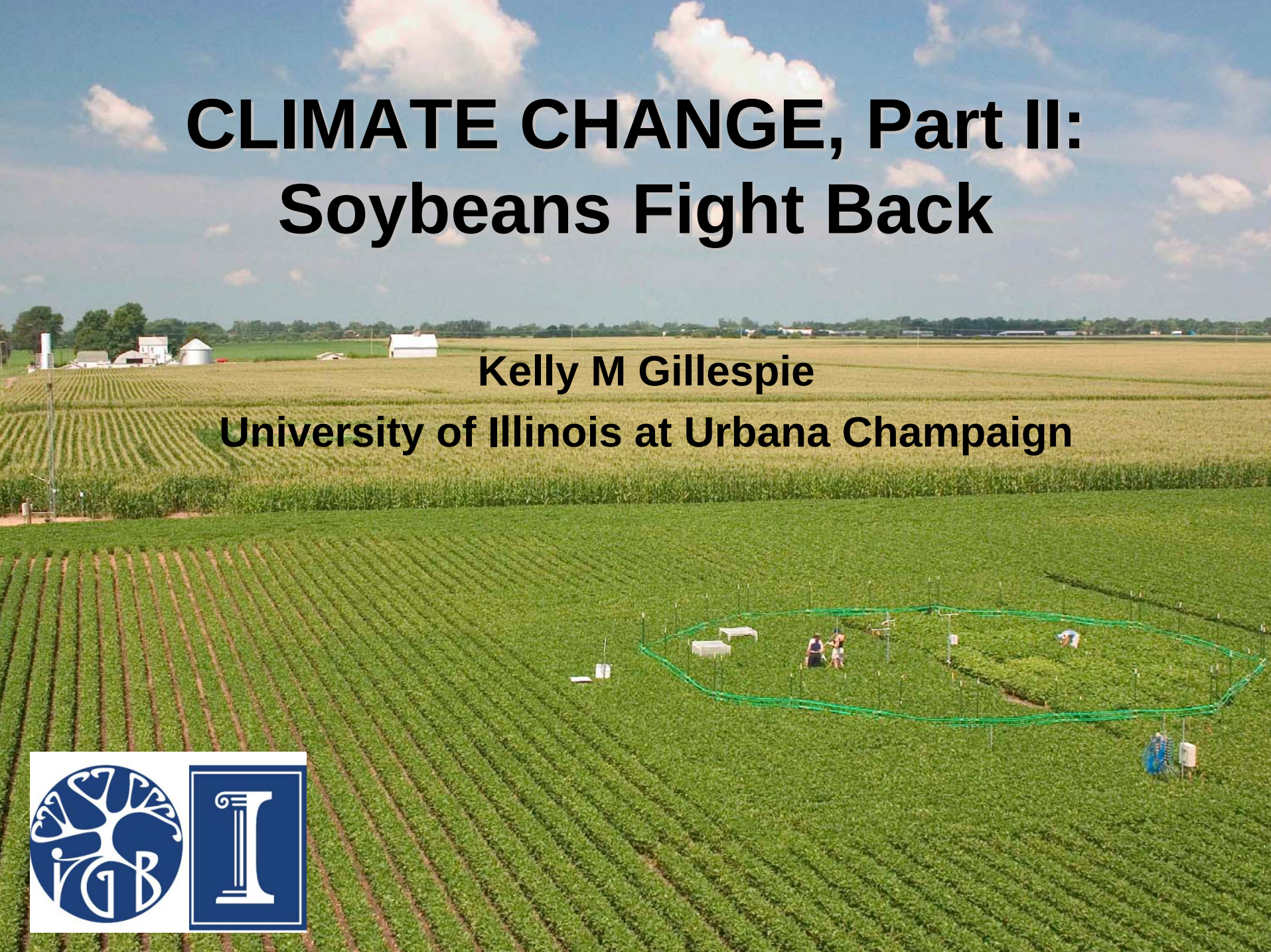
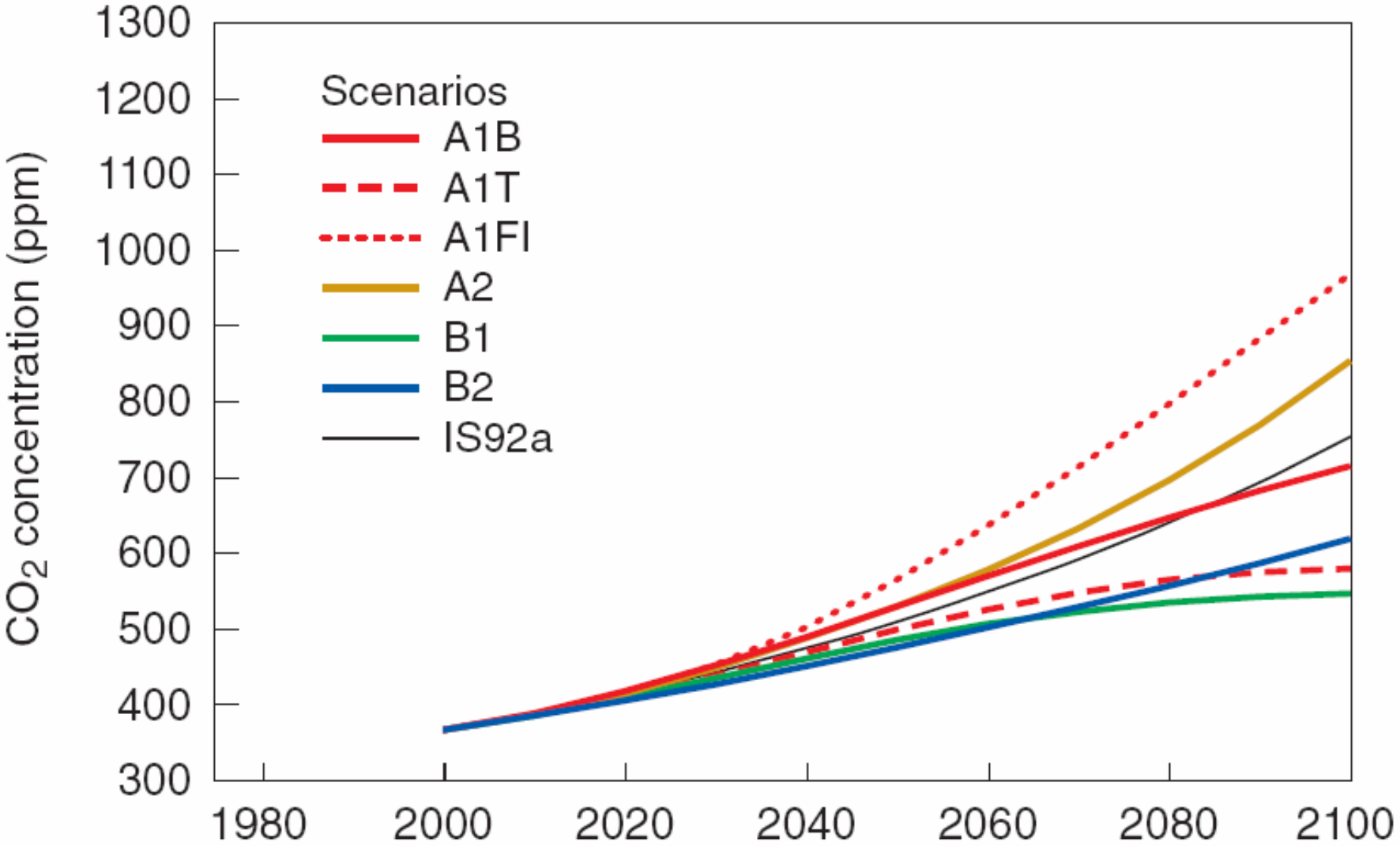
CLIMATE CHANGE, Part II: Soybeans Fight Back

