Communicating the Science:

the number one challenge for climate change

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Full Disclosure

The Paper is meticulously referenced from peer-reviewed journals and mainstream publications. It is intended for leaders, policy makers and all informed citizens. The Paper, including the section on Hard Climate Change Science, has been written in clear language so that some of the most basic questions behind the climate change mechanism are transparently reviewed and clearly explained. As such, it provides a quick but comprehensive read for all those who need to understand how to strengthen core support for climate change response policies.

Brian Olding & Associates is not under contract to any organization, business, governmental or NGO, with respect to the research and writing of this paper. Brian Olding has not been funded by any organization to write this paper and is completely free to express his own views in his own manner.

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Executive Summary

Conclusions and recommendations for climate change secretariats and NGOs

1. *Main conclusion on one of the principal causes for low political support for climate change strategies*

The low political support for climate change strategies is a reality as evidenced from the polling information discussed in this Paper. One of the principal causes for this low support is the outstanding doubts held by many with regard to the reality of global warming and climate change. This scepticism stands in the face of scientific evidence that demonstrates beyond any reasonable doubt that current CO_2 levels are well beyond the record for the last 800,000 years and that global temperatures, which are physically linked to CO_2 levels, are now rising three times faster than the 20th century trend.

One of the central reasons for this scepticism is that we have yet to find a way to communicate climate change science in a meaningful, comprehensive and effective manner. Most secretariats and many NGO websites do have climate science components on their menus, yet the science is not adequately addressed. The hard science behind climate change is rarely communicated effectively, due in part to the complex and interdisciplinary nature of climate change, and due also to the fact that climate change scientists are not policy makers and policy makers are not climate change scientists. Too often information accessibility has been achieved at the cost of superficial interpretation that convinces no one but the converted.

This must change immediately. The science must be interpreted in a comprehensive manner to directly address the persistent doubts held by many that so weaken the critical support for climate change strategies. Initially few will wish to wade into climate change science, but this will change as hard decisions are faced on transitioning away from carbon economies. For many, it will be sufficient to know that trusted and *accessible* science is available on demand at the very secretariats who are designing the climate change strategies.

This is not the time to give up on interpreting the science. This is the time to ramp up the communication of climate change science to the next level.

2. *Identify priority areas of science for improved interpretation*

Climate change secretariats, NGOs and others involved in designing climate change strategies should rigorously review their climate change science component of their websites to determine, first, if they have actually explained the science in a comprehensive, accurate and credible manner, and second, whether this information is accessible. Unsuccessful science interpretation must be identified and prioritized for redress.

3. *Examples of priority areas requiring improved interpretation*

We have reviewed two principal areas of climate change science in this paper:

- the relationship of currently rising levels of CO_2 levels which greatly exceed the known 800,000 year record; and

- the relationship of CO_2 levels to global average temperatures which we know are rising three times faster than the 20th century trend.

4. *Maintain an on-going assessment of advancing climate change science and identify emerging areas that require review, interpretation and communication.*

An additional example that may be reviewed now is the science between competing climate change strategies aimed at achieving greenhouse gas emissions target levels that are either a 3% or a 25% reduction below the 1990 level by the year 2020.

5. *Leaders lead the way*

Government leaders themselves should make climate change statements referencing the hard science to demonstrate their own confidence, and the confidence of their governments, in the science underlying our understanding of climate change and the accuracy of current global climate monitoring conclusions on CO_2 and temperature levels.

6. *Keep the debate open and welcome to all sceptics*

Climate policy makers in government, industry and NGOs must resist the tendency to reference climate change science at a distance and to simply state that the climate change debate is over. Instead, they must make the foundation science of climate change readily available, accessible and current so that citizens can competently inform themselves on established climate change science. This, in turn, will help to firm up the political support required to decarbonise the global economies and will help to support the requisite regional strategies as well as the on-going, post-Copenhagen international carbon negotiations.

7. *A note on considerations for developing economies in international carbon negotiations*

National carbon strategies and international carbon treaties must do more than provide for the option of purchasing international carbon credits, based on emission reduction and enhanced sink productions through decreased deforestation. These strategies and agreements must also provide for financial transfers from high emission and high capacity nations to low emission and low capacity southern hemisphere nations for mitigation and adaptation. In turn, the developing economies must develop their own commitments to national carbon reduction strategies. It will be these commitments that will enable developing economies to survive within the demanding forum of international accords that may provide for local adaptation costs.

Key Components

At this moment, nations around the world are evaluating regional options for pricing carbon emissions while re-evaluating their post-Copenhagen negotiation mandates for participating in subsequent international carbon negotiations targeted at achieving sustainable levels of atmospheric CO_2. The success and effectiveness of these strategies at the national, regional and international levels is hard wired to electoral support.

Recent polling on the support for climate change policies shows that this support is falling. The level of support may, in fact, be even lower still, as the actual level of support will be seen only when clearly explained policies, that clearly detail both the costs and benefits of proposed carbon policies, are made available for close review by voters, policy makers and industry.

The costs of insufficient political support for climate change policies are high, as evidenced by our worst case scenario presented below:

1. At best, thin majorities of national electorates support climate change policies proposed to achieve sustainable levels of atmospheric CO_2.
2. These majorities are fickle and change their allegiance frequently.
3. Government leaders assess this measurement of their mandate when designing carbon caps and negotiating regional and international cap and trade systems.
4. The complexity of the climate change issue is such that many of the electorate will be content with just about any cap and trade system just so long as *something* is seen to be done.
5. The established cap and trade measures that are actually implemented fall far short of what is required to keep global CO_2 emissions at 350 ppm; global temperatures continue to rise and the next generation watches helplessly as the worst case scenarios of the IPPC Reports play out in reality.

This worst case scenario is essentially what took place at the Copenhagen Conference of the Parties in December, 2009, albeit with some important provisos. No countries committed to any specific target reductions at all in the Final Copenhagen Accord. There was only a commitment for individual countries to report out on their own nationally-determined targets (as opposed to the Conference's original goal to determine specific targets within a unified global strategy), and the design and implementation of these solo national reduction targets will take place without any legal structure to provide for their consistent, fair and predictable implementation.

We move on. Political will certainly remains at both the national levels to design effective carbon policies, and at the global level, to eventually hammer out an international accord that will reverse global warming beyond the 2° C increase. But as we said above, this political will is hard wired to electoral support, and that support has been falling for the past year.

We must develop carbon policies that stabilize global warming, but to do so we must first understand why it is that support for climate change policies is so low. One part of the problem of low support for climate change policies is that many people are unsure, in their heart of hearts, of the scientific basis for climate change. This is not particularly surprising, given that the understanding of basic climate change science is all but inaccessible to just about everyone.

The debate over climate change, whether or not sanctioned by climate change secretariats or NGOs, continues unabated in many quarters. And it must be said, unequivocally, that scepticism of climate change science and related policies is healthy, democratic, and is at the basis of scientific advancement. Political correctness has stifled the public climate change discourse.

Consider how many people you know who still question whether the burning of greenhouse gasses such as carbon dioxide has *really* resulted in an abnormal greenhouse effect that has seriously negative responses for the ecological viability of future generations.

It is now becoming apparent that to not acknowledge this widespread basic doubt within electorates is to court policy disaster. As the discussion is forcefully turned away from the basic principles of climate change science, such as the legitimacy of the anthropogenic cause of climate change, and forges on to the design of carbon pricing strategies, large numbers of citizens are left with a growing sense of frustration at having been left behind and their basic questions still unanswered.

The science on which our understanding of climate change is based is undeniably complex. The climate change disciplines, including the science of ecology, as understood in contemporary western science, are generally less than 50 years in development. Also, the multi-disciplinary challenge involved in climate change is remarkable and unprecedented. The range of sciences required to comprehend climate change extends from atmospheric physics, palaeontology, solar irradiation, the examination of climatic proxies due to the absence of direct observation, computerized mathematical models which continue to grow in size and complexity as they attempt to describe terrestrial and oceanic climate change, meteorology, astronomy of the behaviour of our Planet within the solar system, as well as multiple ecological fields.

Up to this point, climate change secretariats and NGOs have taken great pains to present climate change science in the most basic formats so as not to confuse and overload the public. It is now becoming apparent, however, that the basic science is not being effectively communicated and that the electorate remains more confused, and more sceptical, than ever.

A lack of access to the science seals the deal for those who may doubt the anthropogenic contribution to rising CO_2 levels and concurrent rising global temperatures, and who would therefore not provide the political support required to decarbonise the economy or to effectively negotiate regional and international carbon agreements. This must change. We must now dramatically ramp up our developing communication skills to present climate change science in a much more skilful and effective manner.

There will be a component of the electorate that will refuse to accept the climate science that has been clearly demonstrated beyond any reasonable doubt and who may simply not choose to sacrifice any certain costs today for poorly defined presumed benefits at an undisclosed future point in time. Some will be sceptical, and possibly legitimately so, of some of the developmental areas of climate science.

There will also be a component of the electorate that will harbour about even those basic elements of climate science that are now known beyond any reasonable doubt, either because they lack the time to search out trusted information, or because they simply do not currently have access to comprehensive and accessible climate science information from a trusted source.

It is this electoral component that is of critical interest with respect to the communication and availability of accessible climate change science. These are the people, our family members, our neighbours, our work mates, our social networks, who will, at the end of the day, determine the final amount of electoral support that will be available to carry forward carbon reduction policies, to design our national target reductions, and to prepare the negotiation mandates required for the post-Copenhagen negotiations.

We must gage the relative size of these electoral groups and then do our very best to ensure that our communication efforts are directed proportionately to estimated gains in improved understanding of climate change science and increased electoral support for proposed carbon reduction policies.

It is absolutely essential that we communicate the components of climate change science that have now been developed to ‘a beyond any reasonable doubt’ levels. This would include, for example, our empirical understanding of current atmospheric levels of CO_2 (approximately 384 ppm) far exceeding the 172 – 300 ppm range that has persisted over the past 800,000 years. At present, however, this communication is not functioning at the level necessary to achieve potentially available, broad electoral support for climate change policies.

The dismal political support for climate change policies with reference to recent polling is briefly reviewed in the Paper and the current understanding of global warming impacts at the global level is subsequently summarized. Impacts on developing economies, who generally have contributed minimally to global warming but who are disproportionately impacted by emissions in the developed economies, are depicted, using Peru as a case example.

