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

COST Action TD1105

INTERNATIONAL WG1-WG4 MEETING on

New Sensing Technologies and Modelling for Air-Pollution Monitoring

Institute for Environment and Development - IDAD

Aveiro, Portugal, 14 - 15 October 2014

Action Start date: 01/07/2012 - Action End date: 30/06/2016 - Year 3: 2014-15 (*Ongoing Action*)

New Sensing Technologies for Air Quality Control:

Field Evaluation of Micro-Sensors against Standard Methods

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Air quality monitoring strategy

'fixed measurements' shall mean measurements taken at fixed sites, either continuously or by random sampling, to determine the levels in accordance with the relevant data quality objectives;

(Air Quality Directive (AQD) - Directive 2008/50/EC)

(Aveiro/Av.25Abril - Air Quality monitoring station)

Air quality monitoring strategy

‘indicative measurements’ shall mean measurements which meet data quality objectives that are less strict than those required for fixed measurements;

(Air Quality Directive (AQD) - Directive 2008/50/EC)

Example of indicative measurements - Diffusion Tubes

Important to supplement fixed measurements

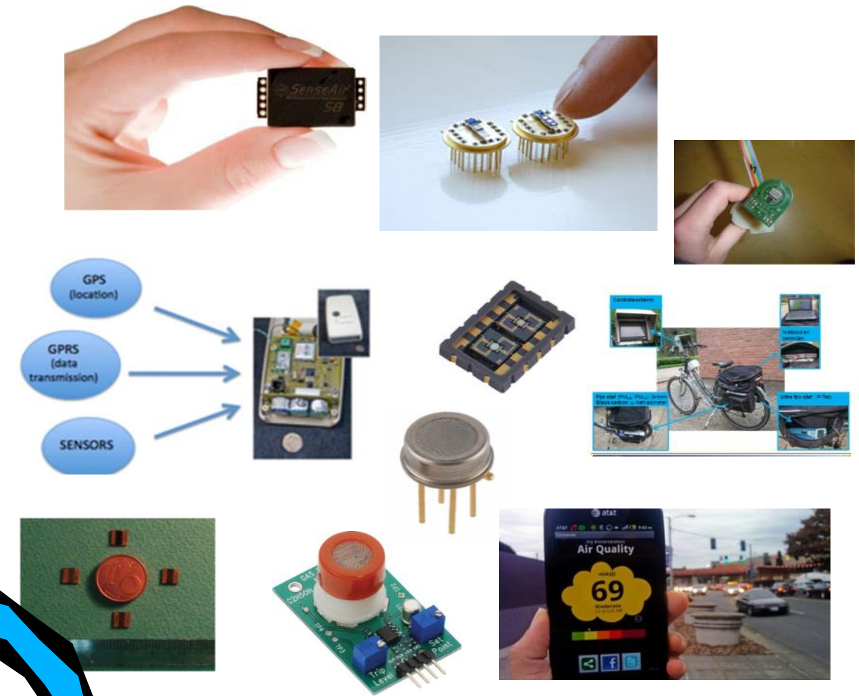
The use of supplementary techniques of assessment should also **allow for reduction of the required minimum number of fixed** sampling points

New sensing technologies for air pollution control

Low-cost sensing technologies

The utilization of micro-sensors is <u>still not mentioned for regulatory purposes</u> in European legislation.

their use can be particularly valuable to have highly spatially and temporally resolved quality data and to improve exposure assessment

