Energy Policy and Environmental Stewardship: Risk Management not Risk Avoidance[1]

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1 Introduction: Playgrounds and China Shops

Suppose you had to look after a group of children for the afternoon. Where would you prefer to take them, to a china shop or a playground? The answer is pretty obvious. Children do not belong in china shops. Everything there is fragile, delicately balanced, breakable and sensitive. A group of children could do a lot of damage. You'd have to yell at them to sit still and not touch anything, or get out. A playground, by contrast, sends the opposite message. You belong here! It's fun, inviting and built to last. Enjoy yourself, keep it neat and don't worry, you won't wreck it just by being yourselves.

These contrasting descriptions sound like the polar ends of the language used to describe the world in which we live. Modern environmentalists use china shop language. The planet is fragile, with a delicate ecosystem in constant danger of being thrown out of balance, which faces ruin with even the slightest touch. The implication is: Humans do not belong here. Sit still and don't touch anything, or get out. On that last item, even mainstream environmentalists sometimes call for a radical depopulation of the world. In 1994 the well-known Stanford scientists Paul and Anne Ehrlich, along with their Berkeley colleague Gretchen Dailey, said that achieving a two-thirds reduction in the size of the human population "reasonably soon" would be optimal. Whenever I show this news item[2] to my students I ask if these three scientists saw the irony of calling for a two-thirds reduction in the world's population, without at the same time identifying which two among themselves were willing to go first.

Anthropocentric schools of thought, including Christian theology, use something much closer to playground language to describe our world. We belong here. The Earth is a hardy, resilient place well-suited to our presence. Have fun, keep it neat and don't worry, you won't wreck it just by being yourselves. That last point is not an invitation to recklessness, it is simply a recognition of the plain

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[1] Prepared for the Greer-Heard Point-Counterpoint Forum held at the New Orleans Baptist Theological Seminary, April 10-11 2015.

[2] See http://news.stanford.edu/pr/94/940711Arc4189.html. 20 years later Paul Ehrlich is still calling for "a massive reduction in the number of humans" though presumably he exempts Stanford professors from the cull. http://www.theguardian.com/environment/2012/apr/26/world-population-resources-paul-ehrlich

fact that the planet is remarkably robust. Not only is the pursuit of ordinary human prosperity not an environmental hazard, but ample evidence shows that it correlates with many forms of environmental improvement, including cleaner air, cleaner water, more land preservation and more efficient use of resources.[3]

I propose to argue that, with respect to the climate change issue, as with many issues before it, we should reject china shop language. The implication that the world is fragile and humans don't belong here is bad theology and flawed science which leads to harmful policy plans. Our challenge is to use the resources we have been given in a way that recognizes risk and manages it, rather than burying them out of fear. This is the essence of stewardship.

I am occasionally struck at the way commentators within the church use the term "stewardship" when what they are actually describing is secular environmentalism. The two concepts are not the same. The doctrine of faithful stewardship is (I presume) based on the parable of the faithful stewards in Luke 19 (and Matthew 25). The faithful ones took the resources given to them by the master and put them to use, even knowing there was a risk of loss. The unfaithful steward was the one who wanted to preserve everything unchanged, who gave into his fears and kept his resources hidden, where they benefited no one. In the same way, finding ourselves in possession of incredibly valuable and beneficial resources (like fossil fuels) our inclination should be towards using them and managing both the changes and the risks such change entails. When we hear rhetoric warning of an impending catastrophe that can only be avoided by imitating the unfaithful steward, we better be prepared to test the claims. That is what I propose to do in this presentation.

2 THE CLIMATE POLICY SITUATION

2.1 DISTINGUISHING THREE TYPES OF EMISSIONS

It is important before proceeding to distinguish three very different issues, all of which fall under the heading "air emissions" but which involve different environmental and economic considerations. First, there are conventional air contaminants (CACs) like carbon particulates (soot), carbon monoxide, sulphur dioxide, nitrogen oxides (NOx), lead and so forth. These are the pollutants people typically think of when they talk about "clean air" or "dirty air" since they tend to accumulate locally and cause immediately noticeable problems. These contaminants have been regulated and controlled in North America since the 1960s with considerable success, mainly because scrubbers, tailpipe emission controls and similar technologies are affordable and effective.[4] In the US and Canada, by the mid-1990s, total particulate and sulphur emissions had fallen to well below levels measured in the 1940s, and concentrations of CACs in urban areas were in most cases within the limits that define clean air in each jurisdiction. It comes as a surprise to many people, including many students, to learn that CACs have been declining steadily for many decades and that in most North American cities they are simply not a problem anymore. But the data on this are quite unambiguous.

[3] For details and numerous examples see McKitrick (2010a) Chapter 1. For detailed Canadian air and water quality records see Yourenvironment.ca.

[4] For Canadian data see yourenvironment.ca. For US data see environmentaltrends.org and epa.gov/airtrends/aqtrends.html. For international surveys see McKitrick (2010a) Ch. 1.

The second issue is ground-level ozone, or O_3. O_3 is not emitted directly by industry but is formed indirectly when specific air contaminants (NOx and volatile organic compounds or VOCs) react over time under intense sunlight, resulting in heavy-feeling air that is uncomfortable to breathe. The process of O_3 formation is complex and requires favourable meteorological conditions, such as an inversion. When the conditions are right, O_3 levels will spike for a few days. These so-called "smog episodes" can sometimes be reduced by sharp cuts in NOx and VOC emissions, but only if the cuts occur in the right proportion at the right time, otherwise such cuts may even cause O_3 levels to go up (Adamowicz et al. 2001). Smog episodes end when the weather changes. Normal levels of O_3 are not typically a problem. Trying to formulate regulations to reduce O_3 is not easy since VOCs come from many natural sources and the relevant NOx sources may be far away, including in other countries. In North American urban areas, O_3 levels have tended to be relatively constant over the past few decades, with some reductions in peak levels, but technical challenges preclude finding simple ways to cut levels further.

