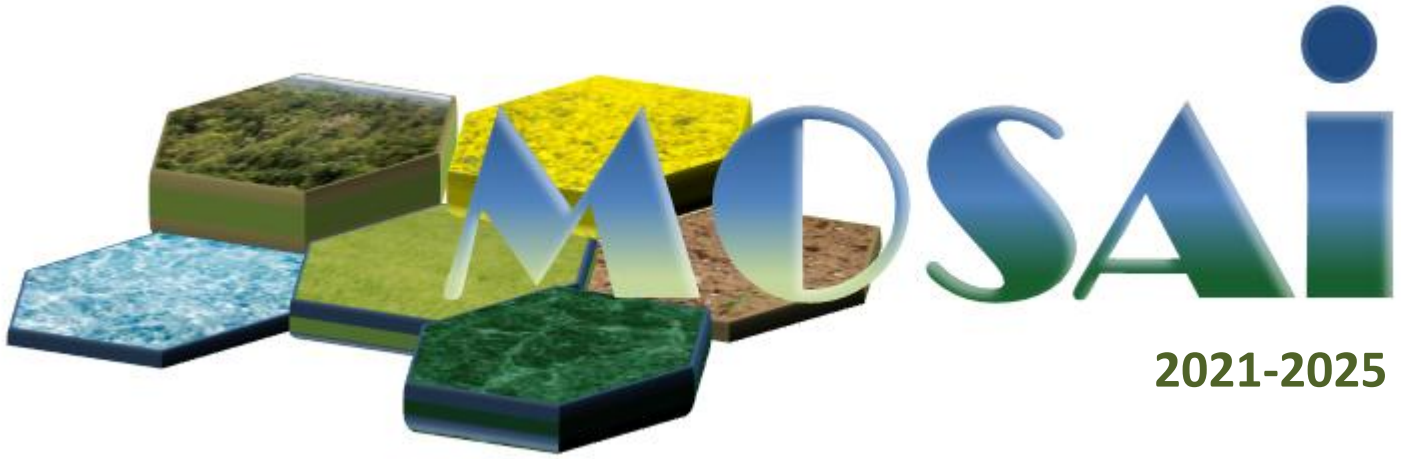


2021-2025

Model and observation for Surface Atmosphere Interactions

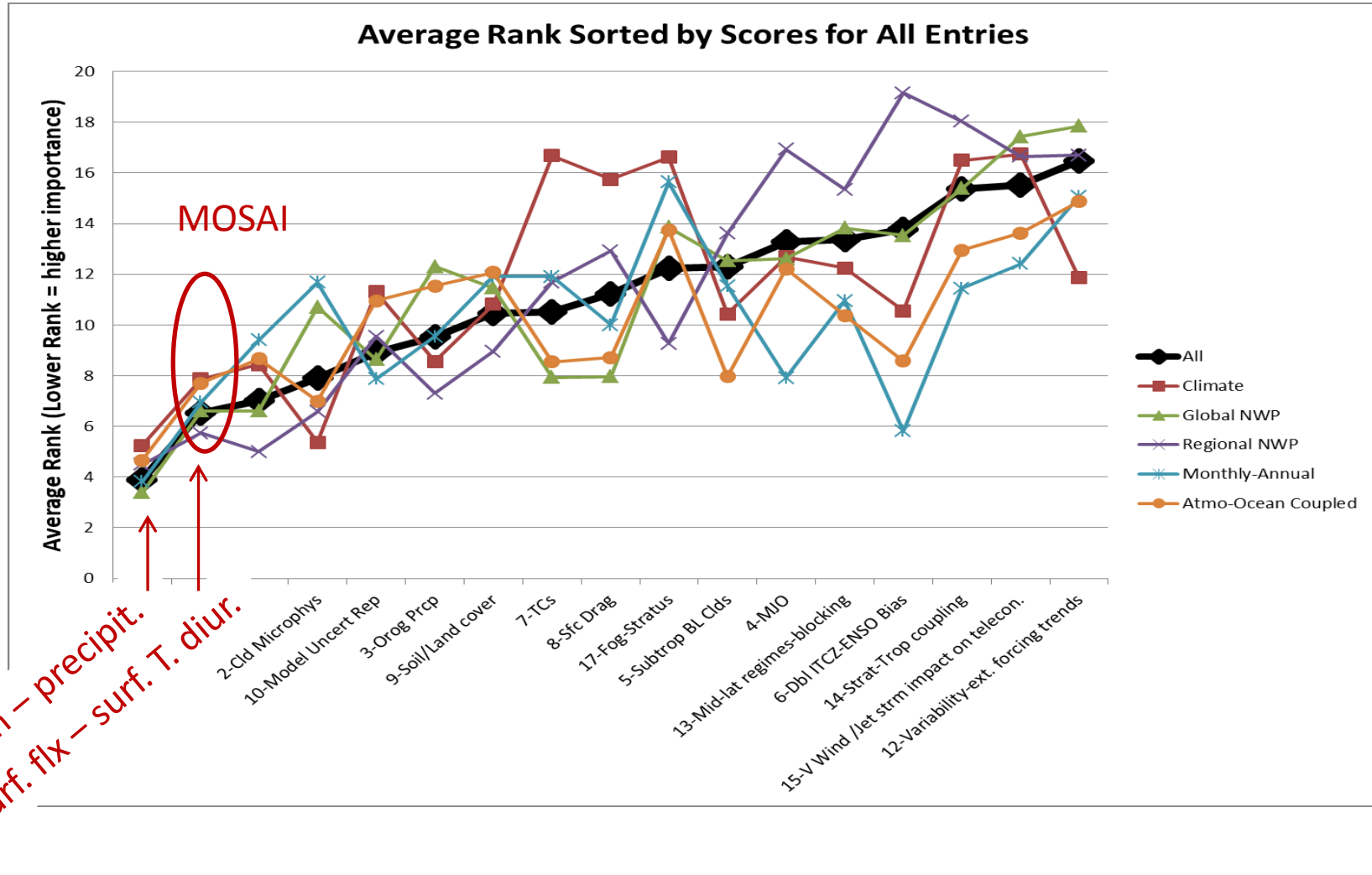
Fabienne Lohou

LOTHON M., BASTIN S., BRUT A., CANUT G., CHERUY F., COHARD J.-M., COUVREUX F., DARROZES J., DUPONT J.-C., FERNANDEZ R., JOME M., LAFONT S., ROEHRIG R., ROMÁN-CASCÓN C., ZOUZOUA M., and MOSAI team

PROJET FINANCÉ PAR L'ANR - PROJECT FUNDED BY THE ANR

Motivations

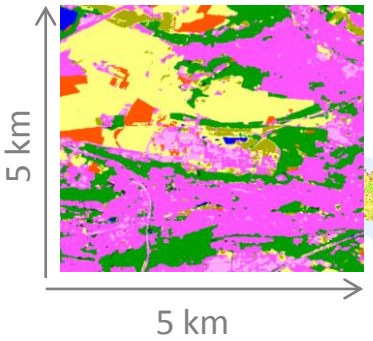
Working Group on Numerical Experimentation (Fev. 2019)



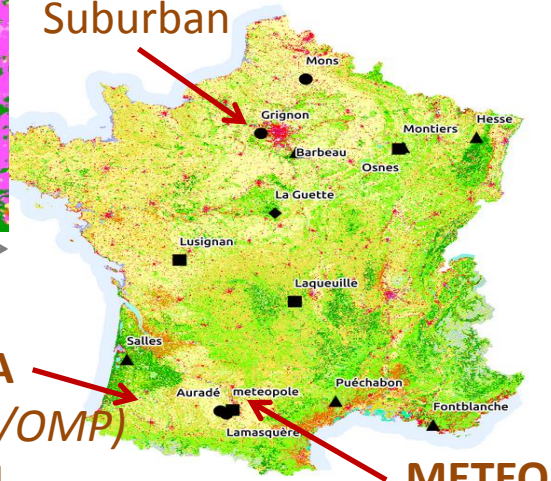
Motivations

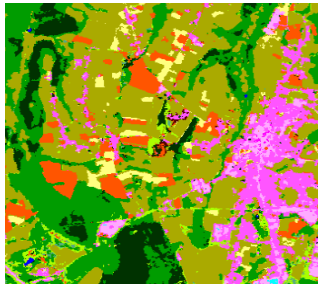
Land use map
(Sentinel-2)

