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Gravity waves at the Venus cloud tops as observed by the Venus Monitoring Camera

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Abstract

High resolution images of Venus Northern hemisphere obtained with the Venus Monitoring Camera (VMC/Vex) allow to study small scale features like wave trains. The waves are observed at the cloud tops (~70 km altitude) and are mainly located in the latitude range 60–80° N. Here we present a preliminary statistical analysis of the wave properties aimed to characterize the wave types and their possible origin.

1. Introduction

A gravity wave is a wave disturbance in which buoyancy acts as the restoring force. It can only exist in a stably stratified atmosphere and can be triggered for example by lower convection or by horizontal flow passing an obstacle. An example is given by the Lee waves formed when a stable air flow passes over a mountain. Gravity waves can propagate both vertically and horizontally and they play an important role in transporting energy and momentum within the atmosphere [4]. Gravity waves have been detected in the atmosphere of most planets both as oscillations on the temperature field and as patterns on the cloud layer [10]. On Earth, gravity waves are frequently observed as mountain waves forced by topography or in relation to vigorous convective ascending motions such as hurricanes and tornados [2]. In the Martian atmosphere the existence of Lee waves has been known since Mariner 9 [1]. In more recent studies, Lee waves were observed in images acquired by the Mars Orbiter Camera on board Mars Global Surveyor [14] and by the High Resolution Stereo Camera on board Mars Express [9]. Fluctuations interpreted as gravity waves were also identified in temperatures measured by the Galileo Atmosphere Structure Instrument (ASI) in Jupiter's stratosphere [13]. Ultraviolet images of Venus cloud tops acquired by Mariner 10 and Pioneer Venus showed cloud features which were interpreted as gravity waves. Vertical propagating gravity waves were detected in the temperature profiles acquired by the Pioneer Venus Probes and by radio occultation experiments [3]. Since 2006 the European mission Venus Express (VEx) [11] is studying Venus atmosphere with a special regard to atmospheric dynamics and circulation. Gravity waves at different cloud layers of Venus atmosphere have been detected in UV and IR images acquired by the Visible and InfraRed Thermal Imaging Spectrometer (VIRTIS)-M and the Venus Monitoring Camera (VMC) on board Venus Express [7,5]. In Venus upper atmosphere gravity waves were revealed by non-LTE CO_2 emissions [2].

2. Observations & first results

Venus Monitoring Camera (VMC) is a CCD-based camera specifically designed to take images of Venus in four narrow band filters in UV (365 nm), visible (513 nm), and near-IR (965 and 1000 nm) [6]. Venus Express orbit allows VMC to capture at the pericentre high resolution images of the planet that are used to study small-scale dynamical phenomena at the cloud tops (~70 km altitude). [12] distinguished three types of waves in VMC images: long straight features, short wave trains and irregular wave fields (Fig. 1). The waves are often identified in all channels, thus excluding to be caused by the UV absorbers. They could be the results of variation in cloud opacity or in the solar illumination angle.

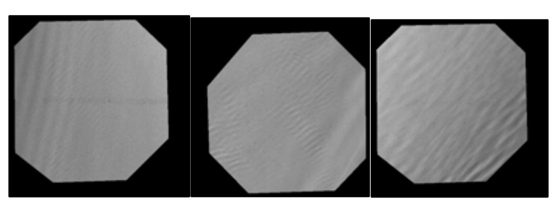

Figure 1: VMC types of waves

We performed a systematic search of waves in VMC images; more than 1700 orbits were analyzed and wave patterns were observed in about 150 images. Waves are located at high latitudes (60–80ºN) in the Northern hemisphere and seem to be concentrated above Ishtar Terra, a continental size highland that includes the highest mountain belts of the planet, thus suggesting a possible orographic origin of the waves (Fig. 2). However, at the moment it is not possible to rule out a bias in the observations due to the spacecraft orbit that prevents waves to be seen at lower latitudes, because of lower resolution, and on the night side of the planet.

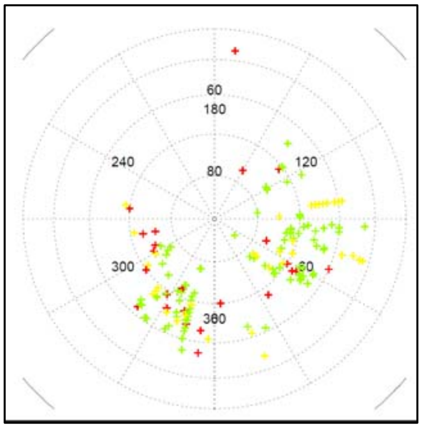

Figure 2: Location of VMC waves (red – long waves; green – short waves; yellow – irregular waves)

We measured wave properties such as location (latitude and longitude), local time, solar zenith angle, packet length and width, orientation relative to the north and wavelength. Long waves generally extend more than a few hundreds kilometers, short wave packets have a width of several tens of kilometers and extends to few hundreds kilometers.

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