



POLYTECH.MONS

# Field monitoring of domestic heat pumps in Belgium: 7 years experience

Commissioning and Auditing of  
Buildings and HVAC Systems  
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Dr. Ir. Eric Dumont  
Prof. Marc Frère  
Faculty of Engineering, Mons



## Background (1/4)

- Experience of 7 years (2000-2007) in monitoring energy consumption and performance of 15 heat pumps installed in single family dwellings
- ELECTRABEL research program (2000-2003): two-year monitoring of 6 heat pumps for space heating of single-family dwellings
  - devoted to performance measurement only (COP-SPF)
- ELECTRABEL-Intermixt-ALE research program (2003-2006): two-year monitoring of 5 heat pumps, 3 for space heating and 2 for domestic hot water production in single-family dwellings
  - devoted to performance measurement (COP-SPF) and heat pump behavior analysis

## Background (2/4)

- FPMs research program, funded by manufacturer (2005-): two-year monitoring of 2 prototype heat pumps for space heating of single-family dwellings
  - devoted to heat pump behavior analysis, performance measurement and improvement of heat pump operational parameters (SPF maximization)
- BEPAC (Minergibat research program) (2006-): two-year monitoring of 2 prototype heat pumps, 1 for space heating, 1 for domestic hot water production in single-family dwellings
  - devoted to heat pump behavior analysis, performance measurement and improvement of heat exchangers design (energy/economical performance maximization)

## Background (3/4)

- Heat pumps for space heating monitored:
  - Dynamic air/air: 3
  - Dynamic air/water: 3 (1 with variable speed compressor)
  - Static air/water: 3 (2 with variable speed compressor)
  - Ground/floor (DX): 2
  - Ground/water: 1 with variable speed compressor
- Heat pumps for DHW production monitored:
  - Ground/water: 2
  - Static air/water: 1

## Background (4/4)

- Evolution of fluids:
  - R22 (2000)
  - R407C (2003-2004)
  - R404A (2003-2005)
  - R410A (2007)
  - Propane (2007)
- Evolution of type of compressor:
  - reciprocating compressors (2000)
  - fixed speed scroll compressors (2003-2004)
  - variable speed scroll compressors (2004-)

## Measurements (1/5)

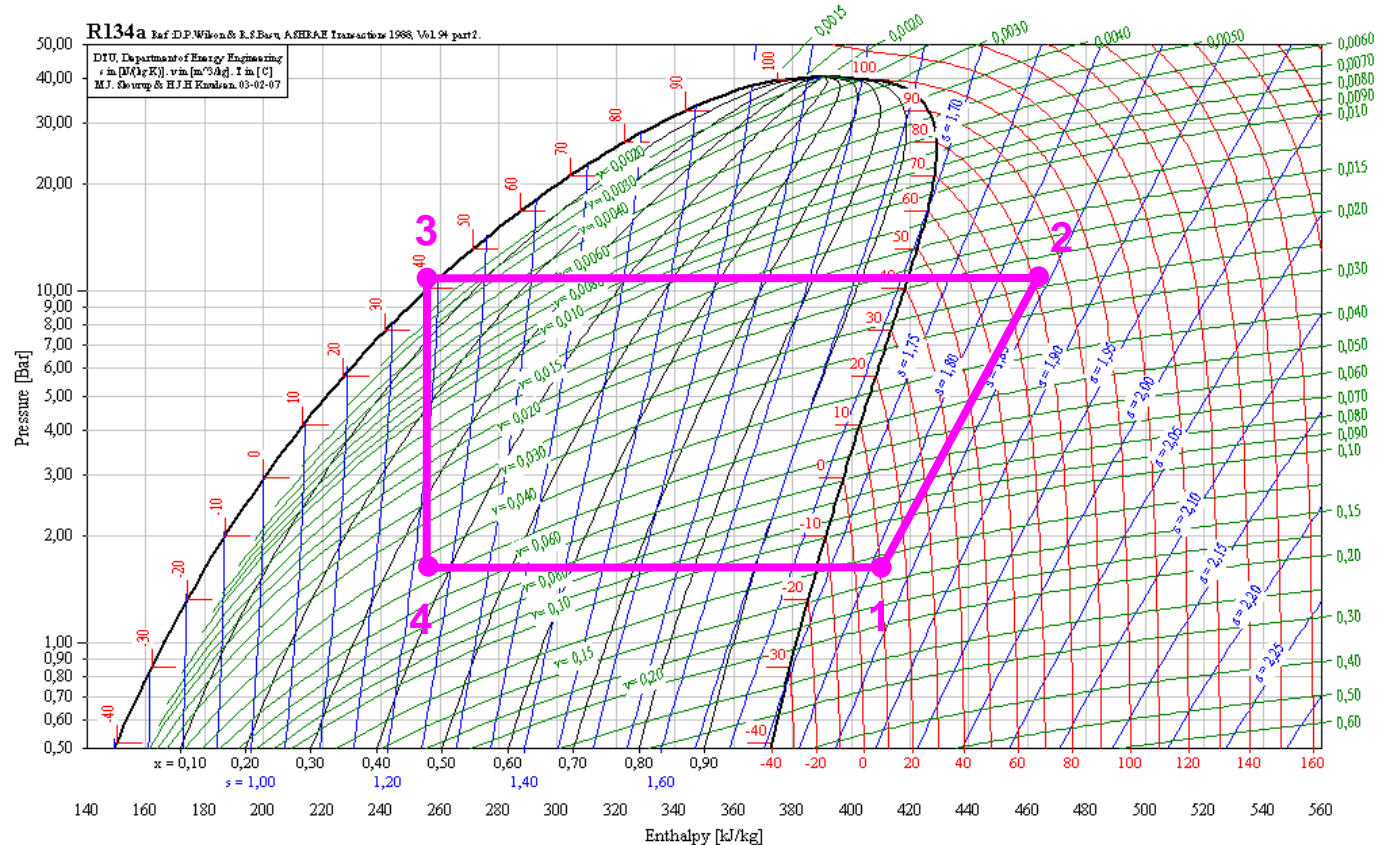
- All heat pumps have been equipped to analyze instantaneous behavior
- Values to be monitored can be:
  - temperatures
  - pressures
  - mass/volumetric flow rates
  - electrical power

## Measurements (2/5)

- From pressure and temperature measurements:
  - $h = f(T,P)$
  - $\rho = f(T,P)$
  - $T_{EVAP} , T_{COND}$
  - pressure drop
- From power measurements:
  - $P_{O COMP}$
  - $P_{O FAN}$
  - $P_{O PUMP}$
  - $P_{O RES}$



# Measurements (3/5)



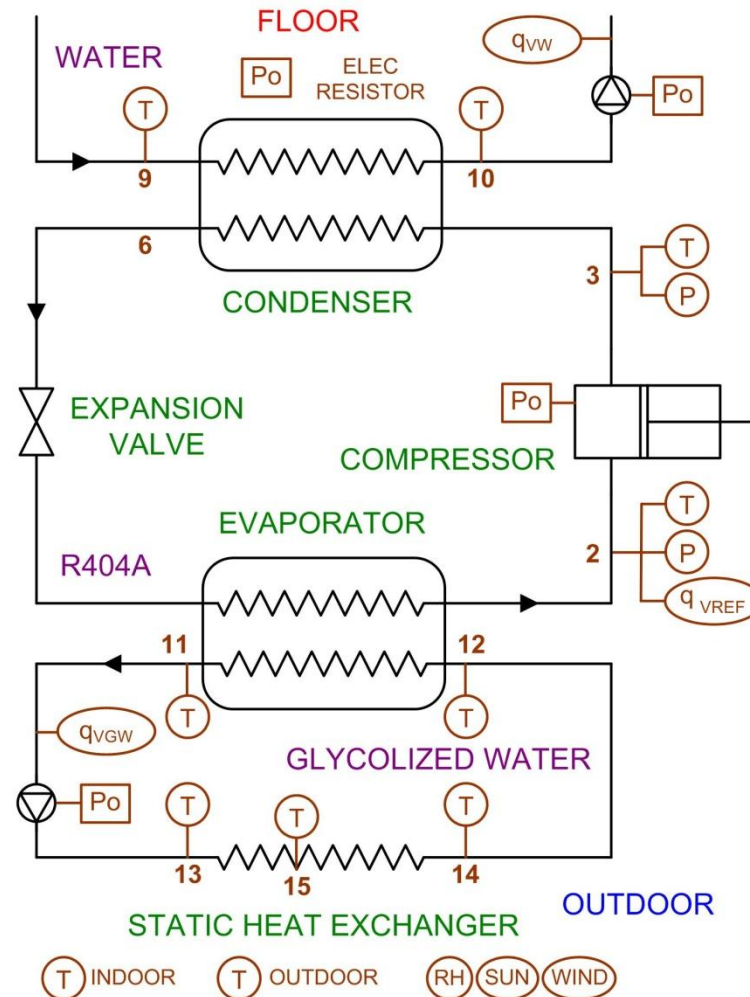
- From flow rate measurements:
- $\Phi_H = q_{VF1} \rho_{F1} c_{PF1} (T_{OUT F1} - T_{IN F1}) = q_{VR} \rho_R (h_3 - h_2)$
- $\Phi_C = q_{VF2} \rho_{F2} c_{PF2} (T_{OUT F2} - T_{IN F2}) = q_{VR} \rho_R (h_1 - h_4)$
- $P_{MEC} = q_{VR} \rho_R (h_2 - h_1)$



