SRDC Research Project
Final Report

Title of the Project: Defeating the Autumn Predictability Barrier

Project Reference Number: JCU027

Name(s) of the Research Organisation(s): James Cook University

Principal Investigator:

Dr Yvette Everingham
School of Engineering and Physical Sciences
James Cook University
Discovery Drive
Townsville QLD 4811
ph: 4781 4475
email: yvette.everingham@jcu.edu.au

Australian Government
Sugar Research and Development Corporation

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Executive Summary

The Issue

The success of an Australian sugarcane cropping season depends on rainfall and the ability to forecast it. The benefits associated with long range rainfall forecasts to reduce the risk and uncertainty associated with decisions impacted by rainfall variability has become increasingly recognized by industry. There are several crucial decisions that must be finalised by March and are severely effected by climate conditions during September to November. These types of decisions had to be made without the aid of climate forecasting technologies owing to the autumn predictability barrier, or, more formally, the *austral autumn persistence barrier*. Around March, April and May traditional rainfall indicators like the southern oscillation index (SOI) and the Niño 3.4 index are unable to reliably forecast across the autumn time zone. To help industry improve preparation for the season ahead, a forecasting system that could provide reliable forecasts about end of season rainfall, early in the year, was needed.

Industry makes many decisions at the beginning of the year (e.g. January to March) that are heavily affected by harvest rainfall. Decisions such as when to start the harvest season have an enormous impact on industry profitability (refer Figure 1). Prior to JCU027, industry had no access to climate forecasting technologies that would assist with these types of decisions owing to the austral persistence barrier. Project JCU027 has overcome this severe limitation and described and tested an approach that allows industry to consult climate forecasts when considering harvest and mill start dates, and planning harvesting scheduling strategies.

Figure 1: Bogged machinery during the 1998 harvest season that devastated the Australian sugar industry due to excessive rainfall during the later half of the harvest season. Industry was unable to harvest all of the sugarcane, and in attempting to do so severely damaged the ground and impeded crop growth for future ratoons. The technique outlined in Everingham *et al*. (2008) would have provided an early warning about the threat of harvest rainfall if it had been operational during 1998. Starting the harvest season earlier, harvesting lower lying paddocks earlier and with greater urgency could have saved industry many millions of dollars.

R&D Methodology

Across the globe there have been widespread and dedicated efforts to develop models that produce long term seasonal climate predictions (e.g. Goddard et al., 2001; McGuffie *et al*., 2001; Mason and Mimmack, 2002). These models vary in complexity, accuracy and the degree to which they are affected by the autumn barrier. As part of JCU027 we pursued the simple and elegant statistical model developed by Clark and Van Gorder (2003) which had claimed success at predicting the important Niño 3.4 rainfall indicator. Moreover, these predictions were made at lead times that spanned autumn and could assist industry leaders enhance longer term planning activities that were impacted by rainfall later in the harvest season. Thus, filling a void that had plagued the Australian sugar industry for so long. Taking a participatory action research approach, case study groups from Tully, Ingham and New South Wales worked with researchers to ensure the model outputs were targeted to the needs of industry and provided model validation from an industry perspective. The project team heeded the advice of industry and performed additional rigorous scientific validation of the Clark and Van Gorder prediction model by using rainfall data from Bureau of Meteorology sites that spanned the east Australian sugar coastline. For the first time ever, the Australian sugar industry has a scientific tool to guide decisions made early in the year that are impacted by harvest rainfall.

Project Deliverables

This project has delivered social benefits by building capacity in local climate co-ordinators who can translate the outputs from the new long lead climate forecast model into terms of reference relevant to industry. This task has been facilitated by the development of a software package called RAIN FORECASTER which allows the local climate co-ordinator to assess how the forecast will impact a region. The long range seasonal climate forecast also offers industry the benefits of improved practices with a greater lead time for planning farming, harvesting and milling activities. Specific practices extend to deciding the harvest start date; planning when to plant and how to plant; deciding which blocks to harvest and when these should be harvested; planning fertilizer practices and trash applications.

Impact

This project has raised awareness to the Australian sugar industry and wider national and international scientific audiences, that it is possible to forecast across the Autumn period. This capability represents a significant breakthrough for industry planning. Whilst detailed economic assessments of the value of this forecasting system remains a topic for future research, industry distinctly perceives a benefit with this new approach and has identified many decisions that the forecasting system can aid. One only has to reflect on the disastrous wet finish to the 1998 harvest season that reduced profitability by hundreds of millions of dollars to understand that the benefits from the JCU027 research outputs are potentially worth many millions of dollars. Surveyed clients displayed enthusiastic comments about the long lead forecasting model and have already grasped ways in which this technology can help with improved planning practices across the industry value chain.

Background

Unexpected wet harvest seasons like 1998 can have devastating consequences for the Australian sugar industry. Wet conditions in the 1998 harvest season reduced industry income by approximately 175 million AUD (Australian Canegrower, 1999). These costs could be attributed to a range of factors such as cane being left unharvested, damage to paddocks from wet weather harvesting and reduced commercial cane sugar (CCS) levels. Revenue was also lost in years that followed due to damaged ratoons. It is undeniable that an early indication of wetter than average harvest conditions during 1998, or in other wetter years, both past and present could save the industry many millions of dollars. Enhanced long lead forecasting capability therefore offers industry the opportunity to reduce losses caused by disruption due to wet weather and improve industry planning activities to maintain competitiveness on the global market.

Operational climate forecasts for Australia have been available for more than a decade. These forecasting systems rely largely on the southern oscillation index (SOI) (Stone and Auliciems, 1992, Stone *et al.* 1996) and sea surface temperatures (Drosdowsky and Chambers, 1998) to indicate the likelihood of rainfall several months into the future. For example, a higher chance of rainfall in sugarcane growing regions along the eastern coast of Australia is expected following lower (cooler) than average sea surface temperatures in the central equatorial Pacific (La Niña - Figure 2a). Cooler than average sea surface temperatures in the central equatorial Pacific often coincide with sustained, positive SOI values. Conversely, a reduced chance of rainfall is expected when sea surface temperatures in the central equatorial Pacific are higher (warmer) than average (El Niño - Figure 2b). A warmer than average equatorial Pacific is typically associated with sustained deeply negative SOI values.

