



# Evaluation of ozone forecasts of ALARO-CAMx and WRF-Chem

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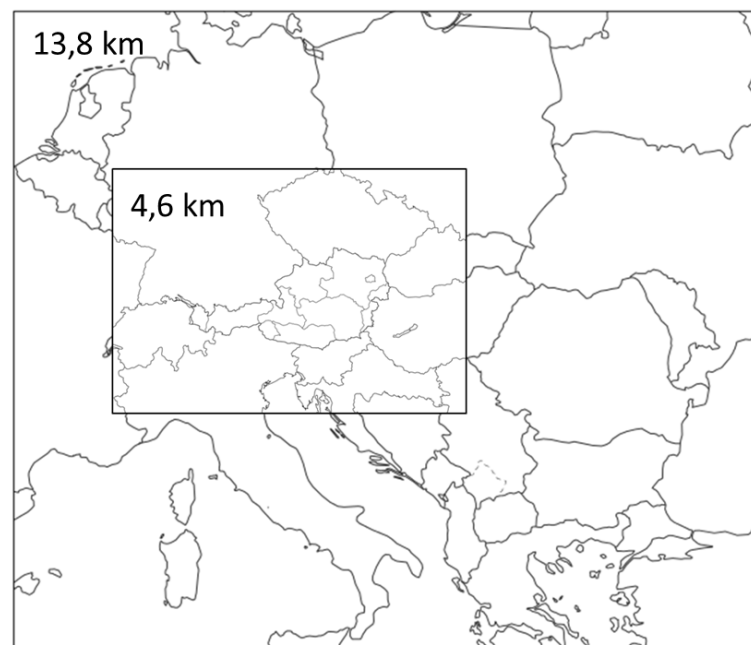
**ZAMG**  
Zentralanstalt für  
Meteorologie und  
Geodynamik

ZAMG runs two models for air-quality forecasts operationally:  
ALARO-CAMx and WRF-Chem.

**ALARO-CAMx** is a combination of the meteorological model ALARO and the photochemical dispersion model CAMx and is operated at ZAMG since 2005.

The emphasis of this modeling system is to predict ozone peaks in the north-eastern Austrian flatlands.

The outer model grid covers Central Europe with a resolution of 13.8 km, the inner domain is centered over Austria with a resolution of 4.6 km. The model runs twice per day for a period of 48 hours.

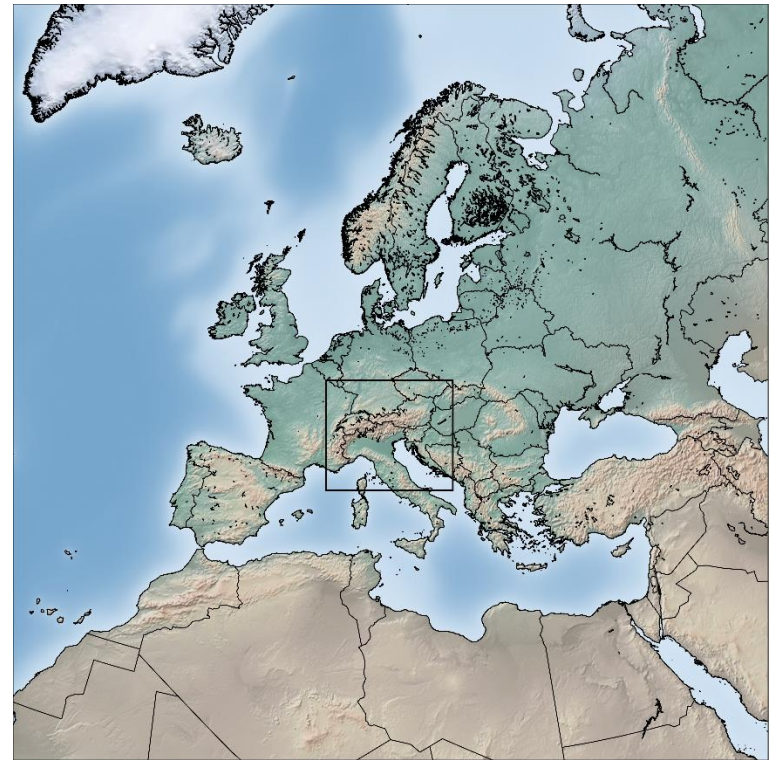


The second operational air quality model at ZAMG is the on-line coupled model **WRF-Chem**.