## Measurements (4/5)

- Other interesting quantities:
  - $\text{COP} = \Phi_H / (P_{O \text{ COMP}} + P_{O \dots})$
  - $\eta_{\text{ELEC}} = P_{O \text{ MEC}} / P_{O \text{ COMP}}$
  - $\eta_{\text{ISOS}} = (h_{2 \text{ ISOS}} - h_1) / (h_2 - h_1)$
  - $\text{UA}_{\text{COND}} = \Phi_H / \text{LMTD}_{\text{COND}}$
  - $\text{UA}_{\text{EVAP}} = \Phi_C / \text{LMTD}_{\text{EVAP}}$

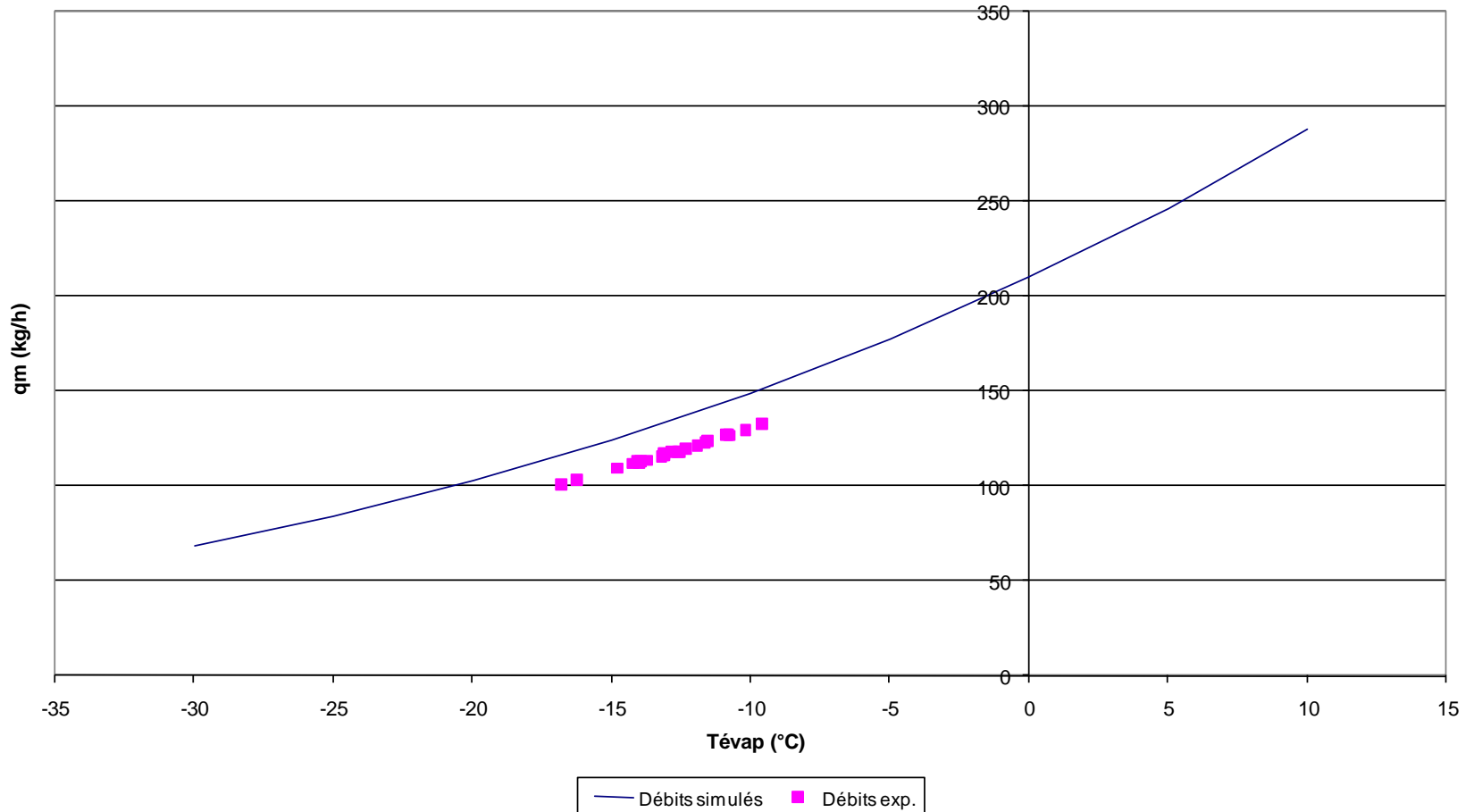
# Measurements (5/5)



# Field experience - manufacturer data (1/16)

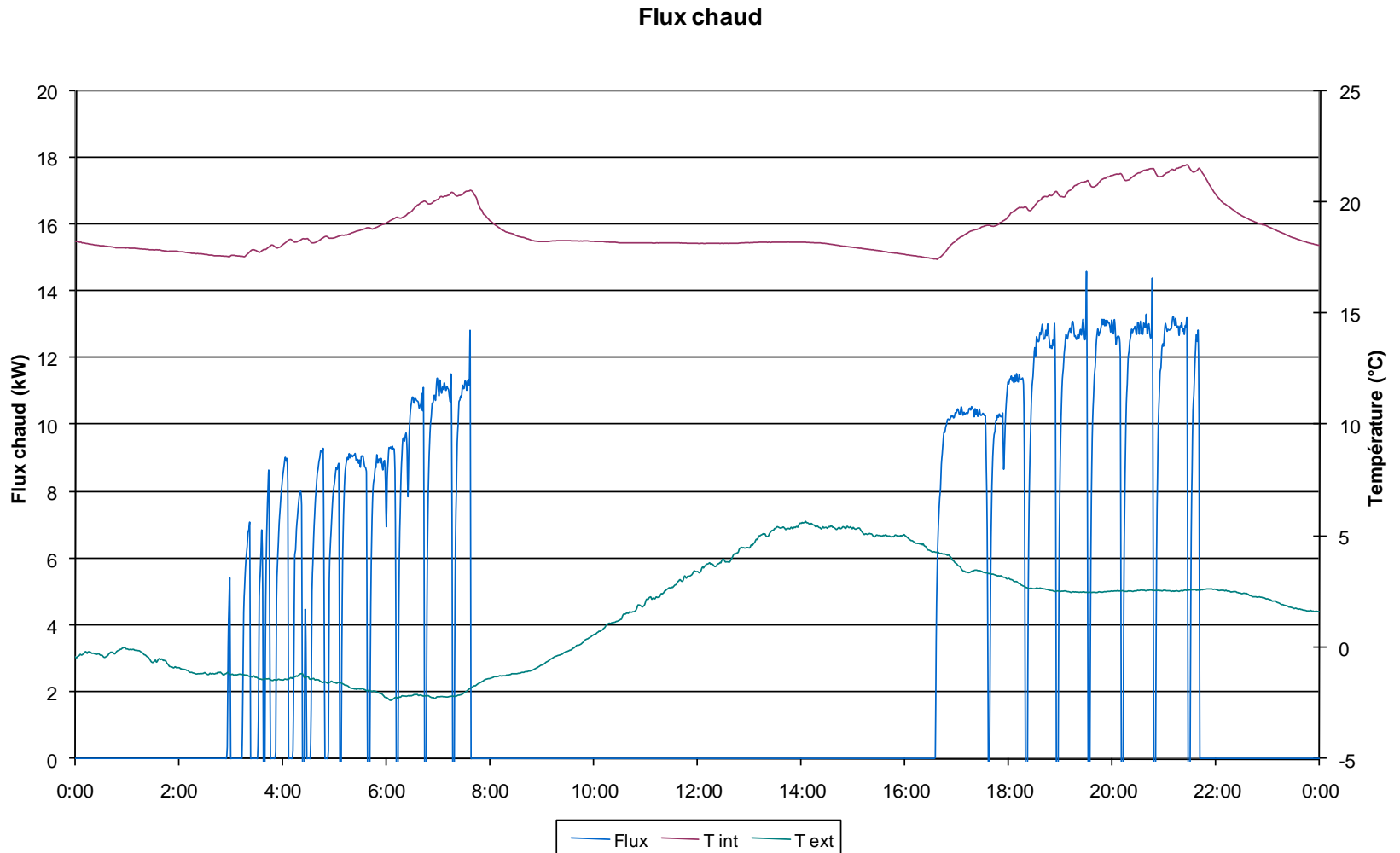
- Manufacturer data  $>$   $<$  measurements:

Débits constructeurs



# Field experience - malfunctioning (2/16)

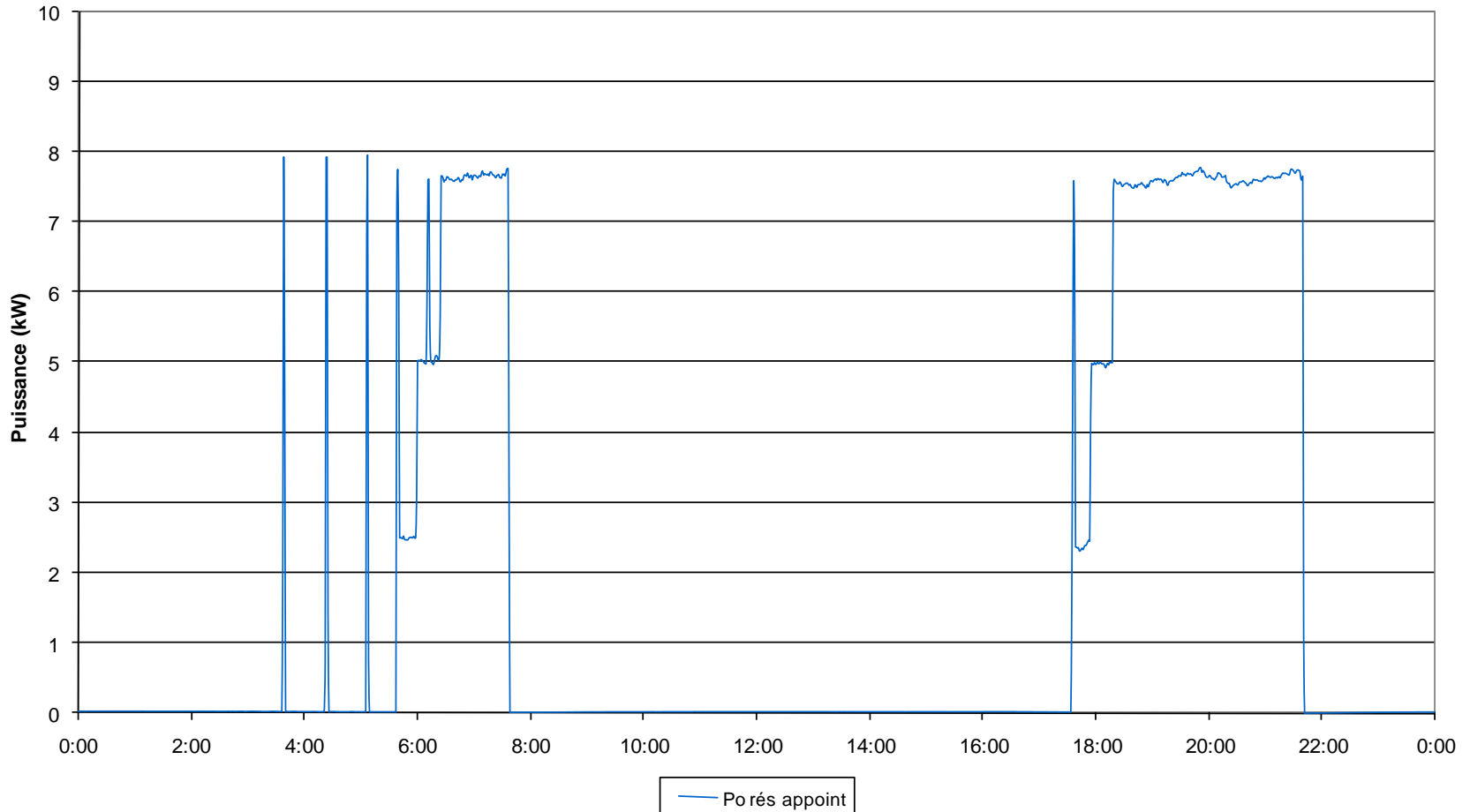
- Heat flow rate too low:



# Field experience - malfunctioning (3/16)

- Resistor heaters too often used:

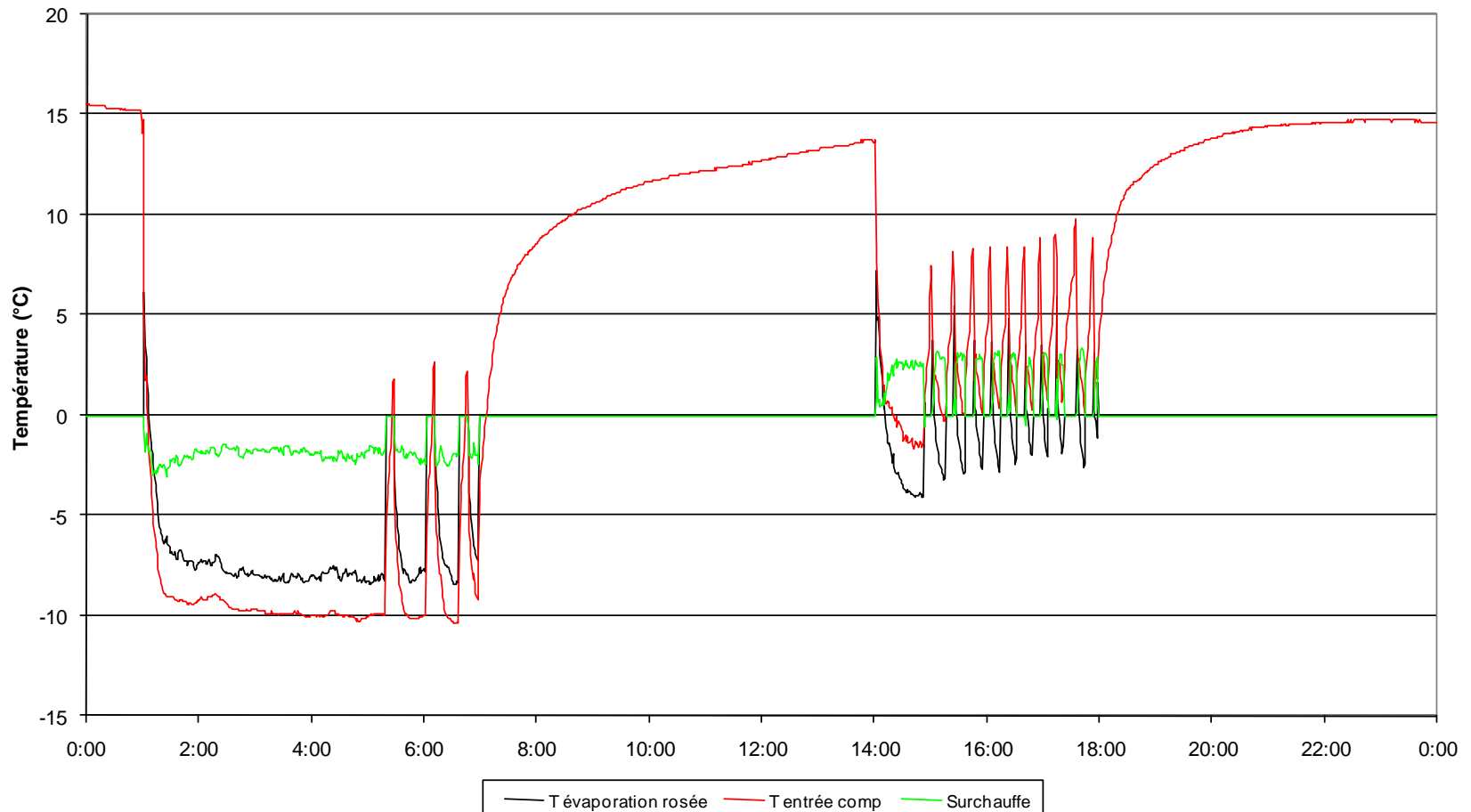
Puissances



# Field experience - heat pump behavior (4/16)

- Evaporator superheating:

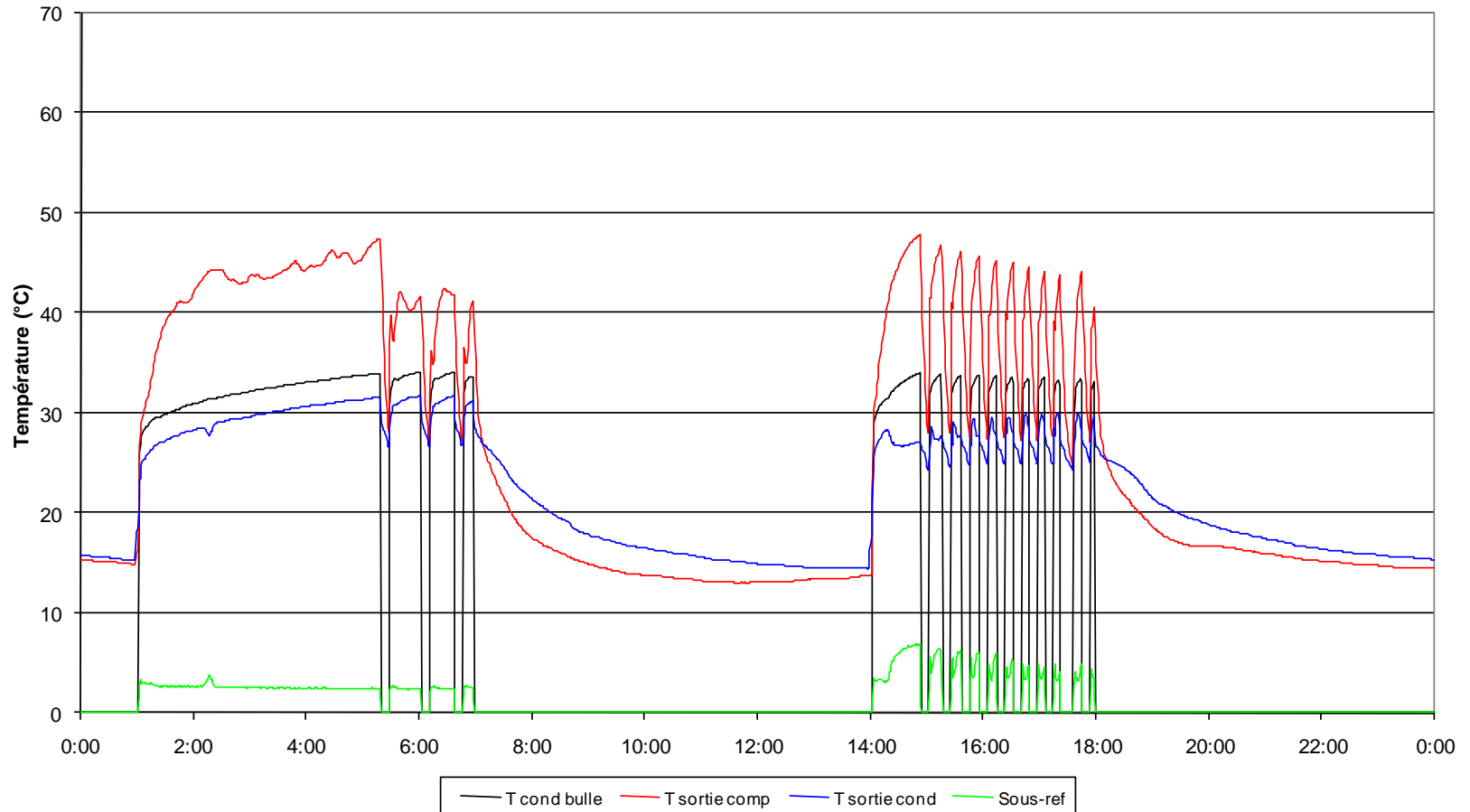
Températures à l'évaporateur (R404A)



# Field experience - heat pump behavior (5/16)

- Condenser subcooling:

Températures au condenseur (R404A)

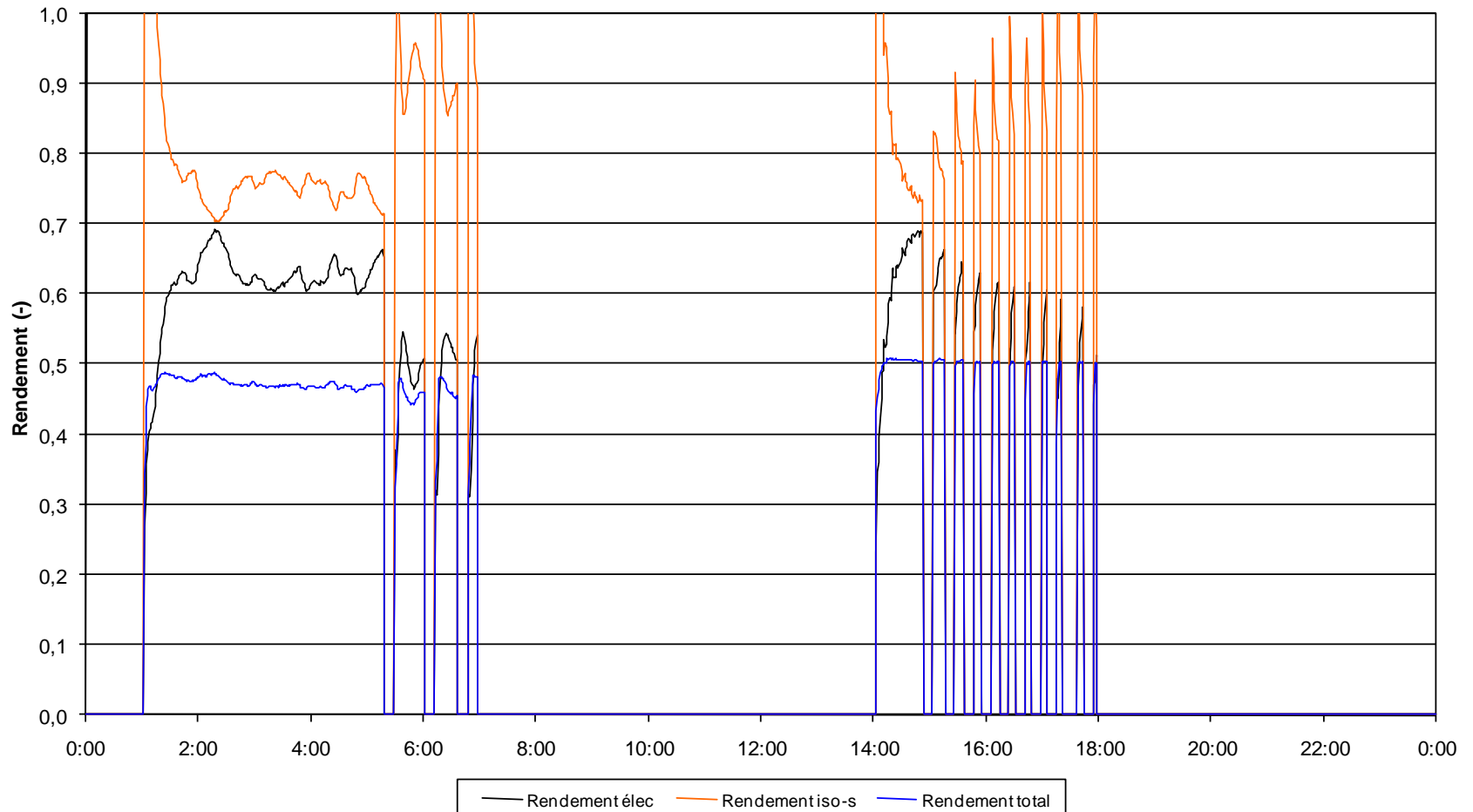




# Field experience - heat pump behavior (6/16)

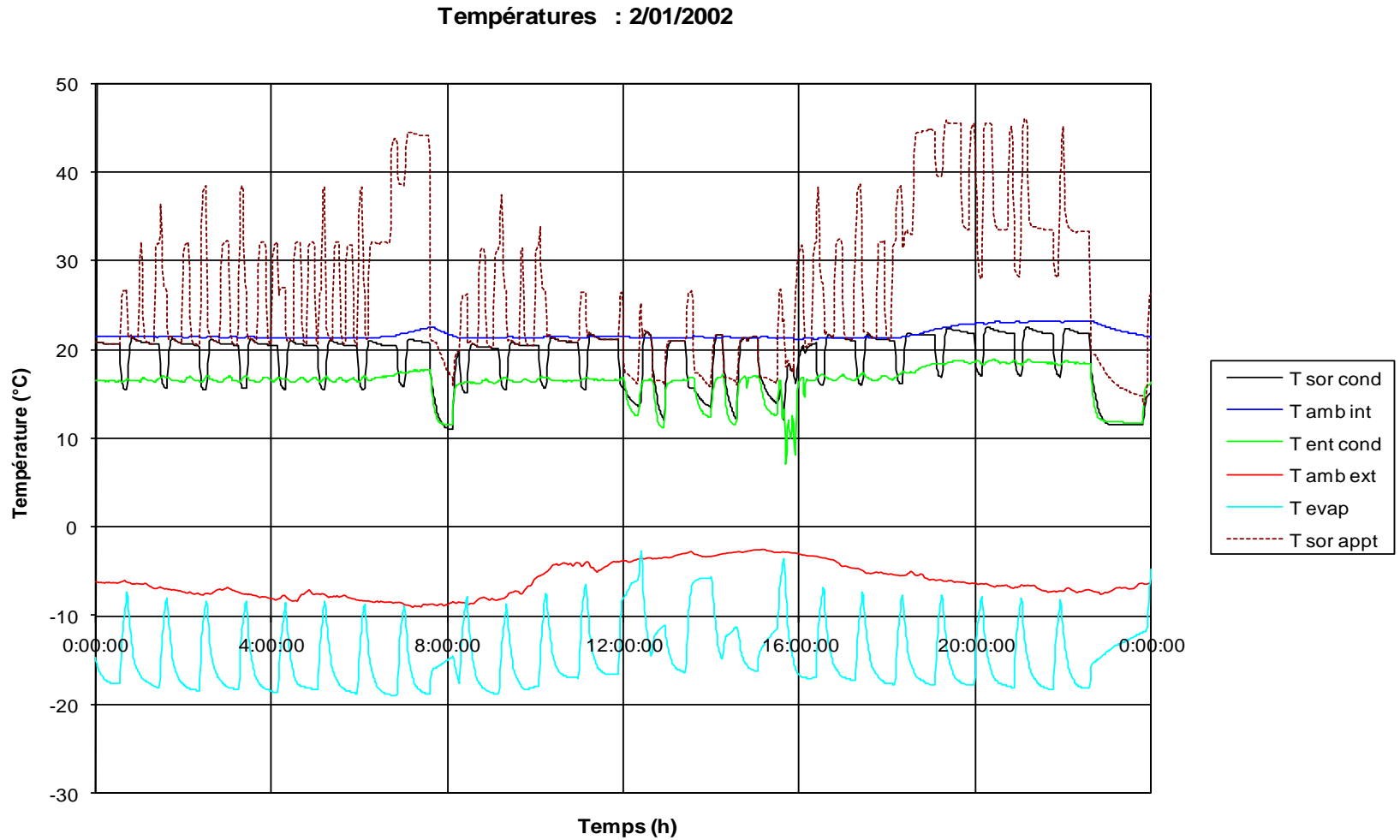
- Compressor efficiencies:

Rendements du compresseur



# Field experience - air source behavior (7/16)

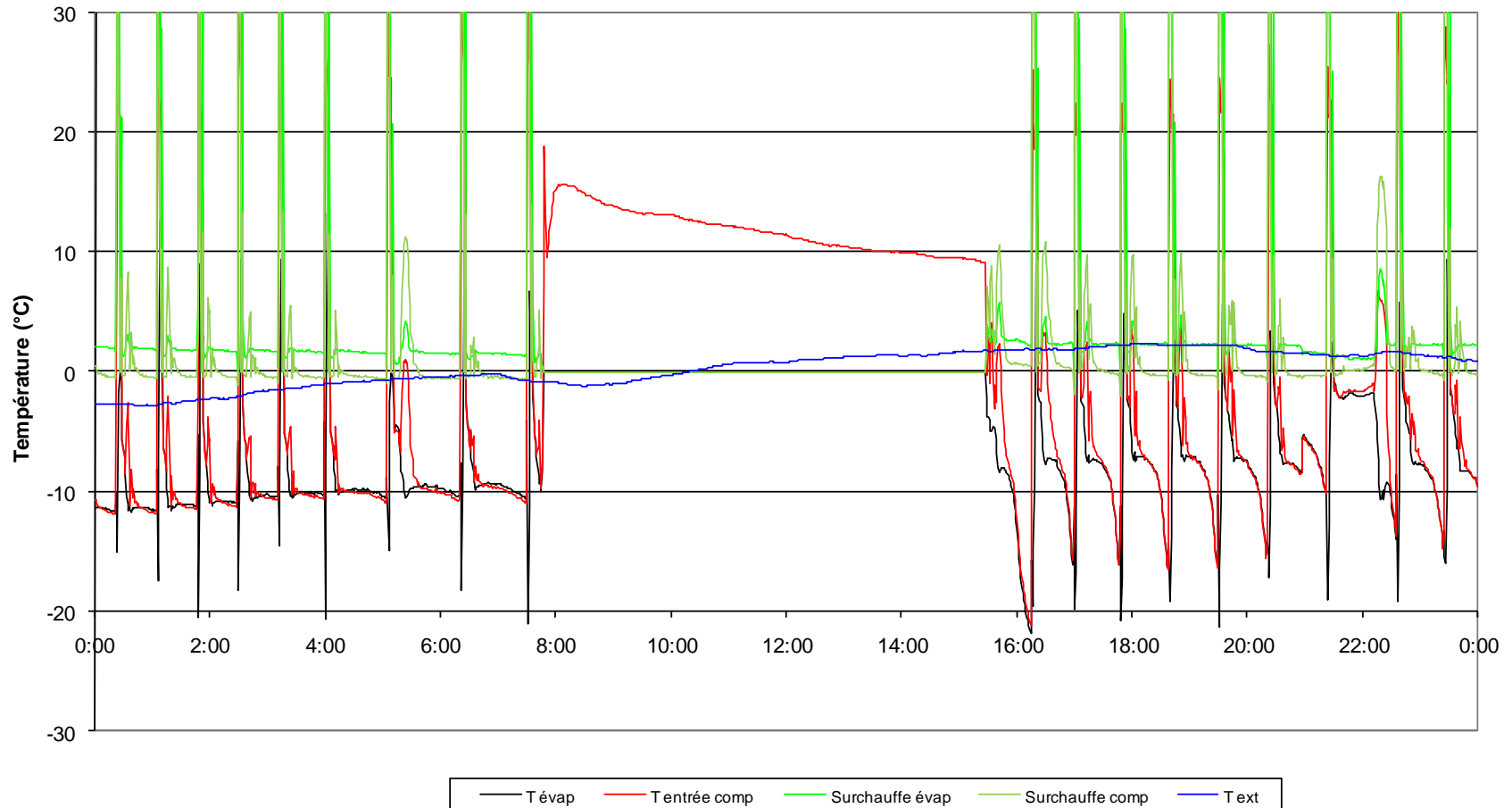
- Bad defrosting:



# Field experience - air source behavior (8/16)

- Good defrosting:

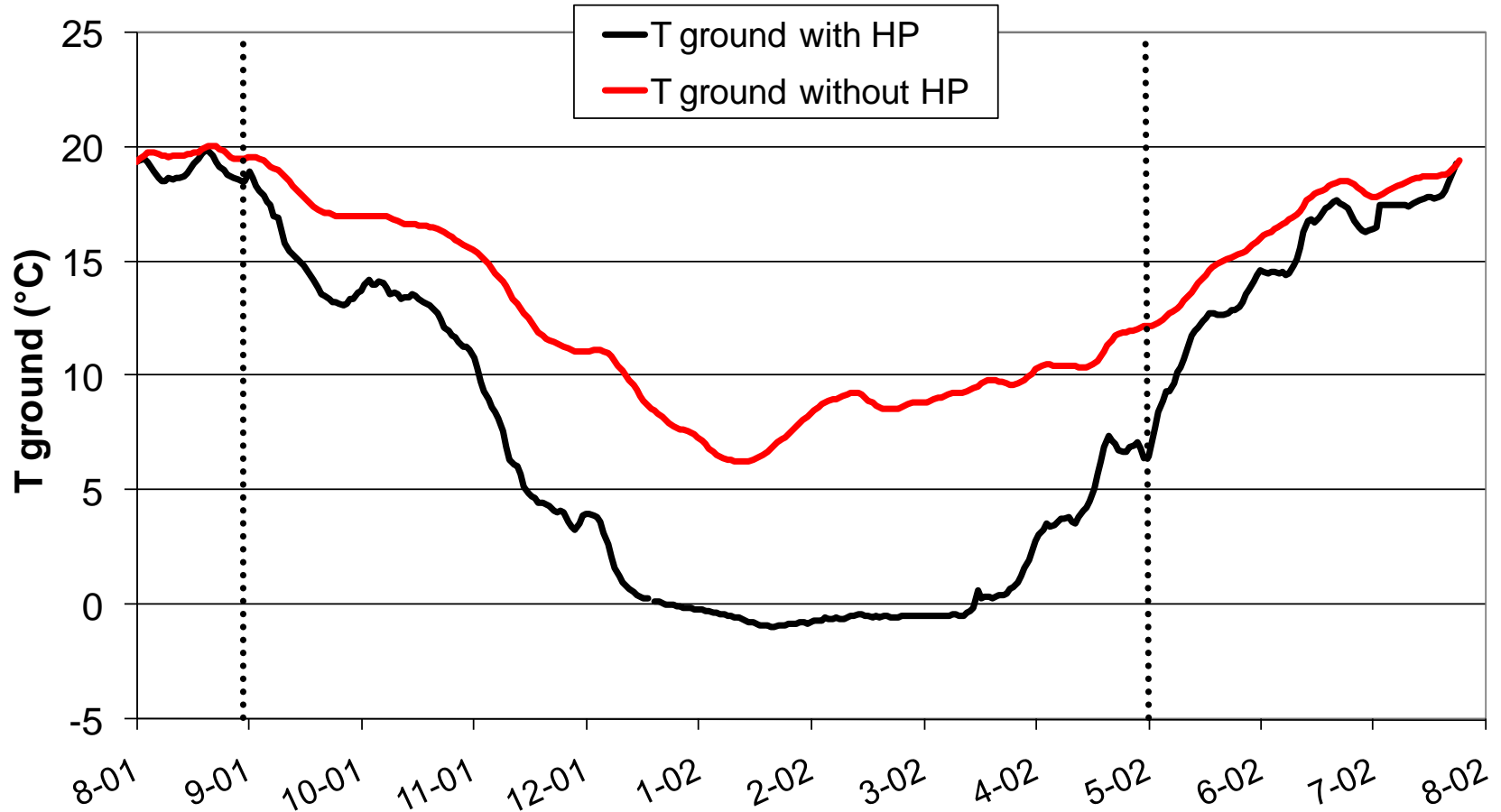
Températures à l'évaporateur (R410A)



