Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Changes in the measurement systems and the impact on the homogeneity of long time series
A study based on parallel measurements from German reference stations

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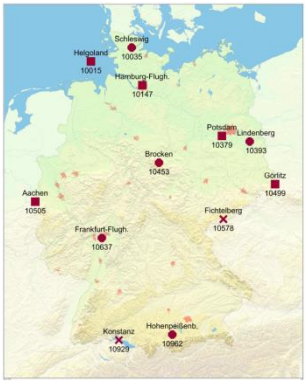
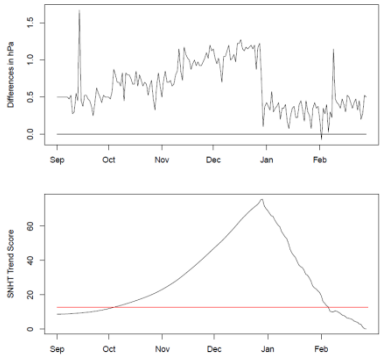
Frank Kaspar
Deutscher Wetterdienst
National climate monitoring

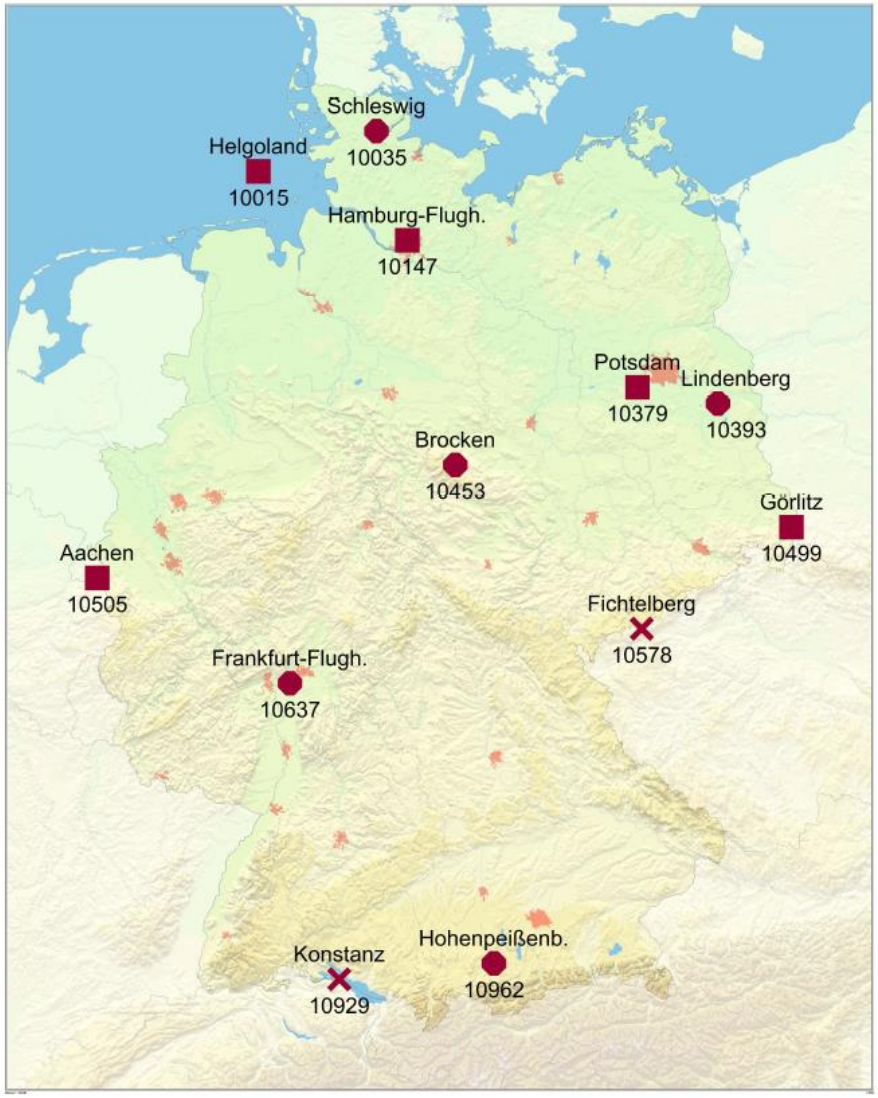
Parallel measurements at climate reference stations

Comparison between manual and automatic measurements



- Motivation
  - Why parallel measurements?
  - Which parameters?
- Results
  - Are measurement systems comparable?
  - Statistical analysis
  - Systematic differences
- Summary and outlook





Station	since	with manual measurements
Aachen	1891	2008 – 2011
Aachen-Orsbach	2011	2011 – 2014
Brocken	1881	since 2008
Fichtelberg	1890	2008 – 2014
Frankfurt	1949	since 2008
Görlitz	1881	2008 – 2014
Hamburg	1891	2008 – 2014
Helgoland	1881	2006 – 2013
Hohenpeißenberg	1781	since 2008
Konstanz	1941	2007 – 2012
Lindenberg	1906	since 2008
Potsdam	1893	since 2008
Schleswig	1947	since 2008

Climate reference stations with parallel measurements of automatic sensors (CRS II)

Climate reference stations with manual measurements (CRS I)

Climate reference stations: Parallel measurements

➔ Parameters:

Air temperature, extreme temperatures, soil temperatures, air pressure, relative humidity, sunshine duration, and precipitation

Climate reference stations: Parallel measurements

- Parameters:
  Air temperature, extreme temperatures, soil temperatures, air pressure, relative humidity, sunshine duration, and precipitation

- The aims:
  - Analysis of comparability of measurement systems and effect on homogeneity
  - Data quality control
  - Analysis of measurement uncertainty
  - Use results to advance homogenization methods

Climate reference stations: Parallel measurements

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  Air temperature, extreme temperatures, soil temperatures, air pressure, relative humidity, sunshine duration, and precipitation

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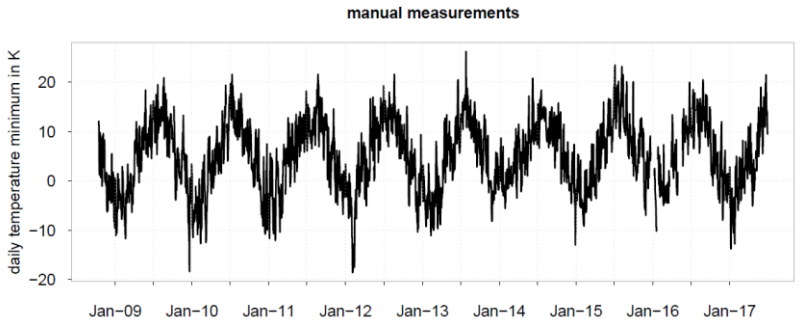
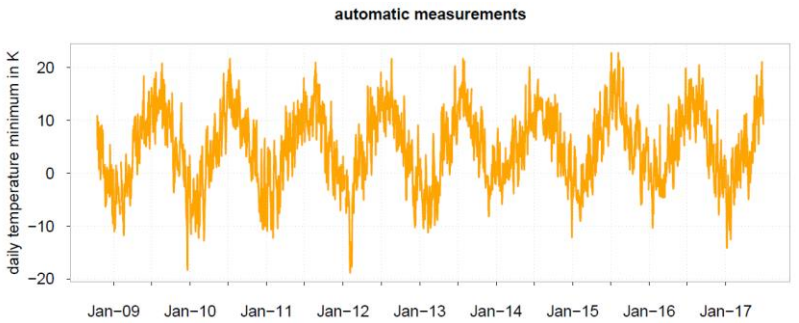
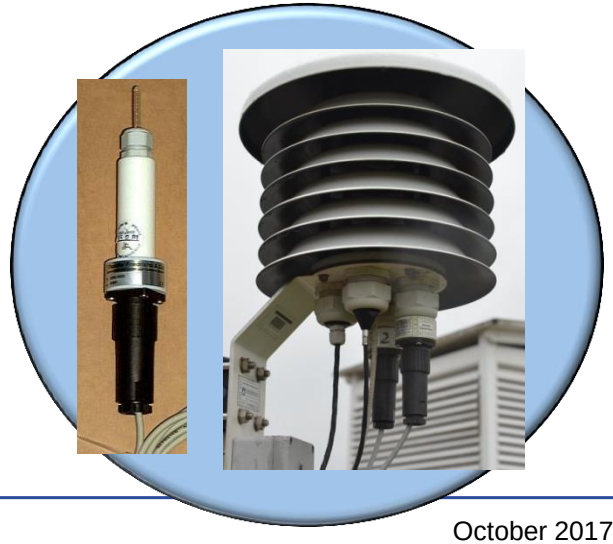
Why parallel measurements?

Analysis of comparability

➔ Compare measurements of manual and automatic sensors







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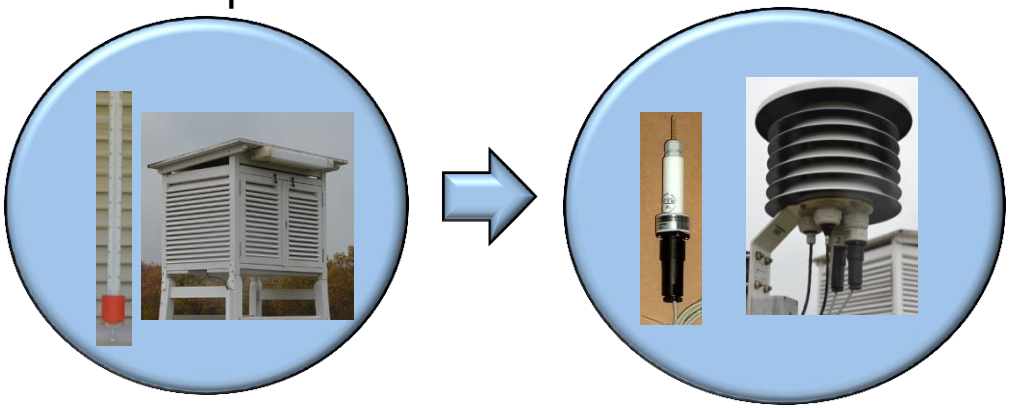

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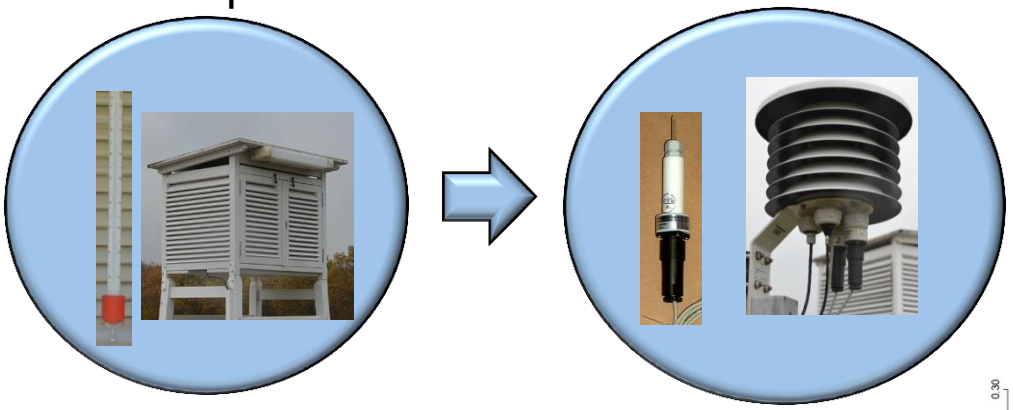
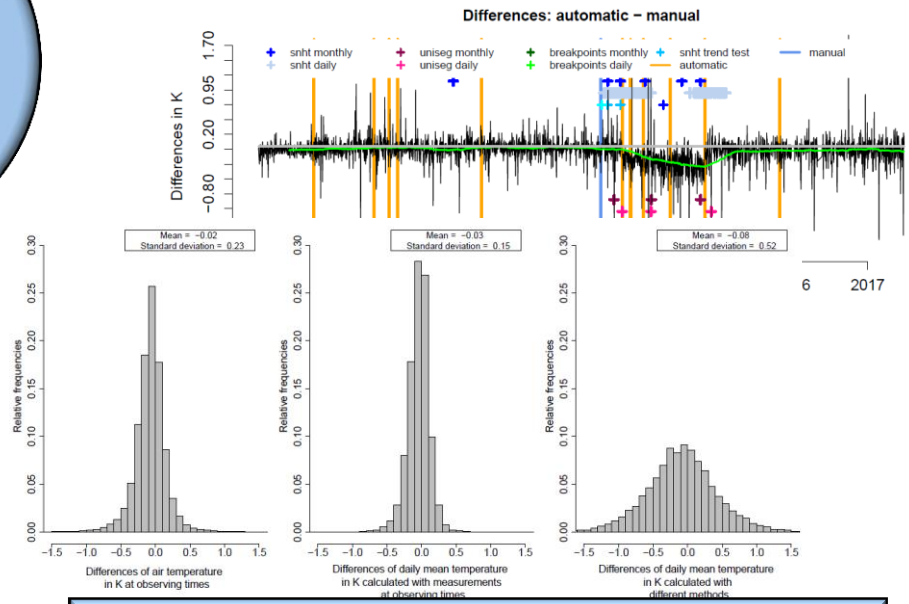
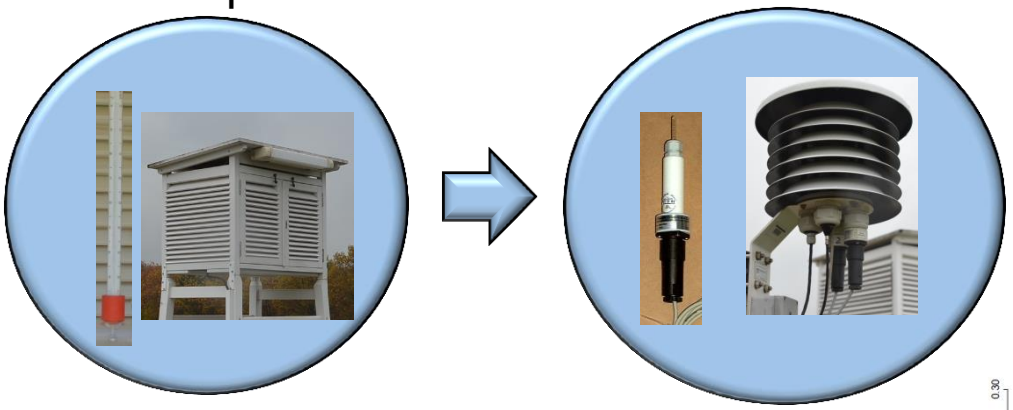


