CLIMATE AND WEATHER FORECASTING: PREDICTION, CHAOS, DIVINATION, OR GUESS?

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Any science worth its salt must judge its value upon the criteria of prediction. In our case we study the atmosphere and climate so as we may better forecast what is going to happen. That is what I wish to talk about this evening. To use the modern idiom, forecasting may be called our core business, not only weather forecasting but also climate forecasting. Many atmospheric scientists focus on forecasting, which is not surprising because that is what most are paid to do. Forecasting is an essential part of their job description.

It is my view that we do this more often, and more directly than most other scientific disciplines. In some, such as botany, you can study for a lifetime and never make a forecast. In others, such as economics, forecasts are common, but seem to be imperfect and vulnerable to unforeseen political and social change. However, we can be assured that if an economic recovery fails to materialise, then the blame will be placed on "unseasonable weather", so that not economic but weather forecasters are to blame!

My usually impeccable source on weather forecasting ("Bluff your way in Weather Forecasting" by David Milsted, Ravette Books, 1990, 62pp) defines a forecaster as:

> "a highly qualified, grossly over-worked and grotesquely underfunded meteorologist".

This book points out that it is hard to become a forecaster and years of training are involved. Milsted claims that it is not recommended for everyone as it has the habit of making people terribly, terribly boring.

In any case it is very difficult to even get selected ... my source believes that a tedium contest is held to do this. Ordinary people are dragged in off the street and subjected to hours of witty chit-chat at the hands of fully qualified meteorologists. After a while even more turgid and dry climatologists are brought in to up the pressure, until finally only one person is left not chewing his or her own feet off in brain-dead exasperation. Thus a winner emerges.

He or she (the source claims this gender differentiation is unnecessary, as they will both probably look the same anyway) is then acclaimed "Meteorologist of the Year", given a pair of silly glasses, and shoved in front of a television camera. Radio forecasters on the other hand are chosen for their hopeless english and impenetrability of their accents.

The word "forecast" can have many meanings. For example it is a prediction, or an estimate, or even a guess. One thesaurus I consulted also mentioned the word divination (an interpretation of omens, soothsaying, sorcery or foretelling), a definition which appears to fit some of what we would call the more crackpot fringe forecasters. The thesaurus also mentioned the word augery ... I'm sure this did not refer to a well known and very competent forecaster in the Met Service with an American accent. Then there is chaos ... we have all heard of Lorenz's butterfly diagram, and the tenet that the atmosphere is inherently chaotic in behaviour, and hence unpredictable in the longterm. Chaos confirms what the vast majority of the general public seem to suspect: namely that the whole point of Scientific Laws is that they don't work properly in Real Life. Imagine their increduli-

ty if they ever hear that scientists seek a Law of Chaos!

So the term forecast has many meanings. Which is appropriate to weather and climate forecasting? That may well depend on the time frame of the forecast, so let's consider these. While most of us are likely to think of forecasts as being for the next day or for the next 5 days, these I believe are only part of a continuum of forecasts that we need to consider (Table 1), which ranges from a second to an epoch. There is also an implied scale here too. At shorter time scales the focus is often on forecasts for local or regional areas, while at the very long time scales, the interest is primarily global.

The two shortest time scales (second, minute) seldom concern us except in highly specialised situations such as microbursts on flight paths near airports. Forecasting for the next hour, sometimes referred to as "nowcasting" has much wider currency. Will it rain before the concrete is set? Or before the cricket is over? Can I have a barbeque this afternoon? Will the wind allow the crane to operate while we are placing this large sign? Will the fog lift to allow aircraft to operate? These are just a fraction of the thousands of weather-related questions that big and small decision makers in the community would like answered.

Table 1. Time Frames for forecasts

- second
- minute
- hour
- day
- week
- month
- season
- year
- decade
- century
- millenium
- epoch

Nowcasting is a lucrative business for some consultants in the USA, especially in large cities. There, weather radar, a dense network of observations, fast communication systems, and models of the boundary layer of the atmosphere all play a part. In New Zealand, the more dispersed nature of both population and critical economic activity mean that such forecasts are less viable, although I understand that they are occasionally offered by MetService. The need is great, but it is hard to see how the product can be simultaneously tailored to the needs of thousands of potential customers and delivered in time.

