European Network on New Sensing Technologies for Air Pollution Control and Environmental Sustainability - *EuNetAir*

COST Action TD1105

3rd International Workshop *EuNetAir* on

New Trends and Challenges for Air Quality Control

University of Latvia - Faculty of Geography and Earth Sciences

Riga, Latvia, 26 - 27 March 2015

THE 1ST EUNETAIR AIR QUALITY JOINT-EXERCISE INTERCOMPARISON: ASSESSMENT OF MICRO-SENSORS VS. REFERENCE METHODS

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MC Member

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1ST EuNetAir Air Quality Joint-Exercise Intercomparison

- **Air Quality Monitoring Campaign** in Aveiro, Portugal, from **13th to the 27th of October 2014**.

Goal: evaluation and assessment of environmental gas/PM micro-sensors versus air quality standard reference methods.




1ST EuNetAir Air Quality Joint-Exercise Intercomparison

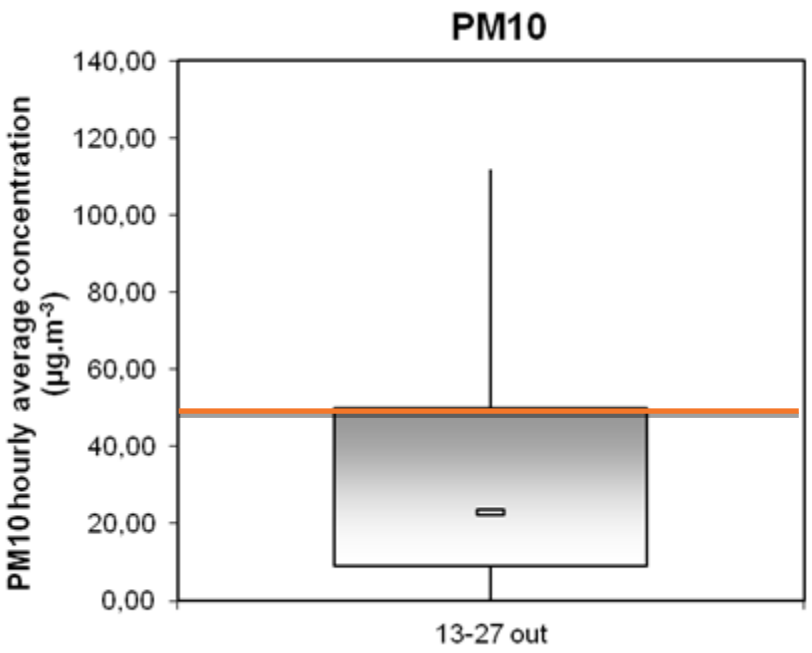
- **Campaign characterization:**
  - **Urban traffic location** in **Aveiro** city centre;
  - **15 teams** from research centres, universities and companies from 12 COST Countries;
  - **IDAD Air Quality Mobile Laboratory** with standard equipment and reference analysers;
  - **Micro-sensors systems** installed side-by-side at IDAD Air Quality Mobile Laboratory

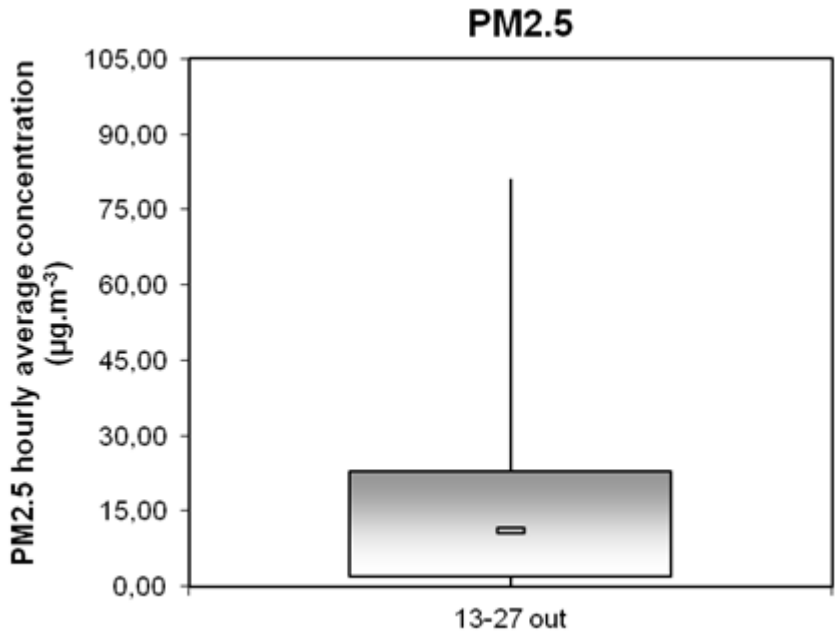
1ST EuNetAir Air Quality Joint-Exercise Intercomparison

- **IDAD Air Quality Mobile Laboratory :**
  - **Monitored variables:**
    - PM10 and PM2.5 (Beta-ray absorption method)
    - CO (nondispersive infrared spectroscopy)
    - NOx (chemiluminescence)
    - Benzene (gas chromatography)
    - O_3 (ultraviolet photometry)
    - SO_2 (ultraviolet fluorescence)
    - meteorological parameters: temperature, humidity, wind velocity/direction, solar radiation, precipitation

IDAD Air Quality Mobile Laboratory

- **Particulate Matter:**



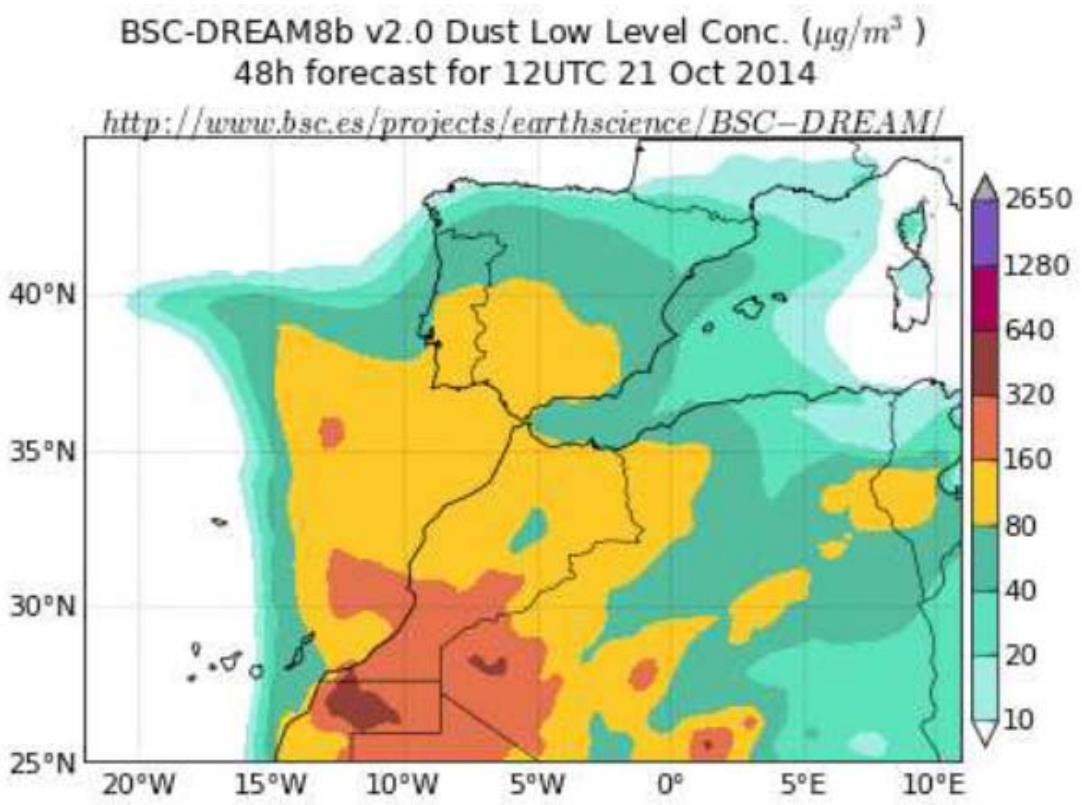


- **PM10 daily limit value of 50 µg.m^{-3}** for the protection of human health **was exceeded 6 times** from the 20th to the 25th of October.

