fugitive Particulate Matter (fPM)

Emissions Modelling and Impact Assessment in Arid and Semi-arid Regions

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Outline

Motivation:
What/Why we (don't) know and **What** we are looking for

Methodology:
What are the tools for measuring, modelling, validation and **how** they were implemented

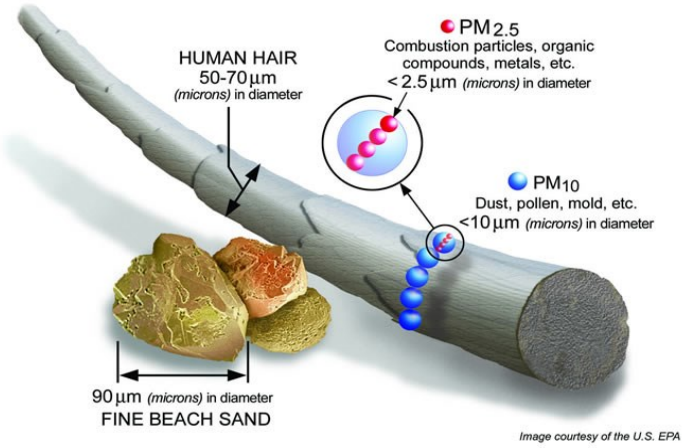
Results:
Modelling of **emissions** and preliminary **impact** assessment

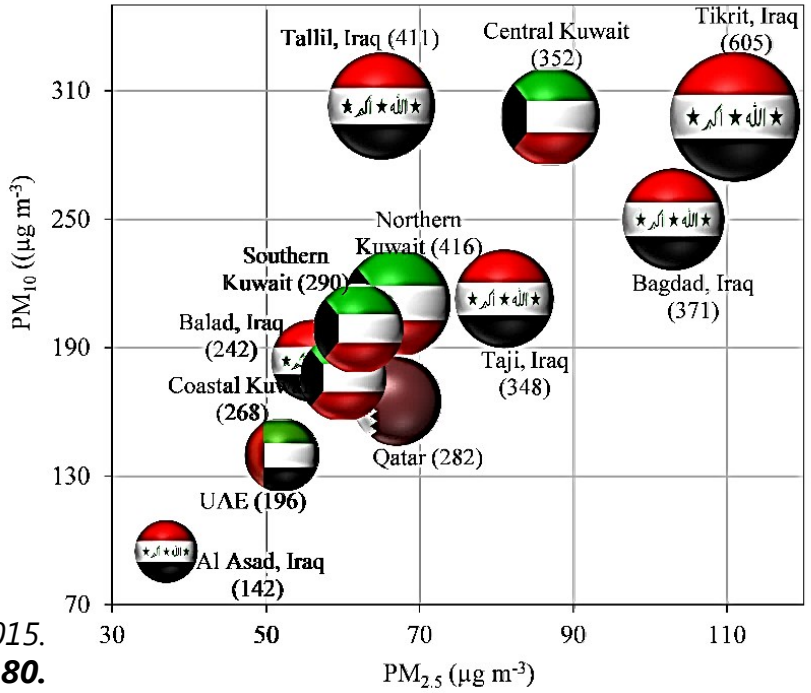
epilogue:
Identified **gaps** and next **steps**

What we know…

- Epidemiological studies provide **considerable evidences** associating exposure to air pollution with a wide range of diseases and mortality
  (Le Tertre et al., 2002, Analitis et al., 2006, Katsouyanni et al., 2003),
- …**even for levels below** air quality standards
  (Pedersen et al., 2013)
- According to the World Health Organization air pollution is the **leading environmental health risk** being responsible for about 1 out of 9 deaths annually *(WHO, 2016)*.
- The International Agency of Research on Cancer classified air pollution and particulate matter as carcinogenic to humans and as the **most widespread environmental carcinogen applying to all regions** worldwide
  (Loomis et al., 2013)

- Particulate Matter…
  - is not only dust
  - size matters
  - composition matters
  - high levels in the Middle East





Tsiouri, V., K. E. Kakosimos and P. Kumar, 2015. Air Quality, Atmosphere & Health, ***8:67-80.***

- Particulate matter in arid/semi-arid developing countries is **not only of natural origin**…
  (Hassan, H., M. Abraham, P. Kumar and K. E. Kakosimos, 2017. Airborne Particles: Origin, Emissions and Health Impacts. NOVA.)
- Source apportionment studies performed in highly populated Middle Eastern cities suggest that a large portion of **PM_{10} particles come from fugitive sources**; eg. construction, tyre and brake markers, and dust resuspensions
  (Saraga, D., T. Maggos, E. Sadoun, E. Fthenou, H. Hassan, V. Tsiouri, K. Kakosimos et al., 2017. Aerosol and Air Quality Research, 17:1156-1168.)
- Most of the **existing inventories** (EMEP, AP-42), however, were developed for European and North American regions with a **very little focus on fugitive sources** *(Hassan, H., P. Kumar and K. E. Kakosimos, 2016: Atmos. Environ., 141:96-105)*
- On **regional scale** most studies address **desert dust emission** modeling focus on North Africa and the Sahel which produce the largest amount of dust globally *(Liora, 2015; Marticorena, 1997 ;Schaap, 2009)*