We are all familiar with the 24-hour forecast. This has been the time scale which has received the greatest attention from forecasters, and the one in which they have achieved their greatest success. For years this is where the bulk of the budget of the former Meteorological Service appeared to go. I am not privy to the workings of the new State Owned Enterprise, but I suspect that they are placing less venture capital in these forecasts. The point is that it is hard to improve the 75-85% accuracy of the 24-hour forecast. Spending millions may only raise it by a few percentage points.

Nevertheless, debate about such forecasts continues. Let me illustrate this with two examples from the southern provinces. About 6% of the population of New Zealand live in Otago and Southland, yet the region produces over 45% of the country's electricity and if tourism is included, 15% of its off-shore earnings. Much of the latter are from farming, horticulture, forestry and fishing. All are resource based activities which are highly dependent on the weather. Not surprisingly then, the weather, which is extremely changeable anyway, is much discussed. Surveys show that 8 out of 10 conversationalists prefer it to sex.

The first example is from a newspaper article (ODT, Saturday, October 2, 1993) that states:

> "The Met Service sees no need to establish a weather office in Dunedin and says forecast accuracy would be no better for it. These comments from the service's chief executive, John Lumsden, follow recent criticism of forecasts by local fishermen and members of the Otago Maritime VHF Association".

He was disagreeing with comments made by a former manager of the Dunedin weather office who claimed the region was not well served after its recent closure and lack of local observing staff. He suggested the Regional Council, or Dunedin City Council, or private individuals should set up their own weather forecasting service in competition with Met Service and tailored to local needs.

There have also been demands for another weather radar in New Zealand to cover the southern South Island, an area not presently served, but one which is often the first to receive the brunt of severe weather.

The second example, also from the Otago Daily Times but two days later (Monday, October 4, 1993) has the banner headline "Snow forecast accurate when it mattered most". The reporter, Paul Gorman, gives credit where credit is due.

> "The Met Service made an excellent prediction of last Monday's snow in Otago as early as 3am the previous Friday".

It goes on to note that they rose to the occasion magnificently and gave early warning of a cold spell which could have cost the country millions of dollars in lost farm animals and crops.

These two examples illustrate that regional weather forecasting for the next 24 hours is likely to be subject to more competition, demands for high-tech observing systems and more specialised products. These sound depressingly like the issues confronting the Health Service, and illustrate a basic problem in providing infrastructure and services in New Zealand. The needs are real, but the population is relatively small and dispersed, while resources and commercial opportunities are limited.

However, I believe that while some small gains in forecasting 24 hours ahead may be gained with new systems and new technology, what is more important is delivery of the message, and the way in which it is packaged. Some exciting developments are happening here. Weather phone lines are more popular. Television presentation of weather has improved, although I am sure that members of this Society would like to see more. If only the computer graphics, so spectacularly applied to the Whitbread Around the World Yacht Race, could be adapted to the weather map so as to show the dynamism of weather systems, fronts and opposing air masses.

Newspapers, long moribund as far as weather presentation has been concerned, have started to use colour and imaginative presentations. I would like to think that the Society's Media Awards are having some impact after all.

Turning to radio forecasts, I am disappointed that "Morning Report" on National Radio no longer crosses to Met Service for the weather from the forecasters themselves. While sometimes lacking the silky voice and delivery style of professional broadcasters, the Met Service announcers gave individuality and immediacy to the forecasts. They certainly impart credibility to the message. Wherever possible it is important that the professional scientist delivers our product. In that respect, Augie Auer's guest appearances on National Radio have been a delight. His conversational chats about recent weather, show that it can be made interesting and part of infotainment. He, and others, allay the claim that forecasters are pathologically boring.

Five-day forecasts have proved to be a valuable innovation and their reliability has greatly improved over the limited area models first tried here in the 1970s. Analyses for the period almost a week ahead and based on a global grid, are now regularly provided by several agencies in the USA and Europe. Some recent forecasts of extreme weather made even four days ahead of time have proved to be remarkably accurate.

The pity about these forecasts is that they are not as widely dispersed as they could be. Radio and newspapers carry verbal report in plain language, but why should maps for five days ahead not also be published, as they are in such countries as the UK and Canada?

The winter of 1993 turned out to be milder than those in 1991 and 1992. This was contrary to many assessments of those brave enough to issue long-range forecasts. I am turning now to what may be called "climate forecasting", and I first consider time scales of a month, year and decade ahead.

There are some meteorologists who argue that such forecasts are ridiculous. They point to research that show how numerical models of the atmosphere become inherently unstable as they project further into the future, and that there is a theoretical upper limit of about 14 days to their effectiveness, even given near perfect data input. Ideas of chaotic behaviour of the atmosphere are also presented to illustrate that climate forecasts are impossible, and there is much handwaving about Lorenz diagrams and strange attractors.

