



Ozone sensitivity to VOCs emissions and lessons learned for the design of the Spanish National abatement plan

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Outline

1. Some insights from the Spanish national ozone plan
2. MONARCH contribution to TFMM and beyond
3. Improving the Characterisation of Anthropogenic NMVOC in Europe
4. Future steps



Some insights from the Spanish national ozone plan



A comprehensive set of emission scenarios in key sectors

EB: base case (2019)

EP: planned scenario (2030 with national plans) →

-12% of VOC emissions
-42% of NO_x emissions
(highest changes in road transport,
some industries and electricity
generation)

EEs: specific scenarios based on EP, but with

- Lower reduction from traffic 
- Higher reductions from industries 
- Higher reductions from solvent use 
- Higher reductions from aviation, national and international shipping  

EXs: extreme scenarios over Spain such as:

- No anthropogenic NO_x emissions
- No anthropogenic VOC emissions 
- No anthropogenic emissions
- No biogenic emissions (in and outside Spain) 

Anthropogenic emissions: HERMES bottom-up
Biogenic emissions: online MEGAN

→ MONARCH air quality model

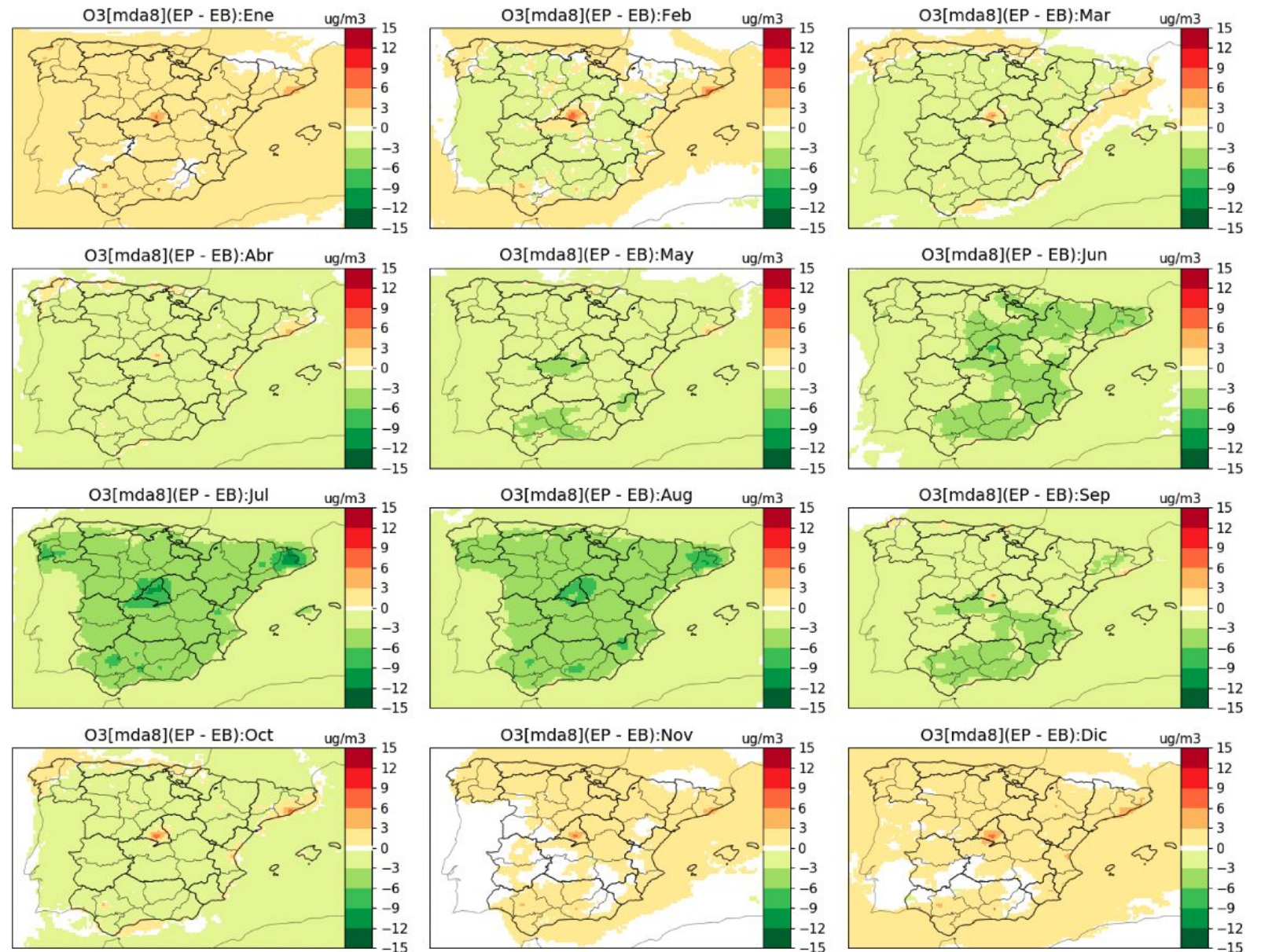
The planned scenario strongly reduce $O_3^{(mda8)}$ levels, especially during the ozone season and key polluted regions



Differences of $O_3^{(mda8)}$ between planned scenario and base case (EP-EB):

Strong reduction of $O_3^{(mda8)}$, especially during Apr-Sep, over most of the country, except in some coastal cities like Barcelona
-3 $\mu\text{g}/\text{m}^3$ on average in Apr-Sep

Key contribution of road transport
(not shown)



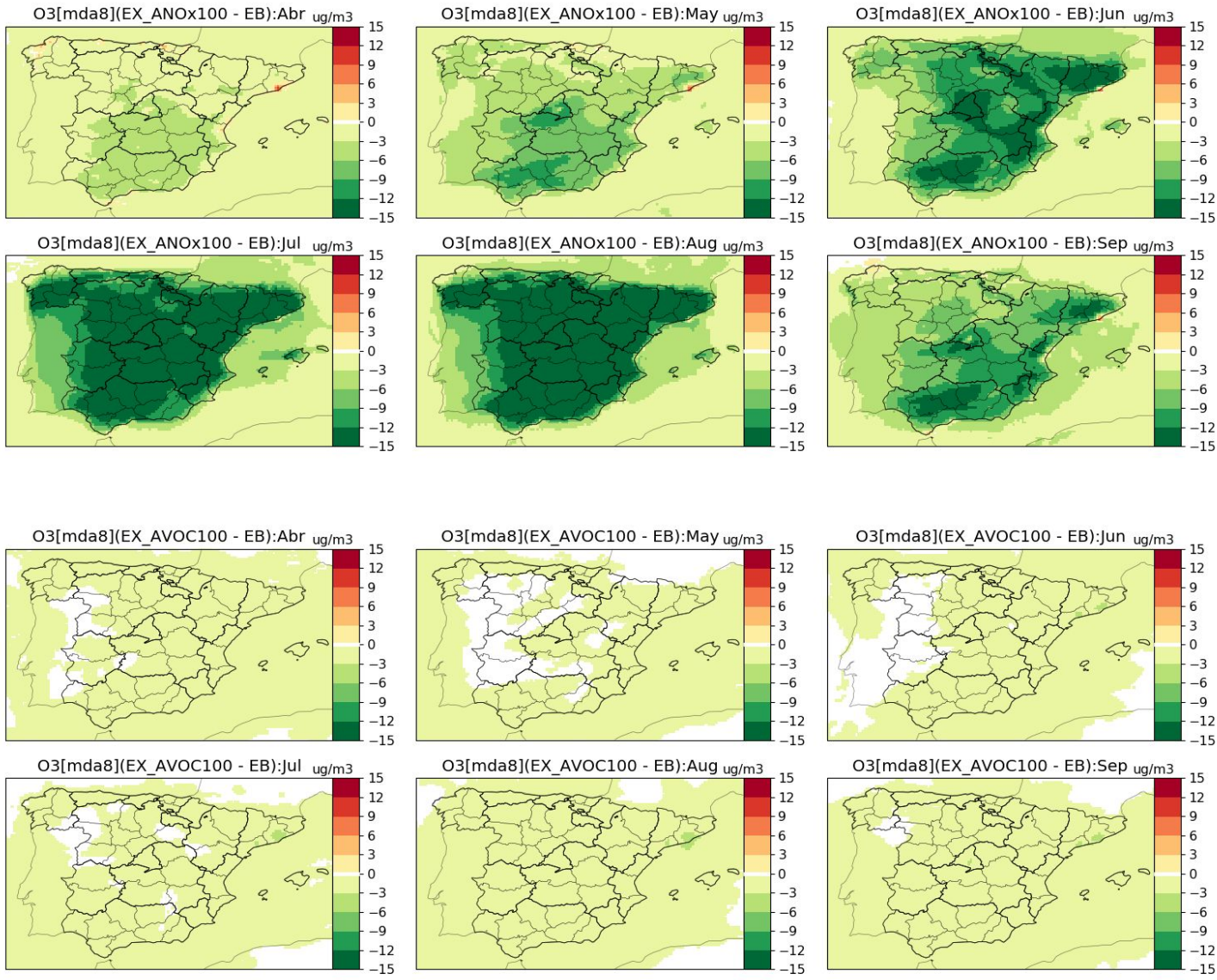
Anthropogenic NOx emissions play a key role in O3 production and VOCs

April...
...September

Impact of removing anthropogenic NOx (above) and VOC (below) emissions on O3^(mda8):

Spanish anthropogenic NOx emissions strongly contributes to ambient O3 levels across Spain
-14 µg/m3 on average in July

Spanish anthropogenic VOC emissions play a much lower role
up to -5 µg/m3 in July over specific locations



Biogenic VOC emissions play a key role (combined with anthropogenic NO_x)

April...



