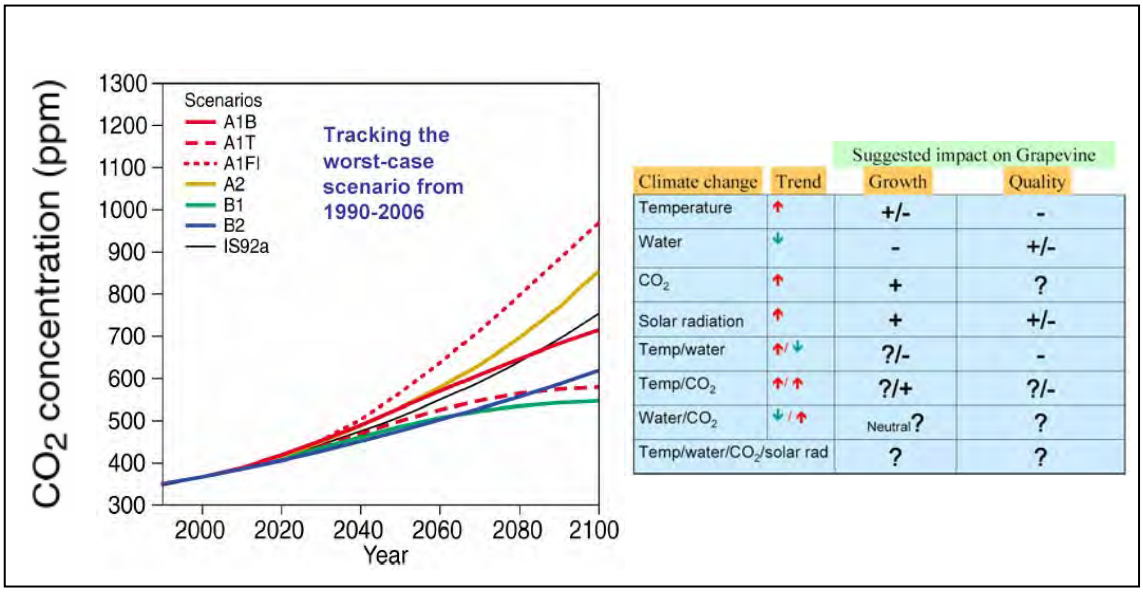
THE UNIVERSITY OF ADELAIDE
AUSTRALIA

Wine 2030

Australian Government
Grape and Wine Research and Development Corporation

Workshop to scope a grapevine FACE facility.



Climate change	Trend	Suggested impact on Grapevine: Growth	Quality
Temperature	↑	+/-	-
Water	↓	-	+/-
CO_2	↑	+	?
Solar radiation	↑	+	+/-
Temp/water	↑/↓	?/-	-
Temp/CO_2	↑/↑	?/+	?/-
Water/CO_2	↓/↑	Neutral?	?
Temp/water/CO_2/solar rad		?	?

FINAL REPORT to

GRAPE AND WINE RESEARCH & DEVELOPMENT CORPORATION

Project Number: **GWRDC 07/01**

Principal Investigator: **Professor Steve Tyerman**

Research Organisation: **University of Adelaide**

Date: **14th August 2008**

Workshop to scope a grapevine FACE facility.

Held May 27th and 28th Adelaide

Professor Steve Tyerman

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- **Selected Presentations**
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  - **Dr Leanne Webb**
  - **Professor Marco Bindi**
  - **Professor David Tissue**
  - **Dr Rob Norton**
  - **Professor David McNeil**
  - **Dr Mark Hovenden**
  - **Dr Nicola Cooley**
  - **Dr Cassandra Collins**
  - **Professor Brian Loveys**
  - **Professor Ary Hoffmann**

Appendix 2 List of Attendees

Appendix 3 Co-sponsors

Appendix 4 Budget reconciliation

Abstract

The aim of the workshop was to scope the research needs of a grapevine free air CO_2 enrichment facility (FACE). This is required to understand the physiological and viticultural responses of grapevines to 21st century climate scenarios of elevated CO_2 and temperature. It was concluded that a grape FACE facility is required and that we undertake a detailed costing of the different options considered from the workshop. We will then investigate the various sources of co-funding that might be available. Presently funding sources are evolving rapidly. It would be optimal for an EOI to go to DAFF in the Climate Change and Productivity Research Program recently announced. A strong case could be made for a grape Face facility at several levels, and DAFF funding could be used to run the facility. For the infrastructure we will aim to have an EOF to the Premiers Science and Research Fund, and if successful we will leverage this to a project proposal for submission to ARC LIEF in March 2009.

Executive Summary

A workshop was undertaken to scope the utility and benefits of implementing a free air CO_2 enrichment (FACE) experiment on grapevines. Horticulture in general, and grapevines as a prime example of a horticulture crop, are not represented in planned FACE experiments in Australia, and nor are we aware of any current or intended grapevine FACE experiments internationally. Due to the high requirements of infrastructure and running costs of such an experiment it was important to gauge the level of potential research input by various groups interested in different aspects of the impacts of elevated CO_2 on grapevines. These range over investigations on phenology, photosynthesis, leaf growth rate and senescence, water relations, fruit quality and maturation rate, carbohydrate partitioning, root performance, and pests and diseases. We had a range of experts in their respective fields presenting on their experiences with, and potential utilisation of FACE experiments. This included Professor Bindi, who is the only researcher to so far carry out a preliminary experiment using FACE on grapevines. The participant list included a broad cross section of researchers in the grapevine area, many of whom have research funding from GWRDC. A GrapeFace blog was established after the workshop to obtain feedback, and a set of questions was posted to guide the responses. All respondents and other supporting communications showed strong support for the need for such an experiment, though there were several comments indicating that costs may be prohibitive, particularly since we would need to run the experiment for at least 3 years, and would probably need to have other interacting variables examined in factorial experiments, eg temperature and water supply. If cultivar came into the mix this would further increase the costs. Pros and cons were examined in terms of using various chamber systems, including open top chambers or FACE. FACE would be optimal for pest and disease investigations, where chamber systems, while more economical to run, would not be as representative of natural conditions for this important research area. On the whole, the consensus was that it would be worthwhile considering a preliminary FACE system with some mechanism (to be investigated) of elevating temperature, which could be used to examine newly planted vines. There was a strong commitment for collaboration between several institutions to further the scoping of a FACE system. Of note was the offer of the considerable expertise and infrastructure available at UWS (Professor David Tissue), The University of Melbourne and Department of Primary Industries Victoria (Dr Rob Norton), and potential collaboration with the Tasmanian Institute of Agricultural Research to enable a cool climate comparison (Professor David McNeil). Professor Bindi has invited Dr Fuentes to travel to Italy and examine their FACE linear system with the possibility of loan or an arrangement to use some of their equipment. It is also intended to obtain more information on current state of the art FACE systems from Professor Bindi's group in order to obtain exact costings of a facility in Australia. Dr Fuentes will be travelling to Italy in October 2008.

The way forward will be to undertake a detailed costing of the different options considered from the workshop. We will then investigate the various sources of co-funding that might be available. Presently funding sources are evolving rapidly. It would be optimal for an EOI to go to DAFF in the Climate Change and Productivity Research Program recently announced. A strong case could be made for a grape Face facility at several levels, and DAFF funding could be used to run the facility. For the infrastructure we will aim to have an EOF to the Premiers Science and Research Fund and if successful we will leverage this to a project proposal for submission to ARC LIEF in March 2009.

Background

Grapevine productivity, water use efficiency, phenology and pest and disease responses are likely to be impacted by climate change over the next 20 to 50 years. Over this time frame, more frequent drought, high temperature events, elevated day and night time temperature are all predicted scenarios. These climate scenarios are driven by elevated CO_2 which will also have direct effects on vine physiology and viticultural outcomes. Recent reports of global carbon emissions indicate we can expect 450ppm by 2025 and 550 ppm by 2050 an effective doubling of pre-industrial CO_2 (Raupach et al 2007)

It is possible to artificially elevate CO_2 concentration and night time temperature using various methodologies, each with different desirable and undesirable characteristics. A free-air CO_2 enrichment facility (FACE) to create a microclimate similar to those predicted for the future is the best methodology. FACE has shown that trees and shrubs are very responsive to elevated CO_2 and it is likely that grapevines will fall into this category (Ainsworth and Long, 2005). An AGO workshop in Canberra in May 2005 reached similar conclusions regarding the FACE methodology which resulted in the jointing funding(GRDC and AGO) and establishment by of a national FACE grains array at Horsham led by the University of Melbourne. Preliminary work on grapevine productivity using a FACE in Italy has shown that such a system is feasible for grapevines (Bindi et al., 2001a; Bindi et al., 2001b), but these experiments have been discontinued. More information is required for different varieties, over a longer term, and for many other aspects of grapevine performance relevant to Australian conditions, particularly in response to drought conditions and episodes of high temperature. Also there is increasing interest in understanding the greenhouse gas footprint of grapevine cultivation, and in this respect projects that investigate nitrogen use efficiency and NO_2 emission and soil carbon sequestration are very important.
A facility that allows elevation of CO_2 and temperature at reasonable running costs, with productivity monitoring and on-line monitoring of basic grapevine performance will allow other projects concerned with predicted climate change to utilise the facility. Portable field chambers for elevation of day-time temperature are already being used by CSIRO and SARDI but do not have the capacity to provide episodes of high night time temperature. It would be worthwhile adding to these facilities with additional treatments and experimentation. The facilities would also link in with a proposed global array of monitored vines and wines that is being proposed by UC Davis. The *climate scenario 2030* facility will become a focus for national and international collaborations. In addition there are likely to be other projects that would utilise the facility.

Approach

To develop a monitored FACE facility, it would be prudent to hold a workshop to:

- Develop collaboration and scope projects that would use the facility, which are relevant to industry priorities within Australia.
- Develop strategies to fund the capex and ongoing maintenence.
- Learn from experiences from other researchers operating FACE systems or elevated CO_2 projects in Australia and internationally.
- Demonstrate to the wine industry the value of experimentation using FACE and other elevated CO_2 systems to understand grapevine responses to climate change and provide greater certainty in the development of adaptation strategies

Objectives

- Evaluate the value of FACE relative to other elevated CO_2 experimental systems in order to determine the response of grapevines to likely climate scenarios.

- Develop prioritised research projects based upon a review of the area covered by presented papers at the workshop.
- Develop a consortium for research on the response of grapevines to elevated CO_2 and temperature.
- Develop a strategy for funding of a grapevine FACE facility and elevated temperature facilities.
- Demonstrate to the grape industry the value of obtaining experimental data and information on the response of grapevines to elevated CO_2 and temperature.
- Collect experimental data to populate current modelling exercises on the impacts of climate change on Australian viticulture and provide greater certainty in the development of adaptation strategies

Method

We proposed to invite a selected group of individuals totalling about 30-40 initially, composed of:

1) Key research group leaders who have an on going interest in climate change and its impact on grapevine physiology and production.
2) Research leaders in Australia who have experience in plant responses to elevated CO_2 and the use of FACE systems.
3) International research leaders in the area of elevated CO_2 responses.
4) Grape industry leaders and funding agency representatives.

These individuals would be invited to present papers on topics such as:

- Scenarios for elevated CO_2 and temperature in Australian grape growing regions.
- Productivity of woody perennial plants under elevated CO_2
- Interactions of elevated CO_2 with nutrition, particularly nitrogen.
- Interactions of elevated CO_2 with elevated temperature.
- Effects of elevated CO_2 on the phenology of woody perennials and deciduous perennials.
- Impact of elevated CO_2 on carbon partitioning and/or plant secondary products particularly in grapevines.
- Impact of elevated CO_2 on plant pests and diseases
- Impact of elevated CO_2 on soil biota and soil carbon storage.
- Pros and cons of chambers versus FACE systems.
- Data requirements of grapevine models to improve climate change impacts studies
- Industry views on climate change and the value of prediction of grapevine responses.

Through the review of these fields, and with reference to industry priorities, it will be possible to outline future research priorities in grapevine responses to climate change. This will be presented as a final report GWRDC.

Outcome, and Conclusions

The general consensus was that it would be worthwhile considering a preliminary FACE system with some mechanism (to be investigated) of elevating temperature, which could be used to examine newly planted vines. There was substantial interest from various sectors of viticulture research to indicate that if a FACE facility was available there would be substantial buy in of research projects that would use the facility. These ranged from soil research, water relations, grape quality, canopy management, phenology and flowering, water use efficiency, and pests and diseases. There was a strong commitment for collaboration between several

institutions to further the scoping of a FACE system. Of note was the offer of the considerable expertise and infrastructure available at UWS (Professor David Tissue), The University of Melbourne and Department of Primary Industries Victoria (Dr Rob Norton), and potential collaboration with the Tasmanian Institute of Agricultural Research to enable a cool climate comparison (Professor David McNeil). Professor Bindi has invited Dr Fuentes to travel to Italy and examine their FACE linear system with the possibility of loan or an arrangement to use some of their equipment. It is also intended to obtain more information on current state of the art FACE systems from Professor Bindi's group in order to obtain exact costings of a facility in Australia. Dr Fuentes will be travelling to Italy in October 2008.

Recommendations

The way forward will be to undertake a detailed costing of the different options considered from the workshop. We will then investigate the various sources of co-funding that might be available. Presently funding sources are evolving rapidly. It would be optimal for an EOI to go to DAFF in the Climate Change and Productivity Research Program recently announced. A strong case could be made for a grape Face facility at several levels, and the DAFF funding could be used to run the facility. For the infrastructure we will aim to have an EOF to the Premiers Science and Research Fund and if successful we will leverage this to a project proposal for submission to ARC LIEF in March 2009.

References

Ainsworth, E. A. and Long, S. P. (2005). What have we learned from 15 years of free-air CO_2 enrichment (FACE)? A meta-analytic review of the responses of photosynthesis, canopy. *New Phytologist* **165**, 351-371.

Bindi, M., Fibbi, L., Lanini, M. and Miglietta, F. (2001a). Free Air CO2 Enrichment (FACE) of grapevine (Vitis vinifera L.): I. Development and testing of the system for CO2 enrichment. *European Journal of Agronomy* **14**, 135-143.

Bindi, M., Fibbi, L. and Miglietta, F. (2001b). Free Air CO2 Enrichment (FACE) of grapevine (Vitis vinifera L.): II. Growth and quality of grape and wine in response to elevated CO2 concentrations. *European Journal of Agronomy* **14**, 145-155.

Raupach, M.R. Marland, G., Ciais P., LeQuere, C., Canadell, J.G., Klepper, G. and Field C.B. (2007) Global and regional drivers of accelerating CO_2 emissions. PNAS 24: 10288-10293.

APPENDIX 1

Communication

Wine 2030 - University of Adelaide

The aim of GrapeFACE and this blog

June 13, 2008 at 6:00 am · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

GrapeFACE is a concept that is being lead by a group of research intitutions in Australia (the University of Adelaide and the University of Melbourne among them) to understand the physiological and viticultural responses of grapevines to 21st century climate scenarios of elevated CO_2 and temperature.

The purpose of this blog is to get feedback on the concept from researchers from around the world.
Contact: Dr Sigfredo Fuentes (University of Adelaide):
sigfredo.feuntes@adelaide.edu.au
Permalink Comments

What is GrapeFACE about?

June 13, 2008 at 5:59 am · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

Grapevine productivity, water use efficiency, phenology and pest and disease responses are likely to be impacted by climate change over the next 20 to 50 years. Over this time frame, more frequent drought, high temperature events, elevated day and night time temperature are all predicted scenarios. These climate scenarios are driven by elevated CO_2 which will also have direct effects on vine physiology and viticultural outcomes. Recent reports of global carbon emissions indicate we can expect 450ppm by 2025 and 550 ppm by 2050 an effective doubling of pre-industrial CO_2 (Raupach et al 2007)

It is possible to artificially elevate CO_2 concentration and night time temperature using various methodologies, each with different desirable and undesirable characteristics. A free-air CO_2 enrichment facility (FACE) to create a microclimate similar to those predicted for the future is the best methodology. FACE has shown that trees and shrubs are very responsive to elevated CO_2 and it is likely that grapevines will fall into this category (Ainsworth and Long, 2005).An AGO workshop in Canberra in May 2005 reached similar conclusions regarding the FACE methodology which resulted in the jointing funding(GRDC and AGO) and

establishment by of a national FACE grains array at Horsham led by the University of Melbourne. Preliminary work on grapevine productivity using a FACE in Italy has shown that such a system is feasible for grapevines (Bindi et al., 2001a; Bindi et al., 2001b), but these experiments have been discontinued. More information is required for different varieties, over a longer term, and for many other aspects of grapevine performance relevant to Australian conditions, particularly in response to drought conditions and episodes of high temperature. Also there is increasing interest in understanding the greenhouse gas footprint of grapevine cultivation, and in this respect projects that investigate nitrogen use efficiency and NO_2 emission and soil carbon sequestration are very important.

A facility that allows elevation of CO_2 and temperature at reasonable running costs, with productivity monitoring and on-line monitoring of basic grapevine performance will allow other projects concerned with predicted climate change to utilise the facility. Portable field chambers for elevation of day-time temperature are already being used by CSIRO and SARDI but do not have the capacity to provide episodes of high night time temperature. It would be worthwhile adding to these facilities with additional treatments and experimentation. The facilities would also link in with a proposed global array of monitored vines and wines that is being proposed by UC Davis. The *climate scenario 2030* facility will become a focus for national and international collaborations. In addition there are likely to be other projects that would utilise the facility.

Permalink Comments

GrapeFACE Q1. Most important climate question

June 12, 2008 at 10:16 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

1) What do you think is the more important broad question with respect to climate change and wine grapevine responses?

a) What will be the impact of temperature (average, yearly patterns and extremes)?

b) What will be the impact of water shortage and water quality decline?

c) What will be the impact of increased carbon dioxide?

d) What will be the interactions of a,b,c?

Permalink Comments (6)

GrapeFACE Q2. Beneficial information to industry?

June 12, 2008 at 10:15 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

2) For the wine grape industry in terms of adaptation to climate change do the questions below align with potential beneficial information for industry? For all of the below assume that the full product chain would be examined, i.e. soil to glass.

a) What will be the impact of temperature (average, yearly patterns and extremes)?

b) What will be the impact of water shortage and water quality decline?

c) What will be the impact of increased carbon dioxide?

d) What will be the interactions of a,b,c?

Permalink Comments (2)

GrapeFACE Q3. Varietal responses to climate change

June 12, 2008 at 10:14 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

3) How important is it to examine varietal differences in responses to climate change? If considered important what varieties would you select if only two could be considered?

a) Shiraz and Grenache (reflecting extreme differences in water relations physiology)

b) Shiraz and Chardonnay (reflecting industry importance and covering a red and white variety)

c) Cabernet Sauvignon and Pinot Noir (or others reflecting a warm and cool preference varietal)

d) Others (please explain)

Permalink Comments

GrapeFACE Q4. Options for investigation

June 12, 2008 at 10:13 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

4) Do you think we should scope other options for investigating the impacts of high CO2 and temperature? eg open top chambers, enclosed chambers, glasshouse?

Permalink Comments (5)

GrapeFACE Q5. Number of sites?

June 12, 2008 at 10:12 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

5) In the case of a possible grapeFACE facility, do you think it would be worthwhile undertaking the experiments in more than one site, taking into consideration that this would represent a potential doubling in cost and that FACE would need to be run for at least 5 years?

Permalink Comments (1)

GrapeFACE Q6. Worthwhile endeavour?

June 12, 2008 at 10:11 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

6) Do you think a grapeFACE system would be a worthwhile endeavour considering that it may cost something of the order of $2.5 million for a basic set-up to run for 5 years?

Permalink Comments (1)

GrapeFACE Q7. Saving money?

June 12, 2008 at 10:10 pm · Filed under GrapeFACE ·Tagged GrapeFACE, high CO2, university of adelaide, wine2030 · Edit

7) How much of this cost (2.5 Mill) would be saved by installing a FACE close to an existing high CO_2 experiment (i.e. HFE in Sydney), where a research vineyard is located nearby, and taking into account researchers that would use it?

Permalink Comments

GrapeFACE Q8. Options for funding?

June 12, 2008 at 10:09 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, win2030 · Edit

8) Do you think it would be realistic to obtain funds from ARC (LIEF grant), Industry (ARC Linkages), Department of Climate Change (ex AGO), GWRDC and State Govs for a grape FACE facility?

Permalink Comments (1)

GrapeFACE Q9. Independent site?

June 12, 2008 at 10:08 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

9) Do you think it is important to establish an independent site (not maintained by a commercial grower) of established or establishing vines for FACE? Should this be close to a research cluster?

Permalink Comments (1)

GrapeFACE Q10. Pilot experiment?

June 12, 2008 at 10:08 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

10) Do you think there is value in undertaking a pilot experiment, particularly if we could obtain second-hand FACE equipment?

Permalink Comments (1)

GrapeFACE Q11. International Cooperation?

June 12, 2008 at 10:07 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

11) How important is establishment of an international cooperation program to coordinate efforts towards climate change impact on wine grapes?

Permalink Comments

GrapeFACE Q12. Would you be involved?

June 12, 2008 at 10:06 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

12) If a full grapeFACE could be established, would you bring a project into the facility? If so, roughly in what area?

Permalink Comments (5)

GrapeFACE Q13. Chamber experiment

June 12, 2008 at 10:05 pm · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

13) If a chamber experiment were to be conducted, could you still bring a project to the facility?

Permalink Comments

GrapeFACE Q14. Modelling grapevine responses

June 12, 2008 at 10:04 pm · Filed under GrapeFACE ·Tagged CO2, GrapeFACE, temperature, university of adelaide, water, wine, wine2030 · Edit

14) How important do you think modelling of grapevine responses to water, temperature and CO_2 would be? Do you think we have enough information to provide realistic predictions based on models that you may be familiar with?

Permalink Comments

GrapeFACE Q15. Your ideas?

June 12, 2008 at 5:34 am · Filed under GrapeFACE ·Tagged GrapeFACE, university of adelaide, wine2030 · Edit

15) Are there any points or suggestions you would like to make regarding experimentation to investigate the impacts of climate change on grapevines?

Comments

Comment	Date	Actions
Mike Keller mike.keller@adelaide.edu.au | 192.43.227.18 Yes, I would propose to investigate the effects if elevated CO2 on invertebrates. It could be valuable to combine research on invertebrates and pathogens, since some interesting interactions betwen them may emerge. For example, changes in amino-acid profiles related to disease would influence the growth and development of insects, nematodes and mites. From GrapeFACE Q12. Would you be involved?, 2008/07/14 at 3:08 AM	2008/07/14	Unapprove | Spam | Delete
Gordon Rogers gordon@ahr.com.au | 202.62.127.60 AHR would like to be involved with the grapeFACE experiment. We are interested in high CO2 research generally, and specifially FACE if is could be linked in some way with the HFE site at Richmond. There are grapes established on the adjacent site at UWS, Richmond (approx 10 years old). From GrapeFACE Q12. Would you be involved?, 2008/07/14 at 12:16 AM	2008/07/14	Unapprove | Spam | Delete
Eileen Scott eileen.scott@adelaide.edu.au | 192.43.227.18 Yes, in effects on disease development.	2008/07/07	Unapprove | Spam | Delete

Comment	Date	Actions
From GrapeFACE Q12. Would you be involved?, 2008/07/07 at 6:49 AM		
 Eileen Scott eileen.scott@adelaide.edu.au | 192.43.227.18 Keeping vines free of powdery mildew in the glasshouse can be a major challenge (at least in the glasshouses at Waite). We have used sulfur pots or topas wicks in the past. Such strategies might need to be monitored for interactions with CO2 concentration. From GrapeFACE Q4. Options for investigation, 2008/07/07 at 6:47 AM	2008/07/07	Unapprove | Spam | Delete
 Eileen Scott eileen.scott@adelaide.edu.au | 192.43.227.18 The effcts of elevated CO2 and temperature on a whole range of diseases also needs to be taken into account. The type of facility, whether free to air or a chamber, would affect both exposure to inoculum (mainly spores) and subsequent disease development. From GrapeFACE Q2. Beneficial information to industry?, 2008/07/07 at 6:43 AM	2008/07/07	Unapprove | Spam | Delete
 Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 I think there is little point in setting up a FACE system without adequate funding and that funding may well need to be more than the Wheat FACE due to the	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
technical difficulties of working in the vineyard. Otherwise, smaller studies using glasshouses and possibly open top chambers would be a better way to go. From GrapeFACE Q8. Options for funding?, 2008/06/19 at 7:41 AM		
 Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 The belowground/soil effects must not be left as a poor second. Big effects on root systems are often seen with eCO2 and they can't all be explained by plant size/root fraction relationships. Also, soil effects may well be important (especially leaf/root litter quality – though I consider these indirect as I have a very hard time believing that the increase in CO2 above the soil surface can have much effect on the several thousand ppm seen within the soil. From GrapeFACE Q2. Beneficial information to industry?, 2008/06/19 at 7:40 AM	2008/06/19	Unapprove | Spam | Delete
 Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 As with many others, I think for grapevines in particular the interaction with temperature must be considered. The 'double whammy' on the leaf/fruit of elevated air temp/VPD and reduced transpiration	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
due to eCO2 could have effects on an unforeseen scale. From GrapeFACE Q1. Most important climate question, 2008/06/19 at 7:39 AM		
Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 I think the timescale would really have to be an absolute minimum of three years and really for it to actually be worthwhile it should be a minimum of five. From GrapeFACE Q5. Number of sites?, 2008/06/19 at 7:38 AM	2008/06/19	Unapprove | Spam | Delete
Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 In my opinion, anything of a significant scale/cost has to be in a commercial vineyard on mature vines under commercial management. Otherwise it will be of limited use even if it is feeding into a mechanistic model that can be applied across other varieties/regions. This means, the mechanism used would have to allow tractors past/spraying/mechanical harvesting etc. As such, I'm not sure that the existing 'linear FACE' idea would work. From GrapeFACE Q9. Independent site?, 2008/06/19 at 7:37 AM	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 Leaf warming due to stomatal closure may also have effects not mentioned at the meeting. For instance, Marilyn Balls group at RSBS and others have shown a big increase in frost sensitivity due to loss of cold hardening. Consequently, this possibility would need to be considered and CO2 would need to be on prior to budburst - increasing cost. From GrapeFACE Q1. Most important climate question, 2008/06/19 at 7:36 AM	2008/06/19	Unapprove | Spam | Delete
Everard Edwards Everard.Edwards@csiro.au | 192.43.227.18 One thing not addressed at the meeting was the implication of the variability in the CO2 control. Within 20% of the target for at least 80% of the time is a lot of variability. I was very impressed with the Tas mini-FACE in that respect. The problem is fairly obvious in that, typically, all the variability above the mean CO2 conc results in the leaf being CO2 saturated and thus has no effect, whereas the variability below the mean will often cause the leaf to be CO2 limited, so only the latter has any significant effect on	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
photosynthesis and thus the mean CO2 conc 'seen' by the leaf can be a fair bit lower than the actual mean and misinterpreted as acclimation. This is something that has largely been ignored by the FACE community because there is no easy solution – as commented on by Roger Gifford a few years ago in New Phytologist. From GrapeFACE Q10. Pilot experiment?, 2008/06/19 at 7:34 AM		
 Steve Tyerman Stephen.Tyerman@adelaide.edu.au | 192.43.227.18 Yes, this came out of Bindi's work and there was an indication in one year at least that anthocyanins were affected. In the seminar he gave the impression that this was observed generally, but the paper shows that the effect was only in one year I think. From GrapeFACE Q1. Most important climate question, 2008/06/19 at 7:22 AM	2008/06/19	Unapprove | Spam | Delete
 Sigfredo Fuentes Sigfredo.Fuentes@adelaide.edu.au | 192.43.227.18 Maybe a FACE from planting could be a bit tricky, since the engineering of the system must considering this scenario to follow the growth of vines (i.e. height and distance of risers, blowers and separation). This will optimise CO2 injection but we need to study the impact in the cost of the project. From GrapeFACE Q4. Options for investigation, 2008/06/19 at 7:19 AM	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
Steve Tyerman Stephen.Tyerman@adelaide.edu.au | 192.43.227.18 Yes I wondered about this when I made the suggestion in the meeting, but if we could get Bindi's gear that would reduce the cost a lot, and if we did establishing vines (from planting) we could add another dimension to what is already known from Bindi's work. It also allows us to plant deliberately (in the Coombe vineyard) for a FACE experiment. It would be interesting anyway to measure CO2 above the UVTs over a daily time course. From GrapeFACE Q4. Options for investigation, 2008/06/19 at 7:15 AM	2008/06/19	Unapprove | Spam | Delete
Steve Tyerman Stephen.Tyerman@adelaide.edu.au | 192.43.227.18 Agree, but I keep wondering that if we could "smell or feel" carbon dioxide there would be a greater inclination from "industry" for us to study it. Temperature is obvious and sometimes rather misleading, since we have already experienced average temperatures that corresponds to 2050. CO2 is changing at a far greater rate than temperature is, though clearly vines are very sensisitve to temperature. From GrapeFACE Q1. Most important climate question, 2008/06/19 at 7:13 AM	2008/06/19	Unapprove | Spam | Delete
Brian Loveys Brian.Loveys@csiro.au | 192.43.227.18 Another very important aspect that can be addressed is to look at CO2/temperature effects of secondary metabolism. We now have a great deal of expertise in this area and we	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
need to think about how we could fund some relevant studies or indeed whether some pilot study could be worked in under our existing framework From GrapeFACE Q1. Most important climate question, 2008/06/19 at 2:12 AM		
 Brian Loveys Brian.Loveys@csiro.au | 192.43.227.18 Maybe what we need to do is run some pilot studies to get some runs on the board before we go to the next step. You may remember that Alex set up a growth chamber with the facility to run at elevated CO2. What we need is several such chambers to do this properly. Another possibility is to use something like Chris Soar s chambers or tents and add a CO2 injection system. This would not be too different to the open top chambers for which there is a good deal of existing expertise. (Ev has had experience in this area). Some sort of static system with boxes could be used to test temperature effects on bunches. All this could be done with relatively little outlay. From GrapeFACE Q4. Options for investigation, 2008/06/19 at 2:11 AM	2008/06/19	Unapprove | Spam | Delete
 Brian Loveys Brian.Loveys@csiro.au | 192.43.227.18 Discussions at the GrapeFACE workshop highlighted the importance of being able to study more than one variable, and temperature (and consequent changes in VPD) are probably as important as CO2. As I said in that occasion industry would probably see projected temperature increases as more threatening than changes in CO2 and would be	2008/06/19	Unapprove | Spam | Delete

Comment	Date	Actions
more likely to support any proposal with a temperature component than one without. From GrapeFACE Q1. Most important climate question, 2008/06/19 at 2:10 AM		
Brian Loveys Brian.Loveys@csiro.au | 192.43.227.18 To build a FACE system applicable for vines would be an expensive option. The Italian experience shows the way and the linear FACE seems like a good way to achieve an outcome, however that system probably did not have enough vines per replicate and did not run for long enough. To correct these problems amplifies the cost even more so I m not convinced that this is a real option in the short term. From GrapeFACE Q6. Worthwhile endeavour?, 2008/06/19 at 2:08 AM	2008/06/19	Unapprove | Spam | Delete

Stats: Wine 2030 - University of Adelaide

2008-07-31

Blog Stats

Total views: 588

Busiest day: 101 — Thursday, June 19, 2008

Views today: 0

Totals

Posts: 18

Comments: 24

Categories: 2

Tags: 23



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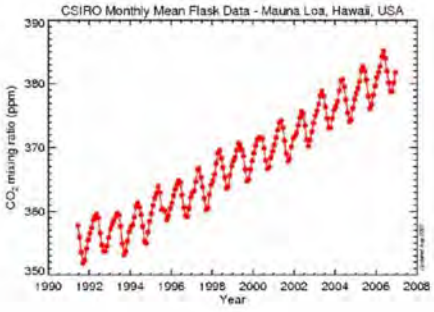
Department of Climate Change

THE UNIVERSITY OF ADELAIDE AUSTRALIA

Wine 2030

Grape FACE

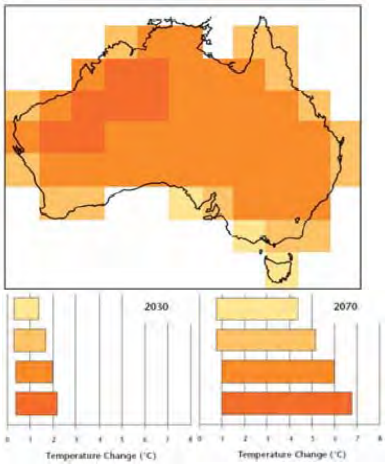
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FACE do we need it?

Temperature?

Temperature and CO_2 ?



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Department of Climate Change

Grape FACE

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Wine 2030

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1. Develop collaboration and scope projects that would use the facility, which are relevant to industry priorities within Australia.
2. Develop strategies to fund the capex and ongoing maintenence.
3. Learn from experiences from other researchers operating FACE systems or elevated CO_2 projects in Australia and internationally.
4. Demonstrate to the wine industry the value of experimentation using FACE and other elevated CO_2 systems to understand grapevine responses to climate change and provide greater certainty in the development of adaptation strategies

Aust. J. Plant Physiol., 1976, **3**, 605–18

Vine Response to Carbon Dioxide Enrichment during Heat Therapy

P. E. Kriedemann,[A] *R. J. Sward,*[AB] *and W. J. S. Downton*[A]

Fig. 3

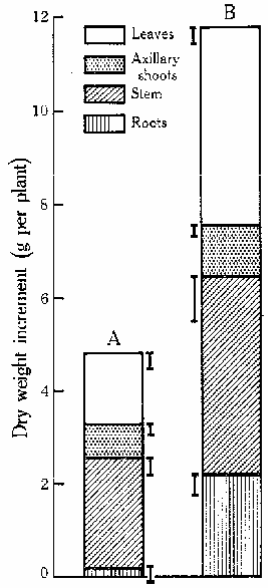
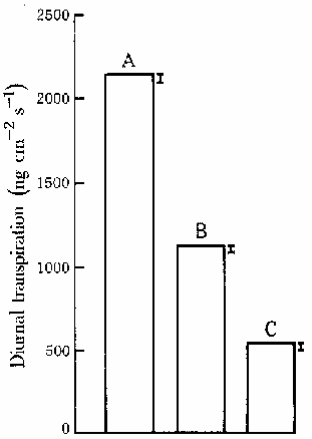
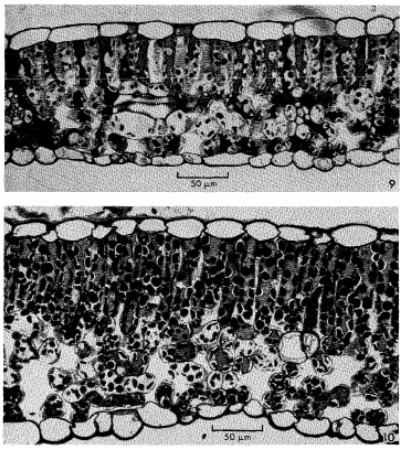


Fig. 4





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Wine 2030

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1. Evaluate the value of FACE relative to other elevated CO_2 experimental systems in order to determine the response of grapevines to likely climate scenarios.
2. Develop prioritised research projects based upon a review of the area covered by presented papers at the workshop.
3. Develop a consortium for research on the response of grapevines to elevated CO_2 and temperature.



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4. Develop a strategy for funding of a grapevine FACE facility and/or elevated temperature facilities.

5. Demonstrate to the grape industry the value of obtaining experimental data and information on the response of grapevines to elevated CO_2 and temperature.

6. Collect experimental data to populate current modelling exercises on the impacts of climate change on Australian viticulture and provide greater certainty in the development of adaptation strategies.

Climate change impact on the Australian wine industry: further research



Dr Leanne Webb
University of Melbourne: Institute of Land and Food Resources
CSIRO: Climate change impacts and risk team, Division of Marine and Atmospheric Research

Climate Change: impact on viticulture

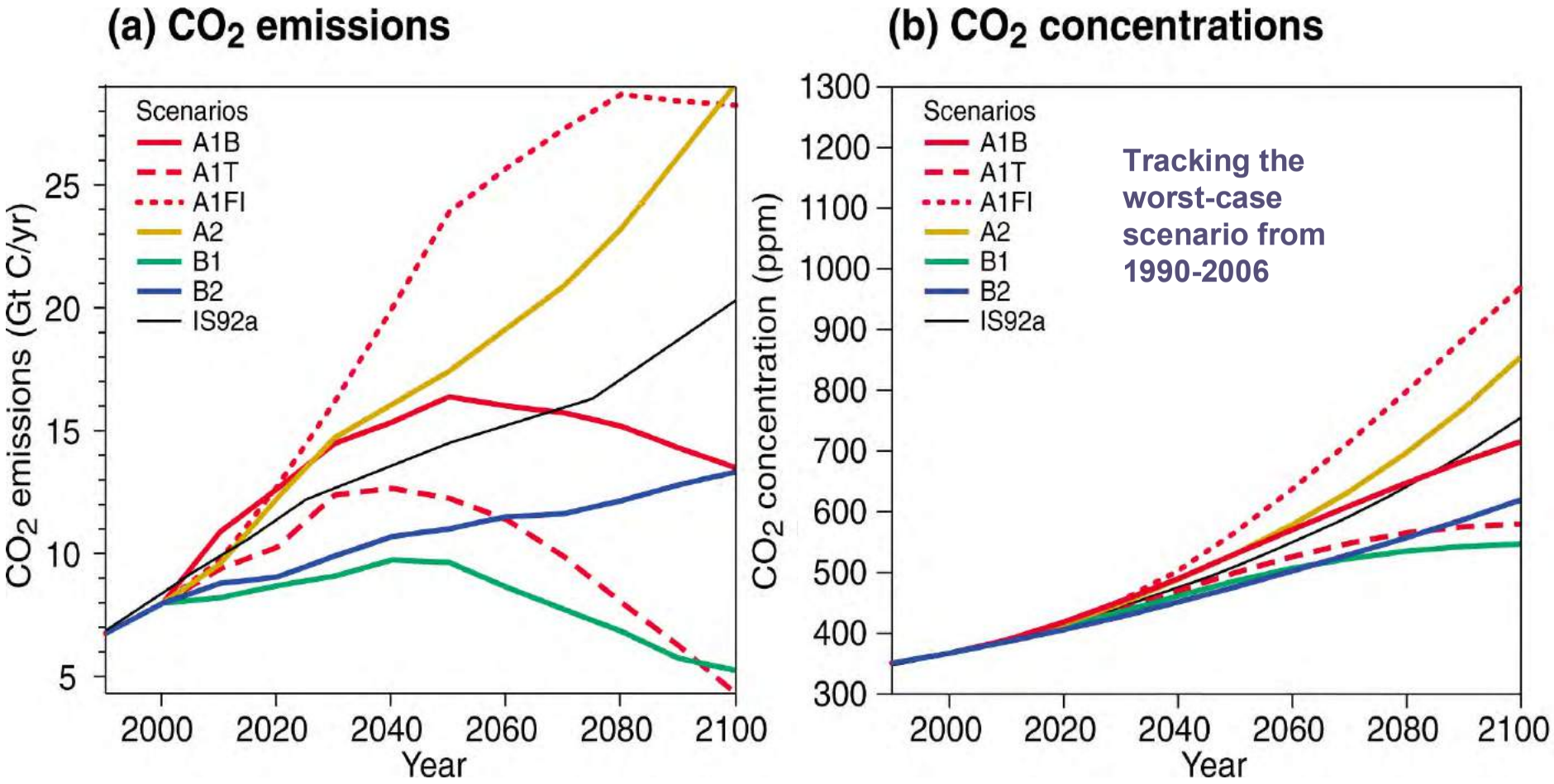
Increasing CO_2 concentration

Impact of temperature and rainfall changes

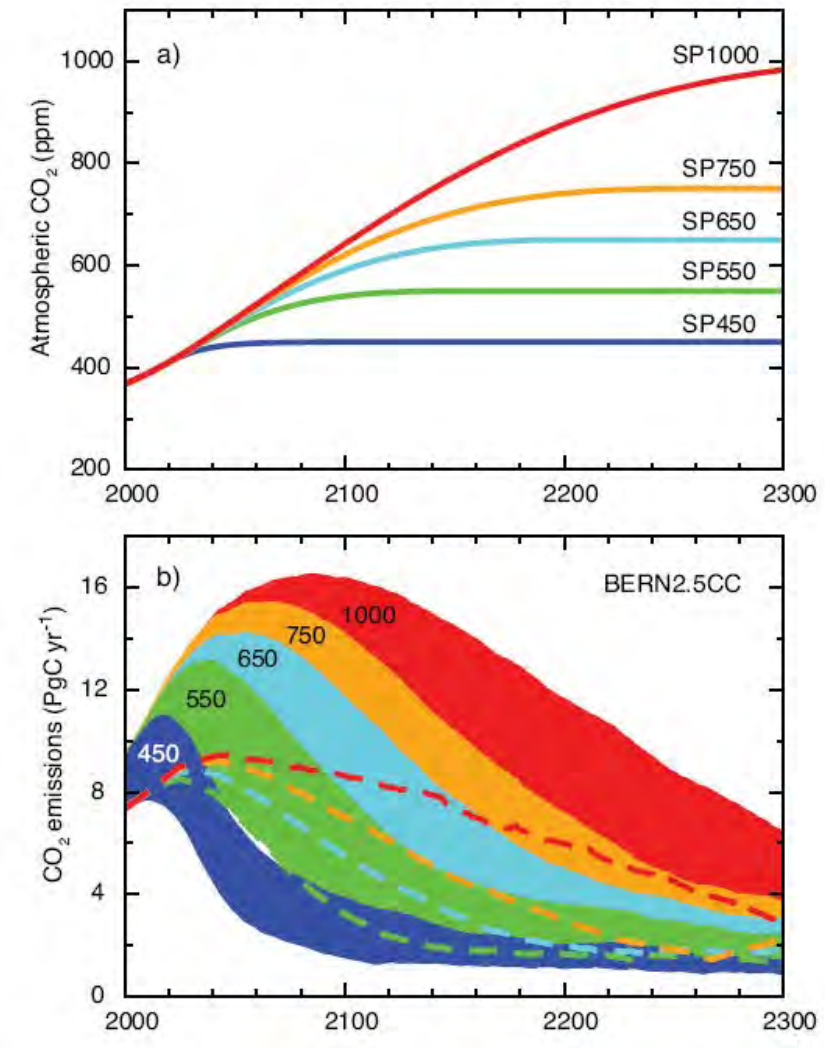
- Phenology
- Quality
- Water use

} How will increasing [CO2] affect these impacts?

Projected increases of [CO_2]



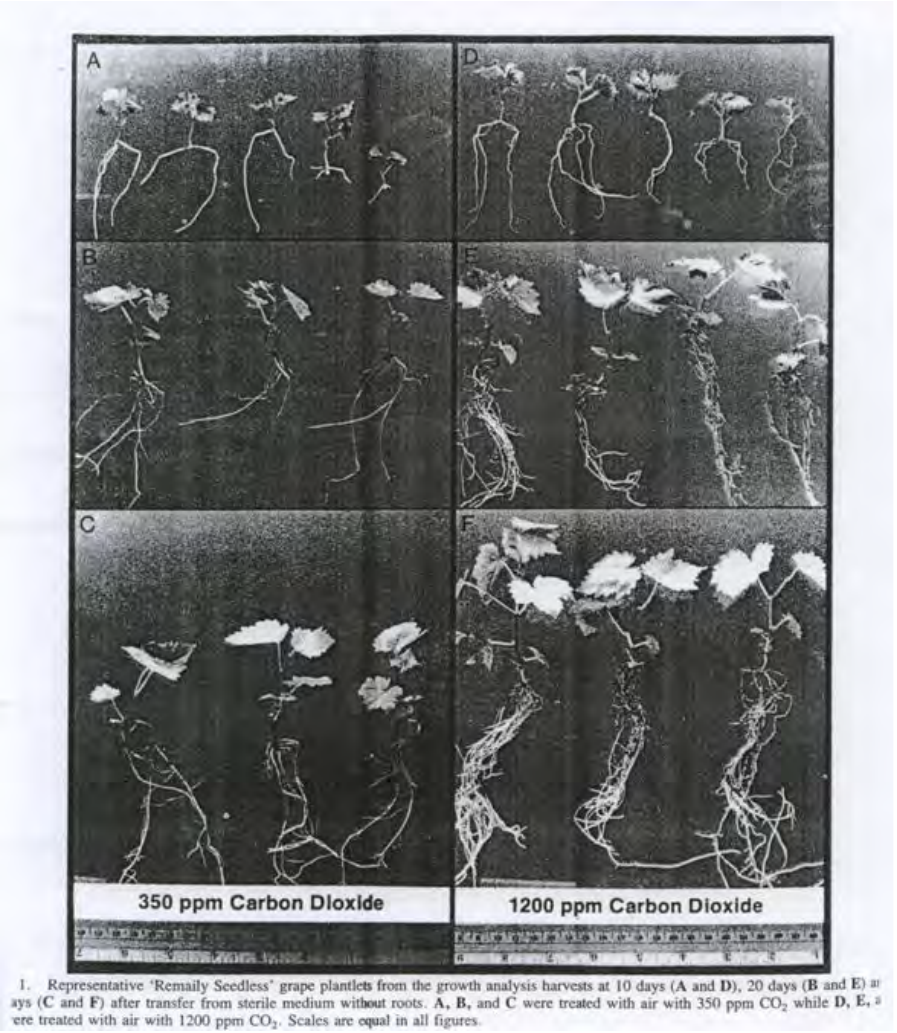
Projected increases of [CO2]



IPCC 2007

Carbon dioxide increase in atmosphere

- CO2 is forecast to rise from 360ppm to 560ppm by mid-century.
- The major driving factor for climate change also fertilizes plants.
- Increased CO_2 produces increased plant growth and yield (where water is not limiting).



1. Representative 'Remaily Seedless' grape plantlets from the growth analysis harvests at 10 days (A and D), 20 days (B and E) a ays (C and F) after transfer from sterile medium without roots. A, B, and C were treated with air with 350 ppm CO_2 while D, E, a ere treated with air with 1200 ppm CO_2. Scales are equal in all figures.

(Lakso et al, 1986)

Questions

- How would increasing [CO2]:
  - affect vine water use efficiency?
  - affect plant disease or susceptibility to frost?
  - affect crop phenology?
  - affect canopy growth, canopy and bunch heat balance?
  - affect grapevine productivity and quality?
  - affect sugar and colour profiles?
- What are the likely [CO2] : temperature : water : plant physiology interactions?

Climate Change: impact on viticulture

Increasing CO_2 concentration

Impact of temperature and rainfall changes

- Phenology
- Quality
- Water use

} How will increasing [CO2] affect these impacts?

Phenology



- The timing of budburst, flowering, fruit set, harvest will be impacted by warmer temperatures.

- Chilling requirements may be affected at some sites

- Will enhanced [CO_2] affect phenology?

Modeled impact to phenology



By 2030 harvest date of Cabernet Sauvignon may be:
(c.f. 1961-1990 baseline)

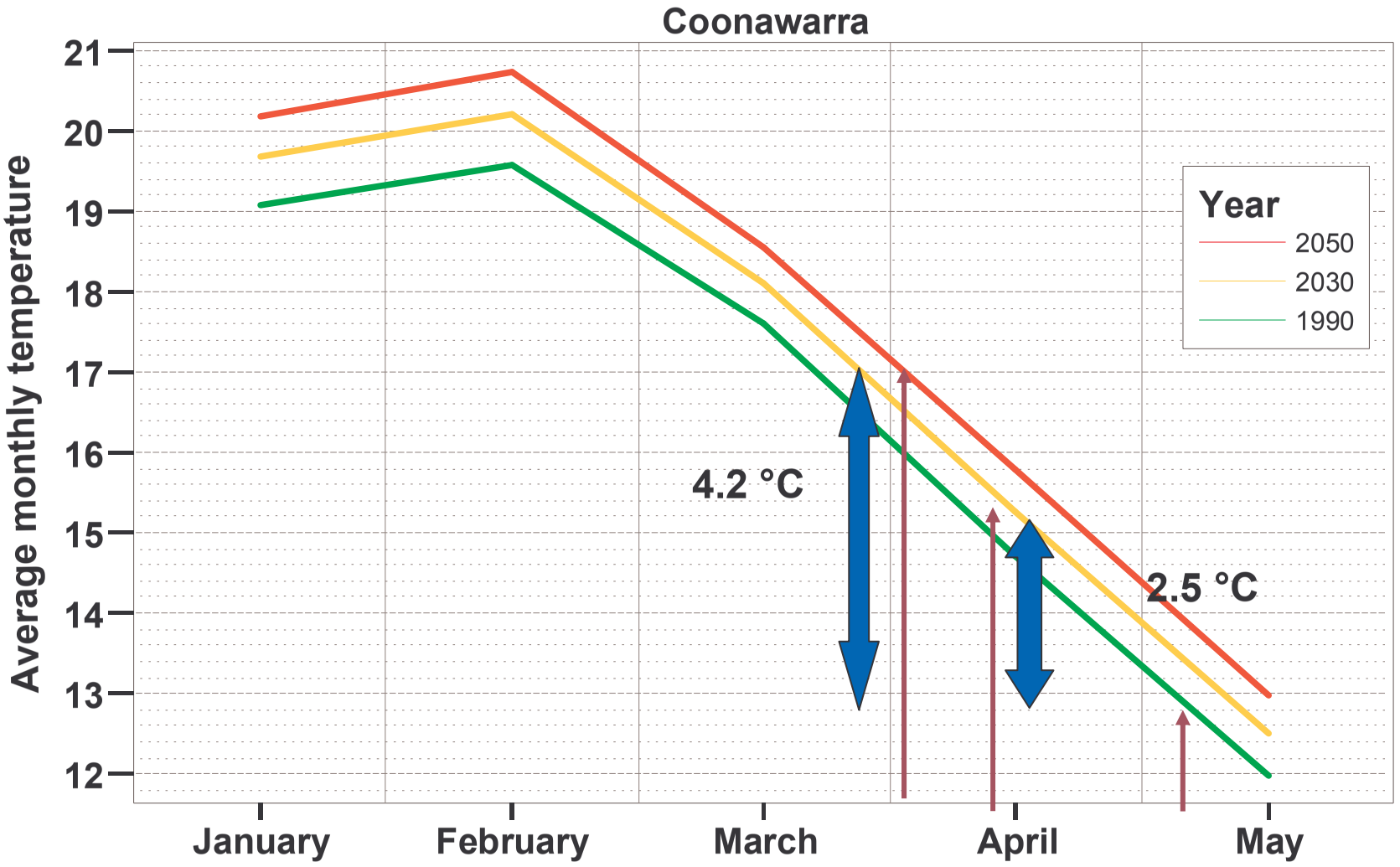
15 to 23 days earlier in Coonawarra

6 to 13 days earlier in the Riverland

10 days earlier to 4 days later in Margaret River

Model used: VineLOGIC Vineyard performance simulator (CRC Viticulture)

Climate change impact on temperature at harvest

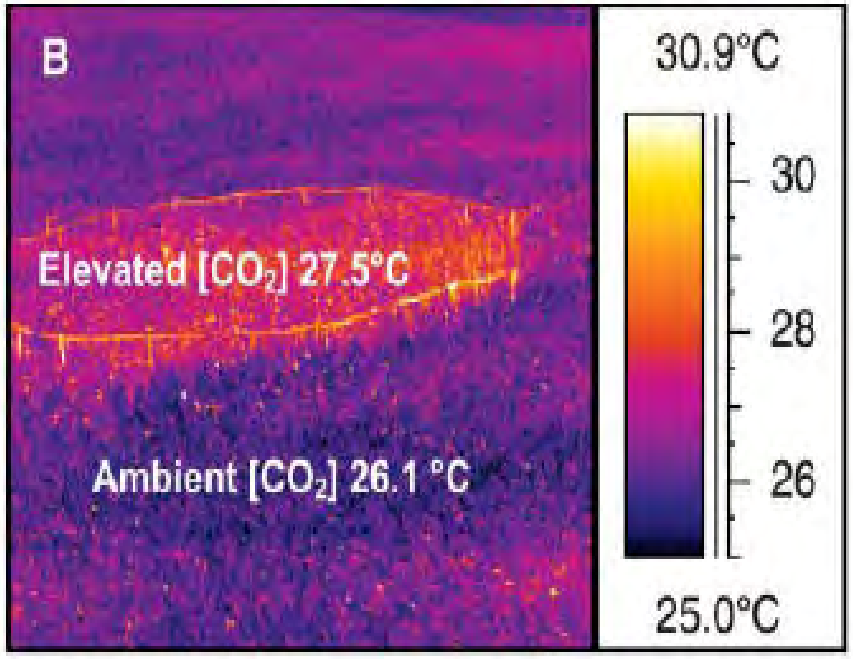


A1B GHG emission scenario, Mid climate sensitivity, CSIRO Mk3 climate model

Elevated CO_2 increases canopy temperature

Will it compound the temperature / phenology impact to harvest temperature?





Source: Long *et al*, 2006

Climate Change: impact on viticulture

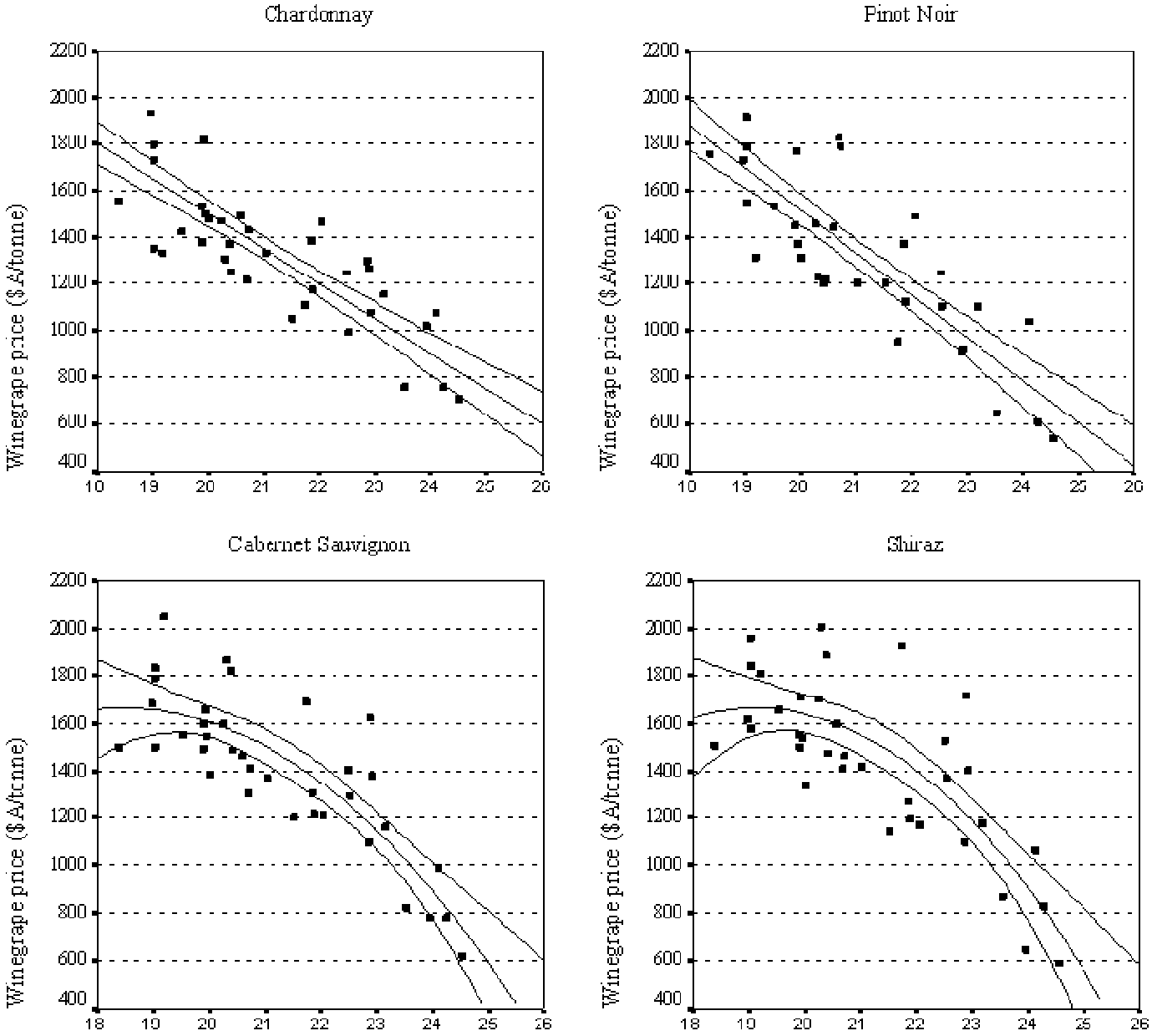
Increasing CO_2 concentration

Impact of temperature and rainfall changes

- Phenology
- Quality
- Water use

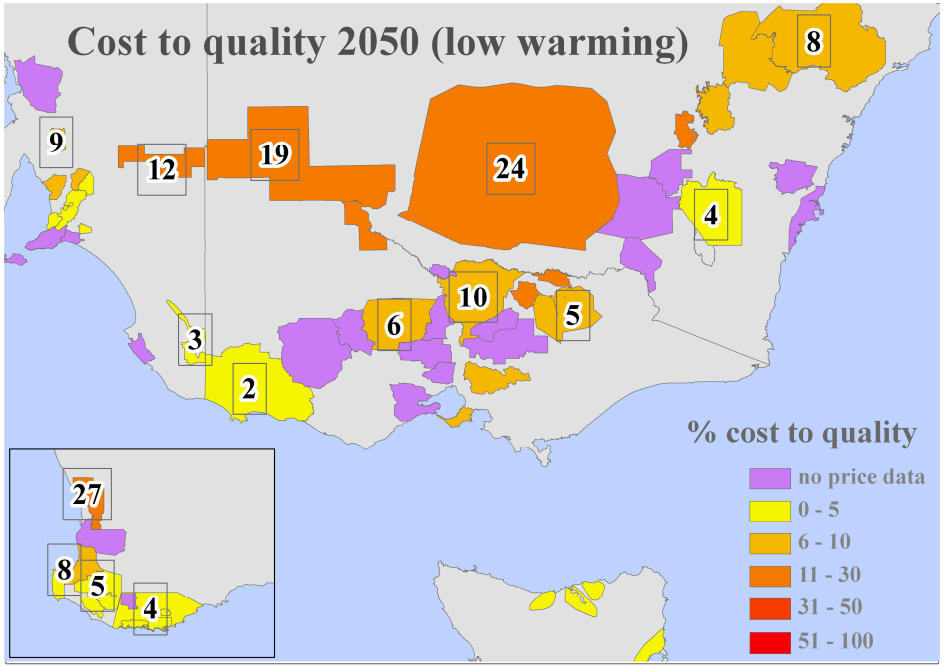
} How will increasing [CO2] affect these impacts?

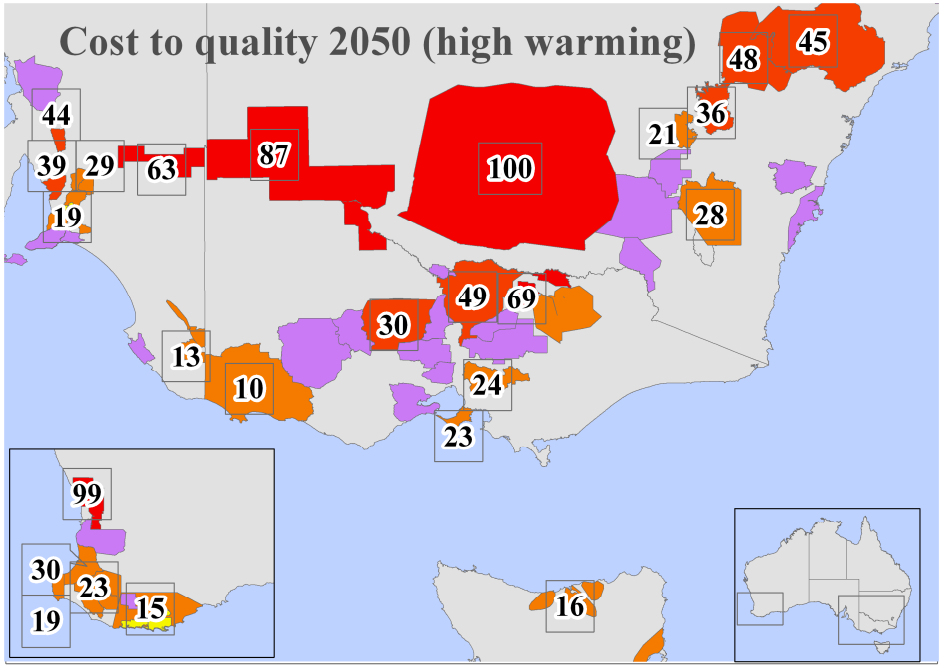
The temperature sensitivity relationship varies by variety:



Will different varieties respond differentially to increasing [CO2]?

