EPSC Abstracts
Vol. 14, EPSC2020-755, 2020
https://doi.org/10.5194/epsc2020-755
Europlanet Science Congress 2020

EnVision Radio Science Experiment

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Introduction:

The primary goals of the radio-science experiment (RSE) of EnVision are to improve our knowledge of the internal structure of Venus and to contribute to the understanding of the atmospheric sulfur cycle, associated to volcanic emissions.

The internal structure of Venus is still uncertain (size and state of the core, average lithospheric and crustal thicknesses, as well as their lateral variations). These are the key parameters to constrain the mantle composition and thermal evolution of the planet. Without the availability of seismic data, the gravity field is the only tool allowing to determine the radial structure of a planet, as well as the regional variations of crustal and lithospheric properties.

The sulfuric acid in the atmosphere is part of the sulfur cycle and may be linked to the volcanism activity. The monitoring of its abundance is important to constrain the outgassing from the interior.

RSE is then divided into two sub-experiments : the gravity experiment and the atmospheric experiment. RSE will be performed by using the transponder system onboard the spacecraft, with the addition of an Ultra-Stable Oscillator (USO) for the atmospheric experiment.

Gravity experiment :

The Doppler shift of the carrier frequency of the Earth-to-orbiter radio-link is used to track the spacecraft orbital motion. The asymmetrical planetary gravity field perturbs the motion of the spacecraft in orbit. This perturbed motion is reconstructed from the Doppler tracking data in order to estimate the planetary gravity field. The spatial resolution and the accuracy of this gravity solution depends on the orbital altitude, the total Doppler noise, the coverage, the a priori knowledge of the gravity field itself, the modelling of the non-gravitational forces due to the atmospheric drag, the radiation pressure (solar radiation, cloud top-layer albedo and infra-red emission) as well as residual accelerations generated by attitude maneuvers [1, 2, 3].

The elliptical orbits of the Magellan spacecraft have indeed provided a gravity field solution with a spatial resolution of about 300 km on average but include large surface areas with worse (500 km) spatial resolution in the northern and southern hemisphere at mid-latitudes [2, 4]. The EnVision gravity field solution will improve the Magellan solution by providing a spatial resolution of 200 km on average. The planned orbit for the EnVision scientific nominal phase is a polar slightly elliptical orbit (220-525 km altitude), allowing to reach this averaged resolution. The accuracy of the gravity field solution is also expected to be improved because of the lower Doppler frequency noise, compared to Magellan, and of a better coverage due to the length of the mission of 6 cycles (i.e. 4 Earth's years, with 3.5 effective hours of tracking per day on average performed during the telemetry downlink passes).

It is expected that the k_2 tidal potential Love number precision will be better than 3% (compared with the 22% for the Magellan solution [5]), which will result in an improved constraint of the state and the size of the core [6].

Radio-occultation experiment:

Earth occultations shall be performed to derive the atmospheric structure (temperature, pressure, number density), the H_2SO_4 absorption and the electron density profile of the ionosphere of Venus [6]. Occultations shall be performed at the beginning and at the end of the telemetry downlink passes, up to 4 ingress and 4 egress observations per day using a one-way X-Ka downlink, thanks to the use of an USO (ADEV better than 5e-13). Because of the short orbital period of EnVision and its near polar orbit, all latitudes, longitudes, local times and solar zenith angles shall be covered. This will allow to observe short-term variations of the temperature and pressure profiles caused by atmospheric waves.

The observation of the H_2SO_4 content is fundamental to understand the cloud formation and convection processes. In particular the sounding by Ka-band (34 GHz) for the first time will allow to derive the H_2SO_4 content in the altitude range between 35 and 55 km, at the 1 ppm level, because of the high sensitivity of Ka-band to sulfuric acid absorption. The dual-frequency downlinks (simultaneous X- and Ka-bands) will distinguish between gaseous and liquid H_2SO_4 absorption features at around 50 km altitude (detection at 1 mg/m^3 level for the liquid part). H_2SO_4 temporal variations from hours to years during the mission time shall be investigated with very good latitudinal coverage.

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