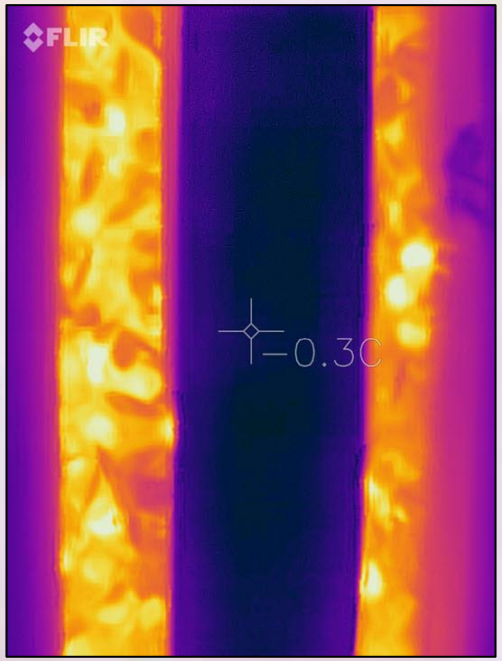
Testing out - IR Camera to take Internal Pictures/Video of a Winter Cluster
&
“Hive Disturbance” a thermal perspective



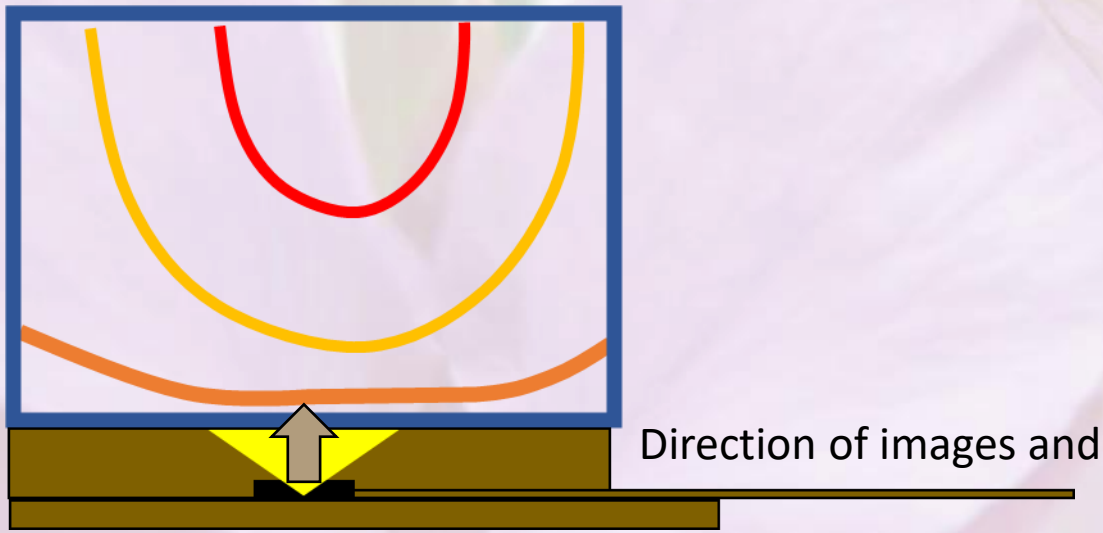
Etienne Tardif

January 2021

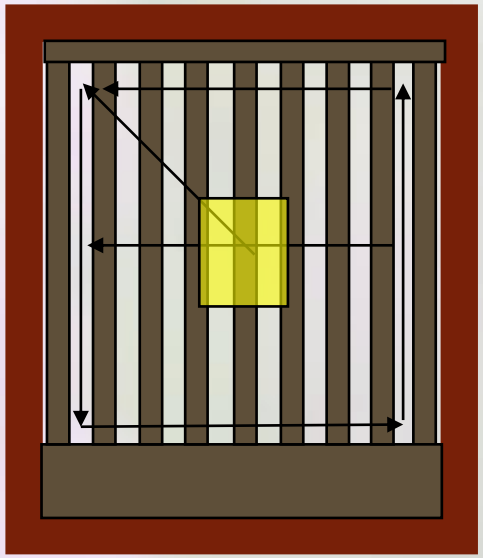
North of 60 Beekeeping
yukonhoneybees@gmail.com

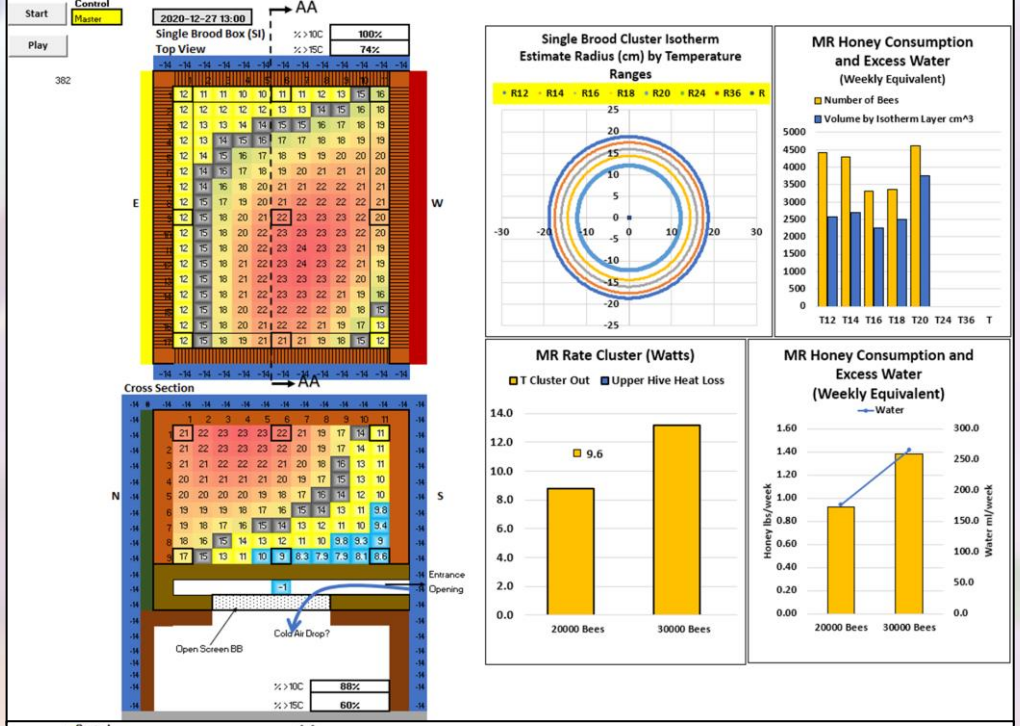
My goal is not to convince folks, but understand why and how things happen in our current bee hives – Feel free to ask any “theory” questions. I will do my best to put things in lay terms.

