EGU21-13639
https://doi.org/10.5194/egusphere-egu21-13639
EGU General Assembly 2021

Effects of ionisation on cloud behaviour in planetary atmospheres

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Cosmic rays cause ionisation in all planetary atmospheres. As they collide with particles in the atmosphere, secondary charged particles are produced that lead to the formation of cluster ions. The incident cosmic ray flux and atmospheric density of the atmosphere in question determine a profile of ion production rate. From the top of the atmosphere to the planetary surface, this rate increases with atmospheric density to a point where the flux becomes attenuated such that the rate then decreases, resulting in a peak ion production rate at some height known as the Pfotzer-Regener maximum. When these ions interact with aerosols and cloud particles, a net charge results on those particles and this is known to affect their microphysical attributes and behaviour. For example, charging may enable the activation of droplets at lower saturation ratios and also enhance collision efficiency and droplet growth. This becomes important when clouds occur at a height where ionisation is sufficient to have a substantive charging effect on the cloud particles. This has very little direct effect on Earth as peak ion production occurs high above the clouds at 15-20 km; however, on Venus for example the Pfotzer-Regener maximum occurs at ~63 km, coinciding with the main sulphuric acid cloud deck. In situations such as this, the direct result of cloud charging due to cosmic ray induced ionisation may strongly influence cloud processes, their occurrence, and behaviour.

This work uses laboratory experiments to explore the effects of charging on cloud droplets. Individual droplets are levitated in a vertical acoustic standing wave and then monitored using a CCD camera with a high magnification objective lens to determine the droplet lifetime and evaporation rate. Experiments were conducted using both the droplets' naturally occurring charge as well as some where the region around the drop was initially flooded with ions from an external corona source. The polarity and charge magnitude of the droplets was determined by applying a 10 kV/m electric field horizontally across the drop and observing its deflection towards one of the electrodes. Theory predicts that the more highly charged a droplet is, the more resistant to evaporation it becomes. Experimental data collected during this study agrees with this, with more highly charged droplets observed to have slower evaporation rates. However, highly charged drops were also observed to periodically become unstable during evaporation and undergo Rayleigh explosions. This occurs when the droplet evaporates until its diameter becomes such that its fissility reaches the threshold at which the instability occurs. Each instability of a highly charged drop removes mass, reducing the overall droplet lifetime regardless of the slower evaporation rate. Therefore, where enhanced ionisation occurs in the presence of clouds the end result may be to reduce droplet stability.