

A BALLOON-BORNE DIFFERENTIAL ABSORPTION SPECTROMETER WITH TEMPERATURE STABILIZED DETECTOR

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ABSTRACT

A small and light commercial spectrograph for differential absorption operation has been adapted in order to be integrated in a standing alone gondola for balloon-borne measurements of stratospheric constituents of interest for the ozone balance. The instrument named ASSOS (Atmospheric Species by Solar Occlusion Spectrometry) will cover the 340-480 nm range where O₃, NO₂, OClO and BrO show structures in the absorption spectra suitable of being measured and will operate in solar occultation mode. It will be ready for a test flight in the summer 1995. A short description of the instrument is presented.

1. INTRODUCTION

The detailed study of the mechanism which balance the stratospheric ozone has become an issue of major concern in recent years after the reporting of a general negative trend not only in the Antarctic region but in more populated areas of high and mid-latitudes of the northern hemisphere (Stolarski et al. 1991). In addition, the more and more papers reporting ozone record low from different times and geographic areas are being appearing frequently (i.e. Kohmyr 1994, EOS, 1995, Von der Gathen et al, 1995).

In last years a number of co-ordinated Campaigns have provided a great amount of ozone related data during the winter and early spring in the Arctic and SubArctic regions (EASOE, AASE, SESAME). While there is a greater evidence that the observed ozone reductions are related to the growing loading of halogen in the lower stratosphere, there are still significant uncertainties

concerning the exact mechanisms which takes place, particularly in the belt outside the Arctic vortex, and after the vortex collapsing in the beginning of the spring.

NO₂ plays a role in the accepted theory since a conversion of this molecule to its reservoirs required for the halogen chemistry to proceed. Since the pioneering work of Noxon in 1979 measurements of this molecule has been performed by ground-based (gb in the successive) and balloon-borne spectrometry (Roscoe et al. 1990 Pommereau and Piquard 1994, a) since its spectrum is highly structured and the absorbance is in the measurable range when long paths are used. The same conditions are fulfilled by the O₃ in the visible Chappuis bands and by other species of stratospheric interest as it is the case for OClO and BrO, which are involved in the ozone depletion chemistry. The detectors based on photodiode arrays provide the possibility of covering broad spectral ranges allowing the simultaneous measurements of those species with structured cross-sections in the region.

The ground-based network deployed in EASOE and SESAME provided a very useful dataset at different latitudes. Our group from INTA was measuring at Keflavik (Iceland) during the passed winters 1991/92, 1993/94 and 1994/95 obtaining a very useful dataset of the temporal evolution on the mentioned species. However, a correct interpretation of the observed features requires information of the vertical distribution of the species which, to present date, only very crudely may be obtained by the gb UV-Vis spectrometers (McKenzie et al. 91). Little information is still at present available regarding the vertical

distributions in different atmospheric conditions, and interesting questions remain to be elucidated. How the profiles at middle latitude compares the those inside the vortex? How may co-exist significant OCIO in presence of NO_2 ?

In order to get information on these issues, an INTA proposal devoted to the design and manufacture of a balloon-borne UV-Vis spectrometer has been developed with the experience gained in gb instruments. The main concept of the design was to build a light, easy to handle, and inexpensive instrument which could be integrated and launched in a short time and with little effort.

In the following sections a short description of the instrument and the analysis used is presented.

2. TECHNIQUE AND INSTRUMENT

The direct solar occultation technique has been selected due to the high levels of light (and consequently low integration times) available and the simplicity of the geometry of the rays for the retrieval procedure. Measurements will be carried out during sunset from 85° solar zenith angle up to the occultation or during sunrise in the opposite direction. Spectra will be continuously recorded during the flight in the spectral range from 330 to 480 nm. The differential absorption between one spectrum when the sun is over the flight level, and those recorded during the twilight (DOAS) is obtained by the same analysis procedure as in the ground-based spectrometers. The technique has been extensively used during the eighties, mainly for NO_2 measurements and is well documented (i.e. Noxon et al. 79, McKenzie and Johnston 82, Solomon et al. 1987 Pommereau and Goutail 1988). In short, the molecules present in the path between the sun and the instrument in the selected spectral range are retrieved simultaneously from the best fitting of the logarithm of the ratio of two spectra, one acting as reference or background, assuming that the number of absorbers and scatterers and their cross-sections data are known in advance. A careful alignment of the spectra before the retrieval is important because structures appearing in the ratio simply as results of a small wrong alignment could be interpreted as molecules structures. This effect has little influence in ozone since the structures in the Chappuis at, say, 470 nm are broad, but can be determinant in OCIO, BrO or even NO_2 , where the size of the structures are only of few nanometers. The expected absorbances as a function of the solar zenith angle are plotted in

