Subaqueous Antidunes on the surface of Venus? K. E. Williams, P. E. Geissler. USGS Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001 kewilliams@usgs.gov.

Introduction: The surface pressure conditions beneath the 92 bar CO_2 atmosphere of Venus are similar to subaqueous terrestrial ocean pressure environments at a depth of approximately 1 km. In addition there is experimental evidence to suggest that sediment transport in the high-pressure CO_2 atmosphere on Venus may be similar to terrestrial fluvial sediment transport [1]. This has lead other researchers [2] to propose that the dunes on Venus may be comparable to subaqueous dunes on Earth that formed at low flow speeds. Another alternative is that dunes on Venus formed under much higher flow speeds as antidunes in turbidity currents. Aeolian antidunes have not been reported on Earth but subaqueous antidunes are relatively common. In this work we proceed under the working hypothesis that aeolian antidunes may exist beneath the atmosphere of Venus. We use characteristics of transverse dunes from the Al-Uzza Undae region of Venus in order to constrain the formative flow properties of putative antidunes.

Background and Model: Antidunes are fluvial bedforms found in supercritical flows. Antidunes are notable in that they move against the flow. Terrestrial antidunes generally form under thin, fast-flowing aqueous environments. Antidunes have also been found to form in terrestrial turbidity currents. It seems plausible that antidunes could form under the thick Venusian atmosphere in a manner analogous to terrestrial turbidity currents. Venus has at least three officially named dune fields: Al-Uzza Udae (Fig. 1), Menat Undae and Ningal Undae.

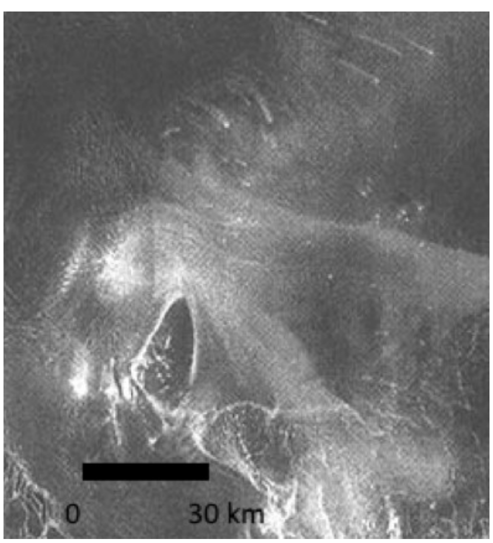

Figure 1.Approximate location of the Venusian Al-Uzza Undae dunefield near 67°N, 90°E. image: NASA/JPL.

Recent work by Geissler [3] has suggested that, given estimates of transverse dune spacing λand an estimate of the operative reduced gravity term g', we may infer flow velocity v using the relation suggested by Kennedy [4] for subaqueous antidunes:

$$\lambda = \frac{2\pi v^2}{g'}$$

where the reduced gravity term g' is defined normally including the gradient of the flow density and the ambient density [5]:

$$g' = g\frac{\Delta\rho}{\rho_a}$$

Here ρ_a is the ambient fluid density and g is the gravitational constant. There is a fair amount of uncertainty with this term, given that it depends on the sediment concentration of the flow.

Ordinarily the Froude number $Fr = \frac{v}{\sqrt{g'd}}$ is used to determine the potential for antidunes formation in a given flow. $Fr \geq 1$ is required for antidune formation, though terrestrial flume work by Kennedy [4] as reported in Geissler [3] suggests that antidunes begin to form once flow velocities reach 80% of wave celerity or flow depths are less than ~14.2% of dune wavelength.

Solving for flow velocity and flow depth as functions of wavelength and reduced gravity provides an opportunity to explore the parameter space (Fig. 2 and 3).