Meteorology is simulated simultaneously with the emission, turbulent mixing, transport, transformation as well as the fate of trace gases and aerosols.

Two modeling domains are used for these simulations. The outer domain covers Europe with a resolution of 12 km x 12 km. The nested domain covers the Alpine region with a horizontal resolution of 4 km x 4 km.

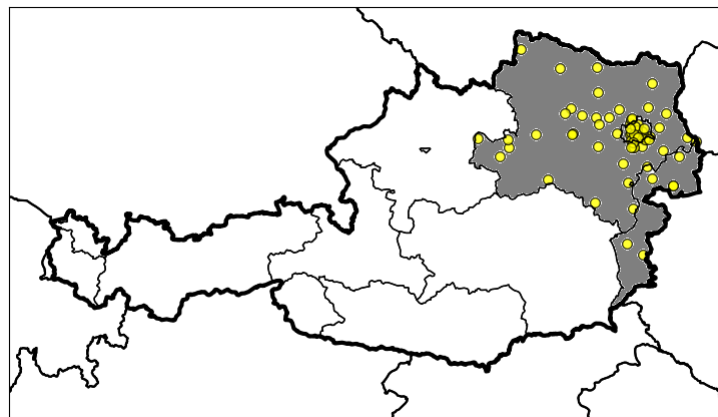
The model runs two times per day for a period of 72 hours and is initialized with ECMWF forecasts.



The evaluation of both models is conducted for the period from January to September 2019 with the focus on ozone.

The summer 2019 was the 2<sup>nd</sup> warmest summer since the beginning of the meteorological measurements in Austria more than 200 years ago. Although this summer had favorable conditions for ozone production (sunny and hot weather, less rain), only a few air quality stations in Eastern Austria have measured exceedances of the ozone information threshold ( $180 \mu\text{g}/\text{m}^3$ ) on overall 5 days.

The measurements of the air-quality stations are compared with the area forecasts for Eastern Austria. Besides the evaluation, air quality forecasts of ALARO-CAMx and WRF-Chem are compared.



*Measurement stations (yellow dots)  
in Eastern Austria (shaded grey)*

# Comparison of the model systems



	ALARO-CAMx	WRF-Chem
Operational Runs	2x daily with ECMWF initial and boundary conditions	2x daily with ECMWF initial and boundary conditions
On-line / offline coupled model	<u>Offline model:</u> Meteorology (ALARO) is simulated separately from chemistry (CAMx).	<u>On-line coupled model:</u> Meteorology is simulated together with emissions, turbulences, transport and chemical transformations.
Feedbacks	no	yes
Horizontal resolution	4.6 km x 4.6 km	4 km x 4 km
Anthropogenic emissions	Austria: emission inventories from the Austrian federal states Europe: emission inventory from TNO	
Biogenic emissions	SMOKE	MEGAN
Data assimilation	Assimilation of the Austrian ozone and PM10 measurements	-

# Summer 2019

## Meteorological conditions (June to August)

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### ZAMG: „Temperature mean records at some stations“

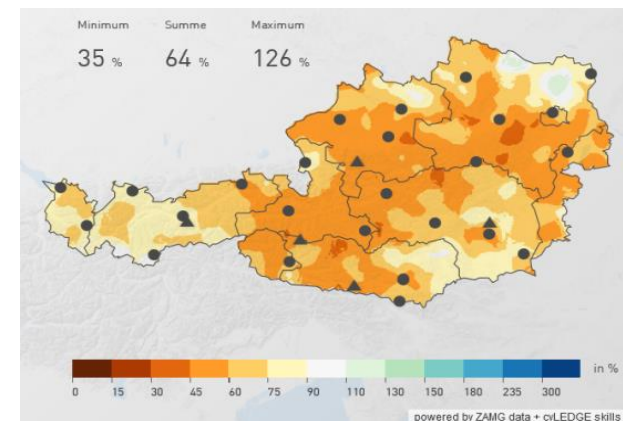
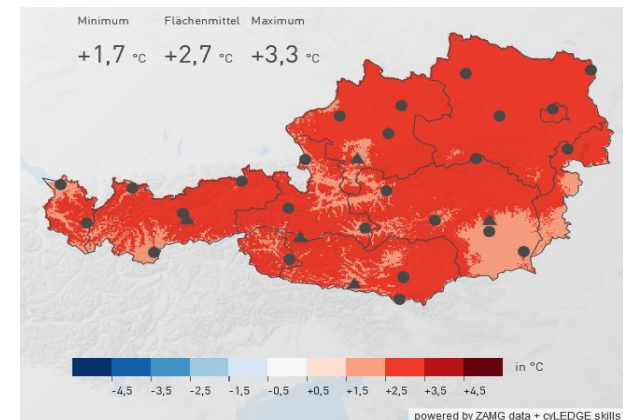
- 2.7 °C above long-term mean (1981 – 2010, upper Figure).
- Compared to the long-term mean, June temperatures were higher than +4.7 °C, July and August only +1.7 °C and +1.9 °C.
- Some of the Austrian meteorological stations have measured the warmest summer since the beginning of the measurements in Austria.