IDAD Air Quality Mobile Laboratory

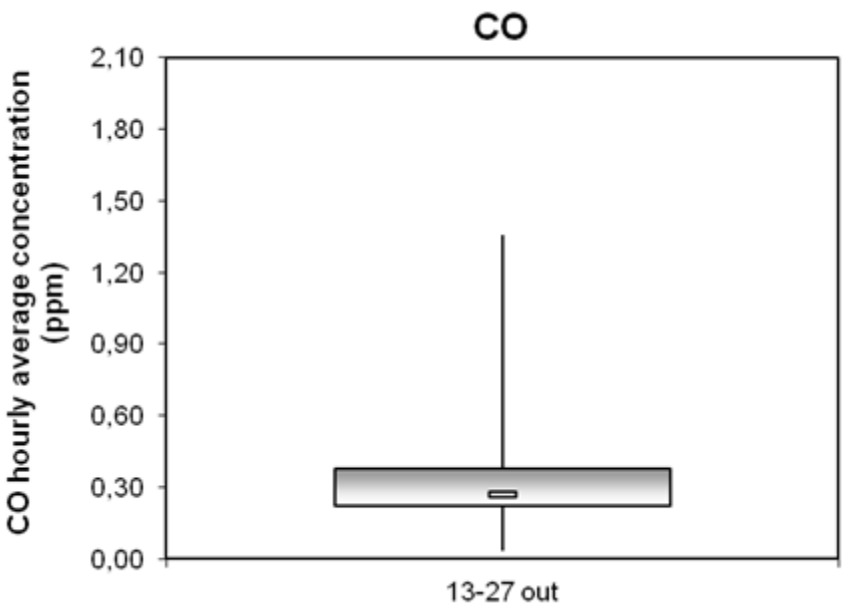
PM10 daily limit value was exceeded due to:

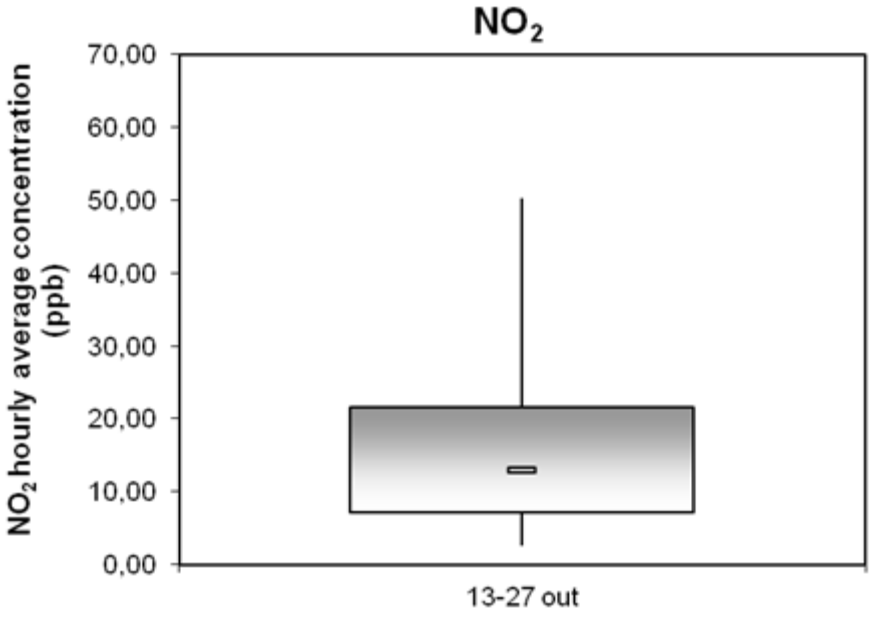
- **traffic emissions and meteorological conditions;**
- **occurrence of natural events due to transport of particles from North Africa, from the 18th to 31st of October.**



IDAD Air Quality Mobile Laboratory

- **Carbon Monoxide and Nitrogen Dioxide:**

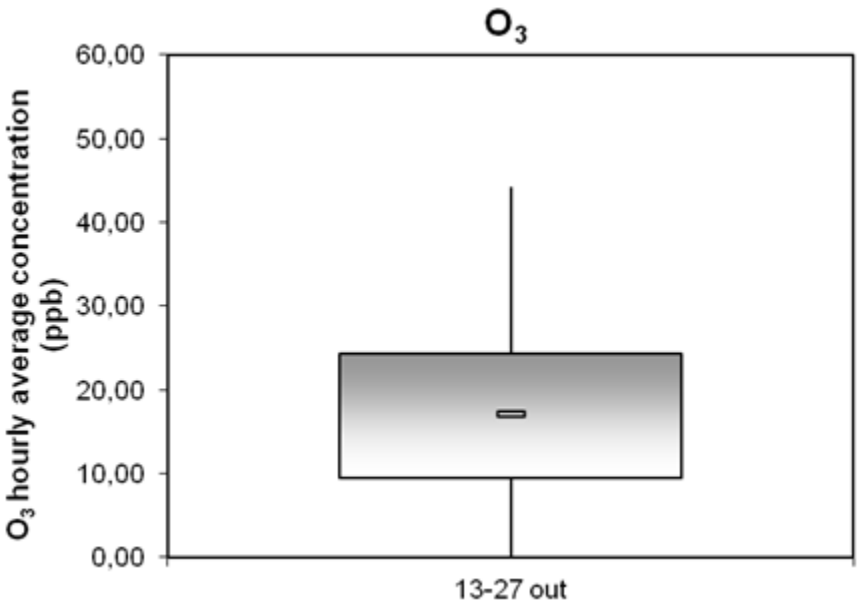


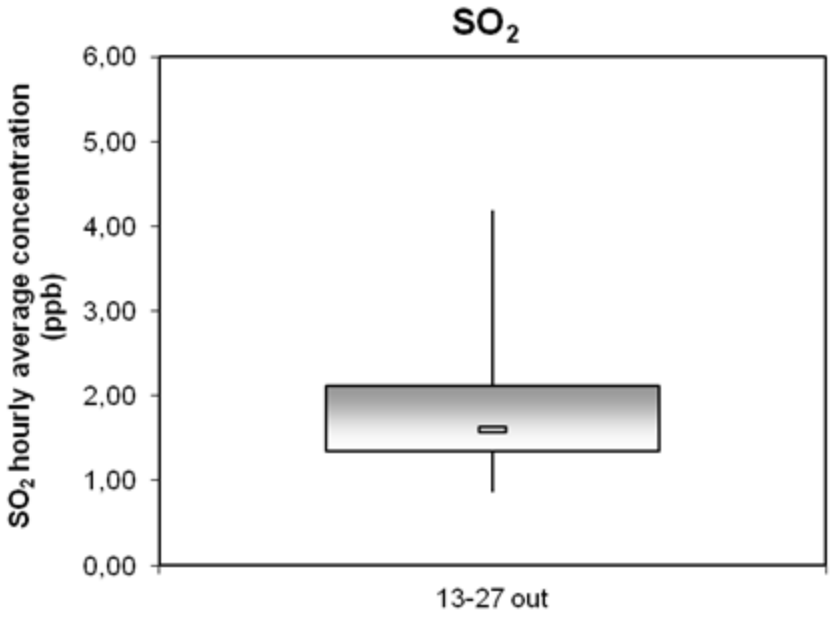


- **CO maximum daily eight hour mean limit value of 10 mg.m^{-3} (8,11 ppm) was not exceeded.**
- **NO_2 one hour limit value of 200 µg.m^{-3} (106,38 ppb) was not exceeded.**