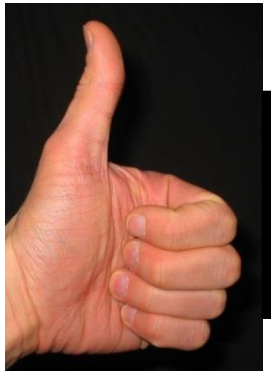


Statistical analysis

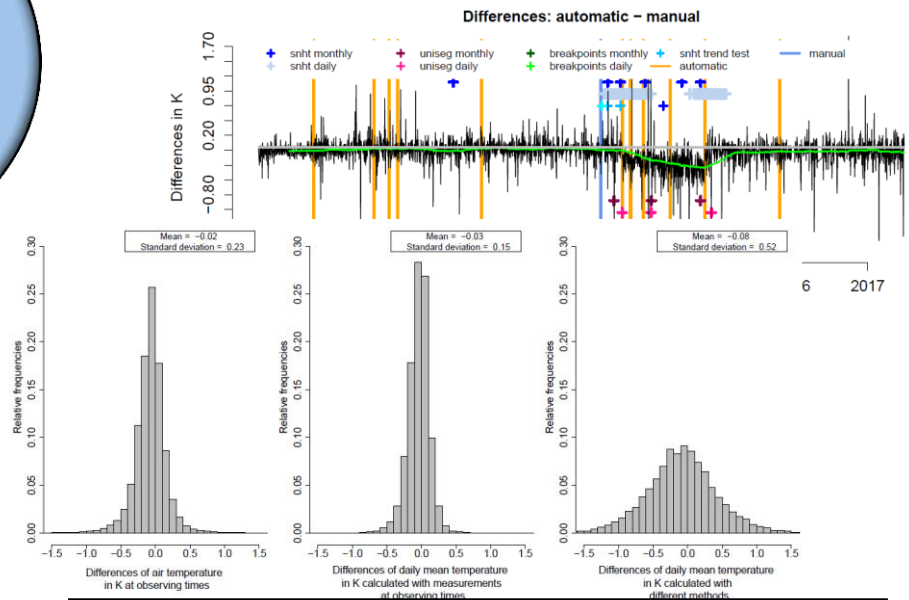
Analysis of comparability

➔ Compare measurements of manual and automatic sensors





Good agreement !



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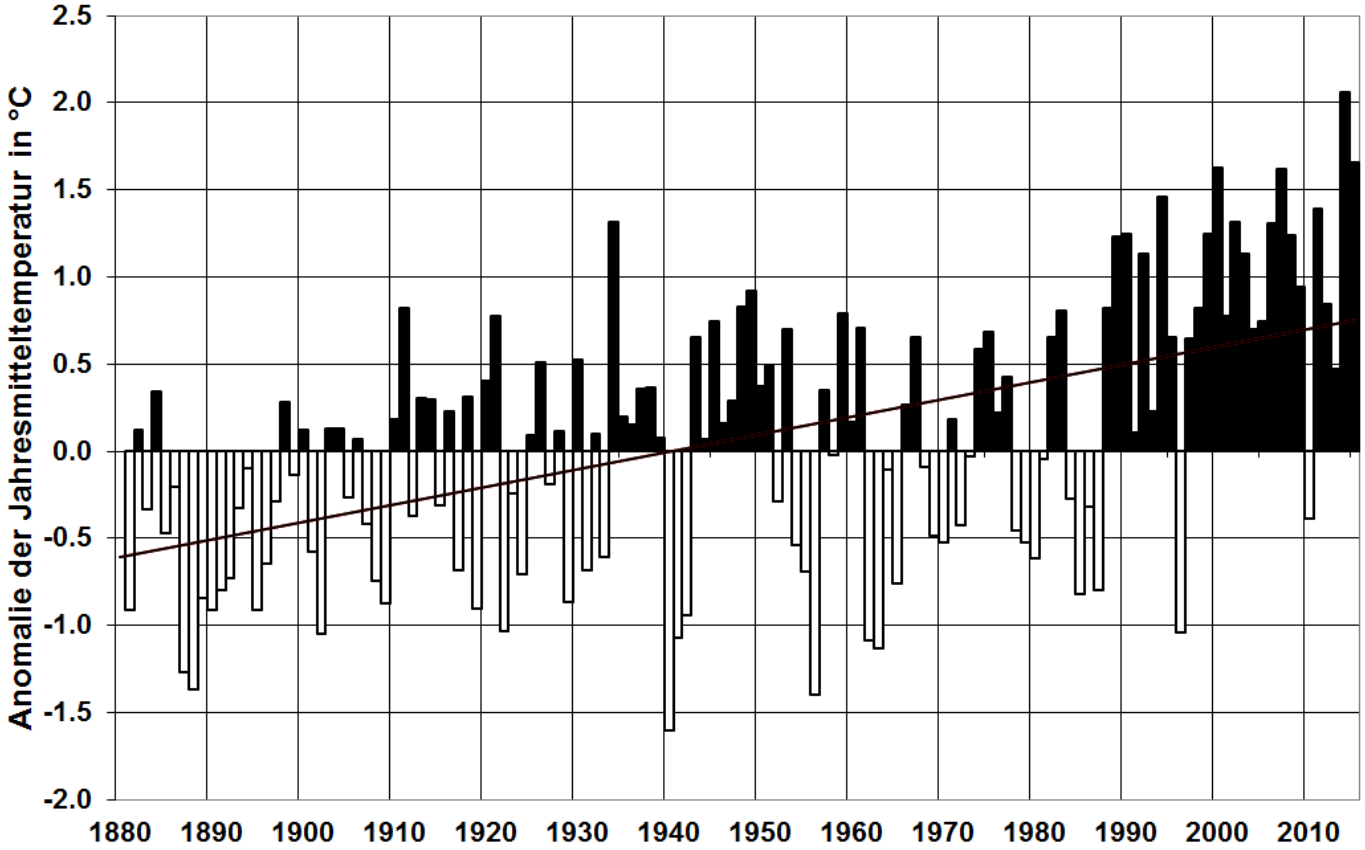

Annual mean temperature in Germany since 1881 as anomalies from the mean value 1961-1990 (Kaspar and Friedrich, 2016)

Analysis of comparability

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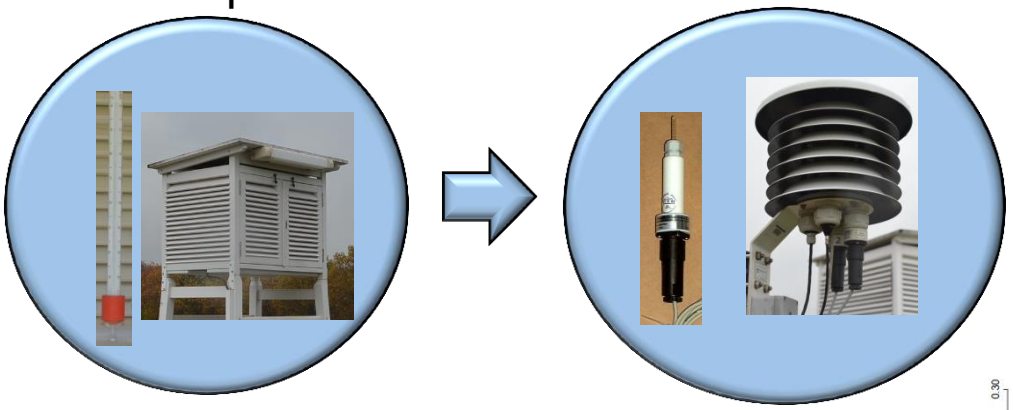
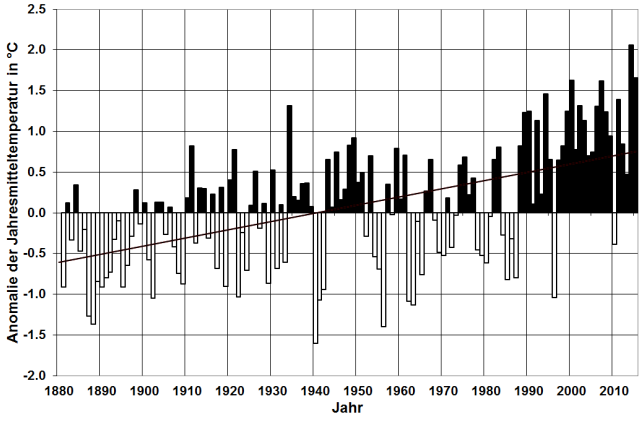
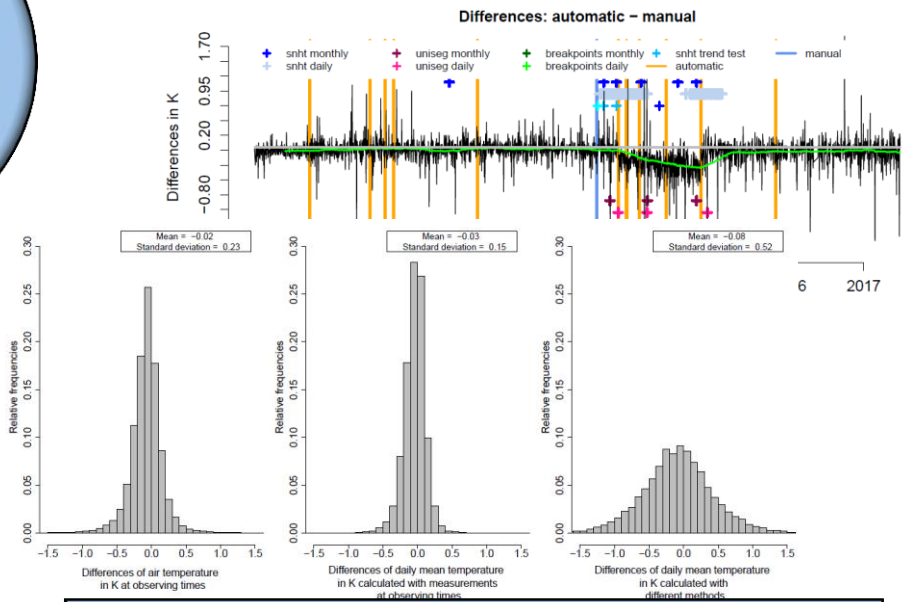


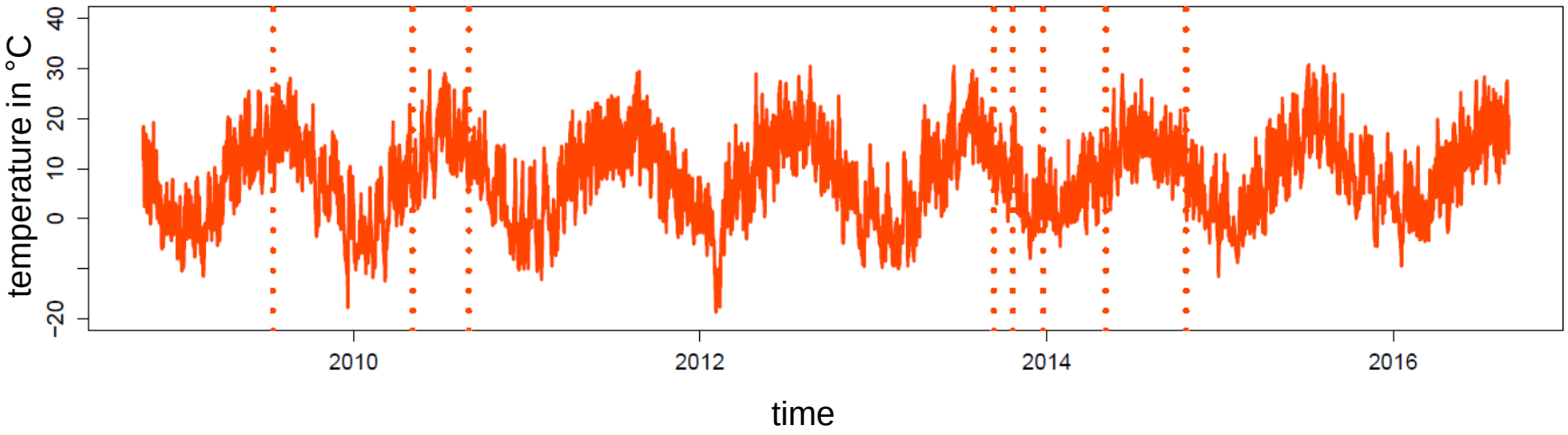




Statistical analysis

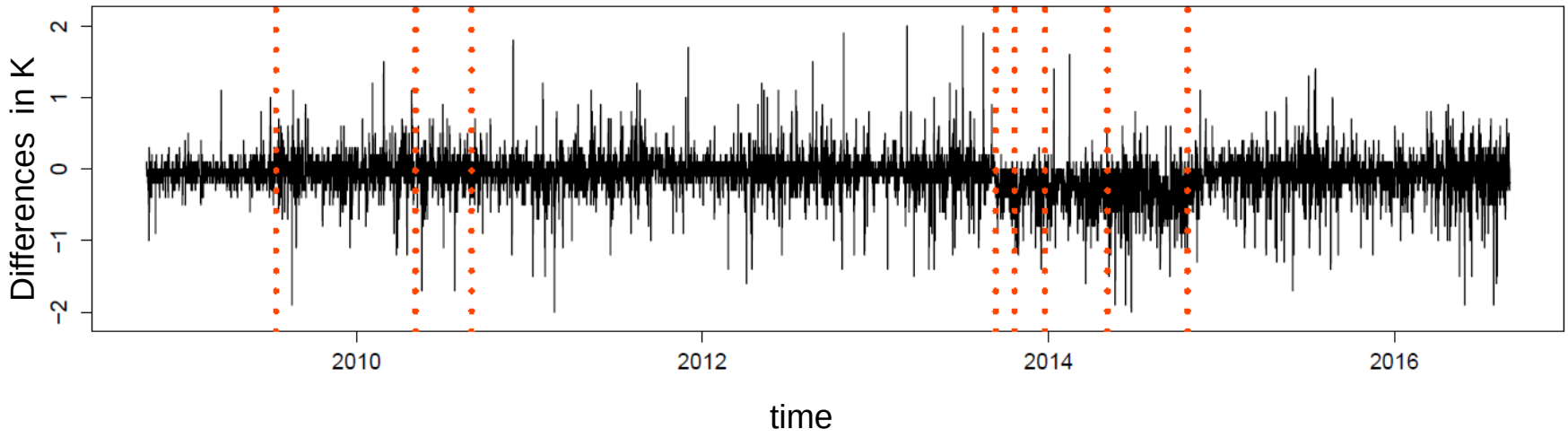
What else?