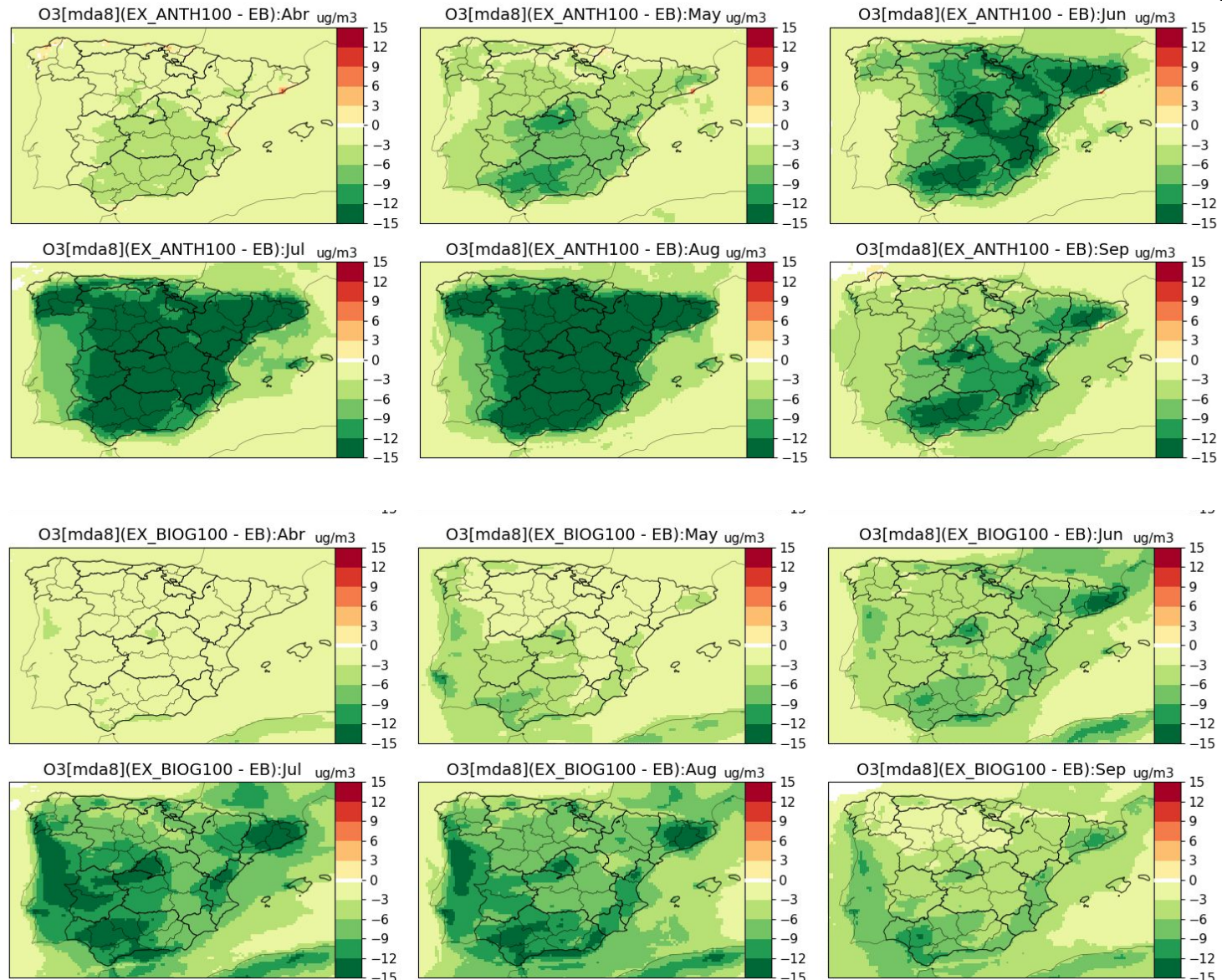
...September

Impact of removing all anthropogenic (above) and all biogenic emissions (below) on O₃^(mda8):

Both anthropogenic and biogenic emissions contribute strongly to O₃^(mda8) levels in Spain during April-September, but anthropogenic emissions contribute more

-9 and -5 $\mu\text{g}/\text{m}^3$ on average in Apr-Sep.

Biogenic VOC emissions combined with anthropogenic NO_x emissions thus appear as the dominant contributors to O₃ production in Spain



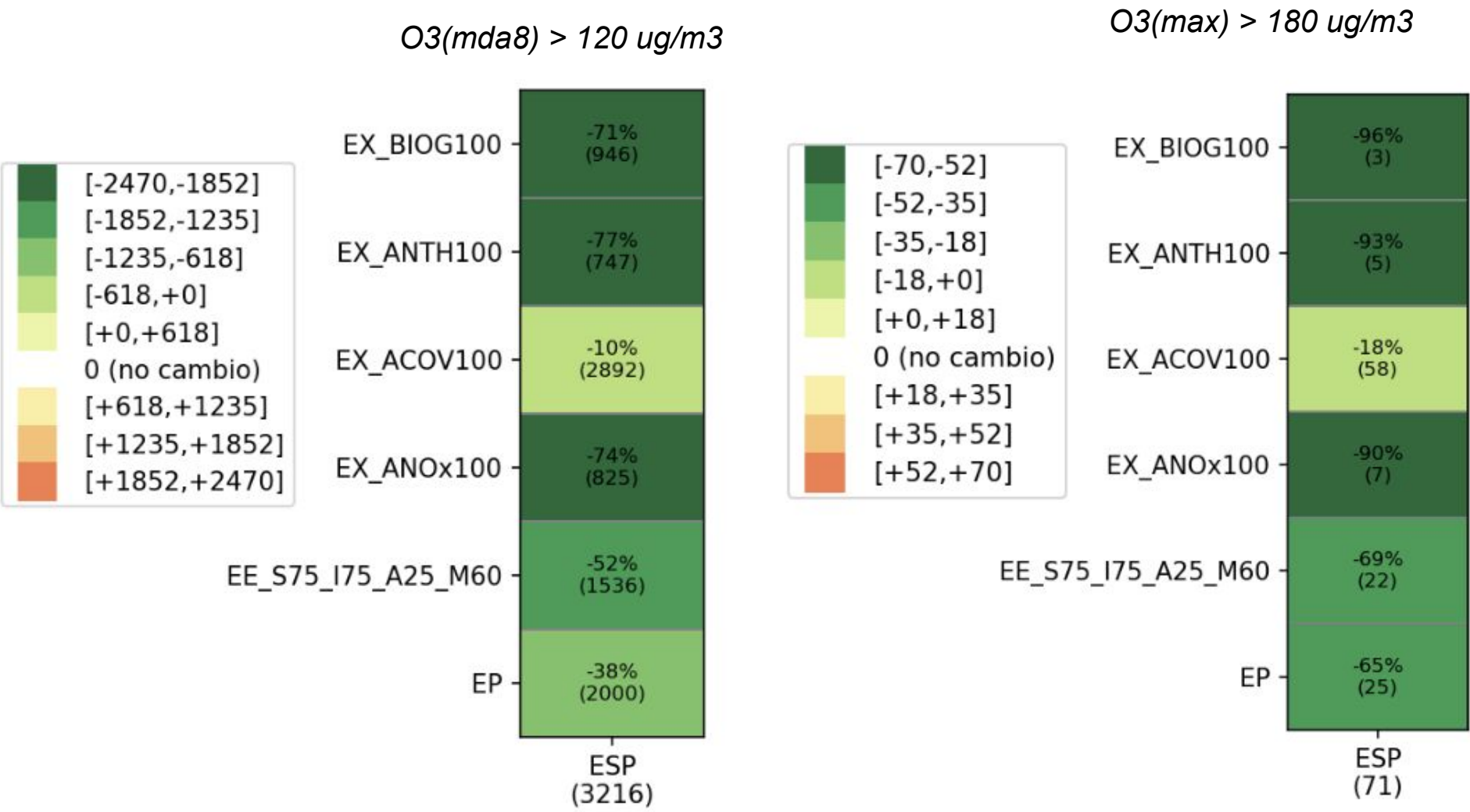
Ozone episode frequency in Spain mainly driven by anthropogenic NOx and biogenic VOC emissions

