

# Understanding evapotranspiration in complex environments

Leveraging models and simulations to improve the estimation of evapotranspiration



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## Outline

1. Context
2. A bit of theory
3. What measurements say?
4. How modeling can help us?
5. Conclusions & Perspectives



What is the common point of all these images?



The medium that evapotranspires is disturbed by obstacles, either PV panels, or trees, or vegetative hedgerows, or buildings, etc...

Do we have formula?

Turbulent flux

$$ET_{flux} \sim \rho_{air} \overline{w'q_v'}$$

M.Z. Jacobson, et al., 2005

R.G. Allen, et al., 1998

$$ET_0 = \frac{0,408\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0,34u_2)}$$

The influence of convection?

B.J. Choudhury, et al., 1988

$$ET_{EBL} \sim \frac{\frac{\rho_{air} C_p}{\gamma} (e_s - e_a)}{r_{stom} + r_{turb}} \rightarrow \sim \frac{\ln\left(\frac{z}{z_0}\right)^2}{\kappa^2 u(z)} \sim \frac{\ln\left(\frac{z}{z_0}\right)}{\kappa u^*}$$

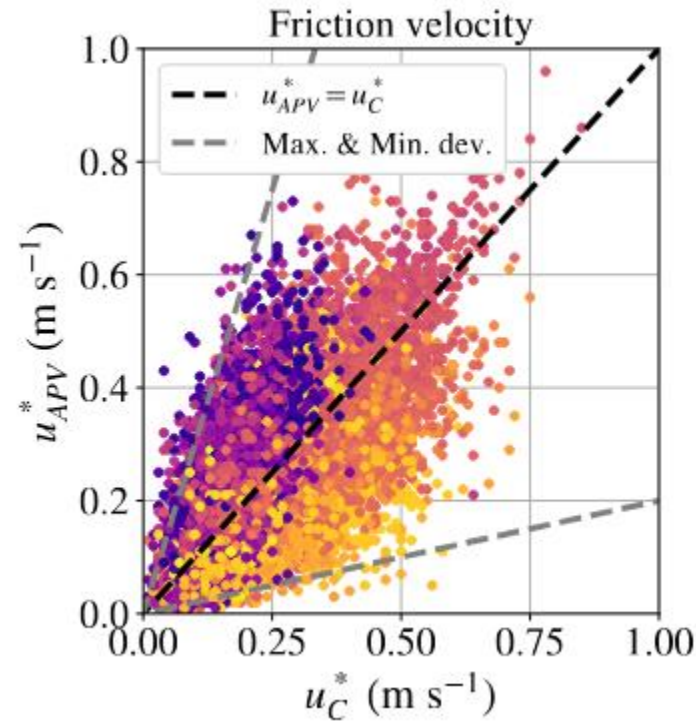
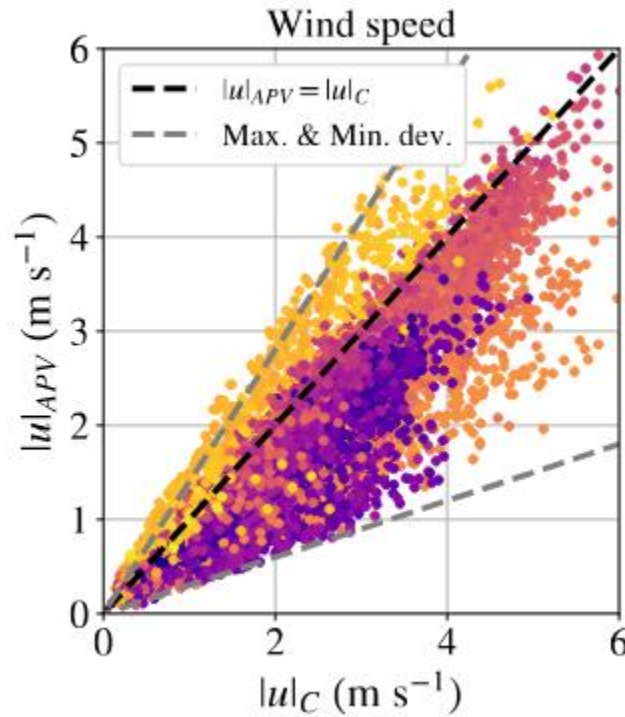
Friction velocity, from turbulent fluxes

Yes, but that are based on assumptions : spatial homogeneity, u is a positive function of turbulence, u and turbulence are correlated through  $\ln\left(\frac{z}{z_0}\right)$

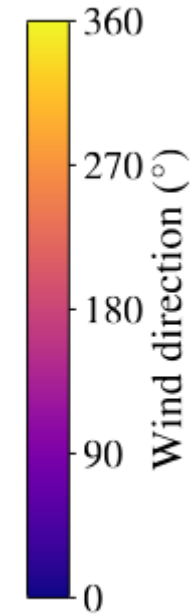


Are the assumptions still valid ?

$$u(z) = \frac{u^*}{\kappa} \ln\left(\frac{z}{z_0}\right)$$



Credit to SIRTÀ and Junni Luo



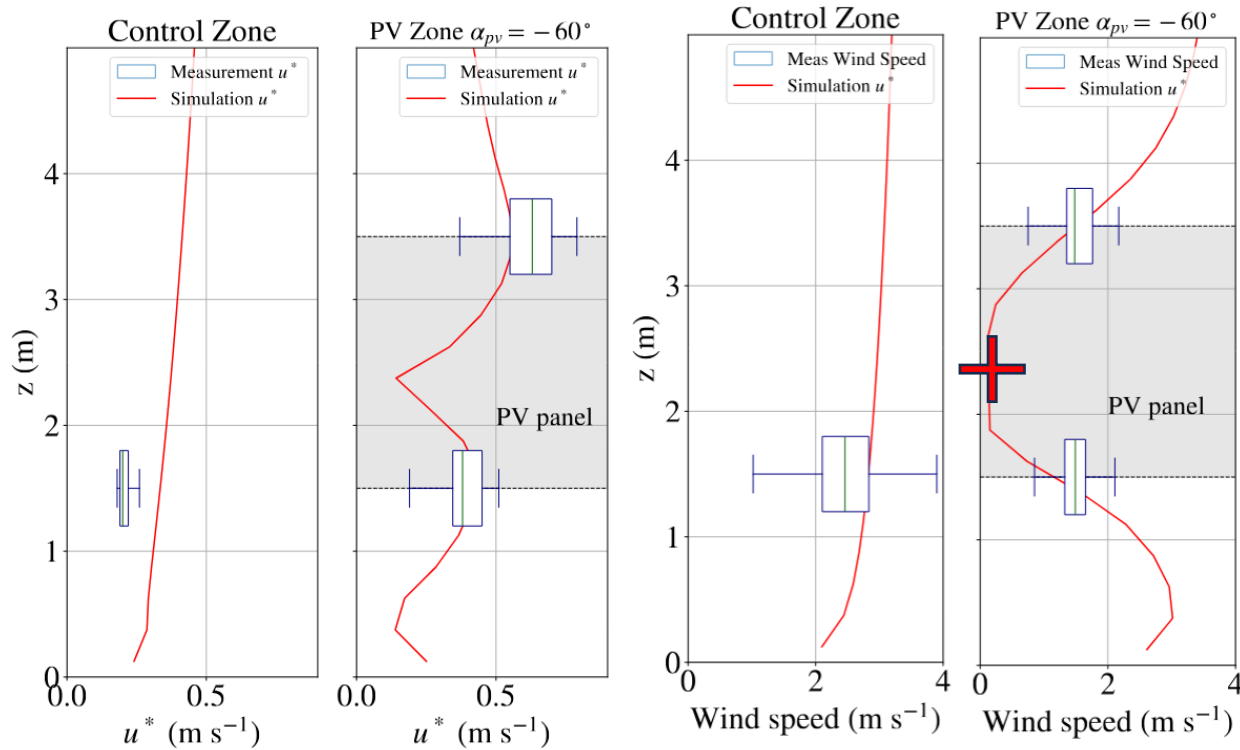
submitted

→ When  $|u|_{APV} > |u|_C$ , then  $u_{APV}^* < u_C^*$ , and reversly.



