EPSC Abstracts
Vol. 14, EPSC2020-34, 2020, updated on 20 May 2022
https://doi.org/10.5194/epsc2020-34
Europlanet Science Congress 2020

Observing system simulation experiment for radio occultation among small satellites introducing real orbits of the Venus atmosphere

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Abstract

Feasibility of radio occultation measurement (RO) among small satellites is investigated by observing system simulation experiment (OSSE) of the Venus data assimilation system in two test cases introducing real orbits. One observes cold collar in polar region. The other observes thermal tides in equatorial region. The reproducibility of the cold collar or thermal tides is investigated by several types of orbits. Results suggests that the cold collar is successfully reproduced with two or three satellites. In addition, zonal wind can be improved by temperature assimilation of the thermal tides with two satellites. Therefore, RO among small satellites would be promising to reproduce global phenomena in the Venus atmosphere.

1. Introduction

Venus atmosphere has a global, thick cloud cover at about 48–70 km altitude. Therefore, it is very difficult to observe under the cloud by the images. One of the most useful methods to obtain vertical temperature profiles is RO. For Earth, daily observations have been performed by GNSS (Global Navigation Satellite System). However, Venus has been observed only between one satellite, e.g., Venus Express or Akatsuki [1], and Earth. For multiple satellites, by transmitting and receiving radio waves between them, more observations, multiple points and better time resolution, could be obtained. In the previous study, we have shown that RO among small satellites can reproduce the cold collar with fixed observational points [2]. In order to check feasibility, however, we have to consider realistic orbits of flying multiple satellites around Venus.

So far, we have developed Venus atmospheric general circulation model (AGCM) named AFES-Venus (AGCM for the Earth Simulator for Venus) [3]. Recently, using the local ensemble transform Kalman

filter (LETKF) [4], we have succeeded in developing the AFES LETKF data assimilation system for Venus (ALEDAS-V) [5]. In this study, we performed OSSE assuming RO among small satellites in two test cases with real orbits targeting the cold collar and thermal tides.

2. Experimental setting

AFES-Venus solves dry 3-D Primitive equation on sphere. The physical parameters are based on Venus. The latitude-longitude grids (128 times 64) with 60 vertical layers are used. The simulation starts from idealized super rotation and spin up for 4 Earth years. Reproduced zonal wind is in good agreement with observations [6]. ALEDAS-V uses the LETKF [4] to produce an improved estimate (called analysis) by combining observations and short time ensemble forecasts of AFES-Venus. The number of ensemble members is 31. Assimilation cycle is 6 hourly interval. Observational errors and inflation are set to 3.0 K and 10%, respectively. Details are described in [2, 5].

Two experiments are conducted; one is evaluated by the cold collar (experiment 1), and the other is evaluated by the thermal tides (experiment 2). Idealized temperature observations at 40-90 km are prepared by the GCMs assuming RO among small satellites. Experiment 1 uses data from IPSL VGCM because the cold collar is more realistically reproduced [7]. Note that temperature bias between IPSL VGCM and AFES-Venus is corrected. Experiment 2 uses data from AFES-Venus itself but experimental settings are different. Observation points are based on real orbits; Experiment 1 covers polar region and experiment 2 does equatorial region. They are assimilated to AFES-Venus by ALEDAS-V and results are compared with frf (free run forecast). The reproducibility of the cold collar or thermal tides is investigated by several orbits.

3. Results

Figure 1 shows the temperature distributions at 30-90°N at ~66 km in experiment 1. Four situations are considered: (a) frf and (b,c,d) has different orbits. p1, p2 and p3 indicate each pair of satellites. Cold collar is most clearly reproduced for (d) in which all 3 satellites proceed RO.

