Climate variability and climate change issues for agriculture in Australia: aspects related to seasonal forecasts and climate change predictions.

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UNIVERSITY OF SOUTHERN QUEENSLAND

Outline – our approach.

Discussion on Australia's already existing high levels of climate variability.

Discussion on long-term shifts in climate, especially those relevant to agricultural production and sustainability.

Linking climate forecasts and projection information to agricultural management decisions across all time scales.

The value of use of crop simulation models and taking a fully integrated approach to seasonal climate forecasting and climate change projections.

Recognise the need to address issues across the entire value-chain in agricultural systems.

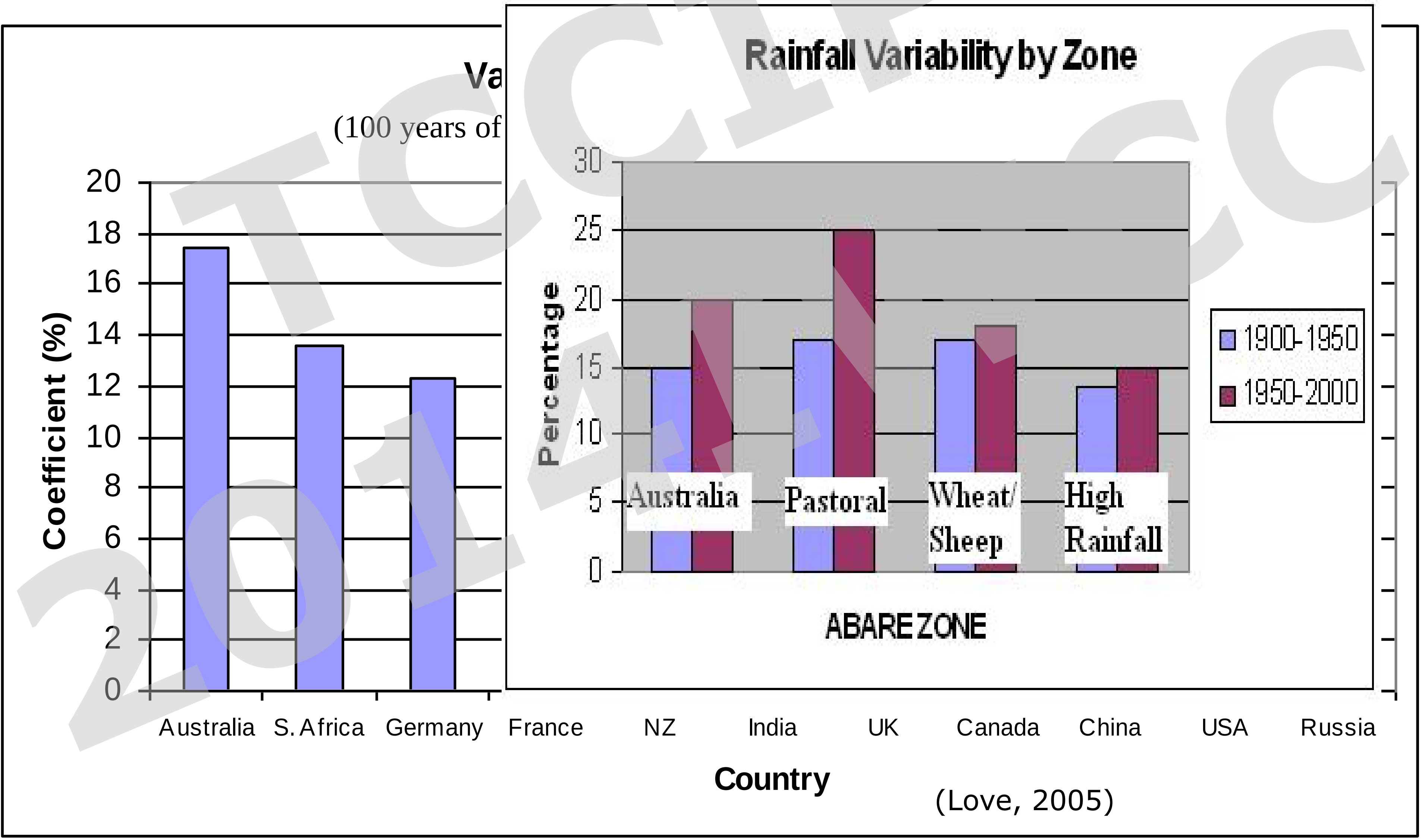
Value in utilising aspects of seasonal climate forecasting to assist incremental shifts in agricultural management on a year to year basis.

Producing outputs that are relevant to agriculture, especially extreme events, includes heat stress for cattle/animals.

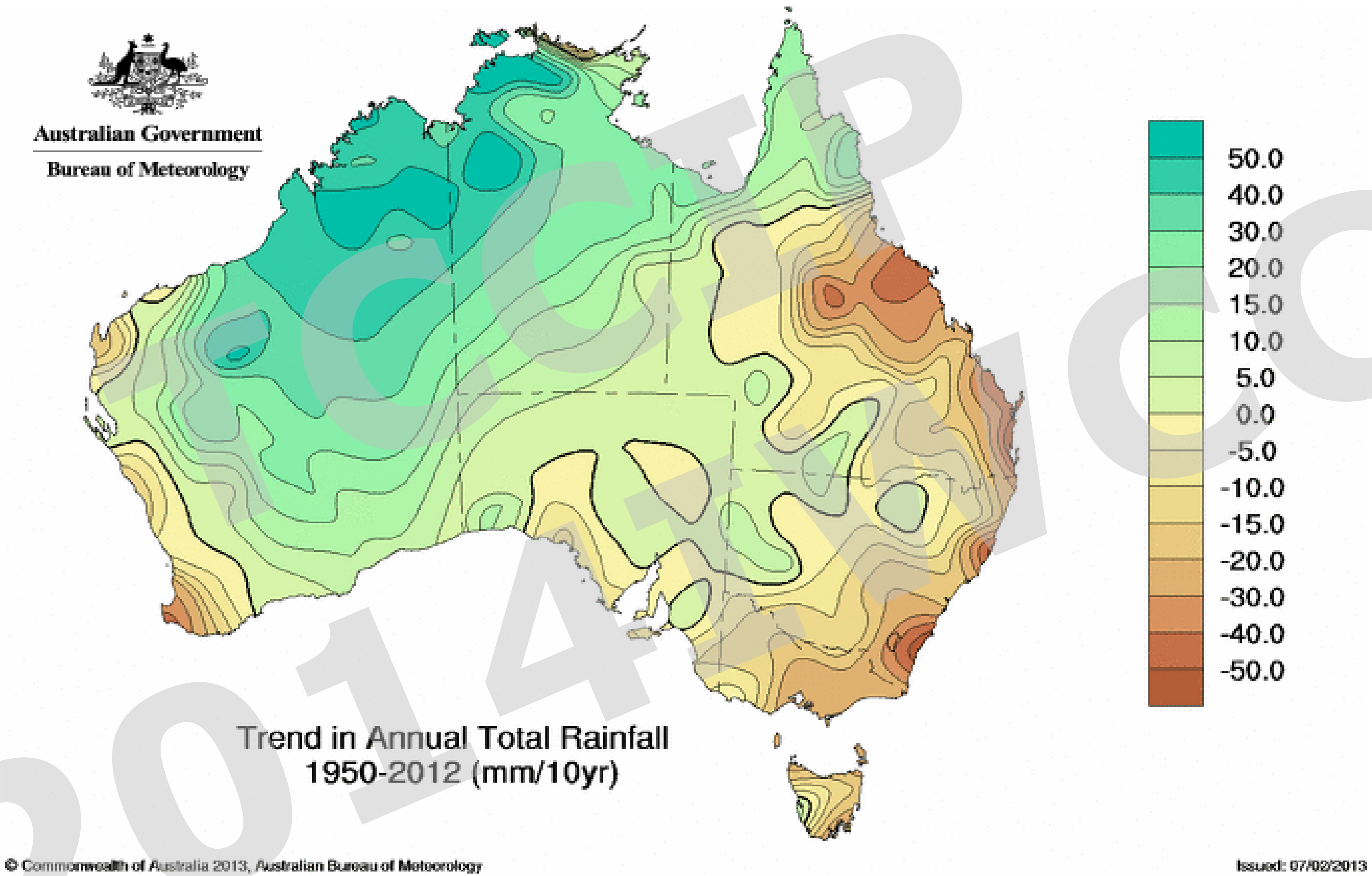
Some examples for various agricultural industry sectors – eg: grains, rice, cotton, grazing.


McARTHUR'S UNIVERSAL CORRECTIVE
MAP OF THE WORLD
S
E
W
N
ALASKA
COMMONWEALTH OF INDEPENDENT STATES

Climate issues dominate - Australia has the world's highest levels of year to year climate variability – which is increasing…



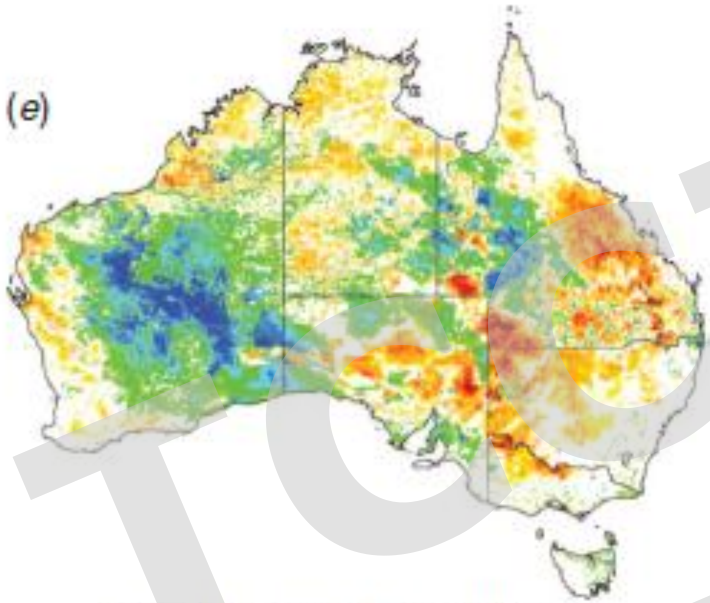
(Love, 2005)



"The 60-year trend may be particularly important as this is the period during which the global climate has moved outside the bounds of experience during the last 1,000 years, at least" (Bureau of Rural Sciences, 2004)

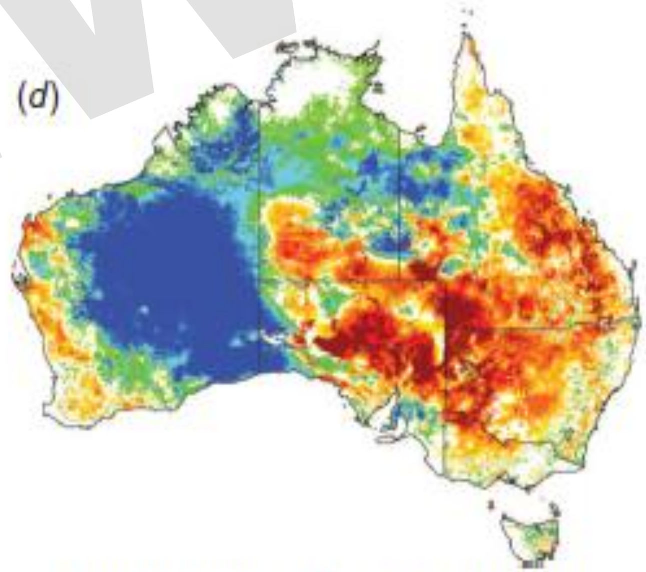
Percent change in components of the grazing system as simulated by AussieGRASS -

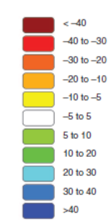
- changes calculated as the average for the period 1991 to 2007 expressed as a percentage of the average for the period 1961 to 1990 – surface pasture cover and forage production/pasture growth (McKeon et al, 2009).



