European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

**WGs and MC Meeting at ISTANBUL, 3-5 December 2014**

Action Start date: 01/07/2012 - Action End date: 30/06/2016

Year 3: 1 July 2014 - 30 June 2015 (*Ongoing Action*)

# IMPACT OF NOx EMISSIONS ON AIR QUALITY SIMULATIONS WITH THE BULGARIAN WRF-CMAQ MODELING SYSTEM

**Emilia Georgieva**

WG Member

**National Institute of Meteorology and Hydrology, Tsarigradsko chausse, 66, 1784 Sofia, Bulgaria**

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

COST is supported by the EU Framework Programme

European Science Foundation ESF provides the COST Office through a European Commission contract

# Motivation - 1

- **Triggered by our participation in AQMEII -2:**
  **A**IR **Q**UALITY **M**ODELLING **E**VALUATION **I**NTERNATIONAL **I**NITIATIVE
  http://aqmeii.jrc.ec.europa.eu

- Establish methodologies for model evaluation, increase knowledge on processes and support the use of models for policy development

- 1 year of simulations for North America and Europe by more than 20 modelling groups (mainly on-line coupled models)

# Motivation - 2

- **Use the common evaluation platform – ENSEMBLE :** a web-based platform developed at the JRC-Ispra:  for model inter-comparison and multi-model ensemble analysis,

- Huge amount of different type of observation data (surface, MOZAIC profiles etc)

- **Find out shortcomings in the model system and outline ways for its improvement**

- **Particular for this work** – how sensitive is our system to emissions input data

# WRF - CMAQ runs - First run (BG1)

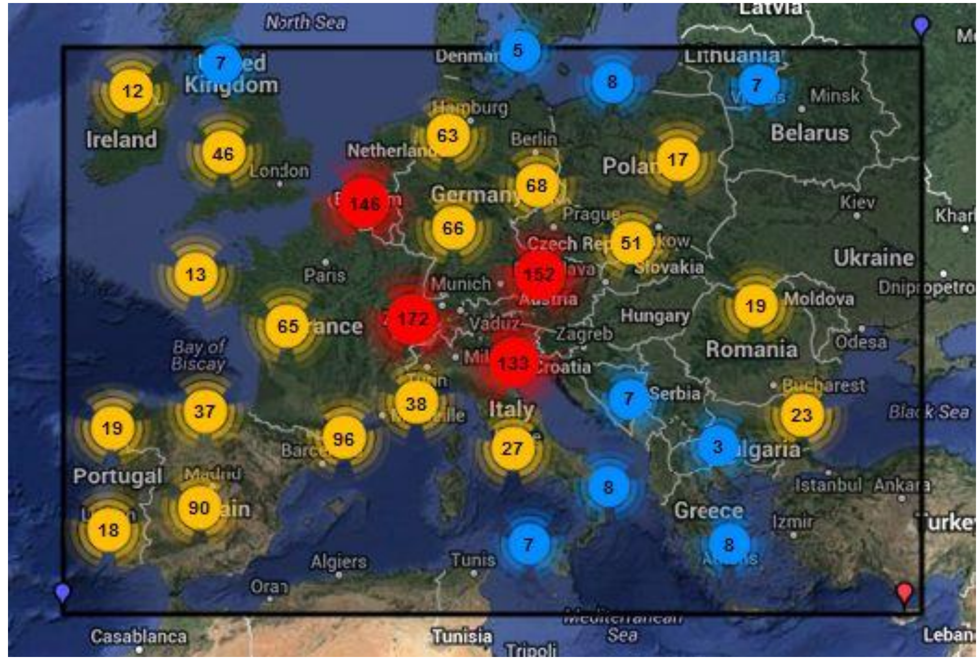
- **EU domain, grid step 25 km, 201 x 201 points**
- **Emissions - provided by AQMEII team**

  *Anthropogenic – TNO inventory 2009, ~ 7-8 km resolution*
  *Biogenic emissions – calculated based on meteorology and land use*
  *Wild Fire emissions – database of FMI, 0.1 ° x 0.1° resolution*
  *Sea-Salt emissions – option in CMAQ switched on*

- **SMOKE – the emission pre-processor is used to:**
  - Merge all type of emissions as input to CMAQ, calculate biogenic emissions
- **Temporal, vertical and speciation profiles – provided by TNO.** Own routines for gridded Area and Point sources emissions (SOx, NOx, VOC, PM2.5)

