CZECH HYDROMETEOROLOGICAL INSTITUTE

The Use of Microsensors for Real-Time Field Measurement and the Comparison of Cairpol Sensor with Reference Analysers

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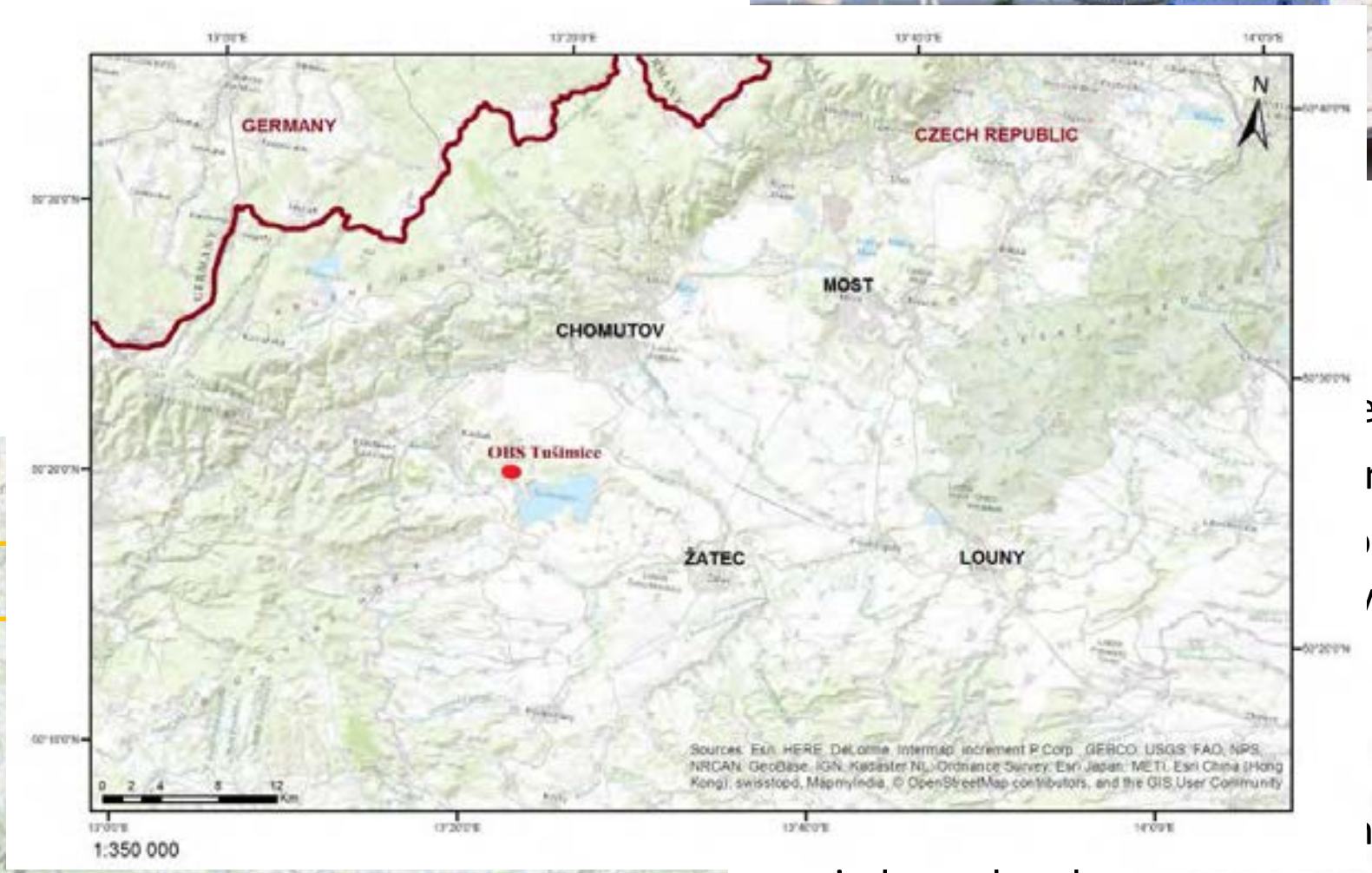

GPS location: 50°22'36.38" N; 13°19'39.58" E
322 meters ASL

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in boundary layer

Our focus and potential use of microsensors

- Focus on **vertical transport of air pollution** (stagnation and normal meteorological conditions)
- Mast meteorological measurement (80 m), SODAR wind profiler (600 m), ceilometer (3 km), LIDAR (in preparation)
- **Use of microsensors for „in motion“ measurement** (in horizontal and vertical scale)
- In cooperation with UAVs producers ans operators – Robodrone Industries, s.r.o. and Kelcom International, spol. s.r.o. (CZ)

Use of New Generation Light-weight Sensors

Experience from abroad:

- OpenSense project - ETH Zurich, CH (http://www.opensense.ethz.ch/trac)
- DISCOVER project - NASA, Houston, USA

Characteristics that must be taken into account

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- Low weight
- Low cost
- Immediately useable
- Portable
- Battery autonomy
- Internal datalogger
- +++ research purposes

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- Usually constructed for the indoor measurement
- ! Air humidity / Temperature ! -> NEED FOR additional data control
- High risk of coincidence and errors
- Higher detection limits
- Lower measurement accuracy
- Limited calibration possibilities
- Limited time of power supply

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source: http://www.co2meter.com

Testing Light Sensors for UAVs platform

Kingfisher

- Dimensions 1200 x 1400 x 220 mm
- Load capacity up to 5 kg
- Flight duration up to 45 min (25 min with Max. load)
- Max. speed 70 km/h
- Max. altitude 1000 m AGL
- Wind resistence 10 m/s
- Temperature range -10 to +50 °C
- Camera + GPS in real-time, videorecords

