3

Long-term forecasting models

Statistical and dynamic models

3.1 BoM and CSIRO stated that the direction being taken by most weather forecasting groups internationally, as in Australia, is to replace existing empirically based statistical schemes with systems based on dynamic models, when the dynamic systems have comparable or better skill than the existing statistical systems.[1]

3.2 DAF succinctly outlined the different model types:

> There are two main approaches to seasonal climate forecasting; statistical methods using statistical relationships between atmospheric or oceanic indicators and seasonal climate variables such as rainfall or temperature, and dynamical methods using global atmospheric and oceanic circulation models.
>
> Each approach has its own advantages and disadvantages. Statistical methods are computationally simpler, but forecasting skill has been weakened in recent decades by trends in both predictors and predicted climate elements … The dynamical approach is potentially the best tool for making seasonal predictions as they simulate the physical relationships that make each year's seasonal conditions unique. They also in principle have the ability to cope with changes in variables as climate change evolves. The major disadvantage is that they require complex

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1 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

computational methods and resources, and remain sensitive to errors in the initial conditions for calculation.[2]

3.3 BoM explained the move from statistical to dynamic forecasting:

> 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.[3]

3.4 BoM and CSIRO, have been developing successive versions of a dynamic coupled modelling system for seasonal forecasting, called POAMA (Predictive Ocean Atmosphere Model for Australia):

> The first version [of POAMA] was implemented in Bureau operations in 2002 and generated forecasts of El Niño sea surface temperature indices. Evaluations of El Nino forecast skill, using retrospective forecasts, showed that POAMA was useful out to at least 9 months into the future.[4]

3.5 The POAMA system was upgraded in 2007 to include forecasts of sea surface temperature in the equatorial Indian Ocean, which is also believed to be an important driver of weather and climate variability in Australia and the region.[5]

3.6 BoM and CSIRO discuss the skill of POAMA:

> Extensive analysis have been done of the capability of the POAMA system for regional forecasting of climate in the south east of Australia and in the subtropical Indian Ocean. These analyses have demonstrated that regional seasonal forecasts for Australia from POAMA have skill equivalent to, or better than, the current statistical approaches, though perhaps the uncertainty of the forecast is under-represented.[6]

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2 DAF, *submission 30*, pp. 3-4.

3 BoM, *transcript of evidence 12 August 2009*, p. 25.

4 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

5 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

6 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

3.7 CSIRO stated that, through the CAWCR partnership, POAMA continues to develop and improve, however:

> The newest version, POAMA-2, is significantly more demanding computationally than its predecessors … and so it will be used in real-time only on the Bureau's new supercomputer, which will be installed in late 2009. The new supercomputer will allow the skill for regional seasonal climate forecasts from POAMA-2 to be fully evaluated and delivered.[7]

3.8 CSIRO discussed the development of a new weather simulation system:

> Australia is building the next generation weather, climate and earth system simulation capability, called ACCESS (the Australian Community Climate and Earth System Simulator). ACCESS will deliver Australia's short-term weather forecasts, seasonal forecasts, and global and regional multi-decadal climate projections from local to global scales. ACCESS already is delivering short-term weather forecasts with greatly improved skill over the current system.[8]

3.9 CSIRO explained further:

> ACCESS will produce the nation's weather forecasts by late 2009 and by 2011 it will provide long-term global and regional climate projections and be a key platform for Australia's contributions to the IPCC [Intergovernmental Panel on Climate Change] Fifth Assessment.[9]

3.10 CSIRO discussed the integration of POAMA and ACCESS:

> The next phase of POAMA development (POAMA-3) will be to include the seasonal forecasting system within ACCESS, which is being developed to provide Australia's next generation weather prediction system and climate simulation system … ACCESS is already delivering much-improved short-term weather forecasts compared to the current operational system and is expected to deliver significant improvements in seasonal forecasts. Both the short-term weather forecasts and longer-term seasonal forecasts from ACCESS will be enhanced significantly by improved

7 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

8 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 9.

9 BoM, *submission 4*, p. 8; CSIRO, *submission 16*, p. 17.

assimilation of data from various land, ocean, automated and satellite sources of observations.[10]

3.11 AAS also discussed the development of ACCESS:

> … the national ACCESS initiative draws on recognised expertise across the Australian research sector, including from a small number of research intensive universities. The approach taken is intended to bring the best international and Australian modelling components together to build an Earth simulation system tailored to Australia's particular needs given its Southern Hemisphere situation.[11]

Requirements for model development

3.12 CSIRO stated that the main needs for more rapid development and deployment of ACCESS are:

> … significant enhancement of supercomputing infrastructure; increased staff capacity; and improved techniques for assimilating observations of the land, air and oceans, especially from satellites.[12]

3.13 CSIRO explained the need for enhanced computing resources:

> Delivering the full benefit of the ACCESS-based system through real-time operation of POAMA-3 will require a further step-change in supercomputing resources available to run the system in ensemble prediction mode at improved spatial and temporal resolution.[13]

3.14 CSIRO stated that the ACCESS project is developing a unified, national weather and climate modelling system, however, many more issues need to be addressed than available resources allow, making progress slow.[14]

3.15 CSIRO explained that some of the key areas of research and development most likely to improve seasonal forecasting skill in all model systems include:

- improving the simulation of El Niño and its different modes;
- improving the simulation of the Indian Ocean variability;

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10 BoM, *submission 4*, p. 9; CSIRO, *submission 16*, p. 9.

11 AAS, *submission 25*, p. 6.

12 CSIRO, *submission 16*, p. 9.

13 CSIRO, *submission 16*, p. 9.

14 CSIRO, *submission 16*, pp. 9-10.

- improving the simulation of weather phenomena (e.g. cut off lows, blocking, tropical cyclones, tropical intra-seasonal waves, etc) and tropical processes that contribute to phenomena such as El Niño, which are all significant drivers of Australia's regional climate; and
- improving data assimilation techniques that incorporate in situ and satellite observations into the ACCESS model.[15]

The dynamic model

3.16 BoM and CSIRO have negotiated a Collaboration Agreement with the United Kingdom Meteorological Office's (UKMO) Hadley Centre to adopt the UKMO Unified Model, atmospheric chemistry module and data assimilation scheme as the core of ACCESS. CSIRO added:

> This heralds a significant strategic alliance between Australia and the UK to collaborate on the development and deployment of a consistent approach to climate and earth system modelling.[16]

3.17 The Unified Model is a 'high-powered computer-based climate and weather prediction program' considered the best in the world.[17] The Model is being adapted to Australian conditions and early tests have shown its use has provided a 'significant improvement on the Bureau's current operational numerical weather predication system'.[18] The Committee was told that the Unified Model supports four-dimensional variational data assimilation (4DVAR) allowing it to use more data more efficiently, exceeding the capabilities of POAMA.[19]

Criticism of model choice

3.18 The Committee heard evidence that the UK model has not had a high success rate with long term weather forecasts. John McLean, an information technology specialist who has applied his skills in analysis to various issues relating to climate change, provided written evidence of the

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15 CSIRO, *submission 16*, p. 10.

16 CSIRO, *submission 16*, p. 17.

17 *Bureau of Meteorology Annual Report 2007-08*, www.bom.gov.au/inside/eiab/reports/ar07-08/, accessed 5 November 2009.

18 *Bureau of Meteorology Annual Report 2007-08*, www.bom.gov.au/inside/eiab/reports/ar07-08/, accessed 5 November 2009.

