Professional paper

Some basic questions about climate models

David B. South, Peter Brown and Bill Dyck[1]

Some foresters are concerned about increasing CO_2 levels in the atmosphere while others doubt that CO_2 has been the main driver of climate change over the past million years or over the past two centuries (Brown *et al.* 2008). We three admit that (1) we do not know what the future climate will be in the year 2100, (2) we do not pretend to know the strength of individual feedback factors, (3) we do not know how much 600 ppm of CO_2 will warm the Earth and (4) we do not know how the climate will affect the price of pine sawlogs in the year 2050 (in either relative or absolute terms). The climate is not a simple system and therefore we believe it is important to ask questions. The following 15 questions deal mainly with global climate models (GCM).

A LIST OF QUESTIONS

1: Have any of the climate models been verified?

Relying on an unverified computer model can be costly. NASA relies on computer models when sending rockets to Mars and the model is verified when the landing is successful. However, when using one unverified computer model, a $125 million Mars Climate Orbiter crashed on September 23, 1999. The model was developed by one team of researchers using English units while another used metric units. This crash demonstrates how costly an unverified computer model can be to taxpayers. At the time, Edward Weiler, NASA's Associate Administrator for Space Science said "People sometimes make errors".

Is it possible that people sometimes make errors when developing complex models that simulate the Earth's climate? Is it possible that some models might have "cause and effect" wrong in the case of feedback from clouds? Is it possible to construct models that produce precise (but inaccurate) estimates of temperature in the future? Do some researchers believe in computer predictions more than real data?

A report by the International Panel on Climate Change (IPCC) shows a predicted "hot zone" in the troposphere about 10 km above the surface of the equator (IPCC 2007b; Figure 9.1f). Why has this "hot zone" not been observed? We do not know of any paper that reports the presence of this, theoretical, hot spot. Is the absence of this hot zone (Douglass *et al.* 2007) sufficient to invalidate the climate models? If not, why not?

IPCC figure TS.26 includes computer projections of four CO_2 emission scenarios for the years 2000 to 2025 (IPCC 2007a). Figure 1 is an updated version with extra data points. The mean of the projections for global temperatures are jagged, suggesting that for some years the temperature is predicted to increase (e.g. 2007) while in others the temperature is predicted to decline slightly (e.g. 2008). However, observed data for 2006, 2007 and 2008 all fall below the projections. Although several models suggest the temperature for 2008 should be about 0.59 °C above the 1961-1990 mean, the value in 2008 was 0.328°C (are all three digits past the decimal point significant?). Although we should not expect any given year to lie on the line, this value is outside the range of "uncertainty" listed for green, red and blue lines and is almost outside the uncertainty range for the orange line. If the observed data falls outside the range of uncertainty for eight years into the future, why should foresters be "believe" the models will be accurate (ie. lie within the uncertainty bar) 100 years into the future? At what point do we admit the Earth's climate is not tracking with the "virtual" climate inside a computer? Is the theoretical "hot spot" above the equator a result of programming error? More importantly, how much money are foresters willing to spend on the output of unverified computer models?

2: Is it possible to validate climate models?

"Verification and validation of numerical models of natural systems is impossible. This is because natural systems are never closed and because model results are always non-unique. Models can be confirmed by the demonstration of agreement between observation and prediction, but confirmation is inherently partial. Complete confirmation is logically precluded by the fallacy of affirming the consequent and by incomplete access to natural phenomena. Models can only be evaluated in relative terms, and their predictive value is always open to question. The primary value of models is heuristic". (Oreskes *et al.* 1994).

3: How accurate are the predictions of climate models?

