Adapting Soybean to Future Growing Conditions

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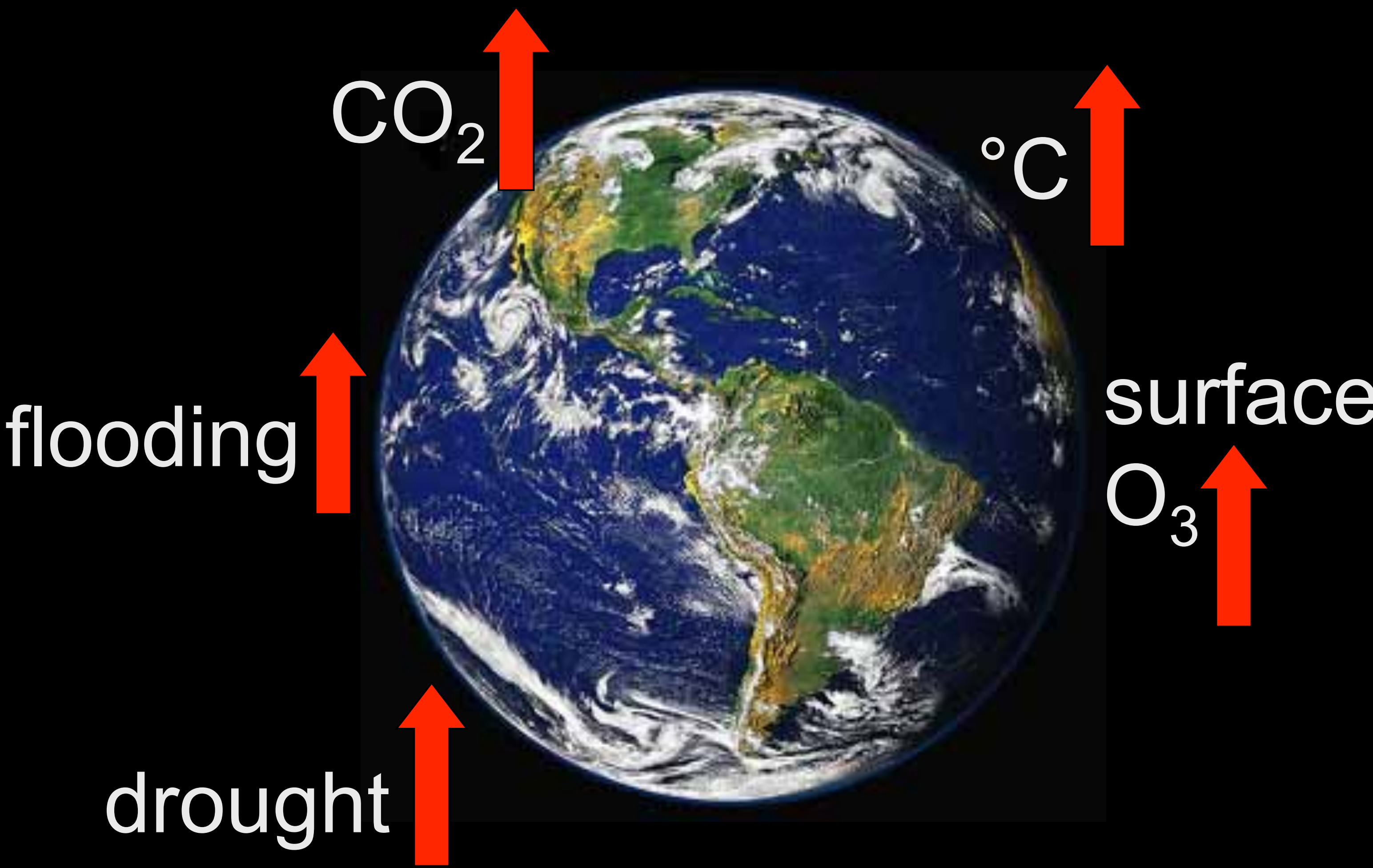
Outline

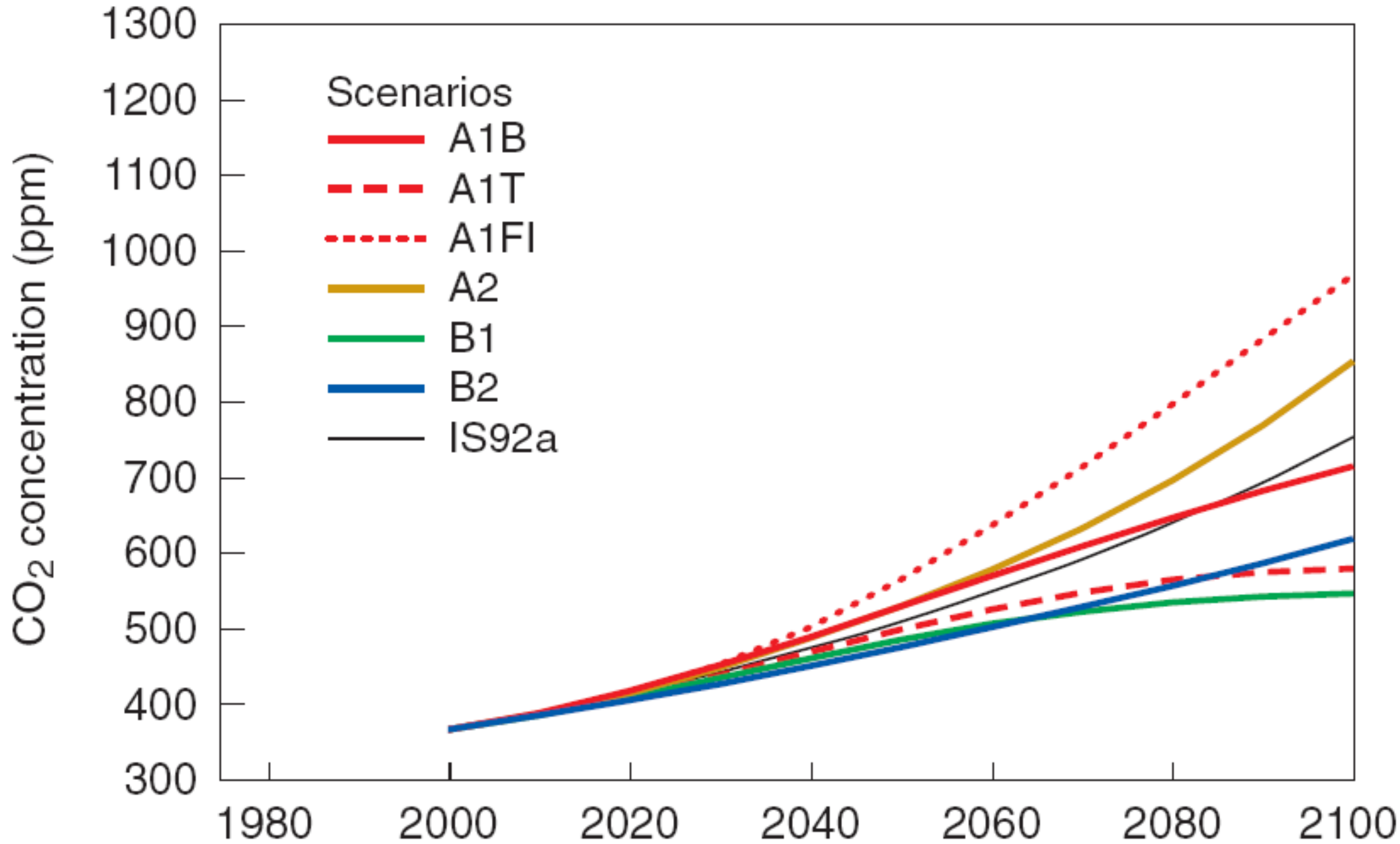
- How is the climate changing?

- Measuring soybean responses to climate change in the field

- Mechanisms of soybean response to climate change and targets for adaption

Climate change is multifaceted





• Carbon dioxide concentration ([CO_2]) is projected to surpass 550 ppm by the middle of the century and top 700 ppm by 2100.

• Despite initial steps taken under the Kyoto Protocol, the world appears to be on a path that is likely to lead to a [CO_2] that exceeds the highest Intergovernmental Panel on Climate Change emissions scenario.

Future Surface Ozone Levels

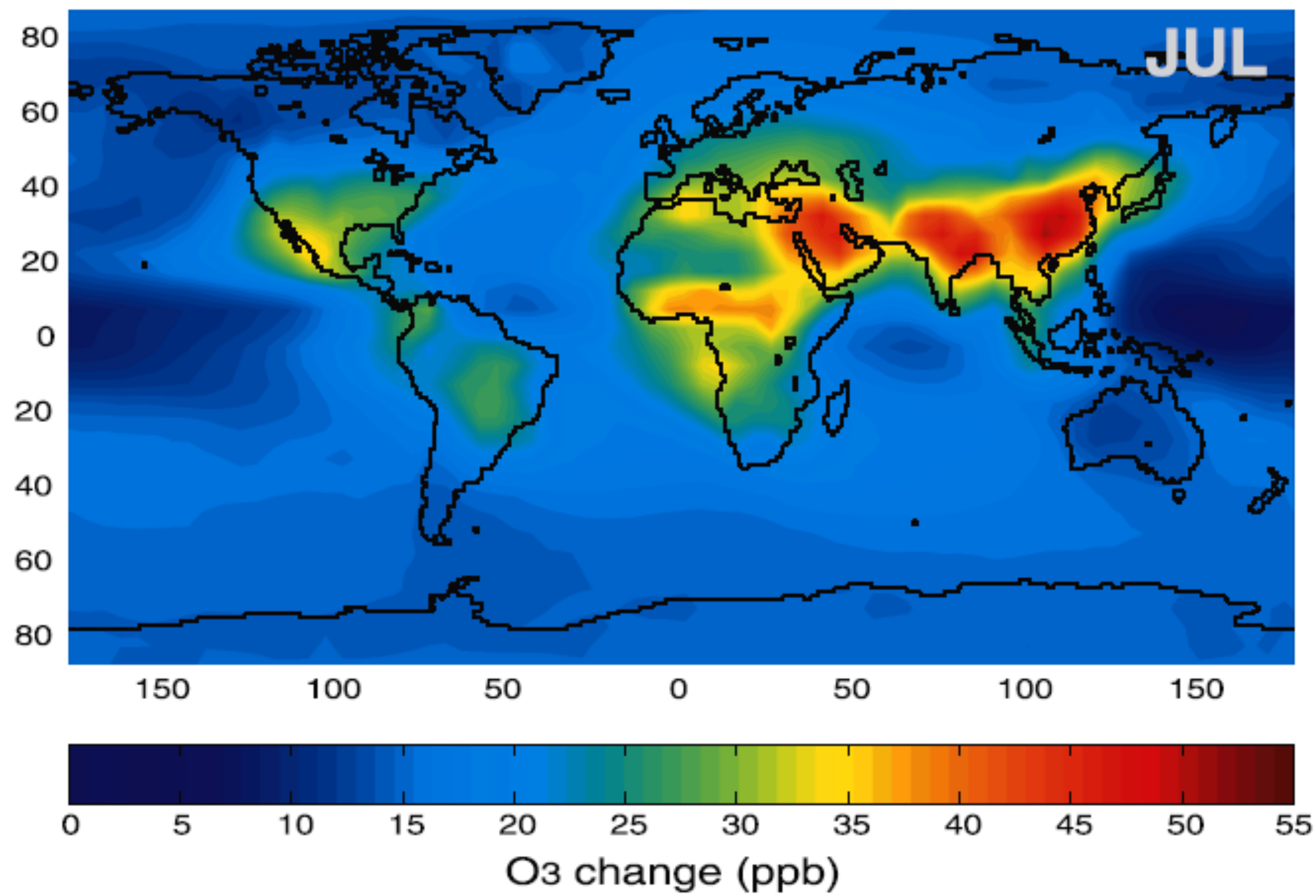
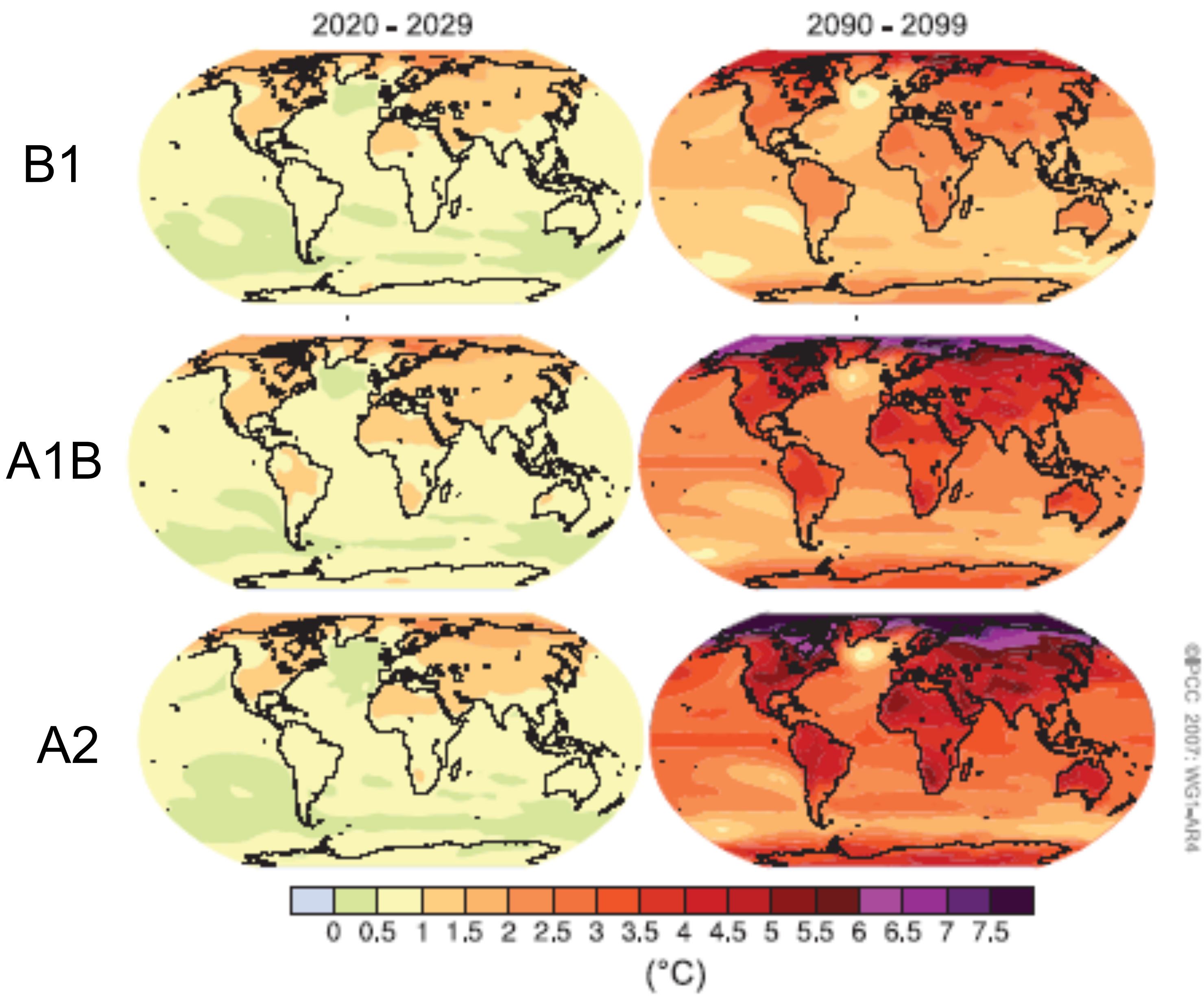
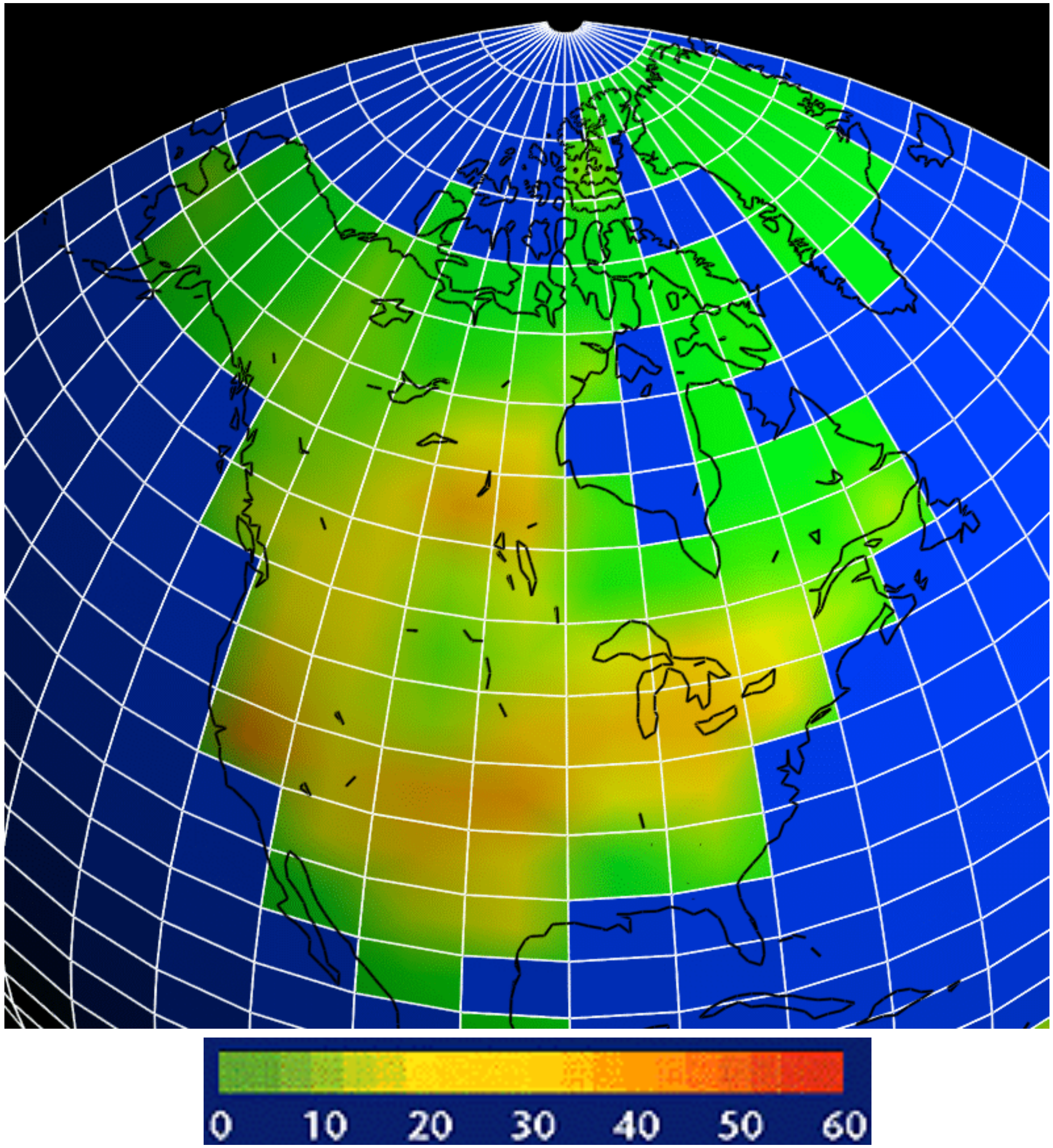


