

Forecasting global climate change: A scientific approach

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Working Paper – June 2014

Subsequently published as “Forecasting Global Climate Change” in *Climate Change: The Facts 2014*. Alan Moran (Editor). Published by the Institute of Public Affairs, Melbourne, Victoria 3000, Australia

Abstract

The Golden Rule of Forecasting requires that forecasters be conservative by making proper use of cumulative knowledge and by not going beyond that knowledge. The procedures that have been used to forecast dangerous manmade global warming violate the Golden Rule. Following the scientific method, we investigated competing hypotheses on climate change in an objective way. To do this, we tested the predictive validity of the global warming hypothesis ($+0.03^{\circ}\text{C}$ per year with increasing CO_2) against a relatively conservative global cooling hypothesis of -0.01°C per year, and against the even more conservative simple no-change or persistence hypothesis (0.0°C per year). The errors of forecasts from the global warming hypothesis for horizons 11 to 100 years ahead over the period 1851 to 1975 were nearly four times larger than those from the global cooling hypothesis and about eight times larger than those from the persistence hypothesis. Findings from our tests using the latest data and other data covering a period of nearly 2,000 years support the predictive validity of the persistence hypothesis for horizons from one year to centuries ahead. To investigate whether the current alarm over global temperatures is exceptional, we employed the method of structured analogies. Our search for analogies found that environmental alarms are a common social phenomenon, with 26 similar situations over a period of two hundred years. None were the product of scientific forecasting procedures, and in all cases the alarming forecasts were wrong. Twenty-three of the alarms led to government actions. The government actions were harmful in 20 cases, and of no benefit in any.

Acknowledgements

We are grateful to Steve Goreham, David Legates, Craig Loehle, Alan Moran, and Willie Soon for their helpful suggestions on this chapter. Hester Green, Jen Kwok, Lynn Selhat, and Angela Sun provided useful suggestions on the writing. The responsibility for any errors or omissions remains with the authors.

“Warming by 2070, compared to 1980 to 1999, is projected to be... 2.2 to 5.0°C.”¹

“By 2100, the average U.S. temperature is projected to increase by about 4°F to 11°F.”²

“If we do not cut emissions, we face even more devastating consequences, as unchecked they could raise global average temperature to 4°C or more above pre-industrial levels by the end of the century. The shift to such a world could cause mass migrations of hundreds of millions of people away from the worst-affected areas. That would lead to conflict and war.”³

Forecasts such as these are made by scientists and repeated by the political leaders they advise. The principal source of the forecasts is the United Nation’s Intergovernmental Panel on Climate Change (the IPCC). The IPCC’s forecasts are the product of a collaboration of scientists and computer modellers working for lobbyists, bureaucrats, and politicians (as documented by Laframboise 2011, and Ball 2014). The forecasts of dangerous manmade global warming and its consequences are made with great confidence, as are recommendations of actions to counter the forecasted danger.

History is replete with experts making confident forecasts. The record also shows that the accuracy of such forecasts has been poor. Consider, for example, Professor Kenneth Watt’s forecast of a new Ice Age in his 1970 Earth Day speech at Swarthmore College:

“The world has been chilling sharply for about twenty years. If present trends continue, the world will be about four degrees colder for the global mean temperature in 1990, but eleven degrees colder in the year 2000. This is about twice what it would take to put us into an ice age.”

Professor Watt is not unusual among experts in making confident forecasts that turn out to be wrong. Evidence from research on forecasting shows that an expert’s confidence in making forecasts about complex uncertain situations is unrelated to the accuracy of the forecast (Armstrong 1985, pp. 138-144, summarizes research). Those who believe that we can learn to avoid poor forecasts from history may wish to consult the diverse examples in Cerf and Navasky’s book *The Experts Speak* (1984).

We suggest that government policy makers and business managers consider whether the IPCC’s forecasting methods are valid before they consider making decisions on the basis of the

¹ CSIRO, *State of the climate – 2014*, “Future climate scenarios for Australia”, <http://www.csiro.au/Outcomes/Climate/Understanding/State-of-the-Climate-2014/Future-Climate-Scenarios-for-Australia.aspx>, viewed on 29 April 2014.

² United States Environmental Protection Agency web page on “Future Climate Change”, <http://www.epa.gov/climatechange/science/future.html#Temperature>, viewed on 29 April 2014.

³ Lord Stern, quoted in *The Guardian* on 14 February 2014 in an article titled “Flooding and storms in UK are clear signs of climate change, says Lord Stern”, <http://www.theguardian.com/environment/2014/feb/13/flooding-storms-uk-climate-change-lord-stern>, viewed on 29 April 2014.

forecasts. To that end, we examine whether or not the IPCC's forecasts of dangerous manmade global warming are the product of scientific methods.

We then investigate whether alternative hypotheses of climate change provide more accurate forecasts than the dangerous manmade global warming hypothesis. Specifically, we test forecasts from the hypothesis of global cooling and from the hypothesis of climate persistence. We then make forecasts of global average temperatures for the remaining years of the 21st Century and beyond using an evidence-based forecasting method.

Finally, we ask whether the IPCC forecast of dangerous manmade global warming is a new phenomenon. To answer this question, we use the method of structured analogies to seek out and analyse similar situations.

Are the alarming forecasts the product of scientific forecasting methods?

The IPCC forecasts are derived from the judgments of the scientists that the IPCC engages. Computer modellers write code to represent the scientists' judgments that, in turn, provides long-term forecasts of global mean temperatures. Is this use of expert judgment a valid approach to climate forecasting?

The science of forecasting

For nearly a century, researchers have been studying how best to make accurate and useful forecasts. Knowledge on forecasting has accumulated by testing multiple reasonable hypotheses about which method will provide the best forecasts in given conditions. This scientific approach contrasts with the folklore that experts in a domain will be able to make good forecasts about complex uncertain situations using their unaided judgment, or using un-validated forecasting methods (Armstrong 1980; Tetlock 2005).

Scientific forecasting knowledge has been summarized in the form of principles by 40 leading forecasting researchers and 123 expert reviewers. The principles summarise the evidence on forecasting from 545 studies that in turn drew on many prior studies. Some of the forecasting principles, such as "provide full disclosure" and "avoid biased data sources," are common to all scientific fields. The principles are readily available in the *Principles of Forecasting* handbook (Armstrong 2001).⁴

⁴ In addition, the ForPrin.com web site provides a checklist of the forecasting principles and software that help users to determine which methods to use in a given situation.