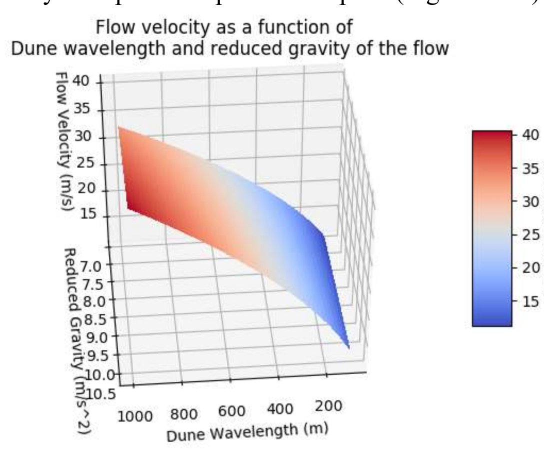

Figure 2. Flow velocity as a function of reduced gravity and dune wavelength. Note the weak dependence of flow velocity on reduced gravity, which is the most uncertain term.

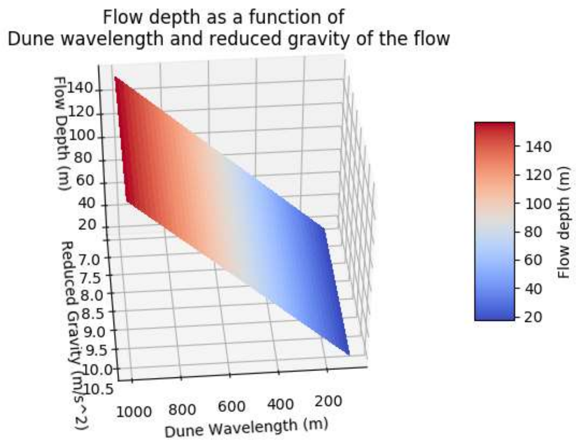

Figure 3. Flow depth as a function of reduced gravity and dune wavelength. Here the Froude number is assumed to be unity. Note the elimination of the dependence on reduced gravity.

Radarclinometric analysis by Lorenz [6] suggests that dune wavelengths in Al-Uzza Undae are approximately 500m, with a few slightly longer wavelengths of up to 1000m. Given these constraints we can infer the flow depths may have been close to 80m thick with a few thicker flows of close to 140m. Similarly, flow velocities may be inferred to be approx. 22 m/s, with a few up to 32 m/s.

Discussion: We find that the suggested Venusian dune mechanisms relating wavelength and reduced gravity to wave speed and depth are more likely to exhibit weak (or zero) dependence on the reduced gravity of the flow. Such finds are encouraging, given that the flow properties (in this case similar to a terrestrial turbidity current) is nevertheless weakly constrained given our general lack of knowledge of the properties of Venusian sedimentary processes.

Conclusion:

The suggested Venusian antidune velocity and flow depth show only a weak (or zero) dependence on reduced gravity, whereas they show a significant dependence on estimated wavelength. We find, assuming the dunes in Al-Uzza Undae are analogous to those produced via terrestrial subaqueous turbidity currents, that we may infer flow depths of 80-140m with flow velocities of 22-32 m/s. While measured surface wind speeds on Venus are generally < 1.5 m/s [7], it is worth noting that turbidity currents, being gravitationally induced flows, are potentially of much higher magnitude than ordinary wind speeds.

References:

[1] Bougan S. (1986) *LPSC XVII, 74-75*.[2] Neakrase, L.D.V. (2015) *Fourth Interplanetary Dunes Workshop,* Abstract #8023. [3] Geissler, P. (2014) JGR-Planets 119, 2583-2599. [4] Kennedy, J. F. (1960) *PhD Thesis Caltech*. [5] Kneller, B.,and C. Buckee (2000) Sedimentology, 47 (Supp. 1), 62–94. [6] Lorenz R. J. (2015) *Fourth Interplanetary Dunes Workshop,* Abstract #8004. [7] Lorenz, R. D. (2016) Icarus 64, 311-315.