# Obzervations on near-surface atmospheric composition at ZOTTO Tall Tower background monitoring station in Central Siberia in 2007 - 2012.

K.B.Moeseyenko, A.I.Skorokhod, A.V.Vasiljeva, R.A.Shumskii, I.B.Belikov

Obukhov Institute for Atmospheric Physics, Moscow, Russia.

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# Motivation

- **Anthropogenic and natural (wildfires) emissions in North Eurasia are climatologically important sources of many pollutants affecting air composition at both regional and continental scale.**
- **The wildfire associated emissions provide up to 20% of global fire emissions of inorganic carbon (CO+CO2) and up to 9 % of soot and 20% of organic aerosols.**
- **High atmospheric residence times of many compounds lead to complex interplay with emissions from other anthropogenic and natural sources.**
- **Hence, correct assessment of wildfire and anthropogenic emissions is needed for better understanding of key factors affecting atmospheric composition, radiative properties, and air quality.**

**The lack of systematic data on the near-surface air composition and emissions for Russian territory complicates studies for air quality, estimates of environmental burden and long-term trends in atmospheric composition on the whole Northern Eurasia.**

**The objective of this study is to partly fill this gap by conducting continuous observations of near-surface air composition at Zotino Tall Tower observatory (ZOTTO) for background atmospheric monitoring in Central Siberia launched in 2007.**

**Background character of the station provide an excellent opportunity to study regional as well as long-range impact of various climatically important sources of pollutants including regional industry and wildfires.**

# ZOTINO project participants

| | | |
|---|---|---|
| E. Vaganov,<br>S. Verkhovetz | V.N. Sukachev Institute of Forest, RAS | Krasnoyarsk, Russia |
| A. Skorokhod,<br>I. Belikov,<br>R. Shumsky | A.M. Obukhov Institute of Atmospheric Physics, RAS | Moscow, Russia |
| M. Heimann,<br>J. Winderlich,<br>E.D. Schultze | Max-Plank Institute for Biogeochemistry | Jena, Germany |
| M.O. Andreae,<br>N. Jurgens | Max-Plank Institute for Chemistry | Mainz, Germany |
| W. Birmili,<br>J. Heintzenberg | Leibnitz Institute for Tropospheric Research | Leipzig, Germany |
| M. Gloor | University of Leeds | Leeds, UK |
| A. Manning<br>E. Kozlova | University of East Anglia | Norwich, UK |

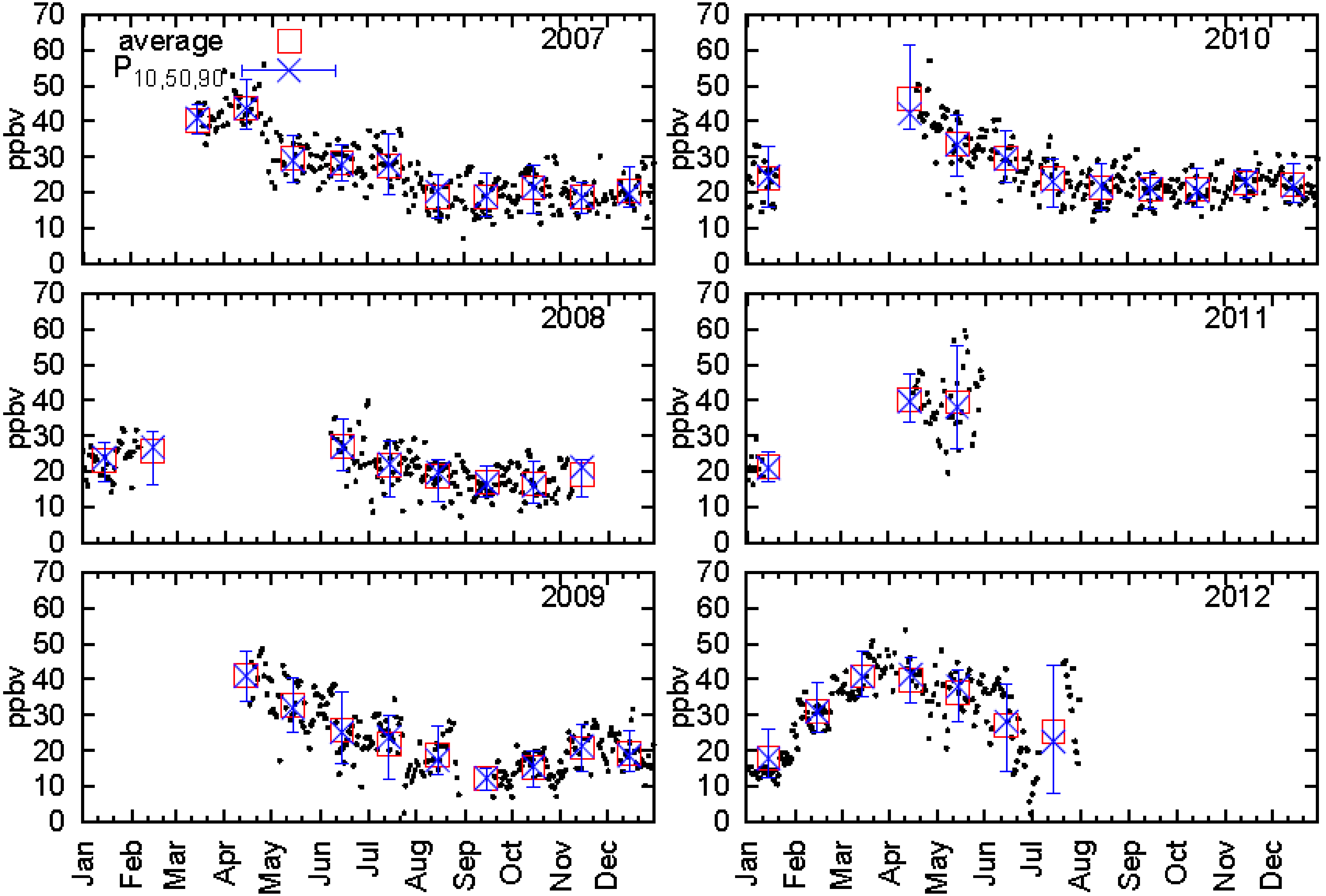
# ZOTTO Tall Tower monitoring station (60°26′N, 89°24′E):

**Studies of regional and trans-boundary effects of atmospheric transport and associated phenomena**

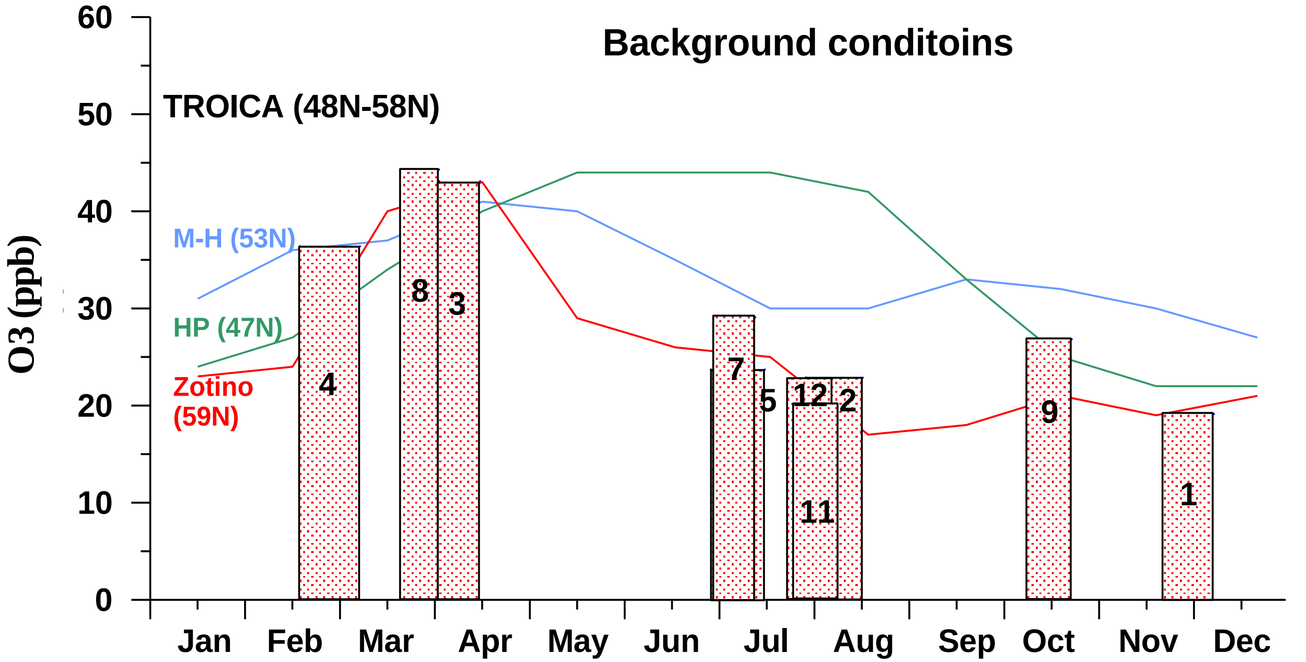
- **Contiuous $CO_2$ and $CH_4$ Gas Measurements at 301, 227, 158, 92, 52, and 4 m height with Cavity Ring Down Spectroscopy (CRDS) by Picarro, Inc.**
- **Contiuous Aerosol Measurements at 301, and 52 m height with self made instrument**
- **Contiuous CO Measurements at 301, and 52 m height with Aero-Laser**
- **Contiuous Ozone, and NOx Measurements at 30 m height**
- **Contiuous Meteorology Measurements at 301, 227, 158, 92, 52, and 4 m height, and on the ground (Temperature, Wind, Humidity)**
- **Biweekly Flask Sampling at 301 m height**
- **Various irregular ecosystem measurements**

