Atmospheric emissions of carbon monoxide from wildfires in Northern Eurasia and their impact on regional air composition in remote Central Siberia

Vivchar A.V.*, Moiseenko K.B.
A.M. Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences
***Corresponding author. E-mail address: vivechar@gmail.com**

1. Motivation

• Seasonal and long-term variations in atmospheric composition are largely determined by variations in natural and anthropogenic emissions in the boundary layer close to the ground.

• Emissions from sources of climatic importance are generally transported quite far from their origins and alter air composition at continental scales.

• The lack of systematic data on air composition and emissions for vast Russian territory complicates studies related to air quality, environmental loads and long-term trends in atmospheric composition over the whole Northern Eurasia.

2. The objective of this study is to partly fill this gap by investigating the influence of wildfire exhausts on atmospheric composition at regional and continental scales.

The study is based on recent data from complex measurements of atmospheric composition obtained by IAP RAS at ZOTINO observatory (Krasnoyarsk district) launched in 2007, as well as Kislovodsk High-Mountain Station, and during TROICA campaigns.

3. Observations

Fig. 1. Tall (300 m a.g.l.) Zotino tower in central Siberia (60°26‘N 89°24‘ E).

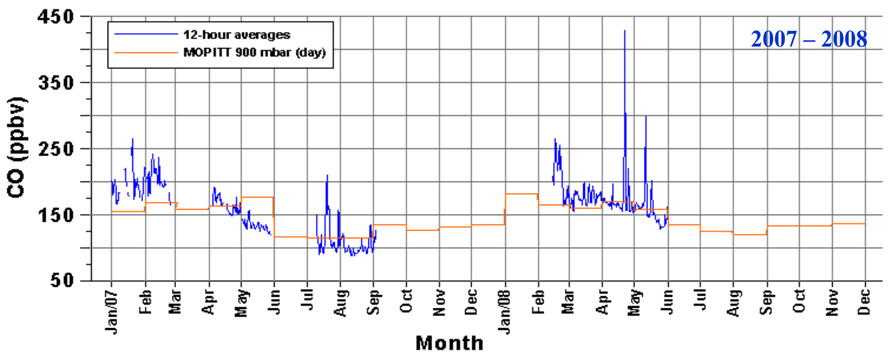

Fig. 2. Concentrations of CO at Zotino: measured at the surface and averaged in 12h intervals (blue line); and taken from MOPITT satellite observations at 900 mbar level monthly (orange line).

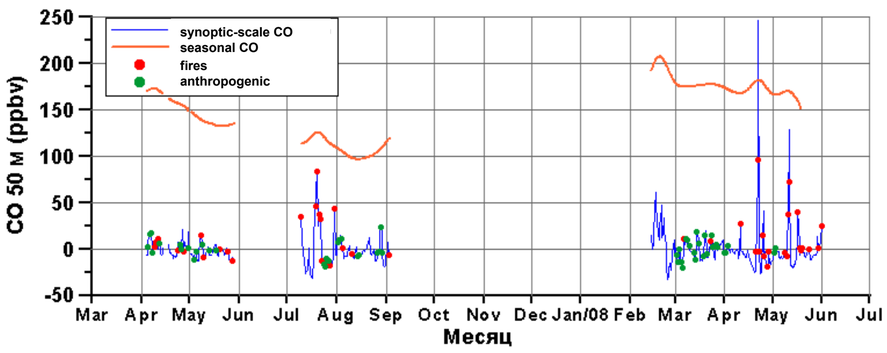

Fig. 3. Timescale-separated CO variability at Zotino: synoptic variations with T from 12 h to 30 days (blue line) and seasonal variations with $T > 30$ days. Episodes of air transport from wildfires (red dots) and anthropogenic sources (green dots) are shown basing on ensembles of 5-day Lagrangian backward trajectories.