Australian Bureau of Meteorology uses computer models to project weather outlook for three months into the future. The Bureau's web page states that "These outlooks should be used as a tool in risk management and decision making. The benefits accrue from long-term use, say over ten years. At any given time, the probabilities may seem inaccurate, but taken over several years, the advantages of taking

[1]*David South is a Forestry Professor at Auburn University, Bill Dyck is a Science and Technology Broker who has worked for the plantation forest industry and Peter Brown is a Registered Forestry Consultant. The authors' statements should not be taken as representing views of their employers or the NZIF. Full citations may be found at: https://fp.auburn.edu/sfws/south/citations.html*

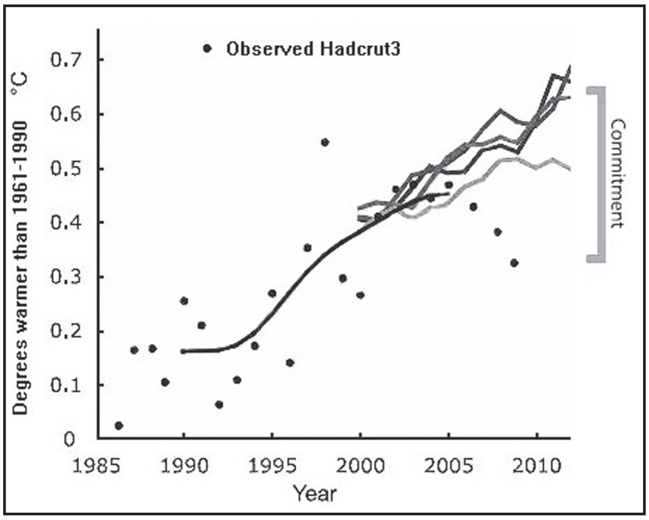

Figure 1. A comparison of observed surface temperature means (Hadcrut3) with model projections of Hadcrut3 global averages (adapted from Figure TS.26 in IPCC technical summary - page 69). Observed annual mean temperatures are shown (black dots) along with decadal averages (1990-2005 line). Multi-model mean projections (2000-2013 lines) from the IPCC (2007a) report for the SRES B1, A1B and A2 scenarios (top three lines) and a "commitment" scenario. The orange "commitment" curve shows means of 16 model projections of warming if greenhouse gas and aerosol concentrations were held constant from the year 2000. The uncertainty range indicated against the right-hand axis is for the "commitment" scenario only. Observed values for 2006, 2007 and 2008 are all below the "commitment" line and the observed value for 2008 might lie below the uncertainty range.

account of the risks should outweigh the disadvantages." Is this statement simply a hope or is it supportable by data? These computer model predictions can be compared with actual temperature data over a ten year period. The results could illustrate if farmers (who invest money based on the predictions) have benefited from the models or have they suffered from use of the models. The difference can provide evidence to illustrate if the 3-month forecasts are any better than flipping a coin. One reason why many farmers do not use these 3-month forecasts is because in some areas, the models are no better than a random guess.

Some claim it is more difficult to predict weather three months into the future than it is to predict the climate 100 years into the future. We question this belief system. What is the record of predicting climate 100 years into the future? Which of the 23 climate models is the most accurate when predicting past events? Is a complex computer program that predicts the average temperature for NZ in the past more accurate than one that predicts the average temperature for the Earth 100 years from now? Which prediction would be more accurate (determined by predicted minus actual °C)? Which set of comparisons has the greater standard deviation?

We know that climate models can vary widely in their guesses about how much rain a specific region on Earth might receive (Singer 2008). So how accurate are climate models when predicting the past? When models predict precipitation for a given location, we can compare the prediction with actual records. For example, Lim and Roderick (2009) provided predictions of annual precipitation for the last three decades of the 20th Century. Examination of the output from 39 computer scenarios reveals that predictions of NZ annual precipitation (Figure 2) ranged from 936 mm to 1851mm/yr (mean of 1293 mm; standard deviation was 226 mm). The recorded mean rainfall/precipitation of 29 AWIS stations (located mostly at towns or cities) for the years 1971-2000 was 1419 mm, but the mean of 27 AWIS stations (not including Milford Sound and Mount Cook) was 1115 mm. Neither value represents the actual mean precipitation value for NZ, in fact we do not know of an accurate estimate. One cannot take 268,680 km^2 and multiply it by some number (say 1.3 m) to determine the mass of water that fell on NZ in 1999. Of the 39 computer estimates of past NZ precipitation, how can we identify the one that is closest to the actual value for NZ if we cannot even determine the actual value?

