Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Analysis of the impacts of the automatization of measurement systems using parallel measurements from German Climate Reference Stations

Lisa Hannak,
Frank Kaspar
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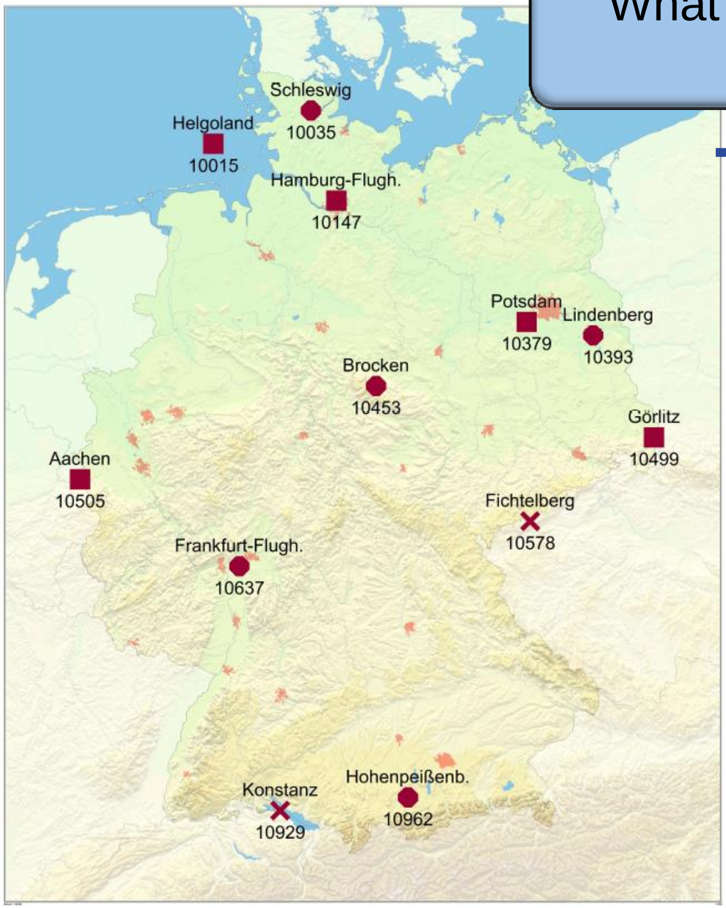
Climate Monitoring

Climate reference stations

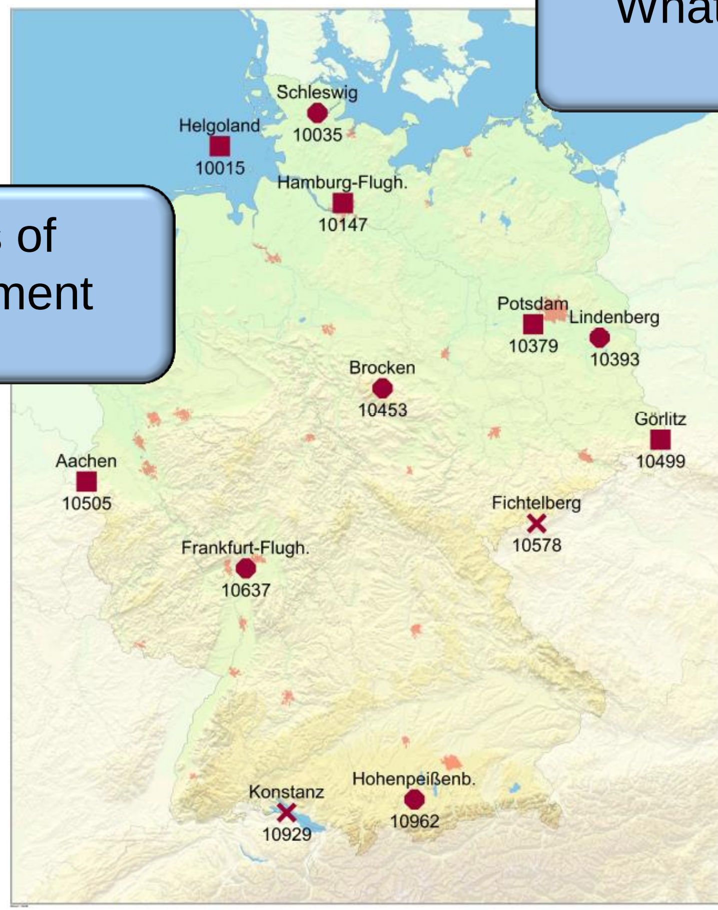


What is special about these stations?

➔ Parallel measurements

Climate reference stations

What is special about these stations?



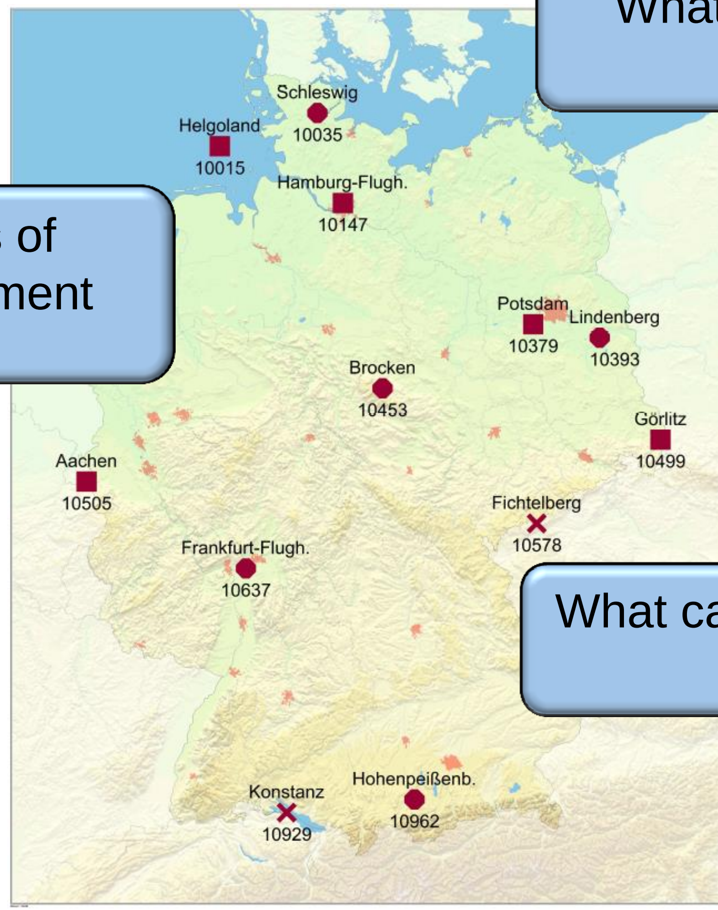
What are the impacts of changing the measurement system?

- ➔ Statistical analysis of the differences

Climate reference stations

What is special about these stations?

What are the impacts of changing the measurement system?



What can we learn from parallel measurements?

➔ conclusions

Climate reference stations: Parallel measurements

The early instrumental warm-bias: a solution for long central European temperature series 1760–2007

Reinhard Böhm · Philip D. Jones · Johann Hiebl ·
David Frank · Michele Brunetti · Maurizio Maugeri

Comparison of daily sunshine duration recorded by Campbell–Stokes and Kipp and Zonen sensors

Tim Legg
Hadley Centre, Met Office, Exeter

The international surface temperature initiative global land surface databank: monthly temperature data release description and methods

J. J. Rennie[1*], J. H. Lawrimore[2], B. E. Gleason[2], P. W. Thorne[1,3], C. P. Morice[4], M. J. Menne[2], C. N. Williams[2], W. Gambi de Almeida[5], J.R. Christy[6], M. Flannery[7], M. Ishihara[8], K. Kamiguchi[8], A. M. G. Klein-Tank[9], A. Mhanda[10], D. H. Lister[11], V. Razuvaev[12], M. Renom[13], M. Rusticucci[14], J. Tandy[4], S. J. Worley[15], V. Venema[16], W. Angel[2], M. Brunet[11,17], B. Dattore[15], H. Diamond[2], M. A. Lazzara[18], F. Le Blancq[19], J. Luterbacher[20], H. Mächel[21], J. Revadekar[22], R. S. Vose[2] and X. Yin[23]

The minimization of the *screen bias* from ancient Western Mediterranean air temperature records: an exploratory statistical analysis

Manola Brunet,[a,b*] Jesús Asin,[c] Javier Sigró,[a] Manuel Bañón,[d] Francisco García,[e] Enric Aguilar,[a] Juan Esteban Palenzuela,[f] Thomas C. Peterson[g] and Phil Jones[b]
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Review

Assessment of parallel precipitation measurements networks in Piedmont, Italy

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[a] *Dipartimento di Scienze della Terra, Università di Torino, Italy*
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THE NATIONAL WEATHER SERVICE MMTS (MAXIMUM-MINIMUM TEMPERATURE SYSTEM) – 20 YEARS AFTER

Nolan J. Doesken *
Colorado State University, Fort Collins, CO

Thermometer screen intercomparison in De Bilt (the Netherlands) – Part II: Description and modeling of mean temperature differences and extremes

T. Brandsma* and J. P. van der Meulen
Royal Netherlands Meteorological Institute (KNMI), De Bilt, the Netherlands

MEASUREMENT OF AIR TEMPERATURE IN THE PRESENCE OF A LARGE RADIANT FLUX: AN ASSESSMENT OF PASSIVELY VENTILATED THERMOMETER SCREENS

EVYATAR ERELL[1,*], VÍTOR LEAL[2] and EDUARDO MALDONADO[2]
[1] *Jacob Blaustein Institute for Desert Research, Ben-Gurion University of the Negev, 84990 Midreshet Ben-Gurion, Israel;* [2] *Instituto de Engenharia Mecânica, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal*

Preliminary results obtained following the intercomparison of the meteorological parameters provided by automatic and classical stations in Romania

Madalina Baciu, Violeta Copaciu, Traian Breza, Sorin Cheval, Ion Victor Pescaru

Climate reference stations: Parallel measurements

- At climate reference stations, conventional observation are measured in parallel to automatic measurement system
  - Air temperature, extreme temperatures, soil temperatures, pressure, relative humidity, sunshine duration, and precipitation

What is special about these stations?