- Urban
- Forest
- Grass
- Crops



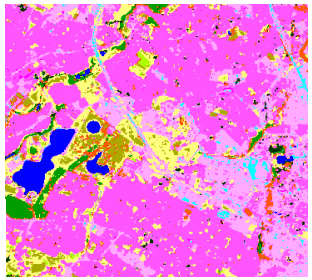
SIRTA *(IPSL)*
Suburban





P2OA
(UT3/OMP)
Rural

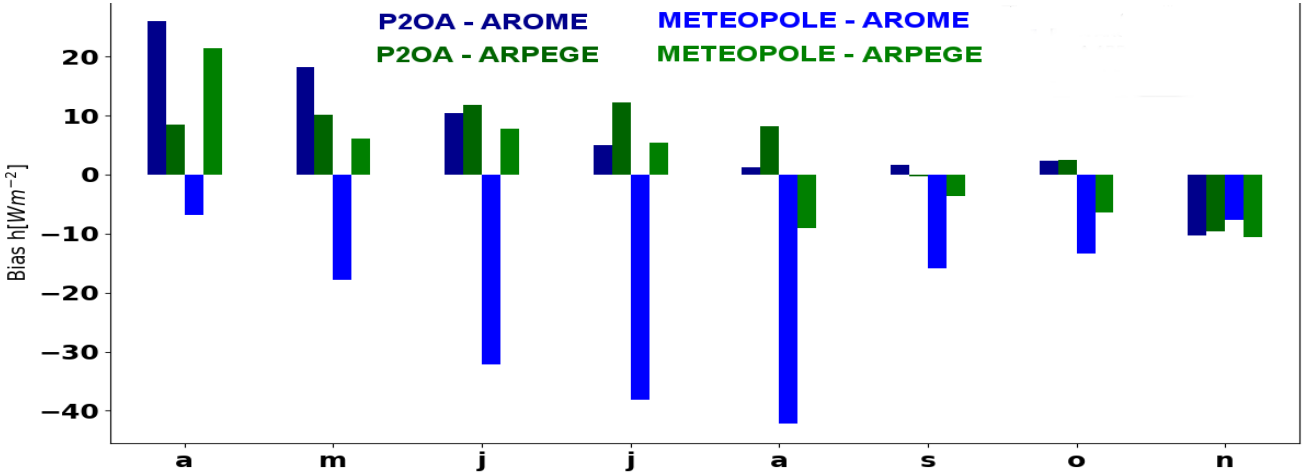
METEOPOLE-FLUX
Urban



ACTRiS FRANCE

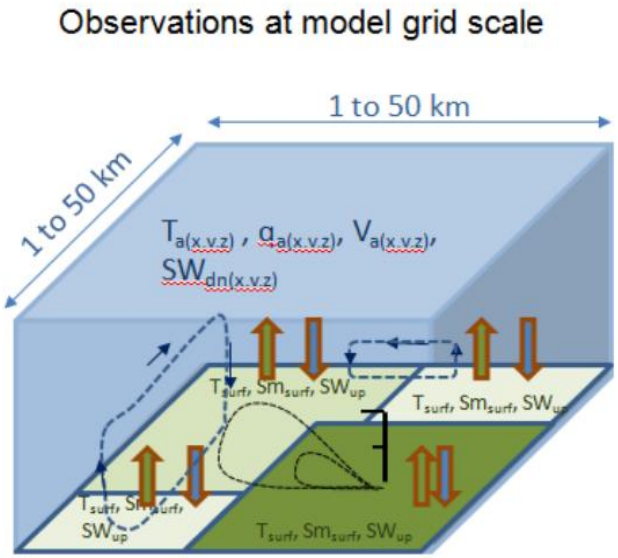
ICOS Integrated Carbon Observation System

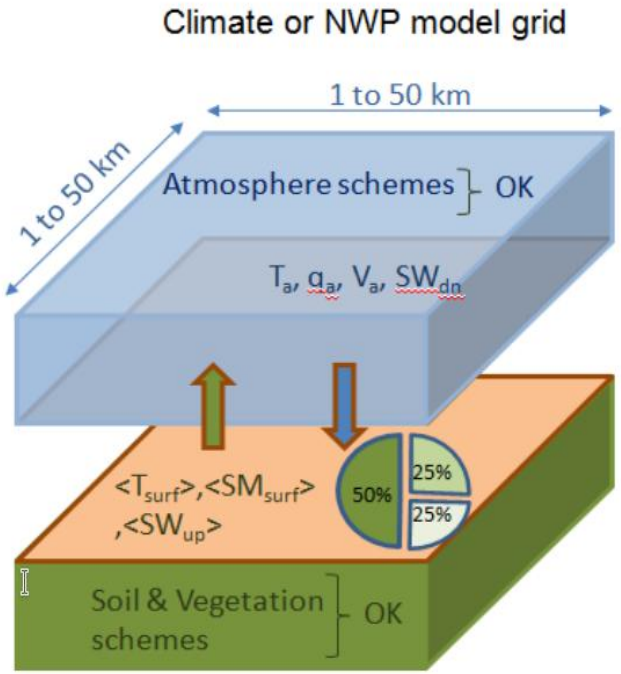
Monthly Bias (Model – Observations) for sensible heat flux



©Guylaine Canut, CNRM

MOSAI Objectives





WP1: uncertainty and horizontal representativeness of L-A exchanges measured over heterogeneous landscape

***WP3:* Improvement of the L-A models coupling**

***WP2:* Model evaluation using long-term measurements**

Outline

- Motivations
- Objectives
- Strategy
- 2023 field experiment
- Some ongoing works for each objective
  - O1: Representativity
  - O2: New methods for model evaluation
  - O3: Improving surface/atmosphere coupling

MOSAI Strategy

Permanent Observations
~ 10 years

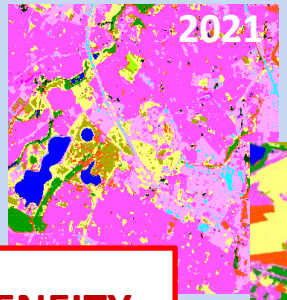
ACTRiS

ICOS Integrated Carbon Observation System

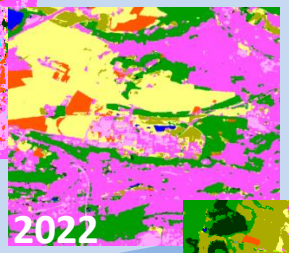
SURFACE HETEROGENEITY

Enhanced Observations
~ 1 year

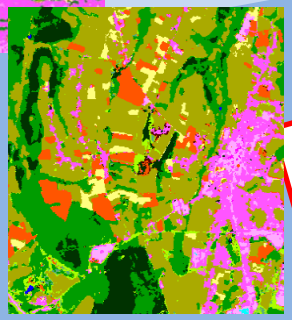
Metepole: urban



SIRTA: sub-urban



P2OA: rural

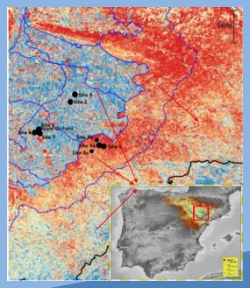


P2OA SOP

Roughness Transition

Intensive Observations

LIAISE
2021



VERTICAL STRUCTURE

Numerical Models

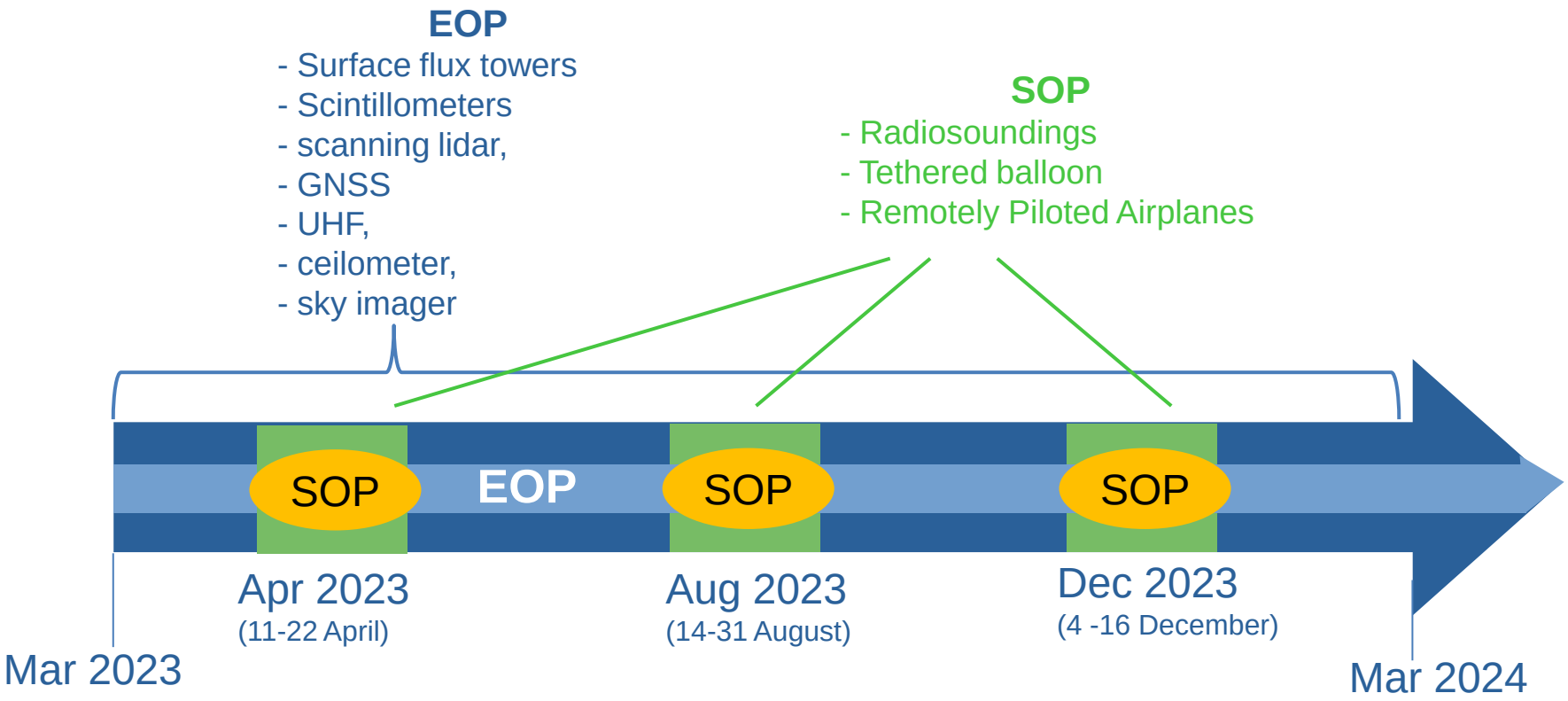
Méso-NH/ SURFEX ; LES
WRF / ORCHIDEE; Régional
AROME / SURFEX; Regional

ARPEGE / SURFEX; Cimate
LMDZ / ORCHIDEE; Climate
DYNAMICO / ORCHIDEE; Climate

Field campaign at P2OA

Main objective :

- Characterize the representativity of the P2OA 60 m tower relatively to the heterogeneous landscape
- Document the vertical structure
- Investigate the impact of a roughness transition

