Improvement of GOME NO₂ Retrieval


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Introduction

Tropospheric NO₂ has its main sources in emissions from the soil, fires, lighting, transport and industry. It plays an important role in the formation of tropospheric ozone and together with SO₂, it is the main cause of acid rain.

The Global Ozone Monitoring Experiment (GOME) is a UV visible spectrometer on board of the European satellite ERS-2. GOME is a 4 channel double monochrometer covering the wavelength range of 230 - 800 nm with a spectral resolution of 0.2 - 0.4 nm. ERS-2 was launched into a polar sun-synchronous orbit in April 1995. With a ground pixel size of 40 x 320 km² (40 x 960 km²) GOME reaches global coverage at the equator within 3 days. The overall aim of the GOME is the global measurements of ozone columns, but other trace gases such as NO₂, SO₂, HCHO, BrO and OClO can be retrieved from the spectra as well.

NO₂ Retrieval from GOME

Using the Differential Optical Absorption Spectroscopy (DOAS) technique, NO₂ is retrieved from GOME spectra in the wavelength range 425 - 450 nm. Only data of pixels with less than 15% cloud cover are taken into account. The result of the fit is the total slant column (SC).

Subtraction of the stratospheric NO₂ amount yields the tropospheric SC. The stratrophic NO₂ amount is derived from data of the stratospheric 3D chemistry and transport model SLIMCAT. On the assumption that the sector at the longitude 180°-190° is virtually free of tropospheric NO₂, the SLIMCAT data are scaled zonally to the GOME measurements in this sector.

The tropospheric SC is converted to a total vertical column (VC) using the radiative transfer model SCIATRAN. The conversion depends on the vertical profiles of NO₂ for each pixel. These profiles are unknown, therefore they are taken from the 3D tropospheric chemical transport models MOZART, TOMCAT and IMAGES. The output of SCIATRAN is the airmass factor (AMF), the ratio between SC and VC.

Airmass Factors

The sensitivity of the GOME retrieval depends on the height of the absorber within the atmosphere. Therefore the AMF of a given layer is a function of the height. The AMF of the total column depends on the concentration profile of the absorber, not on the total concentration. The high concentration near the ground over anthropogenic sources leads to small AMF, whereas the NO₂ above biogenic sources is mostly located in the free troposphere and causes larger AMF.

As the AMF depends strongly on the solar zenith angle (SZA), this variable must be taken into account for the retrieval. The AMF increases with height dependency of the AMF increases with the SZA.

The AMF also depends on the aerosol type. The optical thick aerosol absorbs photons and causes small AMF from ground up to 3 km. The rural and maritime aerosols are reflecting light, which increases the albedo of lower layers. This causes a larger AMF for layers above 500 m since the sensitivity depends on the number of backscatter

The computation time for the AMFs for one day on the grid of MOZART (8192 pixel) with SCIATRAN is approx. 2.5 days on a 0.8 GHz PC. To facilitate an efficient, i.e. fast retrieval the 2D AMF approximation for one day at the resolution of 40 x 960 km² are precalculated. To account for the surface height dependence of the reflectivity of the atmosphere below each layer there is one individual set of AMF for each ground height between 0 km - 9 km in steps of 100 m.

For each day an individual global AMF map is approximated. A comparison between a full SCIATRAN calculation and the 2D AMF approximation for one day at the resolution of MOZART shows a RMS < 3%. The computation time of the 2D AMF approximation is approx. 22s/day on the same PC.

Model Comparison

The distribution pattern of the NO₂ concentrations in MOZART and TOMCAT are mostly alike, but MOZART shows the highest values above Europe and, compared with TOMCAT and IMAGES, lower values above Asia. The emissions over Africa from TOMCAT and MOZART match fine, nevertheless MOZART shows in contrast to IMAGES and TOMCAT virtually no emissions above South America. The different patterns of MOZART on the one hand and of TOMCAT and IMAGES on the other hand are caused by different emission scenarios.

2D Airmass Factor Comparison

The values of the block AMF, which are based on the modelled NO₂ profiles, are almost in every case higher than those of the Standard AMF. An exception to that are the values above anthropogenic source regions: High concentrations near the ground combined with a low sensitivity of the measurements for low layers especially for an urban aerosol leads to small AMF values.

The influence of the shape of the profile on the AMF is clearly visible over the oceans: For all AMF above the ocean a maritime aerosol is applied. The legible increments of the model derived AMF are based on the shape of the absorber profile in which the mean amount of NO₂ is assumed in higher layers and with that in a region of higher sensitivity of the measurement.

Selected References


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