Air temperature at station Hohenpeißenberg



Air temperature at station Hohenpeißenberg

Differences of automatic minus manual measurements at traditional observing times



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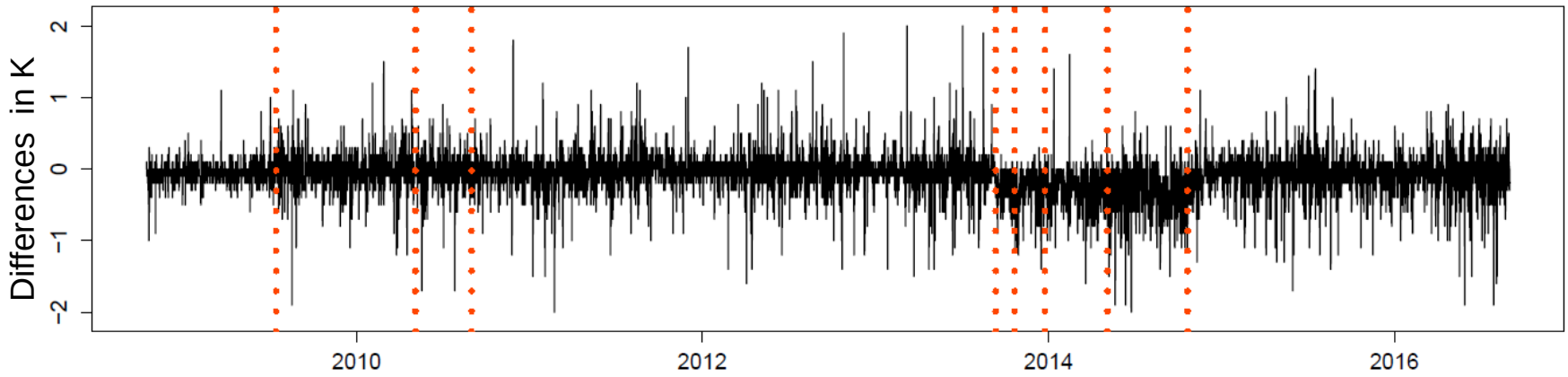


Data quality control

Breakpoint detection methods

uniseg

- ➔ Using dynamic programming algorithm for joint segmentation
- ➔ Maximum likelihood criterion

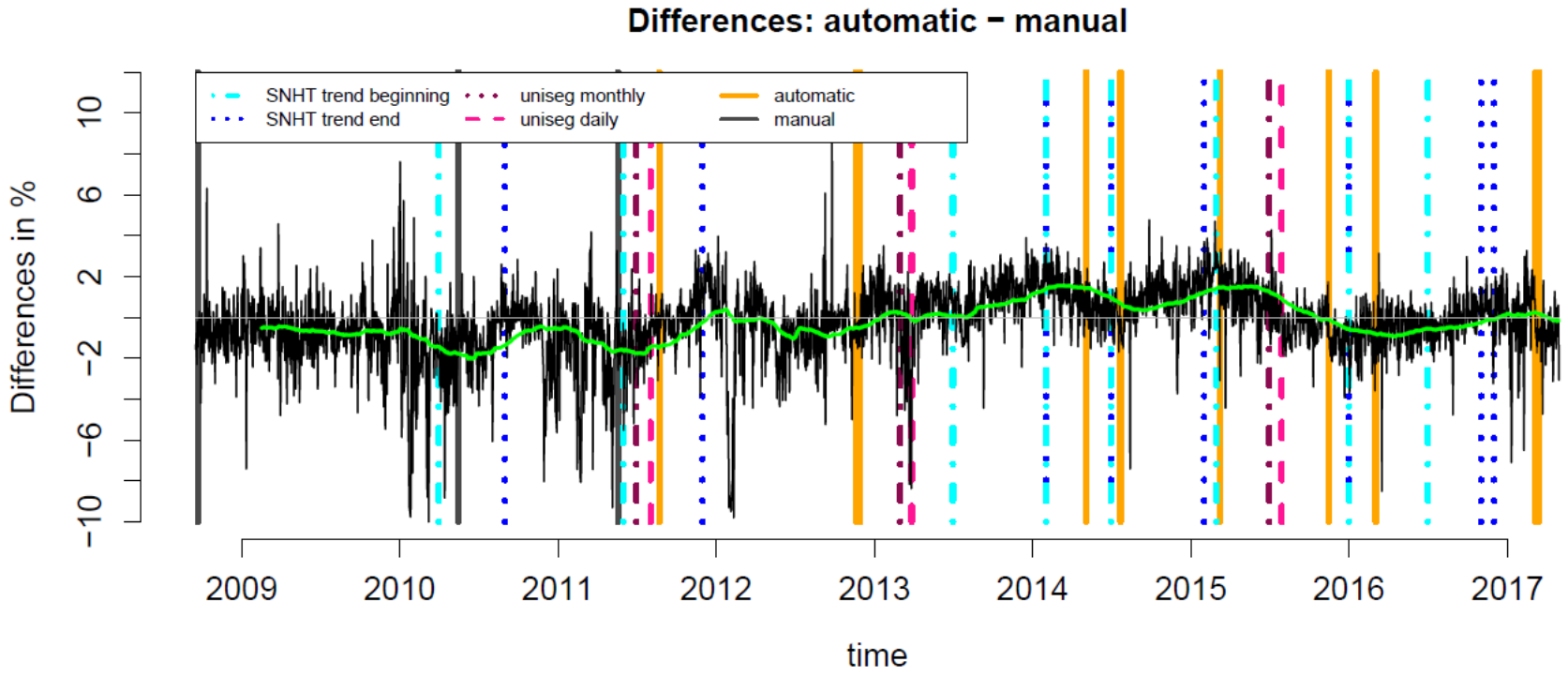
Picard et al., 2016

SNHT Trend Test

- ➔ Detects changes in the mean value
- ➔ Using moving window

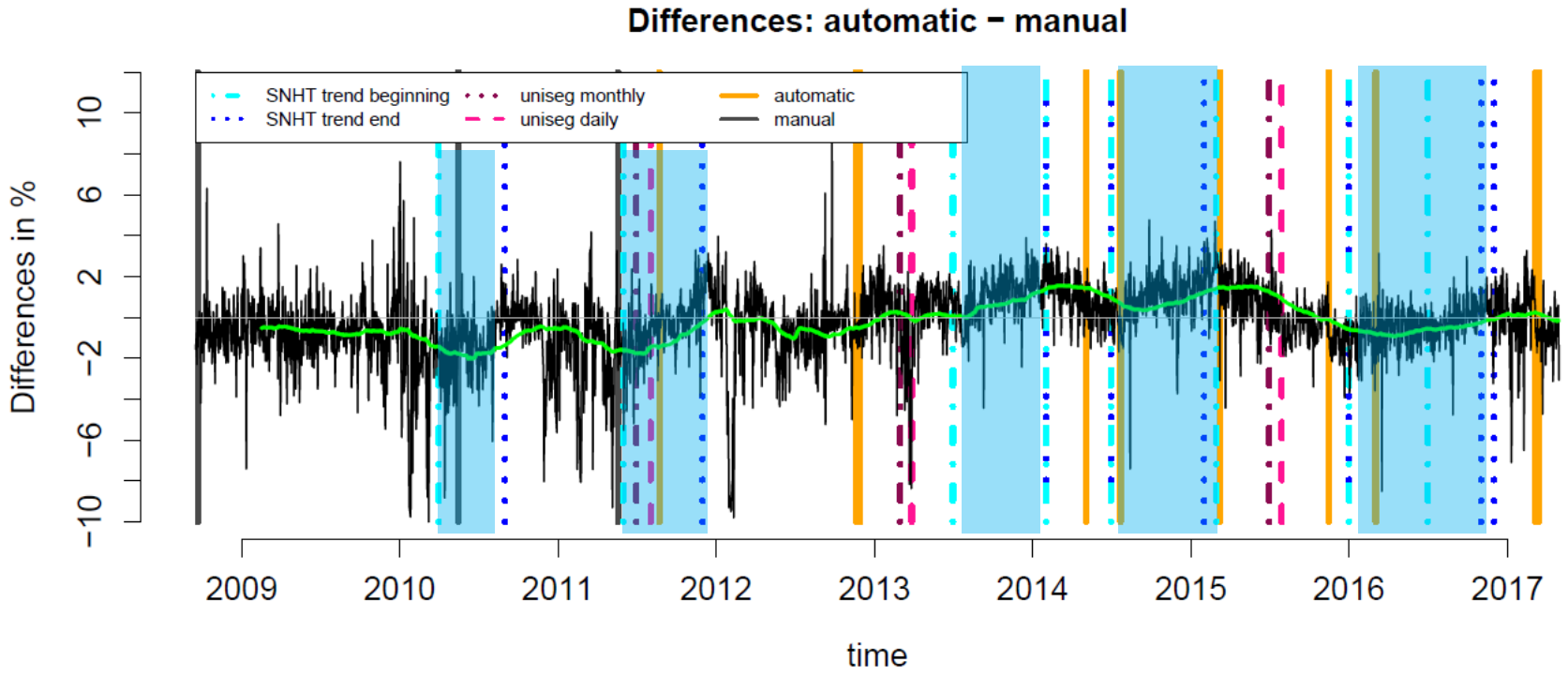
Alexandersson and Moberg, 1997

Data quality control



Relative humidity at station Lindenberg

Data quality control



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Analysis of comparability

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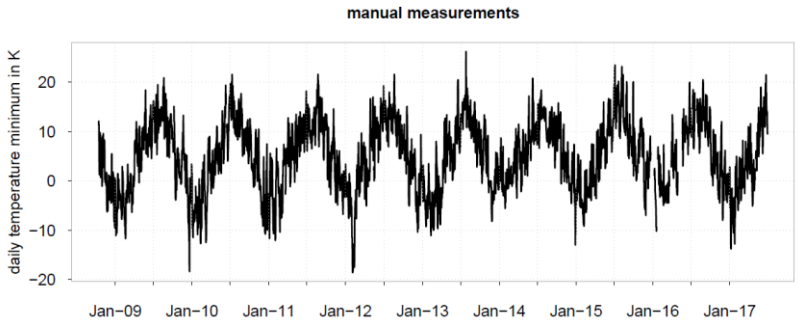
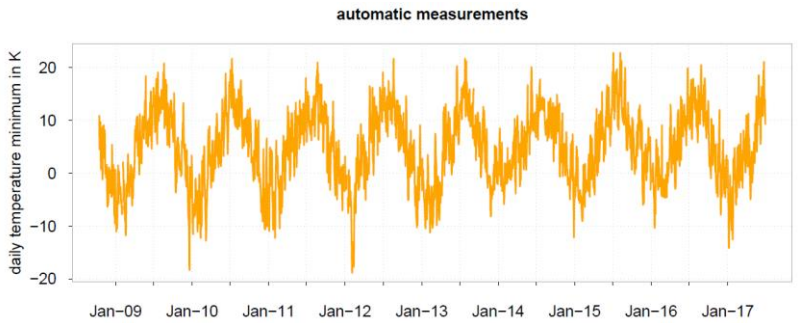


