



HAL
open science

Microclimatic modeling and simulation tools: an academic benchmark

Teddy Gresse, Lucie Merlier, Auline Rodler, Julie Soriano, Felix Schmitt, Mathieu Galtier, Frédéric André, Jean-Claude Krapez, Jean Pierro, Ahmad Raessi, et al.

► To cite this version:

Teddy Gresse, Lucie Merlier, Auline Rodler, Julie Soriano, Felix Schmitt, et al.. Microclimatic modeling and simulation tools: an academic benchmark. 11th International Conference on Urban Climate, Aug 2023, Sydney, Australia. hal-04265599

HAL Id: hal-04265599

<https://hal.science/hal-04265599v1>

Submitted on 31 Oct 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Microclimatic modeling and simulation tools : an academic benchmark

T. Gresse^{1*}, L. Merlier^{1*}, A. Rodler^{2,3}, J. Soriano⁴, F. Schmitt⁴, M. Galtier⁴, F. André⁵, J.-C. Krapez⁶, J. Pierro⁶, A. Raessi^{2,3,7}, M. Musy^{2,3}, L. Roupioz⁷, X. Briottet⁷, L. Soulhac⁸, J. Jacob⁹

1. Univ Lyon, UCBL, INSA Lyon, CNRS, CETHIL, UMR5008, Villeurbanne F-69621, France
2. CEREMA BPE/ LOCIE/ IRSTV, Nantes, France
3. LOCIE, UMR 5271, CNRS & Université Savoie-Mont-Blanc, Chambéry, France
4. Univ Lyon, INSA Lyon, CNRS, CETHIL, UMR5008, Villeurbanne F-69621, France
5. Univ Lyon, CNRS, UCBL, INSA Lyon, CETHIL, UMR5008, Villeurbanne F-69621, France
6. ONERA, The French Aerospace Lab, DOTA, F-13661 Salon cedex Air, France

7. ONERA, DOTA, Toulouse university, France
8. Laboratoire de Mécanique des Fluides et d'Acoustique, University of Lyon, CNRS UMR 5509 Ecole Centrale de Lyon, INSA Lyon, Université Claude Bernard Lyon 1, 69134, Ecully, France
9. Aix Marseille Univ, CNRS, Centrale Marseille, M2P2, UMR 7340, Marseille, 13451, France

* teddy.gresse@insa-lyon.fr / lucie.merlier@insa-lyon.fr

General framework

DIAMS PROJECT

- **Objective:** Evaluate the contribution of thermal infrared satellite measurements in support of numerical modeling for urban climatology for the diagnosis and monitoring of overheating from the urban to the building scale, for use by local authorities.
- **First step:** Qualification of various urban microclimate models developed or used by the consortium

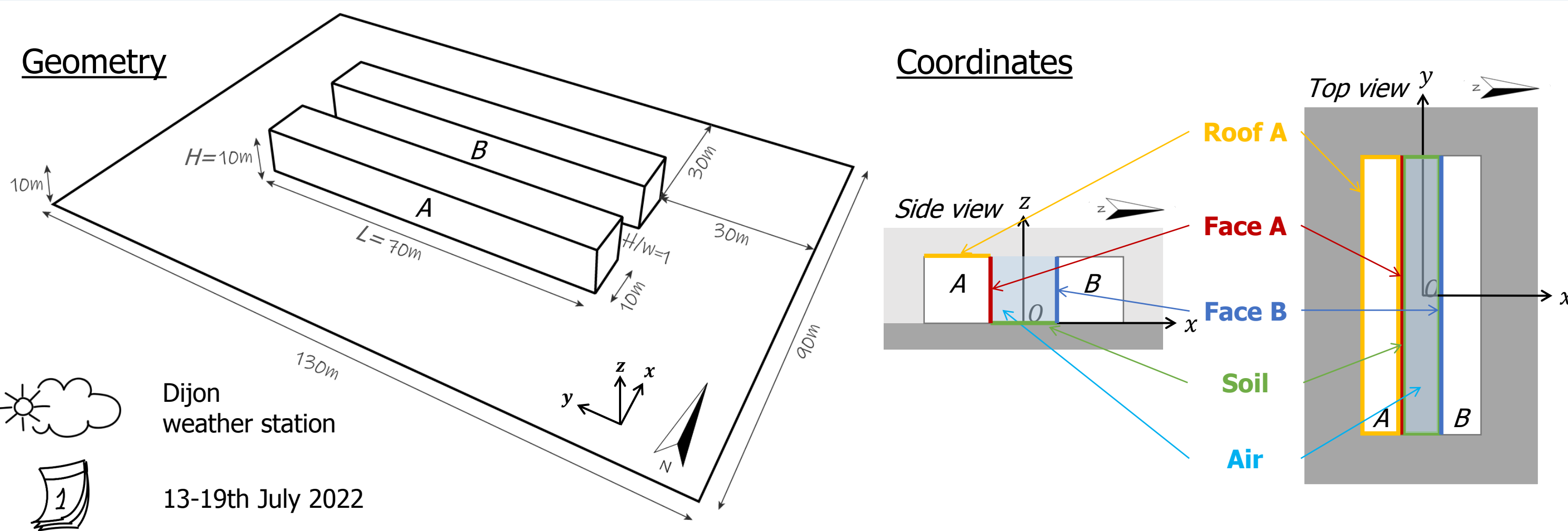
Challenges for the model qualification:

