SHORT-TERM EFFECTS OF IMPACT-RELATED HEATING OF THE UPPER ATMOSPHERE. E. Pierazzo[1] and F. Sassi[2], [1] Planetary Science Inst., 1700 E. Ft. Lowell Rd., Suite 106, Tucson, AZ 85719, USA (betty@psi.edu); [2]National Center for Atmospheric Research, P.O. Box 3000, Boulder, 80307 CO, USA (sassi@ucar.edu).

Introduction. We use WACCM to investigate the effects of a strong, short heating of the upper atmosphere associated with a large impact event, like the one that occurred at the end-Cretaceous (65 Ma). After a large impact, material is ejected ballistically above the atmosphere. As it re-enters the atmosphere at high speed it heats frictionally the upper portion of the atmosphere before reaching terminal velocity. It has been proposed that the resulting infrared radiation from the heated portion of the atmosphere could have been strong enough to ignite surface biomass [1]. Evidence of soot at several K/T boundary sites (see [2], and references therein) suggests that much of the end-Cretaceous biomass was consumed by fire.

Heating from Ejecta Re-entry. Melosh et al [1] estimated the amount of heating released in the upper atmosphere by the re-entry of material ejected from a Chicxulub-size impact. Observations indicate that the Chicxulub distal ejecta layer has a fairly constant thickness around 2-4 mm [3]. Assuming a layer 4 mm thick with an average density of 2500 kg/m^3, Melosh et al. [1] estimated that the layer corresponds to about 10 kg/m^2 of material. To account for a worldwide distribution of ejecta, they assumed that all material was ejected with velocities between 5 and 10 km/s. More recent investigations indicates that even slower ejecta (<5 km/s) could be widely distributed by its interaction with a hot atmosphere [4,5], and material ejected relatively late is probably moving at velocities well below 5 km/s [6]. The total kinetic energy of ejecta moving between 2 and 10 km/s is between 1.5×10^7 and 5×10^8 J/m^2. This energy is released in the upper atmosphere upon ejecta re-entry, and occurs relatively quickly, within a few of hours after impact [1,4,5]. Assuming a 2-hour frame for the re-entry of all impact ejecta, the power released in the upper atmosphere by the Chicxulub impact event is between 2 and 70 kW/m^2. As pointed in [1] and [5] the distribution of ejecta is not globally uniform, and this estimate represents only an average value. Locations at different distances from the impact site will see either much larger or lower energy deposition.

Atmospheric Model. The Whole Atmosphere Community Climate Model (*WACCM*) [7] is a comprehensive numerical model developed to explain the relations and feedbacks between dynamics, chemistry and radiation of the middle and upper atmosphere. The numerical model is based on the National Center for Atmospheric Research (NCAR) Community Atmospheric Model (CAM). The equations of dynamcs and transport are solved by using the explicit flux-form semi-Lagrangian scheme of [8] on a horizontal grid of 2ºx2.5º (latitude by longitude). This numerical method calculates explicitely the mass fluxes in and out of a given model volume, thus ensuring mass conservation. Atmospheric dynamics and physics, and the interactive chemistry and physical parameterizations of the upper atmosphere are solved at each time step in a vertical domain that extends from the ground to about 150 km (66 levels). Its standard vertical resolution is variable, from 3.5 km above ~65 km, to 1.1 km in the lower stratosphere (<30 km) and troposphere (with much higher resolution in the planetary boundary layer). The chemistry module of WACCM is based on the 3D chemical transport Model of Ozone And Related Tracers (MOZART) [9,10,11] and includes detailed processes that describe reactions and photolytic processes in the middle and upper atmospheres. MOZART solves for 51 neutral species, including all members of the O_x, NO_x, HO_x, ClO_x, and BrO_x chemical families, along with tropospheric “source species” such as N_2O, H_2O, CH_s, chlorofluorocarbom (CFCs), etc. [12].

