Low cost weather monitoring

Experiences from WIMEA-ICT and related projects

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Mobilising Trust in Measurements and Engaging Scientific Citizenry
ICTP, Trieste 2017-03-09
http://wireless.ictp.it/citizenscience_2017

WIMEA-ICT (2013-2019)

- Capacity building in Applied Meteorology at
  - Makerere University in Kampala
  - Dar es Salaam Institute of Technology
  - University of Juba
- 8 PhD students/advisors and Msc students
- Four research components
  - Meteorological modeling and forecasting (wrf)
  - Weather Information Management Systems
  - Affordable and robust weather stations (AWS)
  - Dissemination of weather information to end users

Synoptic Weather Parameters
Selected Subset

- Atmospheric Pressure
- Precipitation
- Soil temperature & moisture
- Air temperature and humidity
- Wind direction and speed
- Solar irradiation

Main challenges

- Accuracy, Reliable sensors, Calibration
- Robustness of the whole AWS
  - weather, nature, vandals
- Power:
  - Maximize source and storage, minimize load
- Connectivity:
  - Reliable uplinks

Sensors and calibration

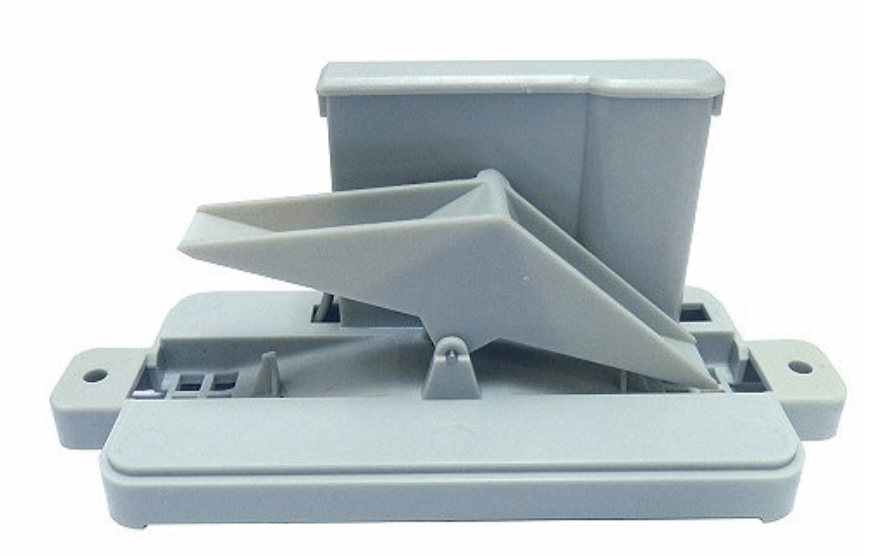
- Atmospheric/Barometric pressure (QFE,QNH)
- Rain + Soil temp and mositure (ground)
- Air temp and humidity (2m shielded)
- Wind direction and Speed (10m)
- Insolation
- Lightning detection and localisation

Atmospheric pressure

- Selected sensor: MS5611
- Pre-calibrated Barometric Pressure Sensor
- High resolution: 0.012mbar, 10cm, <0,01C
- Operating range: 10 to 1200mbar, -40 to +85C
- Resolution temperature: typ. <0,01°C
- Fast conversion down to 1 ms
- Supply voltage 1.8 to 3.6 V
- Low power, 1 µA (standby < 0.15 µA)
- Integrated digital pressure sensor (24 bit ADC)
- Excellent long term stability

Rain

- Experimental 3D-printed designs not stable enough
- Selected rain gauge is Davies 78
- Reed relay pulse generator

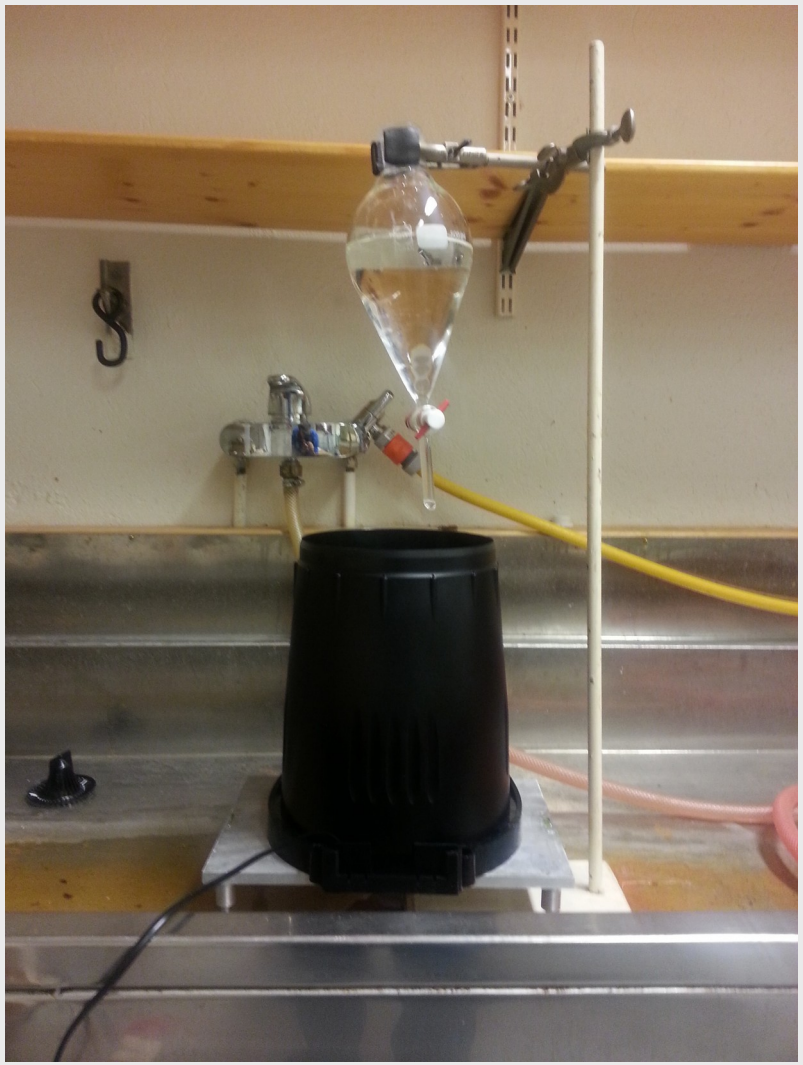


WIMEA-ICT RC1

Davis 7853 Rain Collector Tests

J. Reuder, Andrew Seidl, Bjorn Pehrson, Robert Olsson

Verification



Tested for accuracy at the Geophysical Institute (GFI)

Done by passing a calculated volume of water through the collector, which will give an expected number of tips
•Depends on collector tipping rate (0.2 mm) and collector diameter (0.165 m)

Deployed collector
•Registered average of 95 tips out of an expected 100 (95%)

Experimental Setup

Deployed on afternoon of 11 July 2016 in front of GFI

Installed as close as possible to official rain collector operated by the Norwegian Meteorological Institute

Placed as low to the ground as possible to minimize influence of wind

Has been exposed to some of the rainiest weather Bergen has experienced in decades!

Datalogging

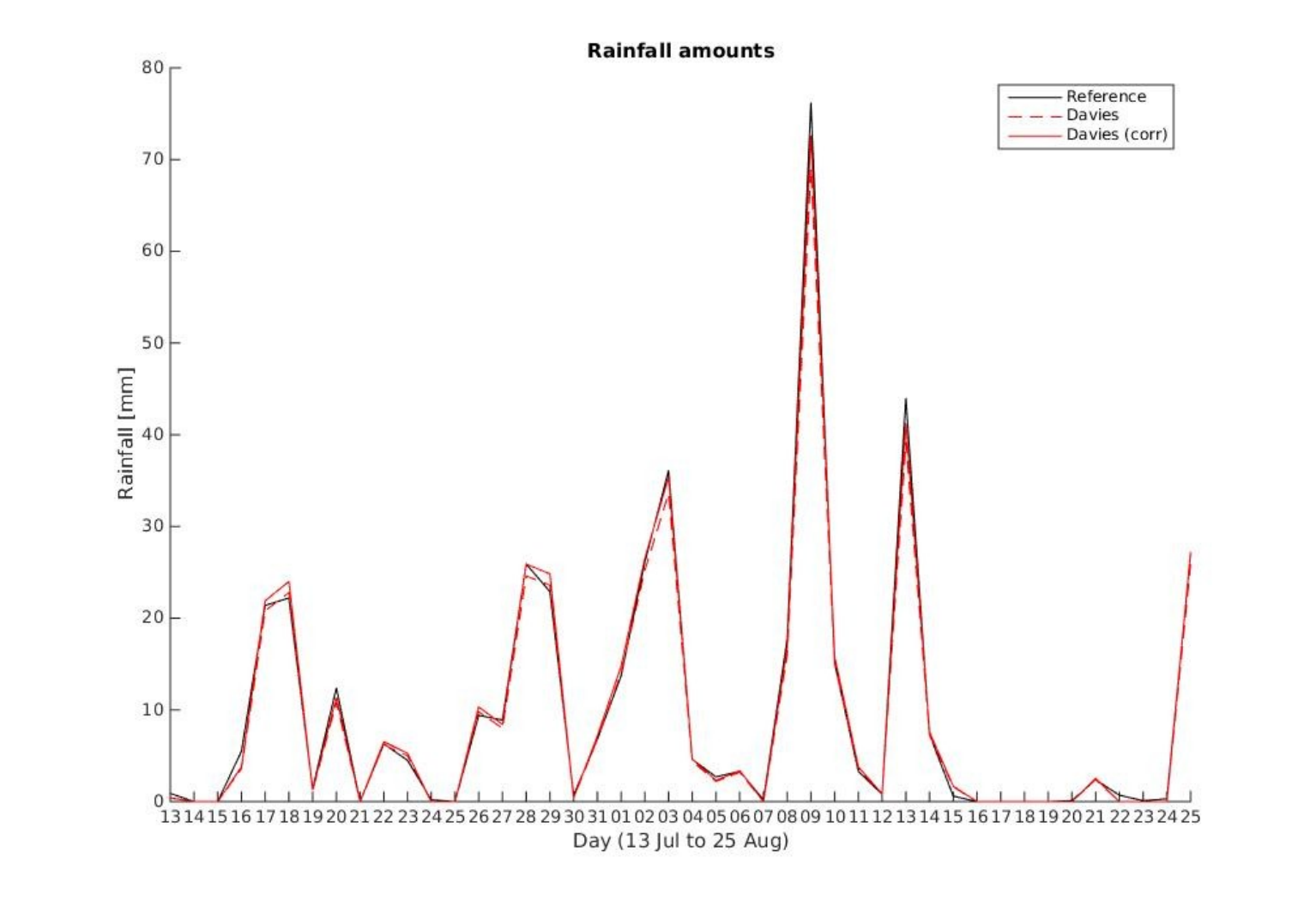
Two methods of tracking tips:

