Assessment of low-cost sensors for air quality in real-world conditions

María Cruz Minguillón, Mar Viana, Cristina Reche, Fulvio Amato, Xavier Querol

Institute of Environmental Assessment and Water Research (IDAEA), CSIC

Meeting on sensor technology for air quality

Bilthoven, 13 February 2017

What is a low-cost air quality sensor?

An instrument to measure air quality that…

- is small ← <1 kg?
- is low-cost ← cheap enough to be replaced rather than fixed if it fails (Morawska, 2016)
- can be deployed outdoors or indoors
- can be deployed for a reasonable amount of time ← 1 month?

- They are **complementary** to air quality networks
- Laboratory performance is satisfactory, although their **validation** in **real-world** conditions still has **limitations**

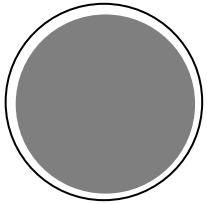
- **OBJETIVE: assess the performance of air quality sensors in real-world conditions**

Methodology

Urban background site in **Barcelona**, with pollutant concentrations typical of the urban background in the **Mediterranean region**

Palau Reial, IDAEA-CSIC

Methodology



PM:
High volume captor and gravimetric determination

PM:
Optical particle counter (GRIMM 180)

O_3:
Ultraviolet absorption
SIR S-5014

NO and NO_2:
Chemiluminescence
SIR S-5012

idaea CSIC Generalitat de Catalunya

Bilthoven, 13 February 2017

Tested sensors

Gaseous pollutants

POD (AQMesh)
NO, NO_2, O_3
Electrochemical

CAPTOR
O_3
Metal oxide

ELM / CANARIT
O
Me l ox de **stopped**

rkinElmer
(before AirBase)

Particulate matter

DYLOS

POD (AQMesh)

AIRBEAM

MICROPEM

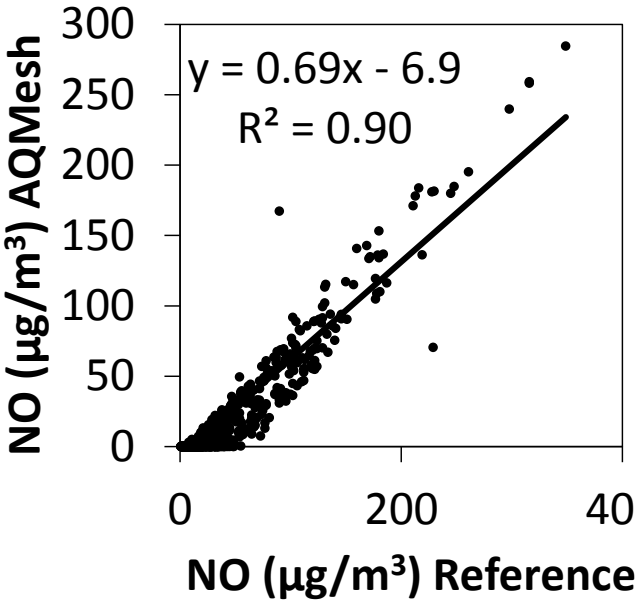
idaea CSIC

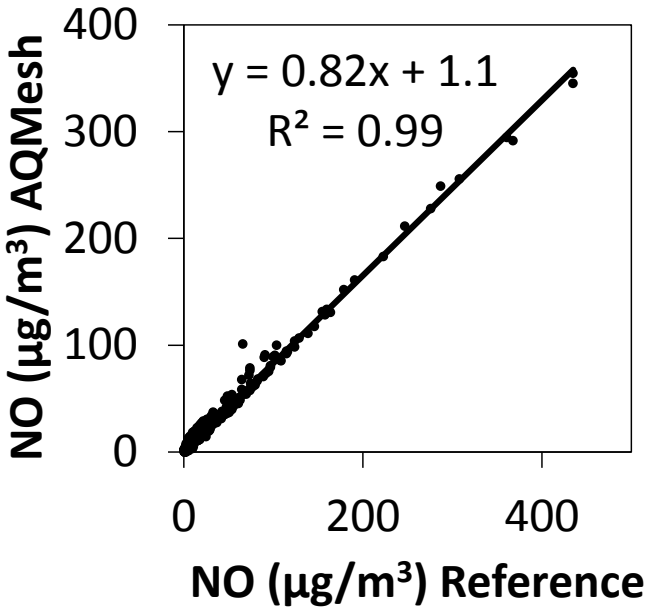
Bilthoven, 13 February 2017

Pod (AQMesh): NO, NO_2, O_3

Equipped with a solar roof to reduce temperature effect

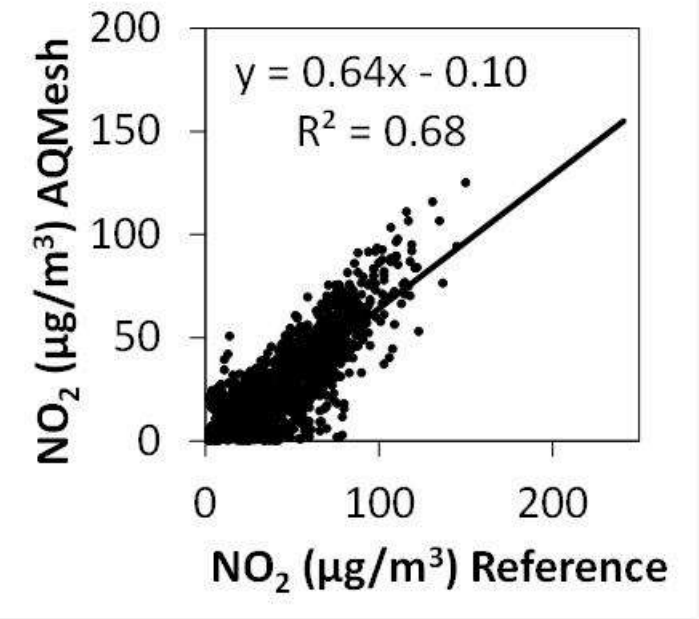
Modification

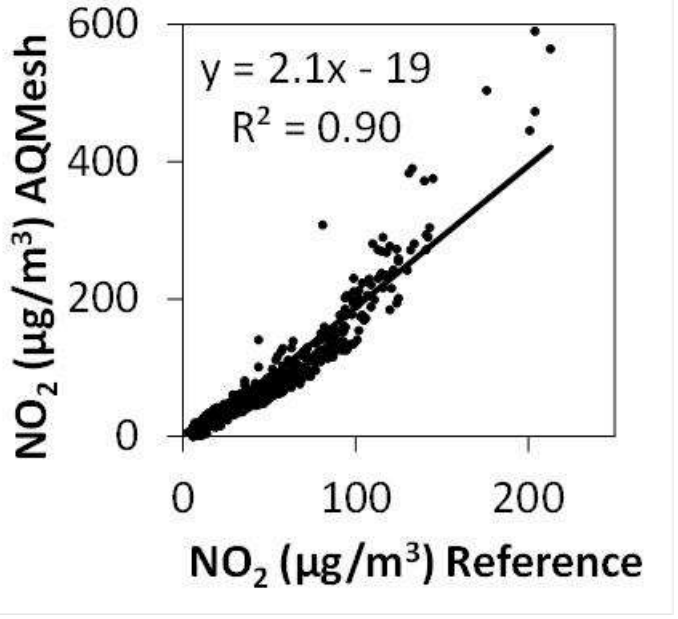




Pod (AQMesh): NO, NO_2, O_3

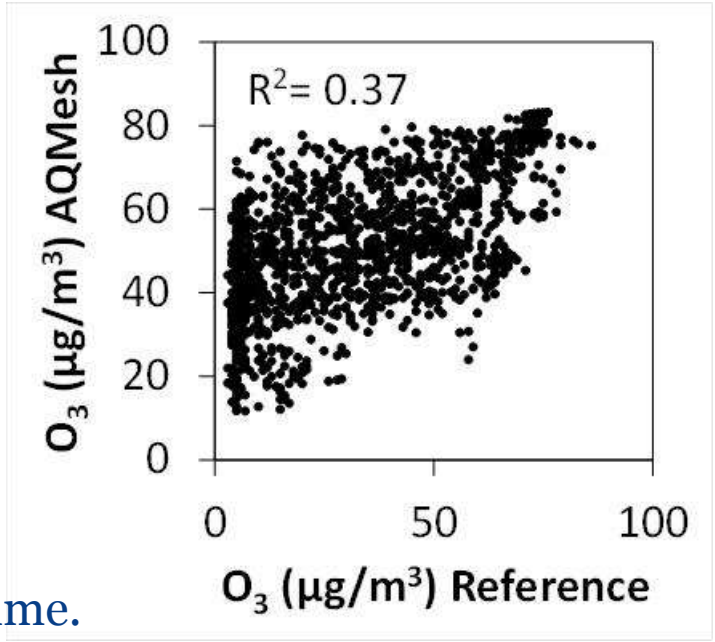
Modification



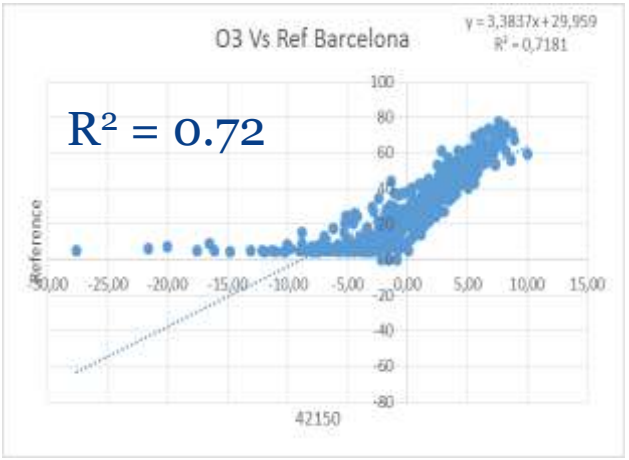


Improve in technology and data treatment results in an increased R^2

Pod (AQMesh): NO, NO_2, O_3



Modification



ATTENTION!

