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A one-dimensional cloud model for Earth-like exoplanets and its stationary solution

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Exoplanets which have flat transmission spectrum are observed in recent years. It is thought that there are two possibility of reasons with flat spectrum. First, it is the case that the exoplanet has an atmosphere which is high average molecular mass. In this case, there are no absorption lines because atmospheres are concentrated at low levels. Second, optical thick clouds cause flat spectrum because clouds disturb starlight. It is difficult to distinguish these two cases, so it is important to predict optical properties of clouds on exoplanets.

There is a prior model of exoplanet's clouds Zsom et al.2012. This model considers microphysics of condensation, on the other hand location of cloud top and sweeping process by rain droplets are free parameters. However, this model has a problem that optical properties of clouds strongly depend on these free parameters.

The main goal of this research is to develop a self-consistent microphysical cloud model for 1D which contains not only microphysics of condensation but also microphysics of coalescence by cloud droplets and rain droplets. We present a self-consistent microphysical cloud model for 1D atmosphere calculating revolution of cloud droplets and rain droplets to consider coalescence process. Furthermore, our cloud model introduces a physical parameter which is updraft velosity, on the other hand location of cloud top and sweeping process by rain droplets are automatically determined.

We apply this model to Earth and obtain the following results. Quiet atmospheres (updraft velocity is less than0.1m/s) and clean atmospheres (number density of cloud condensation nuclei is less than10cm^{-3}) can make optical thin cloud. These results are caused by decreasing cloud droplets by downturn of cloud top, coalescence process and sweeping process by rain droplets. Furthermore, we reveal that rain droplets sweep 70% cloud droplets. These results which argue the possibility of forming optical thin clouds on exoplanets are new results which we can get by considering location of cloud top and coalescence process.

Our cloud model enables to determine the vertical distribution and optical propertiesof exoplanetary clouds as a function of physical atmospheric parameters. The development of this research is to estimate an impact of exoplanet's cloud on transmission spectrum.