19 Dr J Larson, *submission 18*; WRMS, *submission 21*, p. 2.

lack of success of the model from 2007 until 2009.[20] He told the Committee:

> … in the UK the Met Office has been using modelling for seasonal forecasts over the last few years. 2007 was one of the wettest summers since, I think, 1913 and they had predicted a very hot summer. They tried again the next year and it was, again, a very wet summer. Last winter they predicted quite a mild and dry winter, and they had very heavy snow. They ran out of salt and grit for the roads.[21]

3.19 The Committee asked the CPSU if there were any particular risks with the ACCESS model that could be perceived as a weakness:

> The difficult is going to be getting enough resources to do all of the climate processes properly. I think the ACCESS model is already successfully doing single forecasts with data assimilation, which was really part of the main driver for the change—to get that capability into Australia for short-term forecasting. That has been delivered, and the short-term forecasts are improving and are really world competitive. That needed to happen, but that is only for short-term forecasting. To go on to the other processes, where you worry about climate and the longer term properties of the system, a lot more resources and manpower are needed to bring that model up to speed. I think that is what the researchers would say. So, having gone down this path and committed to having a model that does those sorts of forecasts—essentially having to build it and having to migrate it onto new computing platforms and arguing for enough resources to do all that—it is a fly by the seat of the pants affair at the moment. If you had unlimited resources you could try it on, but it could all just fail.[22]

Alternative models

3.20 Dr J. Walter Larson, a computational scientist with extensive climate modelling experience, described the open source models used in the US:

> The best example of combined software and performance engineering in the [climate/weather/oceans] arena is the US Weather Research and Forecasting Model (WRF)

20 John McLean, *supplementary submission 32.1.*

21 John McLean, *transcript of evidence 29 June 2009,* p. 42.

22 CPSU, *transcript of evidence 29 June 2009*, p. 62.

> The major academic-sector climate system model in the US is the Community Climate System Model (CCSM) … CCSM's governance structure engages the academic community as well as [Department of Energy] and [National Science Foundation] scientists, and is worth considering for future [climate/weather/oceans] systems development.[23]

3.21 Dr Larson explained that both WRF and CCSM are open source models:

> … both models are freely available for download at no cost. This means the models are widely used, and bugs are found and fixed. I believe the more "closed" approach in place here marginalises Australian researchers in the [climate/weather/oceans] field … [24]

3.22 Dr Larson discussed some of the benefits of an open source model:

> … open source is a good thing because you can engage more collaborators and you can get people using your code and potentially finding bugs. Again, I think if you are building software you need to change your mindset—finding bugs is a good thing. Your life is no better if that bug was undiscovered. It is just good to find them, fix them and move on.[25]

3.23 Dr Larson discussed the Hadley Centre's Unified Model:

> … something like the Hadley Centre Unified Model is not open source, for better or worse. I think they have found it is a valuable product and, for whatever reasons, they want to keep the source to themselves and control its release.[26]

3.24 Dr Larson explained that a closed source model may have disadvantages:

> … most of the modelling software is held quite tightly … I think I understand why it is held tightly like this. In my opinion, it is that the people who develop these things are strapped for cash, that they do not think of their code as being on par with the publication, that instead they view it as a less valuable thing that they spend evenings and weekends building and getting to work, and that they have only so much support, so it is a way of cost recovery or a source of funding. I would say that to some extent a lot of this closed source approach is something where science is viewed as a cost that must be recovered rather than, 'This is

23 Dr J Larson, *submission 18*, p. 3.

24 Dr J Larson, *submission 18*, p. 3.

25 Dr J Larson, *transcript of evidence 17 June 2009*, p. 6.

26 Dr J Larson, *transcript of evidence 17 June 2009*, p. 6.

> something that we fund,' and there are products that come out of it—software tools—that are meant to be used by the community at large.[27]

3.25 Dr Larson discussed at length the ability to integrate systems and models:

> … why don't we just cherry-pick things and be a really solid system integrator [?] … If we look at things from that perspective, I would say that there are some things about the UM that make it a little harder to couple to other systems …
>
> Most kinds of atmosphere ocean models do something that I would classify as explicit coupling … Because of the UM's numerics … it does what is called 'implicit coupling'. You have to do this kind of computed self-consistent solution between the ocean and the atmosphere for what is going on at the surface. That is a harder problem to solve. Most climate and atmosphere ocean models have gotten away with doing this as explicit coupling. It is a technical detail that makes coupling this to the rest of the system a little bit harder … That is one technical detail that I would say is making things a little bit harder than they need to be.
>
> … I would be perfectly happy with Australia cherry-picking stuff from other places, and then the idea would be to try and come up with better coupling mechanisms. But the coupler that has been imported for ACCESS is a bit of a finicky thing as well—again, this view is from what I have heard from the people working with it. Maybe we ought to concentrate some effort on trying to [develop] our own system for sticking everything together.[28]

3.26 DAF suggested that there is potential to develop advanced statistical methods of seasonal forecasting as an alternative to dynamical methods.

> Research conducted as part of the Indian Ocean Climate Initiative (IOCI, see www.ioci.org.au) demonstrated the potential for non-linear statistical methods in developing seasonal forecasts. These can cope with trends and jumps in data, and allow the strength of relationships between variables to be tested. They are also computationally simpler than global climate models.[29]

27 Dr J Larson, *transcript of evidence 17 June 2009*, p. 6.

28 Dr J Larson, *transcript of evidence 17 June 2009*, p. 9.

29 DAF, *submission 30*, p. 4.

Reliance on one model

3.27 CPSU stated that, with the development of dynamic models and the establishment of CAWCR, other research and modelling was essentially abandoned:

> … the decision was made to form CAWCR as a joint venture between the bureau and CSIRO, to consolidate effort. Part of that involved ditching the legacy models that were there—that is the strategy that was employed—and taking a new system on as a way of getting a step change in capability … I think simply the cost pressures meant that they tried to achieve an outcome within the budget parameters that they had. Essentially the way that was achieved was by cutting off legacy models scientists may have worked on for decades, where they knew how the system responded and they knew what they could get out of that in a scientifically meaningful way. They are now expected to deliver a new system which has a greater planned capacity, but from the working scientists' point of view it was not always a satisfactory way to achieve that expansion of capability.[30]

3.28 CPSU added:

> … from a lot of CSIRO scientists' point of view, [this] was a bit disappointing because there is no overlap there to do side-by-side comparisons to get a proper handover to a new technology.[31]

3.29 When asked if other forecasting models have been or are being considered, as opposed to utilising a single model, and possibly 'putting all our eggs in one basket', CAWCR explained:

> 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

30 CPSU, *transcript of evidence 29 June 2009*, pp. 58-59.

31 CPSU, *transcript of evidence 29 June 2009*, pp. 58-59.

> 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.[32]

3.30 CAWCR further explained the flexibility of its approach:

> 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.[33]

Testing and timeframes

3.31 DERM suggested that the skill of dynamical forecasts has rarely been assessed and compared with the skill of statistically based systems, thereby limiting the evaluation of dynamical forecasts.[34]

3.32 DERM stated:

> Dynamical forecasts are attractive, in that they may be able to better integrate the entire climate system (not just the ENSO component for instance). However, without an assessment of the individual track record of each model, the Queensland

32 CAWCR, *transcript of evidence 12 August 2009*, p. 25.

33 CAWCR, *transcript of evidence 12 August 2009*, p. 25.

34 DERM, *submission 33*, pp. 8-9.

> Government and general public will not be able to properly evaluate the efficacy of these systems.[35]

3.33 DERM explained further:

> There are now sufficient years where various statistical schemes and dynamical models have been operating in parallel, to begin to compare skill levels on an operational basis (i.e. 'as issued'). Notwithstanding the difficulties of evaluating statistical schemes over short time periods (around 10 years in this case), the Queensland Government recognises the importance of conducting such studies in order to benchmark alternative systems.[36]

3.34 BoM commented on the need for considerable testing when moving from one forecasting model to another:

> But just as 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.[37]

3.35 When asked about a transitional phase and a timeframe for adopting a new model, CAWCR explained:

> … 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.[38]

3.36 CAWCR explained further that dynamical models are the future, however there are currently some deficiencies that exist:

35 DERM, *submission 33*, p. 17.

36 DERM, *submission 33*, p. 17.

37 BoM, *transcript of evidence 12 August 2009*, p. 25.

38 BoM, *transcript of evidence 12 August 2009*, p. 24.

> 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 … 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.[39]

Committee comment

3.37 The Committee recognises that it is not in a position to judge the merits of any particular models chosen for forecasting in Australia. However, the Committee is confident that our peak scientific and meteorological agencies are in the best position to be able to make informed and appropriate decisions regarding forecasting model choice based on Australia's needs.

3.38 The Committee would appreciate a transparent approach to decisions made by our peak scientific and meteorological agencies. The Committee recommends that CSIRO and the Bureau of Meteorology provide to the Australian Government detailed explanatory information as to why a particular dynamic forecasting model or system was chosen, and which other models were considered. The report should be completed by the end of 2010.

