GLOBAL TEMPERATURE VARIABILITY REVIEWED

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Abstract

(1) Data, relating to global temperature variability are presented and examined, firstly looking back 400,000 Years in order to gain a general perspective and then analysing the record of the more recent past in greater detail, to enable evidence based conclusions relative to factors which influence the global temperature, to be drawn.

(2) Much of this referenced data has become available only relatively recently, in the 21st Century.

(3) Contextual background information is provided, in order to facilitate a more comprehensive understanding. eg. global atmospheric gas volumes; global atmospheric structure

(4) On principle and as far as possible, quoting the interpretations of others is avoided.

(5) A re-appraisal of historic and more recent data is undertaken in order to enable an assessment of the degree to which the increase in atmospheric CO_2 during the 20th Century was responsible for increased global temperatures and also to allow an identification and examination of additional influences.

(6) Global atmospheric processes & interactions are examined in order to demonstrate -

(i) That any hypothesis attributing increased global temperatures to increased volumes of atmospheric CO_2 is, based on historic and current data, far from secure.

(ii) That whilst CO_2 *is* continuing to accumulate in the atmosphere (and at an increasing rate) the global temperature has *not* continued to rise in concert -
(As did occur during some periods of the 20th Century)

(iii) That Solar Cycle variability influence on the global environment is significant, readily observable and has a measureable effect on the mean global temperature.
Furthermore that solar short wavelength flux variability has a strong influence on the Earth's upper atmosphere as demonstrated by the modulation of Noctilucent cloud formation at the top of the Mesosphere.

(iv) That oceanic effects have a major influence on the global temperature.

(7) Anticipating future Solar behaviour seems likely to remain extremely challenging.

In conclusion, based on the data and interpretations presented in this paper, it is proposed that the Mean Global Temperature, far from increasing over the next 30 years as predicted by the IPCC[17], will decline by approximately 0.5oC over this period with the veracity of this trend verifiable through the 2020s.

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Introduction

Historical Perspective

When Dr.Mann et al presented their Paper "Observed Climate Variability & Change" in 1998 - (subsequently incorporated within the Nobel Prize winning Intergovernmental Panel on Climate Change [IPCC] Report of 2001) - proposing an escalating volume of atmospheric anthropogenic CO_2 as the primary forcing agent responsible for the increasing global temperatures throughout the 20th Century, and in particular for the rapid escalation in temperature during the 1990s, they were able to draw upon only limited and poor quality data resources.
This required the utilisation of innovative techniques in order to extract the desired data buried within "Noisy" and difficult to interpret source material. Dr.Mann was a pioneer in this work.

(a) In the 1990s, the large variability of Solar short wavelength (UV,EUV & Soft X-ray) high energy radiation was mostly unsuspected because this is observable only from outside the Earth's atmosphere, with which it strongly reacts; the data from the few satellites of the period were un-calibrated and of low quality.

That situation has now (2015) been remedied with a number of satellites returning continuous and good quality Solar UV, EUV & Soft X-ray flux data from beyond the Earth's atmosphere.

(b) In 1998 the longest time scale ice core data available was the GISP2 [5] (Greenland) completed in 1993 which revealed information relative to global temperatures during the past 100,000 years - but this extended over only *one* period of Glaciation and did not include the previous (Eemian) Interglacial warm period. Consequently, this was of restricted value.

That situation has now (2015) been transformed with the current availability of two enlarged time scale (Antarctic) ice cores.
These are –

(i) Vostok [1] Encompassing the last 400,000 years
(ii) Epica [4] Encompassing the last 800,000 years

Since 400,000 years is inclusive of greater than four Glacial (cold) and Interglacial (warm) periods it is now much more secure and less complex to derive significant and meaningful patterns of global temperature and global atmospheric CO_2 gas volumes from these data.

(c) Only subsequent to 2009 have initial data from the CLOUD experiment at CERN [3] and a number of other research establishments, investigating (eg.) the interaction of solar variability modulated cosmic rays with the Earth's atmosphere, become available to provide a restricted, currently poorly understood, view of processes which influence atmospheric structure, cloud formation and may thus modify global temperatures.

Future Possibilities

It is suggested that the year 2016 and the subsequent few years, may prove to be a watershed regarding a more general acceptance that there are many interacting factors which control and determine the global temperature and that Solar variability is one major temperature driver which must be correctly incorporated within our comprehension.

There is, perhaps, a dawning realisation that the simplistic hypothesis -

"*An Escalating Level of Anthropogenic Atmospheric CO_2 is responsible for the Increasing Global Temperatures in the 20th and early 21st Centuries* "

- is inadequate to account for and explain historic and current observations and that a more inclusive, comprehensive and sophisticated understanding is required before any predictive modelling may be expected to provide data of sufficient quality on which to base meaningful future decision making.

Data Presentation - Examination - Interpretation

The Significance of Carbon Dioxide and the ‘Greenhouse Effect’

The ‘Greenhouse Effect’ describes the phenomenon where certain constituents of the Earth’s atmosphere act, by their relative opacity to thermal energy, to reduce the loss of global heat by radiation into space and thus maintain a higher global temperature than would otherwise be the case.

Fig.1 below, displays the % volumes of the principal global atmospheric gasses. [6]

Carbon dioxide is much stronger in its ‘Greenhouse’ effectiveness than is water vapour but the latter dominates global atmospheric Greenhouse activity because there is twenty five times more water vapour by volume in the atmosphere than carbon dioxide.

Carbon dioxide is nevertheless a significant component of overall ‘Greenhouse’ thermal energy loss control.

This is why CO_2 is near the forefront of global temperature variability considerations.

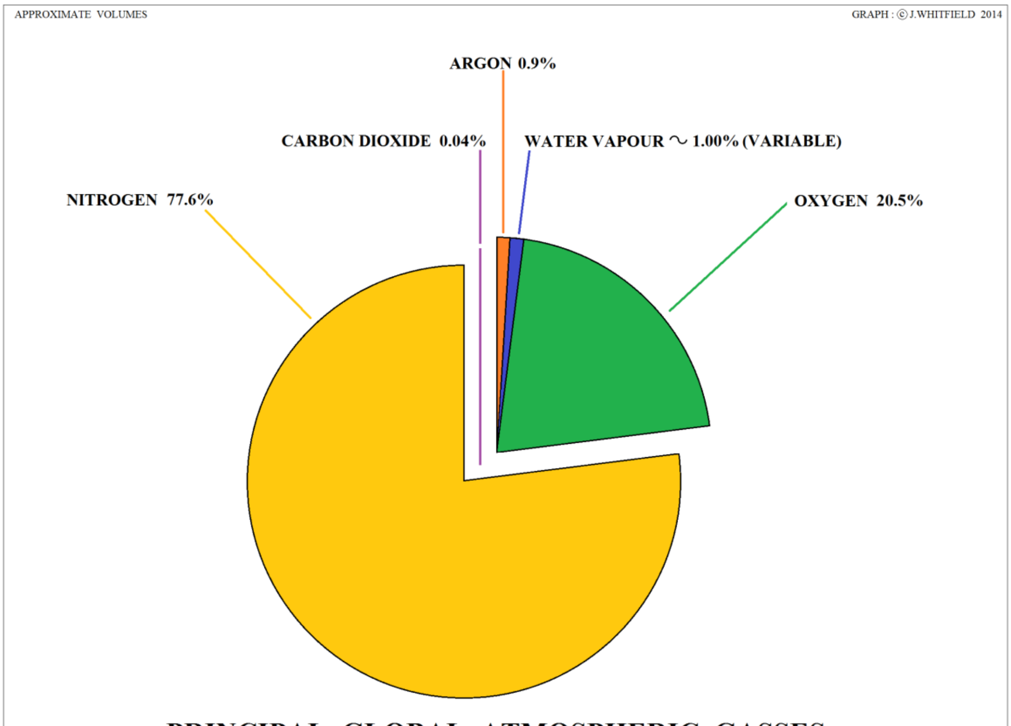


Fig.1 PRINCIPAL GLOBAL ATMOSPHERIC GASSES

The Last 400,000 Years of Global Temperature Variation

Fig.2 below, derived from the Vostok Antarctic ice core [1] data, displays the variation of global mean temperature and clearly reveals the cyclical alternation between warm ‘Interglacial’ conditions and the cold ‘Glacial’ conditions, when significant areas of the Earth beyond the Polar regions, were ice covered.

