Monitoring Spatial and Temporal Distribution of Temperature and Relative Humidity in Greenhouses based on Wireless Sensor Technology

Jos Balendonck, Erik van Os, Rob van der Schoor,
Bart van Tuijl, Paul Keizer

Room 7 : Monday 3.40h

REF 443

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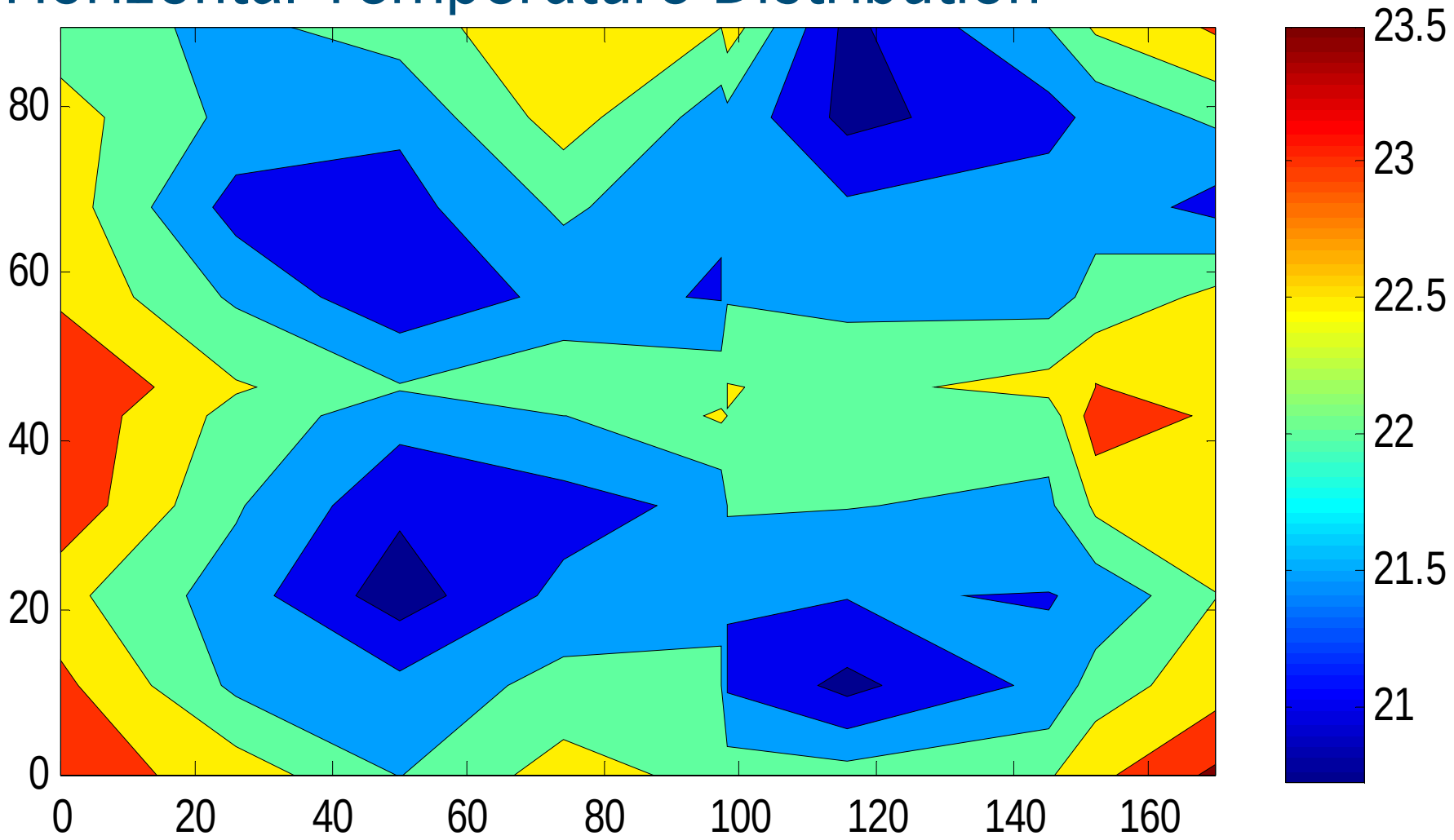
Overview

- Introduction
- Wireless sensors system for RH-T
- Experimental layout
- Evaluation wireless T-RH sensors
- Spatial variability of RH-T in greenhouses
- Sensor density
- Conclusions

Horizontal Temperature Distribution



Cucumber with 100 sensors at 1.5 m height, grid:10 x 24m^2, 1 hourly average

Cold and warm spots

- **Causes:**
  - External circumstances (cold nights, wind, radiation)
  - Greenhouse defects (broken windows, heating, ventilation, infrastructure)
- **Effects:**
  - Irregular growth and diseases (i.e. *Botrytis*)
- **Safety:**
  - More heating
  - Higher energy use

End User Objectives

- Use a dense monitoring system for RH and T
- Find infra-structural defects in the greenhouse
- Reduce energy use and avoid crop losses

