Modelling the impact of the COVID-19 lockdown on air quality in Spain

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23 nd EMEP TFMM Meeting

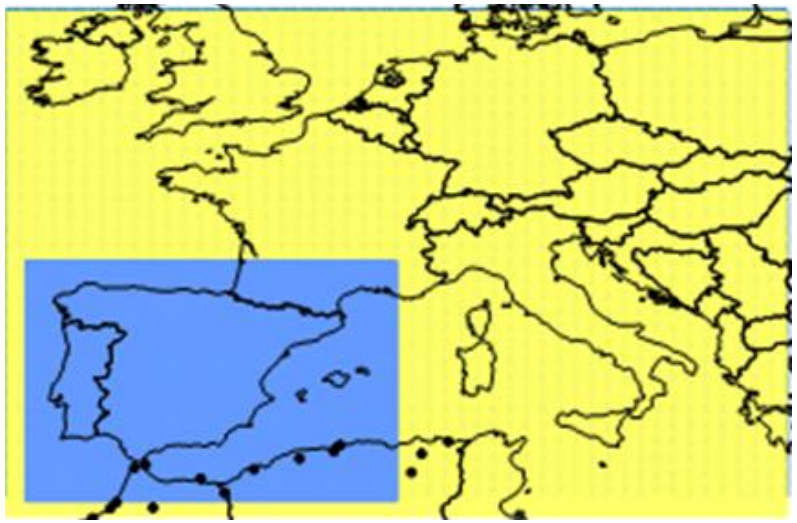
Online Meeting, 3-5 May 2022

1) Does the model respond to the emission reductions in a similar way to the observations?

2) Are there any policy messages?

Model setup

	CHIMERE	
	EU015_cm	**SP005_cm**
Horizontal resolution	0.15º x0.15º	0.05ºx0.05º



Simulations 2020:

Emissions 2018

Emissions : EMEP a 0.1º x 0.1º (http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/; EMEP, 2021), 2018.
Spain: National Emission Inventory (NEI)

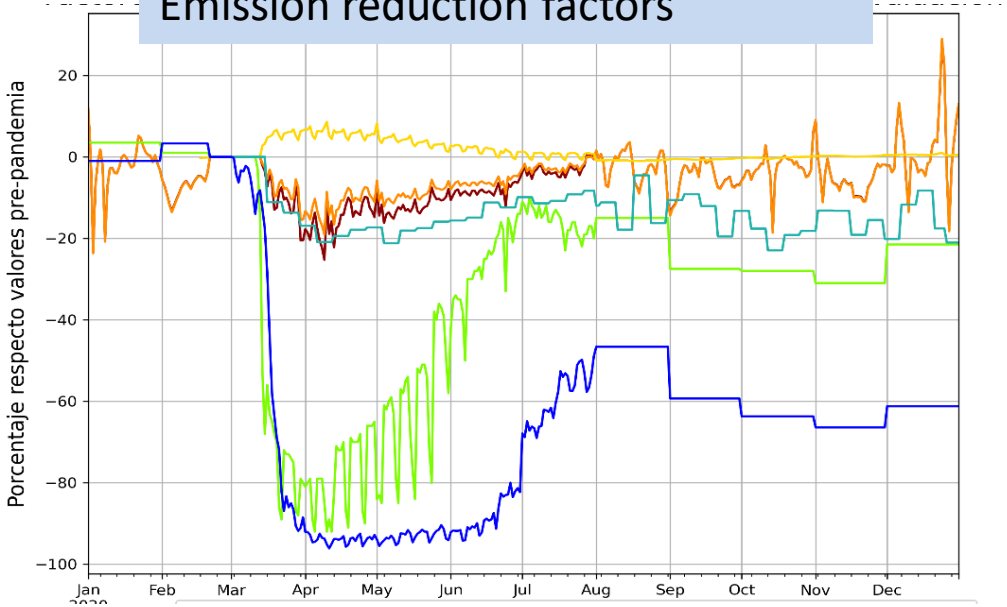
Emissions 2018 with COVID reductions

- **Guevara et al. 2021** Feb 21th-July 31th
- CIEMAT estimates (**Rodriguez-Sánchez et al. 2022**) August, 1st-December 31th, inspired in Guevara et al. 2021

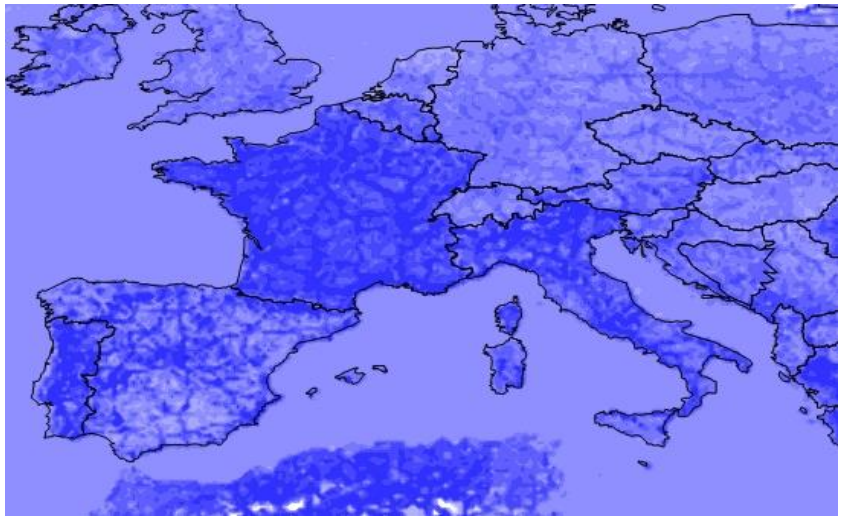
Meteorological outputs from IFS (2020)

- **Guevara, M.,** Jorba, O., Soret, A., Petetin, H., Bowdalo, D., Serradell, K., Tena, C., Denier van der Gon, H., Kuenen, J., Peuch, V.-H., and Pérez García-Pando, C.: Time-resolved emission reductions for atmospheric chemistry modelling in Europe during the COVID-19 lockdowns, Atmos. Chem. Phys., 21, 773–797, https://doi.org/10.5194/acp-21-773-2021, 2021

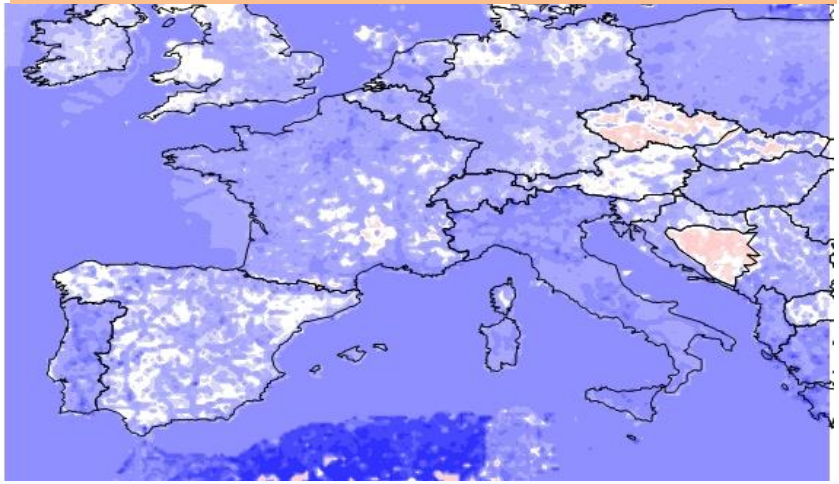
Emission reduction factors



Relative Differences – Annual NOx emissions 2020-2018



Relative Differences – Annual NMVOC emissions 2020-2018



Observations

Methodology A:
meteo-corrected observations (Ordóñez et al. 2020)

Regresion model

GAM (Generalised Additive Model)
https://www.sciencedirect.com/science/article/pii/S0048969720348518.

