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HOUSE OF REPRESENTATIVES

STANDING COMMITTEE ON INDUSTRY, SCIENCE AND INNOVATION

Reference: Long-term meteorological forecasting

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HOUSE OF REPRESENTATIVES

STANDING COMMITTEE ON INDUSTRY, SCIENCE AND INNOVATION

Wednesday, 12 August 2009

Members: Ms Vamvakinou *(Chair)*, Fran Bailey *(Deputy Chair)*, Mr Bidgood, Mr Champion, Mr Cheeseman, Dr Jensen, Mr Johnson, Mr Ramsey, Ms Rishworth and Mr Symon

Members in attendance:*)*, Fran Bailey, Mr Bidgood, Mr Cheeseman, Dr Jensen, Mr Ramsey, Mr Symon and Ms Vamvakinou

Terms of reference for the inquiry:

To inquire into and report on:

Long-term meteorological forecasting with particular reference to:

- The efficacy of current climate modelling methods and techniques and long-term meteorological prediction systems;
- Innovation in long-term meteorological forecasting methods and technology;
- The impact of accurate measurement of inter-seasonal climate variability on decision-making processes for agricultural production and other sectors such as tourism;
- Potential benefits and applications for emergency response to natural disasters, such as bushfire, flood, cyclone, hail, and tsunami, in Australia and in neighbouring countries; and
- Strategies, systems and research overseas that could contribute to Australia's innovation in this area.

WITNESSES

Committee met at 10.14 am

ALVES, Dr Oscar, Leader, Seasonal Prediction and Climate Variability Group, Centre for Australian Weather and Climate Research, CSIRO and Bureau of Meteorology

HIRST, Dr Tony, Research Team Leader, CSIRO

HOWDEN, Dr Mark, Chief Research Scientist, CSIRO Sustainable Ecosystems, CSIRO

MAPSTONE, Dr Bruce, Director, Centre for Australian Weather and Climate Research, CSIRO and Bureau of Meteorology

PLUMMER, Mr Neil, Acting Assistant Director, Climate and Oceans Branch, Water Division, Bureau of Meteorology

STEWART, Mr Bruce, Acting Deputy Director, Water, National Climate Centre, Bureau of Meteorology

CHAIR (Ms Vamvakinou)—I declare open this public hearing of the inquiry into long-term meteorological forecasting in Australia being conducted by the House of Representatives Standing Committee on Industry, Science and Innovation. The inquiry arises from a request to this committee from Senator the Hon. Kim Carr, the federal Minister for Innovation, Industry, Science and Research. Written submissions were called for and 34 have been received to date. The committee is now conducting a program of public hearings and inspections. This hearing is the ninth for the inquiry. I now call representatives of the CSIRO and the Bureau of Meteorology to give evidence.

Although the committee does not require you to give evidence under oath, I should advise you that these hearings are formal proceedings of the parliament and consequently they warrant the same respect as proceedings of the House itself. It is customary to remind witnesses that giving false or misleading evidence is a serious matter and may be regarded as a contempt of parliament. We thank you for your submission and now invite you to make a brief opening statement before we proceed to questions.

Mr Stewart—We are happy to move straight into questions.

FRAN BAILEY—I do not really mind who answers this question, but, given the importance of the direction that weather forecasting is taking with the use of supercomputers, my first question is: do you feel at a disadvantage given that Europe is now onto the 'super supercomputer' and we have just installed a supercomputer in Melbourne? The second part of my question is: given that the overseas trend seems to be towards what they call 'ensemble modelling' are we able to do that here in Australia?

Dr Mapstone—I will make an initial comment on the supercomputers and then ask Dr Alves to talk about ensemble methods. Certainly the supercomputing developments internationally are roaring ahead of Australia's developments. Largely that is underpinned by greater capacity and interest in Europe, where several countries contribute to the cost of those. As you have noted, we are going through a supercomputer upgrade specifically to bring us up to speed on where we are

able to function at the moment—and that is a very welcome advance. The $50 million allocated to supercomputing in the recent Super Science Initiative will help with that.

How that money will be spent and where it will leave us in the supercomputing ranks is being worked through at the moment. There is a working group being formed to advise on that investment. So this is one of those things where we would always like to have a bigger and better supercomputer, but investment in that sort of infrastructure is a policy matter and we have just had a fairly significant upgrade on where we were formerly. We are working through where that will place us in terms of forecasting capacity, climate simulation and so on.

FRAN BAILEY—And what about in regard to ensemble modelling?

Dr Alves—Just to clarify, I cannot comment in terms of weather forecasting—because that is not my area. But in terms of seasonal forecasting maybe you could clarify whether you want to you want to know more about seasonal forecasting or short-term weather forecasting?

FRAN BAILEY—What I learnt recently in Europe was that they are increasingly moving towards ensemble modelling because of the increase in chaotic weather patterns. If they follow this type of modelling, it enables them to provide very timely information to emergency management services and to government in general. I had never heard of this term in Australia. I guess the first question is: do we use ensemble modelling?

Dr Alves—Yes.

FRAN BAILEY—And are we being inhibited in developing this because of our lack of capacity with the next generation of supercomputer, which is what they are all using in Europe?

Dr Alves—Our efforts in seasonal forecasting do use ensemble forecasting. In our current system that we have running at the bureau, we generate a 30-member ensemble every month in real time. For seasonal forecasting, it is absolutely critical to do ensemble forecasting, particularly in a dynamical context. In fact, it is not possible to do it without doing ensemble forecasting, and that has been the basis of our current dynamical seasonal prediction system and our future plans for the development of seasonal prediction. We also regard ensemble as perhaps—

FRAN BAILEY—Can I just clarify. In order to do this, you are relying more on the older methods of weather forecasting rather than the dynamic modelling?

Dr Alves—No, this is using dynamic modelling.

FRAN BAILEY—It is using dynamic?

Dr Alves—Yes, that is right. In older, more statistical methods, you do not do ensemble forecasting. It is not part of statistical forecasting to do ensemble forecasting. It is essential for seasonal forecasting as part of dynamical models. I think every group that is doing dynamical seasonal forecasting does do ensembles. However, the size of the ensembles is different with each centre. It is basically as much as you can afford on your supercomputer. Based on your computing resources, you often have to balance more ensemble members versus increased

model detail. I guess our latest trend has not been to sacrifice ensemble size. It has been quite critical to try and get as much ensemble as possible, to try and average out that chaotic noise so that you get the signal that you are trying to predict.

Mr RAMSEY—Excuse me. This is a new term to me.

Dr JENSEN—A whole lot of runs—

Mr RAMSEY—I suspect it is what we heard about when you were here before, but could you just clarify that for my sake.

Dr Alves—There are two reasons why you would want to do ensemble forecasting. One is that, assuming you have a perfect forecast system, you still want to do ensemble forecasting because we believe that the real climate is chaotic, so if you try and reforecast exactly the same event you may get a slightly different realisation. That is because very tiny effects in the real atmosphere grow and impact your ability to predict the future. That is just a natural limitation. That limitation is what limits our ability to predict the future. It is necessary to generate these ensembles to estimate how rapidly that uncertainty grows.

The other reason for doing ensemble forecasting is that our models and the data that we use are not perfect. Therefore, supposing that we know that something is not perfect, we try to run different realisations, trying to sample that uncertainty that we know exists in our system so that we can try and get a set of forecasts that try and give the uncertainty in the forecasts we are trying to produce. There are different ways of doing that, different levels of sophistication and different—

FRAN BAILEY—It appears to me that the ability for bureaus of meteorology to actively pursue ensemble modelling is really dependent on the supercomputers.

Dr Alves—That is right.

FRAN BAILEY—So the fact that we, here in Australia, are nowhere near the super supercomputer means that we are inhibited in being able to pursue ensemble modelling. The reality is that in Europe they all have the super supercomputers. They are actually in place in Brussels now and are being used for this type of modelling. If we here in Australia have only just installed our first supercomputer—

Mr Stewart—No, we have not just installed them; we have had them previously and we are upgrading in the current process.

CHAIR—So how far behind are we, and what is the level of uncertainty in terms of all the factors and variants that you use for forecasting? Is it a big factor?