Climate change impact on winegrape quality

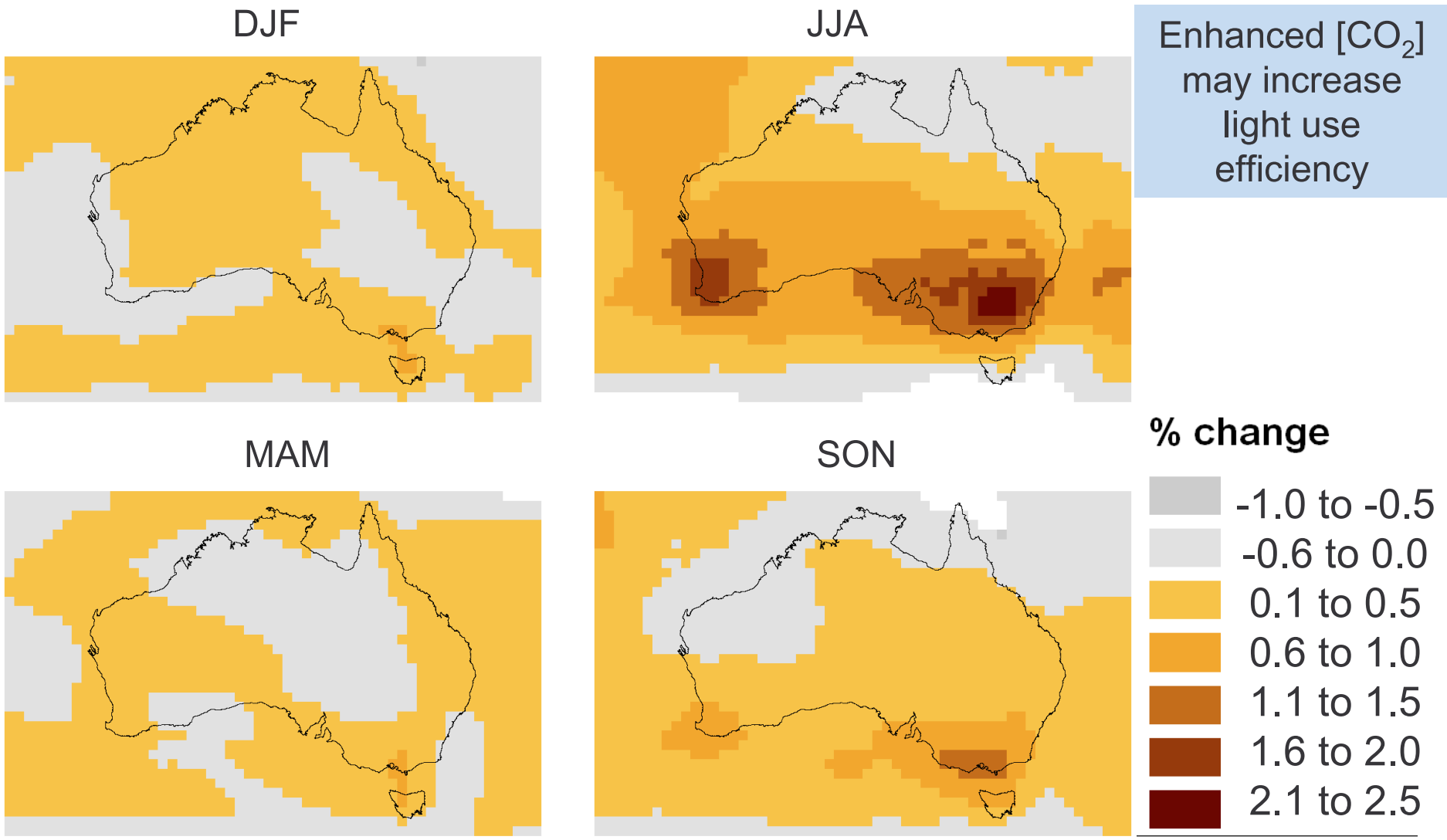




KEY MESSAGES/ QUESTIONS

- Negative impact to quality if no adaptive measures are implemented
- The impact varies regionally
- The variation in the magnitude of the impact demonstrates the sensitivity of the industry to different warming scenarios.
- Will the variation in impact be enhanced, or compensated, with ↑ $[CO_2]$?
- Do not know $[CO_2]$ effects on secondary metabolism and winegrape quality

Changes to solar radiation: 2030 mid warming 50th percentile



Climate Change: impact on viticulture

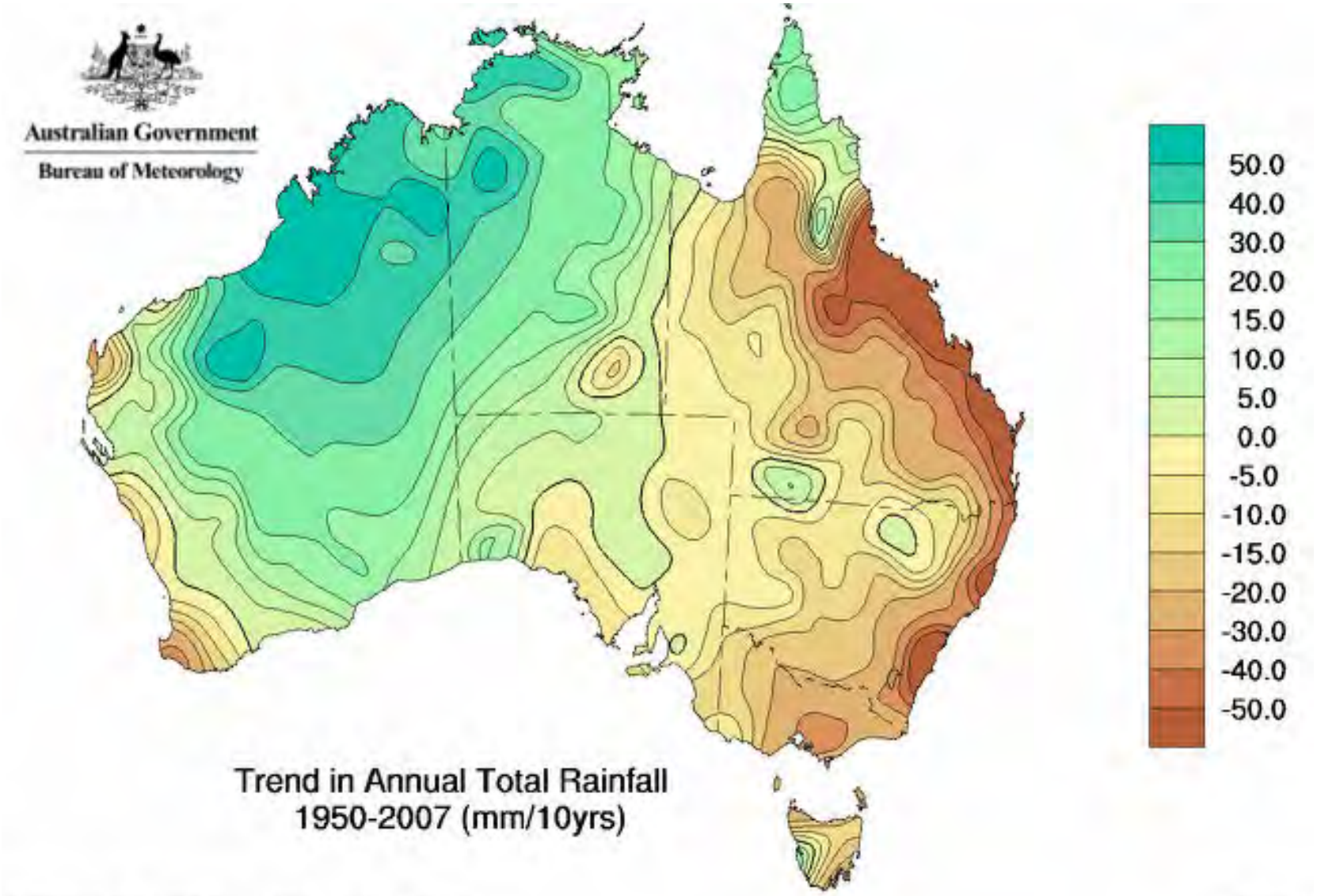
Increasing CO_2 concentration

Impact of temperature and rainfall changes

- Phenology
- Quality
- Water use

} How will increasing [CO2] affect these impacts?

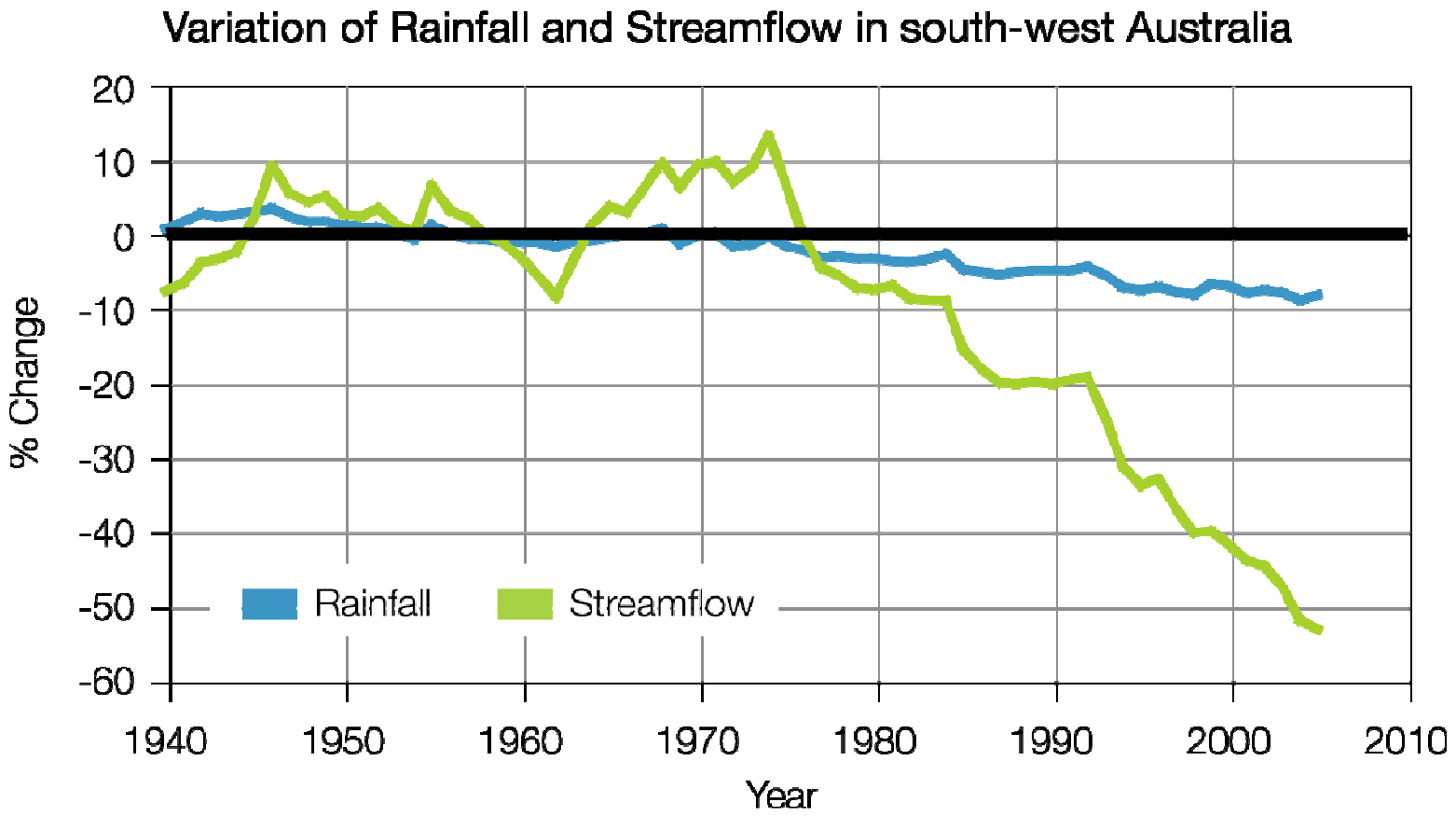
Since 1950: More rain in north-western Australia, less rain in southern and eastern Australia



© Commonwealth of Australia 2008, Australian Bureau of Meteorology

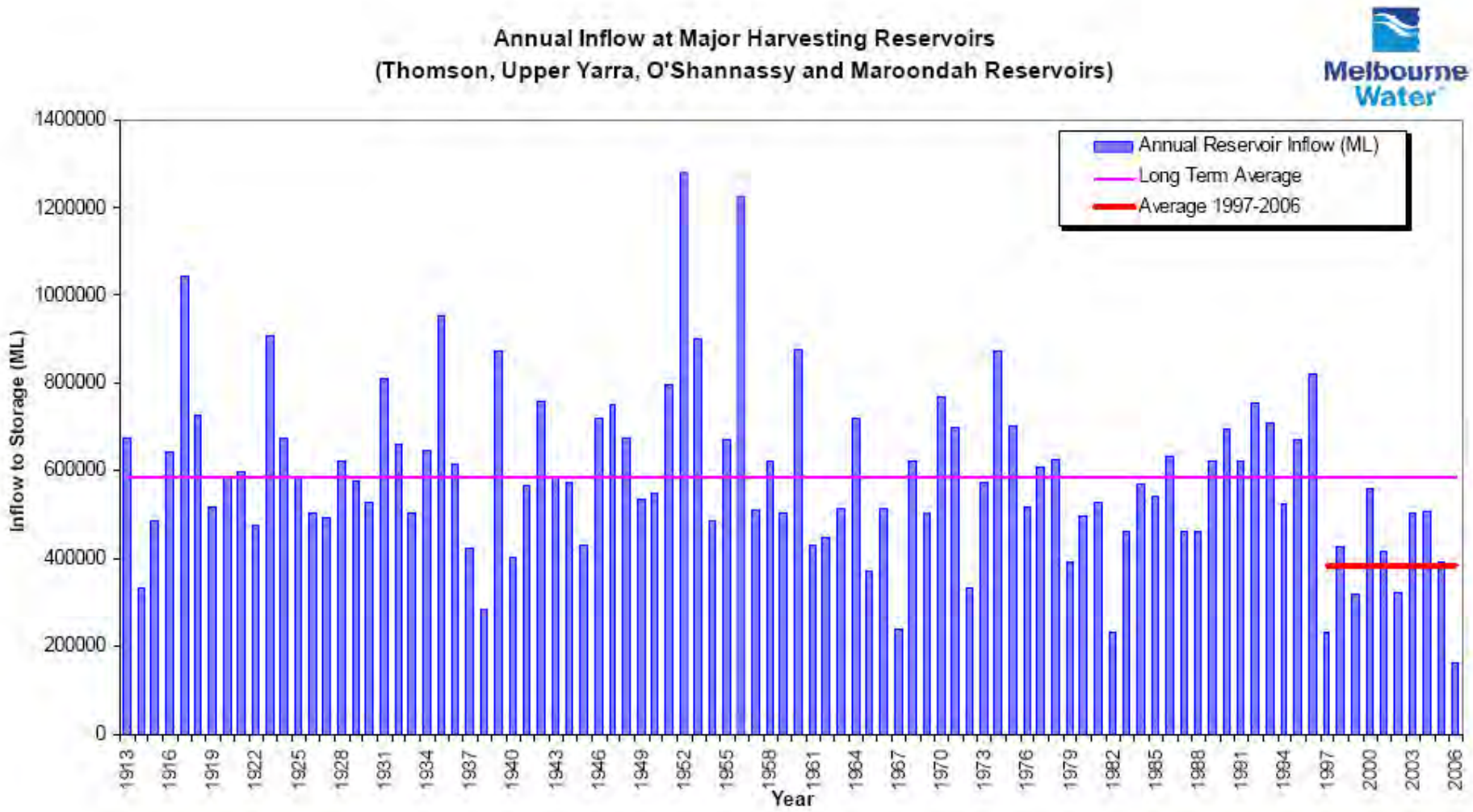
Issued: 11/

SW WA rainfall trends

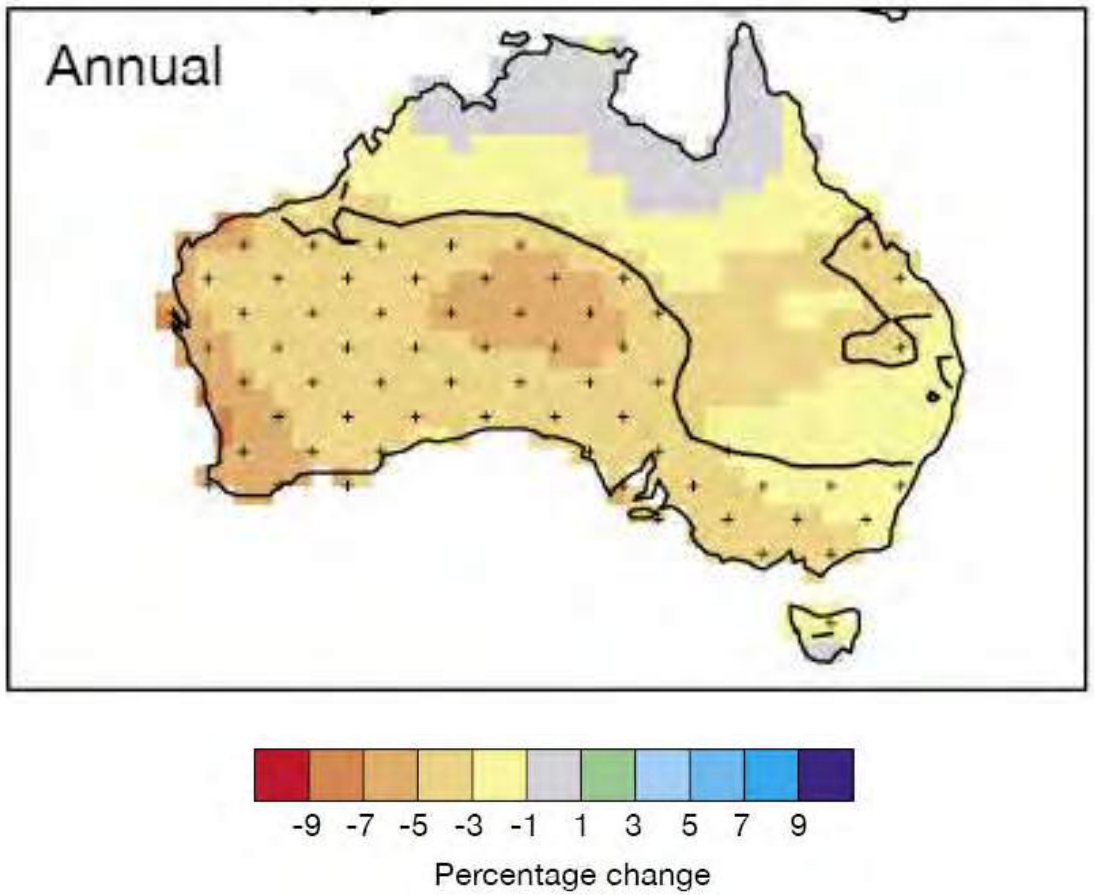


Dam inflows: Victoria

Victoria has experienced a 15% rainfall decrease since the mid-1990s, translating into an inflow reduction of about 30% to Melbourne dams



Projected rainfall change: 2030



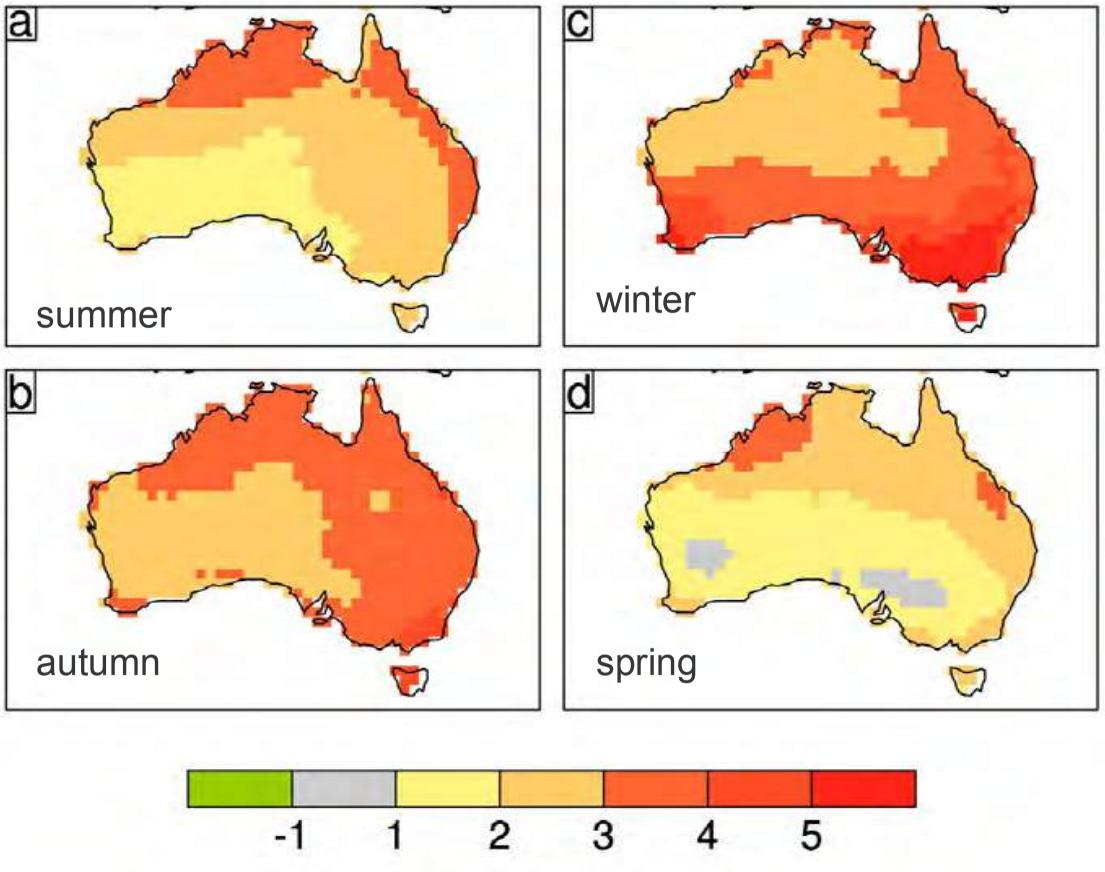
Stippling indicates where decrease is 'likely' (more than 67% probability of decrease)

3-7% decrease is 'likely' in most winegrowing regions regions

No areas show 'likely' increase

Mid-range estimate: 50th percentile, medium emissions

Potential evaporation in 2030



50th percentile, medium emissions

Increases of around 2 to 6% in the viticulture regions, with largest increases in autumn and winter



Vineyard water requirements

Region	Estimated range of extra water requirements (% of calculated present day usage)*	
	2030	2050
Riverina	2.5% to 13.7%	4.2 % to 33.0%
Vic/NSW Murray Valley	2.1% to 9.5%	3.6% to 22.9%

*calculated using Aridity index =Rainfall (mm) - (Class A Pan / 2)

(Results calculated using 3 GHG emission scenarios and 3 climate models)

- No change to vineyard area irrigated
- No change to irrigation efficiency
- No change to plant water use efficiency

Water

- Less available water in areas suitable for growing grapevines: Lower rainfall and reduced runoff
- Greater demand for water: Projected potential evaporation and temperature increases
- Knowledge that ↑[CO_2]:
  - can result in reduced stomatal conductance
  - in some cases result in increased water use efficiency
  - May encourage ↑root:shoot growth??

		Suggested impact on Grapevine	
Climate change	Trend	Growth	Quality
Temperature	↑	+/-	-
Water	↓	-	+/-
CO_2	↑	+	?
Solar radiation	↑	+	+/-
Temp/water	↑/ ↓	?/-	-
Temp/CO_2	↑/ ↑	?/+	?/-
Water/CO_2	↓ / ↑	Neutral?	?
Temp/water/CO_2/solar rad		?	?

Climate Change: Further research in viticulture

Climate change impacts

- Timing of crop stages: earlier, chilling requirement affected
- Quality impacts: negative without adaptation
- Water: reduced rainfall and runoff, increased demand

Grape FACE will inform:

- How will these impacts will be affected by ↑ [CO_2]

Acknowledgements

- Professor Snow Barlow and the University of Melbourne for funding this research
- Penny Whetton and the climate change impact and risk group, CSIRO
- University of Adelaide (Steve Tyerman) for the invitation to speak
- Sigfredo Fuentes

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CSIRO

GrapeFACE Workshop

Climate change and grapevine: Results of experimental and modelling activities in Italy

Bindi M.*, Miglietta F.**, Zaldei A.**

*DISAT-University of Florence,Italy
** CNR-IBiMet, - Florence, Italy

27 – 28 May 2008 Adelaide, Australia

Arguments

- **Description of the Experimental site and campaigns**
- **Research on climate change impact on grapevine:**
  - FACE experimental activities
  - Grapevine simulation model activities
  - Application of grapevine simulation model from site to continental scales
  - Ongoing activities on grapevine and climate change
- **Other FACE facilities**

Arguments

- **Description of the Experimental site and campaigns**

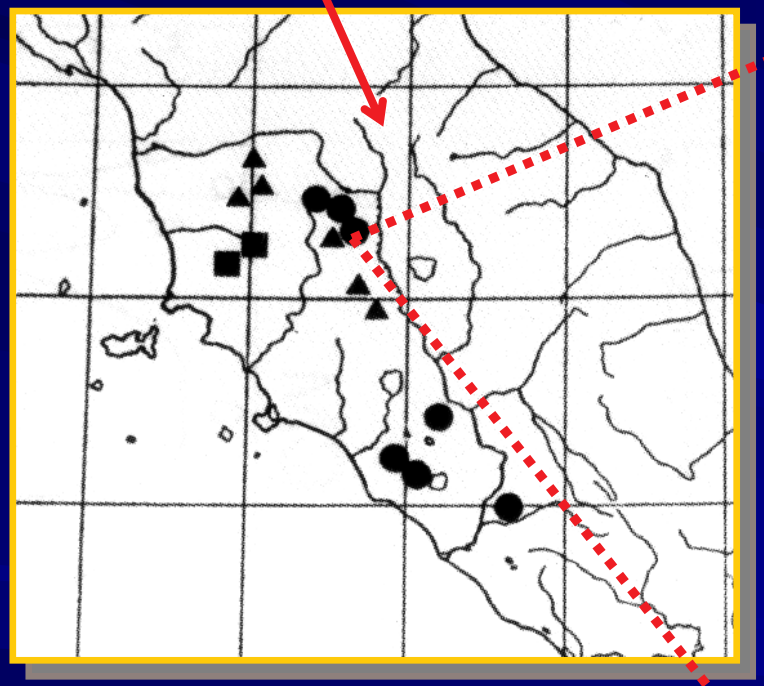
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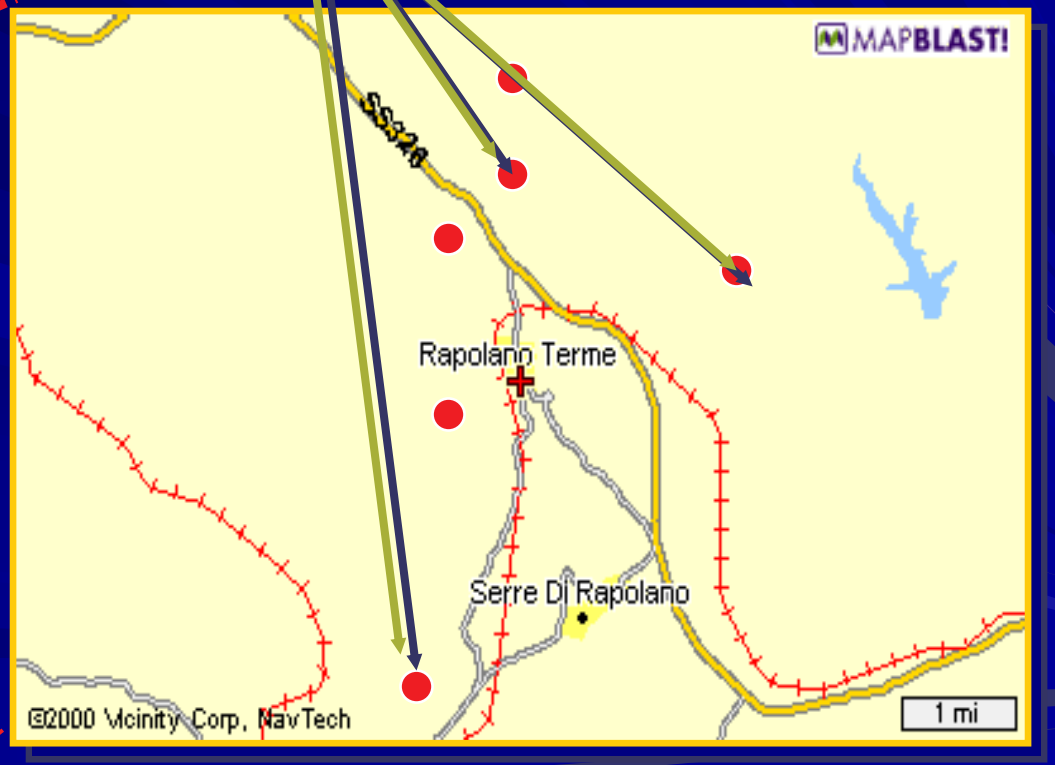
Description of experimental site

Rapolano is located in a zone of the Central Italy that is very rich in carbon dioxide springs

Around **Rapolano** there are several natural springs where CO_2 of deep origin is released at the surface by gas vents



Geographic map with the major representative CO_2 springs



Location of the main CO_2 springs in the area around Rapolano

Use of CO_2 springs for climate change impact studies

Springs in undisturbed areas
were extensively used to study
CO_2 long-term effects on natural vegetation





Springs exploited for industrial CO_2 production
have offered an unique opportunity to get CO_2
at low price making FACE experiments affordable

SYSTEM AND EXP. PROTOCOL OF FACE EXPERIMENTS

Different **FACE systems, CO_2 treatments and measurements** were used to study crops responses

Crop	Year	FACE facility	CO_2 treatment	Other	Measurement
Wheat	1994	MiniFACE	Ambient 60		
Potato	1995	MidFACE	Ambient 560 ppm		
Grapevine	1994-95 1996-97	LinearFACE	Ambient Ambient 70		
Potato	1998-99	MidFACE	Ambient 55		
Olive	1999	LinearFACE	Ambient 550 p		es
Grassland species	1999-01	MiniFACE	Ambient 560 ppmv		ater relations Above and below ground biomass



Arguments

- Description of the Experimental site and campaigns
- **Research on climate change impact on grapevine:**
  - **Methodological approach**
  - FACE experimental activities
  - Grapevine simulation model activities
  - Application of grapevine simulation model from site to continental scales
  - Ongoing activities on grapevine and climate change
- Other FACE facilities

CLAIRE and CLIVARA EU-Projects

- **Periods:**
  - CLAIRE: 1994-1995
  - CLIVARA: 1996-1997
- **Aims:**
  - Develop a model for simulating potential grapevine yield and quality
  - Carry out a series of FACE experiments (3 CO_2 levels)
  - Make climate change impacts analyses from site and continental scales

Approach to study the impact of climate change on Grapevine

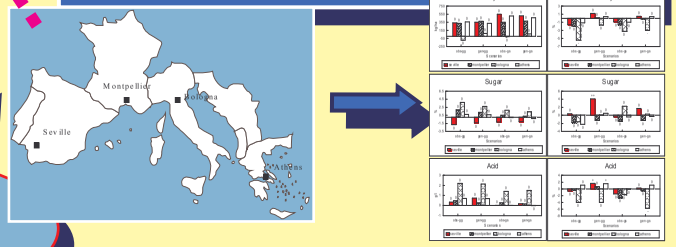
Site assessment on crop development, yield and quality

Changes in climatic variables from GCMS

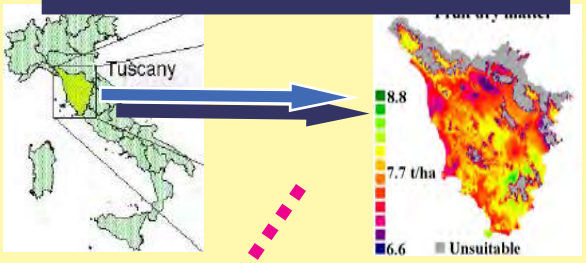
Crop Growth Simulation Model

FACE data

4 sites in the main EU viticultural areas



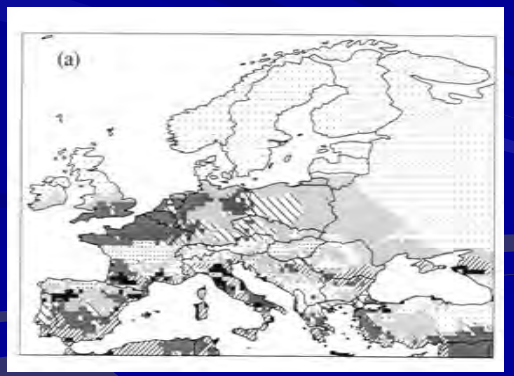
67 sites in Tuscany Region



Country scale



Continental scale



Regional assessment on crop production and quality

Arguments

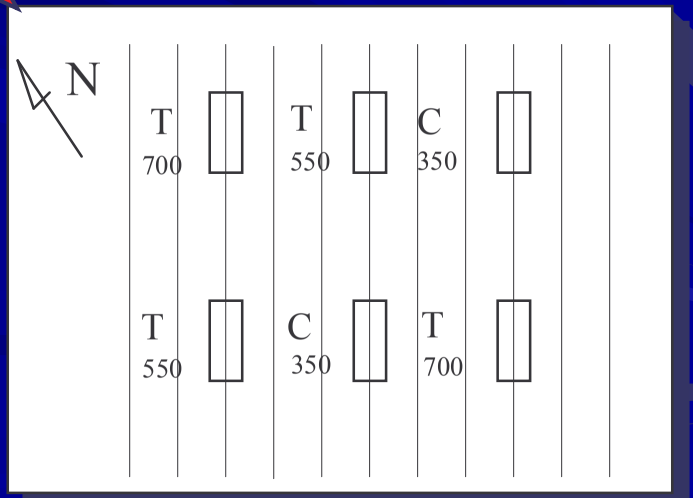
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  - **FACE experimental activities**
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  - Application of grapevine simulation model from site to continental scales
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- Other FACE facilities

Site and Experimental details

Within CLIVARA-Project 2 experimental campaigns were undertaken **in 1996 and 1997** on grapevines of **cultivar Sangiovese** located in a vineyard within the Poggio S, Cecilia Farm

March 1996:
Six FACE arrays enclosing 7 plants each were installed in the vineyard to keep three atmospheric CO_2 levels (ambient, 550 and 700 ppmv) with two replicates per each level.





CO_2 fumigation started at the time of crop budbreak and system and crop performance and weather conditions were monitored

Grapevine - FACE system

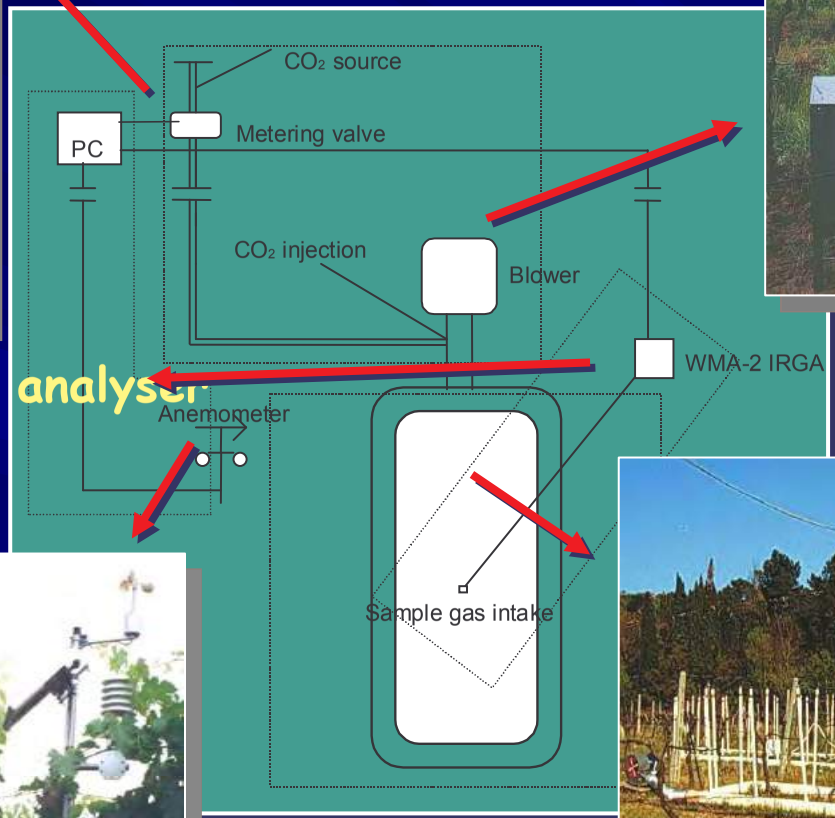
This **FACE system** consists of 4 main components:

4. PC control program



2. High-volume fans





3. Anemometer and gas analyser







1. Rectangular emission arrays

Crop measurements

Crop growth and yield: Non-destructive and destructive measurements were made during the growing seasons and harvest times of plant growth parameters (leaf, shoot and fruit d.w., leaf area, etc.)

Grapes quality: Grape samples were taken at intervals of two weeks between bloom and maturity for assessing total sugar (%) and acid (g l^{-1}) contents

Wine quality: Grape sub-samples were collected at the final harvest for determining wine quality parameters:

- total poli-phenols, total flavonoids, total and free anthocyanins,
- colour intensity and tonality,
- alcohol, total and volatile acidity,
- total and free SO2, pH

Other measurements:

- Leaf water relations: leaf total water, osmotic potential and hydraulic conductivity
- Photosynthetic capacity: assimilation versus intercellular CO_2 concentration (A:Ci)

System performances:
Temporal and Spatial CO_2 control

Temporal control (performance goal of keeping the 1 min average within 20% for over 80% of time was set, Nagy et al., 1994)

Table 3
Fraction of time 1 min CO_2 averages were within ± 20 percent of the set points (700: 560–840 µmol mol^{-1}; 550: 440–660 µmol mol^{-1}) in the enriched plots

	Target	1996	1997
Plot T1	700	0.83	0.80
Plot T2	700	0.82	0.82
Plot T3	550	0.88	0.86
Plot T4	550	0.88	0.84

Control was lower 80%:

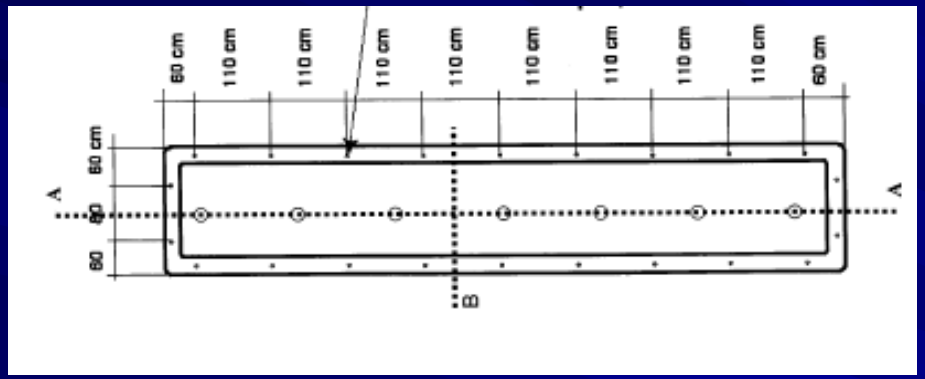
- low and high wind speed
- sunrise and sunset

Table 4
Fraction of time 1 min CO_2 averages were within ± 20 percent of the set points versus: (a) 1 min wind speed averages; and (b) hour of the day.

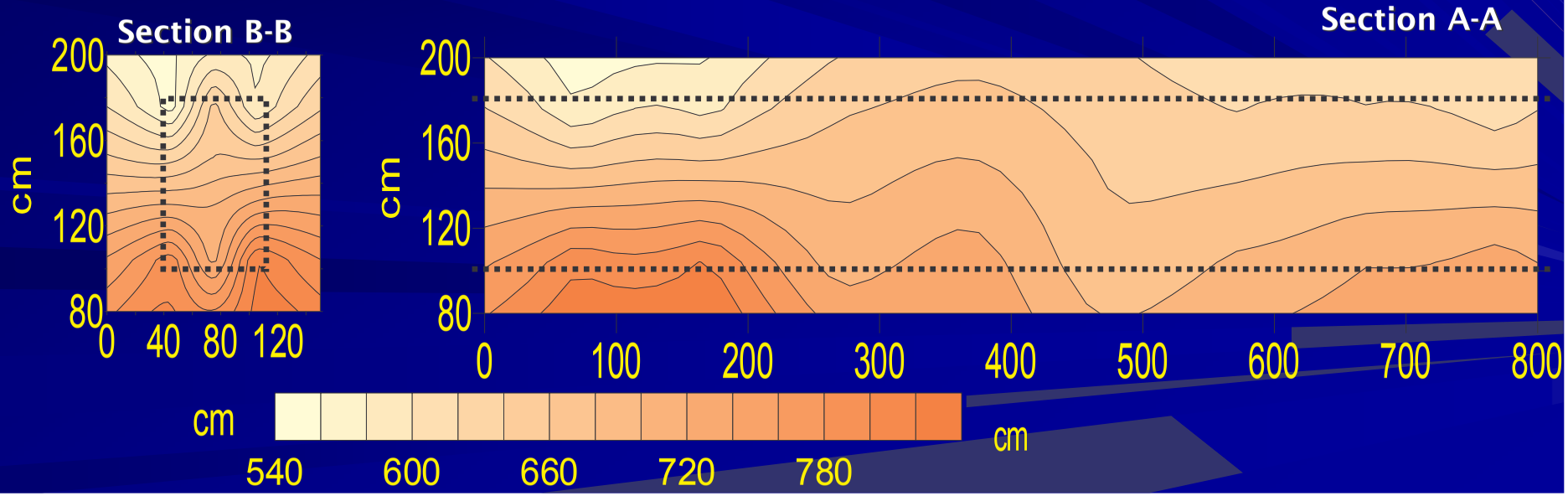
	550 µmol mol^{-1}		700 µmol mol^{-1}	
	1996	1997	1996	1997
Wind speed (m s^{-1}) (a)				
0.0–0.4	0.84	0.75	0.8	0.69
0.4–1.0	0.92	0.84	0.86	0.83
1.0–2.0	0.95	0.9	0.86	0.88
2.0–4.0	0.97	0.95	0.74	0.9
>4.0	0.95	0.96	0.63	0.75
Hour of day (b)				
5–7	0.82	0.78	0.78	0.78
7–9	0.89	0.86	0.88	0.86
9–11	0.92	0.89	0.85	0.89
11–13	0.92	0.88	0.83	0.88
13–15	0.9	0.87	0.82	0.87
15–17	0.89	0.84	0.83	0.84
17–19	0.82	0.75	0.82	0.75

System performances:
Temporal and Spatial CO_2 control

Spatial control (700 ppmv plot)



In the area occupied by the canopy (dished lines) the CO_2 concentration was within 10-20% of the target



Impact of elevated CO_2 : (550 - 700 ppmv) Grapevine (crop development and growth)

Accumulation of vegetative and reproductive grapevine organs was strongly affected by increasing CO_2 (up to 550 ppmv)

	550 ppmv	700ppmv
Crop development:		
Phase length:	↔ (no visible change)	↔ (no visible change)
Leaf area:	↑ (+30-38%)	↑ (+33-41%)
Biomass accumulation:		
Vegetative biomass:	↑ (+33-42%)	↑ (+36-45%)
Reproductive biomass:	↑ (+40-43%)	↑ (+44-51%)

↔: n.s., ↑ ↓: P<0.05

Impact of elevated CO_2 : (550 - 700 ppmv) Grapevine (yield quality)

Grapes and wine quality remain almost unchanged, with only slightly **changes in acidity and sugars content of grapes** and the **increase of a few wine pigments**

	550 ppmv	700ppmv
Grape quality:		
Acidity:	↔ (-2/-5%)	↔ (-4/-7%)
Sugars:	↔ (-4/-7%)	↔ (+2-3%)
Wine quality (18 parameters):		
Total flavonoids:	↑ (+38-25%)	↑ (+35-22%)
Total anthocynins:	↑ (+30-26%)	↑ (+32-25%)
Non-anthocynins flavonoids:	↑ (+38-37%)	↑ (+41-35%)

↔: n.s., ↑ ↓: P<0.05

Arguments

- Description of the Experimental site and campaigns
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  - Methodological approach
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  - **Grapevine simulation model activities**
  - Application of grapevine simulation model from site to continental scales
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Grapevine simulation model

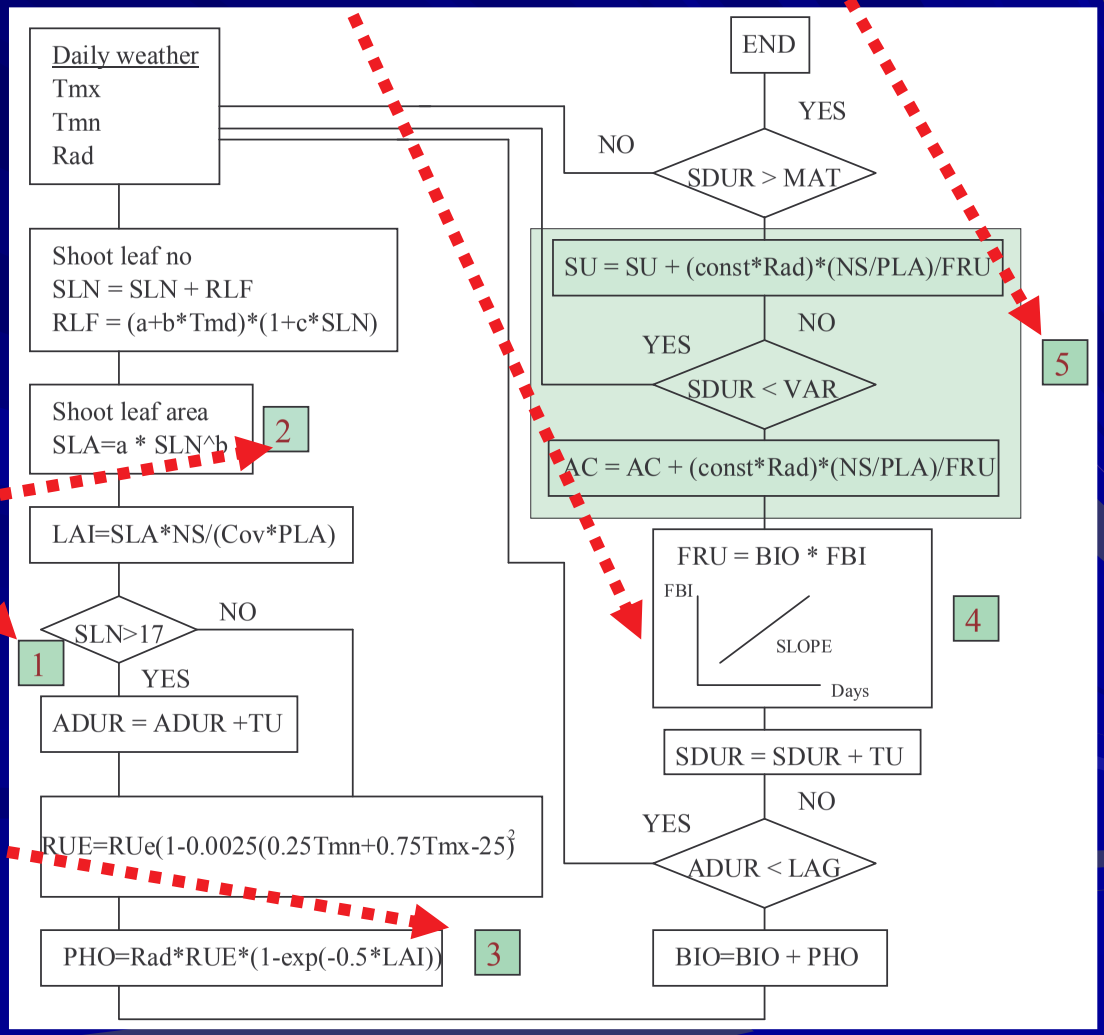
Grapevine yield and quality were simulated developing a simple mechanistic model that reproduces the main processes regulating development, growth, and quality components of grapevine by a few conservatives equations

The daily fruit growth rate is calculated assuming that the fruit biomass index increases linearly during fruit growth

The grape quality is simulated as a function of intercepted solar radiation

Ontogenic development of the plants, including leaf area increase, was simulated on the basis of temperature

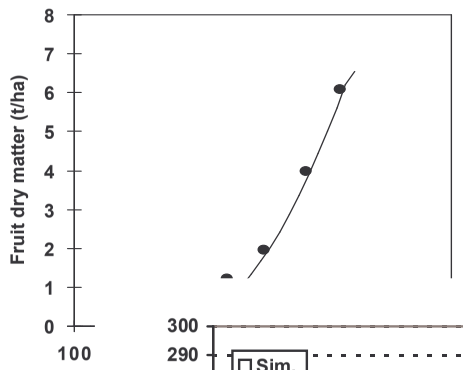
The increase in crop biomass was calculated from the quantity of solar radiation intercepted by leaf canopy by defining RUE

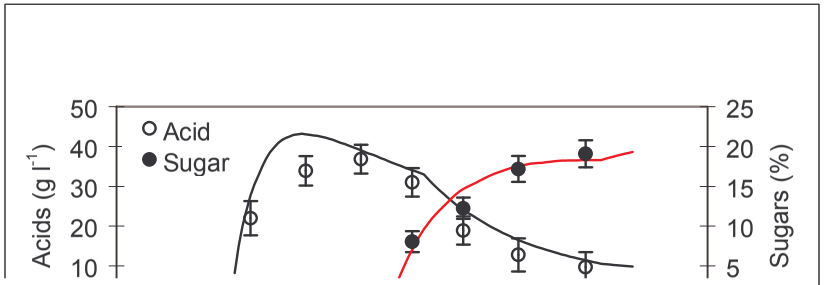


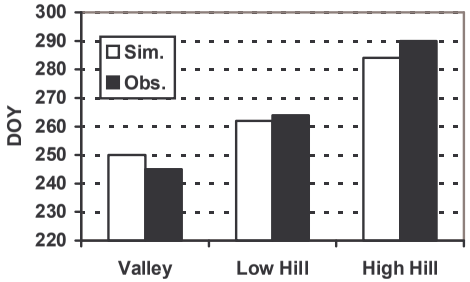
Model tests

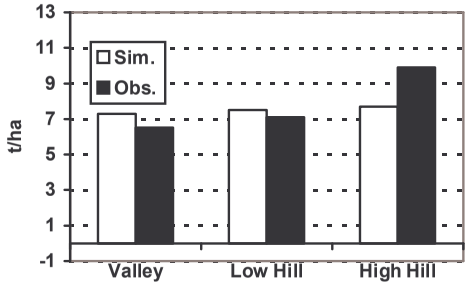
Tuscany:

- site level

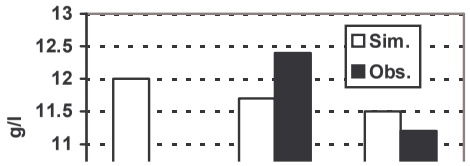


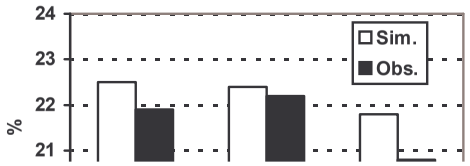






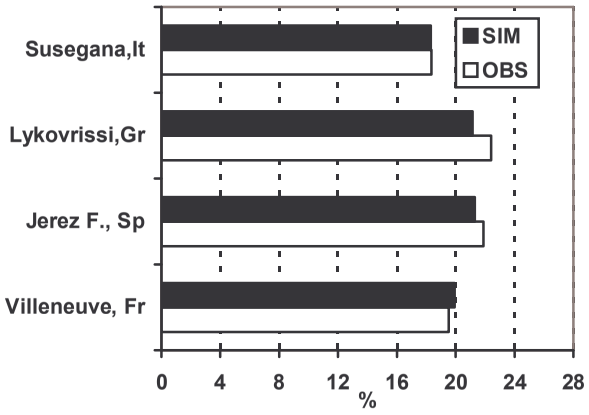
- regional level

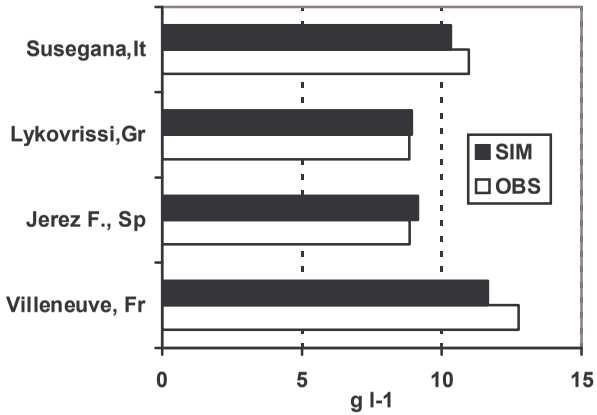




EU viticultural areas:

- site level

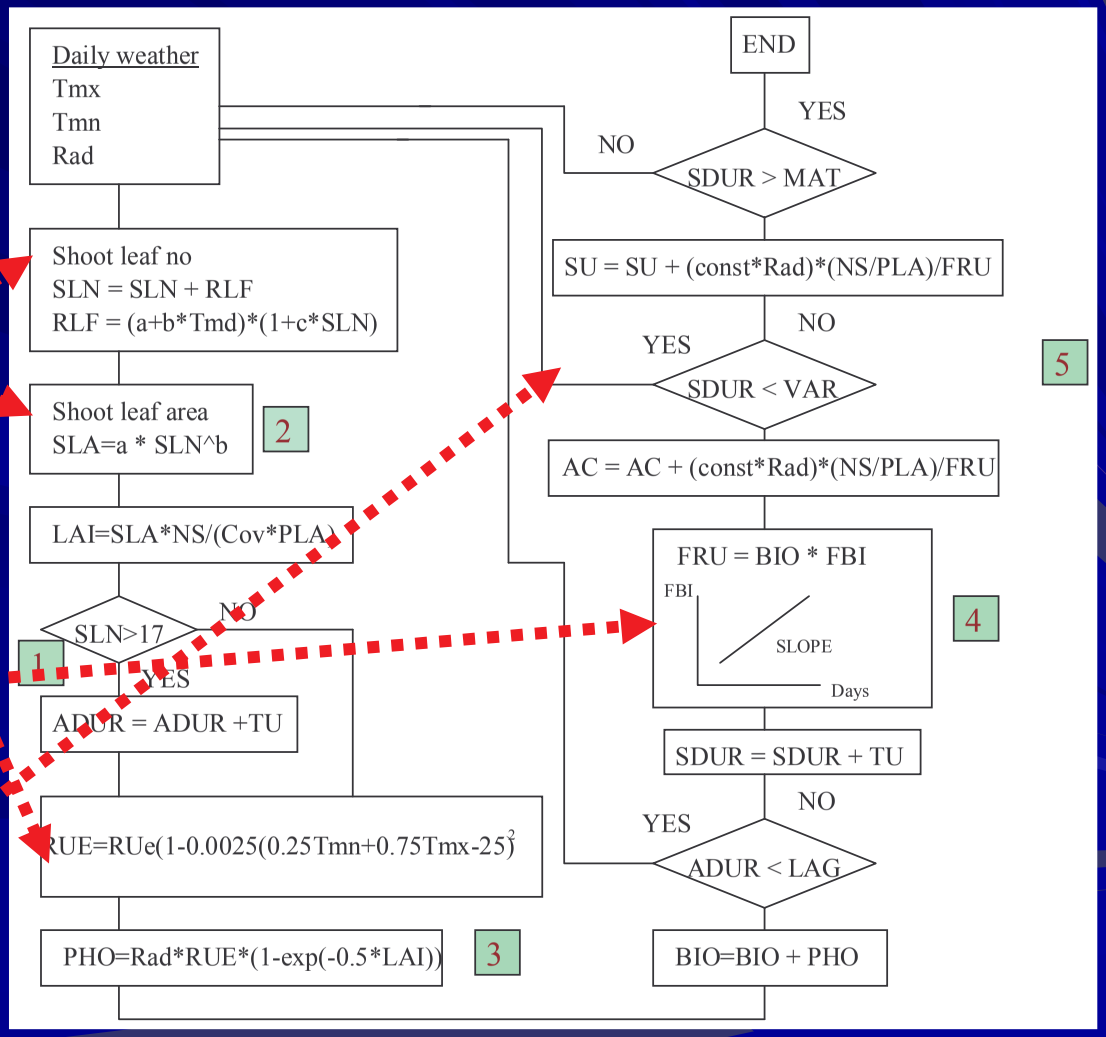




Model calibration for accounting CO_2 effects

Growth and quality model parameters sensitive to increases in CO_2 concentrations:

- Rate of leaf appearance and extension
- Radiation Use Efficiency
- Rate of Fruit Biomass Index
- Rate of sugar and acid accumulation



Effects of CO_2 on growth and quality parameters

RUE only was affected significantly by elevated CO_2

The quality parameters were affected by elevated CO_2

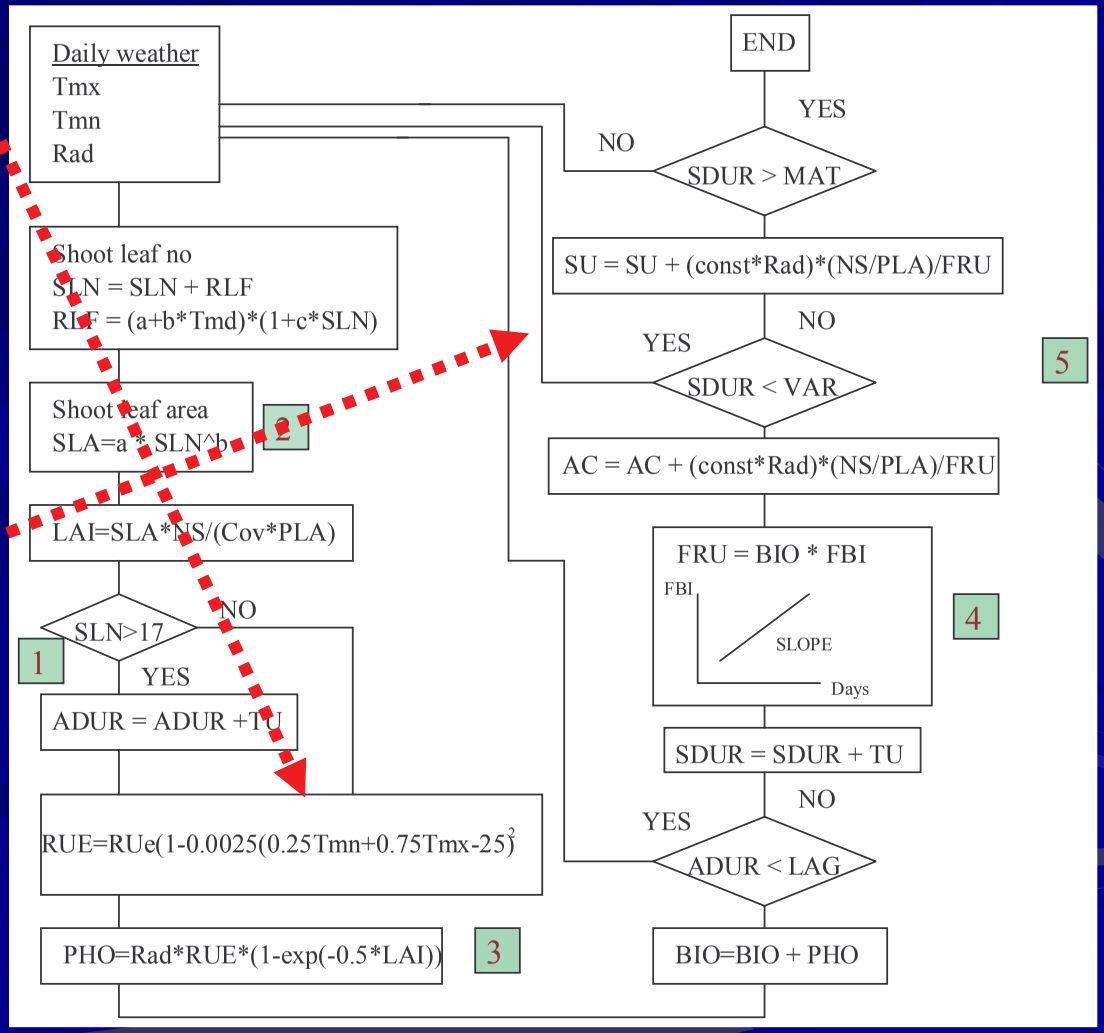
Parameters	CO_2 Treatments		
	350	550	700
Growth			
Leaf appearance	a	a	a
Leaf area/Leaves num.	a	a	a
RUE	a	b	b
FBI	a	a	a
Quality			
Sugar (veraison-maturity)	a	b	c
Acid (Bloom-veraison)	a	b	c
(veraison-maturity)	a	b	b

a, b, c = significant differences at the 5% level using LSD

Implications for modelling

The effect of increasing atmospheric CO_2 concentration on quality and growth of grapevine was incorporated in the model:

- increasing the **RUE** linearly up to 550 ppmv, and then keeping RUE constant for higher CO_2 levels,
- changing the rates of daily **acid and sugar accumulation and acid reduction,**
- considering **unchanged all the other parameters**



Arguments

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- Other FACE facilities

Layout of climate scenario analyses

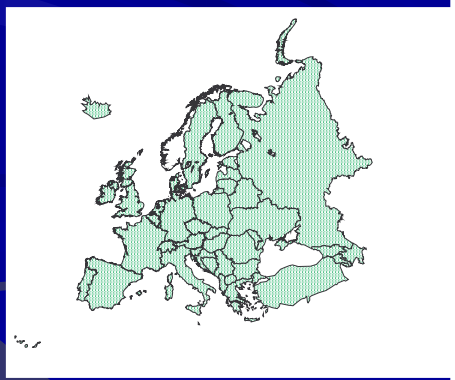
- **Climate scenarios**
  - **The grapevine model was run for present and future climate scenarios including changes:**
    - in climatic mean and variability
    - in greenhouse gases conc't and sulphate aerosols effects

