

# Heat power estimation of a bee colony in a Dadant-hive based on transient hygrothermal evolution

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Emmanuel Ruffio,  
thermal scientist, TREFLE



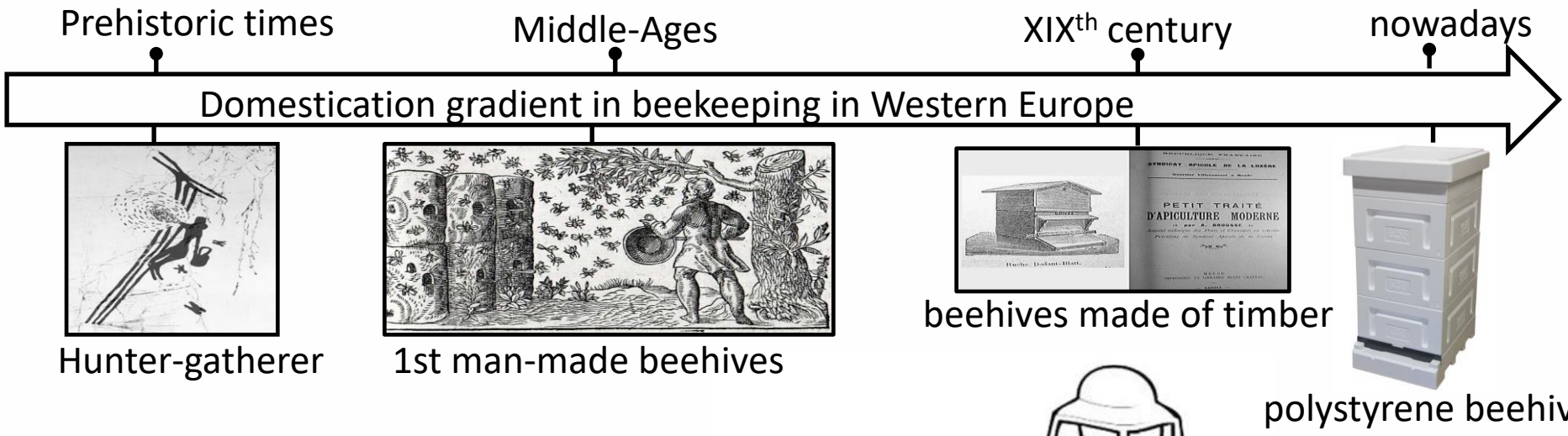
Delphine JULLIEN, mechanical  
scientist, LMGc



46<sup>th</sup> Apimondia Conference 2019 – Montreal  
(Quebec), September 8 - 12, 2019



