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Assessing Climate Change

Temperatures, Solar Radiation and Heat Balance

Third Edition

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Acronyms and abbreviations

ABL	Atmospheric Boundary Layer
ACRIM	Active Cavity Radiometer Irradiance Monitor
AE	Auroral Electrojet (index)
AIT	*An Inconvenient Truth*
AOGCM	Atmosphere–Ocean General Circulation Model
BC	Black Carbon
BP	Before the Present
C&L	Chylek and Lohmann (2008)
CCN	Cloud Condensation Nuclei
CCPI	Climate Change Performance Index
CET	Central England Temperature
CFI	Comprehensive Flare Index
CFR	Climate Field Reconstruction
CME	Coronal Mass Ejection
CNES	Centre National d'Etudes Spatiales
CO2e	Equivalent CO_2 concentration to produce the equivalent effect of all greenhouse gases
CPS	Composite Plus Scaling
CQSM	Constant Quiet Sun Model
DIC	Dissolved Inorganic Carbon
DTR	Diurnal Temperature Range
EA	East Antarctica
EAIS	East Antarctica Ice Sheet
ECS	Esper, Cook, and Schweingruber (2002)
ELA	Equilibrium-Line Altitude
ENSO	El Nino/Southern Oscillation
EOS	Earth Observing System
EPA	Environmental Protection Agency
ERB	Earth Radiation Budget
ERBS/ERBE	Earth Radiation Budget Satellite/Earth Radiation Budget Experiment

EOF	Empirical Orthogonal Function
EPICA	European Project for Ice Coring in Antarctica
GCM	Global Climate Model
GDP	Gross Domestic Product
GHG	GreenHouse Gas
GICC	Glacial–Interglacial CO_2 Cycles
GIS	Greenland Ice Sheet
GISS	Goddard Institute for Space Studies (NASA)
GMST	Global Mean Surface Temperature
GNP	Gross Domestic Product
GRACE	Gravity Recovery And Climate Experiment
GSL	Global Sea Level
GSLR	Global Sea Level Rise
GSN	Group Sunspot Number
GST	Ground Surface Temperature
H&A	Hargreaves and Annan (2009)
HadCM3	Hadley Climate Model 3
HFC	HydroFluoroCarbon
IJC	International Journal of Climatology
IMF	Interplanetary Magnetic Field
IPCC	Inter-government Panel on Climate Change
IR	InfraRed
JGR	Journal of Geophysical Research
LFO	Low Frequency Oscillation
LGM	Last Glacial Maximum
LIA	*Little Ice Age*
LULC	Land Use/Land Clearing
M&M	McIntyre and McKitrick
M&W	McShane and Wyner (2010)
MBH	Mann, Bradley, and Hughes
MDI	Michelson Doppler Imager
MIROC3.2	Model for Interdisciplinary Research on Climate
MM	Maunder Minimum
MOC	Meridional Overturning Circulation (Atlantic)
MPH	Mobile Polar High
MSU	Microwave Sounding Unit
MWP	Medieval Warm Period
NADW	North Atlantic Deep Water
NAO	North Atlantic Oscillation
NCEP–NCAR	National Centers for Environmental Protection/National Center for Atmospheric Research
NDVI	Normalized Difference Vegetation Index
NH	Northern Hemisphere
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation

OHCA	Ocean Heat Content Anomaly
OLR	Outgoing Long-wave Radiation
OPEC	Organization of Petroleum Exporting Countries
PC	Principal Component; Politically Correct
PCA	Principal Component Analysis
PDI	Power Dissipation Index
PFC	PerFluorohydroCarbon
ppmv	parts per million by volume
RE	Radiative Effectiveness
RSL	Relative Sea Level
SAT	Surface Air Temperature
SD	Standard Deviation
SEAS	NOAA's XBT program
SETI	Search for Extraterrestrial Intelligence
SH	Southern Hemisphere
SMAX	Sunspot MAXimum
SMIN	Sunspot MINimum
SMM	Solar Maximum Mission
SN	Sunspot Number
SO	Southern Oscillation
SOHO	SOlar Heliospheric Observer
SOI	Southern Oscillation Index
SORCE	SOlar Radiation and Climate Experiment
SST	Sea-Surface Temperature
TAV	Tropical Atlantic Variability
TIM	Total Irradiance Monitor
TMN	Temperature Measurement Network
TOA	Top Of Atmosphere
TOPEX	Poseidon Ocean Topography Experiment
TSI	Total Solar Irradiance
UAH LT	University of Alabama in Huntsville Lower Troposphere
UARS	Upper Atmosphere Research Satellite
UHI	Urban Heat Island
UNFCCC	U.N. Framework Convention on Climate Change
U/P	Umbra/Penumbra
USHCN	U.S. Historical Climate Network
UT	Upper Troposphere
VEI	Volcano Explosivity Index
VIRGO	Variability of solar IRradiance and Gravity Oscillations
WA	West Antarctica
WAIS	West Antarctica Ice Sheet
XBT	eXpendable BathyThermographs
YBP	years before the present

