Opportunities of TROICA train observations to validate satellite observations

O.V. Postylyakov, I.B. Belikov, N.F. Elansky, A.S. Elokhov, A.I. Igaev

A.M. Obukhov Institute of Atmospheric Physics, RAS, Moscow

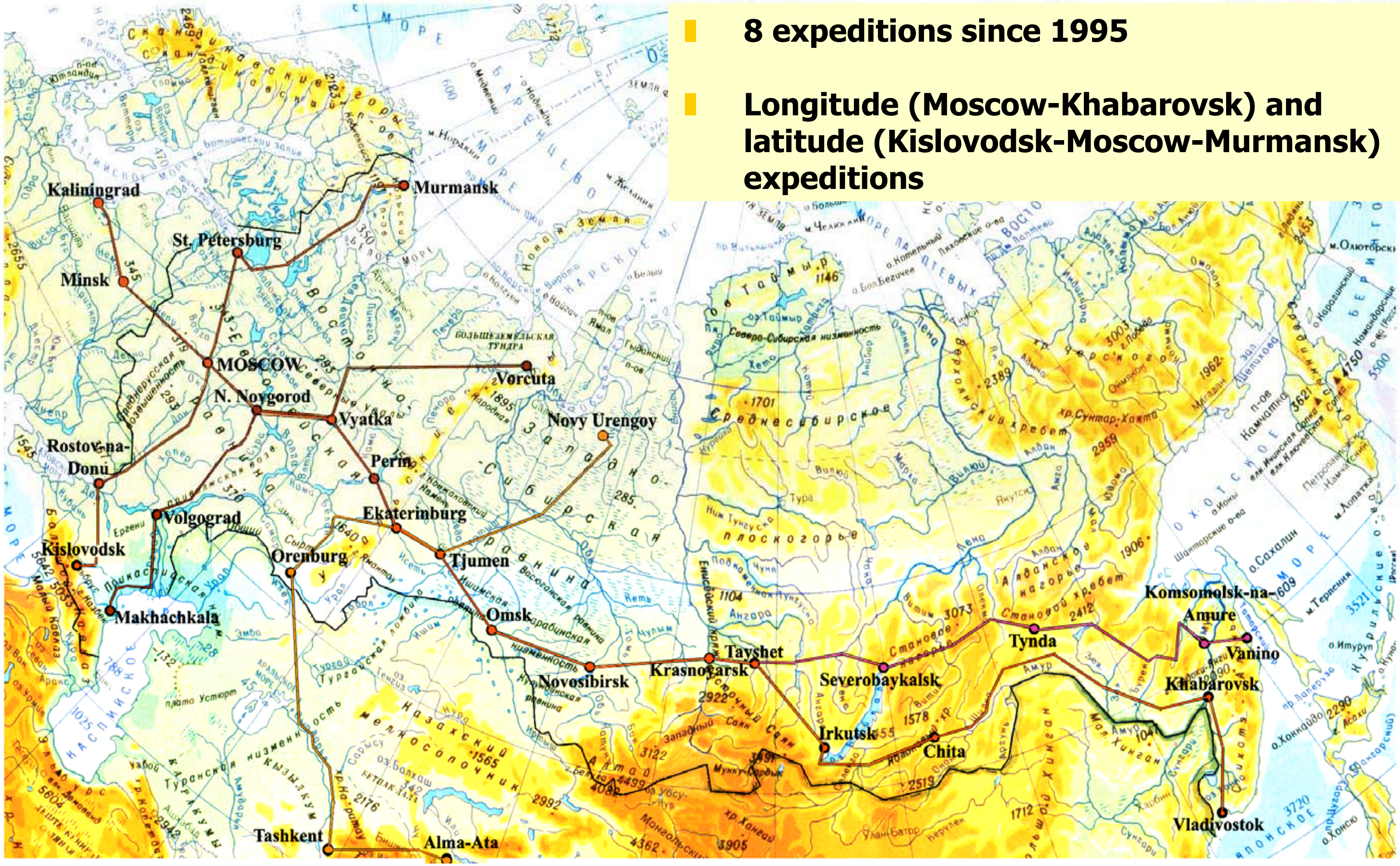
ovp@ifaran.ru

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

The scheme of railway routes in NIS

- **8 expeditions since 1995**
- **Longitude (Moscow-Khabarovsk) and latitude (Kislovodsk-Moscow-Murmansk) expeditions**



TROICA

- 2 railway carrige:
  observatory, and
  chemical laboratory

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

Remote sensing: O3 and NO2 (troposhere-stratosphere), temperature profile (0-600 m)

Surface gases: O3, NO, NO2, CO, CO2, SO2, CH4, THC

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

Solar radiation: integral, UV-A, UV-B, photodissociation rate J(NO_2)

