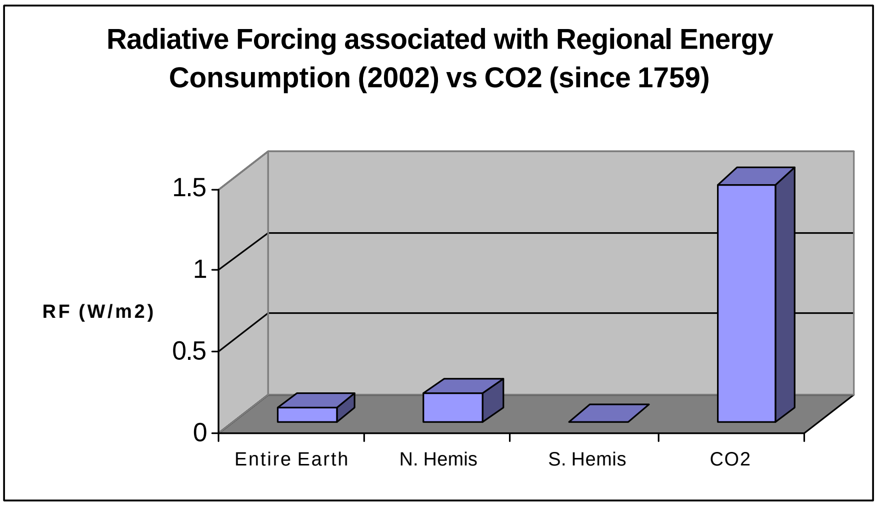

Figure 16: *Regional energy consumption radiative forcings.*

Figure 17 shows the radiative forcings associated with various countries' energy consumption levels for the year 2002. Clearly, the radiative forcing from the consumption of primary energy can vary by an order of magnitude among countries and also between countries and cities, which is due primarily to their surface area diversity. The importance of these large RFs will be revealed later.

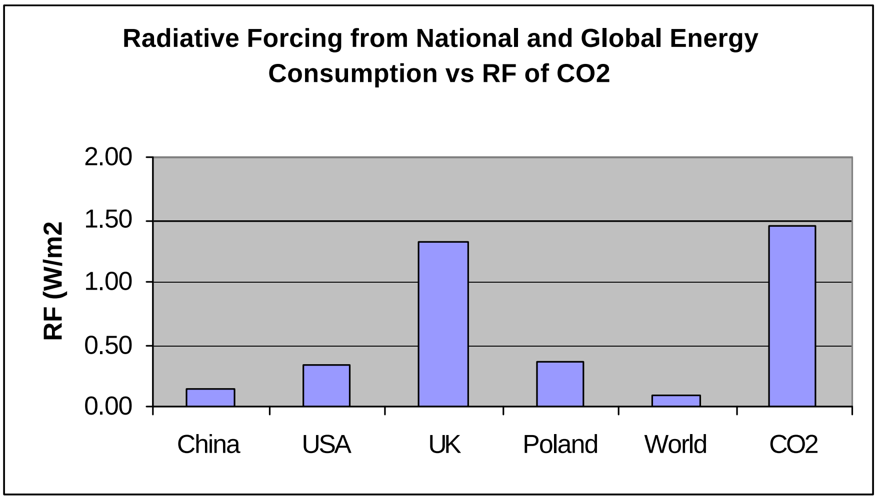

Figure 17: *National energy consumption radiative forcings.* Examples of the radiative forcings of energy consumption for the year 2002 for different countries and the World. Also radiative forcing due to accumulation of CO2 since 1750.

Interestingly, figure 16 & 17 show what the IPCC believe is the radiative forcing associated with the build up of CO_2 in the atmosphere since 1750. The magnitude of global energy consumption (RF = 0.09 W/m^2), which is about 6% of global CO_2 RF (1.46 W/m^2) is fairly significant. However, the even larger national and individual city scale radiative forcings are of greater significance due to their proximity to temperature recording stations.

5.6 Forcing-Response Relationship

The IPCC state (IPCC 2001a, Chapter 6, p353-354) that any change in the net irradiance at the tropopause as a result of externally induced +/- radiative forcings, is a good indicator of the equilibrium global mean surface temperature change. This relationship between surface temperature and radiative forcing is expressed as the climate sensitivity parameter (?) and is defined as:

? Ts / ? F = ?

where, (? Ts) is the global mean surface temperature response to the radiative forcing (? F).

The IPCC consider that for one-dimensional radiative convective models, the climate sensitivity parameter is nearly invariant [typically $0.5K/(Wm^{-2})$] for most climate parameters.

The results from calculations show that an RF of 0.09 W/m^2 (global surface area and global energy consumption) is equivalent to a 0.045 K increase in global surface temperature. This is an insignificant temperature; however, energy consumption and surface area at the regional and national level produce RFs that translates into more significant temperatures. For example, the UK RF of 1.4 W/m^2 (annual) equates to ~ 0.7 K.

Summary

1. Global energy consumption has increased 40% during the period 1980 to 2003.
2. Global energy consumption for the year 2002 equates to a radiative forcing of 0.09 W/m^2.
3. Over 90% of energy is consumed in the Northern Hemisphere.
4. Individual countries can have radiative forcings that vary by an order of magnitude.
5. Cities can have radiative forcings that are an order of magnitude greater than those of countries.

