

**CONTINUOUS MEASUREMENTS  
OF SO<sub>2</sub>, NO<sub>2</sub>, CH<sub>2</sub>O AND O<sub>3</sub> CONCENTRATIONS  
BY DOAS-4R IN OBNINSK IN SUMMER 2002**

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## MEASUREMENT RESULTS (1)

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Continuous synchronous measurements of SO<sub>2</sub>, NO<sub>2</sub>, CH<sub>2</sub>O and O<sub>3</sub> gaseous concentrations were carried out by the ultraviolet open air path gas analyzer DOAS-4R in Obninsk in summer 2002.

**Concentrations averaged by overall period of measurements (ppb):**

SO <sub>2</sub>	NO <sub>2</sub>	CH <sub>2</sub> O	O <sub>3</sub>
0.6	3.3	8.7	26

Daily variations of gas concentration shows a morning (9-10 a.m.) maximum for SO<sub>2</sub>, NO<sub>2</sub> and CH<sub>2</sub>O, a daytime maximum for O<sub>3</sub> and a secondary maximum for NO<sub>2</sub> late at night (10-11 p.m.).

Strong variations of mean daily concentrations (MDC) were observed. Highest possible MDC values of NO<sub>2</sub> matched the temperature inversions.

It was discovered that MDC increase went after the growth of forest fires in Moscow region. MDC dependence on speed and direction of lower atmosphere wind was analyzed.

## MEASUREMENT RESULTS (2)

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290 – 350 nm spectral range was chosen for synchronous measurements of four trace gases - SO<sub>2</sub>, CH<sub>2</sub>O, NO<sub>2</sub> и O<sub>3</sub>.

Measurement frequency was 5 minutes, and signal integration time was 2 – 3 minutes.

Total number of data samples in measurement series was around 20 000.

The assessment of errors was being done simultaneously with residuals calculation.

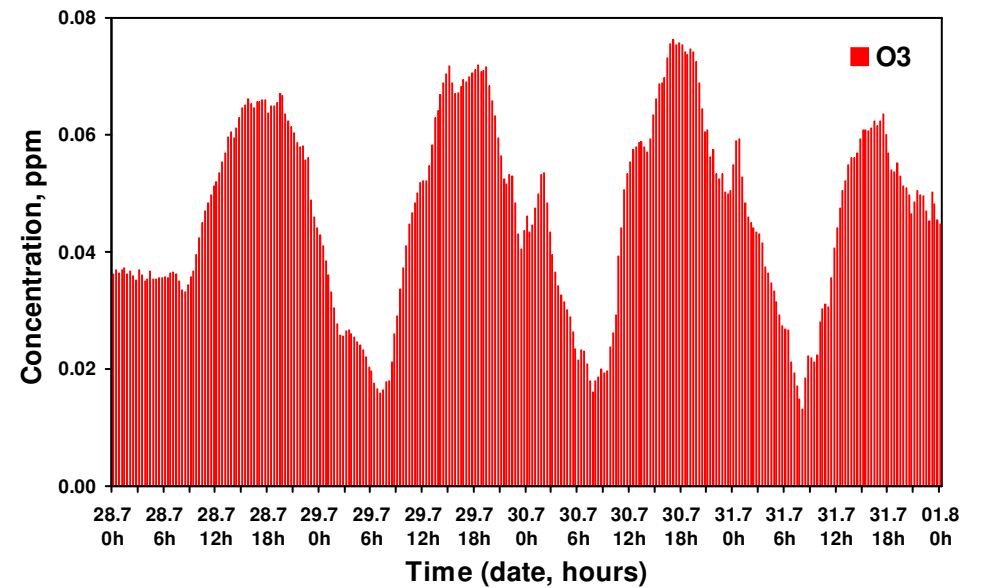
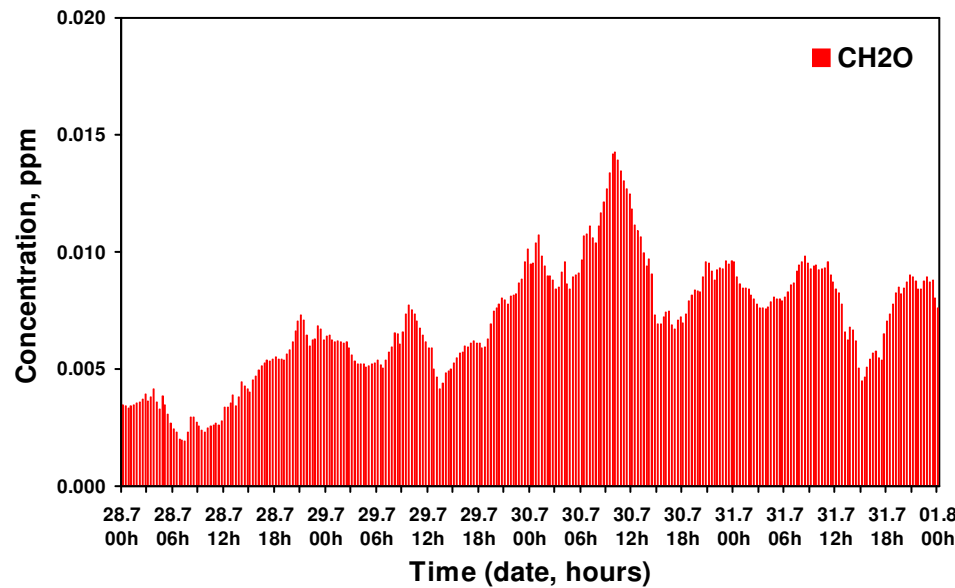
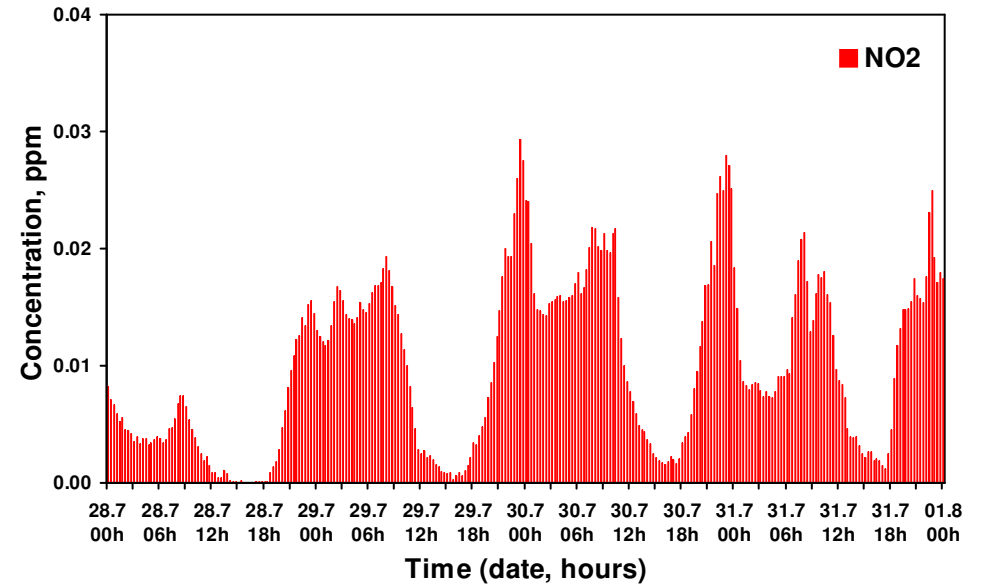
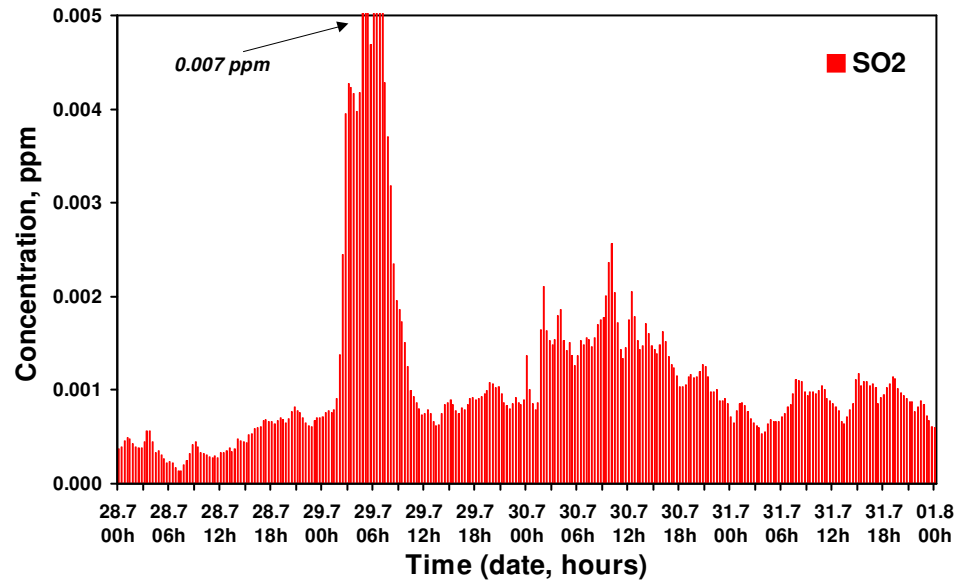
### Gas concentration measurement mean errors (ppb):