The third distinct issue concerns greenhouse gases (GHGs) and in particular, carbon dioxide (CO_2). CO_2 is emitted during fossil fuel combustion but it also comes from many natural sources, it is a normal part of our atmosphere, it is an essential food source for plant life and it is harmless to breathe, even at levels quite a bit higher than those we encounter outdoors. So it has not historically been regulated. The current interest in controlling it arises because it is a GHG and is believed to contribute to global warming. Bear in mind that whether we regulate carbon *dioxide* or not, we have and will continue to regulate all other forms of carbon *pollution.* So when you hear someone talk about the need to start controlling "carbon pollution" they are being misleading since most of it is already regulated. In the US and Canada levels have dropped dramatically since the end of WWII.[5] For instance, from 1980 to 2013, even though US real GDP rose by 145%, carbon monoxide emissions fell by 67% and particulate emissions (PM10) fell by 50%.[6]

Unlike CACs and ozone, CO_2 mixes globally rather than accumulating locally. Its climatic effect is through the average global concentration, which only changes very slowly over time in response to all emission sources together, not in response to any one country's emissions. Hence local action, or even national initiatives, no matter how costly, have very small effects on the climate, and usually only with a long time lag. Moreover, there are no scrubbers that can prevent CO_2 from being released once the fuel is burned. To reduce CO_2 emissions requires either cutting fuel use or implementing a complicated process of CO_2 capture and storage. Each of these options is quite expensive compared to the technologies that control conventional air contaminants, which makes it much more difficult to have economic growth and declining CO_2 emissions.

So these three issues present very distinct scientific and policy challenges. It is of vital importance when analysing the climate topic not to assume that policy options that made sense for CACs would automatically make sense for GHGs. Just because the US and Canada made deep cuts in sulphur dioxide emissions does not imply we could, or should, do the same for carbon dioxide. The question of how much to cut any particular emission source depends on how the costs of the cuts compare to the benefits.

At this point, economists would prefer to have the next part of the conversation using graphs or, even better, mathematical equations, but an important basic point can be made verbally. Because

[5] From 1946 to 1998, particulate (PM10) emissions in the US fell by 77% (epa.gov/ttn/chief/trends/trends98).

[6] See US EPA data at http://www.epa.gov/airtrends/aqtrends.html. Over this period sulfur dioxide emissions also fell by 81% and lead emissions fell by 99%.

sulphur dioxide emissions accumulate locally and cause visible air quality problems, and because smokestack scrubbers (or use of low-sulphur fuels) nearly eliminate emissions at a reasonable cost, economic analysis favours deep emission cuts, as has already been achieved in the US and Canada. But CO_2 is a different kettle of fish, and a close look at the particulars shows why mainstream economic analysis does not favour deep emission cuts.

2.2 WHY CLIMATE POLICY IS SO DIFFICULT

Local and national CO_2 emission cuts have little effect on the global concentration, and therefore little effect on the trajectory of climate change over the coming century. For instance, full international compliance with the Kyoto Protocol would have cost a lot with almost no effect. We would reach the business-as-usual CO_2 concentration projected for the year 2100 in 2105 instead (Wigley 1998), a trivial delay purchased at a massive cost. It also is worth bearing in mind that IPCC business-as-usual growth scenarios project that while developing country CO_2 emissions will rise over the coming century, this will happen because incomes will also rise, by between 10 and 70-fold during the same interval. This will effectively solve most of the poverty-related problems in the world. So let's ask: if we could freeze the status quo forever, would developing country citizens prefer today's climate and today's poverty, or a 10-fold income increase and a risk of some warming? It is far from obvious that poor and cold is better than rich and warm!

Local CO_2 emission control options are limited and costly, and have almost no effect on the problem they are meant to solve. Putting these facts together, economic analysis leads to the conclusion that optimal CO_2 emission reductions are rather modest, or in other words, leaving emissions unregulated is likely not that far from the optimal strategy. The "ideal" policy in a typical economic model is a small tax on CO_2 emissions that charges emitters the social cost of their actions. This would guide people to undertake the cheapest emission reductions, but it would not result in deep cuts since fossil fuel consumption is very valuable and relatively unresponsive to price increases.

Analyses that conclude in favour of deep CO_2 emission cuts typically require unusual and arbitrary assumptions, such as: very large multiplier effects on the damages of climate change; weighting damages hundreds of years from now as if they were economically equivalent to damages today; assuming that small changes in CO_2 levels may lead to catastrophic "tipping points" or bifurcations not presently represented in climate models; or assuming that hitherto-non-existent technology will soon be invented that makes it inexpensive either to replace fossil fuels or use them without releasing CO_2.[7] Absent one or more of these non-mainstream assumptions, economic analyses have consistently argued against adopting deep CO_2 emission reduction targets.

It is not just economic analysis that points away from deep GHG cuts: political reality does as well. For the past 20 years, countries around the world have been signing treaties like the Kyoto Protocol that impose ambitious reduction targets, only to quietly abandon or water them down without achieving them. The reason is that, however easy it is to make a grand promise, when politicians have actually looked at the costs of the policies needed to comply with the treaties, they are unable to present a persuasive justification to the public as to why such costs should be borne. Deep CO_2 reduction policies have never commanded wide political support, even in countries in which people say they are concerned about climate change.

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[7] Dietz and Stern (2015) show how such modifications of the standard framework lead to conclusions in favour of deep CO_2 emission cuts, or alternatively, how such conclusions require such implausible assumptions (though they wouldn't phrase it that way).

