Measurement-based modelling of large atmospheric heat storage tanks

Review of measurement data

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Introduction

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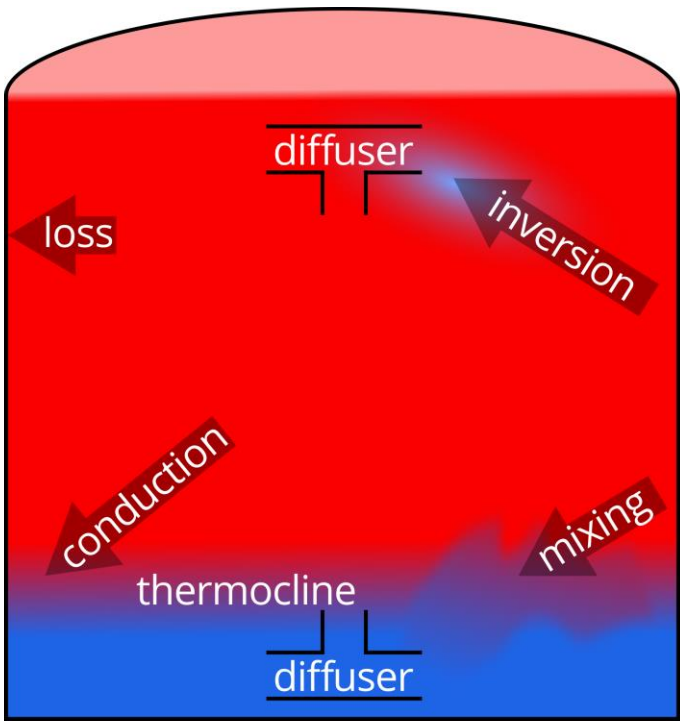
- **Research focus:**
  - Investigate the behaviour of atmospheric heat storage tanks under real operation conditions
  - Detect and quantify inner and outer thermal losses
    → Improve operation management
  - Find appropriate modelling approaches
- 4 one-zone and 2 two-zone heat storage tanks (scales between 2,000 m^3 and 43,000 m^3)
- Use of a distributed temperature sensing (DTS) measurement system



Distributed Temperature Sensing (DTS)

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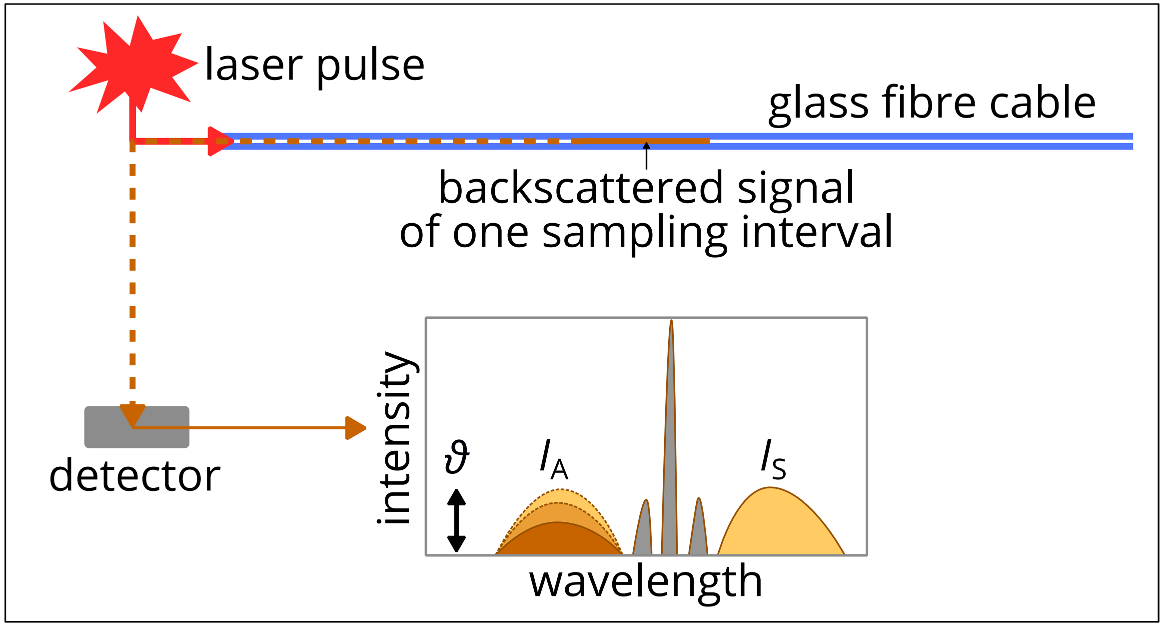
- **Raman effect:**
  Pulsed laser signal in a glass fibre generates a frequency shifted backscattering signal
- Temperature-dependent ratio of Stokes (I_S) and Anti-Stokes (I_A) signal
- Spacial resolution 0.35 m
- Temperature resolution 0.1 K (0.5 km cable, 60 s time averaging)



One-zone heat storage tanks

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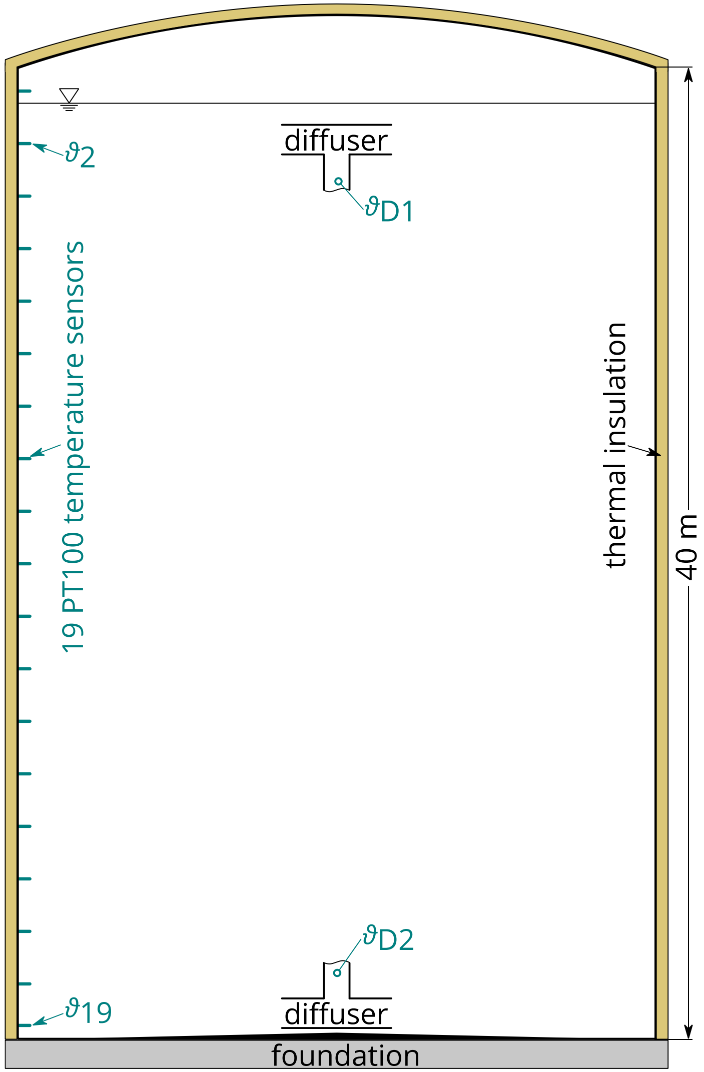

