SEEDS Stakeholder information meeting

23rd March 2022

Environmental impacts of ozone and nitrogen on agriculture and ecosystems

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S. Elvira,J. Sanz, I. Rábago, V. Bermejo

Ecotoxicology of Air Pollution Unit - CIEMAT

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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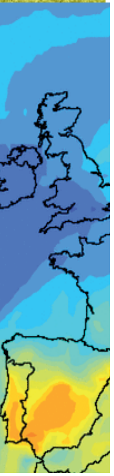
UNECE Convention on Long Range Transboundary Air Pollution

40 years of successful cooperation for clean air
Clean Air 40 YEARS

- Evidences of impacts on crops (focus on water-limited areas)
- Evidences of impacts on semi-natural vegetation
- Indicators for risk assessment
- Modelling and Mapping risk assessment
- Conclusions and recommendations

Ozone sensitivity of Mediterranean vegetation



Crops

- Yield reductions up to 39% for some crops
- Reduction of fruit quality (sugar content, delay ripeness..)
- Predispose some crops to pest infections
- Ozone-induced visible symptoms in leafy crops
- Visible symptoms in watermelon used for biomonitoring

Annual grasslands

- Wide range of O_3-sensitivity among species
- Aboveground and subterranean biomass reduction
- Effects on C allocation: subterranean/aerial ratio
- Decreased nutritive quality
- Reduction in flower and seed production
- Increase N_2O emissions

Forests

- Chronic effects on physiology and growth
- Visible injury
- Predispose to other environmental stress: drought, high temperature and solar radiation

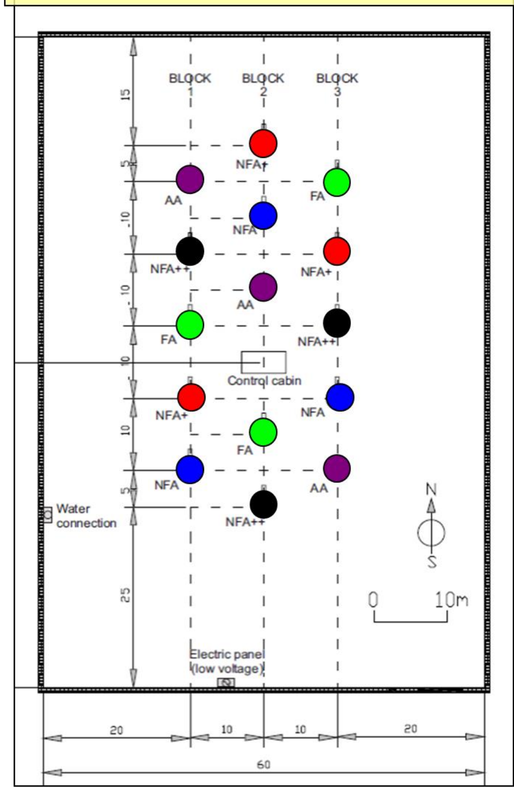
Effects: Terrestrial ecosystems. Experimental work

Ozone treatment:

AA = Ambient Air

FA = Filtered AIr
NFA = Non Filtered Air
NFA+ = Non Filtered Air +20 ppb O_3

NFA++=Non Filtered Air + 40 ppb O_3



Open Top Chambers

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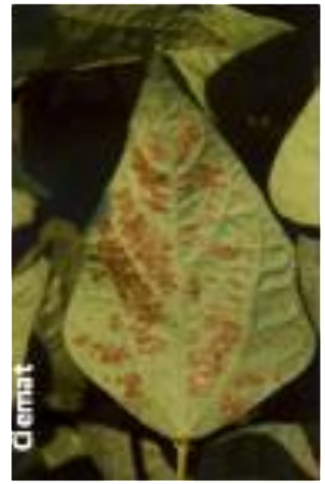
Evidence of ozone effects on crops and natural vegetation