Are the assumptions still valid ?

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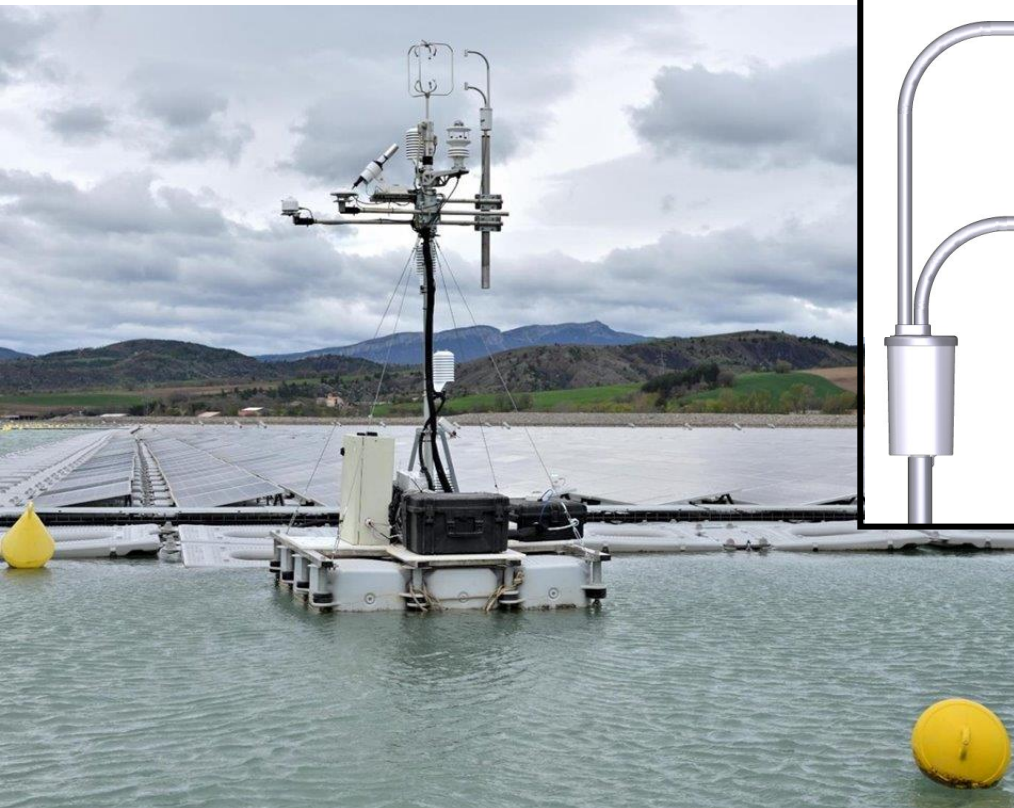
$$ET_0 = \frac{0,4\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0,34u_2)}$$

Is  $u_2$  the right indicator?

→ When  $|u|_{APV} > |u|_C$ , then  $u_{APV}^* < u_C^*$ , and reversly.  
 → Wind speed beneath panels does not follow a logarithm profile

***How do APV and FPV systems modify the microclimate, and what are the resulting impacts on the surrounding environments?***

➤ Crop surface temperature  
*IRradiothermometers*



➤ Evaporation  
*LI-710, combined with uSonic-3*



Picture : FPV demonstrator in 2025, at Lazer

Picture : AgriPV demonstrator in July 2024, at EDF Lab

➤ Radiation balance  
*Up & down pyranometers and pyrgeometers*

Credit to Baptiste Berlioux



<https://www.campbellsci.fr>



Solar radiation  : the starting point,  
But what else?

*The panels absorb up to 70% of the  
incident solar radiation.*

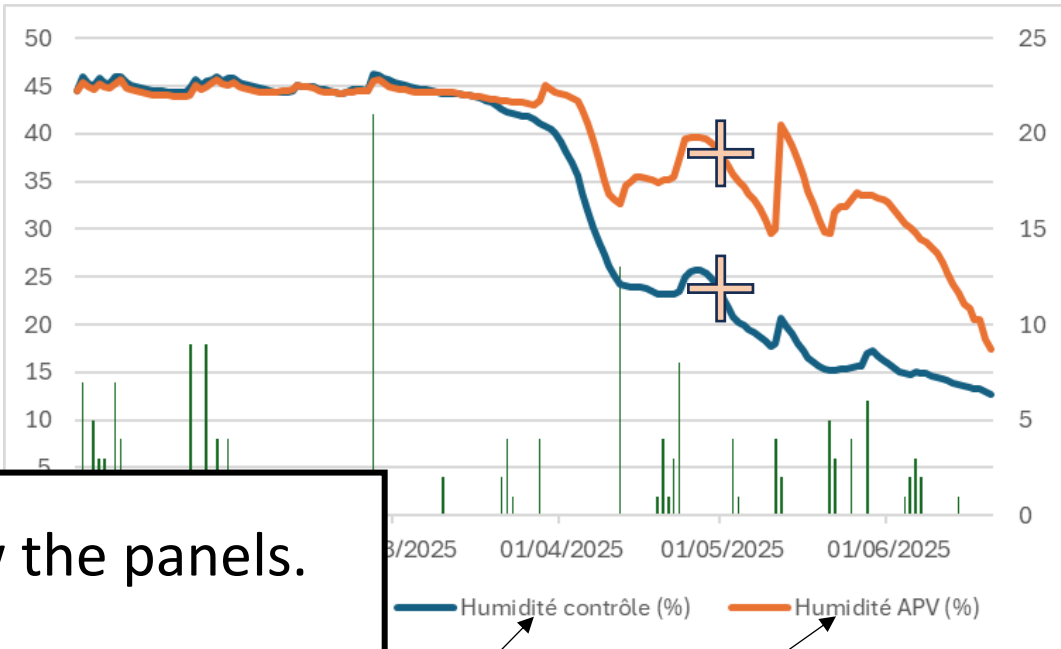
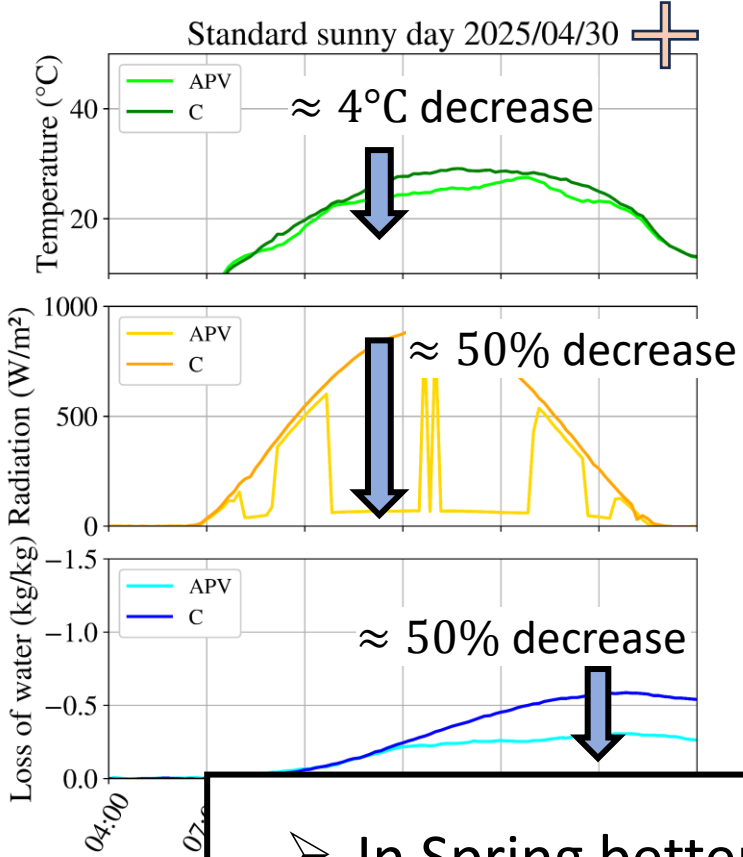