IDAD Air Quality Mobile Laboratory

- **Ozone and Sulphur Dioxide:**

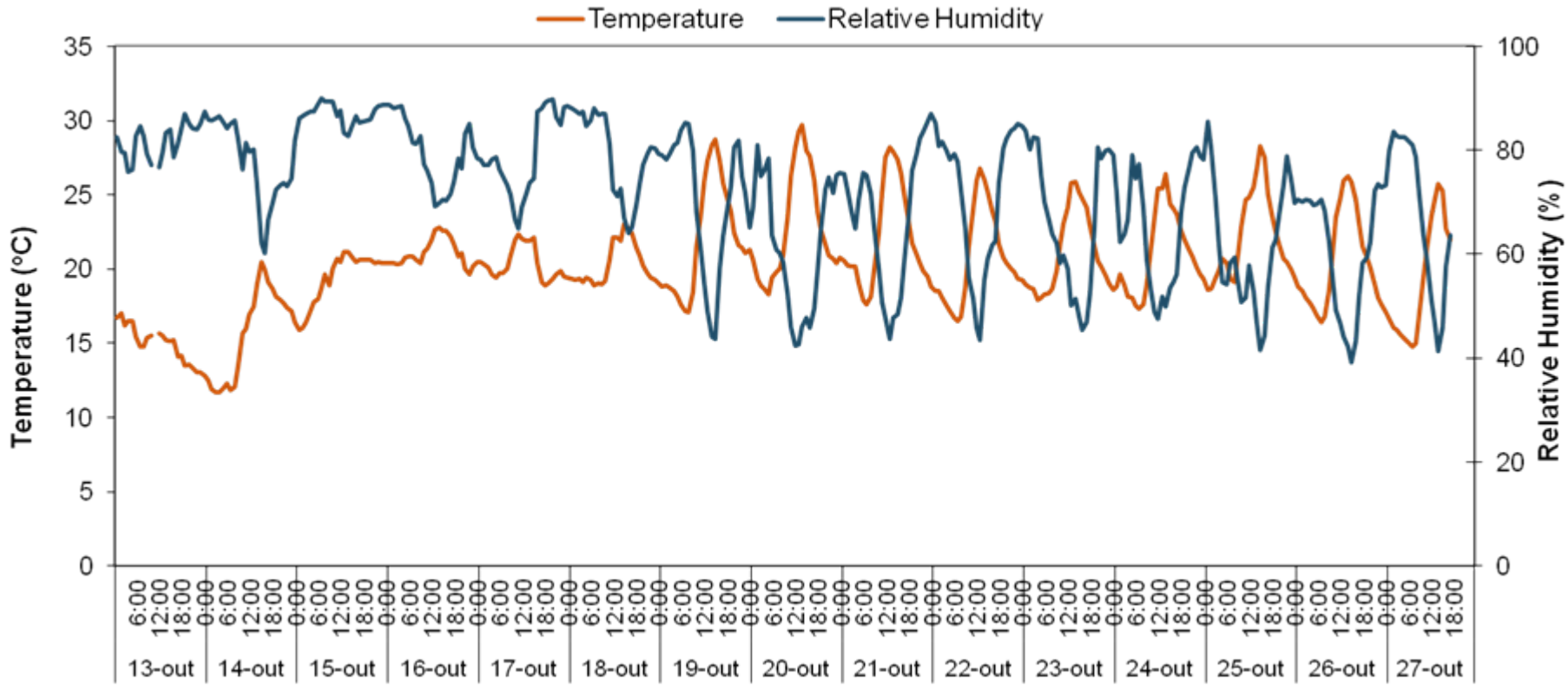




- O_3 one hour information value of 180 µg.m^{-3} (90 ppb) and alert thresholds value of and 280 µg.m^{-3} (140 ppb) weren't exceeded.
- SO_2 one hour limit value of 350 µg.m^{-3} (133,59 ppb) was not exceeded.

IDAD Air Quality Mobile Laboratory

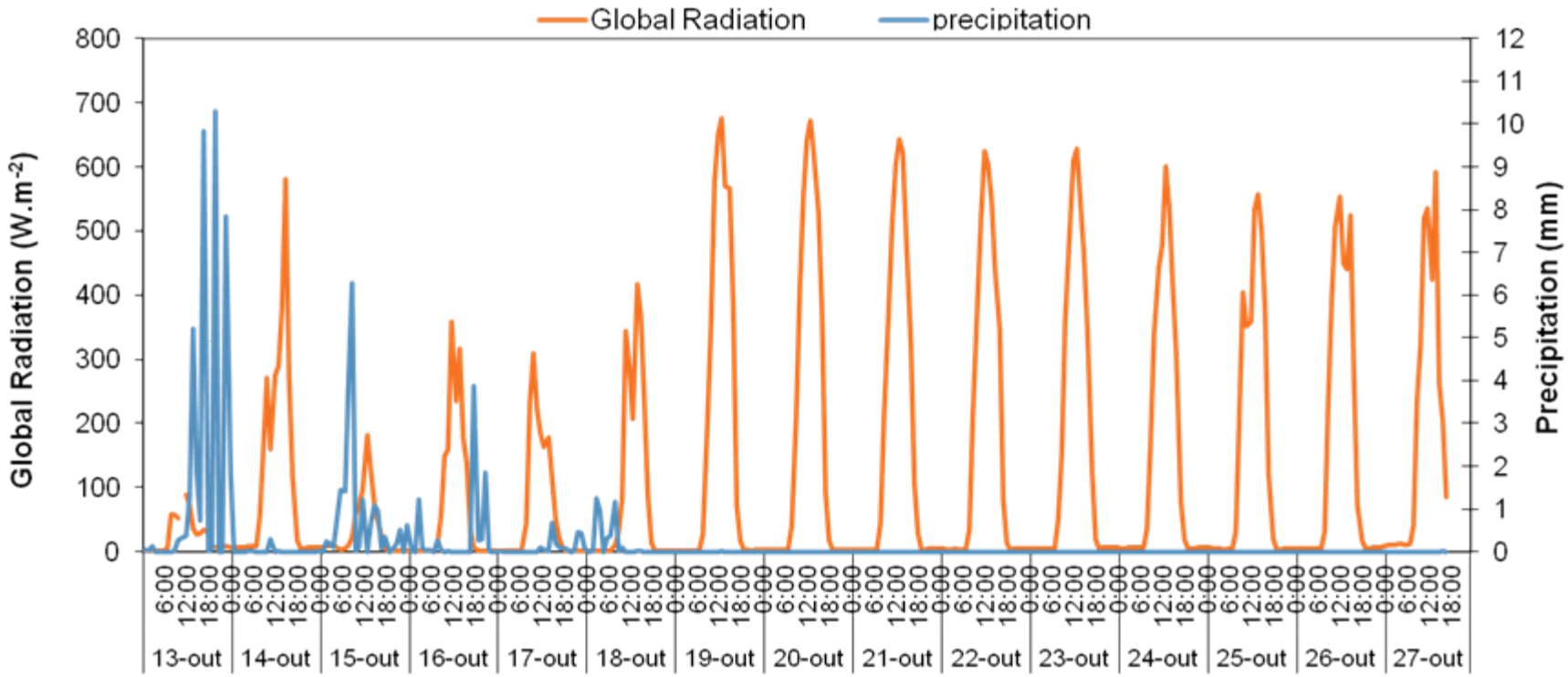
- **Temperature and Relative Humidity:**



- **First week: high relative humidity and lower temperatures.**
- **Second week: lower relative humidity and high temperatures.**

