THERMAL RADIATION FROM ATMOSPHERIC REENTRY OF CHICXULUB EJECTA. T. J. Goldin[1] and H. J. Melosh[2], [1]Department of Geosciences, University of Arizona, Tucson, Arizona USA 85721 (tgoldin@email.arizona.edu), [2]Lunar and Planetary Lab, University of Arizona, Tucson, Arizona USA 85721 (jmelosh@lpl.arizona.edu).

Introduction: The discovery of soot within the K/T boundary sequence [1] led to the hypothesis that thermal radiation from the atmospheric reentry of hypervelocity impact ejecta was sufficient to ignite global wildfires. Survival patterns of terrestrial organisms at the K/Pg boundary are also consistent with a thermal radiation pulse contributing to the biological catastrophe following Chicxulub [2]. Calculations of the expected thermal radiation at the ground support this claim [3, 4]. Here we present modeling work which includes a more accurate treatment of thermal radiation than previously considered. Using the KFIX-LPL code we are able to model the atmospheric reentry of distal Chicxulub ejecta and calculate the transmission of thermal radiation, both throughout the atmosphere and through time.

Numerical Modeling: We model the interactions between distal Chicxulub ejecta spherules and the atmosphere using the two-dimensional, two-phase fluid flow code KFIX-LPL, which has been modified from KFIX [5] to suit the problem of ejecta atmospheric reentry and subsequent sedimentation through the atmosphere onto the Earth's surface. Because most of the high speed deceleration of spherules occurs in the upper atmosphere where the concentration of air molecules is small, we have incorporated drag coefficient and heat transfer functions [6] into KFIX-LPL which are accurate within the required range of free molecular to normal Stoke's flow. In addition we have implemented a full treatment of thermal radiation, which includes the effects of optical opacity. This allows us to examine what effects opacity of the spherules themselves has on the transfer of thermal radiation to the ground.

The initial mesh approximates a 150-km-high slice of the Earth's atmosphere into the top of which 250-μm spherules are injected. The spherules are modeled as a simple incompressible fluid with the properties of basaltic glass and enter our model atmosphere at 8 km/s with a flux based on previous calculations of atmospheric reentry of Chicxulub ejecta [3] and the spherule mass density observed on the ground of 0.5 g/cm^2 [7].

The spherules fall through the thin upper atmosphere, compressing the air as they decelerate. At 70 km in altitude, the spherules accumulate in a band of particles which becomes denser with time. Despite having lost their initial high velocities, the spherules continue to settle downwards at their fall velocities and begin to deposit on the ground after a few hours.

Thermal Radiation: The deceleration of spherules from hypervelocities implies the conversion of a large quantity of kinetic energy. Some of this energy heats the spherules (~1000 K) and some of this energy heats the upper atmosphere (~3000 K), but both phases are kept relatively cool due to efficient loss of heat via thermal radiation. Our models calculate the flux of thermal radiation throughout the mesh assuming the lower boundary (ground) is absorptive but fixed in temperature (273 K) and the upper boundary is 100 % transmission, meaning that any radiation reaching the top of the mesh will escape (into space). We model the maximum flux of thermal radiation at the ground to be ~7 kW/m^2, coincident with the time of peak flux of spherules reentering the atmosphere. However, the thermal radiation flux at the ground rapidly decreases and is less than the normal solar constant (1.4 kW/m^2) after 25 minutes. The reason the high fluxes are not sustained is due to the increasingly opaque layer of settling spherules, which increasingly blocks the transmission of thermal radiation from the decelerating spherules in the upper atmospherer above. Hence, the spherules themselves limit the magnitude and duration of thermal radiation at the ground.