➤ Up to 40% of reduction in evaporation  
thanks to the PV panels!

# Solar radiation ☀️ : the starting point, But what else?



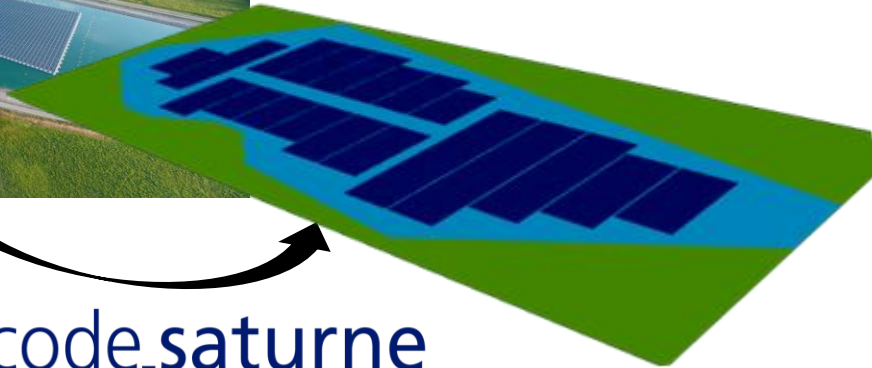
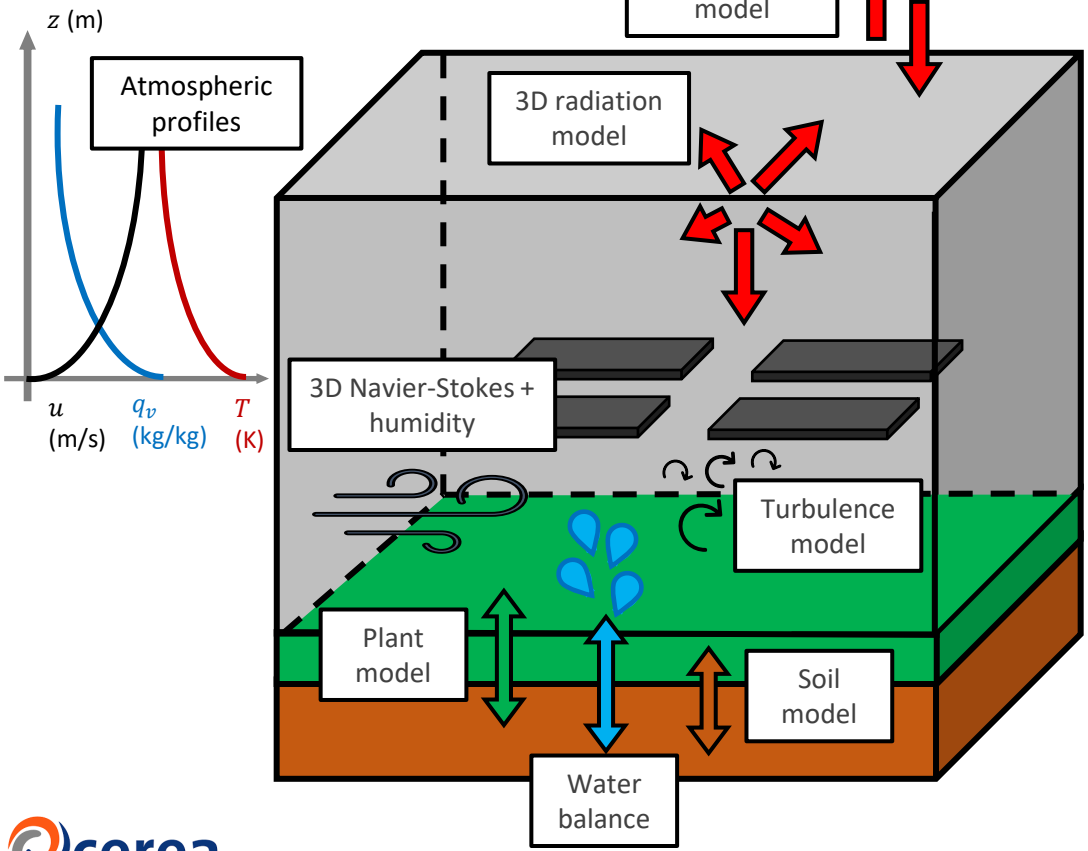
➡ The panels absorb up to 40% of the incident solar radiation.