Recommendation 1

The Committee recommends that CSIRO and the Bureau of Meteorology provide to the Australian Government a report with detailed explanatory information as to why a particular dynamic forecasting model or system was chosen for use in Australia. The report should be completed by the end of 2010.

39 BoM, *transcript of evidence 12 August 2009*, pp. 24-25.

Model variables or inputs

3.39 This section of the chapter discusses some of the variables that are considered in the development of a forecasting model.

El Nino influences and autumn forecasts

3.40 Much of the variability in Australia's climate is connected with the atmospheric phenomenon called the Southern Oscillation, a major see-saw of air pressure and rainfall patterns between the Australian/Indonesian region and the eastern Pacific Ocean. The term El Niño refers to the situation when sea surface temperatures in the central to eastern Pacific Ocean are significantly warmer than normal. This recurs every three to eight years and is generally associated with a strong negative phase in the Southern Oscillation pendulum. El Niño events are associated with an increased risk of dry conditions across large areas of Australia. The period of strongest influence is the six months of winter/spring.[40]

3.41 Professor Neville Nichols suggested that the El Niño – Southern Oscillation (ENSO) allows for the production of skilful seasonal climate forecasts, because:

- El Niño events tend to cause dry conditions in eastern & northern Australia;
- El Niño events tend to last about 12 months; and
- El Niño events tend to start around March/April.[41]

3.42 Professor Nicholls added:

> This means that if in early winter we recognise that an El Niño event is underway, then we can forecast that below average rainfall is likely through late winter, spring and summer in eastern and northern Australia (as well as much of Indonesia and Papua New Guinea).[42]

3.43 Professor Nicholls explained further that there is a major limitation with forecasts based on the ENSO in that:

> … prediction across March/April (e.g. of early winter rainfall) is very difficult, because this is the time that El Niño events are starting to develop but may not yet be sufficiently strong to be

40 BoM, 'El Niño, La Niña and Australia's Climate', www.bom.gov.au/info/leaflets/nino-nina.pdf, accessed 4 November 2009.

41 Prof Neville Nicholls, *submission 12*, p. 3.

42 Prof Neville Nicholls, *submission 12*, p. 3.

> observed. This is known as the "autumn predictability barrier", and its causes are still not understood.[43]

3.44 CAWCR discussed the difficulties in providing a reliable autumn forecast, a seasonal forecast that is particularly important for the agricultural sector:

> We believe the reason for that is that the active period when ENSO [El Niño – Southern Oscillation] develops. That is when an El Niño 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 Niño 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.[44]

3.45 When asked what the key factors were in the development of a reliable autumn forecast CAWCR stated:

> 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 … and then it becomes more straightforward to predict what is going to happen in the future.[45]

43 Prof Neville Nicholls, *submission 12*, p. 3.

44 CAWCR, *transcript of evidence 12 August 2009*, p. 8.

45 CAWCR, *transcript of evidence 12 August 2009*, p. 8.

3.46 When asked what was needed to facilitate an increase in the reliability of autumn forecasts, CAWCR stated:

> There is not a simple answer to that. The primary phenomena, which are important, are El Niño 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 Niño 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 Niño 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.[46]

3.47 CAWCR discussed the El Niño phenomenon at length:

> There have been several theories for the onset of El Niño. None of them fully explain what makes a particular year an El Niño 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 Niño … What we are also realising is that El Niño comes in different flavours. Not every El Niño is the same
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> …
>
> although models do simulate El Niño 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.
>
> …
>
> the oceans 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

46 CAWCR, *transcript of evidence 12 August 2009*, pp. 8-9.

> it interacts with the atmosphere. ENSO events have been going on for a long time … 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 … [47]

3.48 CAWCR added that the Argo program[48] has changed ocean observations dramatically:

> 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.[49]

3.49 When asked if investing in more ocean observation technology was the way forward, CAWCR stated:

> 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.[50]

Indian Ocean influences

3.50 CSIRO discussed the importance of the Indian Ocean Dipole (IOD) on Australia's climate:

47 CAWCR, *transcript of evidence 12 August 2009*, pp. 17-19.

48 Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 metres of the ocean.

49 CAWCR, *transcript of evidence 12 August 2009*, p. 19.

50 CAWCR, *transcript of evidence 12 August 2009*, pp. 19-20.

> We can go back to about 1900 and say that the Federation drought and the World War II drought and the current big dry all seem to be related to the fact that the negative phase of the Indian Ocean Dipole did not occur for a long period of time or occurred very infrequently. The ocean temperatures going back to the 1900s are not as certain as more recently … But nonetheless there is some information there, enough that we think we understand that the Indian Ocean Dipole is really quite important for us.[51]

3.51 CSIRO discussed the IOD further:

> … in the last 10 years, maybe, people have been beginning to understand that the Indian Ocean is important in its own right but it also acts together with the Pacific Ocean. When the two act together, you can get a very strong effect in Australia. When the two oppose each other, you can get parts of Australia wet and parts of Australia dry … Trying to understand where those two effects matter regionally in Australia is quite important. We do not understand the Indian Ocean as well yet. We do not understand some of the dynamical mechanisms of how the Indian Ocean affects us, but there is a lot of research happening right at the moment that is starting to unravel that.[52]

3.52 CAWCR also discussed the importance of the Indian Ocean in influencing Australia's weather and climate, and the need for further research on that influence:

> 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 … In the Pacific Ocean we have a fairly extensive buoys network, as well as the Argo network … 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 is where the engine room of El Niño is. With the recognition that [the Indian

51 CSIRO, *transcript of evidence 18 May 2009*, p. 18.

52 CSIRO, *transcript of evidence 18 May 2009,* p. 18.

Ocean Dipole] is also important for Australian rainfall, that tends to emphasise the Indian Ocean more.[53]

3.53 Professor Roger Stone suggested that the effect of the Indian Ocean is a major gap in core science relating to climate forecast systems:

> … the relevance or otherwise of any independent contribution provided by the Indian Ocean through the Indian Ocean Dipole (IOD) or similar. Climate forecast systems that incorporate the IOD (in addition to ENSO), including that provided by the Bureau of Meteorology, have encountered some problems in operational skill, possibly due to rapid warming of sea-surface temperatures in the Indian Ocean. I understand BoM is working on correcting this problem although the results do not seem to have improved to any extent. This issue needs to be urgently resolved.[54]

3.54 CAWCR commented further on the IOD:

> We presently produce Indian Ocean forecasts in the same way that we produce El Niño forecasts, but the skill from the Indian Ocean is very limited compared to our ability to predict El Niño. 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 Niño. 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.[55]

3.55 DAF discussed Indian Ocean research:

> Research at the Bureau of Meteorology and more recently the University of New South Wales has shown that Indian Ocean sea surface temperatures can affect winter and spring rainfall over southern and south-eastern Australia. This influence is not explicitly captured by current operational seasonal climate forecasts.[56]

53 CAWCR, *transcript of evidence 12 August 2009*, p. 20.
54 Prof Roger Stone, *submission 10*, p. 5.
55 CAWCR, *transcript of evidence 12 August 2009*, p. 22.
56 DAF, *submission 30*, p. 4.

3.56 DAF recommended that:

> Seasonal forecast systems should include climate system influences from other ocean basins such as the Indian and Southern Oceans. These are especially relevant to Western Australia, South Australia and western Victoria.[57]

3.57 DAF added that:

> There is an ongoing need to maintain and enhance weather and climate observing capacity over WA and in the Indian and Southern oceans. This underpins not only dynamical climate methods, but also enables model verification and development of accurate statistics of climate variability and change.[58]

3.58 LWA discussed the performance of the POAMA model, and the need for incorporation of additional data concerning the Indian Ocean:

> … POAMA is exhibiting excellent skill based on 27 years of record to the level that substantial gains in profitability are likely. The story is far different in the northern sector of the wheatbelt where POAMA is exhibiting no skill. We explain this as the limited representation at this time of the Indian Ocean Dipole …[59]

Particulates

3.59 The Committee heard of the significant effect of particulates (or aerosols) in the atmosphere on climate and that Australia's geographic location make it susceptible to these effects:

> Particulates in the atmosphere (commonly smoke from agriculture, deforestation, industry and volcanoes) are now understood to have large effects on the global and regional climates. Australia is just to the south of Indonesia and Papua New Guinea, the most intense source of volcanic particulates in the world and also one of eight major sources of biomass burning and other anthropogenic particulates/smoke. It is now relatively easy to demonstrate a connection between the particulate plumes over this area and drought in south eastern Australia.[60]

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57 DAF, *submission 30*, p. 3.
58 DAF, *submission 30*, p. 3.
59 LWA, *submission 7*, p. 7.
60 Keith Potts, *submission 17*.

