COMPARISON OF TIDAL DISSIPATION MODELS TO GLOBAL DISTRIBUTION OF ACTIVE IONIAN VOLCANOES FROM GALILEO NIMS, PPR AND NEW HORIZONS LEISA. J. A. Rathbun[1], S. Saballett[2], R. M. C. Lopes[3], and J. R. Spencer[4], [1]Planetary Science Institute (1700 E. Fort Lowell, Tucson, AZ 85719 rathbun@psi.edu), [2]University of Redlands (1200 E Colton Ave., Redlands, CA 92373, USA), [3]Jet Propulsion Laboratory (4800 Oak Grove Dr., Pasadena, CA 91109, USA), [2]Southwest Research Institute (1050 Walnut St., Suite 400, Boulder, CO 80302, USA).

Introduction: Tidal heating is a major contributor to active surface geology in the outer Solar System, and yet its mechanism is not completely understood. Io's volcanoes are the clearest signature of tidal heating and measurements of the total heat output and how it varies in space and time are useful constraints on tidal heating. Lopes-Gautier et al. [1] compared the locations of hotspots detected by the Galileo Near-Infrared Mapping Spectrometer (NIMS) to the spatial variation of heat flow predicted by two end-member models. They found that the distribution of hotspots is more consistent with the heating occurring in the asthenosphere rather than the mantle. Hamilton et al. [2] also demonstrated that clustering of hotspots supports a dominant role for astheospheric heating. Current measurements of the strength of tidal heating [3,4,5] are more than twice as large as upper limits from models of steady state heating [6], and Io's orbital radius may be currently decresing [7]. Only [5] have attempted to investigate the temporal variability of the heat flow.

Most previous studies were limited by available data to considering each volcano equally. However, measurements of heat flow and power output from individual Ionian volcanoes from the Galileo Photopolarimeter-Radiometer (PPR) [3], NIMS [8,9], and ground-based telescopes [10,11] vary by several orders of magnitude. Each of these volcanoes, then, is an expression of different amounts of heat being transported to Io's surface. Furthermore, these earlier studies looked at all hotspots observed on Io, regardless of the time the hotspot was observed. Since volcanic activity varies on Io, using all known active volcanoes may not represent the actual heat output at one time.

More recently, [12] examined the thermal emission from 240 volcanoes to quantify the magnitude and distribution of their volcanic heat flow. They found peaks in thermal emission at 315 W and 105 W with a minimum at 200 W, suggesting a shift to the east from predicted heat flow due to tidal heating in the asthenosphere. However, many of the thermal emission quantities they use are model dependent.

NIMS: While the locations of hotspots detected by NIMS have been compared to tidal heating models [1], the measured brightness of the volcanoes has not been taken into account. We have systematically analyzed all Galileo NIMS data cubes to determine the location and spectrum of all observed hotspots [13]. We fit a single temperature blackbody curve to the spectrum from each NIMS grating position individually. We use the average of the fits as the temperature and area and the standard deviation as their uncertainty. NIMS' maximum wavelength of 4.7 µm means that it is not sensitive to endogenic heat radiated at very low temperatures.

PPR: Because it is sensitive to long wavelengths, where most heat is radiated, the PPR dataset is the only dataset that can be directly compared to tidal dissipation models without any assumptions. Rathbun et al. [3] present measurements for approximately one hundred volcano observations. We compare these powers directly to the heat flow predictions of [14] This direct comparison, while not global, makes no assumptions and uses only direct measurements.

New Horizons LEISA: On its way to Pluto, the New Horizons spacecraft flew by the Jovian system and returned data on the Ionian volcanoes. New Horizons made its closest approach to Io at 21:57 UT on February 28, 2007, though observations were made from February 24 through March 4. Observations were made at phase angles from 5° to 159°, and two eclipses of Io by Jupiter were also observed [15]. The Linear Etalon Infrared Array (LEISA), a short-wave IR spectral imager, obtained seven 1.25-2.5-micron image cubes [15].