The challenge of presenting basic climate change science in an accessible and comprehensive manner is then addressed head on. Key areas selected for review are:

1. demonstrating the empirical evidence for the long term variability of CO_2.
2. demonstrating the empirical evidence for the CO_2 – global temperature relationship.
3. reviewing the current global climate monitoring that enables monthly reporting of atmospheric CO_2. levels and global combined sea surface and land temperatures.

1. Demonstrating the empirical evidence for the long term variability of CO_2

If there is one single event that may be understood as a watershed moment in the development of climate change science, that would be the completion of the EPICA (European Project for Ice Drilling in Antarctica) ice core project. The analyses of the EPICA ice cores have been reported in the most prestigious scientific journals (e.g. *Nature* and *Science*), repeatedly referred to in almost all major climate change reports (e.g. ICPP-FAR, Global Climate Change Impacts in the United States) and have been represented in the 800,000 year record of past climate graph familiar to all climate change reviewers.

The analysis of these ice cores proved conclusively, through direct empirical observation, that past CO_2 levels have never varied from a range of 172 to 300 ppm over the past 800,000 years. For the first time in climate history the CO_2 levels have risen outside of this range. By 1955 CO_2 was over 310 ppm, by 2007 it was over 380 ppm and by October 2009, CO_2 had risen to an unprecedented 384 ppm. The reason why these numbers are meaningful to us today is entirely due to the climate history of the Antarctic ice core record.

2. Demonstrating the empirical evidence for the CO_2 – global temperature relationship

By measuring the naturally occurring water isotopes in the ice itself, the scientists were also able to reproduce the surface temperatures from each sample across the same 800,000 time span. Their findings were summarized in two of the most important publications in climate change history. In November, 2005, the scientists published the results from the first round of analyses in the prestigious journal *Science*. This was followed on May15, 2008 with the publication of the final ice core results in *Nature*. Both articles confirmed the CO_2 record and both articles confirmed the strong correlation between surface temperature and atmospheric CO_2 levels. We now know that CO_2 atmospheric levels are physically tied to the global sea surface and land temperatures. A major milestone had been achieved in the demonstration of basic climate change behaviour.

3. Reviewing the current global climate monitoring that enables monthly reporting of atmospheric CO_2 levels and global combined sea surface and land temperatures

Selected global climate monitoring of thousands of land stations, the global arrays of moored and drifting ocean buoys, atmosphere measurements and monitoring from space (e.g. the NASA A-Train of teamed satellites that complete a sweep of the entire global grid every 16 days) are described. While these monitoring systems need ongoing international support, they are now sufficient to enable key climate agencies around the world to issue monthly global CO_2 levels and global temperature reports.

Recent Monthly Global CO_2 Highlights

CO_2 over 310 ppm in 1960
CO_2 over 380 ppm in 2007
CO_2 at 384.38 ppm in October 2009

Recent Monthly Global Temperature Highlights

The combined global land and ocean surface temperature for September 2009 was 0.62°C above the 20th Century average. Within the past three decades, the rate of warming in global temperatures has been three times greater than the 20th century scale trend.

Our review of basic climate change science has provided us, beyond any reasonable doubt, that current CO_2 levels of 384 ppm are well beyond the 800,000 year range of 172-300 ppm and that these levels continue to rise. We also know beyond any reasonable doubt that global temperature is tied to CO_2 levels and that the rate of rise for global temperature is increasing. If just these two considerations are laid to rest in the minds of voters, we have made important progress in providing access to climate change science and enabling consideration of increased support for currently proposed climate change policies.

Other important components will now need to be reviewed, such as the science between competing climate change strategies aimed at achieving greenhouse gas emissions target levels that are either a 3% or a 25% reduction below 1990 levels by the year 2020. Accessible climate change science will at the very least lead to better informed voters. At best it will provide the critical mass to support undecided voters who may then reconsider their position on climate change and lead to increased support for climate change policies required to stabilize atmospheric CO_2 levels and global temperatures.

The 2010 Number One Climate Issue:

where is the political support for climate change strategies?

The Complete Paper

January, 2010

Current political support for climate change strategies

Key Components

At this moment, nations around the world are evaluating regional options for pricing carbon emissions while re-evaluating their post-Copenhagen negotiation mandates for participating in subsequent international carbon negotiations aimed at achieving sustainable levels of atmospheric CO_2. The success and effectiveness of these strategies at the national, regional and international levels is hard wired to electoral support.

Recent polling on the support for climate change policies shows that this support is falling. The level of support may, in fact, be lower than shown in the polls, as the actual level of support will be seen only when clearly explained policies, that clearly detail both the costs and benefits of proposed carbon policies, are made available for close review by voters, policy makers and industry.

The costs of insufficient political support for climate change policies are high, as evidenced by our worst case scenario presented below:

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4. The complexity of the climate change issue is such that many of the electorate will be content with just about any cap and trade system just so long as *something* is seen to be done.
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This worst case scenario is essentially what took place at the Copenhagen Conference of the Parties in December, 2009, albeit with some important provisos. No countries committed to any specific target reductions at all in the Final Copenhagen Accord. There was only a commitment for individual countries to report out on their own nationally-determined targets (as opposed to the Conference's original goal to determine specific targets within a unified global strategy), and the design and implementation of these solo national reduction targets will take place without any legal structure to provide for their consistent, integrated, fair and predictable implementation.

We move on. Political will certainly remains at both the national levels to design at least some carbon policies, and at the global level, to eventually hammer out an international accord that will reverse global warming beyond the 2^{o} C increase. But as we said above, this political will is hard wired to electoral support, and that support has been falling for the past year.

We must now come up with carbon policies that stabilize global warming, but to do so we must first understand why it is that support for climate change policies is so low. Recently, a conservative Canadian policy institution published the following conclusion of climate change science:

> "There is no evidence provided by the IPCC in its Fourth Assessment Report that the uncertainty can be formally resolved from first principles, statistical hypothesis testing or modeling exercises. Consequently, there will remain an unavoidable element of uncertainty as to the extent that humans are contributing to future climate change, and indeed, whether or not such change is a good or bad thing."[1]

In fact, the debate over climate change, whether or not sanctioned by climate change secretariats or NGOs, continues unabated in many quarters. And it must be said, unequivocally, that scepticism of climate change science and related policies is healthy, democratic, and is at the basis of scientific advancement. Political correctness has stifled the public climate change discourse.

Consider how many people you know who still question whether the burning of greenhouse gasses such as carbon dioxide has *really* resulted in an abnormal greenhouse effect, which has seriously negative responses for the ecological viability of future generations.

It is now becoming apparent that to not acknowledge this widespread basic doubt within electorates is to court policy disaster. As the discussion is forcefully turned away from the basic principles of climate change science, such as the legitimacy of the anthropogenic cause of climate change, and forges on to the design of carbon pricing strategies, large numbers of citizens are left with a growing sense of frustration at having been left behind and their basic questions still unanswered.

One part of the problem of low support for climate change policies, then, is that many people are unsure, in their heart of hearts, of the scientific basis for climate change. It is not surprising that support is low when the understanding of basic climate change science is all but inaccessible to just about everyone.

The science on which our understanding of climate change is based is undeniably complex. The climate change disciplines, including the science of ecology, as understood in contemporary western science, are generally less than 50 years in development. Also, the multi-disciplinary challenge involved in climate change is remarkable and unprecedented. The range of sciences required to comprehend climate change extends from atmospheric physics, palaeontology, solar irradiation, the examination of climatic proxies due to the absence of direct observation, computerized mathematical models which continue to grow in size and complexity as they attempt to describe terrestrial and oceanic climate change, meteorology, astronomy of the behaviour of our Planet within the solar system, as well as multiple ecological fields.

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A lack of access to the science seals the deal for those who may doubt the anthropogenic contribution to rising CO_2 levels and concurrent rising global temperatures, and who would not, therefore, provide the political support required to decarbonise the economy or to effectively negotiate regional and international carbon agreements. This must change. We must now dramatically ramp up our developing communication skills to present climate change science in a much more skilful and effective manner.

This Paper explores just how this ramp up in making climate change science much more accessible may be undertaken and by doing so, may enable higher levels of understanding of the hard climate change that has been achieved over the past decades.

There will also be a component of the electorate that will harbour about even those basic elements of climate science that are now known beyond any reasonable doubt, either because they lack the time to search out trusted information, or because they simply do not currently have access to comprehensive and accessible climate science information from a trusted source.

It is this electoral component that is of critical interest with respect to the communication and availability of accessible climate change science. These are the people, our family members, our neighbours, our work mates, our social networks, who will, at the end of the day, determine the final amount of electoral support that will be available to carry forward carbon reduction policies, to design our national target reductions, and to prepare the negotiation mandates required for the post-Copenhagen negotiations.

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It is absolutely essential that we communicate the components of climate change science that have now been developed to a beyond any reasonable doubt levels. This would include, for example, our empirical understanding of current atmospheric levels of CO_2 (approximately 384 ppm) far exceeding the 172 – 300 ppm range that has persisted over the past 800,000 years. While this communication may be absolutely essential, at present, this is simply not happening.

The dismal political support for climate change policies with reference to recent polling is briefly reviewed below and the current understanding of global warming impacts at the global level is subsequently summarized. Impacts on developing economies, who generally have contributed minimally to global warming but who are disproportionately impacted by emissions in the developed economies, are depicted using Peru as a case example.

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Other important components will need to be reviewed, such as the science between the competing climate change strategies aimed at achieving greenhouse gas emissions target levels that are either 3% or a 25% below the 1990 level by the year 2020.

Review of the polls

If you find yourself sitting on the fence with regard to supporting economic regulatory measures to curb the rate of climate change, you are not alone. So are many others, and the polls seem to swing back and forth with what appears to be weak underlying understanding or support for curbing climate change. If you Google for climate change polling, you can find more and more reputable polls now citing a majority lack of support for climate change strategies.

One of the most difficult challenges, for many, is simply to understand whether or not there even *is* a climate crisis taking place. Current polling data would suggest that this question is very relevant, indeed. If the very basic concepts of global warming are not widely accepted by the general public and the educated citizenry, then how can policy makers advise their government leaders on the course of action required to address climate change when a critical mass of voters have not examined or bought into the basic causes of climate change?

This is an important question because if a political leader is unsure of the voters buy-in on the policy makers take on climate change, the leader will focus on the short term option of political survival and will turn away from substantial actions that may be largely unpopular, both within the business community as well as with industry workers and retail consumers.

The presence of conflicting and plummeting polling results confuses both sides, while at the same time giving pause to elected leaders as they review the recommendations of their climate change policy makers. Presented below are a quick take of some of the most recent polls on support for climate change actions.