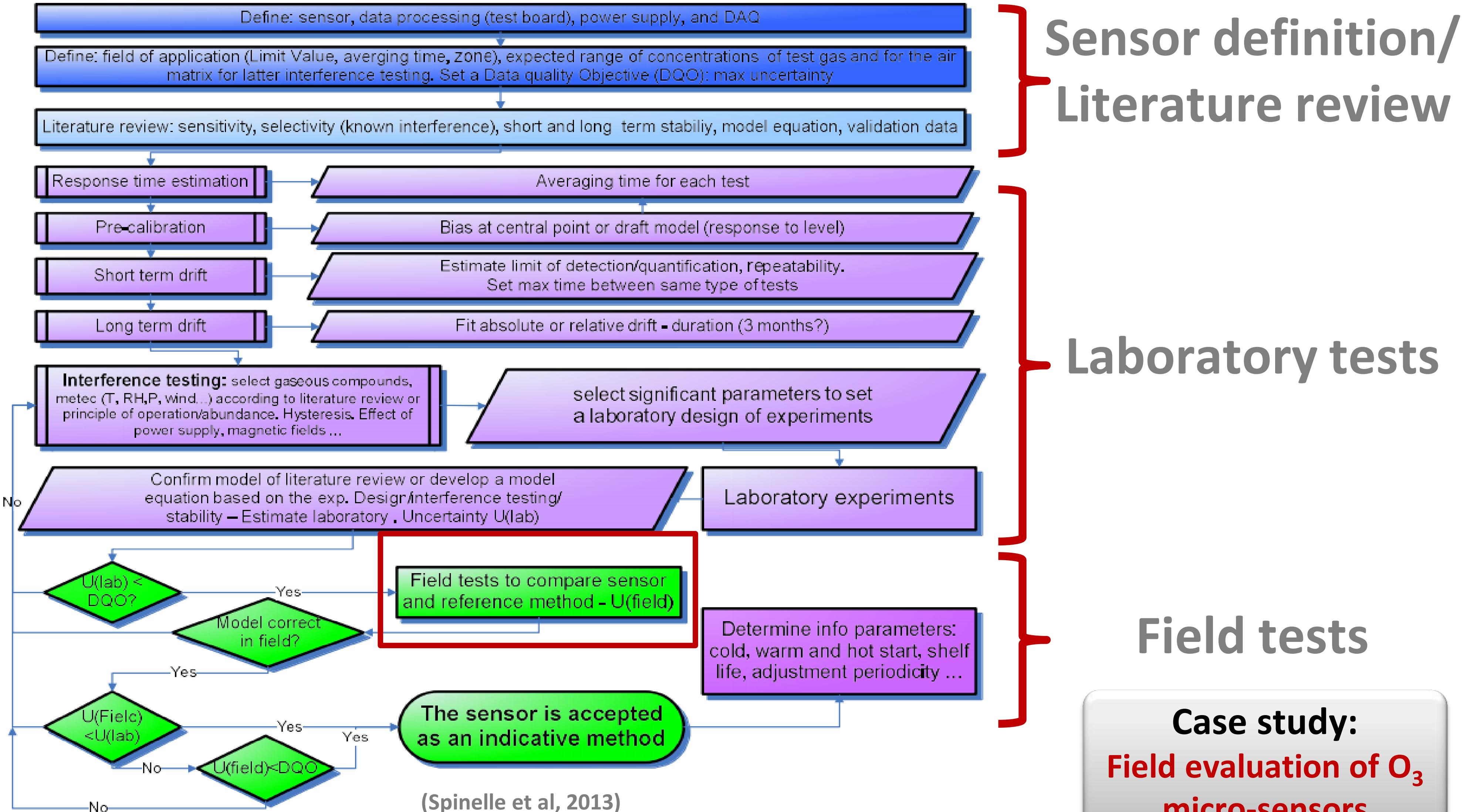


<u>S</u>ensitivity? ppb-ppm?

<u>S</u>tability? Lifetime/maintenance?

<u>S</u>electivity? interferents

Example of protocol for evaluation of low-cost gas sensors



(Spinelle et al, 2013)

Case study:

Field evaluation of O_3 micro-sensors

Evaluation of micro-sensors against standard methods for air quality control during field campaigns

Monitoring points

2 Oporto

4 Lisbon

Data measured

T, RH, WD, WV, R, PP

PM10

CO

O_3

NOx

SO_2

BTEX

Sampling time

Winter - October 2013 / Jan. 2014

Summer - July 2014 / Sept. 2014

(≈7 days each location)

Parallel measurements with SGX micro sensors

3 - CO/VOC

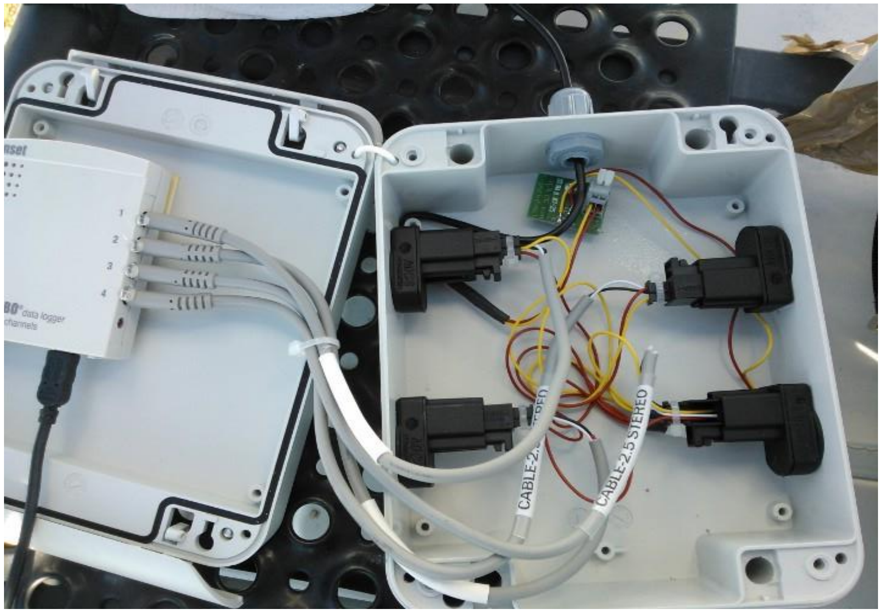
3 - O_3

2 - NO_2

IDAD's mobile laboratory

PM10	Environnement MP101M	ISO 10473: Measurement of the mass of particulate matter on a filter medium **– Beta-ray absorption method**
Carbon Monoxide	Environnement CO11M	EN 14626: Standard method for the measurement of the concentration of carbon monoxide by **nondispersive infrared spectroscopy**
NOx	Environnement AC31M	EN 14611: Standard method for the measurement of concentration of nitrogen dioxide and nitrogem monoxide by **chemiluminescence**
Benzene	Environnement VOC71M	EN 14662: Standard method for measurement of benzene concentrations (**gas chromatography)**
Ozone	Environnement O341M	EN14625: Standard method for the measurement of the concentration of ozone by **ultraviolet photometry**
SO_2	Environnement AF21M	EN 14212 – Standard method for the measurement of concentration of sulphur dioxide by **ultraviolet fluorescence**

SGX sensors



MOS sensors

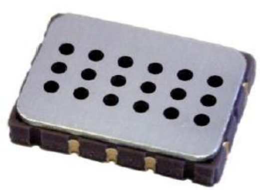
Metal Oxide Semiconductor

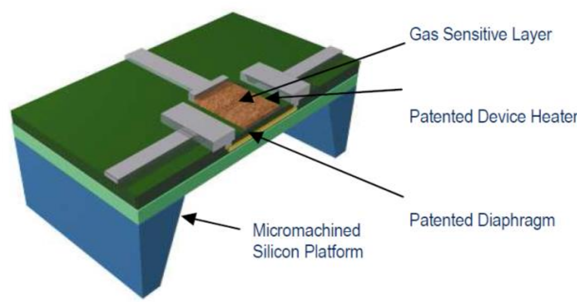
- The gas sensor is a micro-machined structure equipped with a sensitive resistance (R_S) placed on top of a heating resistance (R_h).
- The resistance of a semi-conductor changes with the concentration of the pollutant being monitored.
- The concentration is calculated as the measured resistance (R_S) adjusted by the calibration and temperature compensation parameters.

