CARI conference
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Temperature and insulation of beehives

LMGC, Laboratory of Mechanics and Civil Engineering, Wood Team, Montpellier

Anna DUPLEIX
Post-doctorate
anna.dupleix@umontpellier.fr

Delphine JULLIEN
Associate professor

Dept. TREFLE (Energy, Fluids and Transfers)
Inst. for Mechanics and Engineering, Bordeaux

Emmanuel RUFFIO,
Associate researcher
Emmanuel.ruffio@gmail.com

Jean-Luc BATTAGLIA,
Professor

Plan

Review
What are temperature measurements in beehives used for?

↓

Beehive material
Wood/polystyrene comparison

↓

Beehive structure
Heat losses estimation

↓

Beehive environment
Effect on the temperature

↓

Overview of some commercial products

Part I

Review

What are temperature measurements in beehives used for?

For what reasons is measured the temperature in beehive?

For the bees:

« The ambiant temperature can be considered as one of the environmental factor that influence the most the behavior of a bee colony » [translated] (Dunham, 1931)

- Among the reason that stress bees, few are more dangerous than the weather [translated] (Erickson 1990).
- Hard weather conditions in winter are identified as the fourth most important origin of colony loss in winter in US [translated] (Meixner 2010)
- Climatic variations influence directly the maintenance and control of the temperature of the colony, influencing the development of the offspring [translated] (Souza 2015)

For beekeepers:

« Temperature measurement is an approach for remote monitoring of wintering process » [translated] (Stalidzans 2017).

For researchers:

- Reproduce natural living conditions in modern hives (gradient max. 30°C, Owens 1971) :
- \- Limit stresses on physiological ressource of the bee
- \- Reduce metabolic rate related to thermoregulation of the colony
- \- Increase production by division of labour
- Temperature has no direct consequence (since bees regulate it) but indirectly changes the hive humidity (Anderson 1948)

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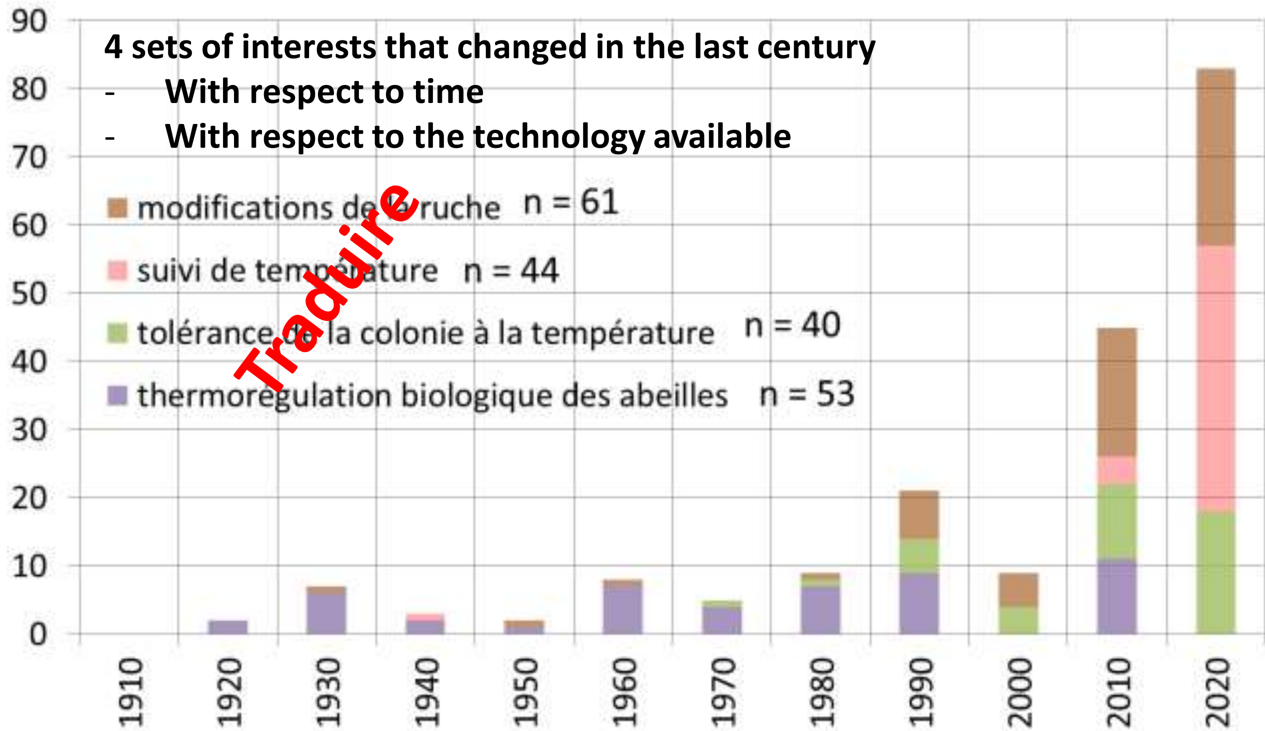
198 articles deal with beehive temperature



thermometer → **electronic** → **micro-electronic**
- size reduction
- wireless
- cost effective sensors

These studies have modified beehives

- Shadowing
- Orientation

Hive environnment

- Inside wintering

Hive properties

- Isolation
  - -matériau de construction
  - - enveloppe
  - -toit
- Volume
- Couleur
- Taille de l'entrée
- Entrée supplémentaire
- Plancher

- Présence de miel

Hive content

- Systèmes chauffe/ventilation internes

Replace the energy (heat) produced by bees (with honey) by electric energy

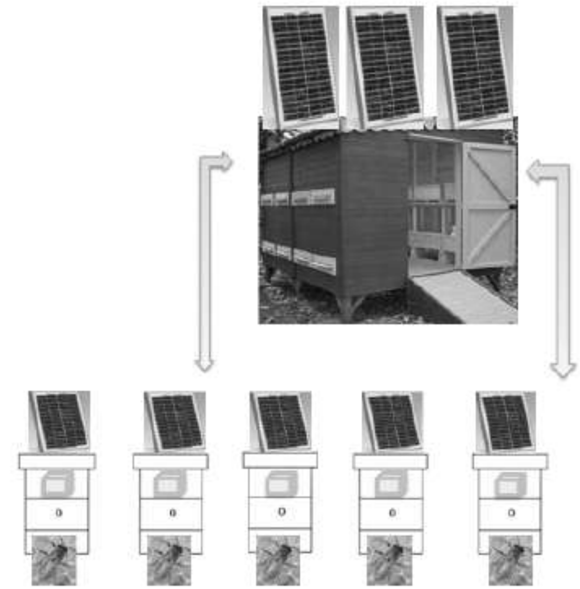
Complex heat/ventilation system

- Regulation, precision
- Energy autonomous
- Wireless control

A bee during its life
= 0.6g miel
= 6840 J = 1.8 Wh

Decrease of 28°C to 17°C
= 7 to 19 W/kg (Southwick 1982).

Bayir 2016, Turquie
inter-frame heating system
International Journal of ***Computing****, 5(4), 220-232.*



Altun 2012, Turquie
Semi-conductors powered by solar energy (Peltier module)
Inter ***Control Engineering*** *and* ***Applied Informatics***

Some exemples of hive modification

	Tests	What change?	Effects on T°C	Effects on bees	Season
	Hive floor opened	Closed floor	none	n/a	winter
	Volume 24 L	31 L, 38 L	Max.: 38 L < 31 L < 24 L	+ prod. (honey, pollen), + brood	winter
	Honey remains when winter ends	None	T°C increase is delayed	+ **temps pour la formation grappe**	winter
	South orientation	East, S-E	Max. Est < S-E < Sud	+ prod. (honey, pollen), + brood	winter
Entrance	Entrance size		None	n/a (empty hive)	winter
Entrance	Second entrance added		None	n/a (empty hive)	winter
Color	Back/blue (dark)	White	Higher T°C	+ prod. (honey), + brood, + pop.	winter
Color	White (light)	Not painted	Lower T°C	+ prod. (honey),+ brood	summer
Environment	Shadowing (high trees)		Thermal comfort	+ production - Abandons	Summer (semi arid climate)
Environment	Indoor bees wintering			- Winter hone consumption No physiological effect	summer

Effects mentioned later in this conference

Insulation tests

	Insulation	Effects on T°C	Effects on bees	Season
Roof	Plastic(PE) Abestos	n/a	+ honey None	Winter
Roof	Cardboard milk box (aluminium towards top)	Lower T°C	n/a	Summer (?)
Roof	Plastic(PET) Fibrous cement	Lower T°C		Summer
Roof	Plaster			
Hive	Ciment-vermiculite	Same stability	n/a	Spring/sum.
Walls	Foam 0.038 $W^{-1}K^{-1}$ Canvas	Wood < Canvas < Foam	+ honey, brood, pollen	Aut./Winter
Walls	Nylon Jute	Higher humidity	- brood	Automn
Walls	PE (plastic)	Higer T°C	+ miel, + brood, + pop.	Winter
Walls	Cork (1cm)	+ T°C stability (1.6°C vs 2.8°C)	- Winter honey cons. (36%) Same pop. and honey production	Winter
Walls	Sawdust, shavings, leaves, hay, straw (10cm)	Delayed T°C increase T°C max pour paille	n/a (Empty hive)	inter

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Many different methodologies for temperature measurement

It's intricate :

- **To compare studies**
- **To draw general results**

- Sensor position, precision
- Acquisition **frequency**
- **Season**: winter, summer, whole year **(winter:** temperature; spring/summer: physiological properties)
- **Populated** or **empty** hives
  (Anderson 1948: « Colonies were not used because the effects of external temperature changes could be estimated with better precision in empty hives, without the unknown effect of bees » [translated].)
- With respect to **outdoor weather** or ou d'une production articifielle de **chaleur interne**
  (Anderson 1948, mesure de conservation de la chaleur dans ruche vide)

Temperature measurements are used with others physical quantities related to the bee colony :

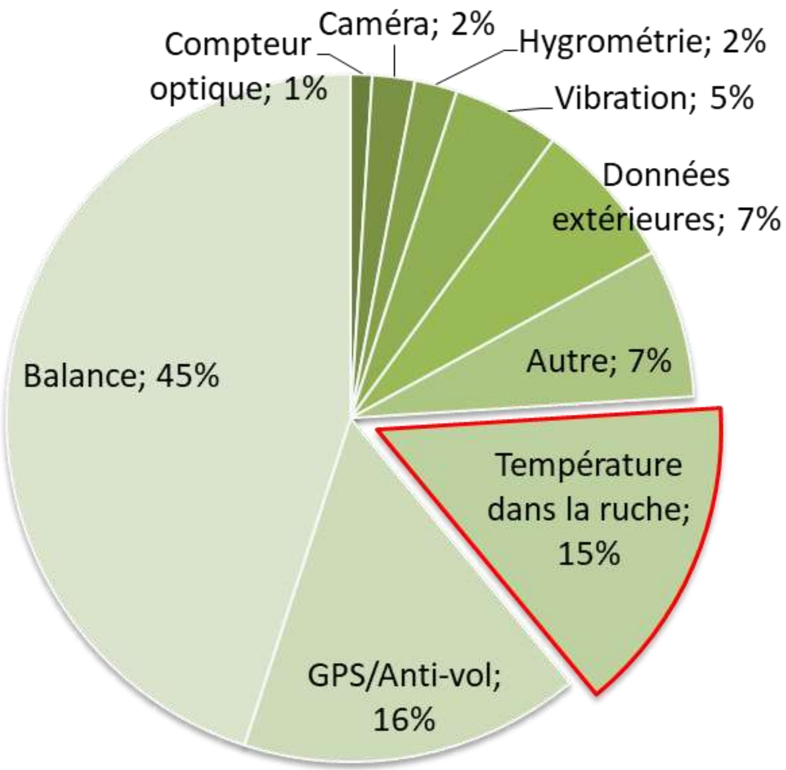
Colony development:
Brood area (opened/closed) (cm^2)
Development of adult bees (number of frames covered)
Flight activity (Nb of foraging bees)

Productivity:
Honey production (Weight increase during nectar period (kg) or nb. Of body frames, in supers)
Pollen production in season (nb. in body frames)

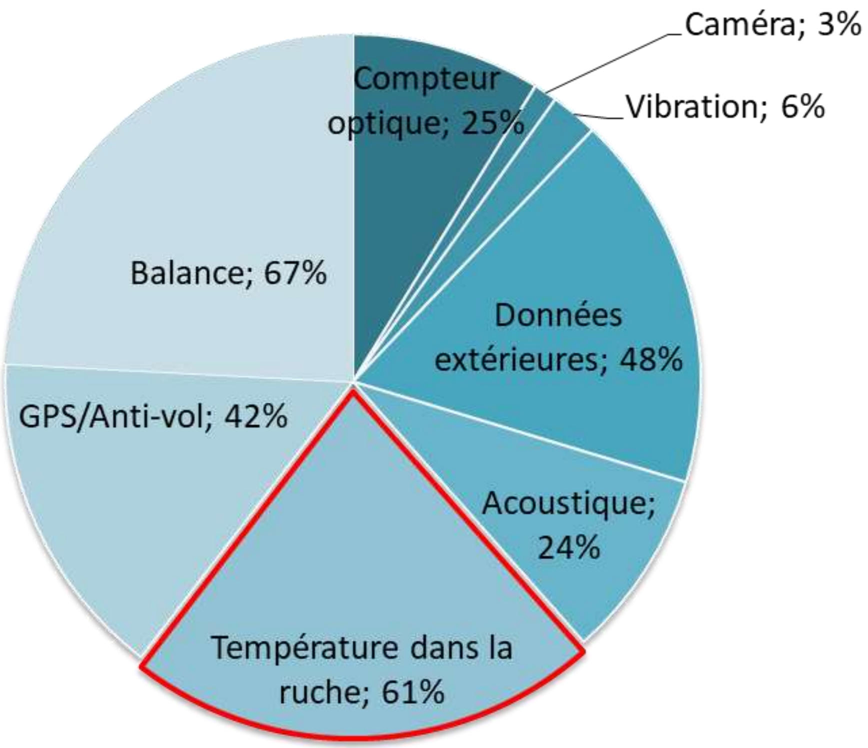
Consumption:
Honey winter consumption (kg)

Beehive monitoring with temperature measurements

- Tools only available for research in **the past**
- **3nd most commonly used quantity used by « connected » beekeepers** (France)
- **2nd most commonly provided quantity given by commercial connected hives** (World)



Repartition % of systems used by 386 french « connected » beekeepers questioned in 2018
(source: Lettmann, M., & Chauzat, M. P. (2018). Les outils connectés en apiculture: Evaluation de leurs application auprès des apiculteurs français.ANSES)



Répartition % of physical quantities provided by 32 connected beehives in the world
(source: data gathered from https://colonymonitoring.com/current-sensors/)

Les mesures de température dans la ruche, un indicateur de la santé des abeilles?