- **Spatial scales and data outputs**
  - **The impact of climate change on grapevine has been investigated:**
    - at site and regional scales comparing changes in mean and in variability of yield quantity and quality
    - at national and continental scales (by ECU) comparing changes in cultivation suitability, phenology, yield



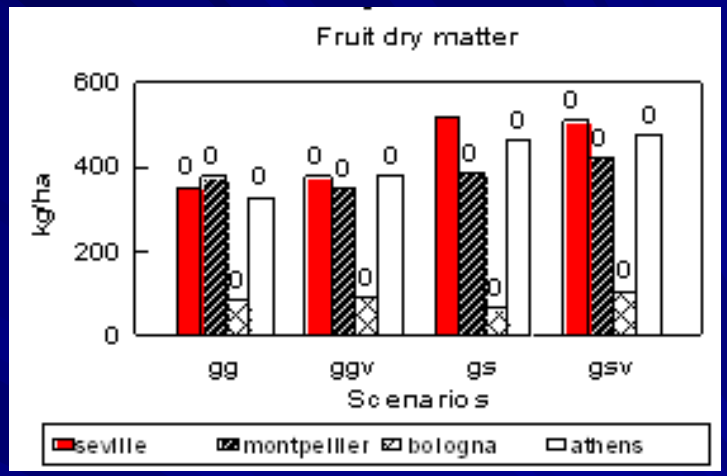




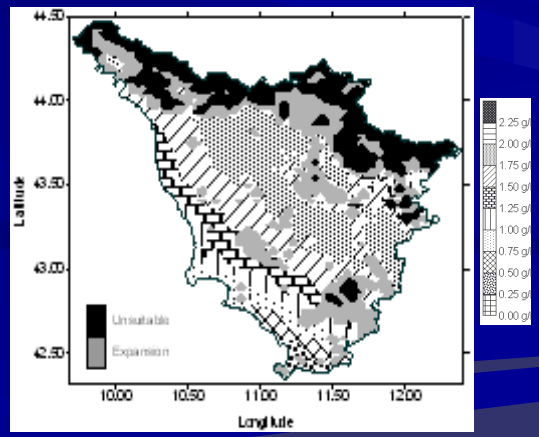


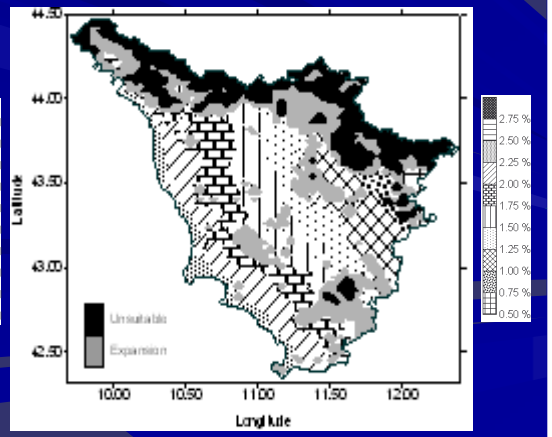
Main results of impact analyses

- **Site level:**
  - **Grapes quantity:** general increases in mean and in inter-annual variability
  - **Grapes quality:** small increases in mean and decreases in inter-annual variability



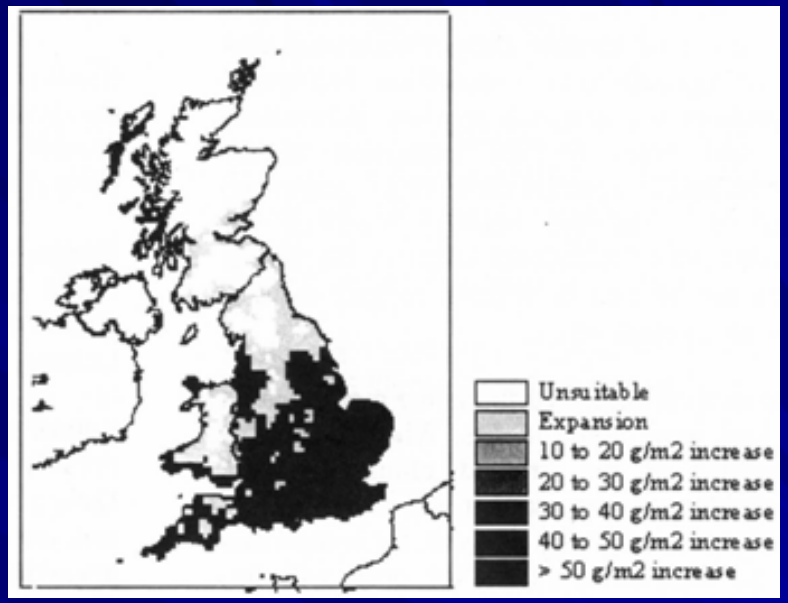
- **Regional level:**
  - **Suitable areas:** Expansion of suitable area into higher hills
  - **Grapes quantity:** small increases in mean and in inter-annual variability
  - **Grapes quality:** small increases in mean and decreases in inter-annual variability

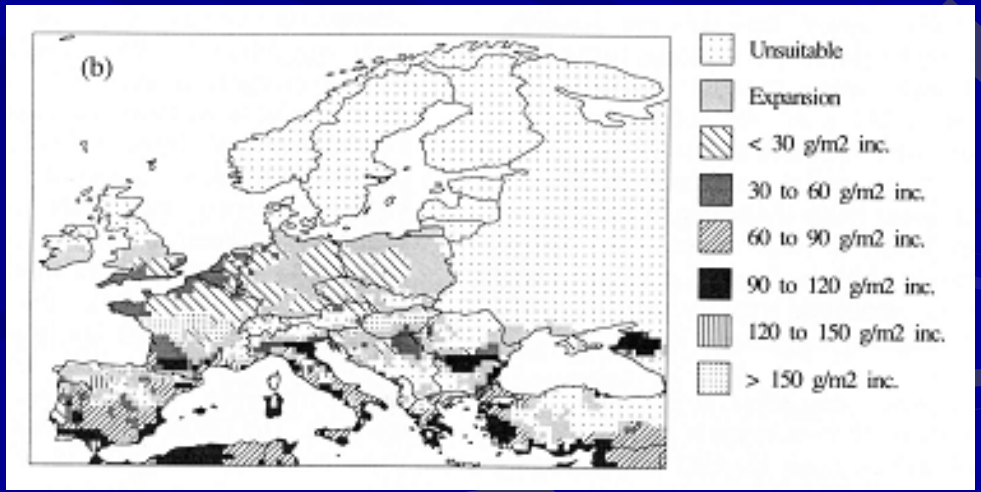




Main results of impact analyses

- **Country level:**
  - **Suitable areas:** Expansion into central and northern England
  - **Grapes quantity:** general increases
- **European level:**
  - **Suitable areas:** expands northwards into central and northern England and eastwards into parts of eastern Poland, Romania, Belorussia and the Ukraine
  - **Grapes quantity:** increases that are larger in Southern Europe than Central and Northern Europe



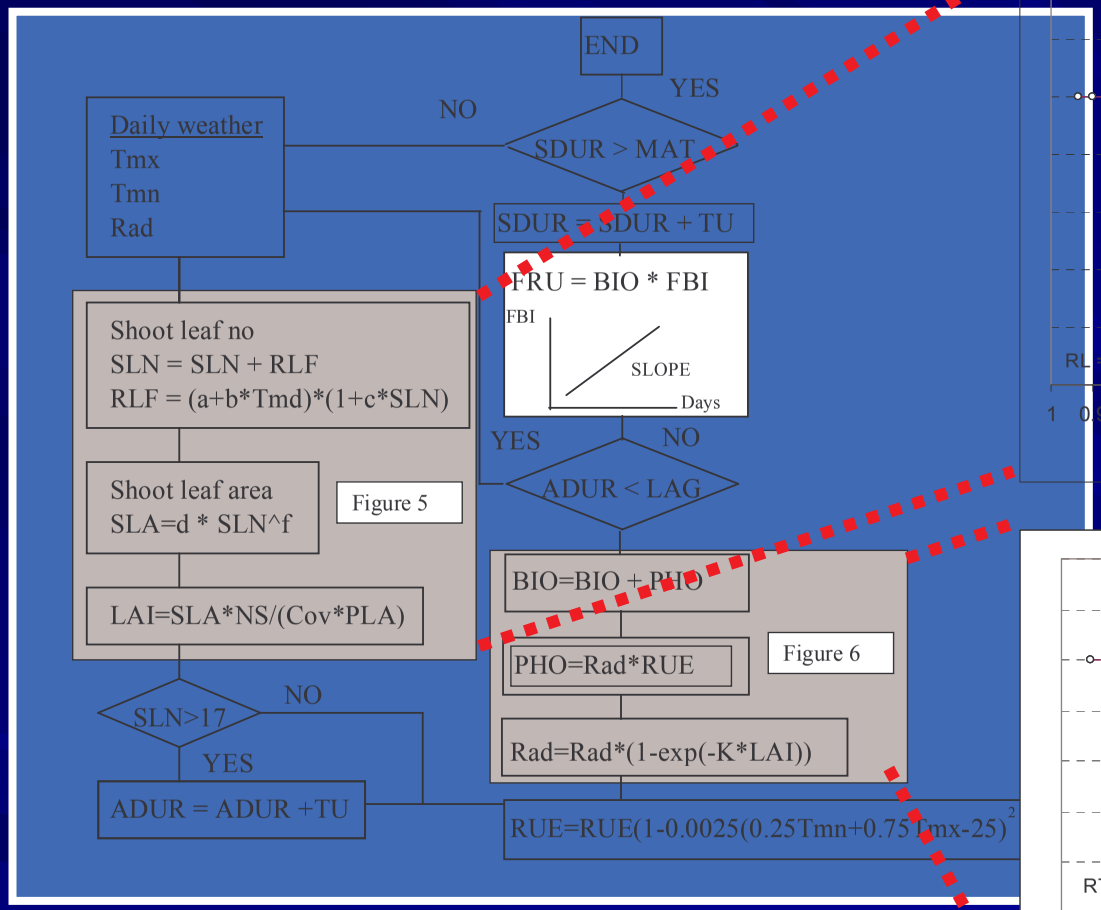


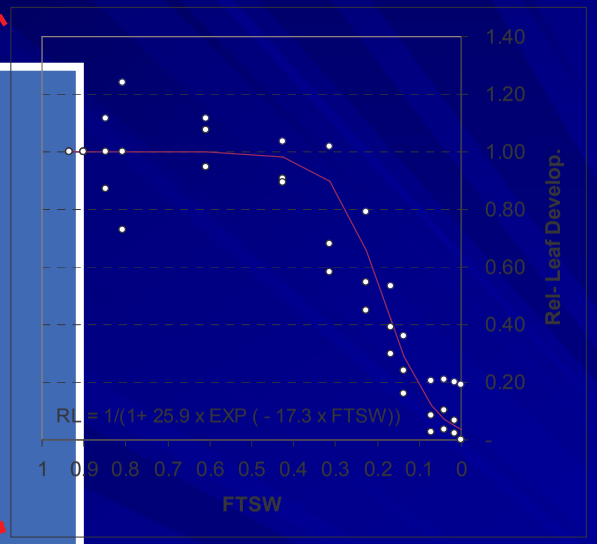
Following model updating

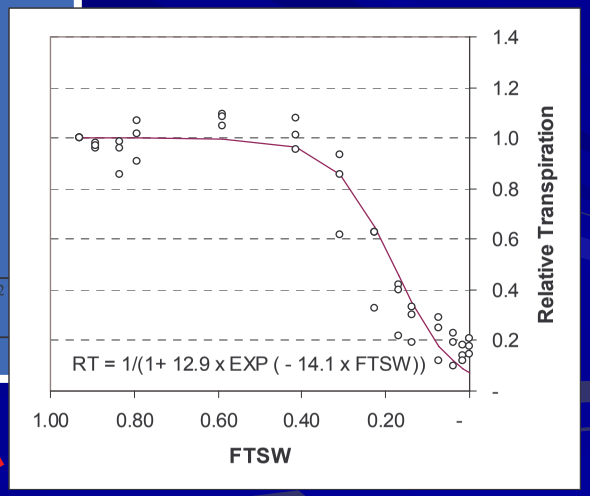
Research actives were mainly focussed on including in the grapevine model the effect of:

- WATER STRESS
- PLANT DISEASES

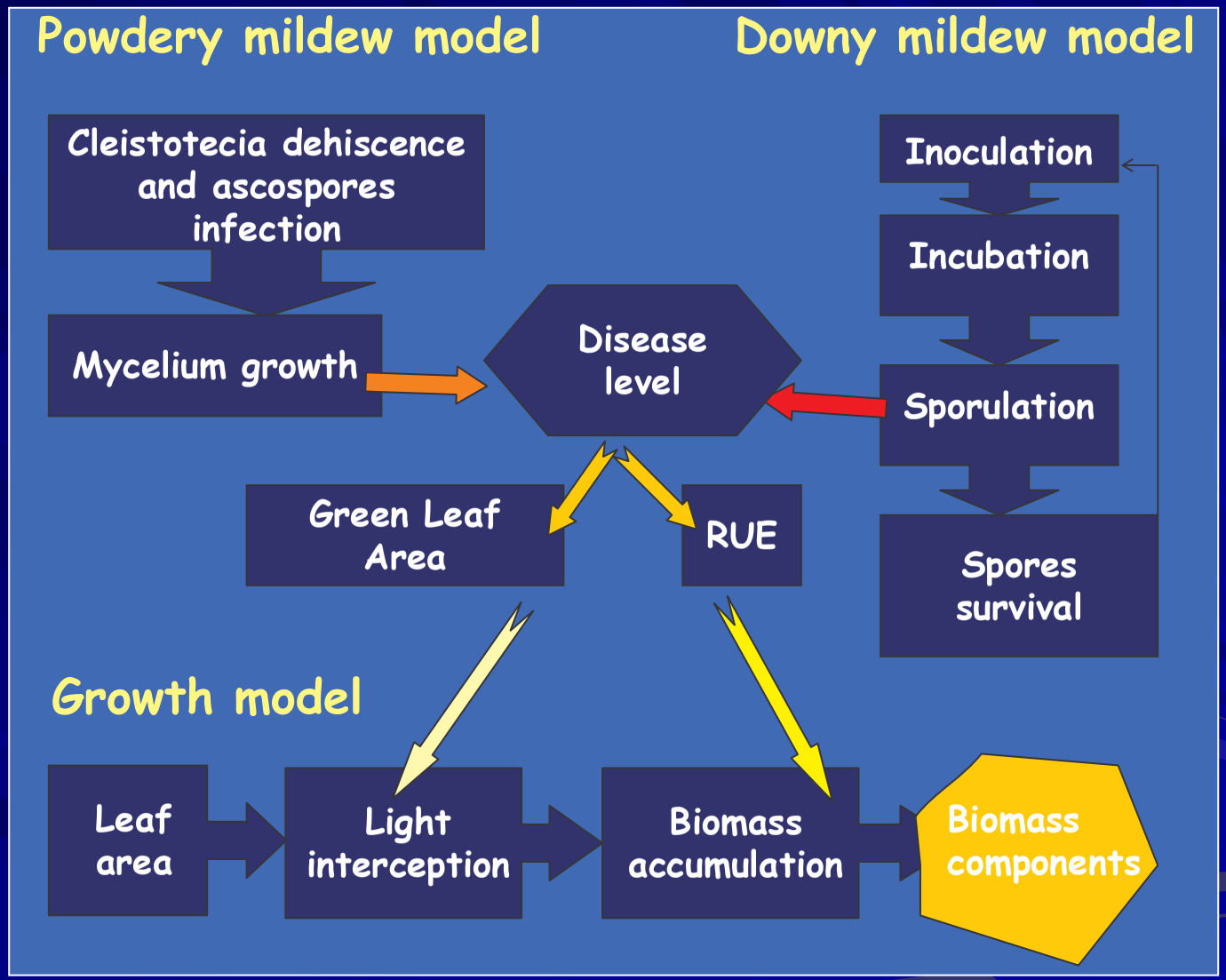
Model Water stress integration







Model Diseases integration:
Powdery and Downy mildew



Arguments

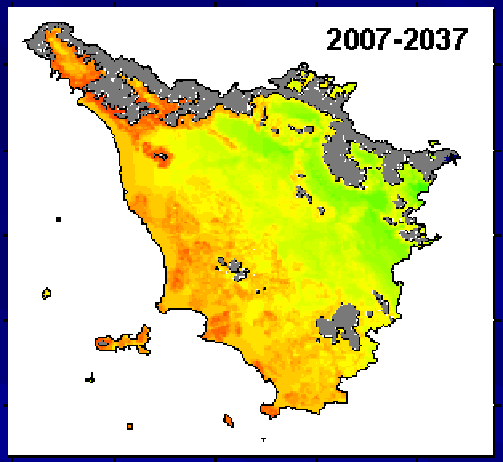
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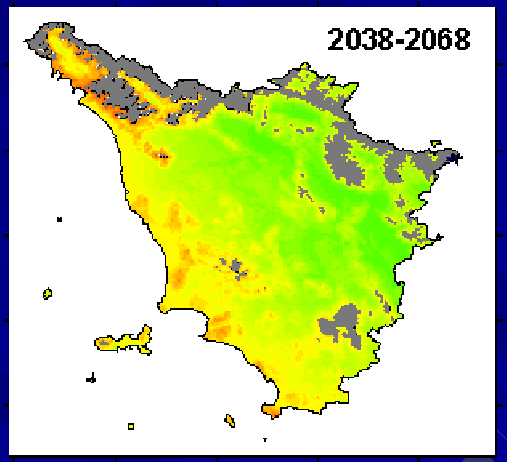
Present activity on grapevine

- **Regional Project on Tuscany Grapevine cultivation (CLARINO):**

Diseases:

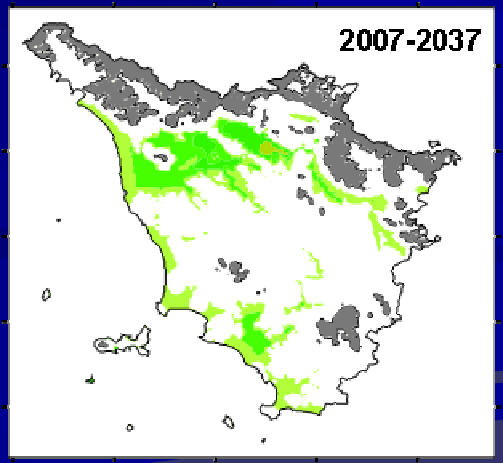
- powdery mildew

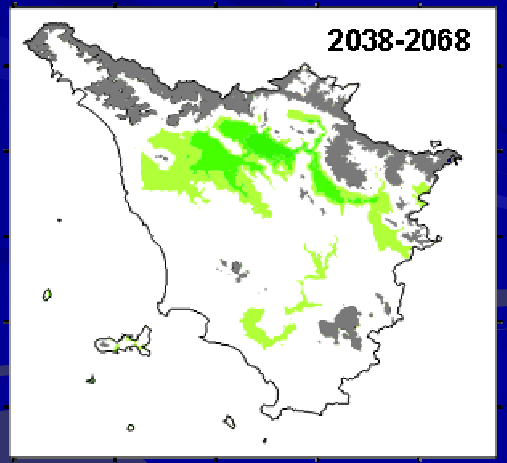




Pests:

- codley moth generations



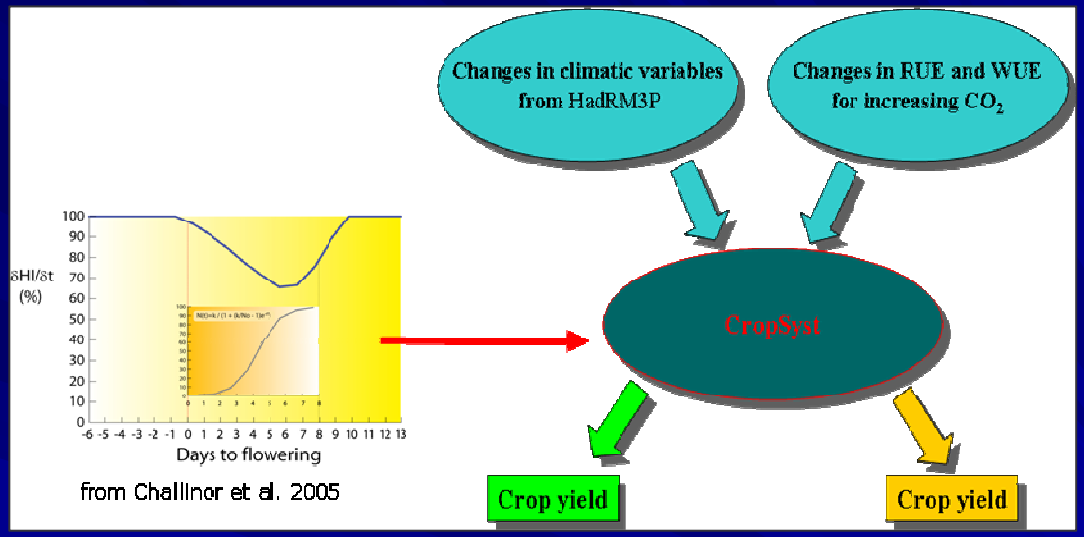


Present activity on grapevine

- **EU-funded IP Project within FP6 (ENSEMBLES and CIRCE):**

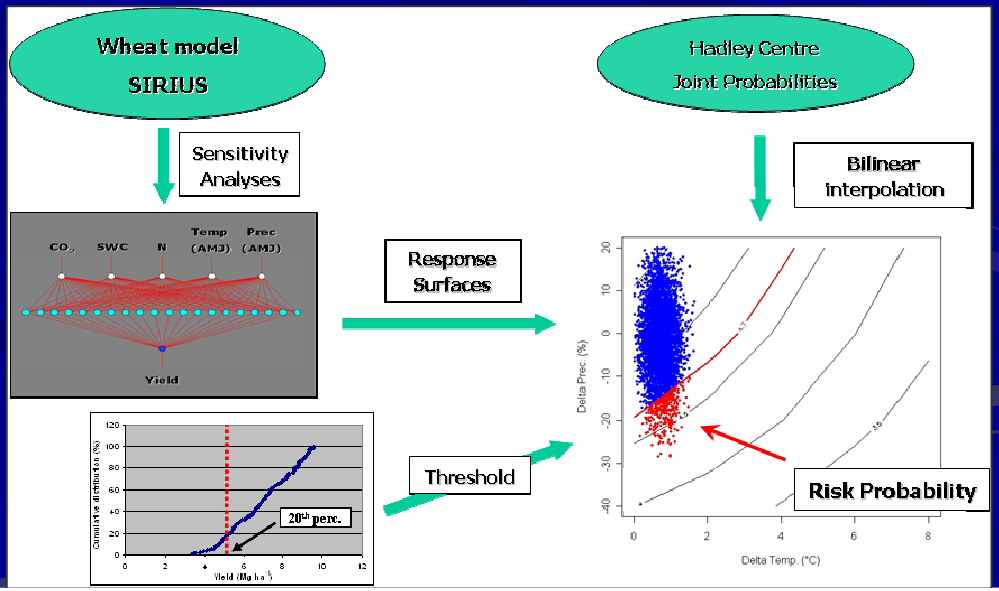
Extreme events:

- Reduction in yields due to extreme events during sensitive dev. stages (e.g. budbreak)



Impact in terms of Risk Probability:

- e.g. grape yields below a fixed threshold



List of publications

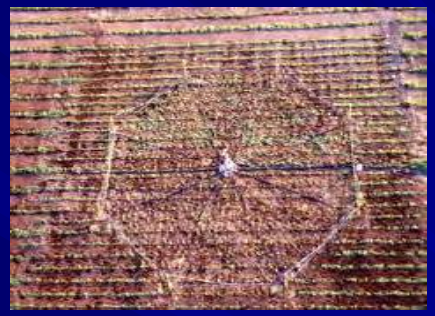
1. Orlandini S., Bindi M., B. Gozzini l993. Effect of CO_2-inducted climatic change on viticultural environments of cool climate regions of Italy. Viticultural and Enological Science, 48:81-85.
2. M. Bindi, B. Gozzini, S. Orlandini, 1995. The combined effects of climate changes and increasing in atmospheric CO_2 concentration on the potential growth of three grapevine varieties. Atti "International Symposium on Viticulture and Enology: Rootstock, Varieties and New Enological. ACTA Horticulturae, 388: 43-52.
3. M. Bindi, L. Fibbi, B. Gozzini, S. Orlandini, F. Miglietta, 1995. Mini Free Air Carbon Dioxide Enrichment (FACE) experiment on grapevine. In: "Climate change and agriculture in Europe: Assessment of impacts and adaptations", a cura di Harrison P. A., Butterfield R. E., Downing T. E. Research Report N°9 to the Commission of the European Union, Contract EV5V-CT93-0294, 125-137.
4. M. Bindi, L. Fibbi, B. Gozzini, S. Orlandini, F. Miglietta, 1995. Modelling the effects of climate change and climate variability on grapevine. In: "Climate change and agriculture in Europe: Assessment of impacts and adaptations", a cura di Harrison P. A., Butterfield R. E., Downing T. E. Research Report N°9 to the Commission of the European Union, Contract EV5V-CT93-0294, 206-220.
5. M. Bindi, L. Fibbi, B. Gozzini, S. Orlandini, F. Miglietta, 1996. Modelling the impact of climate scenarios on yield and yield variability of grapevine. Climate Research, 7: 213-224.
6. M. Bindi, F. Miglietta, B. Gozzini, S. Orlandini, L. Seghi, 1997. A simple model for simulation of growth in grapevine (Vitis vinifera L.). I Model development. Vitis, 36: 67-71.
7. M. Bindi, F. Miglietta, B. Gozzini, S. Orlandini, L. Seghi, 1997. A simple model for simulation of growth in grapevine (Vitis vinifera L.). II Model validation. Vitis, 36: 73-76.
8. M. Moriondo, M. Bindi, L. Fibbi, E. Finocchi, A. Giuntoli, S. Orlandini, 1998. Grapevine Response to Mildew Infections: Simulation of Biomass Accumulation and Final Yield. In: 7th ICCTA - international congress for computer technology in agriculture "Computer Technology In Agricultural Management And Risk Prevention" 15th - 18th november 1998 Florence, Italy, .217-224.
9. M. Bindi, L., Fibbi, M. Lanini, F. Miglietta, 2000. Effects of elevated carbon dioxide on grapevine. In Downing TE, Harrison PA, Butterfield RE and Lonsdale KG (eds.), Climate Change, Climatic Variability and Agriculture in Europe. An Integrated Assessment, Research Report No. 21, Brussels, Belgium: Commission of the European Union, Contract ENV4-CT95-0154, pp.71-81.
10. M. Bindi, L., Fibbi, 2000. Modelling climate change impacts at the site scale on grapevine. In Downing TE, Harrison PA, Butterfield RE and Lonsdale KG (eds.), Climate Change, Climatic Variability and Agriculture in Europe. An Integrated Assessment, Research Report No. 21, Brussels, Belgium: Commission of the European Union, Contract ENV4-CT95-0154, pp. 117-134.
11. M. Bindi, L., Fibbi, F. Maselli, F. Miglietta, 2000. Modelling climate change impacts on grapevine in Tuscany In Downing TE, Harrison PA, Butterfield RE and Lonsdale KG (eds.), Climate Change, Climatic Variability and Agriculture in Europe. An Integrated Assessment, Research Report No. 21, Brussels, Belgium: Commission of the European Union, Contract ENV4-CT95-0154, pp. 191-216.
12. Bindi M., Fibbi L., M. Lanini and Miglietta F., 2001. Free Air CO2 Enrichment (FACE) of grapevine (Vitis vinifera L.): I. Development and testing of the system for CO2 enrichment. European Journal of Agronomy, 14: 135-143.
13. Bindi M., Fibbi L. and Miglietta F., 2001. Free Air CO2 Enrichment (FACE) of grapevine (Vitis vinifera L.): II. Effect on growth and grapes and wine quality. European Journal of Agronomy, 14: 145-155.
14. Bindi M., S. Bellesi, S. Orlandini, L. Fibbi, M. Moriondo, T. Sinclai. (2005). Influence of Water Deficit Stress on Leaf Area Development and Transpiration of Sangiovese Grapevines Grown in Pots. American Journal of Enology and Viticulture. vol. 56, pp. 68-72
15. Moriondo M, Orlandini S, Giuntoli A, Bindi M. (2005). The effect of downy and powdery mildew on grapevine (Vitis vinifera L.) leaf gas exchange. Phytopathology. vol. 153, pp. 350-357
16. Tognetti R, Raschi A, Longobucco A, Lanini M, Bindi M. (2005). Hydraulic Properties and Water Relations of Vitis Vinifera L. exposed to elevated CO2 Concentratiions in a Free Air CO2 Enrichment (FACE). Phyton-International Journal of Experimental Botany. vol. 45, pp. 243-256

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Other FACEs transferred by Florence Team

FACE experiment	CO_2 injection	Crop
POPFACE Project, Viterbo, Italy	Pure CO_2	Poplar
RiceFACE New Delhi, India	Mixed air and CO_2	Rice
SoyFACE, Illinois University, IL USA	Pure CO_2	Soybean
TasFACE, Hobart, Tasmania, AU	Pure CO_2	Grassland
BangFACE, Bangor University, Wales, UK	Pure CO_2	Mixtures of broadleaf species
Gradient FACE, USDA-ARS, Ft.Collins, CO USA	Pure CO_2	Short-grass prairies
CLIMAITE, Denmark	Pure CO_2	Grassland









Acknowledgments

All the people involved in the FACE experiments



These and many others .....

The pros and cons

- Pros
  - Study grapevine responses under field conditions
  - Obtain information for crop modelling applications
- Cons
  - Limited number of plants
  - High plants variability
  - Length of the experiment
  - Costs (CO_2 and maintenance)
  - Complexity (eco-physiological and electronic knowledge)

Designing FACE Experiments
The Importance of Including Multiple Climate Change Factors

David Tissue, David Ellsworth, Nathan Phillips, Jann Conroy, Oula Ghannoum
And Colleagues



New Zealand FACE

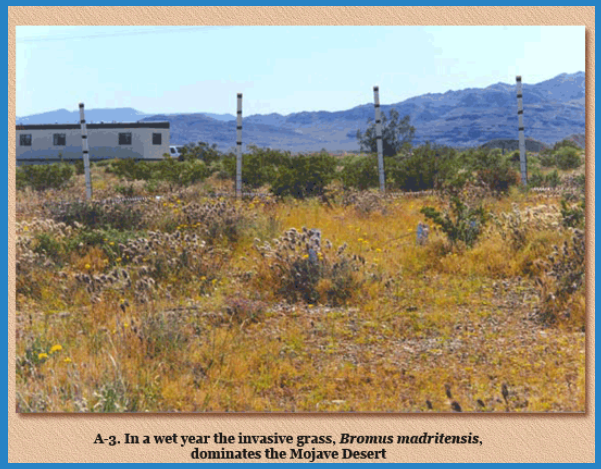
University of Western Sydney
CENTRE FOR PLANT AND FOOD SCIENCE



Duke FACE (N. Carolina)



ORNL FACE (Tennessee)



A-3. In a wet year the invasive grass, *Bromus madritensis*, dominates the Mojave Desert

Mojave Desert FACE (Nevada)



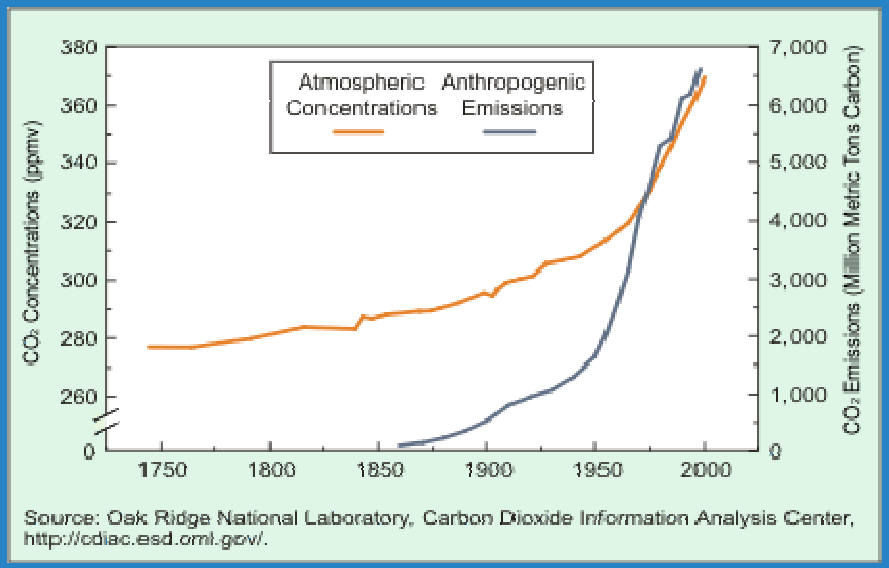
Aspen FACE (Wisconsin)

Talk Outline

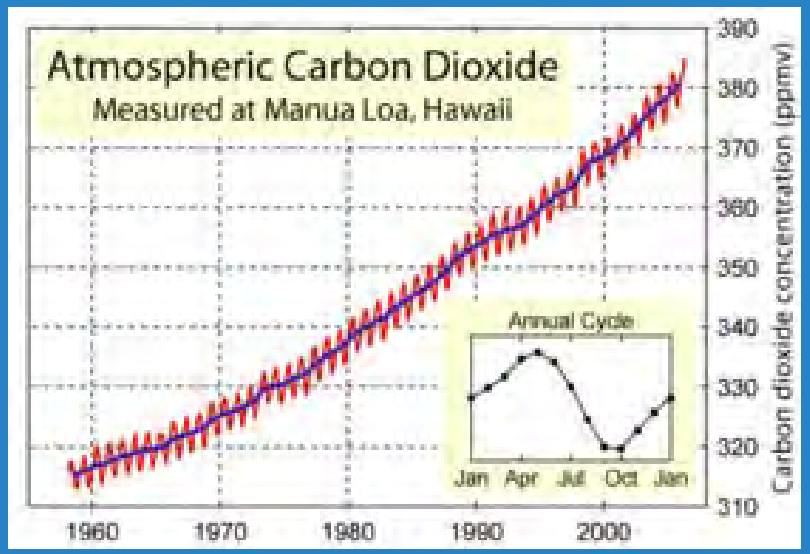
- Climate Change Factors
  - Atmospheric CO_2, Temperature, Precipitation
- FACE Facilities
  - Locations around the world
  - Experimental set up including multiple factor experiments
  - General findings
- UWS Experiments
  - Hawkesbury Forest Experiment (CO_2 x Water)
  - Glasshouse Experiment (CO_2 x Temp x Water)
- Points of Discussion

Rising Atmospheric CO_2

Pre-industrial to Present CO_2



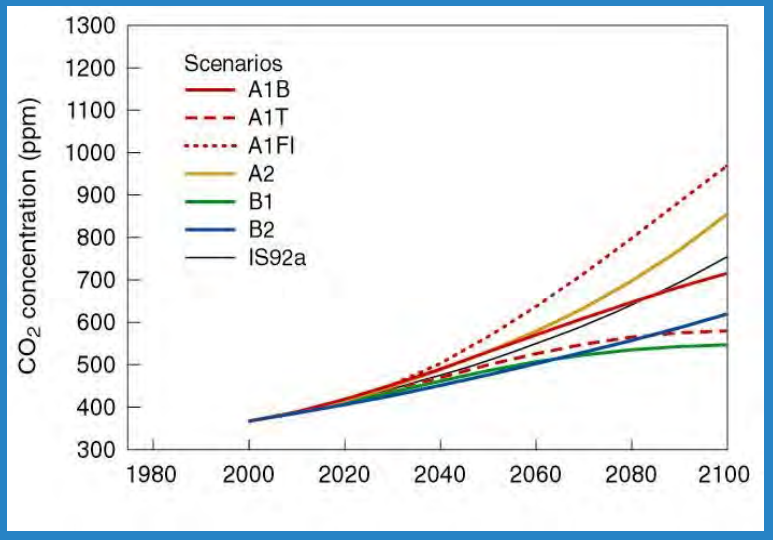
Last 50 Years



1850 – 280 ppm

Present – 385 ppm

2100 – 500 to 800 ppm

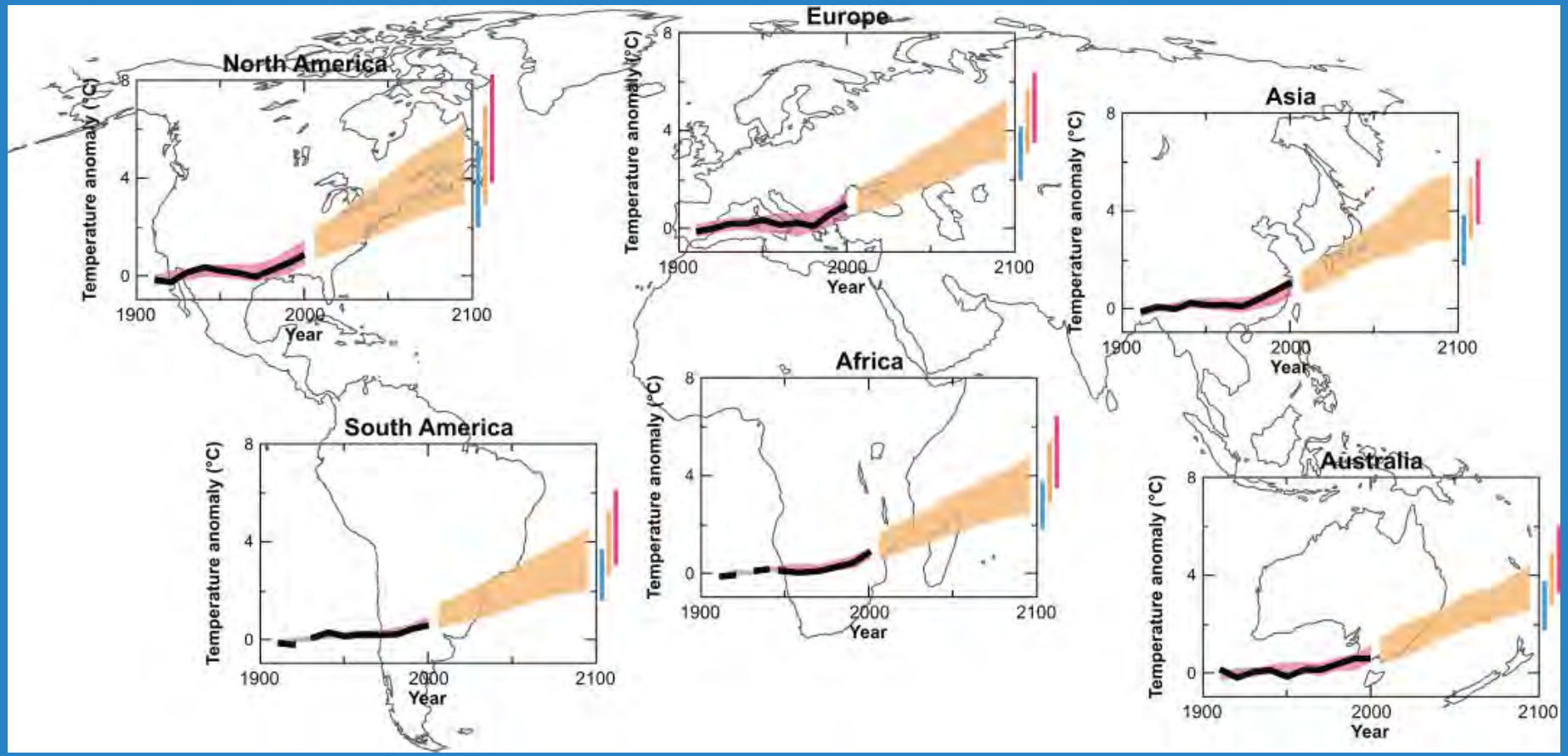


Future Projections

IPCC 2007

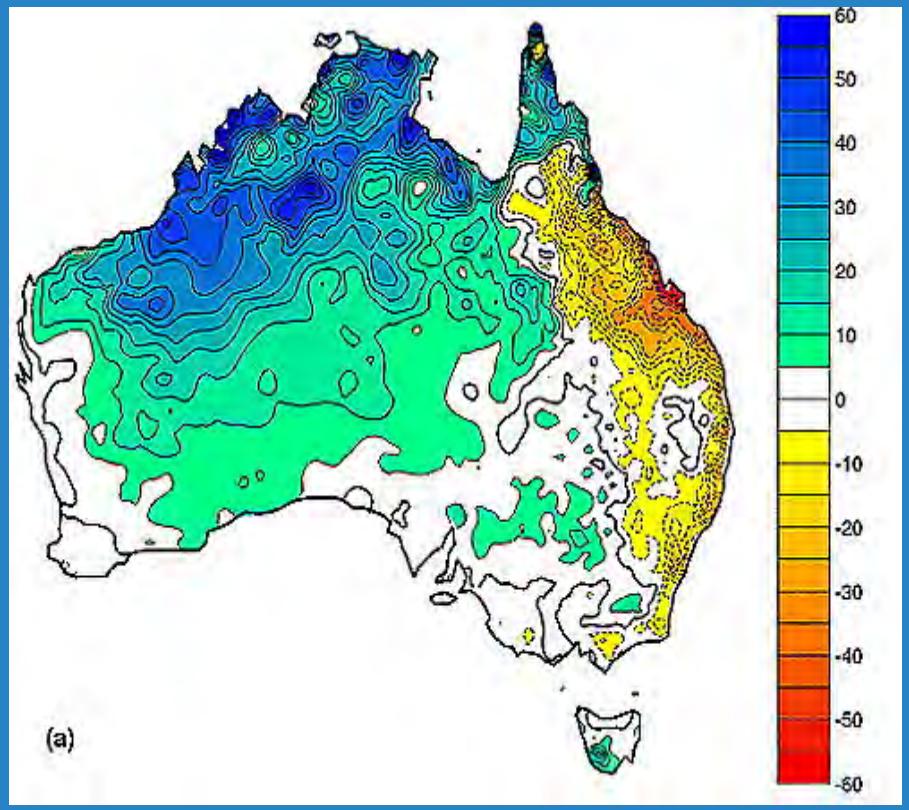
Rising Air Temperature

Australia – 2° to 4° C rise in next century

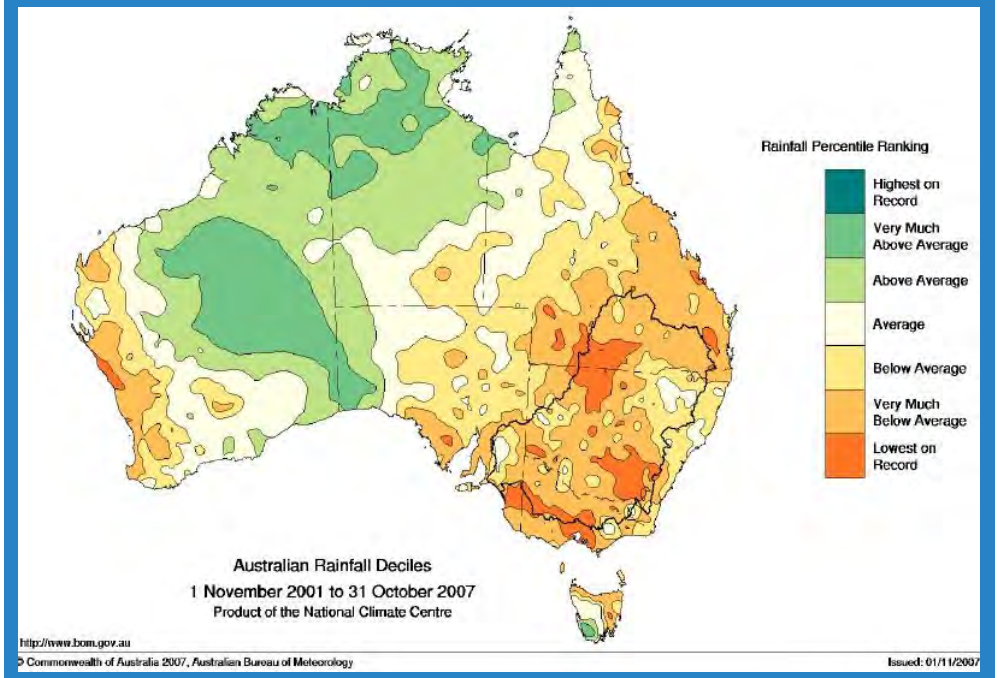


IPCC 2007

Precipitation
Australia Over Past 50 Years



Past 50 years

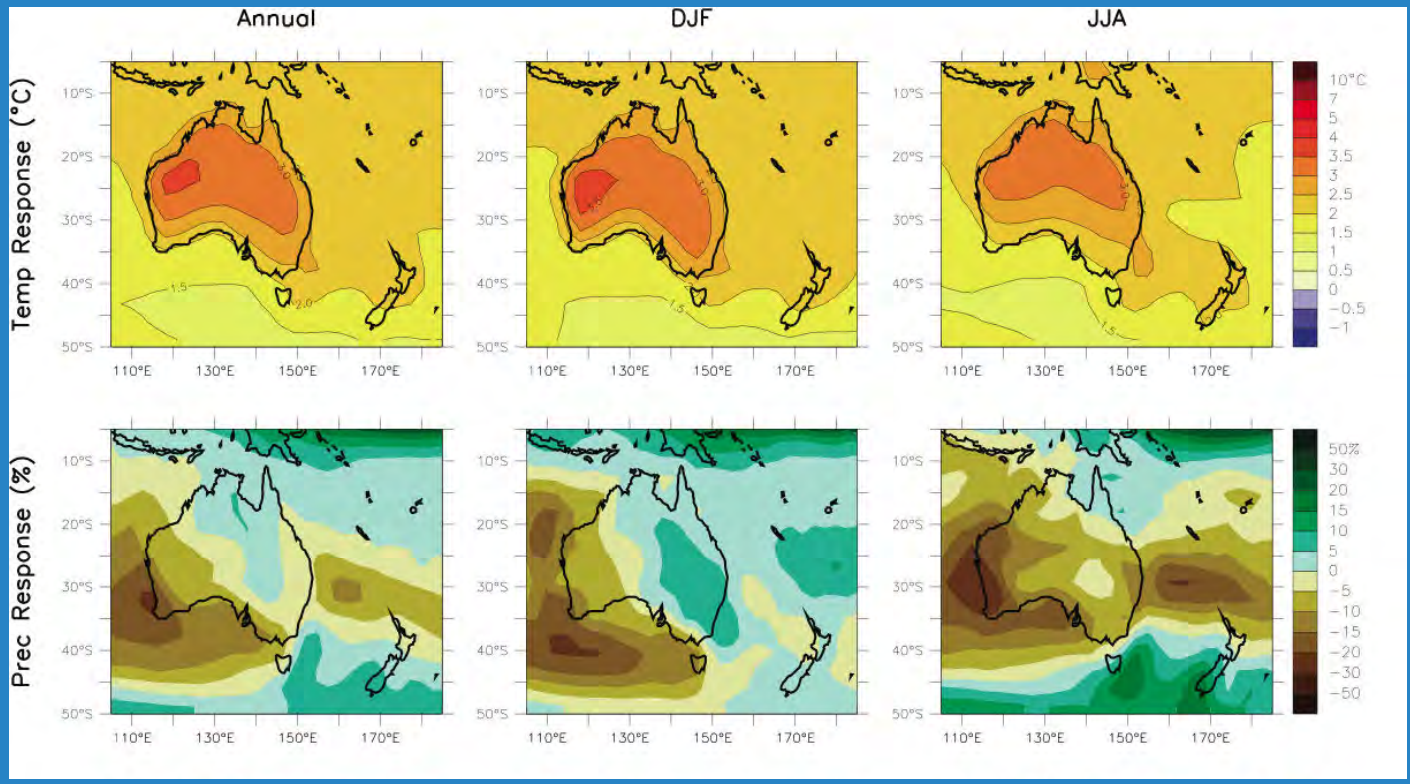


Past 6 years

Australian Bureau of Meteorology

Precipitation - Australia in 100 Years

Annual Summer Winter



5-15% Drier 5% Drier 5-15% Drier

IPCC 2007

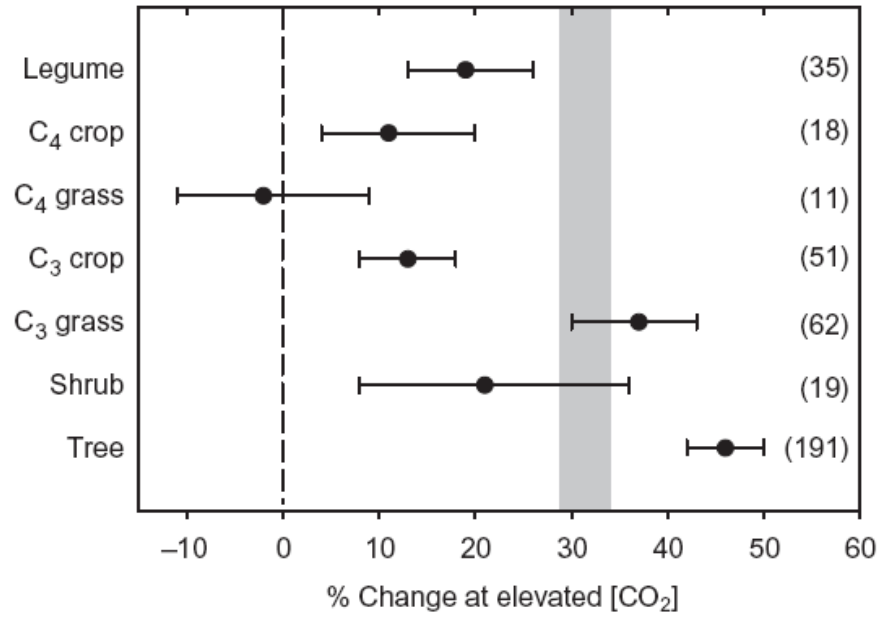
Operational FACE Sites – Worldwide

Country	Site	Location	Ecosystem	CO2 (ppm)	Temp	Water	Other
AUSTRALIA	AgFACE	Victoria	wheat	550			
	TasFACE	Tasmania	grassland	550	+2 C		
CHINA	China FACE	Jiangsu	Rice, wheat	Amb+200			
GERMANY		Braunschweig	crops	550		2 levels	2 N levels
	GiFACE	Giessen	grassland	Amb+20%			
NEW ZEALAND		North Island	Pasture grassland	475	Passive warming		sheep
UK	Bangor FACE	Bangor	Deciduous forest	Amb+200			species
SWITZERLAND	WebFACE	Hofstetten	Mature forest	600			
USA	BioCON	Minnesota	grasses	550			N; species
	PHACE	Wyoming	Prairie grasses	600	+1.5 C day +3 C night		
	Duke FACE	N. Carolina	Pine forest	Amb+200			N
	Jasper Ridge	California	grassland	AmbX2	+ 1 C	2 levels	N
	ORNL FACE	Tennessee	Sweetgum	550			
	ASPEN FACE	Wisconsin	Aspen	Amb+200			ozone
	Soy FACE	Illinois	Soybean	550			ozone

http://public.ornl.gov/face/global_face

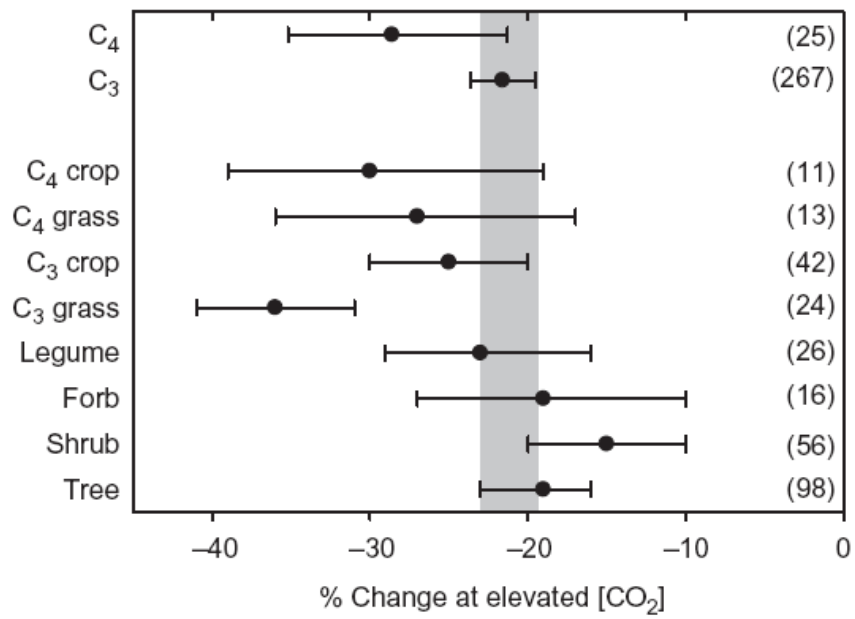
Increased Photosynthesis
Reduced Stomatal Conductance

Light Saturated Photosynthesis



C3 crop/ shrub
Inc 10-20%

Stomatal Conductance



C3 crop/ shrub
Dec 15-25%

Ainsworth & Rogers 2007 PCE

Increased Water Use Efficiency

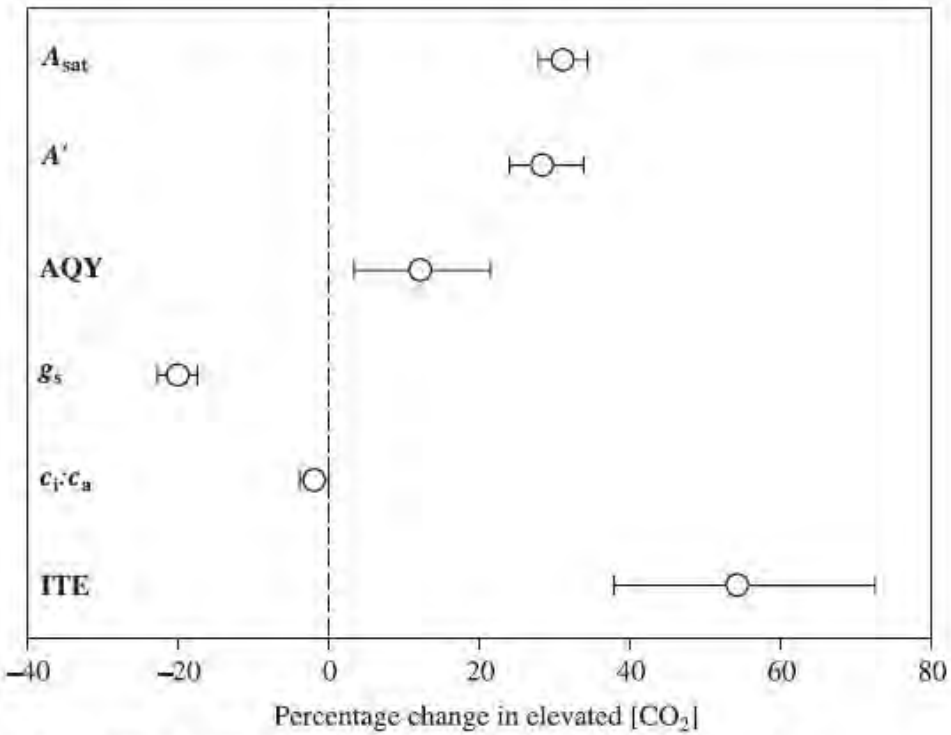


Fig. 1 Mean response to elevated [CO_2] (±95% CI) of light-saturated CO_2 uptake (A_{sat}), diurnal carbon assimilation (A'), apparent quantum yield of CO_2 uptake (AQY), stomatal conductance (g_s), ratio of intercellular (c_i) to atmospheric CO_2 concentration (c_a), and instantaneous transpiration efficiency (ITE). Number of species, FACE experiments and individual observations for each response are given in Appendix 2.

Photosynthesis – Inc 25%

Conductance – Dec 20%

WUE – Increase 50%

Ainsworth & Long 2005 New Phytologist

Photosynthesis and Stomatal Conductance
Impact of Temperature, Low N, Drought and High Ozone

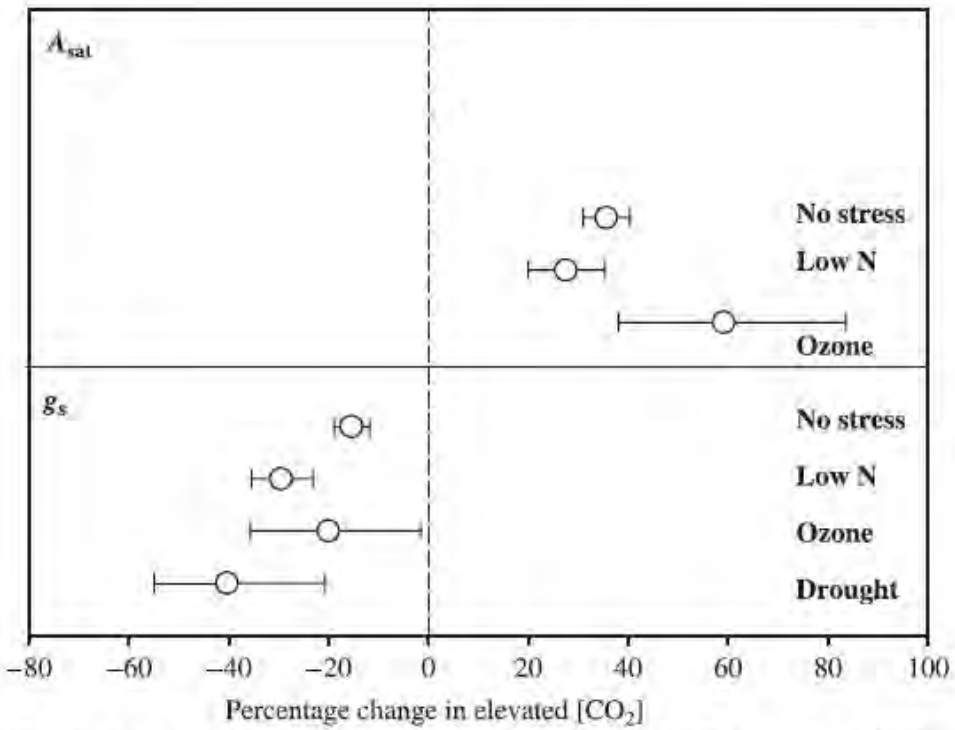


Fig. 4 Comparative responses of light-saturated CO_2 uptake (A_{sat}) and stomatal conductance (g_s) in different growth temperatures and stress treatments. Number of species, FACE experiments and individual observations for each response are given in Appendix 2.

Photosynthesis (A)

CO2 only – inc 35%

Low N – inc 25%
reduce CO2 effect by 30%

High ozone – inc 60%
increase CO2 effect by 70%

Stomatal Conductance (g_s)

CO2 only – dec 20%

Low N – dec 30%
increase CO2 effect by 50%

High ozone – dec 20%
no change in CO2 effect

Drought – dec 40%
increase CO2 effect by 100%

Ainsworth & Long 2005 New Phytologist

Mass Production and Crop Yield
Impact of Drought and Low N

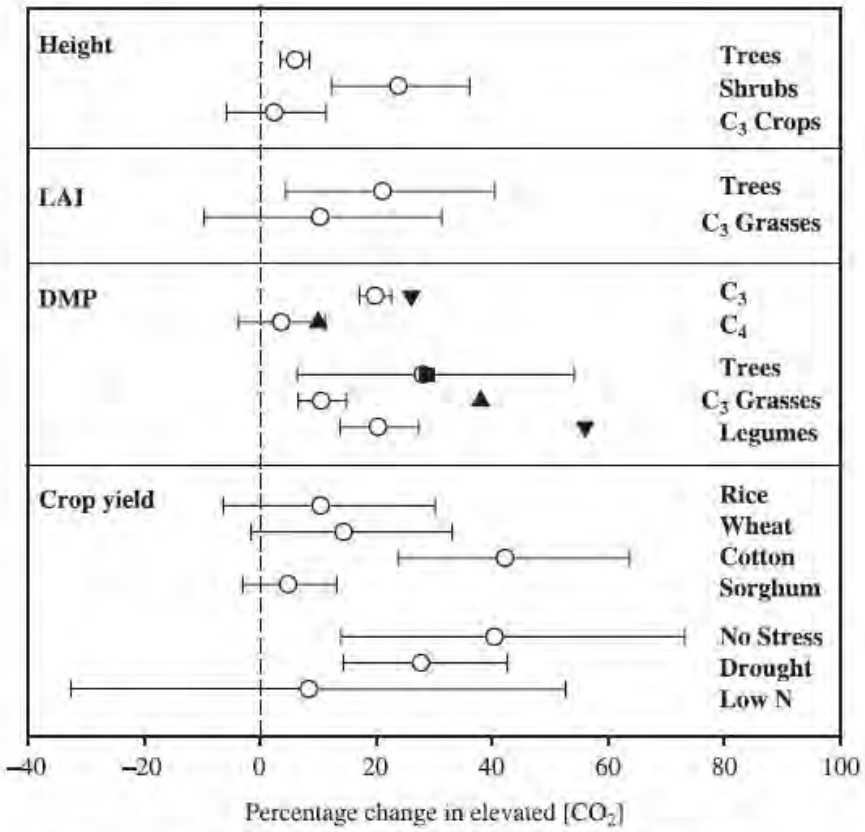


Fig. 8 Comparative responses to elevated [CO_2] of different functional groups and experimental conditions on growth and yield variables. Results from: ○, this meta-analysis; ■, a meta-analysis of tree species (Curtis & Wang, 1998); ▲, a meta-analysis of C_4 grasses (Wand *et al.*, 1999). ▼, comparative results from a meta-analysis of 79 crop and wild species (Jablonski *et al.*, 2002). Number of species, FACE experiments and individual observations for each response are given in Appendix 2.

