TEMPERATURES OF VENTS WITHIN ENCELADUS' TIGER STRIPES. O. Abramov[1], D. Raggio[2], P.M. Schenk[3], and J.R. Spencer[4], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Dr., Flagstaff, AZ 86001 (*oabramov@usgs.gov*), [2]Dept. of Physics & Astronomy, Northern Arizona University, 602 S. Humphreys Dr., Flagstaff AZ 86011, [3]Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston, TX 77058, [4]Southwest Research Institute, 1050 Walnut St., Suite 300, Boulder, CO 80302.

Introduction: The south polar region of Enceladus consists of young, tectonically deformed terrain dominated by four roughly parallel, ~2-km wide linear depressions dubbed "tiger stripes" [e.g., 1]. Observations by multiple instruments on the Cassini spacecraft describe anomalously high heat fluxes associated with these tiger stripes [e.g., 2], along with active plumes of water vapor and ice particles that originate from them [e.g., 3]. Several explanations for the observed elevated temperatures and the resulting plume have been proposed, including venting from a subsurface reservoir of liquid water [e.g., 1], sublimation of surface ice [e.g., 2], decompression and dissociation of clathrates [e.g., 4], and shear heating [e.g., 5]. These mechanisms predict a range of vent temperatures: ~140 K for clathrate decompression [4], >180 K for sublimation of H_2O [2], and up to 273 K for the shallow reservoir of liquid water [1]. In addition, constraining the width of the crack may further elucidate the mechanism: subsurface ice melting is likely unless the crack width is greater than ~10 cm [6].

The present work builds on the foundation established by [7], which sought to elucidate the underlying physical mechanism by constraining vent temperatures and widths, using a model in which the observed thermal signature results primarily from conductive heating of the surface by warm subsurface fractures, or vents. The present work involves: (i) making improvements to the model, as outlined below, and (ii) applying the model to new Cassini Composite Infra-Red Spectrometer (CIRS) tiger stripe spectra, which represents up to an order of magnitude improvement in spatial resolution over the data sets used in [7], as well as a greatly improved signal-to-noise ratio.

Methods: The basic steady-state thermal model that forms the basis of this work was published in [7], and included two free parameters: fracture temperature and fracture width. The parameters of the new model include (i) the temperature of the vent, (ii) the number of vents within a tiger stripe – multiple parallel fractures have been observed in high spectral resolution ISS images to lie within regions of the plume sources, (iii) the width of each individual vent, (iv) surface topography (Fig. 1) and spacecraft observational geometry. The new model rapidly explores parameter space by automatically generating temperature distributions in and around tiger stripes based on specified constraints, acquiring synthetic CIRS spectra of the model surfaces, and comparing them to CIRS observations using statistical methods.

Topography of tiger stripes was constrained using stereo and photoclinometry products derived from the Cassini ISS images of Damascus Sulcus and Baghdad Sulcus (Fig. 1). Numerious cross-sectional profiles were collected and averaged to generate an idealized tiger stripe topographic profile shown in Fig. 2.

Temperature distributions around tiger stripes on Enceladus are modeled in two dimensions using HEATING 7.3, a multidimensional, finite-difference heat conduction code developed at Oak Ridge National Laboratory [8]. The model includes heat transfer by conduction in the subsurface from a vertical fracture held at constant temperature, and by radiation at the surface. Cassini ISS [e.g., 1] and VIMS observations [e.g., 9], as well as thermal modeling [7], suggest coarse-grained crystalline water ice near the tiger stripes, perhaps due to sintering of surface grains by vapor condensed from the plumes. The HEATING library provides temperature-dependent thermophysical parameters appropriate for this material over the full range of temperatures in the model. Emissivity of fresh water ice ranges from ~0.94 to over 0.99 at the wavelengths of interest, and is incorporated into the model. The bottom and right boundaries are insulating, and heat is lost by radiation through the upper boundary, which is radiatively heated to an equilibrium temperature constrained by Cassini CIRS.

Results: A statistical analysis was used to compare model spectra to a combined FP3/FP4 CIRS observation of Damascus Sulcus, acquired during the August 2010 flyby. The automated parameter exploration, including the number of fractures, fracture temperature, and fracture width, was mapped in chi-squared space to visualize trends. Temperatures of the vents were varied from 170 K to 273 K in increments of 1 K; number of vents was varied from 1 to 6; and vent widths were varied from 0 to 20 m in increments of 1 cm. The best model match to data occur at vent temperatures of 175-200 K, multiple fractures within the tiger stripe, and vent widths under 20 m. These moderate temperatures do not necessitate invoking near-surface liquid water, and do not rule out shear heating as a potential heat source, although they are too high for clathrate decompression. This result is also in good agreement with a temperature of 197 ± 20 K and a width of 9 m derived from an April 2012 VIMS observation of Baghdad Sulcus [10].