It is important to realise that the global mean temperature fluctuated between a maximum value of +3oC (Interglacial) and a minimum value of -8oC (Glacial).
Both values are relative to the 1961 to 1990 global average.
This highly significant variation of 11oC caused radical changes to climatic conditions over much of the Earth and rendered large areas extremely challenging for most fauna.

Work by M.Milankovitch [2] in the 1930s, demonstrated that the cause of these fluctuations could largely be attributed to cyclical changes in the Earth’s axial orientation and orbital eccentricity.

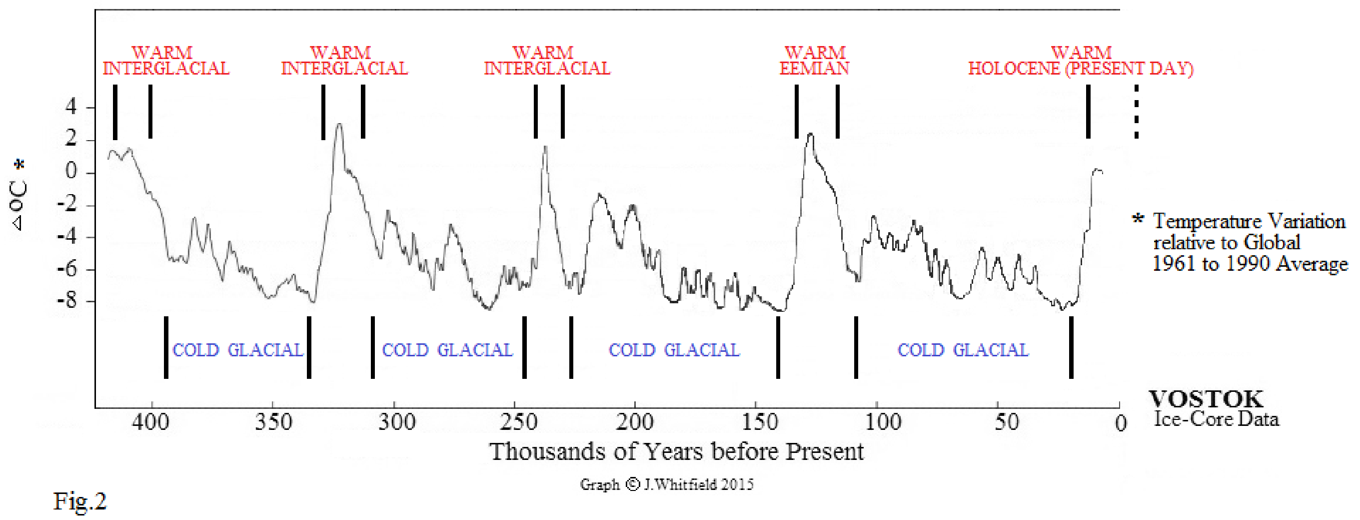


Fig.2

Fig.3 below, also derived from the Vostok antarctic ice core [1] data, displays the variation of global mean temperature over the last 400,000 years. In addition the variability of atmospheric carbon dioxide (CO_2) volume over the same period is displayed.

It is obvious that there is an interrelationship between these two variables and it is fundamental that this is correctly interpreted, clearly understood and that causation is established ie. Cause *before* Effect.

In order to render this generalised effect more obvious, the commencement of the Eemian warm Interglacial has been highlighted with a Red arrow and the termination of the Eemian with a Blue arrow.
Because the temporal resolution of the graph is low, it appears that the rise in global mean temperature and in atmospheric carbon dioxide is simultaneous. (Red arrow)

However, it is very obvious that the reduction in atmospheric carbon dioxide level is very much delayed relative to the global mean temperature reduction. (Blue arrow)
Consequentially, it is not possible that atmospheric carbon dioxide volume is controlling temperature but rather, it is the reverse effect which is taking place.

A reduction in global temperature occurs *In advance* of a delayed reduction in the atmospheric carbon dioxide volume.

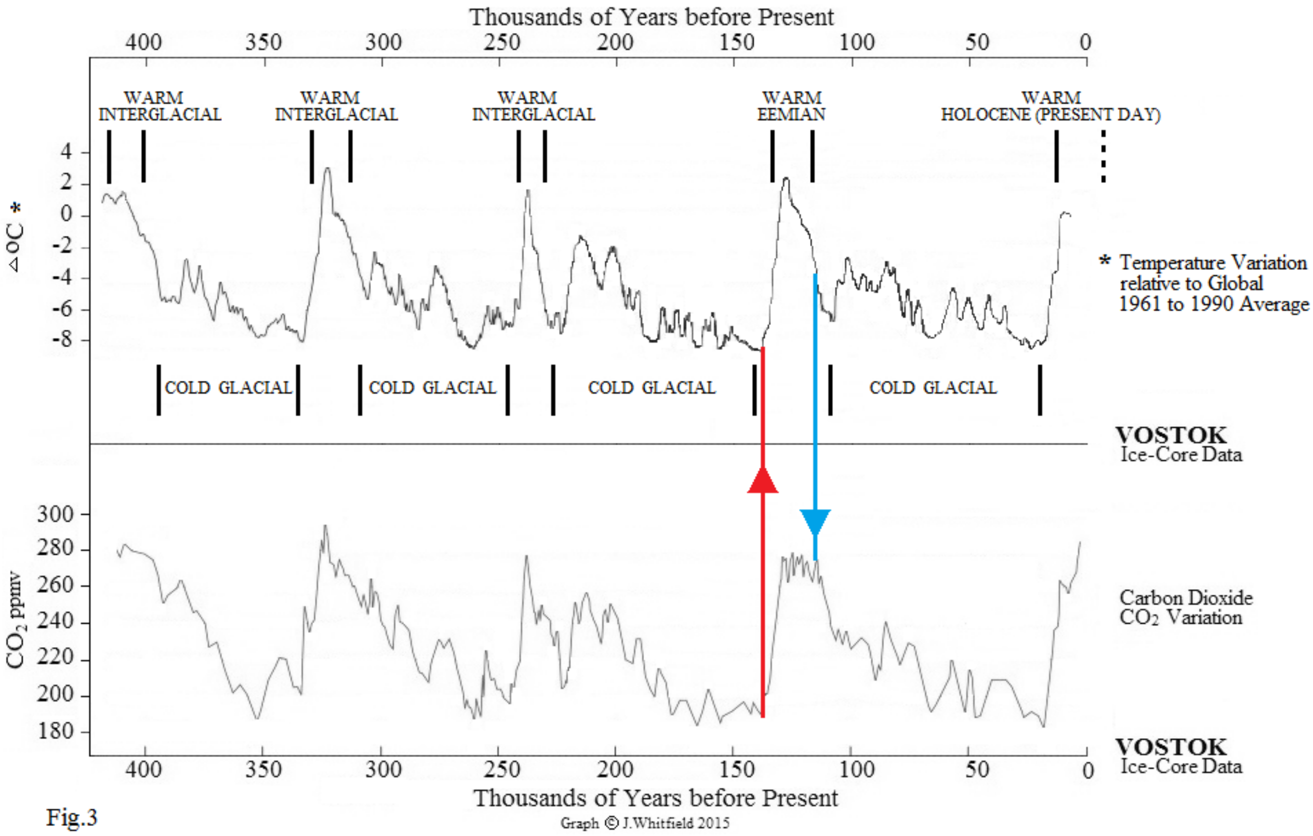


Fig.3

Fig.4 demonstrates why higher global temperatures lead to a higher level of atmospheric carbon dioxide. [6]

This is explained by the fact that the warming oceans release dissolved CO_2 back into the atmosphere and cooling oceans slowly re-absorb (dissolve) a proportion of this into solution.

ie. Cold water is able to dissolve more CO_2 than warm water and, as can be seen from Fig.4, this varies by a factor of 2.5, even over the limited temperature range of 0oC to + 30oC.