Kelly M Gillespie

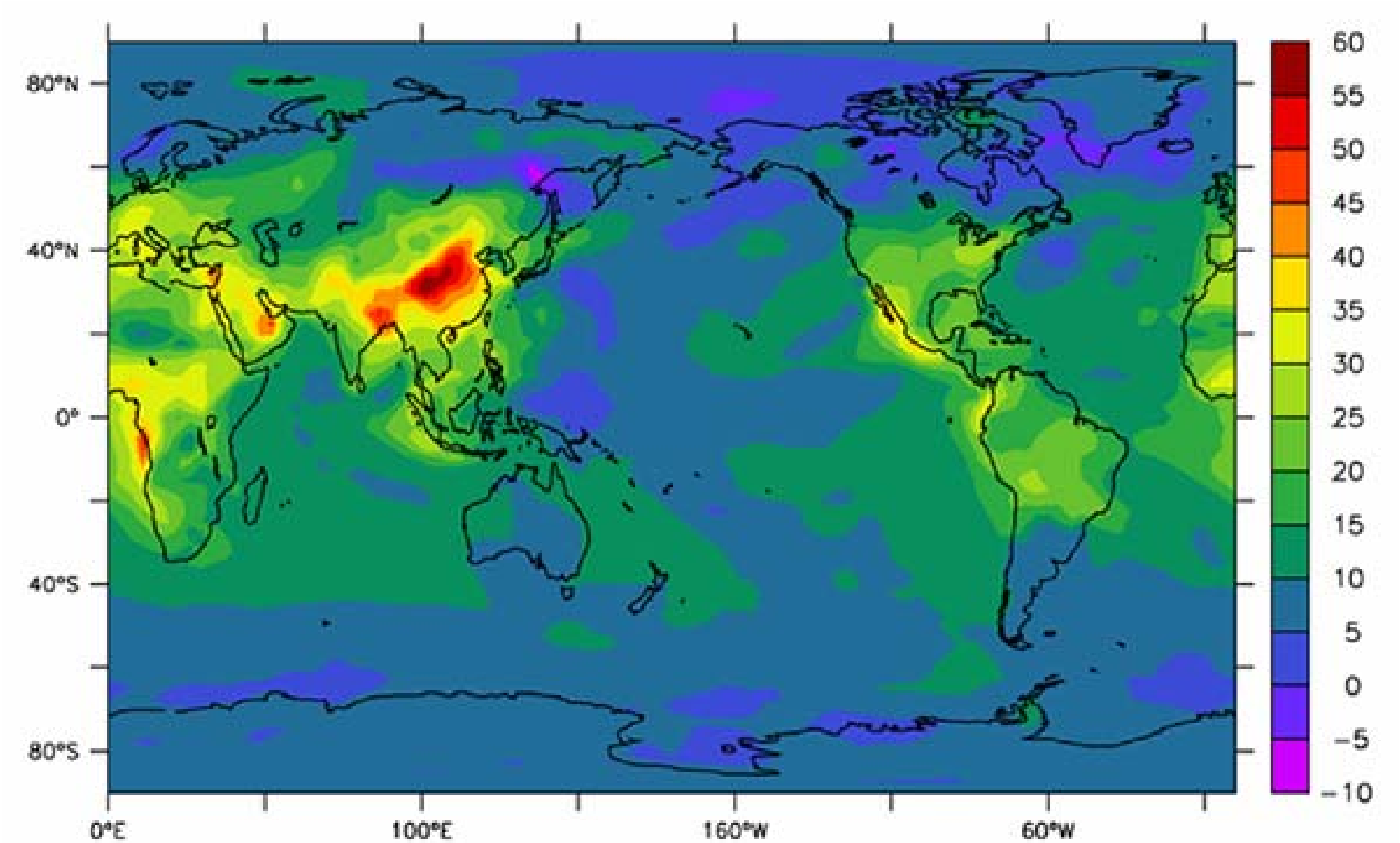
University of Illinois at Urbana Champaign





U.N. Intergovernmental Panel on Climate Change: The Scientific Basis – 3rd Assessment Report (2001)

Predicted Global Change: Increasing Regional Ozone



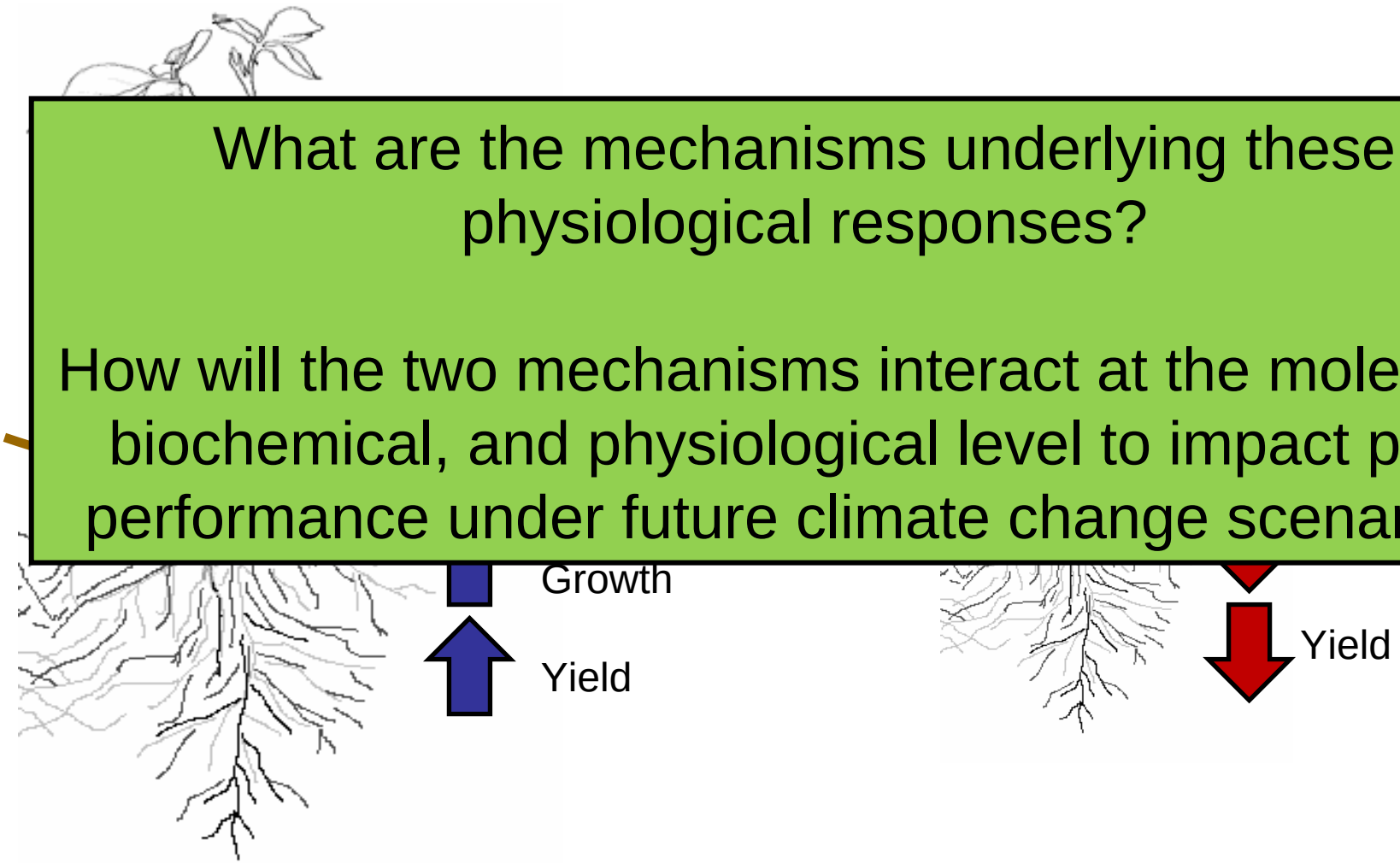
Changes in surface ozone (ppb) in July between 2000 and 2100