Spatial and temporal climate distribution

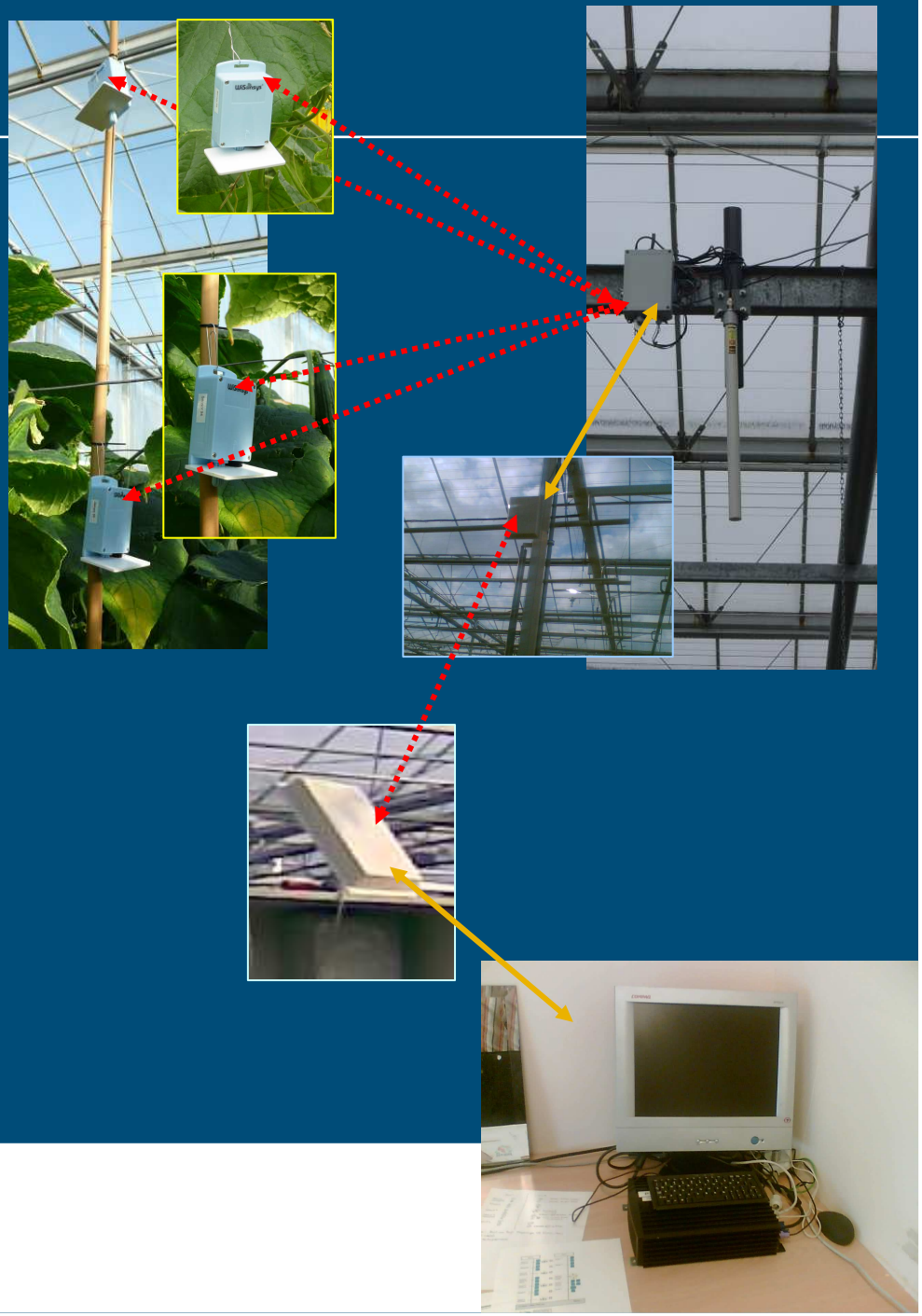
- High density of sampling in space and time
  - to not miss cold or wet spots
- Continious monitoring of T and RH
  - minutes based
- Everywhere, especially around the crop
  - growing tip, products, or leaf mass

Research objectives

- Can cheap and simple wireless sensor systems be applied ?
- How many sensing points are needed to not miss cold or wet spot ?
- Need: Characterization of the climatic horizontal variability for several horticulture crops and conditions

System set-up

- RH-T sensor nodes
  - Radiation shields
  - 1 sample per minute
  - Life time battery: 2 years
- Base Station
  - Antenna, centrally placed
  - Wireless link to computer
- Industrial PC