HSBC Climate Partnership, November 03, 2009

HSBC and a Climate Group of large corporations and governments, released a report today on a recent survey they conducted showing support for action on climate change is dropping substantially.[2] Asked whether they consider global warming among their chief concerns, the responses, compared to 2008, were:

- Canada 26% (from 34%)
- US 18% (from 26%)
- UK 15% (from 26%)
- Worldwide 34% (from 42%)

Pew Research Centre, October 22, 2009

In the U.S. the share of citizens who thought there was solid evidence of rising global temperatures had plunged to 57% from 71% in April 2008. Over the same period, there has been a comparable decline in the proportion of Americans who say global temperatures are rising as a result of human activity, such as burning fossil fuels. Just 36% say that currently, down from 47% last year.

http://people-press.org/report/556/global-warming

EUROPA - Public Opinion analysis, January 02-June 09, 2009.

Number of European residents who saw climate change as the world's gravest problem dropped to 50% from 62% in spring 2008.

http://ec.europa.eu/public_opinion/archives/eb_special_en.htm

CNN/Opinion Research Corporation Poll, April 23-26, 2009. Adults nationwide:

"A proposal called 'cap and trade' would allow the federal government to limit the emissions from industrial facilities such as power plants and factories that some people believe cause global warming. Companies that exceed the limit could avoid fines or higher taxes by paying money to other companies that produced fewer emissions than allowed.

http://www.pollingreport.com/enviro.htm.

Would you favor or oppose this proposal?"

Favor	Oppose	Unsure
%	%	%
44	51	5

If favor 'cap and trade':

"Do you think the 'cap and trade' proposal would reduce global warming, or do you think it would help reduce air pollution in general but would not affect global warming directly?"

Combined responses to this question and preceding question:

Favor Reduce Global Warming	Favor Reduce Air Pollution	Oppose	Unsure
%	%	%	%
18	23	51	8

The Guardian, Tuesday 14 April 2009:

Guardian poll reveals almost nine out of 10 climate experts do not believe current political efforts will keep warming below 2°C.

http://www.guardian.co.uk/environment/2009/apr/14/global-warming-target-2c

Global Monitor ,Angus Reid April 22, 2009:

Only a third of adults in the United States believe global warming is caused primarily by human activity, according to a poll by Rasmussen Reports. 34% of respondents agree with this rationale, while 48% blame long term planetary trends.

http://www.angus-reid.com/polls/view/fewer_in_us_blame_humans_for_global_warming/

The Observer, Sunday 22 June 2008:

The majority of the British public is still not convinced that climate change is caused by humans - and many others believe scientists are exaggerating the problem, according to an exclusive poll for The Observer.

http://www.guardian.co.uk/environment/2008/jun/22/climatechange.carbonemissions

Angus Reid December 22, 2008:

The proportion of people in the United States who are concerned about climate change has dropped this year, according to a poll by Rasmussen Reports. 65% of respondents believe global warming is a very or somewhat serious problem, down eight points since April. In addition, 43% of respondents believe global warming is primarily caused by human activity, while 43% blame long term planetary trends.

http://www.angus-reid.com/polls/view/fewer_americans_worried_about_climate_change/

CanWest News Service, Published: Thursday, November 27, 2008:

PARIS - There is both growing public reluctance to make personal sacrifices and a distinct lack of enthusiasm for the major international efforts now underway to battle climate change, according to findings of a poll of 12,000 citizens in 11 countries, including Canada. Less than half of those surveyed, or 47%, said they were prepared to make personal lifestyle changes to reduce carbon emissions, down from 58% last year. Only 37% said they were willing to spend "extra time" on the effort, an eight-point drop.

And only one in five respondents - or 20% - said they'd spend extra money to reduce climate change. That's down from 28% a year ago. The 11 countries surveyed were Australia, Brazil, Canada, China, France, Germany, India, Malaysia, Mexico, the United Kingdom and the United States. There were 2,000 respondents surveyed in China, including 1,000 in Hong Kong.

http://www2.canada.com/windsorstar/news/story.html?id=f0a1687c-decd-4c72-9d0e-7e6dd92d4ebe

Gordon Jaremko, edmontonjournal.com March 06, 2008

Only about one in three Alberta earth scientists and engineers believe the culprit behind climate change has been identified, a new poll reported today. The expert jury is divided, with 26% attributing global warming to human activity like burning fossil fuels and 27% blaming other causes such as volcanoes, sunspots, earth crust movements and natural evolution of the Planet. A 99% majority believes the climate is changing. But 45% blame both human and natural influences, and 68% disagree with the popular statement that "the debate on the scientific causes of recent climate change is settled."

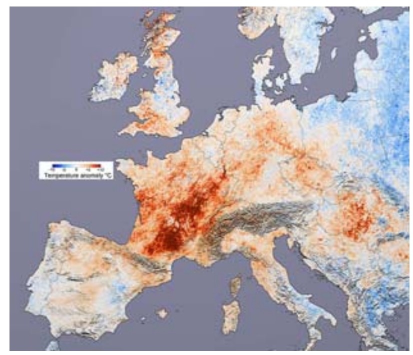
The divisions showed up in a canvass of more than 51,000 specialists licensed to practice the highly educated occupations by the Association of Professional Engineers, Geologists and Geophysicists of Alberta.

http://www2.canada.com/edmontonjournal/news/story.html?id=1d688937-54b7-48f4-a4be-d6979dada5df&k=65311

What is at Risk

Global impacts

Projected impacts from climate change, both at the ecological and socio-political levels, have been made by a wide range of high level policy organizations including the IPCC, the UNFCC, the European Union and recently, by the U.S. Subcommittee on Global Change Research in their report, *Global Climate Change Impacts in the United States*.[3]



We may remember that most national and international carbon reduction policies are currently focused on not exceeding the 2°C increase over the pre-industrial global average temperature of 14°C.

The Fourth Assessment Report of the IPCC (FAR), announced that the Planet has been warming by 0.07°C per decade over the past 100 years (for a total of 0.7°C warming in the past 100 years) and that rate has increased to 0.18°C per decade over the past 25 years (for a total of 0.45°C warming in the past 25 years). Northern hemisphere land areas have been warming about 0.3°C per decade over the past 25 years, compared to a rate of 0.08°C per decade over the past 100 years.[4]

National Geographic produced a program in 2008 entitled *Six Degrees Could Change the World* that was intended to visualize the climate impacts for each degree of global warming increase. The program was based on Mark Lynas' book, *Six Degrees: Our Future on a Hotter Planet,* which was influenced by the IPCCs predictions that the global average temperature will rise between 1.4 to 5.8°C by the end of this century compared to 1980-1999 mean global temperature of 14°C.[5] The global mean temperature for 2008 was 14.31°C.[6]

The Current Carbon Target

Two degree increase scenario –what will it look like?

A two degree increase is considered by many climate scientists to be the limit of climate change before tipping points are reached where we enter into a runaway climate situation. As Canada tundra melts, new temperate forests emerge. The migration of warmer climates polewards brings with it new pest migration routes, such as pine beetle infestations. Increasing rainfall and warming weather promote mosquito-borne disease that exacerbates the West Nile Virus.

Greenland glaciers are melting and the Jakobshavn Glacier, the fastest moving glacier and major contributor to the mass balance of this continental ice sheet, has already doubled its flow of ice into the ocean, raising concerns over the stability of the ice sheet and a one meter sea level rise that would impact infrastructure from London to New York to Shanghai. The less ice there is, the more heat is absorbed, the warmer it gets, and the less ice there is – we have now

reached the tipping point. Global warming has now become an unpredictable chain reaction.

The Himalayan glaciers are the largest storage of freshwater outside of the polar ice caps and are now receding faster than any other glaciers in the world. At current rates, they will be gone by 2035. Initial regional flooding disasters will be followed by drought and the shutdown of water supplies that will wreak havoc for drinking water, agricultural production and hydroelectric power, impacting China (the Amu Darya, Brahmaputra, Ganges, Indus, Mekong, Yangtze and Yellow Rivers), Afghanistan, India, Bhutan, Bangladesh, Pakistan, Myanmar, Laos, Thailand, Cambodia, and Kyrgyzstan. The basins of these rivers provide water to 1.3 billion people, a fifth of the world population. The recent *From Kathmandu to Copenhagen* conference, hosted in August, 2009 by the Nepalese Government and supported by the World Bank, labelled the Hindu Kush - Himalayan region as a highly vulnerable climate change hot spot that will ultimately influence half of the world population.

What if we exceed the 2°C target?

Three degree increase scenarios

The snow caps in the Alps all but disappear as Mid-East temperatures now become the norm for central Europe and the heat wave of 2003 that killed over 30,000 people in 2003 now becomes the European norm for every summer.

Photosynthesis is now breaking down as trees retain their oxygen, are unable to absorb CO_2 , and begin to outgas CO_2 to the atmosphere, signalling the breakdown of another major CO_2 sink. Increasing droughts in the Amazon transform one of the wettest places on earth into a patchwork of arid savannahs. These trees, that produce 20% of the world oxygen, also produce 50% of the region's moisture. Drought leads to more fires which reduces the trees, which reduces the moisture production, which increases the drought, potentially releasing millions of tons of stored carbon in the dying trees, which, in turn, increases global warming by as much as an additional one degree.

100-year storm events now become the norm, and as in the Pleistocene era (the dawn of early hominids) it is three degrees warmer and humans are now experiencing the most violent storms ever. A permanent El Nino exists where the Trade Winds reverse direction and leave Australia in drought conditions, while heated ocean waters cause wild fluctuations in air pressure, unleashing torrential rains on the eastern coast of South America. Category 6 super storms, fuelled by heated ocean water, now exceed the 280 k/hour of Katrina, leaving the floating bodies of New Orleans as only a hint of what our world might be like. It may be the beginning of the breakdown of the Planet's basic life support systems.

What If it gets worse?

A Four Degree Increase Scenario

At this point the science of climate change becomes more and more speculative, and more frightening. The Planet is unrecognizable from the Planet we know today. While Canada becomes one of the most bountiful agricultural zones in the world, the collapse of ice sheets and the melting of glaciers have now raised ocean levels that wash away Bangladesh, flood Egypt and submerge Venice. Storm surges combined with maximum high tides submerge the lower parts of New York, including electrical, water and subway services located underground (the New York subway system is already pumping out 60 million litres of water, even on dry days). Current 100 year storm events now arrive every four years. New York will need the giant three story sea gates already in place in the Netherlands and on the Thames (if you think that sea level rise is a myth, check out the current engineering planning for even larger gates on the Thames based on recent forecasts predicting higher than anticipated sea level rise).