- Minutely tracking: Every minutely report indicates how many tips occurred during the last minute
  - Ex: 08:33 – 2 tips
    10:17 – 1 tip
    15:56 – 2 tips
    Total: 5 tips = 1 mm

- Absolute tracking: Total number of tips since the unit has been powered on
  - Ex: 30 tips at the start of the day
    35 tips at the end of the day
    Total: 5 tips = 1 mm

- This analysis used Absolute tracking

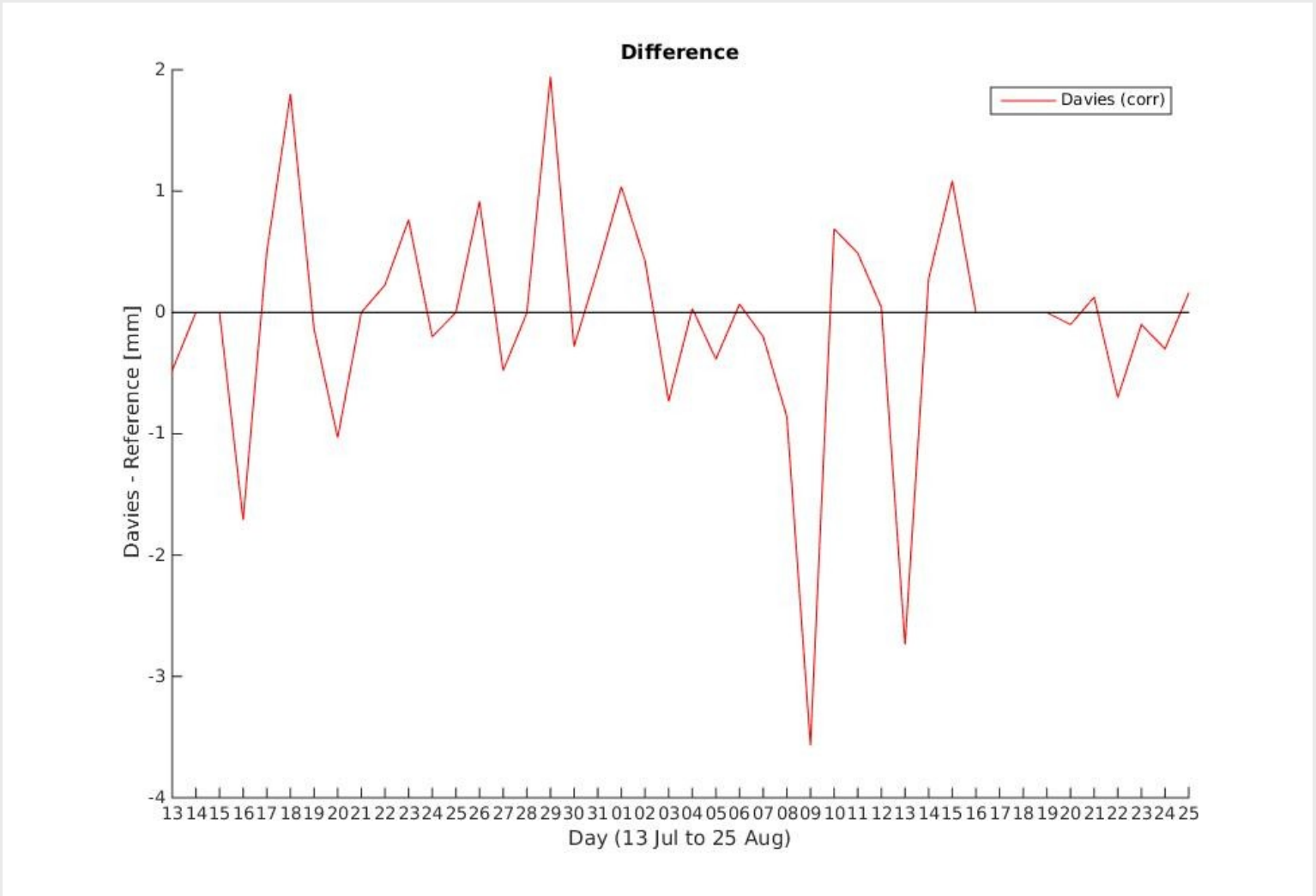
Results



Raw data 95% of expected values (as per testing)