Relative change of # exceedances (and #exceedances):

Key role of anthropogenic NOx emissions

Key role of biogenic VOC emissions, limited contribution of anthropogenic VOCs

Strong improvement with EP scenario, still margin of improvement on with more ambitious scenario



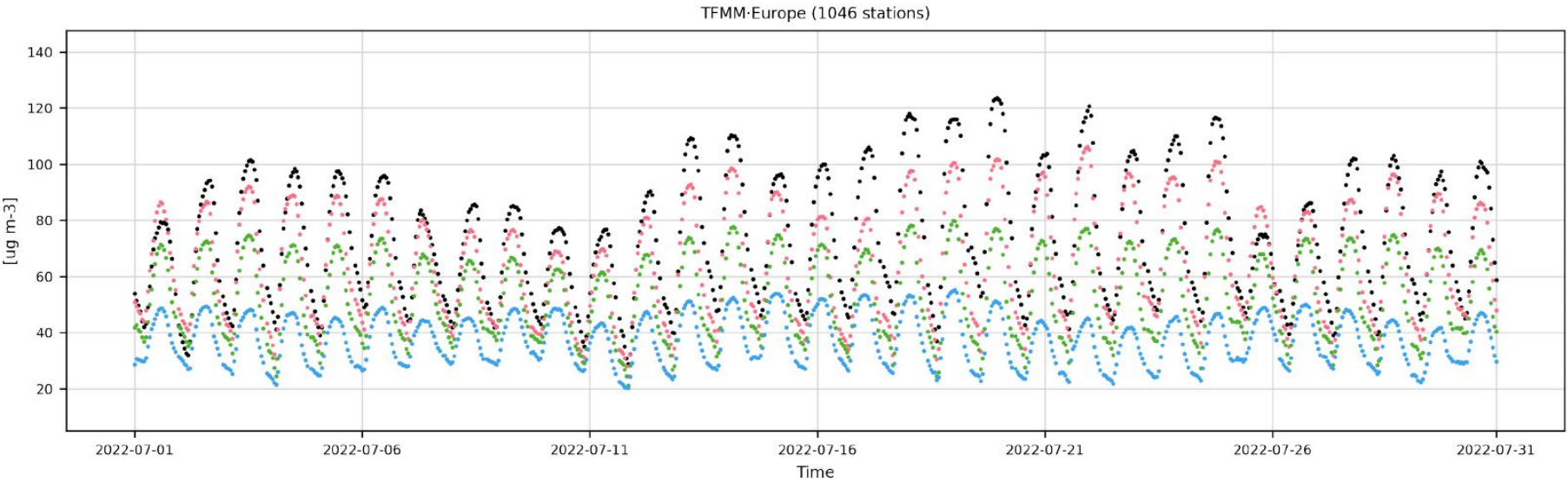
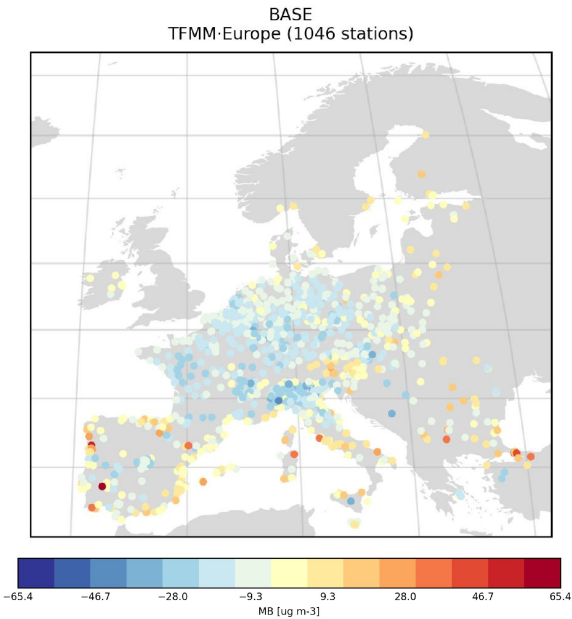
MONARCH contribution to TFMM and beyond



TFMM July 2022 - O3 validation (BASE scenario)

Timeseries (Summary)
eea/eionet|sconco3

● observations ● BASE ● ANT ● BIO



MONARCH has a tendency to underestimate surface ozone in summer.

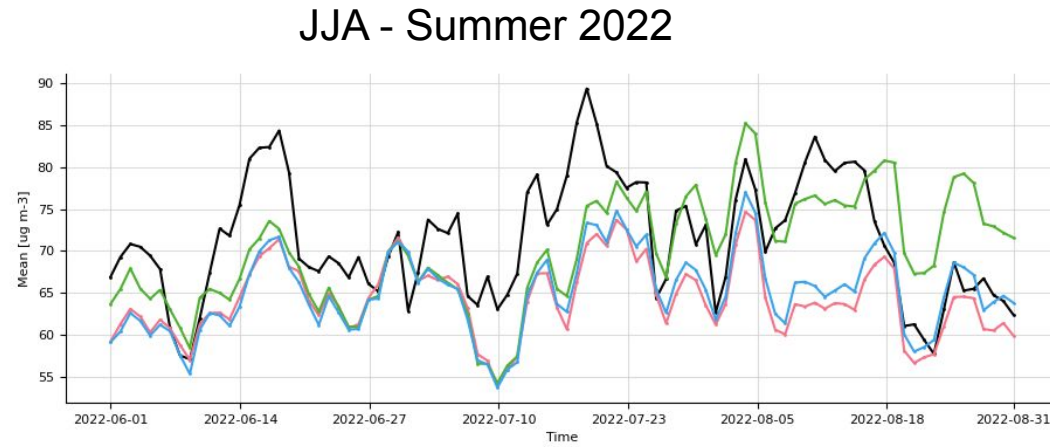
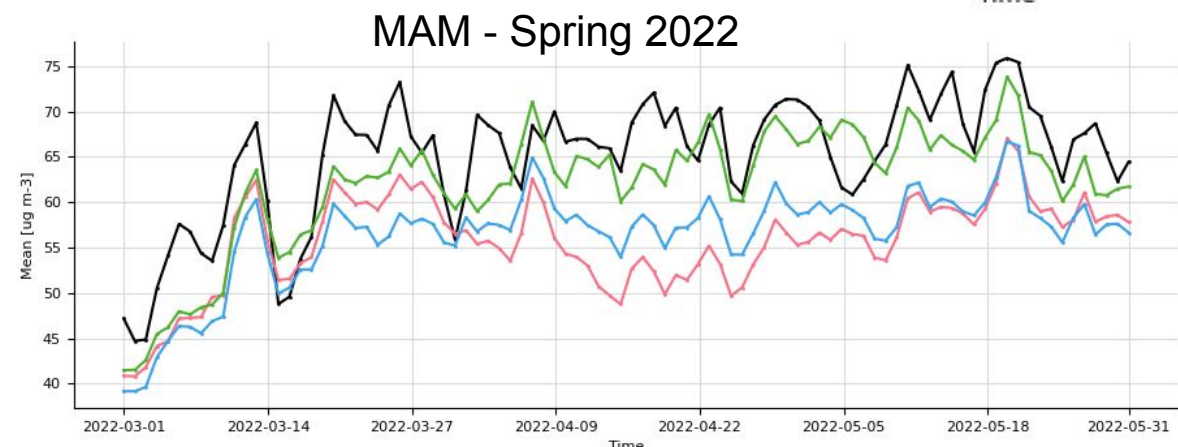
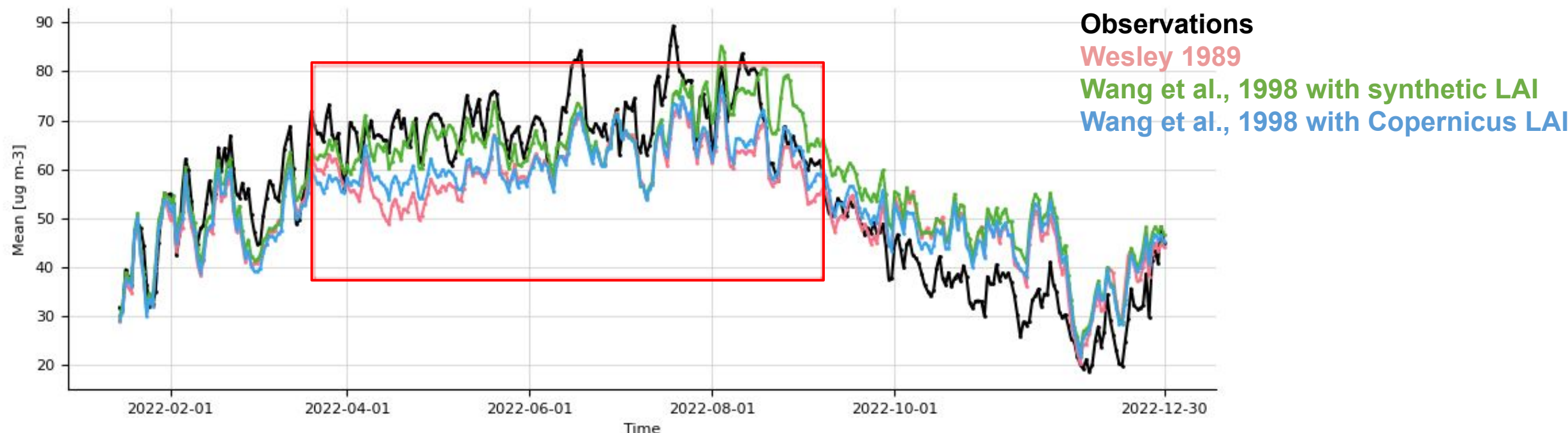
Analysing chemical processes:

- test new dry deposition scheme
- biogenic emissions (not yet)

		Mean	StdDev	NMB	NME	RMSE	r
Europe	BASE	-10.70	-5.34	-14.43	25.81	23.84	0.77
NorthEurope	BASE	-11.16	-5.34	-16.97	25.70	21.85	0.79
SouthEurope	BASE	-1.32	-2.39	-1.72	21.17	21.68	0.75
CentralEurope	BASE	-15.92	-7.67	-20.23	27.10	26.26	0.78

TFMM July 2022 - O3 validation (dry deposition treatment)

Wang, et al., 1998: light correction (using LAI) in canopy stomatal resistance + dependence of LAI on external resistance



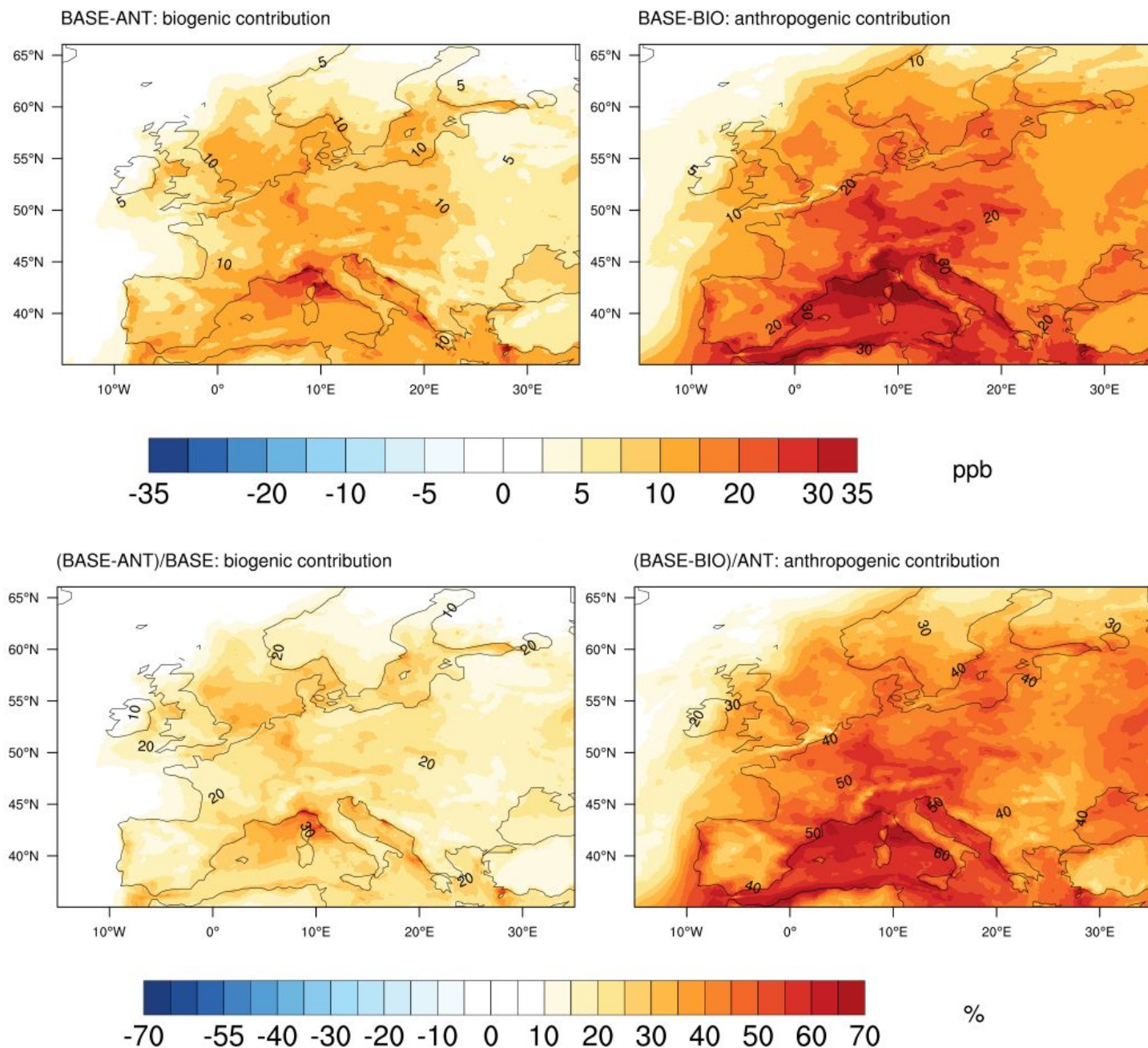
TFMM July 2022: O3

Differences of $O_3^{(mda8)}$ between base case scenario and ANT & BIO scenarios:

- Over land, biogenic sources (VOCs and soil NO_x) contribute between 5–10 ppb (10-20%) to MDA8 ozone.
- Anthropogenic sources contribute between 10–20 ppb (20-50%).
- Shipping emissions make a significant contribution.

Anthropogenic sources contribute more than twice compared to biogenic sources to MDA8 ozone.

MDA8 O3 (18-24 July 2022)