In a four degree world, we will be facing different climatic problems but they will share one thing in common – all of these problems will be extreme.

A Five Degree to Six Degree Increase Scenario

The five and six degree scenarios bring us to the twilight zone of climate change and a nightmarish vision of life on earth where traditional social systems have broken down, the poor have been left behind and survival is based on the ability to be mobile. This is the Doomsday scenario where some of the great cities in the world are inundated and abandoned and the Planet experiences a global wipe-out of species. Water is now extremely scarce in many parts of the Planet. Natural disasters are common events, deserts march across continents like conquering armies and the oceans are marine wastelands. In a world filled with hundreds of millions of climate refugees, it is inconceivable that human civilization could withstand this level of climatic shock.

Does all this sound a little extreme? Did National Geographic lose it? Consider this from the World Bank (not a radical organization) climate change website:

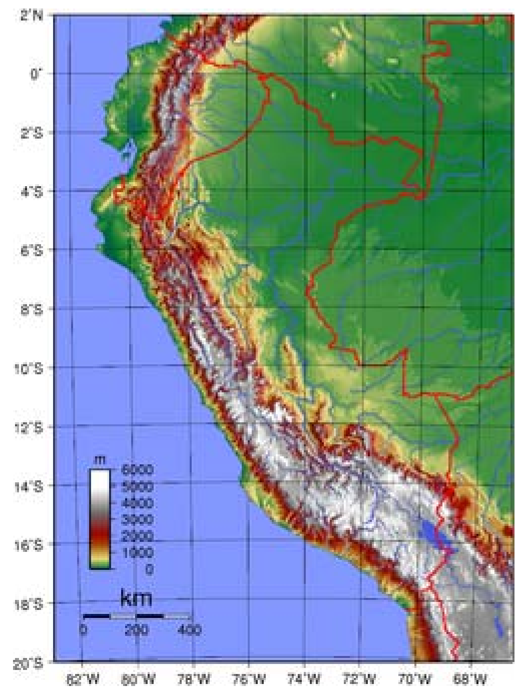
> Many scientists say global temperatures should not be allowed to rise by more than 2 to 2.5ºC above pre-industrial levels to prevent catastrophic harm to people through channels such as health, agricultural productivity, and ecosystem services. However, without dramatic cuts in global emissions, the world is heading toward a rise of as much as 11ºC this century.[7]

And this statement from the U.K. Met Office on September 28, 2009:

> If greenhouse gas emissions continue to rise unchecked, it is likely that global warming will exceed four degrees by the end of the century, research by Met Office scientists has revealed. In some areas warming could be significantly higher (10 degrees or more).
>
> The Arctic could warm by up to 15.2°C for a high-emissions scenario, enhanced by melting of snow and ice causing more of the Sun’s radiation to be absorbed.

Developing Economies

Peru - melting glaciers and Peruvian water security



The impacts of our lifestyles on regions far from our own carbon emissions need to be understood while we are in the process of designing our own carbon reduction strategies and negotiating international carbon agreements. Impacted developing economies, with low capacity to mitigate climate impacts originating in remote regions, will require capital transfers to adapt to these impacts.

Peru is on the front lines of man-made climate change and, apparently, will be forced to pay what amounts to a type of tax for the emissions of industrialized countries. And yet, Peru has a relatively small economy and is estimated to be responsible for only 0.1% of world carbon emissions (compared to the USA emissions at 22%).[8]

Higher temperatures in the Amazon will result in higher frequencies and intensities of droughts. In the 2005 drought in the Amazon, tributaries ran dry and water actually had to be helicoptered into Amazonian villages. Drought leads to more fires which reduces the trees, which reduces the moisture production, which increases the drought, ultimately releasing millions of tons of stored carbon in the dying trees which, in turn, increases global warming by as much as an additional one degree. Higher global temperatures will cause Amazonian photosynthesis to break down as trees are unable to absorb CO_2 or to retain their oxygen and begin to outgas CO_2 to the atmosphere, signalling the breakdown of a major planetary CO_2 sink. Under worst case scenarios one of the wettest places on earth will be turned into a patchwork of arid savannahs.

90% of the Peruvian population live in arid and semi-arid areas and 70% of the population live in the arid coastal plain that lies between the western slope of the Andes and the Pacific Ocean. This population relies on the westward flowing rivers, most of which do not reach the ocean during the dry season, that flow down from the Andean mountain slopes. The Pacific - Atlantic continental divide, situated at the top of the Andes, is located less than 125 kilometres from the Pacific coast. Consequently, most Peruvian precipitation runs down the eastern slopes toward the Amazon drainage to the Atlantic. Much of the easterly wind flow coming from the Amazon basin precipitates out over the Andes, resulting a dry coastal Pacific zone on the western pacific side of the mountains. Lima, for example, receives less than 20 mm of rain per year, while coastal southern Peru is one of the driest places on earth, with rain coming only once in ten years.[9]

Most of the water resources on the Pacific side of Peru come from snow and ice in the Andes (Peru has 70% of the world's tropical glaciers), which act as a critical buffer against highly seasonal precipitation, storing precious melt water for use in the dry season, for ecosystem integrity, domestic withdrawals, agricultural irrigation, mining and hydroelectric uses. Many large cities in the Andes are located above 2500 meters and are, therefore, almost entirely dependent on high altitude glacial water stocks to complement rainfall during the dry season. Surface warming in the Andes is likely to be similar to Arctic warming but with consequences that may be felt much sooner, and which impact a much larger population.

Near surface temperature trends for high elevation, central Peru show a temperature increase of 0.1°C per decade, with over 0.35°C per decade for the central Andes from 1951 to 1999. Climate change projections, based on the higher IPPCC AR4 Working Group assumptions (now thought to be conservative) on global CO_2 emissions, portray a massive warming for the tropical Andes on the order of 4.5 to 5.0°C by the end of this century.[10]

22% of Andean glaciers have already receded in the last 30 years and many smaller, low-lying glaciers will disappear within a few decades.[11] Glaciers grow in the wet season and release their melt water in the dry season, supporting agriculture and hydroelectric production. They are natural storage reservoirs that hold the wet season precipitation and release it when it is needed in the dry season. This dry season water is absolutely critical to the sierra agricultural communities that live down below the glacier and its running rivers that have always provided the irrigation required for agricultural survival.

Glacial retreat has been heavily studied in the Cordillera Blanca of the northern Andes but has also been studied in southern regions of Peru such as the Cordillera Vilcanota. The well-studied Qory Kalis outlet glacier, which is part of the Quelcayya Ice Cap, the largest ice cap in the world after the polar ice caps, lies high up in the Andes (5,470 meters), 100 kilometres southeast of Cusco. The Qori Kalis has been retreating *10 times faster* (60 meters per year) between 1991-2005 than in the preceding measuring period, 1963-1978.[12] Peruvian glaciers will continue to retreat and many will completely disappear within thirty years, with significant consequences for local populations.

The megacity of Lima and its 8 million residents are most critically dependent on diminishing water supply sources. Lima swallows up the entire Rimac River discharge, as well as two much smaller rivers, Rio Chillon to the north of the city, and Rio Lurin to the south expansion. 454 groundwater wells are connected to the Lima water supply system but only 232 are in service and these suffer from over exploitation of the underlying aquifer.[13] The upper tributary basins that feed the Rimac, the Rio Santa Eulalia and the Rio Blanca, are heavily dammed with storage reservoirs and yet already Lima is in an unsustainable situation with insufficient supply to feed its rapidly expanding population.

This has led to new engineering works that are tapping into the headwaters on the other side of the continental divide. Here headwater Amazonian lakes are re-routed from their eastward flow and turned back westward into the mountains where tunnels have been built to send the water through canals that feed into the pacific side Santa Eulalia and Blanca rivers and so augment the Rimac supply to Lima. But without glacial melt water to replenish these headwater lakes in the dry season, the shortages are predicted to continue into the future. Between 2015 and 2020 all glaciers in Peru under 5000 meters will disappear as a result of global warming.

Food security is now becoming a significant issue for water short communities. The political clout of major water users, such as Lima, hydroelectric project users, commercial agriculture and mining companies, will likely ensure that they continue to benefit from national policies that provide for favourable investment legislation, tax breaks, credit facilities and cheap water availability in order to strengthen much needed economic growth. Large scale agricultural producers have the capital and education to buy irrigated lands fed by irrigation projects such as in the Rio Santa valley.

But for those farmers who do not own the land they farm, there is less incentive to irrigate. And small scale agricultural producers who constitute the rural poor and who are especially vulnerable, will be most impacted by glacial reduction and will be the first to feel the impact of low flows during the dry season, possibly fuelling conflicts when scarce water is diverted to hydroelectric facilities and mining projects. Conflicts between water users on the Pacific slopes are already becoming increasingly frequent as water sources are gradually exhausted, pitting downstream agribusinesses against upstream small farmers and Quechua-speaking llama herders in the sierra.

Negotiating international carbon agreements

How will the small producers adapt to melting glaciers caused by climate change? The capacity of rural communities, in particular, to adapt to climatic impacts in the water, agricultural, food security and health sectors is limited by high infant mortality, low secondary school enrolment and high levels of inequality both, in income as well as in access to fresh water and health care services. Half of Peruvians live in poverty and 21% subsist in extreme poverty and malnutrition, putting significant limitations on the implementation of climate change adaptation resources.[14] Current warming rates and their predicted impacts on essential national assets, such as the Peruvian Amazon and water supply from dwindling glaciers, will be felt most by these populations. Given limited financial and technical resources, and high rates of poverty, Peru is much less able to adapt to climate change than more developed countries to the north. Yet, Peru is estimated to be responsible for only 0.1 per cent of the worlds carbon emissions.

Most nations, including Canada and the U.S., do consider the developing world in their national carbon reduction strategies, only as a source of purchasing international emission reduction opportunities, either by introducing low emission technologies or by signing on to offsets such as a reduction in deforestation. Few nations are explicitly providing for monetary transfers for the mitigation and adaptation measures required by developing communities as they experience the climate impacts caused primarily by northern hemisphere countries.

It is important, then, that those nations, now and in the future, most responsible for global warming accept responsibility for both decarbonising their economies and for providing mitigative resources to developing countries most impacted by global warming. Negotiators from Peru, and other developing economies who are participating in international carbon agreements (e.g. Copenhagen), must successfully obtain the mitigative resources required for new water storage structures, efficient irrigation techniques and new crops resistant to thermal shock. To effectively negotiate mitigation assistance, and to demonstrate good faith, these economies will have to develop their own carbon reduction strategies at home. These strategies may be specific and adapted to developing economies but they must be seen to be real and effective.

