Impact of droughts and heatwaves on surface ozone over Southwestern Europe

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AS3.5 COMPOSITION-CLIMATE INTERACTIONS INCLUDING NATURAL AEROSOLS

Tropospheric ozone (O_3)

- Harmful for human and ecosystem health
- Secondary species (CO, CH_4, NMVOCs and NO_x as precursors)
- Key role of meteorological conditions

→ O_3 photo-chemistry

→ Biogenic emissions

→ O_3 dry deposition

} Lack of interactions between biosphere and atmosphere in Chemistry Transport Models (CTMs)

O_3-injured tulip tree foliage

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Biosphere - Troposphere interactions during extremes

Intense and frequent droughts / heatwaves over SW Europe :

- B-T interactions strongly affected during such events
- Difficulties to represent drought effects in CTMs (biomass decrease and soil dryness)

➔ limited knowledge and many uncertainties

Objectives:

A) **Assess the sensitivity** of C_5H_8 emissions and O_3 dry deposition to drought effects

B) **Quantify the variation** of surface O_3 during droughts, isolated or combined with heatwaves

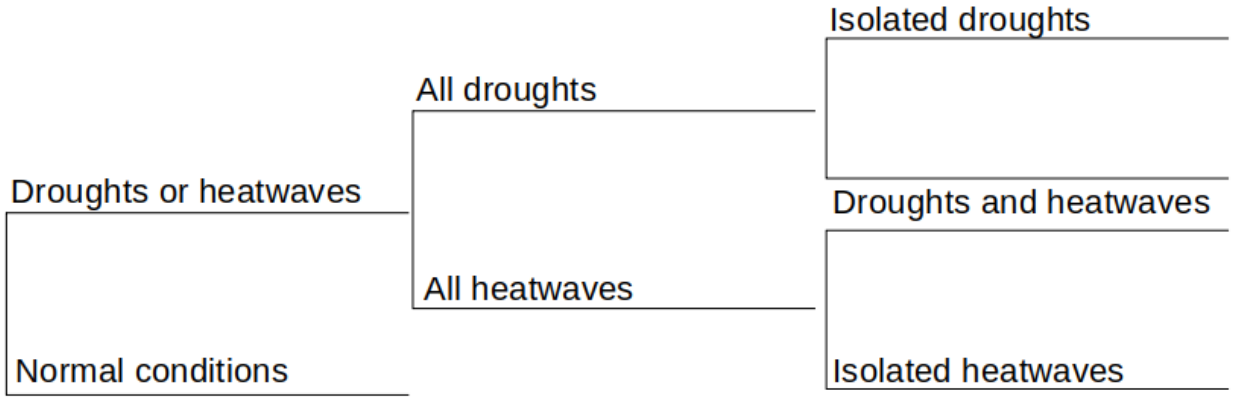
Methods

A) Sensitivity analysis based on WRF-MEGAN-CHIMERE simulations

*Variation of observed LAI
*Implementation of soil dryness indicators

} in emission and deposition schemes

B) Cluster analysis of surface O_3 based on the indicator "Percentile Limit Anomalies"



Material

A) CTM simulations
(CHIMERE, MEGAN, WRF model)
→ summers 2012-2014

Observations of LAI
(MODIS from Terra/Aqua)
→ summers 2012-2014

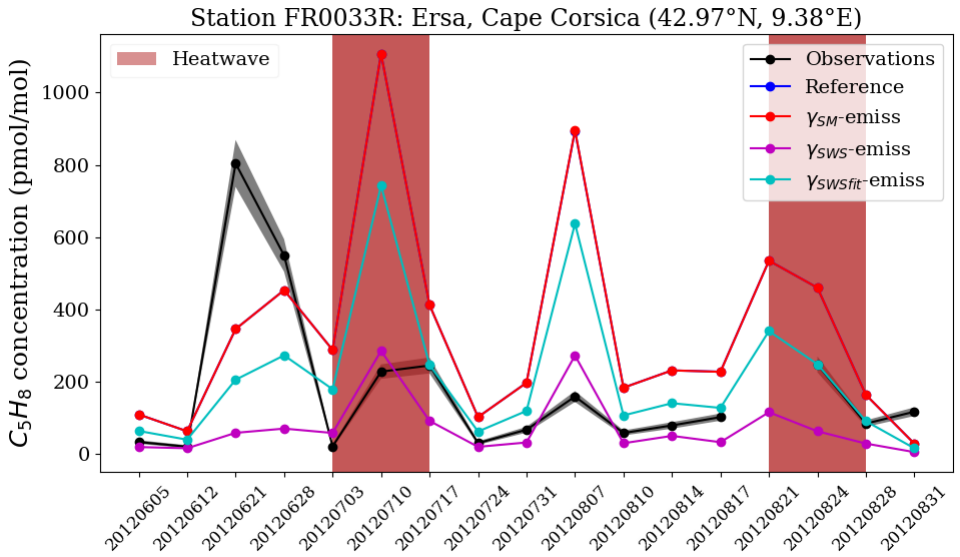
B) Drought (soil moisture) and heatwave (2m t°) PLA indicator
(ORCHIDEE, WRF model)
→ summers 2000-2016

Observations of surface O_3
(AQ e-Reporting from EEA)
→ summers 2000-2016

Results – Sensitivity analysis (A)

Several config. tested for soil dryness:

- soil moisture and wilting point from WRF-Noah (γ_{SM}), Guenther et al. (2012)
- soil water stress function from WRF-ORCHIDEE (γ_{SWSfit}), fitted function of Bonn et al. (2019)

