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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

A method for correcting and determining uncertainties of measurements by the EE-33 humidity sensor for climate reference measurements in Germany

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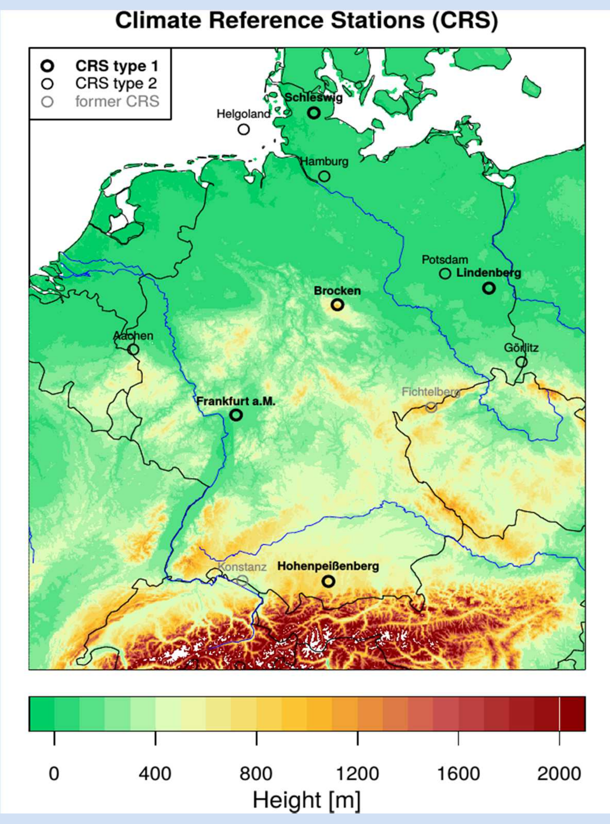
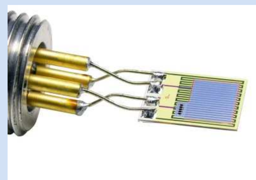
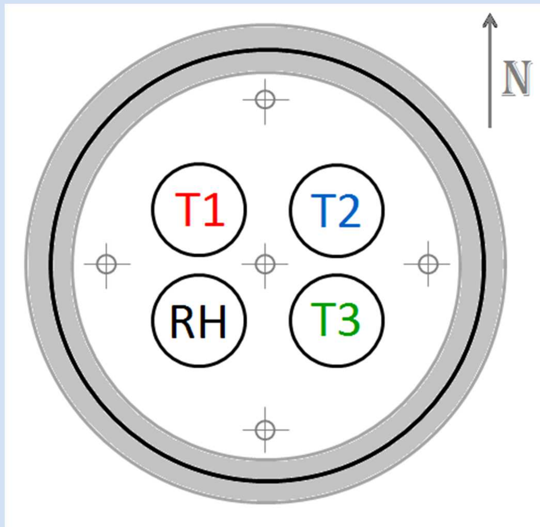




The German Weather Service (DWD) operates 10 climate reference stations (CRS) for surface observations of meteorological parameters. Since 2008, parallel measurements of traditional (manual) instruments and automatic sensors are performed at these stations. Two kinds of housing are employed to shield the temperature and relative humidity sensors: manual instruments are mounted inside a Stevenson screen and automated instruments are placed inside a ventilated LAM-630 screen (picture on the right). Parallel observations of temperature and humidity are performed both with identical and different sensor types to investigate biases and measurement uncertainties.

These comparative measurements are used to identify and correct for inhomogeneities resulting from changes in the measurement systems. Furthermore, measurement uncertainties are estimated using the combination of climate reference data, laboratory analyses and other field experiments involving instrument intercomparisons.

In this study, we present a method for processing relative humidity (RH) data from the heated polymer sensor EE-33. In the first step corrections for known systematic errors due to radiation, nonlinearity and long-term sensor drift are applied. In the second step of the data processing the uncertainty for each data point is estimated by evaluating seven different uncertainty components. The dominant sources of uncertainty are radiation, sensor drift and calibration. Under specific conditions the radiation-induced dry bias can be as large as 10%RH.