# 1) Is ZOTTO station representative at regional scale?

# Ozone observations at ZOTTO in 2007-2012



**Averaged over the continent background ozone concentrations (TROICA expeditions) versus stationary observations on Hohenpeissenberg (HP), Mace Head (MH) and ZOTTO.**

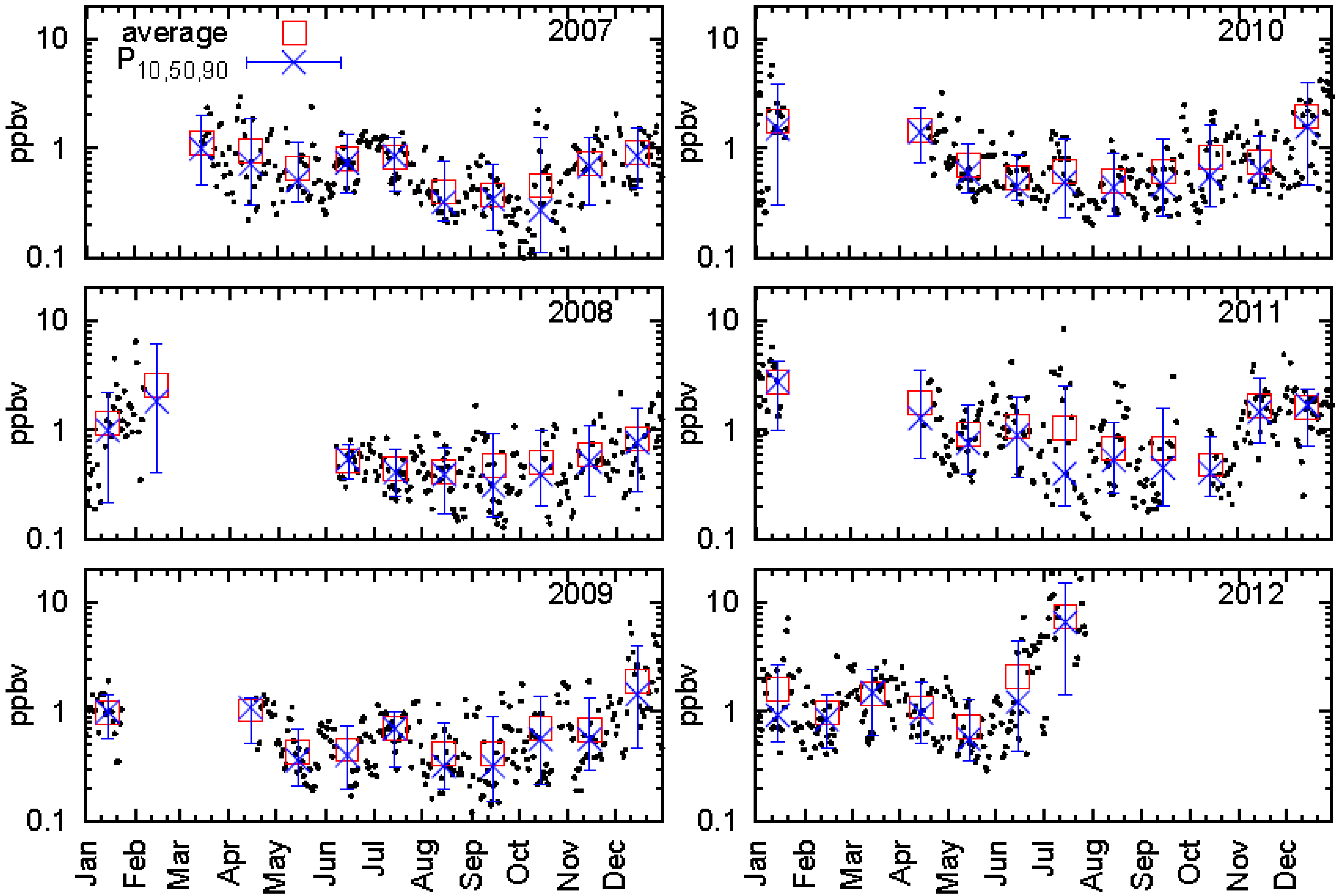



- Atmospheric photochemical system is rather uniform over continental areas of North Eurasia.
- The ZOTTO measurement data are representative at regional scale if considered at seasonal scale (›› synoptic times).

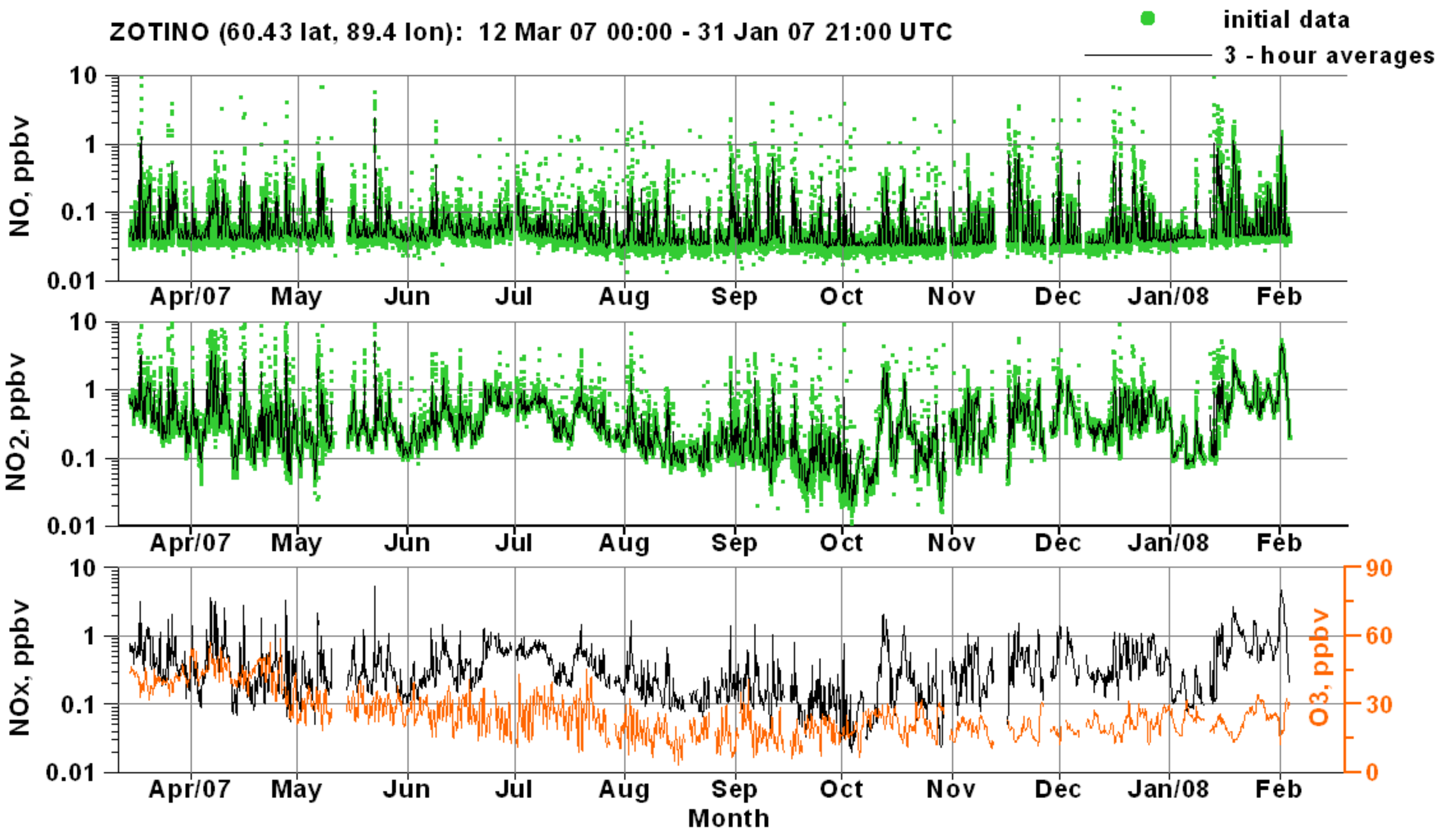
2) To what extent the Tall Tower is subjected to regional anthropogenic emissions?

Use NO+NO2 as indicator of industrial emission-contaminated air.

