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SOURCE APPORTIONMENT ANALYSIS IN PM AND O_3 CONCENTRATIONS DURING COVID-19 LOCKDOWN PERIOD IN MADRID (SPAIN)

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CASE STUDY

- **DOMAINS:**

D1 : Iberian Peninsula (IP) (25 km)

D2 : Madrid Community (5 km)

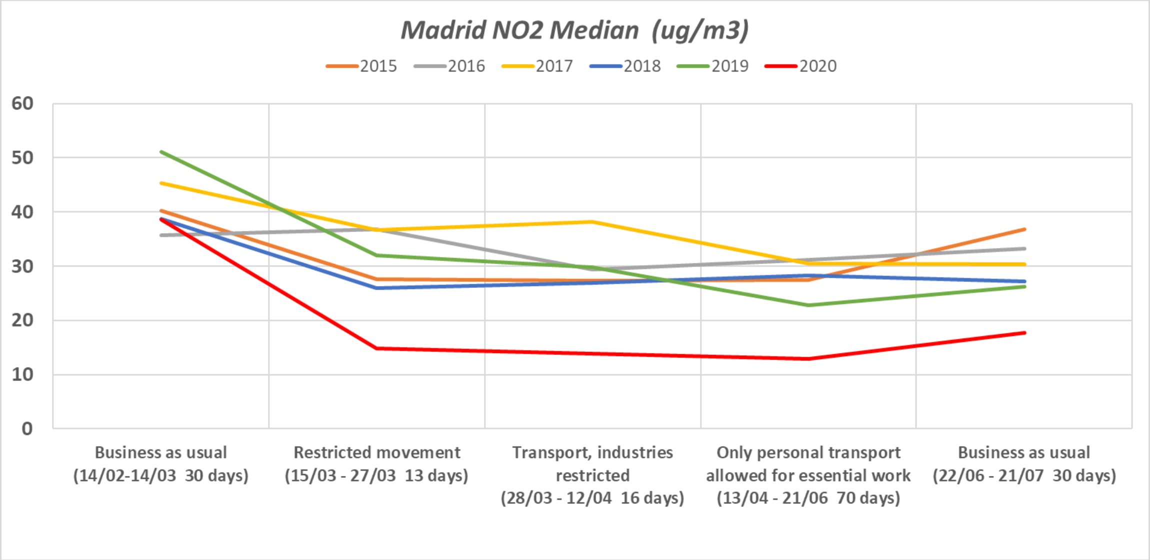
D3 : Madrid City (1 km) (Phase 2)

3D : 35 vertical levels

- **SIMULATIONS (2020 meteorology) :**

BAU: Business-As-Usual (No lockdown)

COVID: Emission reduction: (CAMS-COPERNICUS COVID-19 lockdown scaling factors*)



NO2 observations analysis (Madrid)
(red line effects of the COVID-19 lockdown)

***Time-resolved emission reductions for atmospheric chemistry modelling in Europe during the COVID-19 lockdowns**
Guevara et al. Atmos. Chem. Phys., 21, 773–797, 2021 https://doi.org/10.5194/acp-21-773-2021

CASE STUDY

- **PERIODS:**

- **01/02/2020 – 07/03/2020** (Pre-lockdown) (36 days)
- **08/03/2020 – 12/04/2020** (Lockdown) (36 days)

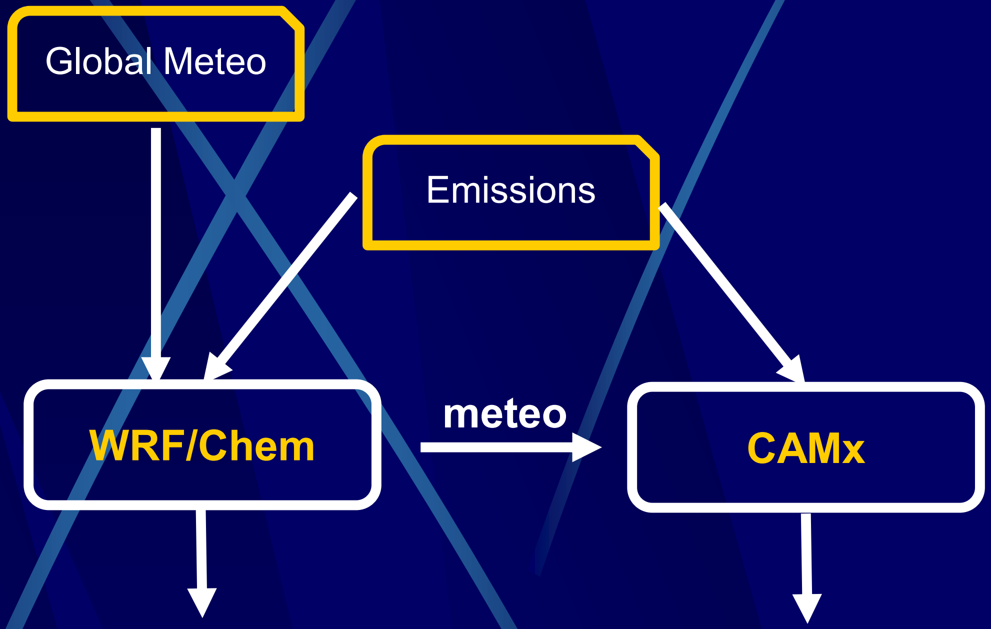
- On March, 8, 2020, the first emission reductions were observed by the initial restrictions
- On March, 15, 2020, the national lockdown was effective.
- On March, 28, 2020, the Spanish government banned all non-essential activity.
- On April, 13, 2020, workers in some non-essential sectors, such as construction and industry, who could not work remotely were allowed to return to work.

CASE STUDY

MODELS:
- **WRF/Chem** CBMZ-MOSAIC
- **WRF-CAMx** CB06-CF

INITIAL & BOUNDARY CONDITIONS:
- **Meteorology:** NCEP GDAS Final Analysis 0.25 (ds083.3) 6-hourly
- **Air quality:** WACCM Forecast 0.9x0.125 (ds313.6) 6-hourly

EMISSIONS:
- **Anthropogenic:** CAMS-REG-AP (v4.2_ry 2019) 0.05x0.1 (COPERNICUS)
- **EMIMO model (UPM)**
- **Biogenic MEGAN**



- **Hourly simulated concentrations** are compared with **observational hourly data** from the Madrid municipality and regional air quality observation networks **(48 monitoring station).**
- Representative and unique value calculated using the **average values of the 48 monitoring stations** and the corresponding **model value**.

WRF/Chem CONFIGURATION

- GAS-AEROSOL MECHANISMS: CBMZ-MOSAIC
- AEROSOL : Yes
- DRY DEPOSITION: Binkowski And Shankar
- WET DEPOSITION: Easter And Chapman
- PHOTOLYSIS: Fast-J

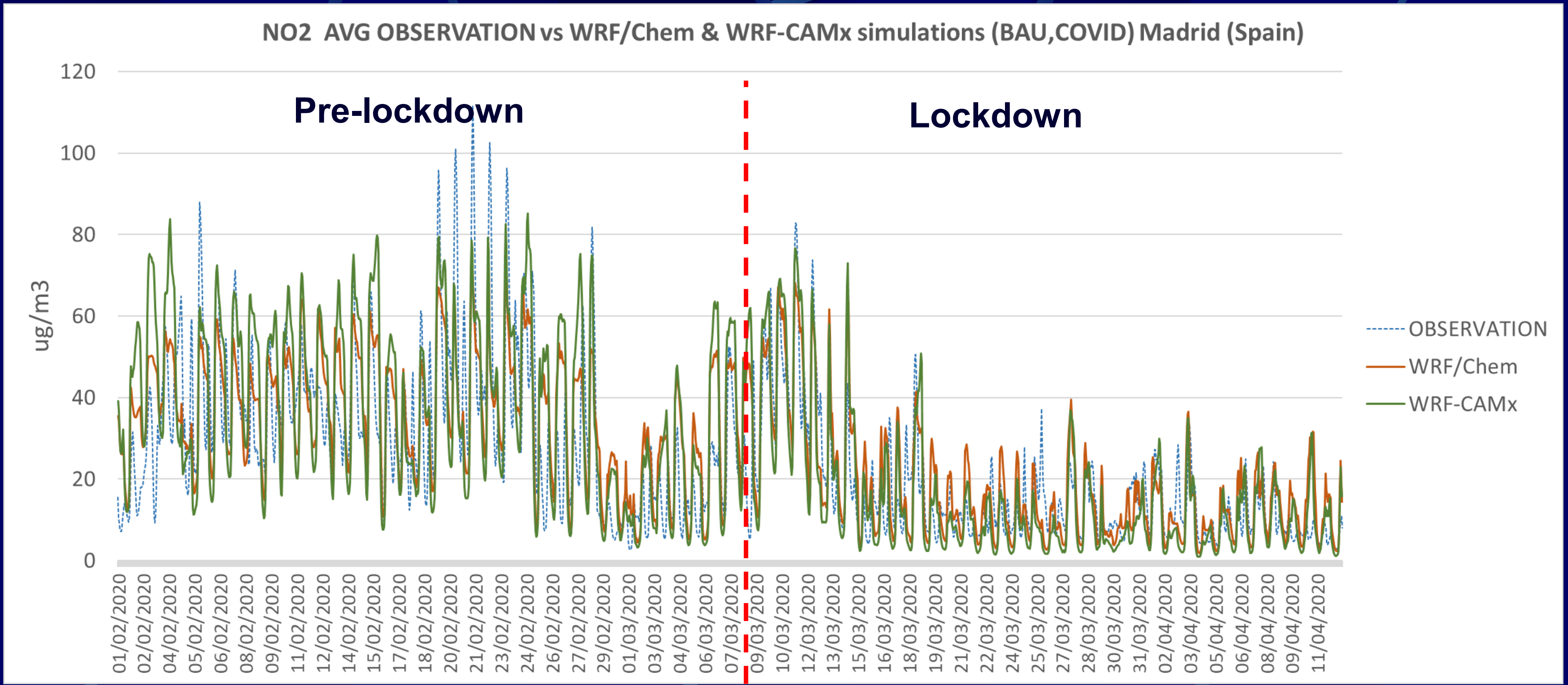
- MICROPHYSICS: Lin
- LW/SW RADIATION: Rapid Radiative Transfer Method for Global (RRTMG)
- PBL: Yonsei University (YSU)
- SURFACE LAYER: Monin-Obukhov
- LAND SURFACE: Noah
- CUMULUS: Grell-3D (G3)

INTERNATIONAL AIR QUALITY ASSESSMENT EXPERIMENT MODEL ASSESSMENT INITIATIVE (AQMEII- USA-EUROPE JOINT SIMULATION EXPERIMENT)

WRF-CAMx OSAT-PSAT CONFIGURATION

- Advection solver: Piecewise Parabolic Method (PPM)
- Chemistry solver: Euler-Backward Iterative (EBI)
- Dry Deposition: ZHANG03
- Chemical mechanism: CB6r4 photochemistry
- Aerosol mechanism: Two mode (Coarse and Fine - CF) scheme.
- Inorganic PM chemical: ISORROPIA (Inorganic gas-aerosol partitioning)
- Organic PM chemical: SOAP2.2 (Secondary organic aerosol)
- Ozone and Particulate Source Apportionment Technology (OSAT and PSAT)

WRF/Chem & WRF-CAMx Performance: NO2



WRF/Chem
NMB: 18%
RSME: 14 ug/m3
R^2: 0.67

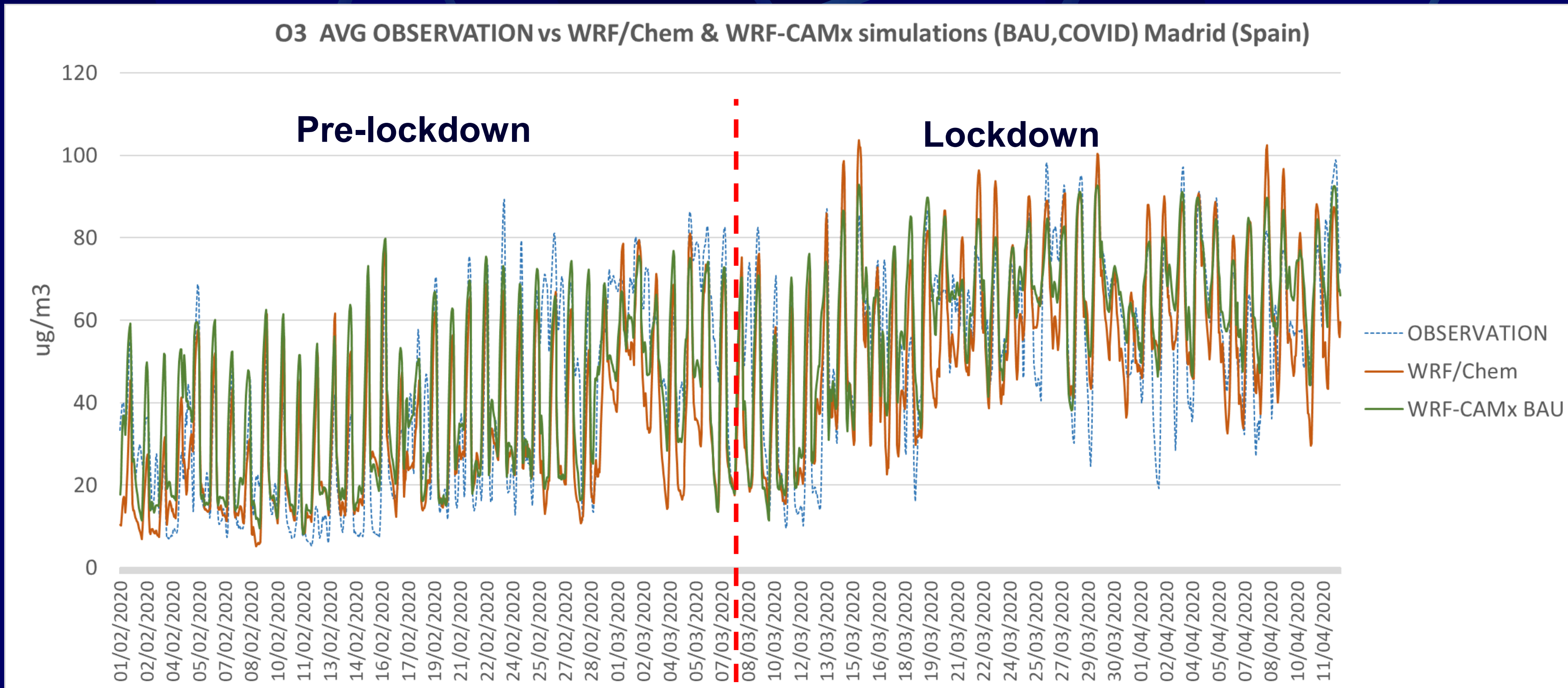
WRF-CAMx
NMB: 15%
RSME: 19 ug/m3
R^2: 0.57

WRF/Chem
NMB: 9%
RSME: 9 ug/m3
R^2: 0.72

WRF-CAMx
NMB: -5%
RSME: 10 ug/m3
R^2: 0.76

AVG: Average of the 48 monitoring station values and WRF/Chem & WRF-CAMx values where the stations are located.