Elevated CO_2

Elevated O_3

What are the mechanisms underlying these physiological responses?

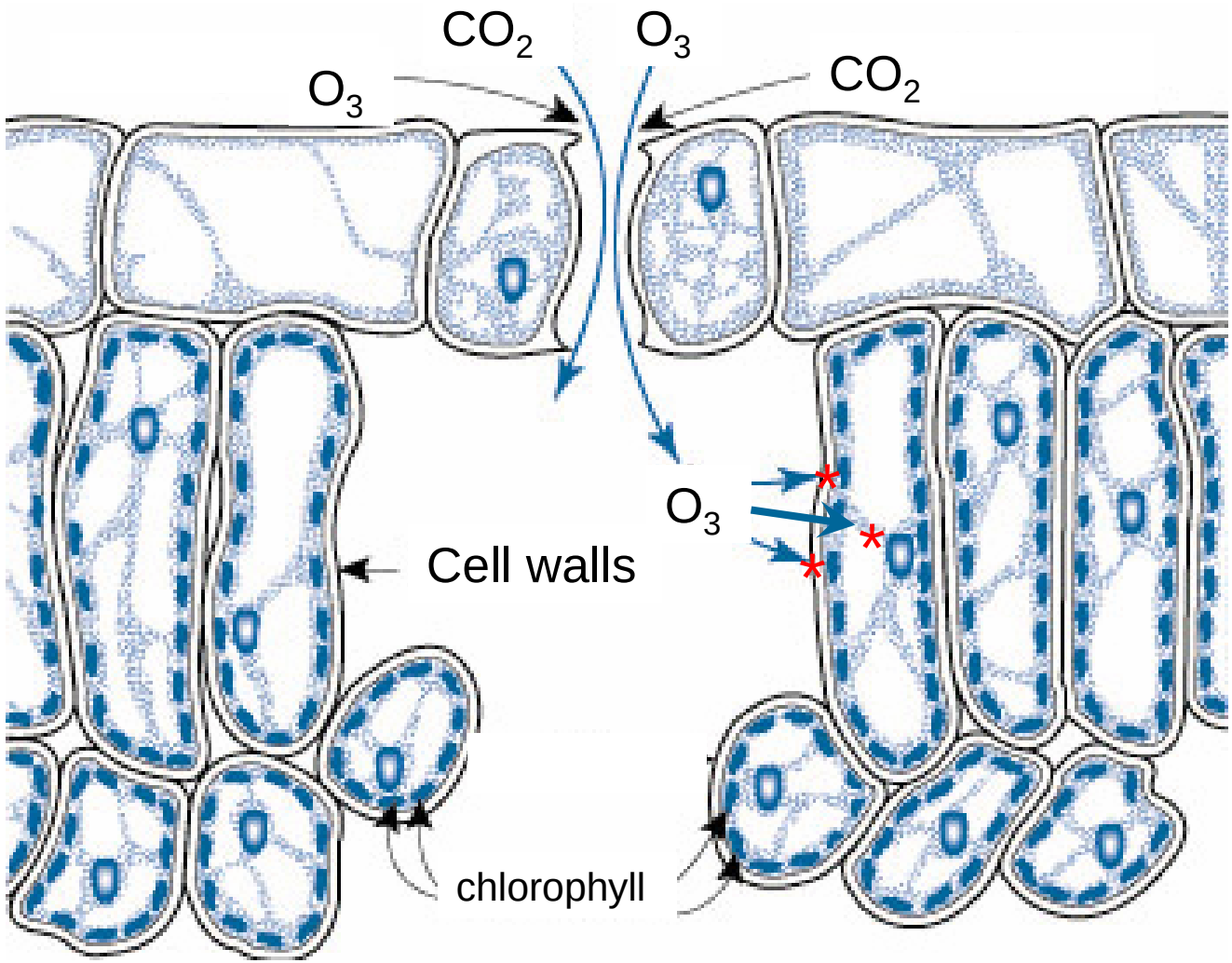
How will the two mechanisms interact at the molecular, biochemical, and physiological level to impact plant performance under future climate change scenarios?



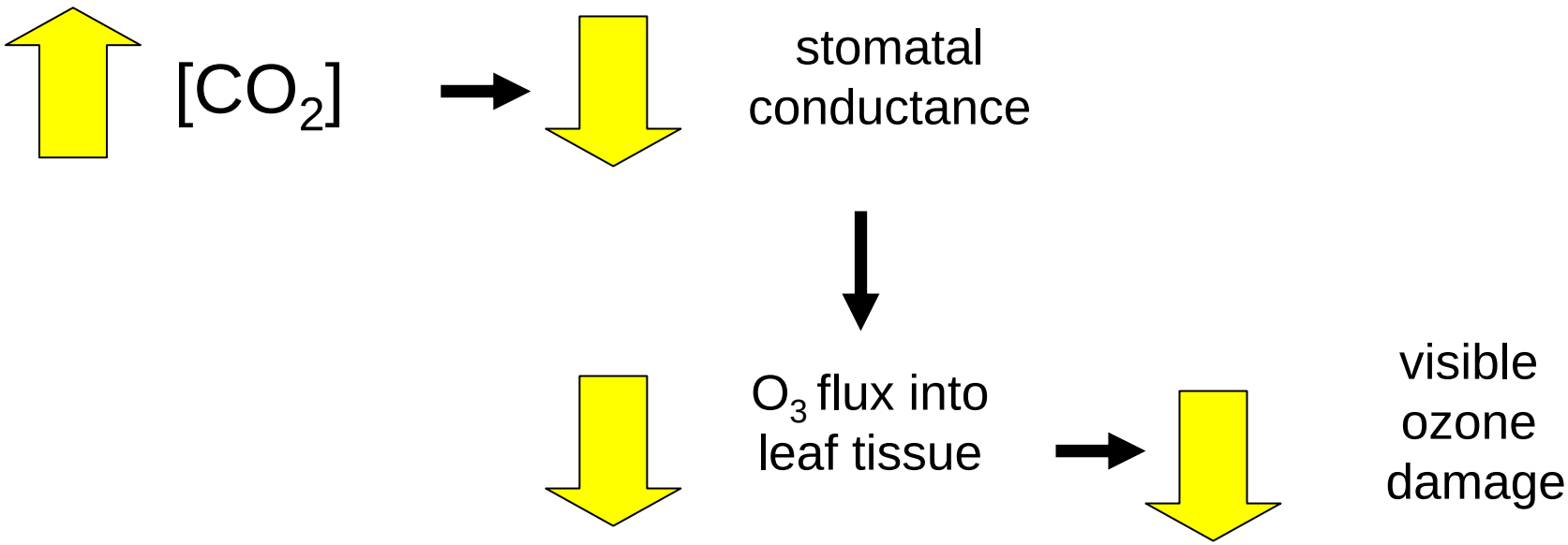
Soybean *F*ree *A*ir-gas *C*oncentration *E*nrichment

