Dust impacts on human health

Aurelio Tobías

Training Workshop on Sand and Dust Storms in West and Northern Africa
Dakar, Senegal, 9th December 2019

Objective

- How do the epidemiologists try to answer the *(apparently simple)* research question

  "does desert dust impact human health?"

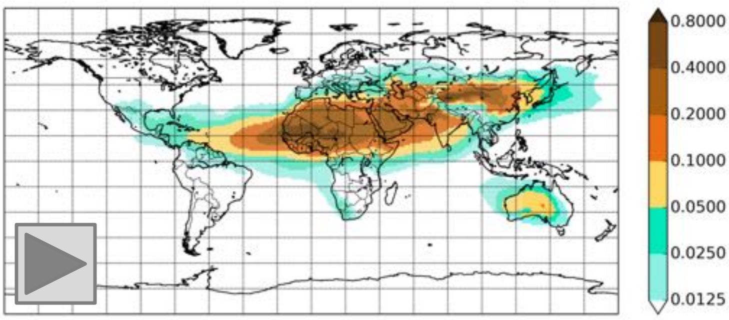
Outlook

- Introduction
- The time-series design
- Dust as binary exposure
- Dust as continuous exposure
- Discussion

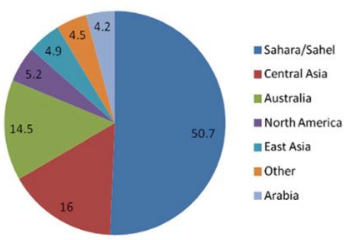
Introduction

- **Desert dust** play a significant role in different aspects of weather, climate and atmospheric chemistry and **represent a serious hazard for environment and health**

Dust optical depth at 550 nm. Average value 2003-2015



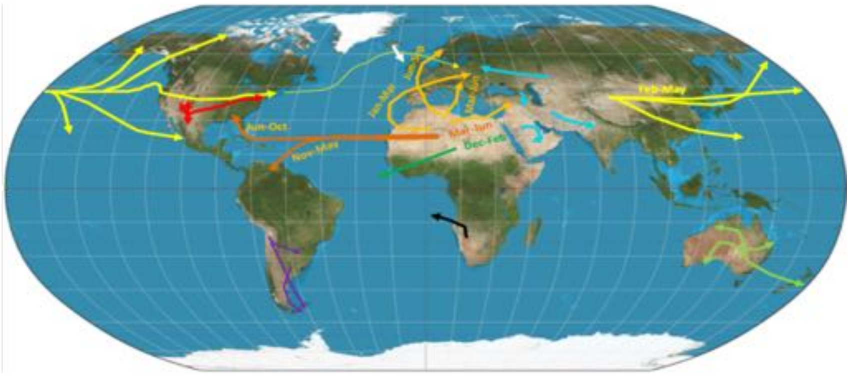
Source: *CAMS reanalysis, WMO SDS-WAS*



(Goudie 2014)

Introduction

- **Dust storms last 1-24h at source points**, and depending on meteorological conditions **can be transported at surface level or lofted to high altitudes** (up to 10 km)



(Goudie 2014)

Introduction

- The **air quality influence of dust** is a complex issue
- Dust is typically **made up of crustal components**, clay minerals and salts, and it can:
  1) **Increase PM ambient concentrations**, PM_{10} 2.5-fold during dust days in East Asia and 1.5-fold in Europe *(Querol et al. 2019)*
  2) **Carry anthropogenic pollutants,** previously deposited in the source areas or trapped by the high dust air mass during its atmospheric transport *(Mori 2003, Rodríguez el al. 2011)*
  3) **Carry microorganisms** and toxic biogenic allergens (*Griffin et al. 2001, Ho et al. 2008)*

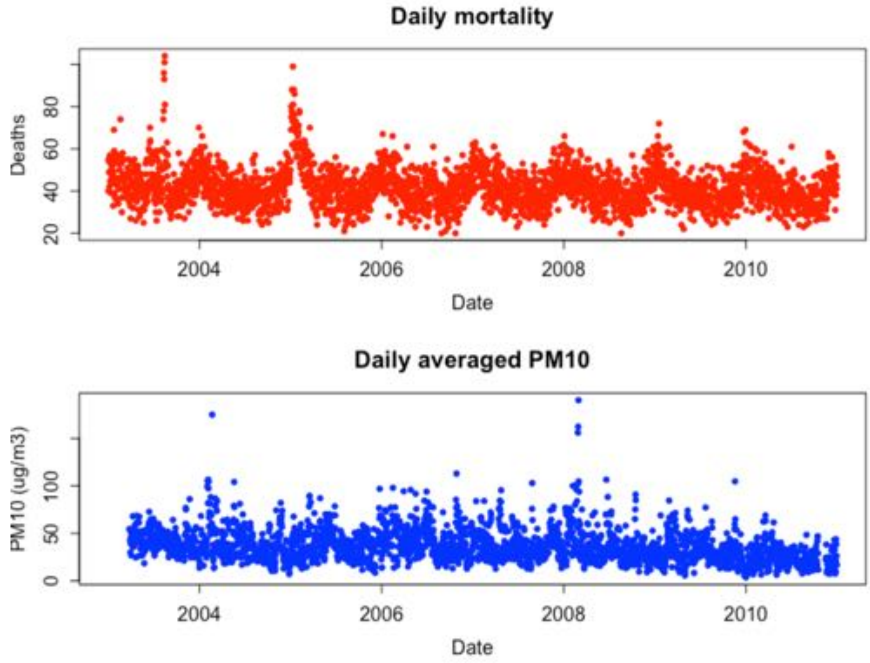
Introduction

- Evidence on **health effects** of desert dust **remains unclear** *(Hashizume et al. 2010, Karanasiou et al. 2012, Longeville et al. 2013, Zhang et al. 2014)*
- Main **differences** on:
  - **a) Study design** and statistical analysis
  - **b) Methods to identify** dust events
  - **c) Metric of dust** exposure (binary or continuous)
- A **Systematic Review with standardized protocol** was recently conducted by the WHO *(Tobias et al. 2019)*

Environmental epidemiology

- Mortality (health outcomes) counts and environmental exposures are characterized by **similar time-trends**

Rome, 2003-2010



Environmental epidemiology

- Mortality (health outcomes) counts and environmental exposures are characterized by **similar time-trends**
- Measures of **individual predictors are not available**
- We need a study design that relies on **between-day comparison** within the same population and able to **control for time-trends**

Time-series design

- **Strengths**
  - Use of administratively-collected data
  - Time-invariant or slow-variant individual risk factors controlled by design
- **Limitations**
  - Ecological design based on aggregated, not individual, data
  - Not applicable to estimate log-term (chronic) effects

