EPSC Abstracts
Vol. 13, EPSC-DPS2019-45-3, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Impact of data assimilation on thermal tides in the case of Venus Express wind observation

Norihiko Sugimoto (1), Toru Kouyama (2) and Masahiro Takagi (3)
(1) Keio University, Yokohama, (nori@phys-h.keio.ac.jp), (2) AIST, Tsukuba, (3) Kyoto Sangyo University, Kyoto, Japan.

Abstract

Impacts of horizontal winds assimilation on thermal tides are investigated by using the Venus atmospheric general circulation model local ensemble transform Kalman filter data assimilation system. The assimilated data are horizontal winds derived from Venus ultraviolet images taken by the Venus Monitoring Camera onboard the Venus Express. The results show that three-dimensional structures of the thermal tides are significantly improved not only in the horizontal winds but also in the temperature field, even though the observations are quite limited. The reproduced temperature fields agree well with recent radio occultation measurements of the Venus Climate Orbiter Akatsuki. The zonal mean fields of the zonal wind and temperature are also improved globally.

1. Introduction

Thermal tides are planetary scale atmospheric waves excited by the solar heating. They are considered to have important roles on the Venus atmosphere. While there are several Venus general circulation model (GCM) studies in which the thermal tides are taken into account, the structure of the thermal tides was not fully investigated nor compared with observations. Recently, we have developed a Venus GCM named AFES-Venus [1] on the basis of AFES (an atmospheric GCM for the Earth Simulator). AFES-Venus has enabled us to reproduce the realistic super rotation, planetary scale waves [2], cold collar [3], and planetary scale streak features [4]. We also investigated the thermal tides [5], but they were not consistent with equatorial thermal structures obtained by radio occultation measurements of Venus Express and Akatsuki [6].

Recently, we have developed a Venus AFES local ensemble transform Kalman filter (LETKF) data assimilations system named VALEDAS. The system has been tested for AFES-Venus simulations excluding the thermal tides [7]. The result shows that the data assimilation works well but its impact is quite limited in the case of daily observation data. In the present study, we proceed to horizontal winds assimilation using AFES-Venus simulations including the thermal tides in order to investigate the impact of the data assimilation on the thermal tides and the general circulation [8].

2. VAFES-LETKF system

VAFES is a full nonlinear Venus GCM with simplified physical processes [1]. The 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. 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 is assumed to be an idealized superrotating flow in solid-body rotation. The zonal wind increases linearly with height from the ground to 70 km. We perform numerical time integrations for about 4 Earth years. Quasi-equilibrium data sampled at 8-hour intervals are for initial conditions of each member of the ensemble.

In data assimilation schemes, an improved estimate (called analysis) is derived by combining observations and short time forecasts. The LETKF [9] seeks the analysis solution with minimum error variance. Using an ensemble of VAFES runs, uncertainty of the model forecast is characterized. Details of the VALEDAS are described in [7].

The observational data used in the present study is horizontal winds at approximately 70 km derived by the cloud tracking of ultraviolet images taken by the Venus Monitoring Camera onboard the Venus Express [10]. Horizontal winds are available approximately once a Earth day only on a dayside region approximately from 60°S to 30°N between 07:00 local time (LT) and 17:00 LT. We have 73 observations for the data assimilation in VALEDAS during a period of about 3 months from 28 January 2008 to 26 April 2008 (Epoch 4). The assimilated data obtained in the last 30 Earth days are analysed.

3. Results

Figure 1 shows the zonal wind and temperature deviations associated with the thermal tides reproduced by AFES-Venus (top panels) and VALEDAS (bottom panels) in a longitude–height section at the equator. These distributions are calculated by the composite means over 30 Earth days at the sub-solar point (fixed at the center of each panel. The phase distributions are changed at 65–75 km levels both for the zonal wind and temperature deviations, although the horizontal winds are assimilated only at the cloud top (~70 km)

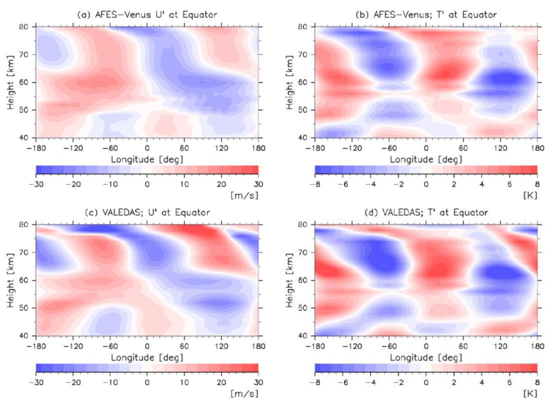

Figure 1: Vertical distributions of (a, c) zonal wind and (b, d) temperature deviations associated with the thermal tides at the equator reproduced in AFES-Venus (top panels) and VALEDAS (bottom panels).

4. Summary and Conclusions

In the present study, we investigated impacts of the data assimilation of horizontal winds on the thermal tides and the general circulation by using the data assimilation system named VALEDAS. The thermal tides obtained in AFES-Venus are inconsistent with observations in terms of phase distributions at the cloud top level. This inconsistency was successfully resolved by the data assimilation, though the observed horizontal winds were available only at the cloud top on the dayside on the southern hemisphere approximately once an Earth day. Furthermore, the zonal mean zonal wind and temperature fields were also improved significantly.

Acknowledgements

This study was conducted under the joint research project of the Earth Simulator Center entitled 'Simulations of Atmospheric General Circulations of Earth-like Planets by AFES.'

References

[1] Sugimoto, N. et al.: Baroclinic instability in the Venus atmosphere simulated by GCM, J. Geophys. Res., Planets, 119, 1950–1968, 2014.

[2] Sugimoto, N. et al.: Waves in a Venus general circulation model, Geophys. Res. Lett., 41, 7461–7467, 2014.

[3] Ando, H. et al.: The puzzling Venusian polar atmospheric structure reproduced by a general circulation model, Nat. Commun., 7, 10398, 2016.

[4] Kashimura, H. et al.: Planetary-scale streak structure reproduced in high-resolution simulations of the Venus atmosphere with a low-stability layer, Nat. Commun., 10, 23, 2019.

[5] Takagi, M. et al.: Three dimensional structures of thermal tides simulated by a Venus GCM, J. Geophys. Res., Planets, 123, 335–352, 2018.

[6] Ando, H. et al.: Vertical structure of the axi-asymmetric temperature disturbance in the Venusian polar atmosphere: Comparison between radio occultation measurements and GCM results, J. Geophys. Res., Planets, 122, 1687–1703, 2017.

[7] Sugimoto, N. et al.: Development of an ensemble Kalman filter data assimilation system for the Venusian atmosphere, Scientific Rep., 7, 9321, 2017.

[8] Sugimoto, N. et al.: Impact of data assimilation on thermal tides in the case of Venus Express wind observation, Geophys. Res. Lett., 46, 10.1029/2019GL082700, 2019.

[9] Miyoshi, T. and S. Yamane: Local ensemble transform Kalman filtering with an AGCM at a T159/L48 resolution. Mon. Wea. Rev. 135, 3841–3861, 2007.

[10] Kouyama, T. et al.: Long-term variation in the cloud-tracked zonal velocities at the cloud top of Venus deduced from Venus Express VMC images. J. Geophys. Res., 118, 37–46, 2013.