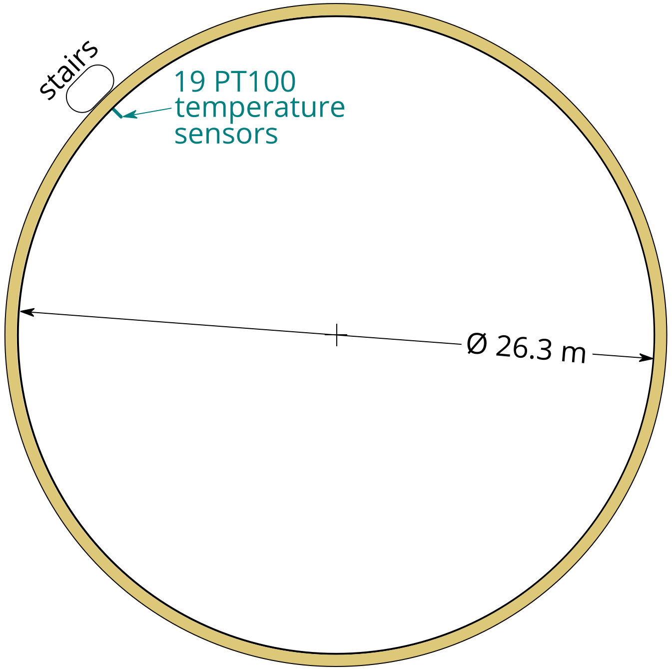

- Vertical cylinder with two concentric diffusers
- Ambient pressure at water level, max. 98 °C
- Capacities of up to several 10,000 m^3

One-zone heat storage tanks

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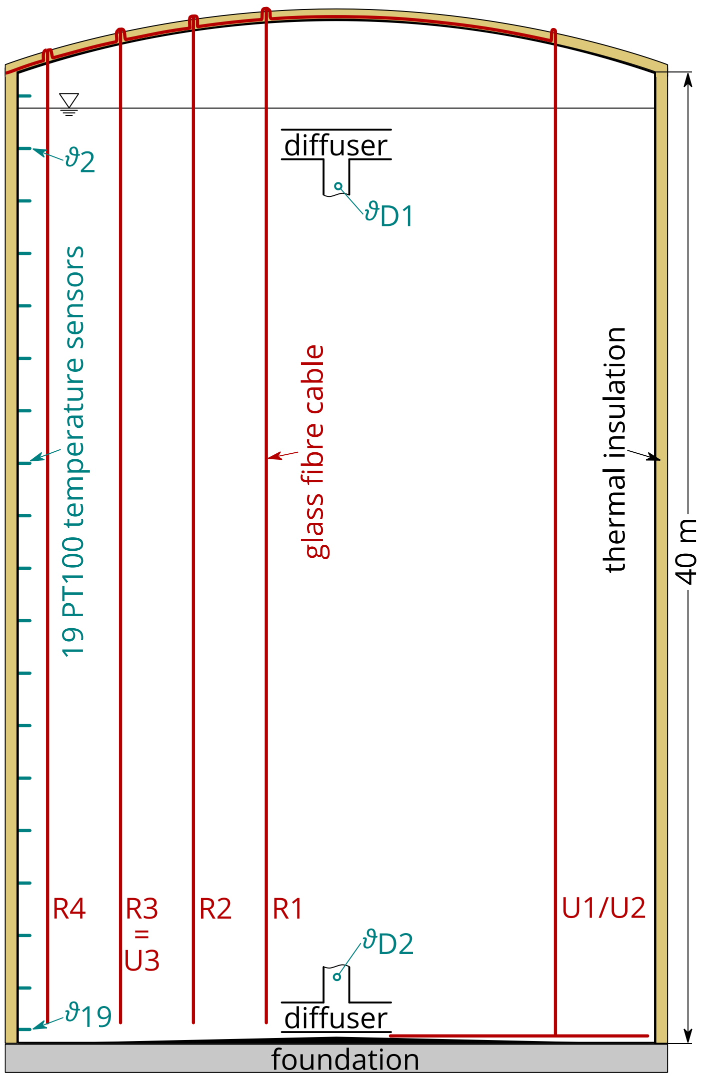

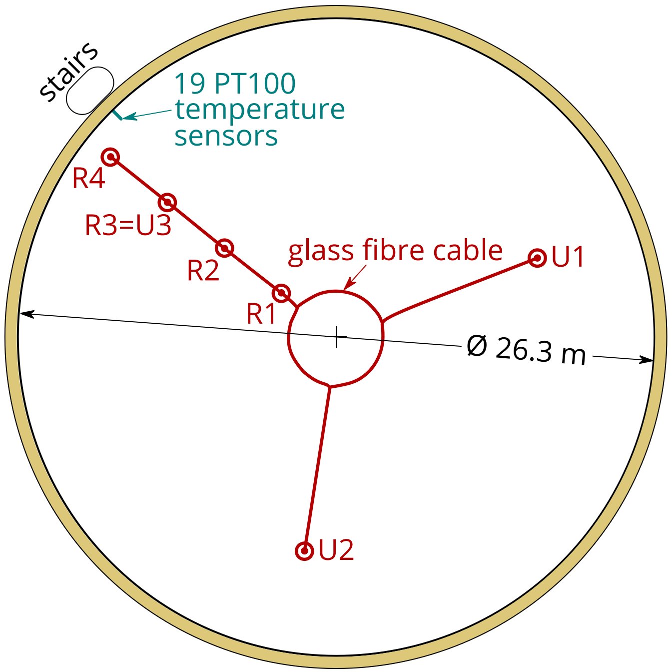

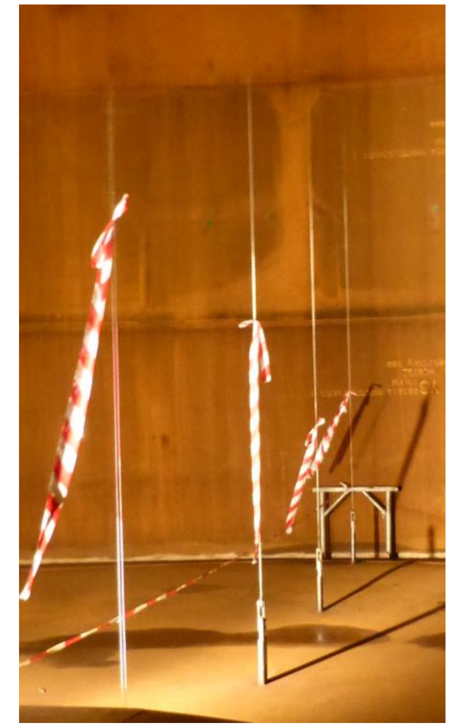

- Temperature field captured vertically
- 4 radial positions (R1-R4) and 2 additional circumferential positions (U1, U2)

