



## **O3 and NO2 remote sensing measurements in TROICA train expeditions**

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## Main goals of TROICA

### **TROICA: TR**anscontinental **O**bservations **I**nto the **C**hemistry of the **A**tmosphere:

- Observations of atmospheric chemical composition over continent
- Estimation of natural and anthropogenic emissions of atmospheric constituents
- Investigations of air quality in different cities and industrial areas



# TROICA collaboration

- A.M. Obukhov Institute of Atmospheric Physics RAS, Moscow, Russia
- Max Planck Institute of Chemistry, Mainz, Germany
- Russian Research Institute of Railway Transport, Moscow, Russia
- L.Y. Karpov Institute of Physical Chemistry, Moscow, Russia
- Climate Monitoring and Diagnostics Laboratory NOAA, Boulder, CO, USA
- Institute for Geophysics, Astrophysics and Meteorology Karl-Franzens-University Graz, Graz, Austria
- UFZ-Center for Environmental Research, Leipzig, Germany





# TROICA



- 2 railway carriage: observatory, and chemical laboratory



# Measurements in TROICA-8, Mar.19 – Apr.1, 2004



**Surface gases:** O<sub>3</sub>, NO, NO<sub>2</sub>, CO, CO<sub>2</sub>, SO<sub>2</sub>, CH<sub>4</sub>, THC

**Surface aerosols:** size distribution (2 nm-10 μm), scattering coefficient, mass concentrations; black carbon

**Remote sensing:** O<sub>3</sub> and NO<sub>2</sub> (troposphere-stratosphere), temperature profile (0-600 m)

**Solar radiation:** integral, UV-A, UV-B, photodissociation rate J(NO<sub>2</sub>)

**Meteorology:** surface pressure, temperature, humidity, wind (speed and direction)

**Sampling:** green-house gases and VOC; chemical, elements and morphological composition of aerosol, isotope composition of CO, CO<sub>2</sub>, CH<sub>4</sub> (<sup>13</sup>C, <sup>14</sup>C, <sup>18</sup>O, D),

**Others:** navigation parameters (GPS), <sup>222</sup>Rn, radionuclides, TV pictures of surrounding (both sides), TV pictures of cloudiness, samples of water, soil, vegetation

## **Main goals of the remote sensing measurements of TROICA**



- Measurements of the vertical distribution and the total content of atmospheric compositions in spacious regions of EuroAsia, where stationer ground-based network stations are absent
- Validation of measurements of satellite instruments GOME, SCIAMACHI, TOMS, SAGE III, OMI, et al. at extended areas
- Regular calibration of scattered over Russia ground-based network instruments using one standard mobile instrument