International Security Threats

The UN Security Council held its first debate on the international implications of climate change for international security in April, 2007. Shortly after this the European Commission and the High Representative for the Common Foreign and Security Policy was invited to present a joint Report, Climate Change and International Security, to the European Council in Spring 2008.[15] The Report indicates that unmitigated climate change beyond 2ºC will lead to unprecedented security scenarios as it is likely to trigger a number of tipping points that would lead to further accelerated, irreversible and largely unpredictable climate changes.

Climate change, it suggests, should be viewed as a threat multiplier which exacerbates existing trends, tensions and instability. The core challenge is that climate change threatens to overburden states and regions which are already fragile and conflict prone. It is important to recognize that the risks are not just of a humanitarian nature; they also include political and security risks that directly affect European interests.

Conflict over resources

Reduction of arable land, widespread shortage of water, diminishing food and fish stocks, increased flooding and prolonged droughts are already happening in many parts of the world. Climate change will alter rainfall patterns and further reduce available freshwater by as much as 20 to 30% in certain regions. A drop in agricultural productivity will lead to, or worsen, food-insecurity in least developed countries and result in an unsustainable increase in food prices across the board. Water shortage in particular has the potential to cause civil unrest and to lead to significant economic losses, even in robust economies. The consequences will be even more intense in areas under strong demographic pressure. The overall effect is that climate change will fuel existing conflicts over depleting resources, especially where access to those resources is politicized.

Economic damage and risk to coastal cities and critical infrastructure

It has been estimated that a business-as-usual scenario in dealing with climate change could cost the world economy up to 20% of global GDP per year, whereas the cost of effective concerted action can be limited to 1%. Coastal zones are the home of about one fifth of the world population, a number set to rise in the years ahead. Mega-cities, with their supporting infrastructure, such as port facilities and oil refineries, are often located by the sea or in river deltas. Sea-level rise and the increase in the frequency and intensity of natural disasters pose a serious threat to these regions and their economic prospects. The East coasts of China and India, as well as the Caribbean region and Central America, would be particularly affected. An increase in disasters and humanitarian crises will lead to immense pressure on the resources of donor countries, including capacities for emergency relief operations.

Loss of territory and border disputes

Scientists project major changes to the landmass during this century. Receding coastlines and submergence of large areas could result in loss of territory, including entire countries such as small island states. More disputes over land and maritime borders and other territorial rights are likely. There might be a need to revisit existing rules of international law, particularly the Law of the Sea, as regards the resolution of territorial and border disputes. A further dimension of competition for energy resources lies in the potential conflict over resources in Polar regions, which will become exploitable as a consequence of global warming. Desertification could trigger a vicious circle of degradation, migration and conflicts over territory and borders that threatens the political stability of countries and regions.

Environmentally-induced migration

Those parts of the populations that already suffer from poor health conditions, unemployment or social exclusion are rendered more vulnerable to the effects of climate change, which could amplify or trigger migration within and between countries. The UN predicts that there will be millions of "environmental" migrants by 2020 with climate change as one of the major drivers of this phenomenon. Some countries that are extremely vulnerable to climate change are already calling for international recognition of such environmentally-induced migration. Such migration may increase conflicts in transit and destination areas. Europe must expect substantially increased migratory pressure.

Situations of fragility and radicalization

Climate change may significantly increase instability in weak or failing states by over-stretching the already limited capacity of governments to respond effectively to the challenges they face. The inability of a government to meet the needs of its population as a whole or to provide protection in the face of climate change-induced hardship could trigger frustration, lead to tensions between different ethnic and religious groups within countries and to political radicalization. This could destabilize countries and even entire regions.

Tension over energy supply

One of the most significant potential conflicts over resources arises from intensified competition over access to, and control over, energy resources. That, in itself, is and will continue to be, a cause of instability. However, because much of the world's hydrocarbon reserves are in regions vulnerable to the impacts of climate change, and because many oil and gas producing states already face significant social economic and demographic challenges, instability is likely to increase. This has the potential to feed back into greater energy insecurity and greater competition for resources. A possible wider use of nuclear energy for power generation might raise new concerns about proliferation, in the context of a non-proliferation regime that is already under pressure. As previously inaccessible regions open up due to the effects of climate change, the scramble for resources will intensify.

Pressure on international governance

The multilateral system is at risk if the international community fails to address the threats outlined above. Climate change impacts will fuel the politics of resentment between those most responsible for climate change and those most affected by it. Impacts of climate mitigation policies (or policy failures) will thus drive political tension nationally and internationally. The potential rift not only divides North and South but there will also be a South - South dimension, particularly as the Chinese and Indian share of global emissions rises. The already burdened international security architecture will be put under increasing pressure.

The American view of security risks

The United States is connected to a world that is unevenly vulnerable to climate change and thus will be affected by impacts in other parts of the world. As we have seen above, American society will not experience the potential impacts of climate change in isolation. In an increasingly connected world, impacts elsewhere will have political, social, economic, and environmental ramifications for the United States.[16]

As conditions worsen elsewhere, the number of people wanting to immigrate to the United States will increase. The direct cause of potential increased migration, such as extreme climatic events, will be difficult to separate from other forces that drive people to migrate. Climate change also has the potential to alter trade relationships by changing the comparative trade advantages of regions or nations. As with migration, shifts in trade can have multiple causes. Accelerating emissions in economies that are rapidly expanding, such as China and India, pose future threats to the climate system and already are associated with air pollution episodes that reach the United States.

Meeting the challenge of improving conditions for the world poor has economic implications for the United States, as does intervention and resolution of intra- and intergroup conflicts. Where climate change exacerbates such challenges, for example, by limiting access to scarce resources or increasing incidence of damaging weather events, consequences are likely for the U.S. economy and security.

Hard Climate Change Science – facts you must know

Political support for climate change strategies aimed at reducing our carbon footprint is, according to the review of polling results above, alarmingly low. And yet, our best modelling predictions for global warming present an unattractive and dangerous future. This situation occurs while nations are currently designing their own local carbon strategies, such as developing carbon price mechanisms, cap and trade systems and offset markets. This is taking place while we are working at the international level to develop a unified approach across nations and regions towards a global carbon strategy. If the political will within the electorates is not sufficiently robust we run a real risk of developing carbon strategies that have the appearance of form and substance, but which are actually ineffective.

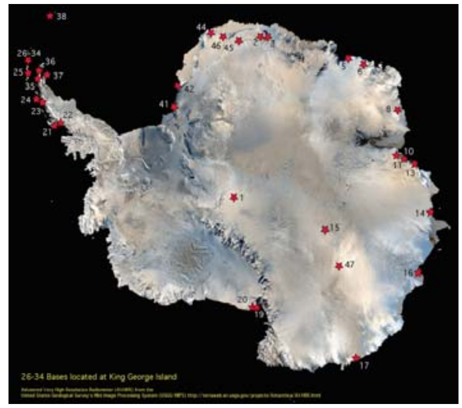
The ambivalence to climate change science runs deep. Many people simply distrust both the science and the policy makers who design the climate change strategies. Much of the key climate change science is sound. It simply has not been openly presented to the electorate on the grounds that it can not be made comprehensible to the general public, or for that matter, to educated lay persons.

This is simply not so. Yes, the science is complex, and in some instances all but inaccessible, save to a narrow audience. But we will proceed below to unravel some of the most basic science that underlies our current understanding of climate change. We will examine how it is that we know beyond any reasonable doubt that present CO_2 levels (384.78 ppm) are far beyond the recorded atmospheric levels for the last 800,000 years (172-300 ppm). We will examine exactly how it is that we know that global temperature is strongly correlated with CO_2 levels. And we will briefly review the current global climate monitoring systems and the efforts being undertaken to synchronize this monitoring which enables the production of both monthly atmospheric CO_2 levels, and monthly global average temperatures for combined land and sea surface temperatures.

This is powerful, enabling knowledge and it takes only minor interpretation to make the primary science on which it is based accessible. This in turn allows many more people to become informed, if they so choose, so that they can select political candidates that put forward carbon strategies that will be successful in addressing the planetary challenge. Let us take a look at some of this foundational science.

Hard Climate Change Science

Antarctic ice cores and the industrial CO_2 rise



If there is one single event that may be understood as a watershed moment in the development of climate change science, that would be the completion of the EPICA (European Project for Ice Drilling in Antarctica) ice core project. The analyses of the EPICA Antarctic ice cores have been reported in the most prestigious scientific journals (e.g. *Nature* and *Science*), repeatedly referred to in almost all major climate change reports (e.g. ICPP-FAR, Global Climate Change Impacts in the United States) and have been represented in the 800,000 year record of past climate graph familiar to all climate change reviewers. The analysis of these ice cores proved conclusively, through direct empirical observation, that CO_2 levels over the past 800,000 years have never varied from a range of 172 to 300 ppm. For the first time in climate history the CO_2 levels have now risen outside of this range. By 1955, CO_2 was over 310 ppm; by 2007, it was over 380 ppm and by October 2009, CO_2 had risen to an unprecedented 384 ppm.[17] The reason why these numbers are meaningful to us today is entirely due to the climate history of the Antarctic ice core record.

The EPICA ice core project follows on the footsteps on the extensive ice core research carried out in Greenland as well as by the neighbouring drilling program at the neighbouring Russian station at Vostok. The EPICA ice core record significantly corroborates and advances these records and constitutes the single most important source about past climates. As such, it is fundamental to understanding anthropogenic contributions to both CO_2 and currently rising global temperatures. It is the basis for much of our current scientific understanding of climate change and it is, therefore, critical that this ground breaking research be clearly understood. This is a key basis for explaining the reality of global warming. While it is often referenced in most climate change reports, it is rarely explained adequately. This constitutes a significant failure in communicating climate change to the public and we will therefore spend a few moments reviewing this work here.

EPICA was coordinated by the European Science Federation and funded by the European Commission as well as by agencies from Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland and the United Kingdom. Antarctic logistics at the Concordia base drilling station in Antarctica, where the ice cores were drilled, were coordinated by France and Italy. The goal was to produce an 800,000 year long record of climate (temperature) and atmospheric record (CO_2 levels).