Visible symptoms

Tobacco var. Well W3

Lettuce var. Romana



Green beans var. Lit

Spinach

Aleppo pine

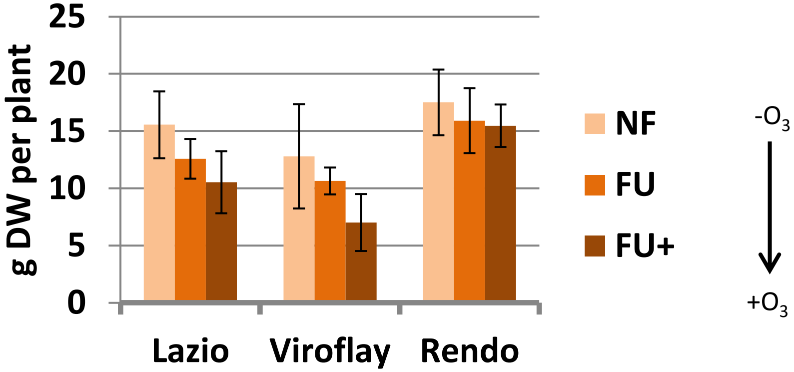
Clover

+ Ozone

Effects of ozone on crops

Crop yield and crop quality reduction

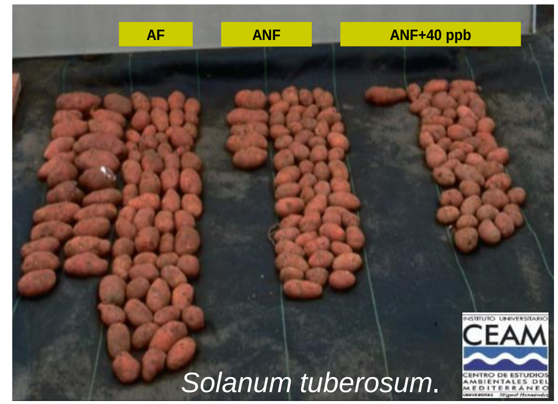
Spinach – comercial biomass



González-Fernández et al., 2016, *Agric. Eco. Env.*

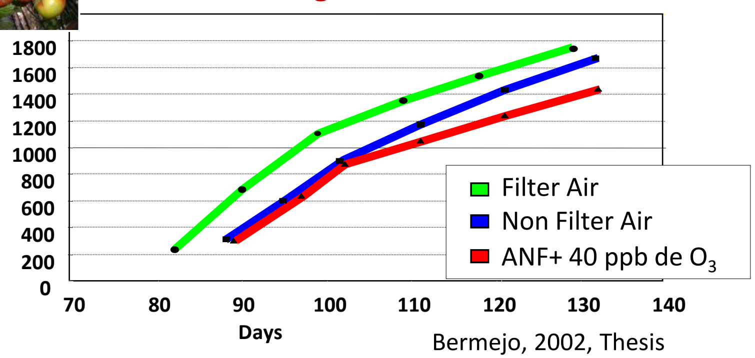
Potato - production

$-O_3$ → $+O_3$

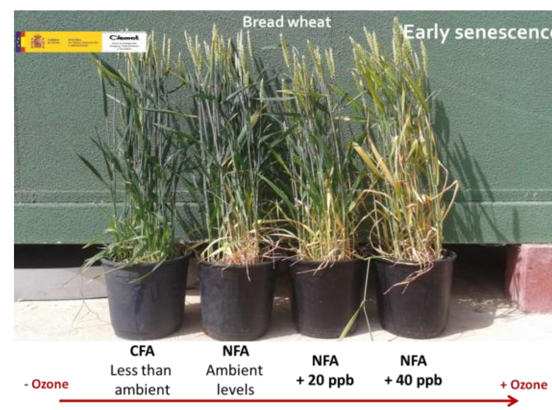


Calvo et al., 2009, *Agric. Eco. Env.*

Tomato – weight of fruits



Bermejo, 2002, Thesis



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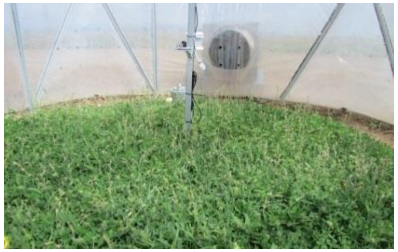
Air pollution effects in semi-natural vegetation