SO <sub>2</sub>	NO <sub>2</sub>	CH <sub>2</sub> O	O <sub>3</sub>
0.1	0.5	1.0	1.8

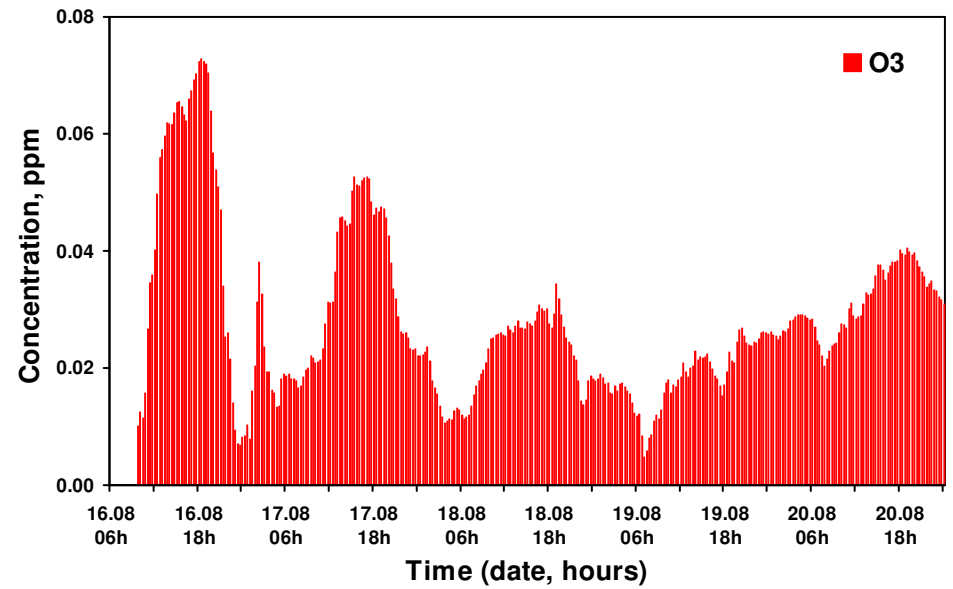
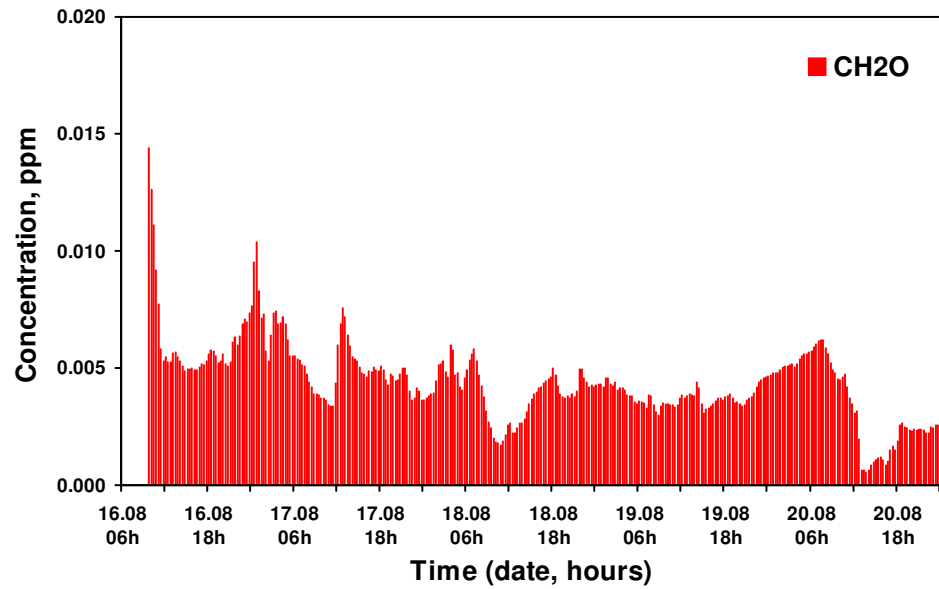
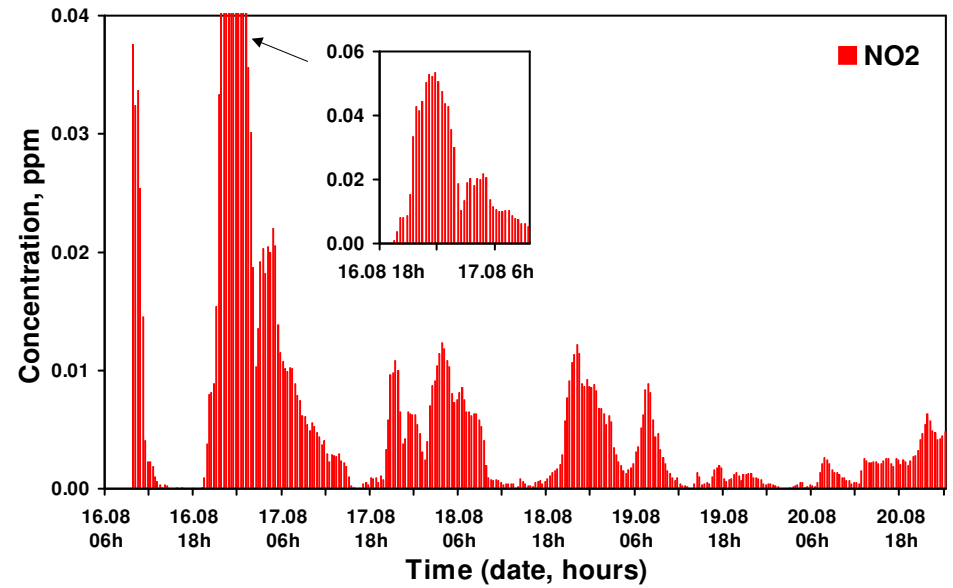
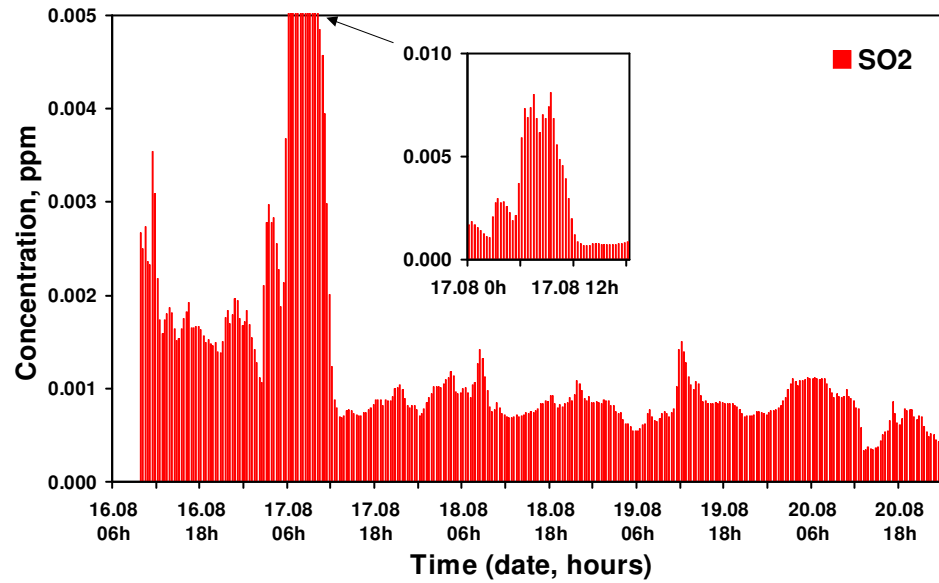
**Information on weather conditions in Obninsk:** In July - August and in the first half of September of 2002 a steady powerful anticyclone and frequently occurring smog from forest fires in Obninsk and Moscow region were observed. Especially dense smog in Obninsk was at the end of July, in the middle of August and on September 5, 8, 10, and 16-17, whereupon autumn rains cleaned the atmosphere.