We used that knowledge to assess whether the IPCC procedures described in Randall *et al.* (2007) amounted to scientific forecasting. To do so, we first examined that IPCC chapter's references to determine whether the authors had relied on validated forecasting procedures. We found no references to validation. We then sent emails to all of the Randall *et al.* (2007) authors for whom we were able to obtain email addresses⁵, asking for references for credible forecasts of global average temperatures and the methods used to derive them. The few useful responses we received referred us to the Randall *et al.* chapter or to works that were cited in it.

Evaluating the IPCC procedures against forecasting principles

We then audited the IPCC forecasting procedures using the Forecasting Audit Software available on ForPrin.com. Our audit found that the IPCC followed only 17 of the 89 relevant principles that we were able to code using the information provided in the 74-page IPCC chapter. Thus, the IPCC forecasting procedures violated 81% of relevant forecasting principles (Green and Armstrong 2007). Appendix 1 of this chapter lists the principles that we found had been clearly violated by the IPCC procedures.

It is hard to think of an occupation for which it would be acceptable for practitioners to violate evidence-based procedures to this extent. Consider what would happen if an engineer or medical practitioner, for example, failed to properly follow even a single evidence-based procedure.

Evaluating the IPCC procedures compliance with the Golden Rule of Forecasting

We analysed the IPCC's forecasting procedures to assess whether they followed the Golden Rule of Forecasting. The Golden Rule of Forecasting requires that forecasters be *conservative*. This means that they should use procedures that are consistent with knowledge about the situation and about forecasting methods. The Golden Rule is the antithesis of the common antiscientific attitude that "this situation is different," which leads forecasters to ignore cumulative knowledge.

The Golden Rule is a unifying theory of how best to forecast. The theory has been tested for consistency with the evidence in a review of the literature from all areas of forecasting that found 150 studies relevant to the Golden Rule. The studies provided findings from experiments on the effect of conservative procedures compared to unconservative ones on forecast accuracy. All of the evidence was consistent with the Golden Rule.

To assist forecasters, the evidence on the Golden Rule is summarised in the form of 28 guidelines, including "avoid bias by specifying multiple hypotheses and methods" and "select

⁵ The IPCC refused to provide the authors' email addresses.

evidence-based methods validated for the situation” (Armstrong, Green, and Graefe 2014).⁶ The median reduction in forecast error from following a Golden Rule guideline, rather than common practice, is 25%. That is, error was reduced by one quarter.

We found that the IPCC procedures violated all 19 of the Golden Rule guidelines that are relevant to long-term climate forecasting, including “be conservative when forecasting trends if the series is variable or unstable” and “be conservative when forecasting trends if the short and long-term trend directions are inconsistent.” As a consequence of the Golden Rule violations, the IPCC forecasts are a product of biased forecasting methods.

Are forecasts of dangerous global warming nevertheless valid?

Having established that the IPCC *forecasting procedures* are unvalidated and are inconsistent with scientific forecasting knowledge, we investigated whether it would be possible to test the validity of the *forecasts*. The most recent global warming scare started around 1976, so testing the validity of short-term forecasts against the few years since then is possible. Such a test is limited, however, given that it is not unusual for temperatures to trend up or down, on average, for several years. Also, policy makers and investors who consider large expenditures that are costly to reverse are concerned with long-term trends. We therefore devised tests of the validity of the IPCC model’s short- and long-term forecasts that made extensive use of available data.

Informal short-term tests

In 1999, Pat Michaels explained that short-term events were responsible for recent elevated temperatures and offered an early test of the IPCC’s short-term forecasts in the form of a bet that temperatures would go down in the next ten years (Michaels 1999). No one took the bet... and temperatures went down.

Over the past nearly two-decades, atmospheric carbon dioxide concentrations have risen while global temperatures have remained flat. Despite the disconfirming evidence, the IPCC claims to have become even more confident about the manmade global warming hypothesis and they continue to forecast dangerous warming. The IPCC’s response is typical of how people tend to react when their forecasts are wrong: by having an even stronger belief that they will be proven correct (e.g., Festinger *et al.* 1956, and Batson 1975). Moreover, scientists, like other human beings, tend to reject evidence that contradicts their beliefs (see, for example, the experiments by Mahoney 1977).

⁶ A copy of the Golden Rule of Forecasting checklist of guidelines can be found at goldenruleofforecasting.com, as can a draft copy of the paper.

By 2007, there still had been no proper validation of the IPCC's forecasts. To generate interest in the importance of validation, one of us (Armstrong) proposed a bet to former U.S. Vice President Al Gore that a "no-change" forecast of global average temperature would be more accurate than any model or forecast that Mr. Gore would support. Gore, advised by Professor James Hansen (see, e.g., Hansen 2004), was at the time warning that a "tipping point" in global temperatures was imminent. In contrast to Gore's expectation of supporting evidence soon, Armstrong expected that a much longer period would be needed to obtain a clear result due to natural variations. Armstrong nevertheless proposed a 10-year bet on the assumption that a shorter term would generate more interest, despite estimating that he had a $\frac{1}{3}$ chance of losing.

In order to have an objective standard against which to compare forecasts from the alternative hypotheses, the bet uses the University of Alabama at Huntsville (UAH) lower troposphere series (Christy *et al.* 2010). As of May, 2014, the errors from the IPCC's business-as-usual forecast of $+0.03^{\circ}\text{C}$ per year—standing in for Mr. Gore's tipping point due to his unwillingness to take the bet—were more than 27% larger than the errors from Armstrong's bet on the no-change forecasts.

Approach to long-term testing

The models that the IPCC uses for forecasting are based on the beliefs of some scientists that exponentially increasing levels of carbon dioxide in the atmosphere will cause global mean temperature to increase at a rate of at least 0.03°C per year. That figure has been the central forecast of the IPCC since 1990 (IPCC 1990, p. xi; IPCC, 1992, p. 17). Because carbon dioxide levels have been increasing exponentially since the beginning of the Industrial Revolution, the IPCC model would seem to apply over this whole period.

