Small commercial low-cost resistive sensors for its use for indicative measurement of toxic gases in ambient

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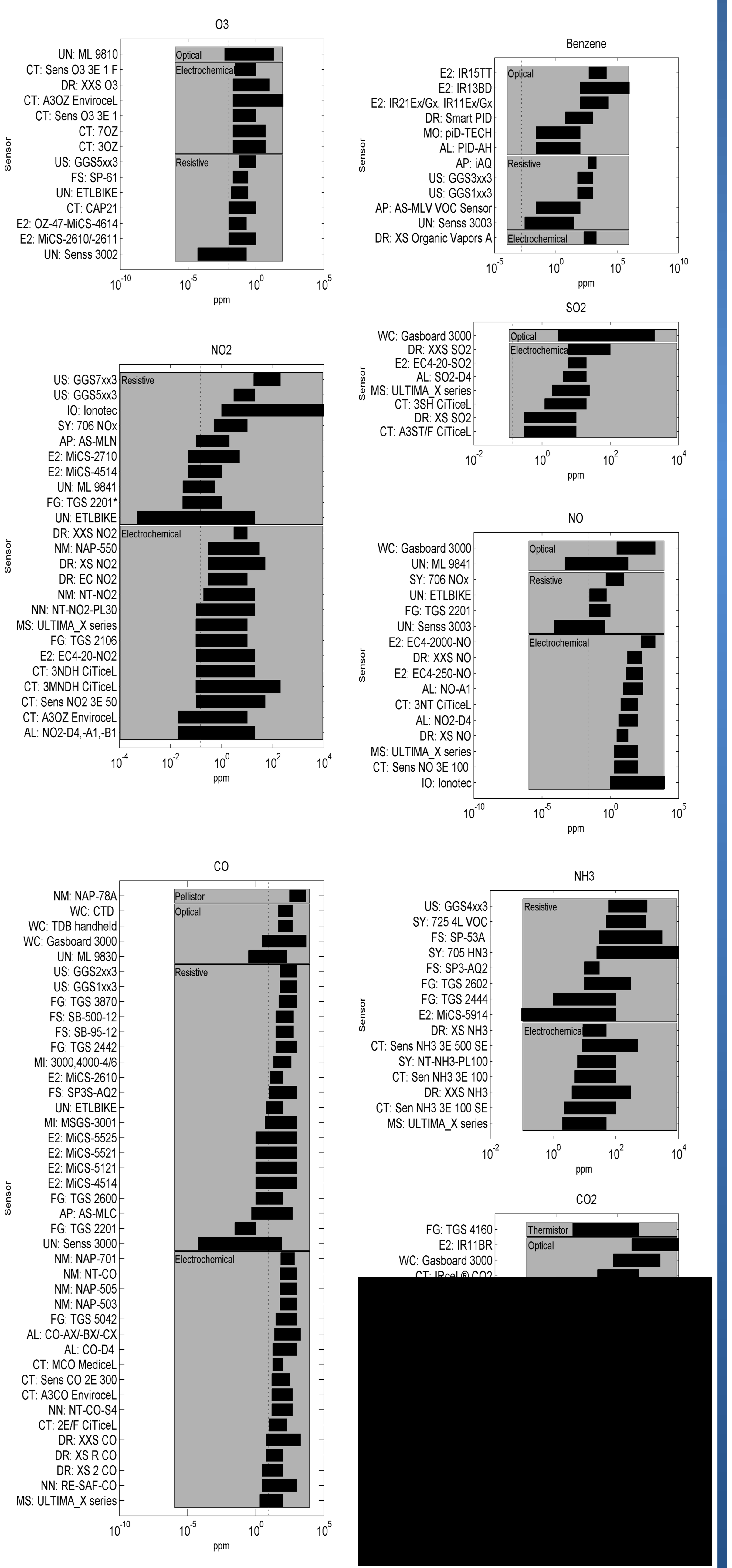
During the MACPoll project we made a review of small commercial sensors. Then based on that review we have selected some of those that claimed to be in the sensitivity range of interest for the study.

We have proposed a physical model to correct for the humidity and temperature and evaluated how that models improved the calibrations performances compared to a simple linear calibration.

Finally we have selected the most promising sensors to include them in a sensor cluster and we have tested several algorithms to see how those techniques improved routine linear calibrations.

Review of small sensors

- In this work we review the literature on commercial sensors used as ambient gas measurement and the specifications of over a hundred commercial sensors
- We compare they performance with the specifications of the European Directive on air quality 2008/50/EC.
- For the majority of the gases a selection of electrolytic sensors with good capacities are recommended.
- To reduce cross sensitivities alternative resistive sensors can help with different sensitivities and information.
- Other kind of sensors like NDIR, pellistor or photo ionization are not suitable because either the low sensitivities to low gas concentrations or high maintenance costs.



