

Analysis of large-scale variability of the surface air chemical composition in the Northern Eurasia

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Preliminary analyses of measurement data on surface air chemical composition over the Northern Eurasia

Primary goal:

Contribution to up-to-date scientific knowledge about main physical and chemical mechanisms influencing minor gaseous and aerosol compounds budget in the Northern Eurasia, including high-latitude regions

Rationale:

- **For the last decades the changes in air composition have been observed not only in the industrial regions, but also in many of clean areas throughout the Globe.**
- **The influence of climatically important biogenic and anthropogenic emission sources is essentially non-local and reveals itself distinctly both on regional and trans-continental scales.**
- **Vast areas of the Northern Eurasia still remain poorly investigated about air chemistry due to exceptionally scarce and incomplete observational network at present.**

The lack of systematic data on the chemical composition in our country prevents strongly the research activities on air quality studies, estimations of ecological burdens, and natural and anthropogenic impact on long-term and climatic variability of air composition and associated problems

Some research activities of Atmospheric Composition Division:

- Observations of chemical and aerosol surface air composition, investigations of spatial and temporal variability of air composition on the territory of Russian Federation.**
- Improvement of present knowledge about key factors affecting atmospheric balance of minor species in the Northern Eurasia (NE), including processes of regional and long-range transport.**
- Obtaining data for verification of CTM models and their adaptation for the NE region, including polar regions.**
- Creating inventories on various near-surface emissions for their including into CTM and climate models.**

Methods of investigations:

(1) Measurements of chemically active gases and aerosols:

- with use of **carriage-observatory** (along Trans-Siberian railroad, experiments TROICA);
- at scientific **monitoring stations** Zotino (Middle Siberia), Lovosero (Kola Peninsular), Zvenigorod (Moscow Region), Kislovodsk High-Mountain Station, MSU observation station.

(2) **Data processing and analyses** with use om mathematical models of various levels of complexity.

TROIKA campaigns:

- Complex measurements of minor gaseous species and aerosols in the atmospheric boundary layer with use of mobile carriage-observatory.

Results

- The first comprehensive data on spatial and temporal variability of surface air composition over the territory of Russian Federation have been obtained.
- The key factors affecting atmospheric composition at local as well as regional scales were analyzed, including various anthropogenic and biogenic emissions, influence of industrial plumes, ABL structure.



TROICA participants:

- **Obukhov Institute for Atmospheric Physics, Russia**
- **Karpov Institute of Physical Chemistry, Russia**
- **Max Planck Institute for Chemistry, Germany**
- **Institute for Railway Transport, Russia**
- **NOAA Climate Monitoring and Diagnostic Laboratory, USA**

Measuring equipment



Surface layer (continuous measurements):

Gases: O₃, NO, NO₂, CO, CO₂, SO₂, CH₄; volatile organic compounds (25 species);

Aerosols: size distribution (2 nm-10 μm), extinction coefficients, mass concentration; black carbon;

Meteorology: P,T,RH, wind speed and direction.

Sampling: composition of VOC and aerosols, isotopic composition of CO, CO₂, CH₄ (¹³C,¹⁴C,¹⁸O, D);

Distant measurements:

- CO (column amount);

- O₃ (column amount and vertical profile from 0 – 45 km (optic range) and 20 – 65 km (microwave range));

- NO₂ (total and vertical and slant column, vertical profile from 0 – 45 km);

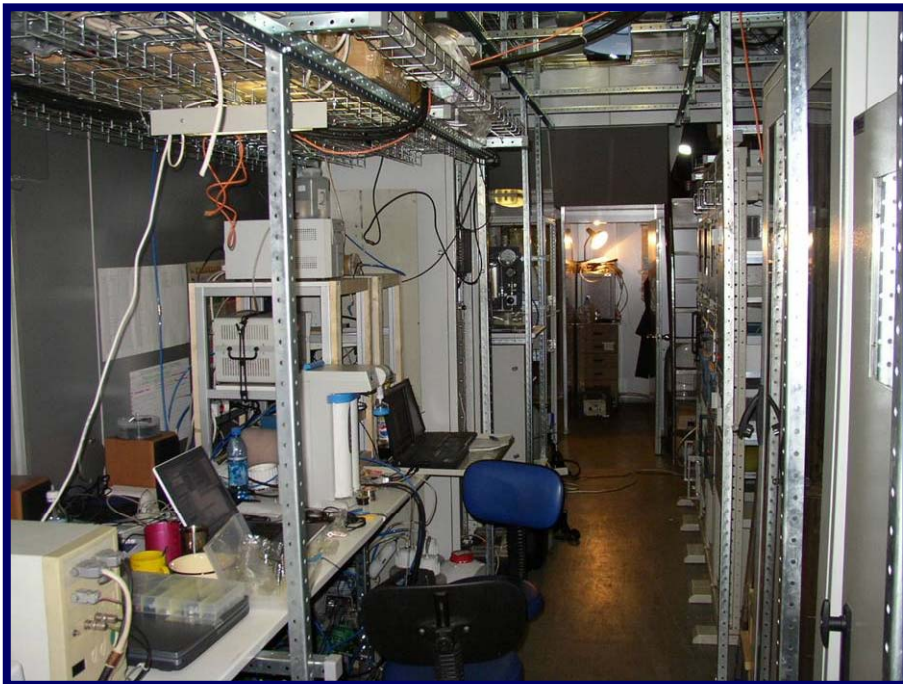
- Temperature profile from 0 – 600 m a.g.l.