Antarctica was chosen for its expansive and stable ice sheet (other ice sheets moving down slope will distort the ice and the CO_2 levels within the atmospheric record). Extensive geophysical research was undertaken to find the right site where ice structure would be vertically stable down to 3000 meters. Drilling started in 1996 at the EPICA Concordia base camp Dome C, and reached an initial depth of only 130 meters in the first year. Most of the work was taken up by setting up the equipment (note that the opening scene in the movie *The Day After Tomorrow* shows a drilling team operating in the Antarctic and portrays actor Dennis Quaid jumping across a chasm of disintegrating Larsen B ice shelf on the eastern side of the continent to save the precious ice cores).

The EPICA drill took individual two-meter core samples which were raised to the surface, extracted and prepared on the surface for shipping to a number of European laboratories (prominent among them are the Physics Institute, University of Bern, Switzerland and the Laboratoire de Glaciologie et Geophysique de l' Environment in Grenoble, France). The drill would then be lowered back down into the hole for another cycle, with drilling cycles and ice core production averaging 5 meters per day. In early 1998, the hole was 364 meters deep but in 1999, the drill became stuck and the entire drilling operation had to be restarted. EPICA drilled down to 112 meters the following year, then to 1459 meters in 2000, and by 2002 they had reached 3200 meters.

In 2004 EPICA drilled an additional 70 meters and on Tuesday, December 21, 2004, the drilling team reached 3270.2 meters, just 5 meters above the bedrock at Dome C, on the central plateau of the east Antarctic ice sheet.[18] The EPICA Antarctica drilling project represented one of the most important scientific explorations in history.

European laboratories analyzed the Antarctic ice cores using standard laser absorption spectrometry in Bern and conventional gas chromatography in Grenoble to measure the atmospheric record through the analysis of CO_2 in air bubbles trapped within the ice core. The data produced by these laboratories was immediately reviewed and analyzed by teams of ice climate scientists. The results of their analyses were spectacular and represented a quantum leap in our understanding of nearly one million years of climate science.

On November 25, 2005, the journal *Science* published what was to become one of the most important papers in the history of climate science. Eleven climate scientists from the Physics Institute, University of Bern, Bern, Switzerland, the Laboratoire de Glaciologie et Geophysique de l' Environment in Grenoble, France, the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, and the Institute Pierre Simon Laplace Laboratoire des Sciences du Climat et de l Environment, University of Versailles, France, published *Stable Carbon Cycle - Climate Relationship during the Late Pleistocene.*[19] They reviewed the EPICA data which, among other things, had produced climate records correlated with temperature and greenhouse gases trapped in the air bubbles of the ice for the past 650,000 years, which represented results up to the 2002/2003 season.

The paper conclusively demonstrated that CO_2, prior to the industrial revolution, has never exceeded 300 ppm over the past 650,000 years.

In March of 2008, the EPICA drilling project was awarded the prestigious European Union Descartes prize for outstanding research in trans-national projects in the natural sciences and the humanities.

The same scientists, now supplemented with colleagues from the Niels Bohr Institute, University of Copenhagen in Denmark, and the National Institute of Polar Research in Tokyo, Japan, published a follow-up paper in *Nature* on May 15, 2008, which extended this record by analysing the lowest 200 meters that were now available. The last drilling of the 2004/2005 season had now brought the depth down to 3270 meters and the climate records were now accessible back to 800,000 years.[20]

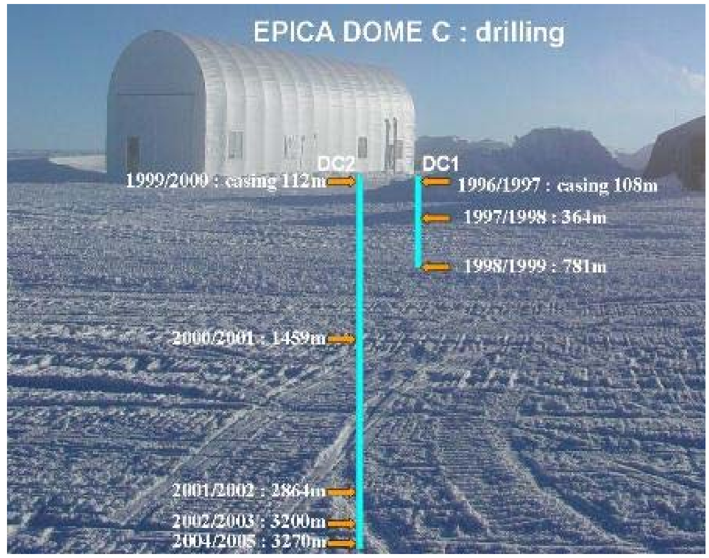
The Bern and Grenoble laboratories employed three different sample extraction techniques and two independent analytical methods (using laser absorption spectrometry in Bern and gas chromatography in Grenoble) to produce a CO_2 data set that confirmed both earlier findings at the Vostok drill site in Antarctica, the findings at a prior EPICA drilling site in Antarctica (Taylor Dome) as well as their own independent analyses of the EPICA Concordia Dome site ice core samples.[21]

The single most important result available from this work was the established record of CO_2 concentrations in the global atmosphere for the past 800,000 years. The published CO_2 natural variability record for the past 800,000 years remained firmly within a range of 172 - 300 ppm. The record stands in marked contrast to our current post-industrial CO_2 concentration of 384.78 ppm published in September, 2009 by the National Oceanic and Atmospheric Administration recorded measurements taken from their world wide research stations, including the Mauna Loa Observatory in Hawaii.[22]

Now let us turn to the relationship of CO_2 to temperature. The second major result of these laboratory analyses of the EPICA ice core data revealed the tight correlation of the surface temperature record to the record of atmospheric CO_2 levels.

Hard Climate Change Science

The CO_2 temperature link



There was more that we needed to learn from the EPICA ice cores. Once we knew the range of naturally occurring CO_2 concentrations in our atmosphere (172-300 ppm), we then very much needed to know how temperature and CO_2 were related across the last 800,000 years in order to understand the global warming implications of our own recent and unprecedented rise in atmospheric CO_2 concentrations.

Fortunately, the invaluable EPICA ice cores had still more of a story to tell as the French and Swiss laboratories, and then the world, soon discovered. Through mass spectrometry analysis, they were able to measure water isotopes in the ice samples and to therefore track the surface temperatures for the past 800,000 years, and to compare the changes in temperatures with the changes in CO_2 composition. What the researchers found finally nailed down the key to understanding the relationship between anthropogenic CO_2 emissions and corresponding temperatures levels. The EPICA lab scientists were able to measure historic temperatures in the ice samples by analysing the presence of naturally occurring isotopes of water, and, to thereby reconstruct surface temperatures over the past 800,000 years (an incredible achievement for our species).

This is the foundational science which has enabled the IPCC and subsequent national government reports to identify the CO_2 –temperature relationship. Before we advance to designing and implementing climate change response measures, we must understand this CO^2 –temperature relationship clearly and unequivocally. But here, we will expand our scientific understanding of water isotopes, because it was the analysis of water isotopes in the solid ice, adjacent to the air bubbles, that enabled scientists to identify the temperature record for the last 800,000 years.

A water molecule is composed of two hydrogen atoms and one oxygen atom. Atoms may naturally vary in their atomic mass by containing different numbers of neutrons. The different forms of the same atom, having different numbers of neutrons, are called *isotopes*. Hydrogen, for example, generally occurs with only one proton and no neutrons (the common isotope of hydrogen), yet it also occurs as deuterium (a rarer isotope of hydrogen), which contains one neutron, making the atomic mass heavier. Heavy water, used in the nuclear industry, is water composed of deuterium (a hydrogen atom that contains one neutron) and oxygen. The common isotope of oxygen normally contains 8 protons and 8 neutrons (^{16}O) but may also occur as the rarer isotope ^{18}O which has two additional neutrons, making the oxygen atom heavier and therefore making the water molecule heavier.

Ocean water contains water molecules with both heavy isotope properties and water molecules with the more prevalent lighter hydrogen and oxygen isotopes. Higher energy and higher temperatures are required to evaporate the heavy isotope water molecules into the air where they are held as water vapour. Colder temperatures cause this water vapour to precipitate as rain or snow, with the heavy water isotopes preferentially precipitating out in colder weather. Warmer temperatures in the atmosphere will therefore have a higher concentration of the heavier isotopes of hydrogen and oxygen. The deuterium content of snowfall, at different temperatures, has been well studied and well documented across geographical East Antarctica and across a large range of temperatures, enabling a clear determination of the linear relationship between deuterium and surface temperatures.[23]

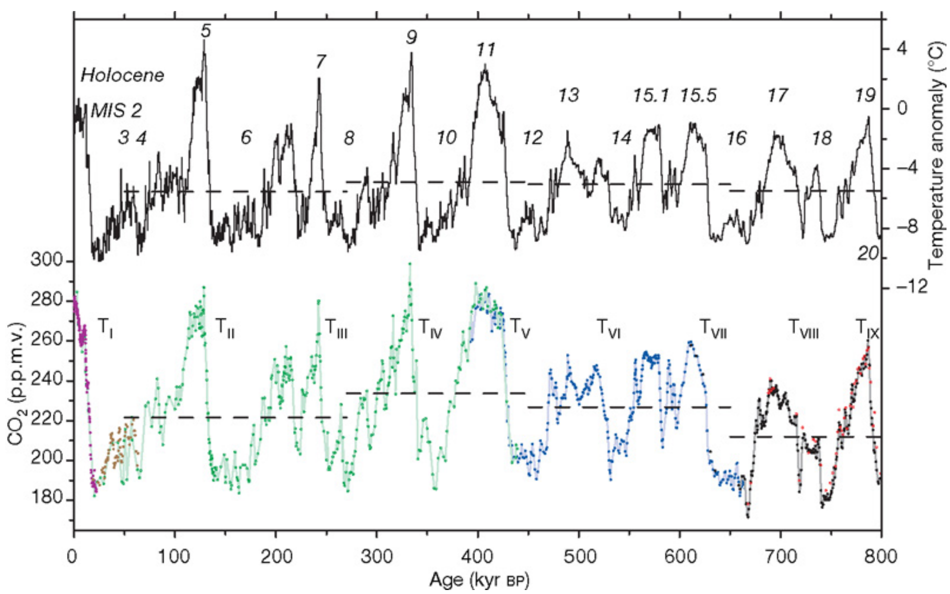
EPICA ice cores were first analyzed for their deuterium content based on the drilling up to the end of the 2002/2003 Antarctica drilling season. The results were published in *Science* in November, 2005 and compared both with the earlier Vostok records as well as with deep ocean drilling cores from bottom sediments that have been assessed for their ^{18}O content which, in turn, reflected corresponding surface temperatures. These comparisons line up in very tightly, corroborating each other and providing an excellent correlation for the accuracy of the EPICA records.[24] The coupling between the CO_2 measurements and the deuterium Antarctic temperature data are very strong. Uri Siegenthaler and his colleagues found it remarkable that the records backed each other up and that the coupling of CO_2 to temperature remained substantially unchanged during the 650,000 of records available in 2003.[25]

In the 2004/2005 Antarctic season EPICA drilled down the final 70 meters. This was followed by the analysis of the lowest 200 meters of ice, which subsequently pushed back the deuterium / temperature records, as well as the CO_2 records, to 800,000 years. Again, atmospheric CO_2 was found to be tightly correlated to the deuterium temperature record.[26] The results were published in *Nature* on May15, 2008. This paper, like its sister paper published in *Science*, November 2005, was equally important for providing the necessary quantum of scientific research to fundamentally anchor our understanding of the CO_2 –temperature relationship.