# Nitrogen oxides (NO+NO2) observations at ZOTTO in 2007-2012



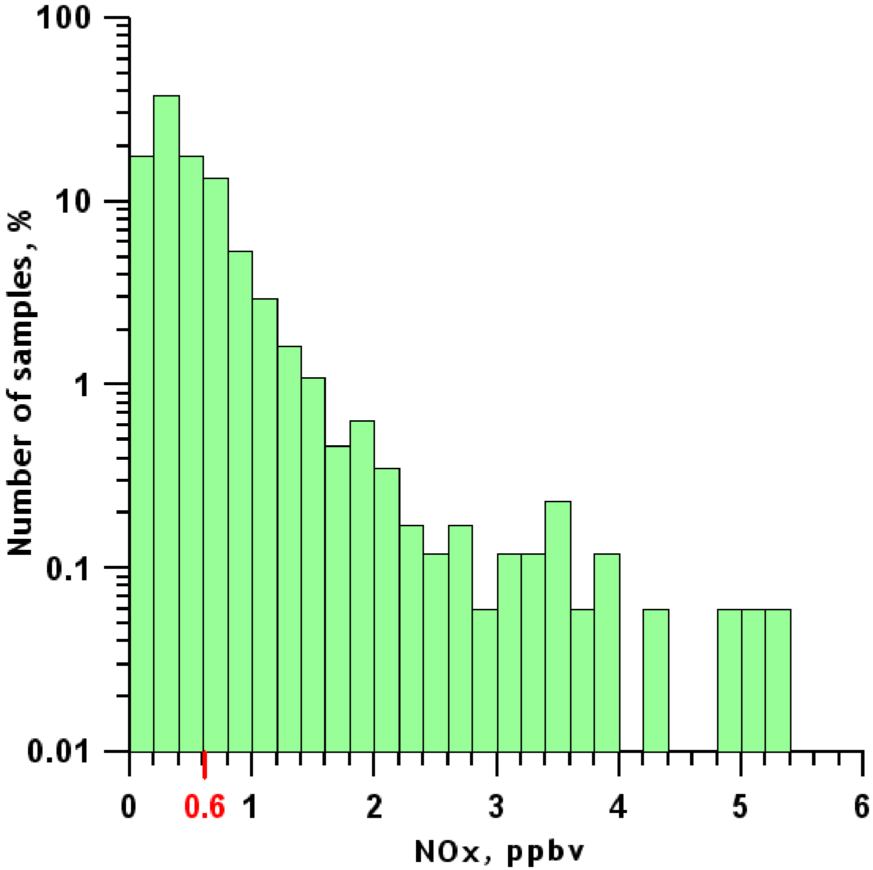
# Surface NO, NO2, $NO_X$ and O3 measured at ZOTINO during 2007.03 – 2008.01




**Measured NOx (as NO + NO2):**

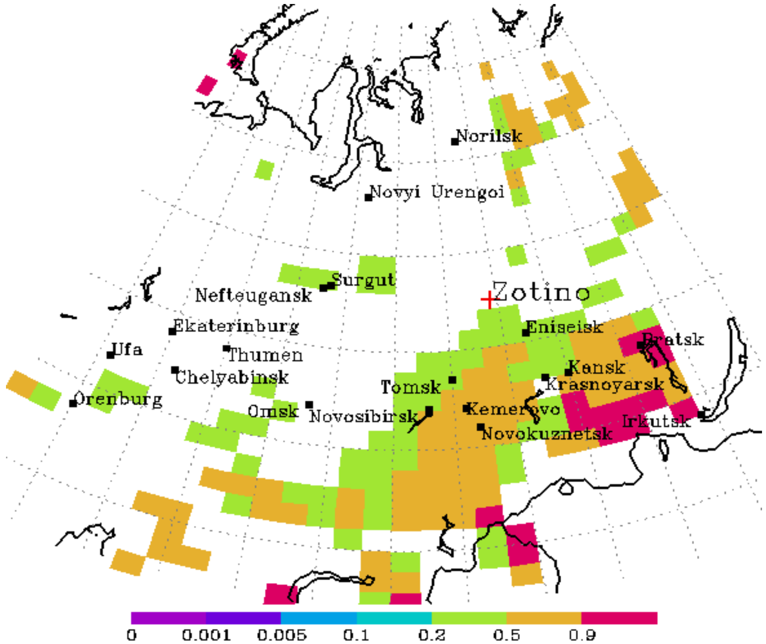
- **low background concentrations (<1 ppbv)**
- **short-term fluctuations from 0.1 to 10 ppbv**

## Histogram of $NO_X$ concentrations for 12 Mar 2007 – 31 Jan 2008



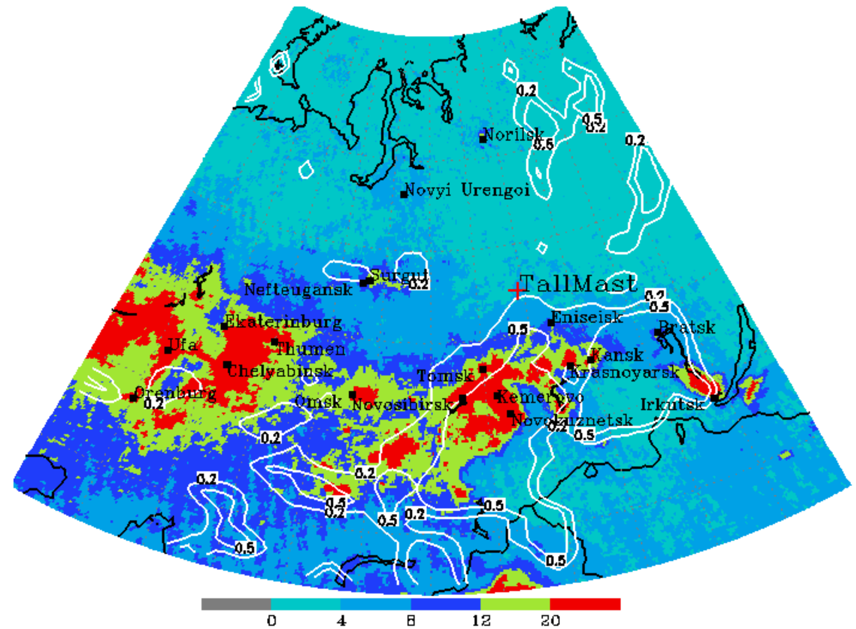

- **Top quartile of NOx concentrations experience seasonal variations within 0.6-0.8 ppbv.**
- **NOx from top quartile serve as indicators of polluted air which could have been transported from distant emission sources.**

# Yearly mean conditional frequencies (CF) of air with high NOx




**Normalized frequency**

**NOx Potential source contribution function**




**$NO_2$ <$10^{15}$ molec / $cm^2$>**

**CF against yearly tropospheric $NO_2$ from OMI**

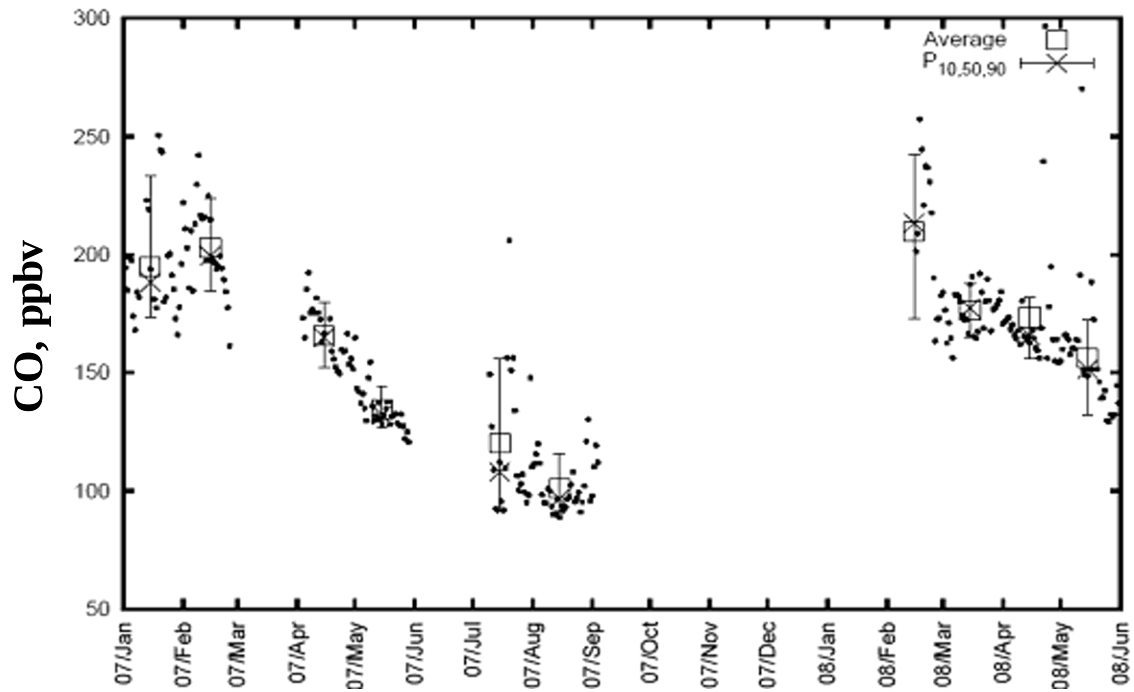
**The climatologically important sources of NOx are primary associated with industrial areas in the South Siberia.**
**Impact of Southern Ural was not revealed probably because of larger distances to ZOTTO.**

# Regional impact of North Eurasia wildfires as seen from ZOTTO CO and O3 observations

# Modeling tools

1) Trajectory ensemble statistical model for residence time analyses (Vasiljeva & Moeseyenko, 2007, 2011);
2) RAMS/CAMx/HYPACT numerical modeling system for regional meteorology / chemistry simulations (www.atmet.com, www.camx.org);
3) GEOS-chem global chemistry – transport model;
4) Wildfire emission model (Vasiljeva 2003, 2011, 2012)