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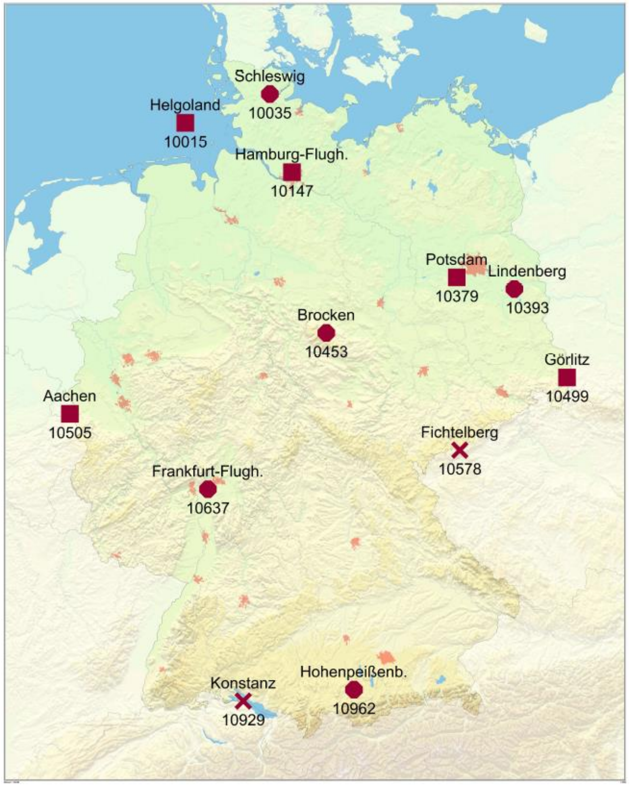


Climate reference stations with manual measurements (CRS I)

Climate reference stations where automatic sensors are measuring in parallel (CRS II)

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

Climate reference stations: Parallel measurements

- At climate reference stations, conventional observation are measured in parallel to automatic measurement system
  - Air temperature, extreme temperatures, soil temperatures, pressure, relative humidity, sunshine duration, and precipitation

- The aims:
  - Quality control of the measurements using these parallel measurements (Identify the uncertainty of measurements devices)
  - Analyze the impact of changing measurement systems on the homogeneity of long time series
  - Transfer of the results from the climate reference stations to other stations in the measuring network (to advance homogenization methods for long time series)

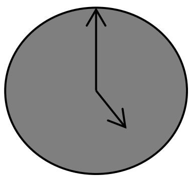
Air temperature

- Conventional observation: mercury in glass thermometer in a Stevenson shelter (most cases) read out at observing times (6:30 UTC, 13:30 UTC, 20:30 UTC)
- Automatic measurements: Pt100-sensor in a lamellar shelter LAM 630 (most cases)

Methods used for the analysis

- **Differences**: automatic minus conventional measurements at observing times (6:30 UTC, 13:30 UTC, 20:30 UTC)
- **Filter outliers**: differences > $\max(4 \cdot \frac{quantile_{0.75} - quantile_{0.25}}{1.349}, tolerance\ value)$

Methods used for the analysis



there are many ways to calculate daily mean values…

- (00+06+12+18)/4
- (05+13+21)/3
- (04+10+16+22)/4 (Regensburg 1841)
- (06+14+22)/3 (Prussia until 1886)
- (00+03+06+09+12+15+18+21)/8 (GDR 1967-90)
- (06+13+22)/3
- (Tn+Tx)/2 (individual stations eg. Bonn)
- (07+14+2*21)/4 (Prussia since 1887)
- …

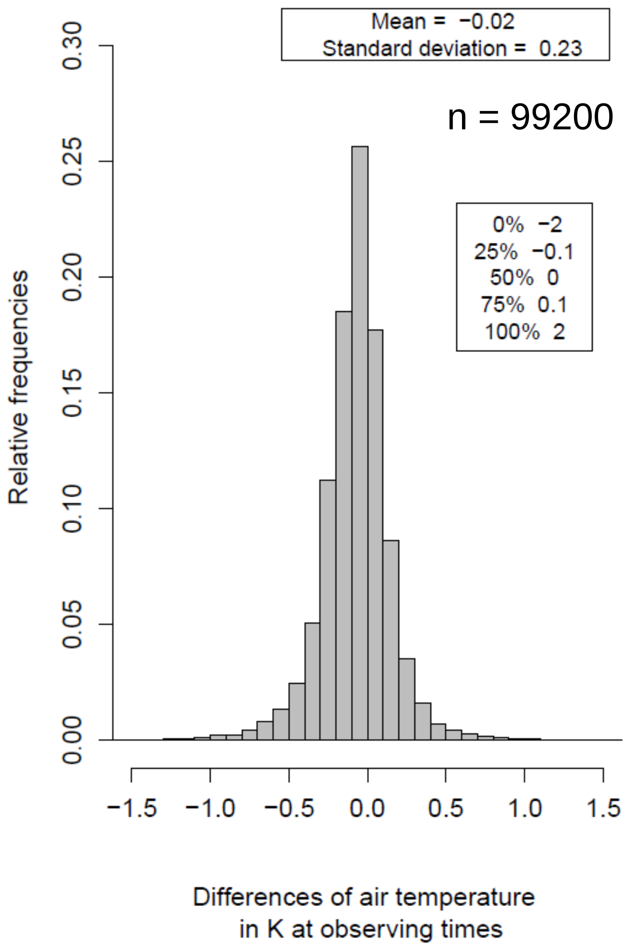
Methods used for the analysis

- **Differences**: automatic minus conventional measurements at observing times (6:30 UTC, 13:30 UTC, 20:30 UTC)
- **Filter outliers**: differences > max$(4 \cdot \frac{quantile_{0.75} - quantile_{0.25}}{1.349}, tolerance\ value)$
- **Daily means**:
  1. Traditional equation:

$$T_{mean} = \frac{T_{06:30} + T_{13:30} + 2T_{20:30}}{4}$$

  2. Arithmetic mean over 24 hourly values (only possible for automatic observations)

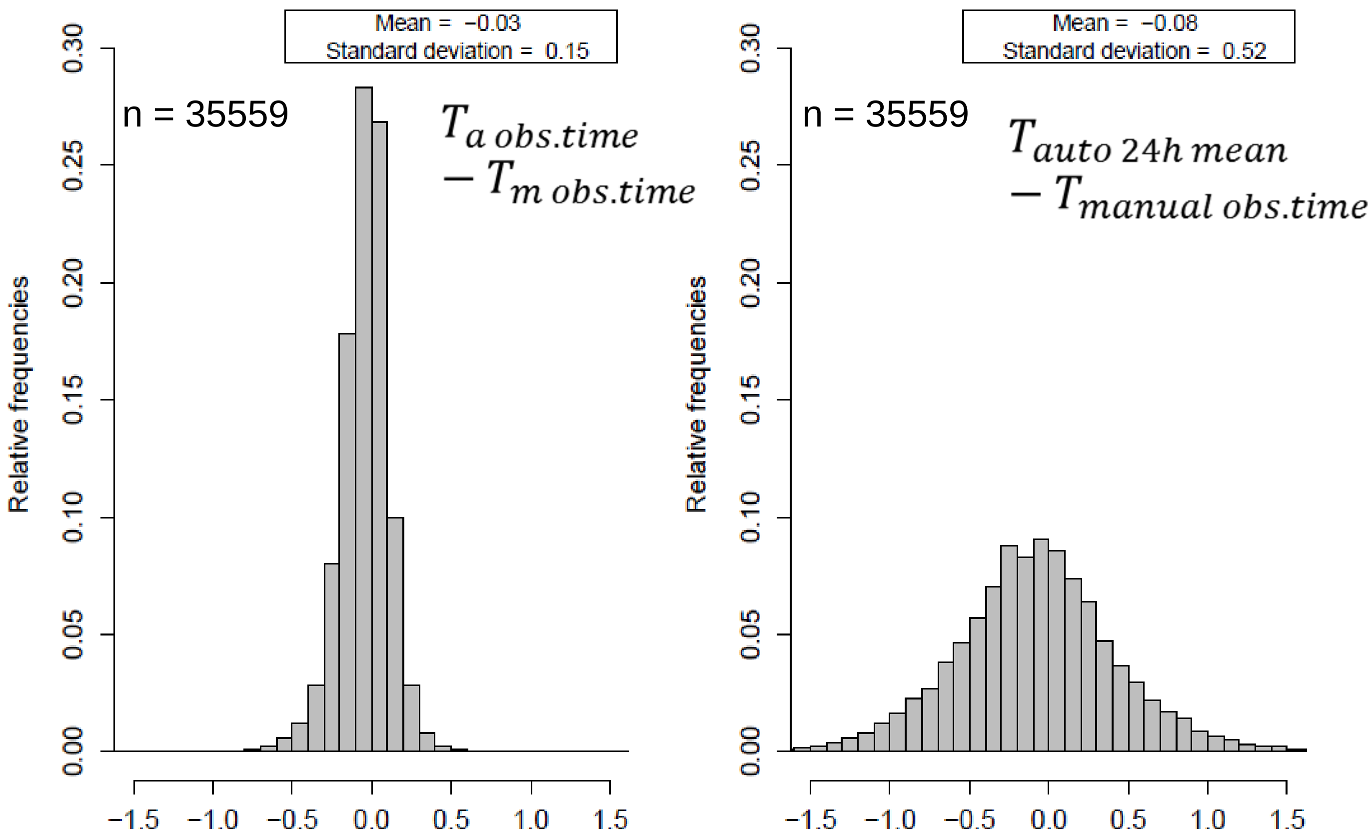
Air Temperature (at observing times)



