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Initial results of the radio occultation experiment in the Venus orbiter mission Akatsuki

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Abstract

Akatsuki radio occultation observation of the Venusian atmosphere has started in March 2016. Temperature profiles were obtained down to 38 km altitude and show distinct atmospheric structures depending on the altitude. The overall structure is close to the previous observations, suggesting a remarkable stability of the thermal structure. The H_2SO_4 vapor profiles suggest condensation above ~47 km altitude. The ionospheric electron density profiles are also retrieved, showing a distinct day-night contrast.

1. Introduction

Radio occultation measurement in the Venus orbiter mission Akatsuki, termed RS (Radio Science), aims at exploration of the vertical structure of the Venusian atmosphere [1]. The main goal of Akatsuki is to understand the mechanisms driving the atmospheric circulation and maintaining the cloud layer [2]. For this purpose, five cameras onboard take images of Venus at different wavelengths to observe the distributions of clouds and minor constituents at different heights. RS is complementary to those imaging observations: radio occultation can precisely determine the vertical structure of the atmosphere, while cameras map the horizontal structure.

2. Observations

One-way downlink at X-band is used in the experiment. Akatsuki is equipped with an ultra-stable oscillator as the onboard frequency source. The primary ground station used so far is the 64-m antenna of Usuda Deep Space Center (UDSC) of JAXA. In addition to UDSC, for increasing the number of observation opportunities, we started to use the 32-m antenna of Indian Deep Space Network (IDSN) of Indian Space Research Organization (ISRO) in 2017. The received signals are down-converted to several hundred kHz by an open-loop heterodyne system and 8-bits digitized.

The orbit around Venus is a 10.5 day-period elliptical orbit near the equator. The apoapsis altitude is ~360,000 km, or 59 Venus radii, and the periapsis altitude is variable in the range 1000-8000 km. Thanks to the near-equatorial orbit, Akatsuki RS mainly probes the low and middle latitude regions in contrast to the previous radio occultation experiments using polar orbiters. The first observation was conducted on March 3, 2016, and 10 occultation experiments, including 10 ingress (entry) and 9 egress (exit) measurements, have been conducted by April 2017.

3. Atmospheric profiles

The temperature profiles obtained at latitudes < 65° by February 2016 using UDSC are shown in Figures 2. They are close to VIRA [4], suggesting a remarkable stability of the Venusian atmosphere over decades. The profiles clearly show differences in the stratification characteristics among the altitude regions. Almost constant lapse rate of ~10 K/km, which is close to the adiabatic lapse rate, is observed in the middle and lower cloud region (50-58 km); this region is considered as a convective layer driven by the heating of the cloud base by the thermal infrared flux from below. The region below the cloud (< 50 km) is weakly stable. The region above 58 km is also stable, and is dominated by short-vertical scale fluctuations, being consistent with the previous observations [5].

Figure 2 shows an example of the H_2SO_4 vapor profile obtained from the intensity time series. About 50% of supersaturation is seen around 46-48 km altitudes. At higher altitudes the vapor profile roughly follows the saturation pressure, suggesting equilibrium with the condensed cloud particles.

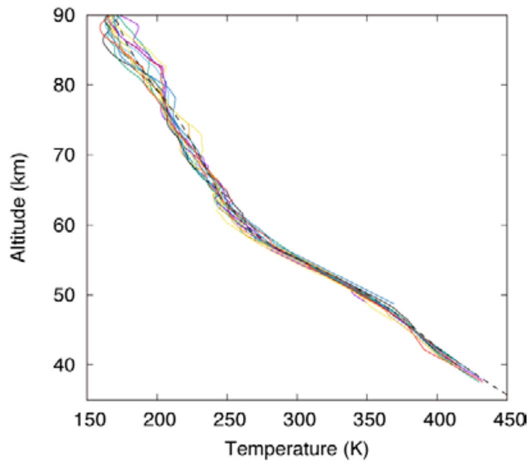

Figure 1: Temperature profiles obtained by the radio occultation experiments. The VIRA temperature profile for the low latitude (< 30°) is also plotted by a dashed curve for comparison [4].

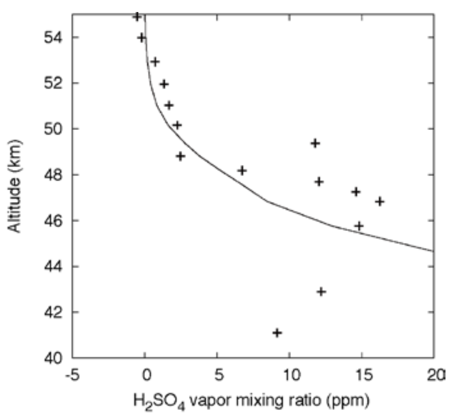

Figure 2: An example of the H_2SO_4 vapor mixing ratio profile obtained from the ingress occultation at 10°N conducted on May 6, 2016 (crosses). The mixing ratios corresponding to the saturation vapor pressure for the observed temperature are also plotted for comparison (solid).

Figure 3 shows examples of the ionospheric electron density profile in an illuminated region and an unilluminated region. The peak electron density of ~3 x 10^5 cm^{-3} and the peak altitude of ~140 km in the illuminated region are typical of the dayside ionosphere [3]. Above 200 km altitude in the illuminated region, the electron density gradually decreases with height and merges into the background noise floor. The electron density in the unilluminated region is marginally detectable at 100-400 km altitudes.

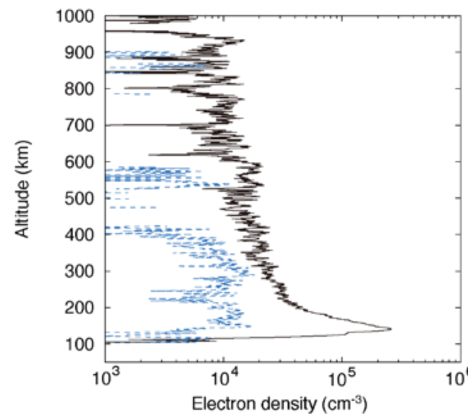

Figure 3: Electron density profiles obtained from the ingress occultation (solid) that sampled an illuminate region (SZA = 78°) and the egress occultation (blue dashed) that sampled an unilluminated region (SZA = 102°) conducted on May 6, 2016.

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