Tropospheric ozone
a threat for the feeding of mankind?

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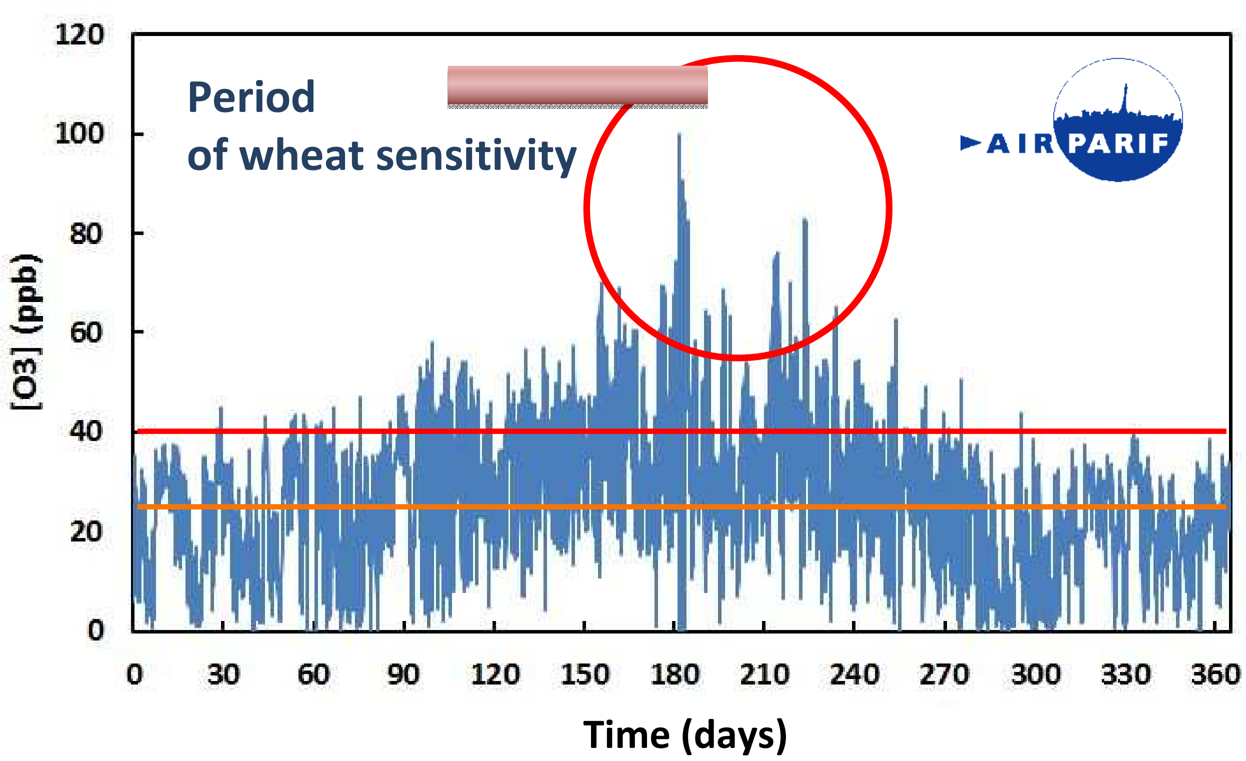
Ozone concentrations are variable over time (... and space)



Hourly ozone concentrations, les Ulis (F), 2015

Pollution peaks
200 µg/m³
(100 ppbv)

« critical level »
80 µg/m³
(40 ppbv)

Exceeding the critical level:
1175 hours

Average :
54 µg/m³
(27 ppbv)

Ozone damage to crops can be a response to:

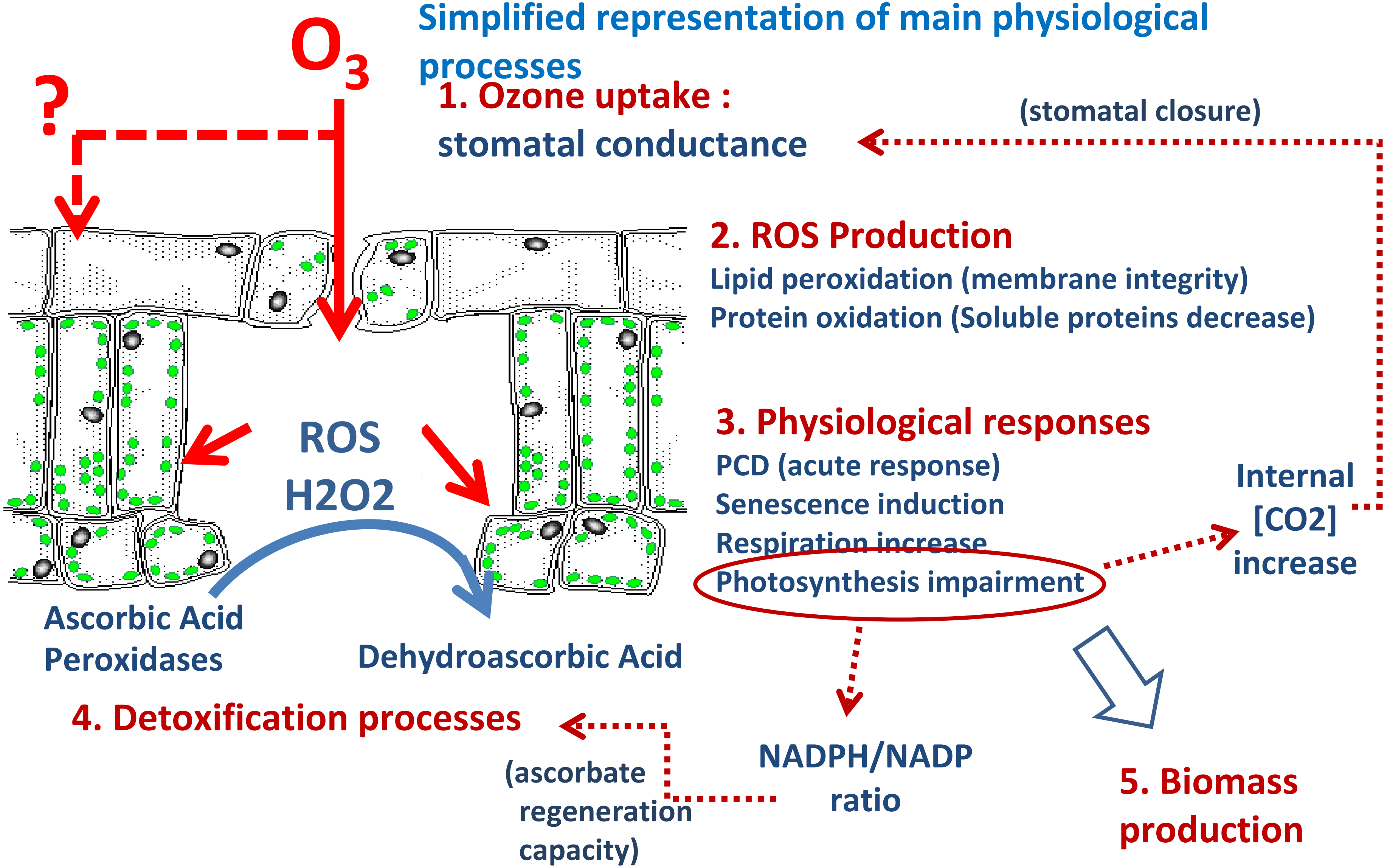
Short-term episodes

Plants develop characteristic injury to the leaves which affects economic value

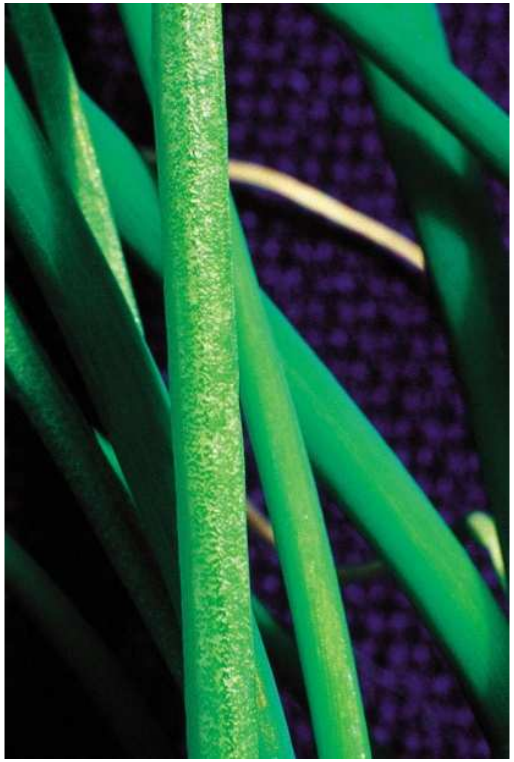
Cumulative exposure

Reduction in yield quantity and quality of **key food crops**

Simplified representation of main physiological processes



Short-term exposure (OTC experiments, Braunschweig)



Ozone injury on spring onion (*Allium fistulosum* cv. Polo)

Ozone injury on spinach (*Spinacea oleracea* cv. Matador)

Short-term exposure: Lettuce

Ambient ozone exposure, Hydroponic Glasshouse
Attica, Greece

100 % commercial loss overnight after a 5 d ozone episode (daily max: 80-100 ppb)

Long-term exposure

Open-top chambers (Braunschweig)