Some examples of gas concentration (twenty-minute averaging) are given below.

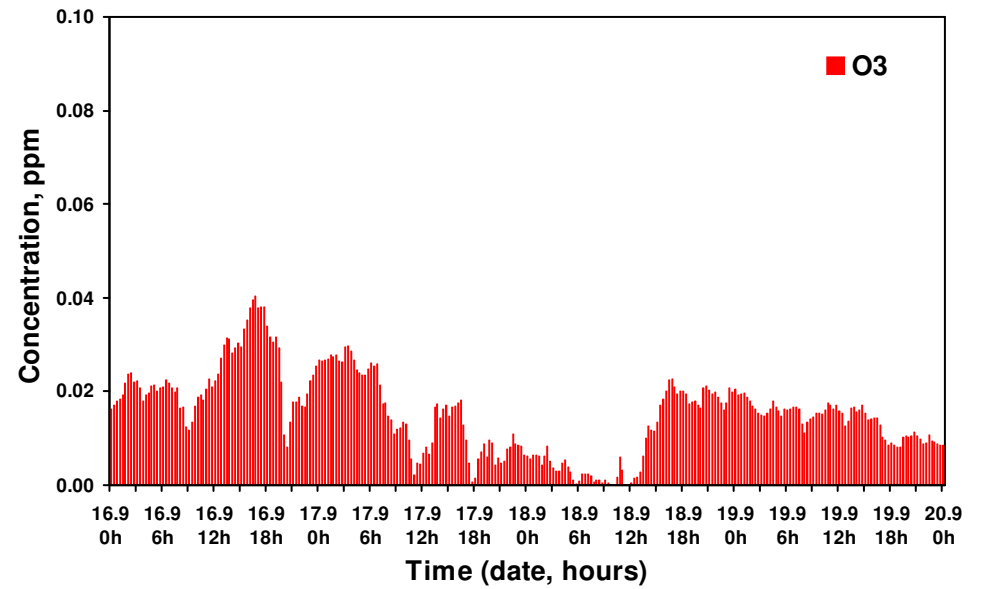
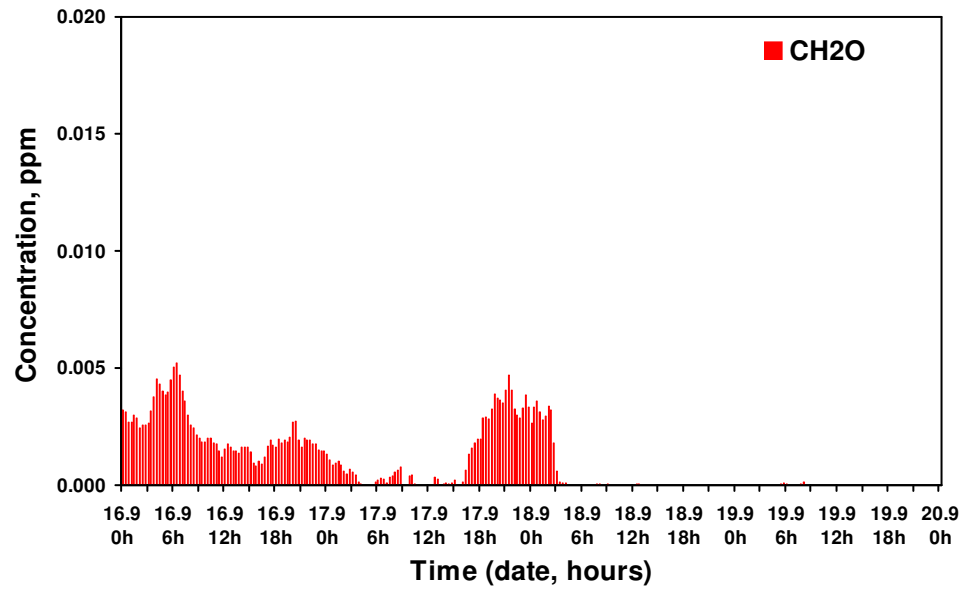
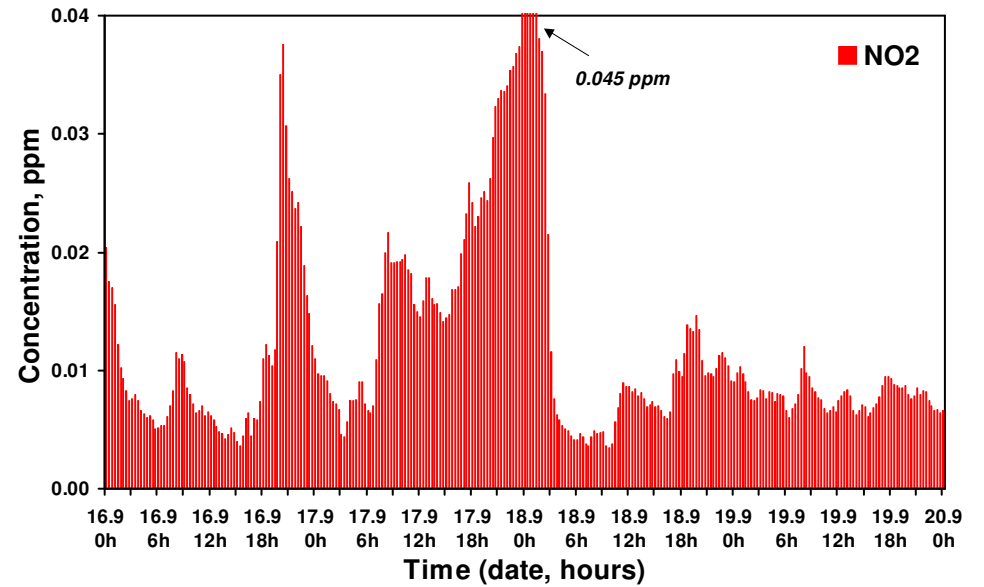
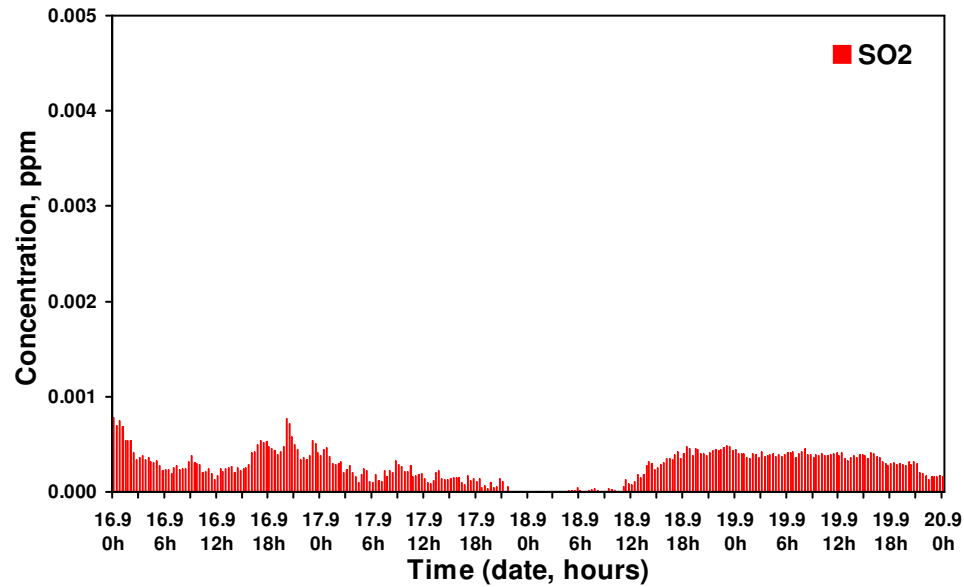
# GAS CONCENTRATIONS, JULY 28-31, 2002