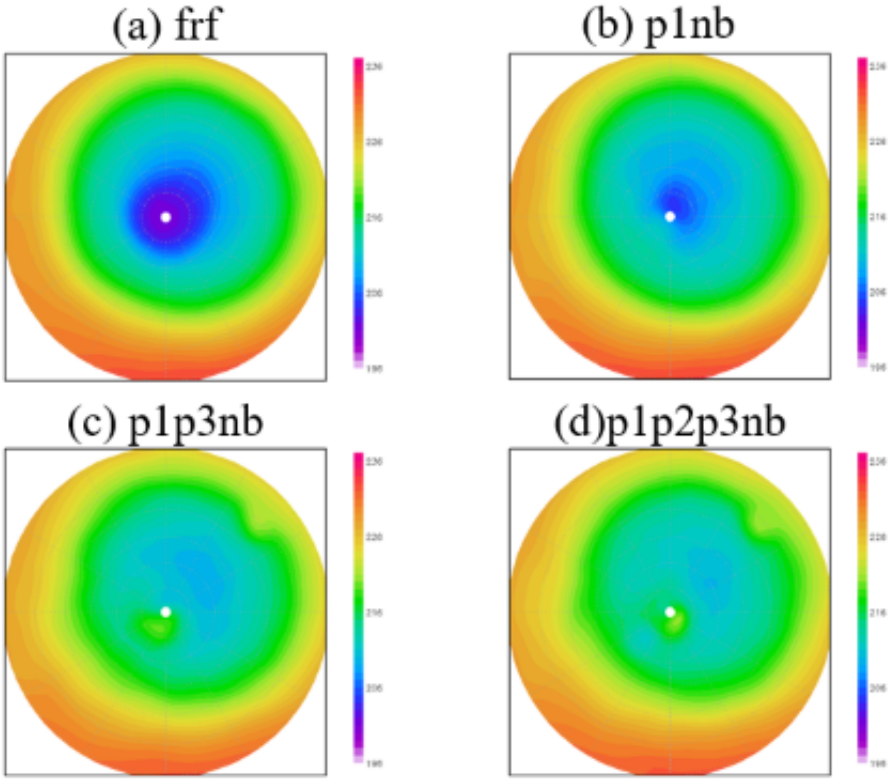

Figure 1: Temperature distributions at ~66 km (at 30-90°N seen from the north pole): (a) frf, (b) 1

pair of satellites (p1), (c) 2 pairs (p1 and p3), and (d) 3 pairs (p1, p2 and p3).

Figure 2 shows latitude-height cross sections of zonal wind (contour) and difference of zonal wind between frf and the Qt8 cases (color) in which the solar heating is reduced to 80% compared with that used in frf. The 4 types of orbits are considered. The zonal wind above the cloud top (~80 km) is significantly decelerated in (d). It is suggested that temperature observations of the thermal tides can improve zonal wind.

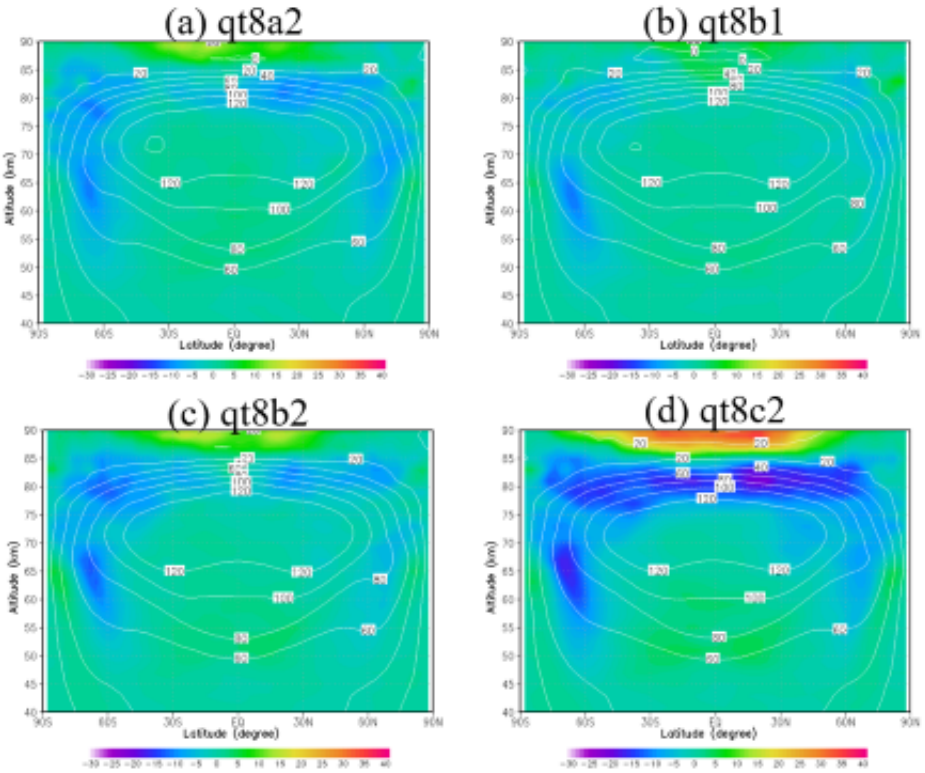

Figure 2: Latitude-height cross sections of zonal wind (contour) and difference of zonal wind between frf and the Qt8 cases (color). 4 types of orbits are shown: a2 (a), b1 (b), b2 (c), and c2 (d). c2 has most observations, following b2, b1 and a2.

Summary and Conclusions

In the present study, we have checked feasibility of the Venus future mission of RO among small satellites by introducing real orbits. In experiment 1, the cold collar is reproduced with 2 or 3 satellites observing polar region. In experiment 2, zonal wind is improved by the temperature observations of the thermal tides in equatorial region. Results suggest that RO with two or three small satellites would be promising to reproduce global phenomena. Furthermore, it is also suggested that this kind of observing system simulation experiment would be very useful to design future missions.

Acknowledgements

This study and supported by the Japan Science and Technology Agency (JST).

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