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Assessment of In-Flight Water Droplet Evaporation: The Contribution of Numerical Approximation Methods

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Preliminary Remarks

The design of an irrigation system must limit the depletion of water due to the evaporation process, for social, environmental and economic reasons. In order to assess the evaporation it is important to fully understand how water, in the form of droplets, behaves during its flight. The state of the art of literature offers at the moment two main ways: the first one consists in adopting a classical viewpoint, using simplifying hypothesis to solve numerical approximation methods [1-12]. The second possibility is to adopt a quantum viewpoint, treating the water droplet as a quantum object [13]. By using this last method one can obtain a description as much as possible complete and doubtless the challenges associated with the quantum mechanics applied to droplets problems will continue to inspire progress in the years to come, but at the present time the fact that is impossible to find analytical solutions for quantum equations makes sometimes preferable to achieve the purpose through numerical approximations. In particular, the numerical approximation can be implemented via suitable codes and in this way a further step in literature has been taken using a Computational Fluid Dynamics (CFD) implementation [14-16].

Problem and Solution

The water droplet evaporation in air depends on many characteristic parameters, affecting both the droplet and air: droplet initial velocity and diameter, air-water temperature difference and diffusion coefficient of vapour in air are the most common ones, capable to define a standard environment for analytical calculations. A recent study modelled and solved the evaporation process by means of the CFD [17] considering the previous parameters as variables for a single spherical droplet travelling between the nozzle and the ground, and making the following approximations: 1) Straight droplet trajectory defined only downwards along the vertical axis; 2) No wind; 3) Influence of solar radiation not considered; 4) Air relative humidity not considered. It is important to point out that is always advisable to find a good equilibrium between reducing the complexity of the problem by ignoring negligible system features and finding practical computational solutions. The method used is a sort of Arbitrary Lagrangian-Eulerian (ALE), which combines the best properties of both the Lagrangian and Eulerian frames [18]. The results obtained show that the parameters which affects droplet evaporation more significantly are droplet initial diameter and air temperature, for both time dependence and space dependence. Droplet initial velocity and diffusion coefficient of vapour in air are still significant data but do not affect so much the evaporation like the first ones. According to such results, the operative conditions that generally help to save water are big droplet initial diameter and low droplet initial velocity.

Concluding Remarks

The general problem of describing the dynamic of a water droplet is common to many scientific and technical fields like fire suppression, sprinkler irrigation, industrial refrigeration and, depending on the particular field different aspects and hypotheses become crucial in the analysis performed.

Also, for some contexts a deeper knowledge of the involved phenomena is still far away to be achieved, while for others the requirement of finding useful remarks is more pressing. At this regard it is possible to state that the classical approach in the form of latest CFD implementation can give good practical responses for irrigation issues. In this way the new challenge is to not fall into the mistake of giving case-bound processes descriptions which almost fail in discovering reliable trends for real phenomena: it is rather necessary build up a strong objective base for the new studies to come.

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