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Annual mean mixing ratios of N_2, Ar, O_2, and CO in the martian atmosphere

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Abstract

The precise mixing ratios of N_2, Ar, O_2, and CO measured by the MSL Curiosity quadrupole mass spectrometer must be corrected for the seasonal variations of the atmospheric pressure to reproduce annual mean mixing ratios on Mars. The corrections are made using measurements the Viking Landers and the Mars Climate Database data. The mean correction factor is 0.899 ± 0.006 resulting in annual mean mixing ratios of (1.83 ± 0.03)% for N_2, (1.86 ± 0.02)% for Ar, $(1.56 \pm 0.06)\times10^{-3}$ for O_2, and 673 ± 2.6 ppm for CO. The O_2 mixing ratio agrees with the Herschel value within its uncertainty, the ground-based observations corrected for the dust extinction, and photochemical models by Nair et al. (1994) and Krasnopolsky (2010). The CO mixing ratio is in excellent agreement with the MRO/CRISM value of 700 ppm and with 667, 693, and 684 ppm recently observed at L_S = 60, 89, and 110° and corrected to the annual mean conditions. Lifetimes of N_2 and Ar are very long in the martian atmosphere, and differences between the MSL and Viking data on these species cannot be attributed to their variations.

1. Introduction

The high-precision measurements of mixing ratios of N_2, Ar, O_2, and CO were made using the quadrupole mass spectrometer as a part of Mars Science Laboratory at the Curiosity rover (Mahaffy et al. 2013, Franz et al. 2015). These measurements must be corrected for the seasonal variations of the atmospheric pressure to reproduce annual mean mixing ratios on Mars.

2. Lifetimes of CO, O_2, N_2, and Ar on Mars

Lifetimes of long-living species are ratios of their column abundances to their column production or loss rates. The calculation is simple for CO, whose production is just the photon flux at $\lambda < 200$ nm times the disk-to-sphere area ratio of 1/4, with the lifetime of six Earth's years. O_2 recycles in some reactions, and only two processes, $O + O + M \rightarrow O_2 + M$ and $OH + O \rightarrow O_2 + H$, result in formation of the O = O bonds and the O_2 lifetime of 60 years. N_2 is affected by outgassing from the interior and is lost by photochemical escape and sputtering (Jakosky et al. 1994). Its current lifetime is ≈1 Byr. Evolution of radiogenic ^{40}Ar was considered by Krasnopolsky and Gladstone (1996, 2005), and its current lifetime relative to sputtering is very long, 19 Byr. Here we confirm the conclusion by Mahaffy et al. (2013) that the differences between the Viking and MSL data on N_2 and Ar cannot be explained by their variations.

3. Seasonal corrections to MSL mixing ratios

Long-living species on Mars have two components of variations: (1) seasonal-latitudinal variations induced by condensation/sublimation of CO_2 on the polar caps and (2) the component related to seasonal variations of the total CO_2 amount in the atmosphere. The first component is significant at high latitudes exceeding 60° and negligible in the MSL observations at 5°S. The second component may be considered as independent of latitude, though it may be affected by weather. To correct the MSL mixing ratios for this component and get annual-mean mixing ratios, the MSL values should be scaled by p_m/p_0.. Here p_m is the atmospheric pressure at the season of the MSL measurements ($L_S \approx 184°$) and p_0 is the annual mean pressure. Both values should be measured at the same conditions anywhere at lowe latitudes on Mars. The most detailed data of this type were published for the Viking Landers (Hess et al. 1980), and we will use them (Fig. 1)

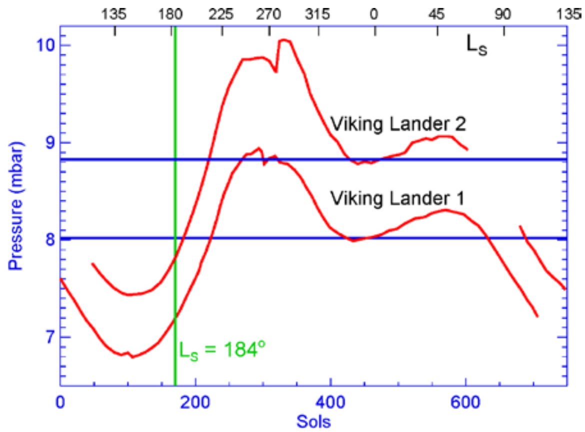

Fig.1. Variations of pressure for the first martian year (669 sols) of Viking Landers. Horizontal lines are calculated annual mean pressures p_0. Vertical line marks the season of the MSL measurements.

The peak-to-peak variation of pressure is a factor of 1.3, the Viking Landers were at the opposite longitudes and different latitudes (22°N and 48°N), and the calculated p_m/p_0 = 0.897 and 0.886 are rather similar. These calculations were also made for two points using the Mars Climate Database (Fig. 2).

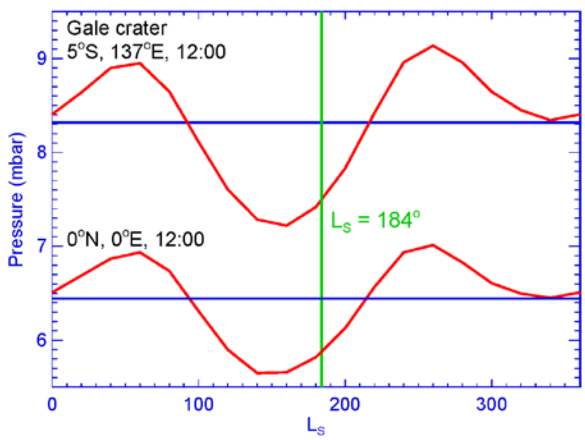

Fig. 2. Same as in Fig. 1 for two points from MCD.

Figure 2 is in the more convenient format (L_S instead sols) but requires corrections for variable angular velocity of Mars. The calculated p_m/p_0 = 0.902 and 0.911 with a mean of the four values of 0.899 ± 0.006. Annual mean mixing ratios can be obtained by scaling the MSL mixing ratios from Franz et al. (2015) by this factor (Table).

4. Comparison with other observations of O_2 and CO

Table

Species	Franz et al. (2015)	Annual mean
N_2	(2.03 ± 0.03)%	(1.83 ± 0.03)%
Ar	(2.07 ± 0.02)%	(1.86 ± 0.02)%
O_2	(1.73 ± 0.06)×10^{-3}	(1.56 ± 0.06)×10^{-3}
CO	749 ± 2.6 ppm	673 ± 2.6 ppm

The seasonally corrected Herschel observation (Hartogh et al. 2010) O_2 = (1.45 ± 0.12)×10^{-3} agrees with MSL. The mean of three ground-based observations is (1.2 ± 0.2)×10^{-3} (Nair et al. 1994). Corrected by a factor of 1.3 for dust extinction, this agrees with MSL as well. The MRO/CRISM observations of CO (Smith et al. 2009) showed the seasonally and globally averaged mixing ratio of 700 ppm. This value was 667, 693, and 684 ppm in the observations by Krasnopolsky (2015) at L_S = 60, 89, and 110°.

Acknowledgement

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