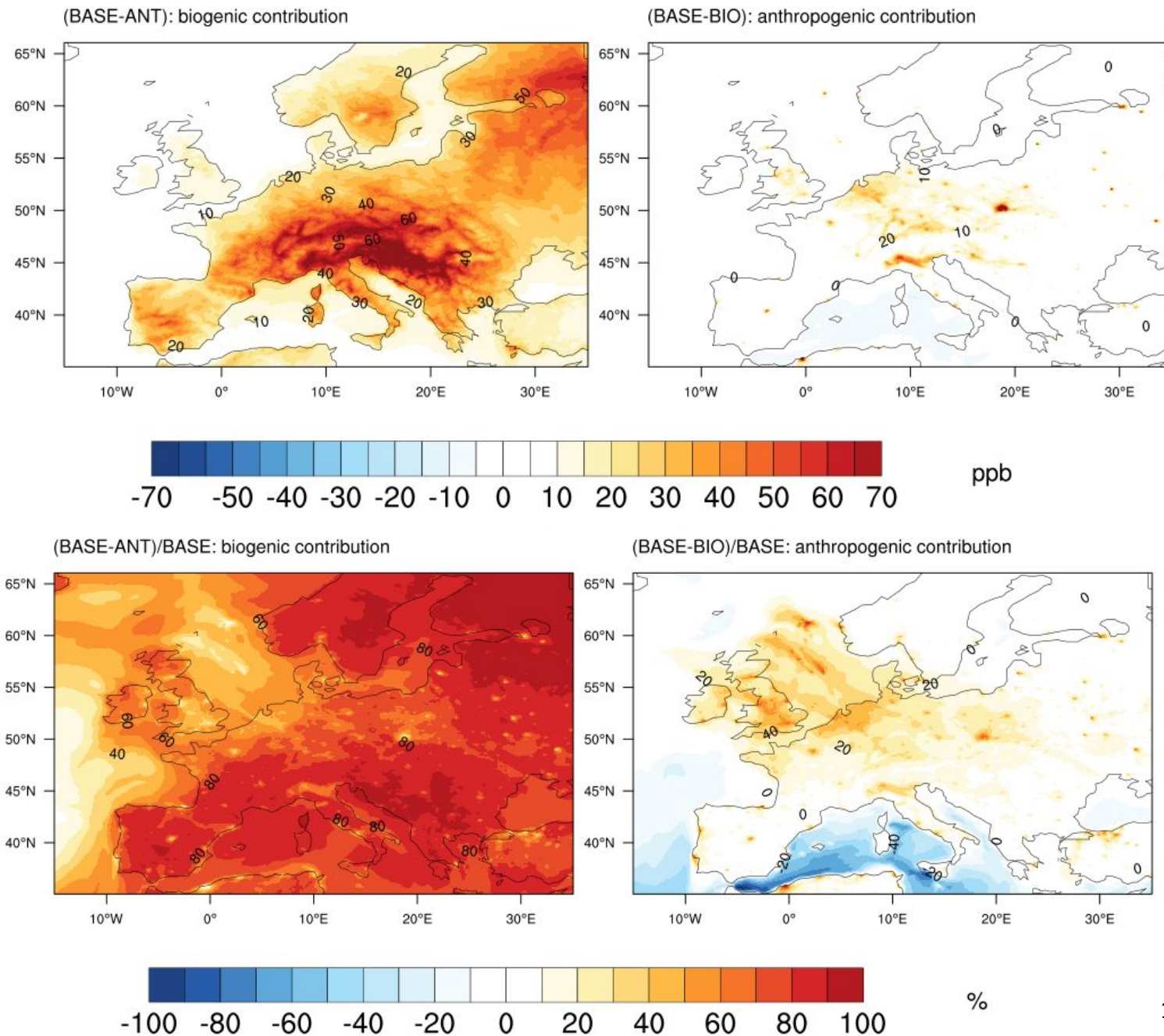


TFMM July 2022: VOC

Differences of total VOC between base case scenario and ANT & BIO scenarios:

- The main source of VOCs over large forested areas in central Europe is biogenic, contributing up to 60 ppb (80%).
- Anthropogenic contributions are concentrated in hotspots such as industrial areas and solvent use.

surf TVOC (18-24 July 2022)



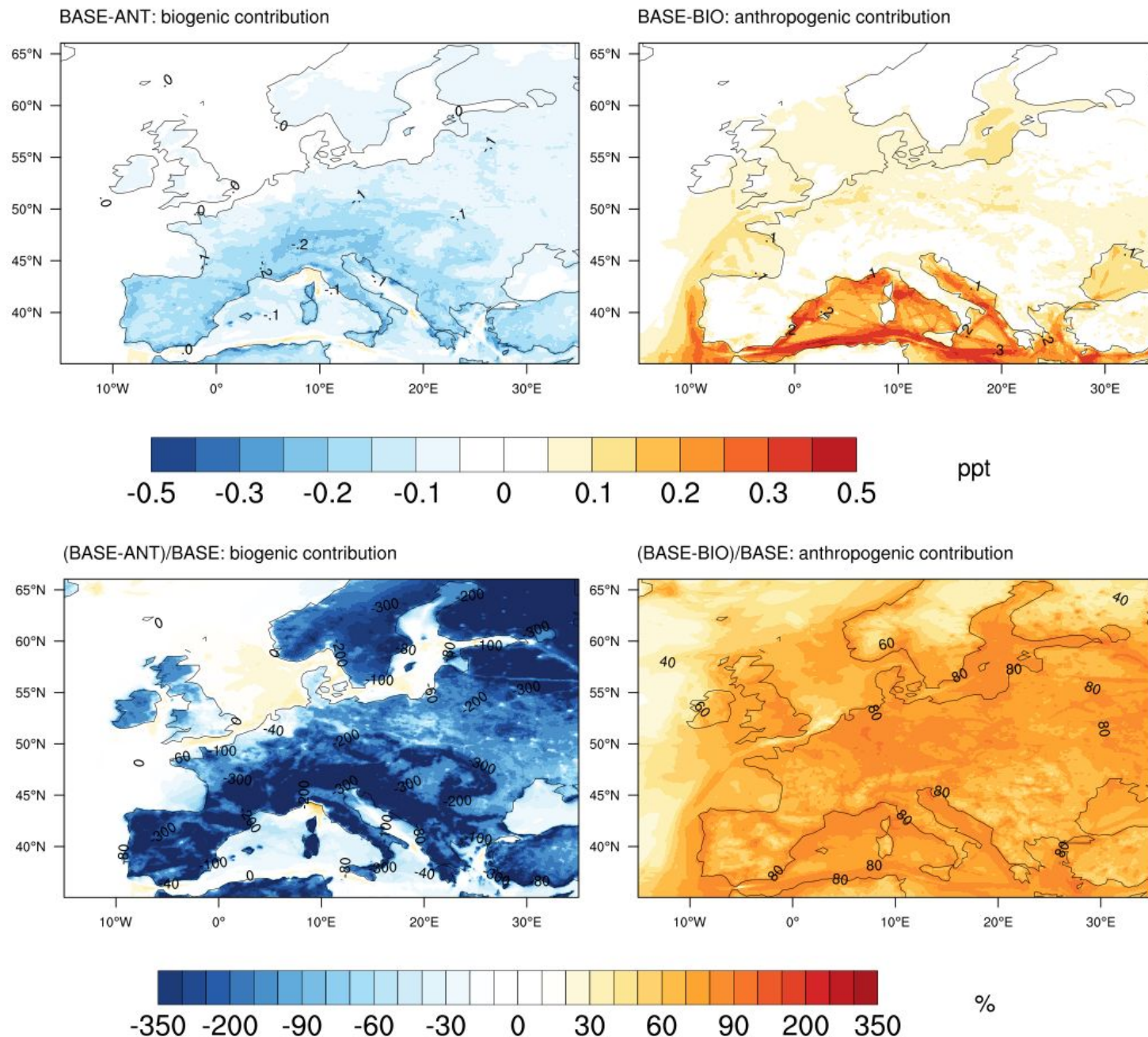
TFMM July 2022: OH

Differences of OH between base case scenario and ANT & BIO scenarios:

- A lower atmospheric oxidation capacity (reduced OH) is associated with the biogenic contribution.
- Anthropogenic emissions contribution lead to enhanced oxidation efficiency (increased OH).

Compare the OH field across models. Do the other groups agree to provide their OH fields?

surf OH (6-18 UTC, 18-24 July 2022)