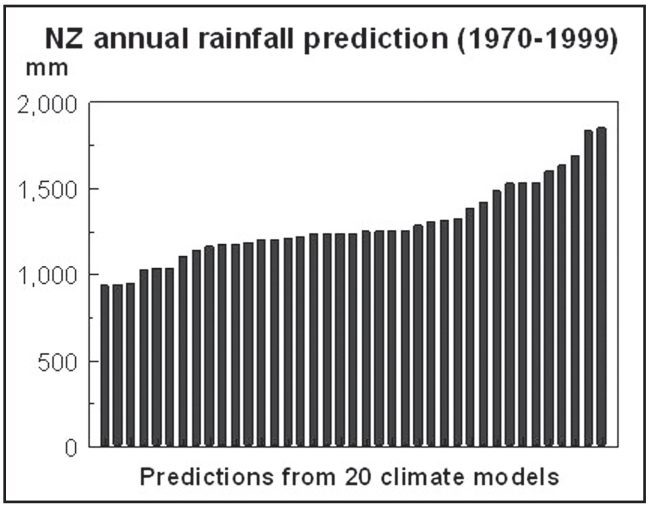

Figure 2. A comparison of predicted rainfall from 20 climate models (adapted from Lim and Roderick 2009). There are 39 output scenarios (bars) with some climate models producing seven estimates and some with only one estimate. Nobody knows the mass of precipitation that fell on NZ during the 30 year period and therefore we do not know which computer simulation is closest to the actual value for average rainfall in NZ.

4: Most climate models have clouds as a positive feedback mechanism. If clouds actually produce a negative feedback, then CO_2 caused global warming is a non-issue (i.e. warming over then next 100 years might be 0.5 °C). Do climate models have clouds modelled correctly?

"All 23 IPCC climate models now exhibit positive cloud and water vapour feedback" (Roy Spencer, personal

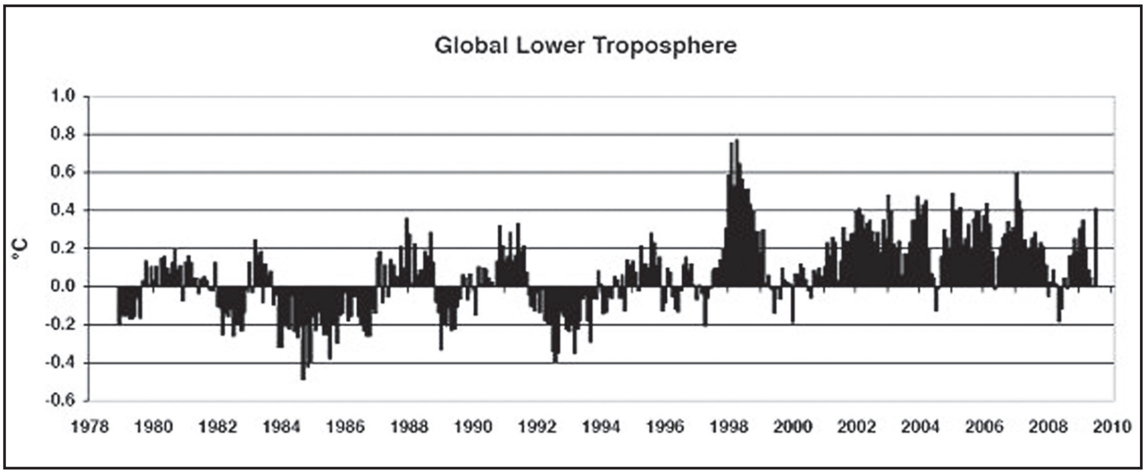

Figure 4. Globally averaged satellite-based temperature of the lower atmosphere (where zero = 20 year average from 1979 to 1998). February, 1998 was 0.76 °C above the 20-year average. Data provided by Professors John Christy and Roy Spencer, University of Alabama, Huntsville.