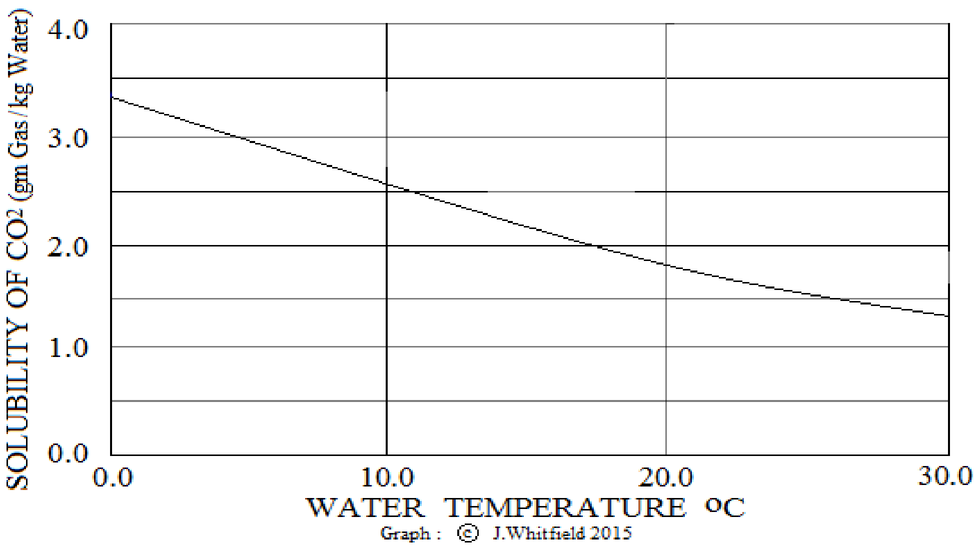


Fig.4

Fig.5 is derived from the EPICA antarctic ice core [4] data and is presented in order to clarify two important facts relative to the warm (Interglacial) and colder (Glacial) periods over the last 400,000 years.

On Fig.5, global temperature has been split into three (3) Energy States -

(i) **'Higher Energy'** - When temperatures are = or > the 1961 to 1990 global average

(ii) **'Intermediate Energy'** - When temperatures are < the 1961 to 1990 global average but > 5oC below the 1961 to 1990 global average.

(iii) **'Lower Energy'** - Temperatures are < 5oC below the 1961 to 1990 global average

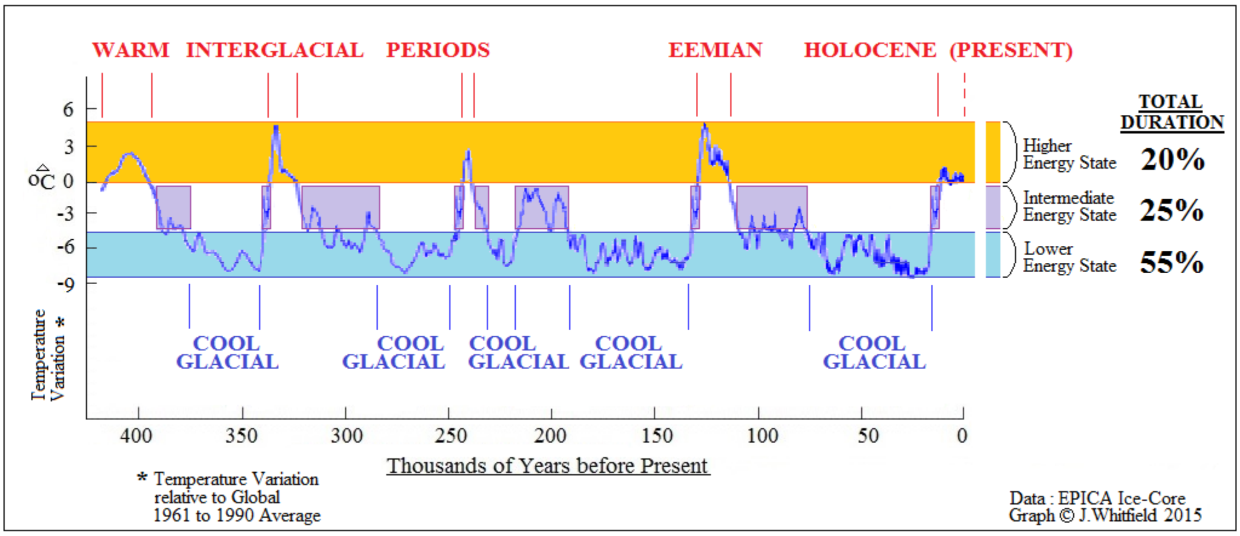


Fig.5

(a) Over the last 400,000 years, the five 'Higher Energy States' (warm Interglacials) have occupied only some 20% of this time interval.

(b) Over the same time scale, the 'Lower Energy States' (cool Glacials) have occurred for 55% of the period with the 'Intermediate Energy States' occupying the remaining 25%.

Fact #1 -

The warm 'Interglacials' have been very much the exception over the last 400,000 years.
The cool 'Glacials' have dominated the last 400,000 years.

Fact #2 -

In terms of Global mean temperature, the 'Holocene' Interglacial warm period (the present warm period) has been weak, with global temperatures approximately 2.0oC lower than during the four preceding 'Interglacials'.

The Last 11,000 Years of Global Temperature Variation

Fig.6 below, displays the variation of global temperature (relative to 1961-1990 average) derived from the GISP2 Greenland ice core [5] data and atmospheric carbon dioxide volume derived from the ‘Epica Dome C’ ice core [4] data.

The period displayed depicts the Holocene Interglacial. This is the global warm Interglacial period which extends to and includes the present day (2015).

In order to clearly demonstrate the salient features of the global temperature variation during this interval, the three warmest periods have been highlighted in red.
For comparison the 2015 global temperature has also been identified and it will be observed that this temperature is lower than during the warmest periods.

Additionally, the levels of atmospheric carbon dioxide which prevailed at these times are noted below.

(1) 7,800 years before the present	CO_2 = 260 ppmv
(2) 6,900 years before the present	CO_2 = 260 ppmv
(3) 3,200 years before the present	CO_2 = 275 ppmv
In 2015	CO_2 = 400 ppmv

As noted above, in 2015 the atmospheric carbon dioxide level had risen to 400 ppmv, much or all of this increase as a consequence of Anthropogenic influence.

Consequentially and on the basis of the above, there is no evidence to suggest that the global temperature was, or is being controlled in any significant manner by the prevalent volume of global atmospheric carbon dioxide.

