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Microscale simulations of convective adjustment and mixing in the Venus atmosphere

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Heat, momentum and material transport processes caused by convective adjustment and mixing are important in subgrid-scale parameterization of the Venus general circulation model (VGCM). Recently, in order to investigate the thermal and material transport processes near the surface, Yamamoto (2011) conducted microscale atmospheric simulations near the Venusian surface by altering the astronomical and physical parameters in WRF (Weather Research and Forecasting model). When convective adjustment occurs, the heat and passive tracer are rapidly mixed into the upper stable layer with convective penetration. The convective adjustment and mixing produce high eddy diffusion coefficients of heat and passive tracer, which may explain the large eddy diffusion coefficients estimated in radiative-convective equilibrium models (Matsuda and Matsuno 1978; Takagi et al. 2010). In the case that values of surface heat flux Qs is larger than a threshold, the convectively mixed layer with high eddy diffusion coefficients grows with time. In contrast, the mixed layer decays with time in the case of Qs smaller than the threshold. The thermal structure near the surface is controlled not only by radiative processes with extremely long time scales (10,000 Earth days), but also by microscale dynamical processes with short time scales (a few hours). A mixed layer with high eddy diffusion coefficients may be maintained or grow with time in the regions where the surface heat flux is high (e.g., the volcanic hotspot and adjacent areas).

In the present study, I applied the abovementioned microscale atmospheric model of Yamamoto (2011) to dynamical processes in the unstable/neutral layer of the Venusian cloud (50-55 km), and examined the eddy mixing and its effective eddy diffusivity. Maximum magnitudes of eddy fluxes of momentum, heat and passive tracer become larger with increasing the vertical negative gradient of the initial potential temperature (Gamma) and the heat flux at the bottom of the lower cloud (Qb). In the unstable/neutral cloud layer, the eddy diffusion coefficients of 10ˆ3 m2 s-1 are estimated for momentum, heat and passive tracer. In the cases that the vertical shear of the initial zonal wind is changed, although the flux magnitudes are somewhat different from those in the cases of the zero initial shear, the sensitivities to Gamma and Qb are qualitatively similar to those in the cases of the zero initial shear. Such microscale simulations are expected to contribute to physical interpretations of the balloon and radio science experiment data and improvements of the eddy diffusion coefficients in VGCM and chemical and aerosol transport models.

Keywords: Venus, Convective adjustment, Convective mixing, Microscale atmospheric model, Eddy diffusion coefficient