Crop Yield

CO2 only – inc 40%

Drought – inc 30%
(reduce CO2 effect by 25%)

Low N – inc 5%
(reduce CO2 effect by 85%)

Ainsworth & Long 2005 New Phytologist

Hawkesbury Forest *Experiment*

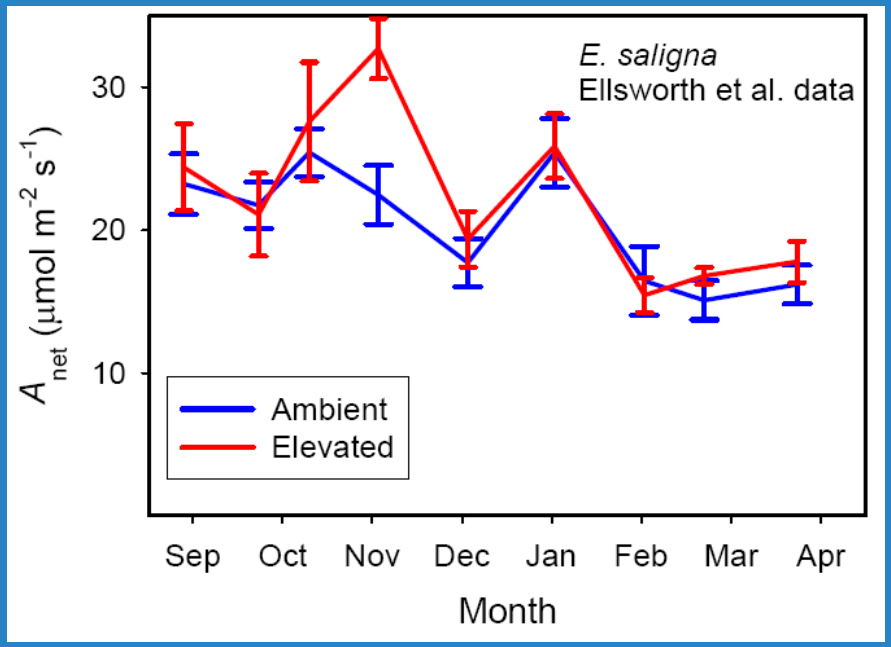
Treatments



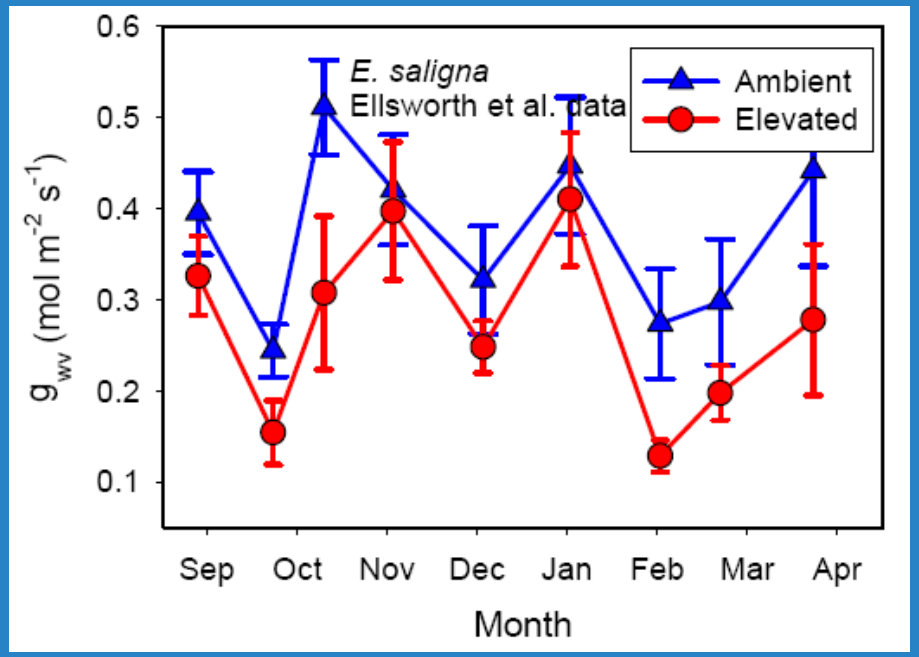
CO_2	Ambient	X	Amb + 240 ppm
Water	Well watered		Periodic drying cycles

Elevated CO_2 Reduces Stomatal Conductance But Does Not Affect Photosynthesis

Photosynthesis



Stomatal Conductance



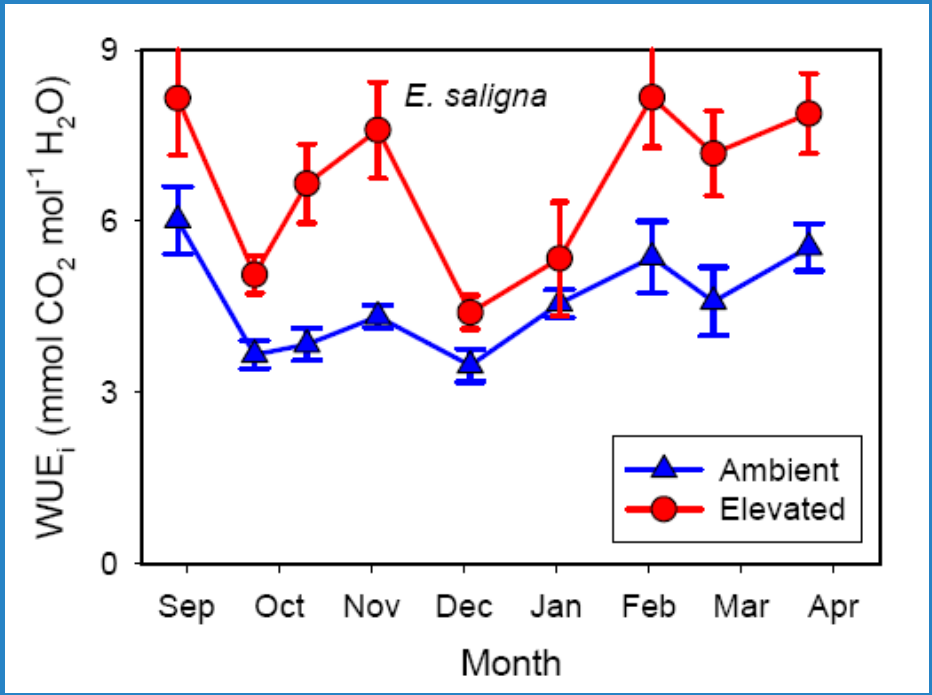
No CO_2 Effect

Reduced 30%

Low Soil N Completely Eliminates Elevated CO2 Stimulation of Photosynthesis (Down-regulation)

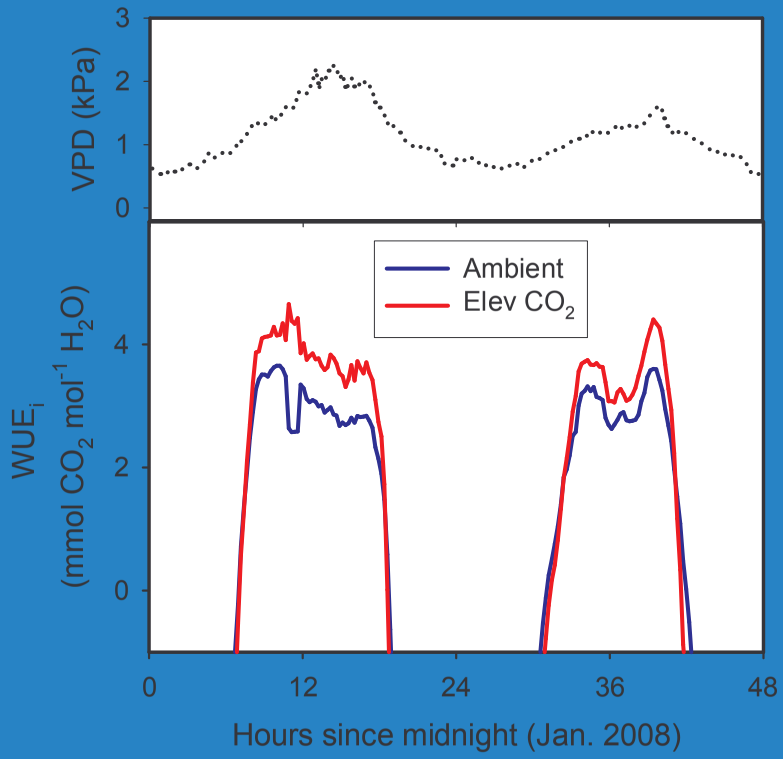
Elevated CO_2 Increases Leaf and Ecosystem WUE

Leaf WUE



Increased 50% Overall

Ecosystem WUE



Increased 20% in Jan

Increased WUE Due to Reduced Stomatal Conductance

HFE Conclusions

- Low soil N eliminated CO2 stimulation of photosynthesis
- Reduced stomatal conductance increased leaf and ecosystem WUE
- No impact of drought after 6 weeks of withholding water



Eucalypt Growth in Past and Future Environments
Understanding the Impacts of Atmospheric CO_2 and Climate





Glasshouse Experiment



CO_2 – Sub-ambient (280 ppm); Ambient (400 ppm); Elevated (640 ppm)

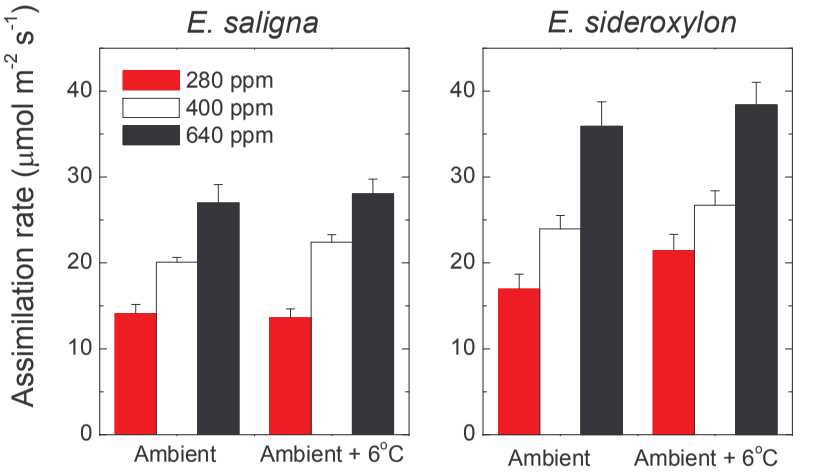
Temperature – Ambient; Ambient + 6°C

Water – Continuously Well Watered; Drying Cycles

Tree Species – *E. saligna; E. sideroxylon*

Impact of Elevated CO2 and Temperature on Photosynthesis and Stomatal Conductance

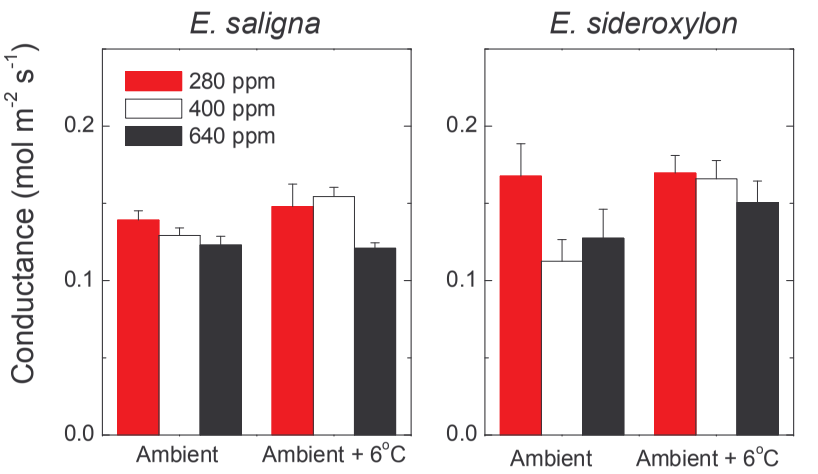
Photosynthesis



At growth conditions

Feb-08				
	Spp.	***	Temp x [CO_2]	ns
	Temp	*	Temp x Spp.	ns
	[CO_2]	***	[CO_2] x Spp.	ns

Stomatal Conductance



At growth conditions

Feb-08				
	Spp.	ns	Temp x [CO_2]	ns
	Temp	*	Temp x Spp.	ns
	[CO_2]	*	[CO_2] x Spp.	ns

Elevated CO2 increased photosynthesis

Elevated Temp increased photosynthesis

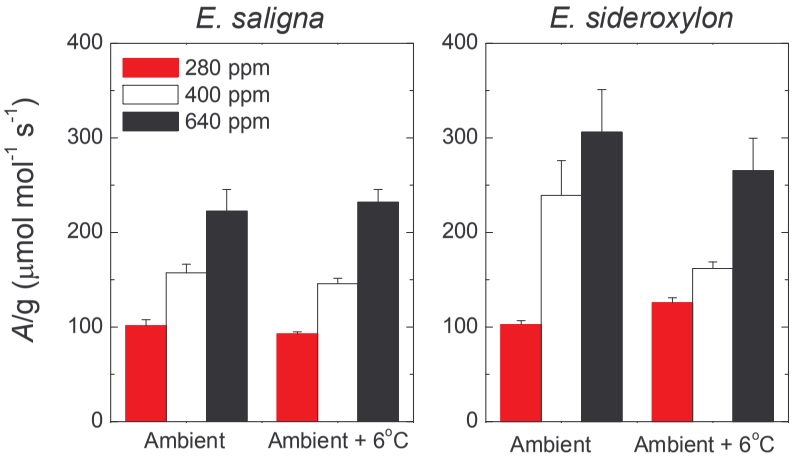
Elevated CO2 decreased conductance

Elevated Temp increased conductance

Stimulation of photosynthesis in high CO2 maintained at high temperature

Impact of Elevated CO2 and Temperature on Water Use Efficiency and Leaf Dark Respiration

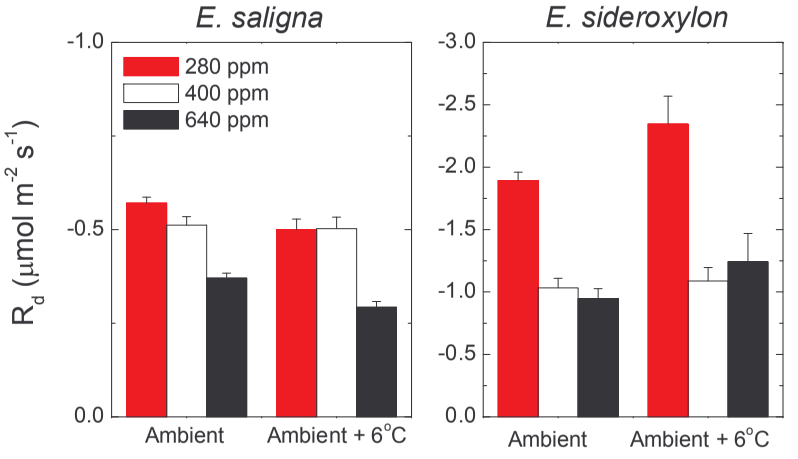
Leaf WUE



At growth conditions

Feb-08				
	Spp.	**	Temp x [CO_2]	ns
	Temp	ns	Temp x Spp.	ns
	[CO_2]	***	[CO_2] x Spp.	ns

Leaf Dark Respiration



At growth conditions

May-08				
	Spp.	***	Temp x [CO_2]	ns
	Temp	ns	Temp x Spp.	*
	[CO_2]	***	[CO_2] x Spp.	***

Elevated CO2 increased WUE

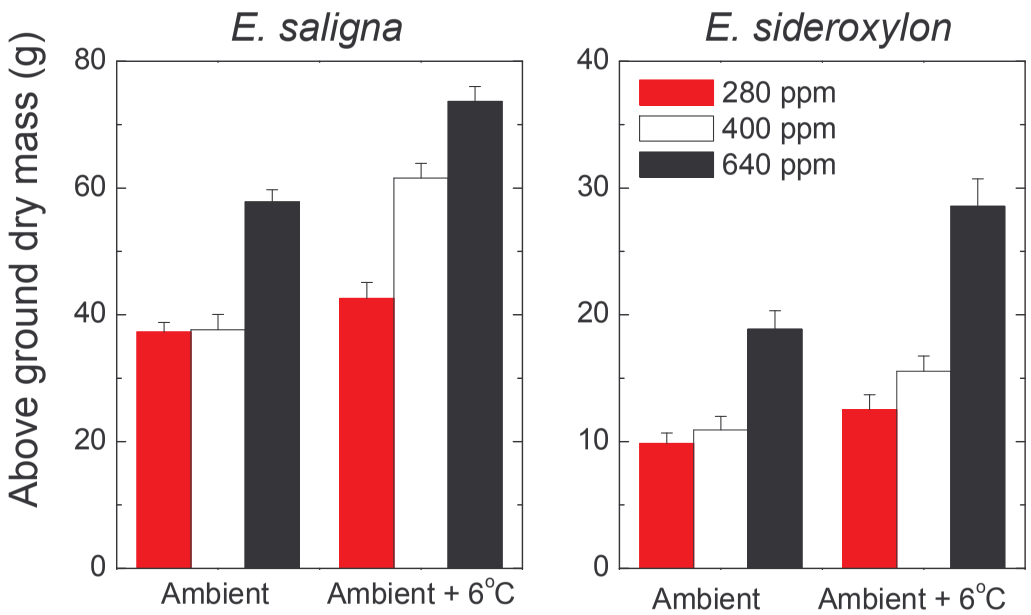
Elevated Temp did not affect WUE

Elevated CO2 decreased respiration in *E. saligna*

Elevated Temp did not affect respiration

Increased WUE in elevated CO2 maintained at high temperature
Reduction in dark respiration in *E. saligna* maintained at high temperature

Elevated CO2 and Temperature Both Increase Above-Ground Biomass

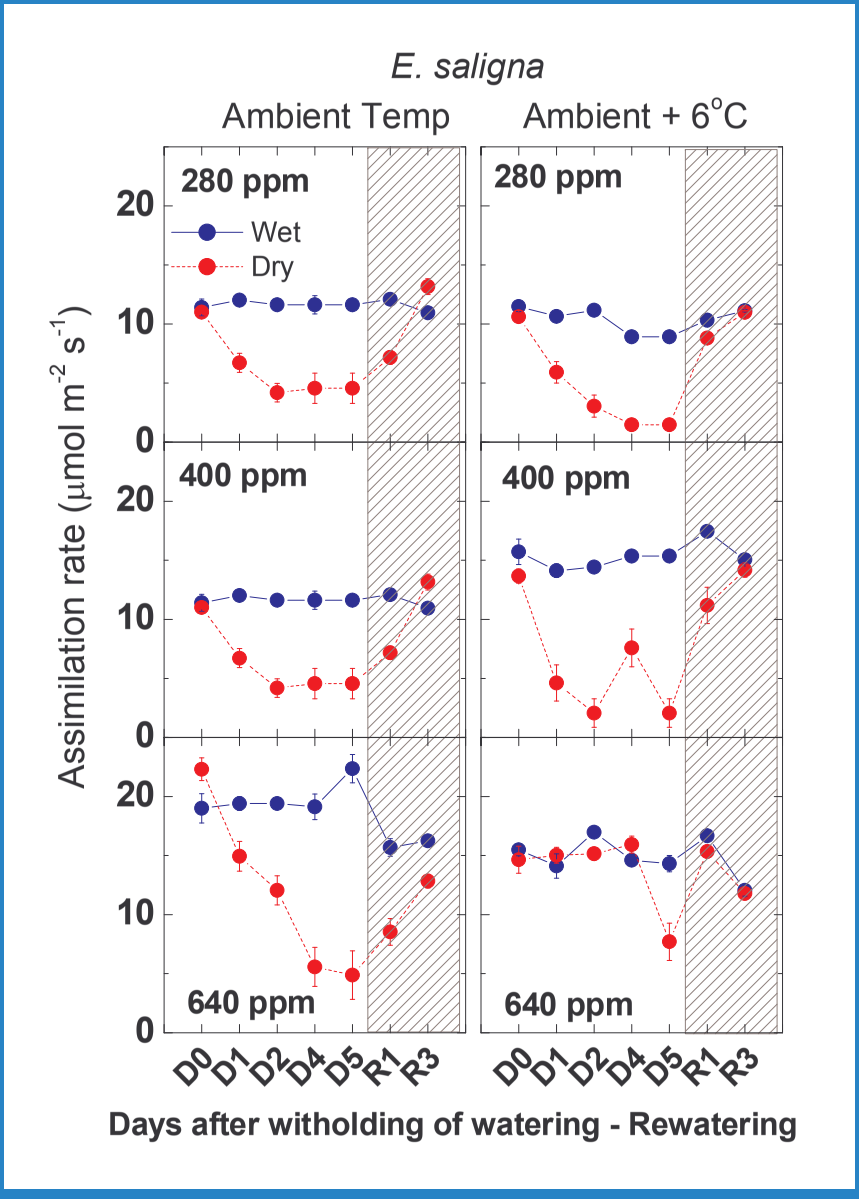


Water (NS)

Apr-08				
	Spp.	***	Temp x [CO_2]	***
	Temp	***	Temp x Spp.	***
	[CO_2]	***	[CO_2] x Spp.	***

Stimulation of above-ground biomass by elevated CO2 maintained at high temperature

Impact of Progressive Drought on Photosynthesis In Elevated CO2 and Temperature



Elevated CO2 effect

Elevated CO2 reduced impact of drought such that plants remained active longer

Elevated CO2 and Temperature Effect

Higher temperature further reduced impact of drought in elevated CO2 plants

Conclusions Based on HFE and Glasshouse Experiments
Eucalyptus saligna

- Photosynthesis
  - Elevated CO2 does not stimulate photosynthesis in low N (HFE)
  - Elevated CO2 does stimulate photosynthesis in higher N (GH)
  - Higher temperature does not reduce elevated CO2 effect (GH)
  - Higher temperature and elevated CO2 reduce impact of drought (GH)
- Water Use Efficiency
  - Elevated CO2 does increase WUE in low N primarily due to reduced g_s (HFE)
  - Elevated CO2 does increase WUE in higher N due to both increased A and decreased g_s (GH)
  - Higher temperature does not reduce increased WUE in higher N (GH)

Multiple Factor Experiments Generate Different Results than Single Factor Experiments
Particularly Important for Models of Plant Response to Climate Change

Application of Different Climate Change Factors

- Importance of Different Climate Change Factors
  - Elevated CO2
    - use Miglietta system (Bindi et al 2001) which is proven technology
    - relatively low cost for CO2
  - Temperature
    - must heat during day and night
    - IR heaters most practical (see Kimble review)
  - Water
    - simple to add, but hard to exclude
    - timing and magnitude of application very important
  - Nitrogen
    - simple to add
    - very important regulator of photosynthesis response to elevated CO2
  - Ozone
    - not really important in Australia

Value of FACE Relative to Other Experimental Systems

- Best system for evaluating grapevine response to natural environmental conditions
  - Natural light
  - Ambient temperature, humidity, precipitation
  - Large soil volume with appropriate microbial communities & soil water
- More difficult to implement treatments
  - Temperature is difficult to control and could be expensive
  - Difficult to exclude water during very wet years
  - Subject to natural environmental variation by season and year
- Must determine cost-benefit ratio
  - Significant funding is required to conduct good experiments
  - Funding must be guaranteed for a minimum of 5 years to justify investment
  - Experiments must be continued for many years to generate useful data
  - Technical staff are required for installation of system
  - Technical staff are required to maintain and run system for many years
  - Significant data management and research coordination are required

Research Priorities for Grape FACE

- Multiple Factor Experiment
  - Elevated CO2 x Temperature
  - Elevated CO2 x Water (both timing and magnitude)
  - Elevated CO2 x Temperature x Water
  - Need sufficient replication to assess treatment differences

- Key Measurements
  - Susceptibility to drought
  - Timing and magnitude of sugar production
  - Carbohydrate production and translocation to fruit
  - Carbon partitioning and plant secondary chemical production

Acknowledgements to Colleagues and Funding Agencies

Glasshouse Experiment

UWS – Renee Smith, Renee Attard, Roslyn Woodfield
Bowdoin College – Barry Logan, Carolyn Hricko
Fordham University – Jim Lewis





HFE Experiment

UWS – Markus Loew, Marion Liberloo, Remko Dursma
UTS – Derek Eamus
Macquarie – Belinda Medlyn
UNSW – Ross McMurtrie
Sydney Uni – Mark Adams





Funding Agencies

Australian Greenhouse Office
Department of Climate Change
Australian Research Council
New South Wales Department of Energy and Conservation
University of Western Sydney

Biochemical, Leaf Chemistry and Carbohydrate Response to Elevated CO2

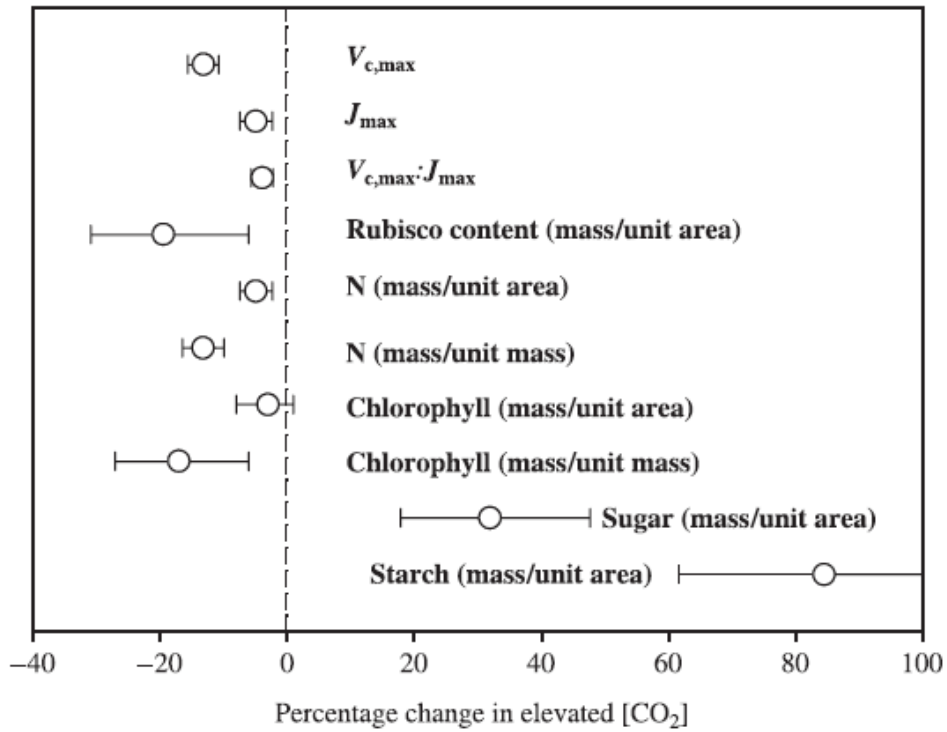


Fig. 5 Mean response of maximum carboxylation rate ($V_{c,max}$), maximum rate of electron transport (J_{max}), ratio of $V_{c,max}$: J_{max}, Rubisco content (mass/unit area), nitrogen content reported on both area and mass basis, chlorophyll content reported on both area and mass basis, sugar and starch content reported on area basis, ±95% CI. Number of species, FACE experiments and individual observations for each response are given in Appendix 2.

Ainsworth & Long 2005 New Phytologist

Do we need FACE or can we use other experimental systems?

Table 3 Comparison of the general results of plant responses to elevated [CO_2] from this analysis of large-scale FACE experiments (FACE) vs previous quantitative reviews of elevated [CO_2] experiments (prior)

Generality	FACE	Prior	Certainty
Order of C_3 functional group responsiveness	Trees > legumes > C_3 grasses	Legumes[1] > grasses[2] > woody plants[3] No difference in functional groups[4]	Low
C_3 vs C_4 response	$C_3 >> C_4$ $C_3 = C_4$[2]	$C_3 > C_4$[5]	Low
Sustained increase in carbon uptake	Yes No[5]	Yes[4,8]	High
Acclimation of photosynthesis	$V_{c,max}/J_{max}$	No change in $V_{c,max}/J_{max}$[4,6]	High
Decrease in leaf N	Specific to and accounted for by Rubisco	Dilution effect[6,8]	Medium
Increase in leaf-area index	Trees only No[8]	Yes[7]	Low
Stimulation in crop yield	Small	Large[9,10]	Medium

[1]Jablonski *et al*. (2002); [2]Wand *et al*. (1999); [3]Curtis & Wang (1998); [4]Nowak *et al*. (2004); [5]Bazzaz (1990); [6]Medlyn *et al*. (1999); [7]Saralabai *et al*. (1997); [8]Drake *et al*. (1997); [9]Kimball (1983); [10]Kimball *et al*., 2002).
General level of certainty of our findings is based on sample sizes and confidence intervals around our meta-analytic results.

Australian Grains FACE Array

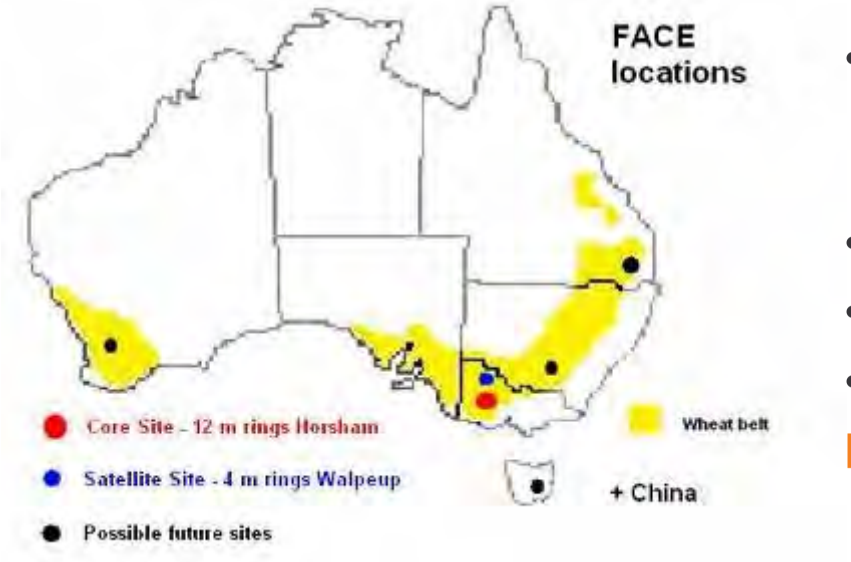
Experiences

Rob Norton

Glenn Fitzgerald



Australian Grains Free Air Carbon Dioxide Array



- **Department of Climate Change / Grains Research & Development Corporation ($1,700k)**
- **Victorian Government ($2,300k)**
- **The University of Melbourne ($736k)**
- **BOC Australia ($300k)**

Funded through to June 2010.

- *Chinese Academy of Agricultural Science ($200k)*
- *Department of Climate Change ($300k)*
- *The University of Melbourne ($50k)*

State Government Victoria Department of Primary Industries

Australian Government
Department of Climate Change

GRDC Grains Research & Development Corporation

BOC



Techniques for studying eCO_2 response

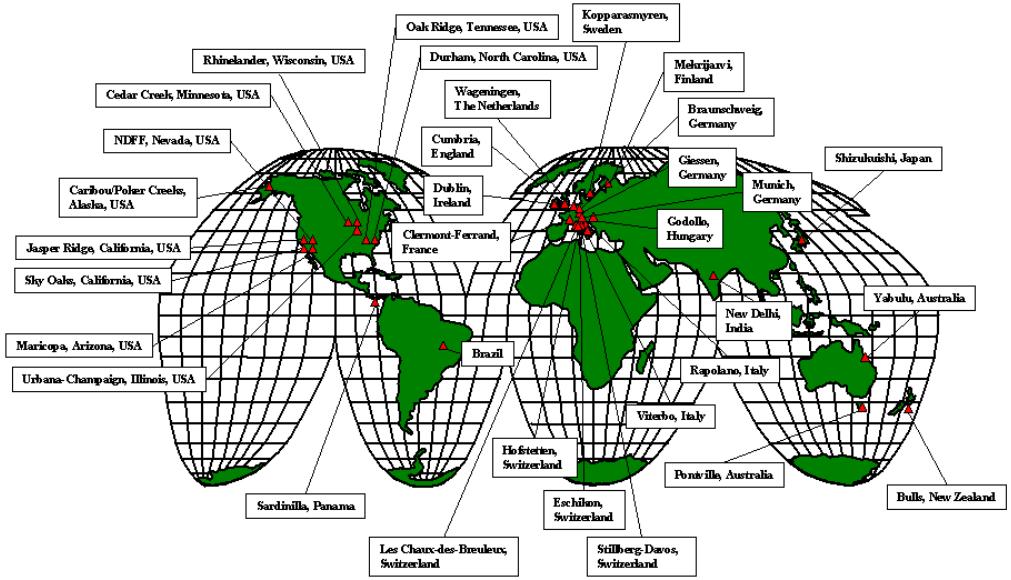
- Enriched atmosphere glasshouses or chambers
- Open topped chambers
- Enclosed Chambers
- Gradient tunnels
- Free Air Carbon Dioxide Enrichment (FACE)





Approximatel world
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CAAS FACI

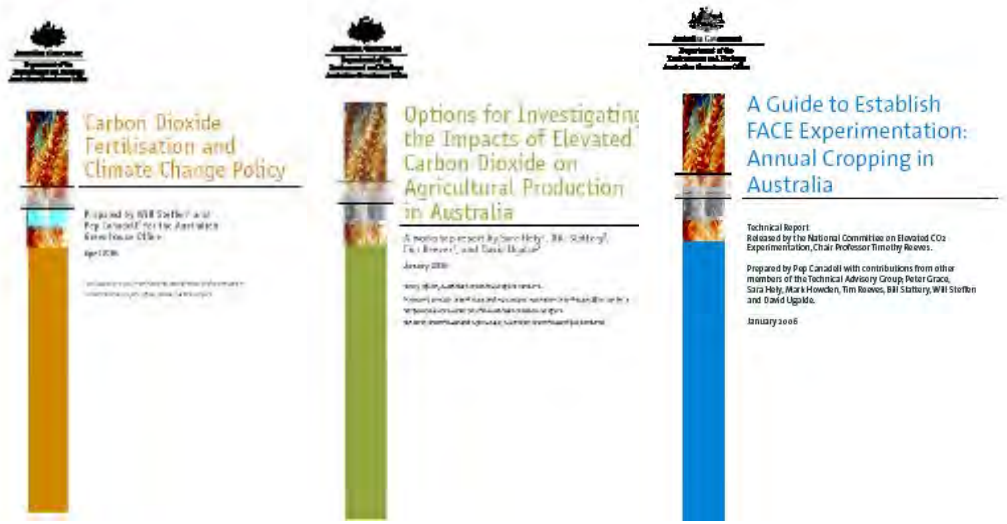


Our starting point for FACE

- In C3 plants – CO_2 & O_2 competition for active sites on 'rubisco' shift to increase gross photosynthetic C fix and reduce C loss in photorespiration.
- In both C3 and C4 plants, stomatal aperture narrows reducing water use.

Therefore C ↑ increases & W ↓ decreases so TE increases eCO_2 reduces

- Reports by AGO recommending FACE as a strategy to address knowledge gaps on the interactions of eCO_2 with
  - Water
  - Temperature
  - Nutrients (esp. N)
  - Genotype
  - *Feedbacks*
- Integrate these effects into crop models.



Our experience with FACE

- Visited several FACE sites to collect information
  - TasFACE (Hovenden)
  - SoyFace (Long)
  - Italy (Miglietta)
  - Germany (Weigel)
  - Denmark (Beier)
  - China (Zhu)
  - *Arizona (Kimball)*
  - *Japan (Kyobashi)*
  - *AspenFACE (Karnosky)*
  - *International Meetings*
  - CHINA MINIFACE

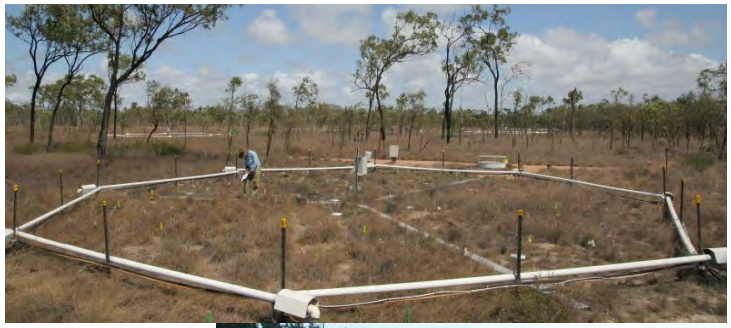
- Well established network of FACE researchers with good collaboration evidenced
- On the surface, we have a good understanding of the primary effects of eCO_2
- Need to work on the interactions

  Water, Temperature, Genotype, Nutrients, biotic factors
- Need to develop adaptation strategies



2 main FACE systems

- Pre-mixed CO_2/Air



OzFACE,

NZFACE

Oak Ridge





- Direct Injection of Pure CO_2



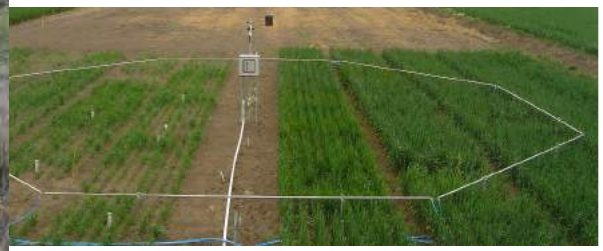
EuroFACE

SoyFACE

AGFACE

TasFACE





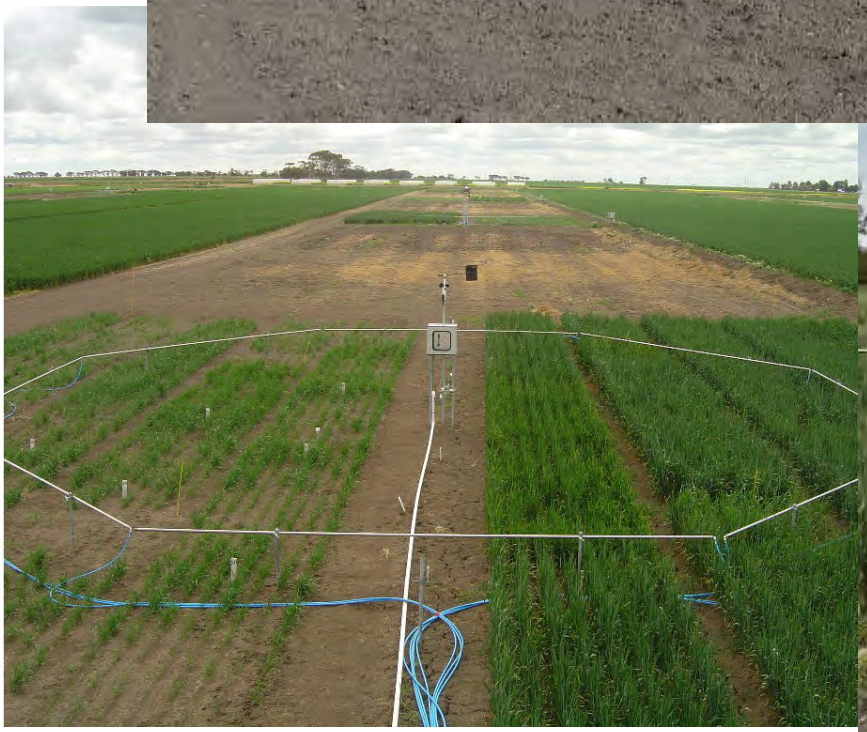
Vent Pipes

Vertical

Horizontal










BOC


BOC
BOC GASES
BOC GASES


DATAPORT
FILL
MODE
DATA ONLINE
REMOTE MONITORING SOLUTIONS



1.5 km of buried CO_2 pipe

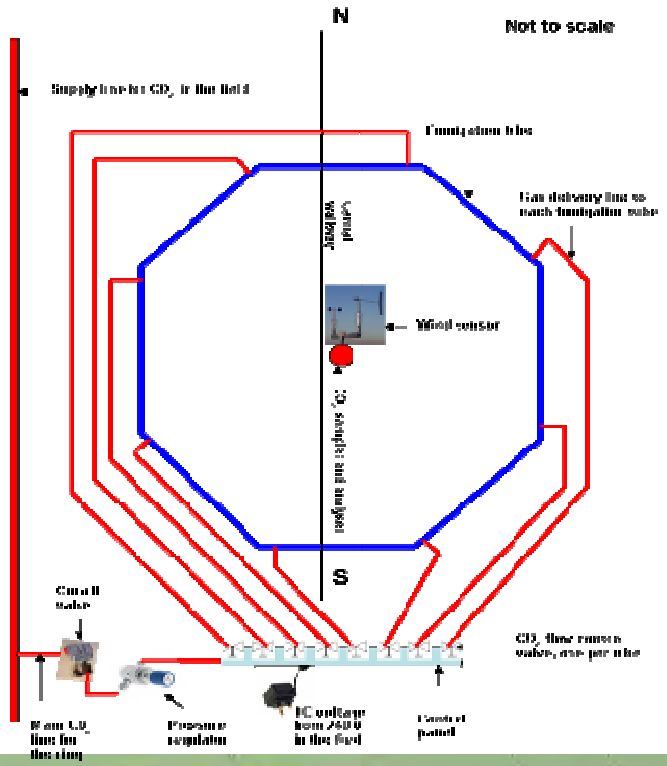


2 km of buried 240 V power line





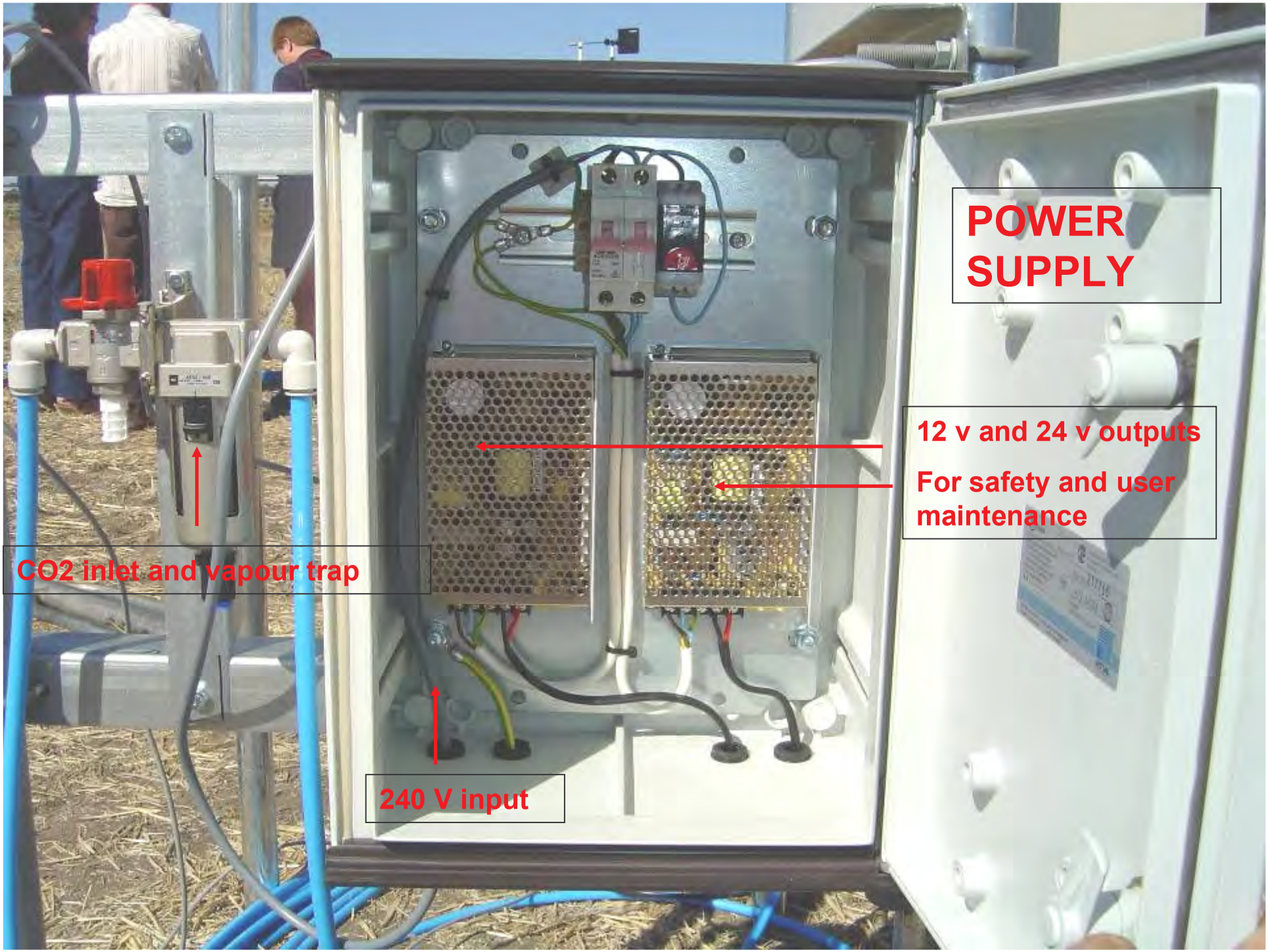
2 km of irrigation networking

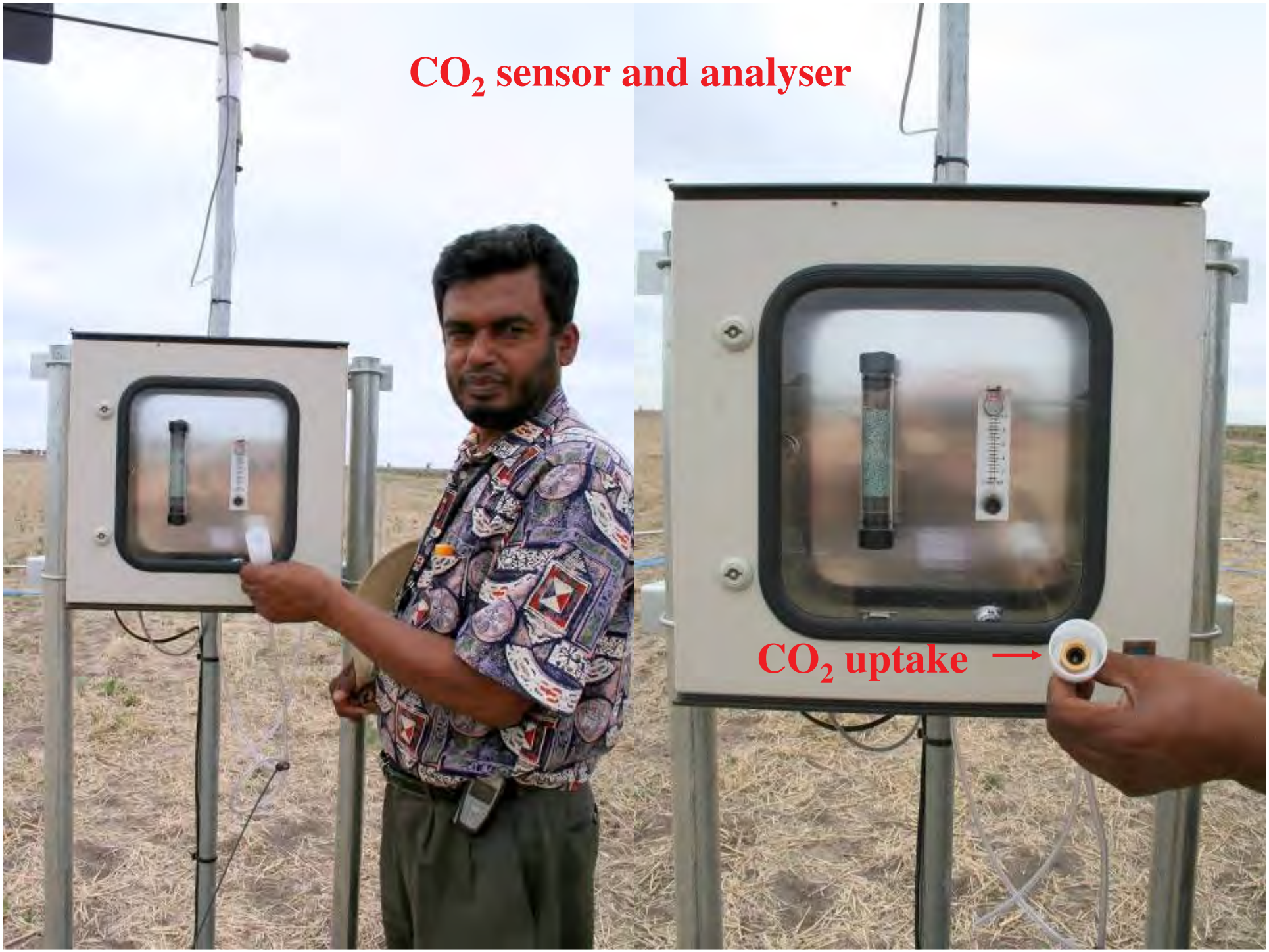

N
Not to scale
S


Construction of AGFACE rings

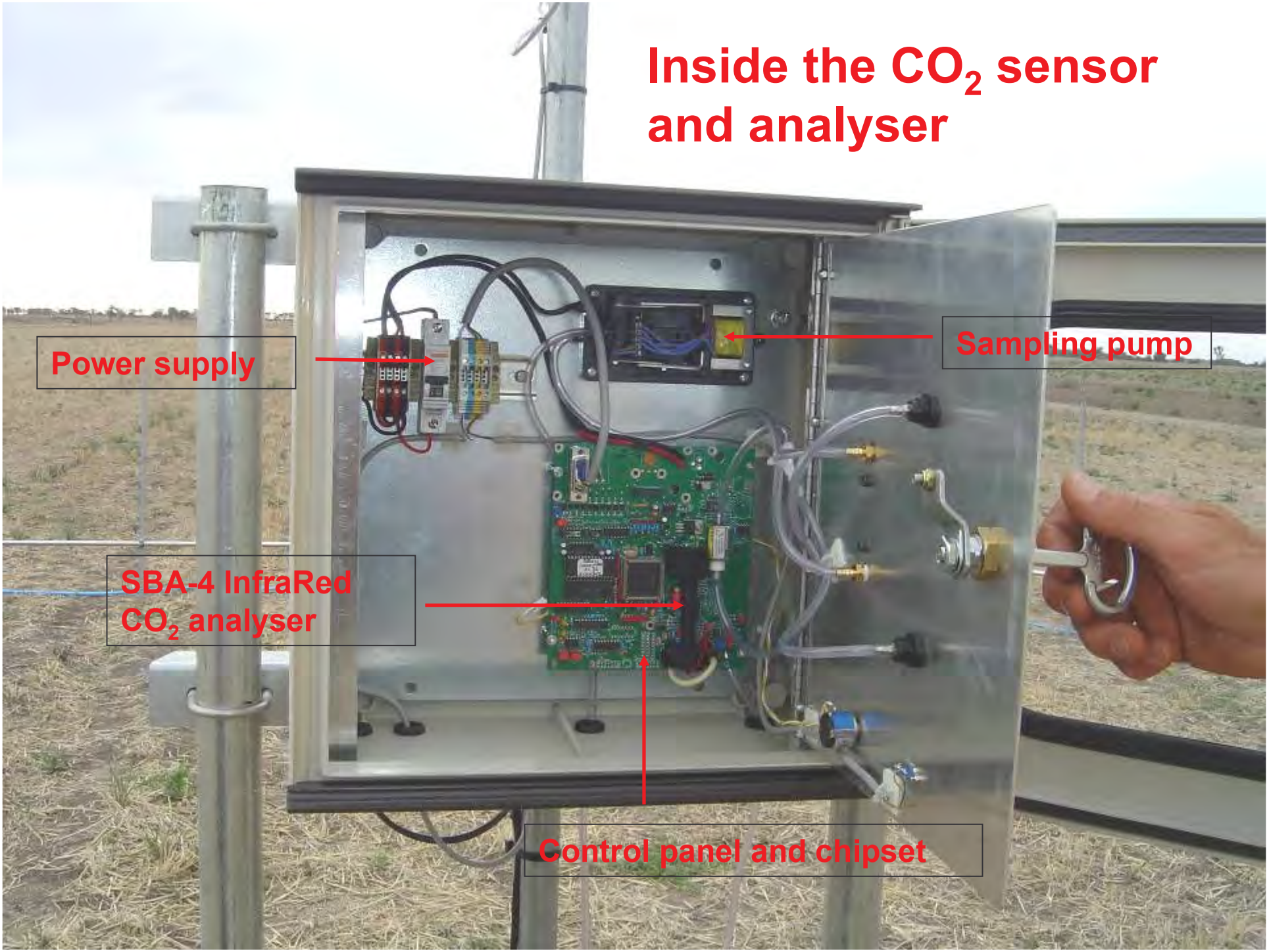


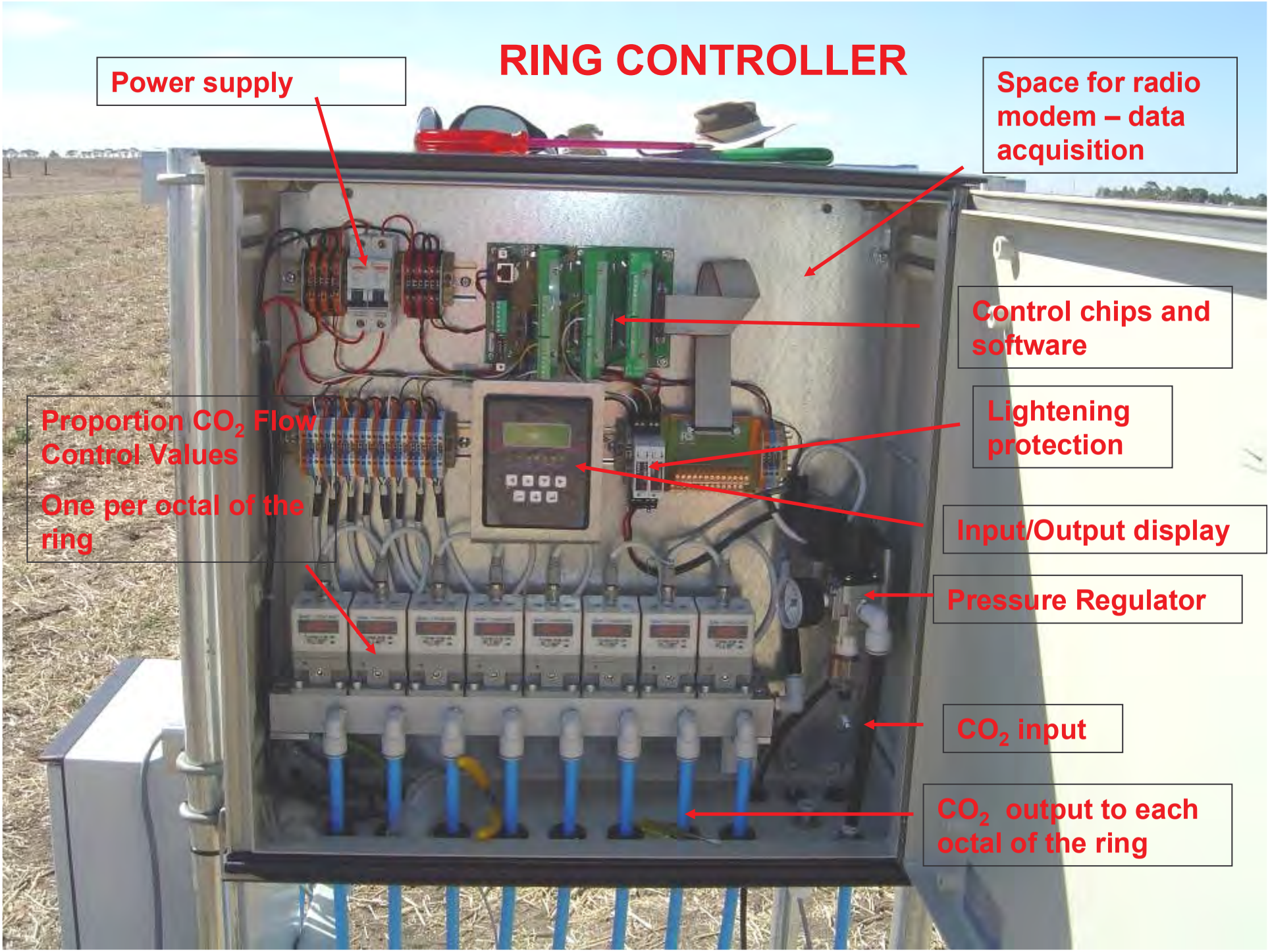



POWER SUPPLY
12 v and 24 v outputs
For safety and user maintenance
CO2 inlet and vapour trap
240 V input

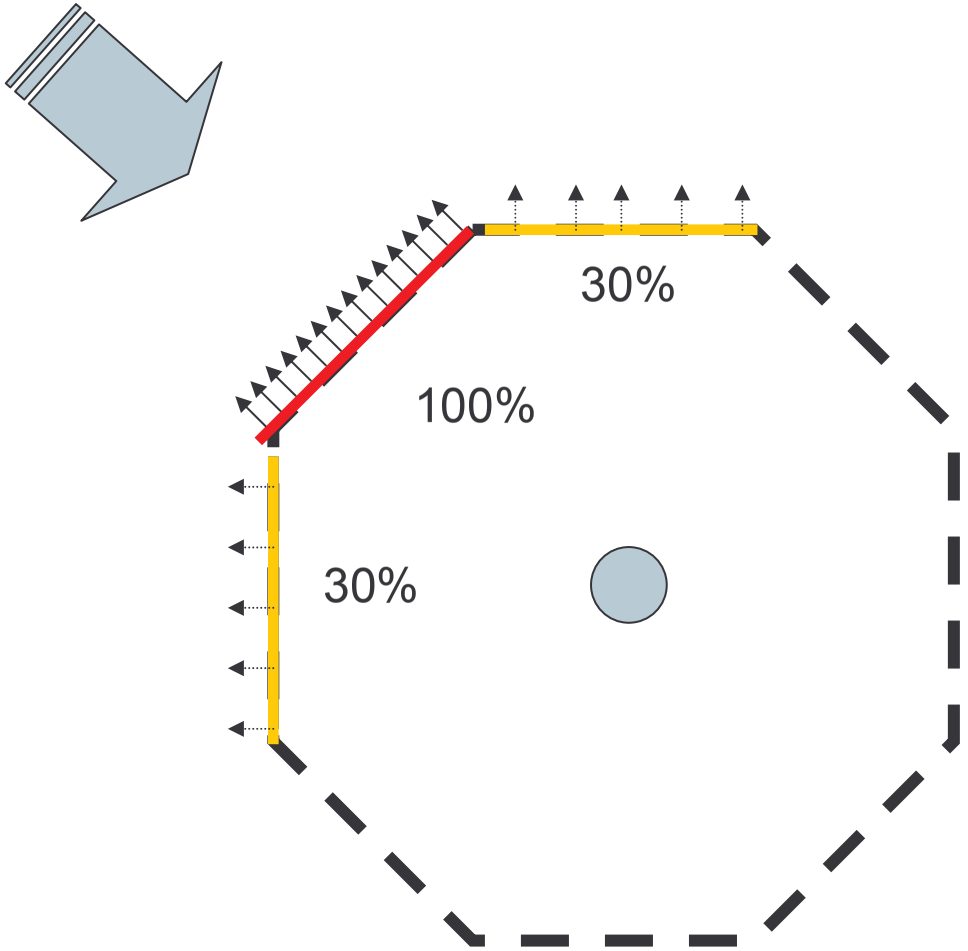

CO_2 sensor and analyser
CO_2 uptake

Inside the CO_2 sensor and analyser




RING CONTROLLER
Power supply
Space for radio modem – data acquisition
Control chips and software
Lightening protection
Proportion CO_2 Flow Control Values
One per octal of the ring
Input/Output display
Pressure Regulator
CO_2 input
CO_2 output to each octal of the ring

