COSMO-ART and ICON-ART at Rosshydromet

Alexander Kirsanov, Gdaly Rivin,
Uliana Kostrova, Anastasia Revokatova

COSMO GM, 3-7 Sept 2018, Saint Petersburg

COSMO-(Ru7)-ART

COSMO-(Ru7)

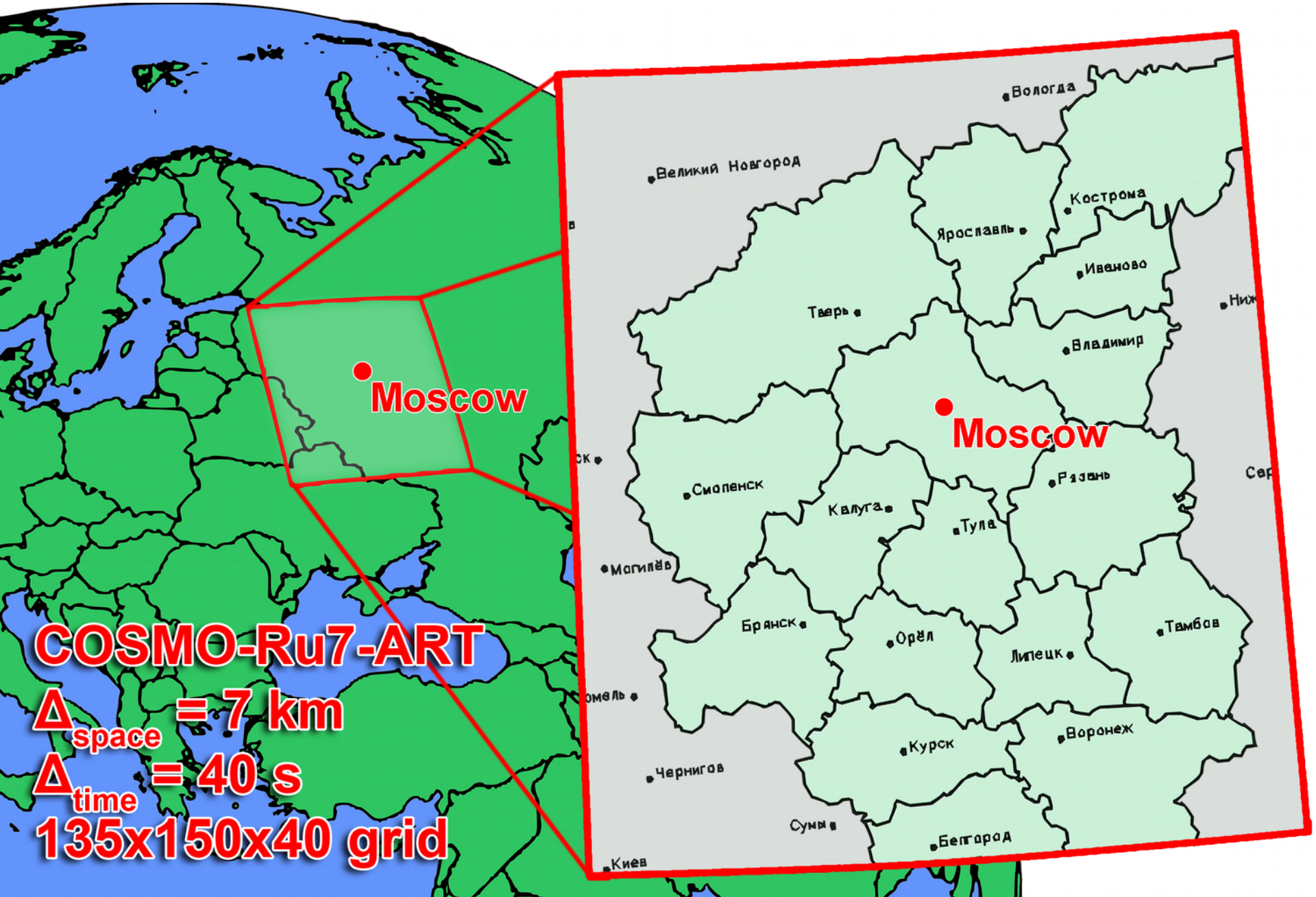
COnsortium for **S**mall-scale **MO**delling

ART

Aerosols and **R**eactive **T**race gases

meteorology ⟷ on-line approach ⟷ chemistry

COSMO-Ru7-ART DOMAIN



COSMO-Ru7-ART

- 60 hour forecast from 12 UTC
- 135x150x40 grid
- ~30-45°E, 50-60°N
- spatial resolution 7 km
- $\Delta t = 40$ s
- initial and boundary conditions

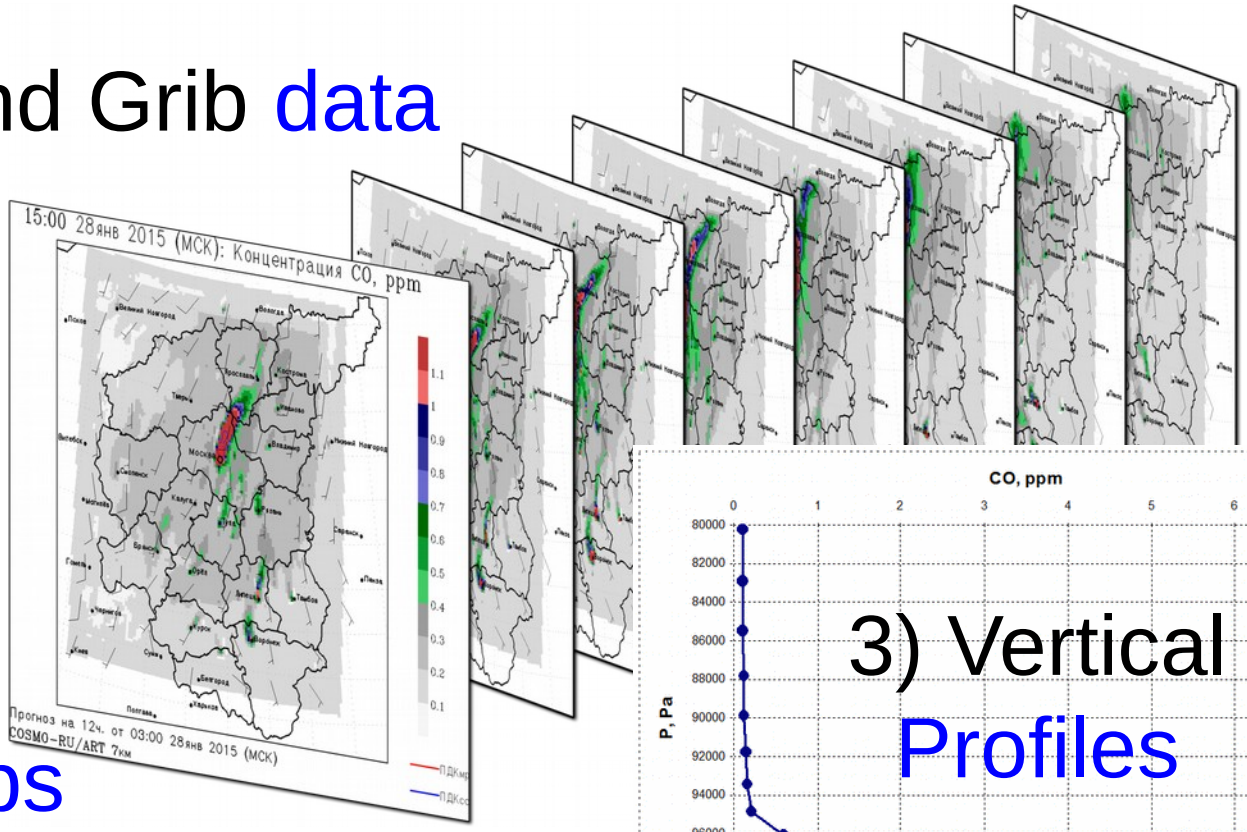
COSMO-RU7

- anthropogenic emissions TNO
- Landuse Data GLC 2000
- CO, NO, NO_2, O_3, SO_2, PM_{10}

