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Water, halides and carbon monoxide in the Venus upper atmosphere

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Abstract

SOIR (Solar Occultation in the IR) instrument allows observations of trace gases in the Venus mesosphere and lower thermosphere, at the terminator for both the morning and evening sides of the planet and for almost all latitudes. We have analysed data obtained over the previous seven years of operation and present up to date results for water vapour, halides and CO.

1. The SOIR instrument

The SOIR instrument has been designed to measure spectra in the IR region (2.2 – 4.3 µm) of the Venus atmosphere using the solar occultation technique [1]. This method derives unique information on the vertical composition and structure of the mesosphere and lower thermosphere [2-5]. SOIR is an extension mounted on top of the SPICAV instrument [6]. SPICAV/SOIR is one of the seven instruments on board Venus Express, a planetary mission of the European Space Agency (ESA) that was launched in November 2005 and inserted into orbit around Venus in April 2006 [7].
SOIR is an Echelle grating spectrometer operating in the IR, combined with an acousto-optic tunable filter (AOTF) for the selection of the recorded wavenumber interval [1, 8]. The wavenumber range covered by the instrument extends from 2250 to 4370 cm^{-1} (2.2 – 4.3 µm) and is divided into 94 diffraction orders (from 101 to 194). The definition and limits of these diffraction orders are given in [10]. The bandwidth of the AOTF was originally designed to be 20 cm^{-1}, as measured on ground before launch [1], to allow light from only one order into the spectrometer. However, the measured bandwidth of SOIR is ~24 cm^{-1}, creating some order leakage on the detector. The AOTF transfer function has subsequently been determined and shown to provide good fits to the data [9].
SOIR measurements all occur at the Venus terminator, morning and evening sides, covering almost all latitudes from the North Pole to the South Pole. The vertical resolution is between 100 and 500 m in the Northern hemisphere, and is poorer at southern latitudes (between 1 and 2.5 km). The typical vertical extent of the profiles ranges from 70 to 120 km (for CO_2 from 70 to 170 km), encompassing thus the mesosphere and the lower thermosphere of the planet. The SOIR instrument is unique in terms of spectral coverage and spectral resolution (0.15 cm^{-1}), and is ideally designed to probe the Venus atmosphere for CO_2 as well as trace gases, such as H_2O, CO, HCl and HF.

2. Water Vapour

Water vapour in the Venus mesosphere is involved in the cloud formation process and contributes to the runaway greenhouse effect. Understanding water vapour abundance, distribution and variability is therefore important to Venus climate and dynamical modelling. In most occultations dedicated to water vapour, both isotopologues, H_2O and HDO, are targeted simultaneously. The SOIR instrument detects H_2O between approximate altitudes of 70 – 110km and HDO between 70 – 95 km. Preliminary H_2O and HDO observations from SOIR data were published in 2007 [6] and 2008 [2]. Previous results show a depletion in the volume mixing ratio (VMR) at 85 km in both HDO and H_2O and an increase in HDO/H_2O ratio above the clouds. No noticeable temporal variability was detected. Numerous subsequent H_2O and HDO SOIR observations have been obtained between 2007 – 2014 and with recent improvements in instrument calibration, data reduction [10] and a longer base line of data, a new analysis has become pertinent.

3. Halides

Densities and volume mixing ratios of HCl and HF are measured in the 65 to 125 km and 65 to 105 km altitude region respectively. We study the latitude and long-term variations of the VMR of both species, from June 2006 to June 2013. Large variations in the VMR profiles are observed. Both hydrogen halides present a positive logarithmic gradient of their VMR with altitude, which shows time and latitude variations. A mean long-term increase of the HCl VMR with time is observed in the equatorial region, while no long-term trends are observed at the poles. HF also presents a mean increase with time in the polar region. Results are compared to previous HCl and HF VMR measurements.

4. Carbon Monoxide

CO is primarily produced through the photo-dissociation of CO_2 at high altitudes by solar ultraviolet radiation. SOIR detects CO between the altitudes of 65 – 125 km. This region of the atmosphere is characterised by the transition between two distinct dynamical regimes: the zonal retrograde flow below 70 km and the subsolar to antisolar circulation above 100 km. The evolution of the detected CO VMR with altitude shows two different trends about 90km. The collective results indicate therefore that the altitude of dynamical transition at the terminator on the morning and evening side of the planet is 90 km. However a surprising observation is the high variability of CO VMR between different observing seasons, some for which it seems the 90 km transition is non-existent.

5. Summary and Conclusions

The SOIR instrument has been collecting data from 2006 until present. Recent analyses of these data provide a unique insight into trace gas abundances, distributions and variations. The latest results for H_2O and HDO are discussed. Long term increases in VMRs for HCl and HF are shown and compared to previous measurements. CO VMR is discussed in terms of the dynamical regimes.

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