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Momentum and heat transports in a superrotating atmosphere

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The atmospheres of Titan and Venus share in common the phenomenon of the superrotation in which the bulk zonal winds have a larger angular momentum than they would in solid-body rotation. Many studies have shown the effects of the variation in the rotation rate and its impacts in the circulation regime. The general agreement between the authors is that the latitudinal extension of the Hadley cell increases as the rotation decreases, and the baroclinic instability is suppressed under slow-rotating regimes. Although the rotation plays a key role in the resulting general circulation patterns, some numerical models are not able to reproduce a strong equatorial zonal flow (where the Gierasch-Rossow-Williams mechanism is required). In this study, we designed numerical experiments based on scaling arguments in the momentum equation and we found a superrotating state was obtained by changing the planetary radius instead the rotation rate itself. We performed simulations with the Weather Research and Forecast Model (WRF) dynamical core driven by a simple heating function and a linear boundary layer drag. This simple treatment derived from the Held-Suarez benchmark allows us to isolate the main physical processes of the superrotation. Starting from an idealized dry atmosphere at rest with no topography, land-sea distribution, diurnal or seasonal cycles, the simulations were run for 5 years to a steady state. In order to reproduce a complete set of regimes and to show the transition to superrotation the simulations ranged from the actual Earth radius to values sixteen times smaller. We analyze the dynamical regimes are analyzed by showing the transports due to the elements of the general circulation (mean meridional circulation and transients eddies), as well as the differences in the spatial scale of cells and jets. Our analysis provides a general vision of the main patterns of momentum and heat fluxes from an Earth-like to a superrotating regime.