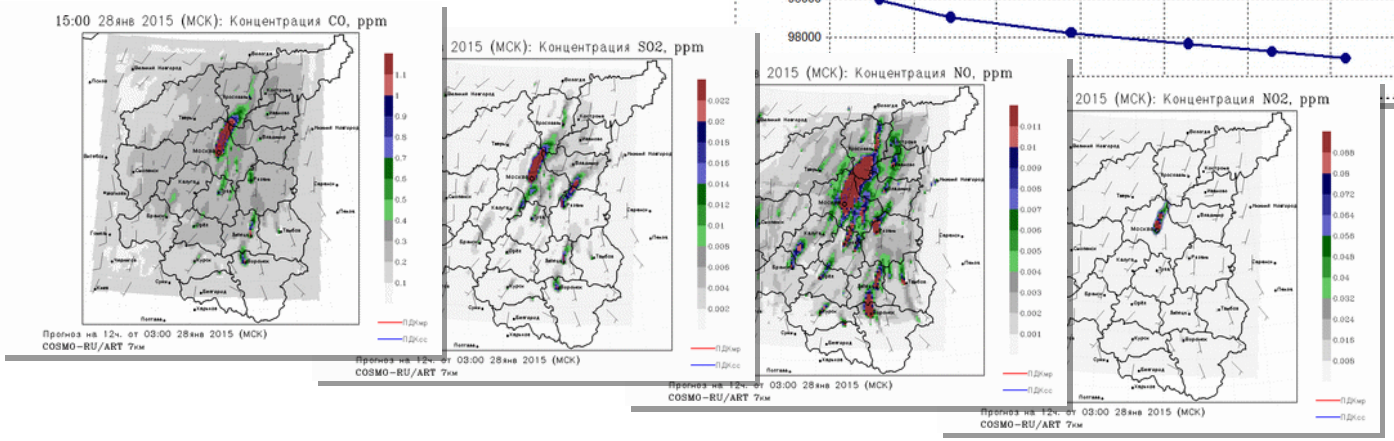
Small domain since June 2017

DAILY PRODUCTION

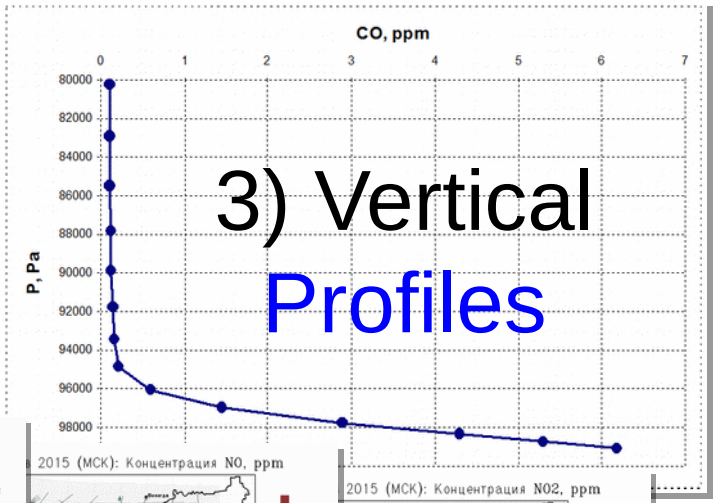
1) Text and Grib data



2) Maps

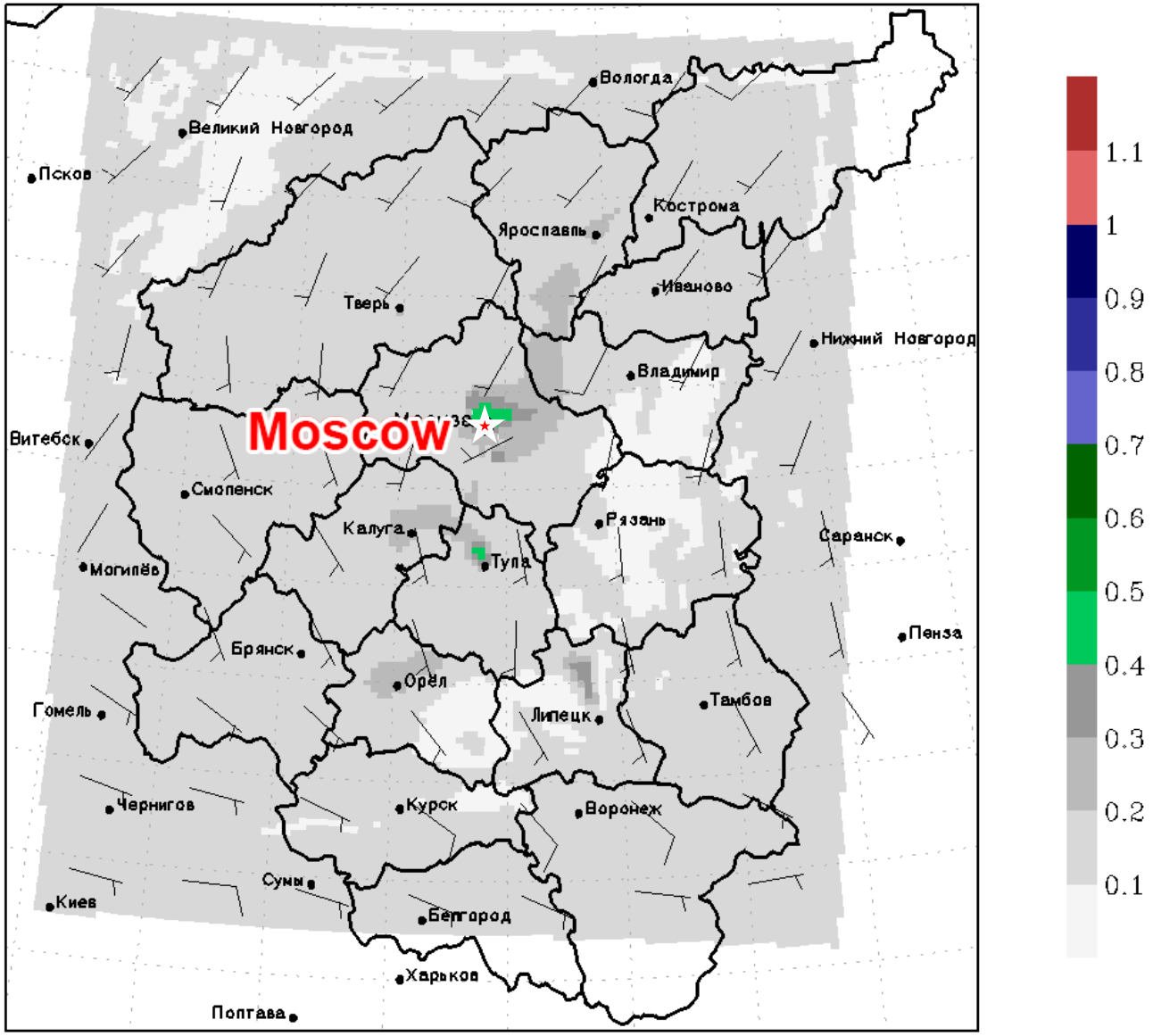


3) Vertical Profiles



COSMO-Ru7-ART FORECAST EXAMPLE

01:00 05 APR 2017 (MSK): CO concentration, ppm

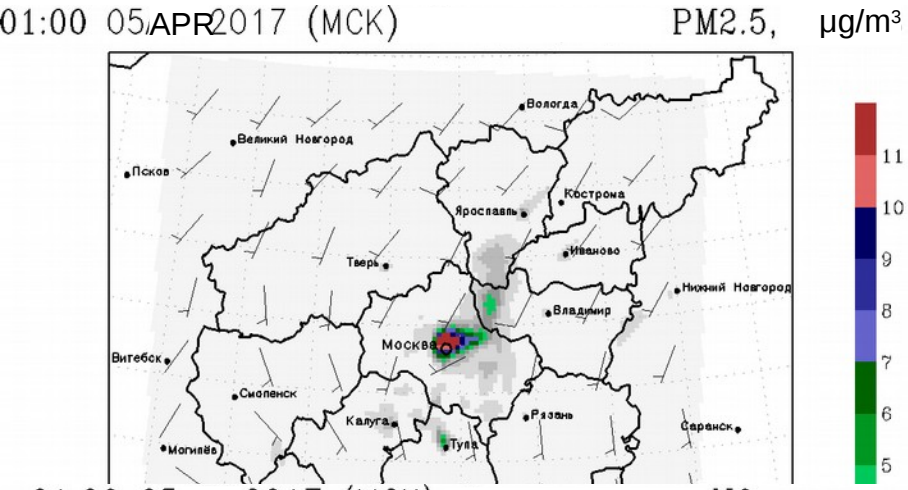


Forecast on 21 h

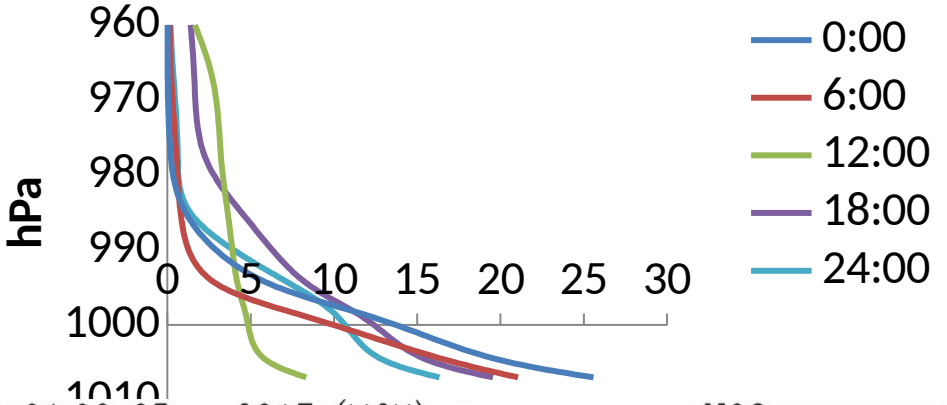
COSMO-RU/ART km

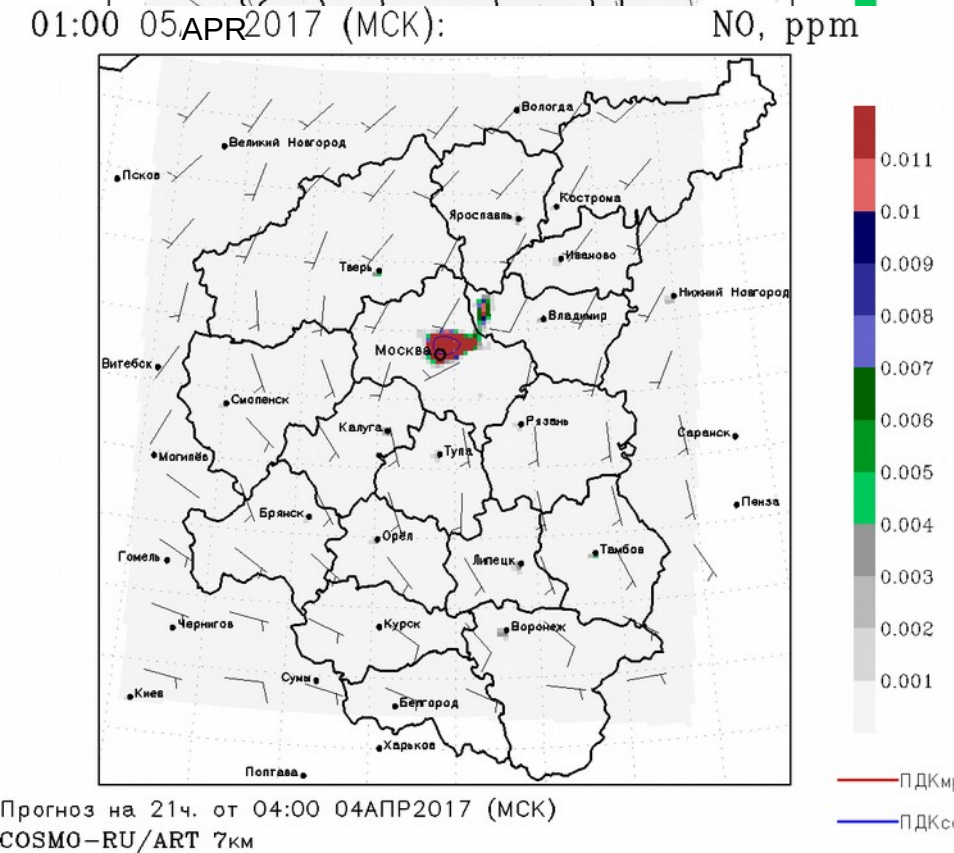
MPC_{da} ~ 2,6 ppm

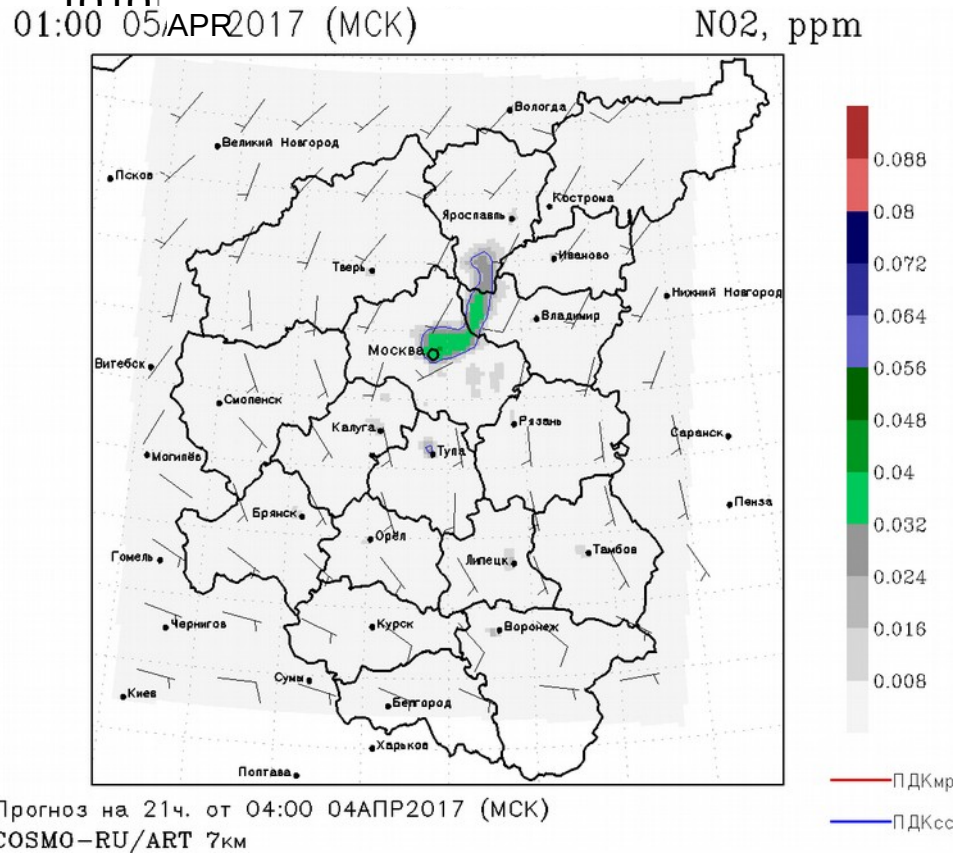
COSMO-Ru7-ART FORECAST EXAMPLE



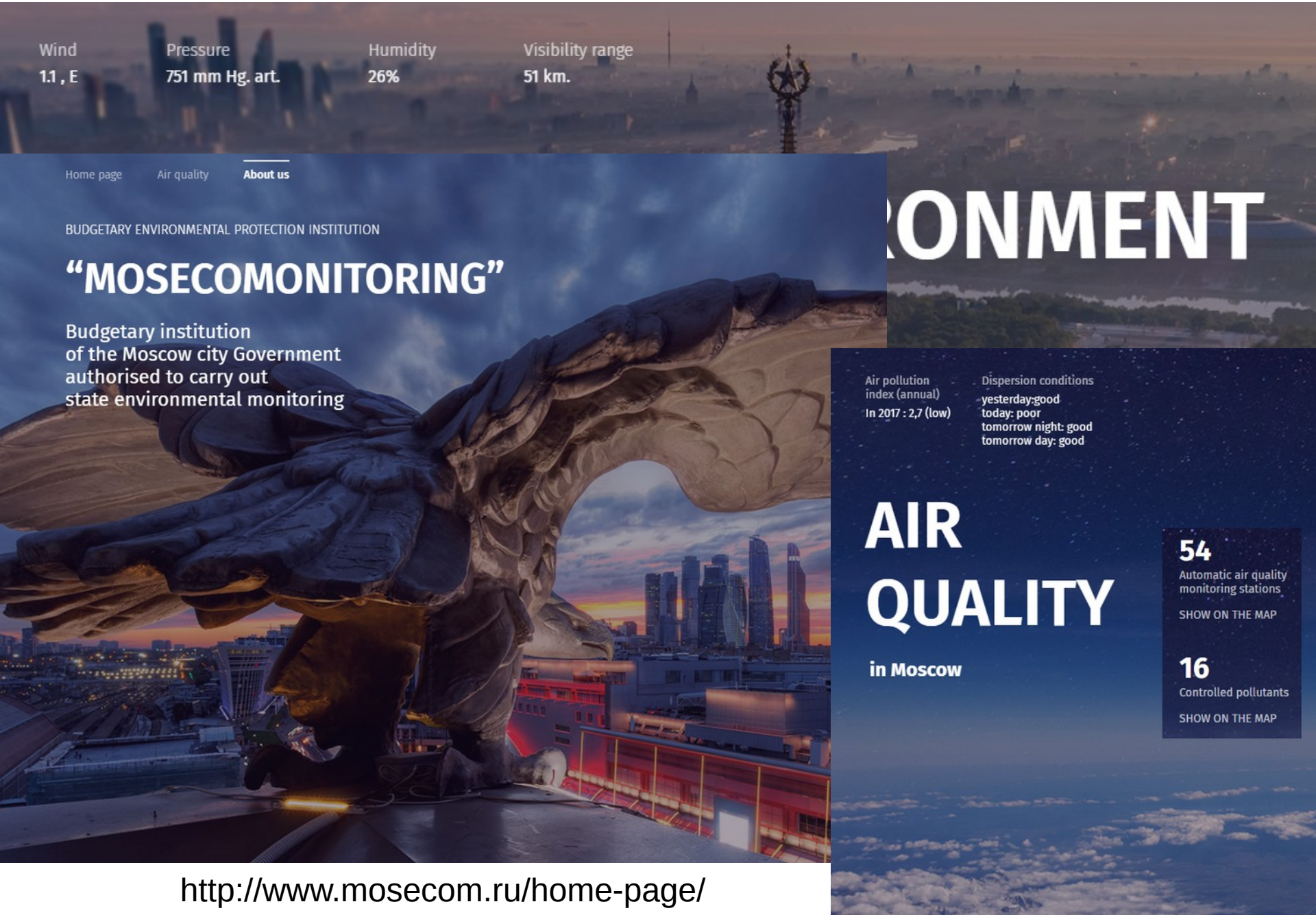
PM10, µg/m3