WRF/Chem & WRF-CAMx Performance: O3



WRF/Chem
NMB: -14%
RSME: 15 ug/m3
R^2: 0.75

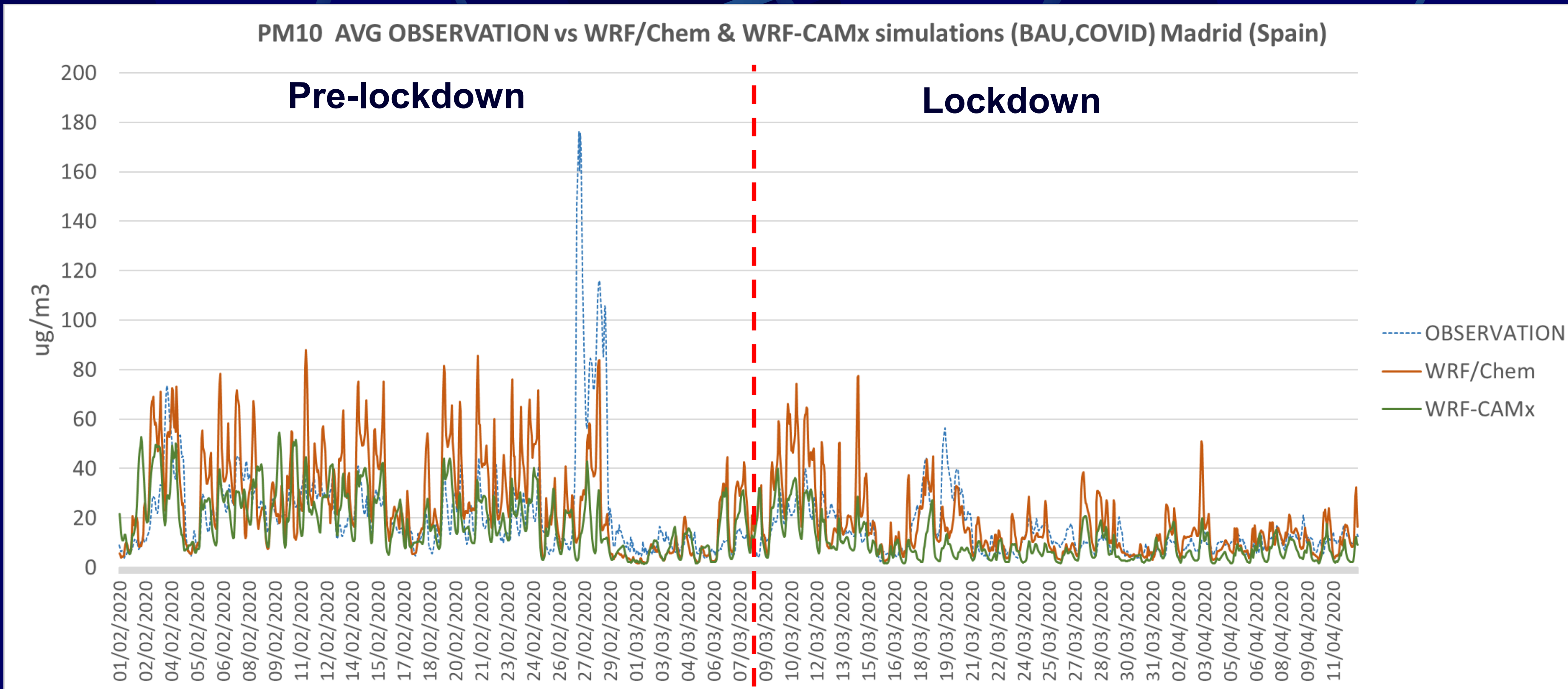
WRF-CAMx
NMB: 3 %
RSME: 15 ug/m3
R^2: 0.74

WRF/Chem
NMB: -2 %
RSME: 13 ug/m3
R^2: 0.78

WRF-CAMx
NMB: 7 %
RSME: 13 ug/m3
R^2: 0.76

AVG: Average of the 48 monitoring station values and WRF/Chem & WRF-CAMx values where the stations are located.

WRF/Chem & WRF-CAMx Performance: PM10



Pre-lockdown

WRF/Chem
NMB: 18 %
RSME: 14 ug/m3
R^2: 0.67

WRF-CAMx
NMB: -18 %
RSME: 20 ug/m3
R^2: 0.46

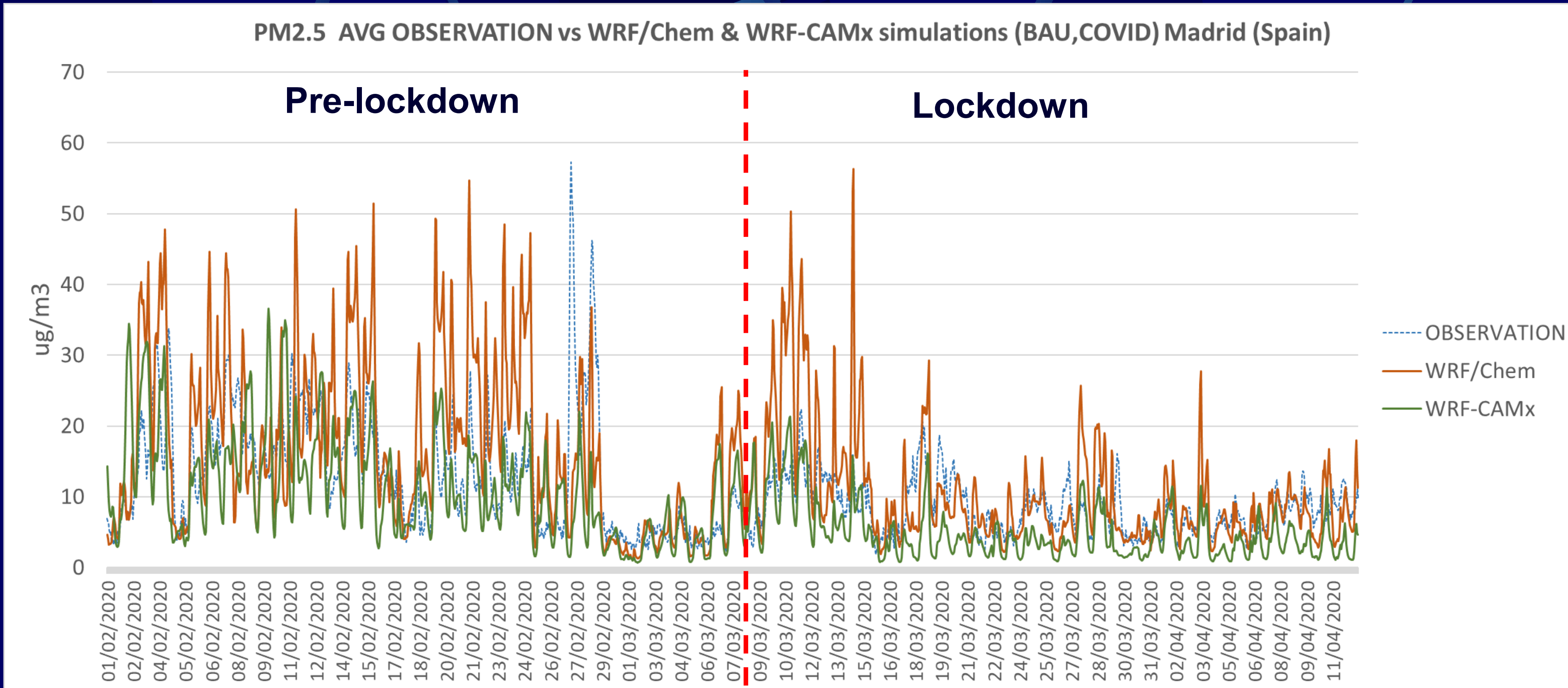
Lockdown

WRF/Chem
NMB: 9 %
RSME: 9 ug/m3
R^2: 0.78

WRF-CAMx
NMB: -11 %
RSME: 9 ug/m3
R^2: 0.67

AVG: Average of the 48 monitoring station values and WRF/Chem & WRF-CAMx values where the stations are located.

WRF/Chem & WRF-CAMx Performance: PM25



WRF/Chem
NMB: 27%
RSME: 11 ug/m3
R^2: 0.53

WRF-CAMx
NMB: -16%
RSME: 9 ug/m3
R^2: 0.48

WRF/Chem
NMB: 24%
RSME: 6 ug/m3
R^2: 0.57

WRF-CAMx
NMB: -14 %
RSME: 5 ug/m3
R^2: 0.55

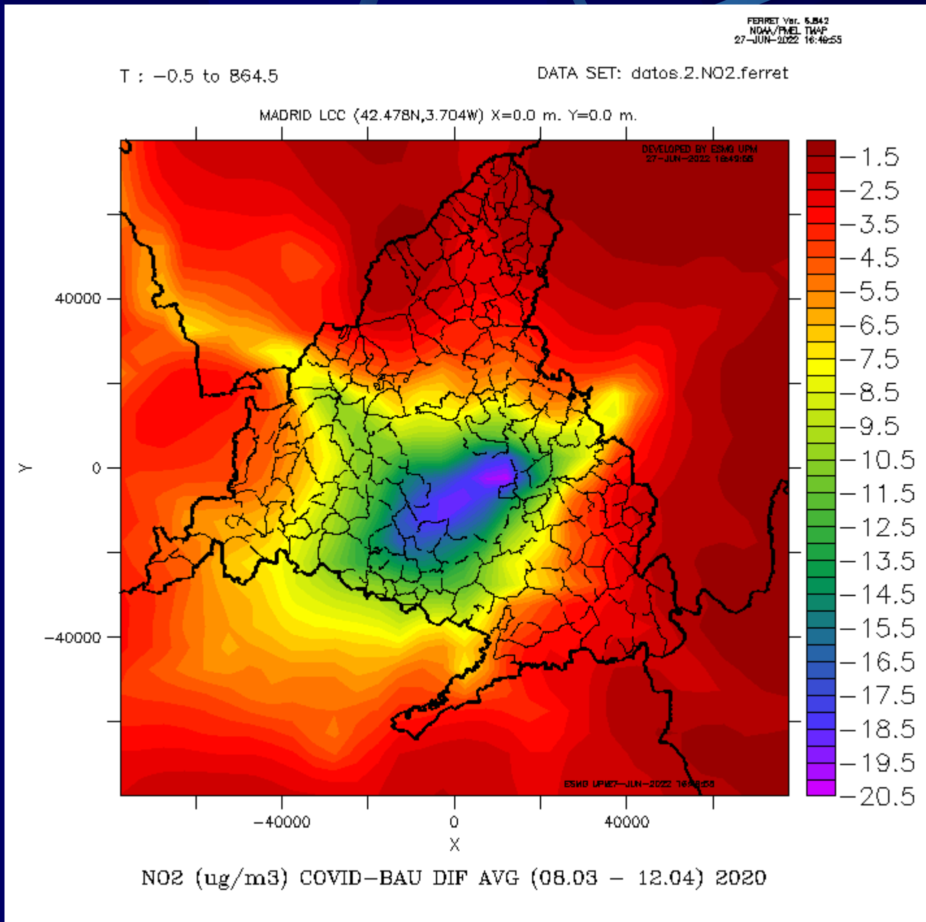
AVG: Average of the 48 monitoring station values and WRF/Chem & WRF-CAMx values where the stations are located.

WRF/Chem & WRF-CAMx Performance: SUMMARY

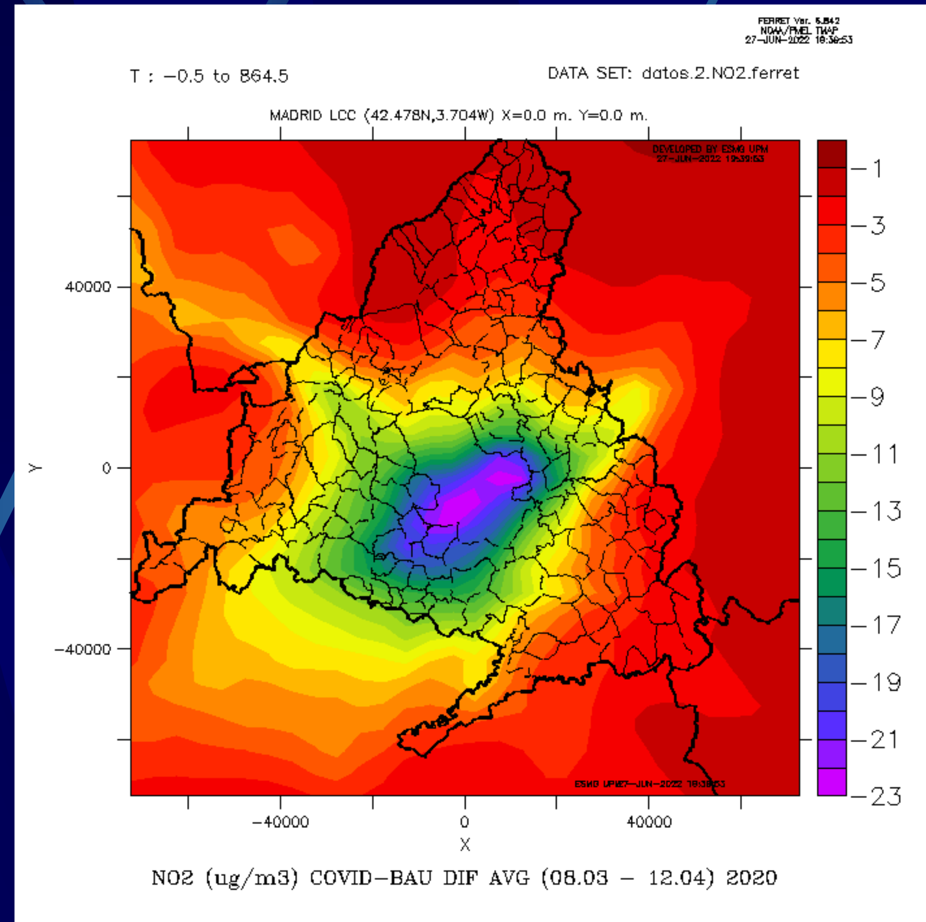
		NMB (%)		RMSE (µg/m3)		R^2 [0,1]	
	Model	Pre-lockdown	Lock-down	Pre-lockdown	Lock-down	Pre-lockdown	Lock-down
NO_2	WRF/Chem	18	9	14	9	0.67	0.72
	WRF-CAMx	15	-5	19	10	0.57	0.76
O_3	WRF/Chem	-14	-2	15	13	0.75	0.78
	WRF-CAMx	3	7	15	13	0.74	0.76
PM10	WRF/Chem	18	-18	14	20	0.67	0.46
	WRF-CAMx	-18	-11	20	9	0.46	0.67
PM2.5	WRF/Chem	27	24	11	6	0.53	0.57
	WRF-CAMx	-16	-14	9	5	0.48	0.55

Both RMSE and R^2 quantify how well a regression model fits a dataset. The RMSE tells us how well a regression model can predict the value of the response variable in absolute terms while R^2 tells us how well a model can predict the value of the response variable in percentage terms.