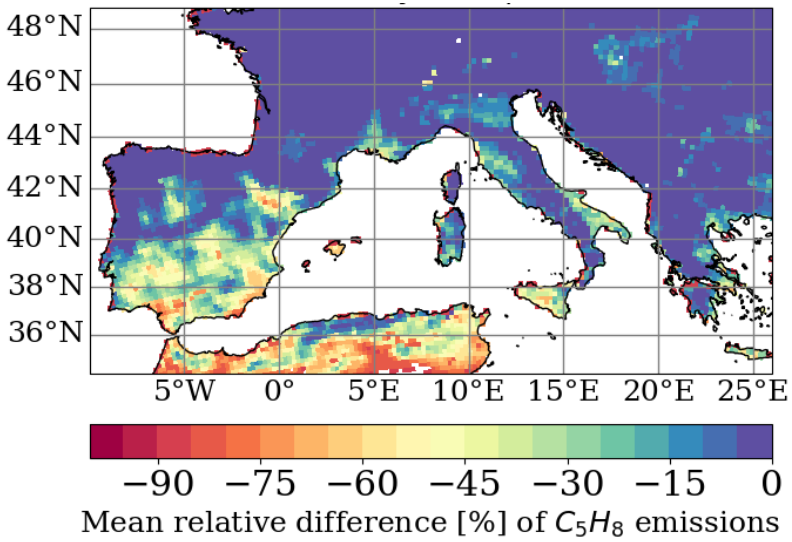


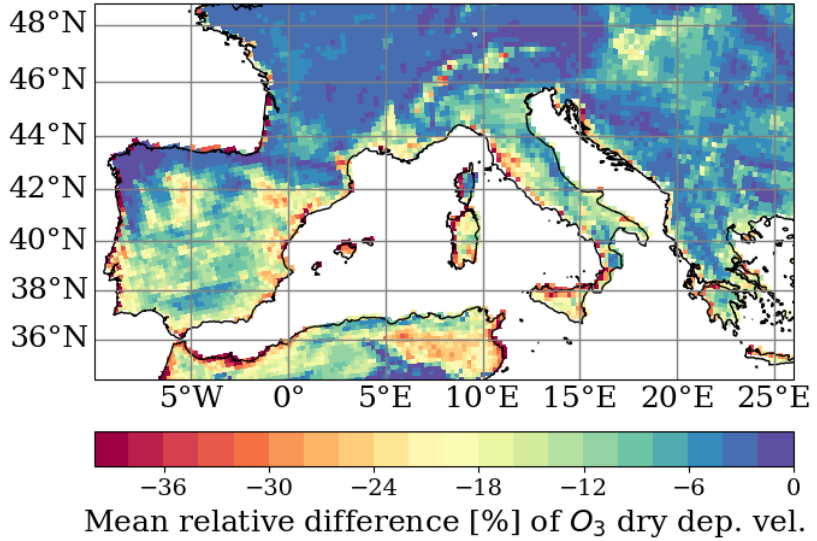
f_{SWSfit} *experiment*

Emissions over e.g. Central Italy

-11% by biomass decr.

-25% by soil dryness





Deposition over e.g. Central Italy

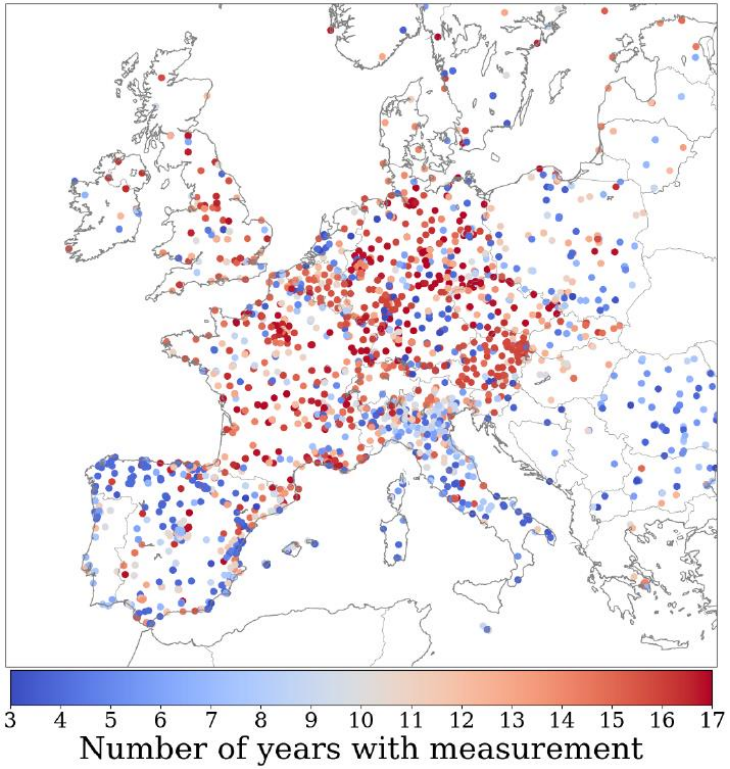
-3% by biomass decr.