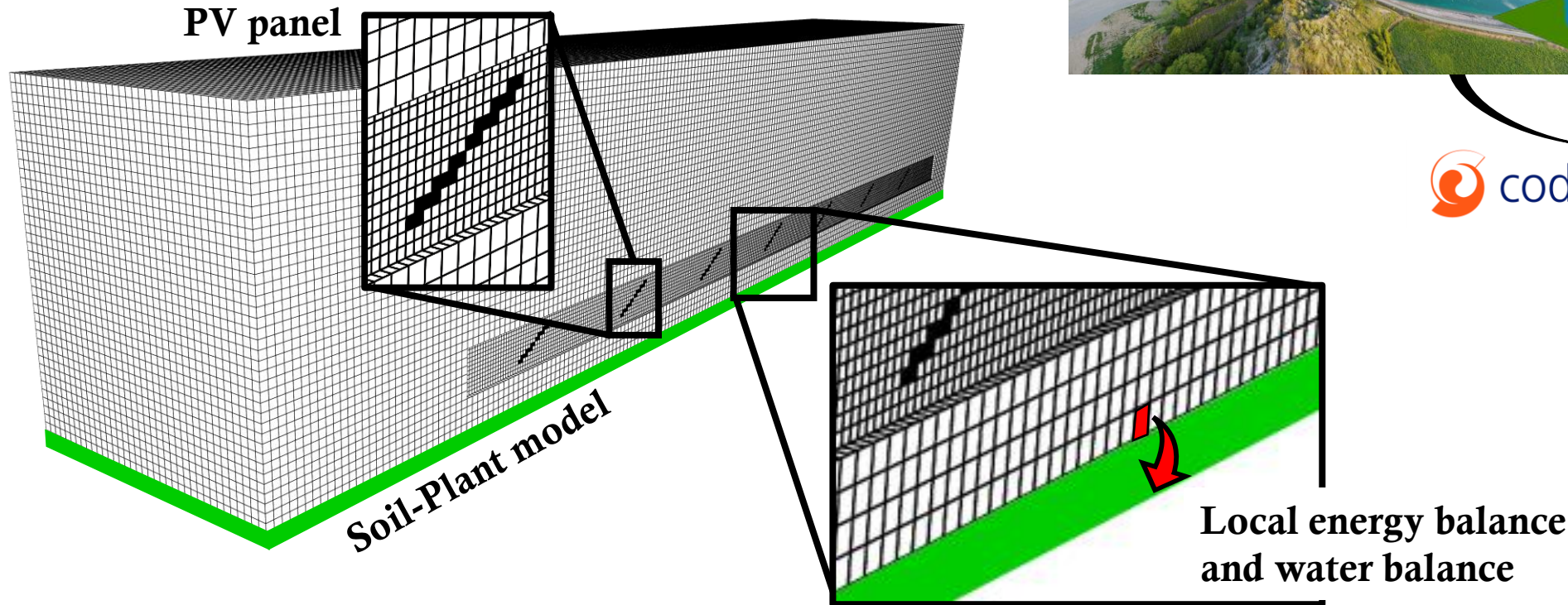
Without PV panels (blue line) vs Below PV panels (orange line)

➤ In Spring better water conservation below the panels.

**Can we optimize the PV design to boost the benefit for the lakes and the crops?**



## Why doing CFD?

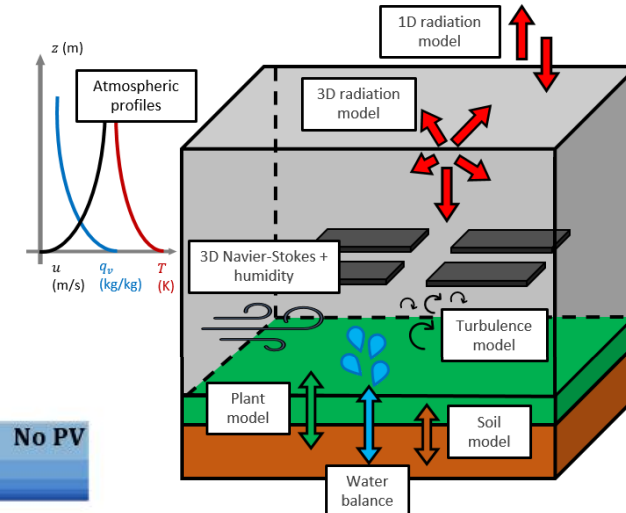


→ Compute locally wind speed and turbulence  
→ Transfers are calculated based on the turbulence at the plant level

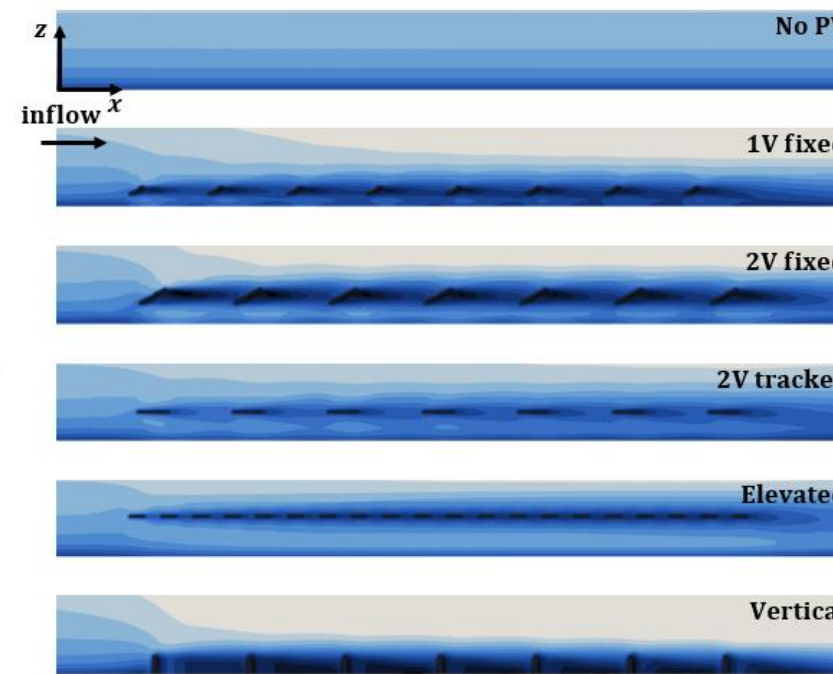
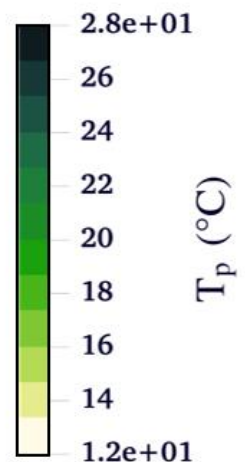
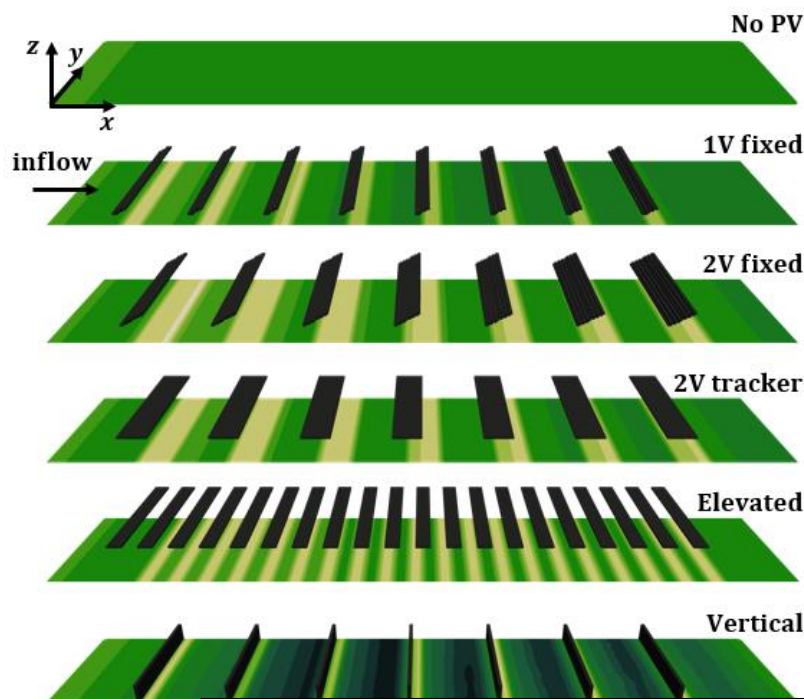
# Can we optimize the PV design to boost the benefit for the lakes and the crops?