They can vary over time.

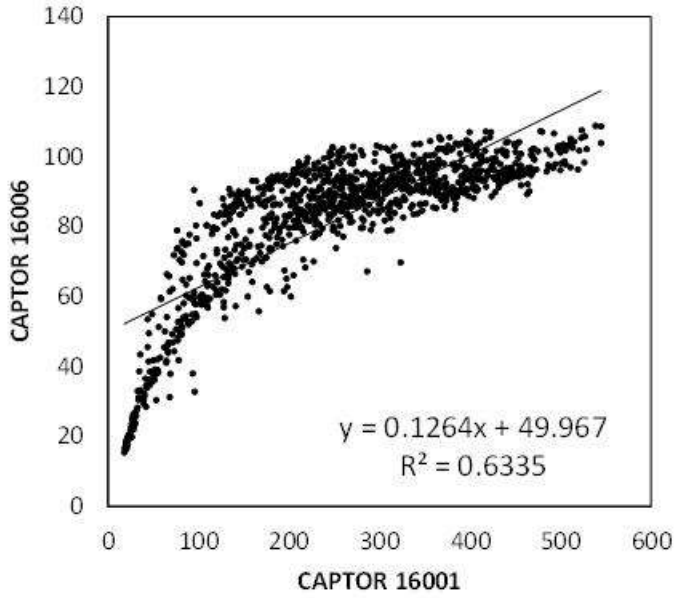
Worse correlations in summer than winter

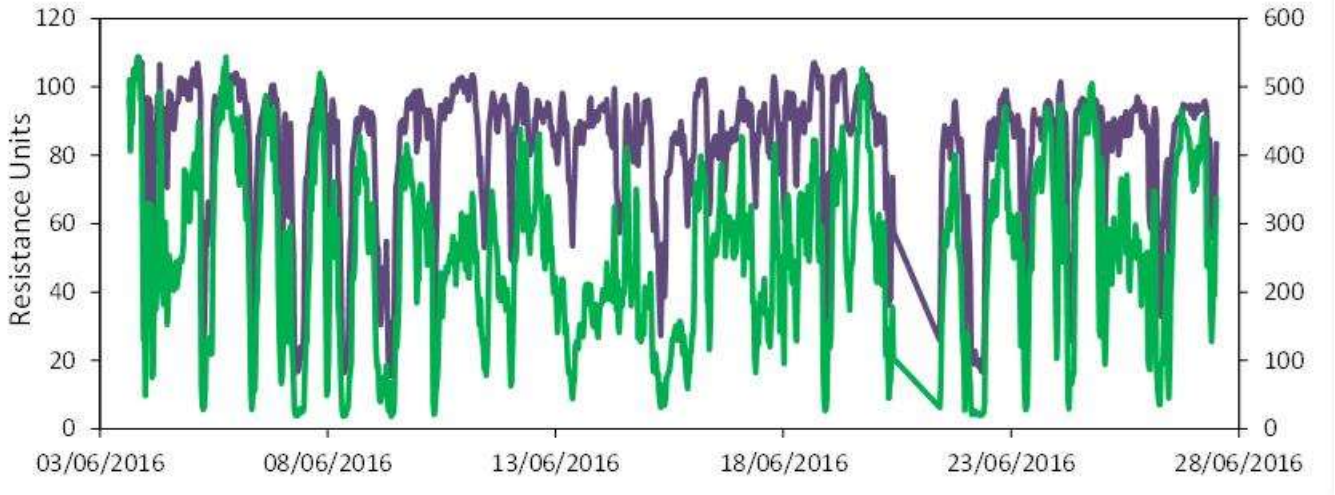
Improve in technology and data treatment results in an increased R^2