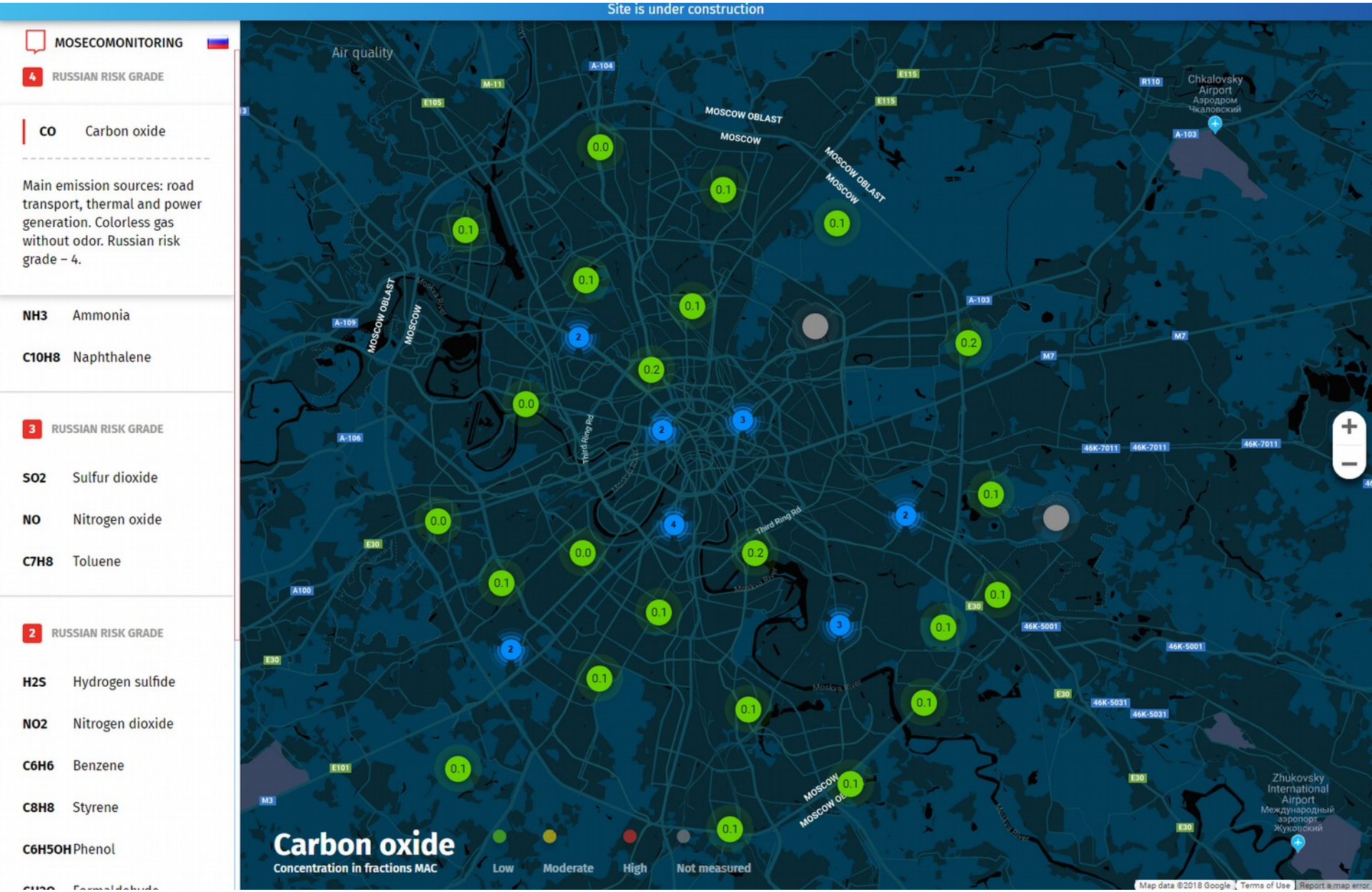


MOSECOMONITORING



http://www.mosecom.ru/home-page/

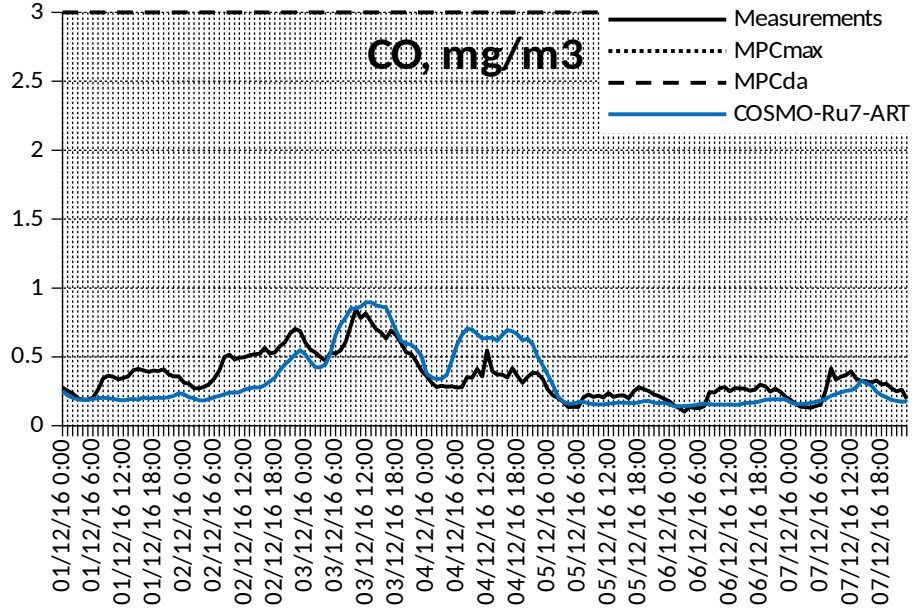
MOSECOMONITORING

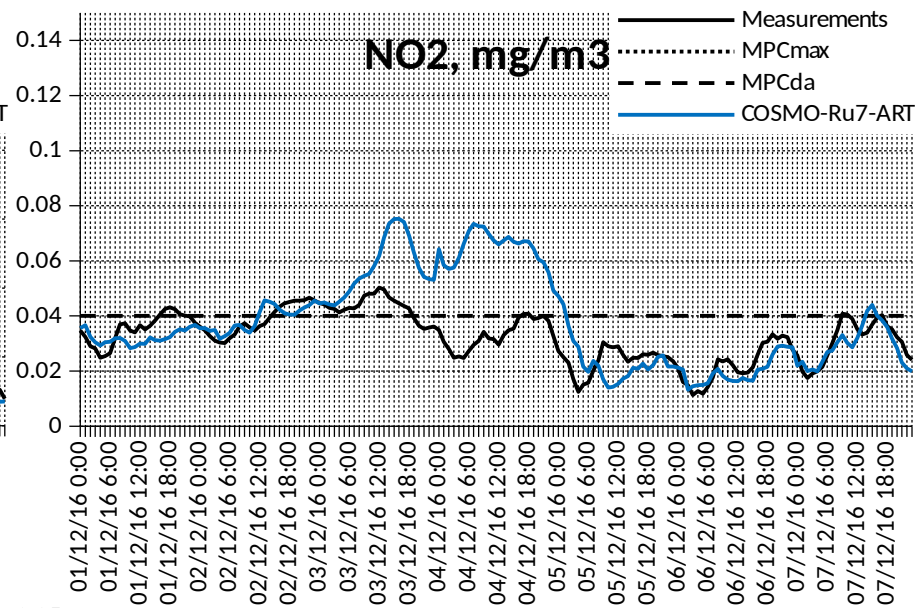


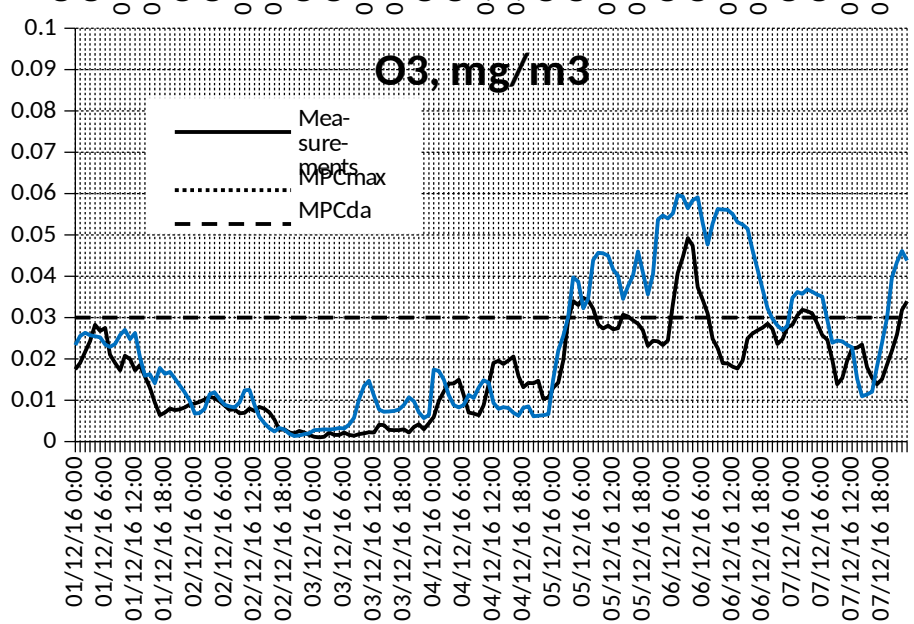
http://www.mosecom.ru/map/

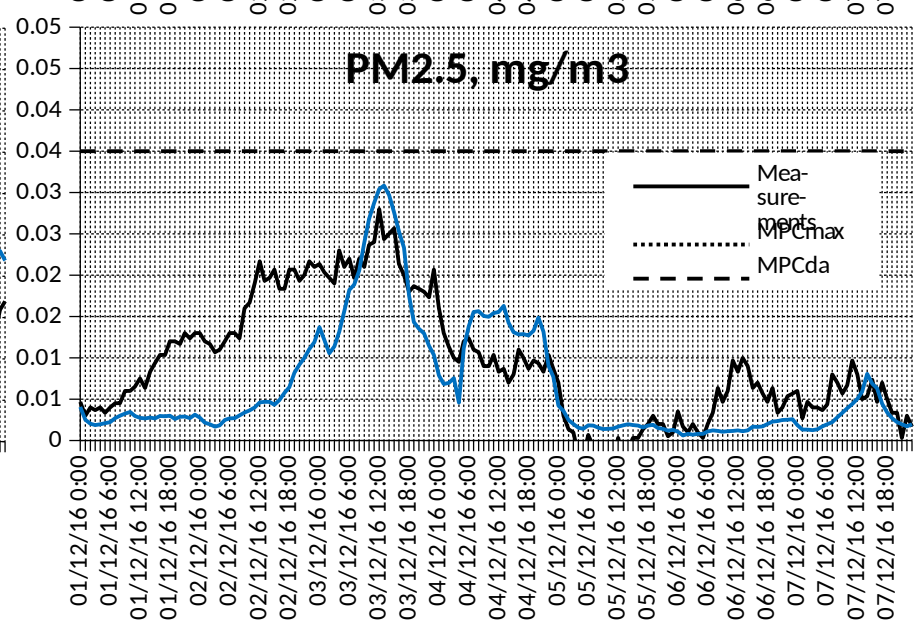
COMPARISON WITH MEASUREMENTS

Pollutant concentrations forecasted on 01.12.2016 – 07.12.2016





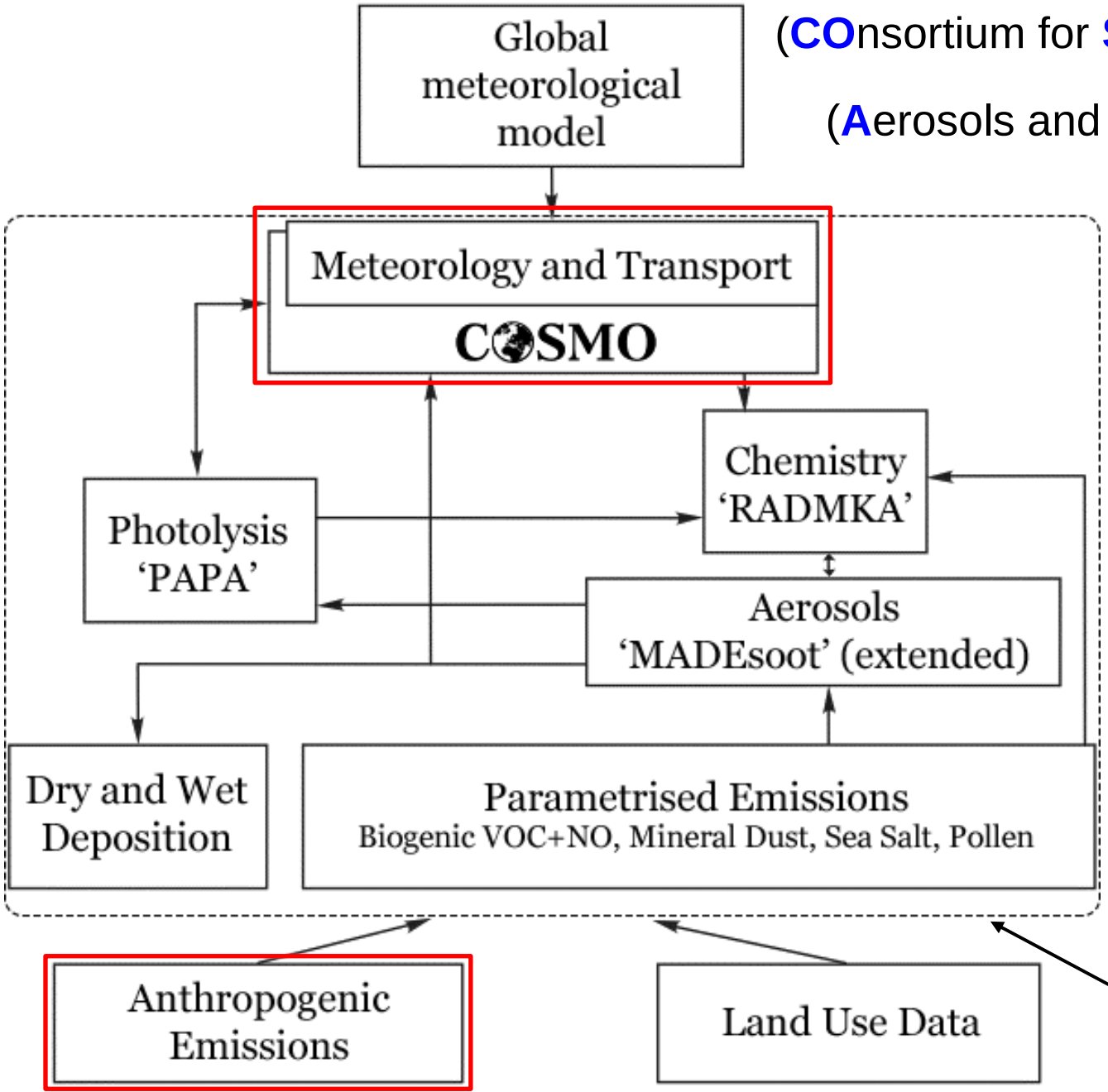




COSMO-ART SYSTEM

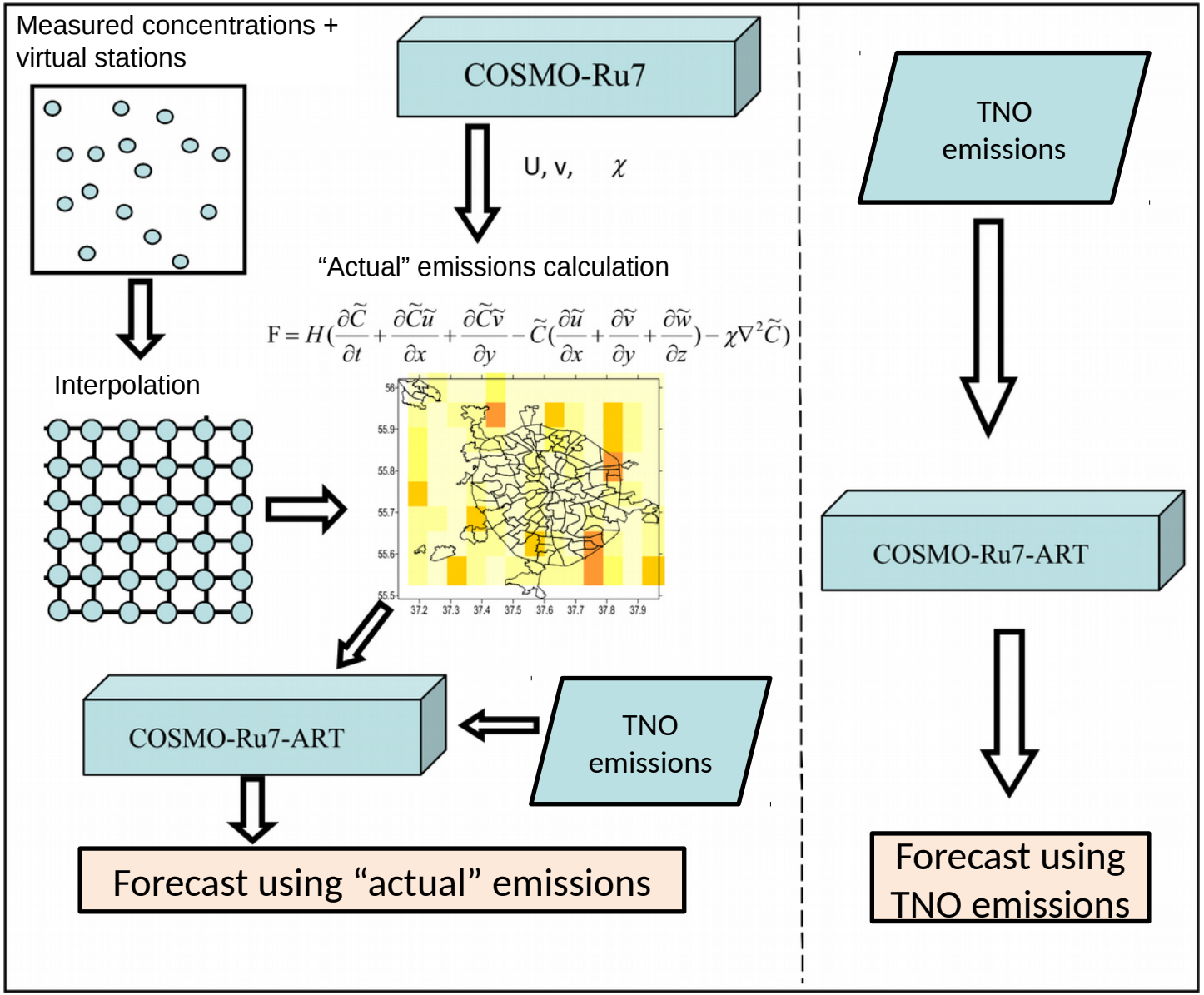
(**CO**nsortium for **S**mall-scale **MO**delling)

(**A**erosols and **R**eactive **T**race gases)