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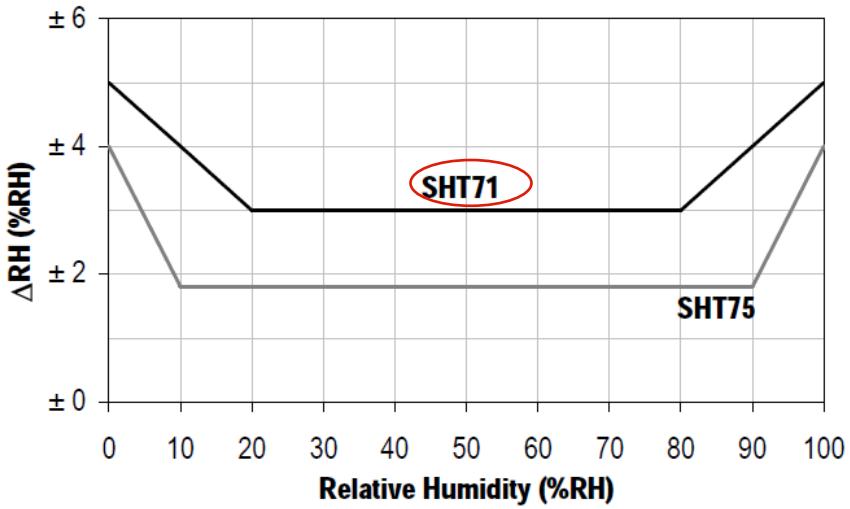
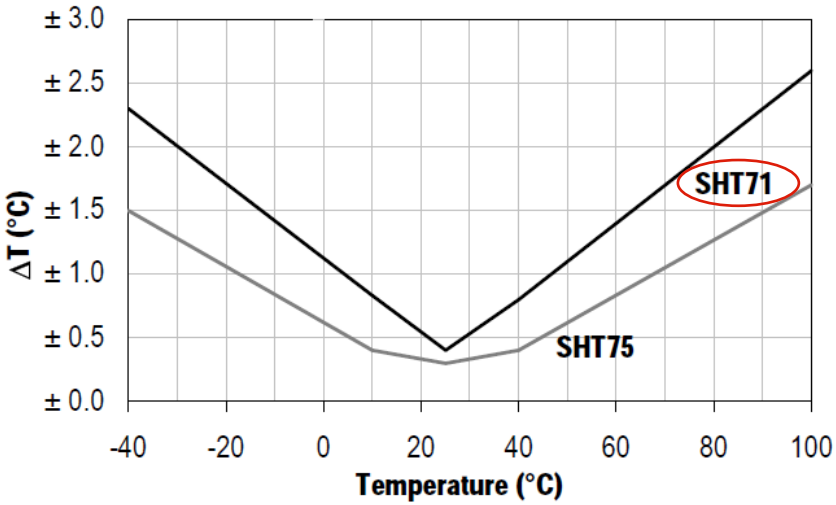
Experimental Approach

- Horizontal T and RH distribution
  - 100 sensors
  - Grid size: 58 – 128 sensors/ha.
  - Near growing tip (flower or fruit)
- 6 trials:
  - Tomato, Cucumber, Matricaria (2x), Gerbera (2x)
  - Autumn/winter period Oct 2008 – April 2009
  - 2 x 5 days
  - Sensor offset comparison
  - Statistical Analyses (Genstat)

Sensor Accuracy





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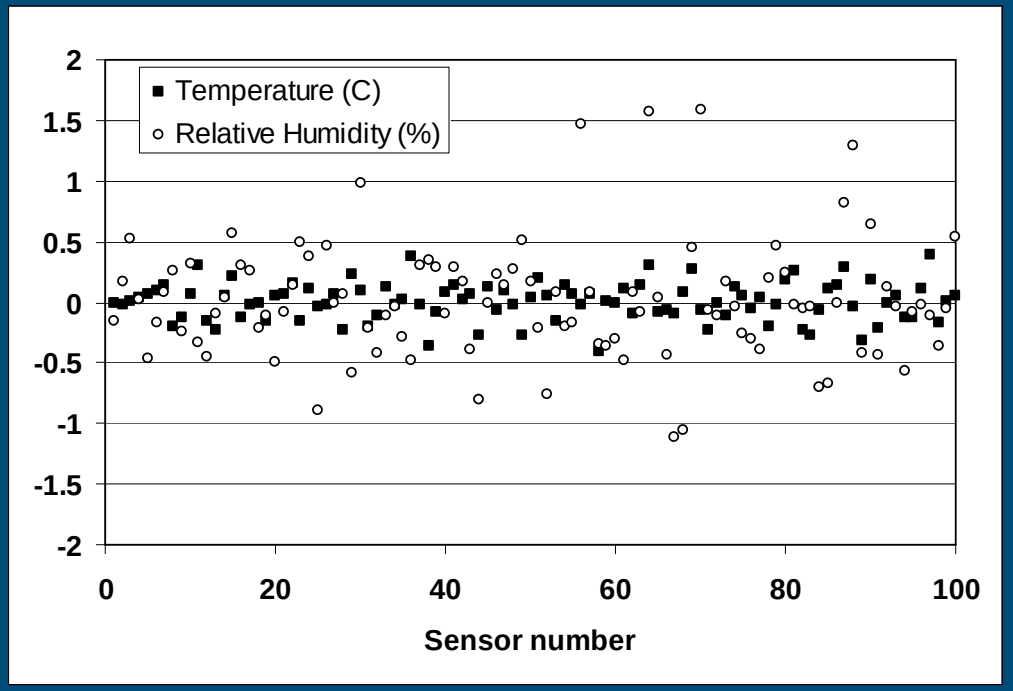
Mutual equality of sensors (offset check)



Observed deviations: ±0.4 °C and ±1.5% (within spec).