We tested the validity of the IPCC model for forecasting horizons up to 100 years using the data on global mean temperatures that the IPCC use: the U.K. Met Office Hadley Centre's HadCRUT3 series⁷. The Hadley temperature series are derived from selected weather stations and sea surface records that are adjusted and aggregated to provide proxy average global temperatures. We derived rolling IPCC-model forecasts of the HadCRUT3 series starting from the year 1851, and ending in the year 1975, before the most recent global warming trend commenced. The forecasting procedure was simple, and is consistent with the IPCC's published business-as-usual forecasts: we added 0.03°C to the previous year's actual temperature to derive a one-year-ahead forecast, and then added the same figure to the forecast for the previous year for each subsequent forecast horizon out to 100 years. By repeating this procedure for each subsequent year, we obtained 125 one-year-ahead forecasts, 124 two-year-

⁷ Available from <http://hadobs.metoffice.com/hadcrut3/>

ahead forecasts, and so on up to and including 26 forecasts for 100 years ahead (Green, Armstrong, and Soon 2009.)

Given that the HadCRUT3 temperature series trends broadly upwards,⁸ one would expect the IPCC-model forecasts that we generated to track the HadCRUT3 series quite well. To determine whether the dangerous global warming hypothesis is a credible one, however, it is necessary to test the forecasts against forecasts from alternative hypotheses, and to do so using scientific forecasting methods.

Short and long-term testing using competing hypotheses

In the 1960s and early 1970s, scientists warned of a new ice age (see, e.g., Kukla and Matthews 1972 and Professor Kenneth Watt's 1970 Earth Day speech quoted above). The scientists provided hypotheses to support their belief that this time the climate really had changed. Some scientists still advance the cooling hypothesis.⁹

Yet despite these forecasts of cooling, starting in the mid-to-late 1970s there was actually a warming trend, and warming alarmists began to inform us that virtually all scientists now subscribed to the dangerous manmade global warming hypothesis. The claim of near unanimity of scientific opinion has been discredited by Legates *et al.* (2014)¹⁰, however, and stands in contrast to the 31,487 U.S. scientists who have publicly signed a statement that they consider the dangerous manmade global warming hypothesis inconsistent with the evidence.¹¹

While scientists who predict warming and those who predict cooling provide reasons for their hypotheses, their reasons have been indecisive. In any event, science does not advance by asking scientists to vote on hypotheses, but by testing them in competition with alternative reasonable hypotheses (Chamberlin 1890).

We tested a cooling hypothesis of 1°C cooling per century against the HadCRUT3 global temperature data. The forecast of cooling is consistent with the various alarms over impending new ice ages that have occurred over the last 100 years and longer, including those mentioned above.¹² And the

⁸ Note that there is evidence that the series tends to substantially overstate any warming trend due to weather station locations becoming increasingly surrounded by buildings, asphalt, and heat sources, and the deployment of more sensitive measurement instruments, together with unexplained adjustments to the temperature readings (McKittrick and Michaels 2007; McKittrick and Nierenberg 2010; McKittrick 2013; Watts *et al.* 2012).

⁹ For examples, search for "Earth undergoing global COOLING since 2002" on climatedepot.com, and George Kukla interview in Krueger (2007).

¹⁰ See also Joe Bast and Roy Spencer's "The Myth of the Climate Change '97%'," *Wall Street Journal*, May 26, 2014, available from <http://hockeyschtick.blogspot.com.au/2014/05/wsj-myth-of-climate-change-97-what-is.html>

¹¹ See the Global Warming Petition Project at petitionproject.org

¹² See, e.g., Dan Gainor's summary of *The New York Times* cooling, and warming, alarms under the title of "Fire and Ice," here <http://www.mrc.org/special-reports/fire-and-ice-0>

rate is arguably consistent with the understanding of scientists who consider that the Earth is still experiencing a cooling period, albeit with fluctuations, that commenced around 4,000 years ago (e.g. Matthes 1939).

For horizons from 1 to 100 years from the year 1851 to the year 1975, 7,550 forecasts in total, the average absolute errors of the 0.03°C per year warming forecasts and of the 0.01°C per year cooling forecasts increase as the forecast horizon increases (see Exhibit A). Because our tests use historical data known to exhibit a warming trend, the warming model has an unfair advantage in this test. Despite that advantage, across all forecast horizons, the average errors of the warming forecasts are more than twice as large as the errors from the relatively more conservative cooling hypothesis. Remarkably, the natural cooling forecasts are more accurate than the dangerous warming forecasts for all forecast horizons.

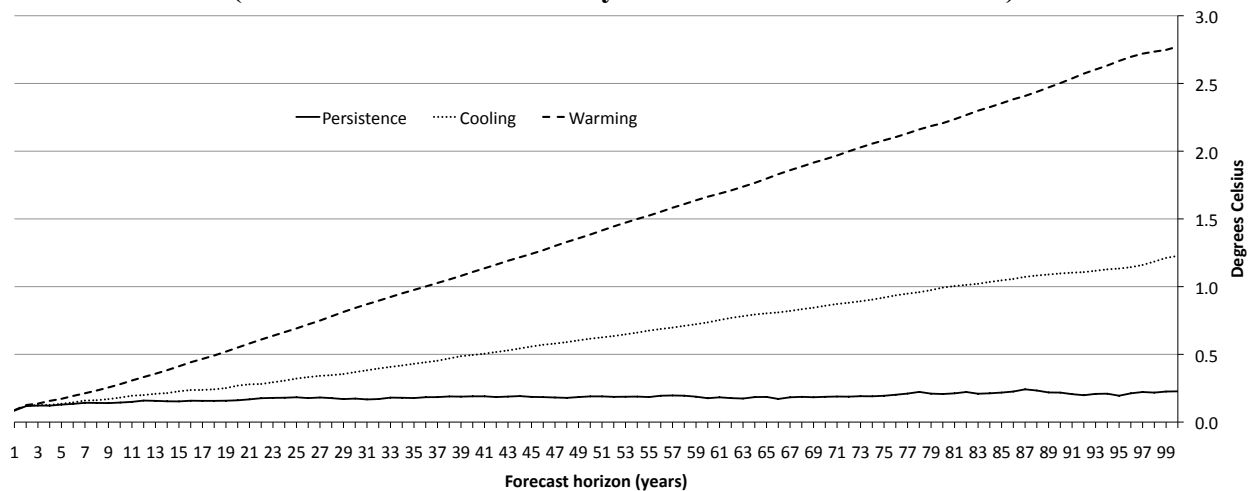
The global warming and cooling hypotheses were developed without the aid of scientific forecasting. To develop a credible forecasting method against which to benchmark the warming and cooling hypotheses, we needed a model that was both consistent with evidence-based forecasting principles and with evidence on climate change. With that in mind, we asked climate expert and astrophysicist Willie Soon to collaborate with us to develop a model and validation tests (Green, Armstrong, and Soon 2009).

