AERONOMY REQUIREMENTS FOR SMALL ORBITING PAYLOADS

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ABSTRACT

Before the development of space tools, aeronomy was supported by ground based observation of upper atmospheric phenomena in the solar system. A very limited number of these phenomena could be documented, with very poor altitude resolution or geographic coverage. As an example of the many aspects which can be investigated from space, the presently sensitive ozone problem is briefly described. One of the many typical small payloads which could be envisaged is briefly described.

1. INTRODUCTION

Since, according to international standards, aeronomy has to deal with air processes wherever dissociation and ionization phenomena take place, its first investigation topic is the sun as the source of electromagnetic and corpuscular radiation for atmospheres. The transport and variability of corpuscular radiation in the interplanetary fields and in the near earth environment has received good attention from ESA which has devoted efforts through several satellites to its study. Approved projects such as SOHO and CLUSTER belong the same family of investigations.

The last segment of the solar-terrestrial relationship, on the other hand, has been particularly neglected. It relates to the ionosphere and the neutral atmosphere of the earth and of the other planets. The approval on the ESA side of the CASINI projects opens the door for aeronomic studies of the neutral atmosphere of an other planet than earth which remains practically unexplored within ESA. Many topics could be investigated. One way of classification could be by molecular species. For instance a study of hydrogen throughout the atmosphere on a global basis from tropospheric water to hydrogen atoms and ions escaping from the exosphere on a global basis. A comprehensive view cannot be achieved without orbiting instruments providing global coverage over a significant length of time.

2. THE OZONE QUESTIONS

As an example, I wish to choose an other species for which scientific knowledge and procedures are directly needed for economic and political decisions, namely ozone. As everyone knows, concern has grown for several years about its abundance being potentially changed by man's activities with harmfull consequences on life on earth at all its levels of sophistication from the most elementary forms to human beings. Governments are conscious of these aspects. In the United States, NASA is in charge in compliance with the Clean Air Act Amendments of 1977, Public Law 95-95, of producing periodic reports on the matter, the last one dating from 1988 (Ref. 1). Two other reports among others have been recently produced by the Federal Republic of Germany (Ref. 2) and by the United Kingdom (Ref. 3). They all have common features. First of all the geophysical observational evidence originating from two main sources : ground based instrumentation mostly originated a relatively long time ago (even before world war II) in Europe and satellite instrumentation mostly from the United States.

Figure 1 shows the longest time record of the total ozone column (Ref. 4). This was initiated by Goetz in Arosa (Switzerland) for purely scientific purposes in cooperation with Dobson whose standard spectrophotometer was later spread over the world for the sake of meteorological application. Lower atmospheric ozone was at that time believed to be totally controlled by air motions. In 1930, Chapman had proposed the photochemical mechanism of ozone formation in the upper stratosphere. It can be summarized as follows with solar radiation being responsible for the initial step

Proceedings of the First European Workshop on Flight Opportunities for Small Payloads, held in ESRIN, Frascati, Italy, 8-10 February 1989 (ESA SP-298, April 1989)