Figure 1. Monthly mean surface O_3 increase (ppb) for Jan and Jul from Y2000 to Y2100 following scenario A2x. Results are the average of 10 models [*Prather and Ehhalt*, 2001]: HGIS, IASB, KNMI, MOZ1, MOZ2, UCAM, UCI, UIO1, UKMO, ULAQ.

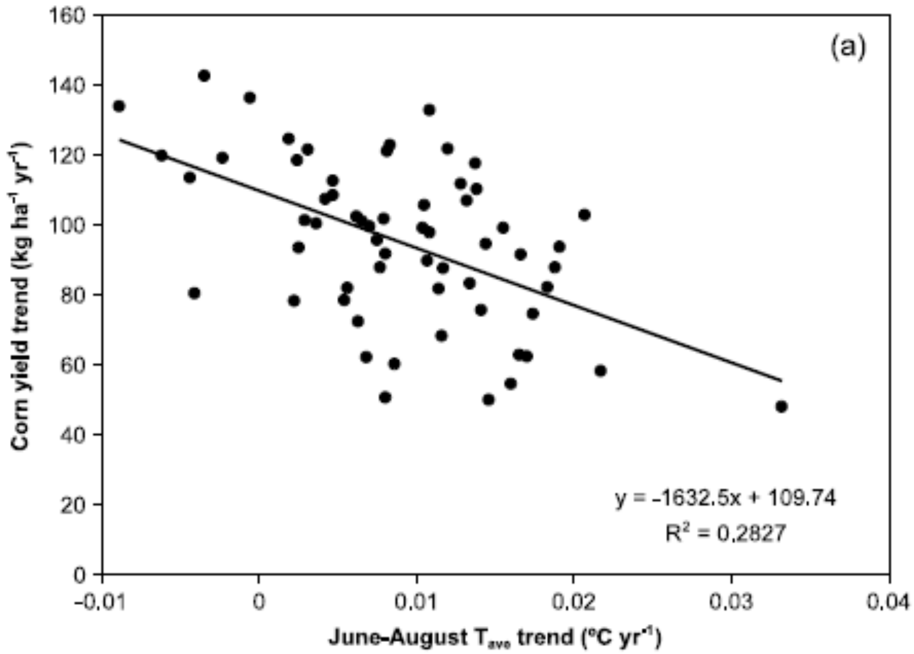
GEOPHYSICAL RESEARCH LETTERS, VOL. 30, NO. 2, 1100, doi:10.1029/2002GL016285, 2003

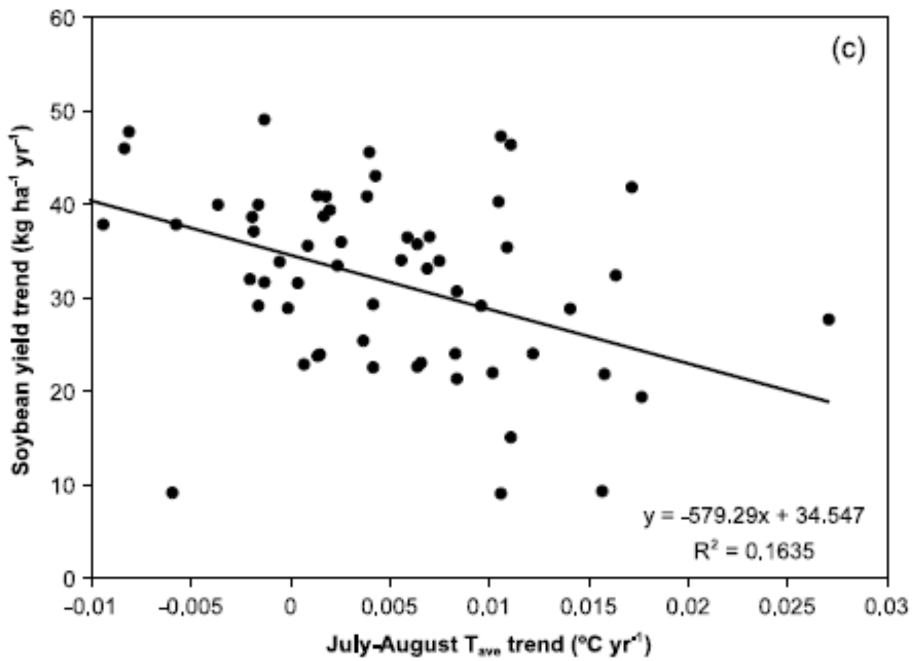
IPCC Projections of Surface





% decrease in summer soil moisture at 2x CO_2





ENVIRONMENTAL RESEARCH LETTERS 3 (2008) 034003 (10pp)

- Analysis of 61 counties in Wisconsin analyzed from 1976–2006.
- There is a negative correlation between temperature and corn and soybean yields.
- Each additional degree (◦C) of future warming during summer months could potentially decrease corn and soybean yields by 13% and 16%, respectively.

What is the cost of ozone pollution?

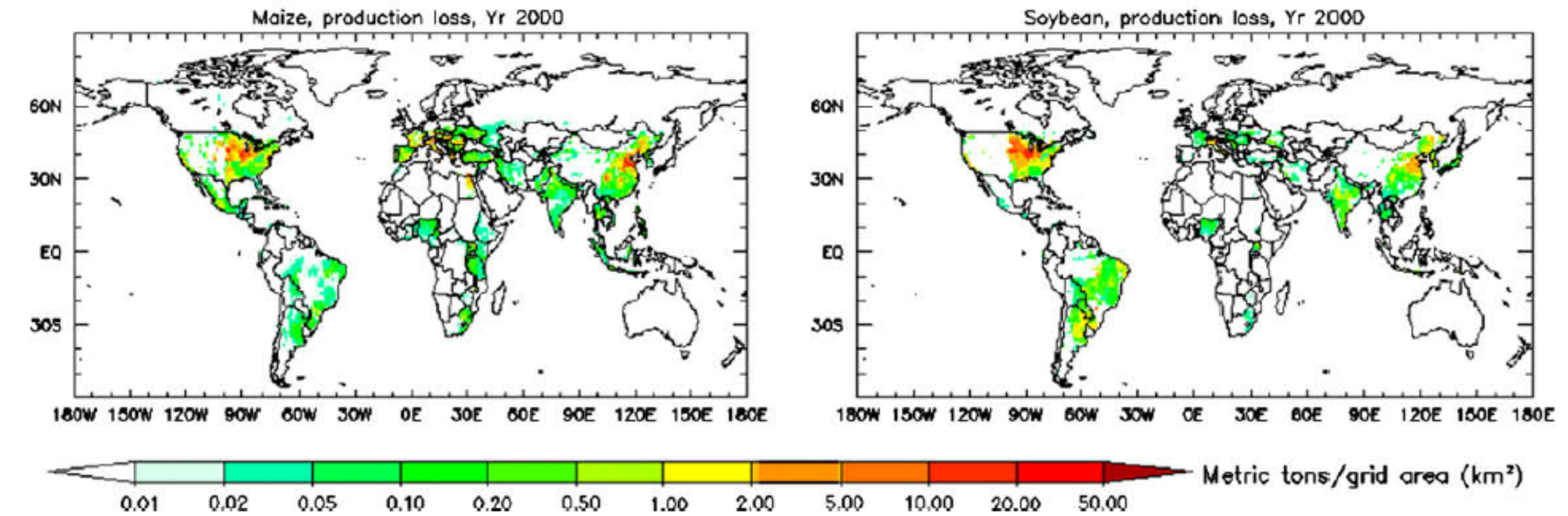


Fig. 10. Average crop production loss from 2 metrics for the 4 crops, year 2000. The production loss numbers are normalized to the grid cell area.

In the Midwest U.S., current ozone concentrations are costing 1-5 metric tons/km^2 of potential corn yields and 5-20 metric tons/km^2 of potential soybean yields.

Atmospheric Environment 43 (2009) 604–618

What is the economic cost of ozone pollution?

