EPSC Abstracts
Vol. 13, EPSC-DPS2019-946-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Haze Influences on the 3.3-micron Spectral Features of Jupiter, Saturn, and Titan

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Abstract

The 3-μm spectra of Jupiter, Saturn, and Titan contain molecular lines as well as haze spectral structure. Therefore, proper spectral analyses of these planetary objects should include the influence of haze on molecular spectra. In order to properly calculate the radiative transfer of haze and molecular radiation in the hazy atmospheres, we updated radiative transfer equations, which include the scatterings and absorptions of haze particles as well as molecular emission and absorption. Taking advantage of the dominance of resonant single scattering in the fundamental transitions of molecules in these cool atmospheres, we adopt single dust and molecular scattering. We constructed synthetic spectra of the 3.3-μm bands of CH_4 and other minor molecules using the radiative transfer equations, and compared the synthetic spectra with the spectra from Cassini/VIMS observations available in the literature. We show the dominance of the haze spectral structure in the 3.3-μm spectral features.
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1. Introduction

Kim et al. [1, 2] analyzed the 3.3-μm spectral features of Saturn and Titan appeared in absorption in VIMS/Cassini spectra obtained from occultation experiments. They found that the absorption features are significantly influenced by haze. Kim et al. [3] analyzed the 3.3-μm emission features of Saturn observed at the limb of a southern auroral region, and derived haze spectra between 375 and 925 km at 78°S. The comparison between their synthetic spectra and the observed spectral features demonstrated that the 3.3-μm emission feature is dominated by the haze emission.

2. Radiative Transfer in Hazy Atmospheres

The updated radiative transfer formulation [3] including the scattering and absorption of haze as well as molecular emission and absorption is given by,

$$\mu^+ \, dI_\nu^+/d\tau_\nu = I_\nu^+ - (I_\nu^+ U_{d\nu}^- + I_\nu^- U_{d\nu}^+) - \tfrac{1}{2}U_\nu^*(I_\nu^+ + I_\nu^-) - \left(U_{od\nu}^+ + \tfrac{1}{2}U_\nu^*\right)F_{o\nu}\exp(-\tau_\nu/\mu_o)/2\pi$$

$$\mu^- \, dI_\nu^-/d\tau_\nu = I_\nu^- - (I_\nu^+ U_{d\nu}^+ + I_\nu^- U_{d\nu}^-) - \tfrac{1}{2}U_\nu^*(I_\nu^+ + I_\nu^-) - \left(U_{od\nu}^- + \tfrac{1}{2}U_\nu^*\right)F_{o\nu}\exp(-\tau_\nu/\mu_o)/2\pi$$

Here, $U_\nu = U_\nu^* + U_{d\nu}^+ + U_{d\nu}^-$ is the total single scattering albedo, where

$$U_{d\nu}^+ = \tau_{d\nu}\varpi_{d\nu}^+/(\tau_\nu^* + \tau_{d\nu})$$
$$U_{d\nu}^- = \tau_{d\nu}\varpi_{d\nu}^-/(\tau_\nu^* + \tau_{d\nu})$$
$$U_{od\nu}^+ = \tau_{d\nu}\varpi_{od\nu}^+/(\tau_\nu^* + \tau_{d\nu})$$
$$U_{od\nu}^- = \tau_{d\nu}\varpi_{od\nu}^-/(\tau_\nu^* + \tau_{d\nu}),$$

and $\varpi_{d\nu} = \varpi_{d\nu}^+ + \varpi_{d\nu}^-$, $U_{d\nu} = U_{d\nu}^+ + U_{d\nu}^-$. The definitions of the symbols are presented in [3, 4].

3. Results: Dominance of Haze Features in the 3.3-μm spectral features

Fig. 1a shows the best fits to the limb spectra of Saturn observed by VIMS/Cassini, and Figs. 1b presents the derived spectra of haze [3]. The derived haze spectra are shown to be very similar to the observed spectra indicating the dominance of haze spectral structure in the VIMS spectra.

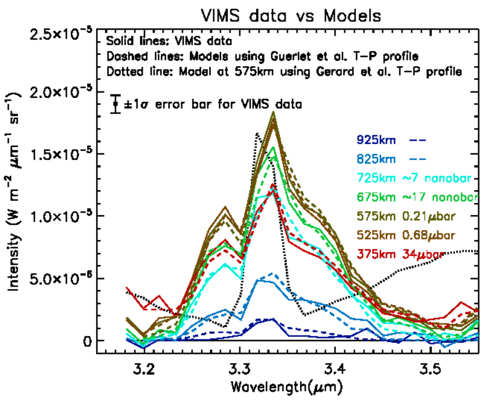

Fig. 1a)

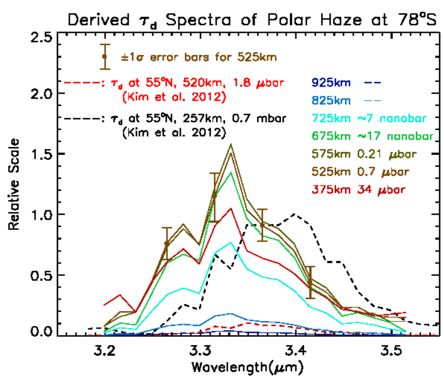

Fig. 1b)

Figure 1. a) Best model fits to the VIMS data of the south polar limb of Saturn [3]. b) Derived haze spectra from the model fits in Fig. 1a.

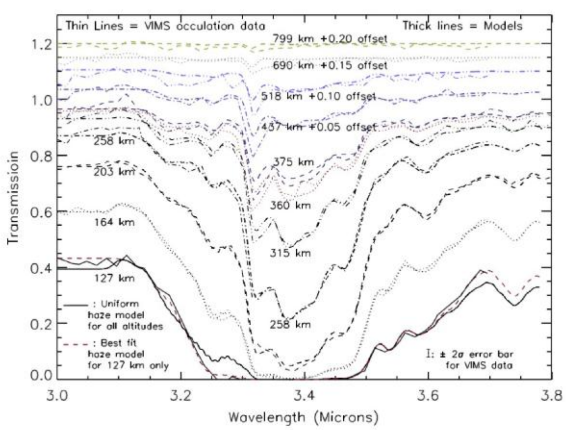

Fig. 2a)

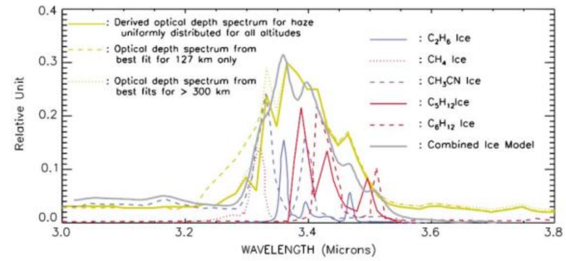

Fig. 2b)

Figure 2. a) Best fits to the VIMS solar occultation data of Titan [2]. b) Derived haze spectra [2] from the model fits in Fig. 2a. Various ice spectra are also shown for comparisons.

Figs. 2a and 2b present the best fits to the VIMS solar occultation spectra of Titan and the derived haze spectra, respectively [2]. A comparison between the two figures shows that the influence of haze spectral structure on the VIMS spectra is significant.

For Jupiter, the existence of haze especially in the infrared images/spectra of polar regions is apparent [e.g., 5]. However, the quantitative influence of the haze on the 3.3-μm spectral feature has not been clearly determined.

Acknowledgement

JP and SJK acknowledge support from the Basic Science Research Program(2018R1D1A1B07046476) through NRF funded by the Ministry of Education, Science and Technology.

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