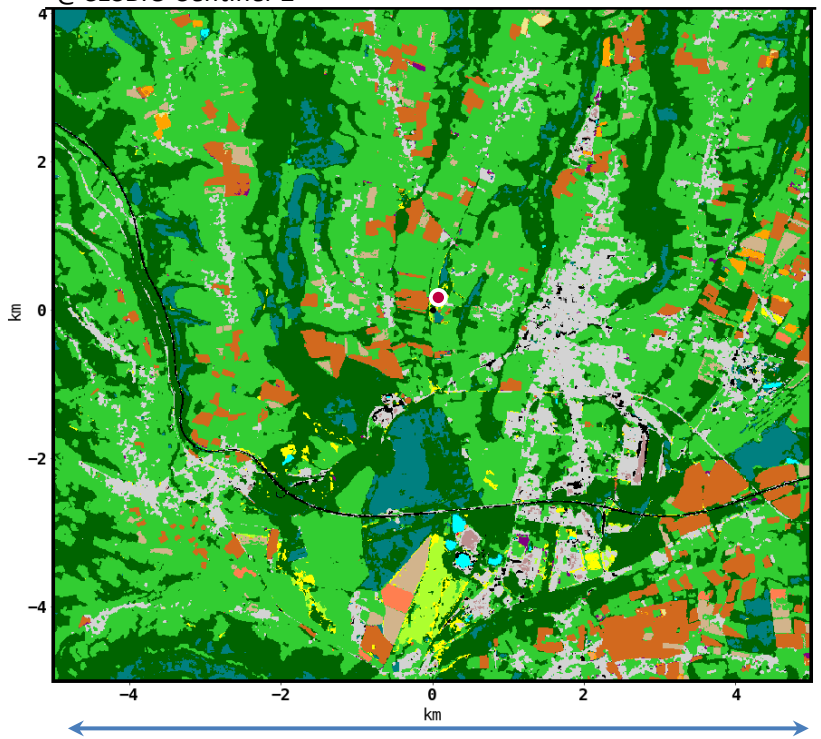


P2OA EOP: Surface heterogeneity

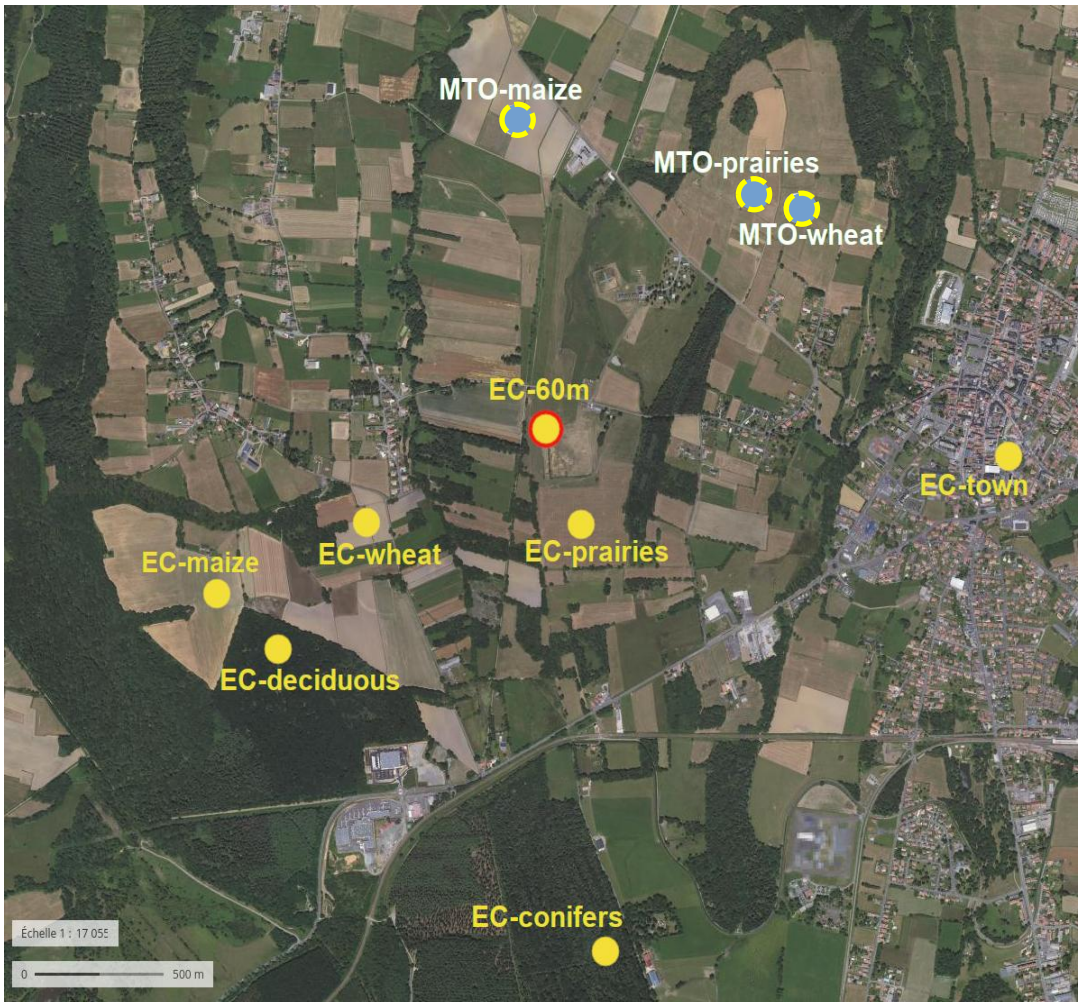
Deployment of flux stations:

- Prairies
- Deciduous forest
- Summer crops
- Urban in Lannemezan
- Winter crops
- Conifer forest / mixt forest

@CESBIO-Sentinel-2



10 km



4 km

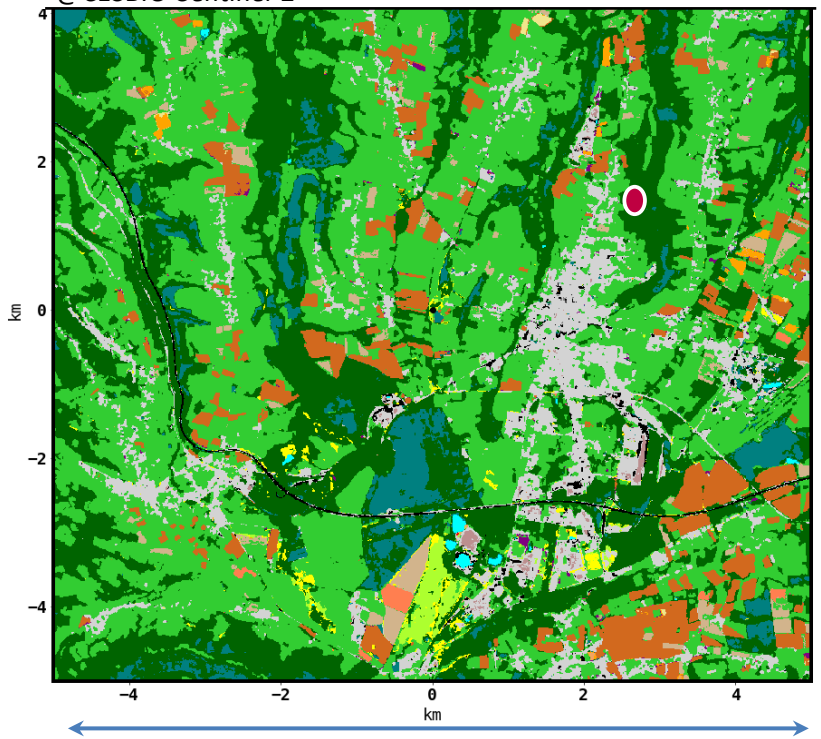
MTO station → Flux estimates: see presentation Jomé et al

P2OA EOP: Surface heterogeneity

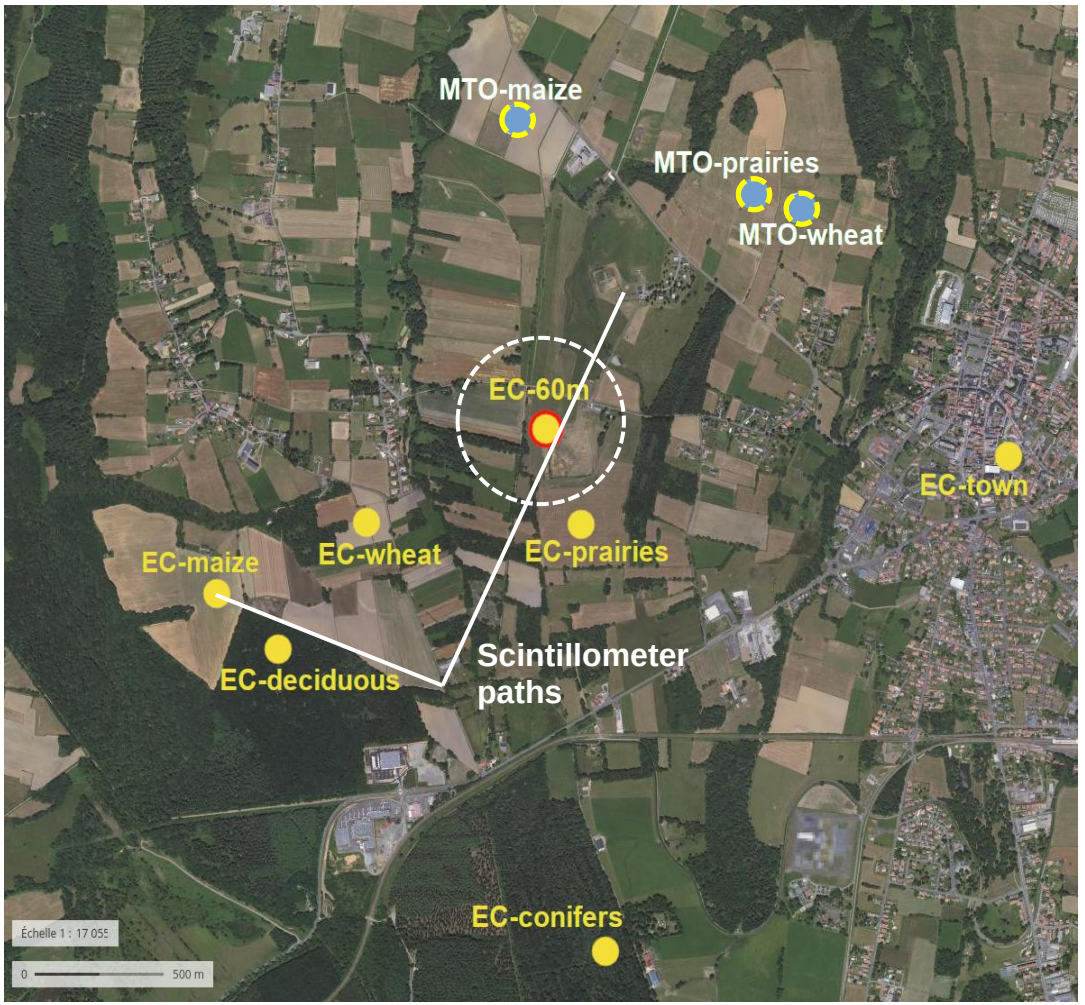
Deployment of flux stations:

- Prairies
- Deciduous forest
- Summer crops
- Urban in Lannemezan
- Winter crops
- Conifer forest / mixt forest

@CESBIO-Sentinel-2

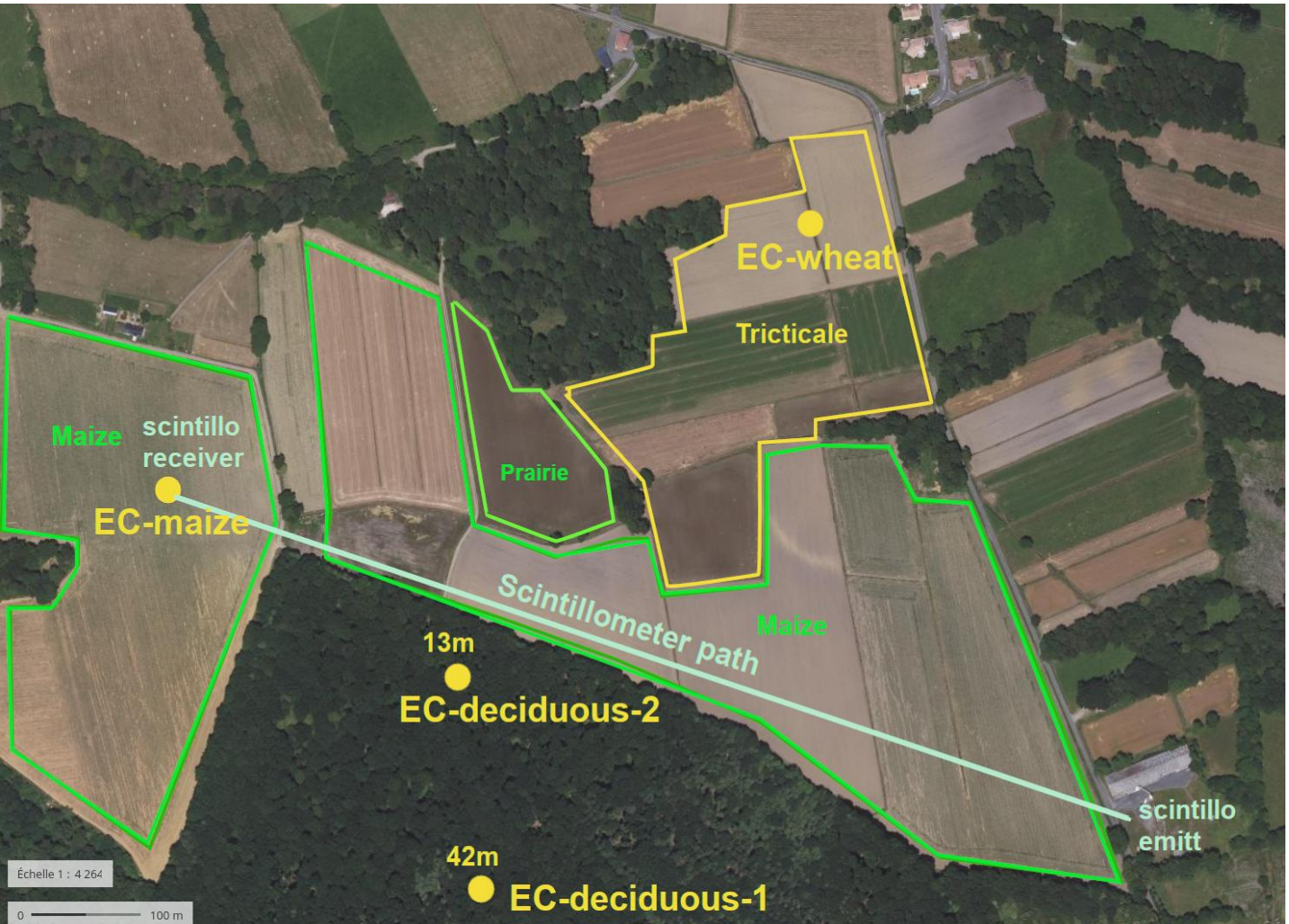


10 km



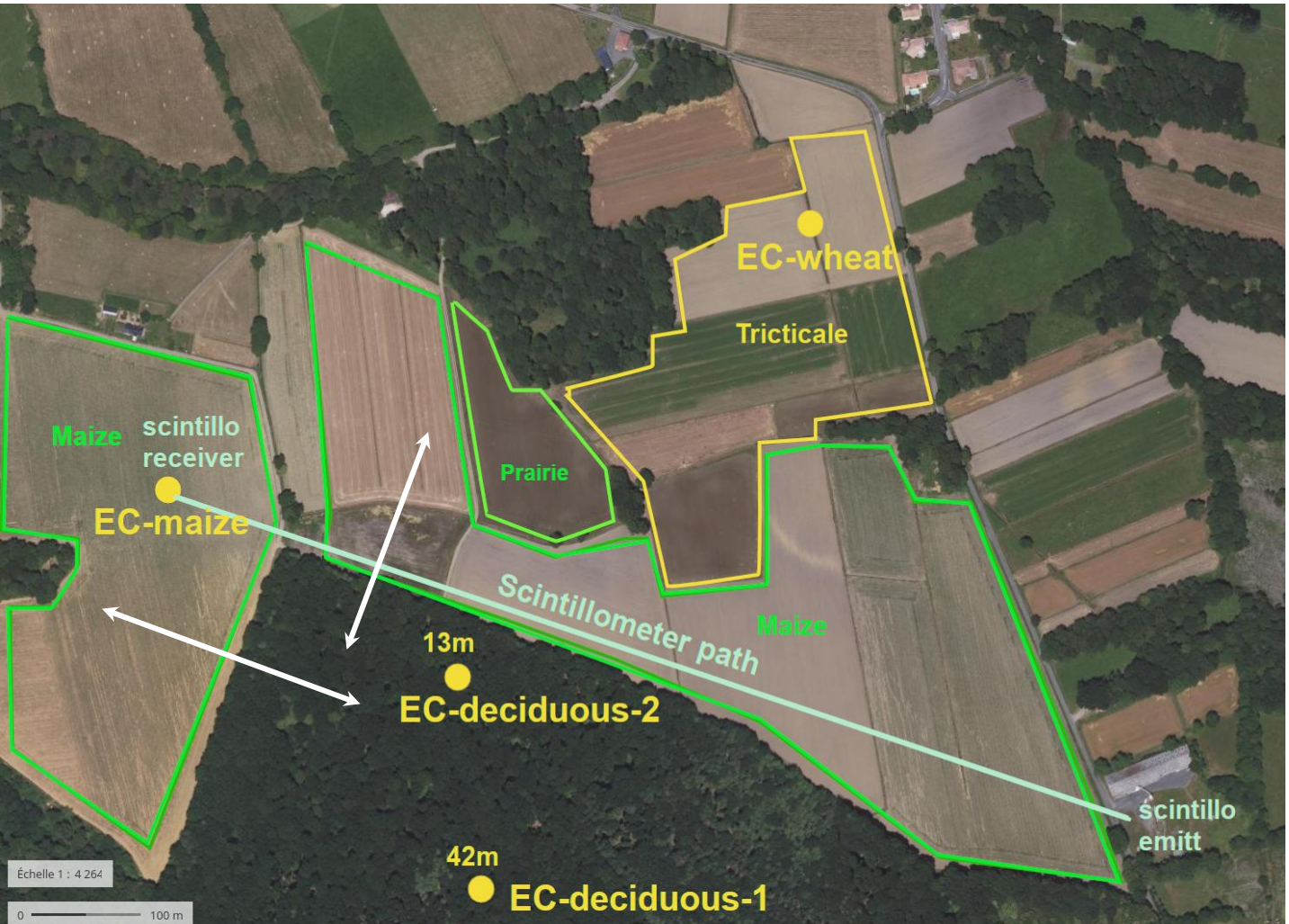
4 km

P2OA EOP: Exploring a specific transition



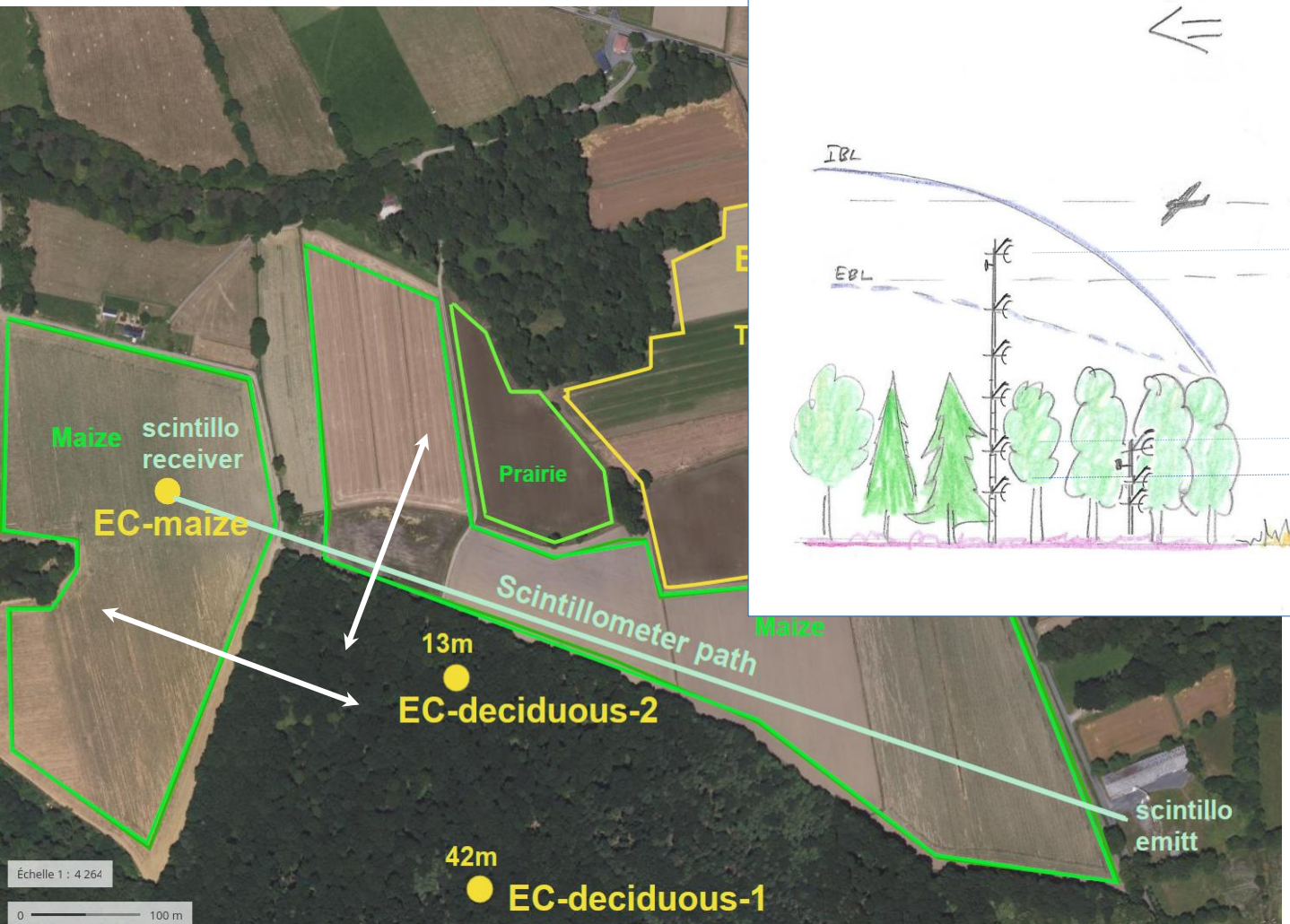
P2OA EOP: Exploring a specific transition

-Vertical structure across the transition
- Impact on fluxes and influence of atmospheric structures within canopees
- Effective roughness



P2OA EOP: Exploring a specific transition

-Vertical structure across the transition
- Impact on fluxes and influence of atmospheric structures within canopees
- Effective roughness



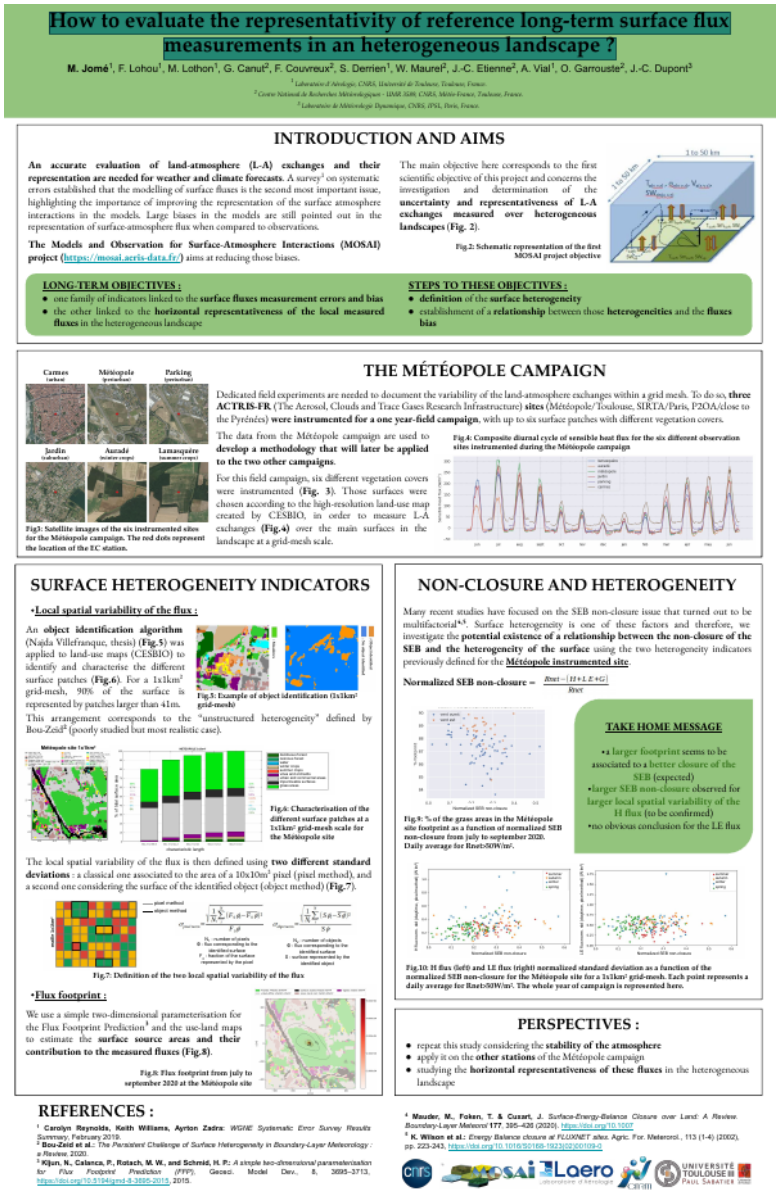
O1- Representativity

How to evaluate the representativity of reference long-term surface flux measurements in an heterogeneous landscape ?

See Poster from Mathilde Jomé (LAERO) !

Based on Meteopole EOP (2021)

- Surface heterogeneity indicators
- Link between
  - surface energy budget residual
  - and flux heterogeneity



How to evaluate the representativity of reference long-term surface flux measurements in an heterogeneous landscape ?

M. Jomé[1], F. Lohou[1], M. Lothon[1], G. Canut[2], F. Couvreux[2], S. Derrien[1], W. Maurel[2], J.-C. Etienne[2], A. Vial[1], O. Garrouste[2], J.-C. Dupont[3]

[1] Laboratoire d'Aérologie, CNRS, Université de Toulouse, Toulouse, France.
[2] Centre National de Recherches Météorologiques - UMR 3589, CNRS, Météo-France, Toulouse, France.
[3] Laboratoire de Météorologie Dynamique, CNRS, IPSL, Paris, France.

INTRODUCTION AND AIMS

An accurate evaluation of land-atmosphere (L-A) exchanges and their representation are needed for weather and climate forecasts. A survey[1] on systematic errors established that the modelling of surface fluxes is the second most important issue, highlighting the importance of improving the representation of the surface atmosphere interactions in the models. Large biases in the models are still pointed out in the representation of surface-atmosphere flux when compared to observations.

The Models and Observation for Surface-Atmosphere Interactions (MOSAI) project (https://mosai.aeris-data.fr/) aims at reducing those biases.

The main objective here corresponds to the first scientific objective of this project and concerns the investigation and determination of the **uncertainty and representativeness of L-A exchanges measured over heterogeneous landscapes (Fig. 2).**

Fig.2: Schematic representation of the first MOSAI project objective

LONG-TERM OBJECTIVES :