idaea CSIC

Captor: O_3

Inter instrument comparison





H2020 project

CAPTOR

UNIVERSITAT POLITÈCNICA DE CATALUNYA

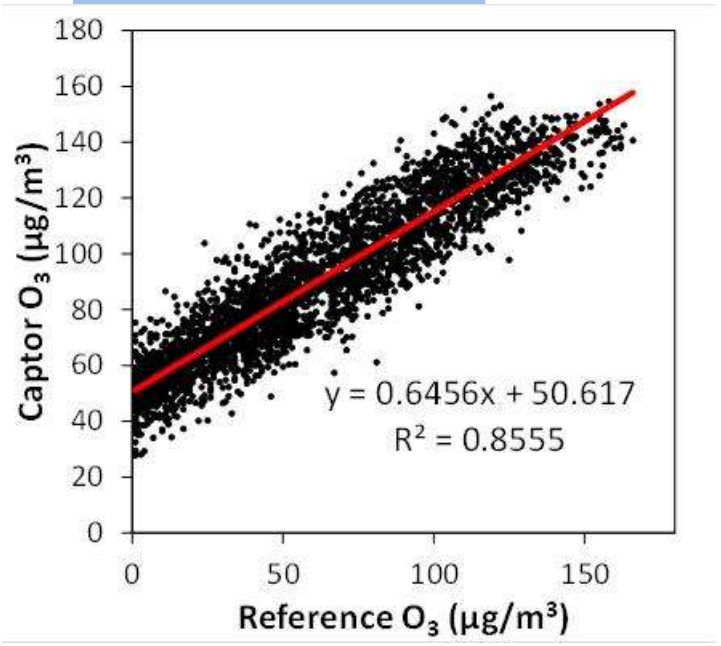
idaea CSIC

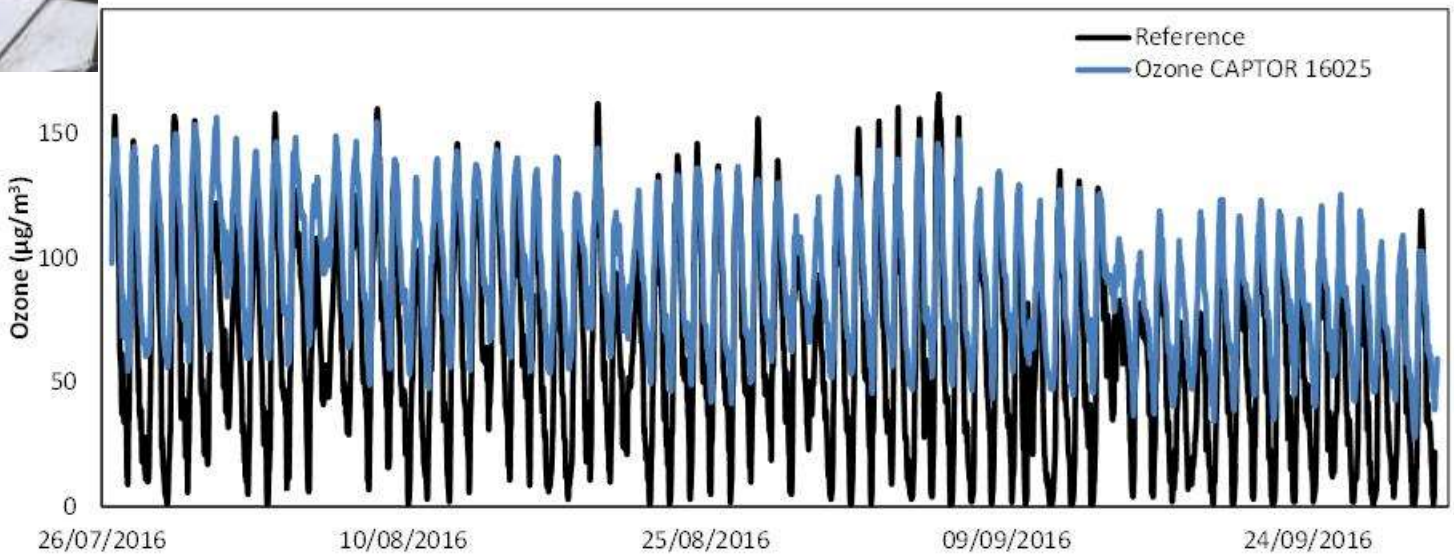
Bilthoven, 13 February 2017

Captor: O_3

Field deployment

Example 1





H2020 project

CAPTOR

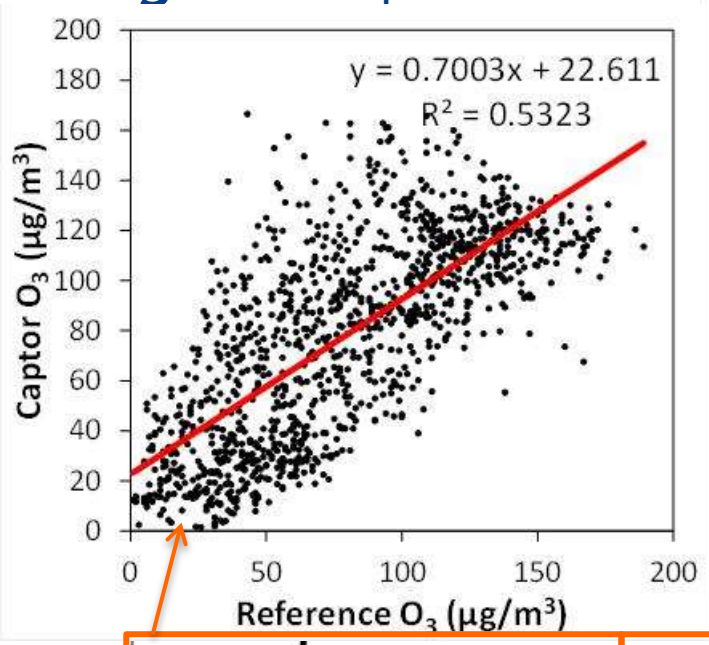
UNIVERSITAT POLITÈCNICA DE CATALUNYA

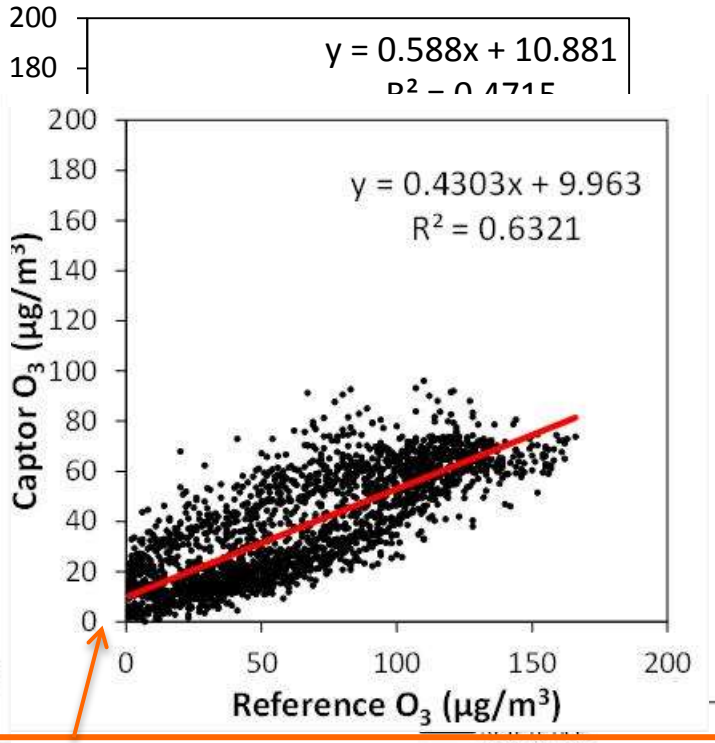
idaea CSIC

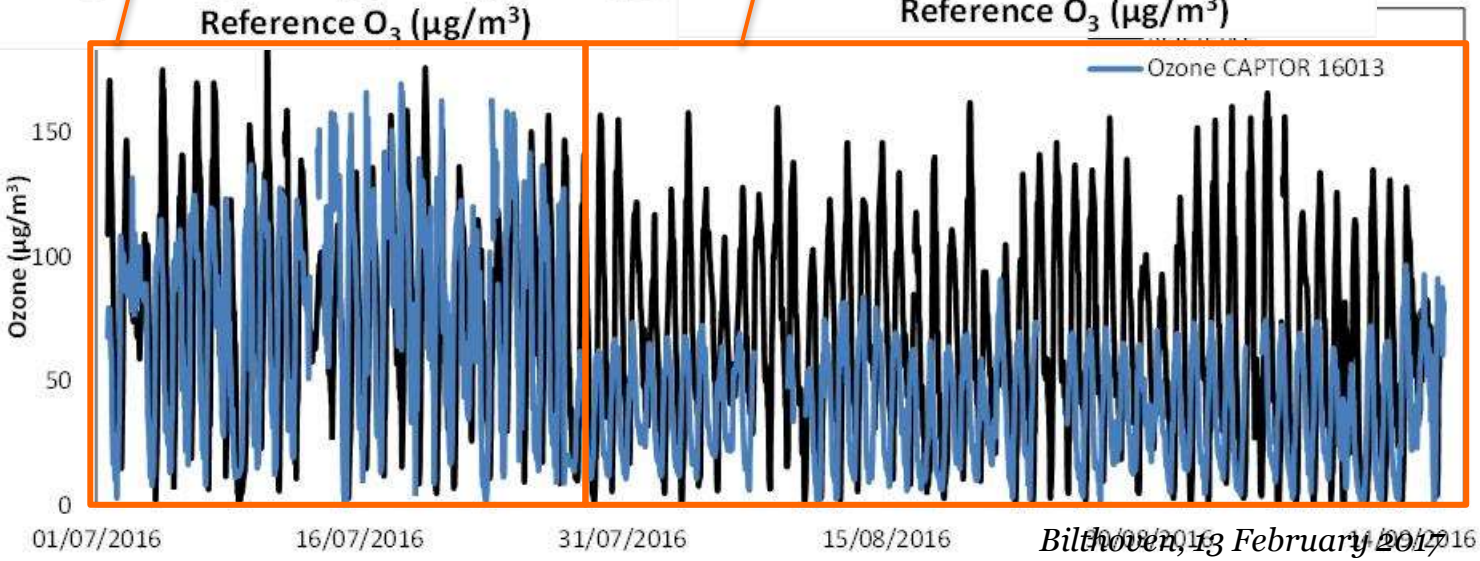
Captor: O_3

Field deployment

Example 2







H2020 project

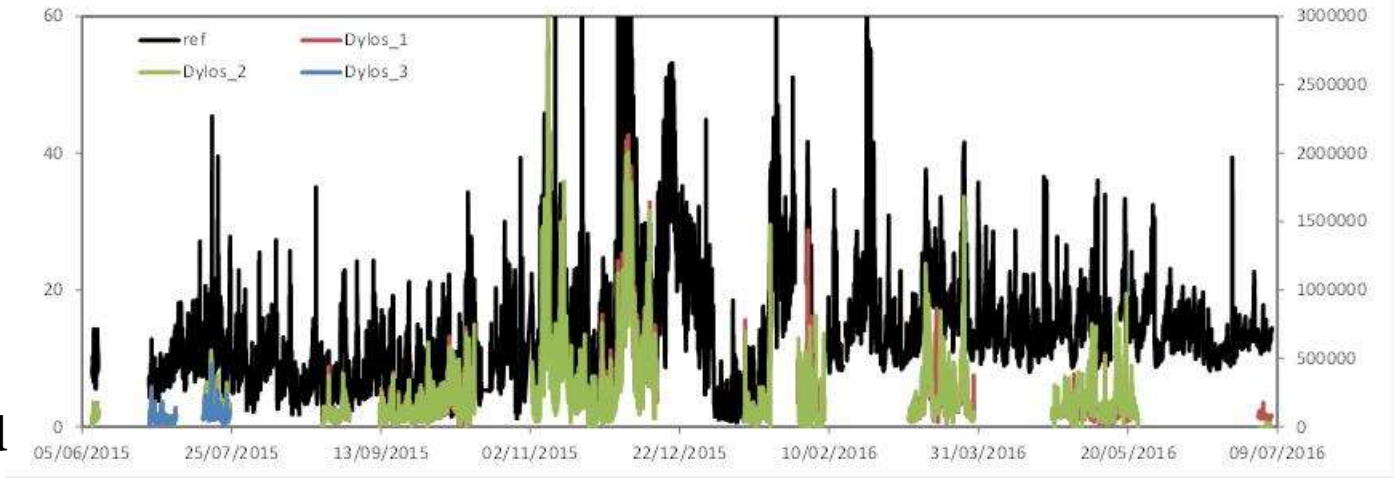
CAPTOR

UNIVERSITAT POLITÈCNICA DE CATALUNYA

idaea CSIC

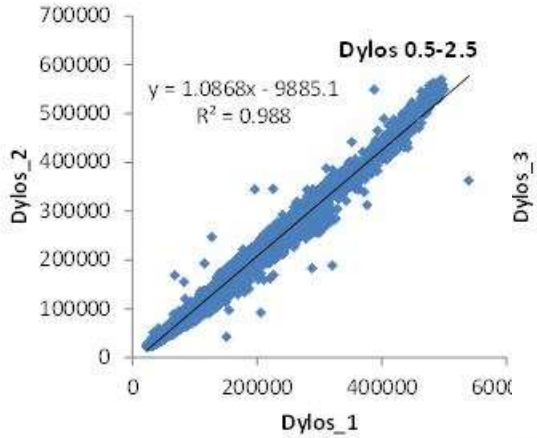
Dylos: $N_{>0.5}$ and $N_{>2.5}$

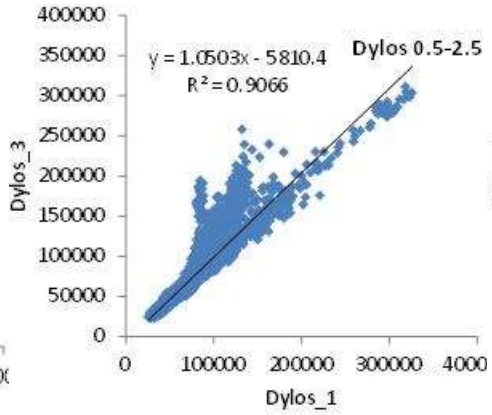
Inter instrument comparison

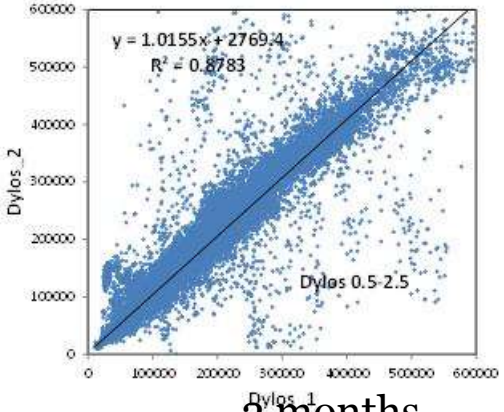


- No.5-2.5 calculated
- Proxy for PM2.5
- Time res: 1min
- Averaged to
  5min or
  30min

