Metrics for evaluating the agricultural impacts of BC and CH_4 interventions.

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What do we mean by ‘Metrics’

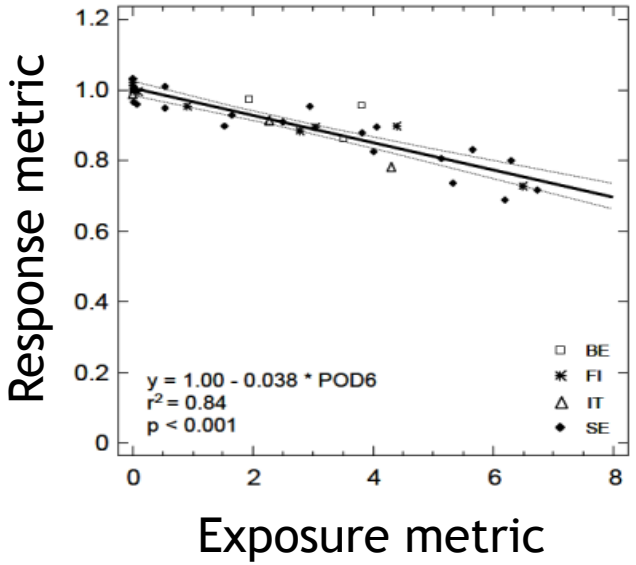
‘Emissions’ — e.g. Mt CH_4/year

‘Exposure’ metrics — e.g. 7 hour mean O_3 concentration / growing season

‘Response’ metrics — e.g. % yield loss

‘Valuation’ metrics — e.g. US $ production loss / year

Dose-Response (DR) function



Is it possible to directly relate 'emissions' to 'valuation' metrics?

'Emissions'

e.g. Mt CH_4/year

'Exposure' metrics

...mean O_3 ...ation / ...ing season

'Respons...

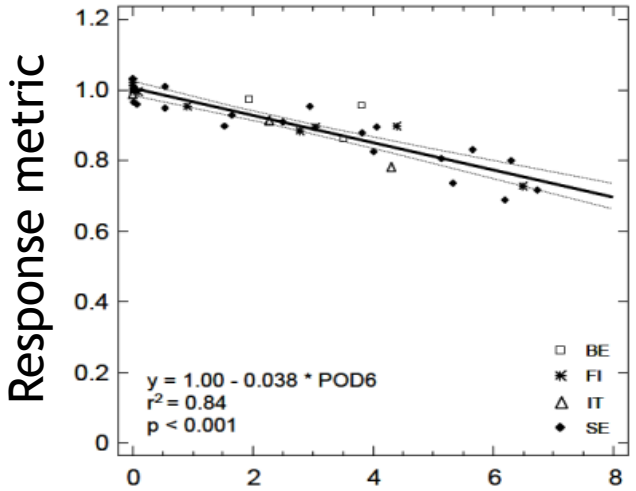
e.g. % yield loss

'Val...tion' metrics

e.g. US $ production loss / year

Only if relationship across other metrics is linear

Dose-Response (DR) function



How will SLCPs contribute to agricultural damage/change?

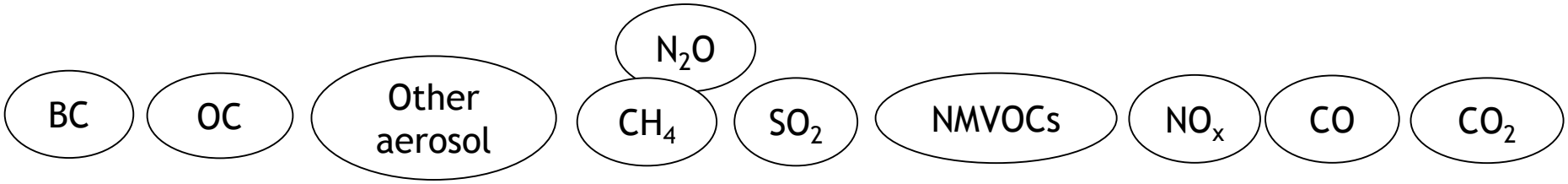
Ozone (O_3)
- crop biomass and yield
- forage quality
- soil carbon

Aerosol
- plant biomass and yield through changes in radiation (Photosynthetically Active Radiation - PAR)
- plant biomass and yield through toxicity and blocking of stomates for gas exchange

Regional climate change
- crop biomass and yield
- CO_2 fertilization effect

How might SLCP interventions affect agriculture

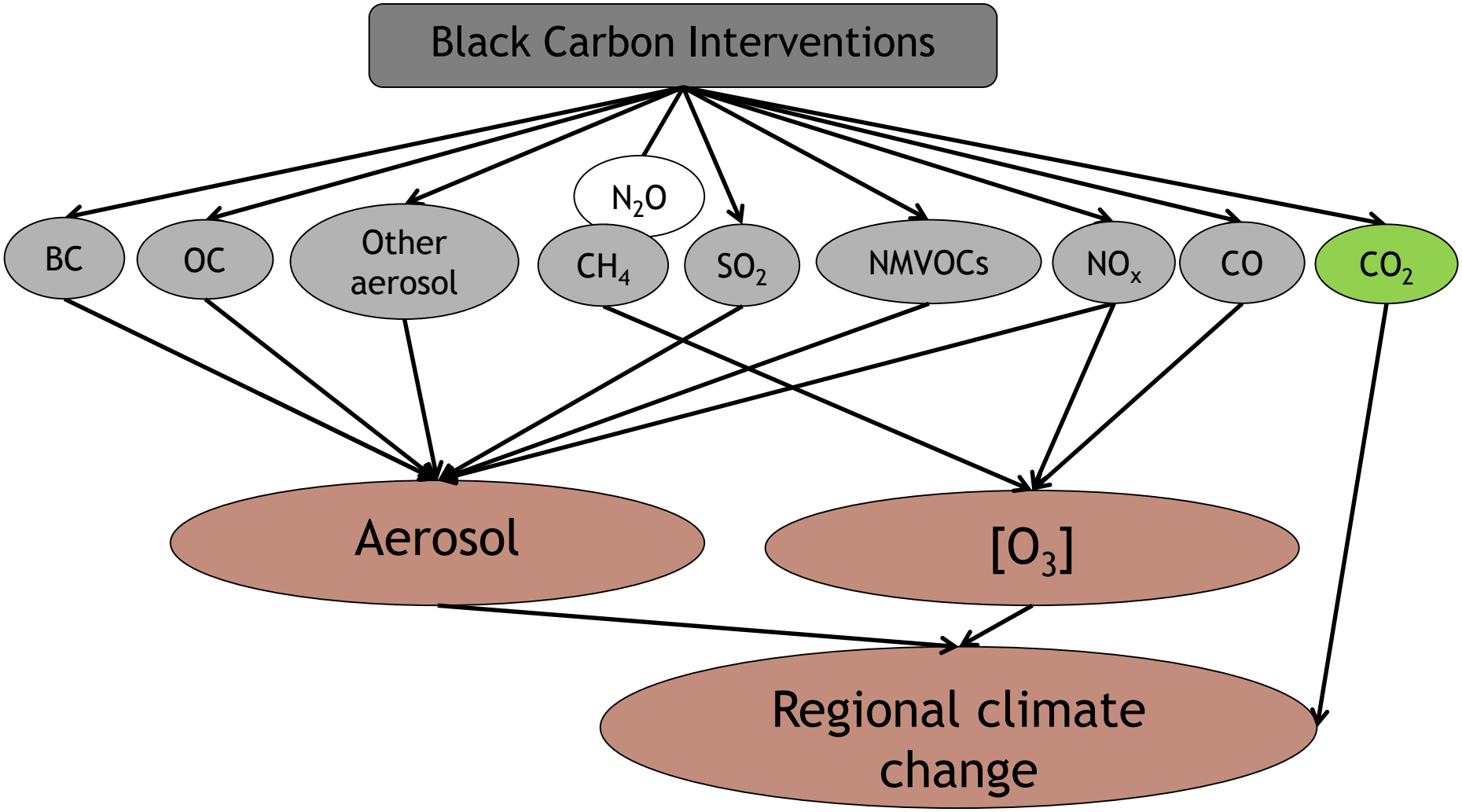
Need to consider the range of pollutant emissions that might be **changed** by SLCP interventions



