Planetary Defense Conference
PROTECTING EARTH FROM ASTEROIDS

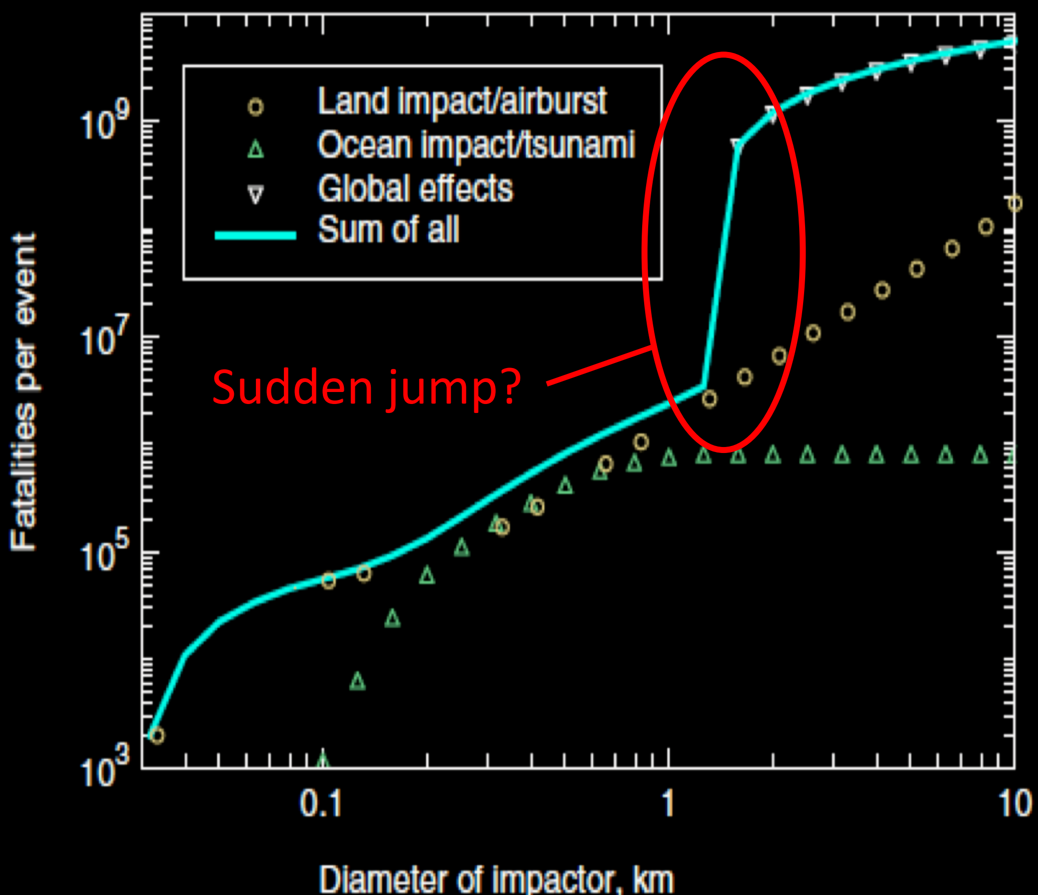
2019 IAA
Planetary Defense Conference
29 April – 3 May
Washington D.C. USA