# **O<sub>3</sub> and NO<sub>2</sub> remote sensing measurements in TROICA**



**TROICA-8**, Moscow-Khabarovsk-Moscow, March 19-  
April 1, 2004:

2 image spectrometers Oriel 260 with CCD matrixes

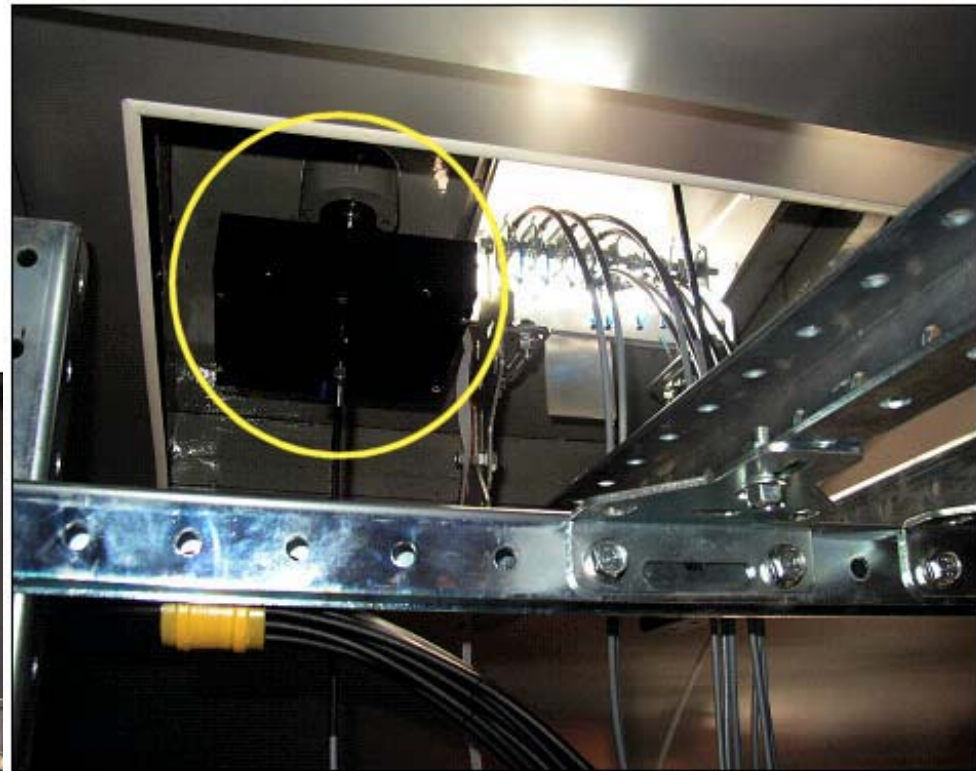
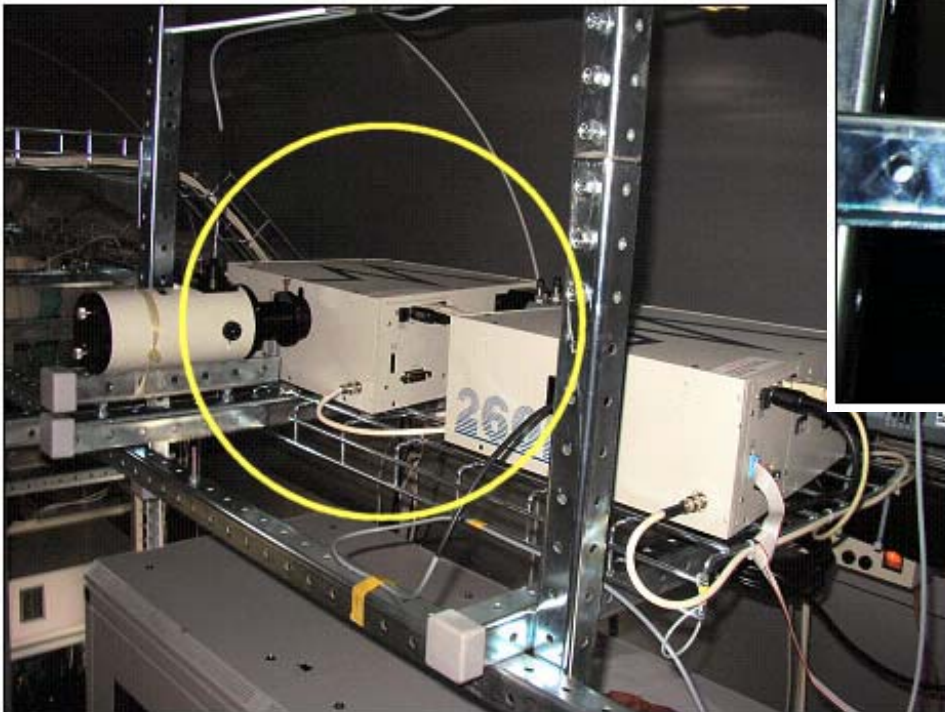
**TROICA-4**, Moscow-Khabarovsk-Moscow, February  
18 -March 5 1998:

LOMO MDR-23 monochromator with PM

## Two image spectographs for remote sensing

Zenith viewing instrument:

- for determination of vertical distributions and total contents of O<sub>3</sub> and NO<sub>2</sub>