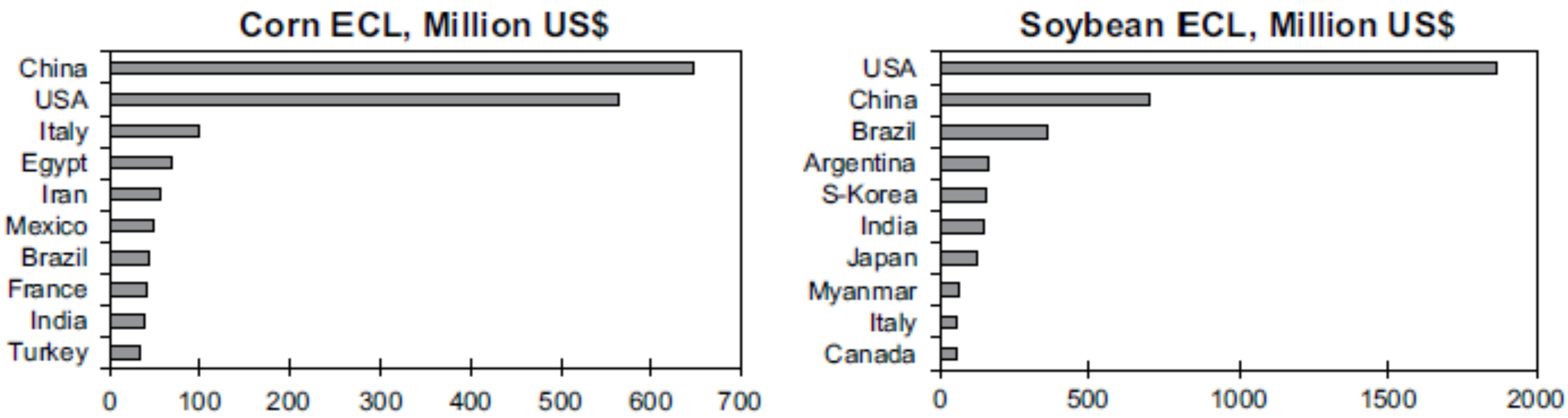
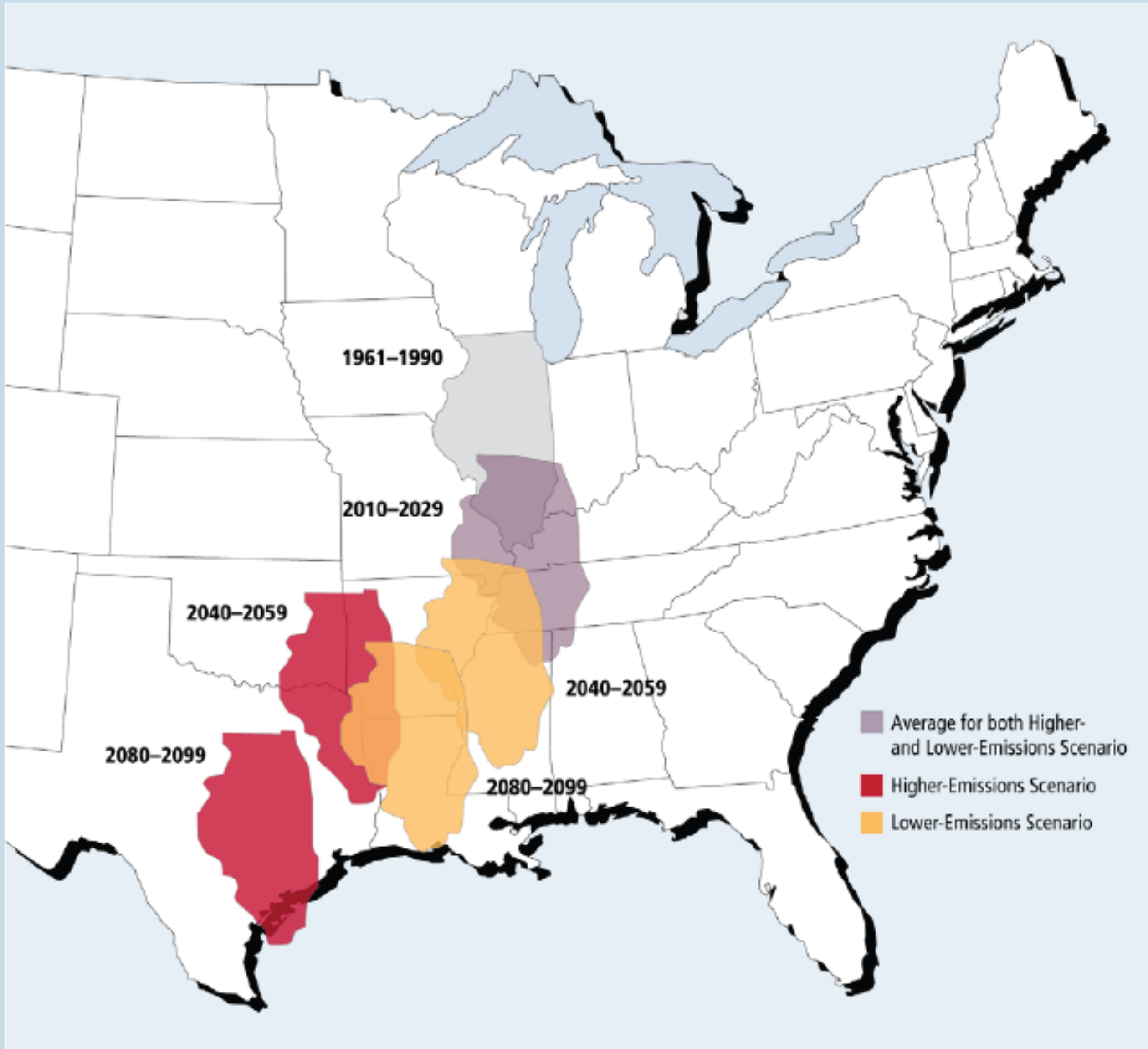


Fig. 11. Estimated economic losses of 10 highest ranked countries for the year 2000.

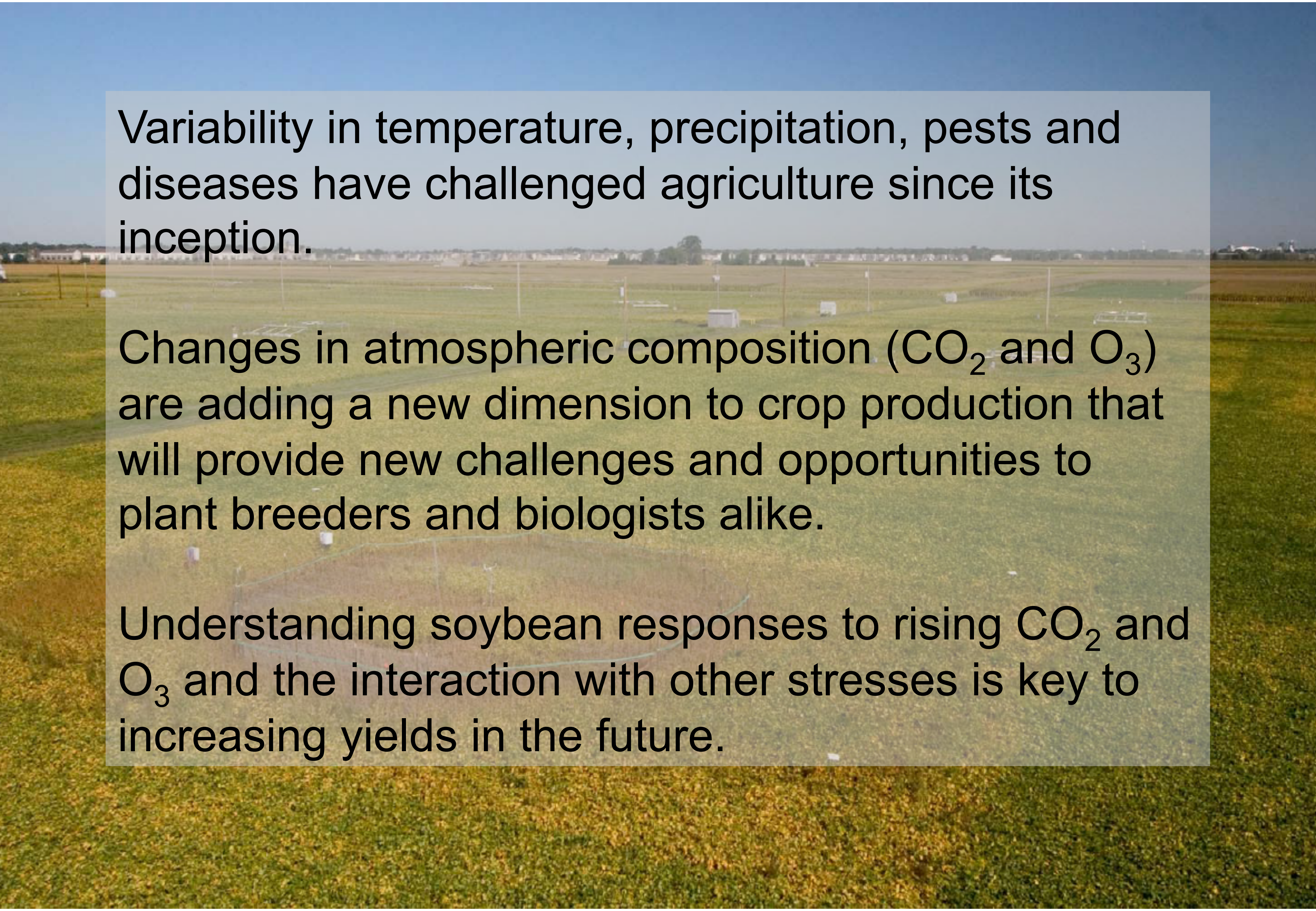
Those yield losses translate to ~$600,000,000 in lost profit for corn and $1.7B in lost profit for soybean.

Atmospheric Environment 43 (2009) 604–618

Climate Projection for Illinois



Donald Wuebbles



Variability in temperature, precipitation, pests and diseases have challenged agriculture since its inception.

Changes in atmospheric composition (CO_2 and O_3) are adding a new dimension to crop production that will provide new challenges and opportunities to plant breeders and biologists alike.

Understanding soybean responses to rising CO_2 and O_3 and the interaction with other stresses is key to increasing yields in the future.