Arguments de vente des sites de ruches connectées (avec température) commercialisées (dans le monde)

Hive Health and Production Monitoring ModuSense

We have been working closely with industry leaders to provide Beehive Health Monitoring solutions

Monitor hive health Hivemind

Help your bees thrive. By monitoring apiary health, you can take action to improve your bees' general health so they're able to focus on building their hive. Hives that are struggling and require intervention are quickly identified, minimising loss of bees.

The **BuzzBox Mini** is your smart hive monitoring assistant. We use artificial intelligence to inspect your hive's health and report updates to your mobile

Much as EKGs help doctors better understand the stresses of their patients, our equipment reveals the health metrics of bee hives. This allows the beekeeper to make hive adjustments based on facts, not hunches. **BROODMINDER**

osbeehives

All the data gathered from these sensors are used by our algorithms to understand your hives and send you suggested actions for improved colony health. ApisProtect

arnia Better Knowledge for Bee Health

Our User Interface enables you to directly compare data from multiple sensors to provide a level of insight into colony health and behaviour that is otherwise unattainable.

Using **Beebot** you are joining the era of digital beekeeping by collecting valuable data, easily accessing it from anywhere on any device and even sharing with advisors and customers. Bee smart and keep healthy bees with **Beebot**! pollenity

Brood chamber temp. sensor wolfwaagen

What about the bee`s health? Profit from the sensors brood chamber temperature measurement. It gives you indication on the health and breeding activities of the bees.

nectar

Raise healthier bees

Make more informed decisions leading to lower mortality and higher frame counts.

Les données, collectées toutes les heures par les capteurs, sont consultables via une application dédiée. Hygrométrie, température… ces informations offrent la possibilité de connaître rapidement l'état de santé de l'essaim d'abeilles. hostabee

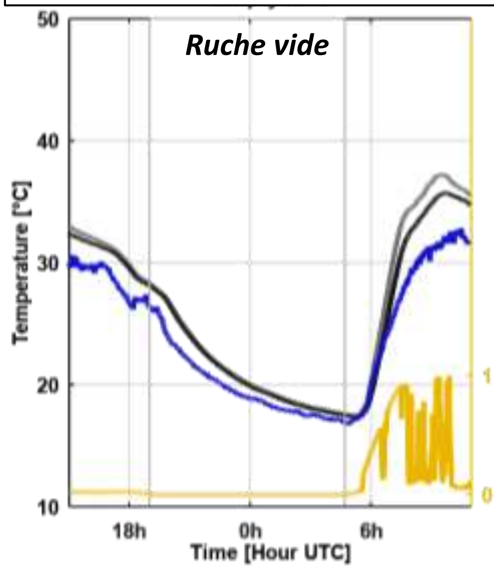
La température est citée dans l’index de l’EFSA pour évaluer la santé de la colonie

Indicator (definition)	Criteria	Rationale
Thermoregulation (the process of warming and cooling the hive to maintain a good brood temperature)	Variable	1) The number of workers engaged in heating or cooling behaviours 2) In-hive temperature 3) In-hive relative humidity.
	Evidence link with bee health	1) Honeybees can regulate the temperature inside the hive; in addition, temperature measurements can help detect events like increased food consumption, the start of brood rearing, the death of the whole colony (Zacepins and Karasha, 2013). Brood volume and winter cluster volume can also be identified by monitoring colony temperature (Zacepins et al., 2015). 2) Numerous studies have demonstrated that either high or low levels of humidity affect the health of the brood and adult bees, either directly, for example at levels < 50% relative humidity in the brood cells no eggs hatch (Doul, 1976), this being particularly relevant for small nuclei, or indirectly by favouring the development of pathologies. For example, raising the humidity from 68% to 87% increases the percentage of brood mummification caused by the chalk brood virus by 8%. *Varroa* destructor and *Nosema* reproductive rate falls with increasing humidity. Thermoregulation and nectar concentration are also intricately linked with humidity levels in the hive (MD Ellis, 2008). 3) Bees normally heat the colony to keep the in-hive temperatures stable for the brood. Additionally, bees may fan to cool the hive. Thermoregulation behaviour will therefore depend on location, weather and season, and would be meaningful evidence of colony health (Seeley, 1985; Fahrenholz et al., 1999).
	Technical feasibility	1) The low cost of data collection, processing and data transfer from temperature measurement systems facilitates many applications of temperature measurements in beekeeping (Zacepins and Karasha, 2013). 2) Compared with temperature sensors, humidity sensors are more expensive and have to be kept clean and protected from bees because water vapour cannot overcome wax or propolis to reach the sensing element (Zacepins et al., 2015). 3) Specific sensors can be used to measure this factor. 4) Beekeepers can use a temperature probe, but this gives evidence of temperature, not thermoregulation behaviour. Instead, a true measure of thermoregulation behaviour requires real-time assessment of heating and cooling behaviours of the workers. This assessment can be done in experimental settings but not in field surveys.

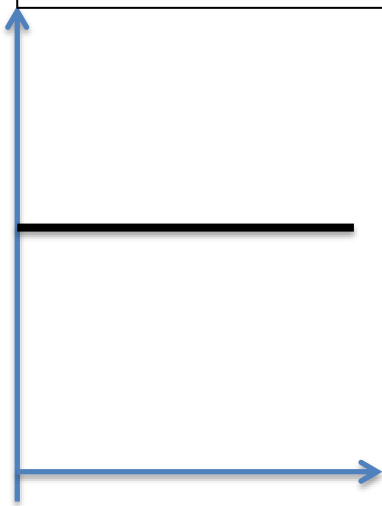
EFSA Panel on Animal Health and Welfare (AHAW). (2016). Assessing the health status of managed honeybee colonies (HEALTHY-B): a toolbox to facilitate harmonised data collection. *Efsa Journal*, *14*(10), e04578.

Origins of temperature change

Empty hive (no colony) : Variations of 20°C!



Weight variation in empty hive



Every weight changes can be attributed to bees.
It's not true for temperature.

Benefits of temperature? Sensors are robust and very cheap
But inducing bees activities from temperature is not straightforward

<u>To assess the colony effect on temperature, one has to separate:</u>

- Natural causes (the environment)
- Variations due to the bee colony activity

Need for a thermal model (mathematic) of the empty hive
This have been our work since 2018

« Insulation » ?

What does it mean « insulation » ?

« to protect it from cold or noise by covering it or surrounding it in a thick layer » (Collins)

Subject of this work : **« thermal insulation »,** ~~hygrometric, phonic, chemical…~~

Outdoor factors (environment)
- -solar radiation
- -temperature/humidity
- -wind (speed/direction)
- -surroundings radiation (ground, trees, hives, mountain, shadow, etc.)
- -beekeeper openings
- -etc.

Beehive structure
- -shape
- -thickness
- -material
- -roof
- -insulation
- -openings (size, position, number)
- -orientation
- -roof
- -etc.

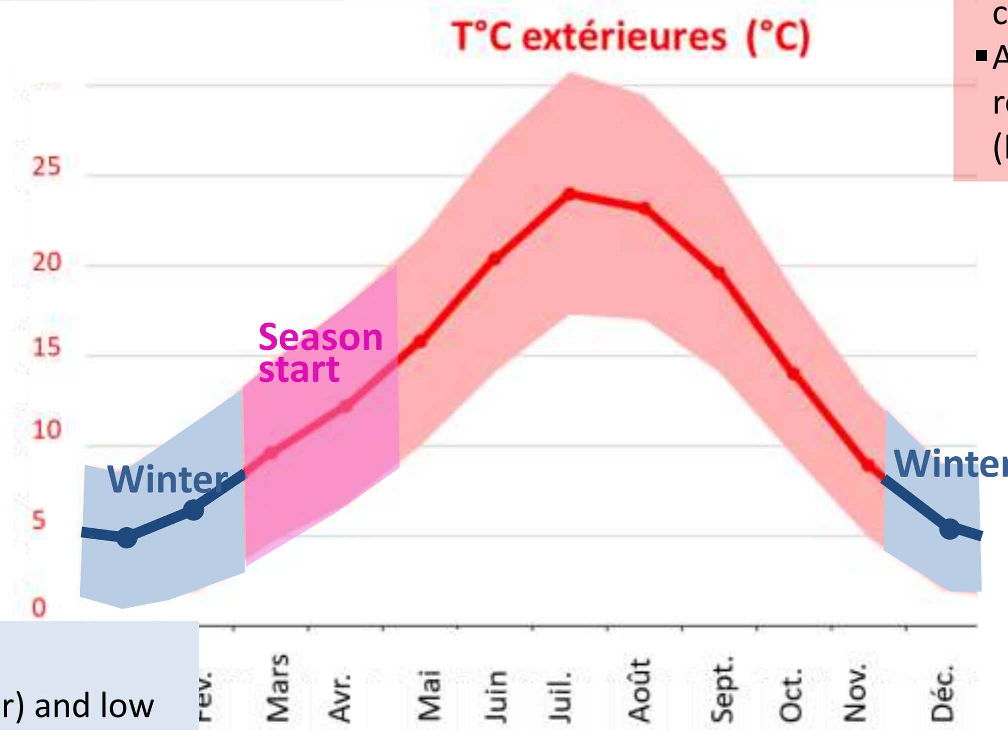
Indoor factors (colony activity)
- - In/out going of foraging bees
- - Nectar evaporation (state change)
- - Thermal inerty (water, honey, nectar, etc.)
- - Regulation depending on the biological state of the colony (brood, cluster, etc.) with air flow, heat generation with muscles, - etc.

Insuation = modifying the hive to better control the effect of outdoor factors

Hive insulation and the season

Season start (spring)
- Early development of brood/colony
- Make use of higher daily T°C

Season (spring/summer…)
- Protect from extreme T°C to limit stresses and limit energy consumption for reguation
- Allow high internal T°C to reduce bee metabolism (Harrisson and Fewell)



Source: https://fr.climate-data.org

Winter:
- Incative colonie (cluster) and low honey consumption
- Stablize T°C and limit extreme T°C

NB: L'hivernage n'est pas directement influencé par le climat ext. (mais par santé et approvisionnement en nourriture)

What kind of insulation for what season?
Is there an ideal temperature/season in the hive?

Part II

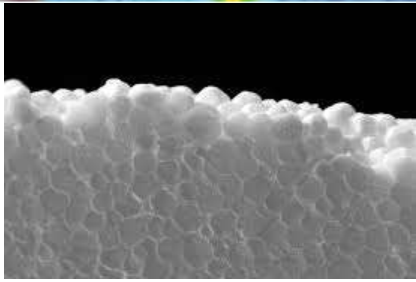
Beehive material

<u>1654</u>: 1st thermometer with graduations in the history by Ferdinand II de Medicis (duke of Toscane). (Alcohol with 50 graduations).
In winter: down to 7 degres
In summer: up to 40 degres.
Melting ice: 13,5 degres.

