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Effects of Thermal Tides in the Martian Atmosphere on the Zonal Mean Circulation and Dust Transport

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The effects of thermal tides on the zonal mean circulation in the Martian atmosphere is one of the interesting topics. However, past studies on this issue were mainly based on the classical tidal theory, and the effects of mean flow on the thermal tides were not considered. Furthermore, meridional circulation driven by thermal tides may have significant impact on the dust transport. That effect, however, has not been investigated yet. In order to reveal the effects of thermal tides on the meridional circulation and dust transport, we investigate the momentum balance of the zonal mean circulation and the dust transport process using a Mars atmosphere general circulation model.

The Mars atmosphere general circulation model used in this study is a spectral model based on the primitive equation system. The horizontal resolution of the model is T10 and is equivalent to 11.25 deg. (longitude) X 11.25 deg. (latitude). The model has 35 layers in the vertical direction from the ground up to about 120 km altitude. The radiative processes concerning CO2 and dust are considered. The present version of the model includes a dust transport scheme and we can investigate the effects of thermal tides on the dust transport processes. In order to interpret the model result easily, we calculate radiative heating rates assuming a time-independent dust distribution. The assumed dust distribution is uniform in the horizontal direction and is uniform up to about 40 km altitude in the vertical direction. In order to investigate a case of planet-encircling dust storm, the global mean dust optical depth in the visible wavelength is assumed to be 5, and the season imposed in the model is northern winter solstice. Under these conditions, we calculate radiatively passive dust distribution with globally uniform dust flux on the ground.

The meridional circulation calculated by the above mentioned model has a cross-equatorial circulation with upward wind in the southern low and middle latitudes and downward wind in the northern hemisphere. In the southern middle and high latitudes below about 30 km altitude, the other circulation is formed with downward wind in southern high latitude. From the evaluation of zonal momentum balance, we revealed that the circulation in the southern high latitude is driven by the thermal tides.

The calculated distribution of radiatively passive dust shows that the dusts are well mixed up to about 40 km altitude from 60 deg. S to 45 deg. N. This dust distribution is mainly controlled by the balance between the transport due to the zonal mean circulation and the gravitational sedimentation. In the southern hemisphere, the zonal mean circulation driven by the thermal tides plays an important role for the determination of the southward limit of the dust distribution. The dusts in the southern high latitude region are fallen out from the atmosphere due to the downward wind associated with the zonal mean circulation driven by the thermal tides. In addition, zonal mean circulation driven by the thermal tides in the southern high latitude transports dusts from the southern high latitude region into the southern low to middle latitude region. This dust transport process would reduce the dust amount deposited on the southern high latitude region.

Mariner 9 and Viking observation of dust distribution during decay phase of the planet-encircling dust storm showed that the dusts in the high latitude decreased more rapidly than those in the low latitude [Anderson and Leovy, 1978; Martin and Richardson, 1993]. Our results suggest that the zonal mean circulation driven by the thermal tides plays an important role in decreasing the dust at high latitude. Our result also implies that the thermal tides may have an influence on generating the layered terrain in the southern high latitude.