Atmospheric Injections from Impacts of Kilometer Scale Asteroids

Darrel Robertson
Donovan Mathias
NASA Ames Research Center

Threat

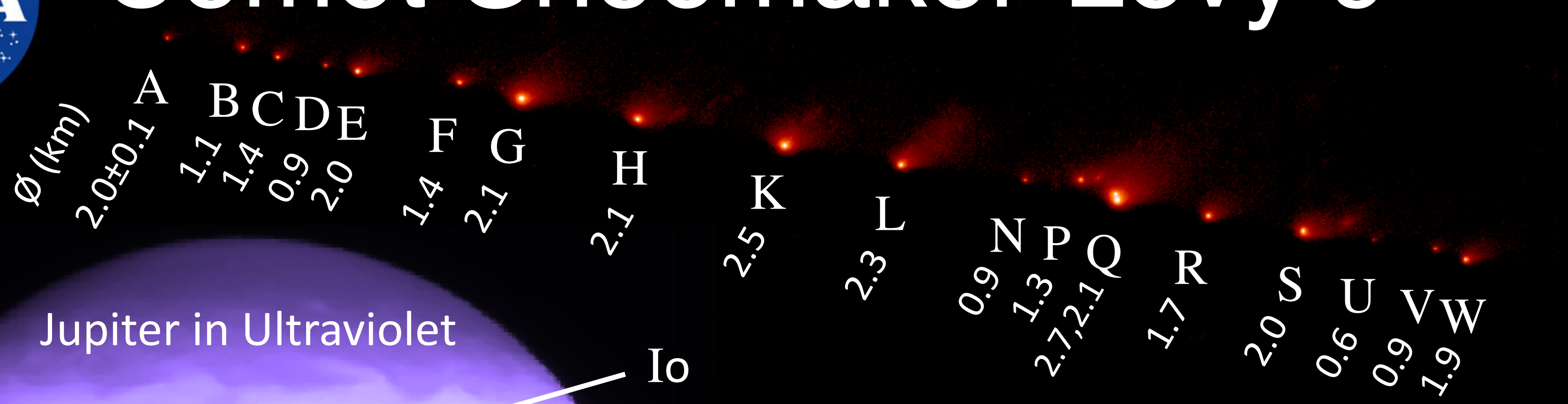
- Ø10 km asteroids cause global extinction events
- Ø300 m asteroids likely only cause localized effects
- Climatic hazard from ~Ø1 km asteroids poorly understood

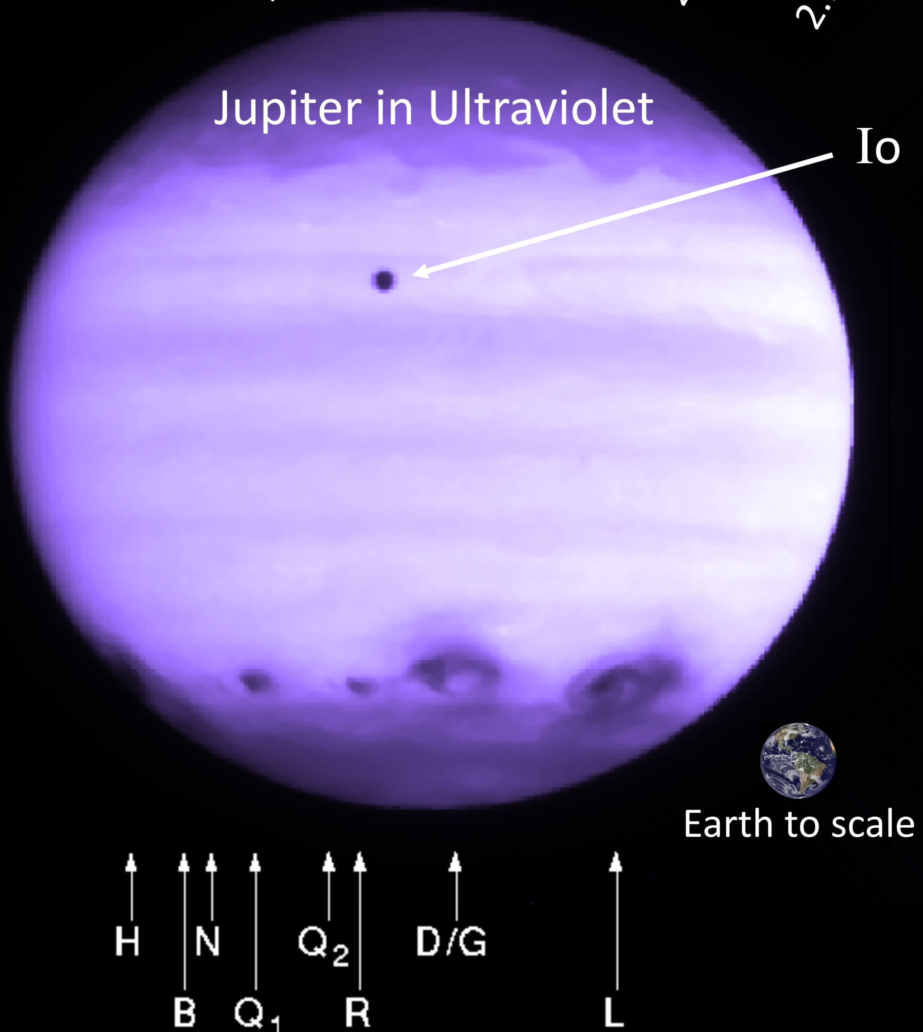


"… the true hazard represented by multi-kilometer impactors is only modestly understood at present. … little modeling has been done on the worldwide environmental effects produced by such impactors other than the one associated with the now-famous impact of an approximately 10-kilometer object 65 million years ago that apparently resulted in the extinction of the dinosaurs. More work in this area is clearly needed."