Characterizing the temperature field

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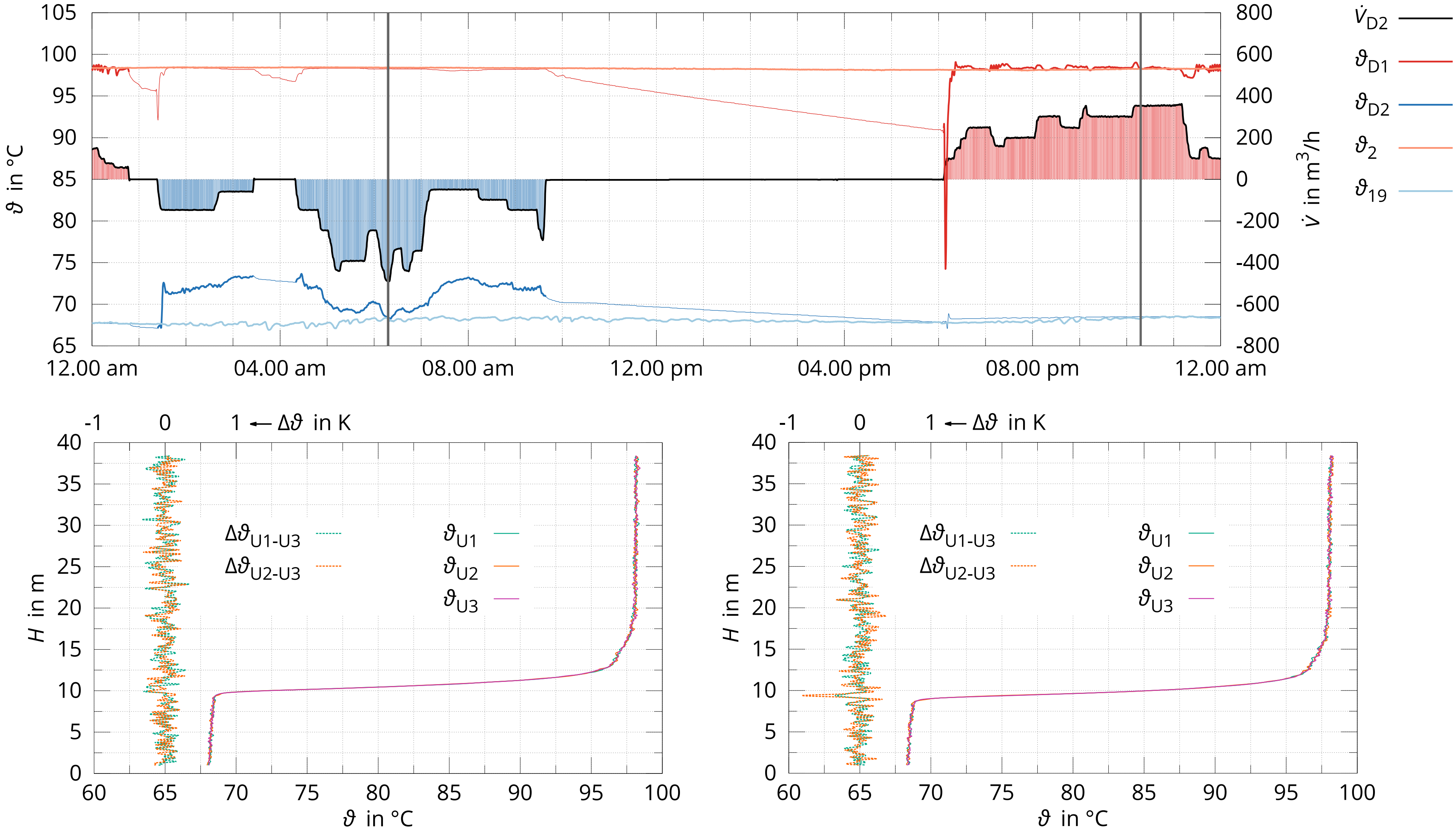

Characterizing the temperature field

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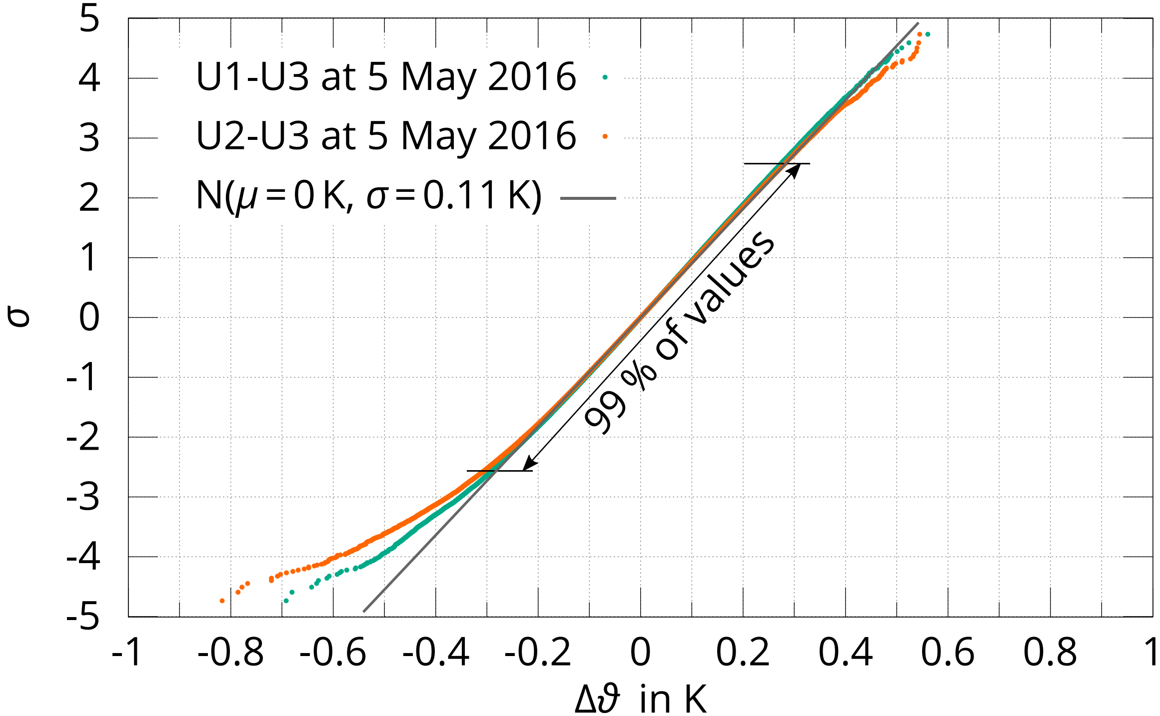

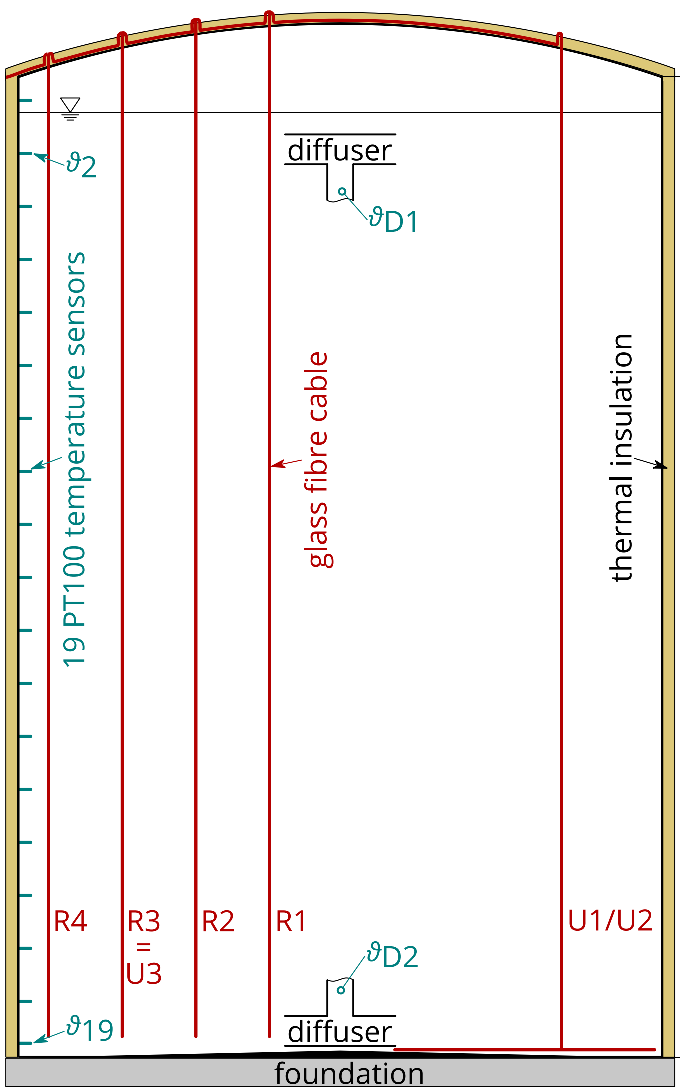

Single, typical day:

- Very few deviations of more than ± 0.5 K (the range expected due to the measurement noise)

Characterizing the temperature field

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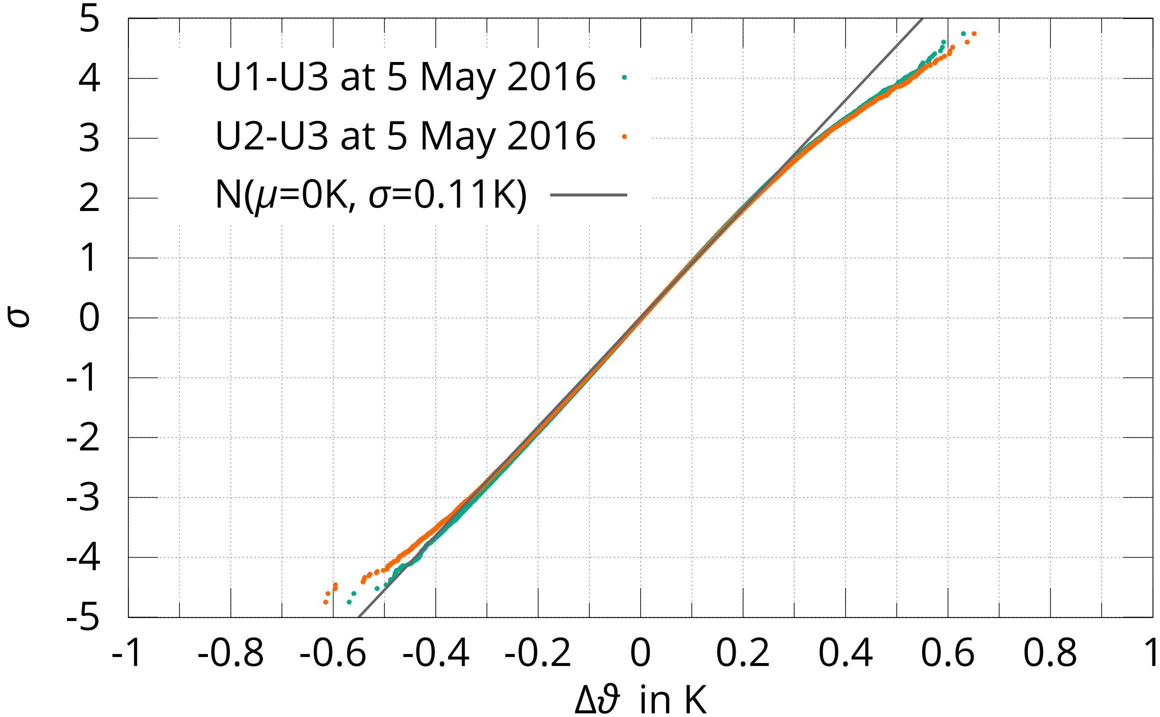
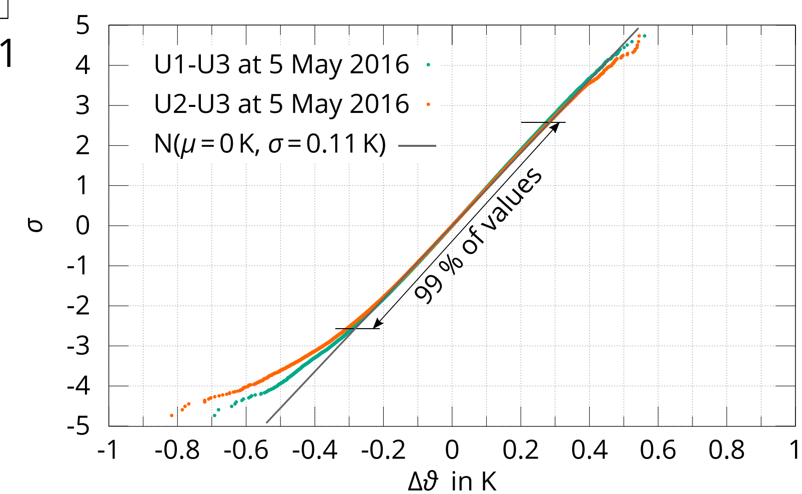


1 cm shift of U2 and U3

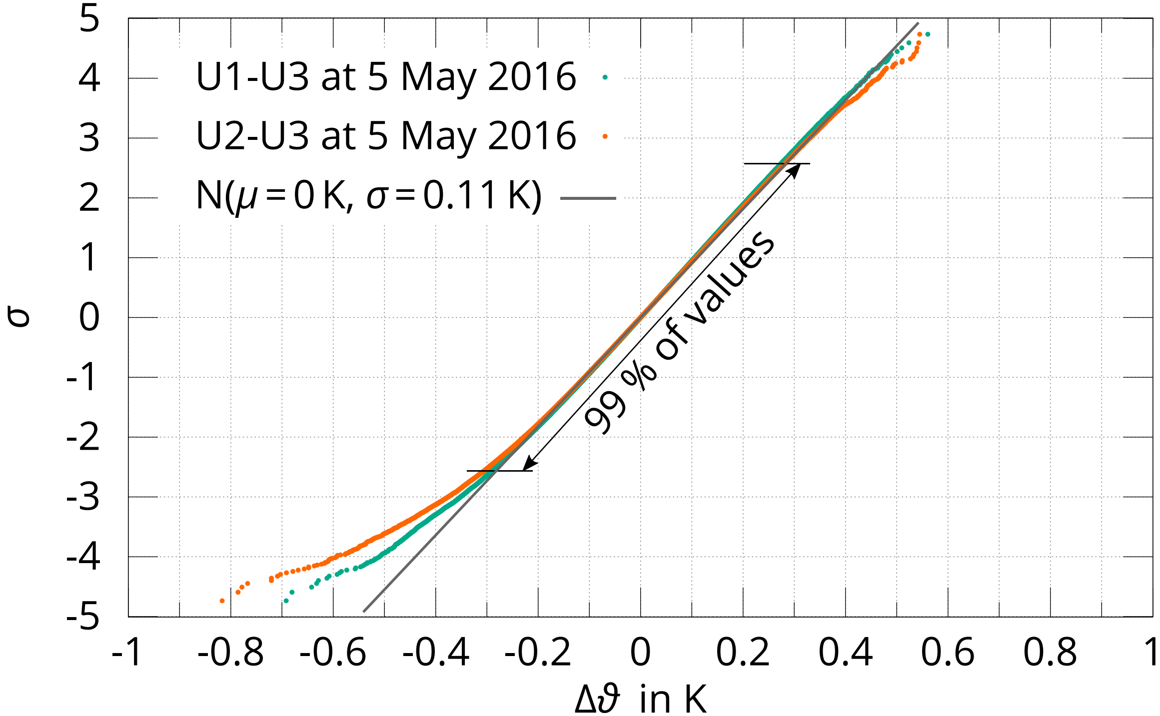


Vertical alignment of measurement positions:

- Very sensitive to very small vertical shift

  → high temperature gradient in thermocline

Characterizing the temperature field



Single, typical day:

- Very few deviations of more than ± 0.5 K (the range expected due to the measurement noise)

$|\Delta\vartheta_{X\text{-}U3}|$ - based on <u>two month</u> of measurement:

- **Mean: 0.1 K** ≈ measure-ment noise
- **$Max_{circumferential}$: 2.3 K**
- **Max_{radial}: 4.0 K**
- Max-values occur in context of inversions
- Deviations from perfect homogeneity in horizontal layers are rare and small

