

Investigation of Transient Gas Phase Column Density Due to Droplet Evaporation

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A NASA robotic refueling mission experiment on board the International Space Station (ISS) was designed to repeatedly transfer simulated cryogenic propellant between two dewars. After each metered transfer, the cryogen was to be vented overboard via sublimation or evaporation. ISS payload providers must conduct analyses to demonstrate that any planned gaseous venting generate no more than a certain level of material that may interfere with optical measurements from other payloads that may be located nearby. This requirement is expressed in terms of a maximum column number density (CND). For the experiment under consideration, fluid droplets likely would accompany any such vapor.

Earlier related studies led to development of analytical expressions for column density along general paths for a number of practical cases under steady conditions, including droplet evaporation. These expressions are not appropriate for rapid evaporation of small droplets however, since the droplets cannot sustain mass flow rates consistent with steady conditions.

In this work, analytical expressions are developed for estimating column density near a rapidly evaporating droplet along general paths. The influence for instantaneous evaporation is created first as a limiting case, where it is found the peak value occurs at the time it takes a wave of vapor to reach the closest point along the optical path traveling at its most probable thermal speed.

Next, the case for finite-period evaporation is evaluated for constant conditions. Compared to the instantaneous case, peak column density occurs shortly after droplet extinction, but at a lower intensity. A new mathematical function is discovered that solves the integrals associated with this case. Finally, ways to account for droplet motion and changes in evaporation rate with size and temperature are discussed in this framework.