A NEW MAP OF IO’S VOLCANIC HEAT FLOW. A. G. Davies¹, G. J. Veeder², D. L. Matson², T. V. Johnson¹
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Introduction: The areal scale and magnitude of thermal emission and effusion rate of high-temperature (silicate) eruptions on Io dwarf terrestrial analogues [1]. It has long been known that the distribution of Io’s surface heat flow should reflect the depth and magnitude of interior tidal heating (see review in [1]). Heating deep in the mantle should lead to a preponderance of surface heat flow at Io’s poles. Mostly shallow aesthenospheric heating should manifest as enhanced heat flow at sub- and antijovian longitudes, although it has long been accepted that a mixture of deep and shallow heating is probable. However, recent work examining the longitudinal and latitudinal distribution of heat flow [2] and the distribution of paterae and a subset of hot spots [3] shows an offset in the peaks of thermal emission and hot spot locations that cannot be explained by current interior heating models. In order to examine this phenomenon more closely we have created a map that shows the distribution of thermal energy from Io’s volcanoes, having quantified the thermal emission from 250 volcanic centres on Io [2].

Io’s volcanic heat flow: Our data are primarily from spacecraft and ground based telescope observations at infrared wavelengths. Previous work [4-6] shows that a preponderance of Io’s volcanic thermal emission comes from paterae. The thermal emission from Io’s volcanoes spans six orders of magnitude. In a series of papers [2,4-6] we have quantified and tabulated the thermal emission from 242 volcanic centres of ongoing or recent volcanic activity and an additional 8 outburst eruptions (Figure 1) to establish Io’s background volcanic activity during the Voyager-Galileo epoch.

As outburst eruptions are transitory and only account for a small percentage (<2%) of Io’s yearly volcanic heat flow [1], we currently omit them from the Io volcanic heat flow map (Figure 2).

Taking Io’s global heat flow to be $1.1 \times 10^{14}$ W [7,5] we account for approximately 55%. The area covered by all of the thermal sources, mostly dark-floored (low-albedo) paterae and dark lava flow fields, is only 2% of Io’s surface. The average heat flow from Io’s active areas is $68$ W m$^{-2}$ [2]. The remaining “unaccounted” heat flow, if averaged over Io’s non-active volcanic surface, is equivalent to a conducted heat flow of $0.98 \pm 0.2$ W m$^{-2}$ [2], still much greater than Earth’s mean heat flow ($0.07$ W m$^{-2}$ [8], and the Moon ($0.03$ W m$^{-2}$ [9].

Volcanic heat flow map: The heat flow map and comparison with the location of Io’s volcanic centres are shown in Fig. 2. The map, highlighting areas of enhanced regional volcanic heat flow, has also been reprojected orthographically to compare thermal emission with expected heat flow (Fig. 3). As previously noted, we find a non-uniform distribution of heat flow. Even without the apparent longitudinal offset, the end-member heating models are not well matched. The sub- jovian point, (0° W) where aesthenospheric heating alone would generate a peak in surface heat flow, is notable for a lack of large or powerful volcanic centres, and a relatively low regional heat flow. Anti-jovian hemispheric heat flow (90°-180°-270°W) is more variegated.

Future work includes: (1) refinement of thermal emission by including temporal variability of thermal emission at individual volcanoes and comparing the heat flow map with the Io Geological Map [10] and global topography [11]; (2) incorporating the map, data and results into the Io Geological Map Database maintained at Arizona State University [see 10]; (3) examining the “missing” heat flow question (e.g., low temperature S, SO$_2$ volcanism, not observed by Galileo?). The issue of accurately determining Io’s polar heat flow, and thus further constraining models of internal tidal heating, will require new spacecraft observations by a future mission to Io such as the proposed Io Volcano Observer [12, 13].

Figure 2. Heat flow map with contours in log(e) power, with power (P) expressed in GW. Background heat flow is taken in this example to be 0.98 W m\(^{-2}\). Transient outburst eruptions are excluded. Note a: this projection assumes a bin area of 2.26 x 10\(^{11}\) m\(^{2}\) (15° x 15° at Io’s equator).

Figure 3. (a) The sub-jovian hemisphere as seen by Voyager and Galileo (USGS). (b) Volcanic heat flow. (c) Volcanic heat flow with locations of individual hot spots. (d) contour plot showing density of hot spots only. (e) Aesthenospheric heat flow model. (f) Deep mantle heat flow model. Our preliminary examination shows sub-jovian heat flow does not map well onto existing models and to the distribution of hot spots alone. The model heat flow plots were published by Hamilton et al. [3].