- heterogeneous, open and large space integrating multiple physical phenomena at different scales
- very large amount of data to have a good knowledge of the area (materials, vegetation, heat sources...)
- very large number of variables (temperatures, air speed and humidity, radiation, surface temperatures...)

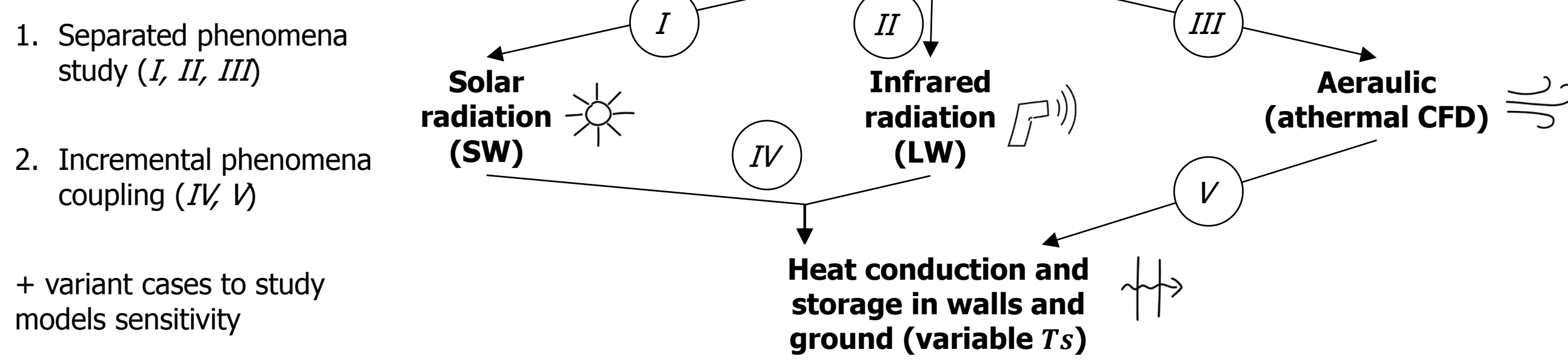
Definition of an academic benchmark based on a simplified configuration

Methodology

CONFIGURATION



PROCEDURE



PARAMETRIZATION

black: base case / Blue: variant

Solar radiation	Infrared radiation	Aeraulic	Heat conduction and storage
albedo soil: 0.15 / 0.3	emissivity soil: 0.9	Surface roughness: 0 m	Walls/Int insulation: 5 / 0.03
albedo walls: 0.4 / 0.55	emissivity walls: 0.9 (0 transmittivity)	Wind direction: 0° / 45°	Roof: 30 / 1.7
albedo roof: 0.2	emissivity roof: 0.9 (0 transmittivity)	Velocity profile: $U_{in}(z) = \frac{u_*}{0.43} \ln(\frac{z+10^{-5}}{10^{-5}})$	asphalt: 5 / 0.7
direct horizontal flux: 194.2 - 603.5 - 112.5 W/m ²	Ts wall: 25 °C / 35 °C (FaceA)	Velocity profile: $U_{in}(10 m) = 3.6 / 5.2 m/s$	soil: 35 / 1.8
diffuse horizontal flux: 128.0 - 263.1 - 115.3 W/m ²	Ts roof: 25 °C	TKE profile: $k_t(z) = 0.03U_{in}^2(z)$	ground: 160 / 0.5
atmosphere: Transparent air	Ts soil: 17 °C	IC T walls and ground: 20 °C	Ts int: 25 °C
	Incident horizontal flux sky model: 394.4 W/m ²	Output variable: surface temperature [°C]	BC: 20 °C
	Isotropic Transparent air	Compared models: code SATURNE, PROLB	hc ext: 30 W/(m ² .K) / CFD coupling