-> Temperature has become intuitive but it appeared recently in the history

Traité élémentaire de Physique, Expérimentale et Appliquée et de Météorologie de A. GANOT, Paris, 1866

Convictions about polystyren



« **Thermal insulation** is 8 times better compared to traditionnal **wood** based hives. »

https://www.achardapiculture.fr/presentation/les-avantages/

« **Thermal conductivity** of polystyren (0,035 W/mK) est 5 imes lower than wood (0,15 W/mK) so the **insulation** is 5 times better »

Résultats d'enquête, Dupleix, A., Jullien, D., Moity-Maizi, P., & Schatz, B. (2020). Practices and knowledge of beekeepers and beehive suppliers regarding the wood material in the South of France. Journal of Rural Studies, 77, 11-20

« **Thermal insulation is far better and winter consumptions are reduced** »

« Apart from the **lightness**, polystyren hives and breeding hives present severals benefits for beekeepers like a better **thermal insulation** which is advisable for all types of climate »

https://www.polycoq.com/fr/polystyrene-pour-lagriculture/21-ruche-et-ruchette.html

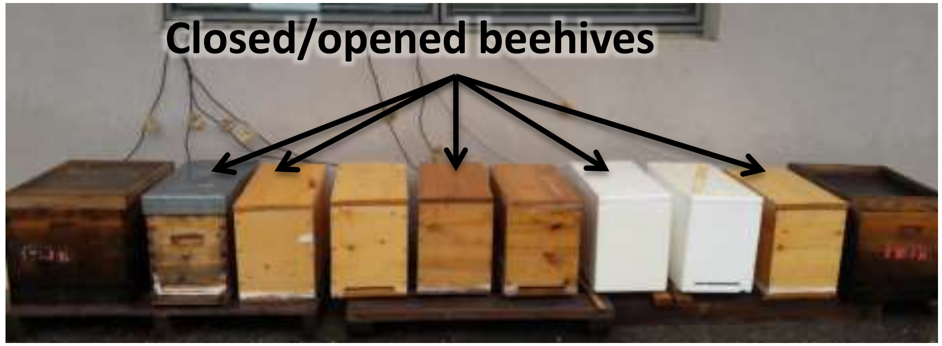
« The **insulation** provided by the **polystyrene** keeps the internal hive **temperature far more constant** than with wood »

« The **amount of insulation** provided by **Polystyrene** far outweighs a **conventional wooden beehive** keeping the bees warm throughout the winter months , so the colony doesn't need to **consume** as much honey for survival, whilst **shielding** the colony from heat during the summer » months."

https://www.ebeehq.com/polystyrene-beehives/

Polystyren-woord comparison

Material:
Polystyren
Chestnut
Spruce
Cryptomeria



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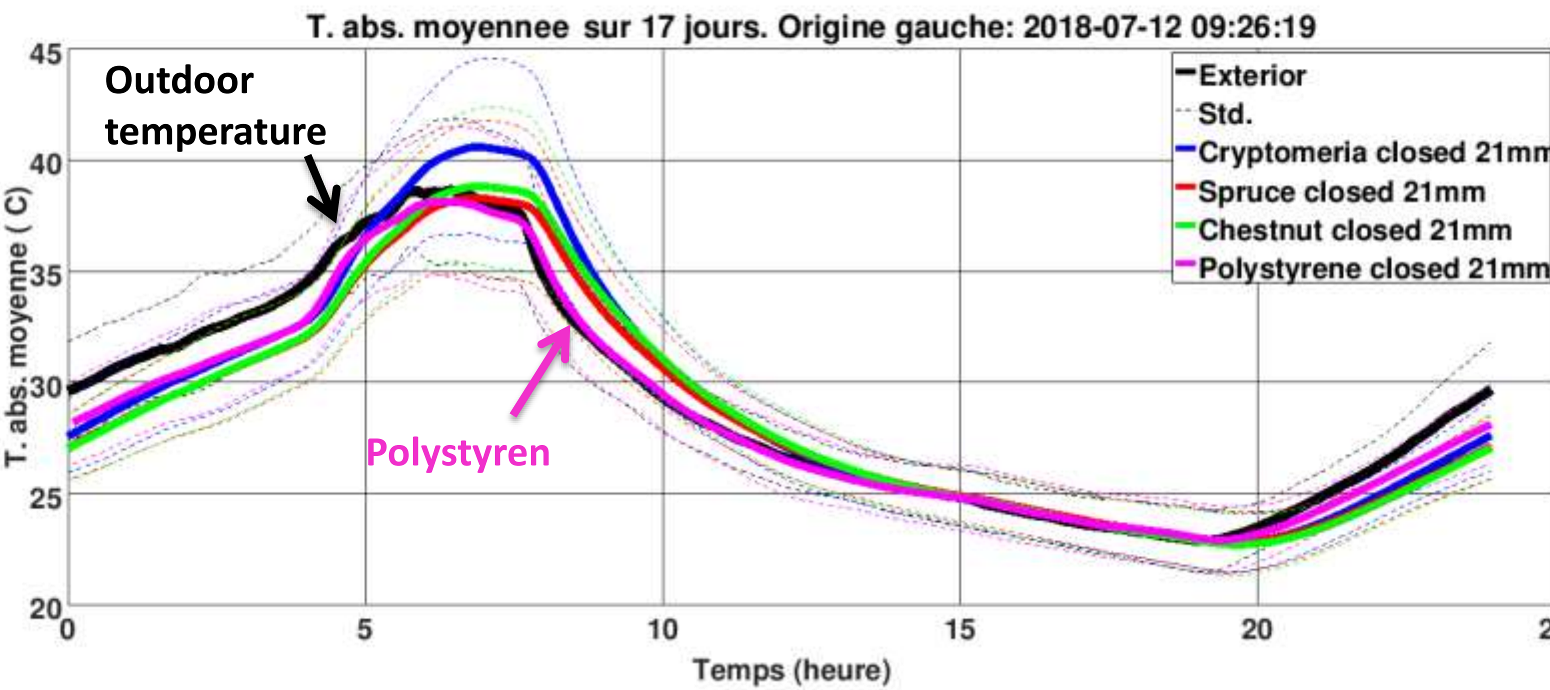
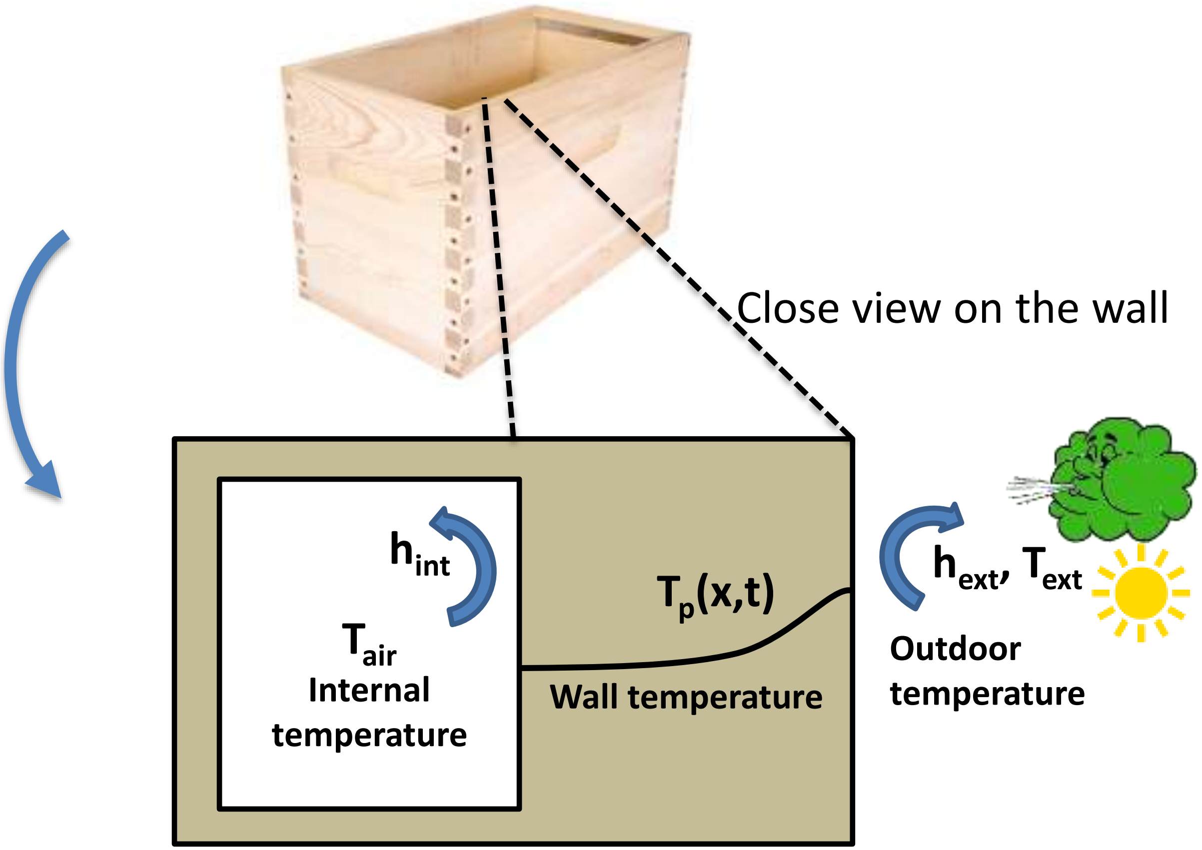
Polystyren, better insulator than wood?



Thermal model of a breeding hive

Thermal model

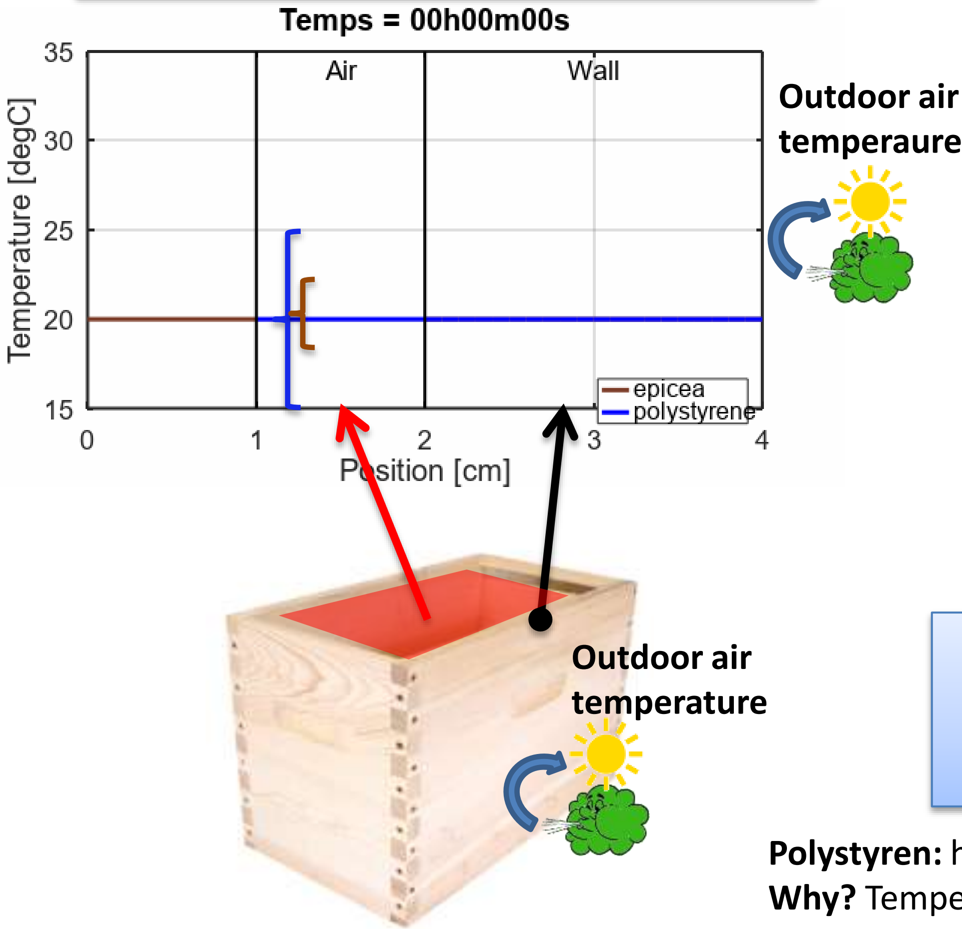


Heat transfer modes

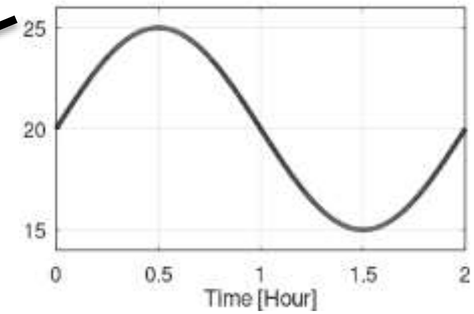
Convection (heat flow fluid-wall)	Conduction	Convection (heat flow fluid-wall)
$-\lambda \frac{\partial T}{\partial x} = h_{int}(T_{air} - T_p)$	$\rho C \frac{\partial T}{\partial t} = \lambda \frac{\partial^2 T}{\partial x^2}$	$-\lambda \frac{\partial T}{\partial x} = h_{ext}(T_p - T_{ext})$

Simulation: Air temperature in the hive

Slow variations (Period>2h)



Outdoor air temperature



This slow variation speads over 2 hours

Exemple of slow variations:
Day/night change
Season change

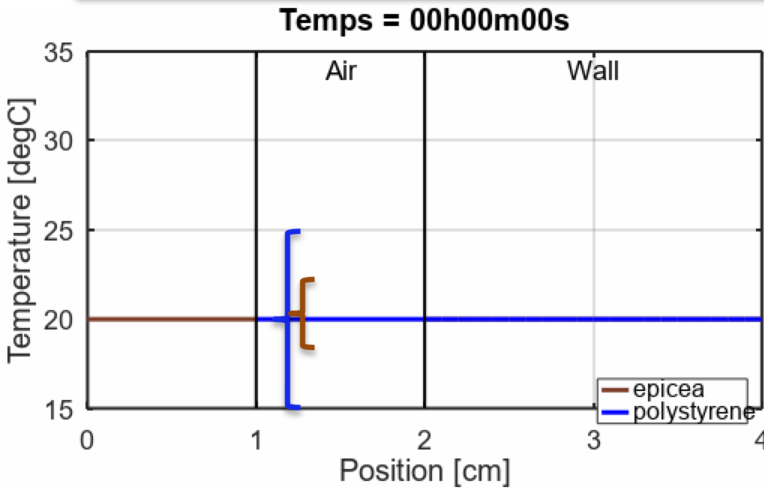
What is **the effect**
of outdoor air temperature
on the **hive internal temperature**?