Dieter Luthi, from the Climate and Environmental Physics Institute, University of Berlin, working with six additional colleagues from the Institute, as well as with colleagues from the Laboratoire de Glaciologie et Geophysique de Environment, Grenoble, and with colleagues from Institut Pierre Simon Laplace / Laboratoire des Sciences de Climat et de Environment, University of Versailles, and the Alfred Wagner Institute for Polar and Marine Research in

Bremerhaven, Germany, had collaboratively analyzed the last 200 meters of the EPICA Dome C ice core to complete an 800,000 years record for CO_2 (analyzed from the atmospheric bubbles trapped in each layer of the ice core) and they produced the same record for the same time period for climatic surface temperature by analyzing the water in the ice core samples for deuterium, thereby providing a continuous record of climate temperature across 800,000 years to complement the CO_2 record. The same ice core is analyzed for atmospheric CO_2 in the trapped air bubbles, while the temperature record is deduced from the water isotopes in the ice adjacent to the air bubbles.

The 800,000 year old EPICA ice core record from Antarctica fully delivered on expectations and provided absolute evidence that carbon dioxide is indeed, strongly correlated with temperature. One of the key graphics published in *Nature* 2008 clearly presents the correlated record for the linkage between atmospheric CO_2 measured in the bubbles trapped in the EPICA ice core samples and the climatic temperature record based on deuterium analysis of the water molecules locked in the adjacent ice. The graphic is reproduced below.[27]



The Dome C temperature anomaly record with respect to the mean temperature of the last millennium[8] (based on original deuterium data interpolated to a 500-yr resolution). Data for CO_2 are from Dome C (solid circles in purple[5], blue[4], black: this work, measured at Bern; red open circles: this work, measured at Grenoble), Taylor Dome[6] (brown) and Vostok[1, 2, 3] (green).[28]

This graph, so important to our current understanding of the relationship between CO_2 and temperature, presents the analytical results for the last 200 meters of the EPICA Dome C drilling, the earlier results for the Dome C drilling published in *Science*, 2005, the results from the adjacent Vostok drilling program, and the results from the adjacent EPICA Antarctica drilling at the Dome Taylor site.[29]

With the CO_2 –temperature correlation now empirically established, scientists were now able to look at details of this critical relationship, and specifically how CO_2 and temperature behave in tight time intervals. This is a challenge for the ice core analysis because the solid ice (and therefore the deuterium) will always appear earlier in time before the adjacent gas bubbles, as it takes longer for the atmosphere to be caught in the surface layers of the snow and slowly compressed into ice that has trapped the air bubbles. We would, therefore, always expect a lag in time of CO_2 in the air bubbles over the temperature record measurement of the water isotopes in the solid ice. CO_2 itself is transferred from the oceans to the atmosphere to the biosphere and to the earth in lengthy cycles, and this further extends the time interval between CO_2 levels and surface temperatures. The glacial ice formation response to lower CO_2 levels pushing lower temperatures will not, therefore, be immediate.

Monthly global temperature monitoring reports are issued below, and we note here that they are issued by the U.S. National Oceanic Atmospheric Administration (NOAA), NASA's Goddard Institute for Space Studies and by the U.K. Met Office, and are reported on annually by the World Meteorological Organization. The linear warming trend over the past 50 years (0.13°C per decade) is now nearly twice that for the past 100 years.[30] The rate of warming has accelerated over the past 30 years, increasing globally since the mid-1970's at a rate approximately three times faster than the century scale trend.[31]

We can now identify two of our first Hard Science conclusions from this discussion:

1. We now know with certainty that CO_2 levels have demonstrated a natural variability range of 172-300 ppm. That means that CO_2 has never gone below 172 ppm and has never gone above 300 ppm over the past 800,000 years. This science is of critical importance to providing context for the instrumental direct observation of CO_2 levels, which have been rising steadily since 1955, when records were first established, and which currently stand at 384.78 ppm.

2. We now know that rising CO_2 levels will result over time in rising global temperatures because of the proven 800,000 correlation record identified in the ice cores. This, in turn, provides context for the global temperature warming trend over the past 50 years (0.13°C per decade) which is now three times greater than the 20th century trend.

What is of critical importance to us is the magnitude and behaviour of the impending temperature response to rising CO_2 levels. The only way in which we can know this is by generating models of the ocean –atmosphere systems that allow us to forecast this temperature response. To do this, we must have increasingly accurate climate models. Climate models must be constantly calibrated to observed behaviour of our climate to accurately enable us to forecast the all important global temperature response to rising CO_2. To accurately forecast global temperature response, we require climate monitoring of the ocean, atmosphere and land components of our Planet, so let us now take a brief look at the current state of global monitoring on our Planet.

Hard Climate Change Science

Global climate monitoring

We have come a long way since the formation of the first meteorological network in northern Italy in 1653 and the invention of the mercury thermometer by Gabriel Fahrenheit in 1714. By the latter part of the 19th century, systematic observations of the weather were being made in almost all inhabited areas of the world. Formal international coordination of meteorological observations from ships (beginning first with the temperature measurement of buckets of drawn sea water) commenced in 1853.[32] Today, with global integration of ocean, land, atmospheric and space based observations, we are closing in on a coordinated and comprehensive global monitoring system such as has never before existed on the Planet.

One of the major issues in global climate monitoring is the international coordination of the thousands of silos of monitoring programs and projects to provide strategic direction and ensure a high quality climate data base that continues to reach towards a critical mass of complete, integrated, global climate monitoring. There are, at present, thousands of on-going climate measurements currently being taken and reported from satellites, dedicated planes, dedicated project ships, volunteer commercial ships, land stations, dedicated climate observatories, tall tower systems, anchored ocean buoys and drifting ocean buoys and tidal gauges (to list only a few), sending in an unprecedented level of climate data.

The World Meteorological Organization coordinates a vast international integration of global climate monitoring through the operation of GCOS, the Global Climate Observing System. The WMO status report published in September, 2009 on the implementation of the GCOS work plan for 2004-2008 addresses the coordination of the global and regional monitoring systems used world wide in global climate monitoring.[33]

GCOS has selected 1000 global climate surface stations and 4000 regional stations selected from a world wide observational set of over 10,000 stations, chosen based on geographical coverage, availability and quality of data. 95% of these stations are operational and about 80% are submitting their data to GCOS (with data quality ensured at German and Japanese meteorological agencies), although submission rates are moderate for South America and low for Africa. These stations provide the essential climate variables such as temperature, wind and precipitation.

Ocean sensors now provide current and sea surface temperature from 1250 drift buoys in the global surface drifting buoy array which are tracked by NOAA through satellite monitoring. The upper ice-free 1500 meters of the ocean are being systematically monitored for temperature for the first time in history, using 3300 Argo profile buoys that automatically monitor the ocean column at certain depths, then rise to the surface to send their data to receiving satellites which beam this back down to NOAA ground stations for analysis and input into the ocean monitoring community. There are 119 permanently moored buoys (anchored with railcar wheels) in the tropical zones of the Pacific, Atlantic and Indian Oceans, reporting in real time on sea surface temperature and current movements at various depths.

147 of a planned 170 global tide gauges are currently operational and provide high-frequency (hourly or better reports), which are necessary for understanding sea level variability and sea level rise.

The WMO explicitly reports out on the challenges of organizing the GCOS undertaking and carefully assesses the performance on the achievement of key objectives. The GCOS report concludes that implementation of the various observing systems in support of the UNFCCC has progressed significantly over the last five years, but that sustaining the project-based funding of many important systems is fragile, there has been only limited progress in filling observing system gaps in developing countries, and there is still a long way to go to achieve a fully implemented global observing system for climate.[34]

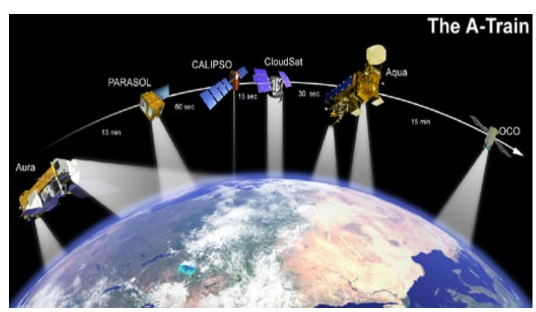
space monitoring

Satellite monitoring complements much of the surface monitoring and helps to fill in the gaps and augment the global grid reporting network. One of the ways this is done, is by providing virtual constellations (a coordinated set of satellites operated by partner space agencies that focus on particular monitoring targets) to measure essential climate variables, such as ocean topography and sea level. Satellite infrared instruments now provide comprehensive monitoring of sea surface temperatures. Infrared monitoring will soon be complemented with all-weather microwave monitoring on board the JAXA and Sentinel satellite missions scheduled for launch in 2012 and 2013 respectively.

Glacier observational networks are now improving for South America. Large gaps continue to exist in Central Asia, and for the Himalayas in particular, although satellite monitoring for global land ice measurements from the Landsat and ASTER missions are providing satellite imagery of land mass observations. The Sentinel mission, scheduled for launch in 2012, will provide enhanced glacier mapping and will be supported by subsequent Landsat missions.

NASA A Train

NASA operates the A Train constellation of five satellites that fly in close formation to each other at 24,000 kms/hour 700 kms above the earth. The train makes 14 orbits per day and has a separation of 24.7 degrees longitude between each successive orbit at the equator. Each day, the orbit tracks 10.8 degrees westward so that a complete global grid is produced in each 16-day period with a separation between orbits of 172 kms on the ground.

