LEGISLATIVE ASSEMBLY FOR THE AUSTRALIAN CAPITAL TERRITORY

STANDING COMMITTEE ON CLIMATE CHANGE, ENVIRONMENT AND WATER

(Reference: ACT greenhouse gas reduction targets)

Members:

MS M HUNTER (The Chair)
MS M PORTER (The Deputy Chair)
MR Z SESELJA

TRANSCRIPT OF EVIDENCE

CANBERRA

WEDNESDAY, 18 FEBRUARY 2009

Secretary to the committee:
Dr H Jaireth (Ph: 6205 0137)

By authority of the Legislative Assembly for the Australian Capital Territory

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WITNESSES

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Amended 21January 2009

The committee met at 1.35 pm.

COUGHLAN, DR MICHAEL JAMES, Acting Chief Climatologist, Bureau of Meteorology

WILES, MR PERRY ROBERT, Manager, New South Wales Climate Services Centre, Bureau of Meteorology

THE CHAIR: Good afternoon and welcome to the public hearing of the Standing Committee on Climate Change, Environment and Water inquiring into the ACT greenhouse reduction targets. I would like welcome Dr Coughlan and Mr Wiles from the Bureau of Meteorology. We look forward to your presentation about the ACT climate projections. This hearing will run till about 2.15, after which time we will meet with the Commissioner for Sustainability and the Environment, Dr Maxine Cooper, in relation to the annual report from her office. I would like to welcome Dr Cooper.

MR SESELJA: Could I flag also, chair, and just apologise ahead of time, that I will have to step out for a few minutes during the hearing.

THE CHAIR: Certainly. Thank you, Mr Seselja.

It is my duty to ensure that you have read the privilege statement card. I believe that was sent. You have read that card and you do understand the privilege implications of the statement; is that correct?

Dr Coughlan: Yes.

THE CHAIR: Thank you very much. Do you want to start with an opening statement before we get started on the presentation?

Dr Coughlan: Yes, we can do that.

THE CHAIR: Thank you.

Dr Coughlan: The Bureau of Meteorology, as you will probably know, is the national agency providing weather, climate, hydrological and oceanographic services for the country as a whole. There is only one Bureau of Meteorology in Australia. As opposed to police departments and departments of health and education, there is one Bureau of Meteorology. It provides the services for the whole of the nation.

The bureau, to support its services, has a vigorous research program ultimately aimed at improving our ability to predict climate over coming seasons, decades and beyond, as well as of course our traditional activities of predicting the weather. The bureau and CSIRO have recently formed a major research partnership called the Centre for Australian Weather and Climate Research. It goes by the strange acronym of CAWCR, but it is the Centre for Australian Weather and Climate Research.

It has been going for a little over a year now—a year to two years. It brings together the critical mass to tackle important climate variability and change research issues, among other things, particularly earth system model development. Modelling the climate system, understanding the climate system, is a huge endeavour, and hitherto we have seen it fragmented across CSIRO, the bureau, universities and so on. There was a recognition that if we needed to keep up with the rest of the world, we had to pool our resources, so that is what has happened.

The other major issue that we would like to bring the committee's attention to is the maintenance of the climate record in perpetuity, which involves the routine sampling of meteorological and related hydrological and oceanographic data across the nation and surrounding oceans, and this remains the cornerstone to understanding and adapting to climate change and variability. If you do not measure it, you do not know what is going on. If you do not know what is going on, you do not understand it and so on, as that story goes.

But it is this data from the climate record which provides us with the understanding of the past climate, and its changes in the ACT and surrounding areas. These evolving climate monitoring and research capabilities enable the Bureau of Meteorology to make comment upon the past, present and possible future state of the climate in the ACT and surrounding areas.