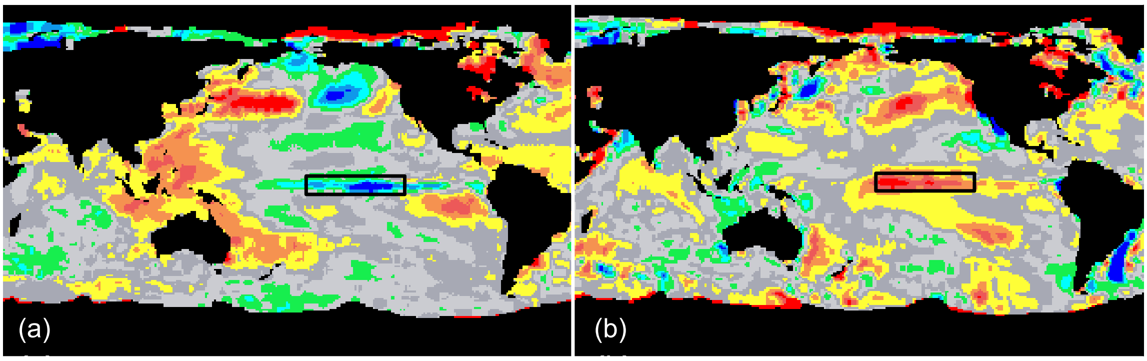


Figure 2: Departures from average sea surface temperatures for (a) September 1998 and (b) September 2002. The black box represents the Niño 3.4 region. September 1998 represents a La Niña pattern since sea surface temperatures were lower (cooler) than average. September 2002 represents an El Niño pattern since sea surface temperatures were higher (warmer) than average.

The impact on the world's climate from the interaction between equatorial sea surface temperatures in the Pacific and the SOI is commonly referred to as the effect due to ENSO (El Niño-Southern Oscillation). ENSO is a major contributor to climate variability experienced all around the world (Trenberth and Caron, 2000) and especially along the eastern coast of Australia (Pittock 1975, Ropelewski and Halpert, 1987; McBride and Nicholls, 1983; Stone and Auliciems, 1992) where sugarcane is grown. Of particular interest are sea surface temperatures in the Niño 3.4 region (refer Figure 2) of the Pacific Ocean (5^{o}S-5^{o}N, 170^{o}W-120^{o}W). Sea surface temperatures in the Niño 3.4 region are closely monitored by climate organisations all around the world because of the strong influence they exert on the world's climate. Small temperature deviations (e.g. from ±0.5^{o}C) in the Niño 3.4 region can significantly alter a region's climate pattern. The temperature deviation or anomaly is measured by the Niño 3.4 index. Figure 3 shows the rolling three monthly averaged Niño 3.4 index from January 1998 to December 2002. Of particular interest is how this index changed during 1998 from an El Niño state to a La Niña state. Accurate and timely predictions of the Niño 3.4 index would be very helpful to sugar industry planners.

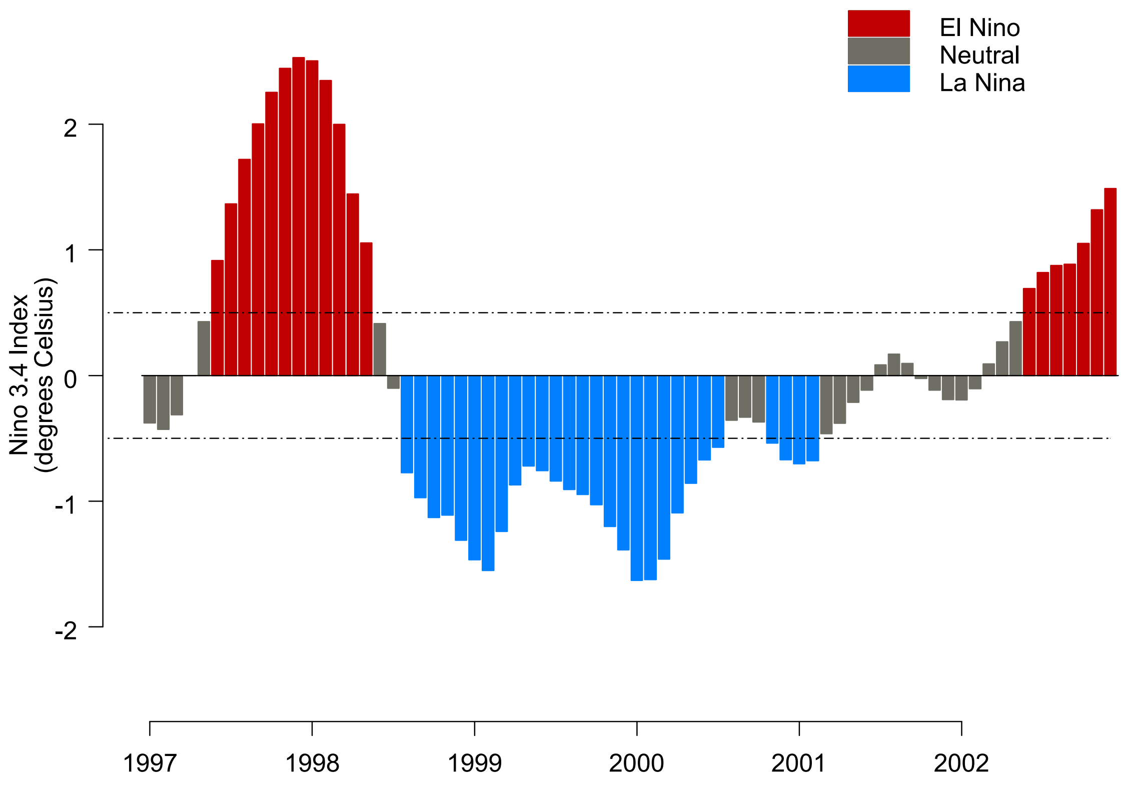


Figure 3: Niño 3.4 index from January 1998 to December 2002.