# BeeWood project

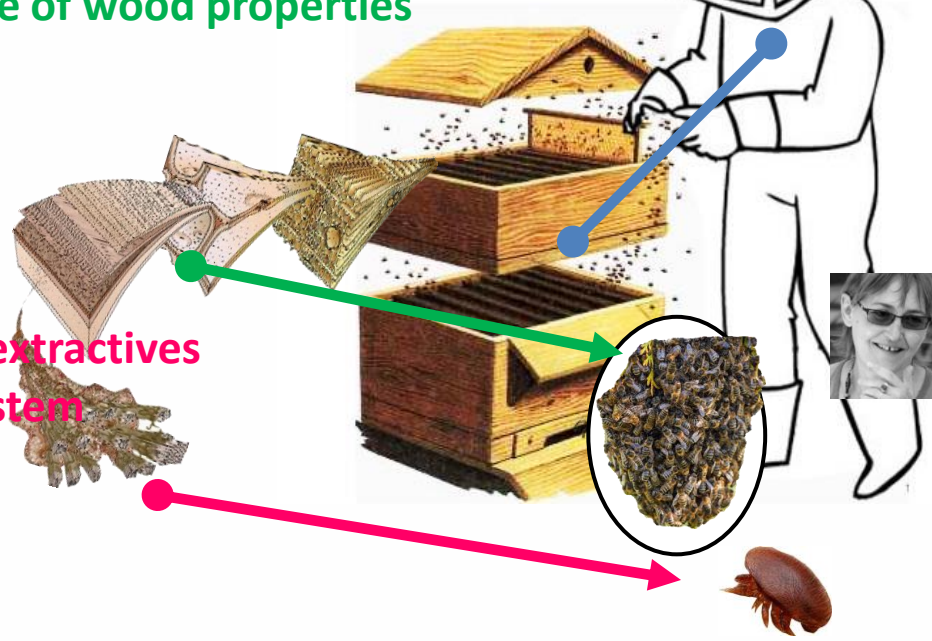


## Physical influence of wood properties

- Wood sciences
- Physics
- Anthropology
- Ecology

Human practices around beehive building material

Pascale Moity-Maizi, anthropologist, IRD



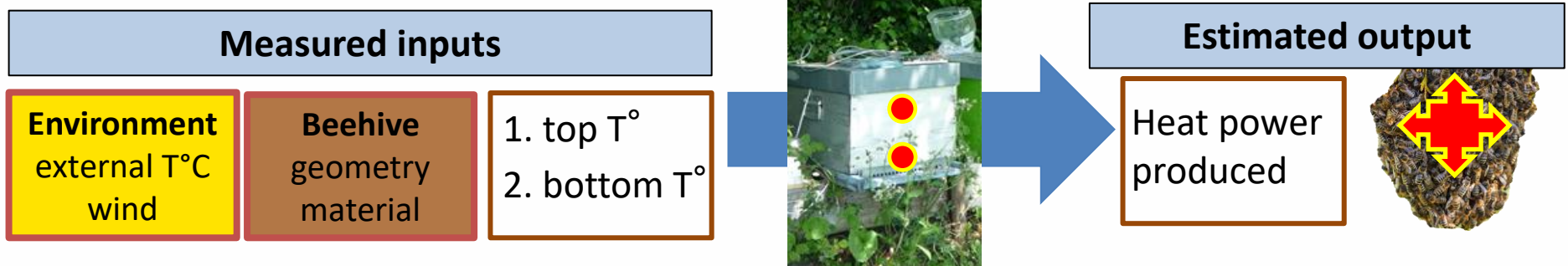
## Chemical influence of wood extractives on bees and bee ecosystem