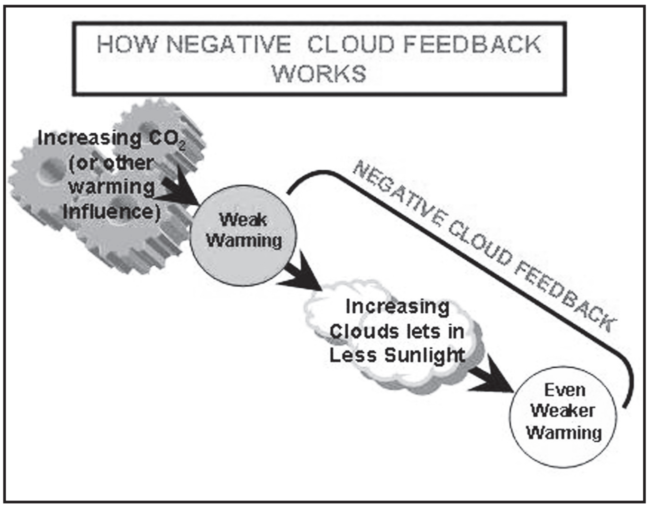

Figure 3 A negative cloud feedback would increase the Earth's albedo (figure provided by Dr. Roy Spencer).

communication). Most climate modellers assume that weak warming will decrease the amount of clouds which reduces the albedo of the Earth. A lower albedo (ie. less cloud cover) results in more warming.

In contrast, Spencer and Braswell (2008) suggest that clouds likely produce a negative feedback. Weak warming seems to increase the amount of clouds which increases the albedo of the Earth (Figure 3). If increases in CO_2 results in more clouds, this will invalidate most climate models. Roy Spencer said that "if feedbacks are indeed negative, then manmade global warming becomes, for all practical purposes, a non-issue." What real-world data prove that increasing CO_2 will result in fewer clouds?

In 1988 Steven Schneider said "Clouds are an important factor about which little is known" (Revkin 1988). "When I first started looking at this in 1972, we didn't know much about the feedback from clouds. We don't know any more now than we did then."

Did climate models have the feedback from clouds correct in 1988? Is the feedback from clouds any different now than it was three decades ago? Does the magnetic activity of the sun affect cosmic rays and the formation of clouds (Svensmark and Calder 2007)? Do climate modellers include cosmic rays in their models? Do climate modellers really believe their 2009 models have the formation of clouds correct in their models?

5: Can we estimate how much of the +0.76°C temperature departure recorded in February 1998 (Figure 4) can be attributed to El Niño and how much can be attributed to the CO_2 that originates from burning of fossil fuels?

Steven Schneider (Revkin 1988) said "To begin with, the magnitude of the various perturbations (to use the scientists' delicate word) of the environment are difficult to predict. And estimates of even the immediate effects of those perturbations are unreliable. Still harder to predict are the ground-level consequences of these effects - for example, the number of feet by which sea level will rise given a particular rise in the temperature of the globe, or the effects on phytoplankton of a particular increase in ultraviolet radiation caused by a particular reduction in the ozone layer. Harder yet to predict - lying, really, entirely in the realm of speculation - are the synergistic consequences of all or some of these effects. And lying completely beyond prediction are any effects that have not yet been anticipated."

"For all these reasons, the margin for error is immense. And that, of course, is the real lesson to be learned from the world's earlier attempts at predicting global perils. What the mistakes show is that in these questions even the most disinterested and professional predictions are filled with uncertainty. Uncertainty in such forecasts is not a detail, soon to be cleared up; it is part and parcel of the new situation - as inextricably bound up with it as mounting levels of carbon dioxide or declining levels of ozone. For the scientists' difficulties do not stem merely from some imperfections in their instruments or a few distortions in their computer models; they stem from the fundamental fact that at this particular moment in history mankind has gained the power to intervene in drastic and fateful ways in a mechanism - the ecosphere - whose overall structure and workings we have barely begun to grasp."

6: How did the IPCC determine that it is extremely unlikely that warming in the past 50 years was caused by natural fluctuations?

