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Review Article

Terrestrial subaqueous seafloor dunes: Possible analogs for Venus

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ABSTRACT

Dunes on Venus, first discovered with Magellan Synthetic Aperture Radar (SAR) in the early 1990s, have fueled discussions about the viability of Venusian dunes and aeolian grain transport. Confined to two locations on Venus, the existence of the interpreted dunes provides evidence that there could be transportable material being mobilized into aeolian bedforms at the surface. However, because of the high-pressure high-temperature surface conditions, laboratory analog studies are difficult to conduct and results are difficult to extrapolate to full-sized, aeolian bedforms. Field sites of desert dunes, which are well-studied on Earth and Mars, are not analogous to what is observed on Venus because of the differences in the fluid environments. One potentially underexplored possibility in planetary science for Venus-analog dune fields could be subaqueous, seafloor dune fields on Earth. Known to the marine geology communities since the early 1960s, seafloor dunes are rarely cited in planetary aeolian bedform literature, but could provide a necessary thick-atmosphere extension to the classically studied aeolian dune environment literature for thinner atmospheres. Through discussion of the similarity of the two environments, and examples of dunes and ripples cited in marine literature, we provide evidence that subaqueous seafloor dunes could serve as analogs for dunes on Venus. Furthermore, the evidence presented here demonstrates the usefulness of the marine literature for thick-atmosphere planetary environments and potentially for upcoming habitable worlds and oceanic environment research program opportunities. Such useful cross-disciplinary discussion of dune environments is applicable to many planetary environments (Earth, Mars, Venus, Titan, etc.) and potential future missions.

Contents

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1. Introduction

Transport of material by wind on the surface of Venus has been the subject of much work and speculation over the years (e.g., Sagan, 1975; Arvidson et al., 1991; Greeley et al., 1992; Weitz et al., 1994), including analog wind tunnel studies (e.g., Greeley et al., 1984; Marshall and Greeley, 1992). While knowledge about sediment availability at the Venusian surface and also about the Venusian atmosphere is limited, there is evidence for aeolian particle transport on Venus (e.g., Keldysh, 1977; Garvin, 1981; Greeley et al., 1992; Weitz et al., 1994). Many works have suggested the possibility that the thick (in terms of fluid density) Venusian atmosphere may entrain sand and dust particles more like aqueous environments on Earth (e.g., Sagan, 1975; Sagan and Bagnold, 1975; Claudin and Andreotti, 2006). Subaqueous fluid particle entrainment conditions could provide better Venusian analogs for studies of dune formation and evolution than traditional Earth-atmospheric conditions, as a result of the higher density of water compared to air. This paper aims to (1) revisit knowledge about the physics of particle entrainment in different environments, (2) review dune parameters of marine and Venus atmospheric particle entrainment literature for application to dunes on the surface of Venus, and (3) discuss similarities of Venusian and subaqueous environments. With this review, we intent to stimulate exchange between the aeolian and marine communities with the aim to advance knowledge about particle transport on Venus and potentially also in other high-density environments.

2. Particle movement on Venus

The existence of saltating grains on Venus has long been debated, based on a handful of observations from the Venera landers and a wealth of wind tunnel experiments (Keldysh, 1977; Garvin, 1981; Marshall and Greeley, 1992) Since the identification of probable dune fields on Venus from Magellan radar data (Greeley et al., 1992; Weitz et al., 1994), there have been nearly no terrestrial analogs for comparison to the high-pressure, high-temperature surface conditions present on Venus. Seafloor dunes on Earth form in a high-pressure (and high-density) environment more analogous to the surface pressures of Venus and could provide context to current Venus surface data and insight into needed future observations.