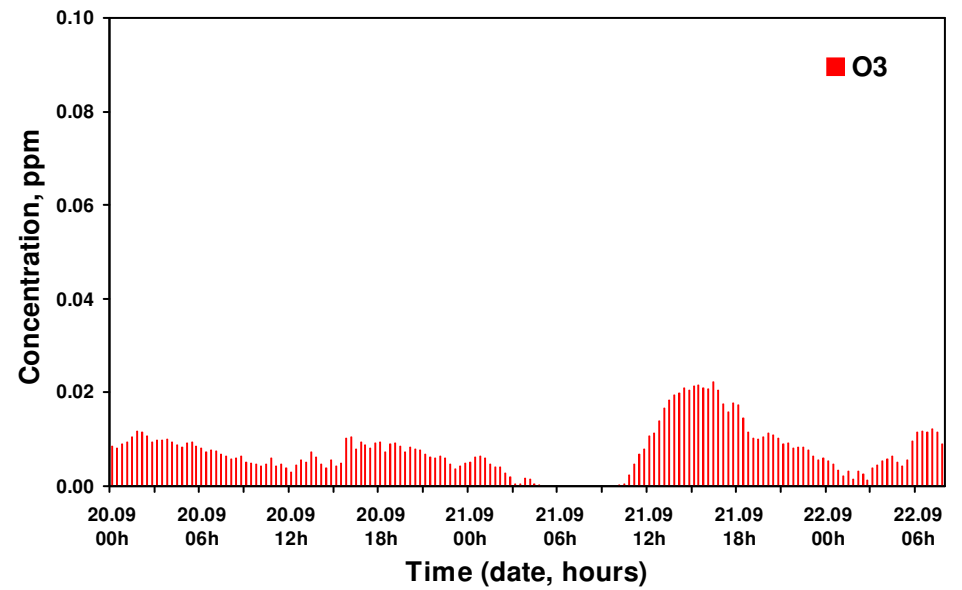
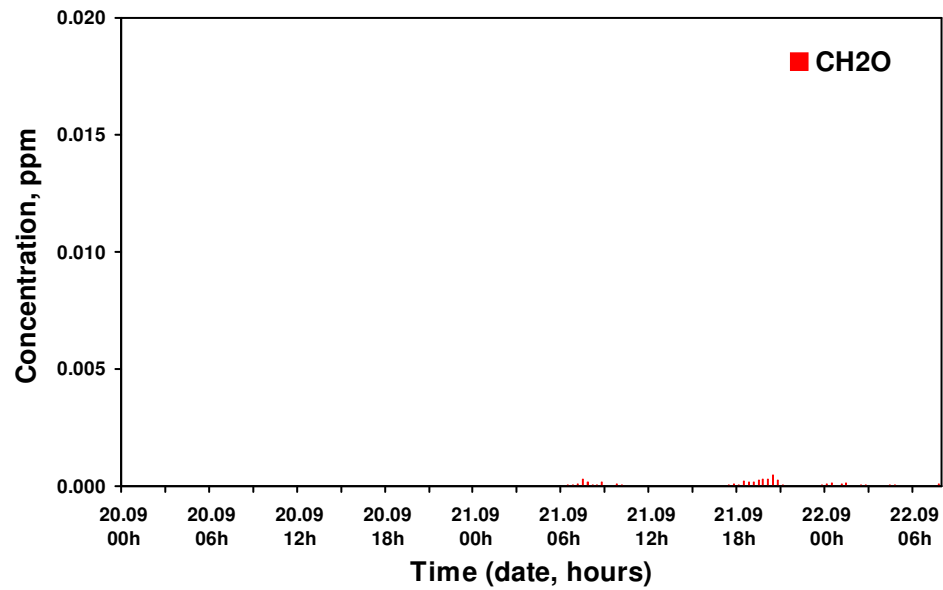
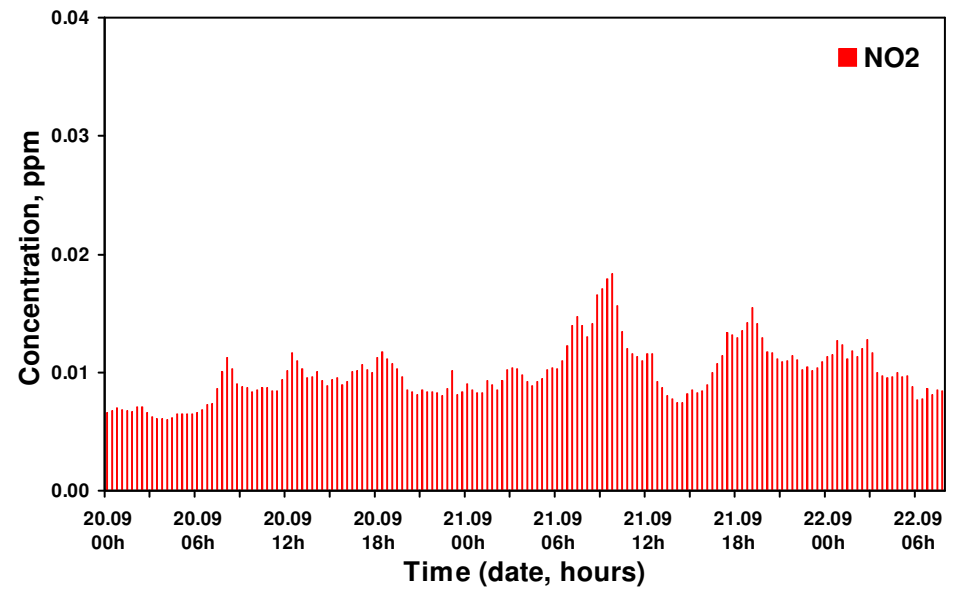
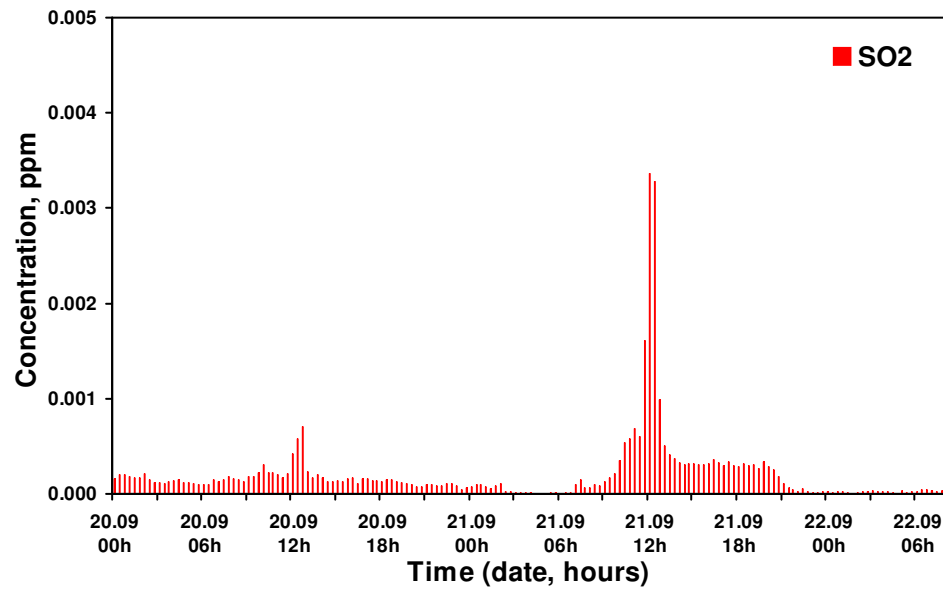
# GAS CONCENTRATIONS, AUGUST 16-20, 2002