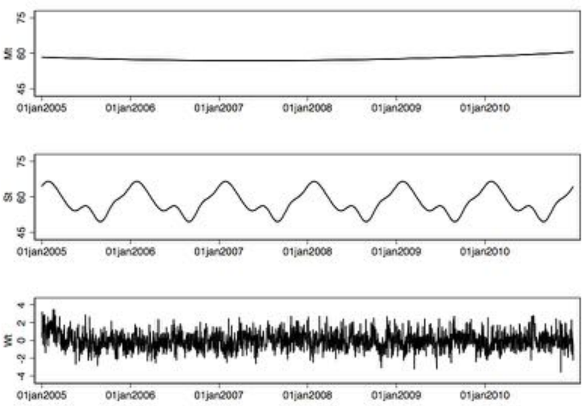
Analytical framework

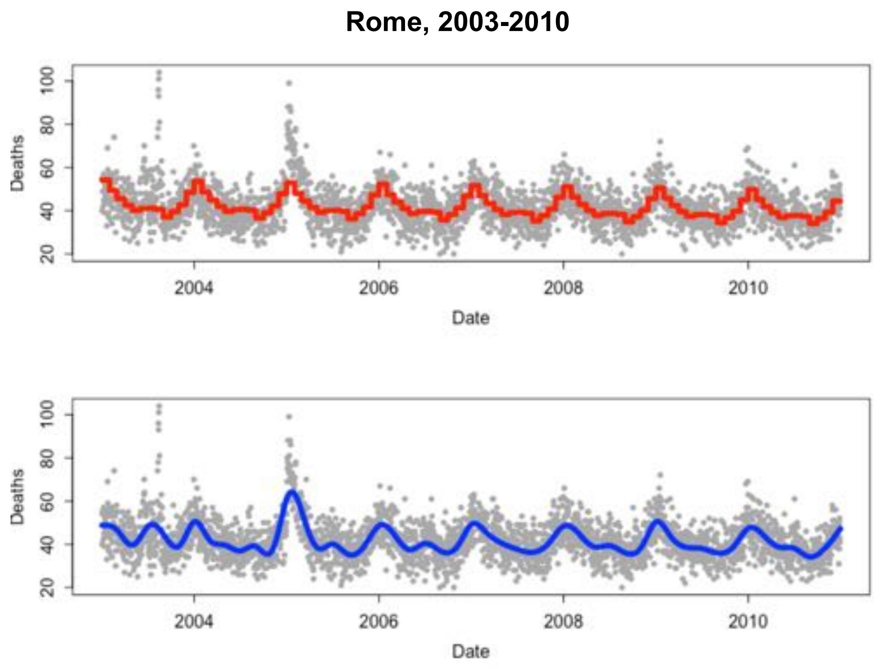
- **Temporal decomposition**,

$$y_t = m_t + s_t + w_t$$

*with **m** and **s** as time components (long trend and seasonality) and **w** as residual series*

- Underlying trends are **filtered-out** from the time series, allowing the inspection of associations at shorter time scale





$y_t = \beta_0 + s(t)$

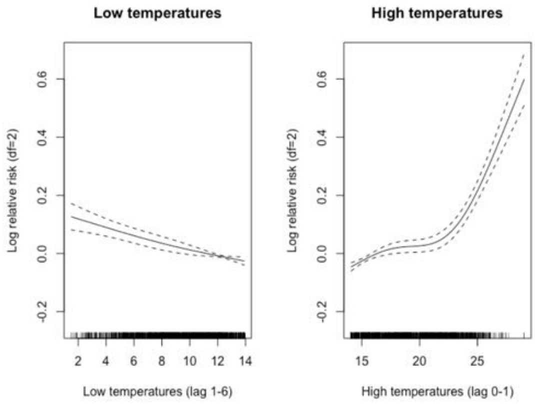
Time-varying covariates

- Besides temporal decomposition, **other calendar effects** should also be considered (e.g., weekdays, holidays)

$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it}$

Time-varying covariates

- Besides temporal decomposition, **other calendar effects** should also be considered (e.g., weekdays, holidays)
- Other **confounders with the same seasonal pattern** as the health indicator (e.g., temperature)

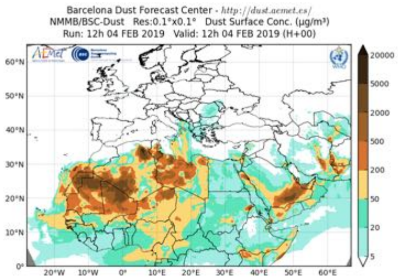


$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t)$

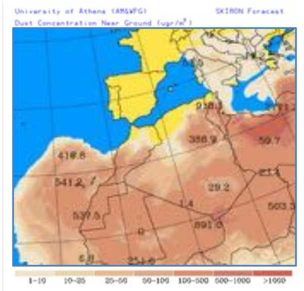
Identification of dust events

- Combination of tools: **aerosol maps** (BSC-DREAM, SKIRON, NAAPS-NRL) **satellite images** (MODIS) and **air masses back-trajectories** (HYSPLIT)