NO2 Madrid COVID-BAU 08/03-12/04 2020

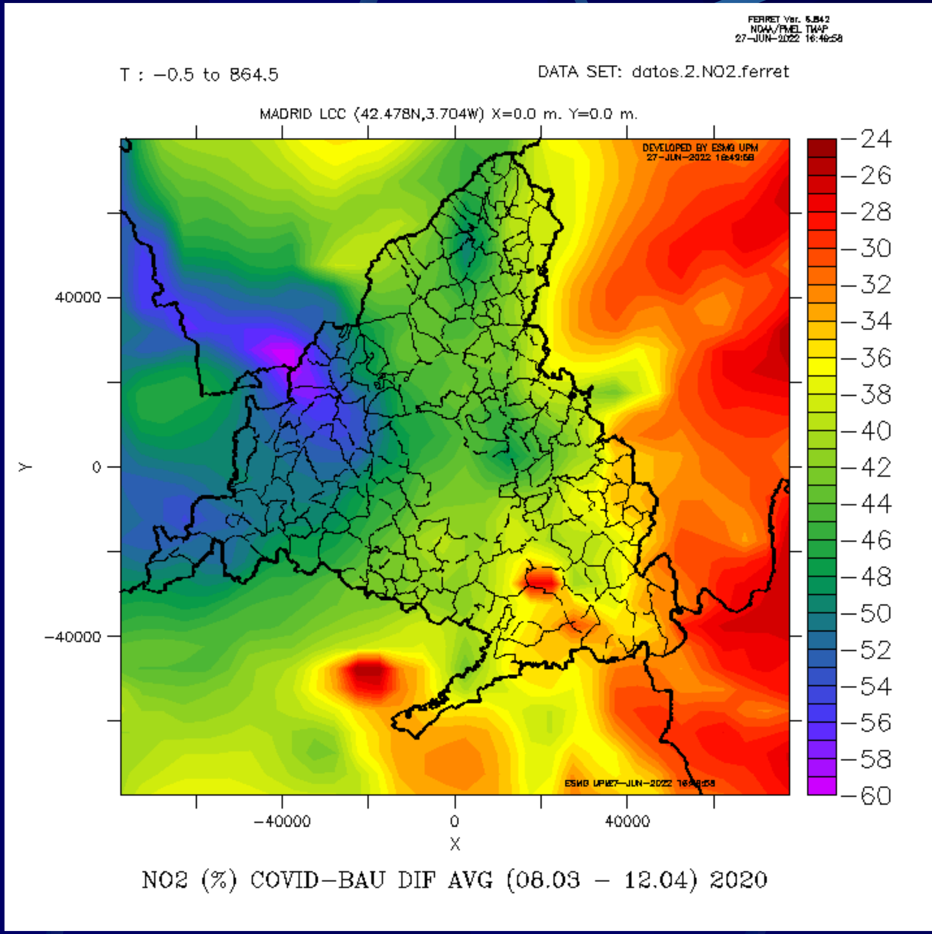


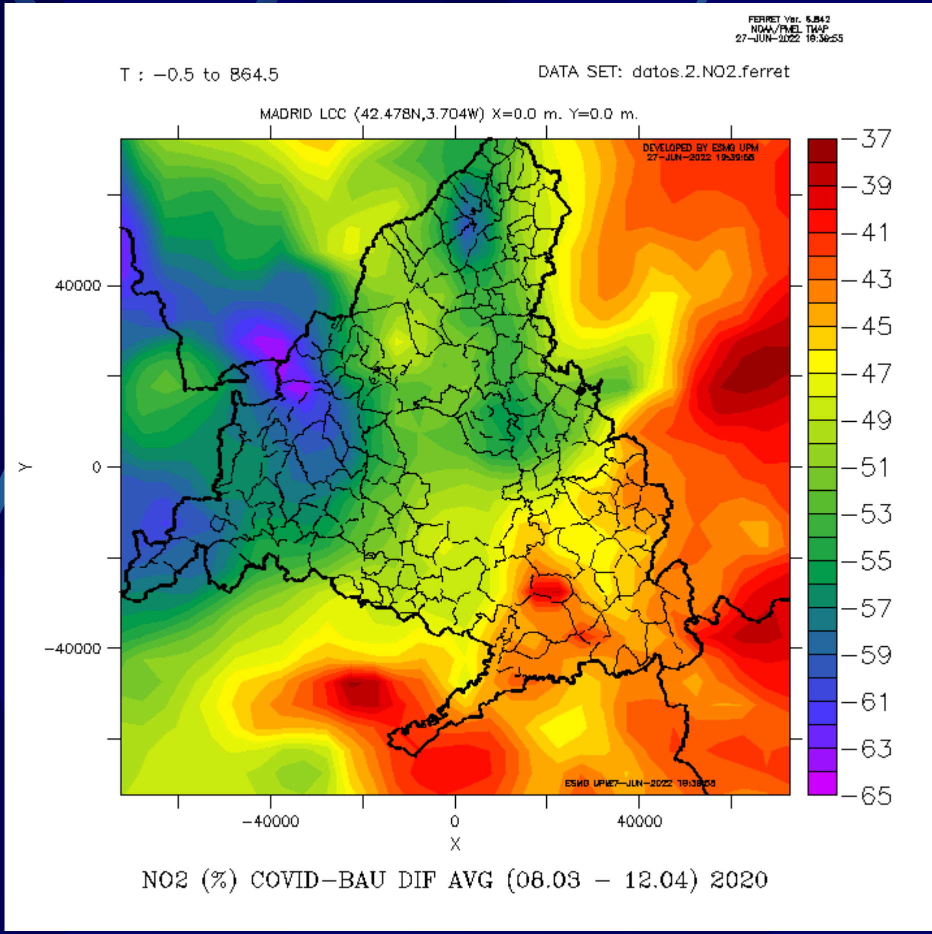
WRF/Chem



WRF-CAMx

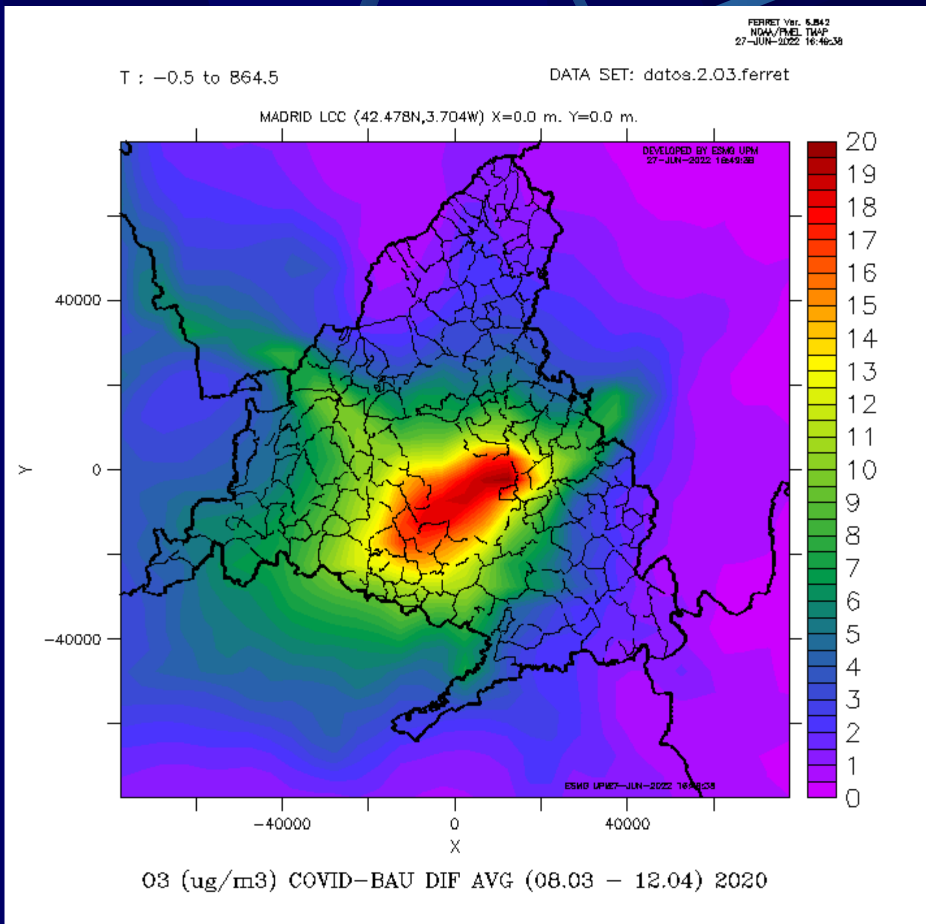
NO2 Madrid COVID-BAU (%)08/03-12/04 2020