…how these changes will influence pollutants (aerosol and O_3) and regional climate change….

and what the implications will be for agricultural damage

How might SLCP interventions affect agriculture



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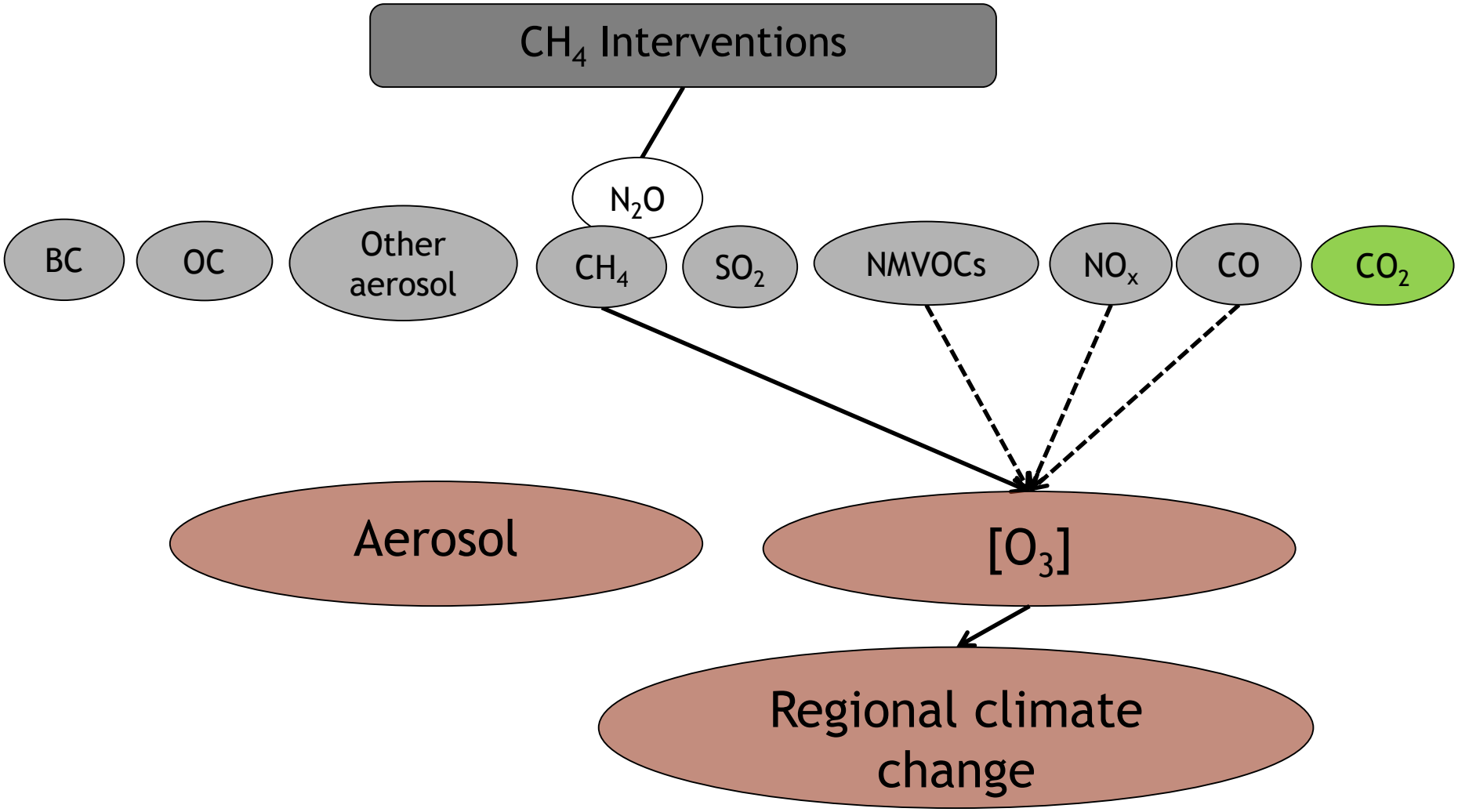

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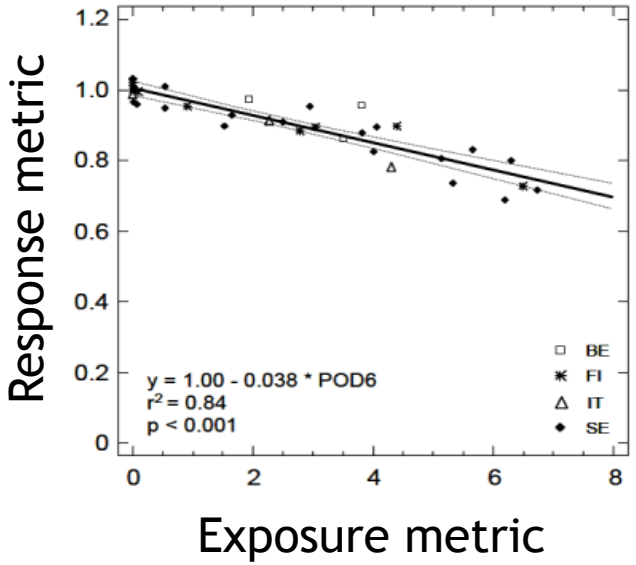

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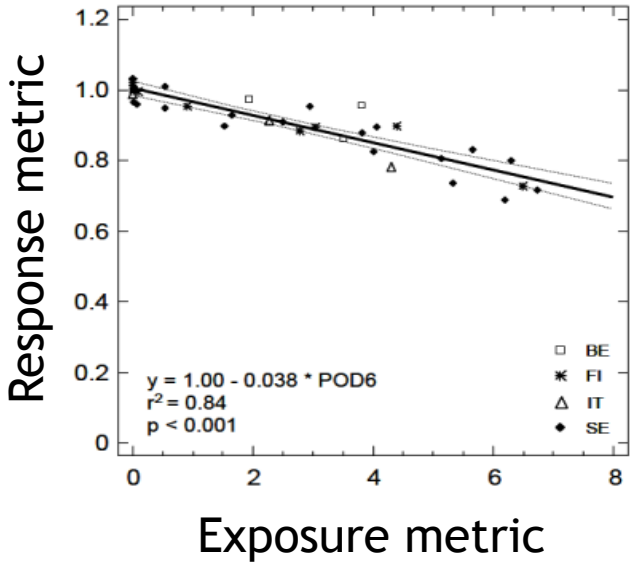


Ozone (O_3) metrics for agriculture

How are exposure and response metrics developed?