In summary, despite uncertainties, most global climate models indicate that over the next 50 years rainfall and run-off will be lower over south-east Australia relative to a base climate period of 1980-1999, and that temperature and associated factors such as fire risk and heatwaves will increase in the south of the Murray Darling Basin, particularly in the southern most parts of the basin, including the ACT. Ten years on from the end of that base period, which you will remember I said was from 1980-1999—we are now 10 years into the period beyond that—and we are already recording data consistent with those trends.

My colleague Perry Wiles, Manager of the New South Wales Regional Climate Services Centre in Sydney, will run through a short presentation that highlights some of these key issues relating to global climate change, and in that context what we can say about climate change with respect to the ACT and surrounding areas. Then we would be pleased, if there is time, to answer any questions that you might have, either now or, if they are too difficult for us, we will take them on notice.

THE CHAIR: Thank you.

Mr Wiles: This presentation basically has three parts. The first bit is an introduction to climate variability and climate change and the main drivers behind that, particularly for the Australian region and the ACT. The second looks at the observed trends that we have seen in the 20th century in relation to climate in the ACT, particularly rainfall and temperature. And then, thirdly, it looks at the projections for the 21st century. We will focus on 2030 as a near horizon, but there is data available beyond that. We acknowledge that most of our material comes from the bureau and CSIRO and I think everyone has been provided with a copy of the *Climate change in Australia* report, which is where a lot of this information derives. We also acknowledge DAFF and DCC.

The climate system varies on all time scales. Obviously we are aware of the day-today change from night to day and season to season and it is important to get a grasp of the different drivers that impact on that. There are two basic categories, those which are external and those which are internal to the climate system itself. The external ones include things like the orbital changes, known as Milankovitch cycles, which are what we believe cause our ice ages over the periods of hundreds of thousands of years. Also there are solar changes. The output from the sun varies from year to year. You are probably aware of the sunspot cycle, the 11-year cycle and so on. So there is a variation in output from the sun.

Thirdly, in the external category, there are volcanic eruptions which, perhaps counter-intuitively, cool the planet because the aerosols that are ejected up into the stratosphere act as a reflector and reflect light back to space and so the earth cools after a major volcanic eruption. Fourthly, and the one I guess we are most concerned with today, are changes in the atmospheric chemistry. Increases in certain gases, known as greenhouse gasses—carbon dioxide, methane, nitrous oxides and so on—can lead to external driving of the climate system. They are external to the system.

Within the system itself, there are oscillations and drivers that impact on it. The most well known of course is the El Nino-La Nina cycle which we are all very well aware of in Australia because of its impact. The next slide shows the great variety of those drivers on the Australian continent and it is partly why the Australian climate is one of the most variable in the world. We are impacted by all these different mechanisms.

The El Nino-La Nina cycle I have mentioned already. There is the impact of the Indian Ocean, sometimes referred to as the Indian Ocean dipole, what is known as the southern annular mode down here at the bottom, which is an oscillation in pressure, in a ring-like pattern around the poles. But there are also more localised things such as these easterly troughs which are very common in summer, east coast lows—Sydney is experiencing one of those at the moment—north-west cloud bands and so on.

All those impact on the Australian climate, and particularly the climate in New South Wales and the ACT. All of them vary on different time scales and, in principle, all of them could be impacted by climate change as well. It is what makes predicting not just the weather but also the climate, in terms of seasonal forecasting, such a devilishly difficult task for the bureau. They are some of the internal factors.

Moving back to the main external factor that we are talking about today, which is greenhouse gases, CO_2, which is the main greenhouse gas, but also methane and nitrous oxide, have been increasing dramatically since the beginning of the industrial revolution, as you can see from this graph here. The red line depicts carbon dioxide, which has gone from a pre-industrial level of around 280 parts per billion up to about 380 currently, and it is going higher.

The significance of that in the longer term history is that it is likely to have been the highest concentration within the last million years. As you can see on this graph on the right here, at the bottom is where the pre-industrial level started and we are now up to here. We have increased the level of CO_2. The magnitude of that increase is comparable to the magnitude of the change in CO_2 levels between ice ages and warm periods, so it is quite a significant change that we have already introduced into the atmosphere. The most likely culprit is human activity in the form of fossil fuel burning.