Preface

THE GLOBAL-WARMING DEBATE

The Earth has gone through incredibly wide climate changes over hundreds of millions of years. A number of factors contributed to this, including a gradually strengthening Sun, drift of continents, incidence of volcanism, etc. But it is widely believed that the Earth's thermostat was mainly controlled by prevailing CO_2 concentrations in the tug of war between CO_2 emissions and CO_2 burial. Thus, the "accepted paradigm" is that, over geological time, variability of CO_2 was the main controller of the Earth's climate (Foster *et al*., 2009). For example, 500 million years ago, the CO_2 concentration was much higher (possibly 20 times) than it is today and the Earth was very balmy. There is little doubt that, if we again increased CO_2 to 20 times the pre-industrial value, the Earth would become considerably more tropical. The question before us now is how the Earth's climate will respond to a much smaller increase in CO_2: a mere doubling from 280 ppm to 560 ppm? There is little doubt that some temperature rise will result from this. Alarmists believe that the temperature rise will be sufficiently great to cause great harm to humanity. Skeptics think we can take in stride the relatively modest temperature rise that ensues. In between, there are so-called "lukewarmers" who are unsure. Perhaps the biggest worry is that, if the alarmists are right, we would require immediate draconian reductions in carbon emissions in which we would ramp down use of fossil fuels by 80% (or more) in a few decades. With world population growing and future energy demand projected sharply upward, how would we provide the world with needed energy while eliminating fossil fuels? There does not seem to be an answer.

Global-warming alarmists (aka "warmists") believe that human production of greenhouse gases, particularly carbon dioxide, with its concomitant water vapor feedback mechanism, has begun to add to the natural greenhouse effect, thereby raising global temperatures inordinately during the 20th century, with predictions of further increases in the 21st century that they claim would be catastrophic.

James E. Hansen, a leading spokesman for the alarmists, said that "Ignoring the

climate problem at this time, for even another decade, would serve to lock in future catastrophic climatic change and impacts that will unfold during the remainder of this century and beyond''. The Earth ''is close to dangerous climate change, to tipping points of the system with the potential for irreversible deleterious effects. ... The planet is on the verge of dramatic climate change''. We ''are forced to find a way to limit atmospheric CO_2 more stringently than has generally been assumed. ... We cannot shrink from our moral responsibilities ... to preserve the planet for future generations''.

Al Gore's film *An Inconvenient Truth* has carried the message to many millions of people. This has spawned a growing world movement that is seeking controls on greenhouse gas emissions. Because such controls would have serious economic consequences and, furthermore, attempts to apply controls have been unbalanced relative to developed countries vs. developing countries, there has been strong resistance to such moves by skeptics.

The majority of research climatologists at universities are alarmists to some degree. In today's political environment, it is necessary to be an alarmist (or at least to appear to be one) in order to obtain research funding. Some university and government agency alarmists have banded together in an informal association to (1) exert pressure on journal editors to prevent contrary views from being published, (2) to very quickly publish rebuttals to those few contrarian papers that slip through their net, and (3) immediately produce nasty, vicious attacks on contrarian papers on their blogs. These alarmists pompously refer to their interpretations as ''*climate science*'', implying that any contrary views are not *climate science*. Yet, most of the work published by these university climatologists is based on sparse, noisy, short-term data and their results typically are based on drawing a dollar's worth of conclusions from a penny's worth of data.

Skeptics span a wide range of viewpoints ranging from uncertainty regarding how much of recent global warming was primarily induced by rising CO_2 levels, to outright denial that there is any connection between rising CO_2 and global warming. Skeptics maintain blogs and circulate reports, but have only occasionally penetrated the peer-reviewed scientific literature that is dominated by alarmist publications. Alarmists provide the impression of scientific integrity through peer-reviewed publications, while skeptics often (but certainly not always) lack the credentials of alarmists. The alarmist position is often ''sold'' on the basis of the number and importance of climatologists and institutions that subscribe to this persuasion. But the important thing is data, not credentials and number of adherents.