The New Horizons observations have much more consistent longitudinal coverage of Io than the Galileo instruments had. Because of orbital and instrumental constraints, Galileo PPR observed primarily the sub-Jupiter hemisphere [3] and Galileo NIMS primarily the anti-Jupiter hemisphere [16], so no single Galileo instrument has the longitudinal coverage of New Horizons LEISA. However, since LEISA covers a much shorter wavelength range, it is sensitive only to recent volcanic eruptions and might not be as good a tracer of heat flow, much of which is radiated at temperatures too low for LEISA to detect.

Tsang et al. [17] determined the location of all hotspots in the LEISA images and determined the brightness, temperature, and area, for those that were bright enough to do so.

Conclusions: For each data set, we determine the power output of each volcano using the derived temperature and area ($P = \sigma T^4 A$, where P is the power, T the teperature, and A the area). Figure 1 shows histograms of the total power as a function of latitude and longitude compared to tidal disapation models for a thin asthenosphere (in blue) and entirely within the mantle (in green). We found that none of the comparison methods conclusivey distinguish between tidal heating models [13]. A dearth of heat flux is observed between 160 W and 200 W in PPR and LEISA data sets, and, to a lesser extent in NIMS. However, this is not observed in the volcanic constructs [2].

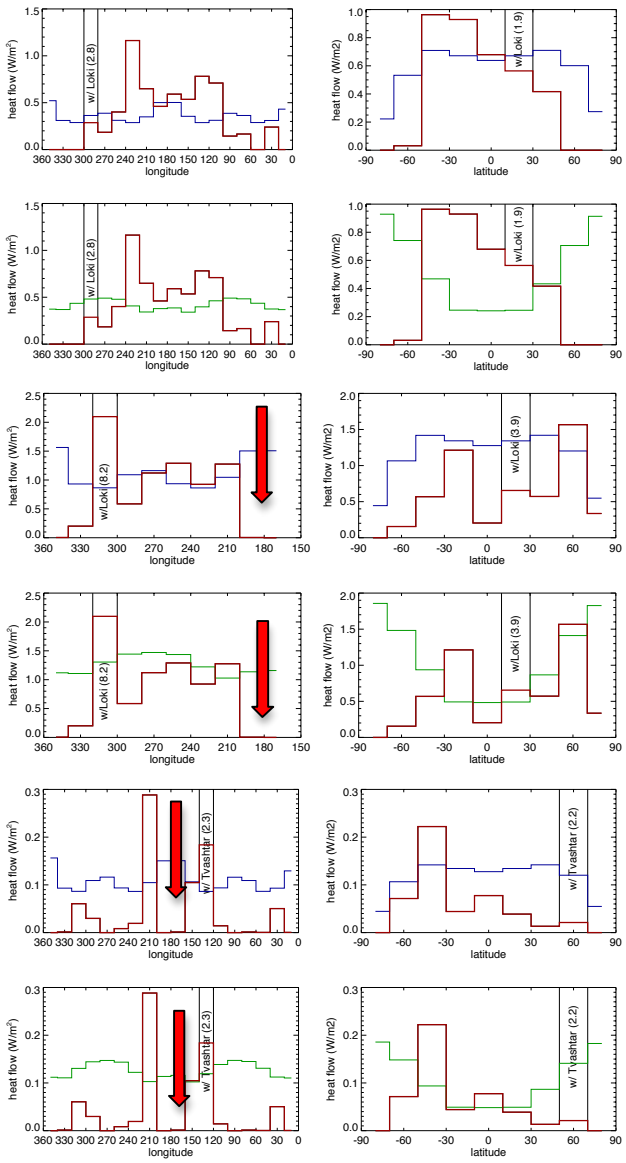

Figure 1: Heat flow from measured volcanoes compared to tidal heating models. The left column shows heat flow as a function of longitude, the right column as a function of latitude. Modeled heating via dissipation in a thin asthenosphere is shown in green, dissipation entirely with the mantle in blue. The top four plots compare to NIMS data, the next four to PPR, and the last four to LEISA.

Variations of heat flow with latitude are more consistent with asthenospheric heating, which predicts less heat at high latitudes. However, hot spots may be more difficult to observe at high latitudes, in some of the data sets. Both the NIMS and LEISA data sets show higher heat flow in the southern hemisphere. The variation of heat flow with longitude does not match models and may imply non-synchronous rotation [13].

Note that we are still verifying our methodology of extracting powers from the NIMS data, so these are preliminary results. We anticipate presenting our final results at the conference.

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