Model Training per pollutant and site

March 15th – April 30th 2015–2019

MDA8 O_3
1-h daily max NO2

Background sites (urban + rural)
AirBase

ERA5

- Daily maximum air temperature at 2 m
- Daily mean fields of the zonal and meridional wind component at 10 m
- 500 hPa geopotential height
- 2-m specific humidity
- Downward solar radiation flux
- Daily accumulated precipitation

ERA5 Prediction:
ERA5 2020

Predicted 2020 concentration

Methodology B:
2016-2019 mean

Rest of metrics and periods (annual values, others except MDA8 O3 and 1-h daily max NO_2 for the period

All sites –National network

2016-2019 mean

No meteo correction

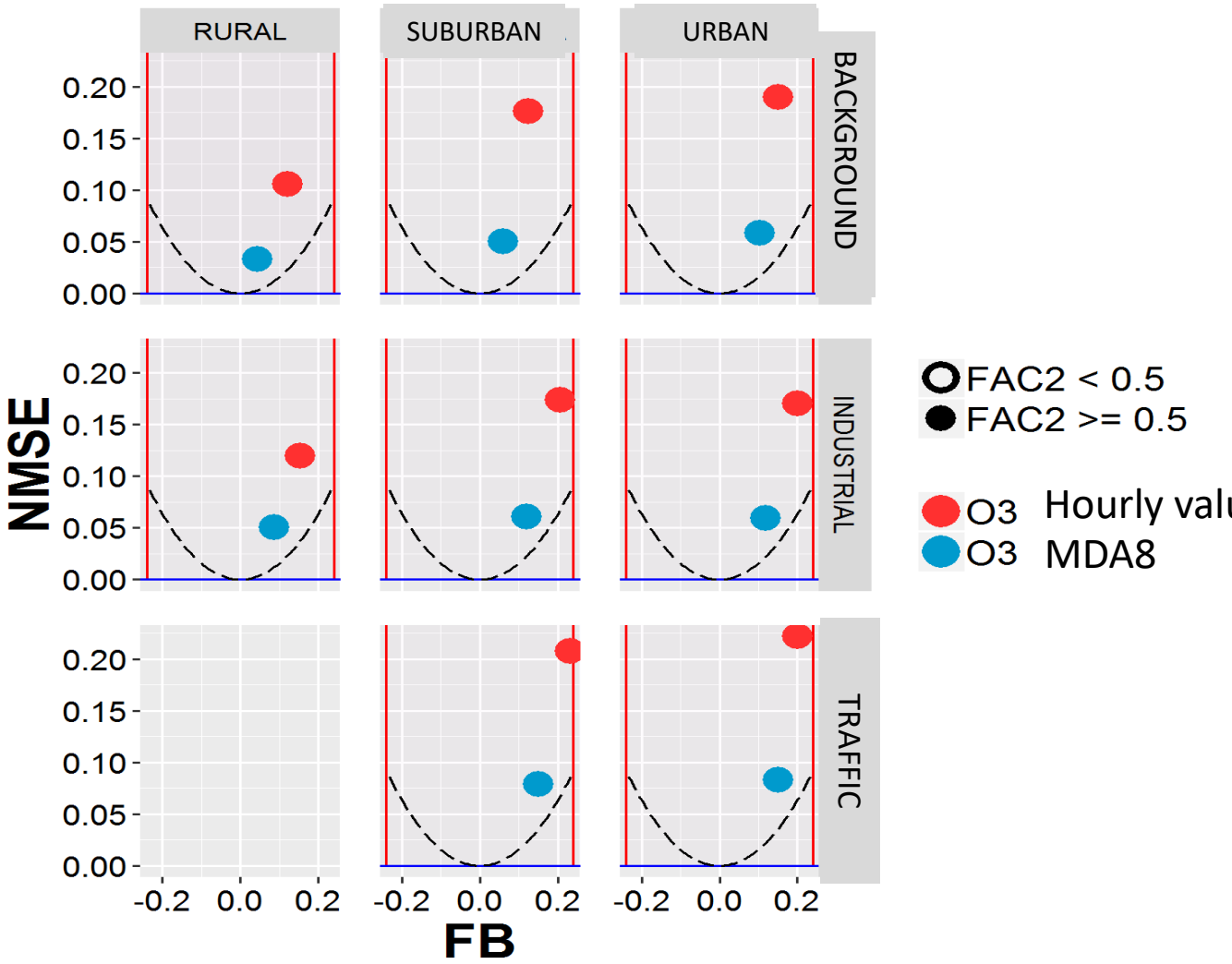
To be compared with Observed 2020 concentrations

These approachs are not an exact reproduction of the real change, but an estimation. Probably some smoothing (regression model (M.A), average (M.B))

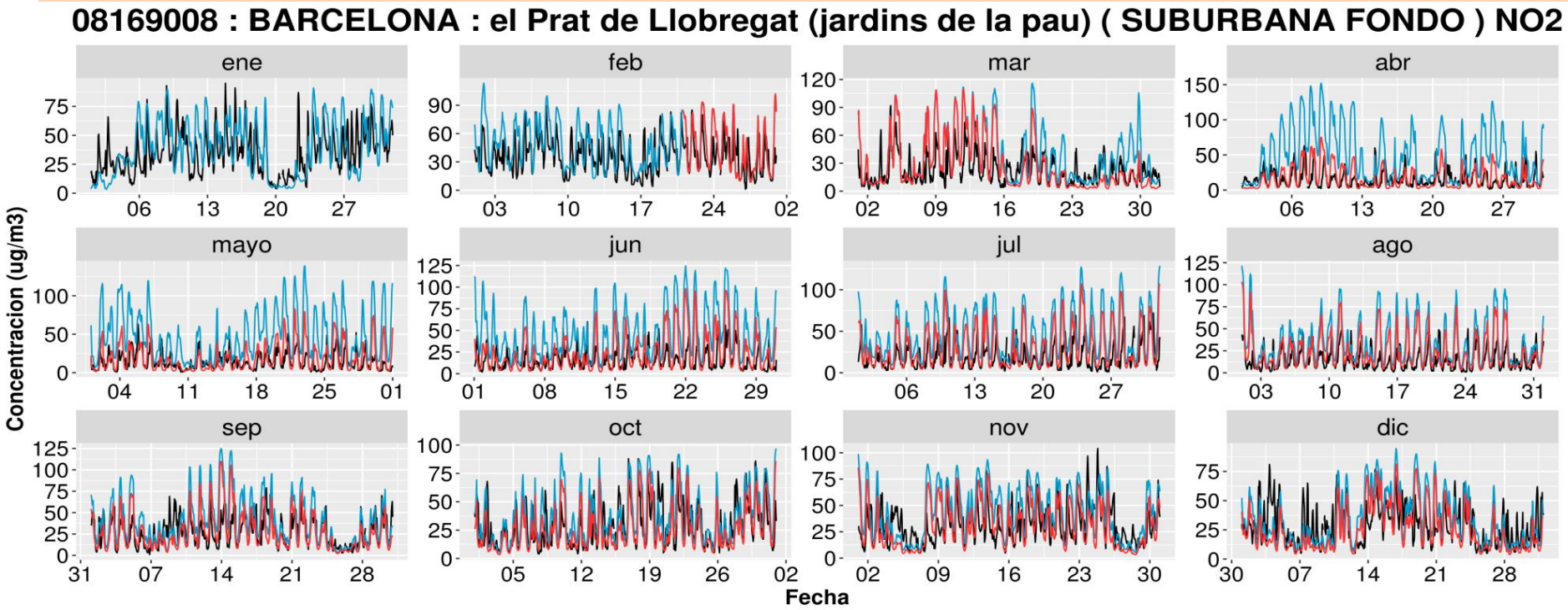
Model performance

Acceptability criteria of Chang and Hanna (2004):