- ➔ Differences from all climate reference stations were used
- ➔ Mean is close to zero, standard deviation is small
- ➔ Comparing the different measurements of temperature at observing times, the differences are small
  - ➔ We do not expect an artificial break

Kaspar et al. (2016), doi:10.5194/asr-13-163-2016

Air Temperature (daily mean)



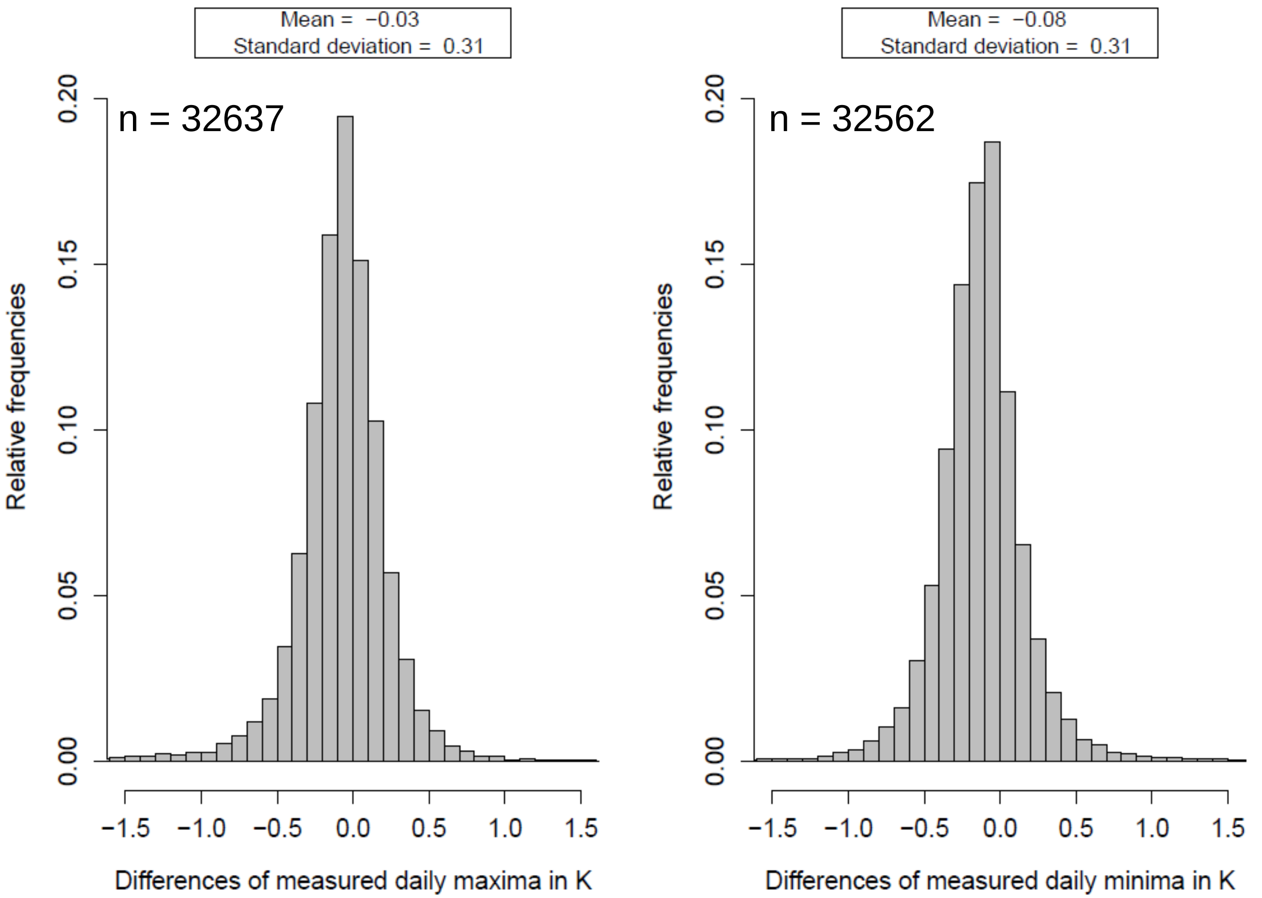
Differences of daily mean temperature in K calculated with measurements at observing times

Differences of daily mean temperature in K calculated with different methods

- All stations
- Left: similar to the results at observing times
- Right: standard deviation is more than three times as large as left BUT: the mean value is small

Kaspar et al. (2016), doi:10.5194/asr-13-163-2016

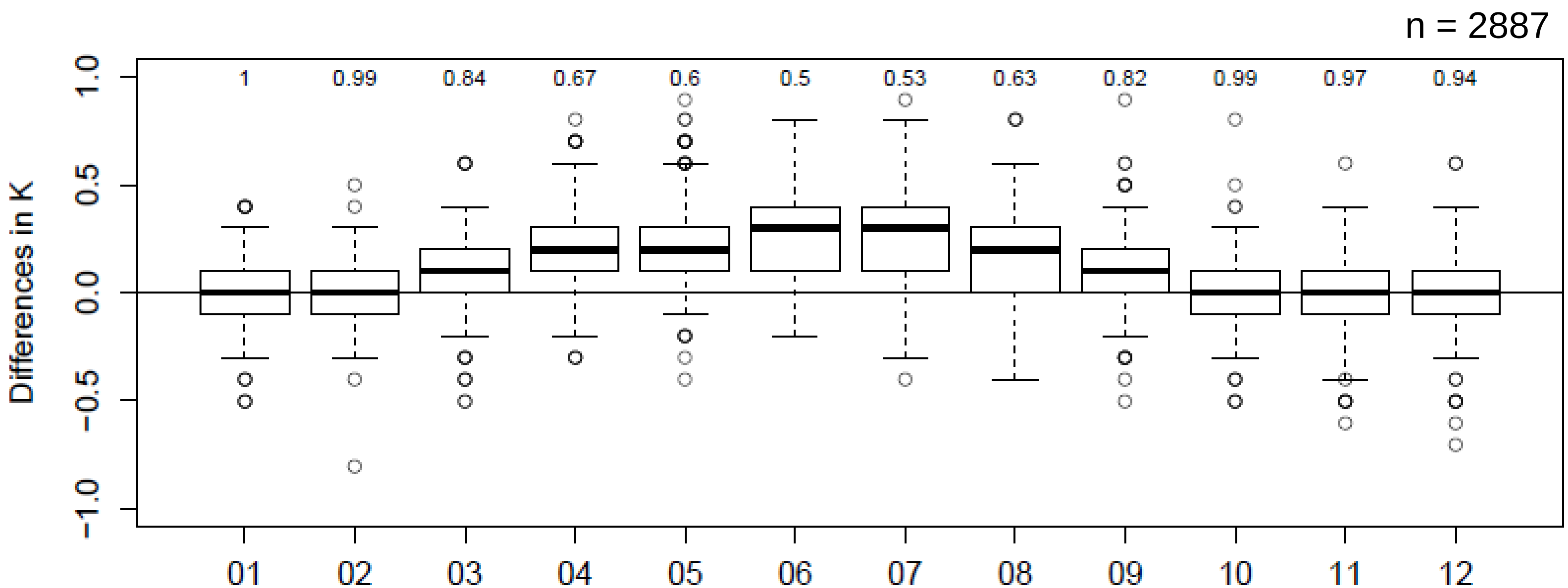
Extreme Temperature (20:30 UTC to 20:30 UTC)



- All stations
- The automatic system measures in average cooler temperature values than the conventional observations
- The standard deviation of the differences of daily extreme values is larger than at observing times

Kaspar et al. (2016), doi:10.5194/asr-13-163-2016

Temperature maxima (Potsdam)

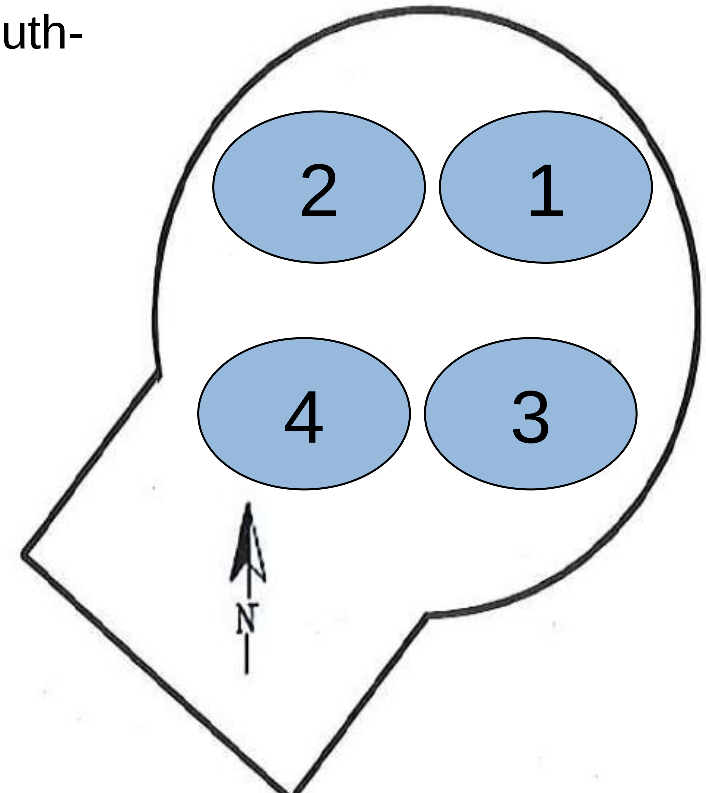


- ➔ Annual cycle in the difference time series
- ➔ Reason:
  - ➔ radiation effect in the lamellar shelter LAM 630
  - ➔ Station positioned on a mountain mostly do not use this kind of shelter and do not show an annual cycle in the differences (e.g. Fichtelberg)