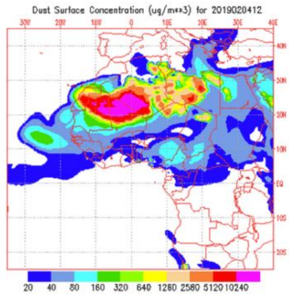
MMMB-BSC-dust



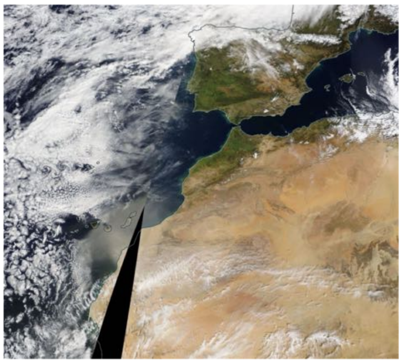
SKIRON



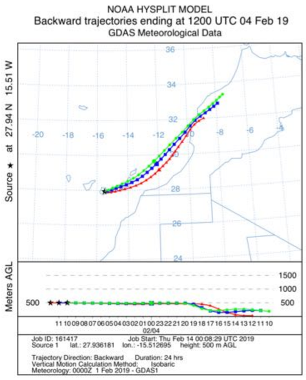
NAAPS - NRL



MODIS

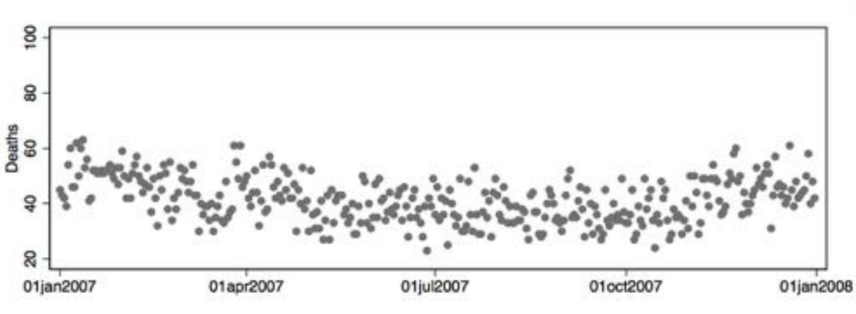


HYSPLIT

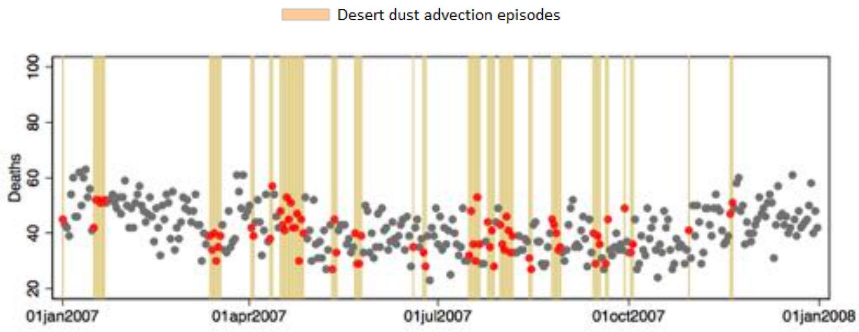


Saharan dust event
Canary Islands,
4 Feb. 2019, 12:00 h

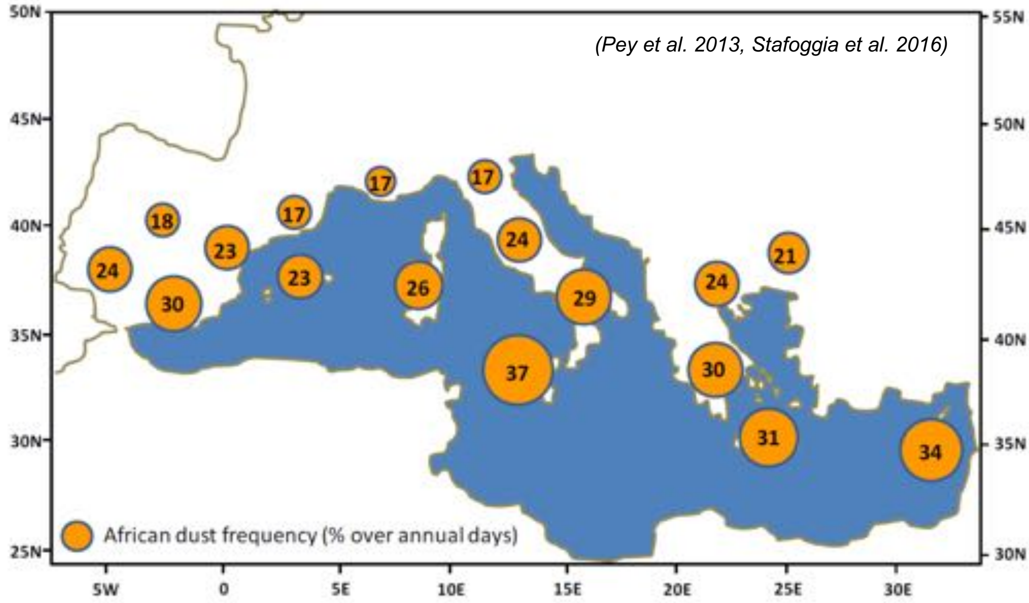
Rome, 2007



Rome, 2007



Identification of dust events



Identification of dust events

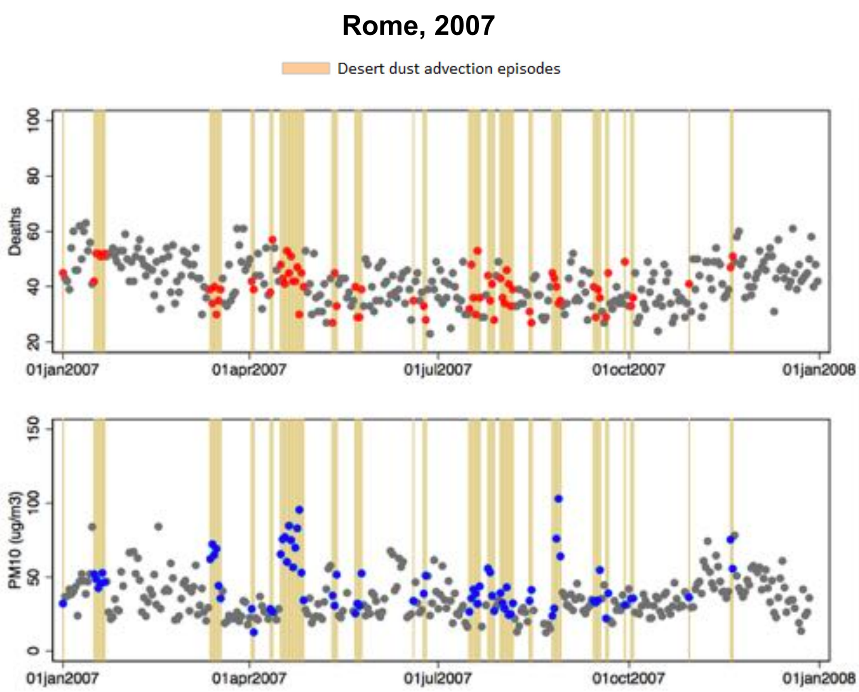
- **Combination of tools**: aerosol maps (BSC-DREAM, SKIRON, NAAPS-NRL) satellite images (MODIS) and air masses back-trajectories (HYSPLIT) *(Pey et al. 2013)*
- **Threshold exceedance** of PM concentrations *(Thalib et al. 2012, Krasnov et al. 2013, Al-Taiar et al. 2014)*
- **Visual inspection** reducing horizontal visibility to <10 km: China (*Ma et al. 2016*), Japan *(Kashima et al. 2016)*, Korea *(Lee at al. 2013)* and Caribbean *(Akpinar-Elci et al. 2015)*

Dust as binary metric

- **Risk factor**

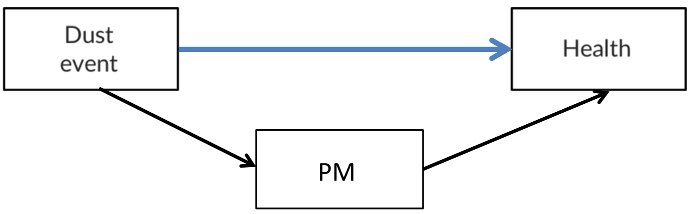
- **Research question** – *Is mortality higher on dust days compared to non-dust days?*
- Mortality increases by **3.5%** on dust days compared to non-dust days

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \boldsymbol{\beta dust_t}$$



Dust as binary metric

- **Risk factor**

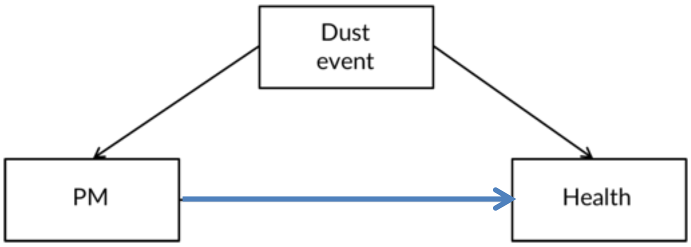


- **Research question** – *Is mortality higher on dust days compared to non-dust days, independently from PM_{10}?*
- Mortality increases by **3.1%** on dust days, independently from PM_{10}

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \beta_1 \mathbf{dust_t} + \beta_2 \mathbf{PM_t}$$

Dust as binary metric

- **Confounder**

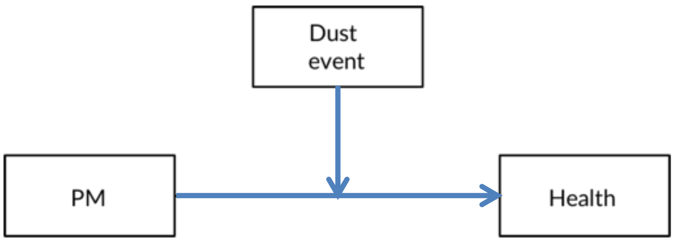


- **Research question** – *Is PM_{10} associated with daily mortality, independently on dust events?*
- Mortality increases by **0.4%** per each 10 $\mu g/m^3$ increase in PM_{10}, independently on dust events

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \beta_1 dust_t + \beta_2 PM_t$$

Dust as binary metric

- **Effect modifier**



- **Research question –** *Is the association between PM_{10} and daily mortality different between dust and non-dust days?*
- Mortality increases by **0.8%** per each 10 $\mu g/m^3$ increase in PM_{10} during **dust days** and by **0.3%** during **non-dust days**

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \beta_1 dust_t + \beta_2 PM_t + \beta_3 dust_t{*}PM_t$$

Dust as binary metric

Risk factor

- **All dust events are treated in the same way** since do not quantify the dust, not providing information on the dose-response relationship
- Studies in Eastern Asia show **increase of cardiovascular mortality** and **respiratory/child asthma morbidity** during days with dust events

Effect modifier

- **PM is a mixture of natural and local sources**, even within the dust days. It is not possible to attribute the health effects to a given source
- Studies in Europe show **larger effect of PM_{10} and $PM_{10\text{-}2.5}$ on cardiovascular mortality** and **respiratory morbidity** during days with dust events, but similar effects for **$PM_{2.5}$**

Quantifying dust events

- EU reference method (Directive 2008/50/EC)