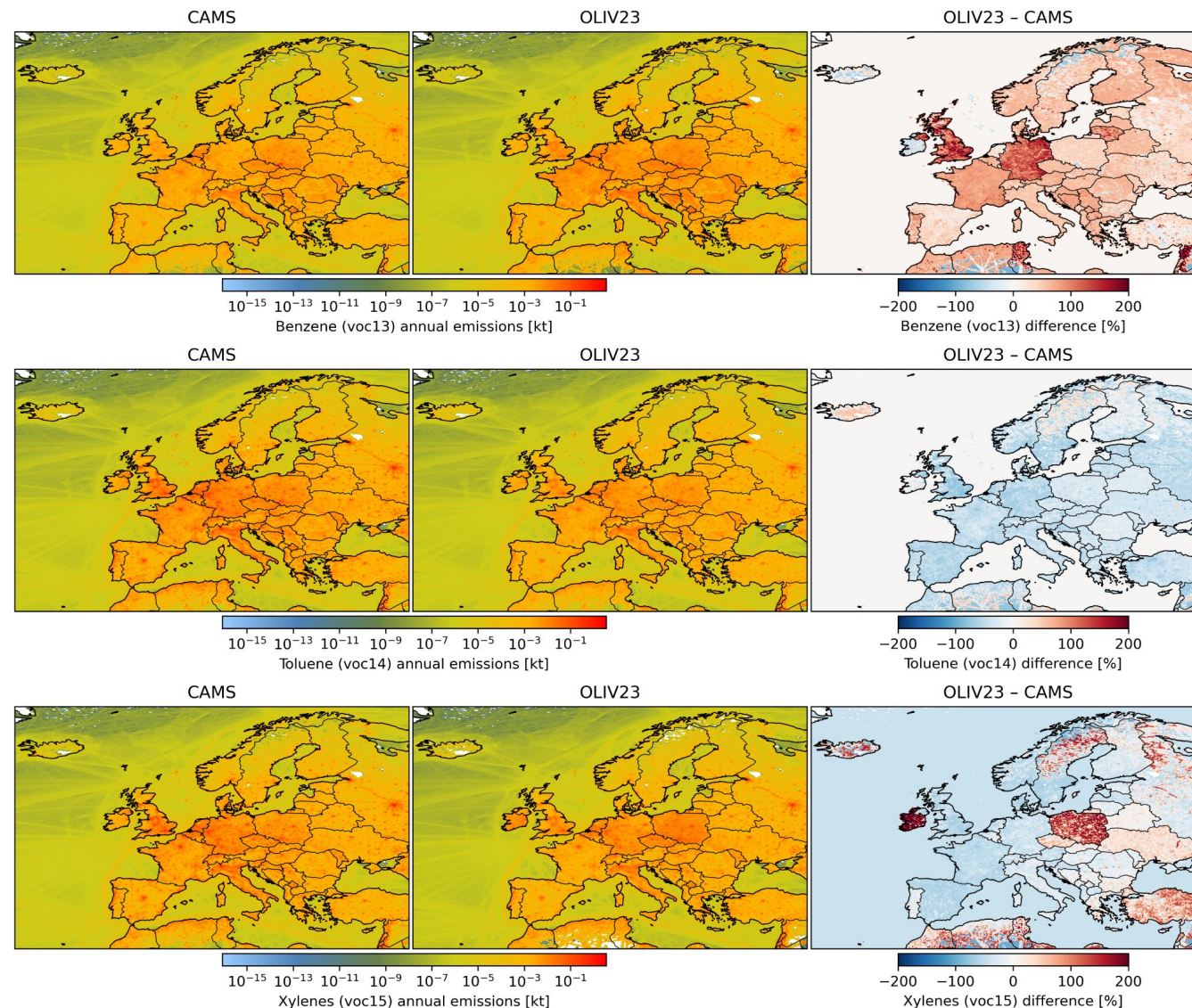
Improving the Characterisation of Anthropogenic NMVOC in Europe



CAMS-REG NMVOC in Europe

- Developed an updated NMVOC speciation profile database for Europe (2005–2020), based on Oliveira et al. (2023, 2025a), fully compatible with CAMS-REG; published on Zenodo (Oliveira et al., 2025b)
- Speciation changes impact individual NMVOC emissions ($> \pm 15\%$) and shift spatial distribution due to shifts in sectoral contributions.

Fig.: Gridded ($0.1^\circ \times 0.1^\circ$) annual emissions of benzene, toluene and xylenes (kt), using CAMS OLIV23 default speciation (col. 1) and (col. 2), along with the relative differences (col. 3).



CAMS-REG NMVOC in Europe

- Improved benzene model performance, especially in winter, due to better characterisation of residential wood combustion

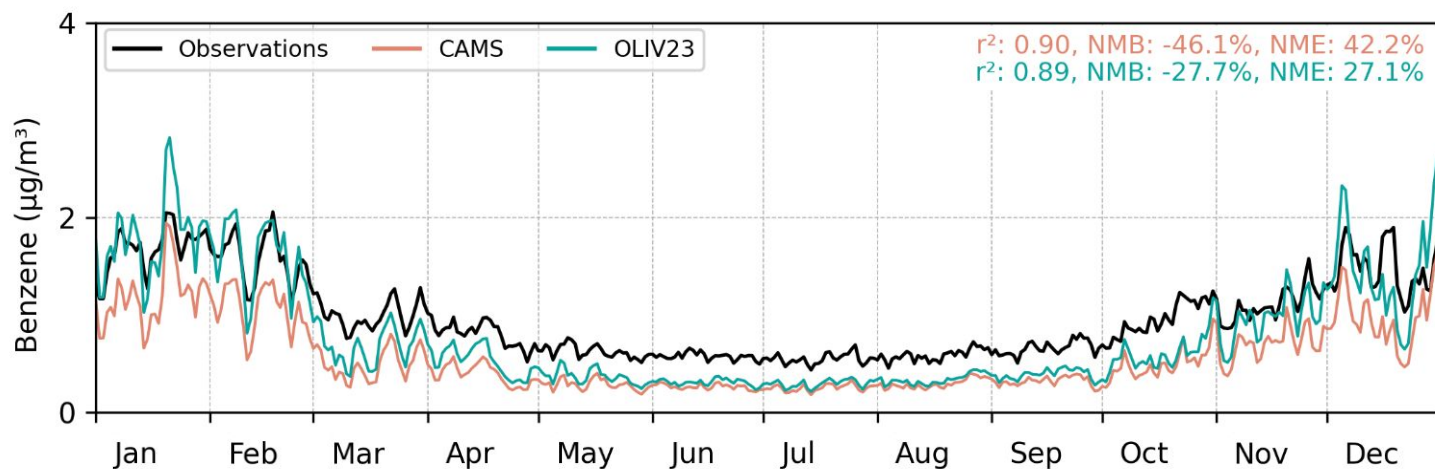
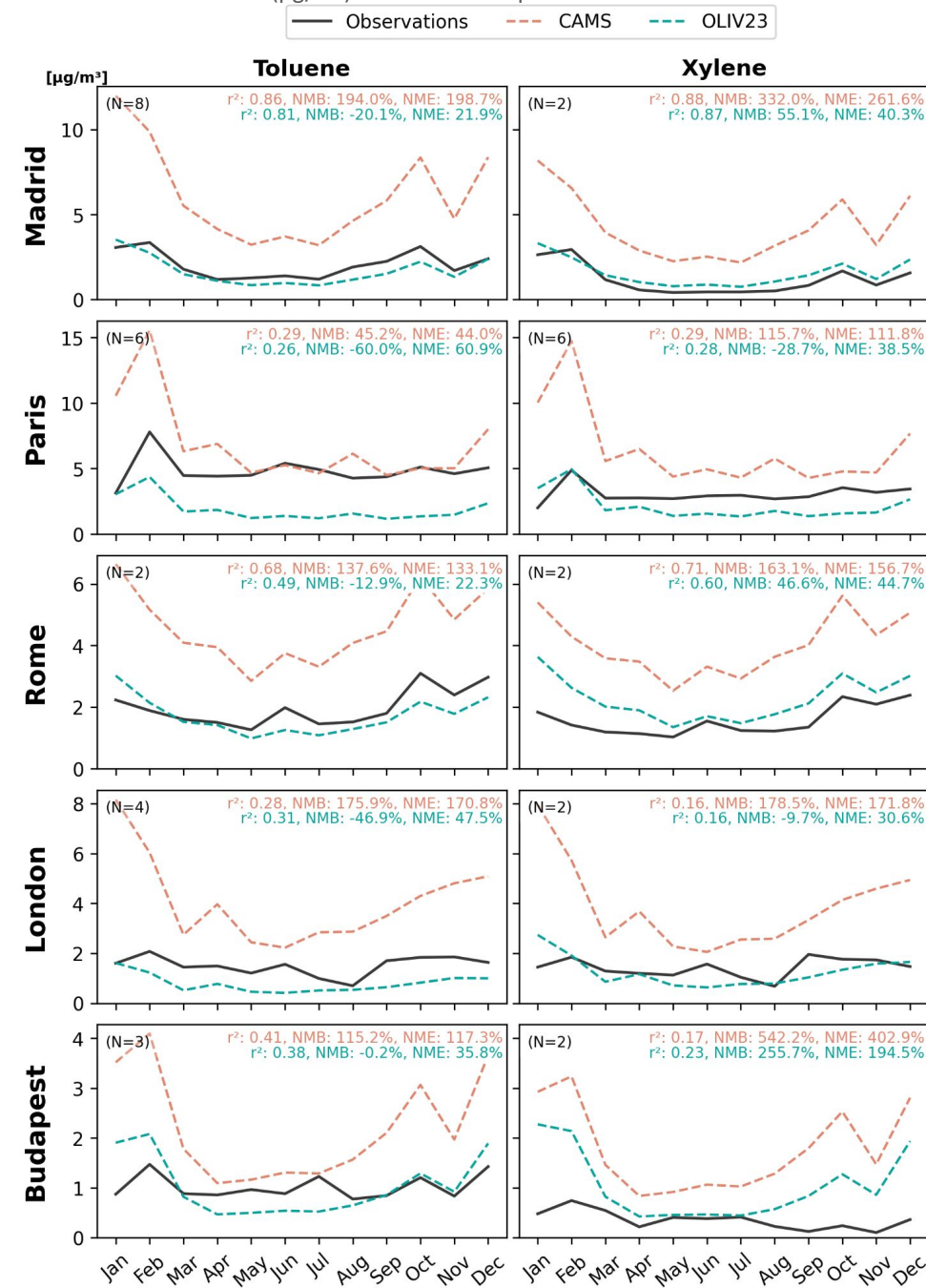