Ozone

↓

Exposure and Uptake

↓

Biochemical Processes

↓

Decreased Photosynthesis

↓

Visible Injury

↓

Enhanced Senescence

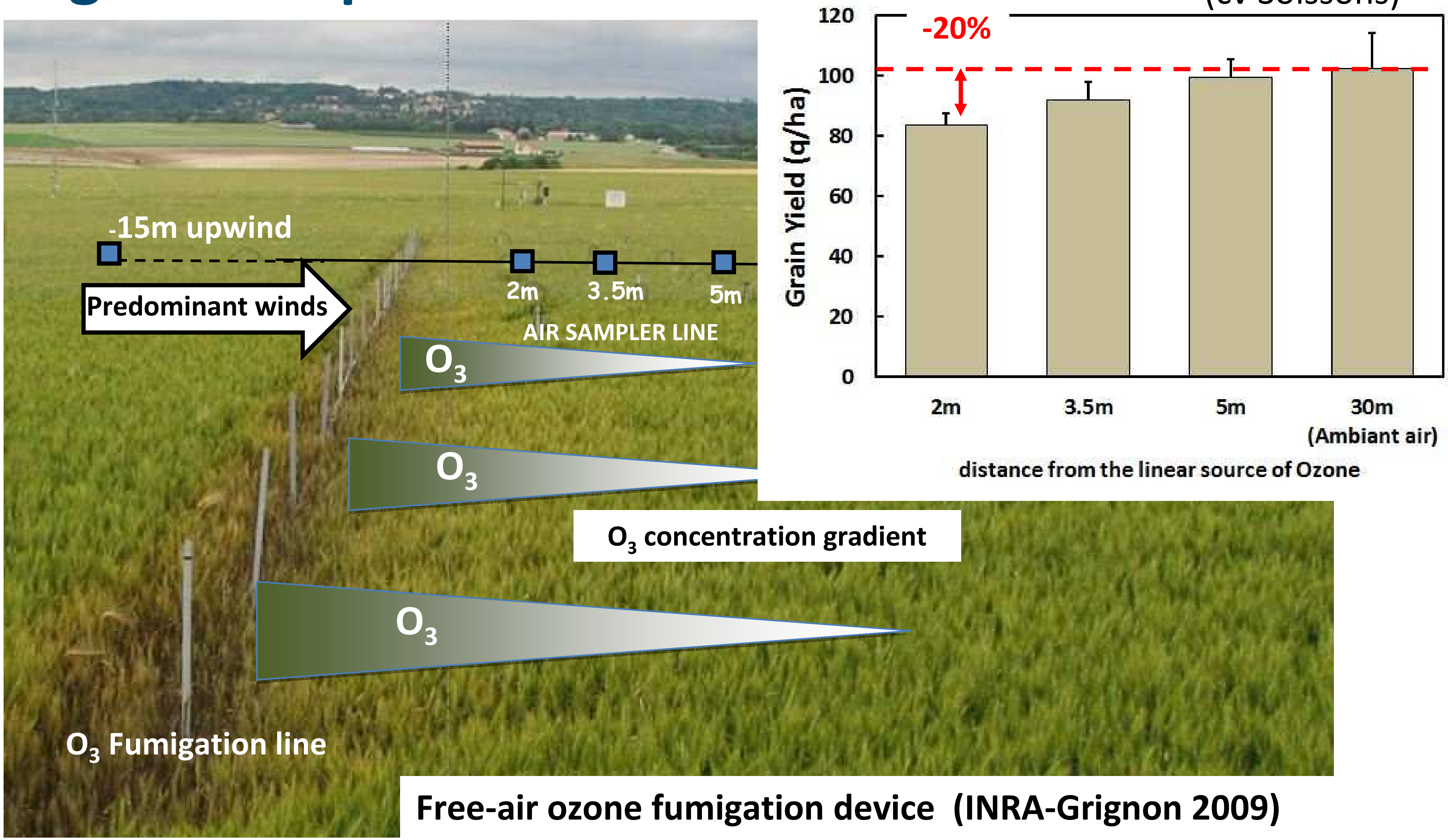
↓

Growth and Yield reductions

Effects on Product quality

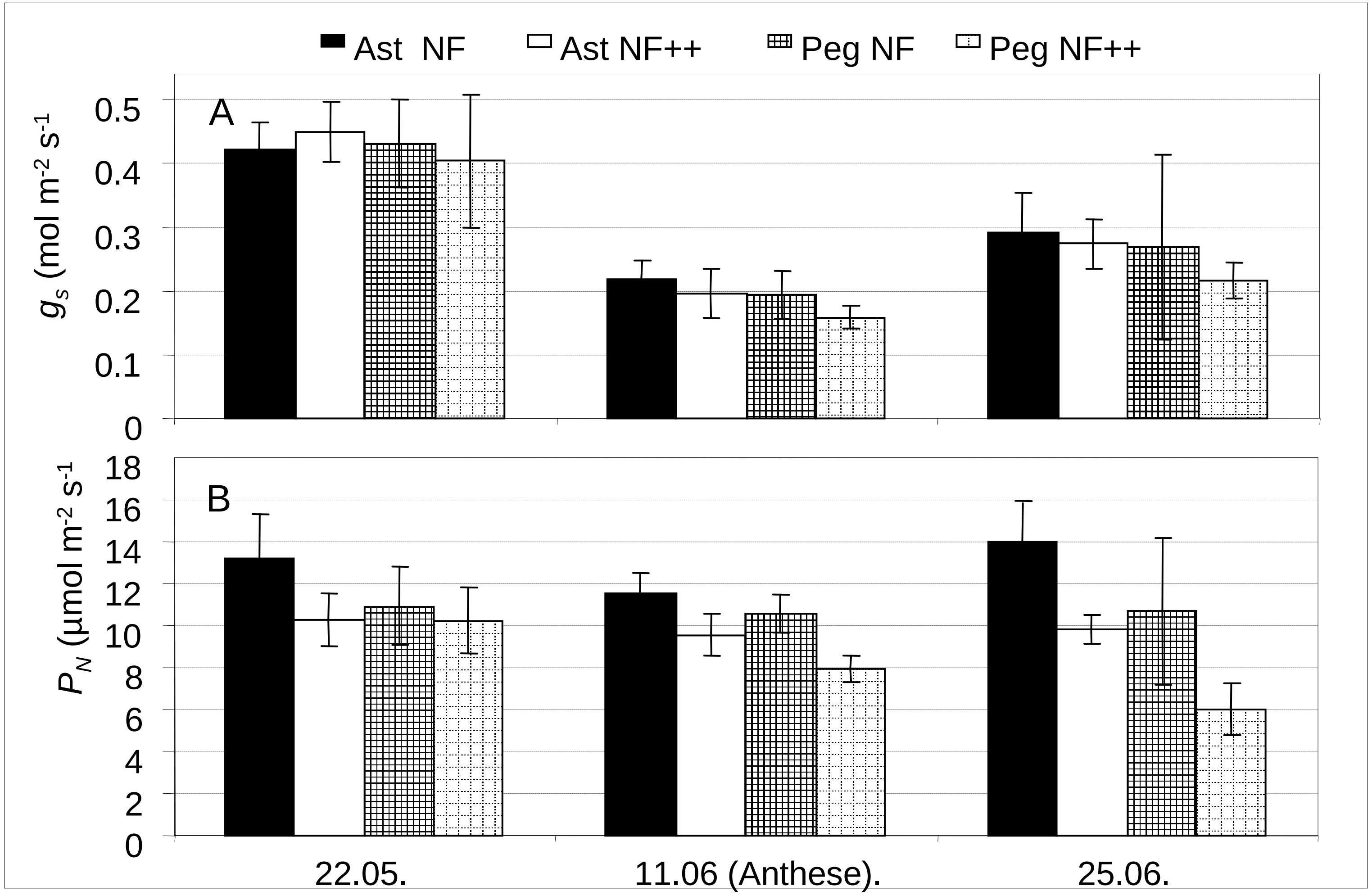
Long-term exposure

wheat grain yield
(cv Soissons)