Table 9.4 in WG1 (page 792; IPCC 2007b) provides a synthesis of "climate change detection results." Regarding surface temperature, the authors state that it is extremely likely (>95%) that "warming during the past half century cannot be explained without external radiative forcing." We wonder, exactly what does this statement mean? Are the authors simply predicting that researchers (e.g. Svensmark and Calder 2007; Spencer and Braswell 2008; Klotzbach *et al*. 2009) will never publish papers to suggest that natural variation in clouds could explain the warming?

We agree that humans have altered surface temperatures by construction of roads and cities, afforestation, producing black carbon (i.e. soot), burning of fuel (which releases heat and water vapour). We have no doubt that temperatures records are biased upwards because of "heat islands" and because thermometers are often located in improper locations (Klotzbach *et al*. 2009). However, it is not clear how the ">95% likelihood" value was obtained. Was it obtained from "an elicitation of expert views" (IPCC 2005) or from a quantitative analysis of output from climate models (Tett *et al*. 1999)?

7: What system was sampled when declaring an anthropogenic change has been detected with less than 1% probability?

In 2001, the IPCC panel concluded that "most of the observed warming over the last 50 years is likely due to increases in greenhouse gas concentrations due to human activities." In 2007, the IPCC authors go on to say that "Anthropogenic change has been detected in surface temperature with very high significance levels (less than 1% error probability)"(IPCC 2007b). We wonder how the authors went about calculating a p-value of <1% if there is confounding between CO_2 increases and natural changes in clouds? We asked a few IPCC experts, they said the p-value was obtained by generating a data set from a computer model. In other words, you create a virtual world without people, generate hypothetical temperatures from the virtual world, compare the two sets (virtual world with people and virtual world without people) and then generate a p-value.

In 2007, Dr. Bob Carter (Adjunct Professorial Research Fellow - James Cook University) wrote "In the present state of knowledge, no scientist can justify the statement: 'Most of the observed increase in globally averaged temperature since the mid-20th century is very likely due [90 per cent probable] to the observed increase in anthropogenic greenhouse gas concentrations,' as stated in the IPCC's 2007 Summary for Policy Makers." We agree with Dr. Carter. We assume that virtual worlds were sampled to determine the 1% probability. We claim that the 1% probability was applied to output from climate models and not to replications made from the real world.

8. One climate model suggests that increasing the albedo of the Earth's surface from deforestation is stronger than the CO_2 effect from deforestation. Would harvesting native forests in temperate and boreal zones (plus making wood furniture and lumber from the harvested logs) and converting the land to pastureland cool the Earth?

After examining a virtual Earth, Bala *et al*. (2007) said "We find that global-scale deforestation has a net cooling influence on Earth's climate, because the warming carbon-cycle effects of deforestation are overwhelmed by the net cooling associated with changes in albedo and evapotranspiration." Has this climate model been verified? If an increase the albedo (from deforestation) is more powerful than the CO_2 effect (South 2008a), why are albedo credits (South and Laband 2008) not included in Climate Trading Schemes?

9. IPCC authors predict an increase in the number of record hot temperatures and that this will often cause a decline in the number of record cold temperatures. Are there data to support this claim? Is it true that an increase in record high temperatures will result in a decline in record low temperatures?

Solomon and others (IPCC 2007a) say that "linking a particular extreme event to a single, specific cause is problematic" and we concur. However, the authors go on to say that "An increase in the frequency of one extreme (e.g., the number of hot days) will often be accompanied by a decline in the opposite extreme (in this case the number of cold days such as frosts)." We do not know of a reference to support this claim. We question the claim that the probability of a record cold event in January or July is less now than it was in the 19th century. In fact, in 2009, six U.S. states set cold temperature records (115 year data) for the month of July (IA, IL, IN, OH, PA, WV). Why did these records occur if the probability of a cold July is less now than it was in 1893?