Yet we often hear claims about a "climate crisis" and warnings of a coming catastrophe, the prevention of which requires us to be prepared to incur heavy economic costs. It is not uncommon to hear calls for "radical decarbonisation" of the world's economy despite the crushing cost such a program would entail. The idea that we should pursue continued economic development and simply adapt to climatic changes as they occur is dismissed as controversial and unacceptable because of the supposed magnitude of the threats we are facing. Some prominent advocates have even argued for the worldwide cessation in the development and use of fossil fuels.[8] What are we to make of these kinds of warnings? There is, after all, a long history of excessive and inaccurate Malthusian gloom among environmental campaigners.[9] I suggest we are hearing echoes of the fearful and unfaithful steward who sought preservation of the status quo above all things and buried his resources, rather than trying to adapt to change and make good use of them. Remember that the master scolded him for giving into his fears when he ought to have realized that the resources were reliable and valuable. Had the steward asked himself harder questions he would have seen that he was being irrational and was making a bad decision.

The policy path called for by those who promote the threat of catastrophic anthropogenic global warming will unavoidably entail severe economic costs, and will consign to permanent poverty many people who would otherwise achieve economic prosperity over the coming decades. Therefore it is only responsible that we thoroughly probe the case for a global warming catastrophe. In doing so we must reject any suggestion that there is a moral imperative simply to believe in the threat without question. Quite the opposite. The situation imposes on us a duty to ask hard questions in pursuit of reasonable and well-informed policies. In the next section I will discuss why the evidence as I see it stands against the arguments for catastrophe.

3 ASSESSING THE CLAIMS OF CATASTROPHE

3.1 THE NOT-SO "BASIC" PHYSICS

It has long been known that CO_2 absorbs infrared radiation, and thus under typical circumstances, increasing concentrations in the atmosphere would be associated with warming. The physics involved in radiative transfer are well-known and relatively simple (at least, to physicists). It is also widely accepted that the direct effect of doubling the concentration of CO_2 would be relatively small: about 1 ^{o}C on average in a typical global climate model. Models that yield larger effects, on the order of 2—6 ^{o}C or more, do so by building in strong positive feedback effects, such as changes in atmospheric water vapour formation, changes in cloud systems and reductions in polar sea ice, that amplify the initial CO_2 effect. All these secondary processes depend on turbulent fluid dynamics operating on scales ranging from local to the global. Therefore *none* of these processes are simple to understand and predict, even for the best mathematicians and physicists.[10] They cannot be computed from first principles because the underlying differential equations are intractable and insoluble. They can only be dealt with through empirical approximations and model parameterizations, which involve unavoidable error and approximation.

[8] See, for example, the divestment movement: theguardian.com/environment/2015/mar/16/argument-divesting-fossil-fuels-overwhelming-climate-change.

[9] See a review in McKitrick 2010a Chapter 1.

[10] For a discussion of the problem of turbulence in climate research see Essex and McKitrick (2007) Chapter 2.

So we cannot take at face value any claim that "basic physics" proves there is a climate crisis, or that all scientists believe catastrophe looms. The known and knowable physics are entirely consistent with the possibility that CO_2 emissions do not pose a big problem for the human race. They are also consistent with the possibility that they pose a big problem, but that it would cost more to try and prevent it than to live with it. And they are consistent with the view that CO_2 emissions pose such a big problem that we need to cut them back radically, the sooner the better. Deciding among these possibilities requires careful assessment of evidence. My reading of it is that the third possibility is the least compatible with reality. I will explain why I hold this view in the next few sections.

3.2 MODELS VERSUS OBSERVATIONS

Since the evidence for large amplification of the direct effects of CO_2 comes from behaviour programmed into climate models (General Circulation Models or GCMs) rather than from first principles, we need to ask how well GCMs simulate the behaviour of the atmospheric system, or at least those parts of it most relevant to the amplification processes. In reviewing the literature on GCM evaluation while writing one of the papers I published on the topic a few years ago (McKitrick and Tole 2012) I was surprised at how weak were the tests of climate models against real-world data. Reports of the Intergovernmental Panel on Climate Change (IPCC) would typically cite evidence that, over the post-1850 interval, GCMs could track the observed global mean temperature reasonably up to the late-1990s, and reproduce large-scale static features of the climate system, namely keeping poles cold relative to the tropics. But they did not test if GCMs could accurately reproduce the spatial variations in temperature trends at the Earth's surface, or how well they could predict global surface temperatures over more recent intervals when the modelers didn't first get to peek at the answer. Nor was there a forthright discussion of the lack of warming in the troposphere over the tropics, a region the models point to as a key source for warming amplification. As it turns out, GCMs do badly on these metrics and their biases are consistently towards overstatement of warming.

3.2.1 Most models can't reproduce spatial variations temperature trend patterns

In my study with Lise Tole we tested whether GCMs could reproduce, not the global average warming pattern, but the spatial variations in warming and cooling trends over land after 1979. I had earlier shown evidence (McKitrick and Michaels 2004, 2007; also McKitrick 2010b, McKitrick and Nierenberg 2010, McKitrick 2013) that the data used to measure temperature trends over land appears to have a warming bias attributable to socioeconomic development patterns such as urbanization, even though the data sets are supposed to be adjusted to remove such effects. Critics of my findings (especially Schmidt 2009) had argued that the effects were spurious and that GCMs showed such warming patterns were attributable to climatic processes. Schmidt presented no supporting evidence for his claim, but Tole and I investigated it thoroughly, using a series of statistical methods to examine the outputs of 22 climate models plus a set of socioeconomic indicators, evaluating 2^{19} possible combinations of explanatory data. We found that 10 of the 22 GCMs in use at the time generated spatial patterns *negatively* correlated with observations (in other words, systematically less informative than random numbers), and of the remaining 12 models, only three yielded data that was systematically informative about surface temperature trends, while the socioeconomic data (which climate experts insisted had no explanatory power) consistently emerged as the most significant explanatory variables. We concluded that most climate models in use had no explanatory power for the spatial pattern of surface temperature trends, and that to explain the temperature data required controlling for contamination due to socioeconomic development, which is associated overall with a warming bias in the temperature records.