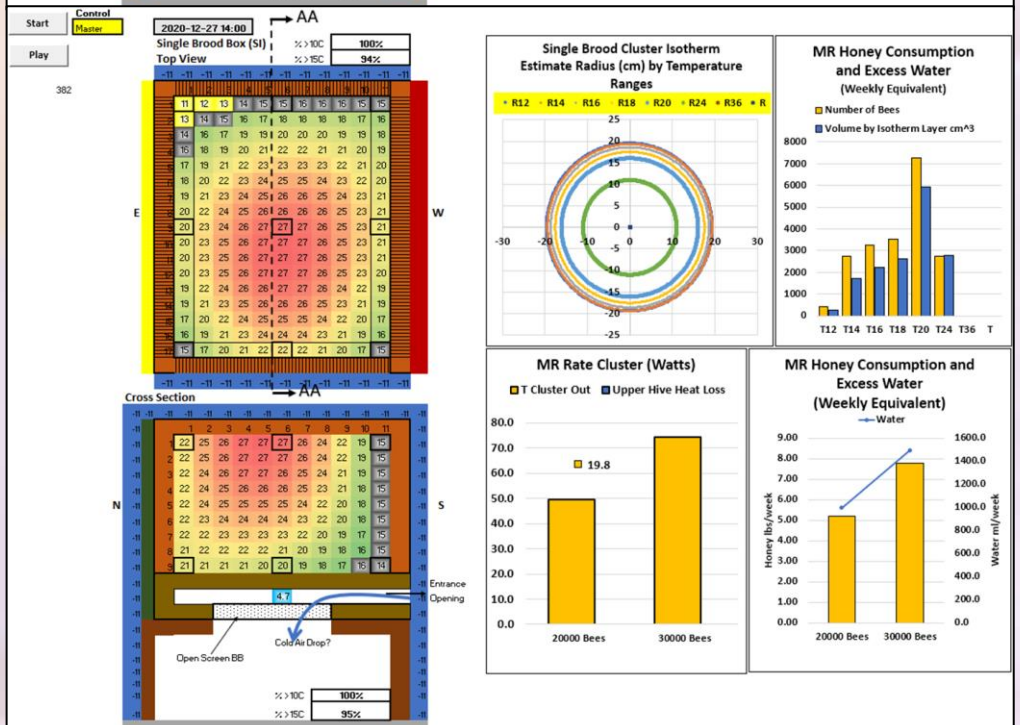
Taking Thermal pictures of a wintering cluster



Direction of images and video taken







Before
IR Images

After
IR Images

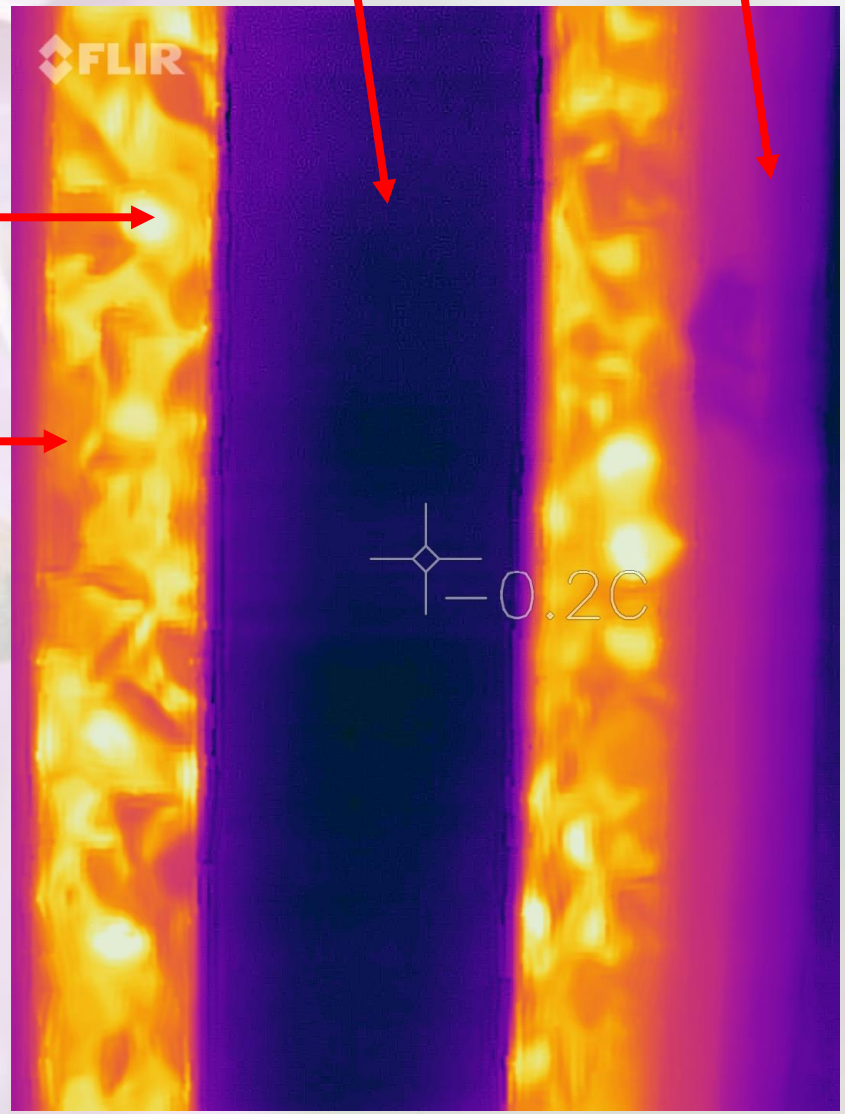
Need to be even more careful to ensure hive does not get disturbed

Bottom of slatted rack bar

Bottom of frame

Bee thorax ~25C to 29C

Back ground temperature 10C to 15C



Video available here: https://youtu.be/TRKnxxaTNwo

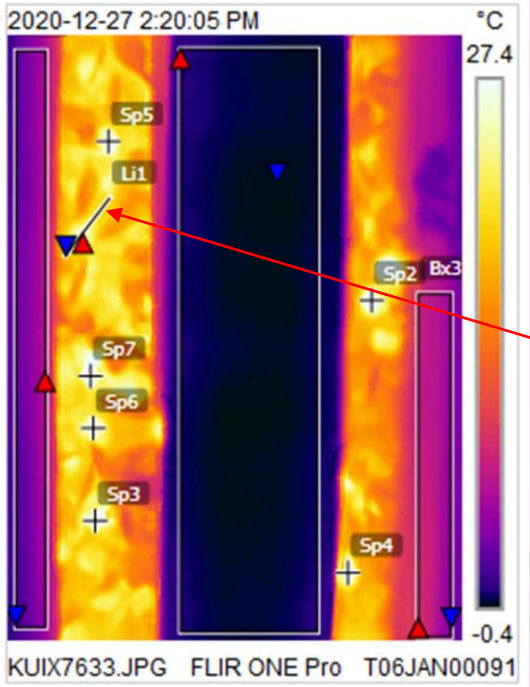
Testing Flir Software Tools

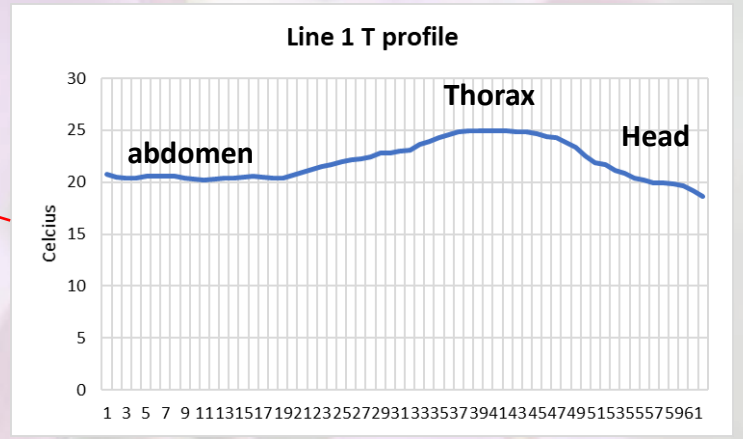
Measurements		
Bx1	Max	0.9 °C
	Min	-0.4 °C
	Average	-0.1 °C
Bx2	Max	7.5 °C
	Min	1.5 °C
	Average	4.2 °C
Bx3	Max	9.3 °C
	Min	3.7 °C
	Average	6.8 °C
Sp2		28.4 °C
Sp3		28.3 °C
Sp4		26.8 °C
Sp5		26.7 °C
Sp6		25.1 °C
Sp7		29.9 °C
Li1	Max	25.0 °C
	Min	18.7 °C
	Average	21.9 °C
Dt1	Bx1.Max - Bx2.Max	-6.6 °C