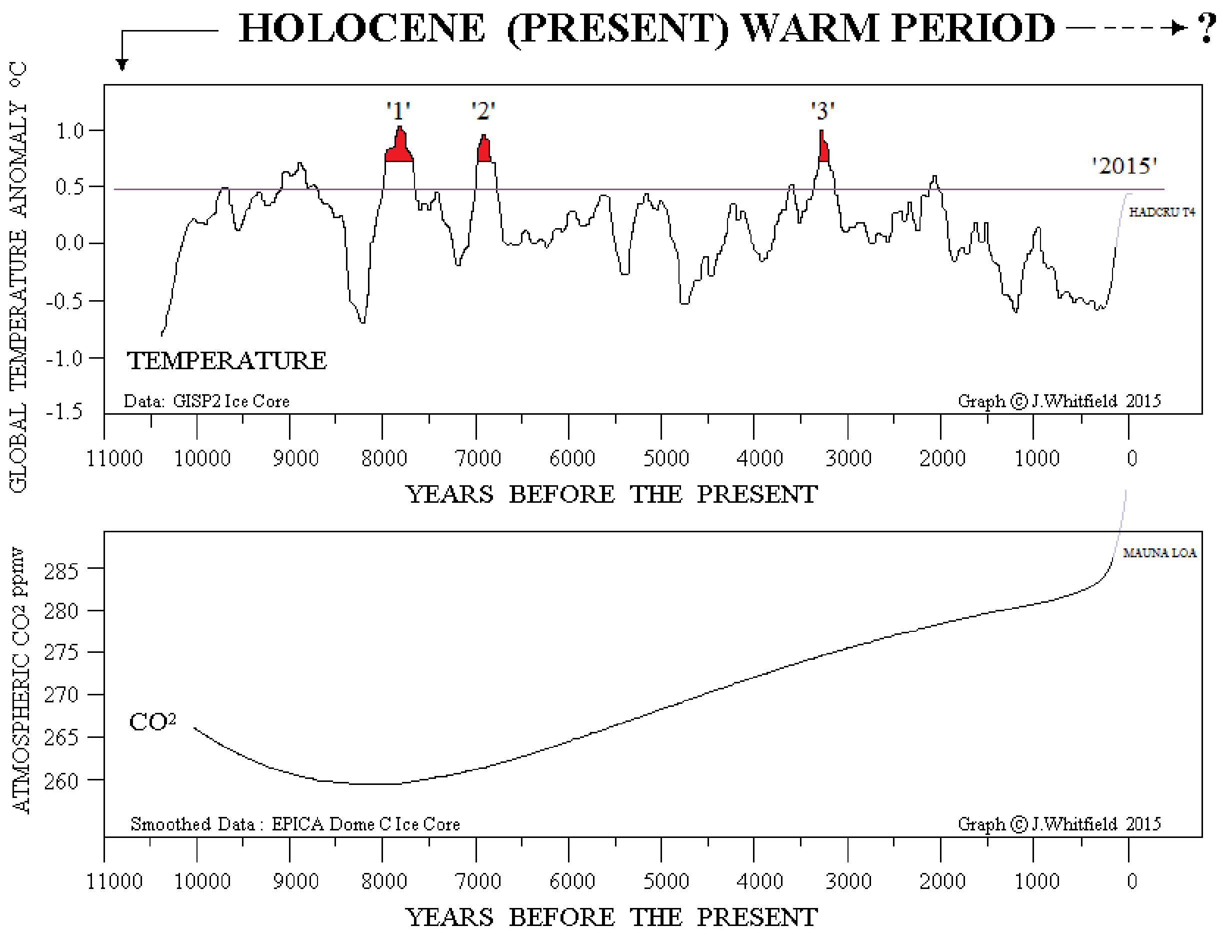


Fig.6

The Last 150 Years of Global Temperature Variation

Fig.7 below, displays the variation of global temperature (relative to 1961-1990 average) as derived from UK Hadley Climate Research Unit HADCRU T4 [7] data.

In addition, the Central England air temperature [8] and the global atmospheric carbon dioxide volume [9] records are displayed in juxtaposition to facilitate a direct comparison.

The Central England air temperature is, in reality, more variable than the global temperature (largely because of a relative reduction in oceanic thermal inertia **) This variability has been significantly damped on the graph by the application of strong low pass filtering in order to reduce the transient high frequency temperature fluctuations on this record.

Whilst the 'Central England' record is representative of the *local* and not the *global* environment, it will be observed that the 'Central England Air Temperature' and 'Global Temperature' records are largely in accord but, for the reason stated above ** the central England air temperatures generally 'react' earlier, in advance of global temperatures.

Consequently, it is possible that the 'Central England' record might be consulted in order to provide a rudimentary advance indication of possible, near future (c 5Years) Global Temperature variations.

Fig.7

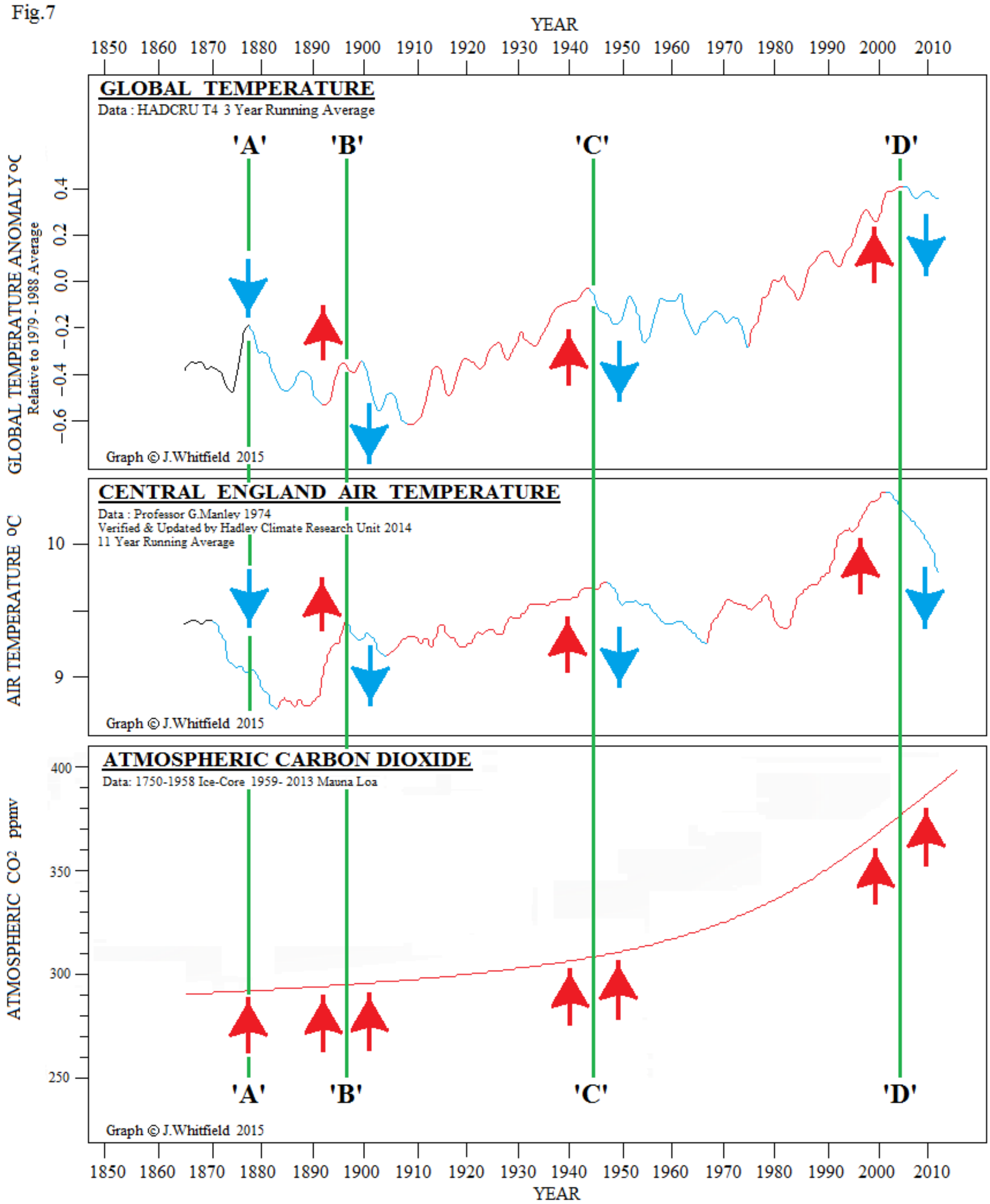


Fig.7 above, has been presented primarily in order to demonstrate four specific dates in the last 150 years when atmospheric carbon dioxide volume and temperature variations have become anti-correlated.

The Four dates, which have been identified by green vertical lines, are -

‘A’ 1877
‘B’ 1897
‘C’ 1943
‘D’ 2004

The lowest graph ‘Atmospheric Carbon Dioxide’ depicts a continuum of increasing CO_2 volume, both before *and* after each of these dates.
This increase is non-linear.

The middle graph displays the ‘Central England Air Temperature’ variation and the upper graph the ‘Global Temperature’ variation.

On or close to each of these dates, it will be observed that the temperature variations reverse from increasing, in phase with the increasing CO_2, to decreasing in an anti-correlation.

These effects persist for Decades and are not transients to be discounted.

Furthermore, they have occurred in the presence of a wide range of atmospheric CO_2 levels.

The repeated occurrence of these events renders it difficult to support the hypothesis that it is an increasing atmospheric carbon dioxide volume that is forcing the global temperature to increase.

Carbon Dioxide Volume v Rate & Magnitude of Temperature Change

Fig.8 below displays the atmospheric carbon dioxide volume [12] and the central England air temperature variations [8] between 1670 & 2010.