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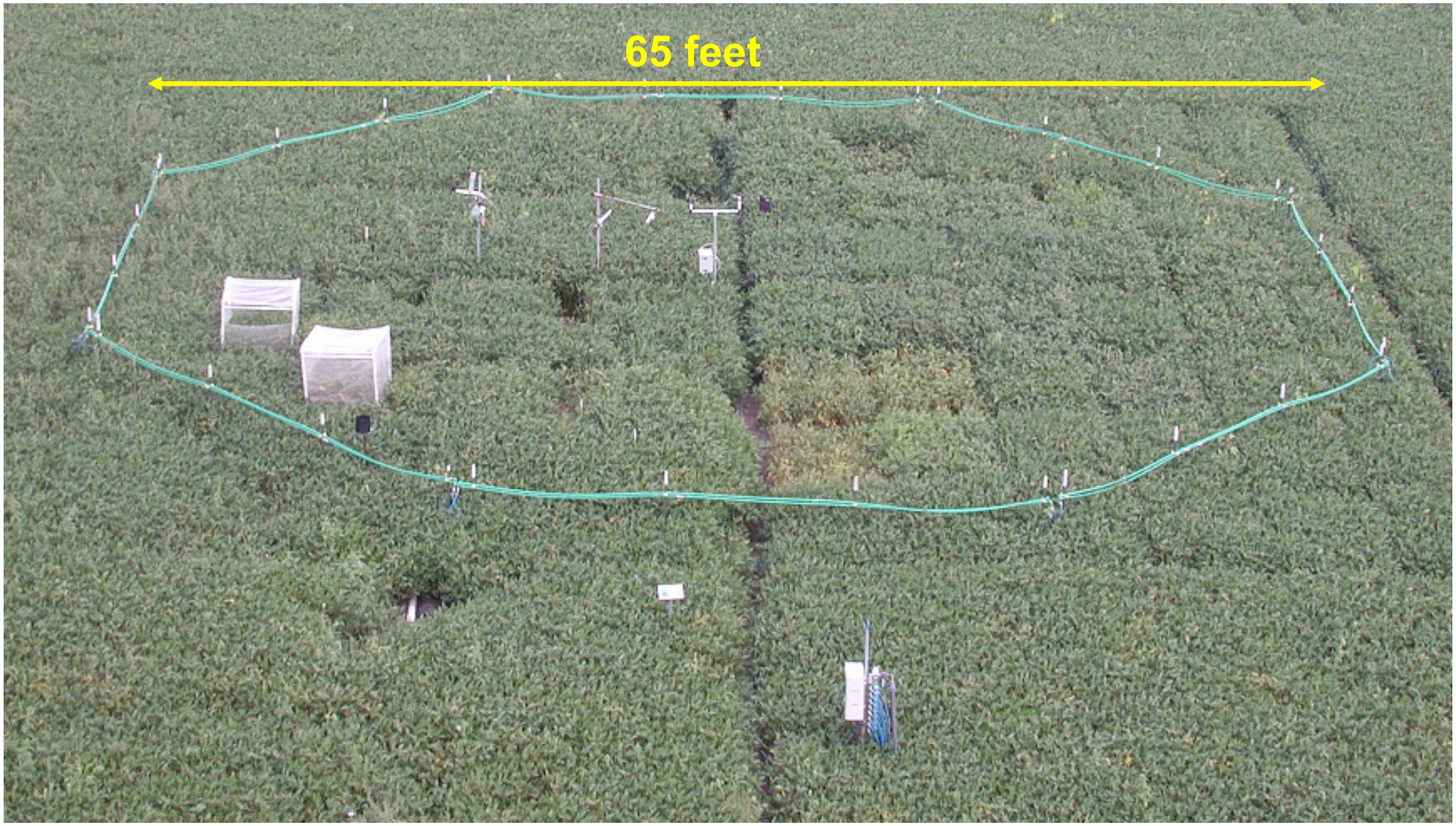
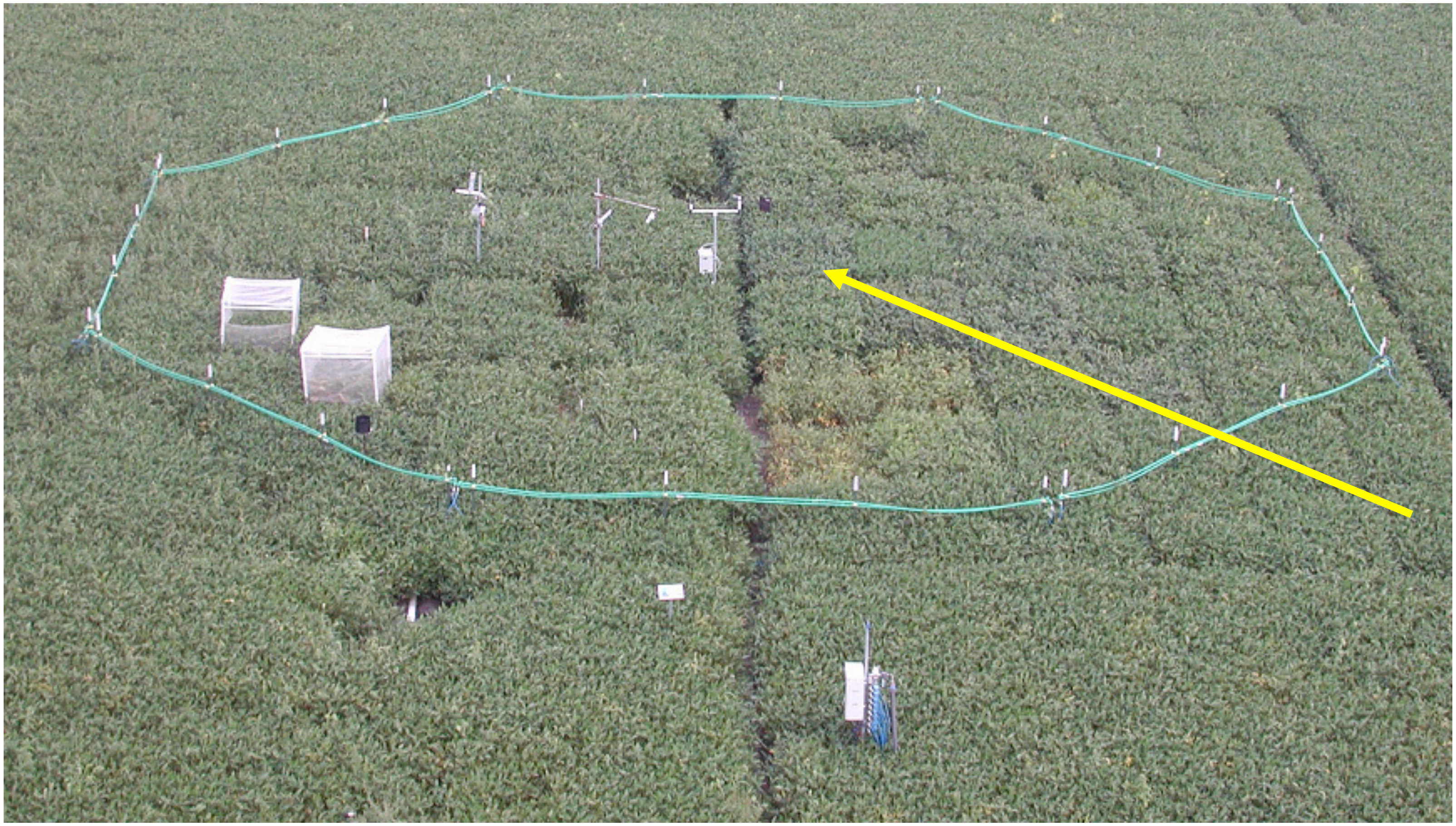
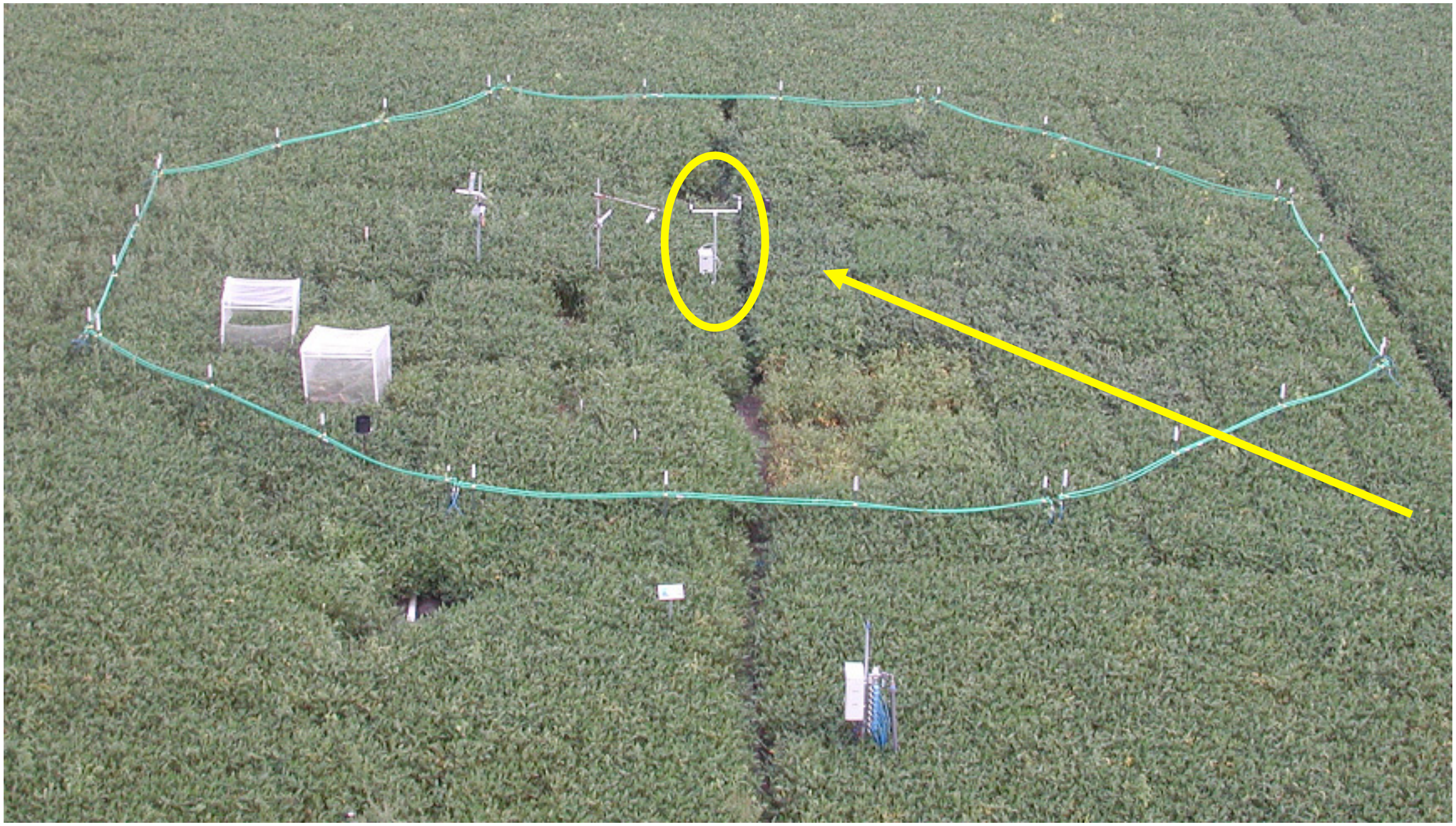
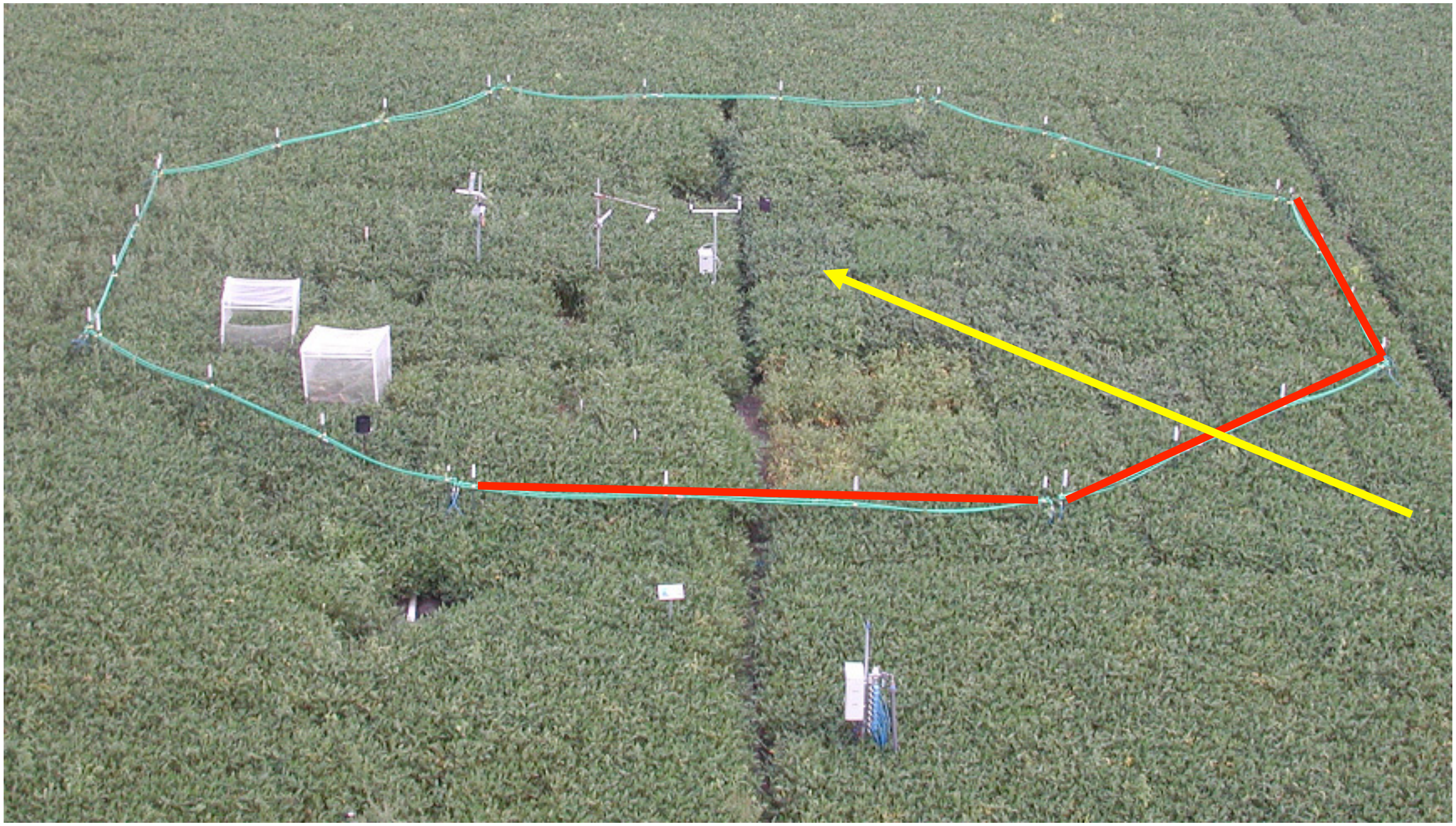
Free Air Concentration Enrichment (FACE)