Parameters	
Emissivity	0.9
Refl. temp.	22 °C

Geolocation	
Compass	0° N

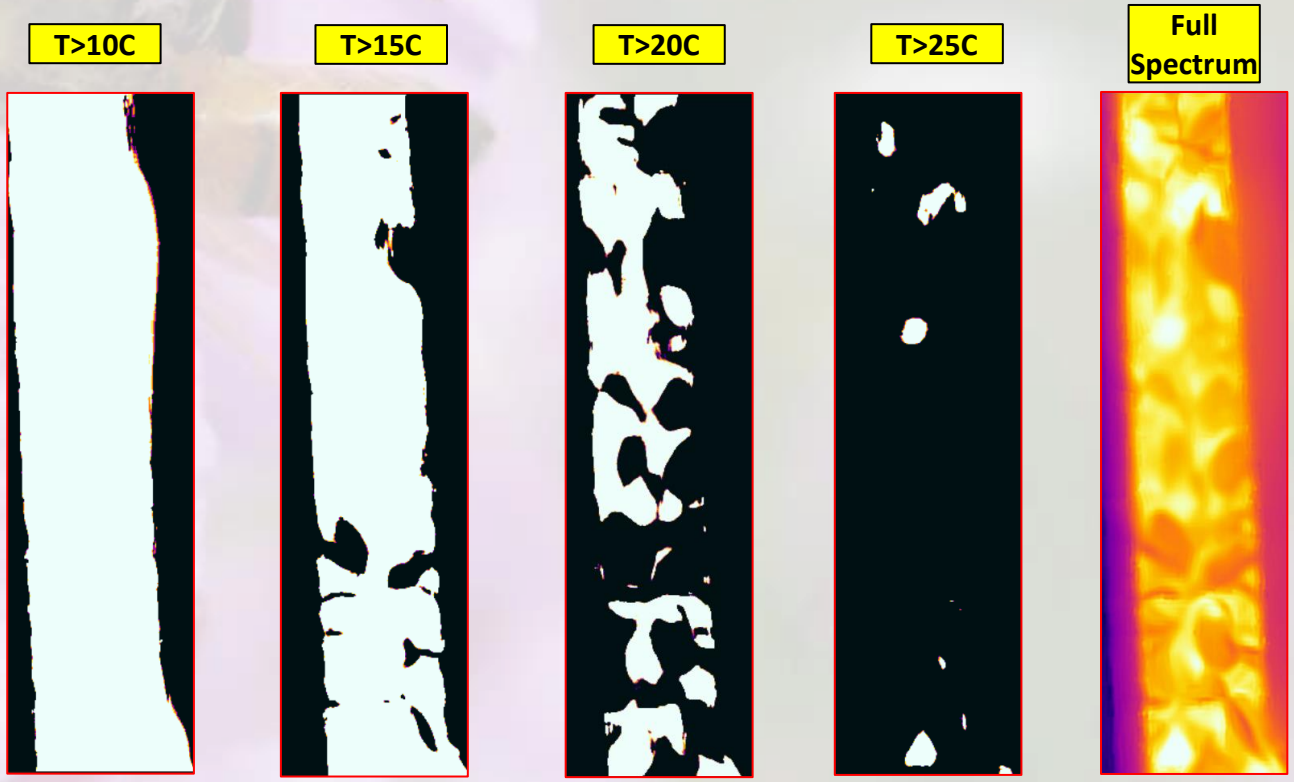
Camera can be used to estimate cluster surface temperature



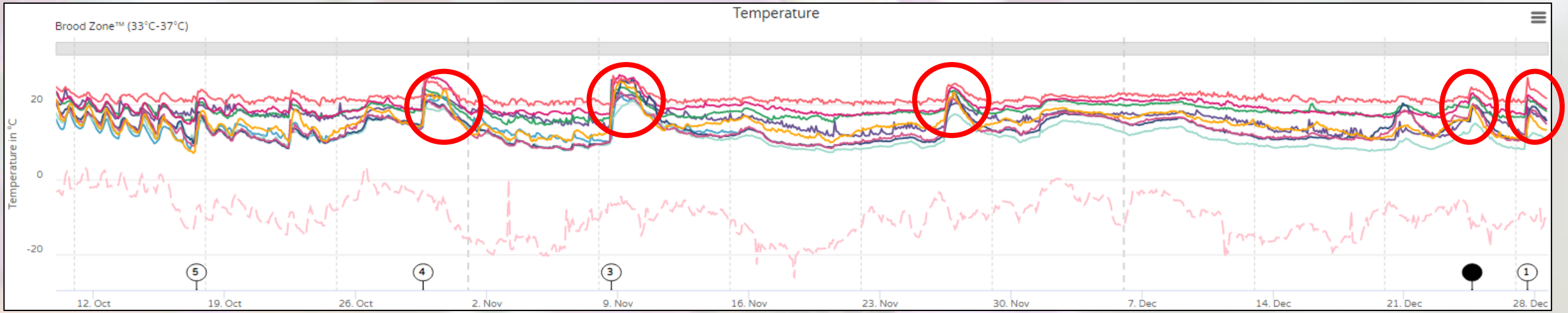


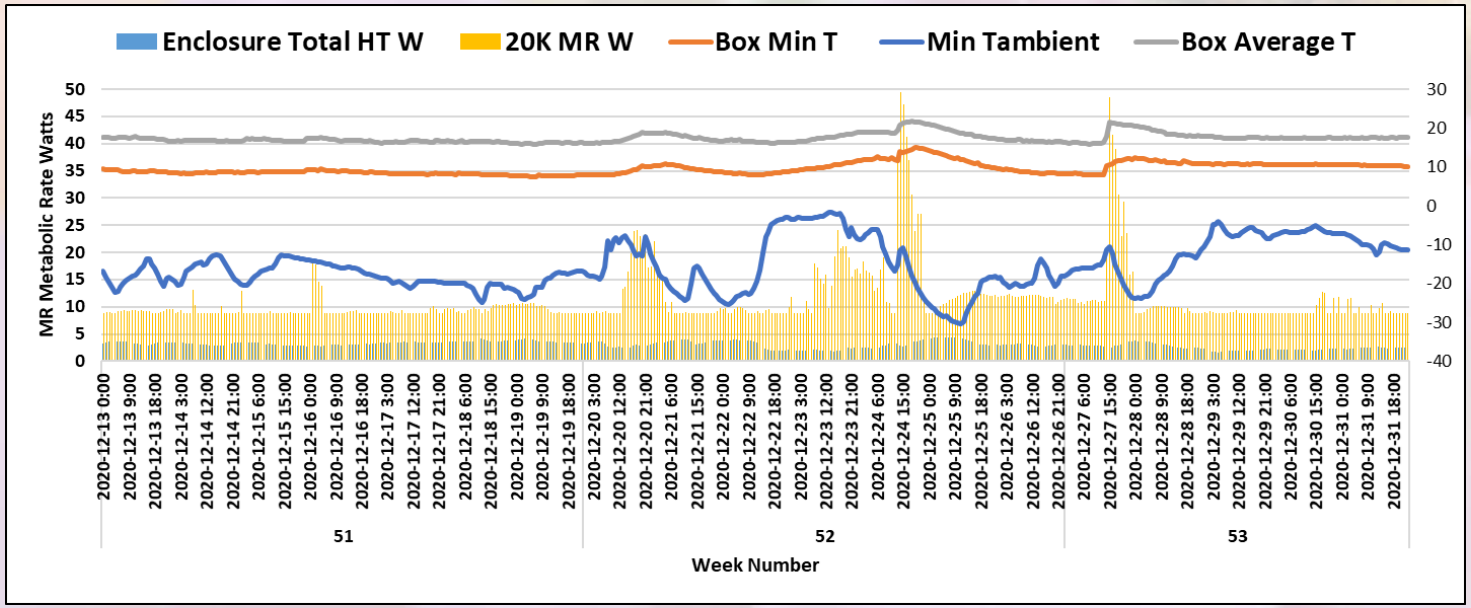
Note: Take pictures as video does not carry temperature data for post-processing