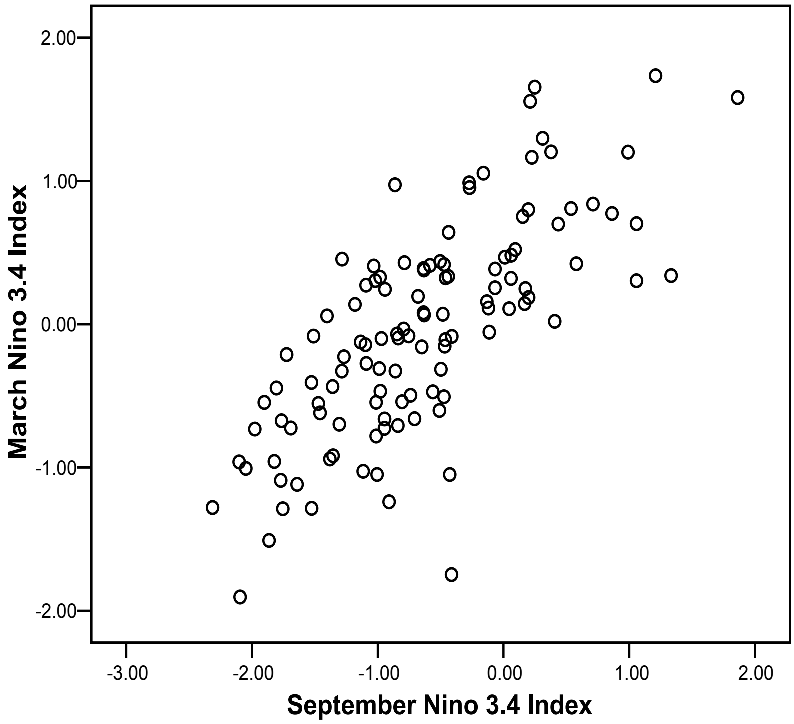
During some periods of the year, there are strong month to month correlations (persistence) in sea surface temperatures in the Niño 3.4 region. These correlations can weaken during other periods. For example, Fig. 4a shows a strong correlation (r = 0.74) between the September Niño 3.4 index and the Niño 3.4 index in March of the following year. However, this persistence in correlation patterns breaks down over Autumn (March-May). Figure 3b compares the March Niño 3.4 index with the September Niño 3.4 index from the same year. The correlation between the March and September Niño 3.4 index in the same year is extremely weak (r = 0.26). This breakdown in persistence is known as the austral autumn persistence barrier. This implies that when climate forecasts are provided by technologies that rely largely on ENSO type signals, industry must wait until the end of autumn or early winter for skilful climate forecasts. There are many important decisions however that Australian sugar industry representatives must make early in the year that are impacted by rainfall much later in the year. To guide these decisions, it would be advantageous for the Australian sugar industry to have some indication about the value the Niño 3.4 index will take during the next harvest, and, to know this by March.

There exist many models that predict the Niño 3.4 index (Goddard *et al.*, 2001; McGuffie and Henderson-Sellers, 2001; Mason and Mimmack, 2002). Some of these models are highly intensive requiring supercomputers to solve many complex equations, while statistical models are computationally simpler. It is not unusual however, for both the numerical and statistical models to be plagued by the autumn predictability barrier. One model which reported skill at predicting the Niño 3.4 index across the Autumn period was described by Clarke and Van Gorder (2003). There were three clear and pressing research needs that would enable us to learn more about this model:

1. Firstly, the findings described by Clarke and Van Gorder (2003) required confirmation.
2. A limitation of the Clarke and Van Gorder model is that it only predicts the Niño 3.4 index. We needed to understand and assess how well the predicted Niño 3.4 index related to rainfall in sugarcane growing regions in Australia.
3. Finally, we needed to gauge if this relationship was strong enough to influence industry planning.

The objectives of the project evolved from these core research needs.

(a)



(b)

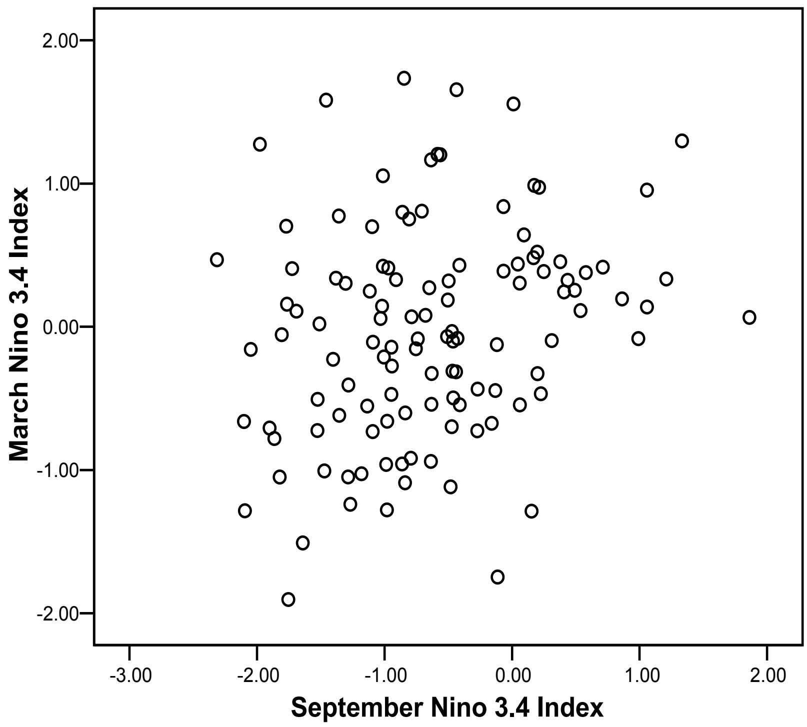


Figure 4: Scatter plots displaying (a) the close relationship between September values of the Niño 3.4 index with the Niño 3.4 index in the following March and (b) the weaker relationship when March and September Niño 3.4 indices are from the same year.

Objectives

Objectives as Stated in the Original Proposal

The objectives were devised as a two stage approach as there was a stop/go decision to be made upon completion of the first year. This stop/go decision was needed in case industry declared that the outputs from the Clark and Van Gorder model were not accurate enough to be useful. The objectives as stated in the original proposal have been listed in Table 1. The project team is pleased to report that all objectives were achieved. The next section of the final report provides a statement of the extent to which the project objectives were achieved.

Table 1: Objectives as written in the original proposal.

Stage	Objective No.	Objective
1	1A	Guided by industry case study groups in QLD and NSW, develop a methodology that can make outputs from a long lead climate forecasting model relevant and useful to industry.
1	1B	Test the skillfulness of the long lead climate forecasting model for a range of a sugarcane growing regions in Queensland and NSW.
1	1C	Assess industry demand for a climate forecasting model that can predict the chance of rain during the second half of the harvest season, early in the year e.g. February.
1	1D	Identify if the project should stop or continue to stage 2.
2	2A	Invite additional key end user collaborators to form part of the project.
2	2B	As part of the participatory research approach, further develop collaborators understanding of the long lead climate forecasting model so they will be able to use the model to minimise risk associated with end of harvest climate conditions.
2	2C	Perform necessary model refinements to meet the needs of potential new collaborators.
2	2D	Develop ways that climate forecasts can continue to be delivered to industry after the project finishes.