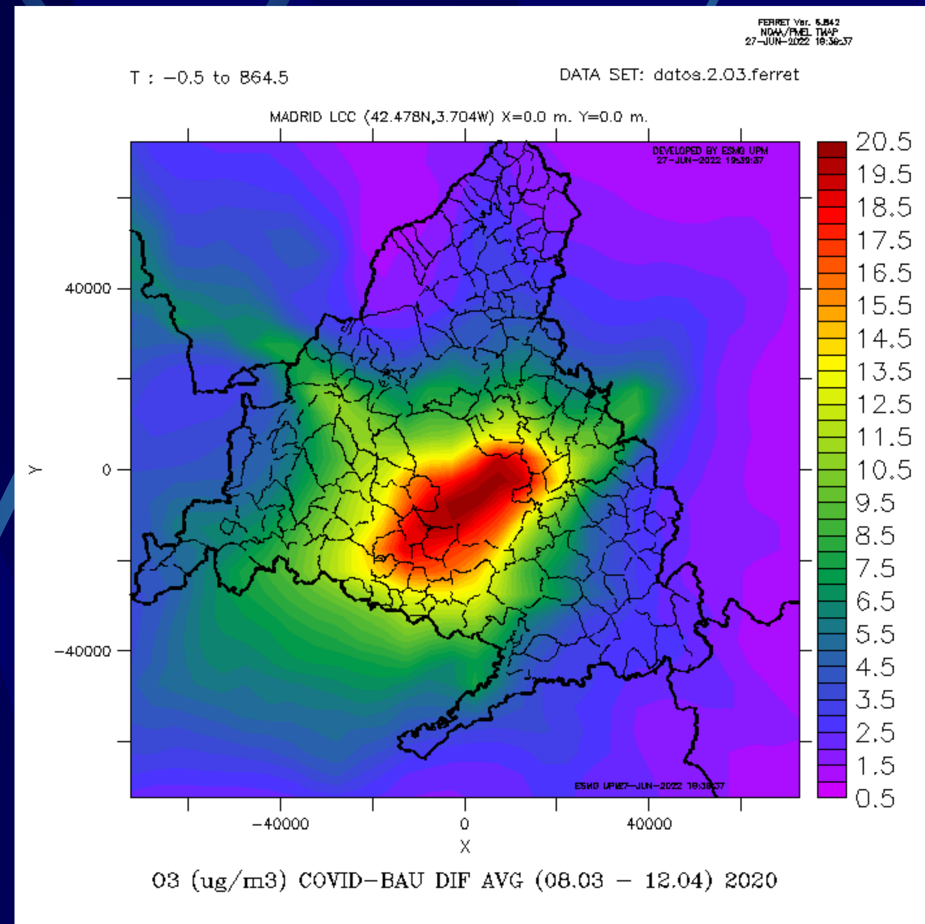




WRF/Chem **WRF-CAMx**

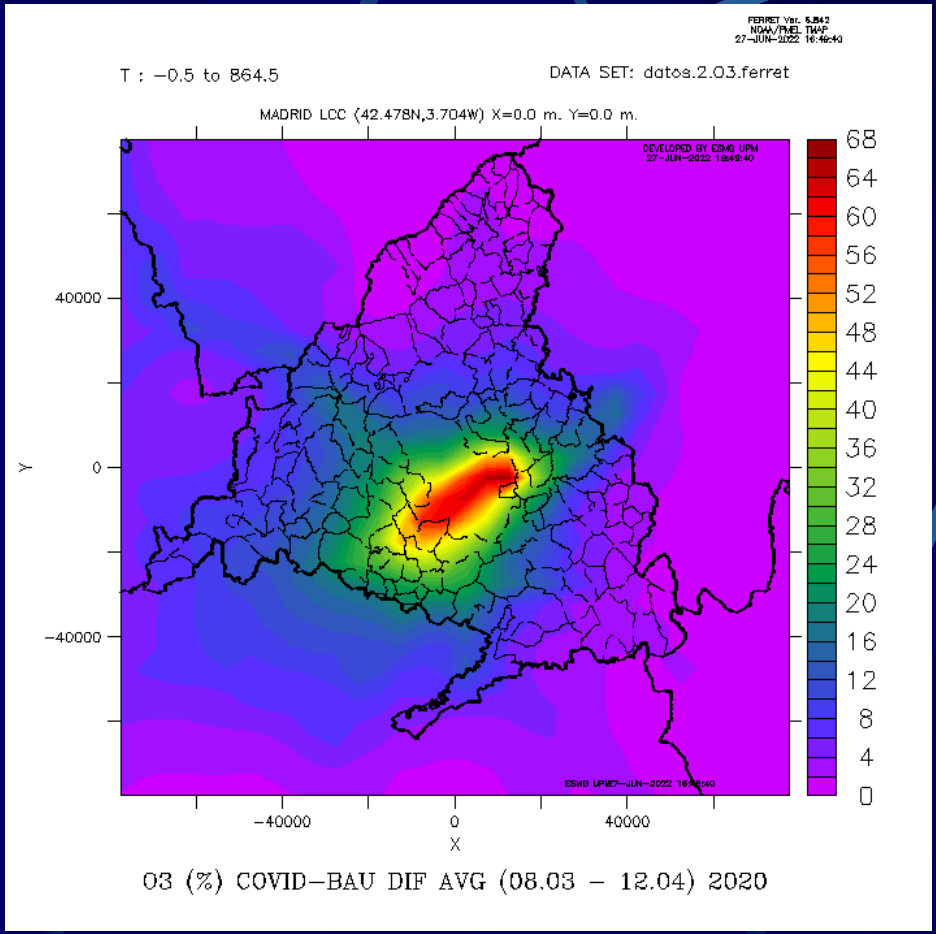
O3 Madrid COVID-BAU 08/03-12/04 2020

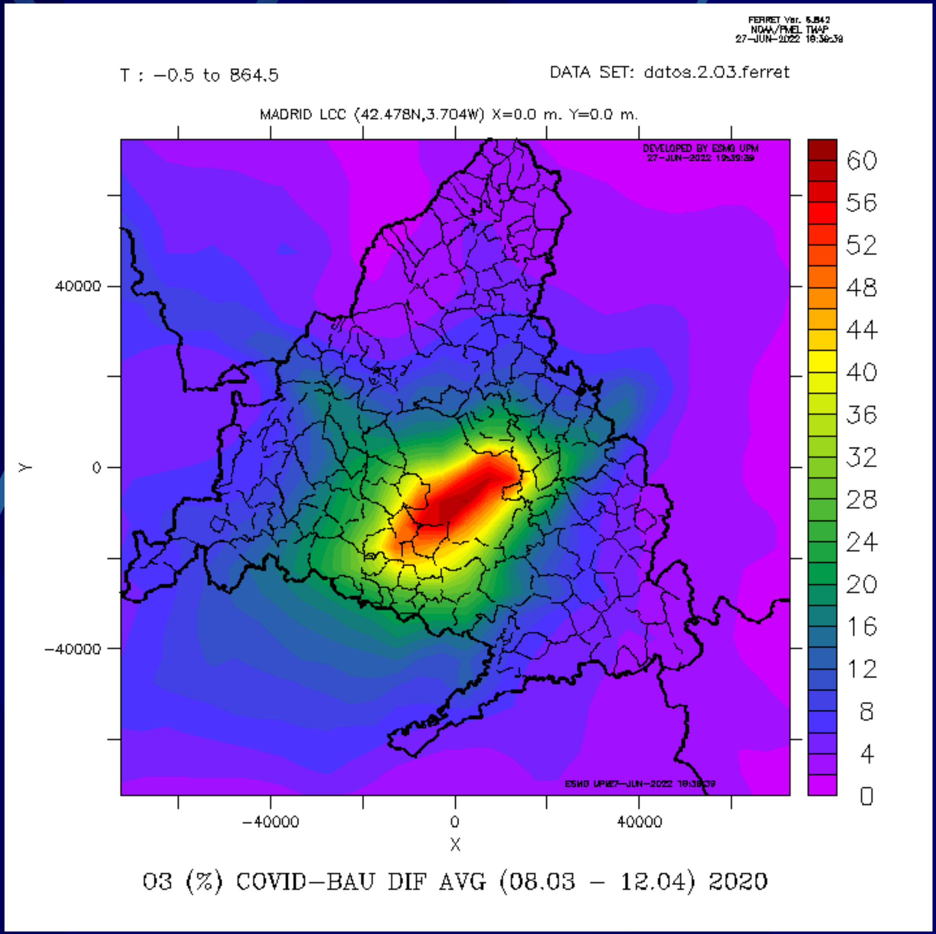




WRF/Chem **WRF-CAMx**

O3 Madrid COVID-BAU (%)08/03-12/04 2020

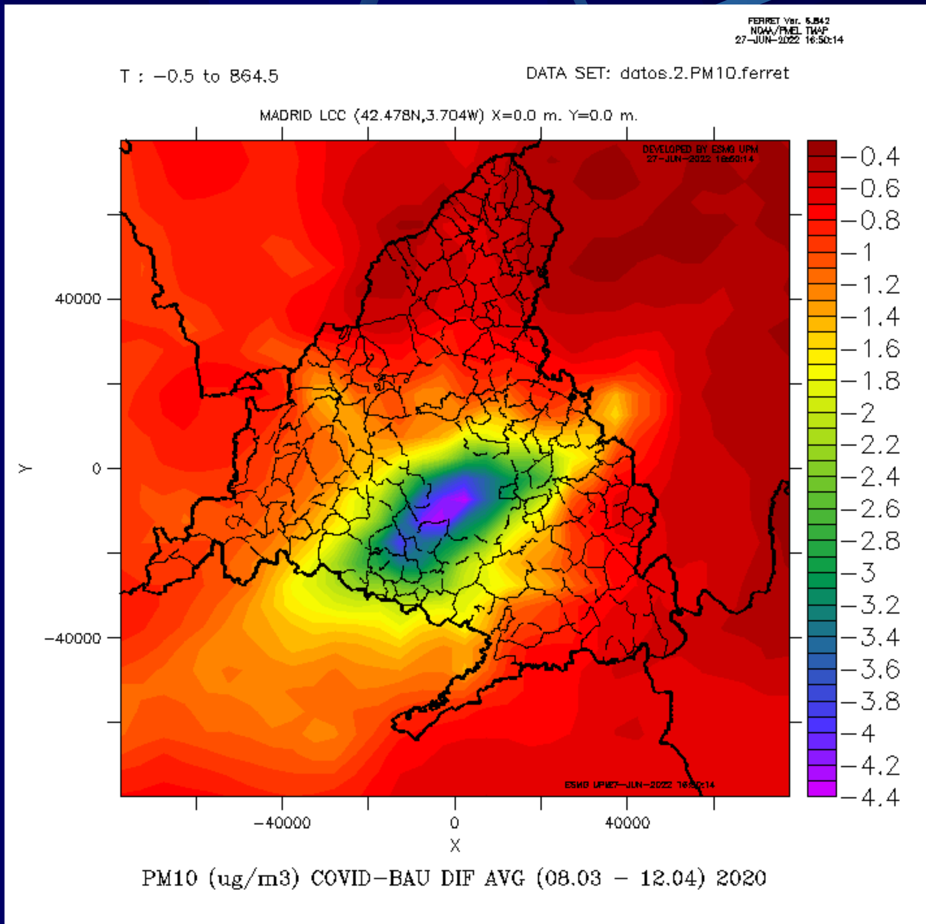


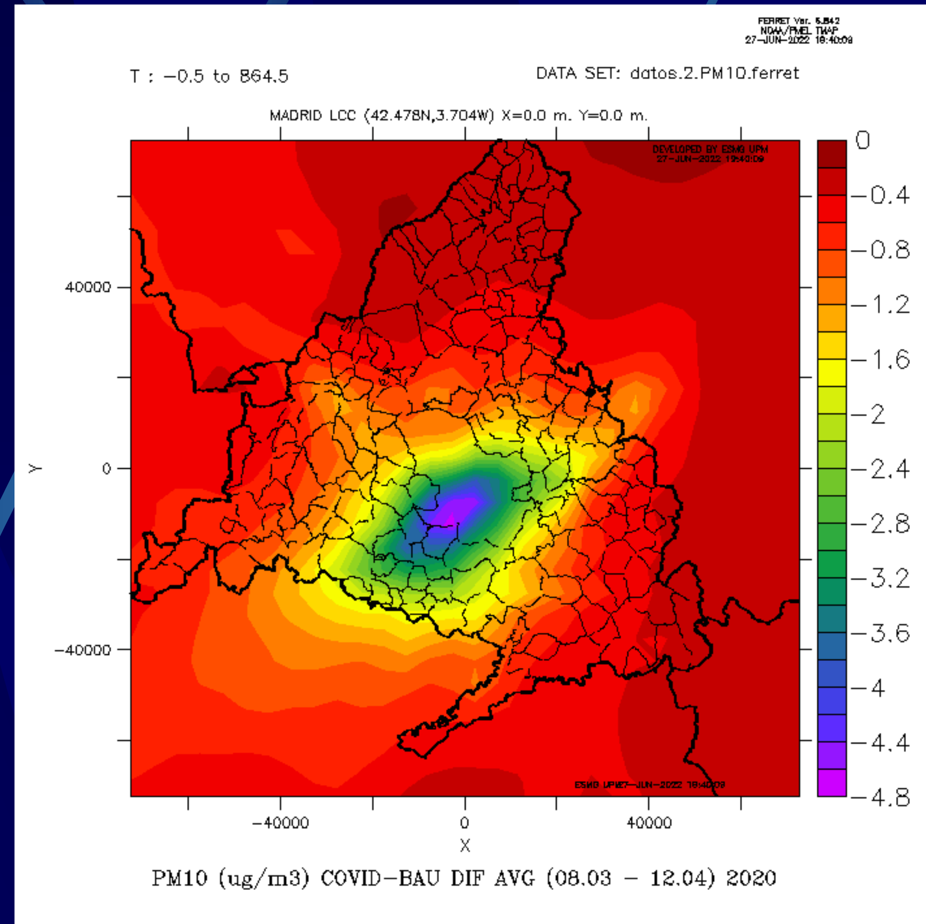


WRF/Chem

WRF-CAMx

PM10 Madrid COVID-BAU 08/03-12/04 2020

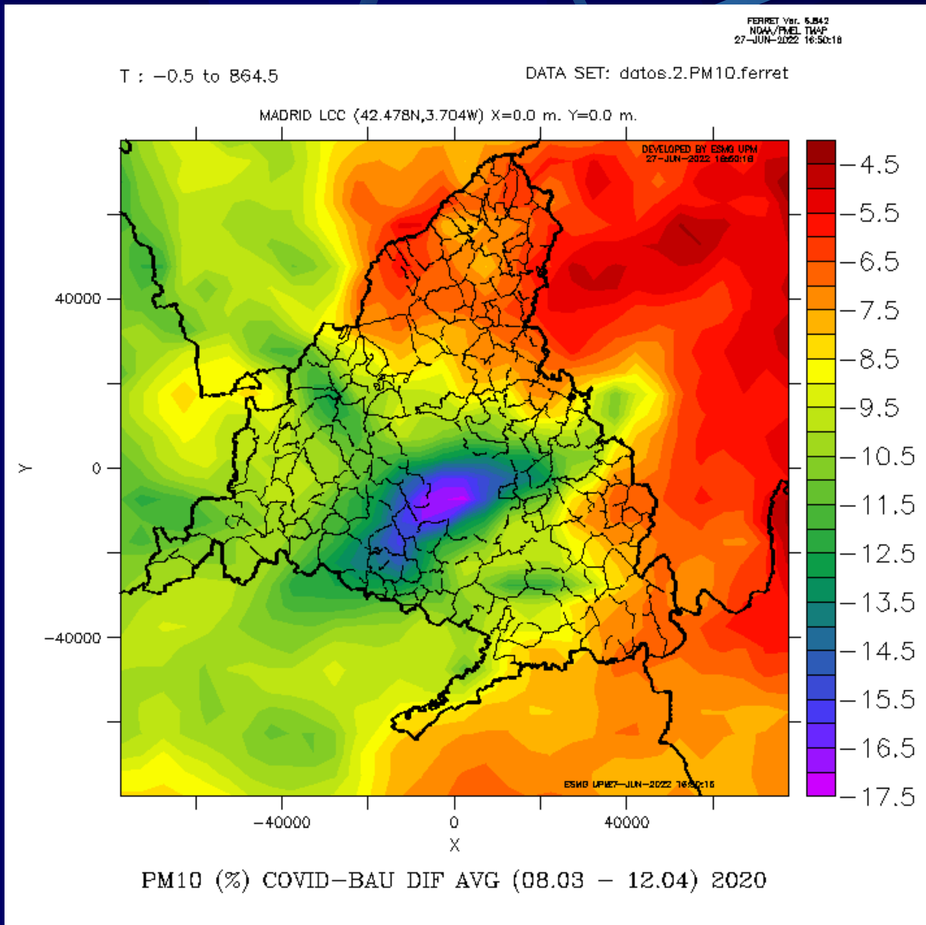


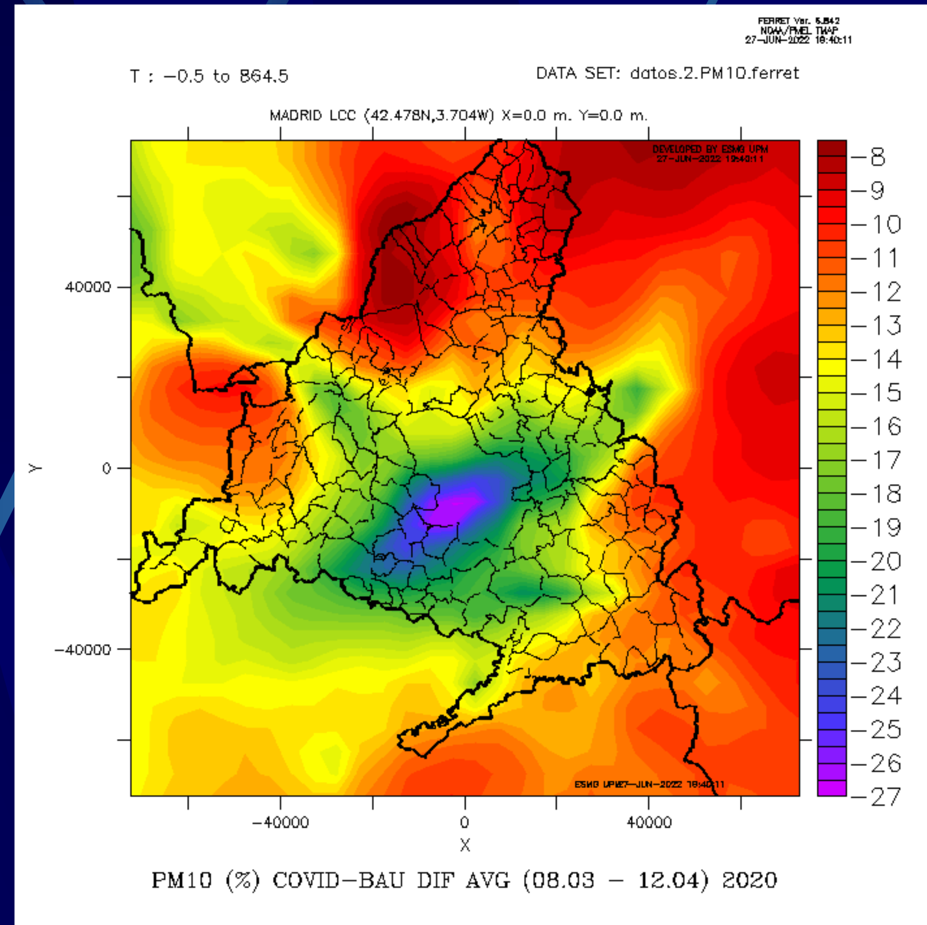


WRF/Chem

WRF-CAMx

PM10 Madrid COVID-BAU (%)08/03-12/04 2020

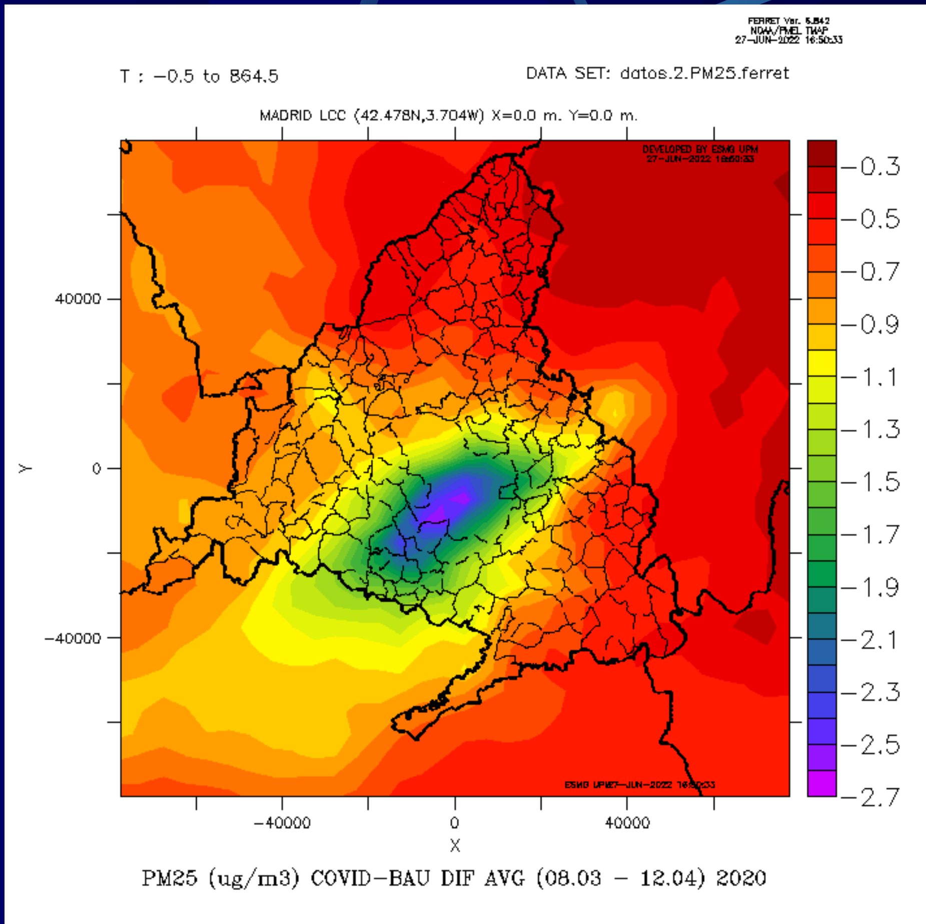