All defined measurements or pictures pixel (640x480) temperatures can be dumped to a csv file



Wintering hives are extremely sensitive to any disturbance



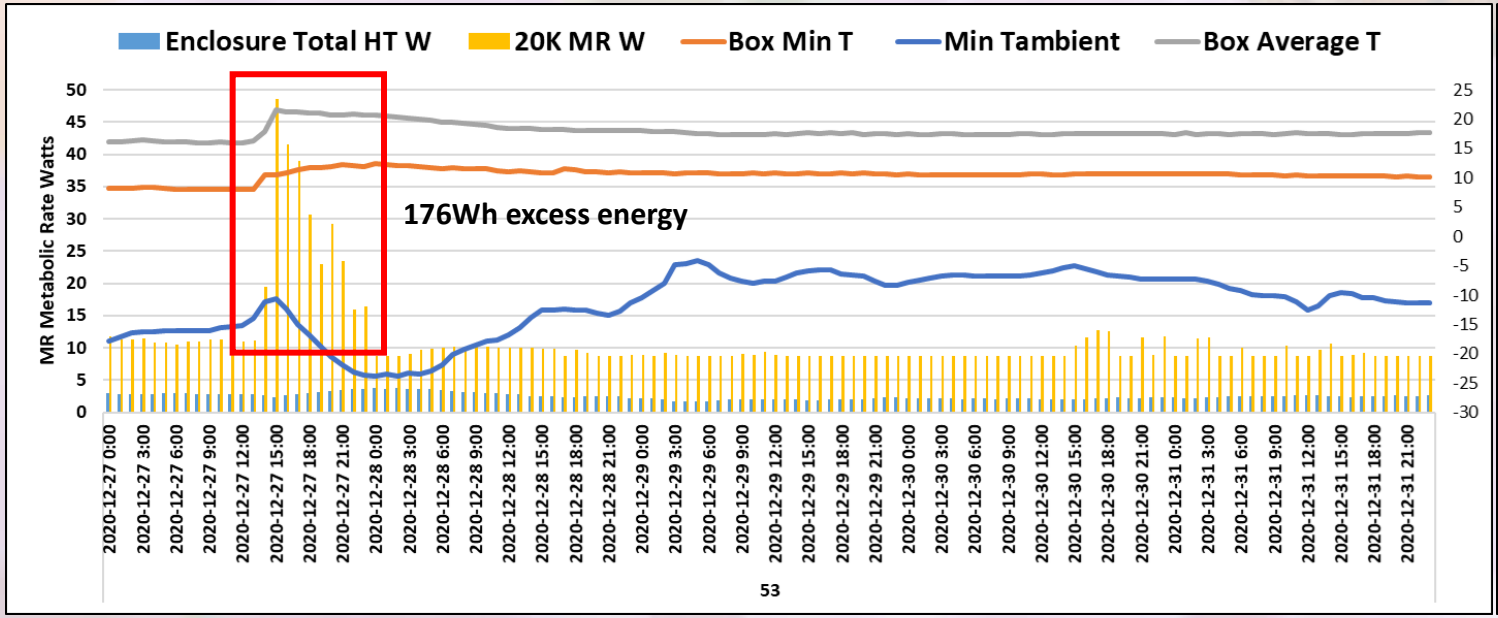


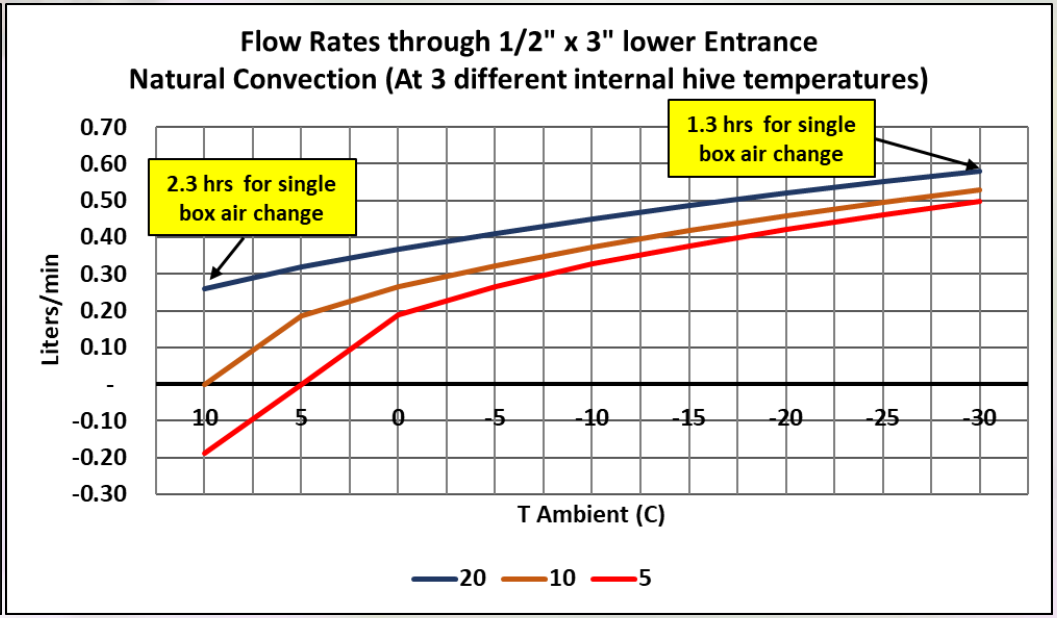
- Event 2 (Black Circle) was my 1st attempt at taking IR images
- Event 1 is my 1st successful attempt using thermal camera.

Notice: Increase in estimate cluster energy output (yellow bars in chart - **Metabolic Rate for a 20K bee cluster**).

Disturbance in insulated hive

- Length of “perceived” higher energy state is due to time required to dissipate extra energy generated (hypothesis)
- 10hrs of higher energy output by cluster from ~8 to 12 W/hr to a peak of ~50 W/hr (surplus of 176 W-hr before getting back to average)
- Excess energy increases box temperature and therefore superorganism “weight” bee mass, wax and honey Stores [~6 frames at 4.09kg each of 24.55 kg (54lbs)]
- The average HT Enclosure Heat Loss is 3.5 Watts/hrs + estimate of 4 Watts via lower entrance.
- Higher internal temperature will increase natural ventilation (larger delta T) likely proportional to increased CO2 generated and excess moisture generated. (**Remember** Delta T in wooden hives is very small where **Tin ~Tambient** so very little natural ventilation will occur in a bottom entrance only setup)
- As shown in the video, many heater bees can be seen in the lower outside surface of the “cluster”





Thermal Energy Balance (Simplified)

	Heat Capacity	Density	Heat per volume
Material	(J/gK)	(kg/m3)	(MJ/m3K)
Water	4,180.00	1,000.00	4.18
Honey	**2,370.00**	**1,400.00**	**3.32**
Wood	0.42	550.00	0.2310

1 std frame = 4.09kg of honey

- 85 Watt-hrs (thermal gain) is equivalent to 8 to 10 hours of steady cluster energy output @-10C.
- Energy created must always balance out.
- Heat loss in wooden hive wood be 6-10 times larger (24W/hr to 40W/hr) for similar temperatures.

