FORECASTING SYSTEM - ZUGLO

Deliverable D.T2.2.4

Version final
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Municipality of Zugló

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Description of the aims

Forecasting systems (1 per each city) able to announce the SAPEs, to categorize them (per different level of pollution) and to evaluate the realiability and effectiveness of provisional systems (linked to AWAIR-APP D.T2.2.7).

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1. The air quality forecasting system in Budapest

For the regional scale modelling the CHIMERE (2017 version) off-line chemical transport model (Mailler et al., 2017) was applied to simulate the transport and chemical transformations of air pollutants in the lower troposphere in Hungary. The model domain covered the greater Budapest area with a roughly 2.5 km (27 × 25 points) grid resolution. The vertical domain included 8 layers and extended to 500 mbar. The anthropogenic emission database compiled by the Hungarian Meteorological Service (2015) was used with a 0.05⁰ x 0.05⁰ spatial resolution. Monthly emissions of the main pollutants were pre-processed in the CHIMERE suite to fit the simulation grid. The AROME numerical weather prediction model (Szintai et al., 2015) provided the gridded meteorological inputs for the chemical model calculations. The horizontal resolution of the AROME meteorological fields was consistent with the CHIMERE horizontal resolution. The initial conditions were coming from the previous model simulation. Global chemical fields from a reanalysis with the LMDz4-INCA3 model were used as boundary conditions for the model top and lateral borders.

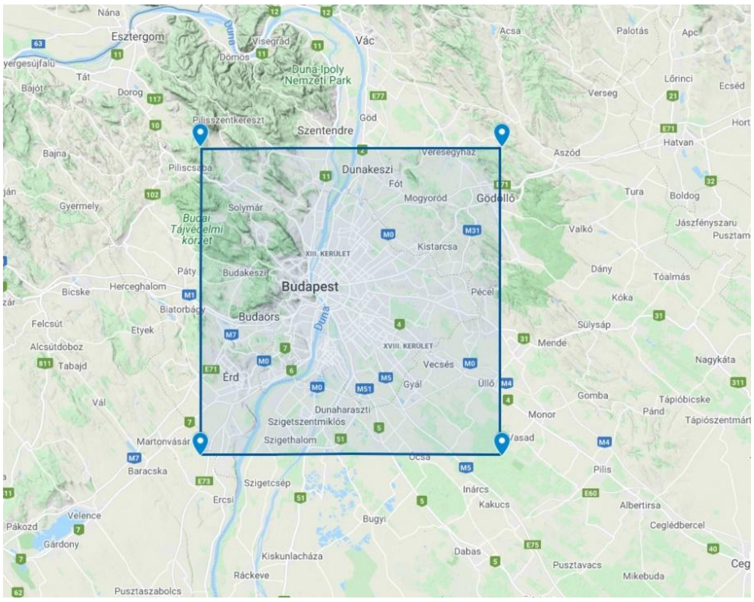


Figure 1: CHIMERE model domain.

References:

Mailler S., L. Menut, D. Khvorostyanov, M. Valari, F. Couvidat, G. Siour, S. Turquety, R. Briant, P. Tuccella, B. Bessagnet, A. Colette, L. Letinois, and F. Meleux, CHIMERE-2017: from urban to hemispheric chemistry-transport modeling , Geosci. Model Dev., 10, 2397-2423, https://doi.org/10.5194/gmd-10-2397-2017.

Szintai, B., M. Szűcs, R. Randriamampianina, and L. Kullmann, 2015: Application of the AROME non-hydrostatic model at the Hungarian Meteorological Service: physical parameterizations and ensemble forecasting. Időjárás, 119, 241–265.