- **FAC2 ≥ 0.5**
- **|FB| ≤ 0.3**
- **NMSE ≤ 1.5**

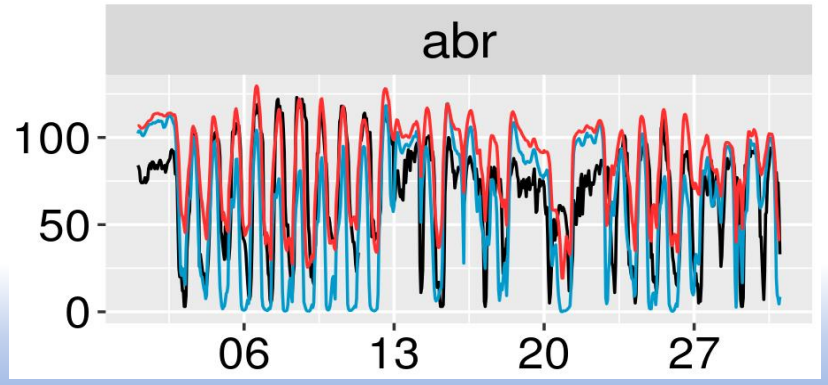


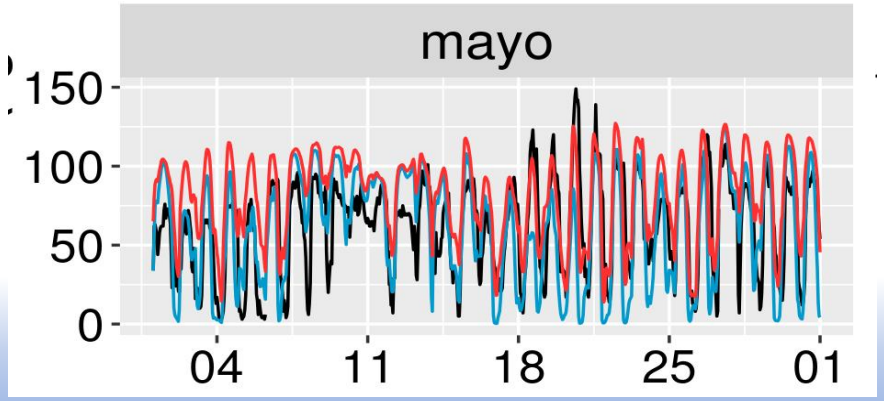
NO2 Obs. 2018 emissions COVID emissions



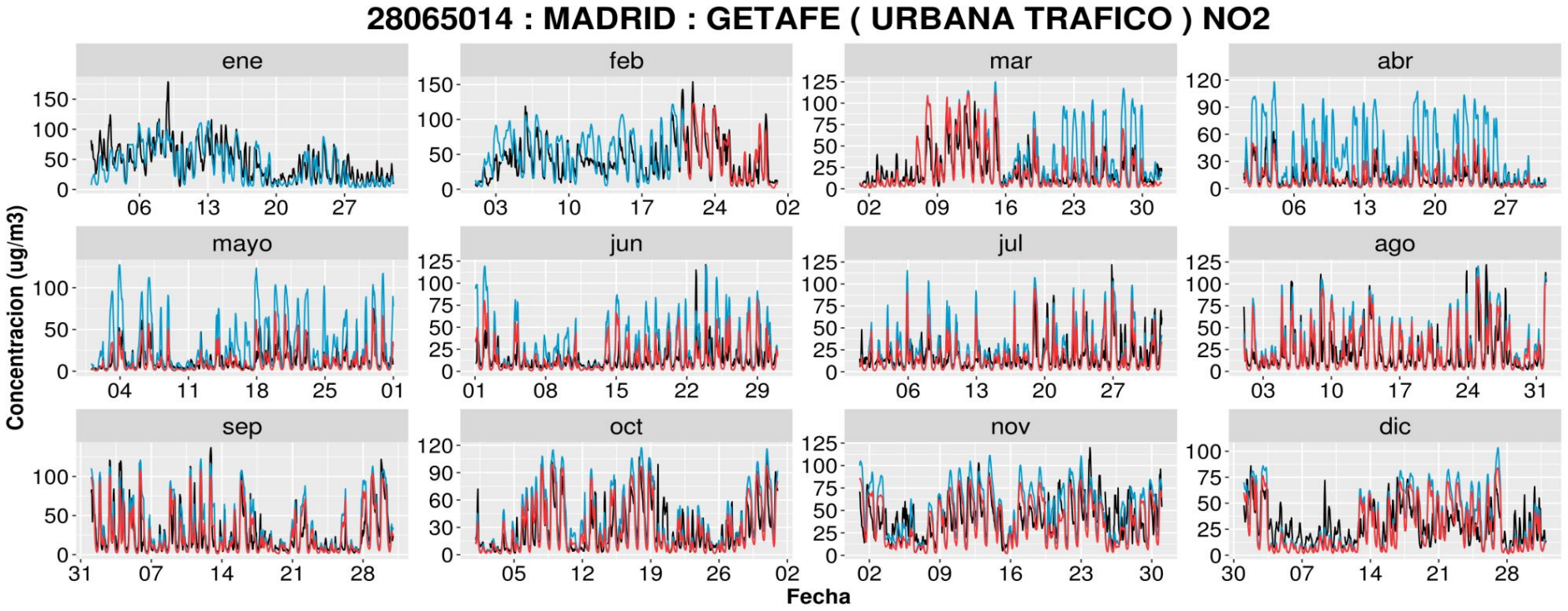
08169009 : BARCELONA : El Prat de Llobregat (CEM Sagnier) (SUBURBANA FONDO) O3