Note: I didn't account for the rate of heat absorption. Honey thermal conductivity is about 0.5 W/mK

The heat or energy storage can be calculated as

q = V d cp dt

= m cp dt (1)

where

q = sensible heat stored in the material (J, Btu)

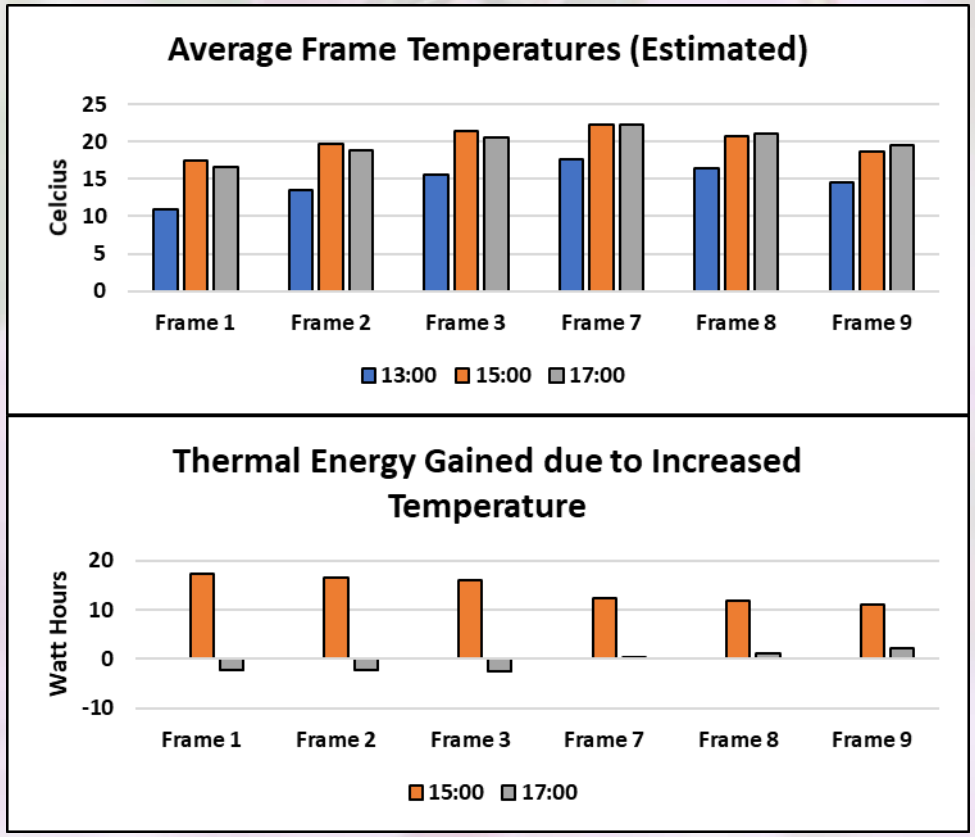
V = volume of substance (m3, ft3)

d = density of substance (kg/m3, lb/ft3)

m = mass of substance (kg, lb)

cp = specific heat of substance (J/kgoC, Btu/lboF)

dt = temperature change (oC, oF)



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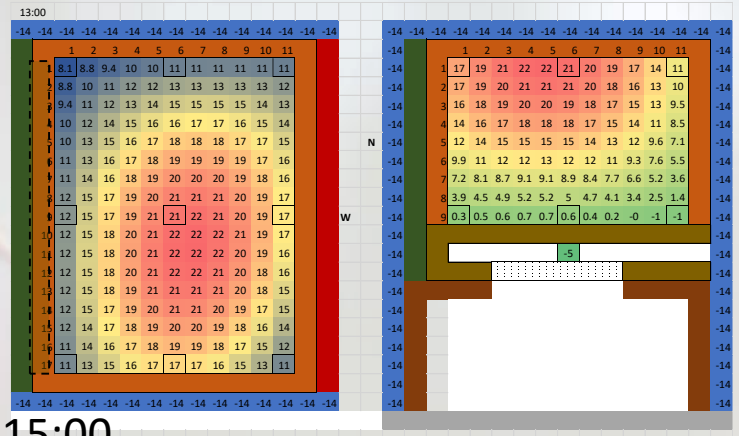

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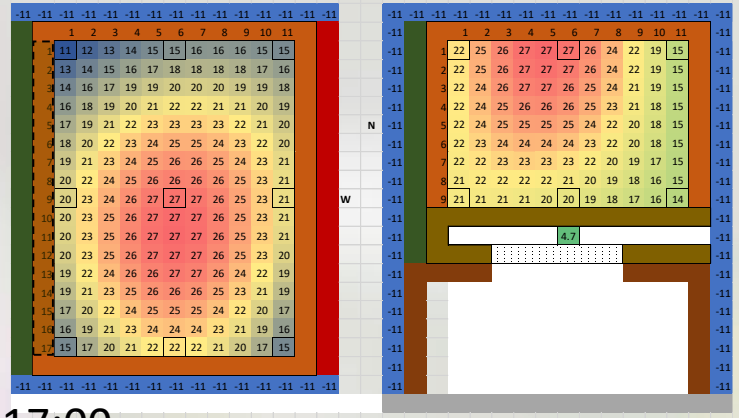

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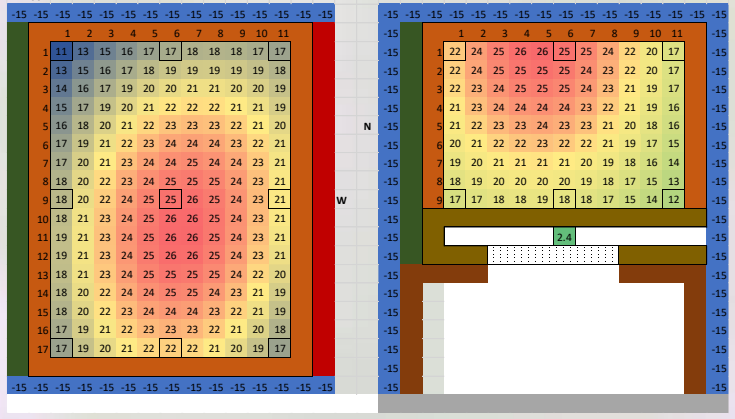


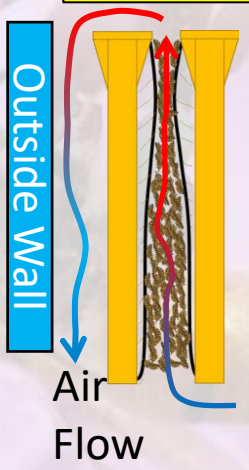
Honey in the winter hive (More the better)

Practical Application

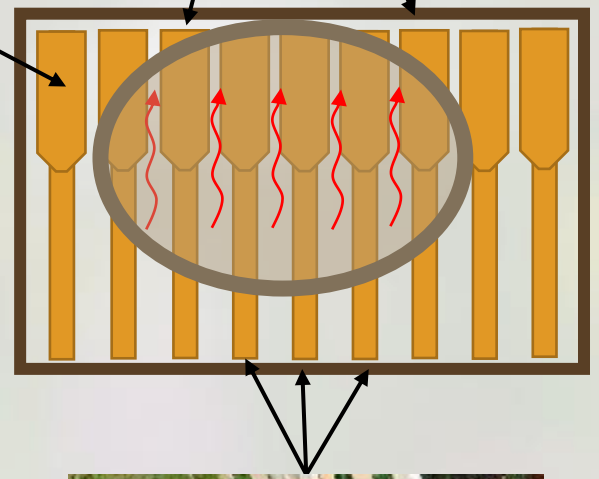
- Does your nest get back filled with “honey” before winter?
  - Why is this important?
- Do you harvest honey from your lower boxes?
- Do you overwinter with bare foundation frames?