Mr Stewart—Again, it depends on the period out that you are forecasting, the premise on which you are forecasting and the relationships there. In terms of our supercomputing size, it is a matter of making the most of the capabilities within the system that we have. The fact that we are increasing the system means that we will be able to do more than we could before and we

will be able to provide a better service. So there will be incremental improvements as a result of the increase.

FRAN BAILEY—To put it bluntly on the table, I just feel that in Europe they have the equipment to do this, yet here we are with fantastic scientists, who are held in very high regard by the rest of the world—and who punch above their weight, to use that phrase—but who are really limited in their capacity to participate in this. Given the increase in chaotic weather patterns, it would seem from what I have learnt that this is the way that we should be going—we should be pursuing this much more actively.

Mr Stewart—Again, if you look at the area they need to cover within the European environment, and the resolution they would want to get within that geographical situation, greater increases may not be that beneficial to us in many areas. So it really is a matter of determining the level of resource you want to put into it versus what you get out of it as well.

FRAN BAILEY—Come on, you are not going to seriously put a proposition to me that you would not want to have access to the super-supercomputer, and you would not want as many of them as they have in Europe. I do not believe that for one minute, Mr Stewart! And from the smiles of your colleagues, I do not think they do either. But look, I am probably taking up a lot of the time of my colleagues.

Mr Hirst—We have had a fair amount of experience in ensemble forecasts, as Dr Alves mentioned. However, we have to do a big trade-off in order to achieve that with the supercomputing we have. Because we have limited supercomputing, we need models that run faster, which means they are much lower resolution than we would like. Important things like El Nino and the Indian Ocean dipole are very important for model resolution. So we have to sacrifice some amount of simulation of those particular features in order to gain experience in ensemble forecasting. Therefore, a more powerful supercomputer would allow us to be able to do both the ensemble forecasting and have the high resolution models that we are looking for.

CHAIR—I will keep taking questions on this issue so we do not have to go back and forth.

Dr JENSEN—I am a bit concerned that we are a bit too enamoured with supercomputers. The reason I say this is that fundamentally a lot of this goes back to the basic physics. For instance, we look at the situation in Europe where Piers Corbyn certainly would not have access to similar levels of supercomputing as the Hadley Centre, and yet his seasonal forecasts have been more accurate than Hadley's. I think this is predominantly because he is looking at solar activity to a greater extent in his models than is the case with the Hadley Centre. Are we getting too sucked into details of supercomputers—'this can give us more' and 'it can give us greater resolution'—to the extent that we might be losing track? Perhaps we need to take a step back and look at some of the fundamental processes.

Dr Mapstone—There seem to be two parts to that question. I will ask Oscar to comment on the seasonal forecasting component. I think the point you make is a good one in that, whilst anyone working in this environment would like the biggest and best supercomputer available, it is important that we also have the people, the skills, the scientists to use those facilities. As a small country with a small population, although we have very good scientists, we do not have the numbers of scientists required to work on some of the problems that we find elsewhere.

There is a trade-off and we do have to balance, in a capability sense, our investments in people and our science capability against the tools that we use. That is the point that I think you are making there. Oscar, do you have a comment about the specifics of the seasonal forecasting?

Dr Alves—I cannot comment on Piers Corbyn. I have not seen any evidence or publications to suggest he has more skills. I cannot comment on that. I would just make the comment that the international trend at every meteorological organisation is to develop dynamic seasonal forecast systems, which are supercomputer intensive. That seems to be the recommendation, we believe, for where—at least in the long term and probably in the medium term also—we will get the most predictive skill on seasonal time scales. We are essentially just doing what weather forecasting did back in the seventies.

Dr JENSEN—It is an issue, though, obviously, about what knowledge and assumptions go into those models. You can have the best computer in the world doing 1+1=2 billions and billions of times, but it is not particularly useful, and this gets back to the fundamental research and processes. The thing I was saying about Corbyn is that—

FRAN BAILEY—Dennis, what I learnt in Europe with this whole principle is that it is actually throwing up a scenario—and this is where the supercomputers come into their own. You throw up a scenario: if A, B and C happen at this time, what is the likely result? That is putting it in very simple terms. While the human factor is, I agree, obviously very important, the role of the supercomputer is a given. Dennis and I might disagree about the increase in chaotic weather patterns and what is or is not causing them, but this is about being able to say: if this scenario happened, what would be the likely result? And then of course you can go that next step of making sure that emergency management services are in the loop on this information.

Mr Stewart—The benefit of the ensemble approach, because of the wide range, that gives you, I suppose, an uncertainty limit or a definition around what the best forecast will be, so it gives you a good statement of the accuracy of the information you are putting out.

Mr BIDGOOD—Can I ask a question, Chair?

CHAIR—Is it on this?

Mr BIDGOOD—Yes. It relates to what Dr Mapstone said about training upcoming meteorologists and climate scientists. Do you have a succession plan? How many people are you training up? What is the situation? Obviously, it is one thing to have a supercomputer or a super supercomputer, but if you have got no-one to run it then you do not have the expertise. What is the situation at the moment in Australia—the number of people you are training up and the succession plan?

Mr Stewart—We run a meteorology course within the bureau each year. Students range in age from 14 to about 20 years old. The majority would come along from a Bureau of Meteorology perspective, but we do provide training to other, external groups as well. We have maintained that program fairly regularly over years, so that keeps the numbers coming in, if you like. As for the numbers going out, that does not tend to be a problem for the bureau because we have an extremely high retention rate—

Mr BIDGOOD—That is good to hear.

Mr Stewart—Yes. Once people come into the organisation, they stay for fair lengths of time, which creates issues at the top end, I suppose, but they are good issues, because we have got highly trained and skilled people as well.

Mr BIDGOOD—It is good to hear that.

Mr Stewart—Probably the thing that has changed a little bit is that when we advertised the courses five, six years ago we would get 200 or 300 applicants for these 20 positions, but in more recent times it has got down to around 100. Now, that is still a good field from which to pick up 20 people, but that is a trend we have noticed—the declining numbers that are applying for the positions—and we assume that that is related, potentially, to the declining number of science graduates coming through. But we certainly have not had any trouble filling the positions. From a succession planning point of view, we are in the process again of revising and reviewing our workforce planning process and framework, and part of the process that we will go through is doing that as well.

Mr BIDGOOD—So you feel that the situation is sufficient for maintenance and growth?

Mr Stewart—Yes, I think so.

Mr RAMSEY—It is related to the computing—and we have received submissions since we spoke to you last—and it is the links between academia, the Bureau of Meteorology and CSIRO and, in particular, their ability to access the high level of computing. We know that they are not growing on trees in Australia; basically, you have them. Do you have formal links with the universities and their meteorological departments, their science departments where their academics can get some time on your computers? I know you would like to use your computing to expand your models, but are there official links to make this happen?

Dr Mapstone—Yes, across both the bureau and CSIRO in research and development. We have strong links with folk in the university sector across a number of universities who are working on climate and meteorological science, basic physics and oceanography, so we do have very strong collaborative links with the university sector. In terms of the model development, which is our sort of future direction, if you like—or where we would like to be in the future—of building the access modelling framework, we have formal structures to engage with the university sector. We have an access coordination committee which meets frequently for the university, the bureau folk and CSIRO researchers to discuss how that collaboration should work. Just this year the National Computational Infrastructure facility dedicated two full-time positions to support that research collaboration on the development and application of access, which is an important step. They are not scientists at the bench; they are people helping scientists at the bench to run their models on the supercomputing facilities.

In terms of access to supercomputers, it is true that the supercomputer at the bureau is not an open-access machine for fairly obvious reasons in that it is providing 24/7 service to Australia and has to be managed very carefully. But the academic community does have access to the National Computational Infrastructure facility here in Canberra at the Australian National University. In fact, that computer is a bigger supercomputer than the one at the bureau and, with

the current upgrades progressing, it will still be a bigger computer than the one at the bureau. To sum up, we have very strong links with the university sector on a number of fronts, across a number of fields that relate directly or indirectly to long-term forecasting. The university sector does have access to large supercomputing facilities, as do we. To give you a tangible recent example, on 7 and 8 July this year we ran a training course for new academics from the university sector to get them up to speed with the development and operation of access. So we are actively building those links.