We also question the claim that "In some cases, it may be possible to estimate the anthropogenic contribution to such changes in the probability of occurrence of extremes." How is this possible? Other than simply guessing, we fail to see how a scientist could estimate an anthropogenic contribution to an increase in frequency of record cold/high

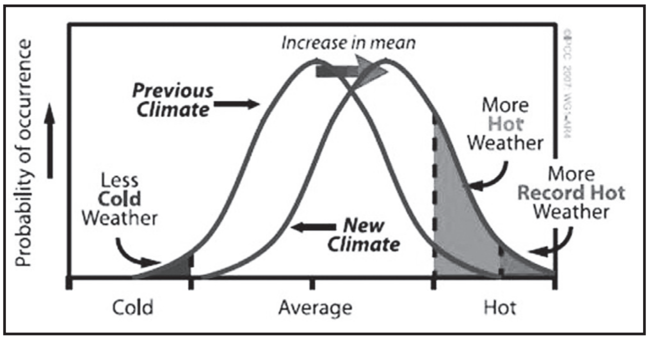

Figure 5. Schematic showing the IPCC view that little or no skew and kurtosis occurs when the mode shifts by +0.7 °C. The authors suggest the probability of extreme low temperatures decrease in proportion to the probability of high temperature (Figure 1, Box TS.5 from IPCC 2007a).

temperatures. Rare events do occur in nature. Researchers can certainly show a correlation, but how would they determine how much of the 0.76 °C departure in Figure 4 is anthropogenic? We "estimate" that 99% of this value is due to El Niño but we admit this estimate can not be verified.

Solomon, Qin, Manning and others suggest temperatures for a given region or for the Earth follow a "familiar 'bell' curve" and when the climate warms (for whatever reason), the entire distribution is shifted to the right (Figure 5). They suggest that a histogram of the pattern of temperature occurrences is similar for both the "previous climate"

Table 1. Dates of record high and low temperatures for some southern hemisphere locations (as of December 2008). Note that in these cases, the record low temperature occurred after the record high temperature. Although these records do not prove anything, they are not hypothetical. Note that no record high temperature occurred after 1975 and all record low temperatures but one occur after 1970.

Country/location	Record	°C	Date
Antarctica	High	14.6	5 January, 1974
	Low	-89.2	21 July, 1983
Argentina	High	48.9	11 December, 1905
	Low	-33	1 June, 1907
Australia	High	50.7	2 January, 1960
	Low	-23	29 June, 1994
New Zealand	High	42.4	7 February, 1973
	Low	-21.6	3 July, 1995
South Africa	High	50	3 November, 1918
	Low	-18.6	28 June, 1996
South America	High	49.1	2 January, 1920
	Low	-39	17 July, 1972

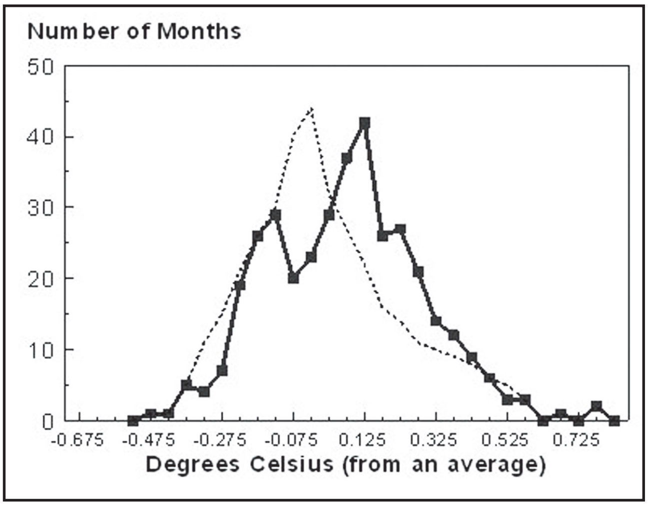

Figure 6. Histogram showing actual data (N = 367) from satellites over the period (December 1978 to June 2009). Each solid square represents the number of months that the temperature of the troposphere (above the southern hemisphere oceans) varied from an arbitrary mean value. Data (ie. solid squares) obtained from the Climate Center University of Alabama at Huntsville (http://www.ncdc.noaa.gov/oa/climate/research/uahncdc.lt). The dashed line represents a hypothetical distribution from a cooler period in the past. In this graph, the tails from both curves are deliberately identical. The hypothetical line was drawn so that the probability of extreme events is not changed.

and the "new" warmer climate. We propose an alternate hypothesis (Figure 6). The distribution is negatively skewed with the tails about the same as before. A third hypothesis suggests that the warmed distribution becomes negatively skewed and flatter (i.e. platykurkic). This hypothesis is supported by predictions of ocean temperatures by the Max Planck Institute (National Assessment Synthesis Team 2000; page 83). Are there any actual data to support the IPCC hypothesis that assumes no change in kurtosis or skewness?