-14% by soil dryness

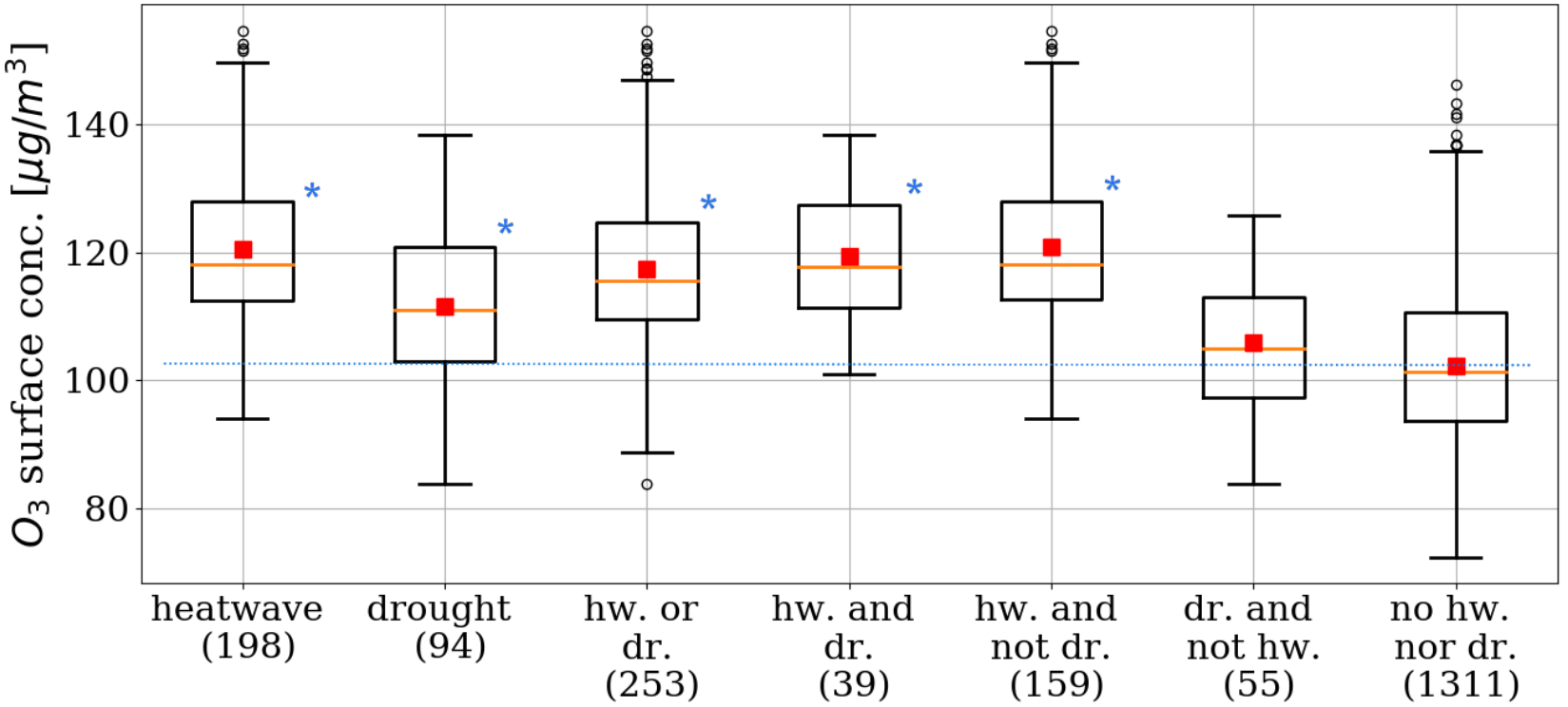
Results – Cluster analysis (B)

- +18µg/m^3 during hw. and +9µg/m^3 during dr., compared to normal conditions
- Non-significant difference during isolated droughts ('dr. and not hw.')

