CliMag

Edition 19 July 2010

Farmers on board to champion climate risk management

Recognising that farmers often look to their peers for the most reliable and relevant information, Managing Climate Variability is taking a fresh approach to communicating its latest research on forecasting, on-farm adaptation and climate management strategies.

Photo: Amanda Hodgson

The program has teamed up with the Grains Research & Development Corporation and Meat & Livestock Australia to select 34 farmers from a broad field of nominees to participate in the Climate Champion program. The farmers selected to date are from Queensland, Western Australia, New South Wales, Victoria, Tasmania and South Australia, and they include grain, meat and livestock, wool, sugar, wine, honey and rice producers.

Australia's already highly variable climate is expected to become even more variable under climate change. The farmers taking part in the Climate Champion program are keen to understand how this increased variability will play out in their respective regions, and how they can adapt to the changes while continuing to run a sustainable and financially viable farming business.

Many of them actively source expert information and are involved in climate research and innovation. Most of them are already trialling new practices and technologies, and they value the opportunity to get early access to research and to discuss their experiences with farmers from other regions.

They will have the opportunity to assess new tools, information and management practices coming out of Managing Climate Variability's research, giving them the potential to influence the research while it is still underway. It is a two-way communication channel, so they will also pass on relevant knowledge about the research to their peers through their own existing networks.

The farmers will also provide feedback about their concerns and needs as farmers and their experiences of adopting new farm management strategies. This information will help Managing Climate Variability steer our research and pass on the feedback from farmers to both national and state government decision-makers.

In upcoming editions of CLIMAG we will profile the farmers taking part in the Climate Champion program and highlight the changes they are making on farm and the trials they are involved in.

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In this issue

MANAGING CLIMATE VARIABILITY R & D PROGRAM

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In this edition, we profile Simon Wallwork, a grain grower from Western Australia.

Simon Wallwork	
Farm:	Julcintra
Region:	Corrigin, Great Southern Region, 200 km east of Perth, Western Australia
Commodity:	Wheat, canola, lupins, barley, cattle
Farming area:	2000 hectares including the home farm and two leases
Rainfall:	340 mm average rainfall per year

Simon Wallwork from Corrigin, Western Australia, is taking part in the Climate Champion program.

Simon Wallwork and his wife Cindy Stevens farm in a Mediterranean climate. They get most of their rainfall in winter and have hot, dry summers. Their average rainfall in Corrigin is about 340 mm and on their lease, 25 km east of Corrigin, it drops to about 300 mm. But that seems to be changing.

'I nominated to be a participant in the Climate Champion program because I have experienced a run of very tough seasons over the last decade', says Simon, 'and I'm concerned that a changing climate presents some major challenges to broadacre farming in my region.

'I've looked at some long-term rainfall figures and plotted trends and, in general, the seasons are getting drier. And we've had some pretty wet summers in recent times. I've also noticed that we're not getting really well defined season breaks. The rainfall can be fairly sporadic and even late at times, so we have to manage that differently.'

These days, Simon doesn't always wait for the seasonal break before he starts seeding.

'In some cases we think we're better off having the crop in the ground, even if it's struggling in the early stages. If you leave it all until that traditional 1-inch rainfall, it might be late May or early June. Then you're really pushing hard to get your crop in good time.

'We're getting very good at growing crops in soils with very little moisture and we are pushing them to their limits when they're young.

'In the past, we have almost killed barley and canola crops by sowing on 5–10 mm and not having any follow-up rain in the next 4–6 weeks. They didn't die, so we're finding out how far we can push that. And then, when it does rain, they just take off.'

Simon also believes that narrowing the sowing window down can increase his frost risk.