Other authors also showed models lack regional explanatory power. Koutsoyiannis et al. (2008) and Anagnostopoulos et al. (2010) compared long term (100-year) temperature and precipitation trends in a total of 55 locations around the world to model projections. The models performed quite poorly at the annual level, but they also did poorly even when averaged up to the 30-year scale, even though this is typically assumed to be the level they work best at. They also did no better over larger and larger regional scales. The authors concluded that there is no basis for the claim that climate models are well-suited for long term predictions of spatial patterns over large regions.

Fildes et al. (2011) took the same data set and compared model predictions against a "random walk" alternative, which simply means using the last period's value in each location as the forecast for the next period's value. Basic statistical forecasting models with no climatology or physics in them typically got scores slightly better than a random walk. The climate models used by the IPCC got scores far worse than a random walk, indicating a complete failure to provide valid forecast information at the regional level, even on long time scales. The authors commented: "This implies that the current [climate] models are ill-suited to localised decadal predictions, even though they are used as inputs for policy making."

3.2.2 Models significantly exaggerate tropical tropospheric warming

All climate models point to the vast troposphere over the tropics (comprising half the planetary atmosphere) as the region where the strongest and most amplified warming response to rising GHG levels will be observed. It has been noted in the literature for the past decade that observations from weather balloons and weather satellites do not show much, if any, warming trend in this region, and the difference between the modeled and observed trends appears statistically significant. A few years ago there was a dispute between two teams (Douglass et al. 2007; Santer et al. 2008) over whether the post-1979 trend difference was statistically significant or not. The IPCC (2007) came down on the side of those arguing it was not. However I noticed that the statistical methodology being used was not valid for these data sets, and I published a study (McKitrick et al. 2010) showing that with proper specification of the trends and variances, the models were indeed significantly overestimating the post-1979 warming of the tropical troposphere, a finding the IPCC endorsed in its last report.

More recently (McKitrick and Vogelsang 2013) I showed that the discrepancy is significant in comparisons using data all the way back to 1958, and moreover the type of warming is misrepresented in climate models. Whereas they represent it as a smooth upward trend, the observations show it as a single step in the late 1970s with no significant warming on either side. The warming around 1977 is associated with a known reorganization of Pacific ocean circulation patterns. The most recent IPCC (2013) report concedes that the models significantly overstate warming in the tropical troposphere but offers no explanation for it. In my view, the absence of a significant warming trend in the tropical troposphere since the late 1950s, and the failure of the IPCC to reconcile that to the current configuration of GCMs, makes it all but impossible to treat the strong positive feedback processes in most models as a valid representation of reality.

3.2.3 Models greatly overstate global surface warming since the late 1990s[11]

[11] Some of the text in this section is taken from my report for the Fraser Institute on the pause in global warming (McKitrick 2014a).

Politicians, journalists, activists and others have lately taken to saying that the climate is now warming "faster than expected."[12] But the data show the exact opposite: over the past two decades the pace of warming has actually slowed to a rate well below almost all model projections. The most recent report of the Intergovernmental Panel on Climate Change[13] (IPCC 2013, Chapter 9 Box 9.2) referred to a "hiatus" or pause in warming, starting around 1998.

Over the whole of the post-1900 interval, the warming trend is just under 0.075 ^{o}C/decade, or about 0.75 ^{o}C per century. But as of the start of the current century, rather than the trend increasing it has fallen to near zero. There is no statistically significant warming trend in the Hadley Centre (Morice et al 2012) surface data in a sample confined to the past 19 years. Over the last 30 years, atmospheric temperature data have also been available from weather satellites. There is no statistically significant warming trend in the RSS lower tropospheric data (Mears and Wentz 2005) in a sample confined to the past 26 years, while the lower troposphere data from Spencer and Christy (1990) suggests a hiatus of 16 years (McKitrick 2014b). Taking all these points together, the data confirm the IPCC's observation that we are currently experiencing a hiatus in global warming that has lasted for just under 20 years.

There have been leveling-off periods before, but what makes this one unusual is that it coincides with 20 years of rapidly increasing atmospheric greenhouse gas levels. Since 1990, atmospheric CO_2 levels have risen 13% from 354 parts per million (ppm) to just under 400 ppm.[14] According to the IPCC, taking into account changes both in GHG and aerosol levels, estimated Radiative Forcing[15] increased by 43% after 2005 (IPCC 2013 SPM-9). Climate models projected that this should have led to a pronounced warming of the lower troposphere and surface. Instead, as noted, temperatures have flatlined.

A small discrepancy between models and observations is not unusual. However the current hiatus is rather long in duration, and it has opened up a large gap between observations and projections from most climate models. The model simulations used for the AR5 are collectively called "CMIP5" – referring to the 5th Coupled Model Intercomparison Project. Figure 9.8 from the IPCC (2013) Fifth Assessment Report (which is denoted AR5) illustrated the comparison between observations and CMIP5 models over the 1900-2020 interval. Climate models were used to backcast, or reproduce, temperatures for the past centuries. Models and observations seem to line up well over the 20th century, but the models are tuned[16] to achieve a match, a point the IPCC itself emphasizes in a number of places (e.g. Ch. 9 Box 9.1). The post-2000 interval is where we get a sense of the accuracy of GCM forecasts of the future climate. It is in that segment that, at some point, modelers could no longer peek at the answer and they had to rely on the model structure to get the temperature

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[12] For example: President Obama "What we do know is the temperature around the globe is increasing faster than was predicted even ten years ago." Press conference November 14 2012, reported in *Washington Post* http://tinyurl.com/an5kxx3; See also "Climate Change Worse Than Expected, Argues Lord Stern" *Scientific American* April 3, 2013; "Climate Changing Faster Than Expected" *Discovery News* February 11 2013; "Global Warming is Accelerating" *National Wildlife Federation* (nwf.org, undated, accessed July 2, 2014); "Earth Warming Faster Than Expected" *Science News* March 25, 2012; "With scientists warning that we have already triggered a climate change avalanche that is only building up speed, the Ontario Government's commitment to develop a climate plan with teeth has come not a moment too soon." Ontario Clean Air Alliance email campaign March 26 2015, etc.