NRC 2010 - Defending Planet Earth

Comet Shoemaker-Levy 9

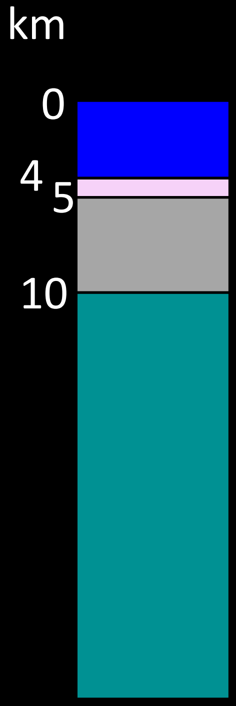


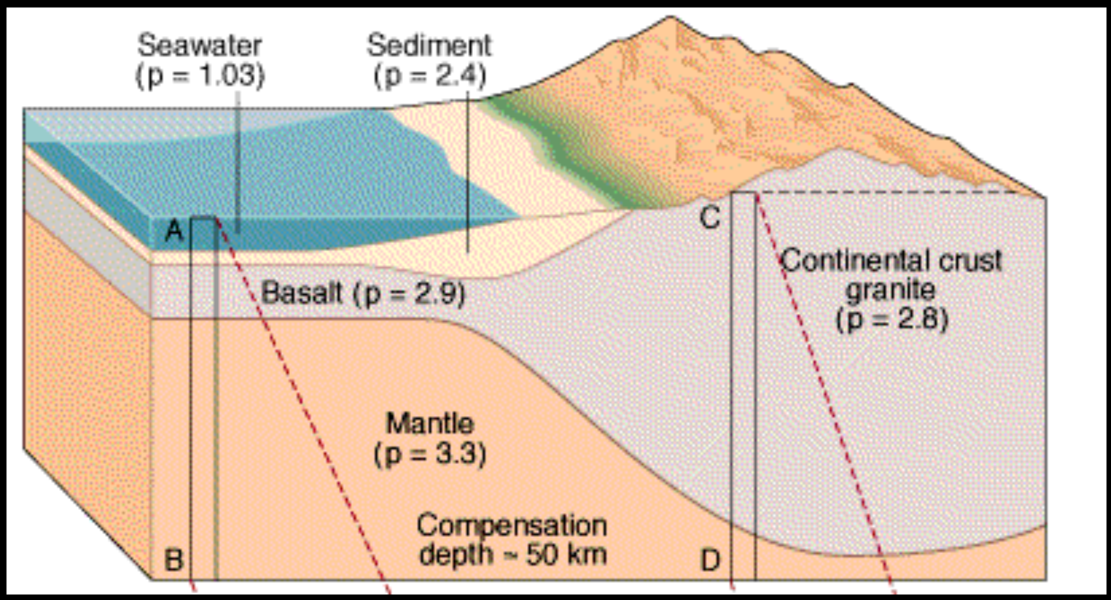


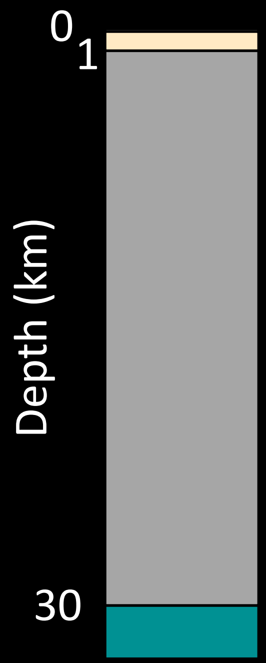
- Fragments few hundred metres to ~3km across
- Impact marks ~diameter of Earth
- Marks visible for many months
- CS_2 persisted in atmosphere >1year.

Simulations

- A couple of groups such as Toon and Pierazzo & Artemieva have coupled hydrocode models of impacts to global climate models
  - 2 km/s, 2 g/cc,
  - Ø250, 400, 630, 1000, 1600, 2500 m
  - 0.86, 3.5, 13.8, 55, 225, 860 Gt

