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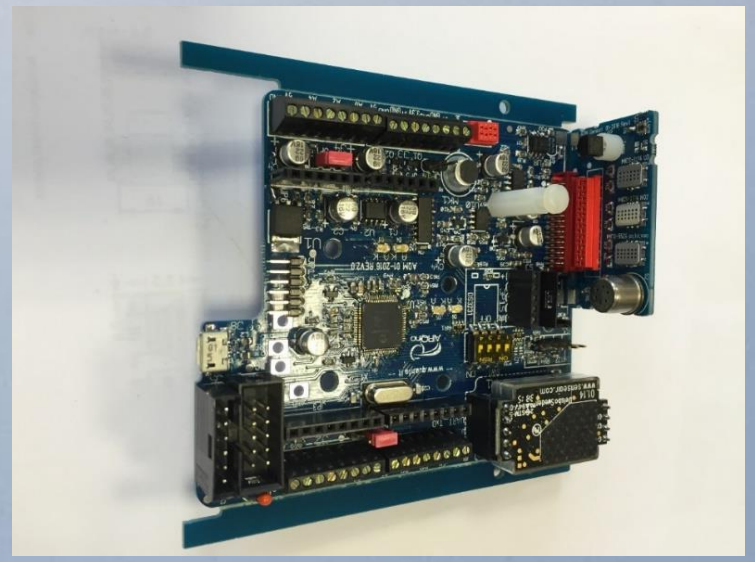
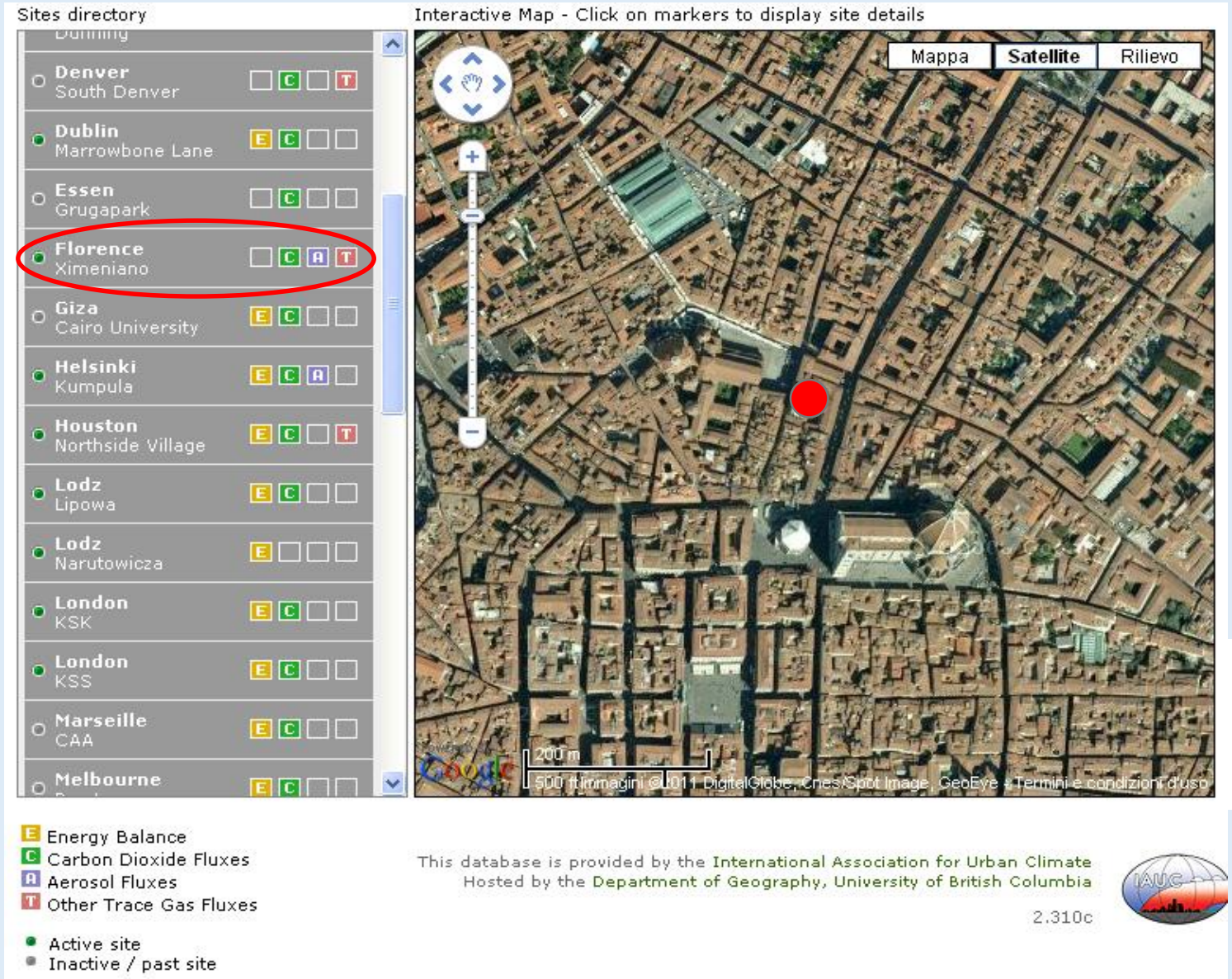
Low-cost sensors and Big-Data for environmental monitoring



Beniamino Gioli
CNR IBIMET

1. Background: urban flux measurements



URBAN FLUX NETWORK

EGU 2013, Session ERE 5.1: Measurement of Greenhouse Gases at the Urban Scale

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2. Eddy covariance flux measurements

Metek sonic (CO_2, H_2O, CH_4)

Li7500 (CO_2, H_2O)

Li7700 (CH_4)

Gill sonic (particles)

EOLO particles inlet

EOLO:

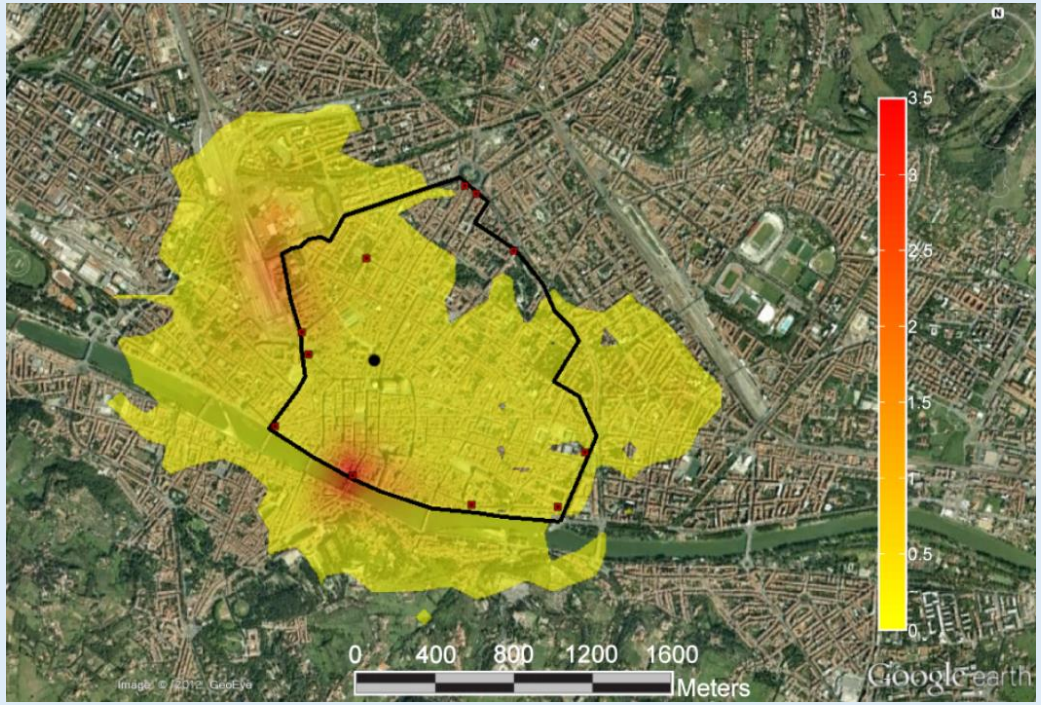
0.32 – 7.00 µm optical diameter particle counter 10Hz, 14 size bins