- Started in 2001
- Located in Champaign, IL, USA
- Randomized complete block design (n=4)
- 4 treatments: ambient air
  elevated [CO_2] (550 ppm),
  elevated [O_3] (1.5 x ambient),
  elevated [CO_2] + elevated [O_3]
- Fumigation from planting to harvest
- **Commercially available microarrays for *Glycine max***
- **Genetically and environmentally homogenous model system**

Ozone enters the leaf through open stomata

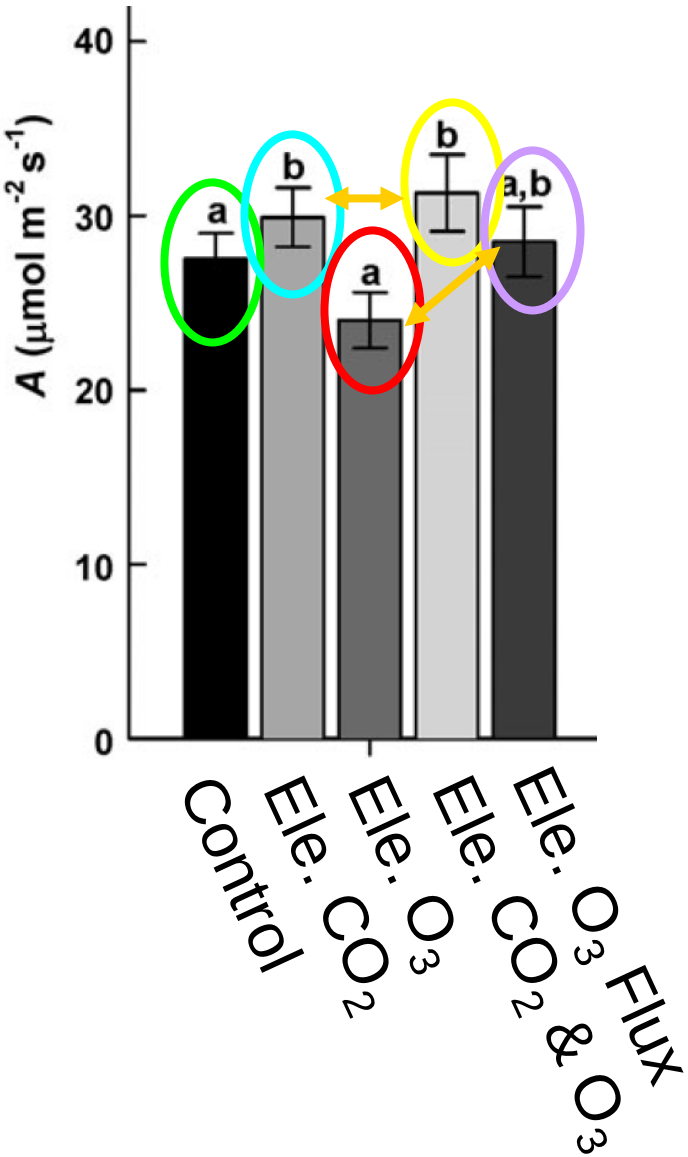


Elevated [CO_2] affords some protection from ozone damage

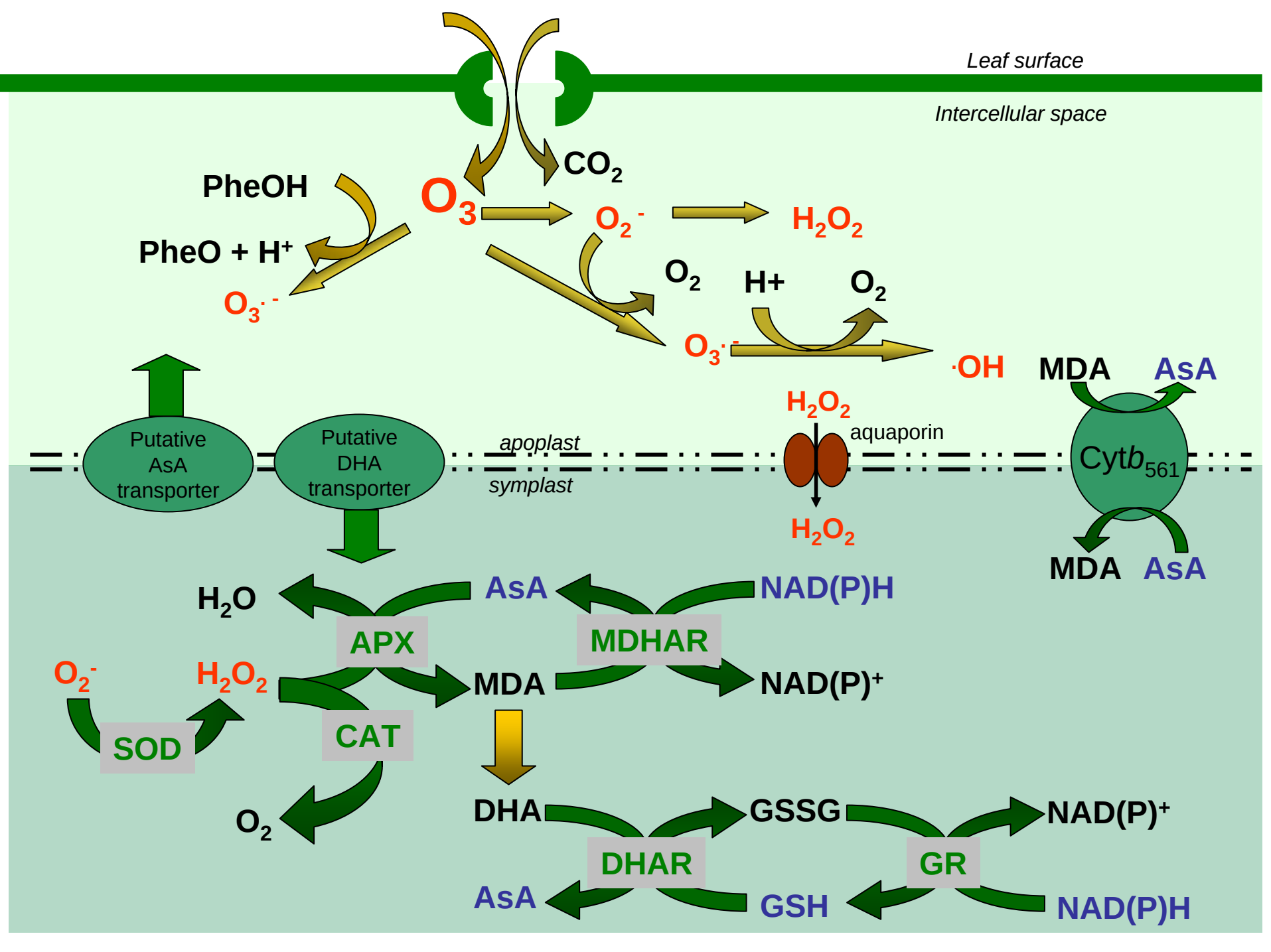


Highly variable among different species and even cultivars!!