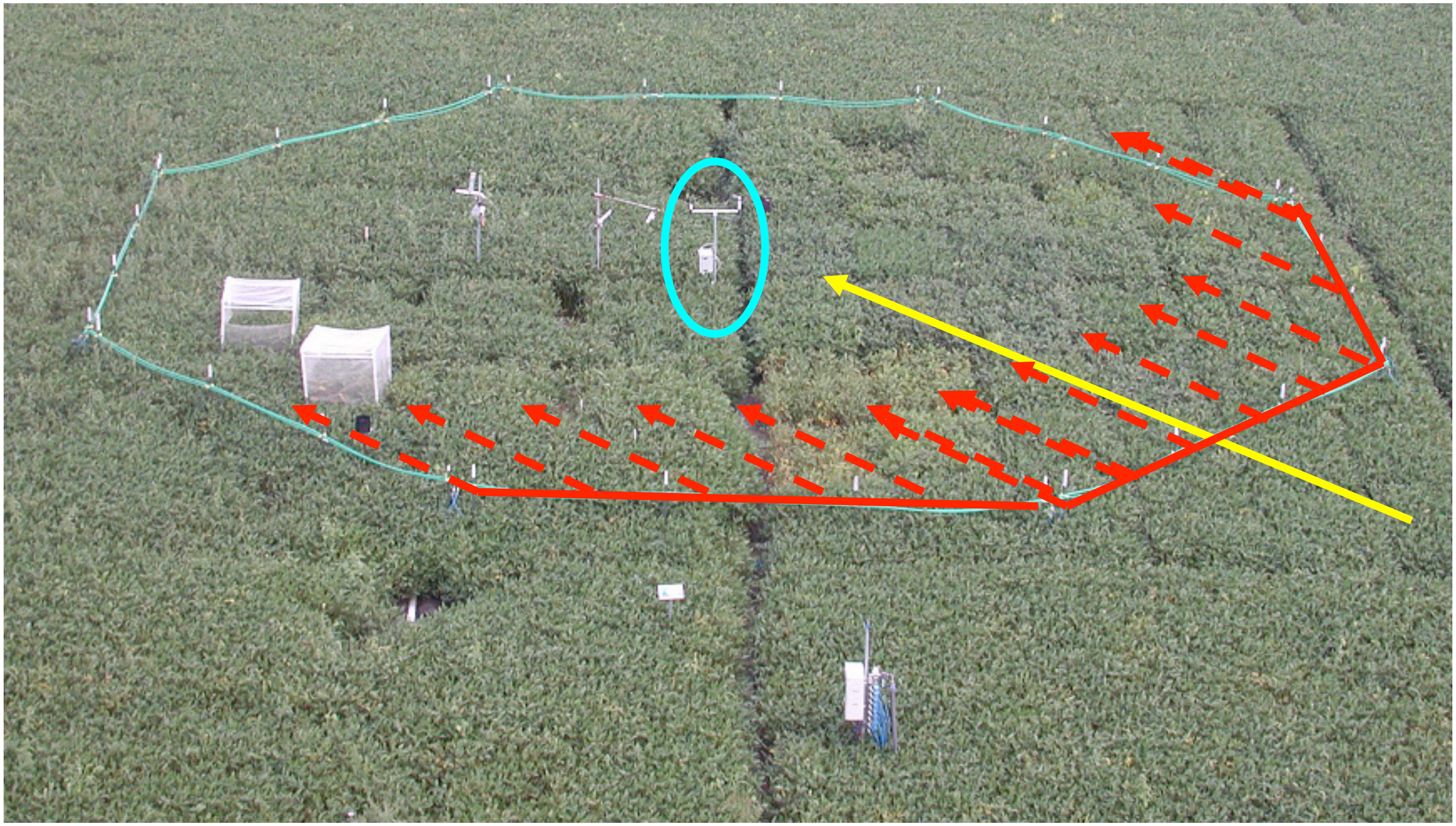
2001 – 2011, Champaign, IL

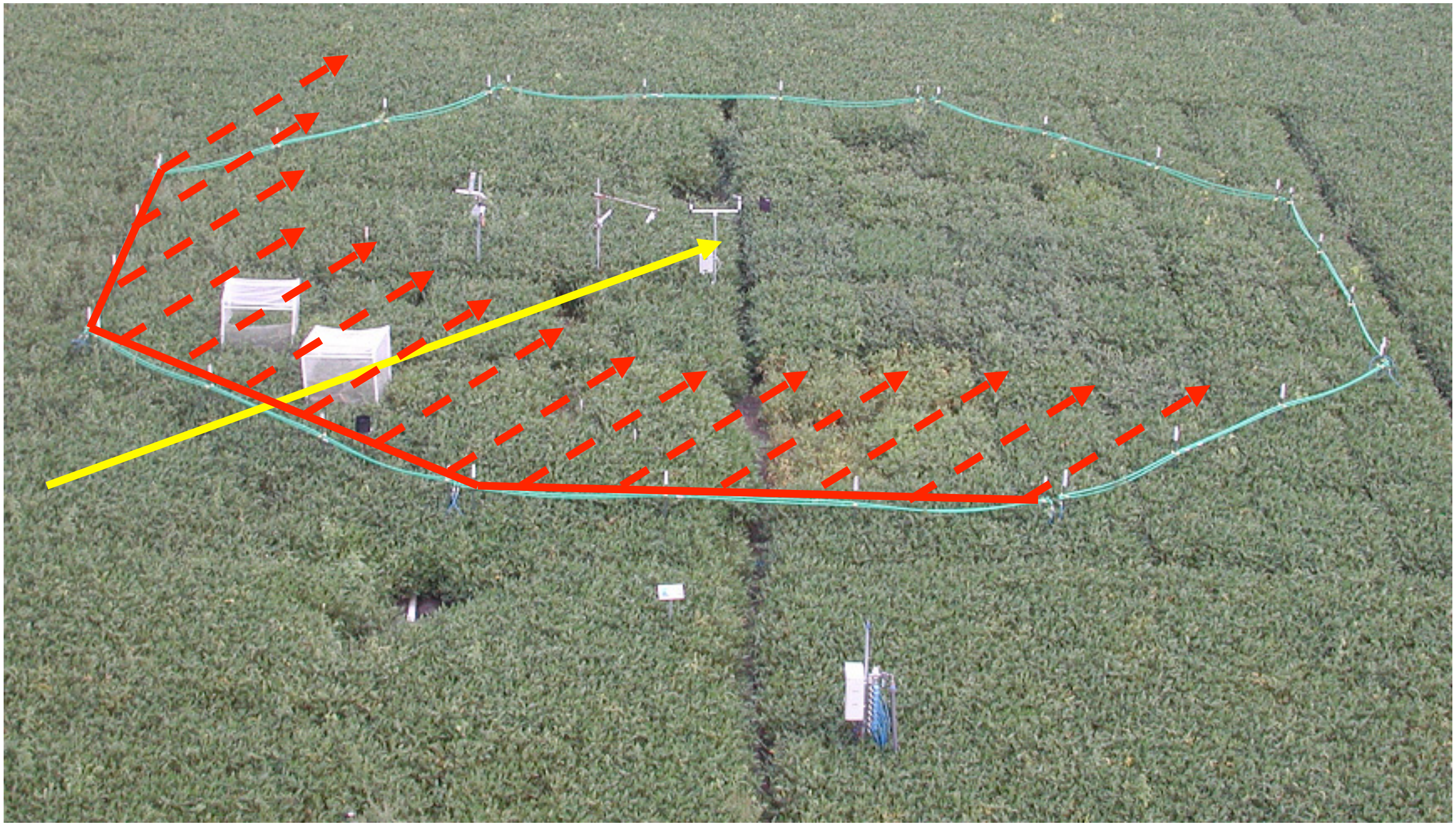

65 feet



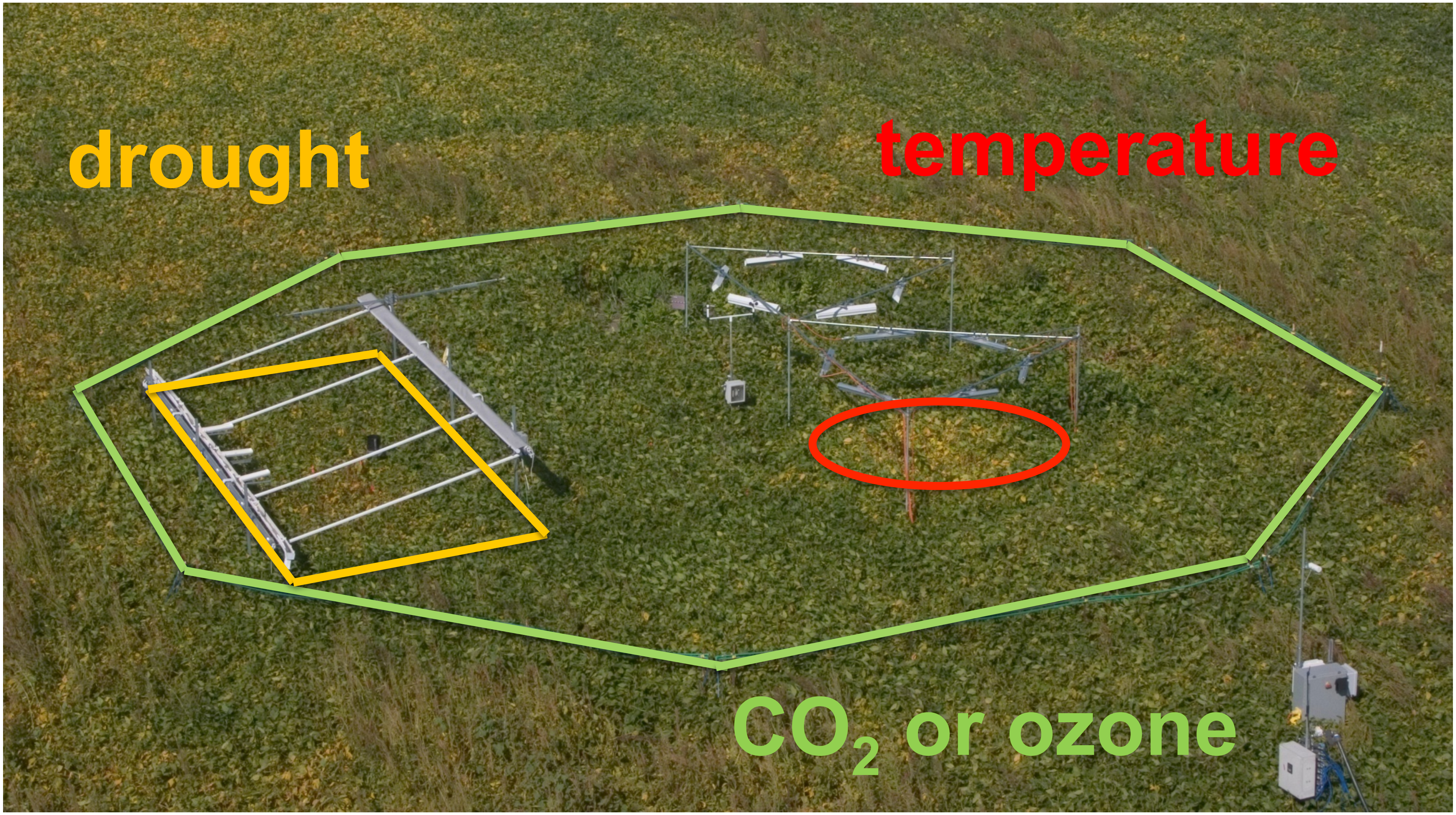








Simulating future CO_2, temperature, drought and ozone in a farm field setting



Outline

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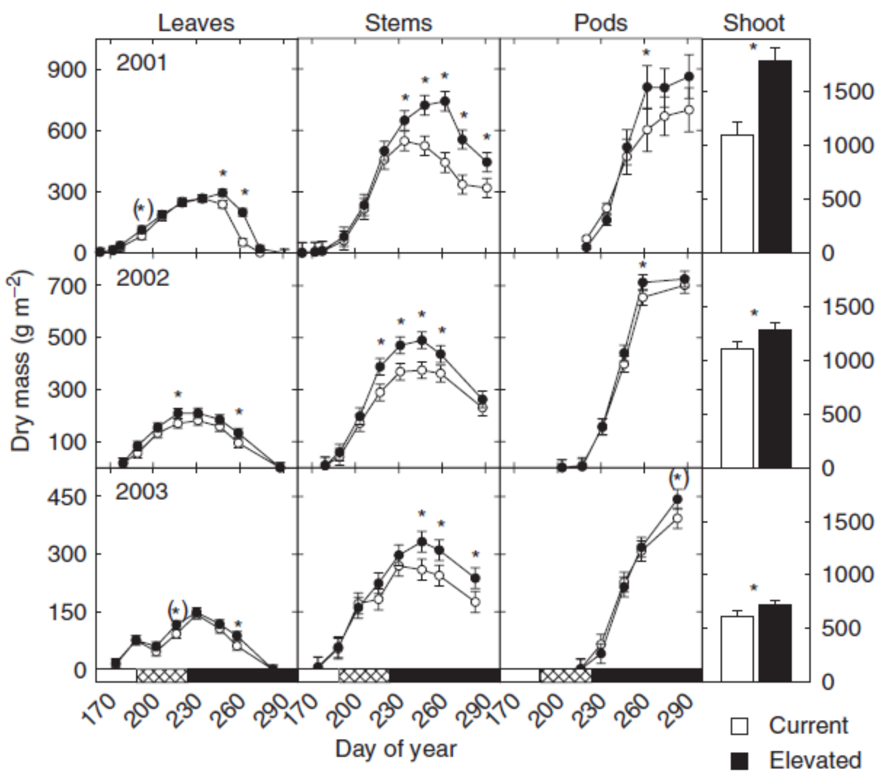
Soybean Response to Elevated [CO_2] (550 ppm)

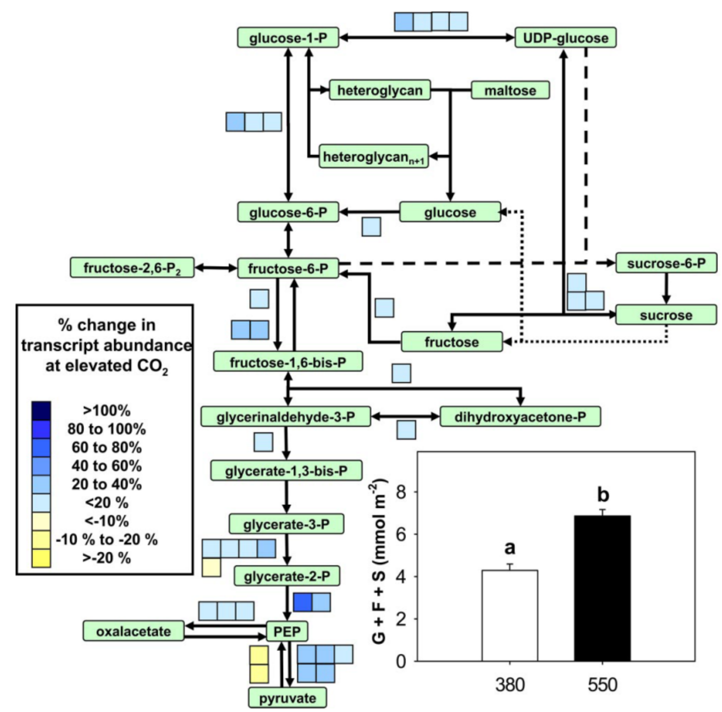
↑ 20% increase in light-saturated photosynthesis

↓ 20% decrease in stomatal conductance



Morgan et al. Global Change Biol 2005

Increased production of carbohydrates, enhanced expression of transcripts for sugar metabolism and respiration, and 39% increase in dark respiration rates



Leakey et al. PNAS 2009

Soybean Response to Elevated [CO_2] (550 ppm)