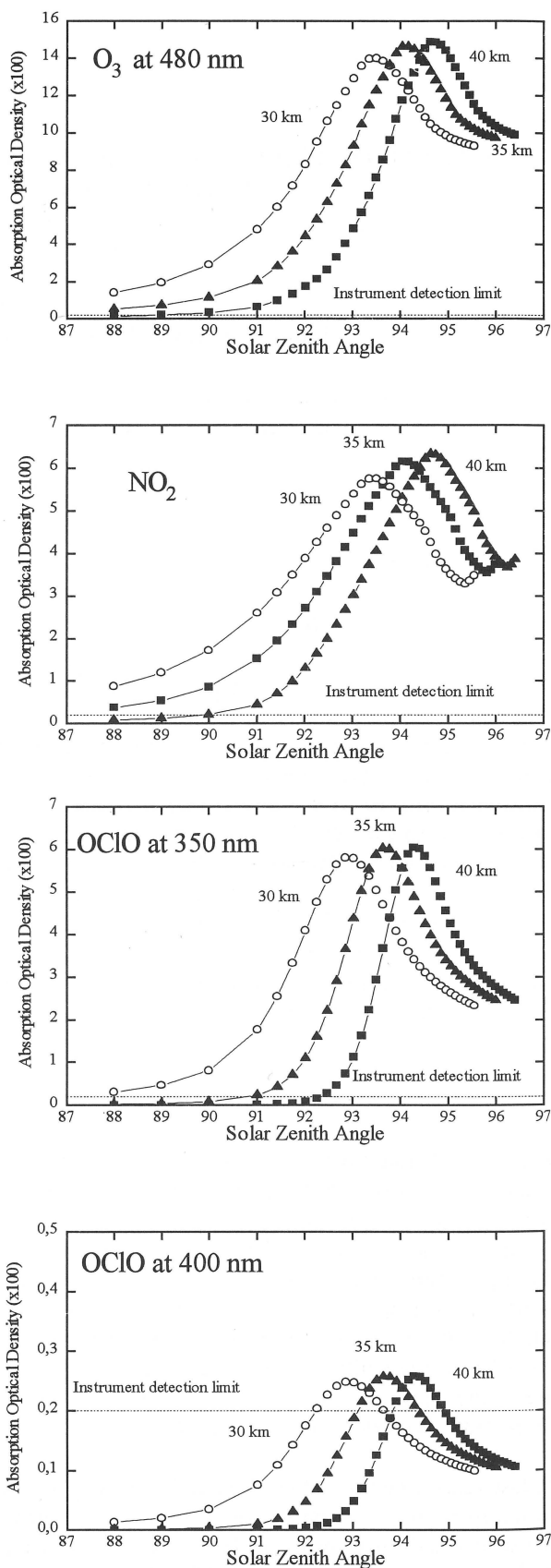


Figure 1 Expected absorbances for molecules of stratospheric interest

figure 1 for the main species and for different balloon altitudes.

At a balloon ceiling of 30 km signal is expected to be strong enough to be measured for typical mid-latitudes profiles of NO₂ and O₃. OCIO profile used for these calculations are that estimated for winter time in the core of the polar vortex. Even in this case, the absorption bands around 400 nm will produce too small differential absorption. On the other hand, in the range around 350-360 nm the absorbances should be well over the detection limit of the instrument.

The instrument follows the SAOZ concept (Pommereau and Piquard 1994 a,b) due to the simplicity of the spectrograph light input. A 1024 diode array detector with a ruled 1200 grooves.mm⁻¹ grating will be used with an entrance slit of 100 μm in a small Jarrel-Ash spectrograph, providing a 8 sample points per resolution element minimising the interpolation errors (see Table 1).

Molecules: O ₃ NO ₂ OCIO BrO Vertical resolution: 1km (estimated) Vertical range: Tropopause to 40km Spectral range covered: 340-480 nm Spectrometer resolution: 1.2 nm Grating: 1200 gr.nm ⁻¹ Detector: Hamamatsu C4845 1024 pixels Detector temperature: +5°C Tracking system: No Tracking Instrument weight: 25Kg
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Table 1

The detector is a commercial HAMAMATSU thermoelectrically cooled operating at +5°C. The light input is performed by means of a teflon sheet acting as scatterer and a small optical system for light focusing to the spectrograph. Spectral data together with the housekeeping information will be sent by telemetry just after each spectrum has been read, by means of an on board dedicated electronics which interface with the CNES telemetry through a serial standard RS232 line. The electronic is based on a Motorola 68302 microprocessor through a VME bus. Dark current is recorded periodically by a mechanical shutter during the observational period in order to subtract from the measurements. We estimate an average vertical resolution of less than 1 km between 12 km and the floating level. A GPS will provide the altitude and co-ordinates data at any time during the flight.

The retrieval scheme to be used for vertical conversion from measurements is still under study, but in any case a model will be used in those molecules which suffer photochemical changes during twilight as it is the case with NO₂ and OCIO to account for the variation in the column during the twilight.

3. FUTURE PROJECTS

The instrument last environmental tests are scheduled for the end of July. The first flight test will be performed in November this year with the launching assistance of the CNES balloon team in the range of Leon.

Scientific flights are under preparation in the years to come in the frame of the Environment and Climate Programme (proposal submitted) and supported by National resources.

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