Both sides have argued like trial lawyers with a case to be made, by craftily selecting (''cherry picking'') bits and pieces of data to support their preconceived viewpoints. Fact, supposition, speculation, and pseudo-science have been mixed together in a brew that is confusing and difficult to resolve. I recently checked *amazon.com* books to see what's available in the way of climate books. There seemed to be about 100 new books in the last two years. All of those written by establishment climatologists present the alarmist view. All of those written by anti-establishment writers present the skeptical view. Both sides are absolutely sure they are right. Neither side has any doubt that I can discern. One thing the world does not

need is another high-level book arguing with assurance on one side of the question or the other, with little actual data content, manipulated to achieve an apparent conclusion based on specious arguments and cunningly selected references.

In this book, I have investigated a large body of technical data relevant to global climate change, approaching each element with necessary (but hopefully neutral) scientific skepticism. As Einstein said: "The goal is to be as simple as possible, but not simpler." Thus, by necessity, this book is quite technical, but hopefully still quite readable.

The essential questions are:

(1) How well has the world monitored near-surface temperatures of the 30% land and 70% ocean areas on the Earth during the past 120 years or more, and how well can we characterize the changes in climate over that time span?
(2) What are the utility and significance of a single global average temperature?
(3) How has the Earth's climate varied over the past Ice Ages, the Holocene, the last millennium, and the past century, and what can we infer about "natural" variability of the climate prior to industrialization by humankind?
(4) How reliable are proxies for historical temperatures? What do we really know about past temperature variations? Is the *hockey stick* version of millennium temperatures credible, in which temperatures were relatively flat for 2,000 years prior to a sudden rise in the 20th century?
(5) How does the current global-warming trend compare with past fluctuations in the Earth's climate, and what is the likelihood that the warming trend we are experiencing now is primarily just another in a series of natural climate fluctuations as opposed to a direct result of human production of greenhouse gases?
(6) How credible are the global climate models that claim that greenhouse gases produced most of the temperature rise of the 20th century, and forecast much greater impacts in the 21st century?
(7) How good were the "good old days"? Was the climate of the *Little Ice Age* ideal, should we abhor warming from that baseline, and do we want to return to the climate of the early 19th century?
(8) How will limits on fossil energy supplies constrain future CO_2 production and climate change, even if the climate models are accurate?
(9) How can the world provide itself with energy needed for a burgeoning population that will demand more and more energy in the future, considering the finite limits on fossil fuel resources?

According to Beckman and Mahoney (1998):

> "The vested interests on both sides of the argument between the 'greenhouse' party and the 'solar warming' party are obvious. Scientifically, the meteorologists, climatologists, and atmospheric physicists, who were responsible for 'discovering' the human contribution to the terrestrial greenhouse effect, have been the most consistent champions of its importance, while the solar physics community, and especially those interested in solar–terrestrial relations, have

> increasingly stressed the possible importance of the long-term variations of the solar constant as the chief cause of climate change. Both communities tend to take the change for granted, and to neglect any purely statistical or chaotic effects which could lead to excursions of the Earth's surface temperature during periods of a couple of decades, without requiring a secular change either in the solar constant or in atmospheric transparency. In addition, the debate is conditioned by more powerful vested interest groups. The oil industry in all its guises would obviously like to believe, and would like the public to believe, that greenhouse warming has been greatly exaggerated, and exploits any genuine scientific differences to undermine the credibility of the climatologists.''

Unfortunately, many global-warming alarmists have weakened their cases by building them around models and analyses of dubious veracity and, in the case of the infamous *hockey stick* temperature profile, mathematically incorrect manipulations of past temperature data from proxies. From this, they have concluded improperly that the late 20th century is far warmer than any time in the distant past, and made other elaborate claims regarding recent warming trends and dire predictions for the near future that are unsupportable by the evidence. Furthermore, the network for monitoring the Earth's temperatures is inadequate to precisely characterize the trends in climate for the past 100 years, and the utility of a single global average temperature in defining the state of the climate is limited.

Projections for the 21st century are typically far out of line with realistic expectations. The credibility attributed to global climate models belies their inherent fragility. This has provided the skeptics with plenty of ammunition with which to debunk these exaggerated claims. On the other hand, most of the skeptics made up their minds *a priori* that global warming in the 21st century due to CO_2 emissions is not a potential problem, and their arguments are often vague and hardly convincing.