  Replace empty frames with foam follow boards with ¼” wooden insert on inside to protect from chewing bees
- Or, ensure 2 or 3 solid honey frames in outside positions

Thermal mass + Slows heat loss from cluster/brood nest (slows air flow between frames)



Heaviest frames of Honey outside edges



Extra Content

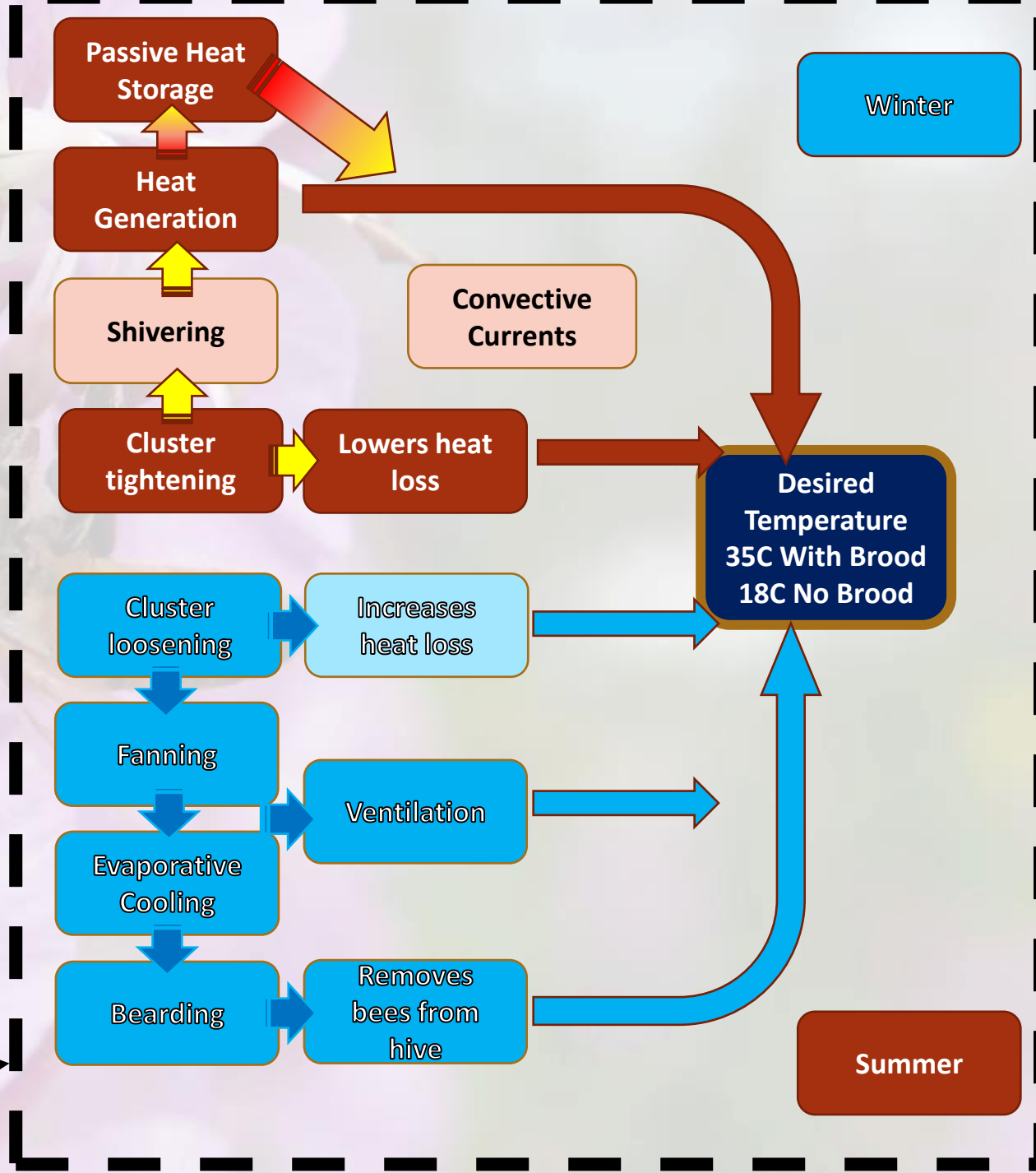
Hive Thermoregulation

Excerpt from “The Buzz About Bees”

By Jurgen Tautz, 2008

- The energy content of a full crop of nectar amounts to 500J (20 to 40mg)
- Hive can produce up to 300Kg of honey in a summer
- 1Kg of honey contains 12,000KJ
- Heater bee burns 120J from sugars in her hemolymph for a max of 30mins
- Up to 2 million J burnt to warm cluster in winter (or higher in colder climates)
- Heat energy for control of the brood nest temperature is equivalent to a continuous power usage of 20W

Hive Enclosure will have an impact on these behaviours



Four critical temperatures
(Seeley and Morse 1978)

1. Brood nest = 32-36C
2. Minimum thorax temperature needed for flight = 27C
3. Minimum temperature needed to pump flight muscles and warm up (analogous to mammal “shivering”) = 18C
4. Bees go into a “chill coma” = 6C

The Winter Cluster (Brood Center T 35C / No Brood T 18C)

Winter Cluster contracts and expands to adjust heat retention (insulative value of outer mantle). It is at its tightest at -10C. Bees start clustering when they are exposed to Temperatures below 14C. Outer bees will point their abdomens outwards and snuggle up tightly to adjacent bees.

**This will be a key point further in the presentation.

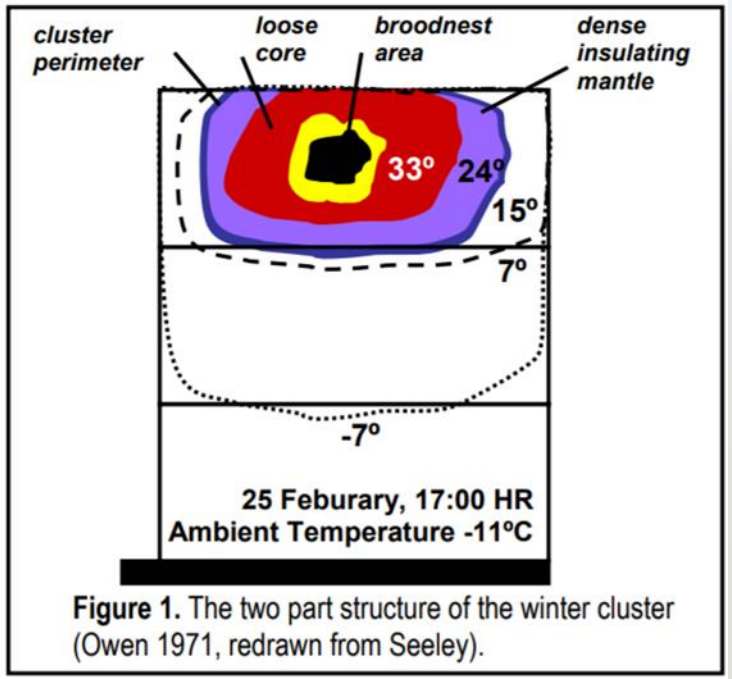
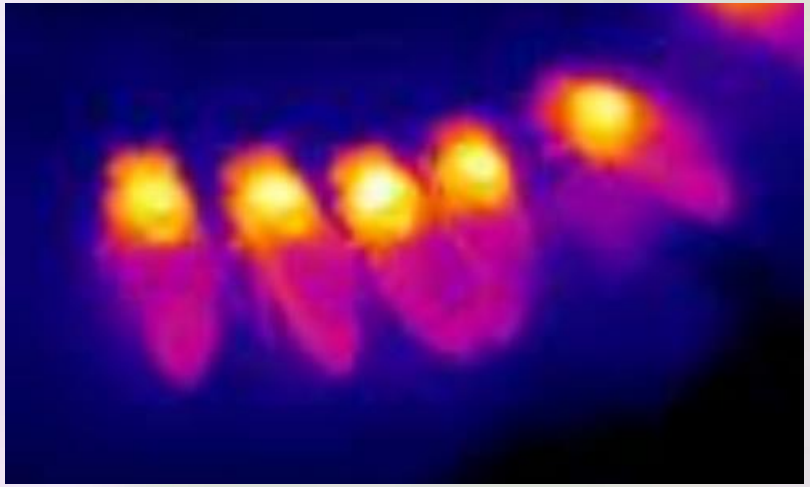


Figure 1. The two part structure of the winter cluster (Owen 1971, redrawn from Seeley).