Solar radiation: total, UV-A, UV-B, photodissociation rate of NO₂;

Others: GPS, ²²²Rn, radionuclides, TV recording, water, soil and plant sampling.

Specifics of the measurement equipment

- **Measurements and quality control are fully automatic;**
- **All the key minor species are measured along with thermodynamic parameters of the surface layer;**
- **Wide range of measured concentrations, ranging from background level to highly polluted conditions;**
- **High temporal resolution (of order 1 sec);**
- **The measurement equipment meets to international standards. The devices are recommended for the use by GAW WMO and have international certificates.**



TROICA expeditions

Expedition	Period	Route
TROICA-1	1995 17.11 – 2.12	N.Novgorod – Khabarovsk – Moscow
TROICA-2	1996 26.07 – 13.08	N.Novgorod – Vladivostok – Moscow
TROICA-3	1997 1.04 – 14.04	N.Novgorod – Khabarovsk – Moscow
TROICA-4	1998 17.02 – 7.03	N.Novgorod – Khabarovsk–N.Novgorod
TROICA-5	1999 26.06 – 13.07	N.Novgorod – Khabarovsk – Moscow
TROICA-6	2000 15.05 – 28.05	Moscow – Myrmansk – Kislovodsk
TROICA-7	2001 27.06 – 10.07	Moscow – Khabarovsk – Moscow
TROICA-8	2004 19.03 – 1.04	Moscow – Khabarovsk – Moscow
TROICA-9	2005 04.10 – 18.10	Moscow – Vladivostok – Moscow
TROICA-10	2006 05.10 – 20.10	Moscow – Vladivostok – Moscow
TROICA-11*	2007 22.07 – 5.08	Moscow – Vladivostok – Moscow
TROICA-12*	2008 20.07 – 4.08	Moscow – Vladivostok – Moscow

* As part of International Polar Year project #32 POLARCAT

TROICA routes



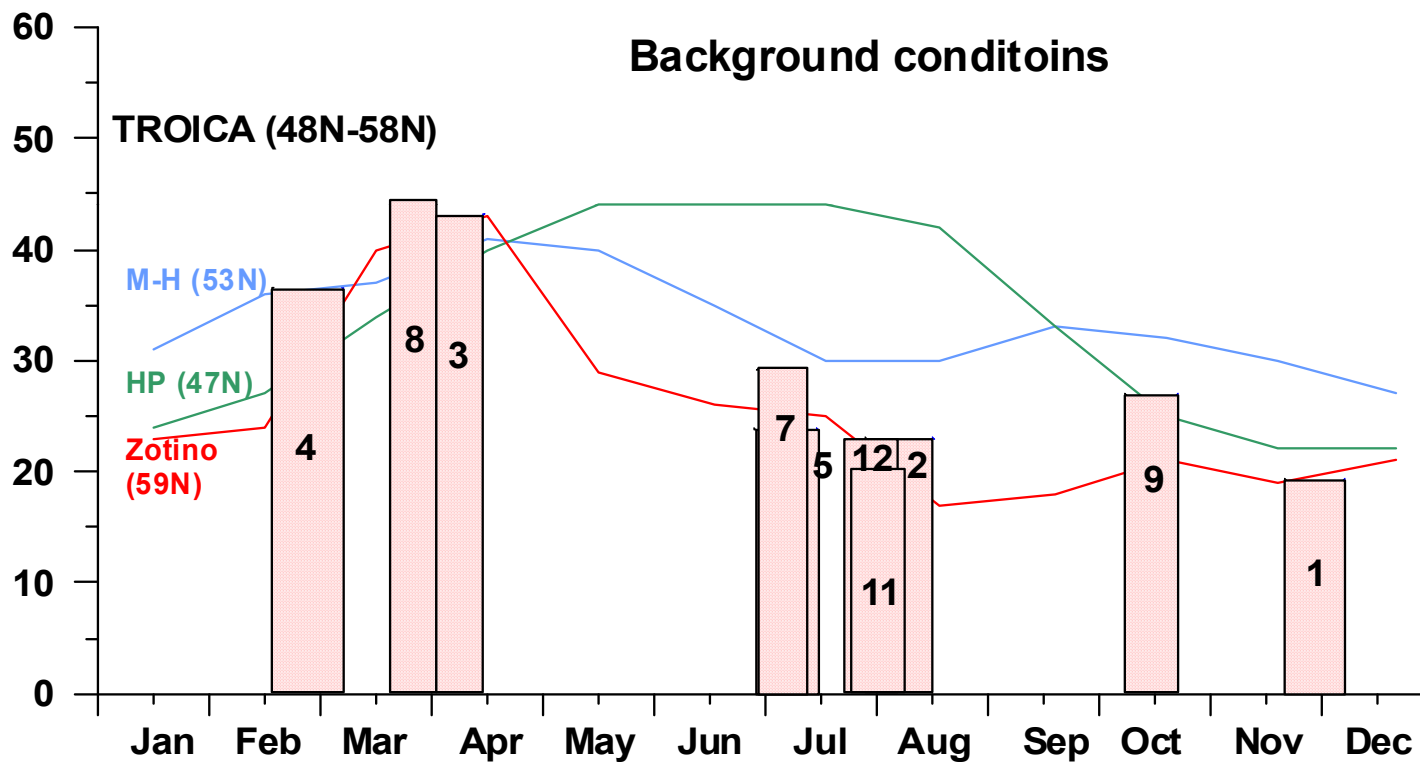
The route transects major industrial regions of Siberia and Far East at their northern boundary, which gives opportunity to assess their ecological burden on the clear territories to the north associated with regional transport and photochemistry processes.