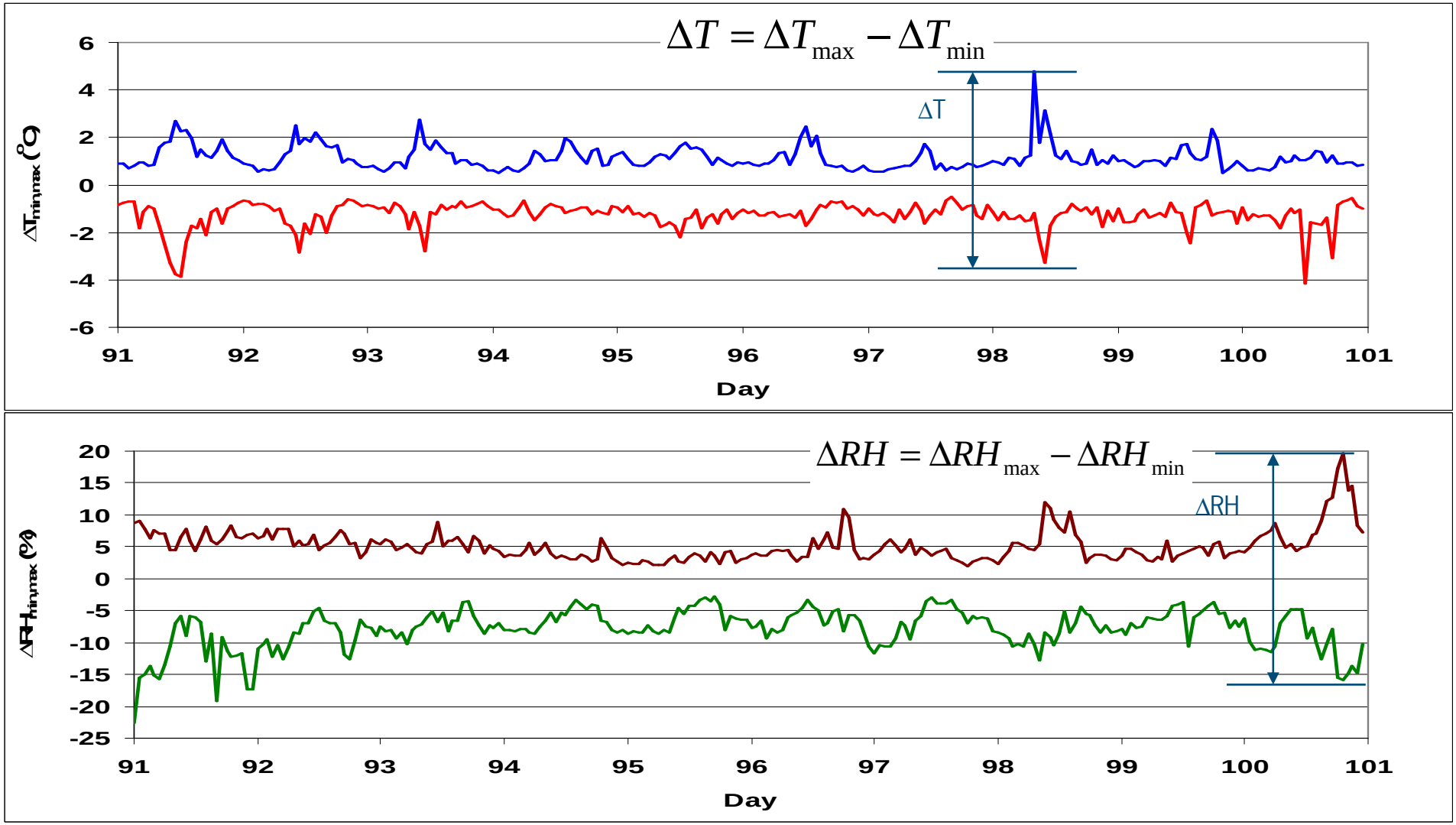
Check and adjust offset by producer.

Use sensor element with higher spec (± 0.3 °C)

Characterizing RH-T distributions

- Instantaneous randomly variations (hour/minute)
- Local specific variations (days/weeks)

Instantaneous climatic variations (Matricaria 2)



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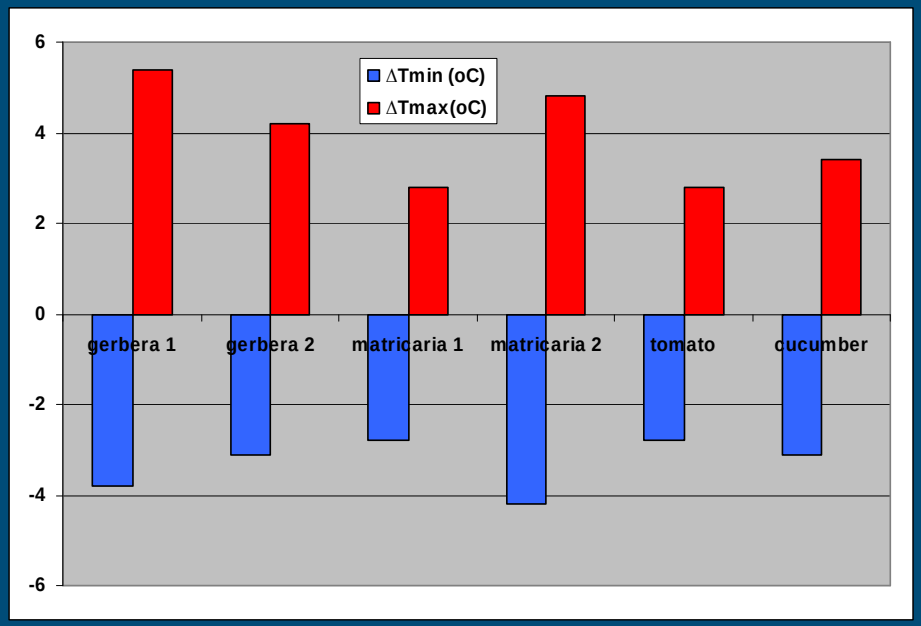
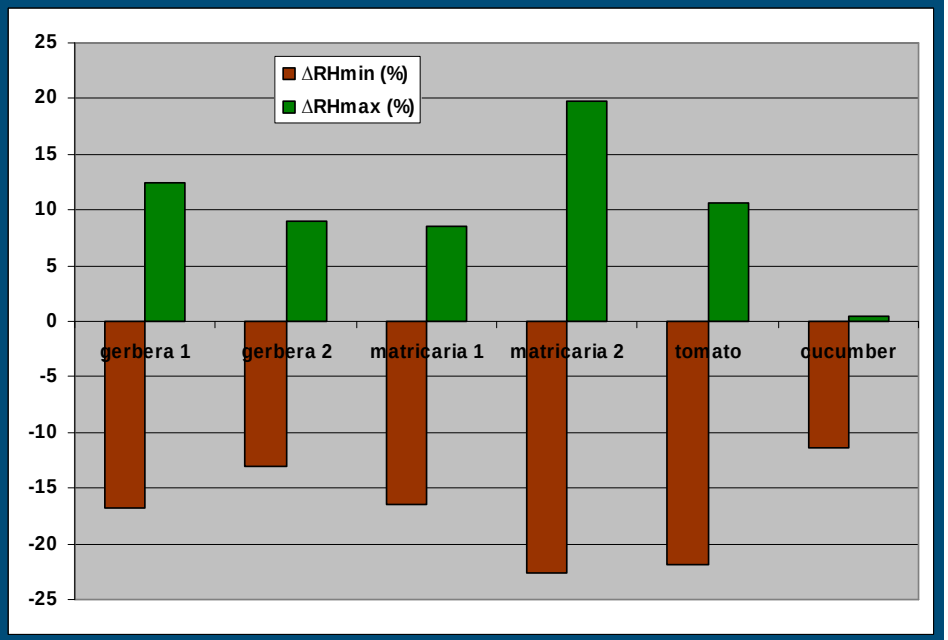
Maximum instantaneous deviations (all trials)