# ZOTTO CO near-surface obs. (Jan 2007 – Jun 2008)

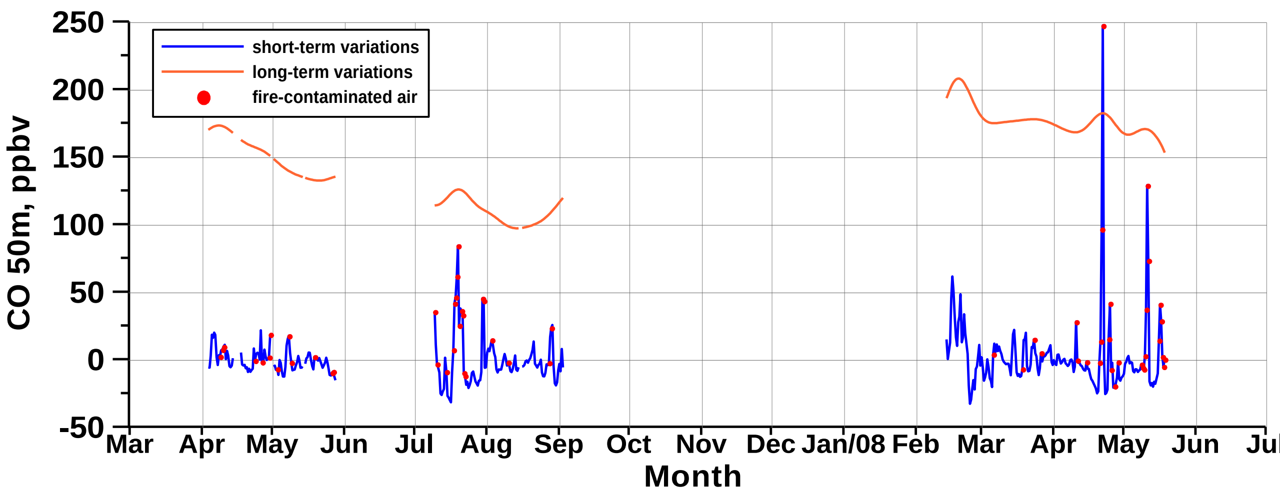



Amplitude of seasonal cycle (winter – summer) ~110 ppb well agrees to:

- TROICA observations (*Elanskii et al*., 2006);
- Mondy station, 1997 - 1999 (*Pochanart et al*., 2003);
- Ryori, Japan (*Kim et al*., 2010);
- Oki, Japan (*Pochanart et al*., 1999)

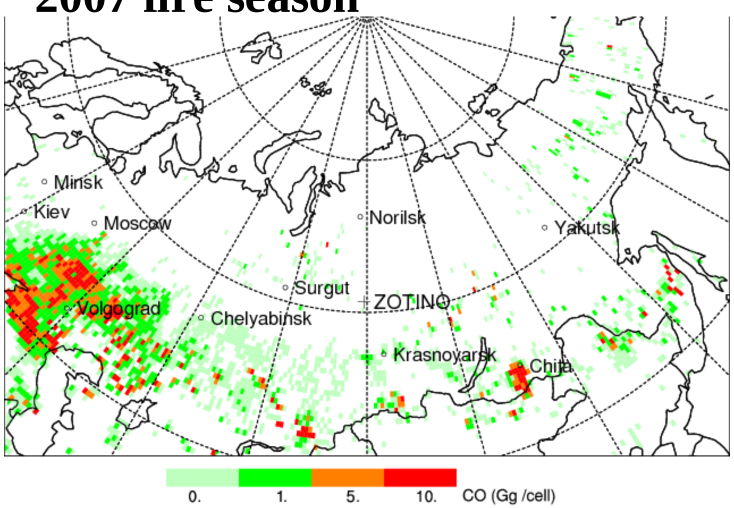
**This manifests for weak spatial gradients of CO (and ozone) over the continent at seasonal scales.**