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,CO2,CH4(^{13}C,^{14}C,^{18}O, D),

Others: navigation papameters (GPS), ^{222}Rn, radionuclides, TV pictures of surrounding (both sides), TV pictures of cloudiness, samples of warter, 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

O3 and NO2 remote sensing measurements in TROICA

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

2 image spectrometers Oriel 260 with CCD matrixes

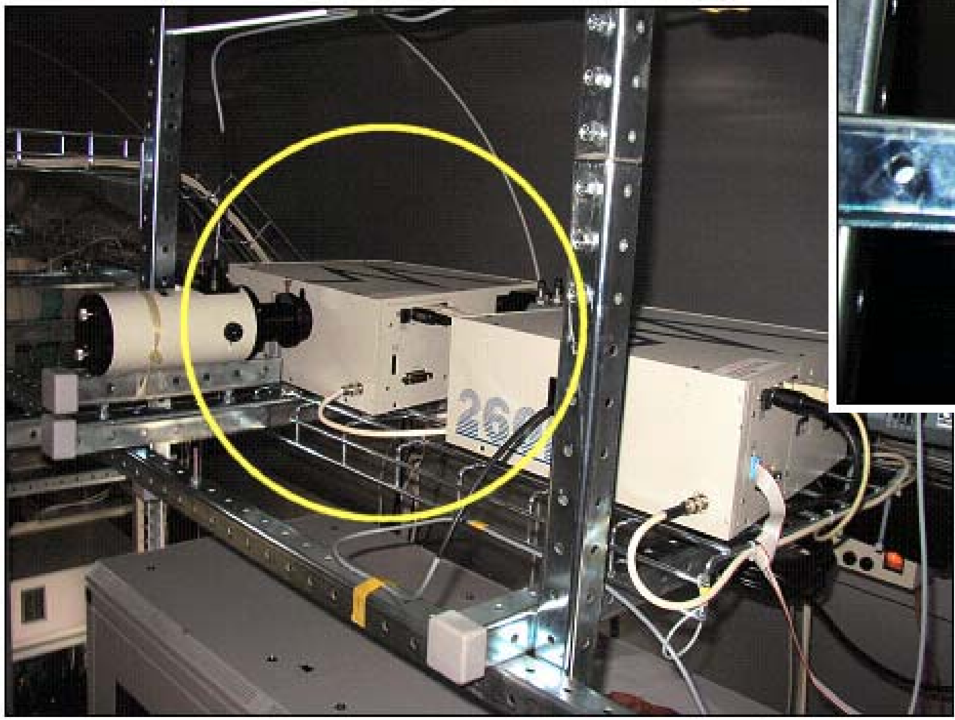
TROICA-4, Moscow-Khabarovsk-Moscow, February 18 -March 5 1998:

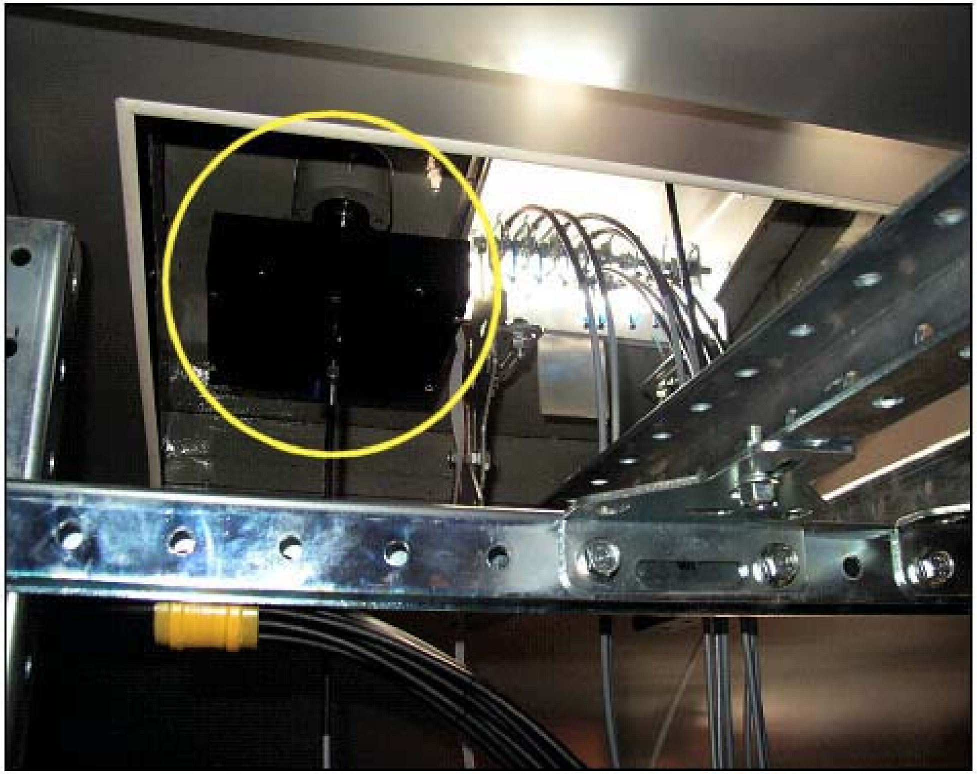
LOMO MDR-23 monochromator with PM

Two image spectographs for remote sensing

Zenith viewing instrument:

- for determination of vertical distributions and total contents of O3 and NO2



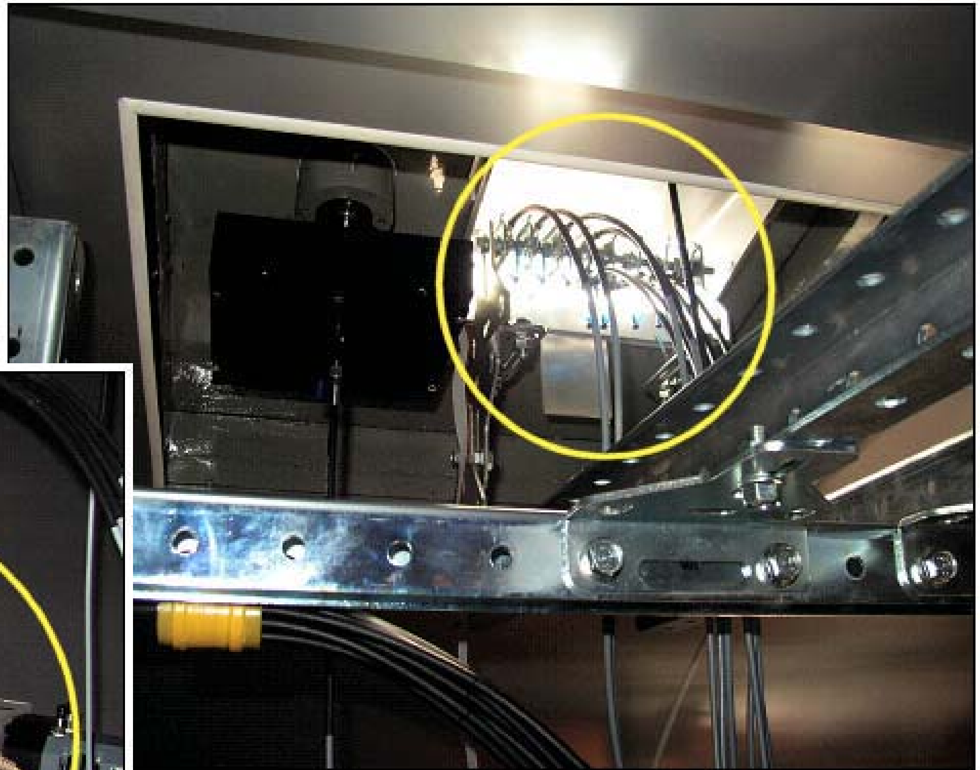


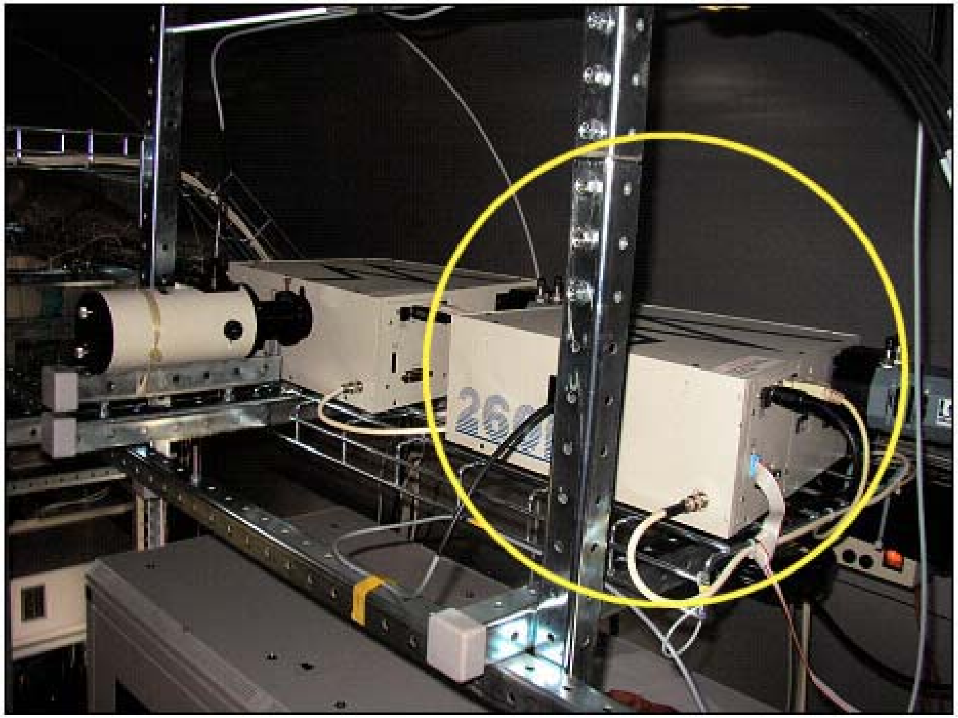
1st Oriel MS260 with CCD detector, UV and visual wavelengths, a resolution of 0.8 nm