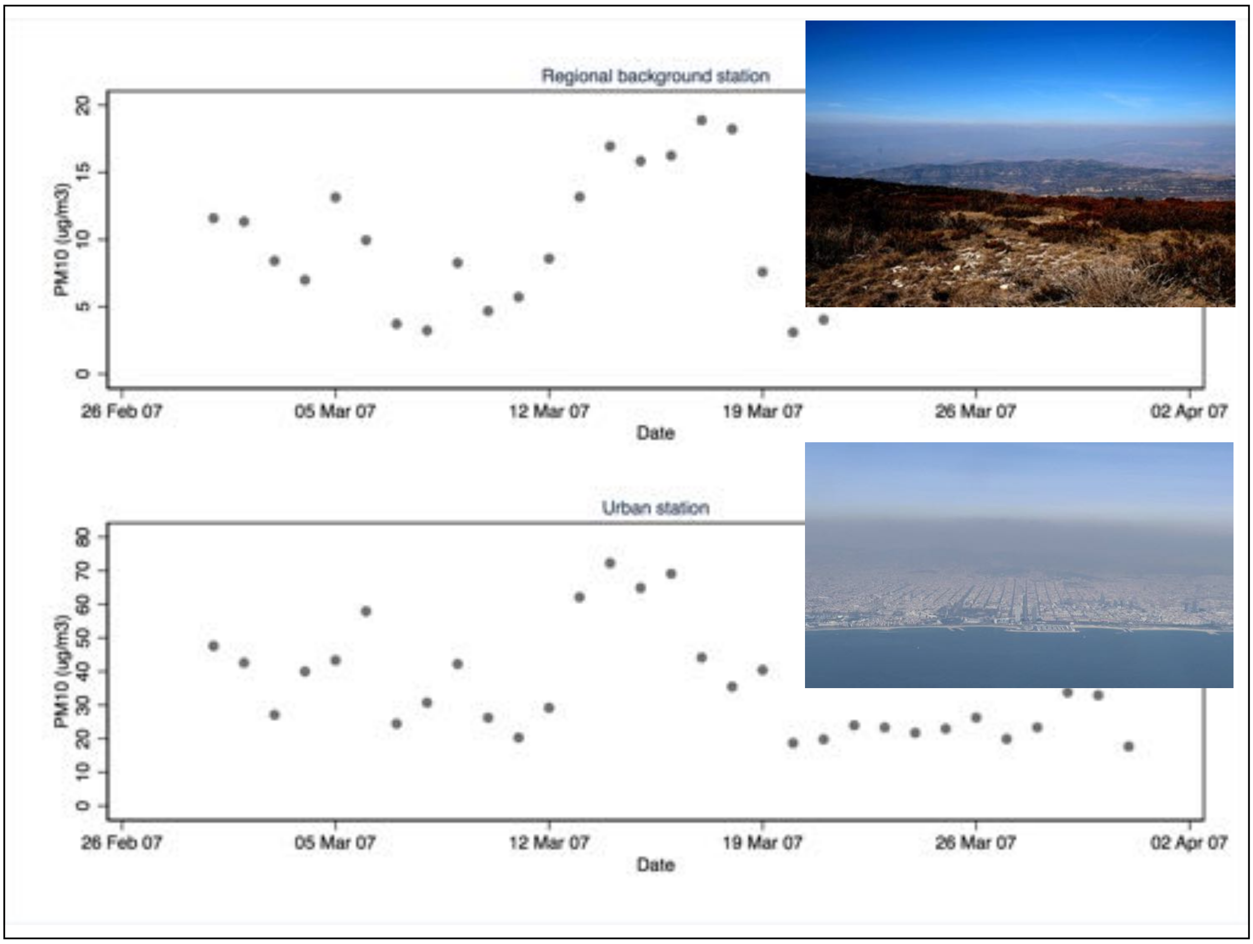
EUROPEAN COMMISSION

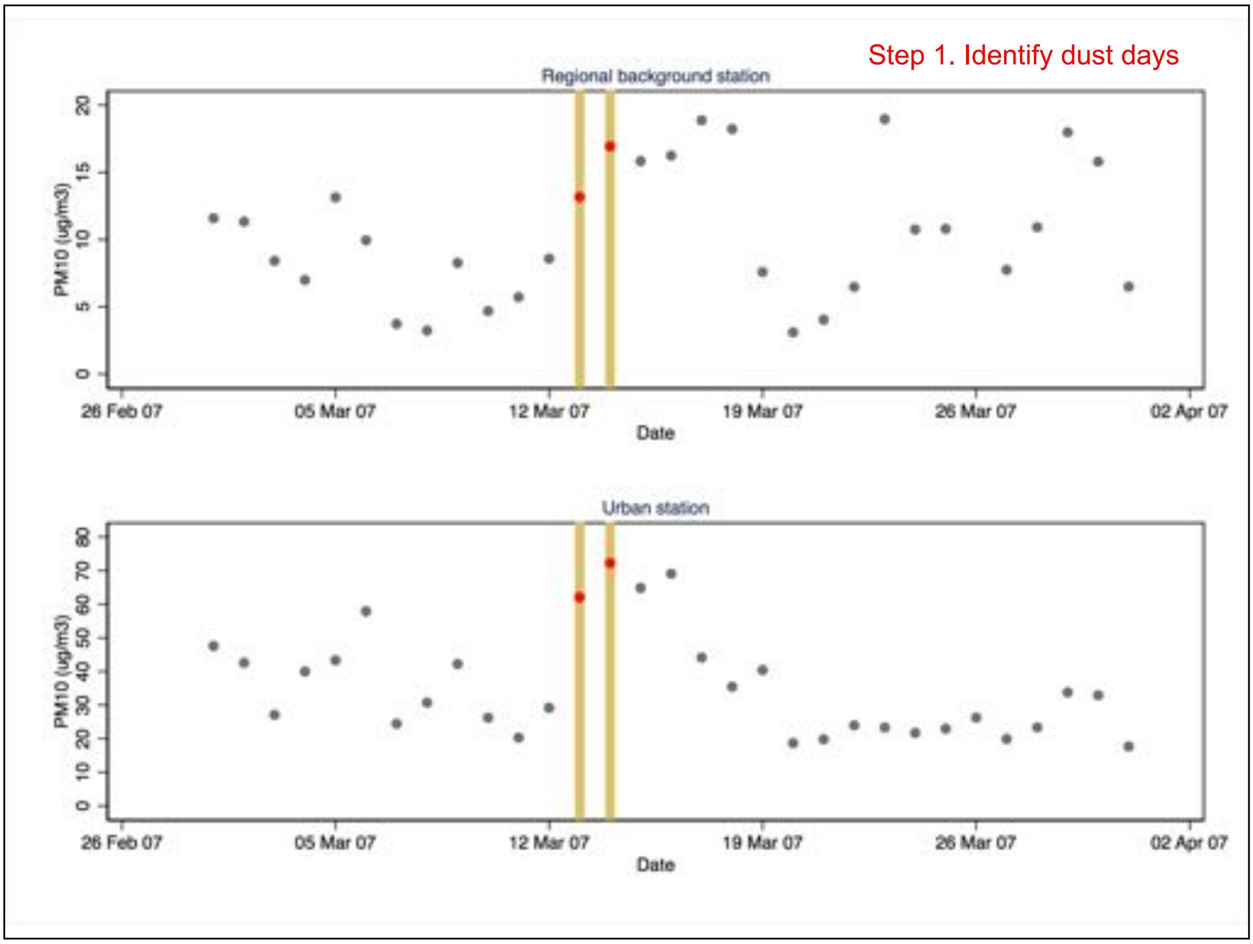
Brussels, 15.02.2011
SEC(2011) 207 final