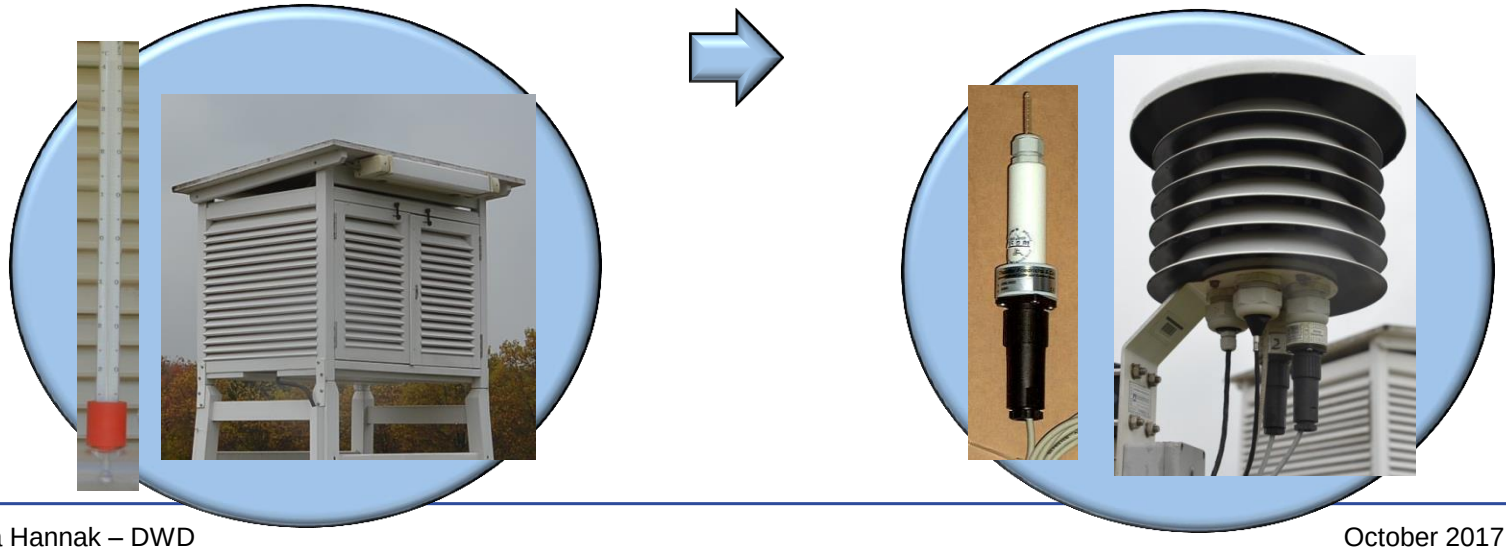


Analysis of comparability - Air temperature

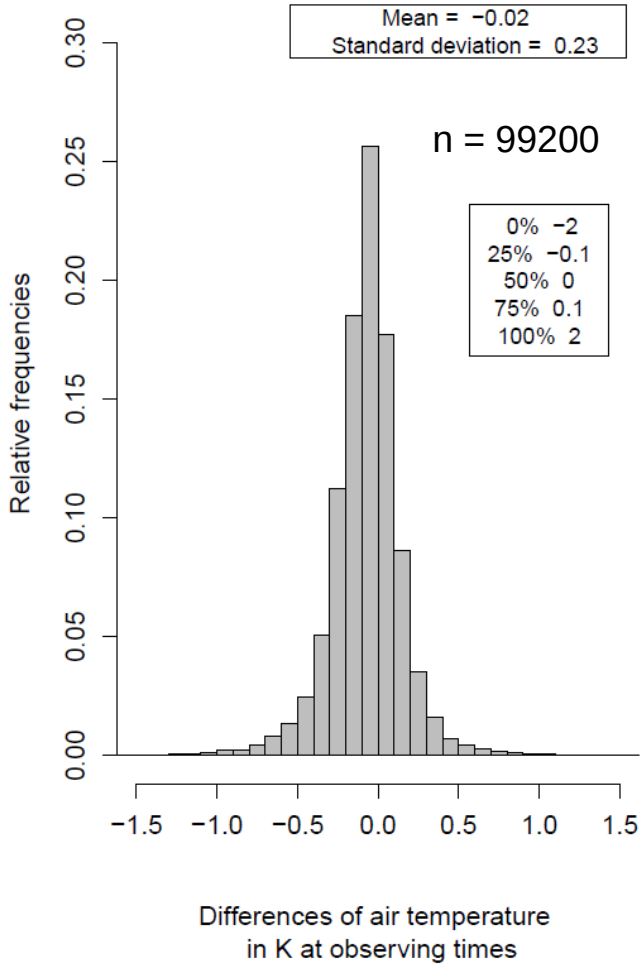
➔ Compare measurements of manual and automatic sensors

mercury in glass thermometer
in a stevenson shelter (most cases)

Pt100-sensor
in a lamellar shelter LAM 630 (most cases)



Air temperature (all stations)



Differences:
automatic minus manual measurements at 6:30 UTC, 13:30 UTC, and 20:30 UTC

Mean is close to zero, standard deviation is small

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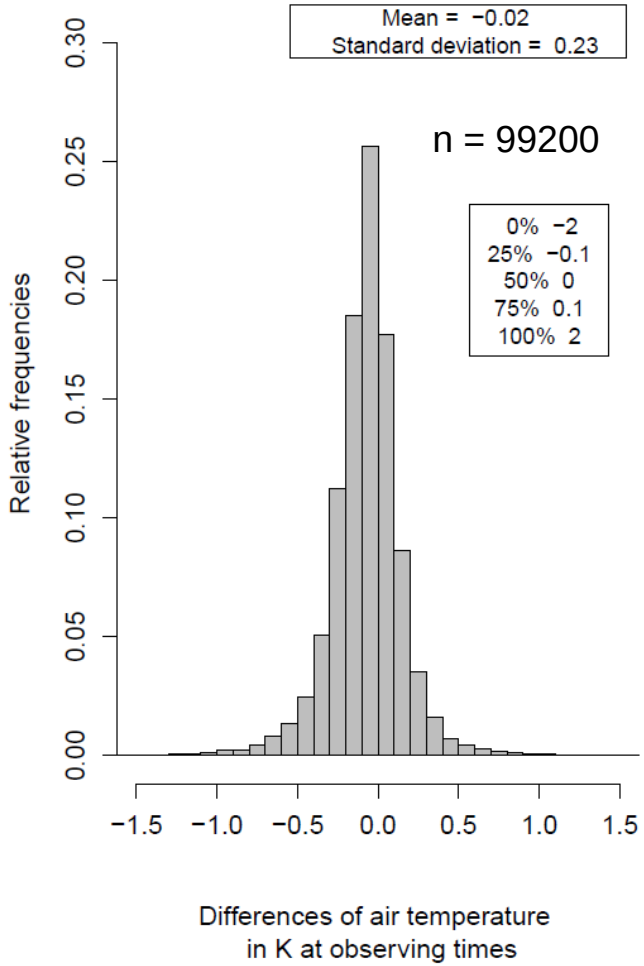

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automatic minus manual measurements at 6:30 UTC, 13:30 UTC, and 20:30 UTC

Mean is close to zero, standard deviation is small

measurement systems seem to be comparable

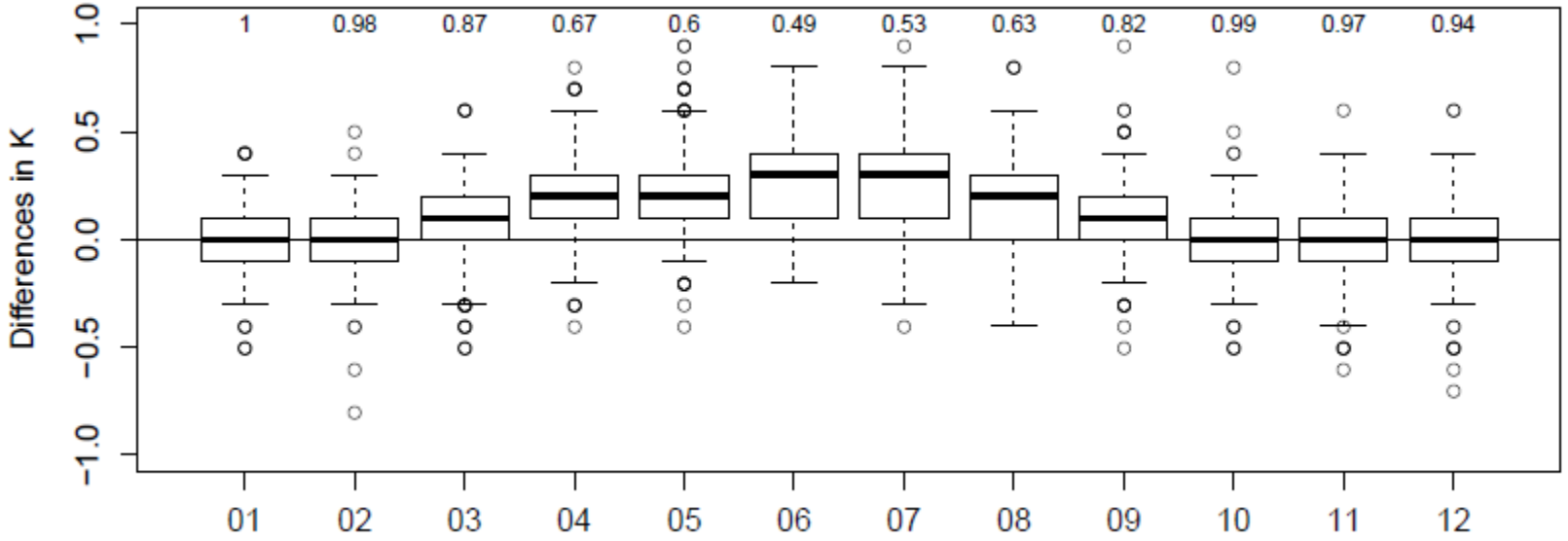
Systematic differences between measurement systems

Systematic differences between measurement systems

Daily maximum temperature

Systematic differences between measurement systems

➔ Differences of daily maximum temperature per months (station Potsdam)



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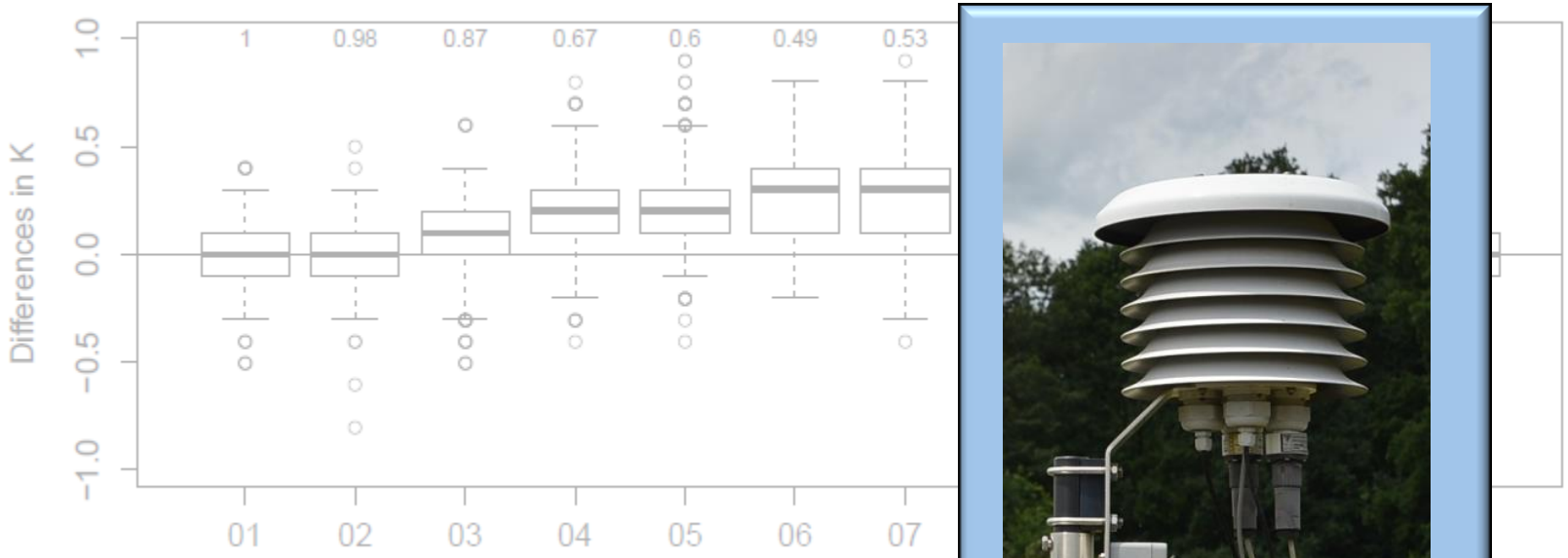


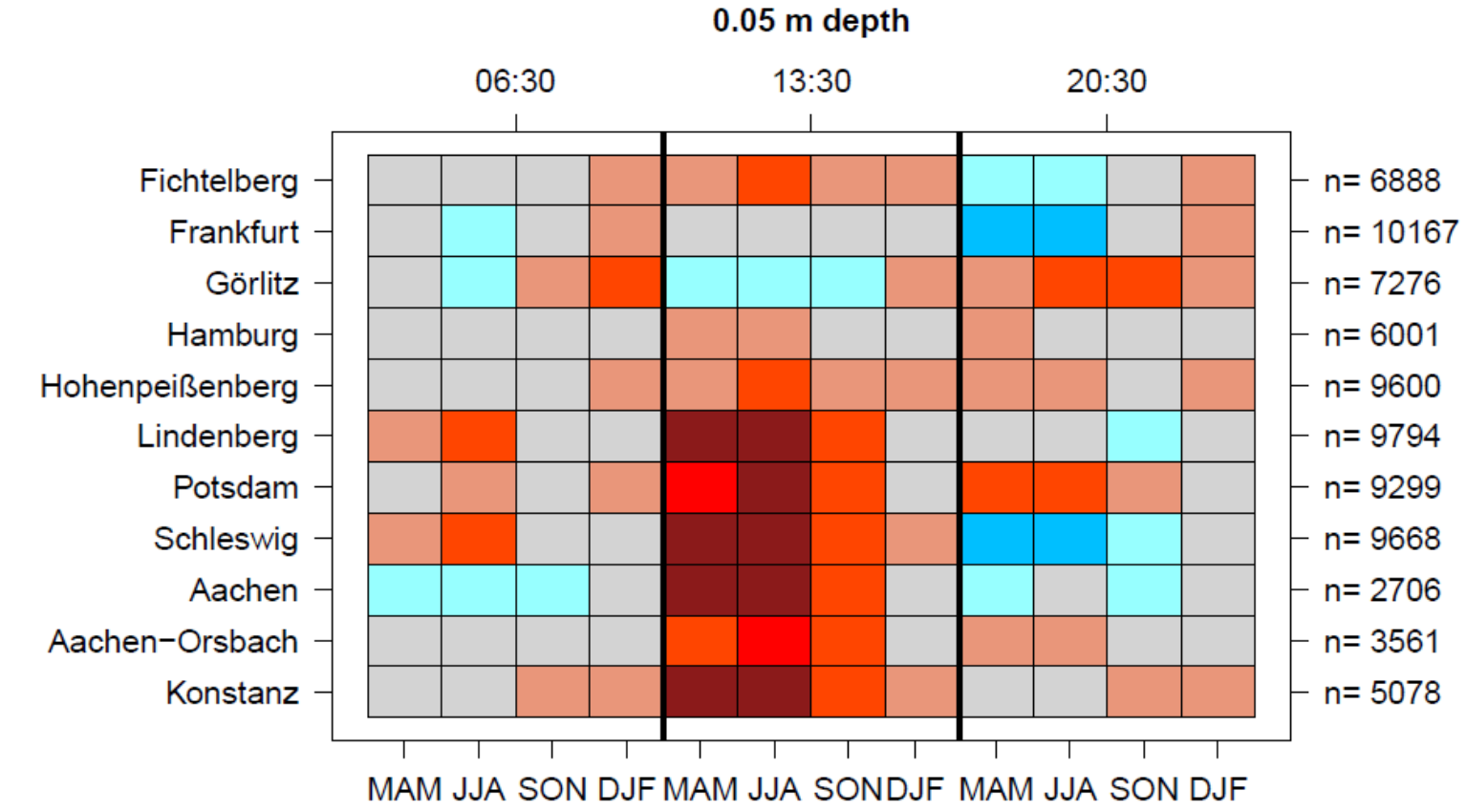
➔ radiation effect in the lamellar shelter LAM 630