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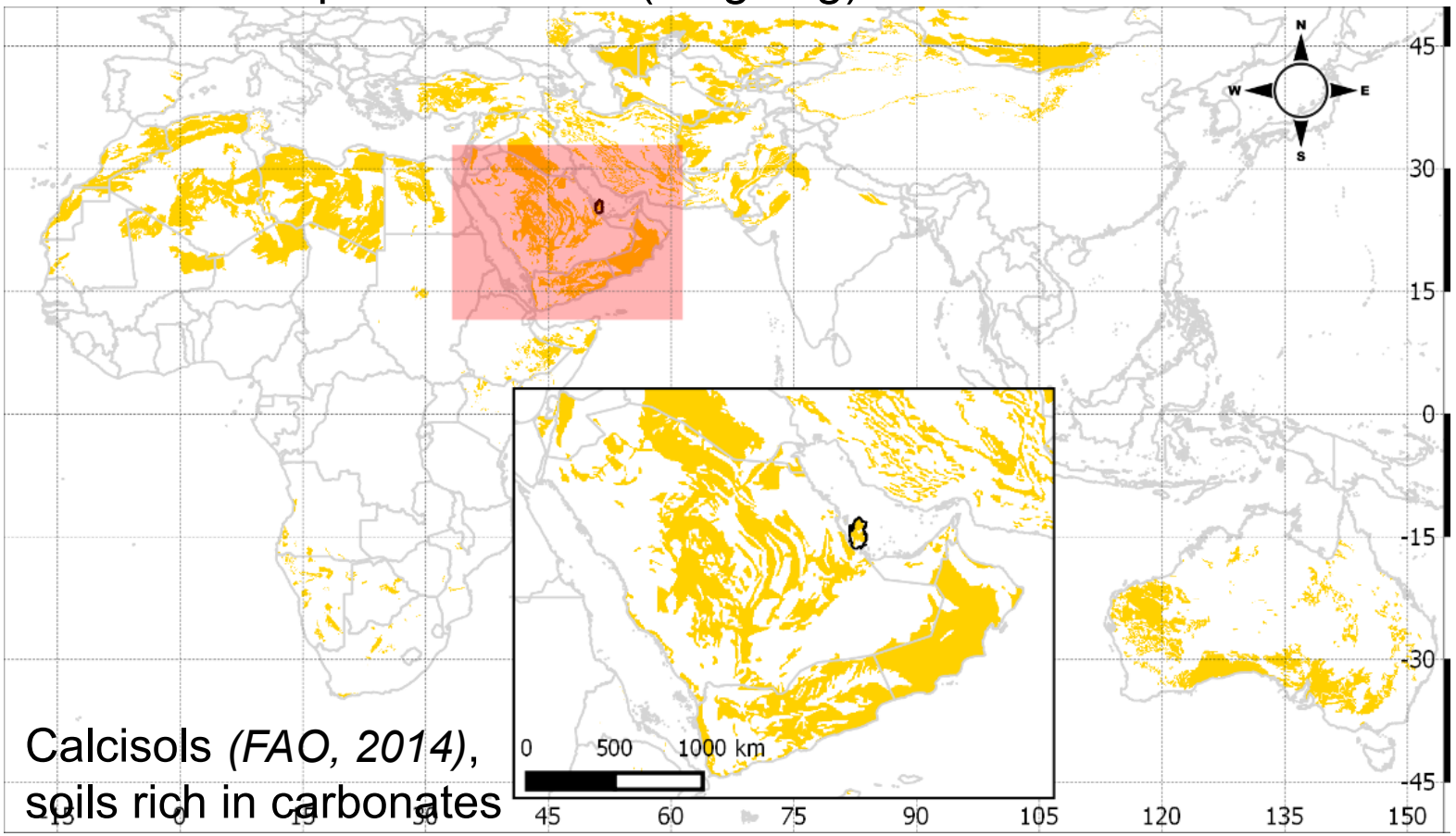
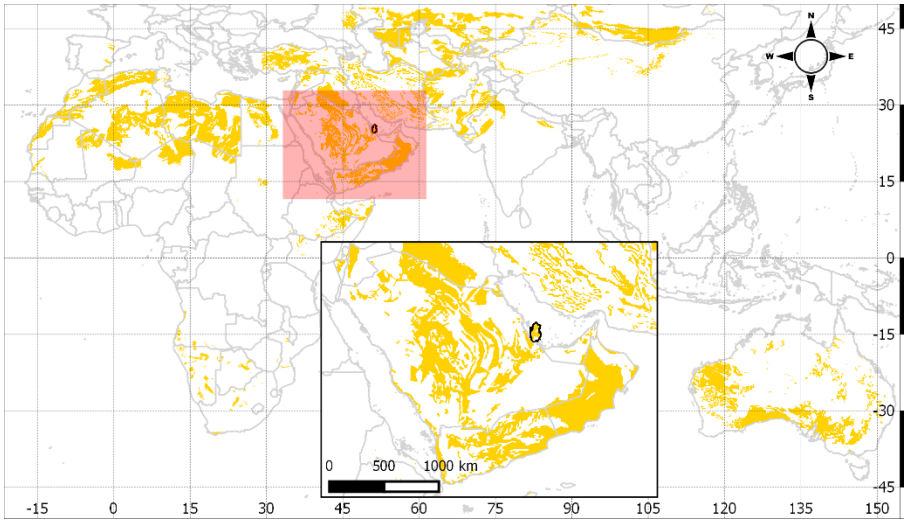
- Measuring Campaigns focusing on…
  - Loose soils in construction areas
  - Traffic produced fPM (on going)