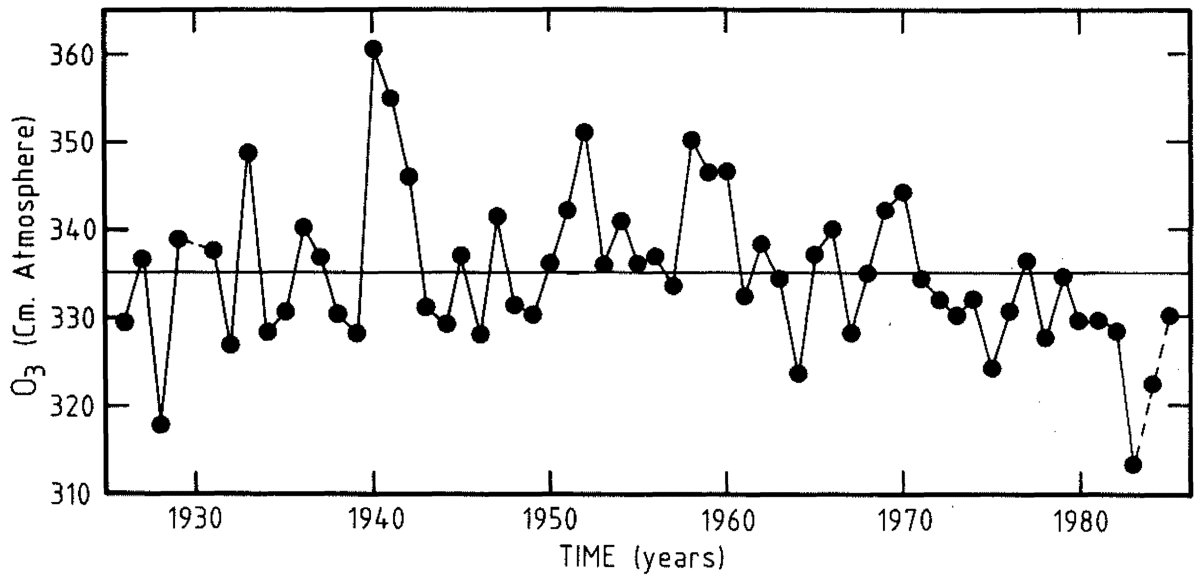

Figure 1. Arosa total ozone serie (since 1926) annual mean values.

$$O_2 + h\nu \rightarrow O + O \quad \lambda < 242 \text{ nm} \quad (1)$$

$$O + O_2 + M \rightarrow O_3 + M \quad (2)$$

$$O + O_3 \rightarrow O_2 + O_2 \quad (3)$$

$$O_3 + h\nu \rightarrow O + O_2 \quad \lambda < 1000 \text{ nm} \quad (4)$$

The reaction (3) of ozone destruction can also be the result of catalytic cycles

$$O_3 + X \rightarrow O_2 + OX \quad (5)$$

$$OX + O \rightarrow O_2 + X \quad (6)$$

$$\text{NET} \quad O + O_3 \rightarrow O_2 + O_2$$

with X as OH, NO, Cl,... implying many trace species and photochemical processes.

Chlorine is now considered as the most critical destruction agent due to the commercial use of chlorofluorocarbon compounds. The data of Figure 1 shown only after 1930 (Ref. 5) have lead to the conclusion of a total ozone amount over Arosa nearly constant until 1970 with a decrease after 1970 attributed to the chlorine effect. Only a quick look at Figure 1 shows more complexity with an unexplained increase from 1926 to about 1960. More research and observation is thus required. Recently, a change illustrated in Figure 2 has appeared in the seasonal variation of total ozone at the south pole (Ref. 6) which has, since the International Geophysical Year, been known to exhibit a very different course than in the northern polar regions. This change is now potentially attributed to an increased chlorine abundance. Since the change originates from the lower part of the stratosphere where the abundance of atomic oxygen is to low,other mechanisms have been suggested involving heterogeneous chemistry in presence of nacreous clouds at very low temperatures, smaller than 200 K.

Satellite observations have provided a three dimensional picture of the south pole phenomena through the monitoring of scattered ultraviolet solar radiation by means of two NASA spectrometers on board of the NIMBUS 7 NOAA satellite. The comparison of these data with extinction observations (Ref. 8) made by means of the UV spectrometer on board of the SMM satellite is shown in Figure 3. The scattering observations would indicated an ozone decrease at 55 km which is contradicted by the extinction. It has now been understood that the apparent decrease is an artefact due to the alteration of optical components. This points to the difficulty of accurate long term observations. Priority should be given to occultation observation less subject to spurious effects linked with the deterioration of optical components. This is illustrated by the extinction data of the NASA's SAGE I and SAGE II satellite experiments leading to the significant determination of trends in ozone, versus stratospheric altitudes, of a few percent over a period of five years as shown on Figure 4 taken from Ref. 1.

Even at higher altitude (80 km) seasonal variations of ozone can be measured through the observation of the 1.27 µm emissions (Ref. 9). It has been shown that these variations can be correlated with variation of CO and H_2O in the mesosphere (Ref. 10, 11). These lead to controversial interpretation (Ref. 9, 12).

