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Venusian general circulation model and its data assimilation system

Norihiko Sugimoto[1*], Y. Fujisawa[1], N. Komori[1], H. Ando[2], M. Takagi[2], H. Kashimura[3], Y. Matsuda[4], AFES-Venus & ALEDAS-V team
[1] Keio University, [2] Kyoto Sangyo University, [3] Kobe University, [4] Tokyo Gakugei University
e-mail (speaker): nori@a2.keio.jp

Introduction

We have developed Venusian general circulation model (GCM) named AFES-Venus (Atmospheric GCM for the Earth Simulator for Venus). Furthermore, in order to make use of observations by the Venus Climate Orbiter "Akatsuki", we have also developed the data assimilation system based on the Local Ensemble Transform Kalman Filter (LETKF) named ALEDAS-V (AFES-LETKF data assimilation system for Venus) for the first time in the world. Here, we will present our important recent results of AFES-Venus and ALEDAS-V. In addition, we have produced first object analysis with Akatsuki horizontal winds assimilation and will release our dataset.

AFES-Venus

AFES-Venus is a full nonlinear Venus GCM assuming hydrostatic balance with simplified physical processes [1]. The basic resolution is set to T42L60 (128 times 64 horizontal grids and 60 vertical levels). The vertical domain extends from the flat ground to ~120 km without topography. The infrared radiative process is simplified by a Newtonian cooling scheme and the temperature is relaxed to a prescribed horizontally uniform temperature field based on VIRA. Other details of the model settings are described in our previous works [1, 2].

The initial state of the horizontal flow is an idealized super rotation in solid-body rotation to save computational cost. The zonal wind increases linearly with height from the ground to 70 km. Temperature field is in gradient wind balance with the zonal wind. We perform numerical time integrations for about 4 Earth years.

AFES-Venus reproduced cold collar in the polar region [3] and planetary-scale streak structure observed by Akatsuki infrared camera [4] (Fig.1). A fully developed super-rotation from the motionless state [5] and spontaneous gravity wave radiation from thermal tides [6] are also obtained for the first time. Recently, by improving the profiles of static stability and solar heating, thermal tides [7] and planetary-scale short periods Kelvin and Rossby waves [8, 9] consistent with observations are reproduced.

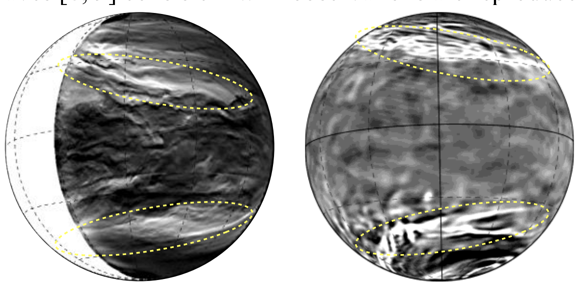

Figure 1. Planetary-scale streak structure: Akatsuki IR2 image (left) and AFES-Venus result (right).

ALEDAS-V

In data assimilation schemes, an improved estimate (called analysis) is derived by combining observations and short time forecasts. ALEDAS-V uses an ensemble of AFES-Venus runs to characterize uncertainty of the model forecast. Then, the LETKF seeks the analysis solution with minimum error variance. Quasi-equilibrium data of AFES-Venus sampled at 8-hour intervals are for initial conditions of each member of the ensemble. Details of the ALEDAS-V are described in [10].

By ALEDAS-V, thermal tides are improved with the Venus Express horizontal winds test assimilation [11]. Akatsuki horizontal winds derived by cloud tracking of ultra-violet images are also assimilated. Then, the phases of thermal tides are improved to be consistent with recent radio occultation measurements (Fig.2). Zonal mean zonal winds and temperature are also modified globally [12] and cold collar is improved also [13]. We will release those objective analysis. Finally, we have conducted several observing system simulation experiments for future Venus exploring missions [14,15] and investigated disturbances using breeding method [16].

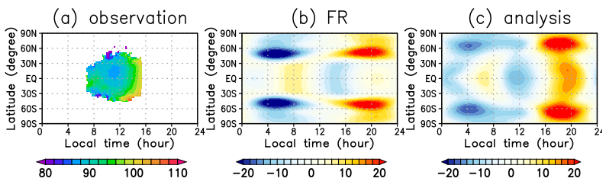

Figure 2. Thermal tides at the cloud-top (~70 km) level: (a) observation, (b) free run forecast and (c) analysis.

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