# GAS CONCENTRATIONS, SEPTEMBER 16-19, 2002



# GAS CONCENTRATIONS, SEPTEMBER 20-22, 2002



## THE HIGHEST POSSIBLE CONCENTRATION VALUES (20-MINUTE AVERAGING)

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<b>Gas</b>	<b>Concentration, ppb</b>	<b>Date</b>	<b>Hours</b>
<b>SO<sub>2</sub></b>	6.6	29.07	06
	6.9	14.08	16
	8.0	17.08	09
<b>CH<sub>2</sub>O</b>	14	30.07	10
	15	05.09	09
	20	08.09	17
<b>NO<sub>2</sub></b>	48	23.07	22
	53	17.08	00
	45	18.09	00
<b>O<sub>3</sub></b>	71	29.07	18
	76	30.07	17
	73	16.08	18



## THE GAS CONTENT CORRELATION COEFFICIENTS OVER THE PERIOD FROM JULY 15 TO SEPTEMBER 30, 2002

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	SO <sub>2</sub>	CH <sub>2</sub> O	NO <sub>2</sub>	O <sub>3</sub>
SO <sub>2</sub>	1	0.532	0.120	0.129
CH <sub>2</sub> O	0.532	1	0.206	0.110
NO <sub>2</sub>	0.120	0.206	1	-0.413*
O <sub>3</sub>	0.129	0.110	-0.413	1

\* The dependence between O<sub>3</sub> and NO<sub>2</sub> was caused by photochemical reactions in the atmosphere and resulted in anticorrelation of concentrations of these gases. Correlation coefficients of O<sub>3</sub> and NO<sub>2</sub> reached -0.8 in various cloudless periods and about -0.3 during days of rainy weather and dense smog.

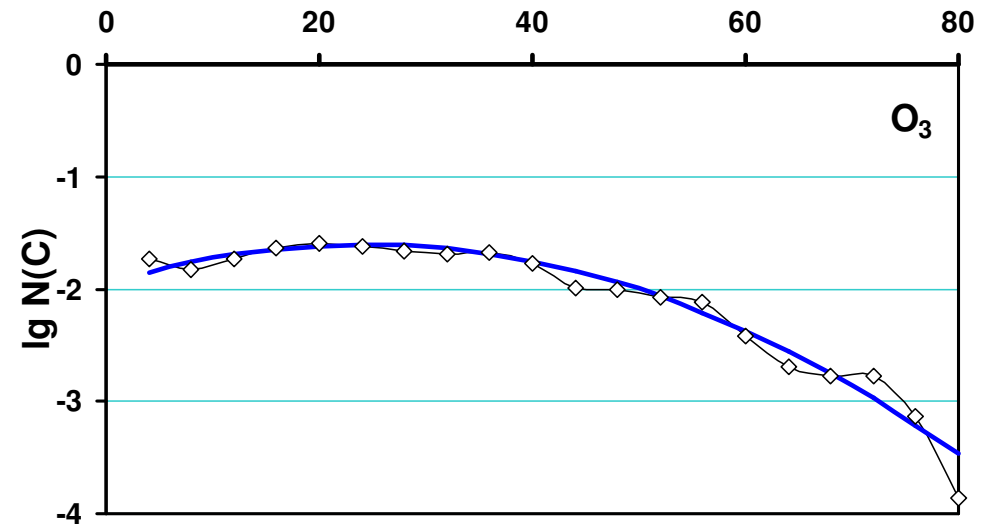
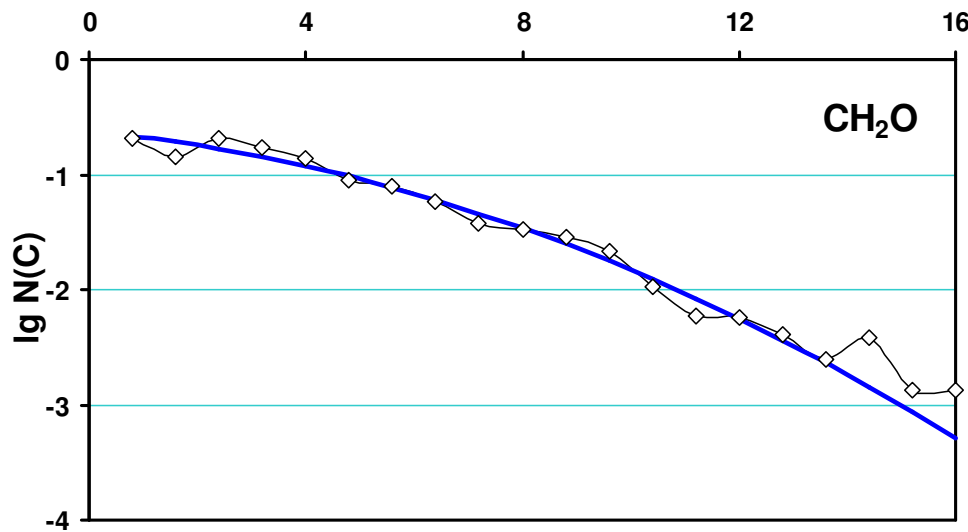
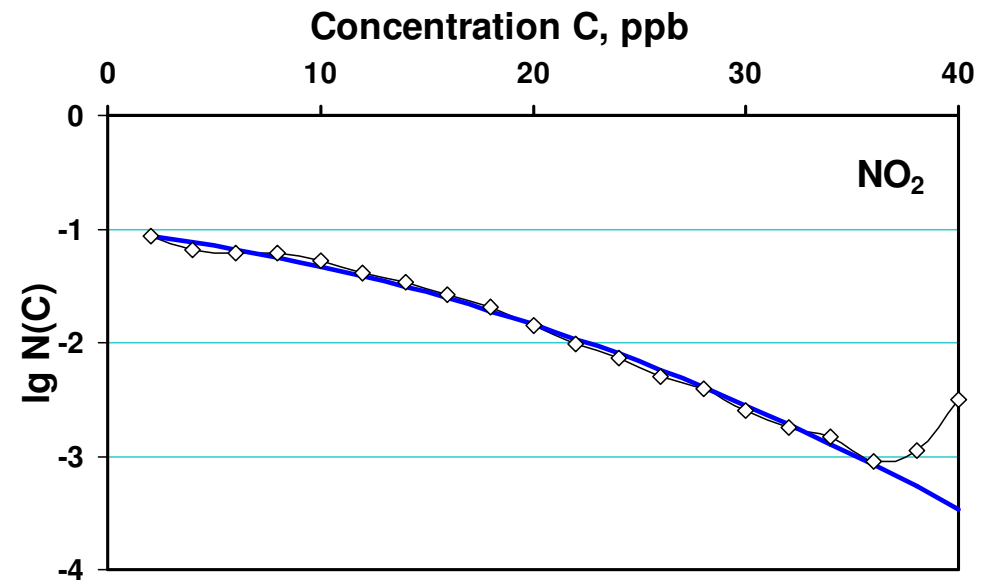
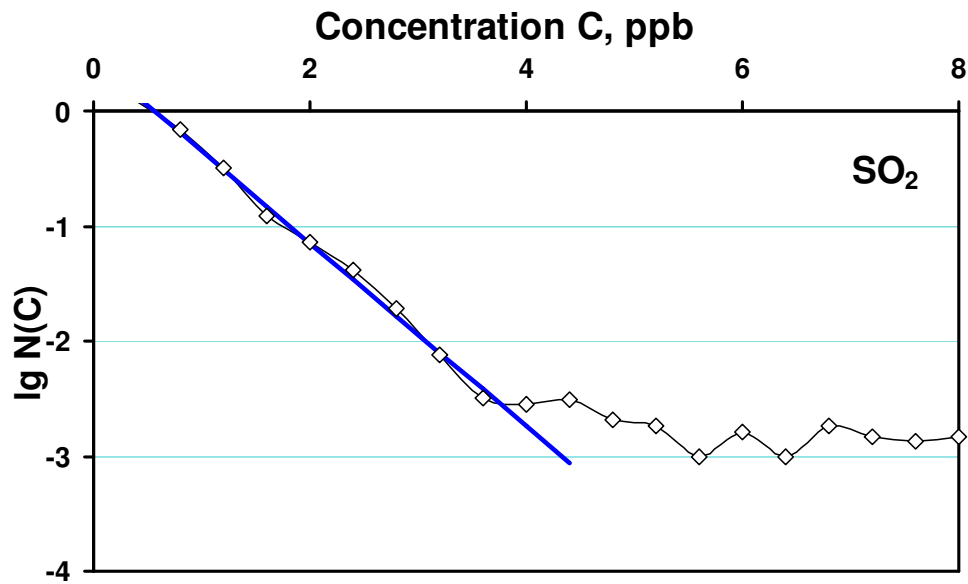
## RELATIVE FREQUENCY OF HIGH CONCENTRATIONS VS WIND DIRECTION AT 121 m ALTITUDE