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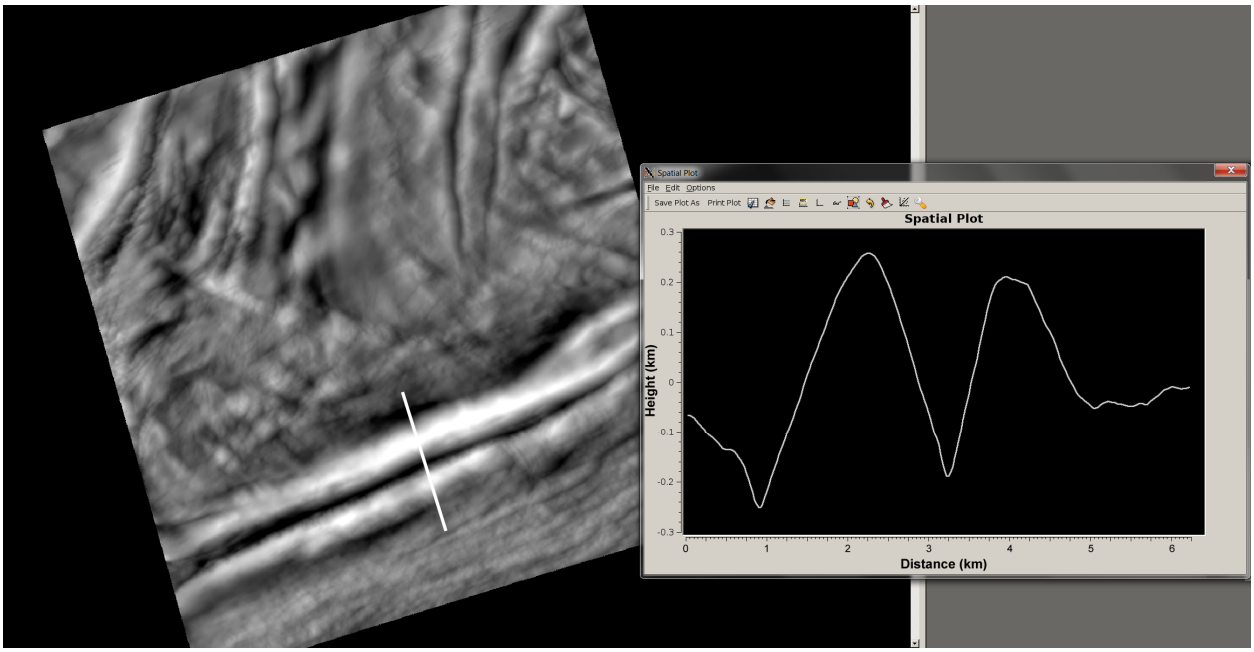

Fig. 1. (left) Topographic map of part of Damascus Sulcus, produced using stereo and photoclinometry techniques utilizing Cassini ISS images from the August 2008 flyby, acquired at 12 to 30 m/pixel. Lighter shades represent higher elevations, darker shades represent lower elevations. (right) Cross-sectional topographic profile across the tiger stripe.

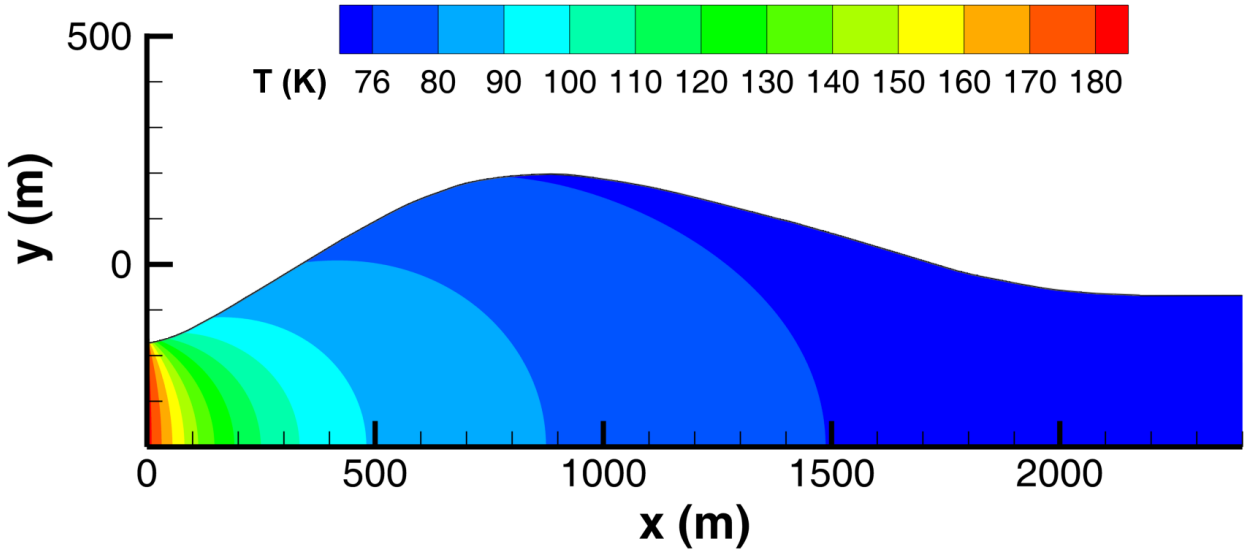

Fig. 2 Model temperature distribution at an idealized tiger stripe, showing temperature vs height (*y*) and distance from the warm fracture (*x*) for a fracture temperature of 185 K. The surface temperature distribution, including the contribution from the identical temperature distribution on the other side of the fracture, is used to generate a model CIRS spectrum, which is then compared to the actual CIRS data. This plot shows approximately the surface that would be sampled by a CIRS footprint centered on the fracture—the full model dimensions are 40 km in the horizontal and 10 km in the vertical.

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