(*Fratini et al, 2009*)

2. Eddy covariance flux measurements

Footprint area :

> 90% urbanized land



Corrections for:

- *Sensor separation*
- *Spectral loss*
- *Storage (1-point)*

Measurement periods:

- CO_2: Long-term**, 2005 – ongoing**
- CH_4: Short-term **6 months 2011**
- PM: Short-term **6 months 2011**

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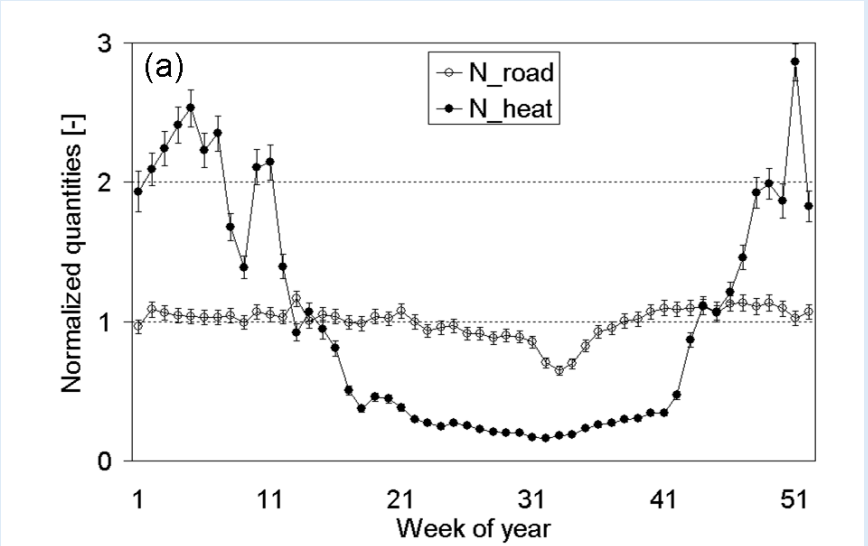
Anthropogenic drivers of CO_2 & CH_4 fluxes

Flux source partition:

CO_2 ← Road traffic
← Domestic heating

Partition factors derived from emission factors and inventorial (normalized) proxies (road traffic amounts & gas network flow-rates) trough multi-regressive approach.

Road traffic → 32%
Domestic heating → 68%



(Gioli et al 2012)

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Anthropogenic drivers of CO_2 & CH_4 fluxes

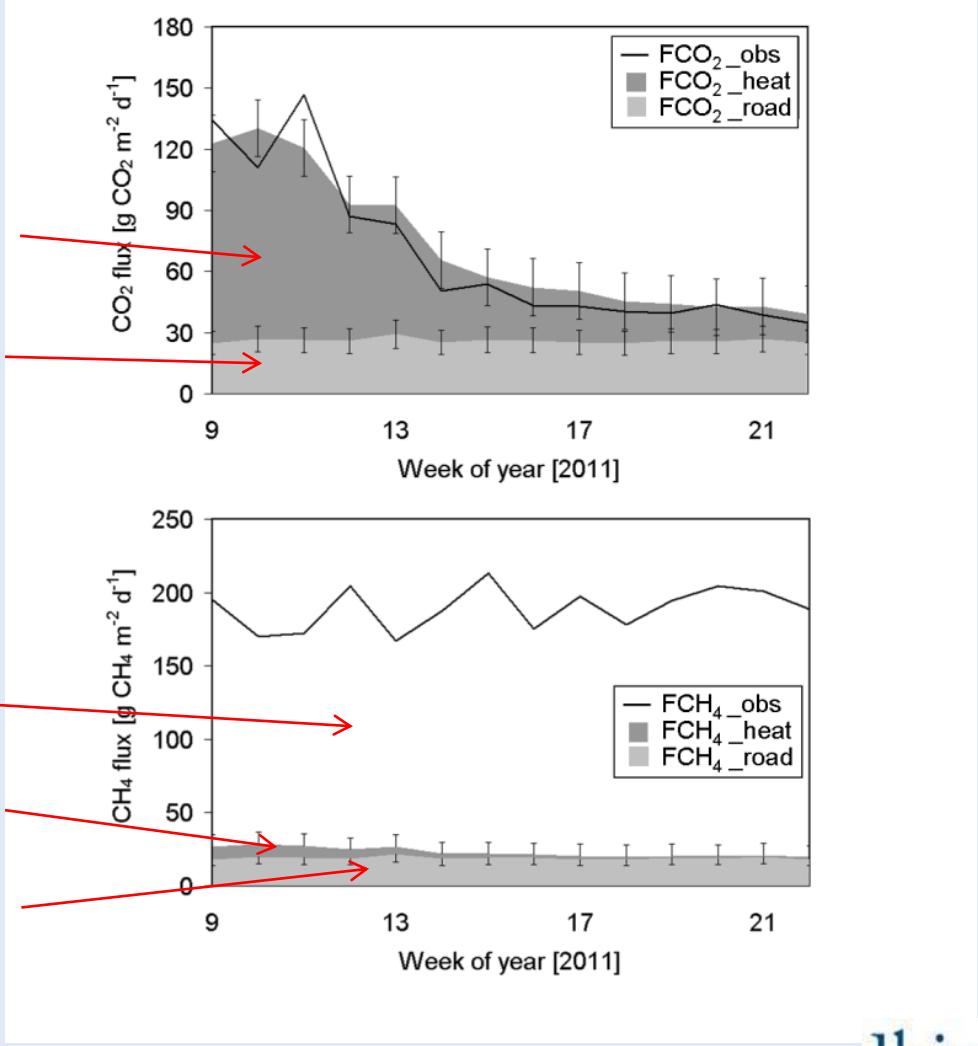
Flux source partition

CO_2

- Domestic heating
- Road traffic

CH_4

- gas network leakage
- Domestic heating
- Road traffic



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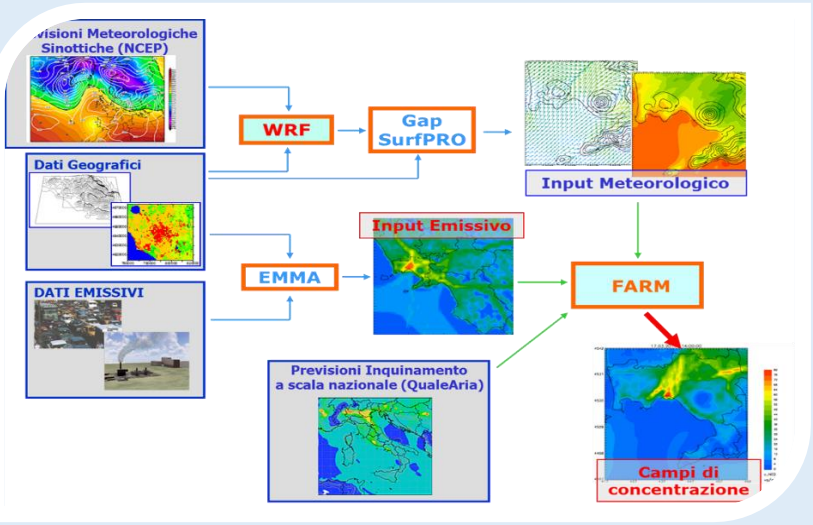
Background: Progetto AriaSana (2013-2015)