The cumulative RF of CO_2 since 1750 is 1.46 W/m^2.

5.7 Discussion

The facts, observations and calculations mentioned above can be combined to form the basis of an argument that challenges the premise that greenhouse gases are the dominating influence on the global mean surface temperature. The following points attempt to illustrate that heat from energy consumption has the potential to influence the global mean temperature record.
The majority of instrumental recording stations are in the Northern hemisphere (see figure 18), they are predominantly on land, and they are mainly in or in close proximity to urban areas, which constitutes only 1% of the global surface area. Since a fair average of any quantity cannot be made without a representative sample, a global mean temperature record that uses data derived from only 1% of the Earth's surface is not truly representative of the global surface temperature.

Secondly, and crucially, this 1% of the Earth's surface that contains the majority of temperature recording instruments, is also where 93% of energy consumption takes place (see figure 15). As detailed earlier the radiative forcings from energy consumption can be regionally/nationally comparable to that of CO_2, and locally? an order of magnitude greater than that of CO_2 (Gray 2000b). Therefore, in terms of Radiative Forcing, the possibility of national/local heat emissions influencing the instrumental record cannot be dismissed lightly in favour of CO_2 forcing.

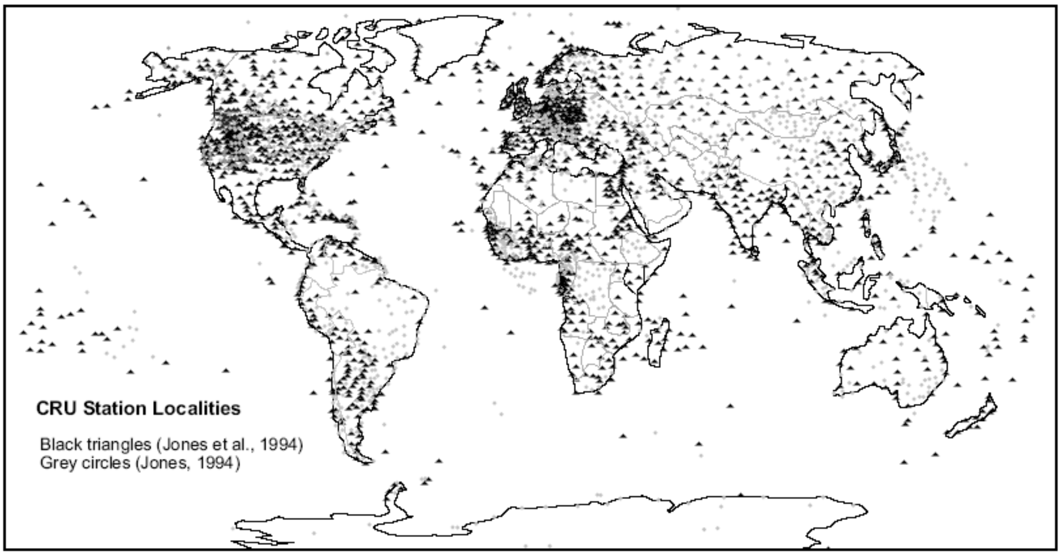

Figure 18: *Locations of climate stations globally* (Freitas 2002).

Thirdly, and in support of the second point; figure 19 shows that the greatest increase in surface temperatures occur in the Northern hemisphere (North America, Northern Europe and Asia), during the winter months (December, January, February). The IPCC attribute the majority of this land based warming to the warm air associated with the warm phase of El Nino and the positive phase of the North Atlantic and Arctic Oscillations (IPCC, 2001a, Chapter 2, p117). However, they do not dismiss an anthropogenic influence. Interestingly, this is a period when energy consumption is at its peak, as the population of the Northern Hemisphere increase their demand for winter heating. Figure 20 displays this correlation (qualitatively) between urban areas and the land based warming observed in figure 19.

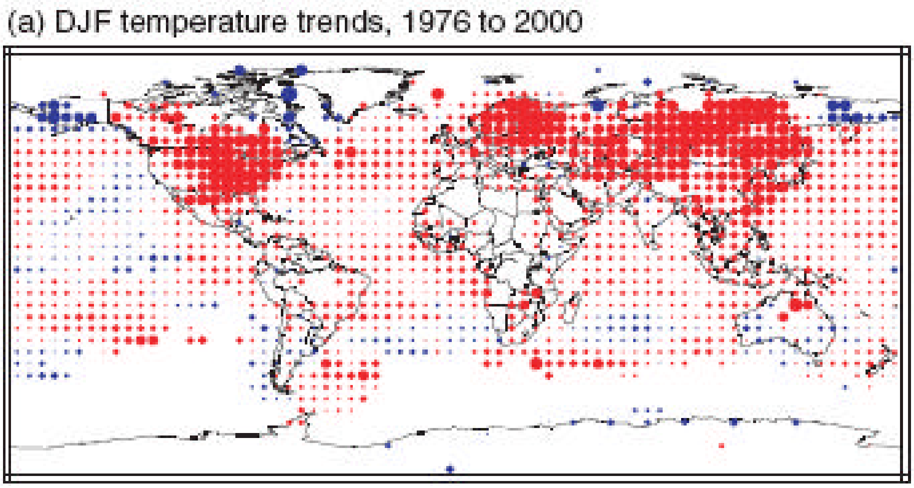

Figure 19: *5x5 grid Global Surface temperature trends* (IPCC, 2001a Chapter 02, p117). The red dots in this figure show the areas that have displayed greatest warming; over the winter months (Dec, Jan, Feb) 1976 to 2000.