The Intergovernmental Panel on Climate Change, which I imagine you are all very well aware of, in 2007 came out with its fourth assessment report. Its two main conclusions were that the warming of the climate system is unequivocal. There is a whole range of evidence for that—temperatures and so on, but also decreasing sea ice, rising sea level and so on. The second conclusion is that most of that observed increase in globally average temperatures since the mid-20th century is very likely due to observed increase in anthropogenic or human caused greenhouse gas concentrations.

How do we know that? One of the ways is by using climate models. Just to focus on one panel here: say we focus on Australia. The black line on this graph shows the observations and the blue line shows the model output. We run the models in hindcast; we initialised them at the beginning, in 1900, and ran them forward. So we get to see how well they reproduce what happened in the 20th century.

If you exclude greenhouse gases you get the blue envelope. It is an envelope because there is a range of models and they all slightly vary, but that blue envelope includes things like the volcanic activity, changes in solar activity and those other four things I talked about earlier. If you include the impact of increasing greenhouse gases you get the pink envelope. As you can see, the pink envelope in every case, in each continent, both in the globe and also in terms of the ocean, is doing quite a good job at matching the observations. The only way we can explain the observations is by including that human factor of increased greenhouse gases into the equations. These models take into account solar activity and account volcanic activity; they take into account all those other things as well.

That brings us to consider what is happening in the ACT. The basic story, as I suggest you will be very well aware, living here, is that it has been getting hotter and drier. The year 2006 was Canberra's hottest year on record. You can see that from this top graph which shows you the annual average maximum temperature. Firstly, you can see the high variability from year to year, as it swings up and down from cooler years to warmer years, but overlying that the black line gives you an 11-year moving average. You can see an increasing trend, particularly post about 1978. It goes up a bit, then down again in the early 1990s, and then since then there has been a fairly steady increase up to current levels. In that period the increase has been about plus 1.2 degrees Celsius.

In terms of overnight temperatures, the increase is about one degree, and again you can see the high variability from year to year; the line jumps up and down. When you filter out the variability using a decadal average, a 11-year moving average, you can see the underlying trend which, again, has been rising since about 1970 by about a degree.

Temperature is relatively straightforward in terms of climate change; the signal is easy to detect. Rainfall is a much more complex phenomenon in itself and therefore what is happening with it is also more complex. This graph shows the rainfall for what we in the bureau call district 70, which includes northern Canberra and goes up to Goulburn, basically the Monaro area.

It is the annual rainfall of that area. You can see, again, the high variability of rain. It ranges from about 350 millilitres to over 1,200 millilitres, a factor over three variation. Another thing to notice is at the beginning of last century there was a decline from a wet period into what we know as the federation drought down here, but that whole first half of the century continued relatively dry until you get to the late 1940s when there was a marked increase in rainfall, into the 1950s, which were very wet, and also the 1970s, and then since about 1990 there has been a gradual decline back to levels which are similar to the beginning of the 20th century. That pattern is relatively similar over most of New South Wales.

If we break it into seasonal falls, this is just showing the 11-year moving average rather than the actual data so you can get a better picture, you can see the yellow is autumn, green is spring, blue is winter and red is summer. As you can see at the time of the federation drought, all four seasons showed a decline. At the time when rainfall increased in the late 1940s all four seasons showed an increase, which is why those were two very marked changes.

In more recent times, since about 1996, there has been quite a steep drop off in autumn rain, which has been the main contributor to the decline in rain in not only Canberra but the whole of southern New South Wales and Victoria. But, as you can see, there has also been a slight decline in the spring, winter and summer as well.