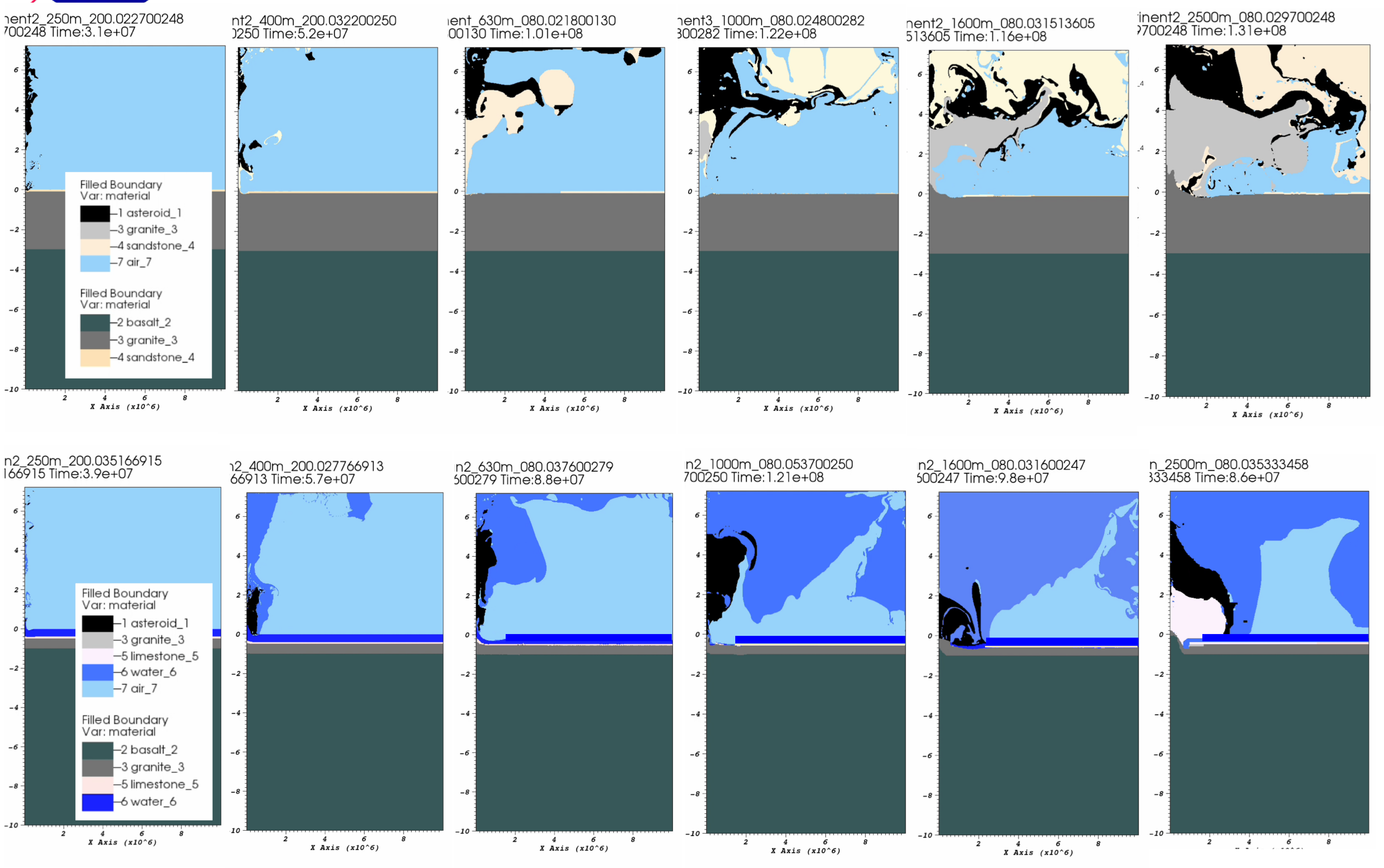






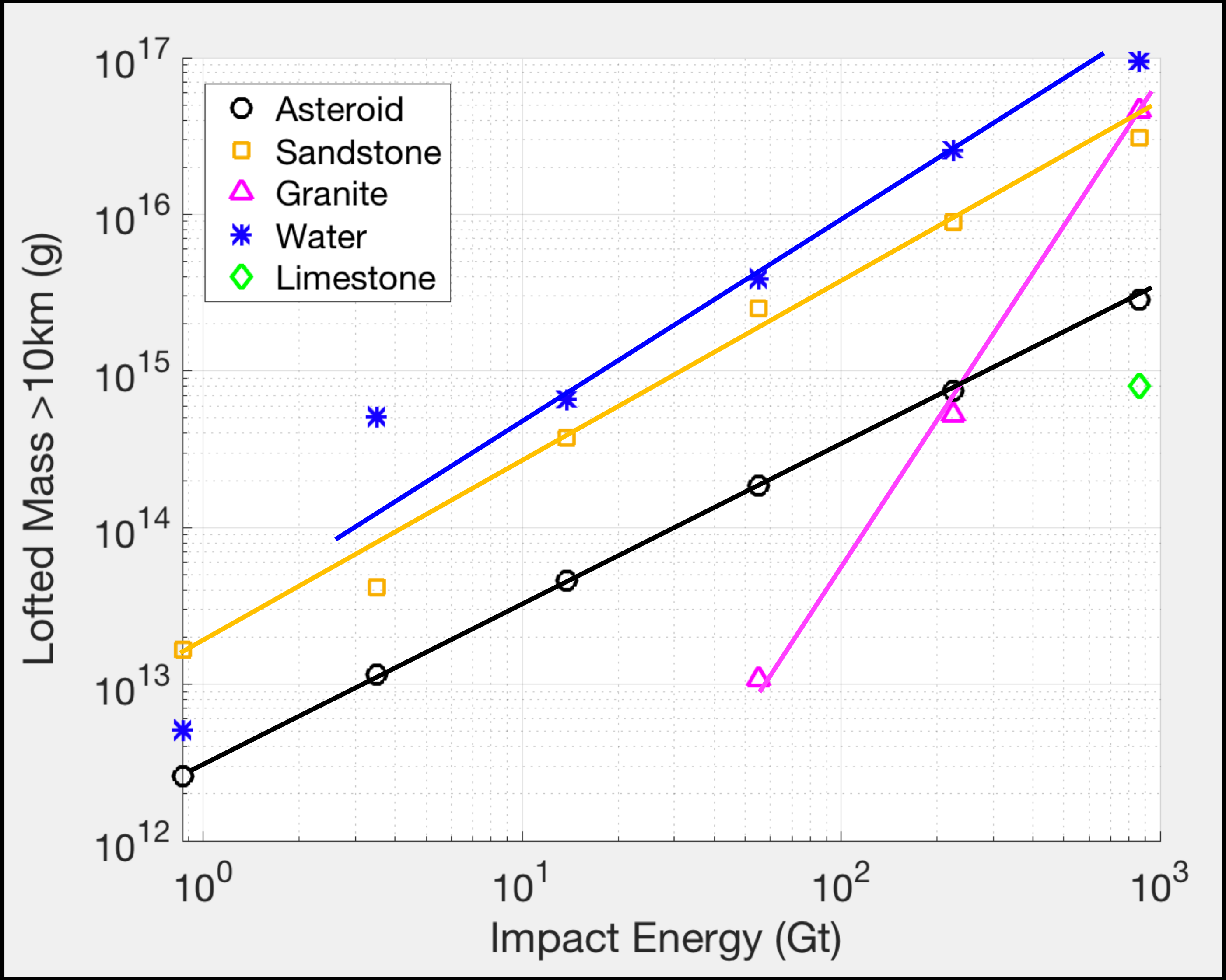
- Ocean impact 4km water, 1km limestone ($CaCO_3$), granite to 10km depth, basalt below.
- Continental impact 1km sandstone, granite (70%SiO_2, 15%Al_2O_3) to 30km depth, basalt $(Mg,Fe)SiO_4$ below