The Biology and Management of Colonies in Winter, Adony Melathopoulos
http://www.capabees.com/shared/2013/02/winteringpdf.pdf

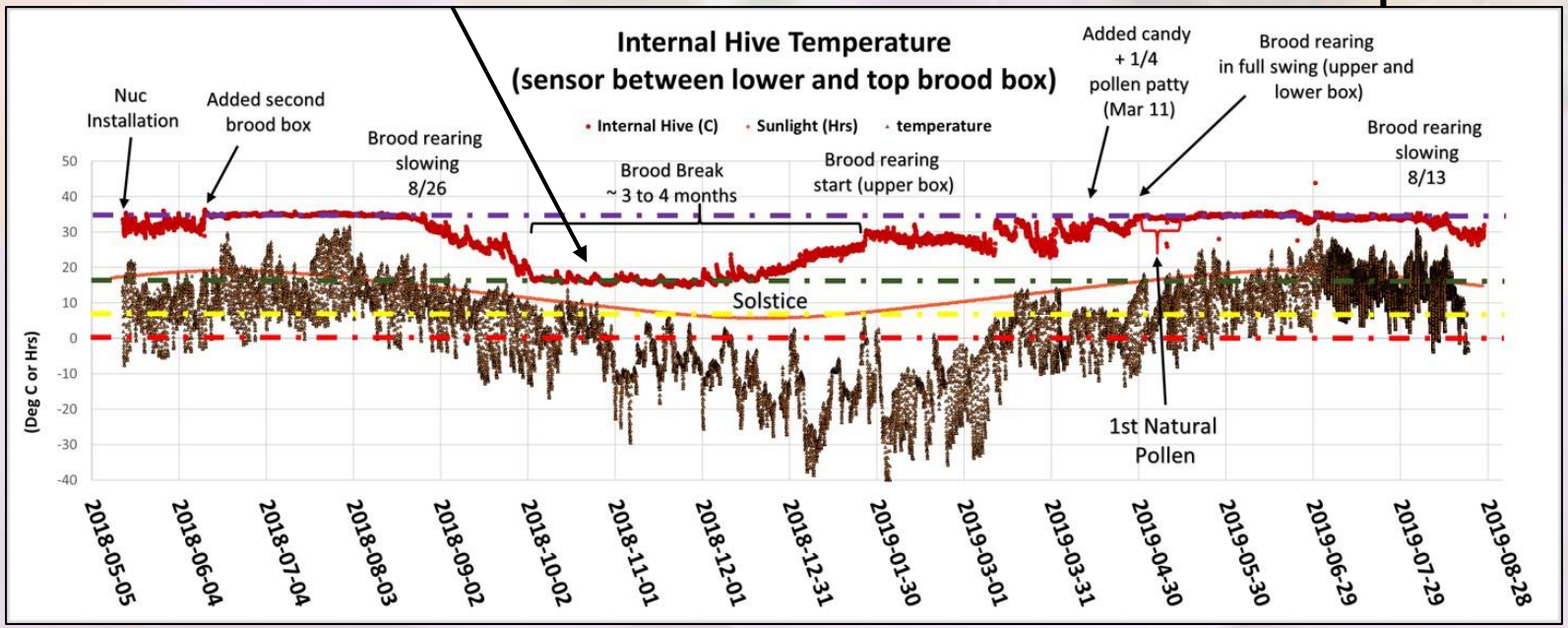
Metabolic Rate of Bees
(Rate of Energy Consumption)

The Biology and Management of Colonies in Winter, Adony Melathopoulos
http://www.capabees.com/shared/2013/02/winteringpdf.pdf

A hive's metabolic rate is lowest when temperatures are 5-10ºC. The bees use the least amount of honey at this temperature.

Typical cold climate honey consumption pre-brood is 1.5 to 2Kg per month. This increases to 7-8kg per month once brood rearing starts.

In the absence of brood the cluster T will drop to ~18C.