CO_2 ventilation



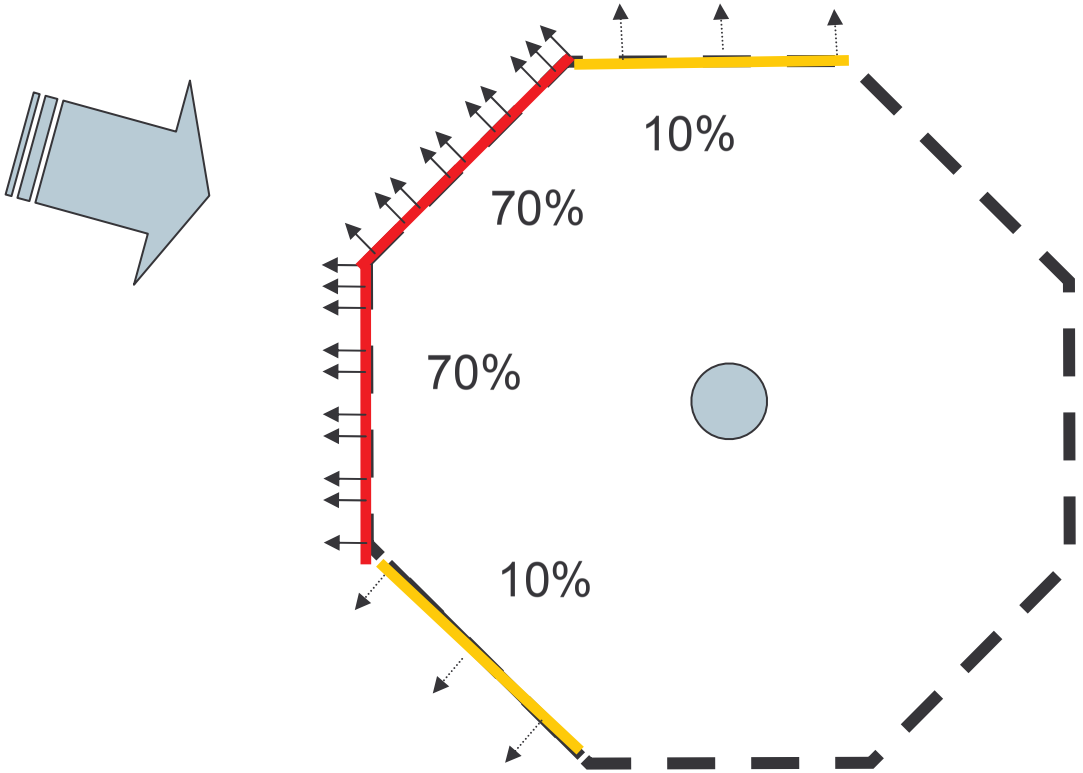
Sensed and adjusted each second

Recorded each 4 s

Quick response time – sensor location

Variable rate controllers – infinitely variable depending on wind direction

CO_2 ventilation



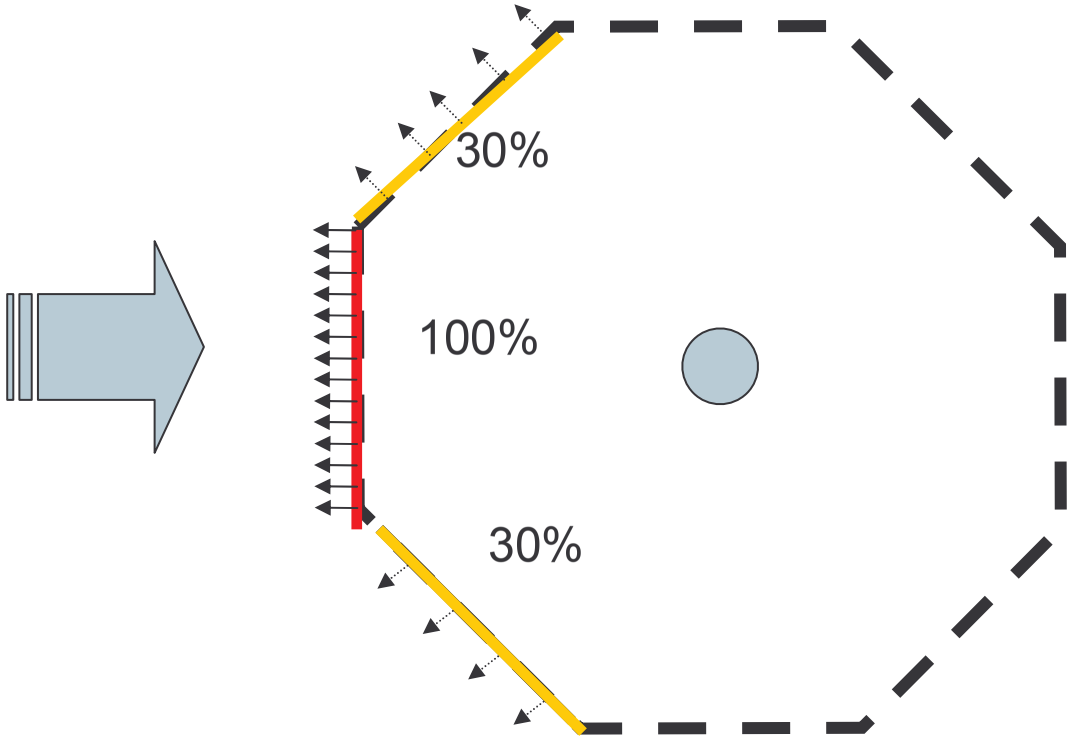
Sensed and adjusted each second

Recorded each 4 s

Quick response time – sensor location

Variable rate controllers – infinitely variable depending on wind direction

CO_2 ventilation



Sensed and adjusted each second

Recorded each 4 s

Quick response time – sensor location

Variable rate controllers – infinitely variable depending on wind direction

FACE Monitor and Logger

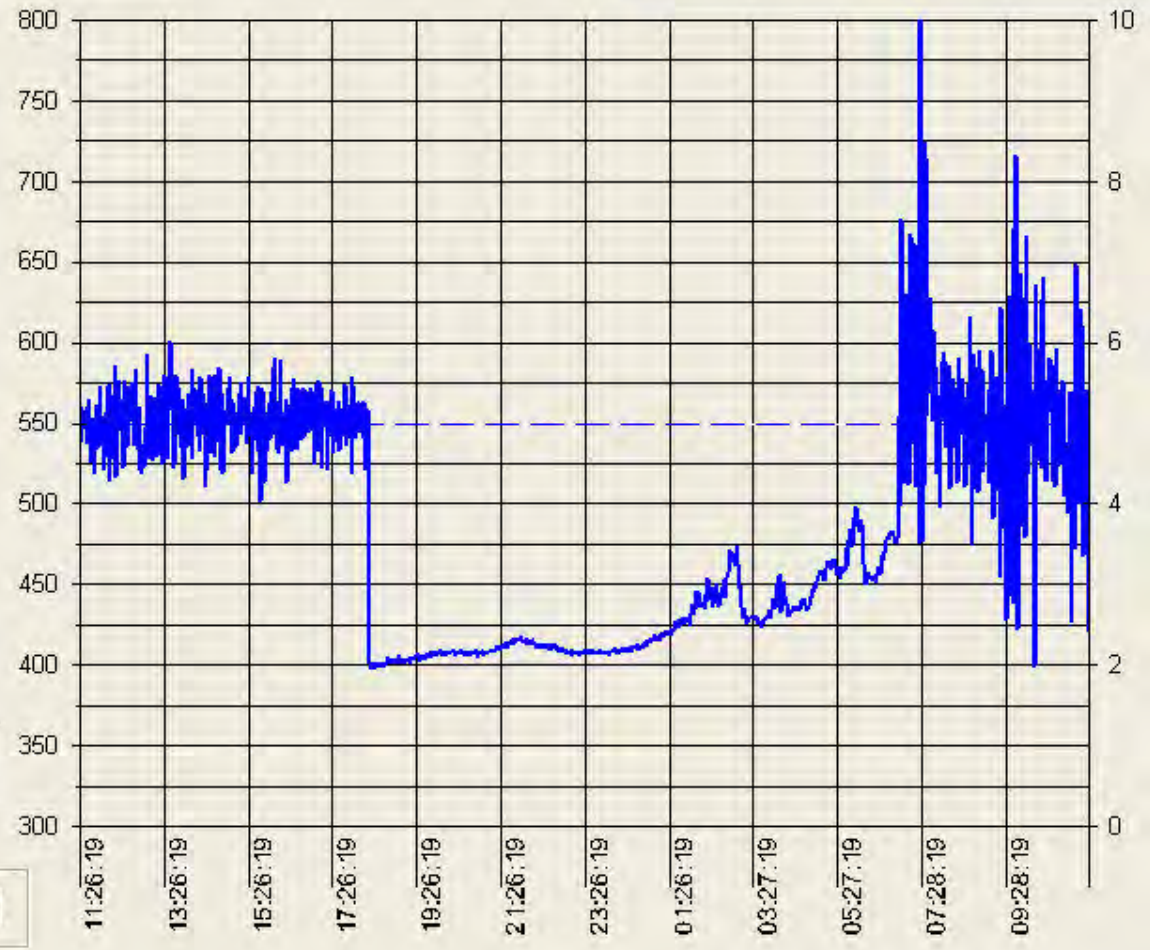
File Setup About

LogMeIn

This computer is being remote controlled by UNIVERSITY\LogMeInRemoteUser from 157.128.140.162

Ring 16

	CO2	Vout	WSpd	WDir	Sector	Status
Ring 1	351					
Ring 2	OFF					
Ring 3	588/550	0.50	1.4	297	7	
Ring 4	418/550	0.54	0.5	198	4	
Ring 5	476/550	0.59	1.4	123	2	
Ring 6	610/550	0.42	0.9	68	2	
Ring 7	OFF					
Ring 8	OFF					
Ring 9	454/550	0.92	1.0	118	3	
Ring 10	545/550	0.90	0.8	60	1	
Ring 11	365					
Ring 12	OFF					
Ring 13	OFF					
Ring 14	OFF					
Ring 15	575/550	0.67	0.5	201	5	
Ring 16	504/550	0.83	0.5	74	2	



Plot Select
- CO2 ☑
- Output ☐
- Wind Spd ☐
- Wind Dir ☐
- Sector ☐

Graph Setup

	Y1	Y2
Max		
Min		

Graph Select: Ring 16

Time Scale: 24

start | FACE Monitor and Lo... | ninemsn.com.au - Mic... | Telstra Turbo Modem ... | EN | 11:25 AM

Horsham Main Plot Layout – 2008/2009





8*12 m eCO

8*12 m aCO

Factorial

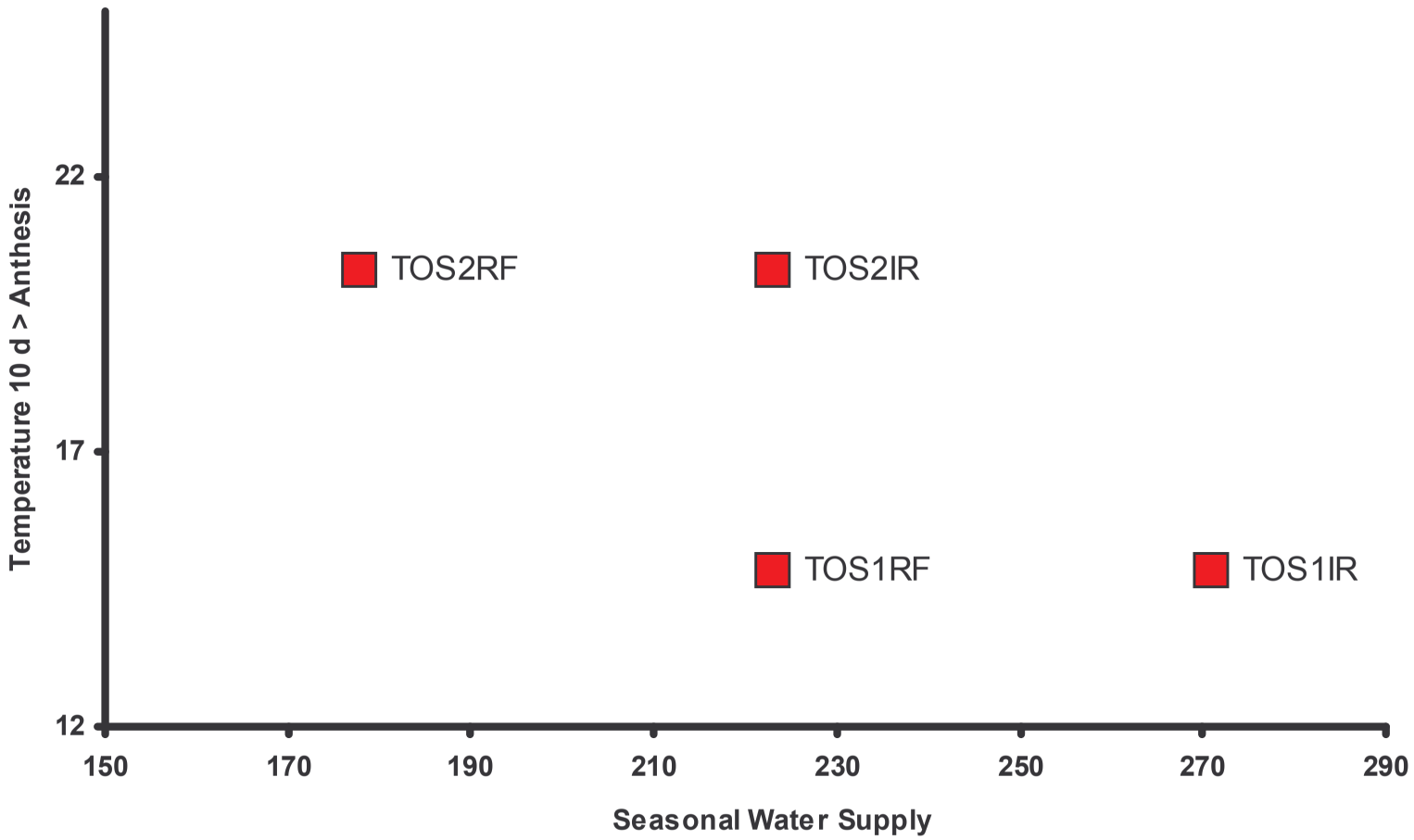
(CO_2 : TOS)

RCB

Each ring s| irrigation

Each half ri| 2 subtreatm (V1N1, V1N2,

4 Replicates



60 m



Split-Split-Factorial-RBC



Where did the Horsham costs lie?

Site Costs

• Overseas visits	$ 20k
• Design & Plans	$ 88k
• CO_2 tank installation	$ 45k *
• CO_2 reticulation	$ 14k *
• Slab/Roadways	$ 16k
• Power to site	$ 20k
• Power to rings	$ 20k
• Water & reticulation	$ 15k
• Irrigation	$ 12k *
• Fencing & Lighting	$ 5k
• IT	$ 10k
• Signage	$ 5k
• Rings & Controllers	$200k *
• Decommissioning	$ 45k
• **TOTAL**	**$515k**

Set up and run for 3 years = $1.5 million

Annual Operating Costs

• Cylinder rental	$ 70k *
• CO_2 use (600t/y)	$150k *
• Energy & Water	$ 6k
• Land Rental	$ 7k
• Technician	$100k *
• Consumables	$ 20k
• **TOTAL/Year**	**$353k**

Additional Staffing

- Project Leader (50%)
- Engineer (100%)
- Technical Support (100%)
- Biometrician (40%)
- Scientists
  - Plant Physiologist (100%)
  - Remote Sensing (50%)
  - Agronomist (20% + 20%)
  - Pathologist (30%)
  - Modeller (40%)

Considerations

- ***CO_2 source*** – purity/price/technical support/transport, isotope signature.
- ***Site location*** – access and services
  - B double for gas delivery
  - 3 Phase and single phase power
    - 3 Phase at the CO_2 storage tank
    - 240 v at the storage tank & through the site
    - We used 12/24 v controlled with current controls (voltage drop across a large network)
  - Water – Mobile Phone Coverage
  - Consider fetch around each ring - turbulence
  - Adequate area to spread rings over (contamination)
- ***Fumigation duration***
- ***Fumigation Target CO_2***
- ***Experimental treatments***
- ***Ring size and ring number***



Fumigation

Duration

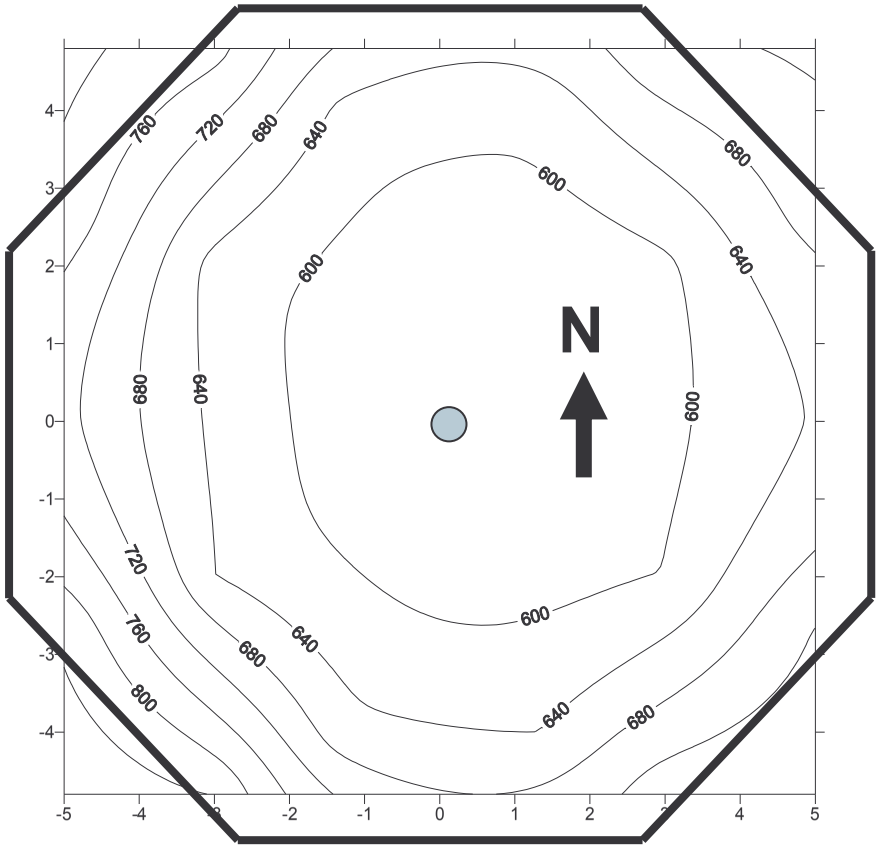
- Annual cycle
  - Seasonal – when active growth occurs?
  - 365 days – to account for full season effects (soil)
  - Allowance for “down-time”
- Daily cycle
  - Photoperiod – when active growth occurs?
  - 24 h – night respiration.
- Most systems are photoperiod/seasonal

Target CO_2 concentration

- IPCC 2050?
- Ambient + 200 ppm
- Higher = more gas use
- Actual CO_2 achieved will have spatial and temporal variation
  - Implications for border areas (ring size)
  - Implications in terms of response
  - Our 550 ppm = 600 ppm!

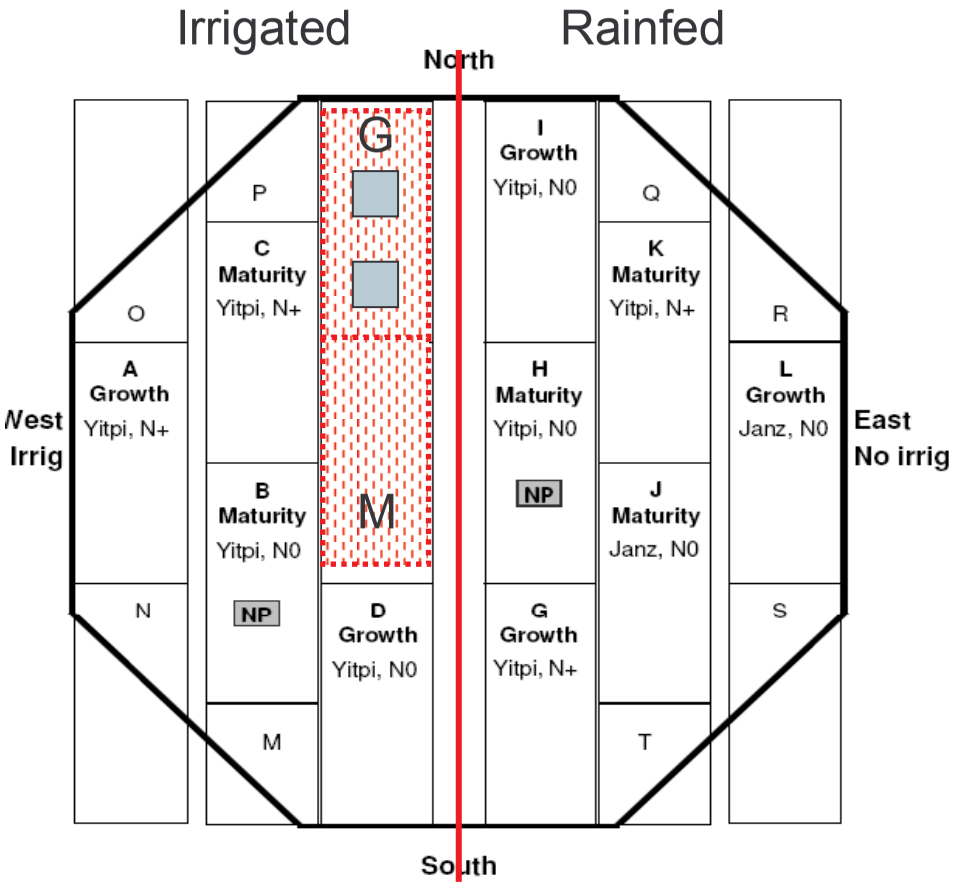
CO_2 distribution – Horsham FACE

- CO_2 at centre is well controlled 550 ppm
- Gradient from the centre to the perimeter
- Skewed in direction away from the dominant wind direction (west)
- Variability increases from centre to perimeter
- Border plots ~1m from ring
- Actual [CO_2] is more like 640 ppm rather than 550 ppm
- Trying to understand the biological implications of this level and the variability.



Treatments/Replicates/Ring Size

- To what height will fumigation be needed?
  - How even is the canopy?
- How many vines will be an experimental unit – plot size
- Can there be more than one treatment per ring?
- What are the treatments to impose?
  - Can the rings be split?
  - Statistical power of interaction
- How many reps will be required
  - Size of difference, trait variability & certainty
  - Statistical power of main plots (20% change?)
  - Blocking



1 treatment needed 8 m of plot

6 treatments per half ring

Ring Size Matters

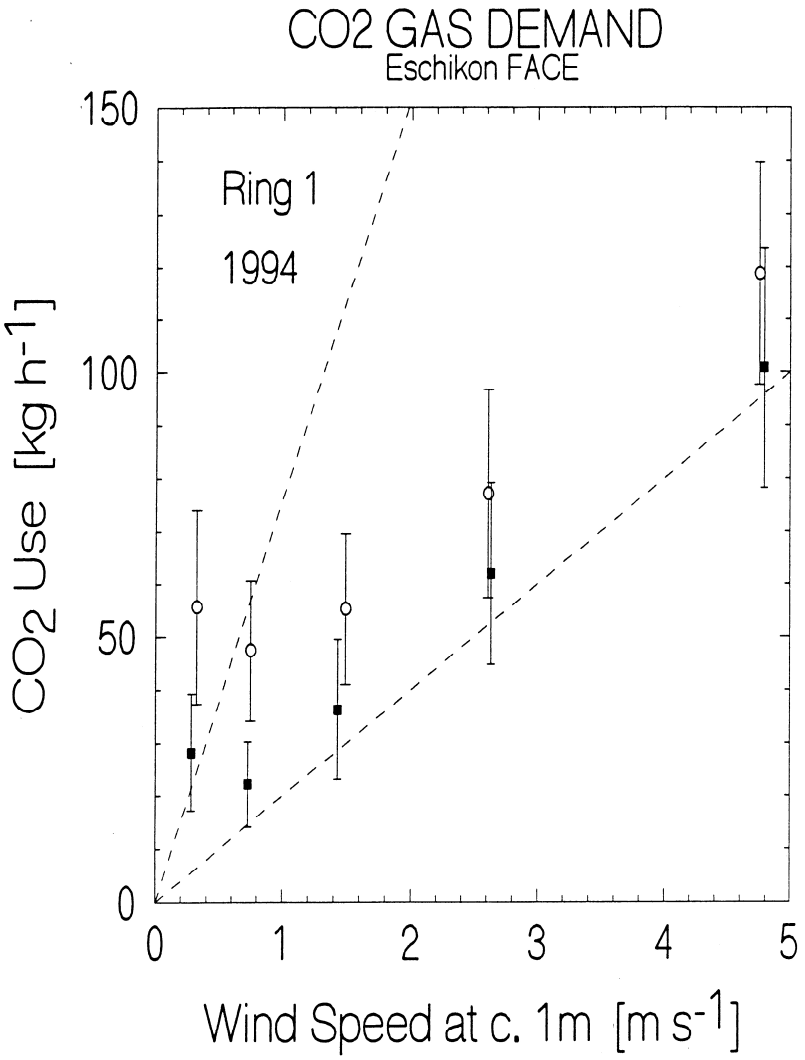
- First design question is the size of the rings
  - which determines how much CO_2 will they use (annual costs & design)
  - which determines the sorts of treatments that can be deployed
  - which determines the sorts of measurements that can be made
  - which determines the number of replicates needed
  - crop height to ring diameter important
  - Bigger is generally better (lower cost/m^2, less edge effect)

- Our 12 m rings in 2007 used 720 t in the first year (150d)
- John Nagy (BNL) has sent some guides to help with estimates of this
  - Gas use decreases with lower barometric pressure (10% less at 1000 m elevation).
  - Gas use decreases with higher temperature (10% difference between 10°C and 40°C).
  - Gas use decreases with higher water vapor partial pressure (5% relative to dry air at 35°C and 89% RH).
  - Gas use scales with mixing ratio increment (target minus ambient).
  - Gas use scales with volume to be enriched – width, length, height

18 m diameter

Vertical Vent Pipes

Short crop



Open circles:

High daytime insolation

Closed squares:

Low daytime insolation

Sample means ± standard deviation

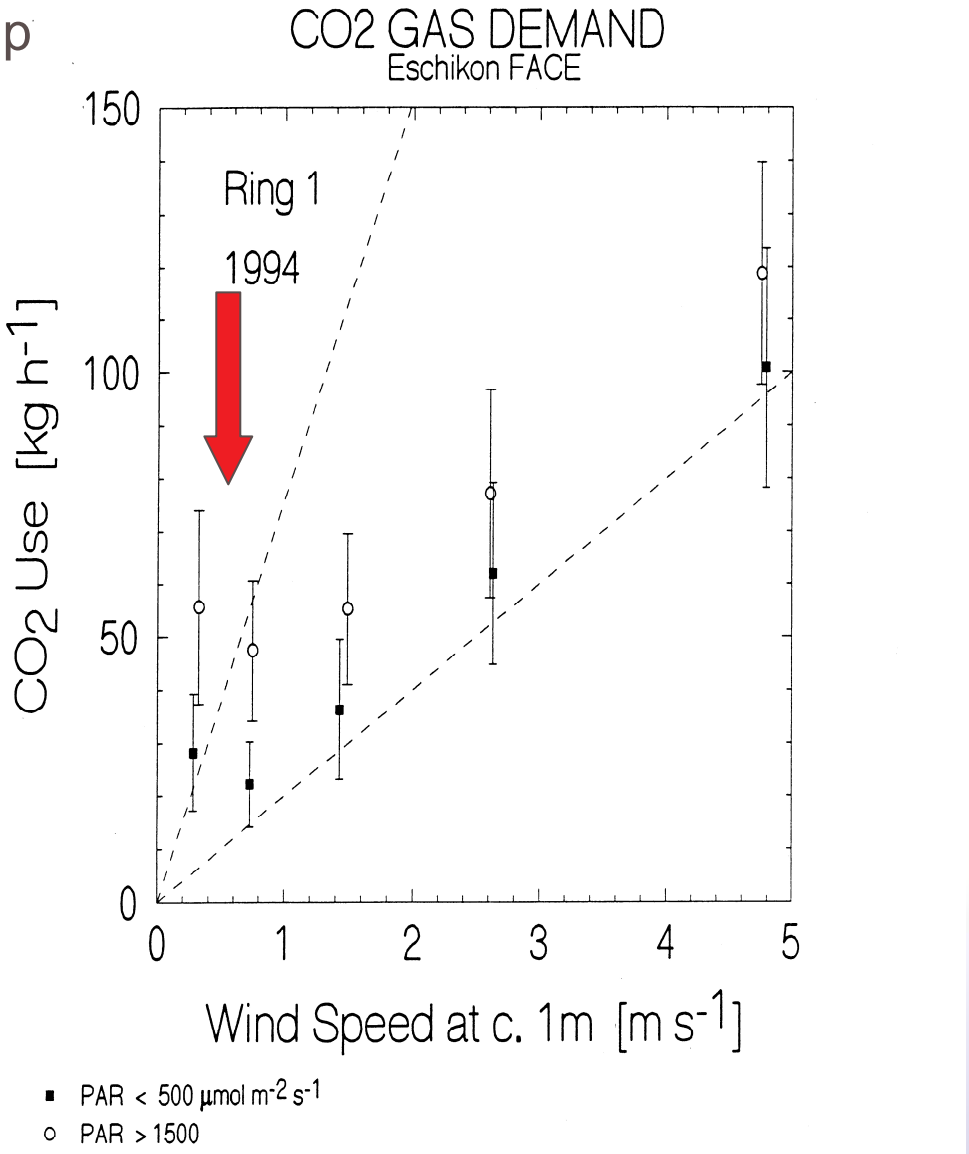
Wind speed groups:

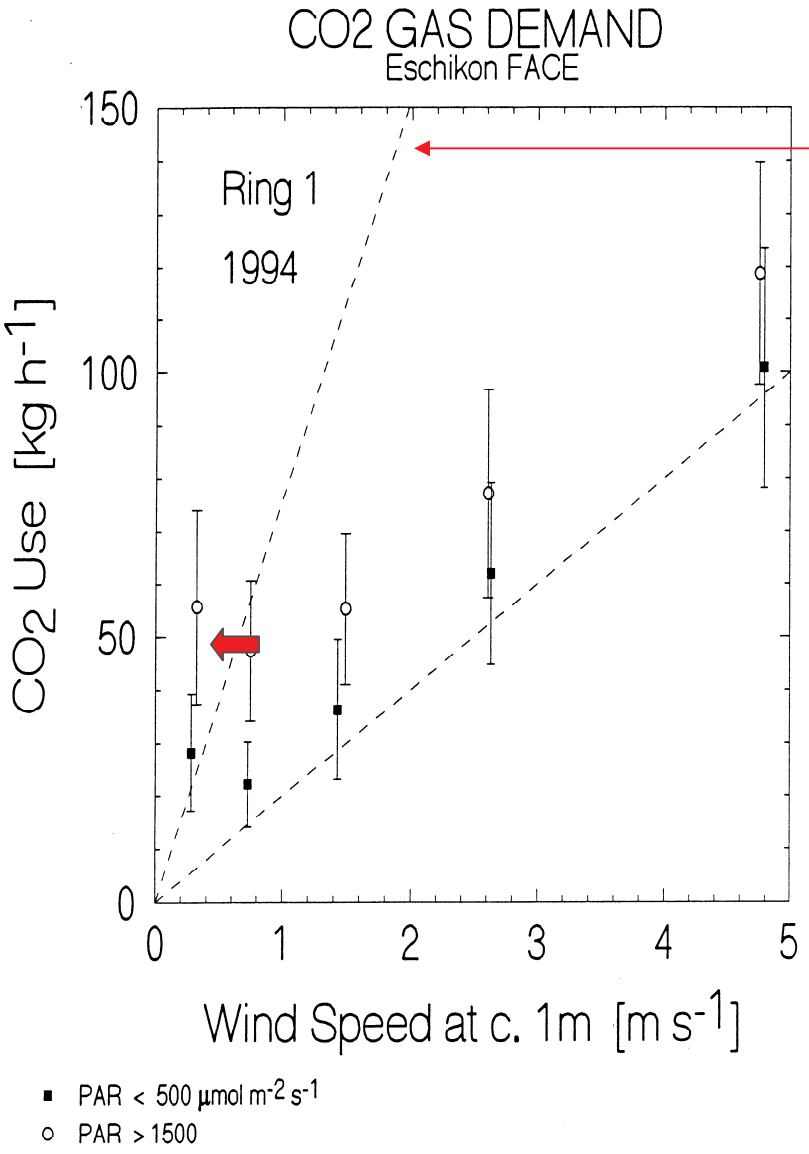
	u < 0.4		m s^{-1}
0.4 <	u < 1		m s^{-1}
1 <	u < 2		m s^{-1}
2 <	u < 4		m s^{-1}
4 <	u		m s^{-1}

RELIABILITY, CO_2 CONCENTRATION CONTROL, AND CO_2 GAS USE OF THE FACE FACILITY AT ETH IN 1993 AND 1994

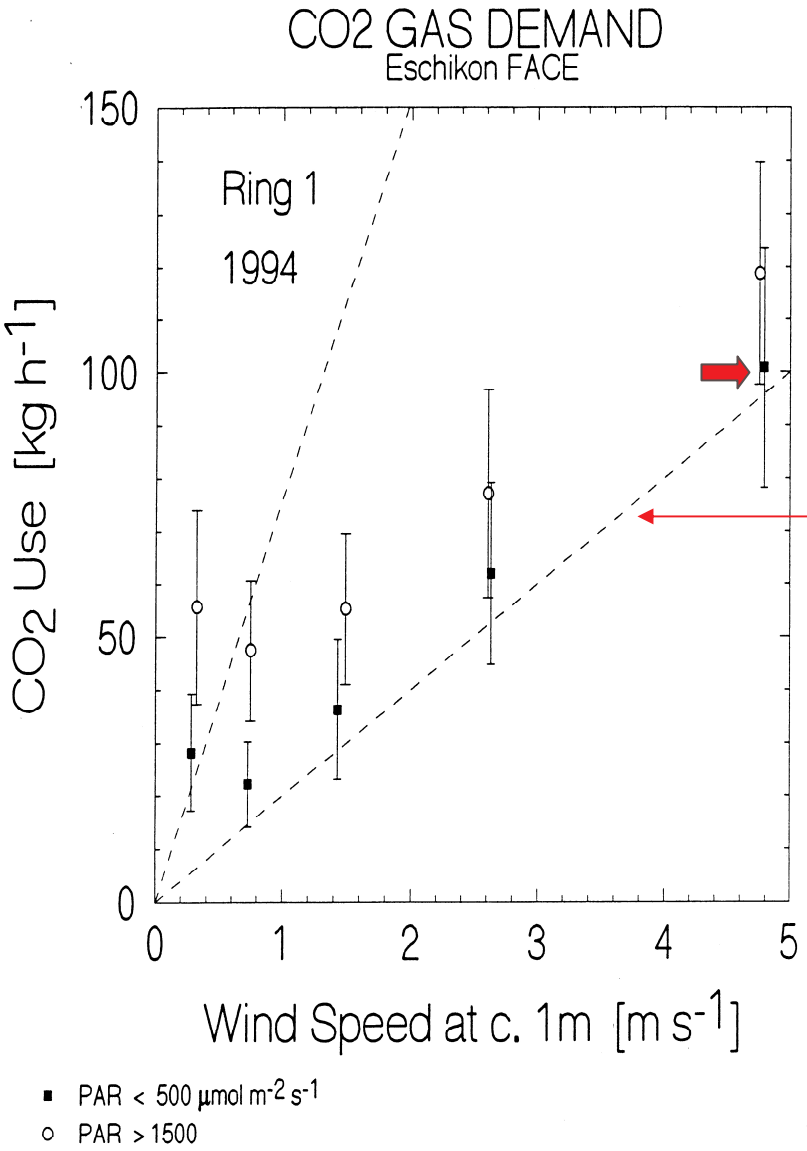
John Nagy,[1] Herbert Blum,[2] George R. Hendrey,[1] Silvio R. Koller,[2,3] and Keith F. Lewin[1]

Wind speed group $u < 0.4$ m s^{-1} is a special case.



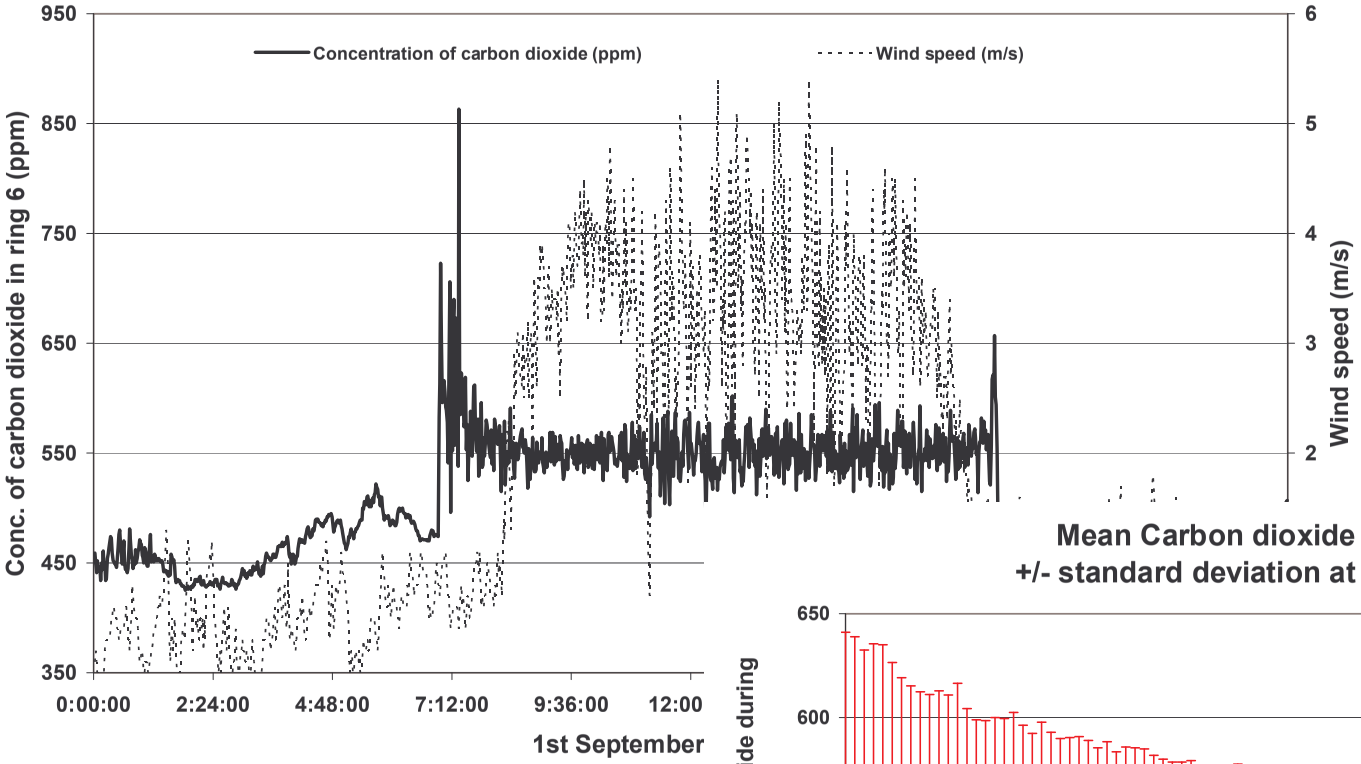


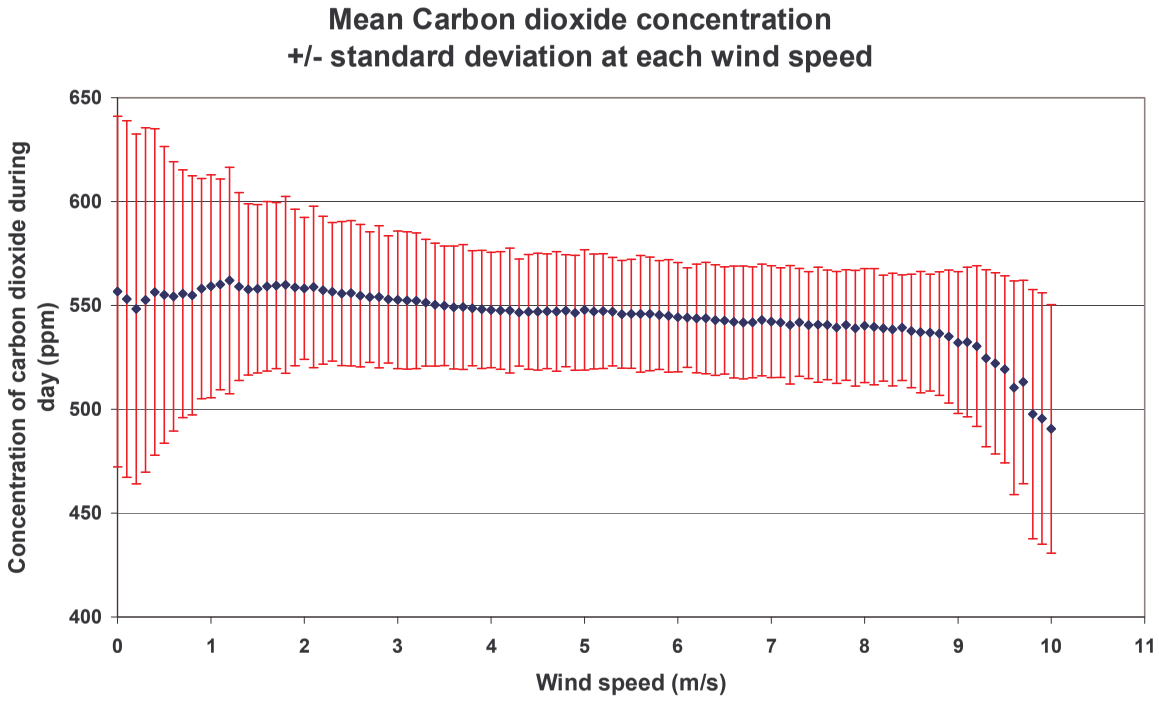
σ/x = 0.20
Pasquill turbulence type A
"Extremely unstable conditions"
Low wind speed
High solar insolation



σ/x = 0.025
Pasquill turbulence type E
"Slightly stable conditions"
Generally, nighttime only

Performance results (auto logging)





Some examples of gas use

Source	Location	Size (m)	Veg Height	Fumigation	Use $Kg/m^2/d$
Beier	Denmark	7	<1 m	PPD/AYR	3.0
Godbold	Wales	8	<3m	PPD/SEA	7.0
Calfapietra	Italy	22	3-4 m	PPD/SEA	3.5
	Italy	22	9-10 m	PPD/SEA	9.0
Norton	Horsham	12	1.4 m	PPD/SEA	5.0
Nagy	Swiss	14	0.3 m	PPD/SEA	4.2
Nagy	Arizona	22	1.5 m	PPD/SEA	4.0

Disrupted and tall canopy = high CO_2 use
Over summer = high CO_2 use (daylength/radiation load)

Bangor FACE

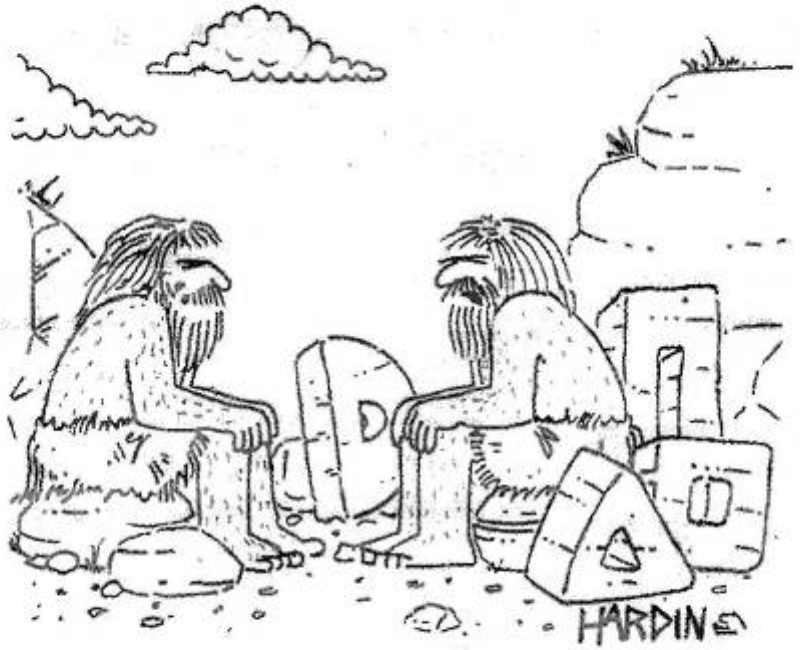


Issues with Vines

- What is an experimental unit?
- Tall, developing and irregular canopy – CO_2 distribution and use?
- Vertical vent pipes or horizontal distributors?
- Impact of CO_2 out of season?
- What is the focus of your experiment?
- Mature or establishing vines (vinelings/vinelettes)?
- Deal with acclimation to high CO_2 (reduced rubisco & its feedbacks)
- How long will the experiment run?
- How much money do you have?
- Is FACE the most appropriate technique to meet the experimental outcomes?

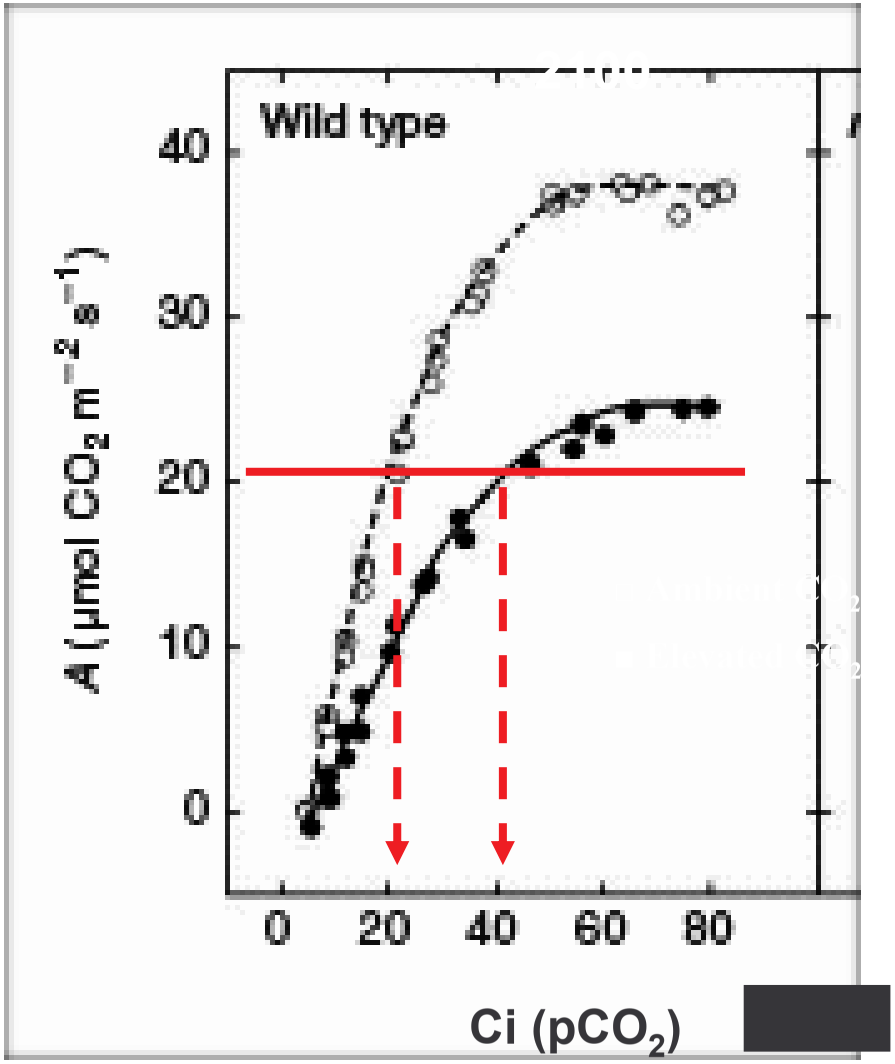
Acknowledgements

- Jeff Huzzey, Bill Pyke and David McNeil for developing the engineering and scientific guidelines on which the project was established.
- Colleagues nationally and internationally for providing guidance and support for this project – especially Mark Hovenden, Franco Miglietta and Steven Long's SoyFACE group in Illinois.
- Russel Argall, Janine Fitzpatrick, Peter Howie, Garry Howard – technical support.
- Project partners for their support and interest.
- Colleagues for their support and tolerance during periods of stress.



"I was close to a breakthrough when the grant money ran out.

Photosynthetic acclimation to elevated CO_2



Plant leaf is able to maintain the same photosynthetic rate at a higher CO_2 concentration with less Rubisco.

When plants are exposed to elevated CO_2 for extended periods, Photosynthetic rates decline. This process is known as "acclimation"

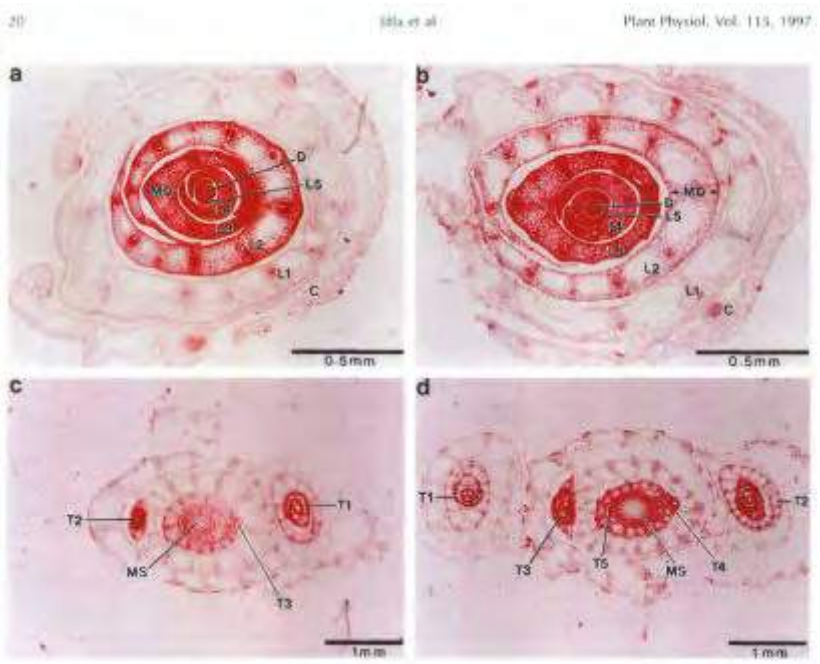
This is a result in less Rubisco (& N) required in the leaf.

This reduction in photosynthesis rates, is accompanied by morphological, biochemical and molecular adjustments.

Seneweera *et al* 2005 Journal of Crop Improvement **13**-31-52

Plant development-rice

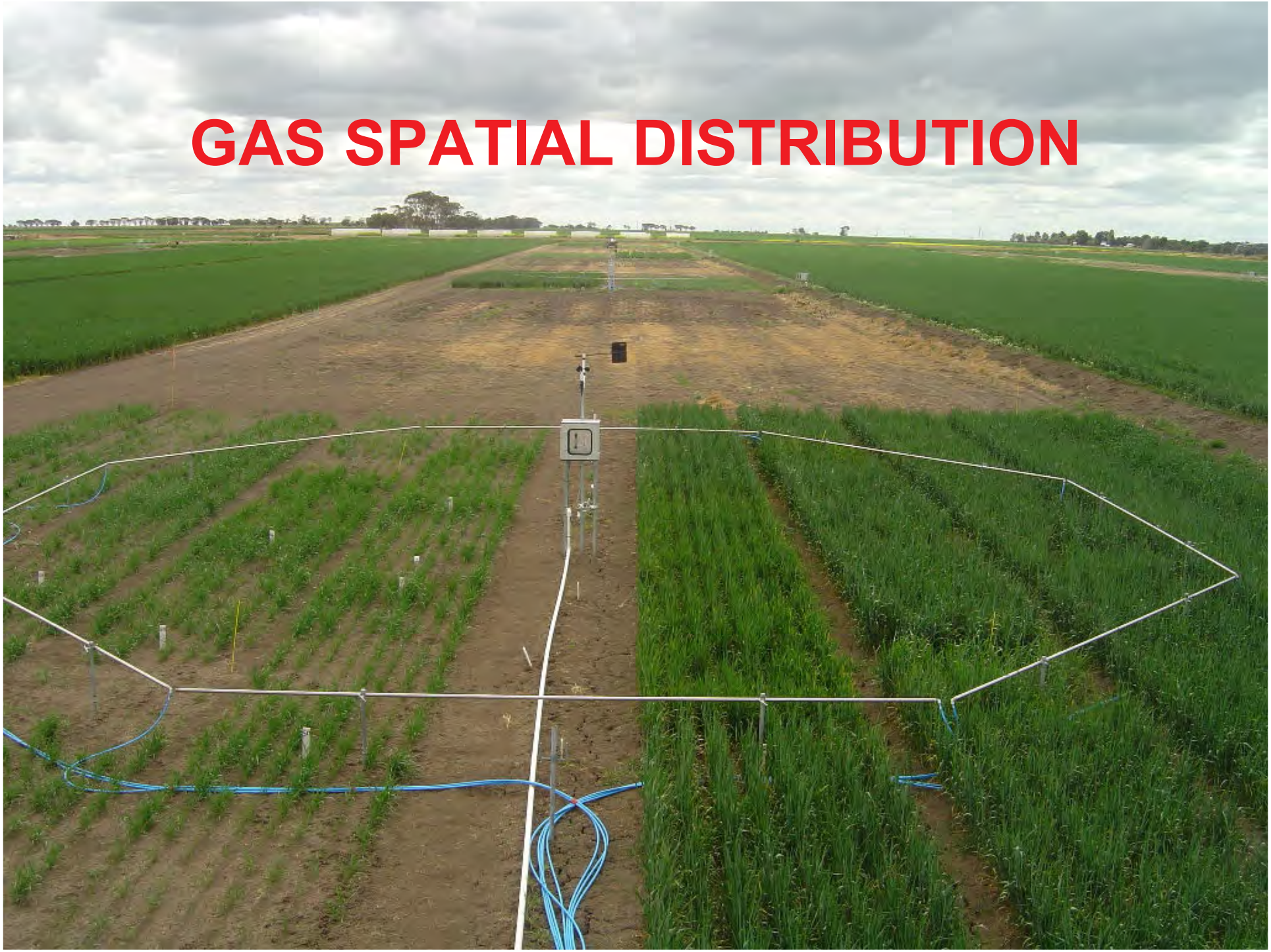
Ambient CO_2 Elevated CO_2



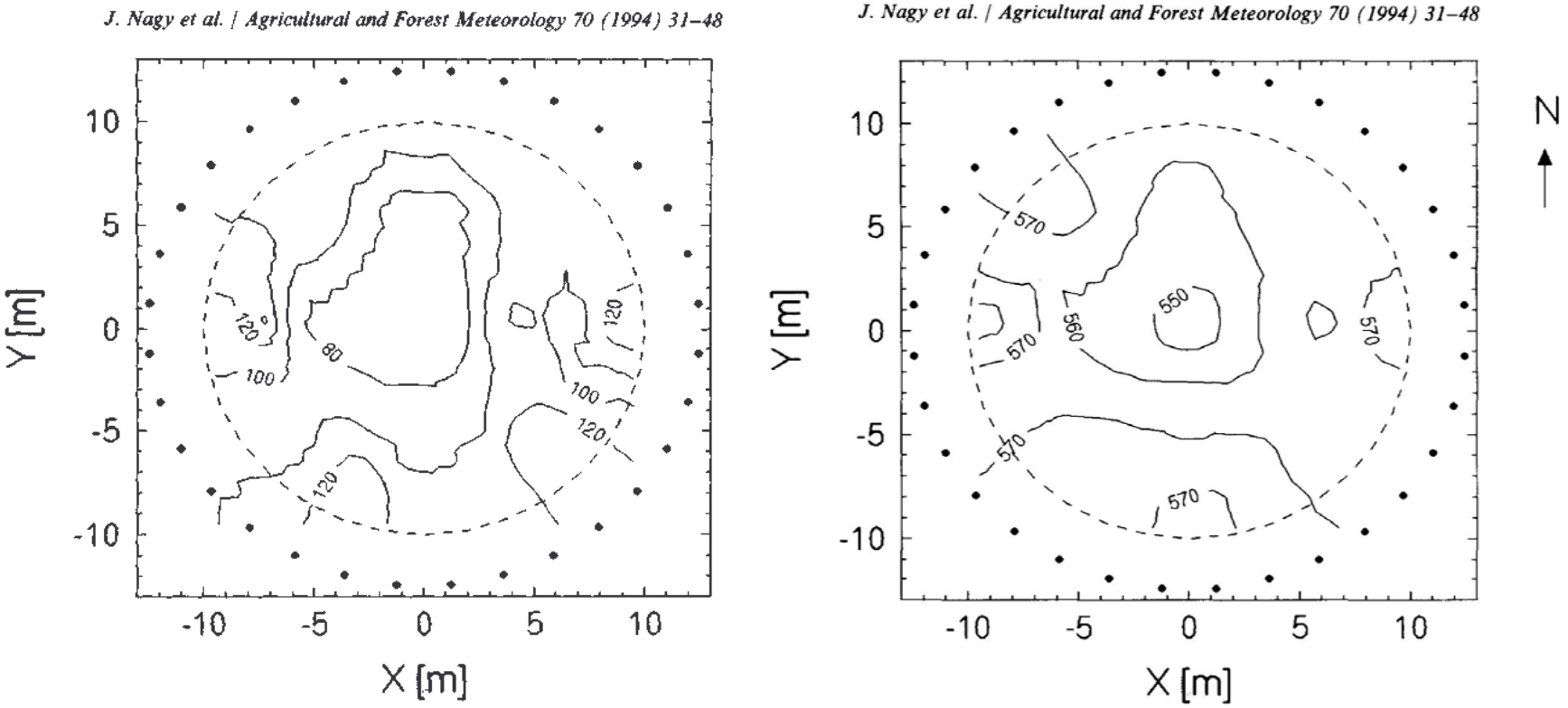
Parameter	CO_2 (µL CO_2 L-1)	Size (µm)
Height of apical dome	350	33
	700	54
Tiller bud length	350	124
	700	194

Jitla, Seneweera & Conroy (1997) *Plant Physiology* 115: 15-22

GAS SPATIAL DISTRIBUTION



$[CO_2]$ and variability – Arizona FACE



22 m rings = 20 m diameter experimental area

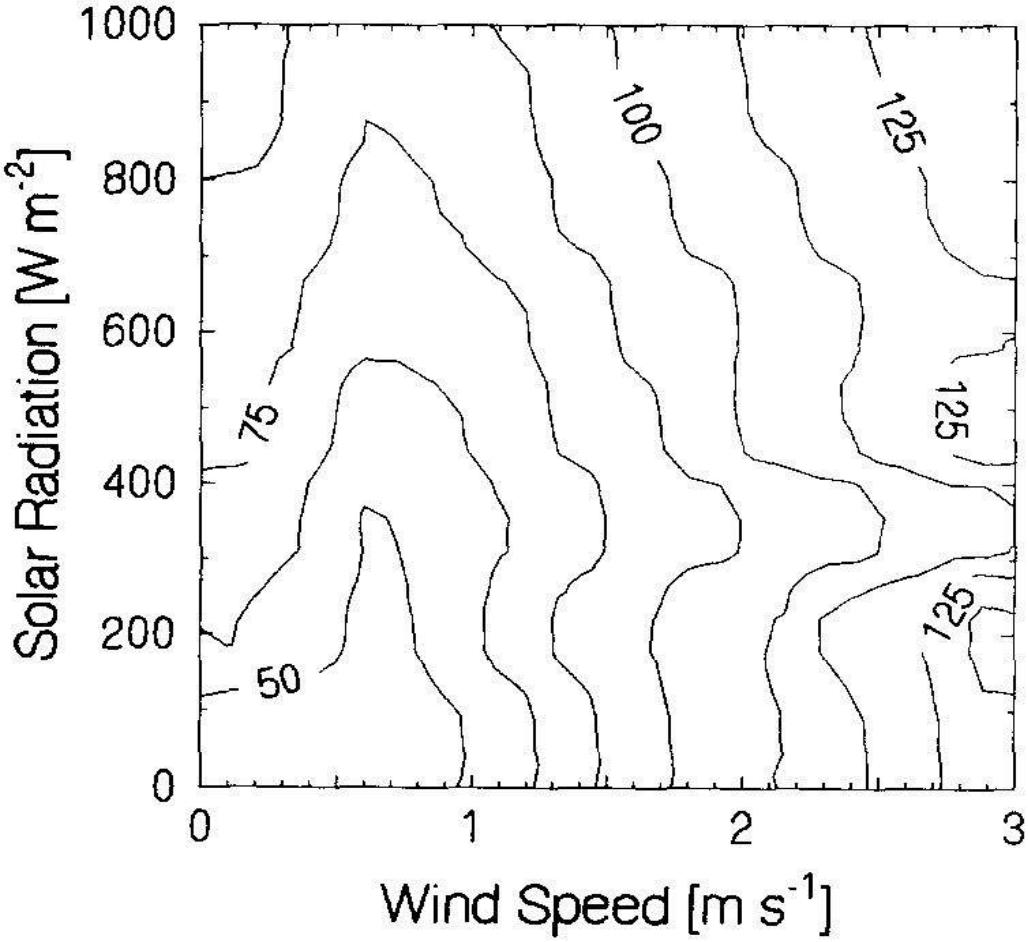


Fig. 10. CO_2 demand rate (kg h^{-1}) vs. wind speed (m s^{-1}) and solar radiation (W m^{-2}).