To solve this task, one should correctly divide observed concentrations onto “background” and “perturbed” components.

To what extent the TROICA measurements are representative on regional and continental scales?

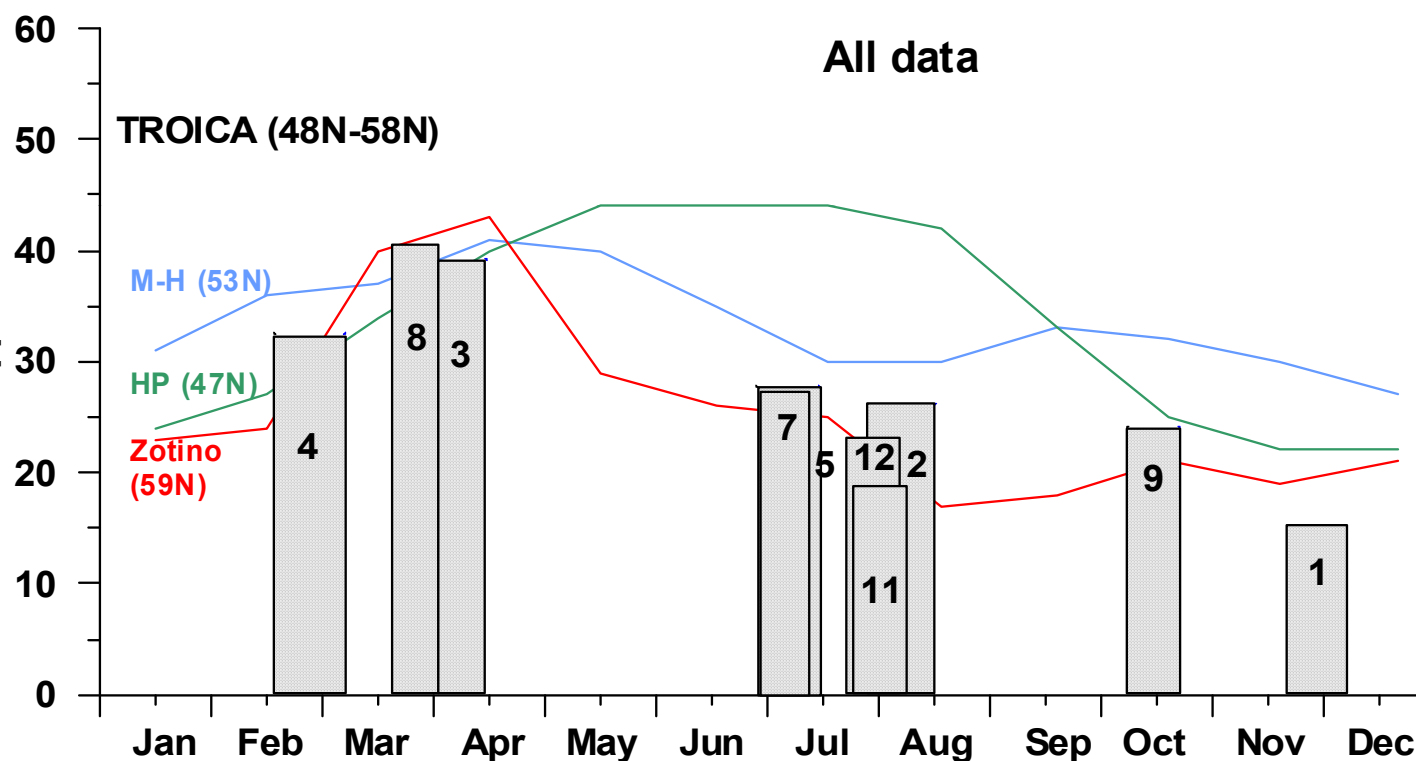
To answer this question, screening effect of local sources must be assessed.

Averaged (over the continent) **background** ozone concentrations for background conditions during TROICA-1 – TROICA-12 expeditions versus stationary observations on Hohenpeissenberg (HP), Mace Head (MH) and Zotino.



TROICA data are representative at regional scale if collected at some distance from strong local pollution sources.