Temperature: 5 – 9 °C

Relative Humidity: 12 – 43 %

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Comparison with ventilated RH-T-box

Advice to producers: Use ventilated boxes or a well-designed radiation shield.

Current sensors can be applied very well during night time when most problems occur.

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Static Temperature Variations

- Long time averages
- Corrected for climate computer set-points, seasonal and daily effects

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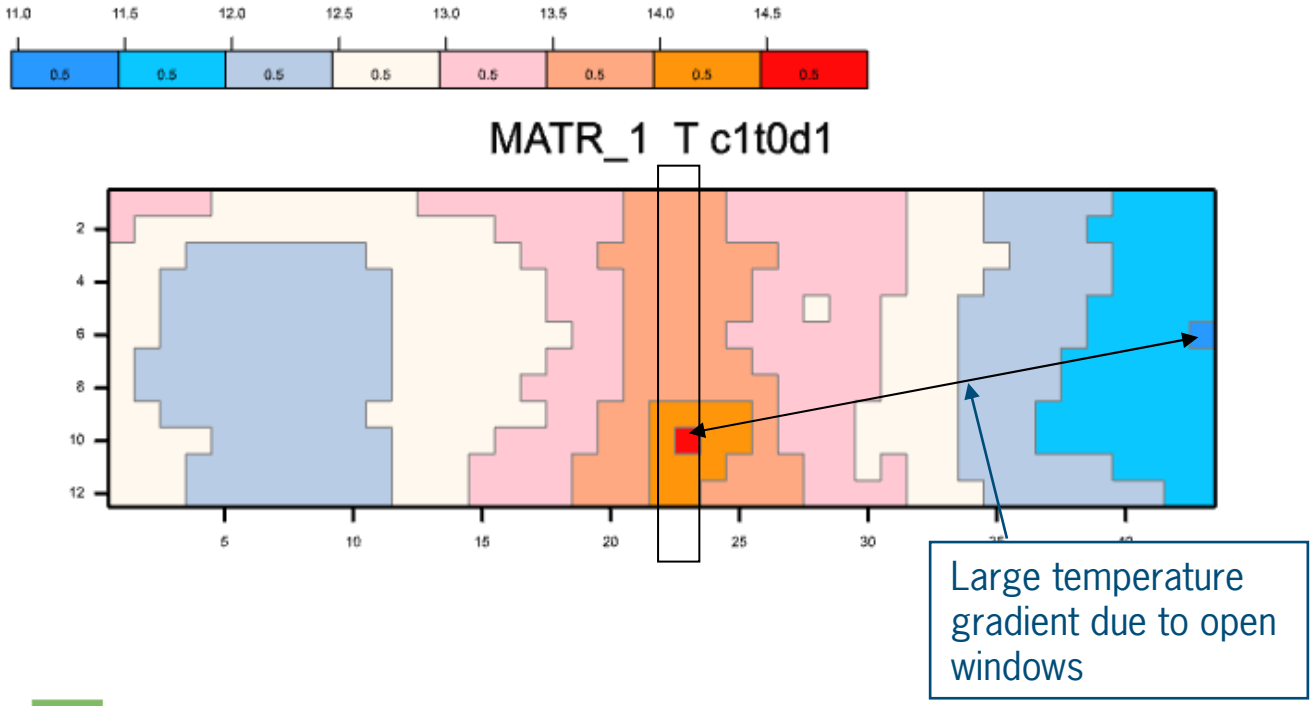