We have implemented in WACCM a simple module that reproduces a uniform, strong, short heating in the upper atmosphere. To take into account the initially strong pulse of re-entering material (as suggested by [1]), we use a decreasing exponential function over 2 hours (the time step of the simulation is set to 3 min). The heating is distributed vertically using a Gaussian centered at 75 km and extending from 50 to 100 km. This simplified approach does not yet include important components like variation in heating with distance from impact site, or the presence of a layer of dust in the upper atmosphere that could increase atmospheric opacity and prevent the atmosphere from of radiating part of the heat into space. Nonetheless, the results provide an indication of the magnitude of the perturbation associated with such a large and sudden energy input in the upper atmosphere.

Results. We carried out several short simulations, at most over 16 days, with heatings of 40, 50 and 70 kW/m^2. All simulations start from Jan. 1 initial conditions. Our first goal is to investigate the change in the atmosphere's thermal structure (energy balance) which, in turn, affects the atmosphere's chemical composition and photolysis rates. Figure 1 shows the change (from unperturbed conditions) in long wave (LW) heating at the surface over time for a 50 kW/m^2 heating. Positive values represent LW emission from the surface. The heating in the upper atmosphere produces a strong LW radiation to the surface (negative values means surface is heated from above). The effect appears stronger in the southern hemisphere (especially at high latitudes) where it is summer time. Overall, however, the effect does not extend beyond the first 12-15 hours after injection. The effect on atmospheric chemistry, however, appears to extend well beyond the period of heating. Figure 2 shows the change in zonally averaged ozone column, (total amount of ozone in the atmospheric column overhead) over time for a 50 kW/m^2 heating. It appears that changes of few percents occur over the duration of the simulation, but it is not clear if they will persist beyond that. Reduction of ozone in the upper atmosphere would result in an increase of damaging UV radiation reaching the lower atmosphere. Analogously, we observe a similarly delayed, significant (100%) increase of toxic NO_s in the lower troposphere.

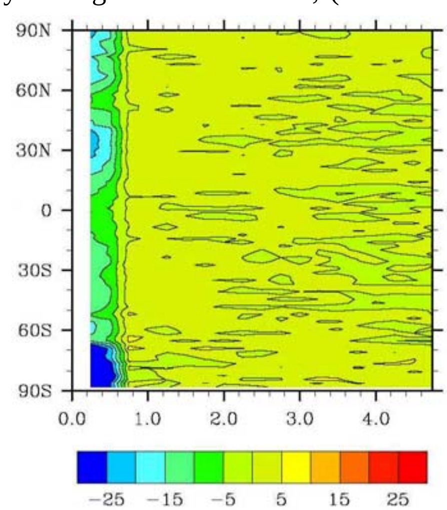

Fig. 1: Zonally averaged surface LW heating (in W/m^2) over the first 5 days after a 50 kW/m^2 heating.

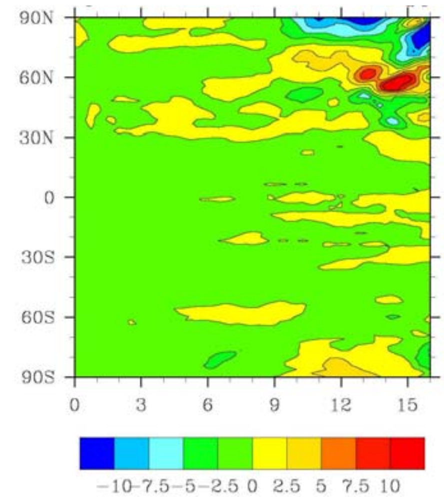

Fig. 2: Zonal average of ozone content in the atmosphere (in Dobson units) over time (days).

Changes in chemistry composition and photolysis rates affect the atmosphere's dynamical structure, with repercussions on the mean meridional circulation, including ozone distribution and production. This effect has never been investigated before and could be extremely important for understanding immediate climatic effects of a large impact.

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