# Kolmogorov-Jurbenko decomposition of original CO data into synoptic (< 20 days) and seasonal components

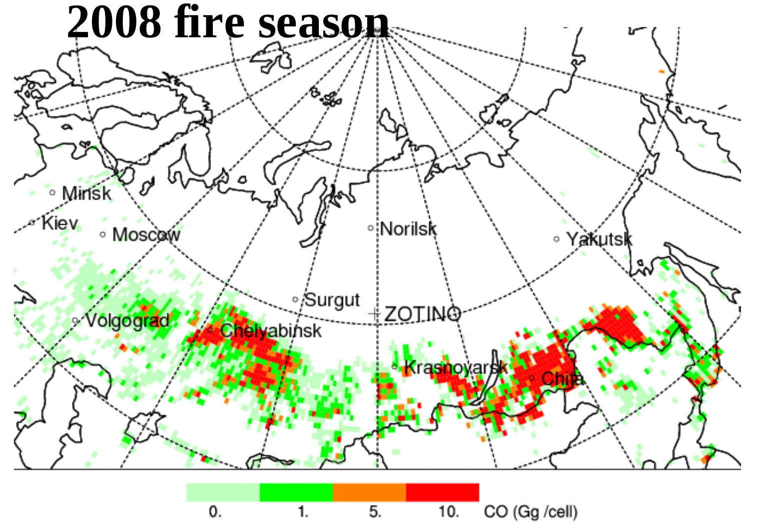



**Red dots show episodes of air transport from wildfires.**

## 2007 fire season

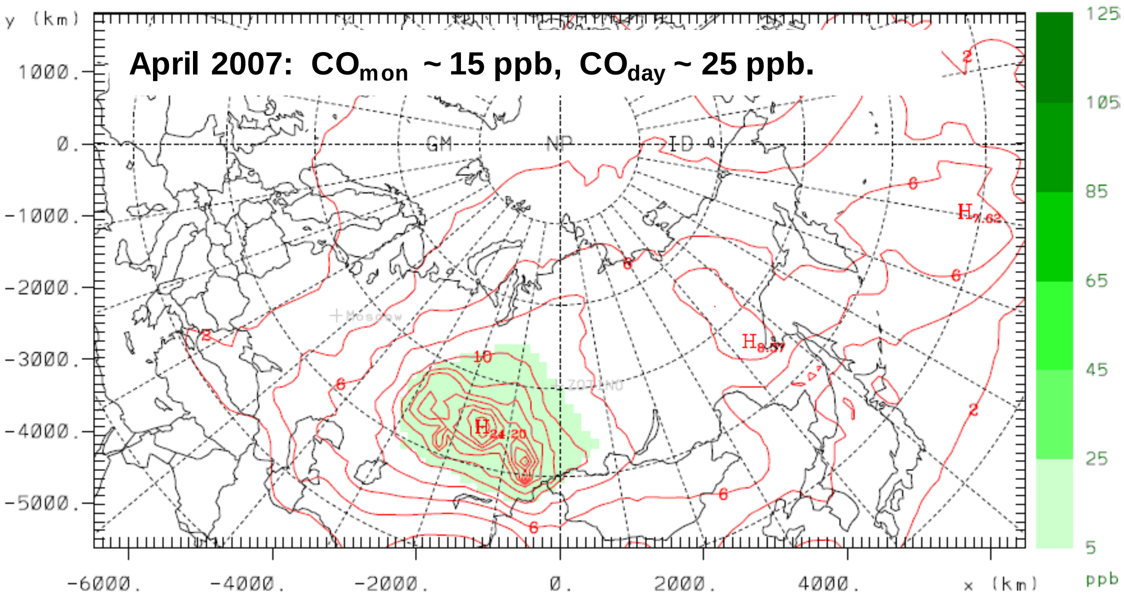


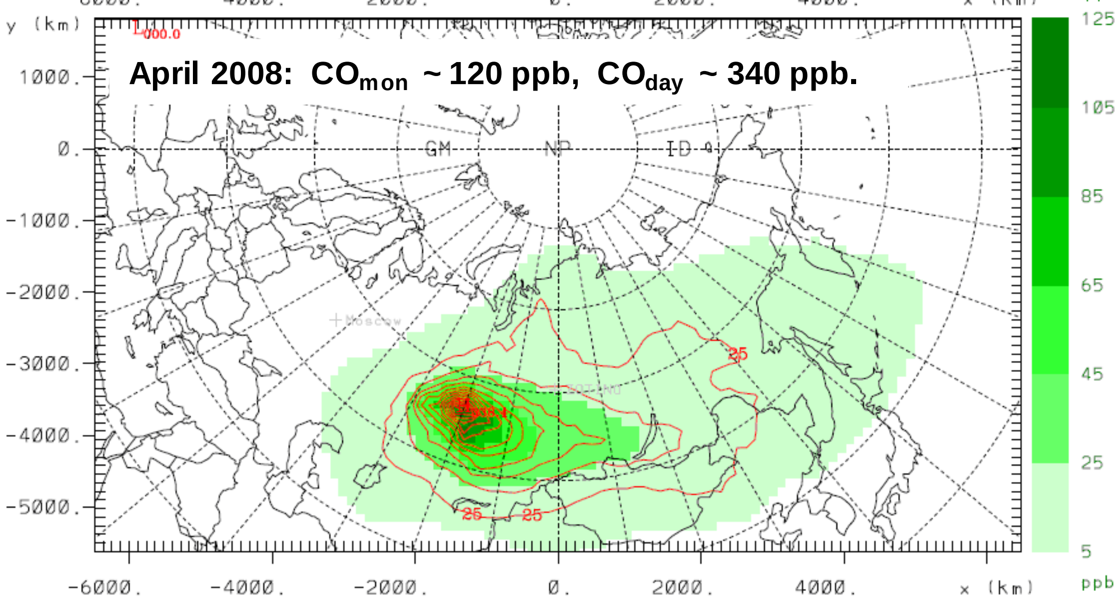

## 2008 fire season



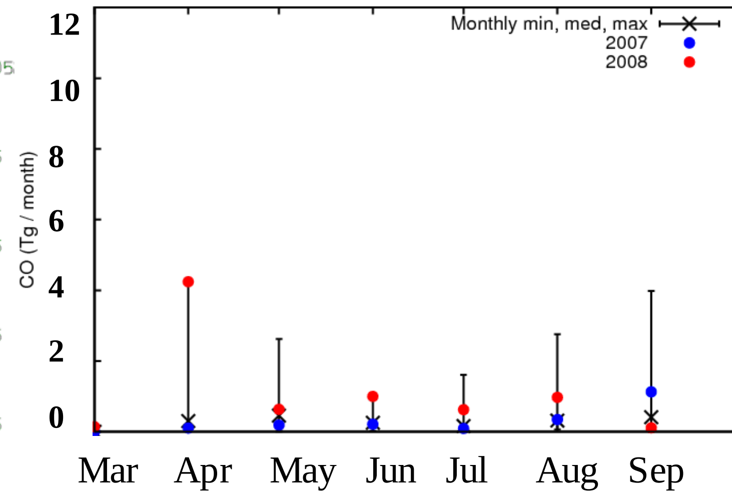

## Wildfires affecting ZOTTO measurements

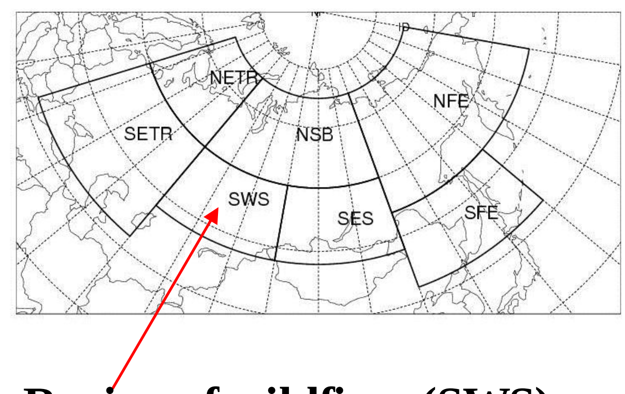
# Near-surface CO response to wilfires in West Siberia during April 2007 and 2008




**Emissions CO Tg/month**



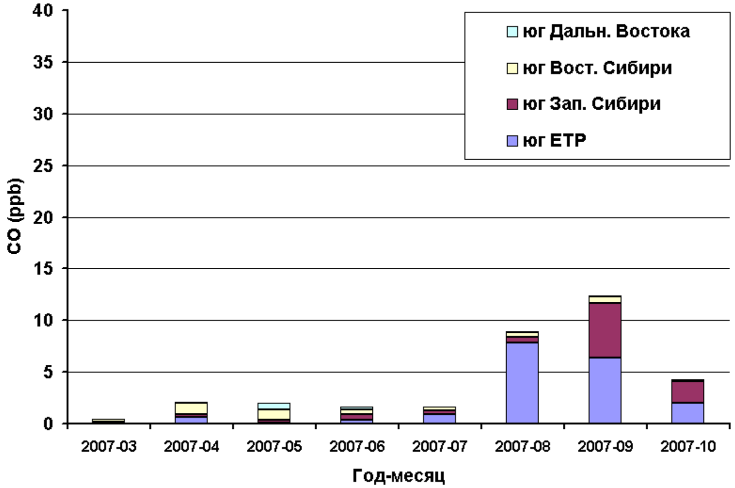




**Region of wildfires (SWS)**

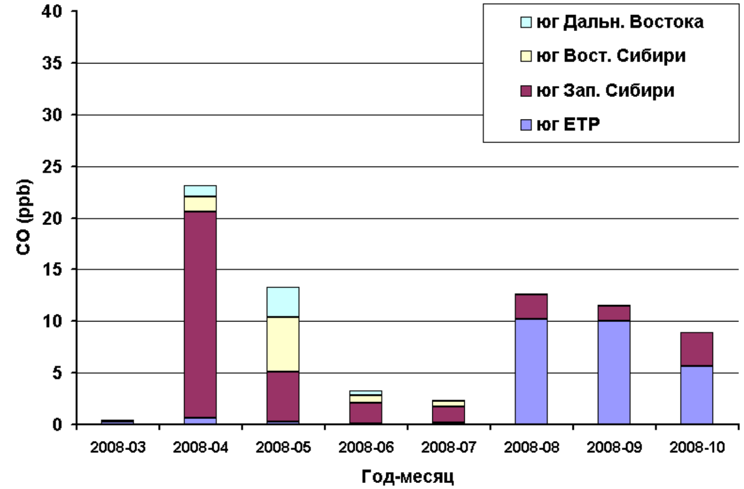
# Model-predicted ZOTTO CO response to wildfire and anthropogenic regional emissions