Calibration/ Nonlinearity

- Calibration in laboratory before and after deployment (typically 12 - 18 months)
- Correction of nonlinearity and linear drift using calibration curve that is interpolated to date of measurement
- Remaining standard uncertainty determined by uncertainty of calibration (±0.52%RH)

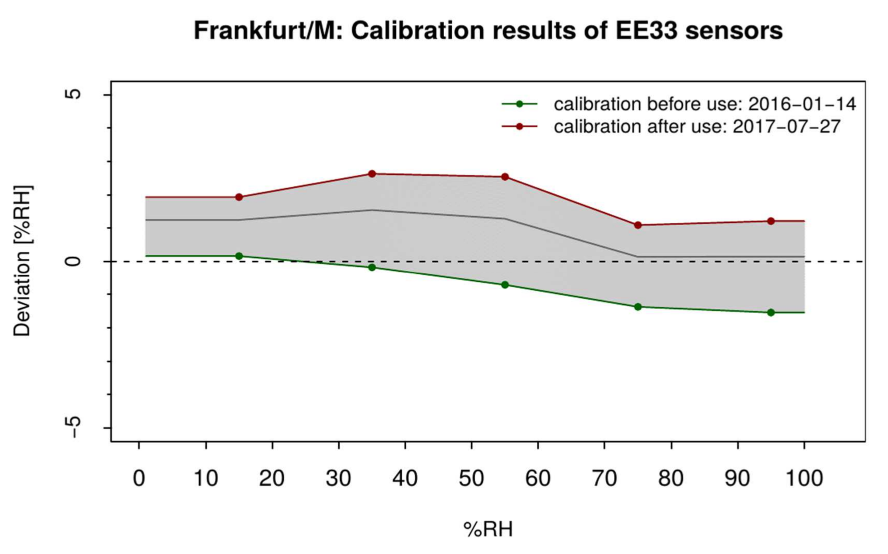
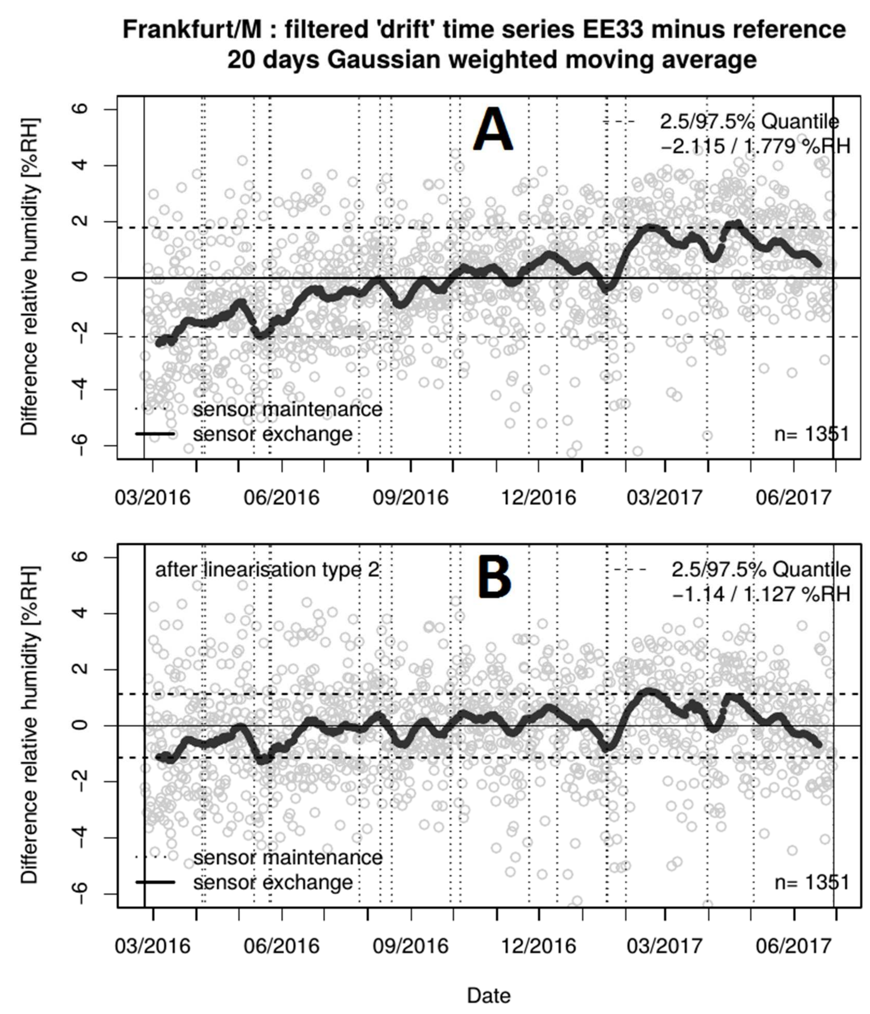


