Icarus 000 (2018) 1–7

Contents lists available at ScienceDirect

Icarus

journal homepage: www.elsevier.com/locate/icarus

Venus atmospheric structure and dynamics from the VEGA lander and balloons: New results and PDS archive

Ralph D. Lorenz[a,*], David Crisp[b], Lyle Huber[c]

[a] Johns Hopkins Applied Physics Laboratory, Laurel, MD 20723, USA
[b] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
[c] PDS Atmospheres Node, Department of Astronomy, New Mexico State University, Las Cruces, NM, USA

ARTICLE INFO

Article history:
Received 13 May 2017
Revised 1 December 2017
Accepted 22 December 2017
Available online xxx

Keywords:
Venus, Atmosphere
Meteorology
Instrumentation

ABSTRACT

The longest-lived in-situ measurement platforms at Venus have been the Soviet VEGA balloons in 1985 and the only high-quality pressure/temperature profile in the lowest 10 km of the atmosphere is that from the VEGA-2 lander. Here we review the mission and the resultant literature and report the archival of numerical data from these investigations on the NASA Planetary Data System Atmospheres Node to facilitate their access to the community. We additionally report some new results, including the striking absence of a signature of the planetary boundary layer in the near-surface potential temperature profile from the VEGA-2 lander, in contrast to the well-defined boundaries seen in a comparable profile at Titan.

1. Introduction

In-situ measurements in the atmosphere of our sister planet Venus remain a tremendous challenge, and it is important that such few hard-won measurements that exist can be fully exploited. The last in-situ measurements obtained, from the Soviet VEGA mission, are already more than 3 decades old. They were acquired during the Cold War, and before widespread internet access and the development of the NASA Planetary Data System (PDS), and thus have received relatively little attention since their initial analysis, in part due to difficulty in access. In the work reported here, we review the mission and the recovery of the balloon data. We summarize the literature to date that examines the data, and document the data set which has now been delivered to the PDS Atmospheres Node for archive (dataset ID VEGA1/VEGA2-V-2/3-VENUS-V1.0, anticipated release early 2018). We also note some findings from a new examination of these products. Code in the open-access computing/analysis package R (https://www.r-project.org/) used to interrogate the data products to make the plots in this paper is included as supplemental information.

2. VEGA mission

The return of Halley's comet in 1985/86 provided a unique opportunity to combine a mission to explore Venus (continuing the Venera lander series) with exploration of Halley by employing a two-element space vehicle comprising a Venus lander (and balloon) and a carrier spacecraft which would go on to Halley (e.g. Dolgopolov et al., 2012). The mission was called VeGa, a contraction of the Russian words 'Venera' (Venus) and 'Gallei' (Halley) and was conducted by the USSR with scientific payloads and ground tracking support from several countries, notably France and the USA.

Like many Soviet planetary missions, Vega comprised two identical spacecraft, Vega 1 and Vega 2. This was a standard Soviet approach to ensure the overall reliability of the mission. If both spacecraft were successful there would be a significant increase in the scientific return, which was particularly valuable in the case of the Halley flybys given the variability of comet activity. The two spacecraft were launched by Proton rockets from the Baikonur cosmodrome on 15 and 21 December 1984, and delivered the balloon/lander entry vehicles to Venus on 11 and 15 June 1985, going on to encounter comet Halley in March 1986. The mission at Venus is described by Sagdeev et al. (1986a, 1986b) – additional references are noted in Section 4.

The spherical entry vehicles (see Fig. 1) were ~1750 kg in mass, including entry thermal protection, extraction parachutes, and the helium tanks for the balloons. The landers themselves were ~750 kg and took about 1 h to reach the surface. The landers carried a variety of instrumentation for study of the atmosphere and surface. Only the meteorology data are discussed in the present paper.

During the descent of the landers, each released a helium-filled balloon to float near the cloud tops. During early planning of the mission, larger French-led balloons had been considered (e.g.

* Corresponding author:
E-mail address: ralph.lorenz@jhuapl.edu (R.D. Lorenz).

https://doi.org/10.1016/j.icarus.2017.12.044
0019-1035/© 2017 Published by Elsevier Inc.

Fig. 1. VEGA lander and entry system on display in the Lavochkin museum in Moscow. (Photo: R. Lorenz – high-quality version of this image and others are included in the /extras directory of the PDS archive). Note the spherical entry vehicle, the silvered spherical lander attached to its landing ring on which various instrumentation is mounted: surface sampling mechanism is at right. At top above the braking disk to provide stable drag in descent are spherical helium tanks to inflate the balloon.