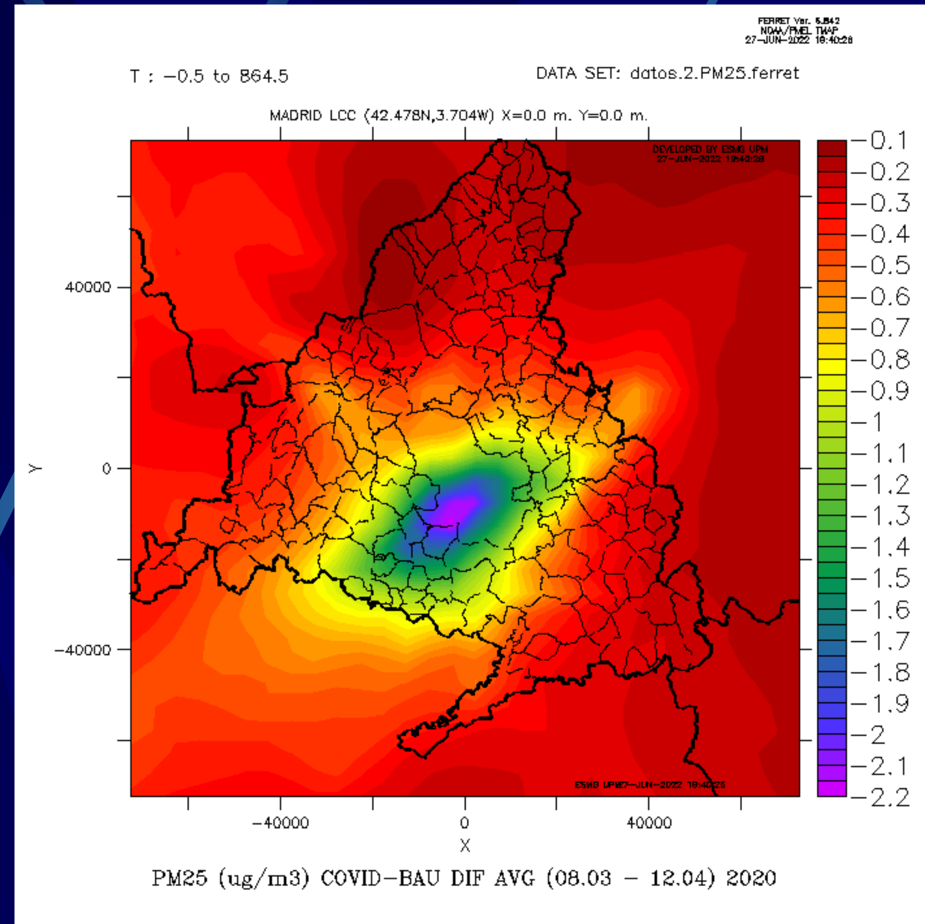


WRF/Chem

WRF-CAMx

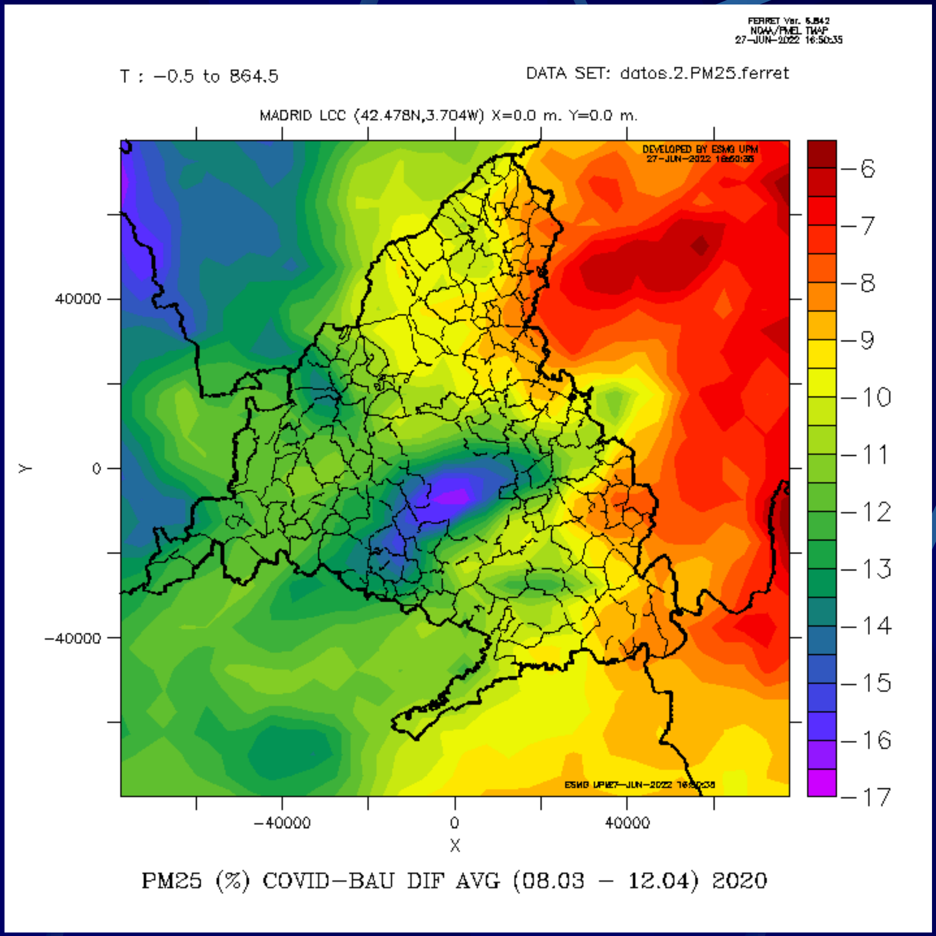
PM25 Madrid COVID-BAU 08/03-12/04 2020

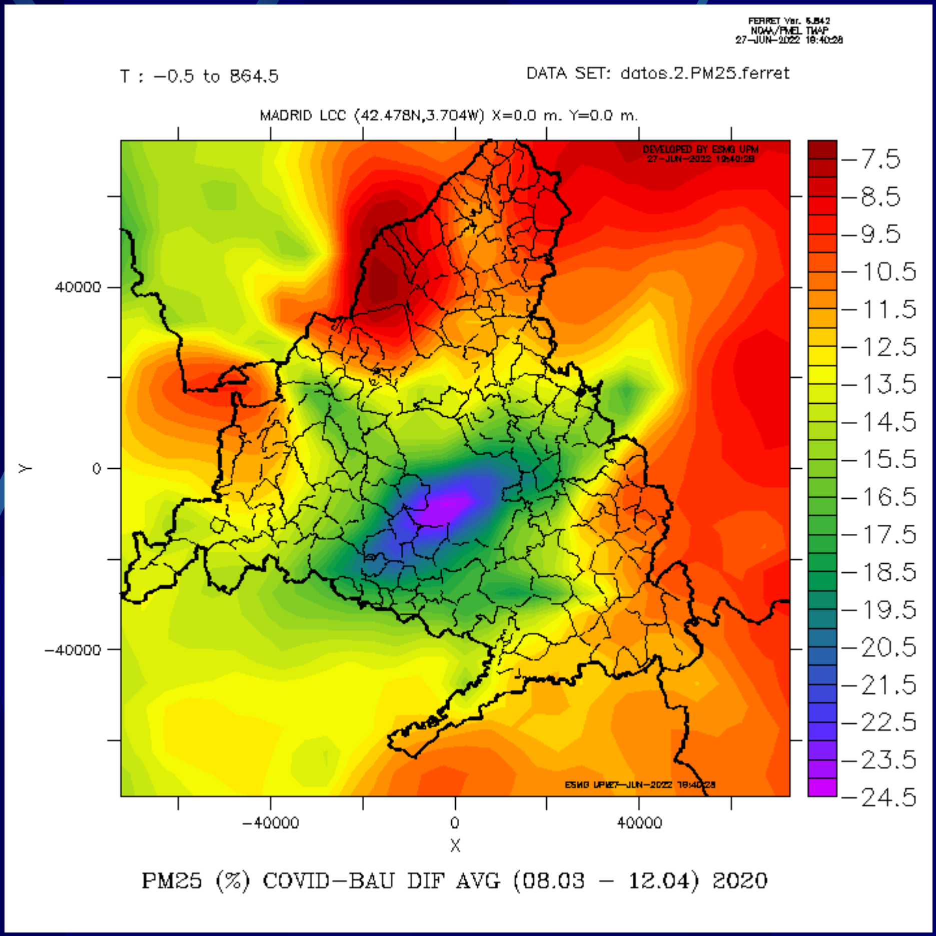




WRF/Chem **WRF-CAMx**

PM25 Madrid COVID-BAU (%)08/03-12/04 2020



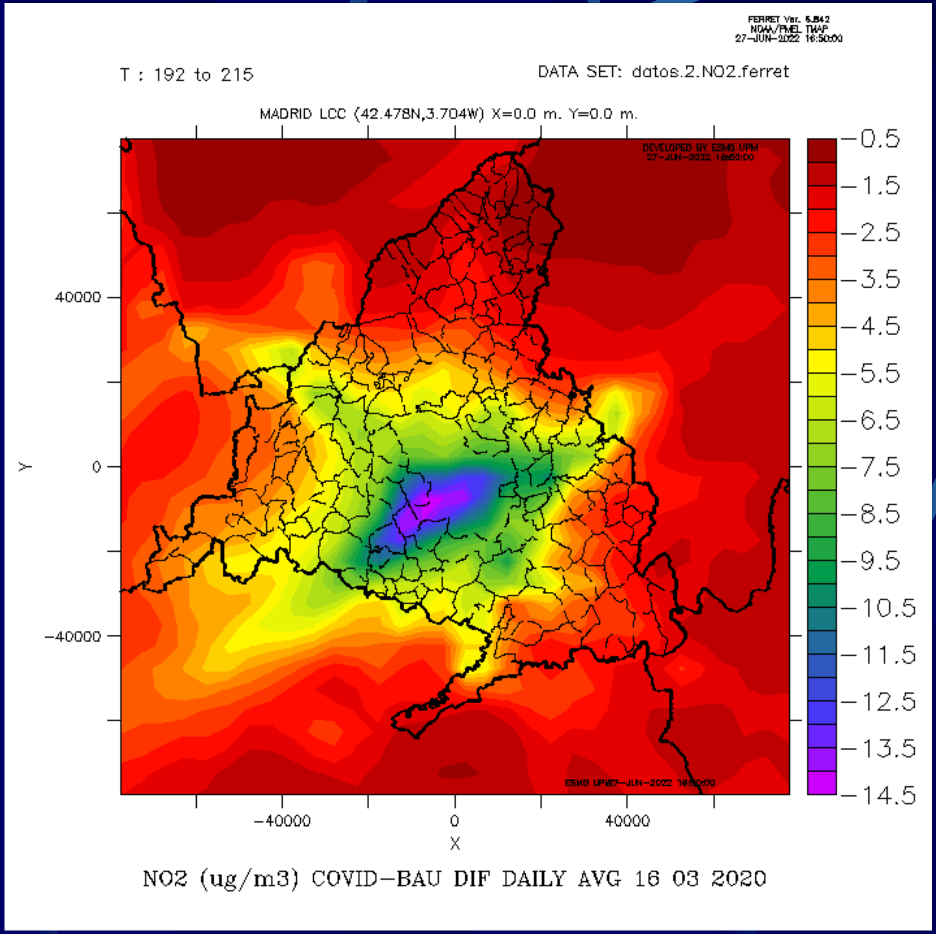


WRF/Chem

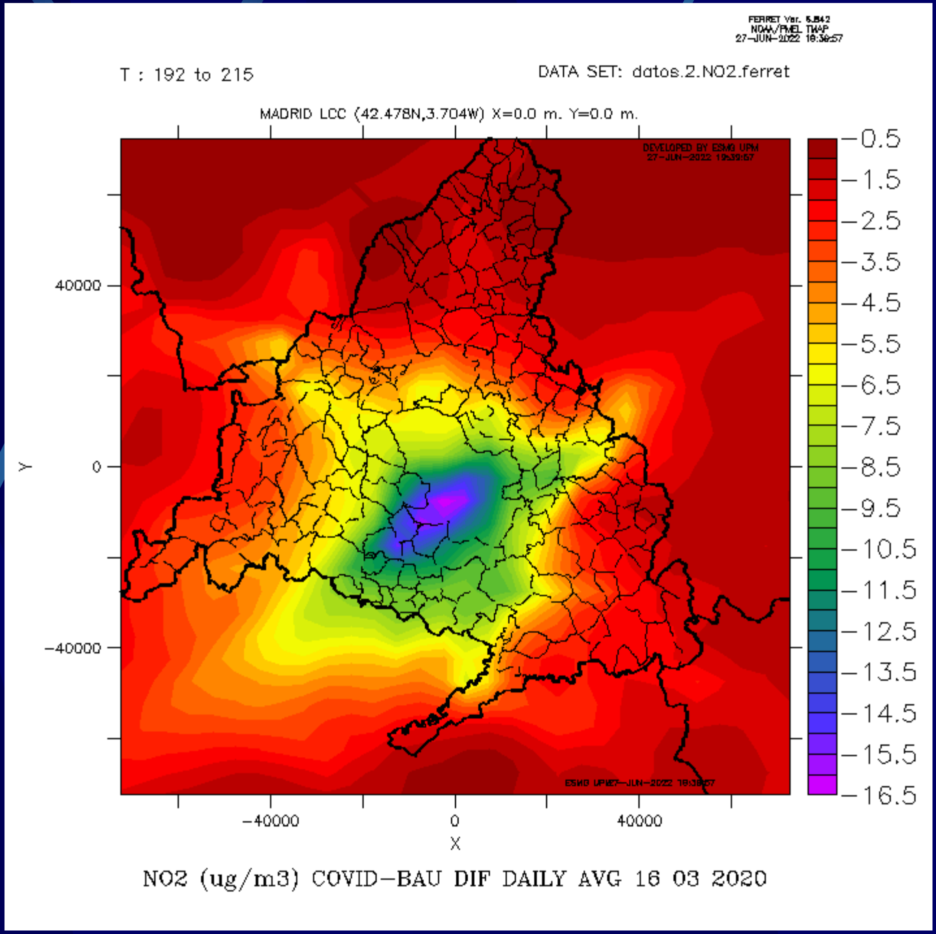
WRF-CAMx

NO2 Madrid COVID-BAU 16/03/2020

National Lockdown (Monday)



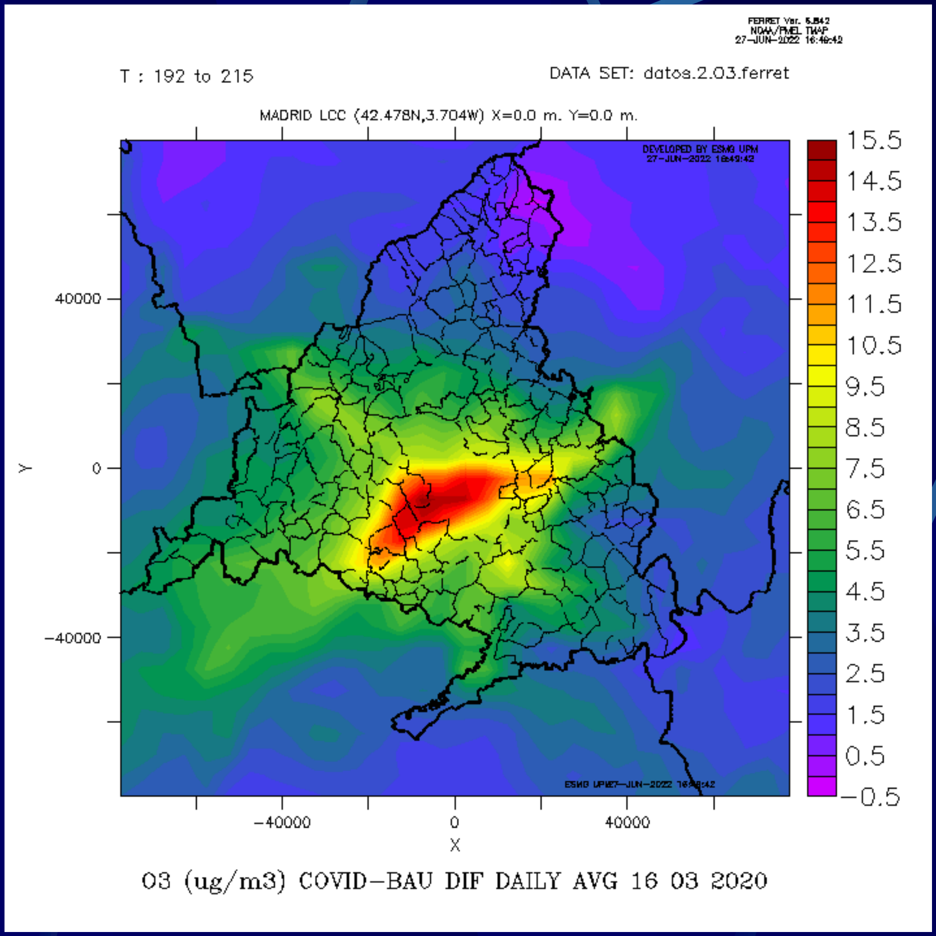
WRF/Chem



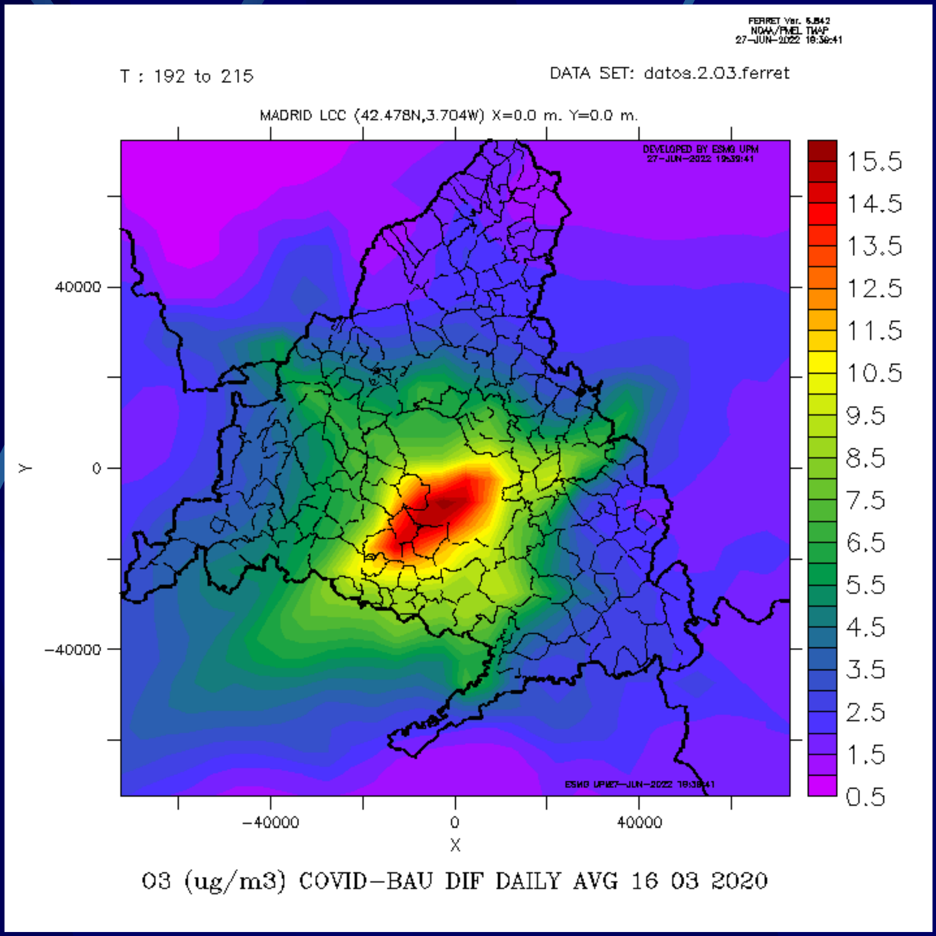
WRF-CAMx

O3 Madrid COVID-BAU 16/03/2020

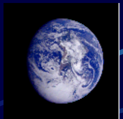
National Lockdown (Monday)