- Solid red line is corrected data

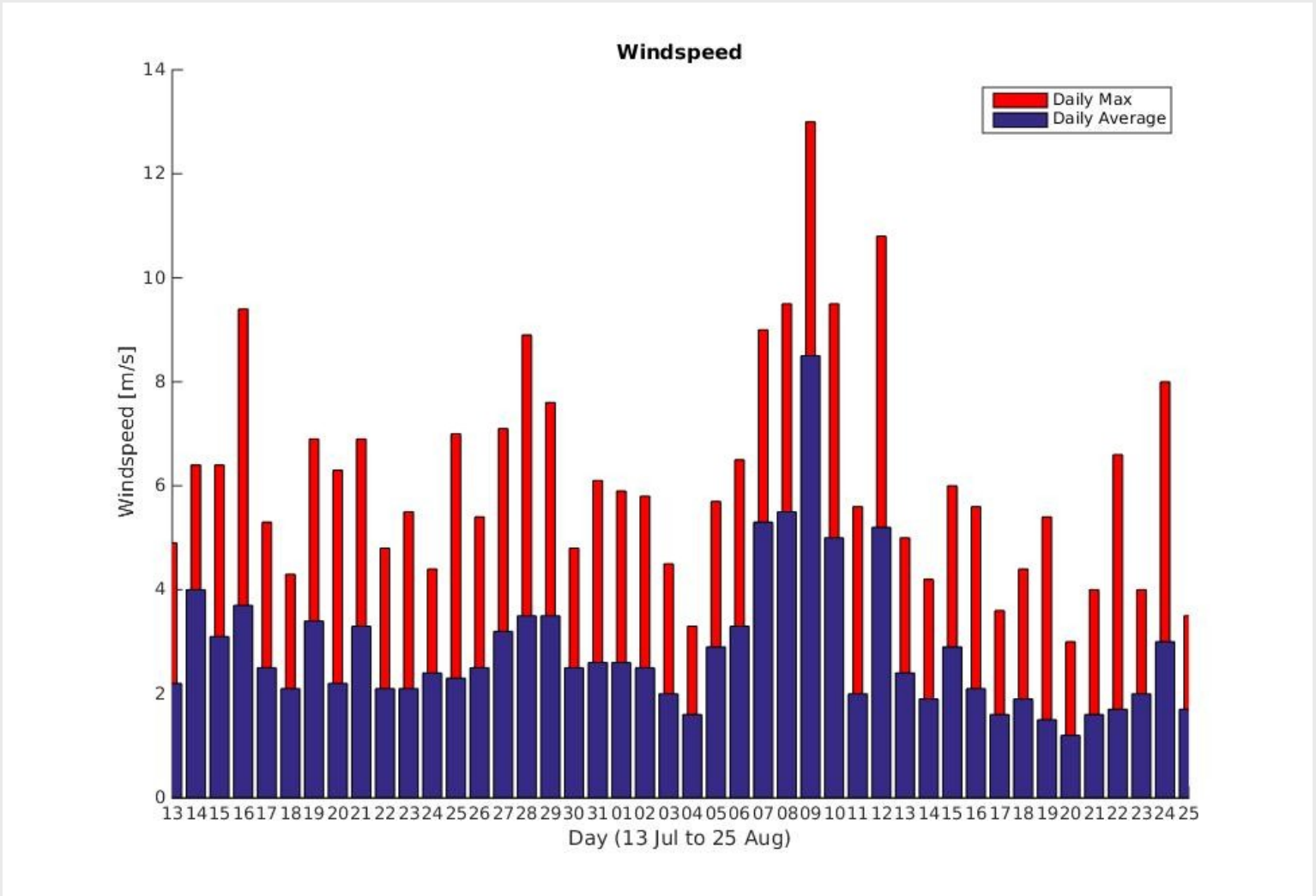
Results



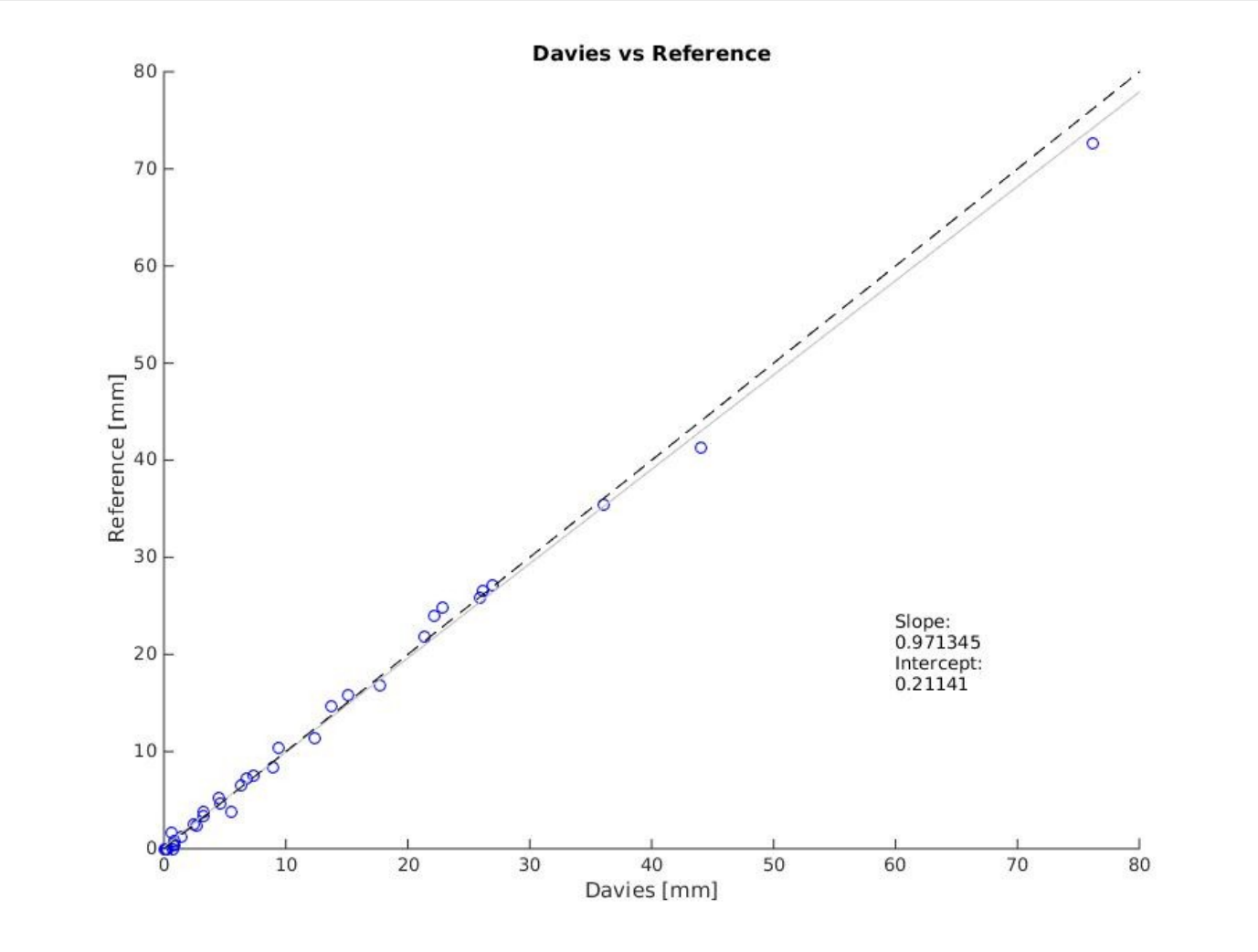
Correlation: 0.998

Root mean square error: 0.94 mm

Results

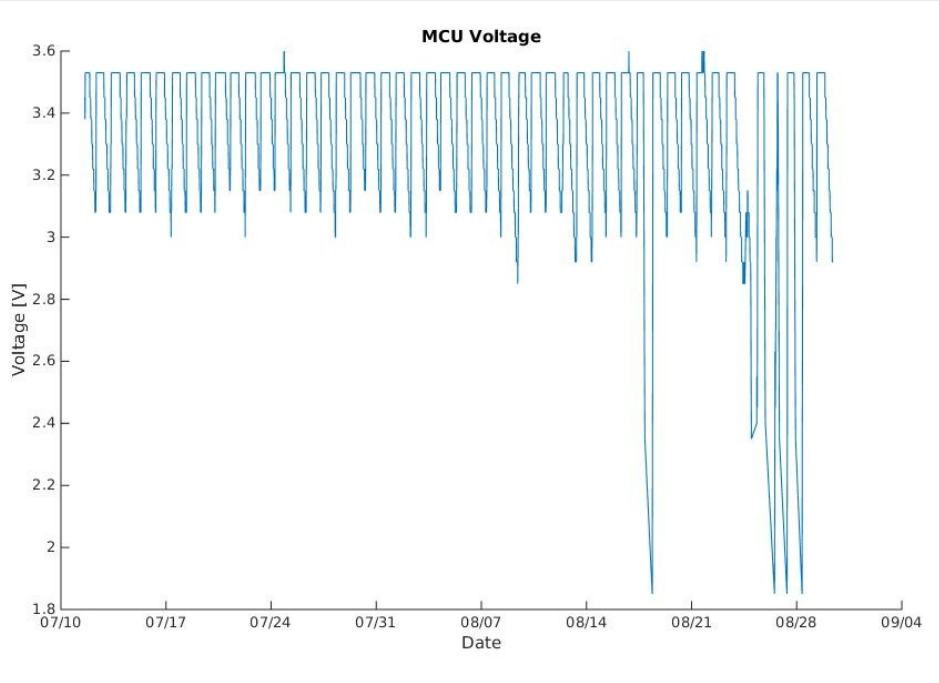

Windspeed
Daily Max
Daily Average
Windspeed [m/s]
0
2
4
6
8
10
12
14
13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Day (13 Jul to 25 Aug)

