Numerical study of the gases and aerosol composition in the background and urban location of Western Siberia: a case study for the record-breaking hot April 2020

P. N. Antokhin, O. Yu. Antokhina, M. Yu. Arshinov, B.D. Belan, D.K. Davydov, A.V. Kozlov, Savkin D.E., Tolmachev G.N., Fofonov A.V.

V.E. Zuev Institute of Atmospheric Optics

V.E. Zuev institute of atmospheric optics, Russian academy of sciences, Siberian branch,1 Academician Zuev square, Tomsk, Russia, 634021

e-mail: apn@iao.ru, antokhina@iao.ru, bbd@iao.ru

Keywords

GHG, aerosol, wildfires, atmospheric blocking

Abstarct

In the present work, we compare the modeled data with observed changes in the gas (CO, NO, NO2, SO2, O3) and aerosol composition during an abnormally warm April.

Background

The study of changes in gases and aerosols composition during the period of observed climatic changes is necessary. There are many feedbacks associated with the chemical composition of the atmosphere and climate system. One of the exciting aspects of this matter is the study of the influence of the extreme episodes related to atmospheric circulation and changes in surface temperature. April 2020 was the second abnormally hot (the first in 2016) for our planet. The global temperature anomaly was 1.06°C [https://www.climate.gov/news-features/featured-images/april-2020-another-month-'s-second-warmest-record]. The most pronounced temperature anomalies were characteristic of Western Siberia, where the average monthly temperature exceeded the norm by an average of 5°C, and in the northern regions of Western Siberia by 10-12°C. According to the Russian weather services departments for western Siberia, April 2020 was the first hottest April [https://ria.ru/20200420/1570277368.html].

Aim

The purpose of this study is to assess the contribution of forest fires to the increase in the concentration of greenhouse gases in April 2020 using the WRF v.4.1. Compare simulation results with measured data.

Model description

To study the effect of different emission on gases and aerosols concentration in Western Siberia under atmospheric blocking conditions, numerical modelling was performed using the WRF-Chem v.4.1. model.

Table 1. Parameters used in the model WRF-Chem.

Domain	45-74^o N and 40^o-105^o E up to level 50 gPa, cells 100x105x21,Lambert projection, dx = 27 km, dy = 27 km
Period calculate	01.04.2020 to 29.04.2020
Meteorology data	FNL (NCEP) [Grace Peng, 2014]
Chemical mechanism	MOZART4, [Emmons et al., 2010] MOZAIC [Zaveri A. 2008]
Initial and boundary conditions	Mozart4 [UCAR]
Emission:	
Anthropogenic	HTAP-2 [Janssens-Maenhout G.,2015], EDGAR V.4.3.2 [Crippa M.,2018]
Biogenic	MEGAN2.1 [Guenther A.,2006]
Fire	FINN v1.5 [Wiedinmyer C. 2011]
Wetland	MACC v1an [Bergamaschi P.,2013]
Microphysics	Morrison double-moment [Morrison H., 2009]
Longwave rad.	RRTM [Mlawer E.J. 1997]
Shortwave rad.	Dudhia [Dudhia J. 1989]
Surface layer	Rev. MM5 [Jiménez P.A. 2012]
Soil model	Noah [Tewari, M., 2004]
ABL	Yonsei Univ. [Hong S.-Y.,2006]
Cloud Parameterization	Grell 3D [Grell 1993, 2002]

Data

To verify the obtained simulation results, we used the measurement data carried out at the TOR station and the Observatory "Background"of the Institute of Atmospheric Optics SB RAS. The TOR-station is located in the background area of the city of Tomsk on the territory of the Tomsk Scientific Center (56^{o}28'41"N, 85^{o}03'15"E, 133 m above sea level). Observatory "Fonovaya"(Background) IAO SB RAS, located in the background area of the Tomsk region (56^{o}25'N, 84^{o}04'E, 80 m above sea level, http://lop.iao.ru). To measure the concentration of small gas and aerosol components of the atmosphere, the following instruments were used: OPTEK 3.01-P - for measuring ozone (O3); OPTEC K-100 - carbon monoxide (CO); OPTEC C-310 - sulfur dioxide (SO2), Thermo Scientific Model 42i (NO, NO2), Teledyne 200e (NO, NO2).

