PhD position at Université de Sherbrooke

Multiscale modeling of the internal and external climate of a Nordic greenhouse

Context: In November 2020, Quebec announced its intention to double its greenhouse cultivation area in 5 years. The objective is twofold: (1) to increase the province's self-sufficiency, and (2) to improve the accessibility of the 44 remote communities to local products year-round and at reasonable prices. Agriculture, which is currently responsible for only 8% of GHG emissions in Quebec, would increase to 30%. It is therefore essential to develop effective solutions to decarbonize this industry while respecting the environmental conditions for cultivar growth.
Greenhouses are complex environments that need to be controlled in terms of temperature, humidity and CO_2 content. They break down into different interacting subsystems: local weather, envelope, soil, plants, and HVAC systems. More than temperature, light is the limiting factor in winter in Quebec for optimal plant growth, and additional lighting is necessary to optimize photosynthesis. To heat greenhouses, the primary energy consumed comes from the combustion of fossil fuels, while dehumidification is achieved by natural ventilation.
Relative humidity is the most critical metric to predict. The observed discrepancies are mainly due to two factors: (1) evapotranspiration models are based on plant-related parameters (notably the Leaf Area Index) that are not always well known for all cultivar types; (2) For the period from October to April, in a northern climate, the interior surface temperature of the envelope drops below the dew point, which causes condensation, a phenomenon that is still poorly taken into account in the models. The formation of droplets causes a loss of luminosity of up to 50% and is favourable to the development of fungal diseases.

The main objective is to develop a multiscale numerical model from opensource libraries able to predict the internal climate of Nordic greenhouses taking into account: local weather conditions including the snow layer in winter, exact structure of the envelop (glass / polycarbonate / polyethylene, simple/double/triple layer, coating or not), hygrothermal behavior of the crops and their growth, all heat and mass transfers (evapotranspiration, condensation, radiation, mixed convection and conduction) inside the greenhouse.

Methodology: The project is essentially based on advanced numerical simulations using the model of Kubilay et al. [1,2]. It is an urban microclimate model, which already contains the effect of wind, radiation and heat and moisture transfers in the air, vegetation and materials such as soil and building materials, and can also predict the deposition of driving rain. This UrbanMicroClimateFOAM model is based on the open-access libraries of OpenFOAM and has been validated for different outdoor climate simulations. This model therefore makes it possible to take into account the physical phenomena at play in greenhouses, and we propose to add the modalities required for the addition of transparent surfaces (radiation, condensation, …). The developments will be done on a machine composed of 64 processors available in the laboratory, while the parametric calculations will be carried out thanks to the resources of the Digital Research Alliance of Canada. The numerical results will be compared with experimental measurements performed at our partners for hot and cold greenhouses with different cultivars. For each greenhouse, local weather data is measured as well as temperatures, relative humidity and CO_2 levels within the greenhouse. Photosynthetic active radiation is measured by a quantum sensor. Additional sensors, e.g. air velocity, will be added as validation needs.

Required skills: Master in civil or mechanical engineering or in a related field. A good knowledge in fluid dynamics is required. Knowledge in numerical methods and a first significant experience in computational fluid dynamics and with softwares like ANSYS or OpenFOAM would be appreciated.

Conditions: The main workplace is the faculty of engineering at Université de Sherbrooke (Québec, Canada) with collaboration with agronomists, greenhouse farmers and engineering companies. Good salary (**net funding of 25000$ per year**) and working conditions are offered. The suitable starting date for this position is any session in 2024.

How to apply: Interested candidates are encouraged to contact both Professors, Dominique Derome (Dominique.Derome@USherbrooke.ca) & Sébastien Poncet (Sebastien.Poncet@USherbrooke.ca). Please send a detailed CV, Master's transcripts, an example of scientific production (paper or project's report…) and the name of 2-3 referees. Incomplete applications won't be considered. Only selected candidates will be contacted.

References

[1] Kubilay A., Derome D., Carmeliet J., Coupling of physical phenomena in urban microclimate: a model integrating air flow, wind-driven rain, radiation and transport in building materials, *Urban Climate*, 24, 398-418, 2018.

[2] A. Kubilay, J. Allegrini, D. Strebel, Y. Zhao, D. Derome, J. Carmeliet. Advancement in Urban Climate Modelling at Local Scale: Urban Heat Island Mitigation and Building Cooling Demand. *Atmosphere* 11(12), 1313, 2020.