CO winter ~200 ppb
CO summer ~100 ppb

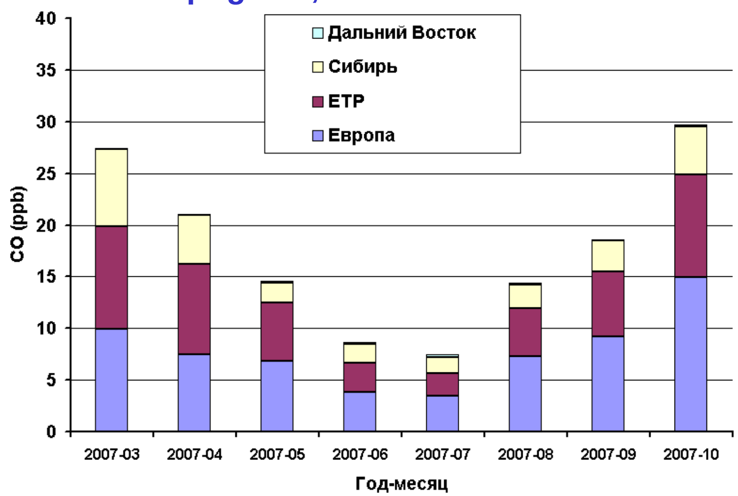
## Wildfires, 2007



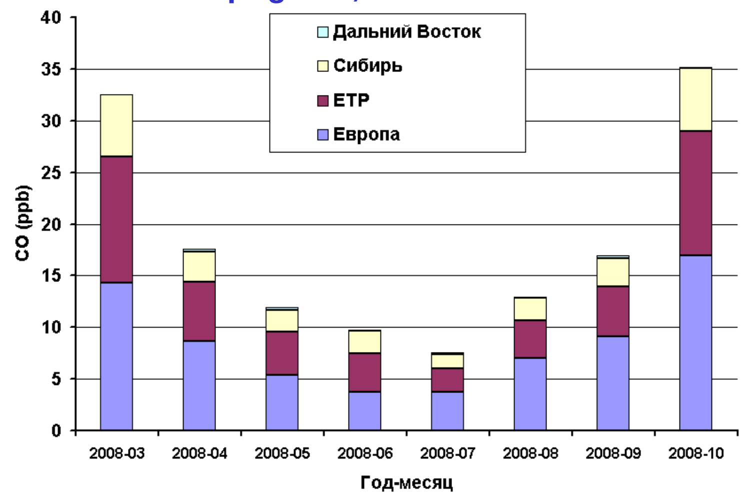

## Wildfires, 2008



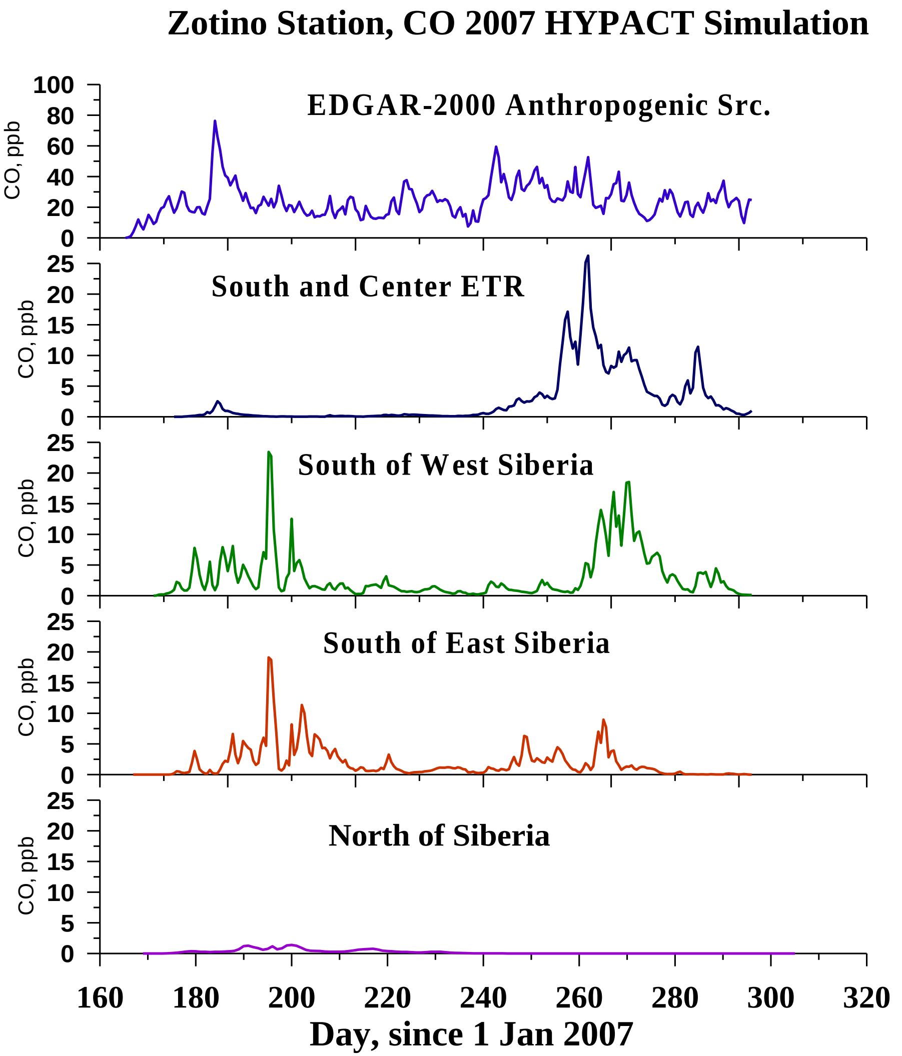

## Anthropogenic, 2007

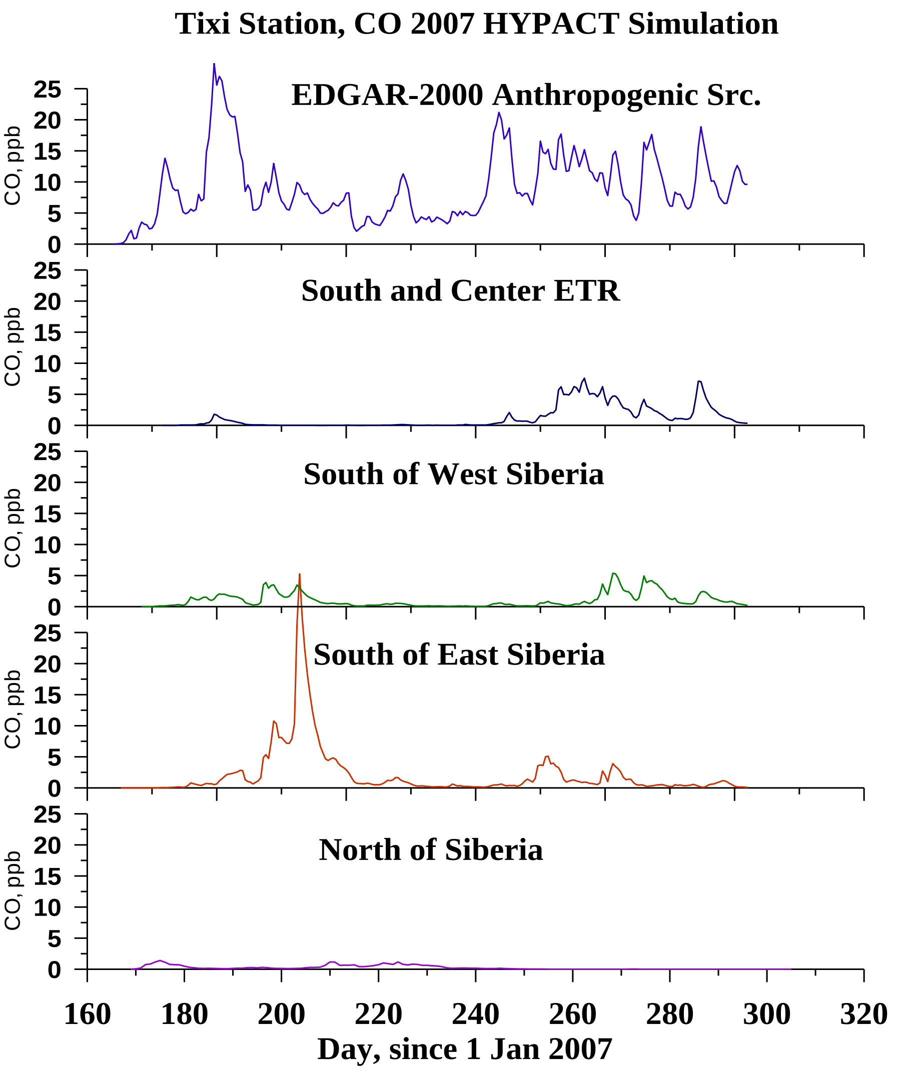



## Anthropogenic, 2008



# Model predicted near-surface CO response to wildfires for ZOTTO and Tixi stations



## Publications


- Vasileva A.V., Moiseenko K.B., Mayer J.-C., Jurgens N., Panov A., Heimann M., Andreae M.O. Assessment of the regional atmospheric impact of wildfire emissions based on CO observations at the ZOTTO tall tower station in central Siberia // J.Geophys. Res. 2011. 116. D07301.
- Vasileva A. Wildfires in Russia in 2000-2008: estimates of burnt areas using the satellite MODIS MCD45 data // Remote Sensing Letters. 2011. Vol.2(1). P.81–90.
- Васильева А.В., Моисеенко К.Б., Панкратова Н.В. Оценки эмиссий оксида углерода от природных пожаров в Северной Евразии в приложении к задачам регионального атмосферного переноса и климата // Изв. РАН. Физика атмосферы и океана. 2010. Т.46. №3. С.307–320.
- Васильева А.В., Моисеенко К.Б., Шумский Р.А., Скороход А.И. Идентификация антропогенных источников эмиссий окислов азота по расчётам Лагранжевых траекторий и данным наблюдений на высотной мачте в Сибири весной – летом 2007 г. // Изв. РАН. Физика атмосферы и океана. 2009. Т.45. №3. С.325-336.


# THANKS FOR YOUR ATTENTION

## Atmospheric spring time response to increase in wildfire CO emissions:

$$\Delta CO^{(median, mean)}_{fires} = CO^{(median, mean)}_{fires+anthrop.} - CO^{(median, mean)}_{anthrop.}$$

$\Delta E$ = $EMIS_{2008}$-$EMIS_{2007}$=5Tg CO (in south Siberia, spring)

| Estimates | 2007 ppb | 2008 ppb | ΔCO ppb | $\Delta CO/\Delta E$ ppb/Tg |
|---|---|---|---|---|
| ZOTTO obs., in plumes* | 3.6 | 39.2 | 35.6 | 6.7 |
| ZOTTO obs., seasonal | 149.1 | 164.8 | 15.7 | 2.9 |
| HYPACT**, seasonal | 2.1 | 18.2 | 16.1 | 3.0 |

* For airmass age up to 2 days

** Numerical calculations with RAMS/HYPACT modeling system.

## Параметры расчетов среднесуточных приземных (39 м) концентраций CO с помощью моделей RAMS и HYPACT

**Периоды:** 1 янв – 31 дек 2007, 1 янв – 31 дек 2008.

**Расчетная область:** Северная Евразия, 40–90° с.ш., 20–180° в.д., сетка 120 x 120 км, 65 x 111 узлов, 40 уровней по вертикали от 0 до 20 км (из них 9 уровней ниже 1 км) в $\sigma_z$ системе координат.

**Входные данные:**

Метеополя – данные реанализа NCAR FNL на сетке 1°x1° за 00:00 и 12:00 GMT,

Эмиссии CO – разработанная система усвоения данных EMIS3.

**Расчеты:**

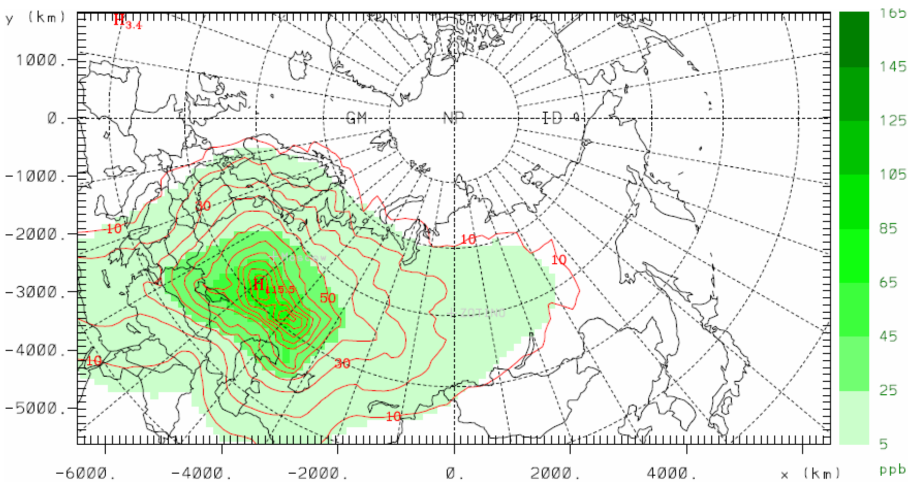
Метеополя, коэффициенты турбулентной диффузии – по модели RAMS в режиме 12-часового прогноза с выводом результатов каждые 3 часа.

Фотохимическое время жизни CO – из работы *Holloway et al*. (2000).