Station distribution

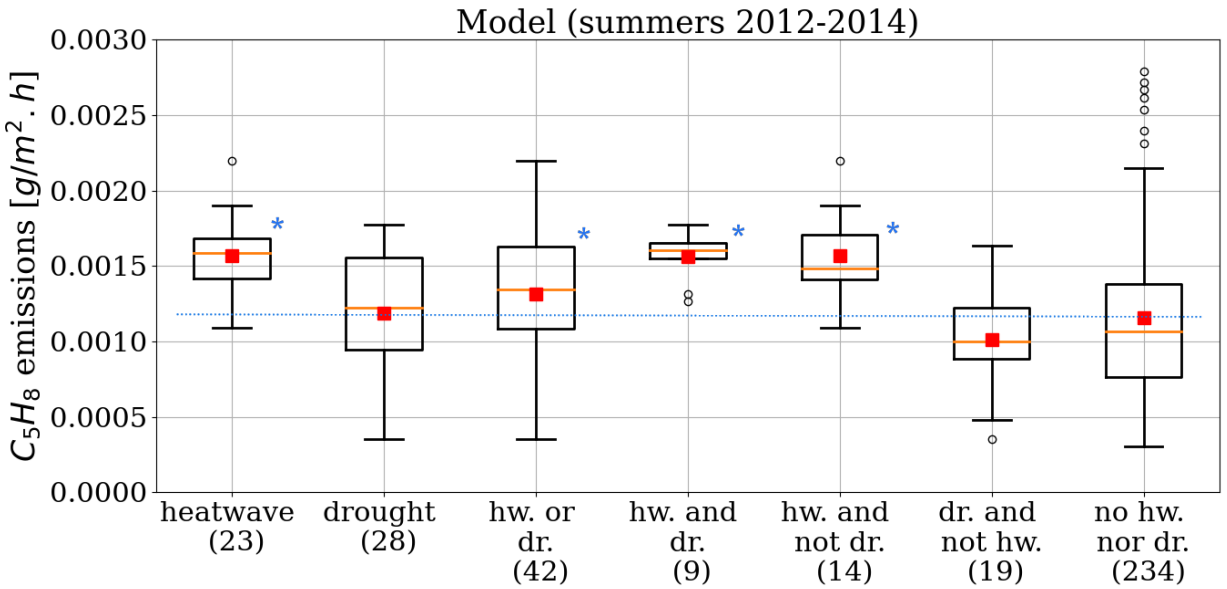


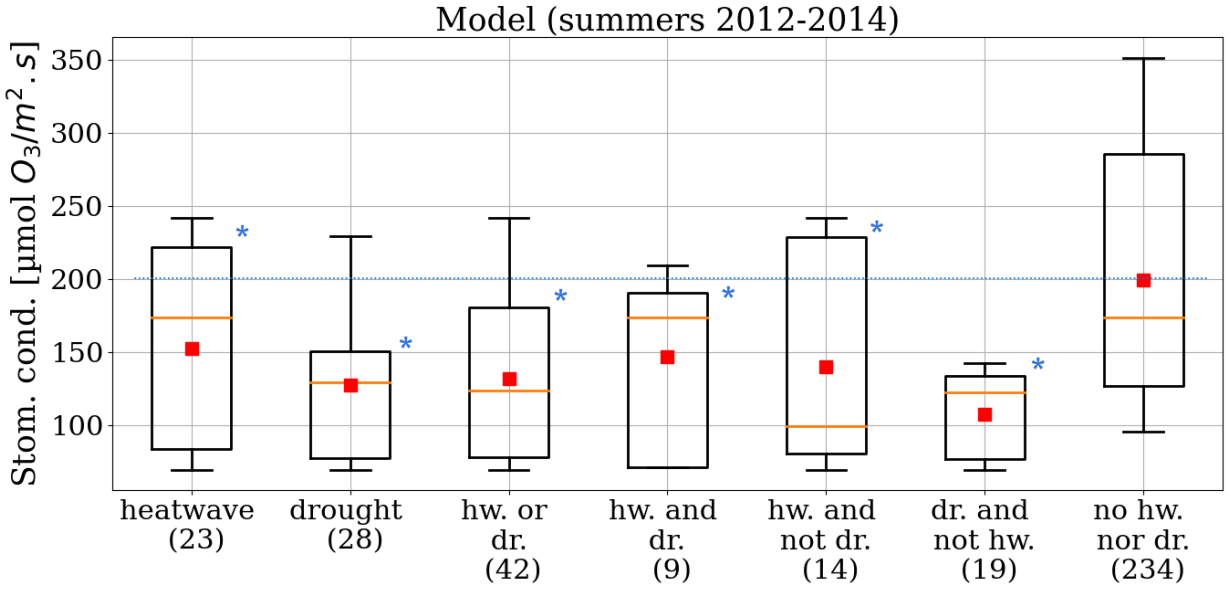
Observed daily maximum (summers 2000-2016)



Results – Cluster analysis (B)

- Including all drought and heatwave effects, simulated interactions (MEGAN-CHIMERE) present signals consistent with O_3 observations
- Negative variation of C_5H_8 emiss. only for isolated dr. ➔ confirmed by HCHO observation (OMI)
- Negative variation of O_3 deposition velocity for all clusters





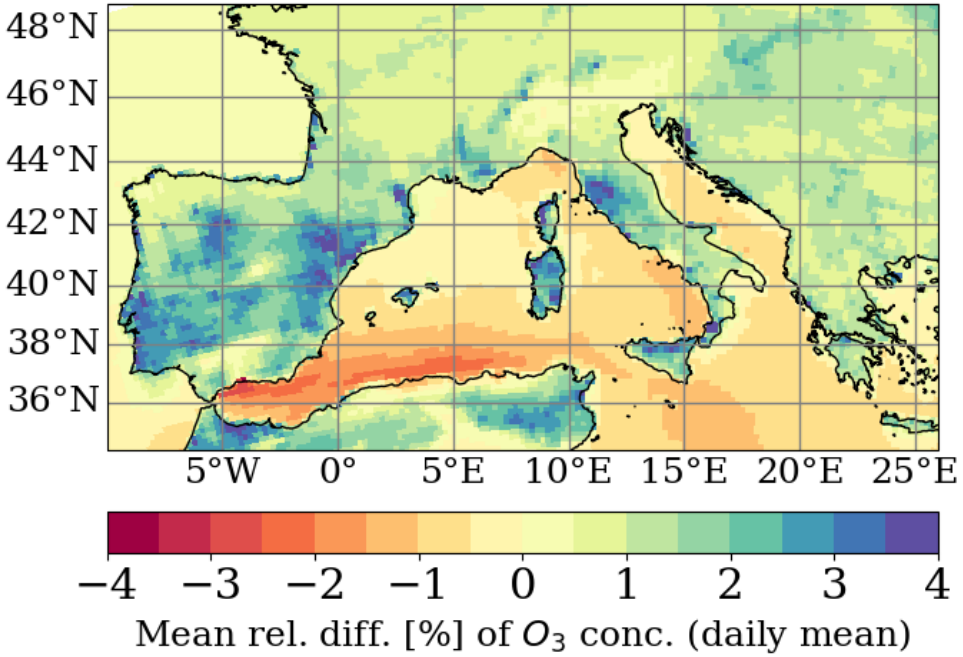
Conclusions and discussion

A) Biomass decrease and soil dryness :

→ critical factors for dynamical BVOC emissions and O_3 dry deposition

→ minor effect on surface O_3 concentration

Drought effects on both C_5H_8 emissions and O_3 dry deposition (MEGAN-CHIMERE, JJA 2012)



Conclusions and discussion

B) Drought and heatwave events :