Operating FACE facilities

AGFACE	Horsham Victoria	37°S, 142°E	12 m	Wheat	550
AGFACE	Walpeup Victoria	35°S, 142°E	4 m	Wheat	550
China CAS	Wuxi, Jiangsu	32°N, 121°E	12 m	Rice & Winter wheat	+200
China CAAS	Changping, Beijing	39°N, 116°E	4 m	Soybean, winter wheat	550
SoyFACE	Champaign, Illinois	40°N, 88°W	20 m	Soy, corn	550
Braunschweig	Braunschweig Germany	52°N, 10°E	20 m	Corn (winter barley and wheat)	550
TasFACE	Pontville Tasmania	43°S, 147°E	1.5 m	Native grassland	550
Bulls	Bulls. New Zealand	40°S, 175°E	12 m	Grazed glassland	475
BioCon	Cedar Creek, Minnesota	45°N, 93°W	C3 & C4 grasses	20 m	550

18 others in the literature = all closed

Operating FACE facilities

PHACE	Cheyenne, Wyoming	41°N, 115°E	3.4 m	Mixed grass prarie	600
Jasper Ridge Global Change Experiment	Jasper Ridge, California	37°N 122°W	2 m	Grassland	X 2 ambient
Sky Oaks	Sky Oaks California	33°N, 117°W	16 m	Chaparral	550
CLIMIATE	Branbjerg, Denmark	56°N, 11°E	6.8 m	Grasslands	510
Nevada Desert FACE	Mojave Desert Nevada	37°N, 116°W	23 m	Desert scrub community	X 1.5 ambient
Oak Ridge National Laboratory	Oak Ridge Tennessee	36°S, 84°W	25 m	Sweetgum plantation	550
Aspen FACE	Rhinelander Wisconsin	46°N, 90°W	30 m	Aspen forest	+200
Bangor FACE	Bangor, Great Britain	52°N, 2°W	8 m	Deciduous forest	+200
Duke FACE	Duke Forest Nth Carolina	36°N, 79°W	30 m	Loblolly Pine Forest	+200

Aspen, Duke and Oak Ridge all in phase down now

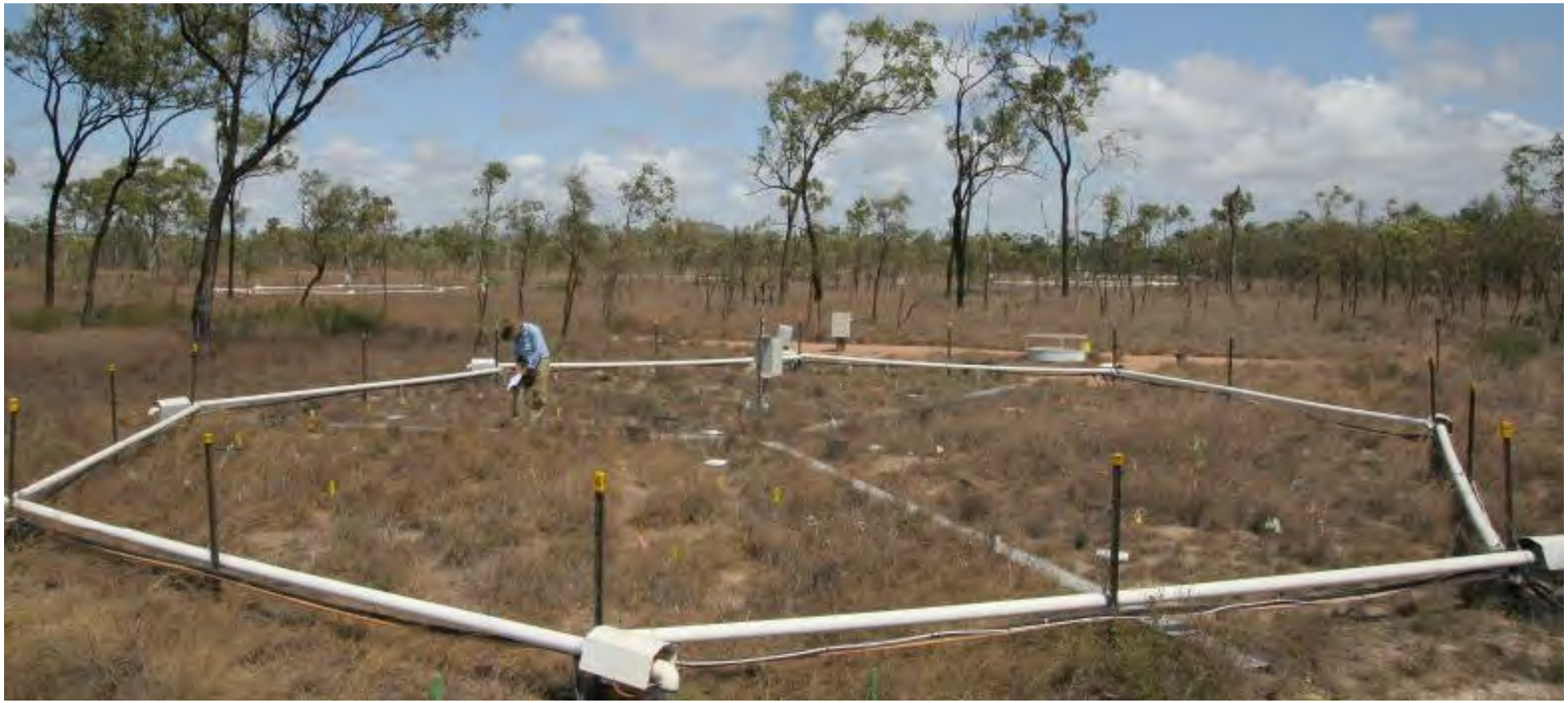
TasFACE



NZ FACE



OzFACE



CLOSED

SoyFACE



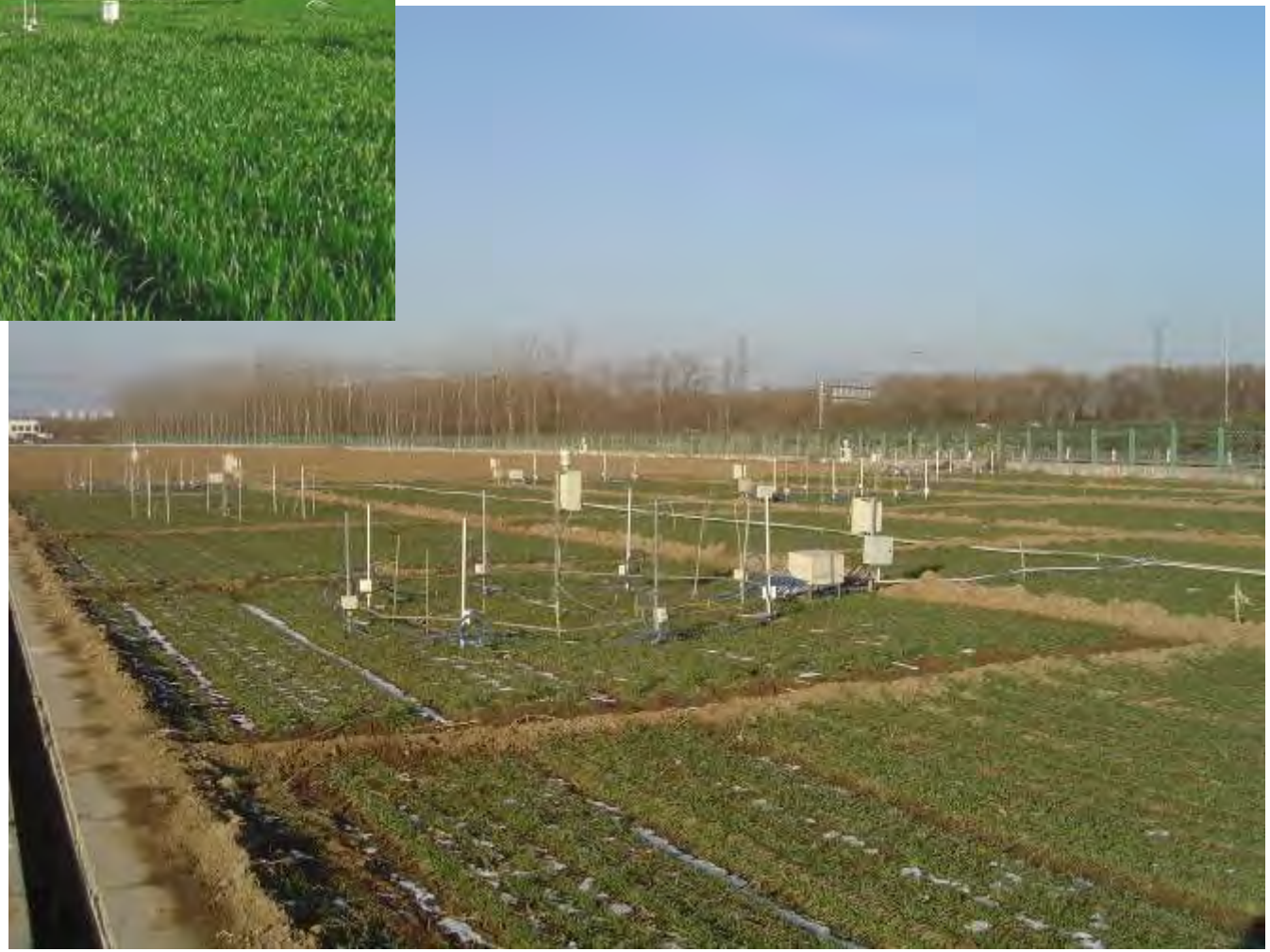


CAS FACE
Wuxi

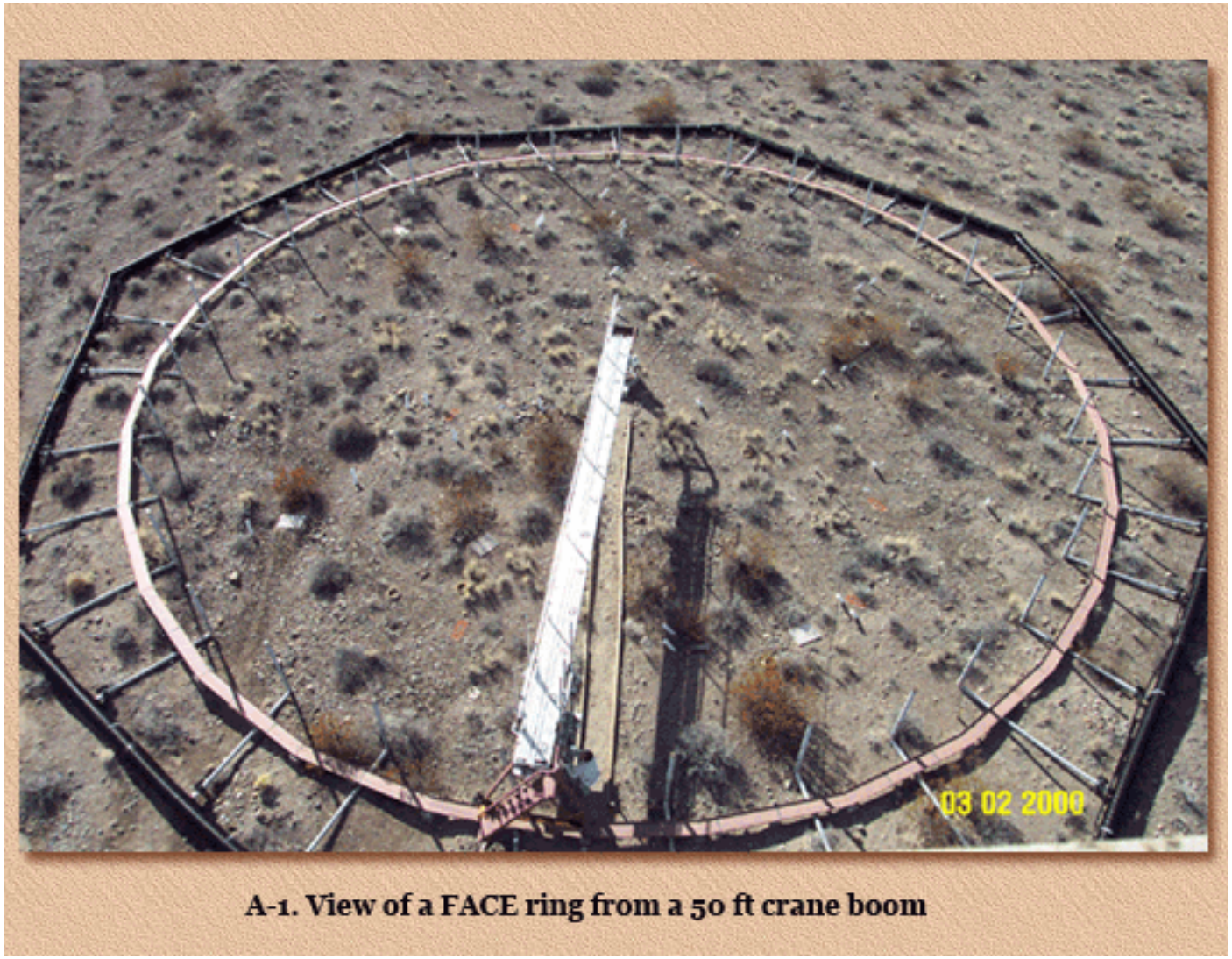


CAAS FACE Changping



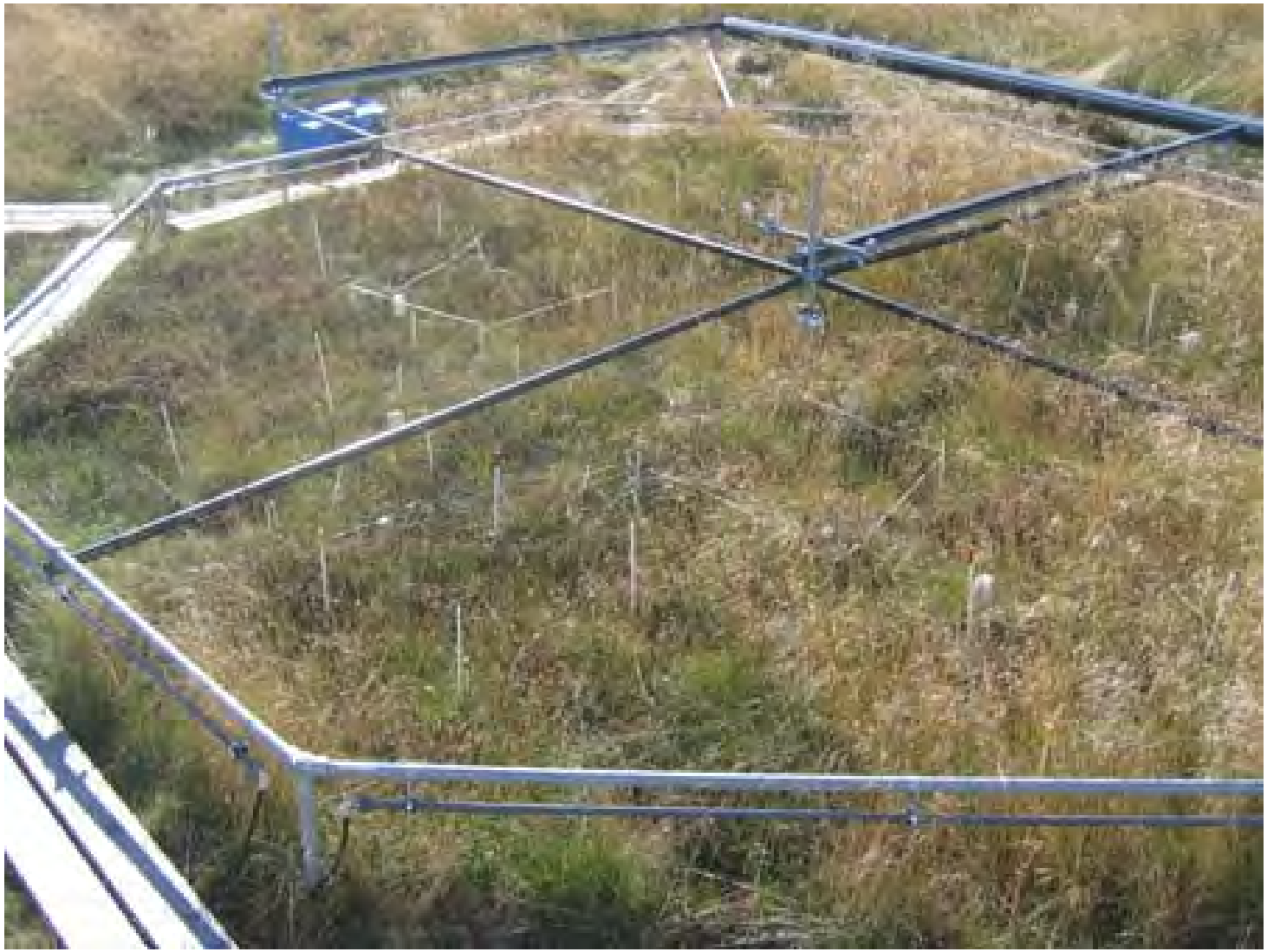


DesertFACE Nevada



A-1. View of a FACE ring from a 50 ft crane boom

Climiate - Denmark



The University of Giessen Free-Air Carbon Dioxide Enrichment Study (GiFACE)



CLOSED

Oak Ridge





Aspen FACE



Duke Forest FACE





How and why Tasmania and TIAR would fit together into a Grape FACE.

tiar
TASMANIAN INSTITUTE OF AGRICULTURAL RESEARCH

- Professor David L McNeil
  - Director TIAR

  – *Rationale, justification and partnerships required for the establishment of this node*

- **Grape FACE workshop.**
  - **27/28 May Adelaide**

Tasmania
Explore the possibilities

UTAS

What is TIAR?

tiar
TASMANIAN INSTITUTE OF AGRICULTURAL RESEARCH

- ***Started 10 years ago as a joint venture between U Tas and DPIW has just signed a new Joint Venture for a further 10 yrs.***

- ***Structure to consist of self contained:***
  - ***Food safety, Vegetables, Dairy centres***
  - ***Perennial Hort & Extensive ag***
  - ***School of Ag Science***
  - ***Cross themes of***
    - ***Natural Resource Management***
    - ***Rural Social Research***
    - ***Ag. Value Chains***
    - ***Education & Training***
    - ***Climate Change***

Tasmania
Explore the possibilities

UTAS

Existing Climate Projects

Adaptation needs :- CERF project fine detail mapping of climate futures in Tasmania. Modelling industry responses to climate scenarios.

Adaptation sociology:- PhD with CSIRO, regional climate change message transfer,

Postdocs on adapted chains, sociology of change, change extension

Adaptation tools:- GRDC/DAL/MLA/Wool projects on irrigation, drought and water management in Tasmania. Linked to new programmable 3x 12 ha centre pivot.

Proposed project in Viticulture FACE,

TFGA/TIAR project on extension messages for climate change.

Existing links;

Locally - M Hovenden TasFACE and other CO2 physiology projects.

Nationally – Ag FACE program, HRZ cropping and irrigation projects

Internationally – Italy, Braunschweig, Illinois, Geisenheim.

Viticulture section in Perennial Horticulture Centre.

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Focuses on providing research for the Tasmanian wine industry, increasingly collaborating with other cool climate research institutes. (Geisenheim, Oregon, TRE, AWRI)

Focus areas include

- Plant pathology
- Reproductive biology
- Wine quality relationships
- Yield regulation
- Soil classification / interaction with vine physiology

Tasmania
Explore the possibilities

UTAS

Present Grape and wine research

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- First PhD project began in 2001
- 6 current postgraduate students
- 2 (3) post-doctoral research fellows
- Number of related supervisors and contributors to projects
- Developing new collaborative projects
- Priorities
  - Deliver good research to industry
  - Provide research training to students and early career researchers
  - Research excellence

Tasmania
Explore the possibilities

UTAS

Existing Viticulture Projects

AUSINDUSTRY – WIT, TRE, Other industry and commercial partners.

Quality relations in pinot noir and sparkling wines. Includes projects on fermentation of sparkling wines,

Node of the AWRI to be established at UTas.

Pathology and management of botrytis, powdery and downy mildew.

Compost teas as control mechanisms, natural elicitors, fermentation spoilage organisms.

Major projects around viticulture management and juice and wine quality water, nutrition, load, exposure, bunch structure. Yield variability projects.

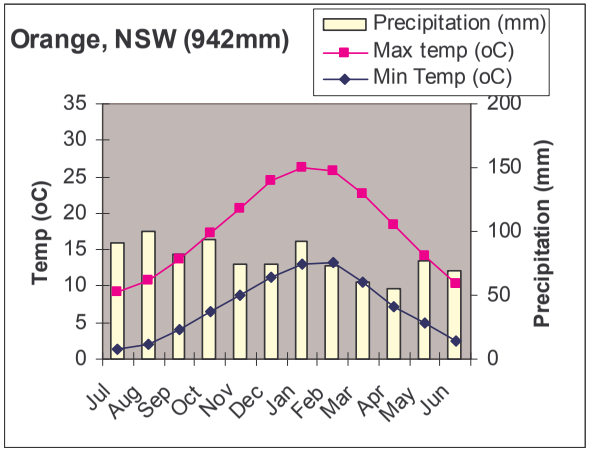
Soils and root exploration by vines.

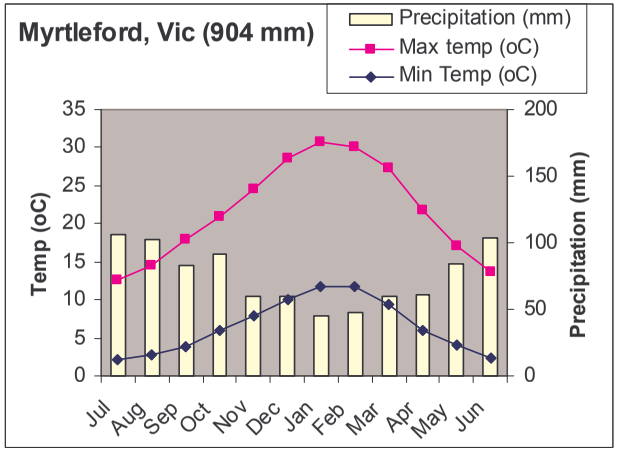
Major resource Food safety Micro group.

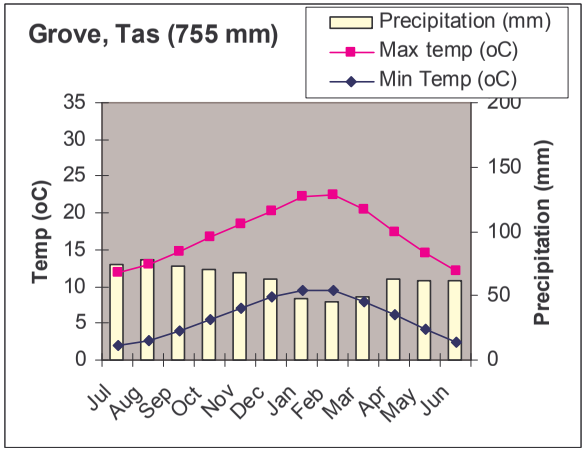
Micro fermentation winery.

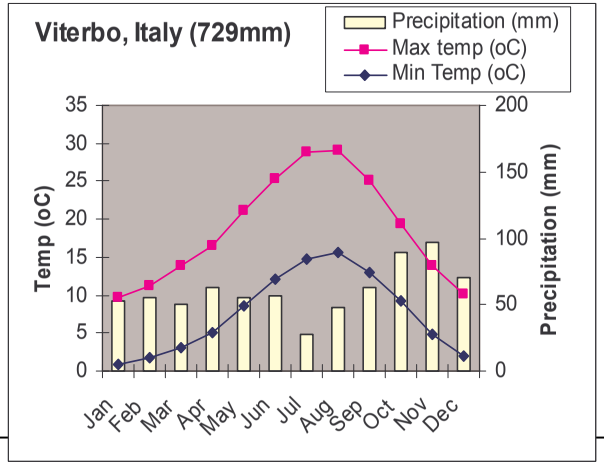
Climatic comparisons, Australia, Italy and Oregon

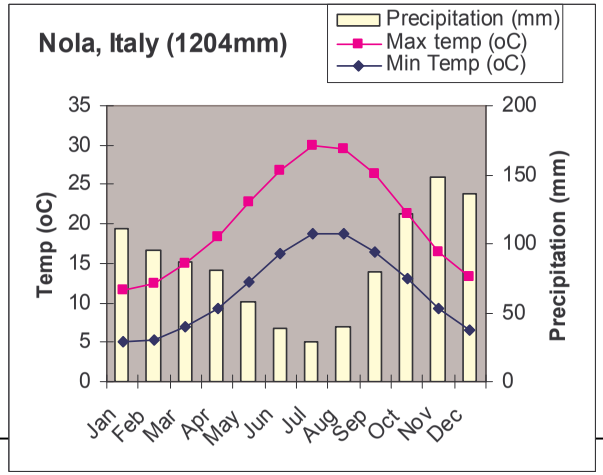
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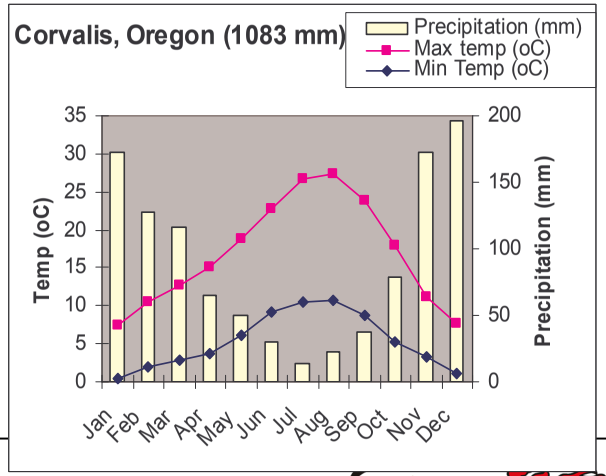






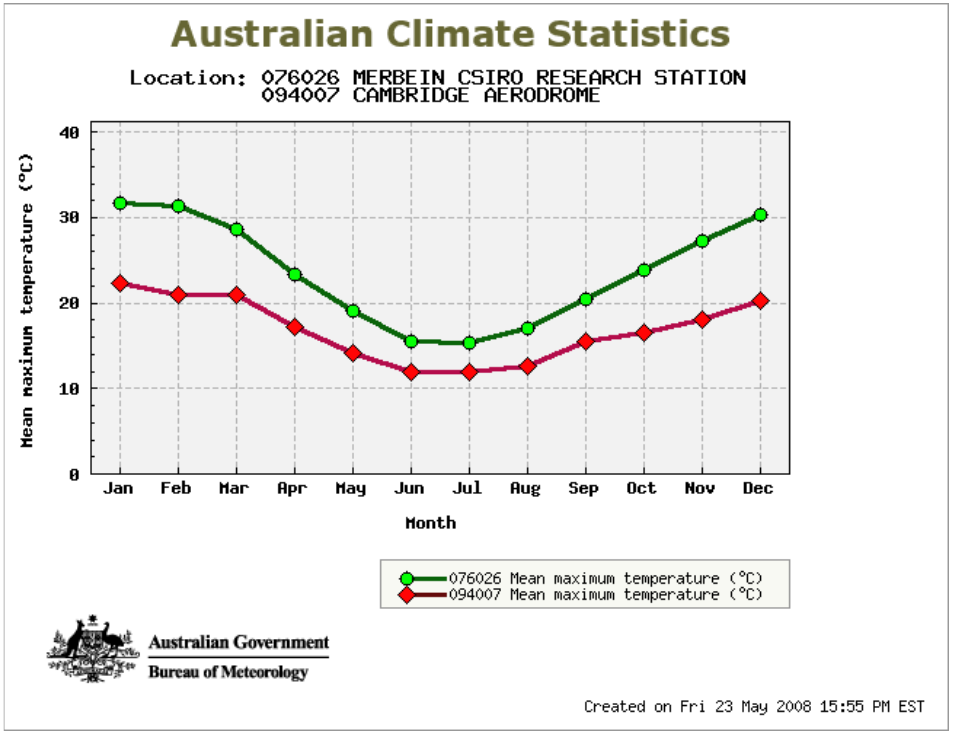


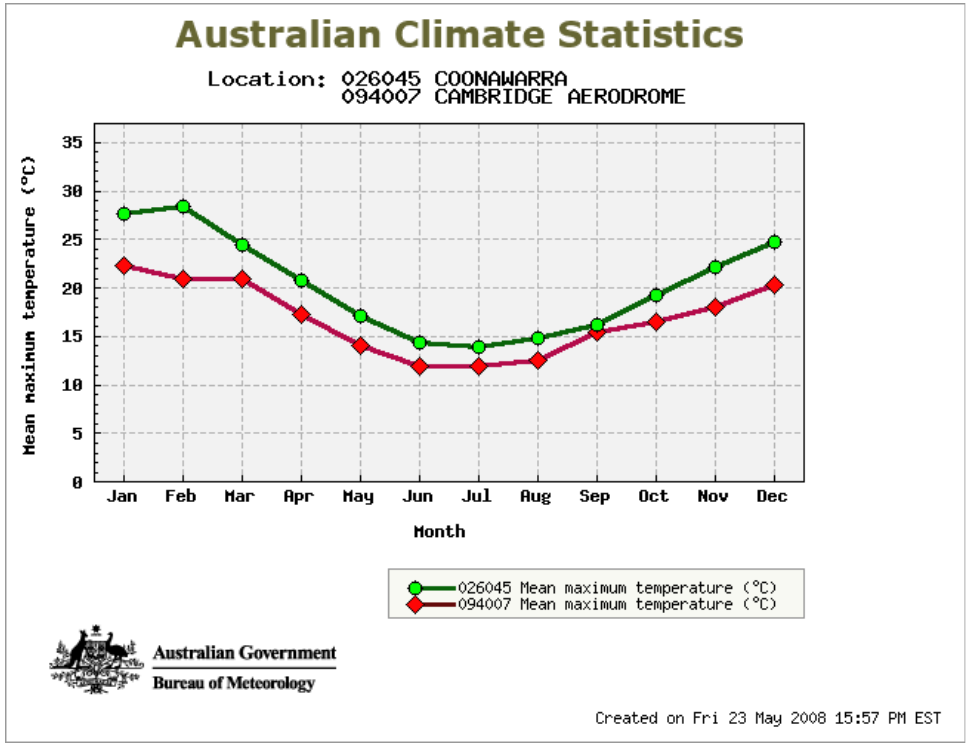




Tasmania
Explore the possibilities

UTAS


Australian Climate Statistics
Location: 076026 MERBEIN CSIRO RESEARCH STATION
094007 CAMBRIDGE AERODROME
Mean maximum temperature (°C)
0
10
20
30
40
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
076026 Mean maximum temperature (°C)
094007 Mean maximum temperature (°C)
Australian Government
Bureau of Meteorology
Created on Fri 23 May 2008 15:55 PM EST


Australian Climate Statistics
Location: 026045 COONAWARRA
094007 CAMBRIDGE AERODROME
Mean maximum temperature (°C)
0
5
10
15
20
25
30
35
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Month
026045 Mean maximum temperature (°C)
094007 Mean maximum temperature (°C)
Australian Government
Bureau of Meteorology
Created on Fri 23 May 2008 15:57 PM EST

Array purpose (after Ag FACE)

- **Mission of Project:**
  - **Through establishment of a Grape FACE (OTC) array to:**

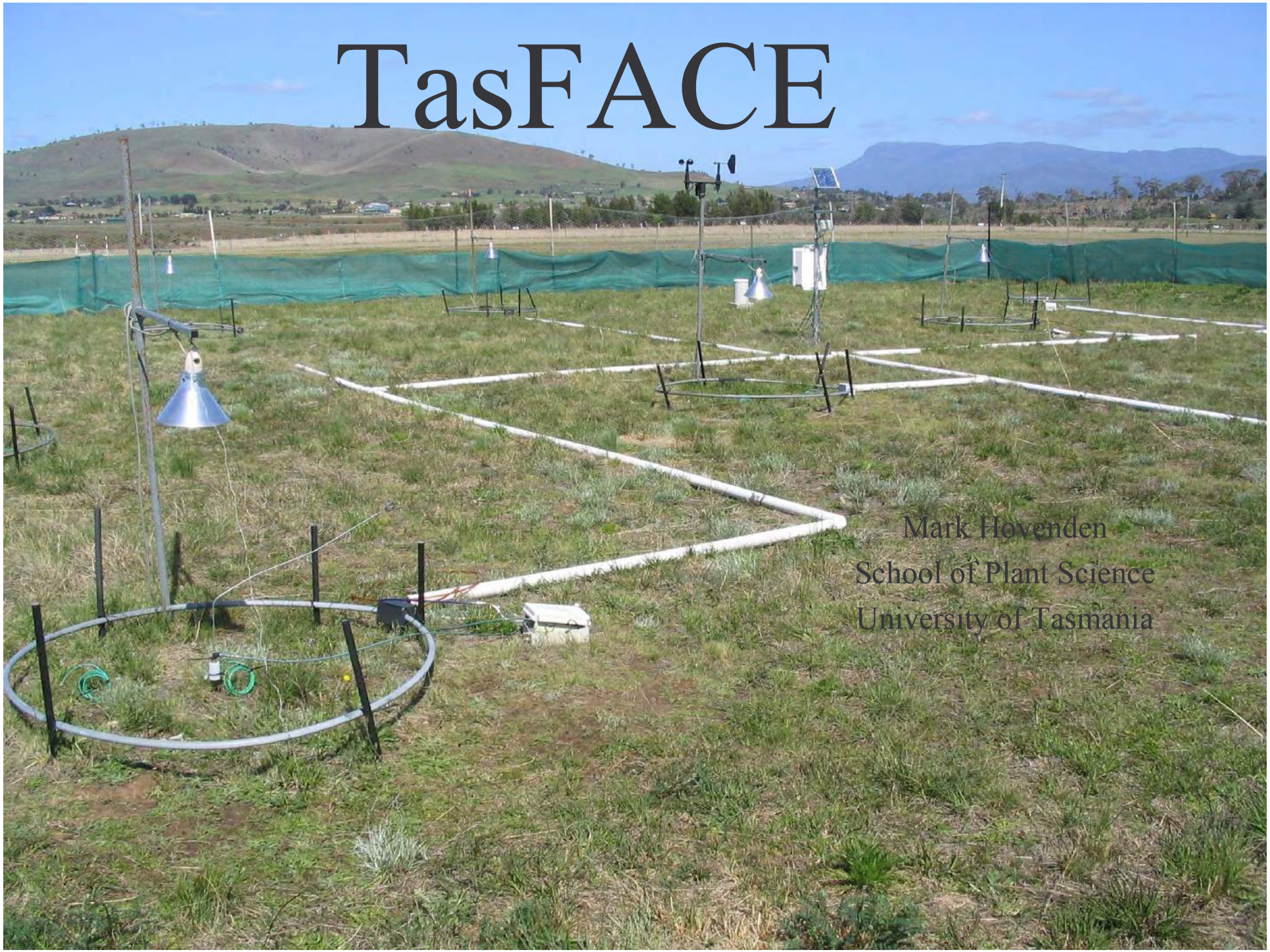
- **Provide an adequate validation data set to allow modeling of wine quality and yield resulting from interactions among N, CO2, water and temperature in possible future climates of the Southern Australian viticulture zone.**
- **(CERF Vinelogic, microwinery quality)**

- **Provide a resource for diverse monitoring and experimentation in Grape crops grown in potential future environments.**
- **(pathology, physiology, entomology initiative)**

Purpose

- Create a resource to validate CO2 effects & interaction effects in a cool climate. Link with warm climates to get a full industry picture.

TasFACE



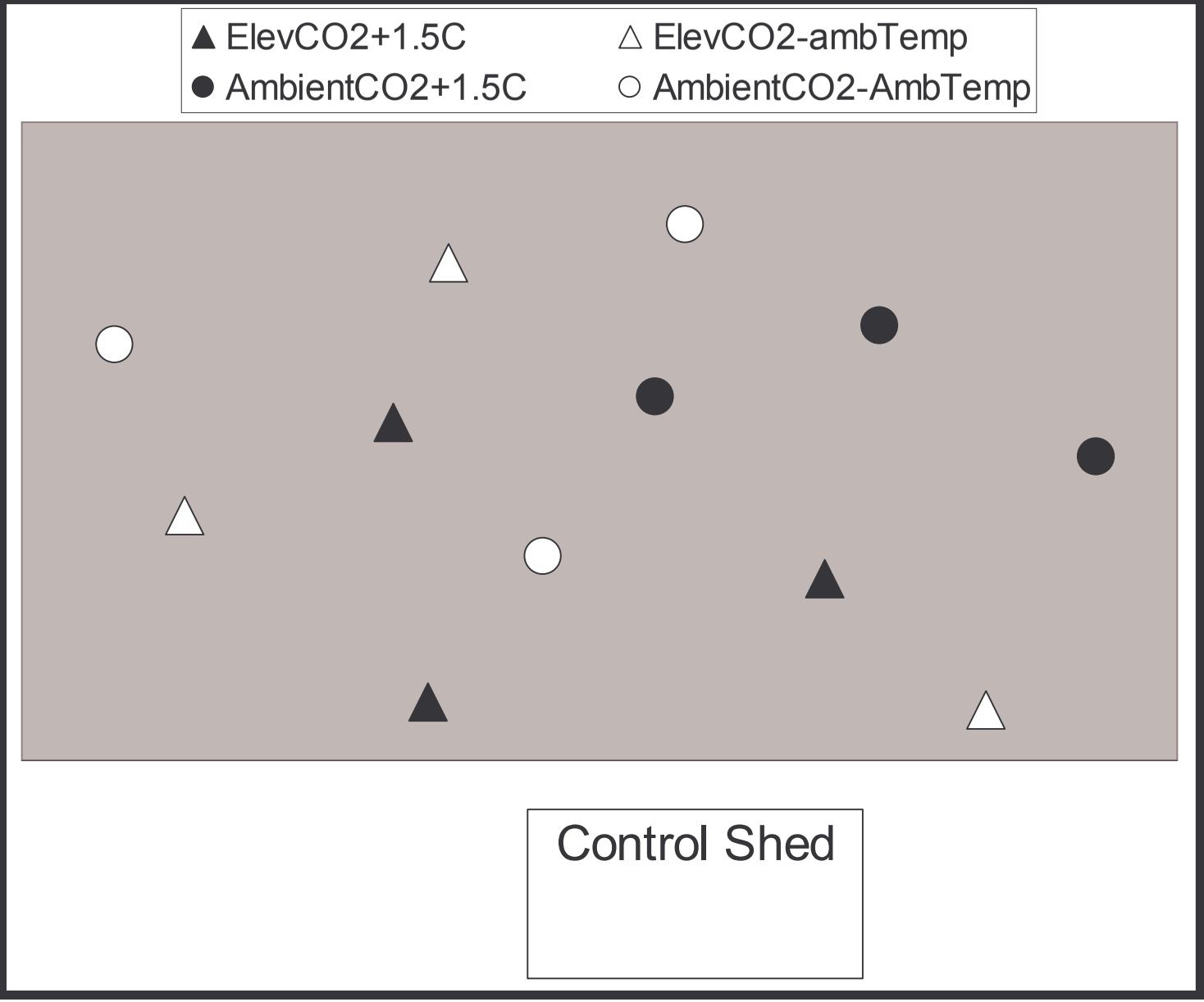
Mark Hovenden
School of Plant Science
University of Tasmania

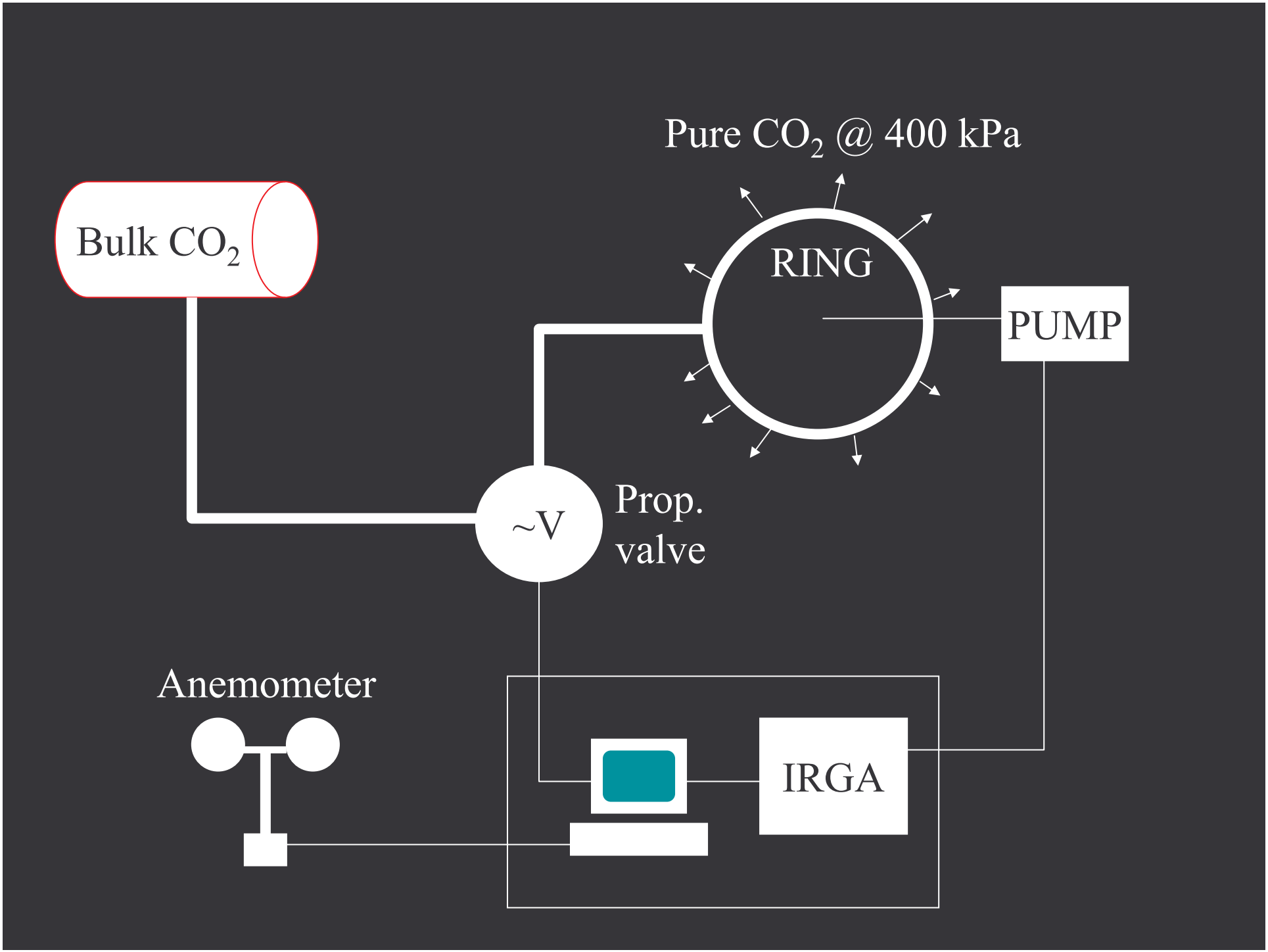
TasFACE

- Pure CO_2 miniFACE
- Rings 1.5 m diam.
- IR treatment gives 2.0ºC canopy warming

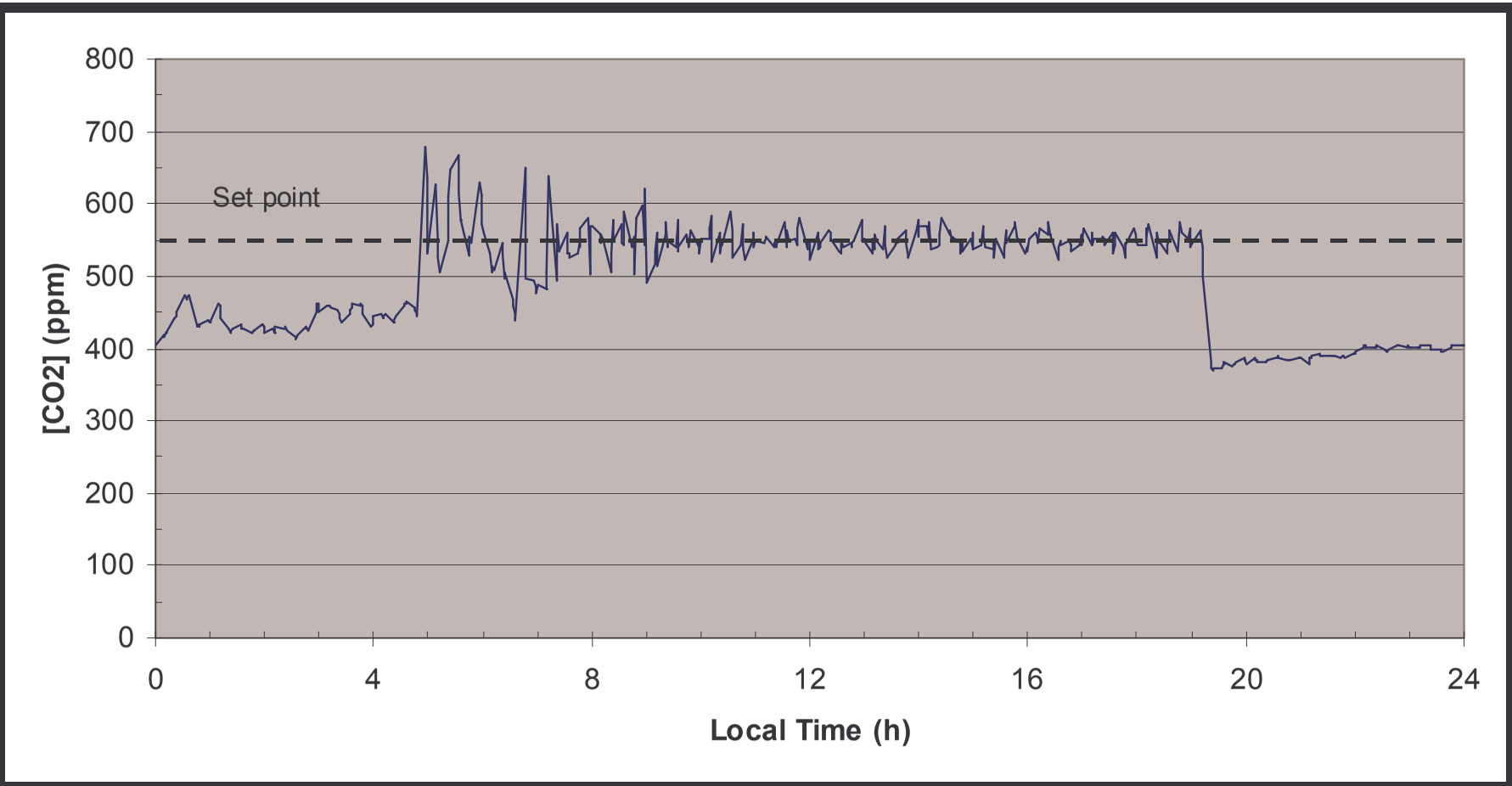


The experimental design

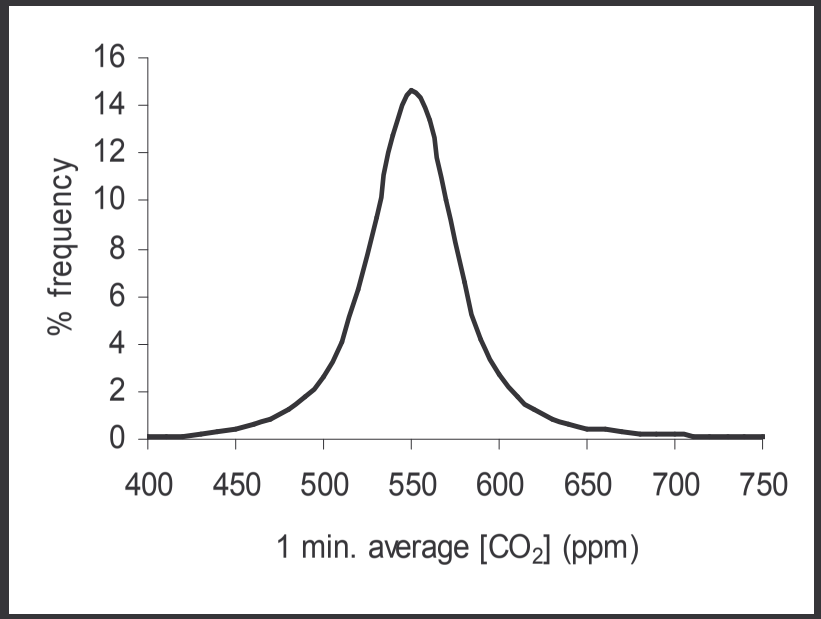


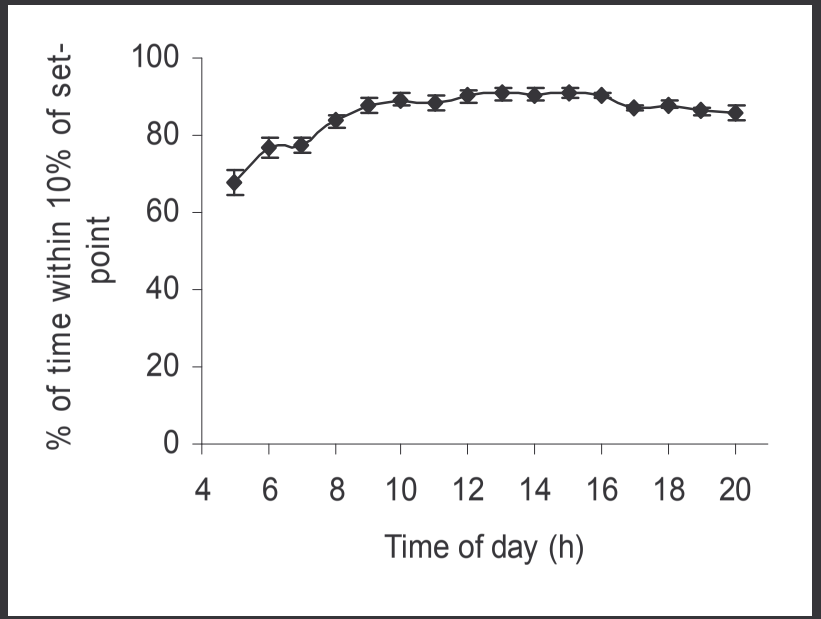

Pure CO_2 @ 400 kPa
Bulk CO_2
RING
PUMP
~V
Prop.
valve
Anemometer
IRGA

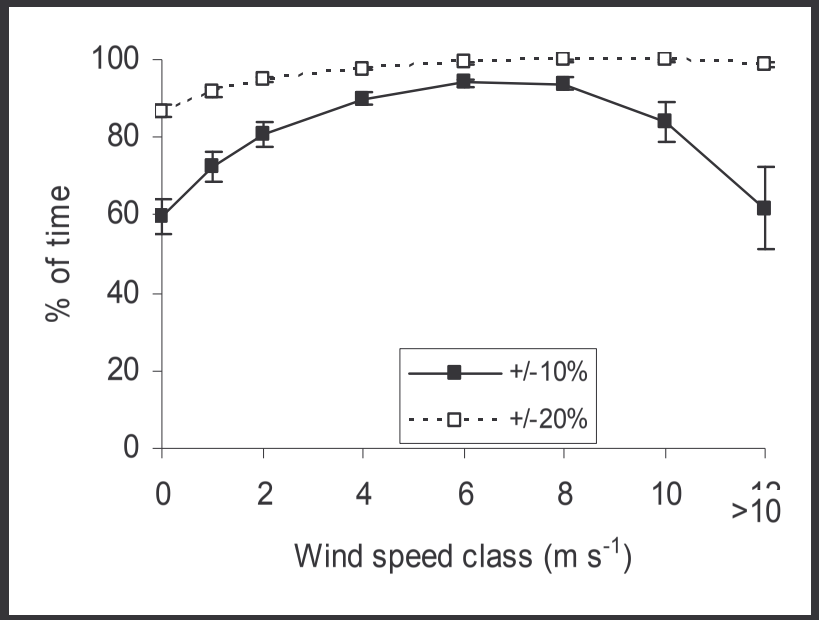

MULTI PORT SERIAL CARD
CD-R

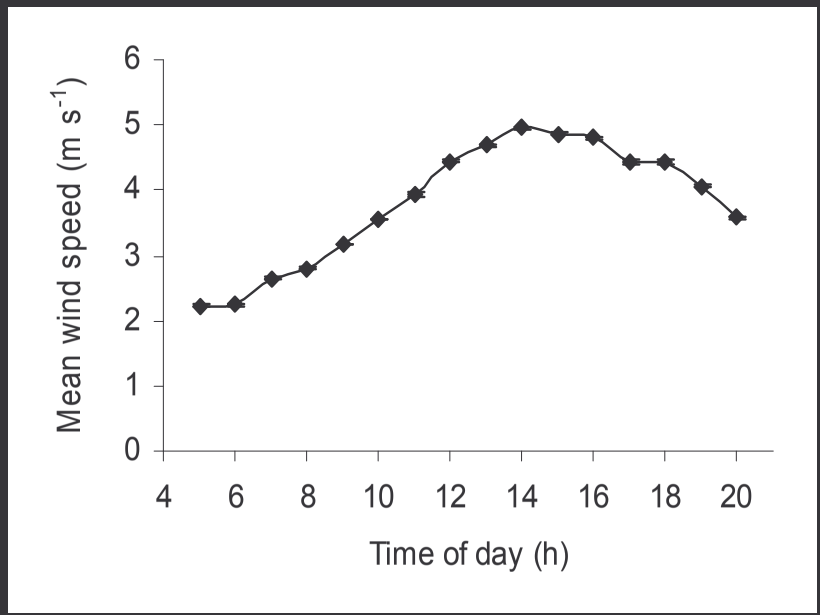


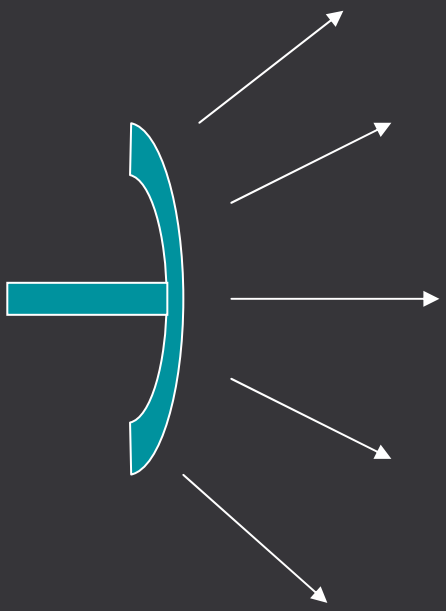
System performance	good	us
% time within 10% of set point	80	95-98
% time within 5% of set point	60	90


% frequency
16
14
12
10
8
6
4
2
0
400
450
500
550
600
650
700
750
1 min. average [CO2] (ppm)


% of time within 10% of set-point
100
80
60
40
20
0
4
6
8
10
12
14
16
18
20
Time of day (h)


% of time
100
80
60
40
20
0
+/-10%
+/-20%
0
2
4
6
8
10
>10
Wind speed class (m s-1)

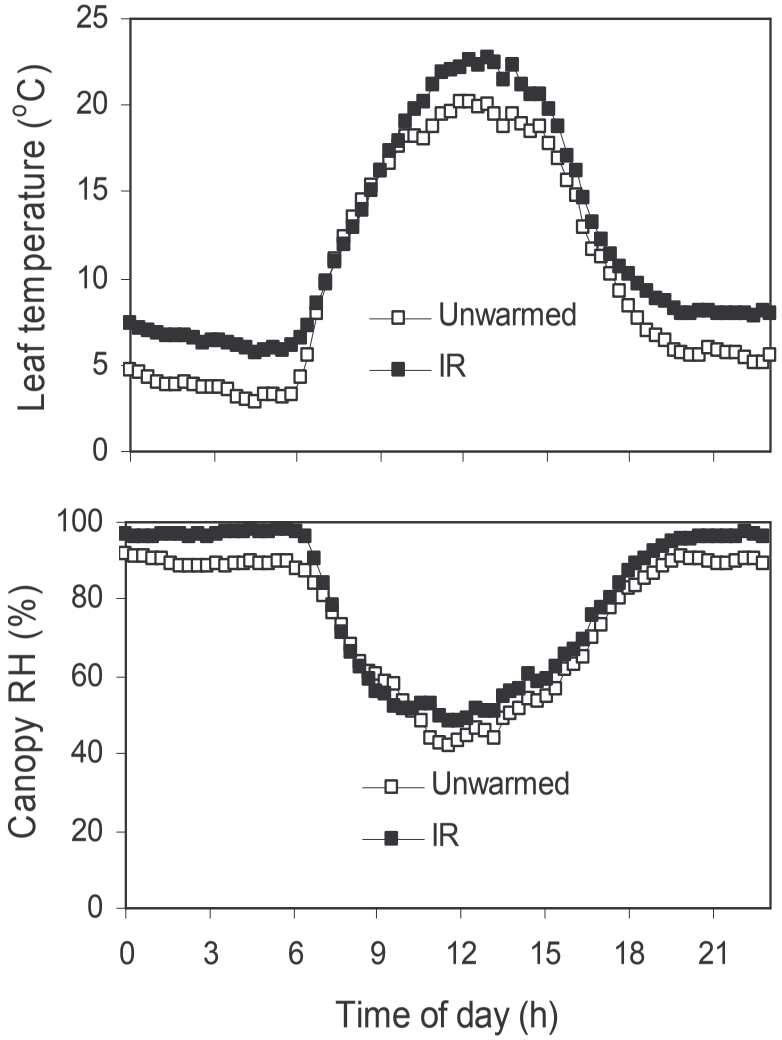

Mean wind speed (m s-1)
6
5
4
3
2
1
0
4
6
8
10
12
14
16
18
20
Time of day (h)



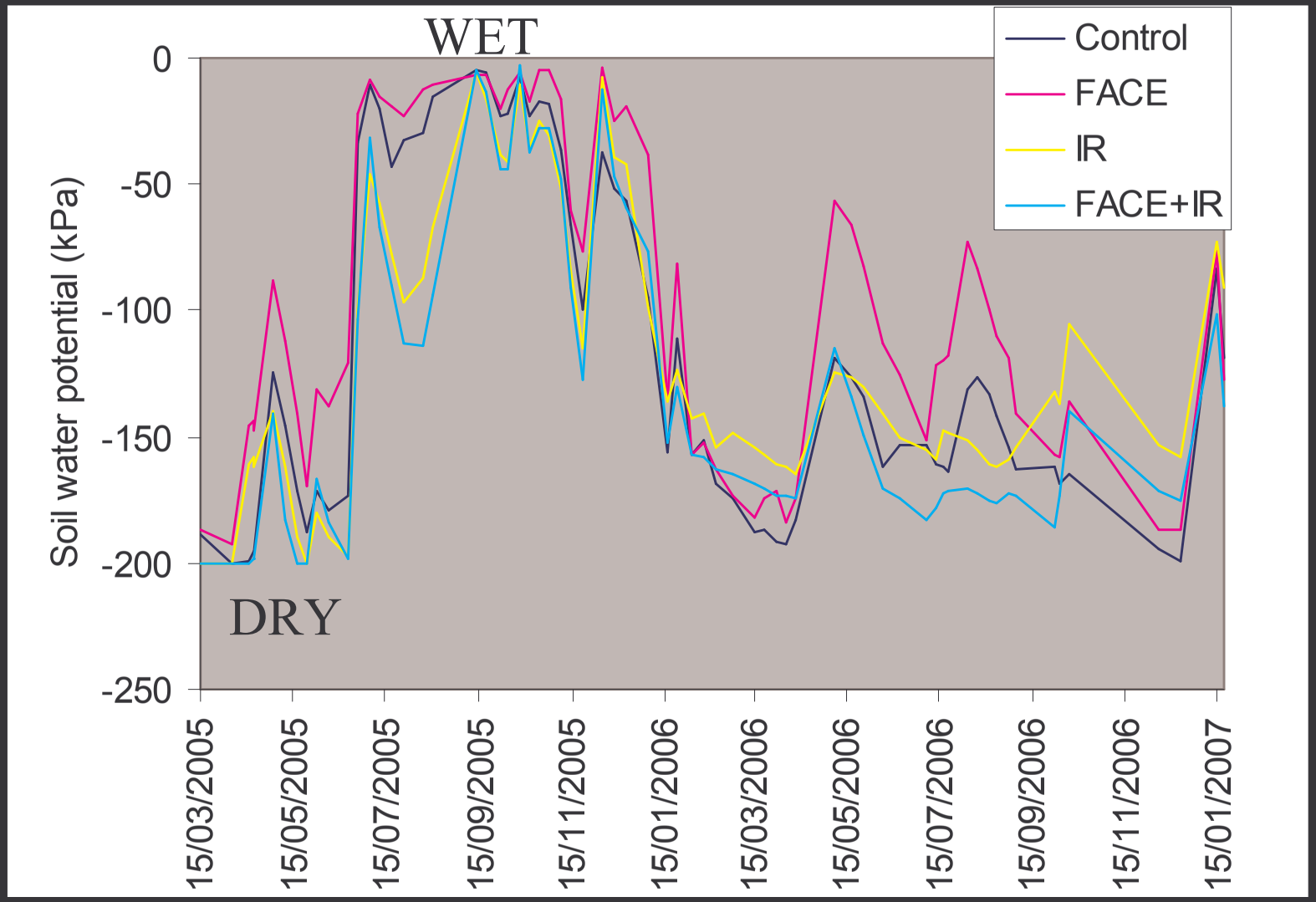

Infrared Salamander



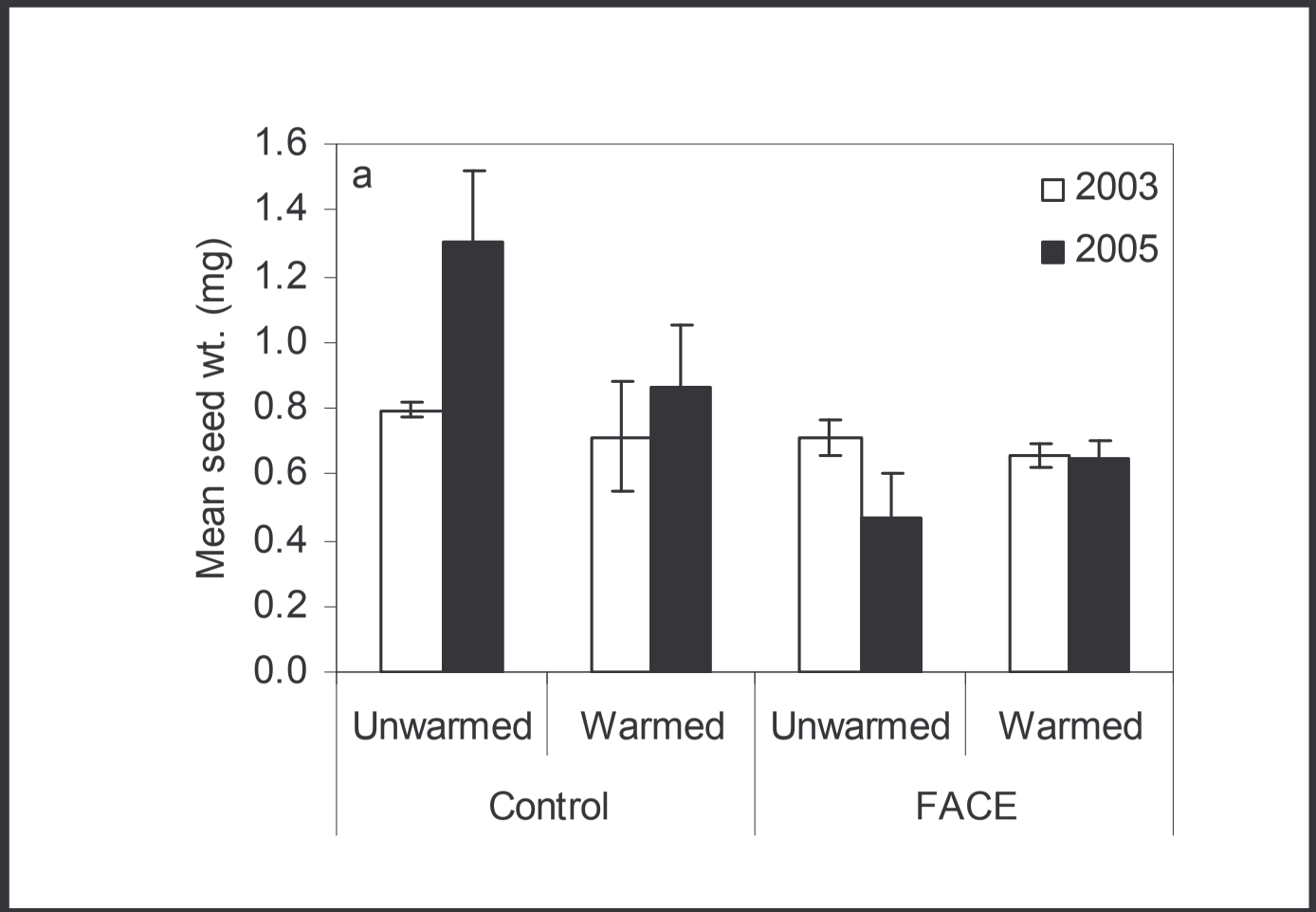
Warming


Leaf temperature (°C)
25
20
15
10
5
0
Unwarmed
IR
Canopy RH (%)
100
80
60
40
20
0
Unwarmed
IR
0
3
6
9
12
15
18
21
Time of day (h)

