Supporting the EU air quality directive over Cyprus through modelling and the FAIRMODE benchmarking methodology

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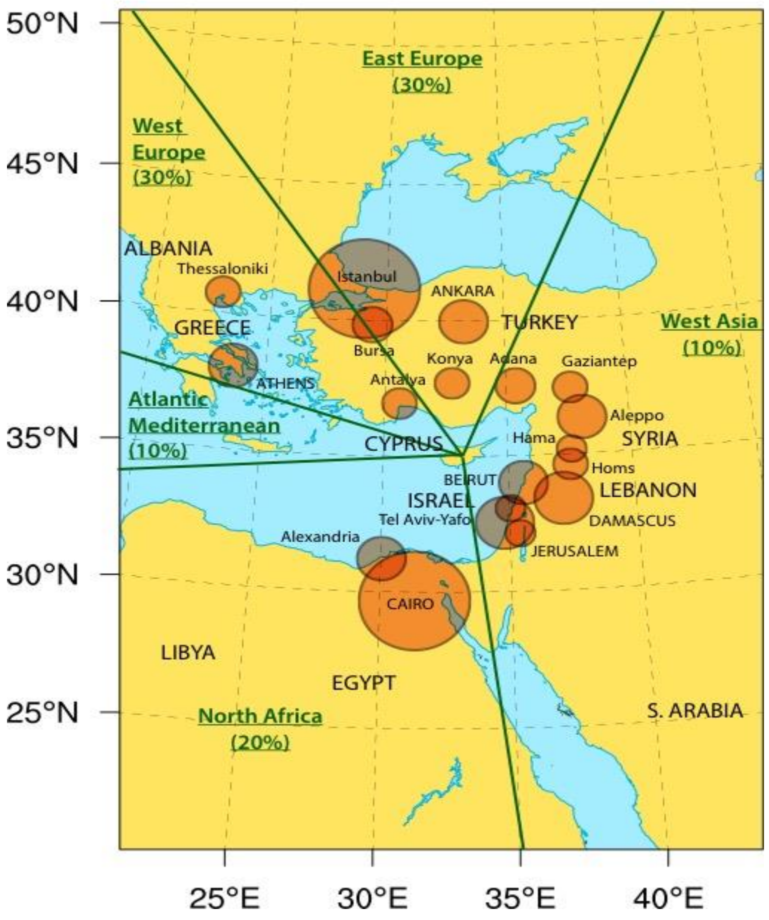
Motivation

Cyprus: A remote island in Eastern Mediterranean at the crossroad of pollution from 3 continents

Limited spatial extend, no land borders, affected by long range transport of pollution from Europe, upwind megacities, intercontinental pollution

An EU member state neighbouring with non-EU members (not regulated activities/emissions) affected by geo-politico-financial factors

High background pollution – multiple natural sources – two of which for mineral dust with changing patterns (due to climate and conflict)



Methods: Measurements

West to east gradient with west stations capturing the transported pollution and the east stations summing up transported and locally produced pollution

Residential stations located within main cities – only one accompanied by a nearby background station (center of the island)

One station at 1700 m altitude ideal for LRT patterns and above boundary layer

Monitoring of NOx and O_3 (all), SO_2 and CO (all urban, only one background), selective PMs in traffic stations

Challenge

Models that exhibit a satisfactory performance can be used to complement observations or even replace them in cases of disoperation, for policy related applications and reporting purposes.

Comparison with observations is a standard procedure to assess the performance of models

A harmonization on the criteria that deem a model successful in reproducing air quality features over a specific region is a necessity when such models are used for reporting national air pollution levels for official purposes and compliance with regulations.

Criteria are defined in order to compare statistical indicators against bound values and hence, benchmark the model application against agreed and/or regulated quality standards.

In the framework of the Forum for Air Quality Modelling in Europe (FAIRMODE) activities, a methodology for unified model evaluation process has been developed to support model application under the European Air Quality Directives.

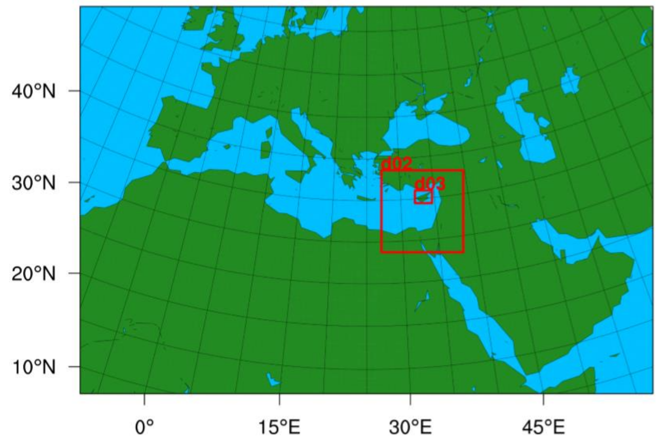
Modelling tools

WRF-CHEM v3.9.1.1

Emissions from JRC EDGAR-HTAP v2 emission estimates for 2010 at a resolution of 0.1 º × 0.1 º, with no further changes to incorporate possible trends that may have occurred in the recent years in the region.

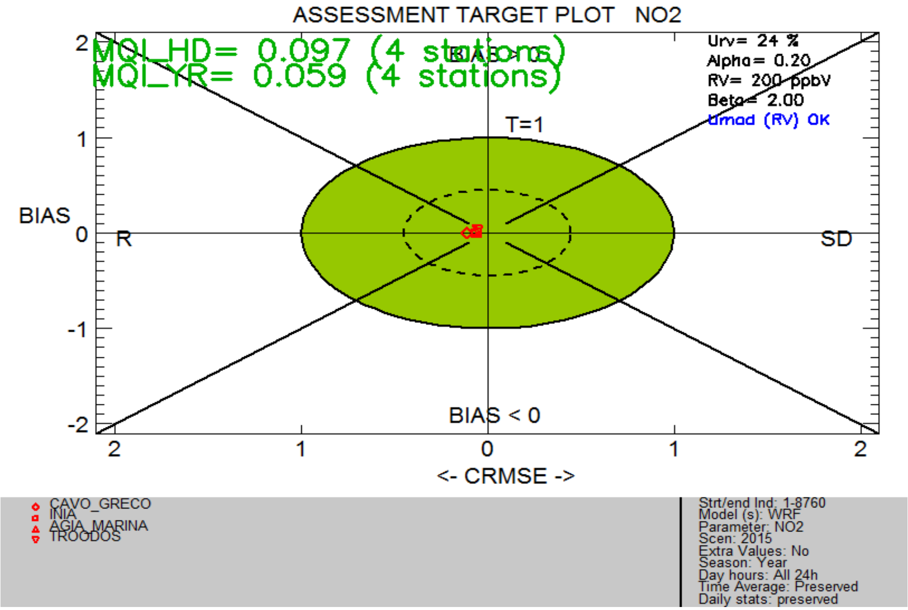
ICBCs for meteorology: National Centres for Environmental Prediction (NCEP) global forecast system (GFS) 6h 0.5 º × 0.5 º horizontal resolution ICBCs for chemical species: global Model for Ozone And Related chemical Tracers (MOZART version 4)

Kushta et al., 2019: Evaluation of EU air quality standards through modeling and the FAIRMODE benchmarking methodology, DOI: 10.1007/s11869-018-0631-z