# *Preliminary results (BG1)*

- **Focusing on EU most problematic pollutants** O3, NO2, PM10 and PM2.5
- **Surface background AQ** monitoring stations (urban rural, suburban)
- About 1400 stations EU domain (AIRBASE, EMEP)
- 400 rural , 600 urban




## O3 surface stations

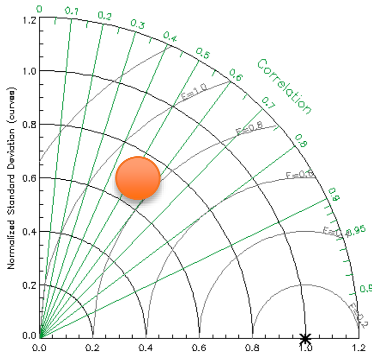
| | $O_3$ | $NO_2$ | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|---|
| **Total** | 1374 | 1395 | 1297 | 500 |
| **Rural** | 410 | 322 | 272 | 99 |
| **Urban** | 566 | 685 | 684 | 311 |
| **Suburban** | 398 | 388 | 341 | 90 |

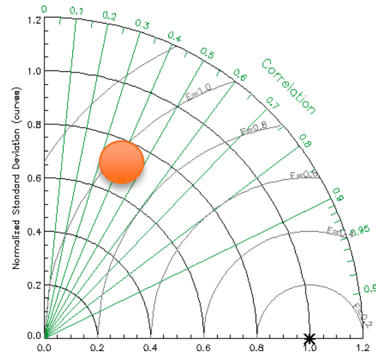
# O3 (BG1): April-September (BG1)

## Rural

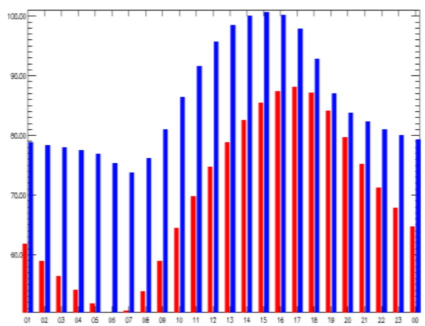
## Urban

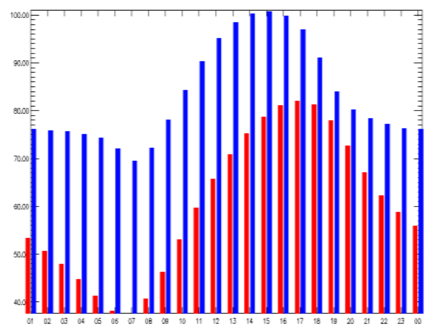
**— MOD.** **— OBS.**



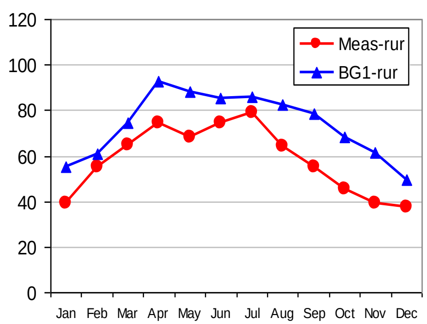



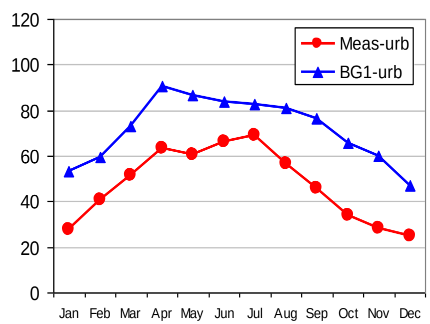

*Taylor diagrams*





*Mean diurnal variation*



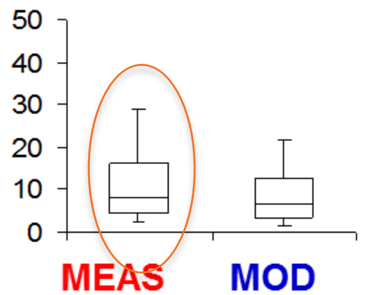

*Monthly mean values*

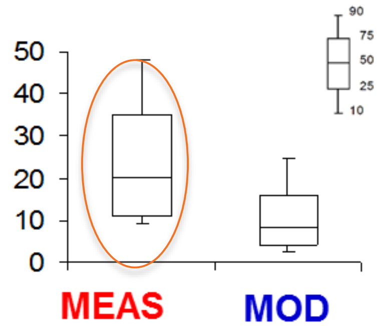
- **Model overestimation**
- **negligible diff. URB-RUR**