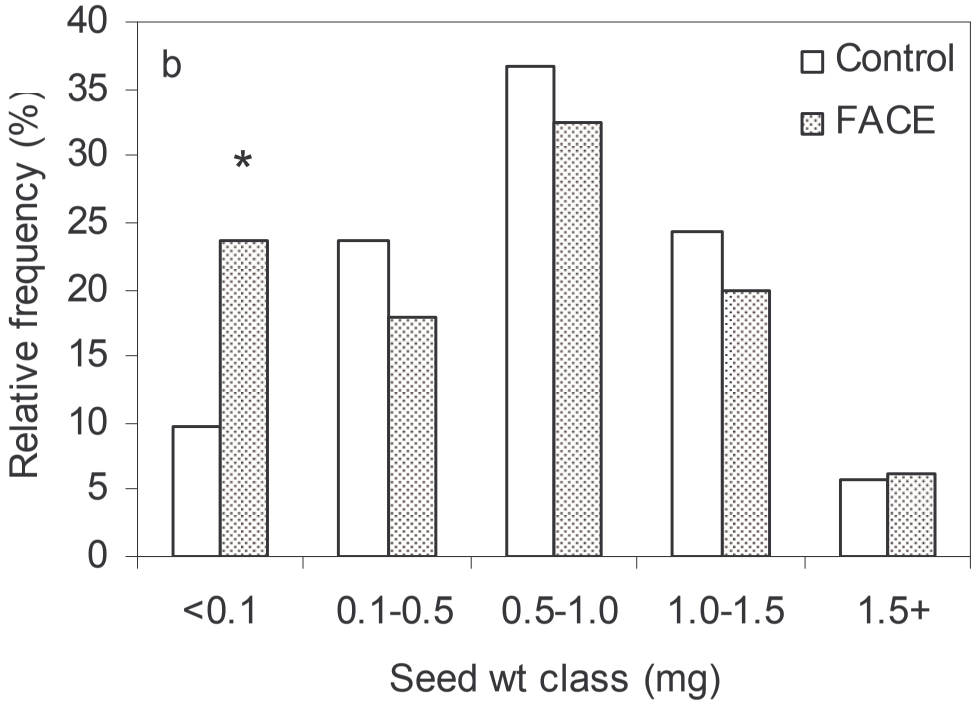
Soil moisture



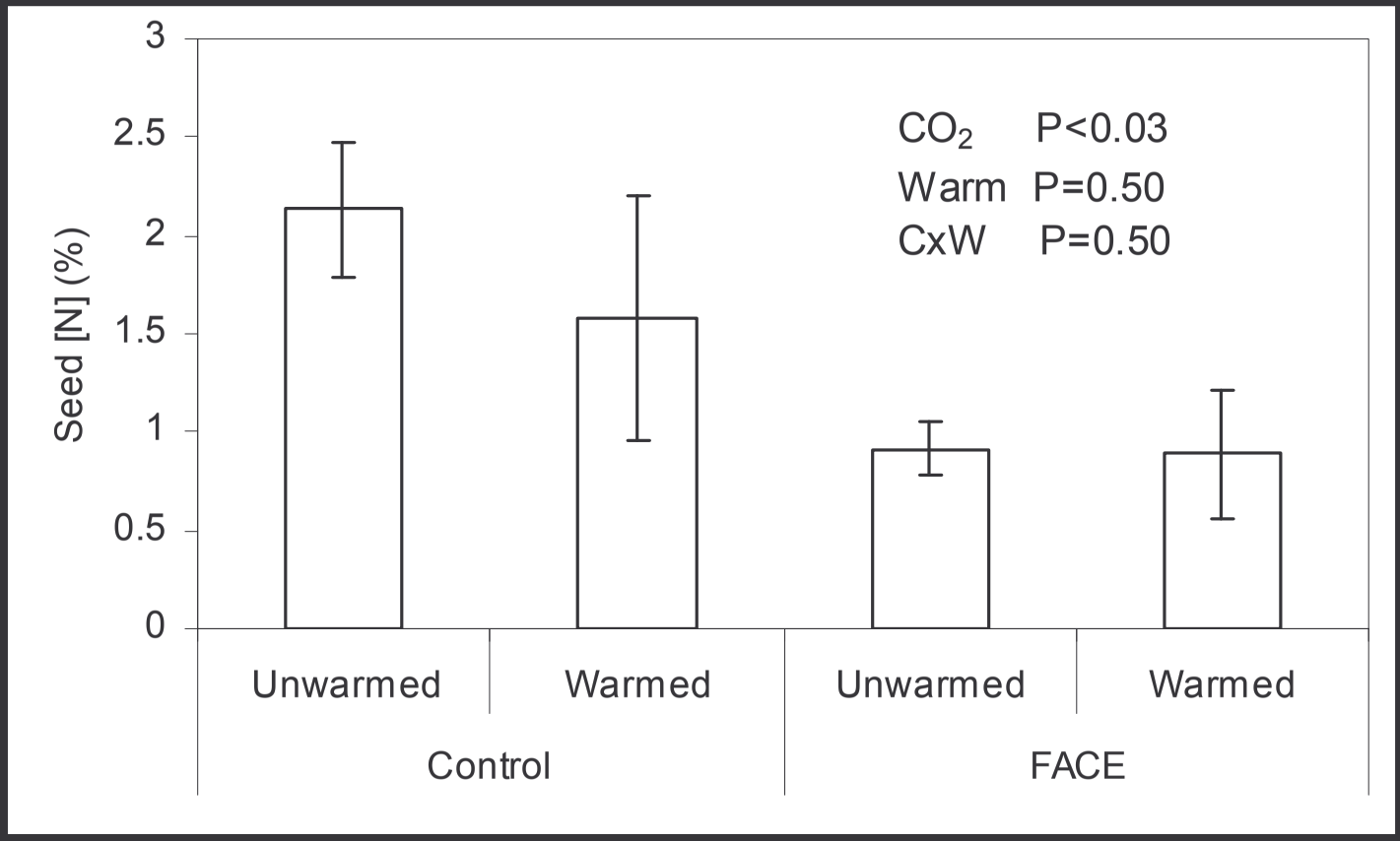
Seed mass of *Austrodanthonia*



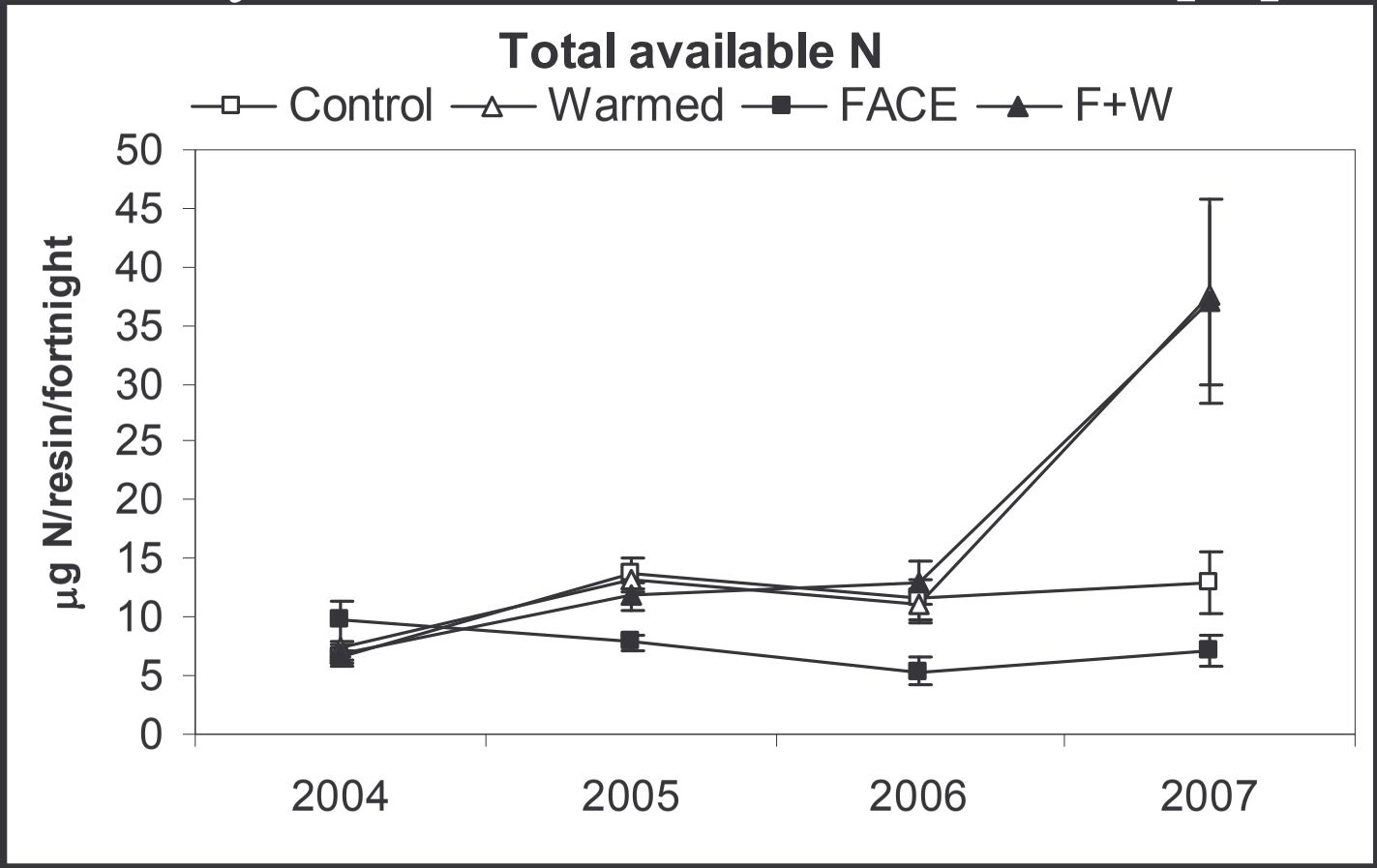
Austrodanthonia seed mass 2003



Seed N conc. in *Austrodanthonia*



So why should FACE reduce seed [N] ?



Elevated [CO_2]

- Reduces seed [N] even when it doesn't affect soil N availability
- Biogeochemical cycles are extremely important
- Need experiments with multiple global change drivers to be truly predictive



Potential effects of elevated CO_2 on carbohydrate dynamics and fertility of wine grapes



N. Cooley, G. Dunn, B. Collins & E. Barlow

Grape FACE workshop
Adelaide, 28th May 2008

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Outline

Introduction - review

High CO_2 concentrations and potential impacts on

1. Photosynthesis – regulation mechanisms
2. Carbohydrate dynamics
3. Fertility



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Introduction

c. 20 million years terrestrial plant evolution has been co driven by the optimisation of CO_2

Most species evolved under CO_2 levels of 240 ppm (Petit *et al.* 1999; Siegenthaler *et al.* 2005)

Current CO_2 concentrations at *c.* 380 ppm exceed plant gases levels since the late Tertiary era
(Pearson & Palmer 2000; Crowley & Berner 2001)



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Introduction

5/120 reviews on agricultural plants (Kőrner 1996)

3 major types of plant response to elevated CO_2
Woodward (2002)

1. Nutrient limitation of plant CO_2 fluxes

2. Stomatal development and opening

3. Plant development

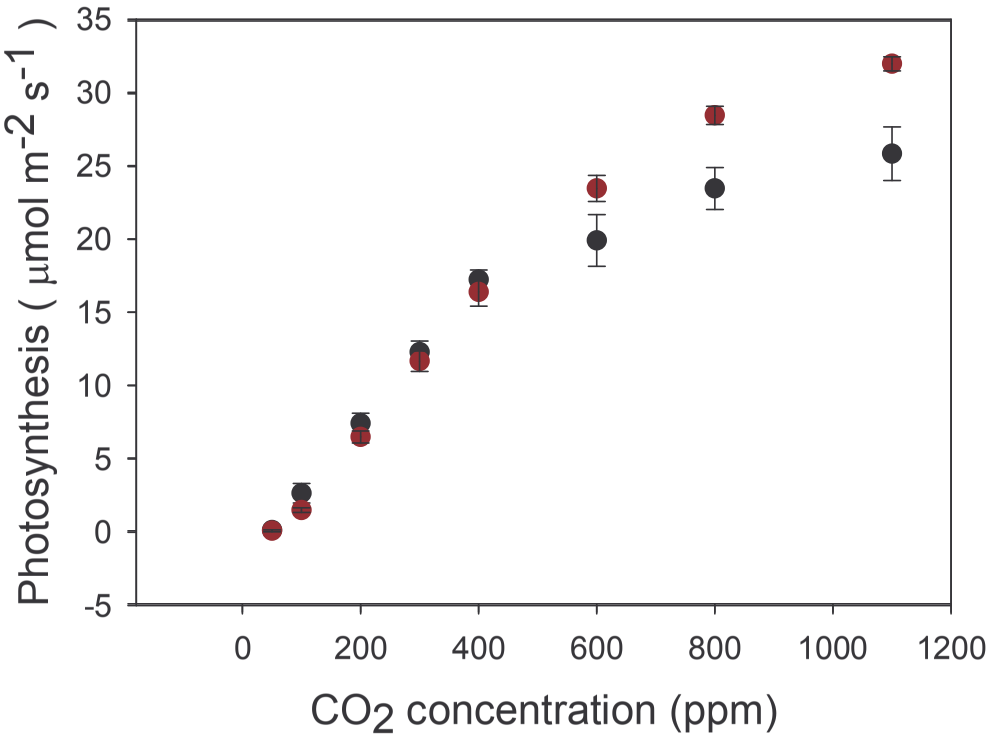


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Introduction

Photosynthesis is not saturated under current concentration of CO_2



Pinot noir
Thomas *et al.*
- March 2006 @ 34ºC
- April 2006 @ 28ºC



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Photosynthesis

Increase in [CO_2] = increase in [CO_2] entering plant

Leaf photosynthesis – increase

Downward regulation of photosynthesis

Increased RuBisCO efficiency (not saturated at current levels)

Elevated [CO_2] inhibits competing oxidation reaction leading to photorespiration



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Photosynthesis

CO_2 fluxes		
Process	**Effect**	**Citation**
Photosynthesis	downward regulation	Griffin *et al.* (2000) Plant Cell and Environ.
Photosynthesis	downward acclimation	Jach & Ceulemans (2000) Tree Physiol.
Respiration	downward regulation	Atkin *et al.* 2000 Plant Cell Environ
Respiration	downward acclimation	Gunderson *et al.*(2000) Tree Physiol.

Summary from Woodward 2002

Photosynthetic stimulation is species specific

7% of legume herbs (Lee *et al.* (2001) New Phytol.)
98% in pine (Tissue *et al.* (2001) Tree Physiol.)

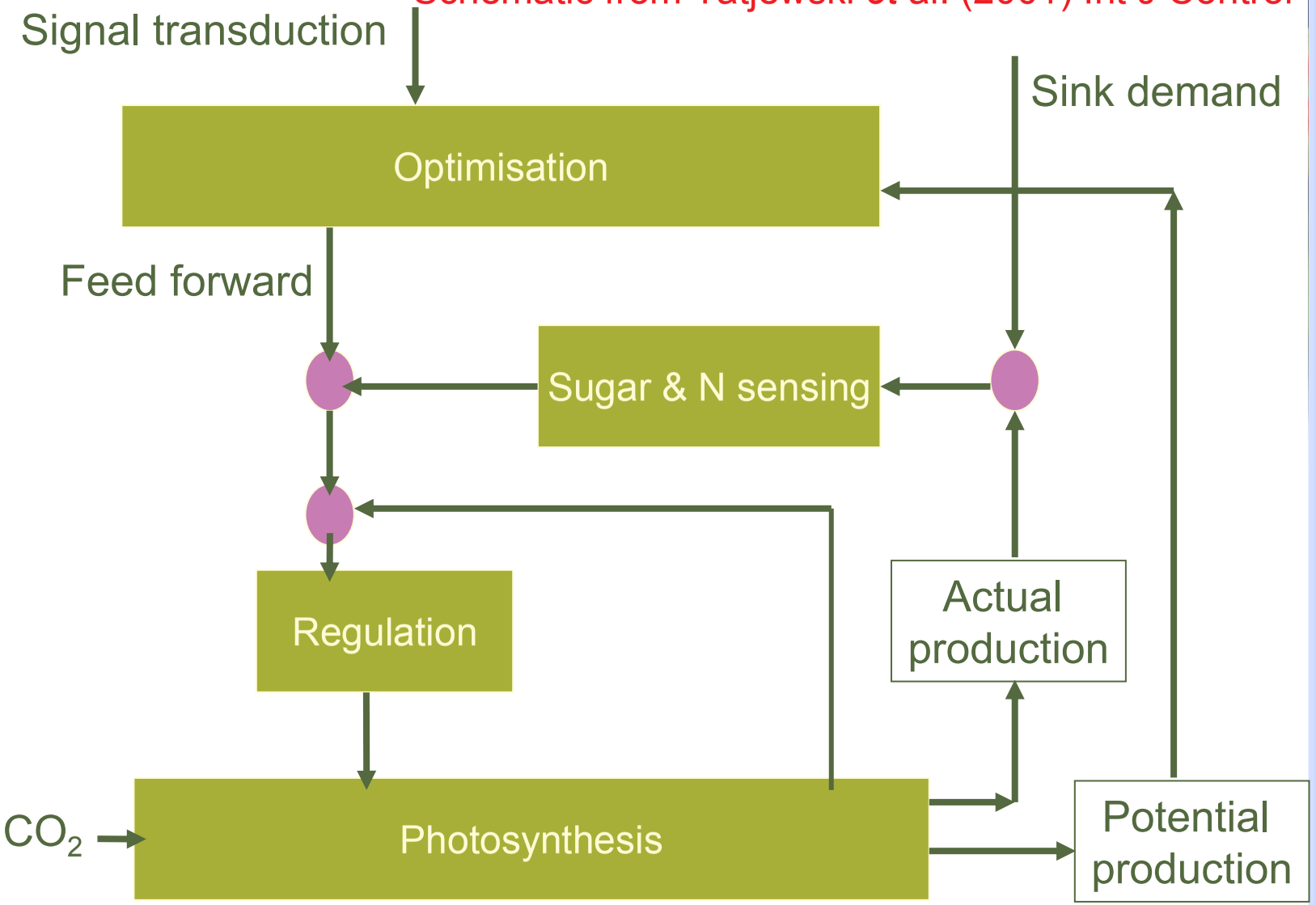


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Photosynthetic feedback controls in response to high CO_2 environments

Schematic from Tatjewski *et* al. (2001) Int J Control





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Yield and growth of oranges in high CO_2

Primary effect is increased biomass

(Eamus & Jarvis 1989 - tree species,
Idso *et al.* 1991, Idso & Kimball 1992 – sour orange, Bazzaz *et al.* 1990 – cherries, Bunce 1992 - apples)

Growth and crop variables	CO_2 concentration (μmol CO_2 mol^{-1}) 400	800
Plant dry mass (g)	1141	1439 (26%)
Total fruit fresh mass (g)	2659	3583 (35%)
Number of fruit per tree	18.3	31.0 (70%)
Soluble solids (%)	12.3	12.2
Skin colour (% orange)	60	95 (58%)

(Based on Downton *et al.* 1987)



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Carbohydrates and elevated CO_2 Concentration

Root:shoot

Leaf area effects
(size, leaf age, genetic plasticity, nutrients, phenology, management)

Sink strength effects
Likelihood of acclimation occurring is reduced with large sinks – important for grapevines?

Carbohydrate-derived signal down-regulation (acclimation) Rubisco (Stitt & Krapp 1999; Long *et al.* 2004)

Potentially offset by N to regenerate Rubisco



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WINDOWS OF SENSITIVITY IN GRAPEVINE REPRODUCTION

Season 1

Season 2

Initiation



Differentiation



Further Branching & Flower formation



Flowering and Fertilisation



berry growth and development



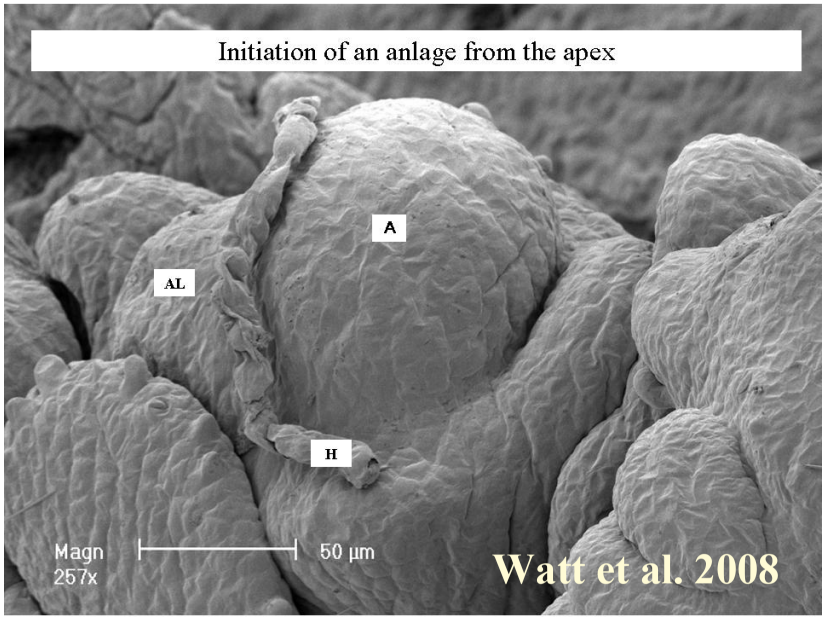
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Initiation of Inflorescence Primordia



Temp.

light



Bunch number
('fruitfulness')

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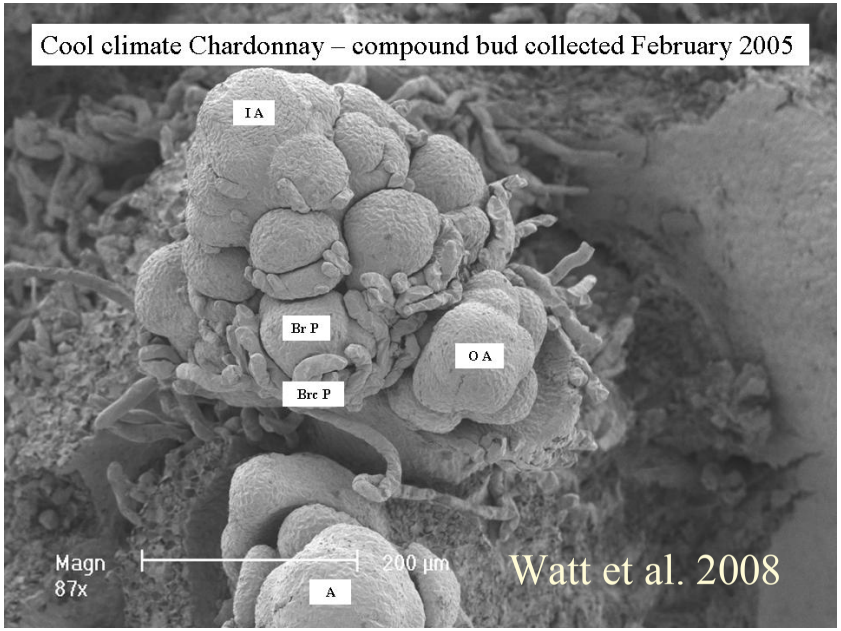
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Differentiation of Inflorescence Primordia

Temp.

light

CHO supply ?



Bunch number
('fruitfulness')
&
Berry number



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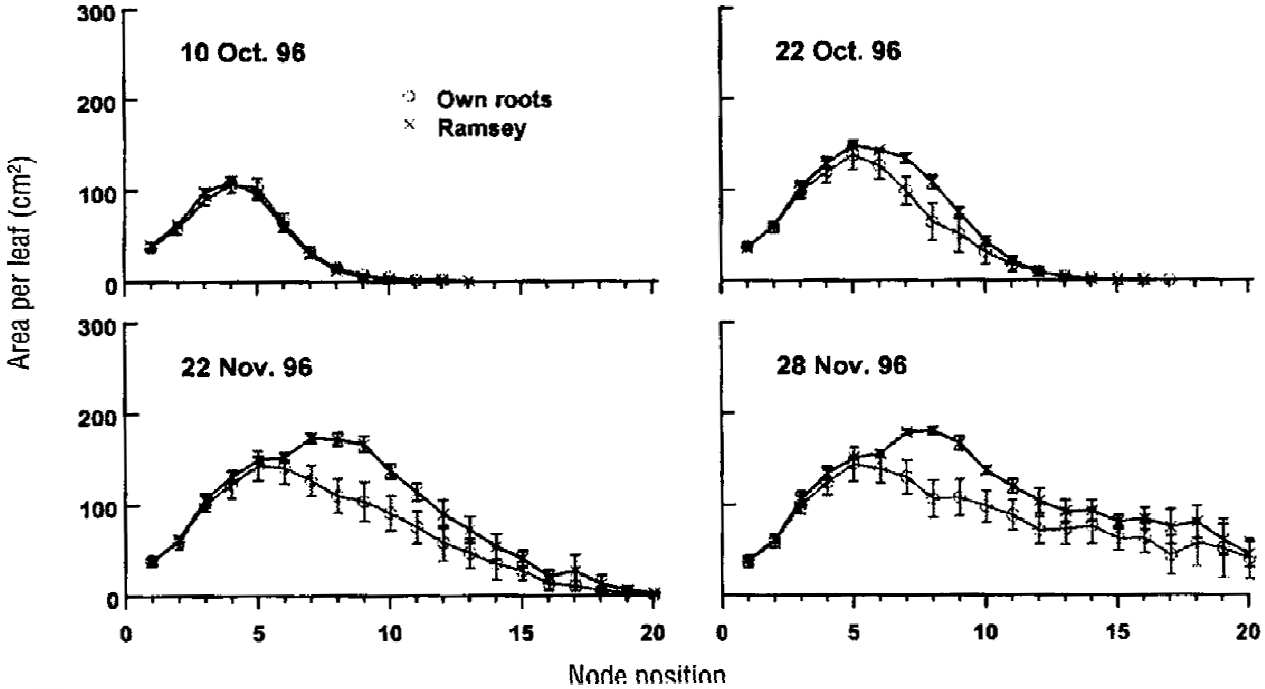


Figure 10. Leaf area development of single leaves as a function of node position during the season of 1996-1997 in Experiment 2 for Ramsey-grafted and own-rooted Sultana vines. Vertical bars show ±SEM.

(Sommer et al. 2000)

- Causal relationship between leaf and bud ?
- Conditions that promote larger leaves also promote higher fertility ?

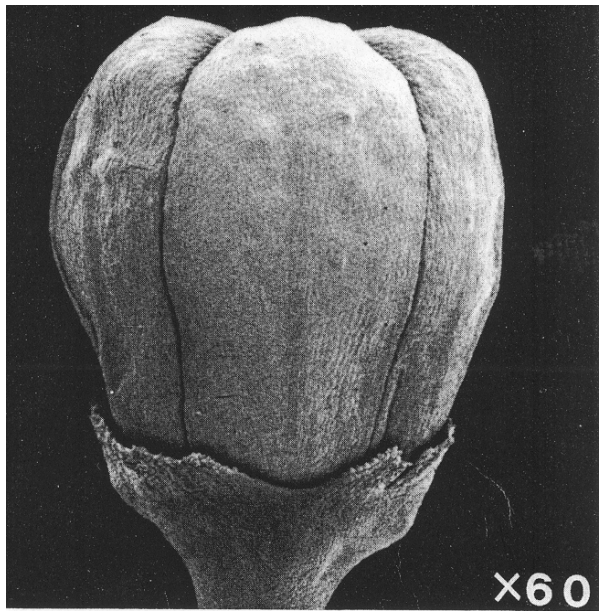
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Differentiation of Inflorescences (budburst)

Retained nodes (CHO supply)

Temp (less imp.)



Flower number (potential berry number)

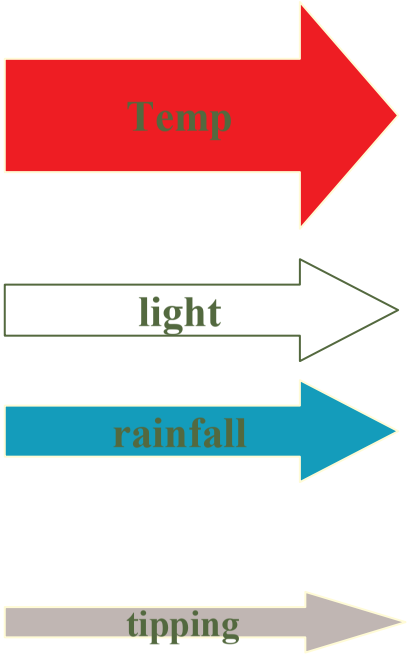


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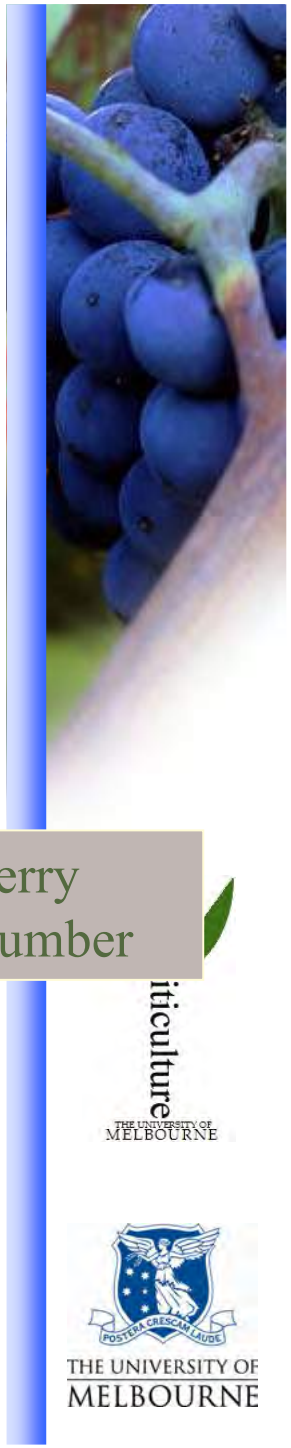
Pollination, Fertilisation and Fruit Set

(adequate nutrition and water)





Berry Number



Yield indicate components processes

Vineyard design

↓

weight / vine x vines / hectare = weight / hectare

=

bunches / vine ← Formation of inflorescence primordia ★

Pruning patterns & budburst conditions ★

x

weight / bunch = berries / bunch x weight / berry

↑ Fertilisation & fruit set ★

↑ Cell division & expansion

Seed number & size ★★★

(Idso *et al.* 2001)



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Potential effects of high CO_2 concentrations

Photosynthesis - positive but with caution

Carbohydrates - positive, root mass & sink size dependent

Fertility - complex & positive, weight per berry

Variety specific responses

Management - potential impacts on yield?



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Unknown, Unknown

Alpine dwarf shrub *Loiseleuria procumbens* (European shrub)

NPK fertilization

Leaf structure

Progressively killed by Snow mould over subsequent winters

Not predicted in the growth cabinet



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Climate change: Implications for early reproductive development in grapevines

Cassandra Collins



THE UNIVERSITY OF ADELAIDE
AUSTRALIA



Australian Government

Grape and Wine Research and Development Corporation

Elevated CO_2 and early reproductive development



- Elevated CO_2 influences flowering time
- Variability between and within species – delayed and accelerated flowering time (Springer and Ward 2007)
- Most crop and cultivated species (80%) display accelerated flowering (Springer and Ward 2007)
- Variability in fruitset under elevated CO_2 (Navas et al. 1997)

Elevated CO_2 and early reproductive development



- Carbohydrate reserves
  - Influence development
  - ie. flower initiation (Rolland et al. 2006)
- Expression of floral-initiation genes (Springer et al. 2008)
- Increases in grapevine fruit weight under elevated CO_2 (Bindi et al. 2001)
- Interactions between elevated CO_2 and other climate change factors such as temperature and precipitation (Springer and Ward 2007)

What is the cause of poor fruitset at a particular site/vineyard?

- **Need to consider what is causing the poor fruitset in the first place?**

Variety susceptibility?

Exposure to wind?

Low temperatures?



High temperatures?

Nutrient deficiency?

Water stress?

Is it really poor fruitset?

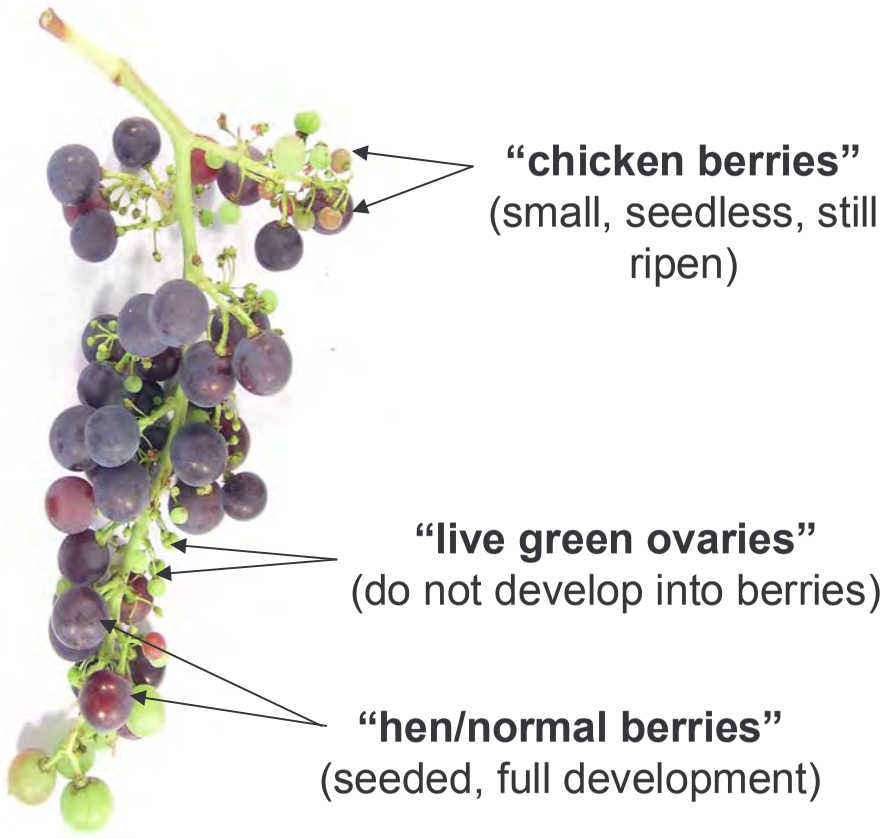
Climate, region, variety and yield components



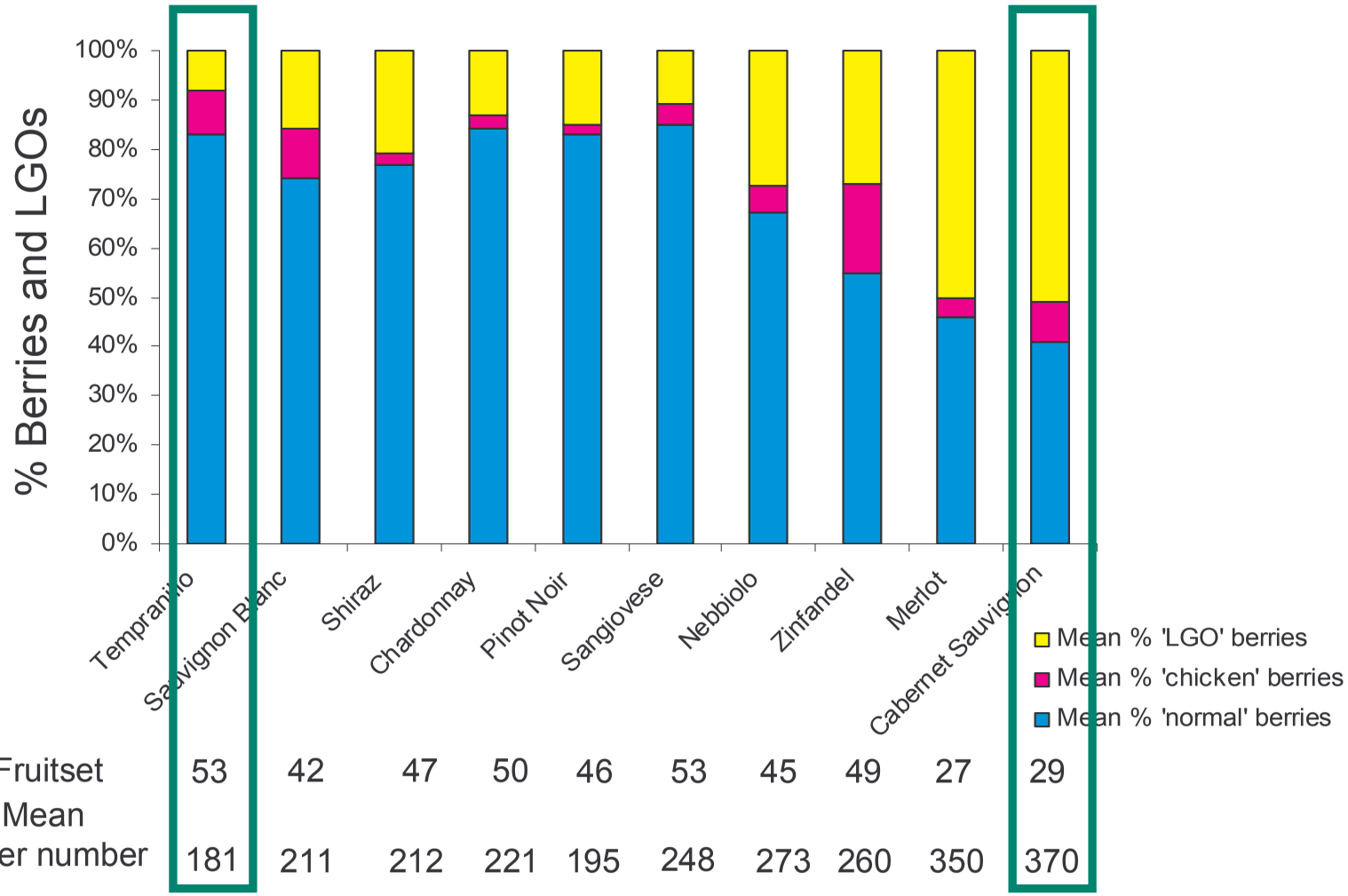
- 2004-present
- Are varieties more susceptible to poor fruitset and development?
- What influence does climate have on this susceptibility?
- Ten varieties in three different wine regions in South Australia
- Weather, phenology, fruitset and yield components
- Long term datasets and models in collaboration with, statisticians and modeller from UniSA

Fruitset – How do we measure it?

Number of berries (“hen” and “chicken”) compared to the initial flower number



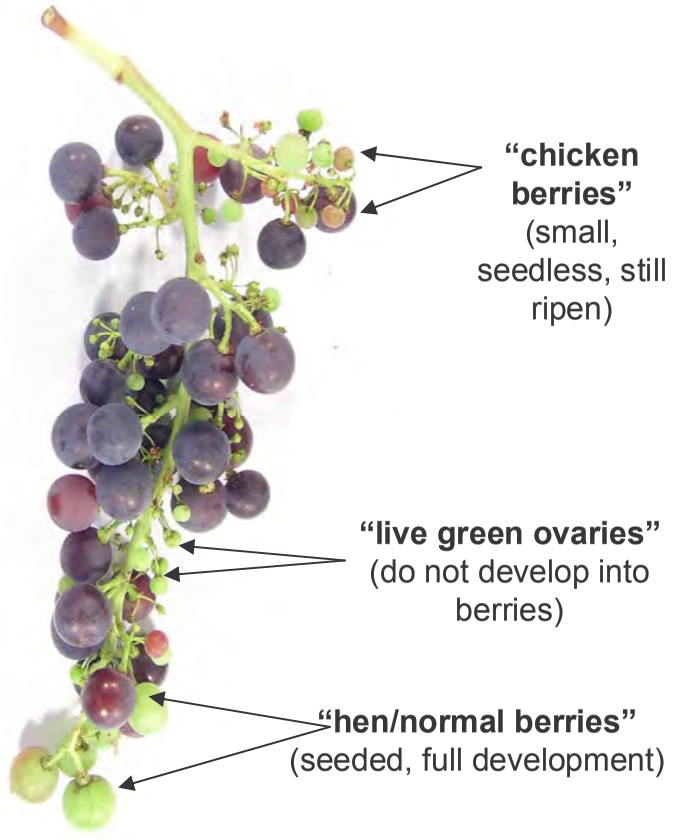
Bunch components (2004-08)



% Fruitset	53	42	47	50	46	53	45	49	27	29
Mean flower number	181	211	212	221	195	248	273	260	350	370

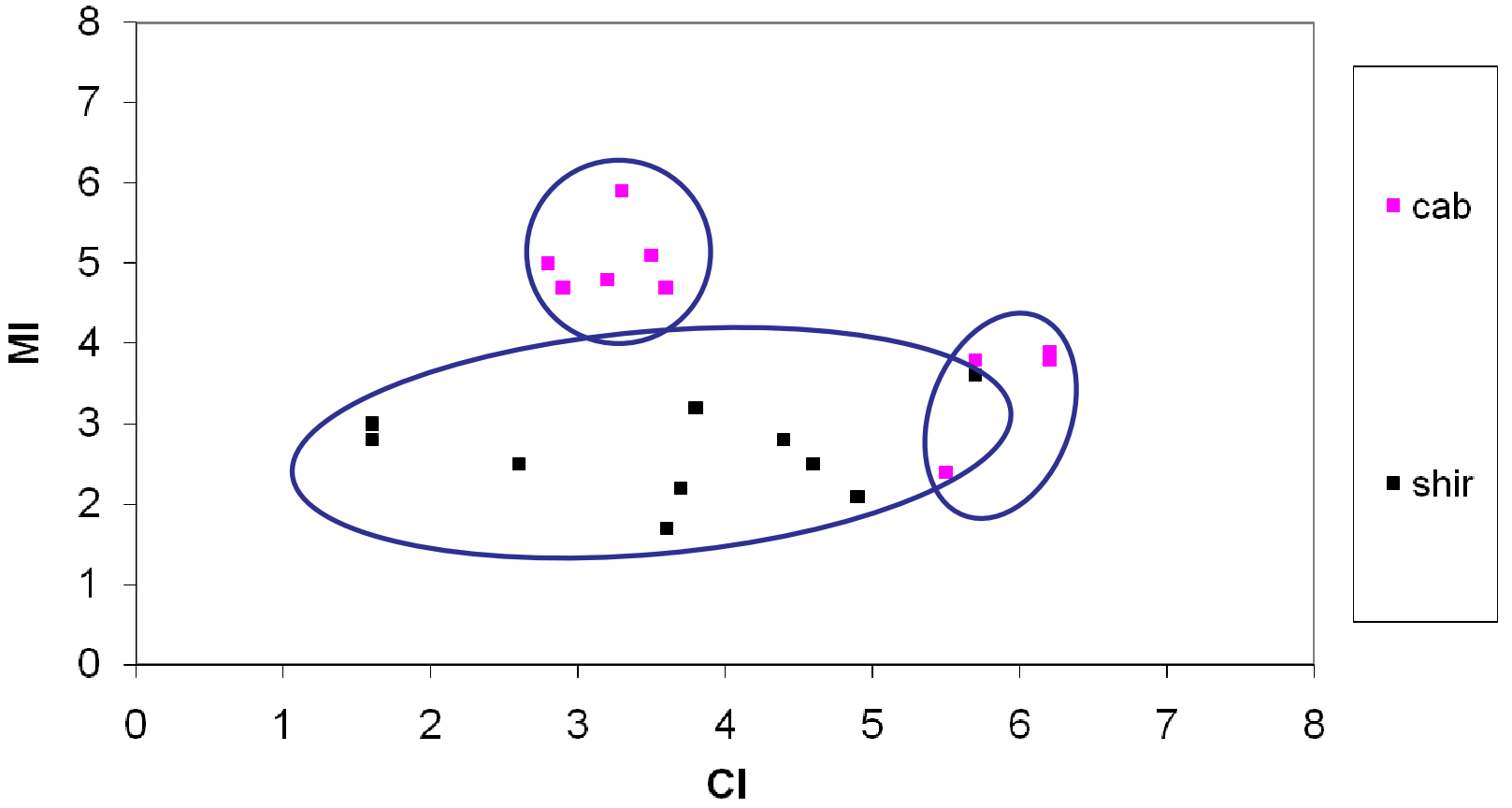
Novel Fruitset Indices

- "Coulure Index"
  - measures the conversion of flowers to berries and LGOs
- "Millerandage Index"
  - measure of incomplete berry development



Both indices 0-10
Higher number indicates greater severity of condition

Novel Fruitset Indices



Variety Susceptibility

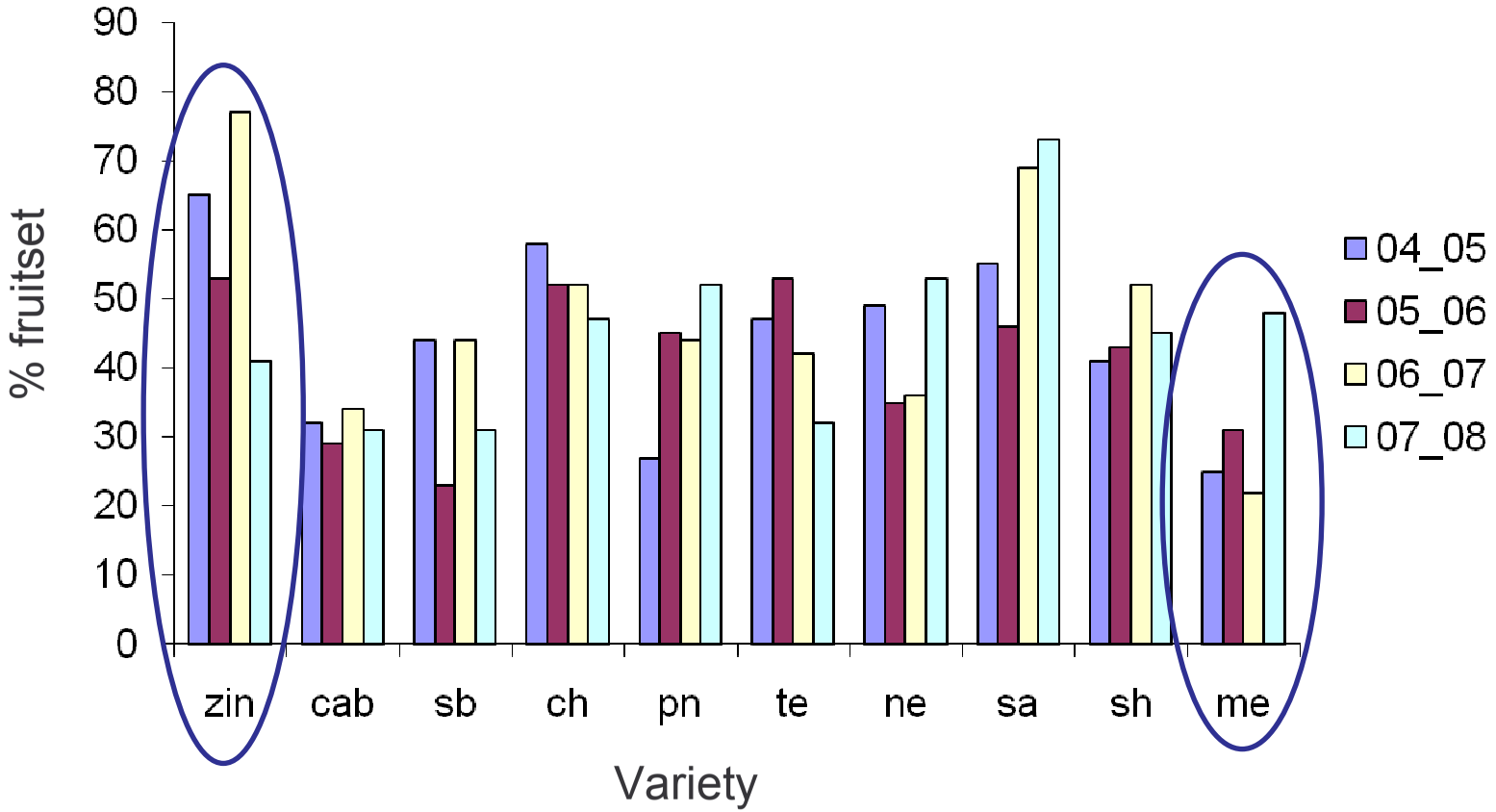
- % Fruitset is very variety dependant

- Yield = bunch number x bunch weight
  - Bunch number – fruitfulness
  - Bunch weight – flower number and fruit set
  - CI and MI

- How might climate change influence these findings?
  - Higher temperatures -earlier flowering
  - Temperatures more variable in early spring
  - Water availability
  - Elevated CO_2



Mean % fruitset over four seasons



Elevated temperatures during flowering, on Shiraz vines, Nuriootpa

- Existing SARDI experiment under-vine tents to increase temperature at key growth stages.
- Temperatures were elevated by approximately 3ºC from the start of the flowering period for 2 weeks.
- Fruitset, bunch number, flower number, berry number, bunch weight, berry weight and final yield per vine determined.





Photos courtesy of Chris Soar

Elevated temperatures during flowering, on Shiraz vines, Nuriootpa



Component	Control	Elevated temperatures during flowering
Bunch number/vine	60.11	61.67
Flower cap number	253.41	255.83
Berry number	118.85	86.42
% Fruit set	48.22	38.14
Coulure Index	4.17	5.54
Millerandage Index	1.65	1.65
Bunch weight (g)	86.56	64.06
Berry weight (g)	0.70	0.68
Yield/Vine (kg)	5.07	3.89

Impact of water stress on early reproductive development

- 2006/2007 season, very little winter rainfall and late pruning
- Ms Catherine Cox and Dr Mike McCarthy (SARDI) -Nuriootpa Research Station, Barossa
- How do rootstocks perform under severe water stress?
- Shiraz vines, five different rootstocks, standard irrigation and zero irrigation





Fruit set and bud fruitfulness

Where to next...



- Will early reproductive performance of different grapevine varieties vary under elevated CO_2 conditions?
- What are the interactions between climate change factors such as temperature, precipitation and elevated CO_2?
- Field studies examining relationship between induced flowering time changes and final yield – cultural practices
- Track changes in gene expression (nutrient and water stress)
- Evaluate rootstock early reproductive performance with increasing temperature, water stress and elevated CO_2

Acknowledgements

- Assoc. Prof. Peter Dry
- Grape and Wine Research and Development Corporation for funding
- Nepenthe Vineyards, Tinlins Winery, Constellation Wines Australia, Foster's group, Gemtree Vineyards, Pridham Viticulture
- Drs Chris Soar and Victor Sadras (SARDI) for allowing us to use material from their elevated temperature experiments.
- Mr Tobias Tennent and Mr Dylan Grigg for technical assistance and other casual staff during the busy periods of the growing season

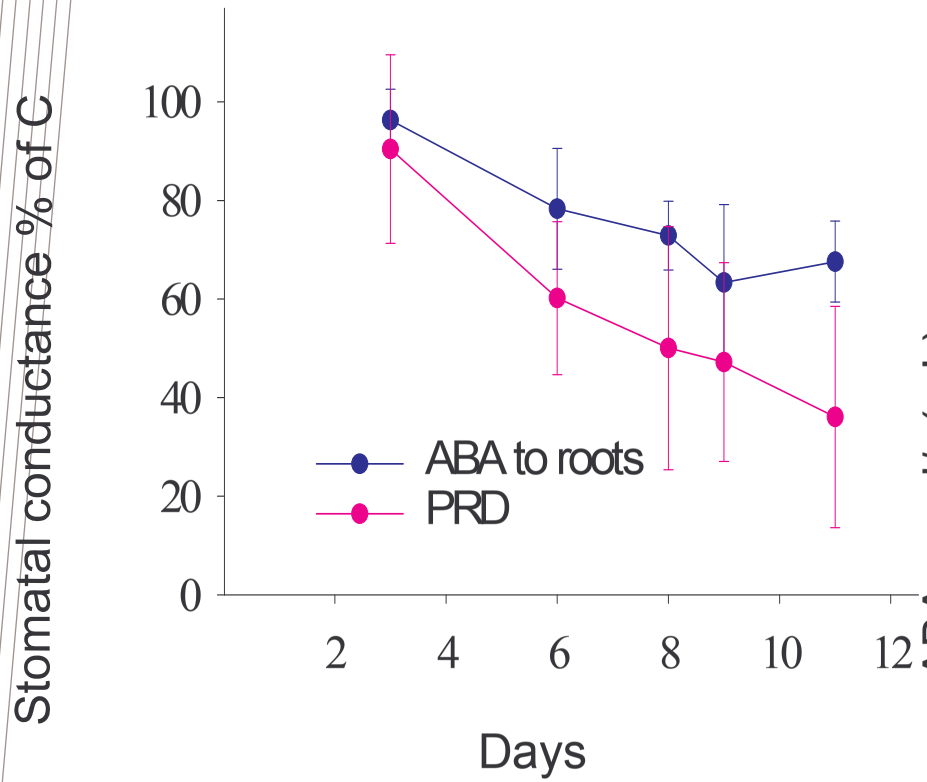
Short term stomatal response to elevated CO2 – how important?



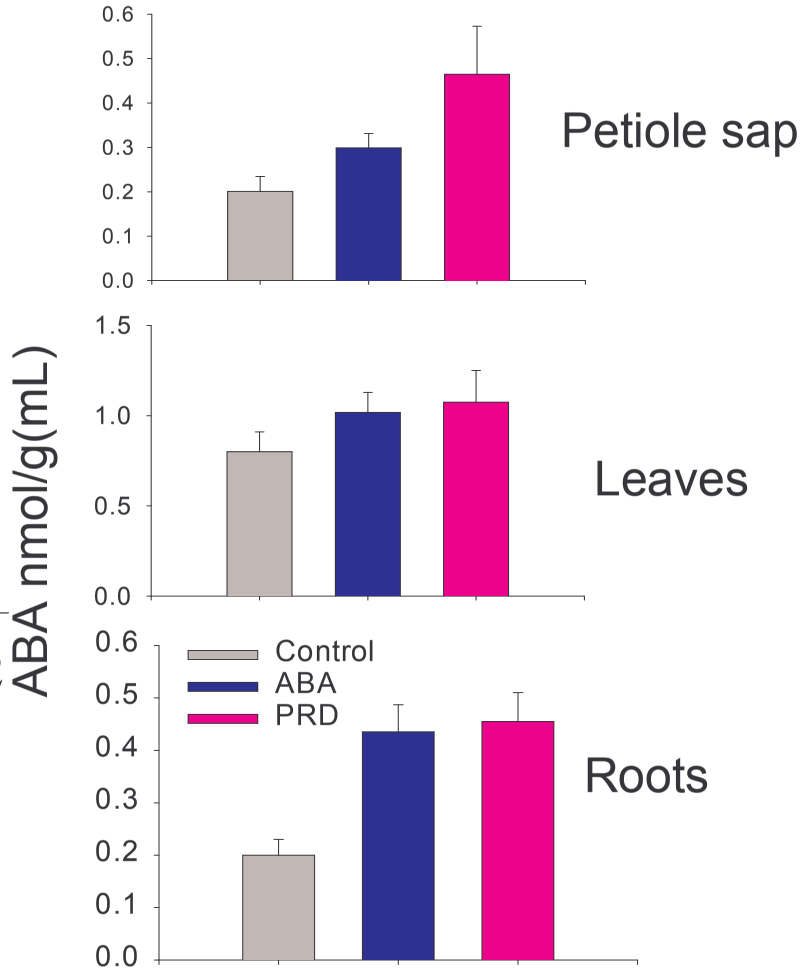
Brian Loveys
Jim Speirs
Marisa Collins
Manfred Stoll
Alex Tucker

CSIRO Plant Industry

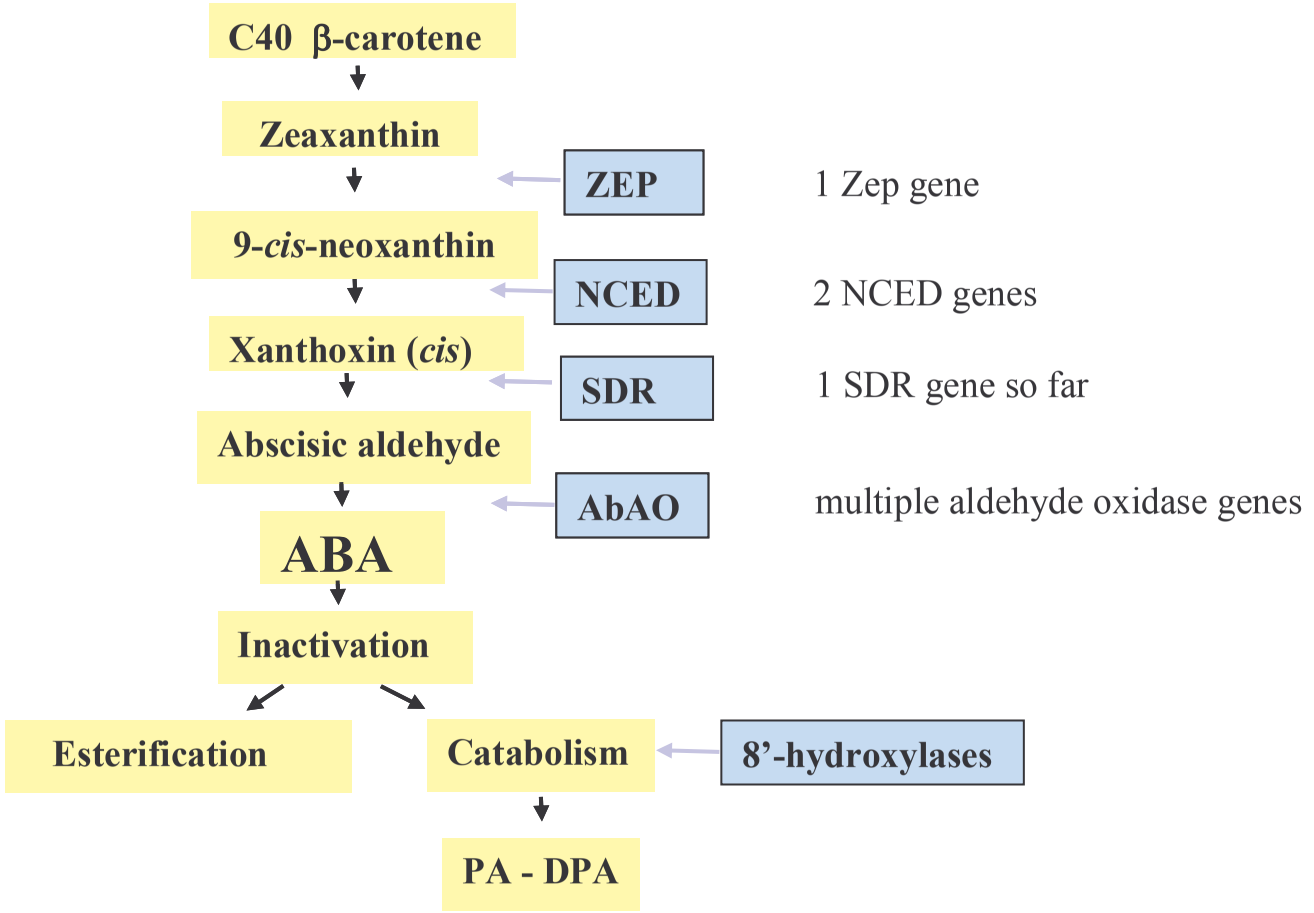
Root drying is simulated by application of ABA



3μM (±)ABA applied to half of root system (Cabernet Sauvignon)



ABA synthesis and catabolism genes



Abscisic acid - mutant



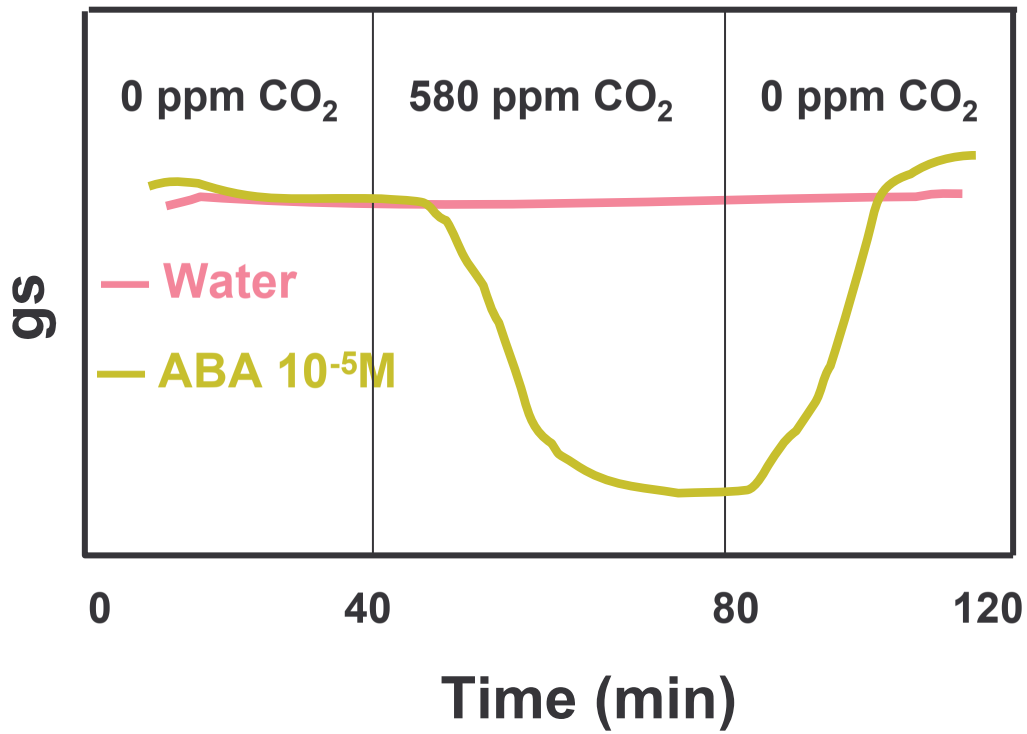
aba2 mutant
90% humidity



aba2 mutant
Standard glasshouse

From: Marin et al.(1996)
EMBO Journal 15(10): 2331-2342.

