CLASSIFICATION OF VOLCANIC ERUPTIONS ON IO AND EARTH USING LOW-RESOLUTION REMOTE SENSING DATA. A. G. Davies[1] and L. P. Keszthelyi[2], [1]Jet Propulsion Laboratory-California Institute of Technology (Ashley.Davies@jpl.nasa.gov, ms 183-501, 4800 Oak Grove Drive, Pasadena, CA 91109-8099) include full mailing address and e-mail address if desired), [2]USGS-Flagstaff (2525 N. Gemini Drive, Flagstaff, AZ 86001, laz@usgs.gov).

Introduction: Two bodies in the Solar System exhibit high-temperature active volcanism: Earth and Io. While there are important differences in the eruptions on Earth and Io, in low-spatial-resolution data (corresponding to the bulk of available and foreseeable data of Io), similar styles of effusive and explosive volcanism yield similar thermal flux densities [1-3]. For example, a square metre of an active pahoehoe flow on Io looks very similar to a square metre of an active pahoehoe flow on Earth. If, from observed thermal emission as a function of wavelength and change in thermal emission with time, the eruption style of an ionian volcano can be constrained, estimates of volumetric fluxes can be made and compared with terrestrial volcanoes using techniques derived for analysing terrestrial remotely-sensed data [e.g., 4]. In this way we find that ionian volcanoes fundamentally differ from their terrestrial counterparts only in areal extent, with Io volcanoes covering larger areas, with higher volumetric flux [e.g., 1-3]. Io outbursts eruptions have enormous implied volumetric fluxes, and may scale with terrestrial flood basalt eruptions. Even with the low-spatial resolution data available it is possible to sometimes constrain and classify eruption style both on Io and Earth from the integrated thermal emission spectrum. Plotting 2 and 5 µm fluxes reveals the evolution of individual eruptions of different styles, as well as the relative intensity of eruptions, allowing comparison to be made from individual eruptions on both planets. Analyses like this can be used for interpretation of low-resolution data (e.g. [5]) until the next mission to the jovian system. For a number of Io volcanoes (including Pele, Prometheus, Amirani, Zamama, Culann, Tohil and Tvashtar) we do have high/moderate resolution imagery to aid determination of eruption mode from analyses based only on low-spatial-resolution data.

Style of activity and spectral shape: Much of the data collected by *Galile*o and all of the data from Earth-based telescopes have low spatial resolution: the volcanically-active areas at an isolated volcano are sub-pixel. Analysis is therefore based on the integrated thermal emission spectrum. The shape of the thermal curve immediately constrains style of activity with more energetic eruptions yielding more thermal emission at short wavelengths due to the exposure of larger areas at high temperature than seen with insulated flows, for example, where thermal emission is dominated by cool crust.

Classification based on thermal spectrum: Constraining eruption style using NIMS (0.7 to 5 µm) low-spatial resolution data has proved successful in predicting emplacement style, for example, at Prometheus, Pele and Pillan before high-resolution data were obtained [e.g., 1,6]. Figure 1 shows a plot of 2 and 5 µm thermal emission for a selection of ionian volcanoes, with Figure 2 showing the trends for Loki Patera, Pillan and Pele. These plots allow comparison not only of evolution individual volcanoes but also of individual eruption episodes.

Insulated flows: Prometheus, Amirani and Zamama are examples of insulated flow fields. Thermal output is dominated by cool crust in the range 300-450 K (so 5-µm fluxes exceed 2 µm fluxes).

Lava-fountains and open flows: The large Pillan eruption of 1997 [1,7] has increased 2-µm emission due to fire fountains and possibly turbulent flow emplacement. As time passes the 2-µm flux drops rapidly as fountaining stops and the emplaced flows cool.

Active lava lake: Pele exhibits the characteristics of an active, overturning lava lake, with a 2-µm intensity that can match the 5-µm intensity. Pele is the only volcano on Io that persistently exhibits this behaviour.

Paterae: Ionian paterae such as Culann and Tupan have 2/5-µm ratios (see Figure 1and Table 1) similar to those of insulated flows. These features may be resurfaced by flows [8] or may be lava lakes [9]. However, no Pele-like (active lake) ratios are seen in data analysed so far. Although the magnitude of activity changes, the 2/5 micron ratio does not. This indicates a change only in area of activity, not style of emplacement.

Loki Patera: Io's most powerful volcano (Fig. 2), Loki's thermal emission is dominated by cool crust, even at the height of its thermal emission cycle. Other constraints such as the surface temperature distribution [8] and long-time periodic behaviour [10] indicate that Loki may be a large lava lake that quiescently overturns, a process that takes place without large exposure of hot material that would increase the 2 -µm flux.

Comparison with terrestrial data: Figure 3 shows data for Kilauea, Etna and Lonquimay. These ratios are produced from temperature and area data supplied by A. Harris from analysis of LANDSAT data. Spectra for individual pixels were created from a temperature-area analysis (Harris, pers. comm.) and integrated over the area of the activity.