Statement of the Extent to Which the Project Objective has been Achieved

1A. The project team consulted closely with case study groups in Tully, Ingham and New South Wales to ensure the outputs from the long lead climate forecasting model would be relevant and useful to industry. The case study groups provided valuable advice such as the response that needed to be forecasted and the lead-time needed for this prediction. Several responses were considered that included rainfall in September to November, October-November rainfall and September-December rainfall. Wetdays were also considered an option, and forecasting wet events early in the harvest season was also considered.

1B. The skilfulness of the long lead climate forecasting model for a range of sugarcane growing regions in Queensland and New South Wales was tested. It was found that the model was able to produced statistically valid forecasts early in the year for rainfall during the later half of the harvest season, but further investigations identified the model was challenged with forecasting rainfall during the early part of the harvest. This can most likely be attributed to the low amount of rainfall variability that is experienced during winter in sugarcane growing regions compared with the more variable spring to summer period. Whilst the model was found to be statistically valid, further consultation with industry was needed to assess if the model passed stringent 'industry validation' protocols. Industry was most impressed that the model worked in years like 1998, 1999 and 2000 all of which had wet finish to the harvest.

1C. Documentation captured through industry consultations provided evidence the industry consultative groups were highly supportive of a model that could that could predict (albeit probabilistically) the chance of rain during the second half of the harvest season, early in the year.

1D. Industry was supportive of the project continuing and the SRDC agreed to fund stage 2 of the project.

2A. Through invitation at ASSCT and via the SRDC eNews facility, additional end user participation was encouraged. The project continued to focus however in Tully Ingham and New South Wales.

2B. The participatory research approach continued throughout the remainder of the project. During this time the project team attempted to build and develop collaborators understanding and ability to correctly interpret the outputs from the long lead climate forecasting model in order to minimise risk associated with end of harvest rainfall conditions. Post-project surveys revealed the consultative groups were able to translate forecasts into meaningful on the ground actions.

2C. From time-to-time new users within the existing regions attended consultative group meetings. The new project participants were comfortable with the continual ongoing improvements that were being made to the model as part of the participatory research approach.

2D. The project team has worked with the consultative groups, primarily the local climate co-coordinators in each region to develop ways that the long lead climate forecasts can continue to be provided post-project. This mechanism comes largely by RAIN FORECASTER together with Allan Clarke's website at Florida State University. The post project survey also revealed that the respondents were confident in knowing how and where to access this information after project completion.

Methodology

Project Process

The project process was guided by the theoretical framework explained largely Jakku et al (2007). This research was developed as part of the SRDC CSE009 project titled - "Moving from case studies to whole of industry: Implementing methods for wider industry adoption". The theoretical framework presented in Figure 5 draws and extends upon concepts from the sociology of science to incorporate four potential outcomes of the participatory development of the decision support system (DSS). In this project, the DSS was the long lead forecasting model. There are three main concepts addressed in Figure 5 – (i) interpretative flexibility, (ii) technological frames and (iii) boundary objects.

Researchers need to be aware that a technology including climate forecasting technologies can mean different things to different people. This idea is referred to as interpretative flexibility. For example millers may see the forecasts as a way of helping to plan labour and mill maintenance schedules, whilst a farmer may see the forecast as way of helping to plan irrigation or harvest scheduling. Different farmers in different regions may also use the object in different ways.

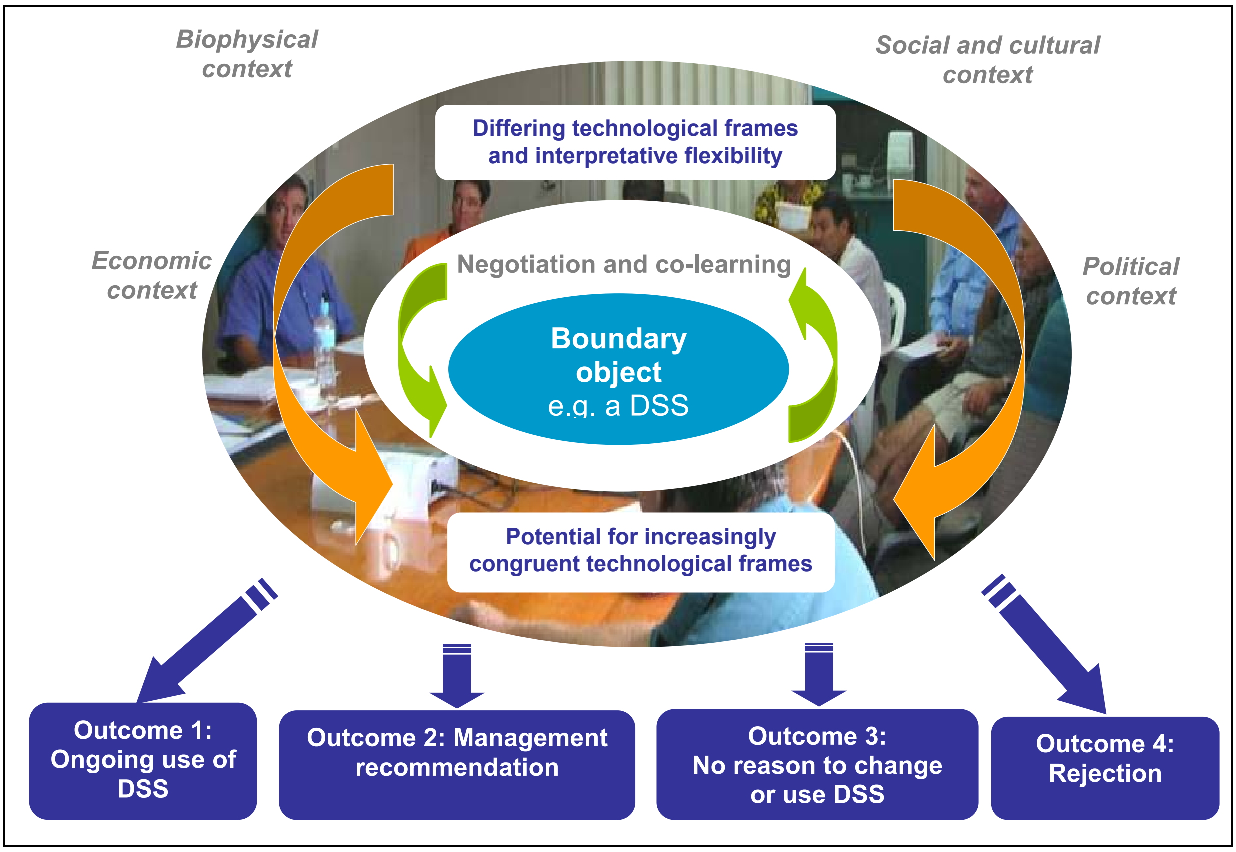


Figure 5: Theoretical framework that guided the participatory development processes associated with the long lead forecasting model developed in this project. (Figure taken from the final report CSE009).

