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金星大気 GCM のベンチマーク実験：モデルおよび天文パラメーターに対する感度について
Benchmark experiments for Venus AGCM: sensitivities to model and astronomical parameters

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Benchmark experiments and inter-comparisons of atmospheric general circulation models (AGCMs) have been conducted in the climate and Geophysical Fluid Dynamics (GFD) communities. Recently, the AGCM inter-comparisons are extended to Venus and hot extrasolar planets. The ISSI inter-comparison project of Venus AGCM (Lebonnois et al. 2013) shows that there are large differences among the models under the same Venus-like condition, and some model parameters influence the general circulation structures. At the present stage, in the inter-comparisons project, the wave analyses have yet to be fully conducted. For Venus' atmospheric modeling, we need to investigate sensitivity to model parameter (such as resolution), in order to understand the numerical properties of the AGCM and to confirm the model results. In terms of GFD, sensitivity to astronomical parameter (such as planetary rotation) is interesting in profoundly understanding the dynamics of superrotation in a mimic slowly rotating planet, which is represented by the base simulation in the inter-comparison. By using the widely-used benchmark, we can easily compare with previous models. In the present study, the base simulation of the ISSI project is applied to a MIROC AGCM for checking the validity of the Venus model, and is extend to the sensitivity experiments for model resolution (T21, T42, T63, and T106) and planetary rotation (Venus, Titan, and Earth), in which the general circulations and waves are analyzed. In the Venus case, as the model resolution is increased, the total angular momentum of the whole atmosphere becomes larger, although the cloud-top superrotation weakens. This indicates that the high-resolution contributes to the accumulation of the angular momentum in the lower atmosphere. The eddy momentum and heat fluxes in the lower atmosphere are also sensitive to the horizontal resolution. Associated with the eddy heat flux, the indirect circulation is also influenced by the resolution. In T42 and higher resolution experiments, the high-latitude jet and polar indirect circulation are extended to the lower atmosphere. The lower-atmospheric high-latitude jet induces large equatorward eddy angular momentum fluxes. In this presentation, we discuss the sensitivities to model resolution and planetary rotation, based on the transformed Euler mean and Eliassen-Palm flux analyses, which are useful even for slowly rotating planet with very small Coriolis force (although they are not widely used in atmospheric researches of Venus).