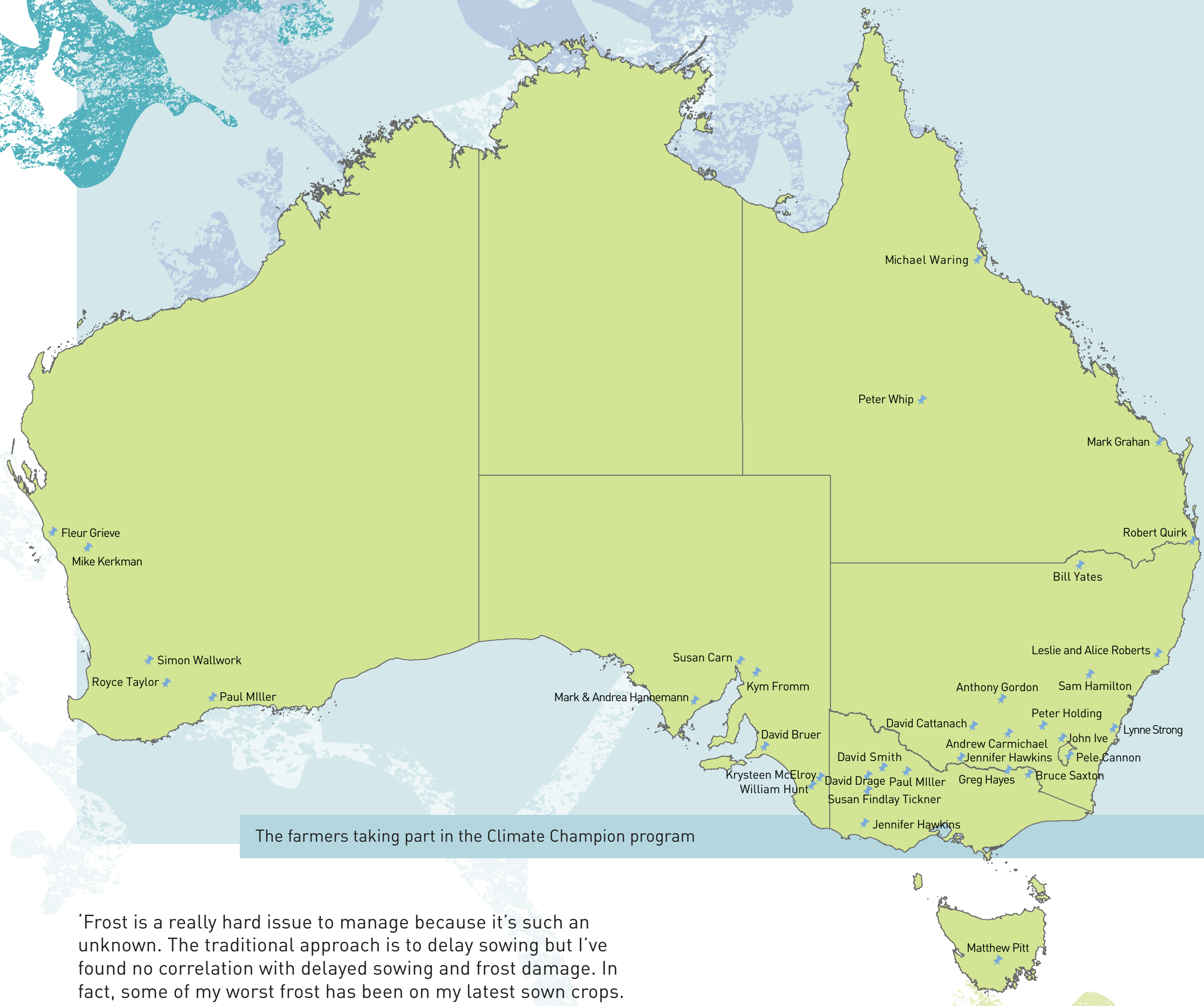
'Frost through this area is a massive cost to a lot of farmers', he says.

'The problem is it happens at the end of the growing season, so you've put a fair bit on the line in terms of inputs. If you lose most of your production in one night, in one frost event, it's just diabolical—financially and emotionally.'

Simon says that, traditionally, locals in the area say that frost has not been a problem.

'I think it depends on the history of your farm. On our property 25 km east of Corrigin, we've had a history of severe frost events in recent times, so I only grow barley out there.

'If the barley gets frosted, you still get a reasonable yield. It might go from 2 tonne to 1 tonne whereas wheat might go under 300 kg, which puts a bit of a floor on your production.



The farmers taking part in the Climate Champion program

'Frost is a really hard issue to manage because it's such an unknown. The traditional approach is to delay sowing but I've found no correlation with delayed sowing and frost damage. In fact, some of my worst frost has been on my latest sown crops.

'We grow a longer-season barley in general so we can sow early and make use of the moisture there and know it's still flowering in a reasonable window.

'Some of the information we've recently got from Managing Climate Variability said that not only is the climate getting drier, the frost window is also opening up, which is a big concern.

'So we need to adapt to that somehow. I'm keen to increase my knowledge on climate change and work out techniques that we need to adopt to allow us to adapt to increasing climate variability.'

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Project updates

The following table lists our current projects.