# NO2 (BG1): 2010 hourly data (BG1)

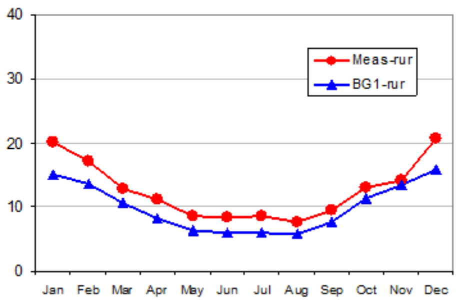
**Rural** **Urban**

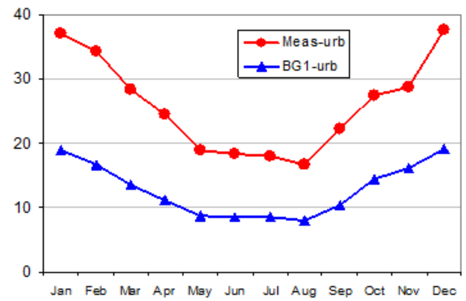
— *MOD.* — *OBS.*



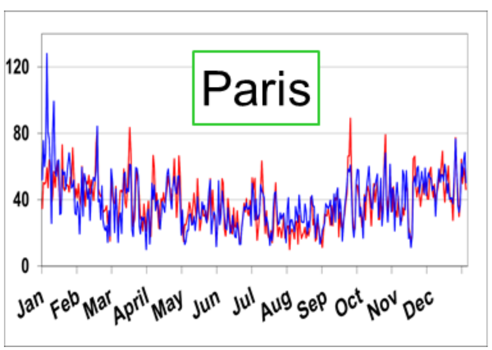



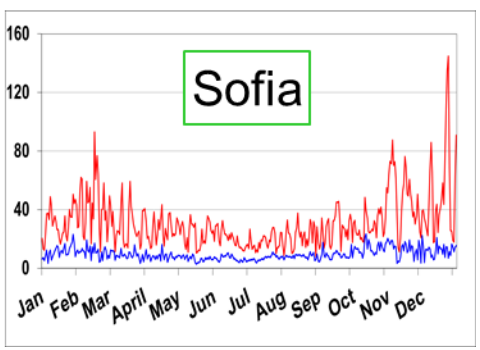

*Box and Whisker*




*Mean monthly variation*




*Daily Mean Paris and Sofia regions*

- **Model underestimation**
- **no diff URB-RUR**

# WRF - CMAQ runs - Second run (BG2)

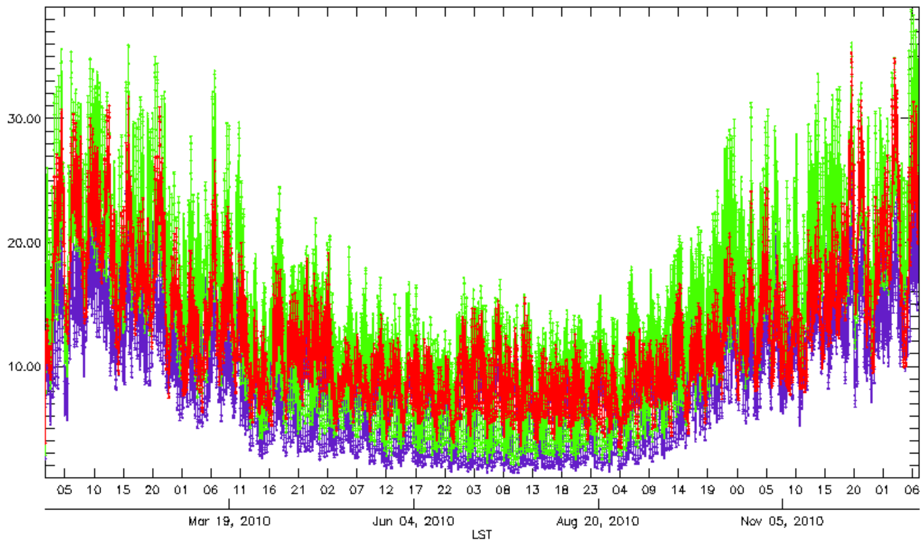
- **BG1:** **O3 is overestimated** ~ 25% at rural, ~ 40% at urban sites
  **NO2 is underestimated by** ~ 25% at rural sites,
  **almost** 2x at urban sites