This last 12-year period has been a decidedly dry one. This is what we call a decile map. The blue areas, which are not quite as blue as they look on my screen, are where it has been above average. The red area is below average, and the redder it is the further below, and this deep red around Melbourne, for example, and also to the west of Canberra, is the lowest on record. So that means this 12-year period is the lowest 12-year period we have on record for those areas. When you look at what the 12-year autumn rainfall is like, the situation is even worse. The whole of the catchment basically for Sydney and Canberra and most of the south-west slopes and the Riverina and down through to Melbourne has had its 12 worst autumns on record in terms of rainfall.

Exacerbating that, of course, has been the temperatures, which have been getting warmer. In terms of the temperature deciles, this map, yellow or orange, means above average temperatures. If it is this bright orange here at the top it is the warmest on record. As you can see, nearly all of New South Wales, and certainly including the ACT, has had its hottest 12-year period on record.

No rain and high temperatures exacerbate water demand, not surprisingly. I pulled out just the Murray because it was easy to get hold of, but I am sure other rivers in this area would be similar.

The long-term average is shown by the green line. The 1997 to 2007 average is that one, but the 2006-07 inflow into the Murray is the black line and 2007-08 is this one here. Quite disappointingly, 2007-08 had a La Nina year in it as well which is when we expect good rain. It is quite disappointing that we did not get a better response in terms of rainfall there, in inflow, from that year. That is what has been happening in the ACT.

Before we move on to look at the projections—this graph shows the global projections—there are various uncertainties in relation to projections. Firstly, there are a number of models, about 23 or so are used, so each of them will have their slight biases and so on. There is a slight variation because of that, but also one of the great uncertainties of the future is what our emissions will be, which I guess is part of what you are doing here today.

The different emission trajectories, if you like, are called scenarios and depending on which one we travel along that will determine where we end up. So, for example, with this bottom orange one, if we were to stop all CO_2 emission today across the globe, that would be the trajectory of temperatures globally. As you can see, it still rises. That is because there is inertia in the climate system and it takes 50 to 100 years for that to work its way through completely.

As to the other scenarios, B1 and B2, B1 is low level emissions. A2 is a fairly high level one. There is one higher called A1FI. At the moment we are tracking slightly above A1FI so we are up the top end of this spread of scenarios at the moment. Obviously, depending on what the world does in terms of emissions, it will partly determine which of those trajectories we move along.

In terms of what is happening in the ACT, all models show a warming. Just to orientate you—this is the smallest graph I had so unfortunately I could not zero in closer to the ACT—the annual one is the top row and then you have the four seasons. The left-hand column gives you the low emission outcome; the middle, the medium emissions; and the third, the high emission scenario. For 2030, there is not that much difference between the scenarios. That is partly because we have effectively locked in a certain amount of climate change because of what we already have emitted. What we are emitting now will determine our trajectory beyond 2030, so there is not much we can do about what is going to happen in the next 20 or so years.

The changes to New South Wales and ACT temperature are projected to be largest in spring and summer, as you can see here, so the summer change and spring. The warming is expected to be 0.6 to one degree across all seasons. That is by 2030. It is relatively independent of the scenario, as I have mentioned. At that level, natural variability in decadal temperatures is small relative to that amount. So the signals should be quite clear, detectable as time moves on. We should be able to quite clearly see that signal emerging from the noise of the climate variability.

I do not have the figures here on the slide, but by 2070—these figures are actually in the book on page 132, if you want to refer to them later—the temperature range is expected to increase by about 1.1 to 4.2, depending on the scenario outcome. That is temperature, the story is relatively clear-cut that warming is occurring, fairly consistently with what is happening in inland Australia and elsewhere and fairly consistent with the global picture.

Rainfall is where the global models have greatest difficulty. Because of the complexity of rain as a phenomena we need to be cautious about how we take data from the models. There is a high degree of agreement between the models that southern Australia is likely to suffer a decline in that autumn-winter sort of rain.

Again, this map shows you the annual, on the top row, and then the four seasons broken up. So the changes for New South Wales and ACT rainfall are projected to be largest in winter and spring. On the annual level, the decrease is expected to be between two and five per cent, but in spring, for example, it reaches up to about 10 per cent.