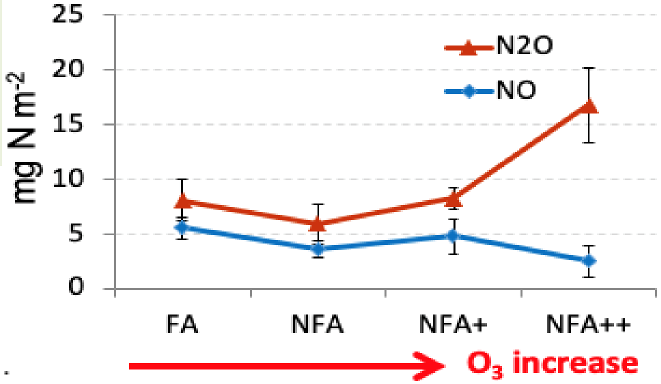
Evergreen oak forest / annual grasslands



- ✓ Ozone is modifying plant physiology and reducing growth of many species (forests, grasslands)
- ✓ Drought stress effects are stronger than O_3 effects
- ✓ O_3 reduces the fertilization effect of N and increases N losses (N_20 emissions) in annual pastures
- ✓ N can compensate for some O_3 effects in annual pastures
- ✓ Complex interactions among factors affecting below and aboveground processes

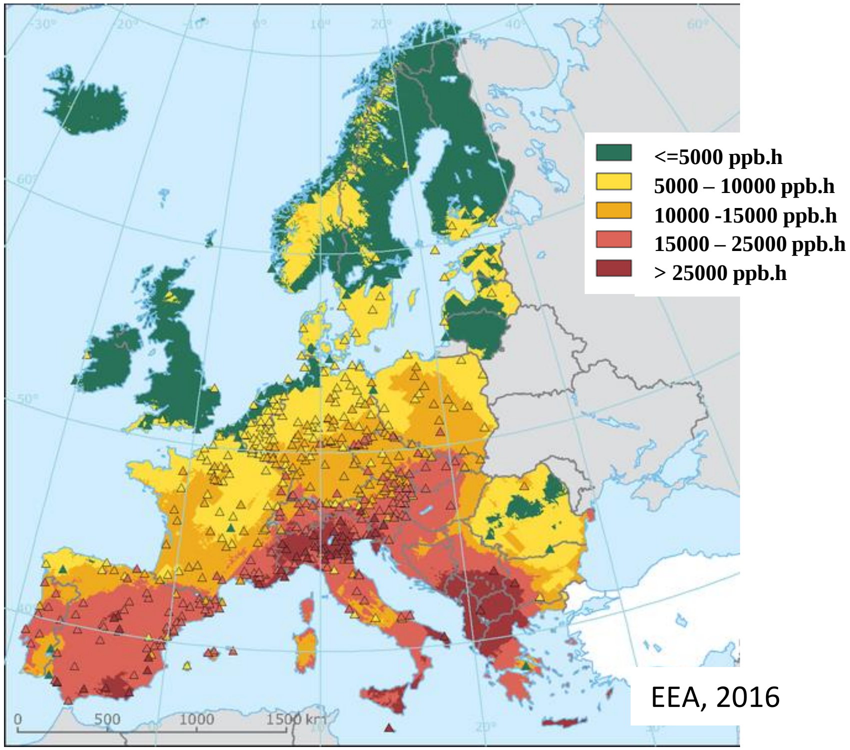
GHG soil emissions

Sánchez-Martín et al., 2017, Atm. Env .