3. FUTURE PERSPECTIVES

An important research effort is needed to understand fundamental upper atmospheric mechanisms. Among other actions NASA has planned the launch of the Upper Atmospheric Research Satellite which will cover a range of altitudes, species and parameters as shown in Figure 5 (Ref. 13). In Europe the participation in the polar platforms should partially fill the gap. The accent is however put in this case on operational aspects. The choice of the local time of ascending nodes of the orbits will

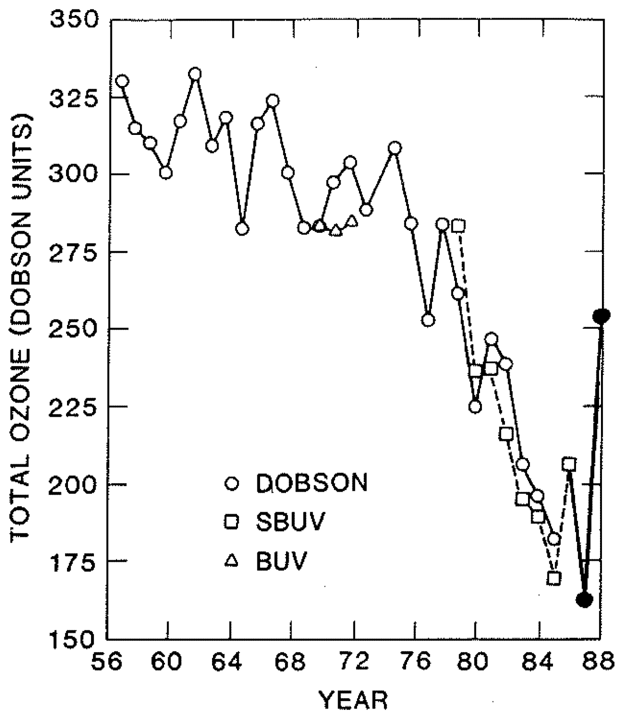

Figure 2. October monthly mean total ozone measured over Halley Bay Station Antarctica.

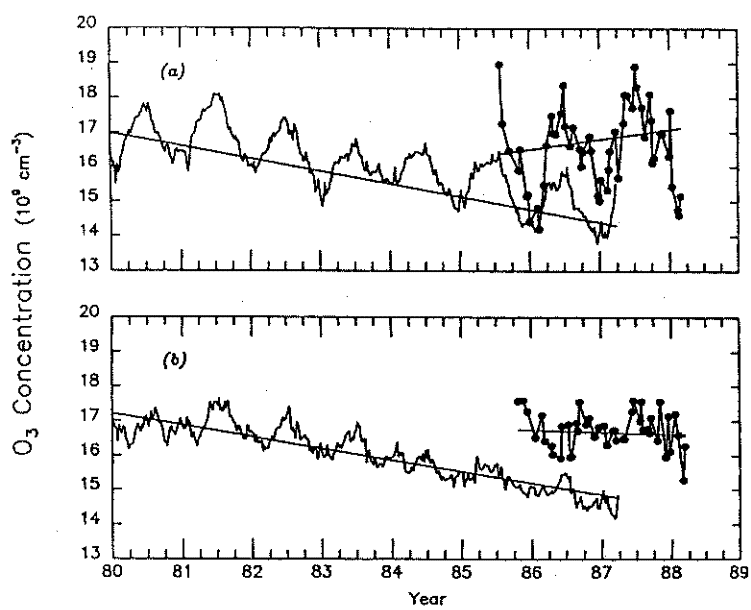

Figure 3. 20° North (a) and 20° South (b) ozone concentration at the altitude equivalent to 0.4 mb (Ref. 8). The data represented by the continuous curves are from the solar backscattered radiation observation. The data represented by the dots are from the solar occultation ultraviolet spectrometer on the Solar Maximum Mission Spacecraft. The straight lines represent trends.