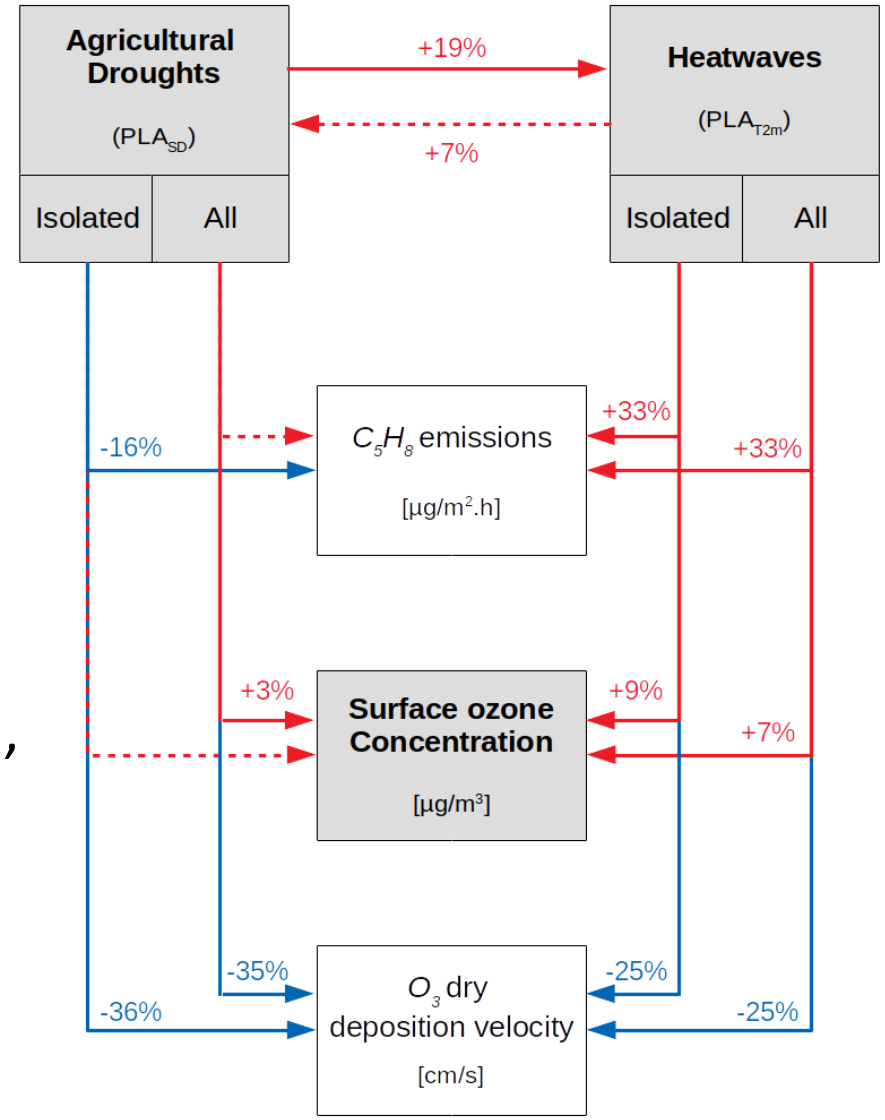
→ overall enhancement of surface O_3 (obs. and sim.)
due to increase of O_3 precursor emissions
decrease of O_3 dry deposition
favored photo-chemistry activity

→ frequent exceedance of threshold values for AQ (not shown here)

→ dynamical representation of interactions |b| vegetation, hydrology, meteorology and atmosph. chem. emphasized

! Considerable uncertaities related to
precursor emissions (BVOCs and NO_X)
meteorological conditions (temp. and PBLH)

MEGAN-CHIMERE (JJA 2012, 2013, 2014)



Thanks for your attention

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Further details on this work:

→ **Guion, A.**, Turquety, S., Cholakian, A., Polcher, J., Ehret, A. and Lathière, J. Interactions between the terrestrial biosphere and atmosphere during droughts and heatwaves: impact on surface ozone over Southwestern Europe. **Atmospheric Chemistry and Physics** (**In review**, 2022).

→ Guion, A. Droughts and heatwaves in the Western Mediterranean, impact on ozone pollution. Sorbonne Université, PhD thesis (2022). https://lnkd.in/ezUPT_U8.