In my view, this is a rather narrow perspective and ignores some effective climate forecasting already demonstrated. Ancient monuments, such as Stonehenge, reminds us

that such structures enabled Neolithic peoples to predict the timing of seasons over 4000 years ago. Predictions of summer and winter, we now take for granted, but remain spectacular examples of climate forecasting. Most years we can predict summer or winter mean temperatures to within 1.5°C, a remarkable achievement. We are able to do this because we understand well the planet's orbital variations and the response of the climate system. It has little to do with concepts normally considered to be important in 24-hour forecasting.

This example shows that approaches different from those used in weather forecasting are necessary in climate forecasting. To improve our skill we must understand the climate system and concentrate on its processes and their variation. Let us return to the case of the 1993 winter. The three factors that underpinned the incorrect forecast of another cold winter were: the continuation ofo El Nino, the persistent influence of volcanic dust in the stratosphere, and negative sea surface temperature anomalies about New Zealand.

The current El Nino, which is the negative phase of the Southern Oscillation, has turned out to be remarkably long lived. It showed signs of developing in January 1990, and was certainly underway by 1991. Only twice this century have El Nino's been comparable. The periods 1911-1913 and 1939-1941 were also characterised by persistent negative anomalies of the Southern Oscillation Index. It does seem though that the persistent pool of cold water in the ocean about New Zealand is an associated phenomena, and has probably accompanied similar El Ninos of the past. There is sufficient evidence that ENSO events have important influences on New Zealand weather and circulation anomalies.

However, it is difficult to make comparisons between the current El Nino and past long-lasting ones because early data as to oceanic and circulation data are inadequate. The Climate Diagnostics Bulletin, which is published monthly out of the USA, contains a Forecast Forum which attempts to predict the behaviour of ENSO events. It presently offers conflicting forecasts and warns potential users that they can expect only modest skill. The Southern Oscilation Index is quasi-periodic in nature, so that forecasting its behaviour probably should be based on physical modelling of both atmosphere and ocean rather than statistical analysis of past trends.

The recent veil of volcanic dust in the global atmosphere is also unusual. The aerosol optical thickness, as measured in the tropics, peaked during September 1991, three months following the eruption of Mt. Pinatubo in the Phillipines. Southern Hemisphere dust has been more persistent due to circulation patterns and further eruptions in South America. At any rate, the atmospheric dust veil experienced over the last 18 months may have been the greatest this century. There is plenty of historical evidence that links substantial dust veils to unusual climatic variations.

It seems then, that from a climatic point of view, we are living through a remarkable time. Climate forecasts in such situations are inherently difficult, especially since many are based on analogues with the past, and the past is not much help because of the rarity of contemporaneous events. Further complicating factors are the very high concentrations of greenhouse gases in the troposphere, the highest perhaps for millions of years, and the depleted ozone in the stratosphere, also probably unprecedented in recent Earth history.

What then are we to do about climate forecasting? Should we give up because this winter the forecasts seem awry? Is the climate system so chaotic that any long range forecasting is impossible? Or are there underlying fundamental causes to climatic variation that are predictable? Maybe if we look harder and gain new insights we will discover these?

These are interesting questions, I think you will agree. Unfortunately, climate forecasting has sometimes been seen in the past as a fruitless exercise only one rung above guessing, astrology, divination and augery. It has received much less than the huge financial and human resources given to say 24-hour and 5-day forecasting.

Yet we know that reliable climate forecasts for "the next season", for "the next year" or for "the next decade" have very high value for those in such industries as agriculture, energy and tourism. Maybe we should adopt the Avis motto and "try harder"? I would like to see more of our scientific brain power and research directed towards climate forecasting.

There is much we can do without gazing into a crystal ball (and one which may be a bit murky at that). We can go about constructing and verifying models of the climate system

and its impacts on physical and human systems. Based on past climate data for 50 or even 100 years, we can construct a statistical summary of past variability. Various scenarios can then be made as to when, and at what rate, the system and its impacts could operate over a coming season. These are probabilistic forecasts, but nevertheless realistic and useful to resource managers. The point is that good understanding and modelling of climate systems can offer practical options and insights as to what is happening and might happen. For those who need forecasts, these are valuable, if partial substitutes.