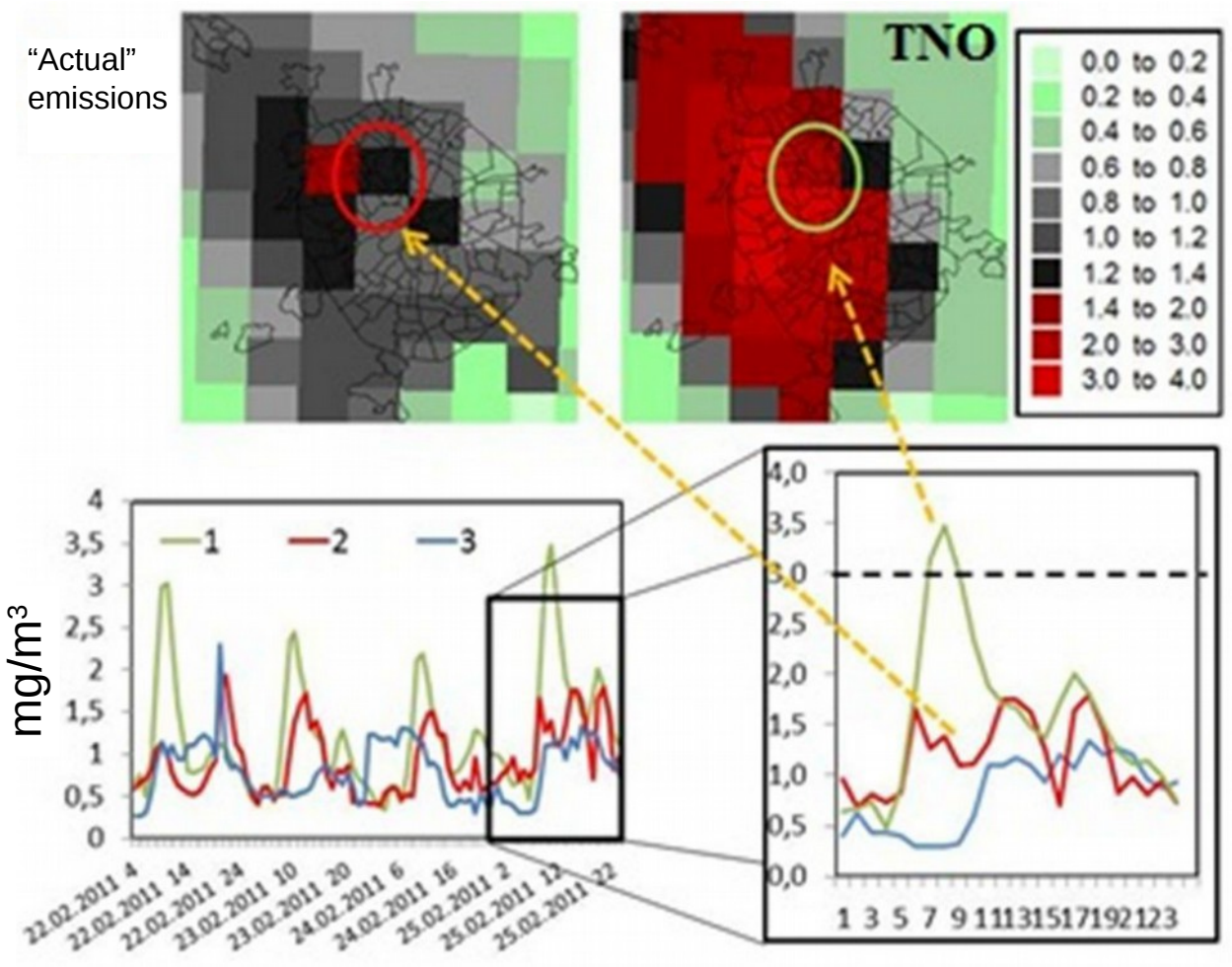


- non-hydrostatic mesometeorological model
- chemical reactions
- photolysis
- coagulation
- condensation
- nucleation
- dry and wet deposition
- on-line approach

FORECAST USING "ACTUAL" CO EMISSIONS



FORECAST USING "ACTUAL" CO EMISSIONS



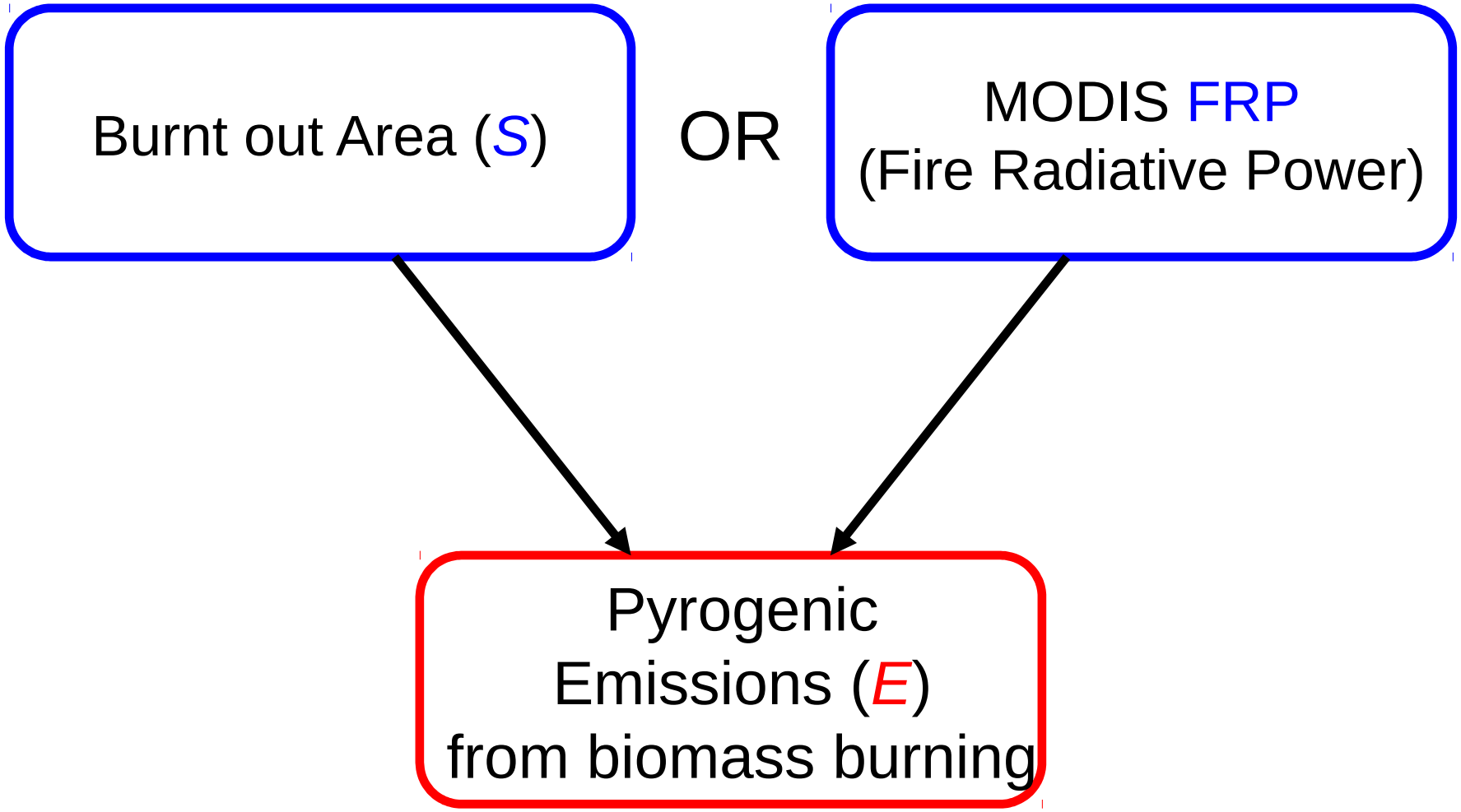
1 – TNO, 2 – "actual" emissions, 3 – measurements

A. Revokatova, G. Surkova and A. Kislov. Short-term forecast of carbon monoxide concentrations over Moscow region. Vol. 15, EGU General Assembly, 2013. Geophysical Research Abstracts - id. EGU2013-879.

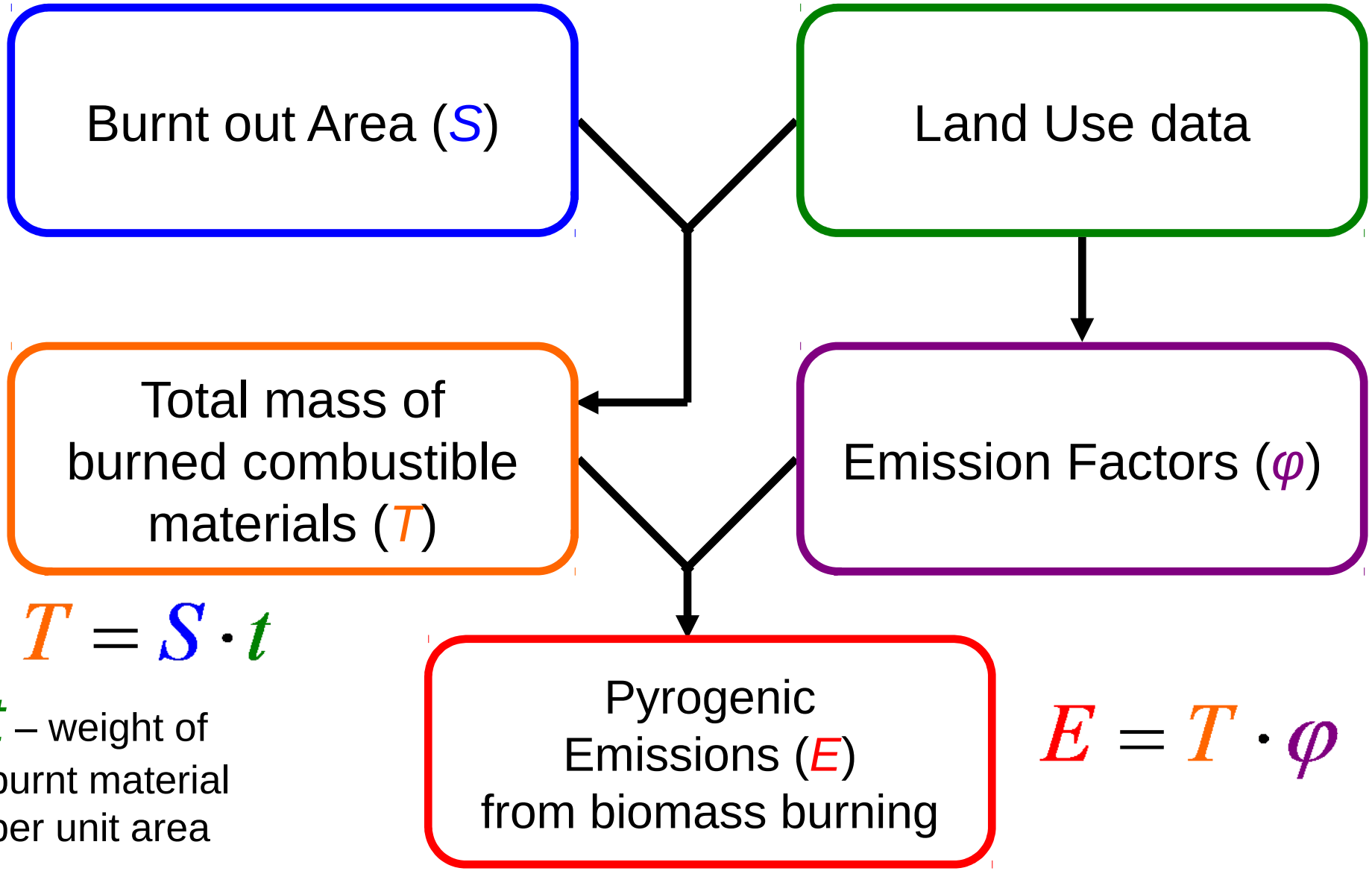
FOREST FIRES OF SUMMER 2010

Moscow, Aivazovsky Street,
17.06.2010 (left) and 07.08.2010 (right)