- one family of indicators linked to the **surface fluxes measurement errors and bias**
- the other linked to the **horizontal representativeness of the local measured fluxes** in the heterogeneous landscape

STEPS TO THESE OBJECTIVES :
- **definition** of the **surface heterogeneity**
- establishment of a **relationship** between those **heterogeneities** and the **fluxes bias**

THE MÉTÉOPOLE CAMPAIGN

Carmes (urbain) | Météopole (périurbain) | Parking (périurbain)
Jardin (rural-urbain) | Auradé (intérieur crop) | Lamasquère (intérieur crop)

Fig3: Satellite images of the six instrumented sites for the Météopole campaign. The red dots represent the location of the EC station.

Dedicated field experiments are needed to document the variability of the land-atmosphere exchanges within a grid mesh. To do so, **three ACTRIS-FR** (The Aerosol, Clouds and Trace Gases Research Infrastructure) **sites** (Météopole/Toulouse, SIRTA/Paris, P2OA/close to the Pyrénées) **were instrumented for a one year-field campaign**, with up to six surface patches with different vegetation covers.

The data from the Météopole campaign are used to **develop a methodology that will later be applied to the two other campaigns.**

For this field campaign, six different vegetation covers were instrumented (**Fig. 3**). Those surfaces were chosen according to the high-resolution land-use map created by CESBIO, in order to measure L-A exchanges (**Fig.4**) over the main surfaces in the landscape at a grid-mesh scale.

Fig.4: Composite diurnal cycle of sensible heat flux for the six different observation sites instrumented during the Météopole campaign

SURFACE HETEROGENEITY INDICATORS

•Local spatial variability of the flux :

An **object identification algorithm** (Najda Villefranque, thesis) (**Fig.5**) was applied to land-use maps (CESBIO) to identify and characterise the different surface patches (**Fig.6**). For a 1x1km² grid-mesh, 90% of the surface is represented by patches larger than 41m.

This arrangement corresponds to the "unstructured heterogeneity" defined by Bou-Zeid[2] (poorly studied but most realistic case).

Fig.5: Example of object identification (1x1km² grid-mesh)

Fig.6: Characterisation of the different surface patches at a 1x1km² grid-mesh scale for the Météopole site

The local spatial variability of the flux is then defined using **two different standard deviations** : a classical one associated to the area of a 10x10m² pixel (pixel method), and a second one considering the surface of the identified object (object method) (**Fig.7**).