3.60 Mr Keith Potts, a geophysicist, explained the dangers of not taking these particulates into consideration:

> Climate models do not currently represent accurately the combined effects of carbon dioxide and continental scale particulate/smoke plumes on the global and regional climates as the sensitivity of the models to changes in these agents varies significantly (CCS Program) and many models do not include all particulate/smoke species (IPCC fourth assessment report). Hence any forecast made using such models may be inaccurate even if they have reproduced the global temperature change during the twentieth century (CCS Program). Reliance on such forecasts is therefore at least questionable and at worst fatally flawed.[61]

3.61 The Committee asked why the influence of particulates is not being given more consideration in the current Australian models and Mr Potts suggested that:

> One of the issues has been that research in this region in this area—this industry if you like, which it now is—is basically done with computer models. The computer models do not have particulates or aerosols in them and therefore they cannot be researched because they cannot be modelled. It is as simple as that. There is no doubt that the models are getting better as computers get faster. Modelling particulates is much more difficult than modelling long-term greenhouse gases, which are well mixed across the whole atmosphere. As you can see in the papers that I gave you, the particulates are not, and they change constantly. Modelling them is much more difficult and therefore they have not been included. Where they are, their effects vary significantly between models.[62]

3.62 CAWCR explained that it is examining the particulates and aerosols issues and incorporating that variable in its models:

> … 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

61 Keith Potts, *submission 17.*

62 Keith Potts, *transcript of evidence 15 July 2009,* p. 23.

> continue to do so. We currently have a group of two scientists looking at the aerosol issue in the models … [63]

Lunar nodal cycle

3.63 Another possible influence on Australia's long term weather patterns was brought to the Committee's notice at its Melbourne hearing. Mr Charlie Nelson, a statistician, has been studying the statistical and historical effects of the lunar nodal cycle on rainfall patterns in Australia, with particular attention to Melbourne and the Murray Darling Basin. In his written submission Mr Nelson explained the lunar nodal cycle:

> The Sun's declination changes from +23.5˚ to -23.5˚ between the solstices due to the Earth's rotational axis being tilted at about 23.5˚ from the axis of orbital motion around the sun (the ecliptic). The Moon also changes in declination by the same average amount over a period of four weeks, the period of the Moon's orbit around the earth. But unlike the Sun, the maximum and minimum declination of the moon varies because the Moon's orbit around the Earth is inclined at 5˚ to the plane of the earth's orbit around the Sun. Thus, the maximum declination varies between 18.5˚ and 28.5˚.
>
> The two points at which the Moon's path crosses the ecliptic are known as the nodes. These nodes slowly move around the ecliptic, taking 18.6 years to complete one cycle.[64]

3.64 Mr Nelson told the Committee that during this cycle the pull of the moon on the Earth's oceans could affect weather and climate:

> The lunar node cycle means that the Moon, which on average, swings as far south as the tropic of Capricorn (just south of Exmouth on the Western Australian coast) has periods when it doesn't reach Port Hedland and others when it is overhead as far south as Geraldton. During the nine years before a major standstill, it is presumably dragging warm water further south and during the nine years before a minor standstill, it would be pulling cool water further north.[65]

63 CAWCR, *transcript of evidence 12 August 2009*, p. 10.

64 Foreseechange Pty Ltd, *submission 23*, pp. 3-4.

65 Foreseechange Pty Ltd, *submission 23*, p. 4.

Other variables

3.65 Land and Water Australia who are responsible for the *Managing Climate Variability Program* discussed a number of other climate drivers that will need to be incorporated into POAMA. These include:

- Southern Annular Mode (SAM);
- Madden Julian Oscillation (MJO); and
- Subtropical Ridge.[66]

3.66 The Southern Annular Mode (SAM), which is an atmospheric phenomena originating over the south pole, is known to affect Australia's rainfall patterns:

> The Southern Annular Mode, or SAM, also known as the Antarctic Oscillation (AAO), is a mode of variability which can affect rainfall in southern Australia. The SAM refers to the north/south movement of the strong westerly winds that dominate the middle to higher latitudes of the Southern Hemisphere. The belt of strong westerly winds in the Southern Hemisphere is also associated with the storm systems and cold fronts that move from west to east.
>
> During a "positive" SAM event, the belt of strong westerly winds contracts towards the south pole. This results in weaker than normal westerly winds and higher pressure over southern Australia. Conversely, a "negative" SAM event reflects an equatorward expansion of the belt of strong westerly winds. This shift in the westerly winds results in more storm systems and lower pressure over southern Australia.[67]

3.67 The Madden Julian Oscillation (MJO) is a phenomenon that enables intra-seasonal forecasts:

> The MJO is a belt of low pressure that propagates eastward across the equatorial Indian and Pacific Oceans usually taking between 30 to 60 days. Its passing can increase the likelihood of rain in northern Australia in particular. It is possible to forecast the likely timing of the MJO passage across the Australian region and, during this period, heightened prospects of rainfall.[68]

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66 LWA, *submission 7*, p. 13.

67 BoM, 'Southern Annular Mode', www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.html?bookmark=sam, accessed 30 October 2009.

68 DERM, *submission 33*, p. 3.

3.68 The Subtropical Ridge is a belt of high pressure which affects Australia's seasonal weather patterns:

> The sub-tropical ridge runs across a belt of high pressure that encircles the globe in the middle latitudes. It is part of the global circulation of the atmosphere.
>
> The position of the sub-tropical ridge plays an important part in the way the weather in Australia varies from season to season.
>
> During the warmer half of the year in southern Australia (November to April), the sub-tropical ridge is generally located to the south of the continent. High pressure systems (also called anticyclones), which are associated with stable and dry conditions, generally move eastwards along the ridge.
>
> In autumn the sub-tropical ridge moves northward and remains over the Australian continent for most of the colder half of the year in southern Australia (May to October). Conditions along the ridge, under the influence of the high pressure systems dry and descending air, tend to be stable and drier.[69]

State, regional and local influences

3.69 The Committee took evidence from across Australia and was told that variables differ from region to region. These differences need to be taken into consideration when developing and applying forecasting models. For example, the Committee was advised by DERM that:

> … practical steps can be taken to improve statistically-based forecast schemes for Queensland: 1) remove indices of little relevance to Queensland (e.g. Indian Ocean sea-surface temperature in BoM's current sea surface temperature scheme); 2) replace these with indices of more relevance to Queensland e.g. an index which is sensitive to fluctuations in the PDO; 3) de-trend climate signals for observed climate change trends; and 4) customise systems to user-needs in terms of lead times and target periods.[70]

3.70 The Fire and Emergency Services of Western Australia (FESA) told the Committee that lack of attention to local influences hampered the usefulness of long term forecasts:

69 BoM, 'The Sub-tropical Ridge', www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.html?bookmark=stridge, accessed 30 October 2009.