- Inlet wind speed at 2m  $\approx 4\text{m/s}$
- Inlet air temperature  $\approx 18^\circ\text{C}$
- Clear sky day



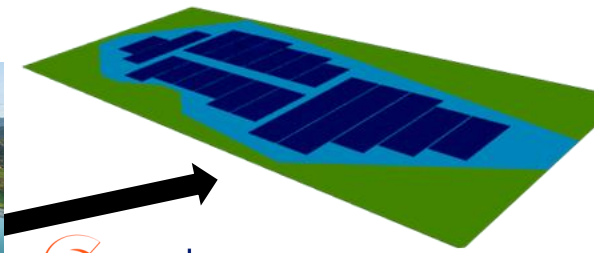
*Windy spring scenario*



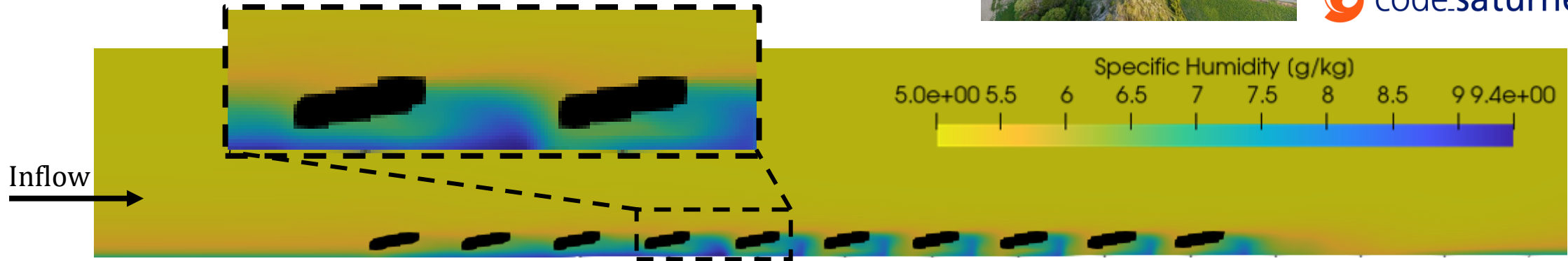
$T_p$  mea

- Elevated design  $\rightarrow -3^\circ\text{C}$  compared to No PV  $\rightarrow$  decrease photosynthesis.
- Vertical design  $\rightarrow +6^\circ\text{C}$  compared to No PV  $\rightarrow$  enhance photosynthesis.

Can we optimize the PV design to boost the benefit for the lakes and the crops?

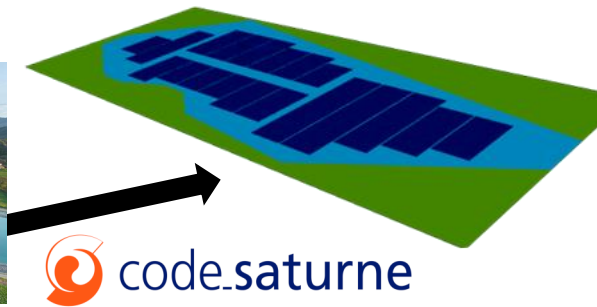


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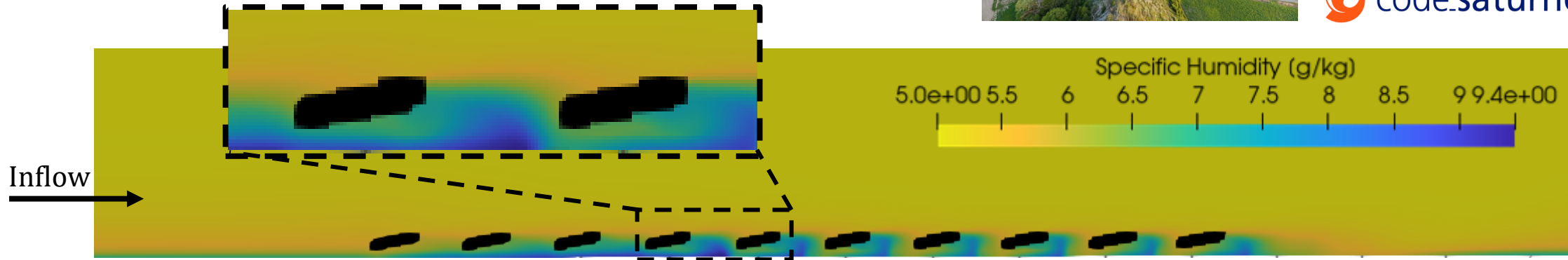


Credit to Baptiste Berlioux

**Can we optimize the PV design to boost the benefit for the lakes and the crops?**



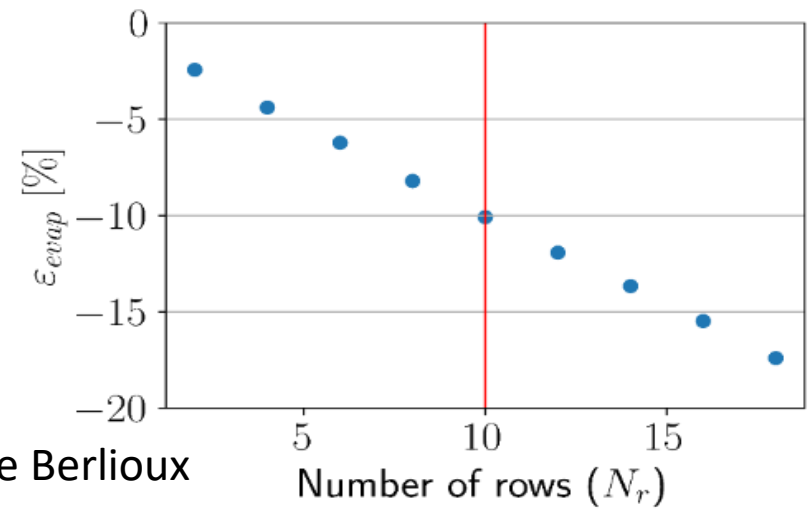
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$$\varepsilon_{evap} = \frac{E_{cov}}{E_{free}} - 1$$