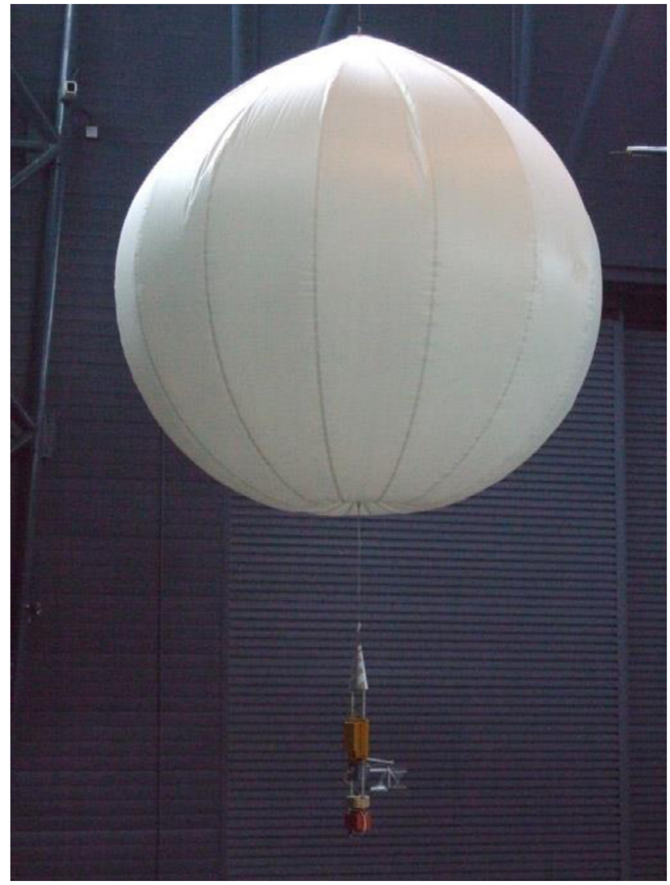

Fig. 2. A view of a mockup of the VEGA balloon and gondola on display at the Udvar-Hazy Center of the Smithsonian Air and Space Museum near Washington D.C. The gondola and balloon are correct in size, but the tether connecting the two was much longer in flight (it is desired to have a long riser to maximize the pendulum period and thereby minimize swing dynamical effects and to minimize the wake effect of the balloon on the instruments during ascent) whereas the practical constraints on the display environment in the museum required a short riser. Notice the anemometer to the right of the gondola, and the conical antenna at the top of the gondola.

Blamont, 1985; Dolgopolov et al., 2012) but the inclusion of comet Halley in the mission plan for the flyby spacecraft forced the use of the smaller Soviet balloons eventually flown.

The primary scientific objective of the Vega balloons was to obtain information about the large- and small-scale motions, structure, and cloud properties of the Venus atmosphere at the float altitude. The probes floated at an altitude of about 54 km in the middle, most active layer of the Venus three-tiered cloud system and measured the local atmospheric dynamics, pressure, temperature, lightning, illumination levels, and cloud properties. Their payload was modest (the whole gondola was 6.9 kg), with pressure and temperature sensors, a light level/lightning detector, a nephelometer (cloud backscatter sensor) and a lightweight 'windmill' vertical anemometer. Additional investigations included Doppler measurements to retrieve turbulence and windspeed, and position measurements using the Very Long Baseline Interferometry (VLBI) technique.

The Vega balloon probe comprised a 3.4 m diameter balloon and a gondola, suspended below the balloon by a 13 m long tether strap (see Fig. 2). The total mass of the deployed balloon probe was 21.5 kg: 12.5 kg for the balloon and tether, 6.9 kg for the gondola, and 2.1 kg of helium in the balloon. The balloon, gondola, parachute, ballast, tanks of helium, and timing electronics and pyrotechnic release devices with a total mass of 120 kg were stored in a toroidal compartment surrounding the lander antenna before deployment.

The balloon was made of a teflon cloth matrix coated with teflon film and filled with helium to 30 mbar overpressure. The diffusion of helium from the balloon was slow enough that the balloon would outlast the probe battery lifetime, losing less than 5% of its helium and 500 m of altitude. The balloon itself was transparent to the downlink radio frequency used.

The gondola was 1.2 m high and had three parts, connected by straps. The upper section, connected to the tether, was a 37 cm long, 15° half-angle conical antenna 14 cm diameter at its base. The middle section was connected by two straps to the upper section with dimensions approximately $40.8 \times 14.5 \times 13.0$ cm. This section contained a radio transmitter and modulator, data-handling system, and signal-processing and power-regulating electronics, together with pressure and illumination sensors and a deployable arm which held temperature sensors and an anemometer. The lower section was $9.0 \times 14.5 \times 15.0$ cm, was also connected to the middle section by two straps, and held the batteries and nephelometer. The gondola was painted with a white coating that resisted corrosion by sulfuric acid and increased the gondola's albedo to help regulate its temperature.