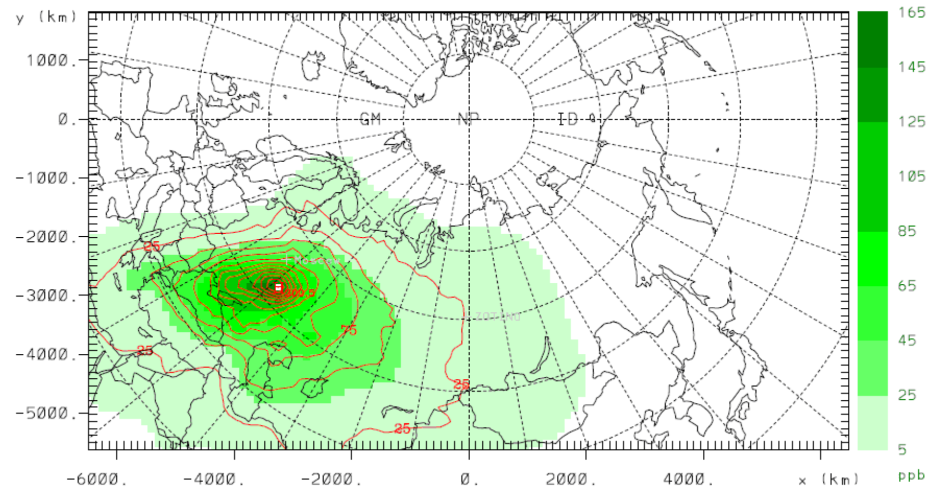
Среднесуточные приземные (39 м) концентрации CO – по модели HYPACT.

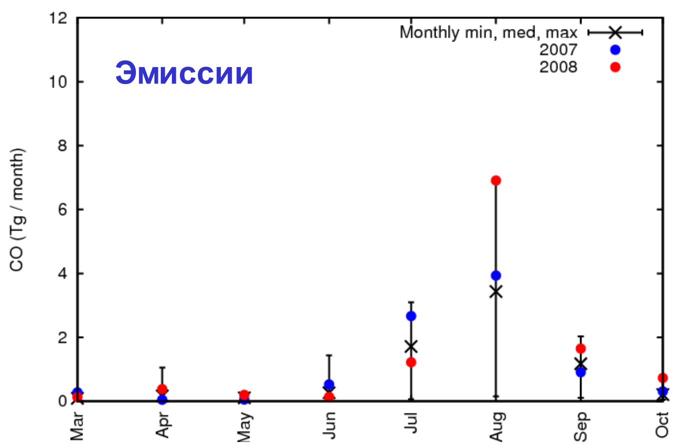
# Эмиссии (MODIS) и приземные концентрации (HYPACT) CO от природных пожаров на юге ЕТР

**Август 2007:** $CO_{mon}$ до 80 ppb, $CO_{day}$ до 115 ppb.



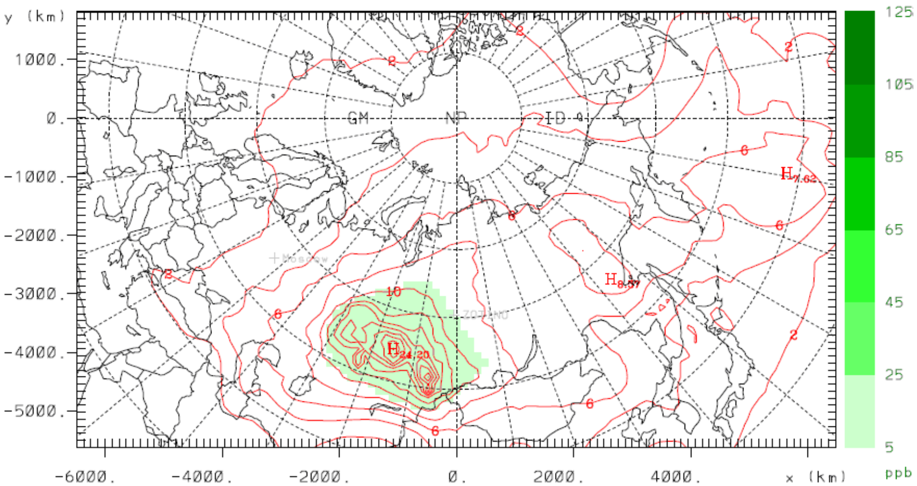

**Август 2008:** $CO_{mon}$ до 170 ppb, $CO_{day}$ до 300 ppb.



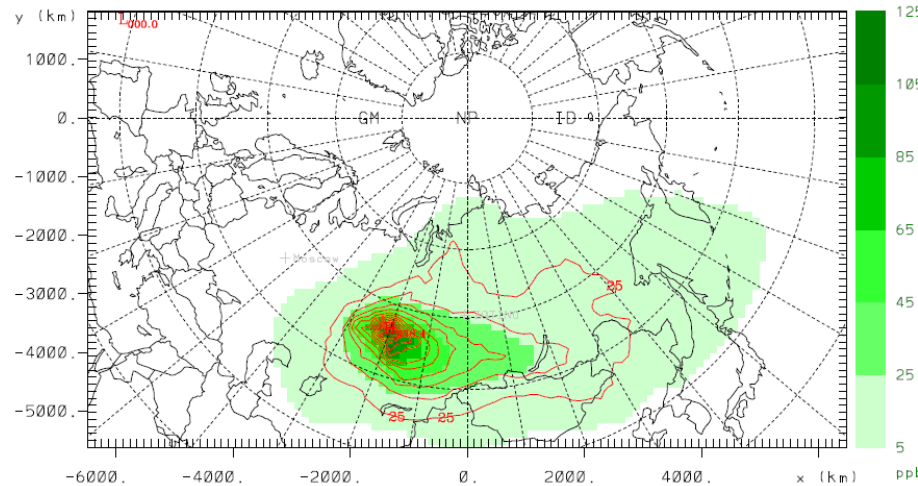



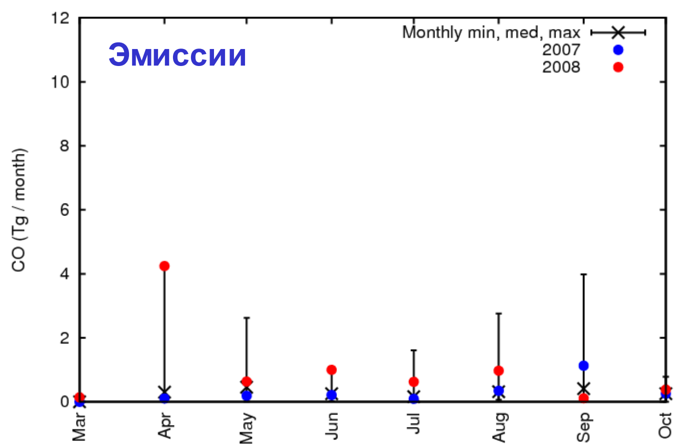
## Эмиссии (MODIS) и приземные концентрации (HYPACT) CO от природных пожаров на юге Западной Сибири

**Апрель 2007:** $CO_{mon}$ до 15 ppb, $CO_{day}$ до 25 ppb.



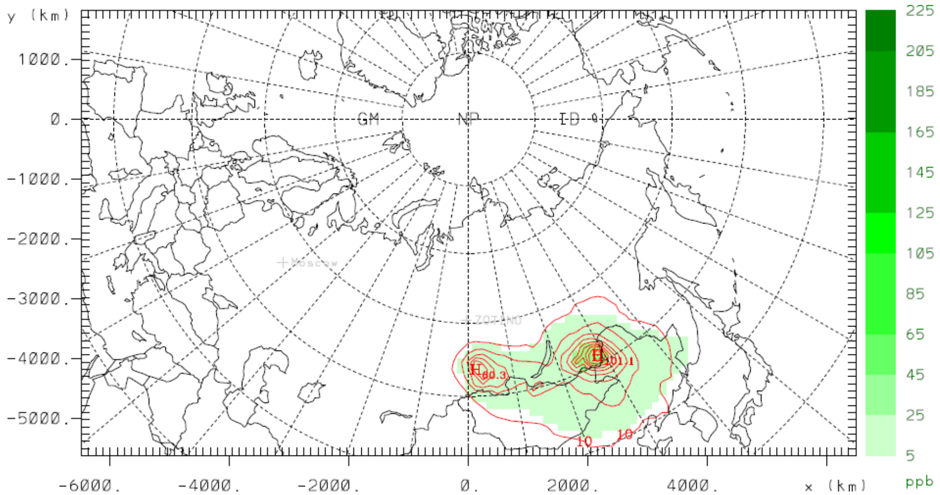

**Апрель 2008:** $CO_{mon}$ до 120 ppb, $CO_{day}$ до 340 ppb.



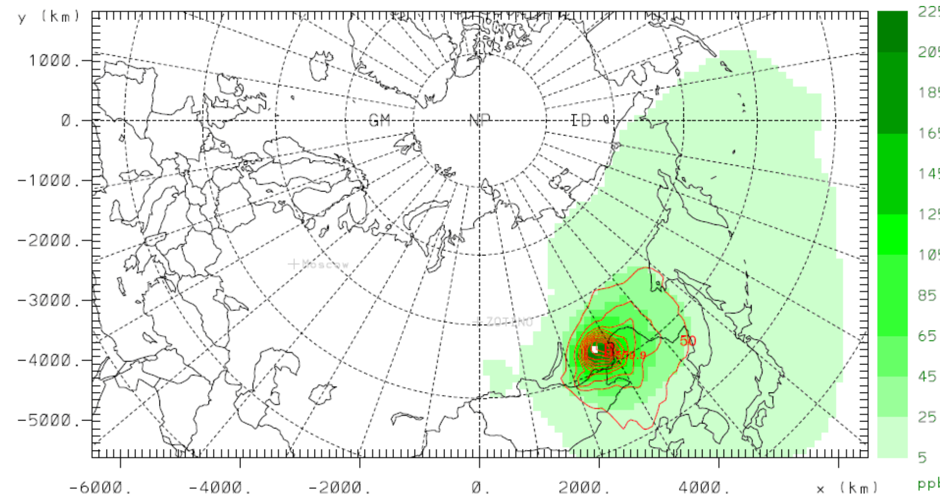



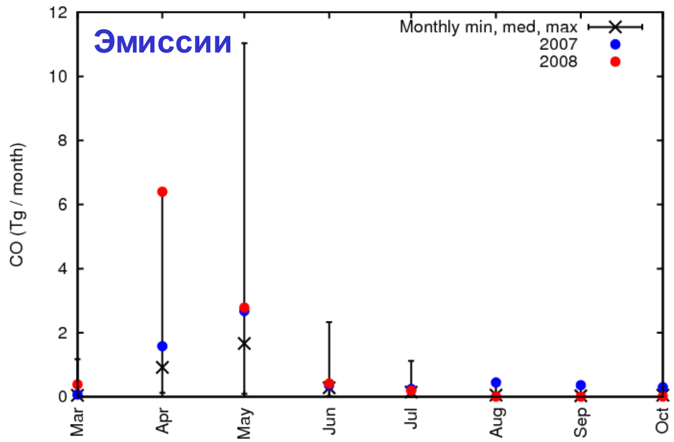
# Эмиссии (MODIS) и приземные концентрации (HYPACT) CO от природных пожаров на юге Восточной Сибири