Lofted Materials



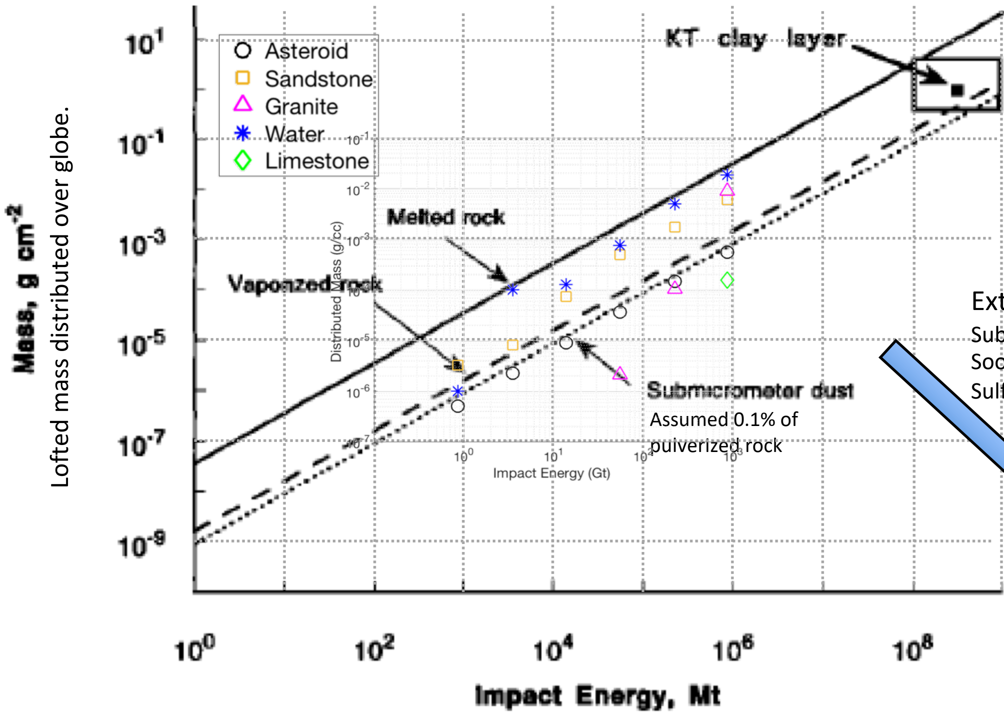
Lofted Mass

- Mass lofted above 10km altitude



Impact Winter

Toon 1997



Extinction cross-section

Submicron Dust 3×10^4 cm^2 g^{-1}

Soot 10^5 cm^2 g^{-1}

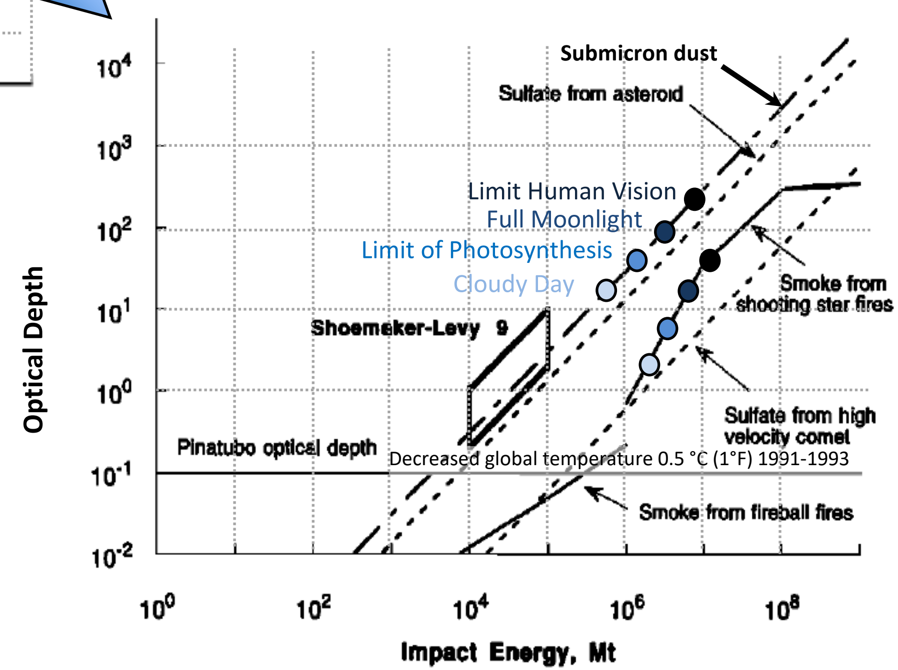
Sulfates 10^4 cm^2 g^{-1}

+

Optical Transmission

$T = Ae^{-\tau/b}$

	A	b
Dust	0.9	6.22
Smoke	0.8	1.03

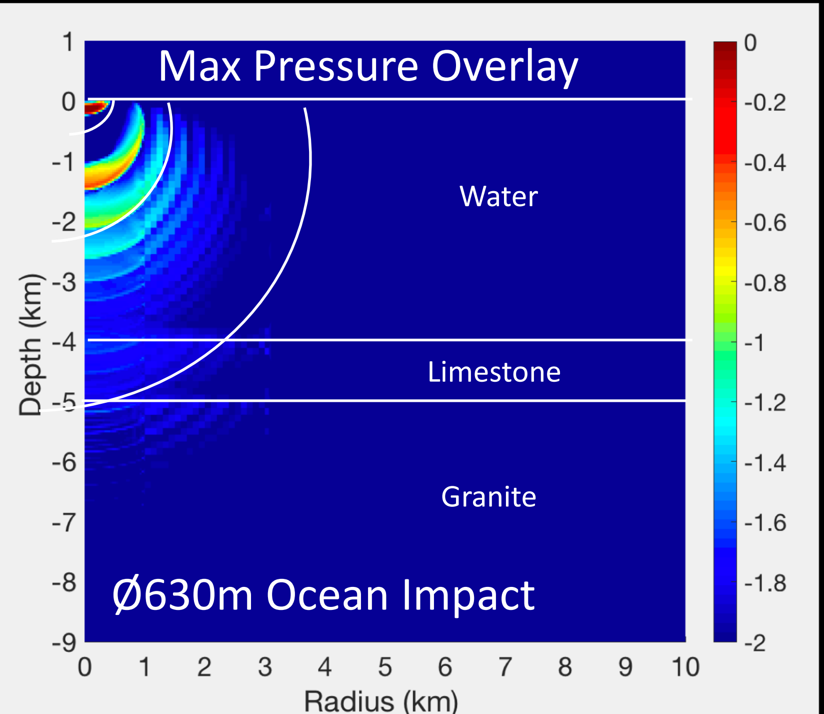


Vapor – Melt – Crush

- Phase based on max pressure which volumes of ground experience and phase diagrams of materials

Values from Pierazzo 1998