Strix

- Load capacity 15 kg
- Flight duration 30 min (15 min with load)

Sparrow

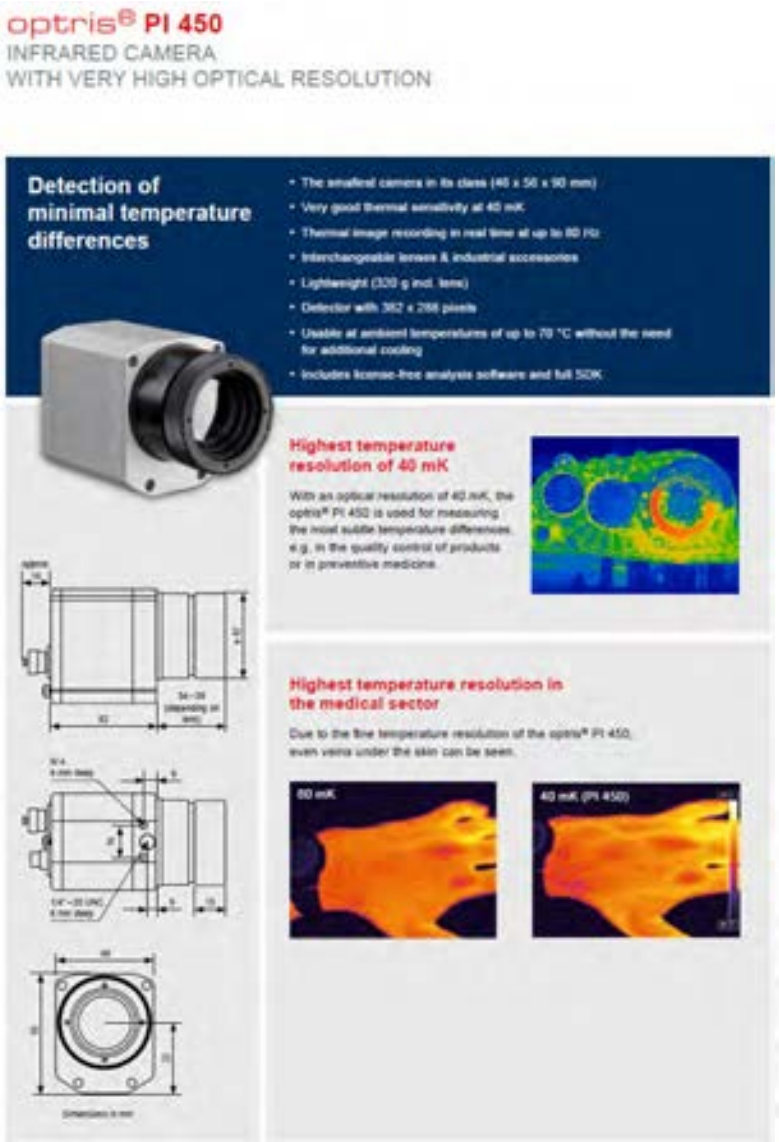
- Load capacity 11 kg
- Flight time 60 min (35 min with Max. load)

Kingfisher - testing flights with particle analyser

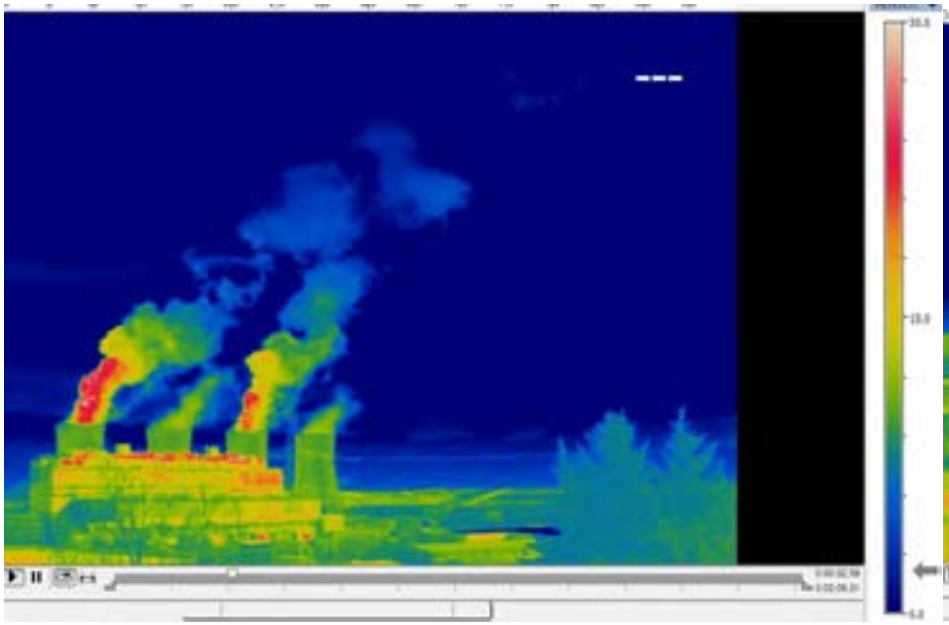
Thermography of stack plumes

IR camera PI 450 (Optris)