Free-air ozone fumigation device (INRA-Grignon 2009)

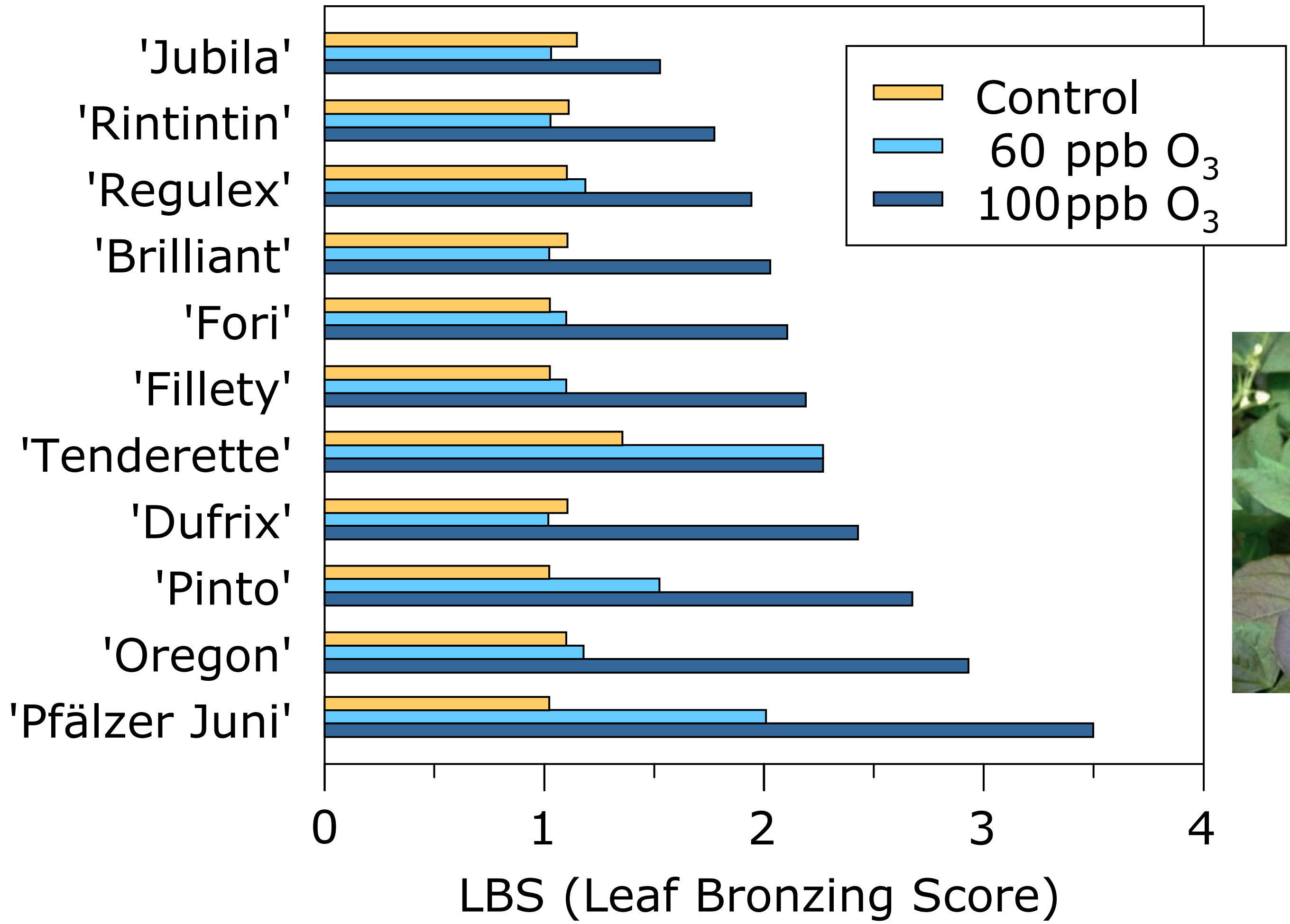
Long-term exposure (OTC experiments, Braunschweig)
Winter wheat cvs. 'Astron' and 'Pegassos'



Sensitive	Moderately sensitive	Tolerant
Peas and beans (including peanut) (30) Sweet potato (28) Orange (27) Onion (23) Turnip (22) Plum (22) Lettuce (19) Wheat (18) Soybean (18)	Alfalfa (14) Water melon (14) Tomato (13) Olive (13) Field mustard (12) Sugar beet (11) Oilseed rape (11) Maize (10) Rice (9) Potato (9) Barley (6) Grape (5)	Strawberry (1) Oat (0) Broccoli (-5)

- ❑ **In brackets: decrease yield at 60 ppb compared to yield at 30 ppb, using 7h mean ozone concentration**
- ❑ **Variety-specific responses, so scope for breeding more O_3 tolerance**
- ❑ **New varieties often more sensitive than older varieties**

Genotypic variation in ozone sensitivity: Bush beans



Food and feed quality (1)