Systematic differences between measurement systems

Soil temperature

Systematic differences between measurement systems

➔ Mean differences of soil temperature per season, station, observing times



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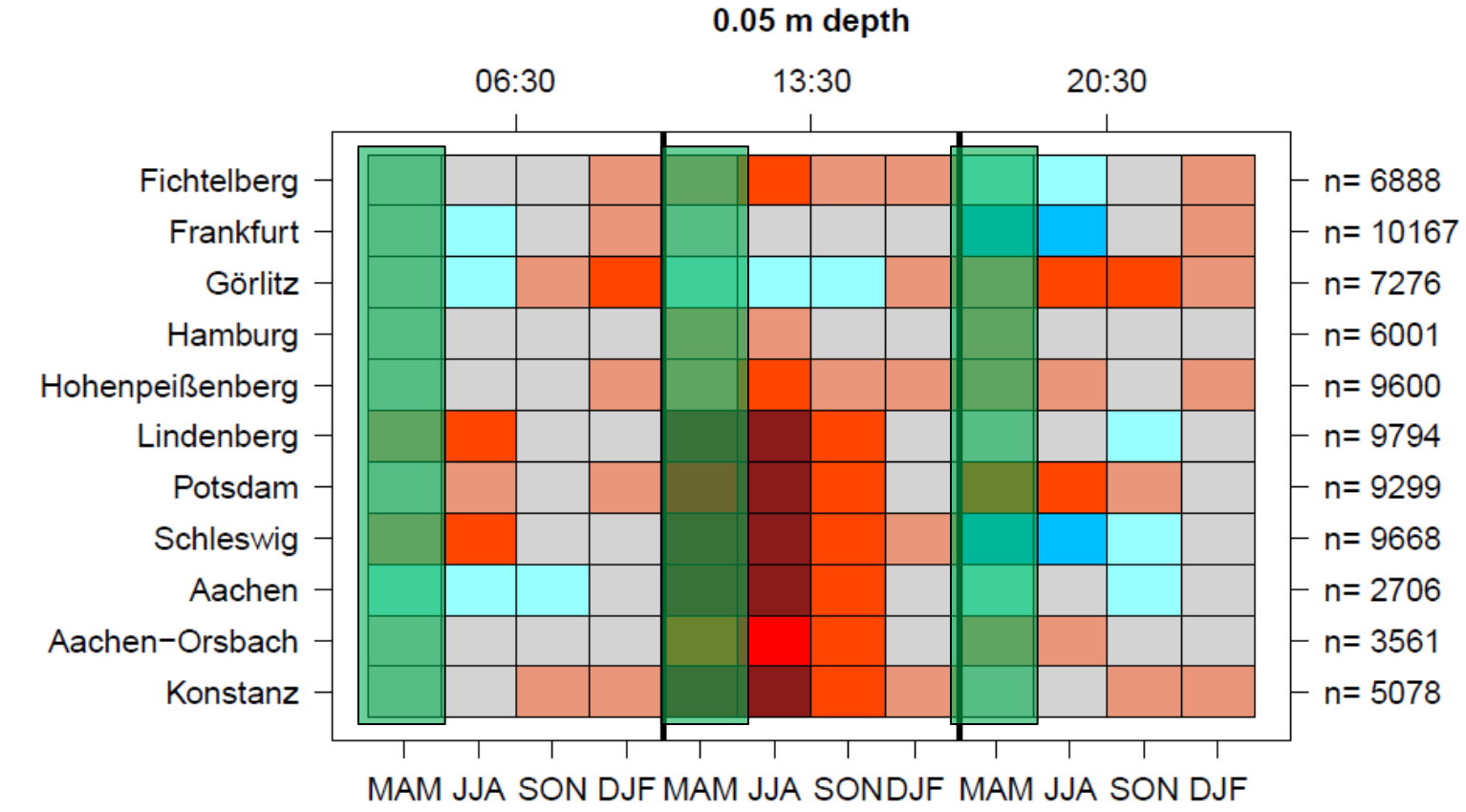

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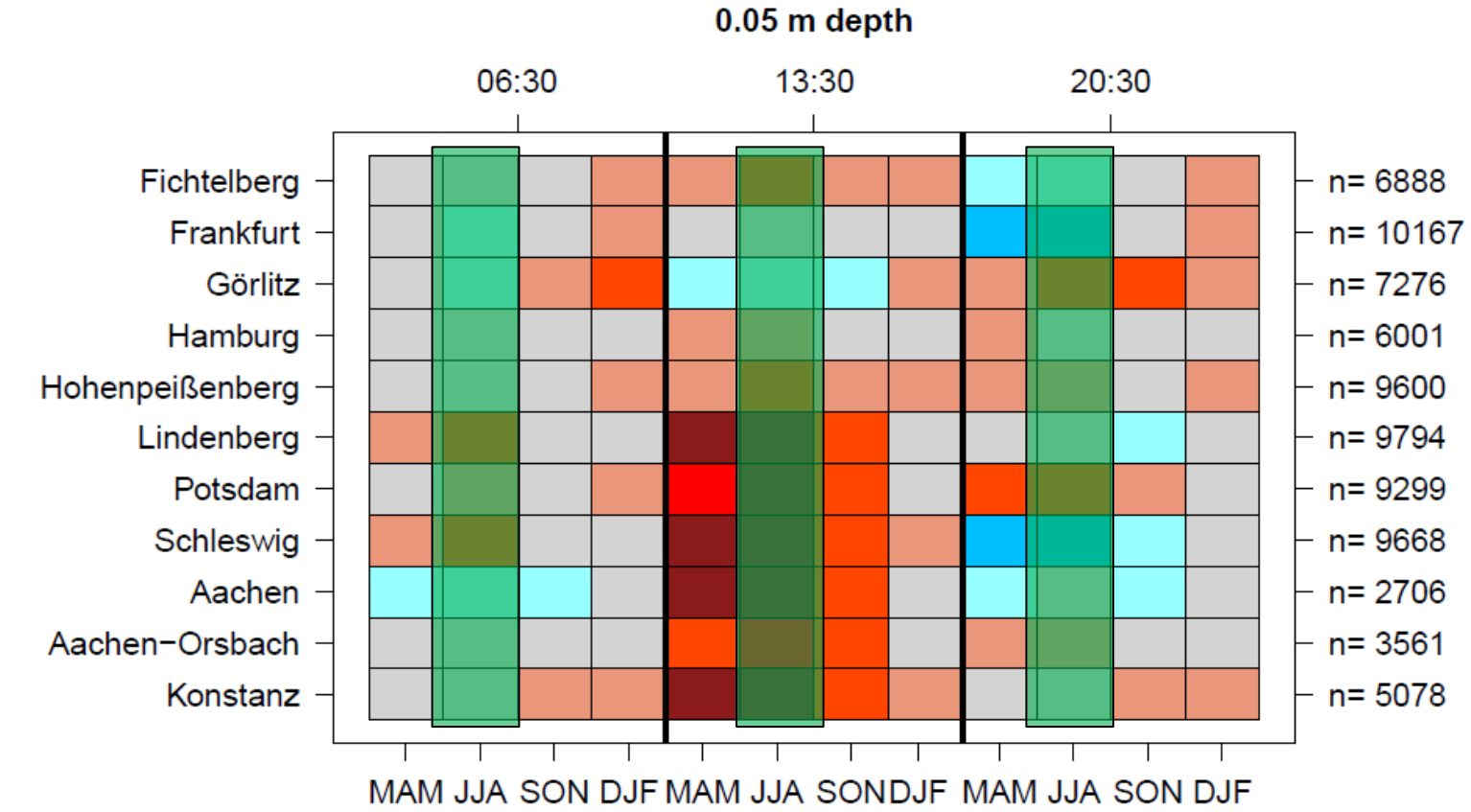

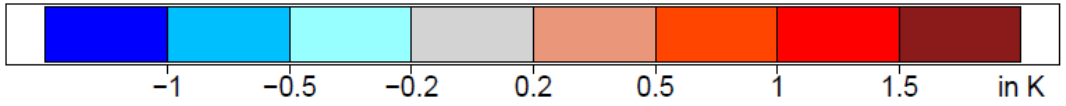

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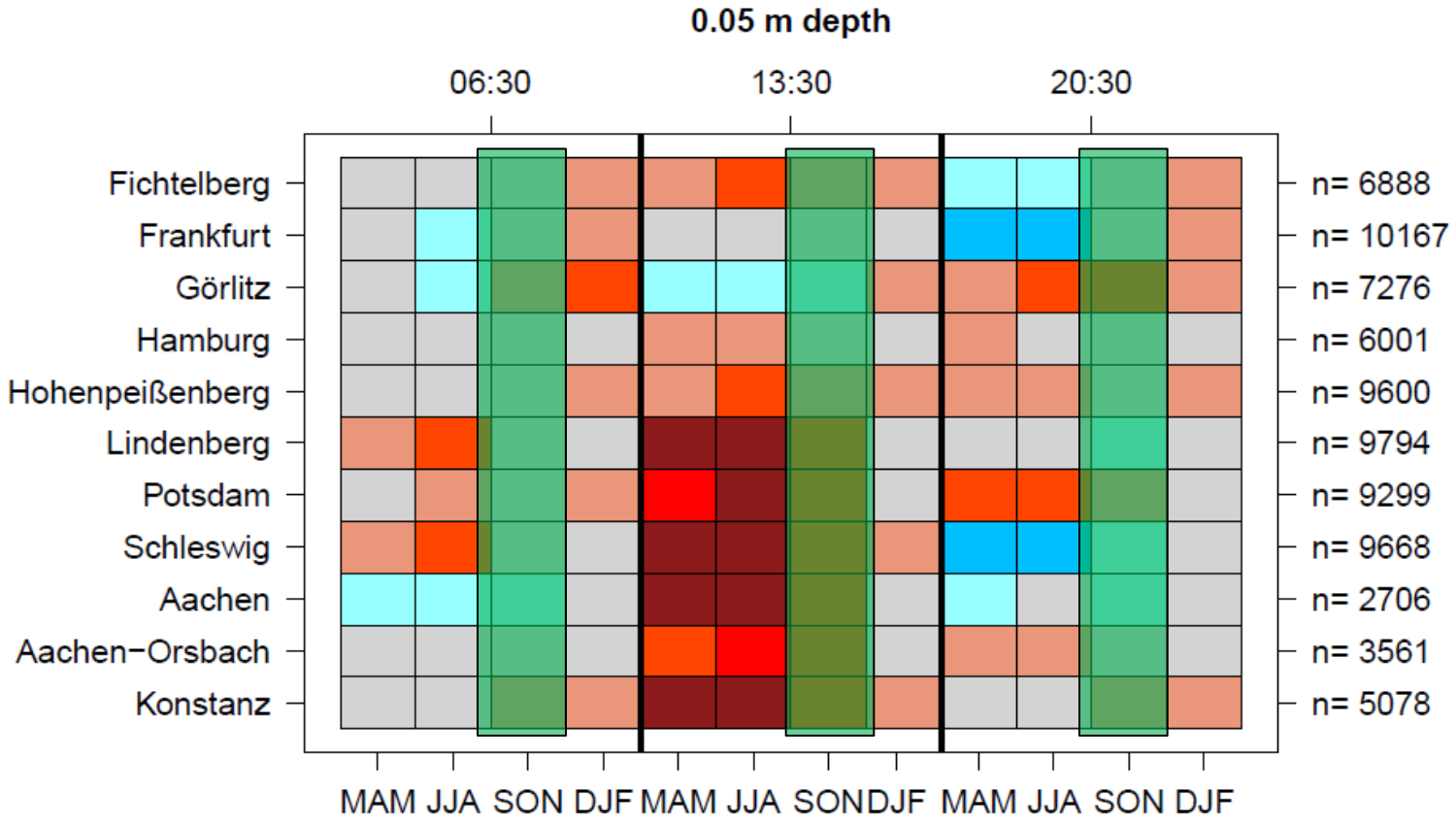

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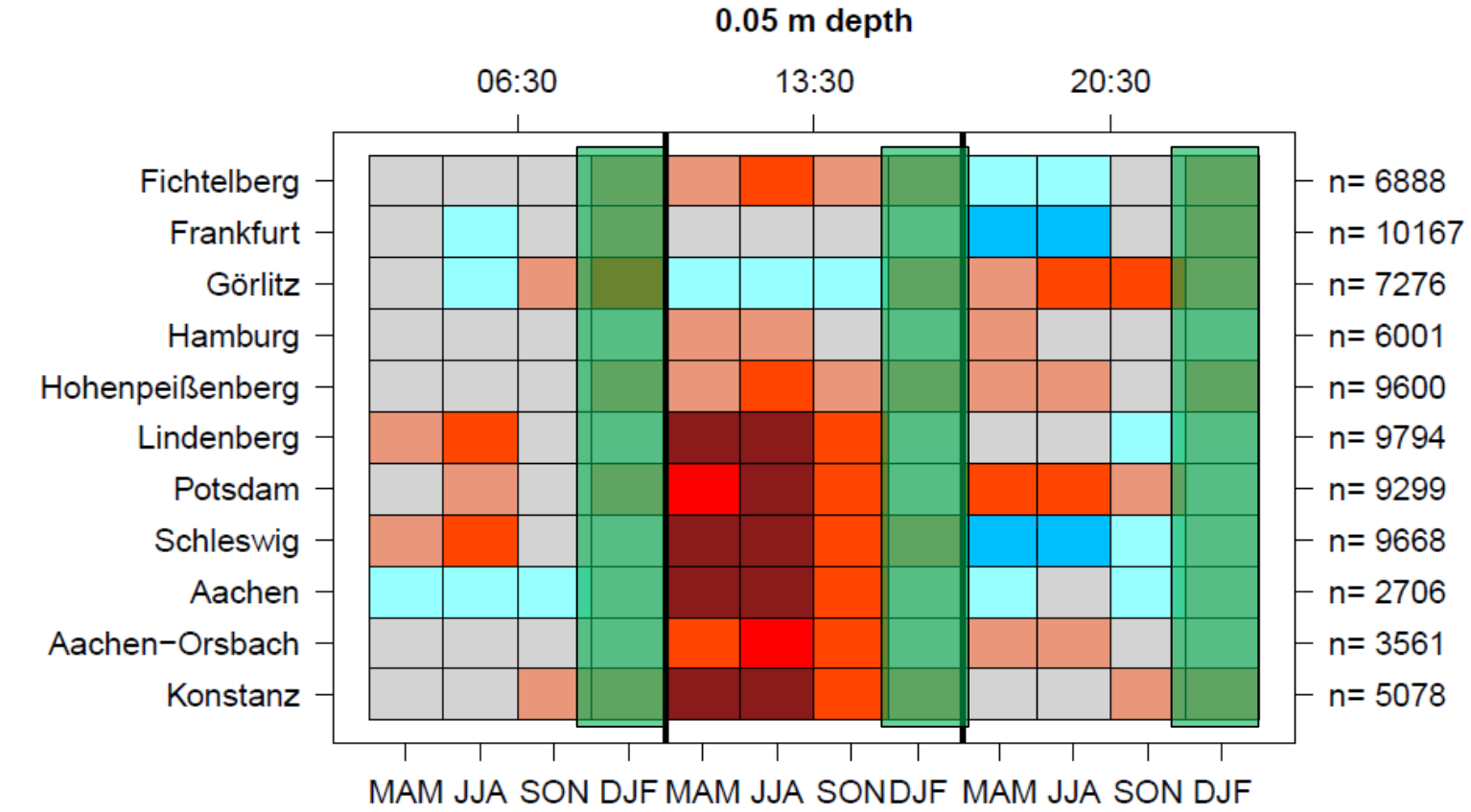