Mr RAMSEY—I think somewhere along this inquiry we were actually led to believe that you had the sole possession of the ability to do this work. You are saying there are other facilities in Australia that can process at this level?

Dr Mapstone—Absolutely. For example, recently we moved the climate development aspects of the access model to the machine at the Australian National University. That was done for a few reasons, partly to spread the load on the supercomputing resources in Australia, which are mostly in two places—there are a few other, smaller supercomputing facilities around the country—but also to enhance this relationship with the academic sector.

Mr RAMSEY—Without naming people or institutions, if we have groups who feel they are not getting access it is more likely that they are in the wrong university, in the wrong department, they have not convinced their line leaders that their work is more important than somebody else's work in that institution?

Dr Mapstone—I do not know about being in the wrong department or wrong institution. It may be that their research priorities do not float to the top in the competitive processes of academia. The use of the National Computational Infrastructure supercomputer does have a large component of merit based allocations of time on it, so it may be that some academics are not competitive and others are.

Dr Hirst—I am on the merit allocation committee for the NCI machine. Each year we review the proposals from the researchers and the stronger ones will get a share of time on that machine. Some will have quite a large share of time on that machine, those that could easily facilitate working with us directly with our modelling systems that we already have on that machine.

Mr CHEESEMAN—I am particularly concerned with the autumn forecast. It seems to me that it is the least reliable of the forecasts but it is the forecast that I think is the most important for the agricultural sector. We are asking the agricultural sector to make billions of dollars of investment at that point of the year, through grains and the like, and it seems to me that the models tend to let us down a lot at that point in time. I am just wondering why that is. Is that because the model has been poorly calibrated for autumn? Is it because we have a lack of supercomputer capacity at that point in time? Is it because we have more chaotic and random weather events at that point in time of the year? I am curious as to why we seem to get it wrong more often at that point around weather forecasting and seasonal forecasting?

Dr Alves—I am just working out when autumn is in the Southern Hemisphere.

Dr JENSEN—That is reassuring!

Dr Alves—One of the reasons why we have problems around autumn is there is what is traditionally known as a Northern Hemisphere spring predictability barrier, which is our autumn down here, which is around March, April, May. Models tend to have a decreased scale in trying to predict before autumn, into autumn and into winter. We believe the reason for that is that is the active period when ENSO develops. That is when an El Nino typically develops, around that time of the year, and that is when models have more difficulty trying to get its triggering. We have made some progress in trying to do that with dynamical models by trying to incorporate subsurface ocean information that allows us to go back a bit further in time and use that information in the ocean subsurface to try to get through that barrier. But that is essentially just pushing the problem a little bit further back in time. It is a known problem of not just models, but also nature, and it is a reflection that that is the time of year when things happen. Once you have an El Nino developing, yes, you can probably predict what is going to happen subsequently, but its triggering is very difficult to predict. And that is probably our major limitation—not just in dynamical models, but in the statistical models as well. In fact, this problem is even worse in statistical models. Statistical models have a clear autumn predictability barrier. Essentially it is saying that is when changes happen.

Mr CHEESEMAN—Is it a data issue? If it is around predicting ocean temperature, is it that we do not have adequate ocean temperature buoys or whatever the hell they are to start picking up that change in data?

Dr Alves—I think it is a combination of lack of sophistication in our system and the specific network, but also it is a natural limitation. It is chaos, and it is when that chaos is most prevalent in the climate system because that is the time of the year when changes are happening and nature itself decides whether it is going this way or that way. That is a really difficult time to predict. Of course, when you get into May, June and July, nature has already started to take a path.

Mr CHEESEMAN—It has sorted that out.

Dr Alves—And then it becomes more straightforward to predict what is going to happen in the future.

Mr CHEESEMAN—Would you make any recommendation or suggestion as to investment that the Commonwealth might make to assist in trying to get a little bit more predictability in that period? Is there a gap in the infrastructure that we have? Is there a gap in the knowledge that we have? What might the Commonwealth do to assist the Bureau of Meteorology, the CSIRO and the Climate Institute to attempt to address that difficulty? We are talking about literally billions of dollars that people are investing, particularly in agricultural sectors. It would be ideal if we could clean up some of that so that they can invest on a surer footing.

Dr Alves—There is not a simple answer to that. The primary phenomena, which are important, are El Nino and the Indian Ocean Dipole. There are various other secondary phenomena. It is fair to say at present that while we understand some aspects of El Nino there are a lot of aspects that we do not understand—and more so for the Indian Ocean Dipole. In summary, we need to invest in trying to understand El Nino and the Indian Ocean Dipole and trying to understand why our models do not simulate it so well. The two go hand in hand. What is holding us back is a combination of lack of sophistication in our modelling capabilities,

supercomputing, but also a lack of many years of the observing network. It is quite a complex situation.

To give you just one example, before Argo we knew very little about salinity in the ocean. It has only been in the last few years that we have known what salinity is doing from year to year in the tropical Pacific and Indian oceans. We have known very little about this major component of our climate and whether or not it plays a significant role in the evolution of El Nino. There has been a lot of speculation that it does. It is quite a complicated question. I cannot say that you have to invest in this or that.

Mr CHEESEMAN—Sure. How much did that salinity measuring cost?

Dr Mapstone—Internationally, it was about 3,500 buoys.

Mr CHEESEMAN—What was Australia's contribution to that? I am just trying to get the scale.

Dr Hirst—It is about $20,000 per buoy. I do not have the exact number that the Australians put in but it could be around 10 per cent globally.

CHAIR—I will add a question and pick up that thread. Have we got a capability in understanding some of these emerging issues but we do not have enough resources to allow our scientific capability to develop further? Have we got that capability and it is being inhibited by lack of resources?

Dr Mapstone—There are obviously some issues. If we knew how the system worked and we thought we were able to simulate it then obviously we need supercomputers and things to be able to do that. Part of the issue at that time of year, and indeed around the whole ENSO phenomenon, is fundamental understanding of the processes that drive the climate. That is not really a supercomputing issue; it is a research—

CHAIR—It is a knowledge issue, isn't it?

Dr Mapstone—knowledge issue. It is an understanding issue.

Dr JENSEN—On the specific issue, are you aware of work done by Keith Potts? I am not sure whether it has been published yet. He has some quite interesting stuff about regional dimming as a result of burning in the north and also pollution. In his view, he has a fair handle on what is driving some of these processes in terms of regional dimming shifting the intertropical convergence zone and so on.

Dr Mapstone—I will answer the first part of the question and then perhaps we can go to Tony for some of the detail. Yes, research folk in both the bureau and the CSIRO have worked with Keith Potts in the past and aware of his theory. There has been quite a bit of time put in by scientists in both organisations on reviewing manuscripts from him and discussing his theory with him. The bottom line is that the theory is not consistent with many observations and the fundamental climate processes that have emerged over many years of research. What we would like to see is those theories subjected to formal peer review and publication in the scientific

literature. That process is the quality control that drives the things that the scientific community nationally and internationally picks up and runs with. Those theories have not been subjected to that process, but we have been engaged with Keith Potts over some years in discussion of them.

Dr Hirst—Keith Potts highlights the possible connection between aerosols over Indonesia and South Australian rainfall. The main drivers of the overall rainfall pattern change during El Nino. The scientific consensus is that it is a coupled process between ocean and atmosphere. With sea surface temperature patterns the warm water moves eastward, dragging the rainfall patterns away from Indonesia and Both Australia. This causes drought over Indonesia and Australia. When there is drought over Indonesia, you then get fires. There is potential for a correlation between the two but not for causation between the two. Having said that, however, it is widely recognised that, certainly in the climate area, aerosols are an important part of the climate system and have a significant effect on radiation balances at the surface. We believe, as other people feel, that aerosols are an important part. We have developed aspects of aerosol treatment in our models and we will continue to do so. We currently have a group of two scientists looking at the aerosol issue in the models—a senior research scientist and a senior project scientist. We believe that is not enough. We will be looking to hire a third junior research scientist in that area because we think it is an important area.

