DETERMINATION OF SENSOR PERFORMANCE CHARACTERISTICS FROM FIELD MEASUREMENTS

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EMPA Materials Science & Technology

Research and Innovation Needs

– How good are sensors for atmospheric pollutants under realistic conditions?

→ procedure for sensor performance evaluation

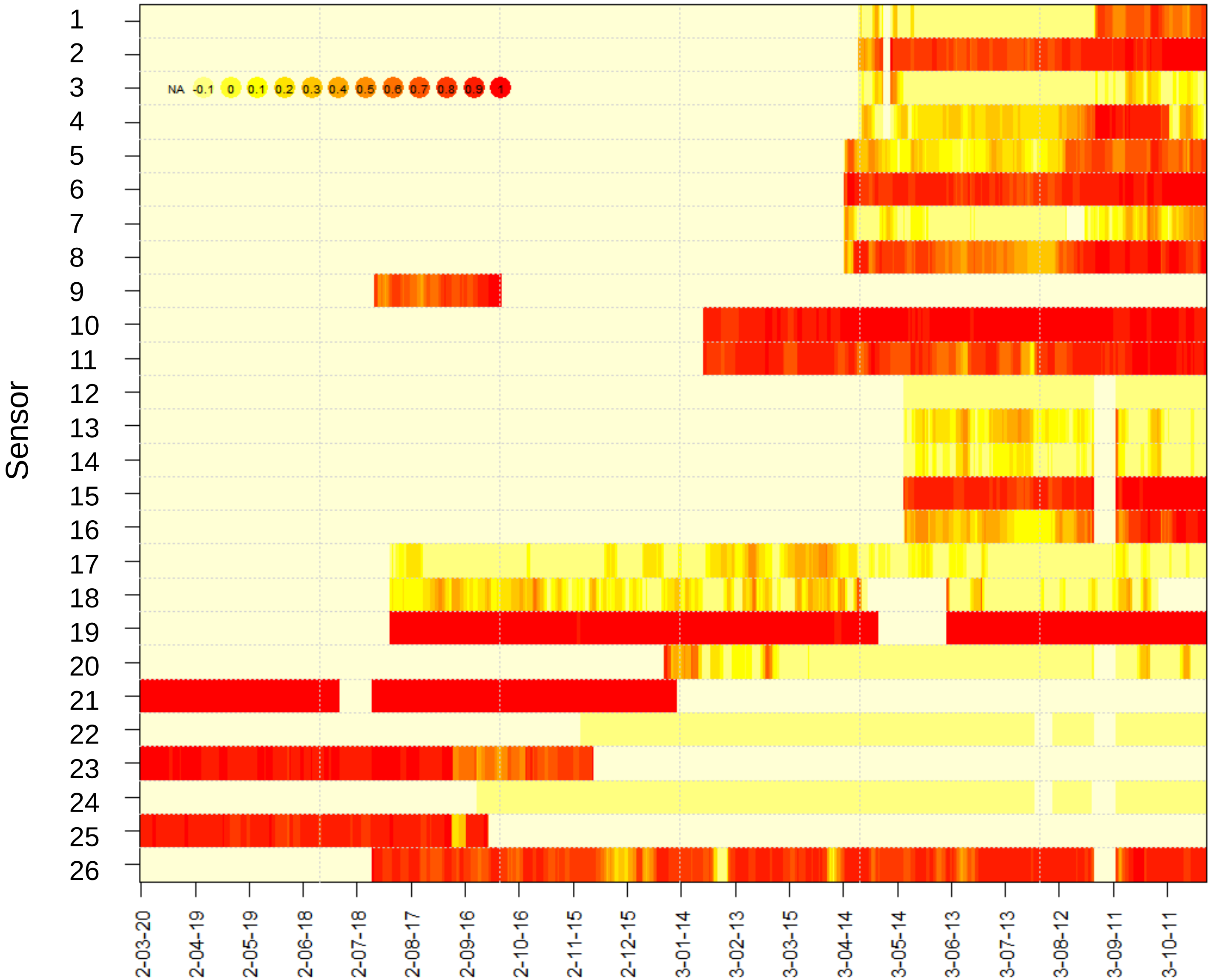
AQ-site in Duebendorf, Switzerland (suburban)

Sensor evaluation project supported by Swiss EPA (FOEN)

– Concepts and strategies for operation of AQ-sensor networks (QA/QC of individual sensors)

Sensor Tests at AQ-Reference site in Duebendorf (suburban site)