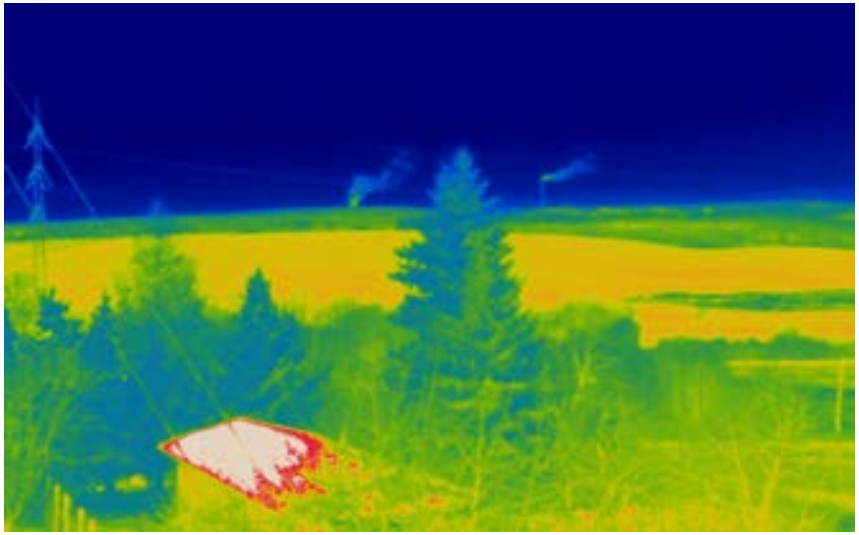
- range: from -20°C up to 900°C
- spectral range: 7.5 to 13 µm
- weight: 320g
- Usable at ambient temperature up to 70 °C
- Detector with 382 x 288 pixels

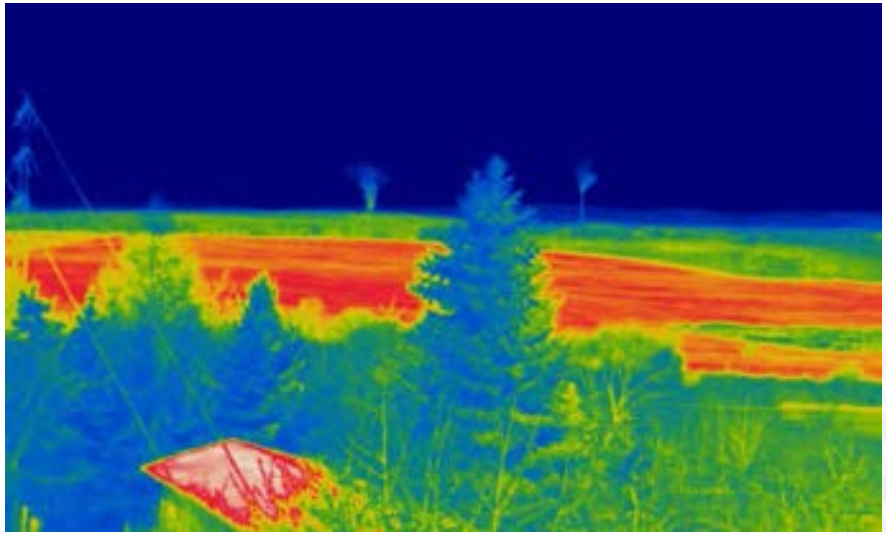


Power Plant Tušimice II – Cooling towers



Power Plant Prunéřov I, II – stacks





Cairpol (FR) Light Sensors SO2, CO2, NOx, NO2 and O3

Miniature air quality monitoring sensors network

SPECIFICATIONS:

- LCD display with concentration levels of the measured pollutants
- Internal data logging capacity: up to 1 year, depending of the setting
- Internal microprocessor for value and time calculation
- Low battery indication
- Operating time: 24 to 36 hours when fully charged for USB versions (daily recharge for optimal use)
- Power supply: 5VDC / 200 mA rechargeable by USB via PC or 220V/110V with 5V adaptor (solar panel option)
- Output: USB or UART (Analog signal on demand)
- Dimensions: diameter 32 mm (1,26"), length 62 mm (2,44")
- Weight: 55 g (1,94 oz)
- IP 42 (according IECC0529)
- Storage condition: 5 to 20°C (41°F to 68°F), 10 to 90% RH, mbar 1013 ffl 200 (psi 14,69 ffl 2,90)
- Operating condition: depending of the sensor, in general -20°C to +45 °C (-4°F to 113°F), 10 to 90% RH, mbar 1013 ffl 200 (psi 14,69 ffl 2,90)
- Electric standards: CEI/UL/CSA N°61010-1: 2008 / EN 61010-1:2001

* Detailed specification per sensor on request

	Ranges :
O_3 / NO_2	0-250 ppb
NO_2	0-250 ppb
CO	0-20 ppm
H_2S / CH_4S	0-1000 ppb / 0-20 ppm / 0-200 ppm
NH_3	0-25 ppm
SO_2	0-1000 ppb
CH_2O / Organic solvents	0-1000 ppb
nM VOC	0-16 ppm

Dust Particles Light Sensors

Particle Analyser (GRIMM MINI-LAS 11E, DE)

- PM10, PM2.5 and PM1
- range: from 0.25 to 32 µm
- weight: 2,1 kg

http://wiki.grimm-aerosol.de/index.php?title=ENVIRO-11E

Fidas Fly 200 (Palas, DE)

- Ultra-light dust monitor **Fidas Fly 100** integrated into **HORUS flight robot**
- PM10, PM4, PM2.5 and PM1
- range: from 0.18 to 18 µm
  from 0.40 to 40 µm
- Weight (Fidas Fly 100): 1,4 kg

http://www.palas.de/en/product/fidasfly200

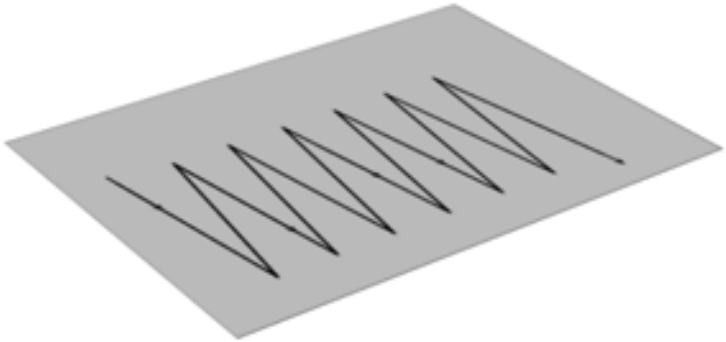
Fidas Frog (Palas, DE)