Kaspar et al. (2016), doi:10.5194/asr-13-163-2016

Lamellar shelter LAM 630

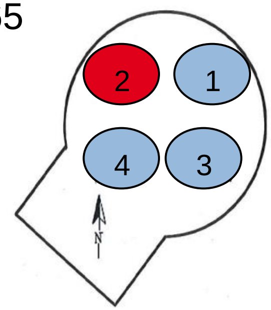
➔ Comparison of sensors which are at Position 1,2,3 show higher temperature at the south-east (3) position during midday



Differences of daily temperature maxima

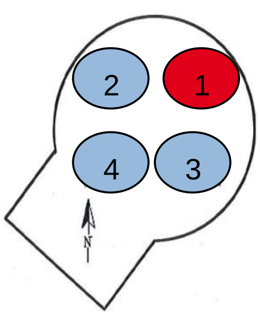
➔ Potsdam until 15.03.2016

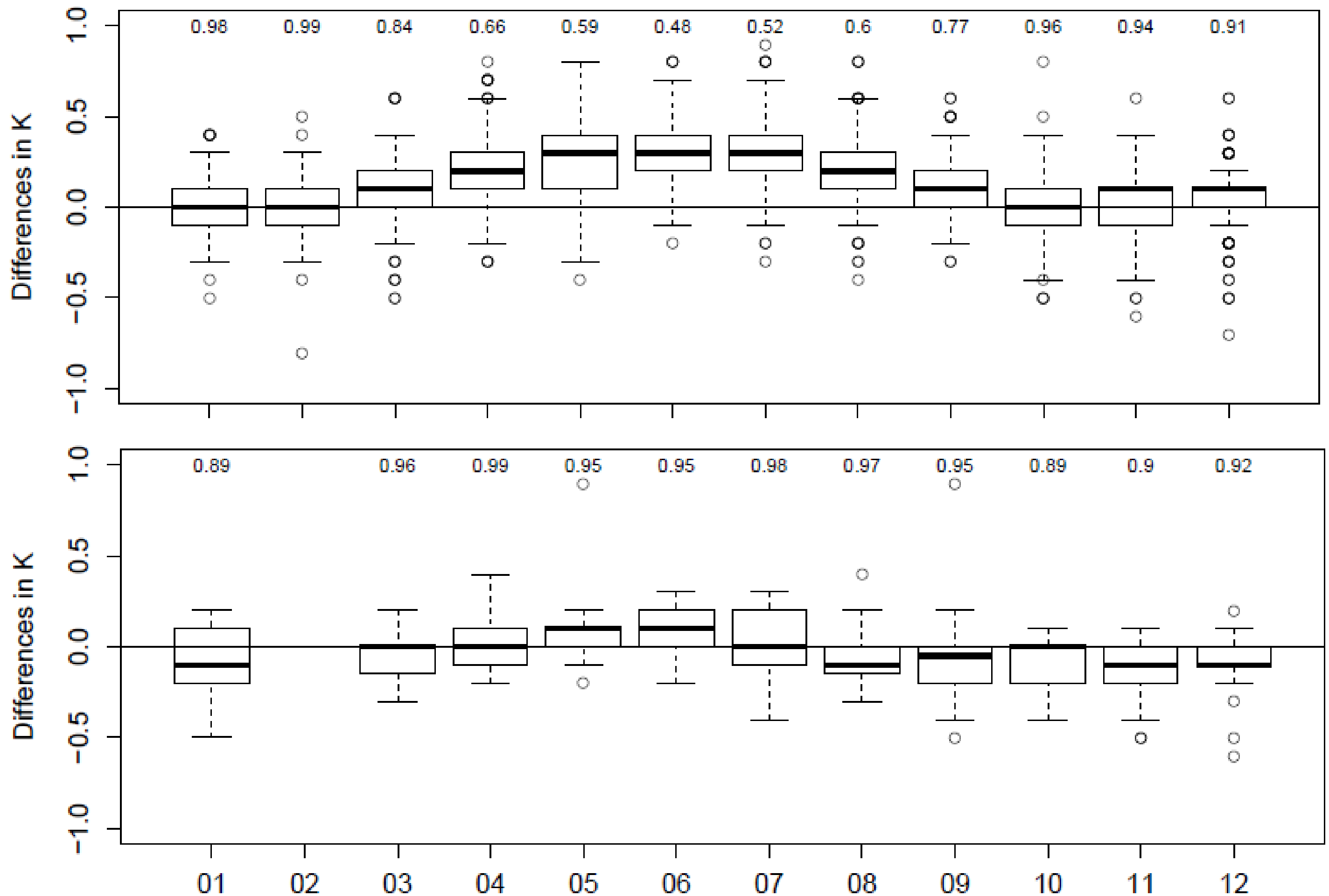
n = 2565



➔ Potsdam from 15.03.2016

n = 322





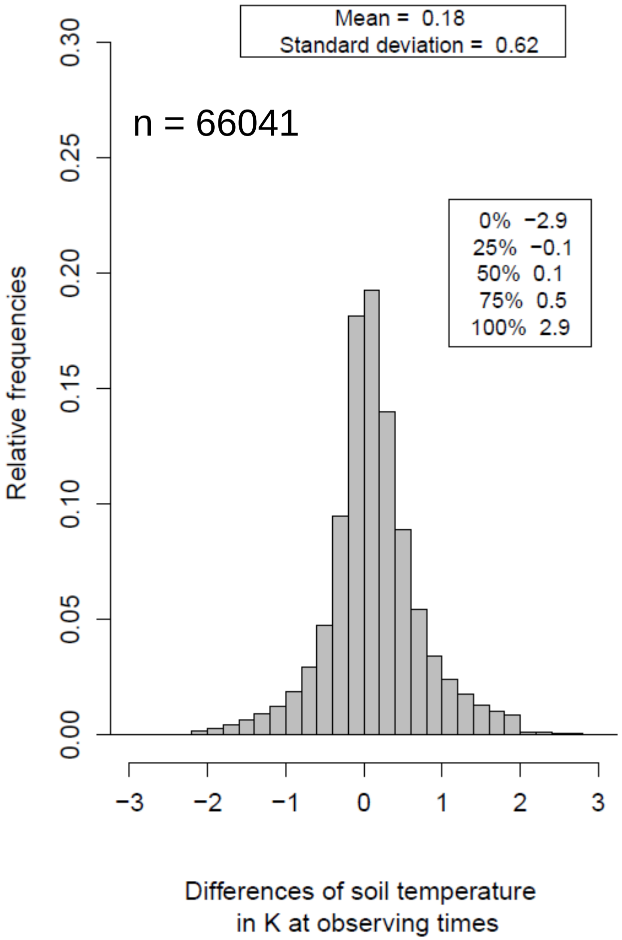
Kaspar et al. (2016), doi:10.5194/asr-13-163-2016

Soil temperature in 0.05, 0.1, 0.2, 0.5, 1 m depth

- **Manual observations**: mercury in glass thermometer
- Scale interval: 0.2 K

- **Automatic measurements**: PT 100 sensors attached on a stainless steel framework
- Maximal allowed deviation of sensor: 0.1 K

Soil temperature (0.05 m Depth) at observing times

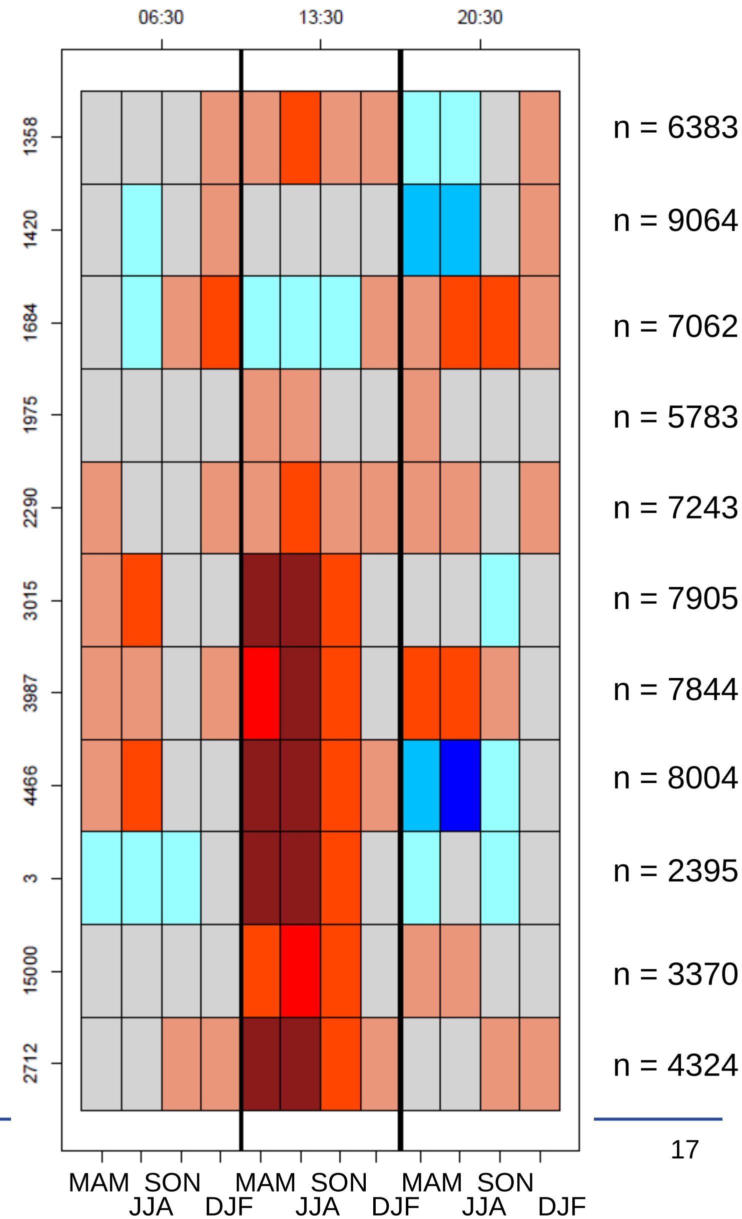


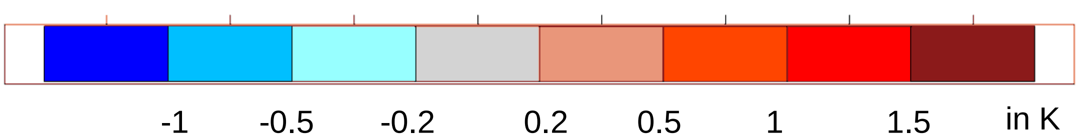
- ➔ Automatic measurements are 0.18 K warmer than manual observations
- ➔ Large standard deviation of 0.62 K
  - ➔ Reason: annual cycle in differences