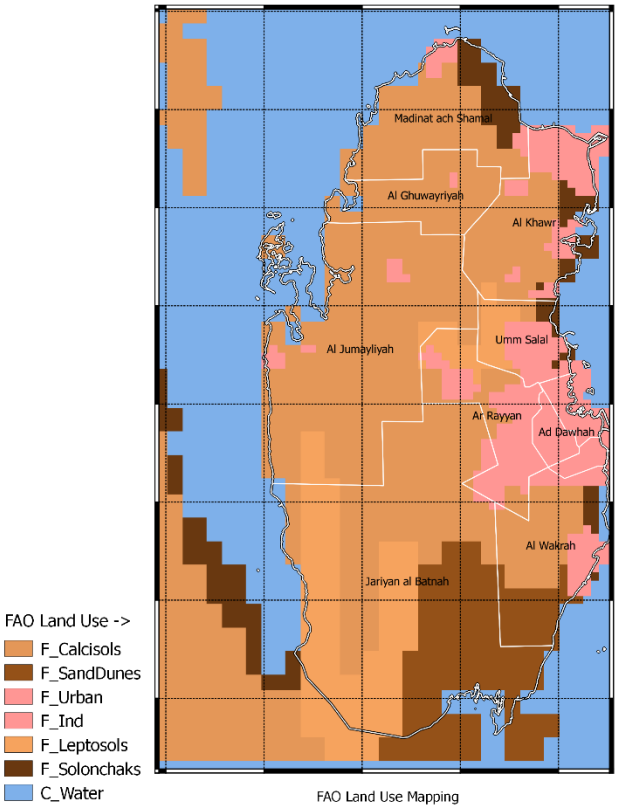
Calcisols *(FAO, 2014)*, soils rich in carbonates

- Measuring Campaigns focusing on…
  - Loose soils in construction areas
  - Traffic produced fPM (on going)
- Emissions modelling based on…
  - Inverse modelling using concentration data
  - Land use and land cover (global and own)
  - Regional and local emission models
- Impact of fPM
  - MM5/WRF (local validation)
  - CALPUFF/CALMET



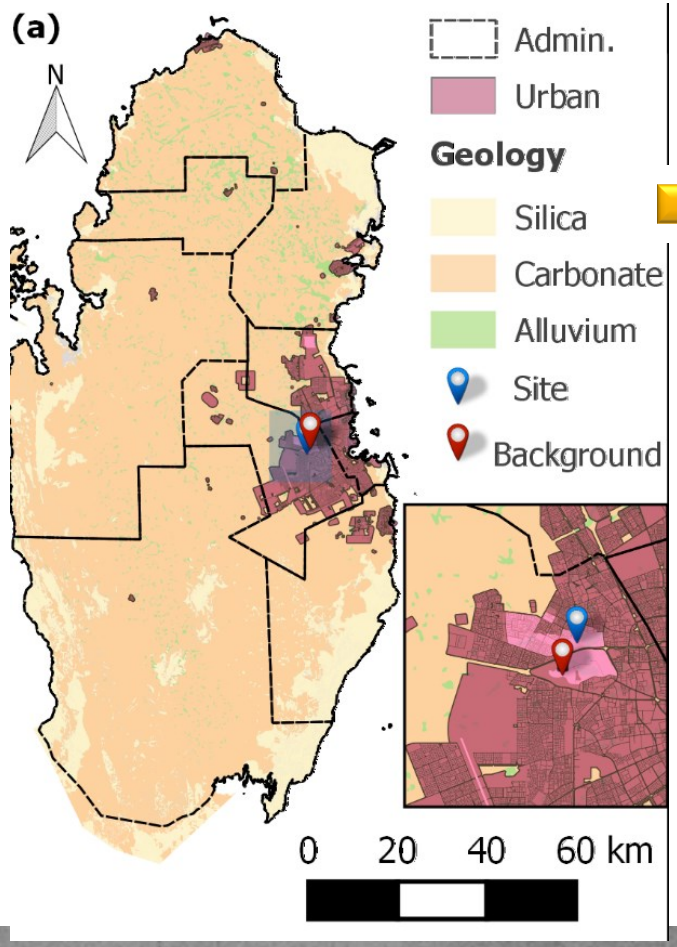
Calcisols *(FAO, 2014)*, soils rich in carbonates

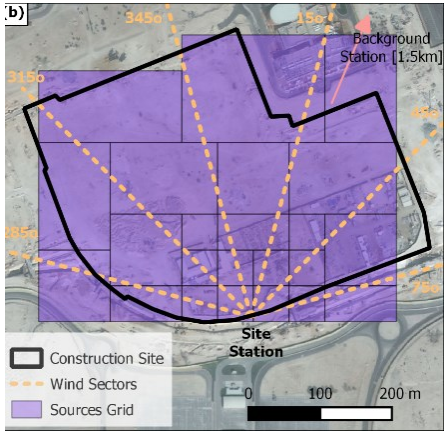
- Same area different information, examples:
  - 60% agreement on urban area
  - Sand (quartz) based desert instead of Loam (carbonates)

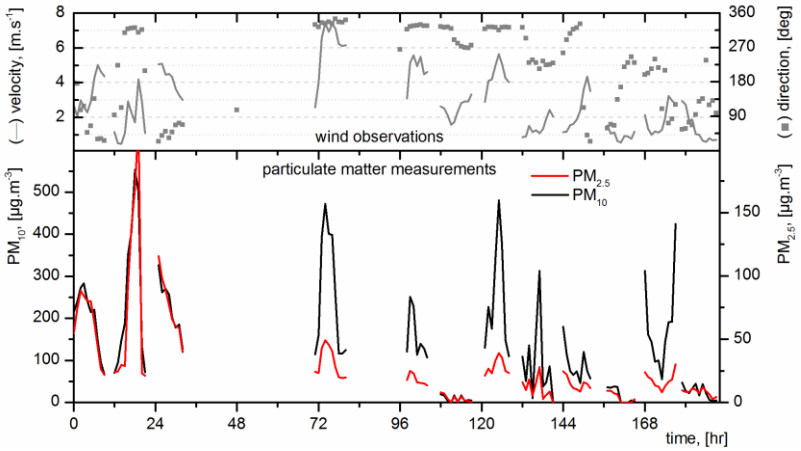


- Harmonized World Soil Database (FAO)
- Global Land Cover (USGS)
- Qatar Geological Study