Percent change in pasture cover

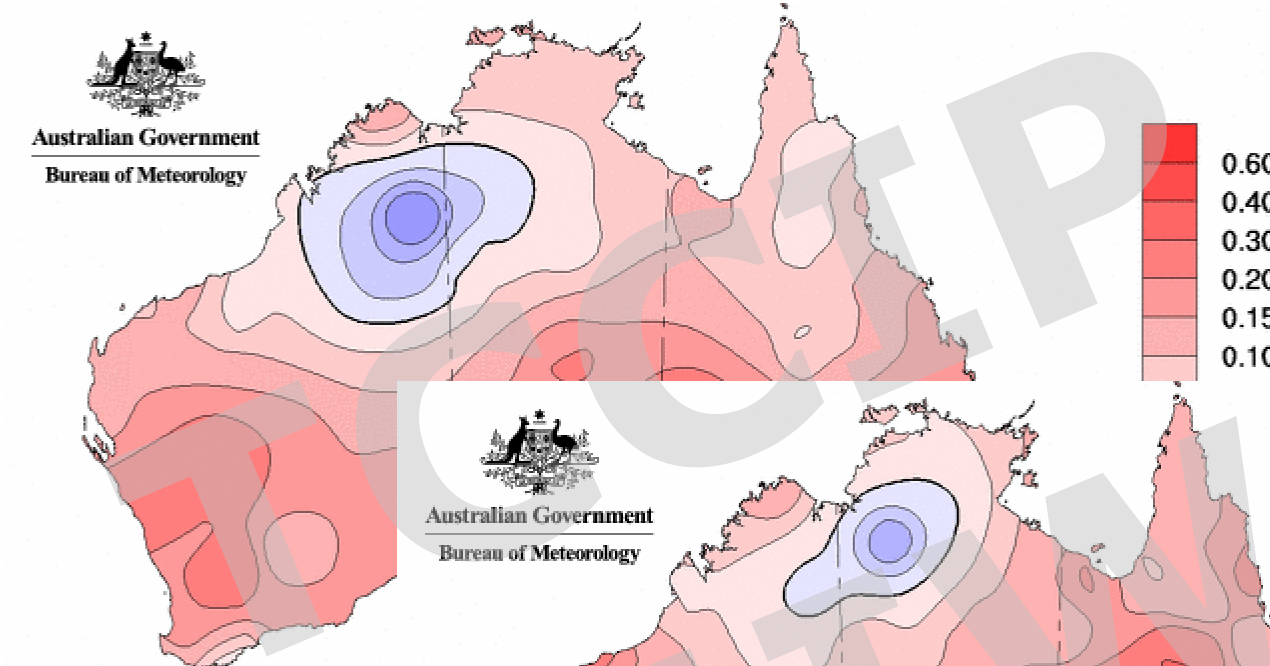
1991-2007

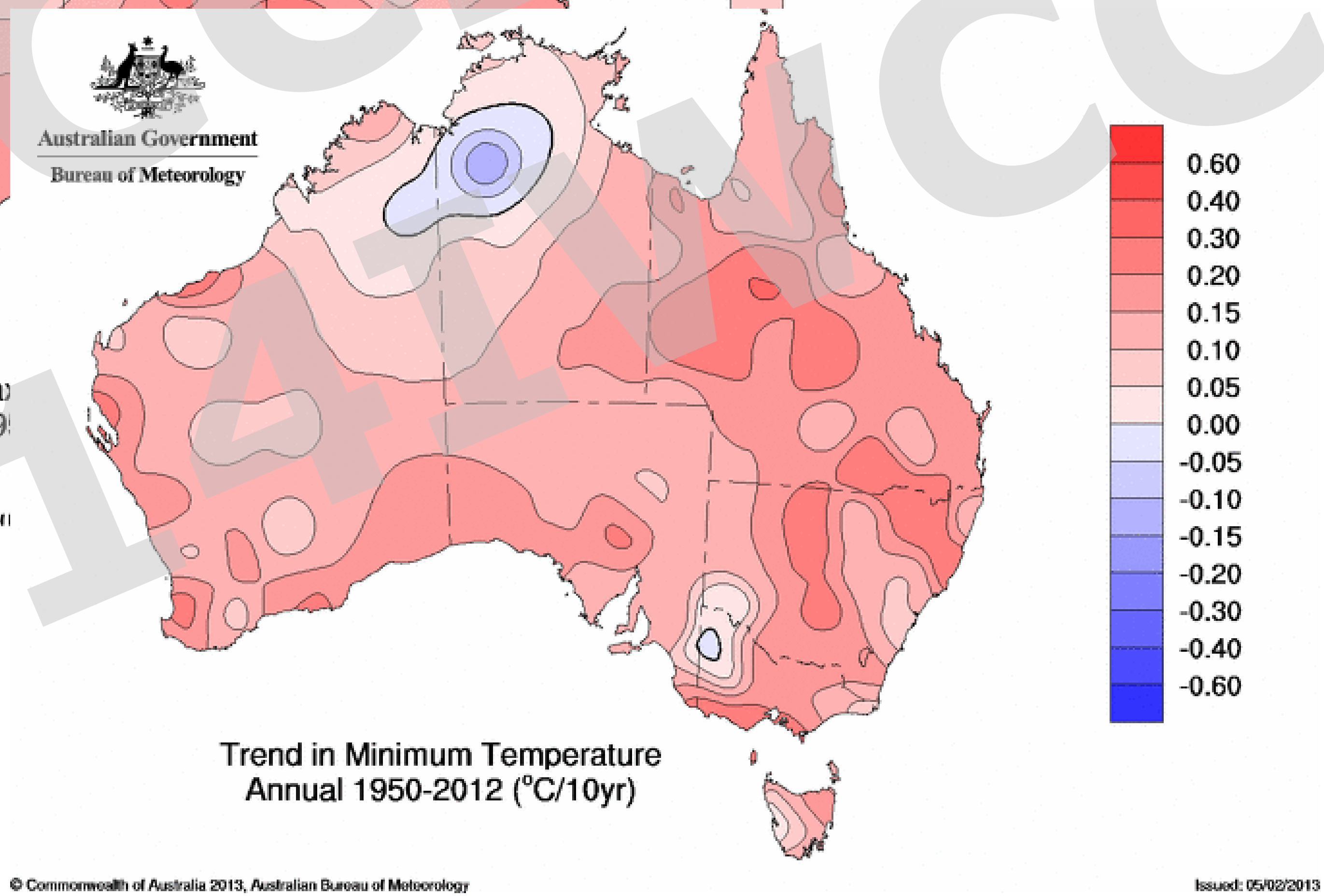




Percent change in forage production

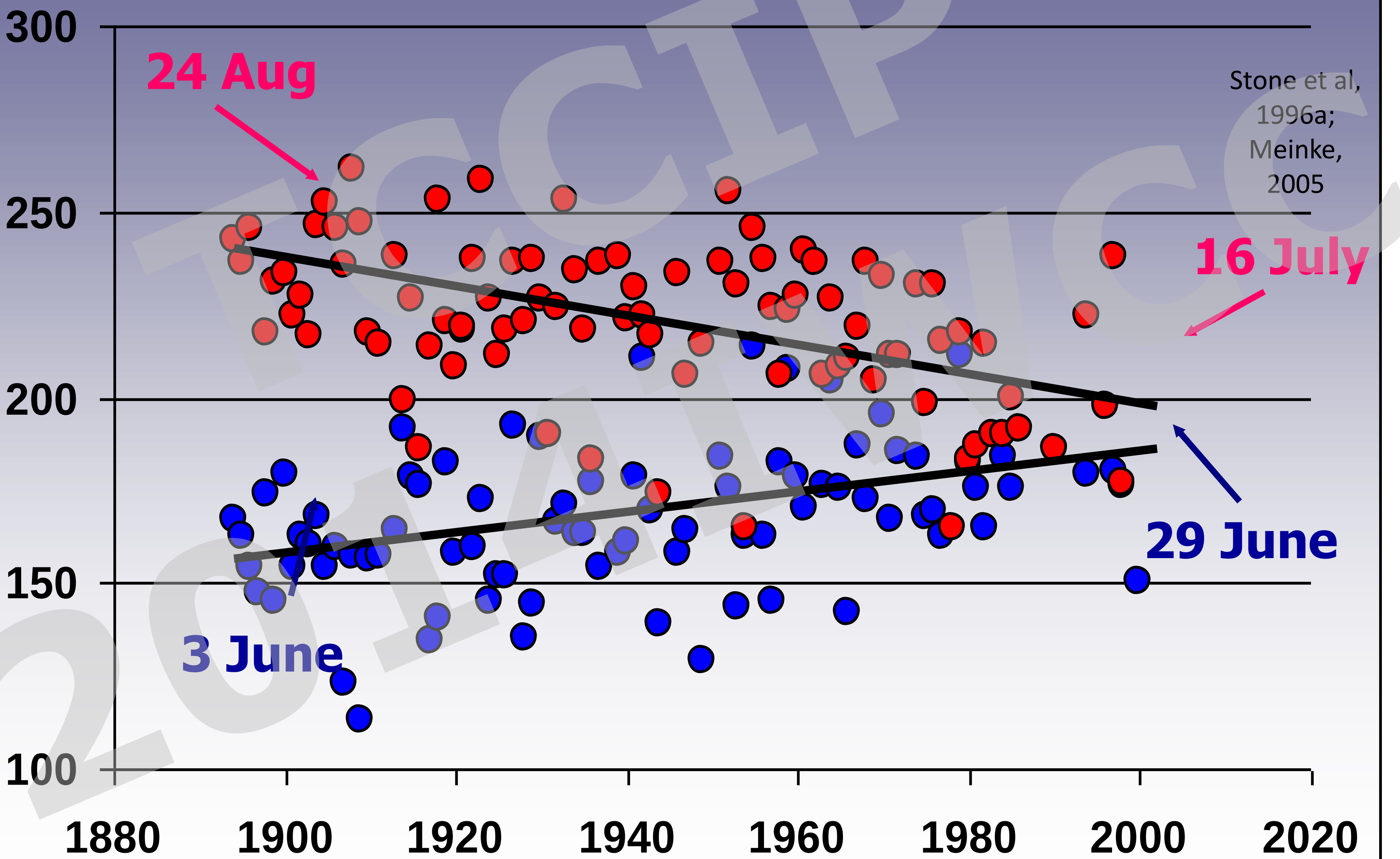
1991-2007





Major trends in Maximum and, importantly, Minimum temperature ....

First and last days of frost at Emerald
(2 degrees in the screen)



A 'whole of climate approach '
Climate systems prevail on many scales - agricultural management decisions occur on many scales -
(Meinke and Stone, 2005; Stone and Meinke, 2005).

Decision type (eg. only)	Frequency (year)
Logistics (eg. scheduling of planting / harvest operations)	Intraseasonal (>0.2)
Tactical crop management (eg. fertiliser/pesticide use)	Intraseasonal (0.2-0.5)
Crop type (eg. wheat or chickpeas)	Seasonal (0.5-1.0)
Crop sequence (eg. long or short fallows)	Interannual (0.5-2.0)
Crop rotation (eg. winter or summer crop)	Annual/biennial (1-2)
Crop industry (eg. grain or cotton, phase farming)	Decadal (~10)
Agricultural industry (eg. crop or pasture)	Interdecadal (10-20)
Landuse (eg. Agriculture or natural system)	Multidecadal (20+)
Landuse and adaptation of current systems	Climate change

Decisions across the value chain – 'climate forecasting has no value unless it changes a management decision'

Understand climate related issues across the whole value chain

The Cane Plant → **Sugarcane Production** → **Harvest & Transport** → **Raw Sugar Milling** → **Marketing & Shipping**

The Cane Plant / Sugarcane Production:

- **Best use of scarce/costly water resources**
- **Better decisions on farm operations**

Harvest & Transport:

- **Improved planning for wet weather disruption**
- **Best cane supply arrangements**
  - **- crush start and finish times**

Raw Sugar Milling:

- **Better scheduling of mill operations**
  - **- crop estimates**
  - **- early season cane supply**

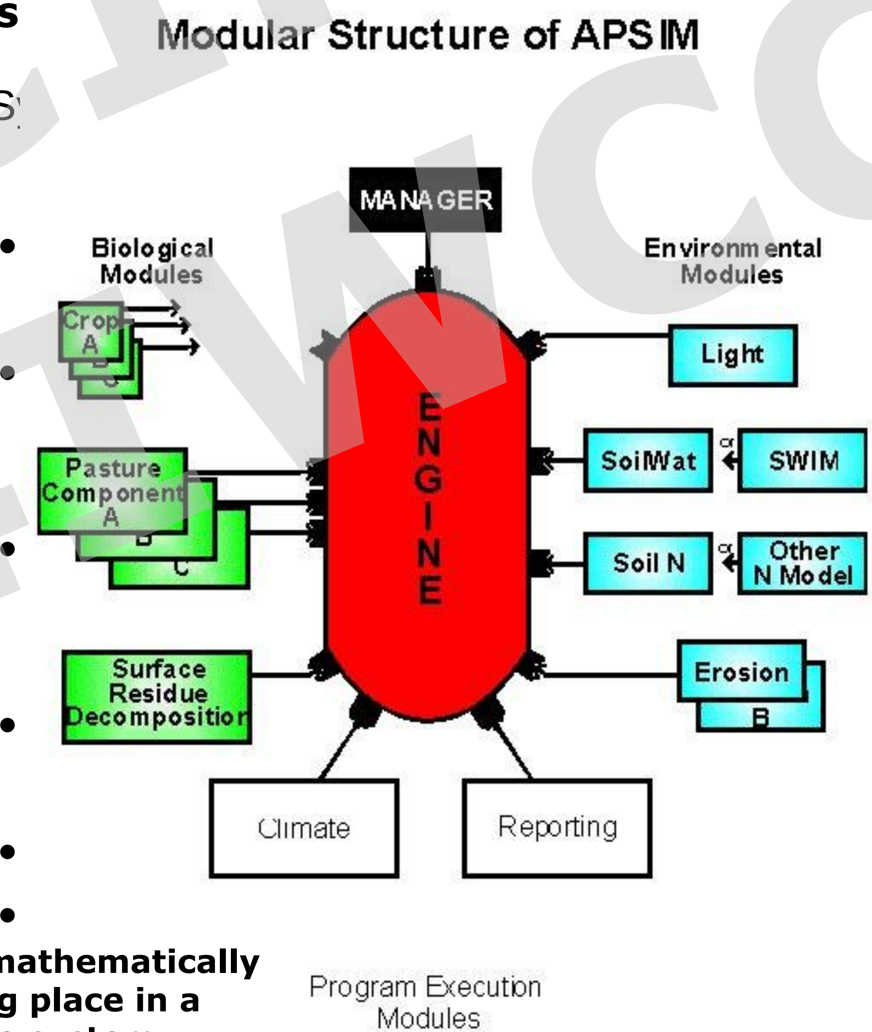
Marketing & Shipping:

- **Better marketing decisions based on likely sugar quality**
- **More effective forward selling based on likely crop size**
- **Improved efficiency of sugar shipments based on supply pattern during harvest season**

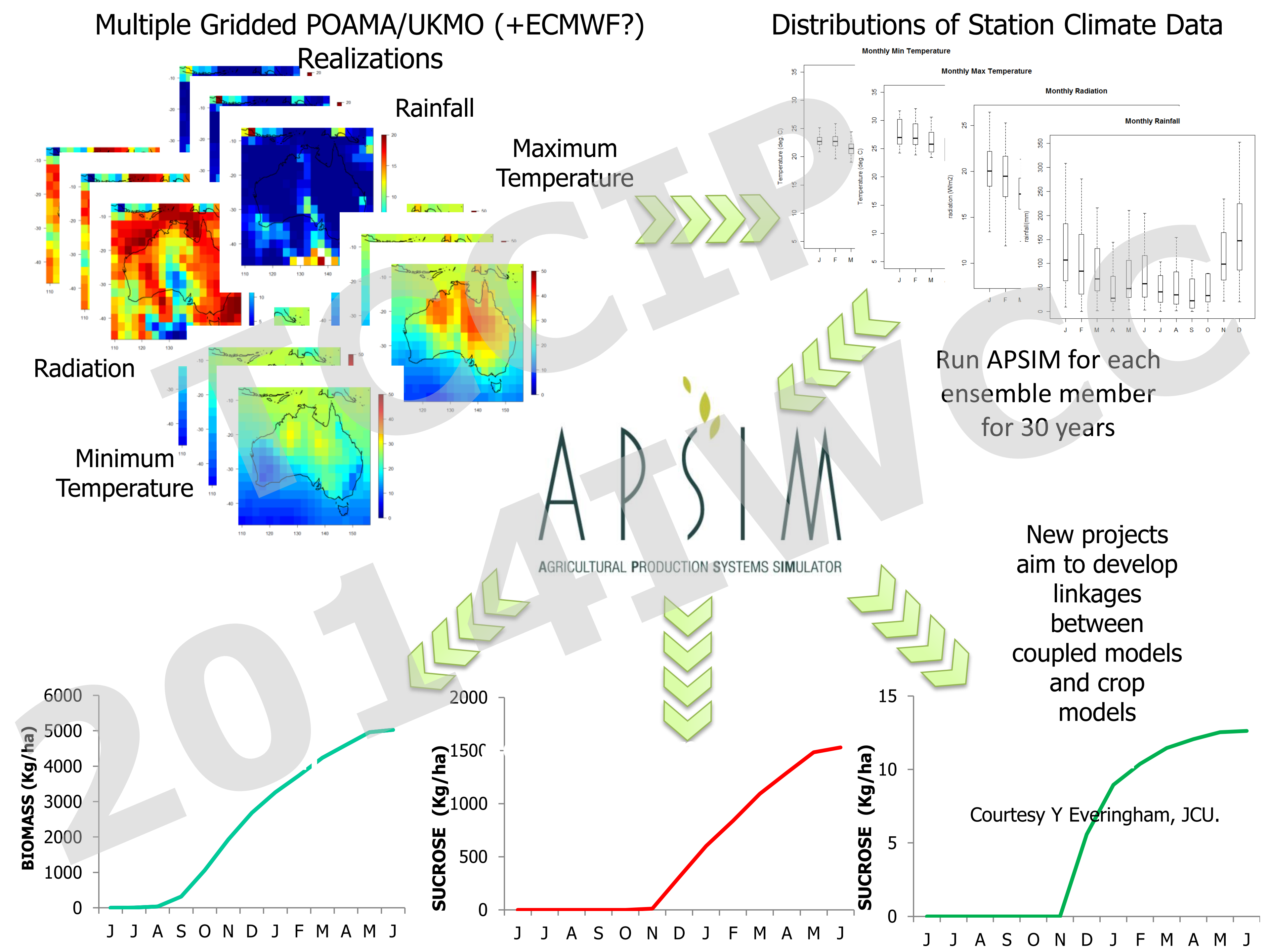
Y.L. Everingham, R.C. Muchow, R.C. Stone, N.G. Inman-Bamber, A. Singels, C.N. Bezuidenhout (2002)