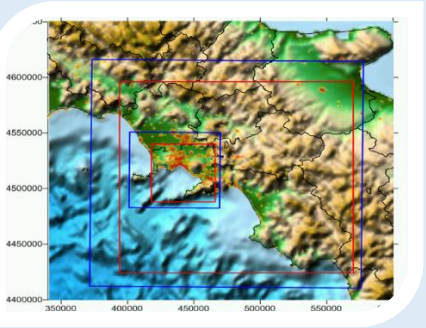
Osservatorio Regionale della Qualità dell'Aria

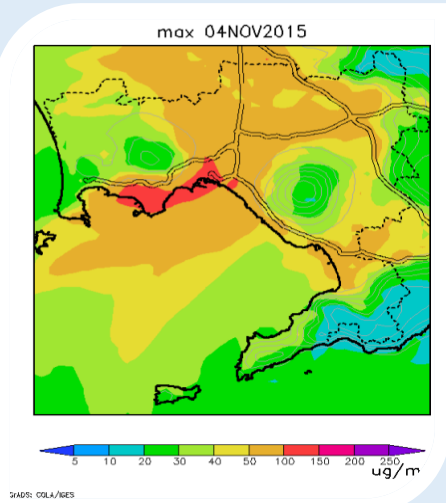
www.ariasana.org
ariasana@isafom.cnr.it

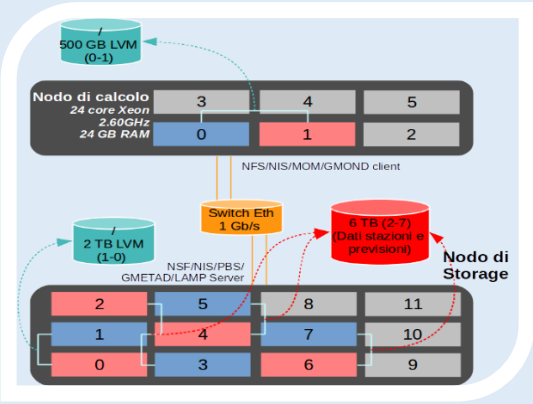
investiamo nel vostro futuro

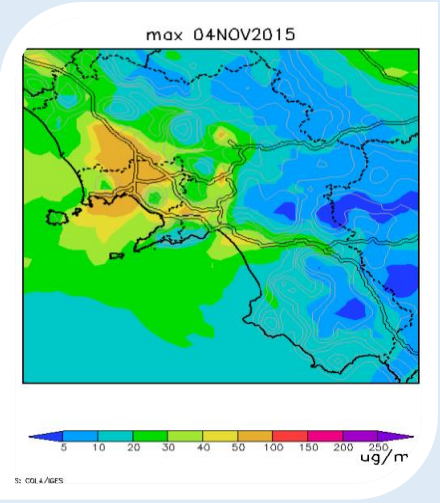
Modellistica: WRF – FARM operational chain



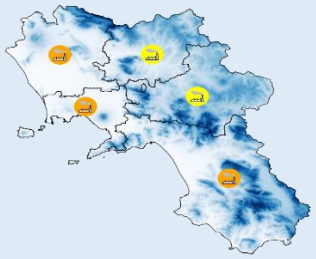


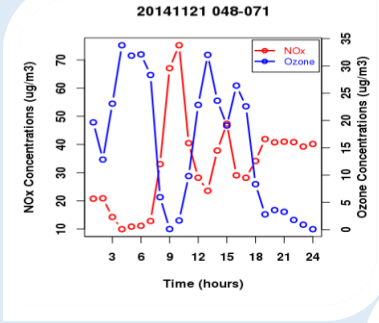


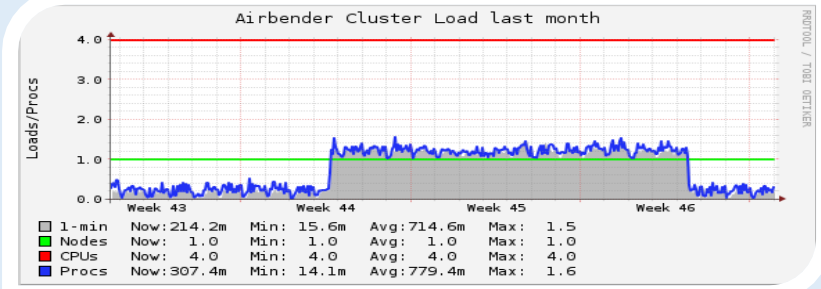


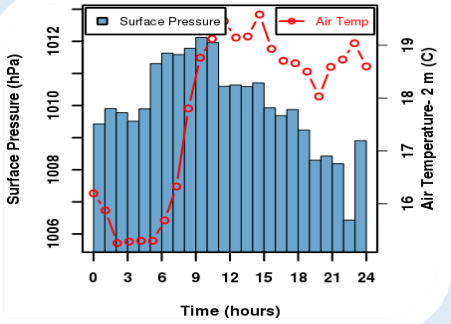


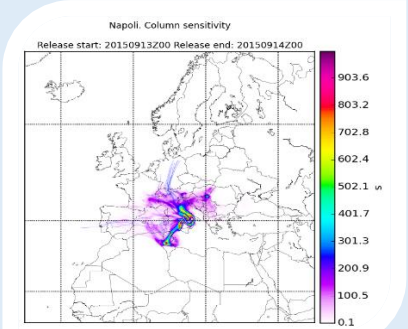
Valore IQA	Cromatismo	Giudizio sintetico
0 – 50		Ottimo
50 – 70		Buono
70 – 100		Accettabile
100 – 150		Mediocre
150 – 200		Scadente
> 200		Pessimo