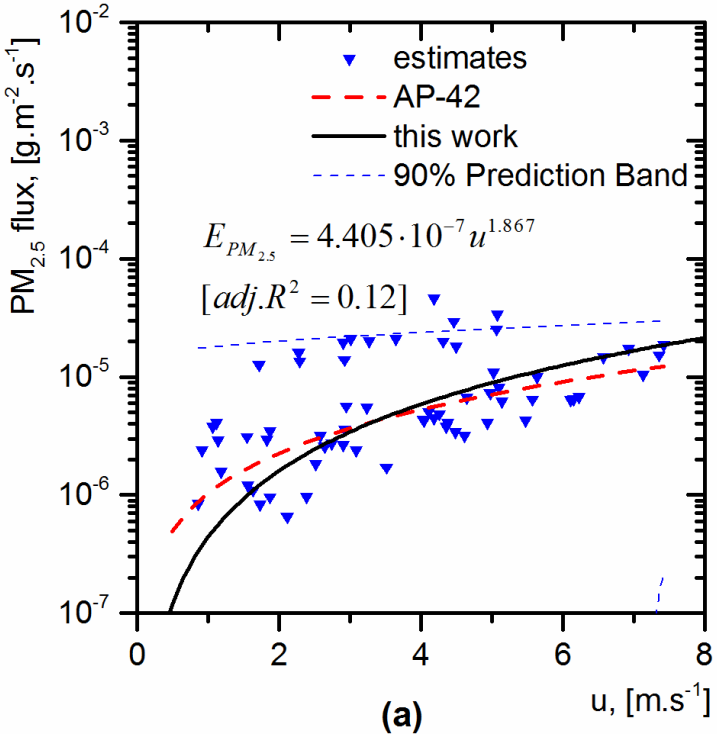
- Construction sites near/in the city.
- Surface soil characterization (4 locations) outside

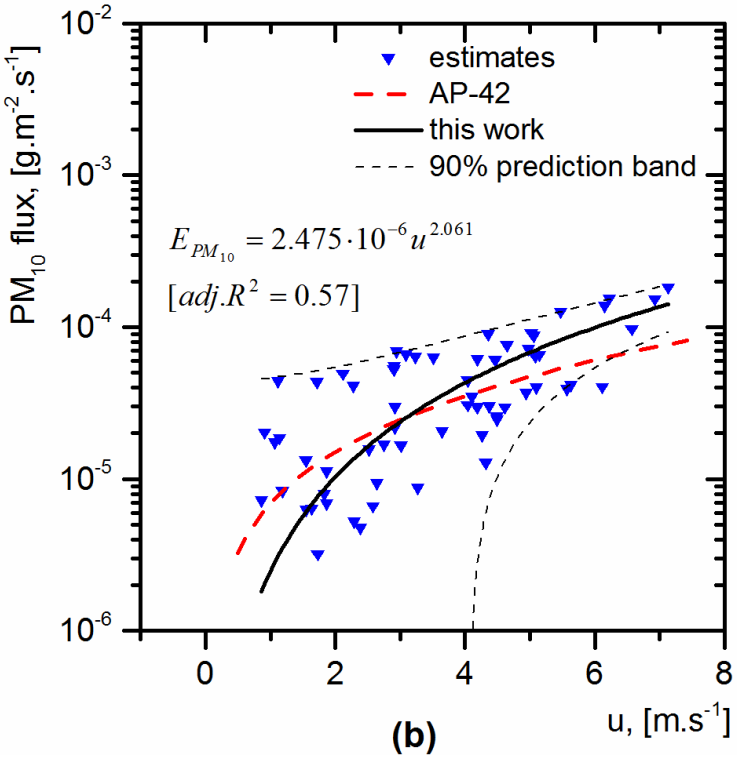






- Loose (Calcisols) soils (e.g. barren land) in the city.