Direction	SO <sub>2</sub>	CH <sub>2</sub> O	NO <sub>2</sub>	O <sub>3</sub>	Pollutant objects
<i>N</i>	-	-	-	-	
<i>NE</i>	<b>0.40</b>	<b>0.40</b>	0.30	0.11	Moscow region
<i>E</i>	<b>0.54</b>	<b>0.46</b>	0.38	<b>0.50</b>	Moscow region; Highway Moscow - Kiev
<i>SE</i>	0.33	<b>0.40</b>	<b>0.60</b>	0.21	Highway Moscow - Kiev
<i>S</i>	0.36	0.36	<b>0.45</b>	<b>0.44</b>	
<i>SW</i>	0.24	0.29	0.24	<b>0.58</b>	
<i>W</i>	0.20	0.20	0.13	0.13	
<i>NW</i>	-	-	-	-	

**Notes:**

1. Relative frequency is a ratio of the number of measured high concentrations to the overall number of measurements.
2. *N* and *NW* winds were not practically observed during the measurement period.

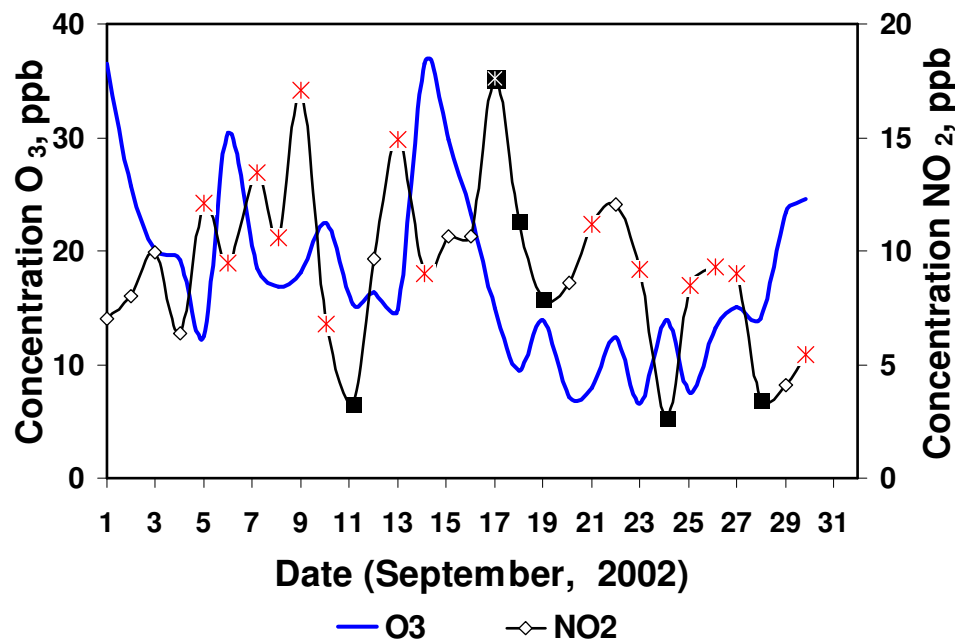
# PROBABILITY DISTRIBUTION OF GAS CONCENTRATIONS



*Bold curves are fits by polynomial of the first (for  $\text{SO}_2$ ) and second (for other gases) power.*

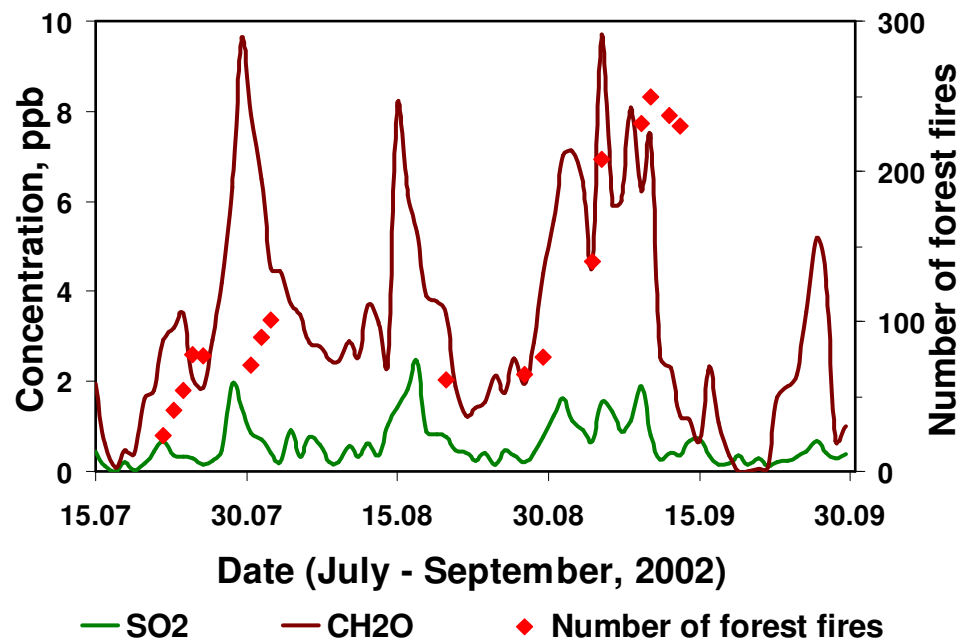
# TIME DEPENDENCE OF DAILY AVERAGE CONCENTRATIONS

Daily average concentrations of  $O_3$  and  $NO_2$  (September 2002)