There does however remain the warming anomaly over Russia/N.Asia (see figure 19); which the IPCC claim is evidence against the urban warming theory, as this is on the whole a rural region that displays marked warming. However, it has been pointed out (Gray 2000a) that proper validation of Russian data is required, especially as it represents such a large proportion of the global mean data set.

Figure 20: *Night-time illuminations from urban areas* (NASA Ref. No.4)

Chapter 6: From Global to Local Perspective

Introduction

The previous sections have shown the fallibilities that are inherent in the Global Mean Temperature Record. They have also highlighted (qualitatively and quantitatively) the possibility of a correlation between global/regional energy consumption and the warming in the instrumental surface temperature record. The following section attempts to zoom in past the large scale (global) weaknesses in the argument, to view part of the local data that the global mean is derived from. The aim of the following section therefore is to display real temperature profiles from various UK localities, and then evaluate their resemblance to the global mean temperature trend.

The data used is based on daily minimum temperatures for specific UK recording stations (Met Office 2004); the yearly average is obtained by averaging the monthly means. Many of the data sets produce trends that cover the last forty years. There are also a number of longer term records dating back to 1853. Importantly, both sets include the recent decades, which are anomalous in the GMTR. It is also important to note that this local data does not suffer the same level of uncertainties associated with the 5?x5? grid averaging that the global mean necessitates.

6.1 Local Annual Temperature Trends, UK

The following graphs are annual minimum temperature trends for Oxford (a), Lerwick (b), Sheffield (c), Paisley (d), Cambridge (e), and Greenwich (f). These locations were chosen randomly from the data made available by the Met-Office; see figure 22 for their spatial position in the UK. Minimum temperature data was plotted instead of maximum temperatures because the lower end of the diurnal temperature range is known to have increased at a greater rate (twice the rate) relative to the upper end, especially in the Northern hemisphere (IPCC 2001a, Chapter 2, p106).