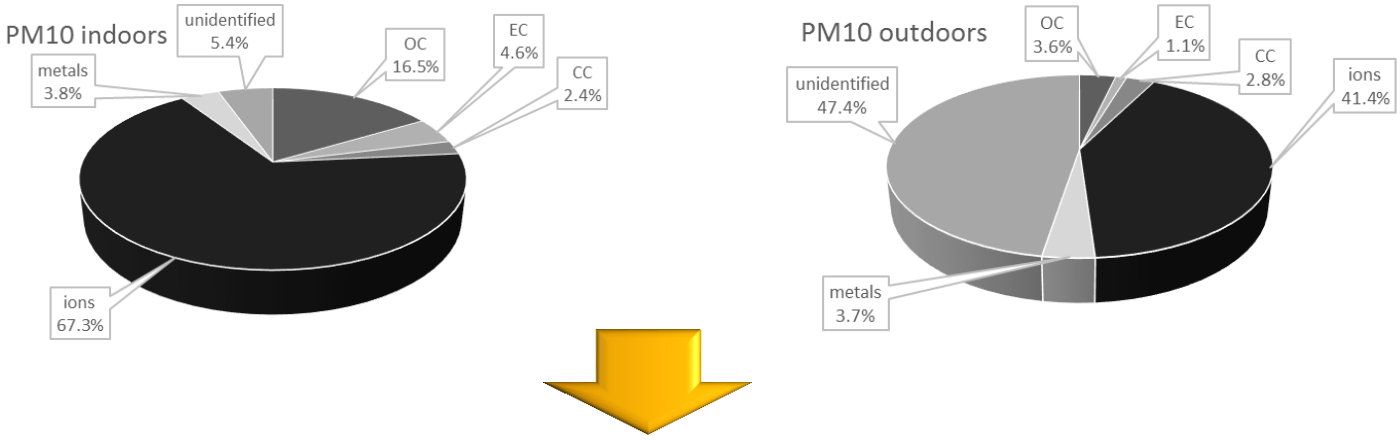




- New emission factors

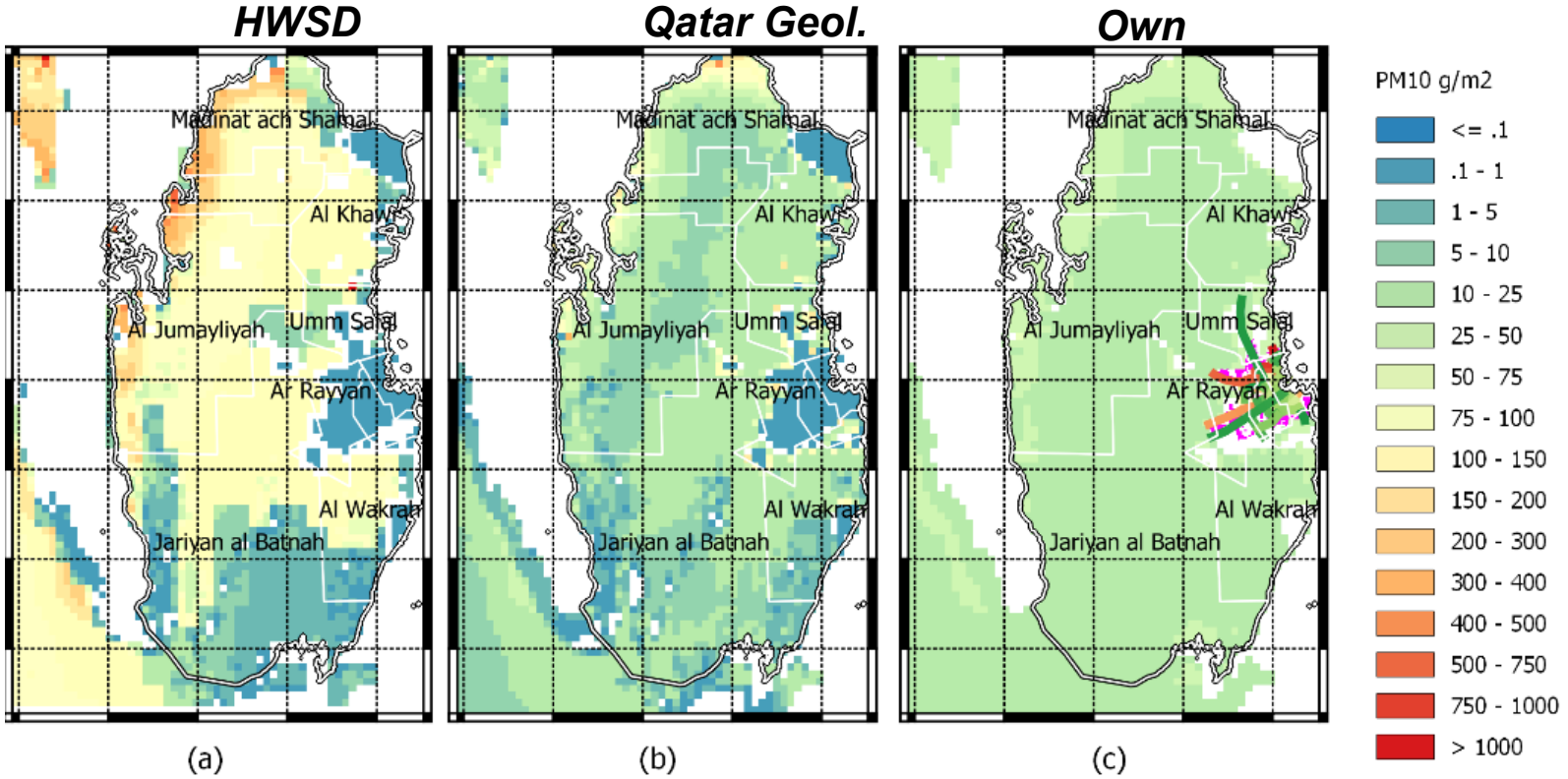
(*Hassan, H., P. Kumar and K. E. Kakosimos, 2016: Atmos. Environ., 141:96-105*)

- Particulate matter characterization indoor/outdoor
  - 2 locations (indoor/outdoor) daily for 2 months, 2015
  - PM composition (PM_{10} and $PM_{2.5}$)
    - organic/elemental/carbonate carbon (OC/EC/CC)
    - ions (NO_3^-,SO_4^{2-}, Cl^-, Br^-, NH_4^+, Na^+, K^+, Mg^{2+}, Ca^{2+})
    - metals (Cu, Pb, Cr, Ni, Cd, Zn, Fe, Al)



- Understand origin, sources, and health effects
- Improve policy making
- Better health care (general public and vulnerable groups)

