ULTRAVIOLET ABSORPTION MEASUREMENTS IN THE ATMOSPHERE OF MARS

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ABSTRACT

The feasability of the observation of ozone and carbon dioxide in the martian atmosphere has been studied for the case of an orbiting limb sounding absorption spectrometer working in the 120-320 nm wavelength range. Vertical profiles of ozone can be measured up to 40 km. Seasonnal and latitudinal variations at lower altitude can also be observed. Carbon dioxide concentrations can be determined up to 150 km of altitude.

Keywords : Mars, Atmosphere, Ultraviolet absorption, Ozone, Carbon dioxide

1. INTRODUCTION

Although carbon dioxide is the major constituent in the Martian atmosphere, trace species such as molecular oxygen, carbon monoxide, water vapor, ozone and odd hydrogen radicals play a crucial role in the chemical and photochemical processes. (See ref. 1 for a review of the chemistry in the Martian lower atmosphere).

Ozone, for example, has been detected for the first time by an ultraviolet spectrometer aboard Mariner 7 (ref. 2) and has been mapped from Mariner 9 (ref. 3). At the present time, no detailed vertical distribution of O_3 is available but observations of the ozone column show a large variability with time and latitude. In fact, over most of the planet, the total amount of ozone is smaller than the detection limit of the spectrometers (3 μm. atm or 8×10^{15} molecules cm^{-2}) but in the vicinity of the polar cap, the concentration increases considerably during the winter and reaches an integrated value of about 60 μm.atm (1.6×10^{17} molecules cm^{-2}).

The enhancement of ozone in the winter polar region appears to be connected with a rapid decrease in the water vapor content which is driven mainly by a variation in the local temperature. In fact, in the Martian lower atmosphere, a decrease of 10 K in the temperature reduces the saturation water vapor pressure by a factor of 10. Most of the water vapor is therefore condensed in winter and the odd hydrogen source (and consequently the odd oxygen loss) is suppressed. The H_2O budget seems also to be related to the amount of air-borne dust and is therefore sensitive to dust storms.

An understanding of the key aeronomic processes occuring in the lower atmosphere of Mars requires simultaneous observations of ozone, water vapor, temperature and pressure profiles. Because of the lack of these data, the knowledge of the chemical composition of the Martian atmosphere as a function of the altitude has still to be based on theoretical models (refs. 4-8). These models which have to account for the surprising low O_2 and CO abundances show the importance played by odd hydrogen radicals and require either high water vapor content or large vertical exhange coefficients in order to fit the available observations.

The purpose of this paper is to show the feasability of an ozone and carbon dioxide profile measurement by absorption spectroscopy in the ultraviolet. Since ozone is entirely of photochemical origin, the measurement of its vertical profile should permit an ideal validation of the current photochemical theory of the Martian atmosphere.

2. THE KEPLER PROJECT

A Mars geophysical orbiter, called Kepler mission, has been proposed to the European Space Agency (ESA-ASE) in order to study the Martian atmosphere, the planetary interior and surfaces and the interaction with the solar wind. An assesment study has been published (ref. 9) and followed by a Phase A study which is still in progress. A model scientific payload has been defined including an ultraviolet spectrometer. This instrument is dedicated to the measurement of radiation emitted by the Martian atmosphere and of solar radiation absorbed by the atmosphere. The airglow measurements are presented in ref. 10. The orbiter will have a periapsis around 150 km and absorption measurements will take place during the limb scanning operation mode. For that purpose, a sunlight diffuser used as a periscope should be included in front of the ultraviolet spectrometer to avoid a solar pointing system aboard the spacecraft.

Absorption measurements will be performed nearby the periapsis in order to provide information on the vertical distribution of atmospheric constituents, in particular ozone and carbon dioxide. The altitude resolution is defined by the orbiter altitude (about 200 km) and varies from 7.3 km to 3.5 km for a ray-grazing altitude from 0 to 150 km. The sensitivity of absorption measurements is enhanced when an occultation technique is used since the optical thickness is increased by a factor of about 70.

3. THE ABSORPTION MEASUREMENTS

In the Martian atmosphere, the ultraviolet absorption spectrum is dominated by ozone between 200 and 300 nm and by carbon dioxide below 200 nm. Both constituents are characterized by absorption bands varying slowly with the wavelength. Therefore, high resolution spectra are not required to determine their vertical profiles from solar occultation measurements.