With Willie Soon, we established that the state of knowledge about the causes of climate change was such that it would be inappropriate to develop a causal model. The strength and even direction of proposed causal relationships, including with carbon dioxide, are much disputed among leading climate scientists (Lindzen 2012; Soon *et al.* 2001). For example, Kukla and Matthews (1972) reported from a meeting of climate scientists that “one conclusion reached at the session was that there is no qualitative difference between the climatic fluctuations in the 20th Century and the climatic oscillations that occurred before the industrial era. The present climatic trends appear to have entirely natural causes, and no firm evidence supports the opposite view” (p. 190). A more recent analysis of two 3,000-year temperature proxy series comes to the same conclusion (Loehle 2004).

We concluded from forecasting principles that because knowledge about climate change is so poor, forecasts from a no-change forecasting model would be more accurate than forecasts from methods that attempt to incorporate knowledge that is tentative at best. Depending on the situation, the appropriate no-change model might be one that forecasts that the level (e.g. current temperature) will not change, that the trend will not change, or even that the rate of change will not change. For forecasting long-term global temperatures, we determined that the benchmark model that is most consistent with the state of knowledge is one that forecasts no change in the level; in other words, no trend.

We compared the forecasts from the no-trend model with the forecasts from the cooling and warming hypotheses. We found that the average error of the no-trend forecasts was smaller than the average errors of both the warming and the cooling forecasts for *all* forecast horizons (Exhibit A, 7,550 forecasts from each method). The average errors of the warming forecasts (dashed line) and the cooling forecasts (faint line) over the short-term (1 to 10 years) were 45% and 10% larger, respectively, than the average errors of the no-trend forecasts (solid line). The average error of the no-trend forecasts for the longer-term horizons, from 11 to 100 years, was roughly one-quarter of the average cooling forecast error, and one-eighth of the warming forecast error. In absolute terms, the average errors of the no-trend forecasts were less than 0.20°C for all horizons out to 75 years; beyond that, the average errors did not exceed 0.24°C. The small and steady forecast errors from the persistence model suggest that the Earth's climate is remarkably stable over human-relevant timescales. This is particularly remarkable given the claims by warming alarmists that we have been experiencing “unprecedented” changes in the climate over the period of the test (see, e.g. IPCC 2013, p. 4).

Exhibit A:
Average absolute errors of 0.03°C warming, 0.01°C cooling, and persistence forecasts
(Forecasts for 1851 to 1975 by forecast horizon. Errors in °C)



Very long-term testing of predictive validity

In order to assess the validity of the hypotheses over very long horizons, we tested the accuracy of forecasts from warming, cooling, and no-trend model hypotheses against the Loehle series of proxy annual temperatures (Loehle and McCulloch 2008). Proxy temperature data are obtained from naturally occurring records of biological and physical processes that vary with temperature. The Loehle series was constructed from 18 series obtained and calibrated by other researchers who used such proxy records as boreholes and pollen counts that each covered most of the Common Era and, between them,

covered much of the globe. The resulting Loehle series extends from AD 16 to AD 1935, allowing us to test forecasts from variations of the hypotheses for horizons of up to nearly 2000 years. The series includes the Medieval Warm Period and the Little Ice Age. Evidence suggests that the current climate is not as warm as that of the Medieval Warm Period when cows grazed and willows grew in Greenland and seals basked on the shores of Antarctica (see, e.g., Soon *et al.* 2003, and ongoing research reported by the Medieval Warm Period Project at CO₂science.org).

A forecaster living 100 years after the beginning of the Loehle series in AD 115 might reasonably have forecast that the average temperature trend that had prevailed over the previous 100 years, an increasing one of roughly 0.003°C per year (0.3°C per century), would prevail indefinitely. Indeed, some researchers have suggested that the Earth has been warmed by human activity for at least 5,000 years (Vavrus, Ruddiman, and Kutzbach 2008). The errors of the warming forecasts increased as the forecast horizon lengthened as the dashed (topmost) line in Exhibit B shows.

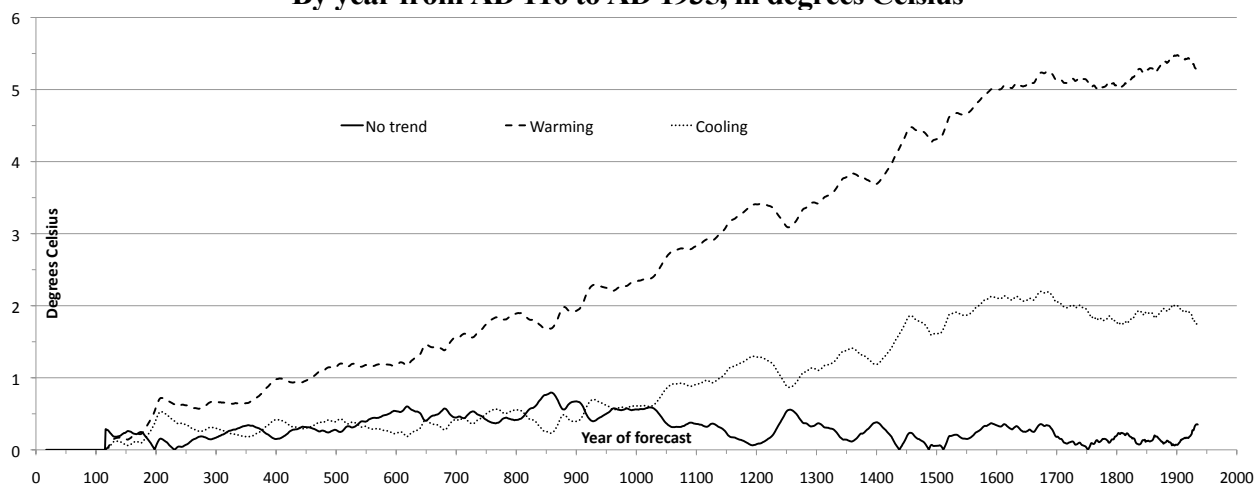
A competing forecaster in AD 115 might well have reasoned from the knowledge of the time that the Sun is like a large fire that must slowly burn down. Given that temperatures over the previous century had been trending more upwards than downwards, she might have proposed that while the Sun's fire may splutter and flare up from time to time, there would be a long slow decline in the energy emitted. With these observations in mind, she might have forecast that the average temperatures would trend downwards at the relatively more conservative rate of 1°C per millennium or 0.001°C per year on average, *a much more conservative forecast than those of the 1st Millennium warmer and of the 20th Century warmers and coolers described above.* While the errors of her cooling forecasts increased only slowly out to the year AD 750, beyond that year the errors of her forecasts tended to increase as the forecast horizon lengthened (middle, dotted, line in Exhibit B).