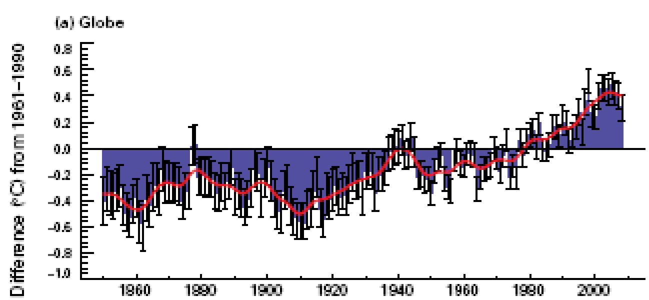


Aqua is the lead spacecraft in the formation, and is responsible for monitoring the earth hydrological cycle, including water, ice and water vapor measurements. *CloudSat* lags *Aqua* by 30-120 seconds and provides 3D analysis of cloud formations important in the understanding of cloud behavior affecting climate change. *Calipso* lags *CloudSat* by no more than 15 seconds and carries out measurements required to understand how clouds and aerosols interact with one another to affect climate change. *Parasol*, launched by the French space agency by an Ariane 5 G+ from the Europe spaceport in Kourou, French Guiana, lags *Calipso* by 60 seconds and focuses on natural and man made aerosols. *Aura* lags *Aqua* by about 15 minutes but crosses the equator only 8 minutes behind *Aqua* due to its different orbital track that allows synergy with *Aqua*. *Aura* monitors the vertical and horizontal distribution of key atmospheric pollutants and greenhouse gases.[35]

OCO, the Orbital Carbon Observatory satellite, was to measure CO_2 emissions and CO_2 uptake by carbon sinks, which would be critical to predicting future greenhouse gases emissions under the new greenhouse treaty. It was intended to be inserted in front of Aqua and to lead the A Train. Unfortunately, the *OCO* launch failed on February 24, 2009. It is currently not clear whether this valuable satellite will be replaced.

Current CO_2 and temperature levels

The state of global climate monitoring provides tangible results with respect to monitoring global atmospheric CO_2 and global surface temperature status and trends. Climate monitoring centers in the U.K., Europe and North America are now able to issue regular reports on CO_2 and temperature variables. The U.K. Met Office organizes global monitoring systems, for example, to issue quarterly reports on global sea surface temperatures, global land surface temperatures, and combined sea surface –land temperatures, generally referred to as the global temperature.



The Met Office uses the 1961-1990 (annual average temperature equals 14.0°C) period as a baseline for average global temperature and then assessed that against the 1850-2008 global temperature record. Both the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.K. Met Center, found 2008 as the tenth warmest year on record (notwithstanding that they use separate methodologies). Since the beginning of the twentieth century, the global temperature has risen by 0.74°C .The Met Office was a significant contributor to the ICCP Fourth Assessment Report.

NOAA operates the GEOSS earth monitoring program, which links up satellite monitoring with ocean buoys and land stations. NOAA issues monthly global CO_2 levels for monthly mean CO_2 atmospheric concentrations, annual mean

CO_2 atmospheric concentrations, and annual mean CO_2 growth rates, for both the globally distributed network of air monitoring sites and for their long established observatory at Mauna Loa, Hawaii. CO_2 levels have risen from their 800,000 maximum of 380 ppm to:

Global CO_2 Highlights

- CO_2 over 310 ppm in 1960
- CO_2 over 380 ppm in 2007
- CO_2 at 384.78 ppm in September 2009.[36]

The World Meteorological Organization issues annual status reports on the global climate, and recently issued the report for 2008.[37] WMO global temperature analyses are primarily based on monitoring datasets maintained by the Met Office Hadley Centre, UK, and the Climatic Research Unit, University of East Anglia, UK, by the United States Department of Commerce National Oceanic and Atmospheric Administration (NOAA), and by NASA's Goddard Institute for Space Studies.

The global mean temperature for 1961-1990 was 14°C . The WMO 2008 report issued the global mean temperature as 14.31°C, indicating an increase over the 1961-1990 baseline period of 0.31° degrees.

NOAA also publishes monthly global temperature trend reports. Since the beginning of the twentieth century, the global temperature has risen by 0.74°C. The linear warming trend over the past 50 years (0.13°C per decade) is nearly twice that for the past 100 years.[38] Excerpts from the NOAA September 2009 monthly report are presented below:[39]

Global Temperature Highlights

> The combined global land and ocean surface temperature for September 2009 was 0.62°C above the 20th Century average. This was the second warmest September on record, behind 2005, and the 33rd consecutive September with a global temperature above the 20th Century average. The last below-average September occurred in 1976.
>
> The global land surface temperature for September 2009 was 0.97°C above the 20th Century average and ranked as the second warmest September on record, also behind 2005.
>
> And within the past three decades, the rate of warming in global temperatures has been three times greater than the 20th century scale trend.

With the growth in global climate monitoring, the increasing synthesis of data systems and the approximation of tighter global grid monitoring for expanding global coverage, particularly from satellite climate monitoring, we now have direct measurement of CO_2 and temperature measurements and trends. These trends can be compared to the EPICA

800,000 climate record to clearly tell us that we have far exceeded natural climate variability for this considerable time period.

Our overriding concern is now centered on monitoring continuing CO_2 emissions, the resulting atmospheric CO_2 concentrations, the current global temperature, and importantly, the predicted global temperatures (using climate models calibrated against reported global climate monitoring) for the coming decades, so that we can take the steps necessary to arrest global warming.

We can now identify two more of our first Hard Science conclusions from this discussion:

3. We now know from the globally distributed climate monitoring system (on land, oceans, atmosphere and space) that CO_2 levels have risen far above the EPICA 800,000 year baseline of 172-300 ppm. CO^2 levels have risen from over 310 ppm in 1960, to over 380 ppm in 2007, to the current level of 384.78 ppm in September 2009.

4. The current combined global land and ocean surface temperature is 0.62°C above the 20th Century average. Within the past three decades, the rate of warming in global temperatures has been approximately three times greater than the century scale trend.[40]

The major uncertainty remaining is with gaps in global climate monitoring (particularly the southern hemisphere) and the predictive accuracy of the climate models. As climate monitoring becomes ever more comprehensive, climate models become ever more accurate. Forecast results are tending toward higher, not lower, global temperature projections.

We have now seen that we can, in fact, unravel even complex climate change science and make it completely accessible to the general electorate. Other important components will now need to be reviewed, such as the science between the competing climate change strategies aimed at achieving greenhouse gas emissions target levels that are either 3% or 25% below the 1990 level by the year 2020. Accessible climate change science will, at the very least, lead to better informed voters. At best it will lead to increased support for climate change policies required to stabilize atmospheric CO_2 levels and global temperatures.

This task is one that government secretariats and NGOs must urgently assume to augment existing outreach programs.

Moving Forward

Conclusions and recommendations for climate change secretariats and NGOs

1. *Main conclusion on one of the principal causes for low political support for climate change strategies*

The low political support for climate change strategies is a reality as evidenced from the polling information discussed in this Paper. One of the principal causes for this low support is the outstanding doubts held by many with regard to the reality of global warming and climate change. This scepticism stands in the face of scientific evidence that demonstrates beyond any reasonable doubt that current CO_2 levels are well beyond the record for the last 800,000 years and that global temperatures, which are physically linked to CO_2 levels, are now rising three times faster than the 20th century trend.

One of the central reasons for this scepticism is that we have yet to find a way to communicate climate change science in a meaningful, comprehensive and effective manner. Most secretariats and many NGO websites do have climate science components on their menus, yet the science is not adequately addressed. The hard science behind climate change is rarely communicated effectively, due in part to the complex and interdisciplinary nature of climate change, and due also to the fact that climate change scientists are not policy makers and policy makers are not climate change scientists. Too often information accessibility has been achieved at the cost of superficial interpretation that convinces no one but the converted.

This must change immediately. The science must be interpreted in a comprehensive manner to directly address the persistent doubts held by many that so weaken the critical support for climate change strategies. Initially few will wish to wade into climate change science, but this will change as hard decisions are faced on transitioning away from carbon economies. For many, it will be sufficient to know that trusted and *accessible* science is available on demand at the very secretariats who are designing the climate change strategies.

This is not the time to give up on interpreting the science. This is the time to ramp up the communication of climate change science to the next level.

2. *Identify priority areas of science for improved interpretation*

Climate change secretariats, NGOs and others involved in designing climate change strategies should rigorously review their climate change science component of their websites to determine, first, if they have actually explained the science in a comprehensive, accurate and credible manner, and second, whether this information is accessible. Unsuccessful science interpretation must be identified and prioritized for redress.

3. *Examples of priority areas requiring improved interpretation*

We have reviewed two principal areas of climate change science in this paper:

- the relationship of currently rising levels of CO_2 levels which greatly exceed the known 800,000 year record; and

- the relationship of CO_2 levels to global average temperatures which we know are rising three times faster than the 20th century trend.

4. *Maintain an on-going assessment of advancing climate change science and identify emerging areas that require review, interpretation and communication.*

An additional example that may be reviewed now is the science between competing climate change strategies aimed at achieving greenhouse gas emissions target levels that are either a 3% or a 25% reduction below the 1990 level by the year 2020.

5. *Leaders lead the way*

Government leaders themselves should make climate change statements referencing the hard science to demonstrate their own confidence, and the confidence of their governments, in the science underlying our understanding of climate change and the accuracy of current global climate monitoring conclusions on CO_2 and temperature levels.

6. *Keep the debate open and welcome to all sceptics*

Climate policy makers in government, industry and NGOs must resist the tendency to reference climate change science at a distance and to simply state that the climate change debate is over. Instead, they must make the foundation science of climate change readily available, accessible and current so that citizens can competently inform themselves on established climate change science. This, in turn, will help to firm up the political support required to decarbonise the global economies and will help to support the requisite regional strategies as well as the on-going, post-Copenhagen international carbon negotiations.

7. *A note on considerations for developing economies in international carbon negotiations*

National carbon strategies and international carbon treaties must do more than provide for the option of purchasing international carbon credits, based on emission reduction and enhanced sink productions through decreased deforestation. These strategies and agreements must also provide for financial transfers from high emission and high capacity nations to low emission and low capacity southern hemisphere nations for mitigation and adaptation. In turn, the developing economies must develop their own commitments to national carbon reduction strategies. It will be these commitments that will enable developing economies to survive within the demanding forum of international accords that may provide for local adaptation costs.

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