This, if anything, emphasizes the difference in scale of activity. Ionian volcanic fluxes are orders of magnitude larger than their terrestrial counterparts. Nevertheless, Kilauea and Etna flows show (from these data) thermal emission dominated by the cool crust component in similar fashion to Prometheus, Culann, Tupan, and other Io volcanoes. More data are being analysed.

Conclusions: Even with the low-spatial resolution data available it is possible to constrain and classify eruption style both on Io and Earth from the integrated thermal emission spectrum. Table 1 shows eruptions classified in terms of 2/5-μm ratio, listed by increasing ratio value as the vigour of the eruption increases.

Table 1. 2/5 μm values for Io and Earth volcanoes

Volcano	2/5 μm ratio	Eruption style
Gish Bar	0.006	lava flows
Lonquimay	0.027	lava dome
Loki	0.052 to 0.012	quiescent lava lake
Altjirra	0.037	cooling flows?
Etna	0.038	lava flows
Kilauea	0.039	insulated flow field
Etna	0.031 to 0.084	lava flows
Kilauea	0.045 to 0.047	insulated flow field
Maui	0.107	flows or quiescent/inactive lake
Amirani	0.162	insulated flow field
Culann	0.176	lava flows or lake
Zamama	0.229	insulated flow field
Prometheus	0.244	insulated flow field
Tupan	0.255	lake? ponded flow?
Monan	0.264	flows?
Pillan	0.091 to 0.725	fire fountain, large flows
Pele	0.565 to 1.480	active lava lake

Telling the difference between insulated flows and quiescent lakes is difficult in a single low-resolution observation. However, the temporal behaviour of individual events is often diagnostic of eruption style [1].

Plotting 2 and 5 micron fluxes reveals the evolution of individual eruptions or different styles, as well as the relative intensity of eruptions, allowing comparison to be made from individual eruptions on both planets. Such an analysis can be used for classification of remotely-sensed data enabling correct application of mode-specific models to derive mass eruption rates and other parameters.

References: [1] Davies A. G. et al. (2001) *JGR*, 106, 33079-33,103. [2] Keszthelyi L. P. et al. (2001) *LPSC XXXII* Abstract #1523. [3] Davies A. G. (2003) *JGR*, 108, 10.1029/2001JE001509. [4] Harris A. et al. (1999) *JGR*, 104, 7117-7136. [5] Marchis F. et al. (2002) *Icarus*, 160, 33,141-33,160. [6] Davies A. G. et al., (1997) *GRL*, 24, 2447-2450. [7] Williams D. et al., (2001) *JGR*, 106, 33,105-33,119. [8] Davies A. G., (2003) GRL, 30, 2133. [9] Lopes R. et al., (2004) Icarus, 169, 140-174. [10] Rathbun J. et al. (2002) GRL, 29, 84-88.

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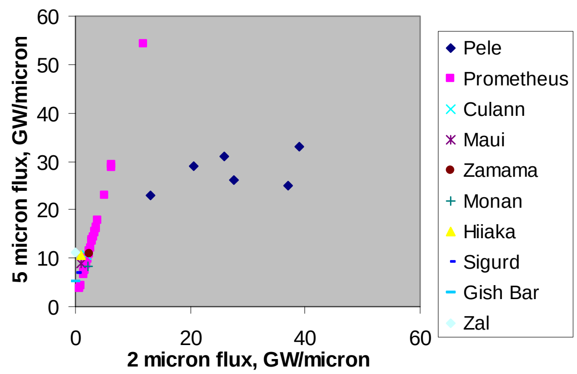

Figure 1: (above) 2 and 5-μm plots for Ionian volcanoes from NIMS data.

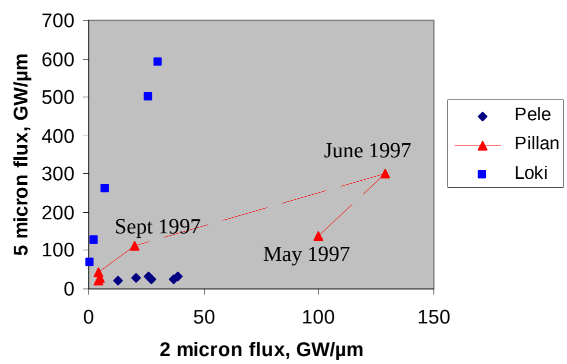

Figure 2: (above) 2 and 5-μm plots for Loki Patera, Pillan and Pele. The Pillan data bracket the massive 1997 eruption.

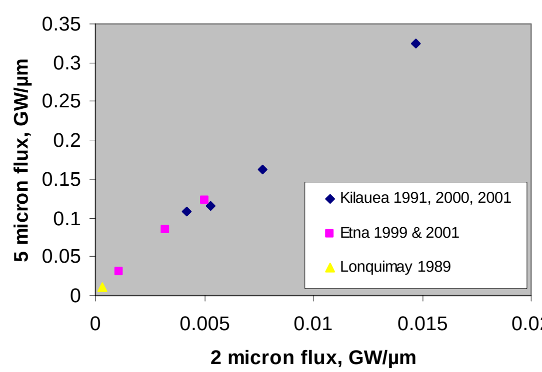

Figure 3: (above) 2 and 5-μm plots for terrestrial eruptions. Similar ratios are found for many Ionian eruptions.