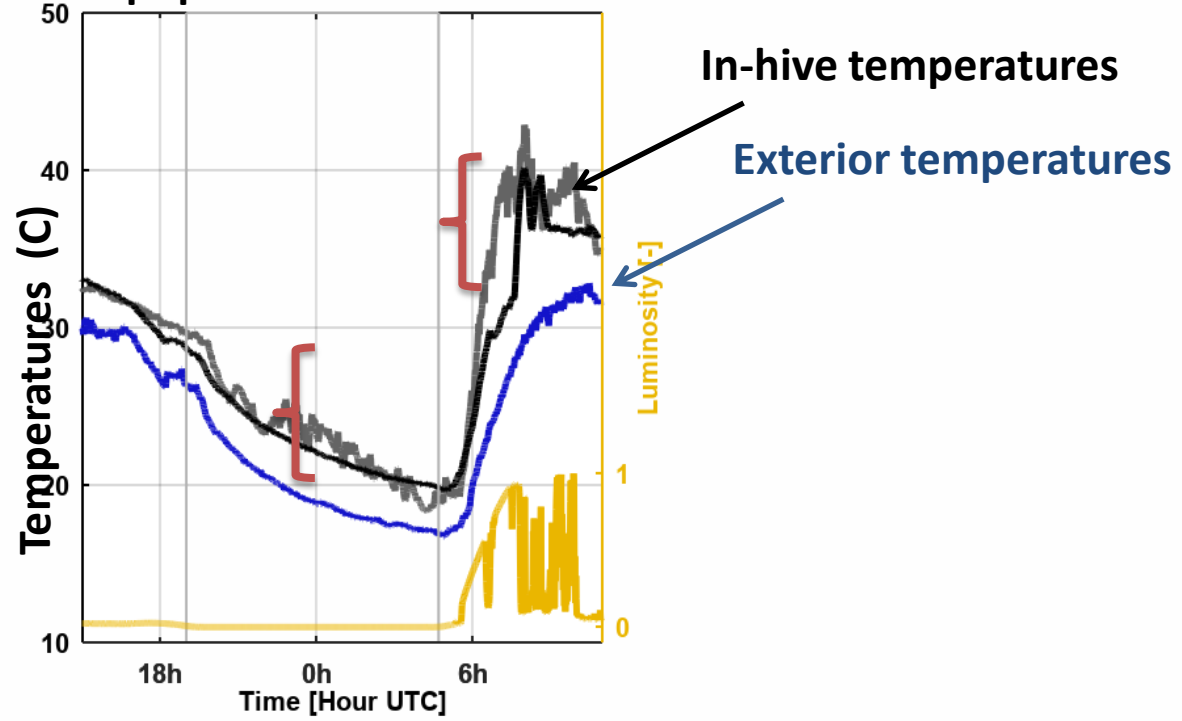
Bertrand Schatz, ecologist, CEFE



# Heat power estimation



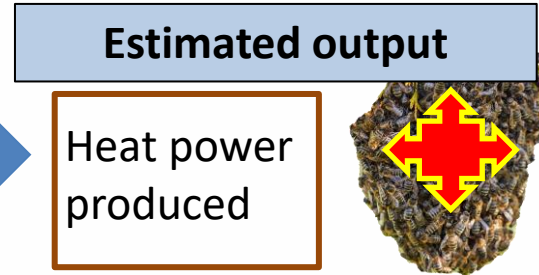
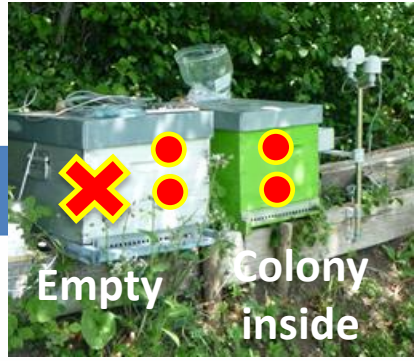
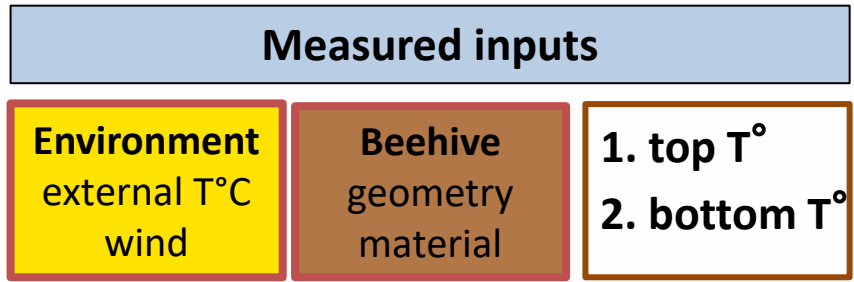
In-hive populated beehive measures



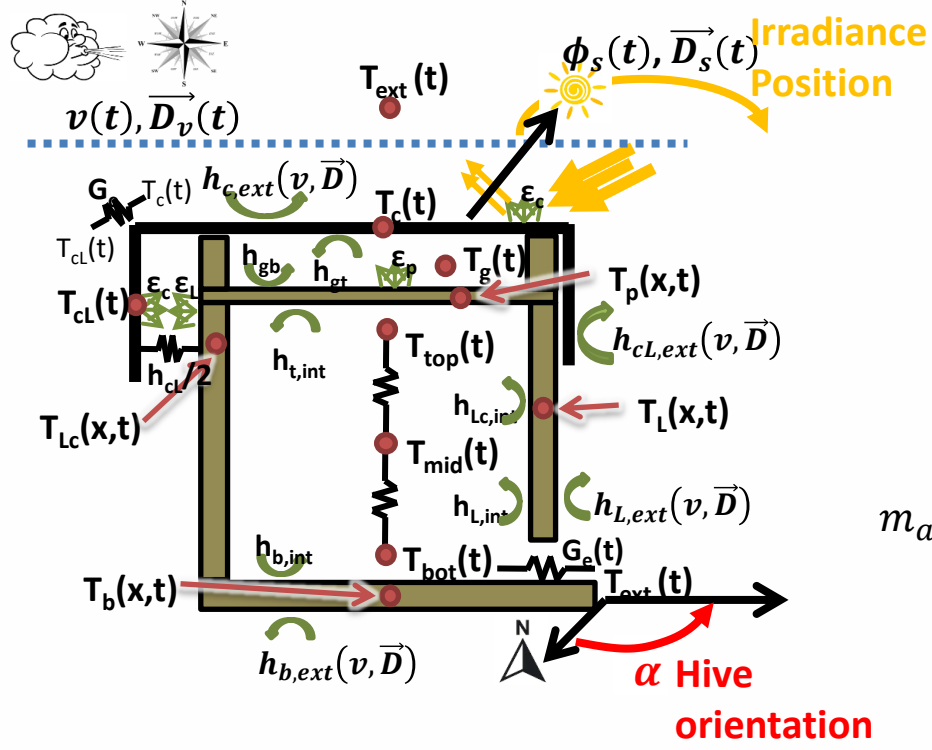
- ➔ 1) Estimate the colony heat power from in-hive temperature measurements
- 2) Correlate heat power, thermoregulation and colony health status (EFSA 2016)