Rolling 7-d correlation coefficient of sensor and reference instrument



Some sensors…

→ change during operation

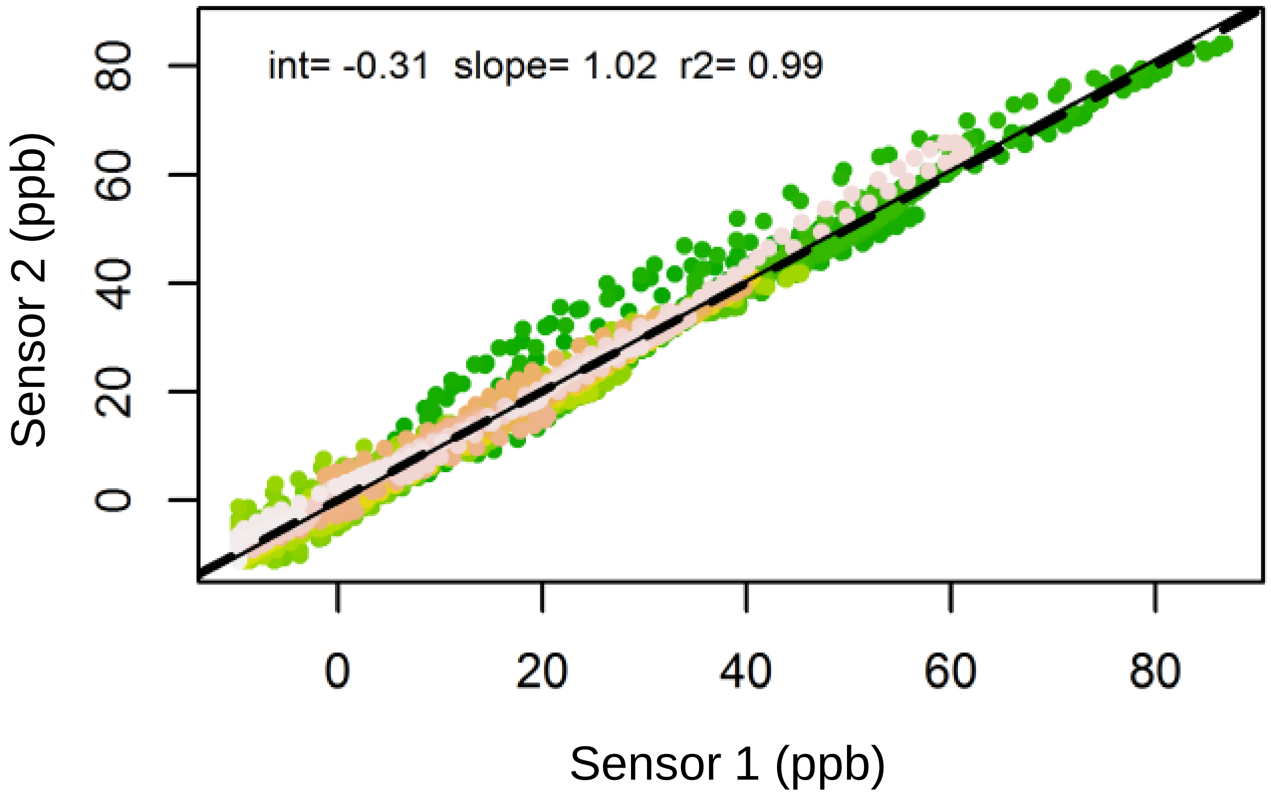
→ work!

→ don't work!

Evaluation of Sensors – Performance Indicators

- between sensor uncertainty (**u_{bi}**)

$$u_{bi} = \sqrt{\frac{\sum_{i=1}^{n}\left(y_{i,\,sensor\,1} - y_{i,\,sensor\,2}\right)^2}{2n}}$$



Evaluation of Sensors - Performance Indicators

- **rmse** (root mean square error)