Two image spectographs for remote sensing

Instrument looking in 9 slant directions:

- for MAX DOAS analisys of NO2 and other gases in tropospher





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

NO2 remote sensing measurements in TROICA

NO2 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.

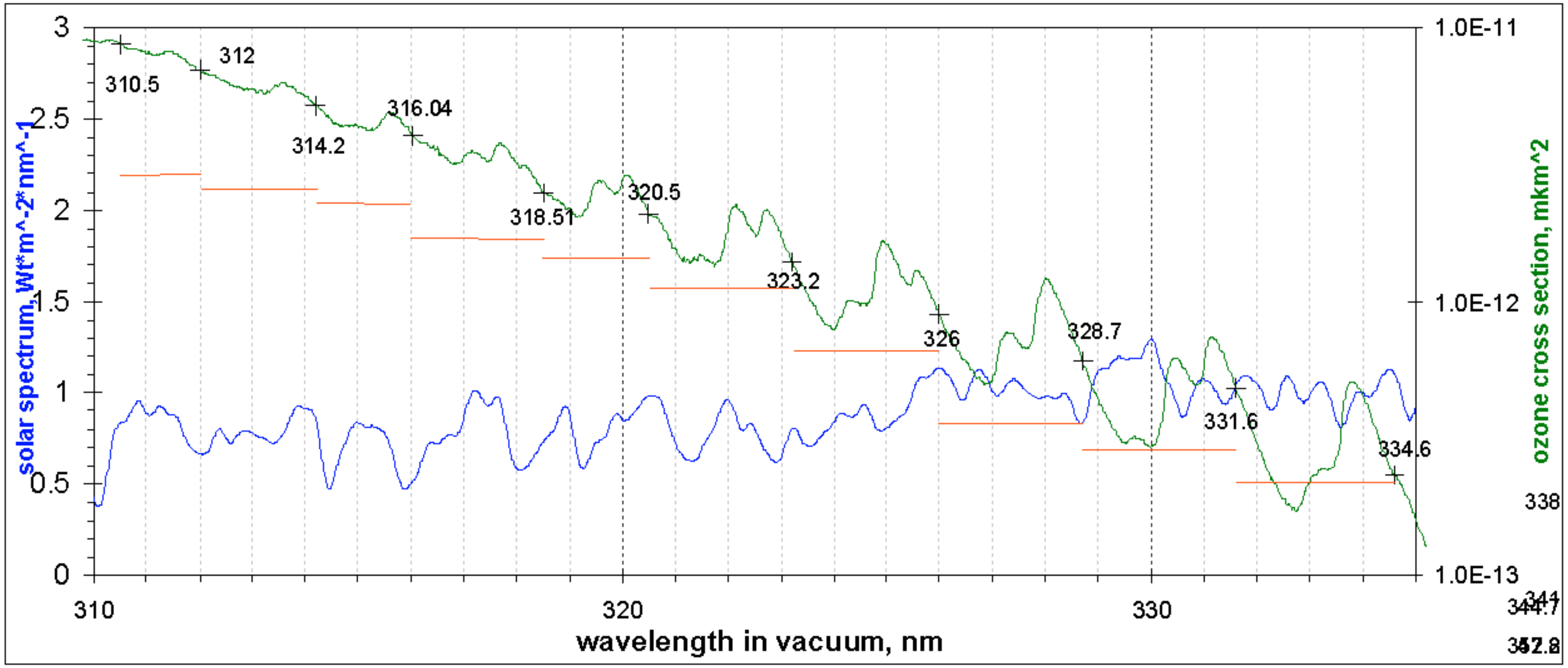
- total content using SZA=84-90 degree
- vertical profile with 5 km grid using SZA=84-96 degree
- precision of NO2 slant columns is better than 1%
- precision of NO2 vertcal profile near maximum about 3-5% for none-polluted boundary layer

O3 remote sensing measurements in TROICA

O3 retrieval:

- zenith radiance at 310-340 nm
- retrieval using differential structures in O3 absorbtion cross section - **new retrieval method developed**
- 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 10-25 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 E8 and G35

- 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), including calculations for twilight
  - surface reflectance
  - fast calculations

Linearized radiative transfer model MCC++

Time of calculation of weighting functions

Also see also posters E8 and G35

Time of calculation of the **NO2** weighting functions at 450 nm with 1% precision for different solar zenith angles (SZA) by the MCC++ model. Time was estimated for atmosphere with 96 layers up to 120 km. PC based on AMD Athlon 1460 MHz was used.