### ZAMG: „Partly new drought records“

- In total, Austria recorded a loss of 36 % precipitation compared to the long-term mean (1981 – 2010, lower Figure)
- June was the driest month since the beginning of the measurements in Austria.

### ZAMG: „sunshine hours above average “

- 10 % more sunshine in Austria
- A plus of 50 % sunshine hours was measured in June compared to the monthly long-term mean.





# Ozone exceedances in Austria



In summer 2019 the information threshold ( $180 \mu\text{g}/\text{m}^3$ ) has been exceeded on overall five days in Austria.

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In Eastern Austria (federal states: Vienna, Lower Austria and Burgenland) four exceedances occurred:

## 27.6.2019

### Burgenland:

- Illmitz ( $183 \mu\text{g}/\text{m}^3$ )

## 26.7.2019

### Vienna:

- Stephansplatz ( $200 \mu\text{g}/\text{m}^3$ )
- Laaer Berg ( $203 \mu\text{g}/\text{m}^3$ )

## 29.8.2019

### Burgenland:

- Kittsee ( $181 \mu\text{g}/\text{m}^3$ )

## 1.7.2019

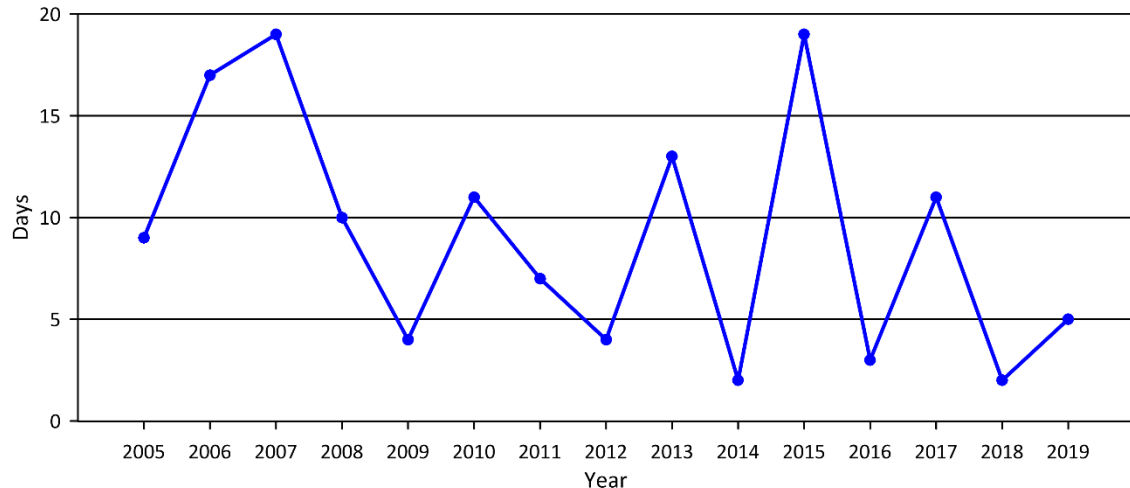
### Lower Austria:

- Wolkersdorf ( $212 \mu\text{g}/\text{m}^3$ )
- Gänserndorf ( $196 \mu\text{g}/\text{m}^3$ )
- Hainburg ( $207 \mu\text{g}/\text{m}^3$ )
- Klosterneuburg ( $226 \mu\text{g}/\text{m}^3$ )
- Mödling ( $190 \mu\text{g}/\text{m}^3$ )

### Vienna:

- Hohe Warte ( $216 \mu\text{g}/\text{m}^3$ )
- Stephansplatz ( $201 \mu\text{g}/\text{m}^3$ )
- Laaer Berg ( $182 \mu\text{g}/\text{m}^3$ )
- Hermannskogel ( $181 \mu\text{g}/\text{m}^3$ )