- 0,50%,100% vaporized water at 4.5,18,43 GPa
- Melt (degas) calcite 10 GPa (50% porous) to 45 GPa (non-porous). 20 GPa compromise value.
- Degas anhydrite 80 – 150 GPa (100GPa nominal)



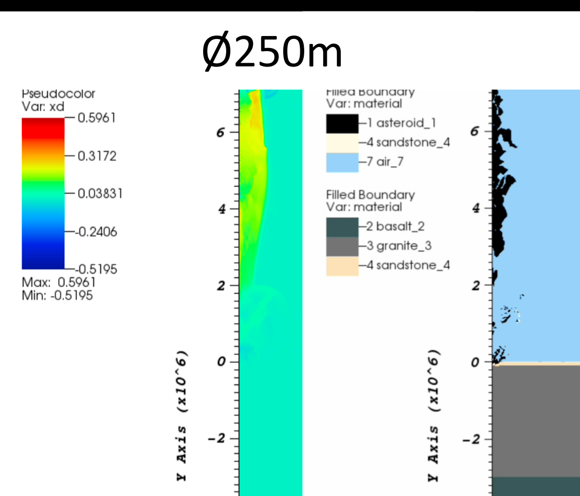
100% Water vaporized

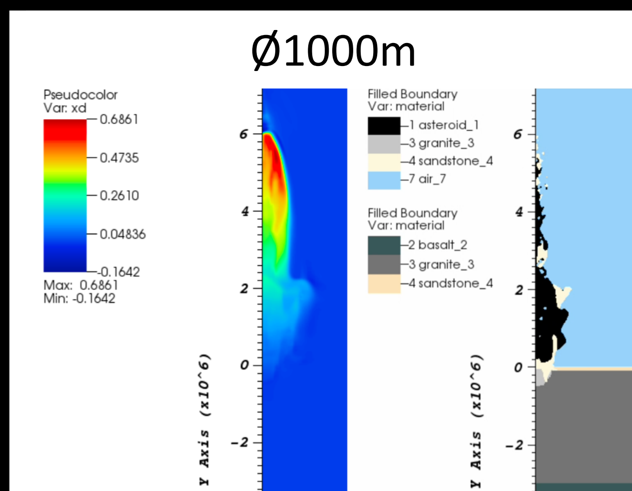
Limestone melted
50% Water vaporized

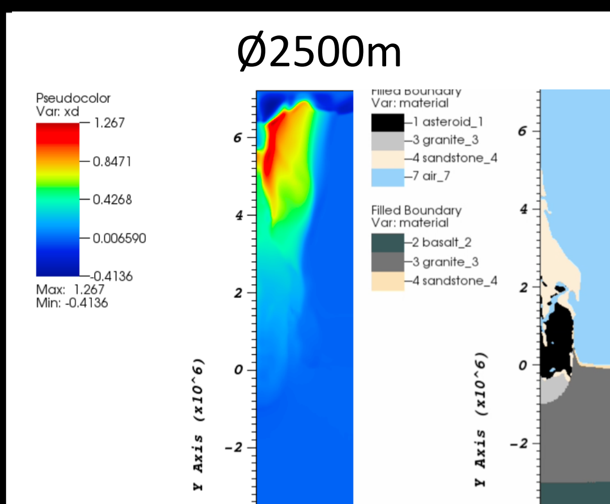
0% Water vaporized

Ejecta

- Upward velocities vs. escape velocity
- What will be globally spread by ballistic trajectories and may cause heating on re-entry.
- What in stratosphere and higher and be globally spread by winds.