# Thermal model

Instrumented beehives



## Empty hive model



Solar radiation absorbed by the cover

$$m_c C_c \frac{dT_c}{dt} = \epsilon_c H_s(\alpha, D_s(t)) \phi_s(t) + \dots$$

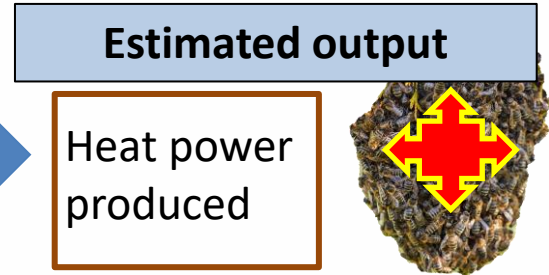
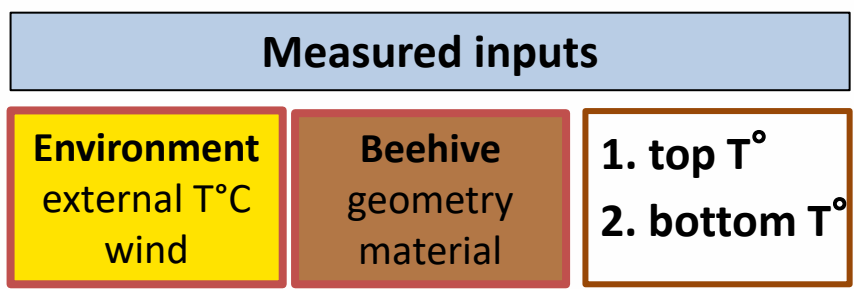
Heat conduction through walls

$$\rho C \frac{\partial T}{\partial t} = \lambda \frac{\partial^2 T}{\partial x^2}$$

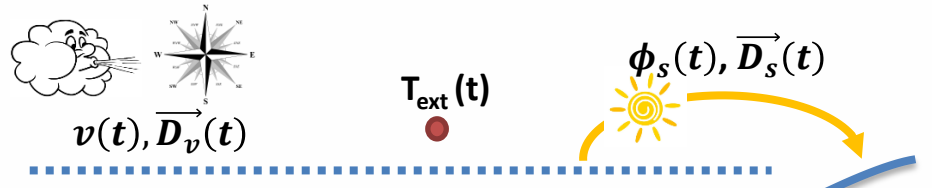
Internal air temperature = in - outgoing heat power

$$m_{air} C_{air} \frac{dT_{mid}}{dt} = h_{L,int} S_L (T_L(0, t) - T_{mid}(t)) + G_{mid,top} S (T_{top} - T_{mid}) + G_{mid,bot} S (T_{bot} - T_{mid})$$

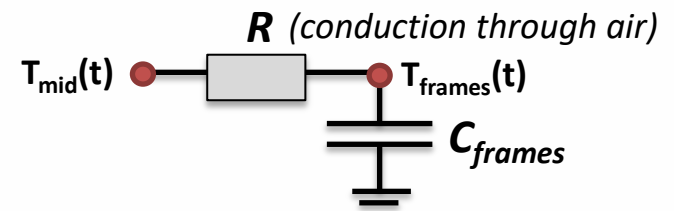
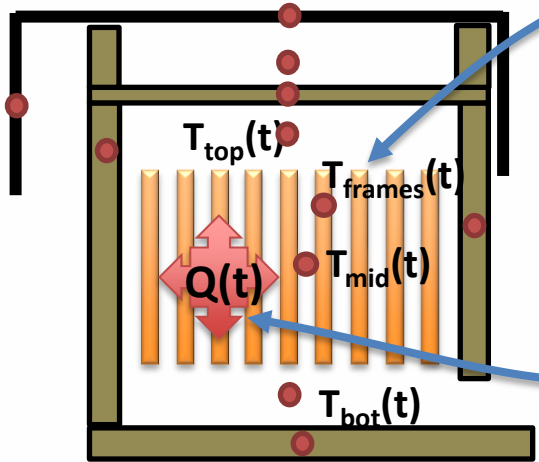
# Methodology



## Populated hive model



Frames and their content are introduced as a single heat capacity

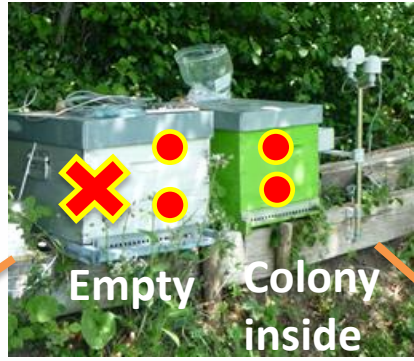


A heat source  $Q(t)$  [W/m<sup>3</sup>] represents the thermal contribution of the bee colony