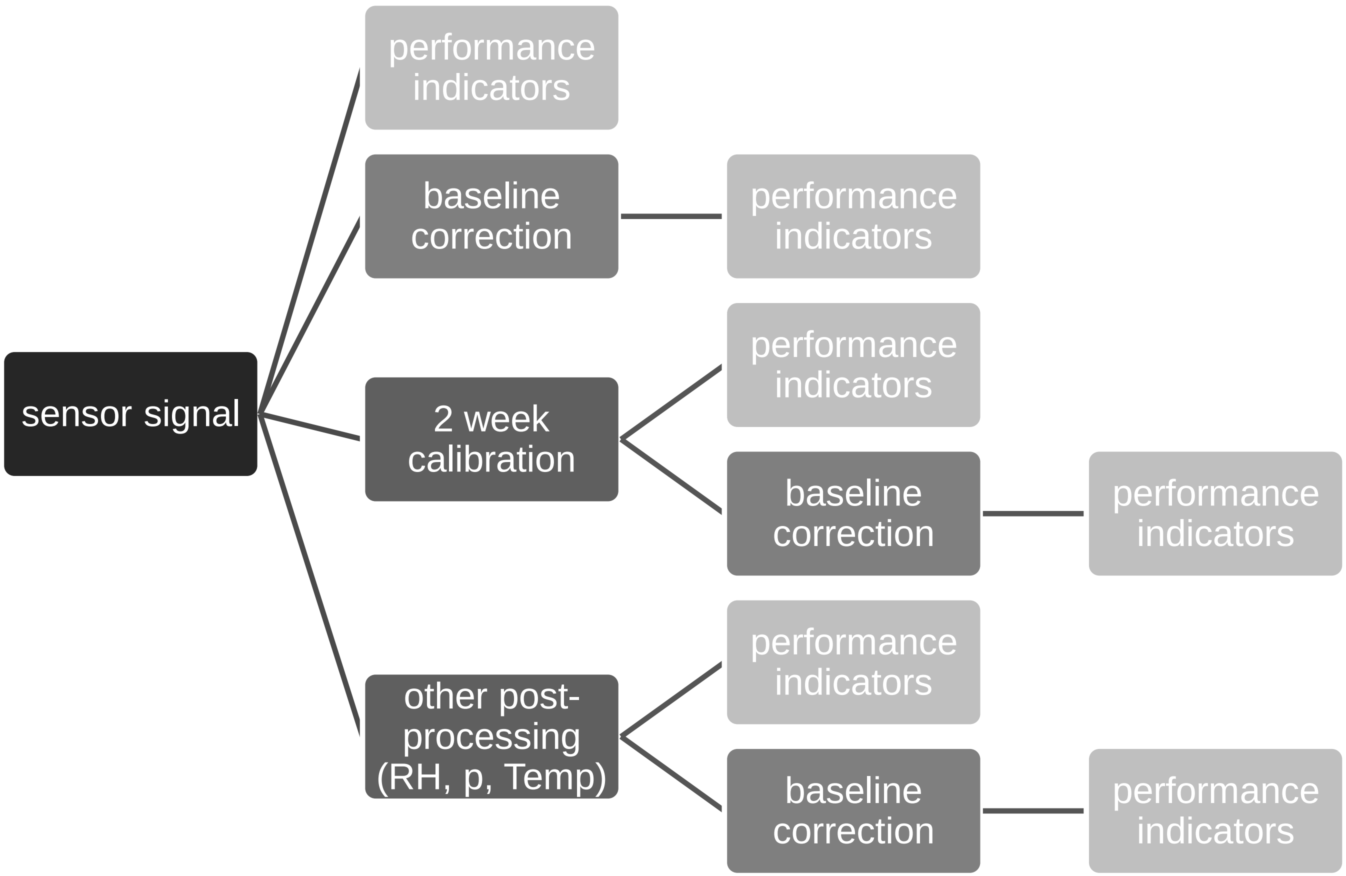
$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_{i,sensor} - y_{i,reference}\right)^2$$

- Offset (**O**), slope (**S**), coefficient of determination ($\mathbf{r^2}$) from linear regression of sensor data against reference data

- Linear drift - derived from difference of signals from sensor and reference site