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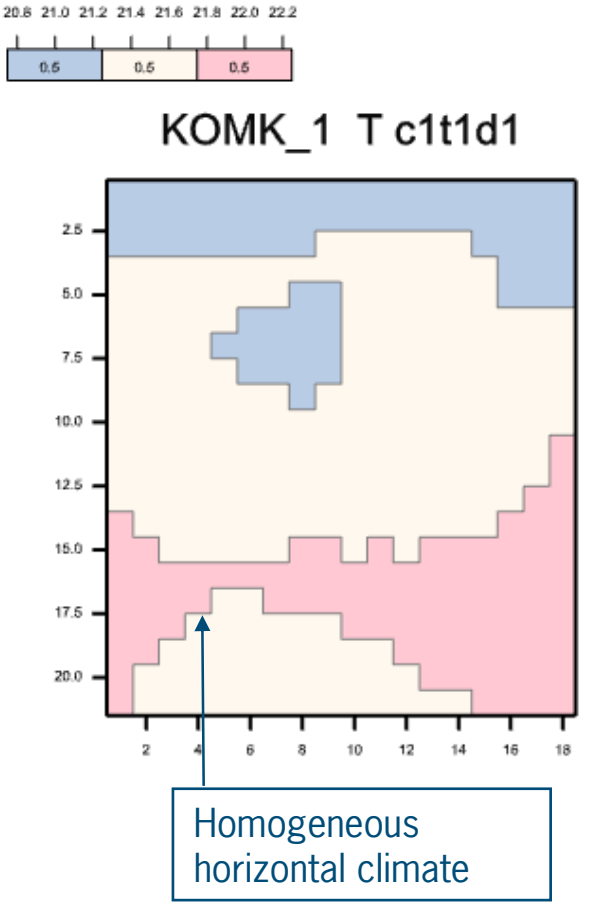
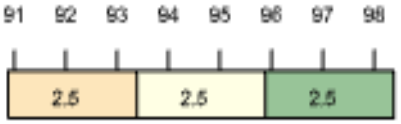
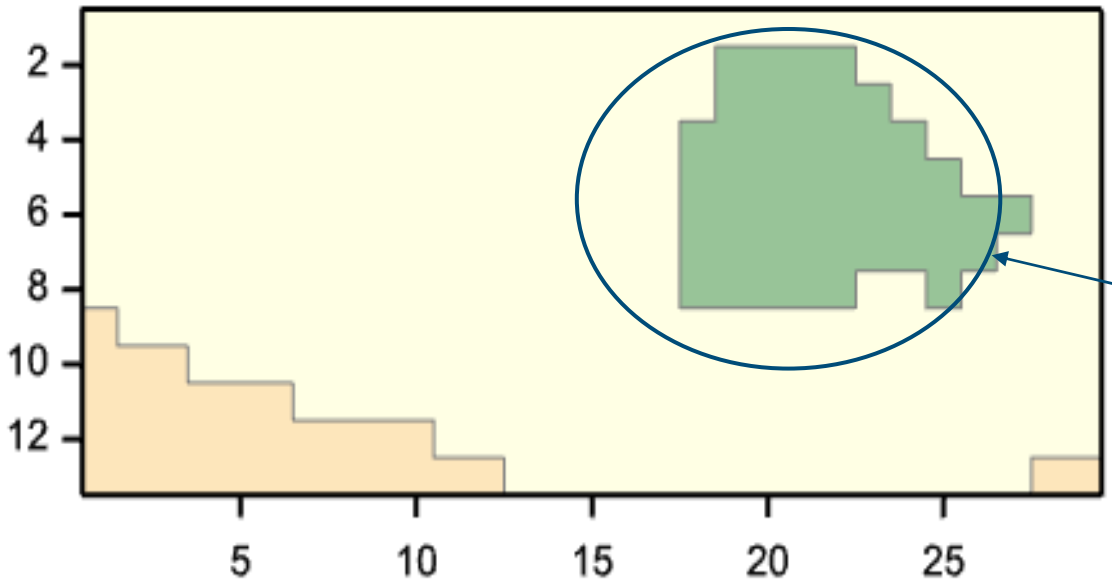