Mr SYMON—I would like to swing the topic around a little bit. Since we heard from both the bureau and the CSIRO in Melbourne, we did a run around the country and heard from quite a few other witnesses. Quite a few third-party providers of long-range forecasts lodged submissions or came along to an inquiry hearing to talk to us. From memory, all of them claimed to have a better rate of success with long-term forecasting than the bureau and that they relied on the bureau to provide them with a lot of the data that they based their forecasts on. Are we only seeing the third-party providers who are actually proven right or this is a wide spread of the field? Could it be that some may have got it completely wrong on the basis of their own methodology outside of what the bureau does? We have heard from people, for instance, who said they predicted the heatwave in Victoria prior to the Black Saturday bushfires and that the bureau had not. Do you think third-party providers provide a service that is useful, or is it more the case that they are aggregating data from different sources outside the bureau and coming up with a slightly different product?

CHAIR—I would just like to add to that. Mike is referring specifically to Dr Christian Werner from Weather Risk Management Services. Are you aware of Dr Christian Werner? He made some very blunt statements in Sydney that he had predicted the circumstances of the Victorian bushfires. He more or less let it be known that no-one consulted him, or he had the information but would not give it. Another issue that has emerged is paying for information in the private sector. That is an area I would like you to comment on. There seems to be if not a proliferation then certainly the existence of private weather forecasters who are selling material. They claimed in this instance to be able to predict the Victorian bushfires, but did not give the information either because they were not asked for it or did not feel that they could—or it was not being bought. He did not say that in those words, but it struck most of us who were there that here was another area we had not contemplated. Could you give us some specifics about who we are talking about in this instance?

Mr Stewart—That was a fairly wide range of topics. I will try to cover each one.

CHAIR—It is just so that we do not have to keep coming back and forward to you.

Mr Stewart—That is okay. Neil will add a bit to what I have to say. It really is difficult to often verify the veracity of the claims of the other groups out there that provide forecasts. And you are right; we do not necessarily have access to all of their forecasts and we quite often hear of their successes and not so much of their failures. That is a fair point. The important part of providing this sort of a service is to assess the quality of the service over a long period of time, and we do that using verification statistics and other methods like that. Certainly within the specific weather forecasting area those statistics from the bureau's perspective are published by groups like the World Meteorological Organisation. They basically publish the skill scores for all of the global model capabilities around Australia. We are very much aware of where we are from that point of view, particularly for weather forecasting.

The general approach that we therefore take is to adopt the best science and provide the information that we get from those models and from that capability. The one thing that I suppose we are never terribly care about too at times is the techniques that other people use to develop their forecasts because obviously they keep those fairly close to their chests—they use them for commercial purposes. So we cannot test them out from that point of view either. I would not like to make any comment on how good they are or not because we are not in a position to be able to do so.

In terms of the private sector, the bureau has a process whereby we put as much of the information we collect and produce through modelling and other capabilities out into the community and we provide a range of services in the public good for the Australian community. Because that information is out there, there is a private sector capability that builds up and it is not only on the seasonal forecasting it is on weather forecasting more targeted at specific users of the information. They are giving them more detailed services that we could not provide to specific groups, and they do it on a commercial basis. We too have small commercial activities where we provide value added services at a commercial cost, but we really have not gone heavily into that market. We believe that it is important that there is a private sector market out there to take that and move it forward. We have a communication mechanism with them. We meet with them regularly and discuss where we are headed, what we are doing and what products we are actually bringing back into the pubic good side of things so that they are aware of what more information will be available and can look at their services and adjust to that accordingly. So it is very much a partnership from that point of view.

One area where we try to tow a fairly hard line is in the area of warnings. We believe, and it is fairly common practice around, that it is not good to have warnings coming from different sources giving conflicting information. That is one area where we expect the private sector not to encroach on, but that is not to say that there are not private individuals out there who do that as well.

In terms of the seasonal outlook for last year, Neil may like to cover that one.

Mr Plummer—In Australia there are providers of seasonal forecasts. In our process for getting seasonal forecasts out the door, or to publish the scientific work in the peer review process, the models we use show the results of the validation, so it is proof that those models actually work and, then how our forecasts over a period of time stack up against observations, so

they are compared with the real world. All of that stuff has to be published, so it is made publicly available. As Bruce said, some forecasters provide that too while others do not. We have tended to collaborate with those who have provided that information, not just in Australia but there are overseas agencies that do forecasts of the evolution of El Nino and so forth, which we publish on our website. We get all of that information out there.

In terms of long lead forecasts, our standard forecast is a three-monthly forecast issued the month before, but there has been for some time now a collaboration between researchers and fire agencies. Workshops are held around September or October for the coming fire season. The one that was held in October last year provided an outlook for the coming fire season and so highlighted areas which had a higher risk of fire danger and so forth. In the outlook that was provided to fire agencies, southern Victoria was highlighted as an area of potential higher fire risk. It is not just public information that we make widely available on the website. We engage with agriculture and with fire agencies to provide more detailed forecasts, and that was done in the lead-up to the last fire season.

Mr Stewart—I would suggest that the capability would be one of being able to say that in a wide regional area we can expect or not expect there is greater potential for a bushfire to occur over the next period. I doubt very much that people are capable of saying three to four months ahead that there will be a bushfire in a particular location. We have to look at these things from the point of view of what the level of capability is.

Mr SYMON—To continue along the same vein, the other third-party provider—I think that is the right word—we heard from is the Weather Channel. Their submission was that they put out similar information but in a more publicly understandable format. Having heard them, from the layman's point of view that is probably a good thing. Does the bureau put out multiple levels of the same information? For instance, do you put out a basic level of information and then maybe a more specialised one for farmers, for instance, for a particular seasonal forecast?

Mr Plummer—Yes, we have a web site at the bureau called Water and the Land, which is directed to provide more detailed information for the likes of farmers. A couple of years ago we got some funding through Land and Water Australia to develop a suite of improved products. It involved workshops where we were directly engaging with farmers and so forth and also a suite of products to build on what we were doing. If you have seen the bureau's outlook, it is a map of Australia with probability lines of getting above-average or below-average rainfall and temperature. Through engagement with the farmers, we have found that they want more information on the chances of getting above or below certain rainfall amounts. This came back very strongly, so we developed a number of products that addressed that issue. They have been rolled out on the website very recently. They are the sorts of improvements we make when we engage directly with the users.

Everybody finds that the communication of probabilistic information is very, very difficult to do. That issue is always going to be there. We are improving things with these products, but there is still some work to be done in that area.

Dr Howden—From a slightly more general perspective, there is a need to differentiate between private and public activities here. There is a long history of private weather forecasters going back to Lennox Walker and people like that. So this is not new, and it is being dealt with in

a constructive way, as Bruce Stewart mentioned before. It is important to recognise that the private forecasters are giving forecasts generally for private benefit. There is an element of market advantage. People would expect to get a market advantage from using those forecasts or to be able to make better decisions, and there is a degree of confidentiality that often would flow from that arrangement. You can understand why that would be so.

In the case of the public activities, where you have public policy or public action, such as the warnings that Bruce mentioned, clearly there is a need for public accountability in relation to that. That means that you have to have a completely different set of processes, which are transparent, verifiable and reliable, to inform those public activities. So there is a different type of client and a different institutional arrangement that is needed in both of those situations. Lastly, both the Bureau of Meteorology and the CSIRO are clearly charged with constructively dealing with our intellectual property in the national interest. We would look always to make sure how we dealt with the information that we have is appropriately communicated for that national interest.

Mr RAMSEY—I would like to carry on on that same subject. You made reference, Neil, to your packages for farmers. I go into that web site and look at it and I noticed that some changes have been made. On a personal note, my daughter, who is a researcher with SARDI, showed me the site that she could get to on the bureau's network that I cannot get to that is at the next level. In particular, she has spraying applications in site specific areas and can check the weather for a week in advance and give wind directions, likely humidity and things like that. That level is not available to me. She was going in to a secure site. Could you explain why? Do you think that that information is dangerous in the hands of other farmers?