Date:	Output variable:	Compared models:
07/18 at 6:30 am - 12:30 pm - 5:30 pm	global incident SW flux [W/m ²]	MATHIS, SOLENE-MICROCLIMAT, TRABOULE, MONTE-CARLO (reference calculation [1])
07/18 at 12:30 pm	incident LW flux [W/m ²]	MATHIS, SOLENE-MICROCLIMAT, TRABOULE, MONTE-CARLO (reference calculation [1])
07/18 at 12:00 pm / 5:00 pm	air velocity [m/s]	code SATURNE, PROLB
from 07/13 to 07/20 (dynamic)	surface temperature [°C]	MATHIS, SUSHI, SOLENE-MICROCLIMAT - code SATURNE, TRABOULE-PROLB

URBAN MICROCLIMATE MODELS

	MATHIS [2]	SUSHI [3]	SOLENE-MICROCLIMAT [4]	TRABOULE [5]
Radiation	Radiosity	Radiosity	Radiosity	RTE resolution (FV) + absorption
Detail levels	1 node per surface	Unstructured surface mesh ($\Delta x \sim H/16$ inside canyon)	Structured surface and volume mesh ($\Delta x = H/20$)	
Heat conduction and storage	FD method	Transfer functions (FS)	RC / FE methods	FD method
Detail levels	1D multi-layers	1D quadrupoles (1/material)	1D multi-layers	1D multi-layers
Aeraulic	Simplified parametrization	Empirical correlations	CFD (code SATURNE [6]) RANS $k-\epsilon$	CFD (PROLB [7]) LBM-LES
Detail levels			Unstructured volume mesh ($\Delta x \sim H/16$ inside canyon)	Structured volume mesh ($\Delta x = H/48$ inside canyon)

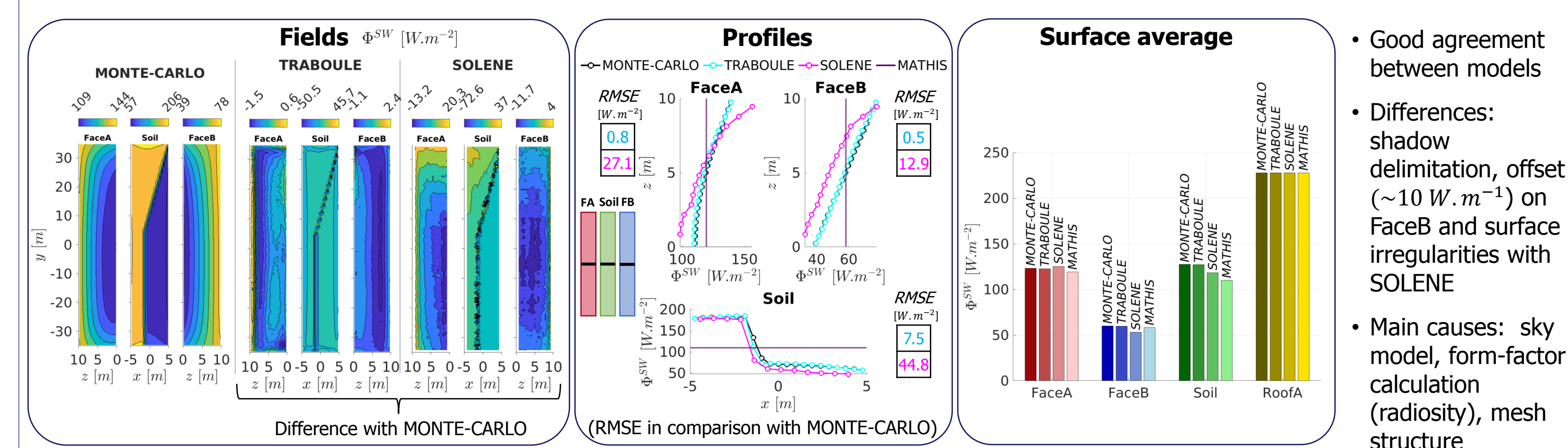
FD: finite differences / FE: finite elements / FS: Fourier space / FV: finite volumes / RC: electrical analogy / RTE: radiative transfer equation