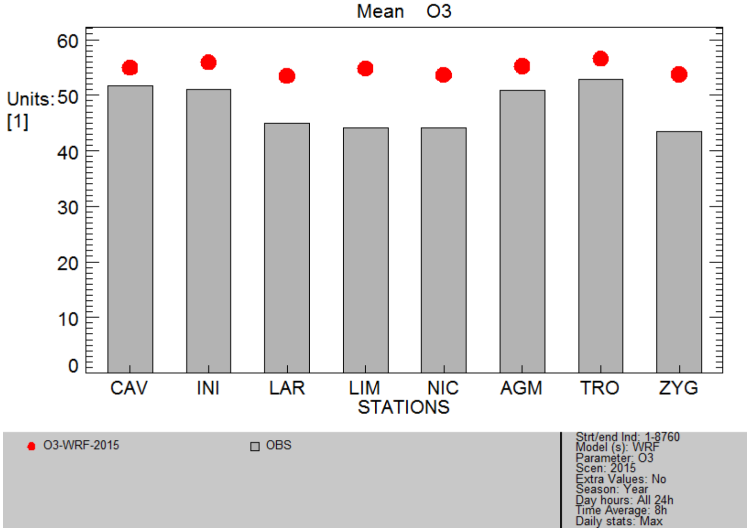
PROCESS	OPTION	Reference
Microphysics	Morrison 2-moment scheme	Morrison et al., 2015
Land-Surface	NOAH Land surface model	Chen and Dudhia, 2001
Boundary Layer	Yonsei University (YSU) Planetary Boundary Layer	Hong et al., 2006
Cumulus	Grell 3D Ensemble Scheme	Grell and Dévényi, 2002
Surface Layer	MM5 Similarity surface layer scheme	Zhang and Anthes, 1982
Radiation	Rapid Radiative Transfer Model (RRTTM)	Iacono et al., 2008
Gas Phase Chemistry	RACM regional atmospheric chemistry mechanism	Stockwell et al., 1997
Aerosols	Modal Aerosol Dynamics Model for Europe (MADE), Secondary Organic Aerosol Model (SORGAM)	Ackermann et al., 1998 Schell et al., 2001

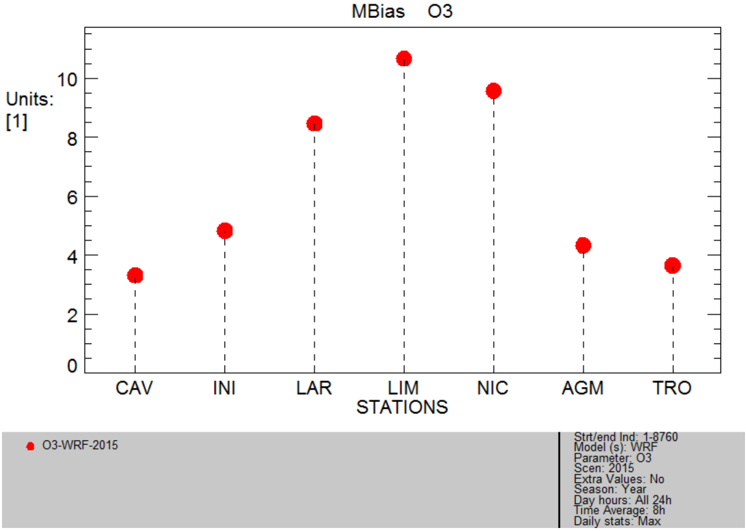
FAIRMODE evaluation methodology

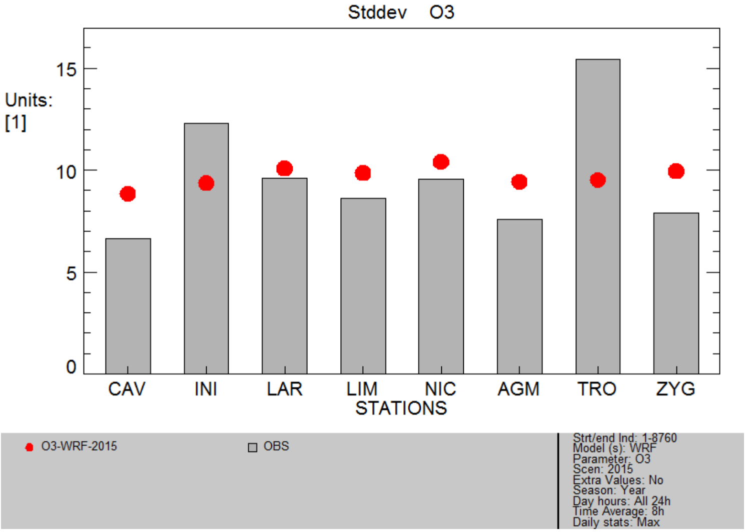


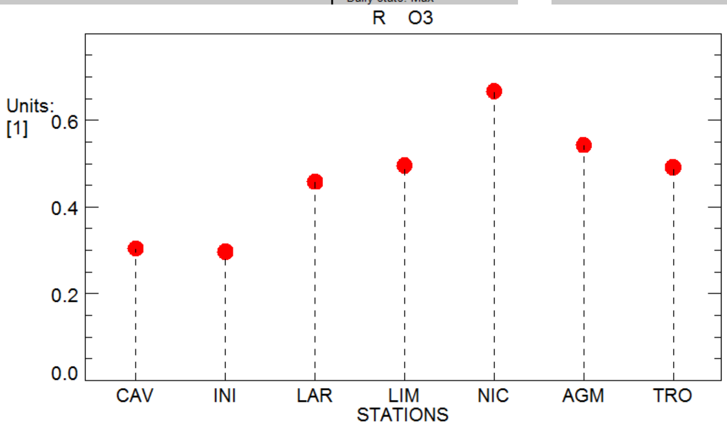
The x-axis represent the Central Root Mean Square error (CRMSE); the y-axis refers to BIAS, normalised by ObsU.
Each station is a dot on the target diagram; distance from the centre of the diagram represents the MQO for that station.
The top (bottom) two zones exhibit positive (negative) bias while the assignment of the station on the left (right) zone of the graph indicates a unsystematic (systematic) RMSE ratio (error dominated by SD or by R).

