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Wind structures after convective adjustment and in convective mixing near Venus' surface

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Abstract

Venus' near-surface wind structures after convective adjustment and in convective mixing are examined using a microscale WRF model. An inverse S-shaped wind profile is formed after convective adjustment for slow superrotational wind. In this case, the angular momentum is supplied by the subrotational wind (with negative zonal wind velocity) near the surface via the surface friction immediately after the convective adjustment. This mechanism of the momentum supply might be important because of large atmospheric density near Venus' surface. The microscale inverse S-shaped profile and its dynamical influences should be additionally considered in the PBL parameterization for slow superrotational wind near the surface.

1. Introduction

The Venusian surface wind is important in the surface-atmosphere interactions (formation of wind streak pattern and sinks/sources of angular momentum, material and heat). The wind distribution has not been observed over the whole planet, although a few observations showed that the near-surface flows have speeds equal to or less than 1 m/s [1]. In Yamamoto and Takahashi [2], the surface winds with speeds of a few m/s are locally driven around mountains in their GCM, although the wind speed is smaller than 1 m/s for the most part of the surface. In contrast, the lowermost-level winds with high speeds of > 10 m/s are locally seen in Herrnstein and Dowling's GCM [3].

The presences of the near-surface unstable layer and volcanic hot spots are expected to influence the eddy transport processes via convective adjustment and mixing. Recently, Yamamoto [4] conducted microscale simulations of Venus' near-surface convective adjustment and mixing using an idealized WRF model. However, the momentum transport and near-surface wind structure have yet to be investigated in the previous works. Thus, the present work examines the wind near-surface structure of superrotational winds of 0.1 to 10.0 m/s

2. Model

The Weather Research and Forecasting (WRF) community model is applied to an idealized Venus situation. The model setting is the same as Yamamoto's work [4]. The convective adjustments are simulated in case A (A1 to A5). The initial lapse rate of potential temperature (Γ_{LAP}) ranges from 1 to 5 K/km below 2 km in case A, and the surface heat flux (Q_{suf}) is set at zero. The maintenance of convectively mixing layer near the surface is simulated in case B (B1 to B5). Q_{suf} is altered from 0.001 to 0.256 K m/s. Γ_{LAP} is set at 0 K/km in experiments of B1 to B5. The present work considers three initial superrotational winds (U_{INIT}) of 0.1, 1.0 and 10.0 m/s, to investigate the sensitivities to the surface wind magnitude.

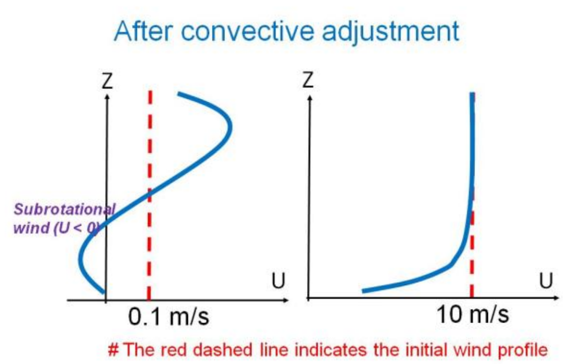

Figure 1: Schematic figures of area-mean zonal wind profiles in the mixed layer after convective adjustment.

3. Results

3.1 Convective adjustment

For fast superrotation (10.0 m/s), the wind speed decreases near the surface via the surface friction and subgrid-scale turbulent viscosity (the right panel of Figure 1). In contrast, an inverse S-shaped wind profile is formed after convective adjustment for slow superrotational wind (0.1 m/s, the left panel of Figure 1). In this case, a subrotational wind is formed near the surface and the momentum is supplied via the surface friction immediately after the convective adjustment.

3.2 Convection by surface heat flux

The wind speed of fast superrotation gradually decreases in the near-surface neutral layer for small Q_{suf} (the left panel in Figure 2). As Q_{suf} is increased, convective mixing smoothes the zonal wind profile in the neutral layer (the right panel in Figure 2). However, these wind structures are not clear in slow superrotation. In the neutral layer with non-trivial surface heat flux, it is difficult to form the subrotational wind near the surface resulting in the momentum supply in microscale thermal convection, because the frequent convective motions mix well the momentum near the surface.

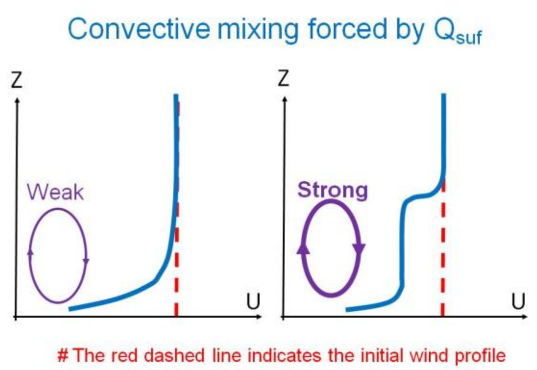

Figure 2: Schematic figures of area-mean zonal wind profiles in the convectively mixing layer induced by the surface heat flux for fast superrotation.

4. Summary

The present work suggests that the inverse S-shaped function of the zonal wind after convective adjustment is considered in the PBL parameterization under the condition that the superrotational wind is weak (U_{INIT} = 0.1 m/s) and the surface heat flux is trivial. In this case, the angular momentum is supplied by the subrotational wind in the lower part of the inverse S-shaped profile after convective adjustment. When convective adjustment intermittently occurs, this mechanism of the momentum supply might be important because of large atmospheric density near Venus' surface, although the wind speed is slow.

When the surface heat flux is high in fast superrotation, the strong wind shears are formed near the top and bottom of the mixing layer via frequent convection. However, the wind structures are not clear in slow superrotation. Differently from the convective adjustment, it is difficult to form the subrotational wind near the surface resulting in the angular momentum supply, because frequent convective motions mix well the momentum near the surface.

References

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