Polystyren: higher temperature variations inside the hive
Why? Temperature propagation is faster in the polystyren

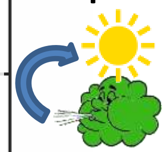
Wood: temperature variations are halved
Cause ? Temperature propagation is slower

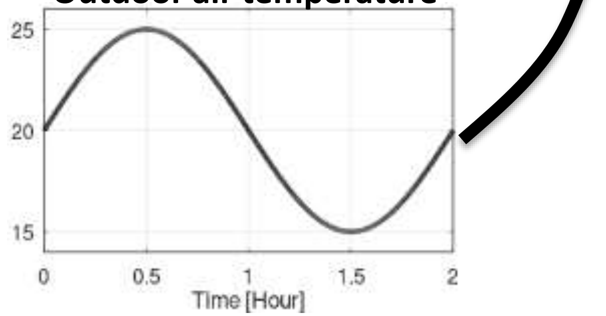
Simulation: Air temperature in the hive

Slow variations (Period>2h)



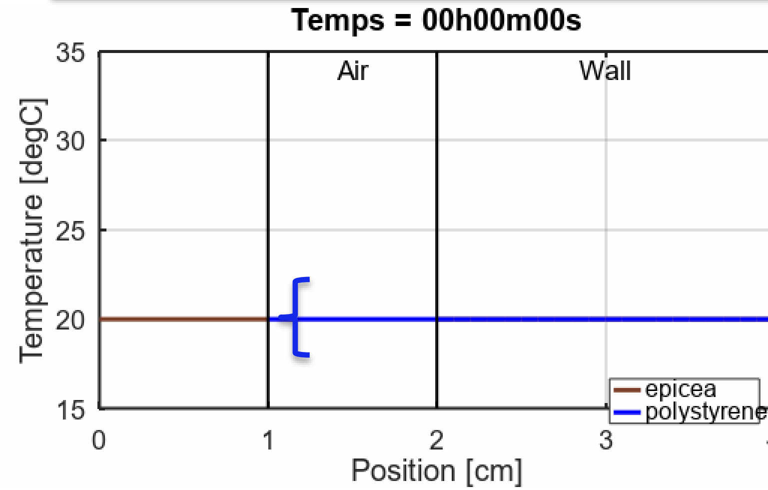
Outdoor air temperaure



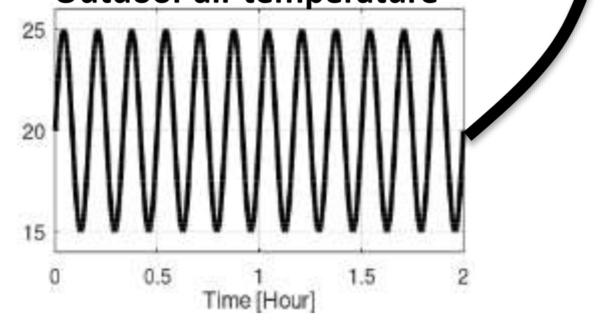


This slow variation speads over 2 hours

Fast variations (Period=10min)



Exemple:
Solar radiation
Clouds
Shadows
Rain



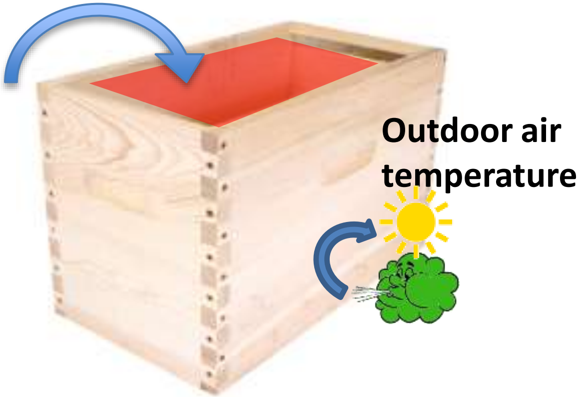
This fast variation speads over 10 min.

Wood: better stability of the hive temperature
Why? Temperature progation is slower. Variations disappeared thanks to the wood wall.

Simulation: Air temperature in the hive

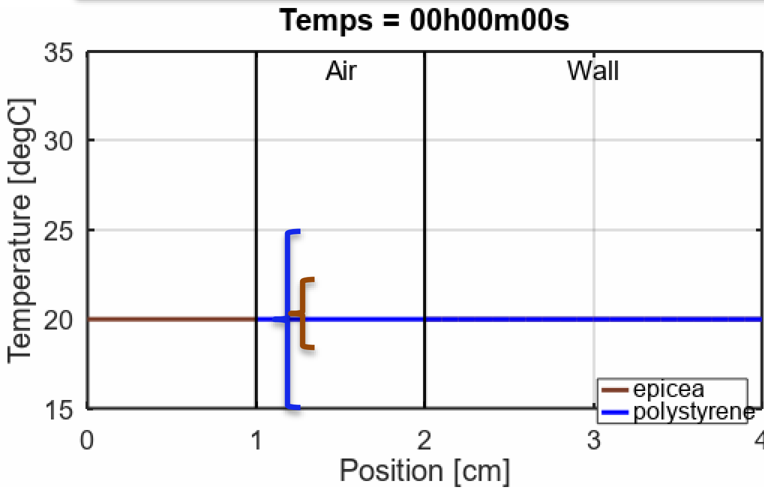
Effect of a « thermal mass » ?
Simulate honey/bees/nectar/beeswax/frames…

An equivalent thermal mass in introduced in the model

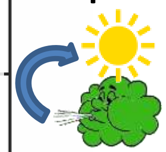


Simulation: Air temperature in the hive

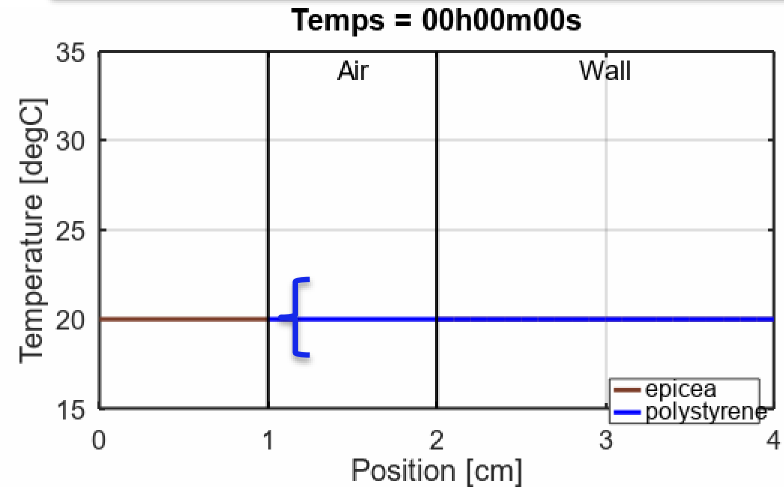
Slow variations (Period>2h)



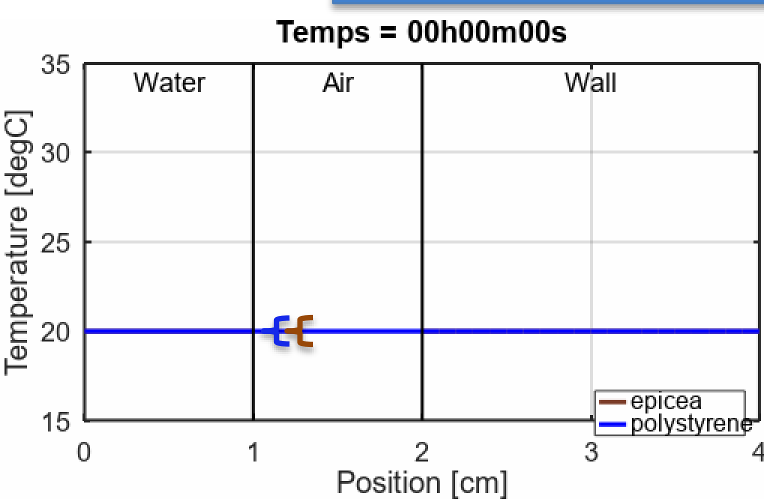
Outdoor air temperaure

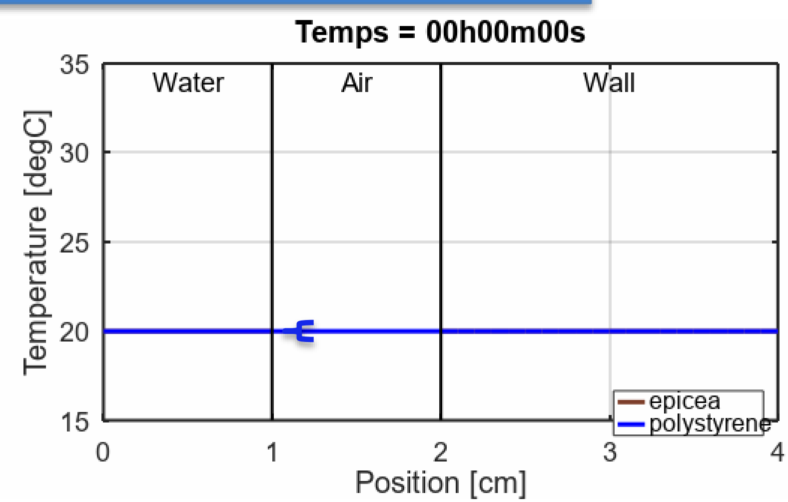


Fast variations (Period=10min)



With thermal mass inside





Distinguish temperature and energy (heat)

Thermal conductivity

λ [$W/m/^{o}C$]

Related to propagation speed of **the energy (heat)**

Often the only parameter mentionned for beehive insulation

	Châtaignier (12% MC)	Polystyrène	x
Conductivité thermique λ W/m°C	0.16	0.035	5

Thermal diffusivity

a [m^2/s]

Related to propagation speed of **temperature**

	Châtaignier (12% MC)	Polystyrène	x
Diffusivité thermique a mm²/s	0.15	1.3	10

Temperature in polystyren propagates **10 times faster** than in wood

BUT

The **heat flow** is **5 times lower**

Link between conducivity and diffusivity ? **Thermal capacity**

$$a = \frac{\lambda}{\rho C}$$

Amount of energy needed to change the temperature of a material by 1°C (wood: 50 times more than polystyren)

	Châtaignier (12% MC)	Polystyrène	x
Capacité thermique ρC MJ/°C/m³	1.1	0.026	50

Exemple du pêcheur

When the box is put inside a car where temperature is 40°C:

Heat flow through polystyrene is very low, BUT

- **If the box is empty**: 5 min later, temperature in the box will be 40°C, because the small amount of energy is enough to heat air.
- **If the box contains sardines**: they will keep the air cold and the energy coming through the box is not enough to heat them.

3500 times more energy is necessary to heat sdarines than air

(and then the cold temperature is kept 3500 times longer)

To summarize

Best insulator (thermal point of view)

21mm thick walls

		Perturbations	
		Fast (<1h)	Slow(>2h)
Thermal mass	Low	**Wood**	~~**Wood/Polystyrene**~~
	Big	**Wood/Polystyrene**	**Polystyrene**

Bad insulation
Situation to be avoided

Exemple: Solar irradiation Cloud covering Rain	Exemple: Day/night change Season change

- Wood hives protect only from fast variations
- Polystyrene protect only if a **thermal mass** is inside
  Bottle of water, stone, brick, piece of wood, honey…

Season start (early spring) (T°C ext. increasing)
(small colony, little reserve)

- **Wood hive**
  - \- - Bad thermal insulation
  - \- Inside temperature is varying slowly (do not protect againt night cold, day/night alternation)
  - \+ Protect against fast perturbations (1 hour) (clouds…)
- **Polystyrene hive**
  - \- - Bad thermal insulation
    Solution: add thermal mass inside the hive
  - \- - - Inside temperature is varying (day/night alternation)

In season (spring, summer) (T°C ext. mild, hot)
(big colony, large reserve)

- **Wood hive**
  - \+ + + Temperature very stable
  - \+ Protect against fast perturbations (1 hour) (clouds…)
- **Polystyrene hive**
  - \+ + Temperature is table

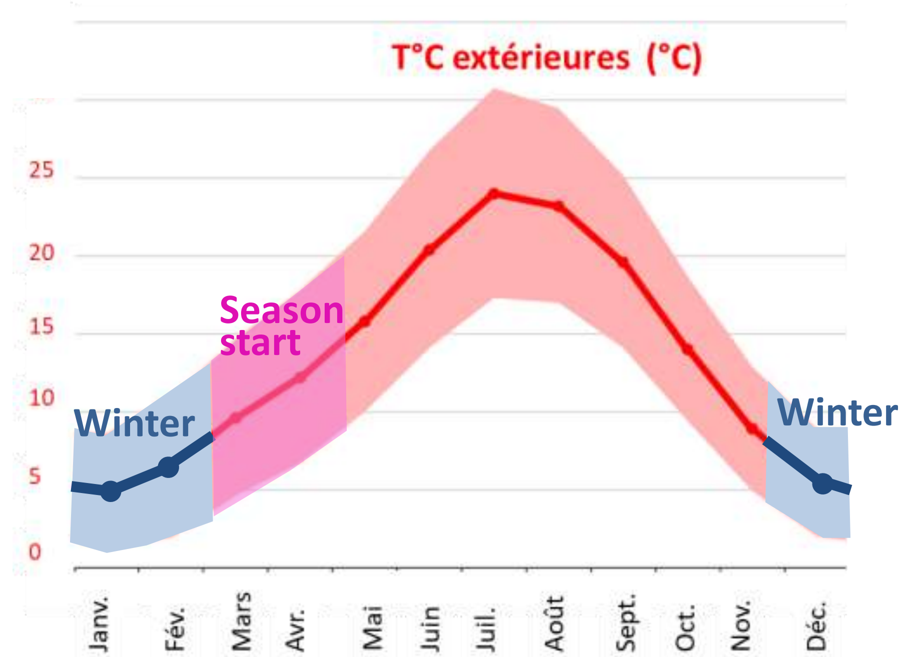
!!! Be carefull to overheatings due to solar irradiation

Which insulation for which season ?
What is the ideal temperature in a hive?
Is there one?