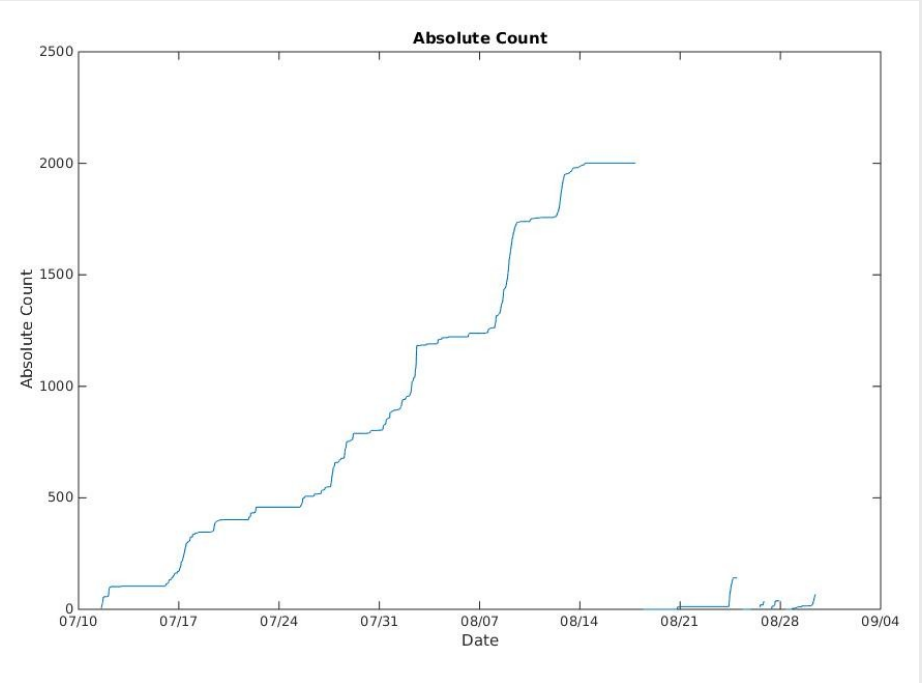
Results



Slope: 0.971345
Intercept: 0.21141

Issues





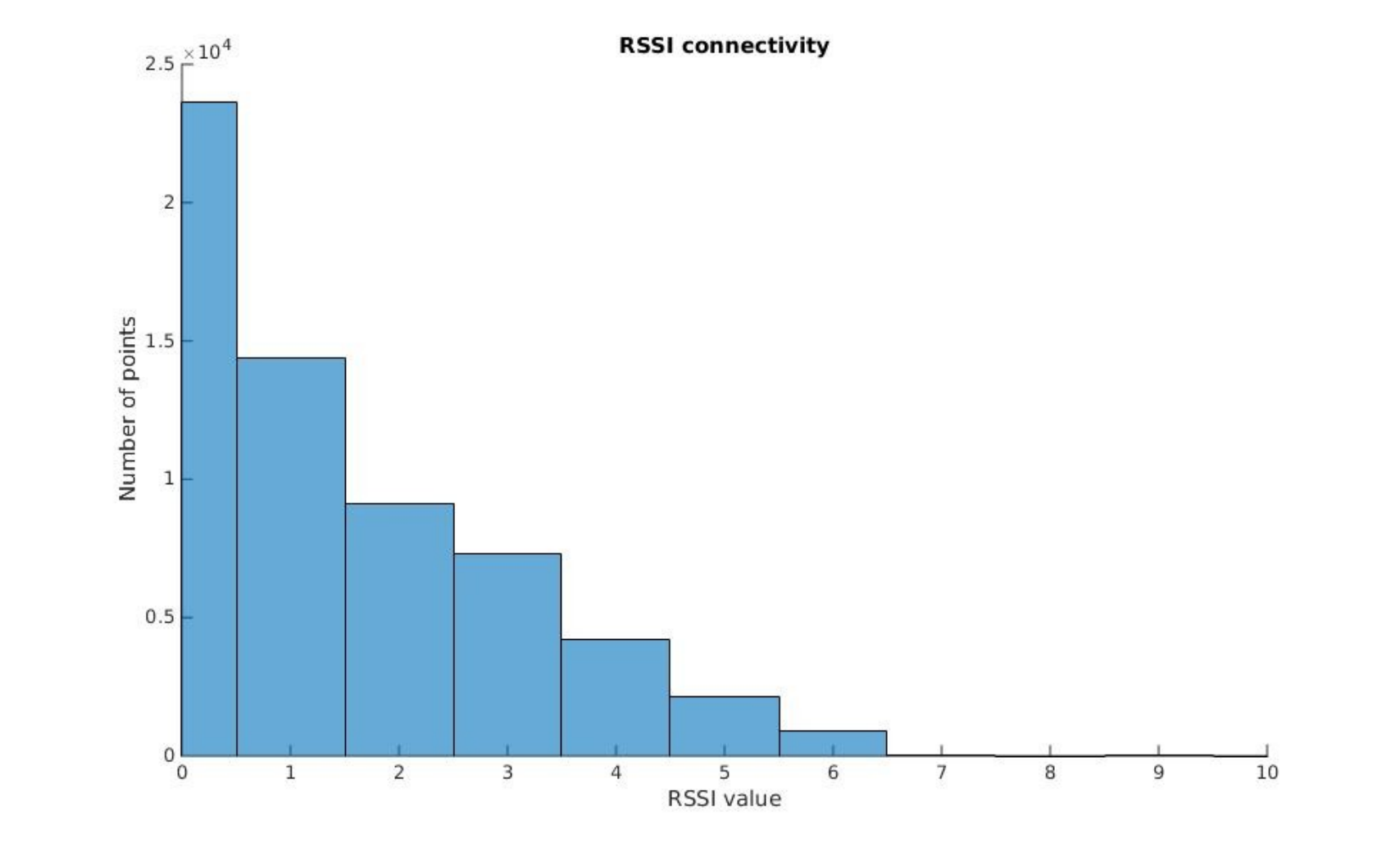
Late evening 24 Aug, MCU voltage dropped below 2.4 V threshold (left)

- As a result, the absolute tip counter reset (right)

Rainy/cloudy weather in Bergen since the 24th

- Solar panel insufficient power?

