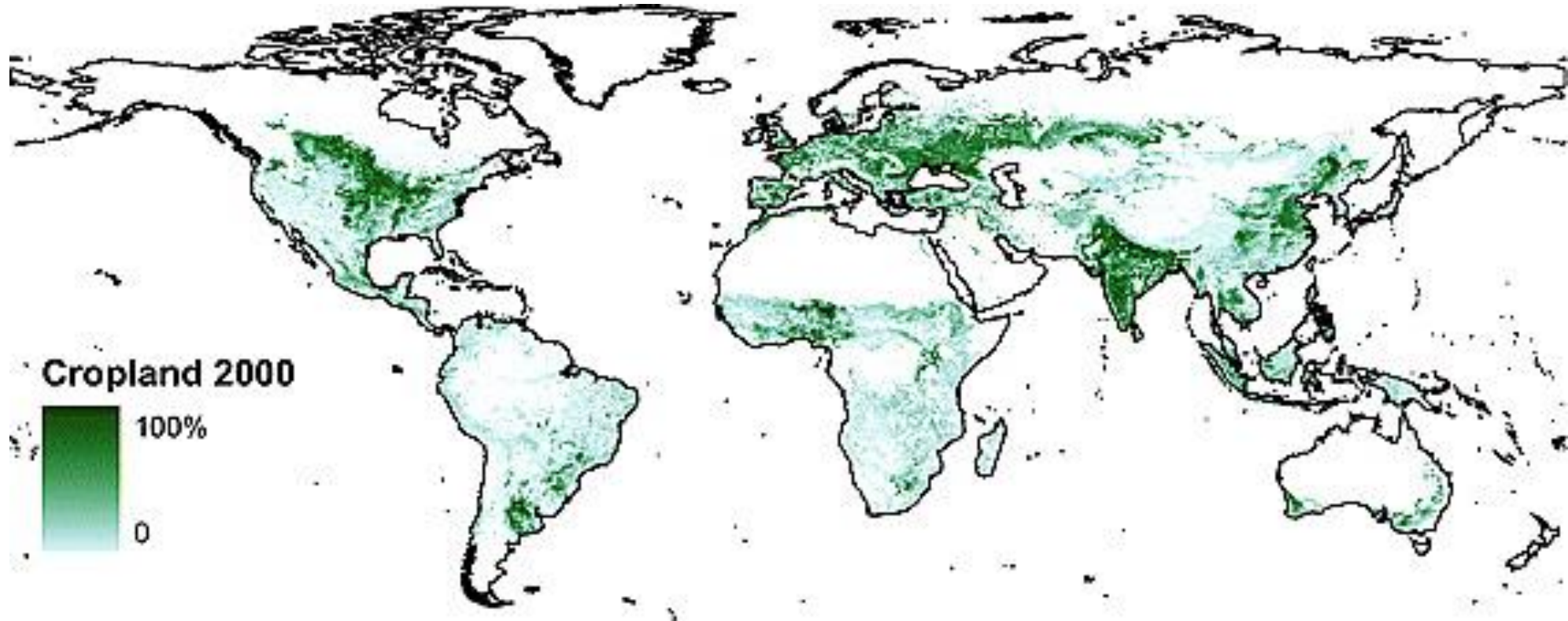


# Ozone: an invisible threat to food security

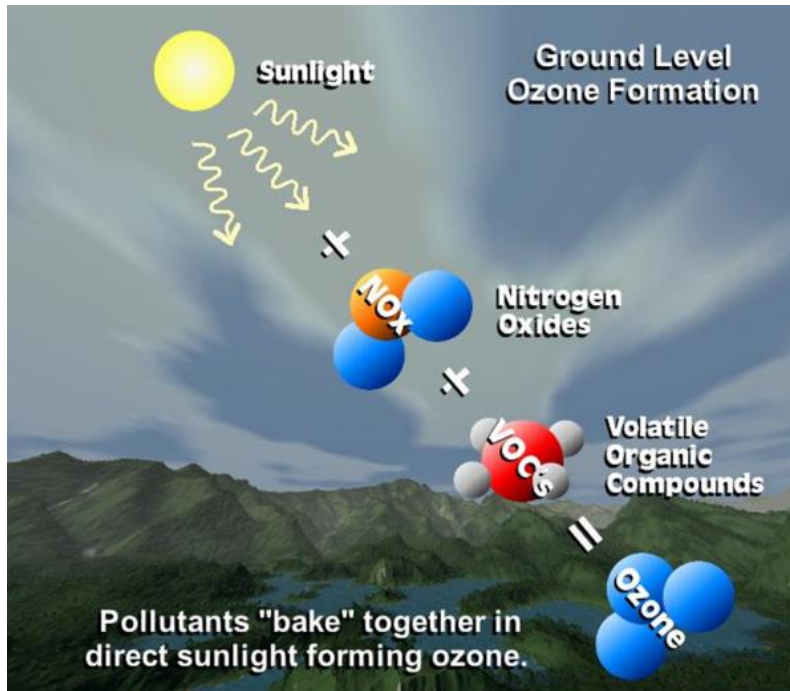
Felix Leung

Department of Geography, The University of Exeter, UK

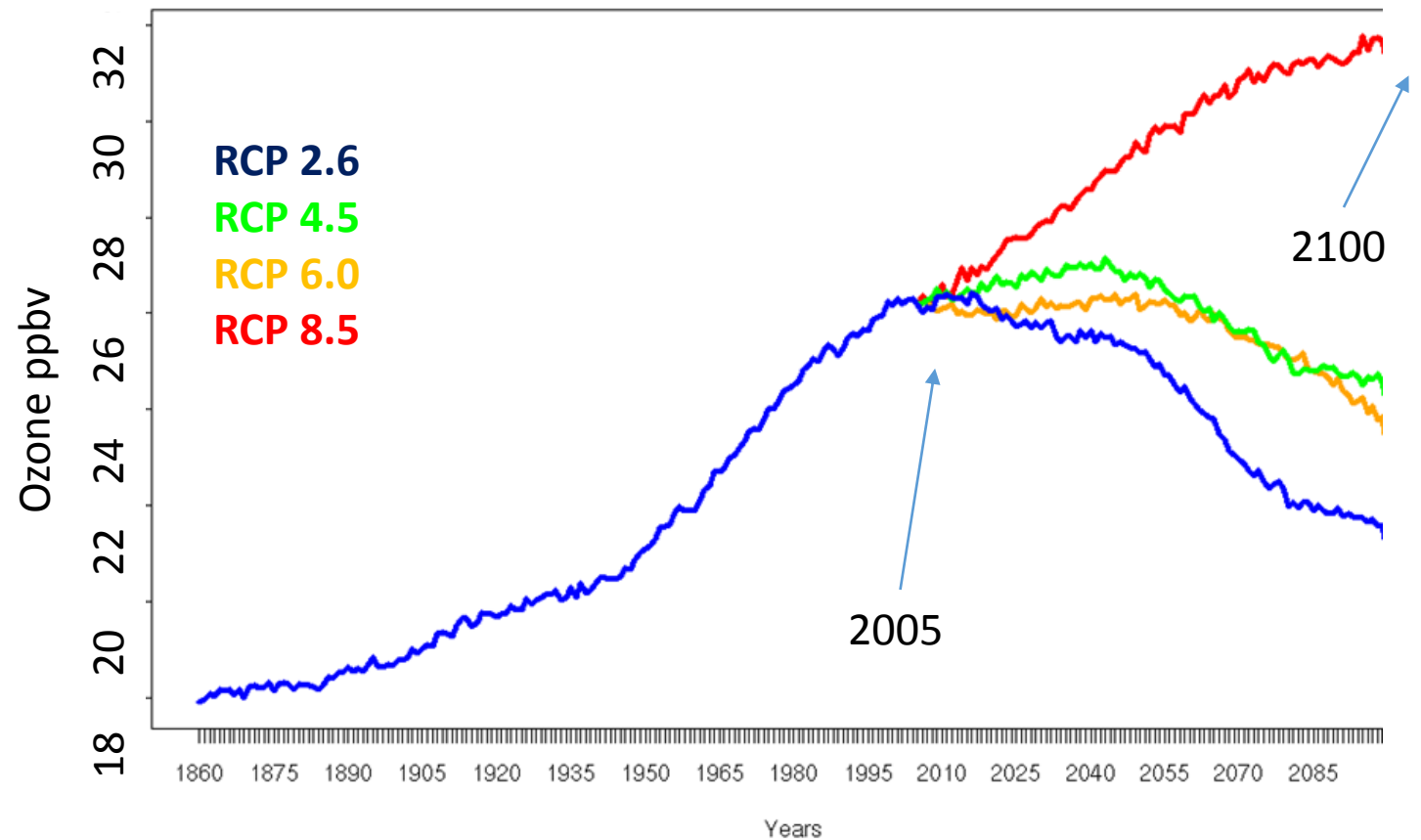
Supervisors: **Met Office:** Dr. Andy Wiltshire, Dr. Jemma Gornall      **University of Exeter:** Prof. Stephen Sitch, Prof. Peter Cox