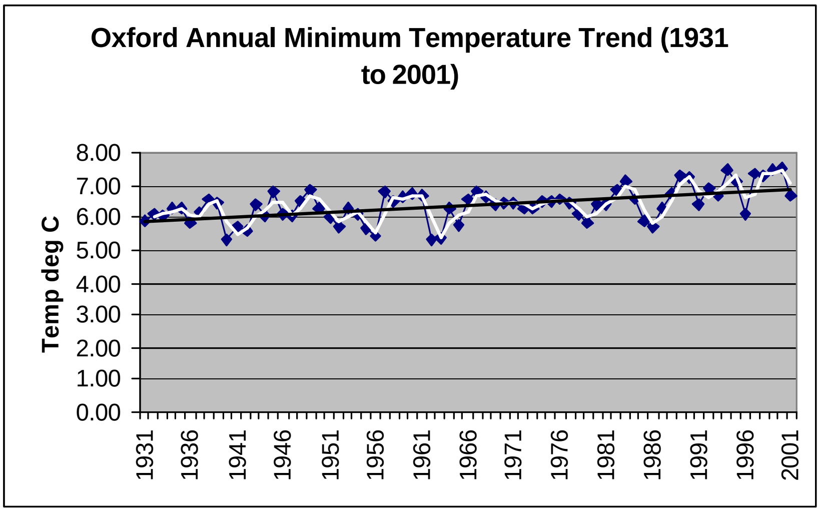

Figure 21(A) *Oxford annual minimum temperature trend - 1931 to 2001.*

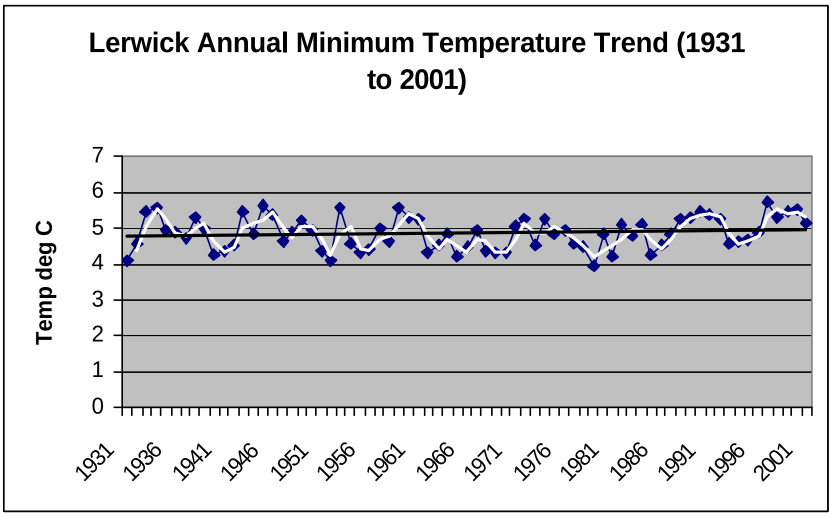

Figure 21(B) *Lerwick annual minimum temperature trend - 1931 to 2001.*

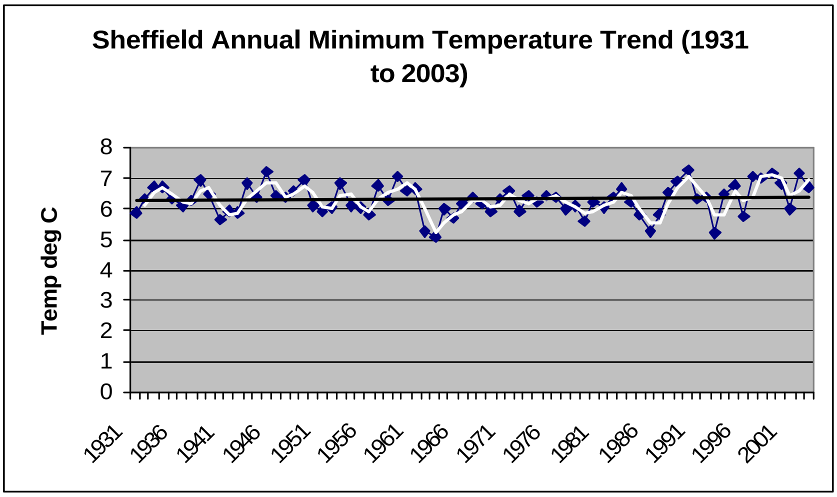

Figure 21(C) *Sheffield annual minimum temperature trend - 1931 to 2003.*

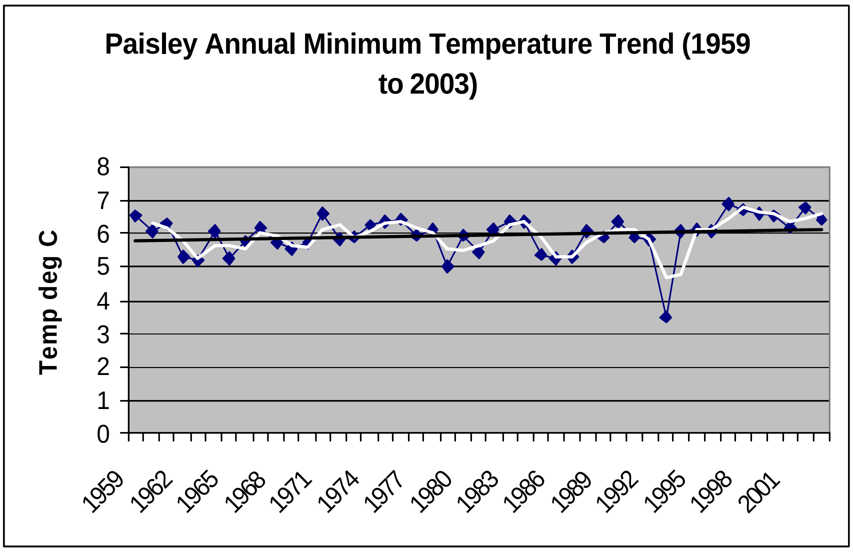

Figure 21(D) *Paisley annual minimum temperature trend - 1959 to 2003.*

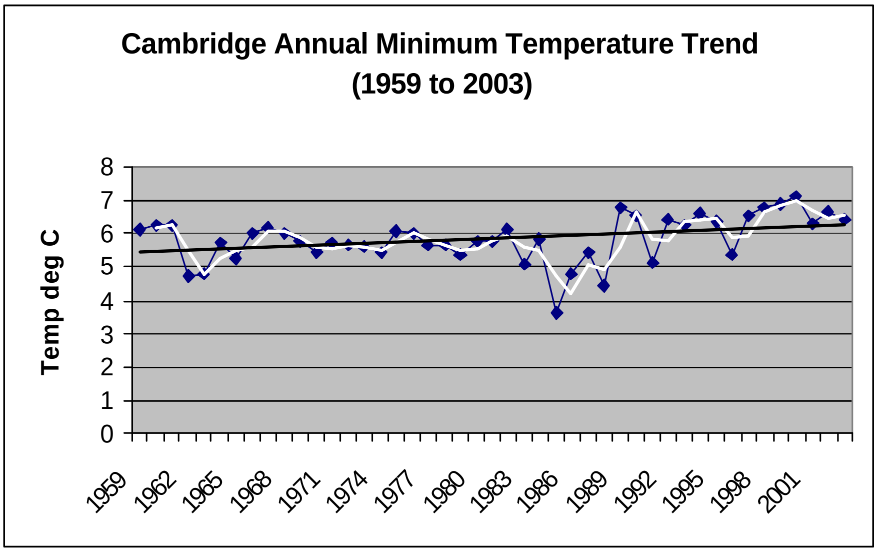

Figure 21(E) *Cambridge annual minimum temperature trend - 1959 to 2003.*

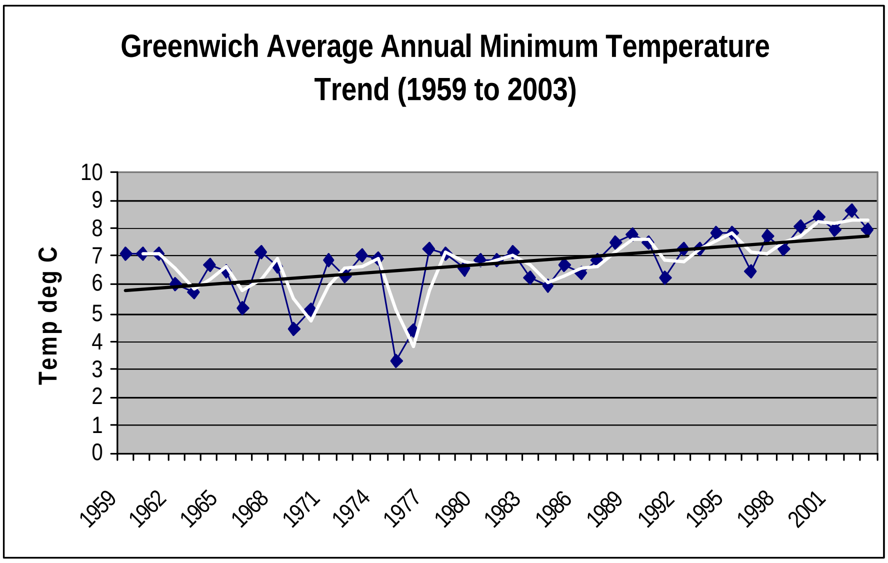

Figure 21(F) *Greenwich annual minimum temperature trend - 1959 to 2003.*

6.2 Interpretation of Trends

The striking observations are that Greenwich, Cambridge and Oxford all display marked warming, with a linear-average increase of between ~1.0 to 1.5?C over the last 50-70 years; whereas the trends for Paisley and Lerwick display a minor warming of about ~0.2 ?C; while Sheffield has a zero gradient average (no change) over the same period.

