THERMAL EMISSIVITIES' RELATIONSHIP TO METEOR ABLATION.

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Introduction: Most meteors bombarding Earth are small and burning up in the atmosphere. A few are large enough to survive entry and cause notable damage. The combination of ablation and fracturing means most meteorites lose greater than 80% of their mass during entry [1]. Ablation rate models require a meteorites emissivity as an input [2,3,4], which has a direct input in the time it takes for a surface material to reach melt conditions. If a material has a lower emissivity at high temperatures it will increase the surface temperature and thus increase the ablation rate [5]. The nonmetals in the meteorites are poor thermal conductors with high emissivity, as temperature increases the thermal conductivity tends to increase and emissivity decrease [5].

Experimental: Thermal emissivity is measured over a broad wavelength range of 8 to 14 µm from 20°C to 1000°C. Emissivity is measured by dual laser infrared thermometers. Emissivity values for up to atmospheric entry temperatures are needed for modeling material response of meteor entry. Surface temperature simulations are performed with the Icarus material response solver, which is a fully implicit, parallel finite volume code, and a 1D grid that represents the stagnation point on the surface of a large meteoroid. Surface is treated with an aerothermal boundary condition using the typical assumption of radiative equilibrium.

Results: Elevated temperatures cause a fluctuation in the emissivity of the different meteorite classes [6]. As temperature increases to 100°C the emissivity decreases then rebounds and stabilizes for the next 100° C. Lowest emissivity for all stony meteorites is between 300-350°C, values below 0.90. Average heated chondrites range in emissivity between 0.85-0.95 between 100°C to 1000°C temperature range. Iron meteorites have a drastically different emissivity profile as a function of temperature with a rapid 0.5 drop in the emissivity in the first 100°C and not rebounding till after 300°C. This different profile is caused by the phase transitions in kamacite as heated.

Material response simulations of surface heating during entry may be performed. To evaluate the influence of the temperature-dependent, solid optical properties on entry, the preheating stage of the meteor is evaluated. In the iron meteorite (Fig. 1A) simulation using heritage values result in the surface temperature reaching the melting point within 0.2 s of entry, while the present work values leads to the time to surface melted being cut in half. The reduction in the time to melt is a result of the 0.5 increase in emissivity of the Sikhote-Alin sample above 300°C. The simulation for Tamdakht (H5) (Fig. 1B) reaches melted surface within 0.02s from heritage dataset and 0.018s for present work. Both heritage and present work for Jbilet Winselwan (CM) (Fig. 1C) time to surface melted in 0.02s.

Conclusion: The emissivity profile of stony meteorites as temperature increases is similar up to 600°C, after that CM chondrites emissivity decreases while other stony meteorites remain flat. Iron meteorites have a different emissivity profile caused by the phase changes in kamacite. Simulation results show time to meteor surface melt conditions has minimal dependence on ordinary and carbonaceous chondrite. Changing thermal emissivity has a major affect on time to surface being melted for iron meteors by cutting time in half to 0.1 second. Time to melt is slower for iron meteorites compared to chondrites because of iron meteorites higher thermal conductivity, which leads to rapid transport of heat from surface into interior.

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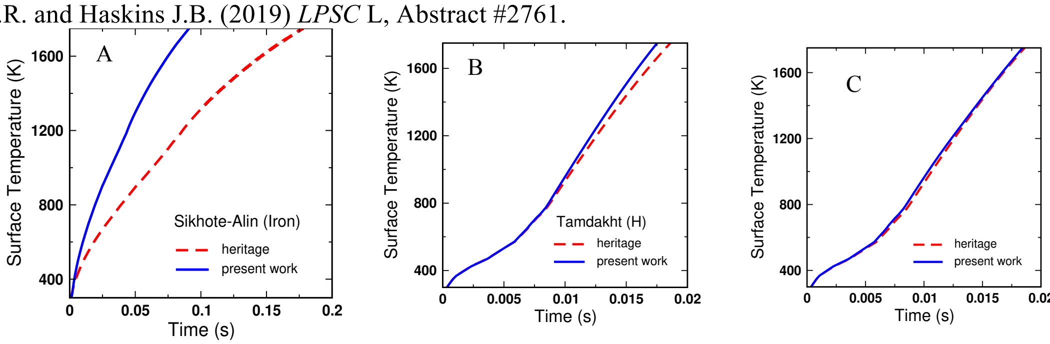

Figure 1: Material response modeling of the surface temperature of (A) Sikhote-Alin (IIAB), (B) Tamdakht (H5), and (C) Jbilet Winselwan (CM). Heritage results based on class average optical properties evaluated at 20° C tem-peratures. Present work takes into account fluctuating emissivity as temperature increases.