That is regardless of the emissions scenario. Again, by 2030, the spread between the emissions is not very high. Irrespective of the emissions scenario, that is what we are expecting. That level of variability is about the same order of magnitude as natural variability. Natural variability could either mask that or enhance it, depending on how and where we are going in terms of all the other factors impacting on the climate.

With climate change what happens in terms of averages is of importance, but the sting in the tail, I guess, is in relation to extremes. We are well aware of that from last week. In terms of temperature extremes, at the far end, in terms of frost, frost days for Canberra are likely to decline, which I guess is not surprising. There is a relative resilience of frost under global warming, and the suspicion as to why that is is because in a drier climate with less cloud at nights you get more chances of frost. So while your temperatures are going up, the environments in which frosts can form are increasing as well, so the frost occurrence does not drop off as fast as you might think in terms of the temperature increase.

In terms of extreme temperature days, associated with the warming is a projected strong increase in frequency of hot days and warm nights. So a small change in the distribution which is like a bell curve, if you just shift it slightly, the area under the tail end, which is the extreme, actually increases disproportionately to the move. So you get a larger increase percentagewise of the extreme than you would perhaps expect.

Canberra currently averages five days above 35 degrees a year. By 2030, our best estimate is that there will be eight, by 2050, 10 and, by 2070, 18 days above 35. So that is quite a significant increase. So a doubling by 2050 of days above 35. Of course, these are averages, so in any one year you could have significantly more or less than that.

Obviously of great concern for Canberra is fire weather. The top graph shows what has been the trend in forest fire danger—we have an index which we use to measure the risk of fire. It is based on rainfall and wind and temperature and so on. The top graph gives you a history of that from 1994, and you can see the spike in 2003 when the tragic fires here were experienced. That work has been done by Chris Lucas, a bureau employee.

Modelling has been done in relation to the Canberra area. That shows a substantial increase in fire risk is likely at most sites in south-eastern Australia. At present the number of days where the fire danger is either very high or extreme is 23.1. We used two models, looking at a low emissions scenario or a high emissions scenario for 2020 and 2050. By 2020 under a high emissions scenario, which is where we are tracking at the moment, the 23 goes up to 27. By 2050 it goes up to 36, using one model, and in the other model, it goes from 28 in 2020 up to 38 in 2050. That is higher than a 50 per cent increase in the number of days when the fire danger is extreme.

That, in a nutshell, is the projections. There is a lot more detail inside this book at the Australian level, and various scientists within the bureau and CAWCR are doing more localised studies. Bertrand Timbal in CAWCR is doing downscaling. He has done some work on Canberra and so on, part of which is included in here. The material in these reports and also in this presentation can be accessed through those websites. The committee may have questions or seek clarification.

THE CHAIR: Thank you for that presentation—a very sobering presentation, I must say. A lot of it draws on a 2007 study on Australian climate change, and we have the next session of the IPCC coming up in Turkey. Are we staying on top? Are we sort of keeping up to date with the latest information coming out? Obviously the work you are doing, this sort of work, is so critically important for everything from our food through to fires and what resources we might have to put into bush management, fire resources and all these sorts of things. Is it moving so fast you cannot stay up? How do you go about doing that?

Dr Coughlan: That is an interesting question. Clearly, the way the IPCC works is a massive undertaking, in the way it has functioned in the past. It does these massive assessments every five to six years. In other words, it waits till a body of literature builds up from the previous lot, assesses that en masse, so to speak, and then produces its reports. The actual process has generated a lot more research into climate and, as a result, there are a lot more results coming out. You will pick up the paper day after day and read that a new scientist has come out with a new finding that shows that we are tracking at the higher range of what the IPCC said a little over a year ago.

But you need to recognise that that IPCC work was probably based on a cut-off of what I think may have been 2005, so another four years of research has been done. The IPCC in that sense does not keep up with the research results that are going out. There is not a real process in place for continuous assessment. I know a lot of people have been looking at that issue, to see how you develop some process of continuous assessment.