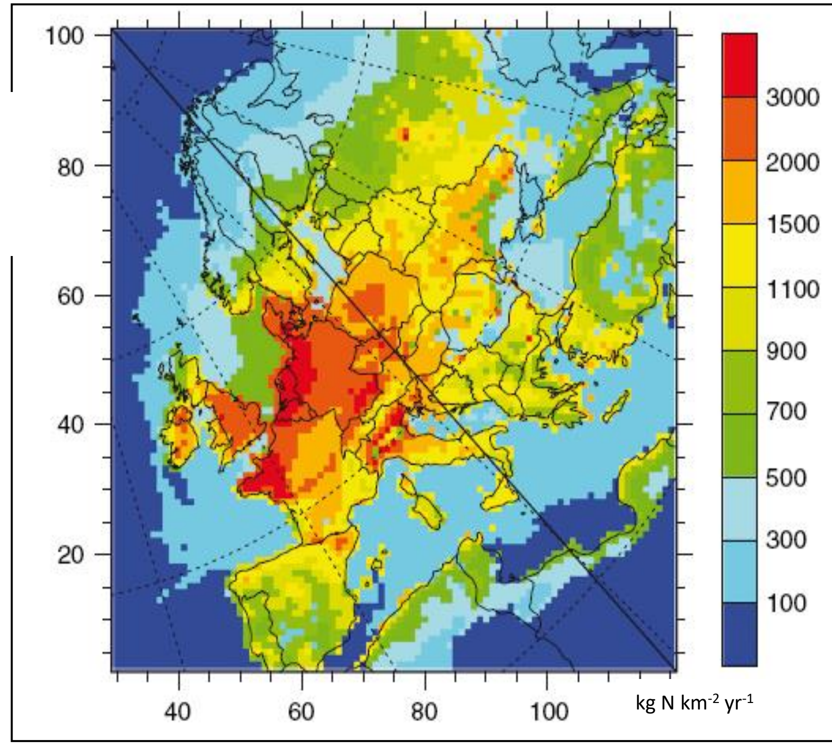
Ozone and atmospheric N deposition

O_3 AOT40 for forests (Apr-Sep) 2013



Chronic O_3 exposure in Spain: above target values for the protection of vegetation

Total N deposition 2009 (EMEP)



Total N deposition in Spain:

up to 30 kg N ha^{-1} yr^{-1}

Dry dep. >> wet dep.

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Risk Assessment: tools used under the Air Convention

40 years of successful cooperation for clean air

Clean Air 40 YEARS

Air Convention, UNECE 1979

First internationally legal binding instrument to deal with impacts of air pollution on a broad regional basis.
Brings together Science and Policy

Critical Loads and Levels
Environmental thresholds for risk assessment

Maximum amount of pollutants that ecosystems can tolerate without being damaged

Exceedance of CL

IF.....

[AP] > CL (AP) → Risk of damage

[AP] < CL (AP) → No risk

AP: Atmospheric Pollutant
CL: Critical Load/Level

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Ozone risk assessment: Critical Level - AOT40

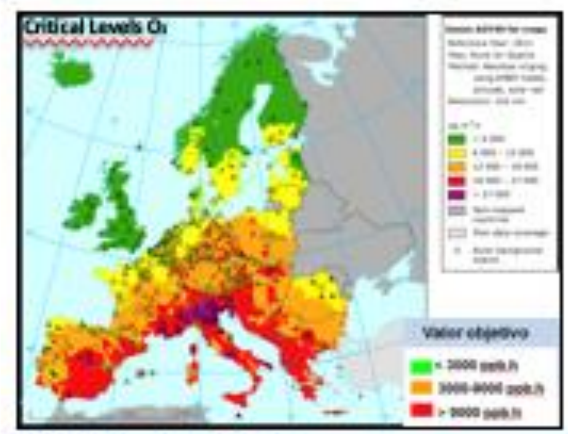
CRITICAL LEVELS for O3
The sum of the differences between hourly ozone concentration and 40 ppb for each hour when the concentration exceeds 40 ppb during a relevant growing season, e.g. for forest and crops (CLRTAP, 2010)

Why effects predicted by risk assessments are not found in the real life in Mediterranean areas?

- Species-specific O_3 sensitivity: critical levels should be based on typical Mediterranean species/cultivars

- Effects more related to O_3 fluxes absorbed: adequate parameterization for flux estimations required

- Interactions with other environmental factors / pollutants



AOT40 May-July 2011 Source: EEA

AOT40 (Accumulated Ozone Exposure over a threshold of 40 Parts Per Billion)

Ozone risk assessment: Effective/Absorbed dose

CRITICAL LEVELS

AOT40 (Ozone exposure)