# Ozone production and trend



Representative Concentration Pathway (RCPs) of tropospheric ozone trajectories



Ozone production and trend

Effect of ozone on plants

JULES-crop

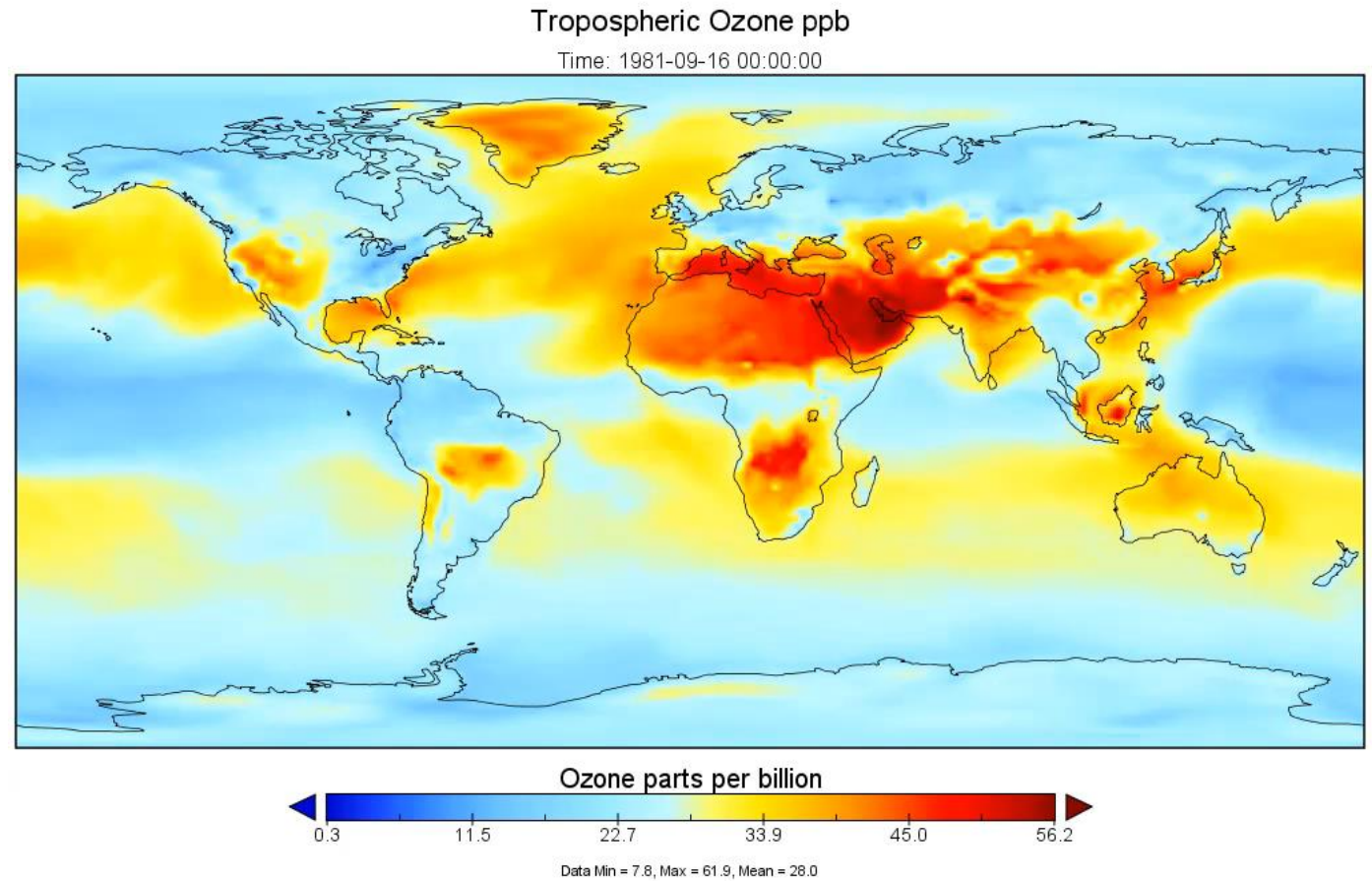
SoyFACE project

Calibration

Key Findings

# Spatial and temporal scale of tropospheric ozone

Hadley Centre Global  
Environmental Model 2-  
Earth System  
1950-2005 Historical ozone  
distribution