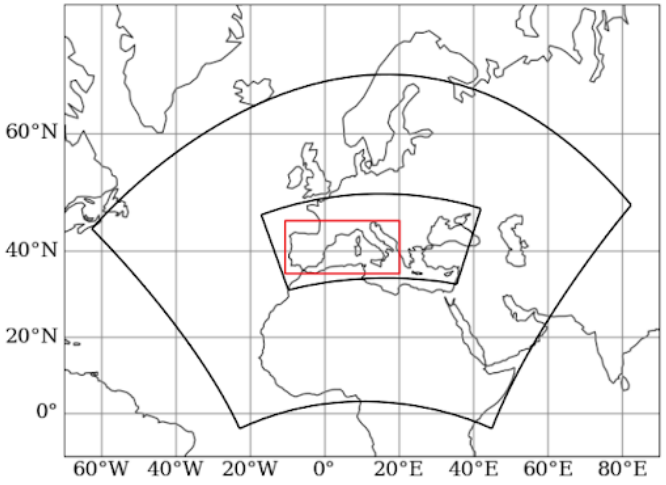
Appendices

MEGAN- CHIMERE simulations

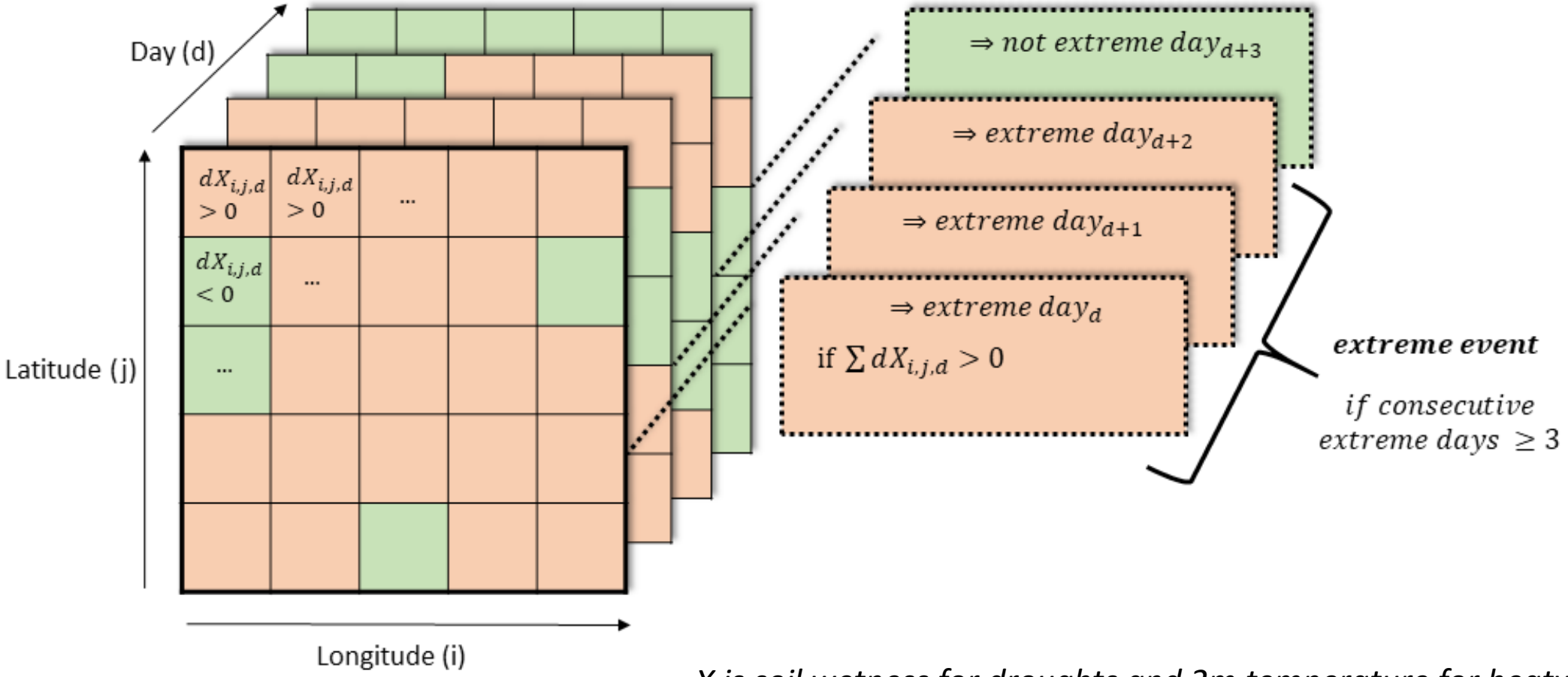
CHIMERE experiments on the nested Med-CORDEX domain for summers 2012, 2013 and 2014

Simulation name	Description	Aim
Reference (R.)	CHIMERE reference (v2020r1)	Default for dry and hot periods
	On biogenic emissions	
NoBio-emiss	R. without biogenic emissions	Contribution of biogenic emissions to O_3
HighLAI-emiss	R. with wet summer LAI	Effect of biomass decrease
γ_{SM}-emiss	R. with γ_{SM} factor from Noah	Effect of soil dryness
γ_{SWS}-emiss	R. with γ_{SWS} factor from ORCHIDEE	Effect of soil dryness
γ_{SWSfit}-emiss	R. with γ_{SWSfit} factor from ORCHIDEE	Effect of soil dryness
	On gas dry deposition	
LAIdecr-dep	R. with prescribed LAI reduction	Effect of biomass decrease
LAIdecr/f_{SWS}-dep	R. with prescribed LAI reduction and f_{SWS} factor from ORCHIDEE	Effect of biomass decrease and soil dryness

Large and nested domain (20km resolution) in black. Study area in red.