Z	Time, min
84	0.003
86	0.005
88	0.009
89	0.012
90	**0.019**
91	0.033
92	0.066
93	0.163
94	0.465
95	1.670
96	12.064

The MCC++ model allows to calculate the weighting functions (taking into account multiple scattering) necessary for inversion of **Umkehr ozone** measurements for 18 min. The Umkehr weighting functions are calculated simultaneously at 6 wavelengths from 306.3 to 329.5 nm and 8 solar zenith angles from 77^{O} to 90^{O}. for 20 atmospheric layers. Time was estimated for calculation with accuracy 0.1-1% at the single processor PC based on the AMD Athlon 1460 MHz.

Comparison of MCC++ model

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Table 2
Comparisons of the radiative transfer model MCC++ with other models

Paper	Other participating models		Geometry	Wavelengths (nm)	Compared characteristics[b]	
	Model properties[a]	Abbreviated name			Calculation with polarization	Derivatives
[6]	s–f	Nikolaishvili-Belikov [50]	Ground-based	311	Yes	No
	s–f	CDIPI [36]	observations in the	332		
	s–f	Dave[c] [51]	zenith direction,	450		
	v–f	GSS[c] [3]	including twilight	800		
[47],	s–p	CDI [32,53]	Space limb-viewing	325		
[30]			observations	345	No	Yes
				600		
[48],	s–f	CDIPI [36]	Space limb-viewing	325		
[55]	v–f	GSS [3]	observations	345	Yes	No
	v–f	GSLS [48]		600		
	v–f	SIRO [52,7]				
	s–p	CDI [53]				
	s–p	LIMBTRAN [54]				
[49]	v–f	SIRO [52]	Precise comparison	325		
			for space limb-viewing	345	No	Yes
			observations	600		

[a]First letter: v/s—vector/scalar model; second letter: f/p—full/pseudo spherical model. All vector models used in the comparisons have scalar versions.
[b]Intensities calculated by scalar versions of the models were compared in all cases.

Linearized radiative transfer model MCC++

Also see also posters E8 and G35

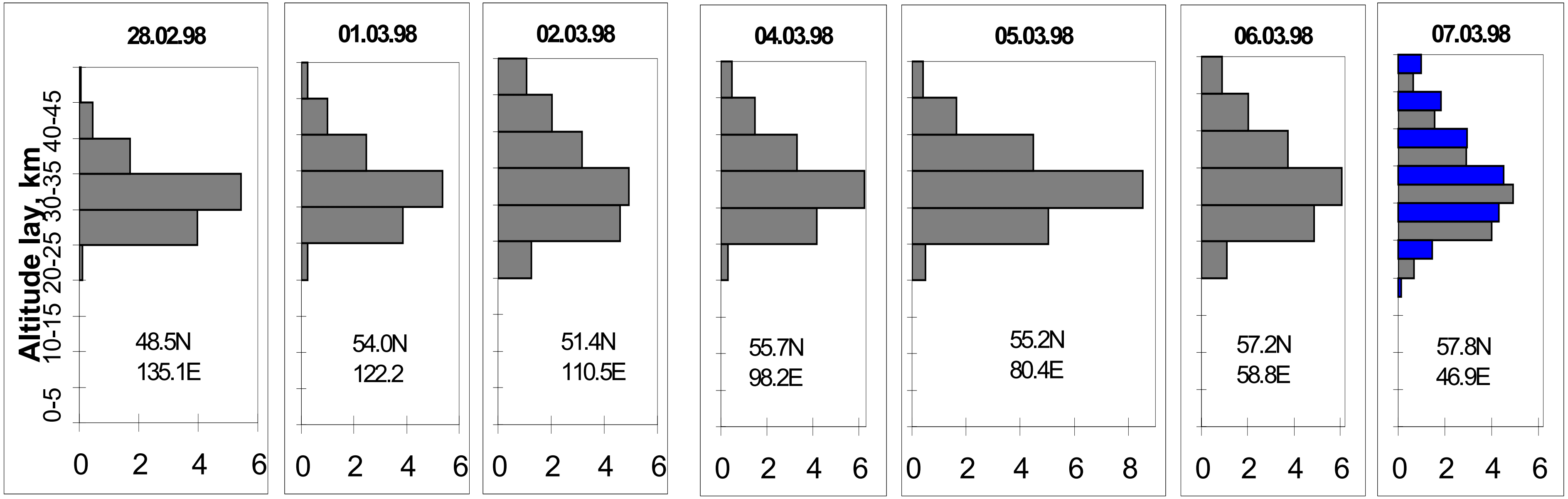
	Approximate changes of retrieved TOC due to different factors
Single scattering, albedo=0	120%
Total scattering, albedo=0	105%
Total scattering, albedo=1	**100%**
Total scattering, albedo=1, clouds	96-99%