$E_{cov}$ : Evaporation with panels

$E_{free}$ : Evaporation without panels



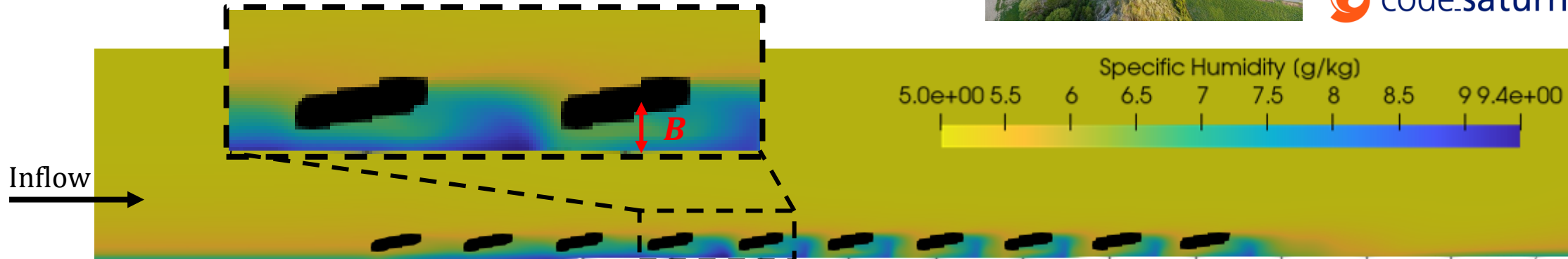
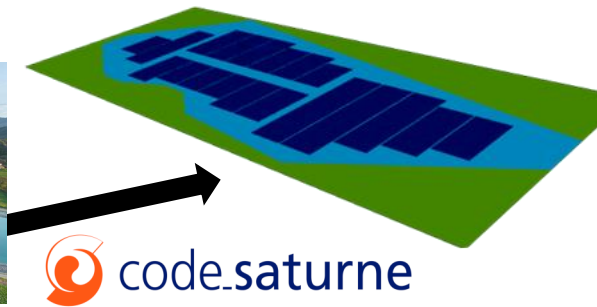
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<sup>1</sup>J. Vernier, et al., Solar Energy, 2025

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J. Vernier ([joseph.vernier@edf.fr](mailto:joseph.vernier@edf.fr)) – SFT – 2025/12/04

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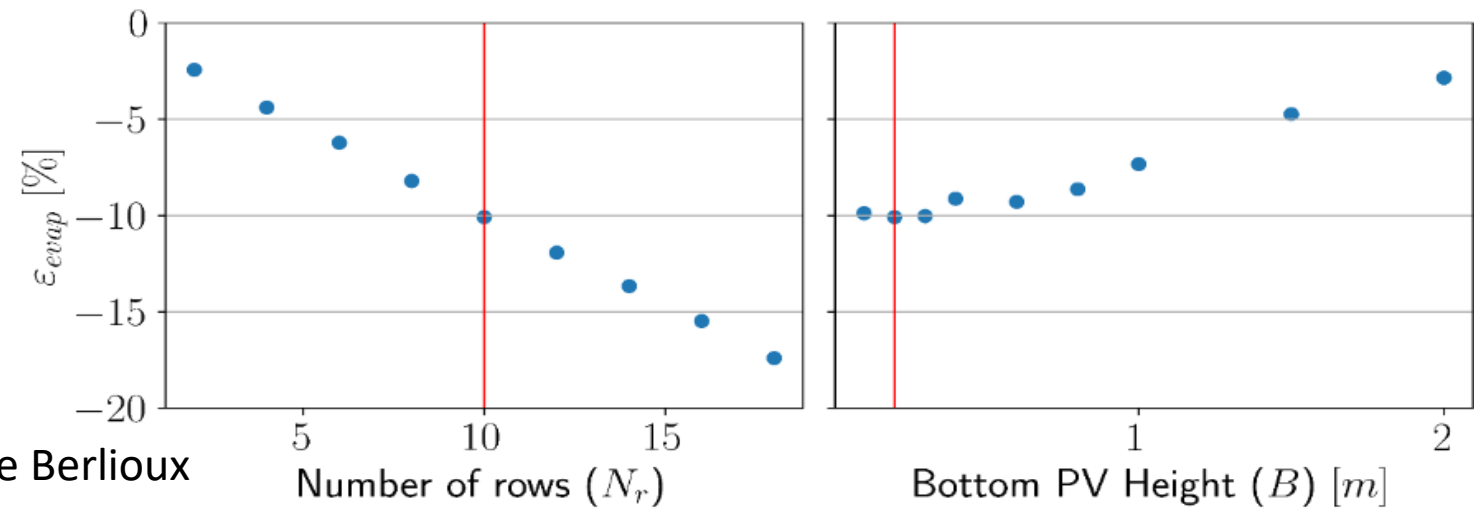
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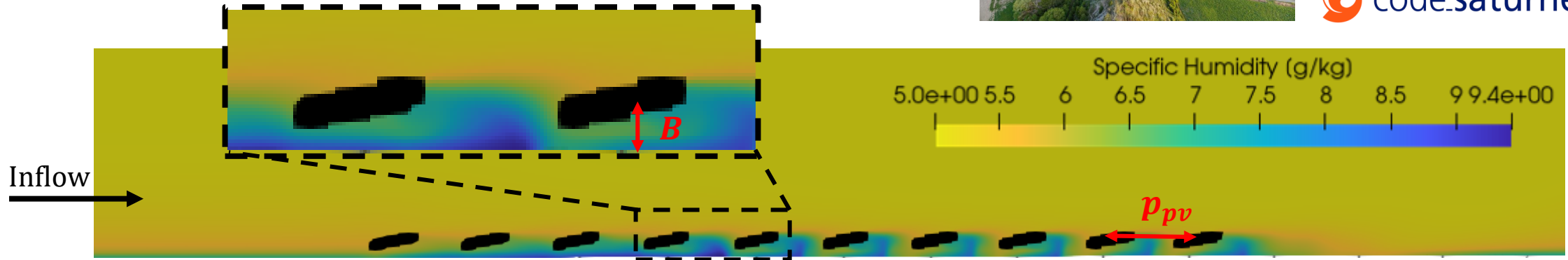
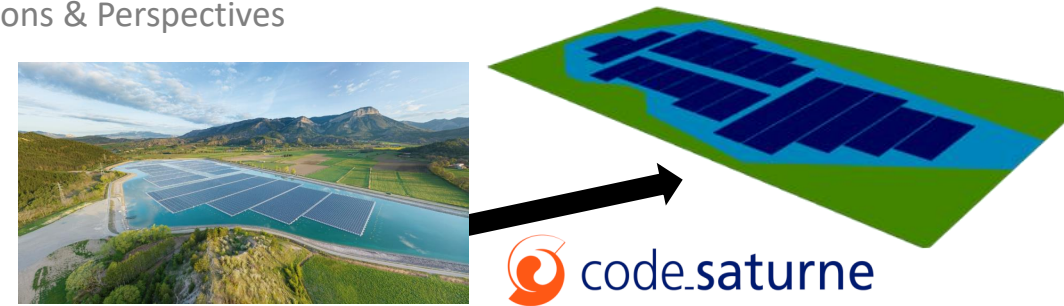
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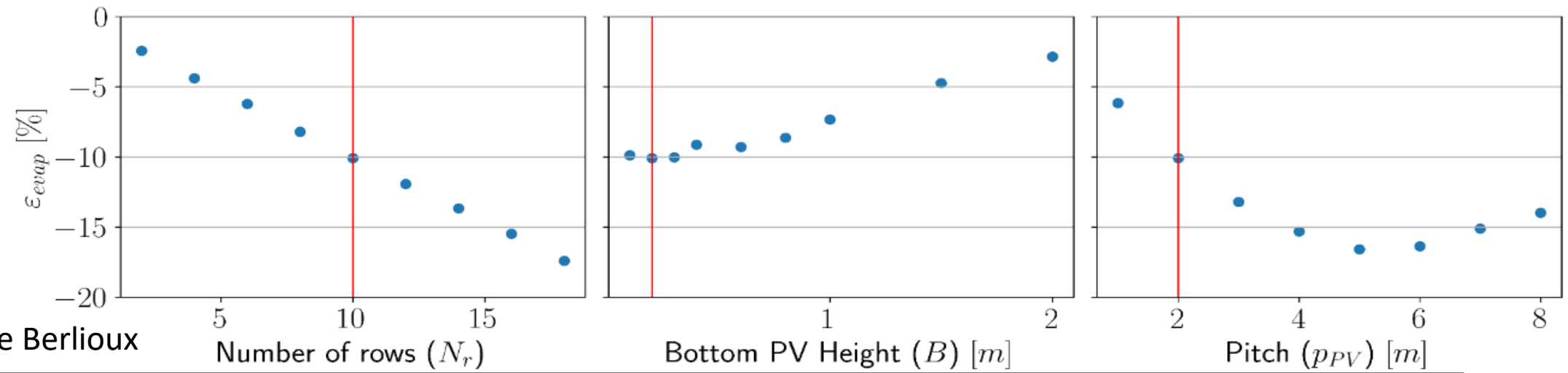
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$$\epsilon_{evap} = \frac{E_{cov}}{E_{free}} - 1$$