# Methodology

Instrumented beehives

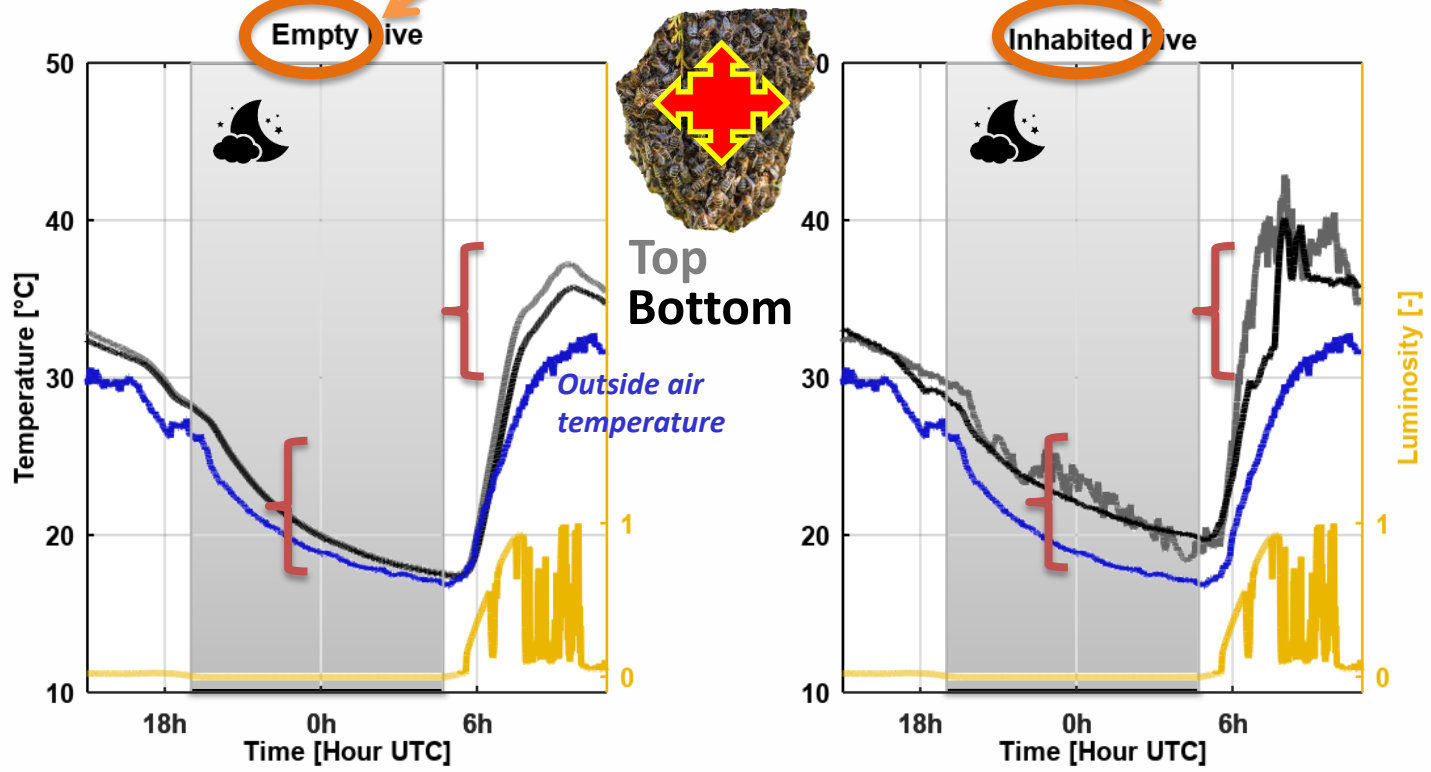


## Measured inputs

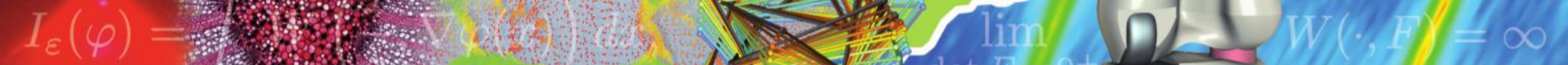
Environment  
external T°C  
wind

Beehive  
geometry  