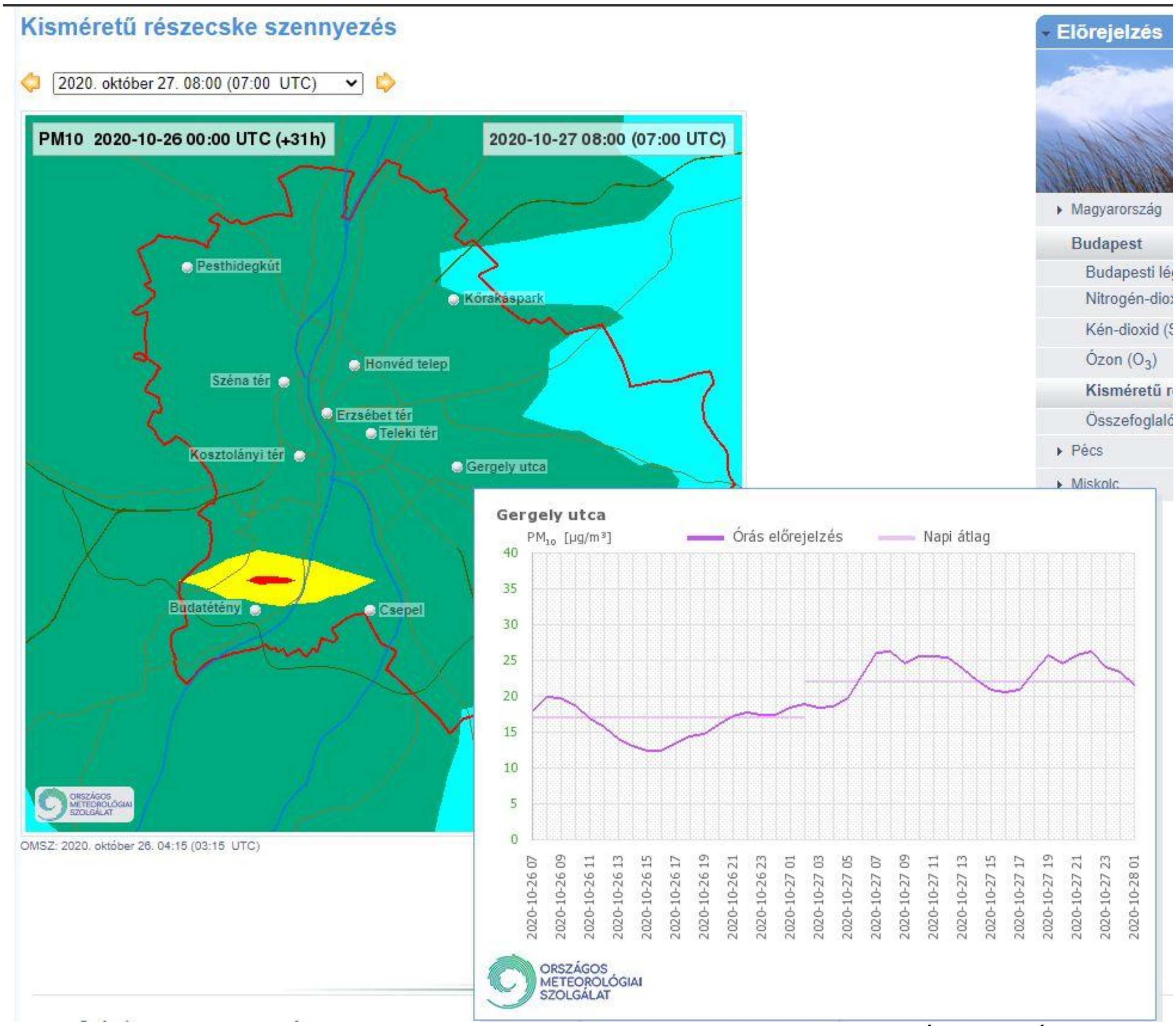
Name of the forecasting system	CHIMERE chemical transport model
Emission input	OMSZ (Hungarian Meteorological Service) emission database
Meteorological input	WRF/AROME
Spatial domain	Budapest
Spatial resolution	0.05° x 0.05° ~ 3,8 x 5,5 km
Type of output	Concentration maps, graphs and tables
Temporal domain of forecasts	36 hours
Postprocessing	HAWK (Hungarian Advanced WorKstation) workstation
Forecasted pollutants	PM10, SO2, NO2, O3
Metrics used for PM10	hourly mean/daily mean
Metrics used for PM2.5	-
Metrics used for NO2	hourly mean
Metrics used for O3	hourly mean/8-hours mean
Metrics used for SO2	hourly mean
Use of air quality index	no

The model performes forecasting every early morning in parameters mentioned above.