To assist in the decision process? the linking role of crop modelling in the application of climate information for agricultural production - the key role is to simulate management scenarios and evaluate outcomes and risks relevant to decisions

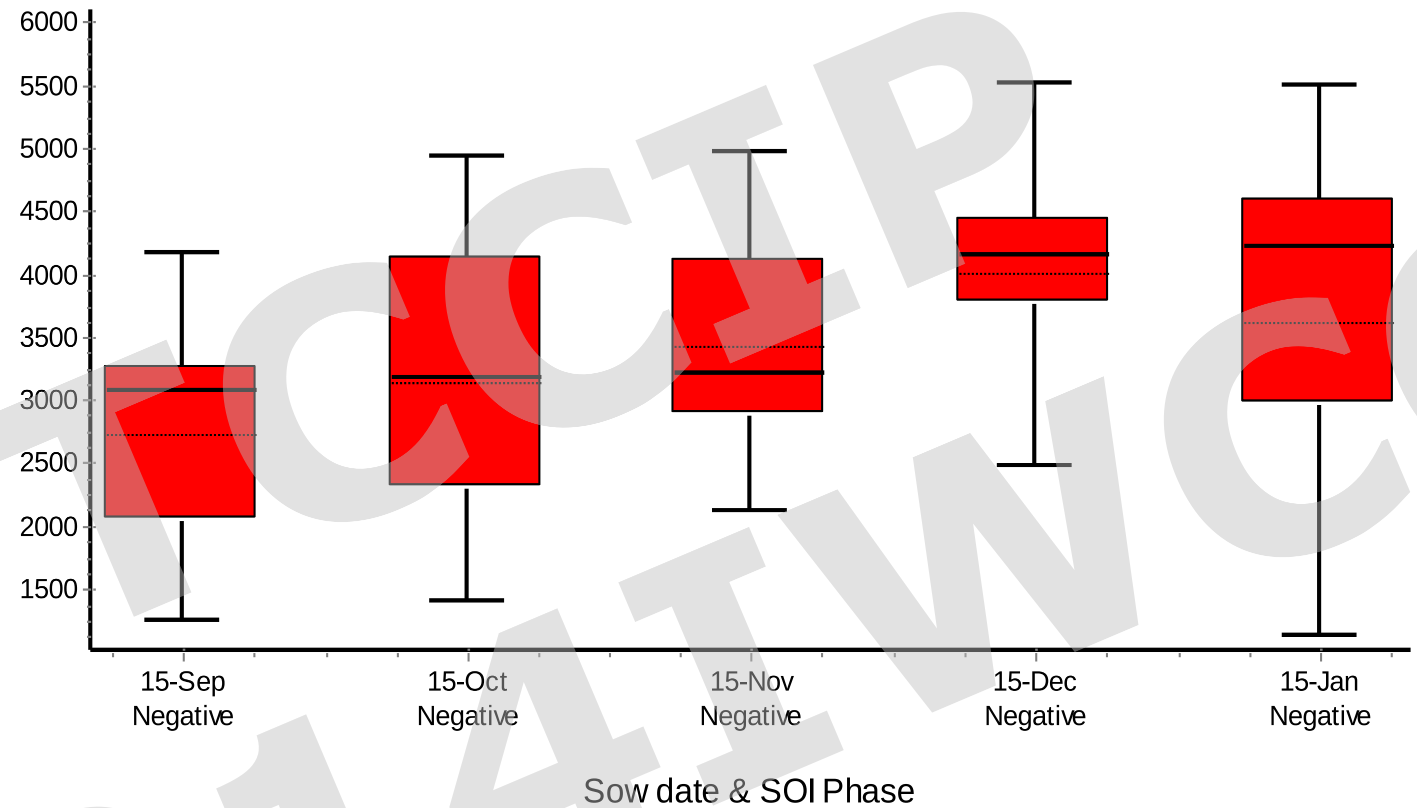
- Simulate management scenarios
- **Evaluate outcomes**
- Agricultural Production Sy



APSIM: precise daily time step model that mathematically reproduces the physical processes taking place in a cropping system – paddock/field scale system



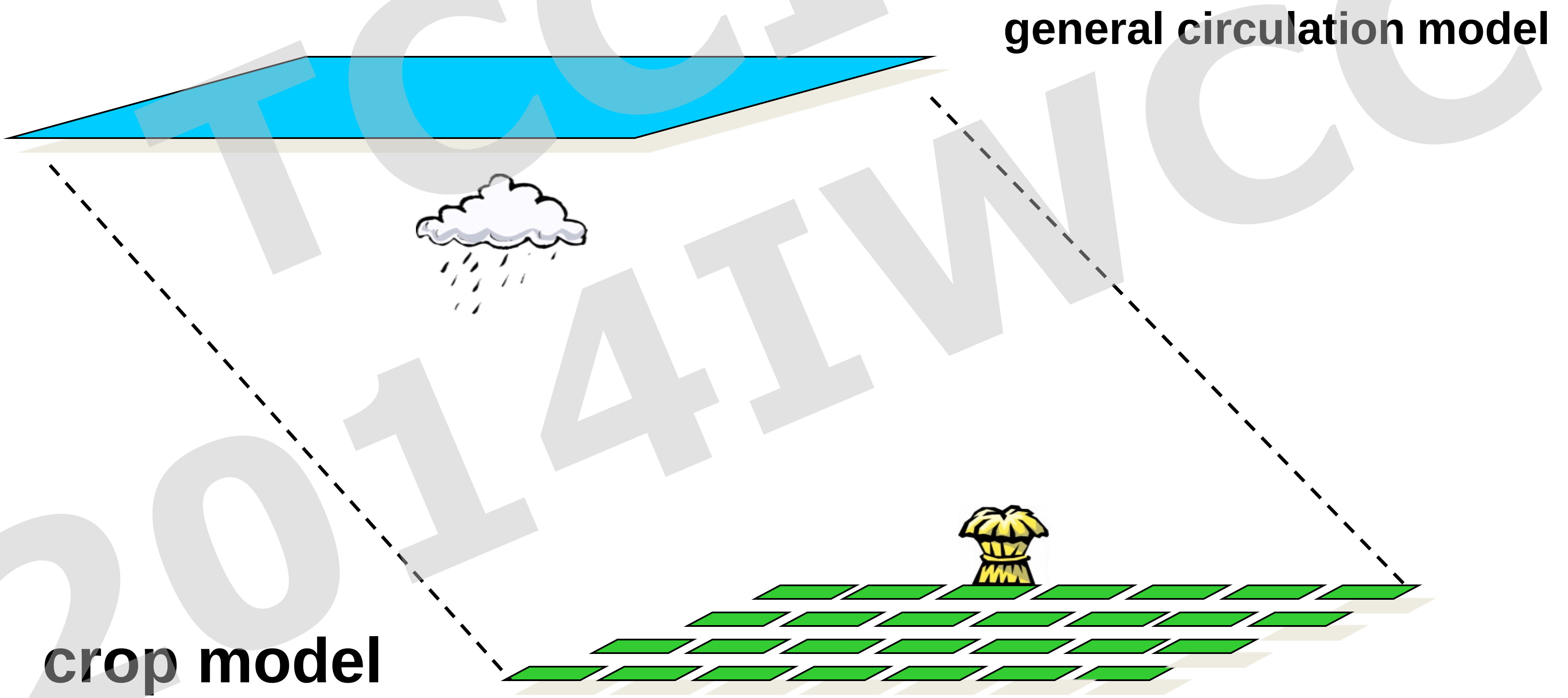
Multiple Gridded POAMA/UKMO (+ECMWF?) Realizations
Distributions of Station Climate Data
Rainfall
Maximum Temperature
Radiation
Minimum Temperature
Monthly Min Temperature
Monthly Max Temperature
Monthly Radiation
Monthly Rainfall
Run APSIM for each ensemble member for 30 years
APSIM
AGRICULTURAL PRODUCTION SYSTEMS SIMULATOR
New projects aim to develop linkages between coupled models and crop models
BIOMASS (Kg/ha)
SUCROSE (Kg/ha)
SUCROSE (Kg/ha)
J J A S O N D J F M A M J
Courtesy Y Everingham, JCU.



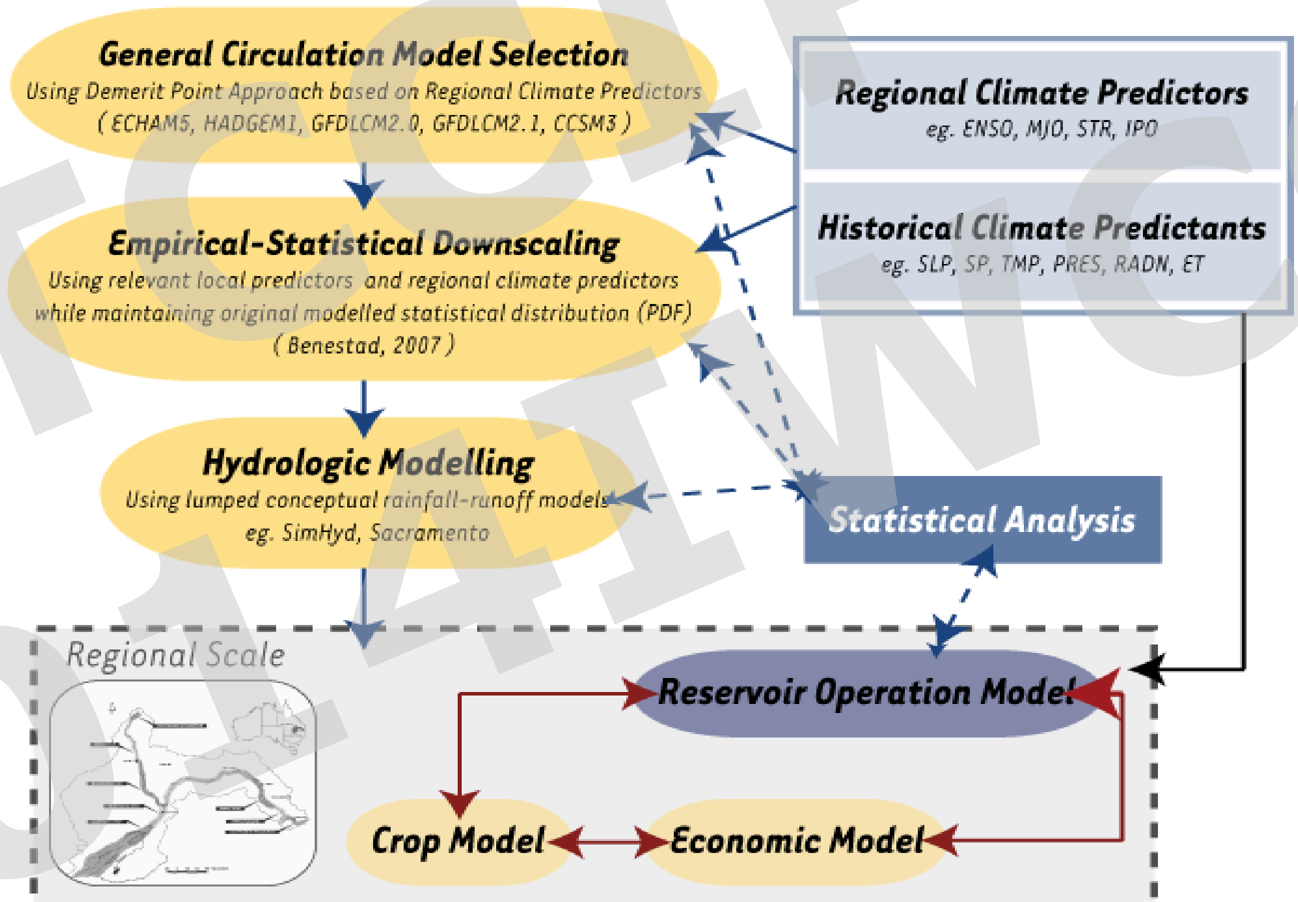
Farm-level decisions - Australia - Utilising seasonal climate forecasts in management and adaptation – eg of forecasts of potential sorghum yields associated with varying climate regimes (example for a 'consistently negative SOI phase') – varying management decisions (sowing dates) : example for Miles, Australia.

Effect of sowing date on sorghum yield at Miles South QLD with a 'consistently negative' SOI phase for September/October (Other parameters - 150mm PAWC, 2/3 full at sowing, 6pl/m2, medium maturity (WhopperCropper)

Key challenge remains – to effectively link 'the new generation' of general circulation models in climate prediction to agricultural models (Challinor et al)



Need for fully integrated systems – example for hydrological modelling for agricultural regions on a seasonal or climate change basis



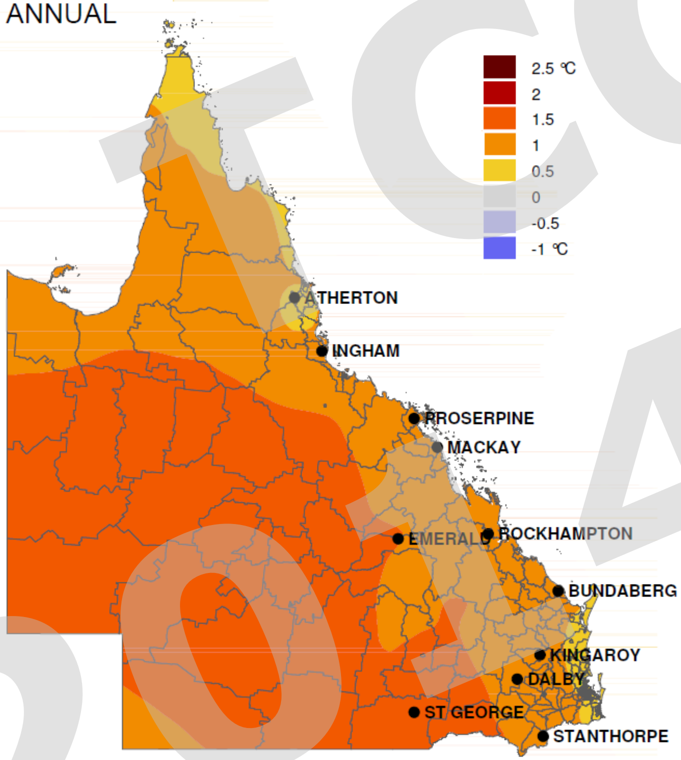
(Wiring aspects of the flow diagram after M. Ward, 2007)