There is also the idea of technological frames which refers to the different perspectives, beliefs and expectations that people hold about a technology. In the case of the long lead and across Autumn rainfall prediction model, some participants could be quite sceptical of a forecasting system whilst others may believe it could be a useful tool based on scientific principles. Technological frames of stakeholders can be incongruent or congruent. Congruent technological frames occur when there is alignment of stakeholder perspectives and beliefs. As part of the project process, surveyed data revealed that at the beginning of the project, the stakeholder technological frames were congruent. Unfortunately, the stakeholder technological frames were congruent because the majority believed that it would not be possible to forecast accurately across Autumn (refer to Question 1, evaluation survey, Appendix 1). The third concept as depicted in Figure 1 is the boundary object, which in our case was a software program referred to as RAIN FORECASTER. This program provided the rainfall forecasts. The boundary object is known to facilitate the negotiation process and co-learning opportunities between the participants and the researcher.

Figure 5 suggests that 'congruent' technological frames can be realised through interaction with the boundary object. The situation in JCU027 was slightly different to that suggested in Figure 5. Initially, industry participants had congruent technological frames, with largely a negative belief about the potential of the long lead prediction model to assist with decisions that require across Autumn seasonal climate forecasts. In our situation, the boundary object facilitated a 180 degree reversal of the perception of the technology to one which was largely shared optimism. Based on surveyed data we believe that most participants comprising of case study groups will not require ongoing interactions with the DSS (RAIN FOECASTER), but rather a series of recommendations that have been developed based on the type of forecast (refer to outcome 2, Figure 5). The model can forecast three types of conditions: (i) La Niña, (ii) El Niño or (iii) neutral conditions to emerge in the Pacific Ocean post Autumn. The evaluation shows how farmers have developed different rules depending on the forecast.

The project process which had strong stakeholder participation lead to the development of new toolboxes in RAIN FORECASTER and provided the motivation for formal scientific publications (e.g. Everingham *et al.* 2007, 2008, 2009). Although all papers relied heavily on industry engagement, Everingham *et al*. (2007) was co-authored by the industry climate co-ordinator in NSW (Peter McGuire) who also presented climate articles as part of grower newsletters. Stakeholders were engaged by face to face meetings. In the Herbert a workshop was conducted as per the recommendation of the consultative group. Table 2 details the dates of industry meetings and workshops. There were three case study regions – Tully, Ingham and NSW. For all three case study regions, stakeholders were representative of the farming, harvesting and milling sectors. In Ingham and NSW, extension officers also attended the case study meetings.

Table 2: Dates of key stakeholder participation events.

Type of Meeting	Location	Date	Number of Attendees
Consultative	Tully	10.05.06	7
Consultative	Tully	16.05.07	8
Consultative	Tully	14.03.08	5
Consultative	Tully	19.03.09	6
Consultative	Ingham	26.09.06	7
Consultative	Ingham	20.03.07	4
Consultative	Ingham	26.02.08	9
Workshop	Ingham	10.10.08	7
Consultative	Ingham	05.03.09	9
Consultative	NSW	27.04.06	11
Consultative	NSW	04.07.06	12
Consultative	NSW	14.03.07	11
Consultative	NSW	18.03.08	13
Consultative	NSW	27.02.09	14

Evaluation

The project incorporated two key evaluation methods. One was via a pre-post project survey, and the other was by documenting minutes at meetings to capture the learning experiences and capacity building of the consultative members. The survey and minutes provided both a quantitative and qualitative way to assess project impact, key learning experiences and capacity building as well as identifying opportunities for future R & D. Project publications were evaluated by the usual scientific peer review process and by oral scientific defence at industry conferences. Full details of the evaluation survey have been presented in Appendix 1 and the full scientific publications which detail the scientific methodologies adopted are contained in Appendix 2.

Outputs

Several outputs were produced throughout the project in the form of knowledge, skills, processes, practices, products and technologies. These outputs are documented in point form below.

- Additional toolboxes in RAIN FORECASTER that incorporate the long lead climate prediction model.
- ASSCT publication that overviews RAIN FORECASTER capabilities and provided details of where information such as updated climate indices can be obtained.
- ASSCT publication that shows preliminary investigations of the FSU model for the NSW sugar region.
- Publication in the International Journal of Climatology that describes the scientific methodology and validation approaches for the long lead forecasting model across all major Australian sugarcane growing communities
- Publication in preparation for submission to the Journal of Applied Meteorology and Climatology that describes a methodology for more accurately estimating the true probability of receiving rainfall in various sugarcane growing regions.
- Increased capacity in consultative members ability to interpret and apply across-autumn seasonal climate forecasts.
- Improved ability to anticipate and better plan for swings between wet and dry years and vice versa.
- Ability to factor in risk of end of season rainfall early in the year.
- Forecasted rainfall probability distributions.
- Enhanced decision making at the farm, harvest and milling sectors of the industry value chain. E.g. improved planning for season start dates, planting windows, planting styles (e.g. cave versus mound), targeting blocks for harvest, fertilizer practices, applying trash and mill maintenance scheduling.
- Preliminary economic investigations on the value of the long lead prediction model.
- Seasonal climate outlooks provided by industry.
- Media releases, newspaper articles and television and radio interviews.
- Pre-post project surveys.
- Skill assessment of long lead climate forecasting capability in different regions.
- An objective method for assessing the risk of rain at the end of the harvest season early in the year.
- Heightened industry awareness of long lead forecasting capability.
- Improved industry understanding on the processes that occur in the oceans and atmosphere that influence the seasonal climate we experience.
- Improved industry understanding of benefits associated with long lead climate forecasting.
- Improved strategic planning practices that mitigate the risk associated with climate conditions during the later half of the harvest season.
- A methodology for easing tension when planning harvest season start date.
- A process for continued delivery of long lead climate forecasts.

Intellectual Property and Confidentiality

The major discovery founded from this project is that it is now possible to consult forecasts pre-Autumn for post Autumn periods. Prior to this project there was a great deal of scepticism about the ability to do this reliably. All research findings have been published and are freely accessible.