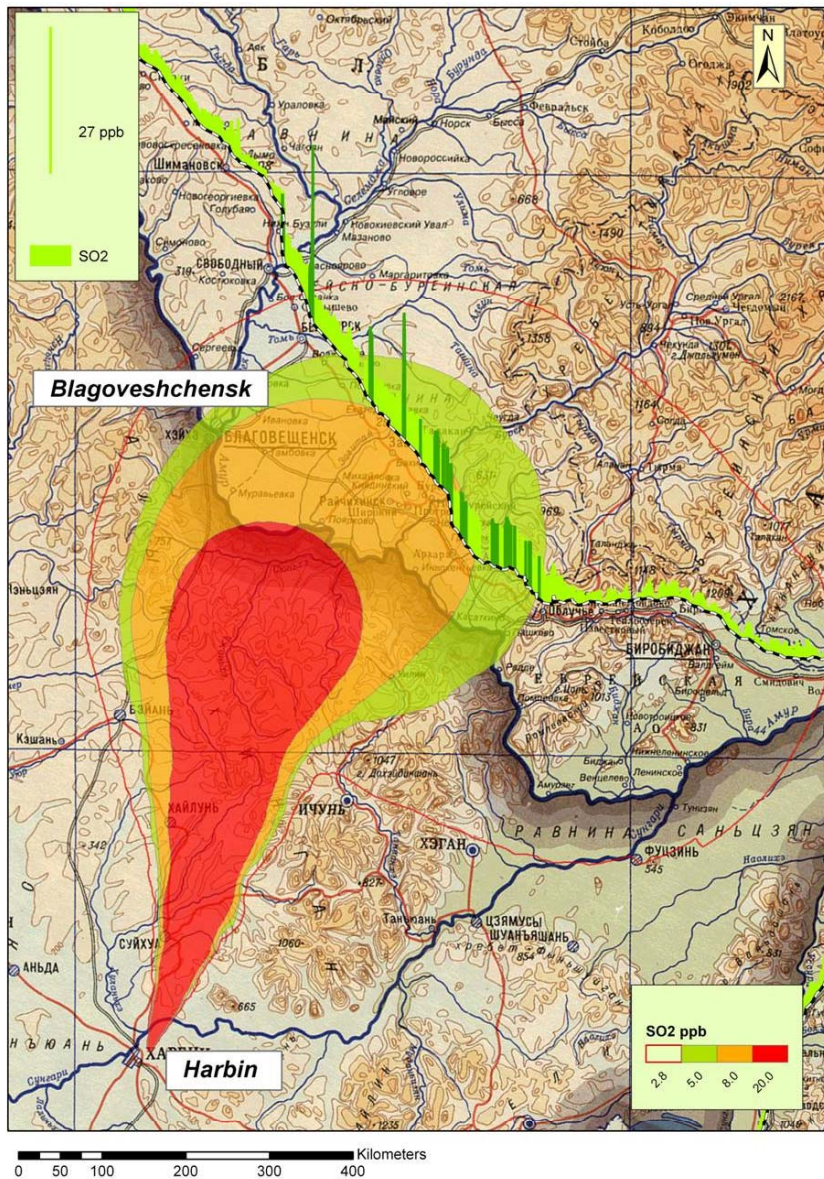
Averaged (over the continent) ozone concentrations for background conditions during TROICA-1 – TROICA-12 expeditions versus stationary observations on Hohenpeissenberg (HP), Mace Head (MH) and Zotino.



Observations along Trans-Siberian Railroad meet the conditions of clear or weakly polluted air during the most of the time.

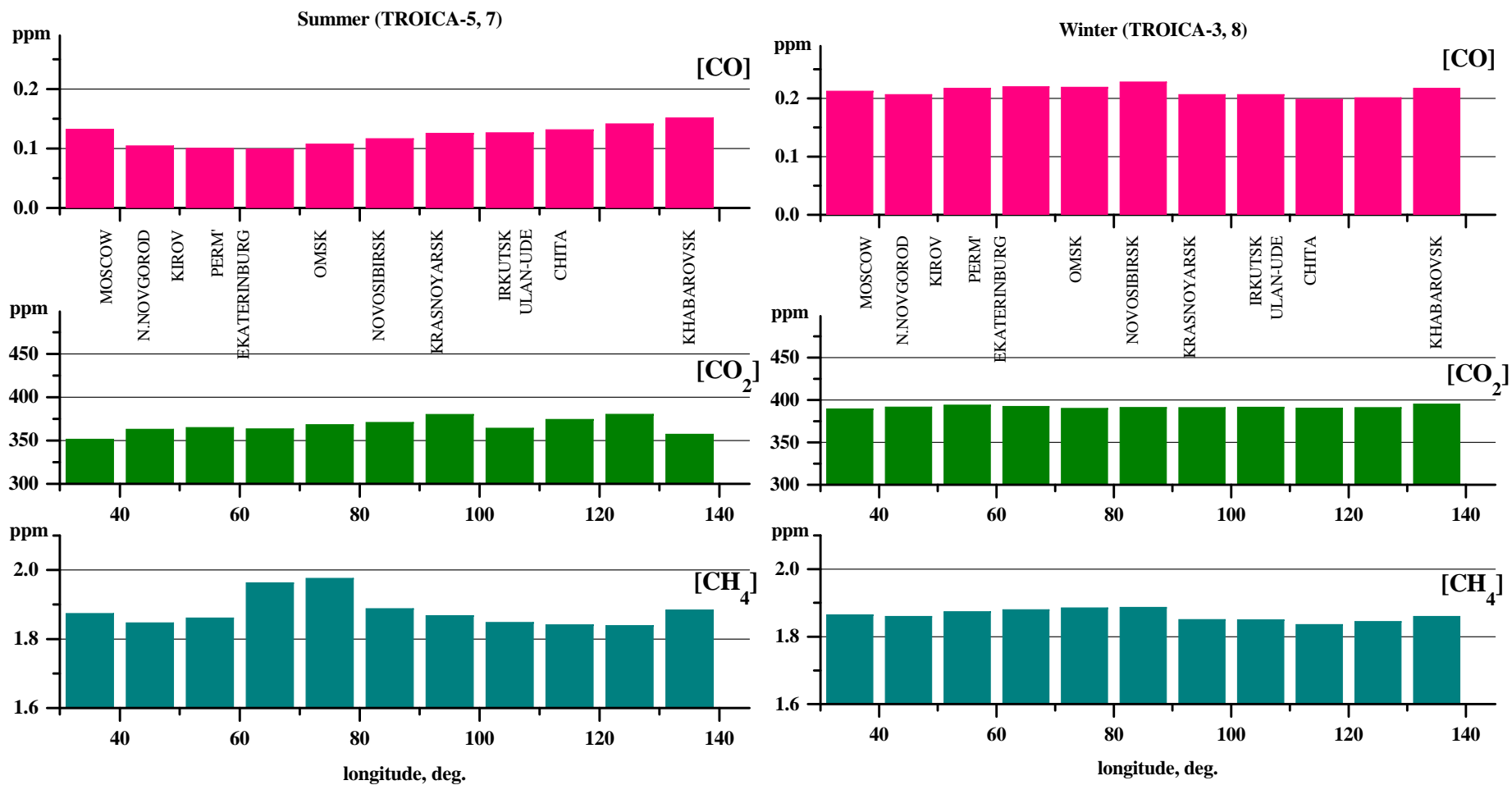
The measurements from carriage-observatory generally prove to be representative at regional scales except for those conducted in the vicinity of strong local sources of atmospheric pollution.