- 3 units
- >1 year



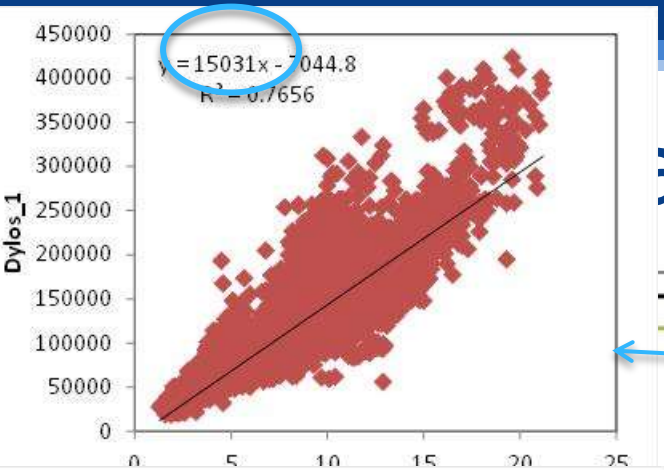


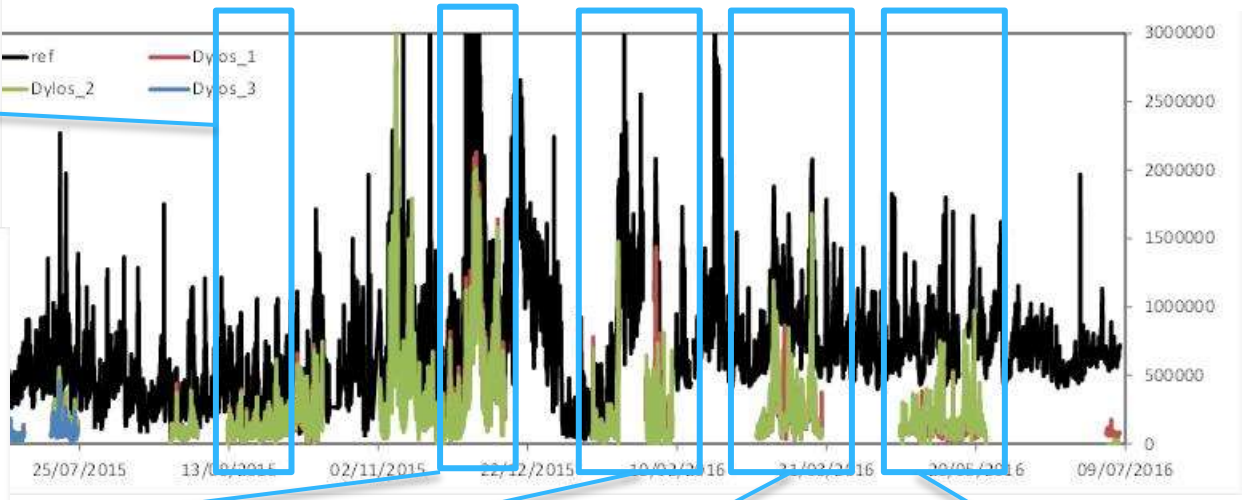


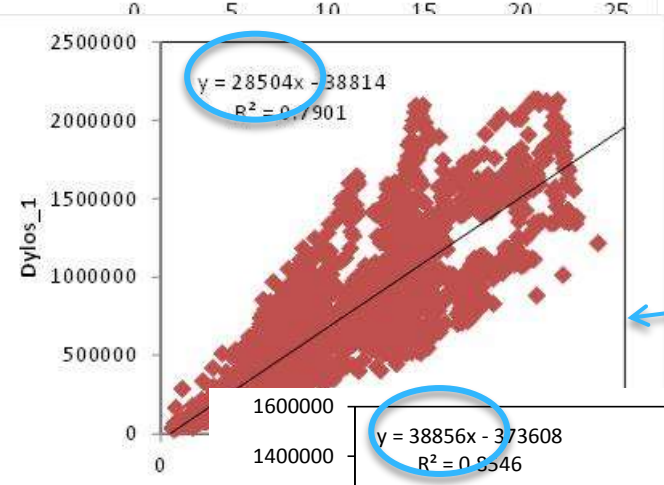
2 months

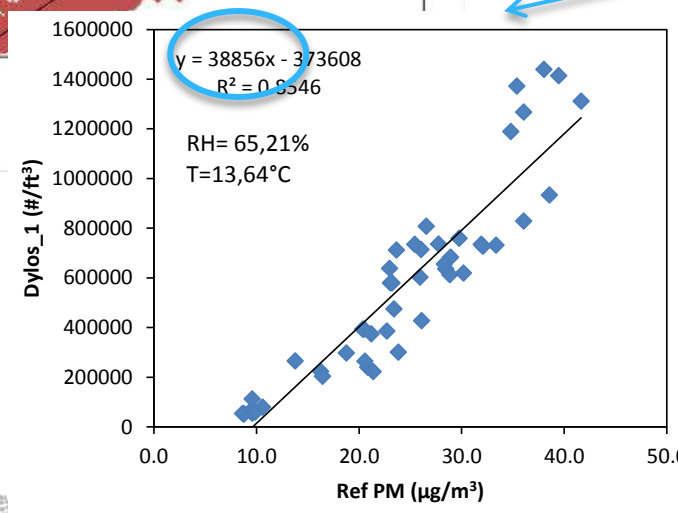
and $N_{>2.5}$

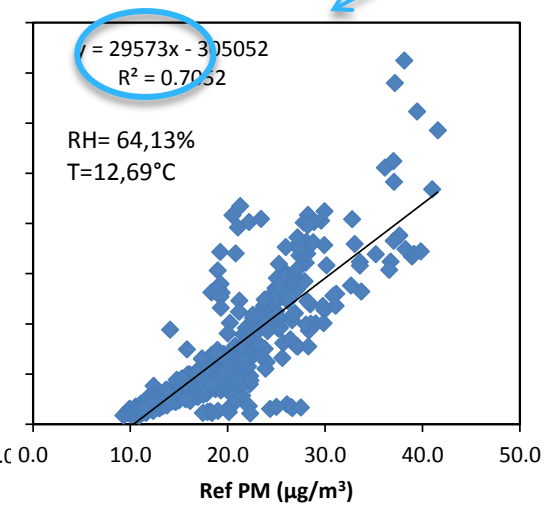
Comparison with reference

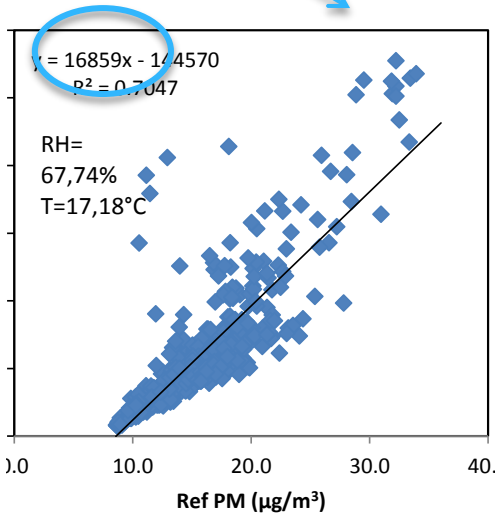










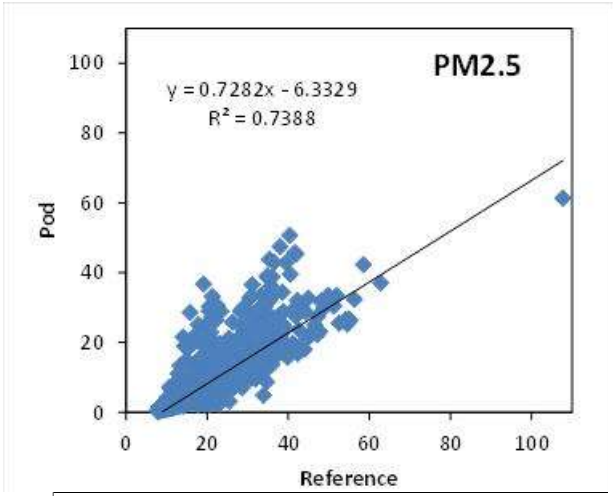


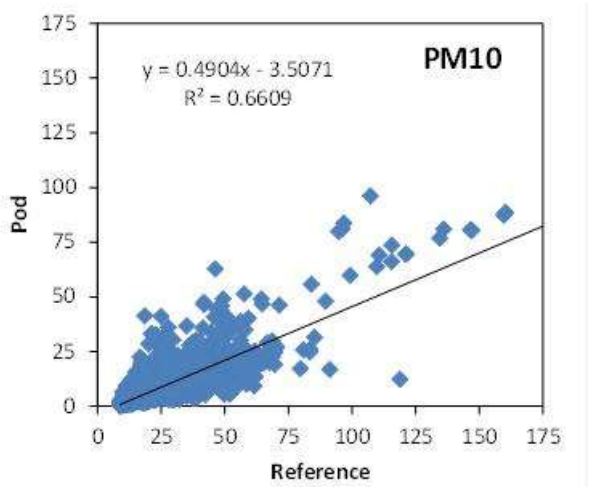
Pod (AQMesh): PM_1, $PM_{2.5}$ and PM_{10}