Mr Plummer—A precursor to the water and the land site was a site called SILO. We got additional funds from Land and Water Australia to develop that site. The way that we could continue to provide some of those products was through sourcing external funds. In time, through efficiencies that we have been able to make, we have been able to transfer a lot of the products and information over to the publicly available WATL site. In time, we expect to that with the remaining SILO products. But there are still a few products on that SILO site which we are yet to do that with. I would expect that over the next few years that transition will be made.

Mr RAMSEY—Okay. It did tie in to some of the evidence that we have had from farmer representatives. You touched before on how hard it is to put statistical likely outcomes in a language that people can understand. I have to tell you that there is a certain degree of scepticism in the farming community about the way those are expressed. People say, 'What on earth does that mean and what's it worth?' A 50 per cent chance of average rainfall, or even the 55/45 type split, is all but useless, I guess.

Mr Stewart—As an organisation, the bureau can always improve the communication of weather information. It is getting information from that scientific perspective back into terms and products that can be made better use of. We are improving from that point of view.

Dr Mapstone—The other place where information will be available, for example, to the research community or to users in the research community is again in the R&D side of the business where we are developing new applications. But they need to be tested. One way of testing then, for example, is to put them up on the web site with restricted access so that people

can look at them and give feedback about whether they are good, bad or ugly. Those experimental products are appropriately often provided on secure access. Because they are in development, it would be irresponsible to be putting out products in the public arena if we were not very comfortable that they were robust and solid products.

Mr RAMSEY—Hence the reason for your very cautious language on much of your forecasting, I suppose. It is so no-one can come back and say, 'You said it was going to do this, and it didn't.'

Mr Stewart—They still do that.

Mr RAMSEY—Yes. But I presume your terms are run through lawyers before you choose to use them.

Mr Stewart—No, I would not say they are run through lawyers.

CHAIR—No-one has sued the bureau yet.

Mr Stewart—They have tried.

CHAIR—I did not know that.

Mr Stewart—We will not go into that.

CHAIR—It sounds like an interesting topic for another day.

Mr Stewart—It is an interesting concept about whether or not we are conservative in the terms we use. I would suggest that our conservativeness relates to our confidence in the information we are putting out. We have much greater confidence in the temperature and potential for rainfall tomorrow so we give specific degrees for the day. As we go further out we have, I suppose, less confidence, and that is reflected in the information and how we provide it. We would not want to be in a position where we gave an overconfident forecast whilst knowing full well in ourselves that we did not have that level of confidence in it. So we have to measure how we put it. And again, I think we do that quite well. We would prefer people to be making use of our services rather than to have a series of times when we have been overconfident and got it wrong and people no longer trust the service. So, again, it is getting that balance in how you give across information.

ACTING CHAIR (Fran Bailey)—In providing information to the emergency management services, and bearing in mind that the fire season is again fast approaching, it has been put to me that the bureau and CSIRO will provide information about the temperature for the day and whether or not high winds are expected, but that air pressure is not automatically given. Is that accurate?

Mr Stewart—I am not sure I can specifically answer that. I would have thought, but I would need to check on this.

ACTING CHAIR—It has also been put to me that air pressure is a critical indicator that should always be given as a matter of course—that air pressure should be given alongside the day's temperature, expected wind velocity et cetera. The reason it was put to me—and there has actually been a submission made to the royal commission on this point—is that four hours before the fires started on Black Saturday, the air pressure plummeted and remained at a very, very low level. If a scientist able to understand that information could view the graph of it, they could say, 'This is a very volatile situation and people should know about it.' I am wondering if this is something that has been brought to your attention and whether it will be part of the information given in the future?

Mr Stewart—Sorry, but like I said, I have no knowledge of that. I do not see that there would be any reason why we would not be able to provide that information if we had it and I would have thought we would have had that sort of information from our monitoring networks.

Mr RAMSEY—It certainly goes to the pilots. They would know what the air pressure is in every area on an instant basis.

Mr Stewart—Yes. It may be that the realisation has only just come to bear that this is a significant factor influencing bushfire activity. In which case, I would think that the bureau should be providing it and would do so.

Mr Plummer—We do publish weather observations on the website. That is updated generally on an hourly basis, but it varies between locations and so forth.

ACTING CHAIR—Does that include air pressure?

Mr Plummer—I believe it does. It may not for every location.

Mr Stewart—But I think what you are referring to is actually providing that information directly as part of the fire service and that may not be the case. I'm sorry, that is just not part of the group I manage.

Dr JENSEN—On the issue of accuracy and the type of data that is provided, one of the submissions was talking about the bad placement of a lot of weather stations in the US. They are placed close to outlets from air conditioning or heating and are pretty much in concrete canyons and car parks where the microclimate plays a significant role. What sort of quality control and assurance do we have in Australia that those stations that we rely on are accurate and do not have these microclimate influences?

Mr Stewart—We have got guidelines for the sighting and placement of our observing networks, depending on the specific type of instrumentation. Those are developed on the basis of guidelines from the World Meteorological Organisation. When you are looking at the accuracy of information you need to look at the quality of the instrumentation that has been put in place: what are the specifications associated with it, what is the sighting and you also look at the fitness for purpose—and that is a very good point that you are making. It may be that groups put stations in certain places because they need to know information for a particular purpose for that place and it is therefore put in at that particular site. But in terms of the stations we use for long-

term climate monitoring, there is a very detailed set of standards that are required to be met, including visitation for recalibration of the sites and those sorts of things.

Dr JENSEN—The point here is that a lot of those sites in the US are actually sites used by the IPCC as far as data is concerned for the case with the US, which brings into question some of the data that you get from the US. What you are saying is that the data here would be far more reliable in that sort of context.

Mr Stewart—I would be surprised if in the IPCC analyses within the US they have allowed data that could be in question being included in the analysis. I would think that the data sets used within the IPCC process are ones where the sites have been checked for all of the standards.

Dr JENSEN—There have been photographs taken of some of these sites where, for instance, they are close to air conditioning outlets and so on, and these are IPCC approved sites.

Mr Stewart—Okay.

FRAN BAILEY—I have one more question on weather stations. Are you concerned at all about the gap in the number of weather stations in regional areas?

Mr Stewart—This is a good question and it comes down to how you would balance your composite data collection network. We operate a range of automatic weather stations and we have people who collect weather information and provide it to the bureau using electronic field books; there are all sorts of methods we use to collect our data and information. You then build that up into a full satellite based data collection. So it is a composite observing system that uses all of those components to add up.

For having automatic weather stations in remote areas there is a burden in terms of the additional cost of maintaining them. We therefore tend to look very closely at how many we need versus the capabilities in terms of remote sensing information, so you use the ones you do have for ground truthing and calibration of your remote sensing capabilities.

FRAN BAILEY—There is a signed agreement—in fact I saw a copy of it when I was at the WMO recently—between the WMO and Australia's Bureau of Meteorology, and I am wondering what we do with this. Does it mean that we share more information? Does it mean that we exchange some of our scientists? How do we utilise this agreement?

Mr Stewart—There is a great list of things that we undertake under the auspices of the WMO. The WMO operates what is called the World Weather Watch, which enables the transfer of meteorological information around all of the national meteorological services that make up the membership of WMO. So, yes, because WMO is in existence we get access to weather information from around the world that feeds into our modelling capabilities. We are very much involved in setting protocols and standards for the sighting of stations for the instrumentation we use, and there is also the element of looking globally at the research that happens within the meteorological community and to some extent within the hydrological community as well. So we gain benefits from that from many regions, particularly a country like Australia that is in the Southern Hemisphere and can gain access—

FRAN BAILEY—They said they were very interested because of our geographic position. They told me that they were not going to give us any supercomputers, though. I did ask on your behalf.

Mr Stewart—Thank you. Actually, John Zillman, the former head of the Bureau of Meteorology some six or seven years ago, was President of the World Meteorological Organisation for about eight years. So we do have very strong ties with them.

FRAN BAILEY—I had never heard of this agreement between Australia and the WMO. Was he responsible for that? I asked them how this came about and no-one could really tell me.