[13] In this report, all references to the IPCC report are to the contribution of Working Group I.

[14] Data from ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt.

[15] "Radiative Forcing" is the term used in climate analysis to describe the overall warming effect of greenhouse gases on the climate, based on the changes in absorption of infrared radiation in the atmosphere.

[16] See the description of the model tuning process in the AR5 Chapter 9, Box 9.1.

predictions right. Over that interval the models predict steady warming in response to the ongoing run-up in atmospheric CO_2 levels, but the observed temperatures instead flattened out, eventually falling below 95% of model runs. The post-1998 gap is something new. It is now into its 17th year, it has reached a large magnitude (about +0.3 C on average) and it is still widening. Even if temperatures were to start rising again today, observations will not catch up to models any time in the foreseeable future.

The IPCC AR5 reports[17] that over the 1998-2012 interval, 111 out of 114 climate model runs overpredicted observed warming. They informally proposed several explanations for this discrepancy, including the possibility that models are simply too sensitive to greenhouse gases, but they did not not favour any one solution to the problem. One possible explanation that has gotten a lot of attention is the proposal that the ocean is absorbing heat at a faster rate than before. But the IPCC notes that 3 of 5 empirical studies have found the trend in ocean heat absorption actually decreased over the past decade.[18]

The absence of warming over the past 15-20 years amidst rapidly rising GHG levels raises a nontrivial question about mainstream climate modeling. In a 2013 interview with the newspaper *Der Spiegel*, the well-known German climatologist Hans von Storch said (emphasis added):

> This is a serious scientific problem that the Intergovernmental Panel on Climate Change (IPCC) will have to confront… **If things continue as they have been, in five years, at the latest, we will need to acknowledge that something is fundamentally wrong with our climate models.** A 20-year pause in global warming does not occur in a single modeled scenario. But even today, we are finding it very difficult to reconcile actual temperature trends with our expectations.
> http://www.spiegel.de/international/world/interview-hans-von-storch-on-problems-with-climate-change-models-a-906721.html

Climatologist Judith Curry of Georgia Tech recently observed (emphasis added):

> Depending on when you start counting, this hiatus has lasted 16 years. Climate model simulations find that the probability of a hiatus as long as 20 years is vanishingly small. **If the 20 year threshold is reached for the pause, this will lead inescapably to the conclusion that the climate model sensitivity to CO2 is too large.**
> http://judithcurry.com/2014/01/20/the-case-of-the-missing-heat/

3.2.4 Empirical estimates of climate sensitivity are lower than models suggest

The sensitivity of climate to CO_2 cannot be calculated from first principles, and as noted above, it certainly cannot be calculated from "basic physics." It has traditionally been inferred from the behavior of climate models, and the usual result is that doubling CO_2 in the atmosphere will warm the Earth by 1.5—4.5C. But in recent years there has been enough data collection to begin to estimate sensitivity directly through observation. A range of statistical methods is being applied to

[17] See Chapter 9, Box 9.2 of the Working Group I Report.

[18] The five studies are Domingues et al. (2008), Ishii et al. (2009), Levitus et al. (2012), Palmer et al. (2007) and Smith and Murphy (2007). The IPCC Report does not specify which three imply a slowdown in OHC rise, but from visual inspection of IPCC Figure 3.2a they are likely Ishii et al., Levitus et al. and Smith et al.

this issue, and what is interesting is that the empirical estimates are concentrated at or below the traditional range from climate models.

The IPCC characterizes GCMs by two sensitivity measures, the Equilibrium Climate Sensitivity (ECS) and the Transient Climate Response (TCR). The first measures the temperature change after CO_2 levels double in the atmosphere, allowing for the climate to fully achieve its new state with all feedbacks having played out. Transient Climate Response (TCR) is an operational concept showing the estimated rate of warming after 70 years with CO_2 levels increasing at 1% per annum, thus doubling. Since it corresponds to real time observations it can be estimated empirically, allowing for a comparison of model structures against the data (Lewis and Crok 2014).

In its 2005 report the IPCC stated TCR is *very likely* between 1.0 and 3.5 °C. Table 9.5 in the AR5 lists the TCR's of 30 CMIP5 models. They range from 1.1 to 2.6, with a median of 1.8, a mode of 2.0 and an average of 1.8. The data are tabulated as a histogram in Figure 1.