Hive materials are not the only parameters beekeepers can change
(see section III)

Winter (T°C ext. low)
(cluster + reserves)

- **Wood hive**
  - \- - - Bad thermal insulation
  - \- - - Higher energy consumption
  - \+ + Temperature is stable
- **Polystyrene hive**
  - \+ + + Good thermal insulation
  - \+ + + Low energy consumption
  - \+ + Temperature is stable



Part III

Effect of beehive structure

Some exemples

Steady state assumption: Temperature are constant

(In practice: « Quasy steady state »: Temperature changes are slow)

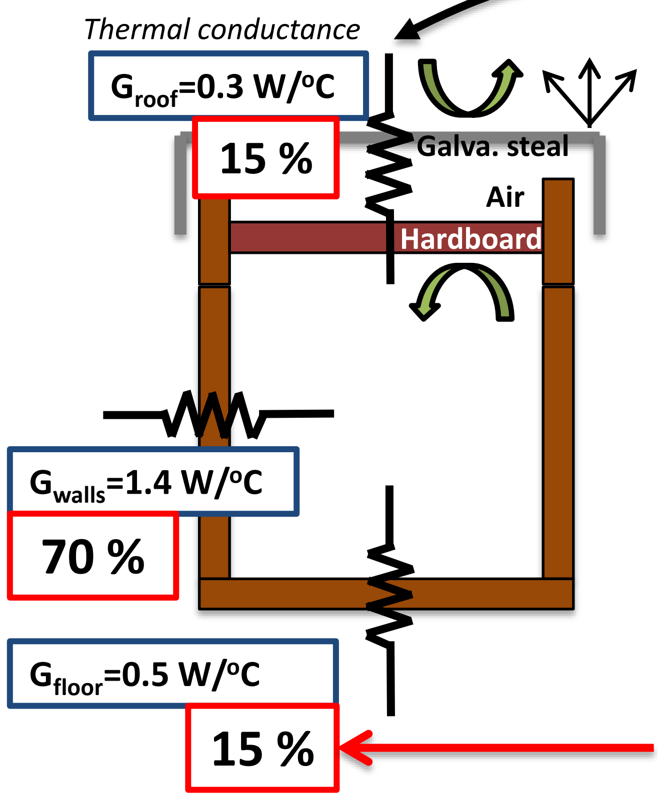
- Elements are replaced by an equivalent « resistance » or « conductance »
- Very simplified approach but not realistic (except in special cases)
- Often used in thermal analysis of buildings

➡ Computations are considerably simplified

Evaluation of heat losses

Dimension int. : 0.5 x 0.43 x 0.34

Thermal resistance R (or conductance **G**)



Proportion of heat loss

Electric analogy

Heat losses computation[1] ϕ [Watt]

$$\phi = G_{roof}\,(T_{int} - T_{ext}) + G_{walls}\,(T_{int} - T_{ext}) + G_{floor}\,(T_{int} - T_{ext})$$

➡ Walls should be insulated first (2 to 4 times more surface area than roof)

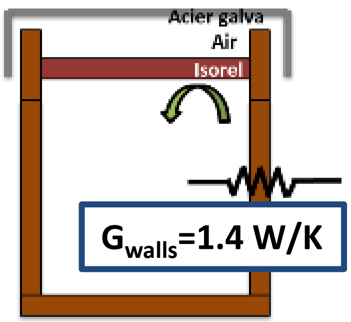
1: In the following, a temperature difference of 5°C between bottom/top is considered => Increase losses through the roof

Reduce losses through walls?

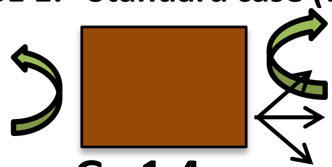
Assumption: 10°C (average) inside and 0°C outside: $\phi \approx 20$ Watt

Amount of heat power bees would have to produce to keep 10°C inside (≈25000 abeilles)[1]

https://low-e.co.uk/blog/how-to-insulate-a-beehive/



CASE 1: Standard case (wood only [+paint])



G= 1.4 W/°C

Convection (50%)

Radiation(50%)

(losses)

CASE 2: Decrease heat conduction through walls
2cm of polystyrene is added around the hive

G=0.43 W/°C

-46% reduction (total loss)

-52% reduction with 4cm

CASE 3: Decrease heat radiation

1: L. Farhenholz & al., Thermal investigations of a honey bee colony […], Journal of Comparative Physiology B, 1989

(One minute break about radiation)

<u>Commonly, heat has 3 ways/modes to propagate:</u>

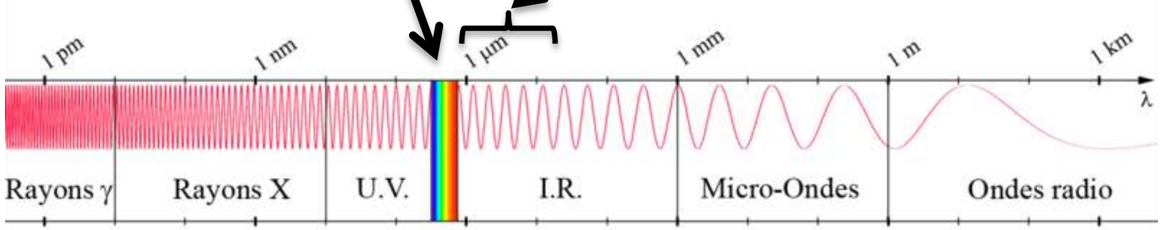
- **Conduction**: propagation inside a solid/fluid of thermal agitation
  *Material properties: Thermal conductivity **λ or k** [W/m/°C] ; Heat capacity **ρC** [J/m³/°C]*

- **Convection**: propagation solid<->fluid (air, water…)
  *Parameter: Convection coefficient **h** [W/m²/°C]*

- **Radiation**: all bodies emit radiation whose type depends on their temperature
  (this physical phenomenon is not so intuitive and is not always well understood)
  *Surface property : thermal emissivity **ε** [-]*

Source Wikipedia

Eye sensitivity **Infrared camera sensitivity**



Body around 6000°C [0,2-2 μm] [5-20 μm] **Body around 0°C and 100°C**

Source Wikipedia

[1,5-10 μm]
Body around 1000°C

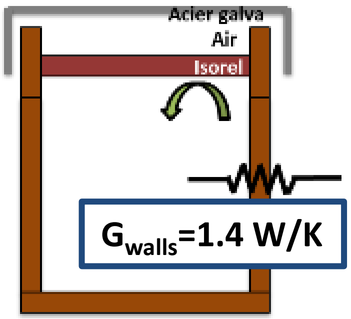

Source Wikipedia

Reduce losses through walls?

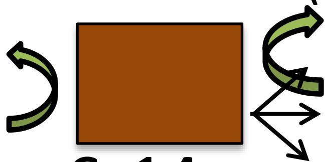
Assumption: 10°C (average) inside and 0°C outside: $\phi \approx 20$ Watt

Amount of heat power bees would have to produce to keep 10°C inside (≈25000 abeilles)[1]

https://low-e.co.uk/blog/how-to-insulate-a-beehive/



CASE 1: Standard case (wood only [+paint])



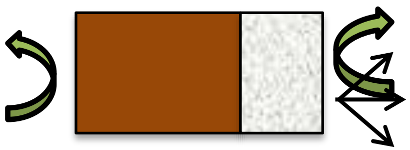
Convection (50%)

Rayonnement (50%)

G= 1.4 W/°C

CASE 2: Decrease heat conduction through walls

2cm of polystyrene is added around the hive



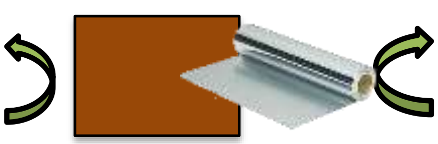
G=0.43 W/°C

-46% reduction (total loss)

-52% reduction with 4cm

CASE 3: Decrease heat radiation

Aluminium sheet on outside walls



Solution not realistic

(Aluminium should be kept clean !)

G= 1.2 W/°C

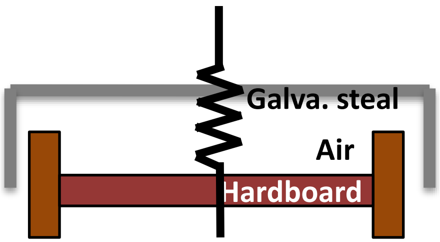
-12% de pertes (totales)

1: L. Farhenholz & al., Thermal investigations of a honey bee colony […], Journal of Comparative Physiology B, 1989

Reduce losses through the roof?

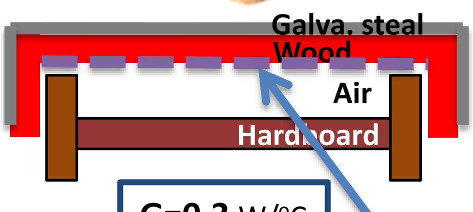
Assumption: 10°C (average) inside and 0°C outside:

Cas 1:
roof not insulated



G=0.3 W/°C

Cas 2:
roof with 1.5cm of wood



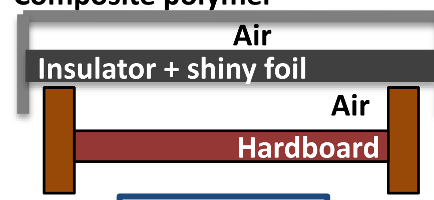
G=0.3 W/°C

No effect?

Wood improve conduction resistance but increase heat radiation flow

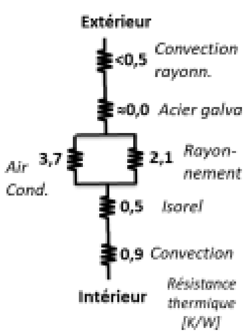
G=0.2 W/°C with aluminium foil on the wood
G=0.2 W/°C by replacing wood by polystyrene

Cas 3:
insulated roof

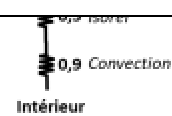


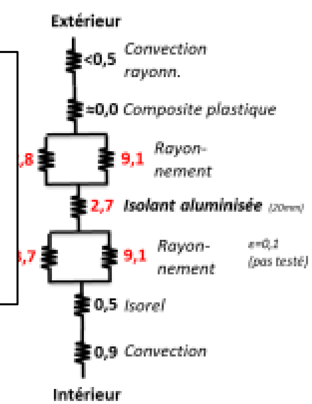
G=0.1 W/°C

Computation:



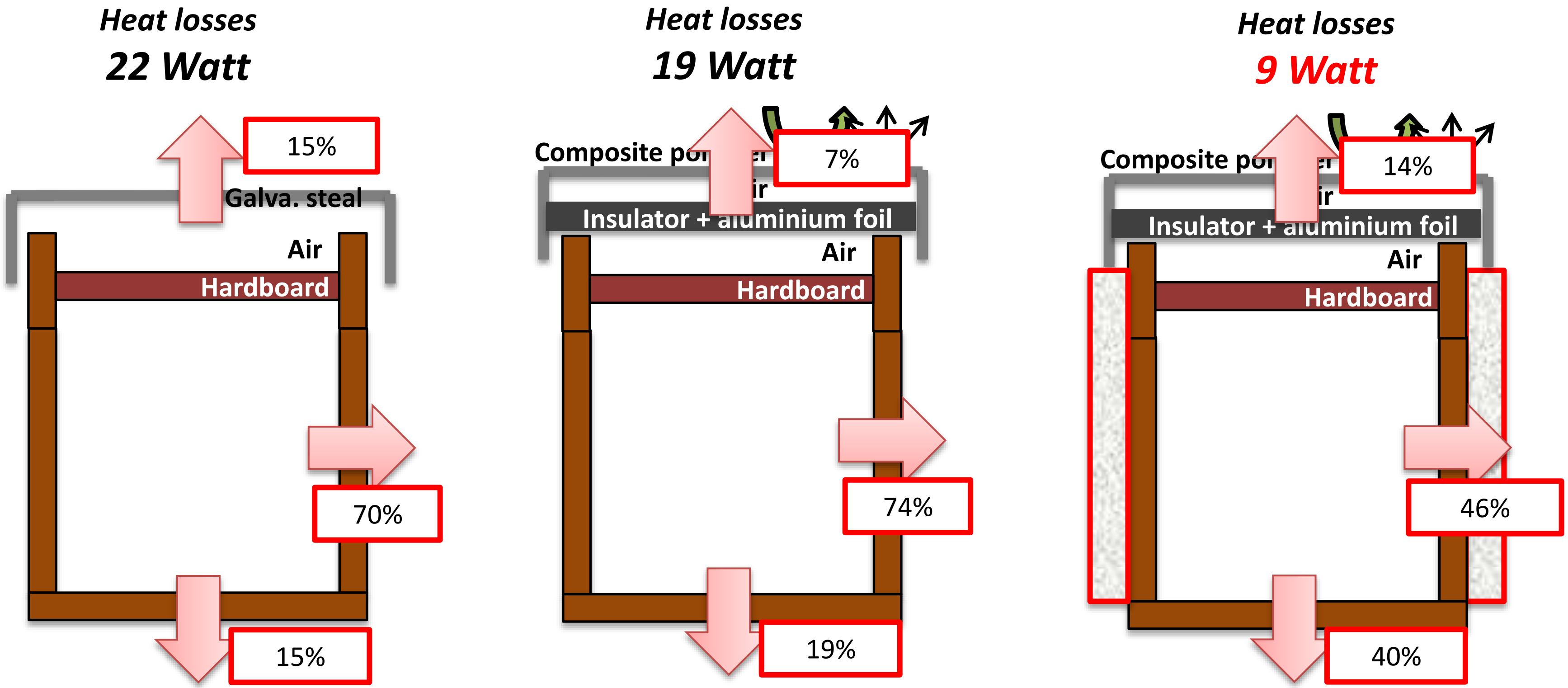
Trap! The sentence:
« wood in the roof hs no effect »
is only true in steady state regime
(slow variations, without fast perturbations)





Insulate roof or walls or both?