- ❑ Change primary metabolites (carbohydrates, proteins)
- ❑ Change secondary metabolites:
  - ➢ vitamins and other anti-oxidants
  - ➢ compounds with range of anti-fungal/bacterial/ microbial activities & anticarcinogenic properties
- ❑ Wheat/potato:
  Decrease carbohydrate, increase protein content
  - ➢ positive & negative impacts on baking/frying quality or further food processing (depending on use)
- ❑ Oil producing crops: often decrease oil content
- ❑ Grapes and watermelon: decline sugar content

Food and feed quality (2)

- **Decline forage quality**:

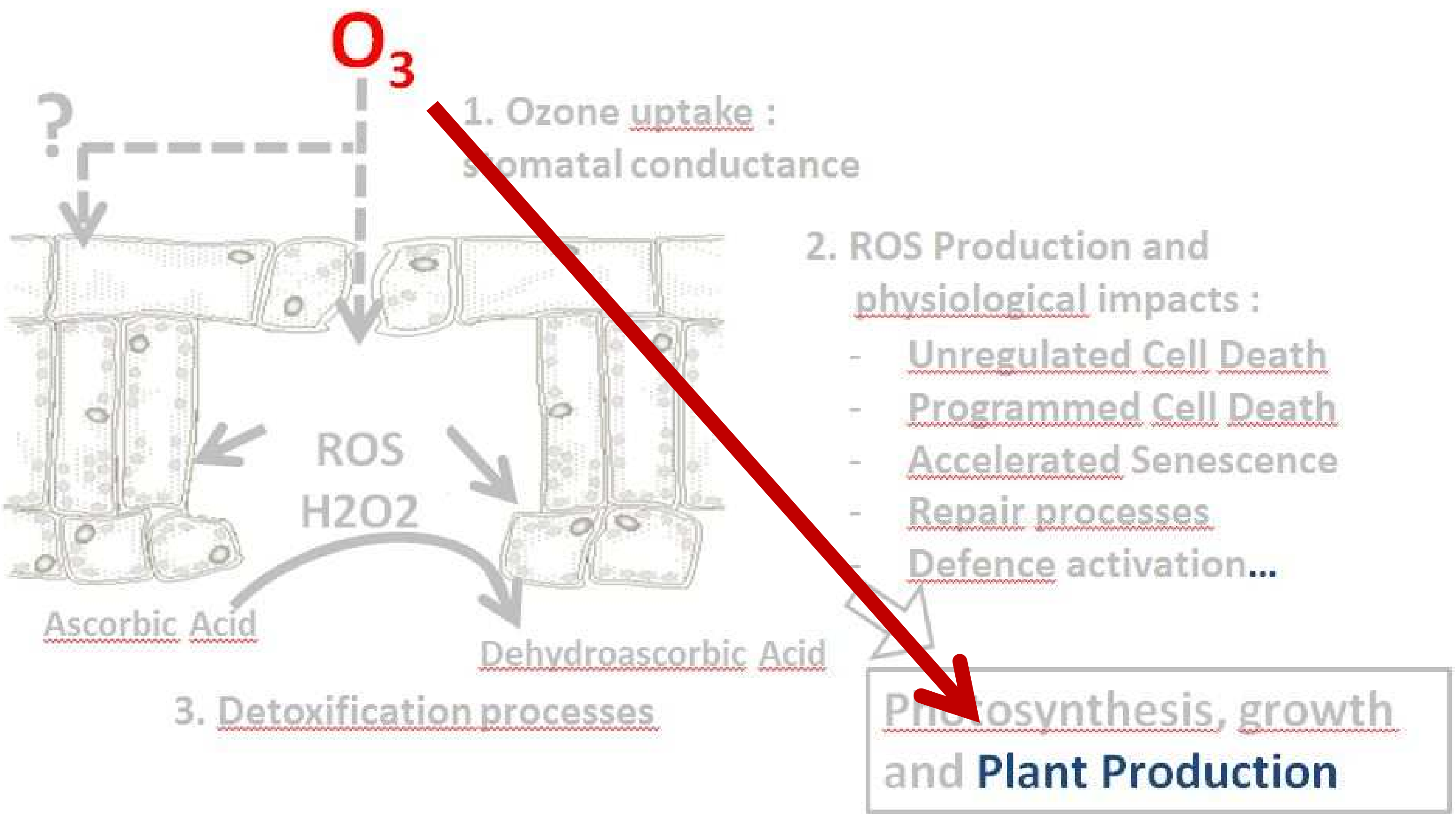
  Can lead to lower milk and meat production

  - reduced digestibility (increase lignine, early die-back, decline legumes)
  - changes nutrient content (protein, sugars, starch, minerals)
  - secondary metabolites ('anti-nutrients')

- **Development of ozone critical levels food/feed quality required**

- **Total loss of consumable food value** (fractional reduction in yield × fractional reduction in nutritive quality) need to be considered in economic impact assessments

Impact Assessments
from simple concentration-response functions (AOT40)