Ozone production  
and trend

Effect of ozone on  
plants

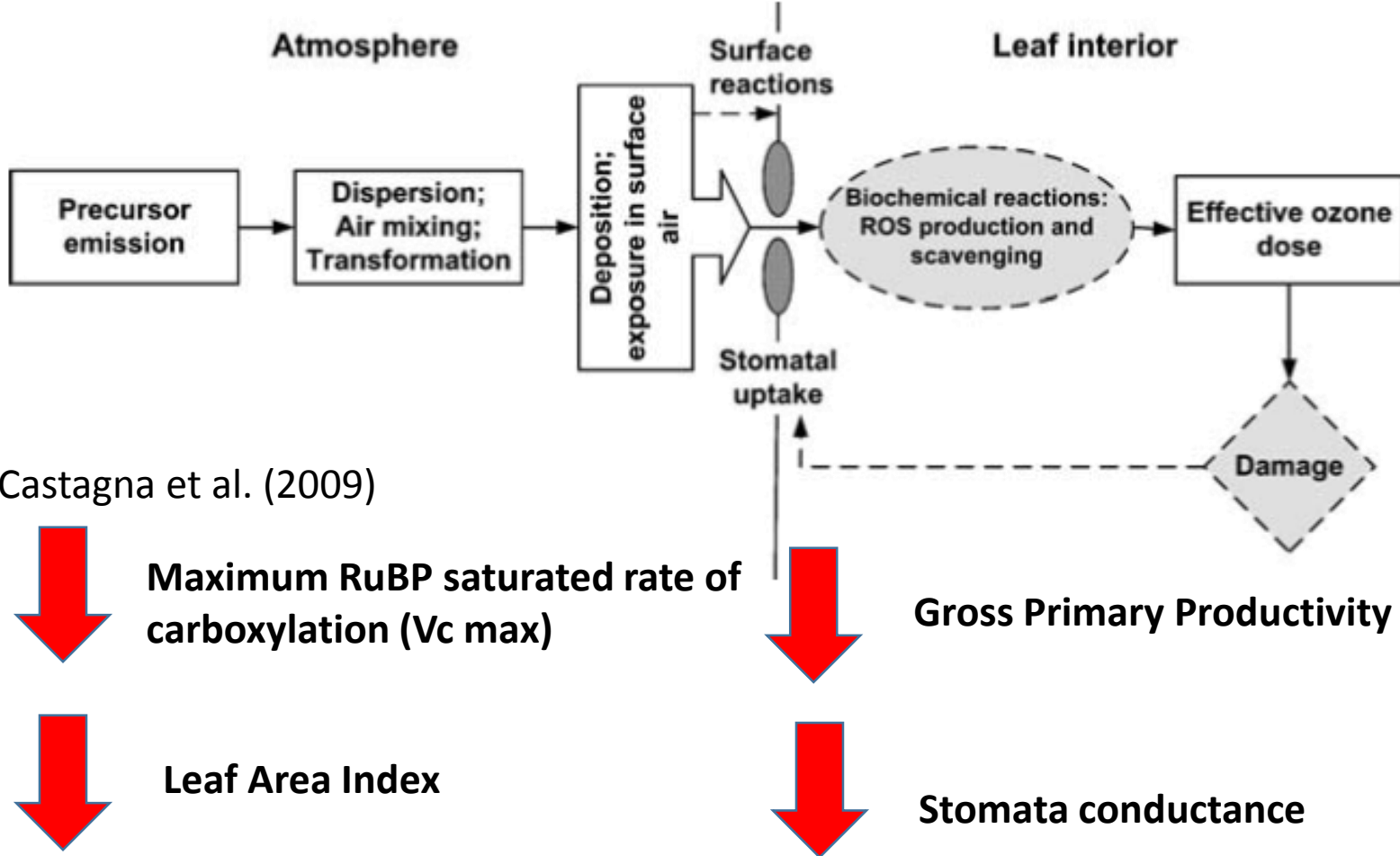
JULES-crop

SoyFACE project

Calibration

Key Findings

# Biochemical effect of ozone on plant



Fitzgerald Booker

# Effect of Ozone on Net Primary Productivity

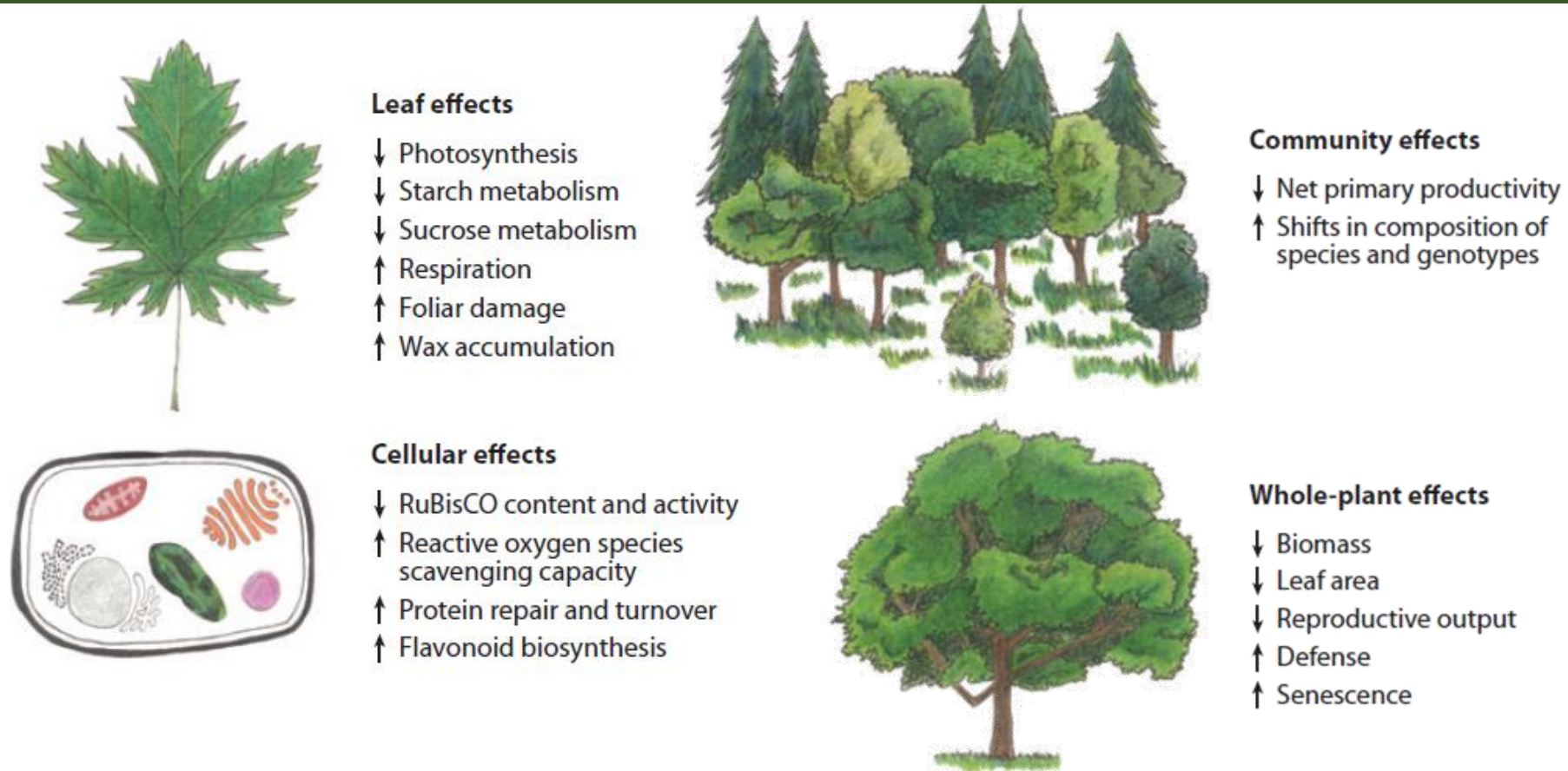


Diagram: Ainsworth et al. (2012). *The effects of tropospheric ozone on NPP and implications for Climate Change*

Ozone production and trend

Effect of ozone on plants

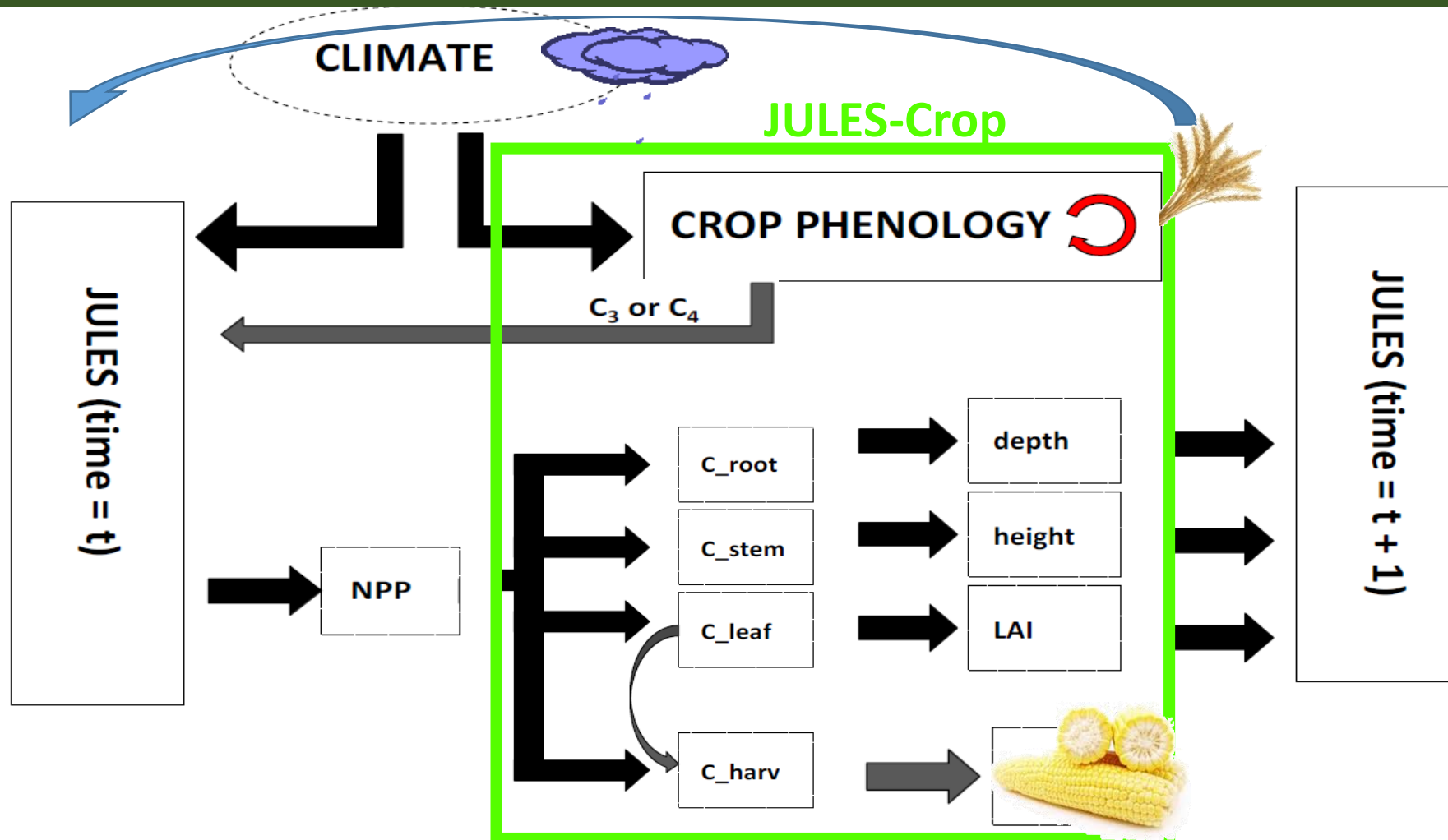
JULES-crop

SoyFACE project

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Key Findings

# JULES-Crop



Ozone production and trend

Effect of ozone on plants

JULES-crop

SoyFACE project

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Key Findings

# Joint UK Land Environment Simulator (JULES)-Crop

- Cropland and pasture represent 12% and 26% of land surface
- 5 normal plant functional types
- C3 and C4 crops
- Different day sensitivity and growth rate.
- Simulate farm-level productivity
- 4 Crop functional types
- Variables associated with climate change e.g. drought, flood, rising temperature



