Tidal Control of Eruptions on Enceladus. T. A. Hurford[1], P. Helfenstein[2], G.V. Hoppa[3], R. Greenberg[4] and B. G. Bills[1,5], [1]Planetary Geodynamics Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA. [2]CRSR, Cornell University, Ithaca, NY 14853, USA. [3]Raytheon, Woburn, MA 01801, USA. [4]Department of Planetary Science, University of Arizona, Tucson, AZ 85721, USA. [5]Institute for Geophysics and Planetary Physics, Scripps Institution of Oceanography, La Jolla, CA 92093, USA.

Introduction: Enceladus is a small moon that Saturn every 1.37 days at an average distance of about 238,000 km, between Mimas and Tethys. Due to its proximity to Saturn, tidal dissipation should have quickly circularized the orbit. However, a 2:1 mean motion resonance with Dione, which orbits just beyond Tethys, and is ~15 times more massive than Enceladus, excites the orbital eccentricity, maintaining its value at the currently observed 0.0047.

In 2005, Cassini's Imaging Science Subsystem (ISS) detected plumes near Enceladus' South Pole in three high-phase (rear illumination) images [1]. Triangulation of the plumes places their sources near the South Pole where the terrain is dominated by a series of youthful-looking parallel rifts called, "tiger stripes" (Fig. 1) [1]. The Composite Infrared Spectrometer (CIRS) showed that the "tiger stripe" features are significantly warmer than the surrounding terrain [2] and are thus considered likely sources of the plumes [1,2].

Tides and Plumes on Enceladus: Saturn creates a substantial tide-raising potential throughout Enceladus, distorting the body. The exact size of the tide raised at the surface is dependent on the physical properties of Enceladus' interior structure. However, even if Enceladus' bulk properties tend to resist deformation, its low surface gravity would still result in a sizable tide. A conservative estimate of the height of the primary tide is 500 m.

Enceladus' finite eccentricity causes daily oscillations in the magnitude and location of the tidal bulge, producing patterns of stresses on its surface similar to those studied on Europa [3,4,5]. The state of stress at each point on the surface cyclically changes as the tidal shape of the body changes. Over Enceladus' orbital period, horizontal stresses resolved across the tiger stripes alternate from compressive to tensile, perhaps allowing the faults to open at some point in the orbit, and expose a subsurface volatile reservoir of liquid water or clathrate [6], creating an eruption. Then, within a few hours, once again the stress becomes compressive, forcing cracks to close, ending any possibility of an eruption until the next cycle. To test the hypothesis that observed eruption plumes come from these cracks, we have analyzed the stresses along each tiger stripe rift to check whether any of the features were under tension during the observations.

The three observing sequences (January, February, and November) showed plume activity at different locations in Enceladus' orbit. During the January observation, Enceladus was about an eighth of an orbit past apocenter. 46% of the total tiger stripe length was in tension during the hour-long imaging sequence (Fig. 2a). An additional ~1% (between 225^o and 45^o longitude) began under tension and switched to compression over the hour. During this part of the orbit, the rifts were in the process of closing as the stresses in the region become compressive.

At the start of the February (Fig. 2b) observations, taken at about at an eighth of an orbit before pericenter, only 16% of the tiger stripes remained in tension and again ~1% switched to tension over the next hour. One would expect that the plumes in the February detection might be similar to the plumes in January.

Finally, during the November observation sequence, taken near apocenter (Fig. 2c), 82% of the tiger stripes experienced tension during the intire imaging sequence and 7% switched from compression to tension. The viewing geometry makes it difficult to determine exactly which tiger stripes are active in the image. However, large portions of the system are in tension allowing multiple discrete sources to erupt as seen in the observations.

A Cassini imaging sequence planned for a 1.5 hour period on 24 April 2007 took place, while Enceladus is about one fifth of an orbit past pericenter. We find that during this time 57% of the tiger stripes will be in tension. Similar to the November 2005 observations, a significant portion (6%) of the features will be in the process of opening up during the upcoming observing sequence, as the tension across them changes from compression to tension (Fig. 2d). Thus, this observational sequence could reveal an especially active phase.

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Stress. *Icarus* **141**, 287 (1999). [5] Hurford, T. A. Tides and Tidal Stress: Applications to Europa. Ph.D. Thesis, The University of Arizona (2005). [6] Kieffer, S. *et al*., *Science* **314**, 1764-1766, (2006). [7] Roatsch, T., et al. High Resolution Enceladus Atlas derived from Cassini-ISS images. submitted to *Planetary and Space Sciences* (2006).