Fumigation / Filtration experiments

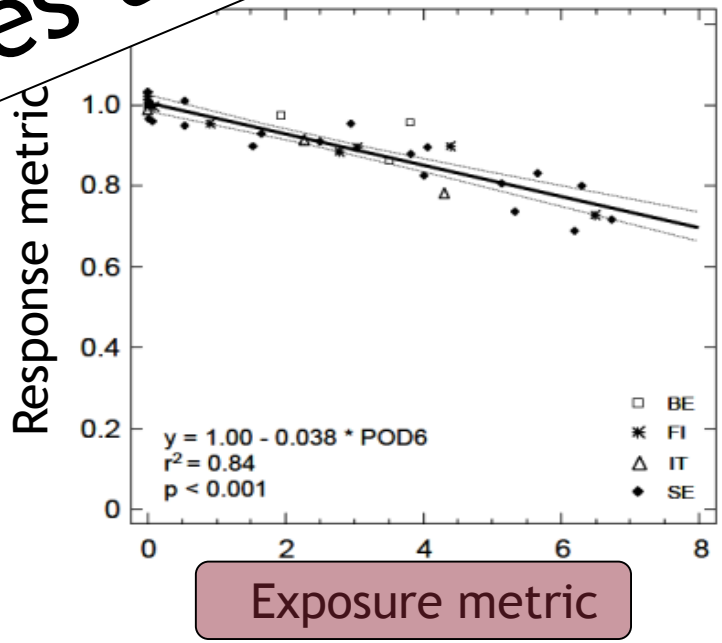
Empirical data

Felicity Hayes talk

data

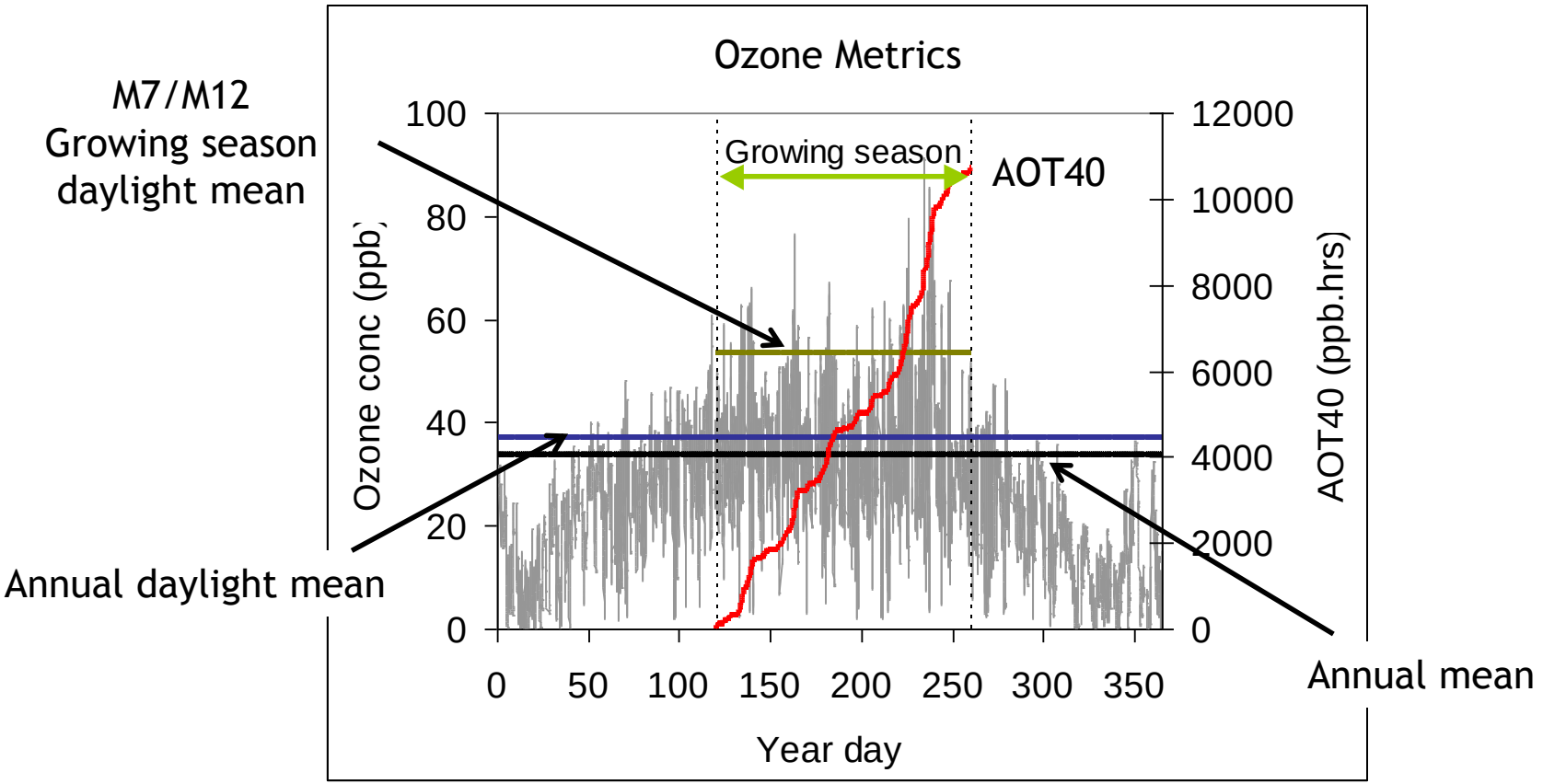
FACE data

e-Response (DR) function



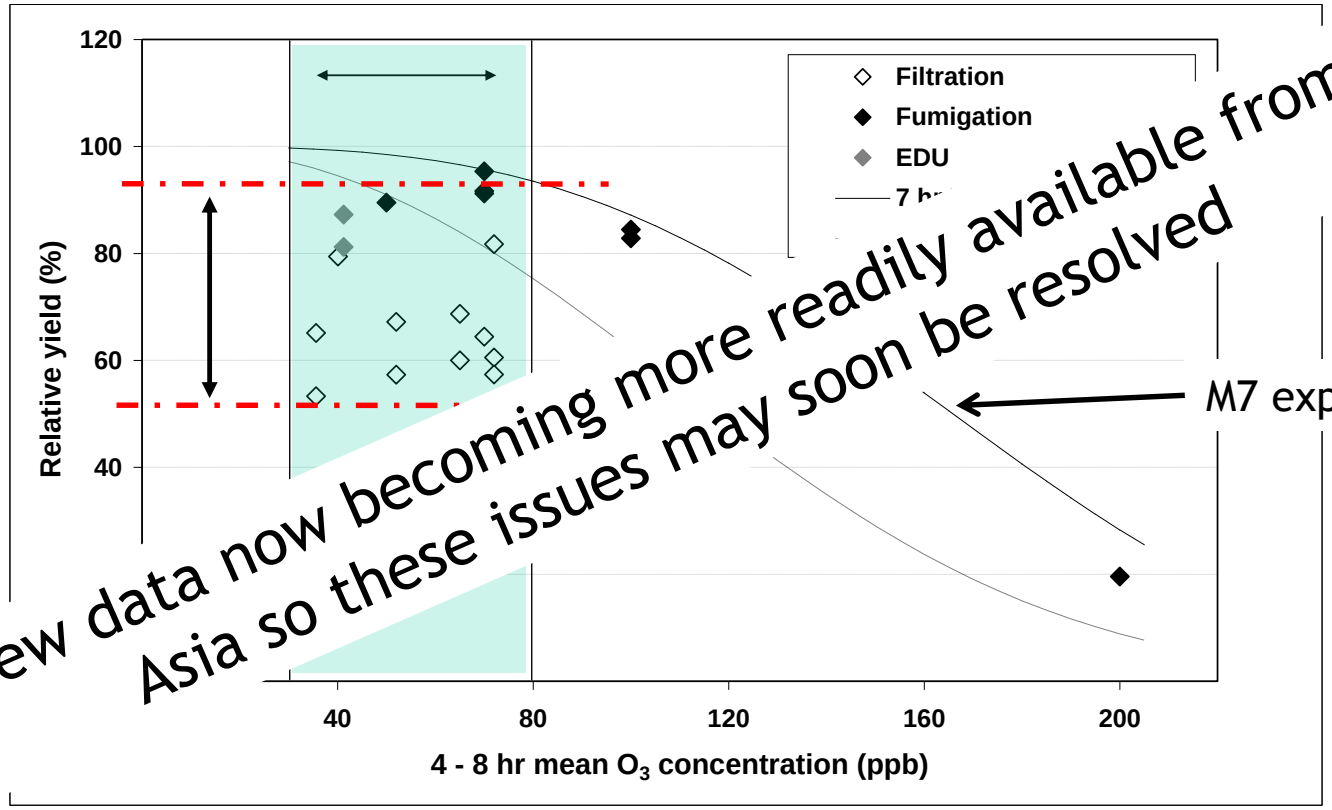
Exposure metric

What are the key differences in exposure metric?



Transferability - Are NAmerican derived DRs suitable for Asian conditions?