Project title	Time	Summary of research objectives	Progress to date	Research contact
Improving seasonal forecasts for south-west Western Australia	2008 –11	Increase the accuracy and value of seasonal forecasts for farmers in south-west Western Australia.	Seasonal rainfall forecasts from POAMA (Predictive Ocean Atmosphere Model for Australia) were benchmarked against other forecasting systems available for Western Australia. The seasonal rainfall forecast from POAMA for the central and southwest wheat belt of Western Australia could be used for nitrogen management decisions in wheat cropping and provide substantial increases in profitability. POAMA does not accurately predict rainfall for the northern part of south-west Western Australia so work is underway to improve the performance of POAMA in the northern wheat belt. Frost forecasts from POAMA and ways to manage frost are also being explored.	**Dr Senthold Asseng** CSIRO senthold.asseng@ csiro.au 08 9333 6615
Critical thresholds and climate change impacts / adaptation in horticulture	2009 –11	Understand the critical temperature thresholds for specific horticultural crops and production regions in Australia. Identify commodities and/or regions which will be significantly impacted by increasing temperatures. Assess the impacts and resilience of production systems and/or regions, and identify adaptation strategies to address these impacts.	The research has confirmed that temperature thresholds for nine important crops will probably not be reached with the projected climate change to 2030. Information on temperature thresholds for an additional set of crops is being compiled. Following this an assessment will be made for all crops and regions as to the need for any 'transformational' adaptation strategies to cope with the predicted higher temperatures.	**Peter Deuter** Queensland Primary Industries and Fisheries peter.deuter@ deedi.qld.gov.au 07 5466 2233
Climate change and variability: Assessing regional impacts of sugarcane production	2008 –10	Determine how the sugar industry in the Mackay Whitsunday region can remain sustainable with the number of extreme weather events set to increase. Identify more stringent regulations about discharges onto the Great Barrier Reef.	A series of workshops have been held with cane farmers and sugar industry representatives to discuss the implications of climate variability scenarios. Management practices that will enable cane farmers to cope with climate variability scenarios are being specified and then trialled through an initiative funded by the Coca-Cola Foundation.	**Will Higham** Reef Catchments will.higham@ reefcatchments. com.au 07 4968 4205
Extremes, climate modes and reanalysis-based approaches to climate resilience	2008– 10	Using the latest atmospheric reconstructions of the last century of worldwide weather, find ways to help mange climate risk of extreme weather events in Australian agriculture, including adaptation, insurance, seasonal forecasting and future strategic projections for heatwaves, hail and other exceptional circumstances.	The reanalysis data set has been assembled and tested against available observations. National heat-stress-risk maps have been produced. High and low potential wheat yield appears well linked to several climate indicators, and research will now seek to further understand this relationship.	**Dr Peter Best** University of Southern Queensland cindualpk@ bigpond.com 07 3844 1777
Assessing and managing heat stress in cereals	2009– 12	Investigate the meteorology and climatology of spring heat events on the southern grains wheat belt. Develop a risk management package for growers.	Heat chambers were designed and successfully used to heat wheat plants at flowering and early grain fill in field experiments during Spring 2009. The impact of heat stress on crop production is being analysed. Farmers have been asked to review a spreadsheet-based analysis that identifies previous heat events.	**Dr Peter Hayman** South Australian R&D Institute peter.hayman @sa.gov.au 08 8303 9729

Project title	Time	Summary of research objectives	Progress to date	Research contact
Teleconnections between climate drivers and regional climate, and model representation of these links	2010–13	Improve Australia's dynamical forecasting by investigating the connection between several weather systems, including the Southern Oscillation Index, Indian Ocean Dipole, Madden-Julian Oscillation, subtropical ridge and Southern Annular Mode.	The project has just started. The first milestone is in late 2010.	**Dr Peter McIntosh** Centre for Australian Weather and Climate Research Peter.Mcintosh@csiro.au 03 6232 5390
Improving forecast accuracy through improved ocean initialisation	2010–13	Improve predictions of conditions in the Indian Ocean and ultimately predictions of regional climate for western, southern and eastern Australia.	The project has just started. The first milestone is in late 2010.	**Dr Oscar Alves** Centre for Australian Weather and Climate Research O.Alves@bom.gov.au 03 9669 4835
Improving multi-week predictions	2010–13	Improve POAMA's weather predictions 2–4 weeks ahead to make them more useful to agriculture and water management industries.	The skill of POAMA's predictions on multi-week timescales is being assessed and work is underway to understand the sources of predictability of regional rainfall and temperature. A draft science paper on POAMA's capability on multi-week timescales has been prepared.	**Dr Debbie Hudson** Centre for Australian Weather and Climate Research D.Hudson@bom.gov.au 03 9669 4796
Understanding frost risk in a variable and changing climate	2010–13	Improve understanding of the variability and changing nature of frost risk at both seasonal and decadal scales for the southern regions of Australia, and implications for the wine and grain industries.	The project has just started. The first milestone is in late 2010.	**Dr Steven Crimp** CSIRO Steven.Crimp@csiro.au 02 6242 1649
Climate drivers and synoptic features – New South Wales, Northern Territory and Tasmania	2010–13	Improve understanding of the links between climate drivers and synoptic features. Describe the climate drivers for the remaining states/territories [NSW, NT and Tasmania] and provide examples of key synoptic features from the Bureau's record of key weather events.	The project has just started. The first milestone is in late 2010.	**Clare Mullen** Bureau of Meteorology C.Mullen@bom.gov.au 03 9669 4859
Multi-week forecasting products (WATL)	2010–13	Using multi-week forecasts identified under the 'Improving multi-week predictions' project, make new forecasting products available on the Bureau's Water and The Land (WATL) website. The products will be tested by farmers participating in Managing Climate Variability's Climate Champion program.	The project has just started. The first milestone is in late 2010.	**Dr Andrew Watkins** Bureau of Meteorology A.Watkins@bom.gov.au 03 9669 4360
Understanding frost and heat stress extremes in the Western Australia wheat belt	2010–13	Quantify the extremes and impact of frost and heat stress on the Western Australia wheat belt. Link with the frost and heat-stress projects underway in South Australia and Victoria to improve understanding of frost and heat stress across southern Australia.	The project has just started. The first milestone is in late 2010.	**Dr Ian Foster** Department of Agriculture and Food, Western Australia ifoster@agric.wa.gov.au 08 9368 3333