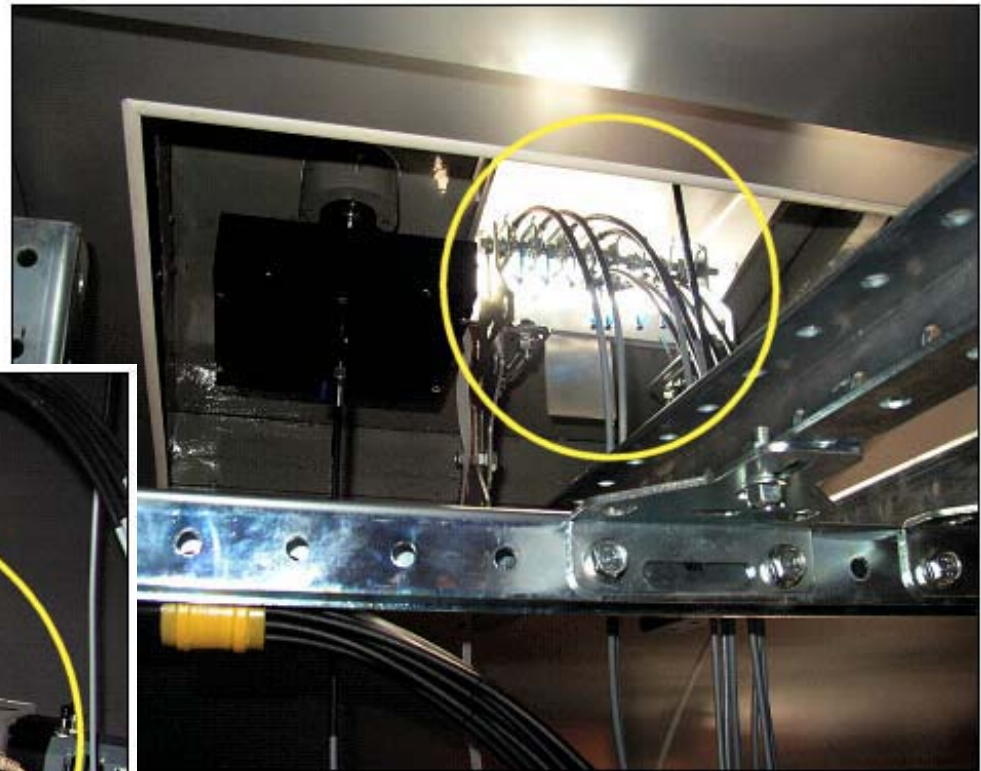
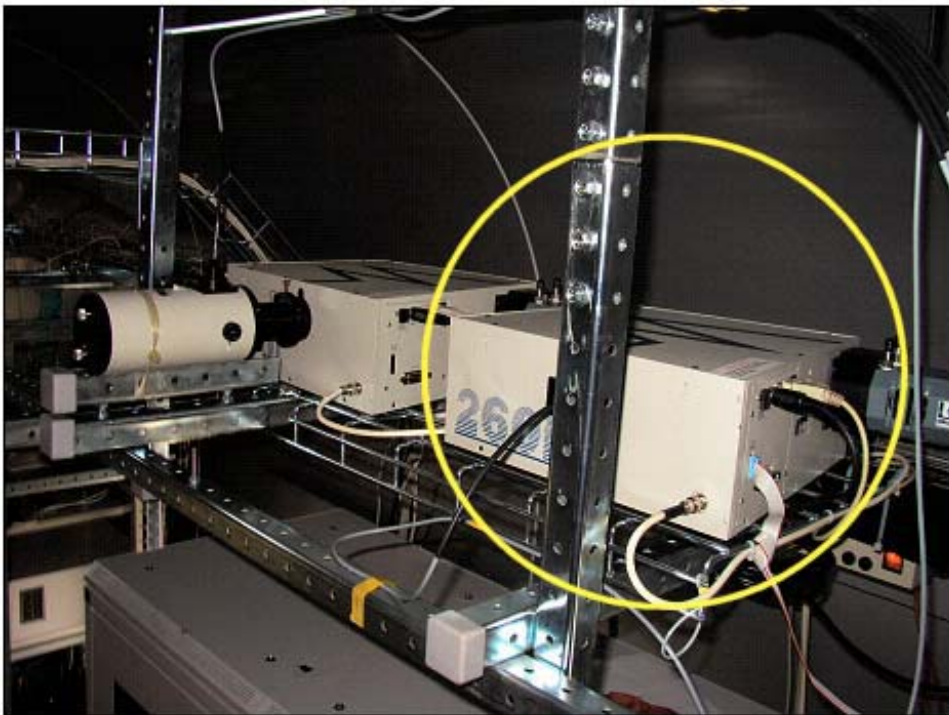


1st Oriel MS260 with CCD detector,  
UV and visual wavelengths, a  
resolution of 0.8 nm

# Two image spectographs for remote sensing

Instrument looking in 9 slant directions:

- for MAX DOAS analysis of NO<sub>2</sub> and other gases in troposphere



2nd Oriel MS260 with CCD detector, 9 fiber optical inputs, visual wavelengths

# NO<sub>2</sub> remote sensing measurements in TROICA

NO<sub>2</sub> retrieval:

- zenith radiance at 430-450 nm
- DOAS technique:

McKenzie R.L., Johnston P.V., McElroy C.T., Kerr J.B., and Solomon S., Altitude distributions of stratospheric constituents from ground-based measurements at twilight. *J.Geophys.Res.* 1991, Vol. 96, N D8, P. 15499-15511.

Elokhov A.N., A.N. Gruzdev. Nitrogen dioxide column content and vertical profile measurements at the Zvenigorod Research Station, *Izvestia, Atm.Ocean. Phys.*, 36, 763-777, 2000.