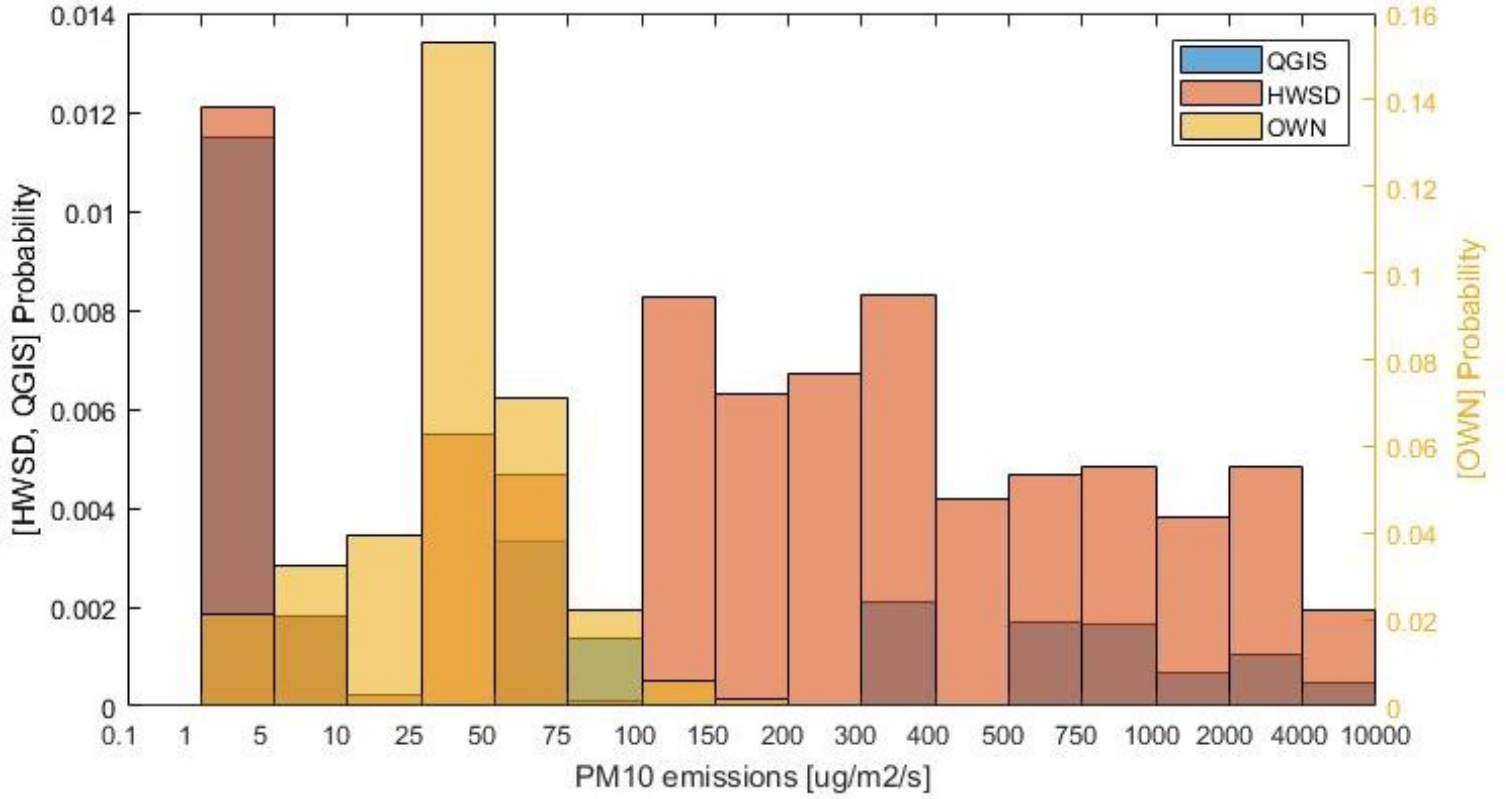
- Using three different schemes (Apr-Jun 2015)



ID	Land Use	Emission Model
HWSD	Harmonized World Soil Database (FAO, 2014)	Regional Modelling for Particulate Matter (Schaap *et al.*, 2009)
QGIS	Qatar Centre for GIS (West and Al-Mulla, 2013)	Regional Modelling for Particulate Matter (Schaap *et al.*, 2009)
OWN	Qatar Centre for GIS (West and Al-Mulla, 2013) and barren-land own-mapping	Emission Factors for Calcisols (Hassan *et al.*, 2016)