Days with exceedances of the ozone information threshold in Austria



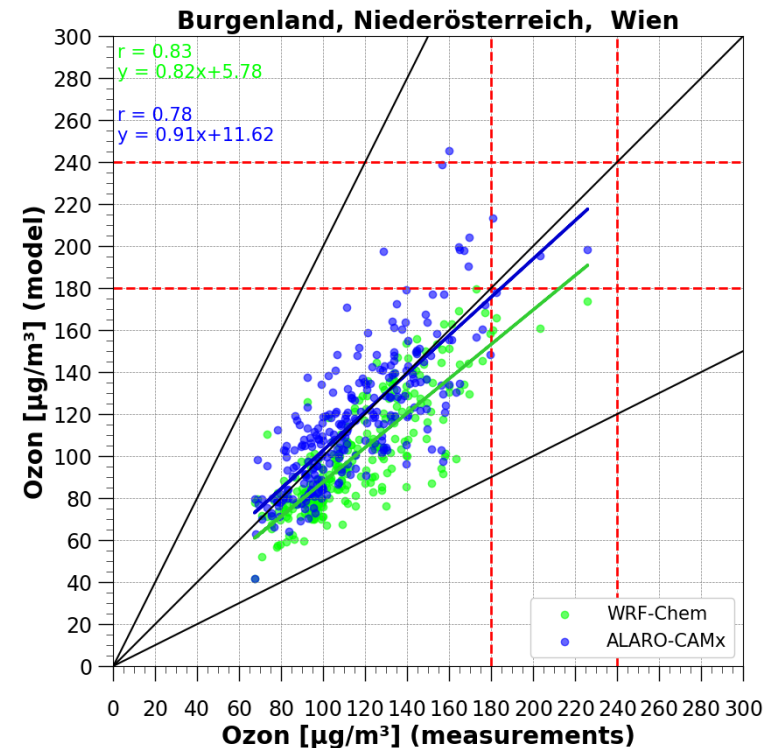
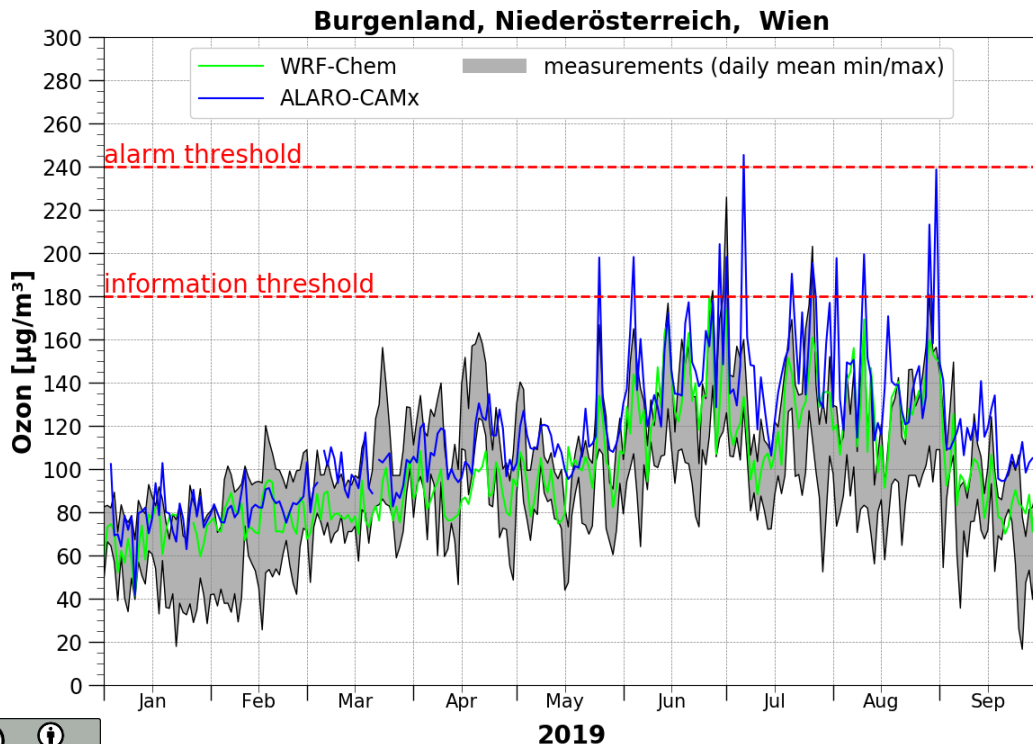
# Evaluation of the ozone forecasts in Eastern Austria

January – September 2019

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The timeseries plot shows the daily maximum of the predicted ozone values in Eastern Austria from the operational model runs (ALARO-CAMx ... blue, WRF-Chem ... green). The shaded area (grey) shows the spread between the maximum and the minimum of the daily maximum values of ozone of all measurement stations in Eastern Austria (Burgenland, Niederösterreich, Wien).