- total content using SZA=84-90 degree
- vertical profile with 5 km grid using SZA=84-96 degree
- precision of NO<sub>2</sub> slant columns is better than 1%
- precision of NO<sub>2</sub> vertical profile near maximum about 3-5% for none-polluted boundary layer

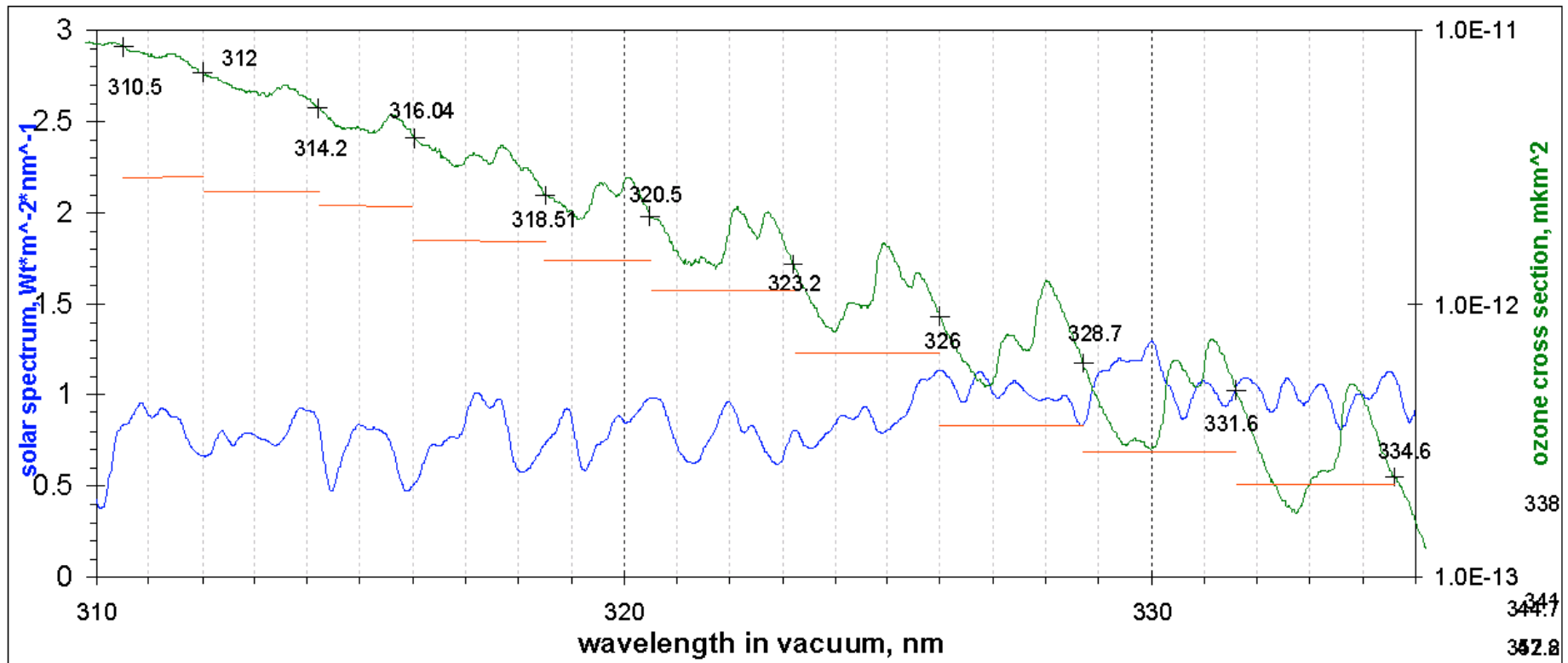
# **O3 remote sensing measurements in TROICA**



## O3 retrieval:

- zenith radiance at 310-340 nm
- retrieval using differential structures in O3 absorption cross section
- total content was retrieved using single UV spectrum at each SZA from 40 to 90 degree
- vertical profile for each spectrum from SZA 80 to 90 degree with different errors
- vertical resolution of 8-10 km as Umkehr method
- TOC retrieval error 10-20 DU
- profile retrieval errors for SZA 90 as Umkehr method

# O3 remote sensing measurements in TROICA



Several DOAS spectral channels give several slant paths

# Linearized radiative transfer model MCC++

*Also see also posters P60082 and P0164*

- was designed for use in algorithms for retrieval of the aerosol and gas distributions in the Earth atmosphere basing on measurements of the visual and UV scattered solar radiation:
  - simultaneous calculation of **derivatives** with respect to absorption, and **intensities**
  - multiple scattering **for both**
  - polarization
  - spherical atmosphere (spherically symmetrical)
  - surface reflectance