- **Deficiency in NOx emissions was found**

- **BG2 run – corrected NOx emissions- about 30% increase**
  **simulations repeated for the entire period – 2010**
- **The results from BG1 and BG2 can be treated as sensitivity test for NOx modelled**

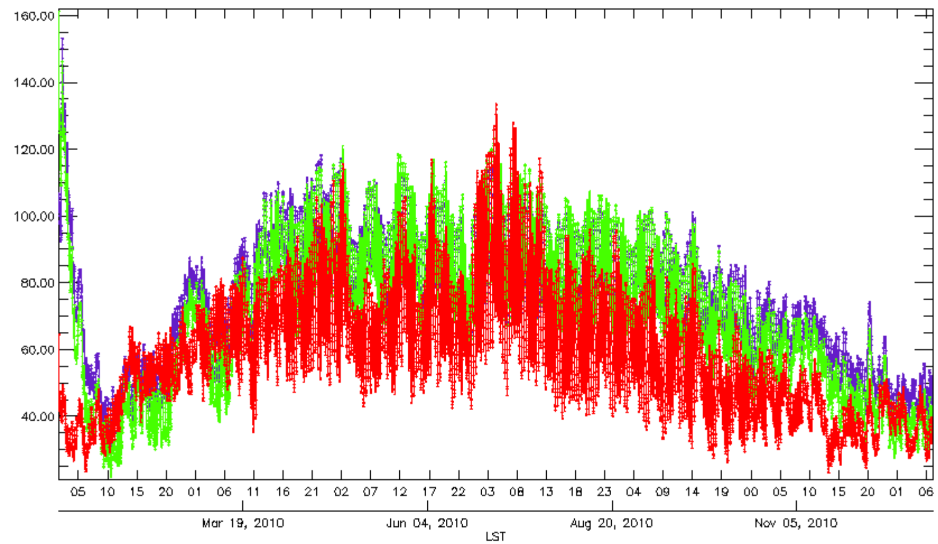
# O3 and NO2 time series  2010 (BG1 & BG2)

- *BG1*
- *BG2*




**NO2   rural sites**

**O3  rural sites**

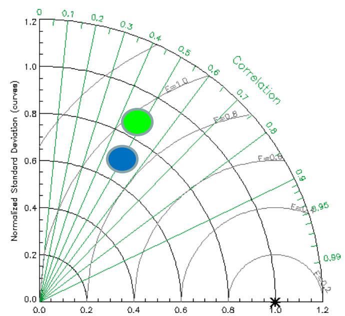
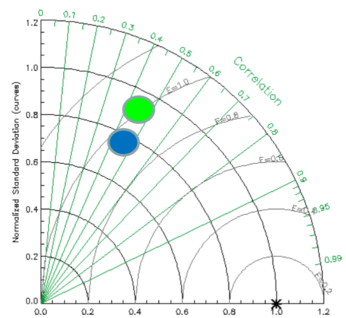



**BG2 closer to MEAS**

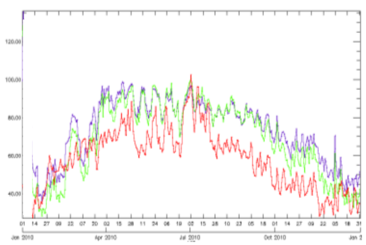
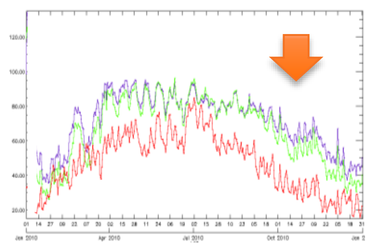
# O3 2010 (BG1 & BG2)

**Rural** **Urban**

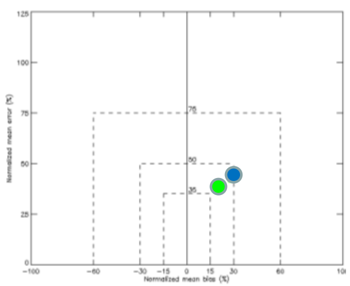
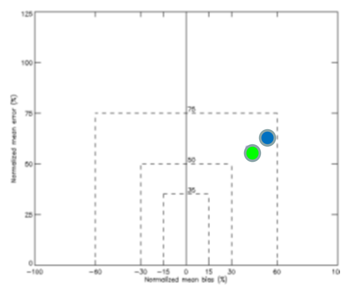
● ***BG1*** ● ***BG2***