Ozone – MiCS-2614

CO/VOC – MiCS-5524

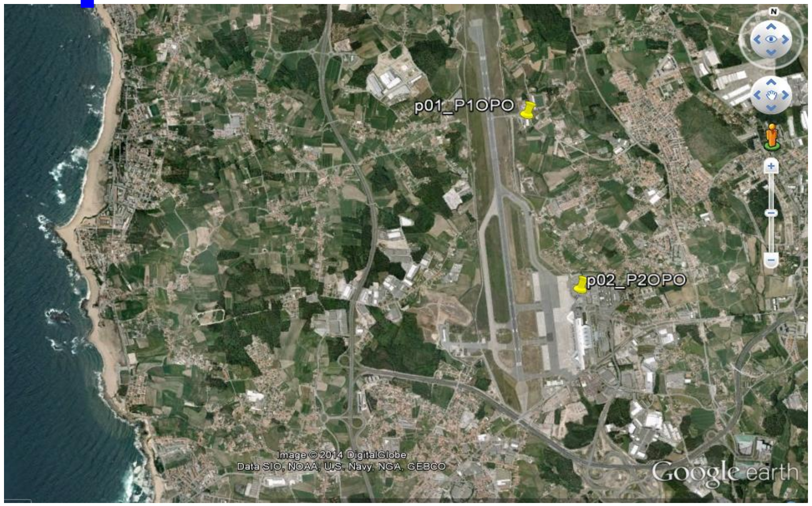
NO_2 – MiCS-2714



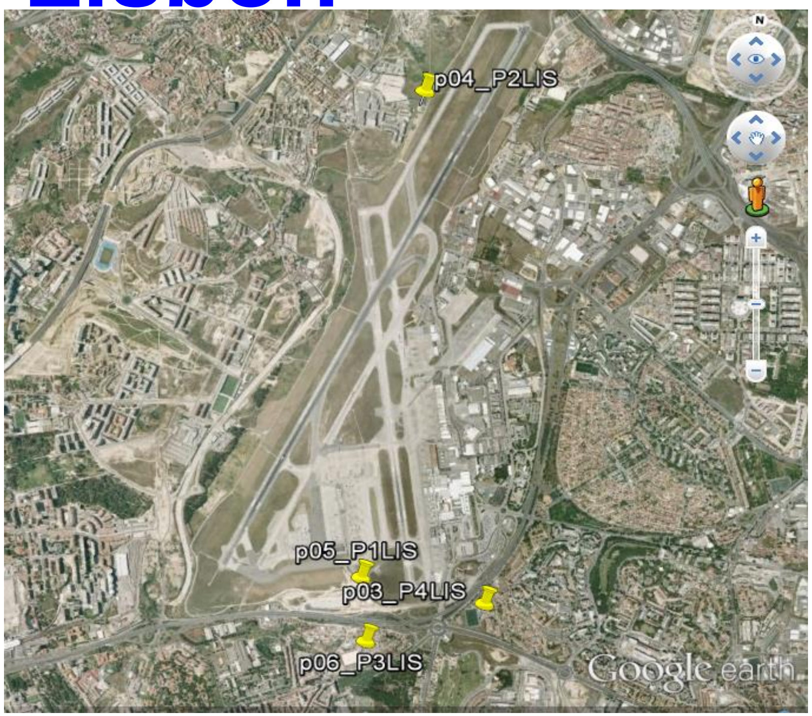


Ozone sensor chip in ceramic package
Chip size 1.7 x 1.9 mm
Package size 5 x 5 mm