Due to high sensitivity of the measurement devices we can identify air masses having different chemical composition with high spatial resolution. Hence, different sources of pollution can be derived from measurement data.

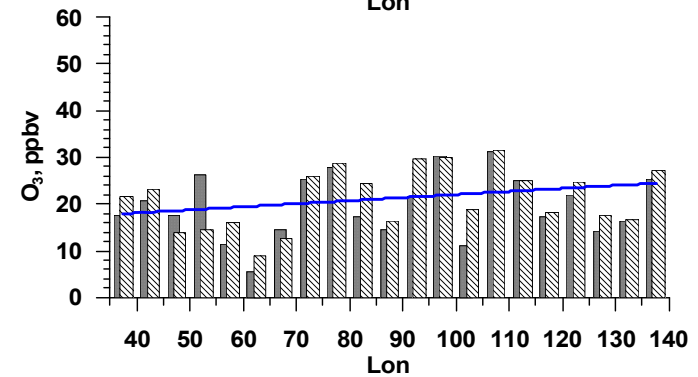
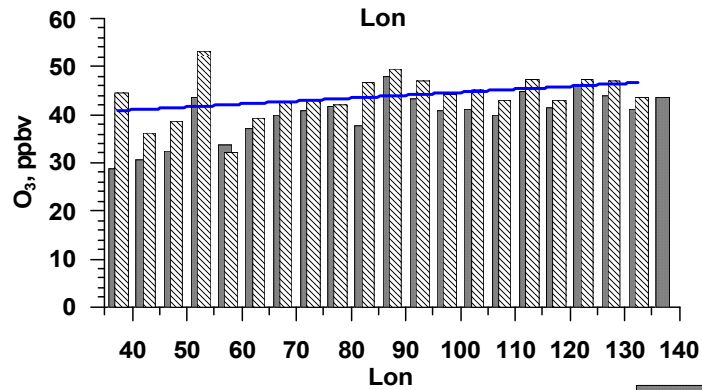
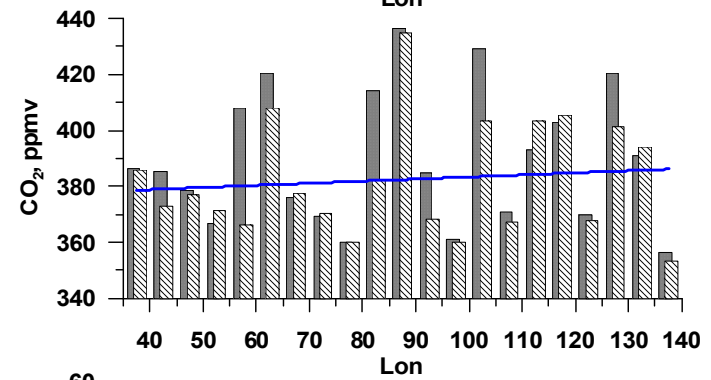
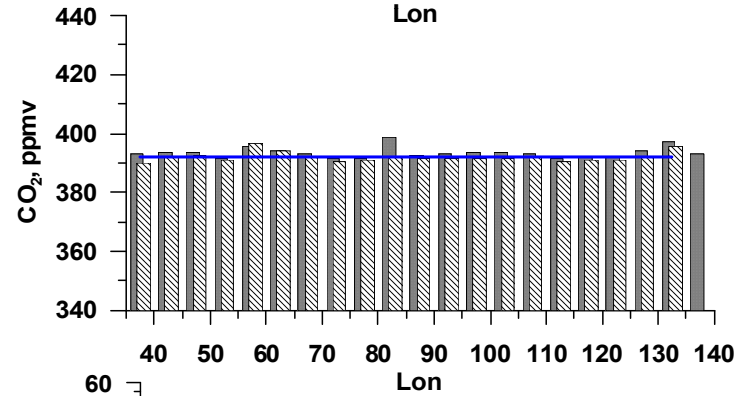
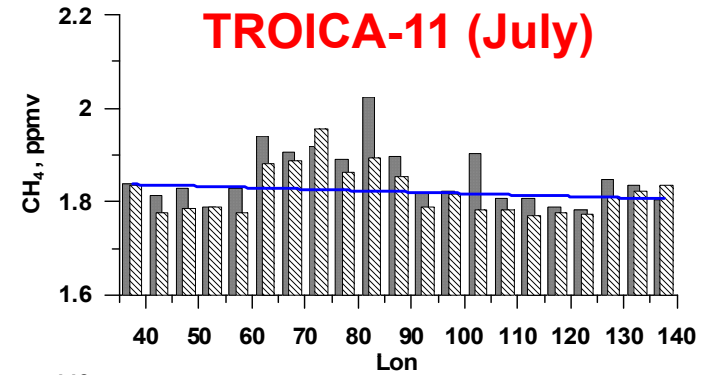
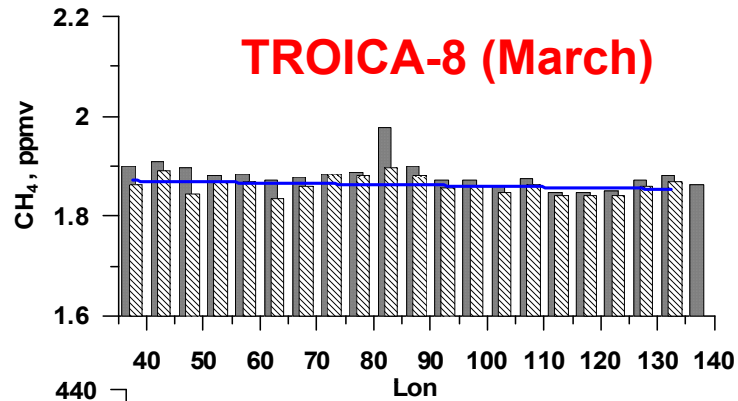