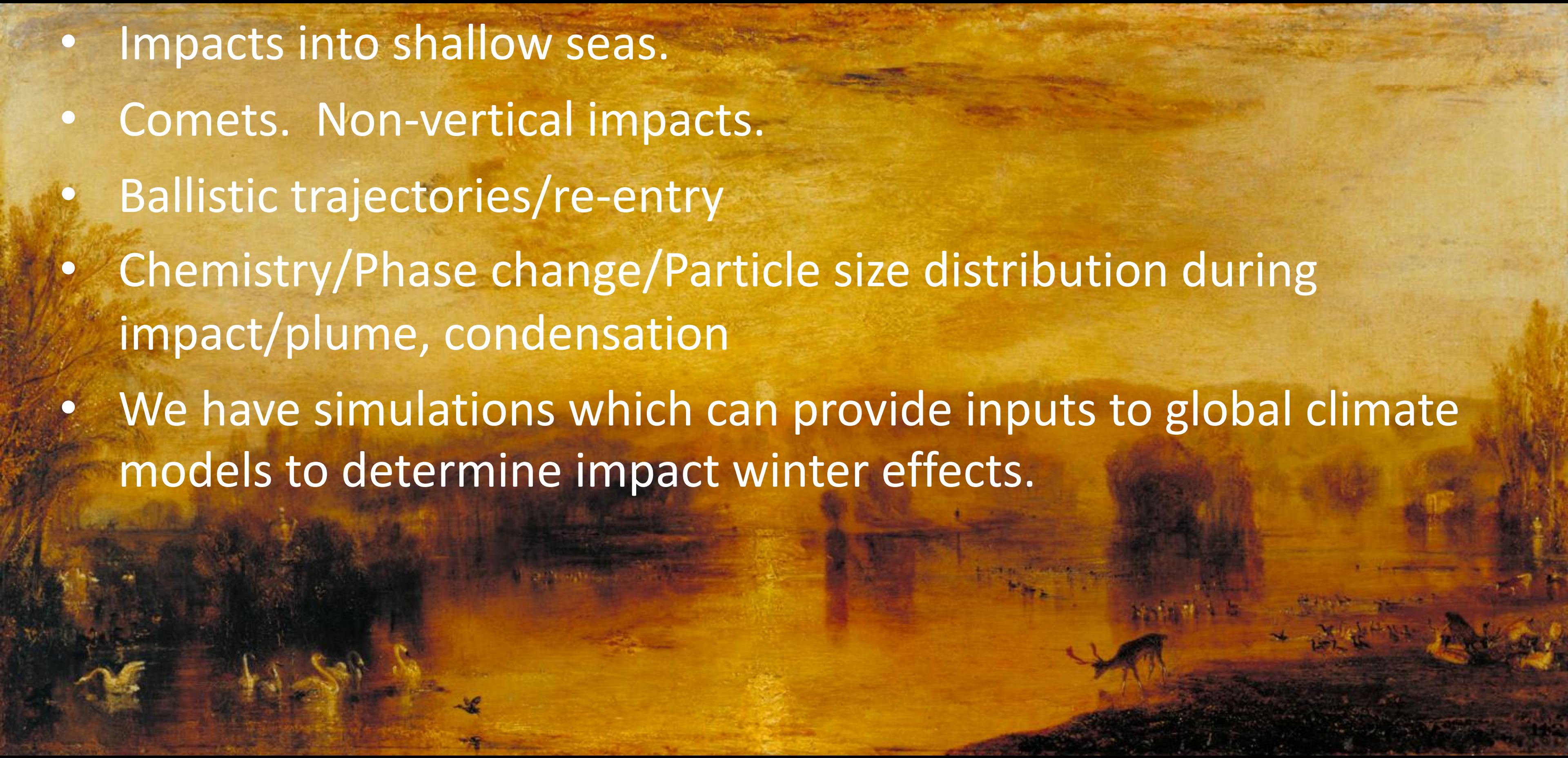






Future Work

- Impacts into shallow seas.
- Comets. Non-vertical impacts.
- Ballistic trajectories/re-entry
- Chemistry/Phase change/Particle size distribution during impact/plume, condensation
- We have simulations which can provide inputs to global climate models to determine impact winter effects.



Yellow skies from the 1816 “Year without summer” following the Tambora volcanic eruption in 1815, as shown in “The Lake, Petworth: Sunset, a Stag Drinking” by J.M.W. Turner