The other issue, too, is that that is just telling you what has happened in the past. If you are going to determine what is going to happen into the future, you have to do these big modelling efforts, and they all have to be done according to a fairly strict regime, because if everybody does their own thing and says, "Well, I will do it with this sort of scenario," and somebody else does it with another sort of scenario, it is very difficult to compare them. So the looking forward part has to be done also according to a fairly strict timetable, and that takes time to do it.

So, yes, the IPCC process does have this fairly fixed set of procedures for doing it, and in the meantime at present we have to rely on the research results coming out, perhaps on a somewhat haphazard basis, but recognising that—the next one will be out in about 2011 or 2012—the IPCC will come out with another assessment of where we are and what we have been through. But in the meantime the Bureau of Meteorology and other organisations around the world will be continuing to track where we are on those trend lines. I am not sure I have given you the answer that you sought there.

THE CHAIR: I think Mr Wiles raised the point that there were 23 different ways to model things. Dr Coughlan, you are talking about strict criteria and being able to follow that. How do you, the Bureau of Meteorology, choose which model? Do some have more credibility? I am just trying to get some sense of that.

Mr Wiles: For this report they were weighted, according to how well they performed in reproducing this region's climate, to get the Australian projections. The other thing to complement what Mike said is that over the four assessment reports that we have had so far the actual temperature projections have stayed very stable, even though the model resolution has improved and the skills of the model, we presume, are improving. The actual range has stayed relatively static between the one to six degree range for the turn of the century. So we have a fair degree of confidence.

Areas of uncertainty are in some of the feedbacks. Massive methane or CO_2 released from frozen soils in the northern hemisphere could be a potential feedback which could ramp up the CO_2 emissions quickly; also how the ice sheets are likely to respond to warming. It has been assumed that they are very stable and will take a long time to melt, but there is increasing evidence that they are not as stable as we thought and, therefore, the sea level rise could be faster than projected. There is an upside risk, I guess, on that level.

Dr Coughlan: The other challenge, of course, to the modellers is to improve their resolution. You saw a fairly coarse resolution that has been done in the CSIRO climate study. One of the major challenges is to try and improve that resolution either by just sharpening up the resolution in the model or by developing statistical methods of so-called down scaling. We know how this particular valley operates in a particular weather pattern, so by understanding the way different parts of the countryside behave under certain weather regimes we can down scale. Even if the resolution of the model is not actually picking up this local valley, we can understand it through the statistical down scaling techniques.

There is a lot of work being done on that area and one would hope that, in time, while in a global model you might be lucky to have one point in that global model representing the whole of the ACT, by the use of so-called down-scaling techniques we will be able to discriminate, even in a small area the size of the ACT, what various gradients might be in climate change as we proceed through time.

MS PORTER: You mentioned before about what drives the climate in Australia and the ACT generally and there is a quite complex diagram on page 3. You mentioned that that makes it very difficult to predict the weather patterns et cetera. You also talked just now again about the melting of the ice and the releasing of different gases. You only talked about the northern hemisphere; you did not mention the southern hemisphere. I note on this map it talks about this southern annular mode, which you said was to do with ice ages.

Mr Wiles: It is a pressure oscillation; it is called "annular" because is like a ring of pressure that oscillates. When it is high at the pole, it is low at the high mid latitudes and vice versa, and that impacts on where the westerly winds are. The westerlies, as you may be aware, bring a lot of our winter rain. So, if that contracts to the pole, it tends to remove the triggers that give us our winter rain.

MS PORTER: Right, so that is to do with rain rather than temperature in the Antarctic?

Mr Wiles: Yes. And the reason the northern hemisphere is significant is that there is a large land mass with frozen soils in the northern hemisphere which is not the case in the southern hemisphere; we have more ocean. And the sea ice in the northern hemisphere is melting very rapidly. The sea ice does not raise the level of the water; it is just like an ice cube in a glass.