This readily demonstrates that the much higher volume and rapid escalation of atmospheric carbon dioxide in the second half of the 20th Century did ***Not*** result in either -

(a) A ***Larger*** temperature rise or (b) A ***Faster*** temperature rise

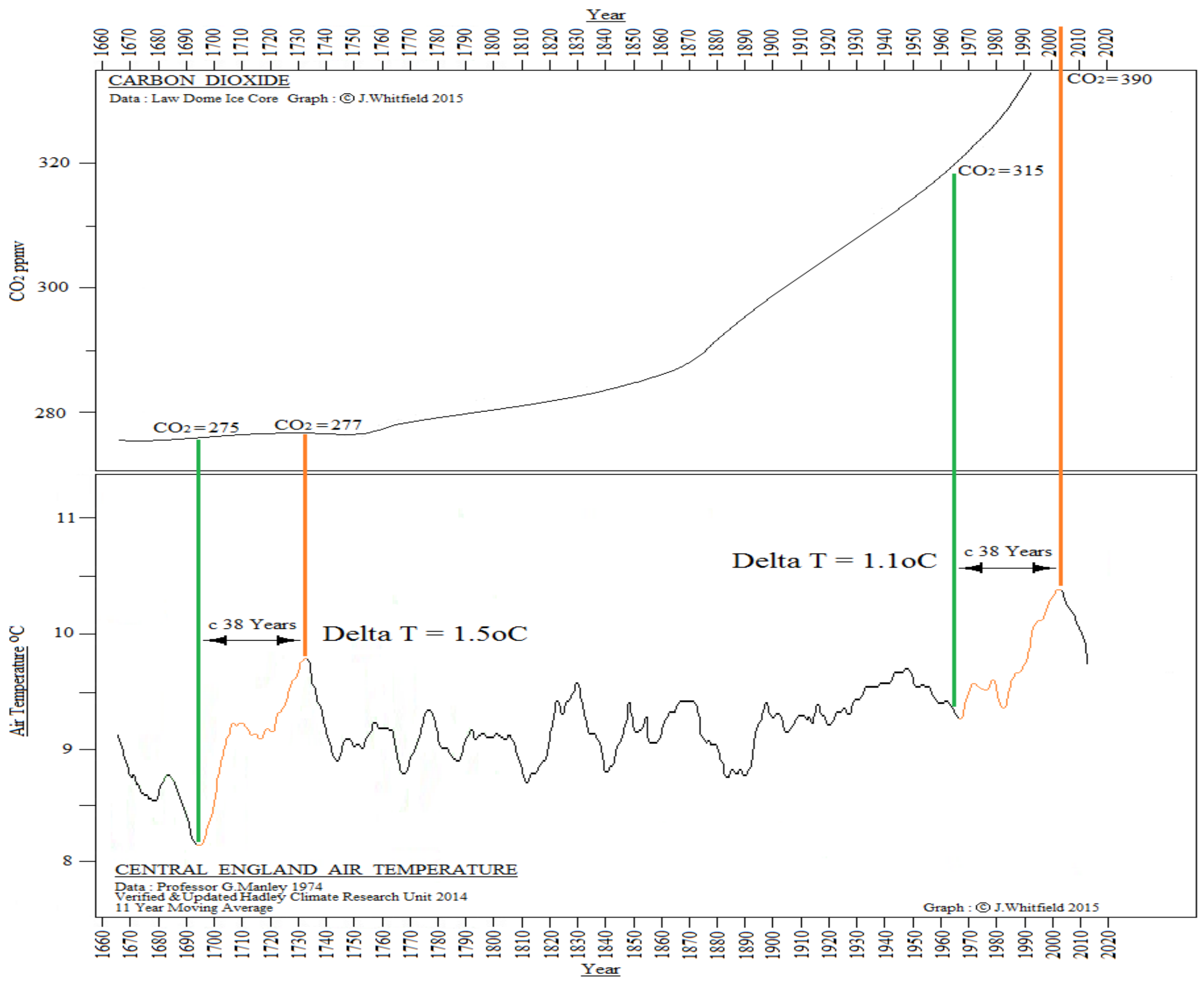
- than had occurred during times when the carbon dioxide volume was very much lower and almost without variation.

As is depicted in Fig.8, the following are the data.

First Time Period :	1694 to 1732
Duration of period :	38 Years
Carbon Dioxide Volume At Commencement :	275 ppmv
Carbon Dioxide Volume At Conclusion :	277 ppmv
Rise in Temperature :	**1.5oC**

Second Time Period :	1963 to 2001
Duration of period :	38 Years
Carbon Dioxide Volume At Commencement :	315 ppmv
Carbon Dioxide Volume At Conclusion :	390 ppmv
Rise in Temperature :	**1.1oC**

Fig. 8



These data strongly suggest that, within the range of volumes of atmospheric carbon dioxide prevalent over this period -

(a) The Higher and Increasing volumes of atmospheric carbon dioxide in the 20th Century did **NOT** lead to an exceptional or unprecedented ***Magnitude*** of temperature increase.

(b) The Rapidly Increasing volumes of atmospheric carbon dioxide in the 20th Century did **NOT** lead to an exceptional or unprecedented ***Rate*** of temperature increase.

Solar Influence on the Global Temperature 1965 - 2014

Fig.9 below displays the global temperature [10] and Solar Cycle (Sunspot Number) [11] variability over the period 1965 to 2014.

Fig.9

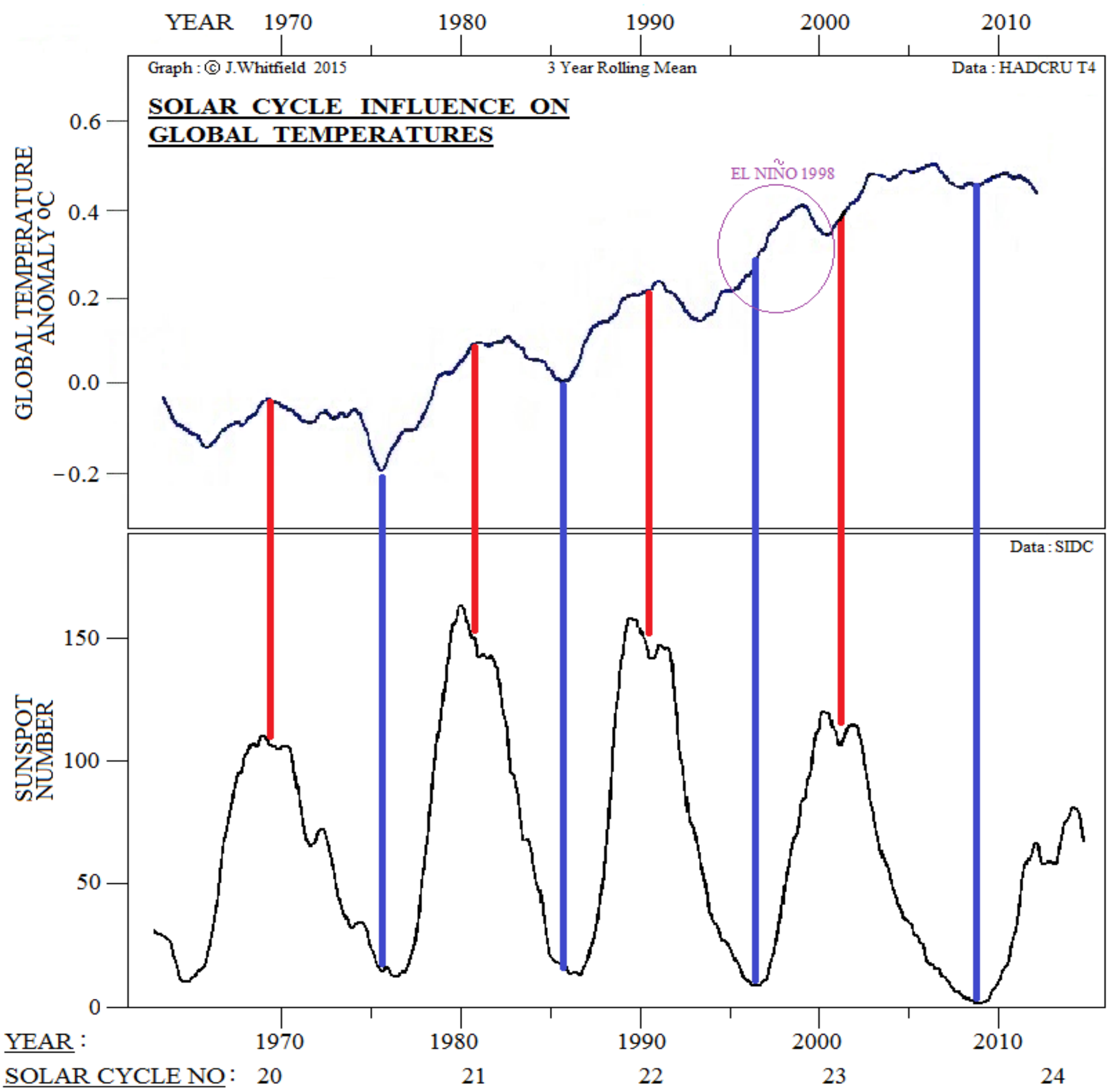


Fig.9 demonstrates an apparent correlation between Solar Cycle variability and global temperatures.