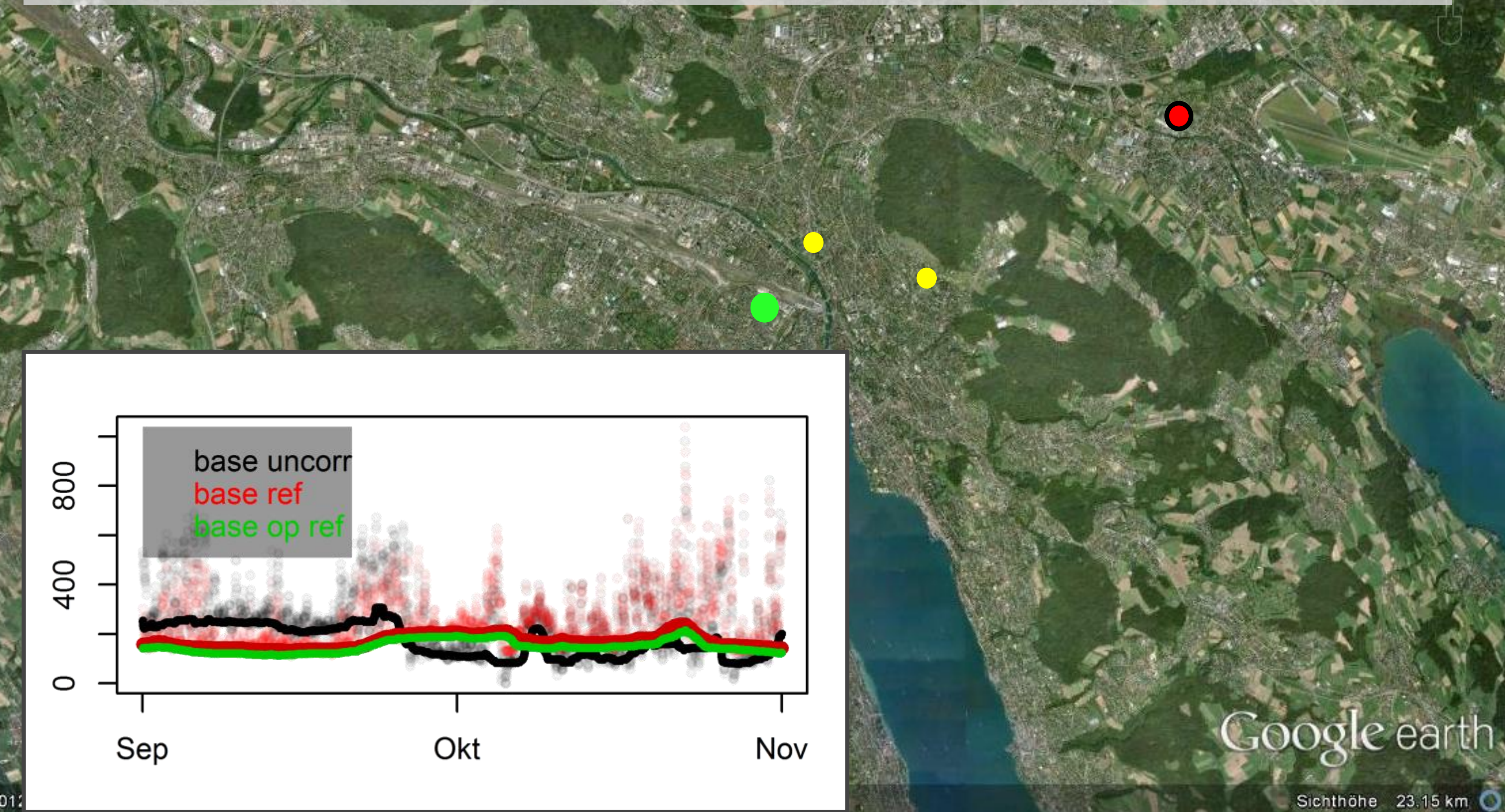
Sensor Test Procedure

10 min values
3 month of data



Ambient air pollutant concentration: Superposition of a lower frequency signal **representing the urban or regional background** and higher frequency signal representing the contribution from local sources.

Extraction of low frequency signal (low pass filtering - **baseline**)



Example CO

Sensor #

Performance indicator

	Sensor 1	Sensor 2	Sensor 3
O_{raw}	-78.49	45.87	73.55
O_{cal}	-13.62	-11.15	-6.22
O_{bm}	40.61	100.91	124.93
O_{rawBL}	-7.17	-6.10	19.68
O_{calBL}	-22.72	-16.38	-11.36
O_{bmBL}	31.45	61.23	84.59
S_{raw}	1.08	0.87	0.68
S_{cal}	1.19	0.93	0.87
S_{bm}	0.76	0.52	0.42
S_{rawBL}	1.14	0.99	0.83
S_{calBL}	1.26	1.06	1.04
S_{bmBL}	0.81	0.54	0.43
r^2_{raw}	0.64	0.55	0.43
r^2_{cal}	0.64	0.55	0.43
r^2_{bm}	0.75	0.65	0.55
r^2_{rawBL}	0.65	0.87	0.84
r^2_{calBL}	0.65	0.87	0.83
r^2_{bmBL}	0.75	0.69	0.55
$rmse_{raw}$	82.70	92.43	99.27
$rmse_{cal}$	64.59	101.45	124.53
$rmse_{bm}$	33.94	73.58	82.99
$rmse_{rawBL}$	60.38	45.30	51.96
$rmse_{calBL}$	69.36	48.24	55.42
$rmse_{bmBL}$	33.97	86.52	99.06
Id_{raw}	0.35	-3.92	-4.53
Id_{cal}	0.42	-4.06	-5.20
Id_{bm}	-0.10	-2.16	-2.26
Id_{rawBL}	0.10	-0.63	-1.07
Id_{calBL}	0.18	-0.55	-0.92
Id_{bmBL}	-0.36	-1.73	-2.16