70 DERM, *submission 33*, p. 7.

> Currently the long term meteorological forecasting and prediction information offered by Commonwealth agencies is limited. To meet the planning requirements in a State the size of Western Australia, data and information utilised needs to be State and region specific to address vulnerable, dispersed and isolated population groups.[71]

Other data issues

3.71 With regard to the efficacy of forecasting models, the Committee heard that consideration will need to be given to the 'appropriate benchmarks and documentation of historical track records' to ensure the consistency and reliability of data.[72] The Department of Environment and Resource Management provided the following example from Queensland rainfall data:

> There is a difference in the rainfall datasets held by the QCCCE [Queensland Climate Change Centre of Excellence] and those available through BoM. The QCCCE dataset commences in 1890, whilst the BoM dataset commences in 1900. The decade of the 1890s is extremely important in eastern Australia, in that it contains very wet years at the start of the 1890s and the Federation Drought, which commences at some locations in 1896 and lasts until 1902. These wet and dry periods are important in terms of ranking current conditions relative to the past (e.g. the drought in south-east Queensland in the early and mid-2000s). these periods also provide an important historical test for climate forecasting systems given the high variability that occurred in rainfall.[73]

3.72 DERM also cautioned that forecasting models need to be tested over time:

> Given that fluctuations in the strength of the relationship between ENSO and local climate has 'waxed and waned' over the years, an important question in evaluating the skill of forecasting systems is: how do such systems perform throughout the entire historical record, including periods such as 1920 to 1950 for example, during which the ENSO signal lacks persistence and there is low correlation between the ENSO indices and Queensland rainfall?[74]

71 FESA, *submission 29*, p 2.

72 DERM, *submission 33*, p. 17.

73 DERM, *submission 33*, p 17.

74 DERM, *submission 33*, p 6.

Committee comment

3.73 The Committee is concerned that CSIRO and the Bureau of Meteorology may have difficulty in considering and incorporating a substantial number of variables into their weather and climate models. Several submissions to the inquiry highlighted some key variables that may influence weather and climate. The Committee is keen to see those variables researched and assessed in detail.

3.74 The Committee recommends that variables and influences be thoroughly examined to assess their degree of impact on our weather and climate, and incorporate those variables into forecasting models as necessary.

Recommendation 2

The Committee recommends that weather and climate variables and influences, for example, particulates, be identified, thoroughly examined to assess their degree of impact on our weather and climate, and incorporated into forecasting models as necessary. Priority areas for incorporating these variables should be published.

3.75 CSIRO reiterated the need for improved techniques for assimilating observations of the land, air and oceans into forecasting models.

3.76 The Committee recognises that without accurate baseline information, our forecasting models will struggle to reach the required level of skill.

3.77 The Committee fully supports increasing funding for continuing and extended research into the effects of weather and climate variables such as El Nino and Indian Ocean Dipole.

3.78 The Committee recommends that the Australian Government increase funding for research into the effects of weather and climate variables such as El Nino and Indian Ocean Dipole that impact on Australia's forecasting abilities.

Recommendation 3

The Committee recommends that the Australian Government increase funding for research into the effects of weather and climate variables such as El Nino and Indian Ocean Dipole that impact on Australia's forecasting abilities.

Modelling limitations

Supercomputing

3.79 Many submissions to the inquiry raised the issue of having sufficient computing power to drive weather and climate models.

3.80 When asked how Australia compares with other countries or organisations, in terms of modelling computing power, LWA stated that Australia will get left behind quite quickly if funding is not increased in this area.[75]

3.81 Professor Christian Jakob, a researcher in the development of weather and climate prediction models, explained Australia's position, in terms of computational resources, in the international arena:

> … we have actually fallen behind the rest of the world significantly. I am co-chairing the World Meteorological Organisation's working group on numerical experimentation, and we review the computing at operational numerical weather prediction centres on a regular basis. I can tell you from the last meeting last year that Australia is at the bottom of the list now and will be at the bottom of the list with its plans for the foreseeable future … We are well behind countries like Brazil, Korea, Canada, India and China, so I am not even talking about big economies like the United States, the UK or Germany. We are well behind much smaller economies.[76]

3.82 The Australian Meteorological and Oceanographic Society (AMOS) also discussed the need for more computational resources:

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75 LWA, *transcript of evidence 24 June 2009*, p. 6.

76 Prof Christian Jakob, *transcript of evidence 29 June 2009*, p. 3.

> … limited human and computational resources continue to hamper efforts in using the [ACCESS] system seamlessly and in particular in the long-range predictions that are the subject of this inquiry. A significant increase in resources, both human and computational, is required to stay abreast of the international community and to provide Australia with a prediction system that is state-of-the art, well supported and can meet society's demand for information on future weather and climate.[77]

3.83 AMOS explained the need for supercomputing and the restrictions placed on models due to a lack of computing resources:

> Meteorological computer models … all require very large investments in computing capabilities, and the availability of supercomputers. Access to supercomputing facilities by the Australian scientists developing and running these models is limited relative to those available to overseas scientists in America, Europe, and, increasingly through Asia (eg., China, India, Singapore and South Korea). The relative inferiority of supercomputer resources available to Australian scientists necessarily restricts the quality of the models run here and the quality of the forecasts available from these models.[78]

3.84 AMOS added:

> Although new supercomputers have just been provided to the Bureau of Meteorology and the Australian National University … these new computers will still leave Australia far behind the resources available in comparable countries.[79]

3.85 When asked if Australia is at a disadvantage in terms of super computing technology, compared with the rest of the world, CAWCR stated:

> 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 … 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

77 AMOS, *submission 11*, p. 4.

78 AMOS, *submission 11*, p. 5.

79 AMOS, *submission 11*, pp. 5-6.

> in the supercomputing ranks is being worked through at the moment.[80]

3.86 CAWCR further explained:

> 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.[81]

3.87 Professor Jakob also discussed failing to attract quality researchers due to the poor state of resources available:

> To attract the best scientists you need to give them the equipment that they need to do the best science. Once you have fallen behind in that it becomes harder to attract the scientists over here. They would rather go to a centre where there is the fastest supercomputer in the world and do their work there. So we really have to work on that.[82]

3.88 Professor Jakob explained the need for vastly improved computing facilities:

> It is important to note and it is often forgotten that the computer required needs to be many times bigger than what you need to make the actual forecasts so that the research to improve those forecasts can be carried out in parallel. Often we buy computers that are just about right to make the predictions operationally so that we have forecasts but there is no space to run experiments to improve them, and that is a very big problem in many, many countries. Here, for instance, I have heard recently that the Bureau and CSIRO have sufficient computing resources for weather and climate but it is a struggle to actually do the very large set of experiments that is required to improve the seasonal prediction system, because that is a very, very big computational task.[83]

3.89 CAWCR explained having to sacrifice some aspects of its work due to the limited computing capacity available, and what could be achieved with more resources:

80 CAWCR, *transcript of evidence 12 August 2009*, pp. 1-2.

81 CAWCR, *transcript of evidence 12 August 2009*, pp. 1-2.

82 Prof Christian Jakob, *transcript of evidence 29 June 2009*, p. 6.

83 Prof Christian Jakob, *transcript of evidence 29 June 2009*, p. 3.

> … we have to do a big trade-off … 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.[84]

3.90 Dr Larson stated that the lack of computational resources in Australia is a problem, explaining that Australia has only one machine in the top 500 listing of the world's fastest supercomputers (New Zealand, by comparison has three machines in the Top 500). Dr Larson added that the one machine is owned by a computer animation company, not a government research body.[85]

3.91 Dr Larson suggested that a significant problem exists in the lack of support for the emerging field of computational science, an interdisciplinary area that combines computer science, high performance computing, software engineering, and numerical analysis:

> Computational scientists seek to solve algorithmic problems relevant to computer modelling in many fields of science and engineering … We are not training future generations of people who have the necessary skills to develop superior, performance-portable algorithms in support of the types of short-to-medium range weather forecasting, seasonal-to-interannual prediction, climate, and other environmental modelling the Australian taxpayer expects from our [climate/weather/oceans] forecasting and research bodies … we are diminishing our future national competitiveness in this field.[86]

Committee comment

3.92 The Committee acknowledges and welcomes the Australian Government's recent additional provision of funds for supercomputing facilities. However, the Committee recognises that, in terms of

84 CAWCR, *transcript of evidence 12 August 2009*, p. 4.

85 Dr J Larson, *submission 18*, p. 2.

86 Dr J Larson, *submission 18*, p. 2.

supercomputing resources for weather forecasting, Australia is significantly behind many other countries.

3.93 The Committee also recognises the need for independence and development of systems here in Australia that address our unique weather and climate forecasting needs.

3.94 The Committee agrees that the supercomputing issue needs to be fully investigated.

3.95 The Committee recommends that the Australian Government conduct a short review to determine what supercomputing facilities are required by CSIRO and the Bureau of Meteorology to conduct crucial forecasting operations and research. Any additional funding to increase supercomputing capacity should be made available as a priority so that all model research, development and application can be undertaken in Australia.