We compared the records of the warming and cooling hypotheses forecasters with the record of our benchmark no-trend hypothesis in the form of a forecaster who predicted that the global average temperature for the 1,820 years from AD 116 to 1935 would be the same as the AD 115 average. The solid line in Exhibit B shows the errors of the no-trend forecasts by year, one forecast error per year. The modest size of the errors and the lack of even a very small persistent trend in them suggest that there have been no changes in the climate system. In other words, the claim that “things are different now,” although often made in relation to forecasting in many fields, is once again unsupported. Over longer policy-relevant periods, annual global mean temperatures are highly stable.

Even with a much more conservative forecast warming rate (one-tenth that of our previous tests), when applied to this series the warming hypothesis again performed relatively poorly. The average error of the 1,820 0.3°C-per-century warming forecasts was more than nine times the average

error of the no-trend forecasts. Again, the errors increased with the forecast horizon. For example, the errors of warming forecasts for the 4th Century made in AD 115 were nearly three times larger than the errors of the no-trend forecasts. The equivalent figures for the 8th, 12th, 16th, and 18th Centuries were 4, 14, 23, and 27 times larger. The findings are consistent with those of Green, Armstrong, and Soon (2009).

Exhibit B:
Absolute errors of warming, cooling, and no-trend forecasts made in AD 115
By year from AD 116 to AD 1935, in degrees Celsius



These findings from a long period of varied climate, then, are consistent with those of our analysis for the 1851 to 1975 warming period above: the more conservative hypothesis and forecasting method provides the more accurate forecasts. In particular, the most conservative model, the no-trend model, has greater predictive validity than long-term trend models under diverse conditions. No matter when one starts forecasting and no matter how global average temperature is estimated, the evidence-based persistence model produces by far the most accurate forecasts. The findings on the accuracy of forecasts from long- and short-term tests of the alternative climate change hypotheses are summarised in Exhibit C in the form of Relative Absolute Errors (RAEs). The reported RAEs are the absolute error of the forecasts from the hypothesis relative to the corresponding absolute error of the forecasts from the persistence (no-change) model over the forecast horizon. Thus, a figure of 0.5 means the error was only half as big as that from the persistence model forecast, and 2.0 means it was twice as big.

Exhibit C:
Relative accuracy of forecasts from alternative climate change hypotheses
Warming, and Cooling, versus Persistence

Data series (Test period)	Forecast horizons (years)	Forecasts (number)	Hypothesis (Rate, °C p.a.)	Relative Absolute Error (v. Persistence = 1)
UAH 2008–2014	1 – 6 1/3	76*	Warming (0.03) Cooling (0.01)	1.27 1.05
HadCRUT3 1851–1975	1 – 10	1,205**	Warming (0.03) Cooling (0.01)	1.45 1.10
	11 – 100	6,345**	Warming (0.03) Cooling (0.01)	8.14 3.62
Loehle 116–1935	1 – 1,820	1,820	Warming (0.003) Cooling (0.001)	9.01 3.16

* Monthly forecasts.

** Successive updating used.

Evidence-based climate forecasts for the 21st Century

Our testing used alternative data sources, different time periods, different starting points, and different horizons. The findings were always the same. Forecasts from the more conservative cooling hypotheses were more accurate than forecasts from the warming hypotheses. Forecasts from the most conservative hypothesis, the no-trend model, were always much more accurate. The no-trend model is consistent with evidence-based forecasting principles and with the state of knowledge about the behaviour of the Earth's climate. The IPCC's alarming-warming model is not. Consistent with knowledge about the proper model for this situation, the predictive validity tests finds no support for the global warming hypothesis for forecasting global mean temperatures over this century and beyond.

Our forecasts for each year's global average temperature for the 100 years to 2113 are that they will be the same, more or less, as the 2013 global average temperature. We suggest that our forecasts should be monitored against the University of Alabama at Huntsville's (UAH) lower troposphere temperature series because this satellite-based measure provides a better assessment of the global average than the Hadley (HadCRUT3) series, and because it is fully and openly documented and is, therefore, less likely to be biased.

Perhaps it is possible to improve on the already very accurate long-term temperature forecasts from the no-trend model, for example by estimating the global average temperature level from a weighted average of temperatures over recent years, rather than from only the latest year. We have not

attempted to improve upon our very simple no-change model, however, because the errors of the forecast from the model are too small to be of concern to policy makers and business decision makers; the no-trend model forecasts are more than good enough.

Are recent temperature trends so unusual that evidence on past climate is irrelevant?

The global warming alarm derives from the claim that recent increases in temperatures are **unprecedented**. As we describe above, the claim is by no means generally accepted. Our long-term tests of predictive validity provide no evidence that anything unusual has occurred.

In a further test of the claim that there are no precedents, we asked forecasters at the 2012 International Symposium on Forecasting in Boston to forecast the next 25 years for two 50-year sequences of monthly global mean temperatures from the Hadley data series (Exhibit D). We told the forecasters that both sequences occurred during the age of industrialism. In other words, both coincided with exponential increases in atmospheric carbon dioxide.

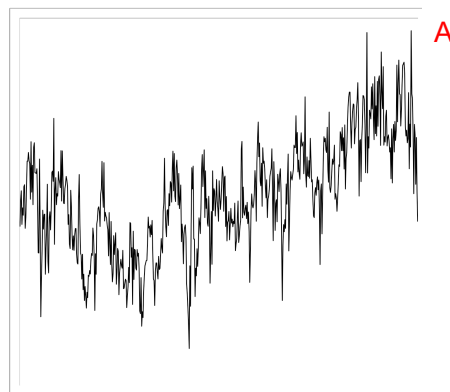
Exhibit D: Forecasting task using Hadley (HadCRUt3) global mean temperatures

Test your forecasting skills:

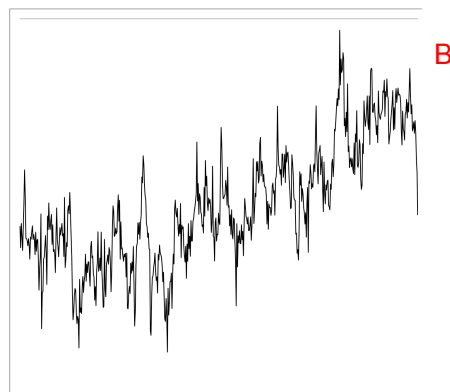
Print this page and draw in your forecasts

Monthly global mean temperatures over two half centuries*

Draw in your forecasts for the next 25 years for both charts.