# Linearized radiative transfer model MCC++

*Also see also posters P60082 and P0164*

	Approximate changes of retrieved TOC due to different factors
Single scattering, albedo=0	120%
Total scattering, albedo=0	105%
<b>Total scattering, albedo=1</b>	<b>100%</b>
Total scattering, albedo=1, clouds	96-99%

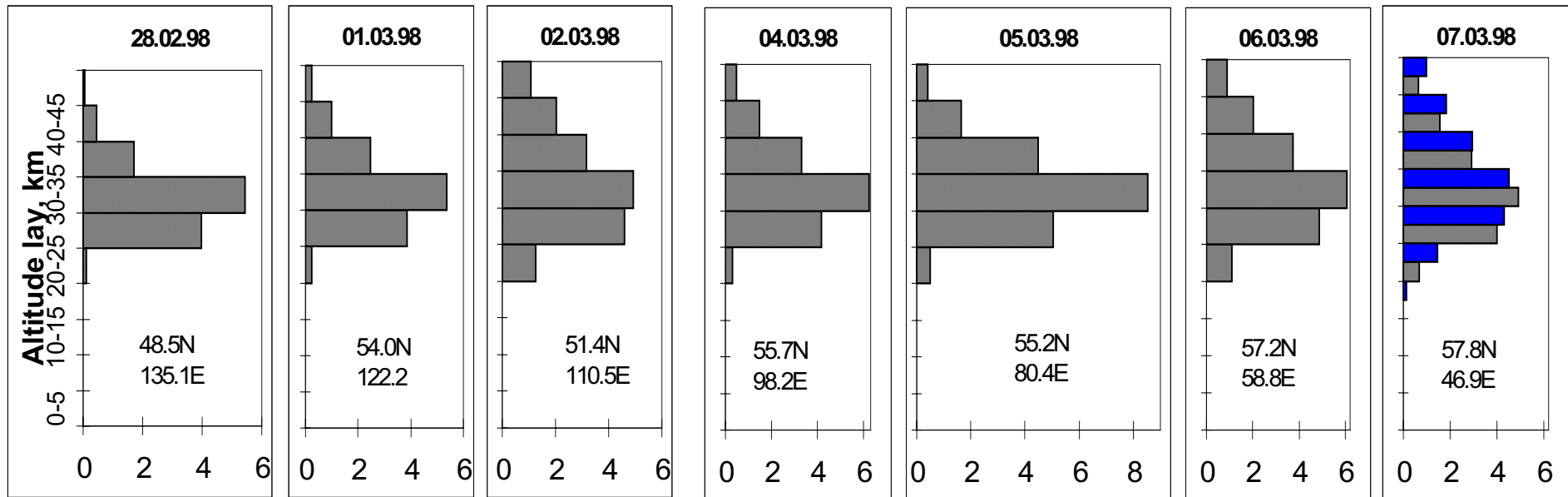
# Remote sensing measurements in TROICA



**TROICA-4**, Moscow-Khabarovsk-Moscow, February 18 -March 5 1998:

- LOMO MDR-23 monochromator
- from 305 to 335 nm in UV for SZA from 40 to 84 degree
- from 434 to 451 nm in visual for SZA from 84 to 96 degree
- a resolution of 1 nm
- the detector was a photomultiplier
- the entrance slit of the monochromator was illuminated using carriage window

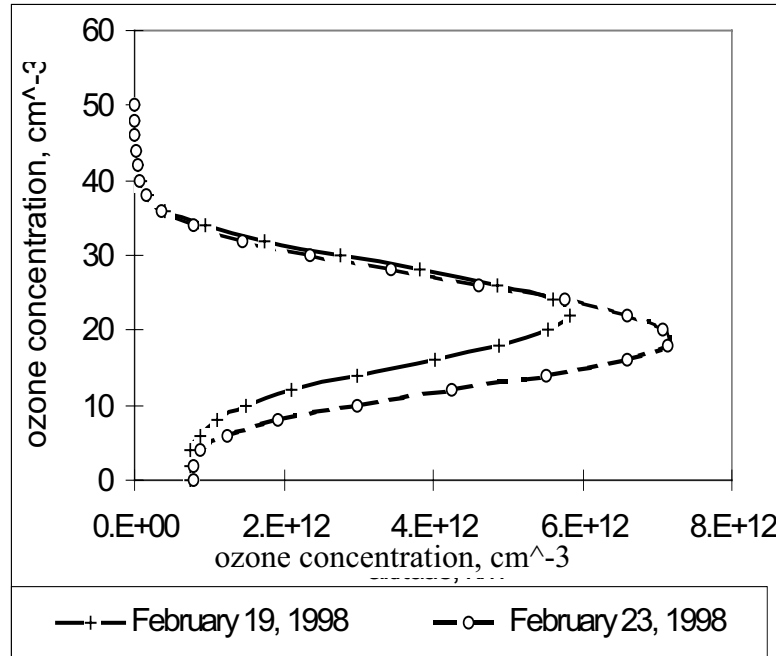
## TROICA-4: Moscow-Khabarovsk-Moscow, February 18 -March 5 1998