Recommendation 4

The Committee recommends that the Australian Government conduct a short review to determine what supercomputing facilities are required by CSIRO and the Bureau of Meteorology to conduct crucial forecasting operations and research. Any additional funding to increase supercomputing capacity should be made available as a priority so that all model research, development and application can be undertaken in Australia.

Weather stations

3.96 A possible limitation on forecast models is the quantity and quality of data coming from the network of weather stations in Australia.

Network and coverage of weather stations

3.97 When asked about the need for more weather stations in particular areas across the country, SAFF stated:

> The Bureau of Meteorology are well aware of that, because that is something that farming organisations across Australia have been calling for over a number of years. Other organisations—like, for instance, our natural resource management boards in South

> Australia—have also been calling for more weather-recording stations, to better provide information to farmers and to community people in rural and regional areas across South Australia. The difficulty for the Bureau of Meteorology, as I understand it, is around resourcing. I do understand that, but that does not stop us from highlighting the need that is out there.[87]

3.98 SAFF suggested that an appropriate number of weather stations would have the potential to take greater account of geographic differences in some areas:

> At the moment the models that they use when they model where rainfall patterns have occurred do not necessarily take into account things like rain shadows—I guess those topographical differences and differences across a regional area. It is just a blanket line that cuts across without taking into consideration where some of those differences could actually be.[88]

3.99 SAFF explained further:

> … it would really take some knowledge and skills within the Bureau of Meteorology to understand where the gaps in information are at the moment and where we actually need additional information … that would help focus attention on where we might need additional data points and even potentially asking organisations like the Farmers Federation, natural resource management boards and some of those other regional based groups that may be able to identify where some of the gaps currently are.[89]

3.100 When asked if any particular regions or areas, such as high-value agricultural production areas, required more weather stations than others, SAFF suggested:

> … we actually do need better information in some of our more marginal areas of the State to better understand what is actually happening there for farmers to be making some really good decisions in those areas so that they are not going to go broke or out of business. We do need them to be there.[90]

87 SAFF, *transcript of evidence 14 July 2009*, p. 15.
88 SAFF, *transcript of evidence 14 July 2009*, p. 17.
89 SAFF, *transcript of evidence 14 July 2009*, p. 18.
90 SAFF, *transcript of evidence 14 July 2009*, p. 18.

3.101 The Western Australian Department of Environment and Conservation (DEC) suggested that there may be particular regional data deficiencies:

> … there are few high-quality daily rainfall datasets for the north-western half of WA. The enhancement and development of these datasets is a major logistical and scientific undertaking … Improving both the spatial coverage of datasets and removing errors in those datasets will allow a more reliable assessment of climate variability, particularly in data-sparse regions, such as the north-west.[91]

3.102 FESA identified the need for a broader range of data collection across the State to support long range forecasting and prediction capability, in particular, by introducing a greater coverage and reporting without the reliance on human presence.[92]

3.103 DAF also commented on weather station coverage:

> Australia has good climate records by global standards, and this has underpinned the availability of information via the Bureau of Meteorology's web site and through computer packages such as Australian RAINMAN. Major degrading issues at present are the poor coverage over much of inland Australia, and the decline in the number of quality observing sites generally. Many computer tools or systems developed to assist with agricultural decision making rely on accurate historical climate data, and so the provision of accurate climate records is vital.[93]

3.104 FESA explained that the weather stations in the northern part of Western Australia are essentially stand alone stations, their coverage does not overlap, and there are significant gaps between one station and the next:

> The northern portion of the state certainly has a deficiency of [weather stations]. To use the Kimberley as an example, there is one in Broome, one in Wyndham, one in Fitzroy Crossing—and just between Fitzroy Crossing and Broome, I think, there is about 400 kilometres. There is one in Halls Creek, which I think is 297 kilometres away from Fitzroy Crossing … [94]

91 DEC, *submission 31*, p. 4.

92 FESA, *submission 29*, p. 9.

93 DAF, *submission 30*, pp. 6-7.

94 FESA, *transcript of evidence 13 July 2009*, p. 18.

3.105 FESA also added that there are similar weather station coverage gaps in the south of the state, however the gaps are not as large as those in the north.[95]

3.106 FESA explained the need for an increased observational network for remote parts of Western Australia:

> As I understand it, about a third of the Kimberley is burnt on an annual basis with unplanned fires. It produces about 48 per cent of the greenhouse gas emissions from the agricultural sector in Western Australia. We spend a lot of time and effort trying to reduce the impact of fires in the Kimberley. Having better forecasting tools and weather stations would improve our fire management in those areas.[96]

3.107 When asked about the gap in the number of weather stations in regional areas, BoM explained:

> … 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 … [97]

Purchasing an automated weather station

3.108 The suggestion that community groups or peak bodies purchase their own weather stations arose during the inquiry.

3.109 BoM discussed the purchase of an automatic weather station:

> The standard [automatic weather station] 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 accuracy then you can purchase lower quality instruments and that would cost less. If you want to get higher

95 FESA, *transcript of evidence 13 July 2009*, p. 18.

96 FESA, *transcript of evidence 13 July 2009*, p. 18.

97 BoM, *transcript of evidence 12 August 2009*, p. 16.

> quality ones, such as those we need for aviation, then they cost about $250,000 … So it does vary but that is the sort of order we are talking about. The average life is about 10 years.[98]

3.110 BoM also discussed maintenance of automatic weather stations:

> [maintenance cost] varies, depending on whether they are in remote localities … It costs in the order of $10,000 or $20,000 per year to maintain.[99]

3.111 When asked about the possibility of having a community purchase their own automatic weather station, BoM explained some of the issues:

> 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.[100]

Inaccuracies

3.112 Mr McLean, bluntly explained his concerns regarding data accuracy:

> Before worrying about the accuracy of the CSIRO's climate models perhaps we need to be more concerned about the accuracy of the temperature data being fed into them.[101]

3.113 Mr McLean added that CSIRO’s climate models are:

98 BoM, *transcript of evidence 12 August 2009,* p. 26.
99 BoM, *transcript of evidence 12 August 2009*, p. 26.
100 BoM, *transcript of evidence 12 August 2009*, p. 26.
101 John McLean, *submission 32.1*, p. 17.

> … manually "tuned" to match historic temperature patterns as closely as possible but if that temperature data is wrong then the whole exercise is rather pointless … [102]

3.114 CPSU also discussed data inaccuracies and their impact on modelling and model verification:

> A model is fantastic and we certainly need research into improving what our models can do, but unless we have observations to input into those models then it is a case of rubbish in, rubbish out. If you do not have good observations to know exactly what is happening now, you cannot expect to have a good understanding of what is going to happen into the future. We also need those observations to be able to, after the fact, ground-truth the models. If the modelling is saying that it is going to be wetter in the next three months then we need to have the observations to be able to say, 'Was it wetter or was it drier?' It is used for verifying the models, as well as initialising the models before they go on.[103]

3.115 BoM discussed its data collection processes, explaining that it has established a good climate record:

> We have many, many stations, as the Bureau has been going for 100 years or so. We have relied on a broad range of different types of stations to collect our data. We have our own stations—about 35 major stations around the country. Clearly that is not enough to get a good characterisation of the climate across the country, but they provide a very strong benchmark for our data. In the past we have relied on cooperative observers—postmasters, police stations, teachers or farmers—to collect the data for us. Some of those records stop and start as we go backward and forward through time. Nevertheless, we have probably trawled through 10,000 or 11,000 different rainfall stations, and we have now come up with a set of rainfall statistics. We have been very carefully looking at them, looking at the history of the site, whether it has shifted and whether or not it has been contaminated by, as you said, a car park, a building or a tree; even a growing tree can contaminate a climatic record. We have been very carefully through a subset of our records to develop a set of, I believe, about 100 of what we would call major climatic stations which we

