Chair: Physics of Fluids group

Mysterious Rings in Evaporating Drops: Numerics

Description

Evaporating droplets are not just ordinary occurrences in our daily lives; they hold the secrets to fascinating phenomena that are waiting to be unraveled. From the morning dew on the grass, the perfume sprayed on the skin, to the coffee stains on the table, these seemingly mundane droplets hide a world of complexity. The evaporation process involves an intricate interplay between heat and mass transfer, as well as the flow of the liquid inside the droplet. But there's more to it than meets the eye. Capillary forces can drive solute towards the contact line, giving rise to the mesmerizing coffee-ring effect [1]. This effect, along with other intriguing deposition and flow patterns, holds immense potential for applications in spray coating, pesticide administration, and inkjet-printing industries.

In these applications, droplets often consist of multiple components, making the evaporation process even more complex. Concentration differences are created, resulting in fascinating flow phenomenon known as Marangoni flow. In certain conditions, we expect to see a specific flow pattern dominated by Marangoni effects. However, recent experiments [2] have shown unexpected behavior: a formation of multiple ring-like deposits related with interplay of Capillary and Marangoni flows, suggesting a more complex flow than predicted. The reasons behind these discrepancies are not fully understood, but it's believed that contaminants play a role by affecting surface tension.

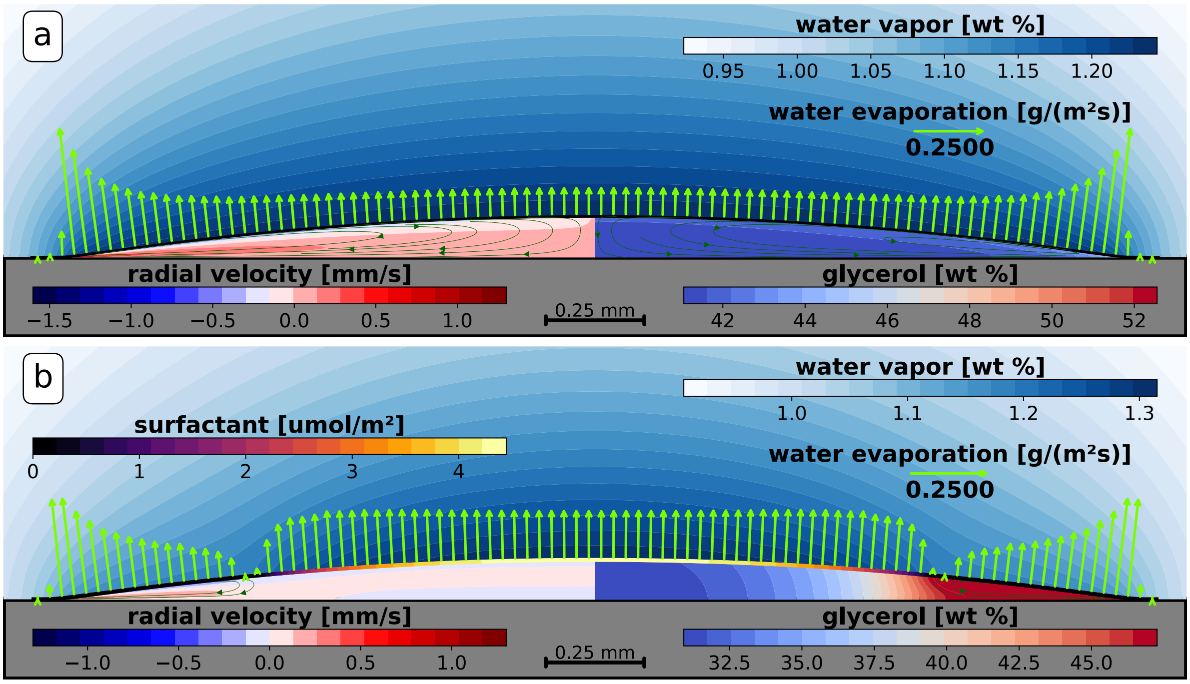

Figure 1: Effects of contaminants in the generation of Marangoni ring [2]. No contaminants, (a), show a single Marangoni vortex. A 0.5% reduction of initial surface tension leads to two competing capillary-Marangoni vortices, (b), resulting in a Marangoni ring.

Assignment

Your mission, should you choose to accept it, will be to perform Finite Element (FEM) simulations to provide further insight and quantitative understanding of the role of contaminants in creating the Marangoni rings. Preliminary simulations show how a reduction of initial surface tension by a mere 0.5%

can lead to the formation of a ring-like deposit, see Fig. 1. Contaminants here are modeled as insoluble surfactants, meaning that they actively reduce surface tension and they diffuse and are transported solely along the liquid-air interface. The project will involve the use of a powerful in-house PYTHON FEM code PYOOMPH, based on the open-source library OOMPH-LIB [3].
The project will be supervised by Duarte Rocha and Christian Diddens, who help with the numerical simulations, and discussions about experimental work with Pim Dekker and Alvaro Marin will take place.

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References

[1] R. D. Deegan, O. Bakajin, T. F. Dupont, G. Huber, S. R. Nagel, and T. A. Witten. Capillary flow as the cause of ring stains from dried liquid drops. *Nature*, 389(6653):827–828, 1997.

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