Effects of the haze layer on Titan's atmospheric dynamics

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Titan’s stratosphere has been observed to be in a strong superrotation state, where the atmosphere rotates many times faster than the surface does. The Huygens Doppler Wind Experiment (DWE) probed Titan’s atmosphere near the equator and observed the eastward winds at all altitudes except near the surface. The zonal wind speed increases as the altitude increases aside from the dormant region at about 80 km, and reaches 100 m/s at about 120 km. In addition, the brightness temperature of the atmosphere above an altitude of 140 km observed by Cassini Composite Infrared Spectrometer (CIRS) has revealed that there is also in the strong superrotation state (Achterberg et al., 2008).

Another major feature of Titan’s atmosphere is the presence of a thick haze layer. Titan’s haze layer absorbs about 90% of solar radiative flux and increases the temperature of the upper atmosphere, significantly affecting the structure of the atmosphere (Mckay et al., 1991). However, the effect of haze layers on the atmospheric dynamics has not yet been well studied. Understanding such effects of the haze layers would provide the key insights into the atmospheric dynamics of terrestrial planets in general as well as Titan.

In this study, we performed numerical experiments using a General Circulation Model (GCM) with the purpose of elucidating the mechanism of superrotation in Titan and understanding the general circulation patterns associated with it. In the experiments, we used DCPAM, a general circulation model based on the primitive equation system for planetary atmospheres, developed by GFD Dennou Club. We newly employed the gray radiation model of McKay et al.(1999), where the greenhouse effects by the atmospheric gases and the absorption of the sunlight by the haze layer with several parameters are represented by several parameters. The phase change of Methane or the seasonal changes are not taken into account so as to focus on the effects of the radiation field structure. Our atmospheric grid consists of T10L55 (55 pressure levels and 32 longitude 16 latitude grids), and we began the experiments with the atmosphere at rest with respect to the surface of Titan, and with a radiative-equilibrium temperature profile. These models ran until the atmosphere is fully spun up, i.e., has reached steady state (approximately 100,000 Earth days).

We found that calculations with the radiation parameters that reproduced the actual temperature structure of Titan yielded the global eastward wind around the equator with a maximum speed of more than 100 m/s at an altitude of ~200 km. This is roughly consistent with the CIRS data (Achterberg et al., 2008). On the other hand, in the lower atmosphere, the mean value of the zonal winds is very small with no strong vertical gradient, in contrast to the observed substantial increase of the wind speed with the altitude. By changing the parameters of the radiation model, we found that the altitude at which the eastward wind reaches its maximum depended on the altitude of the haze layer. In addition, the intensity of the eastward wind increased as the solar flux absorption rate of the haze layer increased. We did not observe superrotation when the solar flux absorption in haze layer was eliminated. In this presentation, we will discuss these parameter dependencies and the differences from the observation.

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