Two-zone heat storage tank 18,000 m³

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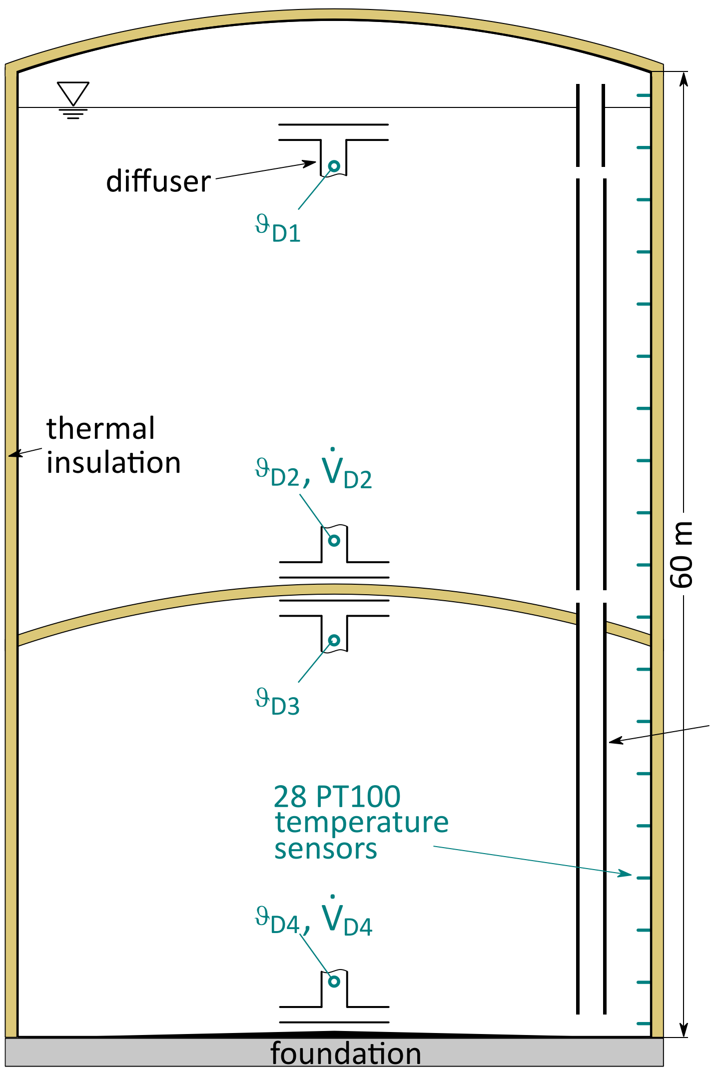

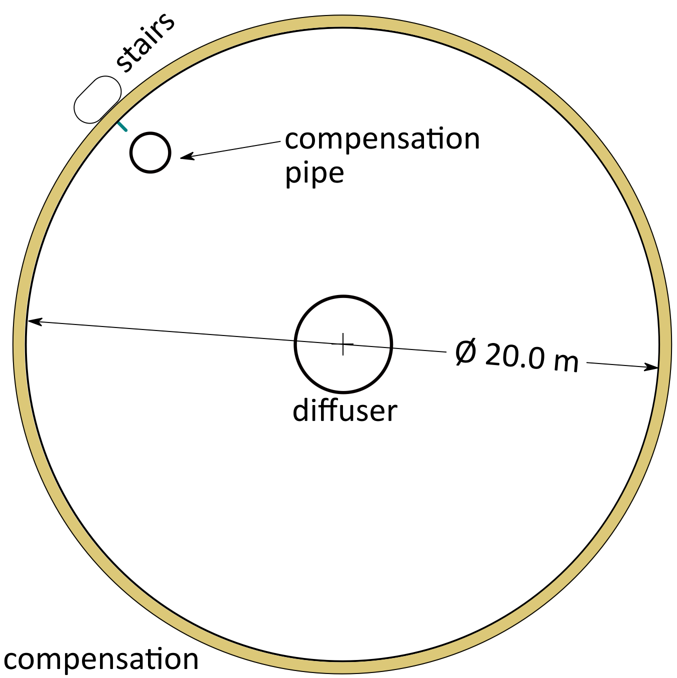

- Active use of both zones
- max. 98 °C in the upper zone
- max. 130 °C in the lower zone

Two-zone heat storage tank 18,000 m³

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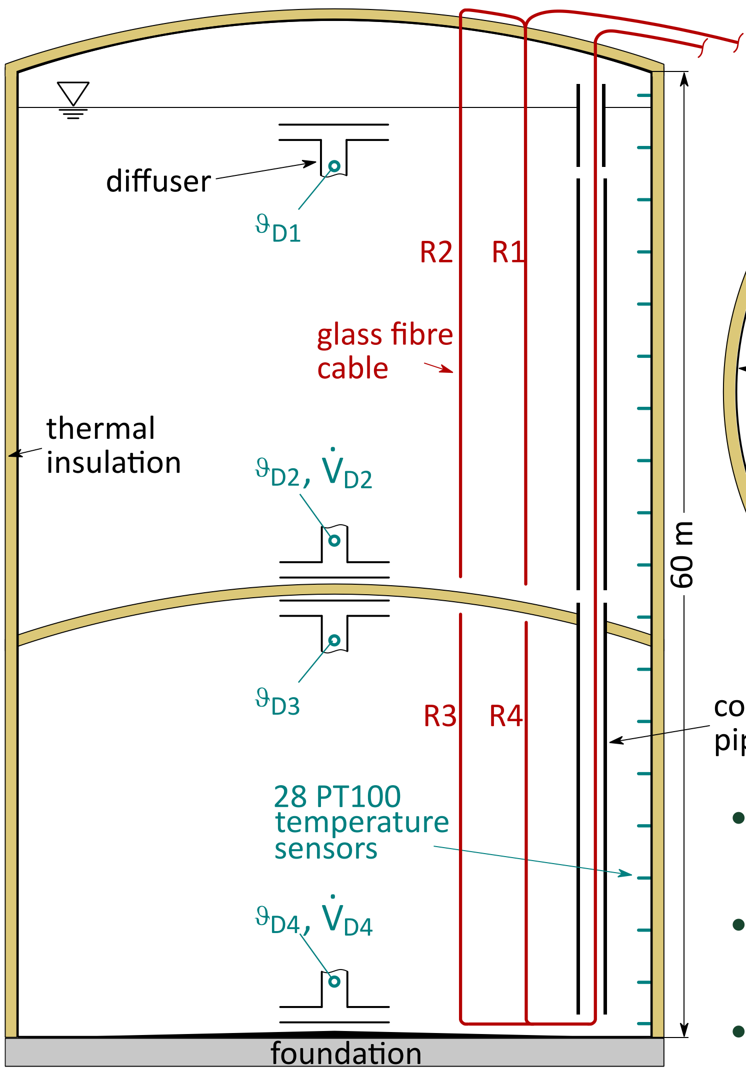