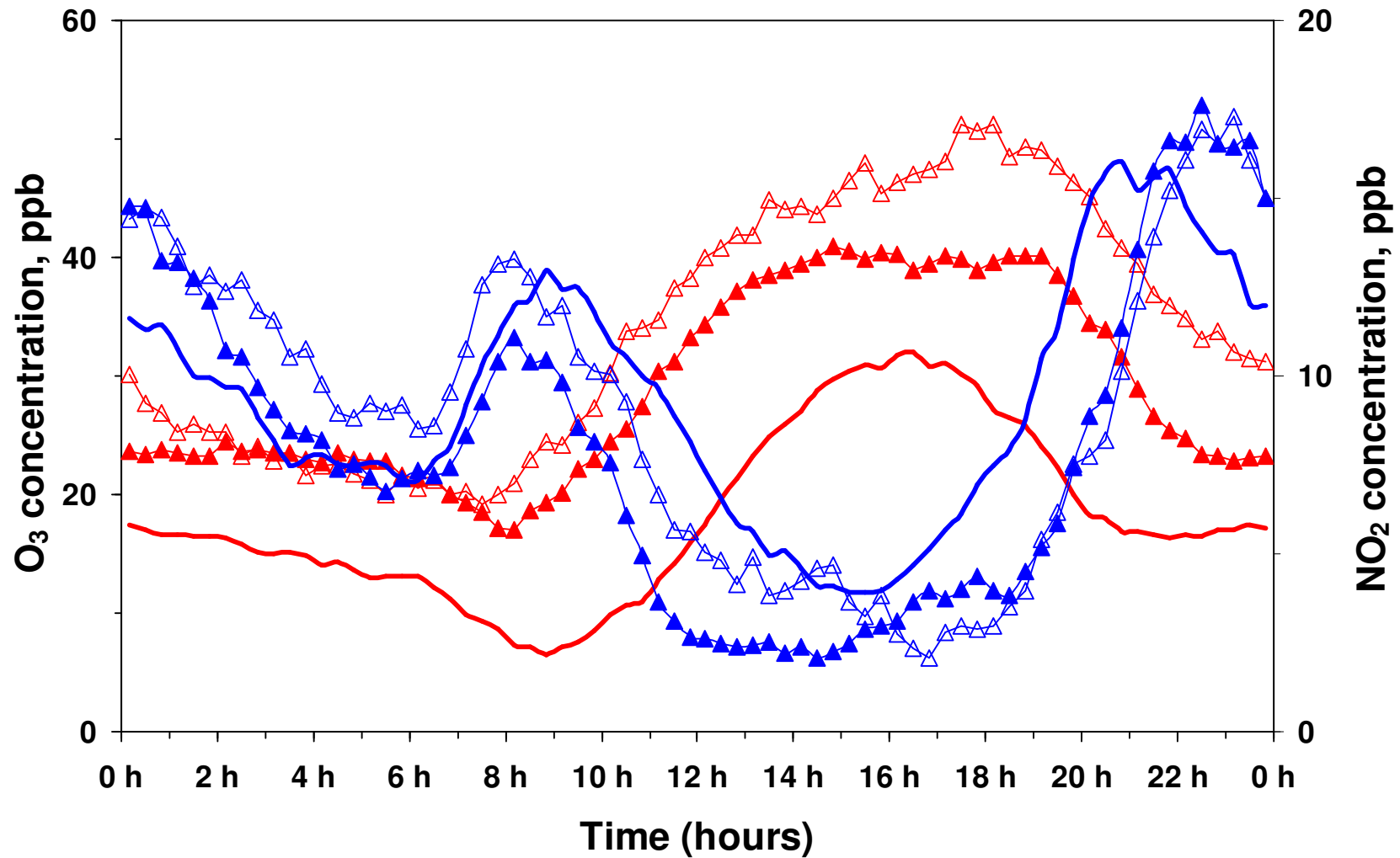


On the  $NO_2$  curve the days with temperature inversion are marked by [ \* ] and rainy days- [ ■ ]

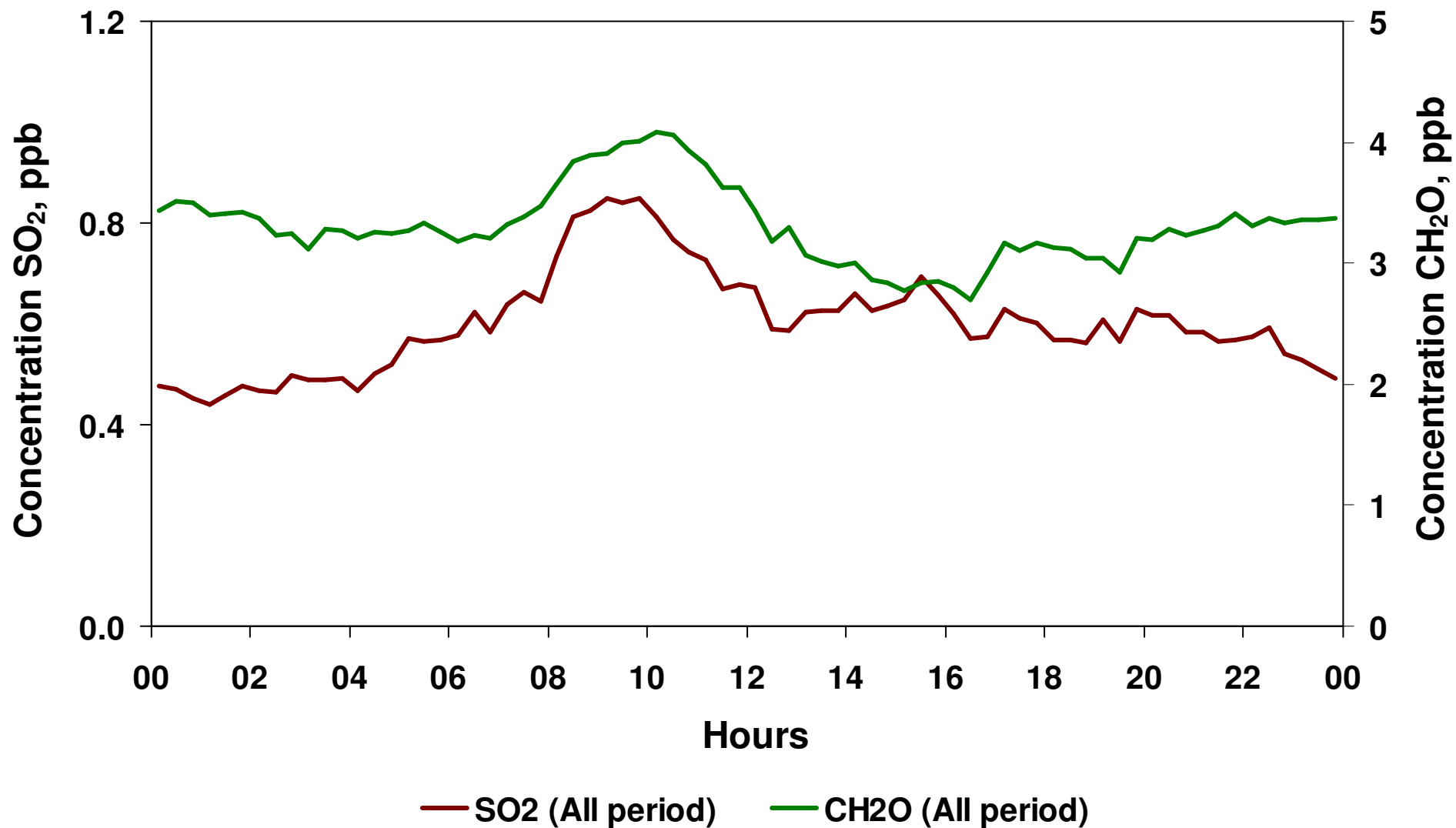
Time dependence of daily average concentrations of  $SO_2$  and  $CH_2O$  (July 15 - September 30, 2002) and the number of forest fires in Moscow region