To render this effect obvious, red vertical lines highlight times of maximum Solar Cycle activity and blue lines the times of minimum Solar Cycle activity.
(Both as determined by 'Sunspot Number')

Whilst it is manifest that the global temperature is elevated at Solar Cycle maximum and depressed at Solar Cycle minimum and that this variation amounts to a consistent and significant cyclical temperature modulation of c 0.1oC, it is not a simple task to determine a precise causation mechanism.

<u>This effect is almost certainly convoluted, involving multiple intermediate steps</u> *

(i) Solar short wavelength variability interacts with & causes changes in the global upper atmosphere (See Fig.11) >
(ii) These changes in the upper atmosphere have 'knock-on' effects lower in the atmosphere >
(iii) (i) + (ii) modulate the level of solar irradiance which is incident on the Earth's surface.
(iv) See also "Introduction" (c) [3] on Page.2

The primary reason why, in the late 20th Century, Solar activity was largely discounted as a possible global temperature forcing agent, was because at that time, whilst it was a well established fact that the total Solar irradiance, as measured outside the Earth's atmosphere ***at a constant 1A.U.,*** was almost constant and unchanging (within 0.1%) it was not understood that the short wavelength portion of the Solar spectrum (UV, EUV & Soft X-ray) was highly variable (by up to 100% or more) over a Solar Cycle. (See Fig.10) [13]

Nor was the level of influence which this high energy Solar radiation exerts on the global upper atmosphere, fully appreciated. (See Fig.11) [14] [15]

An important detail revealed by Fig.9 is that there is one 'Out of Sequence' 'Increase Peak' in the global temperature record. This occurred c the year 1998.

This was caused by the c 1998 Pacific Ocean El Nino (ENSO) event, which was classified (by NOAA [16] & University of Colorado at Boulder) as 'Very Strong' and had a major impact on the global temperature, as recorded.

The presence of this peak on the global temperature record may be fortuitously helpful - potentially providing a datum against which to make a comparison and possibly perform an assessment of the Solar variability (Indirect) forcing effect *

It is important to observe that the period 1965 to 1990 with the apparent Solar cycle / global Temperature correlation was <u>not</u> typical and may have resulted because Solar activity during this period (Cycles #19, 21, 22 & 23) was at a historically elevated level, combined with a simultaneous increase in the level of oceanic thermal energy transfer to the atmosphere.

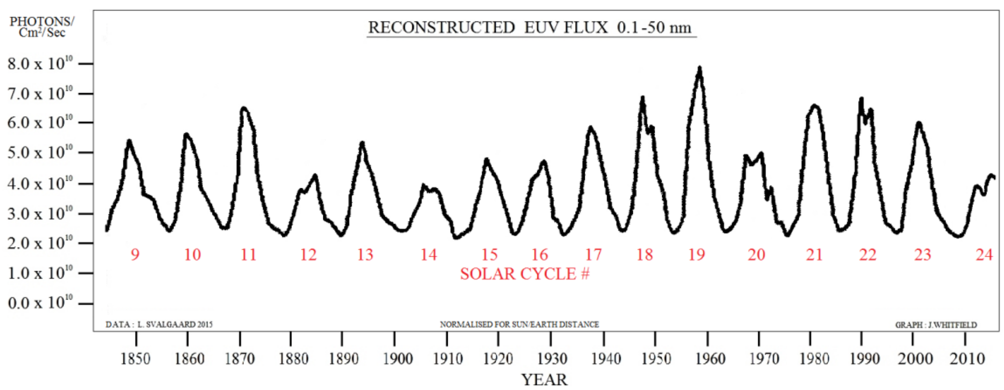
(See Fig.13 & Fig.14)

<u>The Large Variability of Solar Short Wavelength (EUV) Flux</u>

Fig.10 below displays the Solar EUV (0.1-50nm wavelength) flux over the period 1850 to 2014. [13].

The large variability of the EUV flux is readily apparent and amounts to a very significant maximum to minimum ratio of > 2:1

Fig.10



Solar Variability and the Global Upper Atmosphere

In order to demonstrate that Solar flux variability - and in view of the data displayed in Fig.10, this is most likely to be the variation in the Solar *short wavelength* flux - exerts a marked influence on the upper atmosphere, Fig.11 below displays Solar activity, as represented by Sunspot Number [14] plotted against the prevalence of Noctilucent / Polar Mesospheric clouds (NLC) [15] between the years 1964 and 2006.

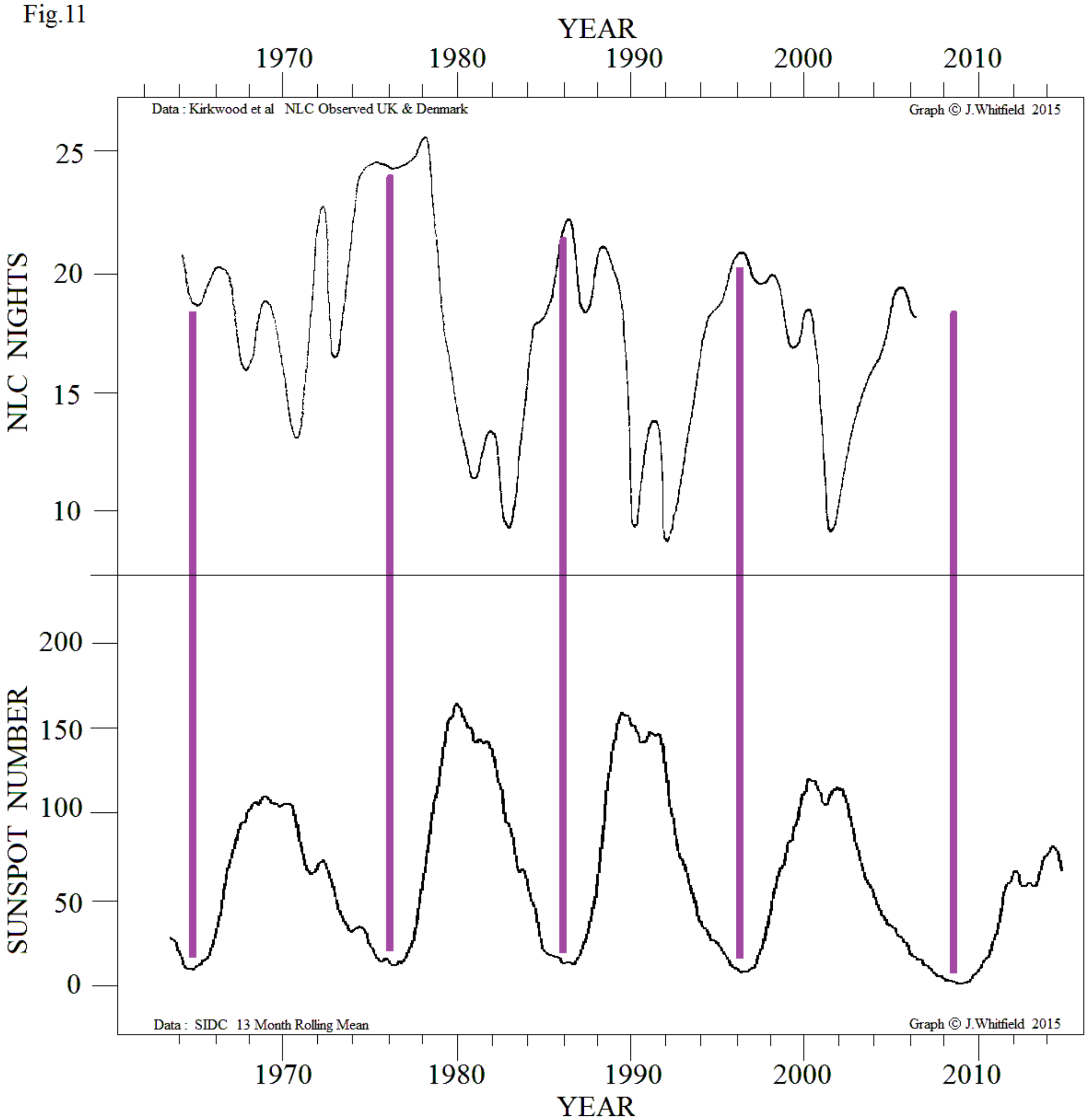
These clouds are very high level water ice clouds which form at an altitude of approximately 85km.