Environmental and Social Impacts

The long lead prediction model has lead to several notable environmental and social impacts:

- End of project surveys reveal that some farmers are using the seasonal climate forecasts to refine fertilizer practices.
- Surveys have indicated that industry would consider using the forecast to plan for a legume crop.
- Social impacts have also been identified, largely by way of easing tensions between farming and milling representatives when deciding season start date.

Expected Outcomes

Likely Impacts, Costs and Potential Benefit

Harvesting in wet conditions is known to impact profitability negatively. Antony et al. (2002) concluded that the wet 1998 season cost the Herbert sugar industry 20 million AUD. These costs were incurred from a combination of failed plantings, soil compaction which limited the productivity of sugarcane in future seasons, not harvesting all of the cane and a reduction in sugar production and content which forms the basis of the cane payment system. Industry calculated that starting the harvest season earlier in 1998 would have avoided a significant portion of these costs. Reduced profitability was not just limited to the Herbert in 1998, but extended to the wider industry. Some have quoted that the wet conditions experienced during the 1998 harvest season cost the Australian sugar industry 175 million AUD (Australian Canegrower, 1999).

It is acknowledged that seasonal climate forecasts post Autumn are very valuable to industry Antony *et al.* (2002). However, there could be further increases in profitability if harvest rainfall predictions were available much earlier in the year to give industry sufficient time to plan the start of the harvest season. This is particularly important in years when the crop is expected to be large. Such benefits would accrue through:

- Enhanced harvest scheduling activities through better and advance knowledge of year type.
- Increase industry profitability through smarter decisions about season start date.
- Increased profitability through better management of mill labour and maintenance scheduling systems.
- Increased profitability through smarter on farm decisions to minimise the impact of climate variability in sugarcane growing regions.
- Reduced risk of leaving standover cane.
- Better industry awareness of productivity supply patterns.

A preliminary study was undertaken to develop a framework that would facilitate assessment of the economic value of the long lead forecasting model that has been the centrepiece of JCU027. This research was undertaken by Mr Justin Cusack as part of his honours degree at James Cook University. Mr Cusack's project which focused on the Herbert region, was supervised Dr Natalie Stoeckl (School of Business) and Dr Everingham (School of Engineering and Physical Sciences). It must be emphasized that whilst Mr Cusack, has made a very valuable contribution to developing the economic framework, the short time-line associated with his project means that more research is needed before the final economic framework and assessment of the economic benefits of the long lead forecasting approach will be realised. Nevertheless, there are some emerging results that require further validation, but are worth reporting.

1. It appears the greatest benefit of the long lead forecasting model will be delivered when the model forecasts La Niña conditions to emerge during the harvest.

2. CCS profiles are influenced by ENSO years, i.e. CCS weekly profiles for El Niño years appear distinctly different (better) than CCS profiles for La Niña years. This means that knowledge of El Niño conditions to emerge during the harvest season may be associated with increased revenue.

Another point worth mentioning, is that even without the formal economic analysis, there is an exceptionally strong belief held amongst the project consultative committees in Tully, Ingham and NSW that the long lead forecasting model is very valuable. For example the consultative members have demonstrated how FSU model outputs have influenced their decision making (see milestone report 6.1). This project has established proof of concept and now we must formally assess if the benefits from using the long lead prediction system outweigh any negative costs.

Demonstrated Learnings

A pre-post project survey that evaluated the perceptions of the benefits of this project was given to attendees during the project meetings that were conducted during and February and March, 2009. Across all case study regions, the surveys reflects a strong degree of positivism about the project findings and the way the project was conducted. The survey also asked case study participants how they would use seasonal climate forecasts. Responses to this question vary from person to person, and with the type of decision. It is clearly demonstrated however, that seasonal climate forecasts are influencing decisions made by industry. Full survey responses which demonstrate key project learnings have been provided in Appendix A1.

Future Research Needs

More detailed economic assessment on the potential benefits of adjusting season start date conditionalised upon forecast scenario, crop size and region would be beneficial to the industry owing to the probabilistic nature and embedded risks associated with climate forecasting technologies.

Recommendations

- It could be opportunistic for industry to have a post-project follow up with climate co-ordinators in Tully, Ingham and New South Wales.
- Information dissemination to non-case study regions has been limited. Avenues for overcoming this limitation could be explored.

List of Publications

1. EVERINGHAM, Y.L., CLARKE, A.J., CHEN, C.C.M., VAN GORDER, S., MCGUIRE, P. (2007) Exploring the capabilities of a long lead forecasting system for the NSW sugar industry. Proc. Aust. Soc Sugar Cane Technol 29:9-17.

2. EVERINGHAM, Y.L., CLARKE, A.J., VAN GORDER S. (2008) Long lead rainfall forecasts for the Australian Sugar Industry. International Journal of Climatology. 28:111-117.

3. EVERINGHAM, Y.L., ZAMYKAL, D., MCKINNA, L.I. (2009) RAINFORECASTER – a seasonal climate forecasting tool. Proc. Aust. Soc Sugar Cane Technol 31:50-64.

4. CLARKE, A.J., VAN GORDER S., EVERINGHAM, Y.L. (2009). Forecasting long-lead rainfall probability with application to Australia's northeastern coast. Journal of Applied Climatology and Meteorology (in preparation).

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Trenberth KE, Caron JM. 2000. The southern oscillation revisited: sea level pressures, surface temperatures and precipitation. *Journal of Climate*. 13:4358-4365.

Appendices

A1. Project Evaluation

A2. Full Publications

A2.1 EVERINGHAM, Y.L., CLARKE, A.J., CHEN, C.C.M., VAN GORDER, S., MCGUIRE, P. (2007) Exploring the capabilities of a long lead forecasting system for the NSW sugar industry. Proc. Aust. Soc Sugar Cane Technol 29:9-17.

A2.2 EVERINGHAM, Y.L., CLARKE, A.J., VAN GORDER S. (2008) Long lead rainfall forecasts for the Australian Sugar Industry. International Journal of Climatology. 28:111-117.

A2.3 EVERINGHAM, Y.L., ZAMYKAL, D., MCKINNA, L.I. (2009) RAINFORECASTER – a seasonal climate forecasting tool. Proc. Aust. Soc Sugar Cane Technol 31:50-64.

A2.4 CLARKE, A.J., VAN GORDER S., EVERINGHAM, Y.L. (2009). Forecasting long-lead rainfall probability with application to Australia's northeastern coast. Journal of Applied Climatology and Meteorology (in preparation).

A1. Project Evaluation

This appendix contains (a) the evaluation form and (b) a summary of the information that was recorded by members of the industry consultative committees in Tully, Ingham and NSW.

(a) Survey Form.