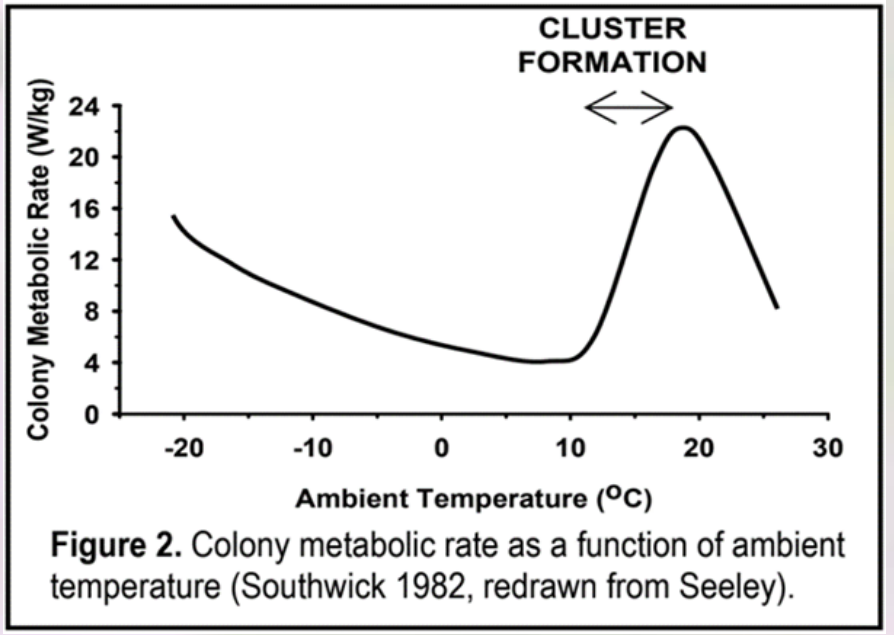
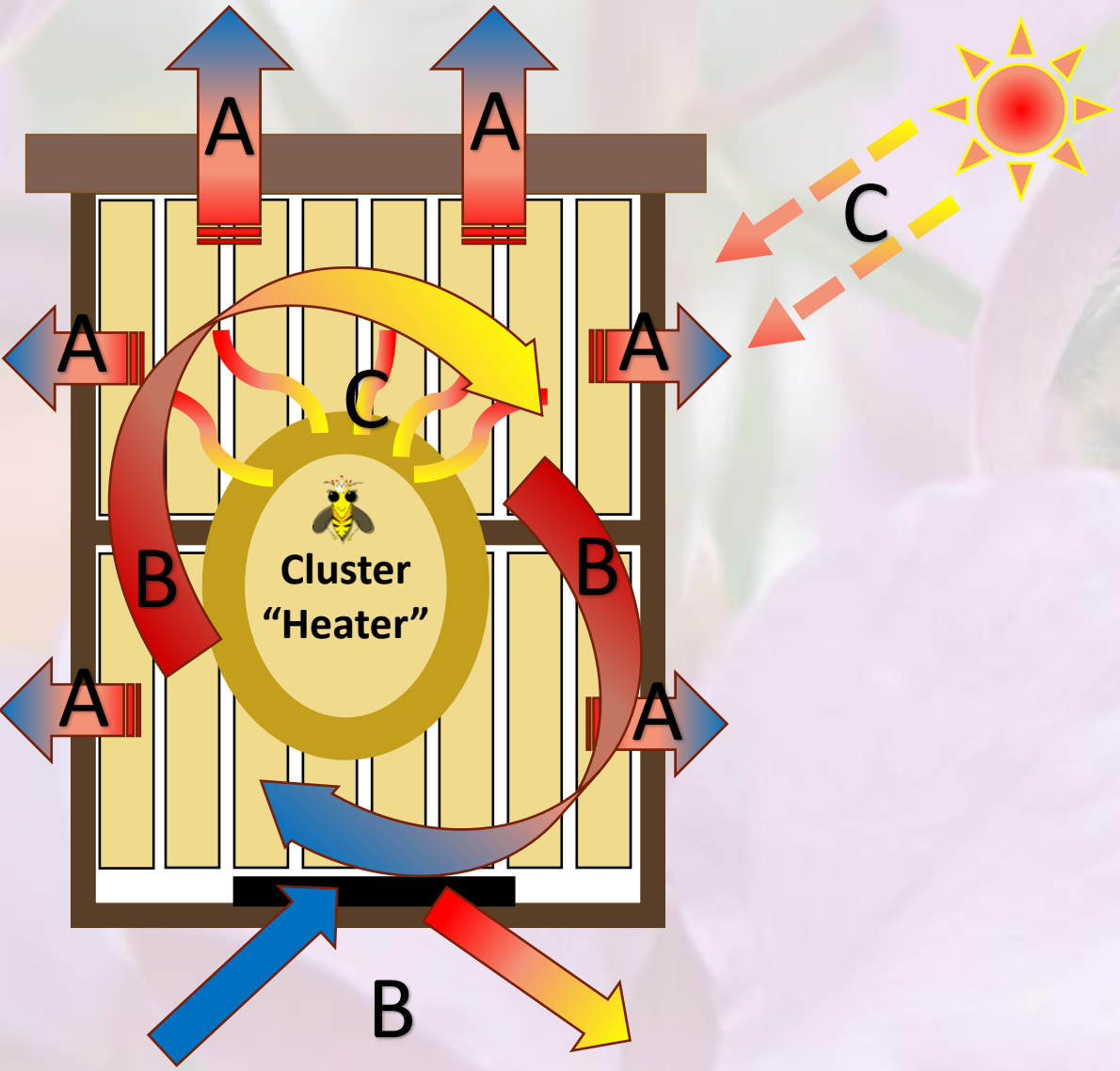


Figure 2. Colony metabolic rate as a function of ambient temperature (Southwick 1982, redrawn from Seeley).

Figure above: Data from my own Hive Monitoring 2018-2019 Season

Types of Heat Transfer

(Conduction / Convection / Radiation)



- **(A) Conduction:** Heat transferred through objects/solids from a hot side to a cold side. This is relates directly to the thermal resistance (R or Rsi) and exposed surface area of the material

Example in the Hive: Heat transfer through the hive walls / top cover (solid with a warm and cold side)

- **(B) Convection:** Heat transferred from one part of a fluid/gas to another via bulk movement of the fluid/gas itself.

Example in the Hive: Warm air in the hive coming off the cluster cause warm air (lower density) to rise and colder air (higher density) to drop

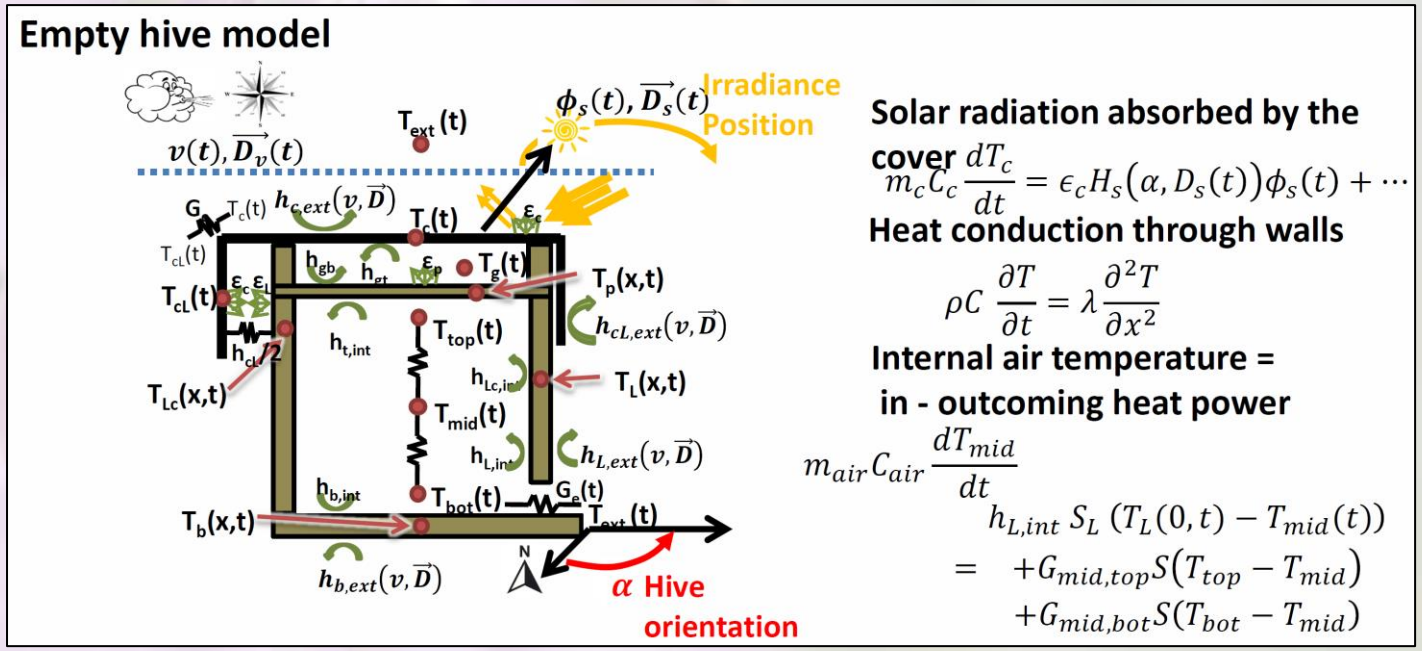
- **(C) Radiation:** Heat transferred by electromagnetic waves through space.

Example in the Hive: Sun warming outside hive wall despite cold ambient temperatures

Thermal mass is the ability of a material to absorb and store heat energy. It provides "inertia" against temperature fluctuations. **Honey frames** are the hives thermal mass storage units.

Hive Thermoregulation / Heat Loss Calculations

- It is a complicated process



Source: Heat power estimation of a bee colony in a Dadant-hive based on transient hygrothermal evolution anna.dupleix@umontpellier.fr

- So let's simplify it to illustrate it in lay terms

H = Ht + Hv + Hi

where

H = overall heat loss (W)

Ht = heat loss due to transmission through walls, windows, doors, floors and more (W)

Hv = heat loss caused by ventilation (W)

Hi = heat loss caused by infiltration (W)