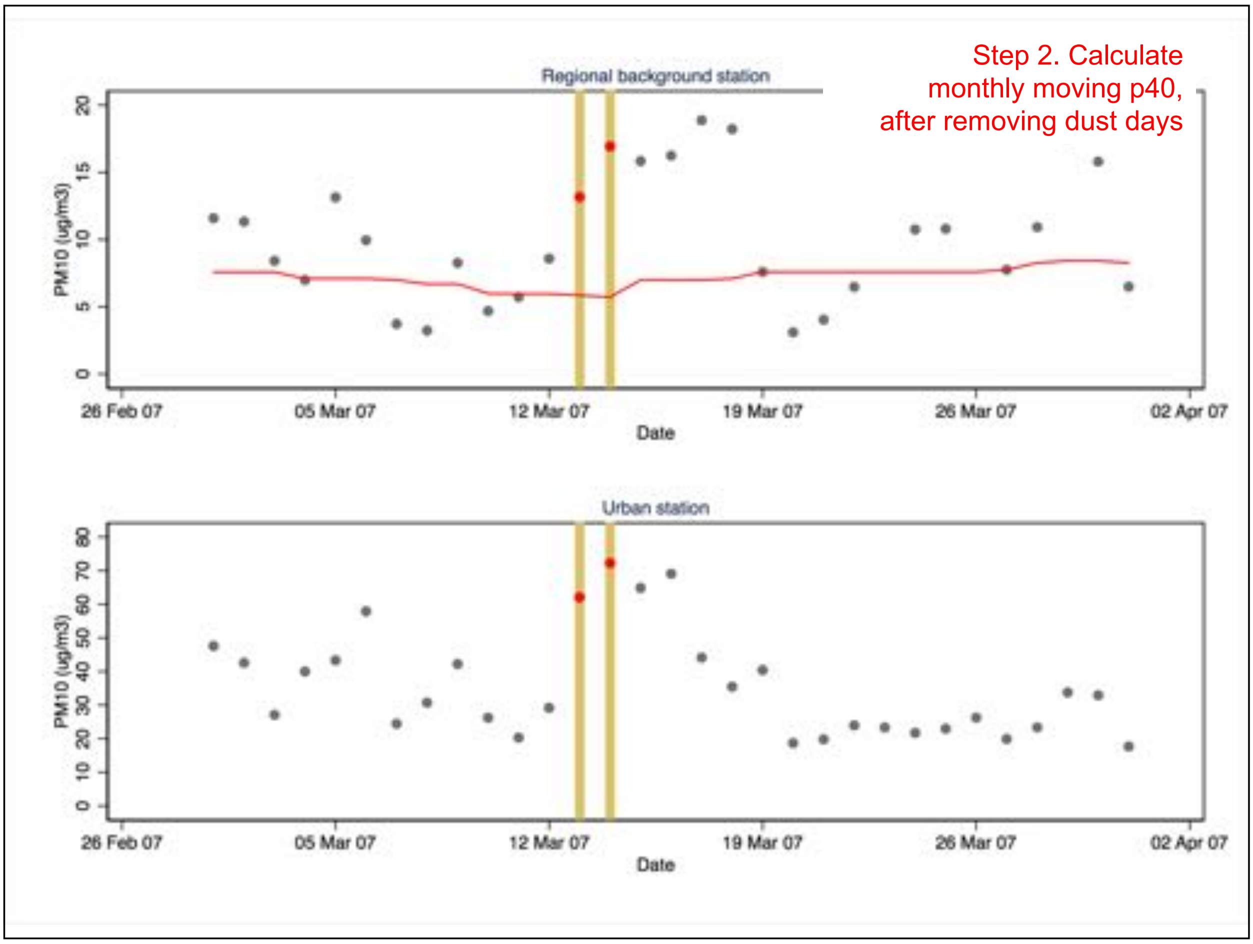
COMMISSION STAFF WORKING PAPER

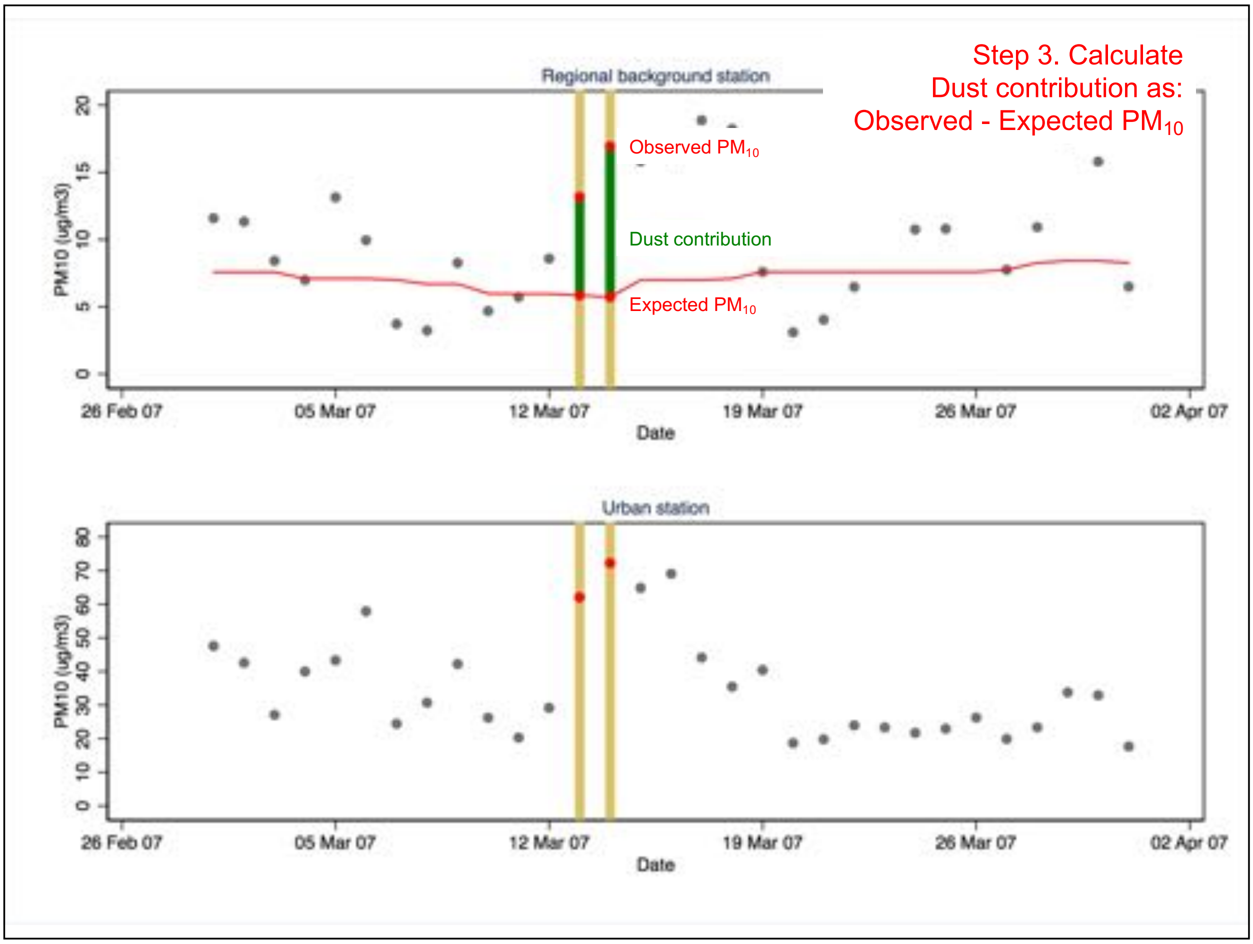
establishing guidelines for determination of contributions from the re-suspension of particulates following winter sanding or salting of roads under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe

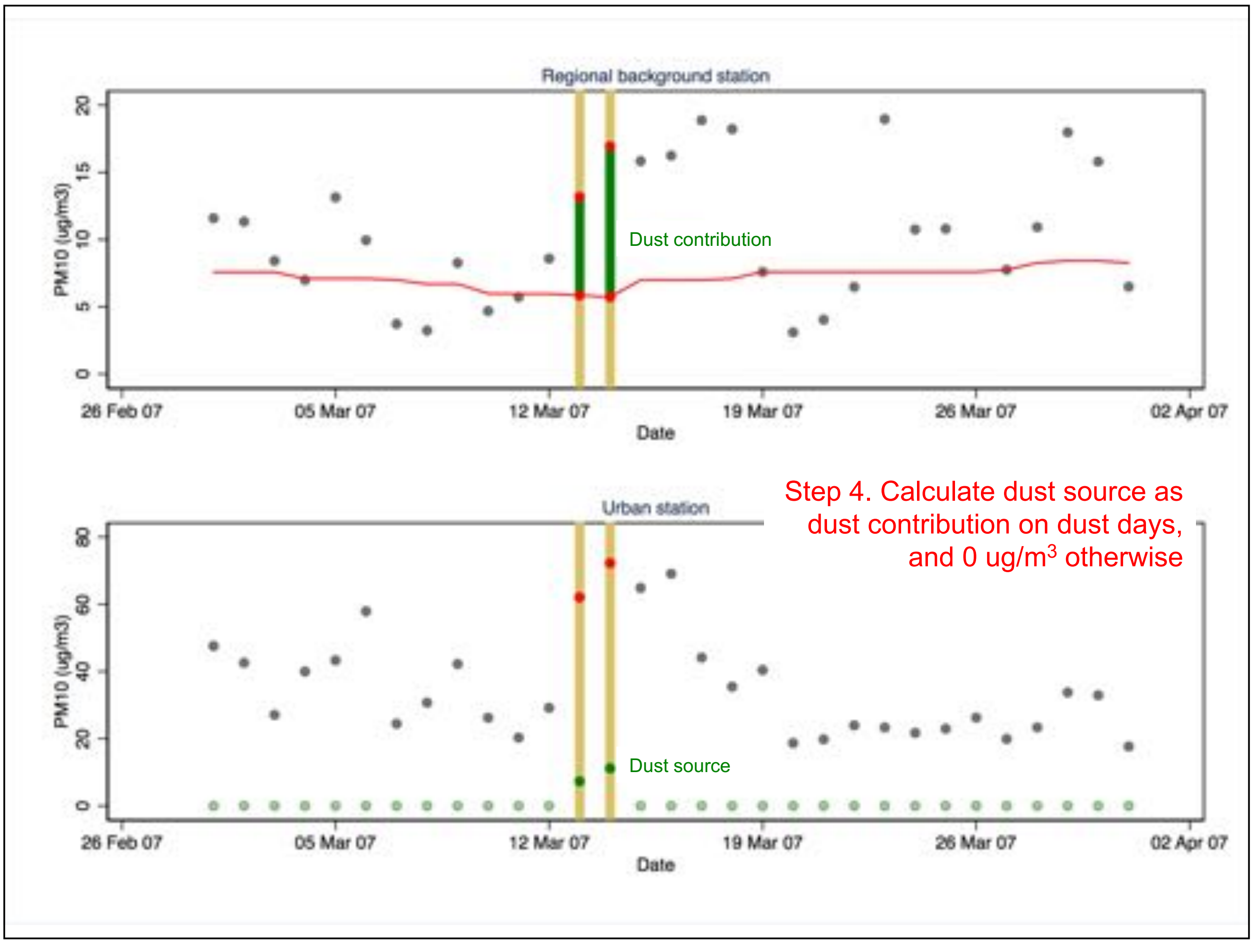
http://data.europa.eu/eli/dir/2008/50/oj