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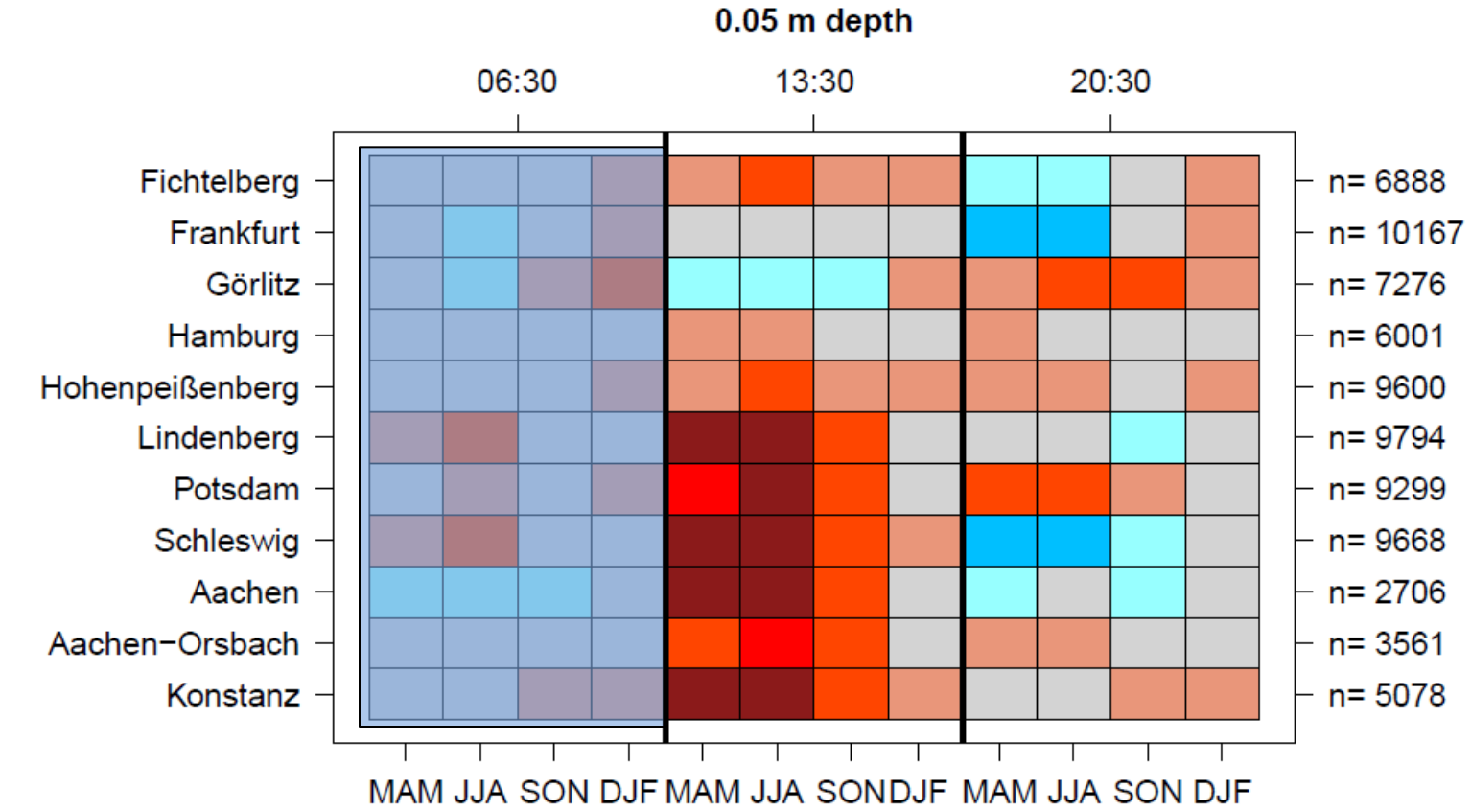

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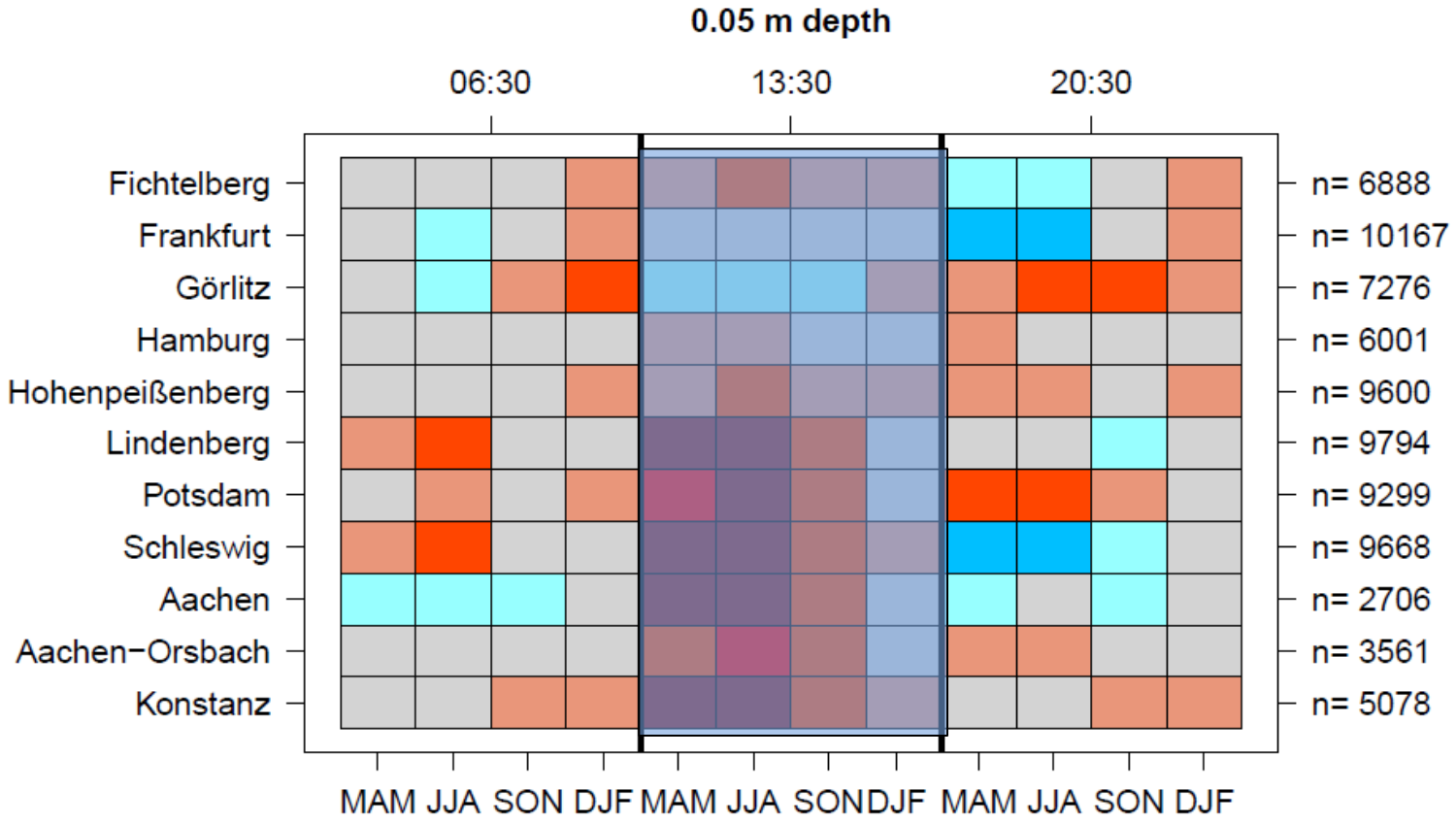

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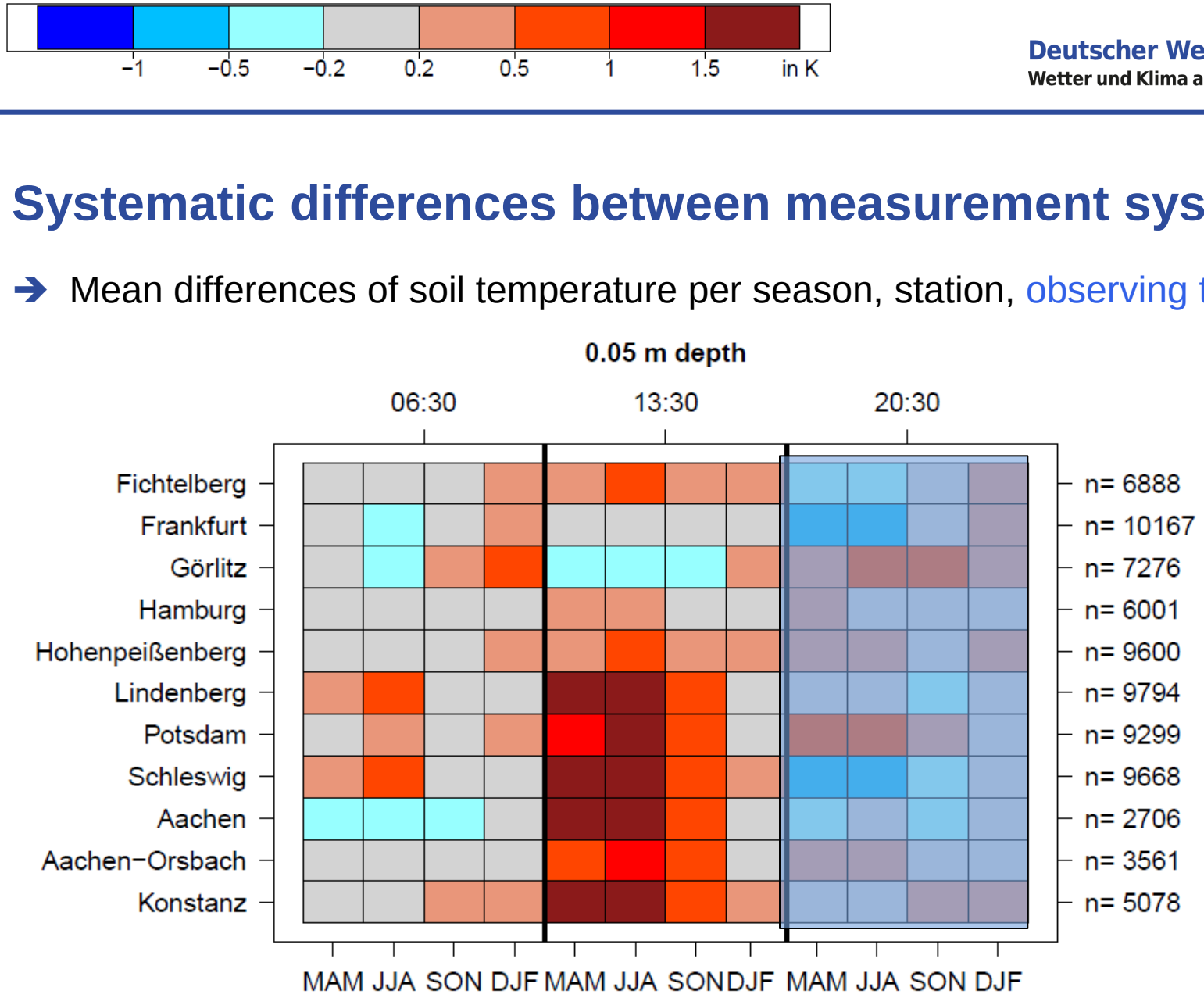