- PM10, PM4, PM2.5 and PM1
- range: from 0.18 to 40 µm
- weight: 2,1 kg

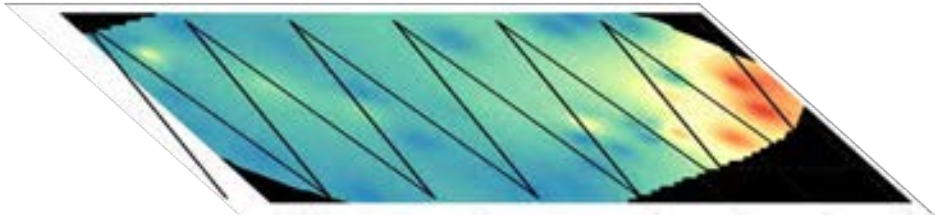
http://www.palas.de/en/product/fidasfrog

Flight Scenarios and Data Processing / Visualisation

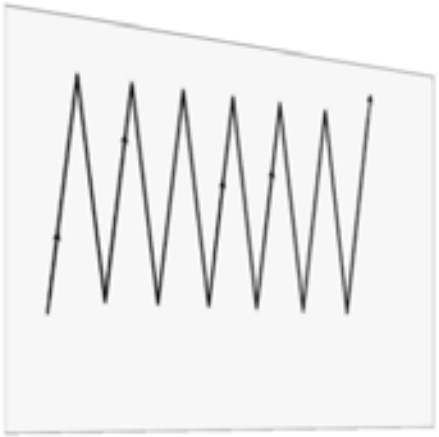
Flight in Horizontal Plane



Measured Values Interpolated



Flight in Vertical Plane



Comparison of CairClip O3 / NO2 Sensor with Reference Measurement

- **CairClip parameters**:

- Equivalent value of O3 + NO2 (ppb)
- Data sampling: 1-min or 15-min
- Range: 0 - 250 ppb
- Detection limit: 20 ppb
- Repeatability in 40% of range: +/-15%
- Uncertainty: < 30%

- **Testing period**:

- At Tušimice Observatory
- 3 month, from June 2015 until September 2015
- Located at the reference height 2 m, in housing (a meteorological shelter)

Reference Measuring Method – NO2, O3

Automated Air Quality Monitoring Network of CHMI

Analyzers: **Teledyn API** (California, US)