Fig.7: Definition of the two local spatial variability of the flux

•Flux footprint :

We use a simple two-dimensional parameterisation for the Flux Footprint Prediction[3] and the use-land maps to estimate the **surface source areas and their contribution to the measured fluxes (Fig.8).**

Fig.8: Flux footprint from july to september 2020 at the Météopole site

NON-CLOSURE AND HETEROGENEITY

Many recent studies have focused on the SEB non-closure issue that turned out to be multifactorial[4,5]. Surface heterogeneity is one of these factors and therefore, we investigate the **potential existence of a relationship between the non-closure of the SEB and the heterogeneity of the surface** using the two heterogeneity indicators previously defined for the **Météopole instrumented site**.

Normalized SEB non-closure = $\frac{Rnet-(H+LE+G)}{Rnet}$

Fig.9: % of the grass areas in the Météopole site footprint as a function of normalized SEB non-closure from july to september 2020. Daily average for Rnet>50W/m².

TAKE HOME MESSAGE
- a larger footprint seems to be associated to a better closure of the SEB (expected)
- larger SEB non-closure observed for larger local spatial variability of the H flux (to be confirmed)
- no obvious conclusion for the LE flux

Fig.10: H flux (left) and LE flux (right) normalized standard deviation as a function of the normalized SEB non-closure for the Météopole site for a 1x1km² grid-mesh. Each point represents a daily average for Rnet>50W/m². The whole year of campaign is represented here.

PERSPECTIVES :

- repeat this study considering the **stability of the atmosphere**
- apply it on the **other stations** of the Météopole campaign
- studying the **horizontal representativeness of these fluxes** in the heterogeneous landscape

REFERENCES :

[1] **Carolyn Reynolds, Keith Williams, Ayrton Zadra:** *WGNE Systematic Error Survey Results Summary*, February 2019.
[2] **Bou-Zeid et al.:** *The Persistent Challenge of Surface Heterogeneity in Boundary-Layer Meteorology : a Review*, 2020.
[3] **Kljun, N., Calanca, P., Rotach, M. W., and Schmid, H. P.:** *A simple two-dimensional parameterisation for Flux Footprint Prediction (FFP)*, Geosci. Model Dev., 8, 3695–3713, https://doi.org/10.5194/gmd-8-3695-2015, 2015.
[4] **Mauder, M., Foken, T. & Cuxart, J.** *Surface-Energy-Balance Closure over Land: A Review*. Boundary-Layer Meteorol 177, 395–426 (2020). https://doi.org/10.1007
[5] **K. Wilson et al.:** *Energy Balance closure at FLUXNET sites*. Agric. For. Meteorol., 113 (1-4) (2002), pp. 223-243, https://doi.org/10.1016/S0168-1923(02)00109-0

O2 - New methods for model evaluation

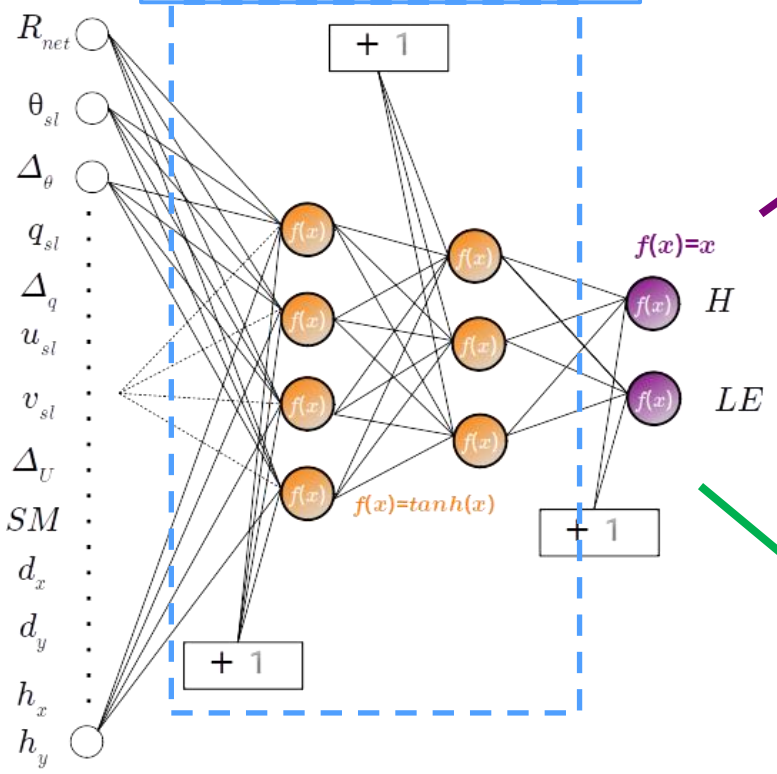
Using neural network to estimate model bias

By Maurin Zouzoua, Sophie Bastin, Marjolaine Chiriaco (LATMOS)

Objective: Make a “fair” model/obs comparison, by freeing from differences in environmental forcings.

Observed environmental variables

Multi-Layer Perceptron



MLP-based turbulent fluxes

To be compared to simulated fluxes

Simulated environmental Variables

MLP-based turbulent fluxes

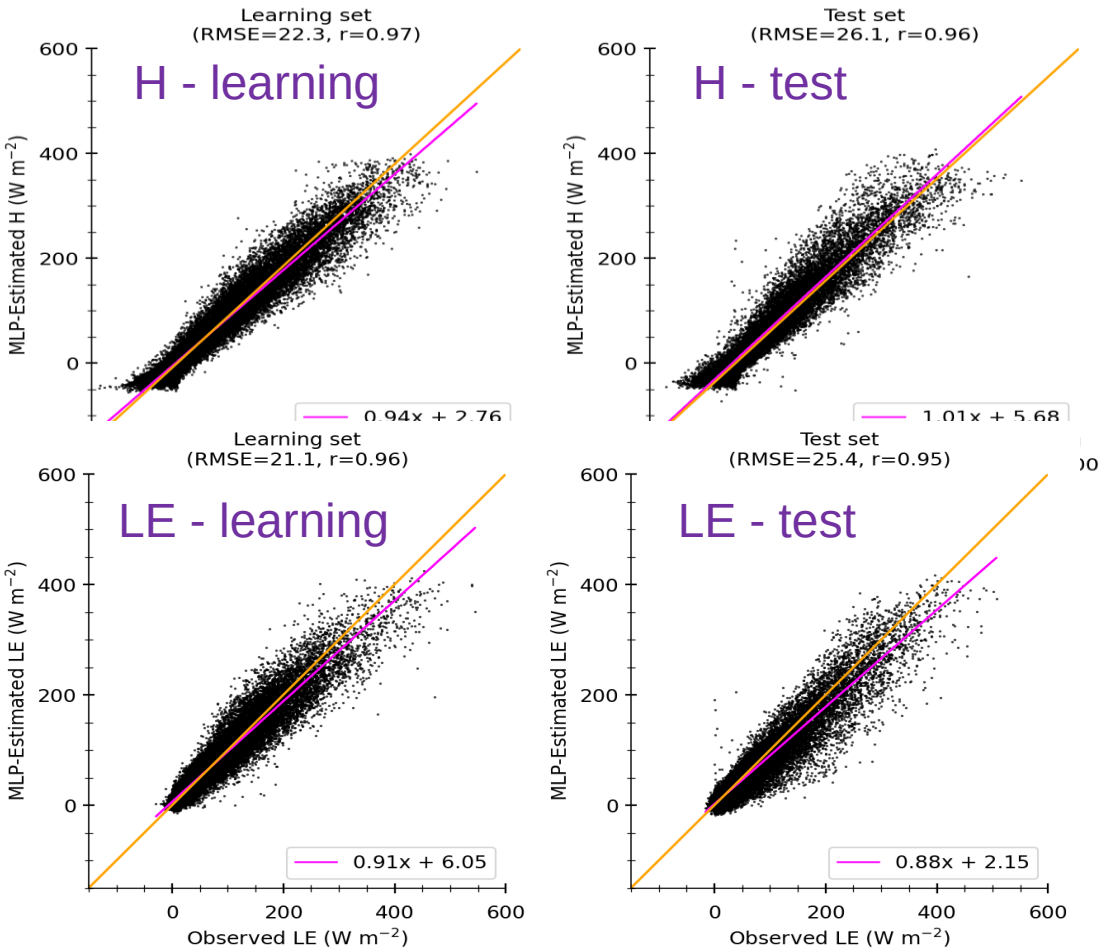
O2 - New methods for model evaluation

Using neural network to estimate model bias

By Maurin Zouzoua, Sophie Bastin, Marjolaine Chiriaco (LATMOS)

Observational data from Meteopole, Toulouse (Jun 2012 - Dec 2021)

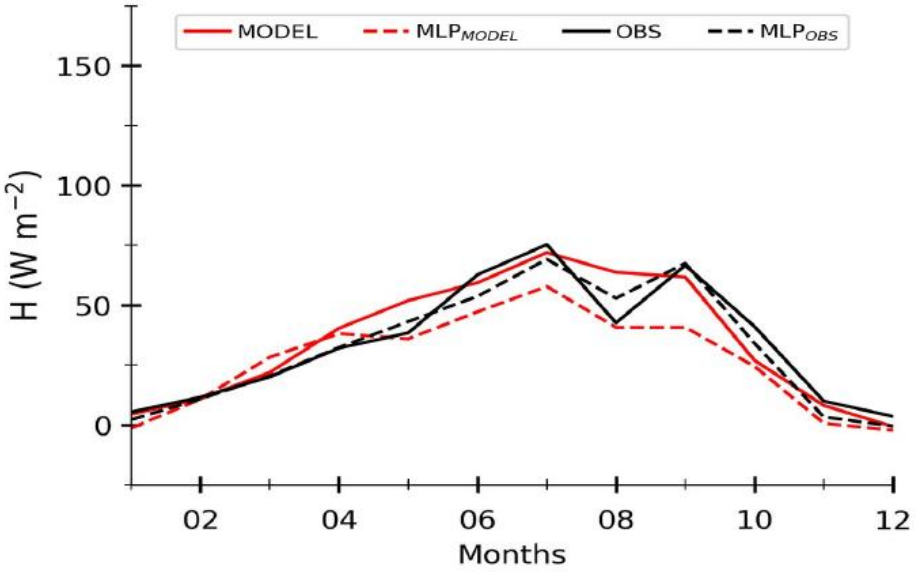
- Trained MLP performs well
- Difficulties for H estimation in strongly stable surface layer
- Difficulties in cases of large LE