Ozone





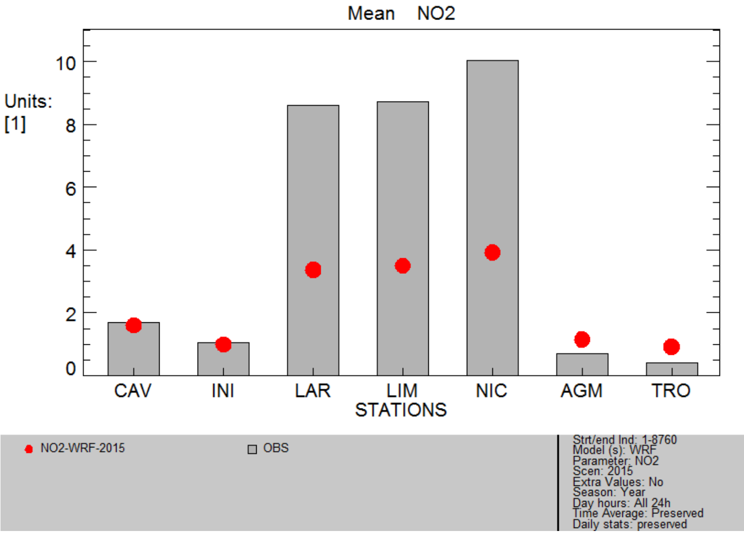


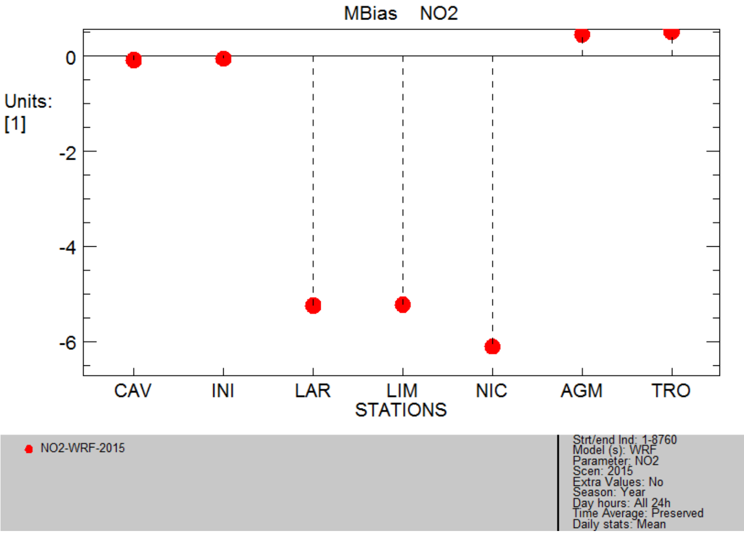


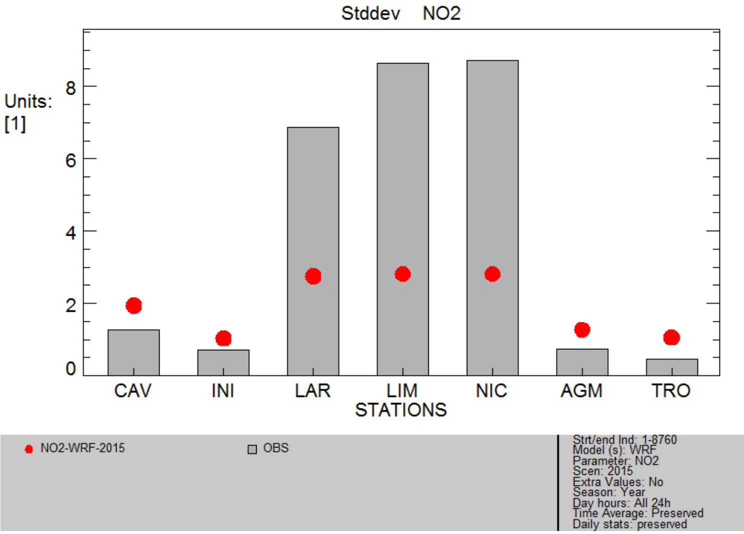
Bar plots of 8-h max ozone mean, standard deviation, mean bias and correlation coefficient for the four background stations, three residential (Larnaca, Limassol and Nicosia) and one industrial site (Zygi) from Kushta et al., 2019.

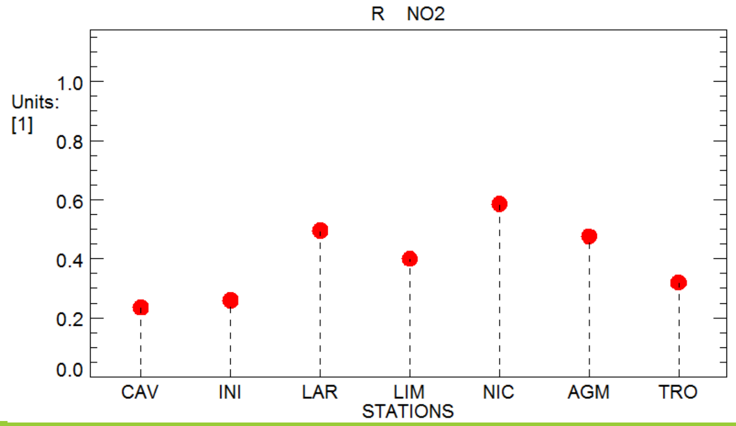
Kushta et al., 2019: Evaluation of EU air quality standards through modeling and the FAIRMODE benchmarking methodology

Nitrogen Dioxide









Bar plots of NO_2 hourly mean, standard deviation, mean bias and correlation coefficient for the four background stations, three residential (Larnaca, Limassol and Nicosia) and one industrial site (Zygi) from Kushta et al., 2019.

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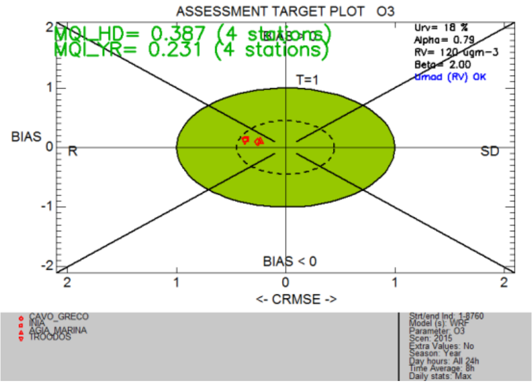
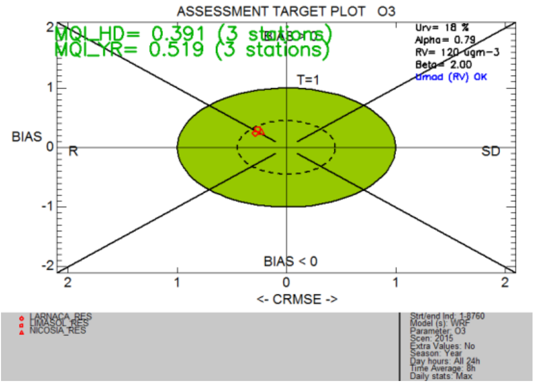
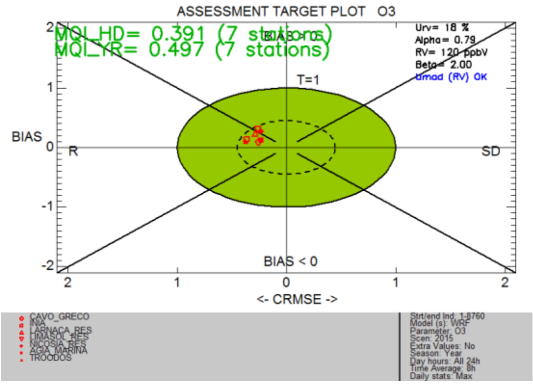
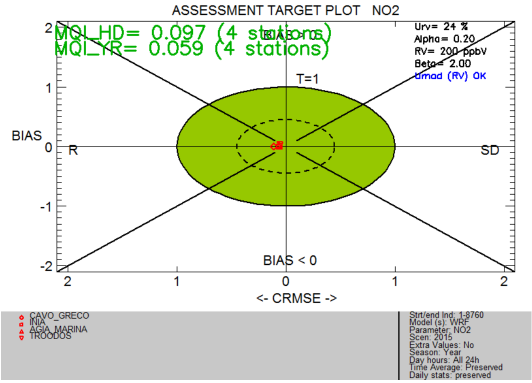
Target plots

