THE EFFECT OF SURFACE THERMOPHYSICS ON TEMPERATURES AT EUROPA.

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Introduction: Europa, the Jovian moon, is completely covered by water ice of spatially varying thickness (~1 - 5 km) [1]. However, it is believed that beneath its ice lies the largest liquid water ocean in the solar system, covering the entire surface of the moon. Additionally, plumes of water from this subsurface ocean have been observed to erupt at a range of latitudes, potentially providing further evidence that subsurface temperatures are conducive to liquid water [2]. We chose to investigate the variation of surface temperatures on Europa in preparation of the arrival of the E-THEMIS thermal imaging instrument aboard Europa Clipper [4], scheduled to launch by 2025.

Methods: To observe the optimal parameters for the warmest feasible surface temperatures on Europa, we used Davinci (http://davinci.asu.edu) to call KRC, a one-dimensional planetary thermal model [5] to model temperatures at the surface of Europa. Since the thermophysical properties are not certain at small scales at this time, we varied the thermal inertia and albedo for different latitudes, local solar time and time of year to characterize surface temperatures. All model results use an emissivity of one, although variations in surface emissivity are to be expected, but are currently poorly characterized.

Results: As expected, the darker streaks seen near the equator on Europa [3] can be significantly warmer (up to ~35 K at peak insolation) than locations at higher latitudes although the observation of plumes of water (perhaps indicating 'hot spots') have been observed above 45° latitude. Peak temperatures occur at a local solar time of 15 at all non-polar latitudes.

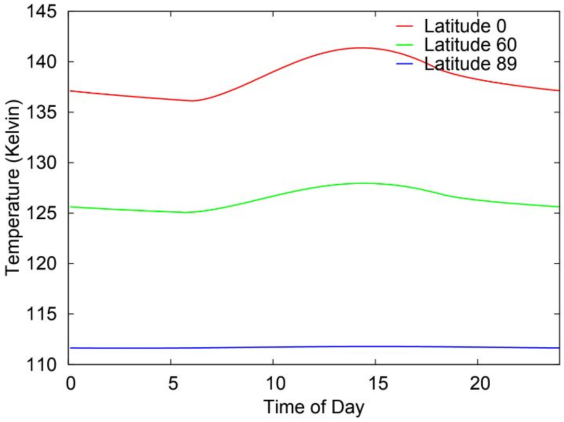

Figure 1. *Modeled surface temperatures at 0° latitude and 1000* $J\ m^{-2}\ K^{-1}\ s^{-0.5}$ *, at a local solar time of 15 at Ls = 100 and albedo of 0.6.*

Temperature is inversely proportional to thermal inertia on Europa; note that the thermal inertia values used here encompass the range of solid water ice (~2000 $J\ m^{-2}\ K^{-1}\ s^{-0.5}$) although thermal inertia values determined from relatively coarse resolution (80 – 200 km) Galileo data indicate significantly lower values, suggesting a particulate surface [6] that is perhaps formed by the recrystallization of ejected plume water.

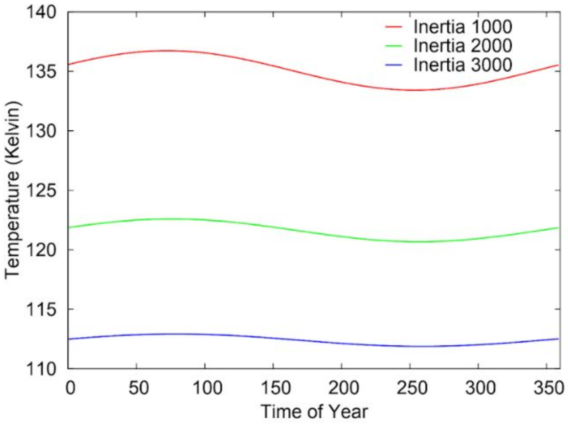

Figure 2. *Modeled surface temperatures at 0° latitude, for a local solar time of 15, an albedo of 0.6 for varying thermal inertia values.*

Temperatures do not vary tremendously throughout the year due to Europa's orbital parameters. As expected, the lowest albedo corresponds to the highest surface temperatures, with surfaces of intermediate albedo (~0.6; similar to those observed from Galileo observations [6]) show little variation.

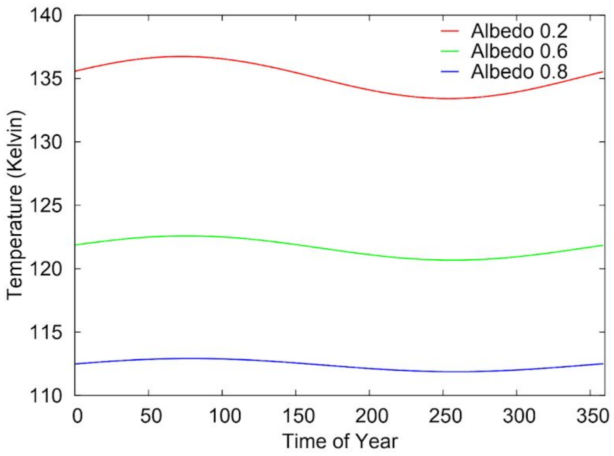

Figure 3. *Modeled surface temperatures over the course of a year, at 0° latitude and 1000* $J\ m^{-2}\ K^{-1}\ s^{-0.5}$*, a local solar time of 15, and a range of albedos.*

Discussion: Differences in modeled surface temperature results shown here from past observations are primarily due to the use of a significantly higher thermal inertia for the surface that is closer to that of water ice, as is expected for the surface of Europa. Discrepancies in the Galileo-derived thermal inertia values [6] and that of solid water ice could be due to the relatively coarse resolution of the measurements. E-THEMIS will help resolve these discrepancies by providing an improvement in spatial resolution by a factor of 10, perhaps highlighting small-scale heterogeneities in thermophysical properties as is observed on Mars (e.g. [7]). It is also important to note that higher modeled temperatures at low albedo regions could perhaps be due to the presence of surficial regolith materials and may not be indicative of pure swathes of water ice at the surface.

The grain size of the surface ice can provide indications on ice age and surface conditions. However, the grain size of the ice at Europa's surface is difficult to determine accurately with current data, and has been estimated to vary between ~50 – 1000 µm [8]. Large ice grain sizes can be difficult to produce by thermal metamorphism at these low temperatures, even if the surface is upturned on 10^7 year timescales [1]. It has been hypothesized that sputtering could cause the formation of large 1000 µm-sized ice grains [8, 9].

Due to the moon's elliptical orbit and resulting varying distances from its planet, it experiences Jupiter's gravity more strongly on its near side. As Europa orbits, the magnitude of the difference in gravity applied to both sides of the moon varies, which creates tides that cause the moon's surface to expand and contract.

Implications for Potential Life: Lake Vostok, a subsurface lake beneath Antarctica (the largest lake on Earth in terms of size and volume) contains traces of life, which consist mostly of bacteria and fungi [10]. The lake has been sealed by ice for ~15 million years, not receiving any sunlight or circulation of oxygen. Despite these harsh conditions, extremophiles on the order of ~10^4 cells/mL have managed to survive there [10]. If that is the case, we might ask, can life similar to that seen in Vostok form on Europa? The variation of tidal forces, coupled with a possible radiation-driven energy system [11] could perhaps lead to conditions conducive to microbial life in the subsurface ocean, similar to those found in Lake Vostok on Earth. The upcoming Europa Clipper will hopefully shed light on this enigmatic Jovian moon and further our understanding of its surface and subsurface.

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