IDAD Air Quality Mobile Laboratory

- **Other meteorological parameters:**



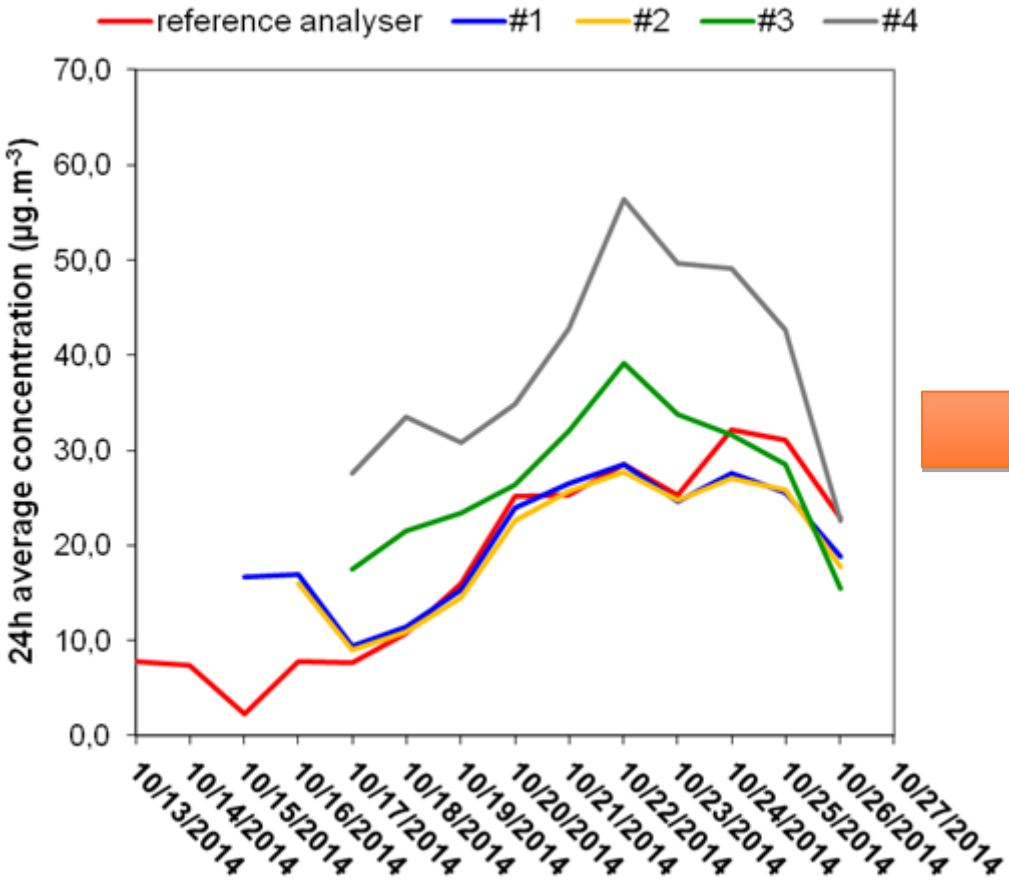
- **First week: long periods of precipitation, low global radiation and strong wind**
- **Second week: no periods of precipitation, higher global radiation and lower wind velocities.**

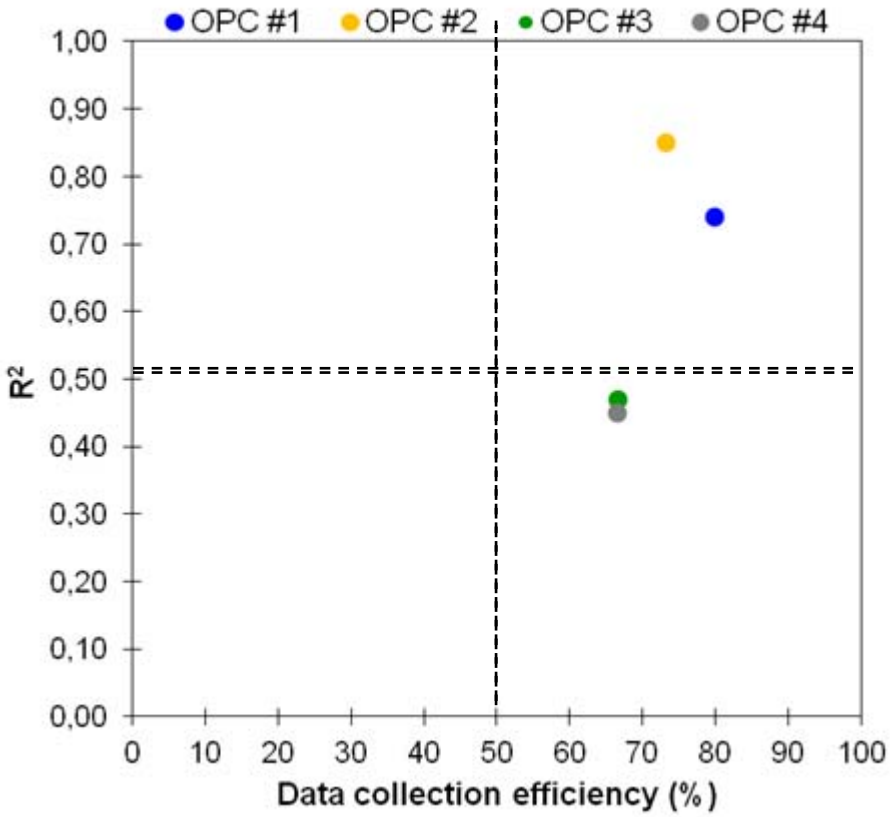
1ST EuNetAir Air Quality Joint-Exercise Intercomparison

- **Micro-sensors typologies and monitored pollutants:**
  - Electrochemical sensors:
    - NO, NO_2, CO, O_3, SO_2
  - Optical sensors:
    - PM1, PM2.5, PM10
  - Metal Oxide Semiconductor based sensors (MOS):
    - NO_2, COV, CO, O_3, SO_2
  - Non dispersive infrared technology sensors (NDIR):
    - CO_2
  - Photoionization detection sensors (PID):
    - COV_t