A



B

Time →

1

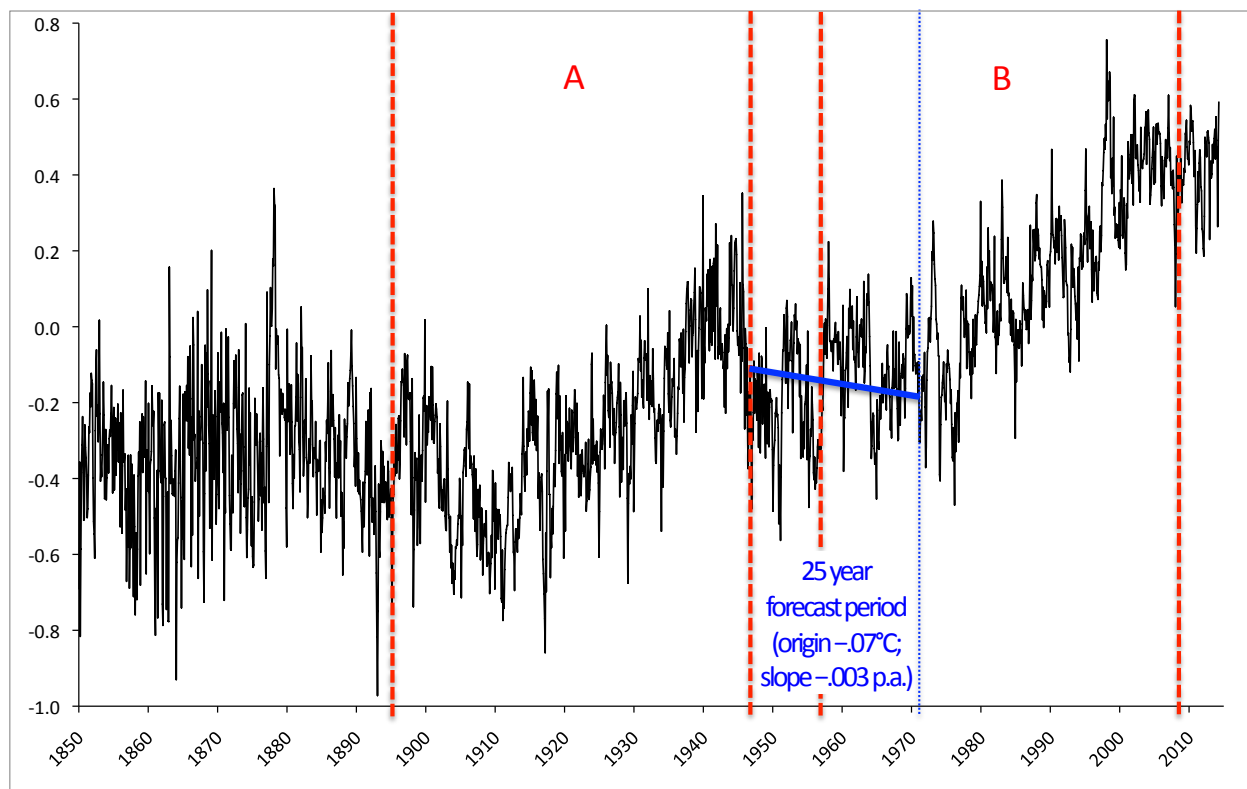
25

**Both during industrial era*

Of the 51 forecasters who responded, 23 made forecasts that were consistent with carbon-dioxide causality, while the others forecast little or no trend. Exhibit E shows the data in context and a trend line for the 25-year period that the forecasters were asked to forecast and for which data are available. The similarity of the two sequences is inconsistent with the hypothesis that climate changes are different now than in earlier times.¹³ In fact, after the decline in the 25 years following series A, there was an effort to get the government to stop global cooling. However, the warming in the series after that led to a switch to ask the government to stop global warming. Many of the leaders in the global cooling movement were then involved in the global warming movement.

Exhibit E: Forecasts for the two similar graphs

Hadley global mean °C temperature anomalies showing selected half-centuries



What do previous environmental alarms tell us?

Having investigated the forecasting procedures behind the IPCC forecasts and found them to lack validity, and having found the forecasts to be much less accurate than no-change forecasts, we were concerned that governments are taking the dangerous manmade global warming alarm seriously, to the extent that they have already implemented costly policies and regulations. We decided, therefore,

¹³ The idea behind this comparison came from a presentation by Meyer (2009).

to examine whether the global warming alarm is an unusual phenomenon. To do so, we used the structured analogies approach (Green and Armstrong 2011).

The structured analogies method involves asking experts to think of similar situations to the situation of interest. Information is then obtained about the outcome of each analogy. We had previously tested the structured analogies method for forecasting complex situations involving interactions between parties with conflicting interests, including a special interest group occupying a public building and demanding taxpayer funding, and an international crisis over access to water. The research found that a structured search for and analysis of analogous situations produces forecasts that are much more accurate than the usual method of asking experts what they think will happen (Green and Armstrong 2007). Other researchers have subsequently found the method useful for forecasting the outcomes of policy initiatives (e.g., Nikolopoulos *et al.* 2014).

With the help of domain experts we have, to date, identified 26 analogous situations (Green and Armstrong 2011). They all began with an allegedly portentous incident or with claims that an apparent trend was ominous. Searches for evidence supporting each alarm followed, along with calls for government action. In no case was there recourse to scientific forecasting. The fact that we were able to identify as many environmental alarm analogies as we did, and the frequency with which they have occurred in recent times, suggest that they are a common social phenomenon and that the global warming alarm is not at all unusual. More generally, it is another example in a long history of calamity forecasts similar to those described in *Extraordinary Popular Delusions And The Madness Of Crowds* (MacKay 1841).

Short descriptions of the analogies are provided in Appendix 2 of this chapter.¹⁴ Evidence on the nature and outcomes of all 26 analogies is provided in our online working paper (Green and Armstrong 2011) at publicpolicyforecasting.com.¹⁵ We welcome further evidence on each of these analogies, invite others to submit their ratings of the analogies for publication at publicpolicyforecasting.com, and encourage others to propose other environmental alarms in case we have missed important analogies.