WRF/Chem

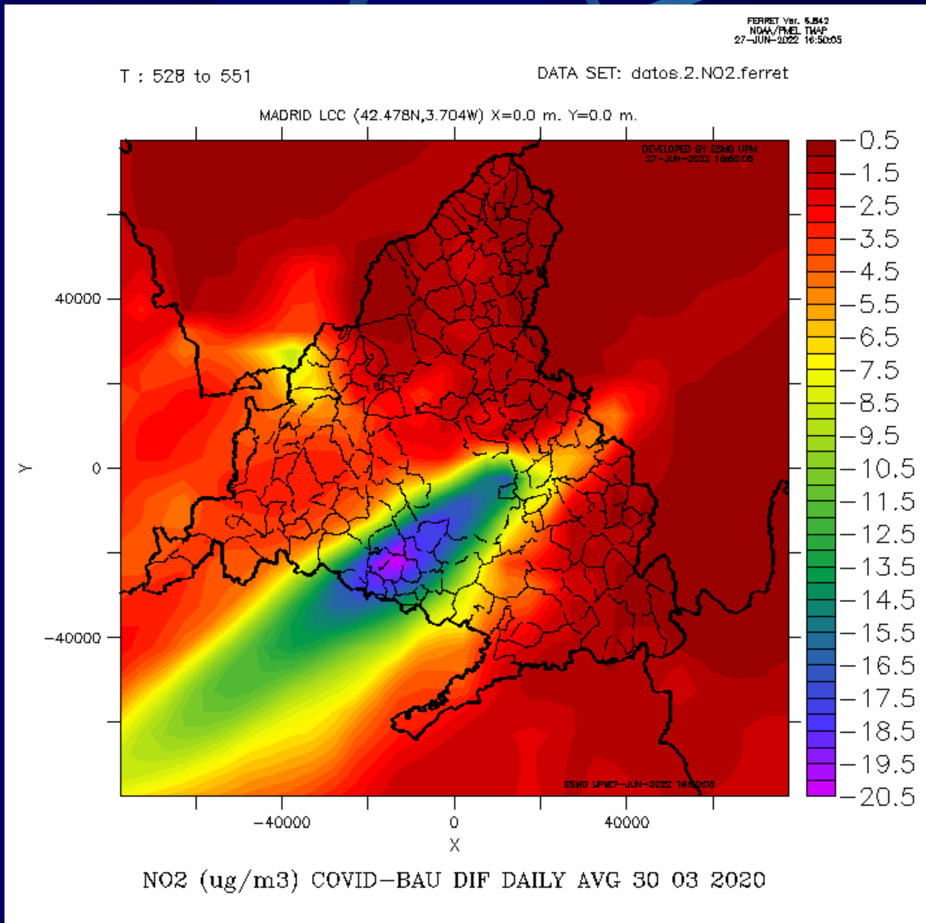


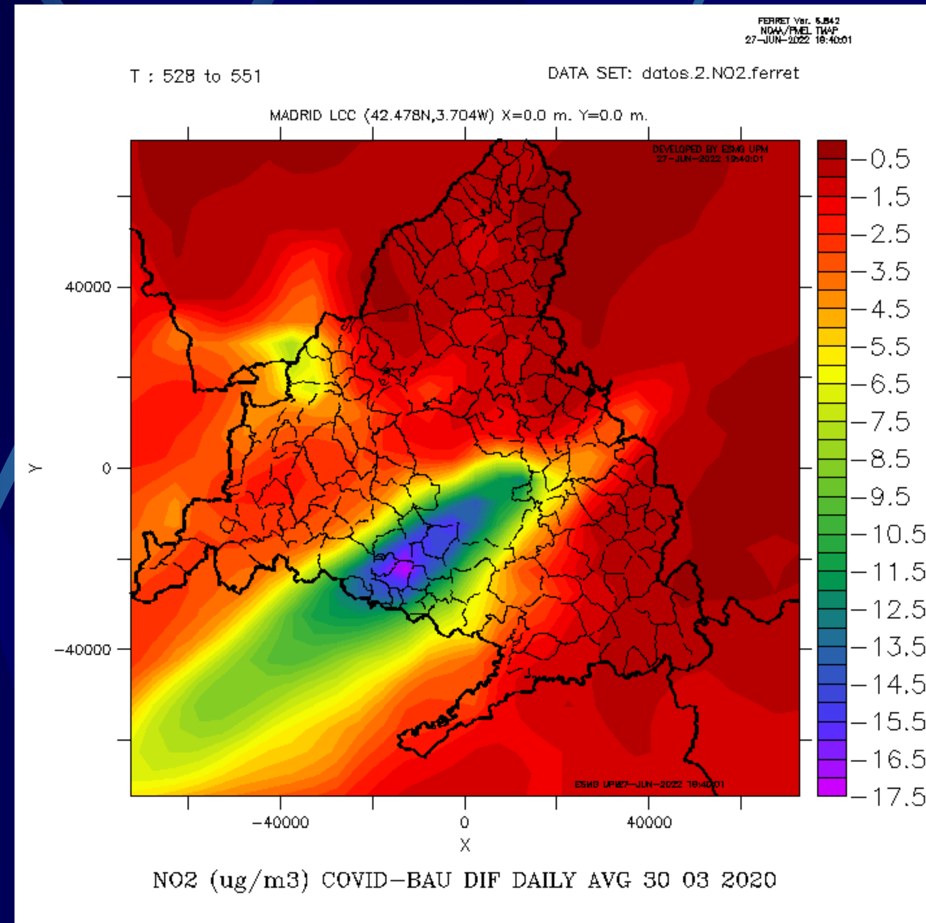
WRF-CAMx



NO2 Madrid COVID-BAU 30/03/2020

Banned all non-essential activity (Monday)

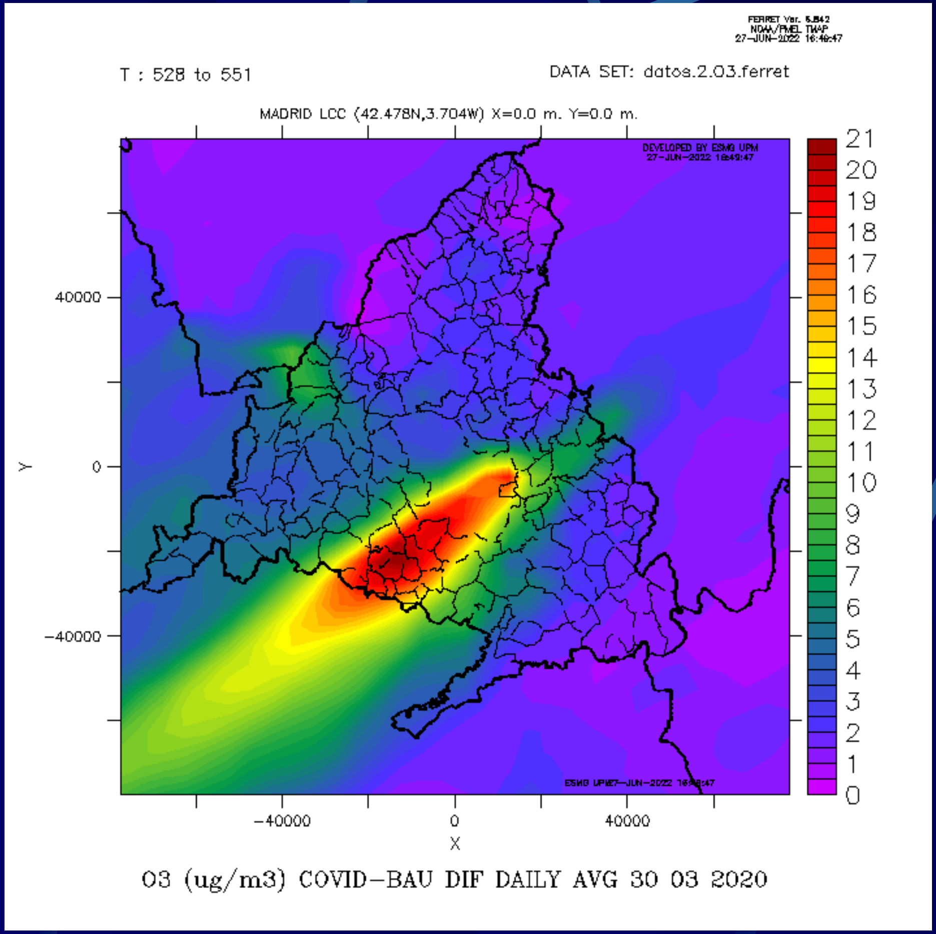




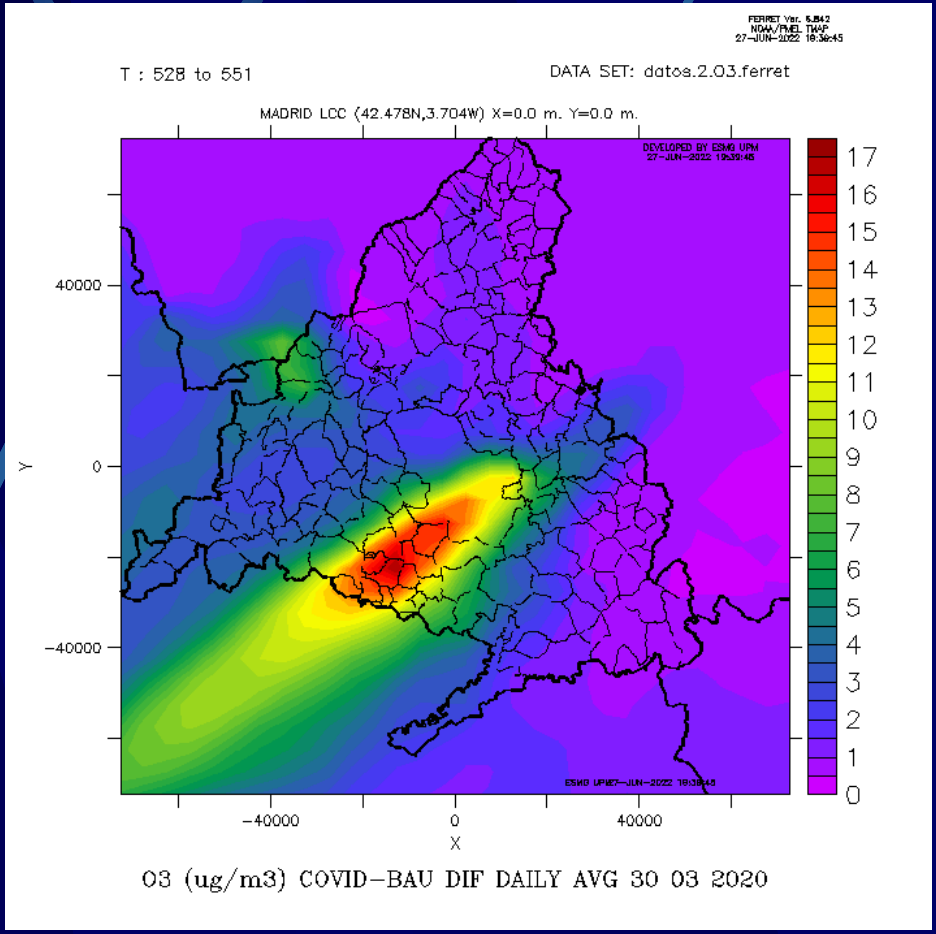
WRF/Chem **WRF-CAMx**

O3 Madrid COVID-BAU 30/03/2020

Banned all non-essential activity (Monday)