OZONE Obs. 2018 emissions COVID emissions

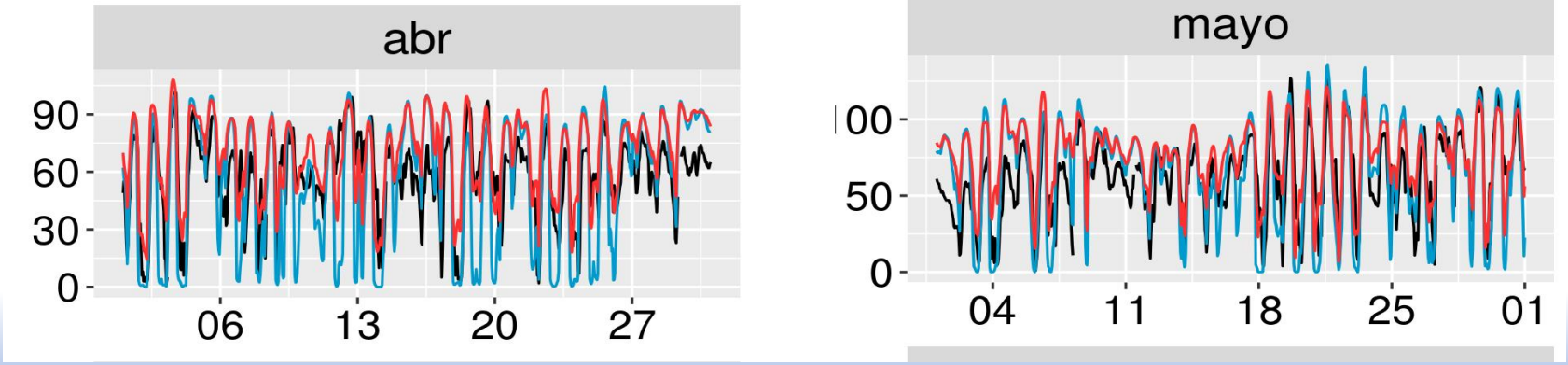




NO2 Obs. 2018 emissions COVID emissions

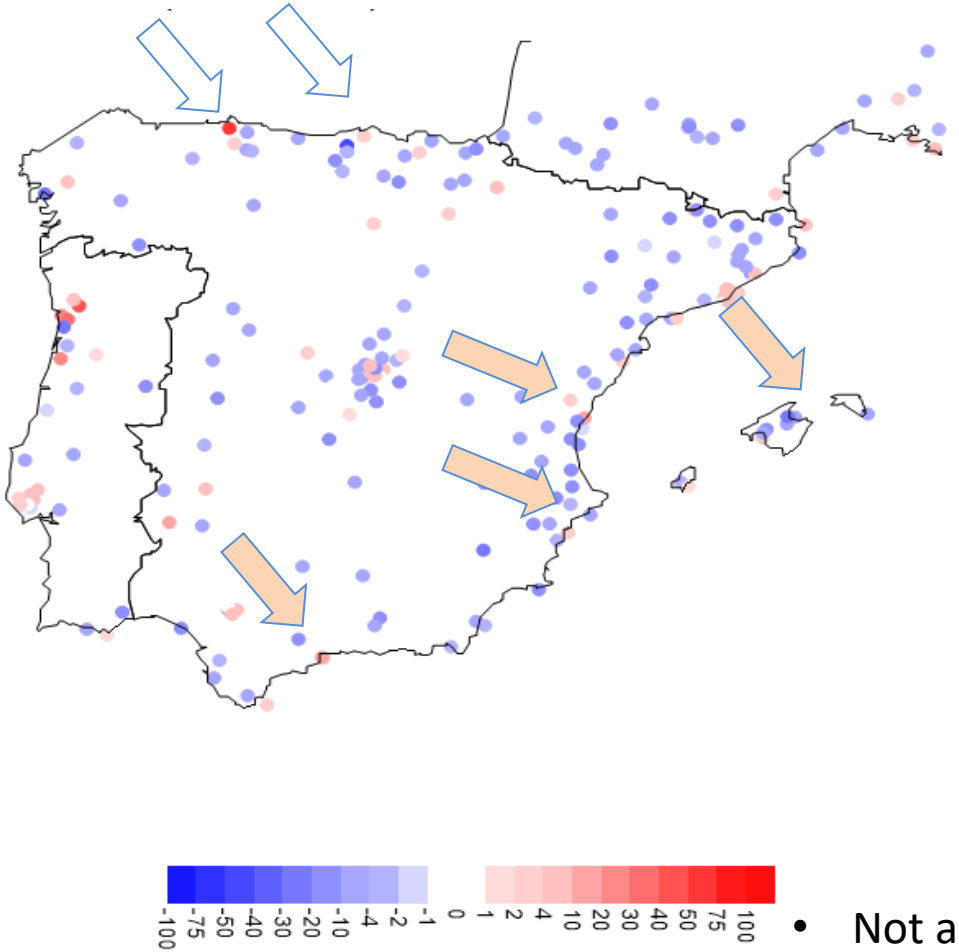


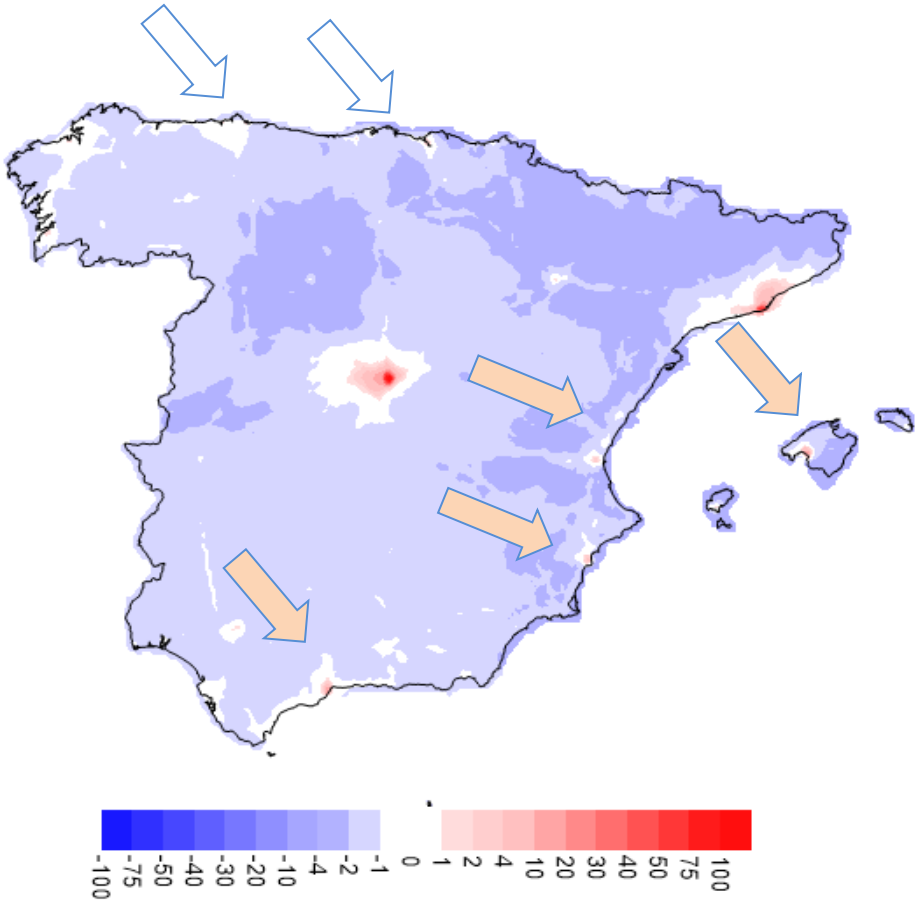
OZONE Obs. 2018 emissions COVID emissions



Relative Differences [15/03-30/04]
O3 MDA8 Maximum daily 8-hourly value (mean for the period)

Methodology A

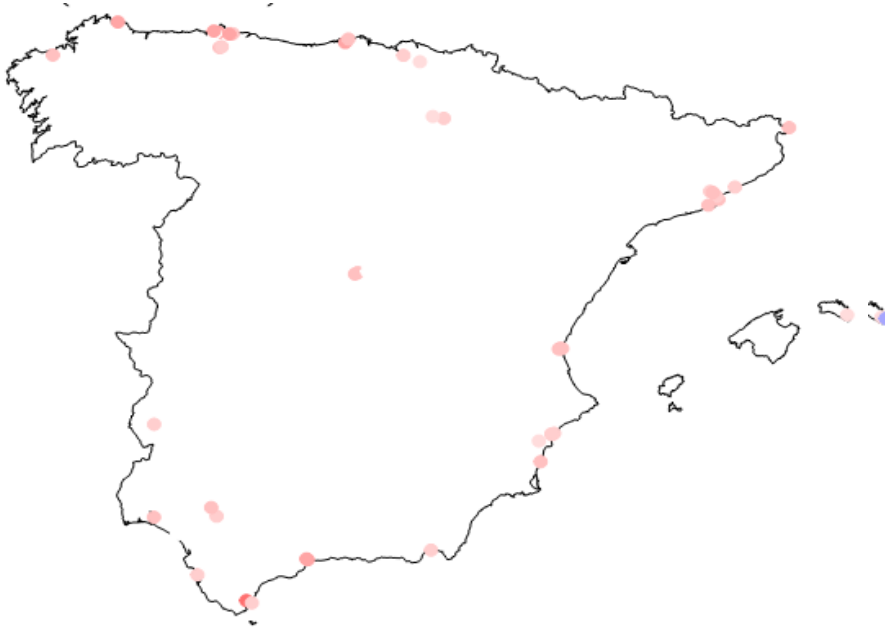


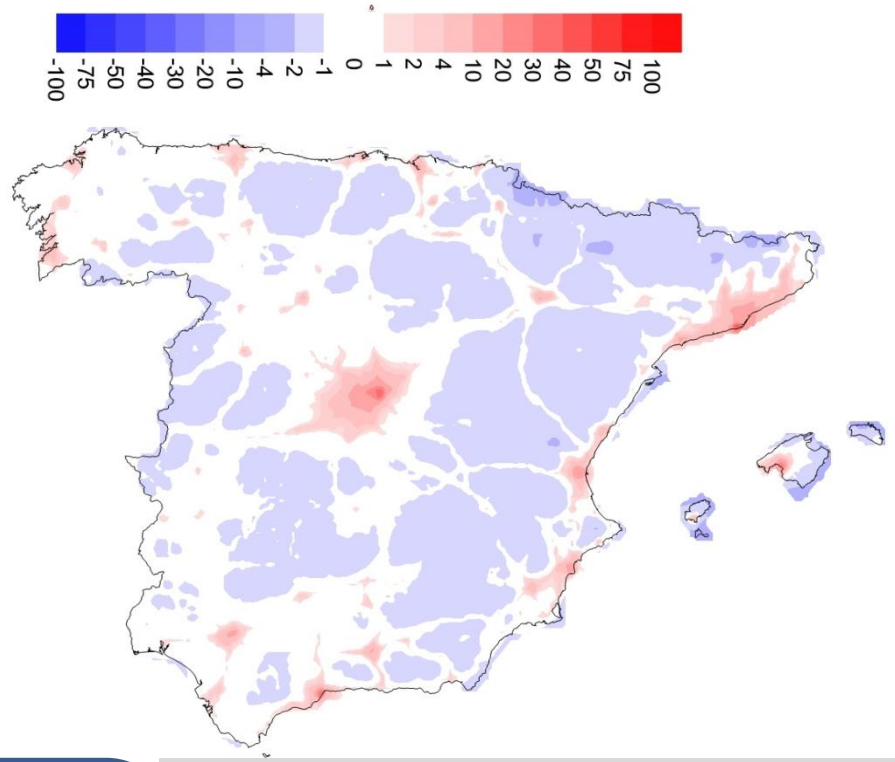


- Not an exact comparison (mean of 4 years for observations; some smoothing could occur)

Differences [15/03-30/04]
O3 Average value (mean for the period)

Methodology B Not meteorology corrected

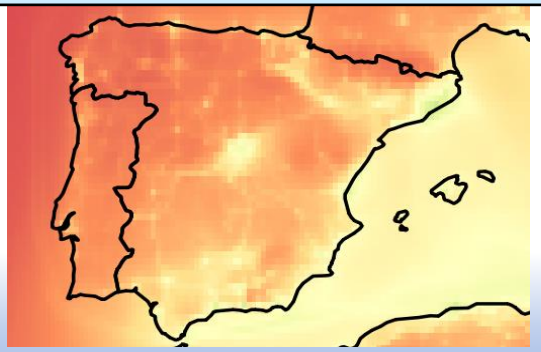




- The model estimates increases in ozone in the same areas where an increase is observed at at least one location
- Model probably overestimates areas with increases due to model resolution (~5x5km2)
- Was an abnormally cloudy and rainy period and so this period in 2020 would be expected to have lower concentrations than the mean values

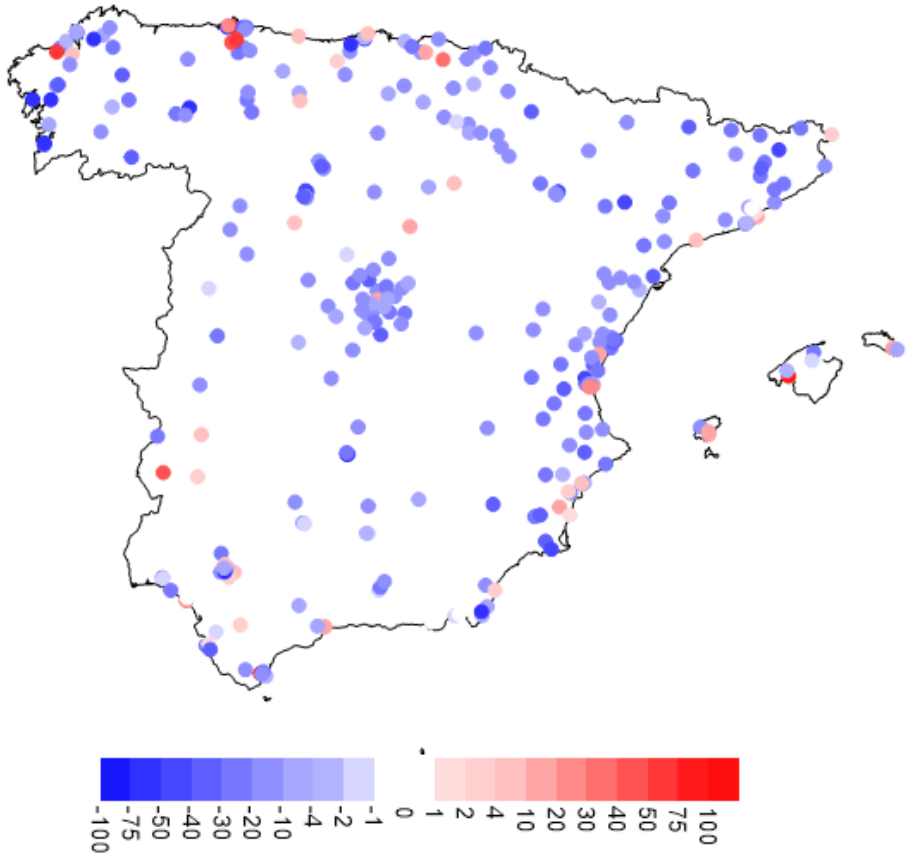
Impact of NO-titration reaction, July, 2016