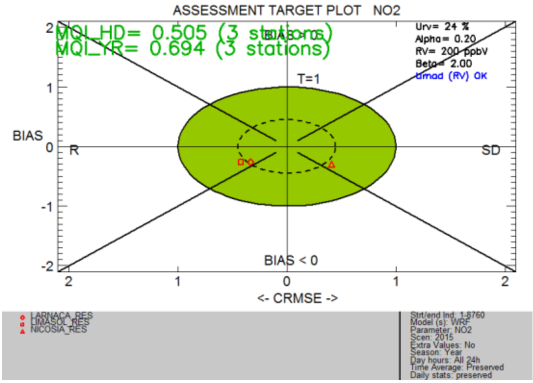


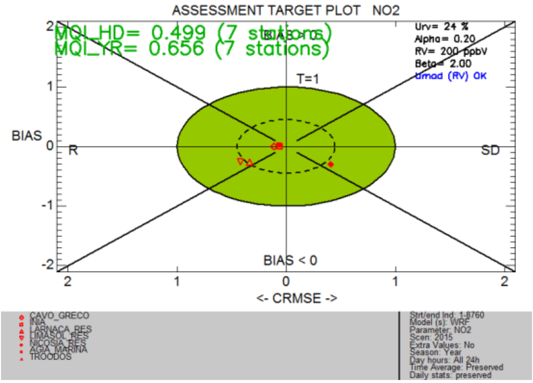




O_3







NO_2

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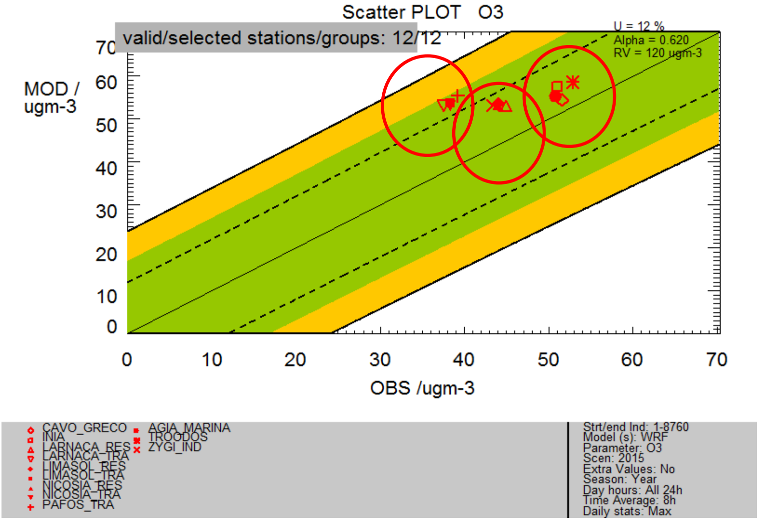
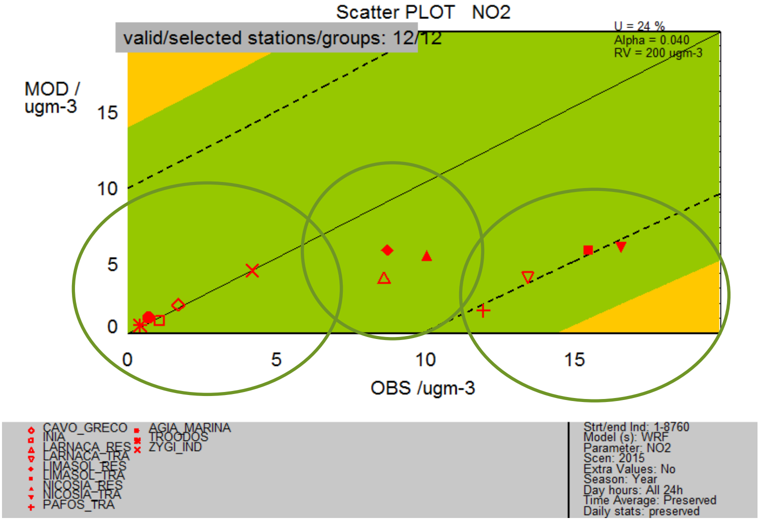
Scatter plots

O_3

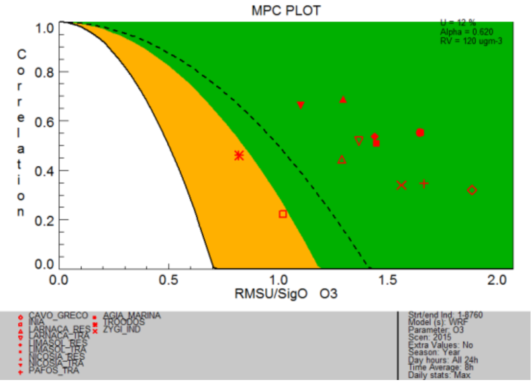


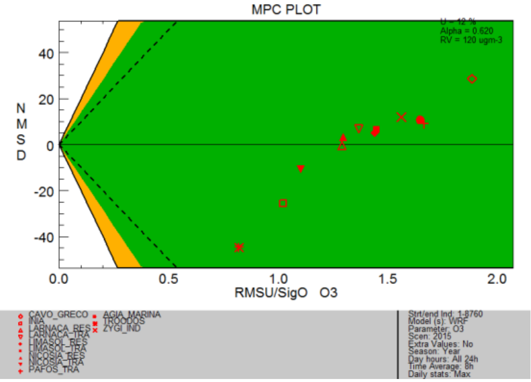
NO_2



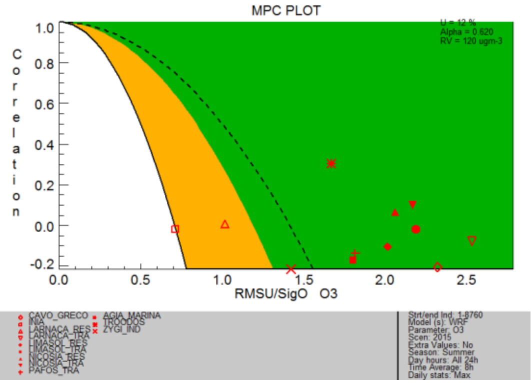
Seasonal/diurnal behaviour

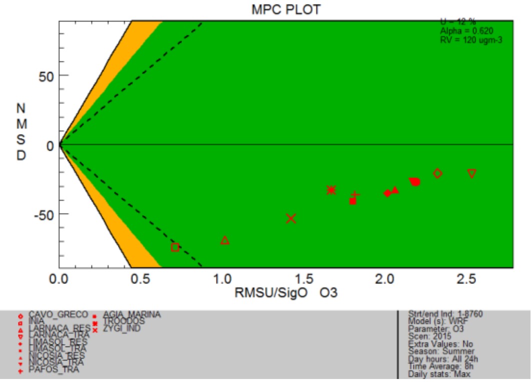
All year (O_3)



