Pergamon

PII: S0022-4073(97)00197-0

J. Quant. Spectrosc. Radiat. Transfer Vol. 60, No. 6, pp. 1025–1031, 1998

Printed in Great Britain
0022–4073/98 $19.00 + 0.00

Reprint of

ATMOSPHERIC REMOTE-SENSING REFERENCE DATA FROM GOME: PART 1. TEMPERATURE-DEPENDENT ABSORPTION CROSS-SECTIONS OF NO_2 IN THE 231–794 nm RANGE

J. P. BURROWS, A. DEHN, B. DETERS, S. HIMMELMANN, A. RICHTER, S. VOIGT and J. ORPHAL*

Institute of Environmental Physics, University of Bremen, P.O. Box 330440, D-28334 Bremen, Germany

(Received 7 August 1997)

Abstract—Absorption cross-sections of NO_2 between 231–794 nm have been measured in the 221–293 K temperature range, using the global ozone monitoring experiment (GOME) flight-model (FM) satellite spectrometer. The spectra have a resolution of about 0.2 nm below 400 nm and of about 0.3 nm above 400 nm. These are the first reference spectra of NO_2 covering at the same time the entire UV–visible–NIR spectral range and a broad range of relevant atmospheric temperatures. The new absorption cross-sections are important as accurate reference data for atmospheric remote-sensing of NO_2 and other minor trace gases.

1. INTRODUCTION

NO_2 is amongst the most important trace gases in the Earth's atmosphere.[1] The chemistry of NO_2 is closely linked to the O_3 cycle, and its atmospheric concentrations vary significantly as a function of altitude, latitude, and season.[2] These variations, partially due to man-made gaseous emissions, need to be monitored in order to provide accurate input for political decisions on environmental protection and the preservation of the stratospheric ozone layer.[3]

For these reasons, the global ozone monitoring experiment (GOME) satellite spectrometer was launched in 1995 onboard the ERS-2 satellite. This instrument measures back-scattered solar radiation for the determination of atmospheric column densities of O_3, NO_2, and other trace gases on a global scale within three days.[4] For the retrieval procedures, absorption characteristics of these gases in the spectral range 231–794 nm are used.

Before launch, laboratory reference spectra of NO_2, O_3, and SO_2 were measured using the GOME FM spectrometer. One important advantage of these spectra is that they cover the entire UV–visible–NIR spectral range and a relevant range of atmospheric temperatures. Furthermore, the GOME FM spectrometer is a well-calibrated instrument, including spectral and radiometric calibration and an accurate determination of its instrumental line shape.[5] Therefore, the new absorption cross-sections measured using the GOME FM spectrometer are essential as reference data for the retrieval of atmospheric NO_2 and other trace gases, not only for GOME but also for medium-resolution zenith sky differential optical absorption spectroscopy (DOAS) observations taken on ground, or from balloon and aircraft platforms.

2. EXPERIMENTAL

2.1. The gome instrument

The GOME instrument is a four-channel Si-diode array grating spectrometer, observing between 231 and 794 nm at a resolution of about 0.2 nm below 405 nm and of about 0.3 nm above 405 nm

* To whom all the correspondence should be addressed.

This article is a reprint of a previously published article. For citation purposes, please use the original publication details; J Quant Spectrosc Radiat Transfer 1998;60:1025-1031.**DOI of original item: doi:10.1016/S0022-4073(97)00197-0

Table 1. Spectral coverage and resolution of the GOME instrument

Channel	1A	1B	2	3	4
Coverage (nm)	231–307	307–316	311–405	405–611	595–794
Resolution (nm)	0.20	0.20	0.17	0.29	0.33

(see Table 1). Three identical instruments were built by an industrial consortium in frame of the GOME project: the bread-board model (BBM), the flight model (FM), and the flight spare model (FSM). All measurements described in this paper were carried out using the GOME FM model.

Light is brought into the GOME spectrometer by a scan mirror and focused onto the entrance aperture by a telescope. A predisperser prism is then used to create a first spectrum, which is separated into the four detection channels (Table 1) by means of a directed prism which picks off and separates channels 1 and 2, and a dichroic mirror which directs light either towards channel 3 or 4. Each channel comprises a high-precision grating and a Peltier-cooled 1024-pixel Si-diode array detector. One advantage of this concept is that the pixel exposure times (PET) can be selected independently for every channel.

The wavelength calibration of the GOME instrument is performed with a built-in Pt–Cr/Ne hollow-cathode lamp. This lamp was spectrally calibrated by high-resolution Fourier-transform spectra in 1994.[6] The radiometric calibration of GOME was performed by the industry, providing accurate key data concerning dark current, pixel-to-pixel gain, stray light, and polarization corrections.[7]

During the measurements described here, the GOME instrument was installed in a White-room at the Institute of Technical Physics (TPD/TNO) in Delft, The Netherlands. In a laboratory room near this White-room, a transportable experimental set-up was installed in order to measure accurate reference spectra using the GOME spectrometer. This set-up, called CATGAS (see below), was linked optically to the GOME instrument by a Quartz glass fiber.

2.2. The CATGAS set-up

The calibration apparatus for trace gas spectra (CATGAS) consists mainly of an optical bench with a 120 cm base-length White-type coolable absorption cell.[8] In this study, the absorption path was varied between 985 and 1465 cm.

The Quartz-cell has a double jacket, with an ethanol–water mixture coolant flow through the inner jacket, the outer jacket being evacuated to provide thermal isolation. In addition, the cell is surrounded by isolating foam (Armaflex). The Ethanol cooling is achieved by a two-stage cryocooler (Haake KT-90). For the measurements described below, temperatures were varied between 221 and 293 K. The temperature stability in the cell was determined to be better than 1 K.

Gaseous mixtures are produced using calibrated flow controllers (MKS). The cell pressure is monitored using capacitive pressure transducers (Baratron). Synthetic air is employed as carrier gas, with typical flow rates of a few hundred ml/min. For this study, NO_2 was taken from a commercial gas bottle (Messer Griesheim) with a certified mixture of 1% NO_2 in N_2. NO_2–air mixing ratios and total flow rates were varied according to the different absorptions of NO_2 between 231 and 794 nm. As broad-band light sources, a D_2 lamp (Heraeus, 200–430 nm) and a quartz–tungsten–halogen lamp (Osram, 340–800 nm) were available.

2.3. Measurement procedure

For all gas mixtures and temperatures (293, 273, 241 and 221 K), the GOME FM measurements were carried out according to the following procedure:[9]

1. Measurement of a spectrum of the GOME internal Pt–Cr/Ne line source, required for spectral calibration.
2. Measurement of a "dark" spectrum without any light source for the selected PET, required for dark current correction.
3. Measurement of a spectrum without any absorber in the CATGAS cell, required as reference for determination of absorption cross-sections.