Observational and Theoretical Limits on Present-Day Cryovolcanic Activity on Titan with application to Planetary Protection

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The search for evidence of recent and present-day cryovolcanic activity on Titan continues. While a positive detection would be of extraordinary interest in its own right, the nondetection is also significant. Should areas of present-day activity be found, they may need to be designated as special regions for planetary protection purposes, in that they would constitute microenvironments where terrestrial biota conveyed on a spacecraft might inoculate bodies of liquid water. It is thus important in planning future missions to Titan to consider what constraints the current and planned Cassini observational coverage may place on the existence of such regions.

With reasonable assumptions, a recent cryolava flow with thin enough ice cover to constitute a special region (i.e. thin enough for an impacting spacecraft could break through) can be equated with an area with a given surface temperature. This can be estimated by equating the conductive heat flow through the ice lid to the convective loss to the atmosphere (radiation loss is negligible at these temperatures) and would be 5-25K above ambient, using convective heat transfer coefficients estimated from the cool-down of the Huygens probe. Such warm surfaces could be detectable in Radar radiometry and in thermal IR measurements. The radiometric resolution of the RADAR radiometer and CIRS instruments is of the order of 1K and thus temperature anomalies filling a significant fraction of the beam footprint (typically tens to hundreds of km across) would be detectable. In practice, emissivity variations raise the radar radiometry threshold by a factor of a few, so we adopt the footprint size as a convenient feature scale. To date about a third of Titan has been observed with close RADAR observations (20-80km resolution) and nearly all of it at 200km resolution. Bayesian calculations, combined with lava spreading and cooling models could be employed to derive a probabilistic constraint on smaller regions of interest.

A tighter theoretical 'constraint' can be derived from the expected geothermal heat flow (6 mW per m2). If (as on Earth) a tenth of this is expressed as latent heat in magma, and noting from the calculation above that a region of interest cools at 50 W per m2, an a priori estimate emerges that less than 1E-5 of Titan's surface (i.e. 1000km2) should be covered in such areas. Some additional information (e.g. from geological interpretation) would be required to revise such an estimate upwards to the level (1E-4) of concern for planetary protection.