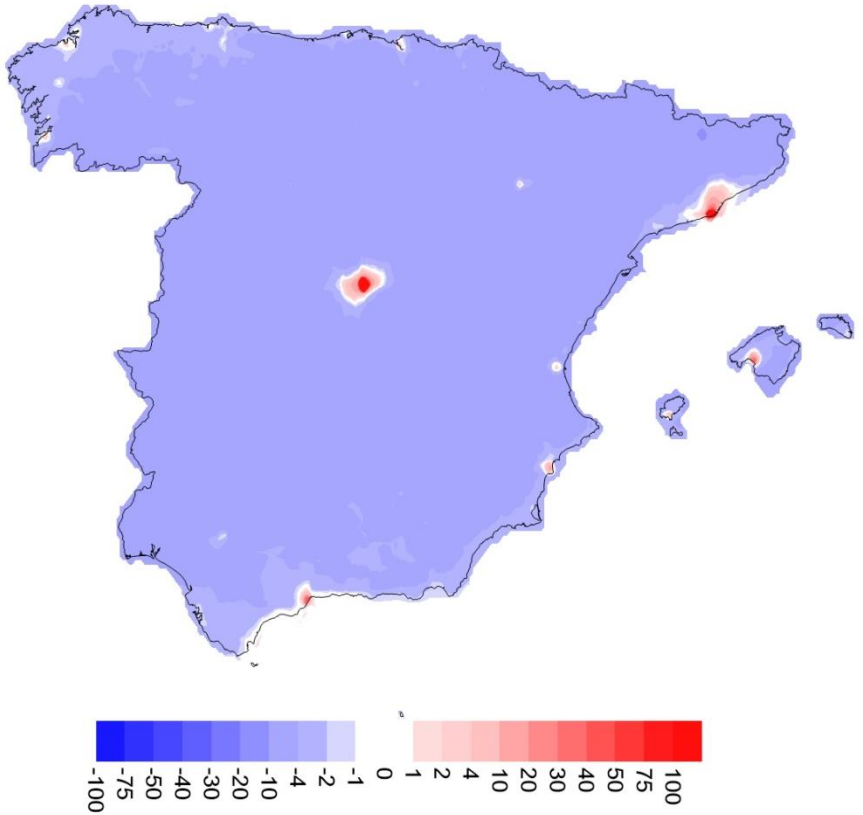
$$O_3 + NO \rightarrow NO_2 + O_2$$



Relative Differences [2020]
O3 SOMO35

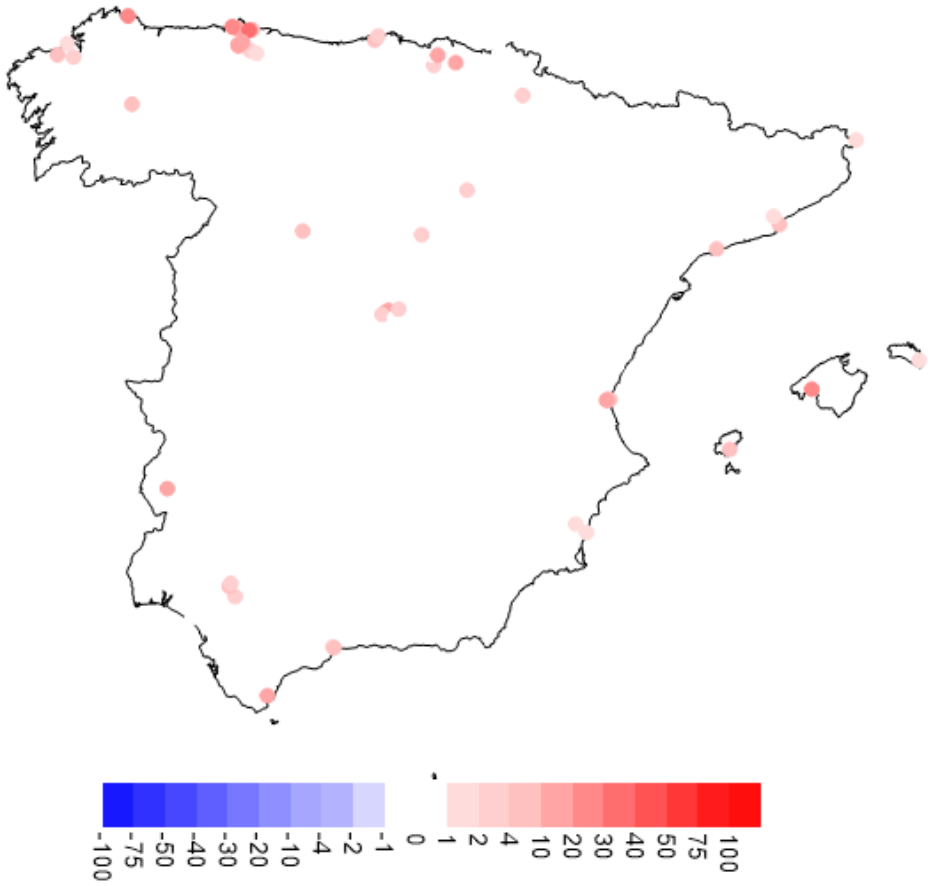
Methodology B

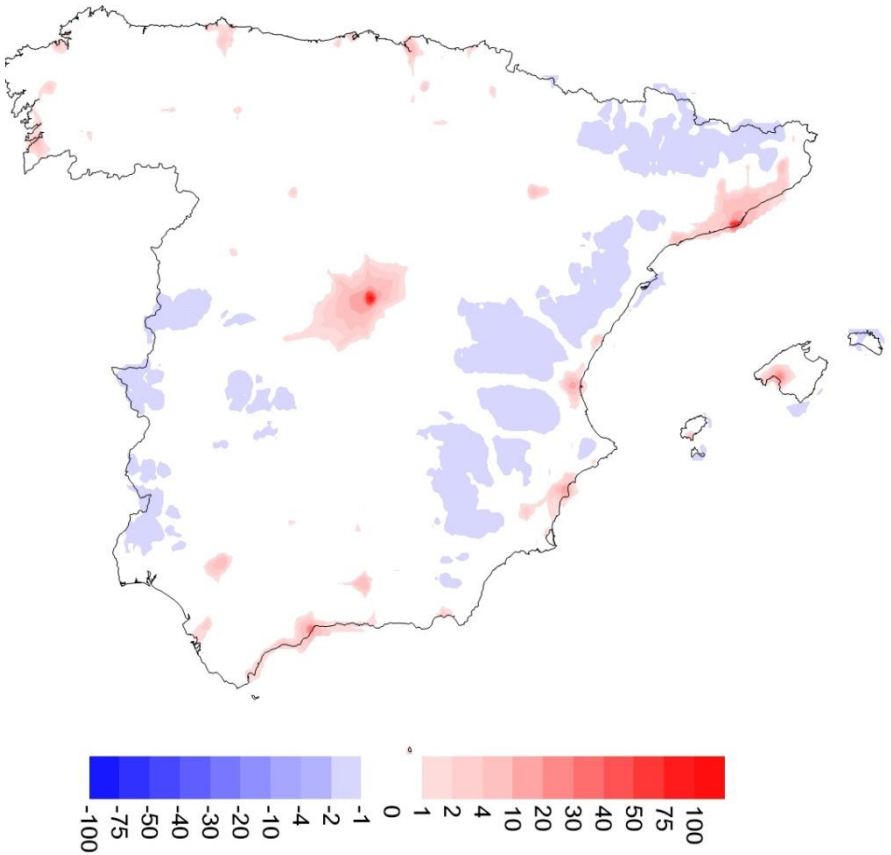




O3 Relative Differences ANNUAL MEAN

Methodology B



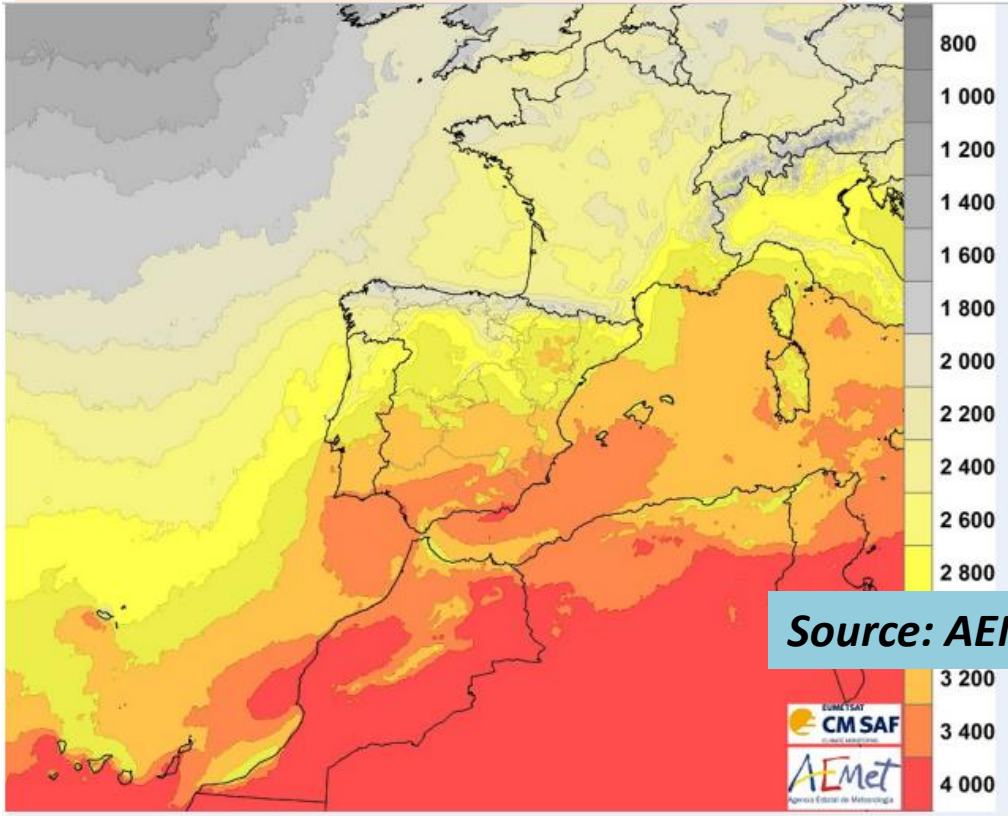


Impacts on ozone

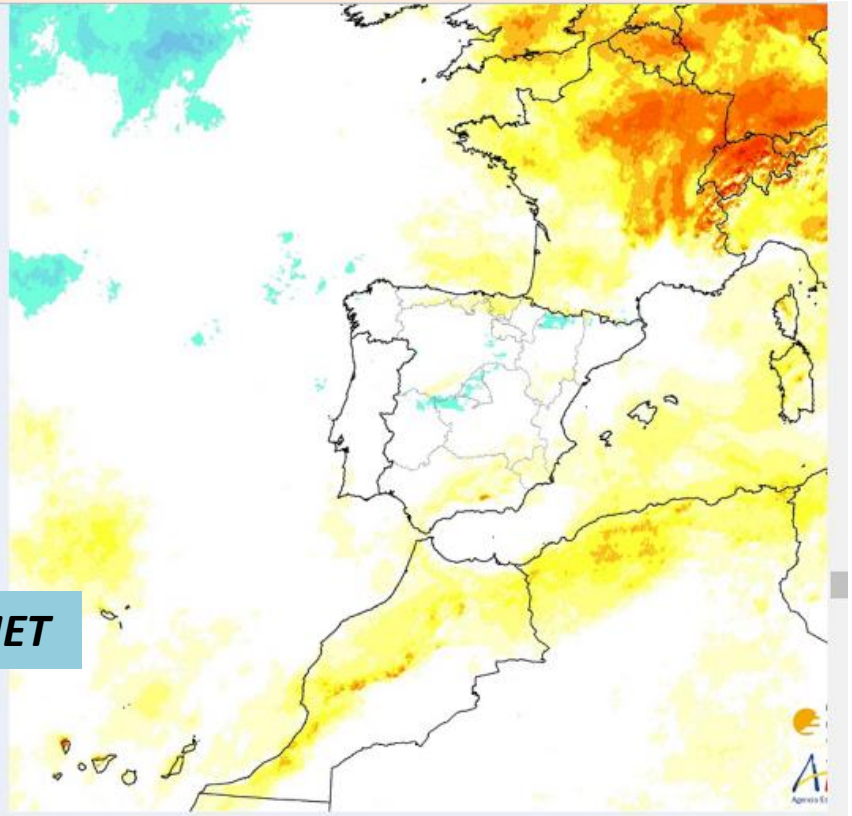
Ozone levels in 2020:
compliance with the air quality directives