Observation of elevated SO₂ concentration in the plume from Harbin basing observed in TROICA-11 (Calculations with dispersion model HYSPLIT)

Spatial distributions of CO, CO₂ и CH₄ from Moscow to Khabarovsk in summer (left) and winter (right)

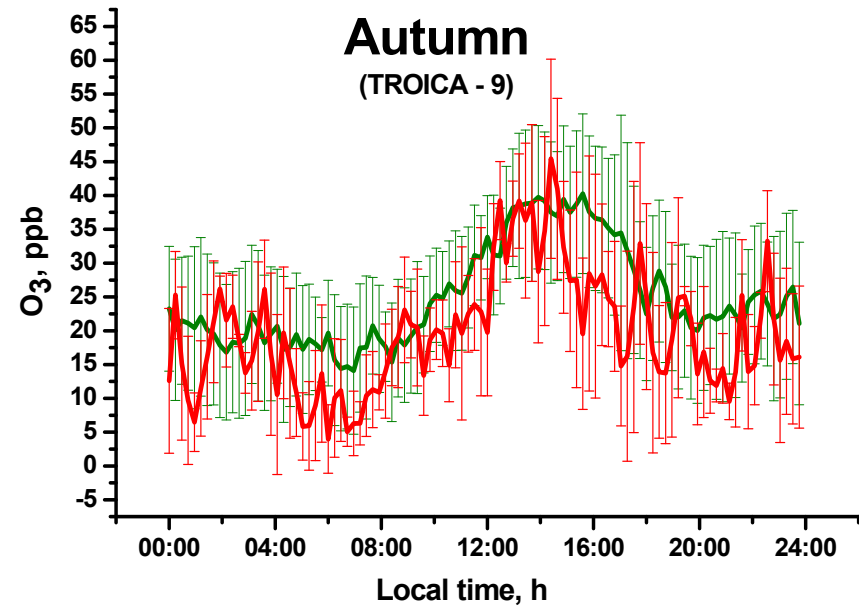
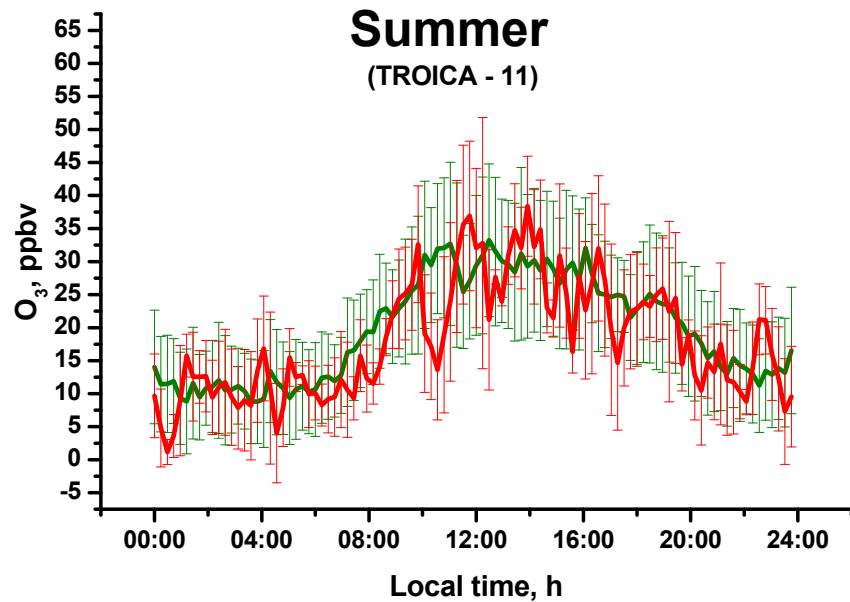
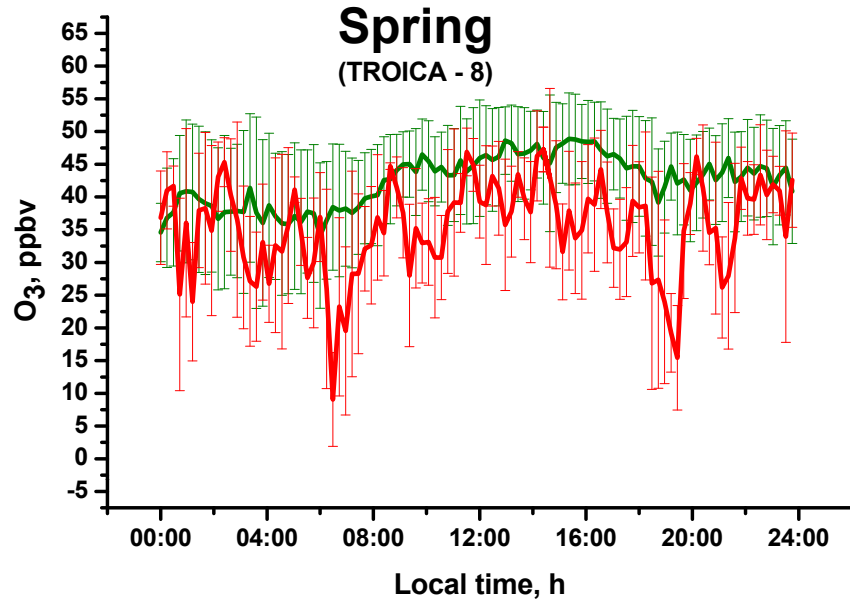


