

# Climate changes during mass extinctions by asteroid-comet impacts and large volcanic eruptions

\*Kunio Kaiho<sup>1</sup>

1. Graduate School of Science, Tohoku University

Cooling and associated drought induce mass extinctions. Warming is difficult to cause mass extinctions, because high latitude areas are good condition for life during hot surface of the Earth. Causes of cooling are soot and sulfate aerosols to cut sunshine. These aerosols in the troposphere fall out soon with rain, which do not cause global cooling, but stratospheric aerosols can live long to cause the global cooling and drought. Energy is needed to carry burned hydrocarbon and sulfur to the stratosphere. The energy can be provided by asteroid-comet impacts and large volcanic eruptions. Soot aerosols and sulfate aerosols are main causes of mass extinctions by the impacts and volcanic eruptions. Cooling on land reaches 1 month after the ejection on soot aerosol case, but one year after the ejection on sulfate aerosol case, followed by gradual recovery in 10 years on both cases. Warming subsequently occurred by CO<sub>2</sub> ejection by the impacts and volcanic eruptions in 10 to 1000 years after the events. The amount of CO<sub>2</sub> is usually smaller on the impact case than on the volcanic eruption case, resulting in no significant warming by the former, but significant warming may occur by the latter. Mass extinctions by the volcanic eruptions can be emphasized by subsequent warming events, resulting in stepwise extinctions.

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