Ozone production  
and trend

Effect of ozone on  
plants

JULES-crop

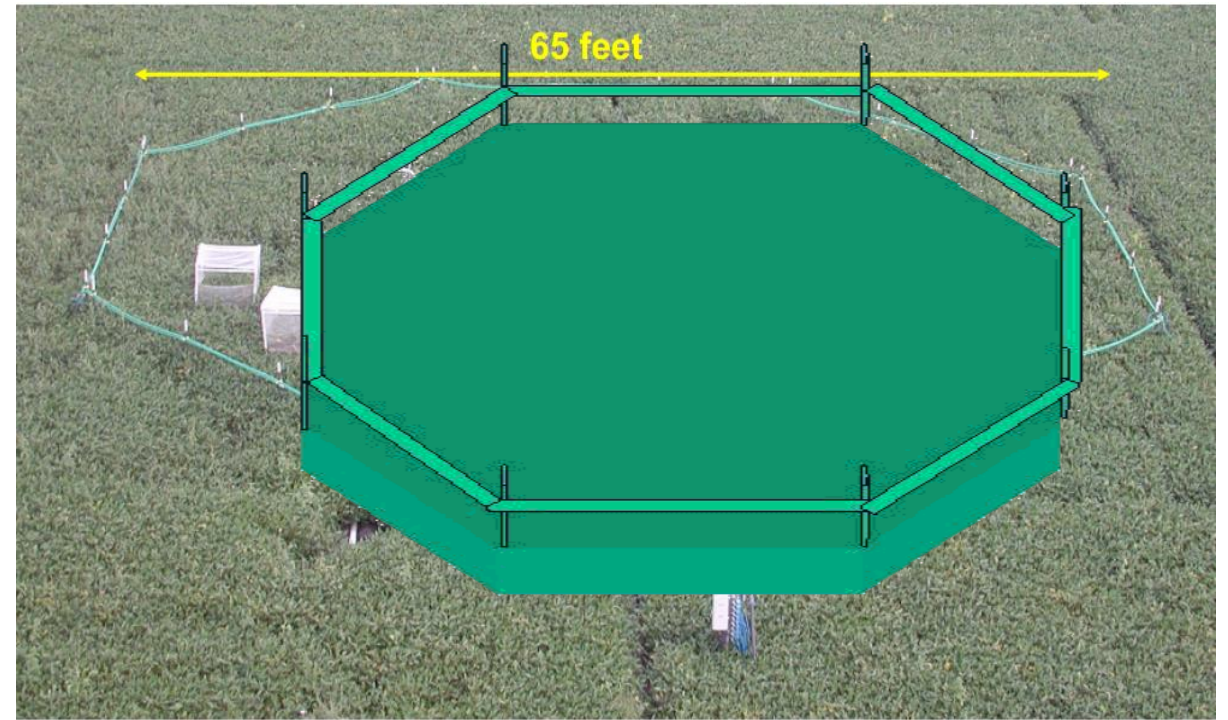
SoyFACE project

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Key Findings

# SoyFACE project

- O<sub>3</sub> Free Air CO<sub>2</sub> Enrichment (FACE-O<sub>3</sub>) on soybean at Illinois, USA
- Chamber environment modifies plant response and underestimate the yield losses.
- SoyFACE allows controlled CO<sub>2</sub> and O<sub>3</sub> enrichment to simulate different RCPs in 2100.
- 20m diameter
- Fumigate 9 hours per day
- Stop fumigation if the leaves are wet



Ozone production  
and trend

Effect of ozone on  
plants

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# Vc max calibration

Sources	Description	Vc max	Unit
Kattge et al. (TRY database , accessed on 12/05/2015)	Average of all literatures with soybean Vc max	121.89	$\mu \text{ mol m}^{-2} \text{ s}^{-1}$
Betzberger et al.	SoyFACE measurement	120	$\mu \text{ mol m}^{-2} \text{ s}^{-1}$
JULES C3 grass	Used as soybean by default	58.4	$\mu \text{ mol m}^{-2} \text{ s}^{-1}$

Ozone production and trend

Effect of ozone on plants

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# Soybean parameters calibration

JULES Parameters	Default	Tuned
Top leaf nitrogen concentration (kg N/kg C)	0.073	0.13
Scale factor of top leaf nitrogen to $V_{c_{max}}$	0.0008	0.001
Ratio of root N to leaf N	1.0	0.1
Ratio of stem N to leaf N	1.0	0.1
Fractional reduction of photosynthesis by $O_3$ (sensitivity) ( $\text{mmol m}^{-2}$ )	1.40	0.825
Threshold of ozone flux ( $\text{mmol m}^{-2} \text{s}^{-1}$ )	5.0	4.0

Ozone production  
and trend

Effect of ozone on  
plants

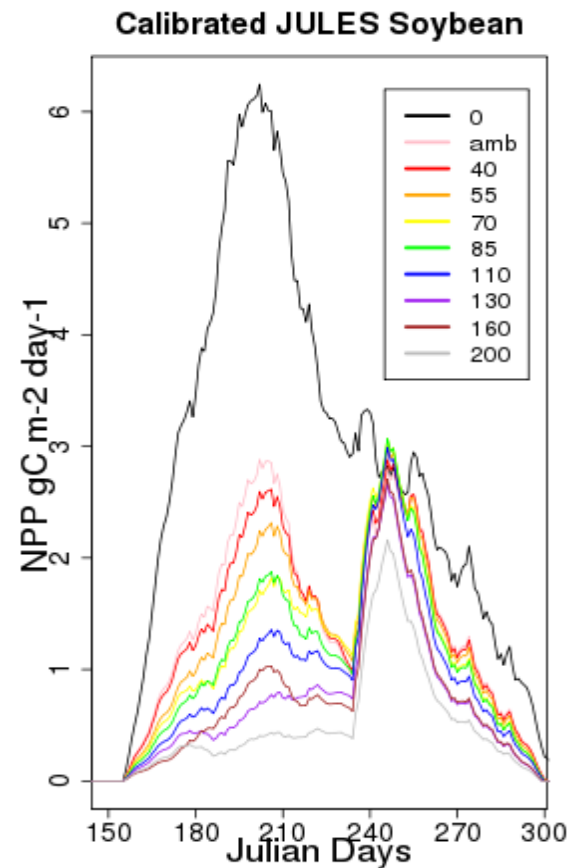
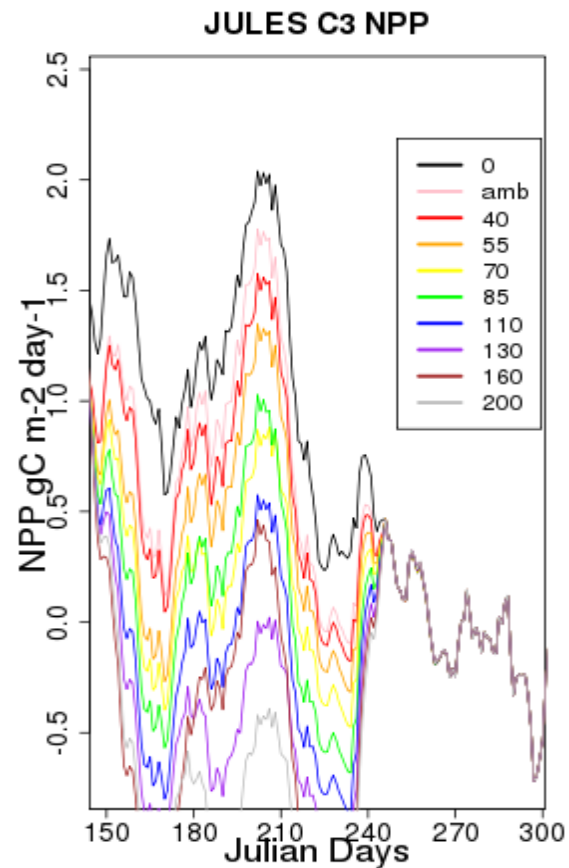
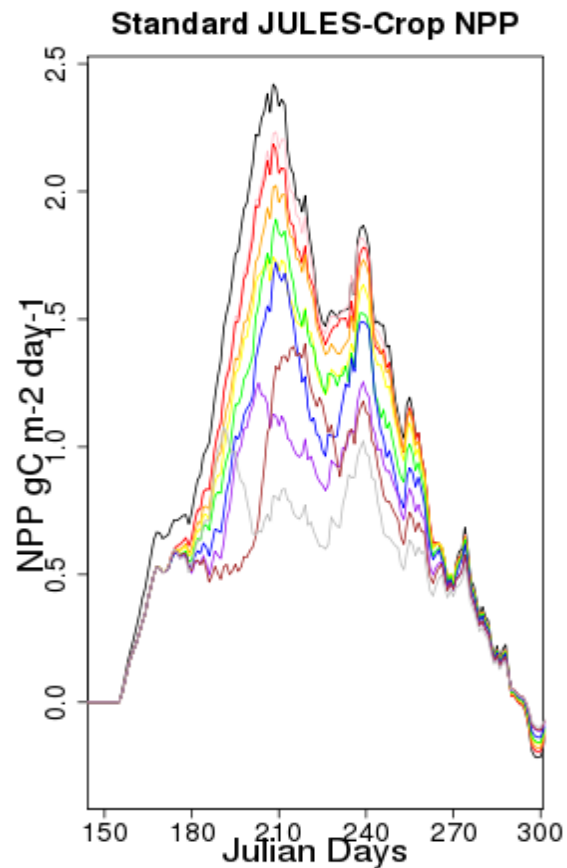
JULES-crop