DIFFERENT APPROACHES TO CALCULATE EMISSIONS FROM BIOMASS BURNING



BIOMASS BURNING EMISSION ESTIMATION USING BURNT OUT AREA

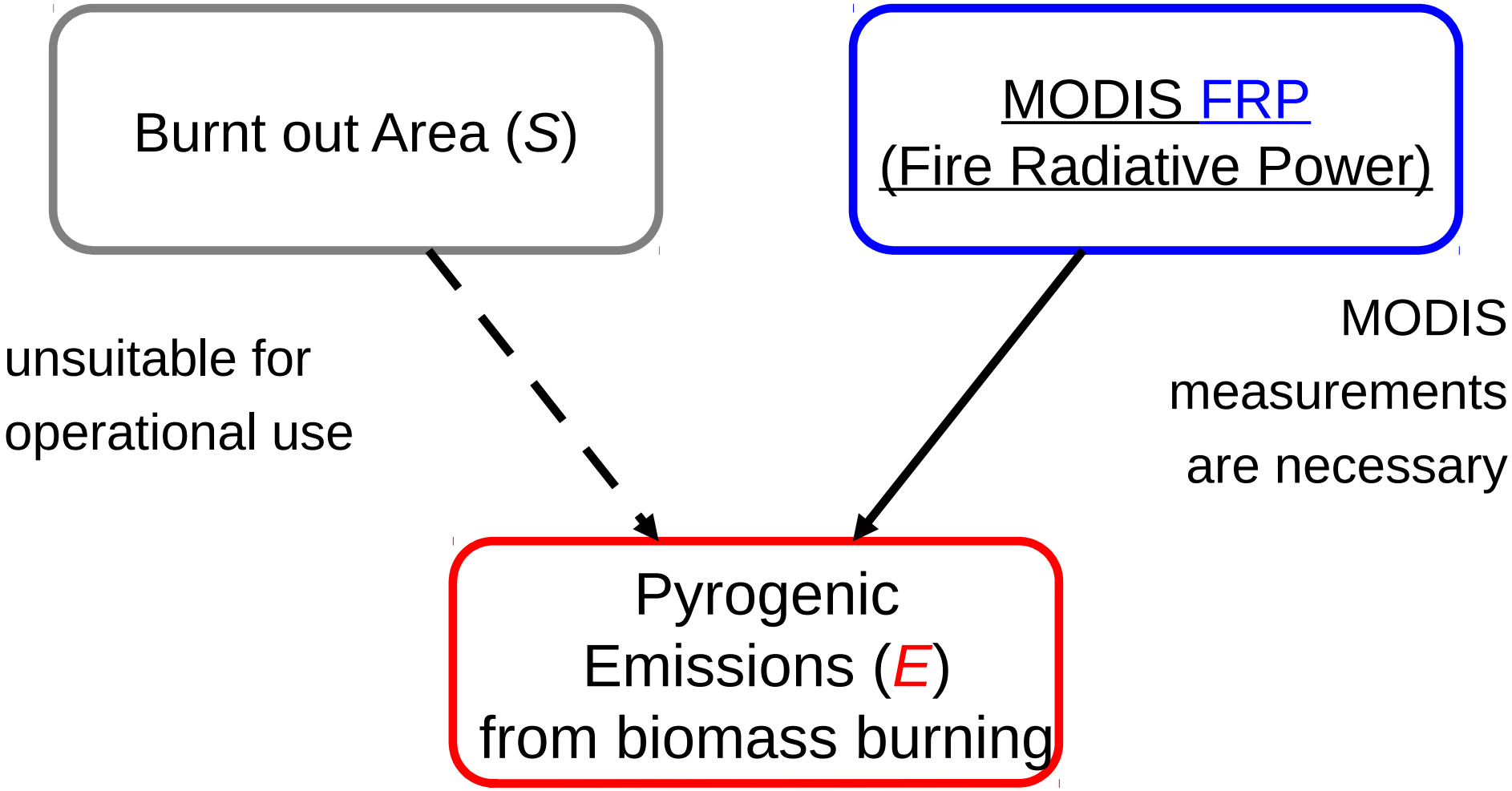


$$T = S \cdot t$$

t – weight of burnt material per unit area

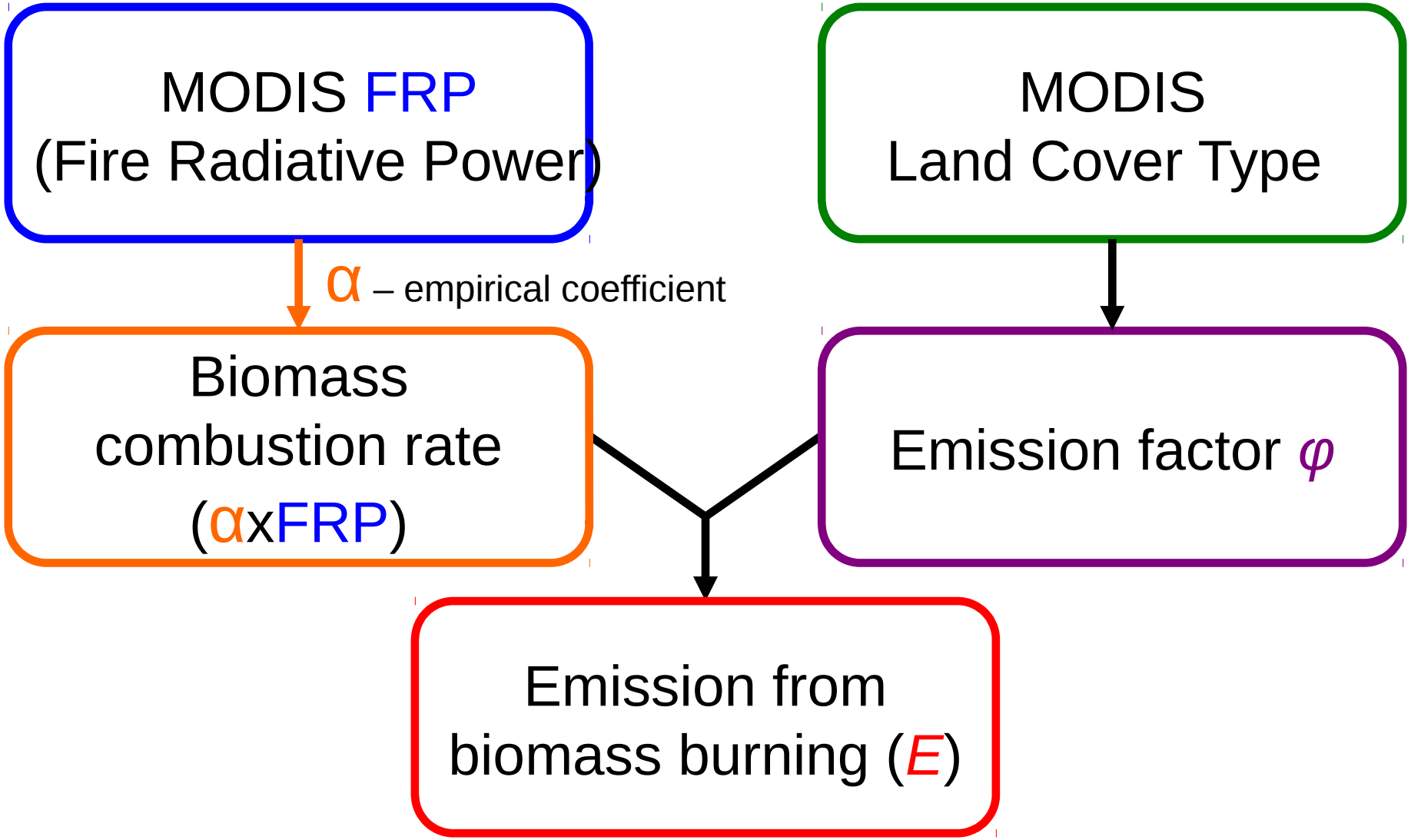
$$E = T \cdot \varphi$$

DIFFERENT APPROACHES TO CALCULATE EMISSIONS FROM BIOMASS BURNING



BIOMASS BURNING EMISSION ESTIMATION USING MODIS DATA

$$E = \varphi \cdot \alpha \cdot FRP$$



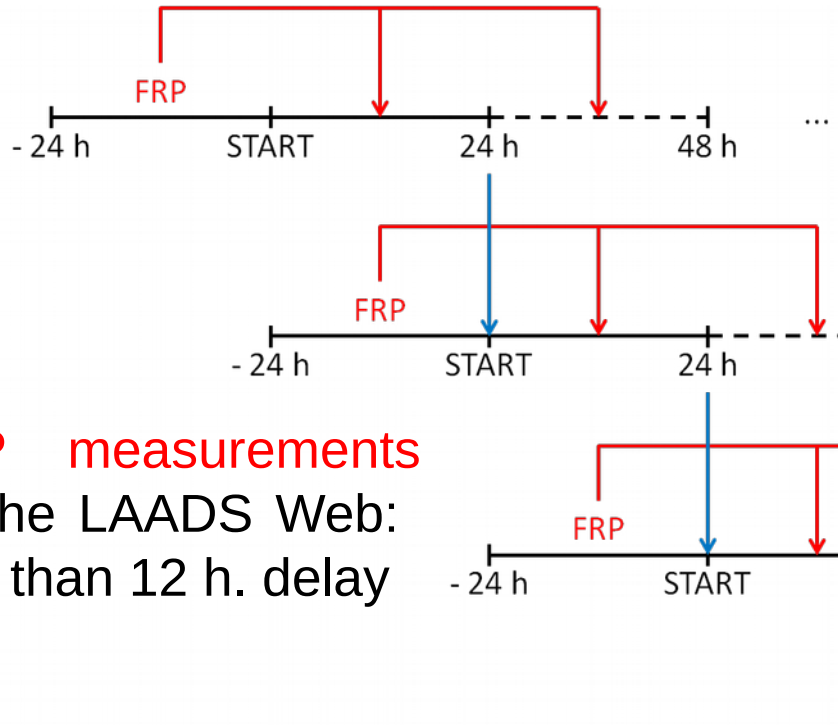
EMISSION OF POLLUTANTS FROM BIOMASS BURNING

The amount and type of emissions during combustion of biomass depends not only on the vegetation type, but also on its moisture content, ambient temperature, humidity, and wind velocity.

Emission of pollutants from biomass burning include primarily:

- CO_2
- CO
- NO_x
- CH_4
- NMVOC
- particulate matter

Operational forecast of the air pollution during forest fire episodes



24 hour forecast used as initial conditions for the next run

FRP measurements on the LAADS Web: less than 12 h. delay

COMPARISON WITH OBSERVATIONS

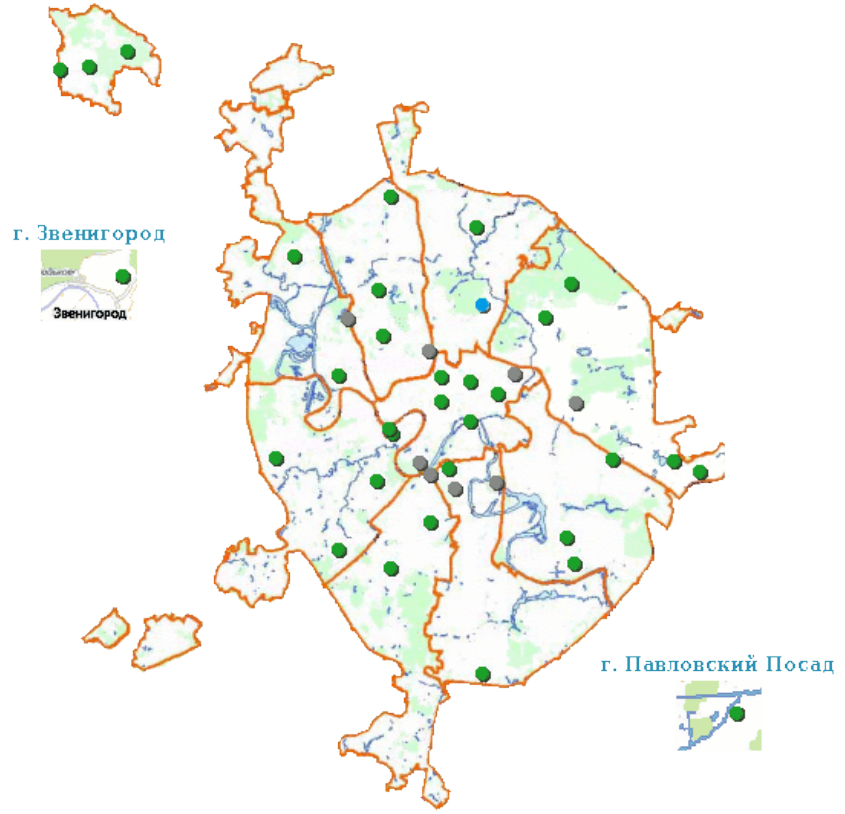
- 22 measuring CO stations
- nearest grid points
- average of all stations
- spatial resolution 1 hour

Calculated:

- ME - mean error (forecast – observation)
- RMSE - root-mean-square error
- CORR - correlation coefficient

For the cases of exceeding MPC*:

- POD - Probability of Detection
- FAR - False Alarm Rate
- FBI - Frequency Bias Index
- TSS - True Skill Statistics
- TS - Threat Score
- ETS - Equitable Threat Score



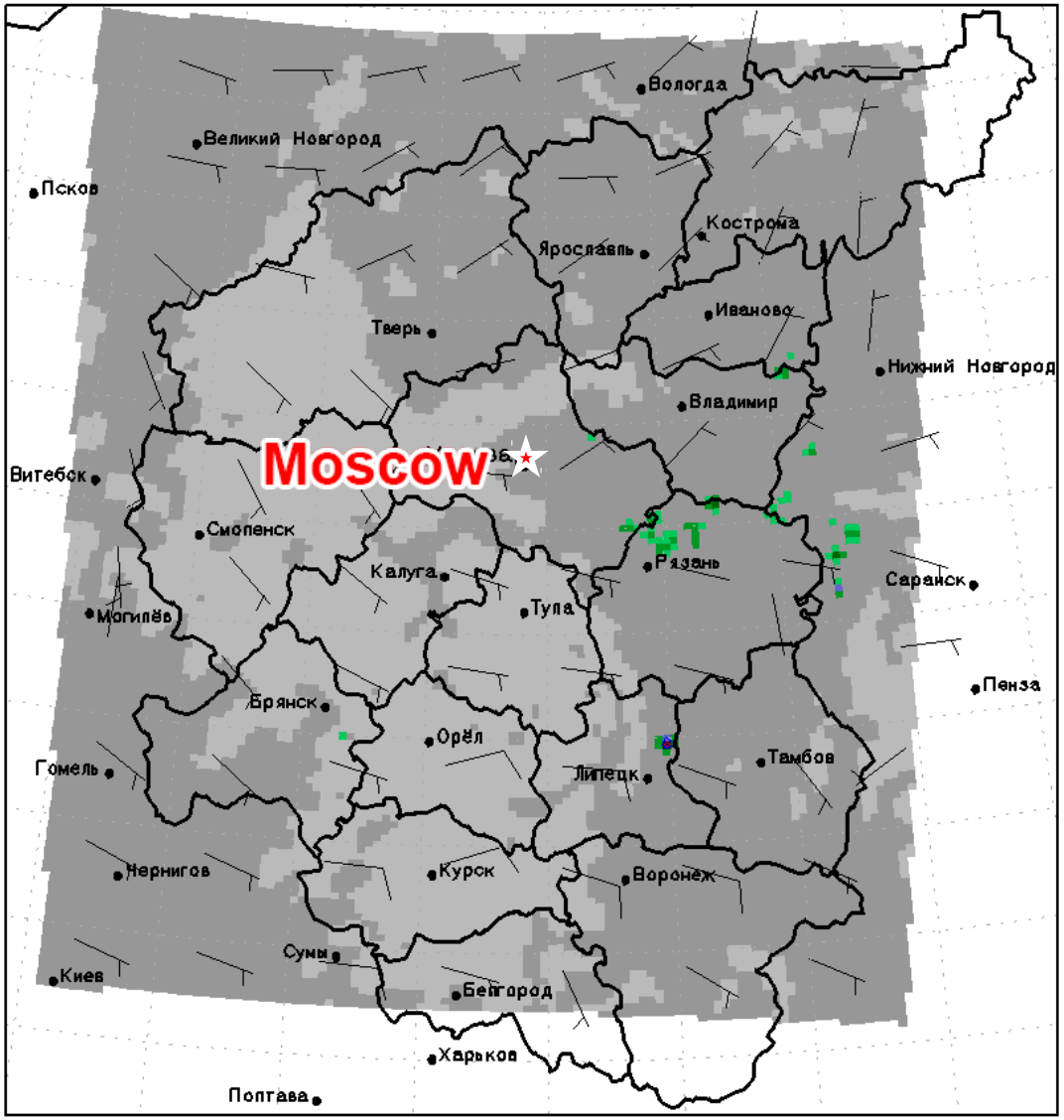
"Mosecomonitoring" station network

*MPC - Maximum Permissible Concentration

4 – 12 august 2010 year
forecast on 24 hour from 00UTC

CO CONCENTRATION FORECAST

00:00 04AUG2010 (UTC) Concentration CO, ppm

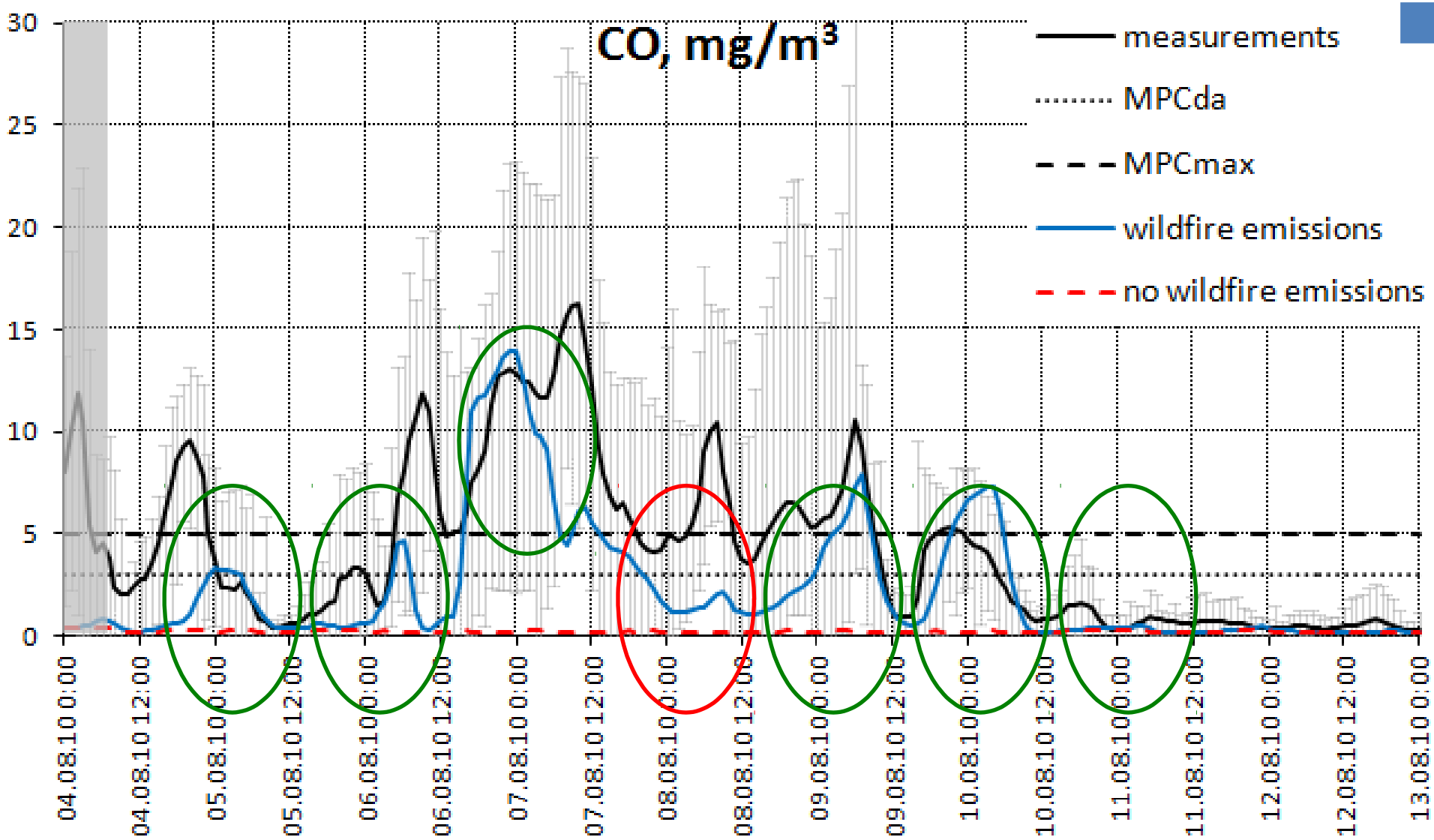


- high spatial variability
- highest concentrations in Moscow when air pollution plumes pass through city
- transfer to upper levels during midday