MS PORTER: Yes, it is the same amount of water.

Mr Wiles: But the ice sheets on Greenland and Antarctica, if they melt, do raise the sea level. So the stability of the Greenland ice sheet and the stability of the Antarctic ice sheets, east and west Antarctica, are very significant.

MR SESELJA: What drove the drier period in the first part of the 20th century? We saw in that model that the first 50 years were relatively dry. We had a relatively wet period and we appear to be headed for a drying period now. What were the factors that led to those drier conditions in the first 50 years of the 20th century?

Mr Wiles: We do not really understand why. We are only really coming to grips with the natural variability of rainfall in Australia. Presumably it is a combination of all these factors. As you saw from the seasonal diagram, all four seasons showed a decline at that point in time, so some of these factors are more significant in summer and some are more significant in winter. That is still an ongoing area of research, but it is not really completely understood at all.

Dr Coughlan: We certainly do know that the circulation of the oceans is pretty important in modulating climate variability on longer time scales. You have probably seen pictures of the so-called conveyor belt, where you see water in one part of the ocean travelling in meandering rivers, coming to the surface in other parts, meandering around and then sinking again. So there is a very complex set of circulations in the oceans which we believe have the capacity to vary the climate on so-called decadal or 10 years or more time scales. They probably largely account for these longer term fluctuations, as to why perhaps the period of the forties was a drier period and the fifties was a wetter period and why the federation drought was for such a long, extended period. You have sufficient variability in the circulation of the oceans to, in a sense, drive those sorts of what we call decadal scale variabilities, as opposed to an El Nino, which is sort of intradecadal.

El Ninos typically come around—or I should say Los Ninos—roughly every three to six years, on those sorts of time scales. We pretty well understand now what the mechanisms are for the El Nino-La Nina circulation pattern. It relates to a sympathetic interaction between the atmosphere and the oceans across the expanse of the Pacific. So we understand on those sorts of time scales. With these longer time scales, because our records of what is happening in the oceans are much lower, we have got very little by way of observations in the deep oceans going back much beyond the last 10 or 15 years, and perhaps 20 years in a few locations. So understanding those longer term circulations is really a challenge that is before us.

MR SESELJA: In terms of detailed modelling on temperature—I apologise if this was dealt with while I was out of the room—are you able to talk the committee through whether it is mainly satellites now, in terms of looking at temperatures and how temperatures have fluctuated on a world scale? Is it mainly done through satellites? Is it mainly done through ground stations? Is it a combination of both, and how has that changed over the last 20 or 50 years? What is the latest technology for measuring temperatures around the world, and how has that evolved?

Dr Coughlan: Meteorologists, like most scientists, are avid users of technology, so if there is a new way of doing something, we will be in there trying to use that technology to get the understanding that we like. But we have to be very careful when we switch from one technology to the other, because all we can be measuring is the difference in different technologies. As we bring one in and then drop one out, we are measuring something that is to do with the technology and not to do with what we are measuring. So we do try to use a combination of both new technology and old technology.

For something as fundamental to our understanding of climate as temperature, we still rely very heavily on really basic instruments, like a thermometer, a mercury-in-glass thermometer. They are gradually being phased out now by the use of electronic systems. What we have done in making those shifts is to make sure that one is calibrated very carefully against the other. So we will keep the old mercury-and-glass thermometer going, perhaps for as long as four or five years, alongside the thermistors, just to make sure that when we do see fluctuations in one, it is also occurring in the other, or we can explain why there are differences between them.

When it comes to satellites, we like to think of the satellites and the ground systems as being complementary to each other. The one advantage that you get with the ground-based systems is that you tend to get a greater precision of what you are measuring. You can actually expose that in a particular environment, a very controlled environment. So we can get precision with that. But what we do not get is good spatial resolution. We can only have so many thermometers sitting out there in little white, louvred shelters around the countryside. The satellite system gives you a very good spatial coverage but you do not have that precision because you are measuring something from so many hundreds of kilometres or, in the case of geostationary satellites, thousands of kilometres into space.