The comparison of measure data and simulation results

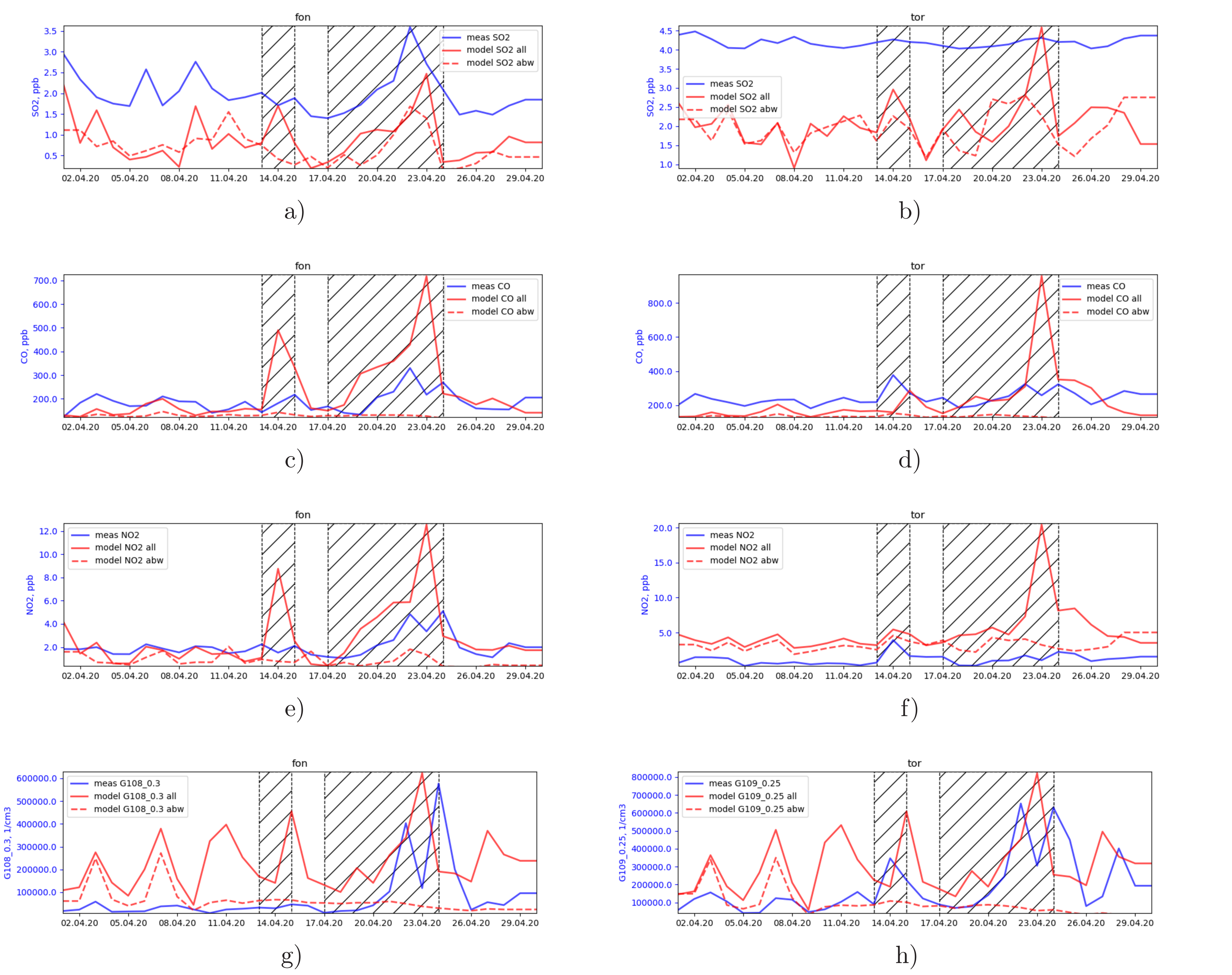

Figure 1. Measurements of gases concentration (SO2, CO, NO2) and aerosol at Observatory "Fonovaya"(a,c,e,g) and TOR-station (b,d,f,g). The dashed line marks the events under consideration. Measurement data is blue, simulation results are red.

Conclusion

The WRF-Chem model reproduces the increase in CO and aerosol concentration for the TOR station for the first episode. For the second episode, the model reproduced the increase in concentration for all considered components; however, for NO, it is absent in measurements. The increase in concentration for ozone was poorly expressed in comparison with the measured data. Emissions from fires were responsible for the main variability in the countable aerosol concentration, CO, for both stations and SO2 for the background area. In other cases, the total contribution of other emissions prevailed. For a more detailed study, it is necessary to identify the areas that had the greatest impact on the measurement posts, for example, you can use the method [Penenko A. 2020].

Acknowledgments

Measurements are carried out under the support of the Ministry of Education and Science of the Russian Federation (IAO SB RAS State Program No. AAAA-A17-117021310142-5), and the studies of small gaseous constituents of the atmosphere and aerosols were carried out with the support of RFBR grants No. 19-05-50024, No. 18-45-700020.