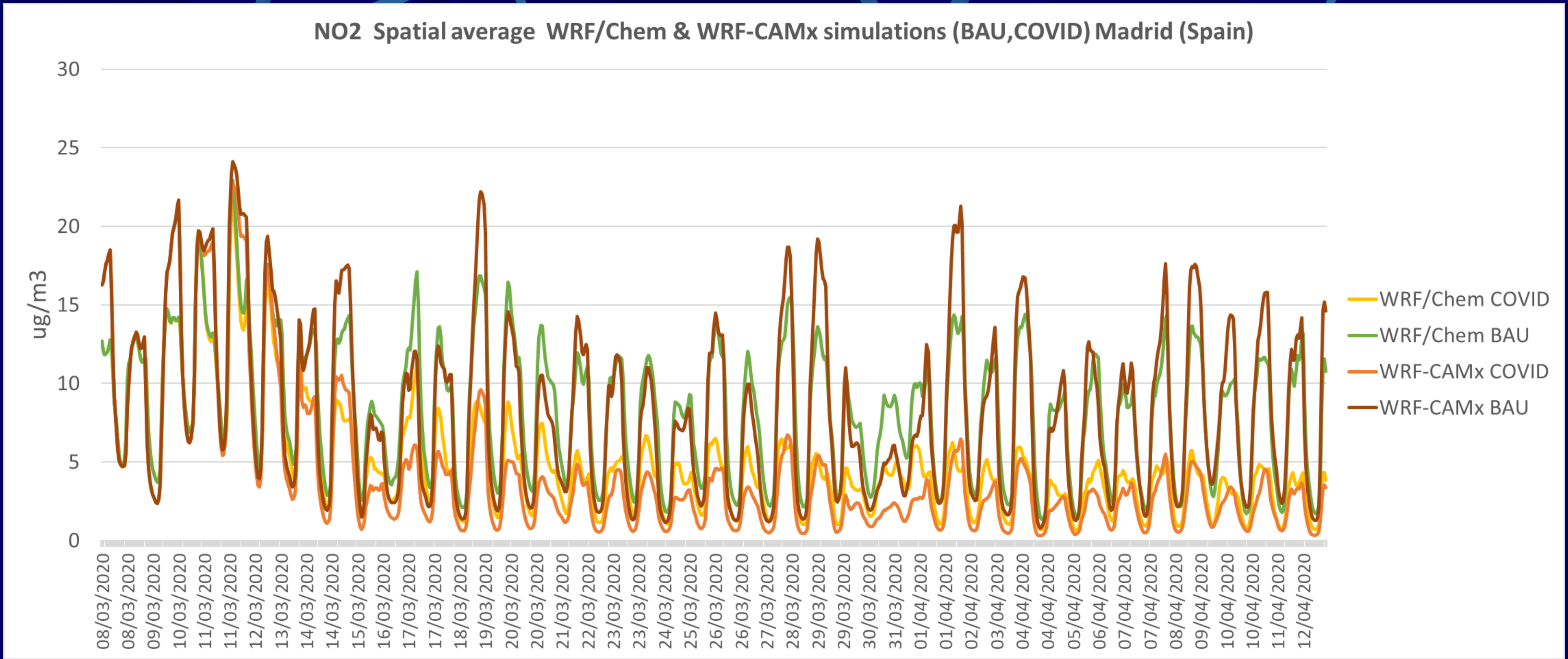
WRF/Chem



WRF-CAMx

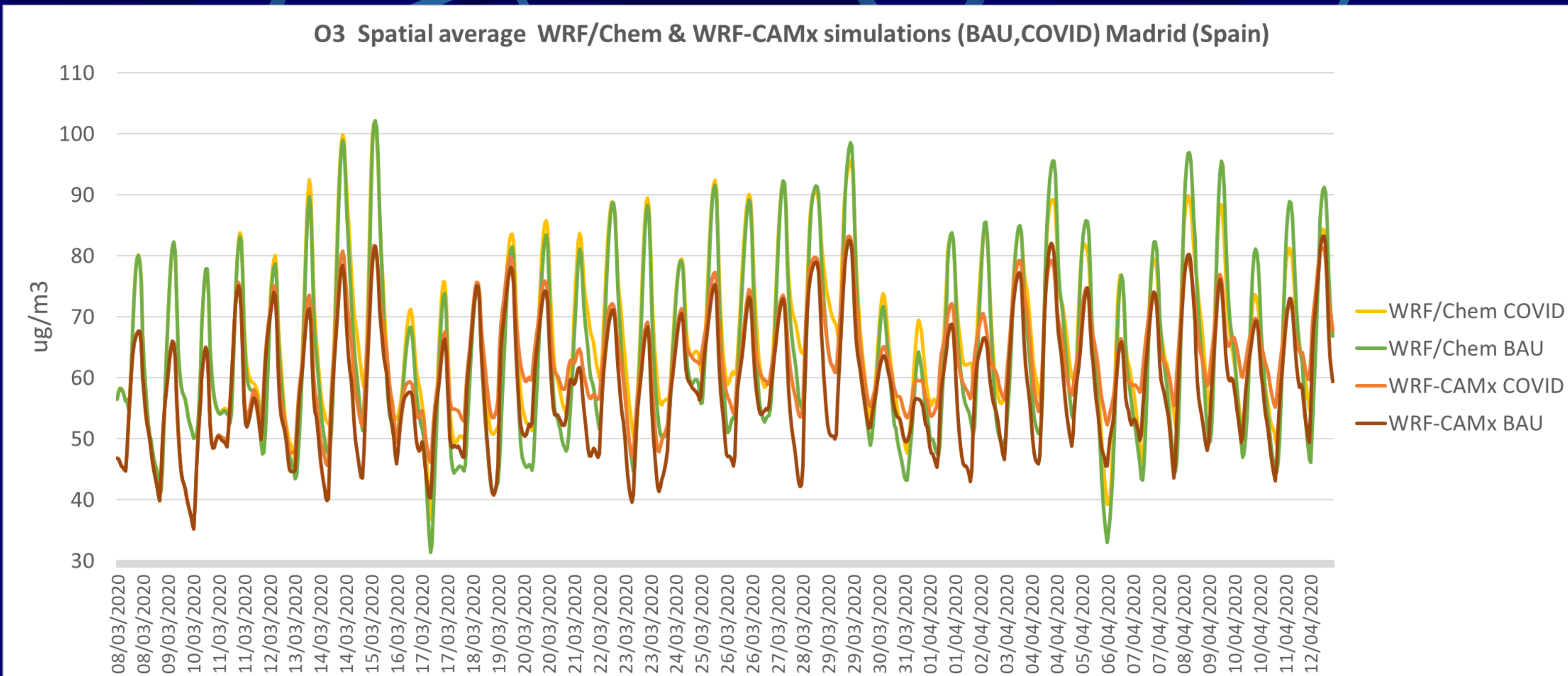
WRF/Chem & WRF-CAMx Madrid BAU & COVID

NO2 08/03-12/04 2020 Spatial average



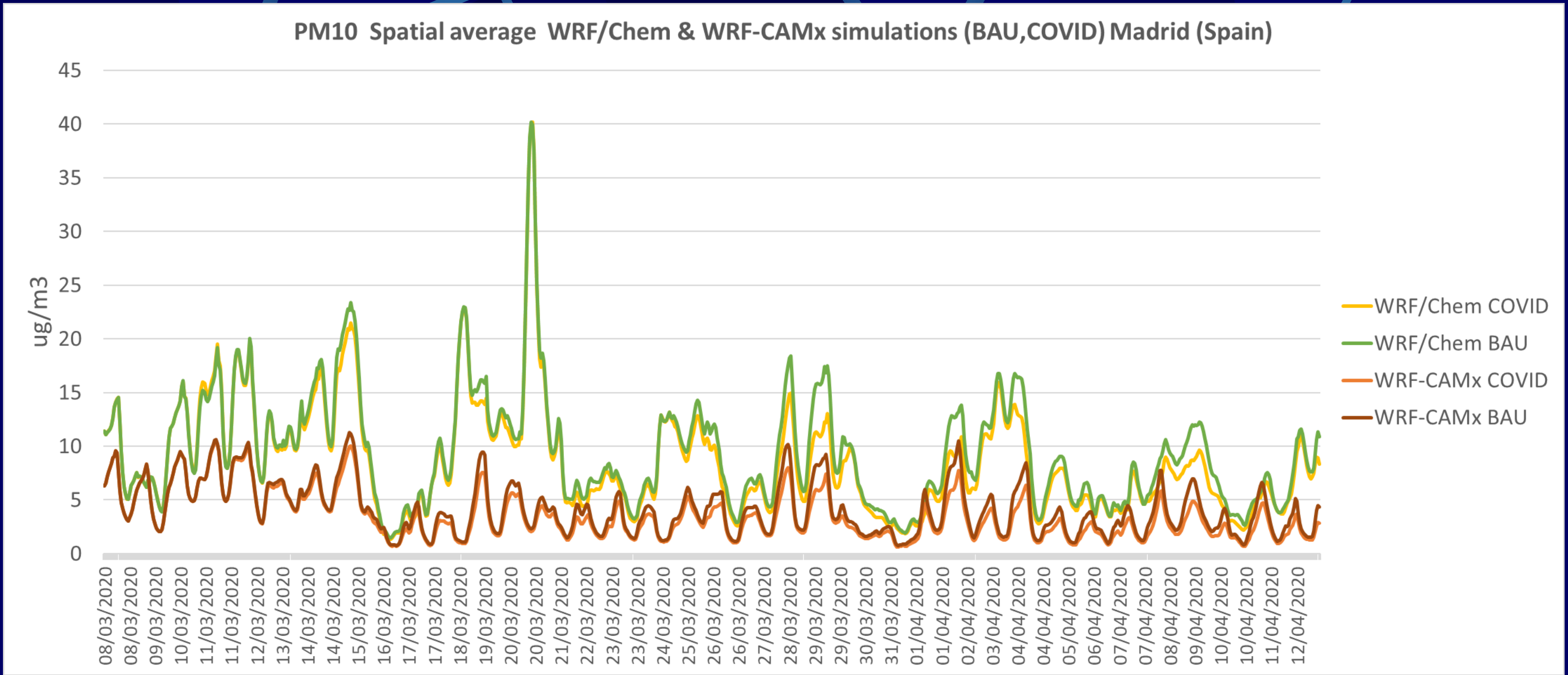
WRF/Chem & WRF-CAMx Madrid BAU & COVID

O3 08/03-12/04 2020 Spatial average



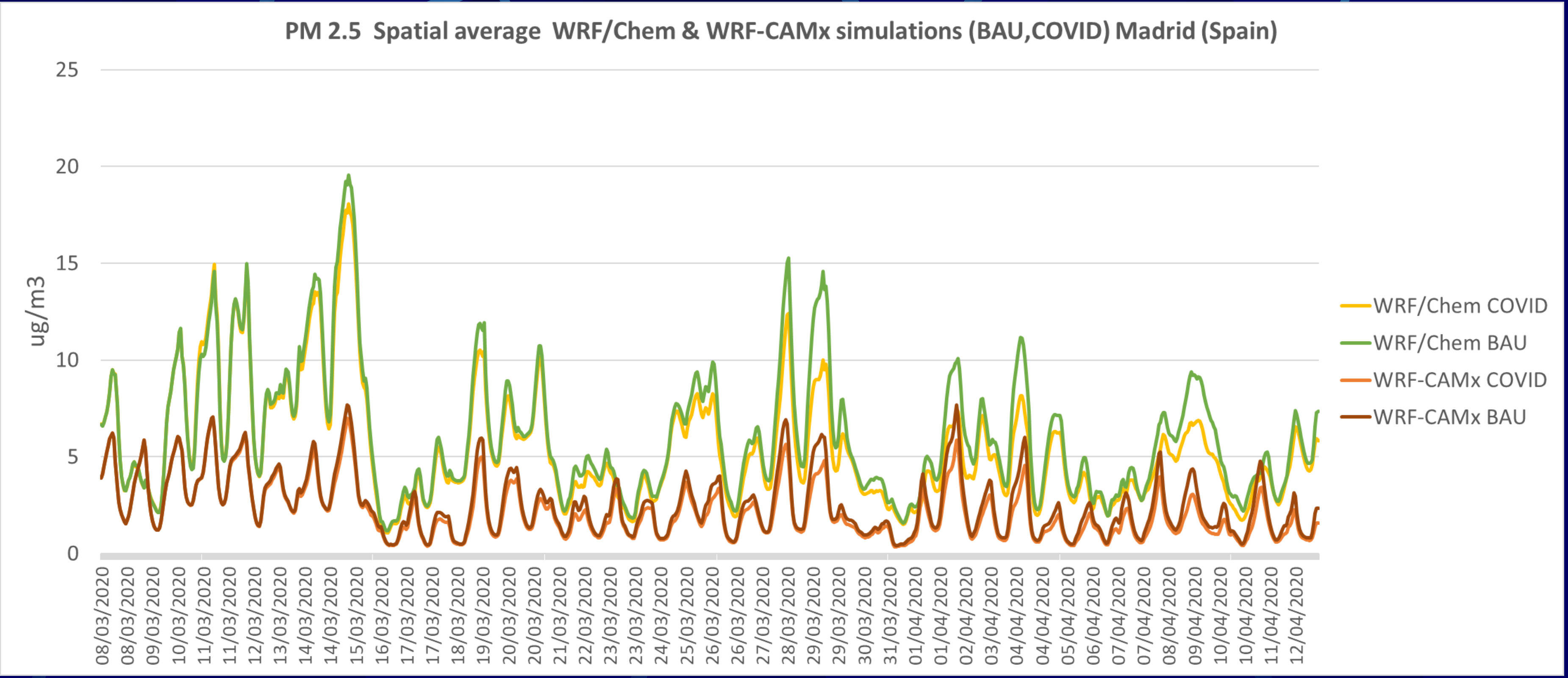
WRF/Chem & WRF-CAMx Madrid BAU & COVID

PM10 08/03-12/04 2020 Spatial average



WRF/Chem & WRF-CAMx Madrid BAU & COVID

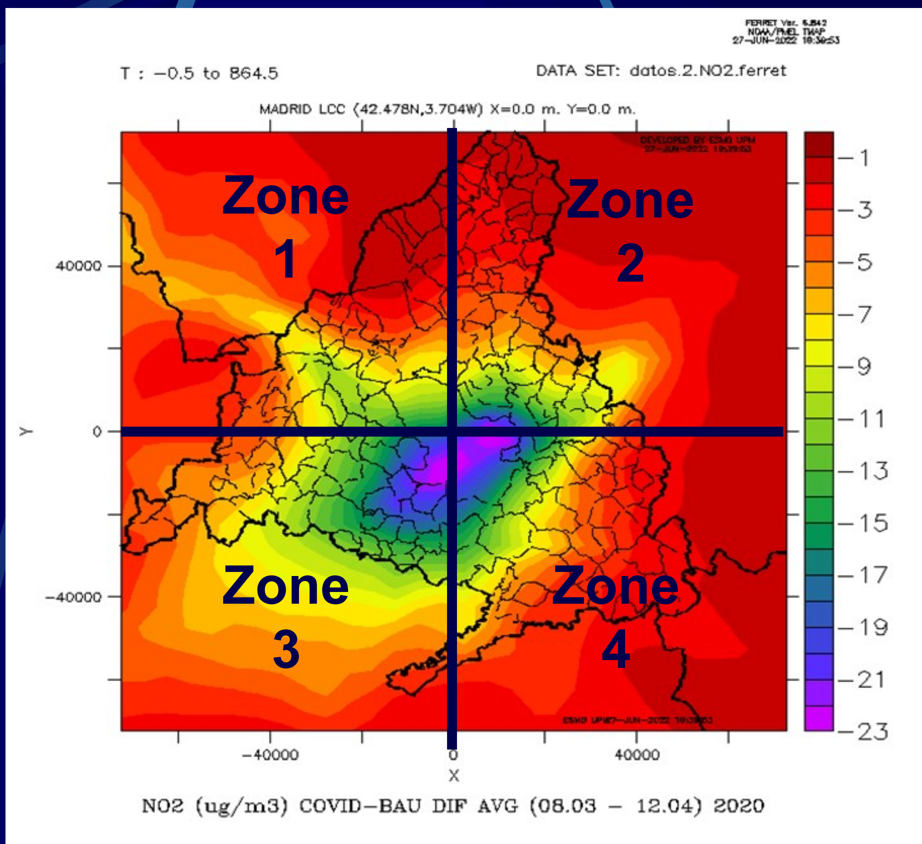
PM2.5 08/03-12/04 2020 Spatial average



CAMx OSAT & PSAT

- Source apportionment (SAT) to estimates the contributions from 4 source areas, 12 emissions categories and boundary conditions for O3 (OSAT) and PM (PMSAT)

- The methodology also estimates the fractions of ozone formed en route under VOC- or NOX-limited conditions



SECTOR	GNFR SECTOR NAME
S1	Public Power
S2	Industry
S3	Other Stationary Combustions
S4	Fugitives
S5	Solvents
S6	Road Transport
S7	Shipping
S8	Aviation
S9	OffRoad
S10	Waste
S11	AgriLivestock
S12	AgriOther

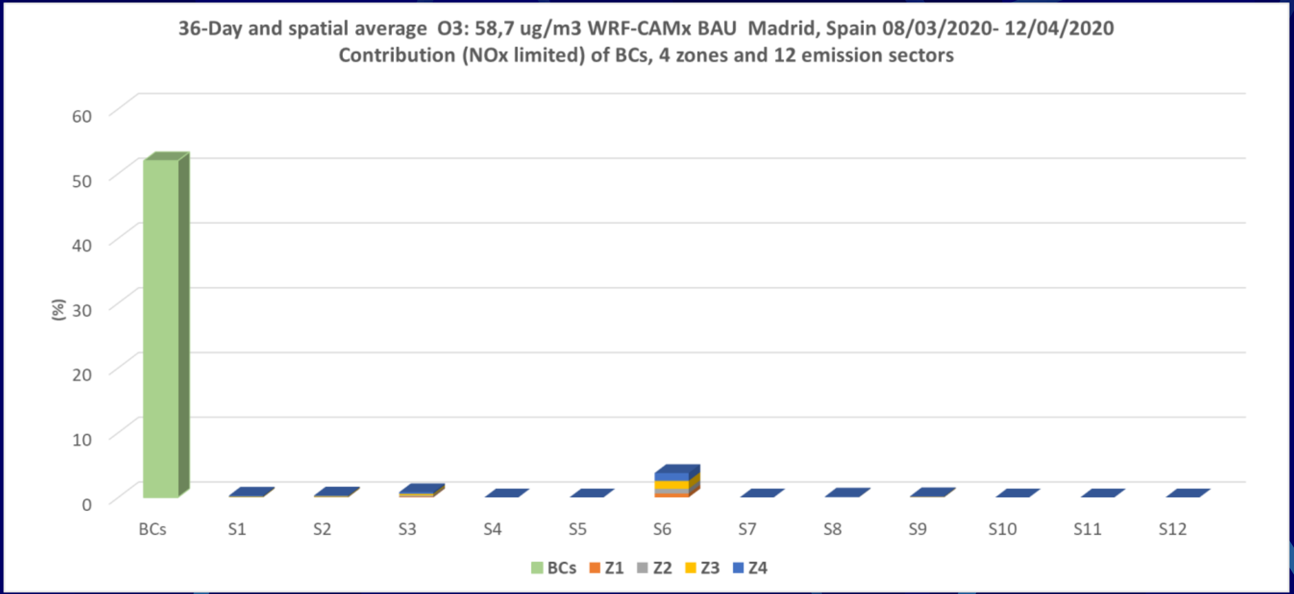
When the rate of OH production is less than the rate of production of NOx, ozone production is VOC-limited. Here, ozone is most effectively reduced by lowering VOCs. Between the NOx- and VOC-limited extremes there is a transitional region where ozone is nearly equally sensitive to each species.