# MONTH-AVERAGED DAILY VARIATIONS OF O<sub>3</sub> AND NO<sub>2</sub>

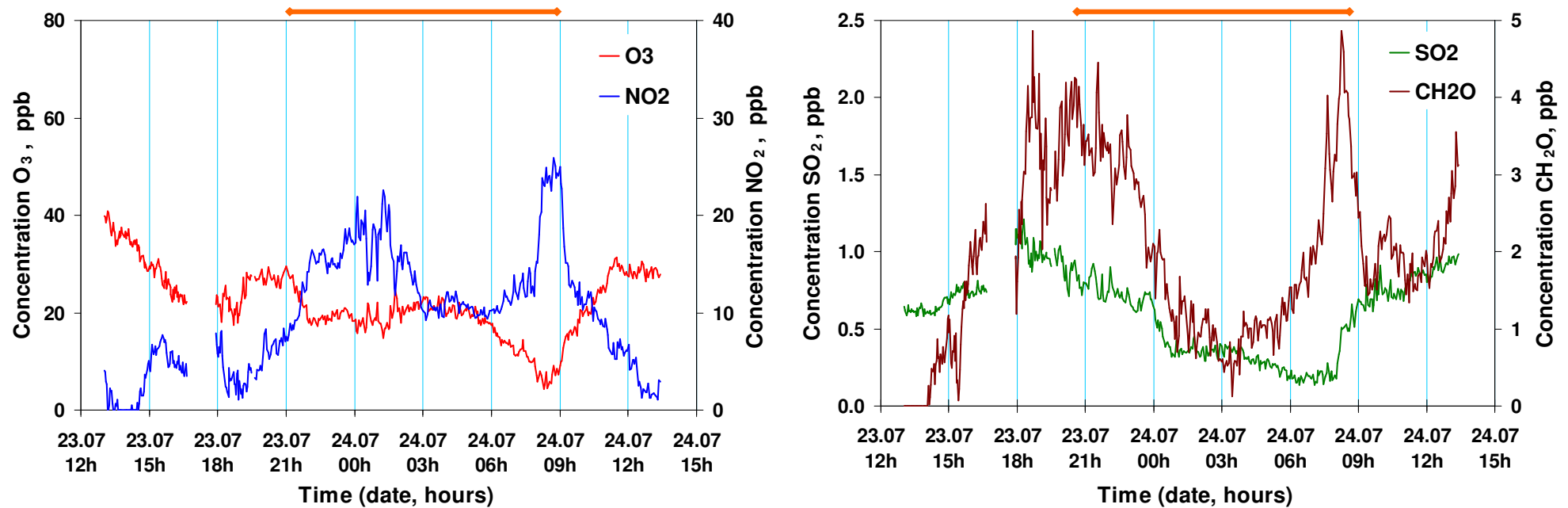


**AVERAGE DAILY VARIATIONS OF SO<sub>2</sub> AND CH<sub>2</sub>O  
(AVERAGING OVER THE PERIOD OF JULY 15 - SEPTEMBER 30, 2002)**



## GAS CONCENTRATIONS TIME DEPENDENCE, JULY 23-24, 2003

Nocturnal ground inversion and calm weather were observed in the period from 9pm of July 23 to 09 am of July 24.



Nocturnal maximum of NO<sub>2</sub> confirms that the source of this gas is ground-based and local .

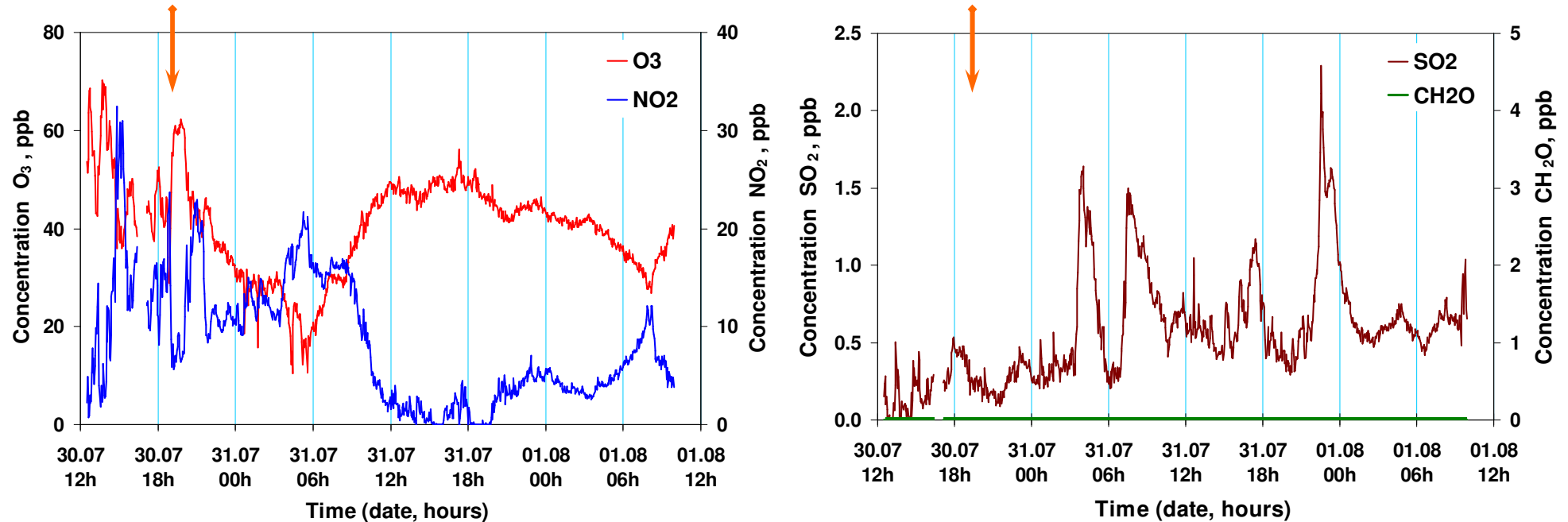
Nocturnal minimum of SO<sub>2</sub> and CH<sub>2</sub>O content confirms assumption of a high-altitude and regional source of these gases.

Morning maximums of NO<sub>2</sub> and CH<sub>2</sub>O can be explained by both morning growth of automobile driving intensity and sinking of gases, accumulated under inversion by night.

The good anticorrelation of O<sub>3</sub> and NO<sub>2</sub> concentrations was revealed ( $r = -0.81$ ).

## GAS CONCENTRATIONS TIME DEPENDENCE, JULY 30 - AUGUST 1, 2003

Weather was serene at that time. Nocturnal ground inversion was not observed. A showery rain was in the evening of July 30 about 7 pm.



During a showery rain the content of O<sub>3</sub> increased sharply as the content of NO<sub>2</sub> diminished. A good anticorrelation of O<sub>3</sub> and NO<sub>2</sub> concentrations was revealed ( $r = -0.57$ ). CH<sub>2</sub>O was not observed during this period.