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

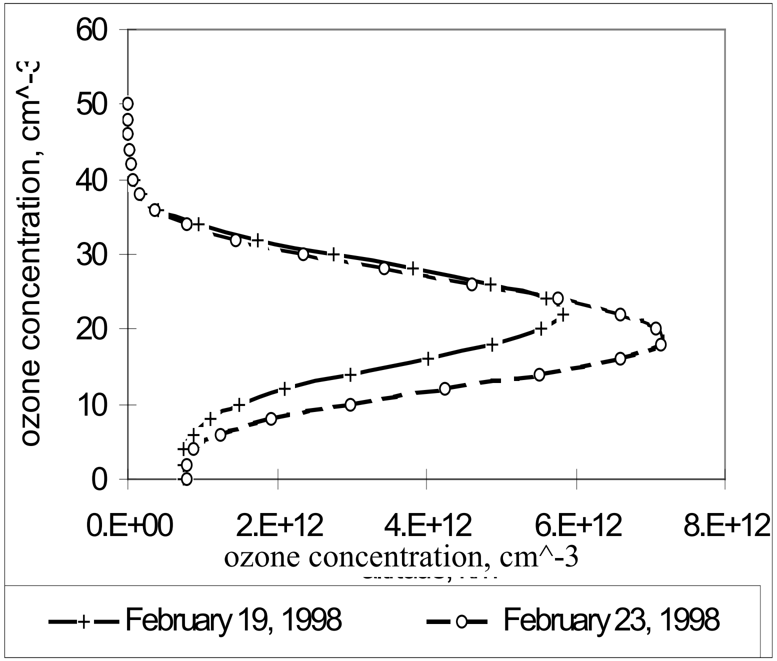
TROICA-4: Moscow-Khabarovsk-Moscow, February 18 -March 5 1998



NO2 content in 5-km layers in 10^{14} cm^2

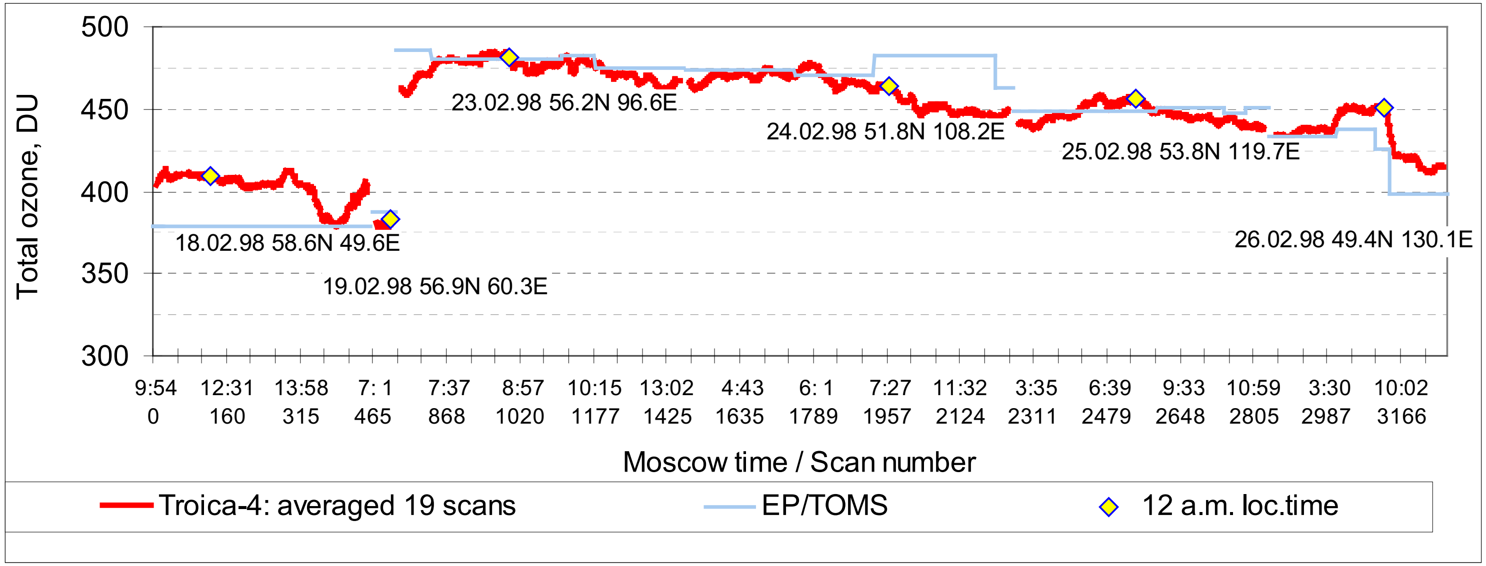
The vertical distribution of nitrogen dioxide at evening from February 28 to March 7, 1998. Integral content for 5-km layers is shown in 1014 cm2. Measurement at stationar Zvenigorod Station (55.69N, 36.77E) is shown for March 7, 1998 in blue color.