Continuing to invest

in climate science

for better forecasts

by Colin Creighton

Following a strategic review of Managing Climate Variability's priorities and the direction of climate science, we have decided to continue to allocate at least half our budget to climate science that improves the skill of forecasts and their value to Australian agriculture.

Photo: Amanda Hodgson

WA participant in the Climate Champion program Mike Kerkmans says: 'I'm really keen to give feedback from farmers in my region about any new climate products.'

This decision reflects the fact that one of the main barriers to farmers using climate risk management strategies in their enterprises is that multi-week and seasonal forecasts are not accurate enough.

Our research is aimed at making multi-week and then seasonal forecasts accurate at least 70 per cent of the time. The Bureau of Meteorology's Predictive Ocean Atmosphere Model for Australia (POAMA) already has this level of skill for temperature forecasts with a 4–6 week lead time, and the model is already helping irrigators to predict heatwaves.

But there is much more to be done in improving the model's predictive skill and then creating climate products tailored to farmers' needs. We are investing in improving:

- the skill and reliability of the dynamical model POAMA, rather than relying on statistical climate models (statistical models use historical climate data which has become less indicative of the future due to increasing climate variability and change)
- our understanding of climate drivers, such as tropical monsoonal circulations (Madden-Julian Oscillation) and improving POAMA's predictive skill for tropical Australia
- predictions of short-term climate extremes—such as floods, frost and heatwaves—up to 1–2 months in advance

Our next priority is to invest up to a quarter of our funds in delivering climate products that meet the information needs of farmers and their advisors. Most of these funds will go to our ongoing partnership with the Bureau of Meteorology to continue to improve the Water And The Land (WATL) section of the Bureau's website <www.bom.gov.au/watl/>.

The Bureau will be road-testing updated products and draft new products with farmers taking part in our Climate Champion program, among others, to make sure that they meet the needs of farmers and advisors.

Less than 20 per cent of farmers use decision-support tools that translate climate information into applications. We want to improve this uptake by not only increasing forecast skill but also by developing tools that are more useful to farmers.

About 15 per cent of our budget will go to improving and developing new climate tools that are specific to commodities and that provide on-farm decision support to farmers and their advisors. These products will be accessible via Climate Kelpie, <www.climatekelpie.com.au>.

We recognise the importance of having a network of innovative farmers who use climate information, so up to 15 per cent of our budget will be invested in fostering the adoption of climate risk management on farm through the Climate Champion program and Climate Kelpie.

Both of these initiatives offer farmers the chance to provide us with feedback about our climate research and product development, as well as being a means of sharing the best available knowledge for managing climate variability.

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Climate change
adaptation plan
for primary industries


Photo: Amanda Hodgson

Following a period of consultation, the authors of the draft 'National Climate Change Adaptation Research Plan: Primary Industries', released in February 2010, are now revising their first draft to include feedback.

The revision takes into account more than 100 pages of feedback received from the public, from an open information day, and from a workshop held in Canberra in late February.

The chair of the plan's writing group, Professor Snow Barlow from the University of Melbourne, says they were 'overwhelmed by the amount of constructive support' they received during the consultation process.

The National Climate Change Adaption Research Facility released the draft plan as part of its mission to generate information that will assist primary industries to better manage climate change risk.

Focus for research areas identified

'We want to acknowledge all the good research that's already happening', says Prof. Barlow. 'What we've really concentrated on is when climate change becomes more serious, when you need to either change or completely transform systems to deal with it. This is where we think there needs to be more investment in climate change adaptation'.

Research carried out under the plan will develop tools for determining:

- what response is required beyond current adaptability, and at what point major change is needed
- how to measure and increase the adaptive capacity of primary industries
- what information is needed to support adaptive change

Research areas in the plan have been clarified for agriculture, freshwater aquaculture, forestry, communities and government.

Under the plan, research progress will continually be evaluated, redirected when necessary, and communicated to researchers and stakeholders.

Primary producers and scientists to learn from each other

The plan emphasises the need for primary producers to learn from each other, for scientists to learn from producers, and for producers to learn from scientists.