Assessment of micro-sensors vs. reference methods

- **PM2.5:**

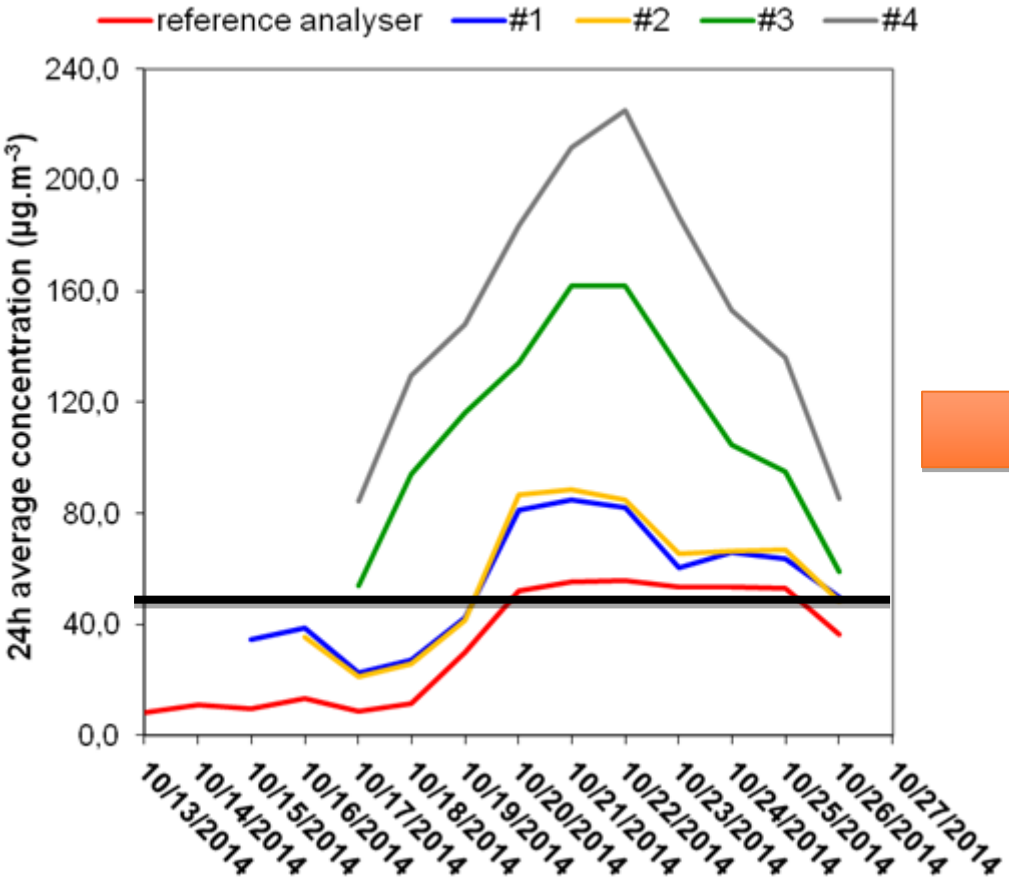


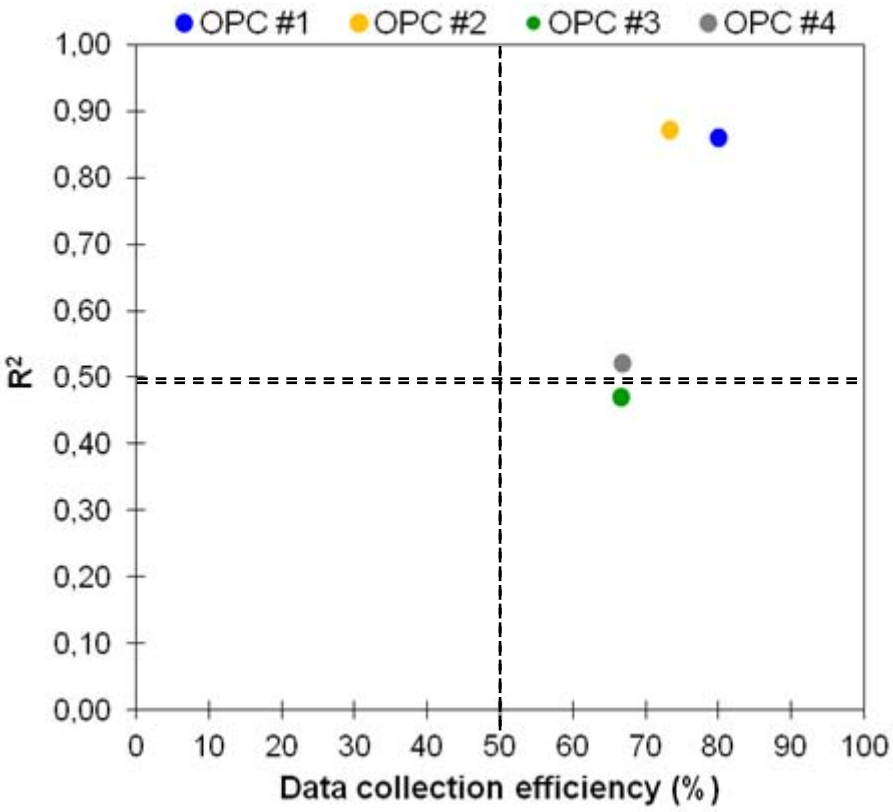


- **The optical (OPC) sensors for PM2.5 presented correlations varying between 0.45-0.85 and data collection efficiencies in the range of 67-80%.**

Assessment of micro-sensors vs. reference methods

- **PM10:**

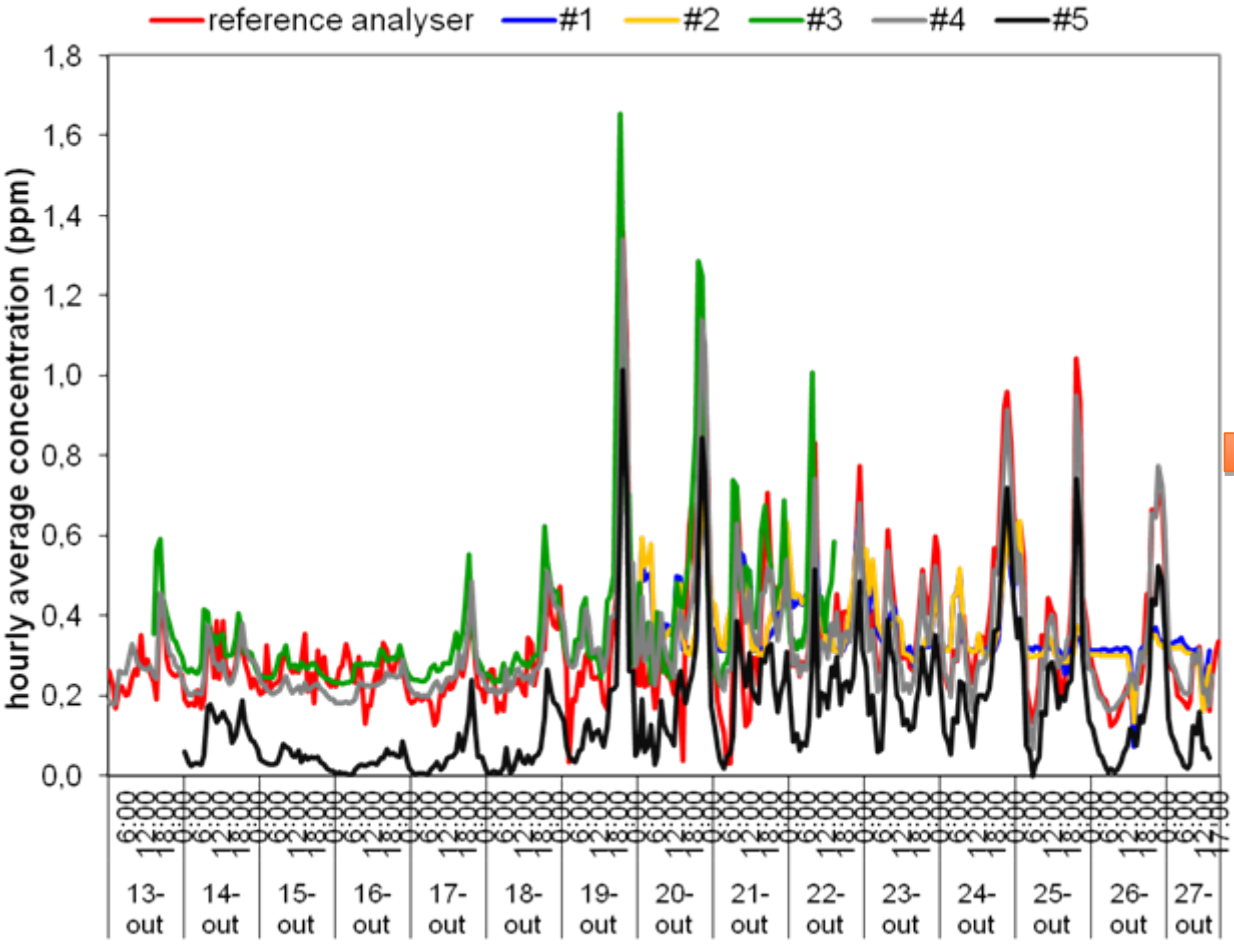


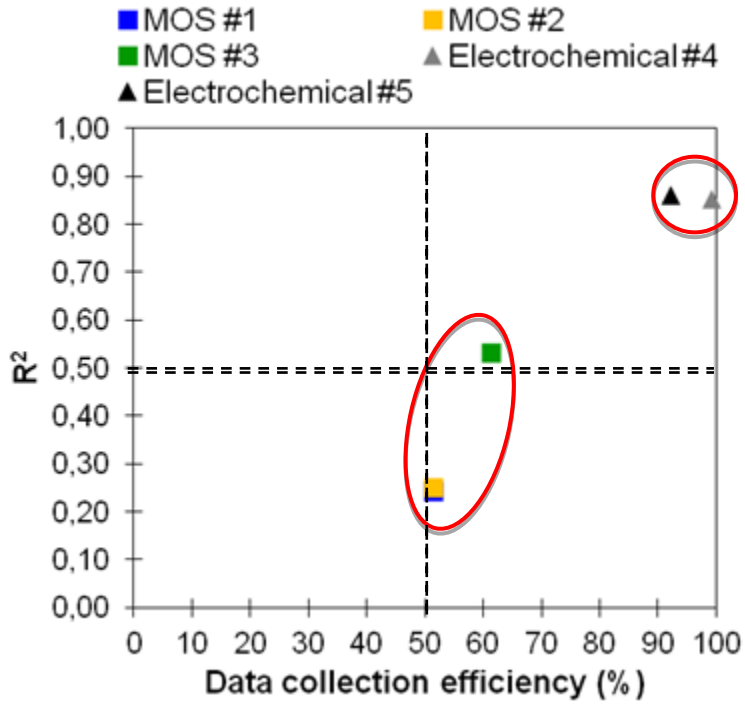


- **The optical (OPC) sensors for PM10 presented correlations varying between 0.47-0.87 and data collection efficiencies in the range of 67-80%.**