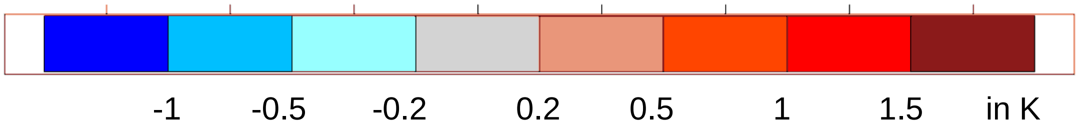
Soil temperature (0.05 m Depth)

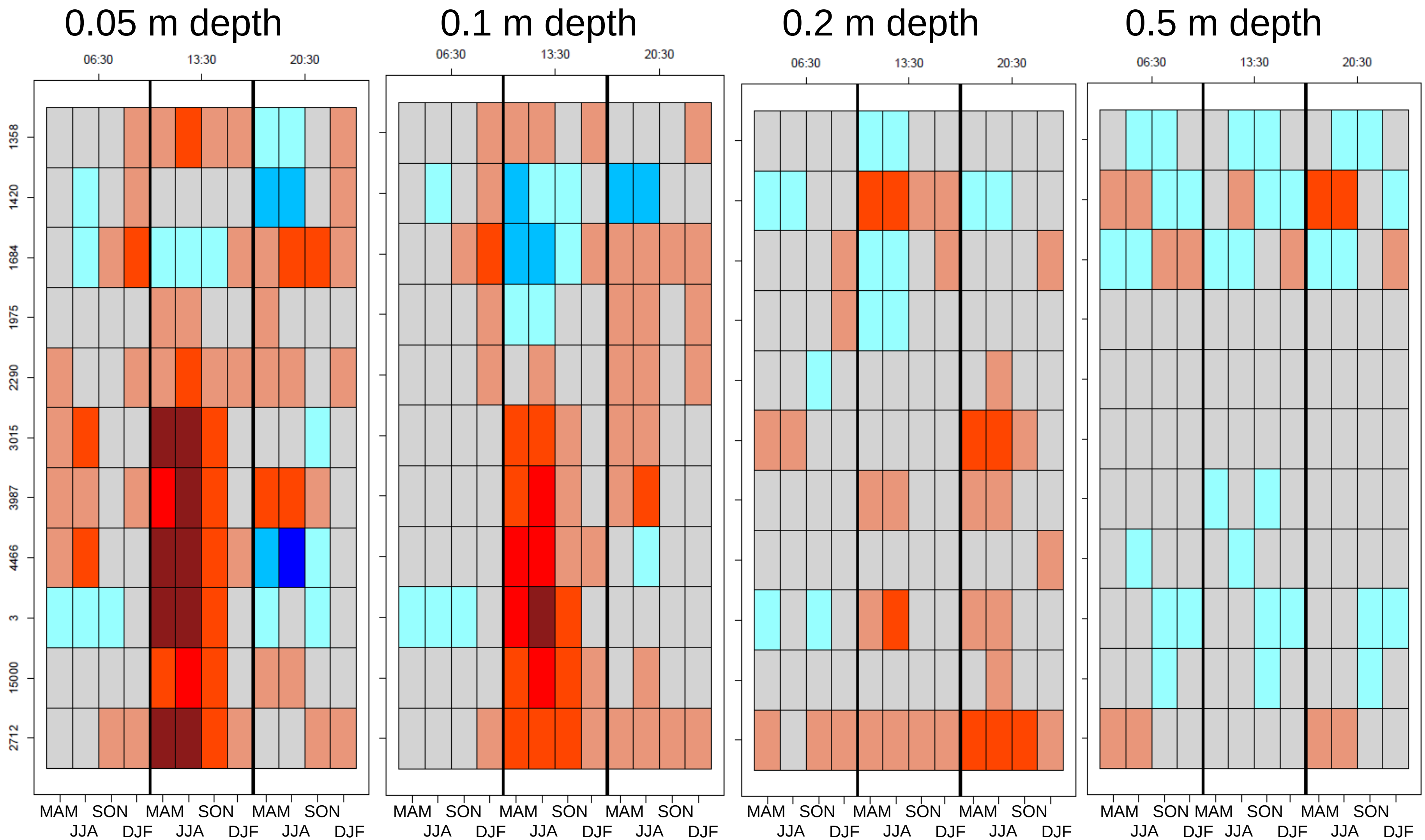
- ➔ Mean differences split in observation time, season, and station
- ➔ In most station larger differences at midday and in spring/summer

- ➔ reason: to be further analyzed






-1
-0.5
-0.2
0.2
0.5
1
1.5
in K

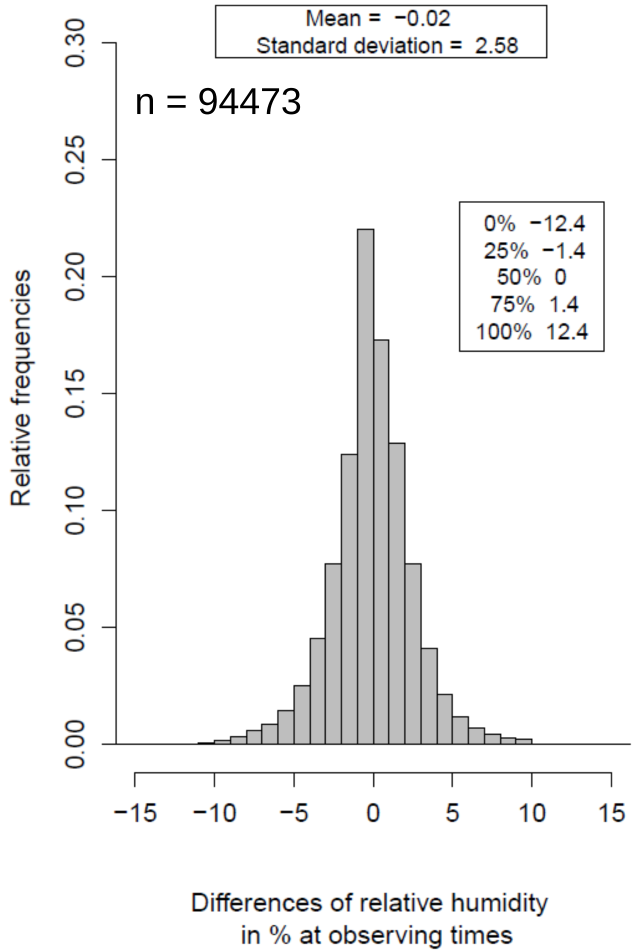

0.05 m depth
0.1 m depth
0.2 m depth
0.5 m depth
06:30
13:30
20:30
1358
1420
1684
1975
2290
3015
3987
4466
3
15000
2712
MAM
JJA
SON
DJF

Relative Humidity

- **Manual observations**: psychrometer (mostly in a Stevenson shelter) at observing times
- Resolution in database: 1%

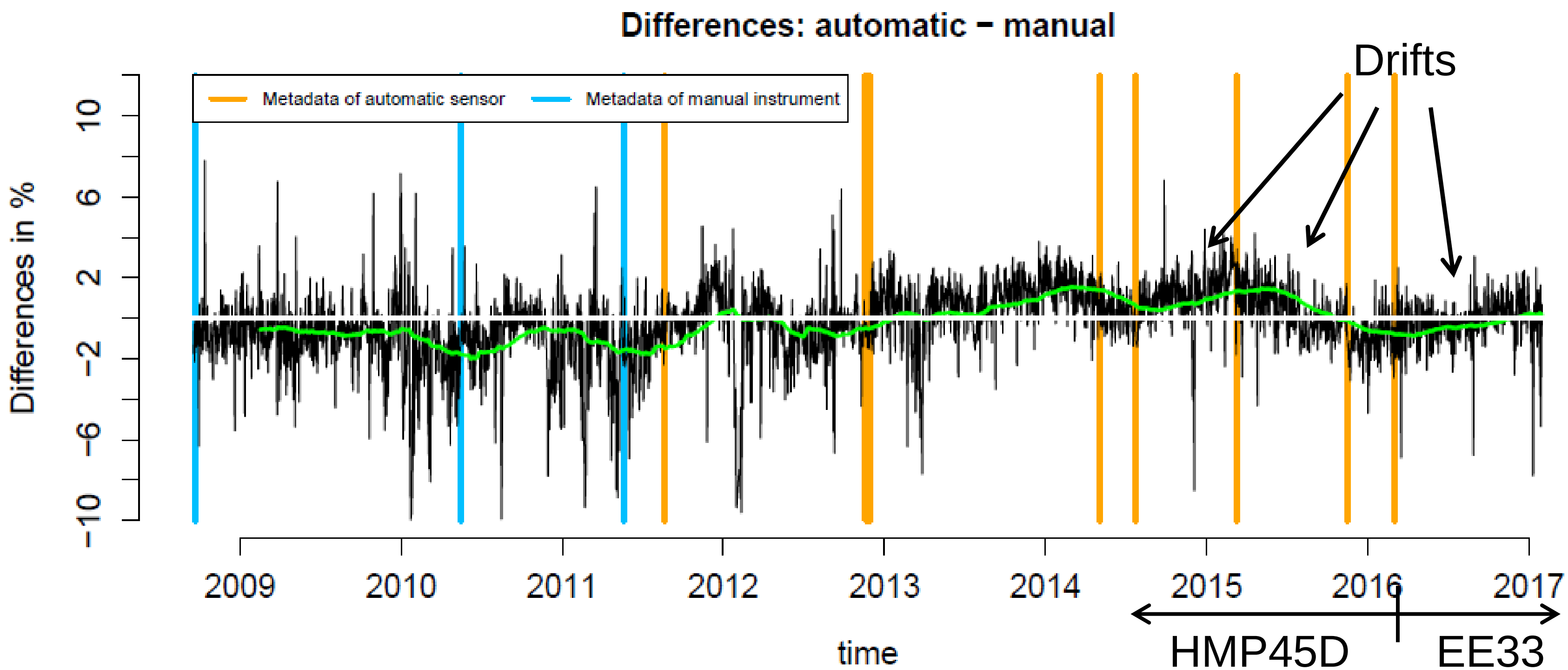
- **Automatic measurements**: HMP45D, Hygromer MP100, EE33 (mostly in a lamellar shelter LAM 630)
- Resolution: 0.1 %