For the scatter plot the maximum of the daily maximum of the measured ozone values in Eastern Austria (top of the shaded grey area in the timeseries plot) has been used.





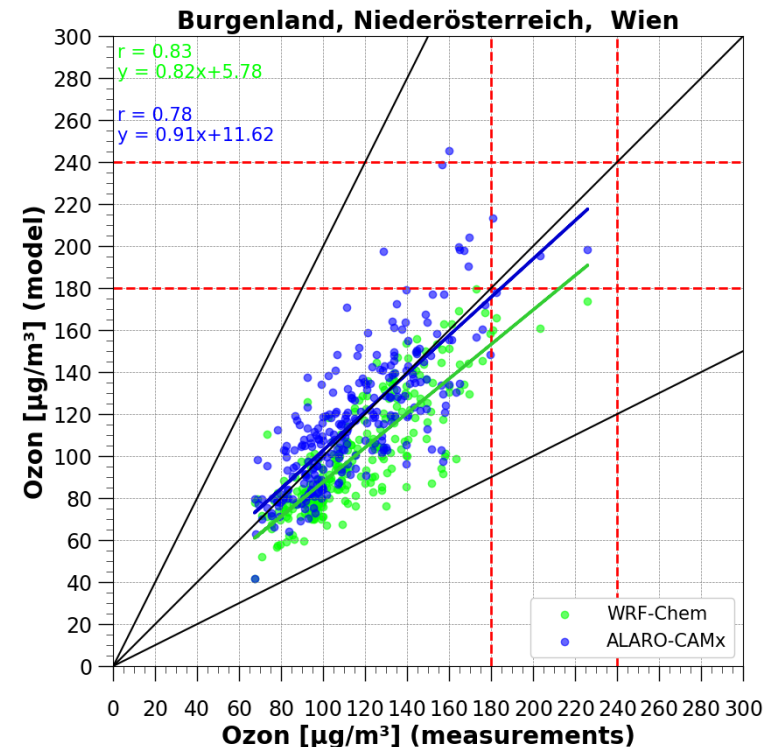
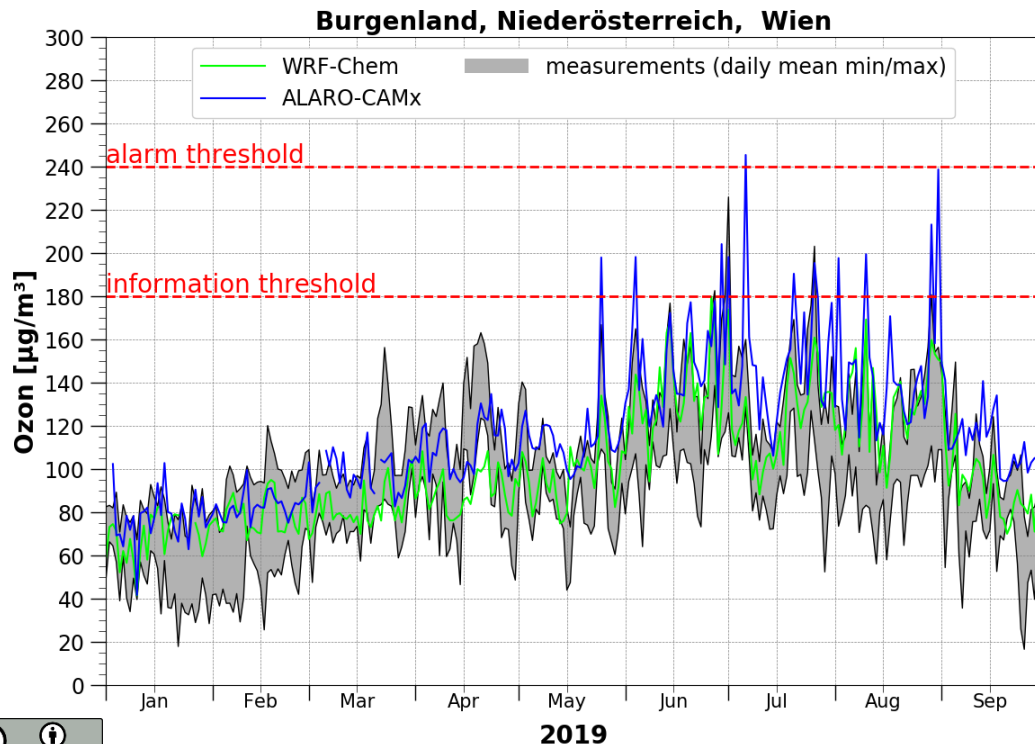
# Evaluation of the ozone forecasts in Eastern Austria