Assumption: 10°C (average) inside and 0°C outside:



Case 1: no insulation | Case 2: roof insulated | Case 3: walls and roof insulated

- Insulate the roof has no significant effect since most losses are due to the walls
- In a populated hive, heat losses through walls would be lower since frames have a insulation effect (at least in one direction).
- These results hold only for slow temperature variations

Part IV

Beehive environment

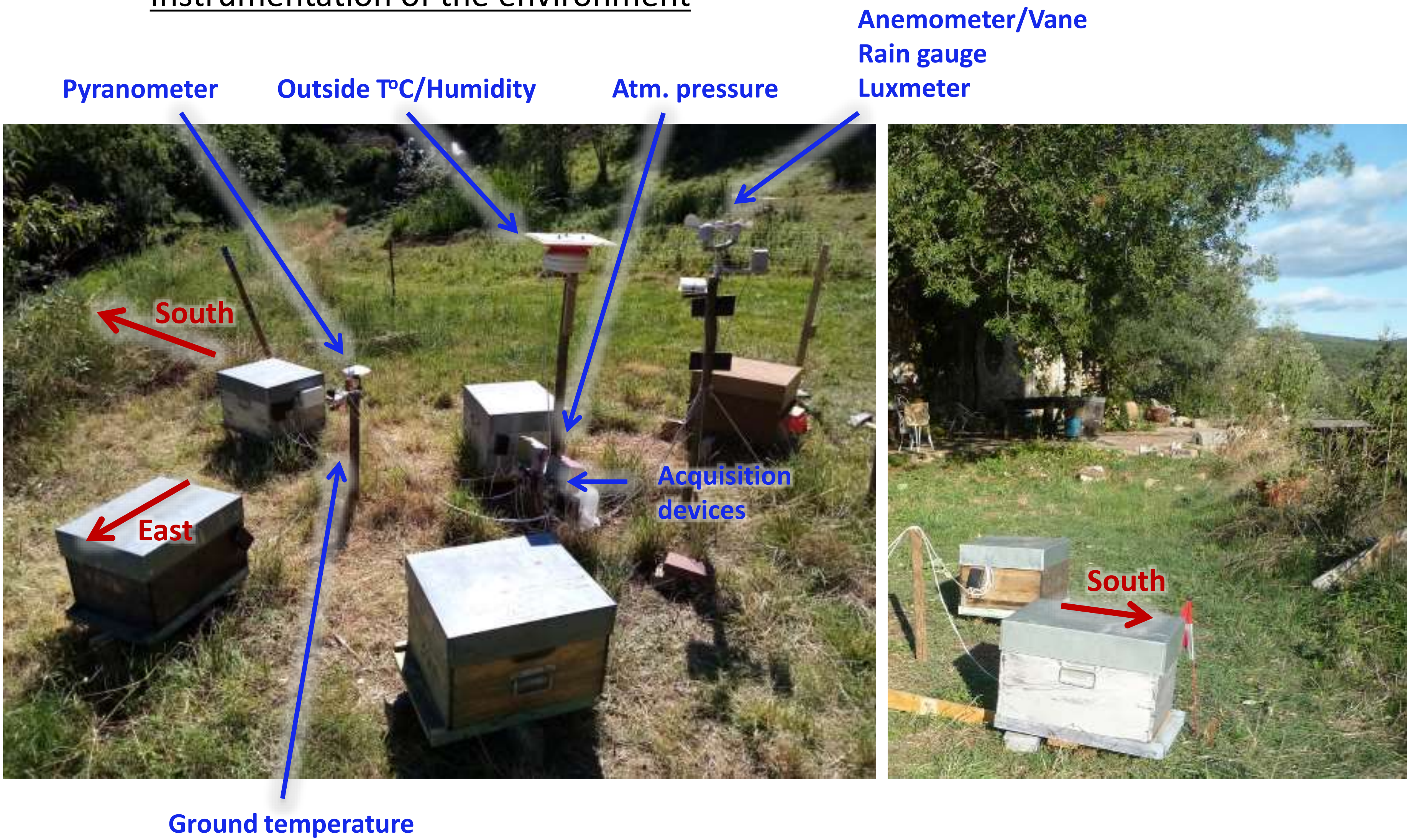
https://blog.defi-ecologique.com/abeilles-domestiques-biodiversite-rucher/

https://www.label-abeille.org/fr/blog/132-ou-installer-ses-ruches-comment-organiser-le-rucher-

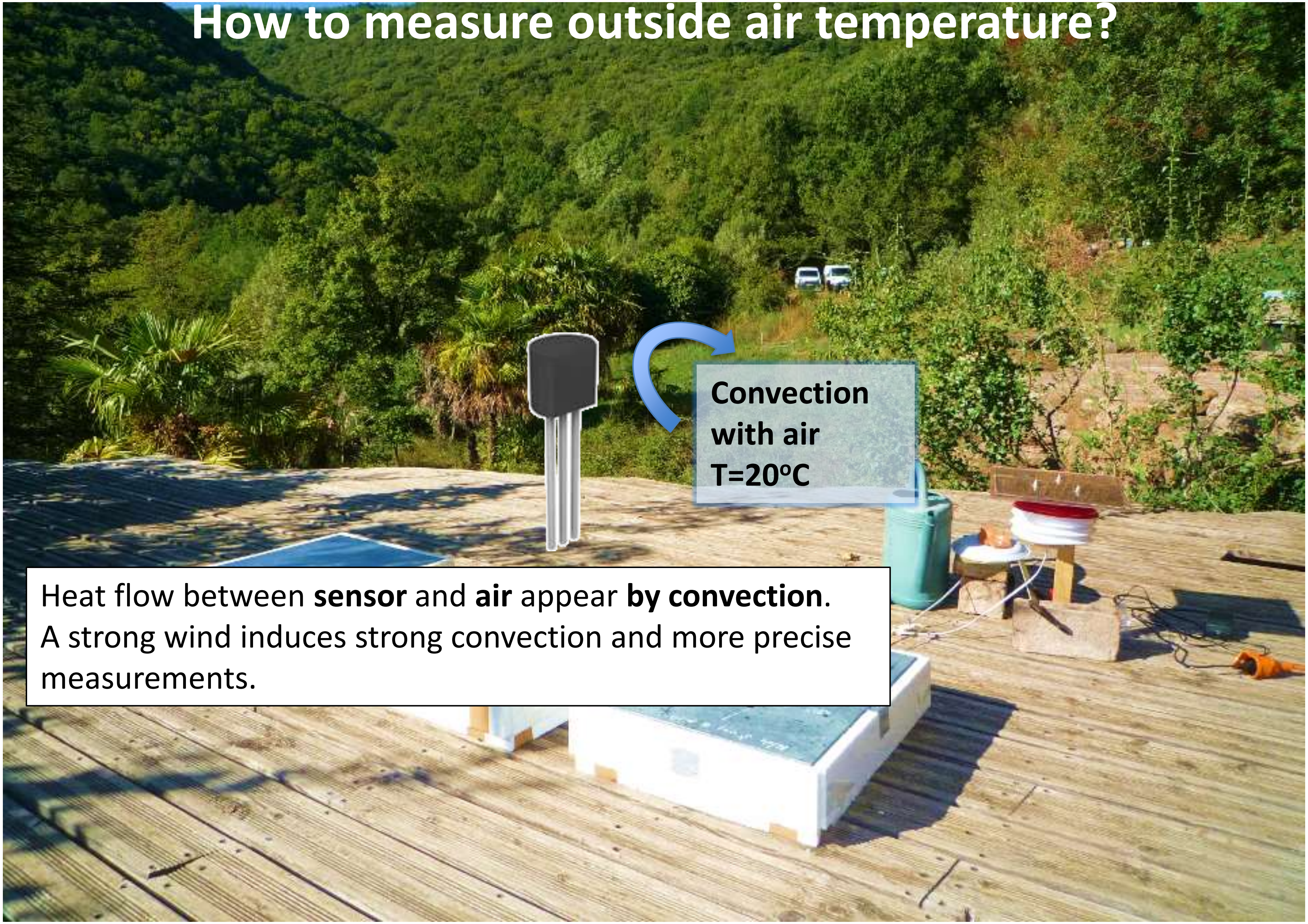
https://cultivetaville.com/encyclopedie/apiculture-urbaine/installer-un-rucher-par-ou-commencer/

Our experimental apiary

Instrumentation of the environment

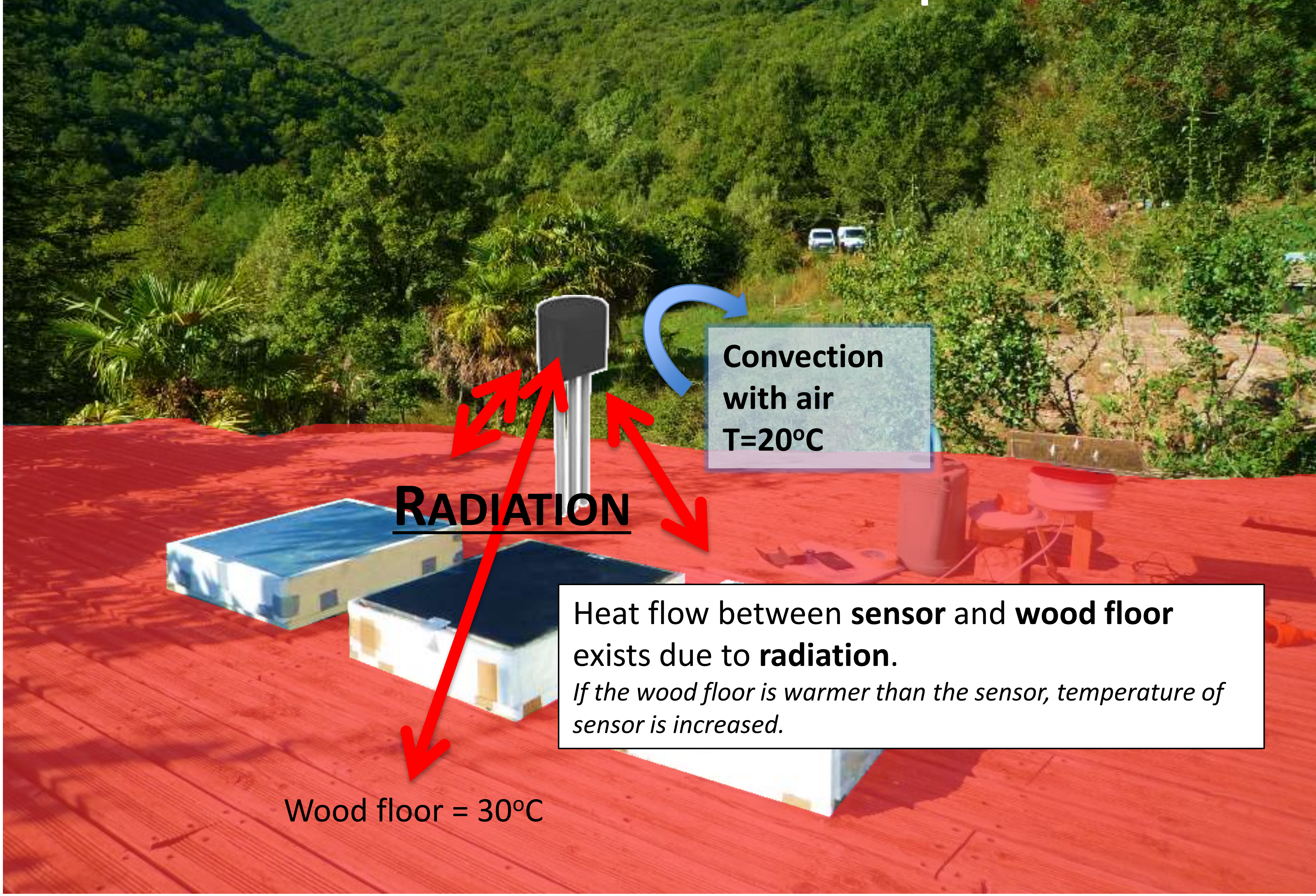


How to measure outside air temperature?



