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Visibility of Active Lava Flows from Venus Orbit

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Abstract

I present a model of the signatures of active lava flows observable through spectral windows from orbit and data processing methods for isolating these signatures in near-infrared images. The model estimates the thermal emission of lava flows based on models for the analysis of remote observation of eruptions on Earth and Io, however adjusted to the different thermal environment of the Venus surface. This thermal emission radiation is only partially transmitted through the diffusely scattering cloud layer and moreover diluted over a diameter of 100 km, an area much larger than the size of most flows. Data processing methods to enhance the chance to detect these signatures include corrections for variable cloud opacity using other spectral bands, subtraction of background thermal emission, and spatial filtering. This model and the implementation of the data processing methods for VIRTIS IR data, arguably the most sensitive and extensive applicable dataset, indicate that only very large and intense eruptions could have been detected with existing data.

1. Introduction

The surface of Venus is geologically young compared to other terrestrial planetary bodies except Earth and Io. Most of the young surface has an origin in effusive volcanism, however a wide range of global rates of volcanism is discussed for Venus. This is due to the fact that the cratering record of the surface - shielded from impacts by the atmosphere - does not constrain whether the volcanism occurs constantly or episodically through time. A significant constraint on the current volcanic activity would contribute much to this discussion. The Venus Express mission included the imaging instruments VMC and VIRTIS, which had the capability to observe volcanic activity. No clear signatures of active volcanism have been reported for VIRTIS M IR data, however transient bright spots in VMC images have been interpreted as most likely to be caused by eruptions [7].

2. Signatures of active lava flows

Thermal emission of active flows: Lava flow thermal emission is modelled as a function of time assuming an effusion rate and flow thickness, which constrains areal growth and age of the flow surface. The flow surface cools rapidly, which greatly diminishes the contribution to thermal emission (Fig 1). The surface cooling occurs mostly by radiation and convection. On Venus surface winds are low and free convection and radiative cooling are coupled due to the IR opaque CO_2 atmosphere [8], which reduces efficiency of both. I assume that an area fraction of 0.1 to 10 % of the flow area corresponds to fractures and exposes lava for only a few seconds, consistent with Earth observations [1]. Finally the model imposes a limit on the areal growth and thus thermal emission if the total heat loss of the flows of the eruption reaches a certain fraction of the heat supplied at the vent, as it is assumed in studies of Earth and Io remote sensing data of eruptions [eg. 3,2].

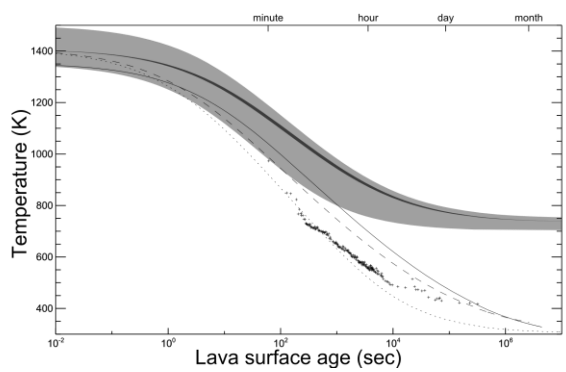

Figure 1 Lava surface temperature as function of time since eruption for Earth and Venus under various assumptions.

Atmospheric scattering: Active flows which are not immediately obvious due to their brightness, are small compared to the area over which its emission is scattered by the atmosphere. Thus I model them as a point source adding to the background radiance. The radiance distribution of a point source observed at the top of the atmosphere is approximately a Gaussian with a full width half maximum of 100 km [4].

3. Data processing methods

Cloud correction: The cloud opacity is variable, and the signature of an eruption needs to be distinguished from this variability in order to be unambiguously detectable. In order to reduce this variability it is possible to correct for cloud opacity if simultaneous observations at a wavelength where the emission originates below the clouds but above the surface are available [5], e.g. the 1.31 micron band of VIRTIS.