January – September 2019

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Both models are able to predict the course of the ozone concentration during the considered time period.

- ALARO-CAMx tends to overpredict the concentration of measured ozone peaks. The modeled values for low and medium concentrations show a good correspondance with the measured values. Overall ALARO-CAMx shows higher variability.
- WRF-Chem shows a higher correlation with the measurement values than ALARO-CAMx, but overall the model shows a negative bias.



# Evaluation of the ozone forecasts in Eastern Austria

## Contingency table for April to September 2019

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measurement/ model	ALARO-CAMx						total	%
	April 2019	May 2019	June 2019	July 2019	August 2019	Sept. 2019		
< 180 / < 180 <i>correct rejection</i>	30	30	27	27	27	30	171	95.1%
> 180 / > 180 <i>hit</i>	0	0	0	2	1	0	3	
< 180 / > 180 <i>false alarm</i>	0	1	2	2	3	0	8	4.9%
> 180 / < 180 <i>miss</i>	0	0	1	0	0	0	1	

**ALARO-CAMx** has predicted three of the four measured exceedances of the ozone information threshold. Eight times the model has predicted an exceedance which has not occurred.

measurement/ model	WRF-Chem						total	%
	April 2019	May 2019	June 2019	July 2019	August 2019	Sept. 2019		
< 180 / < 180 <i>correct rejection</i>	30	31	29	29	30	30	179	97.8%
> 180 / > 180 <i>hit</i>	0	0	0	0	0	0	0	
< 180 / > 180 <i>false alarm</i>	0	0	0	0	0	0	0	2.2%
> 180 / < 180 <i>miss</i>	0	0	1	2	1	0	4	

**WRF-Chem** has a slightly higher percentage of correct forecasts (97,8 %) than ALARO-CAMx. WRF-Chem hasn't predicted any ozone concentrations above the information threshold during the summer 2019.

# Evaluation of the ozone forecasts in Eastern Austria

## Contingency table: Comparison with the previous years

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meas/mod	ALARO-CAMx				% +	% -
	< 180 / < 180 <i>correct rejection</i>	> 180 / > 180 <i>hit</i>	< 180 / > 180 <i>false alarm</i>	> 180 / < 180 <i>miss</i>		
2016	169	1	11	1	93.4%	6.6%
2017	165	5	6	6	93.4%	6.6%
2018	168	0	6	2	95.5%	4.5%
2019	171	3	8	1	95.1%	4.9%

**ALARO-CAMx** has predicted many of the measured ozone exceedances from 2016 – 2019. Overall the percentage of correct forecasts is quite high.

meas/mod	WRF-Chem				% +	% -
	< 180 / < 180 <i>correct rejection</i>	> 180 / > 180 <i>hit</i>	< 180 / > 180 <i>false alarm</i>	> 180 / < 180 <i>miss</i>		
2016	179	0	0	2	98.9%	1.1%
2017	159	0	0	11	93.5%	6.5%
2018	180	0	0	2	98.9%	1.1%
2019	179	0	0	4	97.8%	2.2%

In the last years the percentage of correct forecasts for **WRF-Chem** was quite high, beside the year 2017. WRF-Chem hasn't predicted any of the occurred exceedances of the ozone information threshold.

- Both models predict the ozone concentrations quite well.
- ALARO-CAMx was able to predict some of the measured ozone exceedances in 2019 while WRF-Chem hasn't predicted any exceedance.
- ALARO-CAMx tends **overestimate** the concentration of ozone peaks.
- WRF-Chem shows a **higher correlation** with the measurements, but has a bias.