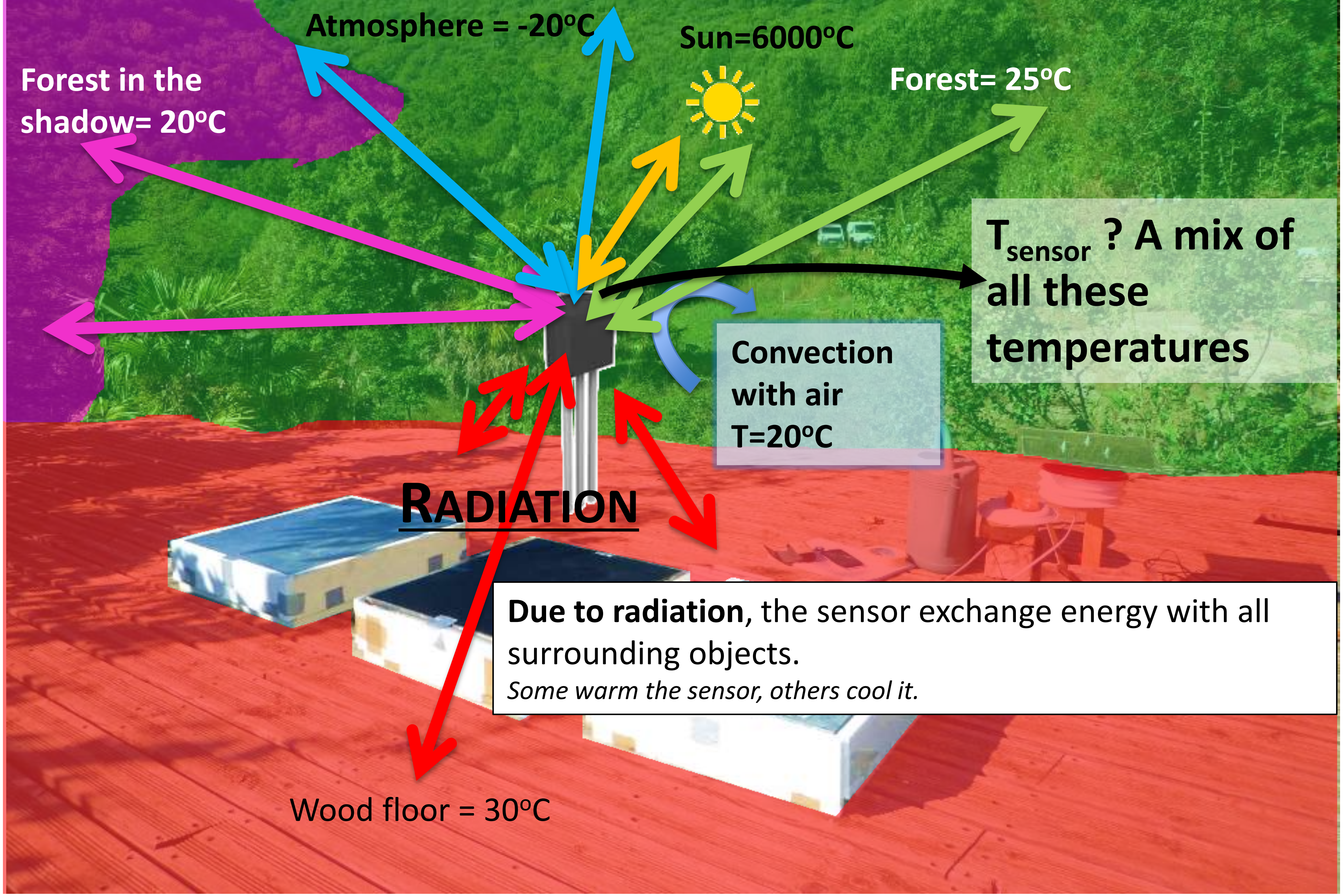
Heat flow between **sensor** and **air** appear **by convection**.
A strong wind induces strong convection and more precise measurements.

How to measure outside air temperature?



Heat flow between **sensor** and **wood floor** exists due to **radiation**.
If the wood floor is warmer than the sensor, temperature of sensor is increased.

How to measure outside air temperature?



Due to radiation, the sensor exchange energy with all surrounding objects.
Some warm the sensor, others cool it.

How to measure outside air temperature?

The common way is tu use « plates » to create
an environment arround the sensor
that has only one temperature = the air temperature

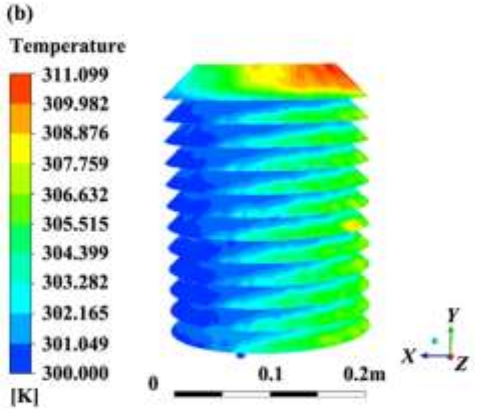
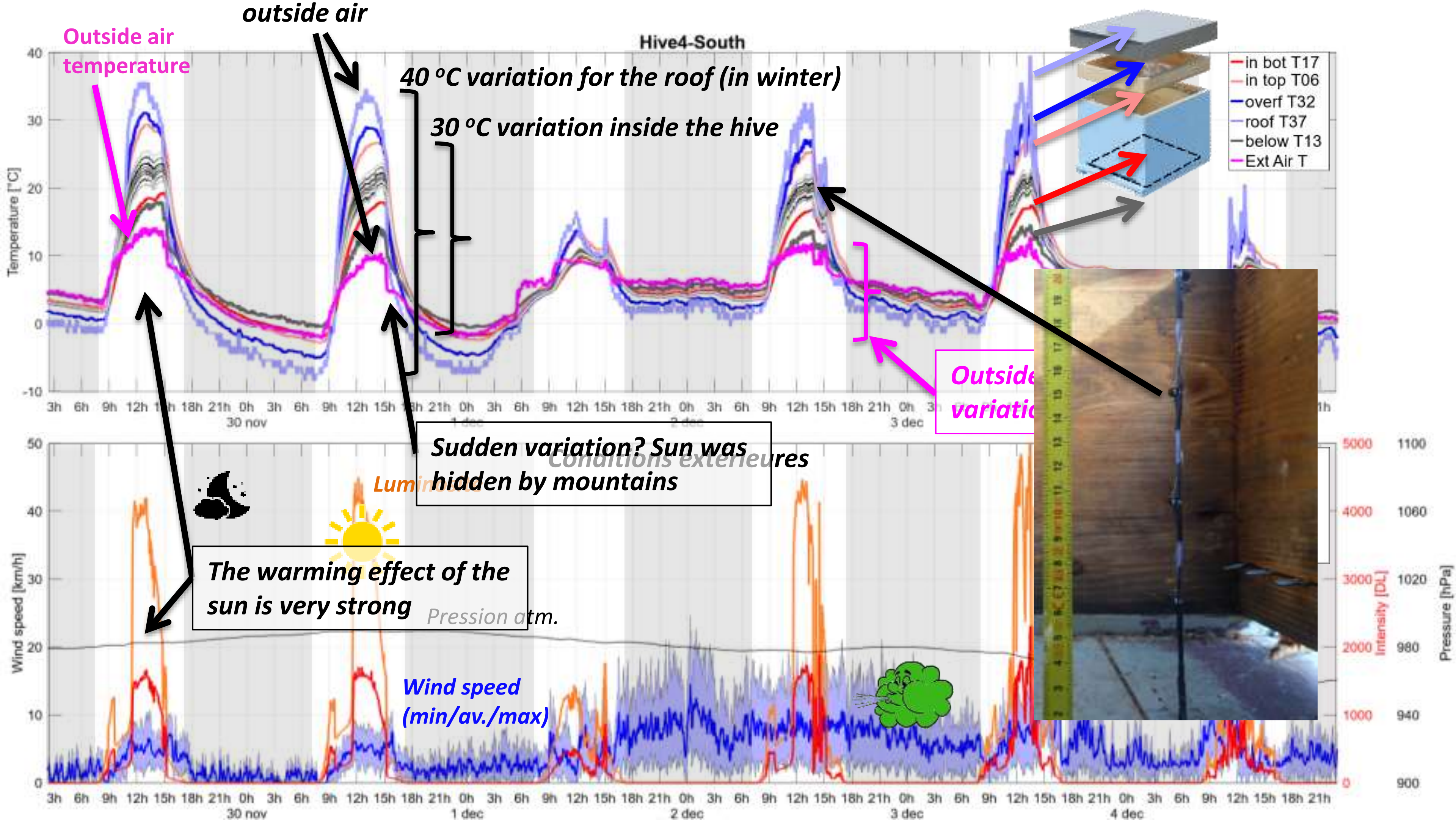


Image: Fluid dynamic design and experimental study of an aspirated temperature measurement platform used in climate observation, J. Yang, Q. Liu, W. Dai, R. Ding, Review of Scientific Instruments **87**, 084503 (2016)

Hive temperature

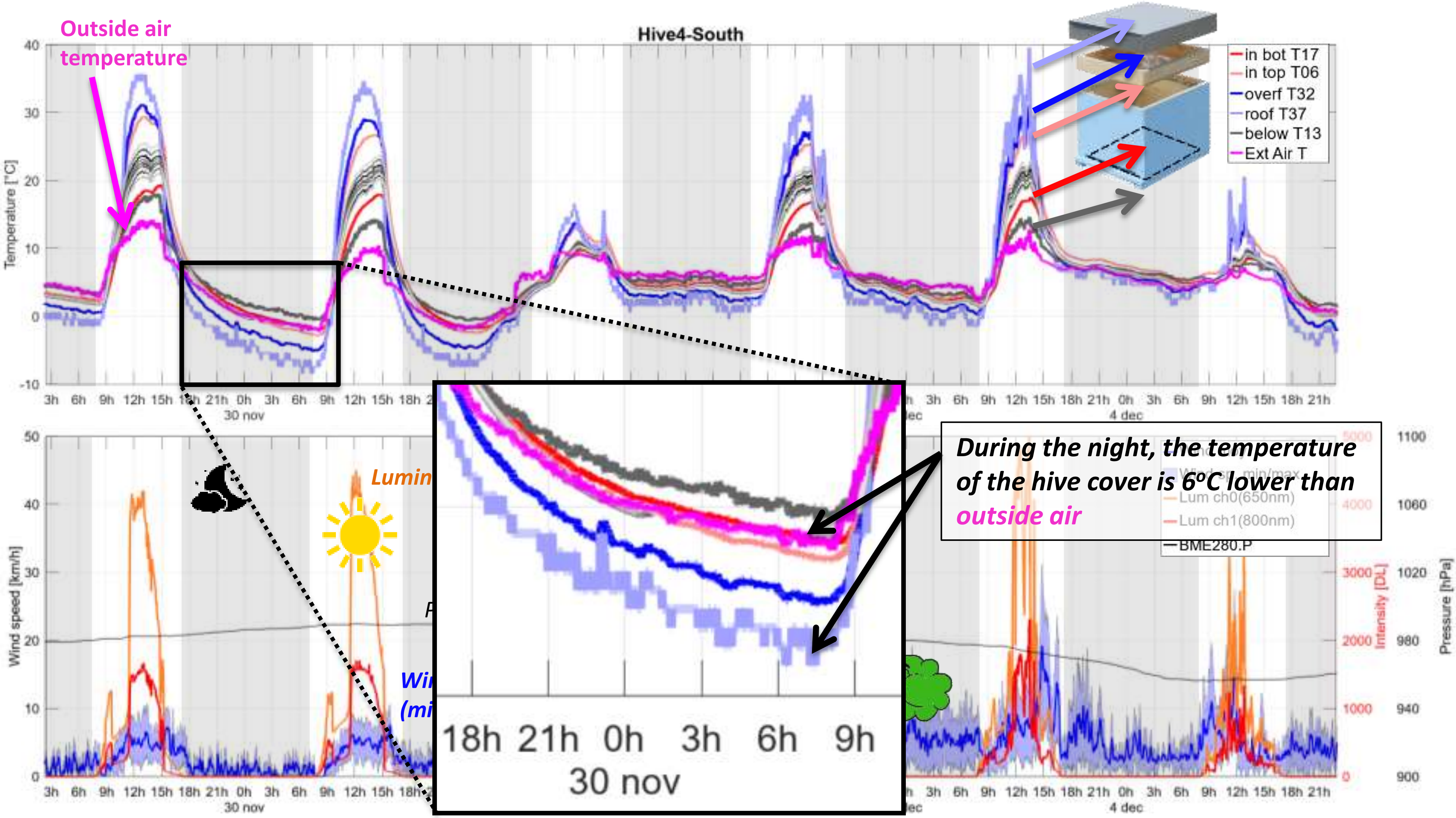
Sun effect



During these measurements, 1kg of water was inside the south hive to test thermal mass effect