Conclusions

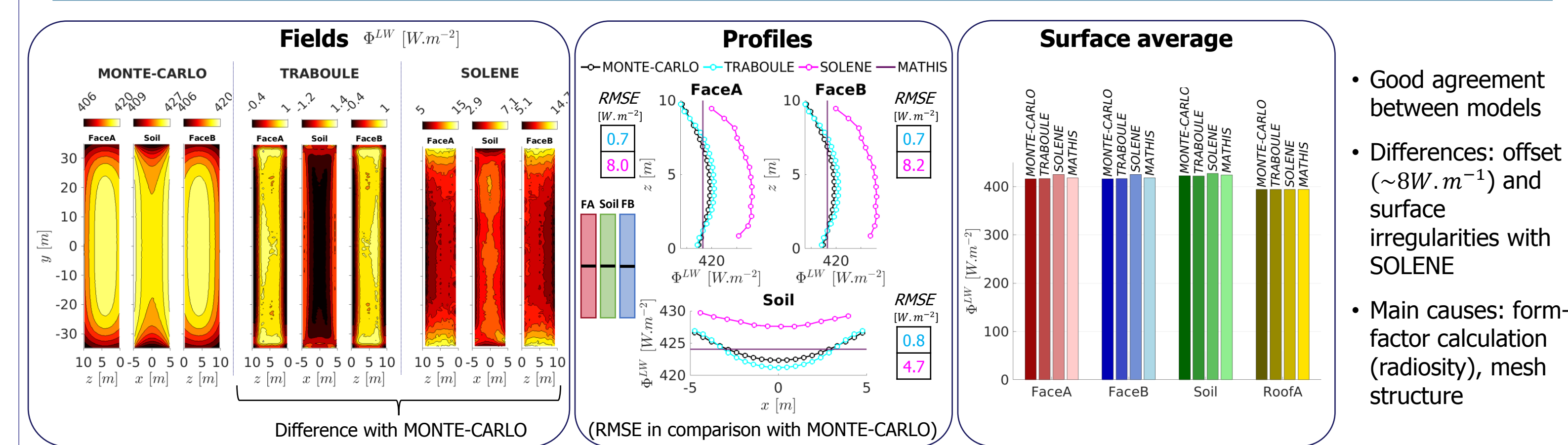
- Definition of a robust strategy to discuss and evaluate the urban microclimate models capabilities
 - Selection of a simplified geometry and common input parameters
 - Gathering of different data types from simulations
 - Results analysis on three levels: surface average, profiles and fields
- Comparable results but with different resolution and objectives for the models

Results

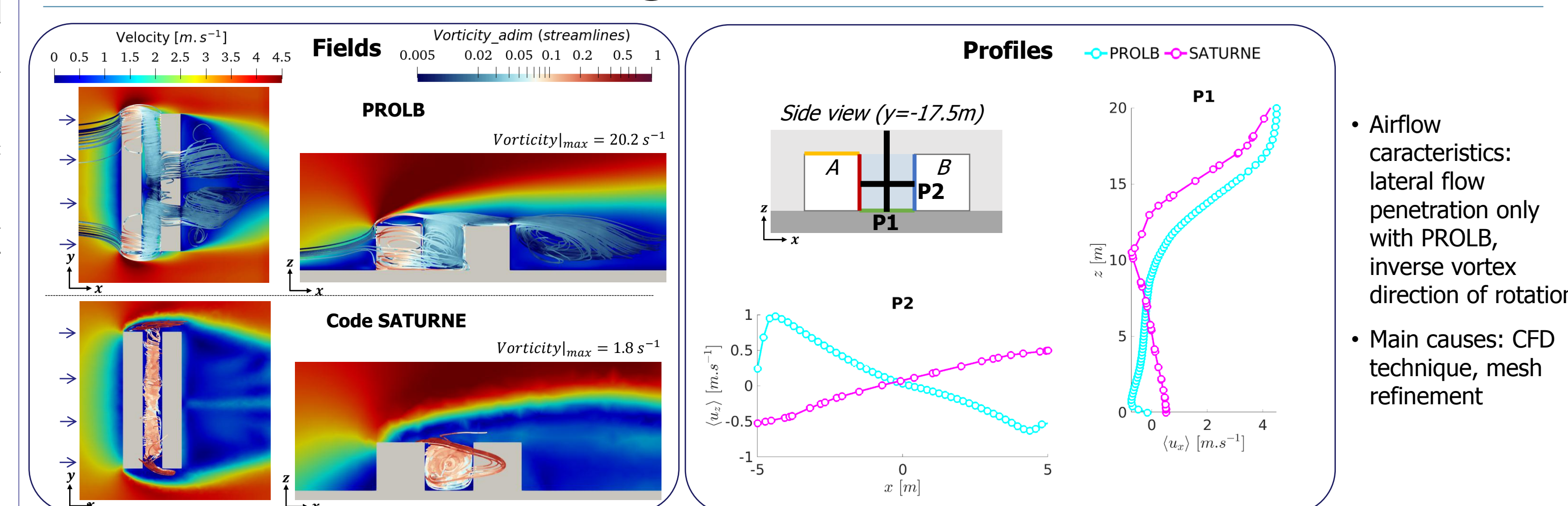
I SOLAR RADIATION (base case, 17:30 pm)