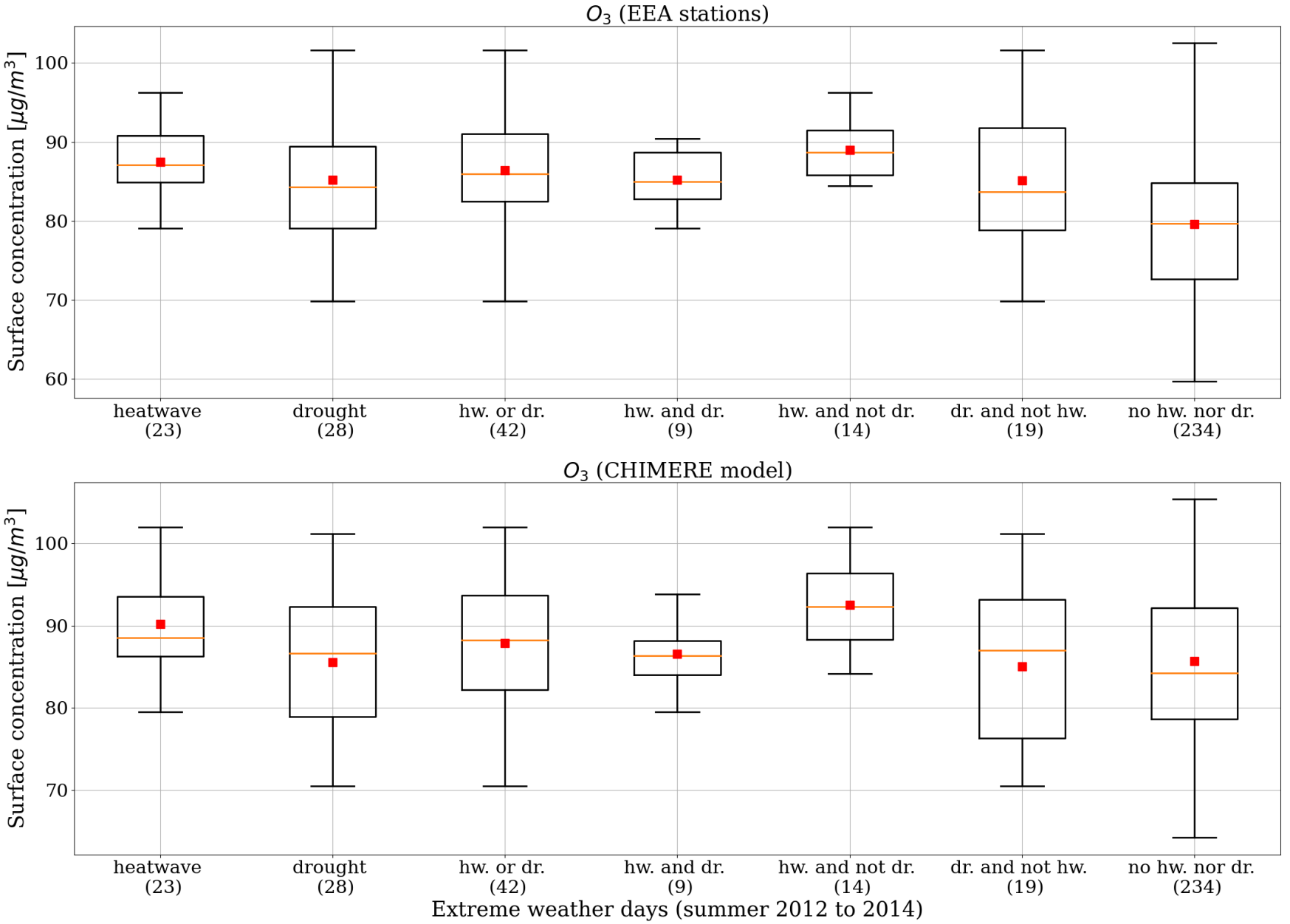


PLA method



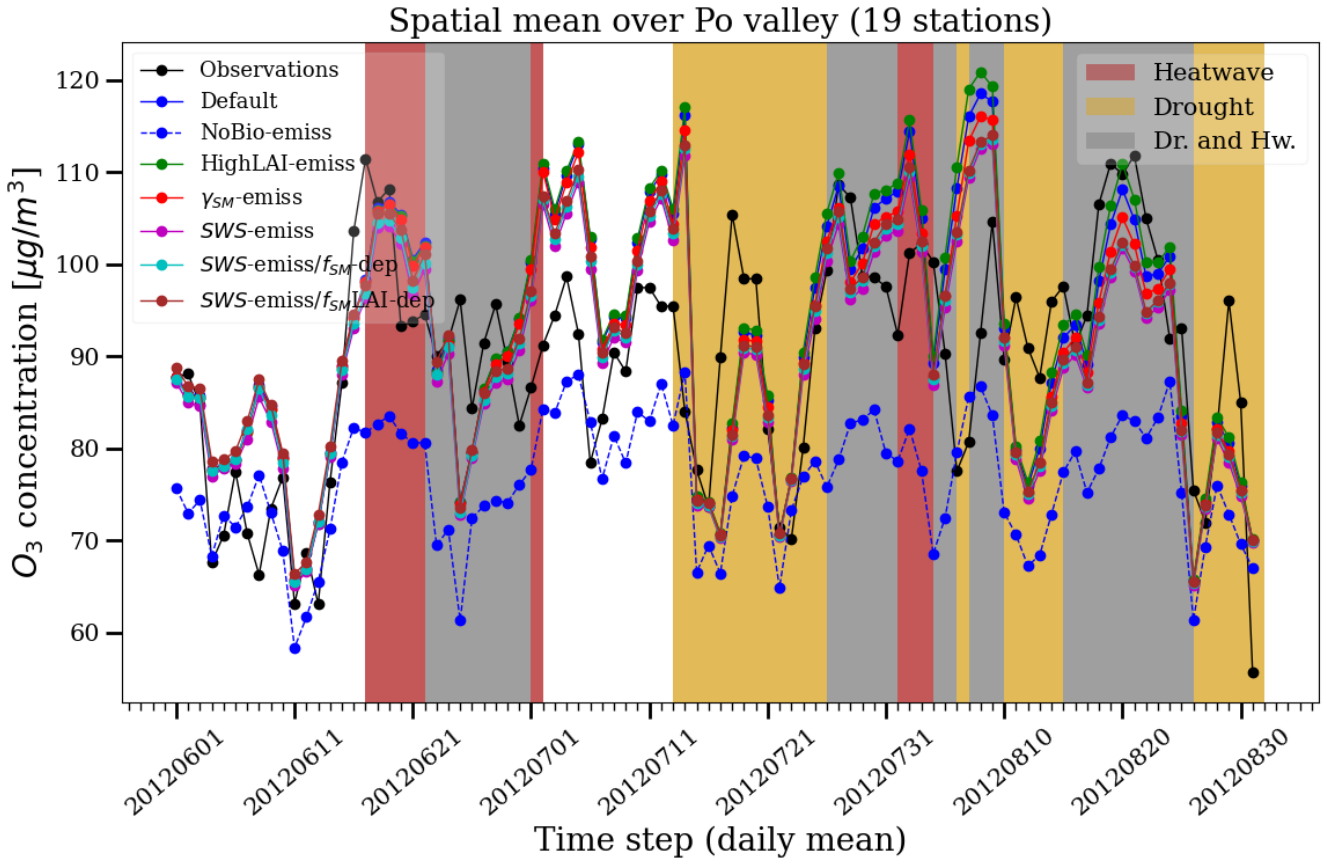
X is soil wetness for droughts and 2m temperature for heatwaves