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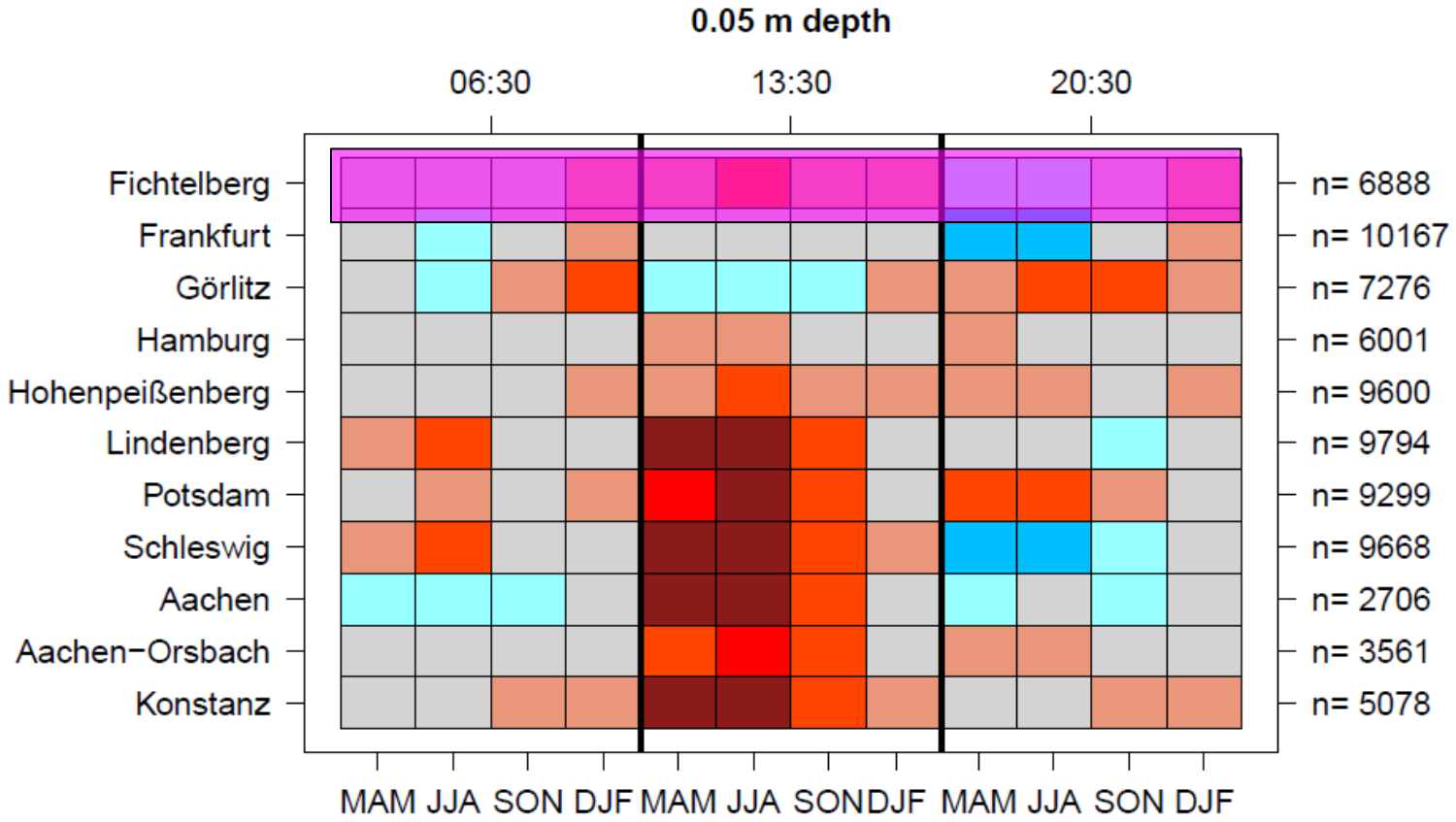

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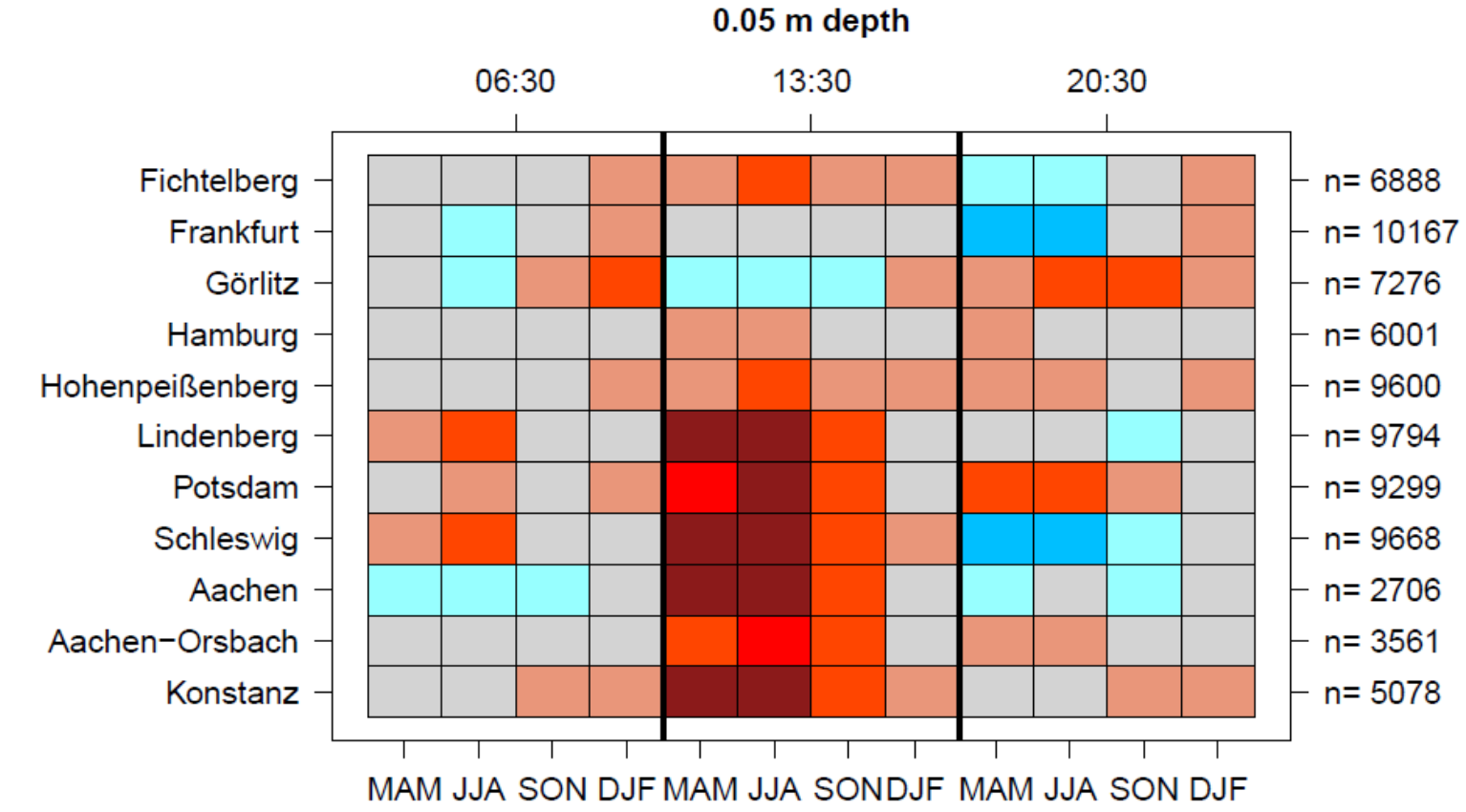
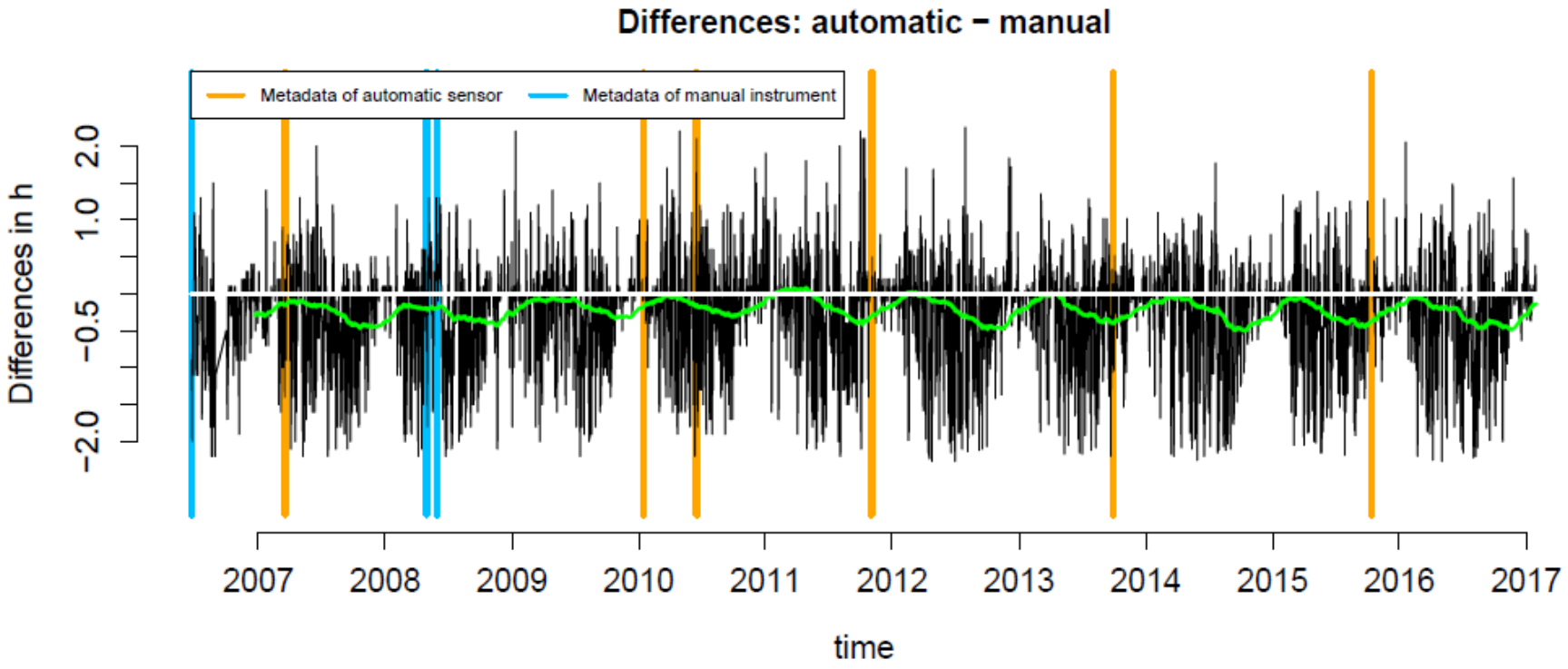


Systematic differences between measurement systems

Daily sunshine duration

Systematic differences between measurement systems

➔ Differences of daily sunshine duration (station Schleswig)



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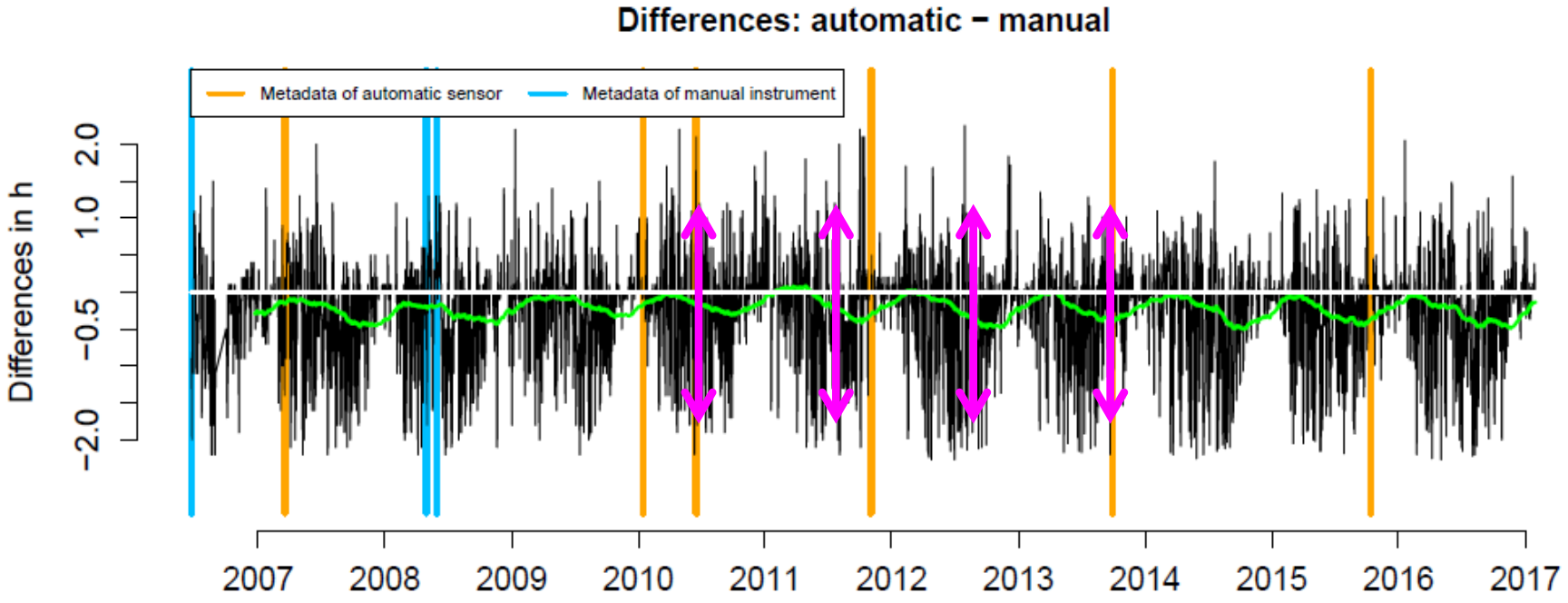
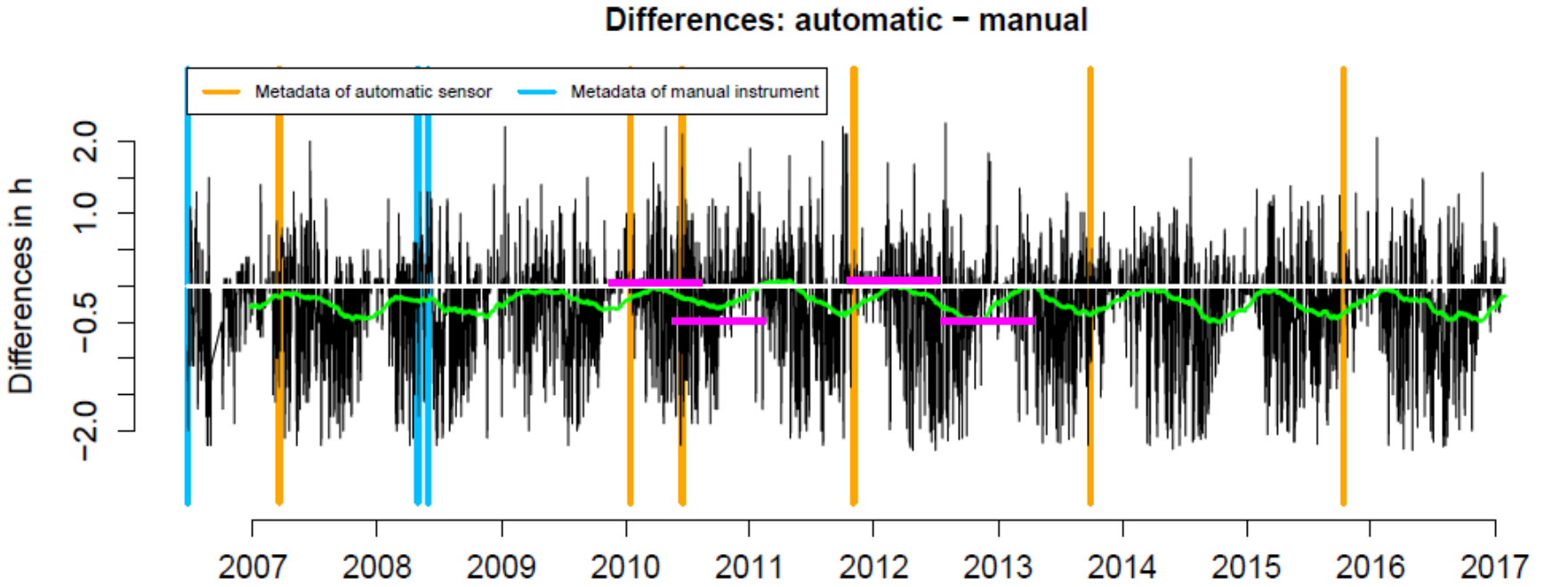