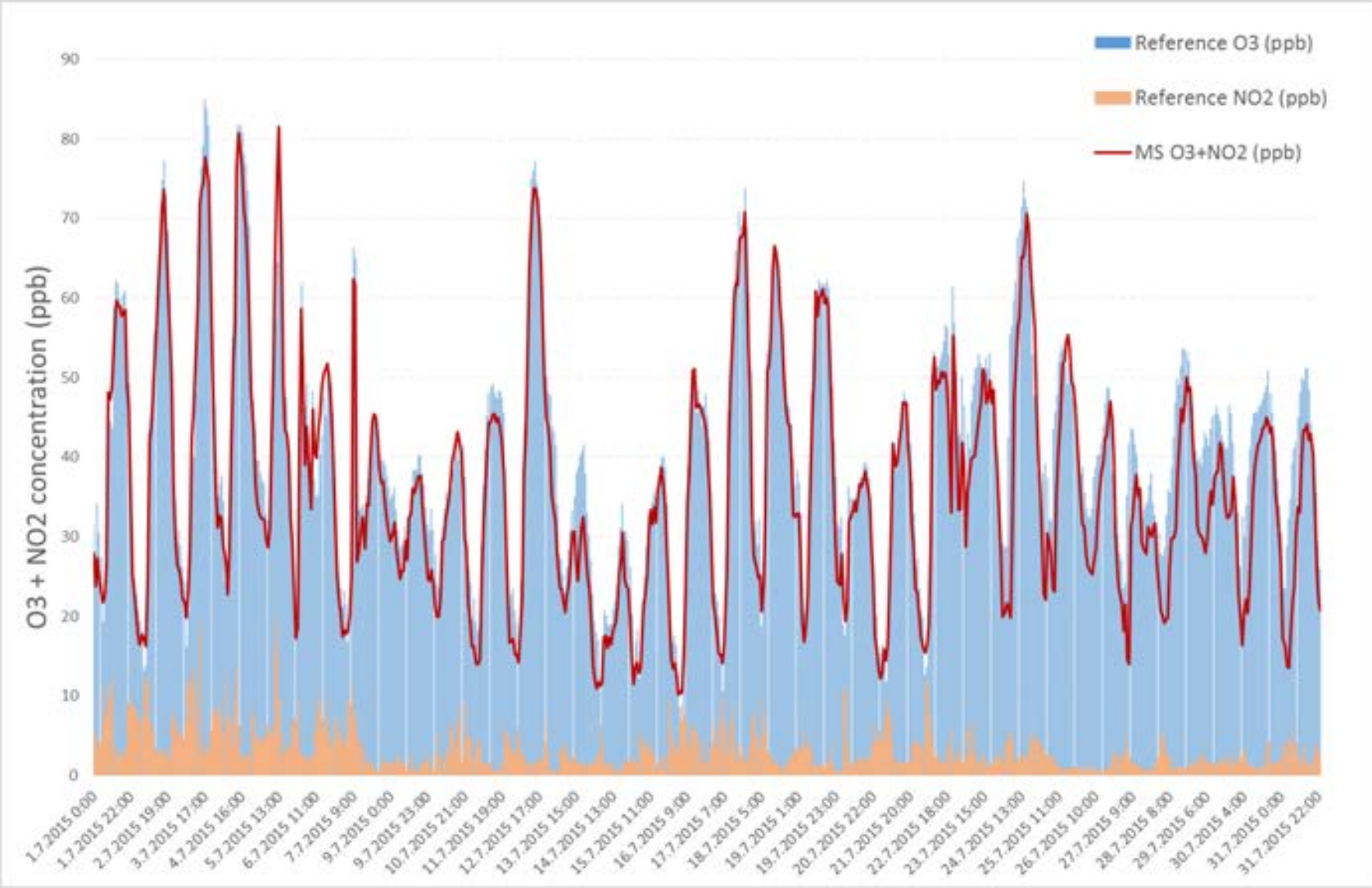
- **O3**: **T400**

Min. range: 0 - 100 ppb
Max. range 0 - 10 ppm
Detection limit: < 0.4 ppb

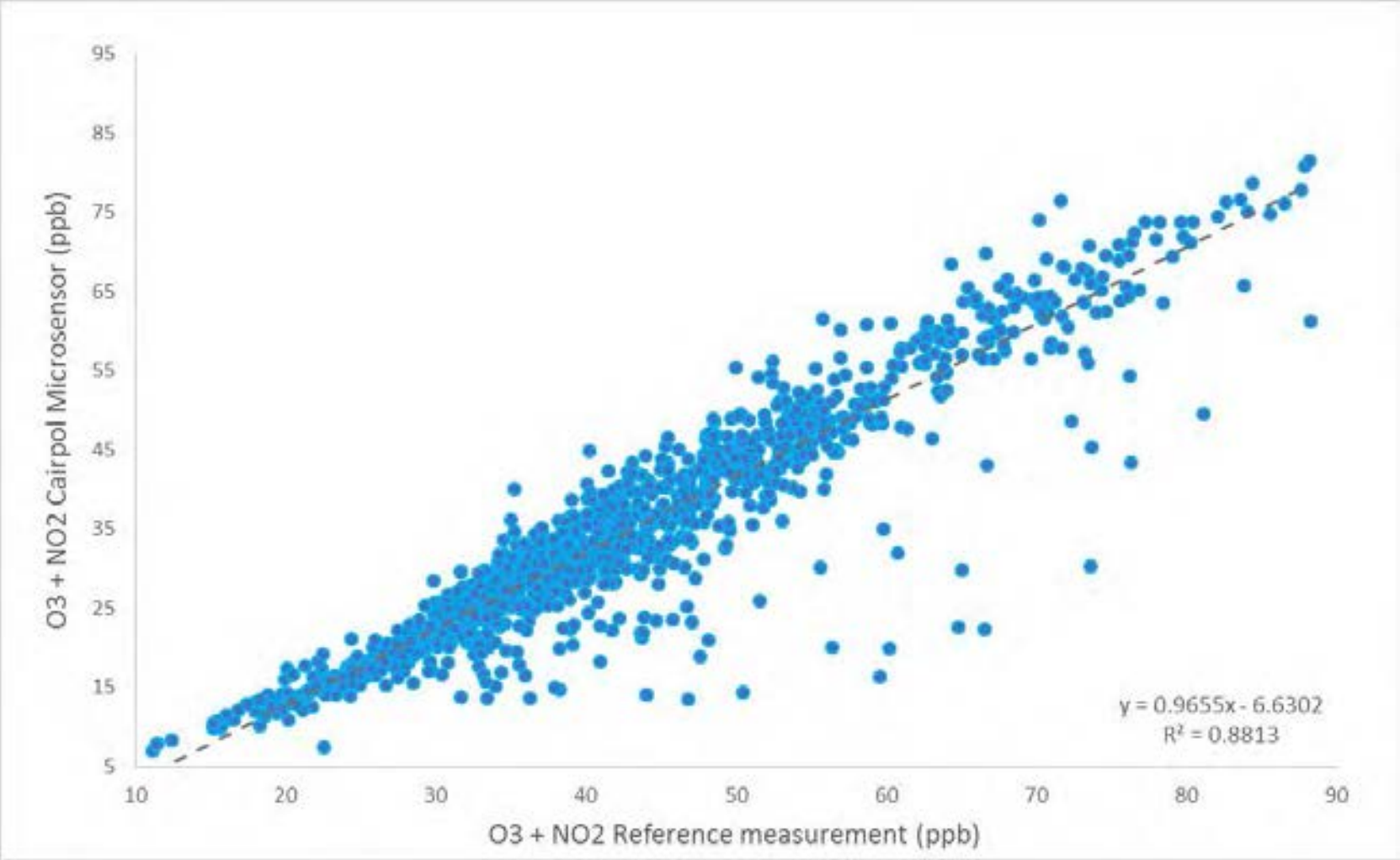
- **NO2**: **T200**

Min. range: 0 - 50 ppb
Max. range: 0 - 20 ppm
Detection limit: 0.4 ppb

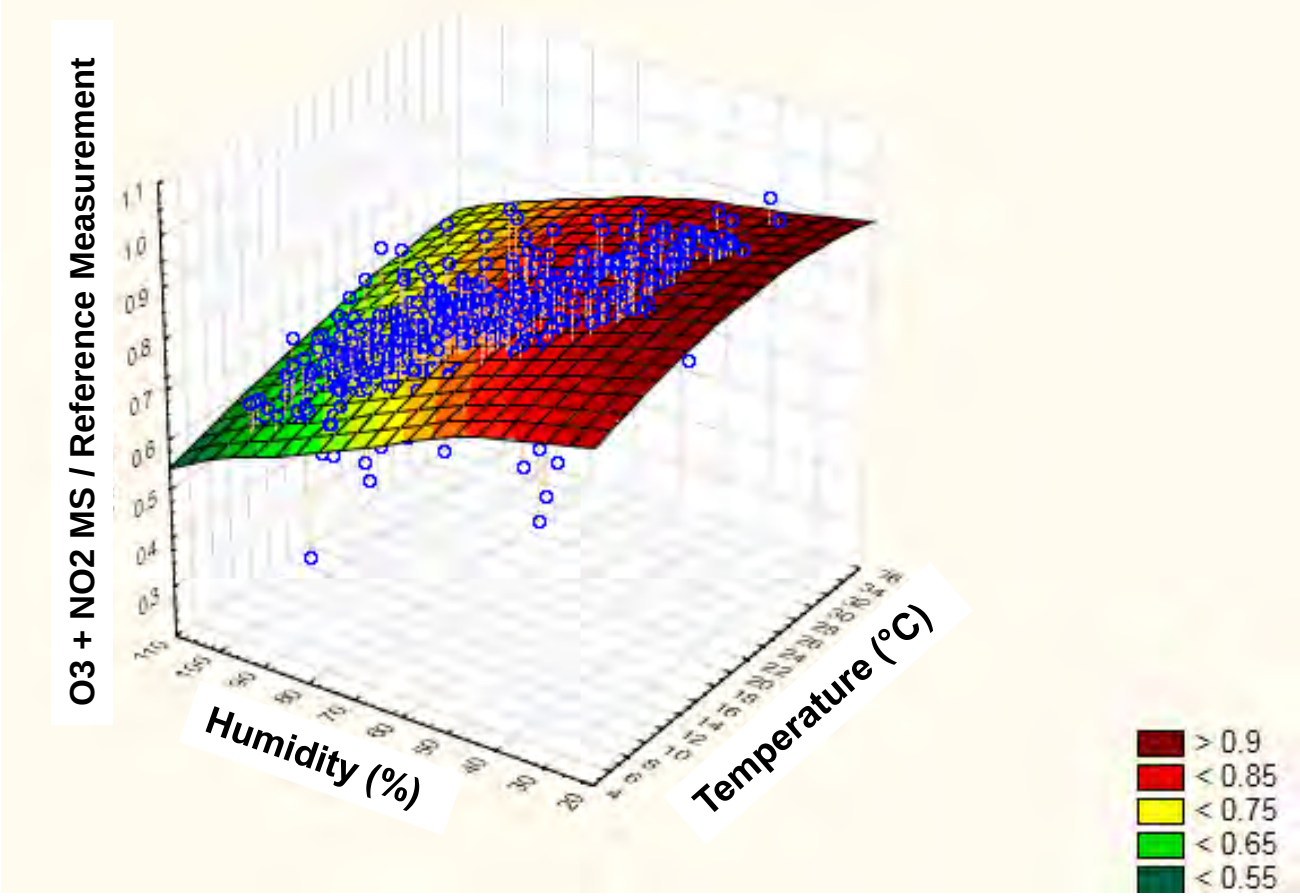
MS vs. Reference Measurement O3 + NO2 (July 2015)



Strong Correlation between MS and Reference Measurement



Influence of air temperature and humidity on measuring accuracy of MS



- The largest deviations between MS and RM in measured values at low temperature and high relative humidity

