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Venus upper atmospheric dynamics inferred from the Doppler-shift observations of submm CO line: Comparison with GCM experiments

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Abstract

Atmospheric dynamics of Venus middle and upper atmosphere is still not fully understood. In early days, the atmospheric circulation at the altitude of ~95–110 km was considered as a combination of two globally uniform circulations: super-rotating retrograde zonal flow and subsolar-to-antisolar flow. However, recent observations have pointed out the presence of further complicated spatial variation of the wind field at the middle and upper atmosphere of Venus. In this study, we summarize the recent observations of Venus submm CO lines, which Doppler-shifted line frequency provides the information about the atmospheric dynamics of the interested altitudes, and compare them with numerical simulations using a Venus atmospheric general circulation model.

1. Introduction

Atmospheric dynamics of Venus middle and upper atmosphere (altitude region of ~70–110 km) is often discussed with two different kinds of circulation regime. One is the super-rotating retrograde zonal flow (RZ) which is well known as the global circulation in the lower atmosphere. Another one is the subsolar-to-antisolar flow (SSAS) that is a wind blowing from the dayside to nightside due to the strong thermal gradient in the thermosphere.

Several remote-sensing techniques have been applied for studying the atmospheric circulations in this middle and upper atmosphere (Lellouch et al., 1997). One is the application of the cyclostrophic-wind equation to the thermal structures obtained by infrared spectrometers (e.g., Piccialli et al., 2008). This method always postulates the validity of the cyclostrophic approximation, which becomes less appropriate at the equatorial region. Another approach is the Doppler-shift measurements of CO absorption lines at the millimeter and submillimeter wavelength using a very high frequency resolution heterodyne instrument ($\lambda/\Delta\lambda$ of ~10^7) (e.g., Lellouch, et al. 2008; Clancy, et al. 2012; Moullet, et al. 2012). This technique enables us to measure the line-of-sight velocity of wind (hereafter denoted as Doppler-wind) at ~95–110 km altitude. Most of the early observations of Doppler-winds made an attempt to describe the atmospheric circulation with a linear combination of globally uniform RZ and SSAS flows. However, the observed Doppler-winds, particularly the spatially-resolved Doppler-wind maps obtained by interferometers, cannot be sufficiently explained by such a simple combination of the two circulation regimes [**Figure 1 (a, b, c)**].

A new interpretation was proposed by Hoshino et al. (2012; 2013) based on a theoretical study using their newly developed Venus atmospheric general circulation model. Their model includes the momentum transport by gravity waves, and has shown the qualitative representation of one of the previously measured Doppler-wind maps [**Figure 2**].

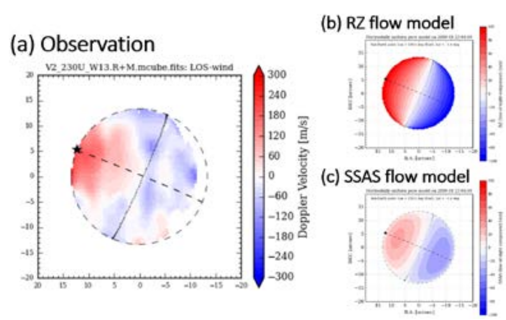

Figure 1: Doppler-wind map of Venus. (a) Observed result obtained from CO (J = 2–1) using the SMA interferometer. Blue color represents the blue-shift i.e. winds blowing toward the observer, while the red color is the red-shift. The point marked with a star symbol is the antisolar point (midnight), and the central

meridional line is the day-night terminator, thus the left-side of the apparent disk is the nightside, and the right-side is the dayside. (b) Theoretical Doppler-wind map of a globally uniform RZ flow. (c) Theoretical Doppler-wind map of a globally uniform SSAS flow. **Note that neither of (b) and (c) can explain the observed blue-shift in the nightside.**

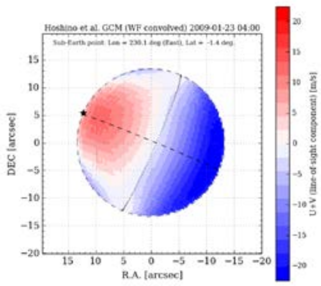

Figure 2: Theoretical Doppler-wind map calculated with the GCM developed by Hoshino et al. (2013). The blue-shit is shown in the nightside, which agrees with the observed result shown in Figure 1(a).

2. Aim of this study

The aim of this study is to expand the comparison between the previously observed Doppler-wind maps (including both single-dish and interferometric observations) with those calculated with the GCM of Hoshino et al. (2013). We collect the observational results from all available past literatures and also our own recent observations. In fact, the observation data provide a wide coverage of the solar phase angles. The detail comparison between the GCM numerical experiments will be discussed in the presentation.

References

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