A major problem in discussing climate change is that we lack a time period that we can objectively define as a base for comparison. As Anon. (N) emphasized, temperatures near the end of the 20th century were generally higher than those of the preceding four centuries. Taken at face value, this seems to imply that the preceding temperatures were normal, while the relatively higher temperatures at the end of the 20th century are comparatively abnormal. However, the preceding four centuries extended across the *Little Ice Age*, and therefore one might state the proposition differently: temperatures during the preceding four centuries were colder than they were at the end of the 20th century. Stated this way, the abnormality is attributed to the *Little Ice Age*. Perhaps the most accurate statement is that there is no normal climate, and the climate of the Earth has always varied widely, and continues to do so to this day. As Balling, Vose, and Weber (1998) said:

> ''... it is entirely possible that the warming in the record of the past century has been caused by an unusually cool period 100 years ago as opposed to an unusually warm period in recent decades.''

By carefully sifting through the evidence, we find that there are no ironclad answers to major questions on global climate change. Our temperature data for the

past are fragmentary and sparse, both spatially and temporally. Urban heat islands and land clearing have affected measured temperatures. Past variations in solar irradiance can only be estimated with speculations. Proxies used to estimate the temperature history of the Earth over past millennia are noisy and inconsistent, leaving us with uncertain indications of the past. Climate models do not deal realistically with water vapor, aerosols, and clouds, resulting in wide variations from model to model.

The thesis of this book is that our data and models are presently inadequate to reach credible conclusions regarding how much global warming is likely to take place in the 21st century. We have emerged from the *Little Ice Age* in the latter half of the 19th century and the Earth has warmed, but the connection to greenhouse gases is uncertain. Estimates for the future depend on climate models that cannot yet properly account for changes in humidity, aerosols, and cloud cover as greenhouse gas concentrations increase.

Scientists (and the public) abhor a vacuum. They can't seem to shrug their shoulders and admit that we just don't know the answers to important questions. They introduce explanations, however speculative. Thus, we are besieged with models purporting to describe the past millennium's history of the Earth's climate, and making firm predictions about the future, none of which stands up to detailed review. The *alarmist cabal* that controls the paleo-climatological literature has a political agenda to promote public concern about greenhouse gases and, in many cases they have lost objectivity. We have ended up with two opposing camps: the alarmists and the skeptics, each 100% convinced they are right, and each firmly for or against a global-warming catastrophe, each seemingly more concerned with furthering their agendas than with discovering truth. What seems to be missing in all this is a little bit of humility. Speculation is rife. Data are lacking. Use of complex models obscures the fact that the data are limited and, in many cases, untrustworthy. Meanwhile, there is much to be gained on a personal basis from the international preoccupation with climate change. Grants and contracts are awarded, often to the most strident voices supporting the orthodoxy. Blogs have evolved like religious factions, swearing allegiance to their orthodoxies, and twisting the facts to fit their preconceived notions. Any moron can have his say—and does.

The world will face a crisis sometime around or after 2030. But that crisis will not be calamitous global warming. While global warming might become a significant problem late in the 21st century, the greater, and nearer-term crisis will be that, with oil, gas, and coal production going at full bore, the world will not able to supply the energy that is demanded by a growing world population intent on using energy at higher rates. This could lead to significantly higher energy costs, resulting in worldwide economic recession or depression. However, on the positive side, it will provide great incentive to develop renewable energy that will then become more competitive. Whether renewable energy can be developed and expanded rapidly enough to stave off economic collapse remains to be seen. The same people who are of the climate alarmist persuasion also seem to be unduly optimistic about the prospects for renewable energy to supplant fossil fuels.

SUMMARY

There is a good deal more that we don't understand about climate variability than we do understand. As Wunsch (1999) emphasized:

> "Sometimes there is no alternative to uncertainty except to await the arrival of more and better data."

The warming of the 20th century represents emergence from the *Little Ice Age*. The quantitative role of greenhouse gases in this warming remains uncertain. We need better data and better models; there are too many speculations that have hardened into beliefs.

Scientists have studied past climates using proxies. Proxies are residual data from processes that occurred in the past, when the processes were dependent on local temperatures at the times they took place, and the evidence is preserved in the present in an accessible form.

Chapter 1 deals with long-term climate change.

Chapter 2 examines what we have learned from proxies about major climate changes that have occurred over the past two millennia. A detailed study of proxy evidence for climate fluctuations in the last millennium or two has led to a controversy. Some climatologists claim that temperature variability in the last millennium or two was small prior to the 20th century, leading to a *hockey stick* graph of temperature vs. time with an unprecedented sudden rise in the 20th century. Alternatively, there is considerable evidence that temperatures varied significantly during the past few millennia, with a warm period about 1,200 years ago and a cold period from about 1600 to about 1850—the so-called *Little Ice Age*. This controversy is examined in considerable detail. Is the temperature rise of the 20th century unique, and must it be attributed mainly to increased CO_2?