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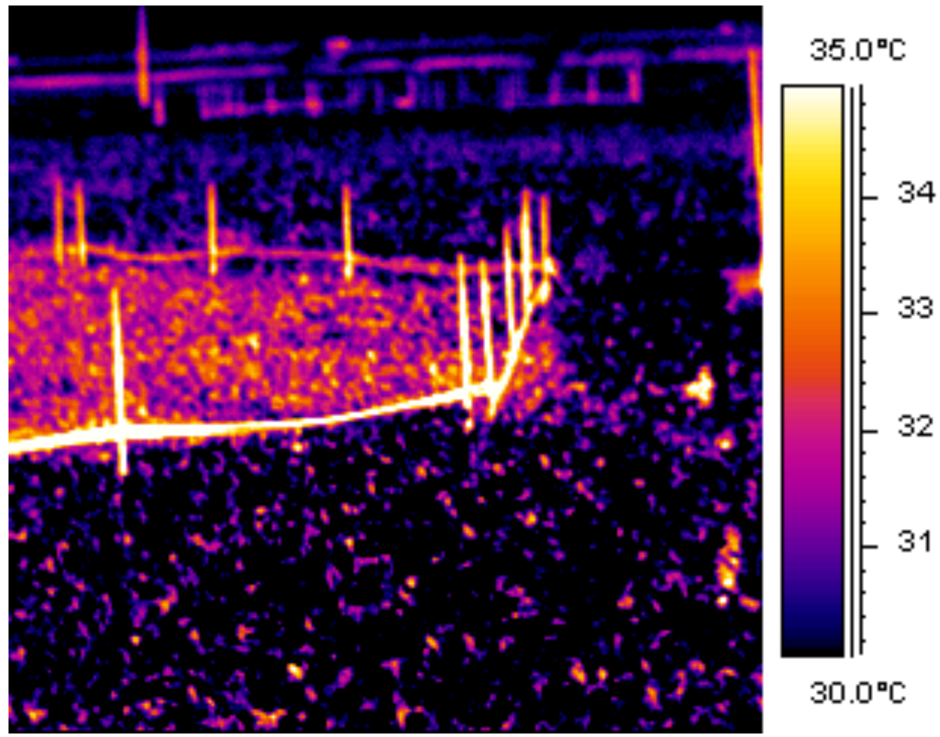
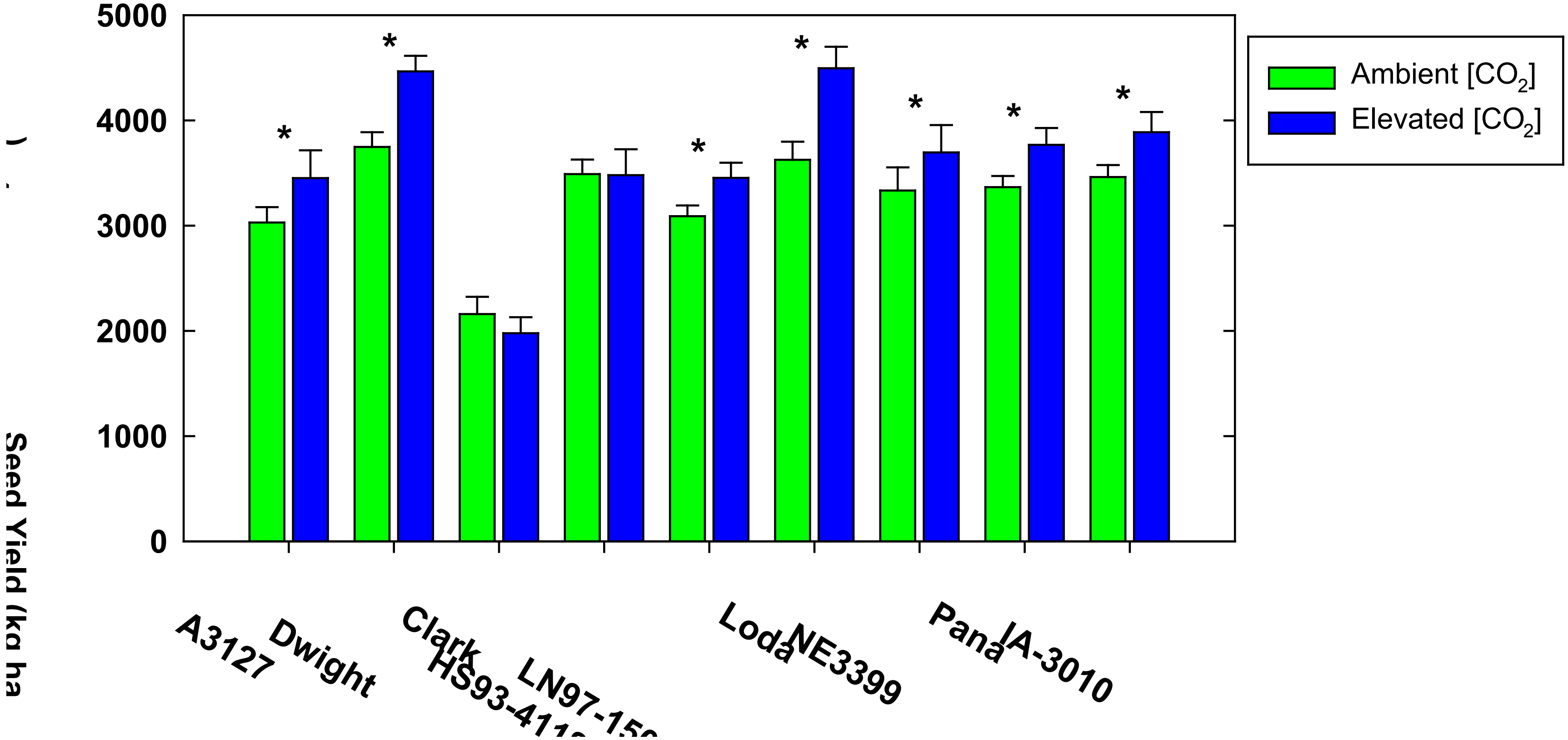


Lower stomatal conductance at elevated [CO_2] reduces evaporative cooling and warms the crop canopy. This can lead to improvements in soil moisture status.

2004 – 2008 Yield Data

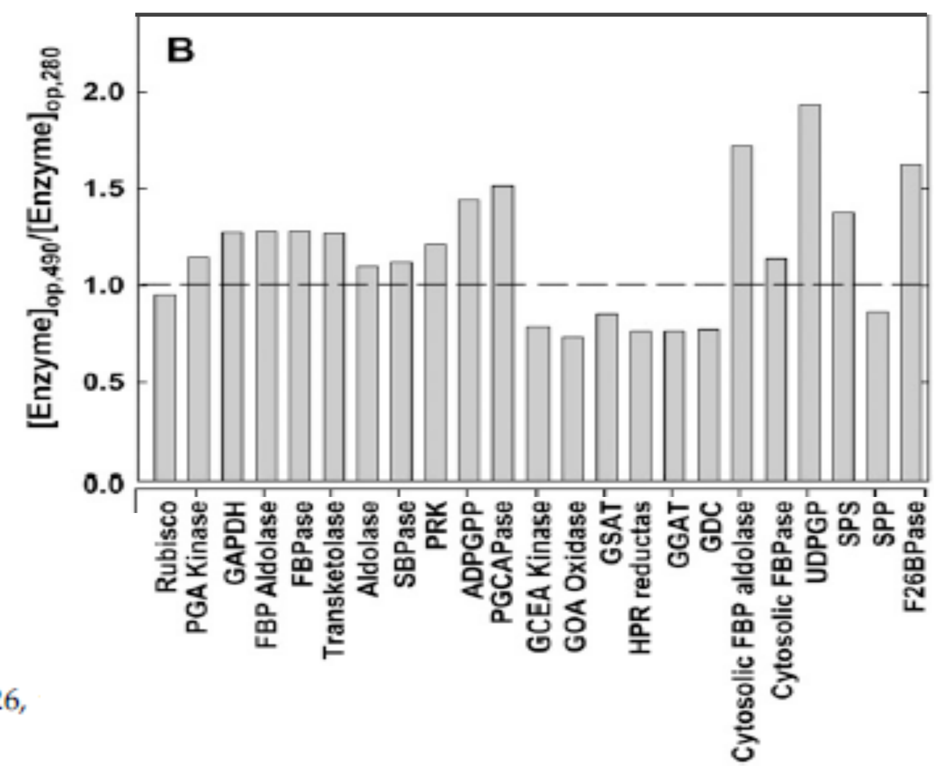


Seed yield is increased by 11% on average with growth at elevated [CO_2] (550 ppm). There is significant cultivar variation in this response – ranging from no response to 25% increase in yield.

Randy Nelson

Targets for improving soybean response to rising $[CO_2]$

- Alter the distribution of resources among photosynthetic enzymes to improve the efficiency of photosynthesis.



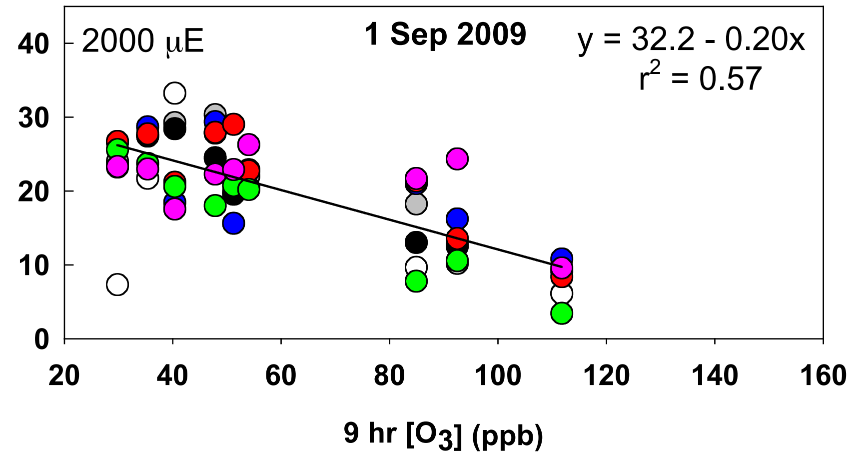
Plant Physiology, October 2007, Vol. 145, pp. 513–526,

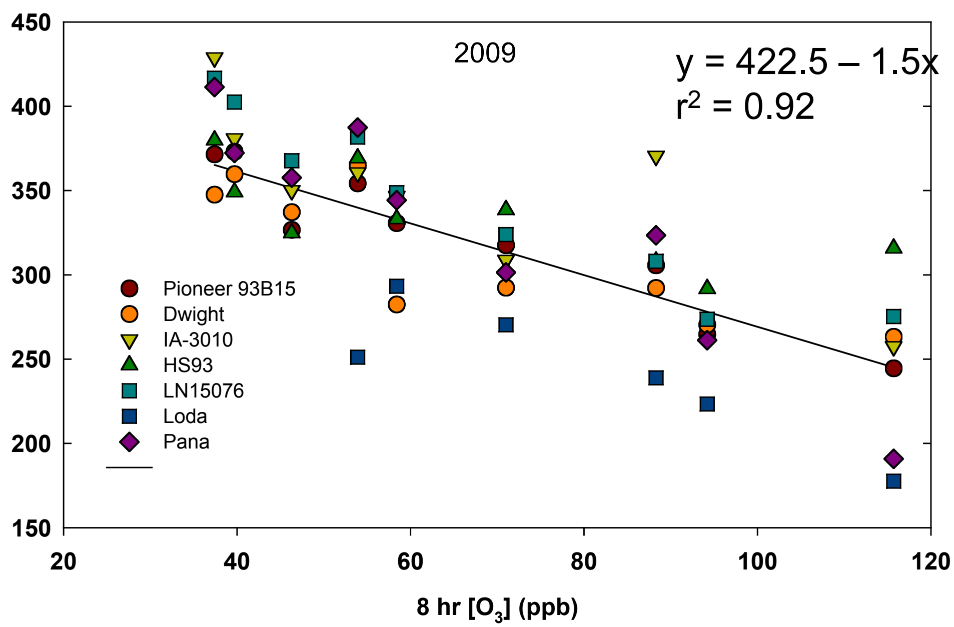
Targets for improving soybean response to rising [CO_2]

- Identify cultivars with strong sink capacity

Test Cultivar	Akitakomachi	Wixiangjing 14	Shanyou 63
Genotype	Japonica	Japonica	Hybrid indica
% Increase in Yield	+12.8%	+12.8%	+34.1%

Soybean Response to Elevated [O_3]



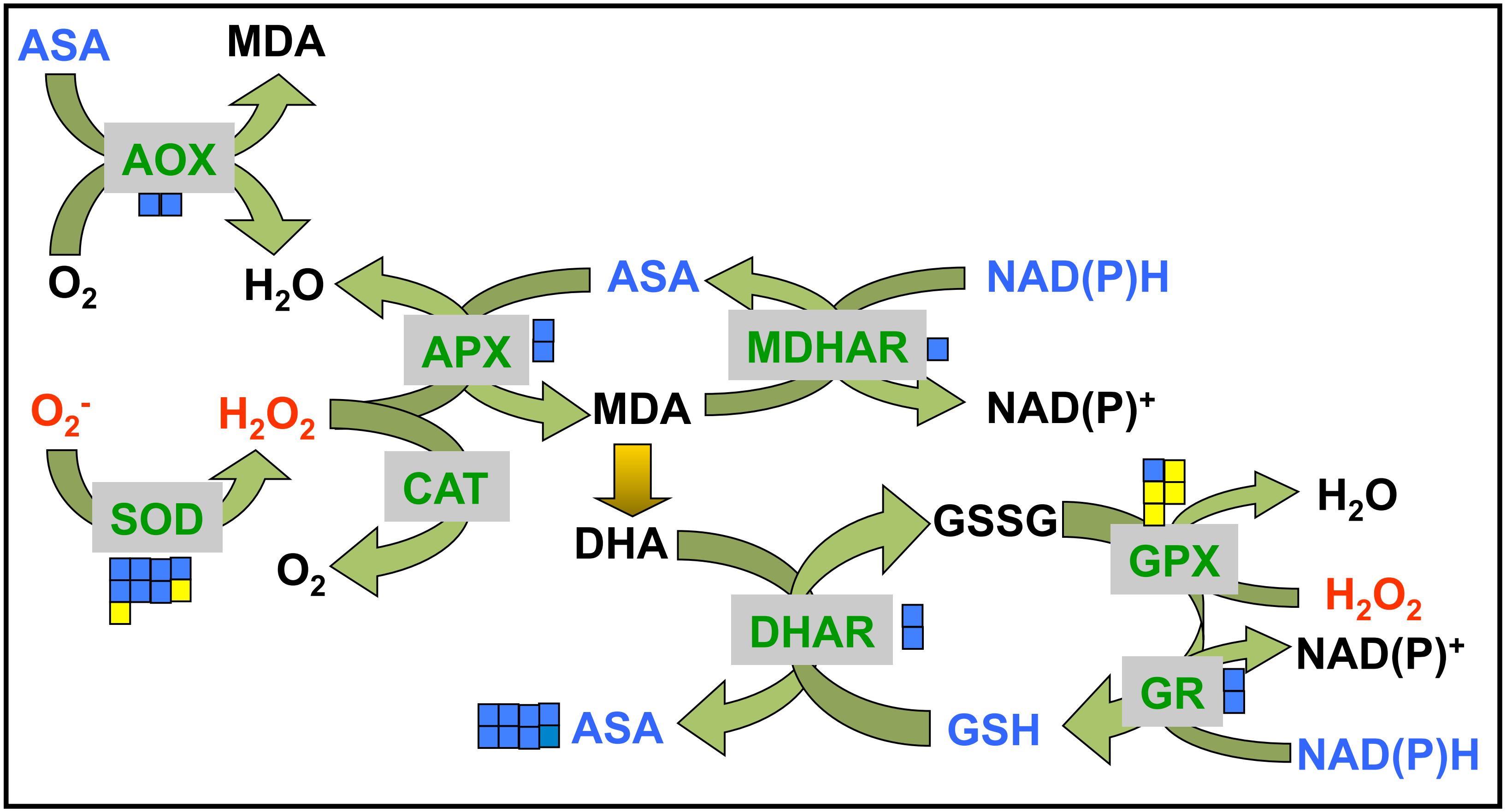


Soybean response to ozone is dependent on dose.

There is a linear reduction in photosynthetic carbon gain and canopy leaf area with concentrations greater than 40 ppb.