Venusian surface pressures measured by Venera 9 and 10 averaged about 90 bar (equivalent to ~900 m, or ~10 m per 1 bar, in the terrestrial ocean) with measured wind speeds 0.4–1.3 m s^{-1} (Keldysh, 1977). Surface images from the Venera landers (9, 10,

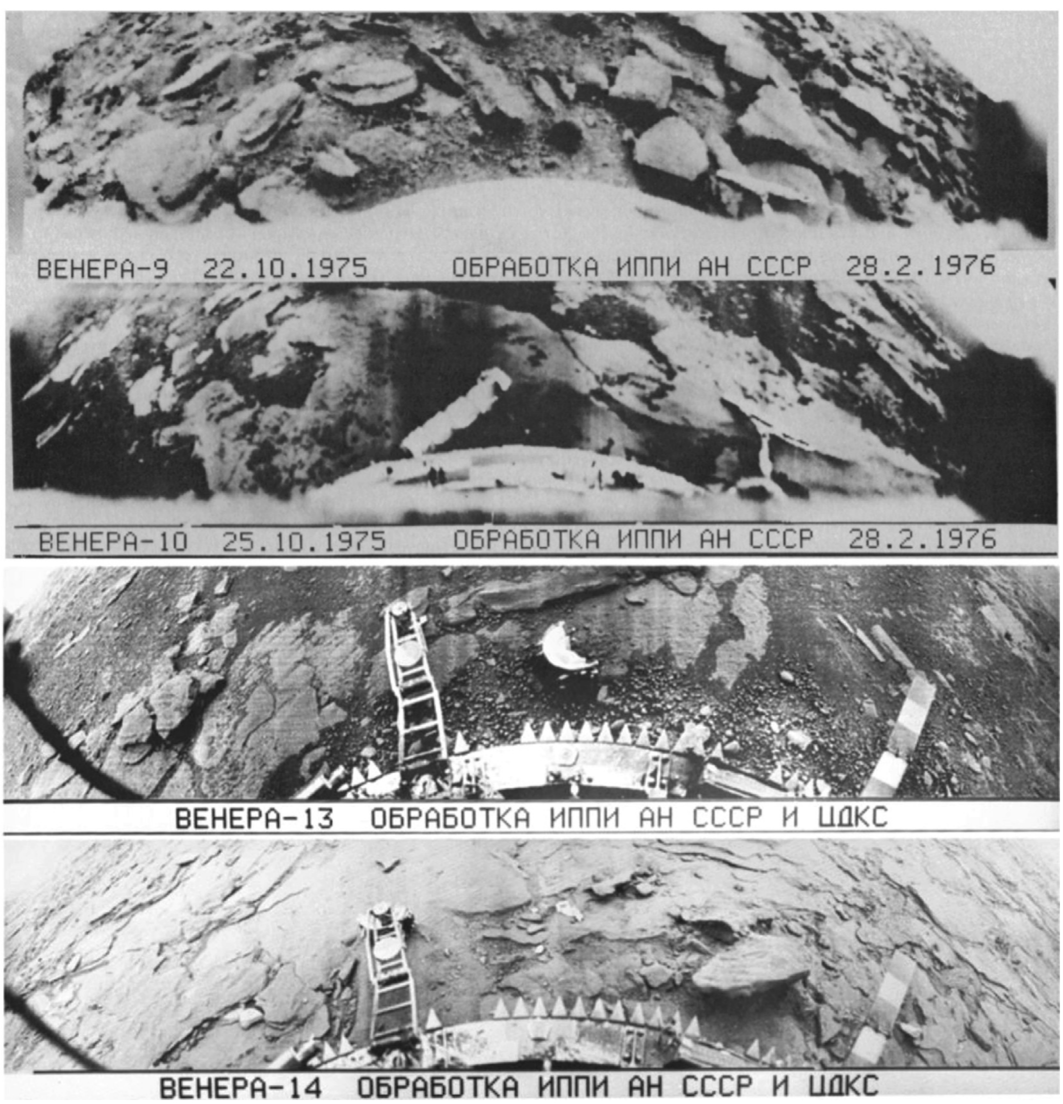

Fig. 1. Comparison of four of the Venera (Венера) landing sites showing differences in sediment availability over the surface of Venus (after Florensky et al., 1977) Venera-13 showed signs of lander-induced dust lofting (Garvin, 1981).

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