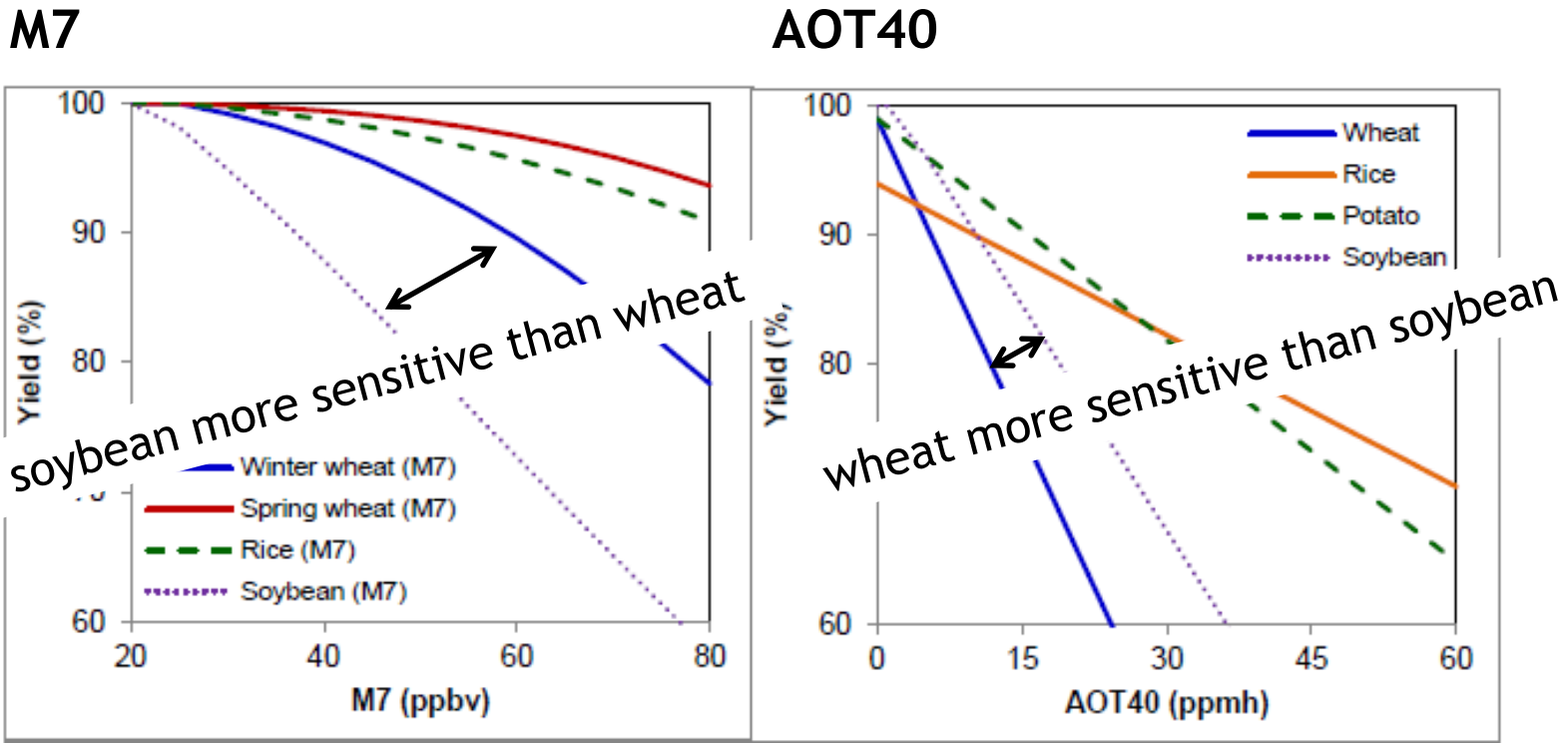
Asian wheat dose-response data



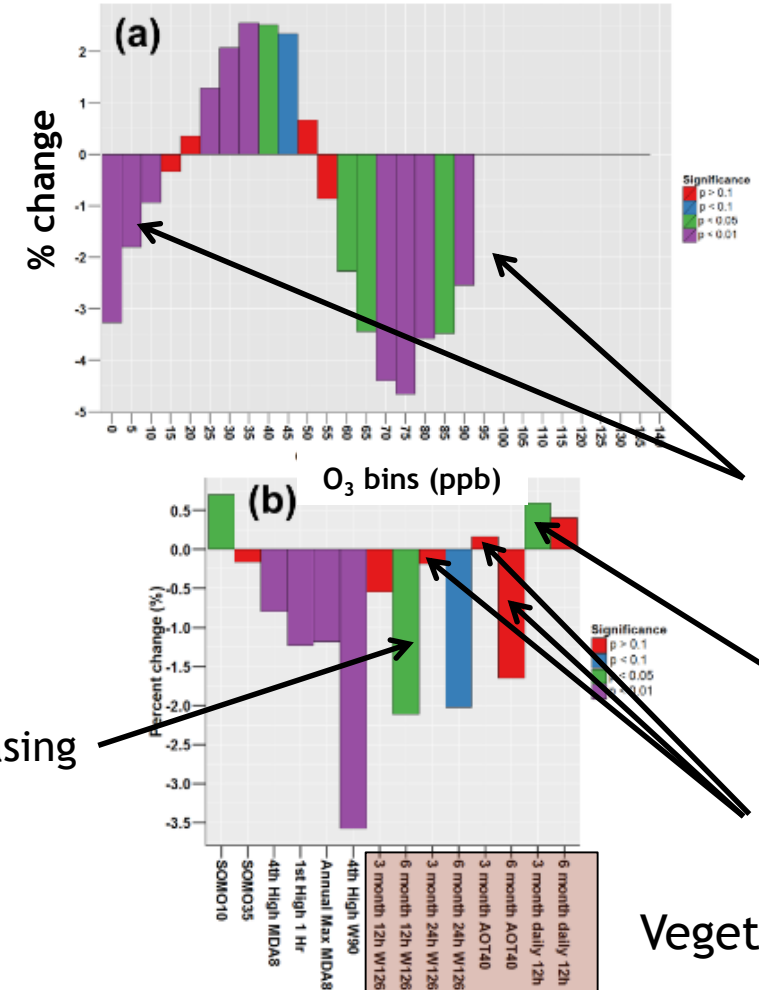
Crop variety, experimental conditions, environmental conditions, O_3 exposure pattern

Emberson et al. 2009

Relative species sensitivity - can vary depending on choice of O_3 metric



Changes in O_3 concentration not always consistently descrbed by O_3 exposure metrics…



Bottesford, UK.
[O_3] trends between 1982 - 2013

Decreasing frequency of both high and low concentrations (narrowing of the hourly ozone concentration distribution).