Amy Betzelberger

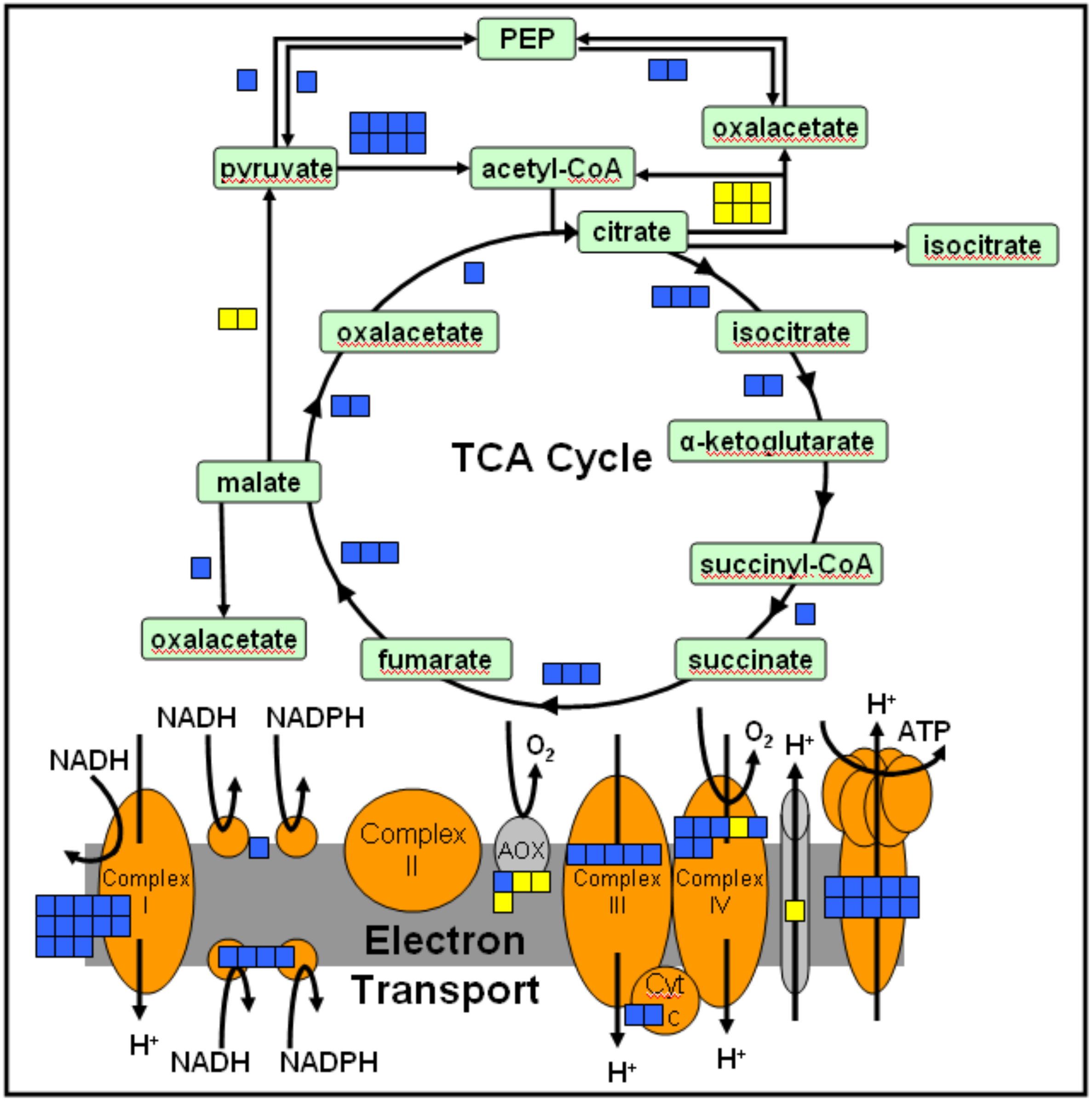
Soybean Response to Elevated [O_3]



Total antioxidant capacity and transcript abundance of antioxidant enzymes is increased by elevated [O_3].

Kelly Gillespie

Soybean Response to Elevated [O_3]

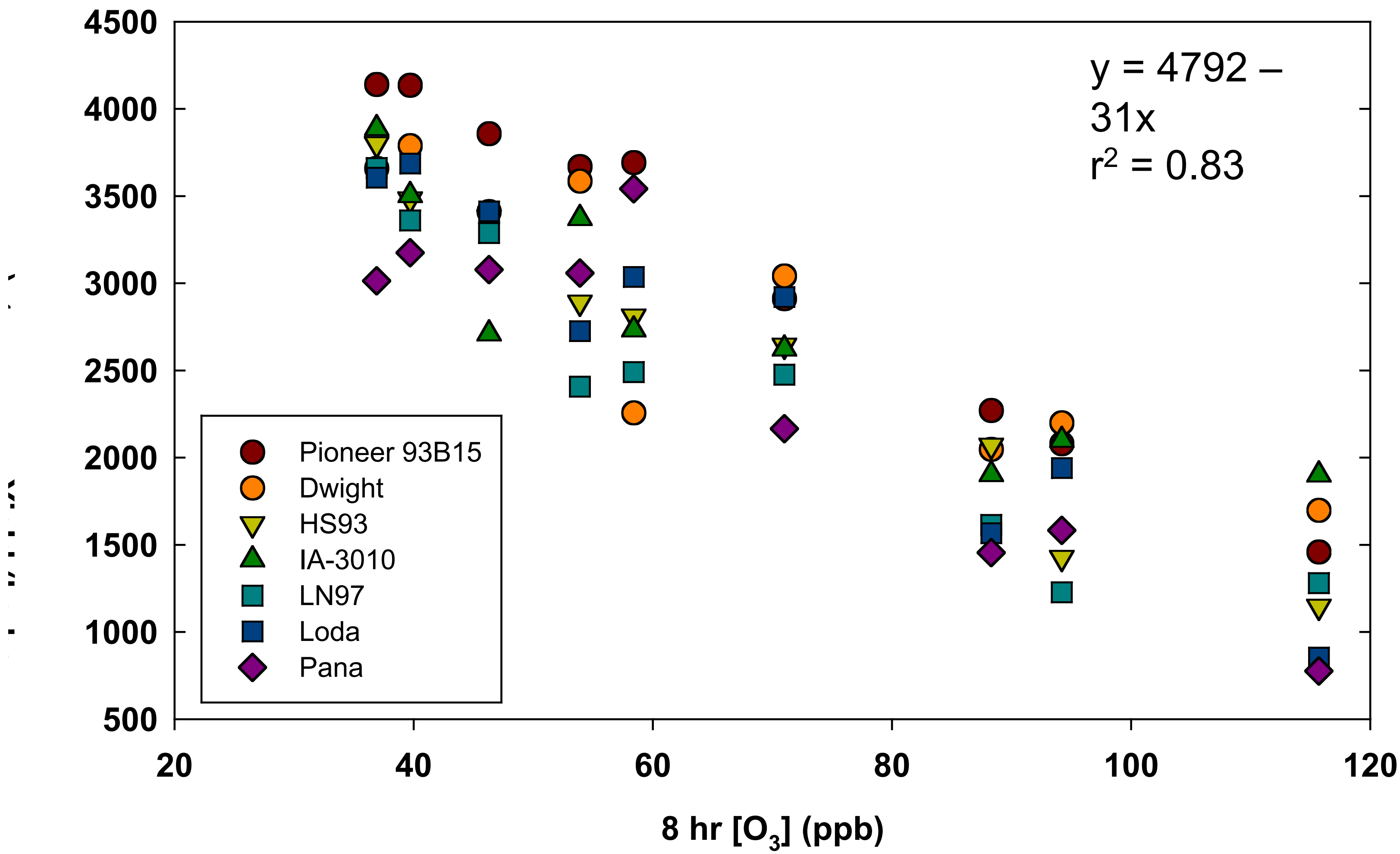


Elevated ozone increases transcripts coding for the components of glycolysis, the TCA cycle and the mitochondrial electron transport.

Increase respiration would fuel increased antioxidant metabolism.

Kelly Gillespie

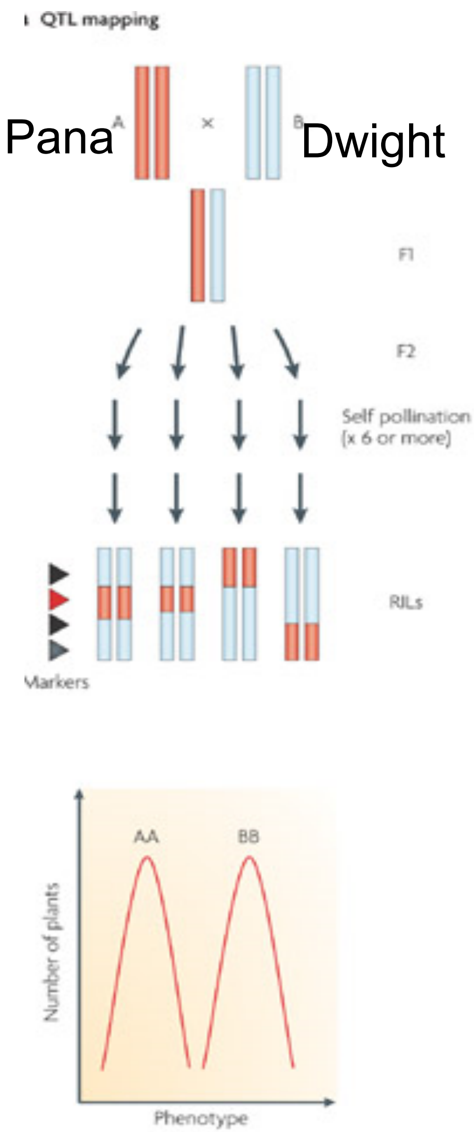
Soybean Response to Elevated $[O_3]$

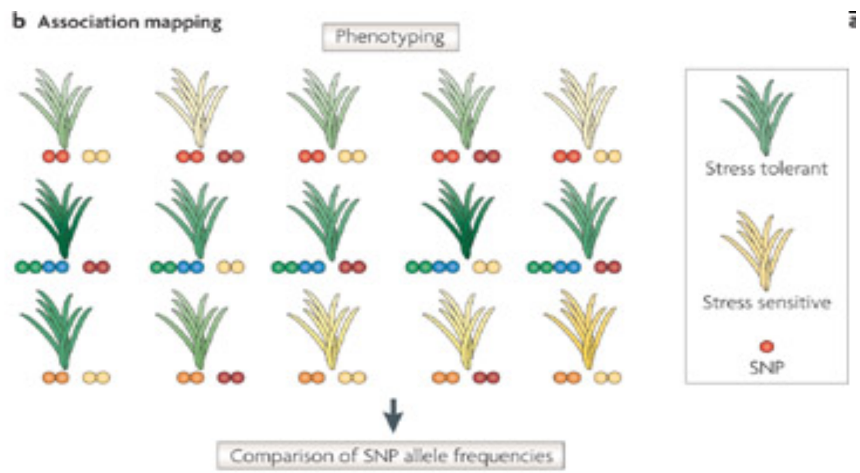


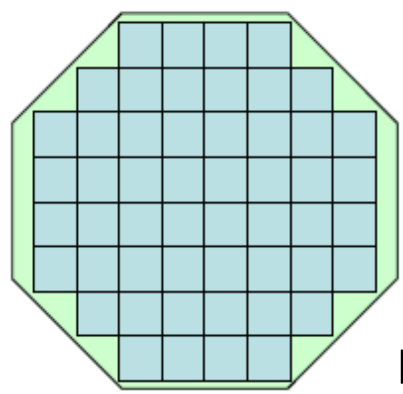
• Linear reduction in seed yield with increasing ozone concentration.