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**➤ There is an optimal pitch  $p_{pv}$  that maximizes the decrease in evaporation!**

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<sup>2</sup>J. Vernier, et al., Agricultural and Forest Meteorology, 2025

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# The key issues of CFD

Computation time, spatial and length scales



Published in Transactions on Machine Learning Research (10/2025)

## AB-UPT: Scaling Neural CFD Surrogates for High-Fidelity Automotive Aerodynamics Simulations via Anchored-Branched Universal Physics Transformers

Credit to Armand de Villeroché

### A solution: Machine learning?

Benedikt Alkin<sup>\*,1</sup>,  
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\*Equal contril  
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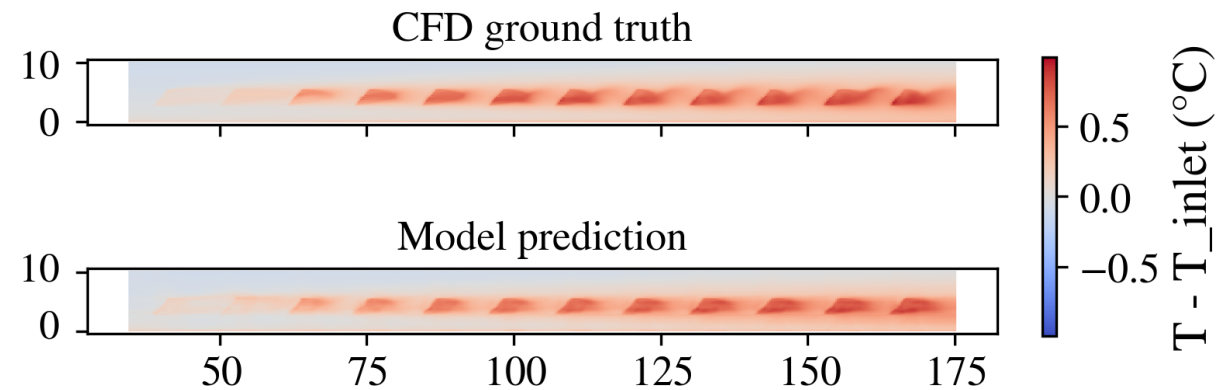
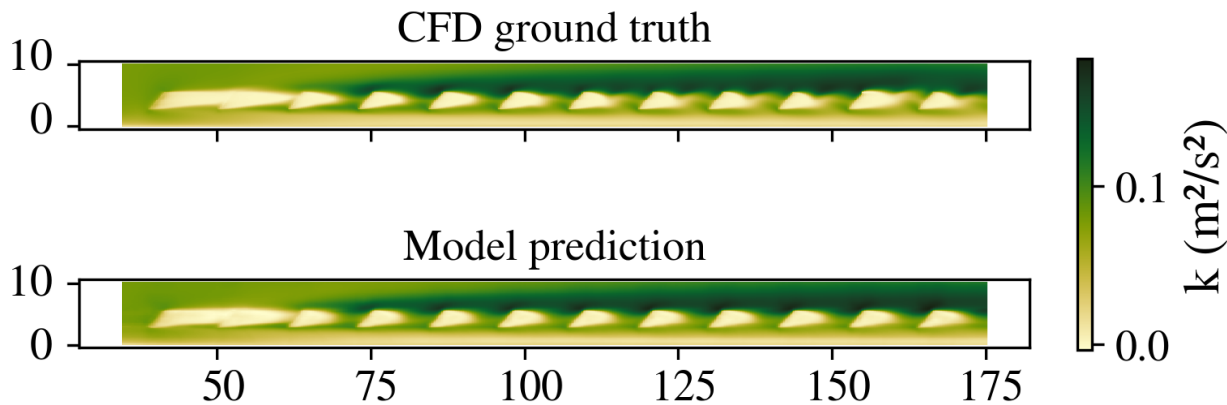
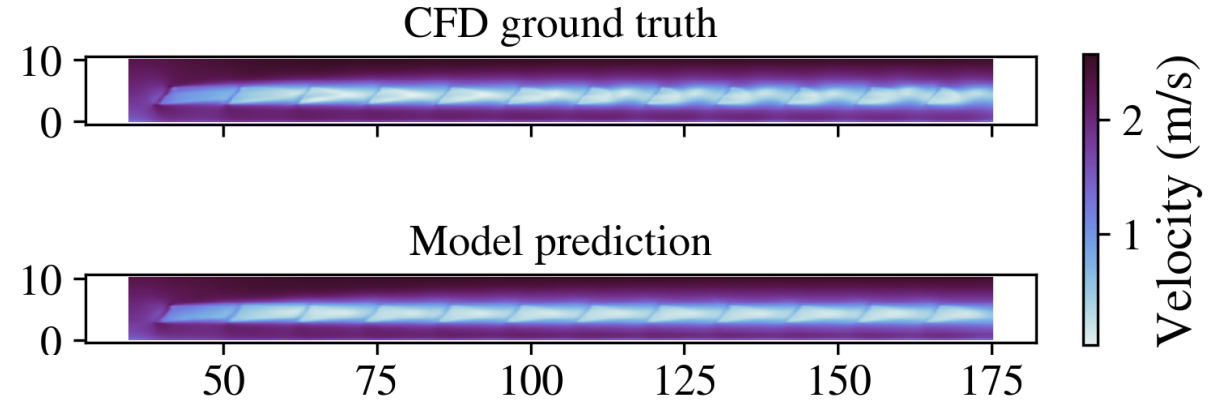


Uncertainty-aware surrogate modeling for urban air pollutant dispersion prediction

Eliott Lumet<sup>a,\*</sup>, Mélanie C. Rochoux<sup>a</sup>, Thomas Jaravel<sup>a</sup>, Simon Lacroix<sup>b</sup>