Prof. Barlow says the plan is a little unusual. 'It can never work as a totally top-down approach. It needs a dynamic combination of bottom-up and top-down approaches to work. For example, producers can help by road-testing potential strategies for industry.'

For more information, visit the National Climate Change Adaption Research Facility:
www.nccarf.edu.au
Phone: 07 5552 9333

Download the plan at Australian Policy Online:
www.apo.org.au/research/national-climate-change-adaptation-research-plan-primary-industries

Frost and heat extremes
under the microscope in Western Australia

In a bid to reduce frost and heat damage to wheat crops, a temperature-risk tool that is location specific is being developed for farmers in Western Australia (WA) through a new Managing Climate Variability project.

After rainfall variability, frost is the second biggest cause of crop loss in the south and south-eastern areas of the WA wheat belt. Crops are at risk of frost damage in spring when the plants are at their most susceptible stages of flowering and grain fill.

While frost is a major issue in the south, high temperatures in the northern and north-eastern areas of the WA wheat belt have also become an issue. Crop losses of up to 50 per cent have been experienced by growers during the spring growing period where high temperature days exceeded 34°C.

Project leader Dr Ian Foster from the Department of Agriculture and Food WA is analysing historical temperature extremes across the WA wheat belt.

Combining this historical data on extreme cold and hot days with climate predictions, he hopes to determine how the frequency and timing of frost and heat episodes are likely to change in the wheat belt in the next 20 years.

Dr Foster says the project will use this temperature data to measure the likely impact of frost and heat on crops, and identify what farm management changes are possible to minimise crop damage.

'Late winter and early spring is always a nervous time for grain growers as their flowering crops become susceptible to frost damage', Dr Foster says. 'This can pose a significant risk to successful cropping in southern grain-growing areas.'

Extreme temperatures at the other end of the scale can also cause problems. 'A wheat crop that is already under water stress and then gets hit with a blistering hot day can record dramatic yield losses', Dr Foster explains.

'Climate models are predicting that we will experience more frequent high temperature days earlier in spring and therefore it is vital that growers know the risk of these days occurring in different areas and at different times of the year.'

Dr Foster is collaborating with two other Managing Climate Variability projects that are also studying frost and heat stress across southern Australia—CSIRO's Steven Crimp is leading a project to better understand frost risk in a variable climate and the South Australian R&D Institute's Peter Hayman is looking at assessing and managing heat stress in cereals.

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Photos: Ben Biddulph, Department of Agriculture and Food, Western Australia

Victorian farmers
have varied opinions on climate change

Most Victorian farmers believe the past decade of drought is part of natural climate variability and nothing to do with human-induced global warming, according to a survey commissioned by the Victoria Department of Primary Industries (DPI).

With just 30% of surveyed farmers accepting that greenhouse gas emissions are causing global warming, farmers are unlikely to adopt strategies to reduce farm greenhouse gas emissions on this basis alone.

The 2009 phone and online survey found that 60% of the 1503 Victorian farmers who responded see the current extended dry period as part of the natural climate cycle and almost 40% expect their region's rainfall to return to average levels soon.

While most farmers were sceptical about human-induced climate change, the majority accept that the weather is changing—88% agree that rainfall and runoff has reduced in the last 10 years, 66% agree that growing seasons are changing and 62% believe that Victoria is experiencing more high pressure systems.

Just over half (56%) of the respondents see global climate change as a serious problem, and exactly half believe that it is affecting their local climate.

As a result of the survey, the Victorian Government's $205 million Future Farming Strategy has launched additional programs to engage farmers, including using workshops and published case studies, to clarify the facts about climate change and greenhouse gas emissions.

DPI Acting Program Manager (Grains) Chris Sounness says there are significant gaps in farmers' knowledge of climate and greenhouse gas issues which need to be addressed by improved communication and engagement with farmers at a local level.

He says part of the problem stems from farmers being expected to accept the science, rather than having explained to them in a logical manner the link between greenhouse gases and the changing energy dynamics of the atmosphere, and how this in turn is contributing to the warming trend they are experiencing.

'Scientists and policymakers need to be clearer in the language they use to improve the way climate and emissions are communicated to farmers and understood by farmers', Chris says.

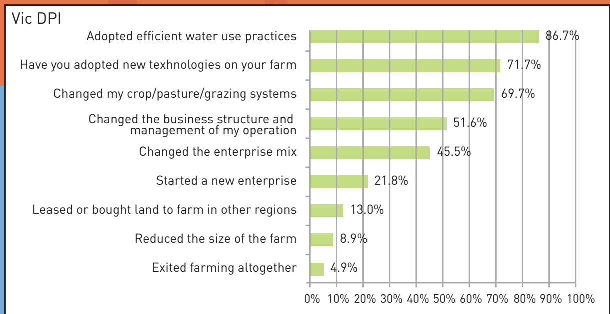
'Climate extension activities are proving to be an effective mechanism in improving climate understanding amongst farmers and this effort needs to be continued and expanded upon.'