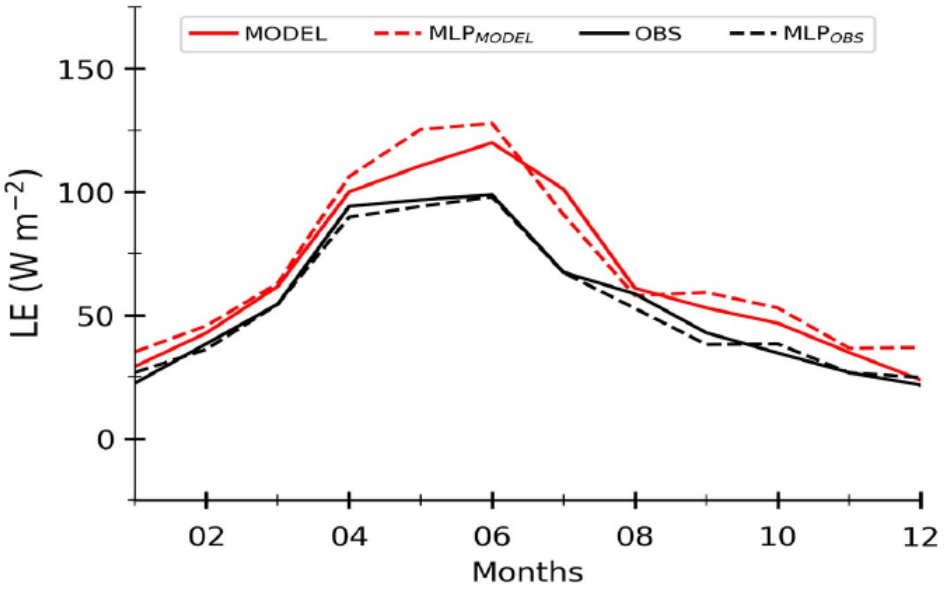


O2 - New methods for model evaluation

Using neural network to estimate model bias

By Maurin Zouzoua, Sophie Bastin, Marjolaine Chiriaco (LATMOS)



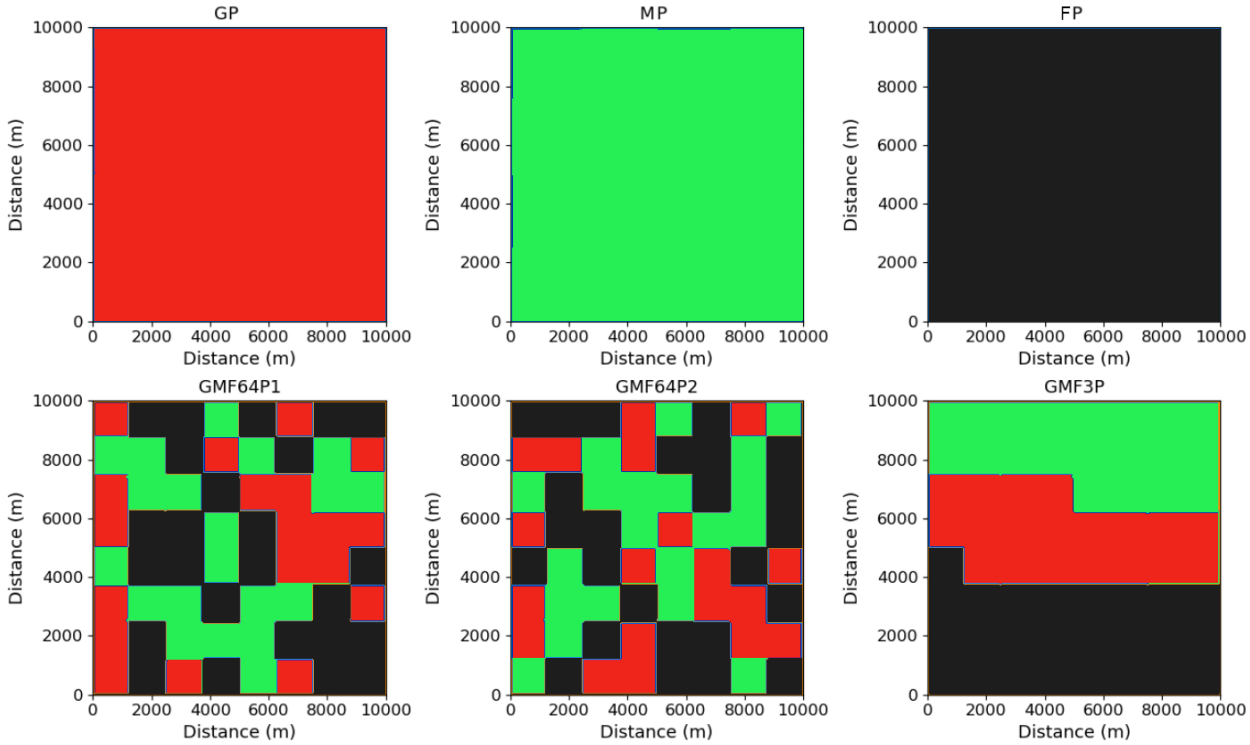


O3 : Improving surface/atmosphere coupling

Impact of surface heterogeneity on the boundary layer flow and near-surface turbulent exchanges in an LES framework.

by Royston Fernandez, Fleur Couvreux, CNRM

MesoNH/SURFEX coupled LES

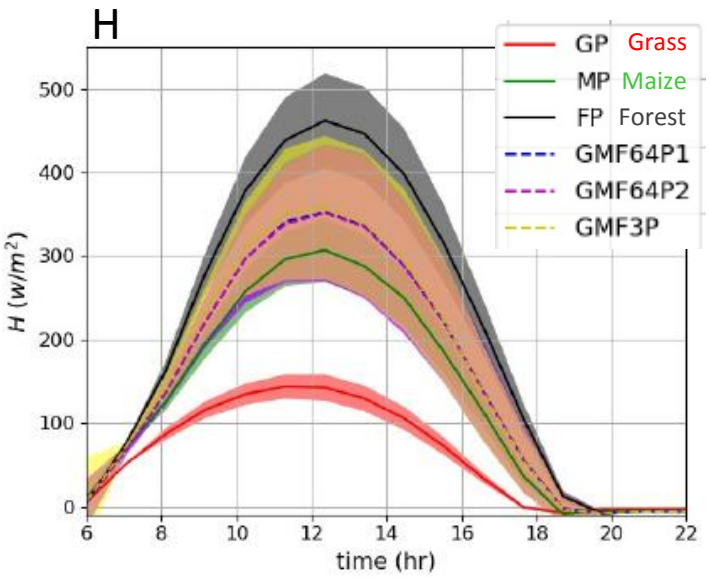


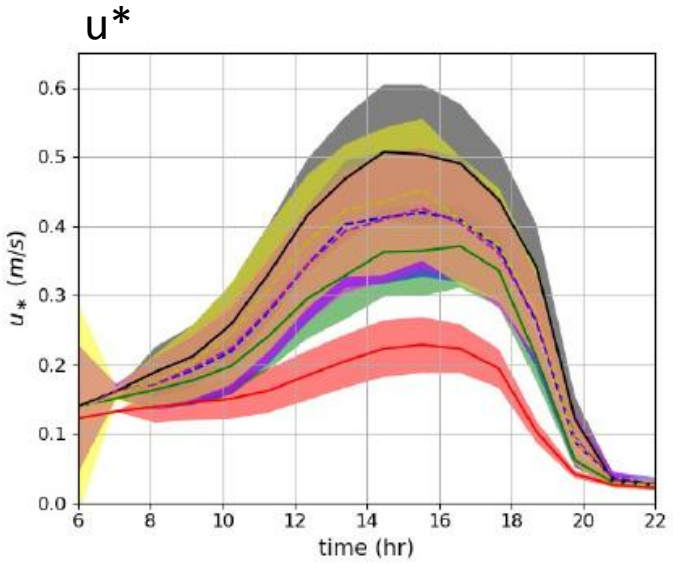
Interactive surface
10 km² x 4 km
dx = dy = 50m
dz1 = 5m, stretched grid

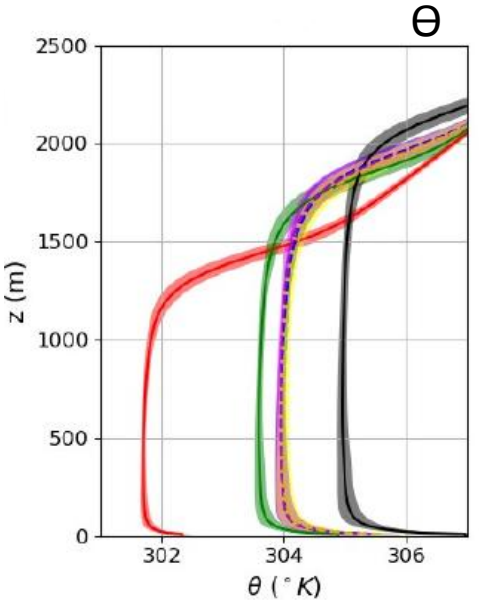
Grass
Maize
Forest

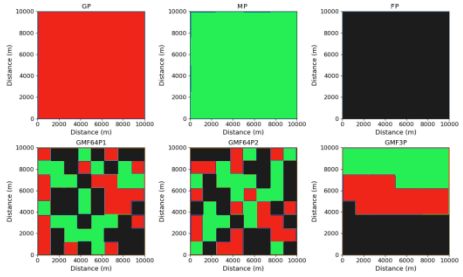
O3 : Improving surface/atmosphere coupling

Impact of surface heterogeneity on the boundary layer flow and near-surface turbulent exchanges in an LES framework.