What were the outcomes of the alarms? The forecasts of harmful outcomes all turned out to be wrong. For the 23 alarms that resulted in government actions, the measures that were taken caused harm in 20 cases. The alarms faded from public attention slowly over time, but harmful policies have remained in many cases. We suggest using the Golden Rule of Forecasting to identify and to expose such false alarms, and to thereby help to minimize the harm that they cause.

¹⁴ Some of the descriptions were previously published in Green (2011).

¹⁵ That site also includes a list of analogies that had been compiled by Julian Simon.

Conclusions

Climate has varied in the past and can be expected to do so in the future. Mankind has adapted to both cool and warm periods, and trade and economic growth over the past 300 years has greatly increased our ability to do so. In that context, forecasts of climate are of little value unless they are for a strong and persistent trend, *and* are accurate.

The IPCC “forecasts” are for a strong and persistent trend, but they have been inaccurate in the short term. Moreover, there is no reason to expect them to be accurate in the longer term. The IPCC’s forecasting procedures violate all of the relevant Golden Rule of Forecasting guidelines. In particular, their procedures are biased to advocate for the hypothesis of dangerous manmade global warming.

We found that there are no scientific forecasts that support the hypothesis that manmade global warming will occur. Instead, the best forecasts of temperatures on Earth for the 21st Century and beyond are derived from the hypothesis of persistence. Specifically, we forecast that global average temperatures will trend neither up nor down, but will remain within half-a-degree Celsius (one-degree Fahrenheit) of the 2013 average.

This chapter provides good news. There is neither need to worry about climate change, nor reason to take action.

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Appendix 1: Clear Violations of Forecasting Principles by the IPCC

Setting Objectives

- Describe decisions that might be affected by the forecast.
- Prior to forecasting, agree on actions to take assuming different possible forecasts.
- Make sure forecasts are independent of politics.
- Consider whether the events or series can be forecasted.

Identifying Data Points

- Avoid biased data sources.

Collecting Data

- Use unbiased and systematic procedures to collect data.
- Ensure that information is reliable and that measurement error is low.
- Ensure that the information is valid.

Selecting Methods

- List all important selection criteria before selecting methods.
- Ask unbiased experts to rate potential methods.
- Select simple methods unless empirical evidence calls for a more complex approach.
- Compare track records of various forecasting methods.
- Assess acceptability and understandability of methods to users.
- Examine the value of alternative forecasting methods.

Implementing Methods: General

- Keep forecasting methods simple.
- Be conservative in situations of high uncertainty or instability.

Implementing Quantitative Methods

- Tailor the forecasting model to the horizon.
- Do not use "fit" to develop the model.

Implementing Methods: Quantitative Models with Explanatory Variables

- Apply the same principles to forecasts of explanatory variables.
- Shrink the forecasts of change if there is high uncertainty for predictions of the explanatory variables.

Integrating Judgmental and Quantitative Methods

- Use structured procedures to integrate judgmental and quantitative methods.
- Use structured judgments as inputs of quantitative models.
- Use pre-specified domain knowledge in selecting, weighing, and modifying quantitative models.

Combining Forecasts

- Combine forecasts from approaches that differ.
- Use trimmed means, medians, or modes.
- Use tracked records to vary the weights on component forecasts.

Evaluating Methods

- Compare reasonable methods.
- Tailor the analysis to the decision.
- Describe the potential biases of the forecasters.
- Assess the reliability and validity of the data.
- Provide easy access to the data.
- Provide full disclosure of methods.
- Test assumptions for validity.
- Test the client's understanding of the methods.
- Use direct replications of evaluations to identify mistakes.
- Replicate forecast evaluations to assess their reliability.
- Compare forecasts generated by different methods.
- Examine all important criteria.
- Specify criteria for evaluating methods prior to analyzing data.
- Assess face validity.
- Use error measures that adjust for scale in the data.
- Ensure error measures are valid.
- Use error measures that are not sensitive to the degree of difficulty in forecasting.
- Avoid error measures that are highly sensitive to outliers.
- Use out-of-sample (ex-ante) error measures.
- Do not use tests of statistical significance.
- Do not use root mean square error (RMSE) to make comparisons among forecasting methods.
- Base comparisons of methods on large samples of forecasts.
- Conduct explicit cost-benefit analysis.

Assessing Uncertainty

- Use objective procedures to estimate explicit prediction.
- Develop prediction intervals by using empirical estimates based on realistic representations of forecasting situations.
- When assessing prediction intervals, list possible outcomes and assess their likelihoods.
- Obtain good feedback about forecast accuracy and the reasons why errors occurred.
- Combine prediction intervals from alternative forecast methods.
- Use safety factors to adjust for overconfidence in PIs.

Presenting Forecasts

- Present forecasts and supporting data in a simple and understandable form.
- Provide complete, simple, and clear explanations of methods.
- Present prediction intervals.

Learning That Will Improve Forecasting Procedures

- Establish a formal review process for forecasting methods.
- Establish a formal review process to ensure that forecasts are used properly.

Appendix 2: Analogies to dangerous manmade global warming alarm

Population growth and famine (Malthus) – 1798

Based on Benjamin Franklin's observation that animals and plants reproduce until they exhaust resources then starve and die, Malthus extrapolated that humans would share this fate as a result of geometric population growth and linear resources growth. He later realized that foresight and innovation prevent this fate in humans.

Lead in petrol and brain and organ damage – 1928

Early observations of harm from heavy exposure of industrial workers led to speculation of wider community effects from exposure to lead from petrol. A ban was called for in the U.K. in 1928. It was phased out in Australia in 2002. There is no scientific evidence that lead from vehicle exhaust was harmful in practice.

Fluoride in drinking water health effects – 1945

Fluoride is poisonous in quantity, but occurs naturally in drinking water in low concentrations. One part-per-million reduces dental decay. Some scientists have warned of potential ill effects and some communities reject fluoridation of water supplies. Claims of ill effects at 1ppm are not supported.

Global cooling; through to 1975 – 1970

Temperatures had been declining since the end of WWII, and some scientists forecast an imminent ice age. Alarming forecasts have alternated between ice ages and the opposite several times since at least the 19th Century. Media coverage of this most recent cooling alarm ceased after temperatures warmed again.

Population growth and famine (Meadows) – 1972

Computer modelling sponsored by the Club of Rome predicted burgeoning population, exhausted resources, and famine. With minor and realistic changes in assumptions, however, the model would produce sanguine forecasts. The Club recanted the original forecasts in 1976.