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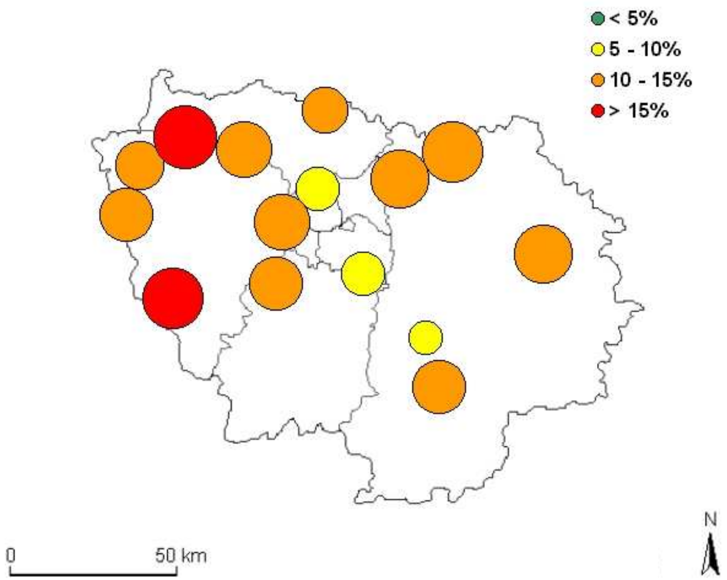
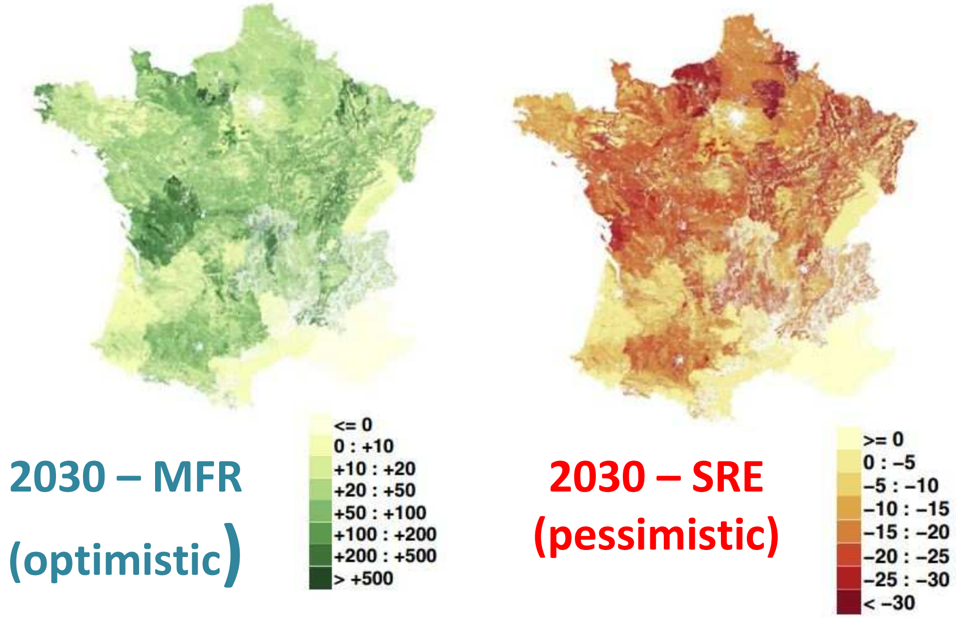
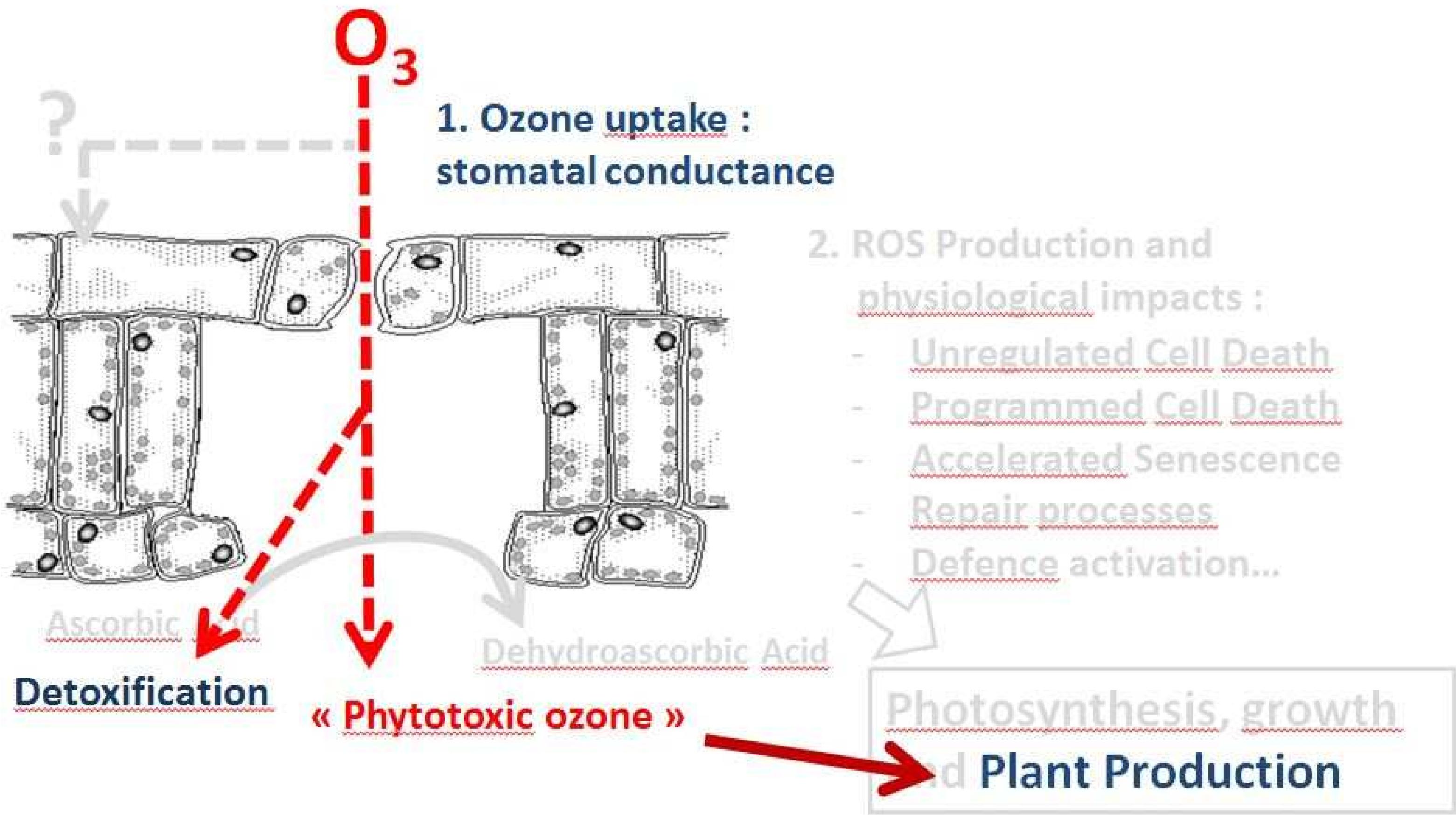