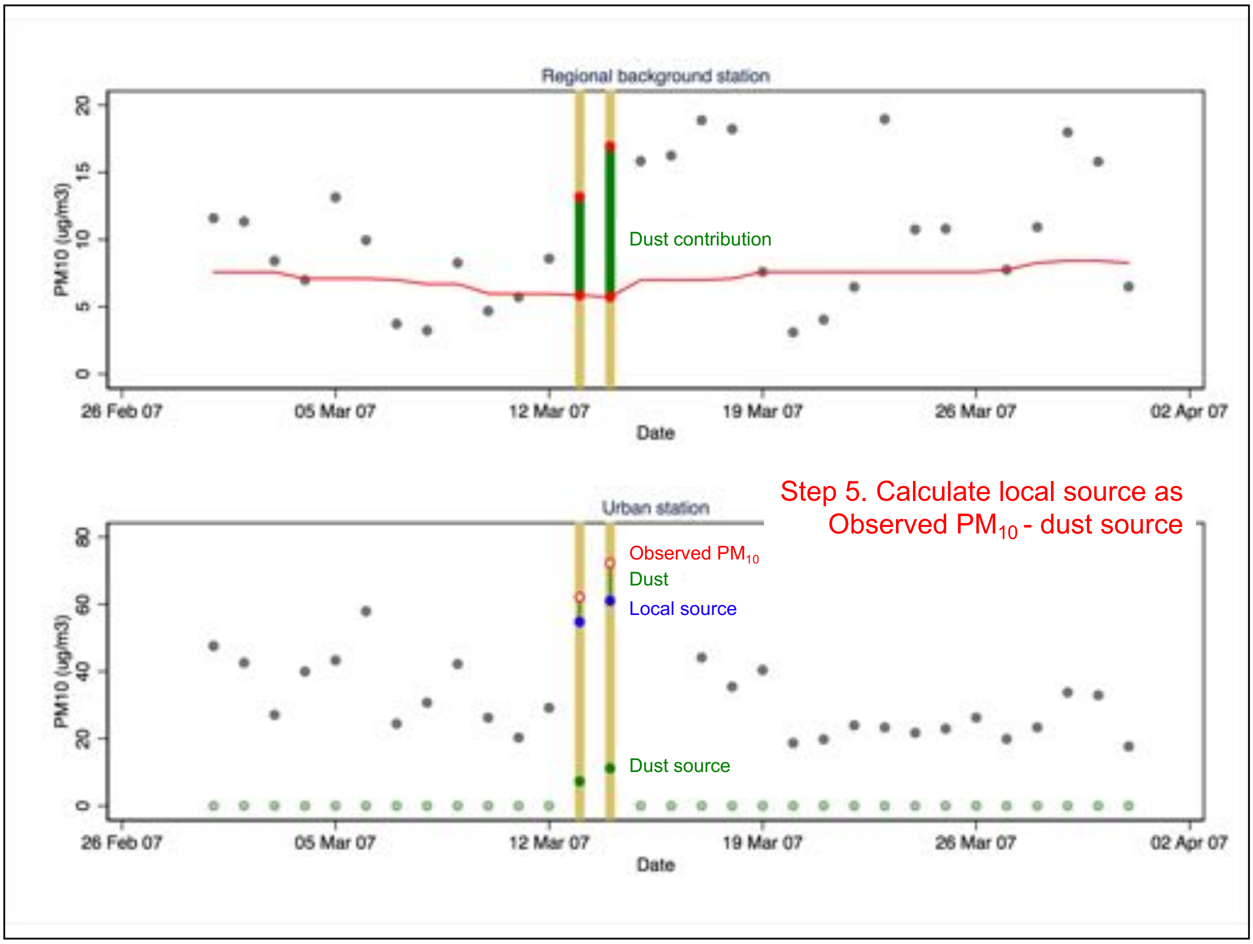

Regional background station
PM10 (ug/m3)
0
5
10
15
20
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date
Urban station
PM10 (ug/m3)
0
10
20
30
40
50
60
70
80
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date

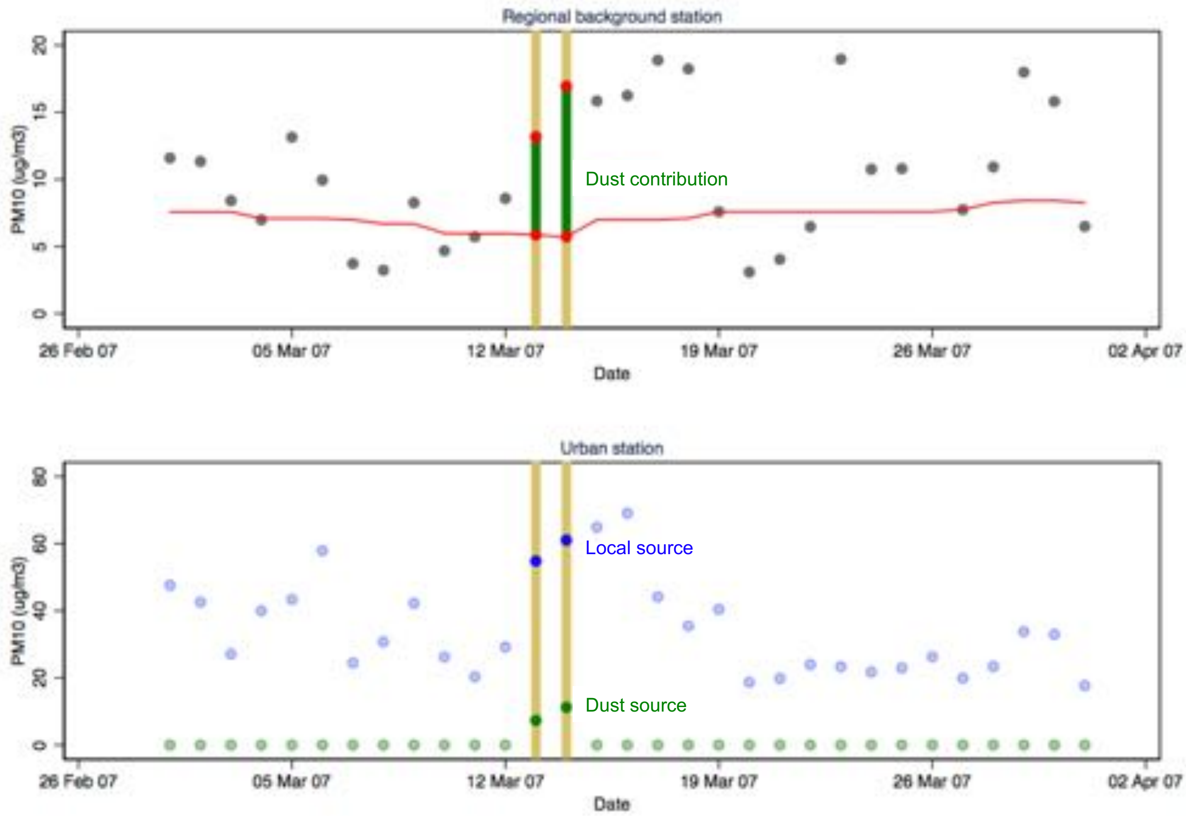

Step 1. Identify dust days
Regional background station
PM10 (ug/m3)
0
5
10
15
20
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date
Urban station
PM10 (ug/m3)
0
10
20
30
40
50
60
70
80
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date