SoyFACE project

Calibration

Key Findings

# Soybean parameters calibration



Ozone production and trend

Effect of ozone on plants

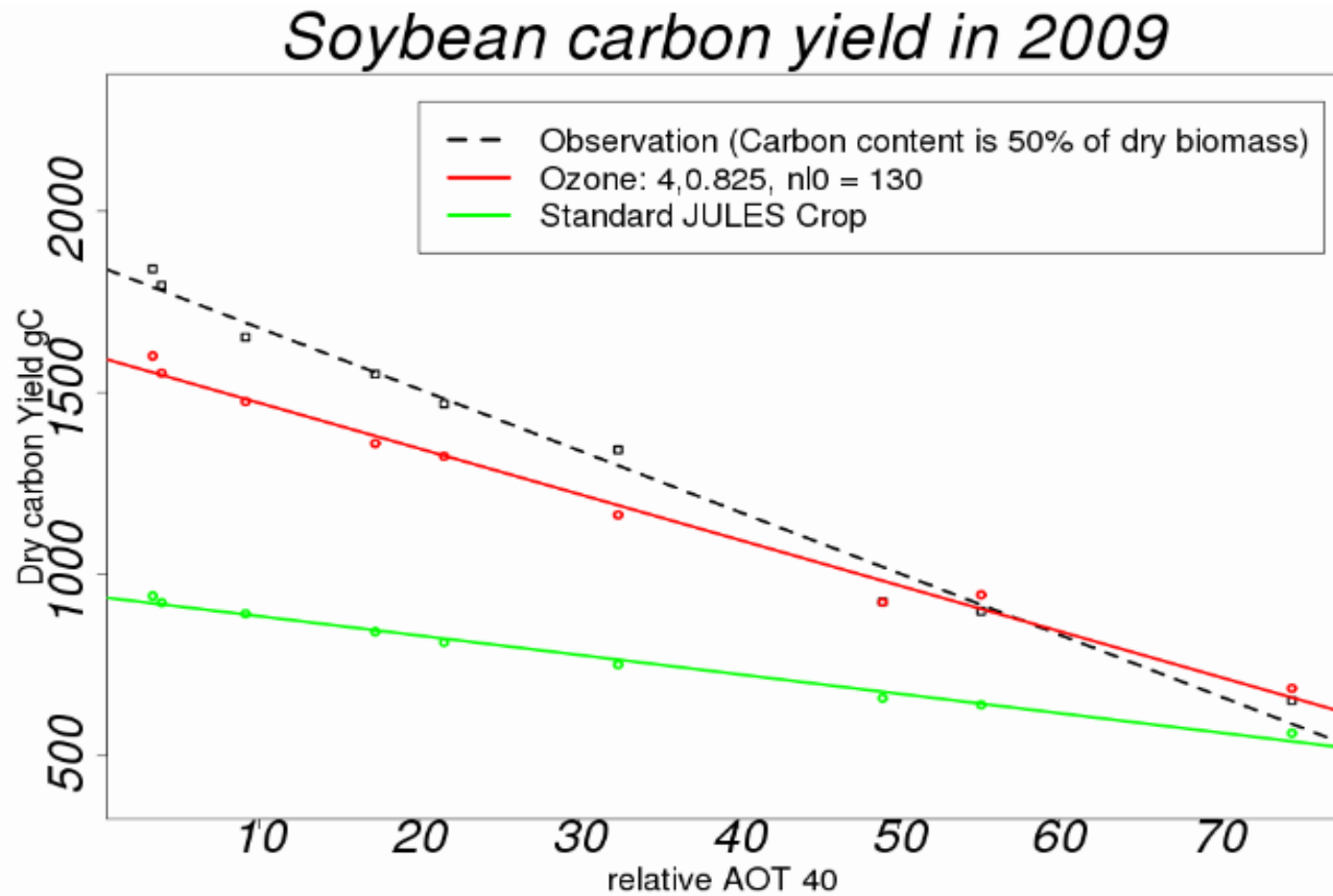
JULES-crop

SoyFACE project

Calibration

Key Findings

# Ozone - yield response calibration



Ozone production and trend

Effect of ozone on plants

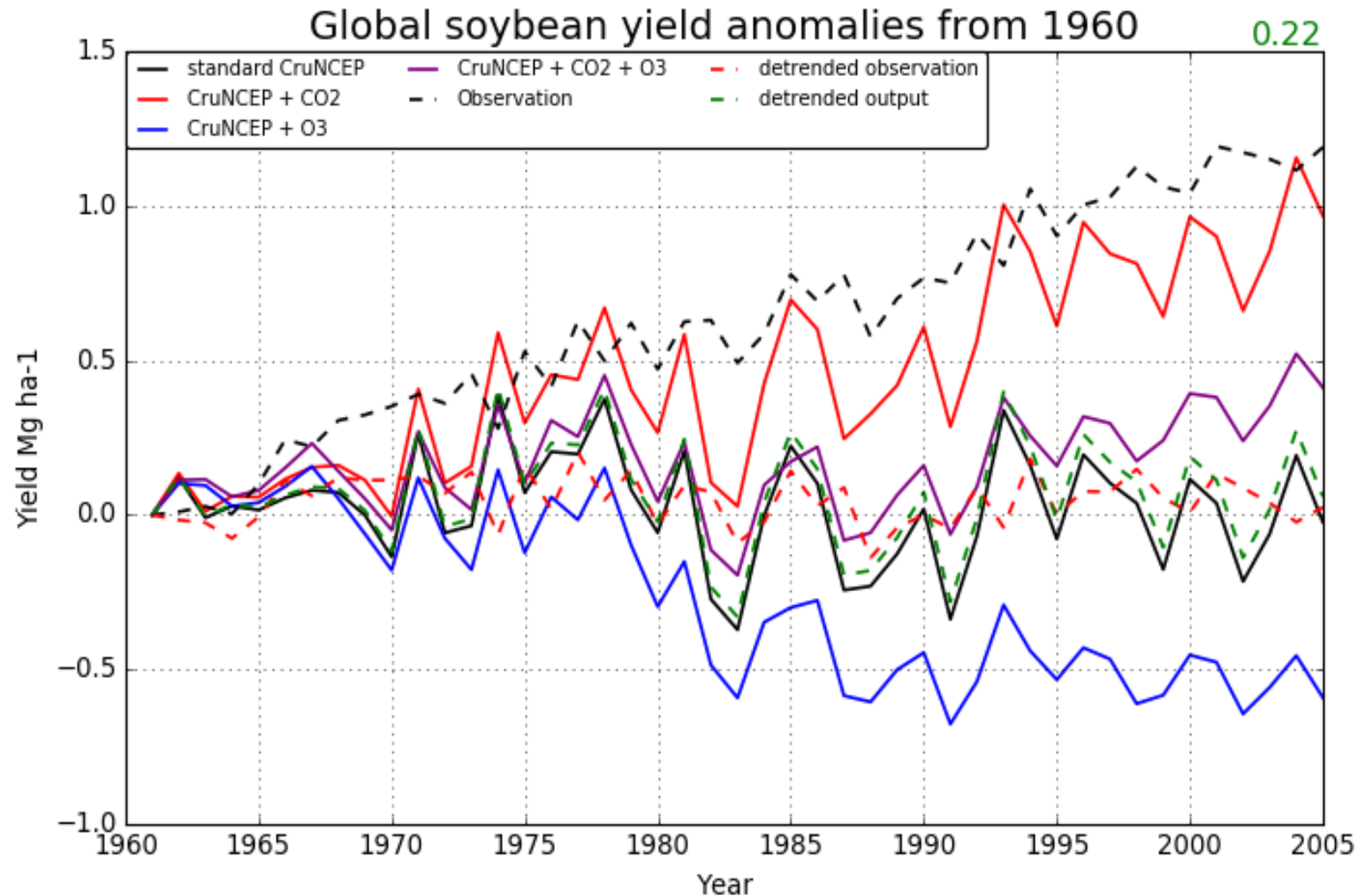
JULES-crop

SoyFACE project

Calibration

Key Findings

# Historical soybean yield change



Ozone production  
and trend

Effect of ozone on  
plants