***NO<sub>2</sub> content in 5-km layers in  $10^{14}$  cm<sup>2</sup>***

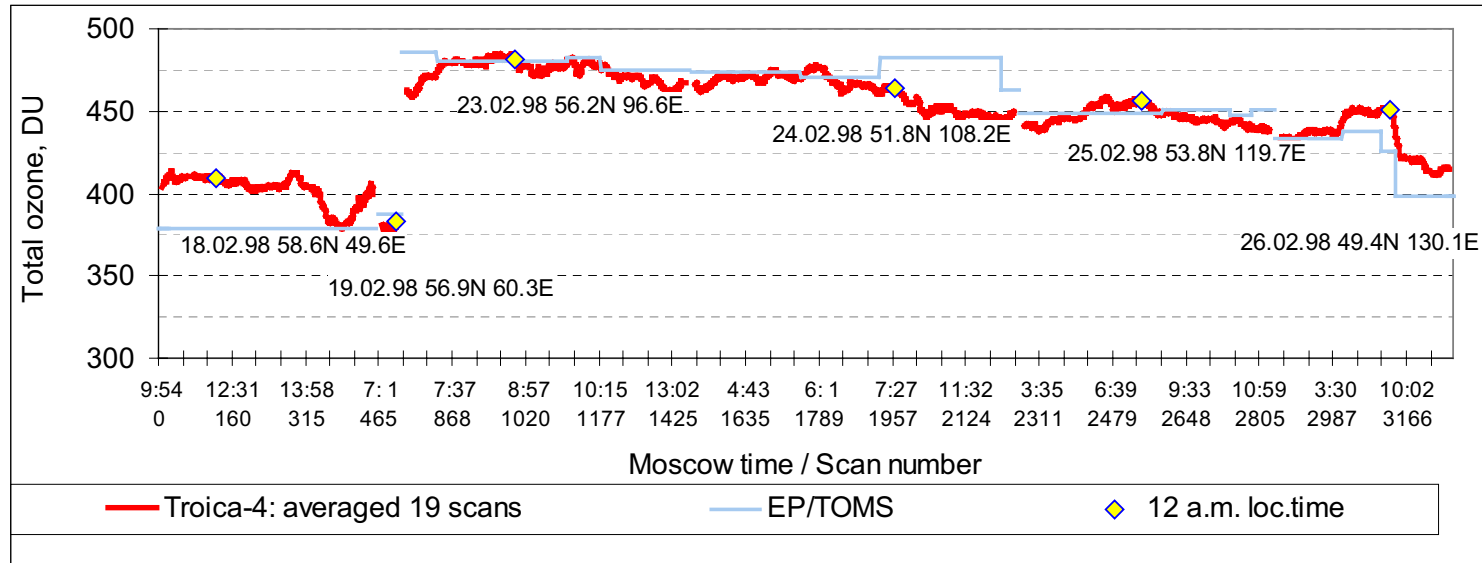
The vertical distribution of nitrogen dioxide at evening from February 28 to March 7, 1998. Integral content for 5-km layers is shown in  $10^{14}$  cm<sup>2</sup>. Measurement at stationar Zvenigorod Station (55.69N, 36.77E) is shown for March 7, 1998 in blue color.