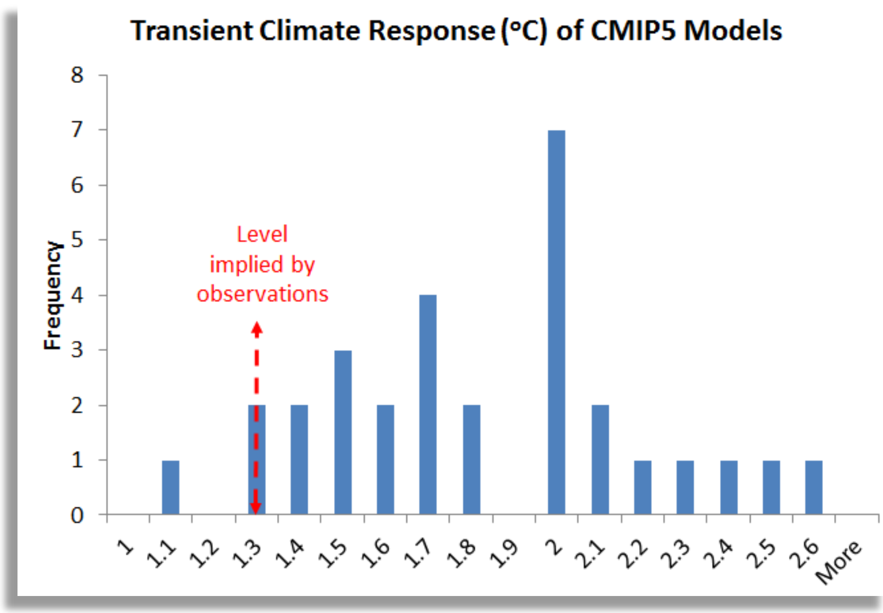

Figure 1 Distribution of Transient Climate Response magnitudes in CMIP5 models, compared to TCR derived from observations.

But the data reported by the IPCC in the same report yielded an empirical estimate of TCR of only 1.3 °C, down at the low end.[19] Only one model has a TCR below the empirical level, two have the same value and 27 have values above it. In other words most models are programmed to yield more warming in response to greenhouse gases than is presently consistent with long term observations.

This same pattern emerges in studies of ECS. The AR4 reported a likely range of 2.0 – 4.5 °C, with a best estimate of around 3 °C. In the AR5 the IPCC changed the range to 1.5 – 4.5 °C but did not offer a best estimate. Six recent papers in top-quality peer-reviewed journals have used diverse

[19] The derivation of the 1.3C figure from the IPCC data is shown in Box 1 of McKitrick (2014a).

empirical methods that incorporate up-to-date temperature data (including Ocean Heat Content) in order to constrain the estimate of equilibrium sensitivity to values consistent with observations. They all yielded ECS estimates below 2.0 °C. These papers are:

- Aldrin, M. et al (2012): ECS best estimate **1.76 °C**, likely range 1.3 – 2.5 °C
- Ring, M.J. et al. (2012): ECS best estimate **1.80 °C**, likely range 1.4 – 2.0 °C. (Note ECS falls to 1.6 °C using updated surface temperature data.)
- Lewis, N. (2013): ECS best estimate **1.64 °C**, likely range 1.3 – 2.2 °C
- Masters, T. (2013): ECS best estimate **1.98 °C**, likely range 1.2 – 5.2 °C
- Otto, A., et al., (2013): ECS best estimate **1.91** °C, likely range 1.3 – 3.0 °C
- Lewis, N. and Curry, J. (2014): ECS best estimate **1.64**°C, likely range 1.3 – 2.5 °C

A new paper by Johannsen et al. (2015) yields an ECS best estimate of 2.5 °C with a likely range of 2.0 – 3.2 °C. This puts the ECS in the low end of the model range.[20] But they also point out that use of data up to 2011 "effectively eliminates" the upper ECS tail above 4 °C, assigning it a probability of less than 0.02%. This effectively eliminates the basis for a handful of recent economic analyses that have called for aggressive CO_2 emissions controls based on the possibility of very high upper tails of climate sensitivity (e.g. Weitzman 2009, Dietz and Stern 2015)

3.3 A Bias Towards Overstating

On the key measures of model performance, we do not see a random pattern in which models both overstate and understate the warming problem, instead the discrepancies systematically lean one way, towards overstatement. So it is not mere error, it is bias. Models get the spatial pattern of warming trends over land wrong in a way that implies too much greenhouse warming. Almost all (97%) of model runs overestimate the surface warming of the past 15-20 years. They also significantly overestimate warming in the tropical troposphere, whether we look at data back to 1980 or even back to the late 1950s. And the models embed CO_2 sensitivity that skews too high to reconcile with long term observations.

One explanation for the pattern of exaggeration came in a remarkable analysis by Kyle Swanson (2013). He showed that during the development phase between the 4th and 5th IPCC Assessment Reports, models became more and more like *each other*, but less and less like *the real world.* The earlier (CMIP3) models tended, in some respects, to overstate observed warming, but formed a dispersion that at least encompassed observations. The CMIP5 models are less dispersed overall, but instead of converging on reality, they converged on the model mean itself, and in the process moved farther away from reality.

The only region where CMIP3 models underestimated warming was in the high Arctic. Swanson conjectures that modelers have subtly tuned their GCMs to do a better job of replicating the sharp Arctic warming, but in so doing they made them worse everywhere else. And he noted that even though they started getting the Arctic warming correct, they seemed to be getting it right for the wrong reasons since they were inconsistent with the spatial layout of warming everywhere else.

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[20] While the authors attribute this to their use of ocean heat content data down to 2000m rather than 700m, that only accounts for a small part of the difference since several other studies also used deeper ocean data. Nicholas Lewis has argued that the main reason for their different results is use of an older aerosol forcing estimate, one which has been superseded by more recent research (http://www.carbonbrief.org/blog/2015/04/climate-sensitivity-is-unlikely-to-be-less-than-2c-say-scientists/#comment-1940526844).