Physical Model

- The measurements were made in laboratory in an exposure chamber.
- The humidity range was (40, 50, 60, 70, 80 80) % of relative humidity
- The temperature was in the values of (12, 17, 22, 27, 32) ºC.
- The resistive sensors model for the temperature and humidity combined:

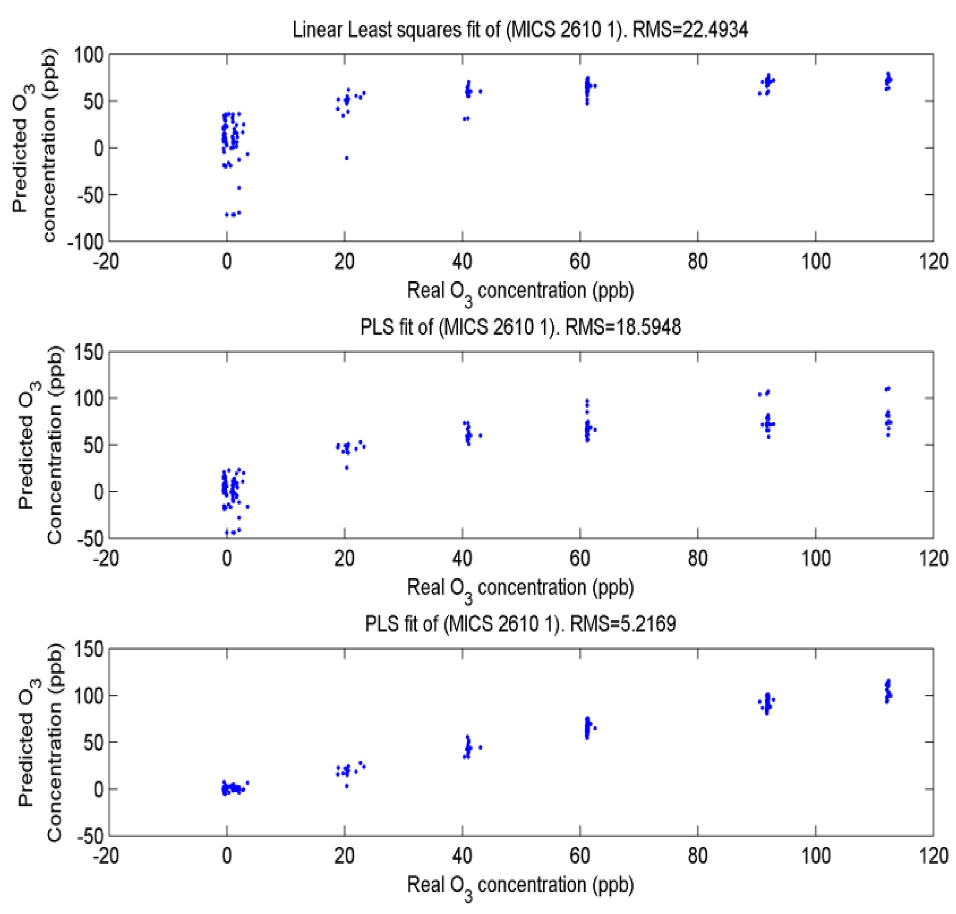
$$R=R_0 \cdot Hd^{\alpha} \cdot \exp(-T \cdot \beta + \delta)$$

- For the electrochemical sensors the model is:

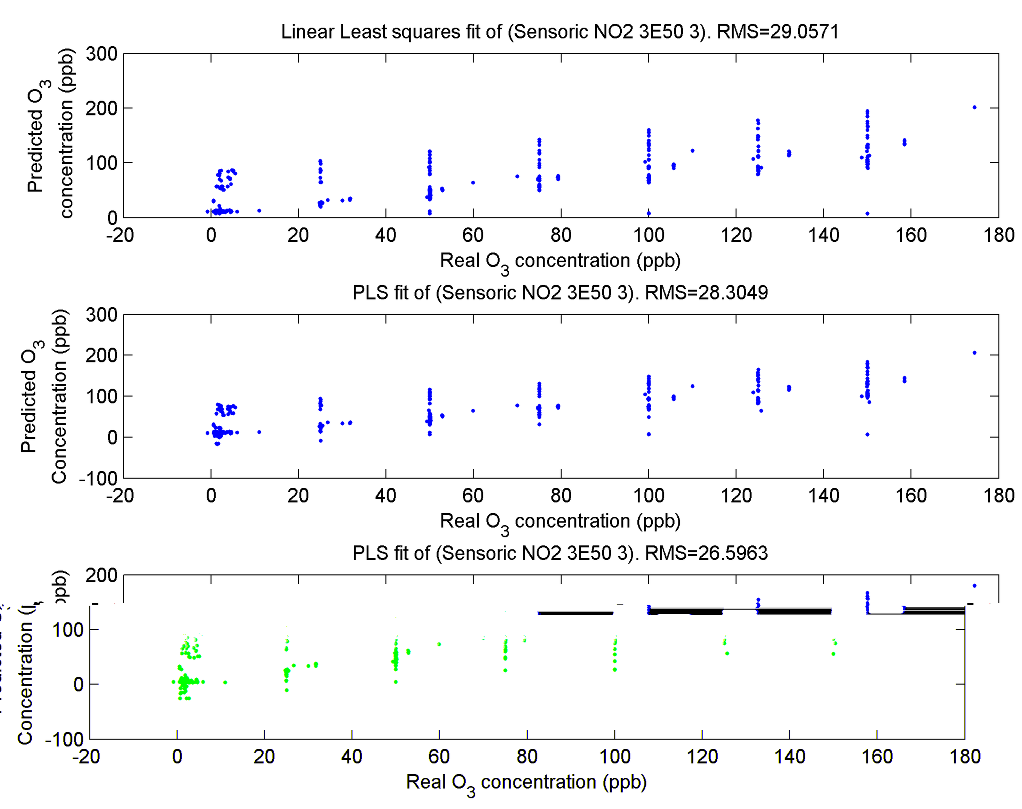
Reaction limited	$V=V-K\,T\ln(K_2\,C + K_3\,H)$
Diffusion limited	$V=V-T\,K\,C - K_1\,(C/H)$

- To fit our model we search the parameters α, β and δ by a Nelder-Mead unconstrained nonlinear optimization.
- Regressions made with and without the models to asses the improvement.

Example of resistive sensor



Example of electrochemical sensor



Summary of results

Type of sensor	RMS Regresion (ppb)	RMS PLS (ppb)	RMS Model+PLS (ppb)	PLS Improv. (%)	Model+PLS Improv. (%)
Electrochemical	45.9	43.3	35.8	5.6%	22.1%
Resistive	27.0	23.5	21.8	13.8%	19.8%

Cluster of sensors

- Measurements made on the field during four months with a cluster of sensors. Averaged by 10 minutes.
- Several algorithms trained and validated with 30% of the measurements.

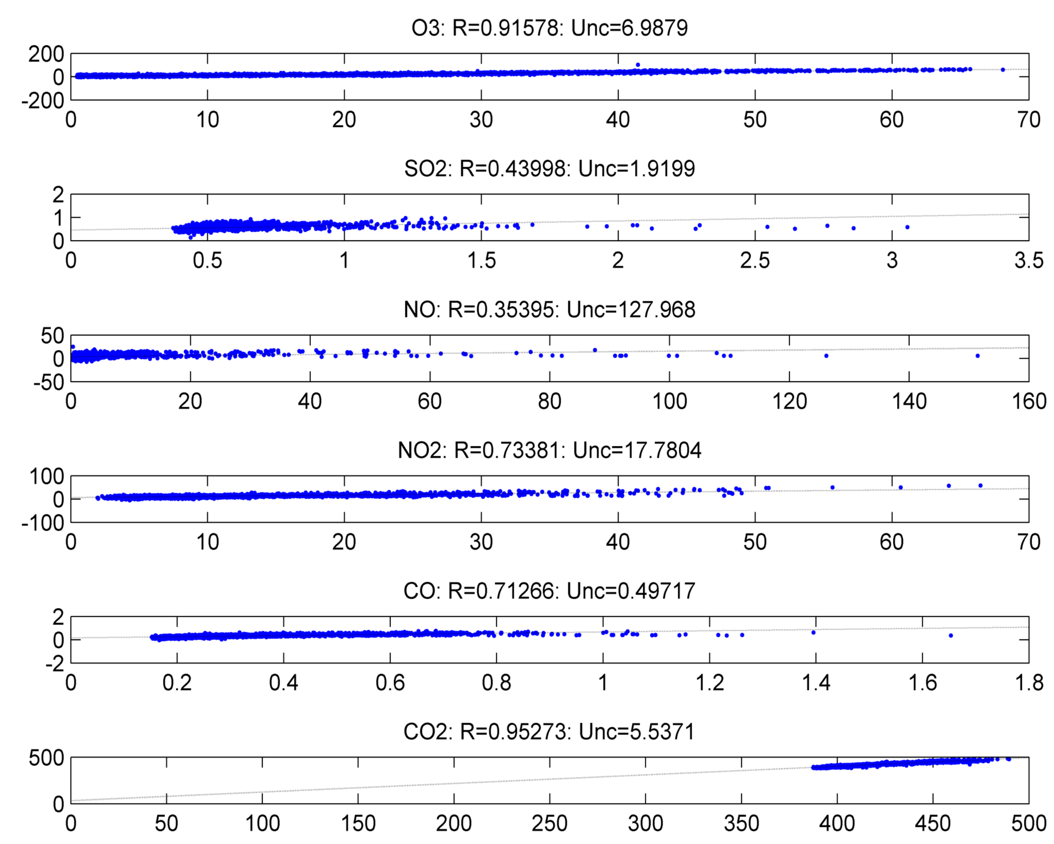
Without ambient parameters:

- Multilinear calibration with PLS
- Artificial Neural networks organized in committees

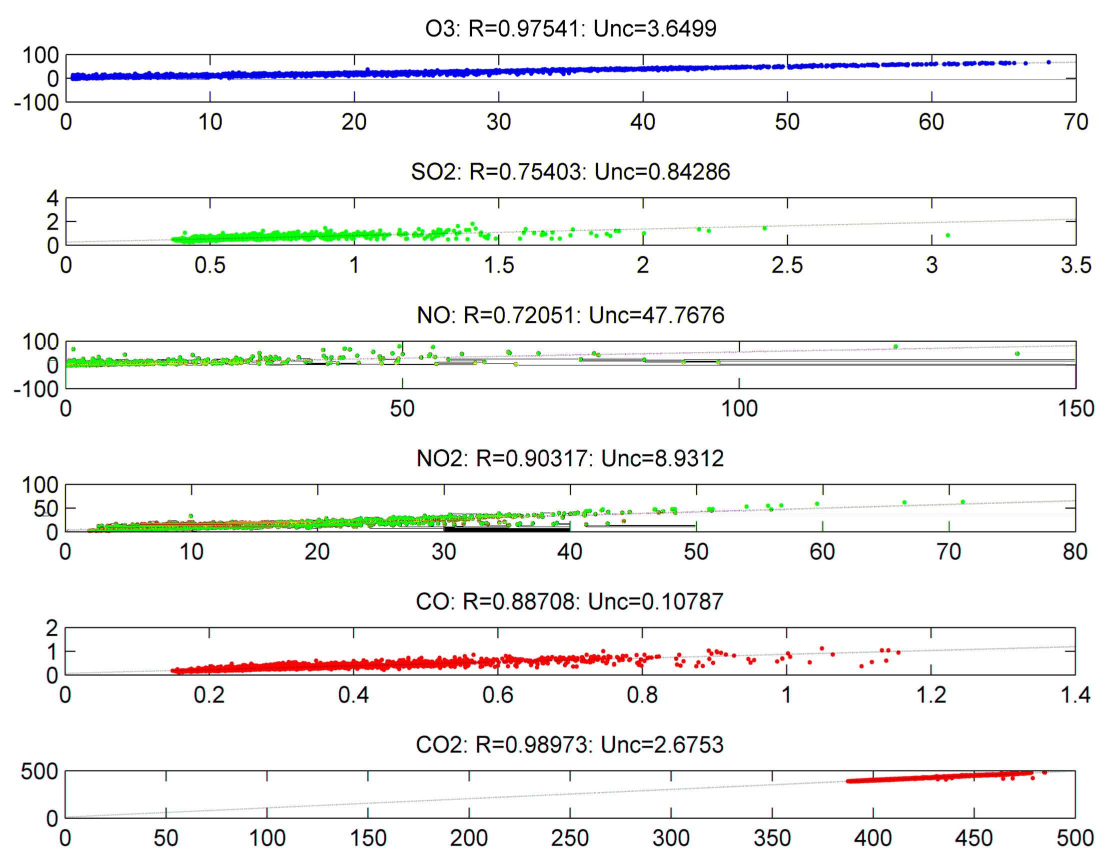
With ambient parameters:

- Multilinear calibration with PLS
- Artificial Neural networks organized in committees
- Artificial Neural networks with PLS input
- Artificial Neural Network with pysical model parameters input

Linear Calibrations of field measurements



ANN with physical model of field measurements



Summary of results

GAS	PLS	ANN	PLS	ANN	ANN+ PLS	ANN+ MODEL
	No Ambient		Ambient			
O3	9.4	5.6	7.0	4.0	4.1	3.7
SO2	1.3	0.9	1.9	0.8	0.9	0.8
NO	129.5	91.7	128.0	105.5	111.8	47.8
NO2	18.3	10.1	17.8	9.6	11.2	8.9
CO	0.7	0.4	0.5	0.2	0.2	0.1

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