Is decreased O_3 flux at elevated [CO_2] the whole story?

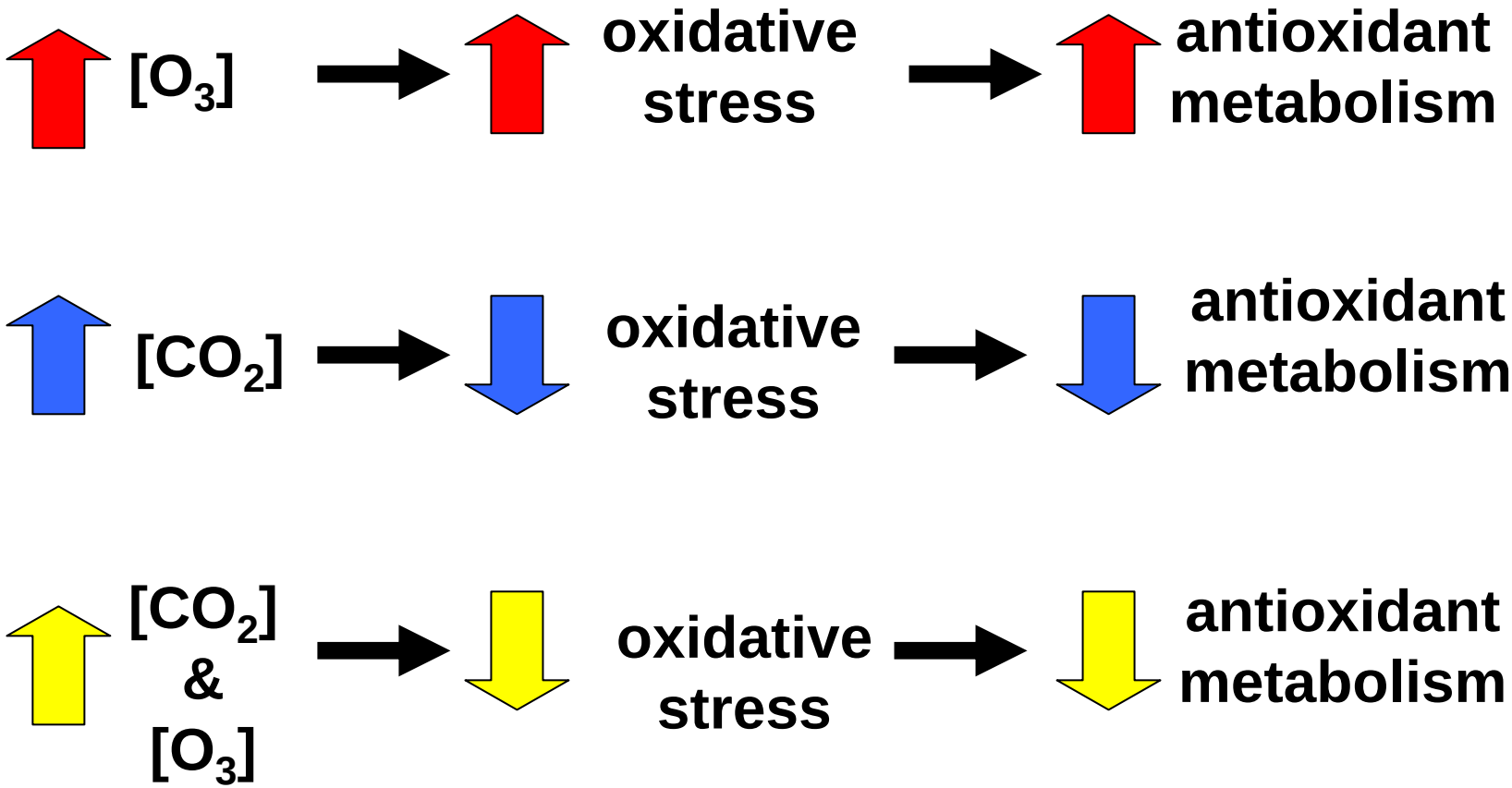


Booker & Fiscus. J. Ex. Bot. (2005)


Leaf surface
Intercellular space
CO2
PheOH
PheO + H+
O3
O3·-
O2-
H2O2
O2
H+
O2
O3·-
·OH
MDA
AsA
H2O2
aquaporin
Putative AsA transporter
Putative DHA transporter
apoplast
symplast
Cytb561
H2O2
MDA
AsA
H2O
AsA
NAD(P)H
APX
MDHAR
O2-
H2O2
MDA
NAD(P)+
SOD
CAT
O2
DHA
GSSG
NAD(P)+
DHAR
GR
AsA
GSH
NAD(P)H

Predictions

Throughout the growing season, plant antioxidant capacity will increase to balance the internal redox status that is challenged by accumulated stress.



Gas Exchange, Chlorophyll Fluorescence at midday.