Forecast on 0ч.
COSMO–RU/ART 7 km

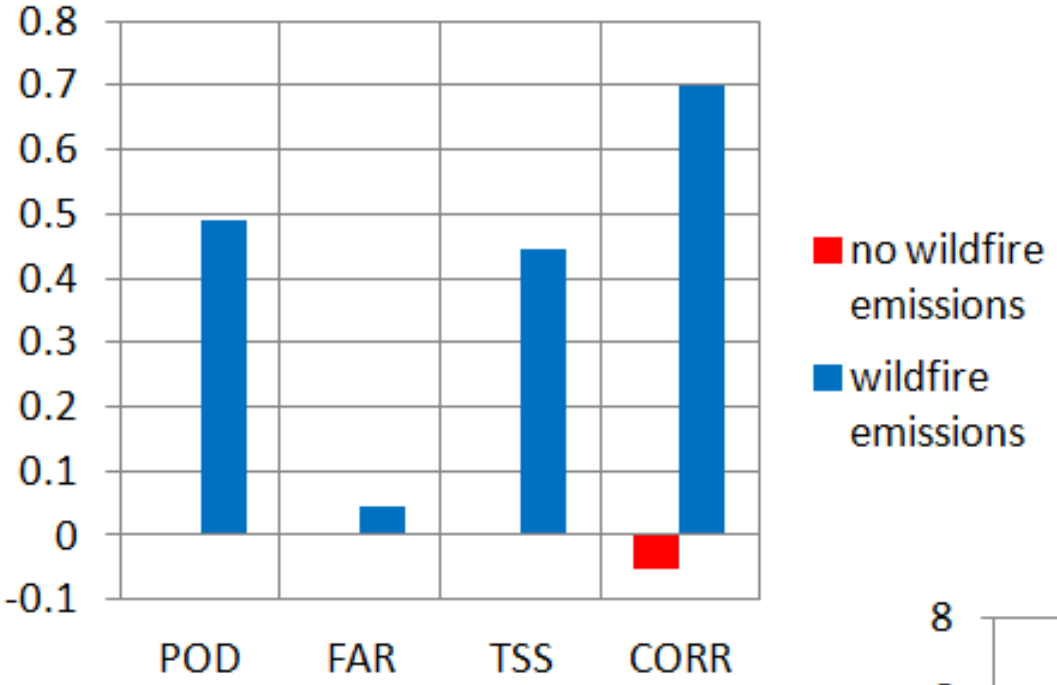
——MPC_{da} ~ 2,6 ppm

CO CONCENTRATION FORECAST

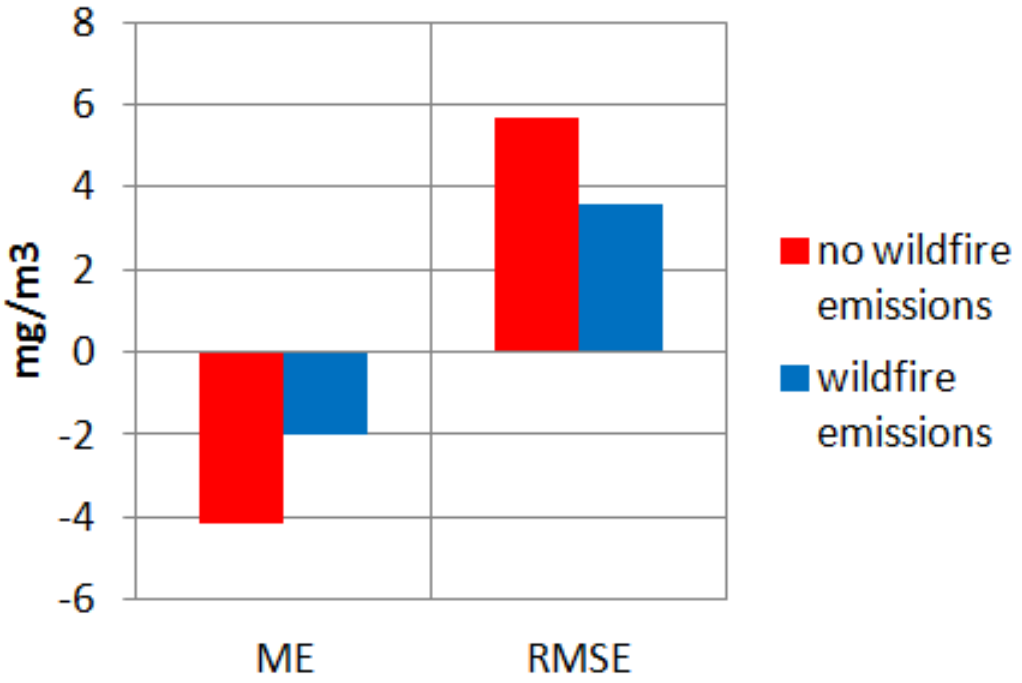


- MPCda – maximum permissible concentration daily averaged = 3 mg/m^3
- MPCmax – maximum permissible concentration 20 min. averaged = 5 mg/m^3

CO CONCENTRATION FORECAST SCORES

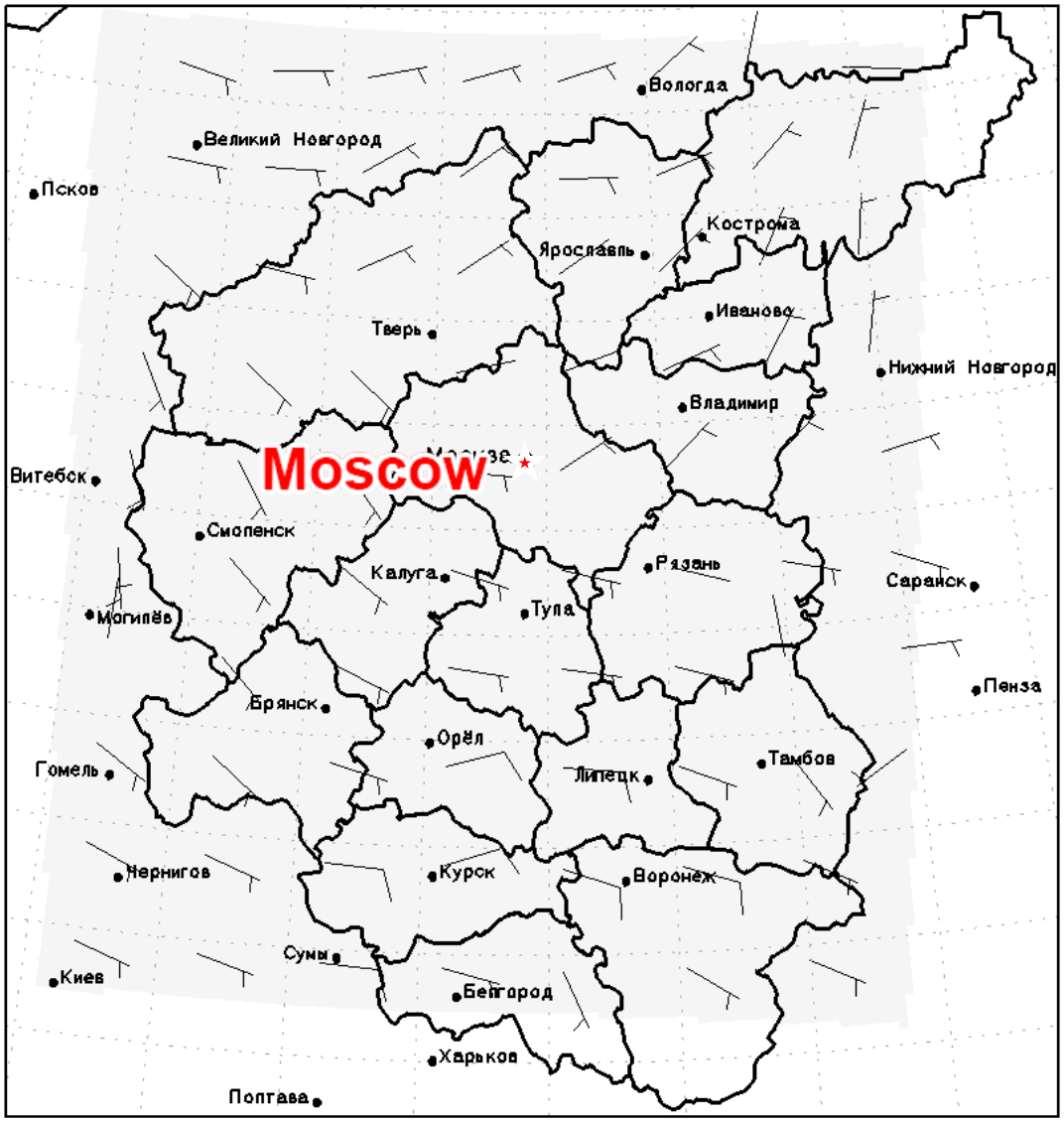


- without pyrogenic emissions no cases of exceeding MPC_{da} were detected
- 211 all station average pairs forecast-observation



- no fire emissions – anthropogenic emissions only
- fire emissions – anthropogenic and pyrogenic emissions
- MPC_{da} – maximum permissible concentration daily averaged = 3 mg/m^3

$PM_{2.5}$ CONCENTRATION FORECAST

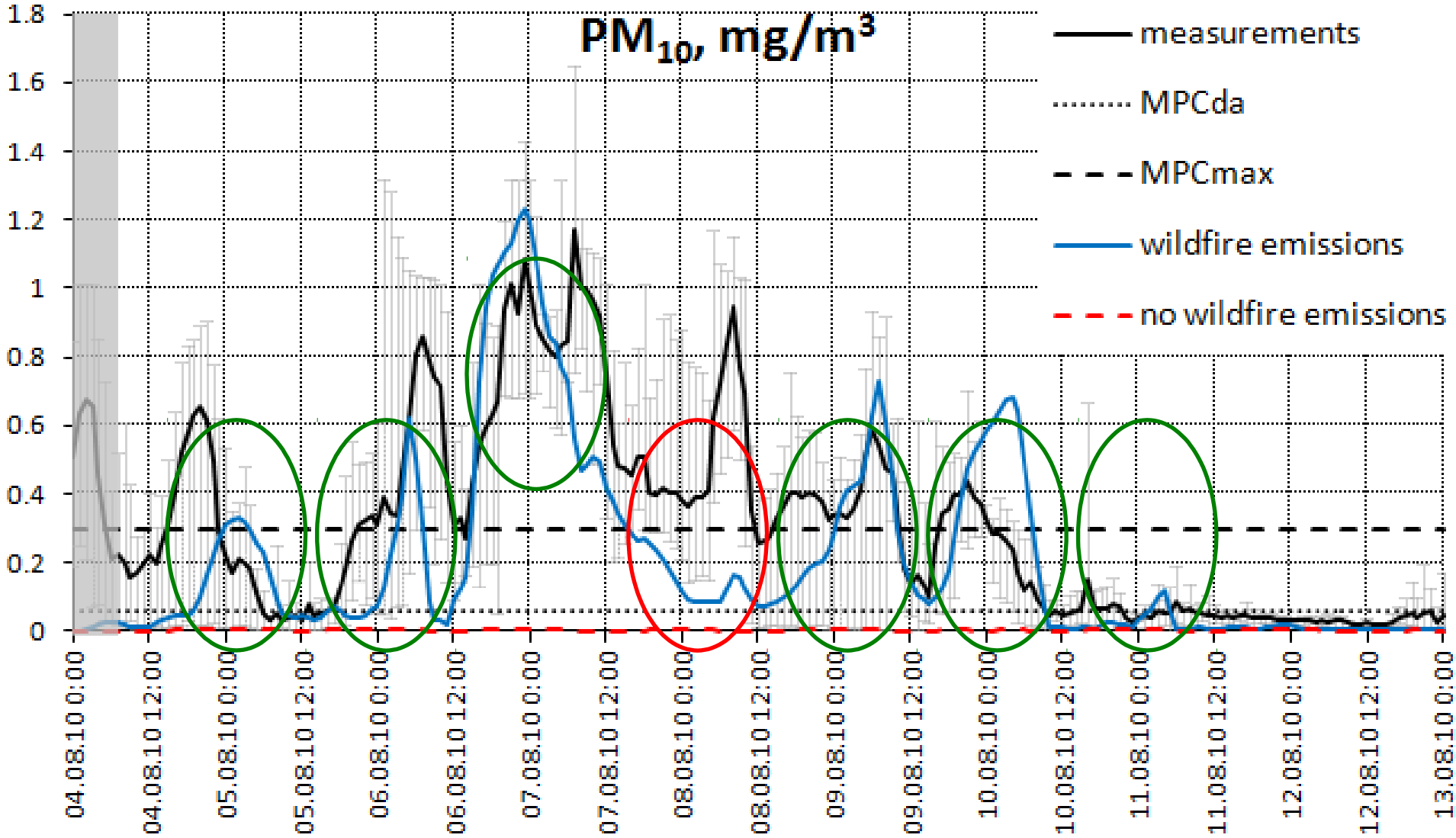


- high spatial variability
- highest concentrations in Moscow when air pollution plumes pass through city
- transfer to upper levels during midday