**Апрель 2007:** $CO_{mon}$ до 40 ppb, $CO_{day}$ до 100 ppb.

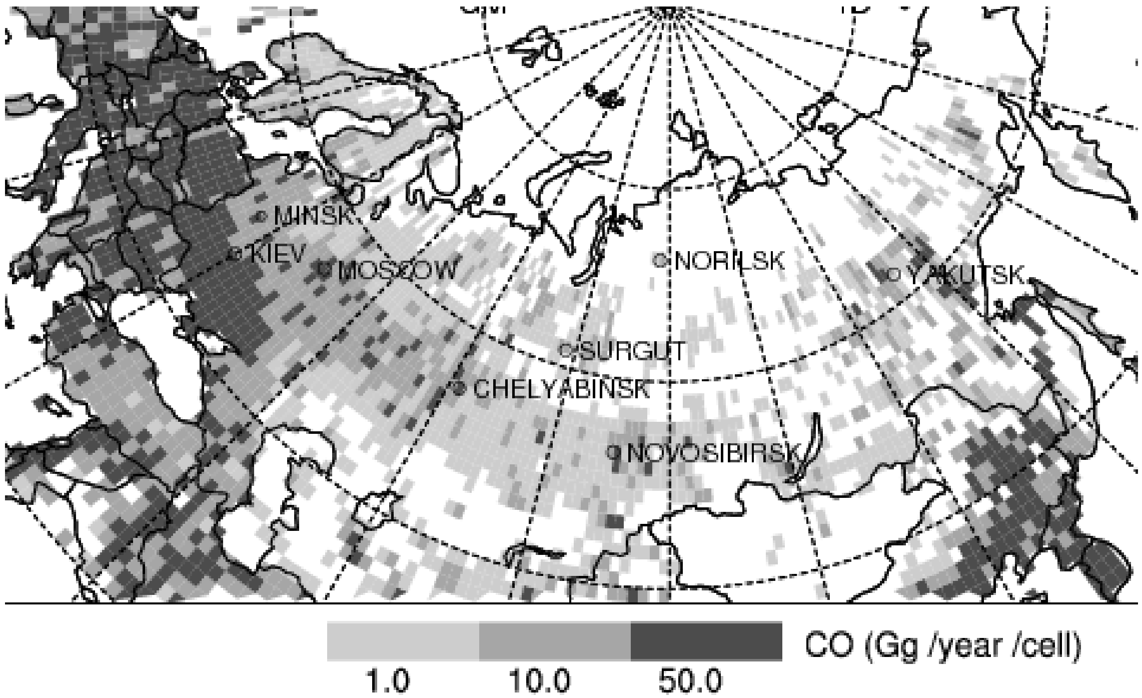



**Апрель 2008:** $CO_{mon}$ до 225 ppb, $CO_{day}$ до 560 ppb.



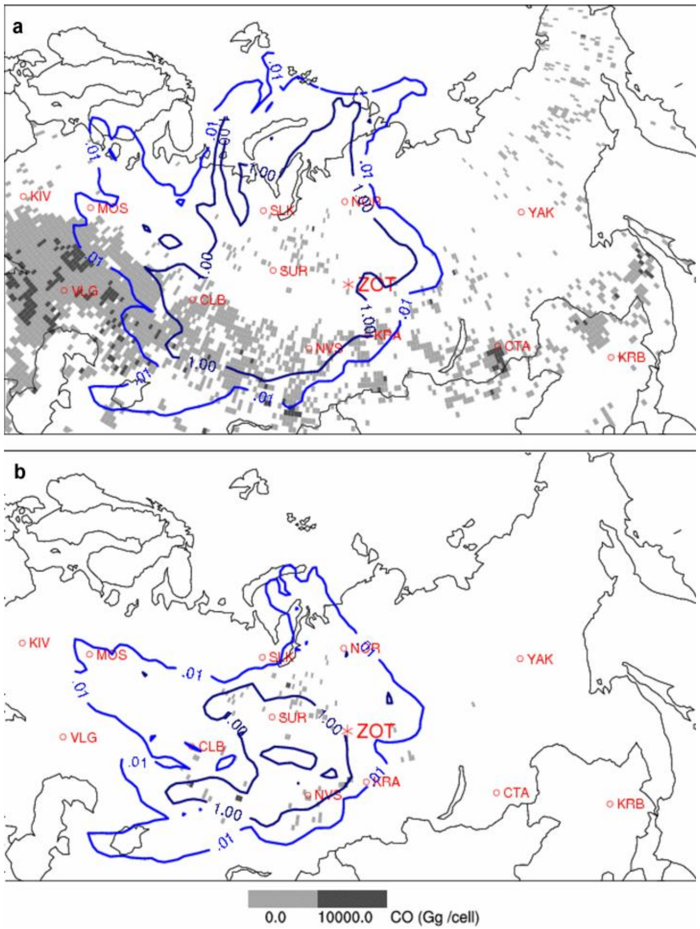
## Оценки крупномасштабных эффектов от пожаров на фоне антропогенных источников



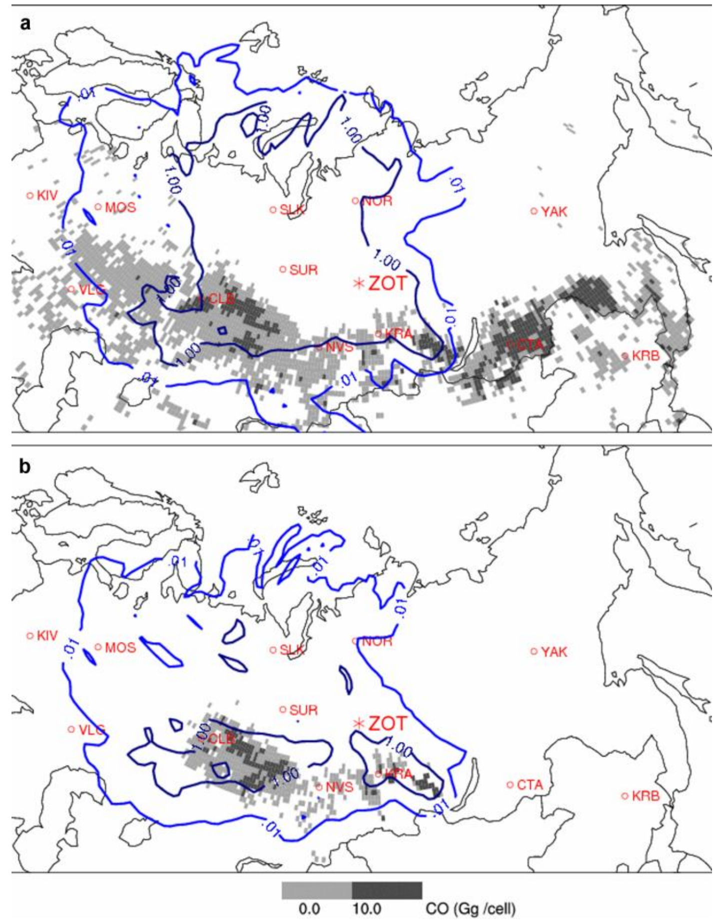

Антропогенные эмиссии CO по данным EDGAR-2000.

# CO source contribution function (SCF) for ZOTTO

**Weak fire activity**
JUL-AUG 2007




**Strong fire activity**
APR-MAY 2008




**Top:** SCF and total wildfire CO emissions in summer 2007 (left) and spring 2008 (right).
**Bottom:** SCF for the upper quartile 12-hour CO and fire pixels crossed by backward trajectories.

## Rationale: Wild land fires as a source of atmospheric emissions

√ **Boreal forests in 45º – 70º N belt constitute 1/3 of the total forest area on the planet, with carbon storage in vegetation and soil constituting 10 – 17 % of the planetary budget.**

√ **Russian boreal forests contribute 22% to the overall forest area on the planet**;

√ **Boreal forest fires contribute 4 – 12% to the global biomass burnt annually, with emissions of soot and organic aerosols in individual years contribute up to 9% and 20% respectively, and of non-organic carbon (mainly as CO and CO2) – up to 20% of annual global emissions.**

√ **Large fires (>200 ga) play important role**

√ **Climatic temperature rise → prediction of increase in wildfire intensity → increase in number of severe pollution events and ecological hazards**