The website of Hungarian Meteorological Service (OMSZ)

https://met.hu/levegokornyezet/varosi_legszennyezettseg/elorejelzes/budapest/no2/

shows the predicted air quality of 4 pollutants in a map of Budapest in 1 hour resolution. Pointing a location (which is one of an immission monitoring stations) the website shows a graph about the predicted air quality from the recent time to the end of the last computed forecasting period (see an example in the following picture).

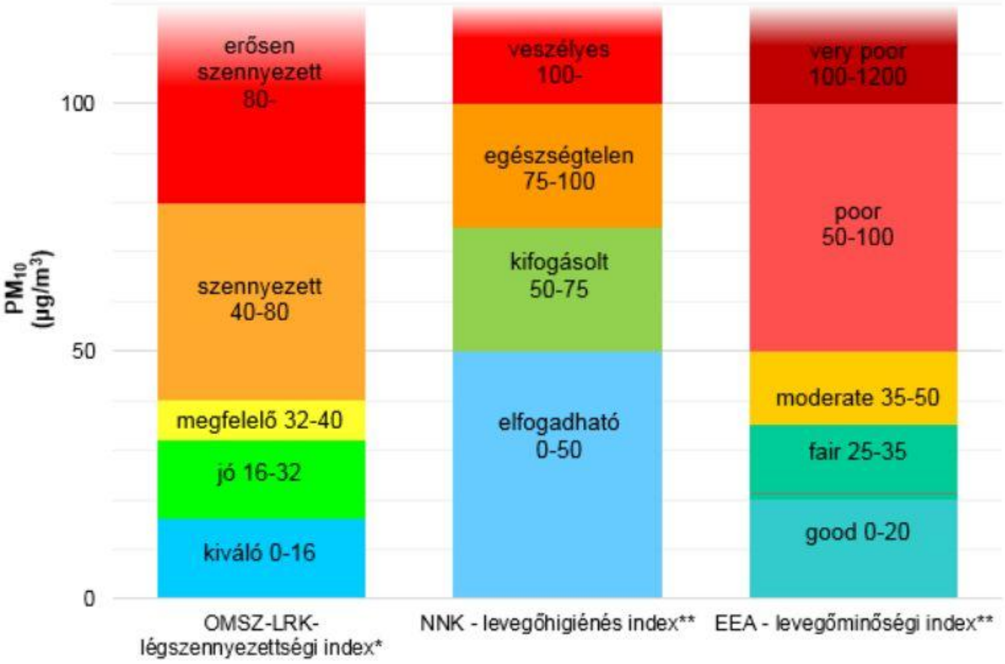


In AWAIR project we ordered forecasting data for a location of Zugló (Bosnyák square) where unfortunately there is no monitoring station.

2. The air quality index

In Hungary officially there is no evaluation in Air Quality Index.

The OMSz and the National Healthcare Institute (NNK) use different color scale in evaluation of air quality:



* in based on yearly average ** in based on daily averages

Our goal in the the AWAIR project to achieve the general use of EEA AQI:

Pollutant	Index level (based on pollutant concentrations in µg/m3)					
	Good	Fair	Moderate	Poor	Very poor	Extremely poor
Particles less than 2.5 µm ($PM_{2.5}$)	0-10	10-20	20-25	25-50	50-75	75-800
Particles less than 10 µm (PM_{10})	0-20	20-40	40-50	50-100	100-150	150-1200
Nitrogen dioxide (NO_2)	0-40	40-90	90-120	120-230	230-340	340-1000
Ozone (O_3)	0-50	50-100	100-130	130-240	240-380	380-800
Sulphur dioxide (SO_2)	0-100	100-200	200-350	350-500	500-750	750-1250

3. Performance of the forecasting system in the Zugló FUA

AWAIR partnership agreed in assessing the performance of the forecasting systems used in the three FUAs using a common set of indicators.