Larger standard deviation in summer because of longer days

Systematic differences between measurement systems

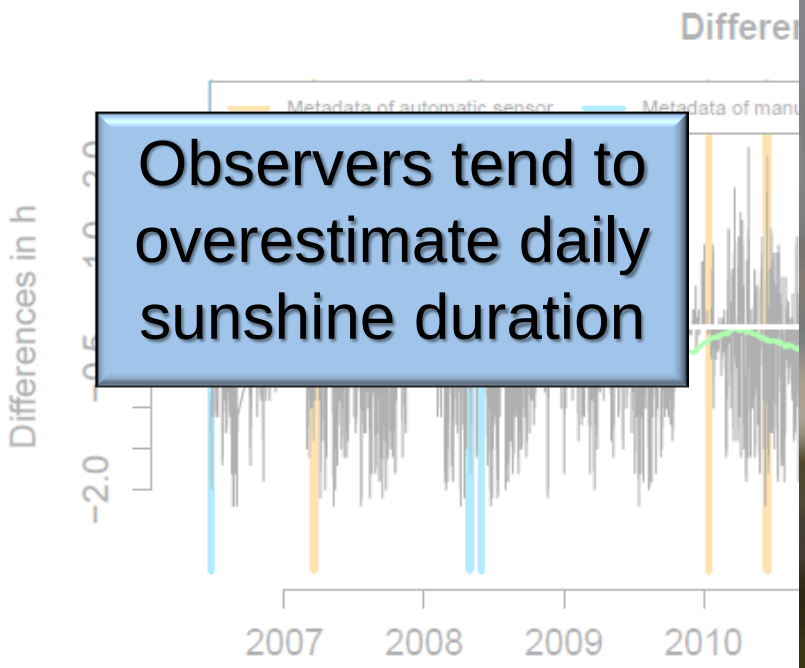
➔ Differences of daily sunshine duration (station Schleswig)



Summer: more sunshine (mean) in manual observations

Systematic differences between measurement systems

➔ Differences of daily sunshine dura

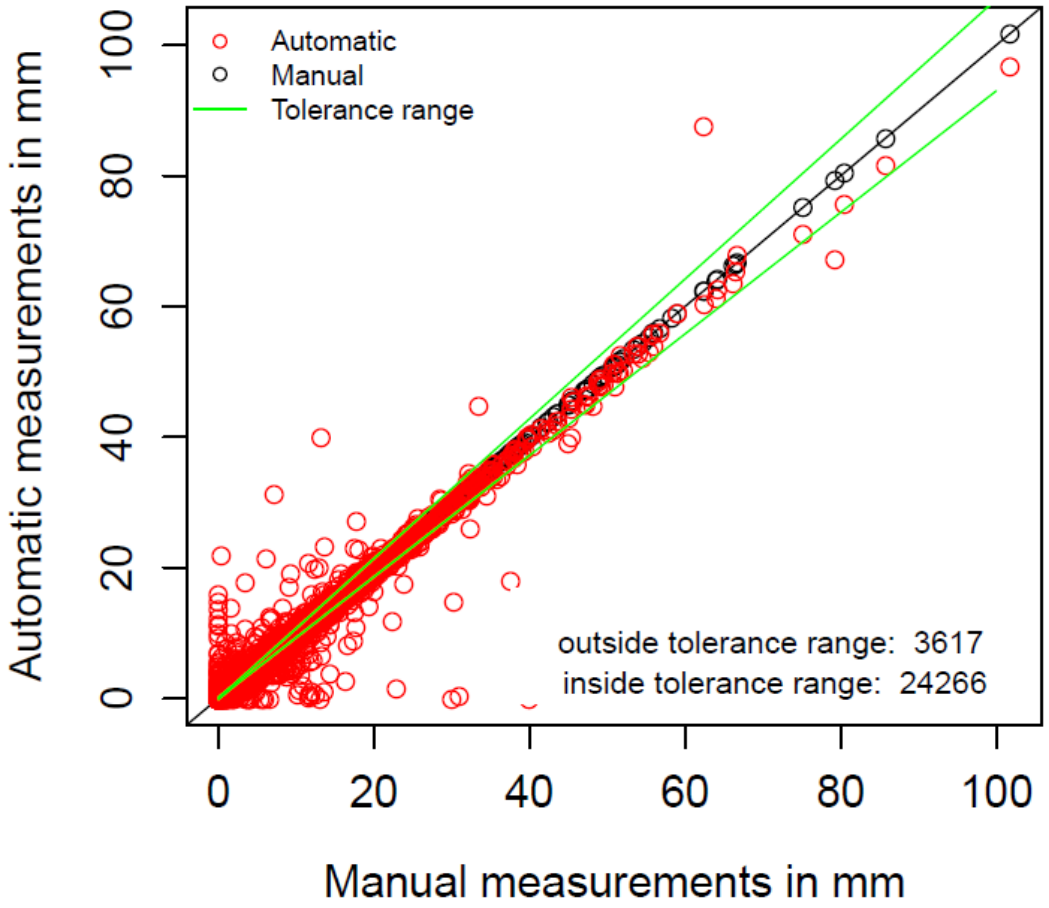


Observers tend to overestimate daily sunshine duration

Systematic differences between measurement systems

Daily precipitation amount

Systematic differences between measurement systems

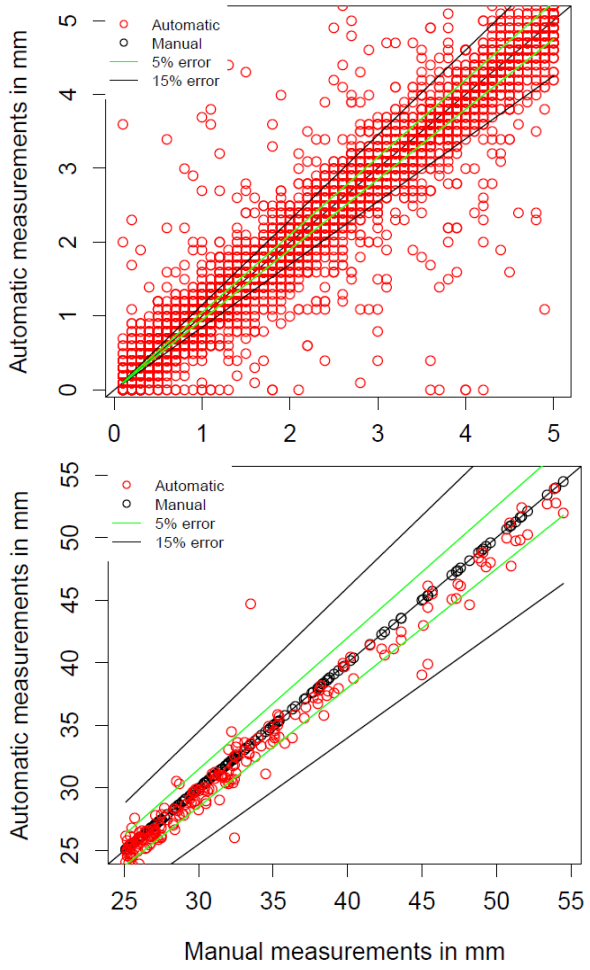


- Daily precipitation amount
- Reference = manual observations
- 87.1% inside tolerance range

Systematic differences between measurement systems

Small precipitation amounts:
Large relative error

Large precipitation amounts:
Underestimation of automatic observation



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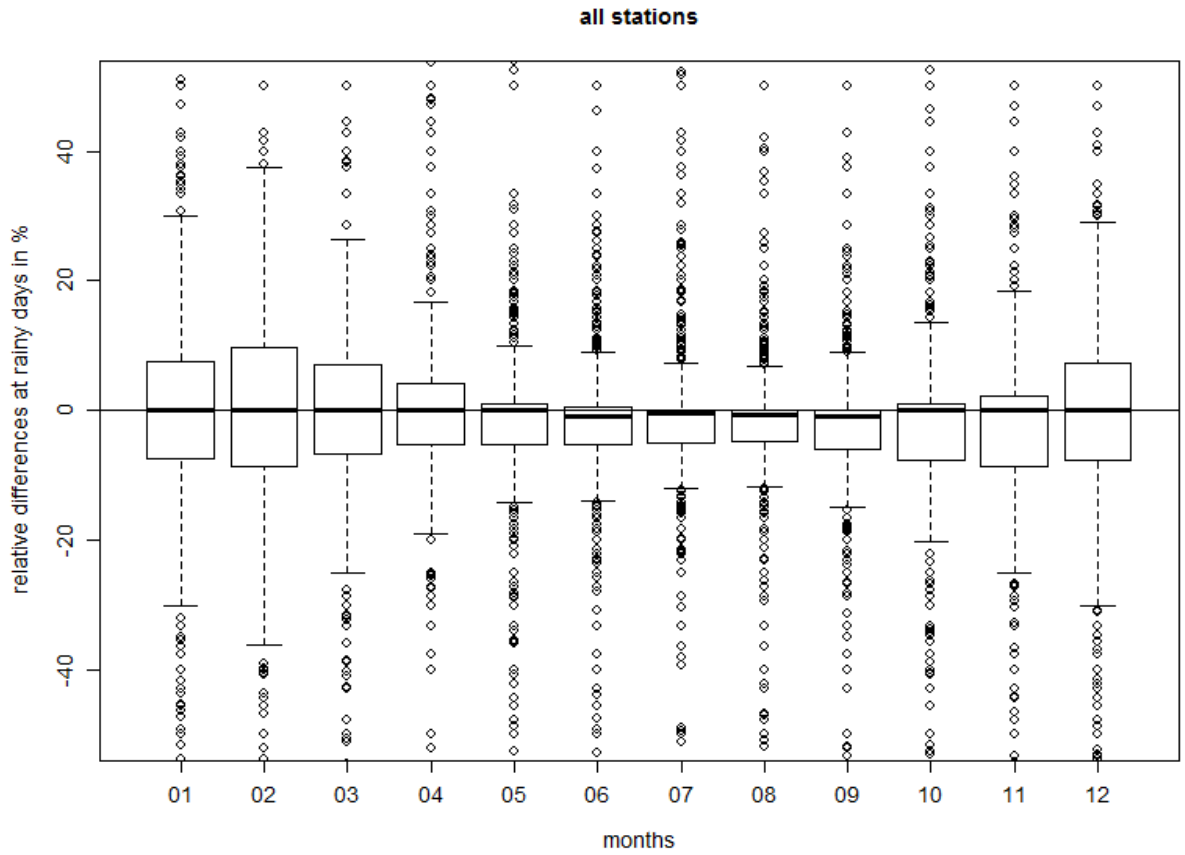

Relative error in winter larger than in summer

Summary and outlook

➔ Parallel measurements can be used for data quality control and analysis on homogeneity

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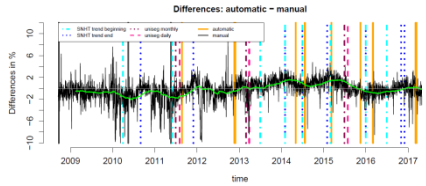
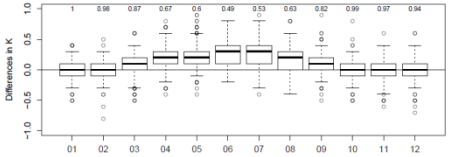
➔ Parallel measurements can be used for data quality control and analysis on homogeneity

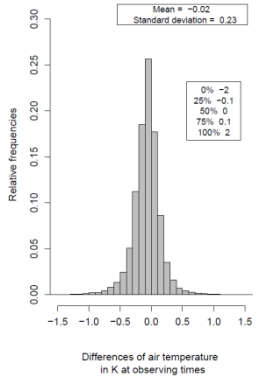
➔ Trend periods in automatic measurements of relative humidity





➔ Annual cycle in differences of daily maximum temperature, soil temperature, sunshine duration

➔ Temperature measurements at traditional observing times seem to be comparable



Summary and outlook

- Parallel measurements can be used for data quality control and analysis on homogeneity

- Trend periods in automatic measurements of relative humidity
- Annual cycle in differences of daily maximum temperature, soil temperature, sunshine duration
- Temperature measurements at traditional observing times seem to be comparable

- To do:

  Homogenization of time series

  Correction of systematic differences

Summary and outlook

- Parallel measurements can be used for data quality control and analysis on homogeneity

- Trend periods in automatic measurements of relative humidity
- Annual cycle in differences of daily maximum temperature, soil temperature, sunshine duration
- Temperature measurements at traditional observing times seem to be comparable

- To do:
  - Homogenization of time series
  - Correction of systematic differences

Thank you for your attention!