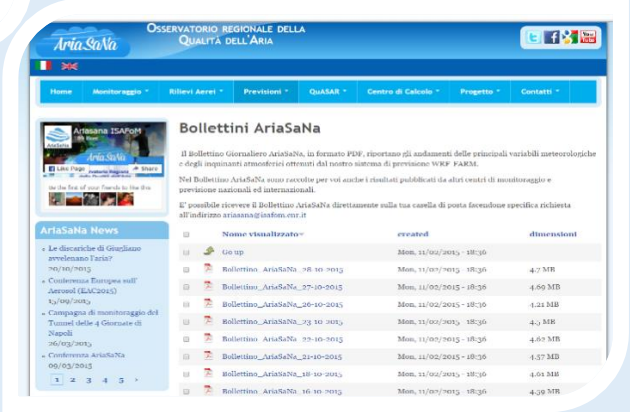












BIGDATACHALLENGE2015

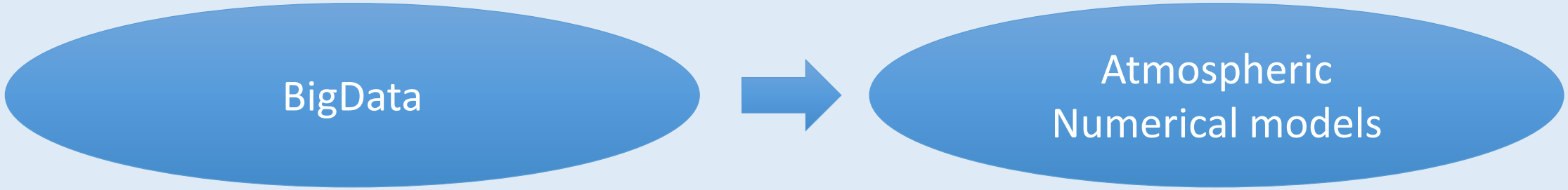
BigAir

BigData driving next generation of Air quality numerical models

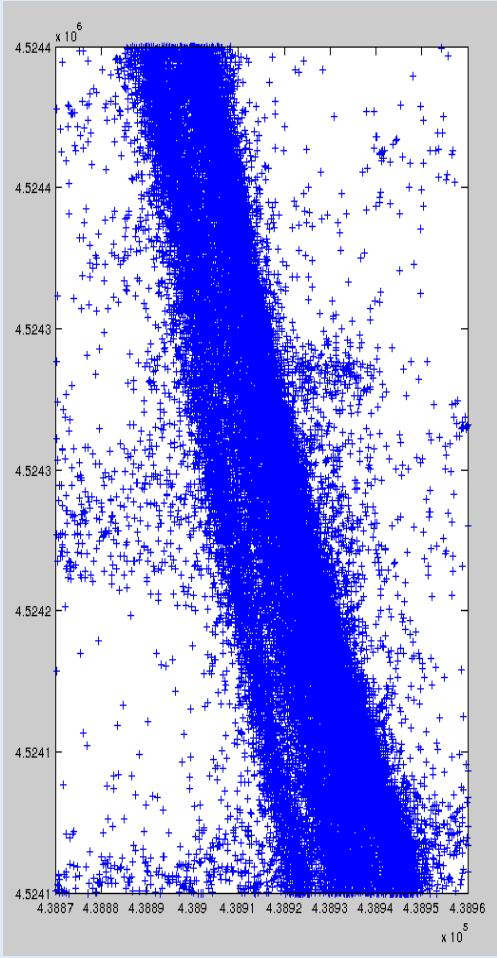
Goals

- 1. To develop an air quality modelling framework based on TIM BigData as estimators of:
  - **Road traffic amounts** at model grid-cell (1 km)
  - **People presence** at model grid-cell (1 km)

- 2. To **quantify** how this framework improves current state-of-the-art based on *inventorial data*



Cellular phones Big Data



•Floating Car Data have been assessed in terms of spatial accuracy by overimposing on the road network, and in terms of representativeness by comparing them with traffic counters available at selected locations:

•<u>Example: Corso Malta</u>

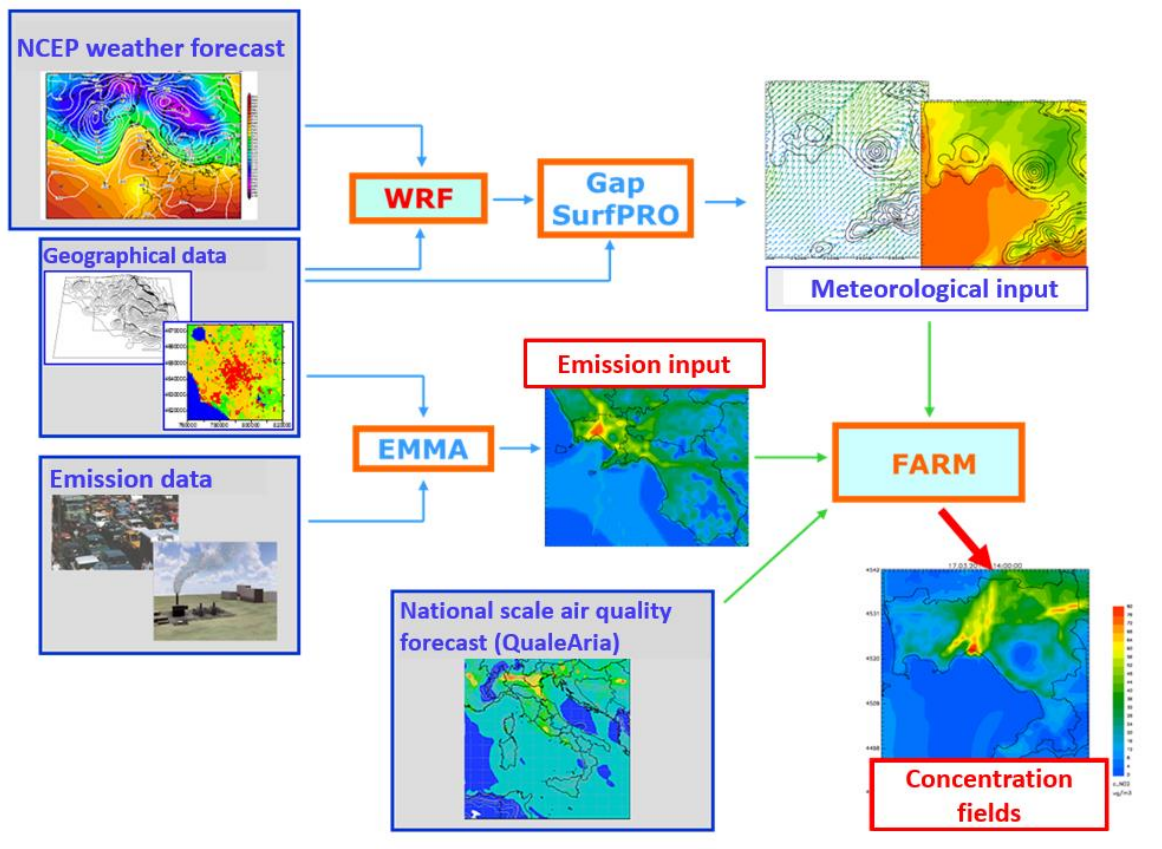
•- 38140 BigData points in 61 days (~600/day) both directions

•- Traffic counter: ~40k points/day south-bound

•- BigData representativeness: ~0.75%of total traffic

Air quality modelling framework

•State-of-the-art approach to develop air quality forecast framework is based on the coupling of atmospheric models and air quality models:

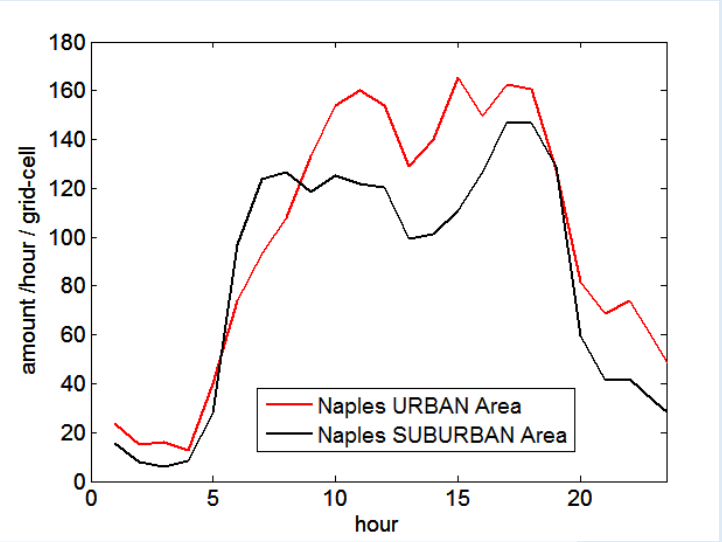


- **Atmospheric models (WRF)**: simulate atmospheric motion, at 15 min-temporal and 1 km-spatial resolutions

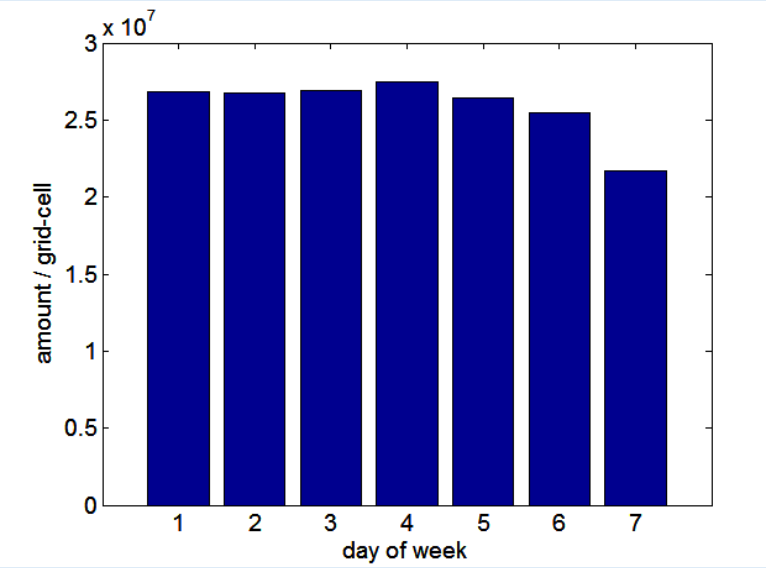
- **Air quality models (FARM)**: simulate chemical transformation of pollutants and their interaction with the atmosphere;