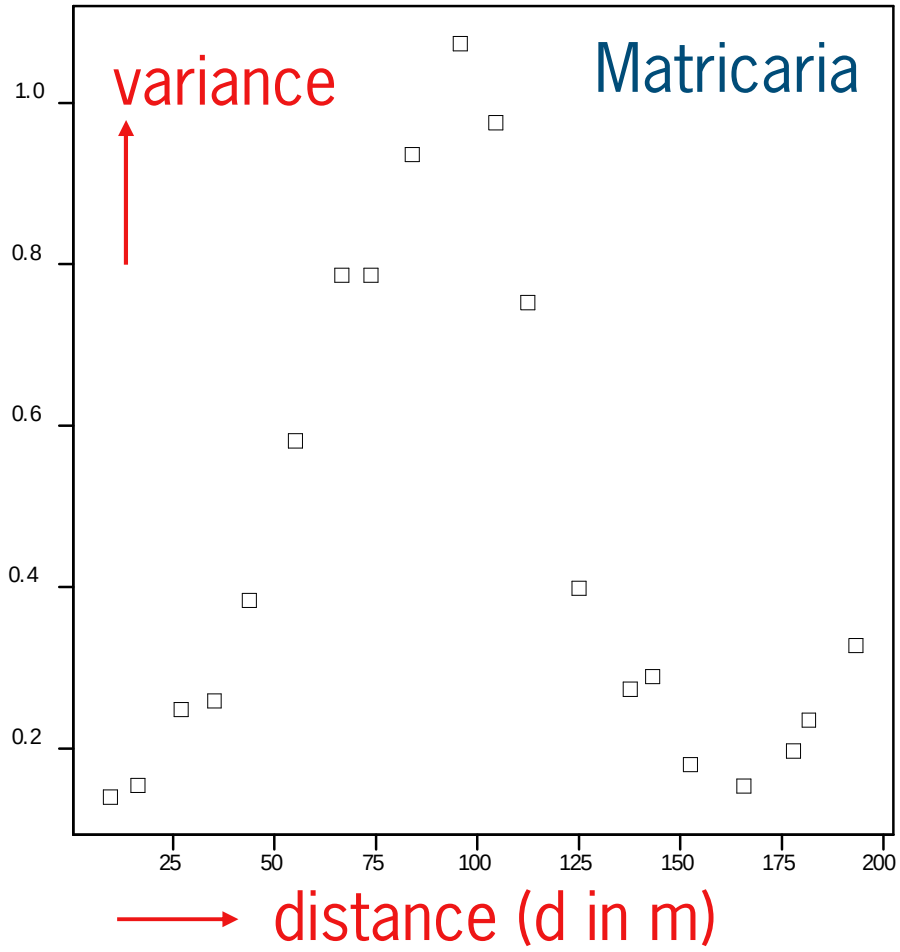
Static distribution of Relative Humidity Gerbera 1 (night, period D1)

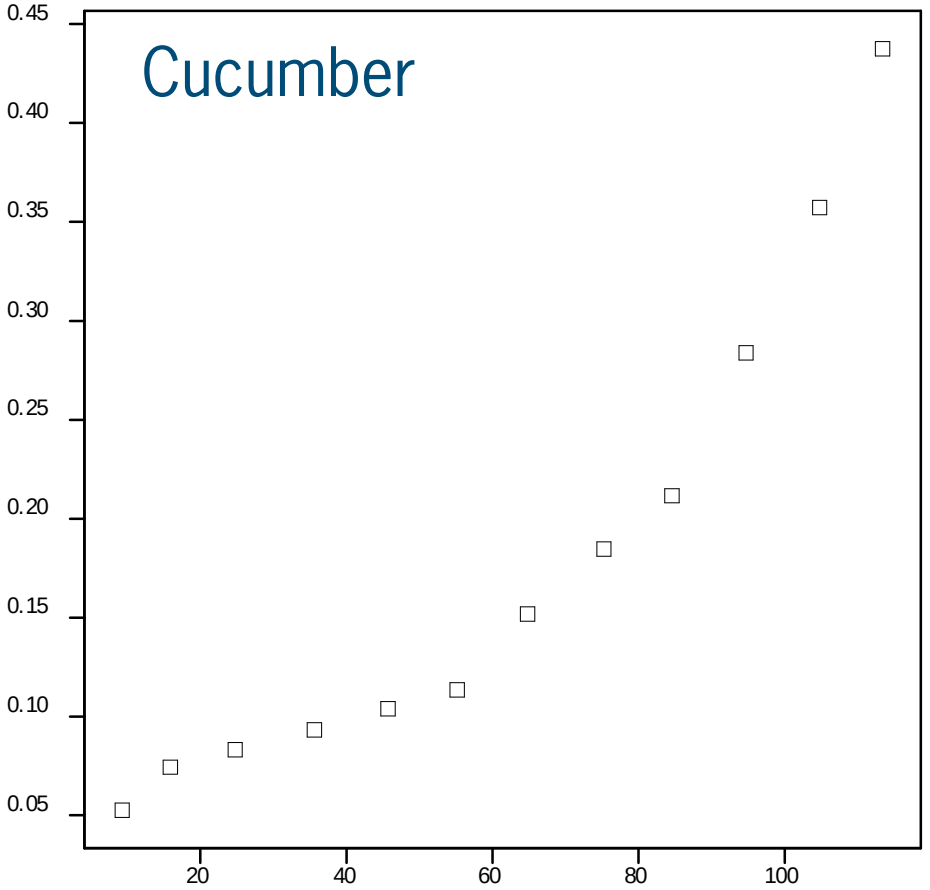




Wet region, confirmed by grower

Variability of Temperature (Variogram)