When the rate of OH production is greater than the rate of production of NOx, indicating that NOx is in short supply, the rate of ozone production is NOx-limited. In this situation, ozone concentrations are most effectively reduced by lowering current and future NOx emissions, rather than lowering emissions of VOCs.

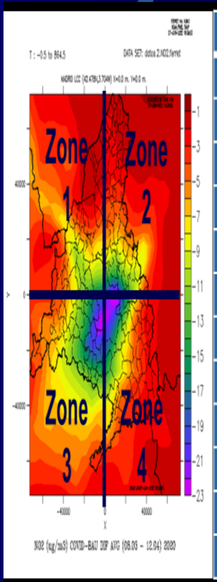
Solvents in products such as coatings, inks, and consumer products can emit substances into the air known as Volatile Organic Compounds (VOCs).

VOC emissions from solvent-based products are regulated to protect air quality.

CAMx OSAT BAU



- 50% of the O3 comes from BCs
- O3 formation is dominated by VOC limited conditions
- Solvent use is the main emission source (zone 3 and 4 south of the Madrid Community)



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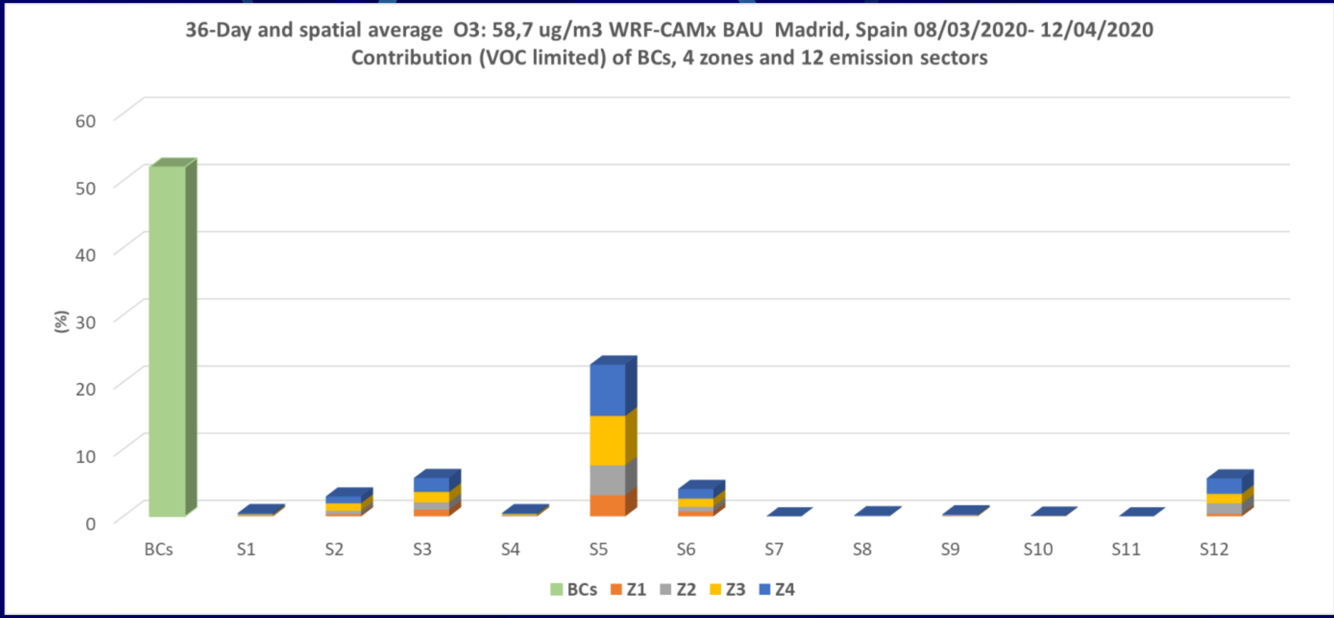
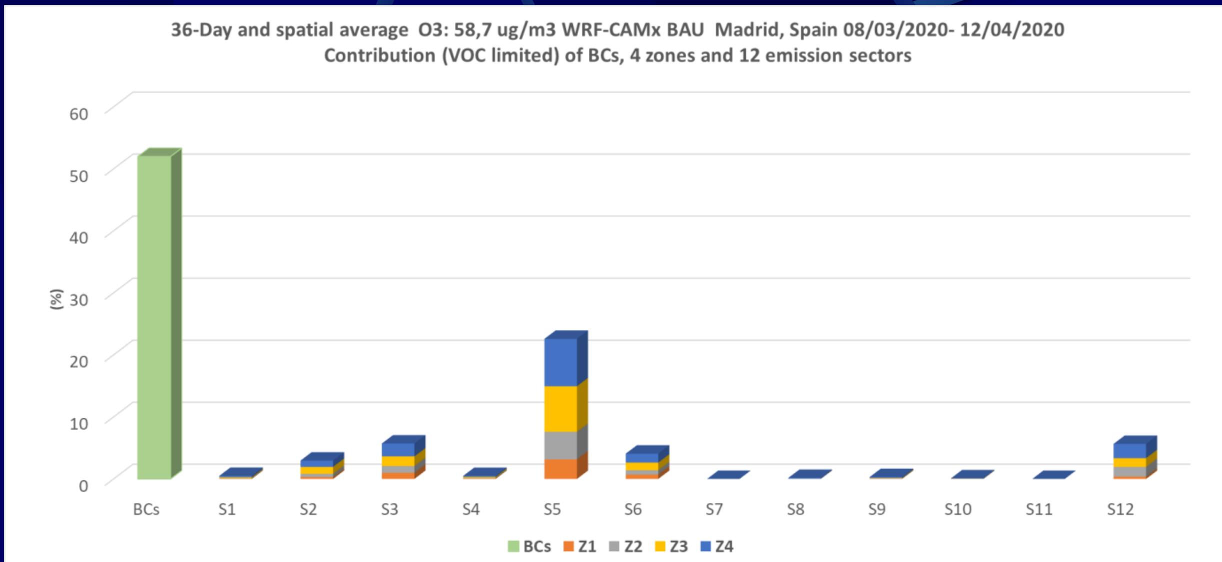
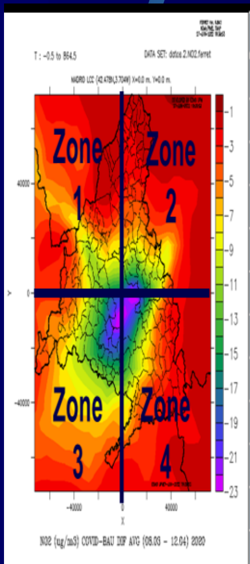


CAMx OSAT BAU vs COVID



- **Lockdown increased O3 concentrations (58->62 ug/m3)**
- **Lockdown (COVID simulation) reduce the contribution of road transport but increase the contribution of solvents under VOC limited conditions**



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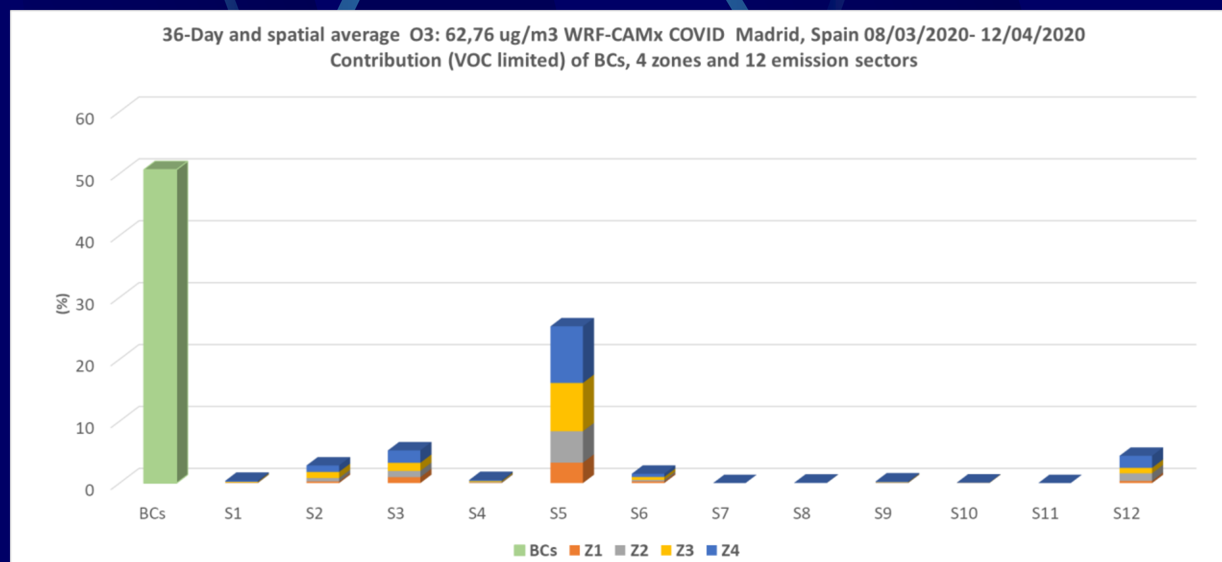
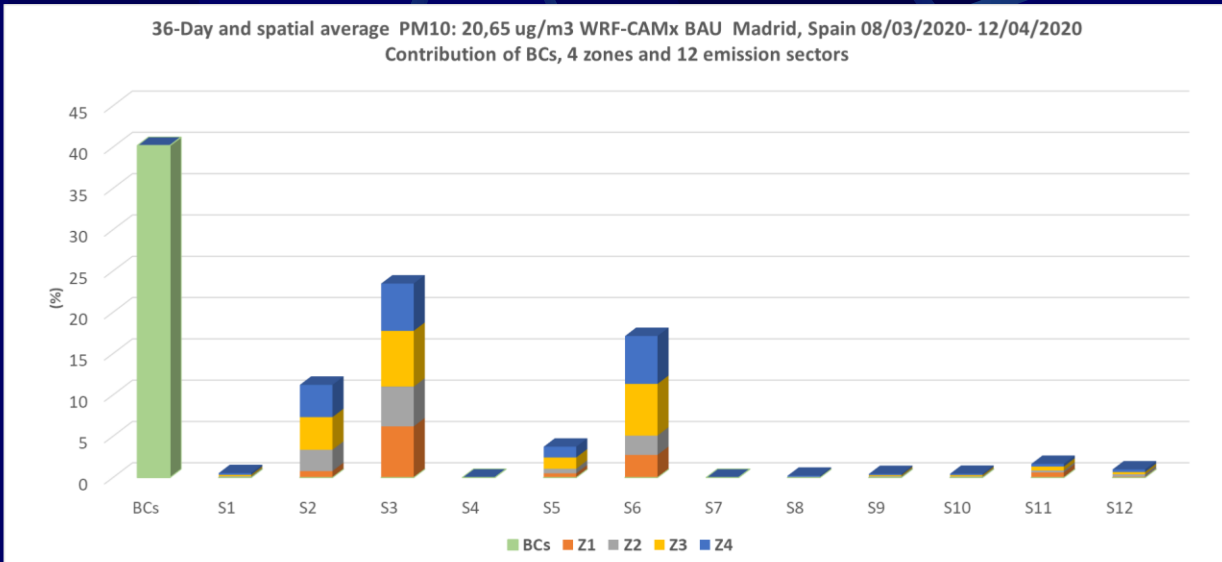
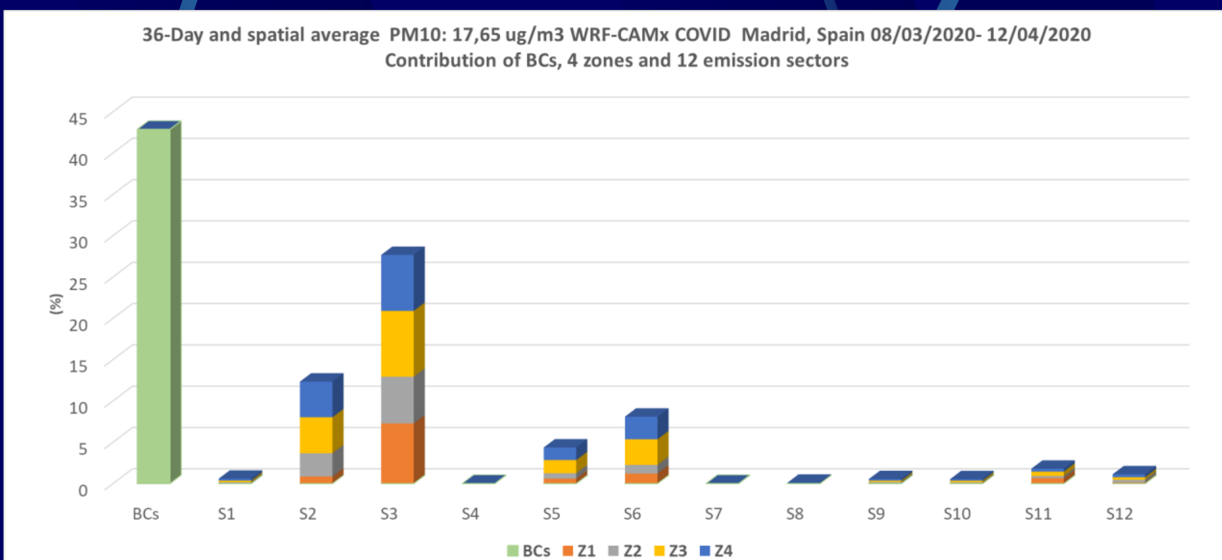
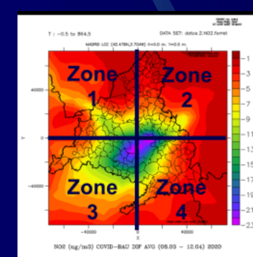


CAMx PSAT BAU vs COVID





- 40% of the PM10 comes from BCs
- Lockdown decreased PM10 concentrations (21->18 ug/m3)
- Lockdown (COVID simulation) reduce the contribution of road transport (15%->7%) and small increments of S2 and S3 sources.



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S4	Fugitives
S5	Solvents
S6	Road Transport
S7	Shipping
S8	Aviation
S9	OffRoad
S10	Waste
S11	AgriLivestock
S12	AgriOther

CONCLUSIONS (I)

- The impact of COVID lockdown on Madrid Community (Spain) air quality is estimated by running two simulations, one simulation considers the emission reductions during the lockdown (COVID simulation) and a second simulation, ”business as usual” (BAU simulation) with an emissions scenario without restrictions with two air quality models: WRF/Chem and WRF-CAMx

- Simulated results for the lockdown period, using the adjusted emission inventory agree better with surface observations than the pre-lockdown period, where the BAU emission inventory is applied.

- In general, the performance results show that the simulations capture the magnitude and temporal evolution of the four key air pollutants reasonably well, with the statistical indicators within the expected ranges.

- WRF/Chem underestimates O3 concentrations (-14%) and WRF-CAMx gets better results (+3%) with a small overestimation. WRF/Chem overestimates PM concentrations and WRF-CAMx underestimates them. WRF/Chem gets better correlation coefficients than WRF-CAMx.

CONCLUSIONS (II)

- The spatial distribution of the impacts of the lockdown are similar in WRF/Chem and WRF-CAMx. WRF-CAMx produces higher impacts than WRF/Chem.

- BAU-COVID results reflect an important reductions in NOx concentrations and important ozone increases. These increases are higher in WRF/Chem than in WRF-CAMx.

- Boundary conditions are the main source of the air pollution concentration (40-50%).

- The O3 formation is dominated by VOC limited situation. This produces increases of O3 during the lockdown period (NOx reduction). The O3 is more offectively reduced by reducing VOC's.

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