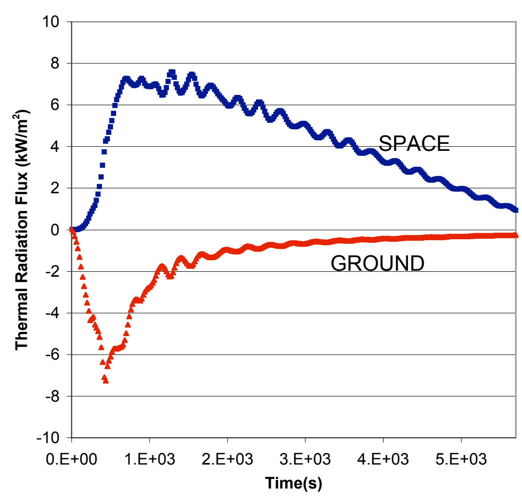

Figure 1. Vertical flux of thermal radiation as a function of time at the bottom of the mesh (red) and the top of the mesh (blue), which represent the ground and space respectively. Negative fluxes are towards the ground.

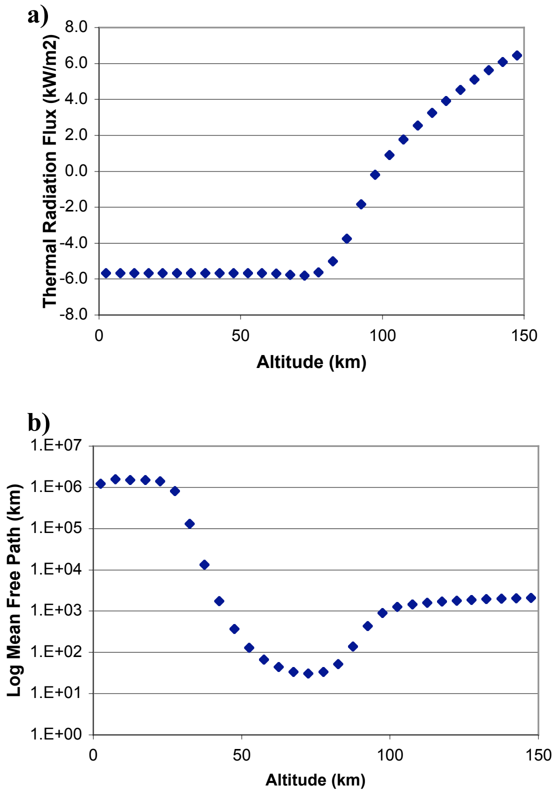

Figure 2. (a) Flux of thermal radiation as a function of altitude at the time of peak spherule reentry (600 s). Negative fluxes are towards the ground. (b) Optical mean free path as a function of altitude, also at 600 s. Shorter mean free paths indicates a higher opacity (or higher concentration of spherules at that altitude).

Discussion: Our KFIX-LPL models calculate a half-hour long pulse of high thermal radiation at the ground, peaking at ~7 kW/m^2. This is less than previous calculations [3, 4] of >10 kW/m^2 sustained over an hour or more. Previous calculations, however, did not include the effects of spherule opacity. Our model shows that, although a pulse of thermal radiation exceeding the solar norm is maintained for over an hour in the upper atmosphere where there are few spherules, the settling cloud of ejecta has sufficient opacity to limit transmission of thermal radiation to the ground. Absorption by the air will further reduce the thermal radiation reaching the ground and future models including an accurate treatment of air opacity will add further constraints.

7 kW/m^2 is analogous to an oven set on "broil" and there are mechanisms by which the thermal radiation experienced on the Earth's surface may be even more severe. A non-uniform distribution of spherule reentry may produce gaps in the opaque spherule layer through which the downward thermal radiation may be concentrated. Our current model also only considers the 250-µm spherules, not the unknown quantity of fine dust particles which are thought to have also been injected into the upper atmosphere from the expanding impact plume. An opaque cloud of dust in the upper atmosphere would act to reflect some of the space-bound thermal radiation downwards.

References: [1] Wolbach W. S. et al. (1988) *Nature*, 334:665-669. [2] Robertson D. S. et al (2004) *GSA Bulletin*, 116:760-768. [3] Melosh H. J. et al (1990) *Nature*, 343:251-253. [4] Toon O. B. et al. (1997) *Rev. Geophys.*, 35:41-78. [5] Rivard W. C. & Torrey M. D. (1977) *Los Alamos National Laboratory Report* LA-NUREG-6623. [6] Melosh H. J. & Goldin T. J. (2008) *LPSC XXXIX*, Abstract #2457. [7] Smit J. (1999) *Annu. Rev. Earth. Planet. Sci.*, 27, 75-113.