*Taylor diagrams*

*Time series mean daily*

*Soccer plot*

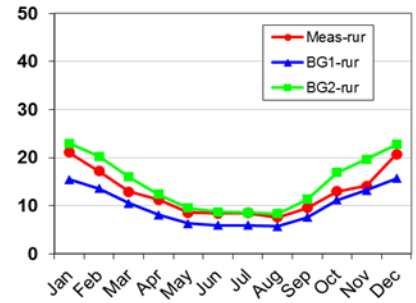
**- Effect more evident at urban sites in winter**

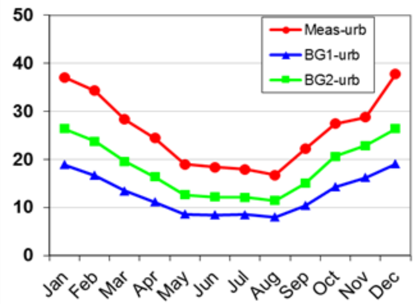
**- Still significant over estimation**

# NO2 2010 (BG1 & BG2)

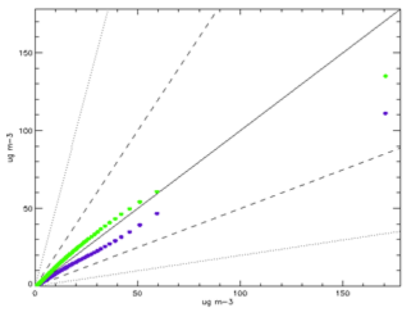
**Rural** **Urban**

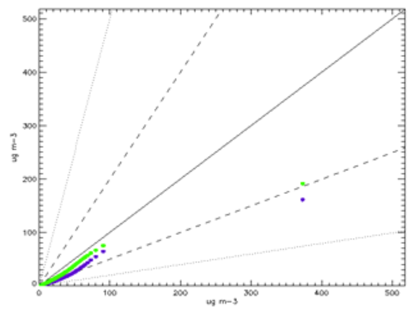
**BG1** **BG2**



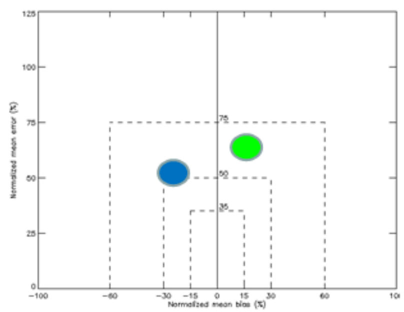



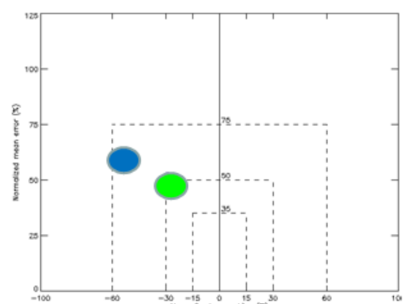

*Monthly mean*





*Quantile-Quantile plot*





*Soccer plot*

- **Effect more evident at urban sites in winter**
- **Still underestimation in urban sites**