Spatial distributions of CH₄, CO₂, and O₃ for cold and warm seasons basing on TROICA-8 and TROICA-11 measurements (averaged by 5° longitude, all data and background conditions)



All data
 Background conditions

Daily ozone variations basing on TROICA measurements



Application of TROICA data for assessment of the influence of climatically important anthropogenic sources on remote regions of the Northern Eurasia.

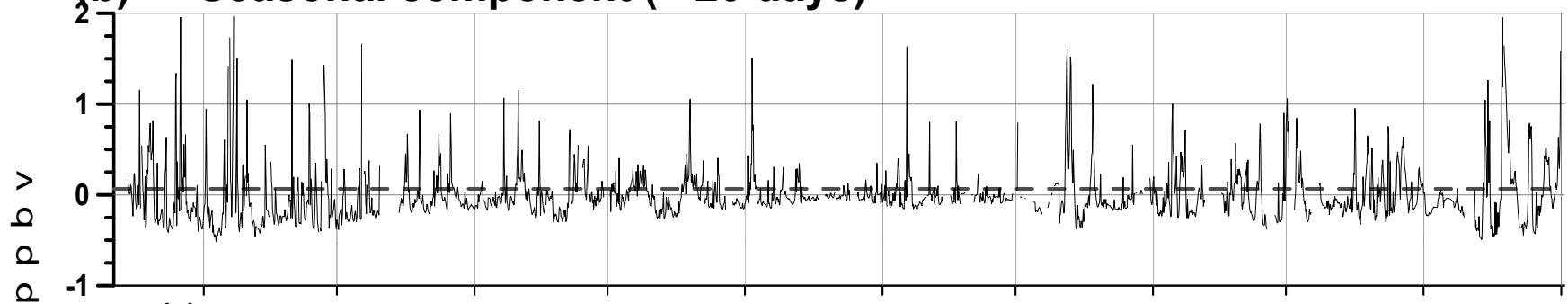
- **Influence area of atmospheric transport for Zotino station overlaps industrial regions of Western Siberia and Krasnoyarskii Krai.**
- **Surface air chemical composition in these regions can be measured directly in TROIKA expeditions.**

- **Comparison of data measurements at Zotino and during TROIKA expeditions gives some important information on the air chemical transformation under regional advection.**
- **Some key parameters of ecological burden of industrial regions on remote areas can be estimated as well (on seasonal scale).**

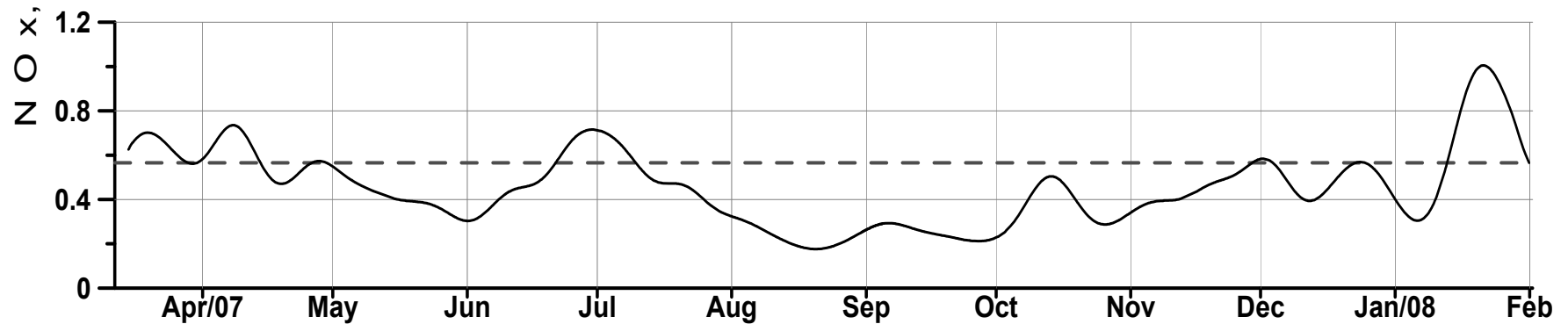
Decomposition of initial data on NO_x (with use of Kolmogorov-Zhurbenko filter)