JCU027 End of Project Survey

1. Did/Do you think it is possible to forecast the chance of rainfall during the later half of the harvest season, early in the year e.g. February,?

Before the project:

(not possible at all) 1 2 3 4 5 6 7 8 9 1 0 (very easy to forecast)

After the project:

(not possible at all) 1 2 3 4 5 6 7 8 9 1 0 (very easy to forecast)

2. If someone else in your region was interested in understanding more about the FSU longlead forecasting model would be willing to help them understand more about the forecasting approach?

Before the project: (not willing) 1 2 3 4 5 6 7 8 9 1 0 (very willing)

After the project: (not willing) 1 2 3 4 5 6 7 8 9 1 0 (very willing)

3. Was your time investment in the project (e.g. attending, travelling to meetings) worthwhile?

Before the project: (not worthwhile) 1 2 3 4 5 6 7 8 9 1 0 (very worthwhile)

After the project: (not worthwhile) 1 2 3 4 5 6 7 8 9 1 0 (very worthwhile)

4. What planning would you consider taking if the FSU forecast in February predicts that the Niño 3.4 region will be El Niño-like during the harvest?

5. What planning would you consider taking if the FSU forecast in February predicts that the Niño 3.4 region will be La Niña-like during the harvest?

6. What planning would you consider taking if the FSU forecast in February predicts that the Niño 3.4 region will be in a <u>neutral</u> pattern during the harvest?

7. Now that the project has finished how will you access the FSU forecasts?

8. How will others not involved in the project access the information?

9. What did you enjoy the most about the project?

10. What would you have like to have seen done differently?

11. What concepts were most difficult to understand?

12. Would you like to add any other comments?

(b) Survey Results.

Project Survey Summary.

1. Did/Do you think it is possible to forecast the chance of rainfall during the later half of the harvest season, early in the year, e.g. February?

Response summary.

	New South Wales								Tully			Ingham								
After Project	7	6	6	10	6	5	6	4	8	9	7	7	1	8	8	8	7	7	na	9
Before project	1	3	3	2	3	5	2	1	1	2	2	3	4	5	2	2	4	2	na	na
Difference	6	3	3	8	3	0	4	3	7	7	-3	4	5	3	6	6	3	5	na	na
Average	**3.75**								**3.67**			**4.57**								

2. If someone else in your region was interested in understanding more about the FSU longlead forecasting model, would you be willing to help them understand more about the forecasting approach?

Response summary.

	New South Wales								Tully			Ingham								
After Project	9	10	5	6	8	8	7	7	8	9	6	9	na	6	7	8	8	8	7	7
Before project	2	4	3	2	na	na	7	3	1	2	2	na	na	2	3	4	2	1	3	3
Difference	7	6	2	4	na	na	0	4	7	7	4	na	na	4	4	4	6	7	4	4
Average	**3.83**								6.0			**4.71**								

3. Was your time investment in the project (e.g. attending, travelling to meetings) worthwhile?

Response summary.

	New South Wales								Tully			Ingham								
After project	8	10	10	7	7	8	9	7	9	10	9	na	10	9	3	8	7	10	10	9
Before project	4	4	6	7	6	8	5	4	5	2	7	na	na	7	7	7	5	3	5	3
Difference	4	6	4	0	1	0	4	3	4	8	2	na	na	2	-4	1	2	7	5	6
Average	**2.75**								**4.67**			**2.71**								

4. What planning would you consider taking if the FSU forecast in February predicts that the Niño 3.4 region will be El Niño-like during the harvest?

Responses from New South Wales.

i) Harvesting maintenance.
Farm management e.g. plant window rationing etc.

ii) Less cultivation of planting areas to reduce moisture loss.
Look at harvesting frost prone varieties and paddocks before chance of frost if possible.
More trash or ratoon paddocks to maintain moisture levels.

iii) Still have a very poor idea of how the harvest may be affected by rainfall.

iv) NA

v) El Niño predictions do not appear to be too accurate. So will be cautious changing mill start dates.

vi) Start harvest season at normal time.
Not take too many actions that require an expectation of dry conditions.

vii) Skill level mills, so no change.

viii) Advise growers that season could be drier than normal (median).
Factor this into cave planting program-need to conserve soil moisture.
Take prediction into account when making herbicide recommendations.

Responses from Tully

a) Less rain, reluctant to harvest in rainfall events.

b) Plant early to avoid moisture stress.

c) Dryer Harvest A bit more relaxed.
Planting can start early (may) less risk of destruction.

Responses from Ingham

1) Target blocks for harvest.

2) NA.

3) Might try to harvest earlier to get a legume crop in.

.

4) NA.

5) Harvest selected blocks best suited to yield.

6) This may influence decisions about starting dates for the harvesting season. With an El Niño-like event predicted we would push for a later starting date and increase the pre-season maintenance on our factories.

7) Hopefully have a good harvest with minimal interventions.

8) Plant early and maximize CCS.

9) Publicize information so that growers can plan operations and harvest schedules.

5. What planning would you consider taking if the FSU forecast in February predicts that the Niño3.4 region will be La Niña-like during the harvest?

Responses from New South Wales.

i) Consider starting season earlier.
Consider the possibility of wetter conditions-implications for farm management, e.g. mill mud applications, herbicide/weed control, planting window.

ii) Harvesting maintenance.
Farm management e.g. plant window rationing etc.

iii) Where possible prepare ground for planting earlier.
Harvest water prone blocks when conditions allow.
Leave less trash in paddocks.

iv) This shows that we have a good chance of having a wet harvest and can thus plan accordingly.

v) NA.

vi) Better accuracy-perhaps look at extra 300hrs wet weather stops in the mill. Start crushing 2 weeks earlier.
Make sure stations can handle high mud leadings in factory. - High dirt and Ash issues.

vii) Start harvesting early.
Get drains cleaned and pumps maintained.
Put lower tonnage cane in last harvest round.

viii) If dry in earlier harvest rounds, more forward blocks that may be more prone to wet weather harvesting (I did this in 2007).

Responses from Tully

a) More rain – keep harvesting in low rainfall events.

b) Wet harvest ahead. Most likely we will persevere with starting early and progress with stops and start during the year.
Planting-Mound plant not early but in June July.
Keep work up to date as many interruptions ahead.

c) Early mill start.
Split fertilizer application.

Responses from Ingham

1) Publish information to allow for debate on the starting and finish dates to plan operations.

2) Plant later or not at all.
Maximize rationing and cut wet blocks.

3) Earlier start to harvest.
Advise growers to plat early.