Relative Humidity



- Differences from all climate reference stations were used
- When averaging over all available data, the differences between the measurement systems seems to be small

Relative Humidity (Lindenberg)



➔ BUT: Looking at the difference time series, trends are visible which are caused by the automatic sensor settings
(for example in Lindenberg)

What are the impacts of changing the measurement system?

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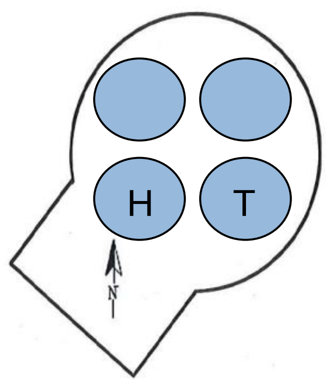
Relative Humidity EE33

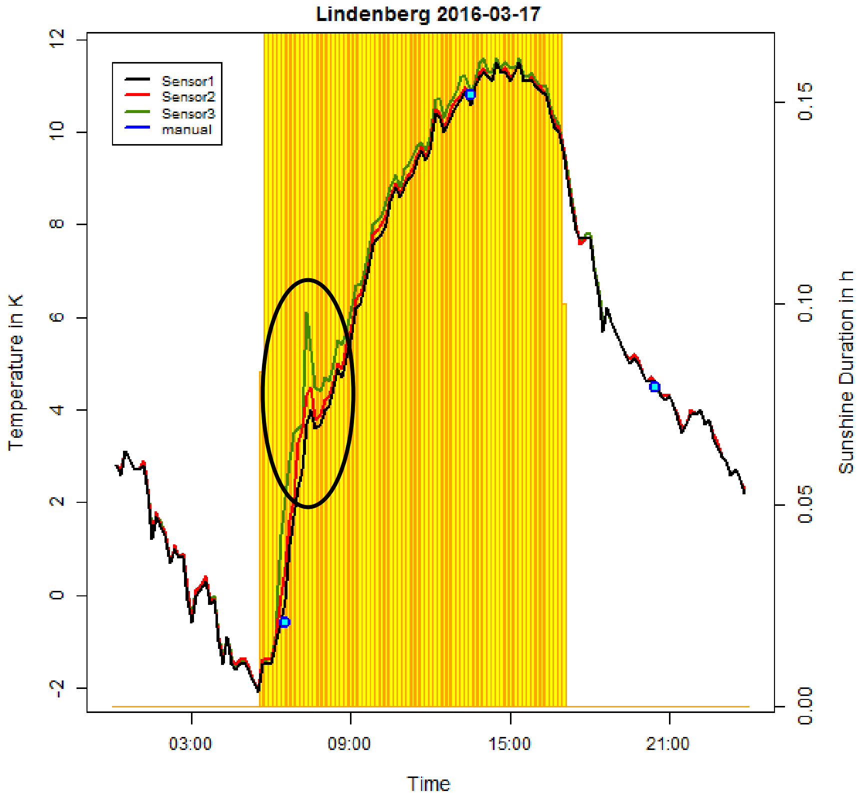
- relative humidity > 76 %: heating starts
- Calculation of dew point with integrated temperature sensor
- Calculation of relative humidity with separate temperature sensor

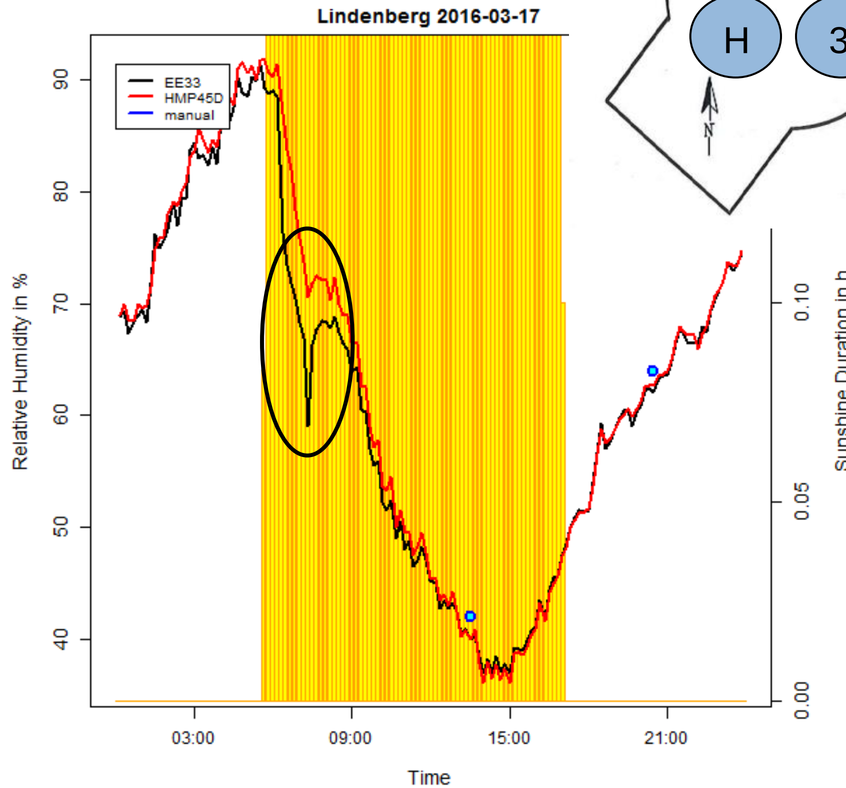
Temperature sensor (T)

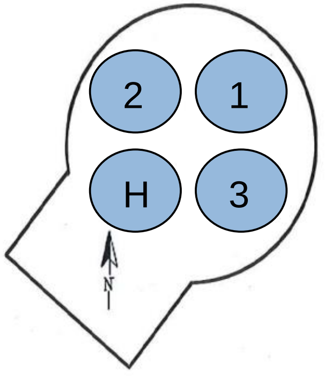
Humidity sensor with heating system (H)



Relative Humidity EE33

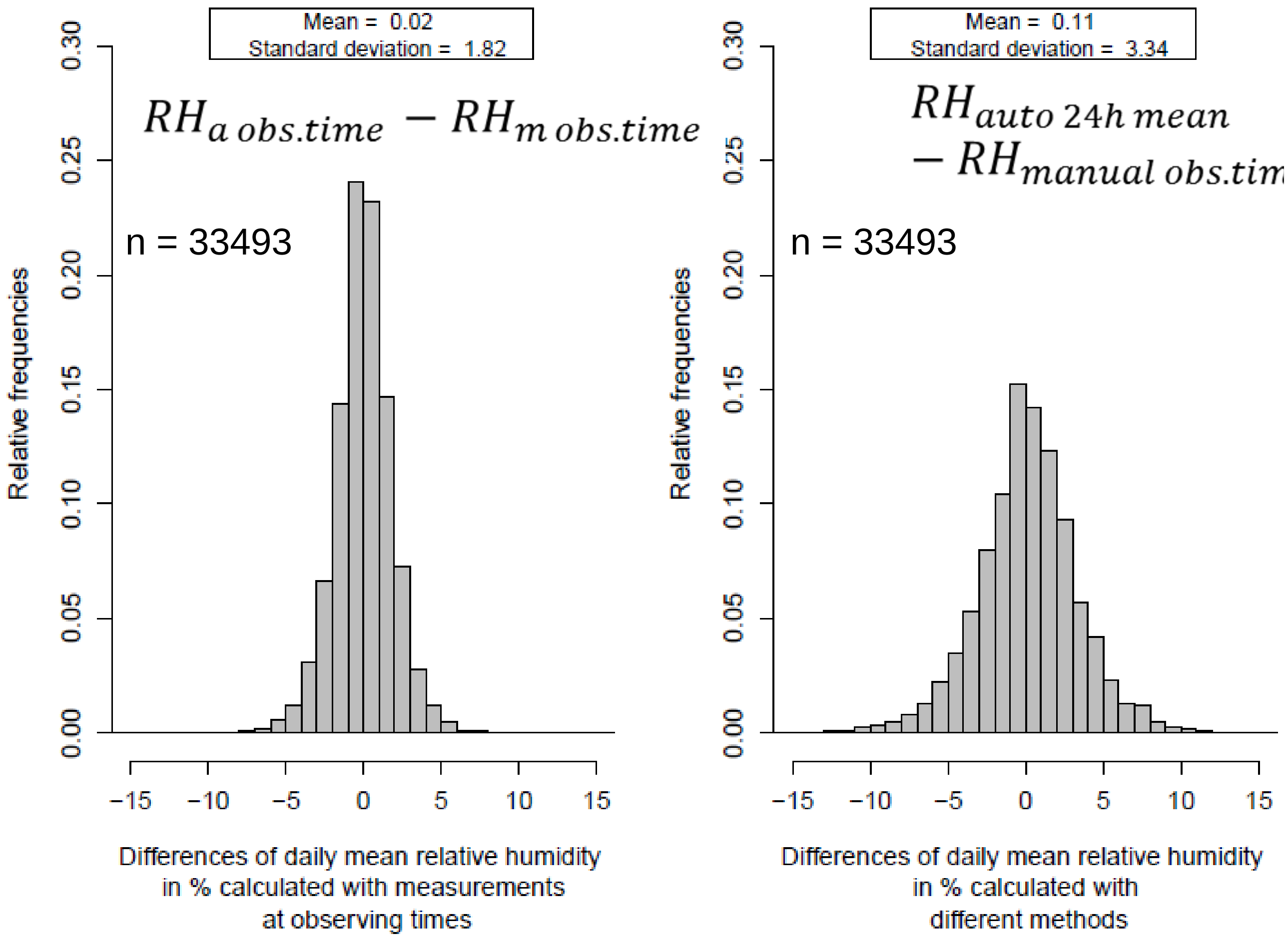






➔ Overestimation of temperature at position 3 leads to an underestimation of relative humidity