Mr Stewart—No, it came about well before that. It is a specialised UN agency that was established back in the fifties, I think. It really came out of the fact that meteorologists recognised that, if you want to know what is going to happen in this part of the world today, you need to know what happened in other parts of the world in the days before. I think it has achieved a lot. It does have an additional focus on assisting developing countries, so a lot of the work is targeted at bringing the capabilities of developing countries up to improve their meteorological services. It probably had a little bit of its genesis out of aviation, too—the need for weather services for aviation. So it does a range of things. I am slightly biased—I am president of its Commission for Hydrology.

Mr RAMSEY—My question takes us right back to where we started, with Darren's questions about the autumnal forecasts. I was just sitting here minding what you said. My understanding is that the basic cause of the La Nina is the plus or minus in the SOI. If we have higher pressure over the eastern Pacific, as averse to the western Pacific, that sets up the ocean current. I am not sure whether my understanding is correct, but those are layman's terms. I guess the question is: do we really know what causes an El Nino to get going in the first place, or are we just sitting there waiting to see the water starting to move this way or that way and then that is when we know one is developing? Do we actually know what the driver is? Of course, that comes back to, I presume, sunshine and whether we can predict where the sun is going to shine—I don't know. I want a basic understanding of the science for my purposes.

Dr Alves—There have been several theories for the onset of El Nino. None of them fully explain what makes a particular year an El Nino or why you would expect one in a particular year. Some of those theories suggest that the stochastic part of the system, the random part, does play a role. Some theories relate to the slow movement of ocean currents over many years giving you a semi-regular cycle. I think each of those theories is partly right, but there is no unified theory that explains El Nino.

Mr RAMSEY—It is not there.

Dr Alves—What we are also realising is that El Nino comes in different flavours. Not every El Nino is the same. That is part of ongoing research at present.

Mr RAMSEY—So really we are sitting there waiting to see which way the water moves and then we start to make a prediction based on that. That is about where we are?

Dr Alves—That is what our models do. They take all the observations of what is happening right now and they project that forwards.

Mr RAMSEY—But we have not got as far as trying to understand what is actually causing that water to start to move that way? That is still the unknown, where we are hoping to go?

Mr CHEESEMAN—There are some of the predictors, too, aren't there? When it is happening, we know it is happening but we do not necessarily know the circumstances behind—

FRAN BAILEY—What causes it.

Mr CHEESEMAN—Yes, and some of the predictors as to when it is going to happen.

Mr RAMSEY—These are both questions, I think, from Darren, not assumptions.

Dr Hirst—I can answer that a little bit more. As Oscar says, we have some theories of why ENSO occurs. They are not complete. Part of the story is that in the subsurface ocean the winds will set up uplift or subsisdence in the thermocline, and that then propagates some kind of slow wave to the western Pacific. Part of the story is in the subsurface ocean, where the winds will cause an uplift or subsidence in the thermocline. That then propagates like some kind of slow wave to the western Pacific. It gets reflected back there and its dynamics in the equatorial zone work to then influence the sea surface temperature a lot later. That is the basic mechanism in the ENSO theories. But the ENSO theories only tell a part of the story. There is also quite a strong positive feedback going on the tropical Pacific. If you have water, say, warming up in the eastern Pacific then the winds along the equator will start blowing more towards that warm water. That will push more warm water towards the eastern Pacific and so it tends to build up on itself.

The basic theory is that there is a strong positive feedback going on but that the water drawn there is raising the thermocline, which then propagates to the western Pacific and then comes back along the equator, as I described earlier. That tends to raise the thermocline there and allow cooler water at depth to come up to the surface and kill of an event. That is sort of the El Nino cycle. Because there is this positive feedback involved, it is quite difficult to predict exactly how that will go. There is a known dynamical element and an unknown aspect which amplifies it through positive feedback. There is some longer term ability to use the subsurface ocean temperature anomalies, but there is a significant unknown aspect as well.

Mr RAMSEY—So to some extent we do not really even know what we are looking for. We do not know what the drivers are. It is very complex.

Dr Hirst—It is very complex, yes. We know to a certain point, but we do not know the whole thing. As Oscar said before, although models do simulate El Nino in a fashion there are significant differences between what the models will simulate and what can actually happen. The sea surface temperature anomalies might be too wide or too far east and so forth. Those particular aspects can be tightened up some what by a higher resolution model, we believe.

CHAIR—For the benefit of the committee and also for *Hansard* can you please explain the thermocline?

Dr Hirst—Sure. The tropical ocean has a warm layer above a colder deeper layer. The tropical has warming at the top layer, whereas in the deeper layers the water moves in from the mid-latitudes. If you have winds which pile water up or take water away, that thermocline will deepen if the winds are pushing in or, if the winds are forcing the water away, the thermocline will rise. That thermocline perturbation will then tend to move, partly with the currents but also partly on its own accord like a wave on the ocean's surface would, only at a very much slower rate, so it takes quite a few months to go from, say, the central Pacific to the western Pacific.

Dr Mapstone—The thermocline is effectively, relative to the other zones of the ocean, a narrow band of transition from the warmer surface waters to the colder deeper operations.

Dr JENSEN—I did sub operations research, so we delved into oceanography a fair bit. I thought it was important to get that on *Hansard*.

Dr Mapstone—One other point that is perhaps worth making here is that, as Tony and Oscar have said, the ocean play a very important part, we believe, in the processes that generate ENSO activity. And it is only relatively recently that we have had the technology or the capability to be getting the richness of observations from the oceans that will allow us to test some of the physical theories about how the ocean works and how it interacts with the atmosphere. ENSO events have been going on for a long time. As Oscar alluded to, some people have a belief that the ENSO runs on a longer term cycle. We are really a bit behind the eight-ball in our observational richness regarding the ocean, because we do not have a long history of detailed observations of the ocean. We are only now just starting to get those, largely because of the ARGO initiative.

CHAIR—So you would consider that area an important area to develop observation in?

Dr JENSEN—To invest in, too.

CHAIR—And invest in? I want to get to that. And the whole concept of coordinated research will be my next question, so we may as well lead into that now.

Dr Mapstone—I think the area of where we put our observational effort is an interesting question. Certainly, historically the oceans have been an area of sparse observations. The Argo program has changed that a lot. We have 3,000-odd floats scattered around the globe and if you look at a map of where they are you would infer there is a fairly rich cover. I think some oceanographers have said that we have got more information out of the Argo program in the last couple of years than we have out of the complete history of oceanography from ship-based observations.

The point there, I suppose, is that that richness of observation that we are now getting from the ocean is short-lived. We do not have a long history of it. Whether in the next 10, 20 or 50 years that would be where it would make most sense to put additional observational expenditure, is a question that would have to have a business case looked at around it. This is because it may in fact make more sense to build up our observational capabilities over the land or over the polar regions. I would not like to make a judgment call here on whether the oceans necessarily automatically are the places where we would put most of our future observational investment.

But I think that is a case that would have to be evaluated in the context of the observations that come from all other sources.

FRAN BAILEY—Given what you said earlier about Australia's geographical position and the importance of the Indian Ocean, is this an area of research where Australia could really take a lead?

Dr Mapstone—I think it is clearly in Australia's interests to be leading that area. Probably the Indian Ocean—relative to some parts of the Pacific and certainly elsewhere, as in the Atlantic and so on—is a bit underdone, observationally and in research. So yes, that is an area where we would like to have more information. It is a difficult area to work in, in some ways, because some of the most interesting areas for Australia take a while for us to get to. Tony, would you like to comment for us?

Dr Hirst—Yes. In the Pacific Ocean we have a fairly extensive buoys network, as well as the Argo network that we have mentioned before. They give us a reasonably good sample of what is going on in the actual Pacific. We do not have that in the actual Indian Ocean; partly it is funding and partly it is because the Pacific has had the higher priority because that it where the engine room of El Nino is. With the recognition that IOD is also important for Australian rainfall, that tends to emphasise the Indian Ocean more.

FRAN BAILEY—In an earlier private hearing, one of you mentioned the importance of the Indian Ocean and that there was an increased importance about the Indian Ocean in relation to Australia's weather.