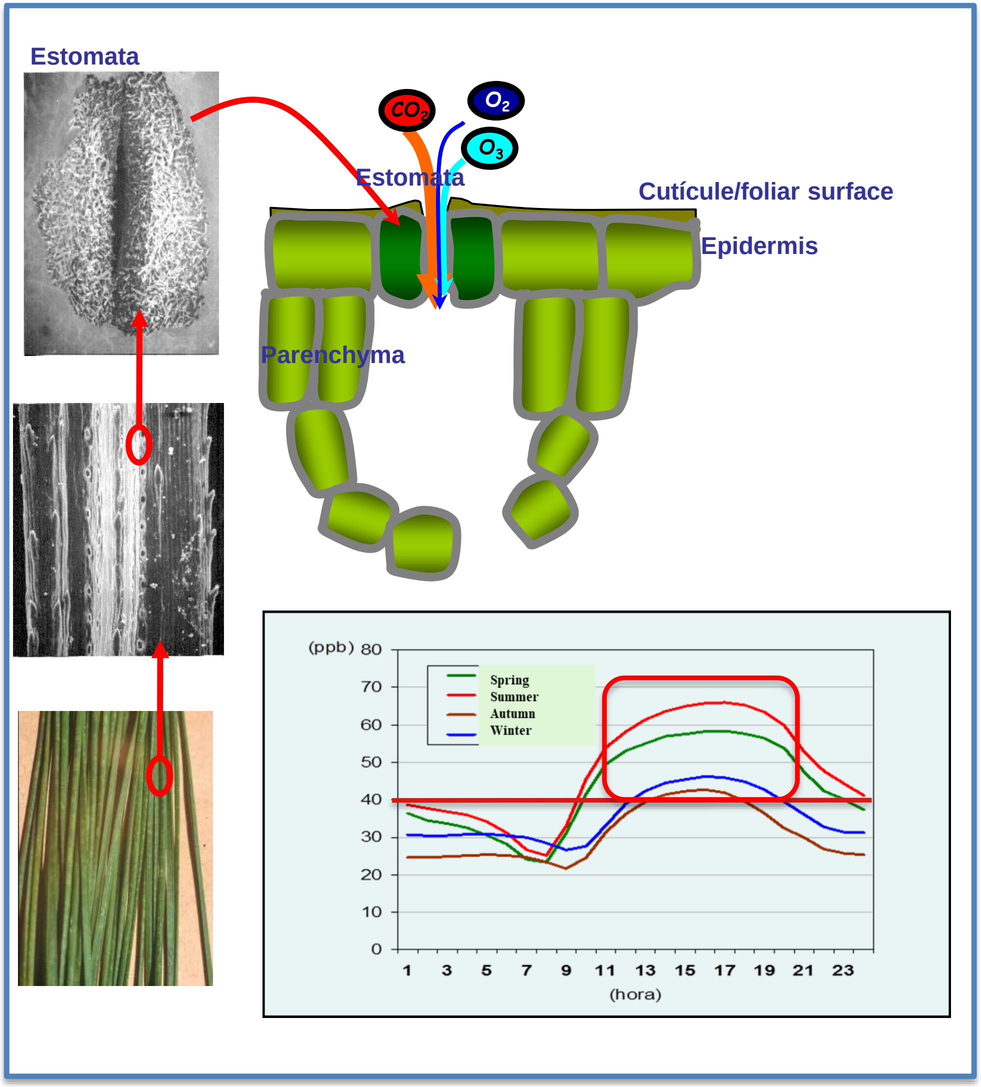
Dose = [Ozono] * t

Ozone absorption

Stomatal ozone flux

POD (Phytotoxic Ozone Dose)

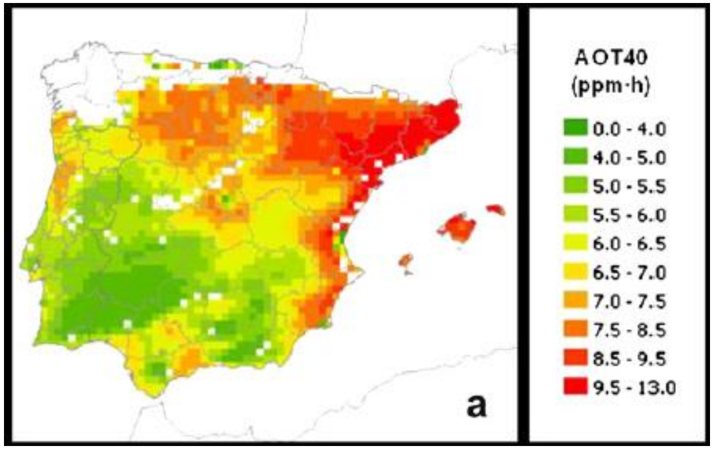
- [O3] in air
- Temperature
- Light
- Humidity (VPD)
- Soil moisture
- Plant development