4. Emissions

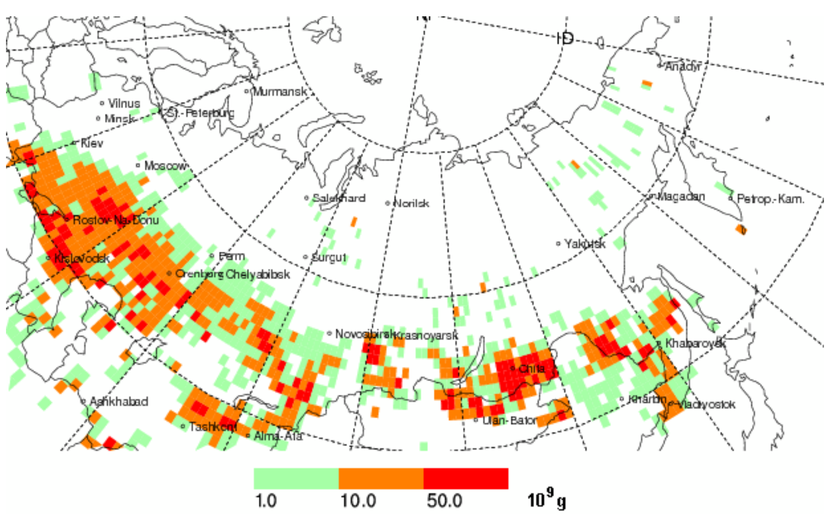

Fig. 4. Total wildfire CO emissions for year 2007 estimated with the model of Seiler and Crutzen (1980) basing on the satellite MODIS MCD45 Level3 Global Monthly 500m Burned Area data.

Table 1. Total annual CO emissions from anthropogenic sources (EDGAR-200) and wildfires (mean values and standard deviations are shown for 2000–2008).

Region	Emitted CO (Tg / year)	
	EDGAR-2000 anthr.	Wildfires (mean ± σ)
SER	23.5	7.2 ± 3.2
SWS	2.8	4.3 ± 2.6
SES	1.1	5.8 ± 5.9
SFE	9.0	4.7 ± 3.5
NSB	1.3	0.2 ± 0.2
NFE	3.7	1.8 ± 1.6
NETR	1.4	< 0.01

Geographical domains in Table 1:

SER – south of the European Russia (41–75° N, 27–60° E),
SWS – south of the Western Siberia (49–75° N, 60–90° E),
SES – south of the Eastern Siberia (49–75° N, 90–120° E),
SFE – southern Far East (42–75° N, 120–180° E),
NSB – northern Siberia (60–75° N, 60–120° E),
NFE – northern Far East (54–75° N, 120–180° E),
NETR – north of the European Russia (60–75° N, 27–60° E).

Total emitted CO (wildfires + EDGAR): 66.7 ± 11.6 Tg / year
Wildfires / EDGAR: 15–100 %
Forest fires / all wildfires: 10 – 40 %

4. Trajectory model-based air mass age statistics

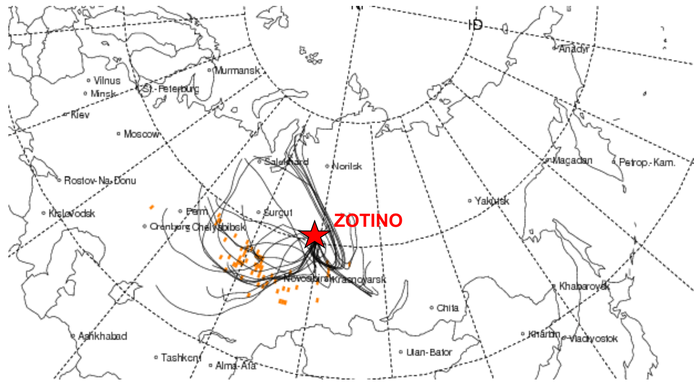

Fig. 5. Distribution of MODIS MCD45/MOD14 fire spots affecting Zotino (orange dots) with corresponding Lagrangian 3-day backward trajectories (black lines) for 2008.

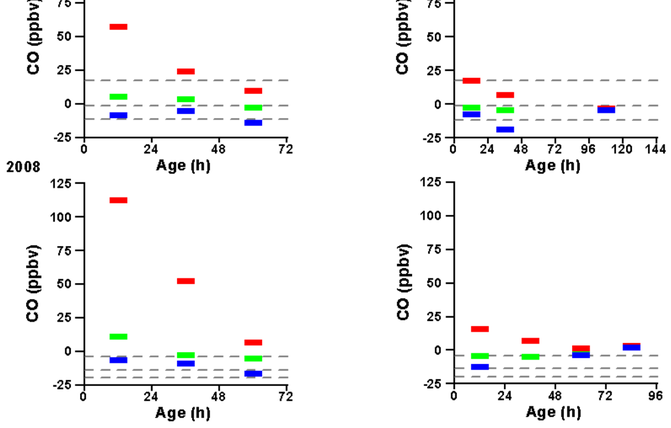

Fig. 6. Distribution in 24h airmass age intervals of CO concentrations (synoptic timescale component of the original data) associated with wildfire (left column) and anthropogenic (right row) emissions in 2007 (top row) and 2008 (bottom row). Top 10% (green bars), median (blue bars) and 90% (red bars) values are shown. Gray dashed lines show CO distribution in clean air.