Chris says farmers' in-depth understanding of local weather systems and their historical experience can be related to the broader body of climate science and how some of the drivers of climate are now shifting. The climate drivers work done under Managing Climate Variability has been part of the essential information required by farmers [see 'What drives South Australia's weather?' in this edition and 'What drives Victoria's weather?' in edition 17].

'We are working with farmers who have witnessed various weather changes, and we are explaining why some of these changes are happening. We believe that, in time, this will allow farmers to be better informed about the link between the local weather and seasonal rainfall, the key climate drivers and how those drivers are responding in a warmer world, and the implications for farmers if current trends continue.'

While the farmers' views on climate change are split, the survey found that most of the farmers were concerned about future water supply security (76%) and a warmer and drier climate (75%).

The survey also found that farmers' views and knowledge about climate change seem to be related to their sector. Forestry farmers and those whose farms border urban areas are most likely to believe that changes to climate and local weather patterns are a result of human-induced climate change. Mixed farmers are less likely to believe that climate change is serious. Grain and livestock farmers have the highest knowledge of seasonal climate drivers, such as the Southern Annular Mode and the El-Niño Southern Oscillation.



Q9. This next question is about some of the changes you may have made on your farm to manage the impact ofclimate change and variability. Have you...? Base: All respondents, n=1503

Almost all of the farmers surveyed have taken action to manage the impact of climate change or variability.

Adapting to change

Most of the farmers who responded to the survey are seeking ways to adapt to the effects of climate change.

The most common ways farmers are adapting to a changing climate are by adopting practices to increase water-use efficiency (87%); adopting new technologies (72%); and changing crop, pasture and grazing systems (70%).

Other common adaptations were: changing the business structure or management (52%) and changing enterprise mix (46%).

More research is required before any link can be made between a change in practice and the farmers' motivation for making the change, Chris says.

'For example, reduced fertiliser use is likely to be driven by cost issues rather than a desire to reduce greenhouse gas emissions', he says.

'However, it does show there are plenty of other reasons to be managing climate issues and reducing greenhouse gas emissions. Reducing costs and improving efficiency will have a ready audience in the agriculture sector.'

The survey report, entitled '*Understanding farmer knowledge and attitudes to climate change, climate variability and greenhouse gas emissions*', is available at <www.widcorp.com>.

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What drives South Australia's weather?

Continuing our state-by-state series describing what drives Australia's weather, in this edition we look at South Australia.

The major climatic drivers in South Australia are:

- the subtropical ridge
- the Indian Ocean Dipole
- the Southern Annular Mode
- El Niño - Southern Oscillation

These drivers translate into synoptic features, such as blocking highs, cut-off lows, frontal systems and cloud bands, which give South Australia its weather.

Climatic drivers

Subtropical ridge

The subtropical ridge, an extensive area of high pressure, is a major feature of the general circulation of our atmosphere and is a major influence on the climate of southern Australia. Its position varies with the seasons, allowing cold fronts to pass over South Australia in the winter, but pushing them to the south in summer.

Indian Ocean Dipole

Sea surface temperatures in the Indian Ocean have a profound impact on rainfall patterns over much of Australia. The Indian Ocean Dipole is a measure of changes in sea surface temperature patterns in the northern Indian Ocean. It is derived from the difference in sea temperature between the western Indian Ocean, near Africa, and the eastern Indian Ocean near northern Australia. These changes in sea surface temperature contribute to the formation of rain bands.

The Indian Ocean Dipole is positive when waters are warmer than normal near Africa, and cooler than normal to the north-west of Australia. This usually results in less rainfall over South Australia.

The opposite is broadly true. The Indian Ocean Dipole is negative when waters are warmer than normal off north-west Australia. This usually results in increased rainfall over South Australia.

These patterns vary over periods of weeks to months.

The Indian Ocean Dipole effect was proposed as recently as the late 1990s, and is the subject of ongoing research and debate. As modelling of the ocean and atmosphere improves, our ability to forecast these patterns of sea surface temperature is also improving. Better forecasts with longer lead times will become available as we learn more about the Indian Ocean Dipole and how it interacts with other climate drivers. Managing Climate variability is investing in this research with CSIRO and the Bureau of Meteorology.

Southern Annular Mode

The Southern Annular Mode (SAM) can affect rainfall in southern South Australia. The effect is strongest along the coastal fringe of south-eastern parts of the state.

The SAM describes a north-south movement in the belt of strong, westerly winds across the south of the continent which varies chaotically over periods of weeks or months. This region of strong, westerly winds is associated with cold fronts and storm activity.