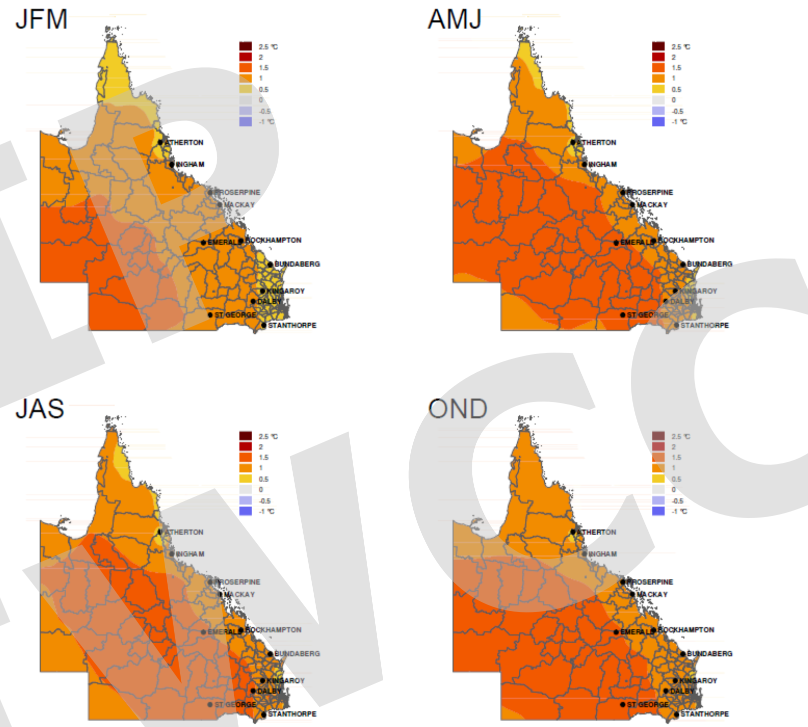
Change in Air Temperature

between (1961-1990) and (2010-2039)
based on the A1B change scenario

Australian Centre for Sustainable Catchments

ANNUAL

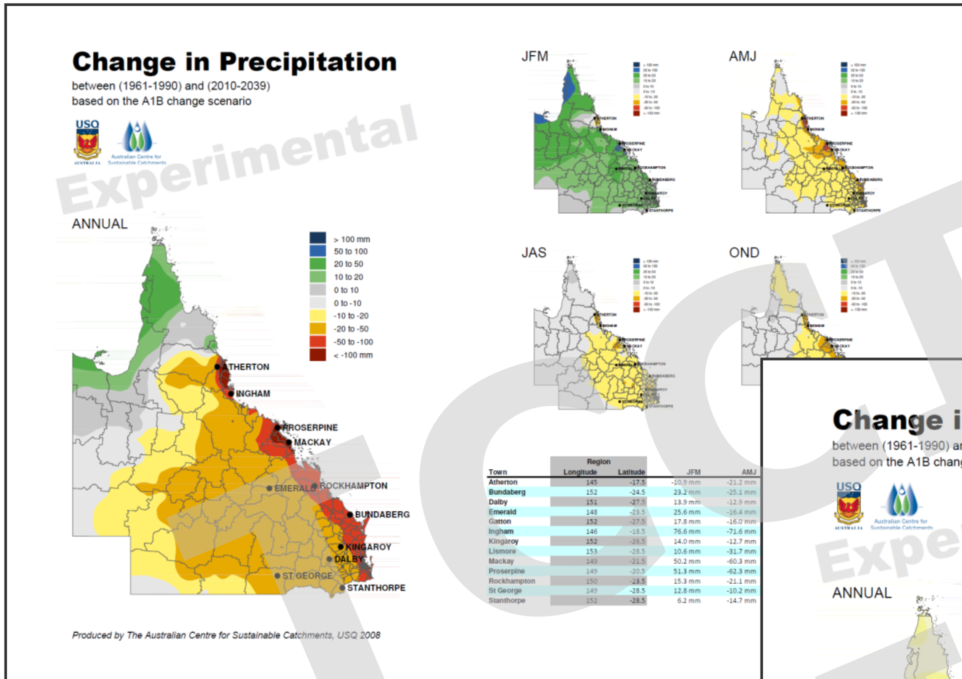




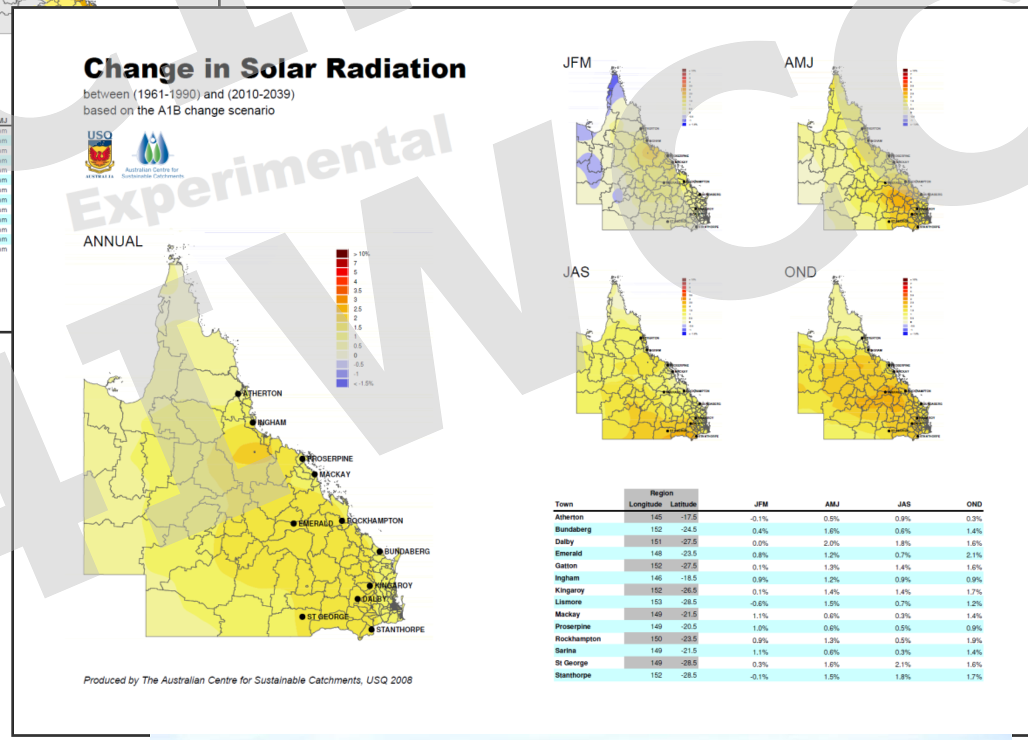
Town	Region Longitude	Latitude	JFM	AMJ	JAS	OND	ANNUAL
Atherton	145	-17.5	0.8°C	0.8°C	0.8°C	0.9°C	0.8°C
Bundaberg	152	-24.5	0.9°C	1.3°C	1.4°C	1.2°C	1.2°C
Dalby	151	-27.5	1.1°C	1.5°C	1.6°C	1.5°C	1.4°C
Emerald	148	-23.5	1.3°C	1.7°C	1.6°C	1.6°C	1.6°C
Gatton	152	-27.5	1.0°C	1.4°C	1.6°C	1.3°C	1.3°C
Ingham	146	-18.5	1.2°C	1.3°C	1.3°C	1.2°C	1.2°C
Kingaroy	152	-26.5	0.9°C	1.2°C	1.4°C	1.2°C	1.2°C
Lismore	153	-28.5	0.9°C	1.1°C	1.1°C	1.1°C	1.0°C
Mackay	149	-21.5	1.0°C	1.2°C	1.1°C	1.1°C	1.1°C
Proserpine	149	-20.5	1.0°C	1.0°C	1.0°C	1.0°C	1.0°C
Rockhampton	150	-23.5	1.2°C	1.4°C	1.4°C	1.3°C	1.3°C
St George	149	-28.5	1.4°C	1.7°C	1.8°C	1.6°C	1.6°C
Stanthorpe	152	-28.5	1.0°C	1.1°C	1.2°C	1.1°C	1.1°C

Produced by The Australian Centre for Sustainable Catchments, USQ 2008

Climate change projections indicate continued warming for the future for Queensland – in all seasons (source: ACSC/USQ 2010,2012)..



Town	Region		JFM	AMJ
	Longitude	Latitude		
Atherton	145	-17.5	-10.9 mm	-21.2 mm
Bundaberg	152	-24.5	23.2 mm	-25.1 mm
Dalby	151	-27.5	13.9 mm	-12.9 mm
Emerald	148	-23.5	25.6 mm	-16.4 mm
Gatton	152	-27.5	17.8 mm	-16.0 mm
Ingham	146	-18.5	76.6 mm	-71.6 mm
Kingaroy	152	-26.5	14.0 mm	-12.7 mm
Lismore	153	-28.5	10.6 mm	-31.7 mm
Mackay	149	-21.5	50.2 mm	-60.3 mm
Proserpine	149	-20.5	51.3 mm	-62.3 mm
Rockhampton	150	-23.5	15.3 mm	-21.1 mm
St George	149	-28.5	12.8 mm	-10.2 mm
Stanthorpe	152	-28.5	6.2 mm	-14.7 mm



Town	Region		JFM	AMJ	JAS	OND
	Longitude	Latitude				
Atherton	145	-17.5	-0.1%	0.5%	0.9%	0.3%
Bundaberg	152	-24.5	0.4%	1.6%	0.6%	1.4%
Dalby	151	-27.5	0.0%	2.0%	1.8%	1.6%
Emerald	148	-23.5	0.8%	1.2%	0.7%	2.1%
Gatton	152	-27.5	0.1%	1.3%	1.4%	1.6%
Ingham	146	-18.5	0.9%	1.2%	0.9%	0.9%
Kingaroy	152	-26.5	0.1%	1.4%	1.4%	1.7%
Lismore	153	-28.5	-0.6%	1.5%	0.7%	1.2%
Mackay	149	-21.5	1.1%	0.6%	0.3%	1.4%
Proserpine	149	-20.5	1.0%	0.6%	0.5%	0.9%
Rockhampton	150	-23.5	0.9%	1.3%	0.5%	1.9%
Sarina	149	-21.5	1.1%	0.6%	0.3%	1.4%
St George	149	-28.5	0.3%	1.6%	2.1%	1.6%
Stanthorpe	152	-28.5	-0.1%	1.5%	1.8%	1.7%

Need to address key variables relevant to agriculture: long-term trends projected in key variables between now and 2040:

•Precipitation - increase in summer (JFM) but decrease in other seasons.

•Solar Radiation - increase overall.

•Windspeed - decrease, especially in southern feedlot areas..

•Humidity - increase in critical summer months – decrease in other seasons (source: USQ/ACSC, 2010; 2012).

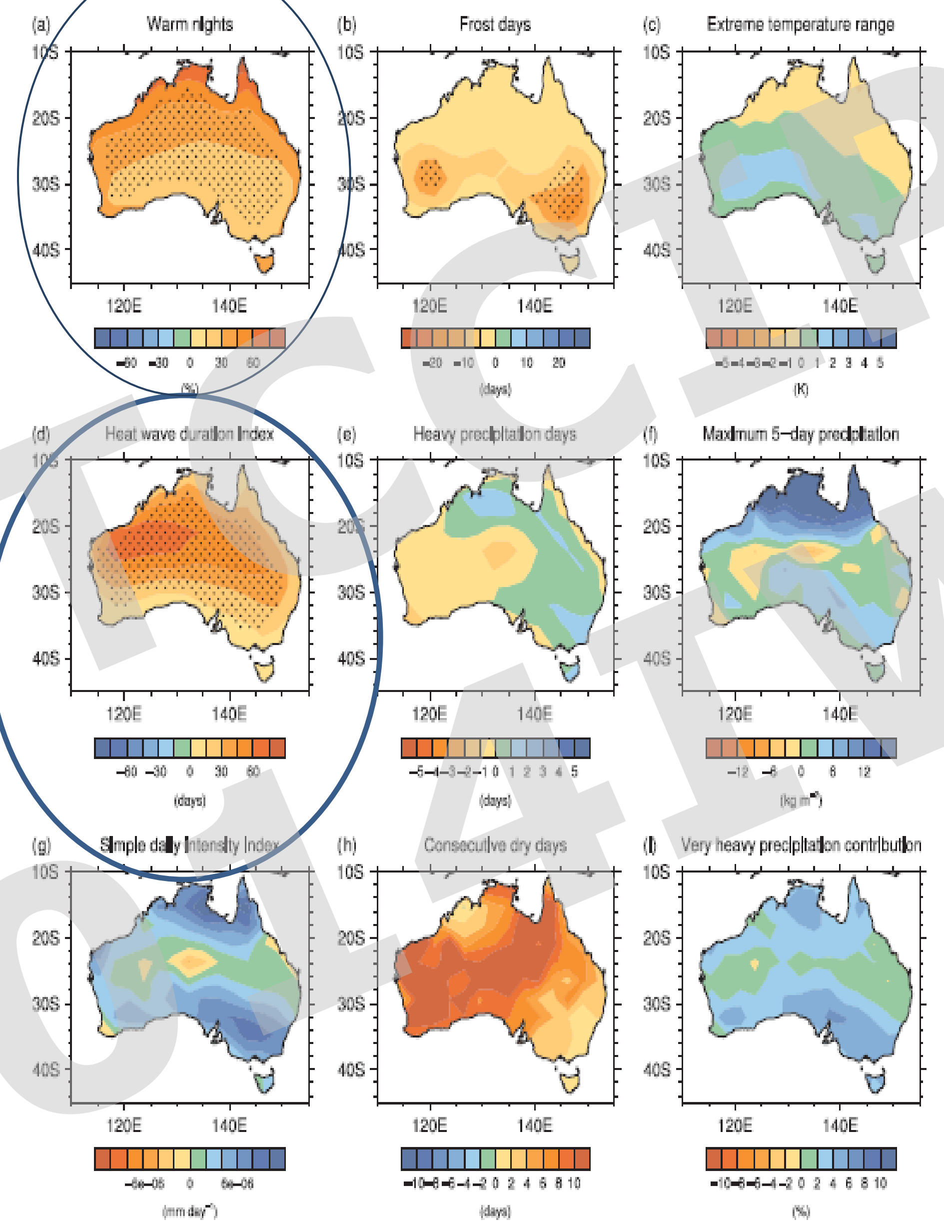


Figure 10. Ensemble mean projected changes (2080–2099 minus 1980–1999) in the extremes indices used in this study (Table I) from the CMIP3 multi-model dataset SRES A1B scenario. Stippling indicates that at least five out of nine models agree that the change is significant (Tebaldi *et al.*, 2006).

<u>Drought issues:</u>

Important changes are being projected in some key variables related to heat stress – note the increases in 'warm nights; and 'heat wave duration'.

(Climate model ensemble mean projected changes (2080-2099 minus 1980-1999) in extremes from the CMIP3 (Tebaldi et al., (2006) in Alexander and Arblaster, 2009).

Box 3: Statistical estimates of future exceptionally low rainfall

The range of changes in exceptionally low rainfall in response to projected reductions in mean rainfall can be estimated statistically (see Supplementary Information). In Figure 9, the probability of future exceptionally low rainfall (relative to the historical record) is graphed against the percentage reduction in mean annual rainfall (see also selected results in Table 6).

A 10 per cent decrease in mean annual rainfall across most of Australia is a possible scenario by 2030 (see Section 3). This decrease roughly doubles the risk of exceptionally low rainfall in five of the study regions, and almost triples the risk for the Vic&Tas and SW WA regions. A 20 per cent mean rainfall decrease triples the risk of exceptionally low rainfall in the same five regions and increases by more than six-fold the risk for the Vic&Tas and SW WA regions.

