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Modification of the retrieval tool JACOSPAR for the Martian limb observation

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1. Introduction

Previous studies of the Martian atmosphere with limb/solar occultation observations generally use a radiative transfer code to retrieve atmospheric species. To reduce the potentially huge computational time, there are some approximations to the calculation system and to the scattering properties. For Limb observations, the pseudo-spherical approximation was found to be accurate within a few percent and was two orders of magnitude faster than the exact Monte Carlo calculation with the accuracy of a few percent [1]. There are potential requirements for the fast and accurate radiative transfer code that treats the multiple scattering of light by aerosols in a fully spherical system. JACOSPAR [2] [3] [4] is a fast radiative transfer model with multiple scattering. JACOSPAR has been already applied to the study of Earth's atmospheres to retrieve the slant column density of NO_2 and O_3[5]. We modified JACOSPAR in order to apply it to the limb observation of Martian atmosphere. Here we present test simulations to optimize the code for the Martian atmosphere.

2. Modification of JACOSPAR

2.1 Introduction of JACOSPAR

JACOSPAR considers refraction and multiple scattering of light by aerosols in the full spherical atmosphere. It can calculate radiance and Jacobians effectively with requested accuracy by applying "backward Monte Carlo method" that treats absorption and scattering of the radiation as a probability process of the model photons and track its trajectory from observed point to the space. It also adopts the "Dependent sampling method" [6] which simultaneously and multi-spectrally estimates the radiance and Jacobians, reducing the calculation amounts. The radiation sources can be solar beam or internal thermal emission, so that the model can be applied to both solar and infrared spectra in the same framework. Single scattering components are calculated analytically by integrating the source function. For multiple scattering components, JACOSPAR uses backward propagating Monte Carlo method. In order to run the radiative transfer codes for Martian atmosphere, gases absorption coefficients and mixing ratio profiles, aerosols scattering/absorption coefficients, phase functions and vertical profiles, temperature and pressure profiles, and the solar spectrum, are required as input information. The absorption coefficients of CO_2, H_2O, and CO were calculated with the line-by-line method. The single scattering optical properties of dust and water ice in the Martian atmosphere were calculated with the Mie-theory [7] and then integrated with the modified gamma distribution [10]. The refractive indices of dust and water ice are referred to from Wolff and Clancy (2003) and Warren (1984), respectively [11][12]. The mixing ratio of the gases in the Martian atmosphere were assumed to be 95.32% of CO_2 at 0-79km, 300ppm of H_2O at 0-79km, and 800ppm of CO at 0-79km. A Martian vertical temperature-pressure profile selected from the Mars Climate Database has been considered. [13]

2.2 Modified points

We modified two points of JACOSPAR in order to stably calculate the radiance in the thin atmosphere of Mars. (1) In the upper atmospheric layer of Mars where the multiple scattering rarely happens, the radiance can vary

20-30% depending on whether the observed light is the single scattered one or multiple one. This can cause unstable computation results. Thus, we modified the threshold to decide the occurrence of the scattering event. (2) When considering the finite size of field of view (FOV), the radiance is averaged by taking the number of line of sights(LOSs) within the FOV. The LOSs were selected randomly in JACOSPAR. However, a slight difference of LOSs can cause significance on the number of scatterings in the limb geometry. We modified to set the LOSs uniformly within the FOV.

3. Results

In order to validate the codes, a test simulation has been performed under the framework of UPWARDS project, by comparing with the codes, MITRA [13] which has been used for the retrieval of water vapor with PFS/MEx [14]. Comparisons of the outputs by the two codes are in excellent agreement with the accuracy of less than 1 % on average. This demonstrated that these codes were ready to be applied to the data analysis of limb observations in the Martian atmosphere.

In addition to the validation, the output radiance and Jacobians have been investigated in order to confirm the JACOSPAR performance. By optimizing the number of the calculation points in the FOV, the calculation error of radiance and Jacobians related to the absorption less than 2% and those related to the scattering less than 10% were achieved. This work gives the baseline for the retrieval of vertical profiles of gases and aerosols from OMEGA/MEx limb observation, as reported by companion paper [15].

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