The SAM can be in a positive or negative phase. During a positive phase, the belt of strong, westerly winds contracts towards the South Pole. This causes weaker-than-normal westerly winds and higher pressure over southern Australia. Winter rainfall may be reduced. During a negative phase, the belt of winds contracts away from the South Pole. This causes stronger-than-normal westerly winds and lower pressure over southern Australia. Winter rainfall may be increased.

We can identify the phase SAM is in by observing the pattern of westerly wind flow and pressure to the south of Australia. The US National Weather Service records this as the Antarctic Oscillation Index.

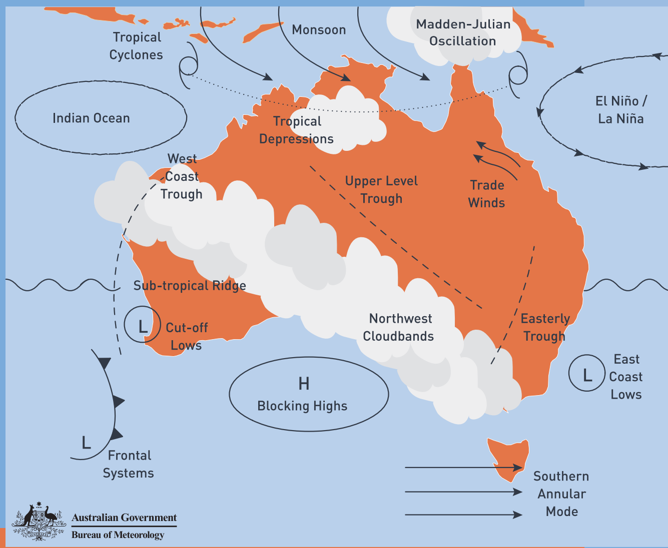

Figure 1. Australia's major climate and weather drivers (Bureau of Meteorology)

El Niño - Southern Oscillation

The El Niño - Southern Oscillation (ENSO) is the oscillation between El Niño and La Niña conditions, interspersed with neutral periods, which describe the variations in sea surface temperatures in the central and eastern tropical Pacific Ocean.

ENSO is a major influence on Australia's climate, though its effect is less marked over much of South Australia than for areas further east.

El Niño is associated with extensive warming of the sea surface in the central and eastern tropical Pacific, and, usually, cooling around northern Australia. These changes are normally associated with lower-than-average winter/spring rainfall over much of eastern Australia. Air temperatures are normally warmer during El Niño events.

La Niña is associated with extensive cooling of the sea surface in the central and eastern tropical Pacific. We usually see a warming of the waters to the north of Australia and higher than average winter/spring rainfall over much of eastern Australia. Temperatures are normally cooler in La Niña events, though there are some indications that when hot spells do occur they can last longer in South Australia.

Table 1. Summary of South Australia's main climatic drivers of weather and synoptic features

Climatic driver	Potential effect	When	Where in South Australia it has most effect
Subtropical ridge	cold fronts	autumn/winter, mostly	statewide
Indian Ocean Dipole (positive)	less rain	May – December, but strongest in September/October	statewide
Indian Ocean Dipole (negative)	more rain	May – December but strongest in September/October	statewide
Southern Annular Mode (positive phase)	less rain	all year	coastal fringe of south-eastern South Australia
El Niño - Southern Oscillation	El Niño - less rain La Niña - more rain	May – November	eastern South Australia, Kangaroo Island and the south-west coast most of the state north of Whyalla
Synoptic feature			
Blocking highs	generally hot and dry if the high is in the Tasman Sea increased chance of cut-off lows if the high is to the south or southeast of the Bight fog and frost	October – April April – October	statewide
Cut-off lows	rainfall with strong, gusty winds	March – October	statewide
Frontal systems	heavier rainfall	March – October	statewide
Cloud bands	rainfall	April – September	statewide

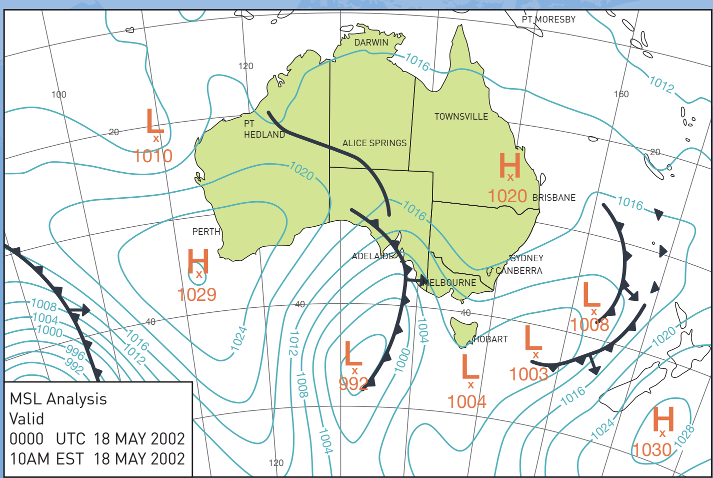

Figure 2. A cold front moving across South Australia on 18 May 2002 caused severe wind squalls and heavy rain. Tornadoes were reported in Adelaide. (Bureau of Meteorology)