Figure 1: Calibration results from DWD laboratory for an EE33 sensor before (green) and after its use (red). Linear interpolation between the green and red curve yields the calibration curve for a specific date (grey). With this method both nonlinearity and a linear sensor drift can be corrected.

Sensor Drift



- Comparison with manual psychrometer
- Moving average filter (width 20 days) to eliminate other sources of uncertainty
- Positive sensor drift for all 5 tested sensors
- Correction of nonlinearity and linear drift
- Remaining standard uncertainty based on statistics of 5 stations: ±0.55%RH
- Correction due to assumed drift of psychrometer data: ±0.45%RH

Figure 3: Time series of the difference between EE-33 sensor data and psychrometer data (grey circles) and Gaussian moving average over 20 days (black line). The positive sensor drift (panel A) is consistent with the calibration results in figure 1. After correction of nonlinearity and linear drift the remaining uncertainty is reduced (panel B).

Radiation/ Temperature

- EE33 with temperature controlled (heated) humidity sensor
- Temperature measurement by Pt1000 used to calculate RH
- This sensor (SE position) is sensitive to radiation
- Radiation error correlates with exposure to sun and wind speed
- Recalculation of RH using less affected Pt100 sensors (NW, NE)
- Remaining standard uncertainty by temperature calibration (tolerance and uncertainty), radiation, electronics and rounding errors: ±0.5 to 5%RH