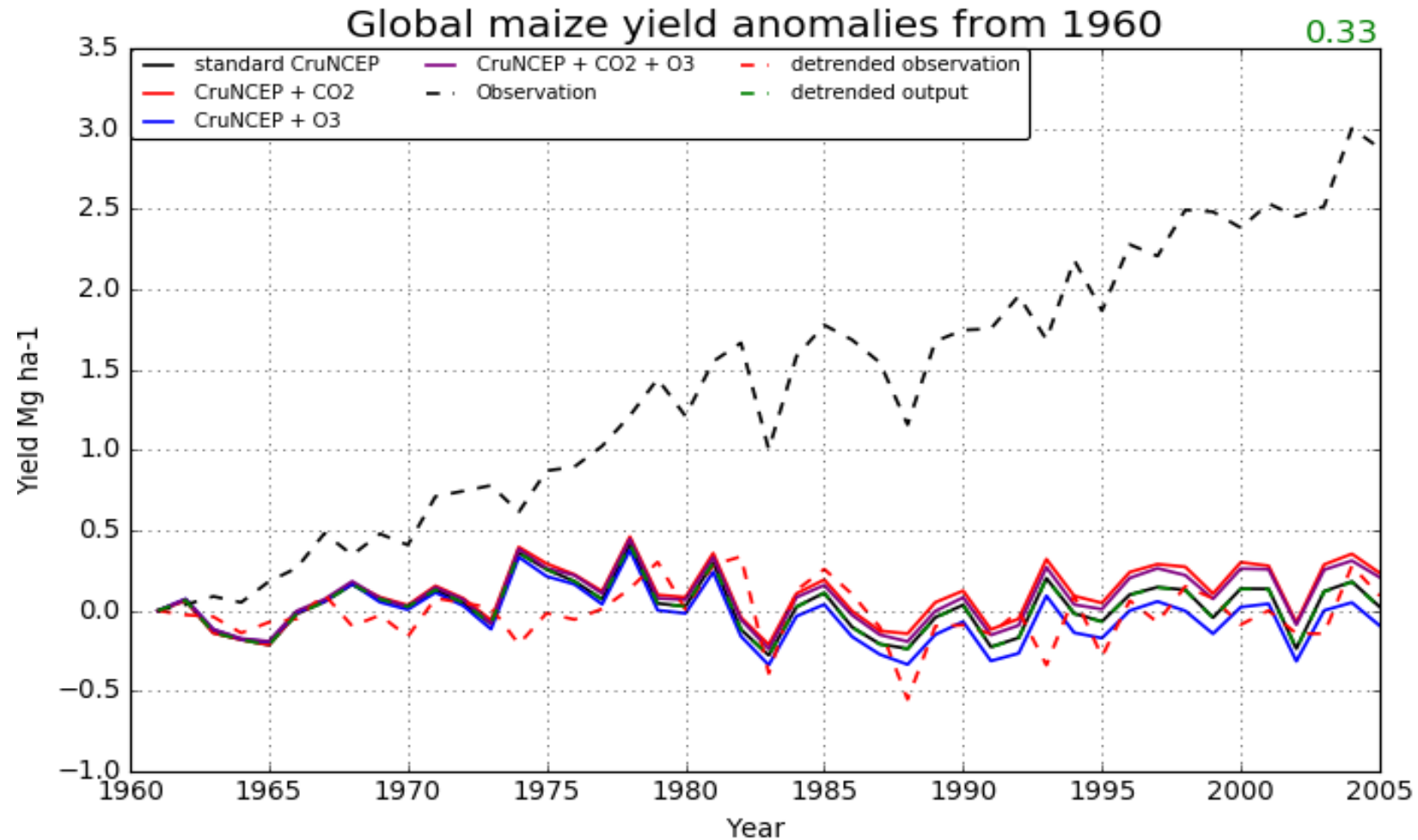
JULES-crop

SoyFACE project

Calibration

Key Findings

# Historical maize yield change



Ozone production and trend

Spatial distribution of ozone

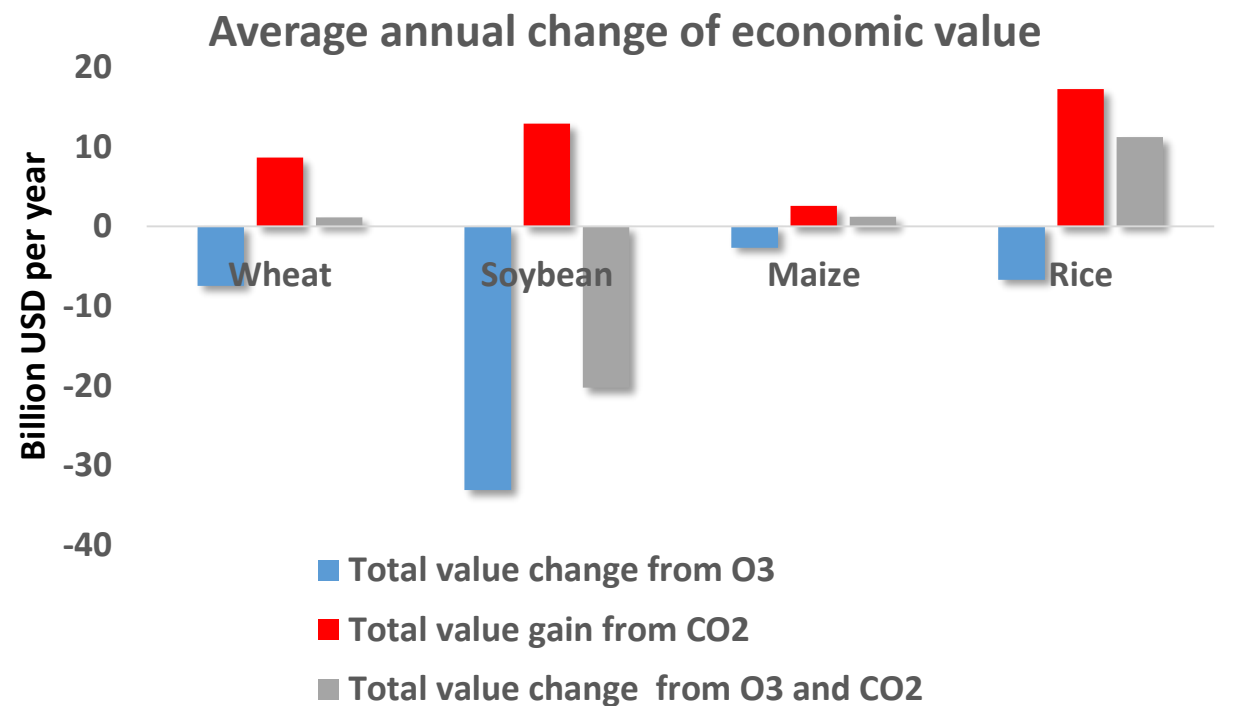
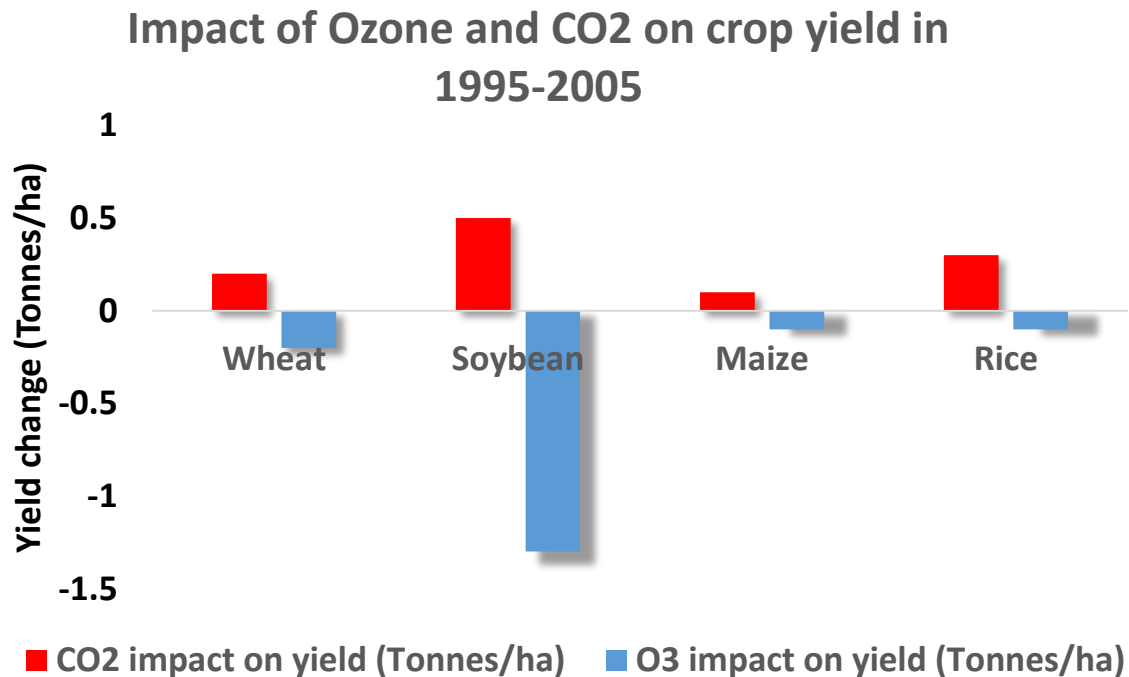
Effect of ozone on plants

JULES-crop

SoyFACE project

Key Findings

# Global economic impact of O<sub>3</sub> and CO<sub>2</sub>



Economic value of crop is taken from FAO statistic using data from 1991-2005. Harvested area from FAO was multiplied with the model yield output