Relative Humidity (daily mean)



- ➔ The differences of the histograms left and right are smaller than in the comparison of temperature sensors
- ➔ It is advisable to calculate the daily mean with the same formula

Pressure

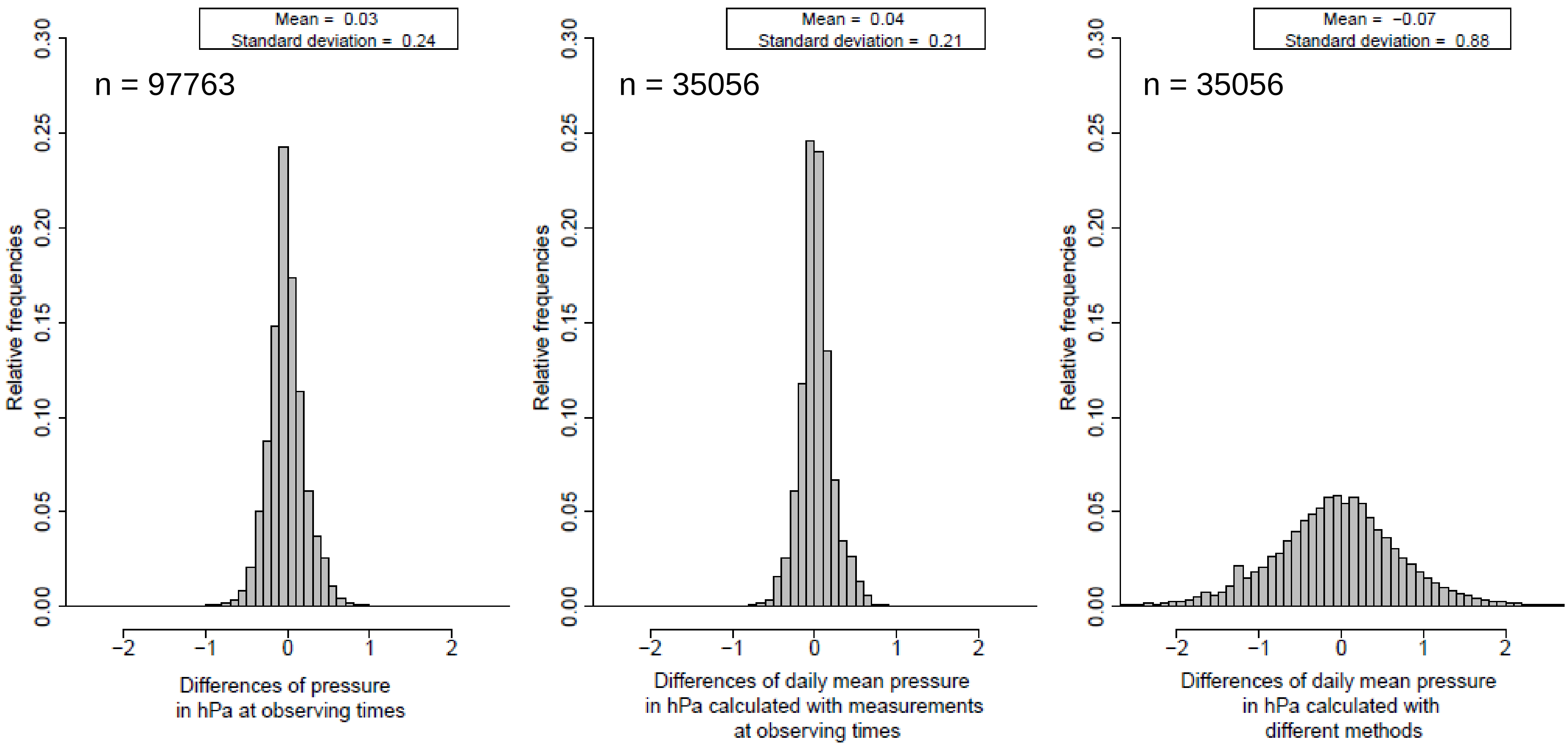
- **Manual observations**: mercury barometer at observing times
- Measurement uncertainty: 0.3 hPa
  - Reading accuracy: 0.1 hPa

- **Automatic measurements**: digital barometer
- Measurement uncertainty: 0.15 hPa
  - Linearity: 0.1 hPa
  - Calibration uncertainty: 0.07 hPa
  - Hysteresis: 0.03 hPa