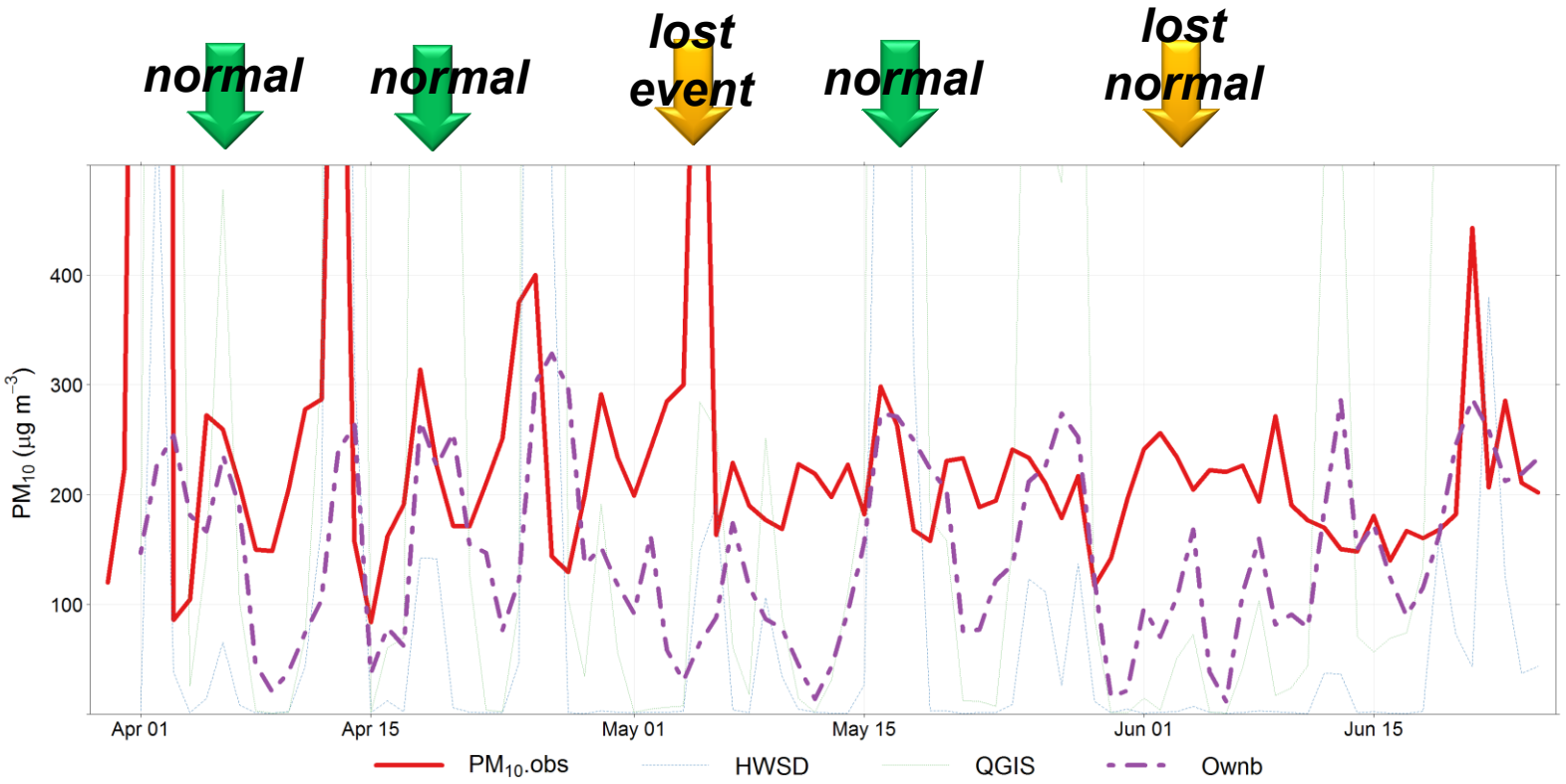
fPM emissions country wide

- HWSD and QGIS show two modes
- HWSD has mainly high values (>100 $\mu g.m^{-2}.s^{-1}$)
- QGIS same low peak as HWSD (1-5 $\mu g.m^{-2}.s^{-1}$)
- OWN between 1-100 $\mu g.m^{-2}.s^{-1}$



Modelling vs Measurements

- Daily averages (PM_{10} µg.m^{-3}) Apr-Jun 2015
  - HWSD & QGIS capture events but overestimate (>400 µg.m^{-3}), opposite is noted for the normal days (<400 µg.m^{-3})
  - OWN approaches better measurements' variability and level
  - Important sources are missing (transboundary, sea salt, traffic…)



Impact of Loose Soil (e.g. barren land)