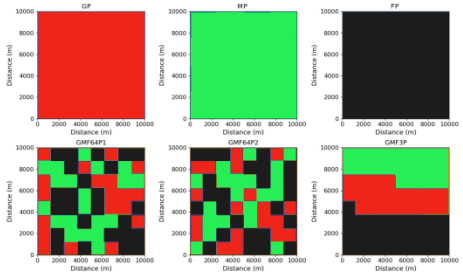


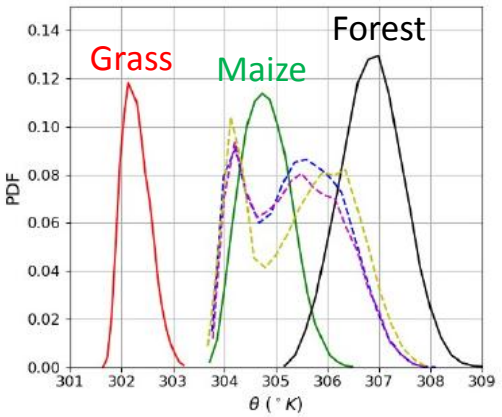
- Heterogeneity slightly increases mean flux and roughness (larger than the weighted average)
- Near surface wind is more influenced
- BL slightly deeper, but remains well homogeneous, and independent of patch size and distribution

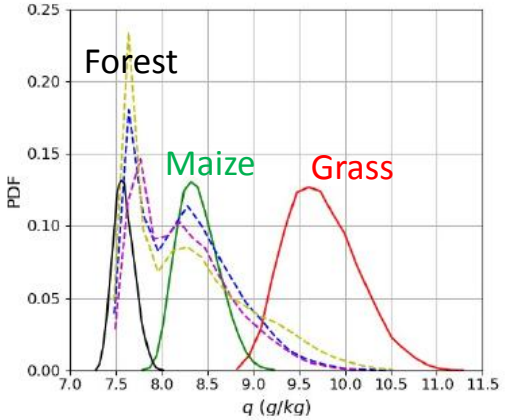
O3 : Improving surface/atmosphere coupling

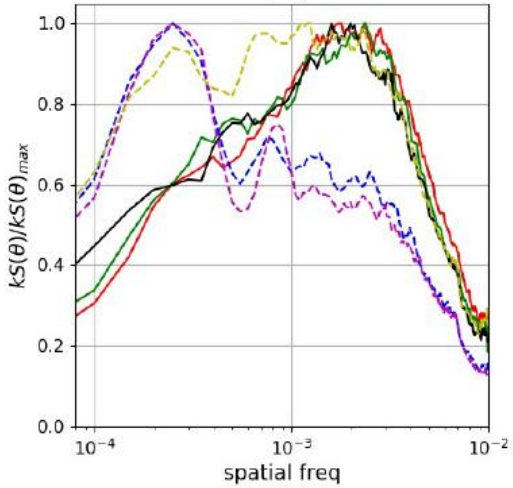
Impact of surface heterogeneity on the boundary layer flow and near-surface turbulent exchanges in an LES framework.

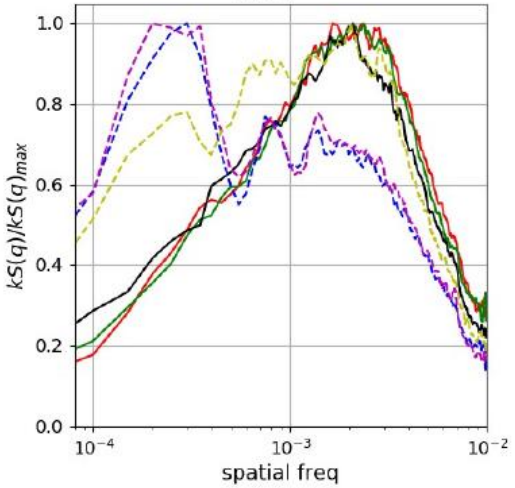
Heterogeneity induces
Bimodal distributions and excess of energy at larger scales
→ due to **secondary circulations**





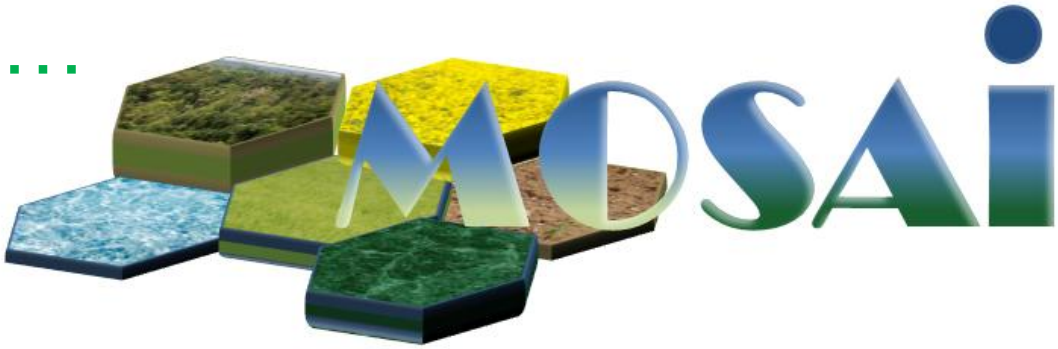






More to come soon…

Thank you !



Web site & Data base:

https://mosai.aeris-data.fr/

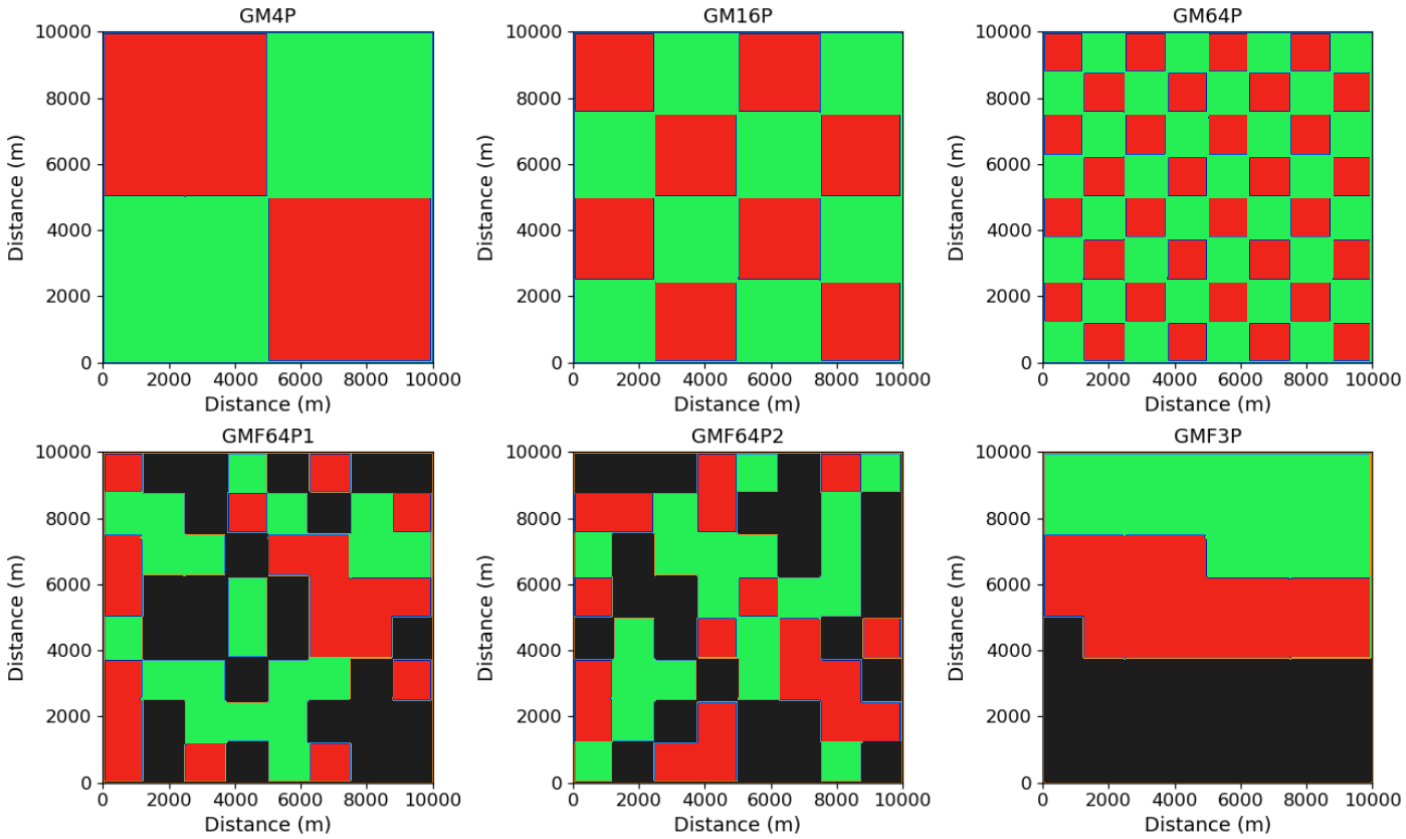
LMD IGE CNRM CESBIO LATMOS GET Laero Laboratoire d'Aérologie

O3 : Improving surface/atmosphere coupling

Impact of surface heterogeneity on the boundary layer flow and near-surface turbulent exchanges in an LES framework.

by Royston Fernandez, Fleur Couvreux, CNRM

MesoNH/SURFEX coupled LES



Interactive surface
10 km² x 4 km
dx = dy = 50m
dz1 = 5m, stretched grid

Grass
Maize
Forest

O3 : Improving surface/atmosphere coupling

Impact of surface heterogeneity on the boundary layer flow and near-surface turbulent exchanges in an LES framework.