Electrical wiring and cancer, etc. – 1979

A small epidemiological study reported an association between hypothesized exposure to electromagnetic fields and childhood leukaemia. In the U.S., regulations intended to reduce exposure cost \$1 billion annually. Thousands of studies have failed to establish a link between actual exposure and any health effect.

Timber famine economic threat – 1865

Forecasts that we will run out of wood for construction and paper occur from time to time around the world. Despite the alarms, the world's forested area has increased since WWII, as has wood production. Planting and efficiency have increased in response to demand and competition.

Soil erosion and agricultural – 1934

Despite periodic alarms from lobbyists and politicians over soil being washed and blown away, there has been a net *gain* in soil on most U.S. cropland; and erosion rates have been slowing. In Australia, too, soils have improved with fertilization and new plant species, and erosion has declined as land management practices have improved.

DDT and cancer – 1962

In *Silent Spring*, Rachel Carson forecast that birds would die out and people would be afflicted by cancer due to increasing exposure to the insecticide DDT. There was no plausible biological mechanism identified and research failed to support the claims. DDT was nevertheless banned. Millions have died unnecessarily from malaria as a result.

Supersonic airliners, the ozone hole, and skin cancer, etc. – 1970

Forecasts that water vapour emitted by planes would harm the ozone layer led to calls to ban them. The forecast cause of ozone decline changed to nitrogen oxides. The forecast outcome then vacillated between harm and benefit over the decade. Then the alarm faded from public discussion.

Industrial production, acid rain, and forests – 1974

Sulphur dioxide from burning coal can increase the acidity of rain. Scientists ascribed fish deaths and predicted harm to forests and people. The U.S. National Acid Precipitation Assessment Program found little environmental damage and no harm to people. Acidity of rain varies naturally. The costly Clean Air Act is still in effect.

CFCs, ozone hole, and skin cancer – 1985

Speculation that the Earth's ozone layer was being depleted by chlorine from chlorofluorocarbons, and forecasts that skin cancer rates would increase, led to an international ban. Knowledge about the relationships is poor. Chlorine from the sea is 400 times CFC peak production. Replacement refrigerants are dangerous.

Uncontrolled reproduction and degeneration (Eugenics) – 1883

The idea of eliminating "undesirable" people and encouraging elites to breed was motivated by forecasts of being by "inferior" people. Intellectuals in the 1920s and 1930s were advocates. After the Nazis, the policy is anathema to many, though population control policies in different guises are still advocated by some.

Asbestos and lung disease – 1939

People who worked with some kinds of asbestos over extended periods developed lung cancer more often. Researchers and lobbyists, extrapolating to the general population, hypothesized effects from miniscule exposure to any kind of asbestos, and improperly predicted millions of excess deaths. Asbestos was banned in Australia in 1991.

Population growth and famine (Ehrlich) – 1968

Butterfly biologist Paul Ehrlich warmed up Malthus, and also forecast global cooling and, later, global warming disasters. In *The Population Bomb*, Ehrlich wrote, "The battle to feed humanity is over. In the 1970s, the world will undergo famines. Hundreds of millions of people are going to starve to death."

Environmental tobacco smoke – 1971

Lobbyists extrapolated the evidence that long-term smoking causes lung cancer and heart disease to forecast the same effects from "second hand" tobacco smoke. Proper epidemiological studies failed to support the forecasts of serious harm to third parties. (Which is not to say that smoking around others is not an unpleasant and inconsiderate imposition.)

Organophosphate poisoning – 1976

Insecticides that work by enzyme inhibition rapidly degrade in the environment. Forecasts of adverse health effects among agricultural workers *et al.*, and the general population, are common. While there are cases of deliberate poisoning and accounts of nerve damage among workers, harm to the general population is not evident.

Listeria in cheese – 1985

Listeria monocytogenes occurs in soft cheeses, but most strains do not cause listeriosis. Listeriosis can be fatal for high-risk people such as young children. Detection is now easy, resulting in listeria being more often identified in food and deaths more often being attributed to it than in the past, thus precipitating alarms.

Radon in homes and lung cancer – 1985

Radon historically caused lung cancer in miners working in dusty uranium-rich mines. A small survey found elevated levels in some houses and the U.S. EPA estimated 8 million homes were affected and forecast up to 30,000 lung cancer deaths per annum. More rigorous studies have shown any effect is small, or non-existent.

Mad cow disease (BSE) – 1996

Speculation that a variant Creutzfeldt-Jakob disease might be contracted from eating beef from cattle with BSE, and forecasts that the disease would kill 10 million people by 2010, led to the slaughter of 8 million cattle in Britain at a cost to the taxpayer of £3.5 billion. *Suspected* vCJD deaths never exceeded 28 per year and any link to BSE remains unconfirmed.

Mercury in childhood inoculations and autism – 2005

Robert F. Kennedy, Jr. claimed on CBS News that “The science connecting brain damage with thimerosal is absolutely overwhelming.” Thimerosal is a vaccine preservative that contains mercury that the industry claims is safe. When it was eliminated, autism cases continued to climb. Researchers found no link.

Salmonella in eggs – 1988

Careless investigations of food poisoning in Britain attributed some to eggs. Minister Currie asserted that “most” egg production was infected with salmonella. Demand plummeted. Costly flock testing was imposed. There were calls to kill the entire laying flock—one million were. Salmonella has likely never been present inside eggs.

Dioxin in Belgian poultry – 1999

Dioxins occur naturally, and are produced incidentally and deliberately by industry. Some are toxic. When breeder chickens became ill, the cause was traced to dioxin-contaminated feed. Seven million chickens and 60,000 pigs were destroyed. People were consequently exposed to more dioxin as a result of substituting fish for chicken in their diets.

Cell phone towers and cancer, etc. – 2008

Periodically, community activists raise alarms that the towers will cause cancer and miscellaneous other health problems. The towers transmit and receive weak radiofrequency signals. The signals are centimetres-long wavelength non-ionizing radiation that, like heat and visible light, cannot damage DNA. Scientific studies have found no health effects.

Environmental toxins and breast cancer – 1990

Long Island breast cancer survivor and lobbyist Barbara Balaban and some scientists speculated, against understanding of biological mechanisms, that toxins in the environment, such as DDE and PCBs, were causing cancer. Congress ordered studies that cost \$30 million. They found no link.

Mercury in fish – 2004

Extrapolating from insupportably low “safe” levels, a U.S. EPA employee predicted that 630,000 babies would be born with potential brain damage each year. Women were warned to avoid fish. Mercury occurs naturally in the environment and most Japanese have higher than EPA “safe” levels from eating a health-promoting high-fish diet.