material

1. top T°
2. bottom T°



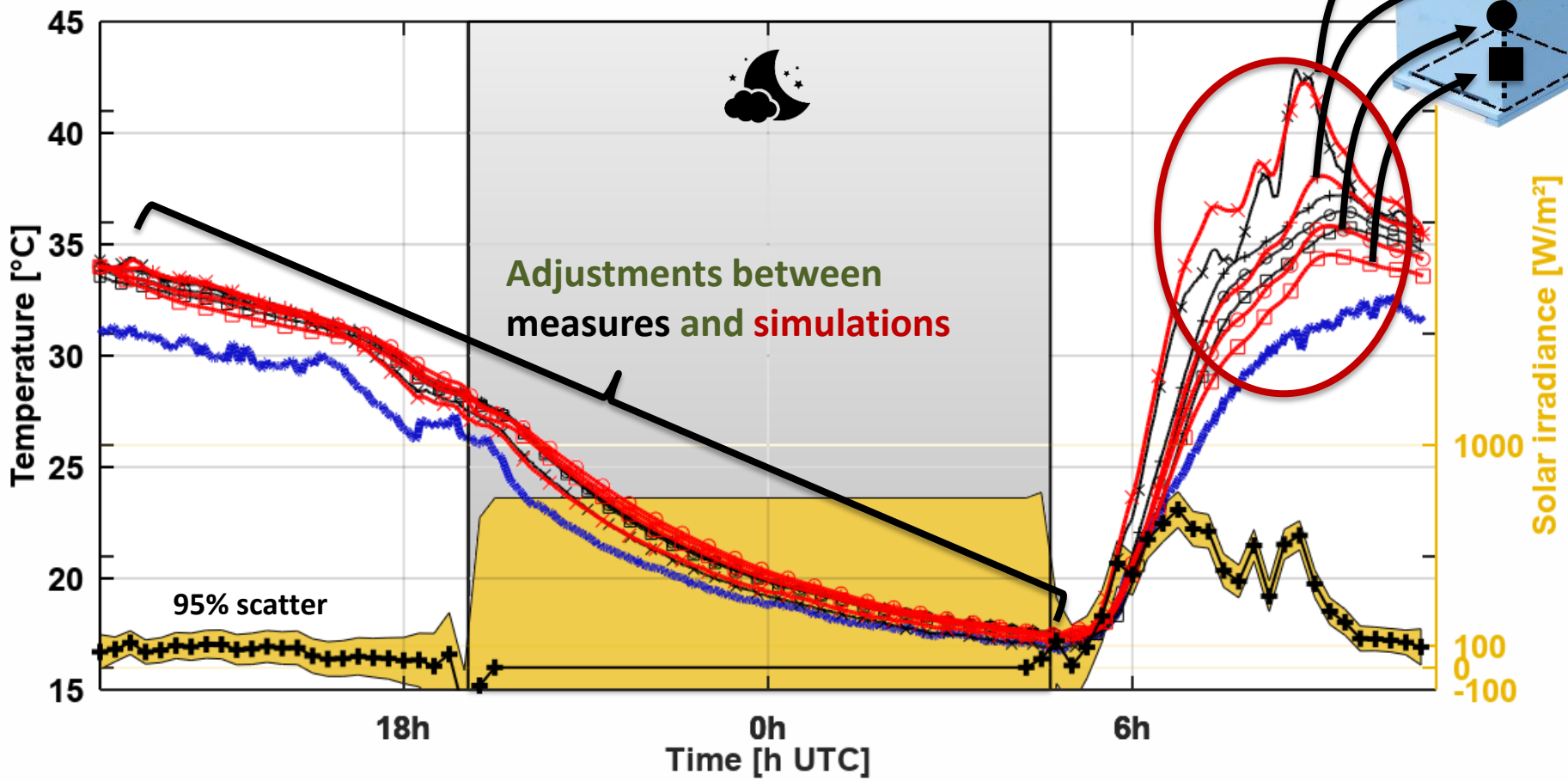
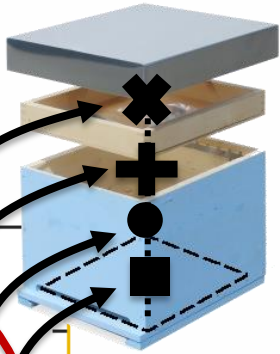
➔ 1) Estimate the colony heat power from these temperature differences



