File Revision Date:
October 1, 2019

Data Set Description:

| | |
|---|---|
| PI: | Aleksandr Elokhov |
| Instrument: | Visible spectrometer |
| Site: | Zvenigorod, 55.7 N, 36.8 E |
| Measurement Quantities: | NO2 |

Contact information:


| | |
|---|---|
| Name: | Aleksandr Gruzdev |
| Address: | A.M. Obukhov Institute of Atmospheric Physics,<br>Russian Academy of Sciences,<br>Pyzhevsky per.3, Moscow 119017, Russia |
| Phone: | +007-916-487-7876 |
| Fax: | +007-095-233-1652 |
| Email: | a.n.gruzdev@mqil.ru |


Reference articles:


Elokhov A.S. and Gruzdev A.N. Nitrogen dioxide column content and vertical profile measurements at the Zvenogorod Research Station. Izvestiya, Atmospheric and Oceanic Physics, 2000, Vol 36, No 6, pp. 763-777.

Gruzdev A.N. and Elokhov A.S. Validation of Ozone Monitoring Instrument NO2 measurements using ground based NO2 measurements at Zvenigorod, Russia. International Journal of Remote Sensing, 2010, Vol. 31, No 2, pp. 497-511.

Gruzdev A.N. and Elokhov A.S. Variability of stratospheric and tropospheric nitrogen dioxide observed by visible spectrophotometer at Zvenigorod, Russia. International Journal of Remote Sensing, 2011, Vol. 32, No 11, pp. 3115-3127.


Instrument description:

The instrument is a 0.6 m grating spectrometer with asymmetric optical Fastie's scheme. It has an aperture F/6 using 100x100 mm, 1200 grove/mm grating optimized in 500 nm, with spectral dispersion 1.3 nm/mm. The slits width is 0.5 mm nominal to provide a resolution of 0.65 nm FWHM. The detector is a photomultiplier. Wavelength is scanned by rotation of the grating using a sine bar mechanism driven by stepper motor. One step of the motor is equivalent to 1/300 nm step of wavelength. The working scanning rate is 51.2 nm/min and is synchronized with ADC (analog-digital converter) operated by a master quartz generator, so that one step of the stepper motor corresponds to one conversion of ADC. The wavelength region measured is 434 to 451 nm. Normal processing uses 435 to 450 nm of this spectrum. Forward and reverse scans together take 40 s. Polarization effect of the instrument is less than 15%. The use of a photomultiplier as a defector does not require correction procedure due to polarization effect.

Algorithm Description:

Given measured transmittance spectra, $NO_2$ contents in slant atmospheric column are calculated as a function of the solar zenith angle. A slant column content is the weighted average integral content of $NO_2$ along trajectories of propagation of the solar radiation registered by the instrument. Slant $NO_2$ columns are calculated with the differential optical absorption spectroscopy (DOAS) technique taking into account absorption of $NO_2$, $O_3$, water vapour, and O2?O2 dimer, molecular and aerosol scattering, and the Ring effect. As a reference spectrum, the transmittance spectrum is used measured at high elevation of the sun under conditions of stable unpolluted atmosphere. Values of slant $NO_2$ columns are averaged within solar zenith angle ranges of 0.5 degree width. The obtained mean values and associated mean square root deviations are input parameters in an inverse problem.

A solution to this problem is the vertical profile of $NO_2$ presented by $NO_2$ contents in 10 layers of 5-km thickness and in a thin boundary layer of a priori unknown thickness. The kernel of the inverse problem consists of air mass factors for these $NO_2$ layers, which are calculated with the help of a spherical single-scattering model accounting for refraction and a one-dimensional photochemical model. The scattering model takes into account the seasonal variations of air density and temperature. The photochemical model is used for accounting for photochemical changes in the $NO_2$ concentration during twilight measurements. The model takes into account basic photochemical processes important for nitrogen oxides, including the oxygen, hydrogen, nitrogen, and chlorine photochemical cycles. Vertical distributions of air temperature and pressure as well as vertical profiles of ozone, methane, nitrous oxide, water vapour, nitric acid and long-living chlorofluorocarbons are seasonally and latitudinally dependent in the models and are taken from the empirical reference models or observations (if available) for the dates of $NO_2$ observations. Using the photochemical model, slant $NO_2$ columns measured during a concrete twilight are put to a uniform time (to one zenith angle, for example 90 degree angle). When solving the inverse problem, values of slant $NO_2$ columns are varied randomly within experimentally estimated variance around experimentally determined mean values. Using an ensemble of solutions (400 profiles), a statistically mean $NO_2$ profile and its left and right mean square root deviations for all layers are calculated. These deviations characterize random errors of retrieval of a $NO_2$ profile.

Expected Precision/Accuracy of Instrument:

The total error of retrieval of stratospheric column $NO_2$, which has a random character, includes a few parts. One is the random error of the retrieval itself that is between 1.E14 1/cm2 and 3.E14 1/cm2 depending on conditions of measurements (atmospheric variability, cloudiness, etc). Next is the systematic error of determination of the $NO_2$ amount in the residual spectrum, which is equal to about 1.E14 1/cm2. Since the sign of this error is unknown, this error also contributes to the total random error. Third is the uncertainty in stratospheric temperature due to day-to-day variability, which results in uncertainty in $NO_2$ cross sections. The associated error in an $NO_2$ column is about 2.E13 1/cm2 in winter and 1.E14 1/cm2 in summer. Fourth is the uncertainty in calculated air mass factors due to day-to-day variability, which is about 1%, resulting in uncertainty in an $NO_2$ column of about 5.E13 1/cm2. Therefore the total error of unpolluted $NO_2$ columns, which has a random character, is within (3.?6.)E14 1/cm2. The total random error of determination of boundary layer $NO_2$ is contributed mainly by the random error of the retrieval which varies significantly depending on conditions of measurements and is typically within 5?100%. The error is usually small for stable atmospheric conditions with large$NO_2$ amount trapped under a near-surface inversion.

<u>Instrument History:</u>

The instrument operates since 1990. There were no changes in instrument or algorithm.