BigData can drive emission parameterization

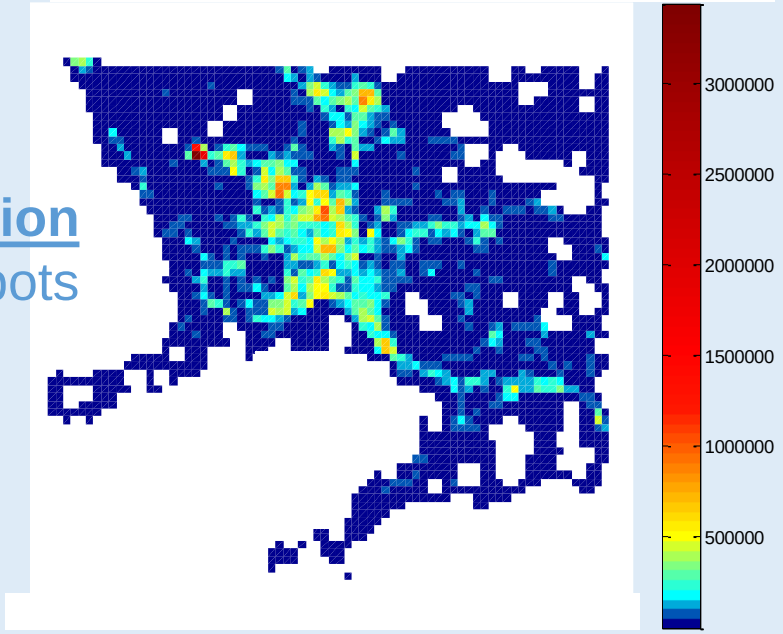
•1. Temporal modulation at **hourly time scale** → different citizens behaviours: morning peak delayed in central vs peripherical areas, evening peak less pronounced in central area



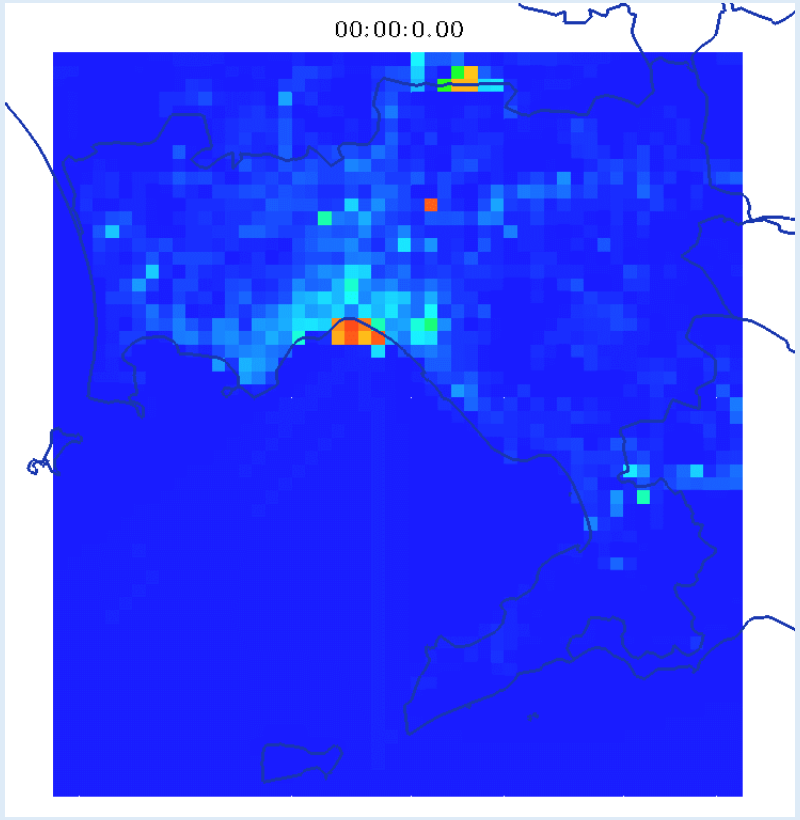
2. Temporal modulation at **daily scale** shows weekend reduction



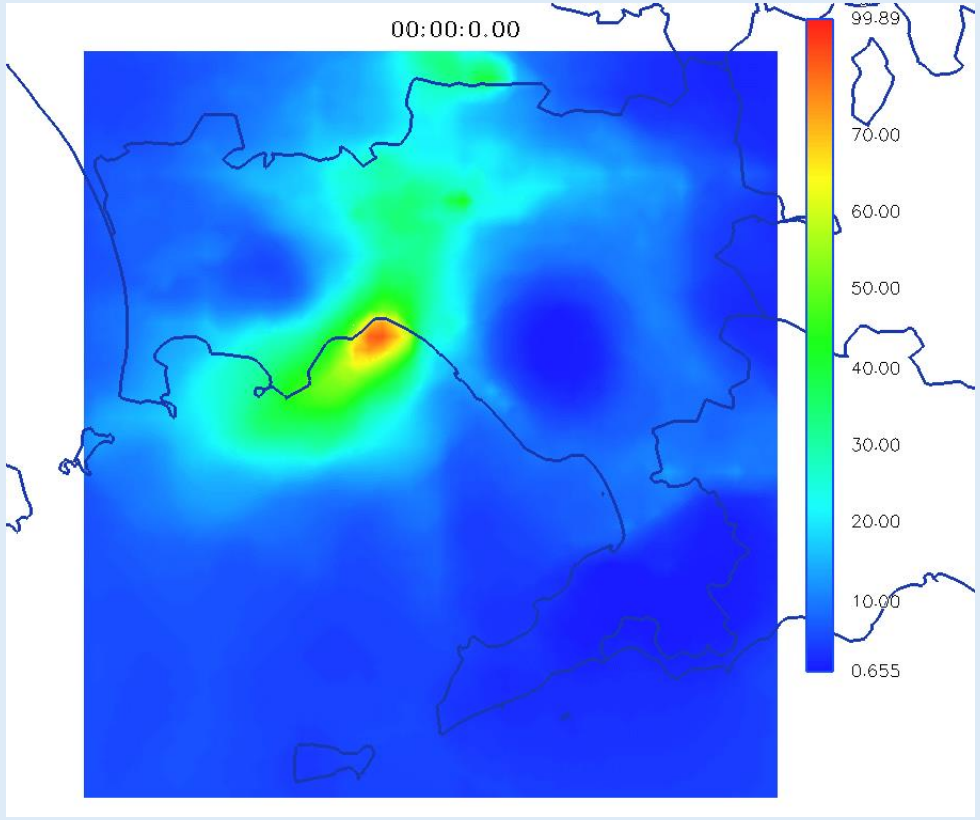
3. **Spatial modulation** reveals urban hot spots



Results:
Pollutants emission and concentation – Napoli Caserta



BigData road traffic emissions

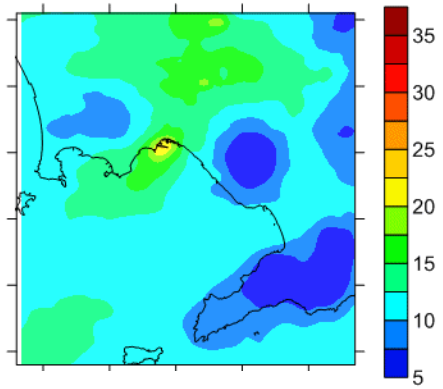


NO_2 concentration (µg/m³)