# Statistics O3 and NO2 for different type of stations (BG1 & BG2)

| | *Mean obs. (µg/m$^3$)* | *Mean mod. (µg/m$^3$)* | *NMB (%)* | *NMSD (%)* | *RMSE (µg/m$^3$)* | *FA2 (%)* | *PCC* |
|---|---|---|---|---|---|---|---|
| | *Ozone (April to September)* | | | | | | |
| **Rural** | **69.3** | **84.8 (85.7)** | **22.5 (23.8)** | **-13.4 (-27.1)** | **28.7 (27.2)** | **84.3 (84.5)** | **0.49 (0.49)** |
| **Urban** | **60.4** | **81.5 (83.4)** | **35.1 (38.2)** | **-11.4 (-24.4)** | **30.3 (28.6)** | **74.6 (74.6)** | **0.46 (0.47)** |
| **Suburban** | **63.3** | **83.1 (84.6)** | **31.1 (33.6)** | **-13.8 (-27.3)** | **30.4 (28.9)** | **77.0 (77.0)** | **0.48 (0.48)** |
| | *Ozone (January to December)* | | | | | | |
| **Rural** | **58.2** | **70.1 (74.3)** | **20.2 (27.8)** | **6.0 (-9.6)** | **29.4 (27.7)** | **77.4 (78.4)** | **0.54 (0.53)** |
| **Urban** | **47.6** | **67.2 (72.3)** | **41.0 (52.1)** | **5.3 (-9.1)** | **30.1 (28.6)** | **65.7 (64.4)** | **0.54 (0.52)** |
| **Suburban** | **50.7** | **68.9 (73.7)** | **35.7 (45.5)** | **2.3 (-12.1)** | **30.4 (28.9)** | **68.2 (67.5)** | **0.54 (0.52)** |
| | *$NO_2$ (January to December)* | | | | | | |
| **Rural** | **12.7** | **14.7 (9.9)** | **17.2 (-21.2)** | **7.2 (-23.6)** | **12.2 (10.7)** | **57.1 (56.9)** | **0.56 (0.56)** |
| **Urban** | **25.9** | **18.2 (12.7)** | **-29.3 (-50.5)** | **-15.6 (-33.6)** | **17.9 (17.1)** | **49.3 (42.5)** | **0.53 (0.52)** |
| **Suburban** | **22.1** | **17.9 (12.5)** | **-18.4 (-43.1)** | **-11.4 (-31.3)** | **17.0 (16.0)** | **58.2 (48.0)** | **0.51 (0.51)** |

# Some acceptance criteria for *BG2*

## A. According to Derwent et al., 2010

**O3 summer** | **NO2 yearly**

| Statitstics | Criteria | Rural | Urban | | Criteria | Rural | Urban | SubU |
|---|---|---|---|---|---|---|---|---|
| FA2 | >50% | 84.3 | 74.6 | | >50% | 57.1 | 49.3 | 58.2 |
| NMB | <20% | 22.5 | 35.1 | | <20% | 17.2 | -29.3 | -18.4 |

*Criteria fulfilled at rural sites*

## B. According to Thunis et al. (2013) and Pernigotti et al. (2013) (taking into account observation uncertainty)

**O3 summer** | **NO2 yearly**

| Statitstics | Rural | | Urban | | Rural | | Urban | |
|---|---|---|---|---|---|---|---|---|
| | Criteria | Mod | Critt. | Mod | Criteria | Mod | Critt. | Mod |
| NMB | <37% | 22.5 | <41% | 35.1 | <159% | 17.2 | <79% | -29.3 |
| PCC | >0.40 | 0.49 | >0.51 | 0.46 | >0.0 | 0.56 | >0.29 | 0.53 |
| NMSD | <107% | -13.4 | <97% | -11.4 | <200% | 7.2 | <117% | -11.4 |

# Conclusions – 1

- In spite the model system hardy sees differences between urban and rural type of stations predicting very similar results at both types, **the model performs better at rural than at urban stations.** This is not surprisingly in view of the coarse model grid resolution and lack of particular urban parameterizations in the mode;
- **BG2 still overestimates mean $O_3$ at all type of stations, with about 30% during summer** that is particularly evident during night time;
- **The O3 differences BG1 vs BG2 in terms of statistical indexes is negligible, only with a few percent. These differences are more noticeable during the winter months;**

# Conclusions - 2

- BG2 still underestimates $NO_2$ in urban areas.

- BG2 to BG1 differences in NO2 at all stations are small: 3-5%, Both BG2 and BG1 do not “see differences” urban-rural for $NO_2$ while the observations show difference up to 2 times.

- Statistical indexes PCC and RMSE do not change, FA2 is slightly higher for BG2, and more noticeable change is the lower NMB values for BG2

# Work in progress

- Check meteorological variables and models performance
- Analyse emissions input and their spatial distribution
- Compare to other models from AQMEII-2
- Urban parameterizations


## *Acknowledgements*

**US EPA, NCEP, EMEP, TNO** for providing free-of-charge models and data.

This work is based on the results obtained within the **ENSEMBLE Consortium which is acknowledged.**

**Deep gratitude is due to EC Joint Research Centre in Ispra, Italy,** for supporting the AQMEII and ENSEMBLE activities.


THANK YOU !