5. HYPACT model simulations

HYPACT (HYbrid Particle Concentration Transport) – numerical eulerian-lagrangian model for simulation of atmospheric transport and dispersion of a passive tracer on the basis of a system of hydrodynamic equations (http://atmet.com).

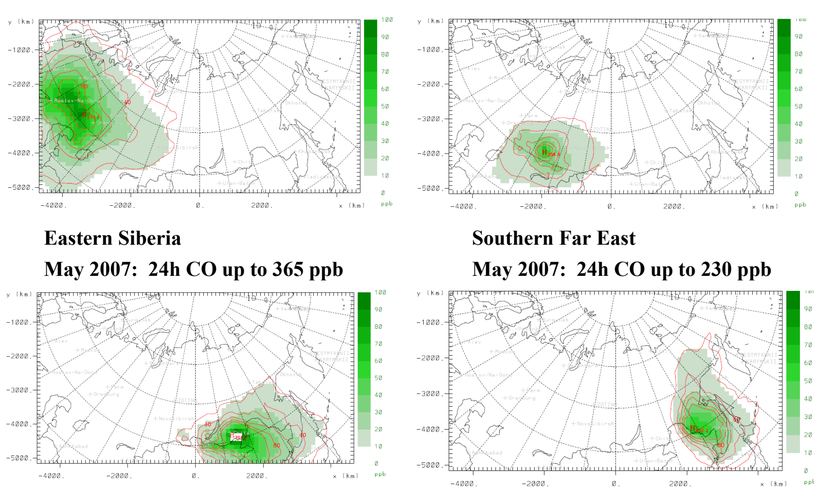

Fig. 7. Distributions of monthly mean (green scale) and maximum (red contours) CO from regional wildfires in 2007 simulated with the HYPACT model.

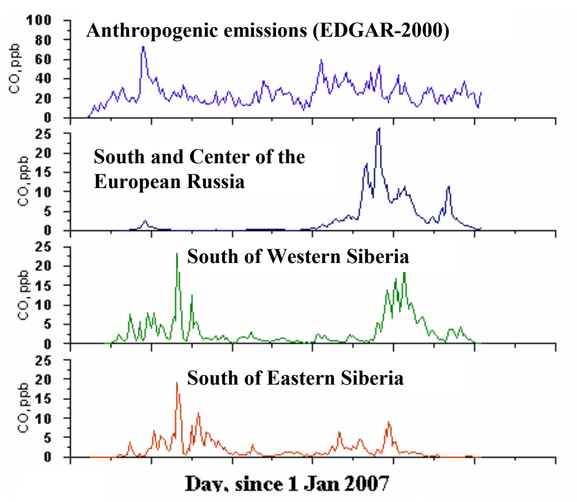

Fig. 8. Daily mean CO concentrations from regional wildfires in 2007 at Zotino station simulated with the HYPACT model.

6. Basic results

6.1 Emissions

• A special software toolkit was developed for calculating atmospheric wildfire emissions of reactive and greenhouse gases in Northern Eurasia and assimilating the emissions in numerical models (HYPACT and CMAQ) of atmospheric transport and chemistry.

• A data set of daily wildfire emissions at regular 0.5° grids was prepared for 2000–2008.

• First HYPACT model simulations were performed to estimate effects of regional 2007 wildfires on air composition in Northern Eurasia on the whole and particularly in remote Central Siberia where the Zotino measurements station is located.

6.2 Measurements

• The measured concentrations at Zotino station are characteristic for atmospheric composition and transport in remote areas of Western Siberia and can be used in studies of long-range atmospheric transport over the continent, although the screening effect of the nearby regional climatic sources of atmospheric emissions (natural and anthropogenic) should be accounted for.

• The major sources of anthropogenic emissions affecting surface air composition at Zotino at synoptic timescales are located in industrial region of southern Siberia.

• Large wildfires in southern Siberia in spring and in European Russia in autumn can elevate monthly mean CO concentrations at Zotino by several ppb and produce episodes of extremely high (250-300 ppb against the typical 100 ppb in warm seasons) CO concentrations during time intervals from several hours to a day and transport times (from fire spots) of 48 hours or less.