GALILEO OBSERVATIONS OF VOLCANIC HOT SPOTS ON IO: PREDICTIONS FROM THERMAL DATA OF HAWAIIAN ERUPTIONS. P. J. Mouginis-Mark and Luke P. Flynn, Hawaii Institute Geophysics & Planetology, SOEST, Univ. Hawaii, Honolulu, Hawaii, 96822.

Introduction: By the end of 1995, the Galileo spacecraft should be in orbit around Jupiter, and will provide the opportunity to observe the thermal characteristics of active volcanism on Io during both the initial high resolution fly-by and the longer-term low-resolution observing phase. While the average heat flow from Io is ~2±1 W/m^2 (1), active eruption sites may be several orders of magnitude more energetic. Data from the Near Infrared Mapping Spectrometer (NIMS), collected between 0.7 - 5.2 μm, should therefore be particularly good for studying elevated surface temperatures. In addition, as we describe below, we believe that nighttime observations with the Solid State Imager (SSI) between 0.6 - 1.1 μm will also be useful for observing hotter targets, particularly because of the higher spatial resolution of the SSI compared to NIMS (10 μr/pixel vs. 0.5 mr/pixel). The availability of these thermal observations for Io would enable many aspects of Ionian volcanism to be interpreted from the same process-related perspective that active terrestrial volcanoes are now studied. High on the list of phenomena that should be studied are the active lava lakes (e.g., Loki), plumes (e.g., Pele), and the large areas of the surface that could be active lava flows (e.g., Lerna Regio; ref. 2).

Since late 1987, we have been measuring the temperatures of active volcanic features on Kilauea volcano, Hawaii, by using field spectrometers that operate between 0.4 - 3.0 μm, and aircraft data that extend from 1.0 - 5.0 μm. To date, we have studied several phases of activity at an active lava lake (3), a vigorous eruption (~1.2 x 10^6 m^3/day) that produced an active lava channel ~20 m wide and 60 m long (4), active lava tubes (5, and unpublished data) and made nighttime observations of cooling pahoehoe flow lobes (6). We describe here some of our terrestrial observations that are probably relevant to the study of Io, and the observational constraints that the morphology and duration of the volcanic phenomena and the SSI/NIMS spectral coverage should place on the Galileo imaging sequences.

Lava Flows and Tubes:

One of the questions that may be resolved about lava flows on Io through the use of temperature data is their emplacement mechanism, specifically if the flows are tube-fed, are analogous to a'a flows, or constructed as a compound lava flow field. While individual lava flows such as those from Ra Patera may be sulfur flows (7), other flows may be the products of silicate volcanism (8). Appreciable spatial variability in flow temperatures may be detected on Io. A 2-component thermal mixing model applied to data that we collected of an active lava channel during the Phase 50 eruption of Pu'u O'o gave, in the most powerful instance, (1.8 x 10^5 W/m^2) a crustal temperature of 940°C, a hot component temperature of 1120°C, and a hot radiating surface of 60% of the total area (4). Measurable radiance was observed at 0.7 μm for the center of this channel and at 0.8 μm for the cooler channel margins. This Hawaiian flow was so energetic that it was also observed in 1 km/pixel AVHRR observations made between 0.725 - 1.10 μm (4), comparable to data to be collected by the SSI. Nighttime observations of cooling lava pahoehoe flows (6) showed that individual lobes cooled at a rate of 15°C/min over a period of 52 minutes. These observations imply that, provided that the SSI data have a sufficient dynamic range, measurements made longward of 0.7 μm could detect the thermal flux from vigorous eruptions on the nighttime side of Io. Also, while an active flow may be easily detected in the Galileo NIMS data, if the plains materials on Io are recently emplaced compound flow fields then the thermal signature of an individual flow unit on Io may be difficult to detect against a warm background.

Lava Lakes:

Our field spectrometer observations of the Kupaianaha lava lake in 1987 and 1988 show that terrestrial lava lakes can have great temporal variability (3). Transient events lasting a few seconds to tens of seconds were seen to be associated with fountaining on the lake surface, or by rupturing of the cooling crust. A longer-term variability was also observed to occur on the tens of minutes time scale, wherein periods of quiescence were followed by rapid (1-2 m/s) movement of the solid surface or a foundering of the crust over areas tens of square meters in area. These different stages of the lakes activity also presented different fractional areas of hot material: Average flux densities up to 9.1 x 10^4 W/m^2 were observed for overturning lava lakes, with up to ~30% of the surface being the hot component. For rifting events on a solid surface, average flux densities of ~5.3 x 10^3 W/m^2 were observed with ~0.01% of the surface being hot. Significantly for Io observations, the period of quiescence of the lake had typical flux densities of only 2 - 3 x 10^3 W/m^2, and much cooler temperatures (80 - 345°C) than had been expected for an active silicate lava lake (3, 9). It would be of great value to try to use NIMS to detect these different stages on large lava lakes on Io (e.g., at Loki and Creidne Paterae). Time series data on the thermal variability of a lava lake on Io would provide valuable insights into the short-term replenishment of the magma reservoir.

Plumes:

Voyager data and ground based observations have provided ample evidence for long-duration explosive eruptions on Io. By analogy with terrestrial plumes (e.g., 10), we can predict that the Io plumes are very cold (<-20°C) while the vent area should have an elevated temperature (>~200 - 300°C). Furthermore, it is possible that some of the Io plumes eject significant amounts of lithic material that then fall back to the surface as warm pyroclastic material and form mountain material (11). At the time of the Voyager encounters, Haemus Mons (70°S, 50°E) may have been an example of mountain material that was forming by this process of active explosive volcanism and near-vent deposition of lithic material (2, 11).

Conclusions and Recommendations for Galileo Imaging:

1) SSI observations should be made on the night side of Io. Provided that the measurements are made with a high dynamic range, data collected at 0.75μm and 1.0 μm would enable active hot spots to be located more precisely than with NIMS due to the higher spatial resolution of SSI.

2) One of the planned observing sequences for NIMS at Io involves the identification of SO_2 at 3.9 μm. We know from our observations of Kilauea volcano that the emitted energy from active flows is extremely high at this wavelength, so that if SO_2 plumes were to be observed "drifting" over active flows or lava lakes (presumably a highly likely event, since active flows give off large volumes of SO_2), then the gain settings of NIMS would cause the detector to saturate over these sites. Careful use of this limited spectral range for mapping is therefore recommended, and should be supplemented with a few wavelengths < ~2.4 μm.

3) We know that terrestrial eruptions show many orders of magnitude variation in thermal flux on the time scale of seconds to tens of minutes. At Io, it will be necessary to obtain thermal data that can cover a large range of temperatures and energy fluxes, which will require data over the full spectral range (0.7 - 5.2 μm) of the instrument. Collecting SSI data that can identify the structure of the lake surface (looking for the average dimensions of plates on the surface, or tracking the drifting of features to determine the overturning rate of the surface) would also be very helpful.

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