CO_2 response is dependant on ABA



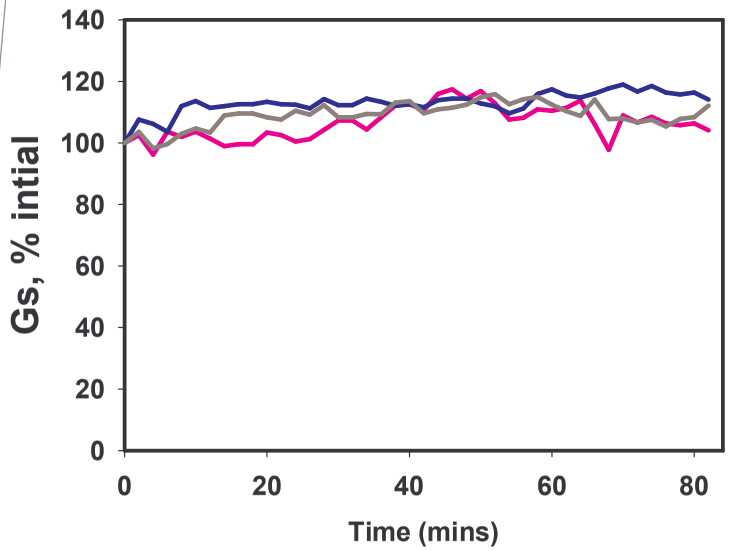
"No stomatal response to ABA in CO_2-free air"

"No stomatal response to CO_2 in absence of ABA"

Raschke K (1975) Planta 125, 243-250

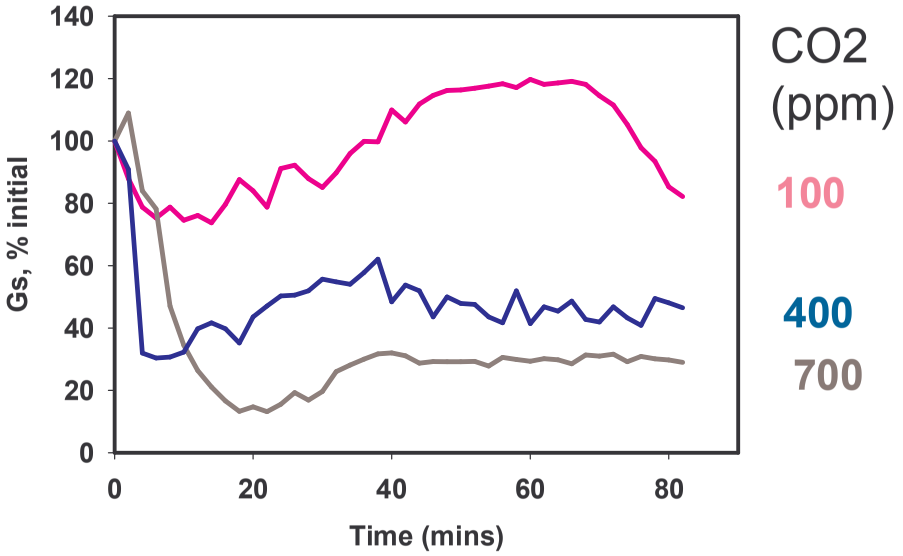
Grapevine stomatal response to CO_2 is dependant on ABA

CONTROL (no ABA)

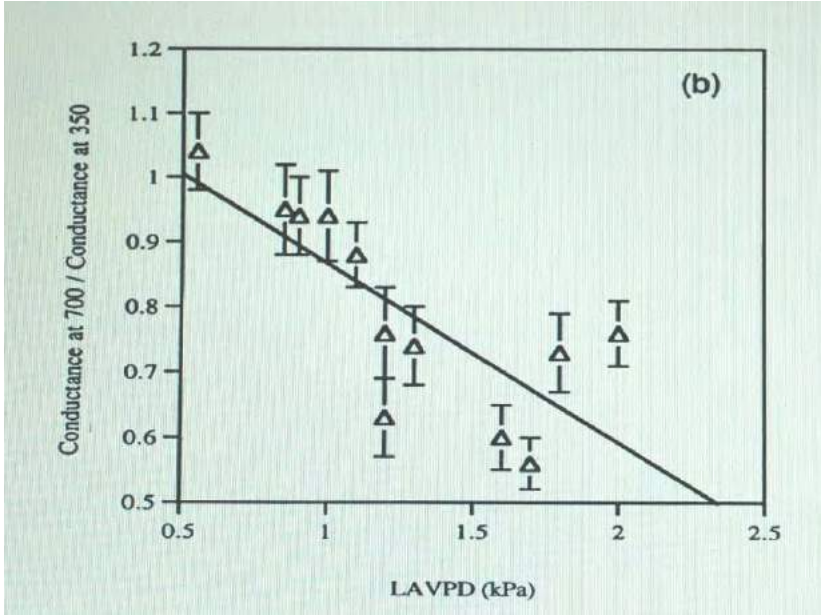




0.7 nmol/mL (±) ABA



Humidity response



Barley stomata respond more sensitively to a change in CO_2 as LAVPD increases

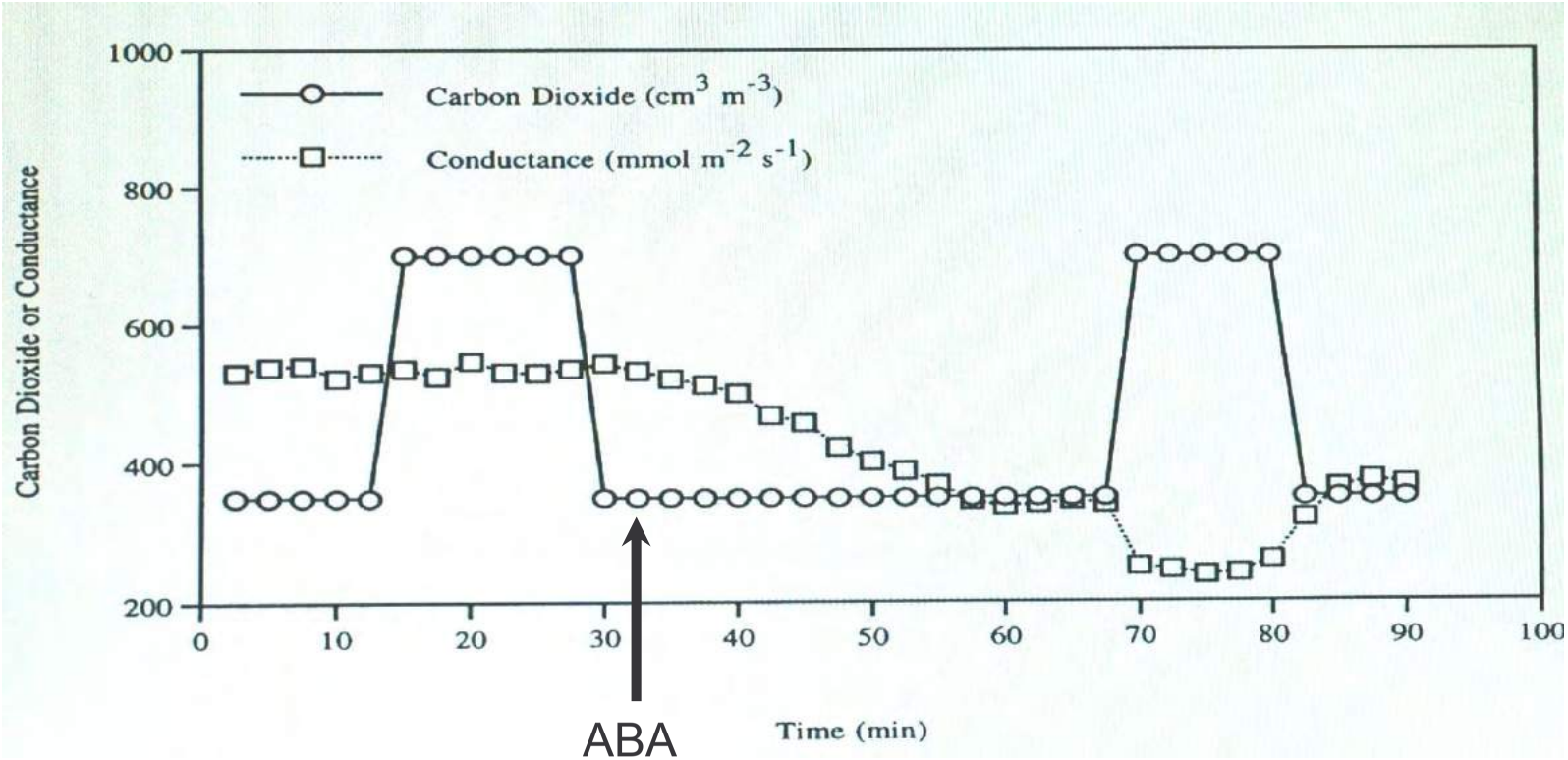
Similar results for wheat, soybean, sunflower and Amaranthus

LAVPD	ABA	g700/g350
Low	none	0.98
Low	50nmol	0.78*
High	none	0.74*

soybean * P<0.05

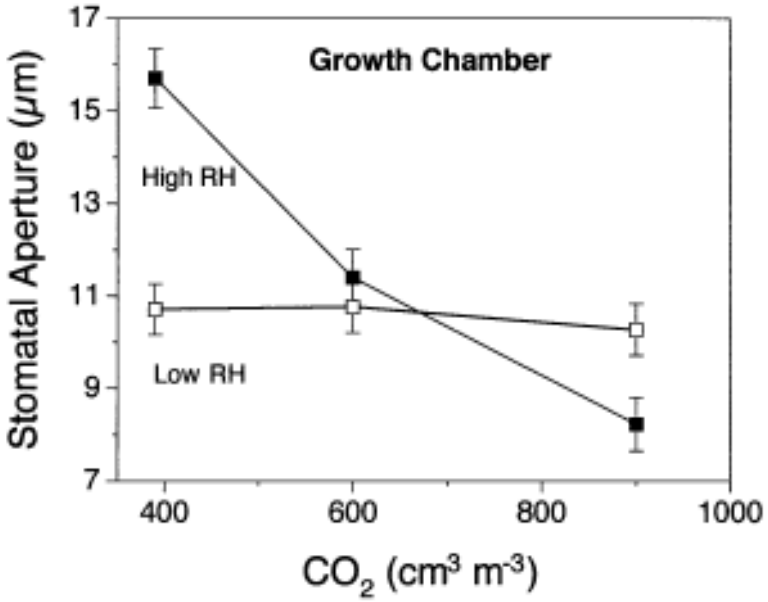
Bunce J.A. (1998) PCE 21, 115-120

Gas exchange response - soybean

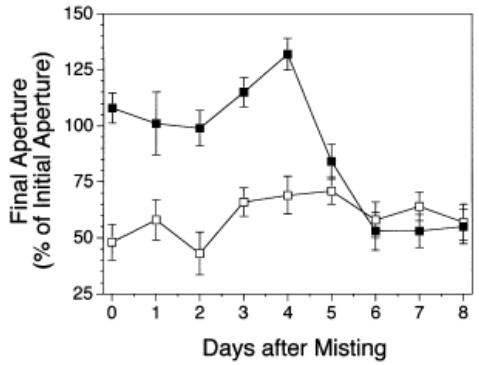


Bunce J.A. (1998) PCE 21, 115-120

Broad bean response is different



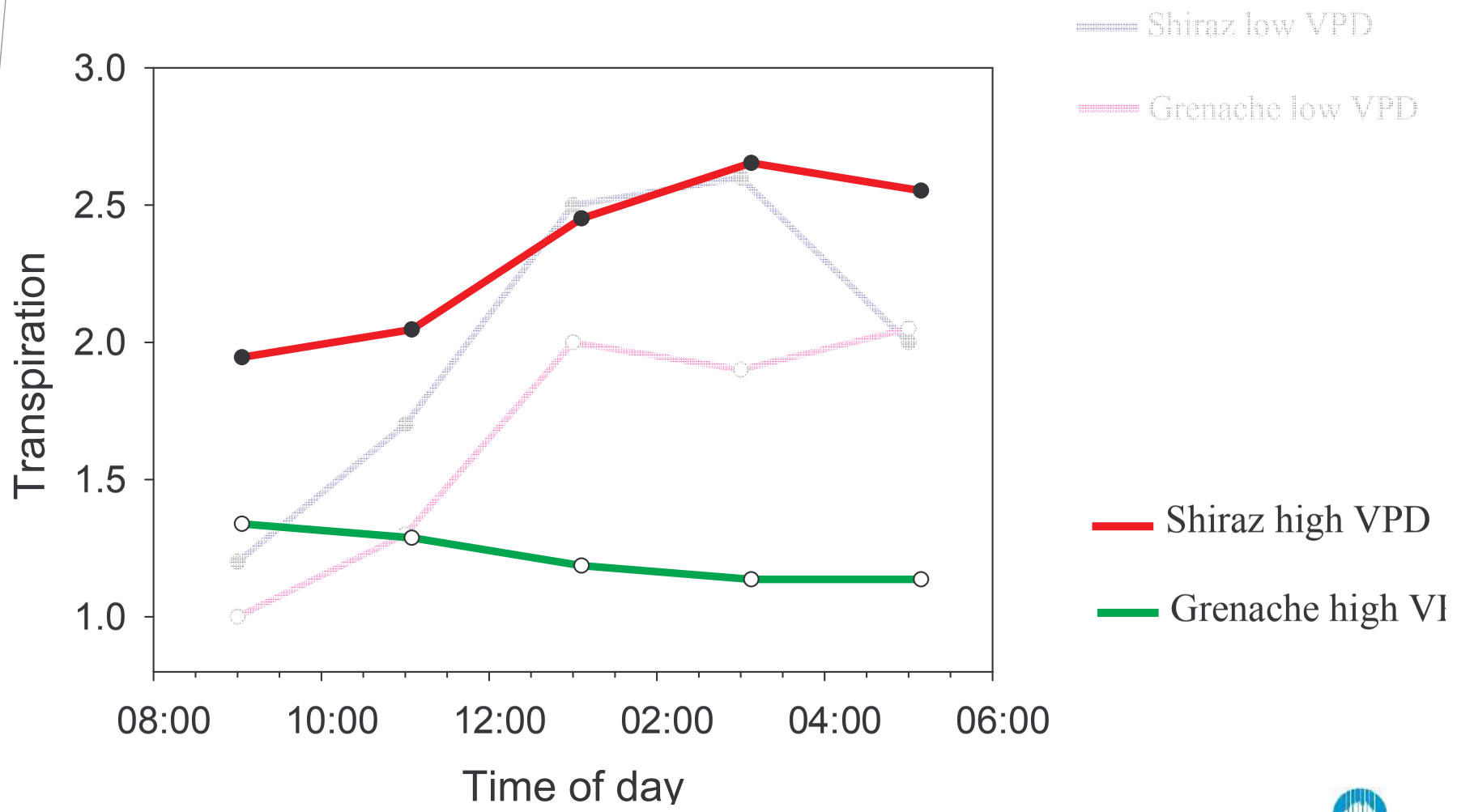
Vicia faba plants grown at low or high relative humidity in a growth chamber and exposed to increasing CO_2 for 1h



Plants grown at low RH required 6d to acquire stomatal sensitivity to CO_2 when transferred to a high RH environment

Talbott et al (2003)JEB 54 2141-2147

Grenache and Shiraz- response to environment



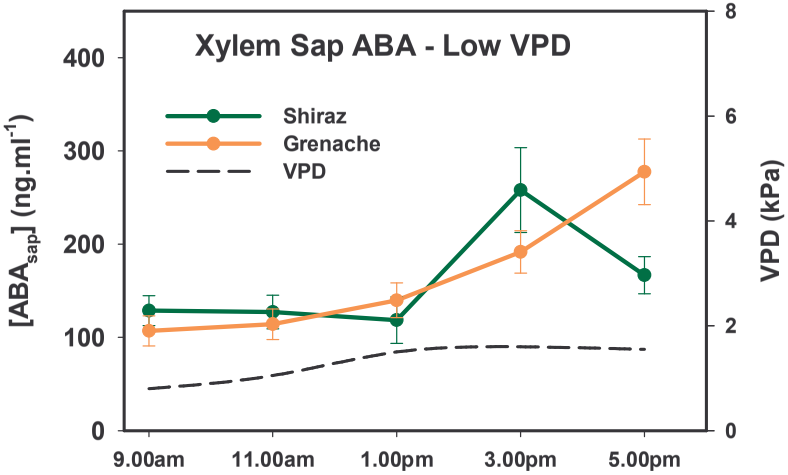
Vapour Pressure Deficit - Field

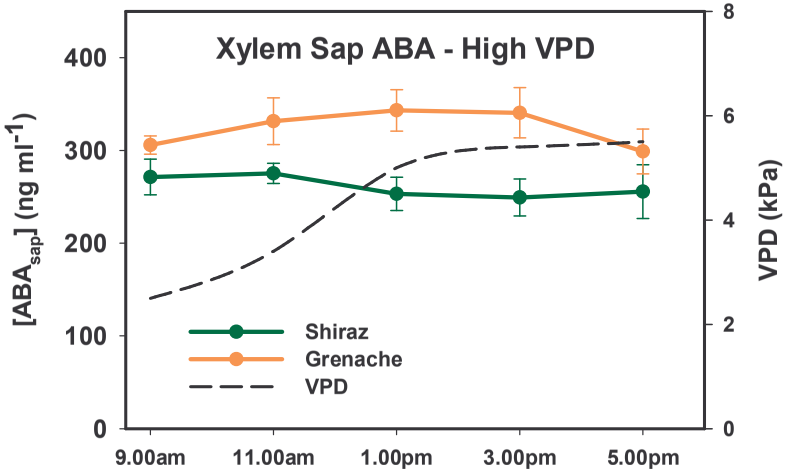


Low VPD

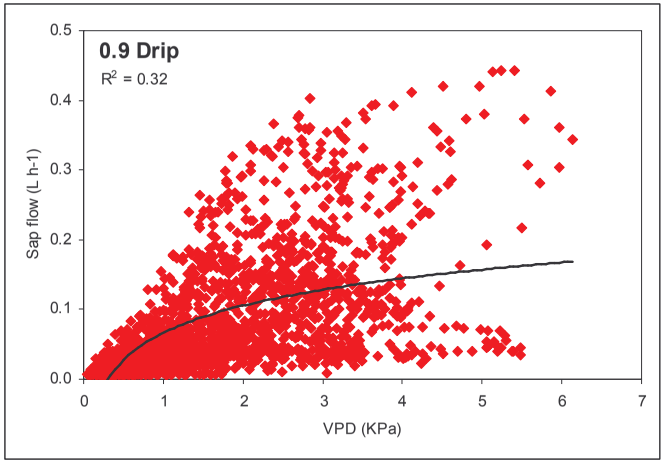


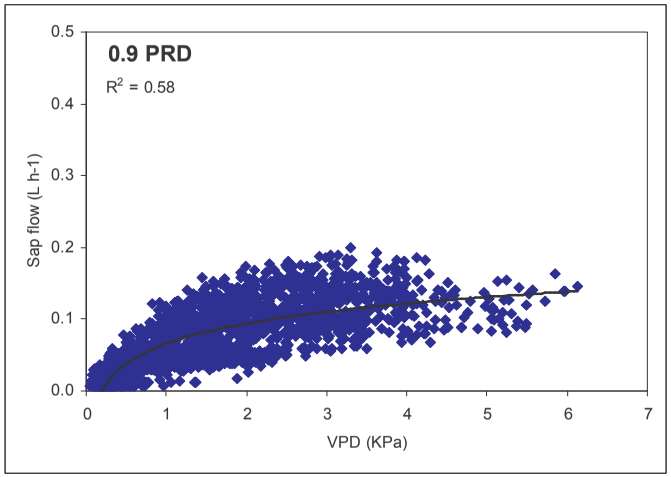
High VPD

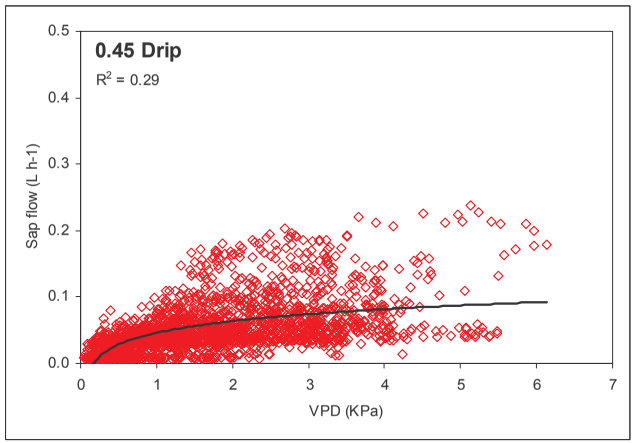


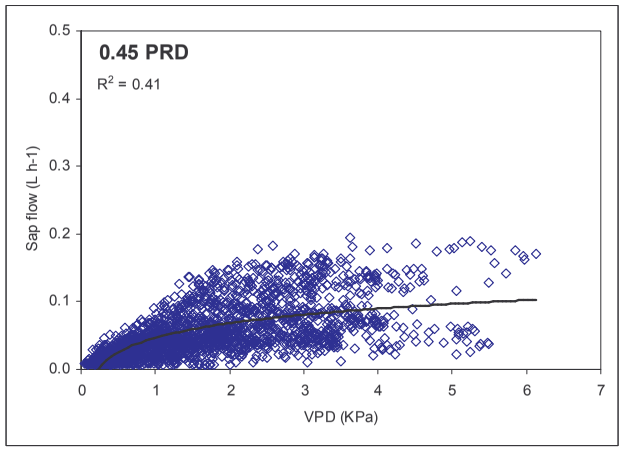


Irrigation management and water use - Shiraz









Barley – effects of high CO_2 and drought

Days of drought	WUE (g dm/kg transpired) 350ppm	700ppm
0	3.7±0.03	9.6 ± 0.50*
9	10.4 ± 1.41	15.6 ± 1.63
13	13.7 ± 0.09	21.9 ± 0.09*
16	11.4 ± 0.7	23.3V0.81*

*P<0.05

- Soil moisture less depleted (lower gs)
- RWC, ψw, ψs higher
- Net photosynthesis higher
- Delay in onset and severity of water deficit due to reduced soil water use

Robredo et al (2007) EEB 59, 252-263

Summary

- higher ambient CO_2 has the potential to:
  - Increase WUE through changes in stomatal conductance and net assimilation
  - Interact with ABA to change responsiveness to ambient humidity (VPD)

Questions:

- What are the consequences of long-term exposure to high CO_2 ?
- What are the implications of climate change for deficit irrigation techniques such as PRD and RDI ?
- What are meaningful experiments to be done using existing and new facilities?
  - Cultivar specific responses to ABA/humidity/temperature/CO_2
  - Temperature/humidity/CO_2 effects on grape/wine composition

Responses of viticultural pests to climate change

Ary Hoffmann, Linda Thomson, Sarina Pearce

Centre for Environmental Stress and Adaptation Research, the University of Melbourne

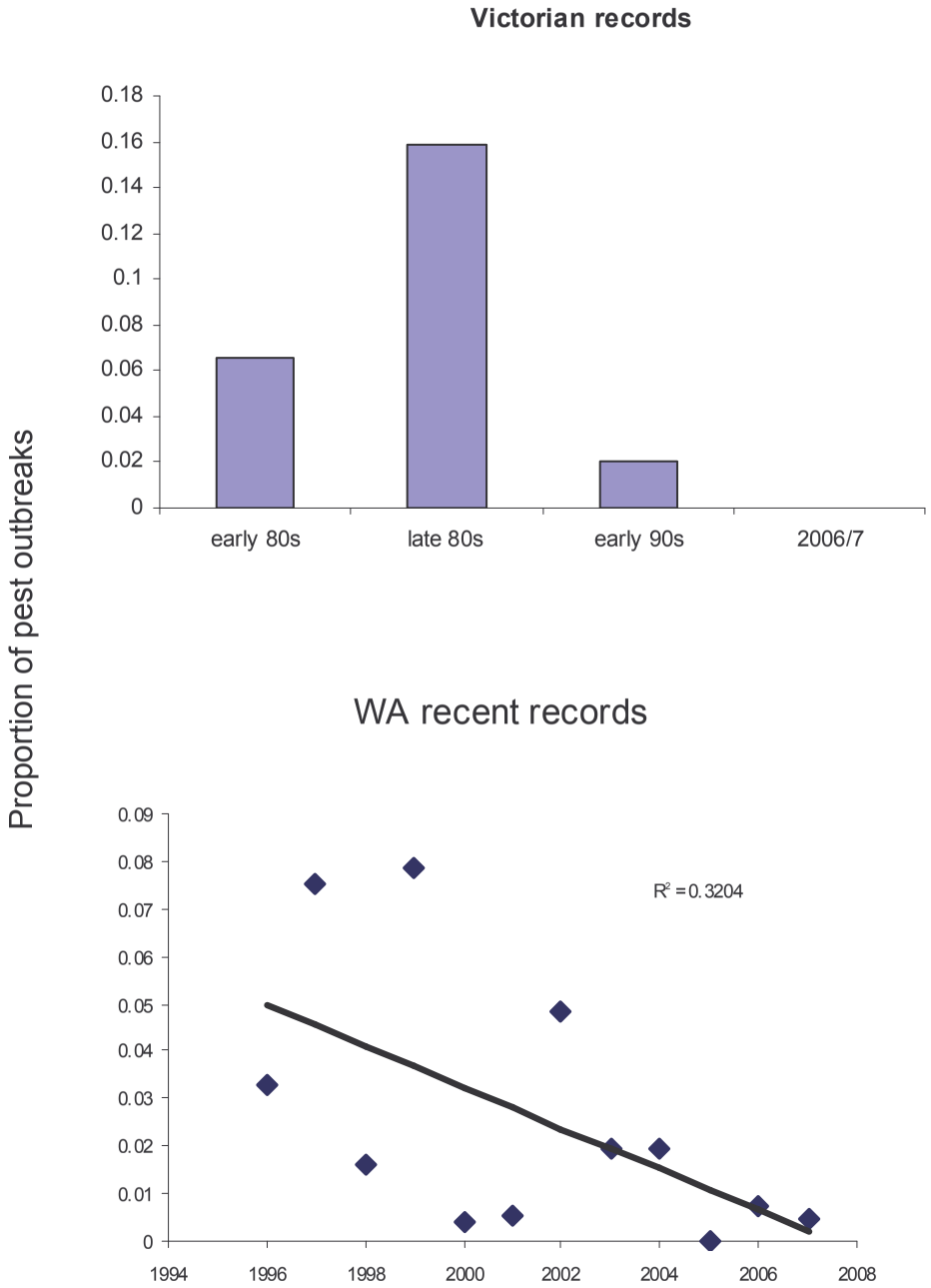






Will pest problems change?

- Weevils, scale and mealybugs considered as local pest problems
  - weevils in Tasmania, parts of WA, parts of SA and Hunter
  - long tailed mealy bugs in Yarra, parts of NSW and WA
  - Scale problems in Sunraysia, parts of WA
- Species likely to differ in distribution but this poorly characterized
- No longitudinal data for the grape industry, no mechanism for collecting this information

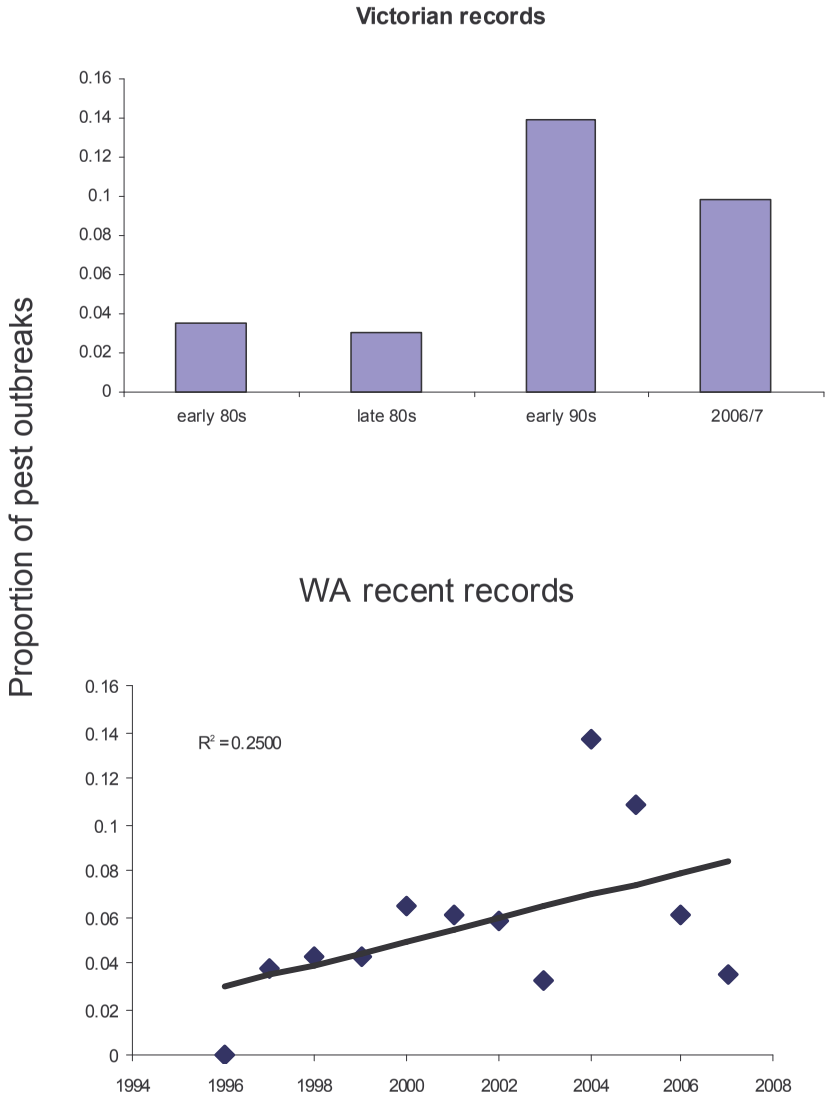


Grains pest: Armyworms





Hoffmann, Weeks, Mangano, Umina subm



Grains pest: Lucerne Flea



Hoffmann, Weeks, Mangano, Umina subm

Information needed

- Record bank for viticultural pest and disease outbreaks
- Validation of records
- Accurate distribution maps for pest species and key natural enemies
- Web-based access to data



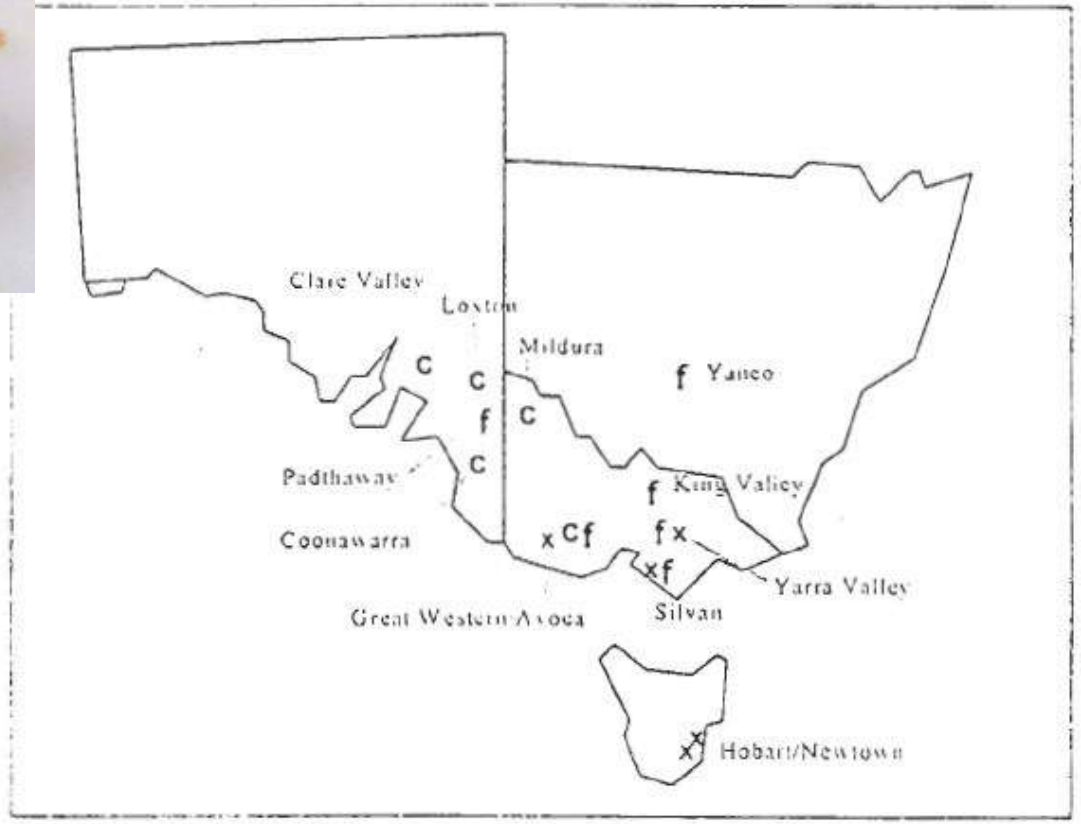


Fig. 1. Collection sites of *Trichogramma* (*Trichogrammanza*) species. c, *T. carverae*; f, *T. funiculatum*; x, *T.* sp. *x*.

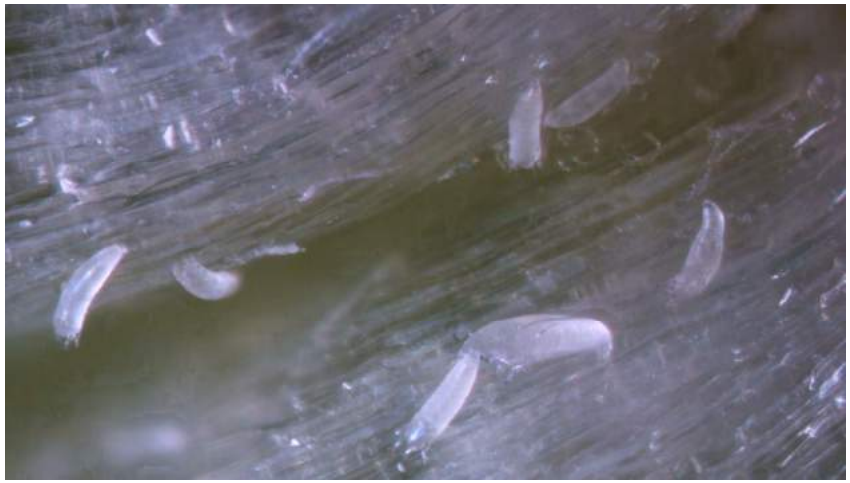
Glenn, Hercus, Hoffmann 1997

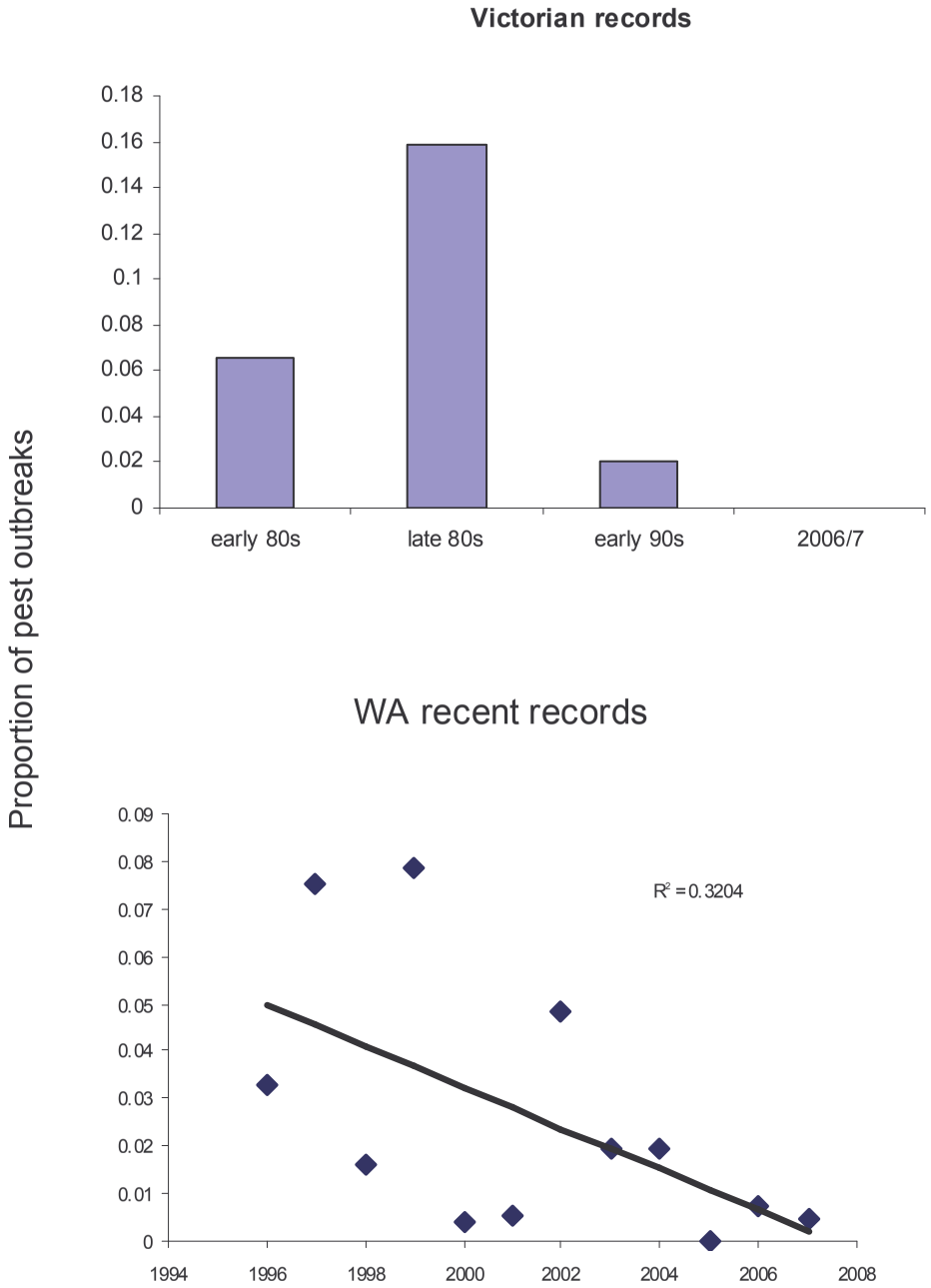
Multiple factors contribute to changes:

- Crop and value
- Management
- Direct and indirect effects of changing chemicals
- Climate effects on pests
- Climate effects on natural enemies

Eriophyoid mites

- Normally controlled by predatory mites
- Cause damage to grapevine shoots
- Outbreaks occurred after increase in use of fungicides in vineyards in recent years
- Predators susceptible to fungicides





Grains pest: Armyworms





Hoffmann, Weeks, Mangano, Umina subm

Predicting distribution changes

Climate envelope (BIOCLIM, CLIMEX)
Regression models

Tolerate (partial)
Move (perfect)
Evolve X
Management changes and human adaptation X

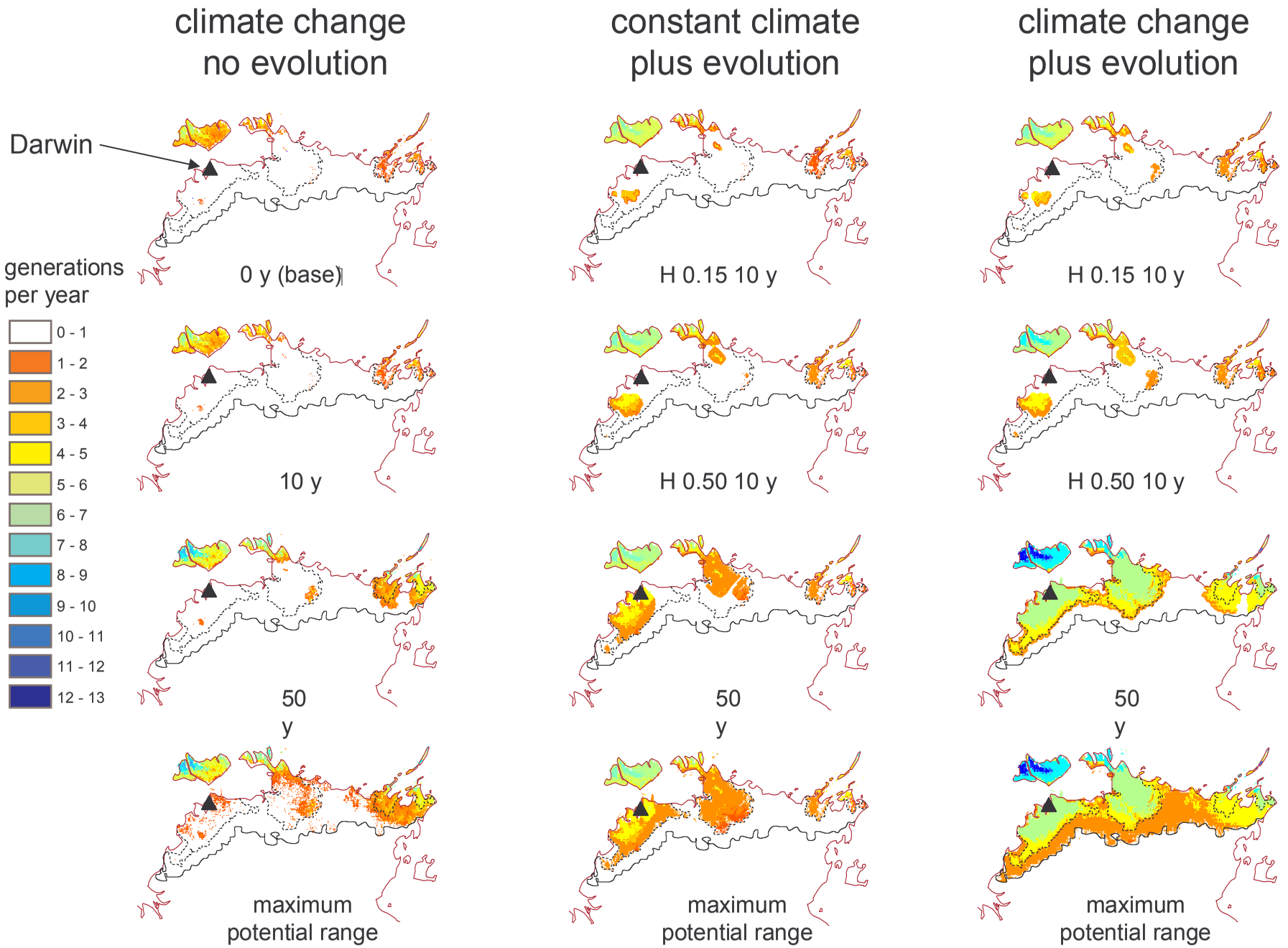
Mechanistic models

Tolerate (potentially)
Move (potentially)
Evolve (potentially)
Management changes and human adaptation (potentially)

Example: *Aedes aegypti*



- Physiological data available on thermal thresholds, responses to humidity at different stages
- Mechanistic models indicate distribution limited by egg desiccation resistance
- This depends on humidity, temperature, time of extreme temperature/humidity



Kearney Ritchie Ryan Hoffmann subm



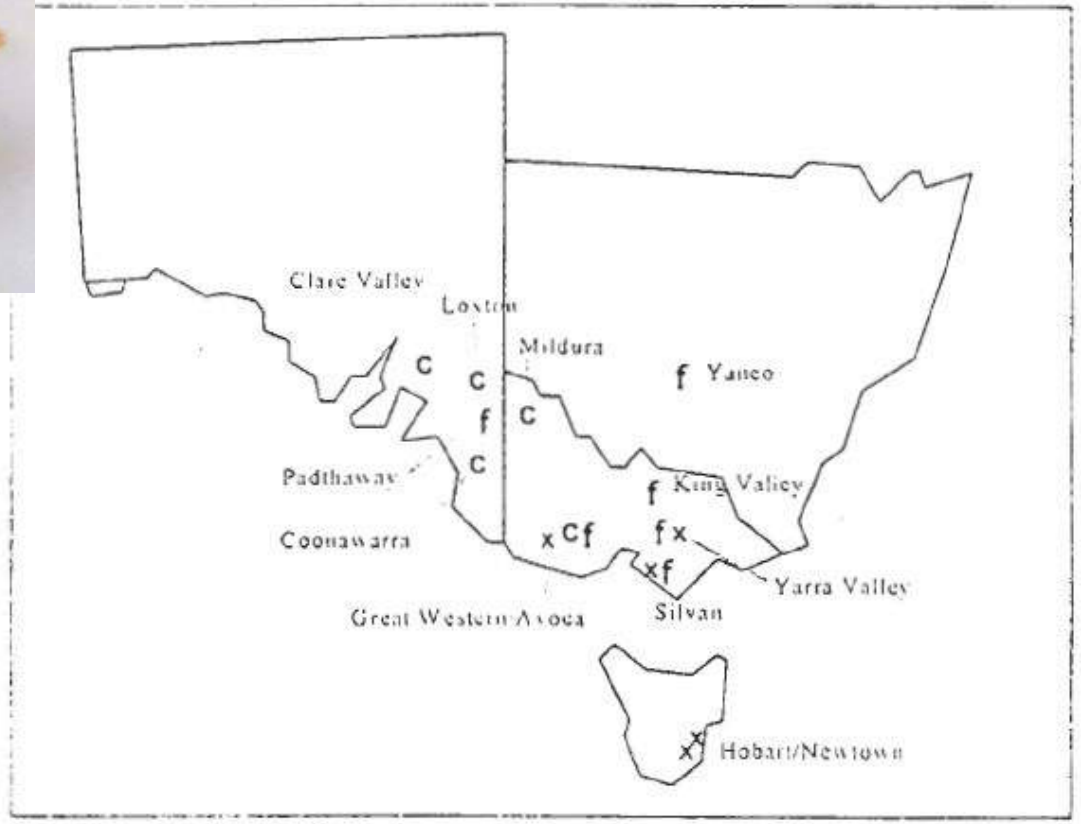


Fig. 1. Collection sites of *Trichogramma* (*Trichogrammanza*) species. c, *T. carverae*; f, *T. funiculatum*; x, *T.* sp. *x*.

Glenn, Hercus, Hoffmann 1997

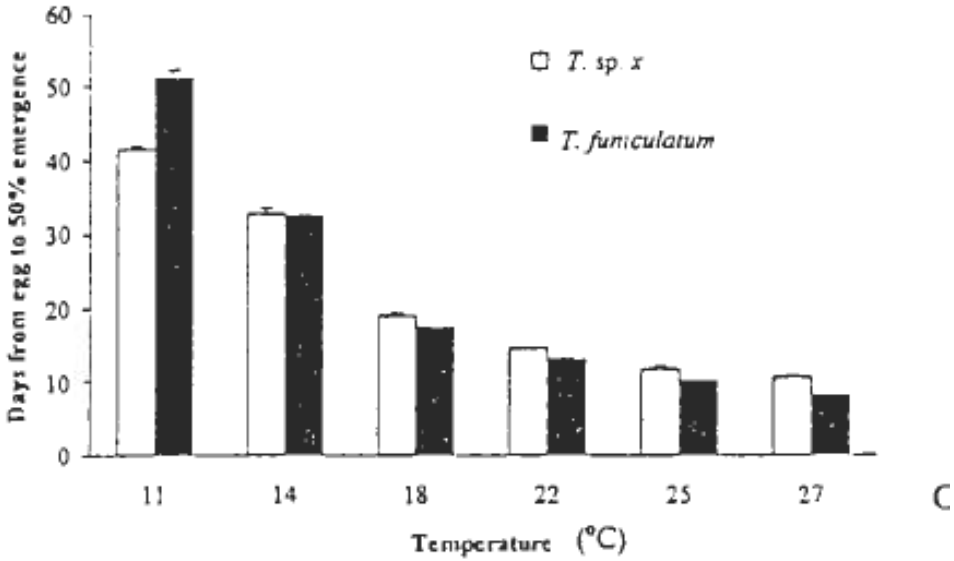
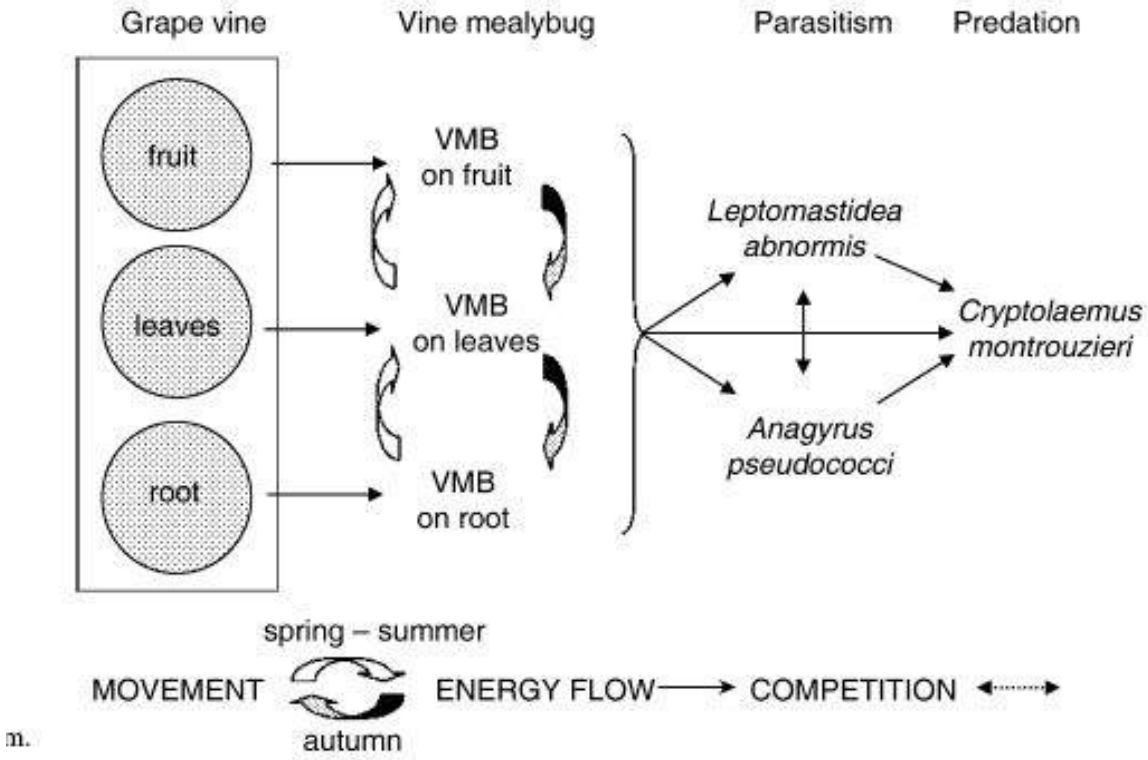


Fig. 5. Development time of *T.* sp. *x* and *T. funiculatum* measured as time taken for 50% of wasps to emerge. Bars represent standard errors.



m.

Journal of Applied Ecology 2008, **45**, 524–536 doi: 10.1111/j.1365-2664.2007.01356.x

Prospective evaluation of the biological control of vine mealybug: refuge effects and climate

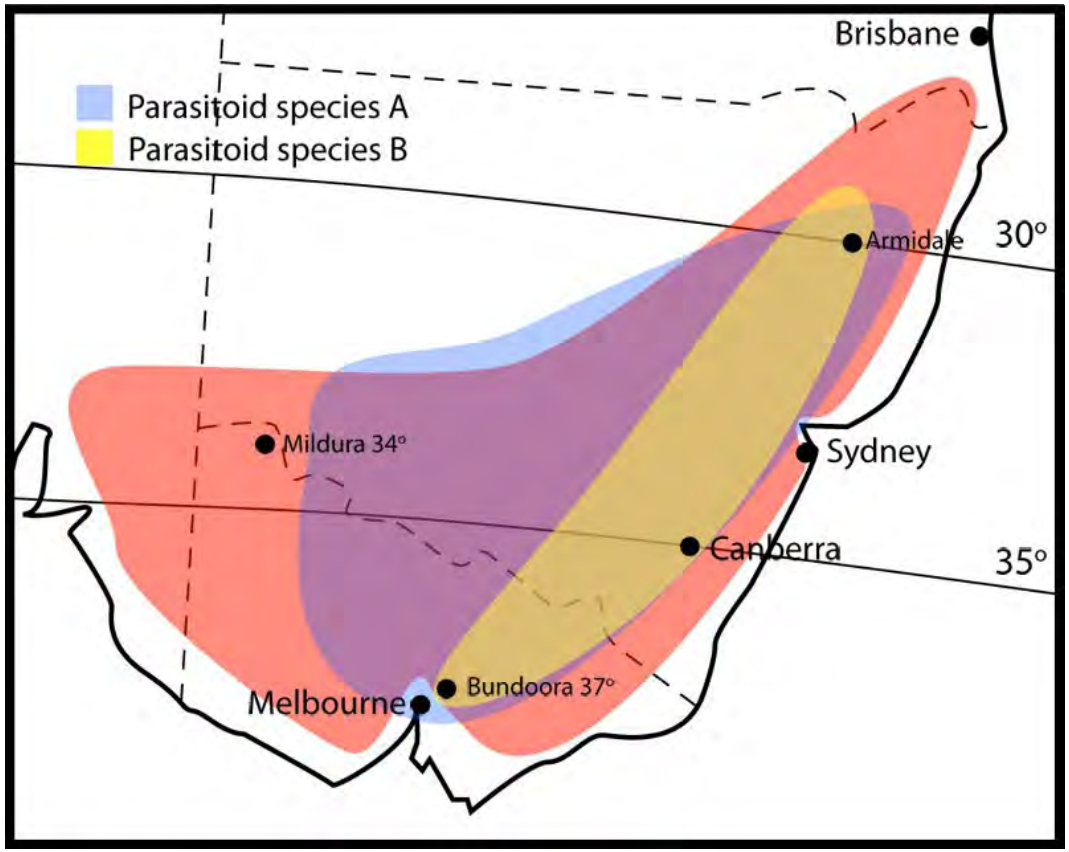
Andrew Paul Gutierrez[1,2*], Kent M. Daane[1], Luigi Ponti[1], Vaughn M. Walton[3] and C. Ken Ellis[1]

Information needed

- Physiological data on pests and beneficials to parameterize models
- Models that include interactions with plants across multiple trophic levels
- Validation of models
- Predictions on pest pressures and controls for different regions/climate scenarios

Parasitoid community range alteration

Example: *Epiphyas postvittana* light brown apple moth



Increased CO_2 - herbivores

- Emerging consensus about herbivore effects from increasing CO_2
  - Lower nutrition value from plant material
  - Increased consumption rates
  - Prolonged development, decreased fitness of herbivores
  - May increase (from increased feeding) or decrease (from less effective feeding) plant damage

Increased CO_2 – natural enemies

- Herbivores may be more susceptible to attack
  - by predators (low fitness, fewer defences, smaller size)
  - by parasitoids (prolonged development period, reduced defences)
- Herbivores may be less susceptible to attack
  - by predators (lower nutrition value of prey decreases predator fitness)
  - by parasitoids (reduced searching efficiency because of additional plant material)

CASE BY CASE evaluation

Information needed

- Responses of key viticulture pests and beneficials to plants grown under increased CO_2/temperature/water
- LBAM, rust and bud mite, predatory mites, parasitoids, generalist predators
- Potential for interaction among effects incorporated (temperature, moisture, validation)
- Incorporation of information into models

Management

- Pest species will respond to:
  - Cultivars
  - Irrigation
  - Pruning
  - Cover crop/compost
  - Chemical load
  - Landscape level changes (shelterbelts, remnant vegetation etc)
- Natural enemies will respond to:
  - All of the above

APPENDIX 2

List of Attendees

Attendees

NAME	EMAIL
1. Ary Hoffman	ary@unimelb.edu.au
2. Ayalsew Zerihun	A.Zerihun@curtin.edu.au
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12. Dean Lanyon	dean.lanyon@csiro.au
13. Eileen Scott	eileen.scott@adelaide.edu.au
14. Everard Edwards	Everard.Edwards@csiro.au
15. Greg Dunn	gdunn@unimelb.edu.au
16. Greg Jones	**gjones@sou.edu**
17. Ian Goodwin	Ian.Goodwin@dpi.vic.gov.au
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19. Leanne Webb	**leanne.webb@csiro.au**
20. Marco Bindi	**marco.bindi@unifi.it**
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33. Rob Norton	**rnorton@unimelb.edu.au**
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43. Wendy Sullivan	wendy.sullivan@adelaide.edu.au

APPENDIX 3

Co-Sponsors

Sponsors


Australian Government
Grape and Wine Research and Development Corporation


Australian Government
Department of Climate Change


THE UNIVERSITY OF ADELAIDE
AUSTRALIA
SUB CRUCE LUMEN
Wine 2030


POSTERA CRESCAM LAUDE
THE UNIVERSITY OF
MELBOURNE

APPENDIX 4

Budget reconcilliation

Australian Government
Grape and Wine Research and Development Corporation

END OF PROJECT FINANCIAL STATEMENT

Statement of Receipts and Expenditure

At the conclusion of each Project, the GWRDC requires a Statement of Receipts and Expenditure of GWRDC funds received in relation to the Project.

Project Title:	**Scoping a Grapevine FACE Facility workshop**

GWRDC Project Number	Project Start Date	Project End Date
UA 07/01	**1 January 2008**	**30 June 2008**

Financial Year (e.g. 2006/07)	**(a)** ***Funds brought forward from previous year***	**(b)** **#Approved GWRDC Budget (full year)**	**(c)** **Total budget available** *(a)+(b)*	**(d)** **Actual expenditure ($)**	**(e)** **Difference ($)** *(c)-(d)*
Year 1: 2007/08	–	$10,000	$10,000	$7,612.76	$2,387.24
Year 2: 20__/__					
Year 3: 20__/__					
Year 4: 20__/__					
Year 5: 20__/__					
TOTAL					

Note 1 – The unspent fund of $2,387.24 (excl GST) is to be returned to GWRDC upon receipt of a tax invoice.

* "Funds brought forward" refers to any unspent GWRDC funds from the previous year and approved by the GWRDC to be spent the following year (i.e. column *(e)* from previous year).
# "Approved GWRDC Budget" is the funding amount specified in the Project Agreement, including any approved Variations after Project commencement.

Was funding expended as approved in the Project Agreement? Yes ☐ No ☐

*If **NO**, please provide reasons:*

Has the cash and/or in-kind funding from Contributing Agencies been received and applied to the Project as approved in the Project Agreement? Yes ☐ No ☐

*If **NO,** please provide reasons:*

I hereby certify that this statement is true and accurate.

(Signature of duly authorised representative) ……

…… …… ……

Name: Prof S Tyerman ***Title:*** ***Chief Investigator*** ***Date:***