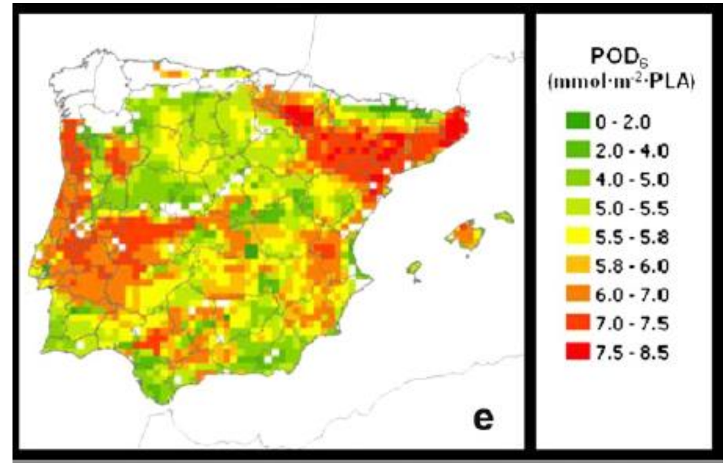
Ozone risk assessment: AOT40 *vs* POD

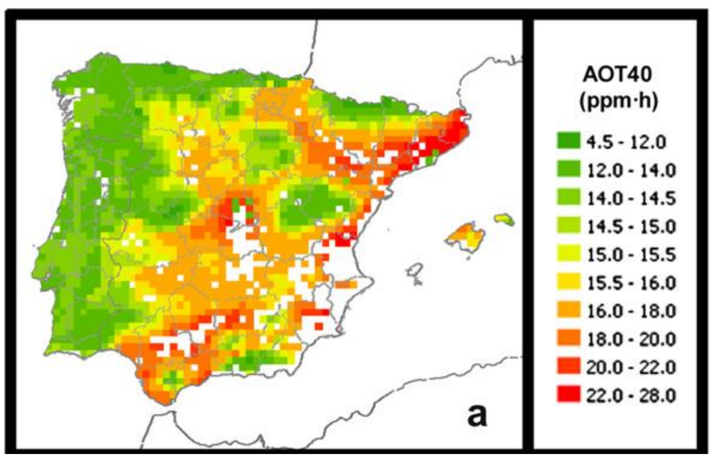
Risk based on exposure (AOT40)

Risk based on flux uptake (POD)

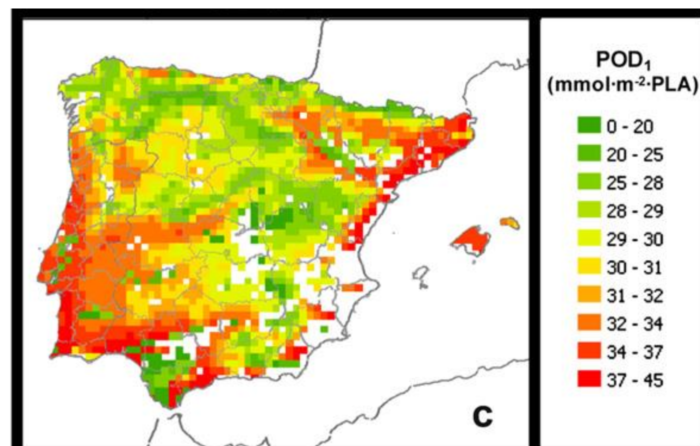


Wheat





Holm oak (*Quercus ilex*)



De Andrés et al., 2012, Env. Pol.