Issues

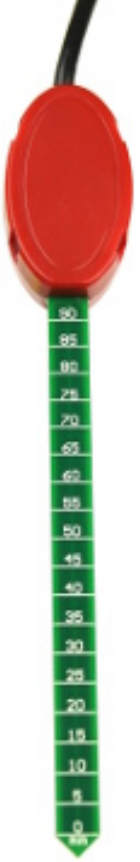


RSSI: 0 -> Limit of connectivity

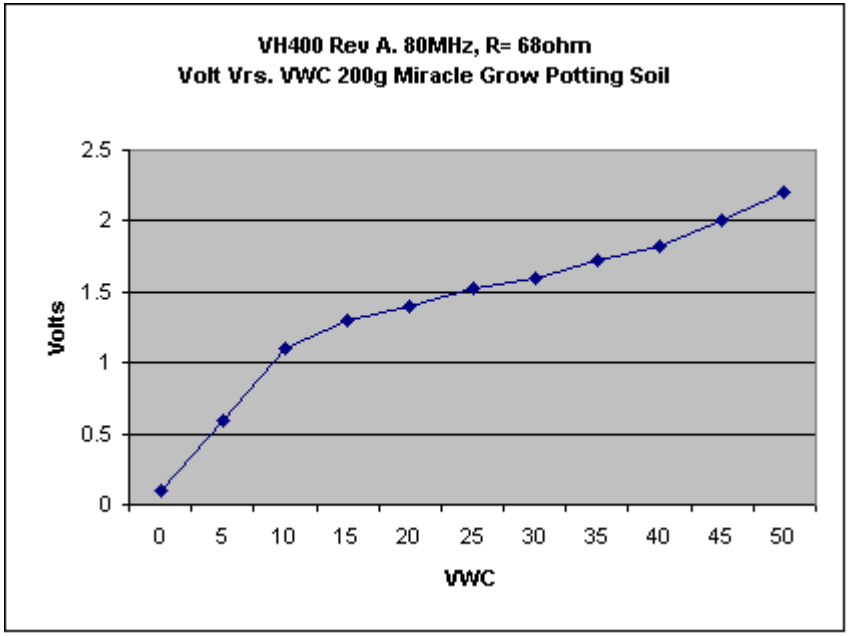
Going Forward

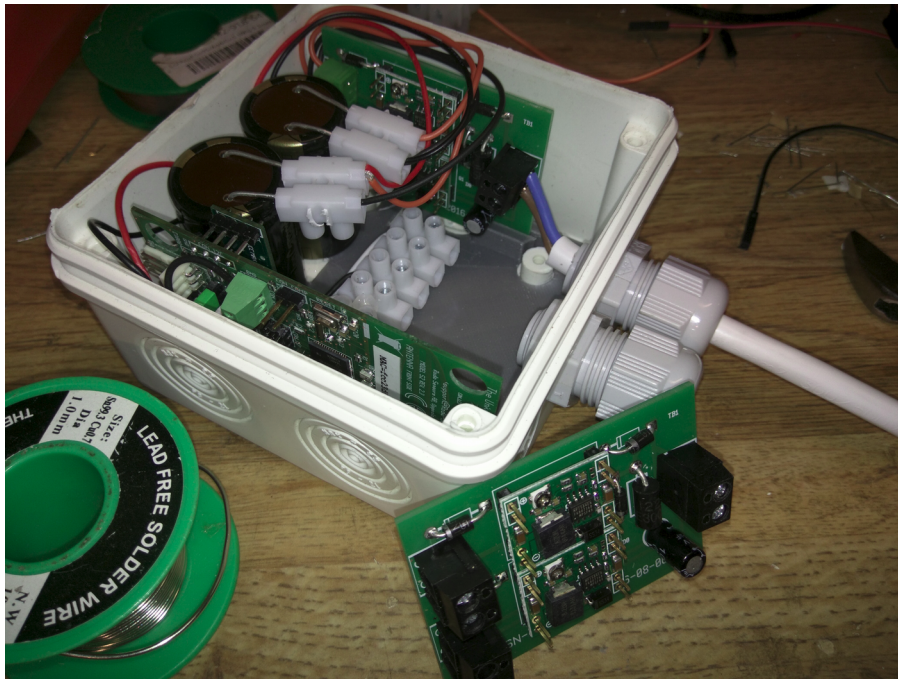
- Davies Rain Collector has performed well, but more analysis and data will be needed to make an informed conclusion
  - Hourly data analysis next
- Second rain collector will be deployed soon, with adjustments, removing need for 95% correction
  - Will be installed next to existing collector
- Need to ensure power and wireless connectivity are adequate
  - Low power leads to absolute tip counter reset and connection loss
  - Poor connectivity leads to missed minutely reports

Soil temp and humidity



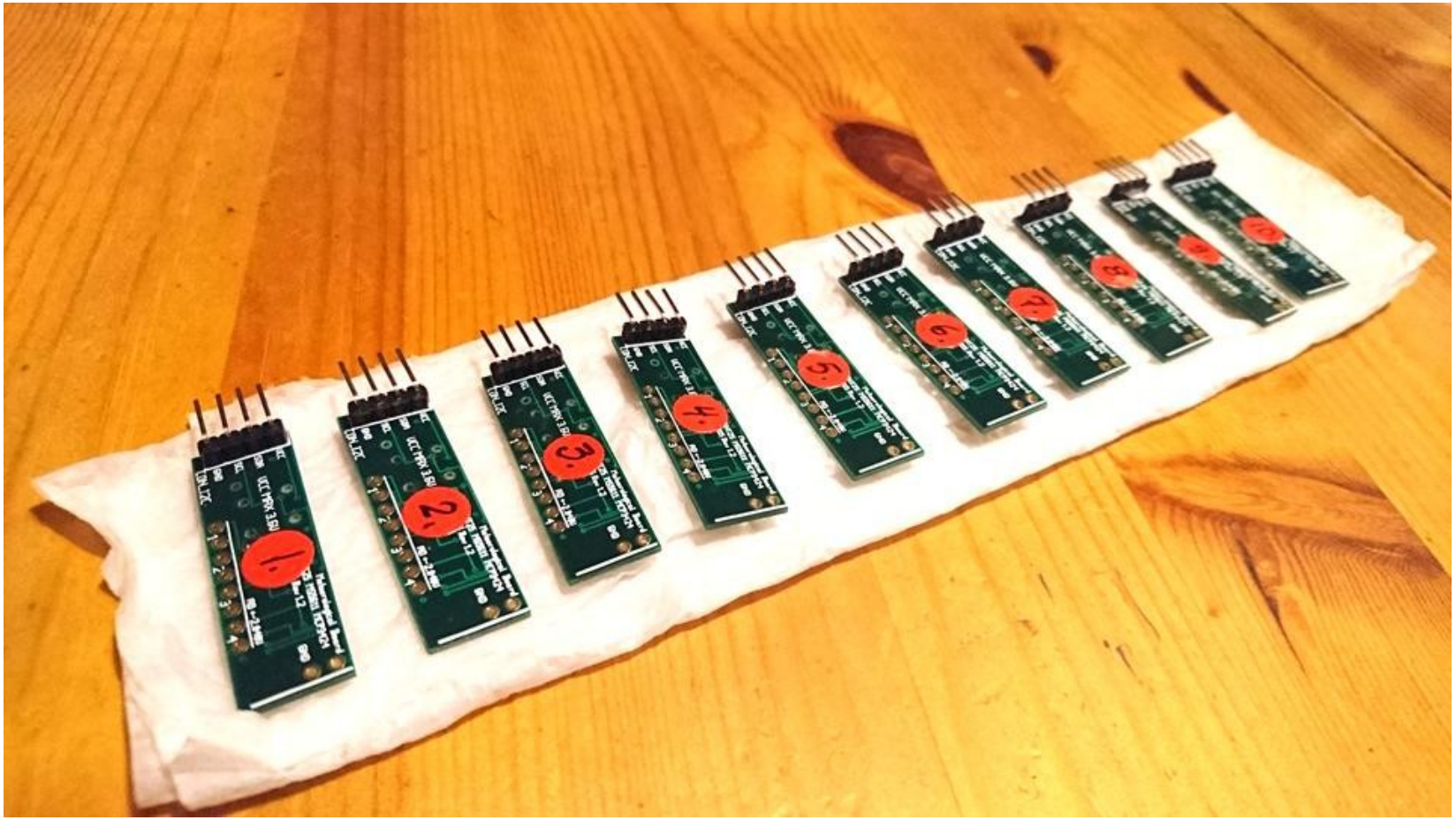
- DS18B20 digital one-wire bus
- Vegetronix VH400 analog feed 3.5-20V, measures the dielectric constant of the soil using transmission line techniques
- Both pre-calibrated