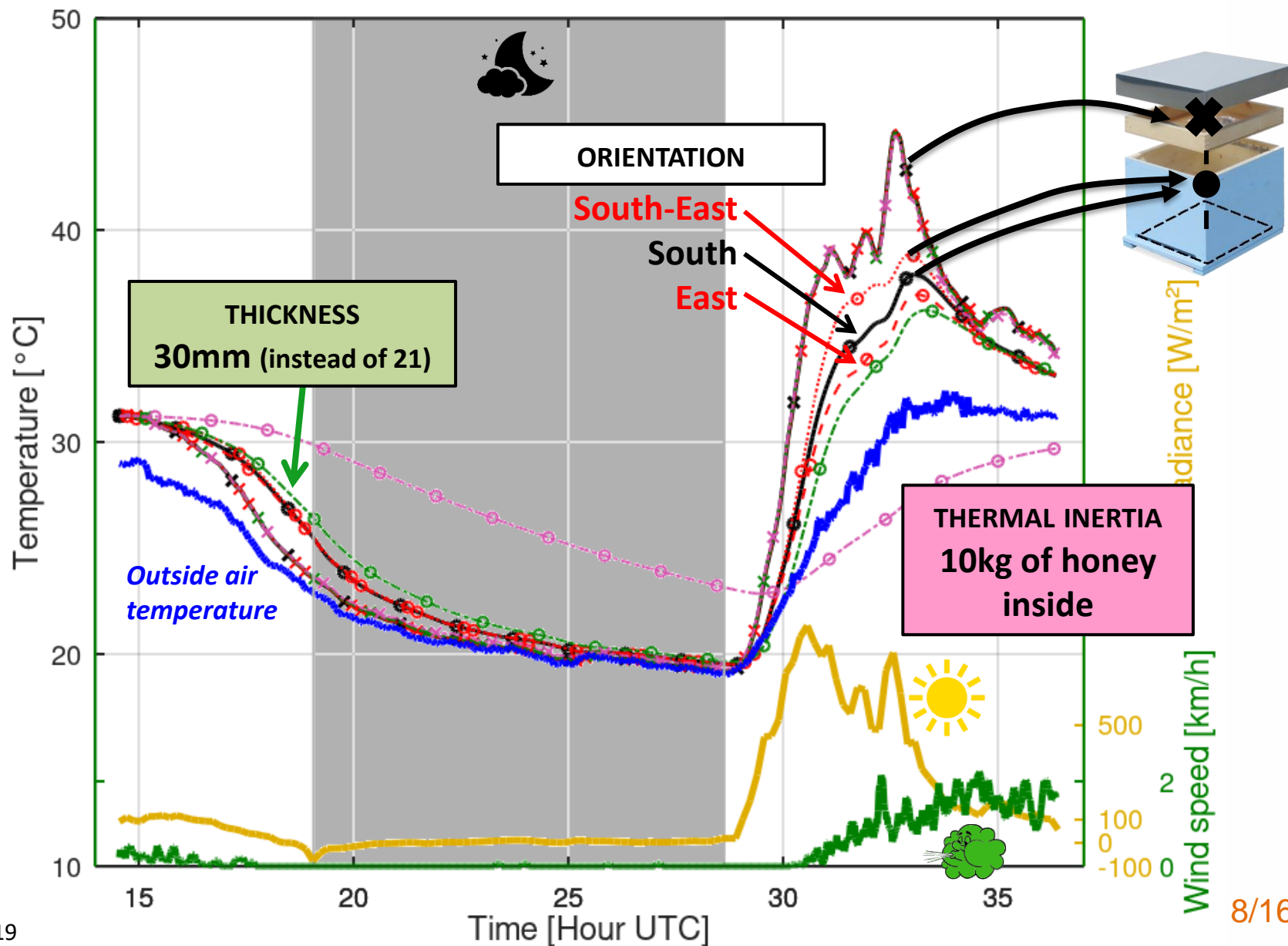
# Building the empty beehive model: estimating solar irradiance

**Unknowns ?** (conductivity, heat capacity, emissivity, convection coefficient, solar irradiance...)

Least sum of squares:  $J(\beta) = \sum (T_{model}(\beta, t) - T_{measures}(t))^2$