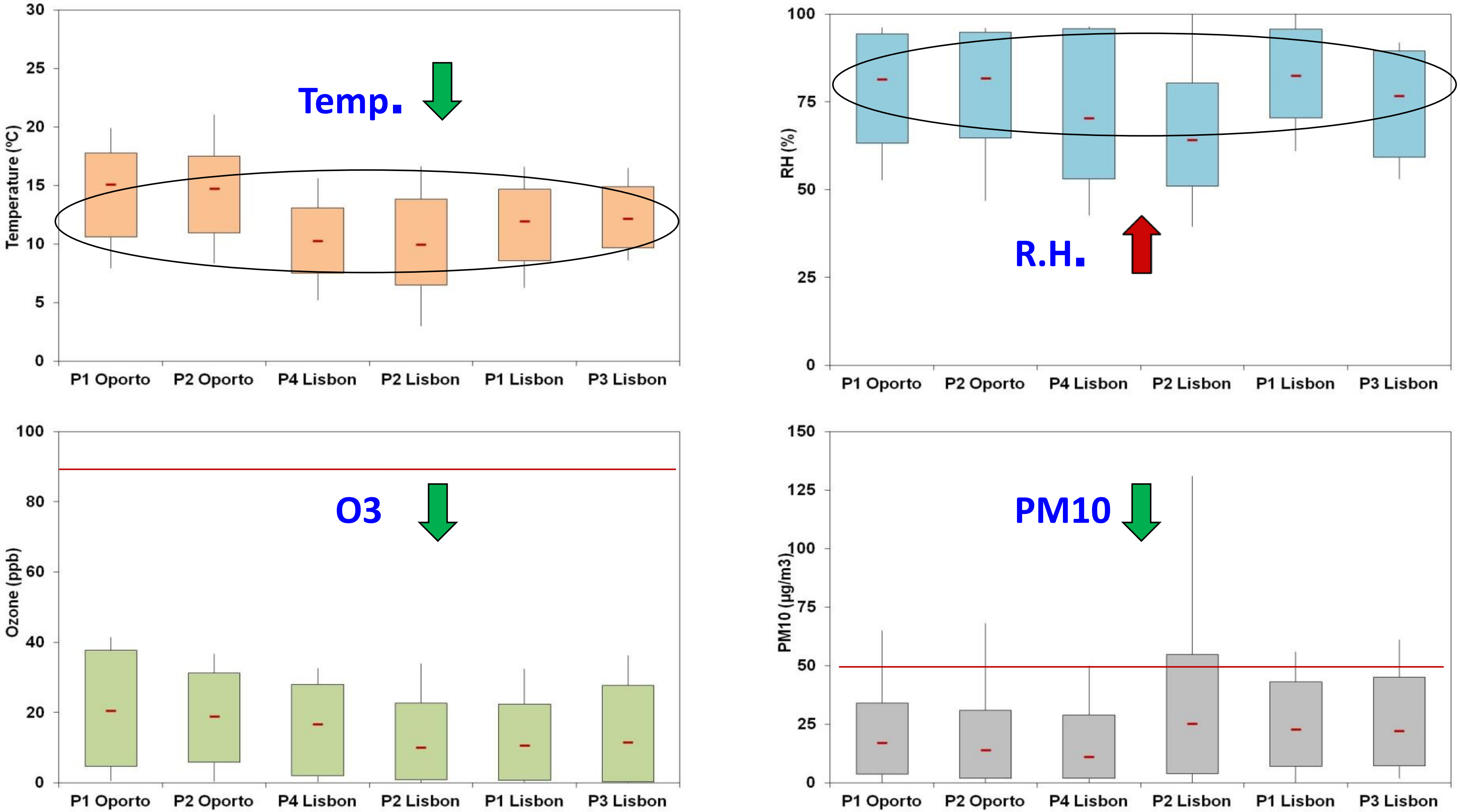
Oporto



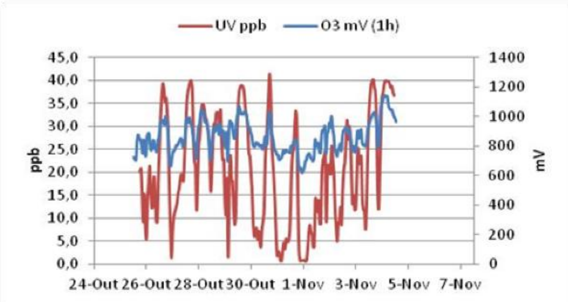
Lisbon



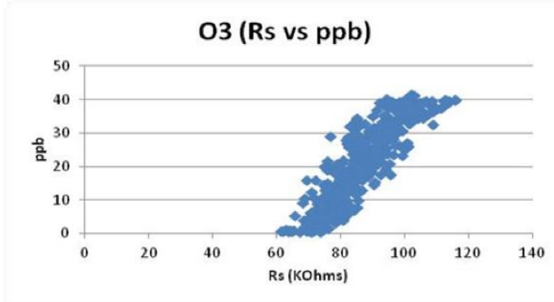
Environmental conditions during field campaigns



Methodology for data treatment



Raw data

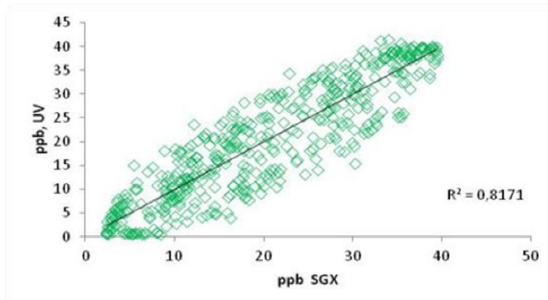


mV / Rs

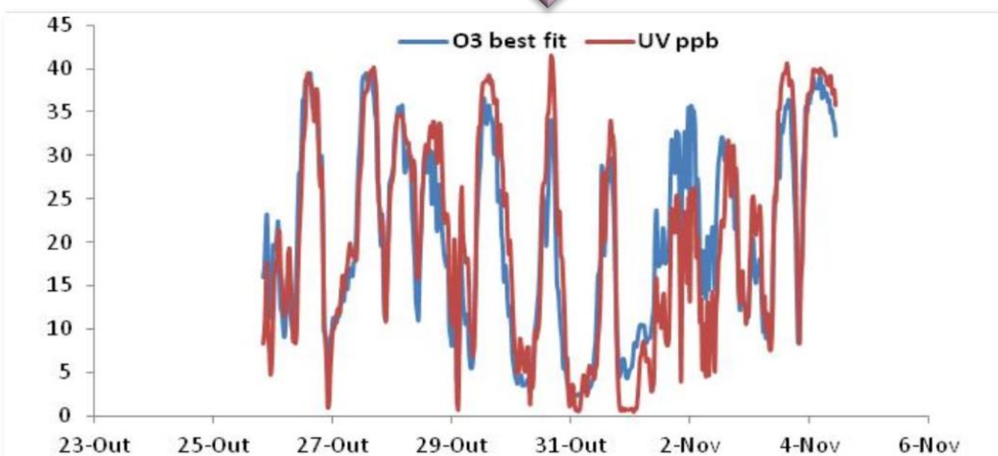
RS@25°C [kΩ] = RS@T * EXP[K*(T – 25 °C)]