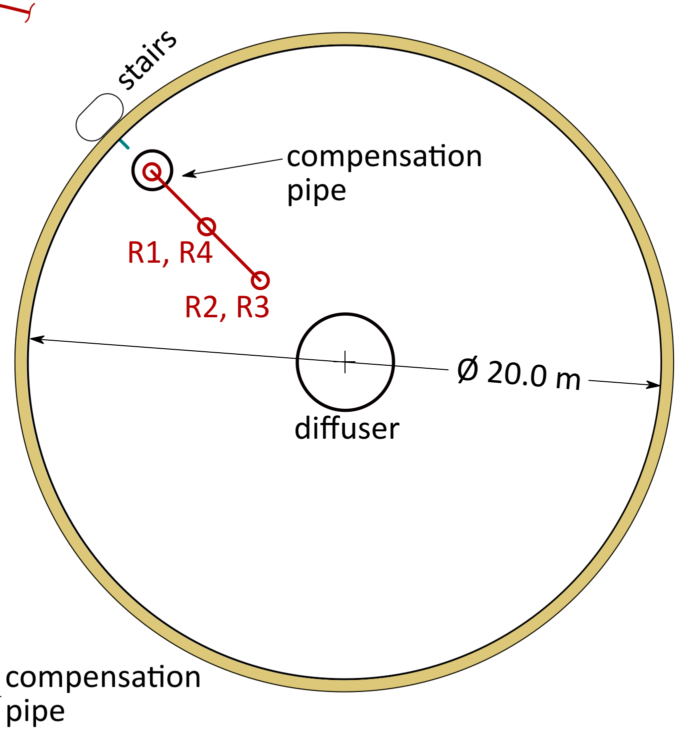

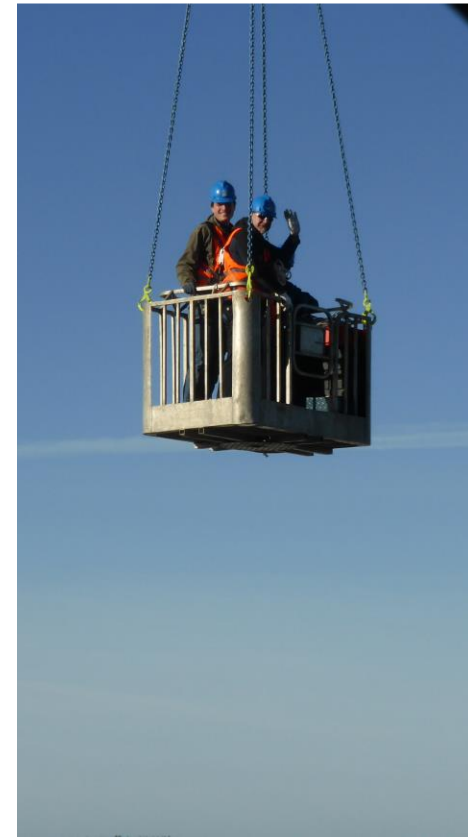

- Active use of both zones
- max. 98 °C in the upper zone
- max. 130 °C in the lower zone

Radial homogeneity

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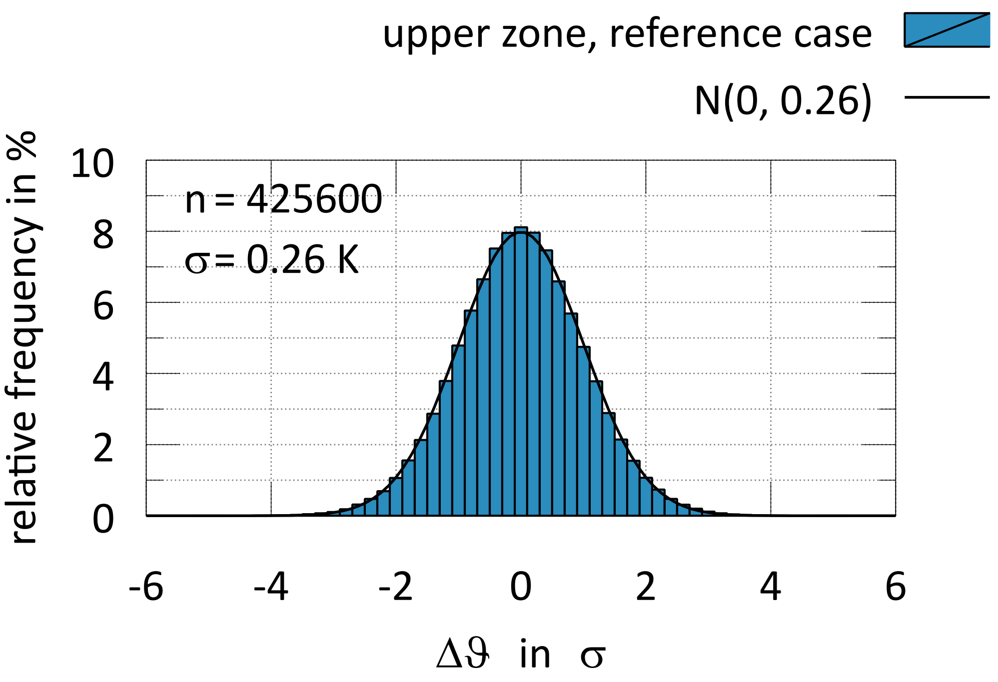
- Investigation of a reference case during a standstill phase
  → standard deviation
  (consecutive time steps)
- Separate calculations for upper and lower zone
- histogram and normal probability plot
- Study of a case in normal operation mode
  → Investigation of radial temperature differences (same time step)



Visualisation of the monitoring data

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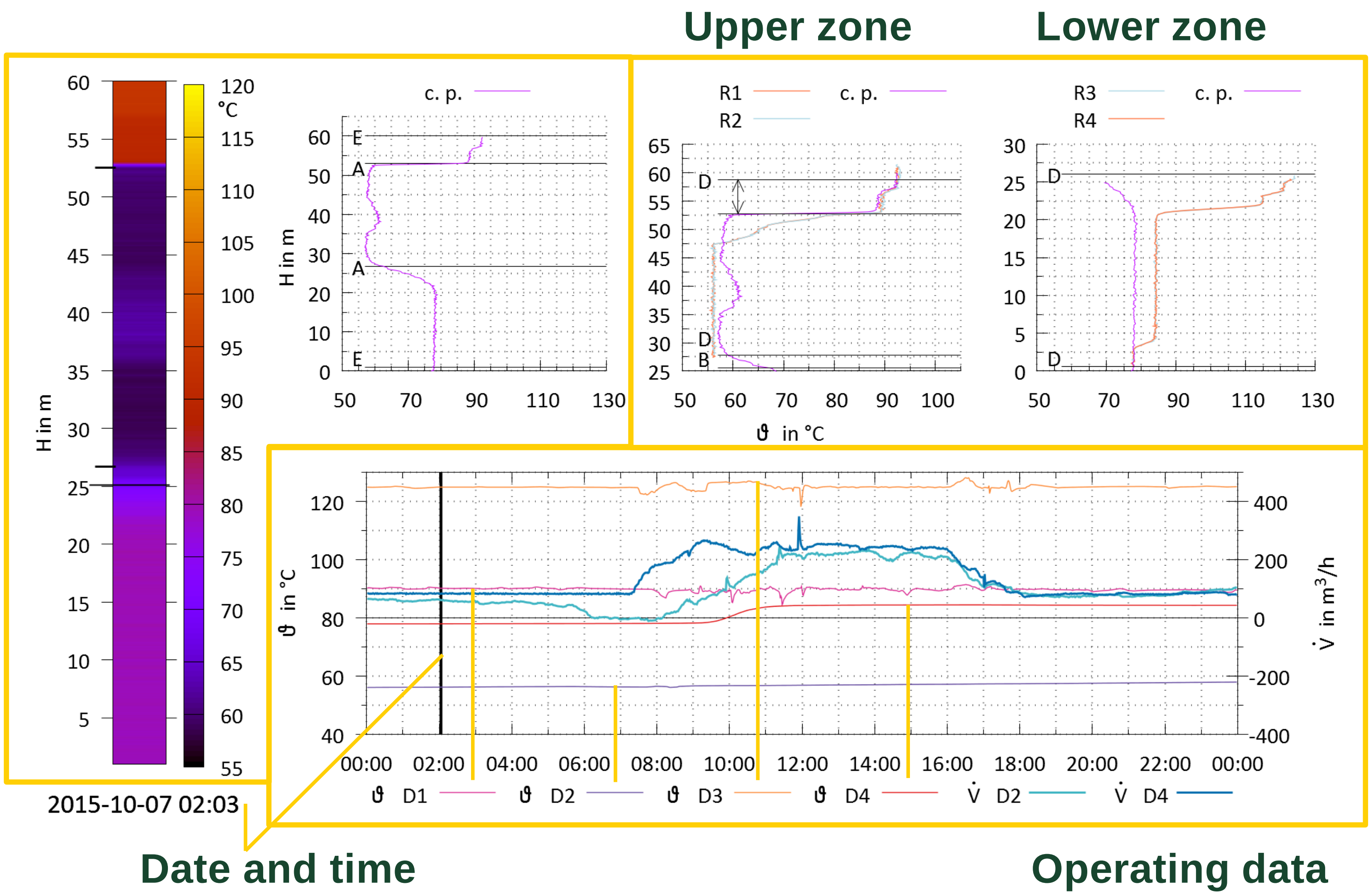