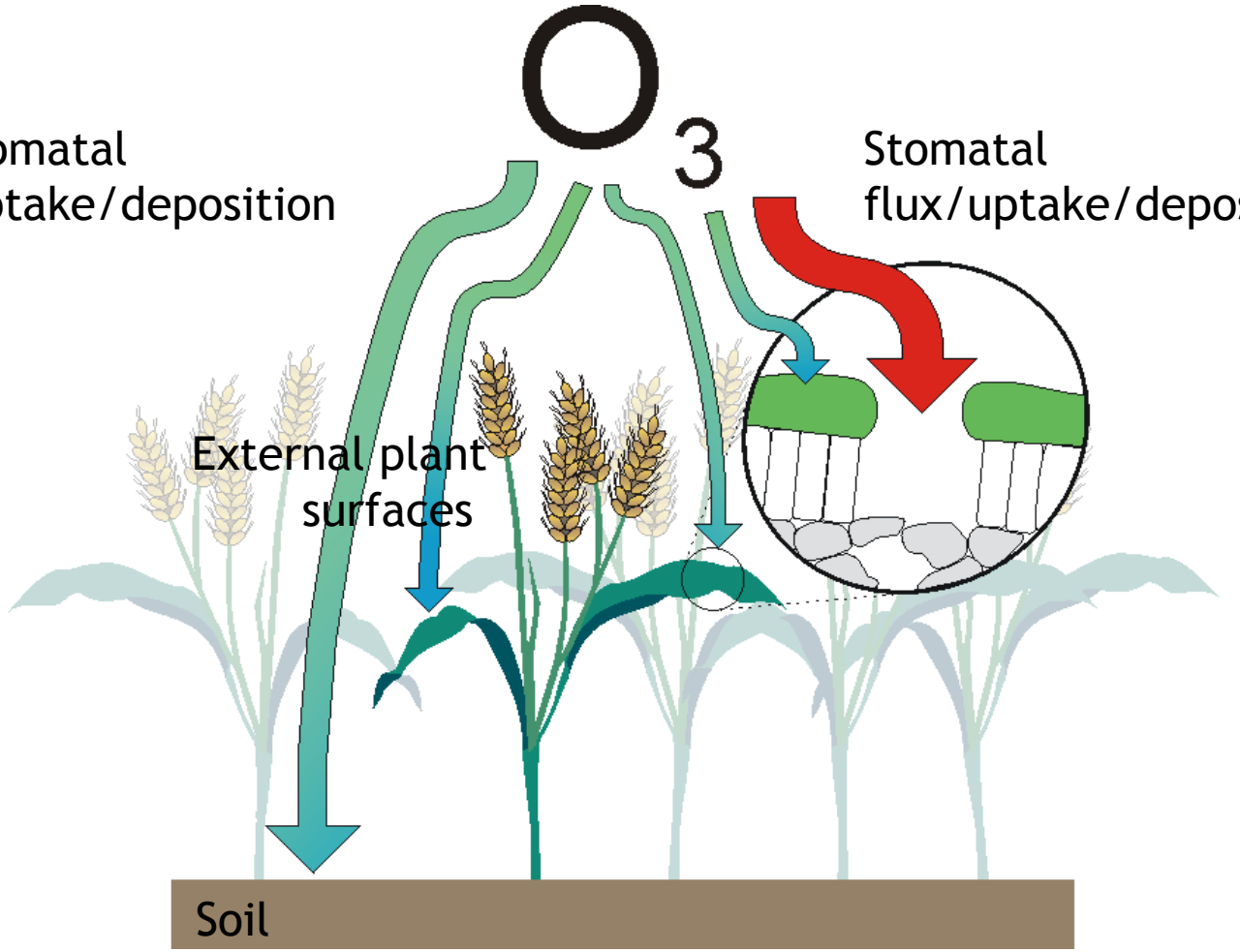
Increasing

Decreasing

Not significant

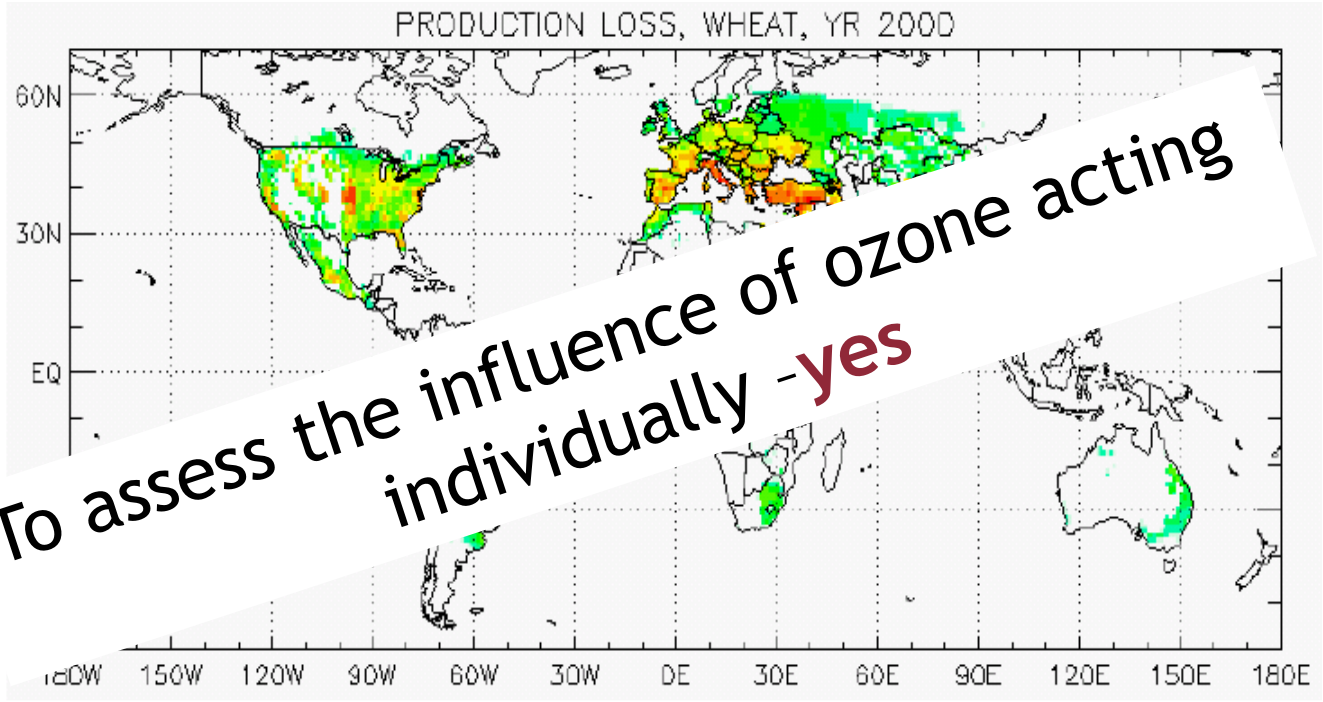
Vegetation ozone metrics

‘O_3 flux’ (or uptake) more biologically relevant than concentration based ‘exposure’ metrics



Species, cultivar, Phenology, Environmental variables (e.g. irradiance, temperature, VPD, Soil water status, CO_2 concentration)

Are concentration based metrics 'good enough'?



van Dingenen et al, 2009

Global relative yield losses estimated using M7/M12 and AOT40

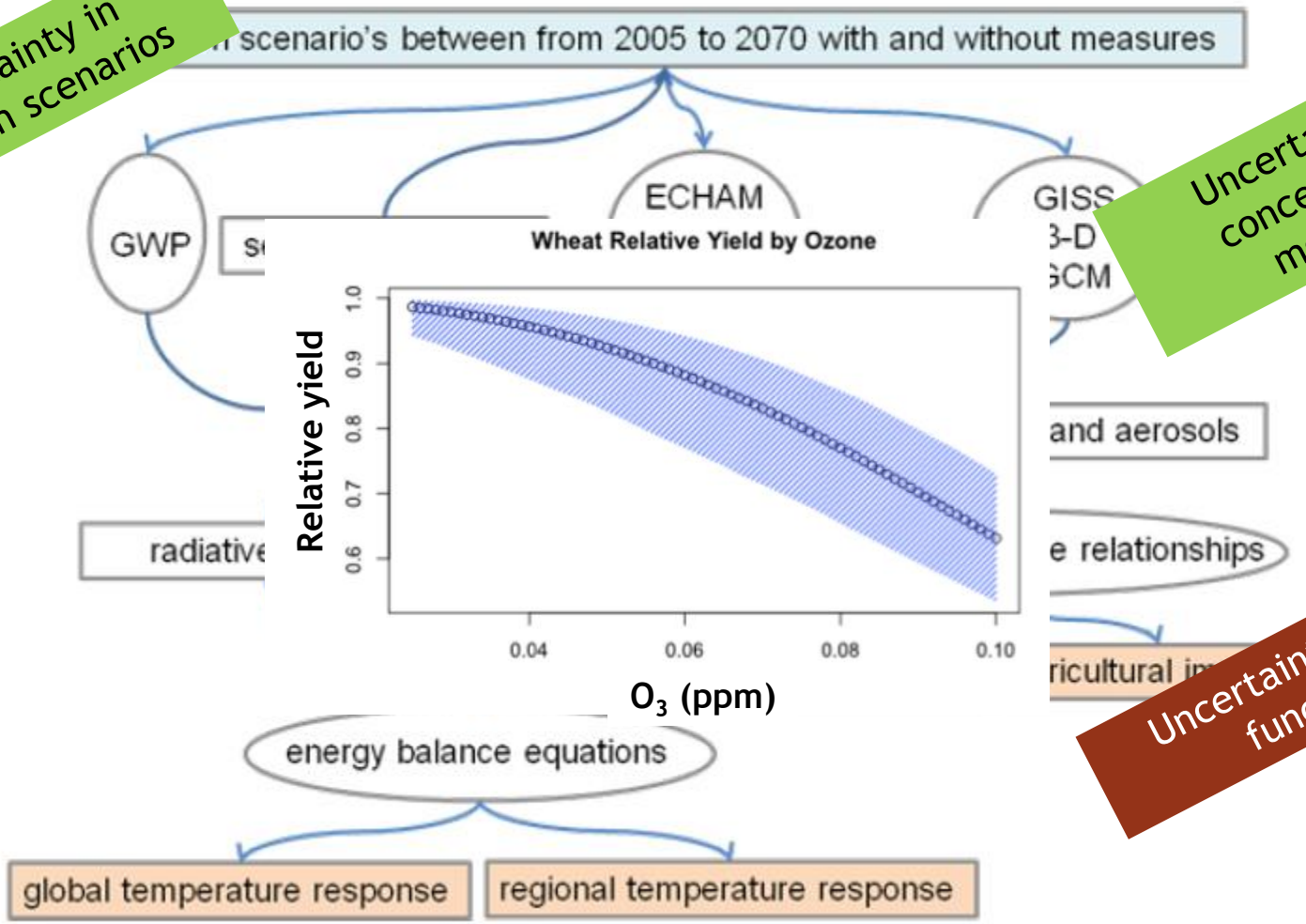
Wheat	: 7% to 12%	Rice	: 3% to 4%
Soybean	: 6% to 16%	Maize	: 3% to 5%