Background subtraction: The background thermal emission can be estimated based on altimetry as proxy of surface temperature [6], however if longterm observations of the surface in question are available it is additionally possible to account for variable surface emissivity. By subtracting the average radiance over time, short term deviations such as eruptions, are more visible.

Spatial filtering: Since the size of an eruption signature is well known, it is possible to spatially filter the data. The most straightforward is a filter with highpass properties, such as subtraction of a moving average with a diameter larger than 100 km. This removes residual cloud variation and instrumental straylight. If the instrumental resolution is high enough, a highpass filter additionally can reduce instrumental noise.

4. Conclusions

Using the above data processing on VIRTIS-M IR data I estimate that it would be very likely to detect active eruptions with 1 km^3 lava effused within 10 days or a sustained effusion rate of >800 m^3/sec. This corresponds to a 1GWum^{-1}sr^{-1} signature, with a maximum that is ~1.2 times background emission. Under less conservative assumptions the same brightness can be achieved with 0.01 km^3 lava and effusion rates >30 m^3/sec. [9] presents historical eruption data from 1840 to 1980 for three volcanos that can be compared to these detection criterions (Fig. 2). Only under optimistic assumptions some of the more intense eruptions would have been detected, had they happened in the field of view of VIRTIS. The bright spots observed by VMC at Ganiki Chasma, with an emerging flux of more than 2 times the background [7], would be consistent a lava flow of at least 250 m^3/sec even with optimistic assumptions. On Earth this is a rare event on historical timescales. Several eruptions like this per year on Venus could significantly contribute to ongoing resurfacing on geological timescales.

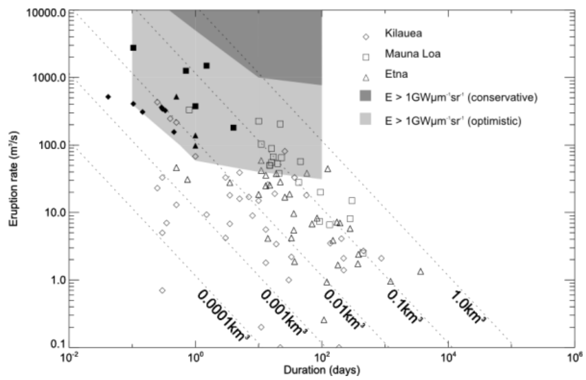

Figure 2 Historical eruption data compared to the capability of VIRTIS to detect eruptions for different assumptions.

References

[1] Crisp and Baloga: A model for lava flows with two thermal components. *JGR*, 95:1255–1270, 1990

[2] Davies. Volcanism on Io: Estimation of eruption parameters from Galileo NIMS data. *JGR*, 108:5106, 2003

[3] Harris,et al. A chronology of the 1991 to 1993 Mount Etna eruption using advanced very high resolution radiometer data: Implications for real-time thermal volcano monitoring. *JGR*, 102:7985–8004,1997

[4] Hashimoto and Imamura. Elucidating the Rate of Volcanism on Venus: Detection of Lava Eruptions Using Near-Infrared Observations. *Icarus*, 154:239–243, 2001.

[5]Hashimoto and Sugita. On observing the compositional variability of the surface of Venus using nightside near-infrared thermal radiation. *JGR*, 108:13–18, 2003.

[6] Lecacheux et al. 1993: Detection of the surface of Venus at 1.0 micrometer from ground-based observations. *PSS*, 41: 543–549, 1993.

[7] Shalygin et al.: Bright transient spots in Ganiki Chasma, Venus, #2556, 45th LPSC, Houston, USA, 2014

[8] Snyder. Cooling of lava flows on Venus: The coupling of radiative and convective heat transfer. *JGR*, 107:5080–5088, 2002

[9] Wadge. The variation of magma discharge during basaltic eruptions. *Journal of Volcanology and Geothermal Research*, 11:139–168, 1981.