In Table 1, we provide some extreme high and low temperatures for selected land based locations in the Southern Hemisphere. Note that for these locations, no record high temperature occurred after 1975 and all but one record low temperature occurred after 1970. The occurrence of extreme low temperatures following record high temperatures in the southern hemisphere is interesting, especially since this is counter to the "no change in skew or kurtosis" hypothesis. The theory presented in Figure 5 suggests a 0% probability of a record extreme cold event occurring after global warming.

We predict that one or more of the records in Table 1 will be broken by the year 2100. If Antarctica drops below -90 °C, someone might claim it was caused by humans (perhaps due to chemicals depleting the ozone layer). Likewise, if a record high temperature occurs in Australia or New Zealand, we will likely read that it was caused by humans. The experts quoted might even take an unscientific approach and provide a probability in an attempt to prove the event was anthropogenic.

10. Solar irradiance that reaches the Earth's surface has declined since 1950. How much of reduction in irradiance is due to an increase in clouds and how much is due to an increase in pollution (i.e. soot and aerosols)?

"As the average global temperature increases, it is generally expected that the air will become drier and that evaporation from terrestrial water bodies will increase. Paradoxically, terrestrial observations over the past 50 years show the reverse" (Roderick and Farquhar 2002). How much of the "global dimming" (Stanhill 2005) is due to humans caused air pollution and how much is due to a negative feedback from clouds?

11. Why do some forest researchers use statistical downscaling approaches when the scenarios have largely been regarded as unreliable and too difficult to interpret?

Wilby and others (2004) have pointed out that some modellers combine coarse-scale (i.e. hundreds of kilometres), global climate models with higher spatial resolution, regional models sometimes having a resolution as fine as tens of kilometres. Most of the statistical downscaling approaches "are practiced by climatologists rather than by impact analysts undertaking fully fledged, policy oriented impact assessments. This is because the scenarios have largely been regarded as unreliable, too difficult to interpret, or do not embrace the range of uncertainties in GCM projections in the same way that simpler interpolation methods do. This means that downscaled scenarios based on single GCMs or emission scenarios, when translated into an impact study, can give the misleading impression of increased resolution equating to increased confidence in the projections" (Wilby *et al*. 2004).

12. When comparing similar locations and the same number of weather stations in NZ, has the average temperature changed much since 1860?

We agree that natural events affect the Earth's temperature (e.g. McLean *et al*. 2009). We also agree that human activities such as deforestation, afforestation, irrigation, road construction, city construction, etc. can alter the albedo of the Earth's surface. However, we are uncertain that average temperatures experienced in NZ during 1971 to 2000 are that much different than the temperatures experienced from 1861 to 1866 (Table 2). Why do temperatures records from Hokitika, NZ (since 1866) show no increase in temperature (Gray 2000)?

Predicted annual temperature changes (in °C) relative to 1980-1999 have been predicted for 12 climate models (Table A2.1 Ministry for the Environment. 2008). All 12 models predict an increase in temperature for NZ (for the period 2030 to 2049). A German model predicts only a 0.33 °C increase while a Japanese model predicts a 2 °C increase. In contrast, an older model (of unknown origin), predicts that NZ will be cooler in July 2029 than it was in July of 1987 (Revkin 1988). There are only about two decades to go before the year 2030, so it will be interesting to see which of the 13 models is closest to the observed data. When compared to 1987, will NZ be cooler in the winter of 2028 than most other locations in the world (Revkin 1988) or will it be about 2 °C warmer (e.g. miroc32 hires)?