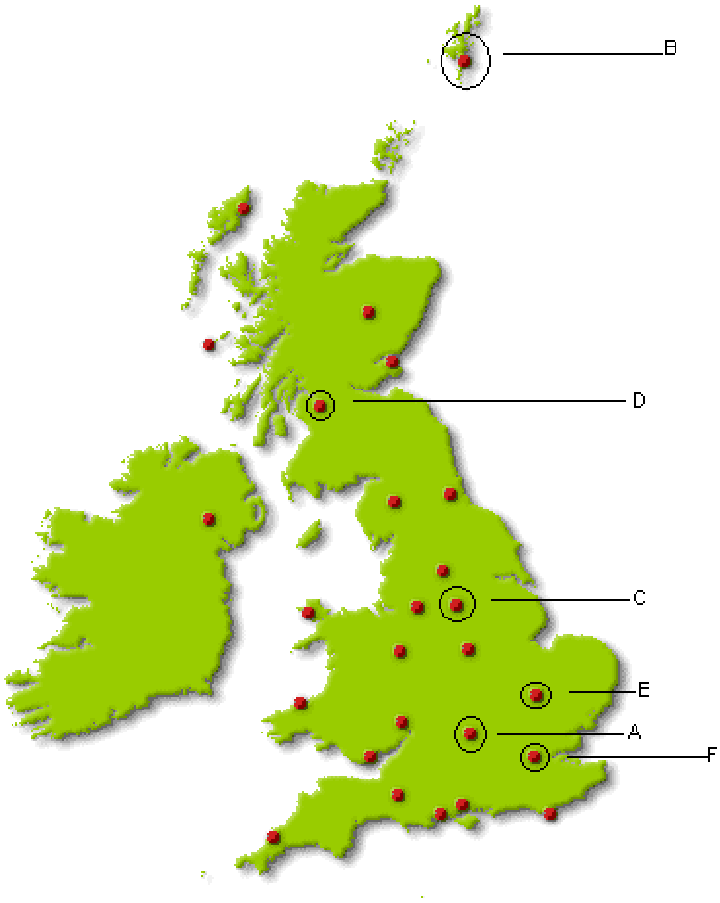

Figure 22: *Weather station location map of UK* (Met office 2004). The circled red dots indicate the locations of the data for figures 21(A - F).

Speculation as to the causes of these trends could be exhaustive, covering numerous variables and factors. However, in the context of urbanisation, energy consumption and the global mean, these trends provide noteworthy support for the UHI phenomenon. For example, the data for Greenwich (figure 21 F), which displays the largest linear average increase (~1.5?C over 40 years), could be correlated with the fact that Greenwich is located within the highly urbanised South East where energy consumption is also significantly high. Also, in support of this correlation is the fact that the neighbouring trends of Oxford and Cambridge have also displayed similar warming, whereas rural Lerwick displays only a slight warming trend.