[ppb] = X3*RS^3+ X2*RS^2+ X1*RS + X0

Calculation of the function



ppb / ppb



Other analysis:

- •% output Error
- •Influence of Temp, RH
- •Cross sensitivity with other pollutants

Correlation matrix (example for P1 Oporto)

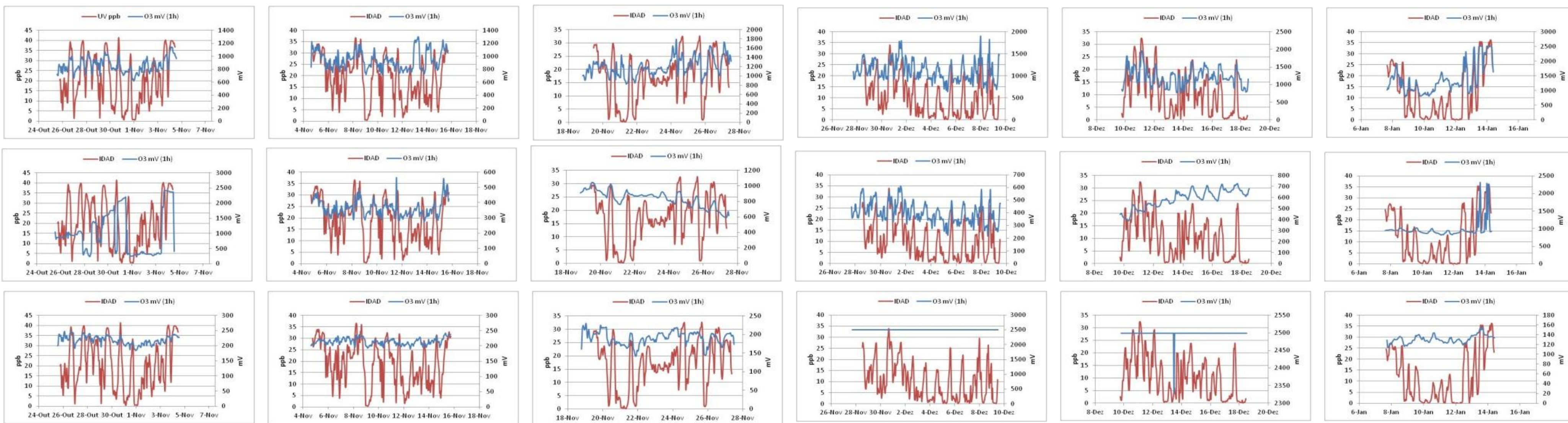
		Micro-sensors								Reference measurements								Meteorological parameters					
		CO	O_3	O_3	NO_2	CO	O_3	CO	NO_2	SO_2	NO	NO_2	NOx	O_3	PM10	CO	Benzene	Temp	RH	Rad	WV	WD	Prec.
		KOhms	KOhms	KOhms	KOhms	KOhms	KOhms	KOhms	KOhms	ppb	ppb	ppb	ppb	ppb	µg/m3	ppm	µg/m3	ºC	%	W/m2	m/s	ºN	Mm
Micro-sensors	CO	1,00	-0,03	0,13	0,03	0,71	-0,14	0,91	0,30	-0,26	-0,22	-0,15	-0,20	-0,31	-0,01	-0,04	-0,03	-0,60	0,27	-0,24	-0,01	-0,13	0,12
	O_3	-0,03	1,00	0,32	-0,02	0,12	0,84	0,22	-0,12	0,06	-0,43	-0,73	-0,61	0,90	-0,51	-0,74	-0,68	0,32	-0,29	0,11	0,45	0,24	0,10
	O_3	0,13	0,32	1,00	0,20	0,19	0,30	0,22	0,05	-0,08	-0,17	-0,20	-0,20	0,18	0,02	-0,14	0,03	-0,35	-0,39	0,04	-0,18	0,05	-0,23
	NO_2	0,03	-0,02	0,20	1,00	-0,22	0,31	-0,12	0,66	-0,09	-0,03	0,07	0,01	-0,04	0,06	-0,04	0,14	-0,26	-0,15	0,11	-0,32	-0,08	-0,22
	CO	0,71	0,12	0,19	-0,22	1,00	0,02	0,87	0,02	-0,36	-0,27	-0,32	-0,31	-0,20	-0,16	-0,11	-0,20	-0,54	0,51	-0,52	0,00	-0,03	0,13
	O_3	-0,14	0,84	0,30	0,31	0,02	1,00	0,06	0,02	0,00	-0,49	-0,71	-0,64	0,83	-0,55	-0,77	-0,67	0,25	-0,27	0,12	0,21	0,20	-0,04
	CO	0,91	0,22	0,22	-0,12	0,87	0,06	1,00	0,16	-0,28	-0,38	-0,38	-0,40	-0,10	-0,19	-0,24	-0,27	-0,49	0,32	-0,32	0,11	-0,05	0,13
	NO_2	0,30	-0,12	0,05	0,66	0,02	0,02	0,16	1,00	-0,24	0,10	0,25	0,18	-0,24	0,33	0,19	0,25	-0,31	0,16	-0,22	-0,10	-0,21	-0,05
Reference measurements	SO_2	-0,26	0,06	-0,08	-0,09	-0,36	0,00	-0,28	-0,24	1,00	-0,04	-0,06	-0,05	0,19	-0,15	-0,13	-0,05	0,34	-0,29	0,47	0,18	0,04	0,05