Long range climate forecasting is now in vogue due to concern about the enhanced greenhouse effect and possible global warming. Huge funding has poured into General Circulation Models (GCMs). As a small nation, New Zealand does not have its own. The level of expertise, capital and computer resources required by a country to develop, run, maintain and evaluate a GCM is not unlike that required to join the Nuclear Club. Therefore, it makes sense for us to colaborate with a GCM nation and participate through supplying input data and through verification testing. This is what we seem to be doing, and some members of this Society play a leading role in this activity by visiting and working with the Australians at CSIRO in Aspendale.

Undoubtedly, we must try to predict the effects of ozone depletion, enhanced concentrations of greenhouse gases, and sulphates on longterm climate change and sea level rise, as part of a risk analysis for our planet. After all, it is the home of the human species and we have nowhere else to live ... the whole 5.5 billion of us now, and the expected 10 billion by the year 2030. As world population grows, the hazard from extreme weather increases, if only because more people are exposed. Risks are increasing faster in Third World countries faster than anywhere. In this context, climate prediction is serious stuff.

There is enough evidence to suggest that a commitment to change is already built into Earth's geosphere systems. Consider the following scenario. After vacillating until the year 2030, we decide global warming is real, by which time sea level may have risen 18 cm. We take fright and so greenhouse emissions are drastically reduced. Yet there is sufficient lag in the system that will commit us to a further 23 cm of sea level rise by 2100. Similarly, the ozone hole is forecast to last until 2070, even though, under the Montreal protocol and subsequent agreements, CFC output is markedly reduced, such is the level of anthropogenic chlorine already in the stratosphere.

Of course the possibility exists that climate forecasts of global warming are wrong, even though they represent the consensus view of the Intergovernmental Panel on Climate Change. So can we choose to ignore them because the models on which they are based are imperfect? I think not. There is strong feeling for the Precautionary Principle, defined in the Intergovernment Agreement on the Environment (May 1992, para 3.5.1) as:

> "Where there are threats of serious or irreversible environmental damage, lack of full scientific understanding should not be used as a reason for postponing measures to prevent environmental degradation."

To some extent this is difficult for scientists to accept. Many are reluctant to commit themselves without full scientific understanding, and we do not yet have that as far as global and regional climate change is concerned. Nevertheless global warming is our current, collective best guess, so its possibility must be included in land use and coastal planning.

Despite all this, one wonders if the investment balance is correct as far as climate forecasting is concerned. Development of both atmospheric and oceanic GCMs proceeds apace. They are being coupled and run in transient mode. Grid scales are now finer. Important processes involving clouds are being included. The investment is enormous. All this is good for our science and job opportunities. Yet none of the results will benefit any of us in this room, although our grandchildren may be grateful for the insights they may bring.

What is more important to us, and our struggling, resource-based, weather-dependent economy, are variations at inter-annual and decadal scales. Disruptions caused by El Ninos, cyclone Bolas, east coast droughts or late snows are what cause gliches in economic output and bring misery to people. These represent natural variability in the climate system, but for which society is are often poorly prepared. The challenge for us is to first forecast this decadal scale of variability, and

the climate between now and 2000, then worry about climate change to the year 2100.

Who then, wants to know about the climate in the next few thousand years? Climates of the past 130,000 years, which include the whole of the last glacial cycle, offer fascinating insights of global climate change and evolution of flora and fauna, including the human species. Yet there ARE some who need forecasts for the next 10,000 years. Much nuclear waste has a half life of that order, so must be secure for millenia. This is so far into the future that another glaciation is possible. Will the ice reach the waste repository, and if so will it survive intact? Research contracts in the UK have already been let to make these climate forecasts.

As for climate forecasts for an epoch ... well that is sufficiently zany that only Gary Larsan could contemplate it. At least the forecaster won't have to worry about losing a job if he, or she, is wrong!

Let me conclude. In our business, forecasts are required at all time scales from the next hour to the next millenium. Different methods are required, depending on time scale. All methods should be scientifically based, and divination and augury should be exposed for the guesses they are. Most human and financial resources are given to 24-hour, 5-day and 100-year forecasts. This seems an inappropriate balance. More resources are needed for forecasts at seasonal to decadal scales, for it is these that receive least attention, yet significantly affect human activity. At the very least we should try to better understand and model climate systems in these time frames.

Therefore a daunting challenge lies ahead of us. At least we who consider weather and climate variations in the future haveplenty to study and some really big issues to consider. However, it is nice to remember the old forecaster's maxim:

"If the weather did not exist, it would be necessary to invent it."
Voltaire (1649-1778)