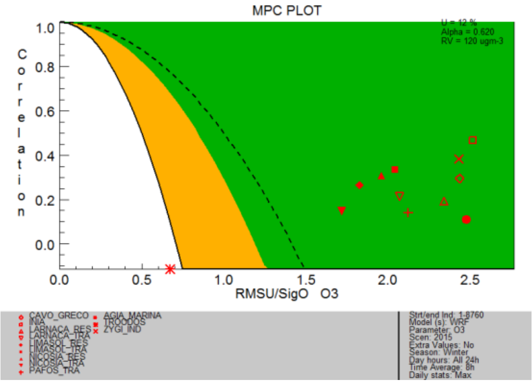


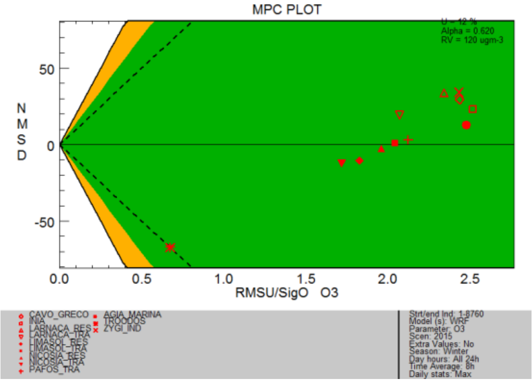
Summer



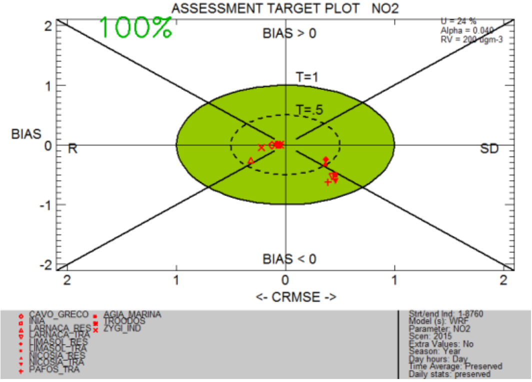


Winter

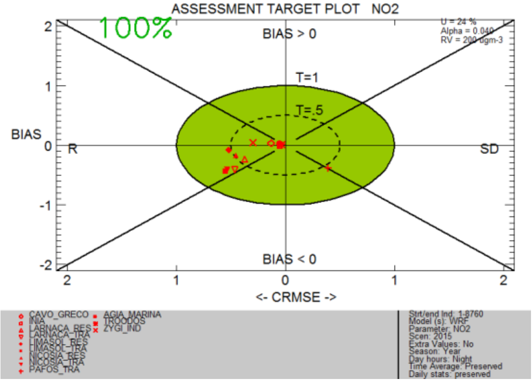




Day (NO_2)



Night



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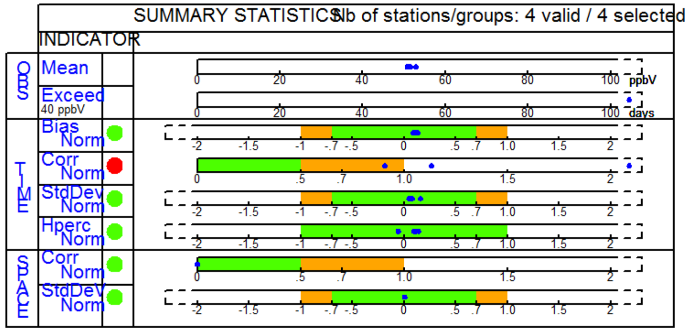
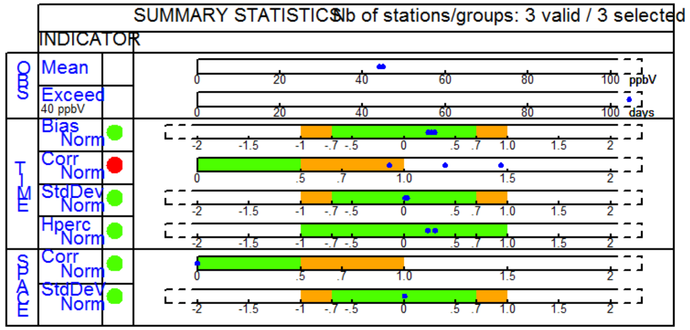
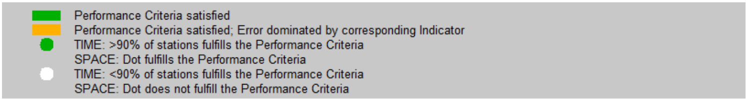
Threshold analysis

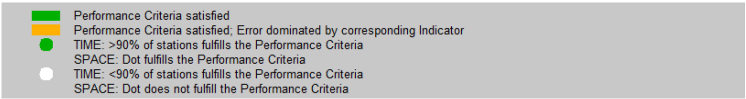


40 ppbV

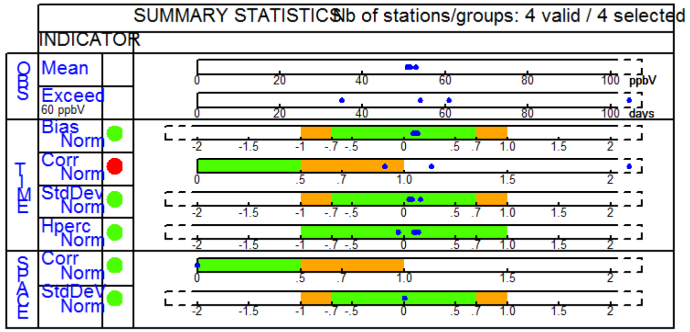


Rural

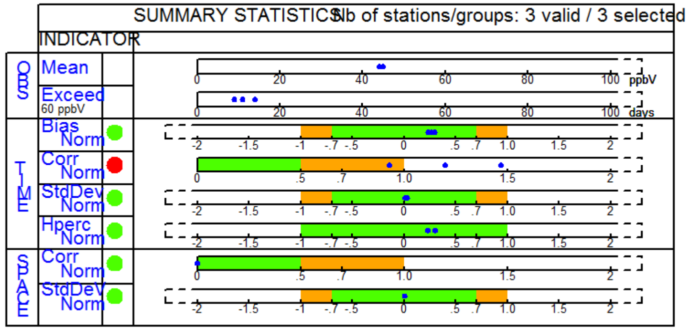




Urban



60 ppbV



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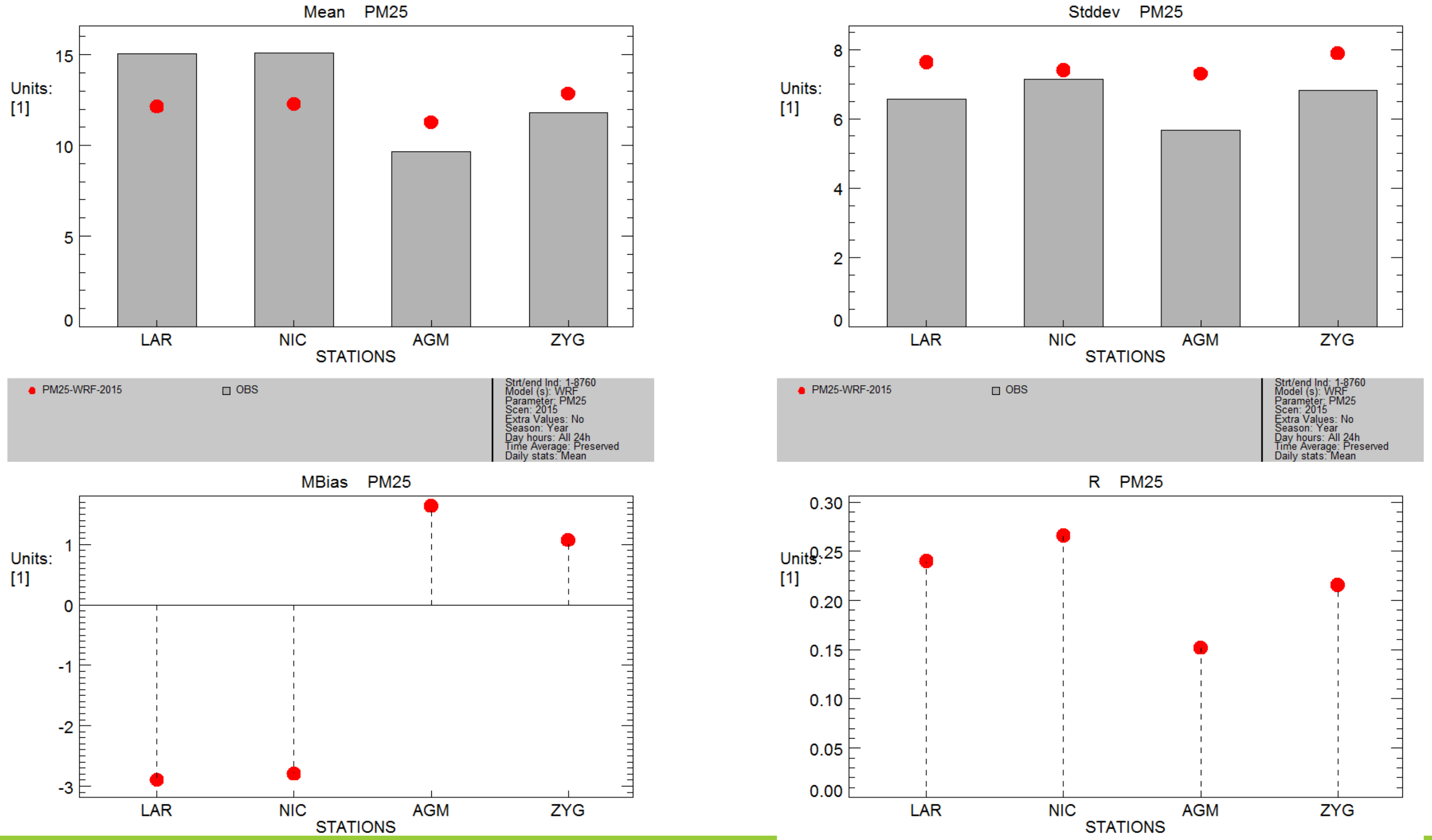
Fine Particulate Matter