Hive temperature

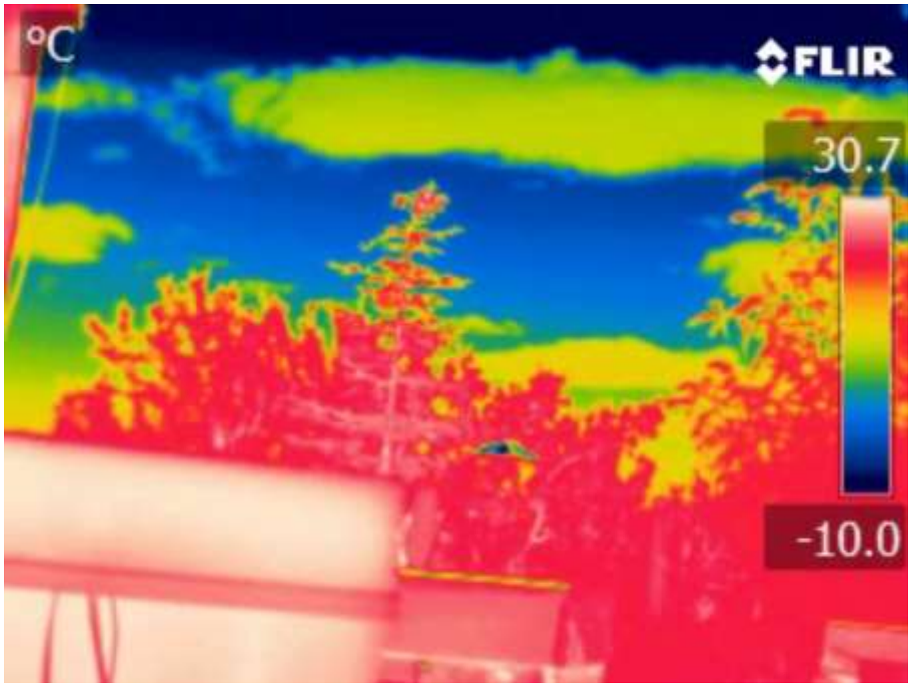
Effet de l'atmosphère froid

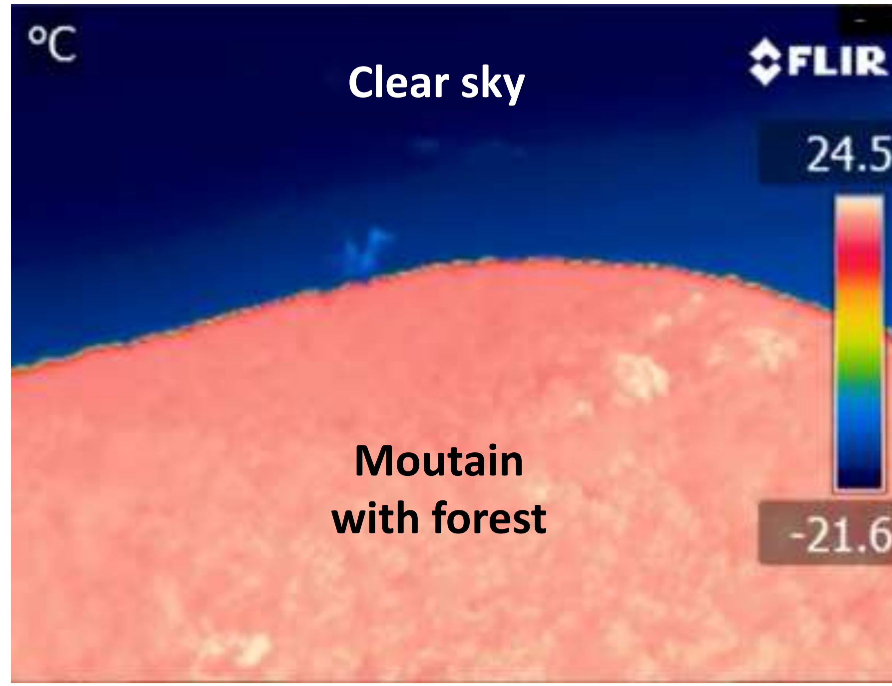


During these measurements, 1kg of water was inside the south hive to test thermal mass effect

Sky temperature

Infrared views of beehives and environment





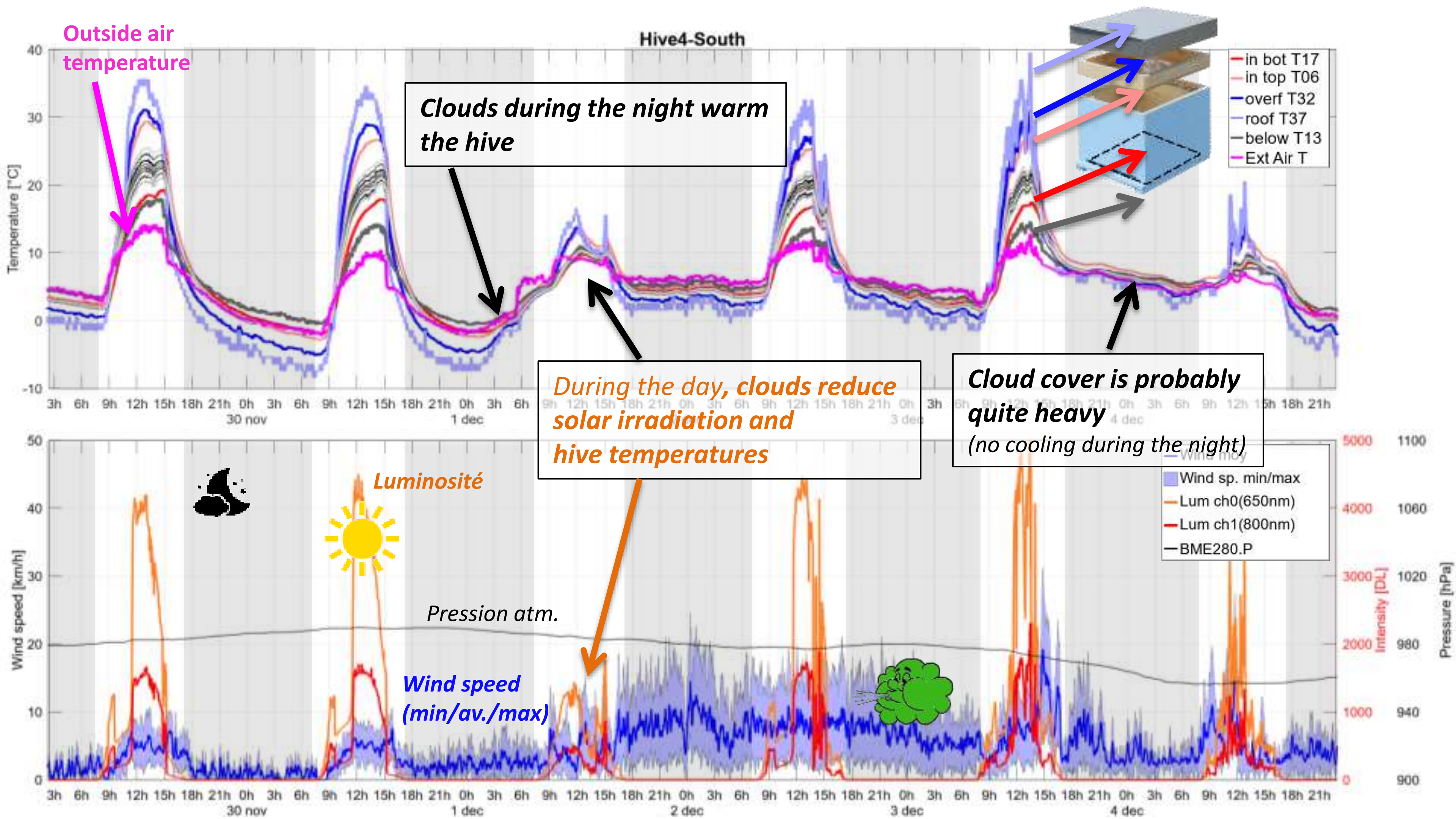
The sky behaves like a body at **-20°C**
Clouds behaves like a surface at about **5 to 10°C**

Special attention is required when reading temperature with infrared cameras

The hive **is loosing energy by heat radiation** with the sky/atmosphere
The roof is more exposed to this cooling

Hive temperature

Cloud effects



During these measurements, 1kg of water was inside the south hive to test thermal mass effect

Some exemples

https://blog.defi-ecologique.com/abeilles-domestiques-biodiversite-rucher/

- Dry lands reflect solar radiation toward the hive (high albedo)
- Exposed to sun radiation
- Exposed to cold atmosphere

https://cultivetaville.com/encyclopedie/apiculture-urbaine/installer-un-rucher-par-ou-commencer/

- Exposed to cold atmosphere
- Exposed to wind
- Albedo of small stones needs to be characterized

https://www.label-abeille.org/fr/blog/132-ou-installer-ses-ruches-comment-organiser-le-rucher-

- Permanent shadowing which limits the effect of cold atmosphere and sun radiation.
- Wet lands (low albedo) absorb sun radiation.

Solution (to reduce sun effect):

- Adapt the hive cover to reduce sun radiation absorption (reflecting paint…)
- Put hives in low albedo lands
- Use paint on walls that reflects sun radiation
- Place the hives next to each other to increase shadowing effect
- Etc…

The effect is reduced in winter if plant are not evergreen. May be preferable to let the sun warm the hive.

Influence of beehive entrance

Automatic and periodic opening/closing of the entrance

Firsts results:

- No measurable effect (no heat loss) through the entrance when the internal air is warmer than the outside air (a 10W heater is put inside the hive body)
- Very small temperature variations could be detected when the air is cooler than the outside air. The cold air is going down and leaves the hive.

In winter:
The entrance in the bottom part allows warm air to stay in the hive.

In summer:
Cool air is leaving the hive which could contribute to increase extreme temperature.

Is it significant?
What about a second entrance/hole?
(To be studied)

Part V

Overview of some commercial products

Roof insulation

Foam, wood fiber, polystyrene -> Similar

What about condensation?

Un isolant disposant d'une protection thermique élevée (λ = 0.038 w/m*k) est idéal pour vos ruches !

Tr: « An insulator with a good thermal protection perfect for you hives »

APIFOAM est une mousse isolante à positionner sous le toit de votre ruche.

Tr: « APIFOAM is a insulating foam to be installed below the hive cover »

Le PHALTEX est obtenu par feutrage et séchage de fibres de b
résineux imprégnées de bitume en cours de fabrication.

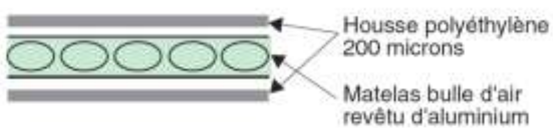
Le panneau isolant Phaltex est un isolant pour ruche qui s'encastre dans le couvre-cadres ou le toit.

Isolant de 20mm polystyrène intégré.

Tr: « insulation with integrated 20mm polystyrene »

More efficient? With aluminium foils

(depends on thickness, the more, the better)



L'Isoruche est un matelas isolant

Tr: « Air bubble insulation with aluminium foils »

https://www.icko-apiculture.com/

Air bubble insulation

A priori quite efficient. Several layers could be stacked up.

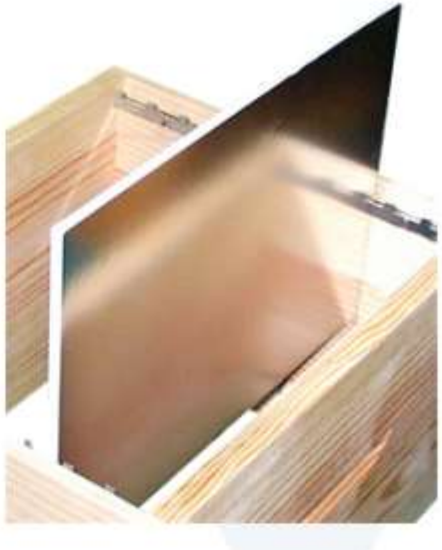
Isoruch est un couvre-cadres isolant pour ruche, idéal pour apporter du confort et de la chaleur à vos abeilles. Ce matelais "bulle d'air", revêtu d'aluminium procure une isolation équivalente à 80 mm de laine de verre.

Insulated cover with second air layer, 2cm of insulating materials, and shiny foil to reduce heat radiation.

(air-holes to prevent condensation)

Insulating frames

https://www.naturapi.com/nourrisseur-partition-cadre-dadant-corps-bois-super-isolante-avec-isolant-recouvrant-445-465-280mm.html



https://www.naturapi.com/partition-dadant-superchaud-452-320mm.html

Combining insulation and feeder

Increase thermal mass when full

Insulating frame

Sealing efficiency?
Two frames needed?
Reduce the surface area of non insulated walls
Thickness? 1cm is not much

Manufacturers took some cares to use **shiny surface** (need to be clean) to reduce heat radiation
Insulate inside/outside the hive? Internal: Care should be taken to avoid condensation on hive internal surfaces ?

To conclude

Identify the objective:
Insulate against what phenomenon? Cold air? Sun?
What are the thermal characteristic?

Slow changes (Season, weeks) ≠ Fast changes (sun, clouds…)

These two categories require different insulation practices
which are mostly simple and inexpensive

No general solution for all situations.

Solutions are specific to an **environment**.

Thermal analysis is only one point of view and need to be combined with another approaches/knowledges.

Temperature and insulation of beehives

Contact: anna.dupleix@umontpellier.fr
emmanuel.ruffio@gmail.com

Thanks for your attention!

Thanks to all the team!

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