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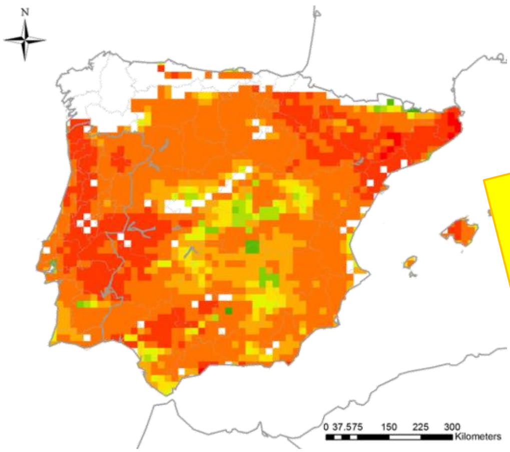
Ozone risk assessment: POD

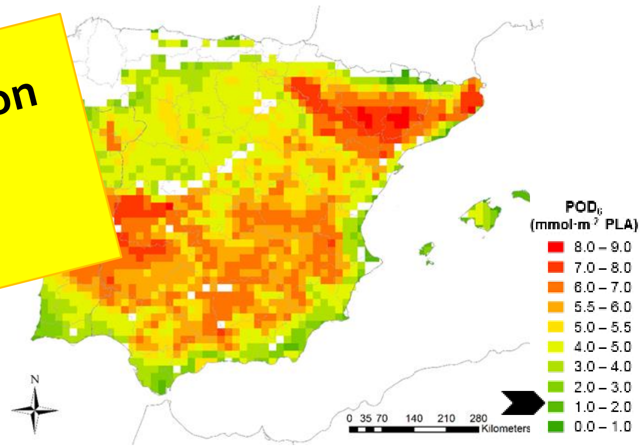
Central European parameterization

Mediterranean parameterization



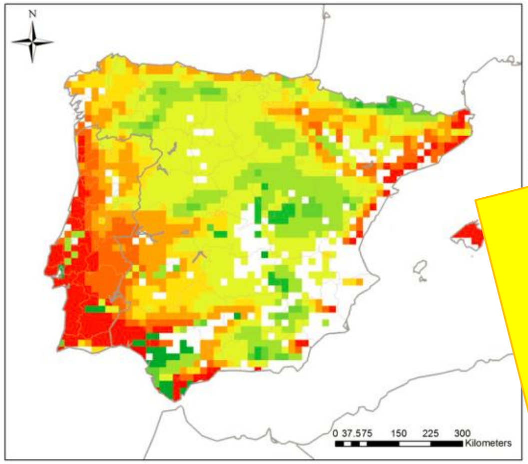
Wheat

Flux model parameterization affects outcome of risk assessment



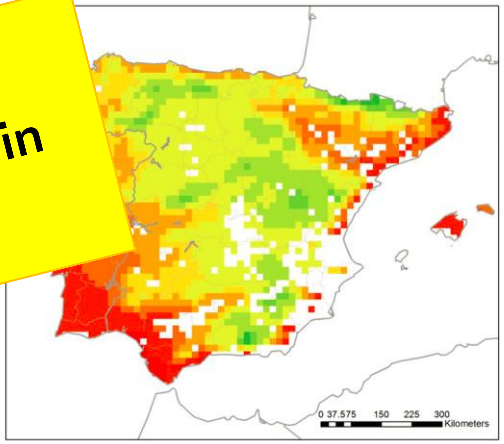
Including soil moisture content

No soil moisture content considered



Holm

Uncertainties in modelling the influence of soil moisture in O3 fluxes



CMAQ v 4.6 model + gs (DO3SE model) + Soil Moisture content, data 2007)

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Main messages

- ✓ Ozone is modifying plant physiology and affects yield production, and fruit quality
- ✓ O_3 reduces the fertilization effect of N and increases N losses ($N_2$0 emissions) in annual pastures
- ✓ N can compensate for some O_3 effects in annual pastures

Progress is needed for:

- Reducing uncertainties in modelling the influence of soil moisture and drought on fluxes and physiology (water-limited areas and extreme events)
- Validation of ozone concentration and uptake estimations in high mountain areas
- Include interactions with other global change factors

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