Forecast on 0ч.
COSMO-RU/ART 7 km

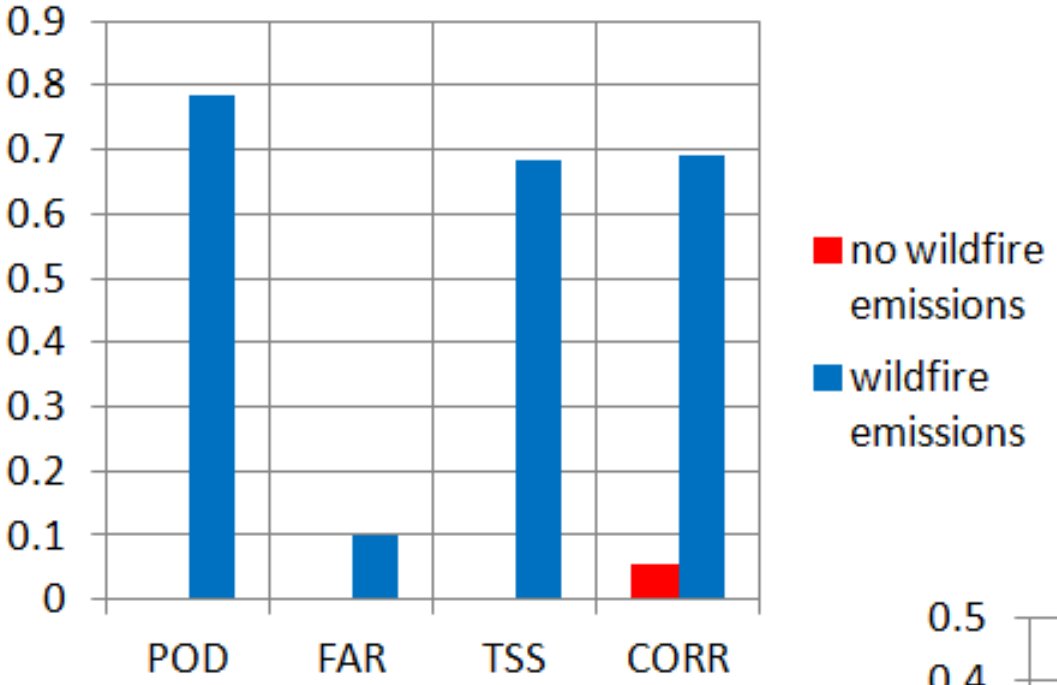
MPC_{da} = 35 μg/m^3

PM_{10} CONCENTRATION FORECAST

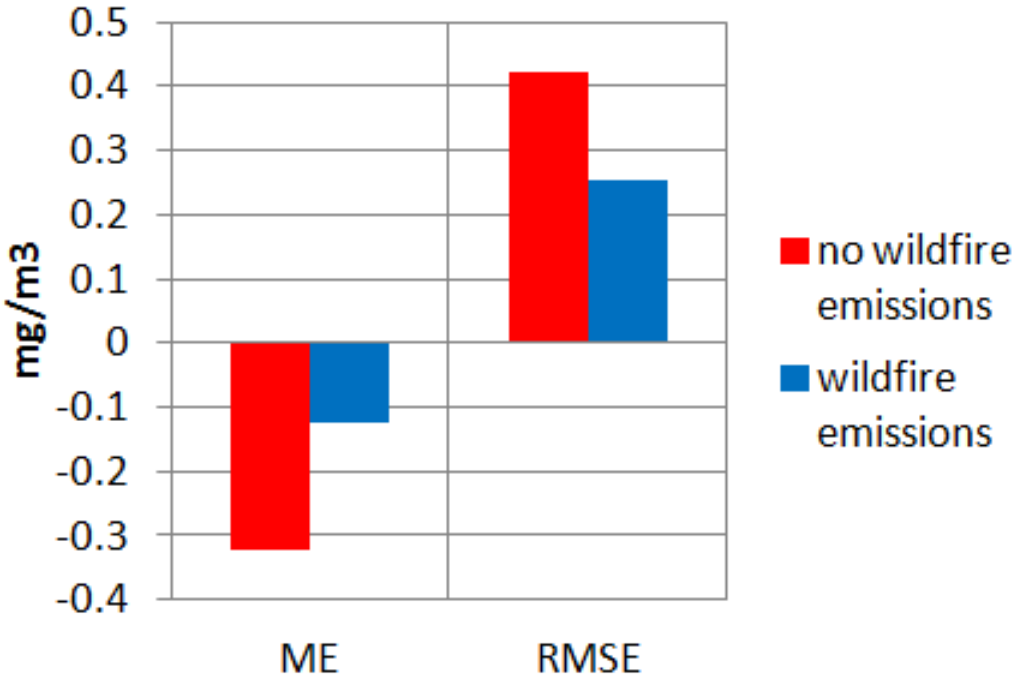


- MPCda – maximum permissible concentration daily averaged = 0.06 mg/m^3
- MPCmax – maximum permissible concentration 20 min. averaged = 0.3 mg/m^3

PM_{10} CONCENTRATION FORECAST SCORES



- without pyrogenic emissions no cases of exceeding MPC_{da} were detected
- 211 all station average pairs forecast-observation



- no fire emissions – anthropogenic emissions only
- fire emissions – anthropogenic and pyrogenic emissions
- MPC_{da} – maximum permissible concentration daily averaged = 0.06 mg/m^3

IMPACT OF AEROSOL-RADIATION INTERACTION ON AIR TEMPERATURE FORECAST

- 4 – 12 august 2010 forecast on 60 hour from 00UTC

- standard verification package for members of COSMO consortium VERSUS (**VER**ification **S**ystem **U**nified **S**urvey) were used

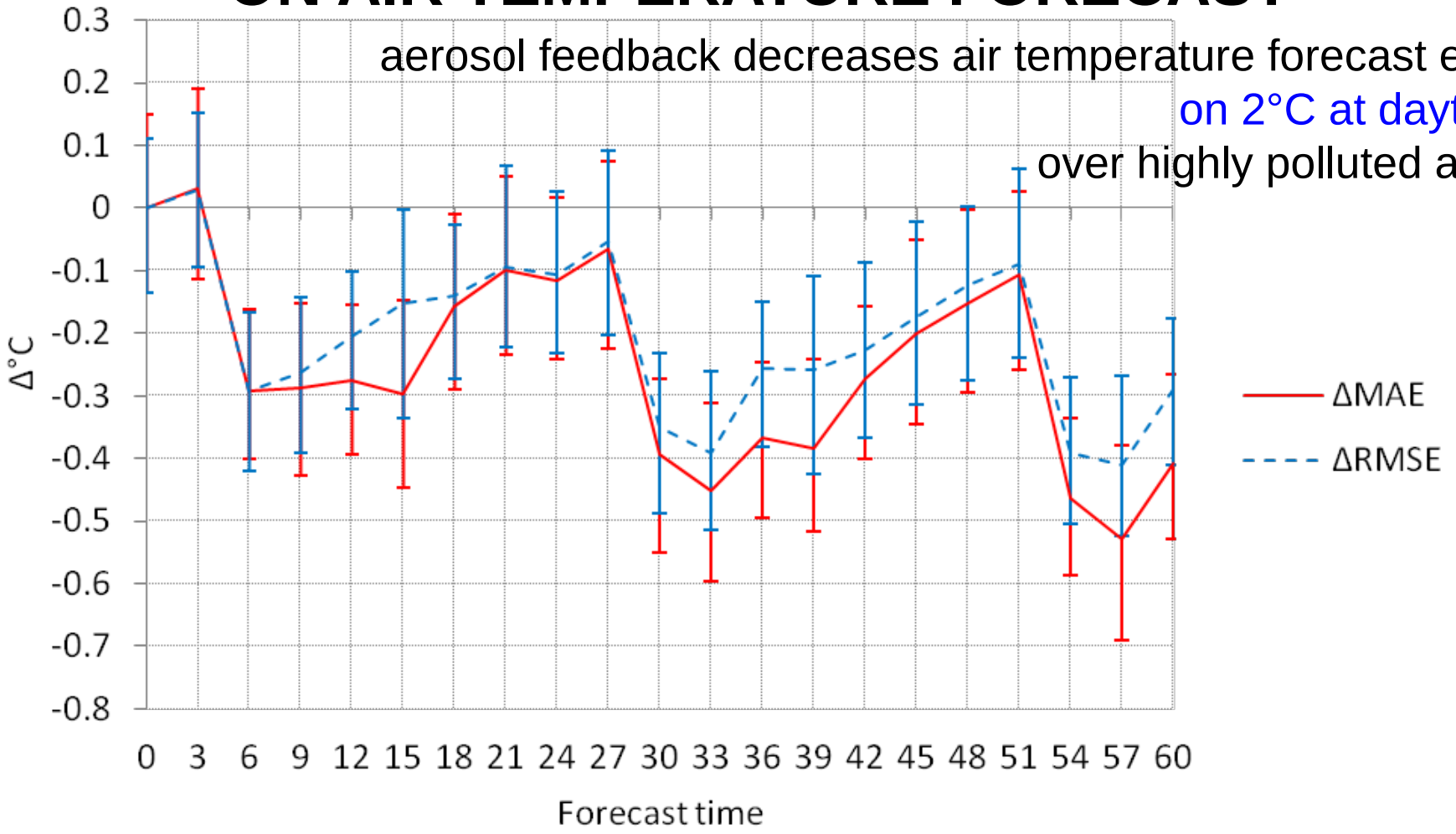
- calculated mean error, mean absolue error and root-mean-square error of forecast over 164 stations in area of 30°E - 45°E, 50°N - 60°N (over all forecast domain, about 1300 pairs forecast-observation for every forecast time)

- calculated confidence intervals with 95% confidence level

- to control the quality of observations method used in the COSMO consortium was implemented: observations were excluded if their difference with forecast exceeded 30° for T2m and Td2m, 25 hPa for PMSL, 50 m/s for wind speed at 10 m

IMPACT OF AEROSOL-RADIATION INTERACTION ON AIR TEMPERATURE FORECAST

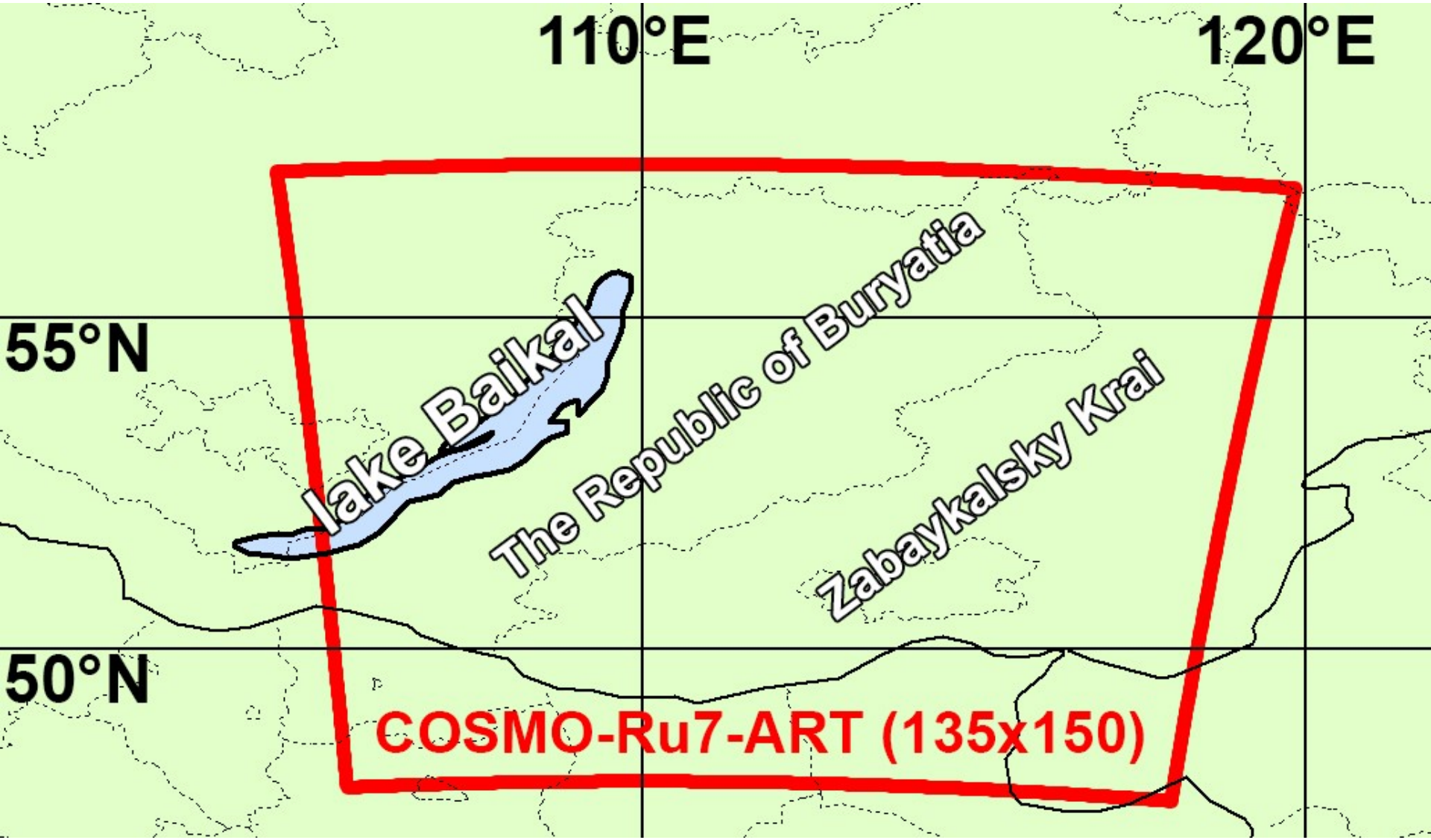
aerosol feedback decreases air temperature forecast error on 2°C at daytime, over highly polluted areas



$$\Delta MAE = MAE_{feedback} - MAE_{control} \qquad \Delta RMSE = RMSE_{feedback} - RMSE_{control}$$

control – experiment without aerosol radiation interaction
feedback – experiment with aerosol radiation interaction

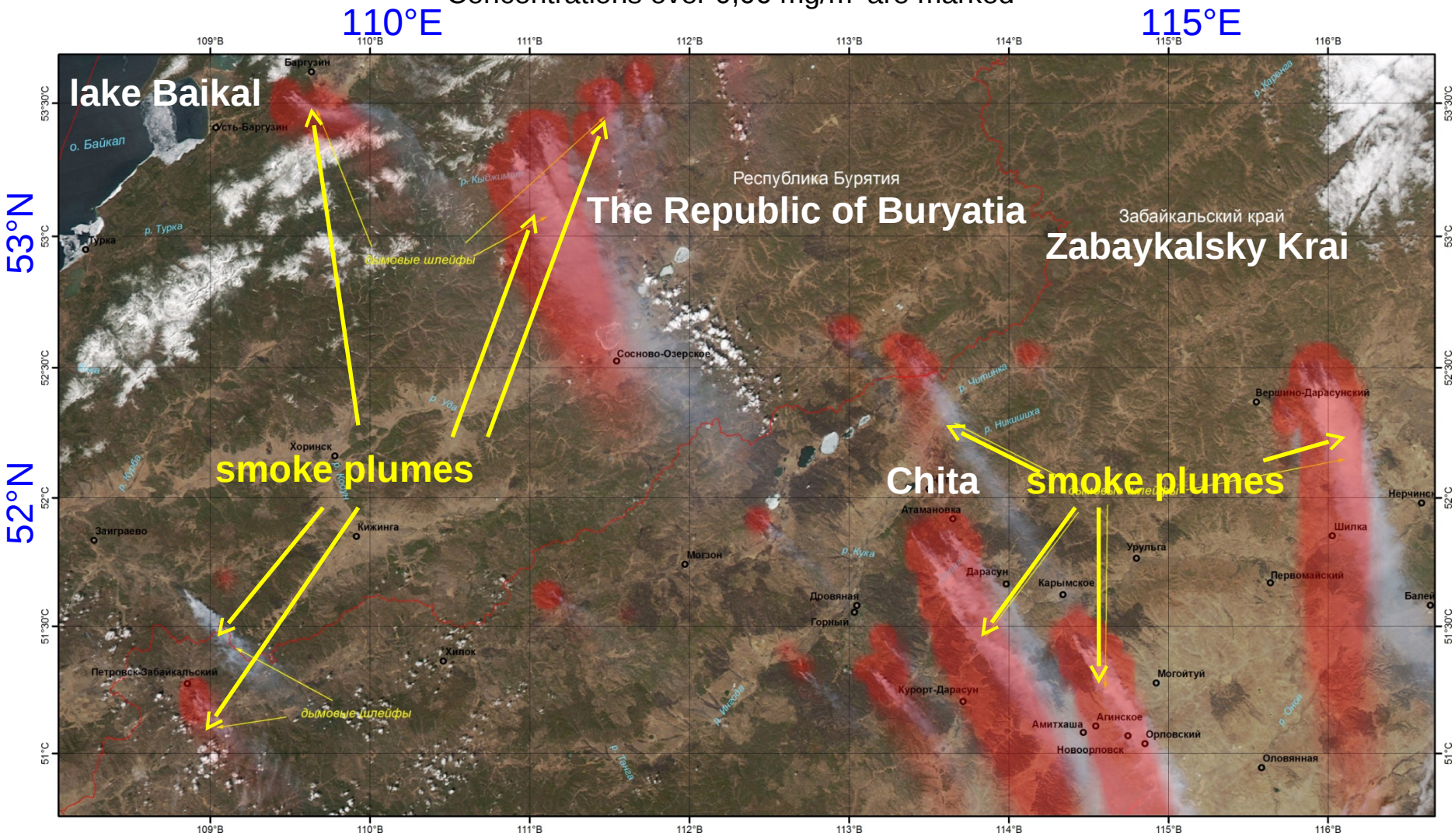
ZABAYKALSKY KRAI AND REPUBLIC OF BURYATIA FORECAST



- forecast on 48 hours from 0:00 UTC 12.05.2015
- no anthropogenic emissions, initial and boundary conditions from ICON