Air temperature and humidity

- Measured at 2m with solar irradiation shield
- Benchmarking of Pagodas
- Sensor selection: Sensirion SHT25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2.
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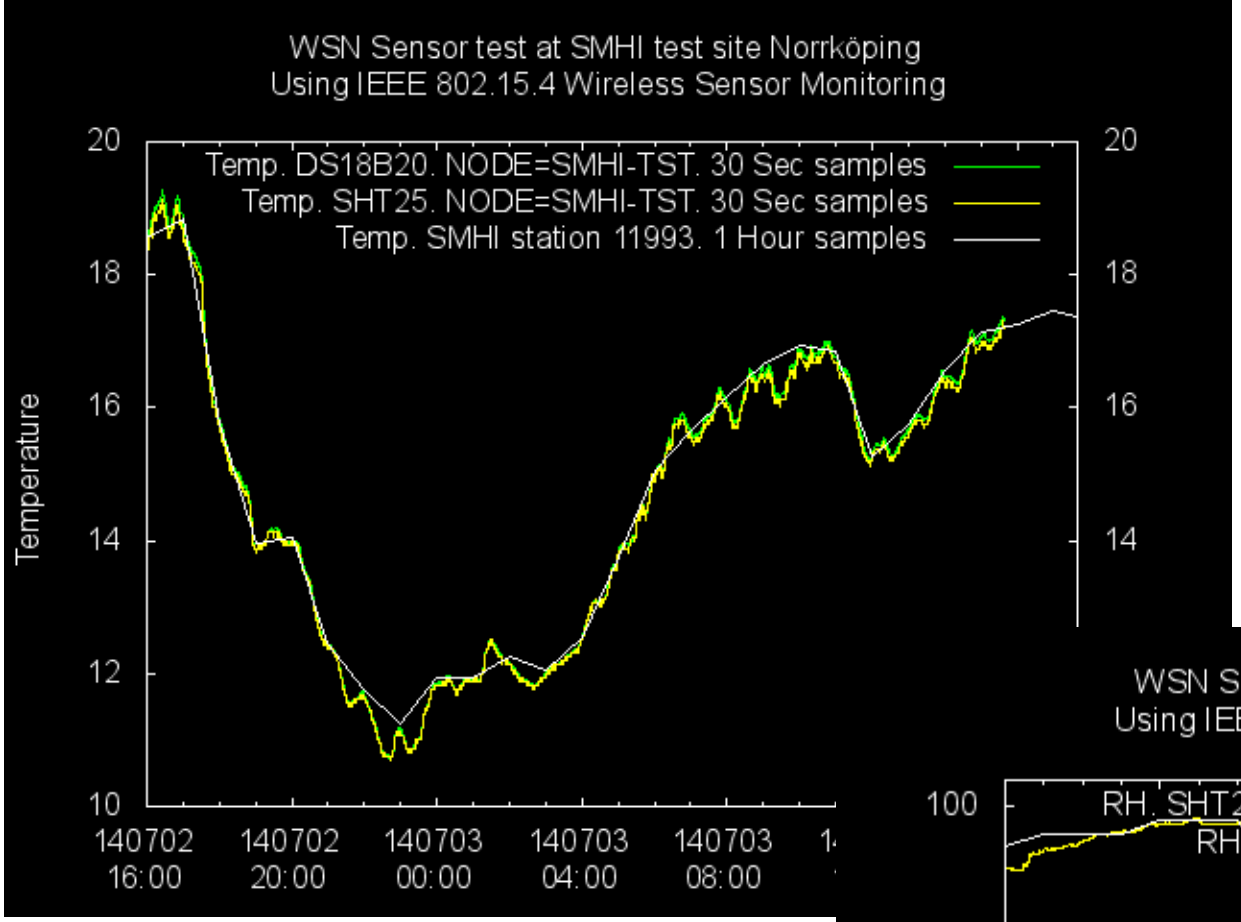
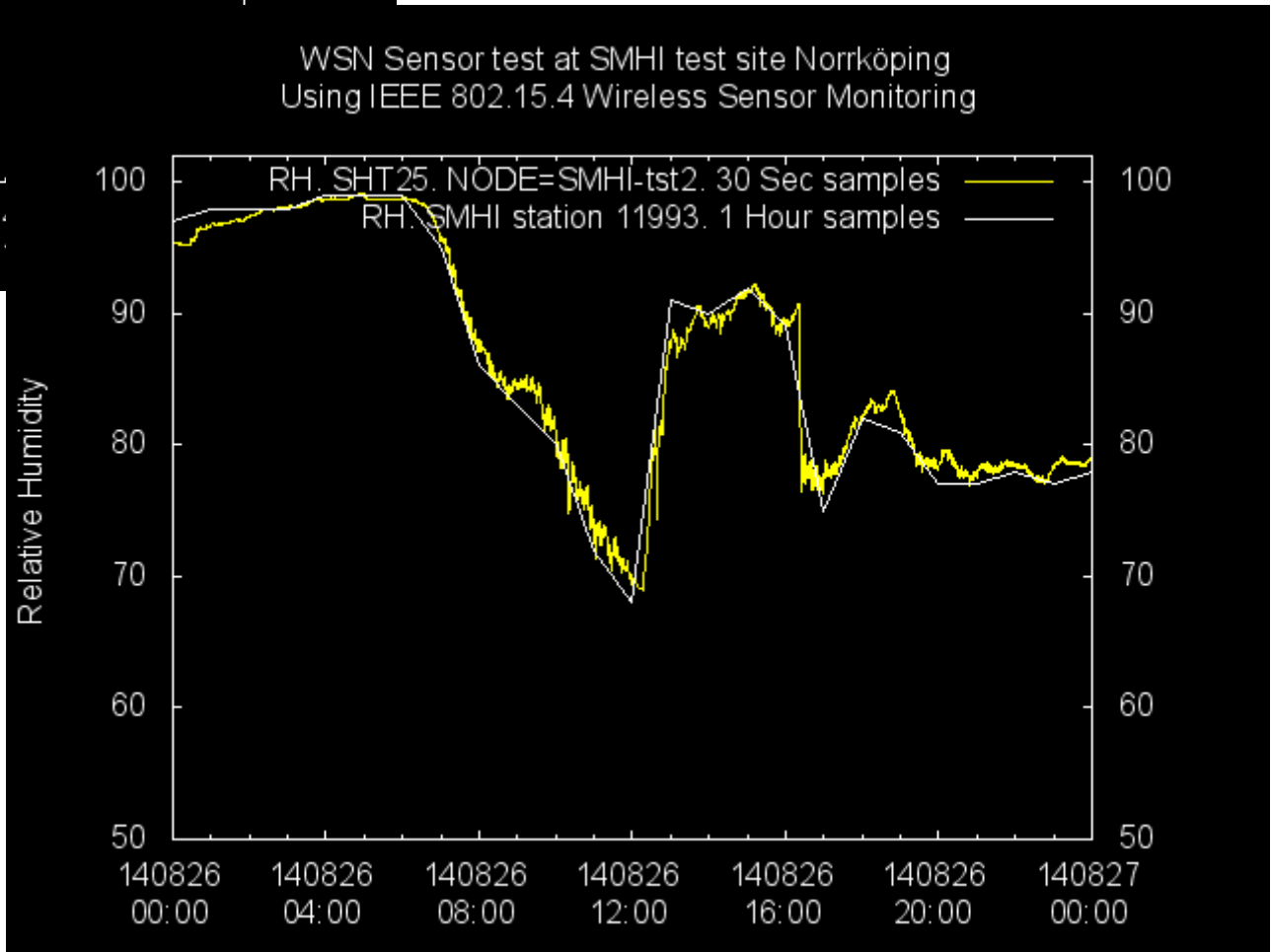
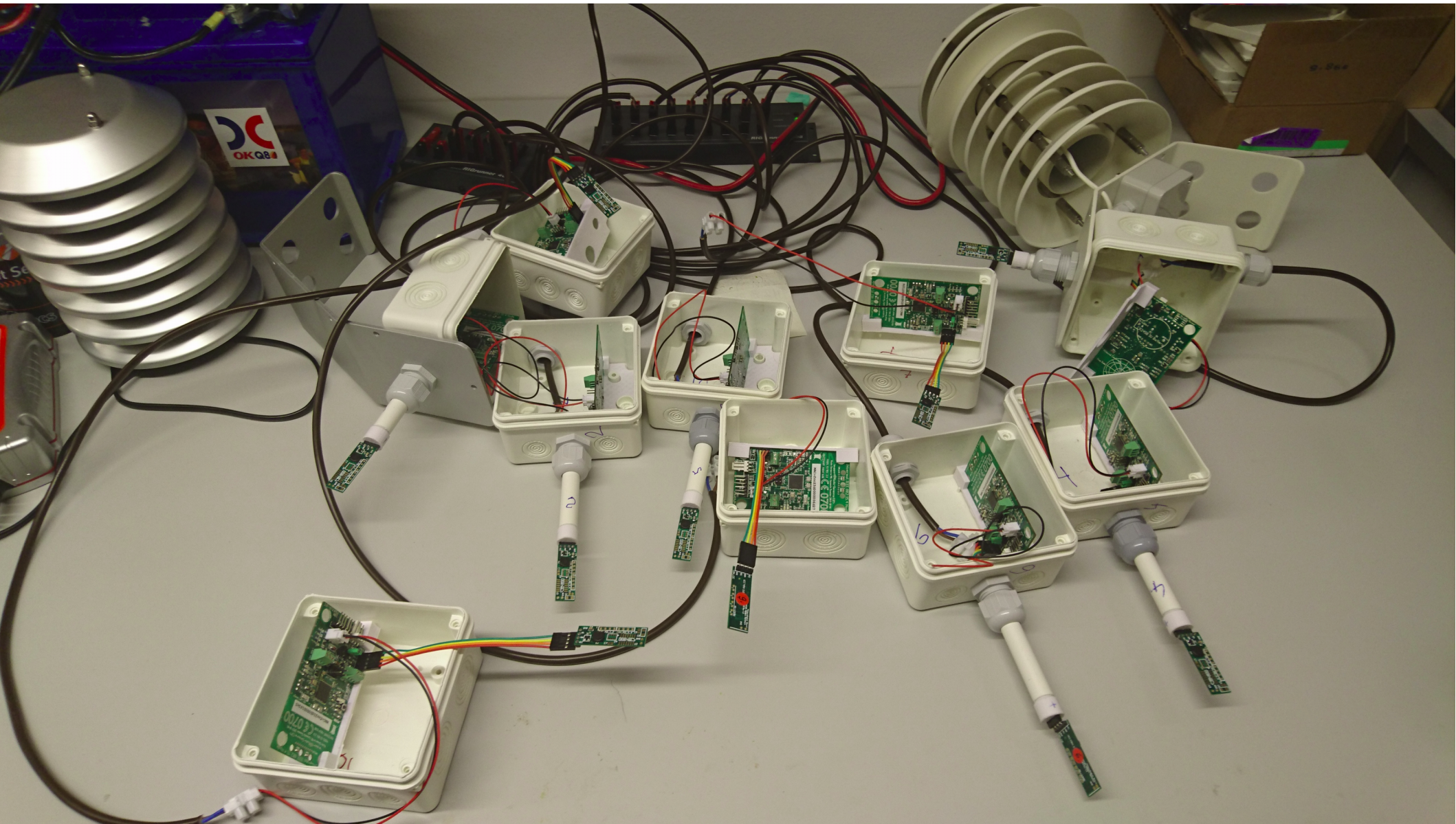
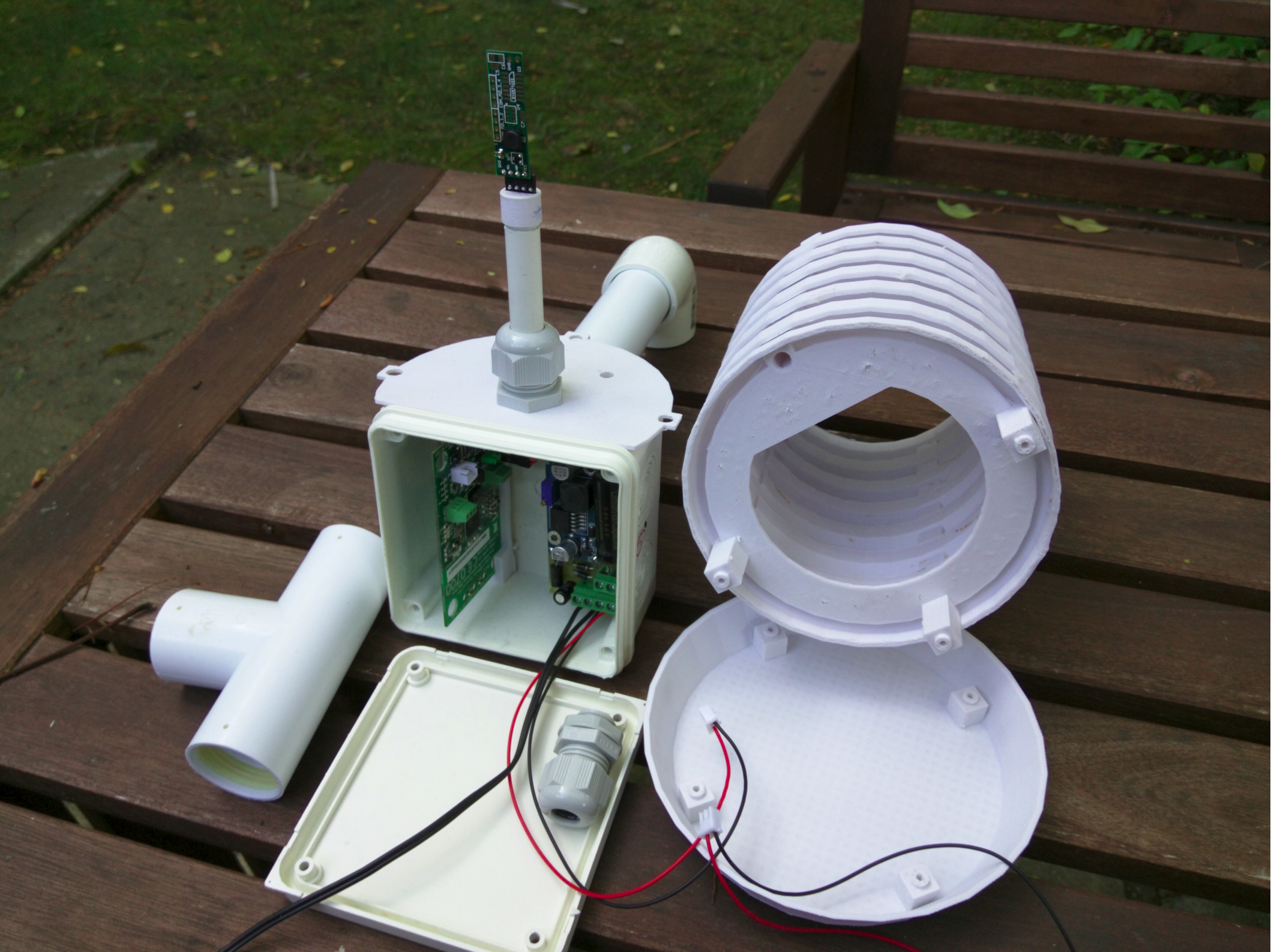