Ozone production and trend

Effect of ozone on plants

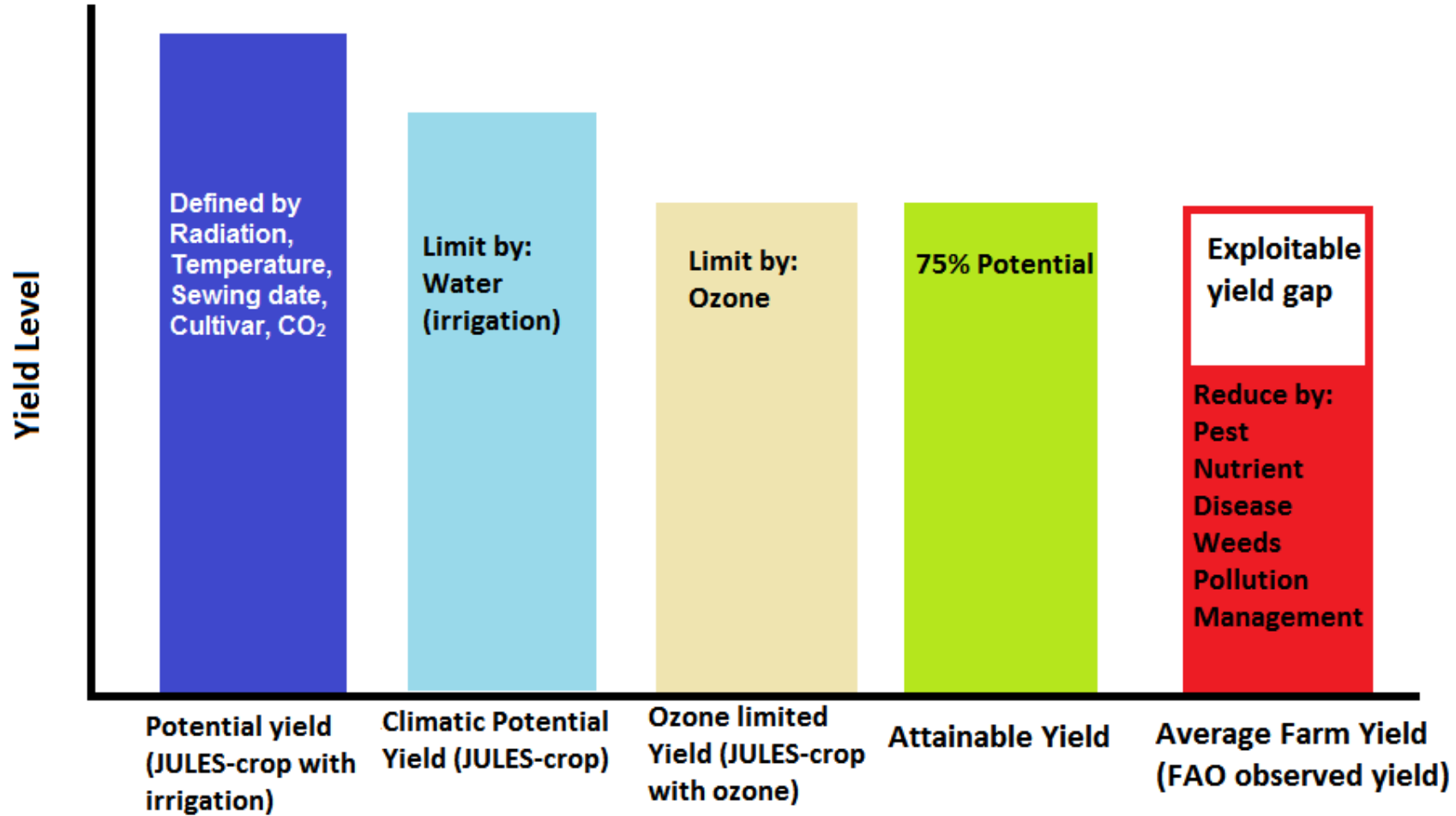
JULES-crop

SoyFACE project

Calibration

Key Findings

# Yield gap



Ozone production and trend

Effect of ozone on plants

JULES-crop

SoyFACE project

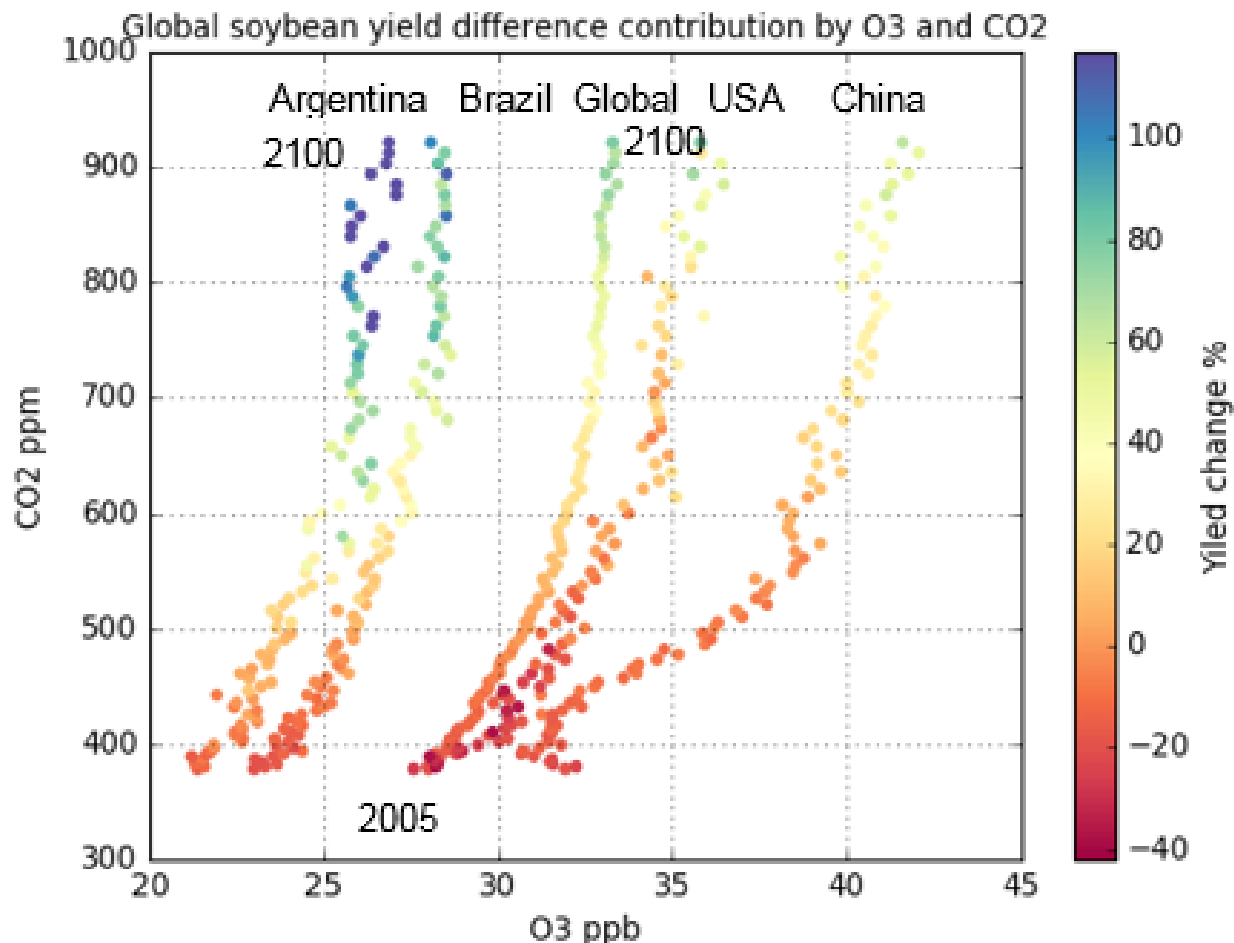
Calibration

Key Findings

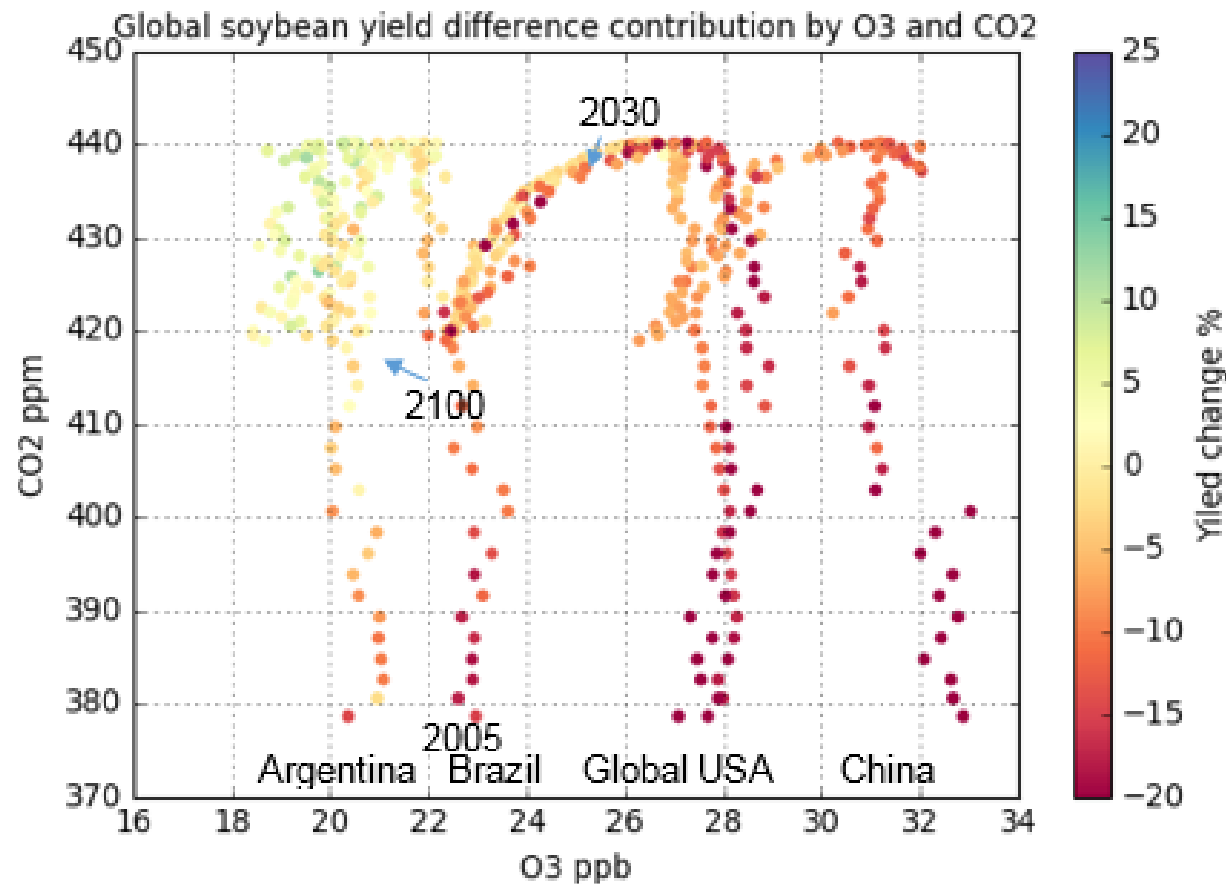