Pressure

$$P_{auto\ obs.time} - P_{manual\ obs.time}$$

$$P_{auto\ 24h} - P_{manual\ obs.time}$$

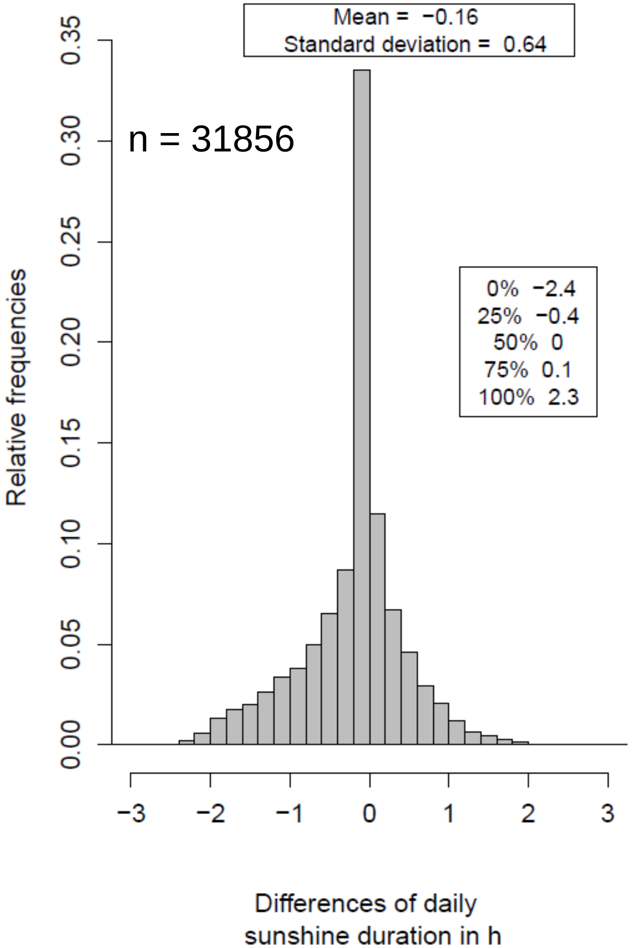


Sunshine duration

- **Manual observations**: Campbell-Stokes

- **Automatic measurements**: SONIe

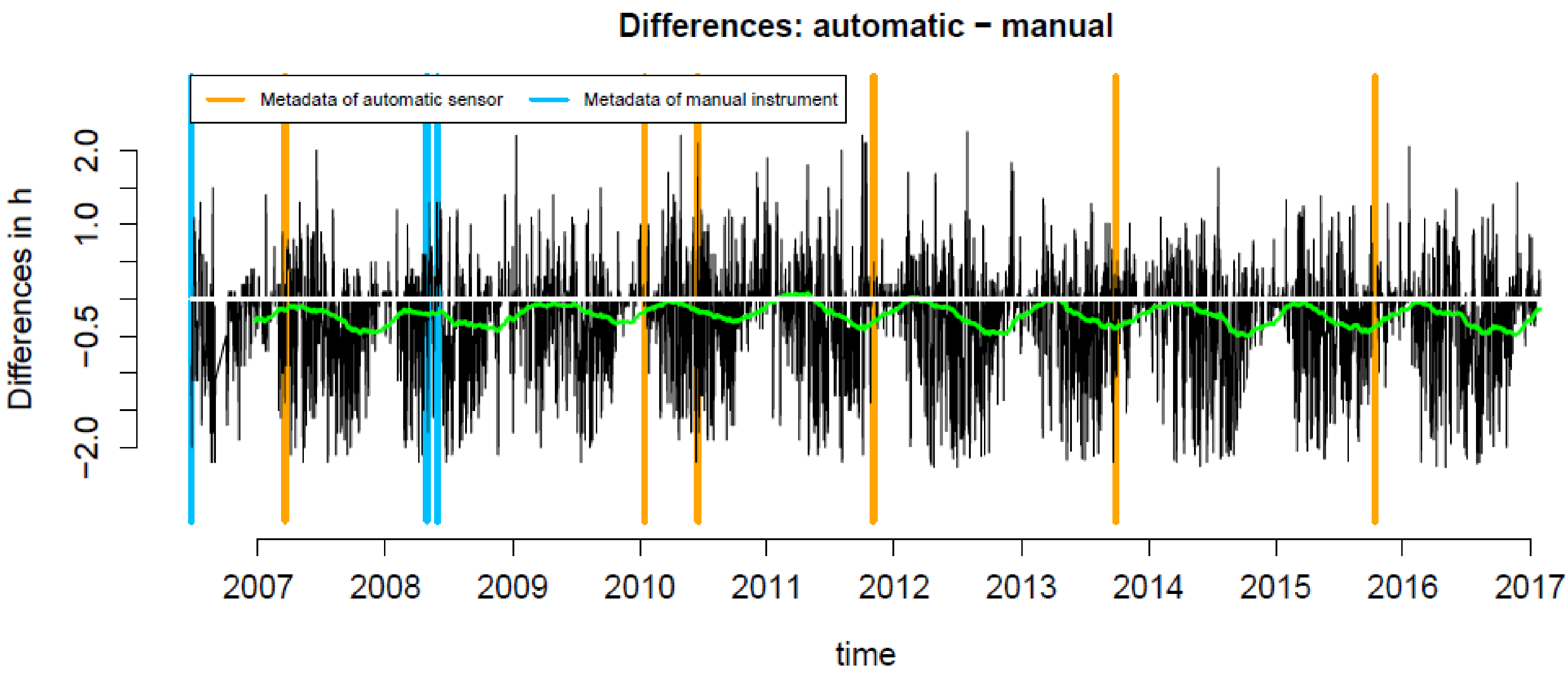
Sunshine duration



- Automatic instrument measures less sunshine (mean)
- Standard deviation is large
- Distribution not symmetric

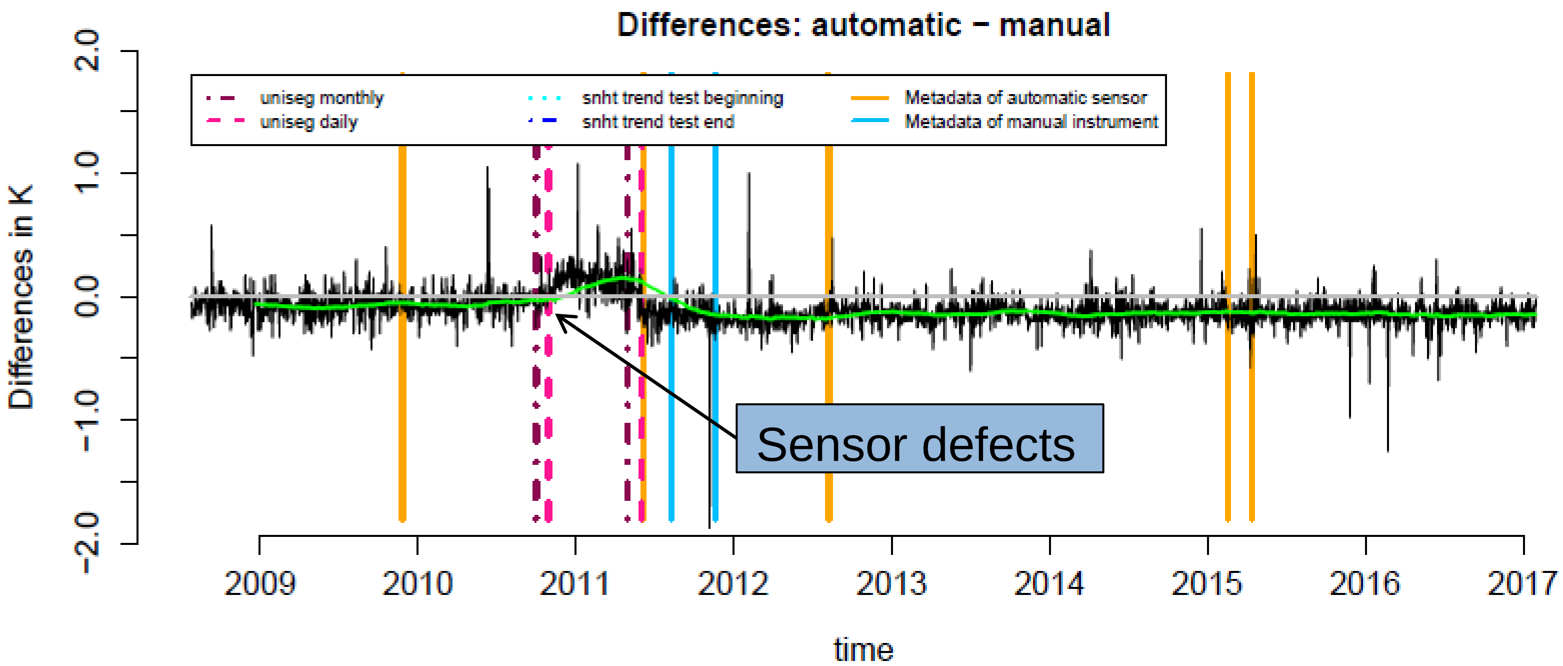
- Reason:
  uncertainties of manual observations in cloudy conditions cause annual cycle in time series of differences
  (mostly overestimation; see Legg, 2014)

Sunshine duration (Schleswig)



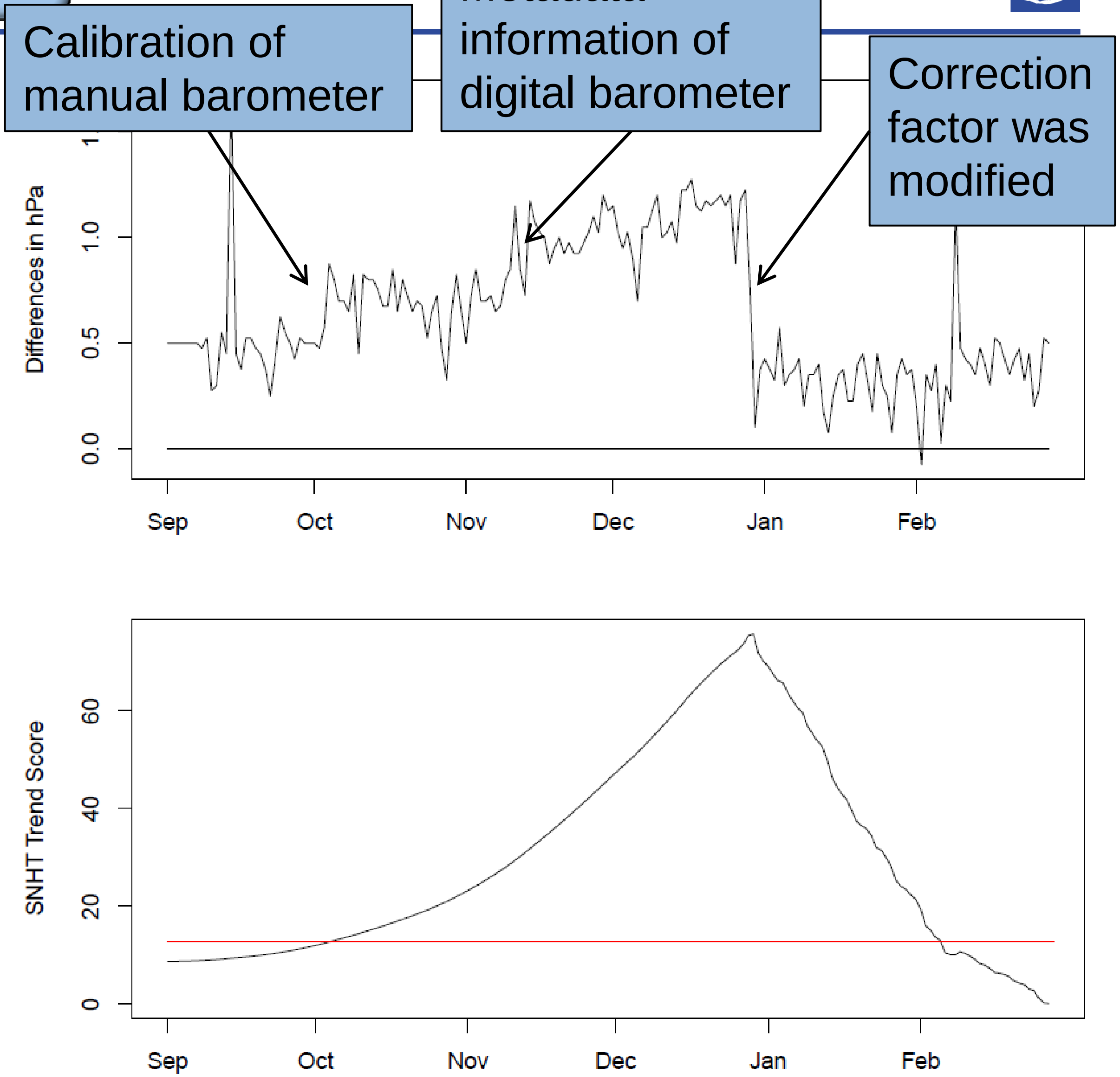
Outlook

- Breakpoint detection by using parallel measurements
  - Differences of air temperature at observing times (station Brocken)



Outlook

- Monitoring observations using parallel measurements
- Brocken: Differences of pressure (top) and SNHT Trend Test Score (bottom)



Summary

- **Air temperature at observing times**:
  mean of differences close to zero, standard deviation small
- **Extreme temperatures**:
  annual cycle in the differences due to radiation effect in the lamellar shelter (temperature maxima)
- **Soil temperatures**:
  annual cycle in the differences, reason unclear
- **Relative humidity**:
  drifts partly over several months, radiation effect of lamellar shelter
- **Pressure**: small differences
- **Sunshine duration**:
  annual cycle due to the reading accuracy of the manual observations

Thank you for your attention

Summary

- **Air temperature at observing times**:
  mean of differences close to zero, standard deviation small
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References

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