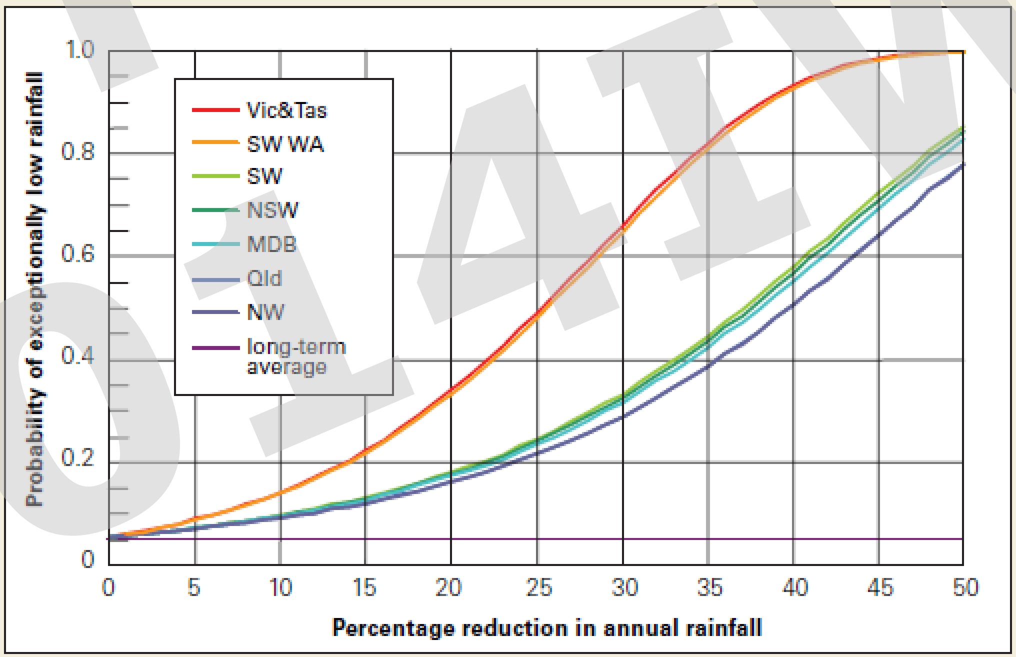


Figure 9. Probability of exceptionally low rainfall for mean rainfall decreases of up to 50% in the seven regions. The results for the Qld and NW regions are almost identical and overlap.

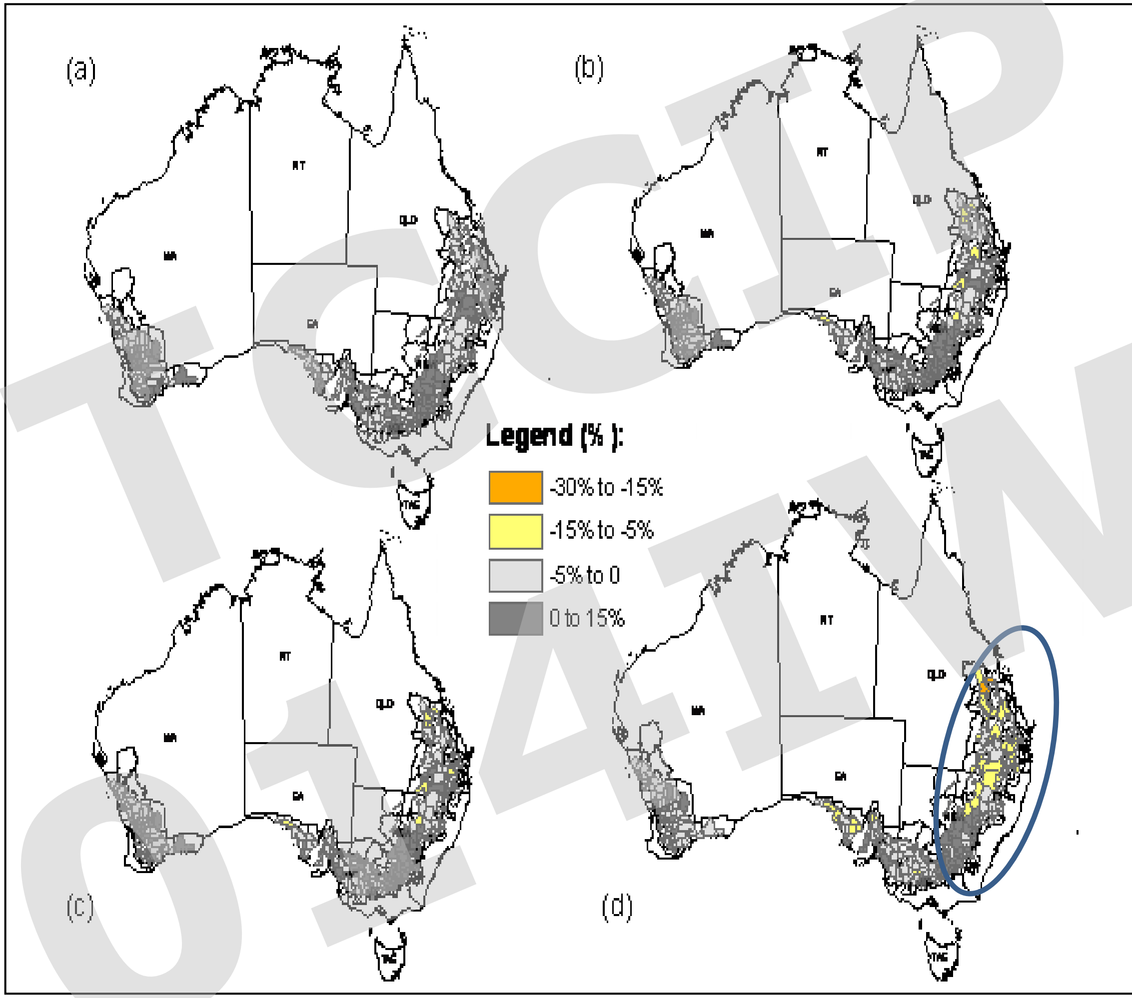
Table 5. Present (1964-2003) and projected number of days above 35°C at 20 Australian locations. Low (L) and high (H) scenarios are based on data shown in Fig. 14. All values are rounded to the nearest integer.

City	*Present*	*2020*		*2030*		*2040*		*2050*		*2060*		*2070*		*2080*	
		L	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*	*L*	*H*
Adelaide	17	18	23	19	25	19	29	20	32	21	39	22	46	22	53
Alice Springs	89	94	114	96	125	99	129	101	153	104	173	106	191	108	207
Brisbane	1	1	2	1	3	1	4	1	7	2	13	2	26	2	42
Broome	54	61	90	64	119	69	163	72	208	80	258	84	293	87	316
Cairns	3	4	7	4	9	4	19	5	34	5	74	5	119	5	159
Canberra	5	6	9	6	12	6	15	7	19	7	27	8	35	8	45
Charleville	65	70	91	72	105	75	108	77	135	80	157	82	177	83	195
Cobar	41	44	57	45	65	47	68	48	92	50	111	51	127	52	144
Coffs Harbour	2	2	2	2	2	2	3	2	4	2	7	2	11	2	16
Darwin	11	15	46	18	73	20	123	23	177	27	256	31	305	31	332
Halls Creek	156	164	189	166	205	172	218	175	241	179	268	182	290	185	307
Kalumburu	140	153	197	158	230	167	262	171	291	178	320	185	337	187	346
Launceston	0	0	0	0	0	0	1	0	1	0	2	0	3	0	4
Longreach	115	121	147	123	163	129	164	131	199	134	222	136	239	139	256
Melbourne	10	10	13	10	15	11	17	11	21	11	26	12	31	12	36
Mildura	33	35	42	35	47	37	53	38	61	39	74	40	85	40	98
Perth	27	28	35	29	38	30	43	31	48	32	58	33	68	33	79
Sydney	3	4	5	4	6	4	7	4	9	4	13	4	18	4	26
Townsville	4	5	8	5	12	5	21	6	36	6	77	7	127	7	164
Woomera	51	54	64	56	70	58	78	59	88	60	104	62	120	63	135

Major increases in the projected number of days above 35C at key Australian locations (using the approach of Suppiah et al (2007; 2010)

2020

2050

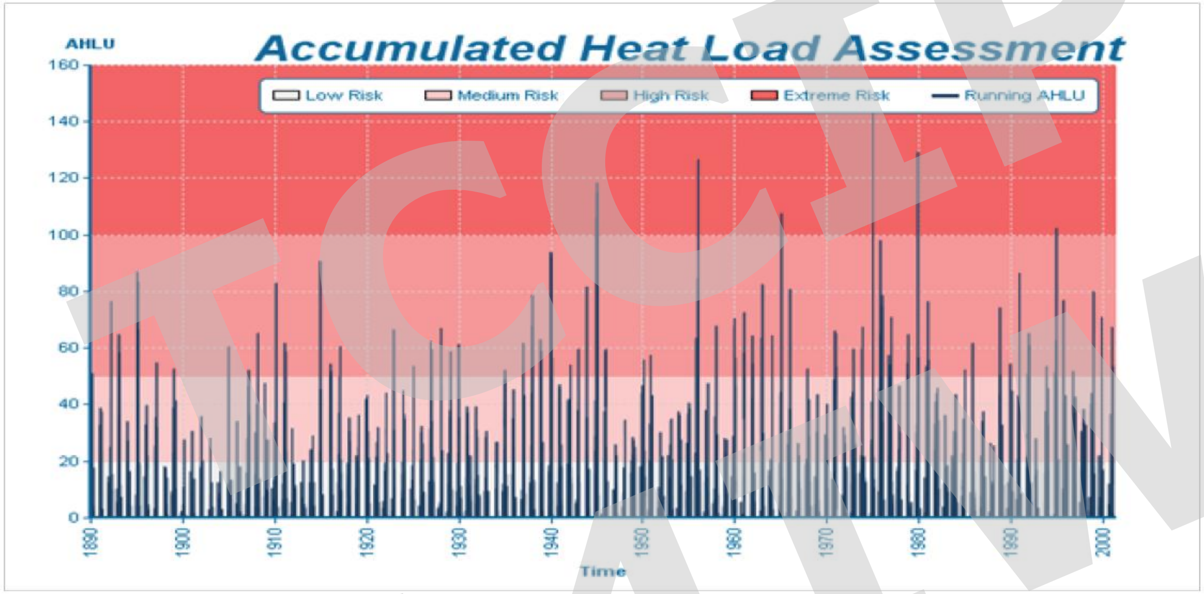


Future Australian agricultural production - wheat yields - Percentage shire yield change for low and high CO_2 emission rates for 2020 (a – low, b – high) and 2050 (c – low, d – high) (Potgieter et al., 2008; 2012) CSIRO climate model outputs.

Simulated median % change in days to flowering (DTF), fallow rainfall, in-crop rainfall and yield, for 2020 and 2050 CC scenarios (Potgieter et al., 2008).

NSW	2020 Low	2020 High	2050 Low	2050 High
DTF	-3	-6	-6	-15
FallowRain	-1	-3	-3	-8
InCropRain	-2	-6	-6	-14
Yield	0	0	0	-2
QLD				
DTF	-3	-6	-6	-14
FallowRain	-2	-4	-4	-10
InCropRain	-3	-8	-8	-15
Yield	0	-1	-1	-5
SA				
DTF	-3	-6	-6	-14
FallowRain	-1	-2	-2	-5
InCropRain	-3	-6	-6	-11
Yield	0	0	0	-3
VIC				
DTF	-3	-6	-6	-14
FallowRain	-1	-2	-2	-5
InCropRain	-3	-5	-5	-15
Yield	0	-1	-1	-2
WA				
DTF	-3	-7	-7	-15
FallowRain	0	-1	-1	-3
InCropRain	-2	-6	-6	-12
Yield	0	0	0	-1

Excessive Heat Load for feedlot cattle - 20th Century Reanalysis has provided improved long-term assessment of the return periods and trends of the Accumulated Heat Load Index.



ALHI for the Darling Downs, Australia

• Utilising the 20th Century Reanalysis Process, the AHLI has now been calculated from the 100 year reanalysis data – **results shows that in the *Darling Downs region* the AHLI has *reached extreme risk levels on six occasions in 100 years – and the number of high or extreme values appears to be increasing.***

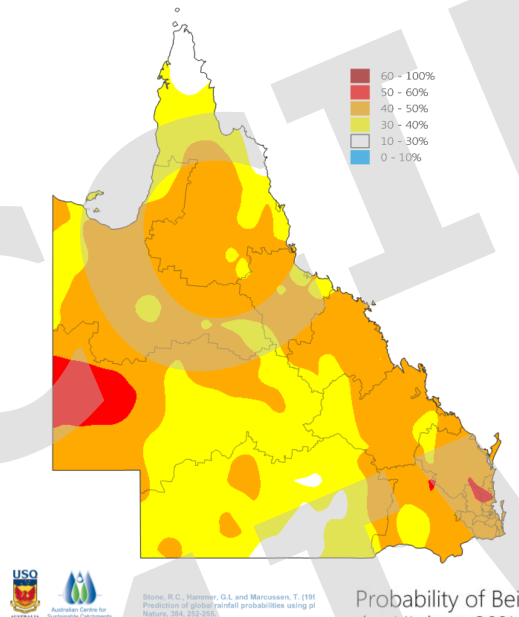
•**The ALHI also used to calculate recovery times from excessive heat load (EHL). (The best recovery from heat load occurs when the HLI below 74 between four to six hours during the night. - longer periods may be needed if exposure to EHL has been prolonged**).

<u>Using Seasonal Climate Forecasting so users may make incremental adjustments –</u>

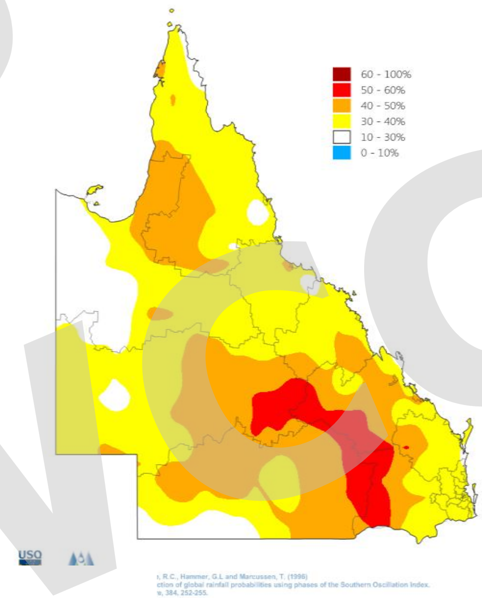
eg extremes and key components of heat stress – this offers the capability for improved preparedness for climate extremes: the ability to forecast extreme levels <u>for the coming season</u> of Probability of being in Highest 20% of <u>Maximum and Minimum Temperatures and in Relative Humidity</u> :

(Stone et al., *Nature*, 1996b; Stone and Marcussen, 2012).

