An integrated computational approach for wind-driven rain on buildings in urban environments: Eulerian modelling, turbulent dispersion, lubrication, volume of fluid and transport in porous media

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ABSTRACT

Wind driven rain (WDR) is the type of rain which has a horizontal velocity vector due to the effect of air flow. WDR is one of the main moisture sources with potential negative effects on the hygrothermal performance and durability of buildings facades. Deterioration of building materials due to WDR is relevant for retrofitting old or historical buildings by adding insulation, planning energy efficient cities, assessing soiling of facades and leaching of harmful biocides and nanoparticles from building envelopes. An accurate estimation of the WDR intensity on buildings within urban environments will lead to a better understanding of phenomena such as droplet spreading, splashing, bouncing, absorption, evaporation, film forming and run-off.

In a first step, field measurements and computational fluid dynamics (CFD) calculations of WDR are performed in order to improve the current understanding of the physics involved in surface wetting on building facades due to WDR. Field measurements of WDR are performed on multiple buildings in two different urban configurations built in Dübendorf, Switzerland. The field measurement data are used to validate the Eulerian multiphase (EM) model with the turbulent dispersion modeling of raindrops [1]. The EM model allows for less computational complexity, a simpler quantification of the influence of turbulent dispersion of raindrops and ability to estimate WDR on all surfaces in a complex geometry compared to other models used in literature. The calculations of the wind flow fields are conducted based on large eddy simulation (LES) in order to estimate the sensitivity of WDR to deficiencies of Reynolds-averaged Navier-Stokes (RANS) simulations in the wake of buildings. WDR calculations with EM-LES are also used to study the unsteady behavior of WDR and the variation of WDR intensity on building facades compared to mean WDR.

Once in contact with the building surface, the fate of the droplet is studied, first at the scale of one droplet on a porous medium, with high speed imaging to capture the physics of deposition and with neutron imaging to document absorption. The imaging of an impacting droplet is used to validate theVolume-of-Fluid CFD simulation and neutron radiography to validate finite-element modeling of the moisture transport in different porous media, with exact boundary conditions. In a next step, the WDR intensity, calculated using the EM model, and the droplet behaviour when impacting the wall are combined to study the impingement of discrete droplets on a single building façade. Subsequent to saturation of the surface layer of the building façade porous material, film forming and gravity-driven runoff are calculated based on the lubrication theory, which captures the wave dynamics.

Such methodology is applied to study the influence of facade details on WDR deposition in various configurations. With a more detailed understanding of WDR, this work may lead to improvements of engineering and industrial applications, such as modifications of surface properties of building materials or the improvement of coating materials.

REFERENCES

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