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Atmospheric general circulation on Venus simulated by AFES (Atmospheric GCM For the Earth Simulator)

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Abstract

An atmospheric general circulation model (AGCM) for Venus is being developed using AFES [4] (Atmospheric general circulation model For the Earth Simulator). AFES is highly optimized for the Earth simulator, one of the largest vector super-computers, and enables us to study the planetary atmospheric dynamics with high resolution. In order to reexamine the generation mechanisms of the superrotation so far proposed, the physical processes are being changed for the Venus atmosphere. Results of parameter survey will be presented in the meeting.

1. Introduction

The superrotation of the atmosphere on Venus is one of the most interesting topics in the planetary science. Although several hypotheses have been proposed to explain this special phenomenon, the generation mechanism of the superrotation remains unsolved.

In order to study the atmospheric general circulation on Venus, many numerical studies using Venus-like atmospheric general circulation model (GCM) have been carried out in recent years. The results suggest that both the thermal tide mechanism and the Gierasch mechanism can work to generate the superrotation. However, these models have only coarse resolutions. It is unclear the previous results could hold in the case of high resolution simulation. Moreover, the parameter studies, such as resolution, horizontal and vertical eddy viscosity, topography, solar heating, and radiative processes, are not sufficient, while it is quite common to investigate how numerical models depend on these parameters in geophysical fluid dynamics on Earth.

AFES [4] is Atmospheric general circulation model For the Earth Simulator. AFES is highly optimized for the Earth simulator, which is one of the world's largest vector super-computers provided by Japan Agency for Marine-Earth Science and Technology (JAMSTEC). Many studies have been carried out in the terrestrial atmospheric science by using AFES. AFES has been also extended to the Mars atmosphere [2]. In the present study, we develop AGCM for Venus by modifying AFES, and achieve extremely high resolution numerical simulation for the Venus atmosphere.

The main objectives of this study are as follows. We modify AFES in order to simulate the Venus atmospheric dynamics with high resolution, and reexamine the previous works by the parameter survey. As a first step, we check the mechanism of the effects of thermal tides (Takagi and Matsuda [6]). The important parameters are horizontal resolution, horizontal and vertical eddy viscosity, and Newtonian cooling, and distribution of the solar heating. Sequentially, we also verify Gierasch mechanism by introducing more realistic physical processes. Our final goal is to understand the fundamental mechanism of the superrotation.

2. Model description

A full nonlinear dynamical model on the sphere is constructed for the atmosphere on Venus. The basic equations are primitive ones in sigma coordinates on the sphere. Values of physical parameters are chosen for Venus. Physical processes for the Earth atmosphere have been replaced by simplified version for the Venus atmosphere. Experimental settings are basically based on Takagi and Matsuda [6].

The resolution is now T21L50 as a preparation for high resolution simulations, and will be extended to T42 and T63. Vertical domain extends from the ground to about 100 km with almost the constant grid spacing of 2 km. The model includes vertical and horizontal diffusion. Horizontal eddy viscosity is represented by the second-order hyperviscosity. Unlike the many previous studies, Rayleigh friction (or sponge layer) is not used in the present model except at the lowest level, where the surface friction acts on horizontal winds. In addition, the dry convective adjustment scheme is used to restore the temperature lapse rate to the neutral one when an atmospheric layer becomes statically unstable.

The solar heating is prescribed in the present study. The vertical profile is based on the works of Tomasko et al. [7] and Crisp [1]. Vertical distribution of the specific heat at constant pressure is taken from the Venus international reference atmosphere (VIRA) data (Seiff et al. [5]).

The radiative forcing in the infrared region is simplified by Newtonian cooling. The coefficients are based on Crisp [1]. The temperature field is relaxed to the prescribed horizontally uniform temperature field, which is taken from the VIRA data. The thermal relaxation to a horizontally uniform temperature field is consistent with the exclusion of the mean zonal component of solar heating.

The initial state for time integration is an atmosphere at rest. We do not assume the background atmospheric superrotation and the meridional gradient of temperature at all throughout the present study.

3. Preliminary result

First, we have checked the dynamical core of our model by the method written in Held and Suarez [3]. Mean zonal jets and temperature distributions reproduced by the present model are very similar to those of Held and Suarez. Next, we perform numerical simulation for the atmosphere on Venus. The thermal tide mechanism will be reexamined by the high resolution model. But unfortunately it has not been carried out due to the lack of computational time. We also plan to perform parameter sweep experiments with high resolution AFES. It was reported in Takagi and Matsuda [6] that Newtonian cooling influences the magnitude of the superrotation rather than vertical eddy viscosity. We also plan to investigate the dependence of the height of cloud layer, as well as those of the resolution of the numerical model in future.

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