Effect of temperature and humidity

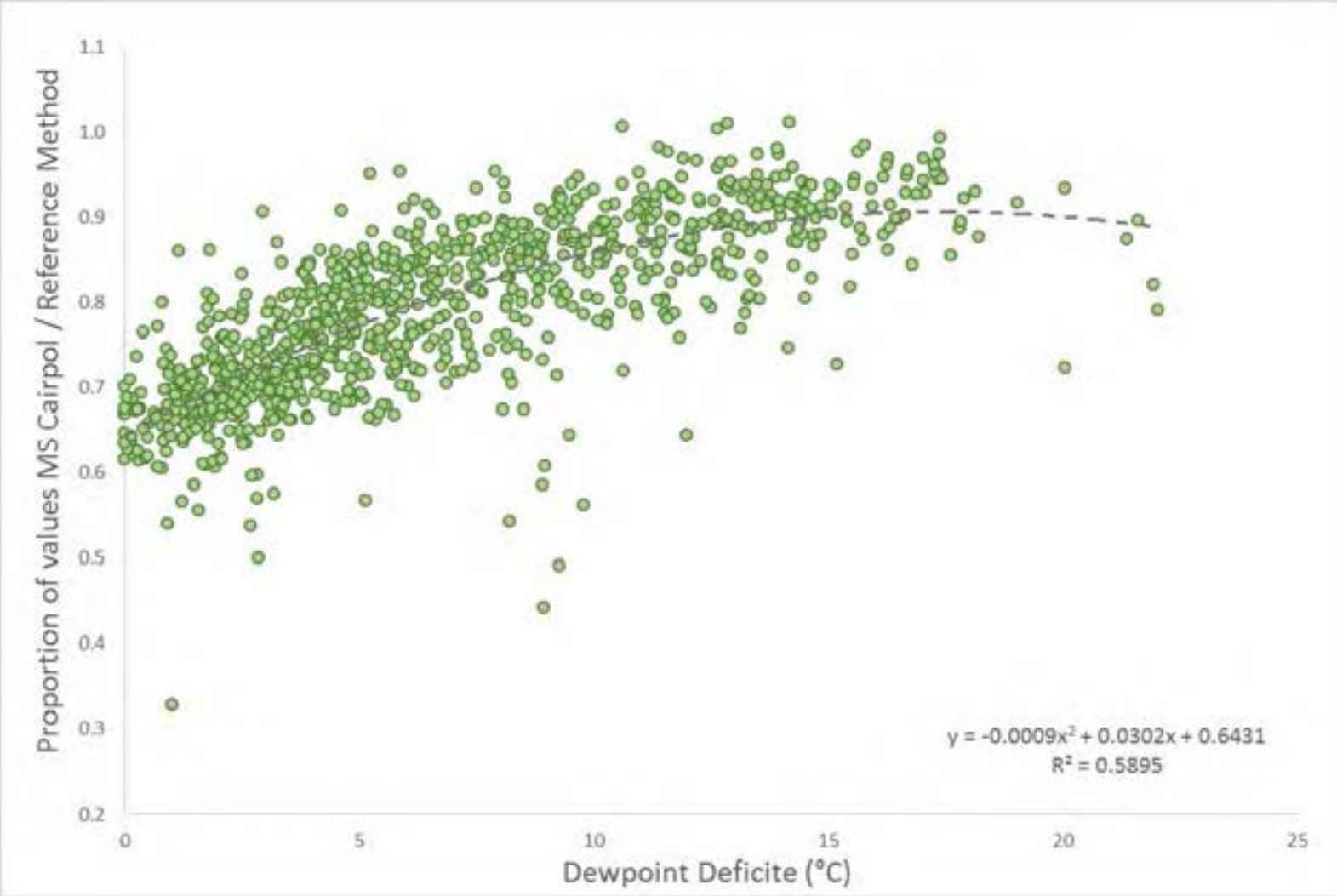
- **Dewpoint temperature calculation**

$$T_d = \frac{240.97}{[(17.502/A)-1]} \qquad A = [\ln(RH/100))] + \left[\frac{(17.502 \cdot t)}{(240.97+t)}\right]$$

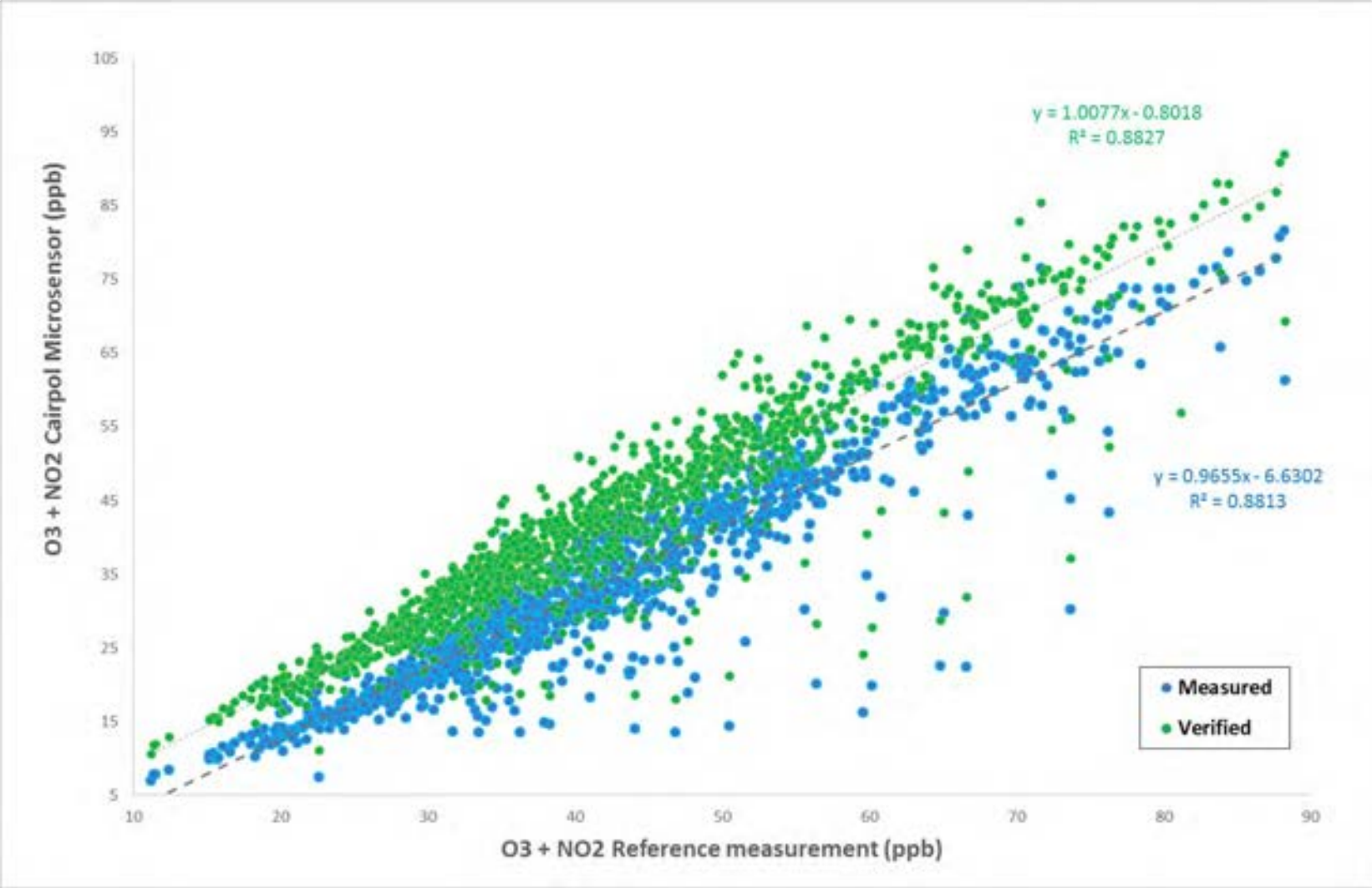
- **Dewpoint deficite**

Td $_{deficite}$ = T – Td

MS measurement quality increases with decreasing air humidity



Data verification according to Dewpoint Deficite



Summary
Comparative Measurement MS vs. RM

- Accuracy of MS measurement is lower than the accuracy of Reference Analysers
- Cairpol MS O3 + NO2 values are highly correlated with reference measurement of O3 and
- Measurement quality of microsesor depends on meteorological conditions (air temperature and humidity)
- Possibility to validate data according to relevant meteorological variables