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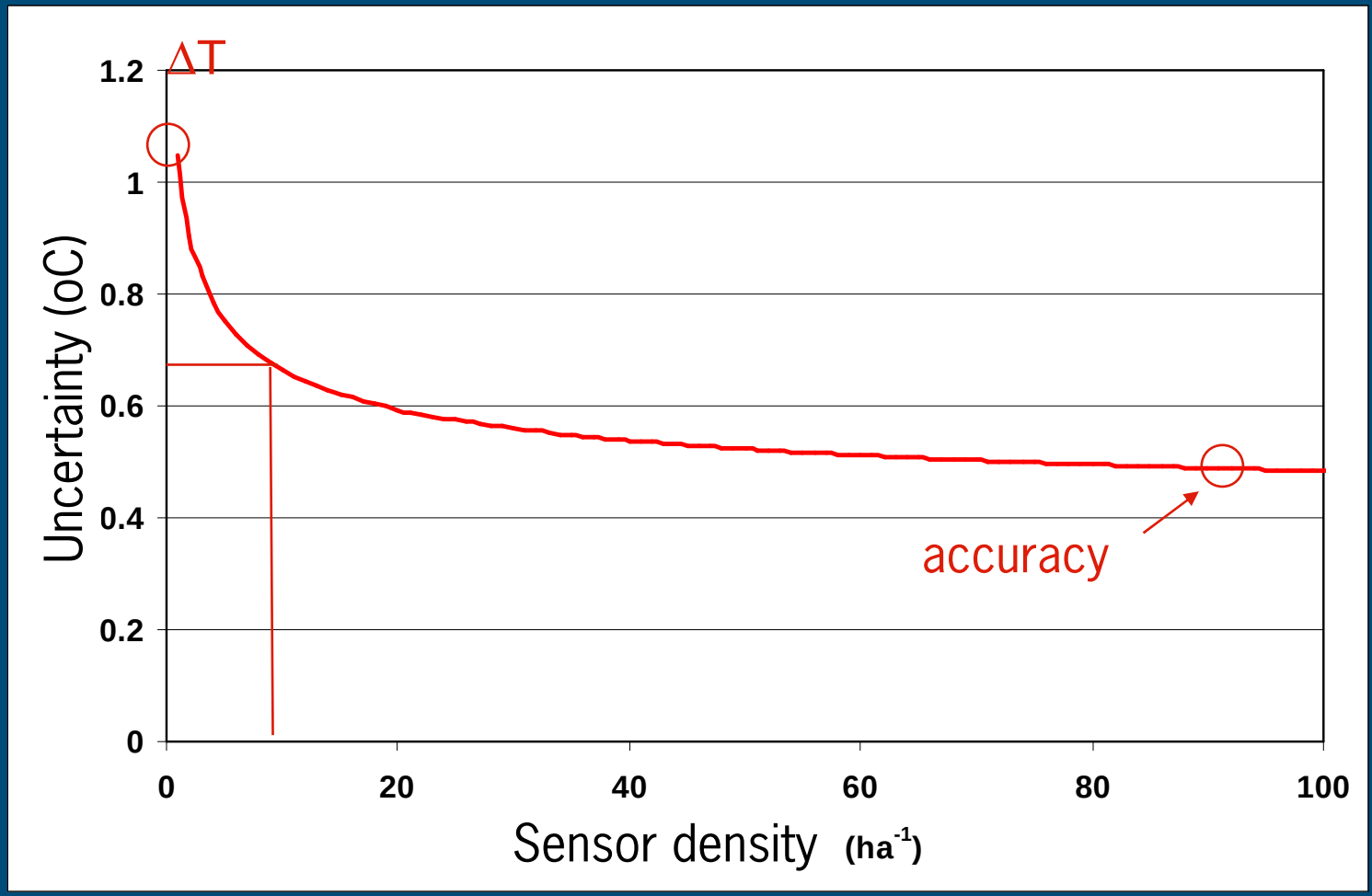
$$Var(T,d) = 0.0344 + 0.0024 \cdot d$$

Sensor density



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Conclusions

- Large instantaneous and static differences
- Sensors worked best during the night (no radiation)
- At least 9 sensors/ha ($\Delta T < \pm 0.75$ ^{o}C)
- More than 30 sensors/ha is not useful or:
- Sensors must be made more accurate
- Graphs are only indicative (average over 6 trials)
- Large individual differences between greenhouses

Thanks

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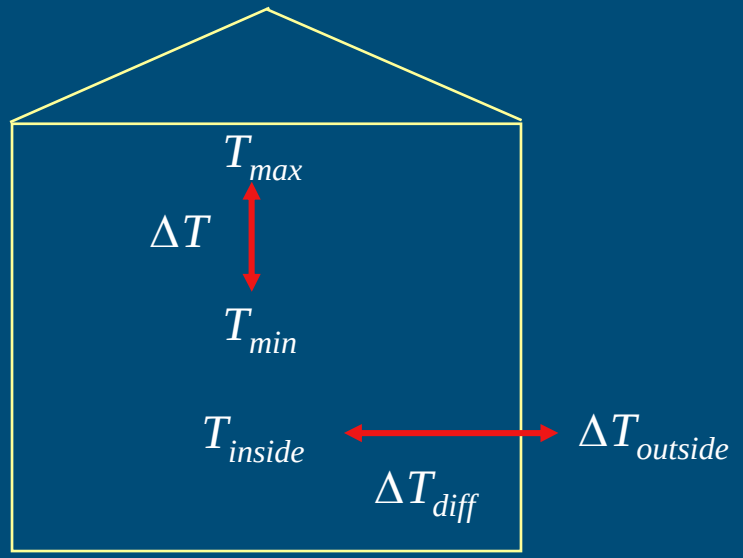
Model for ΔT (a rule of thumb)

Campen et al. (2007) showed that for Dutch greenhouse conditions, ΔT depends strongly on the difference between the greenhouse outside and inside temperature according to:

$$\Delta T = f \cdot \Delta T_{diff}$$

$$\Delta T_{diff} = T_{inside} - T_{outside}$$

with f = 0.20 – 0.25



We used the same model for all trials, but observed for the parameter f a weak correlation (R^2 = 0.46), with:

$$f = 0.4497 - 0.02037 \cdot \Delta T_{diff}$$

for 5 < ΔT_{diff} < 20 °C, which is in accordance with Campen for situations with about 10 °C differences between inside and outside temperature.

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