The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of Yi Yao

The public defense will take place on **Wednesday 31st January 2023 at 4:00 pm** in room **D.0.05** (Building D, VUB Main Campus)

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THE ROLE OF IRRIGATION IN THE EARTH SYSTEM: PAST, PRESENT AND FUTURE

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Abstract of the PhD research

As the biggest freshwater-use practice, irrigation is an important climate forcing, with its cooling effects on the near-surface temperature being highlighted. However, three frontiers exist in previous studies: (i) huge inconsistency among Earth system modelling-based studies; (ii) over-simplified irrigation representation in Earth system models; and (iii) limited explorations of irrigation-induced impacts under future scenarios.

We first initiate the IRRigation impact Model Intercomparison Project (IRRMIP), in which three Earth system models were employed to conduct two group of simulations to detect impacts of historical irrigation expansion on near-surface climate. Multi-model results reveal that irrigation reduces the frequency of heat events (exceeding 99.0%, 99.5%, and 99.9% percentile value of 2-meter air temperature) by more than 4 times over the grid cells with substantial irrigation expansion, and even reverses the warming trend by reducing the hours/year exposed to these events. In contrast, the impact of irrigation expansion on moist-heat events (apparent and wet bulb temperature) is negligible or even tends towards increased heat stress. These results reveal a general over-optimism regarding the irrigation’s cooling impacts in the context of human health, and highlight the need to critically scrutinize irrigation as a possible future heat extreme adaptation strategy.

Second, we developed a new irrigation module for the Community Earth System Model version 2 (CESM2) consisting of four different irrigation techniques, to address the underestimation in irrigation water withdrawal indicated by IRRMIP outputs. The new parameterisation is tested in a set of simulations that employs existing spatial information on the occurrence of these techniques. Simulated irrigation water withdrawal is higher in the new irrigation scheme, thereby substantially reducing the bias over the USA (-10.58 to -0.03 km$^3$ year$^{-1}$) and other countries (-64.74 to -7.67 km$^3$ per year) but causing a slight overestimation over China. At three cropland sites, results show that sprinkler and flood irrigation have little impact on surface fluxes, but paddy irrigation substantially increases model’s performance in terms of evapotranspiration estimation.

Finally, (i) a new dataset of future irrigation techniques share under varying shared socioeconomic pathways is generated, (ii) CESM2 is further developed to represent multiple irrigation techniques for one crop type within one grid cell, and (iii) fully-coupled simulations are performed with the improved CESM2 model both in historical (1985-2014) and future (2015-2049) periods. Outputs reveal that irrigation still has cooling impacts on 2-meter air temperature, but the impacts on apparent and wet bulb temperature become less pronounced. Even for the 2-meter air temperature, irrigation is unable to reverse or alleviate the warming signals caused by other forcings. These results highlight the limited potential of irrigation as a local climate adaptation strategy and underscore the importance of reducing greenhouse gas emissions as a prime mitigation strategy to reduce escalating heat stress.