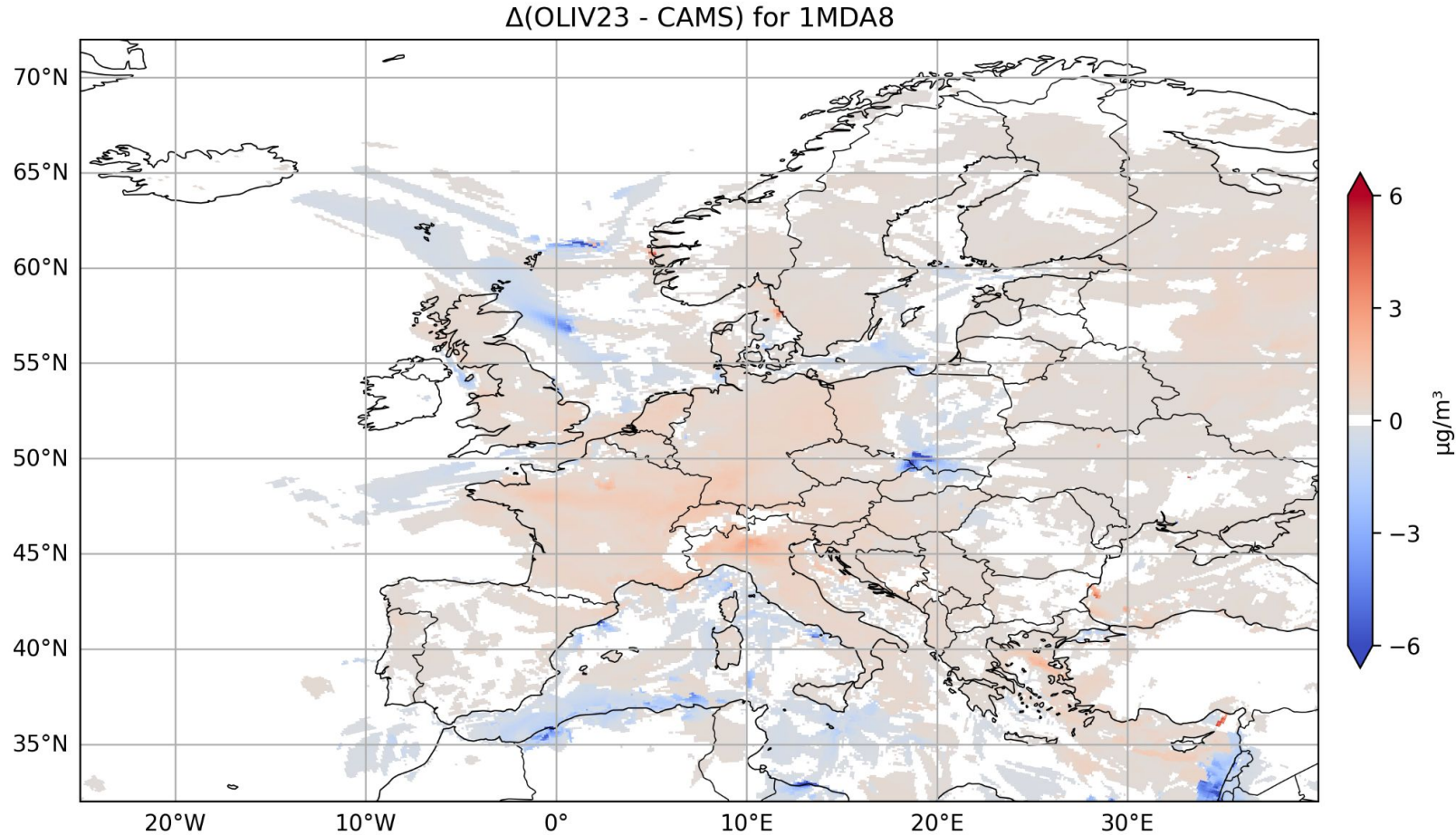
Fig.1: Averaged daily benzene concentrations ($\mu\text{g}/\text{m}^3$) modelled and measured for all stations in 2019.

- Improved toluene/xylene performance in cities by reducing overestimations through better characterisation of the solvent sector

Fig.2: Modelled and measured monthly average concentrations of toluene and xylenes ($\mu\text{g}/\text{m}^3$) across six EU capital cities



Difference in the MDA8 between CAMS and OLIV23



- NMVOC speciation updates have a limited impact on modelled O_3 .
- Moderate decrease of around 6 $\mu\text{g}/\text{m}^3$ in the southern region of Poland
- We plan to study the impact of NMVOC speciation on aerorols.

Future steps



Future steps

TFMM exercise:

- Further analysis, specific VOC.
- Changes in ozone chemical regimes
- Analyse the modelled HCHO:NO₂ ratio with TROPOMI (tropospheric column)

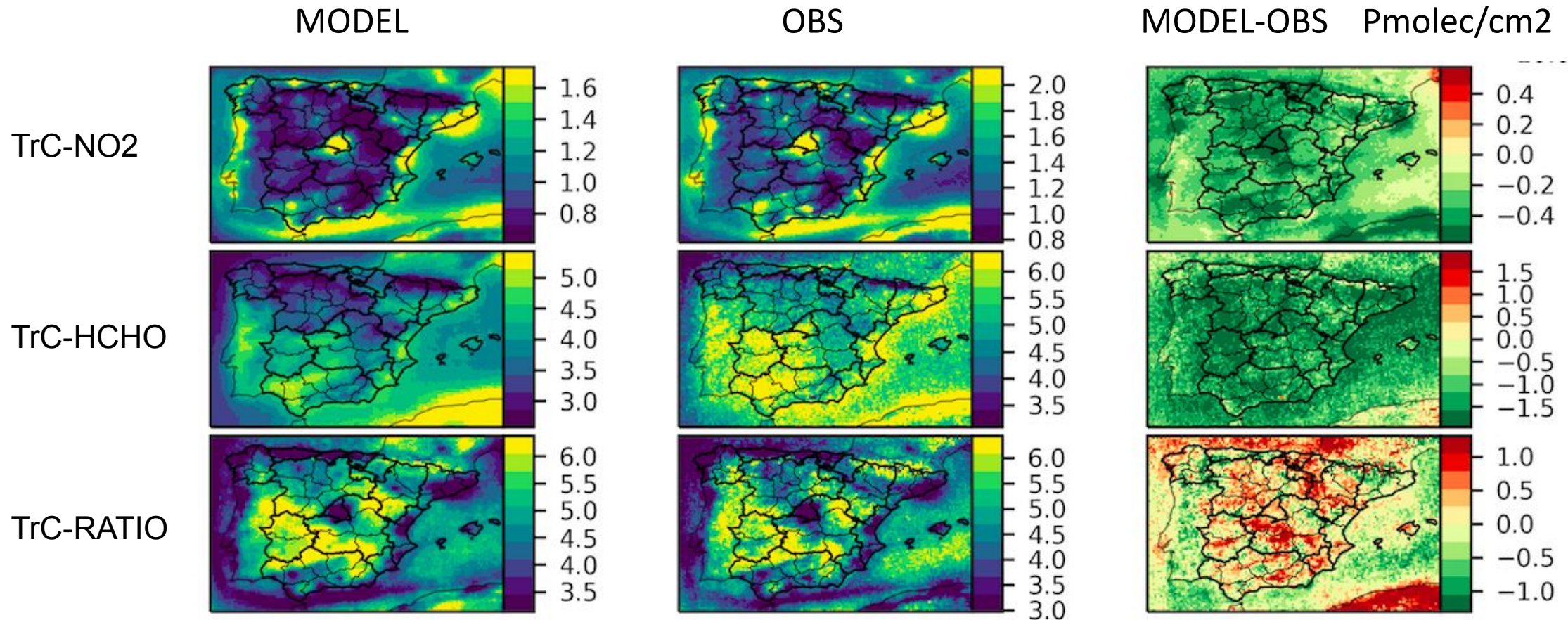
O₃/VOCs chemistry:

- Sensitivity of O₃ to different dry deposition treatments
- Sensitivity of biogenic emissions (MEGANv3..., soil NO)
- Sensitivity to other chemical schemes (e.g. CB06, CRACM)

Other activities:

- Extending O₃ analysis to particulate matter formation in Spain (new activity after Plan O₃ studies)

Future steps: NO₂ and HCHO tropospheric columns (TROPOMI) against models



Do the other groups agree to provide NO₂ and HCHO fields?