The CO_2 optical depth can be estimated either from models (ref. 4) or from measurements performed by the Viking 1 and 2 missions. Considering the maximum value of the absorption cross-section around 130-135 nm, absorption of the order of 12 percent is still existing at an altitude of 150 km.

The computation of the O_3 optical depth can be based on theoretical vertical profiles calculated for instance by Shimazaki (ref. 8) using a photochemical 1-D model which includes seasonal and diurnal variations in temperature, water vapor and solar radiation (fig. 1). The adopted ozone profile corresponds to the mid-winter models. Values of the ozone concentration versus altitude are given in table 1 with the corresponding absorption cross-section required to get an optical thickness equal to 1, which corresponds to the best conditions of observation

Table 1. Ozone vertical profile adopted in this work.

Altitude (km)	O_3 concentration (cm^{-3})	Absorption cross-section for $\tau = 1$ (cm^2)
5	5.6×10^{10}	6.2×10^{-19}
10	2.7×10^{10}	1.3×10^{-18}
15	1.3×10^{10}	2.6×10^{-18}
20	5.4×10^{9}	6.2×10^{-18}
25	2.6×10^{9}	1.3×10^{-17}
30	1.4×10^{9}	
35	6.6×10^{8}	
40	2.1×10^{8}	

Air mass factor : 73
Scale height : 4 km

by absorption spectroscopy. From this table, the wavelengths of measurements can be deduced using, for instance, the absorption cross-section of Inn and Tanaka (ref. 12). The useful wavelength interval needed to cover the altitude range from 0 to 40 km is illustrated on fig. 2. The lower limit of detectability of ozone is determined by the maximum value of the absorption cross-section around 255 nm. Considering that an absorption of 5 percent is still measurable with a good accuracy, it clearly appears from fig. 1 that the ozone profile can be measured up to 40 km during the winter. Seasonal variations can be also easily detected below 25 km if the lower profile calculated for mid-summer conditions by Shimazaki (ref. 8) is considered.

In conclusion, an ultraviolet spectrometer aboard a Mars orbiter, scanning the 120-310 nm wavelength range at low resolution is well adapted for determining carbon dioxide profiles up to 150 km and ozone profiles below 40 km of altitude, by solar occultation measurements in the Martian atmosphere. Seasonnal and latitudinal variations of O_3 can be also measured in the lower atmosphere.

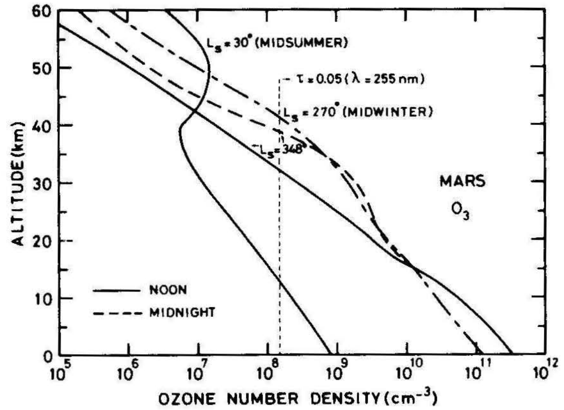

Figure 1. Profiles of ozone densities for different seasons as calculated by Shimazaki (Ref. 8). L_S is the aerocentric longitude. The dashed vertical line corresponds to an optical depth of 0.05 at 255 nm.

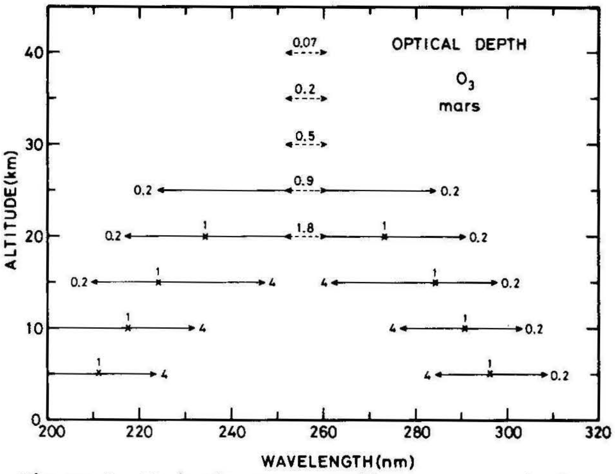

Figure 2. Altitude corresponding to an optical depth whose value is quoted in the figure, as a function of the wavelength, for an occultation geometry

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