(a) – Synoptic component (3 hour – 20 days),

(b) – Seasonal component (> 20 days)



(a)



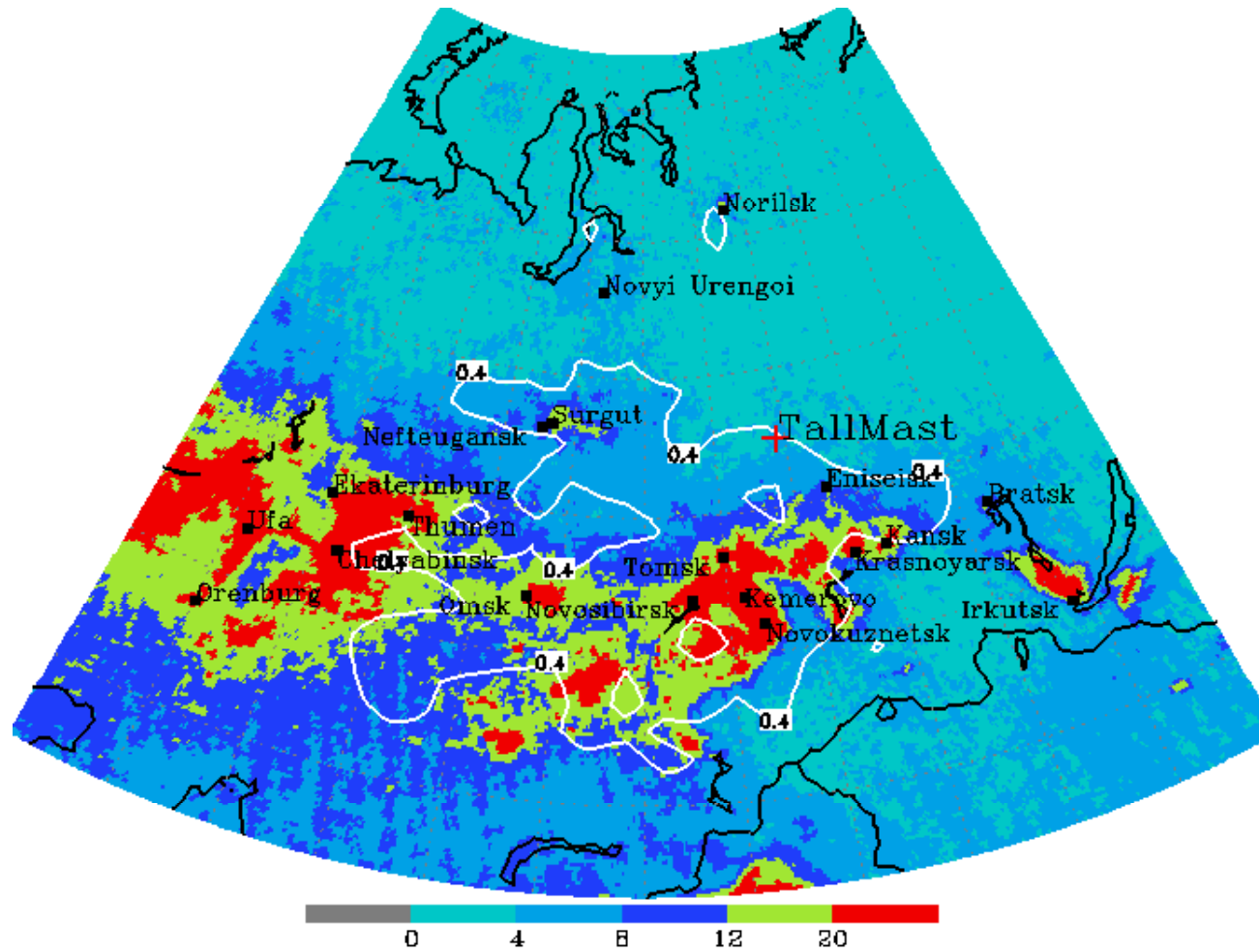
(b)

! Synoptic variability can be largely attributed to the influence of regional NO_x sources

Conclusion

- **At present, large amount of data has been obtained on chemical and aerosol composition of the surface air across the continent during 11 TROICA expeditions as well as stationary observations. These data are collected in the regions, which are expected to have significant influence on remote clean areas on the Northern Eurasia.**
- **Methods for data quality control and assimilation have been developed.**
- **Methods of data analyses applied to the task of regional transport have been developed and tested basing on existing data.**
- **The data obtained will be used in subsequent studies of regional transport and photochemistry basing on mathematical models of various level of complexity.**

Potential source contribution function for upper quartile of NO_x(=NO+NO₂) measured at Zotino during 2007-2008



Total tropospheric NO₂ (10^{15} molec.*cm⁻²)
OMI data