It is readily apparent from Fig.11 that there exists an anti-correlated relationship. At present the causation is not well understood and considerable current research is being undertaken to progress this important investigation.

However, the fact that the inter-relationship is robust and readily observable *is* sufficient to enable the conclusion to be securely drawn, that Solar variability *is* exerting a marked influence on the Earth's upper atmospheric levels.

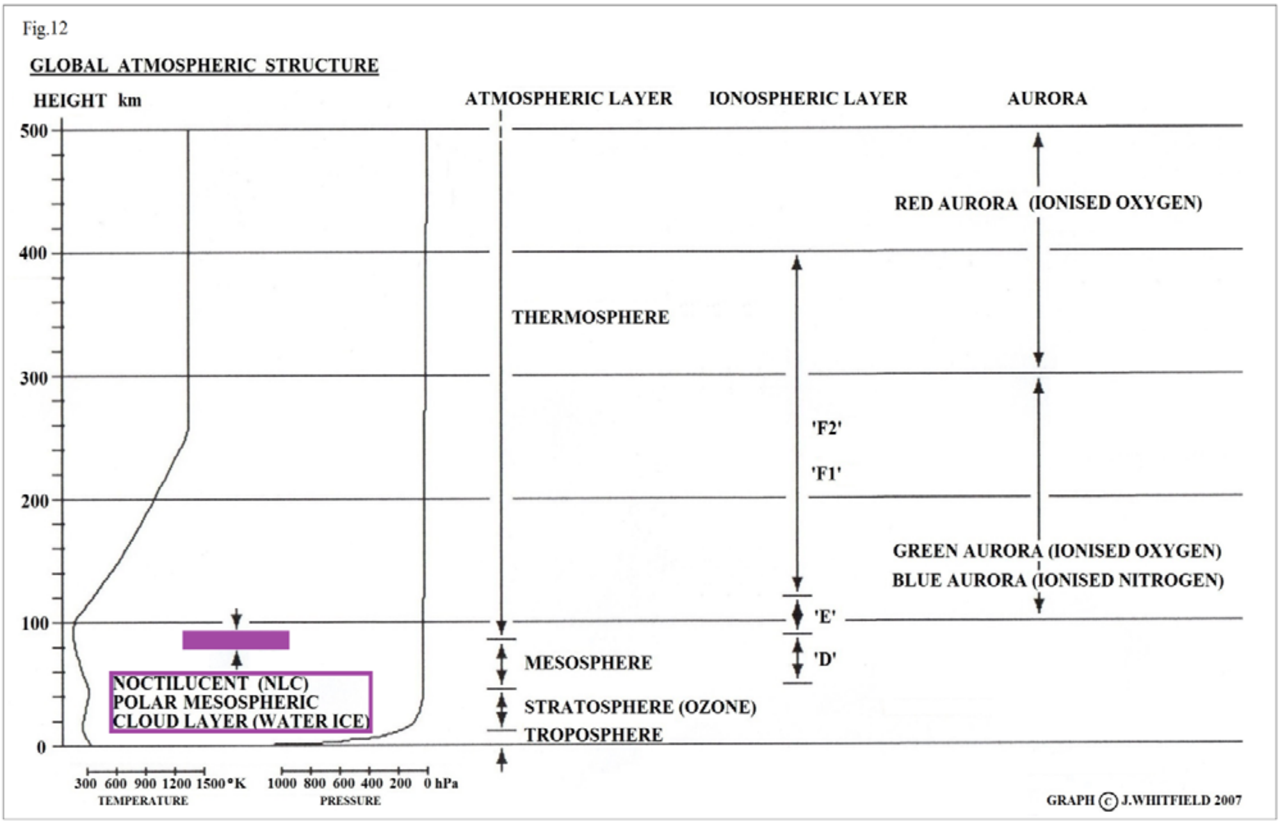
This effect is in addition to the fully recognised UV/Stratospheric Ozone production at c 25km and Solar plasma, resulting from Solar Coronal Mass Ejection and Coronal Hole events interacting with the global Ionosphere and Magnetosphere.

Fig.11


YEAR
1970
1980
1990
2000
2010
Data : Kirkwood et al NLC Observed UK & Denmark
Graph © J.Whitfield 2015
NLC NIGHTS
25
20
15
10
SUNSPOT NUMBER
200
150
100
50
0
Data : SIDC 13 Month Rolling Mean
Graph © J.Whitfield 2015
1970
1980
1990
2000
2010
YEAR

Global Atmospheric Structure

Fig.12 below clarifies the global atmospheric physical structure [6] and the location of NLC (Noctilucent / Polar Mesospheric) clouds and other entities, within this.



Differential Rates of Global Sea Surface & Air Temperature Increase

Fig.13 [10] below, demonstrates the ***Rates*** of global Sea Surface and Air temperature changes over the period 1850 to 2014, by means of displaying the ***Slope*** of these variations - (Delta Temperature v Delta Time) -

The steeper the slope the more rapid the change.

It may be noted that between c 1910 and 1945 both the global Air and Sea Surface temperatures increased at approximately the same Rate.
ie. SLOPE 'A' = SLOPE 'C'

However, an examination of the period c 1975 to 2010 reveals two important and contrary effects -

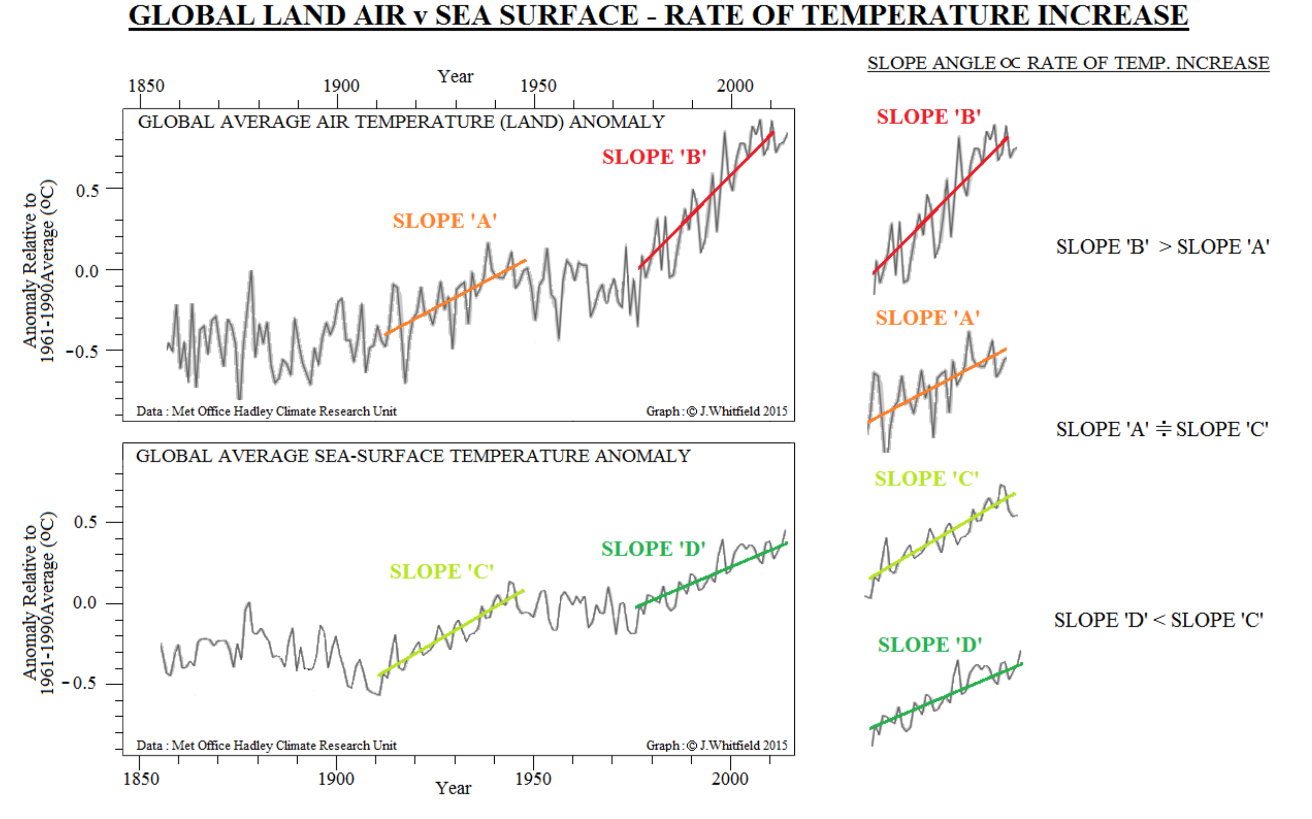
(i) The global Air temperature increased at a ***Greater*** rate than 1910 – 1945.
ie. SLOPE 'B' > SLOPE 'A'