	NO	-0,22	-0,43	-0,17	-0,03	-0,27	-0,49	-0,38	0,10	-0,04	1,00	0,78	0,94	-0,38	0,55	0,76	0,68	-0,01	-0,03	0,01	-0,13	-0,21	-0,05
	NO_2	-0,15	-0,73	-0,20	0,07	-0,32	-0,71	-0,38	0,25	-0,06	0,78	1,00	0,94	-0,67	0,69	0,87	0,80	-0,12	0,09	-0,05	-0,23	-0,33	-0,13
	NO_x	-0,20	-0,61	-0,20	0,01	-0,31	-0,64	-0,40	0,18	-0,05	0,94	0,94	1,00	-0,55	0,66	0,86	0,79	-0,07	0,03	-0,02	-0,19	-0,32	-0,09
	O_3	-0,31	0,90	0,18	-0,04	-0,20	0,83	-0,10	-0,24	0,19	-0,38	-0,67	-0,55	1,00	-0,51	-0,74	-0,69	0,54	-0,42	0,24	0,41	0,39	0,08
	PM10	-0,01	-0,51	0,02	0,06	-0,16	-0,55	-0,19	0,33	-0,15	0,55	0,69	0,66	-0,51	1,00	0,76	0,79	-0,33	0,00	-0,24	-0,31	-0,19	-0,07
	CO	-0,04	-0,74	-0,14	-0,04	-0,11	-0,77	-0,24	0,19	-0,13	0,76	0,87	0,86	-0,74	0,76	1,00	0,89	-0,31	0,23	-0,21	-0,31	-0,43	-0,06
	Benzene	-0,03	-0,68	0,03	0,14	-0,20	-0,67	-0,27	0,25	-0,05	0,68	0,80	0,79	-0,69	0,79	0,89	1,00	-0,42	-0,01	-0,07	-0,47	-0,30	-0,16
Meteo. parameters	Temp	-0,60	0,32	-0,35	-0,26	-0,54	0,25	-0,49	-0,31	0,34	-0,01	-0,12	-0,07	0,54	-0,33	-0,31	-0,42	1,00	-0,20	0,43	0,63	-0,09	0,13
	RH	0,27	-0,29	-0,39	-0,15	0,51	-0,27	0,32	0,16	-0,29	-0,03	0,09	0,03	-0,42	0,00	0,23	-0,01	-0,20	1,00	-0,68	0,11	-0,31	0,29
	Rad	-0,24	0,11	0,04	0,11	-0,52	0,12	-0,32	-0,22	0,47	0,01	-0,05	-0,02	0,24	-0,24	-0,21	-0,07	0,43	-0,68	1,00	0,17	-0,01	-0,12
	WV	-0,01	0,45	-0,18	-0,32	0,00	0,21	0,11	-0,10	0,18	-0,13	-0,23	-0,19	0,41	-0,31	-0,31	-0,47	0,63	0,11	0,17	1,00	-0,24	0,33
	WD	-0,13	0,24	0,05	-0,08	-0,03	0,20	-0,05	-0,21	0,04	-0,21	-0,33	-0,32	0,39	-0,19	-0,43	-0,30	-0,09	-0,31	-0,01	-0,24	1,00	-0,09
	Prec.	0,12	0,10	-0,23	-0,22	0,13	-0,04	0,13	-0,05	0,05	-0,05	-0,13	-0,09	0,08	-0,07	-0,06	-0,16	0,13	0,29	-0,12	0,33	-0,09	1,00