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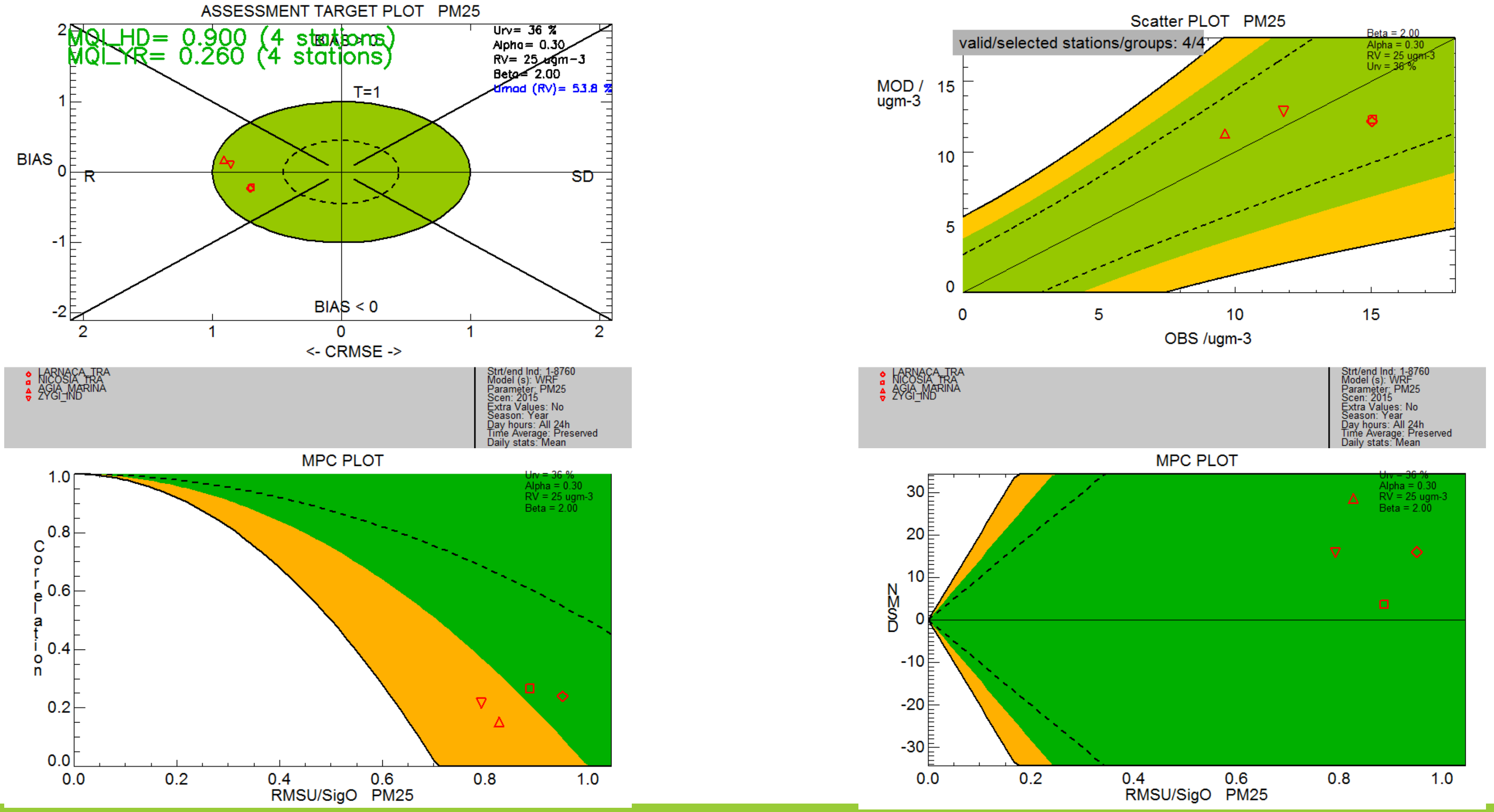
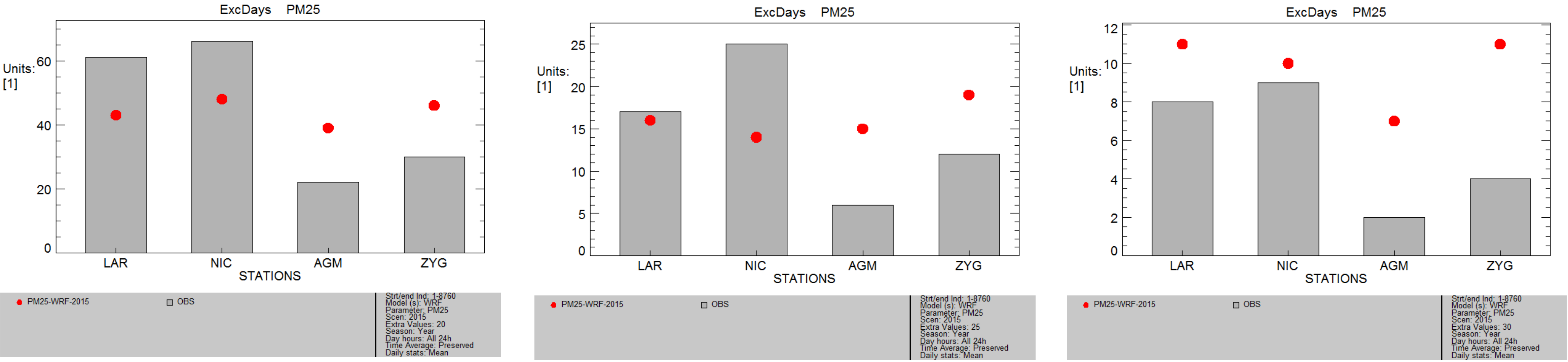
Fine Particulate Matter (cnt'd)



Threshold analysis $PM_{2.5}$



Threshold exceedance plot for 20 µg m^{-3} (middle 25 µg m^{-3} and right 30 µg m^{-3}) for mean daily $PM_{2.5}$ concentrations for two urban stations (Nicosia and Larnaca), one background station (Agia Marina) and one industrial (Zygi).