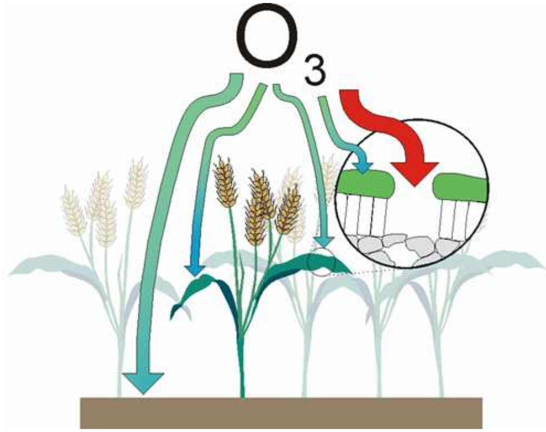
Estimation of yield losses caused by ozone in the Ile-de-France region in 2001
(Castell & Lebard, 2003, Poll. Atm.)

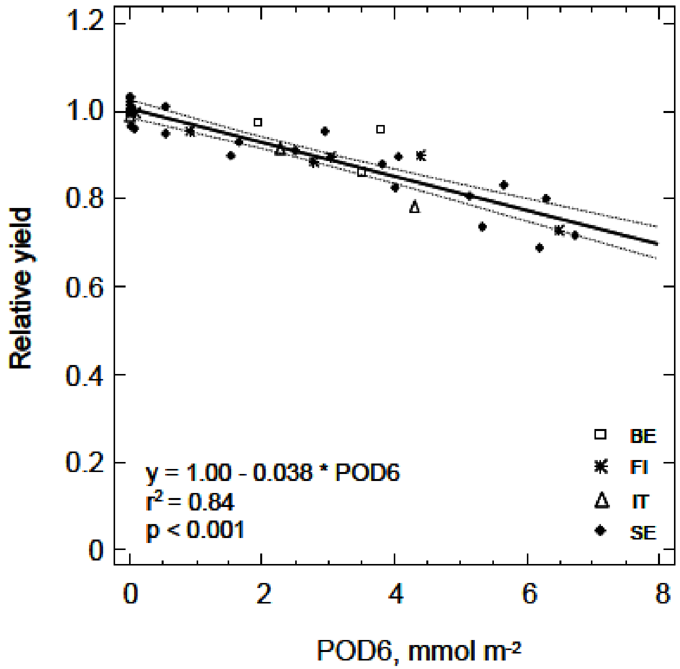
Changes in Wheat production (kg/ha) estimated from two climate scenarios wheat, using economic model (AROPAj) coupled with simple ozone dose-response functions
(Humblot *et al*., 2013, Ecol. Economics)

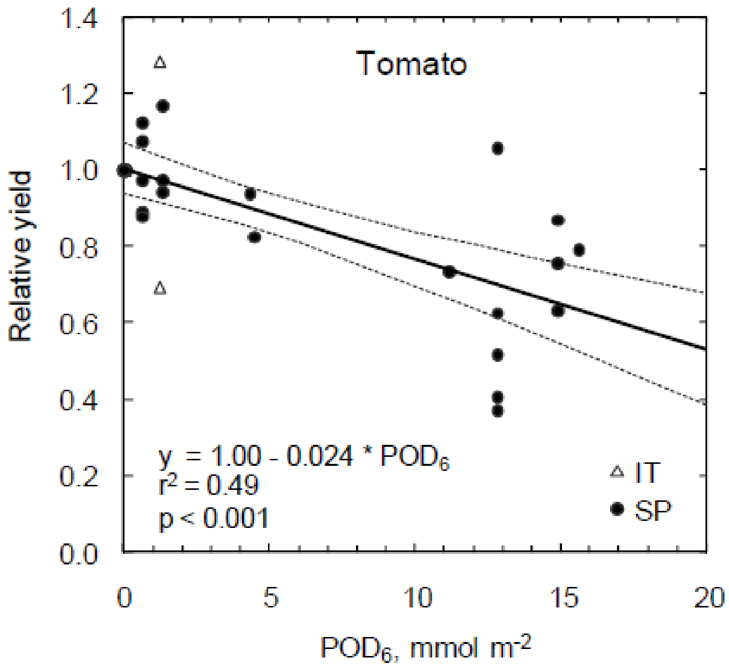
Impact Assessments using Flux-based Yield Response functions