They are what you would call inferred temperatures. You can ground-truth them down to the actual measurement that you are doing. What the satellite gives you is that it fills in all the gaps in between. So if you can ground-truth a satellite to a few ground stations, you can then start to say something about all the temperatures that you have in between.

It is a similar thing with measuring through the atmosphere itself. We send balloons up with thermometers and thermistors actually dangling off the bottom. We measure the temperature as these balloons go up through the atmosphere and radio the temperature down. You can do the same thing from a satellite. By doing a whole lot of algorithms and so on, by measuring the temperature in different so-called windows of radiation, you can actually get a profile of temperature through the atmosphere.

Again, by ground-truthing those satellite profiles with the places where we send balloons up, you can then fill in all the gaps by using the satellite where we do not have those sorts of—

MR SESELJA: Primarily, when we are talking about the increases in temperature, even though we use satellites and other technologies to help fill in the gaps, we are primarily saying that the temperature on the ground in any given place has gone up by a certain amount over a period of time. That is the measure that we are using?

Dr Coughlan: Right. We can give you a thousand different temperatures, but that would not be particularly helpful. If we wanted to give you the 1,000-foot temperature, the 3,000-foot temperature, the 5,000-foot temperature and the 30,000-foot temperature, we can do that, but to make the message and the information load reasonable, we tend to refer everything down to what is called the standard screen height, which is 1.2 metres above the ground level. That is what we mean by the temperature.

THE CHAIR: This has been a fascinating presentation. I do have one more question before we move on. We do have an annual report hearing. I would very much like to continue our dialogue, and that might be by sending other questions through. Obviously, you are the first people who have appeared before our inquiry.

The Commissioner for Sustainability and the Environment's *State of the environment* report—it is an ACT report—includes information about the possible unreliability of climate measurements at Canberra International Airport and refers to the need for a new BoM weather station. I was wondering if you had any comment to make on that.

Dr Coughlan: We are fairly particular about our sites, particularly the airports. Our city sites have been compromised over the years, simply through building, and we cannot stop growth in cities just because we are measuring temperature. We have had a rethink on that issue, and if we do have a city temperature measurement, we can continue it. We like to continue it, because it is a useful measure of what is happening within the city. But because we are trying to measure what is happening to the general climate, we still like to keep our stations pristine and unchanged by anything except the climate and not be as a result of changes in technology or changes in the environment that have nothing to do with that larger issue.

Airports have generally been very good for that purpose, but we have seen what has happened in many airports which started out as small airports, where the thermometer sat outside the terminal and everybody could see it, and then the terminal grows and, ultimately, you are measuring the growth of the terminal as opposed to any changes in the climate. And that is what has happened at Canberra airport. But we could see it coming. We knew that it was coming, so we now have another location which is well away from the growth. I think there is a car park going up where the original site was. The new site is right between the runways, and we do not think anybody is going to build a building between the two runways. In fact, we have a picture here which will show you where the new site is.

THE CHAIR: Dr Coughlan, is that operating now?

Dr Coughlan: I believe that it is operating now. The new site now is quite close to the runway. The original site was over here in the photo, where the car park is being built. I can provide you with a full picture of that, if you are interested in that.

THE CHAIR: That would be lovely.

Dr Coughlan: But we are certainly aware of that, and we will run those two sites now for two years. They will run together. As this site gets affected by growth and by people parking their cars or whatever, we will be able to see that difference there. But, hopefully, that site right out there, right next to the runway, will not be built out and we will continue to measure as best we can the variation in climate in the ACT and not the variation due to the growth of buildings.

THE CHAIR: Thank you very much, Dr Coughlan and Mr Wiles. We will be in touch, I am sure.

The committee adjourned at 2.25 pm.