Conclusion

- Microsensors are very promising instruments in air quality research
- Conectable to mobile carriers (car, plane, drone, public transportation) => getting real-time hetero-spatial data
- Use of data in air quality modeling and hotspots identifying
- The need to know the „behavoiur“ of the sensor
- The need for appropriate interpretation of measured data! (regarding to measurement quality of MS)

References

- http://www.uav.kelcom.cz/
- http://www.robodrone.com/produkty-a-sluzby#robodrony
- http://www.palas.de/en/product/fidasfly200
- http://www.cairpol.com/index.php?option=com_content&view=article&id=57&Itemid=166&lang=en

Thank you for your attention!

O3/NO2

CAIR POL

MINIATURE AIR QUALITY MONITORING SYSTEMS

P049D OZ Technical Data Sheet O3-NO2 160812

Technical Data Sheet CairClip O_3-NO_2

(document prone to modification)

Range	0-250 ppb (0 - 240 ppb analog)
Limit of detection [1, 2]	20 ppb
Repeatability at zero [1, 2]	+/- 7 ppb
Repeatability at 40 % of range [1, 2]	+/- 15 %
Linearity [1, 2]	< 10%
Uncertainty	< 30% [1, 2]
Short term zero drift [1, 2, 4]	< 5 ppb/24 H
Short term span drift [1, 2, 4]	<2% FS [7]/24 H
Long term zero drift [1, 2, 4]	< 10 ppb/1 month
Long term span drift [1, 2, 4]	< 2% FS [7]/1 month
Rise time (T10-90) [1, 2]	<90s (180s if large variation of RH)
Fall time (T10-90) [1, 2]	<90s (180s if large variation of RH)
Effect of interfering species [5]	Cl_2: around 80% Reduced sulphur compounds : negative interference
Temperature effect on sensitivity [2]	< 0.5 % / °C
Temperature effect on zero [2]	+/- 50 ppb maximum under operating conditions
Maximum exposure	50 ppm
Annual exposure limit (1 hour average)	780 ppm
Operating conditions	- 20°C to 40°C / 10 to 90% RH non-condensing 1013 mbar +/- 200 mbar
Recommended storage conditions	Temperature: between 5°C and 20°C Air relative humidity: > 15% non-condensing
Power supply [8]	5 VDC/200mA (rechargrable by USB via PC or 100V-240V/5V 0.8A-1.0A with adapter)
Communication interface	USB, UART Analog (UART & 4-20 mA / 0-5 V converter)
Dimensions	Diameter: 32 mm - Length: 62mm
Weight	55g
Protection	IP42 (according IEC60529)
Electrical certification	Conform to UL Std. 61010-1 Certified to CSA Std. C22.2 N°. 61010-1 CE
Parameters Set up / Downloading	CairSoft

[1] According to our operating conditions during tests in laboratory: 20°C +/- 2°C / 50% RH +/- 10% / 1013 mbar +/- 3%
[2] Values possibly affected by exposures to high gradients of concentration
[3] In accordance with the Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
[4] Full scale continuous exposure
[7] FS = Full Scale
[8] The complete discharge of a device (screen turned off) can lead to a deterioration of its performances
Any use of the sensor not complying with the conditions specified in herein, including exposures, even short ones, to environments other than ambient air, to dry and / or devoid of oxygen air or other atmosphere not composed in majority of air, even during calibration, will invalidate the warranty

CO

CAIR POL

MINIATURE AIR QUALITY MONITORING SYSTEMS

P078D OZ Technical Datasheet CO 230113

Technical DataSheet CairClip CO (preliminary version)

(document prone to modification)

Range	0 - 20 ppm (0 - 19 ppm analog)
Limit of detection [1, 2]	0.05 ppm
Repeatability at zero [1, 2]	+/- 0.05 ppm
Repeatability at 80 % of range [1, 2]	+/- 15 %
Linearity [1, 2]	< 10 %
Uncertainty	< 25 % [1, 2]
Short term zero drift [1, 2, 4]	< 0.2 ppm / 24 H
Short term span drift [1, 2, 4]	< 1 % FS [7] / 24 H
Long term zero drift [1, 2, 4]	< 0.4 ppm / 1 month
Long term span drift [1, 2, 4]	< 2 % FS [7] / 1 month
Rise time (T10-90) [1, 2]	< 60 s
Fall time (T10-90) [1, 2]	< 60 s
Effect of interfering species [5]	H_2 < 60% Long term high concentration levels (> CO) of H_2S, NO_x, SO_2 or acid gases may interfere the signal
Temperature effect on sensitivity [2]	< 1 % / °C
Temperature effect on zero [2]	+/-1 ppm maximum under operating conditions
Maximum exposure	100 ppm
Annual exposure limit (1 hour average)	90000 ppm
Operating conditions	-20°C to 50°C / 15 to 90 % RH non-condensing 1013 mbar +/- 200 mbar
Recommended storage conditions	Temperature: between 5°C and 20°C Air relative humidity: > 15 % non-condensing
Power supply [8]	5 VDC / 200 mA (rechargrable by USB via PC or 100 V-240 V /5 V 0.8 A-1.0 A with adapter)
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Atmos. Chem. Phys. Discuss., 7, 11429–11463, 2007
www.atmos-chem-phys-discuss.net/7/11429/2007/

Atmospheric Chemistry and Physics Discussions

Capturing vertical profiles of aerosols and black carbon over the Indian Ocean using autonomous unmanned aerial vehicles

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Article

Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use

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