- 95th Daily Average, PM_{10}

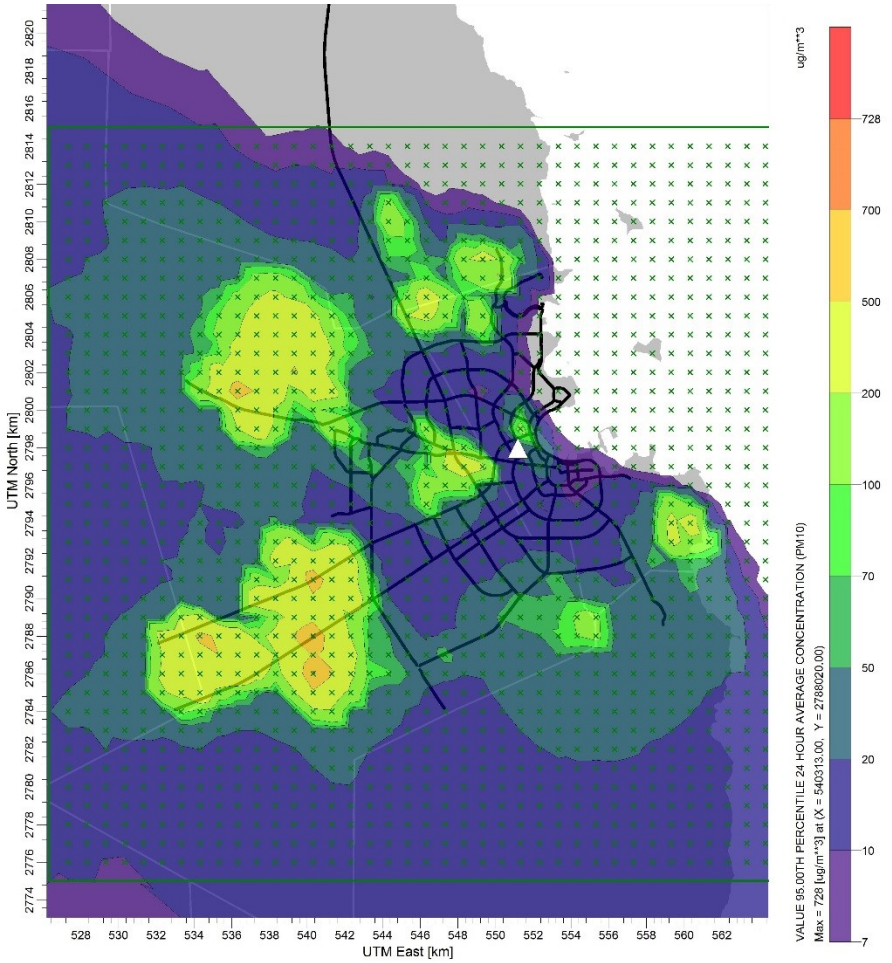
>200 $\mu g.m^{-3}$ inside the areas

>70 $\mu g.m^{-3}$ at 500m away

>50 $\mu g.m^{-3}$ at 1.5km away

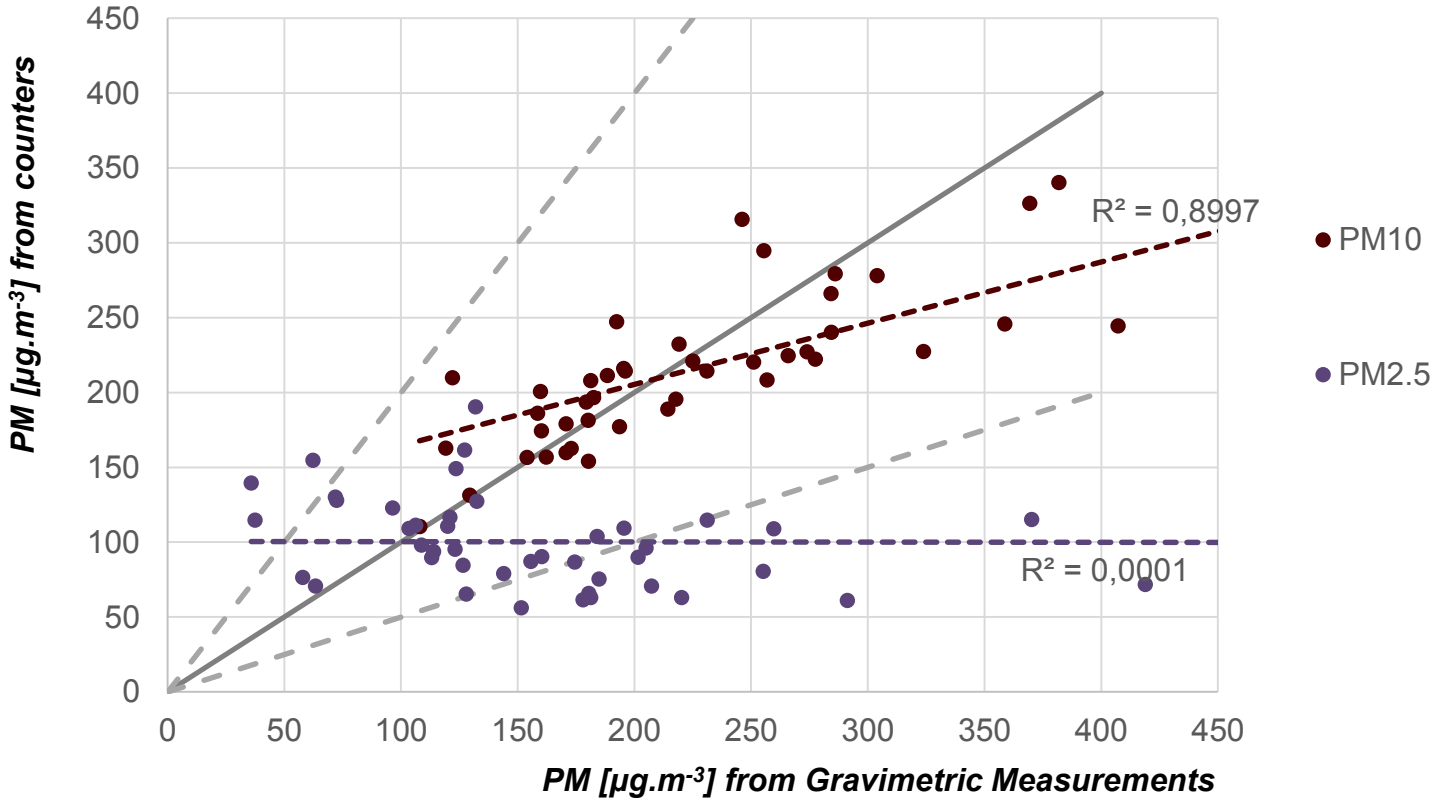
>20 $\mu g.m^{-3}$ everywhere else

- Just from the loose soil
  - Higher than the EU/EPA limit value
  - Often higher than the threshold (alert) value
- No:
  - traffic,
  - Natural
  - Sea salt
  - industry



Improvement of measuring/ calibration methods

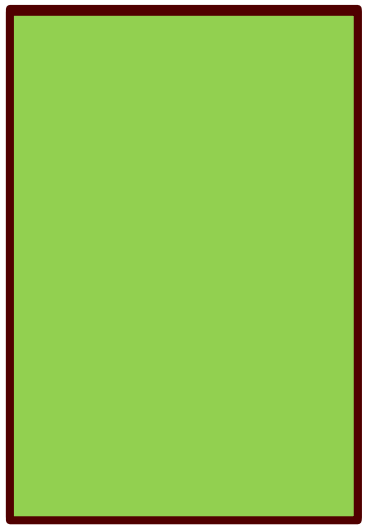
- Particle counters vs filter measurements (EN 12341:2014)
- Indications that most PM measurements based on light scattering are not as good…in Qatar (non Arizona dust)



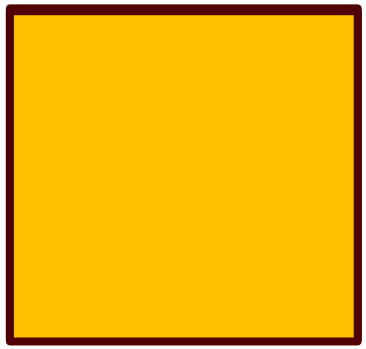
Are these emissions universal for all modelling tools?
(*Disclaimer: limited experience on regional modeling*)

e.g. CAMx ***e.g. WRF-Chem*** ***e.g. CALPUFF***

unit cell: 28 m height



unit cell: 14 m height



unit cell: ~5 m height

in 1 hour = 3.6×10^3 µg.m^{-2}

“one soil”
1 µg.m^{-2}.s^{-1} of PM

- The differences between the three scenarios and emissions modelling approaches are profound although all results are plausible.
- Existing models successfully evaluated against measurements located hundreds of kilometers away and not very close to the actual source

- OWN approach
  - similar level concentrations compared to the field measurements
  - temporal variability is also captured
  - overall agreement is still not satisfactory. Underestimation of concentrations but other significant fPM sources have not been included **yet** (e.g. traffic, industry, sea salt)

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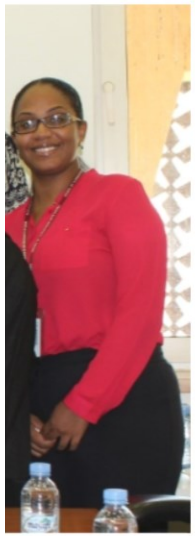
…Research team



Hutchison Medal
IChemE 2015

Int. Conf. on H_2 Production
best Paper award 2016

Laboratory Safety Award
TAMUQ 2016

Research Excellence
Early Carrier, TAMUQ 2017

Thank you شكرا Ευχαριστώ

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