13. Do outputs from climate models allow some researchers to selectively ignore real-world observations?

Farman *et al*. (1985) were the first to report a reduction

Table 2: A comparison of temperature data from five locations in New Zealand with predicted temperature in 2040. Pre-1868 data are from New Zealand Institute Transactions and Proceedings 1868 (http://tinyurl.com/7ycpl6) and post-1970 data are from National Institute of Water and Air Research (http://tinyurl.com/a5nj3c). Guesses for annual mean temperature for the year 2040 are in brackets (from Table 2.2 Ministry for the Environment. 2008). Table adapted from Vincent Gray.

Station	Years of data	Before 1867	Years of data	1971-2000	2040
		°C		°C	°C
Auckland	15	15.7	25	15.1	[16.0]
Taranaki - New Plymouth	12	13.7	20	13.6	[14.5]
Nelson	16	12.8	25	12.6	[13.5]
Christchurch	11	12.8	26	12.1	[13.0]
Dunedin	15	10.4	26	11.0	[11.9]
Mean		13.1		12.9	

in the Antarctic ozone hole. Some experts at first dismissed the observations of the British scientist since Farman's findings differed with predictions generated using NASA computer models (Schell 1989). This is not the only case where output from an unverified computer model was initially given more credence than actual observations. Recently, Svensmark and Calder (2007) provide data to propose a new theory of global warming. Have researchers relied on an unverified computer model to disprove a new theory of climate change (Pierce and Adams 2009)?

14. Do foresters rely on predicted timber prices that are generated from combining three complex computer models?

A climate model, a biogeochemistry model and an economics model were used to predict standing timber prices for the United States (Joyce *et al*. 2001). Prices were predicted to increase by 5 to 7% from 2000 to 2010 but no error bars were included the graph. In contrast, actual prices for standing sawlogs in 2009 are generally lower than they were in 2000 (in some cases 40% lower). Would any forestry consultant rely on 10-year price forecasts generated by combining three complex computer models? Do researchers actually believe they can determine what the price of standing timber would be in the year 2050 if CO_2 levels in the atmosphere were kept at 355 ppmv (Ireland *et al*. 2001)?

15. To capture the public imagination, should foresters offer up scary scenarios?

Stephen Schneider (Schell 1989) said "as scientists, we are ethically bound to the scientific method, in effect promising to tell the truth, the whole truth, and nothing but - which means that we must include all the doubts, the caveats, the ifs, ands, and buts. On the other hand, we are not just scientists but human beings as well. And like most people we'd like to see the world a better place, which in this context translates into our working to reduce the risk of potentially disastrous climatic change. To do that we need to get some broad-based support, to capture the public's imagination. That, of course, entails getting loads of media coverage. So we have to offer up scary scenarios, make simplified, dramatic statements, and make little mention of any doubts we might have. This 'double ethical bind' we frequently find ourselves in cannot be solved by any formula. Each of us has to decide what the right balance is between being effective and being honest. I hope that means being both."

Conclusions

We are concerned the scientific method is being downplayed in today's world. Hypothesis testing is an irreplaceable tool in science, but some no longer test hypothesis and others do not declare their doubts. Now, all that is needed to set policy is an unverified computer model, some warnings about the future, some name calling, and a good marketing program. Debate is essential to scientific progress, but it seems it is no longer in vogue. Sometimes, those who ask questions (like the 15 above) are ignored, suppressed, or attacked with name calling (e.g. see Witze 2006; Seymour and Gainor 2008; South 2008b).

Our profession should be a place where questions about computer models (either process based forestry models or three-dimensional climate models) are welcomed. Debate should be encouraged and hypotheses should be tested (not simply proposed). However, it now seems a number of researchers and foresters have accepted the hypothesis that CO_2 is the primary driver of a changing climate. Some ignore factors such as changes in cloud cover, changes in surface albedo (Gibbard *et al*. 2005), changes in cosmic rays, increases in soot (in air and on ice), and the Pacific Decadal Oscillation. Ignoring these factors appears to be driven by the idea that the Earth's complex climate system is relatively easy to control by planting more trees on temperate and boreal grasslands.

We hope our profession will rise above soothsaying and will encourage debate on topics and policies that affect our forests. As NZIF members, if we choose not to question authority, we might be accused of violating our code of ethics.