Temperature field over time

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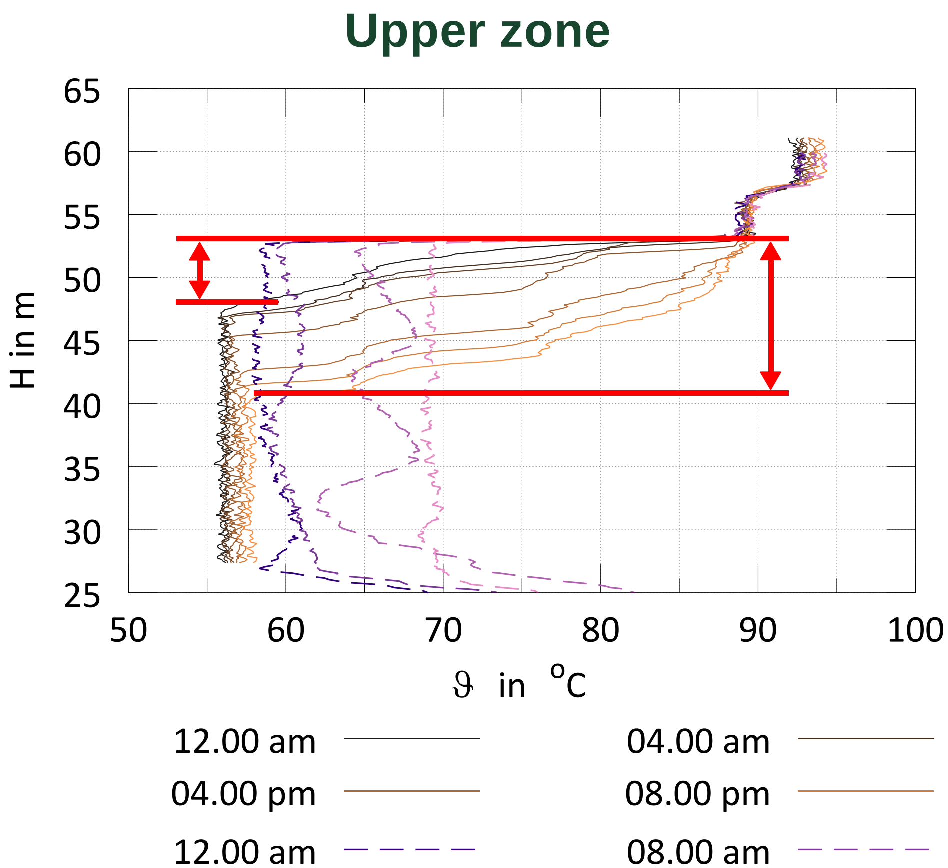
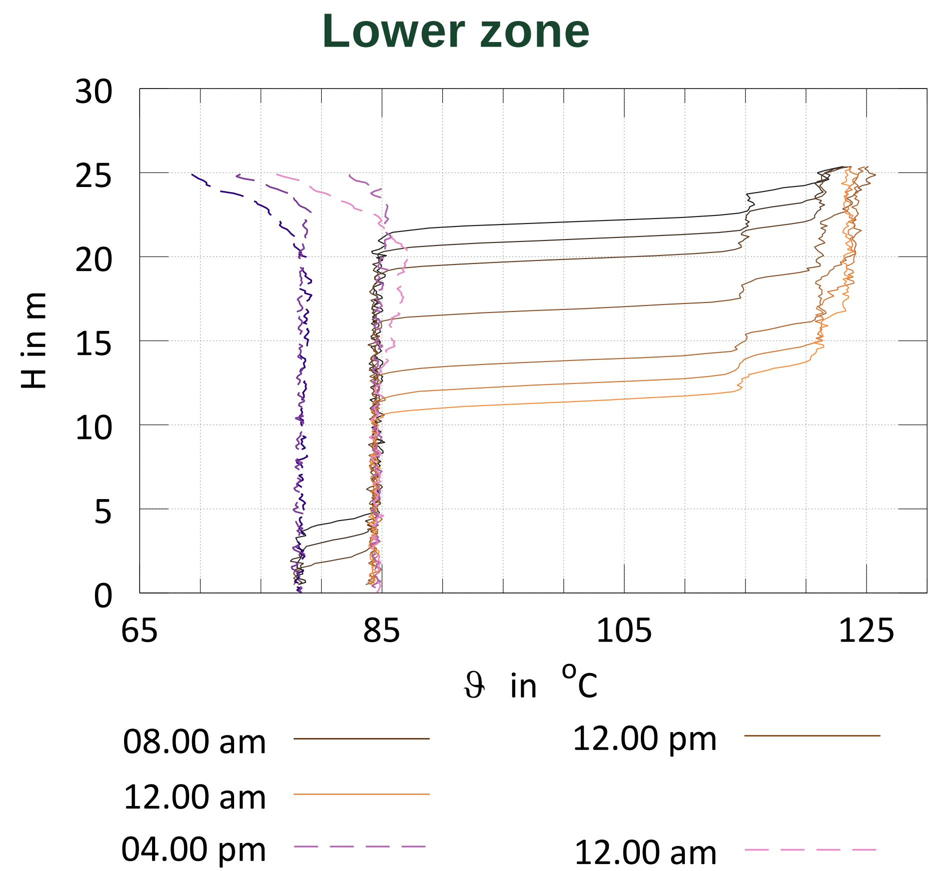
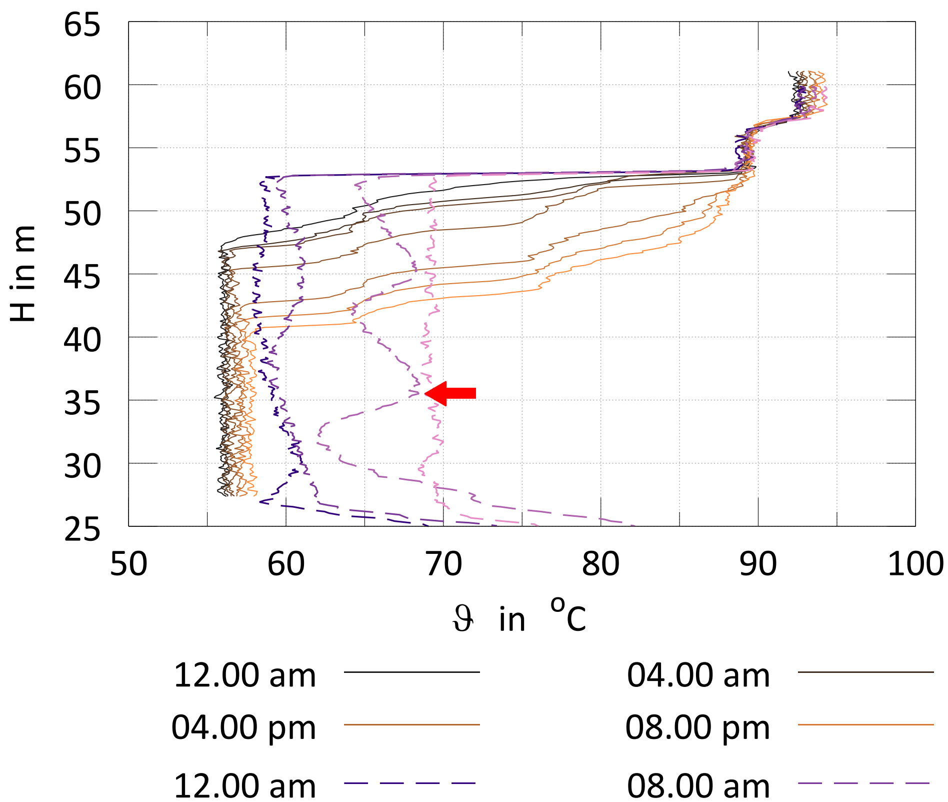


