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Long-term Variation of Temperature and Dynamic at the Morning Terminator in Venus Upper Atmosphere from Ground-Based Infrared Heterodyne Spectroscopy

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Abstract

We report on temperatures and wind velocities at the morning terminator in the Venusian upper mesosphere/lower thermosphere, deduced from analyzing very high resolution infrared spectroscopic data of CO_2 emission lines acquired between 1990 and 2013.

1. Introduction

The dynamics of the transition zone between the region dominated by sub-solar to anti-solar (SS-AS) flow above 120 km and the superrotation dominated region below 90 km is not yet fully understood. Temperatures in the same region are not very well constrained either. Measurements are essential to gain a global understanding of the atmosphere and to validate global circulation models. Space based observations can only partially provide temperatures and do not offer direct wind measurements at these altitudes [1,2,3 & 4]. Ground-based results still lack in time coverage and spatial resolution. Hence measurements on various time scales and different locations with sufficient spatial resolution on the planet are important. Such observations are carried out with the infrared heterodyne spectrometers THIS from University of Cologne, HIPWAC and IRHS from NASA Goddard space flight center.

2. Instrument and Technique

Infrared heterodyne spectrometers provide a high spectral resolution (R>10^7). In addition compared to mm and sub-mm observations a high spatial resolution on the planet is guaranteed. The Instruments can be operated between 7 and 13 μm [5]. Temperatures and winds in planetary atmospheres are retrieved from detection of narrow non-LTE emission lines of CO_2 at 10 μm. These emission lines are induced by solar radiation and occur only in a narrow pressure/altitude region around 110km [6]. Resolving this single molecular feature allows retrieval of temperatures and wind velocities. Wind velocities can be determined from the Doppler-shifts of the emission lines with a precision of 10m/s. Temperatures with a precision up to 5K can be calculated from the Doppler-width of the emission lines.

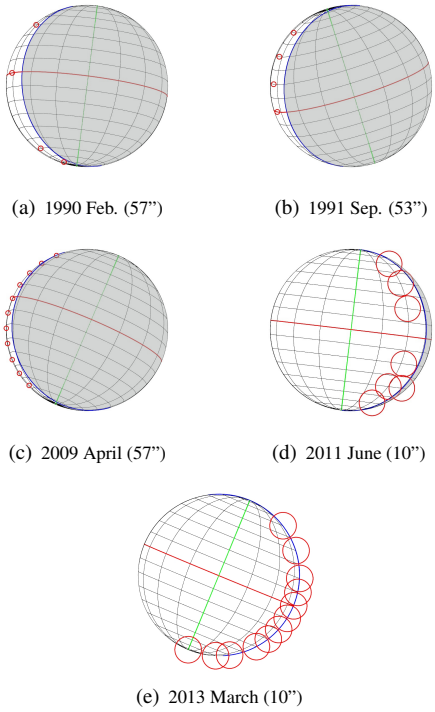
3. Observations and Results

During the last decades several observing runs were dedicated to collect day-side information from the Venusian upper atmosphere. These observing runs delivered comprehensive data sets to investigate long term temporal variability. In this presentation we will focus on mesurements at or close to the morning terminator (Figure 1). Table 1 gives an overview of relavant observational conditions of the different campaigns. In all cases the distance from the terminator is smaller than 2h.

Table 1: Overview of gathered data

date	illu.[%]	size["]	Fov ["]	data[1]
1990 Feb.	11	53	0.9	W,T
1991 Sept.	8	53	0.9	W,T
2009 April	3	60	1.6	W,T
2011 June	96	10	1.6	W,T
2013 March	100	10	1.6	W,T

[1] W: wind data received, T: temperature data received



(a) 1990 Feb. (57")

(b) 1991 Sep. (53")

(c) 2009 April (57")

(d) 2011 June (10")

(e) 2013 March (10")

Figure 1: Observing geometries for campaigns at and close to the MORNING TERMINATOR of Venus. Equator (red), Terminator (blue) and the Central Meridian Longitude (green) are indicated. Each observing geometry includes a red circle indicating the relative size of the telescope beam on the planet. The number behind the date gives the apparent diameter of Venus in arcseconds.

As an example Figure 2 shows the temperatures at the morning terminator of all campaigns. Temperatures in the range of 150-240 K are observed. We will present in detail the long-term behavior of the temperatures and give a comparison to temperatures at the evening terminator. In addition the line-of-sight wind velocities were investigated. For comparison of different observing geometries it is necessary to correct the measurements to the extended beam on the planet. Here we also present a detailed study of the long-term behavior of this extended beam corrected wind values. Furthermore we will also compare the wind values of the morning termintor to the evening terminator.

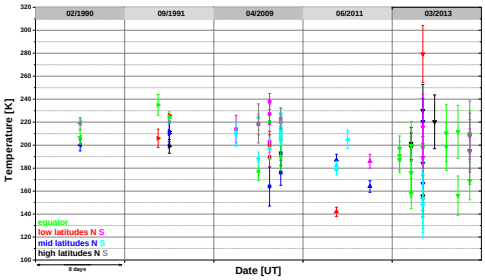


Figure 2: Temperatures at the morning terminator from different observations between 1990 and 2013

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