Analysis of the influence of other parameters on the micro-sensor results / **Cross sensitivity**

Correlation with temperature and Relative humidity

Results - Raw data (ppb$_{UVanalyser}$ / mV$_{O3\ (MiCS\text{-}2614)}$)

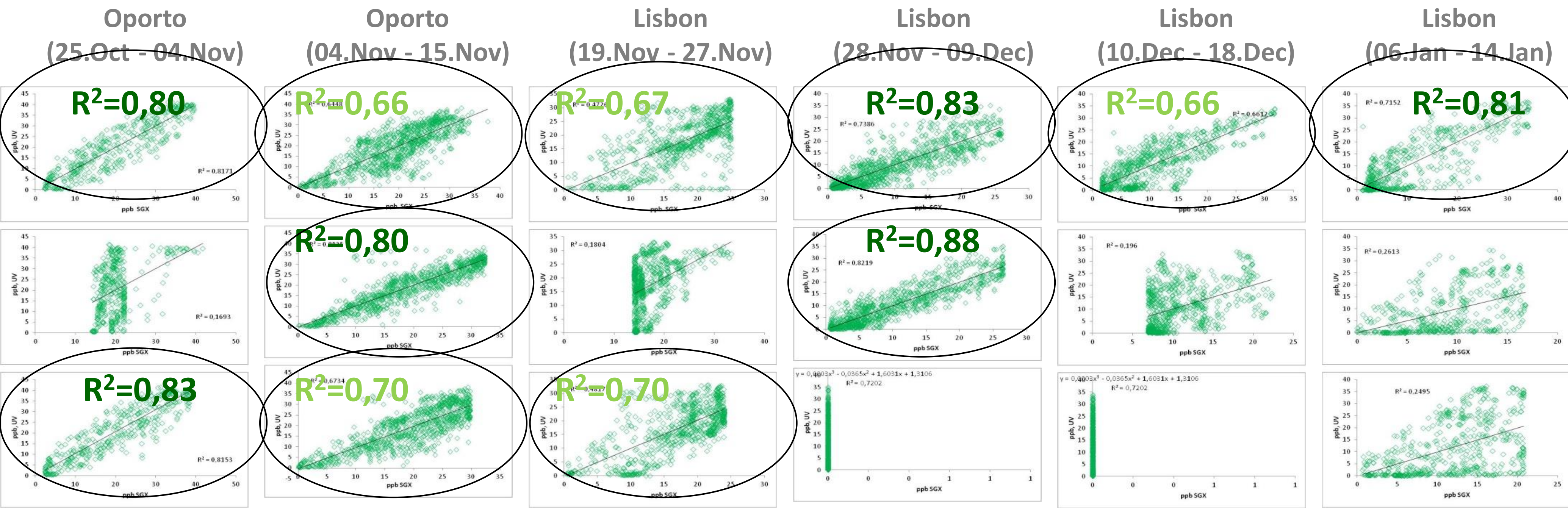
Oporto	Oporto	Lisbon	Lisbon	Lisbon	Lisbon
(25.Oct - 04.Nov)	(04.Nov - 15.Nov)	(19.Nov - 27.Nov)	(28.Nov - 09.Dec)	(10.Dec - 18.Dec)	(06.Jan - 14.Jan)



Different behaviour in each location/sensor

Some cases with erratic behaviour, saturation, problems with electricity stability

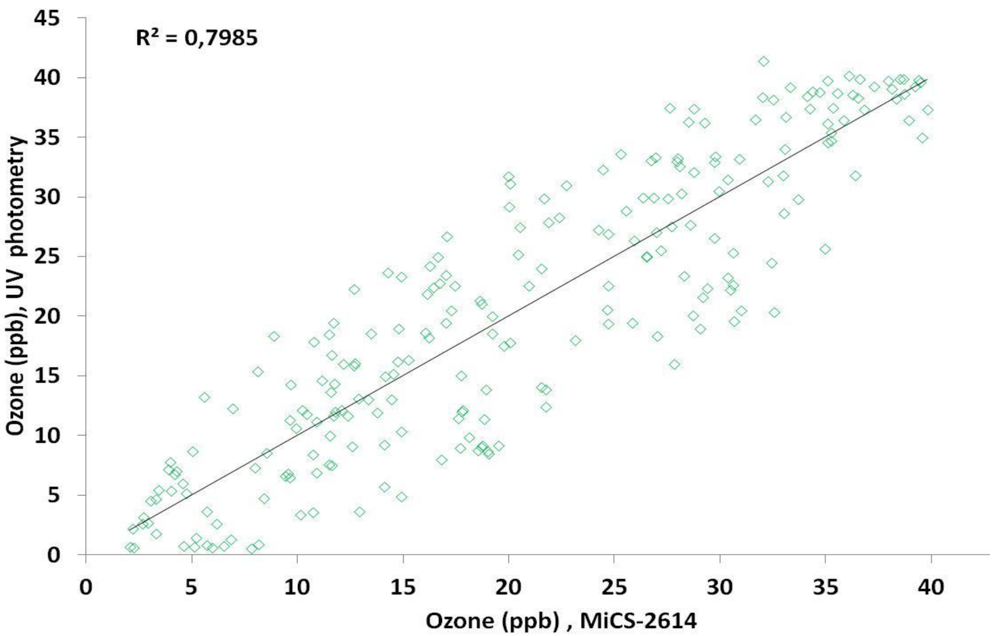
Results - Correlation (ppb_{UV} vs $ppb_{MiCS\text{-}2614}$)



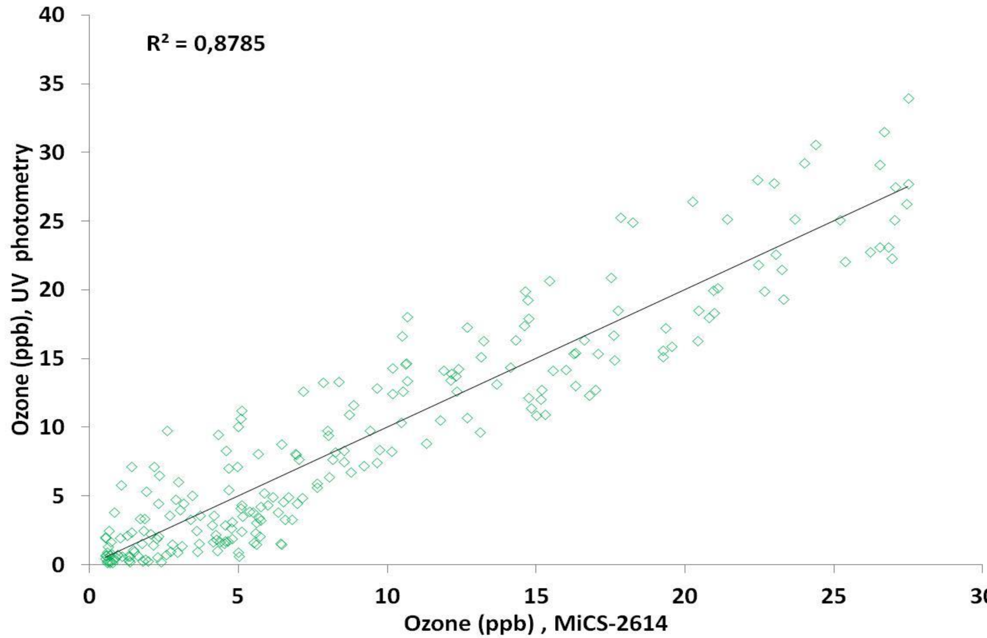
Measurements with correlations > 0,8

Global correlation could be improved with more detailed analysis of the data (summer data)