4) If a La Niña –like pattern is predicted we would look to having an earlier starting date and complete less maintenance before the start of crush-Maintenance can be carried out during rain stops.

5) Organize early farming practices.

6) NA.

7) Harvest good blocks/plant cane early.
Try to harvest areas that are wet earlier.

.

8) Targeting blocks for harvest.
Attempt to base planting decisions on possible outcomes.
Consider use of crop ripeners early in the season.

9) NA.

6) What planning would you consider taking if the FSU forecast in February predicts that the Niño3.4 region will be in neutral during the harvest?

Responses from New South Wales.

i) Nil. No skill.

ii) Unlikely any action required

iii) From mill perspective, would err on side of caution and so would treat as possible wet year and would most likely not start change start times.

iv) NA.

v) Again this does not give us a very good indication of how wet the harvest will be.

vi) Continue as normal because of uncertainties of outcomes in weather in neutral pattern.

vii) Business as usual-would not make any decisions/recommendations.

viii) Not so sure, but will watch closely

Responses from Tully.

a) Mainly standard farm operations.

b) Proceed cautiously.
Study possible indicators for possible directions.

c) Normal year, watch weather predictions.

Responses from Ingham

1) Plan to minimize risk.

2) NA.

3) Difficult to plan as the FSU will not be too helpful. Will look at different forecasting techniques closer to the time.

4) NA.

5) Uncertain.

6) Toss a coin.

7) Be cautious. Keep an eye on SOI during harvest.

8) Normal operations.

9) Publish info.

7.) Now that the project has finished, how will you access the FSU forecast?

Responses from New South Wales
i) Via sunshine news.
Via Forecaster (probably via P. McGuire).

ii) Internet.

iii) By whatever means are available. Electronically.

iv) Via the website.

v) Website.

vi) Yes will try and review regularly and incorporate results into any long term planning.

vii) Sunshine sugar news.

viii) Alen Clarks website.

Responses from Tully.

a) Websites

b)www.ocean.fsu.edu/faculty etc.

c) Website.

Responses from Ingham.

1) Website

2) Through HCPSL.

3) Www.

4) Using rain forecaster V4.1.

5) Via HCPSL.

6) Through Sue.

7) Using the designed program
Access the website.

8) NA.

9)-website
-HCPSL

8. How will others not involved in the project access the information?

Responses from New South Wales

i) Sunshine sugar newsletter.

ii) Sunshine sugar news.

iii) At mill discussed, at department head and management integration. Need to involve cane supply department.

iv) Website and sunshine news.

v) Via sunshine news article.

vi) Same means as me but will need some training.

vii) Internet and published papers.

viii) Sunshine news.
Website

Responses from Tully.

a) Rain forecaster program.

b) Maybe through cane growers' newsletter.

c) Cane grower's newsletters.
Web.
Shed meetings.

Responses from Ingham

1) HCPSL newsletter.

2) NA.

3) By going to see HCPSL.

4) NA.

5) Handouts (Rain gauge)

6) By distributing via e-mail.

7) Sending out newsletters with information on predicted forecast for the harvest.

8) Not sure-Workshop and shed meetings.

9) We will invite them unto our email list.

9. What did you enjoy the most about the project?

Responses from New South Wales.

i) Time taken to explain aspects.

ii) A new outlook on forecasting.

iii) It shows that in February if predicted to be wet, it will be –otherwise we are guessing.

iv) The discussion and interactions.

v) Seeing results coming from data collected from various sources and time frame.
Ability to use results and compare to other data to see –CCS, yields etc.

vi) Learning more about climate forecasting.
Understanding of FSU model for Tweed, Richmond and Clarence areas.

vii) Discussing which is out there in prediction tools.
Finding out that it is extremely difficult to get results with skill.

viii) Learning the basis behind models.

Responses from Tully.

a) The learning.

b) Interaction between group and ability to ask question if not keeping up.

c) Learning about probability.

Responses from Ingham.

1) Better understanding of what is available and what was being done to improve forecasting.

2) Professional presentation and practical focus.

3) Very interesting to see how the forecast are predicted using SST (Sea Surface Temperature) and how this relates to the east coast of Australia.

4) I only attended once but find all of the information easily digestible.

5) Climate awareness.

6) The information itself. Very interesting

7) Understanding the weather pattern better and being able to forecast and help improve decision making.

8) NA.

9) Interaction with researchers to develop industry desired outcomes.

10 .What would you have like to have seen done differently?

Responses from New South Wales.

i) Percentage of how much we exceed annual rainfall.

ii) day.

iii) NA

iv) Nothing.

v) Nothing.

vi) Nothing really.

vii) Nothing for this project.

viii) NA

Responses from Tully.

a) None.

b) NA

c) Nothing.

Responses from Ingham.

1) NA.

2) None.

3) Nothing.

4) NA.

5) Can’t say as I only attended once.

6) Nothing.

7) NA.

8) NA.

9) NA.

11. What concepts were most difficult to understand?

Responses from New South Wales.

i) Nothing.

ii) prediction of a prediction.

iii) Probability.

iv) Skill level in predicting-P values.

v) Nil – Well explained by Yvette.

vi) That the FSU model is a forecast of a forecast.

vii) Most of the forecasting. Only the basic concepts have been grasped-but this is sufficient for usefulness.

viii) Initially FSU and relationship to predicting.

Responses from Tully.

a) El-Niño and La Niña.
FSU.

b) Probability.

c) Autumn unpredictability.

Responses from Ingham.

1) SOI autumn flip.

2) Everything was explained well.

3) None.

4) NA.

5) Initially some terminology .But was explained well.

6) FSU graphs are predicted and not relevant to actual pattern that occurred.

7) Understanding how the systems were designed.

8) NA.

9) NA

12. Would you like to add any other comment?

Responses from New South Wales

i) NA

ii) This information could be used now to develop a model to make decisions on planning for the season in February.

iii) It's been a worthwhile project and once the industry emerges from its present survival mo de, climate forecasting will be a useful tool to maximize returns.

iv) Good presentation.

v) Where does IOD fit with this?

vi) NA.

vii) NA.

viii) Look foreword to the next one and maybe looking at rainfall the cost to growers in CCS fall on harvesting and crop returns.

Responses from Tully.

a) A worthwhile project. It will be of benefit to those who use it.

b) Project was delivered by Yvette excellently. Project content was excellent. Would do it again.

c) Very well run.

Responses from Ingham.

1) NA

2) NA

3) NA

4) NO

5) Well presented.

6) NA.

7) NO.

8) Great project delivering red benefits.

9) NA

A2. Full Publications