Development of a radiative transfer model for planetary atmospheres: Application for Venus atmosphere

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Several planets in solar system have its atmospheres, and those planets maintain surface environments different from that of the Earth. In addition, a lot of exoplanets have been discovered since late 1990s, and those exoplanets may maintain surface environments which may be different from those observed in solar system. In order to discuss a variety of surface environments in a lot of planets, a first step in consideration on a radiative energy budget.

However, it is not easy to perform a radiative transfer calculation under a various atmospheric conditions. Such difficulties are resulted from uncertainties of optical parameters of gases in pressures and temperatures which are different from those in Earth's atmosphere. In fact, several studies have investigated uncertainties of such radiative transfer calculations in thick CO_2 atmospheres (e.g., Halevy et al., 2009; Wordsworth et al., 2010).

In such studies, validation of radiative transfer calculation is an important issue. In such contents, Venus atmosphere is an accessible target, which is different from Earth's atmosphere, significantly, and can provide reference data for validation. In fact, several missions, such as the Venera probes, the Pioneer Venus mission, and the Venus Express, provided valuable data on radiation field in Venus atmosphere. In addition, the Japanese Venus orbiter Akatsuki is observing Venus atmosphere, now. At the same time, several theoretical and numerical studies have investigated radiation field in Venus atmosphere (e.g., Takagi et al., 2010; Haus et al., 2015; Lee et al., 2016). They show recently measured optical parameters under the high CO_2 pressure are appropriate in use of radiative transfer calculation of Venus atmosphere. We are developing a radiation model which can be applied to a variety of planetary atmospheres. In this study, we perform radiative transfer calculation in a condition of Venus atmosphere, and compare with existing observation results of Venus atmosphere. In performing the calculation, we follow above-mentioned previous studies and check its validity in our model. The comparison in this study is an important step to validate our model in the condition significantly different from that of the Earth.

In developing a radiation model, a line-by-line model is developed, first. Then, we develop a correlated k-distribution radiation model, which can be used in atmospheric circulation models. The line-by-line calculation is performed with Voigt line profile calculated with Humlicek (1982) method, with a line shape modification based on Perrin and Hartmann (1989) for carbon dioxide absorption lines. Gas absorption line parameters are obtained from HITRAN2012 (Rothman et al., 2013) and HITEMP2010 (Rothman et al., 2010). In addition to line absorption, we include continuum absorptions based on several sources, following previous studies such as Lee et al. (2016). Continuum absorption by water vapor is considered by the use of the MT_CKD model (Mlawer et al., 2012). Continuum absorption by carbon dioxide is based on Lee et al. (2016). But, in addition to those by Lee et al. (2016), we include a continuum absorption in 8363-9434 cm-1 based on Bezard et al. (2011). This additional absorption improves nighttime spectrum in this wavenumber range. In ultraviolet and visible region, we include absorption by sulfur dioxide.

By the use of this model, we calculated radiative flux profiles, radiative spectrum, and albedo under the condition of temperature profile of the VIRA, composition profiles of Crisp (1986) and Pollack et al. (1993), and cloud profiles of Crisp (1986). The results show good agreements with existing observation

data. However, the results are sensitive to assumed profiles of composition and clouds. In the presentation, we will present some sensitivity of the model results. Further, we will present a radiative-convective equilibrium temperature profile in a condition of Venus with our k-distribution model.

Keywords: Venus, Planetary atmosphere, radiative transfer