*Figure extracted from the "Informe sobre el estado del clima de España 2020. Resumen ejecutivo. Agencia estatal de meteorología, **AEMET**"* Source: CM SAF (EUMETSAT).

Total number of hours of sun in 2020



Anomaly of hours of sun in 2020



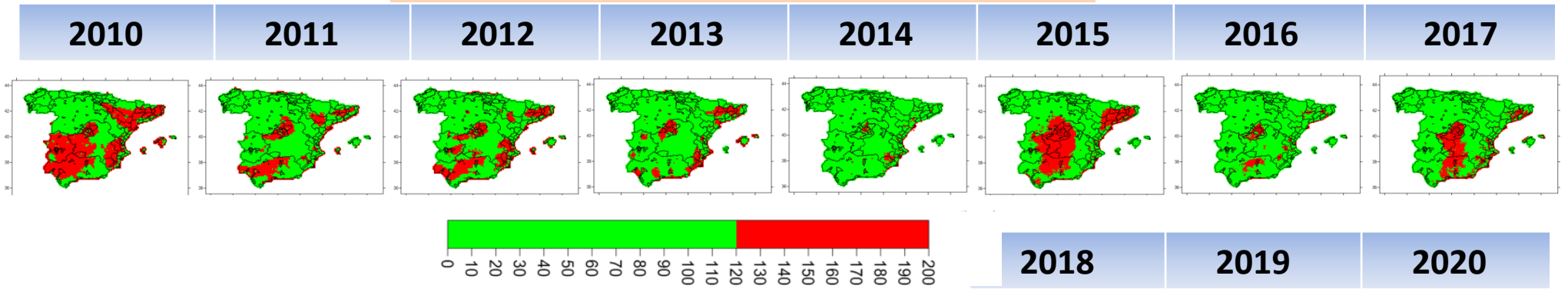
Source: AEMET

*Figure extracted from the "Informe sobre el estado del clima de España 2020. Resumen ejecutivo. Agencia estatal de meteorología, **AEMET**"*

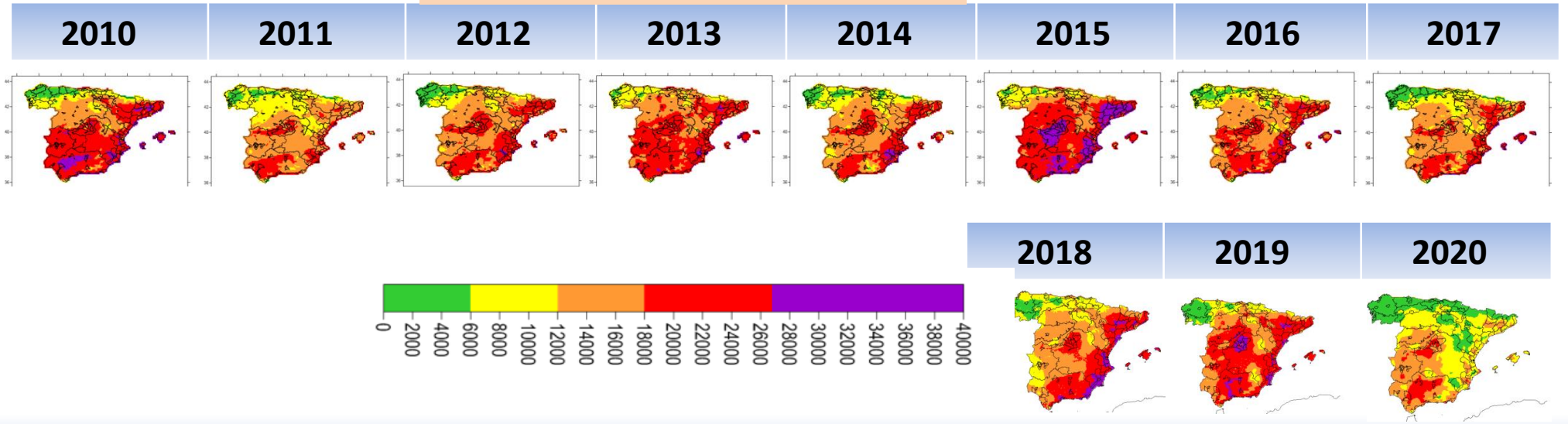
Source: AEMET

Accumulated Precipitation Percentage in 2020 with respect to the 1981-2020 mean value