(ii) The global Sea Surface temperature increased at a ***Lower*** rate than 1910 – 1945
ie. SLOPE 'D' < SLOPE 'C'

Note: The important fact is that –

Slope 'B' is GREATER than Slope 'A'
But Slope 'D' is LESS than Slope 'C'

Fig.13



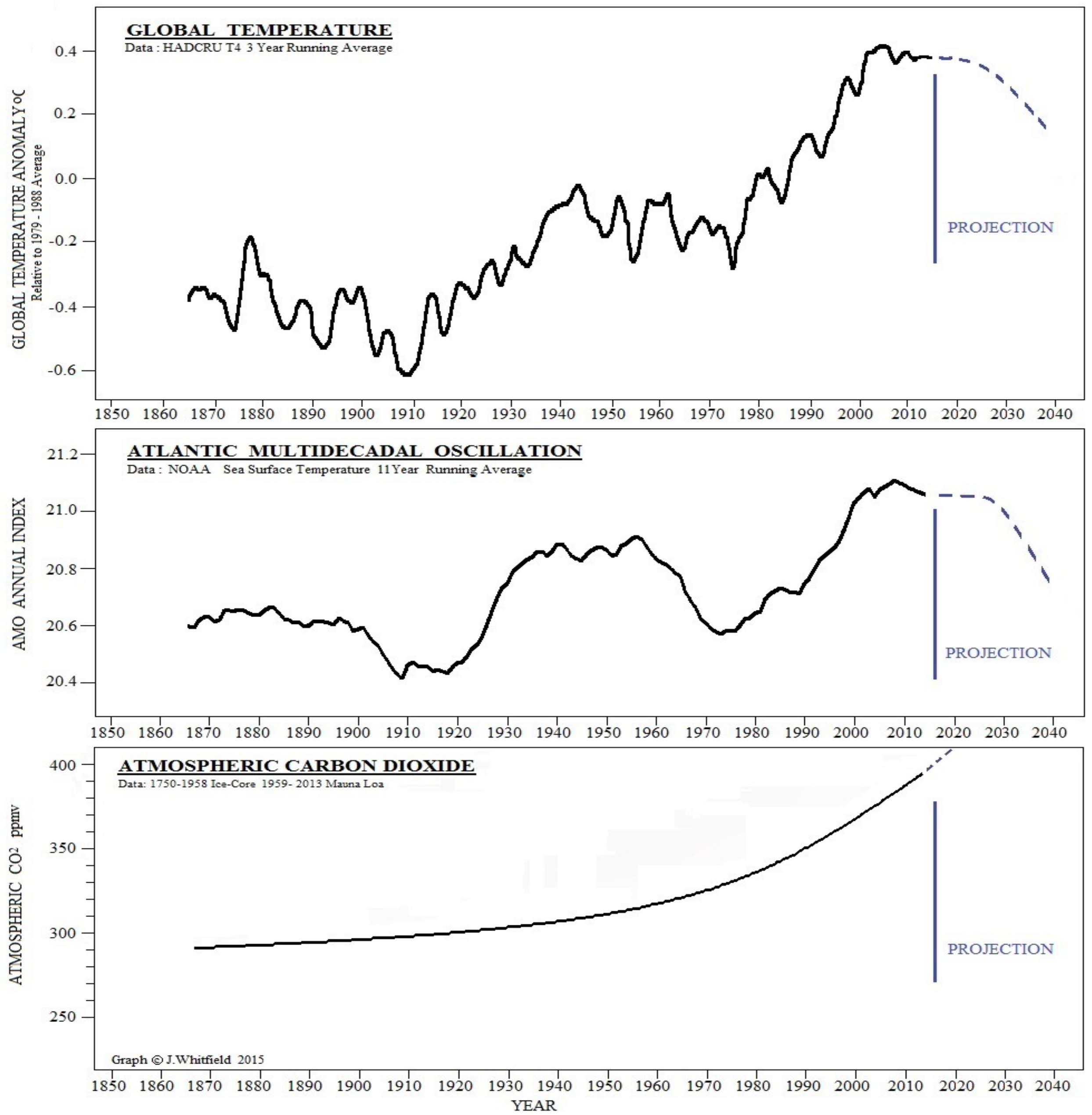
Whilst a comprehensive and accurate analysis of (i) & (ii) will undoubtedly lead to enhanced understanding of global temperature variability, a possible tentative explanation may be derived from the fact that the period 1970 to 2010 - with the Solar Cycle modulation of the global temperature - was not typical, and may have resulted because Solar Cycles #18, #19, #21 & #22 (1940 to 1990) were amongst the most active in more than 160 years (eg. See Fig.10).

The cumulative effect of these may have resulted in an enhanced oceanic reservoir of stored thermal energy, subsequently available as a source for atmospheric heating between 1980 and 2005 which elevated the global Air Temperatures but slowed the rate of global Sea Surface Temperature increase.

One example of such an effect is displayed on Fig 14 [16] below.

It is most important to note that the Atlantic Multidecadal Oscillation is a robust phenomenon already well established and manifest long before the 20th Century - when Carbon Dioxide Volumes started to rise more rapidly.

Fig.14



Conclusions

(1) Over the last 400,000 years and inclusive of the year 2015, there has been no substantive or convincing evidence that changes in the global atmospheric carbon dioxide volume have exerted any controlling influence on global temperatures.

(2) Strong variability in solar short wavelength energy has been identified & recognised (Fig.10) Furthermore, the evidence presented in this paper clearly demonstrates significant solar interactions with the global environment (Figs.9 & 11) the details of which must now be fully investigated and incorporated within any new predictive climate models if these are to prove of any value to future policy decision makers.

(3) There are very significant indications that oceanic effects such as the Pacific El Nino and the Atlantic Mulidecadal Oscillation strongly influence the mean global temperature (Figs.9,14)

(4) If the interpretations which are presented in this paper are substantially correct.

If the quasi-cyclical Atlantic Multidecadal Oscillation enters the anticipated declining temperature phase (Fig 14).

If the next Solar Cycle (#25) proves to be as weak as the current, decaying, Solar Cycle #24 (Figs.9,10).

It is proposed that the Mean Global Temperature, far from increasing over the next 30 years as predicted by the IPCC[17], will decline by approximately 0.5oC over this period with the veracity of this trend verifiable through the 2020s.

References & Acknowledgements

[1] VOSTOK Antarctic Ice Cores - Temperature & Carbon Dioxide Reconstruction
[2] M.Milankovich (Papers,1930s)
[3] CLOUD Experiment Cosmics Leaving Outdoor Droplets
[3] CERN European Organisation for Nuclear Research
[4] EPICA Antarctic Ice Core (European Project Ice Core Antarctica)
[5] GISP2 Danish-Swiss-USA Greenland Ice Core (Greenland Ice Sheet Project - Two)
[6] Standard Subject Textbooks
[7] HADCRU T4 Hadley Climate Research Unit, University of East Anglia
[8] Professor Manley 1974 & Hadley Climate Research Unit, University of East Anglia
[9] Ice Core & Mauna Loa Observatory Data
[10] HADCRU T4 Hadley Climate Research Unit, University of East Anglia
[11] SIDC (Solar Influences Data Centre, Belgium)
[12] Morgan et al 1997 Law Dome Ice Core (East Antarctica)
[13] Leif Svalgaard Stanford University (EUV Reconstruction)
[14] SIDC (Solar Influences Data Centre, Belgium)
[15] Kirkwood et al NLC (Polar Mesospheric Cloud) Observations
[16] NOAA National Oceanic & Atmospheric Administration
[17] IPCC Intergovernmental Panel on Climate Change