Chapter 3 analyzes the measurements of Earth surface temperature that were made in the past century or so and discusses the limitations of the measurement network. Temperature data are reviewed in considerable detail. The primary trend during the 20th century has been upward from the base of the *Little Ice Age*, but this temperature rise has not been uniform, either geographically or in time. The limitations of attempting to describe the Earth with a single global average temperature are emphasized.

Chapter 4 provides a discussion of generic global scares. It also discusses subjective science: the science of inference when we cannot go back in time to validate our hypotheses of what might have taken place in the past. It then goes on to discuss the alarmist movement and the ways that climatologists think.

Chapter 5 provides an in-depth review of solar irradiance: historical observations, recent measurements, theories, and models, and use of proxies to estimate past irradiance. Reliable measurements only exist for the past 30 years. There remains considerable uncertainty as to how solar irradiance varies over time periods of centuries. There are a number of models that attempt to estimate solar intensity in the past, but each of these is based on assumptions that are impossible to validate.

In Chapter 6, the Earth's heat balance and the greenhouse effect are discussed. Recent estimates of energy transfer within the Earth system are reviewed. The Earth's current energy balance is discussed with emphasis on the heat content of the oceans—which represent most of the heat capacity of the Earth's surface. Climate variability due to volcanoes and El Niños are reviewed. The concept of climate sensitivity is introduced. Finally, the relationship of CO_2 concentration to climate over 500 million years is reviewed.

Chapter 7 deals with anthropogenic influences on climate change. While most studies have focused exclusively on the putative effects of greenhouse gases, other important effects include the deposition of Arctic black carbon snow and ice, land modification, and generation of sulfate aerosols. The major challenge of the 21st century is not global warming, but rather providing the people of the world with energy. Problems due to climate change must be discussed as a subsidiary element of energy production and consumption.

Chapter 8 deals with the potential impacts of future global warming by contrasting the views of alarmists and skeptics. While alarmists have exaggerated many risks, a significant concern is the potential future rise in sea level. Other threats of global warming have been exaggerated by alarmists.

Chapter 9 deals with climate change and public policy. Governments are rushing to judgment on the putative role of CO_2 and enacting policies that will cost trillions, and may induce economic disaster. Economists have invaded the field of climate change and as with all aspects of climate change, there are opposite viewpoints expressed with great certainty based on flimsy foundations.

Chapter 10 provides a summary and conclusions. The Earth's climate is very complex. There is more that we don't know than we do know about climate change. Past temperatures; long-term variation of solar irradiance; variations in ocean circulation; reaction of cloud cover, humidity, and aerosols to rising greenhouse gas concentrations; heat exchange between the Earth and the atmosphere all remain (like most analyses of climate) speculative, conjectural, and unproven. Nevertheless, the predictions of alarmists can be treated as worst-case possibilities and these are a cause for concern. The bigger problem, however, is an increasing population with growing need for energy.

Appendix I reviews the widely viewed Al Gore film *An Inconvenient Truth*, for which he received a Nobel Prize. This glossy, glib presentation has little actual content, and much of it is wrong. Appendix II provides a model for warming of the oceans as greenhouse gas concentrations increase. While some websites claim that increased greenhouse gas concentrations do not warm the ocean, we show that in fact they do.

In this Third Edition, I have added more than 285 new references, over 180 manuscript pages of new text, and more than 80 new figures. Particularly notable are the following additions:

- Additional data and discussion related to the Medieval Warm Period and the Little Ice Age.
- Information and discussion of so-called "climategate" revelations

- Further revelations on manipulations of proxy data and the "*hockey stick*"
- Expanded coverage of the connection of climate to El Niños
- Updated data on global and regional temperatures
- Data and discussion of weather extremes
- Expanded data and discussion of mountain glacier retreat
- Greatly expanded treatment of Earth heat balance
- Greatly expanded treatment of global warming due to CO_2
- Expanded discussion of humidity and cloudiness effects
- Inclusion of Spencer and Eschenbach models
- Extensive discussion of estimates of climate sensitivity from paleo geological data
- Updates on heat content of the oceans
- Greatly expanded treatment of climate forcings
- Expanded discussion of models for future emissions
- Expanded discussion of the role of black carbon
- Greatly expanded treatment of sea level change
- Greatly expanded treatment of sea ice extent
- Comparison of Holocene to previous deglaciations
- Expanded discussion of "Stern Report" and other economic analysis of remediation of climate change
- Discussion of ocean warming due to increased greenhouse gas concentrations