There are other examples that could be given about the pattern for exaggeration. While working on the notorious "hockey stick" debate, it was apparent that the climate science community was far too quick to endorse and promote the claim that the world is the warmest it's been in the past 1000 years, even though the underlying statistics were far too dubious and uncertain to support such a bold claim.[21] In the aftermath of Hurricane Katrina in 2005 we were repeatedly told that global warming would make extreme weather events more frequent and more intense. Yet since then the global hurricane frequency has continued falling,[22] the overall intensity (accumulated cyclone energy) has fallen[23] and the rate of US-landfalling extreme tropical systems has fallen to all-time lows.[24]

The drumbeat of alarmism never seems to stop, helped along by a media that seems incapable of elementary fact-checking when environmental issues are raised. In an April 2014 article about the mortality risk associated with summer heatwaves in Toronto,[25] Globe and Mail reporter Karen McColl claimed that they are getting worse due to climate change, quoting an activist alongside various government experts who offered the following prediction (emphasis added):

> Heath Canada describes extreme heat as the potential for hot weather conditions to result in an unacceptable level of health effects, including increased mortality. Clean Air Partnership, a non-profit that addresses climate-change issues, says **maximum temperatures in Toronto are expected to rise 7 C over the next 30 to 40 years** and a fivefold increase in extreme heat events is predicted over the same time period.

Seven degrees over 40 years? That works out to 1.75 ^{o}C per decade, or *seventeen* degrees per century. Did it not occur to Ms McColl that this is obviously nuts? That neither a reporter nor her editor at a major national daily newspaper in Canada saw any problem with this claim indicates how mainstream alarmism has become. Elementary fact-checking using Environment Canada weather records for Toronto would show that, far from showing a tendency towards double-digit increases, summer daytime highs have not changed in over 100 years.

The data are shown in Figure 2. The trend since the year 1900 in the July data is -0.02 $\pm$ 1.1 $°C$ /decade and in the August data it is +0.02 $\pm$ 0.8 $°C$ /decade. It is impossible that Toronto summertime highs could be trending upwards by a rate equivalent to 7 degrees over 40 years.

21 See McKitrick (2014c) for a review of this debate.
22 Data at http://policlimate.com/tropical/global_major_freq.png
23 Data at http://policlimate.com/tropical/global_running_ace.png
24 Data at http://www1.ncdc.noaa.gov/pub/data/cmb/images/cei/step6.02-01.gif
25 See http://www.theglobeandmail.com/life/health-and-fitness/health/climate-change-and-health-extreme-heat-a-silent-killer/article18343936/

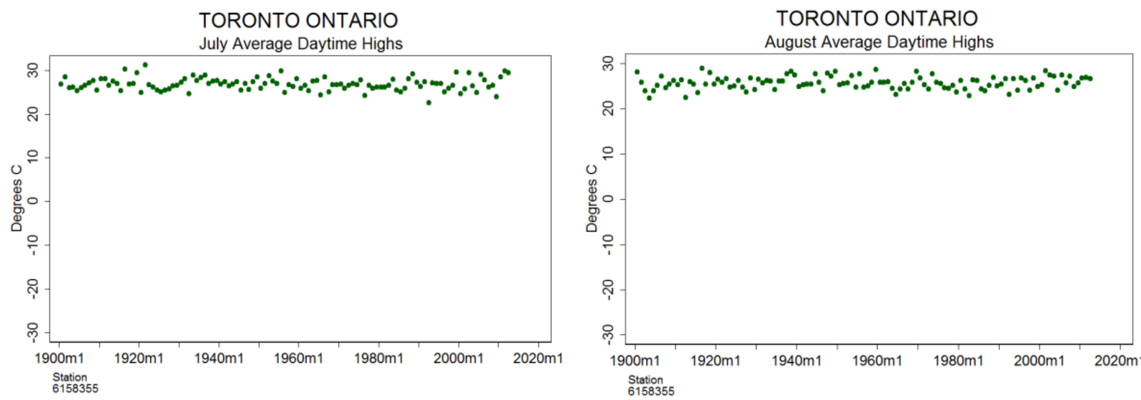

Figure 2: July and August average daytime high temperatures, Toronto, 1900 – 2013.
Data source: yourenvironment.ca

At this point, rather than go on with what could turn into limitless examples, I will conclude this section by simply stating my impression that, in both the academic community and the popular press, there is a systematic bias towards overstating the risk of global warming. There is also a widespread failure to perform even simple due diligence, perhaps because nowadays to question any of the climate change narrative is to risk being attacked and denounced as a "denier" or an anti-science industry shill. But nature always gets the last word, and cares nothing for our name-calling. Long-term climate data refute projections of high or even moderate warming trends from climate models, and are inconsistent with the assumptions of high GHG sensitivity presently encoded in the vast majority of models. Multiple lines of evidence based on careful observation and data analysis repeatedly draw our attention to the low end of the scale when it comes to rates of warming, and perforce the likelihood of future problems.

In other words our climate system is not like a china shop.

4 DIGRESSION: A POLICY SUGGESTION

At this point I want to pre-empt any suggestion that I am simply opposed to climate policy in any form at all. Far from it, in fact, those who believe that we face a crisis of rapid warming will be relieved to know that I have put a lot of effort into advocating for a rapidly increasing tax on CO_2 emissions. And for those who believe we are not in for any global warming at all, you will be equally relieved to hear that I have put a lot of effort into advocating for a minimal tax on CO_2 emissions that would stay low indefinitely.

How can both these statements be true?

Simple: I have argued at some length for the introduction of a carbon tax tied to atmospheric temperatures.[26] I won't go into the technical details here, but I will sketch out the idea in just enough detail hopefully to interest readers in looking further into it.

[26] See McKitrick (2010c, 2013b). Some of the text in this section is taken from McKitrick (2013b).

A low carbon tax coupled with reductions in income taxes would likely be neutral or mildly beneficial at the macroeconomic level. But we then have to ask how the tax should evolve over time, and this is where views get polarized and agreement breaks down.

One side considers CO_2 a great threat and wants the tax to rise rapidly. The other side doesn't view global warming as a problem, and would like the rate to stay low or even decline. There is no grand scientific answer to this dilemma. Large economic models have been built on the false assumption that we understand the key parameters of the climatic and economic systems, and each one prescribes a tax path based on these assumptions, but differing groups have their reasons for dismissing any particular answer so they are usually dead on arrival.