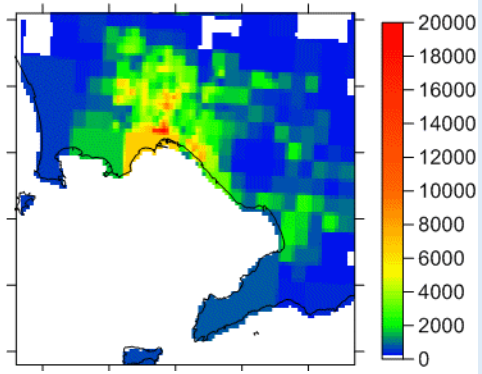
Exposure of citizens to pollution – Napoli Caserta

Exposure = Pollutant concentration **x** Population density

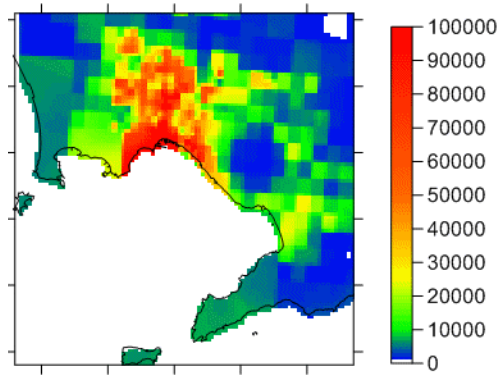
PM10 average concentration at 00:00 (ug/m3)



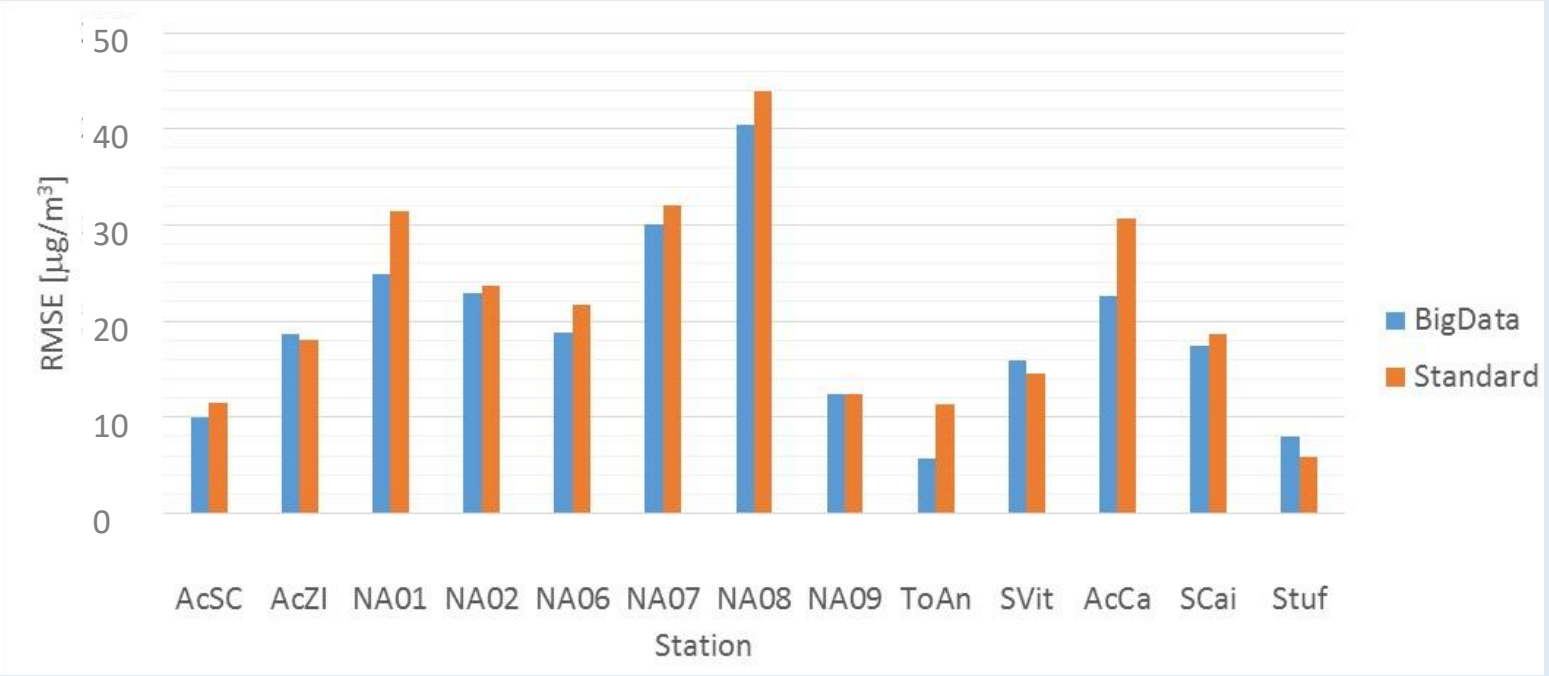
Average population at 00:00 (ug/m3)



Average exposure to PM10 at 00:00 (ug*p/m3)



With BigData model performance improves



Model error assessed against ARPAC air quality station network. With BigData:

- model error improves in 11 out of 14 stations (78%)
- error against air quality network improves from 103 to 92 μg/m^3 (10 %)

The result is significant since error includes meteorological model error, that is not controlled by BigData

Vision on next citizen observatories …..

- New type of BigData: air quality at your smartphone, measured by citizens

Presence

Road Traffic

Air quality!

- Current technology is not yet sufficiently miniaturized (see Airquino work at CNR)

citizens becoming actors: you know quality of air you're breathing…
and feed a large scale data assimilation system based on BigData

Airquino developed at CNR since 2013

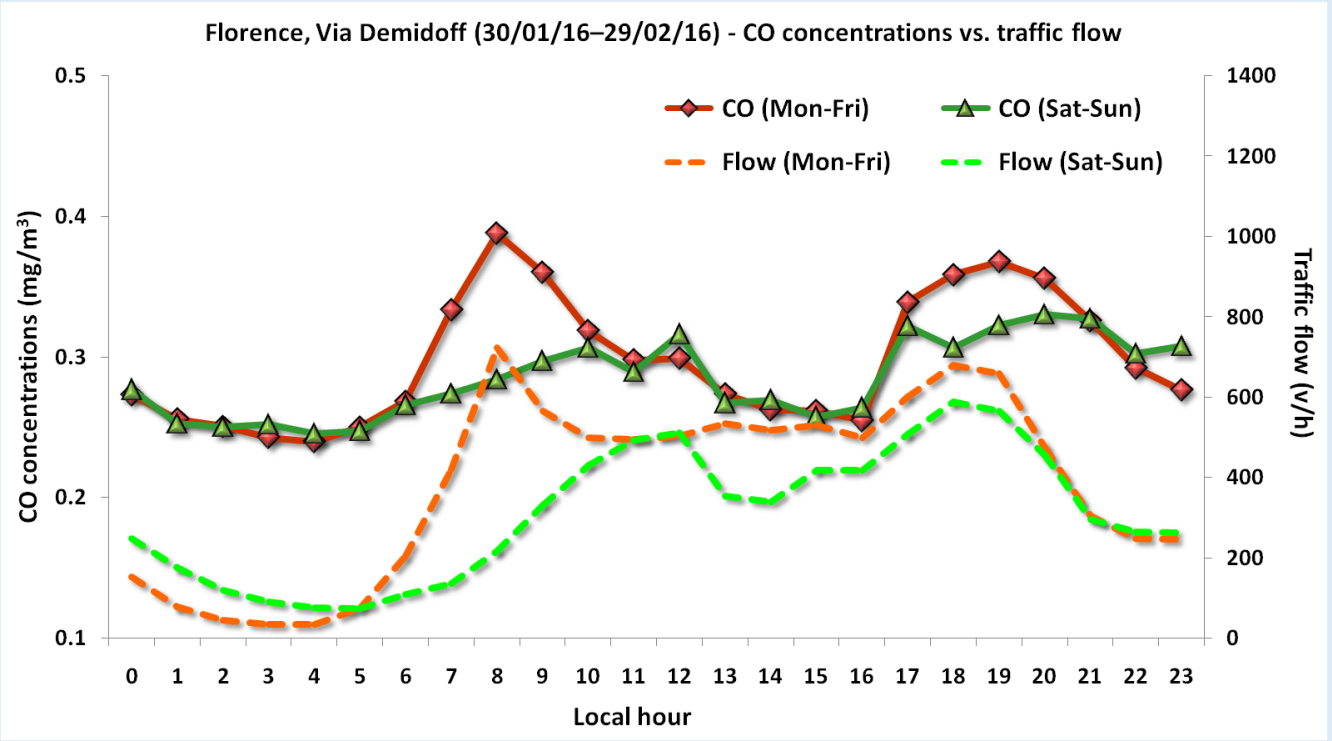
- Developed with the “Arduino” open source technology integrated with low cost sensors, for environmental and air quality monitoring, today running at:
- Firenze (Tram, Bus); Napoli (Bus, Bikes); Siracusa (Bikes, Totems); Bologna (Street lamps)