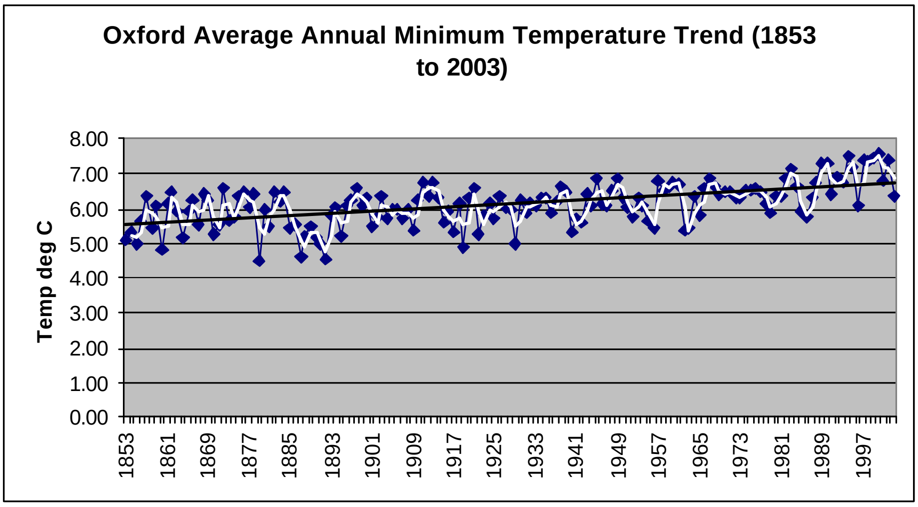

Figure 23: *Oxford annual minimum temperature trend - 1853 to 2003.*

6.3 Summary

The massive global consumption of energy, confined primarily to 1% of the Earth's surface, the same area within which surface temperatures are recorded, presents an interesting position for discussing the validity of the Global Mean Temperature Record. The Urban Heat Island effect is a well established phenomenon that is recognised as having an influence on the instrumental record (some say underestimated influence). But, the UHI component due to heat from energy consumption is barely given attention in the climate debate, even though it has the potential (radiative forcing) to cause a major effect, especially at the local level.

Chapter 7

7.1 Discussion

There have been direct attempts made to determine whether urban data has had a significant impact on the GMTR, from which the IPCC conclude that there has been and it is no more than a 0.05?C influence up to 1990 (IPCC 2001a, Chapter 2, p106). The Peterson et al (1999) study separated the rural data from the full set of data (rural and urban) and calculated that the rate of warming for the rural data was similar to that of the full set. They therefore argue that urban warming does not have a significant impact on the GMTR. The IPCC quote the figures from this source (IPCC 2001a, Chapter, 2, p105), which claim an urban data warming of 0.10?C/decade and a rural data warming of 0.80?C/century; however, interestingly, they do not state the value of rural warming per decade. Simple division reveals that this figure would be about 0.08?C/decade, which is actually less than their value for urban warming.

There is further criticism of the Peterson et al (1999) study based on their method of differentiating between urban and rural data by population number. Results from other studies have shown that the method of classifying between urban and rural data can have a significant impact.

Bohm (1998) found significant to strongly significant warming trends of up to 0.6K in 45 years, for the city of Vienna, Austria. The author went on to say that classifying heat islands or urban areas by their population number should not be relied upon as a means of differentiating between urban and rural data. Kalnay and Cai (2003) also support this view based on their study, which found that when urban data was identified based on satellite measurements of night light it differed significantly to urban data that was identified by population data. Gallo et al (2002) used satellite data to detect a UHI temperature influence; they found that urban stations in the Northern hemisphere were 0.9?C warmer than their surroundings, and interestingly, rural stations were also warmer than their surroundings by 0.19?C. They concluded that more analysis of rural stations being influenced by their surrounds in required. It is clear that there are not only criticisms of the methods used to construct the GMTR (detailed in chapter 4) but that there are also justifications to criticise the work done to defend the validity of the GMTR.

The IPCC claim that the period 1990 to present can be accredited the hottest years on record, with regards to both the instrumental global mean surface temperature record, and also the proxy record reconstruction for the last 1000 years. From examination of localised data this statement is certainly analogous in part with the trend for the Oxford data set (see figure 23). However, it is important to note that it is not a universal feature of all individual temperature trends. It is also pertinent to note that from the specific UK data examined, the trends that displayed the greatest warming occurred in the high population/energy consumption region of the south.

The latter claim that the most recent decade is the warmest (within the previous 1000 year period) (IPCC 2001a, Chapter 2, p101) has been heavily criticised, (McIntyre and McKitrick 2003a & 2003b, Baliunas and Soon 1999), with most of the criticism aimed at the Mann et al "Hockey Stick" graph (see figure 24). One of the criticisms of this graph is that it is composed of two data sets: the proxy data extending up to the beginning of the twentieth century, and the instrumental temperature data from then on. This combination resulted in the steeply curved end to the graph. However, as has been detailed in this thesis, the instrumental record is fraught with uncertainty and potential warming bias; for this reason it is fair to question the premise that this is unprecedented warming.

It is interesting to note that the warming of the last 100 years still lies within the zone of uncertainty associated with the proxy data (see figure 24: grey area above and bellow the black trend line). There is also contention over the 11th century medieval warming and the 14th century "little ice age". The IPCC stand by the assertion that these were regional features of climate, and not globally synchronous. Therefore, from their perspective, recent temperatures remain unprecedented and greenhouse gases are implicated. McIntyre and McKitrick contest the validity of the graph from their identification of a number of significant collation errors, extrapolation of source data, obsolete data, geographical misallocations and other serious defects; all of which resulted in a depressed proxy temperature record (McIntyre and McKitrick 2003b).