Example of correlations



P1-Oporto



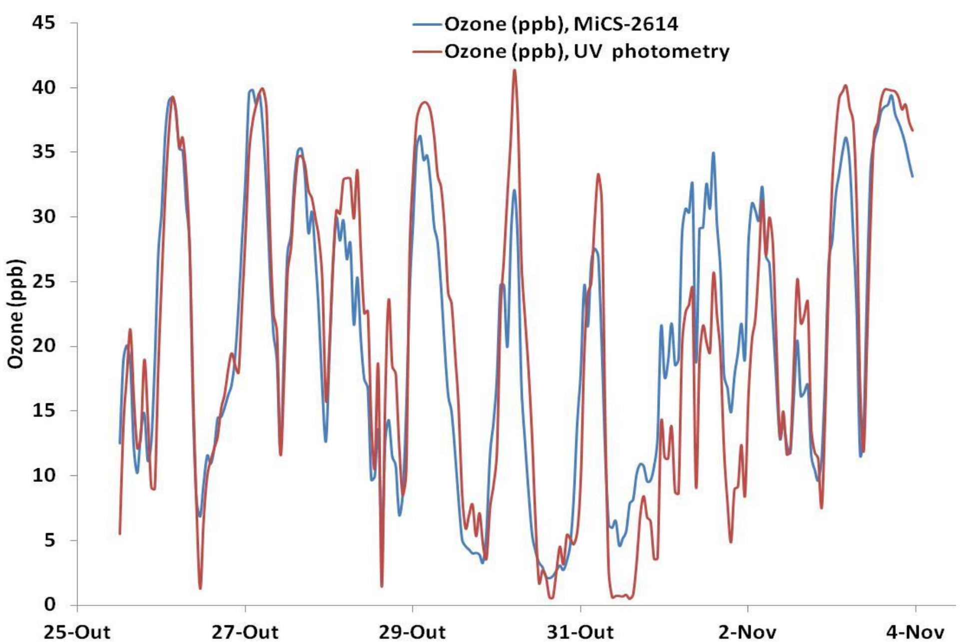
P2-Lisbon

Strong correlation for different sensors and locations

Sensitivity for low concentrations (O_3<40ppb)

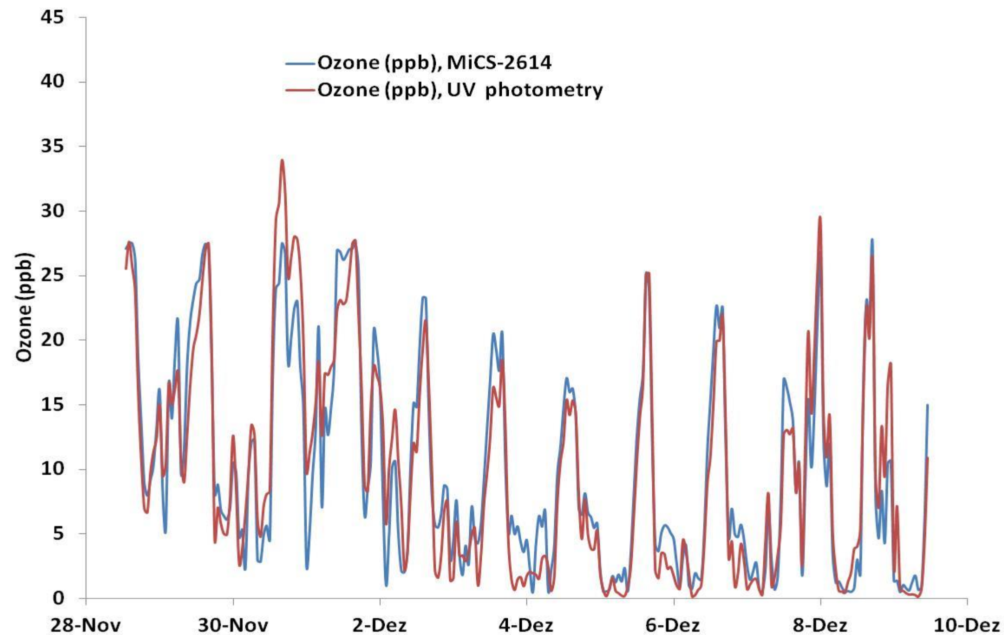
Example of final results

O_3



•R^2=0,80

O_3



•R^2=0,88

Equivalent profile variations

Accurate detection of concentration peaks

CONCLUSIONS

• Strong correlation in a significant part of the measurements, between micro-sensors and standard method **(≈0,7 to 0,9)**;

•Their performances allow new strategies for air quality control, validation of dispersion models or evaluation of population exposure.

• Some cases with saturation, erratic behaviour – need to improve sensor performance and characteristics

Next steps

• Additional field campaigns / different concentrations / different weather conditions;

•Evaluation of influences in the error/uncertainty (RH, other pollutants,..);

EuNetAir Air Quality Joint-Exercise Intercomparison 2014 – Aveiro

Thank you!

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http://www.ua.pt/idad/