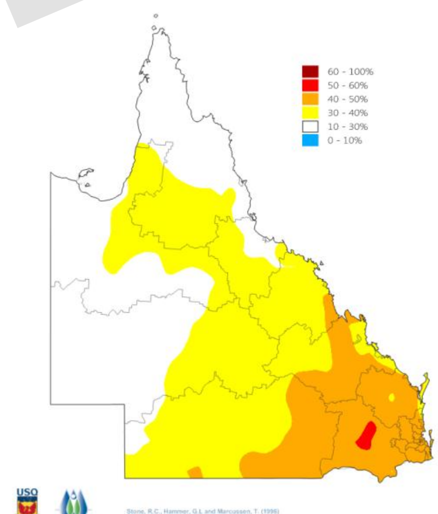
Probability of Being in
the Highest 20% of Maximum Temperatures
January / March
Based on Consistently Negative phase
during November / December

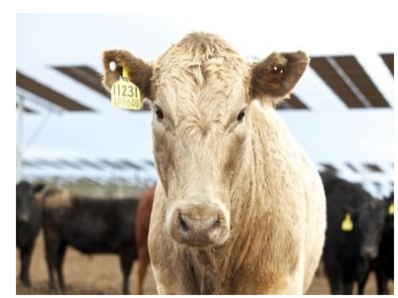


Probability of Being in
the Highest 20% of Minimum Temperatures
January / March
Based on Consistently Negative phase
during November / December

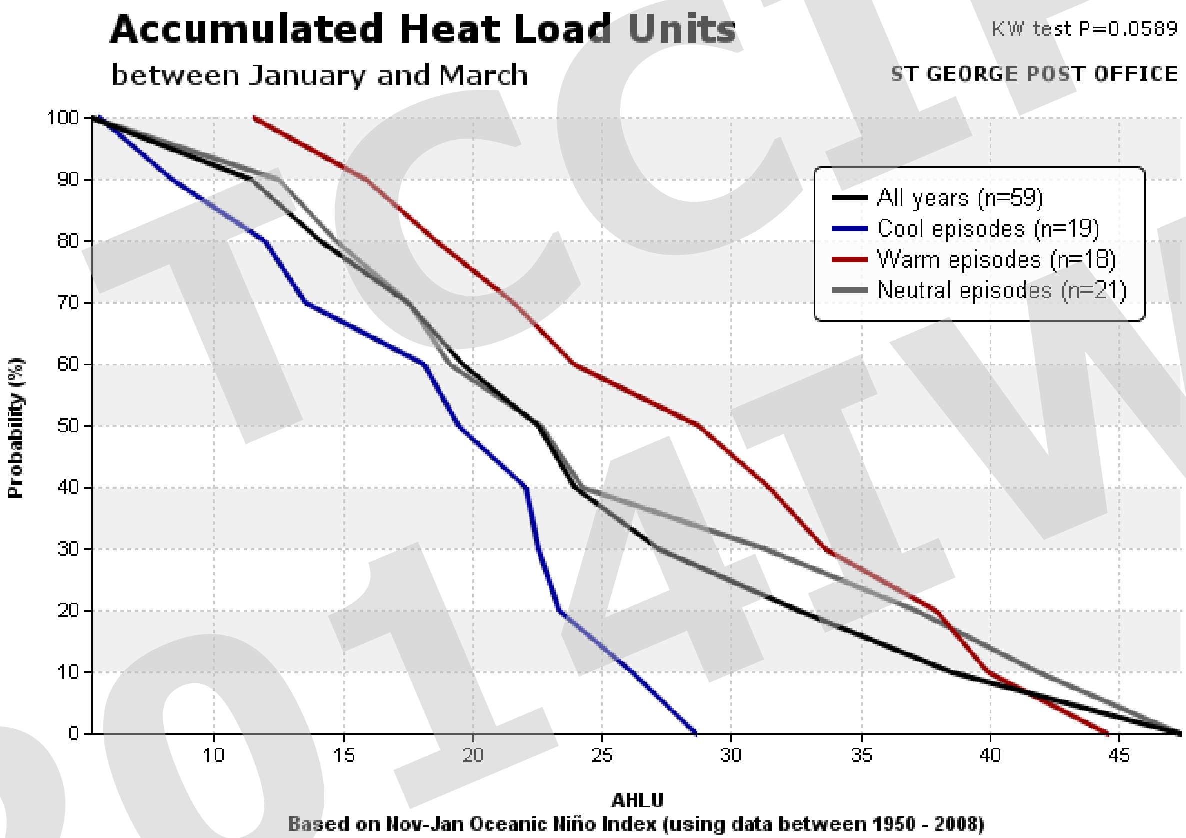


Probability of Being in
the Highest 20% of Relative Humidity
January / March
Based on Consistently Positive phase
during November / December





Combining all elements - Forecasting Accumulated Heat Load Units for the coming season using key climate systems – El Niño and La Niña



'Warm episodes' = El Niño pattern in the Pacific Ocean at end of December – mean number of heat load units Jan to March=28.

'Cool episodes' = La Niña pattern in the Pacific Ocean at end of December - mean number of heat units Jan to March=19.

Probability of exceedence distributions - Number of excessive heat load units exceeding critical thresholds according to ENSO types – example for St George, southern inland Queensland.

Adaptation to climate change – example of value of plant breeding programs - TC Larry: Effects of Polysora Rust on maize in North Queensland: ability to better withstand impacts of through plant breeding programs!!

Key examples - Grains.

- **Development of crop varieties with appropriate thermal time** and vernalisation requirements, heat shock resistance, drought tolerance (i.e. 'staygreen wheat'), high protein levels, resistance to new pest and diseases and capability to set flowers in hot/windy conditions.

- ***Alter planting rules* to be *more opportunistic*** depending on environmental condition (soil moisture), climate (e.g. frost risk), markets.

- **Develop further risk amelioration approaches** (zero tillage/other minimum disturbance techniques, retaining residue, extending fallows, row spacing, planting density, staggering planting times, erosion control infrastructure) controlled traffic approaches.

- **Provide tools and extension** to enable farmers to access climate data **at the scale needed** for their decisions/analyse alternative management and land use options including in real-time using approaches akin to DSS 'Yield Prophet'.

- **Research and revise soil fertility management** (fertilizer application, type and timing, increase legume phase in rotations) on an ongoing basis.

- **Analyse value-chain** and regional adaptation options that translate climate scenarios into meaningful quantities for the stakeholders involved and that include technical, managerial, structural and policy.

Key example - Cotton.

•**Improve whole-farm and crop water use efficiencies** by enablin further improvements in water distribution systems (to reduce leakag and evaporation) irrigation practices such as water application metho irrigation scheduling and utilizing moisture monitoring techniques.

•**Select varieties with appropriate: heat shock resistance, drought tolerance,** higher agronomic water use efficiency, improved fibre quality, resistance to new pest and diseases (including introgression of new transgenic traits).

•**Provide information to cotton growers on the likely impacts at their business level** (downscaling climate change predictions to regional scales). Maintain R&D capacity, undertake further adaptation studies which include costs/benefits and streamline rapid R&D responses.

•**Conduct research into the development of cotton systems in northern Australia**. Research the integrated affects of climate change (temperature, CO2, and water stress) on cotton growth and yield need further analysis.

•**Conduct research into avoiding resistance of pests (both insects and** weeds) through appropriate integrated pest and weed management systems to maintain transgenic technologies.

•Enhance capacity to predict and forecast pest issues in relation to climate change and variability…

Key example: Rice.

- Assess cost-benefits of **investing in *more efficient irrigation methods*** and farm layouts, as a function of soil type and location.

- Consider cost-benefit of ***reducing water conveyancing*** losses both on-farm and in irrigation districts.

- Increase water productivity of cropping systems, through *continuing efforts to reduce rice water use, consideration of new crops and rotations, irrigation technologies* and farm layouts.

- Assess potential for aerobic and alternate-wet-and-dry (AWD) rice culture in Australian environments; investigate potential benefits and limitations; define optimal water management strategies.

- Develop approaches to managing water resources that *take into account climate change projections* ***as well as seasonal to decadal drivers of climate variation*****.**

(Stokes and Howden, 2008) .

Key example - Grazing.

•**Promote and enhance use of seasonal climate forecasts in grazing management**, and incorporate considerations of projected trends in climate change.

•Research and promote greater use of strategic spelling and other improvements in grazing land management that reduce exposure to risks of climate variability and uncertain climate change.

•**Develop tools to determine regional safe stocking rates** and pasture utilization levels linked to seasonal and projected climate conditions.

•Improve breeding and management of animal heat stress, particularly where livestock are handled more intensively.

•Develop guidelines or building codes for energy and water efficient production sheds, particularly focussing on passive cooling or heating. Link these to revised capability to assess heat stress on livestock.

•Understand the risks to feed supplies due to climate and variability or reduction through competition from other users of feedstock.

Key issues – summary/conclusions.

Australia has the highest level of rainfall variability in the world – and this variability is increasing in many key agricultural zones.

Major trends occurring in both temperature (incl min temp) and precipitation – although in a country as large as Australia these trends are not uniform across the country.

Key in agricultural applications is to recognise management responses relevant to varying the temporal scales in climate systems - these intersect with the long-term temporal scale of climate change.

Further key in agricultural applications is to address issues across the entire value-chain in agricultural systems.

Need to include integrated climate-agricultural modelling systems, although the challenge is to address scale issues between GCMs and crop/pasture models.

Value in utilising 20th Century reanalysis and similar to detect important shifts in major impact variables – such as heat stress in feedlots.

Value in utilising aspects of seasonal climate forecasting to assist capability to manage increased levels of climate variability – and to assist incremental shifts in agricultural management on a year to year basis.

Summary/Conclusions Cont'd:

Utilise options that are extensions or enhancements of existing activities and **aimed at managing the impacts of existing climate variability**.

Climate change (adaptation) R&D needs to be *undertaken in a participatory way with industry groups* so as to deal effectively with their key concerns, draw on their valuable expertise.

Develop crop varieties with appropriate thermal time and vernalisation requirements, heat shock resistance, drought tolerance (i.e. 'staygreen wheat'), high protein levels, resistance to new pest and diseases and capability to set flowers in hot/windy conditions.

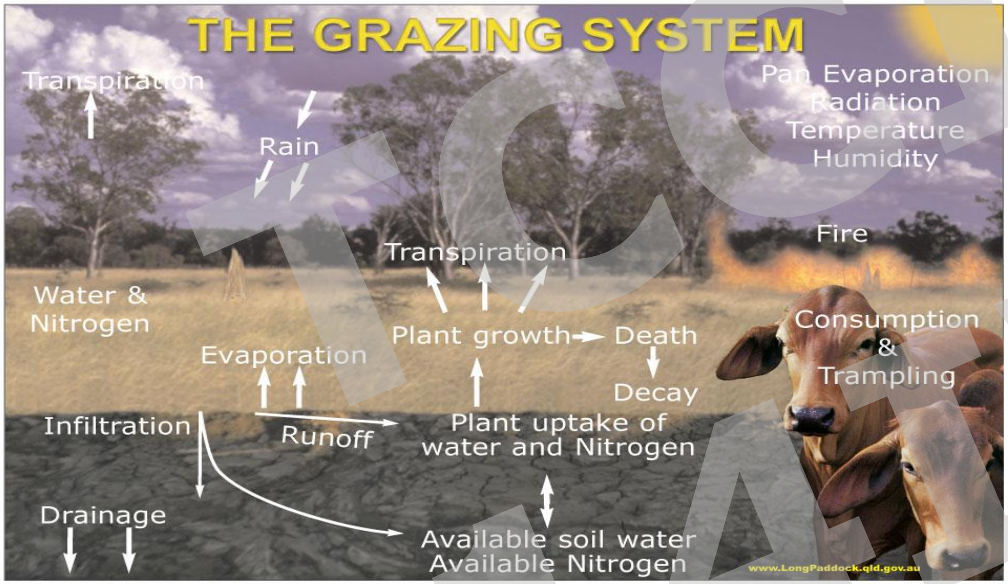
Improve whole-farm and crop water use efficiencies by enabling further improvements in water distribution systems (to reduce leakage and evaporation) + irrigation practices such as water application methods, irrigation scheduling/moisture monitoring techniques.

Increase water productivity of cropping systems, through efforts to reduce rice water use, use of new crops and rotations, irrigation technologies.

Improve breeding and management of animal heat stress, particularly where livestock are handled more intensively such as feedlots.

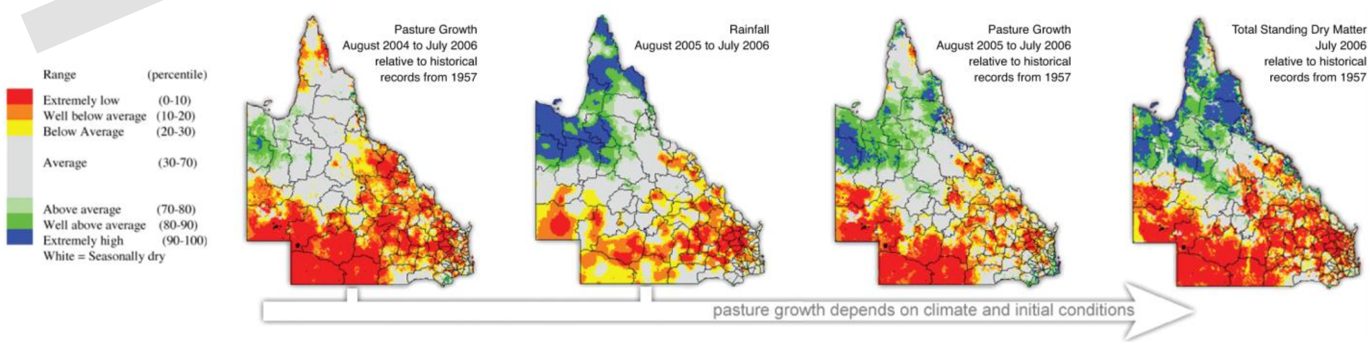

THANK YOU
Flávio Gassen

AussieGRASS Pasture Model



- Pasture growth & water balance daily model run nationally each month
- Products: rainfall, pasture biomass, growth, cover, ‘streamflow’, soil moisture
- Products in near real time as absolute values and percentiles relative to >100 years
- Linked to climate outlook to provide climate risk assessment
- General environmental calculator

Rangeland condition depends on more than cumulative rainfall e.g. pattern of rainfall; soil moisture; grass basal area; grazing etc



Climate assessment for the Wyaralong Catchment and Mary River areas of South-East Queensland.

<u>Use seasonal forecasting </u>to gain incremental advances in management

6 October 2010

Roger Stone, Torben Marcussen, Shahbaz Mushtaq;
Australian Centre for Sustainable Catchments, University of Southern Queensland

As the La Niña pattern continues to become stronger the probability of higher than normal rainfall and streamflow will increase as the year progresses. There are aspects related to an excessively wet summer and associated flood risk for some areas including SE Qld.

Sugar.

Improve farming practices, especially precision irrigation, on-paddock water use and off-paddock water quality impacts and the management of increased climate variability through seasonal forecasting.

Promote innovative farming and processing systems that take an integrated and sustainable approach to risk and opportunity across all inputs.

Capitalise bio-energy opportunities and carbon trading potential for value adding, preferably integrated within innovative farming and processing systems to maximise cross industry benefits.

Focus research on sugarcane physiology and plant improvement in varietal characteristics that enhance resilience to climate change, linked to industry adaptation to higher temperatures, reduced water availability, and extreme events. This will also require knowledge of the genetic x environment x management (G*E*M) interactions.

Enhance human capital through building skills and enhance science capability in climate understanding and risk management across the sugarcane industry.