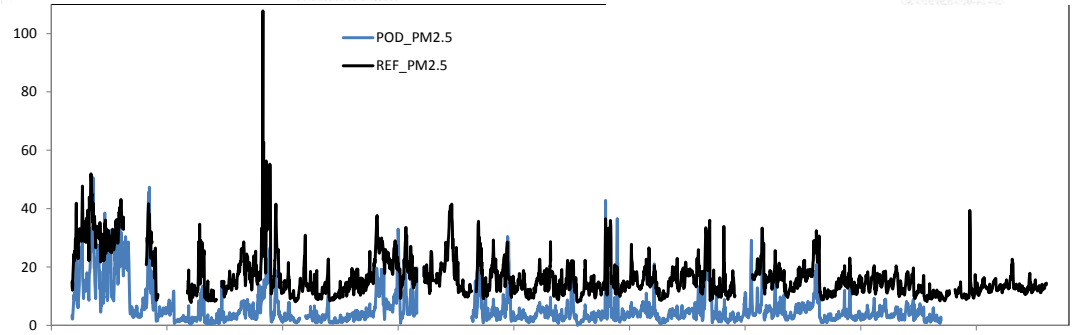
- Time res:
  1 min every 15 min
- Averaged to 1h

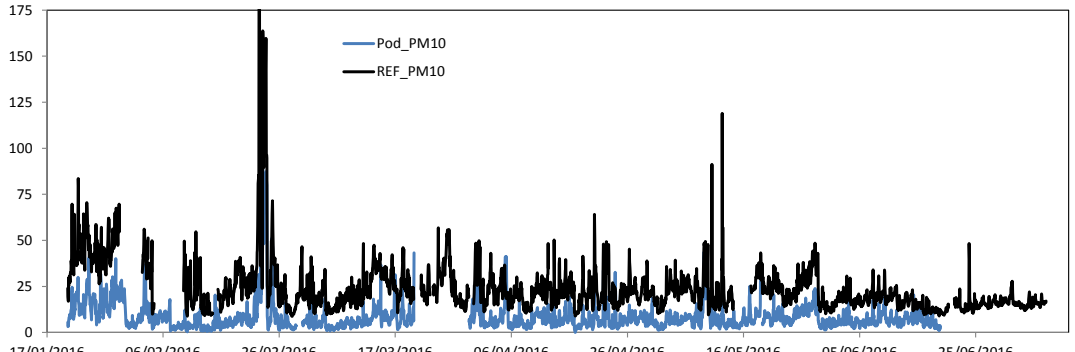
- 1 unit
- 5.5 months

Comparison with reference









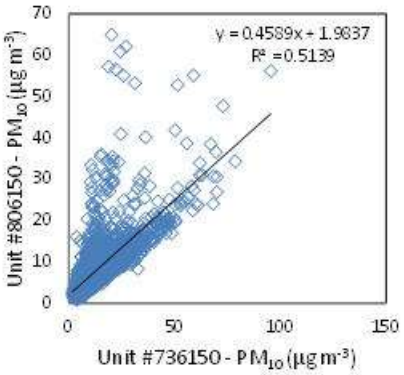
idaea CSIC CREAL

ary 2017

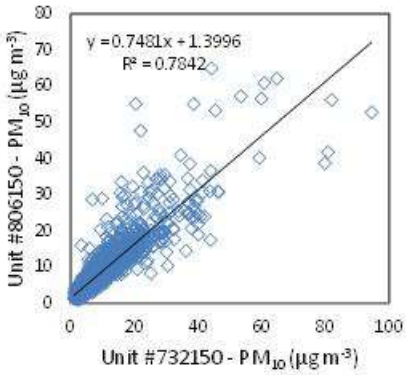
Pod (AQMesh): PM_1, $PM_{2.5}$ and PM_{10}

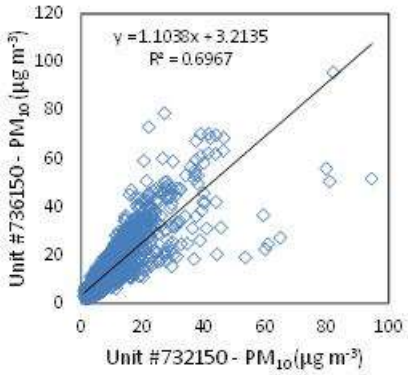
- Time res:
  1min every 15 min
- 3 units
- 1 month

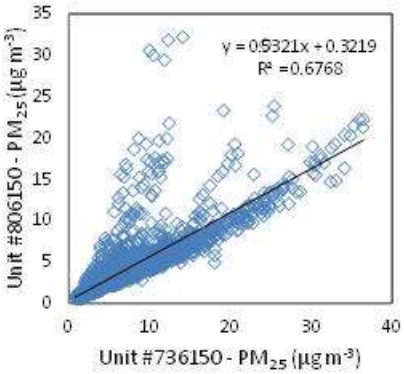
Inter instrument comparison



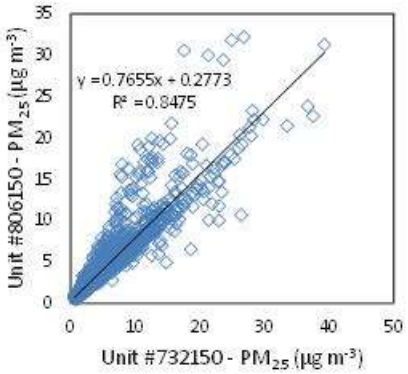
PM_{10}

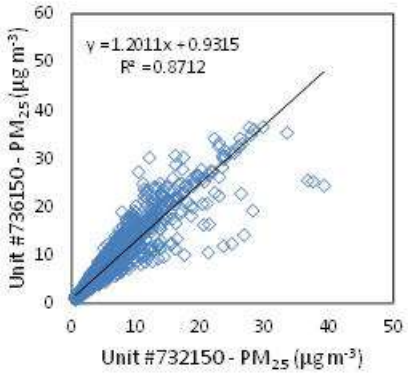


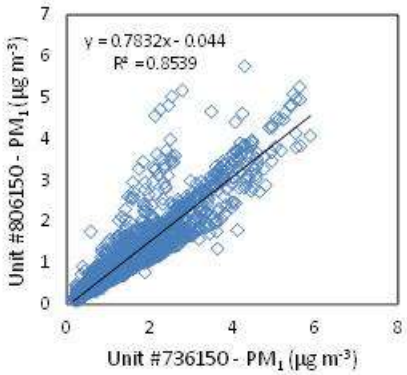




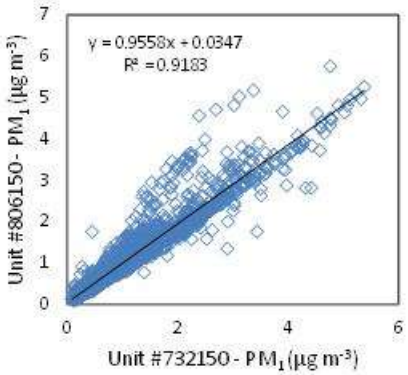
$PM_{2.5}$

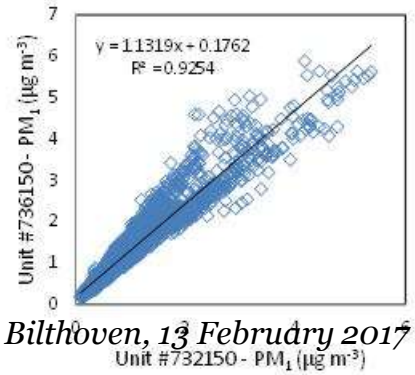






PM_1



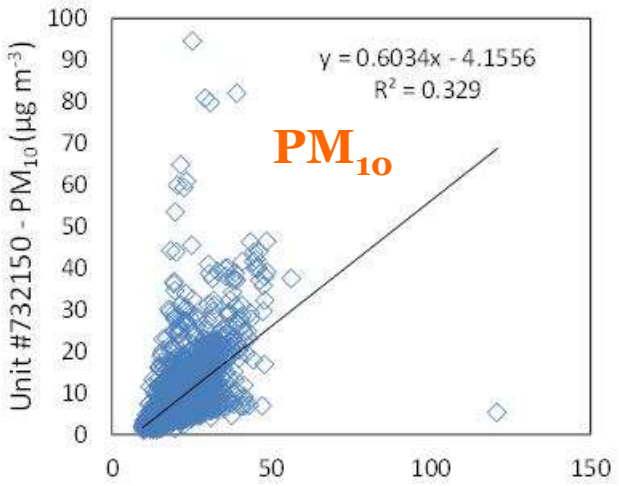


ZEROHUB NZEB, LCA & IEQ · Liquens Panell ambiental · idaea · CSIC

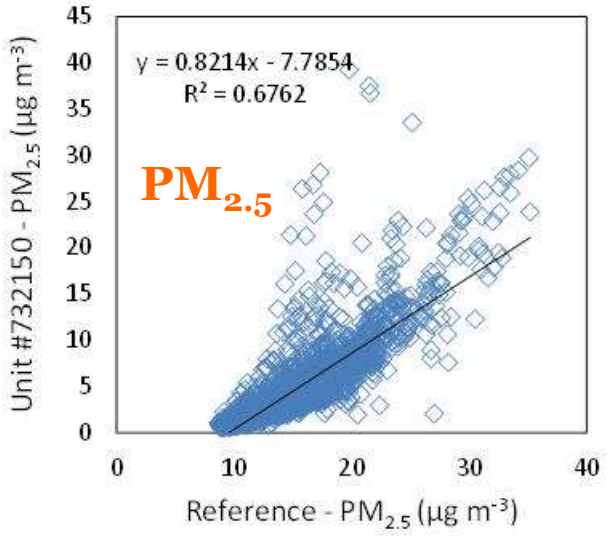
Pod (AQMesh): PM_1, $PM_{2.5}$ and PM_{10}