Step 2. Calculate monthly moving p40, after removing dust days
Regional background station
PM10 (ug/m3)
Date
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Urban station
PM10 (ug/m3)
Date

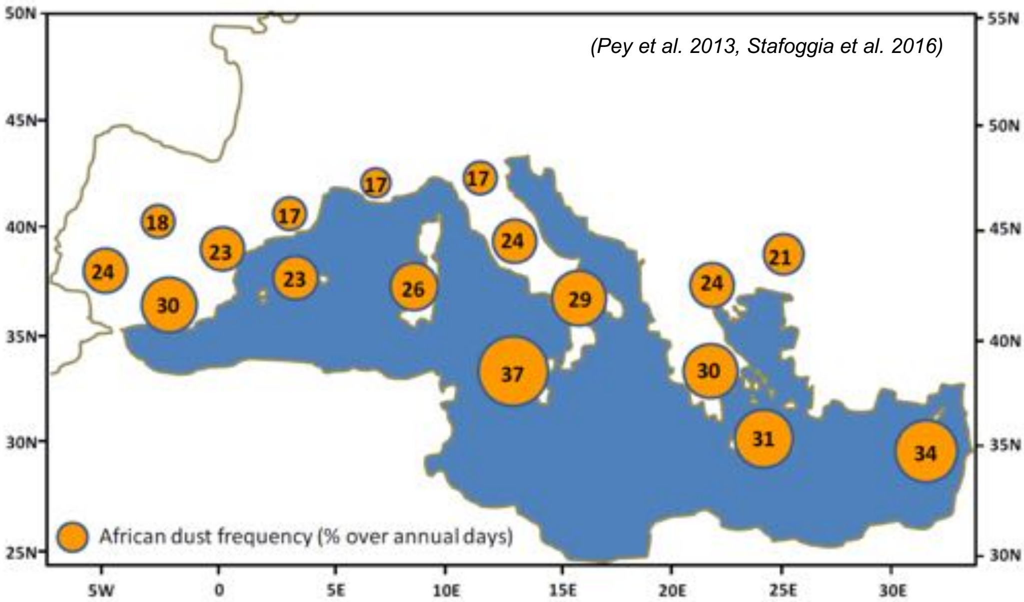

Step 3. Calculate Dust contribution as: Observed - Expected PM_{10}
Regional background station
Observed PM_{10}
Dust contribution
Expected PM_{10}
PM10 (ug/m3)
Date
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Urban station
PM10 (ug/m3)
Date


Regional background station
PM10 (ug/m3)
20
15
10
5
0
Dust contribution
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date
Step 4. Calculate dust source as dust contribution on dust days, and 0 ug/m3 otherwise
Urban station
PM10 (ug/m3)
80
60
40
20
0
Dust source
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date

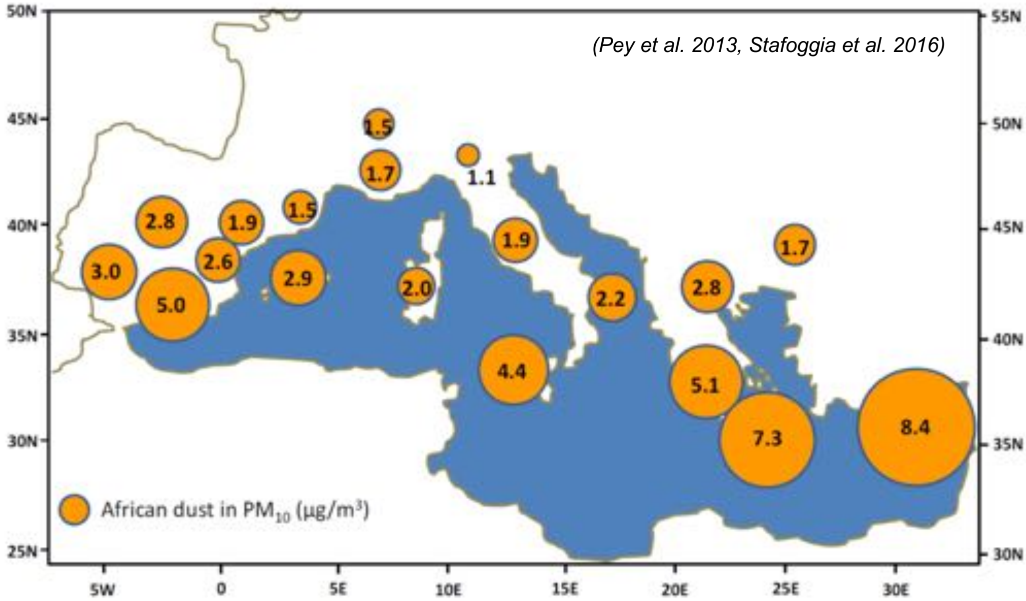

Regional background station
PM10 (ug/m3)
20
15
10
5
0
Dust contribution
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date
Step 5. Calculate local source as Observed PM10 - dust source
Urban station
PM10 (ug/m3)
80
60
40
20
0
Observed PM10
Dust
Local source
Dust source
26 Feb 07
05 Mar 07
12 Mar 07
19 Mar 07
26 Mar 07
02 Apr 07
Date



Identification of dust events



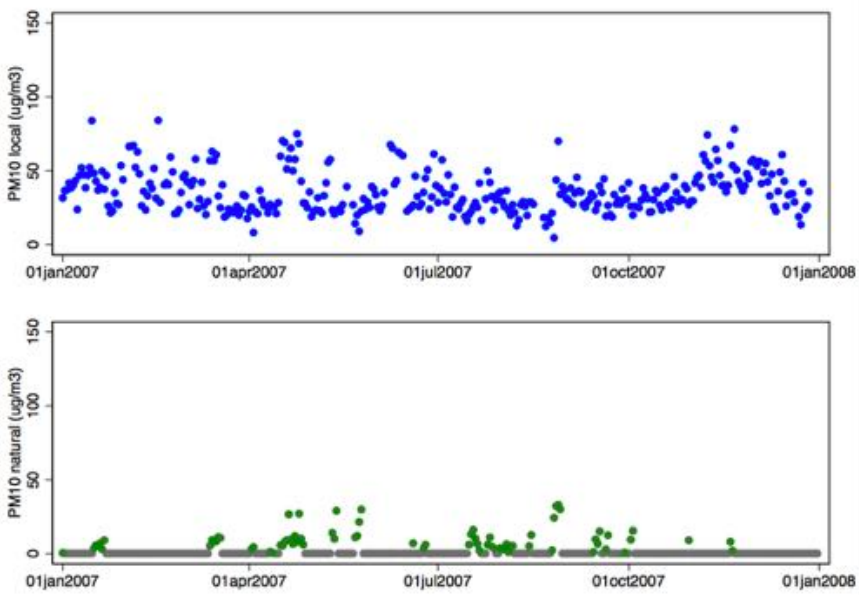
Quantification of dust events



Quantification of dust events

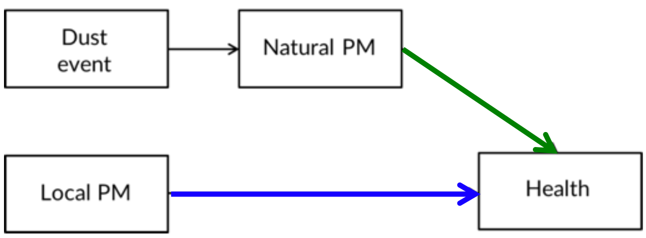
- **EU reference method** (Directive 2008/50/EC)
- **LIDAR** (Light Detection and Ranging) measurement
- Dust concentrations at surface from **ensemble multi-model products**
  - **SDS-WAS**: Prepares regional forecast of a numerical weather prediction model incorporating parameter of all de major phases of the atmospheric dust cycle
  - **MERRA-2**: Global reanalysis to assimilate space-based observations of aerosols and their interactions with other physical processes in the climate system