Benchmarking SHT25 at SMHI



Assembly and test of Gen2-2m nodes

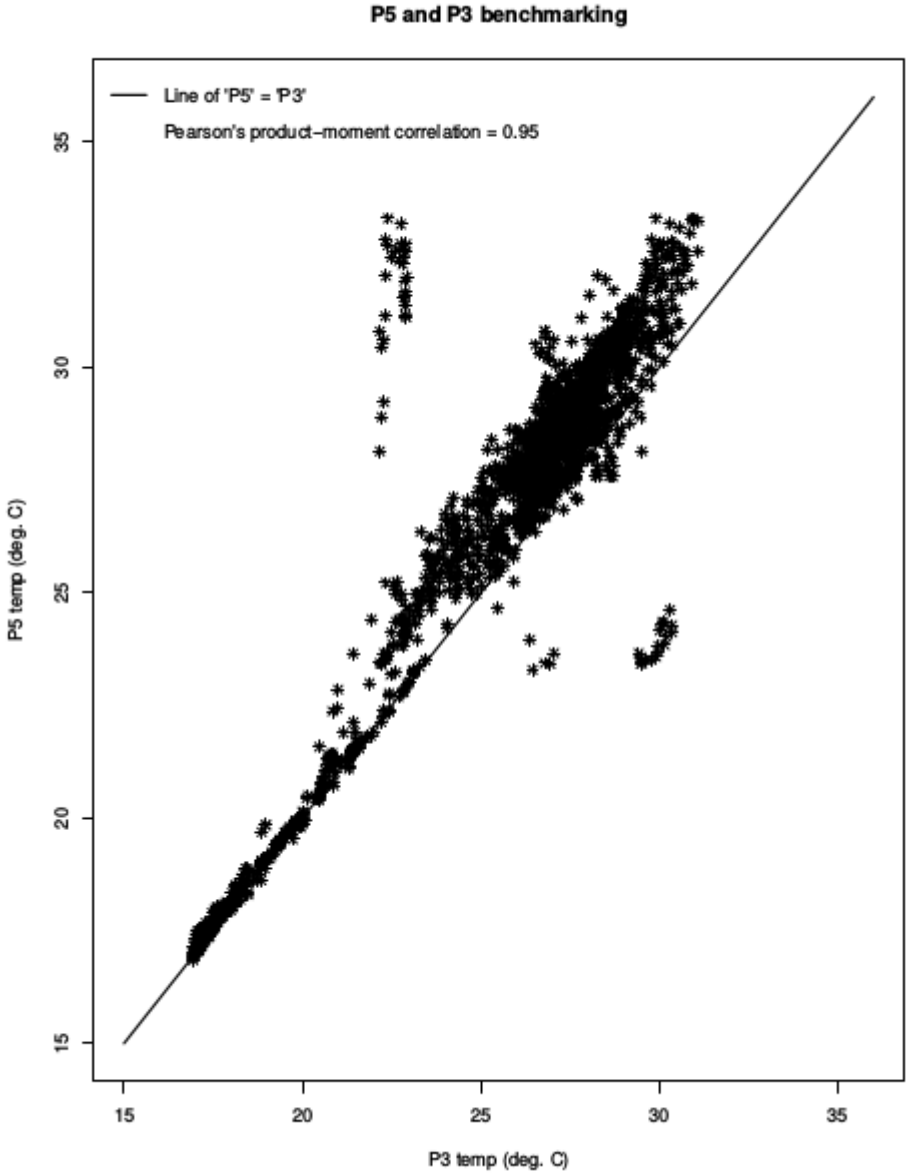


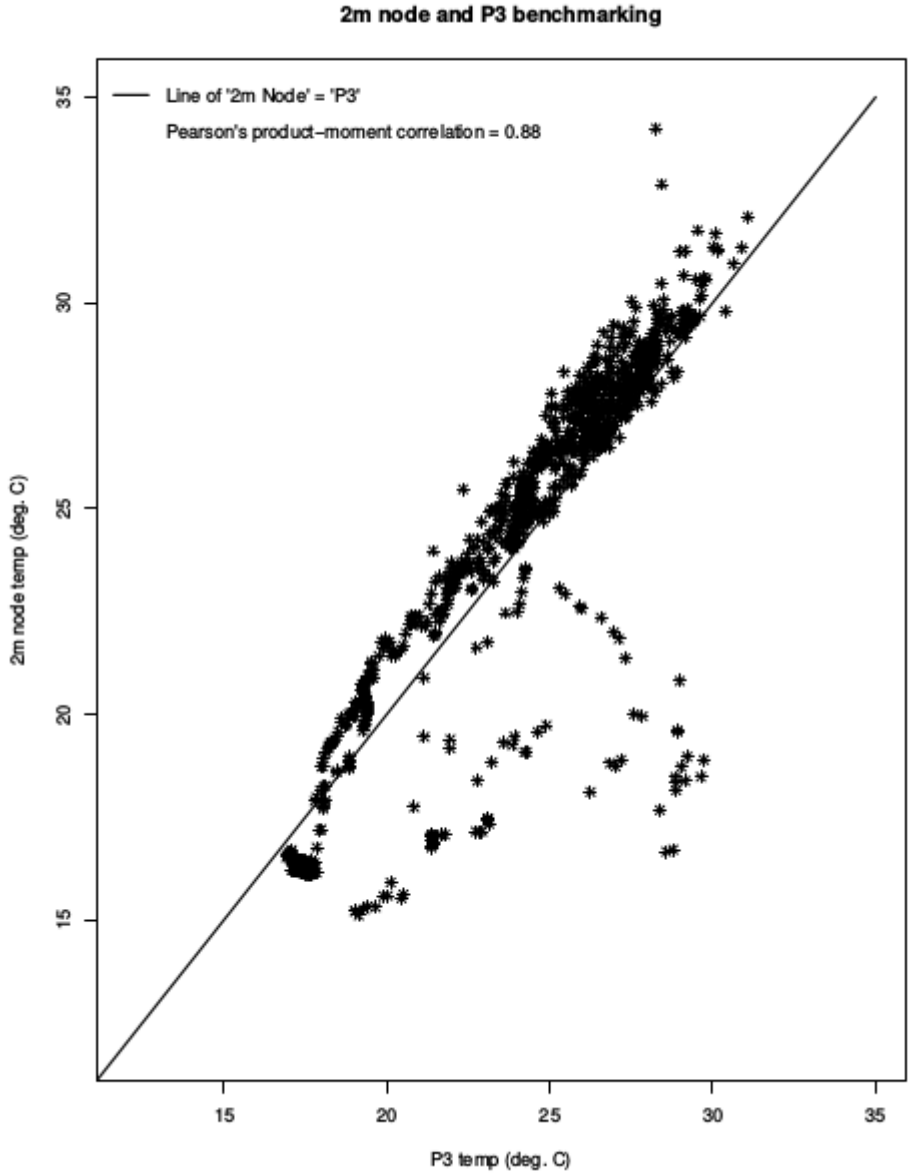


Pagoda benchmarking

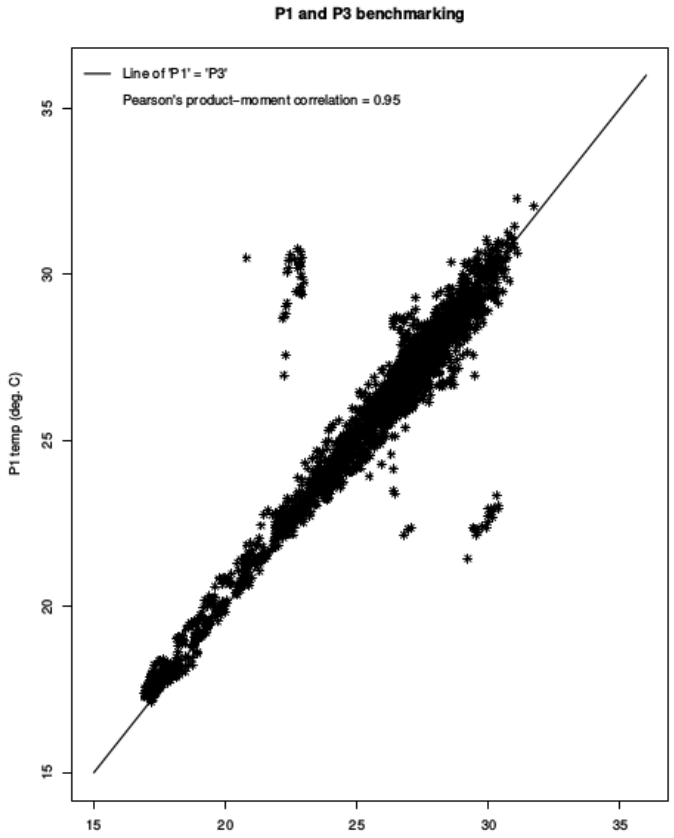
- Three commercial (one ventilated)
- Three own 3D-printed design

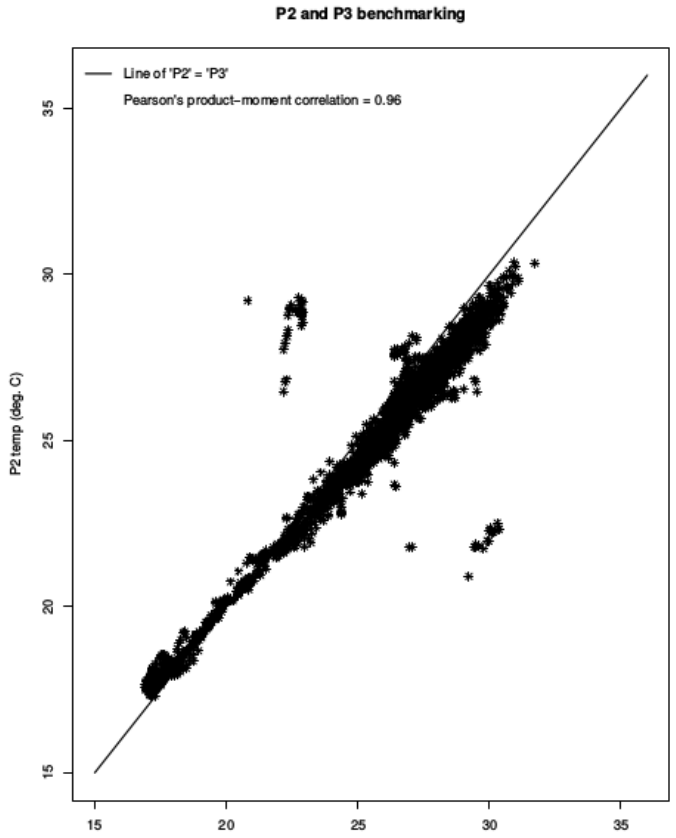
Benchmarking of commercial and 3D-printed Pagodas (1)

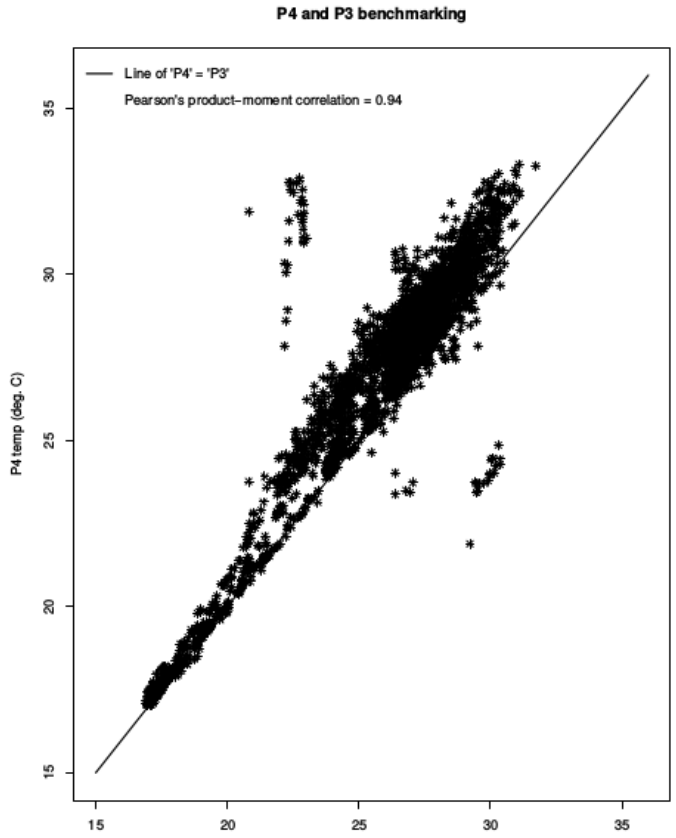




Benchmarking of commercial and 3D-printed Pagodas (2)



