SUBLIMATION RATES IN ICY CRATERS, TRENCHES, AND CREVASSES ON COMETS; J.E. Colwell, B.M. Jakosky, and B.J. Sandor, Laboratory for Atmospheric and Space Physics, University of Colorado, Boulder, CO 80309-0392

Numerical models of the temperature distribution inside topographical features (e.g. Adorjan 1970, Hansen 1977, Colwell and Jakosky 1987, and Spencer 1987) have shown that temperatures inside craters may become enhanced above that of the surrounding terrain. Colwell and Jakosky (1987) solved the energy balance equation for an infinite cylindrical trench of water ice and found that the sublimation rate inside such a trench could be significantly enhanced over that of a planar surface. Their study was limited to only one geometry and to low-albedo water-ice surfaces. In this extension of that work, we solve the energy balance equation for a spherical crater and for two additional trench shapes. We have extended the model to include multiple reflections off the walls of the concavity, thus allowing high-albedo surfaces to be modeled more realistically.

We solve the new energy balance equation for the temperatures in cylindrical trenches, spherical craters, and V-shaped crevasses. We include the trapping of thermal IR radiation of the cavity walls, sticking of molecules striking other points in the cavity rather than escaping to space, shadowing, and reflection of sunlight. This yields the temperature at all points in the cavity for several times of day, with the feature assumed to lie on the equator. The sublimation rates reported in Colwell and Jakosky (1987) were gross sublimation rates calculated directly from the equilibrium temperature of the cavity. We now calculate a net sublimation rate which is the gross sublimation rate minus the rate of sticking of molecules sublimed from other points in the cavity. Calculated in this way, the sublimation rates for the cylindrical trench are somewhat less than those reported in Colwell and Jakosky (1987). For hemispherical trenches close to the sun ($R<2$ AU), the bottom of the feature has a lower net sublimation rate than a plane surface. Thus, as the topography grows it will reach a cutoff stage where the sublimation rate inside the feature is roughly equal to that outside the feature, and it will cease to grow.

For spherical craters we solve the energy balance equation with opening angles of 15, 45, and 90° using the geometry of Hansen (1977). The craters are assumed to lie on the equator of the comet, so the east and west rims receive more insolation than the north and south rims. For an albedo of 0.1, the net sublimation rate at the bottom of all craters is less than the surroundings for $R<2$ AU. There is a tradeoff between thermal focusing and particle trapping that depends sensitively on distance from the sun, crater opening angle, and albedo. Shallow craters have less ability to trap radiation and so are not much warmer than a planar surface. Sticking of molecules travelling from one wall to another lowers the net sublimation rate to below that of the surroundings by a few percent, however. This does not occur in the trench case because there is less trapping of sublimed molecules. The relative sublimation rate is lower closer to the sun because there the trapping of sublimed molecules is more important than thermal radiation.

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In some cases the net sublimation rates of some points on the crater (near the north and south rims) are negative. The sticking of molecules from other, more-active points in the crater is greater than the sublimation of molecules from the relatively cool north and south rims. This implies that as the crater evolves there will be a net transfer of mass from the east and west rims to the north and south rims and the crater will elongate. A crater north of the equator will have its north rim receive more energy than the south rim, and there will be a net transfer of mass from the north to the south and the crater would deform towards the pole. This mechanism would also shut off once the increased shadowing shut off the thermal focusing. The effect of a precessing pole or a scattering coma would be to provide insolation to all points in the feature more equally, and there would be a simple growth in depth and size of the crater or trench.

A V-shaped crevasse shows no enhancement of sublimation rate at an albedo of 0.1. For this shape, the shadowing is more important than the thermal focusing. The walls of the crevasse always receive sunlight at high zenith angles. Also, a point on one wall receives secondary energy only from the far wall. Thus, there is much less trapping of energy in the crevasse than in the trench or the crater, and the sublimation rate is correspondingly lower. Crevasses may have relatively high sublimation rates due to the presence of bright, dirt-free volatiles, but there is no enhancement due to thermal focusing.

The evolution of concave features on a comet due to sublimation is seen to depend sensitively on the shape of the feature, solar distance, surface albedo, and the orientation with respect to the Sun's path. Craters may diminish in size if close to the sun. Here, however, there may be a significant coma which would make all points in the crater receive direct insolation. This would cause the thermal focusing to play a role and may cause the feature to grow. Cylindrical trenches tend to become deeper with steeper walls up to some cutoff shape, while focusing does not enhance the sublimation rate of crevasses beyond that of a plane surface.

Depending on the conditions (albedo, solar distance, crater depth, etc.) there may be significant enhancement of sublimation rates in trenches and craters due to thermal focusing. This mechanism may play a role in the formation of jets and the splitting of comet nuclei.

References:
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