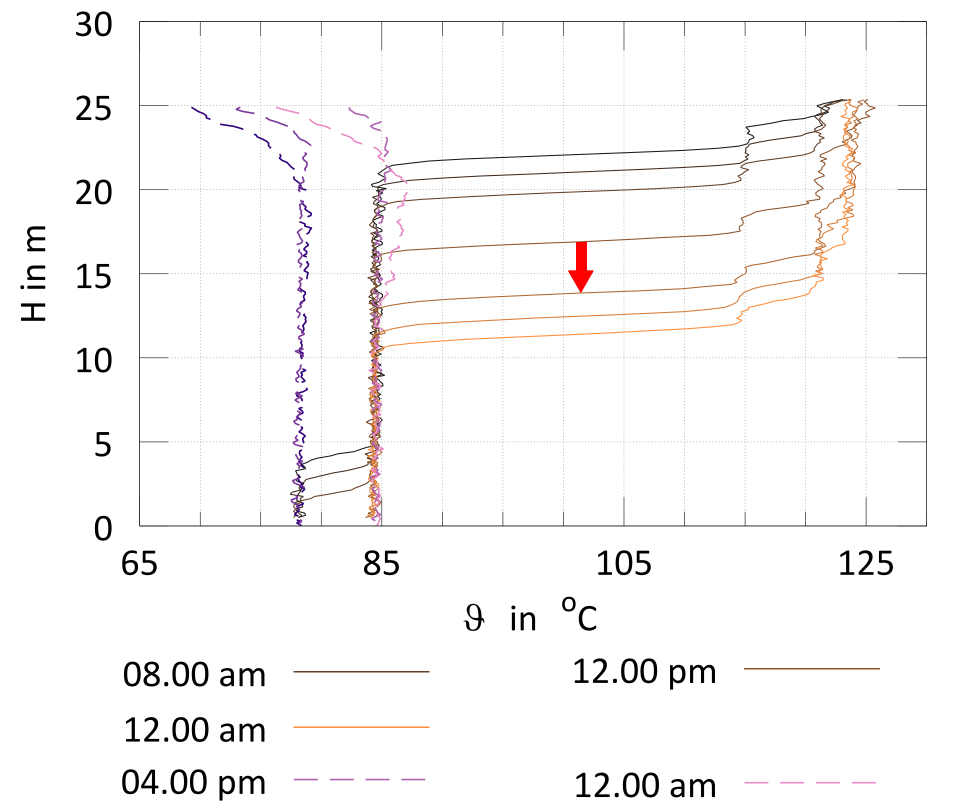


Temperature field over time

Upper zone



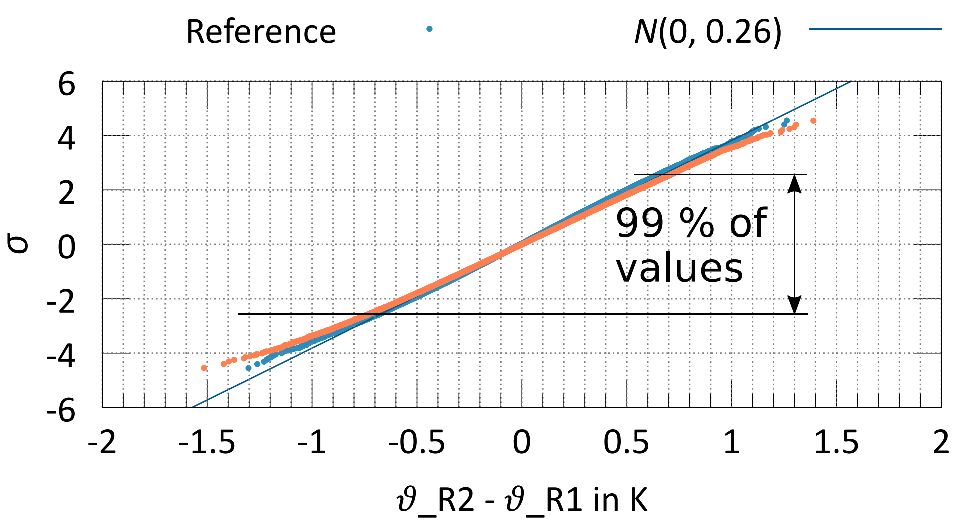
Lower zone



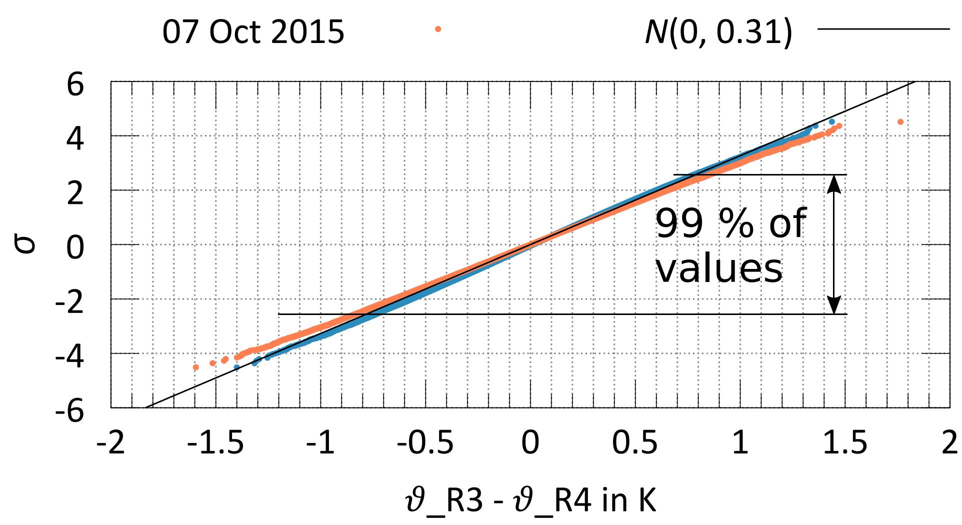
Final results

- Interaction of the two storage zones via the compensation pipe
- Good thermal stratification, especially in the lower storage zone
- Proof of radial homogeneity of the temperature field in both storage zones
  → Normal probability plot:

Upper zone



Lower zone



Summary

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- One-zone heat storage tanks
  - Circumferential effects of the temperature field are even smaller than radial effects.
  - Proof of very good homogeneity of the temperature field in horizontal layers.

- Two-zone heat storage tanks
  - Thermal stratification remains stable although an interaction between the two zones through the compensation pipe had been shown.
  - Occurring radial effects through the compensation pipe are too small to prove them. Rather thermal stratification is influenced in the upper zone.

Thank you for your attention!

Project: **SPICE (<u>Spe</u>i<u>c</u>her<u>e</u>ffizienz) –
Measurement of temperature fields in large hot water storage tanks in CHP based District Heating Systems as a tool to increase efficiency**
Research project founded by the Federal Ministry for Economic Affairs and Energy following a resolution of the German Bundestag
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Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

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