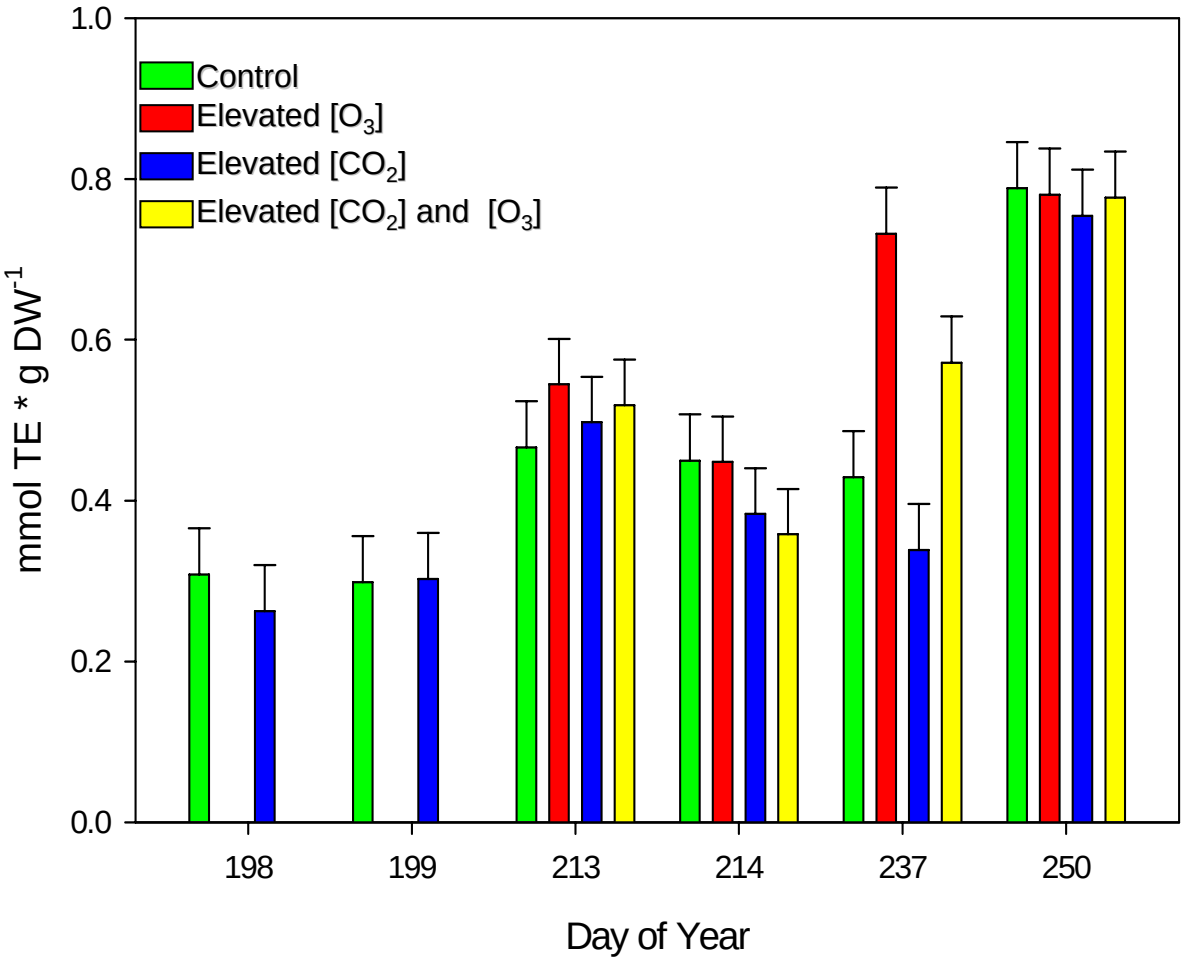
Leaf antioxidant biochemistry was assessed on samples collected at midday.

Samples were also collected to assess the activity of key antioxidant recycling enzymes

Six leaves per plot were harvested for RNA extraction and transcriptome analysis with Affymetrix gene chips.

All measurements were repeated six times throughout reproductive development

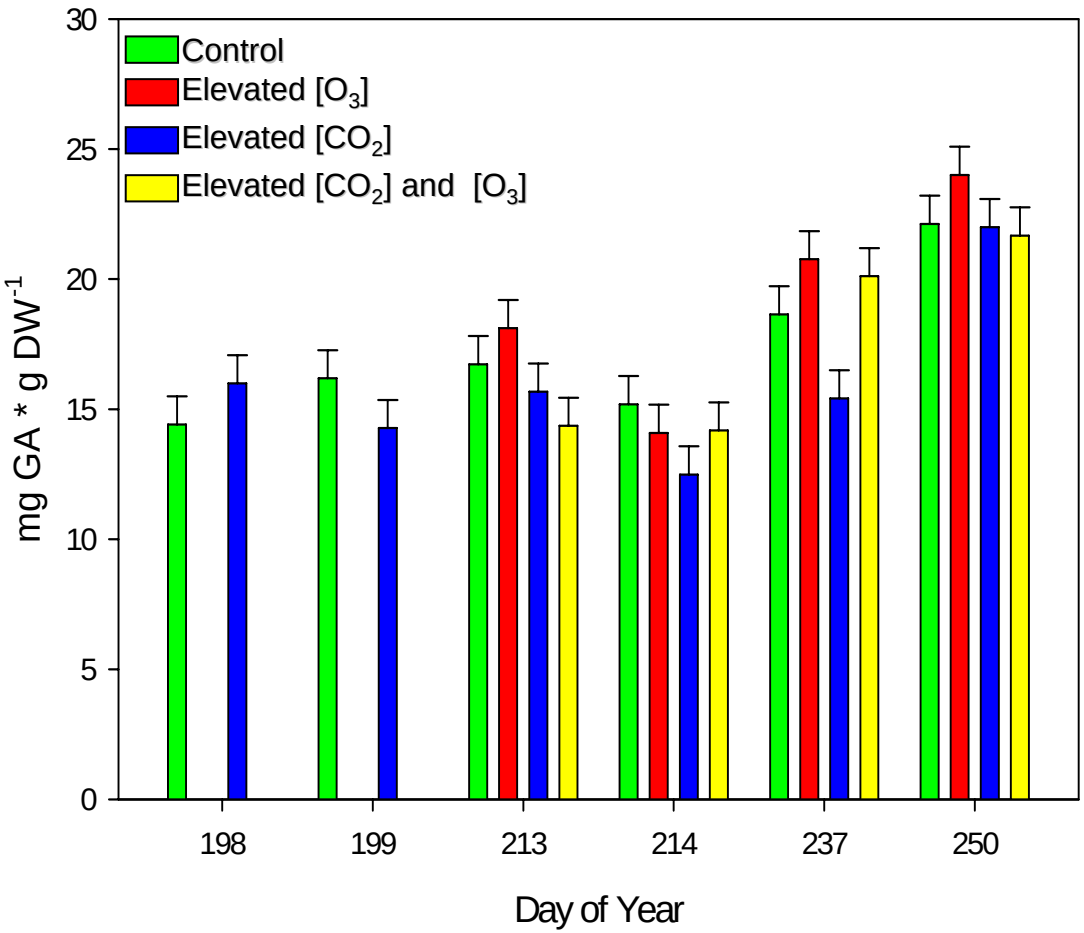
Total Antioxidant Capacity



- **Increased as plants aged (<0.0001)**
- **Lower under ele. [CO_2] (0.0988)**
- **Higher under ele. [O_3] (0.0040)**