# Field experience - ground source behavior (9/16)

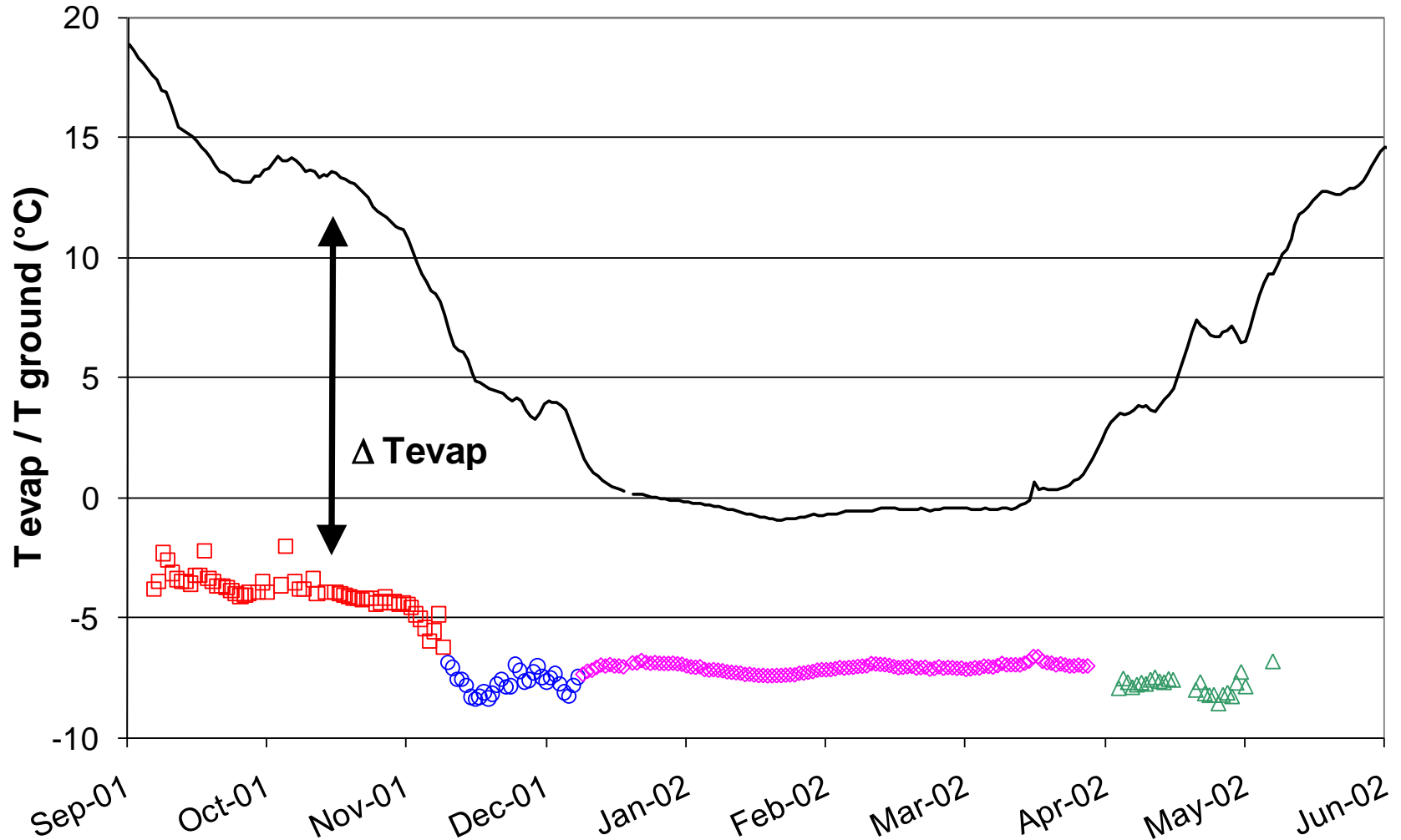
- Influence of heat pump on ground temperature:

## Ground temperature at 60 cm depth



# Field experience - ground source behavior (10/16)

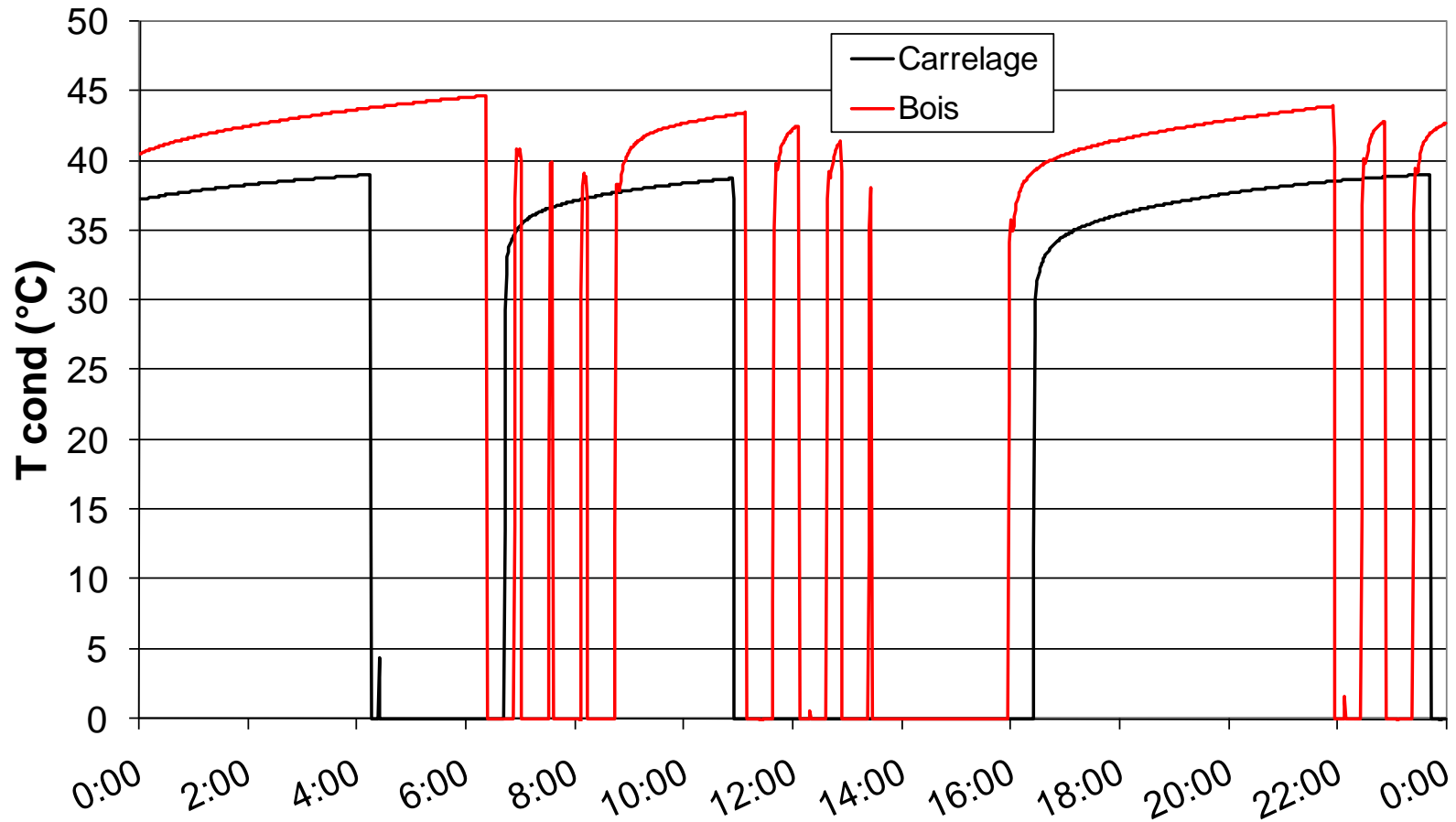
- Ground behavior:



# Field experience - floor behavior (11/16)

- Condensation temperature:

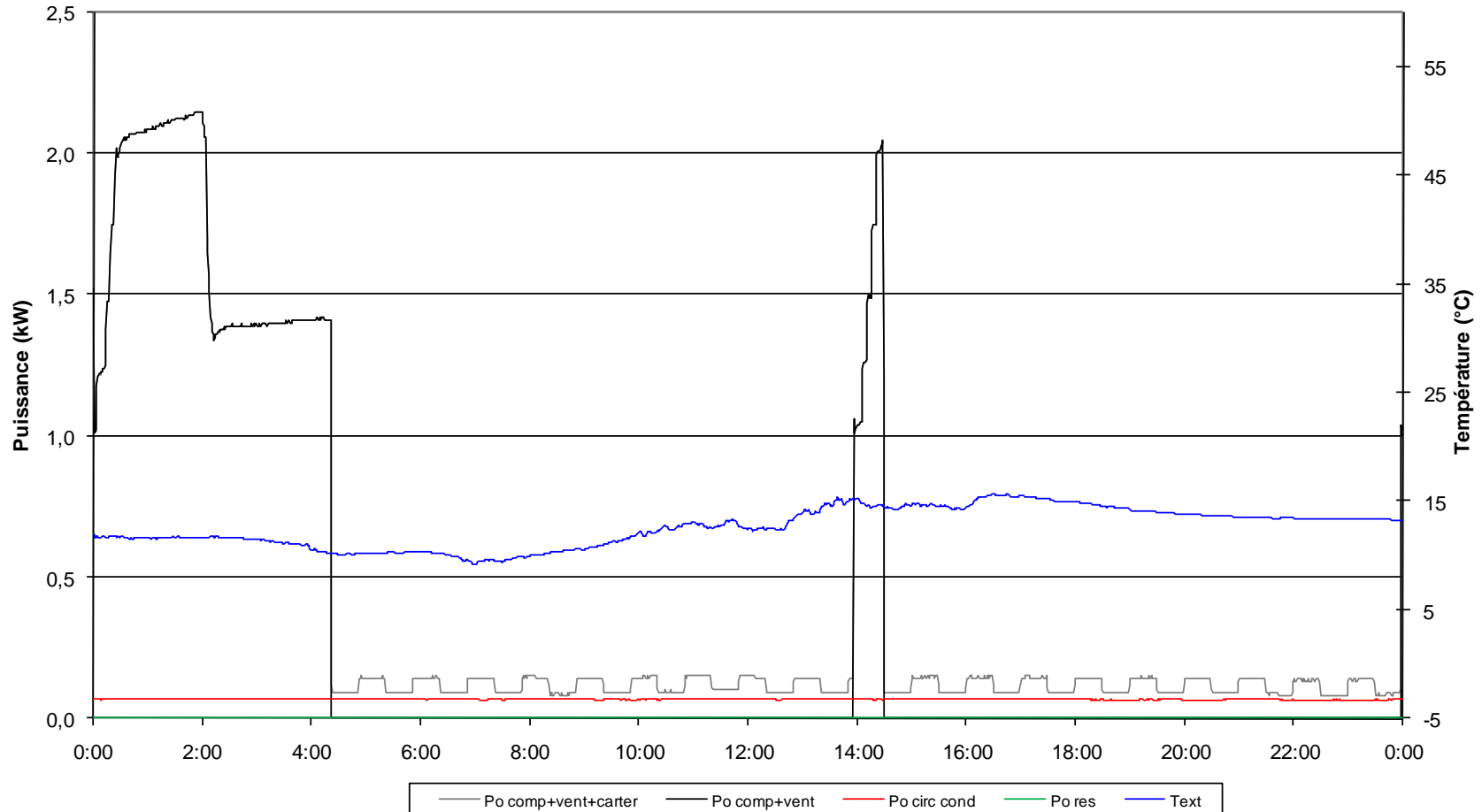
## Influence du type de plancher



# Field experience - optimization (12/16)

- Condenser pump running time:

Puissances

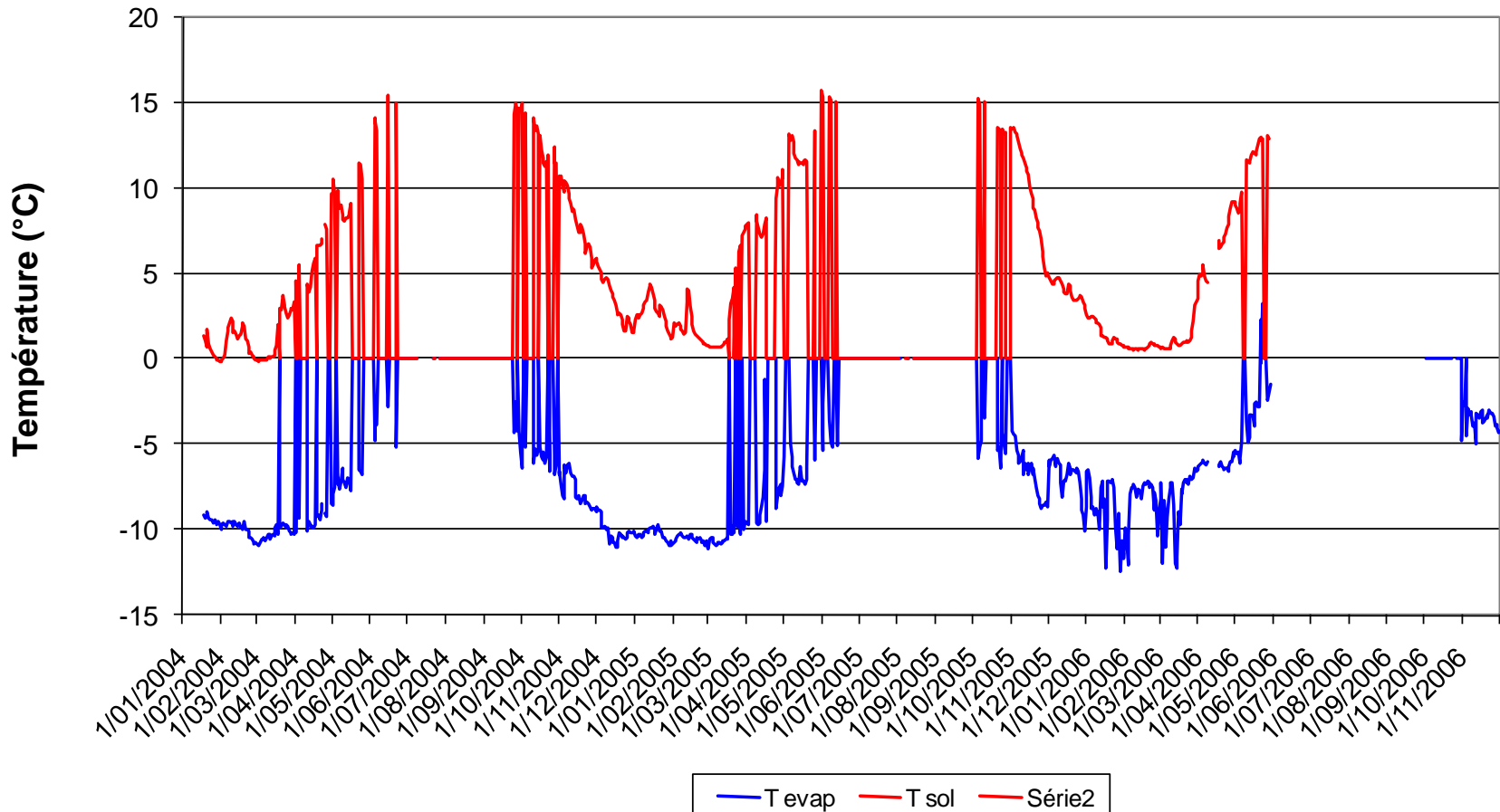




# Field experience - optimization (13/16)

- Variable speed compressor:

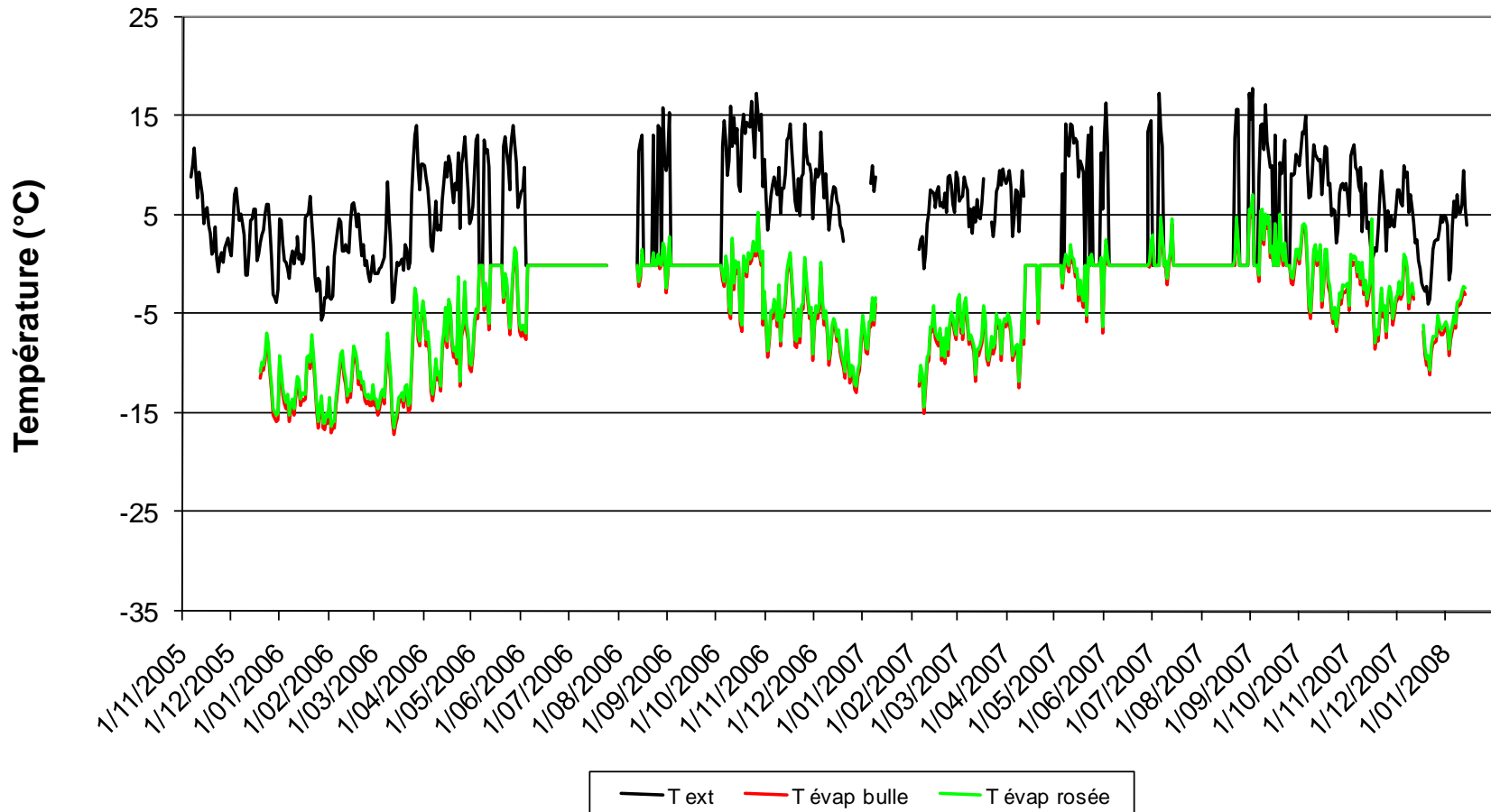
**Températures  
Janvier 2004 - Novembre 2006**