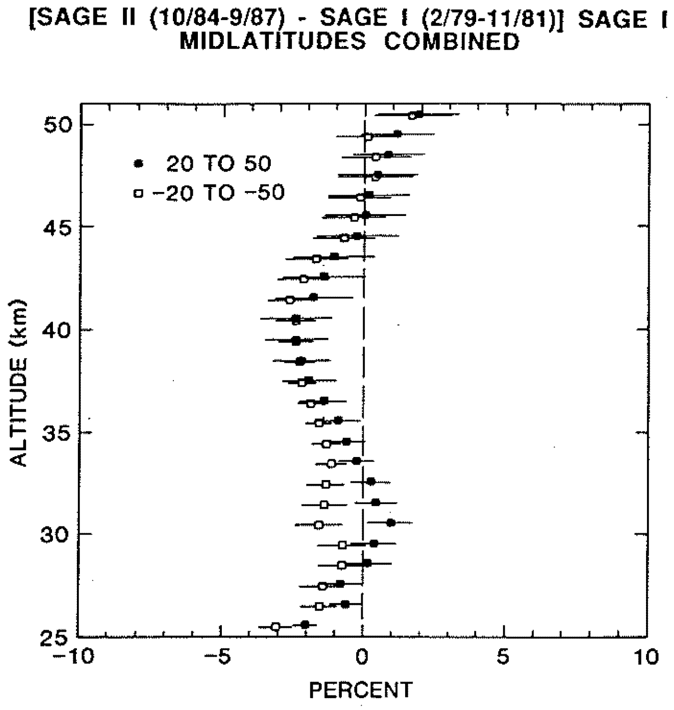

Figure 4. Mean percentage difference between SAGE II and SAGE I versus geometric altitude (SAGE I is the reference). All intersections occuring between 20°N and 50°N (or 20°S to 50°S) were combined into one sample. The horizontal bars are the standard errors of the sample of percentage differences. Within each hemisphere approximately 2500 SAGE I profiles and 6000 SAGE II profiles were used in computing the statistics.

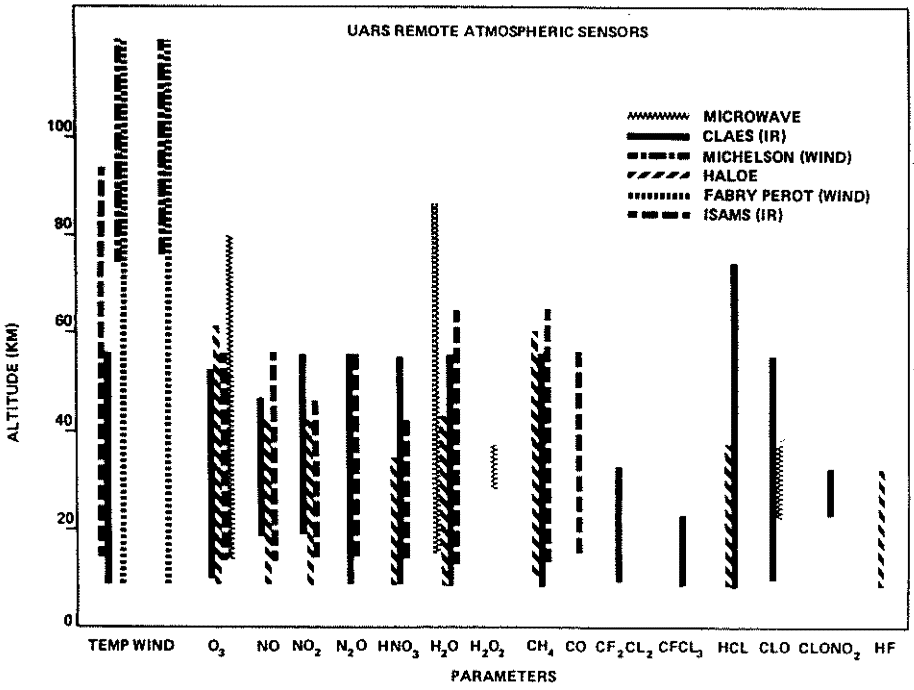

Figure 5. Altitude coverage of the atmospheric parameters measured by the UARS remote sensors.

limit the research objectives, for solar occultation observation for instance (Ref. 14).