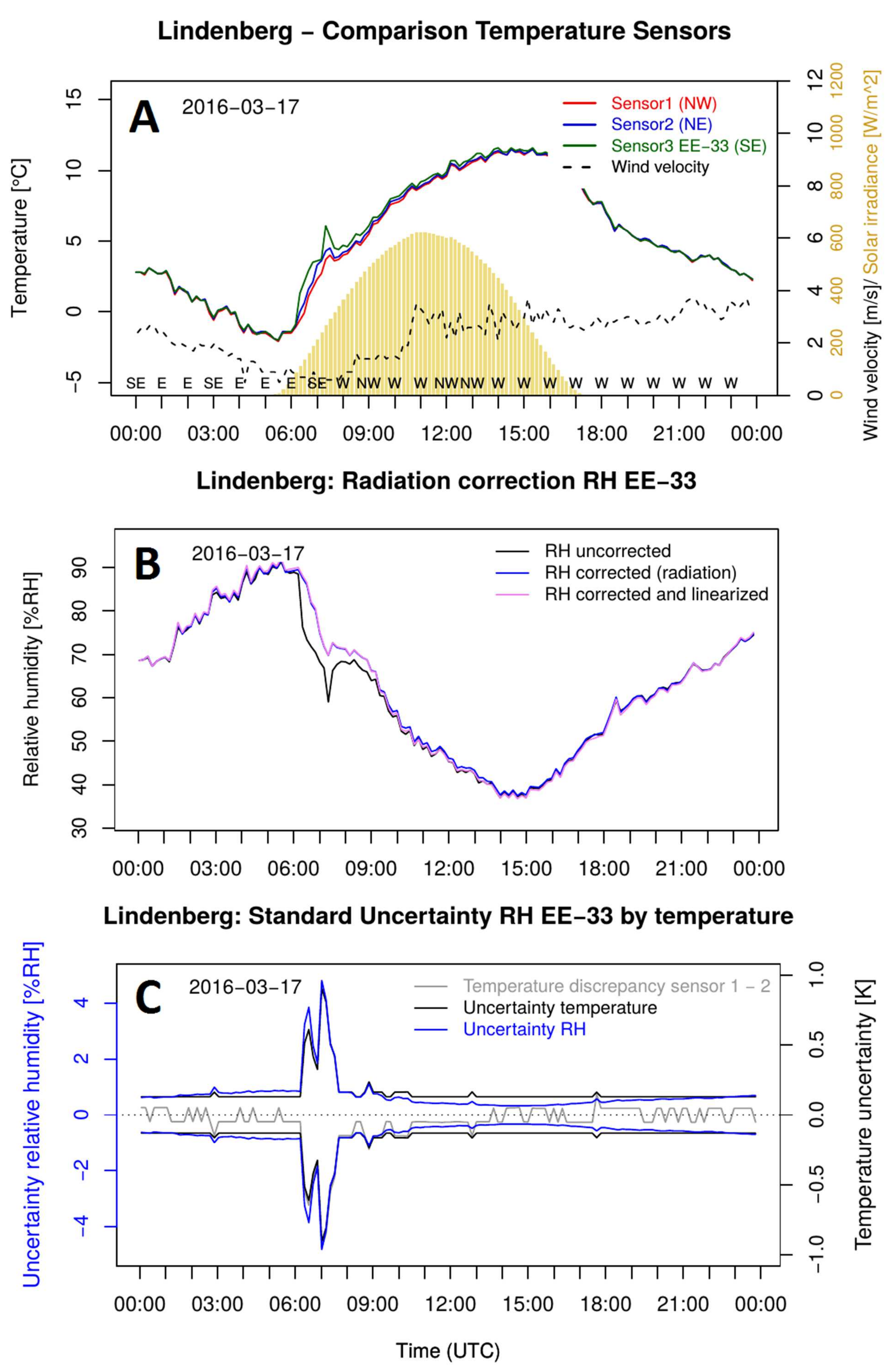
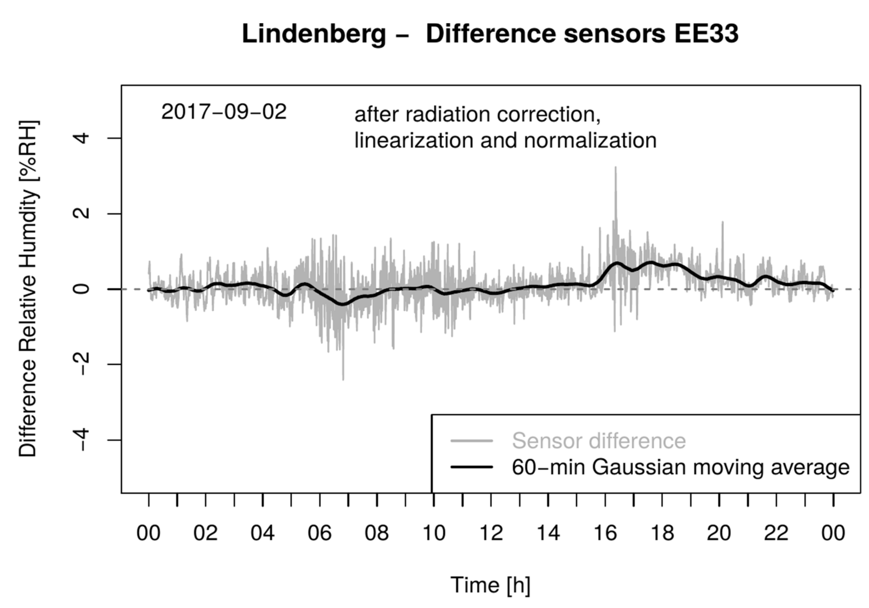


Figure 2: Correction of temperature errors and related errors in RH and assumption of remaining uncertainties. The temperature of the EE-33 is affected by solar radiation under conditions with low wind speed and high exposition to sun of nearby LAM-630 screen walls (panel A). RH is recalculated using the mean of regular temperature data (2 sensors at North position; panel B). Panel C: Standard uncertainties of temperature and related RH after correction.