# Field experience - optimization (14/16)

- Variable speed compressor:

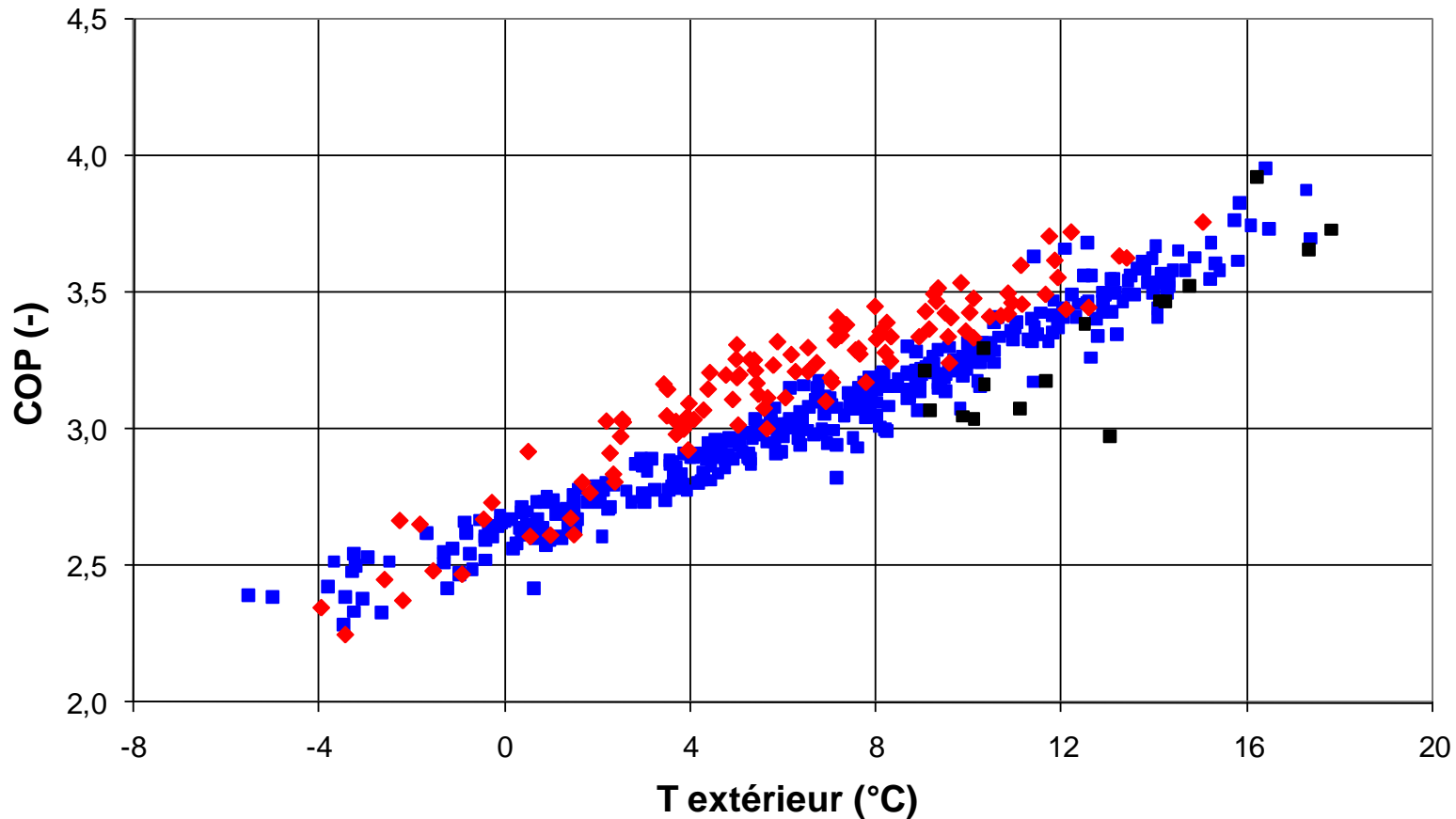
**Evaporateur**  
**Novembre 2005 - Janvier 2008**



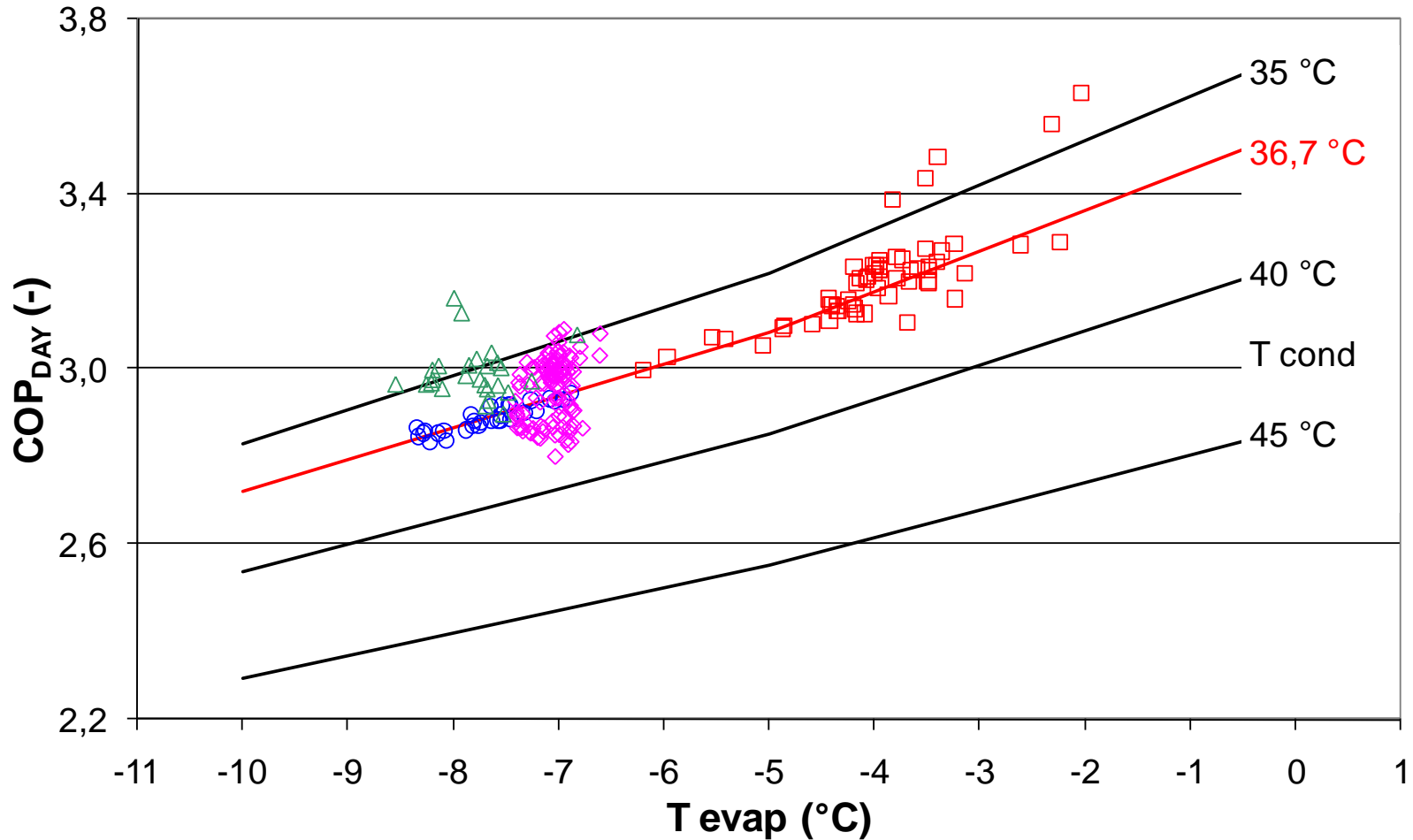
# Field experience - optimization (15/16)

- Variable speed compressor:

**COP**  
**Novembre 2005 - Janvier 2008**



# Field experience - model development (16/16)



# Conclusions

- Monitoring gives many interesting results about the real behavior of heat pumps:
  - comparison between real measurements and manufacturer data
  - malfunctioning of heat pump
  - source/sink behavior
- Measurements can be used:
  - to maximize the performance of the machine
  - to develop assessed theoretical models