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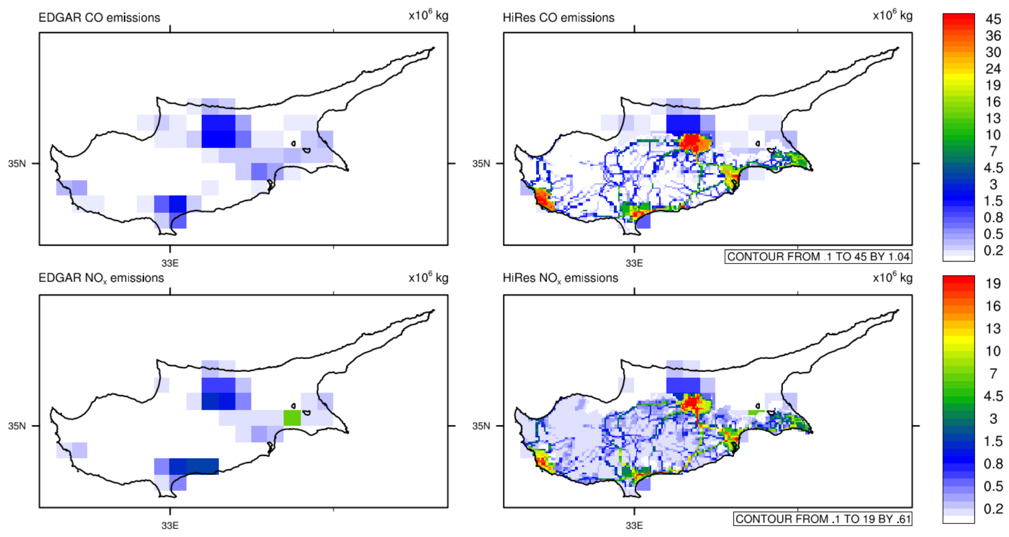
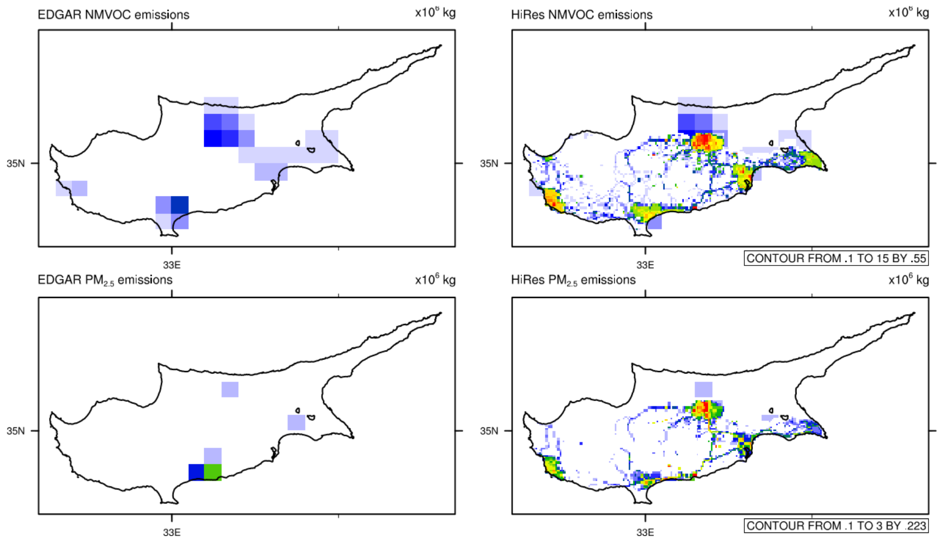
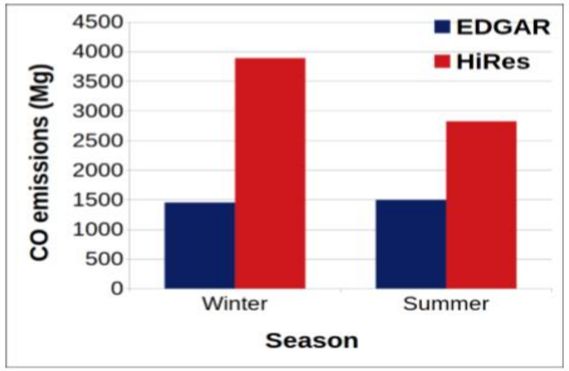
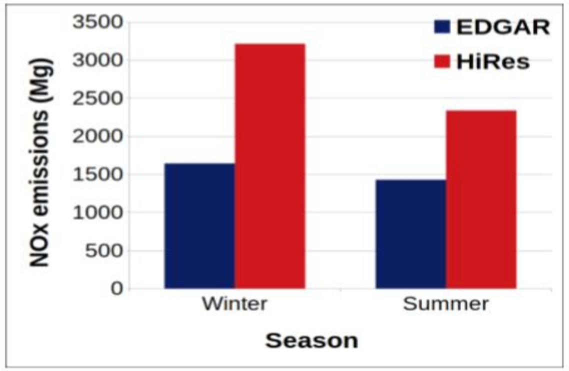
Preliminary results on high resolution emissions and their significance

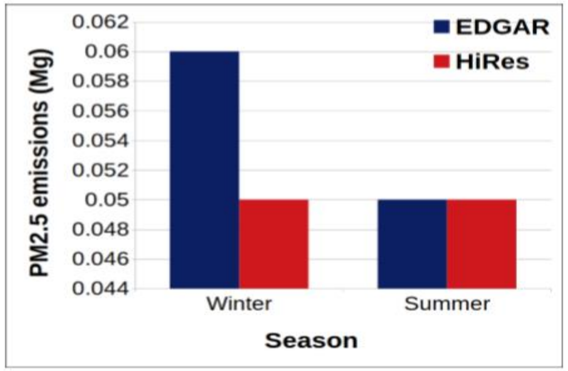
With the support of and collaboration with air quality officers at the Department of Labour Inspection, Ministry of Labour, Welfare and Social Insurance, Republic of Cyprus