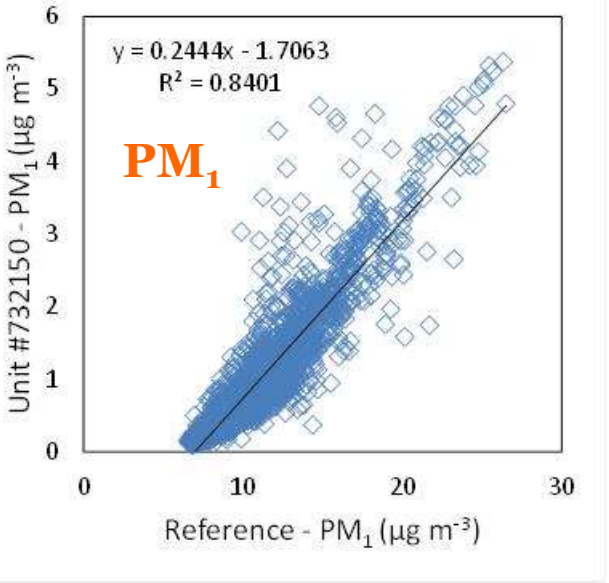
Comparison with reference

Matched to 5min reference average



- Time res:
  1min every 15 min
- 3 units
- 1 month





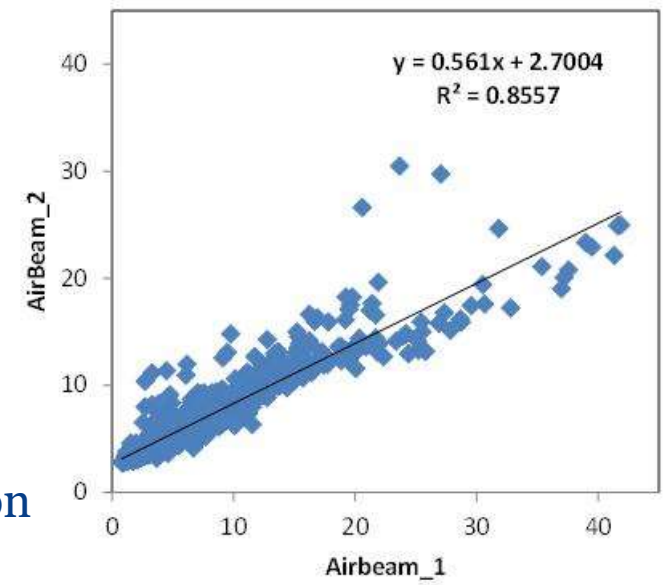
ZEROHUB NZEB, LCA & IEQ

Liquens Paneli ambiental

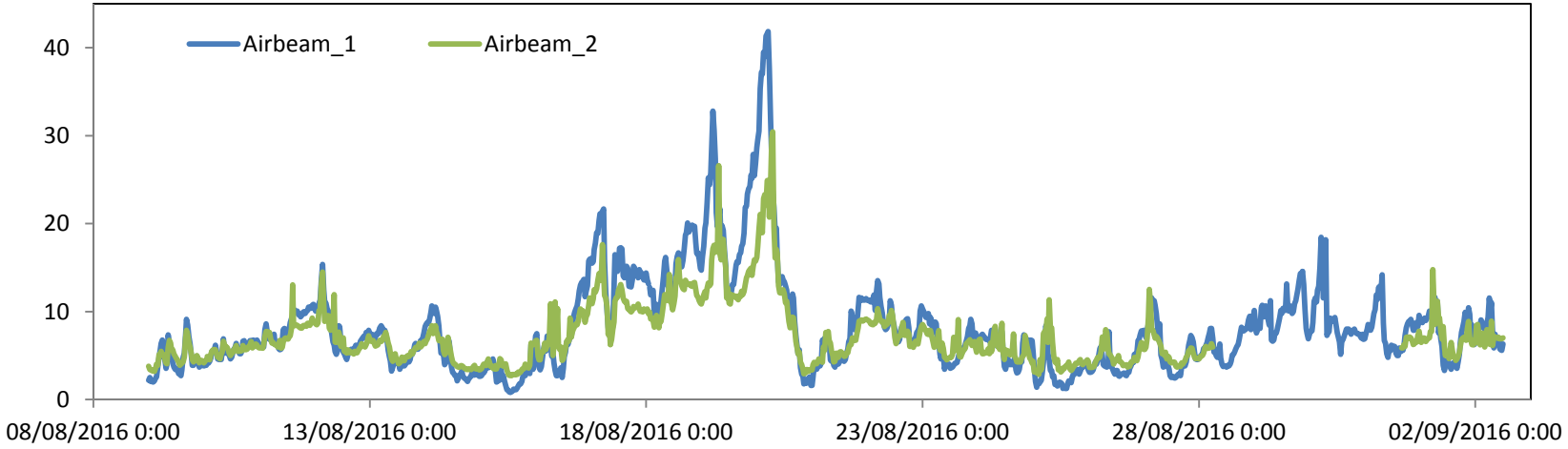
idaea CSIC

Airbeam: $PM_{2.5}$

- PM2.5
- Time res: 5min
- Averaged to 30min
- 1 month

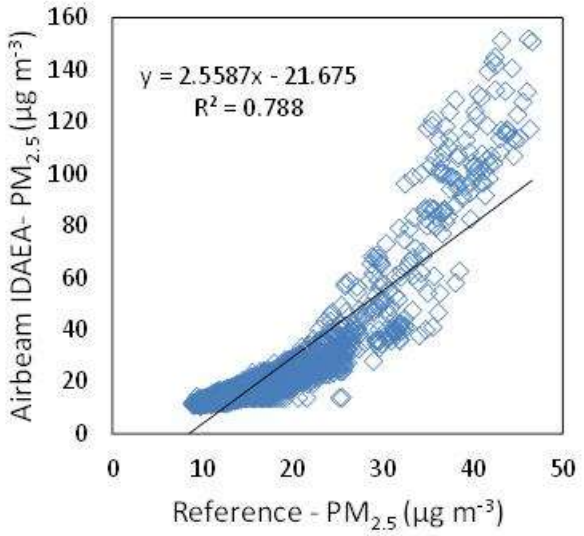


Inter instrument comparison