## TROICA-4: Moscow-Khabarovsk-Moscow, February 18 -March 5 1998



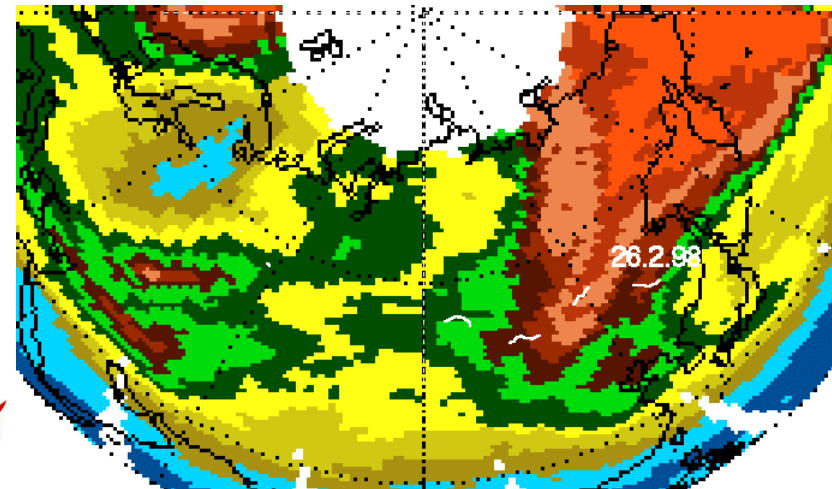
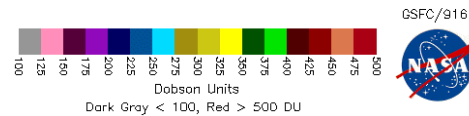
The vertical ozone distribution measured at evening of February 19 and 23, 1998.