The specific set of indicators, in addition to Pearson correlation coefficient calculated between measured and forecasted concentration of PM_{10}, partners agreed on two selected sets of statistical indices. The first group includes Mean Error (ME, which corresponds to the bias), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE) calculated with the following formulas (where predicted and observed daily values are indicated as P_i and O_i, respectively):

$$ME = \frac{1}{N}\sum_i (P_i - O_i)$$

$$MAE = \frac{1}{N}\sum_i |P_i - O_i|$$

$$RMSE = \sqrt{\frac{1}{N}\sum_i (P_i - O_i)^2}$$

The second group focuses on the performance of the forecasting system in predicting PM_{10} exceedances at different thresholds (50, 75 and 100 $\mu g/m^3$) and includes indices based on a contingency tables. The selected indices are Probability Of Detection (POD), False Alarm Ratio (FAR) and Threat Score (TS). Here below the definitions:

$$POD = \frac{A}{A + C}$$

$$FAR = \frac{B}{A + B}$$

$$TS = \frac{A}{A + B + C}$$

where “A”, “B”, “C” are the entries of the 2x2 contingency table and stand for the number of “hits” (events observed and predicted), “false alarms” (events predicted, but not observed) and “misses” (events observed, but not predicted) at each selected threshold.

Municipality of Zugló ordered an assessments about the model performance from the Hungarian Meteorological Service (who runs the CHIMERE model). They calculated the 6 statistical indicator (see above) and report in every 3 months.

The first performance assessment was based on period of July 2020 – October 2020.

The script computes the BIAS, MAE and RMSE indices every day from the daily means of the predicted and the observed data, for example:

PM_{10} (daily mean) **station: Teleki tér**

date	O_DailyMean	P_DailyMean		BIAS	MAE	RMSE
2020. 7. 9. 0:00	32,25	10,63		-21,6227	21,6227273	467,5423
2020. 7. 10. 0:00	34,72	11,07		-23,6492	23,6491667	559,2831
2020. 7. 11. 0:00	10,72	12,86		2,138333	2,1383333	4,572469
2020. 7. 12. 0:00	13,32	15,21		1,888333	1,8883333	3,565803
2020. 7. 13. 0:00	63,06	11,94		-51,1139	51,1138889	2612,63
2020. 7. 14. 0:00	24,13	15,04		-9,08333	9,0833333	82,50694

etc.

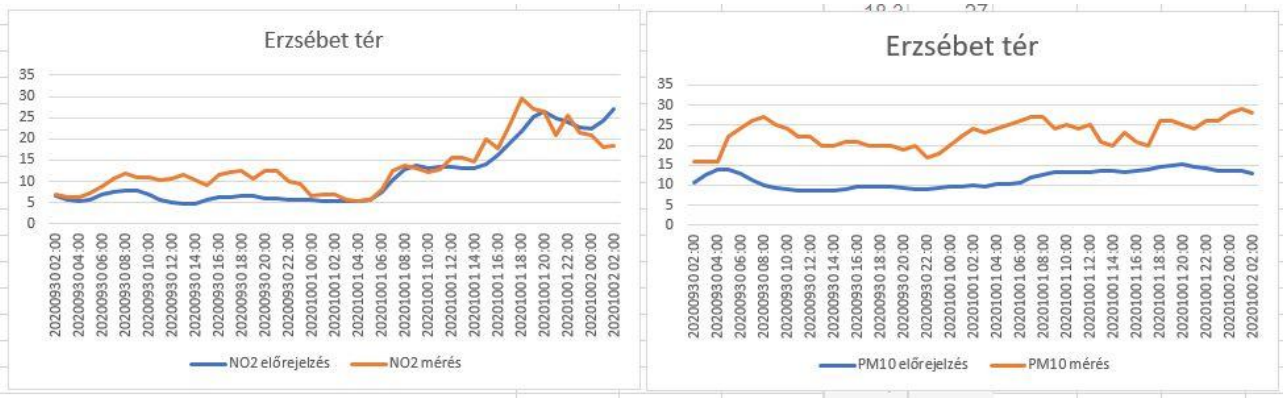
O: observed; P: predicted

The average of indices of any kind of period can be calculated from the daily data:

The averages of the last 3 month:

PM_{10} (daily mean)	
RMSE	**20,8**
BIAS	**-14,9**
MAE	**15,7**
NO_2 (hourly mean)	
RMSE	**23,8**
BIAS	**-14,5**
MAE	**18,0**
O_3 (hourly mean)	
RMSE	**47,3**
BIAS	**27,2**
MAE	**40,6**

Evaluation: In this period of the year we didn't have extreme events in the air quality. The CHIMERE model tends to underestimate in case of PM_{10} and NO_2 forecasting and overestimate in case of the O_3 prediction.



1. Figure: Comparation of predicted and observed NO2 and PM10 data in 48 hours period at Erzsébet tér monitoring station

The second calculation focuses on the prediction of

- PM_{10} exceedances at different thresholds (50, 75 and 100 µg/m^3)
- NO_2 exceedances at different thresholds (100, 350 and 400 µg/m^3)
- O_3 exceedances at different thresholds (120, 180 and 240 µg/m^3)

and computes indices based on a contingency table. The indices are: probability of detection (POD), false alarm ratio (FAR), threat score (TS), and equitable threat score (ETS).

Contingency table		
	Observation	
Forecasting	Yes	No
Yes	A	B
No	C	D

A	correct alarm	The event was predicted end happenned
B	false alarm	The event was predicted but not happenned
C	not predicted alarm	The event was not predicted but happenned
D	correct prediction	The event was not predicted and not happenned

Results of the last 3 months (station: Teleki tér)

PM_{10}	50 µg/m^3	
	Observation	
Forecasting	Yes	No
Yes	0	0
No	6	74

NO_2	100 µg/m^3	
	Observation	
Forecasting	Yes	No
Yes	0	1
No	19	1939

O_3	120 µg/m^3	
	Observation	
Forecasting	Yes	No
Yes	5	38
No	21	1873

PM_{10} (daily mean above 50 NO_2 (hourly mean above 100 O_3 (hourly mean above 120 µg/m³)

POD	HAMIS
FAR	NaN
TS	0
ETS	0

µg/m³)

POD	0
FAR	1
TS	0
ETS	0

µg/m³)

POD	0,2
FAR	0,9
TS	0,1
ETS	0,1

PM_{10} 75 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	1	79

NO_2 350 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	0	1959

O_3 180 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	0	1937

PM_{10} (daily mean above 75 µg/m³)

POD	0
FAR	NaN
TS	0
ETS	0

NO_2 (hourly mean above 350 µg/m³)

POD	NaN
FAR	NaN
TS	NaN
ETS	NaN

O_3 (hourly mean above 180 µg/m³)

POD	NaN
FAR	NaN
TS	NaN
ETS	NaN

PM_{10} 100 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	0	80

NO_2 400 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	0	1959

O_3 240 µg/m³

Forecasting	Observation	
	Yes	No
Yes	0	0
No	0	1937

PM_{10} (daily mean above 100 µg/m³)

POD	NaN
FAR	NaN
TS	NaN
ETS	NaN

NO_2 (hourly mean above 400 µg/m³)

POD	NaN
FAR	NaN
TS	NaN
ETS	NaN

O_3 (hourly mean above 240 µg/m³)

POD	NaN
FAR	NaN
TS	NaN
ETS	NaN

Evaluation: In this period of the year we hadn't many exceedances at different thresholds, we got only a few cases of alarm predictions (at the lowest level). In case of O_3 the results are not too promising (FAR=0,9; TS=0,1).

In our opinion much longer period is needed to evaluate the performance of the running model. Probably we'll get more informative general aspect after the winter season. We are going to refresh this report in February.