# Future soybean yield

## RCP 8.5



## RCP 2.6



Ozone production and trend

Effect of ozone on plants

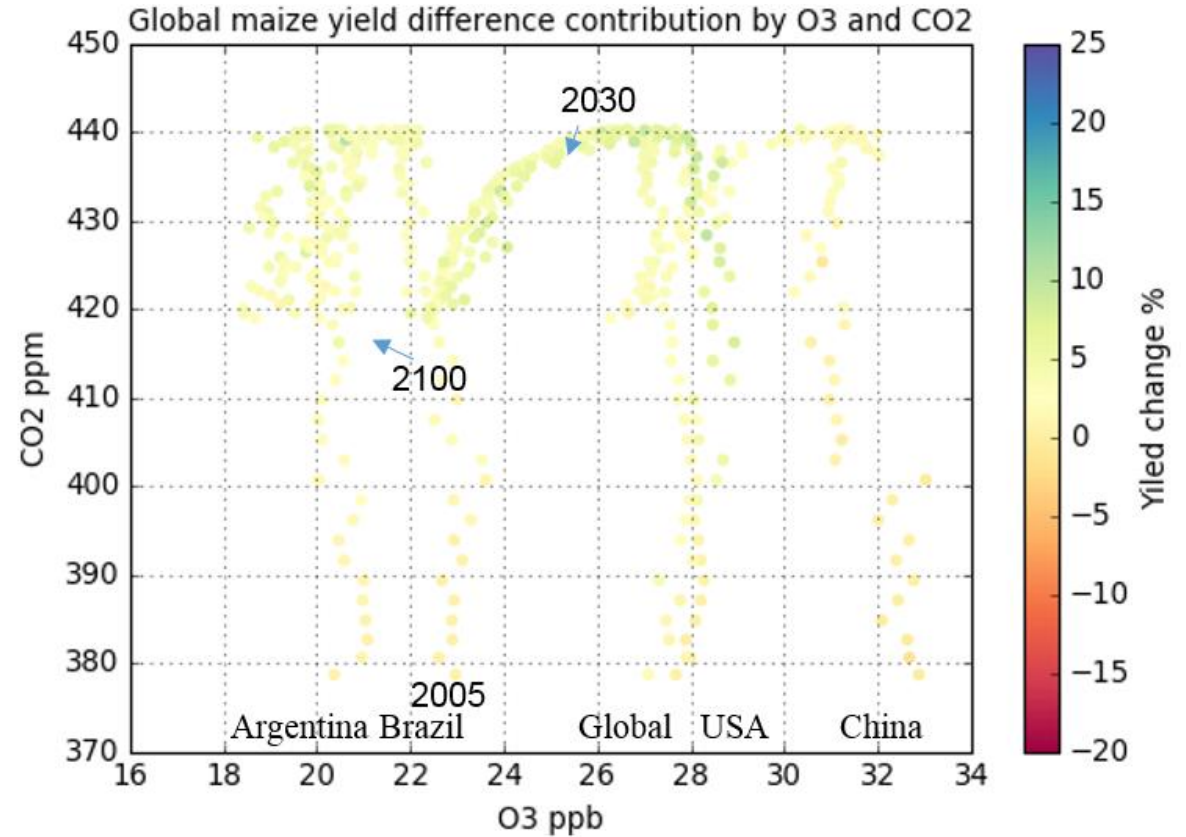
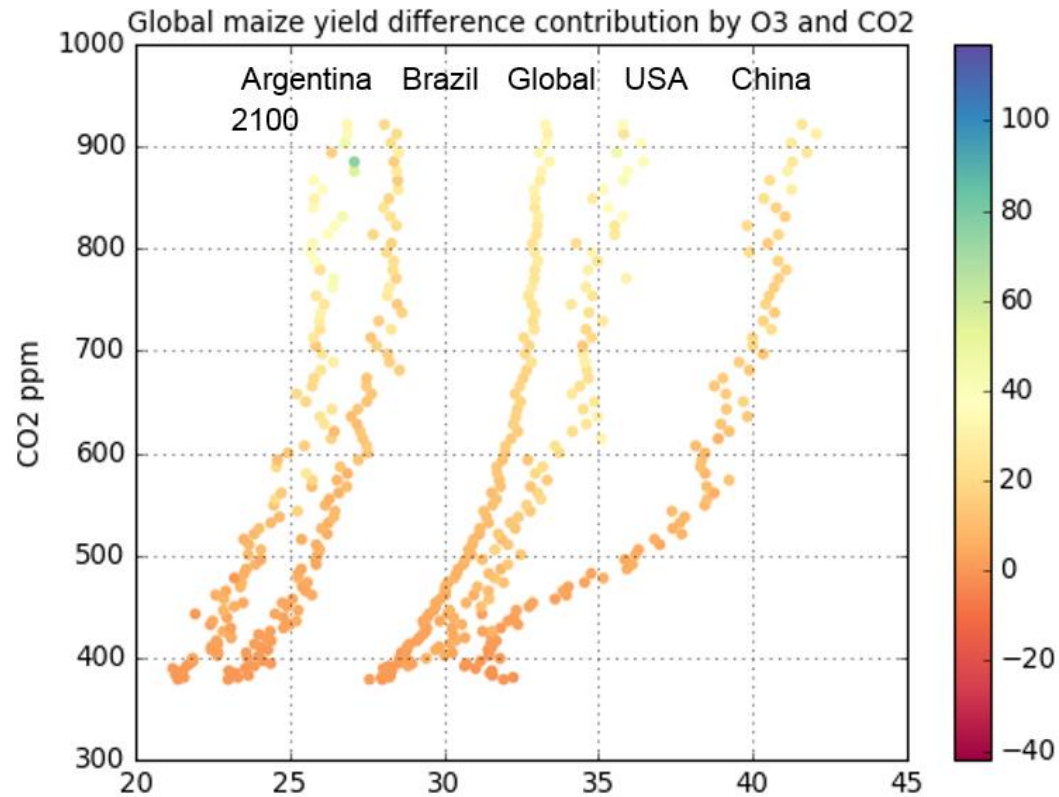
JULES-crop

SoyFACE project

Calibration

Key Findings

# Future maize yield



Ozone production and trend

Effect of ozone on plants

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SoyFACE project

Calibration

Key Findings