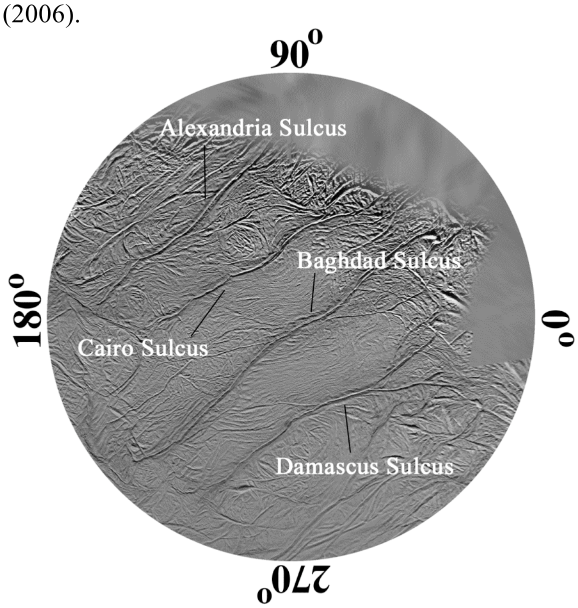
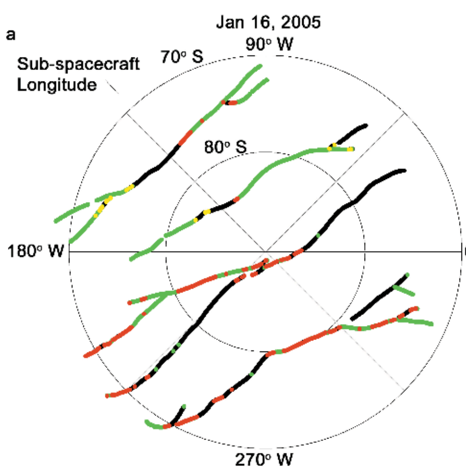


Fig. 1. The south polar region, from a high resolution atlas of Enceladus by Roatsch *et al*. [7], is shown from 65°S poleward.



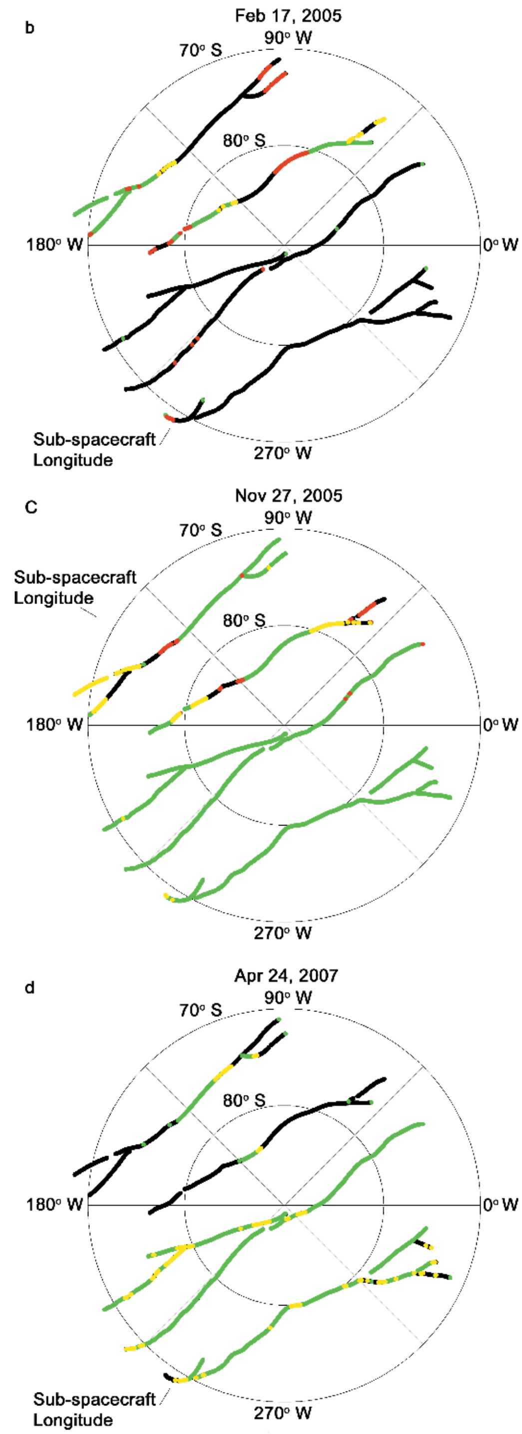


Fig. 2. The stress state across the faults is shown during each observation sequence (a-c), along with the predicted state during the planned April 2007 observation (d). Along each tiger stripe, the color indicates its stress state. Black means that portion of the feature was in compression during the entire imaging sequence while green means that it was in tension. Yellow indicates that the stress normal to the feature switched from compression to tension, opening the rift during the imaging sequence and red indicates that the stress normal to the feature switched from tension to compression.