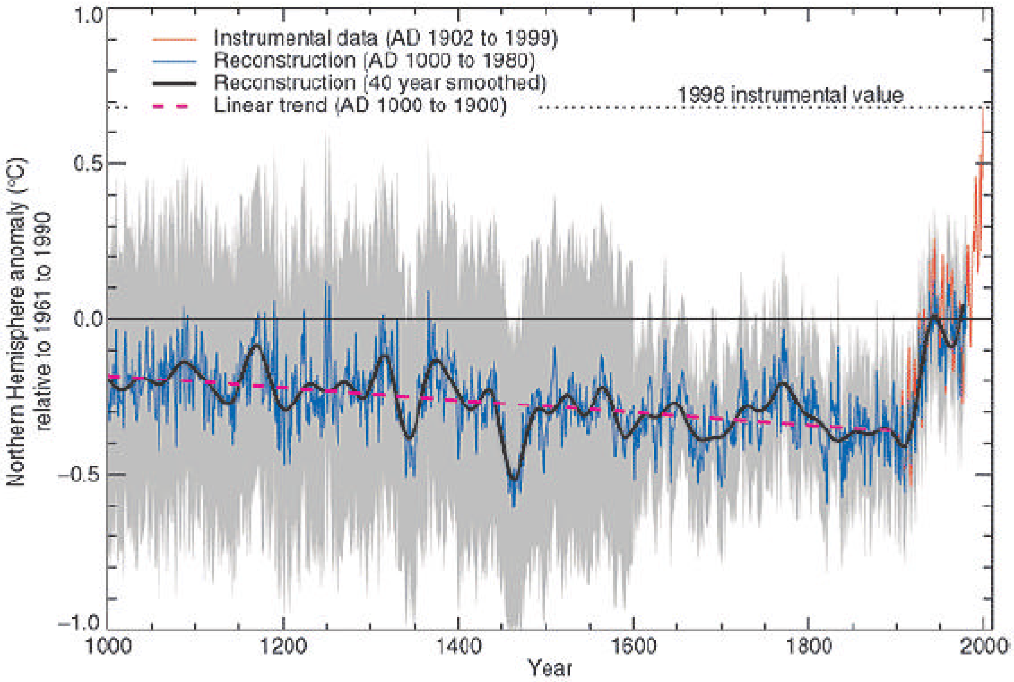

Figure 24: *Mann et al 'Hockey Stick Graph'* **(**McIntyre, S. and McKitrick, R. (2003b). From AD 1000 to 1900 proxy reconstruction data is plotted, and from 1902 to 1999 instrumental data is plotted. The instrumental data shows a distinct warming increase compared to the proxy data.

The use of instrumental temperature data in this manner presents the opportunity for misleading conclusions to be drawn. The information for policy makers is of particular concern as this user group are often not privy to the underlying science and depend on a summary of the science to aid their decisions. The Mann et al graph featured prominently in the IPCC Third Assessment Report, which was ultimately used to brief policy makers.

7.2 Conclusion

7.2.1 General Conclusions

The scientific understanding behind climate change and global warming has developed and evolved into a comprehensive body of knowledge. On the one hand this has enabled scientists to develop and unravel the workings of climate more precisely, but on the other hand it has increased the number of climate parameters that need to be considered to generate accurate climate models. Unfortunately, uncertainty remains a major problem, especially with respect to the value of various climate parameter's radiative forcings. As a result, climate model outputs have (or should have) a low confidence attached to them.

The focus of this thesis was the instrumental temperature record, in particular decomposing its construction to reveal the inherent weaknesses and thereby assess the validity of the IPCC's interpretations as to the causes of the observed warming. The concerns of a number of authors were highlighted, which showed that the GMTR is not globally representative and that the individual instrument data is subject to local bias affects.

Through calculations it was shown that recent warming in the global instrumental temperature record could potentially be contributed to by local heat emissions from energy consumption.

7.2.2 Summary of Contributions

The instrumental global mean temperature record is at the forefront of the global warming debate, forming the main line of evidence in support of anthropogenic induced warming. This thesis has highlighted the process involved in deriving the global mean record and has surmised that there are a number of features which bring into question the validity of the GMTR.

Based on the well known influence that the Urban Heat Island effect has on the instrumental temperature record, this thesis has attempted to quantify the radiative forcing associated with the not so well known component ? heat from energy consumption. It has been revealed that annual energy consumption at the national and local level has the potential to exert an equal and often greater forcing than CO_2. These findings have been supported by examination of actual temperature data from individual UK sites, where locations of high energy consumption and population are concurrent with greater positive temperature trends.

7.2.3 Future Research

1. The use of Stevenson screens as climate monitoring stations and in particular their unsystematic positioning is criticised (Gray 2000a) for producing data inconsistencies. Computer modelling using Esp-r could be used to simulate the screen under various climate conditions and various orientations to the surrounding built environment and solar ecliptic.

2. Correlation analysis of global 5° x 5° grids, between individual grid temperature trends and the associated energy consumption (trend or annual figure) for each grid square (land grids only). The Torok et al (2001) equation for calculating temperature difference based on population number could be used to generate grid data.

References

Baliunas, S & Soon, W. (1999). Fraser Institute: Solar Variability and Global Climatic Change.
http://oldfraser.lexi.net/publications/books/g_warming/solar.html

Bohm, R. (1998):Urban bias in temperature time series. A case study for the city of Vienna, Austria. *Climate Change*, **38** (1), p113-128.

Clarke, J. (2003): Climate Change: Fact or Fiction? Faculty of Engineering, University of Strathclyde.