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



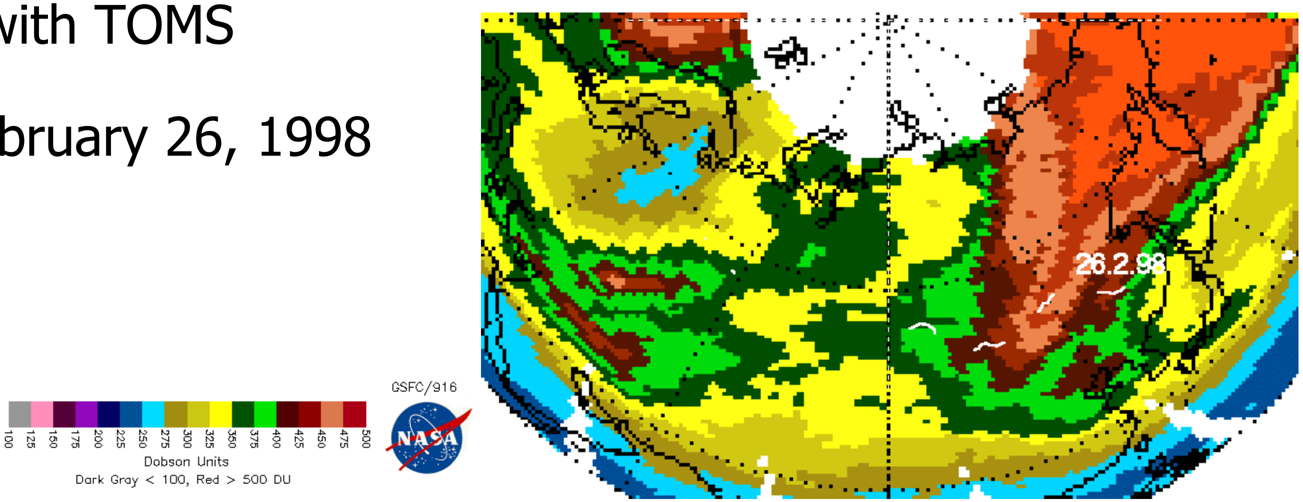
The vertical ozone distribution measured at evening of February 19 and 23, 1998.