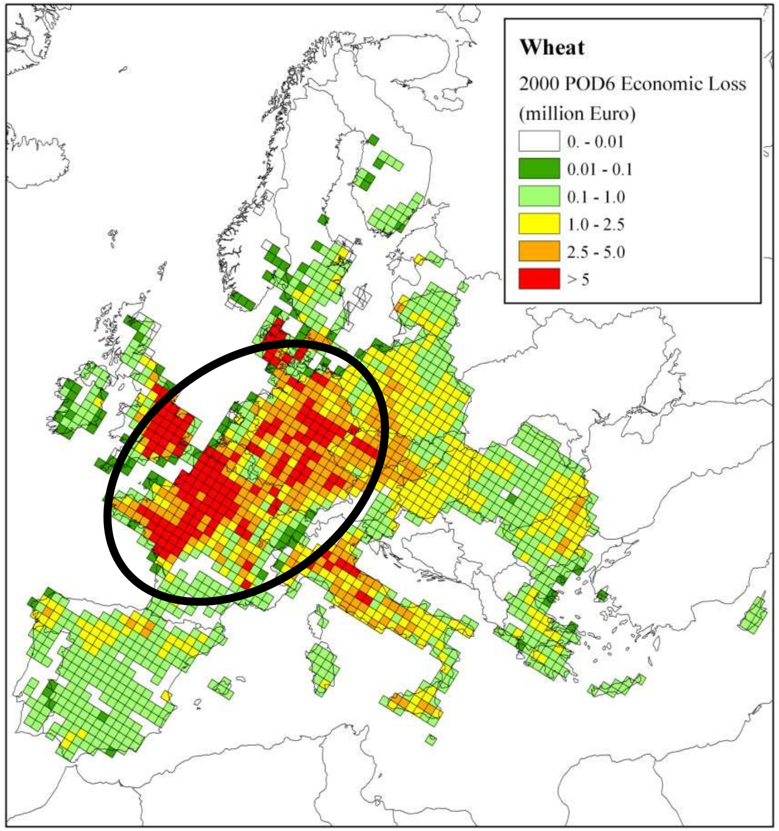
Impact Assessments using Flux-based Yield Response functions



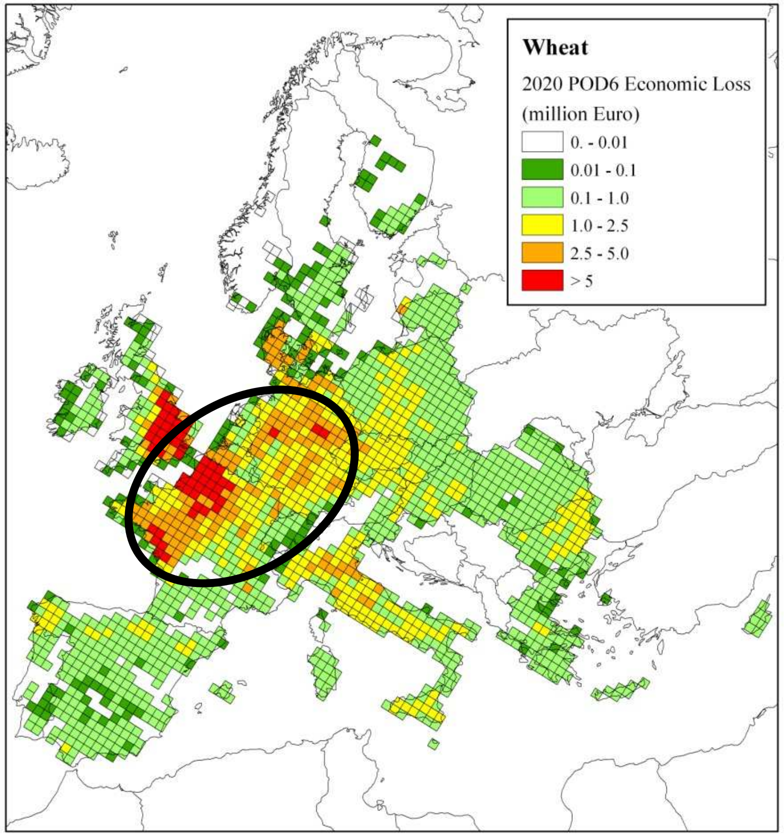




2000



2020



* Assumes adequate soil moisture available

Losses are in million Euro per 50 x 50 km grid square:

0 – 0.01 | 0.01 – 0.1 | 0.1 – 1.0 | 1.0 – 2.5 | 2.5 – 5.0 | > 5

ICP Vegetation, Food Security Report (2011)

Losses wheat and tomato
EU 27 + Norway + Switzerland

	Wheat		Tomato	
	2000	**2020**	**2000**	**2020**
Yield loss per grid square (%)	13.7[1]	9.07[1]	9.4[2]	5.7[2]
Production loss (million t)	26.89	16.45	2.64	1.62
Economic loss (billion Euro)	**3.20**	**1.96**	1.02	0.63
EMEP grids exceeding CL (%)	84.8[1]	82.2[1]	77.8[2]	51.3[2]

[1]based on all grid squares with wheat production,
[2] based on grid squares with > 1 tonne of production

ICP VEGETATION

What research for the future?

Replace empirical dose-response functions with more mechanistic models

- Better understand and integrate tolerance mechanisms (detoxification, etc.)
- Identify indicators of ozone tolerance to better describe intra- and interspecific variability

Develop knowledge on quality, including nutritional quality

Conclusion

- Ozone is actually the main air pollutant responsible for crop yield losses.
- Economic impacts are considerable
- Empirical impacts estimation tools need to be improved
- Significant effects on crop quality
- More research is needed to assess the impacts of ozone on nutritive value

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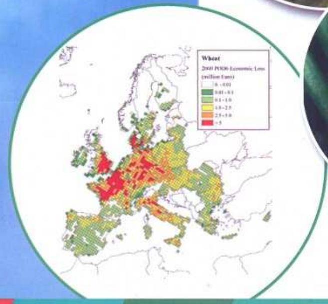
OZONE POLLUTION: A hidden threat to food security







Report prepared
by the ICP Vegetation
September, 2011

Editors:
Gina Mills
and
Harry Harmens

wge Working Group on Effects of the Convention on Long-range Transboundary Air Pollution