Randy Nelson, Amy Betzelberger

Genetic dissection of ozone tolerance



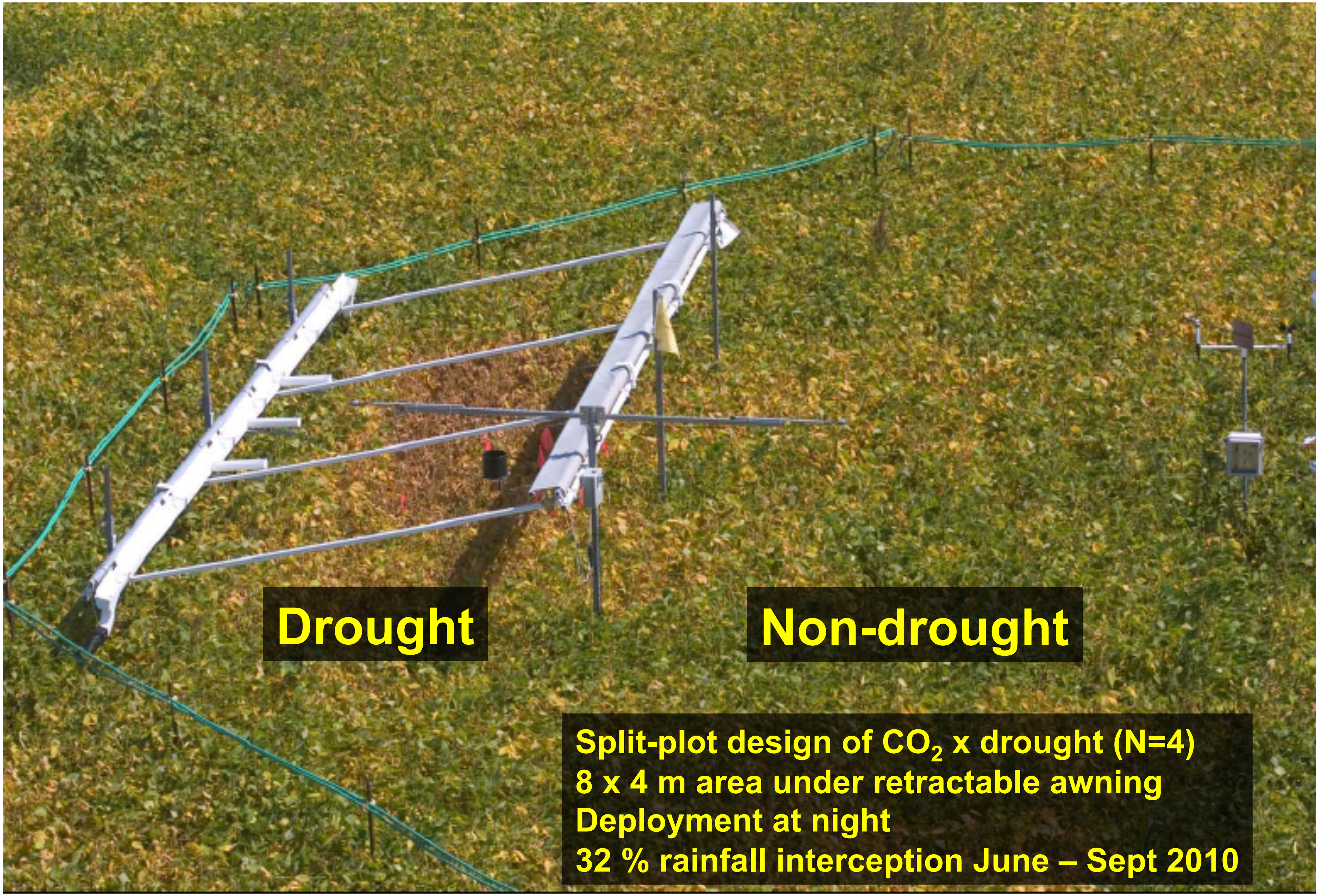


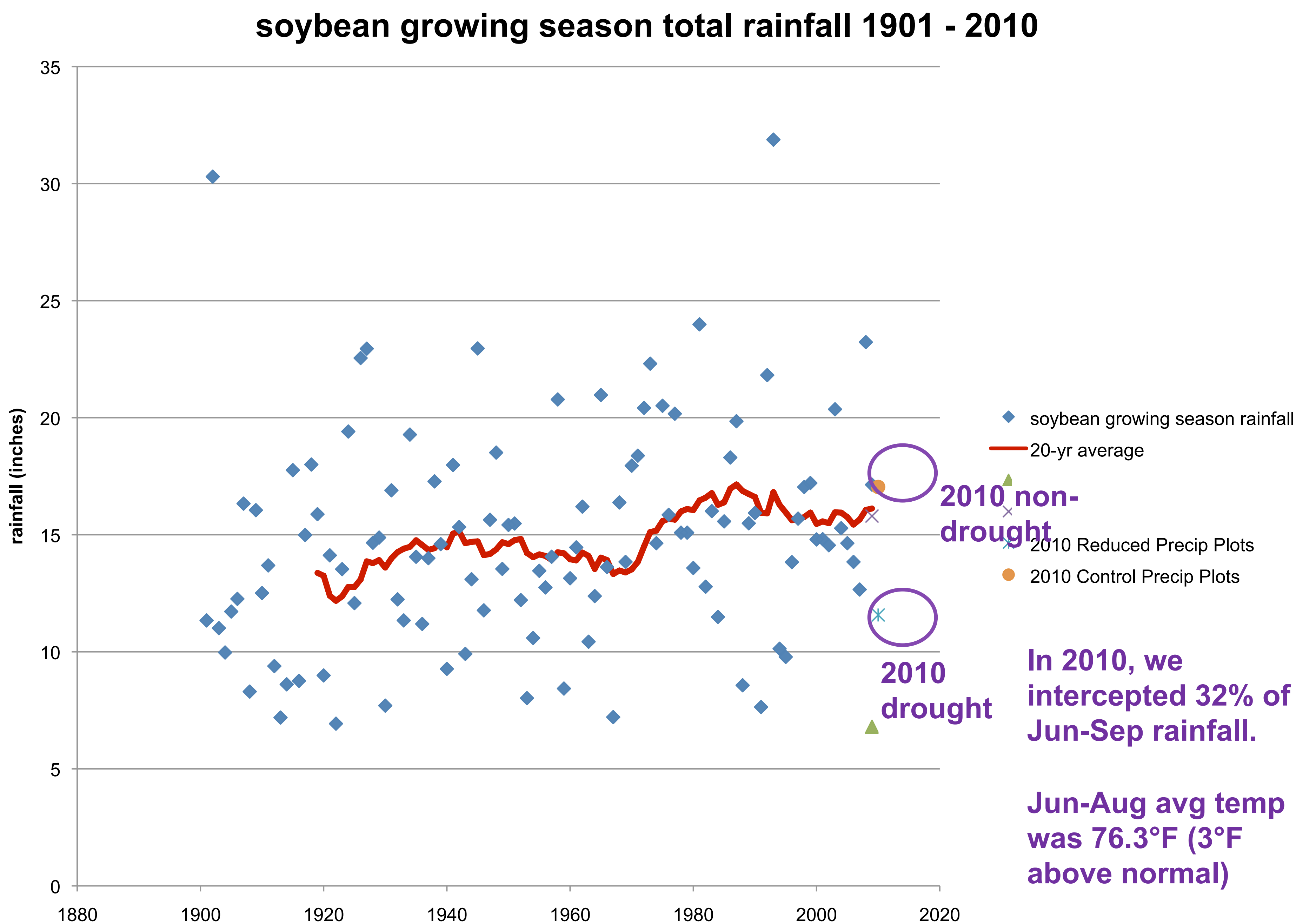


In 2011, 2012, we will grow 200 - 250 recombinant inbred lines at elevated [O_3] at SoyFACE in order to identify quantitative trait loci (QTL) related to ozone tolerance and sensitivity.

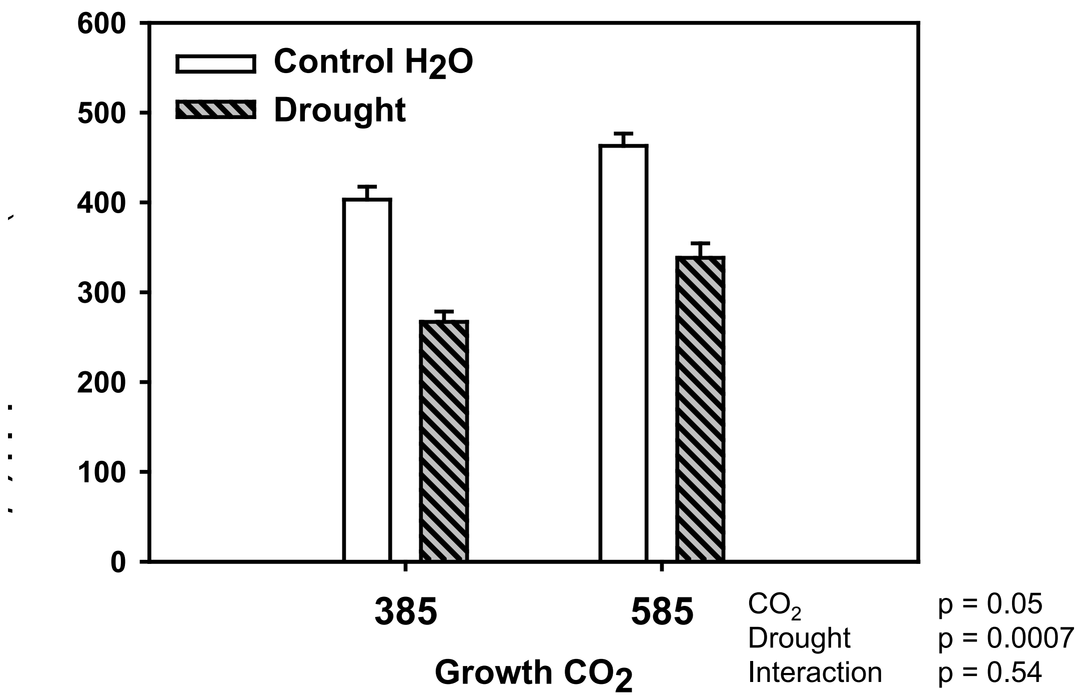
Randy Nelson, Jeff Skoneczka

Drought by Rainfall Interception in FACE (DRIFACE)




soybean growing season total rainfall 1901 - 2010
rainfall (inches)
35
30
25
20
15
10
5
0
1880
1900
1920
1940
1960
1980
2000
2020
soybean growing season rainfall
20-yr average
2010 Reduced Precip Plots
2010 Control Precip Plots
2010 non-drought
2010 drought
In 2010, we intercepted 32% of Jun-Sep rainfall.
Jun-Aug avg temp was 76.3°F (3°F above normal)

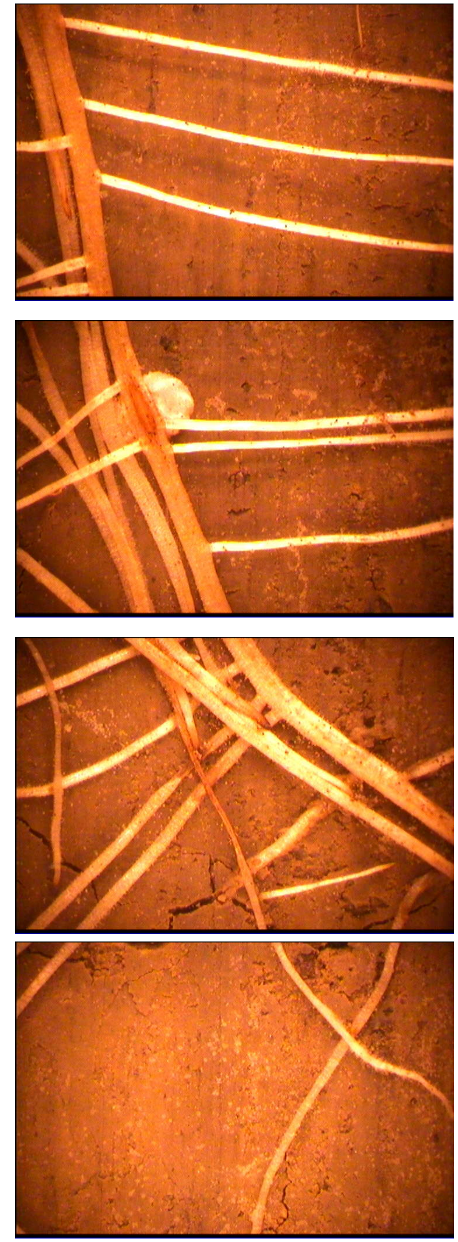
Leakey et al, unpublished



Elevated CO_2 did not protect against yield loss to drought.

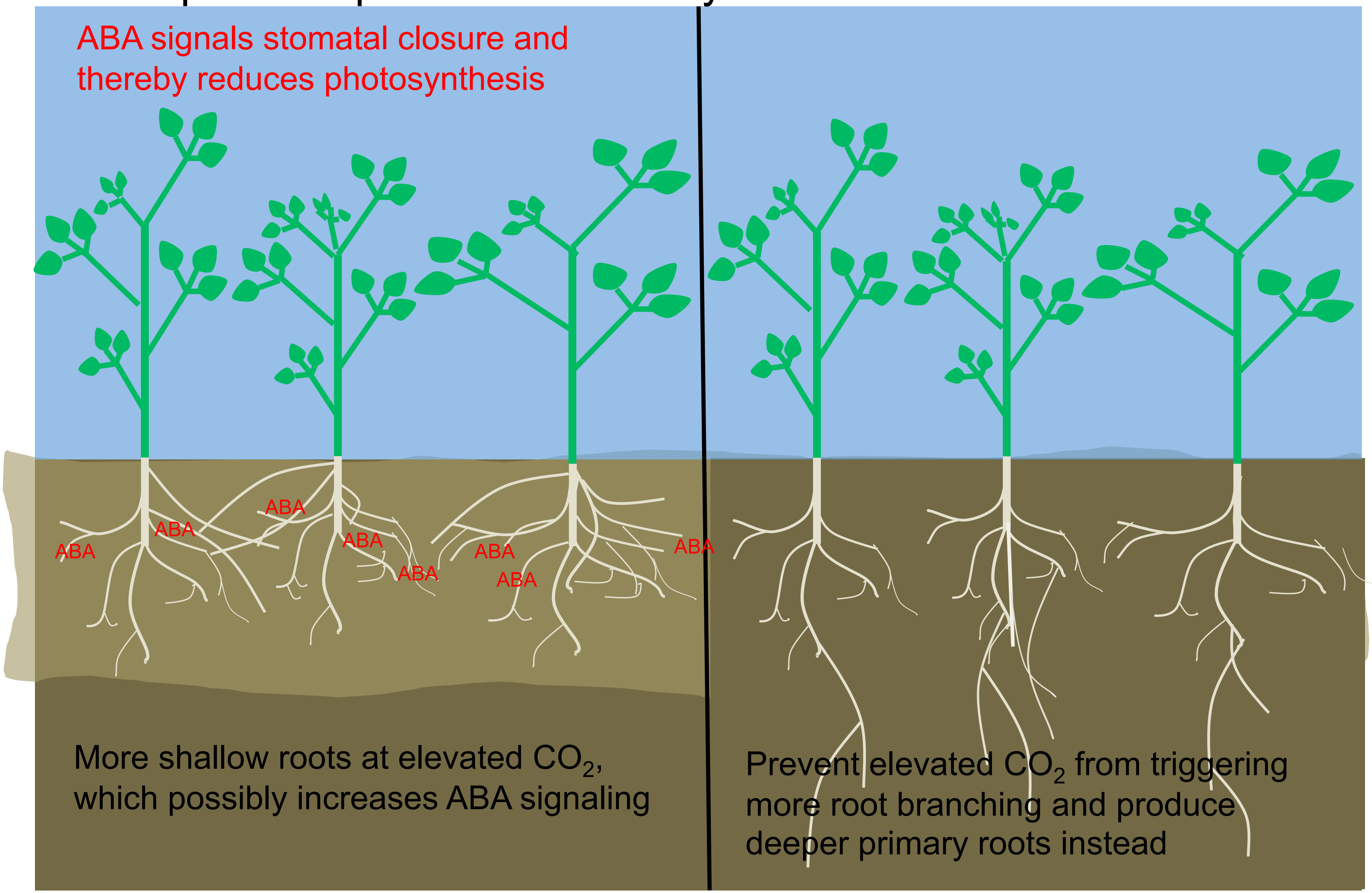
The combination of drought and elevated CO_2 anticipated for 2050 led to a 16 % decrease in yield relative to today's growth conditions.

Could non-optimal rooting be to blame?



depth 64 cm - 67cm

Elevated CO_2 stimulates growth, but may not do so in a way that optimizes performance and yield in Illinois.



Global climate change will add at least three new dimensions to agriculture:

(1) the production environment will be more variable and more stressful
(2) climatic variation will be greater between years and locations of field trials making breeding and production more challenging
(3) the environment for which crops are being designed will be a rapidly moving target

Acknowledgements

Don Ort
Randy Nelson
Andrew Leakey
Carl Bernacchi
Steve Long
Tim Mies

Craig Yendrek
Jeff Skoneczka
Amy Betzelberger
Kelly Gillespie