as measured using: Gillespie, *et al.* (2007) Nature Methods

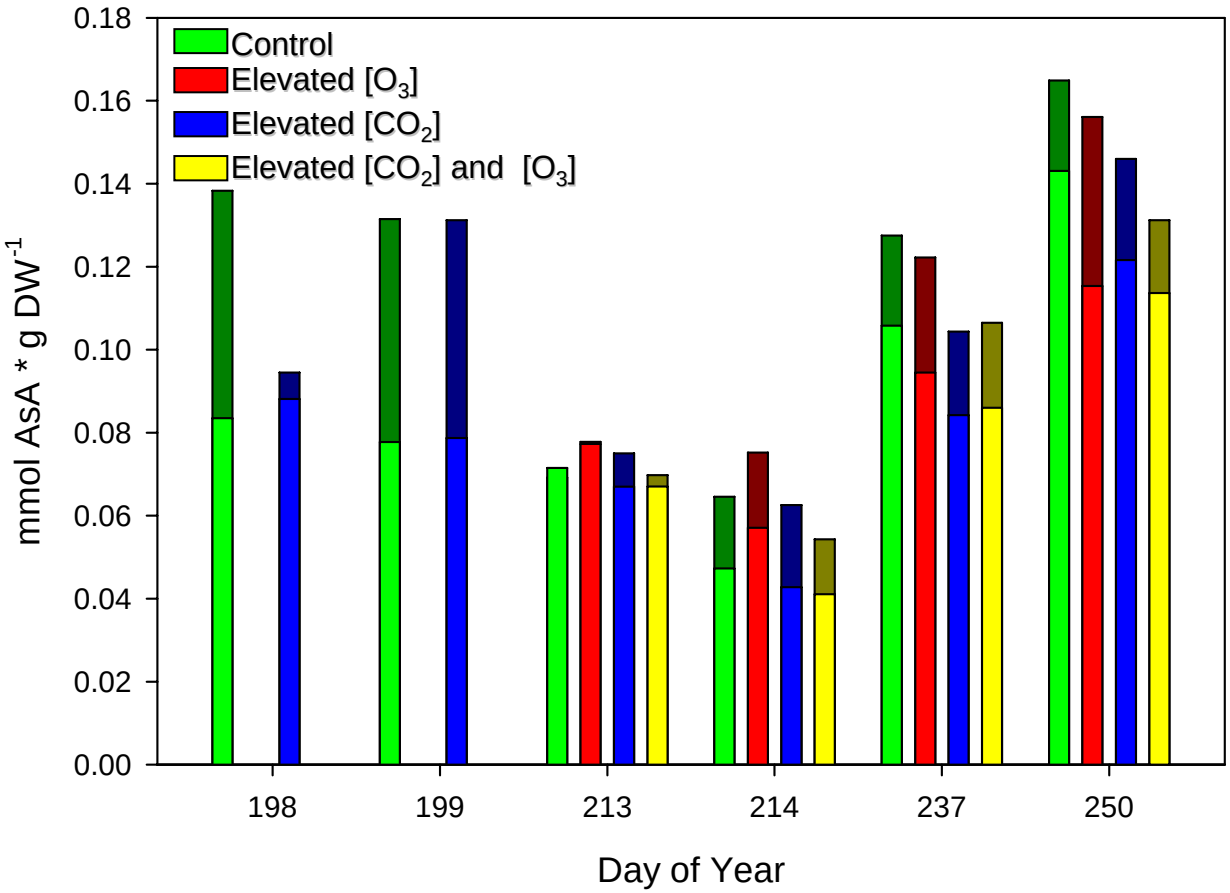
Total Phenolic Content



- **Increased as plants aged (<0.0001)**
- **Lower under elevated [CO_2] (0.0699)**
- **Higher under elevated [O_3] (0.0325)**

as measured using: Ainsworth & Gillespie (2007) Nature Methods

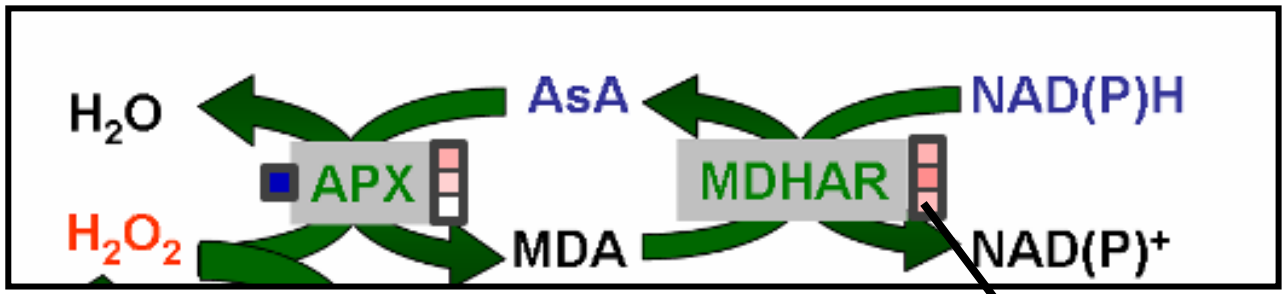
Ascorbic Acid Profile

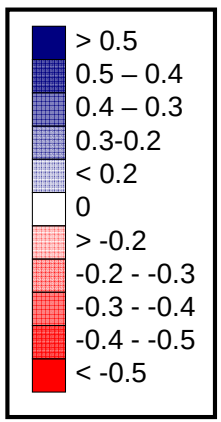


- **Total AsA increased as plants aged (<0.0001)**
- **Elevated [CO_2] increased the redox potential of the pool (0.0002)**
- **Combined elevated [CO_2] and [O_3] increased redox potential relative to elevated [O_3]**