Example O_3

Sensor #

Performance indicator

	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5	Sensor 6	Sensor 7	Sensor 8	Sensor 9
O_{raw}	28.48	53.12	43.80	6.99	5.21	1.61	18.34	6.26	6.26
O_{cal}	-0.65	-1.89	-0.47	-0.94	0.79	-29.94	8.64	-2.82	-2.97
O_{bm}	-0.87	3.30	2.39	-1.01	-0.98	-1.63	3.16	4.37	4.08
O_{rawBL}	1.27	-2.45	-3.31	0.56	1.89	57.99	12.94	4.95	4.93
O_{calBL}	1.10	7.74	6.45	0.21	2.10	-2.09	13.53	5.17	5.54
O_{bmBL}	1.74	7.03	6.40	0.36	2.59	6.80	4.79	2.92	2.94
S_{raw}	0.50	1.91	1.76	0.77	1.08	-0.72	1.14	0.95	0.81
S_{cal}	0.69	0.96	0.95	0.99	1.03	1.52	1.26	1.05	1.06
S_{bm}	0.77	0.87	0.91	1.00	1.03	0.81	1.02	0.72	0.73
S_{rawBL}	0.58	1.90	1.75	0.83	1.18	-0.42	1.20	0.69	0.61
S_{calBL}	0.74	0.99	0.98	1.03	1.14	1.70	1.31	0.74	0.72
S_{bmBL}	0.81	0.91	0.93	1.03	1.10	1.03	1.00	0.70	0.70
r^2_{raw}	0.52	0.71	0.85	0.98	0.99	0.43	0.31	0.62	0.60
r^2_{cal}	0.52	0.71	0.85	0.98	0.99	0.43	0.31	0.62	0.60
r^2_{bm}	0.66	0.93	0.95	0.98	0.99	0.64	0.88	0.71	0.72
r^2_{rawBL}	0.62	0.80	0.88	0.96	0.97	0.11	0.41	0.57	0.55
r^2_{calBL}	0.59	0.79	0.87	0.98	0.97	0.49	0.40	0.56	0.54
r^2_{bmBL}	0.74	0.90	0.92	0.98	0.97	0.75	0.90	0.66	0.67
$rmse_{raw}$	23.97	86.34	70.43	5.21	7.55	70.62	38.80	12.18	10.66
$rmse_{cal}$	10.01	11.31	7.35	1.96	2.63	37.34	38.99	12.26	12.94
$rmse_{bm}$	8.22	4.94	3.95	1.91	1.84	15.06	8.06	7.85	7.82
$rmse_{rawBL}$	8.48	35.29	27.05	3.22	7.66	36.36	32.92	9.92	9.96
$rmse_{calBL}$	8.38	11.76	8.94	2.02	6.74	43.20	37.72	10.33	10.62
$rmse_{bmBL}$	6.31	7.08	6.60	2.03	6.17	14.08	7.96	8.84	8.68
Id_{raw}	-0.05	-0.08	-0.03	-0.02	0.01	-0.04	0.45	-0.24	-0.16
Id_{cal}	-0.10	-0.06	-0.04	-0.04	0.02	-0.13	0.45	-0.29	-0.31
Id_{bm}	-0.13	-0.04	-0.03	-0.04	-0.01	-0.13	-0.01	-0.04	-0.05
Id_{rawBL}	0.00	-0.04	-0.02	0.01	-0.10	0.11	0.29	-0.03	-0.01
Id_{calBL}	-0.04	-0.05	-0.04	-0.01	-0.09	0.22	0.32	-0.03	-0.02
Id_{bmBL}	-0.03	-0.04	-0.04	-0.01	-0.08	0.15	0.00	-0.09	-0.09

Conclusions

- Test procedures for sensors that provide information about the performance under realistic conditions needed

- Some of the available sensors work, others don’t work!

- Performance of individual (identical) sensors can vary (constant quality of manufactured sensors?)

- Concepts and strategies for operation of sensor networks needed – QA/QC of individual sensors in networks?

- Sensors can be linked (in smart ways) to reference instruments from traditional AQ sites

- Low cost of sensors does not necessarily mean low costs for operation