Parameter	Unit	Range
Temperature	°C	-40 – 80
Relative Umidity	%	0 – 100
Noise	dB	0 – 100
Road pavement quality	g	-5 – 5
CO_2	ppm	0 – 2000
O_3	ppb	0 – 400
NO_2	ppm	0.05 – 5
CO	ppm	1 – 30
CH_4	ppm	1 – 30
VOC	ppm	1 – 1000

http://ed2014.makerfairerome.eu/project/sensorwebike-292/

Maker Faire
THE EUROPEAN EDITION
SensorWeBike

ANALYSIS OF RESULTS: MEASURED AIR QUALITY

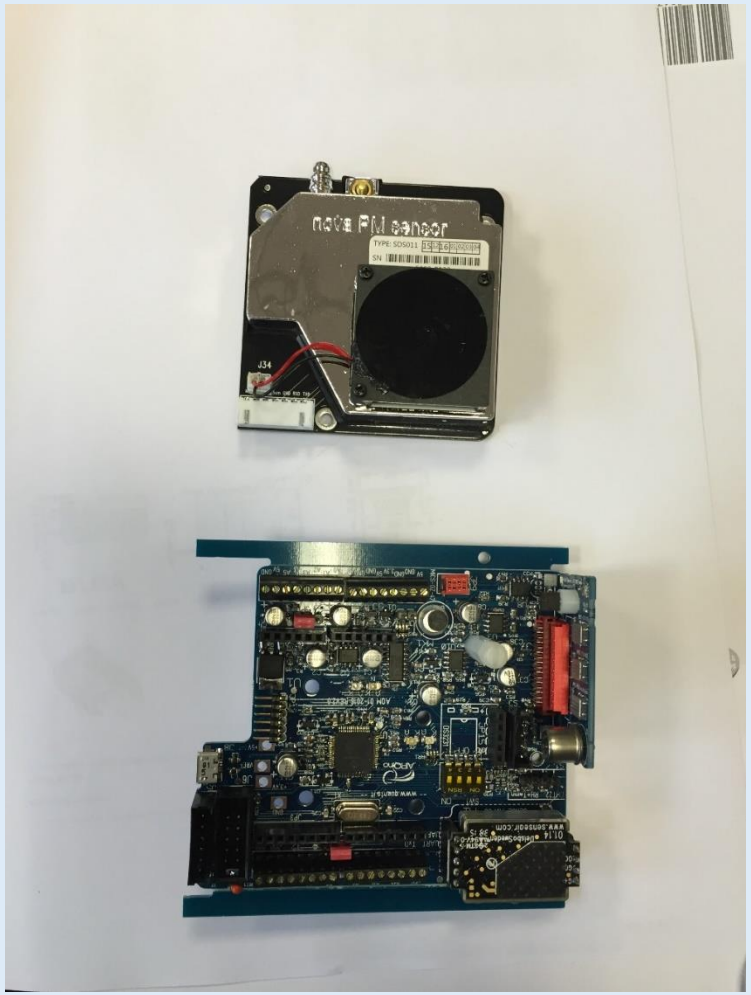


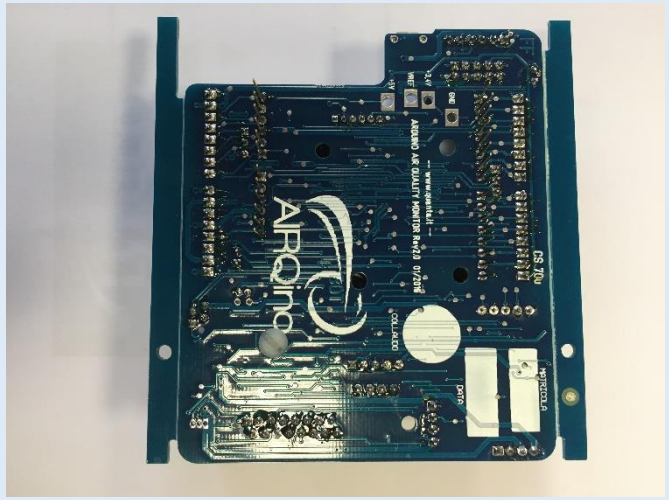
Mean concentrations:

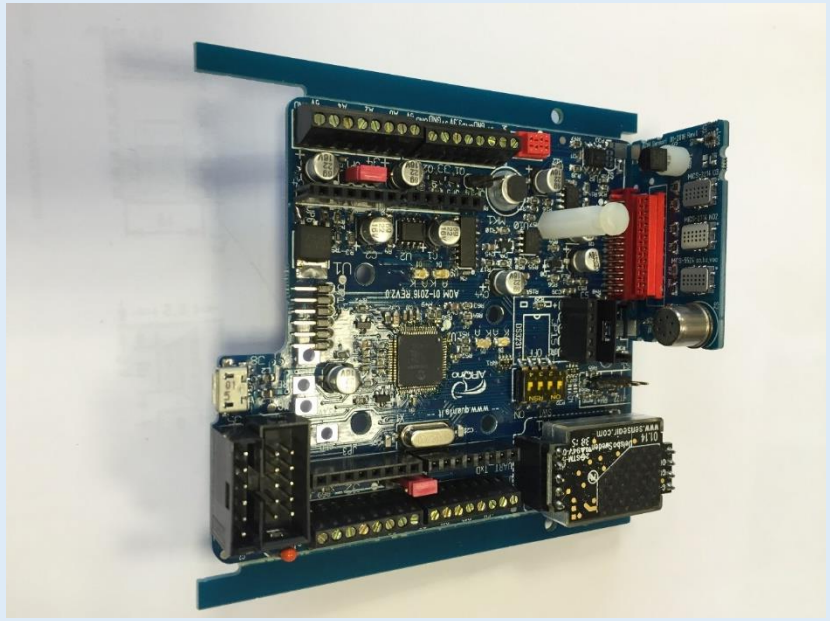
	CO (mg/m³)	NO_2 (µg/m³)	CO_2 (mg/m³)
Weekdays	0.30	49.4	809.9
Weekends	0.28	43.7	794.5
Overall	0.29	47.5	804.7

Gualtieri et al 2016

AIRQino 2.0 (2016)