FORECAST OF $PM_{2.5}$ CONCENTRATION (MARKED IN RED) FOR ZABAYKALSKY KRAI AND REPUBLIC OF BURYATIA

Concentrations over 0,06 mg/m³ are marked

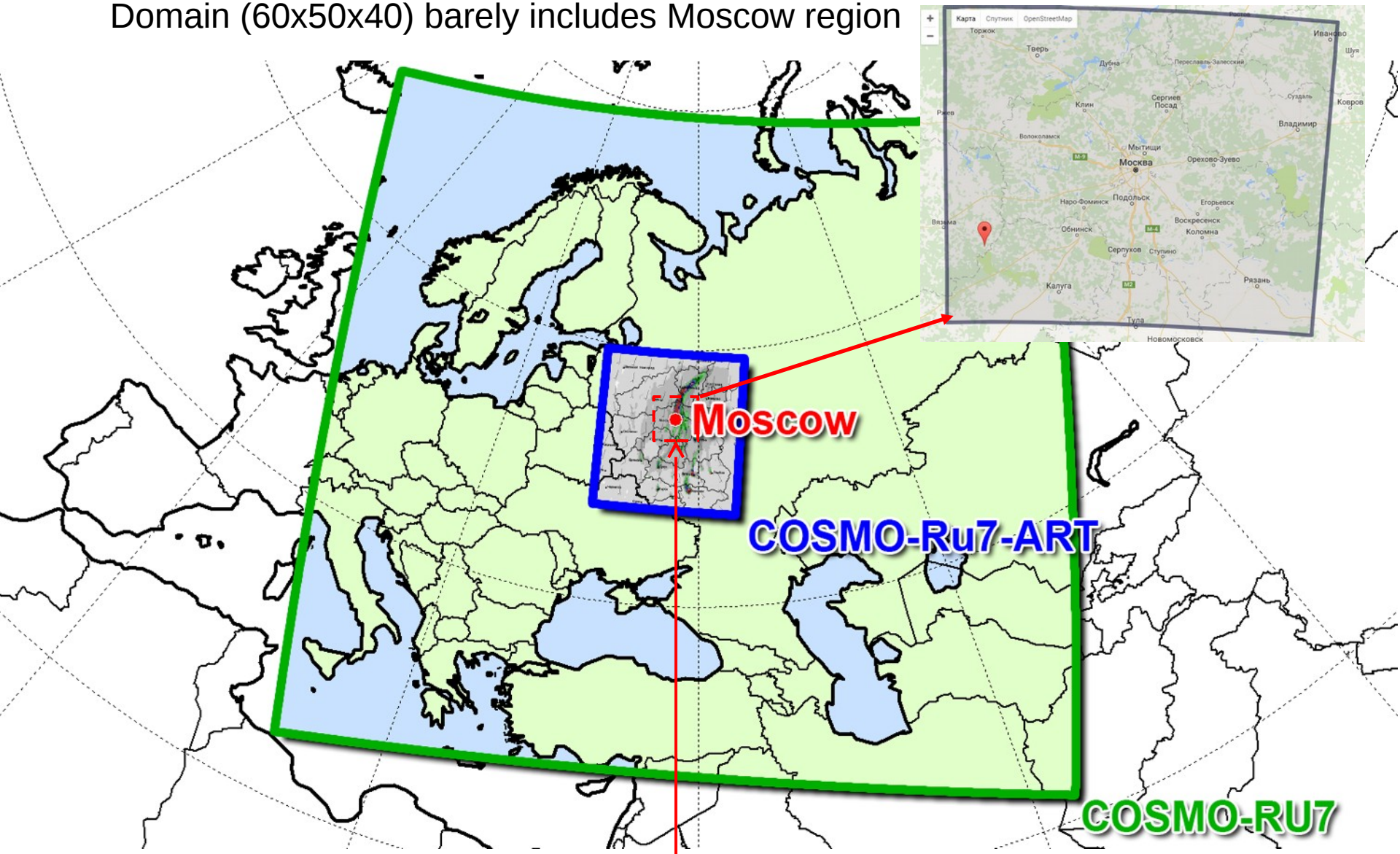


Artificial Earth satellite AQUA/MODIS 13.05.2015 05:26 UTC (SIC “Planet")

Republic of Buryatia, Zabaykalsky Krai

COMPUTATIONAL RESOURCE PROBLEM

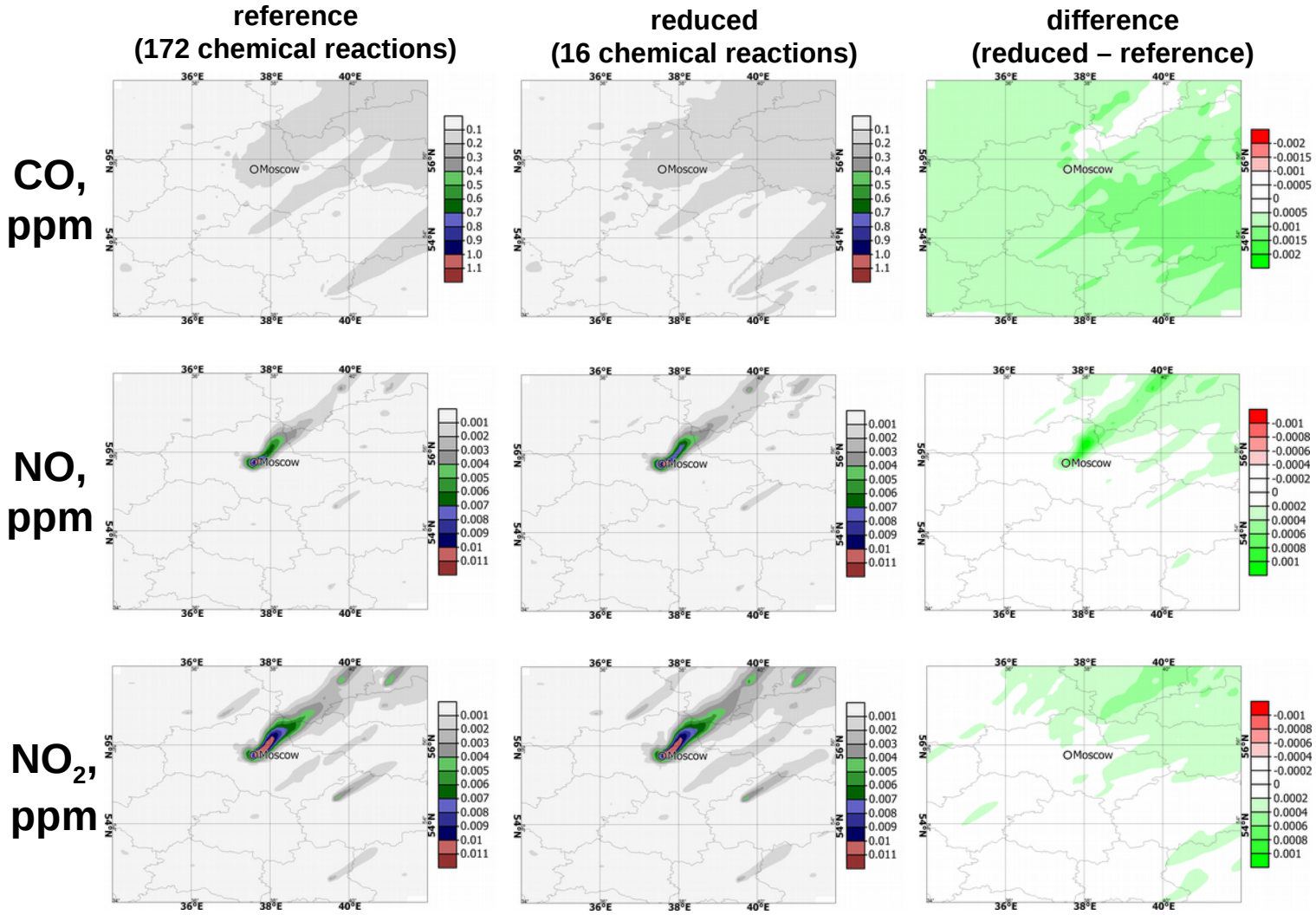
Domain (60x50x40) barely includes Moscow region



Small domain since June 2017

Forecast of COSMO-Ru7-ART with the reduced scheme of chemical reactions

Forecast of trace gases concentration on 11.04.2017, 12:00 UTC



Forecast of COSMO-Ru7-ART with the reduced scheme of chemical reactions

Mean values over one week and difference between the experiments with full and reduced schemes of chemical reactions

	CO	NO	NO_2	O_3
Reference experiment, mean concentrations, ppm	0,20808	0,01565	0,01837	0,01252
Reduced reaction scheme experiment, mean concentrations, ppm	0,20873	0,01621	0,01797	0,0116
Mean difference (16 reaction experiment – reference experiment), ppm	0,00065	0,00056	-0,0004	-0,00092
Difference in %	**0,3**	**3,6**	**-2,2**	**-7,3**

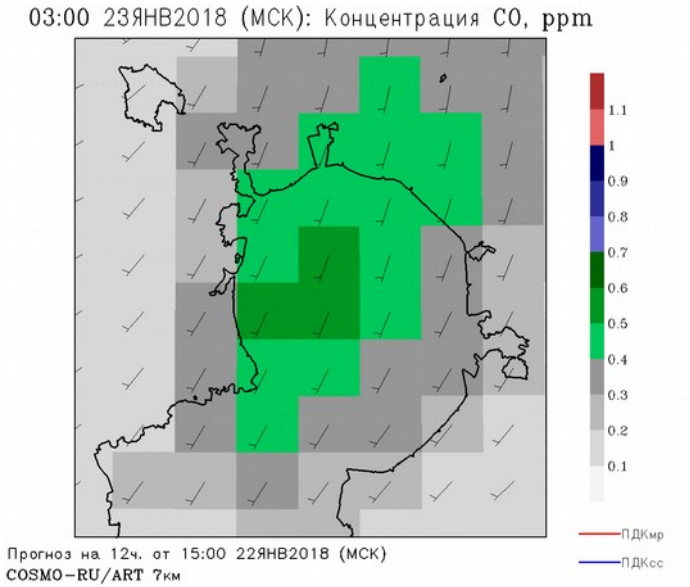
Diurnal variability of pollutant concentrations with full and reduced chemical reaction scheme differ considerably, reduced reaction scheme produces less distinct daily cycle.

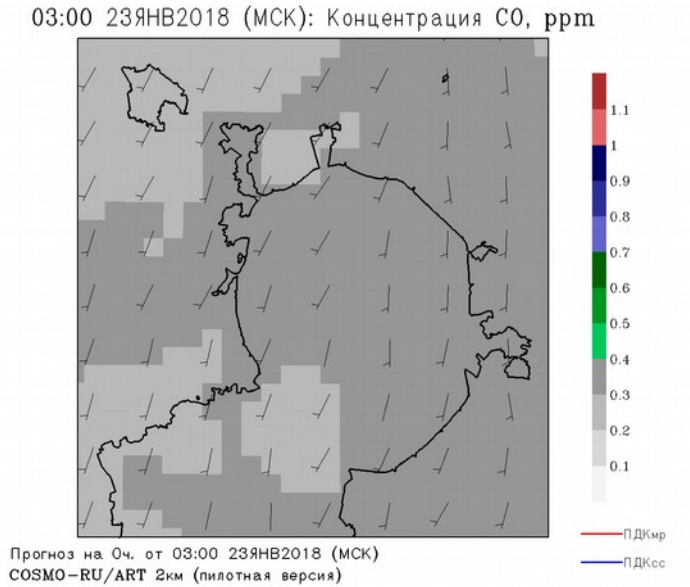
Additional analysis is required (possibly with ICON-ART).

2 KM GRID SPACING TEST RUNS

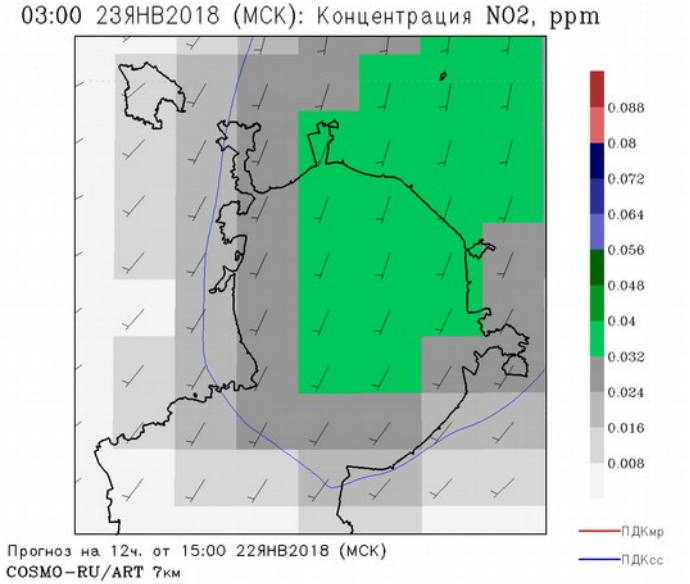
7 KM AND 2 KM

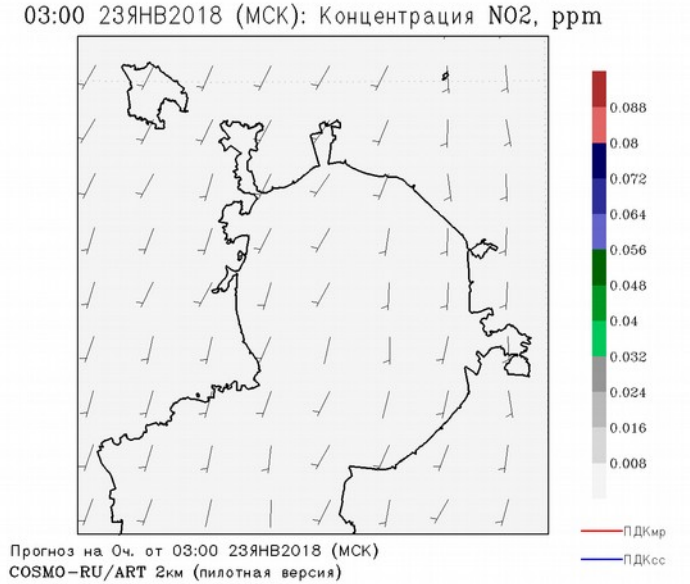
CO





NO_2





CONCLUSIONS

- COSMO-Ru7-ART is the system for operational pollutant concentration forecast for the Moscow region
- Forecasted concentrations are compared to the measurements of “Mosecomonitoring” station network
- Model is capable of producing realistic results, which could be improved with better emission estimations
- Emissions are being estimated and tested using CTMs (chemical transport models), including 2 km emission data
- There is a module for operational estimation of biomass burning emissions
- ART module can improve temperature forecast

FUTURE PLANS

- Running all the experiments we have planned when the new computer becomes available
- ICON-ART and ICON-LAM-ART implementation
- Chemical reaction scheme optimization for our tasks
- Anthropogenic emission correction and estimation
- Aerosol climatology improvement using ART data, comparison with measurements at Meteorological Observatory of Moscow State University
- Initial and boundary conditions optimization
- Pollen forecast
- Doing all the same and more with ICON-LAM-ART

Thank you for your attention!