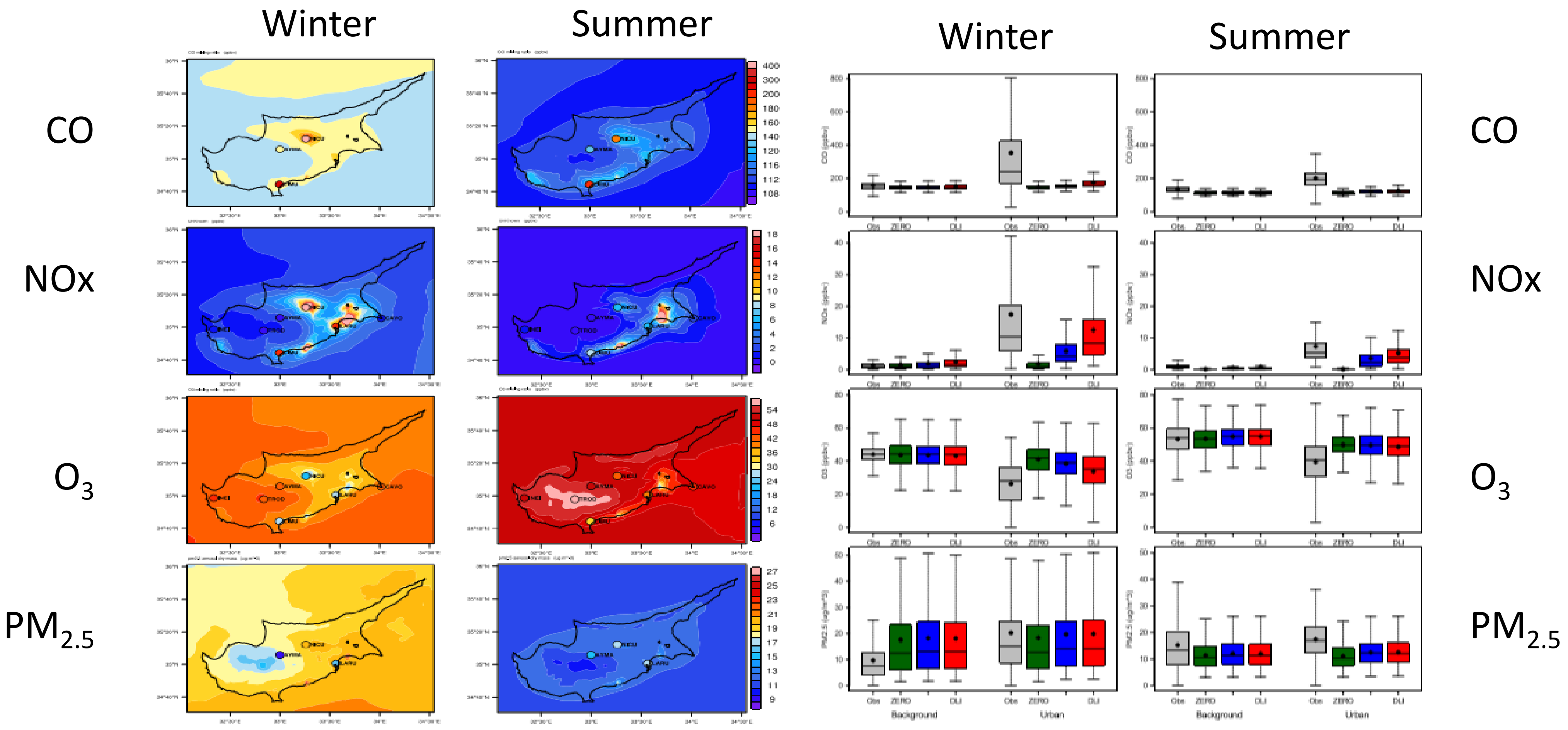






Georgiou et al., 2019: Air quality modelling over the Eastern Mediterranean: Seasonal sensitivity to anthropogenic emissions

Impact of high resolution emissions



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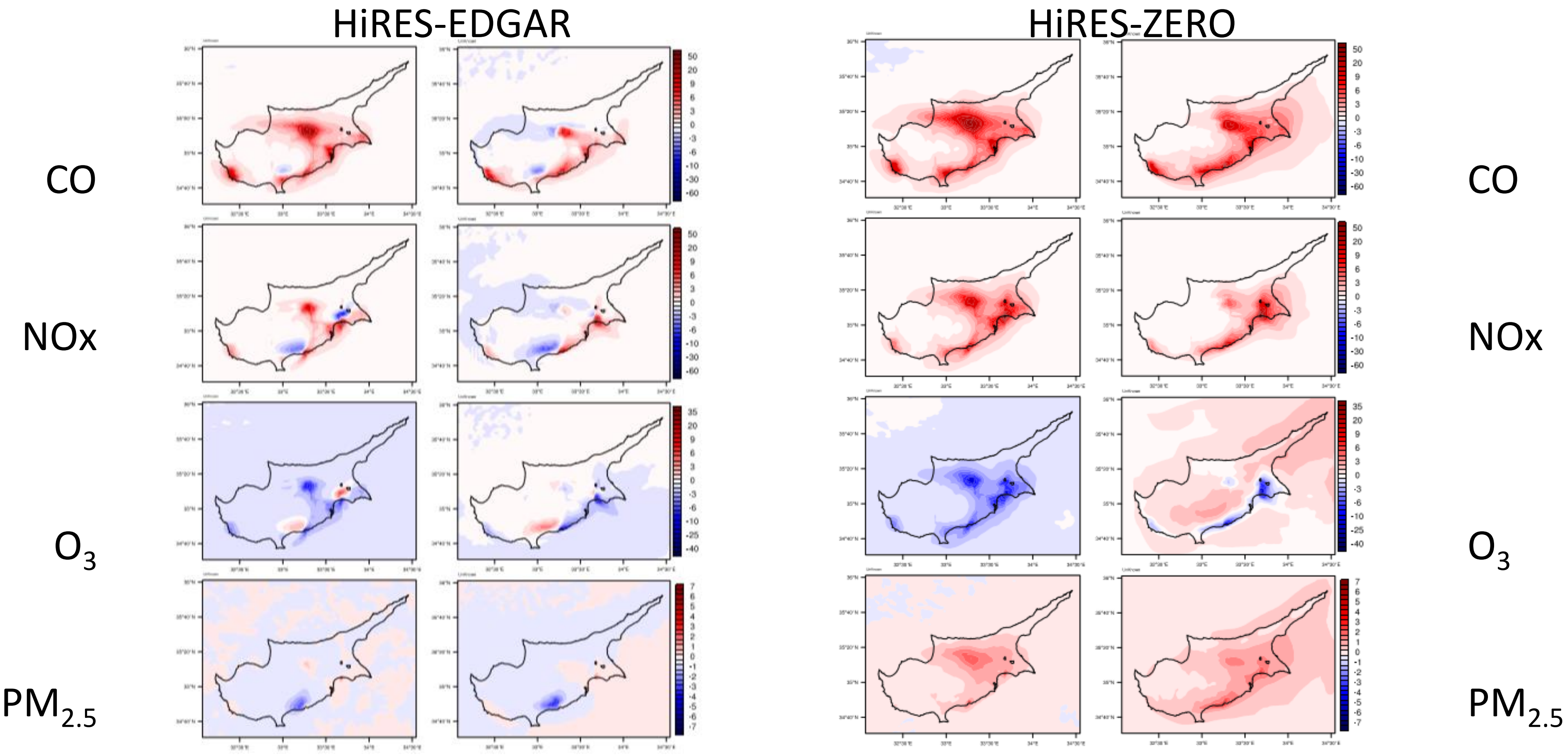
Impact of national emissions an air quality



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Concluding remarks

Cyprus can strongly benefit from an efficient air quality modelling approach to assess atmospheric composition near ground for both scientific and policy applications.

Emission fluxes play a significant role in the investigation of local features, seasonality of air pollution patterns and rural – urban pollution gradient.

FAIRMODE provided a compact tool that helps analysing model performance in a harmonised way allowing for a high confidence level in the methodology.

This is ongoing work keeping always in mind:
Models and tools are as efficient and useful as the ability of the user to assess the results.

Special acknowledgment to FAIRMODE pioneers and participants for help & support.
Thank you to HARMO organizers!