References: *Committee Guides Metrology, Joint. (2008). Evaluation of measurement data – Guide to the Expression of Uncertainty in Measurement (GUM 2008).*

Other sources of uncertainty



- Systematic contributions to uncertainty on time scale of hours
- Statistical uncertainties of RH
- Uncertainties by sensor response time based on laboratory experiments and field data with high resolution (10 sec)

Figure 4: Statistical and systematic variations of sensor difference for example day.

Budget and overall uncertainty

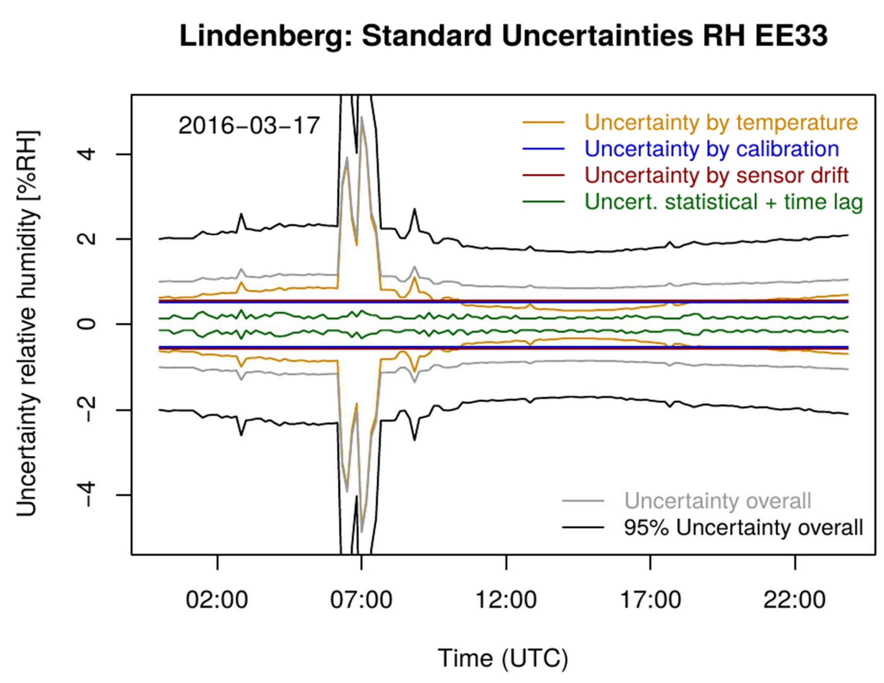
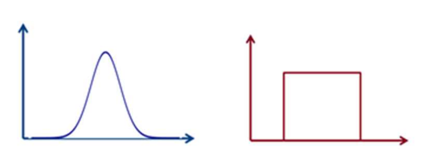


Figure 5: Standard uncertainties subdivided by four main components and overall uncertainty for example day.

Standard uncertainties according to GUM (2018):

Δ_{cal}: Calibration ±0.5%RH
Δ_{nlin}: Non-linearity → correction (time-variable)
Δ_{drift1}: Drift over months → linear correction ±0.5%RH
Δ_{drift2}: „Drift“ over hours ≈±0.2%RH
Δ_{rad}: Radiation → correction ≈±0.6%RH ±0.2%RH
Δ_{stoc}: Stochastic variability ≈±0.15-0.3%RH
Δ_{resp}: Response time ≈±0.1-0.5%RH

assumed distributions: 

linearly independent components: $\Delta^2 = \Delta_1{}^2 + \Delta_2{}^2$

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