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

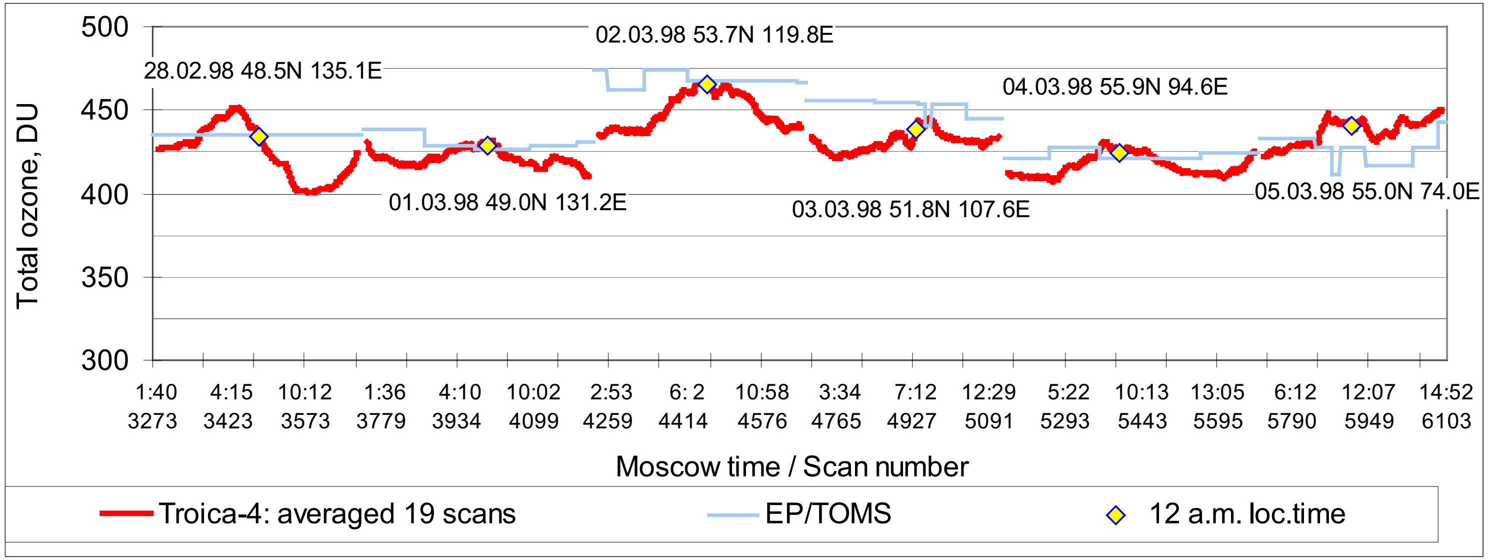


Comparison with TOMS

February 26, 1998



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



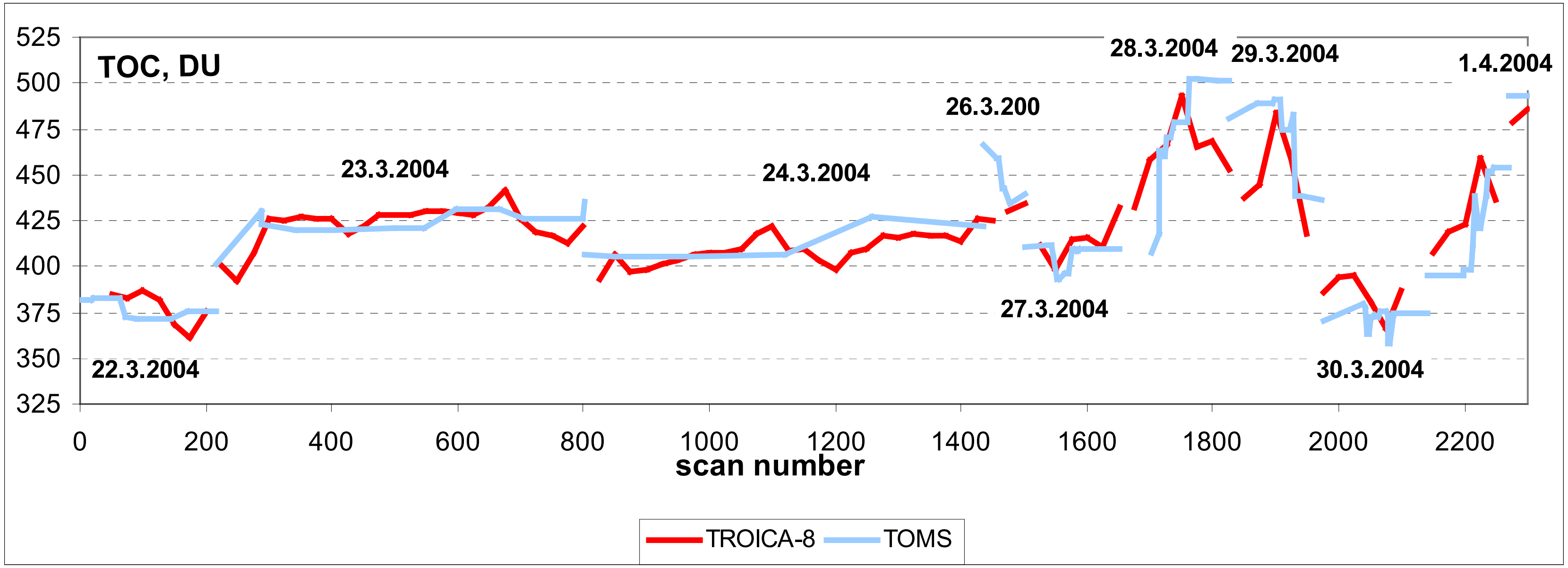
Comparison with TOMS

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



First preliminary results: comparison with TOMS. Results for individual spectral scans are shown (each 25th scan is used).

Validation opportunities of TROICA

- Measurements of various surface atmospheric gases and aerosol, and gases by remote sensing
- Spacious ground-based measuremets by one set of instruments - no calibration dependence
- Investigation of effects of spacial 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)

Conclusion

- Opportunity to modify the spectrometers used at the stationer observatory and to employ they at a mobile train-carriage laboratory has been shown
- Method for retrieval of O3 by measuring differential structure of UV radiation was developed
- The retrieved O3 and NO2 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

Thanks!