Assessment of micro-sensors vs. reference methods

- **CO:**

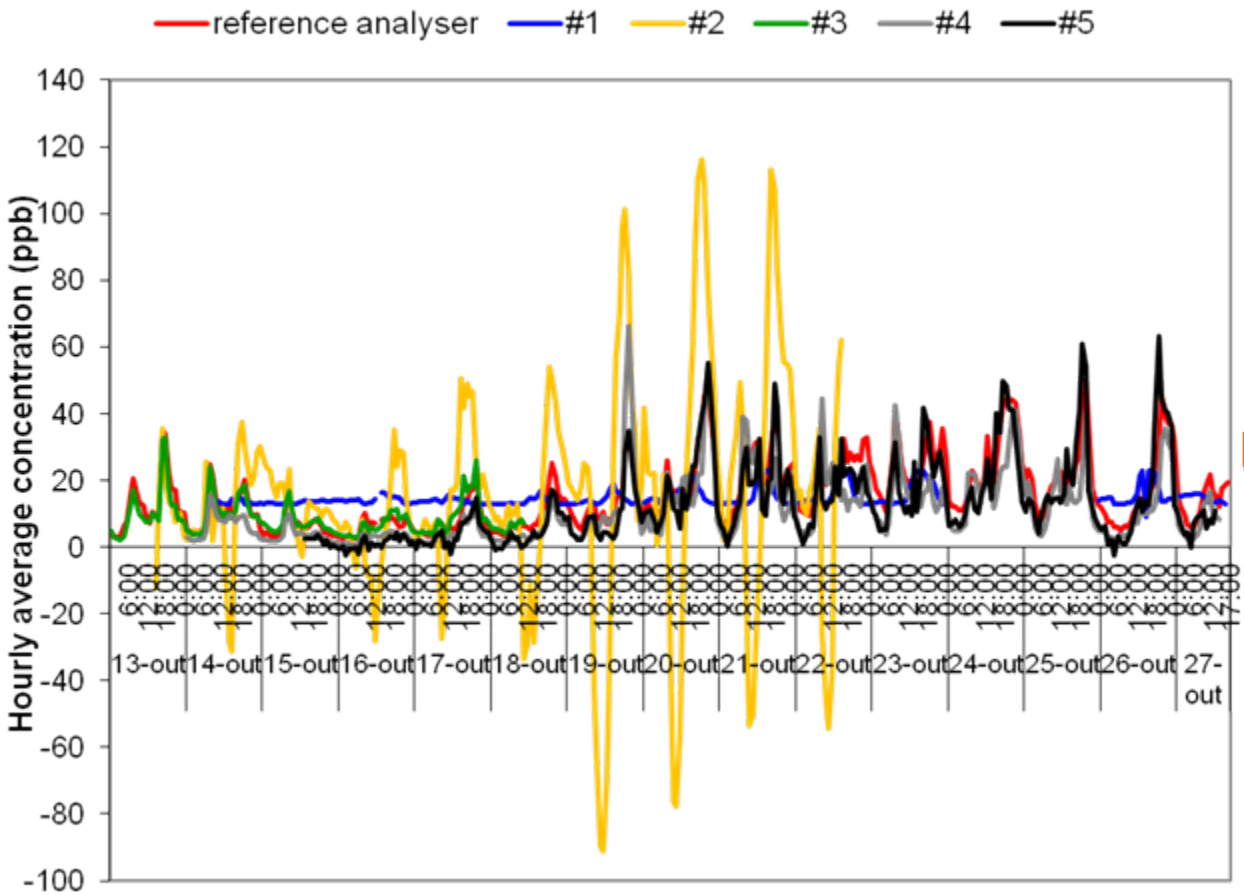


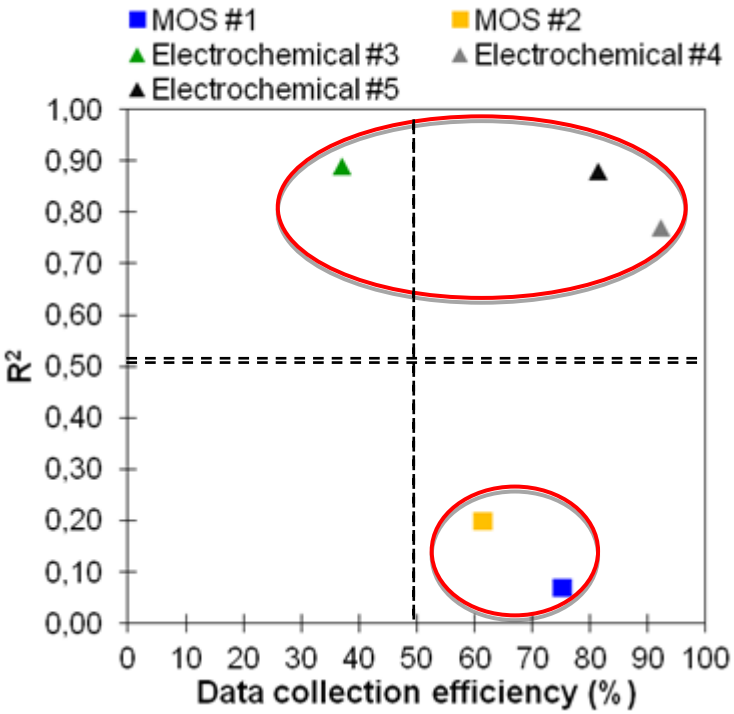


- **Electrochemical sensors showed a greater correlation with the reference method and a higher efficiency collecting data than metal oxide semiconductor (MOS) sensors.**

Assessment of micro-sensors vs. reference methods

- NO_2:

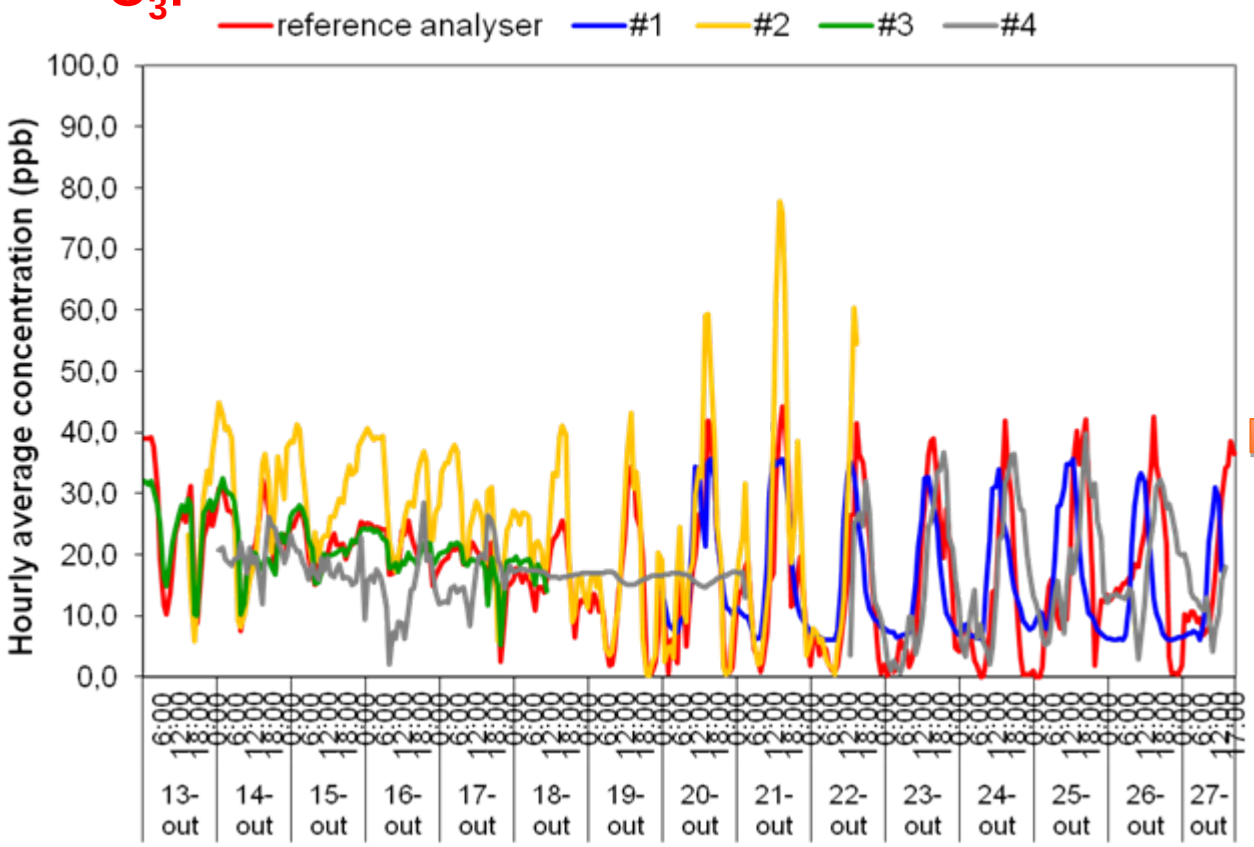


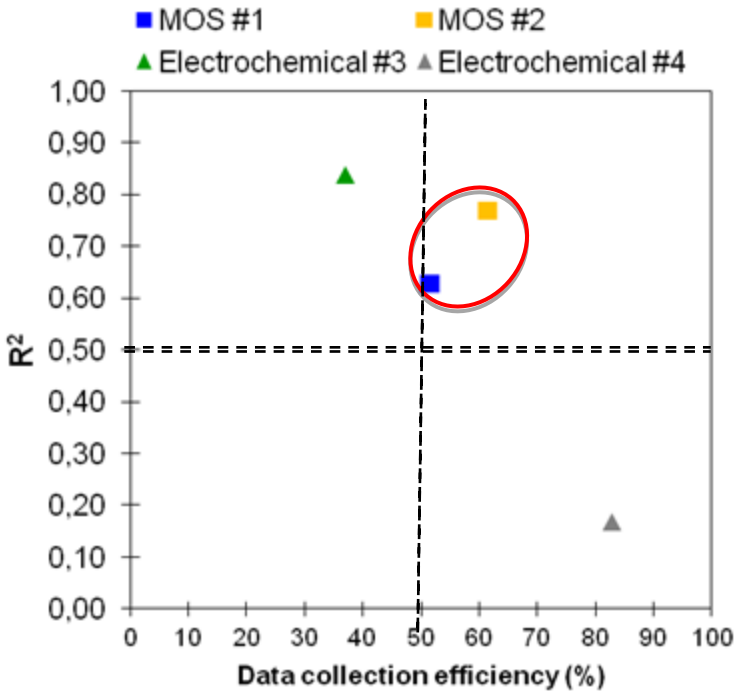


- **Electrochemical sensors showed a greater correlation with the reference method and in most cases a higher efficiency collecting data than metal oxide semiconductor (MOS) sensors.**

Assessment of micro-sensors vs. reference methods

- O_3:

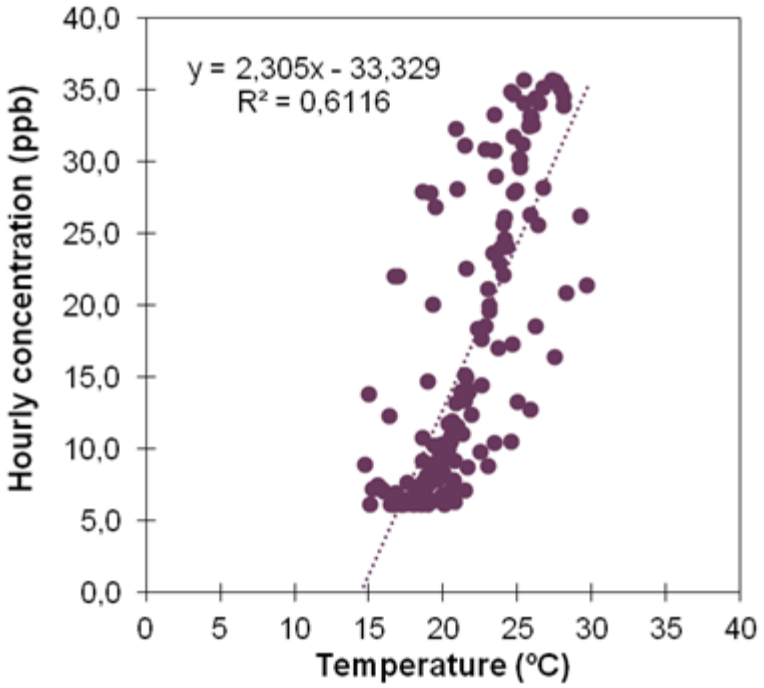


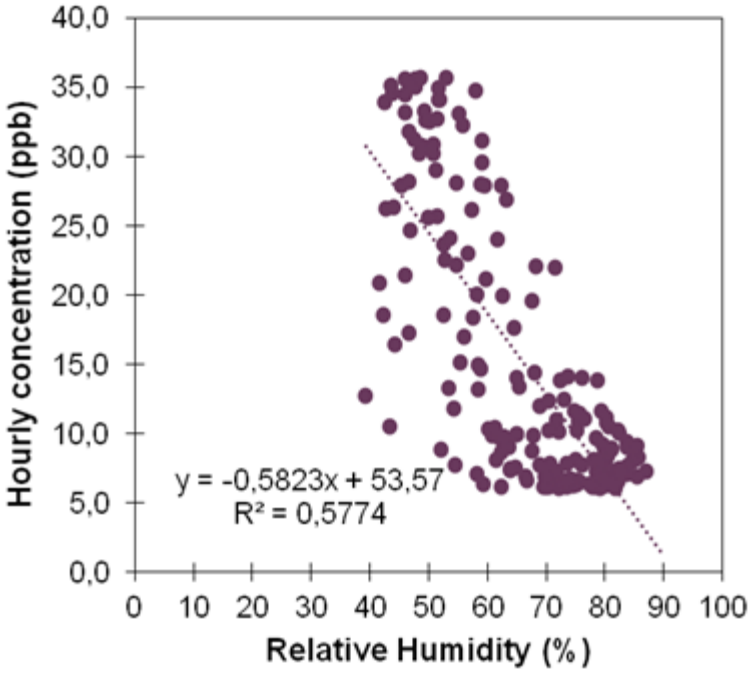


- **Electrochemical sensors: correlations between 0.17-0.84 and data collection efficiencies in the range of 37-83%**
- **Metal oxide semiconductor (MOS) sensors: correlations between 0.63-0.77 and data collection efficiencies in the range of 52-62%.**

Interference of meteorological parameters in micro-sensors measurements

- O_3:

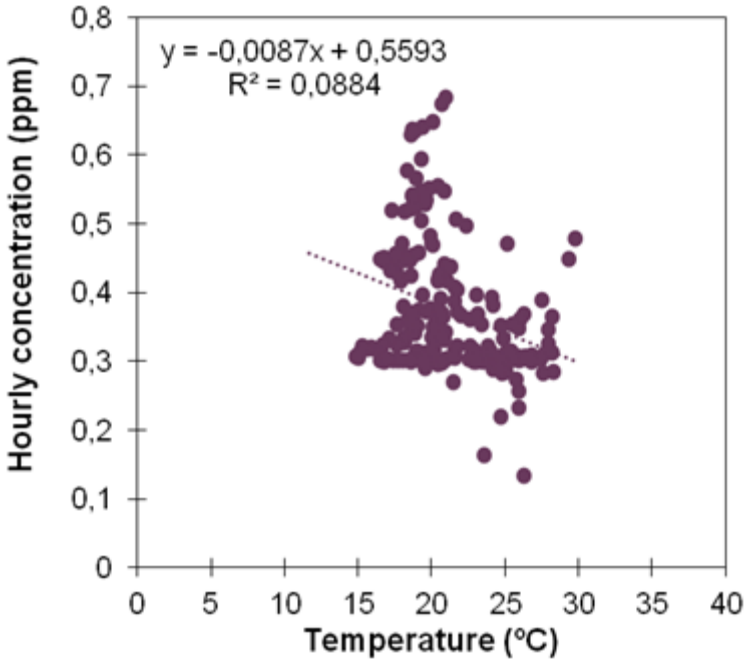


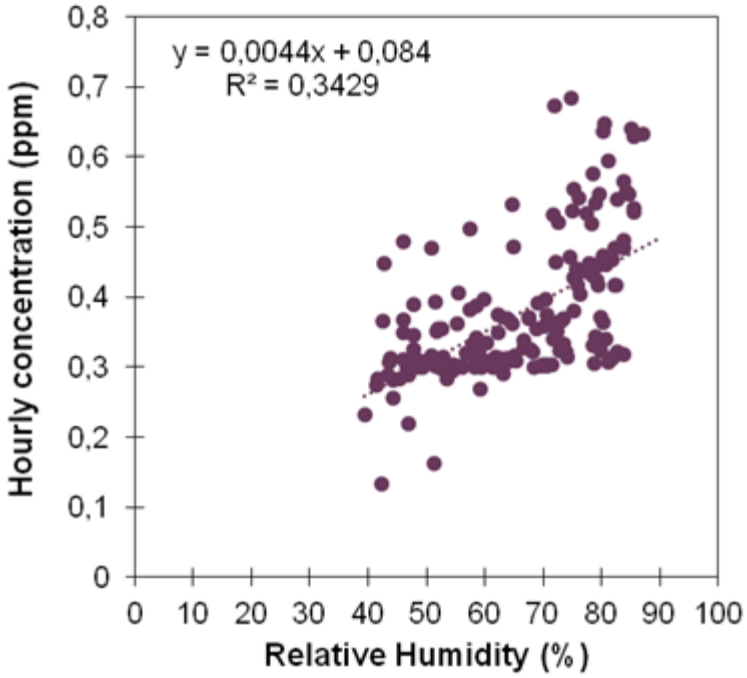


- Good degree of linearity between hourly concentration and **Temperature** ($R^2 = 0.6116$) as well as with **Relative Humidity** ($R^2 = 0.5774$).

Interference of meteorological parameters in micro-sensors measurements

- **CO:**





- **Weak correlation between hourly concentration and Temperature (R^2 = 0.0884).**
- **Acceptable degrees of linearity with Relative Humidity (R^2 = 0.3429).**

Interference of meteorological parameters in micro-sensors measurements

- **Absolute Humidity:**

Knowing temperature and relative humidity, the concentration of water vapour can be expressed according to Eq. 1 using the Clausius-Clapeyron relation where:

-**$[H_2O]$:** concentration of water vapour in $g.m^{-3}$

-**e_{s0}:** reference saturation vapour pressure (6.11 hPa at T_0=273.15 K)

-**RH:** relative humidity

-**l_v:** latent heat of vaporisation ($2.5x10^6$ J)

-**T :** temperature in K

-**M:** molar mass of water in g

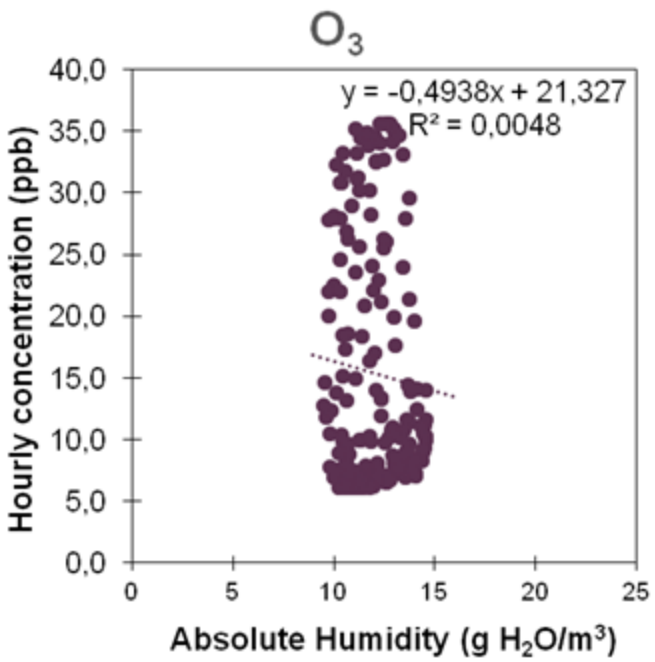
-**Rv:** gas constant for water vapour (461.5 $J.K.kg^{-1}$).

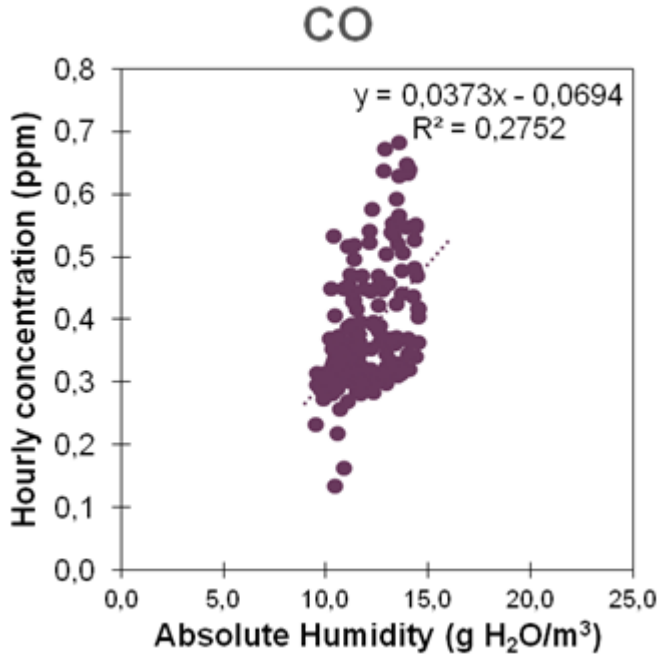
$$[H_2O] = RH.e_{s_0}.\exp\left(\frac{l_v}{Rv}.\left(\frac{1}{T_0}-\frac{1}{T}\right)\right).\frac{M}{R.T}$$

The use of $[H_2O]$ as a covariate allows avoiding the highly anti-correlated temperature and relative humidity parameters. Their high correlation in field tests confuses their specific effect in sensor responses.

Interference of meteorological parameters in micro-sensors measurements

- **Absolute Humidity:**





- Poor degree of linearity between **hourly O_3 concentration** with **Absolute Humidity** ($R^2 = 0.0048$).
- Nearly acceptable degree of linearity between **hourly CO concentration** with **Absolute Humidity** ($R^2 = 0.2752$).

CONCLUSIONS

- **Results only for 7 teams out of 15**
- **Problems in data collection efficiency of the sensors related to:**
  - **high relative humidity and temperatures;**
  - **intermittent communication failures;**
  - **instability and reactivity caused by interfering gases.**
- **It is important to perform laboratory experiments under controlled conditions to determine uncertainties associated to the sensor performance, allowing a better assessment of the field experiment results.**
- **It is necessary to stablish an evaluation protocol approaching issues as sensitivity, selectivity (known interference), short and long term stability, parametrized sensor equations, data validation and fit for purpose.**

REMINDER

TEAM	MONITORED VARIABLES	DATA UPDATE STATUS
ECN	PM1, PM2.5, PM10, NO_2	**UPDATED**
VITO NV	NO, NO_2, CO, O_3, VOC, T, RH	**UPDATE CONC. UNITS**
NILU	CO, NO_2, O_3, T, RH	**UPDATED**
SenseAir AB	CO_2, CH_4, T, RH	**UPDATED**
IMEC – MSP Team	NO_2	**NO DATA UPLOADED**
IDAEA-CSIC (Geothech)	NO, NO_2, CO, O_3	**UPDATED**
Centre for Atmospheric Science	CO, NO, NO_2, O_3, SO_2, VOC, CO_2, PM2.5, PM10, T, RH, WS, WD	**VALIDATE CONC. UNITS**
3S – Sensors, Signal processing, Systems	VOC, T, RH	**UPDATE CONC. UNITS**
Aristotle University of Thessaloniki	NO_2, O_3, T, P, RH	**UPDATE CONC. UNITS**
SGX – Sensortech	CO, O_3, NO_2	**UPDATED**
ENEA	NO_2, O_3, SO_2, CO, PM10, T, RH	**NO DATA UPLOADED**
SST/ICTM/ELEN	RH, P, T	**UPDATED**
Materials Center Leoben	CO, H_2S, SO_2, RH	**NO DATA UPLOADED**
Siemens AG	VOC, H_2, CO, EthOH, O_3, T, RH	**UPDATE CONC. UNITS**
IDAD	CO, NOx, O_3, SO_2, PM10, PM2.5, BTEX T, RH, P, WD, WS, SR, PP	**UPDATED**