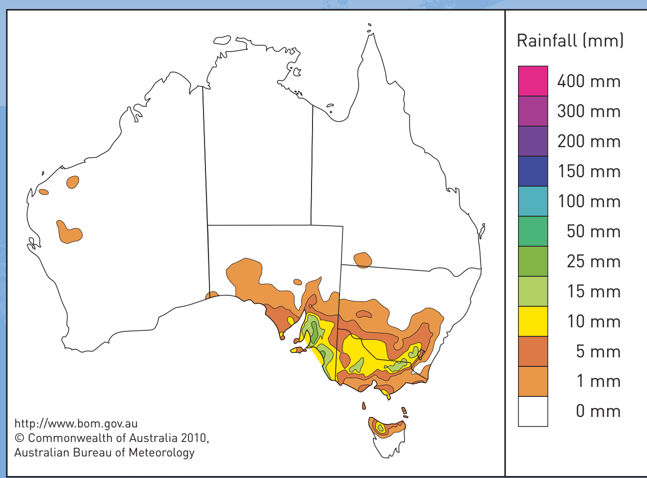

Figure 3. Rainfall in South Australia, 18 May 2002 (Bureau of aMeteorology)

Every El Niño and La Niña event is different. The start and finish times can vary, as can the exact patterns of sea surface temperatures around Australia. This results in varying rainfall for South Australia, especially when combined with the influence of other weather and climate drivers. One outcome of human-induced climate change will be more frequent El-Niño-like conditions as the trade winds along the equator, which influence ENSO events, weaken.

In 2002, we saw a strong El Niño influence on rainfall across Australia, resulting in record low rainfall across much of South Australia's pastoral areas. This may have been moderated to some extent in the state's agricultural area by a strongly negative Southern Annular Mode, the likely cause of the high rainfall in western Tasmania.

Synoptic features

Blocking highs

Blocking highs are strong high-pressure systems that form well south of the subtropical ridge, and remain near-stationary for an extended period of time. They block the west-to-east progression of weather systems across southern Australia, and are usually formed in the Great Australian Bight or the Tasman Sea.

A blocking high's impact on the weather varies depending on its location, the time of year and the systems around it. A blocking high can produce hot and dry conditions for South Australia, such as the heatwaves of March 2008 and January/February 2009.

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Blocking highs are closely linked with the development of cut-off lows which bring significant rain to South Australia on occasions. They can also contribute to fog and frost occurrence, due to the lighter winds around the high-pressure system.

Cut-off lows

Cut-off lows are low-pressure systems that break away from the main belt of low pressure that lies across the Southern Ocean. They are associated with sustained rainfall and can produce strong, gusty winds and high seas. Each event may last several days and the heavy rainfall can make or break a cropping season.

Storm surges along South Australia's coastline are typically associated with prolonged strong west-to-southwest winds associated with cut-off lows, as occurred in late October 2007.

Recent research for the Murray-Mallee region and western Victoria indicates that cut-off lows produce, on average, 50 per cent of growing-season rainfall. However, since the early 1990s the influence of cut-off lows has declined. These findings also apply to other parts of South Australia.

Frontal systems

Frontal systems, such as cold fronts, generally move from west to east across the Southern Ocean and vary in their intensity and speed.

More intense systems are generally associated with heavier rainfall. If frontal systems are slower moving, rainfall may occur for extended periods and may be heavy at times.

The intensity and track of cold fronts is affected by broader scale influences. A period with a stronger subtropical ridge or positive Southern Annular Mode can cause frontal systems to track further south and have less effect on South Australia. Importantly, as the tropics expand under climate change, the subtropical ridge is expected to strengthen, and is already starting to do so. Also, there has been a trend towards the positive phase of the Southern Annular Mode in recent decades which has been attributed to human activity through increased greenhouse gas levels and stratospheric ozone depletion.

On 18 May 2002, a vigorous cold front (Figure 2) moved across southern South Australia. It caused severe wind squalls and heavy rain (Figure 3). Tornadoes were reported in Adelaide.

Cloud bands

A cloud band is an extensive layer of cloud that can stretch across Australia, often from north-west to south-east. Cloud bands are mostly upper-level cloud that does not produce rain, but they can be associated with good rainfall under the right conditions.

The conditions for rainfall can form when either:

- a trough of low pressure occurs in the upper atmosphere or
- warm, moist tropical air originating over the Indian Ocean moves towards the pole (generally south-eastward), and is forced to rise over colder air in southern Australia

For more information, visit the Bureau of Meteorology: www.bom.gov.au/watl/about-weather-and-climate/australian-climate-influences.html

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