All this would change if we put a small tax on CO_2 emissions, and tied its subsequent evolution to a suitable measure of atmospheric temperatures. If temperatures go up, so will the tax. If they don't, the tax won't change. Either way everybody will expect to get the policy they think best, and whoever turns out to be right deserves to be so.

An important additional component to the policy would be for the government to establish a futures market for certificates that exempt an emitter from paying the tax on a tonne of CO_2 emissions in a specific year. By creating futures certificates for up to, say, 25 years ahead and allowing them to be traded in the market, investors could fully hedge against the future tax obligations associated with major projects and undertakings, such as large factories or power plants.

It is possible to show, with a bit of mathematics, that a temperature-indexed tax would, over time, yield a close approximation to the unobservable path of optimal emission charges that we would have imposed if we had full information about the long term effect of CO_2 emissions on the climate.

As to why it works, consider the incentives facing an investor if the stringency of future climate policy were going to be determined only by the pace of global warming. No one would have an incentive to make investments they privately believed were at odds with the likely progress of global warming and the implied evolution of climate policy. Suppose we set the initial carbon tax at about US $10 per tonne, which is low enough not to do any real economic harm as long as we use all the revenues to pay for income tax cuts. IPCC models have predicted warming rates between 0.1 and 0.6 degrees C per decade throughout this century. Using a simple adjustment formula, the upper end of warming forecasts would imply the tax could reach over $200 per tonne of CO2 by 2100, forcing a major shift towards planning for low-carbon energy sources.

What if no one believes the forecasts? With the futures market, we will be able to see at a glance what the market believes will be the most likely path of the tax, and hence of temperatures. Anyone who believes the temperature forecasts – and hence the futures prices – are too low could buy up certificates confident that they will go up in value, thereby making some money. If an investor believes they are priced too high, he or she could profit by shorting them. Either way, there is no incentive for investors to promote or use wrong forecasts, because when the day comes, the actual value of the certificate will depend on the actual temperatures. The greatest economic benefits will accrue to those who use the most accurate climate forecasts. In one stroke we will solve the politicization of climate science by using the market to weed out biased models.

In effect the futures market would become the world's most accurate climate model. With billions of dollars at stake, investors will ruthlessly sift information sources for an edge in predicting the value of tax exemption certificates, thereby bringing all the world's knowledge to bear on the future path of climate.

This is emphatically not a "wait-and-see" approach: in fact it is the most ruthlessly forward-looking approach possible. New information will get incorporated into policy plans instantly. If a scientist concludes from his analysis that we are nearing a "tipping point" at which rapid temperature increases are inevitable, market participants won't ignore him, instead they will objectively assess whether his warnings are credible. Futures prices will reflect objective forecasts of future temperatures. Indeed if a scientist believes his own forecast of the coming climate tipping point, he will be able to earn significant profits by investing his savings in carbon tax futures while they are still cheap. And if he doesn't trust his own science enough to bet his pension on it, then he can hardly blame others for ignoring it too.

5 STEWARDSHIP AND THE REAL QUESTION

So, back to the big picture. Regarding climate change and environmental issues generally, we face many scientific and economic questions but behind them we ultimately face a theological question: *Do we belong here?* Everything follows from the way you answer this question. Are we in a china shop we should never have entered, or on a playground that suits us admirably? If most people in a society come to believe we are in a cosmic china shop, then we will lose our cultural nerve and start devoting increasingly anxious efforts to reducing our "ecological footprint," i.e. our presence on the planet. If people believe that we do belong here, and the world will not be shattered by the ordinary pursuit of prosperity and human well-being, then let us make proper use of the world, which begins by actually using it. Our job is to manage risks rather than to try and avoid them, and that requires a willingness actually to take risks.

In making environmental valuations, specifically as regards the climate, I think that where costs and benefits are roughly equal, or so ambiguous and uncertain that a decision comes down to a value judgment, we should take a lesson from the parable of the talents. The world in which we live repeatedly shows unexpected robustness and fruitfulness, and western environmental experts have a longstanding track record of overstating risks and alarms. People in general have shown an amazing capacity to live and prosper in every climate, from the tropics to the Arctic regions, and to cope with large variations in weather and climate during their lifetimes. My value judgment is that, other things being equal, we should favour putting the talents and resources of our world, including fossil energy, to work in ways that are known to be of benefit to people. My preferred policy plan is a temperature-indexed CO_2 emissions tax coupled with a futures market in tax exemption certificates. This would provide the ideal way of handling the deep uncertainty, by using market incentives to bring all available information to bear on projecting the most likely path of global warming and the most efficient ways of responding to it. Personally I expect such a futures market would settle on a low and relatively flat trajectory of expected temperatures and certificate prices, but who cares what I think. In the policy system I propose my own expectations would have as little weight as anyone else's: ultimately nature would set the price of emissions according to their actual effect, and this is as it should be.

Refusing to take the catastrophic global warming narrative at face value is not recklessness. Indeed refusing to question it is recklessness. Small local GHG reductions, however costly, have no global effect. The only climatically-relevant policy would involve deep emission reductions around the world. Under current technology, as far as I can tell, there is no way to do this without scaling back energy availability and global income by a large fraction, and doing so would entail massive human costs. So I could only envision supporting an aggressive global effort at climate mitigation if it were known with a high degree of certainty that the risks of GHG emissions were so high as to justify widespread reversal of economic development. I don't find the arguments for such a stance the least bit persuasive, and I think the arguments against such a stance are convincingly supported by the data. Wise stewardship of the Earth's fossil fuel resources therefore involves their continued actual *use*, and that being the case, abundance and affordability are good things.

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