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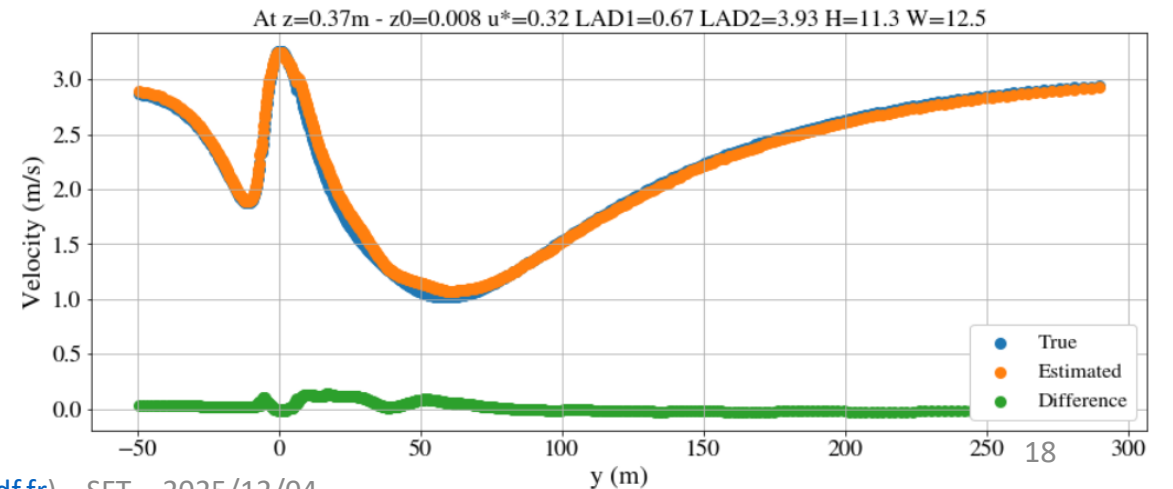
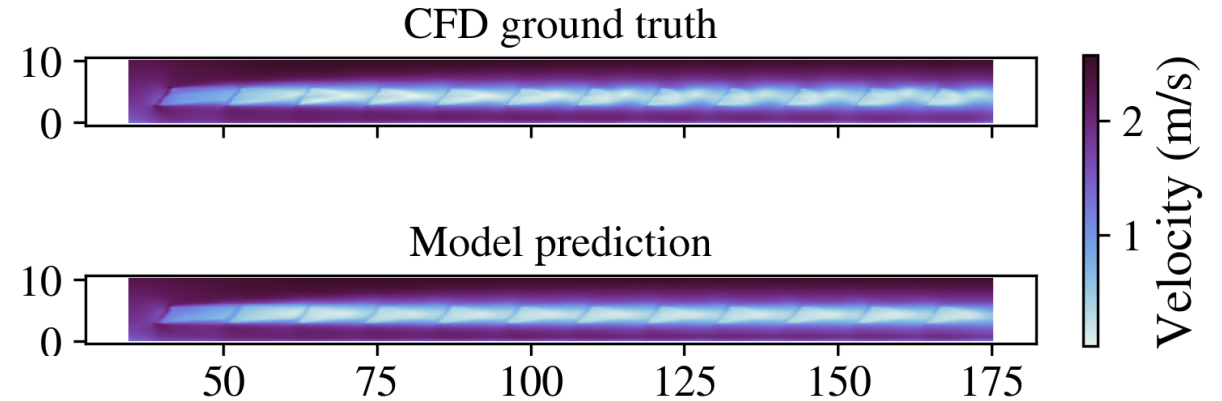
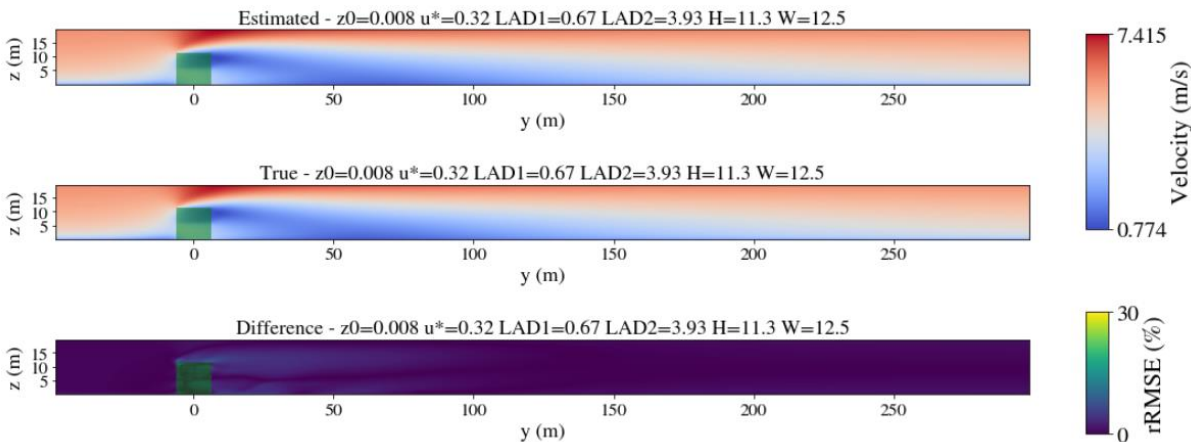


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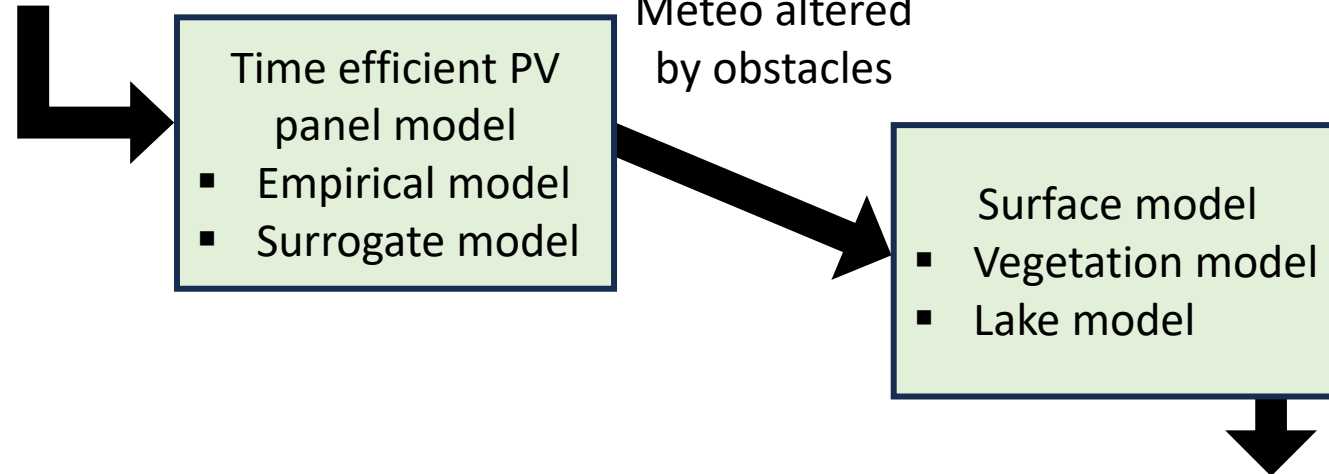


## Conclusions and Perspectives

*Simulations can indeed provide insight into evapotranspiration complex domains.*

→ *We need to bridge the gap between the different length and temporal scales!*

Meteo data





Thanks for listening!

Any questions?