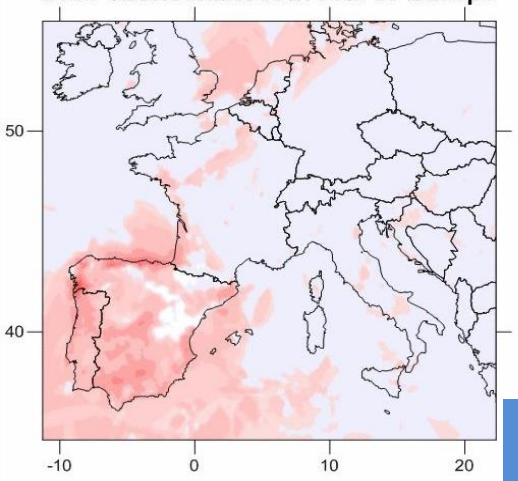
26th MDA8 $\mu g/m^3$



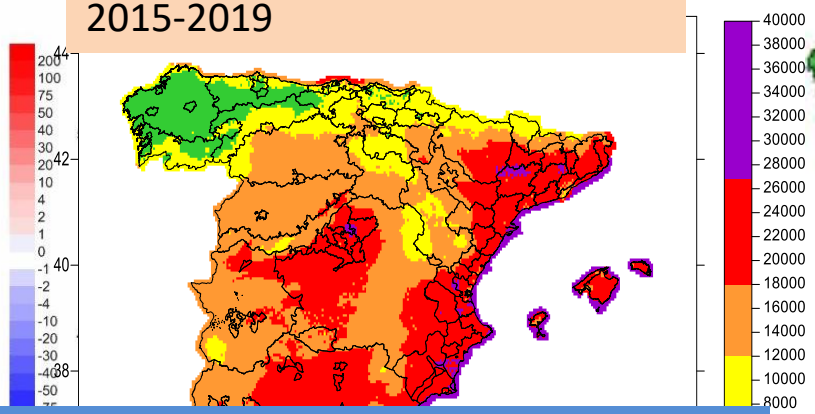
AOT40 $(\mu g/m^3)h$



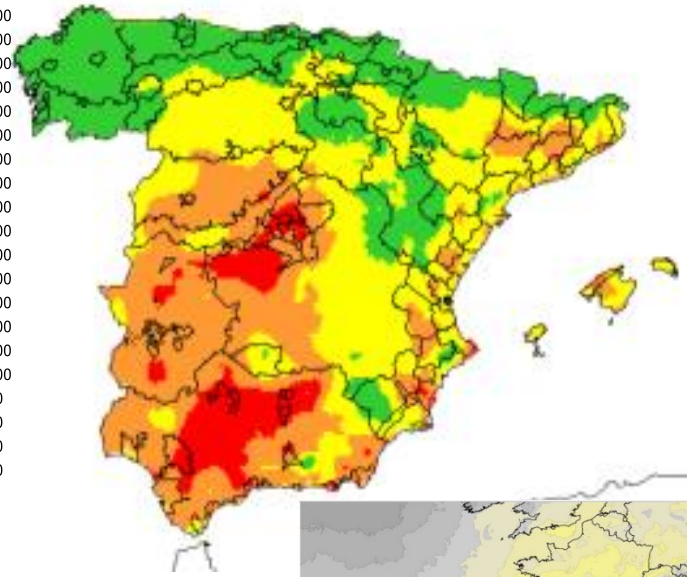
Effect of Spain emissions on annual 2016 ozone maxoct in rest of Europe



O_3 AOT40 ($(\mu g/m^3)h$) : average 2015-2019



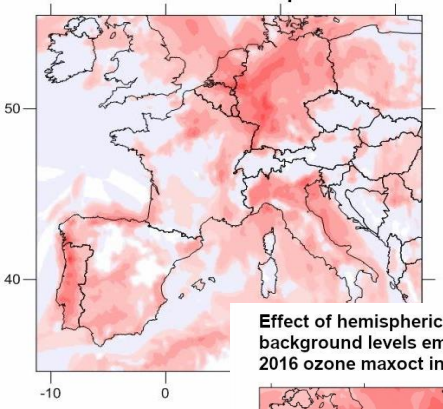
O_3 AOT40 ($(\mu g/m^3)h$) : 2020

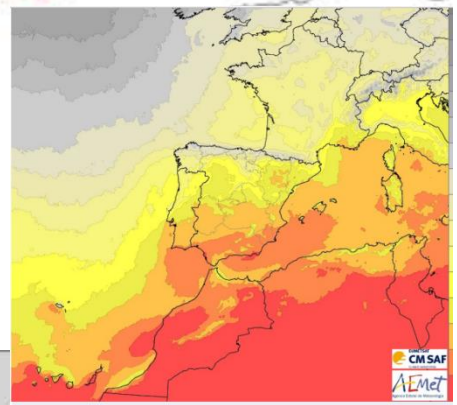


Further studies:

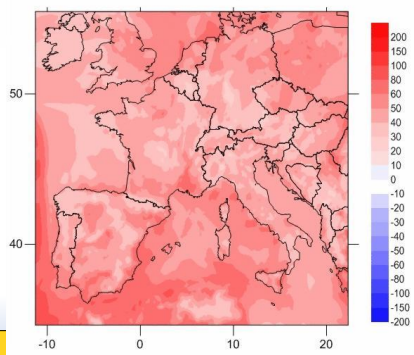
- Isolate meteo and emission effects
- A contribution of sources for 2020
- A complete study coupling with global model
- Higher resolution

Effect of biogenic emissions on annual 2016 ozone maxoct in Spain

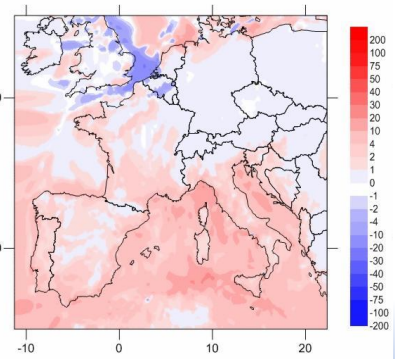


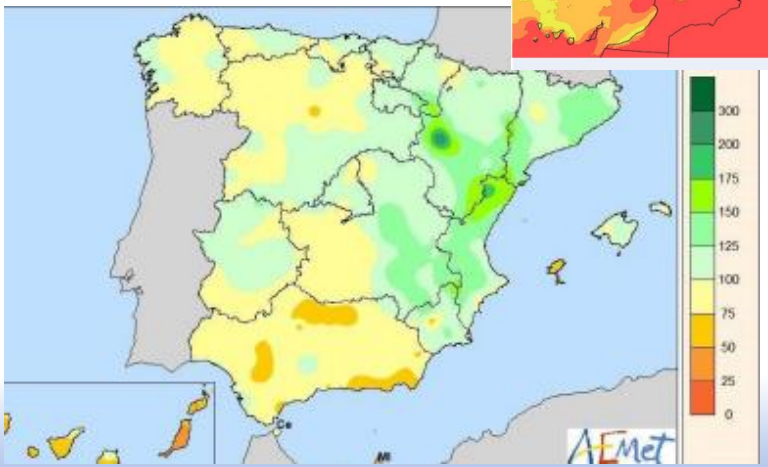


Effect of hemispheric transport and background levels emissions on annual 2016 ozone maxoct in Spain



Effect of shipping emissions on annual 2016 ozone maxoct in Spain





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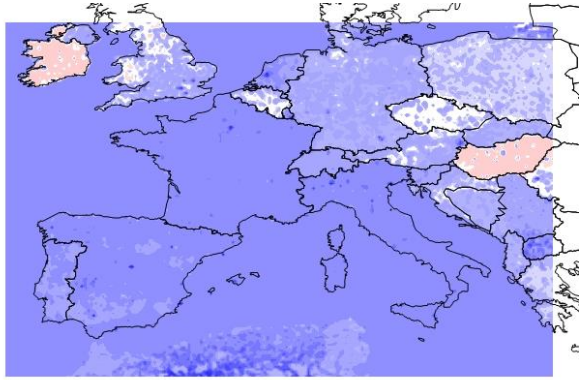
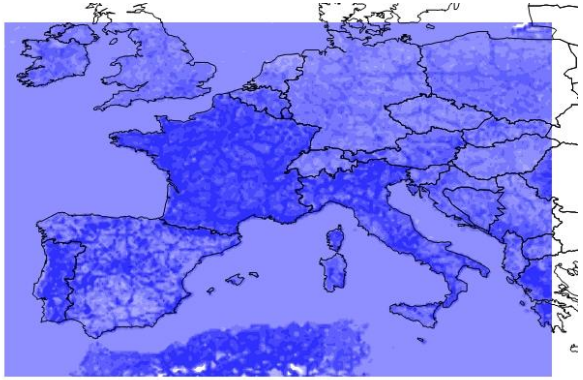
Decrease of SOx (and NOx) emissions drove increases in NH_3 concentrations

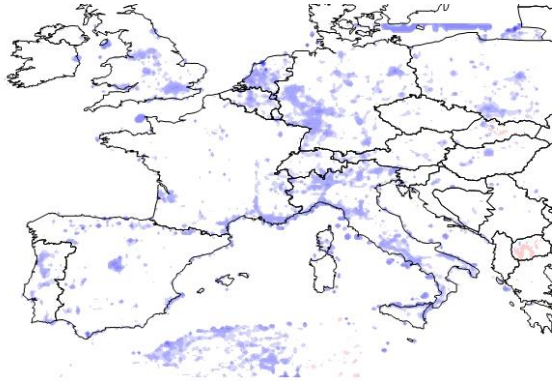
Relative Differences – Annual SO_2 emissions 2020-2018