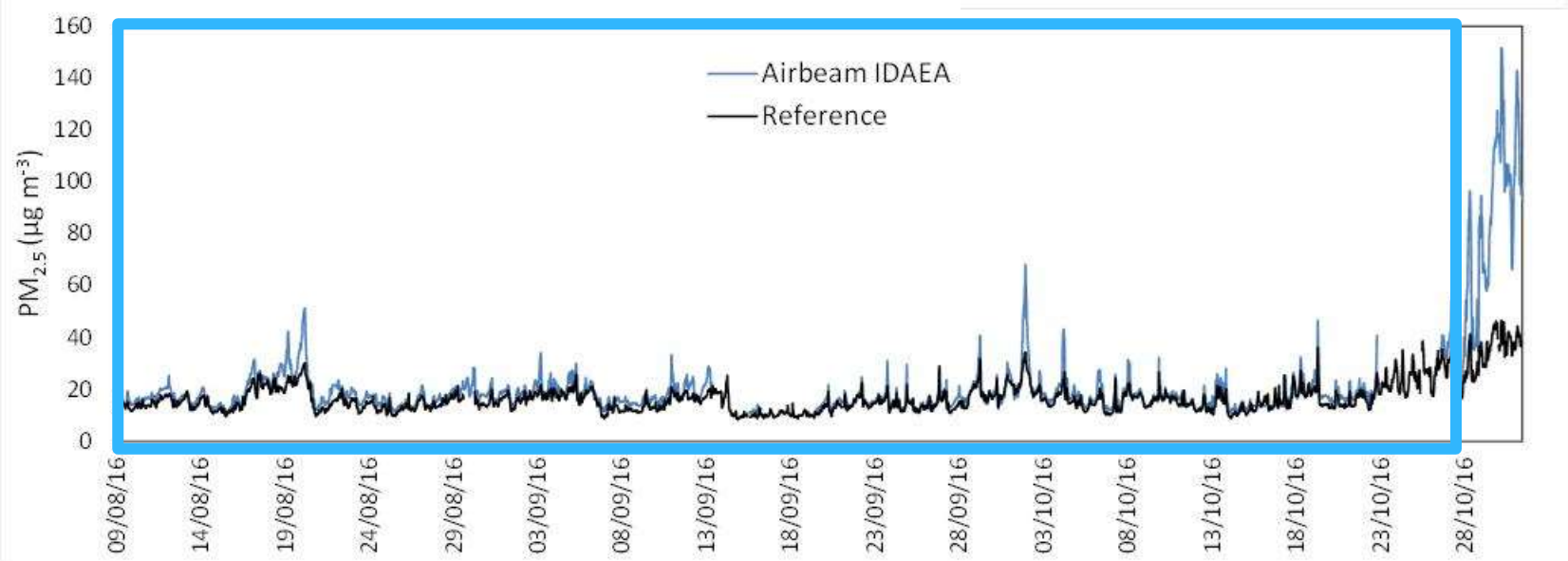


Airbeam: $PM_{2.5}$

- PM2.5
- Time res: 5min
- Averaged to 30min
- 3 months



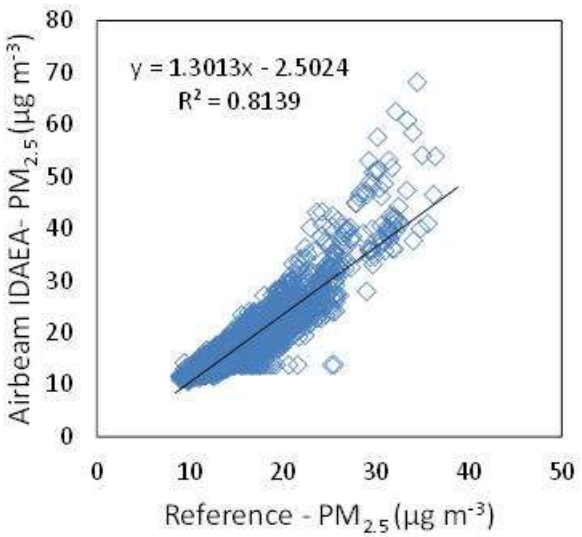
Comparison with reference

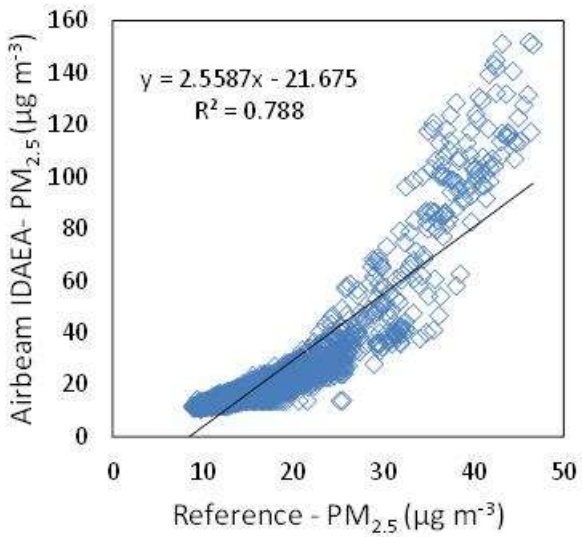


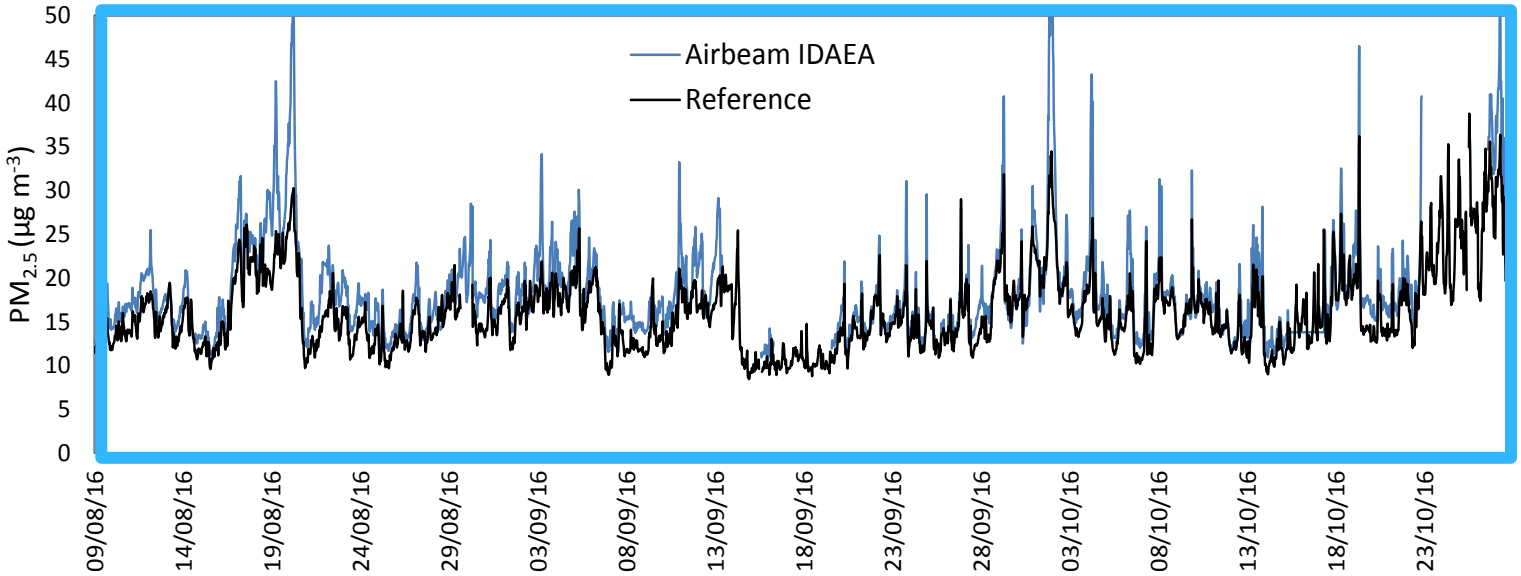
Airbeam: P

- PM
- Ti
- Av
- 3

Con







idaea CSIC Fundación BBVA

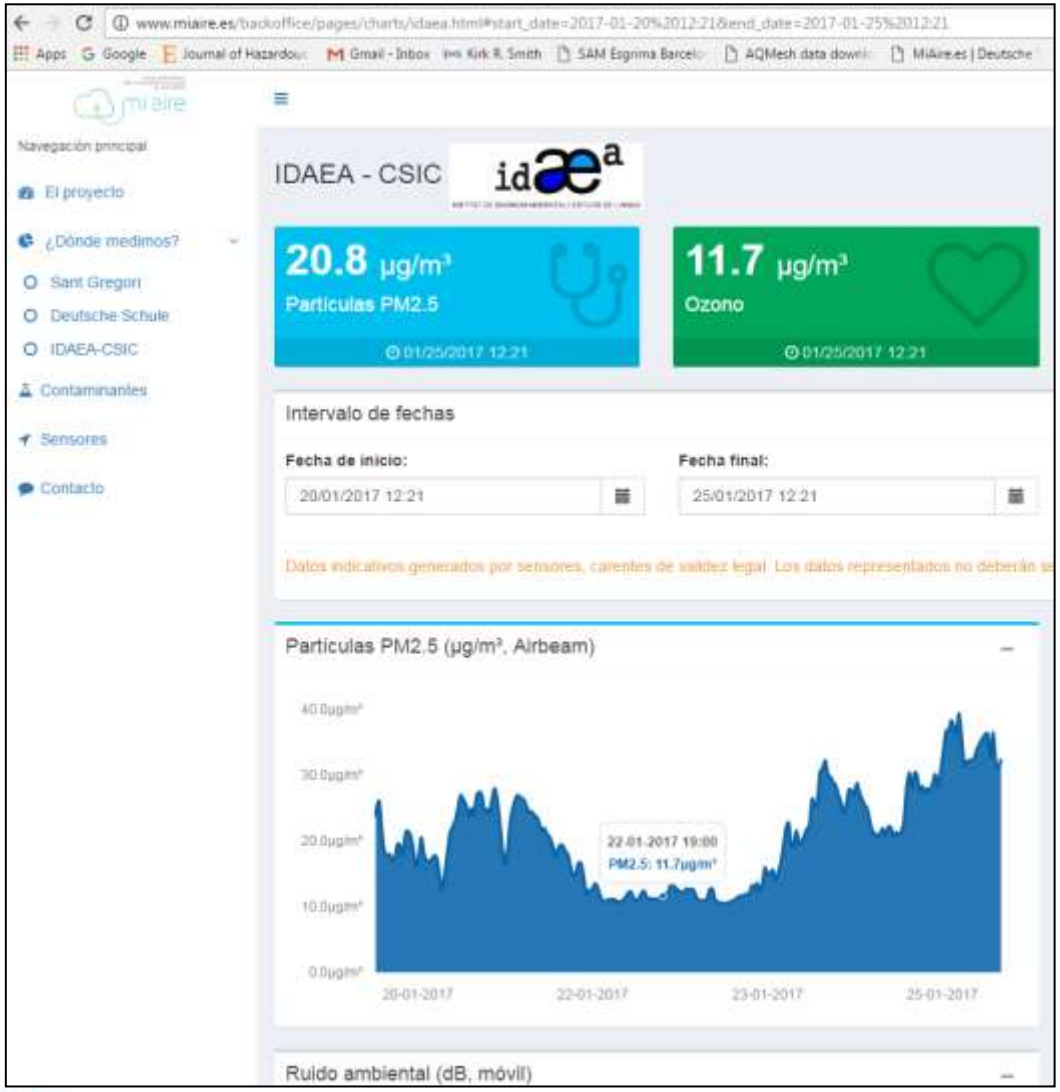
Bilthoven, 13 February 2017

Airbeam: $PM_{2.5}$

Application:

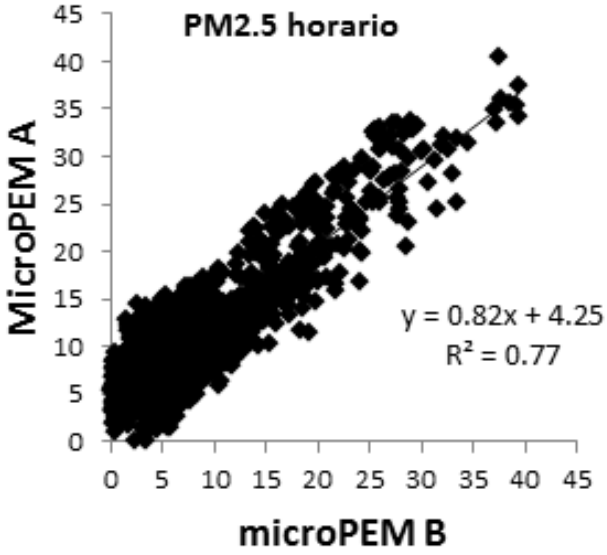
Awareness raising,

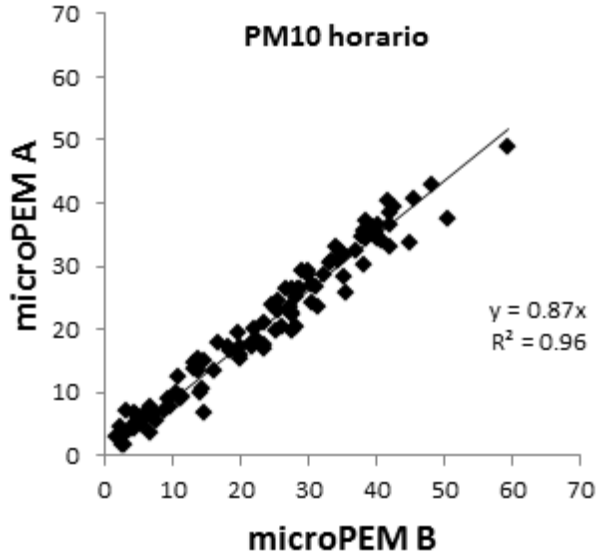
teaching in schools



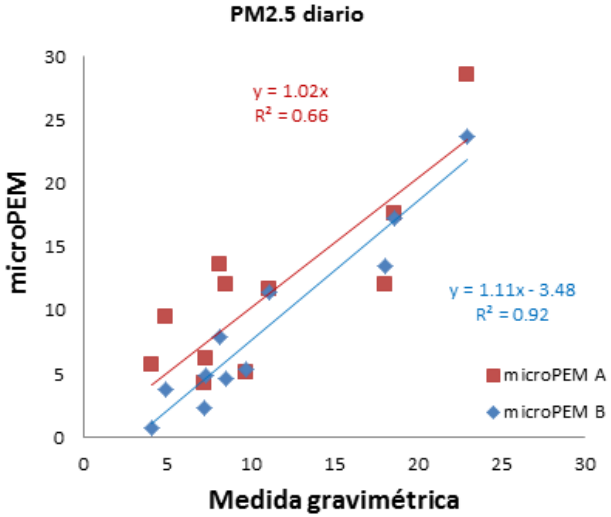
MicroPEM: $N_{<2.5}$ or $N_{<10}$

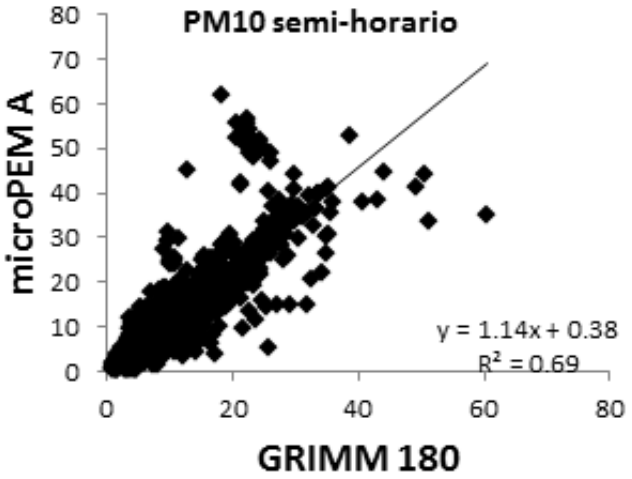
Inter instrument comparison



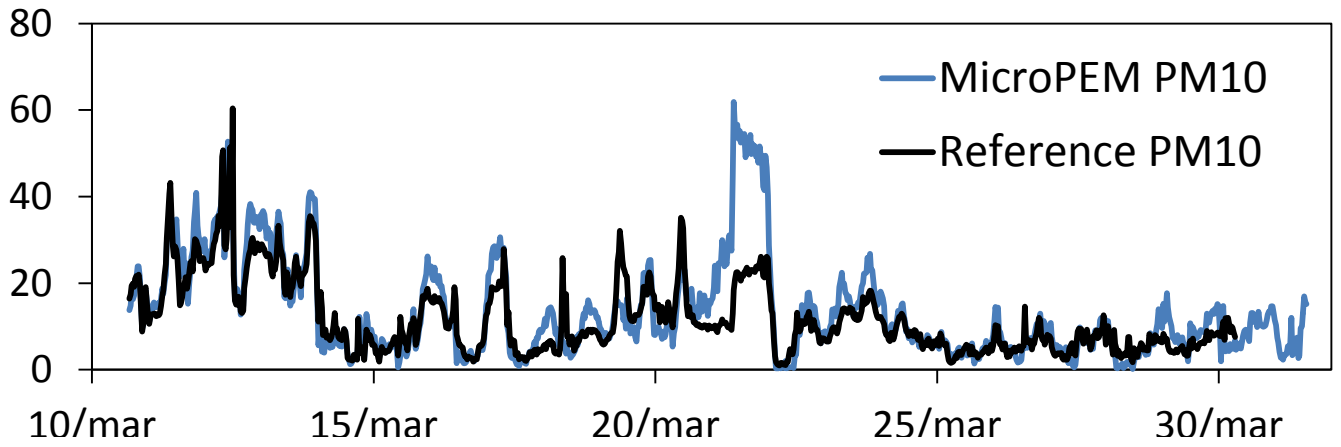


MicroPEM: $N_{<2.5}$ or $N_{<10}$





Comparison with reference



Intercomparison exercise

- 15 participating teams
- 130 microsensors
- 27 working sensors

1st EuNetAir Air Quality Joint Intercomparison Exercise
Aveiro (Portugal)

13-27 October 2014

Atmospheric Environment 147 (2016) 246–263

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

Assessment of air quality microsensors versus reference methods: The EuNetAir joint exercise

C. Borrego [a, b], A.M. Costa [a], J. Ginja [a, *], M. Amorim [a], M. Coutinho [a], K. Karatzas [c], Th. Sioumis [c], N. Katsifarakis [c], K. Konstantinidis [c], S. De Vito [d], E. Esposito [d], P. Smith [e], N. André [f], P. Gérard [f], L.A. Francis [f], N. Castell [g], P. Schneider [g], M. Viana [h], M.C. Minguillón [h], W. Reimringer [i], R.P. Otjes [j], O. von Sicard [k], R. Pohle [k], B. Elen [l], D. Suriano [m], V. Pfister [m], M. Prato [m], S. Dipinto [m], M. Penza [m]

[a] IDAD – Institute of Environment and Development, Campus Universitário, 3810-193 Aveiro, Portugal
[b] CESAM, Department of Environment and Planning, University of Aveiro, 3810-193 Aveiro, Portugal
[c] Department of Mechanical Engineering, Aristotle University, 54124 Thessaloniki, Greece
[d] Smart Networks and Photovoltaic Division, ENEA, C.R. Portici, 80055 Portici, NA, Italy
[e] Department of Chemistry, University of Cambridge, UK
[f] Institute of Information and Communication Technologies, Université Catholique de Louvain, Belgium
[g] NILU Norwegian Institute for Air Research, Instituttveien 18, 2027 Kjeller, Norway
[h] IDAEA-CSIC, Spanish Research Council, Jordi Girona 18, 08034 Barcelona, Spain
[i] 3S – Sensors, Signal Processing, Systems GmbH, 66121 Saarbruecken, Germany
[j] ECN – Energy Research Center of the Netherlands, Petten, Netherlands
[k] Siemens AG, Corporate Technology, Germany
[l] VITO – Vlaamse Instelling voor Technologisch Onderzoek, Mol, Belgium
[m] ENEA, Laboratory of Functional Materials and Technologies for Sustainable Applications, 72100 Brindisi, Italy

IDAD-Institute of Environment and Development Air Quality Mobile Laboratory

Measured parameters:

- CO, NO_x, O_3, SO_2,
- PM_{10}, $PM_{2.5}$,
- temperature, relative humidity

Bilthoven, 13 February 2017

Conclusions

- Some nodes provide satisfactory or acceptable results
- Usually good agreement between different nodes of the same type
- Changes over time: required frequent validation with reference instrumentation
- Influence of temperature for gaseous pollutants measurements
- Optical particle counters valid as proxy for fine particles (<2.5 µm)
- Most particle nodes not adapted for outdoor deployment
- More tests and improvement of technology and data processing required
- The possibility to use sensors for air quality assessment can be a fact provided some improvements and validations are applied

Thank you for your attention

mariacruz.minguillon@idaea.csic.es

Acknowledgements

Anna Ripoll, Marc Padrosa, Francesco Miacola, Giorgos Spais