Dr Hirst—That is right.

FRAN BAILEY—That is why I am sort of asking this.

Dr Hirst—This is a good question. That is right. Basically, the Indian Ocean Dipole—IOD—is a situation where you have either cold water in the eastern equatorial Indian Ocean and warm water in the west; or vice versa: warm water in the east and colder water in the west, at the surface. When it is cold water in the east and warm water in the west, it has been shown over the past few years to be quite related to torrential patterns over parts of Australia, including Victoria. It is important that forecasting models are able to capture that and that we can better have that in these latest models.

As for observations in the Indian Ocean, there are some issues in maintaining moorings—like I mentioned in the Pacific. There tends to be much more piracy and vandalism of moorings in the Indian Ocean. It happens with fishermen tying their fishing boats to moorings and the like. So that is one issue. So there is higher maintenance; you have to repair them more often. However, there are a significant number of Argo floats in the Indian Ocean now. We are not quite up to full quota yet but the Argo floats do not have that problem of piracy or anything like that. So, it would be a way to get more information from that area.

The Argo floats last about three to five years—something like that—so they will need to continue to be replaced. Even though we may put new investment here or there we do need to

ensure that we are investing enough to keep the existing network of Argo floats going. It is important to realise that.

Mr RAMSEY—Are they moored?

Dr Hirst—No, they float around.

Dr JENSEN—And they dive to 2,000 metres, then come up, then dive again.

Dr Hirst—Yes.

Mr RAMSEY—So what stops them all just ending up in Western Australia?

Dr Hirst—It is a good question. The currents will tend to move them around but, you are right, not in a systematic manner necessarily to where we would want them. So you will get situation where you want to sample an area of ocean but the currents are for whatever reason tending to move them away so you have to keep redeploying them.

Mr RAMSEY—So they can be quite expensive to maintain.

Dr Hirst—It can be quite expensive to maintain a very nice coverage, which is what we have now.

CHAIR—What sort of figures are we talking about in terms of the current deployment and the need to replace them?

Dr JENSEN—There are 3,500.

Dr Hirst—There are 3,500 and they cost $20,000 each. But of course this is an international effort.

CHAIR—How many do we lose? What percentage do you have to repair?

Dr Hirst—They have got a three to five year life—say, four years—so we would now be losing about a quarter every year. So you are looking at 800 a year times US$20,000.

CHAIR—Do they need to be replaced?

Dr Hirst—Yes.

Mr RAMSEY—Do you actually go out retrieve them and load them on the back of a ship and take them back where they belong or do you just drop another one?

CHAIR—Yes, what happens to the wayward ones?

Dr Hirst—We keep monitoring them even if they are wayward. Any information anywhere is useful so even if they are bunched in a certain area they still transmit to satellites and we will get

the information. I am not in the Argo deployment area; I just talk to colleagues who are. The answer they would give is that it would cost an awful lot to go out and pick up a few buoys by ship. It is probably cheaper to actually make another five and put them where you want them.

Dr Mapstone—I think it is worth noting as well that the fact that they disperse or aggregate is actually providing us with information about the ocean currents; it is party why they are free-floating. Dr Alves has a comment on the Indian Ocean question.

Dr Alves—We presently produce Indian Ocean forecasts in the same way that we produce El Nino forecasts, but the skill from the Indian Ocean is very limited compared to our ability to predict El Nino. It is true of every model internationally. We have identified that as one of our priority areas for research to try to understand why that is. It could be that there are not enough observations to initialise the models, it could be model deficiencies or it could be that that is the way that nature is, because the Indian Ocean Dipole is much more short-lived than El Nino. Our suspicion is that it is probably all three; we do not know to what extent it is one compared to the other. But it is an area that we have identified as a priority area for future research.

CHAIR—On the matter of future research, an issues has arisen in relation to the coordination of research. The bureau and the CSIRO are the predominant bodies involved in research. What is your vision for coordination of research? There seems to be quite a bit going on outside of your own areas of influence and control. Do we need to have a centre of excellence that looks at research, because research is obviously the key to understand the how as opposed to modelling on the basis of what is actually happening? Are we lacking there, do we need more resources or do we need to concentrate them more? Have you got it under control or would you like to see something else develop that would allow you to coordinate the research effort within and outside of your spheres of influence?

Dr Mapstone—The resources in some respects is always a bit of a no-brainer in that everyone would like to have more resources for everything. Where the resources go is a policy issue for government, obviously. The coordination question is an important one because we are a small nation and we do not have the wealth of some of the European Community and US contributions in research. That was the primary motivator for CSIRO and the bureau getting together to form the Centre for Australian Weather and Climate Research. It was a deliberate effort to coordinate their activities in climate and weather research and, although it is a young partnership—it is only a couple of years old—I think it is working very well.

Is it the right model? I think it is certainly an improvement on separately seeking to do work in similar areas—a situation that has perhaps been on in the past. There is probably always going to be room for improvement but towards the end of the term of this partnership, which is a five-year agreement, we will be in a better position to ask if we can improve on the model.

In the university sector it has also been recognised that it is in everybody's interests—the nation's interests, the university researchers' interests, the universities' interests and, we would say, in our interests—for climate researchers across the university sector to be working more tightly together. There are processes by which they can do that through applications for centres of excellence from the ARC and so on.

There is a general recognition that the coordination of our research activities is a very important thing to do. We just cannot afford to be building separate camps and competing for resources. That is also part of the reason why in the access development space we have formal links with the university to say, 'How are we going to collaborate in building this model and applying it to questions of national interest or research curiosity so that we do not duplicate jobs and do not use resources unproductively?' So we are working hard at collaborating across the research sectors in this space in Australia. As I said, I am sure as you review how things are going you find ways to improve that coordination.

Mr RAMSEY—Was the formation of the joint body driven by the way that the buckets of money were set up? Or did the bureau and CSIRO just decide to put their heads together and allocate part of the budget to it saying, 'This needs to happen; otherwise we will be reinventing the wheel'? I am asking this in order to ascertain if there are threats to your lines of funding that we need to keep our eye on to ensure that they remain open.

Dr Mapstone—I was not involved in the negotiations of the partnership, but my understanding is that the decision was made to get together on this because there were some major challenges facing the nation, and both CSIRO and the bureau had research towards those challenges. One of them was building an earth system modelling capability, and that is the access framework. There was recognition in both organisations that just logistically, pragmatically and economically it could not work if one organisation did not have the resources to do that on their own. So I think the partnership was motivated by need and by a sensible coalition of resource expertise. There was some expertise in CSIRO that the bureau did not have and vice versa. It made good sense to put them together.

Mr RAMSEY—So it was largely a joint operational decision that was funded within the two organisations' existing budgets?

Dr Mapstone—Yes. I think that is a fair depiction, and it is ongoing—

Mr RAMSEY—That makes it pretty robust, I would have thought?

Dr Mapstone—I think it is a robust partnership. There is certainly very strong support for it from both organisations; from the bench scientists right through to the executive. I think it does provide more coherence and advantage when looking for external sources of funding for major projects to be able to bring both organisations to bear on a problem, whether it is for funding from the former—

FRAN BAILEY—Do you regard it as a centre of excellence?

Dr Mapstone—In a manner of speaking. We do not use that terminology, but, yes. So whether we are looking for funding from government or from government instruments—formerly Land & Water Australia, or research and development corporations—we can actually now go and say, 'We can give you a package which draws on outstanding expertise in both organisations.' So that is an advantage as well.

Mr Stewart—It will obviously be essential that we maintain the direct linkage between the bureau and Corker and we are part of that, because taking the research into operations is a key

requirement from us and we really need to work closely to get over the barriers that come up from that point of view.

Dr Howden—There is another aspect to that, and that is the coordination of the application of the farmer sites to user needs. The bureau has a role in that, as does the CSIRO and other agencies. At least within CSIRO, we have internally organised ourselves into what we call the climate adaptation flagship. All our climate applications work is under one banner and coordinated effectively. That deals with agriculture and urban issues and a range of other things. Obviously, we have links to other organisations, and they are both formal and informal through project by project activities and individual linkages. Because we are a small nation with a relatively small sized community, those linkages generally work pretty well. There is a strong degree of interaction between the different players.