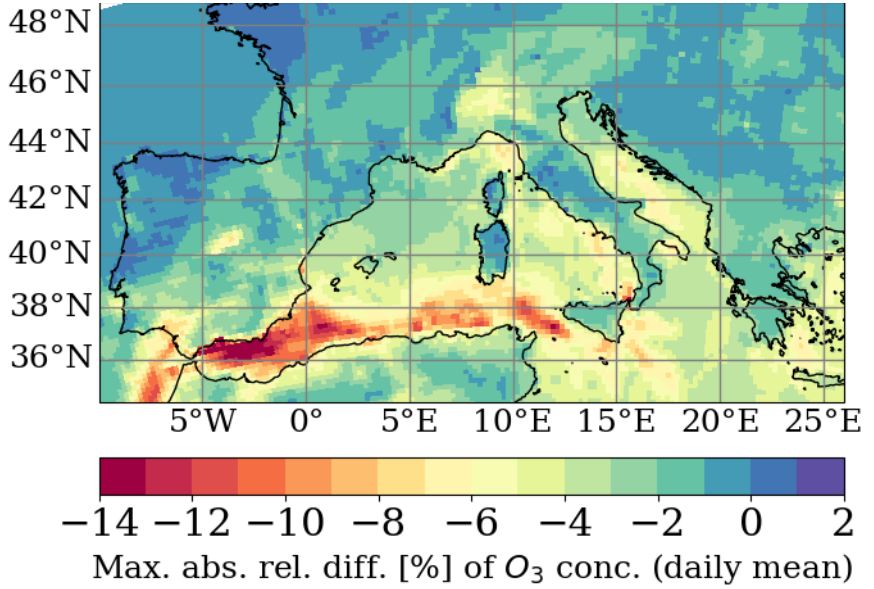
O_3 signals (daily mean)

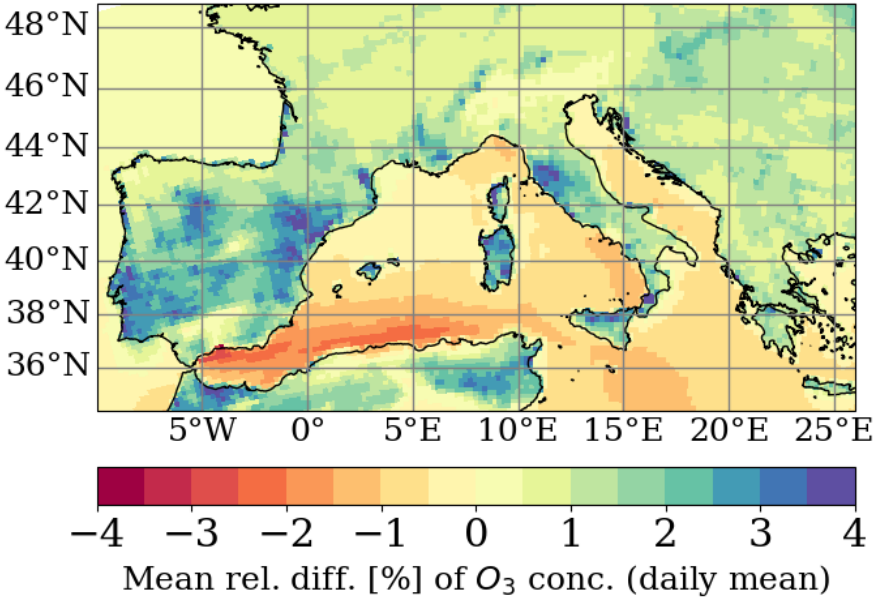


O_3 sensitivity

Drought effects on both C_5H_8 emissions and O_3 dry deposition (MEGAN-CHIMERE, JJA 2012)







Validation

CHIMERE simulation (JJA 2012): validation of O_3 and NO_2 against AQ e-Reporting and T_{2m} against E-OBS

O_3	Obs. (µg/m³)	Mod. (µg/m³)	Bias (µg/m³), Obs - Mod	RMSE (µg/m³)	Pearson correl. (R)
Daily mean	83.93	84.06	-0.13	14.31	0.53
Daily max	116.32	105.39	10.94	21.49	0.54

NO_2	Obs. (µg/m³)	Mod. (µg/m³)	Bias (µg/m³), Obs - Mod	RMSE (µg/m³)	Pearson correl. (R)
Daily mean	7.55	2.60	4.95	5.24	0.40
Daily max	14.65	6.08	8.57	9.87	0.37

T_{2m}	Obs. (°C)	Mod. (°C)	Bias (°C), Obs - Mod	RMSE (°C)	Pearson correl. (R)
Daily mean	22.25	22.25	-0.01	8.19	0.76
Daily max	29.13	28.34	0.56	12.63	0.75

Threshold exceedance

EU standard for AQ : daily maximum (8 hour mean) surface concentration < 120 µg/m³

EEA stations with ≥ 1 exceeding day during summers 2000-2016 (JJA)	
Average fraction of concerned stations	54%
Average number of days per station	27 days

Extreme events	Percentage of exceeding days	Exceeding values
Hw. or dr.	48%	+22µg/m³
Hw.	34%	+24µg/m³
Dr.	27%	+18µg/m³
Isol. dr.	14%	+15µg/m³