Daly, J.L. (2000): "The Surface Record: 'Global Mean Temperature' and how it is determined at surface level"
www.greeningearthsociety.org/Articles/2000/surface1.htm

Easterling, D.R. et al (1997): Maximum and minimum temperature trends for the globe. *Science*, vol **277**,p364-367.

Ellsaesser, J. (1993): Global Warming: A Different View
www.coaleducation.org/issues/different.htm

Freitas, C.R. (2002): Are the observed changes in the concentration of CO2 in the atmosphere really dangerous. *Bulleting of Canadian Petroleum Geology,* **vol. 50**, no. 2, pp297-327.

Gallo, K.P. et al (2002): Satellite-based detection of global urban heat island temperature influence. *Journal of Geophysical research - atmospheres*, **107** (D24), article no.4776.

Gray, V. (2000a): The Surface Temperature Record
www.john-daly.com/graytemp/surftemp.htm

Gray, V.(2000b): Global Warming: What Evidence?
www.john-daly.com/tar-2000/ch-3.htm

IPCC 2001a, Climate Change 2001: Third Assessment Report, The Scientific Basis. Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J. and Xiaosu, D. (eds.). Cambridge University Press, New York, NY, 752
www.ipcc.ch

IPCC 2001a, Chapter-01: The Climate System: an overview.

IPCC 2001a, Chapter-02: Observed climate variability and change.

IPCC 2001a, Chapter-03: The carbon cycle and atmospheric CO2.

IPCC 2001a, Chapter-06: Radiative forcing of climate change.

IPCC 2001a, Chapter-07: Physical climate processes and feedbacks.

IPCC 2001a, Chapter-08: Model evaluation.

IPCC 2001a, Chapter-09: Projections of future climate change.

IPCC 2001a, Chapter-12: Detection of climate change and attribution of causes.

IPCC 2001a, Chapter-13: Climate scenario development.

IPCC 2001, SPM: Summary for Policy Makers.

IPCC, TAR Appendices:

Jones et al (1990): Assesement of urbanization effects in time series of surface air temperature over land. *Nature*, vol **347**, p169-172.

Kalnay, E. and Cai, M. (2003): Impact of urbanisation and land use change on climate. Nature, vol **423** (6939), p528-531.

McIntyre, S. and McKitrick, R. (2003a): Corrections to the Mann et. al. (1998) Proxy data base and Northern Hemispheric Average Temperature Series. *Energy & Environment*, **vol. 14**, no. 6, p751-771.

McIntyre, S. and McKitrick, R. (2003b): The IPCC, the "Hockey Stick" curve, and the illusion of experience. Marshall Institute (http://www.marshall.org/pdf/materials/188.pdf).

Morris, J. Urban Heat Islands and Climate Change - Melbourne, Australia. www.earthsci.unimelb.edu.au/~jon/WWW/uhi-melb.html

Peterson, T.C. and Vose, R.S., (1997): An overview of the global historical climatologic network temperature data base. *Bull. Am. Met. Soc*, **78**, 2837-2849.

Peterson, T.C. (2003): Assessment of urban versus rural in situ surface temperatures in the contiguous United States. *Journal of Climate*, **16** (18), p2941-2959.

Peterson, T.C. et al (1999): Global rural temperature trends. *Geophysical research letters.* **26**, p329-332.

Schloerer, J. (1996): Why does Atmospheric CO2 rise?
www.radix.net/~bobg/faqs/scq.CO2rise.html

Schneider, S. and Moss, S., (2002): Scientific Uncertainty. *Nature*, **418**.

Theroux, M. (1998): Global Warming or Urban Heating?
www.borderlands.com/newstuff/research/cycle23/warming.htm

Torok, S.J. et al (2001): Urban heat island features of South East Australian towns. *Australian Meteorological Magazine,* **50** (1), p1-13.

Websites

IPCC

Intergovernmental Panel on Climate Change
www.ipcc.ch

NASA

Ref. No.1 Hansen, J. (2002): Water Vapour and Cloud Feedbacks. NASA, GISS.
www.giss.nasa.gov/edu/gwdebate/j.hansen.html

Ref. No.2 Arnold, J.E. Global Hydrology and Climate Centre: Climate Variability and Climate Change.
http:///weather.msfc.nasa.gov/ghcc_home/html

Ref. No.3 Tropospheric Global Temperature Anomaly (data from 1979-2003)
www.weather.msfc.nasa.gov/temperature/html

Ref. No.4 Lighting up the ecosphere (2000)
http://science.nasa.gov/headlines/y2000/ast15nov_1.htm

Energy Information Association (EIA)

Energy Information Association (2003): International Energy Outlook
www.eia.doe.gov

Energy consumption figures
www.eia.doe.gov/oiaf/ieo/world.html

Miscellaneous

The Greening Earth Society (2004): More Local, Less Global.
www.greeningearthsociety.org/wca/2004/wca_18c.html

Union of Concerned Scientists (2002): The IPCC Assessment Process
www.ucsusa.org/global_environment/archive/page.cfm

Met Office (2004): Historic Station Data for the UK
http://www.met-office.gov.uk/climate/uk/stationdata/index.html

CFC (2000): Composition of the Atmosphere, relative abundance.
http://www.c-f-c.com/charts/atmosph.htm