as measured using: Gillespie & Ainsworth (2007) Nature Methods

Transcript Analysis

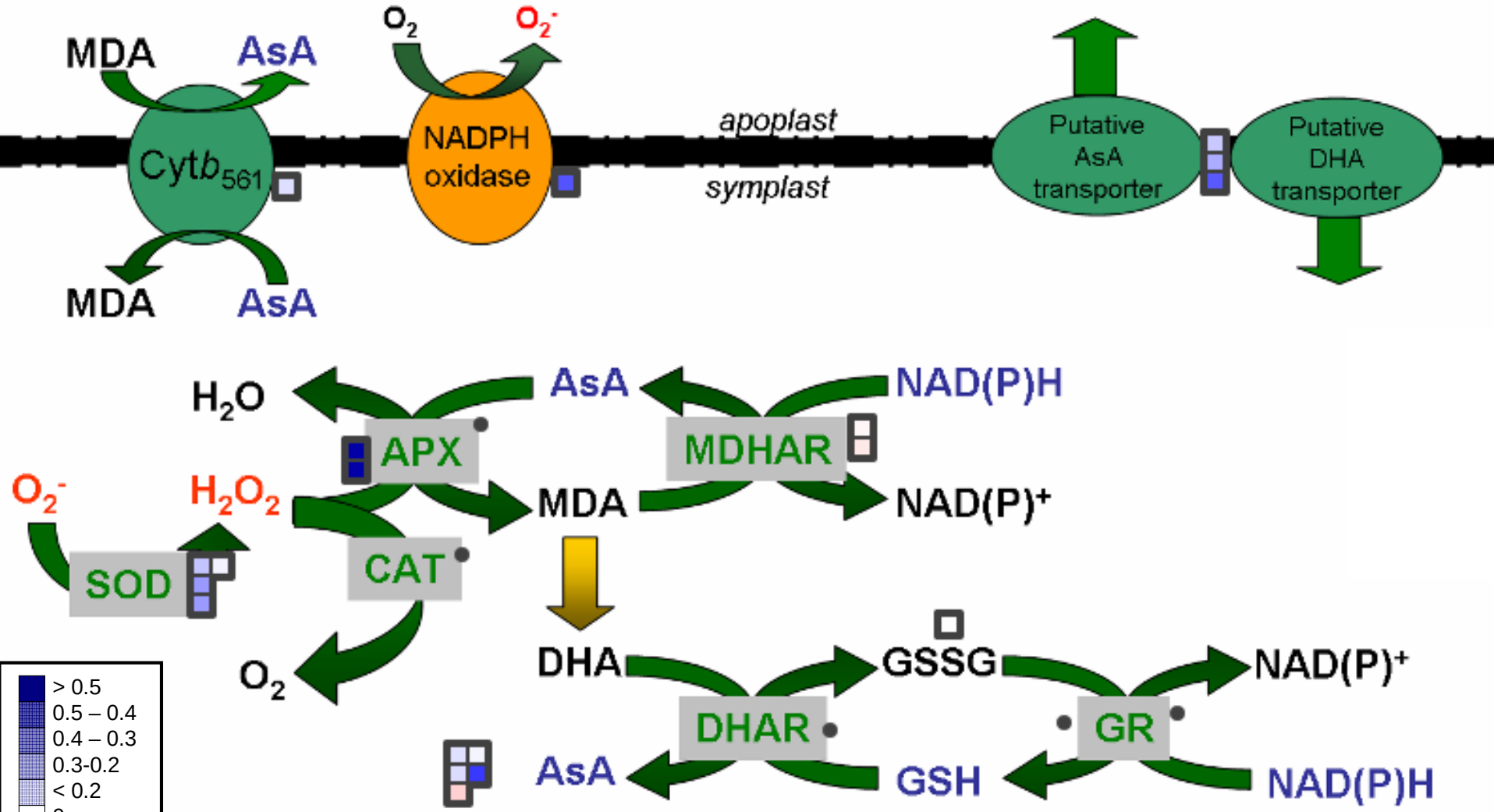


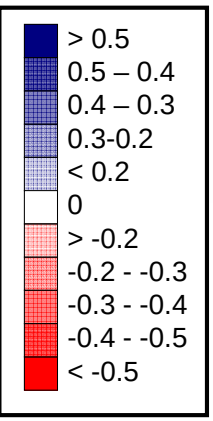


Log_2 transformed scale of significant transcripts responding to elevated [O_3] treatment compared to ambient

Each box represents one Affymetrix "probe set" or gene associated with the linked process, i.e. enzymes annotated as having monodehydroascorbate reductase activity

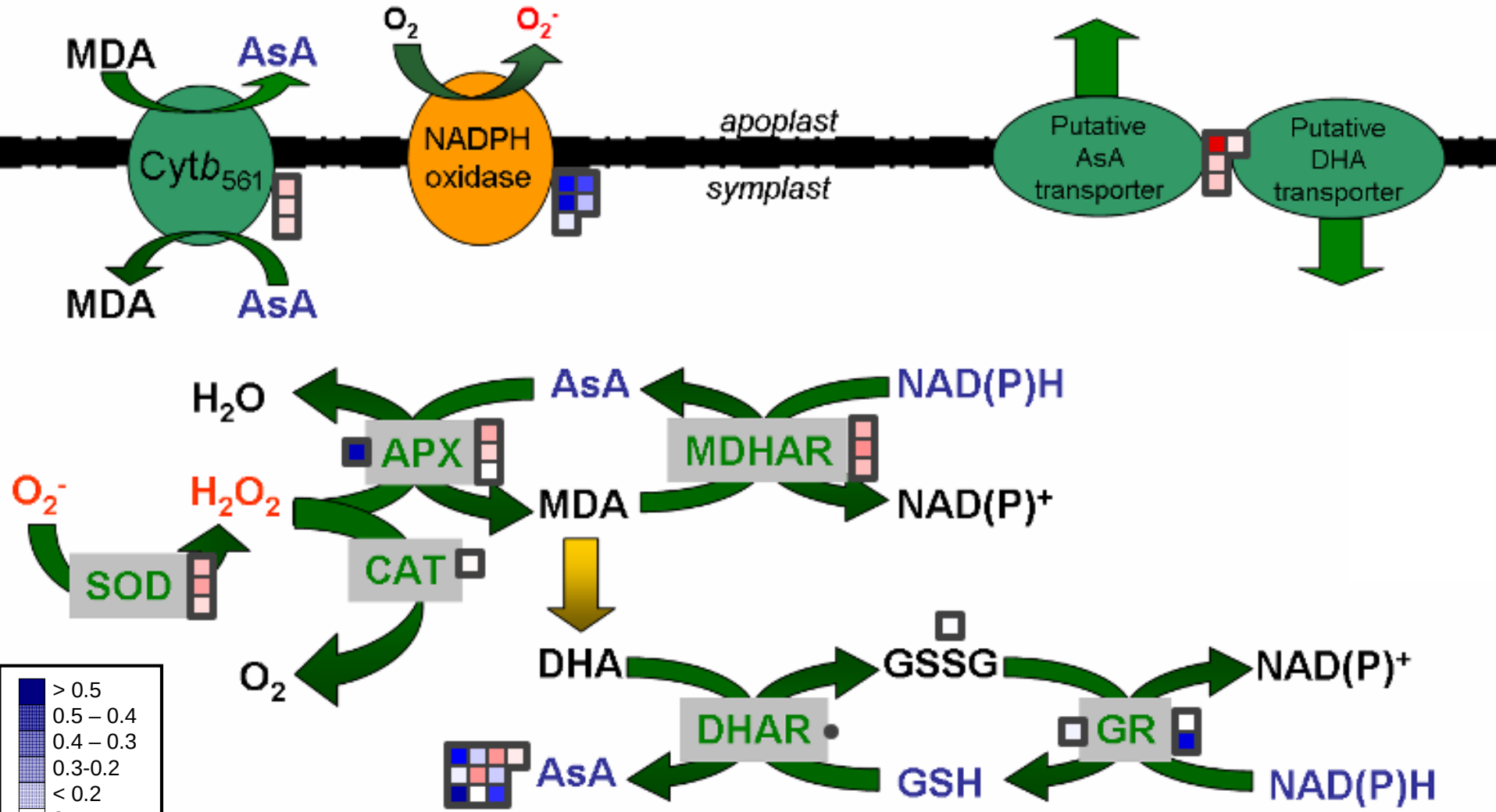
Elevated [CO_2]





Log_2 transformed scale of significant transcripts responding to elevated [CO_2] treatment compared to ambient

Elevated [O_3]



> 0.5
0.5 – 0.4
0.4 – 0.3
0.3-0.2
< 0.2
0
> -0.2
-0.2 - -0.3
-0.3 - -0.4
-0.4 - -0.5
< -0.5

Log_2 transformed scale of significant transcripts responding to elevated [O_3] treatment compared to ambient

Conclusions

- Total Antioxidant Capacity as well as ascorbate and total phenolics increases as plants age, supporting the hypothesis that oxidative stress is cumulative across plant growth

- Growth at elevated [CO_2] decreased both total antioxidant capacity and total phenolics, but improved redox status of the ascorbate pool and increased transcript abundance for the recycling enzymes suggests a faster turn over of the reducing capacity

- Growth at elevated [O_3] increased both total antioxidant capacity and total phenolics but lowered transcript abundance of the recycling enzymes

- Growth at the combination of elevated [CO_2] and [O_3] only caused an improvement of the redox status of the ascorbate pool compared to growth at elevated [O_3] alone suggesting some minor enhancement in defense mechanisms due to elevated [CO_2]

Thank you

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