102 John McLean, *submission 32.1*, p. 17.

103 CPSU, *transcript of evidence 29 June 2009*, p. 55.

> believe fairly represent the broad-scale climate. They do not represent the building of cities, changing farming practices or what we would call non-climatic effects; they truly represent the climate. So we are now quite confident that the stations that we have to document what we call the climate record of Australia are well established, and of course we do everything in our power to maintain that climate record. We believe that is the *sine qua non* of any meteorological service. If you do not have a sound climatic record then it compromises a lot of what you do.[104]

3.116 BoM also explained that it collects data from standard automatic weather stations:

> 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 … The basic [automatic weather stations] across the Bureau at the moment are fairly standard.[105]

Poor placement of stations

3.117 Mr McLean discussed changes that may occur at weather stations that have the potential to impact on accurate recordings:

> The recorded data is a verbatim record of observations but notes are supposed to be made about changes to the local environment that might influence temperature and researchers are advised to draw their own conclusions. I know of three worrying situations in Victoria - Nhill where about 20 years ago the instruments were moved from an old airfield (a training base in World War II) to a site on the edge of town, Cape Nelson, where coastal scrub is now higher than the instrument and shelters it from wind, and Laverton, a former military airfield that was in open country until about 15 years ago and is now being progressively surrounded by housing. I wonder how many Australian observation stations have seen their local environments undergo change, not just in the 3 members of the reference network that I mention here but right across Australia.[106]

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104 BoM, *transcript of evidence 18 May 2009*, p. 8.

105 BoM, *transcript of evidence 12 August 2009*, p. 7.

106 John McLean, *submission 32*, p. 13.

3.118 When asked if there had been particular spikes or changes in the data from those stations, Mr McLean stated:

> In the two instances that I listed, I do not think so. Cape Nelson, down at Portland, would be very difficult, because you would have a slow change over time as the vegetation grew.[107]

3.119 Mr McLean added that some examples might show significant changes in data:

> I have seen examples out of the US where there have been quite sudden jumps, and they can attribute it to some change in the local environment. But a slow change over time is much more difficult to spot.[108]

3.120 In discussing the example of Laverton raised in his submission, Mr McLean stated:

> [Laverton] is becoming a part of the metropolitan area, yes, at a slow change. That one is interesting because it is blocking the south and south-westerly winds, or interfering with those, and they are our core winds here in Melbourne … The Bureau of Met is supposed to log these changes … [109]

3.121 Mr McLean suggested that the BoM reference network of high-quality stations with quite long data was supposed to be monitored carefully, and stated that a log was to be kept of what had changed in the local area that could conceivably have impacted temperatures.[110]

3.122 Mr McLean also suggested that in the USA:

> … something like over 80 per cent of stations are not [sited] in accordance with the defined standards. They have been put in parking lots or near air-conditioning ducts, barbecues and things like this. It has been an absolute shocker. I think they expected maybe 20 per cent, but there would be lucky to be 20 per cent that actually comply with their requirements.[111]

3.123 When asked about weather station placement, BoM explained:

> We have got guidelines for the sighting and placement of our observing networks, depending on the specific type of

107 John McLean, *transcript of evidence 29 June 2009*, p. 46.
108 John McLean, *transcript of evidence 29 June 2009*, pp. 46-47.
109 John McLean, *transcript of evidence 29 June 2009*, p. 47.
110 John McLean, *transcript of evidence 29 June 2009*, p. 47.
111 John McLean, *transcript of evidence 29 June 2009*, p. 48.

> 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.[112]

3.124 When questioned further about data integrity in the US example, BoM stated:

> 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.[113]

Resources and staffing

3.125 CPSU discussed the potential long-term impact of under-funding on BoM's services and the potential impact on Australia's economic performance:

> "A degraded observation network (which is what will happen if the Bureau continues to be under funded) will result in inaccurate measurement of inter-seasonal climate variability, and will have negative feed-on effects to all sectors of the community".[114]

3.126 CPSU commented on the downgrading of data collection as a result of funding constraints:

> One member noted that: "Our observations base has been seriously eroded and that affects the climate record and the amount of data available for weather and climate models to

112 BoM, *transcript of evidence 12 August 2009*, pp. 15-16.

113 BoM, *transcript of evidence 12 August 2009*, p. 16.

114 CPSU, *submission 3.1*, p. 4.

> diagnose weather … Other nations have much denser networks for surface based, upper air and climate data collection".[115]

3.127 CPSU explained that, of Australia's 17 global upper-air network stations:

> … five of them actually face a reduction in the number of qualified bureau staff who are going to be working there under a current observations reconfiguration plan, and that observations reconfiguration plan has been brought about because of staffing pressures.[116]

3.128 CPSU commented further on the need for adequate staffing:

> … the number of observers that we have is just getting lower and lower, so people have to be spread around this network in a more efficient way. If we had more money to support these then, in an ideal world, certainly at these particular stations we would have the highest staffing level required to do the duties to the proper level that we need.[117]

3.129 CPSU further discussed observation station staffing issues at length:

> According to the information I have about the observer reconfiguration, 160 of those technical staff work across the 50 stations that are staffed. About 140 are permanently located at one station or another, and the rest are relief staff. They move around quite a lot, as you can imagine, because people need to take leave and they get sick. Last October, which is when these figures are from—and I think the situation remains the same—most of those stations had between two and five employees. A proposal of the Bureau is that 23 stations each be staffed by a single trained observer. That obviously goes to the points that have been made about the staffing needed to cover those areas, even with our improved equipment.[118]

3.130 CPSU added that its members have particular industrial concerns including redeployment of staff across the country and health and safety issues.[119]

3.131 CPSU also explained that staff have very strong concerns about the integrity of data collection:

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115 CPSU, *submission 3.1*, p. 5.

116 CPSU, *transcript of evidence 29 June 2009*, p. 55.

117 CPSU, *transcript of evidence 29 June 2009*, p. 55.

118 CPSU, *transcript of evidence 29 June 2009*, p. 60.

119 CPSU, *transcript of evidence 29 June 2009*, p. 60.

> It really concerns them that some of the changes being made in this area are going to mean that data is not as good as it could be … that has impacts when you are trying to do your long-term science and check your previous hypotheses … This is a clear example of where those funding pressures are biting.[120]

3.132 BoM discussed the move away from the human observer and towards the automatic weather station:

> In other words, all we need now is a place to put the instrumentation. It is telemetered automatically into the Bureau. We are then able, of course, to get measurements not every three hours but measurements as frequently as we like. We can even go down to one minute; we can be recording the wind, the temperature and the pressure every minute or every six minutes or whatever period we want. The move towards automation is really the way to go. We get much better, consistent and reliable data.[121]

3.133 CPSU also raised the issue of transferring maintenance responsibility to observers.

> … they are attempting a program of multi-skilling the observers so that they can do some of the routine maintenance on the equipment. I have seen that sort of thinking in the CSIRO in the maintenance of high-end scientific equipment where they have tried to cut corners. It can be a false economy. The real value of some of the highly trained people looking at equipment and servicing it regularly is in spotting problems when they are minor. It takes a lot of expertise to do that. They might not have to make serious interventions on a day-to-day basis but if they spend years looking at equipment they have enough skill and understanding to detect problems before they become catastrophes, and that is a great efficiency in the system which is hard to capture … [122]

3.134 A CPSU representative explained further:

> Expensive equipment requires dedicated people with a lot of knowledge to maintain it, keep it running and keep the integrity at the plant level. You cannot find that as an efficiency, particularly if you try to cut corners by saying, 'We'll buy better equipment. It should require less maintenance. We can train our operator to just

120 CPSU, *transcript of evidence 29 June 2009*, p. 60.

121 BoM, *transcript of evidence 18 May 2009*, pp. 9-10.

122 CPSU, *transcript of evidence 29 June 2009*, p. 59.

> change the oil or whatever, and she'll be sweet.' Sad to say, that thinking does operate in organisations. But I have to caution against that and make sure that I put in a word to support technical people on the ground, who probably are not recognised enough in organisations and can sometimes bear the brunt of the costs and have workloads shifted onto them, which ultimately causes a lot of problems for the organisation.[123]

Committee comment

3.135 The Committee notes the importance of data integrity and understands that data integrity is threatened, not only by the loss of weather stations, but by a range of factors affecting the stations, including age and changing conditions.