There is plenty of room for additional research where space tools are unique for the full-fillement of important tasks. As an example the observation of stratospheric and mesospheric ozone simultaneously with sensitive species and dynamically related aspects such as the turbopause mapping could be the task of a small payload. Expertise has been acquired in Europe for such a task (see Figure 6). The main characteristics of such a payload could be :

Orbit : 80° inclinaison
500 km altitude
circular
Stabilisation : 3 axes
Pointing : Sun (1 arc. min.)
Instruments : first priority
- 4 etalons (NO, CO, H_2O (high), H_2O (low)
- 1 UV photom. (O_3 UV)
- 1 limb scanner (O_2 1.28 µm for O_3 high)

second priority
- 1 CO_2 etalon (turbopause mapping)
- 1 557.7 nm limb scanner (O)

Payload weight : 50 kgr. (60)
Total weight : 300 kgr.
Nominal lifetime : 5 years
Data transmission : 15 megabits per day
Duty cycle : 10 min/orbit
5 orbits/day

Such a task cannot be conducted without a Space Agency support as well as other ones related to the same topic.

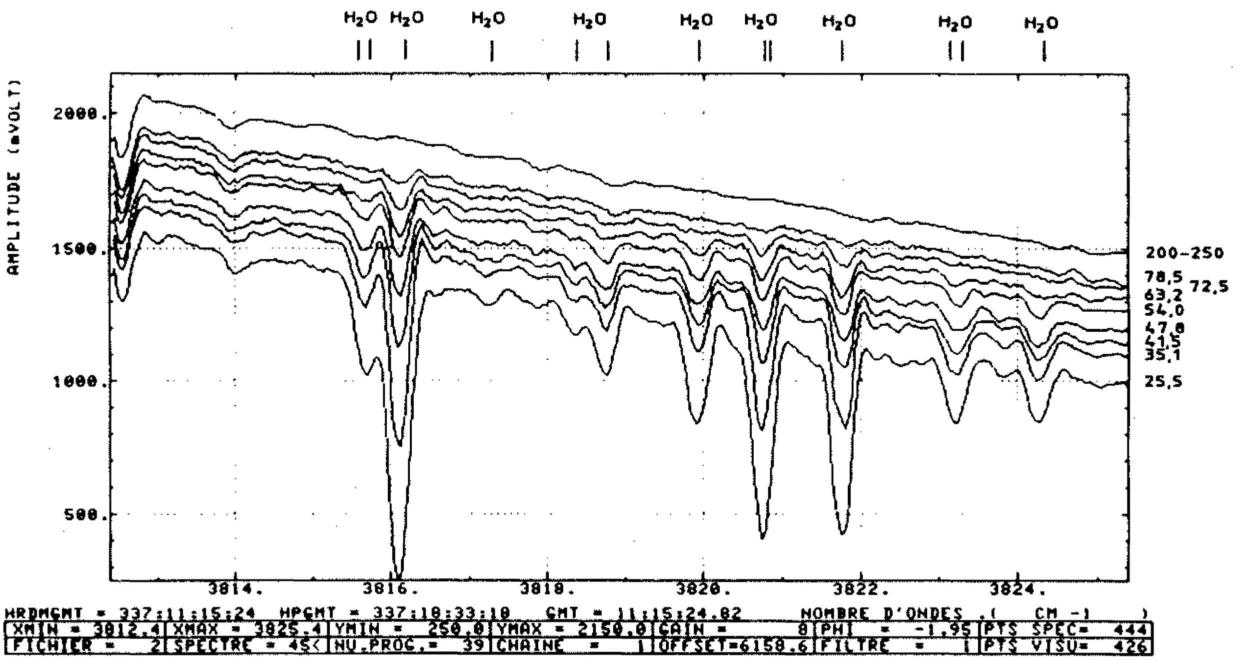

Figure 6. Water vapor occultation absorption line spectra recorded by the infrared spectrometer on Spacelab 1 (Ref. 15) leading to the determination of H_2O abundances from 80 to 25 km altitude. Intensity is plotted versus wavenumber. The spectra have been shifted for the sake of clarity.

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