Having said that, Land and Water Australia had a significant role in coordinating the climate applications work. That in a sense has been a bit more limited because some of the projects are now located within one research and development corporation and there is a question about how effective that will be in dealing and delivering with other research and development corporations. If it is in grains research and development, how will that deliver to the meat industry, for example? So there are some issues there that might arise with coordination in that space. Lastly, there has to be the link back the climate science and CAWCR and other groups that are doing that climate science. That is working pretty well as well.

CHAIR—It has become obvious to us that the traditional statistical modelling is moving towards dynamic modelling systems. You seem to be in a transitional phase. Is there a timeframe for when you will adopt the new model? Do you ditch statistical modelling or keep it as a back up? Are you considering the possibility of pursuing other models of value or is it just a case of you having made a decision on the dynamic modelling? If that is the case, is it sufficient to put all eggs in one basket? Any comments on that?

Dr Alves—In terms of the statistical modelling, at this point in time we already have some operational products from the dynamical models, which include El Nino forecasting, Indian Ocean dipole forecasting and Great Barrier Reef bleaching risk forecasting. Those are already produced by the bureau as operational products from dynamical models. At this point in time, we have some trial regional rainfall and temperature products available, but they are still at the research level. There are still some issues with those. We are taking the approach that as we get to a level where we feel that dynamical products are superior than statistical products in every way then we transition those to an operational state.

Our strategy is that dynamical models are the future. But in this point in time there are some deficiencies that exist. We are trying to address those by maybe making some statistical corrections to the dynamical models. For things like regional rainfall there may be more of a hybrid approach initially—over the next two or three years. Some qualities of dynamical models tend to be not quite right. For example, they may have skill but they might be overconfident. Statistically correcting that overconfidence is something that we are looking at. So I suspect that there will be a gradual transition over the next few years.

Dynamical models provide new products that do not presently exist with statistical models. We will be developing those. When we feel that skill levels are demonstrated and published, we

will be transitioning those to an operational level. It is a gradual transition. There will be many new products. Two or three years ago we would never have thought of having a Great Barrier Reef bleaching risk product available. If there is a user who demonstrates an interest and we manage to demonstrate that there is useful skill, then those products will be transitioned.

CHAIR—I do not expect you to give me the year or whatever. I am just trying to get a timeframe. The second part of the question was about whether there are other models that you would consider or not.

Mr Plummer—The bureau has had this statistical model, and it has evolved over the last 20 years. One of the drivers towards dynamic forecasting is concern that those historical relationships, which are a foundation for the statistical models, between ocean temperatures and rainfall and temperatures may be changing as the climate is changing. So we are seeing some very strong trends in ocean temperatures and rainfall and temperature, and in some cases moving into new territory where those relationships have not been tested. So that is a further driver for bringing on these dynamic systems. But just as like when we shift from one statistical model to another, we need to go through all of the model validation and verification process, which takes time. Once we are satisfied that we have got a better model that is when the shift will be made. That work is being done now in terms of looking at the dynamic models and comparing them with statistical models.

Dr Mapstone—The second part of your question was around whether we are putting all of our eggs into one basket. I think the answer there is: certainly no more so than in the past, and I would argue less so. There is certainly a strategy in place for us to move to the access modelling framework. That is a fairly well-considered strategy. We are putting a lot of effort into developing that framework. But I think the important thing to recognise is that that is not a single model—it is not a case of having one egg in one basket. So access is put together as a combination of an atmospheric model, an atmospheric chemistry model, an ocean model, a sea ice model and a land surface model. All of these things have to be put together into the framework. We at CSIRO and the Bureau of Meteorology have spent quite a bit of time looking at the best performers in each of those different areas around the world and we have, if you like, cherry picked from those available—from the top one, two or three ocean models or atmospheric models—to build the framework, a combination of all of those models, that we think will best serve Australia.

In some respects that might be seen as saying, 'Well, you actually just picked one basket to put your eggs in in the ocean space,' but in fact what that allows us to do is to build flexibility into the framework. So the ultimate goal is to have a system which allows us, for example, if somebody comes up with a better ocean model to say, 'Let's have a look at that ocean model,' and to bring that into the framework. So we retain flexibility partly because we are working closely with the best people in all of the other research centres internationally. We use some of their models, we feed back to them the improvements we make and we benefit from then getting the upgrades that they have been making. So I think really far from putting all our eggs in one basket we are building an approach to climate, weather and long-term forecasting in Australia which is more flexible than it has been in the past. The step we have taken to go to the access system I think really does represent a significant quantum step forward that we would not have been able to make if we had just stuck to our own history, if you like.

Mr SYMON—Earlier on we briefly touched on gaps in the automatic weather station network, and my memory is that that issue was brought up at both the Perth and Adelaide hearings. I do not think we have asked the question up until now, but I was wondering what is the cost of setting up an AWS and how much does it cost to run?

Mr Stewart—Again, there are no straightforward answer to that question—

Mr SYMON—There never is.

Mr Stewart—The standard AWS that we operate on average would cost $100,000 to install and purchase. That does the standard set of parameters. If you want to do fewer sets of parameters at lower accurate accuracy then you can purchase lower quality instruments and that would cost less. If you want to get higher quality ones, such as those we need for aviation, then they cost about $250,000—but they do do a certain amount of processing as well within the site to produce information for aviation. So it does vary but that is the sort of order we are talking about. The average life is about 10 years.

Mr SYMON—What is the maintenance cost?

Mr Stewart—Again, it varies, depending on whether they are in remote localities.

Mr SYMON—Of course.

Mr Stewart—It costs in the order of $10,000 or $20,000 per year to maintain.

Mr SYMON—I am sure that at one of the hearings—perhaps in Adelaide; my memory is fading a bit—having a community purchase their own AWS was raised. Is that something the bureau can tie into? Is that already happening?

Mr Stewart—It has happened in some places. There are issues with that sort of thing. A lot of the issues come down to the investment they want to put into it. Again, it is a fit-for-purpose thing for the data. If you are talking about long-term climate information, then you need really good quality stability—consistency across the country in those sorts of things. We talked before about siting. You need to look at the standard of the equipment, the information flow, how that gets into the bureau, who would handle the communications, costs and things like that. We would need to look at it from that point of view. There is also the issue of replacement. My understanding is that we cannot just take something like that and put it into our capital program, and then the government has to fund it. It is really up to the group to recognise that, if you are going to purchase one, there will be a long-term commitment to its operation. We have had situations where we take data from other groups. We just need to go through the hoops and jumps to make sure of the quality and that sort of thing before we bring it into our systems. In the fire area, too, we now work with various groups in Victoria to get more information from their sites for our forecasts. That is occurring as well. So it does happen, but there are a few things that we have to tack on before that happens. It is interesting that, as part of the new Water Act and water information requirements for the bureau, there is a certain amount of meteorological information—rainfall and the like—that will now flow to the organisation. We will be storing that as well as part of that process.

Mr SYMON—To follow up, you mentioned different levels of automatic weather stations. I take it there is the aviation version. You also mentioned different levels of, dare I say it, a base station—different levels of equipment, accuracy et cetera.

Mr Stewart—Yes, there is.

Mr SYMON—In terms of the network that is installed at the moment, is it consistent? Is there a base level or are there various versions that have been installed over the years—some more accurate than others?

Mr Stewart—At the moment the automatic weather station has pretty much a standard set of equipment. We are currently looking at the next generation of that, in terms of what will come along and replace it. We are primarily looking at it from the point of view of greater levels of quality control at the site itself to make sure that the instrumentation is working well. Again, from that point of view, you reduce the number of site visits you need to do, because you can do better things to fix the equipment from afar. The basic AWSs across the bureau at the moment are fairly standard.

Mr SYMON—Thank you.

CHAIR—There appear to be no other questions. Thank you. That was a very interesting two hours.

Resolved (on motion by **Mr Ramsey**):

That this committee authorises publication of the transcript of the evidence given before it at public hearing this day.

Committee adjourned at 11.58 am