Include climate change considerations in biosecurity management.
Develop an understanding of the global context of climate change impacts on worldwide production, profitability and markets relative to the Australian sugarcane industry.

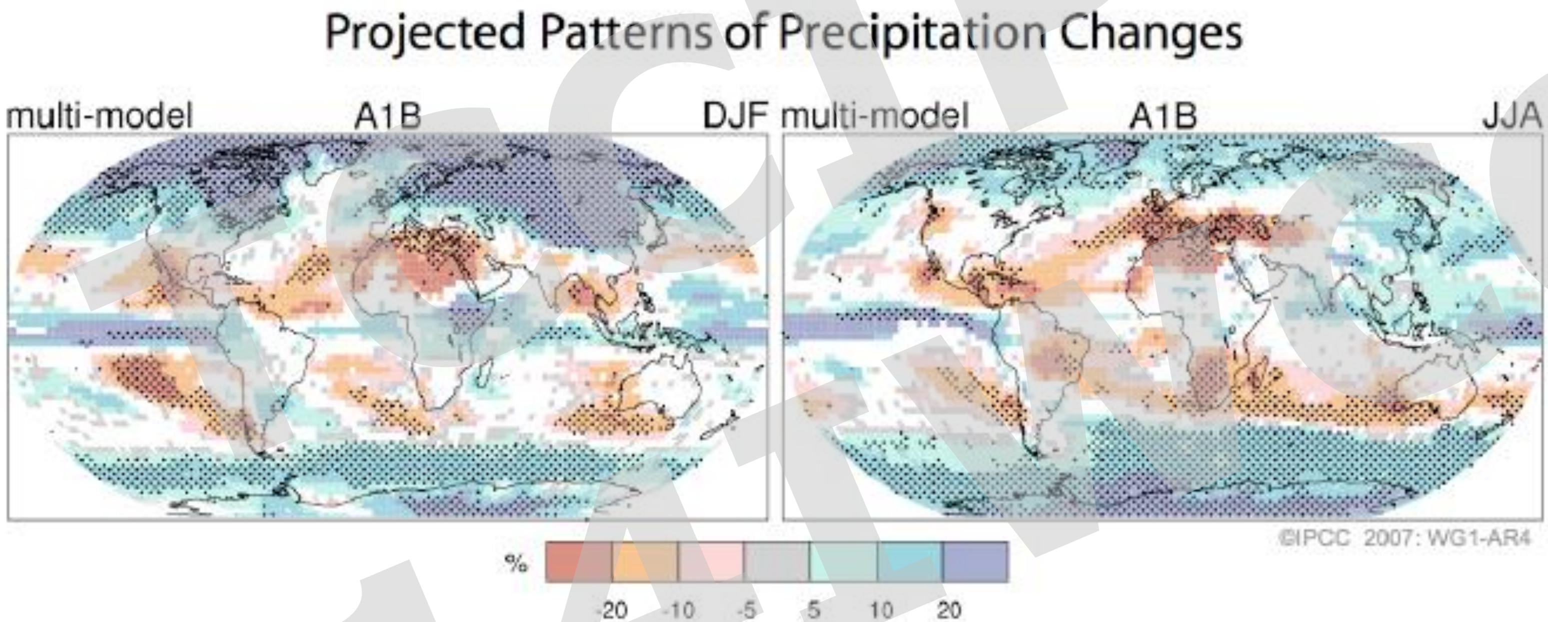
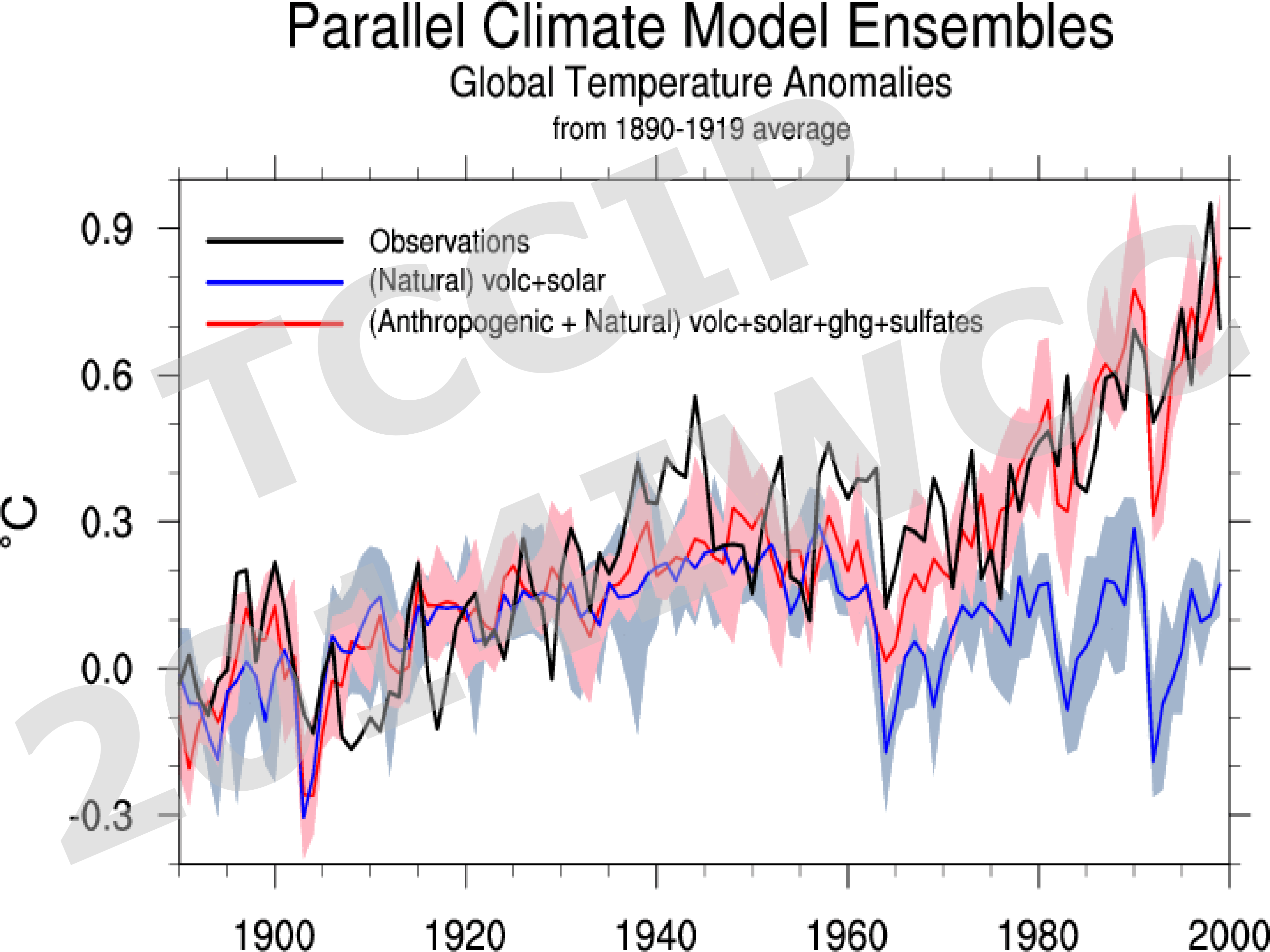
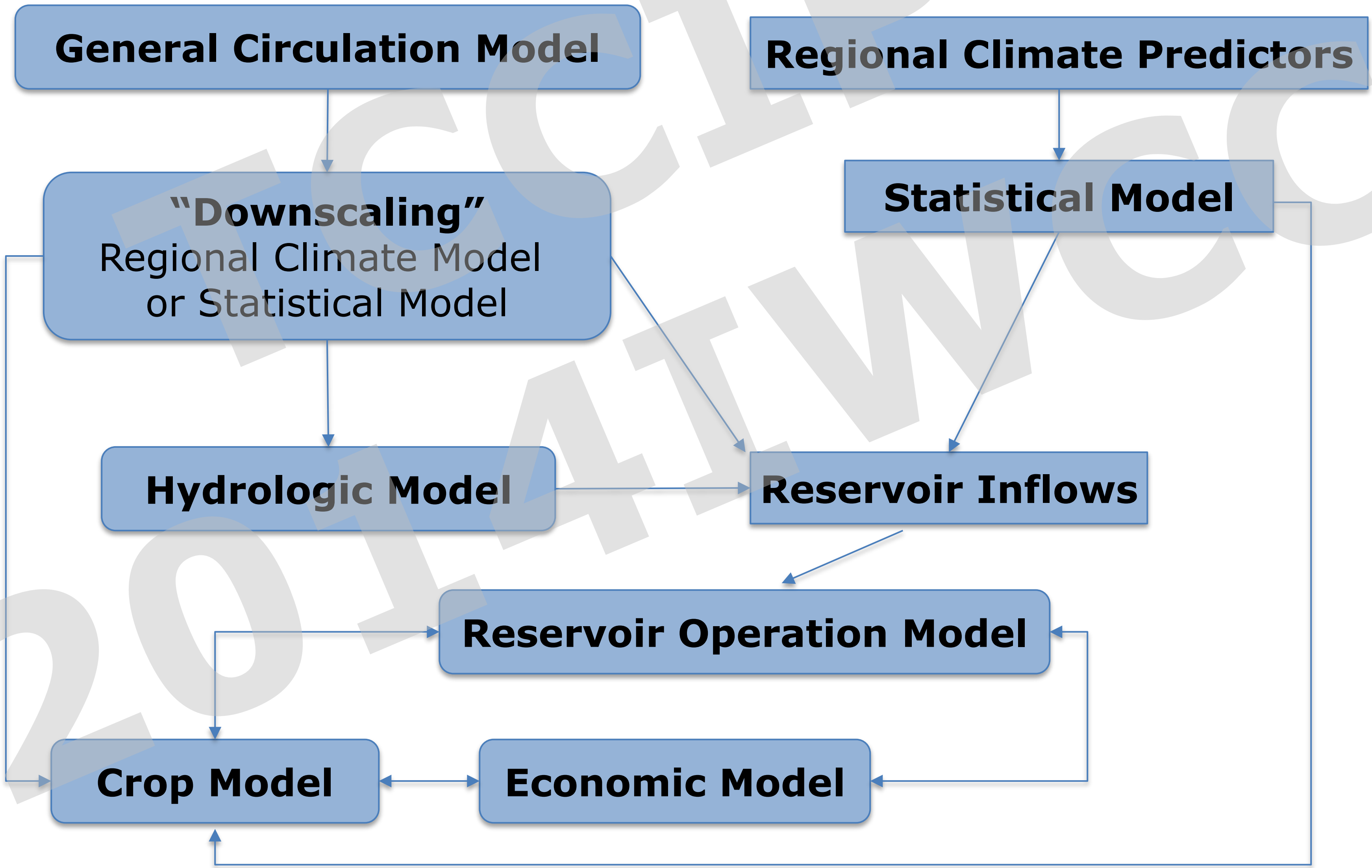


FIGURE SPM-6. Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}



Parallel Climate Model Ensembles
Global Temperature Anomalies
from 1890-1919 average
Observations
(Natural) volc+solar
(Anthropogenic + Natural) volc+solar+ghg+sulfates
°C
0.9
0.6
0.3
0.0
-0.3
1900
1920
1940
1960
1980
2000

Assisting sustainable catchment management under climate variability and climate change - key aspect: *integrated* climate and hydrological models – underpinning climate science capability



combination with clear skies can also increase tissue temperature to approach or exceed air temperature. Two known consequences of direct tissue damage from severe heat stress are:

- Parrot Beaked Bolls – High temperatures reduce the viability of the pollen at flowering. This reduces boll size and can reduce yield. The result is small bolls with uneven seed numbers between the locks caused by poor pollination /seed set particularly in one lock. There are no known studies to show if the plant compensates for parrot beak bolls by having other normal bolls grow bigger.

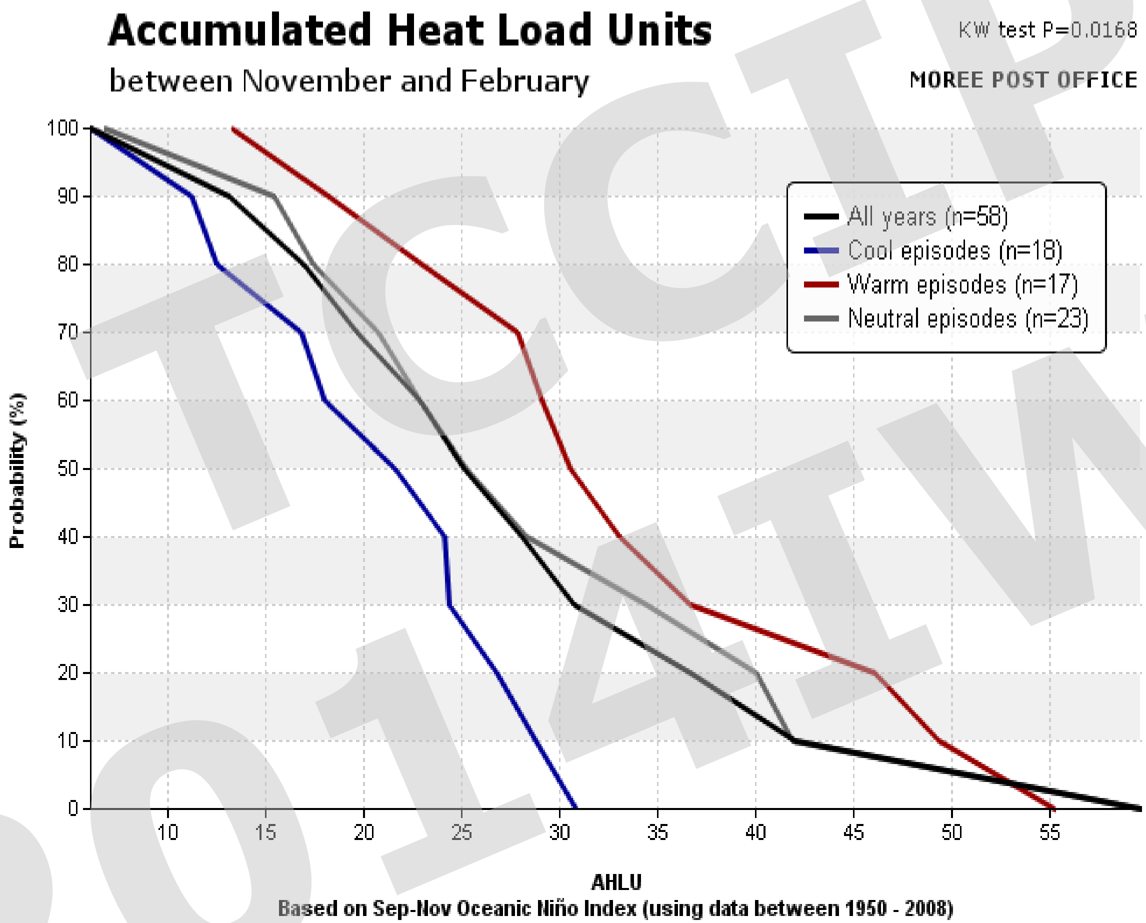
- Boll Freeze, Cavitation or Boll Dangle – Occurs when young bolls die before the abscission layer forms. Again this loss of fruit may cause the crop to grow excessively vegetatively (rank) following these symptoms.