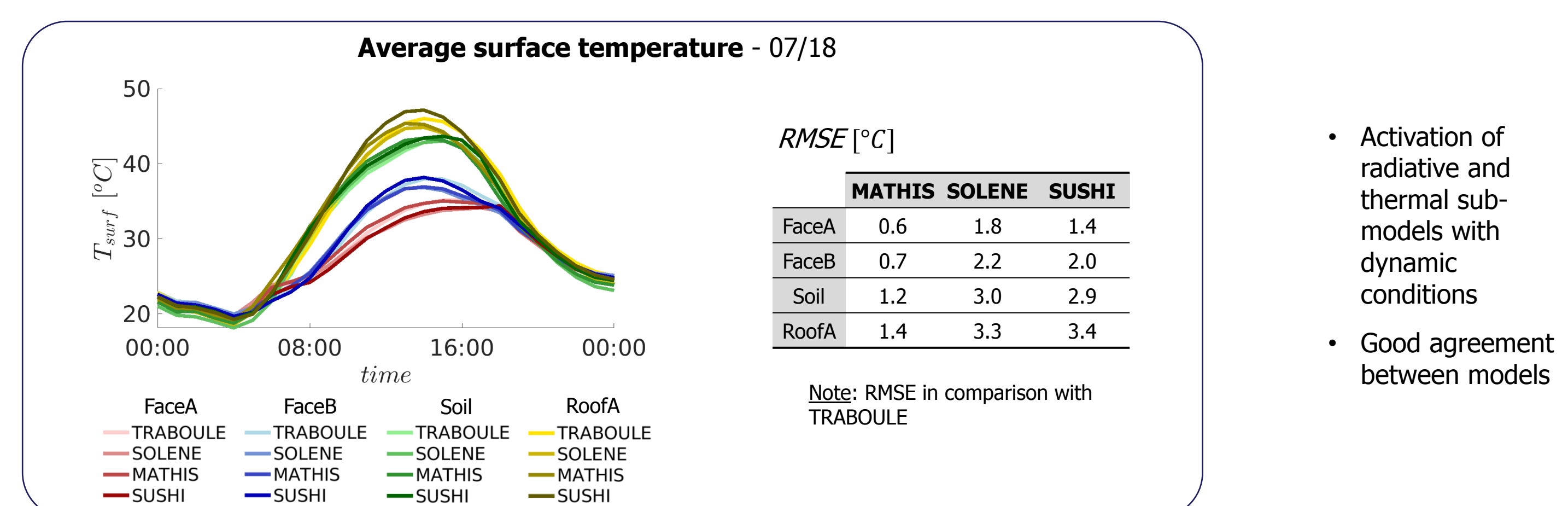
II INFRARED RADIATION (base case)



III AERAULIC (base case)



IV HEAT CONDUCTION AND STORAGE (base case)



Perspectives

- Ready-to-use datasets allowing modelers to validate and compare urban microclimatology tools
- Application to a real-life configuration: the experimental campaign CAMCATT (oral presentation n°75)
- Implementation of a complete approach for the validation of urban microclimate models (oral presentation n°191)

References and acknowledgments

[1] M. Galtier et al. (2022) <https://doi.org/10.1016/j.applthermaleng.2022.119020>
 [2] J. Soriano et al. (2021) <https://doi.org/10.26868/25222708.2021.30279>
 [3] N. Lalanne, et al. (2015) <https://doi.org/10.1080/17686733.2015.1066134>
 [4] M. Musy, et al. (2021) [10.1007/978-3-030-65421-4_13](https://doi.org/10.1007/978-3-030-65421-4_13)
 [5] F. Schmitt et al. (2022) <https://doi.org/10.1615/TFEC2022.emt.041362>

[6] L. Malys et al. (2015) <https://doi.org/10.1080/17512549.2015.1043643>
 [7] L. Merlier, et al. (2019) <https://doi.org/10.1016/j.buildenv.2018.11.009>

This work was supported by the ANR DIAMS project, grant ANR-21-CE22-0010 of the French Agence Nationale de la Recherche.

This work was granted access to the HPC resources of TGCC under the allocation 2023-A0132A13804 made by GENCI