Thank you!

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Additional slides



Key additional improvement expected with reduced shipping emissions

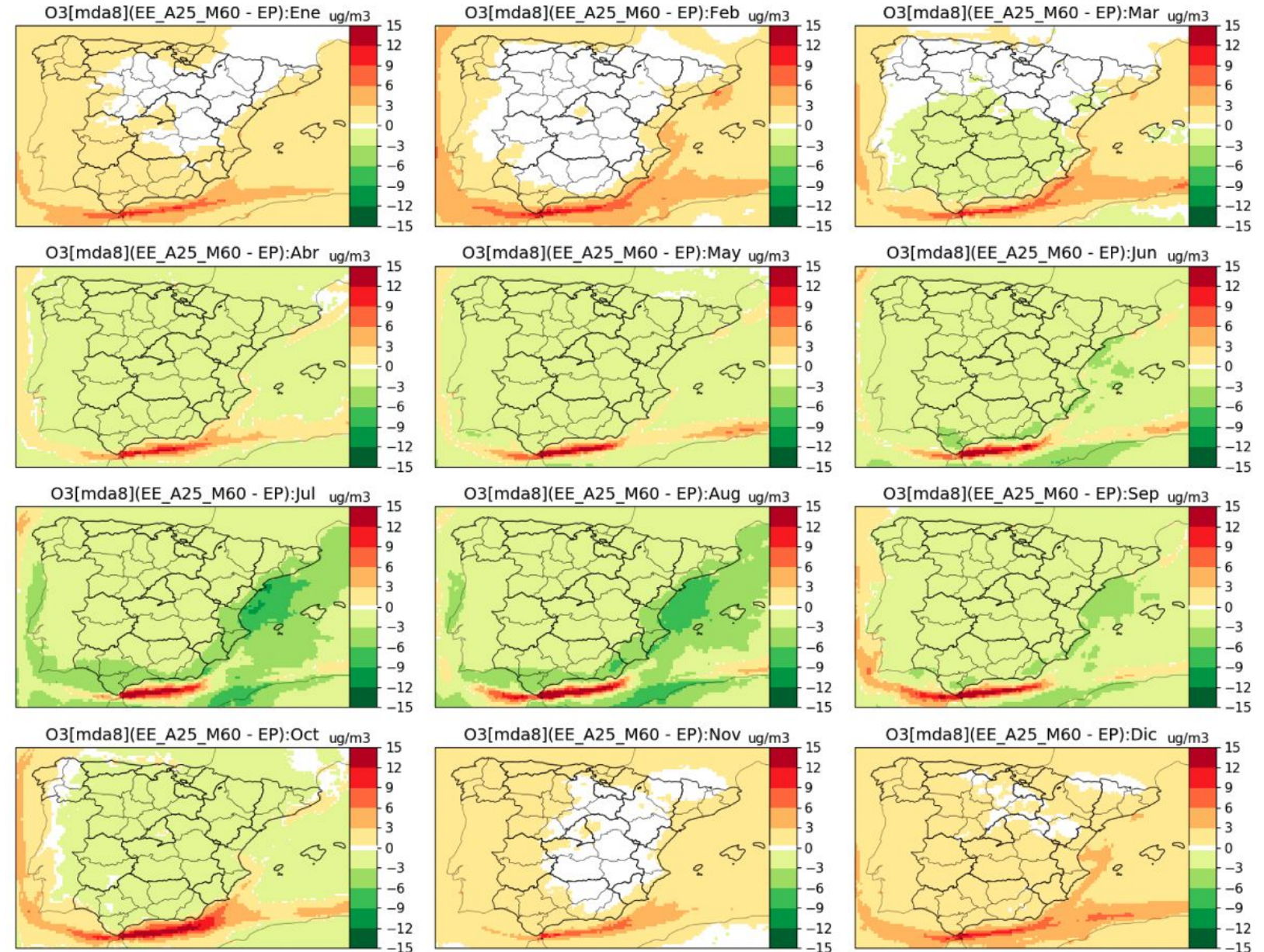
January...
... December



Strong improvement of $O_3^{(mda8)}$, especially along the coast but also over the entire península

-2 $\mu g/m^3$ on average in Jun-Aug and Spain, up to -8 $\mu g/m^3$ in specific coastal locations

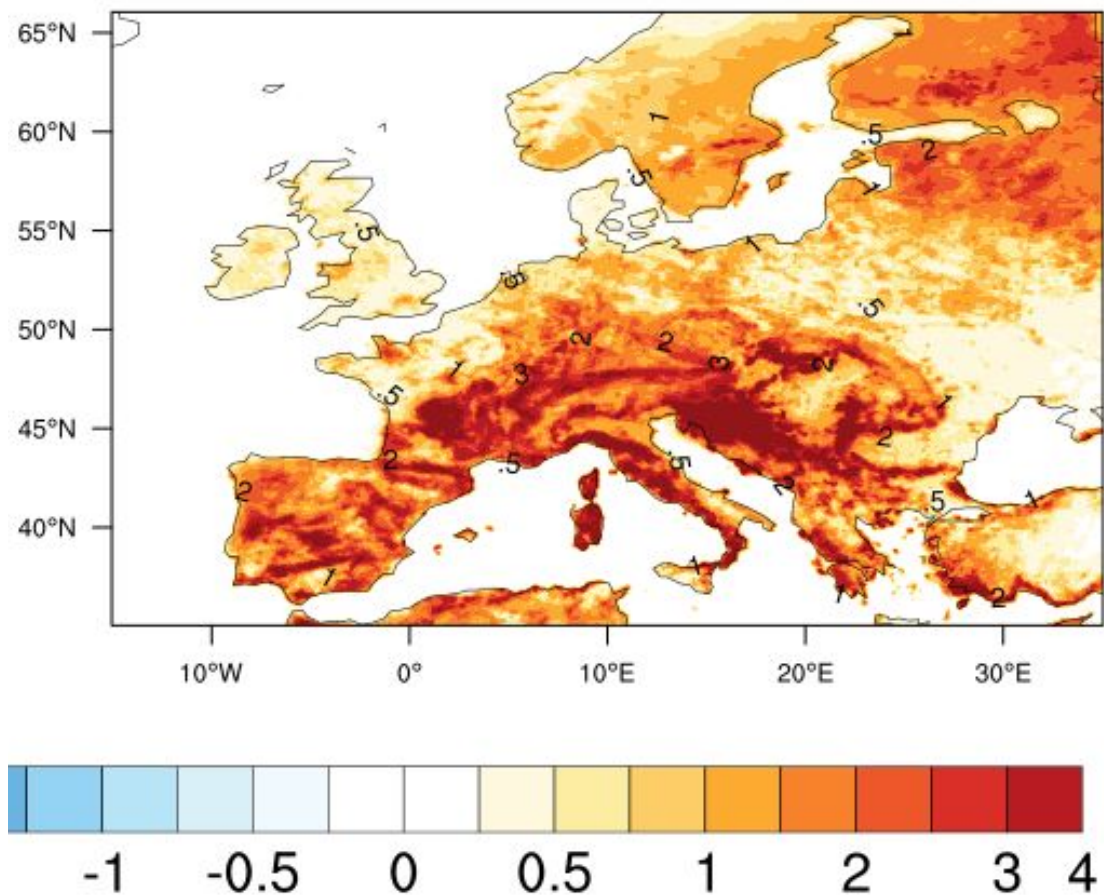
Up to -29 $\mu g/m^3$ in specific days and in specific cells



TFMM July 2022: isoprene, all biogenic

surf ISOP (18-24 July 2022)

(BASE-ANT): biogenic contribution



TFMM July 2022 other analysis: OH concentration

surf OH (6-18 UTC, 18-24 July 2022)