Large increases in temperature also reduce the interval between flowering and boll opening, shortening the time to maturity and reducing yield. This may increase final micronaire by limiting the number of late set bolls that can have lower micronaire. Fibre length can also affected by sustained periods of high temperatures as the time required for fibre elongation is reduced, not allowing for genetic potential for fibre length to be reached. Stockton and Walhood (1960) found that as boll

Most Australian cotton farms are owned and operated by family farmers, are typically betwee
2000 hectares, are highly mechanised, capital intensive, technologically sophisticated and req
levels of management expertise. About 80 per cent of cotton farms are irrigated and as pa
enterprise mix generally grow other crops such as wheat and sorghum and/or graze sheep and

Figure 3.1: Australian cotton growing regions (Cotton Catchment Communities CRC)

Combining all elements - Forecasting Accumulated Heat Load Units for the coming season using key climate systems – El Niño and La Niña



Warm episodes' = El Niño pattern in the Pacific Ocean at end of October– mean number of heat load units November to February=30.

'Cool episodes' = La Niña pattern in the Pacific Ocean at end of December - mean number of heat units Jan to March=21.

Also, the diagram shows there is just a 30% risk of more than 25 ALHUs following a La Niña event compared to almost an 80% risk following development of an El Niño event.

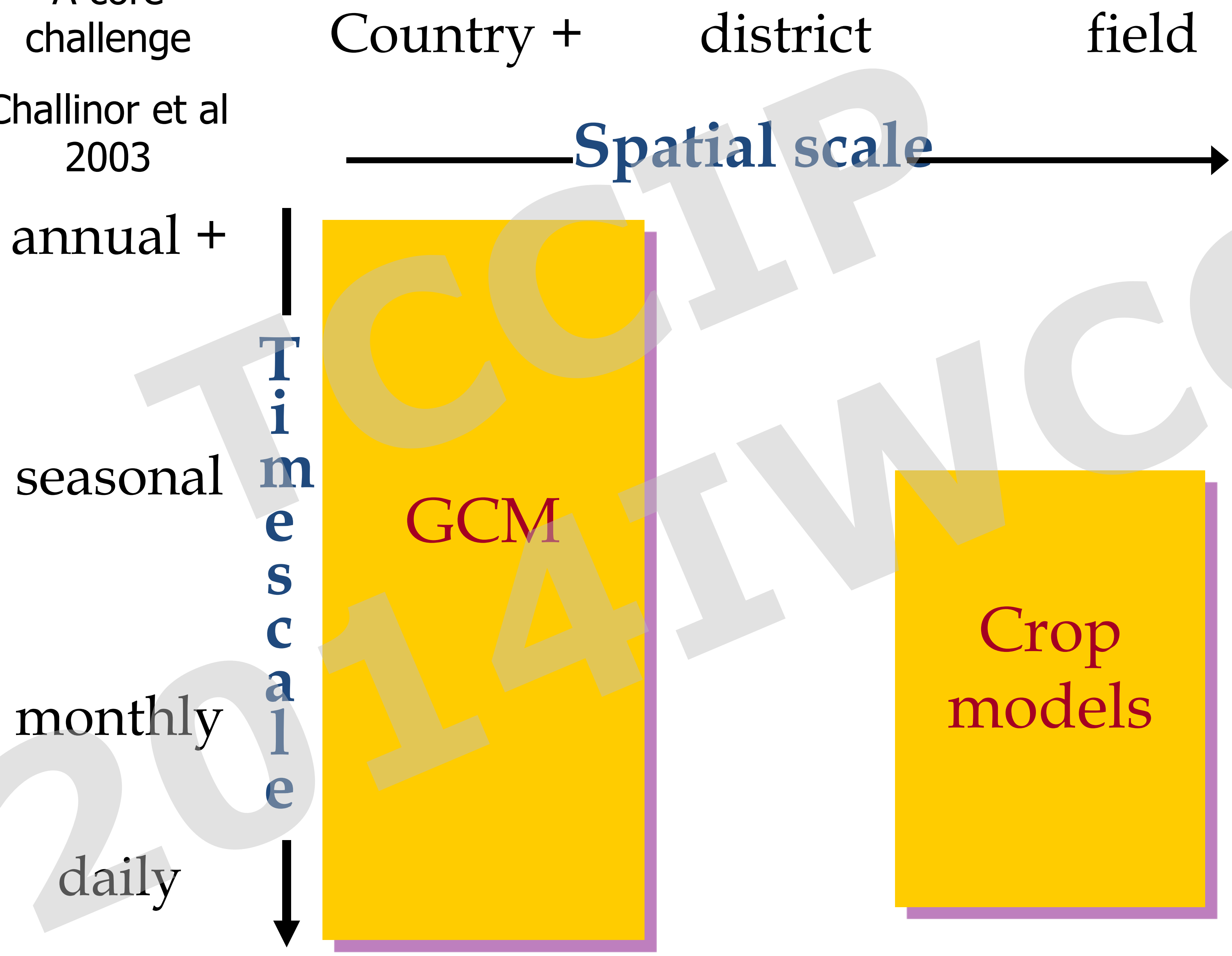
Number of excessive heat load units exceeding critical thresholds according to ENSO types – example for Moree, northern inland New South Wales.

Careful selection of GCMs

GCM	Description
Hadley Centre (UK)	HADCM3
Geophysical Fluid Dynamics Laboratories (US)	GFDL2.0 -also referred to as GFCM2.0.
Geophysical Fluid Dynamics Laboratories (US)	GFDL2.1 -slightly different structure to GFDL2.0 - also referred to as GFCM2.1
Center for Climate System Research (CCSR), Japan	MIROC 3.2
Max Planck Institute for Meteorology DKRZ (Germany)	ECHAM5 - also referred to as MPEH5.

A core challenge

Challinor et al 2003



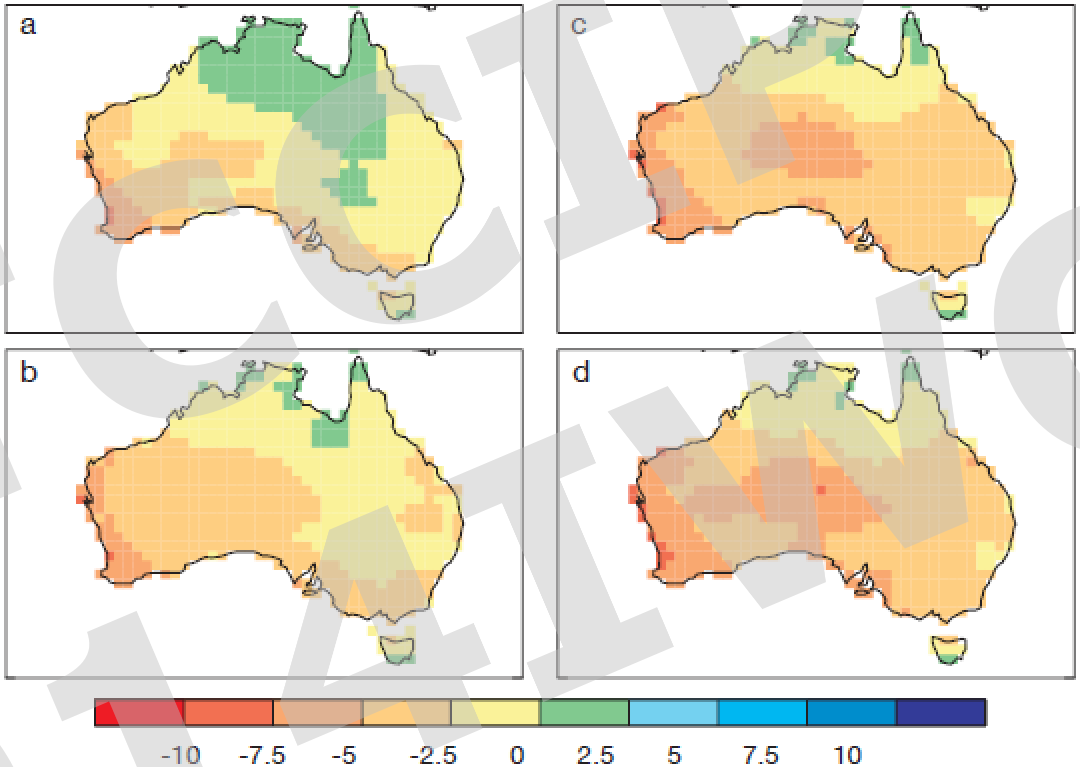


Figure 5.14: Change in annual precipitation across Australia scaled by amount of global warming (unit % per ºC) averaged over the CMIP3 models, using four different approaches: **(a)** means for 2070-2099 relative to 1990-2005; **(b)** the multi-model mean trend in precipitation in mm per day, as a percentage of the multi-model mean for the standard period 1961-1990; **(c)** the mean of trend as a percentage; **(d)** as **(c)** but using the model weights (from Table 4.1).

Climate Change Projections CSIRO/BoM (2008)

Temperature - percentage area

Region	1900-2007	2010-2040 low	2010-2040 mean	2010-2040 high
Qld	4.6	48.9	62.2	73.8
NSW	4.5	43.5	62.1	81.0
Vic&Tas	4.6	60.5	76.1	95.0
SW	4.6	49.1	68.4	86.3
NW	4.6	50.0	63.5	82.0
MDB	4.5	45.2	64.9	90.1
SW WA	4.6	63.1	81.9	97.1

Table 4. Simulated percentage area having exceptionally hot years for 1900-2007 and 2010-2040, based on 13 climate models. The low and high scenarios represent the lowest and highest 10% of the range of model results.

Australian Government

Bureau of Meteorology

CSIRO

Rainfall – percentage area

Region	1900-2007	2010-2040 low	2010-2040 mean	2010-2040 high
Qld	5.5	1.7	5.8	9.7
NSW	5.6	2.2	5.6	10.9
Vic&Tas	5.4	3.0	9.7	13.9
SW	5.6	5.0	8.4	12.1
NW	5.6	1.8	5.3	8.0
MDB	5.6	2.7	6.0	11.1
SW WA	5.5	9.0	18.4	26.5

Table 7. Simulated percentage area having exceptionally low annual rainfall for 1900-2007 and 2010-2040, based on 13 climate models. The low and high scenarios represent the lowest and highest ten per cent of the range of model results.

Soil moisture – return periods

Region	1957-2006	50 years centered on 2030		
		Low	Mean	High
Qld	16.5	19.4	12.6	9.3
NSW	16.4	22.0	14.0	10.2
Vic&Tas	16.8	14.3	9.4	7.5
SW	16.3	15.1	11.5	8.8
NW	16.3	21.7	13.5	10.3
MDB	16.2	19.8	13.4	9.6
SW WA	17.0	7.0	6.0	4.9

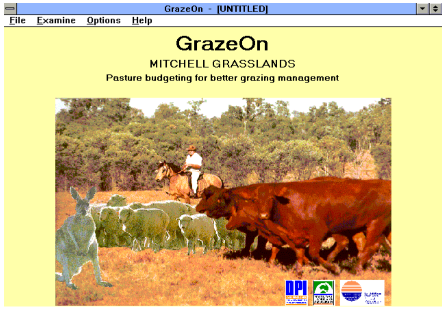
Table 10. Simulated return periods (years) for exceptionally low annual-average soil moisture for 1957-2006 and 50 years centred on 2030, based on 13 climate models. The low and high scenarios represent the lowest and highest ten per cent of the range of model results.

Adapting to climate change - potential options”

•*Many options are extensions or enhancements of existing activities that are aimed at* ***managing the impacts of existing climate variability*** and improving the sustainability and efficiency in the use of natural resources.

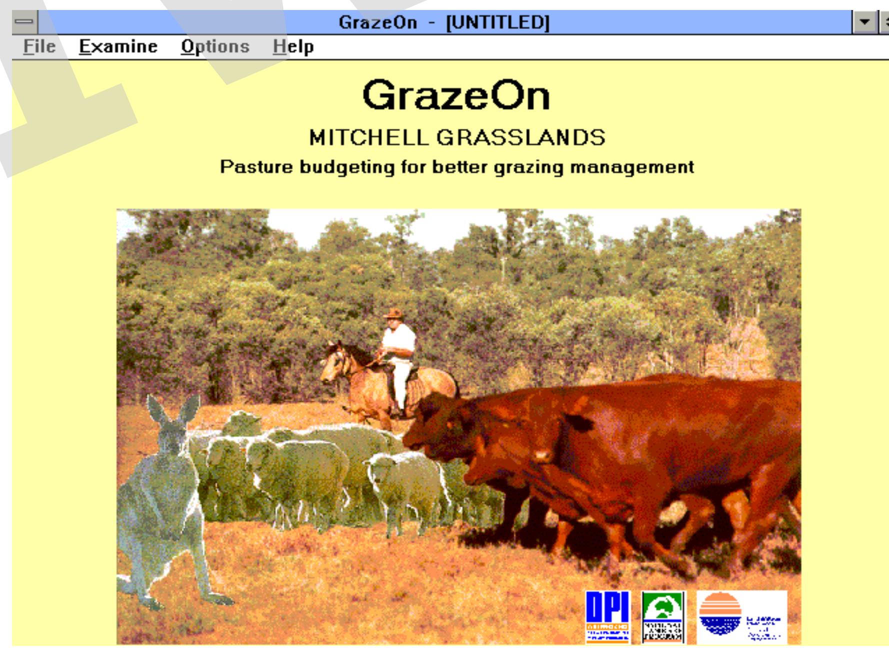
•Few of these potential adaptation options have been evaluated for their utility in reducing the risks or taking advantage of climate change impacts! - Only a couple of adaptations have been evaluated in relation to the broader costs and benefits of their use.

•Analyses show that practicable and financially-viable adaptations will have very significant benefits in ameliorating risks of negative climate changes and enhancing opportunities where they occur - benefit to cost ratio of undertaking R&D into these adaptations is very large (indicative ratios greatly exceed 100:1)(Stokes and Howden, 2008).



- This **R&D needs to be undertaken in a *participatory way*** with industry groups so as to deal effectively with their key concerns, draw on their valuable expertise and also contribute to enhanced knowledge in the agricultural community.

- A key recommendation is to **progress more adaptation studies which *analyse the costs and benefits of implementation of adaptations*** (including socio-economic aspects as well as potential feedbacks through greenhouse emissions).



Key issue - Water Resources.

•**Develop approaches to managing water resources that *take into account climate change projections as well as seasonal to decadal drivers of climate variation*.**

•*Evaluate the costs and benefits of:* increasing on-farm and systems efficiencies via better use of technology, co-ordination of delivery mechanisms, evaporation control, retrofitting leaky systems, the provision of probabilistic seasonal forecasts, improved scheduling and better understanding of what is needed to implement such measures in a range of different circumstances.

•*Incorporate climate change considerations more effectively into integrated catchment management*, addressing the relationships between water quality, surface and groundwater extraction, waterway management and land-use,. Institutional arrangements may need reviewing to encourage such integration.

•Evaluate the *implications of moving to full cost pricing and water trading* so as to maximise the potential for adaptation and minimise perverse incentives.

•*Evaluate whether there are clear thresholds in irrigated agriculture* (e.g. loss of flows from the Murray Darling Basin leading to the death of tree crops; in-stream salinity becoming too high for irrigation)..