Rome, 2007



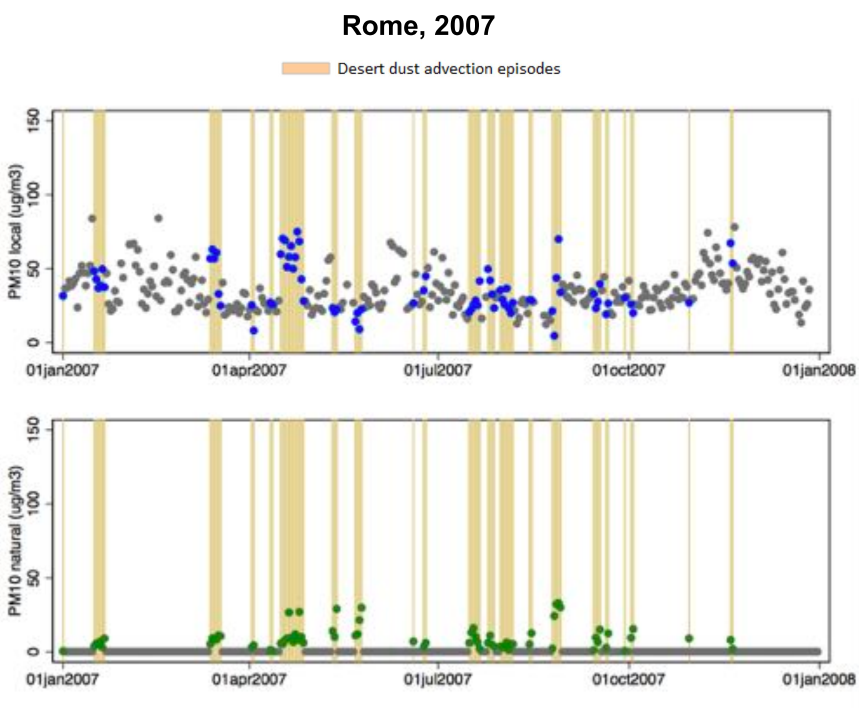
Dust as continuous metric

- **Two sources**
  - Natural (dust)
  - Local (non-dust)



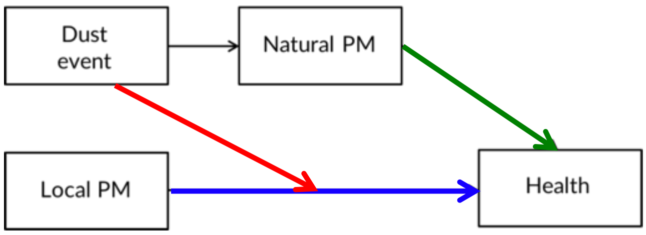
- **Research question –** *Are natural and local sources of PM_{10} independently associated with mortality?*
- Mortality increases by **1.3%** per each 10 $\mu g/m^3$ increase in **natural** PM_{10} and by **0.4%** in **local** PM_{10}

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \beta_1 PM_{natural} + \beta_2 PM_{local}$$



Dust as continuous metric

- **Two sources**
  - Natural
  - Local on dust days
  - Local on non-dust days



- **Research *questions* –** *Is the association between local PM_{10} with mortality different on dust versus non-dust days?*
- Mortality increases by **1.6%** per each 10 $\mu g/m^3$ increase in **local PM_{10} on dust days** and by **0.3%** on **non-dust days**

  – Are these associations independent from natural PM_{10}?
- **Natural PM_{10}** is no associated with daily mortality **(-0.1%)**

$$y_t = \beta_0 + s(t) + \Sigma\beta_i dow_{it} + s(temp_t) + \beta_1 PM_{natural} + \beta_2 PM_{local} + \beta_3 dust + \beta_4 dust*PM_{local}$$

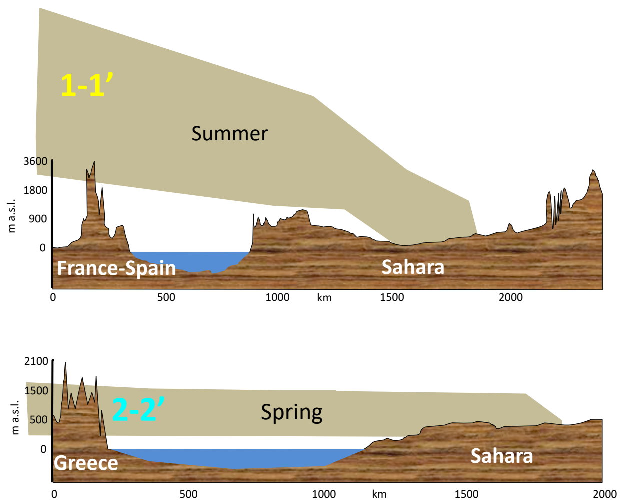
Dust as continuous exposure

- Suitable to **estimate concentration-response functions** between PM sources and health outcomes, applicable in health impact assessment studies
- In regions **with large dust events and high concentrations of local pollutants,** would probably make no sense to investigate independent effects of desert and anthropogenic sources
- Studies in 5 prefectures in Japan – **Larger effects of Asian dust on cardiovascular mortality outcomes and ambulance calls** for respiratory causes than SPM
- Study in 13 European cities – **Similar effects of PM_{10} from local and natural sources** for daily mortality and hospitalizations
- Study in Barcelona – L**arger effects of the local contribution to PM_{10} on dust days than non-dust days**, and the natural contribution to PM_{10} on cardiovascular mortality

Discussion

Transportation

- Dust events over the **western basin** are more frequent with a moderate intensity and dust travels at very high altitudes
- While **eastern** induced by cyclones transporting dust at surface levels with shorter and intense events *(Karanasiou et al. 2012, Pey et al. 2013)*



Discussion

Sources

- The **western** Mediterranean basin is affected by air masses from South Algeria and west Sahara, while **eastern** is from Libya and Egypt *(Pey et al. 2013)*
- Dust **clouds can absorb industrial pollutants** through journey over industrialised areas *(Rodríguez et al. 2001)* also microorganisms and toxic biogenic allergens *(Griffin 2001)*

Toxicity

- Local particles can be more toxic on dust days due to **reactions with gases or condensation of organic compounds** on the particles *(Pérez et al. 2012)*
- Dust episodes associated with a **lowering of the MLH enhancing local pollution** *(Pandolfi et al 2014)*

Discussion

- A **proper understanding of dust exposures** in epidemiological studies would help to develop **appropriate measures to reduce local pollution** during dust events
- Need to **standardize epidemiological studies** with same methodological characteristics to **make health effects comparable** in and near to hot spots

http://www.cost-indust.eu/

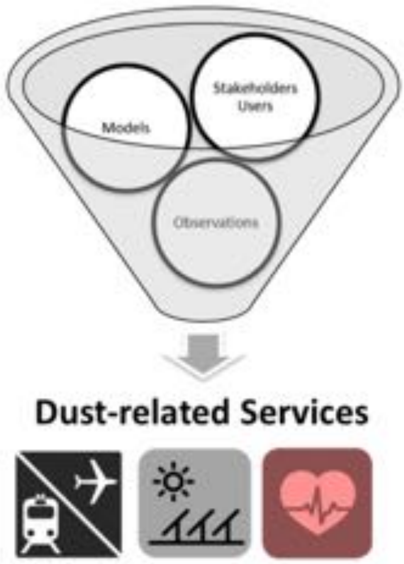
International Network to Encourage the Use of Monitoring and Forecasting Dust Products

COST Action CA16202

Chair: Sara Basart (Spain)
Vice-Chair: Slobodan Nickovic (Serbia)

Period: 14 Nov 2017 – 14 Nov 2021

Barcelona Supercomputing Center
Centro Nacional de Supercomputación



- WG1 Dust observations
- WG2 Dust modelling and forecast
- WG3 Assessment of user and societal benefits
- WG4 Transfer of dust products to user-oriented application and service value
- **WG4-Health** transfer of dust products for epidemiological studies

Acknowledgements

- To the **International Network to Encourage the Use of Monitoring and Forecasting Dust Products** (inDust Cost action, CA16202)
- To the **Japanese Society for the Promotion of Science** (S18149) fellowship for research in Japan
- The systematic review has been funded by the **World Health Organization**, supported by the **Ministry of Foreign Affairs of Norway**

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Dakar, Senegal, 9th December 2019

WMO

EGAR idaea CSIC Consejo Superior de Investigaciones Científicas inDust BSC