# TROICA-4: Moscow-Khabarovsk-Moscow, February 18 -March 5 1998

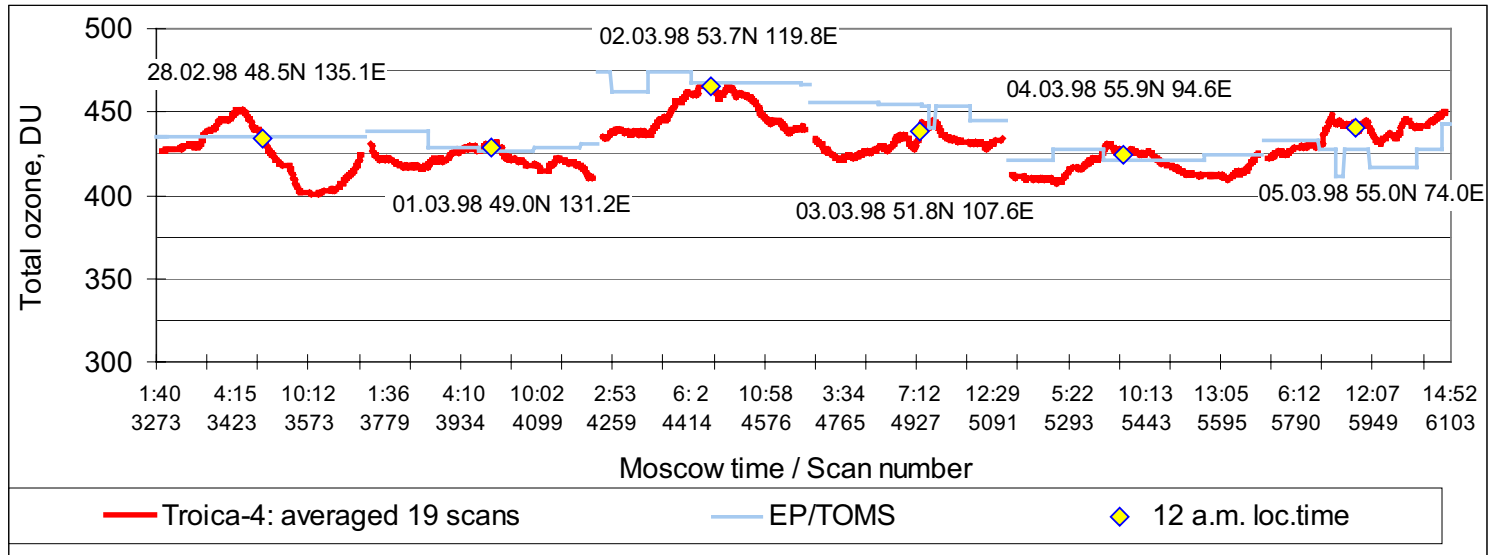


## Comparison with TOMS

February 26, 1998



# TROICA-4: Moscow-Khabarovsk-Moscow, February 18 -March 5 1998



Comparison with TOMS

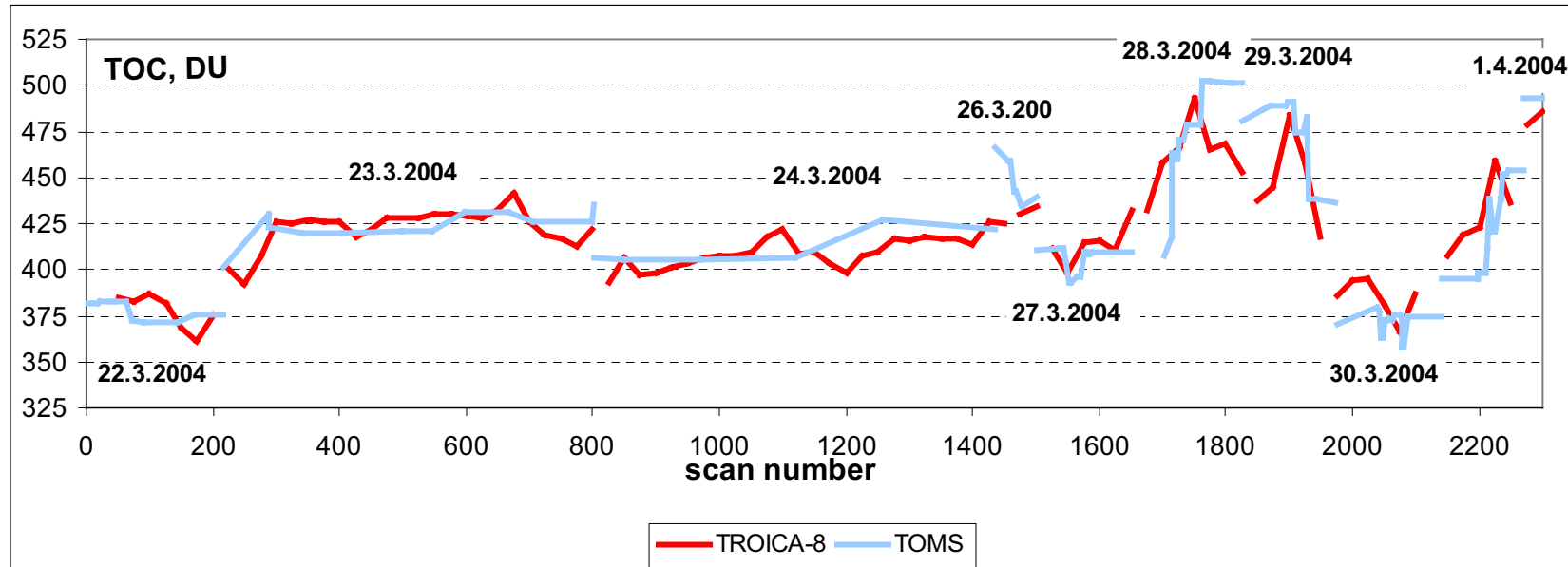
# Remote sensing measurements in TROICA



**TROICA-8**, Moscow-Khabarovsk-Moscow, March 19-April 1, 2004:

- Oriel MS260 with CCD detector
- from 300 to 345 nm in UV for SZA from 40 to 90 degree in the zenith direction
- from 400 to 480 nm in visual for SZA from 84 to 96 degree in the zenith direction
- a resolution of 0.8 nm for zenith-viewing instrument
- from 400 to 480 nm in visual in 9 slant direction
- a resolution better than 0.8 nm for slant-viewing instrument

# TROICA-8: Moscow-Khabarovsk-Moscow, March 19-April 1, 2004



Comparison with TOMS

# Conclusion



- Opportunity to modify the spectrometers used at the stationer observatory and to employ them at a mobile train-carriage laboratory has been shown
- Method for retrieval of O<sub>3</sub> by measuring differential structure of UV radiation was developed
- The retrieved O<sub>3</sub> and NO<sub>2</sub> contents have been compared with data of TOMS and stationer ground-based stations
- Analysis of the TROICA-4 experiment allows conclusion on validity of obtained data and on potential effectiveness of using a moving laboratory for remote sensing of gases

# Validation opportunity of TROICA



- Measurements of various surface atmospheric gases and aerosol, and gases by remote sensing
- Spacious ground-based measurements by one set of instruments - no calibration dependence
- Investigation of effects of spatial distribution of gases inside pixel on satellite data:
  - Autumn 2004: Expedition at the circle railroads inside Moscow city (D=20 km) and in Moscow Region (D=300 km)

# Current and future development



- To equip train observatory with microwave instrument for ozone sounding during night (20-65 km)
- Sounding of total CO using IR measurements
- Multi-axis sounding of troposphere, including investigation of tomographical problems
- Continue comparison with satellite data of SCIAMACHY, GOME, SAGE III et al.



**TROICA**

**Thanks!**