Uncertainties in application of metrics

Uncertainty in emission scenarios

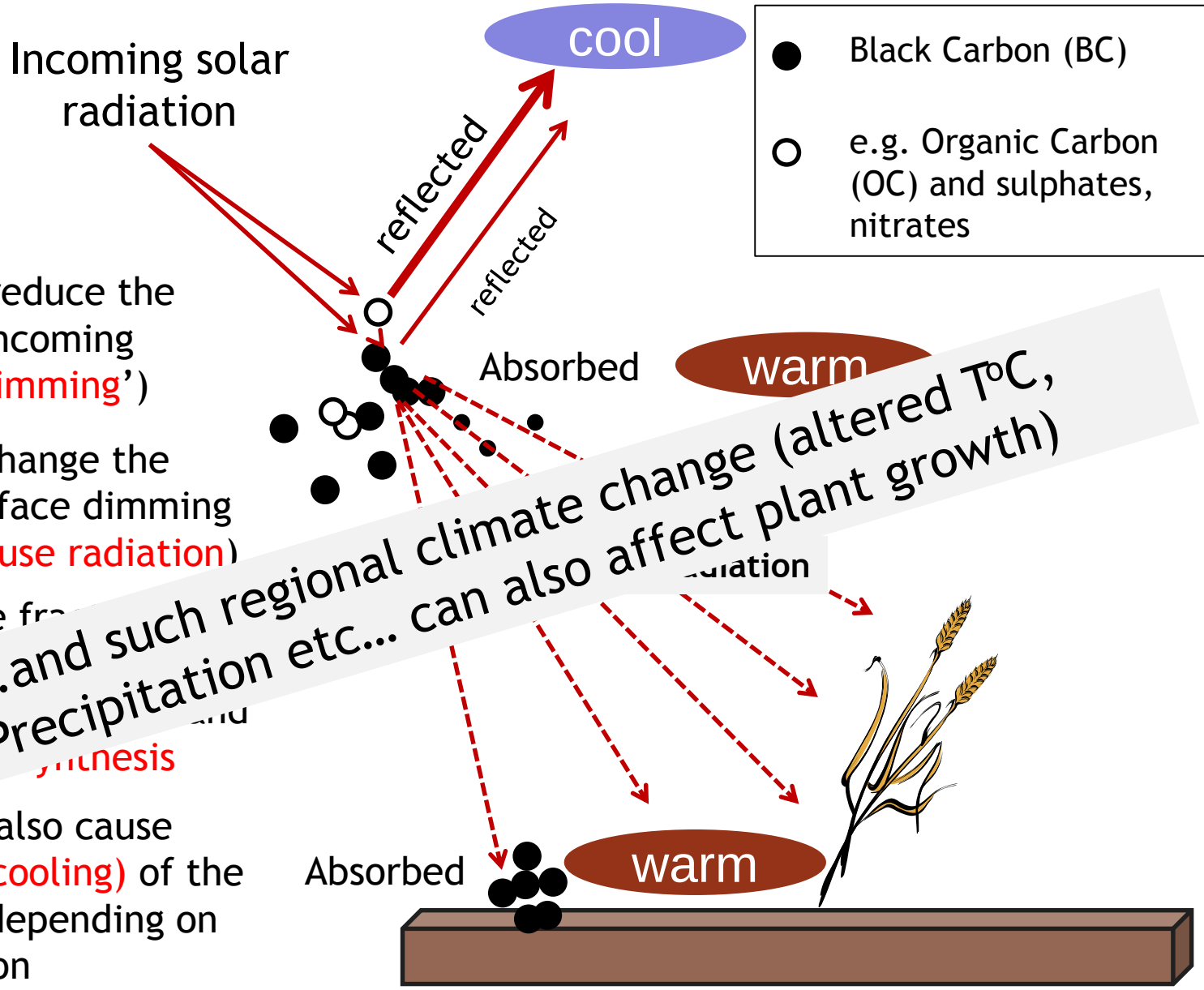
Uncertainty in concentration modelling

Uncertainty in DR function



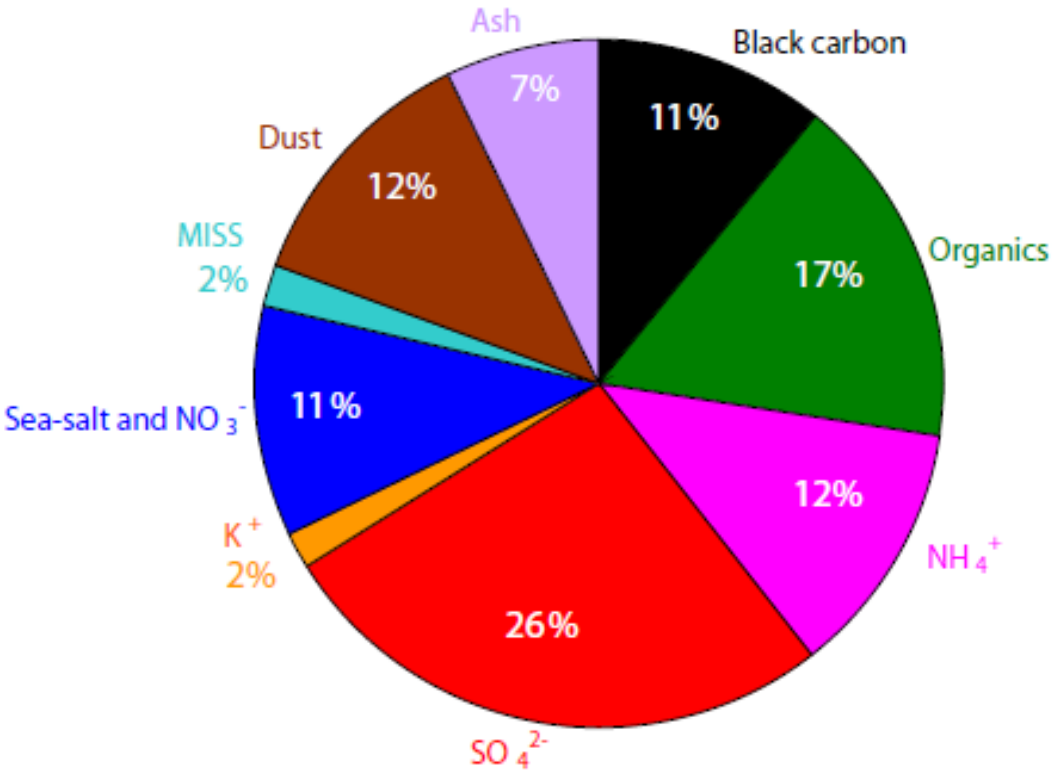
BC metrics for agriculture

Mechanisms by which aerosol influence crop yield…



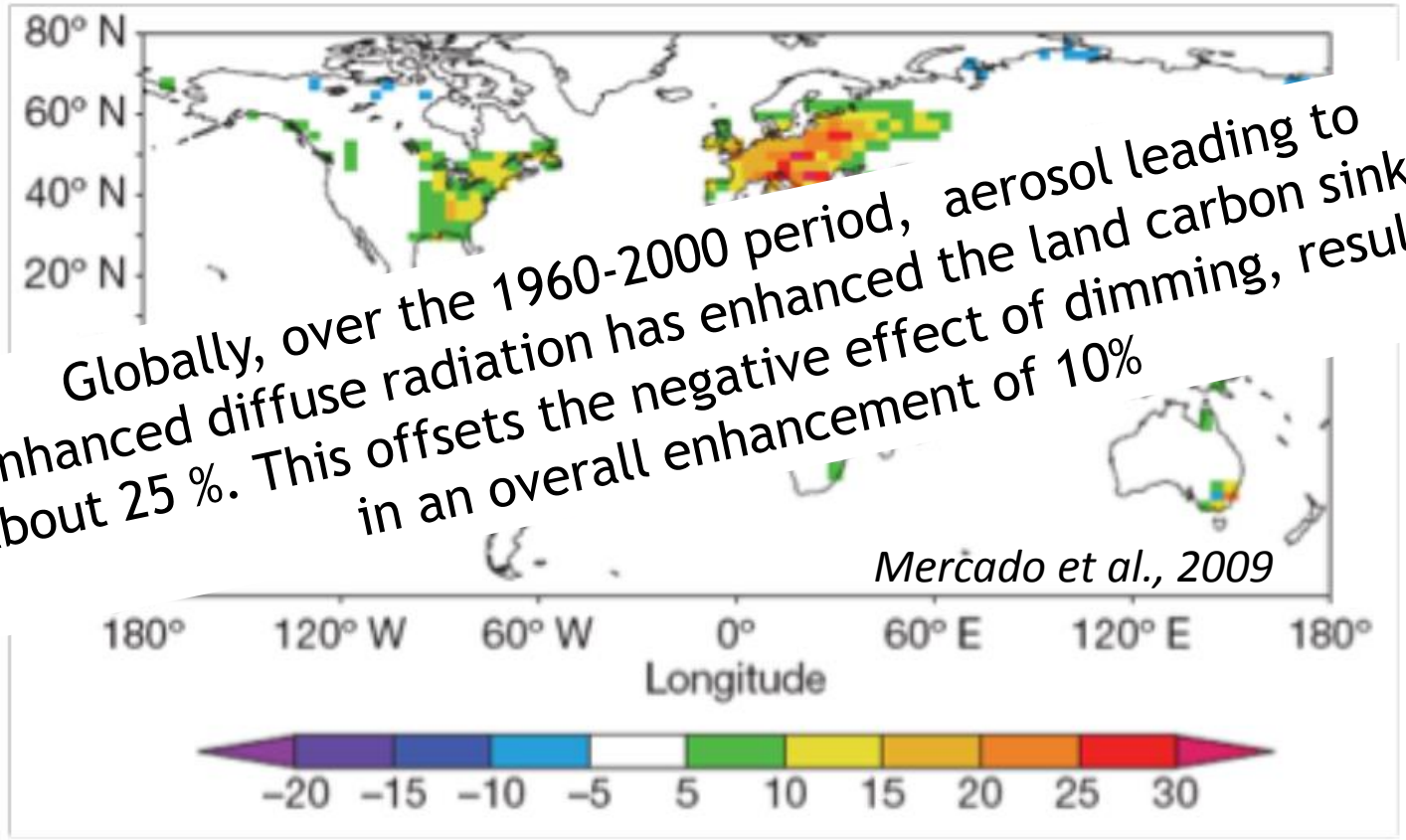
- Aerosol can reduce the quantity of incoming radiation ('dimming')
- Aerosol can change the quality of surface dimming (increase diffuse radiation)
- Higher diffuse fra… increas… all l… incre… …nesis
- Aerosols can also cause warming (or cooling) of the atmosphere depending on BC/OC fraction

Contribution of various aerosol species to Aerosol Optical Depth



BC makes up ~10 % of total aerosol

Effect of aerosol on net primary productivity (NPP)



Globally, over the 1960-2000 period, aerosol leading to enhanced diffuse radiation has enhanced the land carbon sink by about 25 %. This offsets the negative effect of dimming, resulting in an overall enhancement of 10%

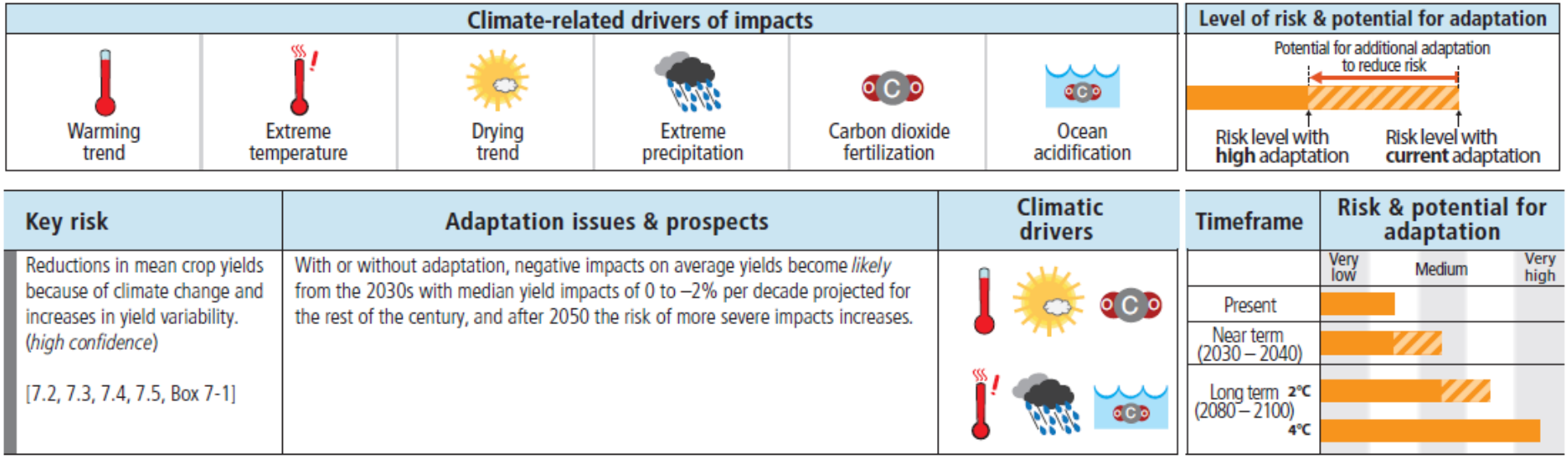
Mercado et al., 2009

Global dimming period (1950-1980)
Δ in diffuse fraction of -5 % to 30 %
Increased regional C sinks (NPP) by 30 g C/m^2/yr across Europe, the eastern USA, East Asia and some tropical regions in Asia.

Regional climate change metrics for agriculture

Climate metrics for impacts on agriculture

Impact assessments use experiments and models (e.g. crop models)



IPCC AR5, 2014

Problem

Pollutants (O_3 and aerosol) and climate change are acting 'together' on crop productivity and agricultural systems

e.g. O_3 and heat & water stress

???

Can we use of models to understand (& quantify) the influence of multiple stresses (i.e. O_3, aerosol and regional climate change) on productivity?

Way forwards…?

Short term – continue focus on O_3 pollution

– Extend metrics for additional crop species (e.g. pulses, cotton, tomato, grasslands (for forage quality)…

- Identify 'traits' that could be used to group species into 'sensitive', 'moderate' and 'resistant' groups

Medium term – develop methods to assess influence of aerosol (BC)

- Move to flux-based ozone DRs
- Use models to understand the influence of aerosol on PAR and crop productivity

Long term – develop modelling methods to assess influence of stresses in combination

- Move away from simple metrics to…..
- Use models to assess impacts of O_3, aerosol and regional climate change acting in combination
- Use these models to optimise mitigation efforts

Thanks