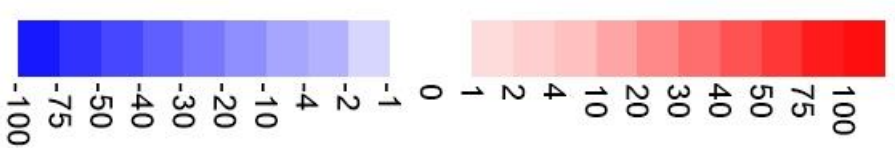


Relative Differences – Annual NOx emissions 2020-2018



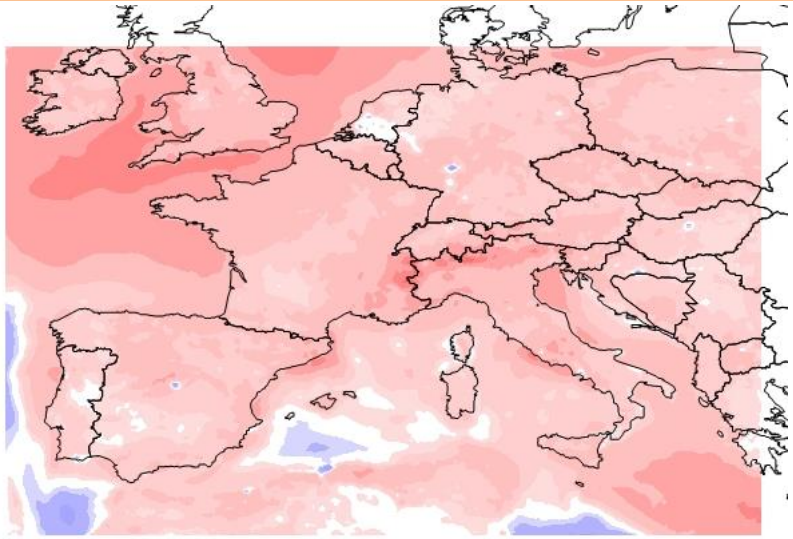
Relative Differences – Annual NH_3 emissions 2020-2018



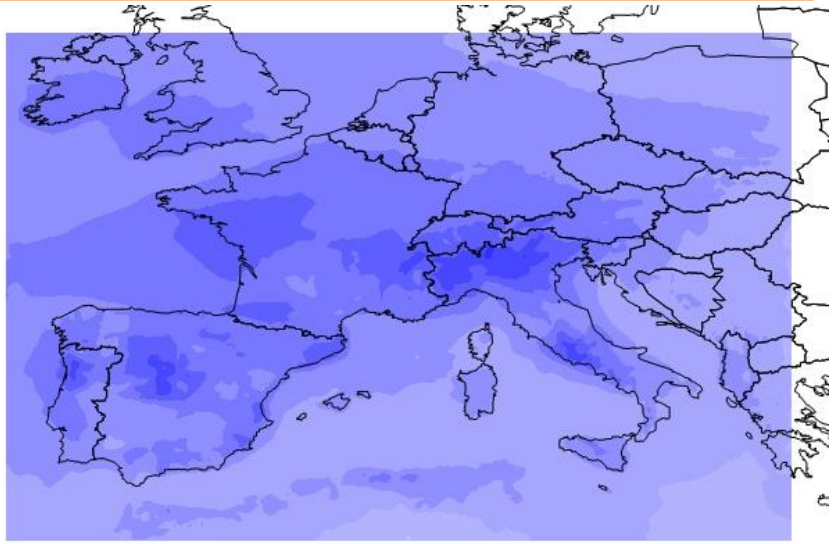


Decrease of SOx (and NOx) emissions drove increases in NH_3 concentrations (model results)

Increase (%) in NH_3 concentrations (lockdown period)



Decrease (%) in NH_4^+ concentrations (lockdown period)



Decrease of SOx (and NOx) emissions drove increases in NH_3 concentrations

Can also be seen in the observed concentrations at EMEP sites

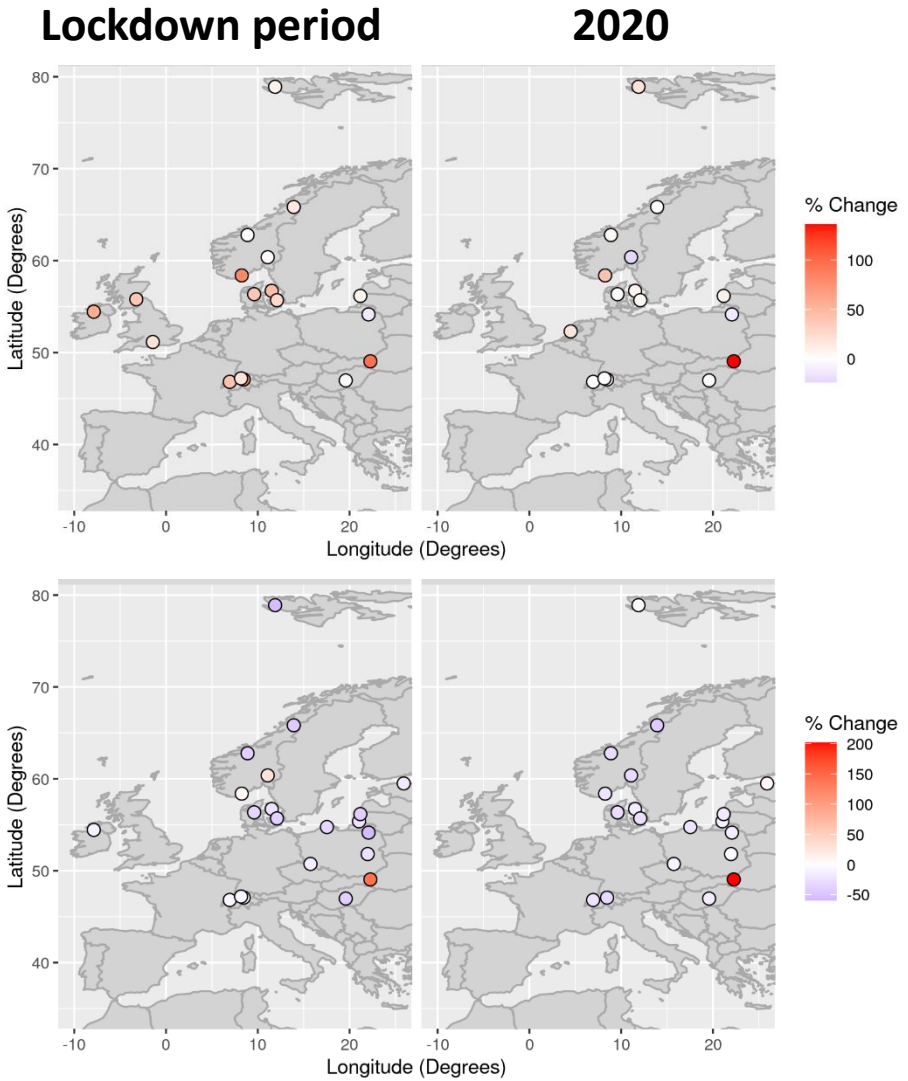
Data coverage criteria:

Sites used with:

- ≥ 75% of period with valid data
- At least 3 years with valid data for 2016-2019

% Change in NH_3 concentrations with respect to mean 2016-2019 (mostly increases)

% Change in NH_4^+ concentrations with respect to mean 2016-2019 (mostly decreases)



Summary

- All methods (observations and/or models) to estimate the impact of lockdown on air quality have considerable uncertainty
- The model estimates increases in ozone in the same areas where an increase is observed at at least one location (NO-titration areas)
- Model probably overestimates the extension of the areas with increases due to model resolution (~5x5km2)

- NOx emission reductions increased mean and MDA8 O3 concentrations in some NOx source areas of Spain
- They also increased human health impacts of ozone (SOMO35) in urban areas although impacts from NO2 will have decreased
- Ozone impacts to vegetation (AOT40) decreased for most of Spain, especially in the east (climate, shipping…). Difficult to decrease in Southern Spain (climate…)
- Reductions of SOx (and NOx) emissions probably produced increases in NH3 concentrations across most of Europe

Thank you

Aknowledgments:

- *Ministry for the Ecological Transition (MITERD) for providing emissions, observations and financial support*
- *AEMET for access to MARS (ECMWF, IFS meteorological data)*
- *Marc Guevara for providing emissions reductions until 31/07/2020*

Retos-AIRE: *Ai**R** pollution mitigation actions for **E**nvironmen**T**al p**O**licy **S**upport. **AIR** quality multiscale modelling and evaluation of h**E**alth and vegetation impacts* ***RTI2018-099138-B-100 Plan Nacional I+D+i***

www.retos-aire@ciemat.es

- **Carlos Ordóñez** a,∗, Jose M. Garrido-Perez a,b, Ricardo García-Herrera (2020) , Early spring near-surface ozone in Europe during the COVID-19 shutdown: Meteorological effects outweigh emission changes Science of the Total Environment 747 (2020) 141322
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- Alejandro **Rodríguez-S´anchez** *, Marta G. Vivanco, Mark Richard Theobald, Fernando Martín. Estimating the effect of the COVID-19 pandemic on pollutant emissions in Europe. Atmospheric Pollution Research 13 (2022) 101388
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