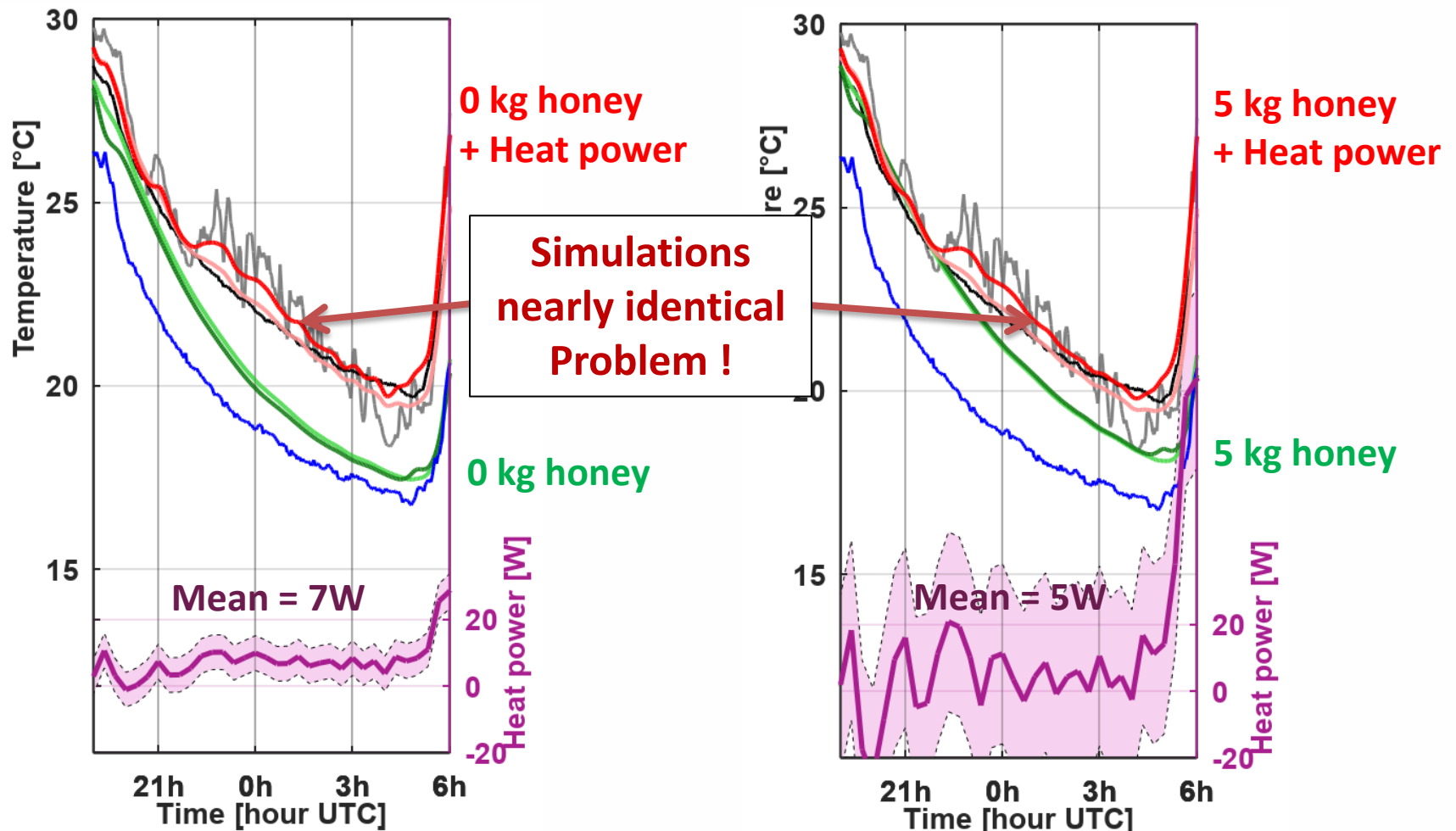
# Results of empty beehive model: beehive parametric study





# Results of populated beehive model

Results over one day of measurements



A temperature change could be explained by in-hive variation of thermal capacity and/or colony heat power.



# Conclusion

- First results on empty hive model:

Parametric study for possible beehive improvements ?

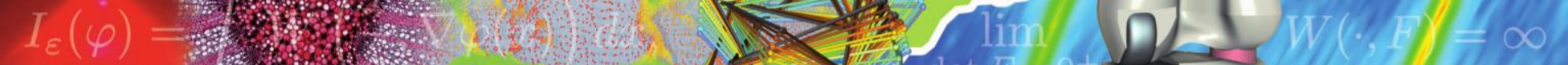
- 1- What about improving thermal insulation of walls ? Of roof ?
- 2- Effect of changing the geometry ? (square/rectangular/ tree hive)
- 3- Orientation of beehive with respect to the sun ?
- 4- Impact of entrance size ?

To better understand transient hive insulation under any climate

- First results on populated hive model:

- 1- The method is now implemented
- 2- Use more and different measurements (scale) to separate heat capacity/power effect
- 3- Validation needed (a controlled heater was built to simulate a colony)

To quantify heat power produced as indicator of colony health status



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Thanks for your attention!  
Thanks to all the team!

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