3.136 The Committee is concerned at the loss of qualified observational staff from the BoM and the effect this is having on manning weather stations. The Committee is also concerned with the move to multi-skilling staff and expecting observational staff to perform maintenance and repairs on sensitive, scientific equipment.

3.137 The Committee notes the importance of weather station placement and understands that stations have not always been optimally placed.

3.138 The Committee recommends that the Australian Government undertake an audit of weather stations that contribute data to forecasting models, to ensure that they comply with World Meteorological Organization guidelines. All necessary actions should be taken to ensure that all stations comply.

Recommendation 5

The Committee recommends that the Australian Government undertake an audit of weather stations that contribute data to forecasting models, to ensure that they comply with World Meteorological Organization guidelines. All necessary actions should be taken to ensure that all stations comply.

123 CPSU, *transcript of evidence 29 June 2009*, pp. 59-60.

3.139 The Committee understands that more weather stations are required to increase accuracy and coverage to support seasonal forecasting and prediction capability. There is a need to identify critical areas where there are data deficiencies and look to add additional stations to address those areas.

3.140 The Committee recommends that the Australian Government budgets for the purchase, installation and maintenance of additional weather stations in critical areas around the country. There should be broad consultation to consider the number of new stations needed and their placement.

Recommendation 6

The Committee recommends that the Australian Government budgets for the purchase, installation and maintenance of additional weather stations in critical areas around the country. There should be broad consultation to consider the number of new stations needed and their placement.

Model outputs and products

3.141 An issue raised by many witnesses to the inquiry was how to transform the data generated by long-term weather forecasting into useful, accessible information for stakeholders. AMOS explained the challenge:

> … how do you get the information that we have across to, on the one hand, the general public, the media and people who have broad interest in whether there is going to be a drought next season or not, and to an individual user who is worried about the farm gate, his or her particular farm and what decisions he or she might be making now. We have really struggled with this. It is a really complex problem and it is easy to get confused. Because of the chaotic nature of the atmosphere … these forecasts are all probabilistic.[124]

3.142 AMOS told the Committee that there is always a danger that consumers will be overwhelmed by the amount of information available and will not be able to use it for important decision-making. One solution is tailoring forecasts for individual needs but this too presents problems:

124 AMOS, *transcript of evidence 29 June 2009*, p. 10.

> This is feasible but it is very person intensive. ... It is very demanding to have people sit down with farmers or groups of farmers and say: 'You're really interested in this decision. This is the sort of information that the science can provide that will be useful,' but we aren't going to put that on a website or publish it in the Australian or a weekly rural magazine because it is too much information for most people and we find that most people overreact to it or underreact to it.[125]

3.143 AMOS added that, rather than improving decision-making, supplying more information via the BoM web site had the potential to lead to rash or unwise decisions.

> The Bureau can quite easily provide more information about those details than you see on their website, but we do not think it is useful in a broad sense. What we would like people to do is not make decisions based on a one-inch headline on the front of the Herald Sun.
>
> We think it is really important to get that message across. For instance, we are concerned at the moment we are slipping into a new El Nino which may increase the chances of drier than normal conditions over much of eastern Australia over the next few months. … It is great to have a one-inch headline in the Herald Sun, but we do not want farmers to go out and sell the whole kit and caboodle and bet their last shirt that there is going to be a drought. It just depends on what sorts of decisions you are making, how much you should value that forecast.[126]

3.144 In their submission to the inquiry, DERM also identified lack of understanding, rather than lack of access or information as a root problem:

> Rather than lack of access to seasonal climate forecasting information, a major limitation to adoption is likely to be the confusion resulting from the range of the number of available forecasts/climate risk assessment systems. A lack of understanding of the underlying science, and the lack of a transparent track record will also limit the adoption of some systems, even if these systems result in improvement to skill and lead-time (e.g. global climate models, QCCCE's SPOTA-1 system).[127]

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125 AMOS, *transcript of evidence 29 June 2009*, p. 10.

126 AMOS, *transcript of evidence 29 June 2009*, pp. 10-11.

127 DERM, *submission 33*, p. 18.

3.145 To combat this problem, AMOS suggested that help be provided to ensure optimal use is made of the complex information being generated by current forecast systems, not just by the agricultural sector but all stakeholders:

> We would like the situation where they can come to an adviser, who understands the science, understands the farmers' decision-making processes and what they have to do, and match the needs of farmers with the abilities of the science much better than we can just by broadcasting a very broad forecast.[128]
>
> …
>
> But the point is, we have talked about the agricultural sector but there are other sectors that do not make optimal use of existing forecast information on all timescales—on seasonal timescales and also on weather timescales. There is a lot that could be done, working with the users to make them use the products in an optimal way. There is no perfect way. It is difficult because of the chaotic nature of the problem, the probabilistic nature of the forecasts. It is much harder to deal with.[129]
>
> …
>
> That is why every user has a different need and so the agricultural sector will not have the same need as someone else. That is why it is such a labour-intensive, human resource intensive problem, because you need to work with all these sectors and it is all very complicated and different. So it is a big problem.[130]

3.146 The Committee heard that the Queensland Government is a world leader in delivering information to end users and matching their requirements.[131] In their submission to the inquiry DERM detailed some of the programs they have developed to assist stakeholders to gain the maximum benefit from long-term weather forecasts:

> Despite several years of drought, Queensland has been able to largely maintain agricultural production which can, in part, be attributable to the application of tools by primary producers to better manage climate risk. Queensland has developed a range of tools such as RAINMAN, WhopperCropper, APSIM, APSFarm,

128 AMOS, *transcript of evidence 29 June 2009*, p. 11.
129 AMOS, *transcript of evidence 29 June 2009*, p. 12.
130 AMOS, *transcript of evidence 29 June 2009*, p. 12.
131 AMOS, *transcript of evidence 29 June 2009*, p. 11.

> Irrigation Optimiser, Nitrogen Calculator, and DROUGHTPLAN that can use the Southern Oscillation Index (SOI) phase system to make forecasts. Other states and territories have similar programs.[132]

3.147 DERM also provided examples of how they have tailored forecasts to meet the needs of stakeholders:

> Seasonal climate risk forecasts in Australia are generally issued on a rolling basis for the next three months (e.g. the SOI Phase system, BoM's sea-surface temperature scheme). This rolling three-month forecast at zero lead-time makes it difficult for agricultural managers, particularly pastoralists in Australia managing large properties, to implement key decisions based on the forecast, when the lag between the predictor and predictand is zero. Several surveys of pastoralists in northern Australia indicated that longer lead-times would be useful. These surveys showed that forecasts for the northern Australian wet season (November-March), issued firstly in June using the April/May SOI phase and reissued each month for the same forecast period counting down from five- to zero-month lead-time, would be most useful for application in management in these regions.[133]

3.148 DERM explained that this process must go beyond simply tailoring forecasts and translate the data into relevant information:

> Not only is there a need to tailor or customise forecasts to meet the needs of decision makers and other stakeholders (e.g. a forecast targeting a particular season at a certain lead-time) it is also important to translate seasonal forecast information into terms that can readily be incorporated into management and decision-making. This may involve systems analysis and the use of models to translate climate information into more relevant information for decision makers (e.g. pasture or crop production rather than rainfall).[134]

3.149 However, even with this type of assistance, witnesses stressed that end users require more education and training to make the best use of outputs and products from long-term weather forecasts. AMOS spoke of an 'education program for users'[135] and DERM told the Committee that the

132 DERM, *submission 33*, p. 18.

133 DERM, *submission 33*, pp. 17-18.

134 DERM, *submission 33*, p. 18.

135 AMOS, *transcript of evidence 29 June 2009*, p. 12.

uptake and availability of their programs 'could potentially be improved by providing training to growers and consultants'.[136]

Committee comment

3.150 The Committee noted the difficulties inherent in translating meteorological forecasting data into useful end user products.

3.151 The Committee was impressed by the model outputs and products developed by DERM. The Committee would welcome greater coordination and dissemination of these products. The Committee would encourage a future institute of meteorology, as proposed in Recommendation 10 of this report, to take a leading role in this process.

3.152 The Committee noted the need for the media to be better educated and informed regarding the interpretation and translation of forecasting data and information and urges restraint regarding sensationalist headlines.

136 DERM, *submission 33*, p. 18.