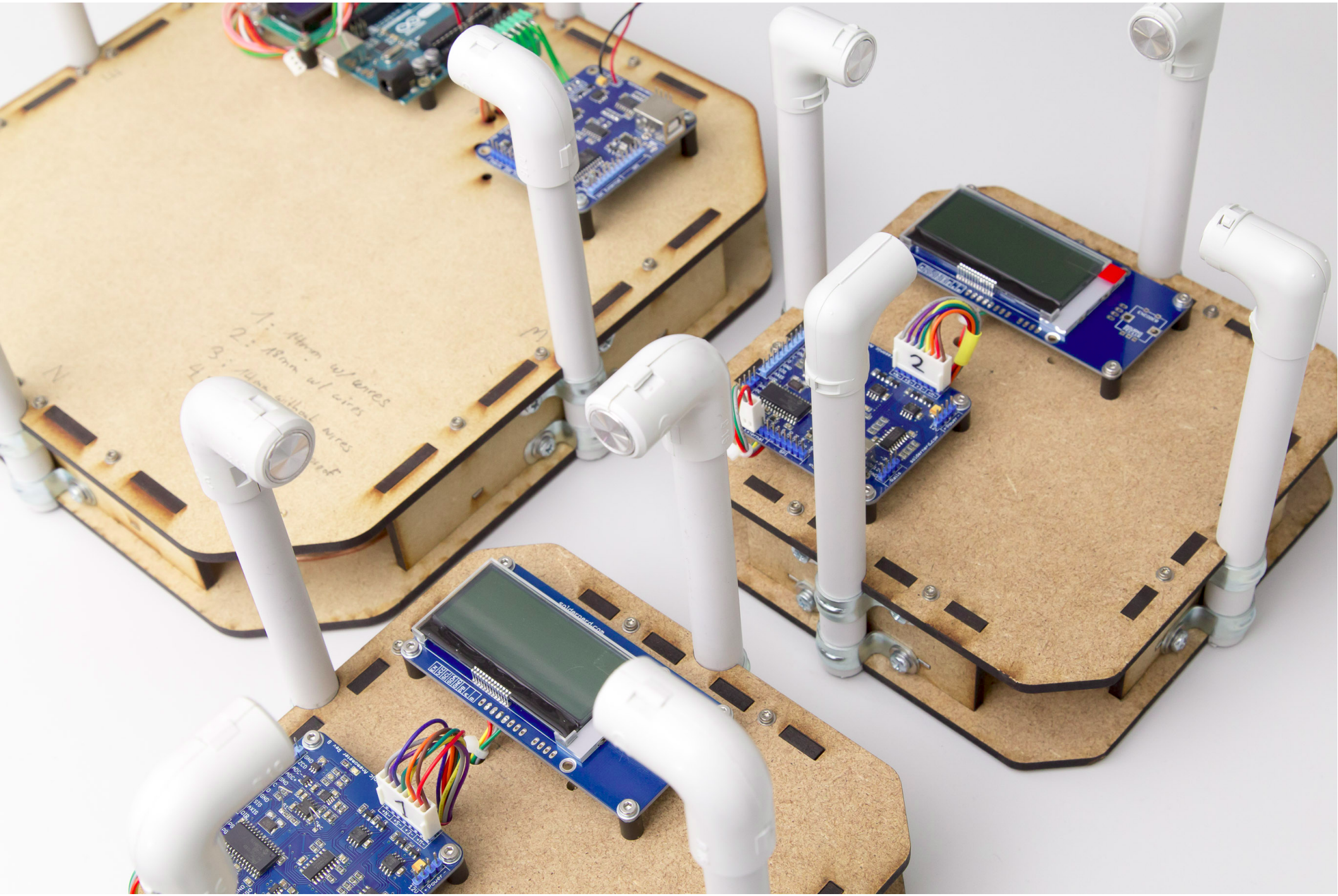




Wind direction and speed

- Wind Vane/Anemometer
  - Selected brand Inspeed.com
  - Type calibrated in windtunnel
  - Individuals calibrated by benchmarking

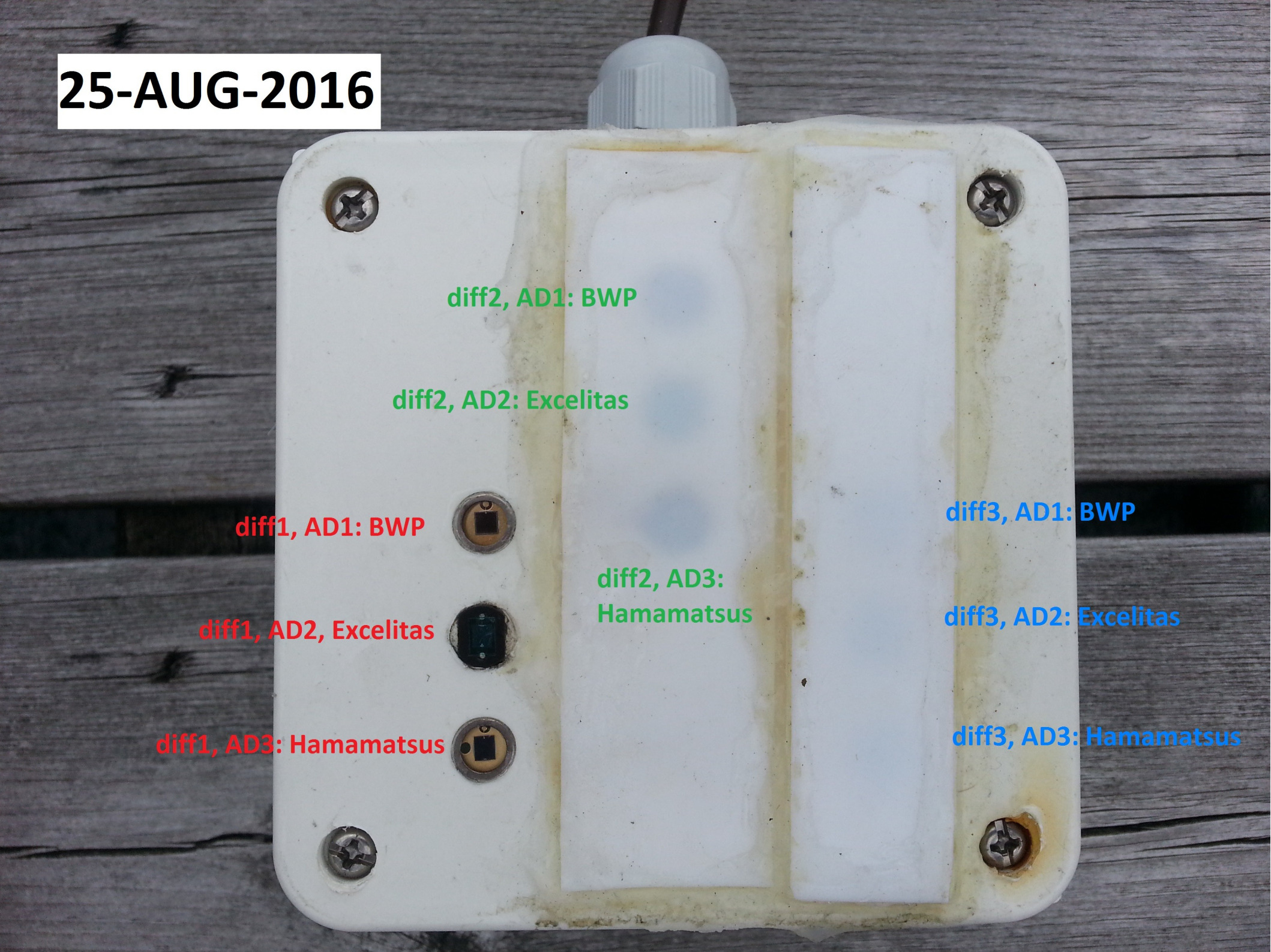
- Ultrasonic anemometer



https://soldernerd.com/wp-content/uploads/2017/02/20170203_Anemometer_011.jpg

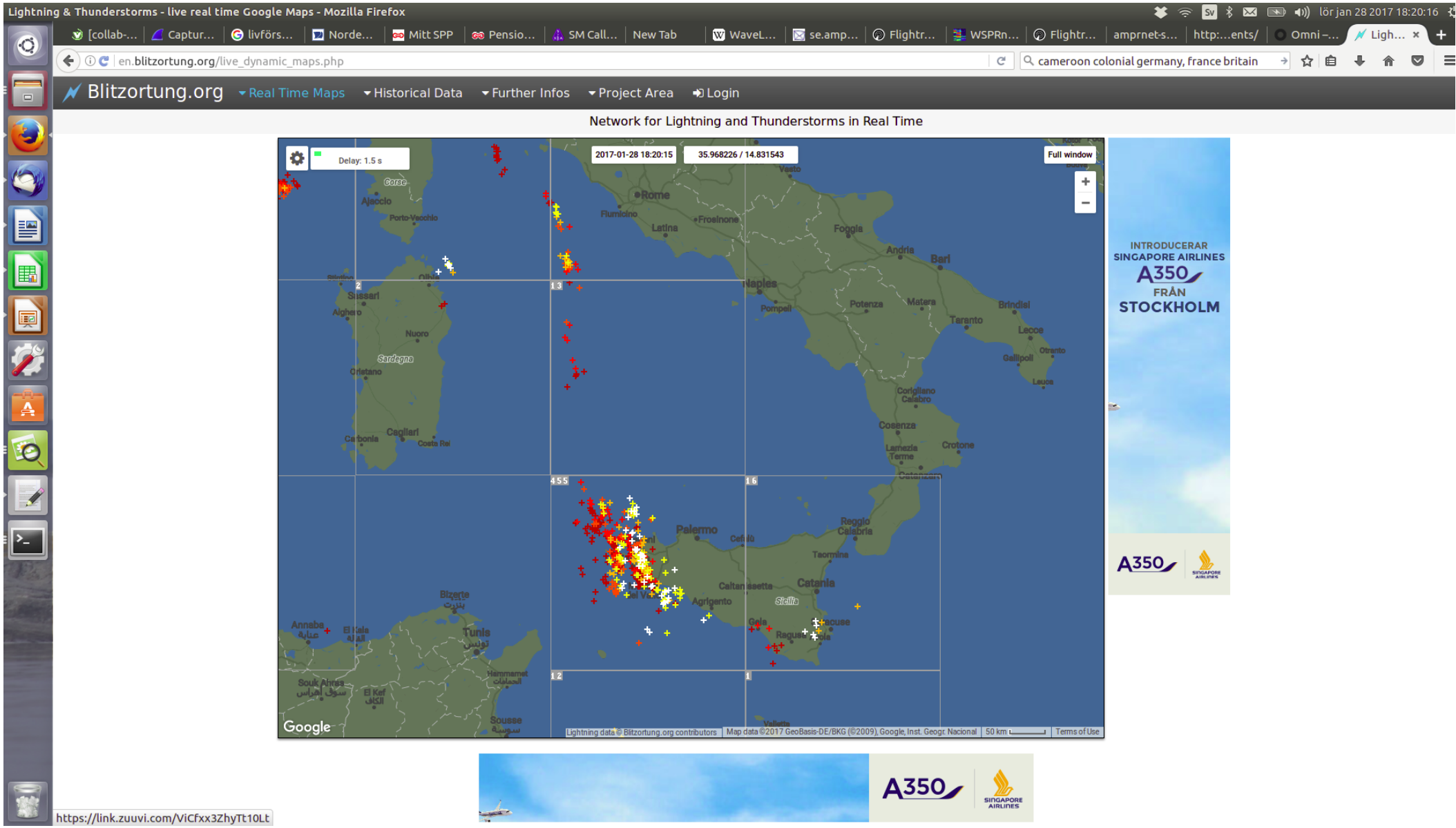
Insolation/Solar Irradiation

- Insolation is measured using a pyranometer
- In our case a photo diode with an opaque diffusor to adapt the signal range
- We have tested three different diodes
- And three different diffusor thickness
- Calibration by benchmarking with professional installation at Norwegian Meteorological Institute/University of Bergen


25-AUG-2016
diff2, AD1: BWP
diff2, AD2: Excelitas
diff1, AD1: BWP
diff2, AD3:
Hamamatsus
diff3, AD1: BWP
diff1, AD2, Excelitas
diff3, AD2: Excelitas
diff1, AD3: Hamamatsus
diff3, AD3: Hamamatsus

Test of photo diodes and teflon diffusors

Lightning detection and ranging



Discussion?