Bando FAR-FAS 2014 Reg. Toscana

Progetto S.M.A.R.T

Sensori di Monitoraggio Ambientale per le Regione Toscana

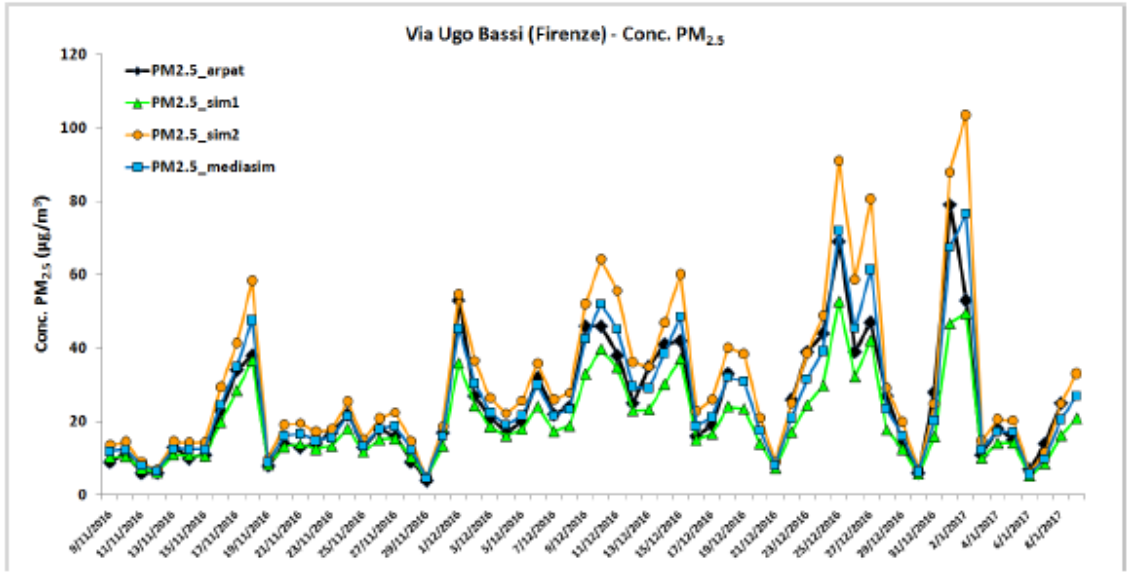
Obiettivo: sviluppo di prodotto di mercato

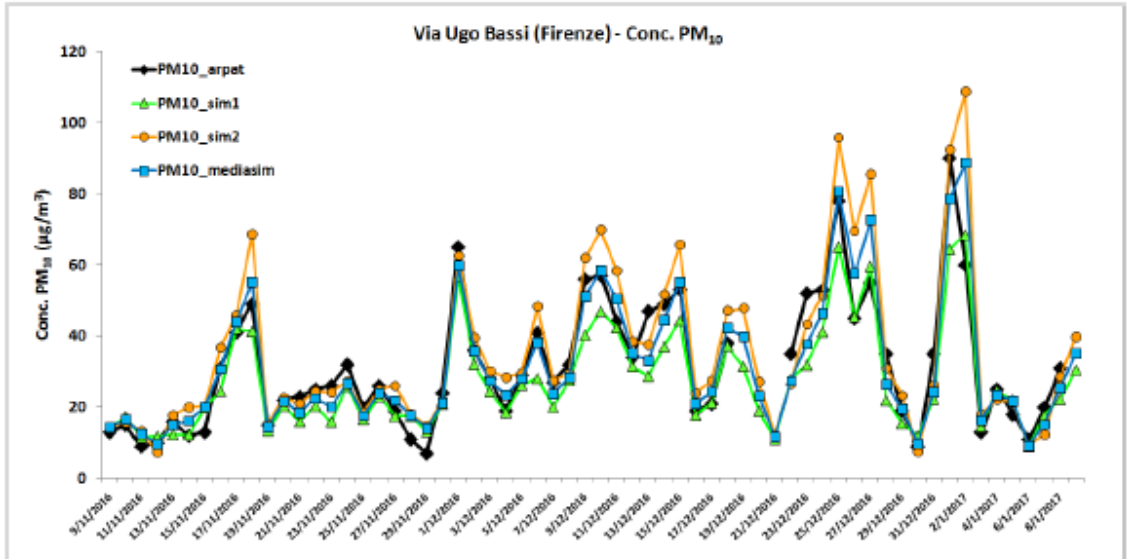
AIRQino 2.0

PM 2.5 and PM10
AIRQino vs ARPAT

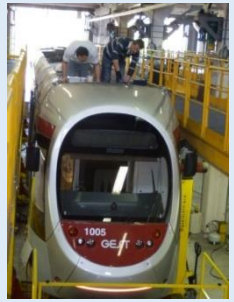
testing of two different inlet designs

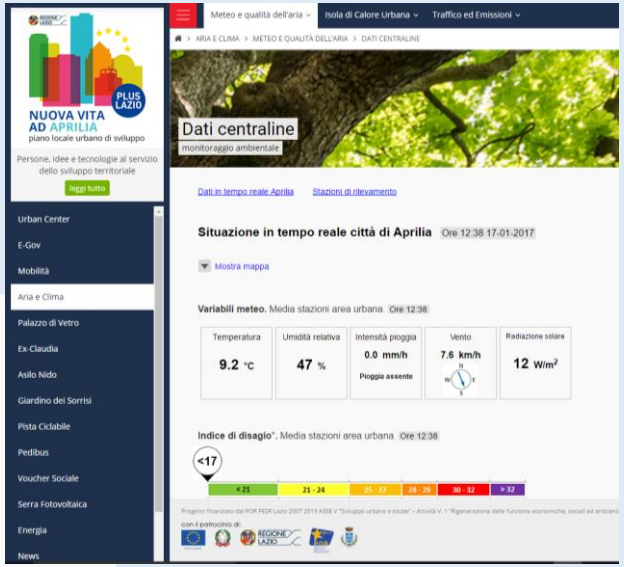
CONFRONTO SENSORWEB–ARPAT A VIA UGO BASSI
CONC. MEDIE GIORNALIERE DI $PM_{2.5}$ E PM_{10}
PERIODO: 09/011/2016–09/01/2017

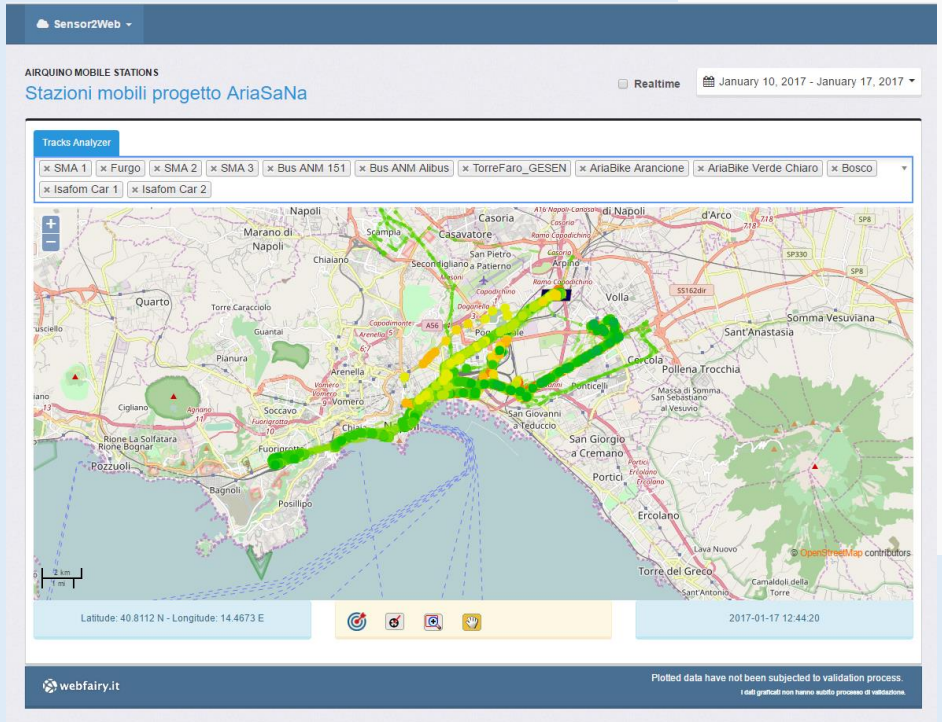




AIRQino Networks - Italy







Acknowledgments

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www.dispaa.unifi.it

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www.terrasystem.it

www.quanta.it