# Quantifying the contribution of desert dust episodes on PM concentrations for epidemiological analyses

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*Pre-conference workshop: Desert Dust & Sand Storms, 29th October 2018*
*First Global Conference on Air Pollution and Health:*
*Improving Air Quality, Combatting Climate Change – Saving Lives*
*Geneva, 30th October to 1st November 2018*

World Health Organization

1. Environmental Geochemistry & Atmospheric Research Group, Institute of Environmental Assessment & Water Research, Barcelona, Spain

# Outline

- Desert dust outbreaks, relevant patterns for health studies
- Impact of dust outbreaks on PM levels procedure for the detection and quantification of natural dust contributions
- Examples of applications of the method
- Final considerations

# PM and atmospheric relevant patterns

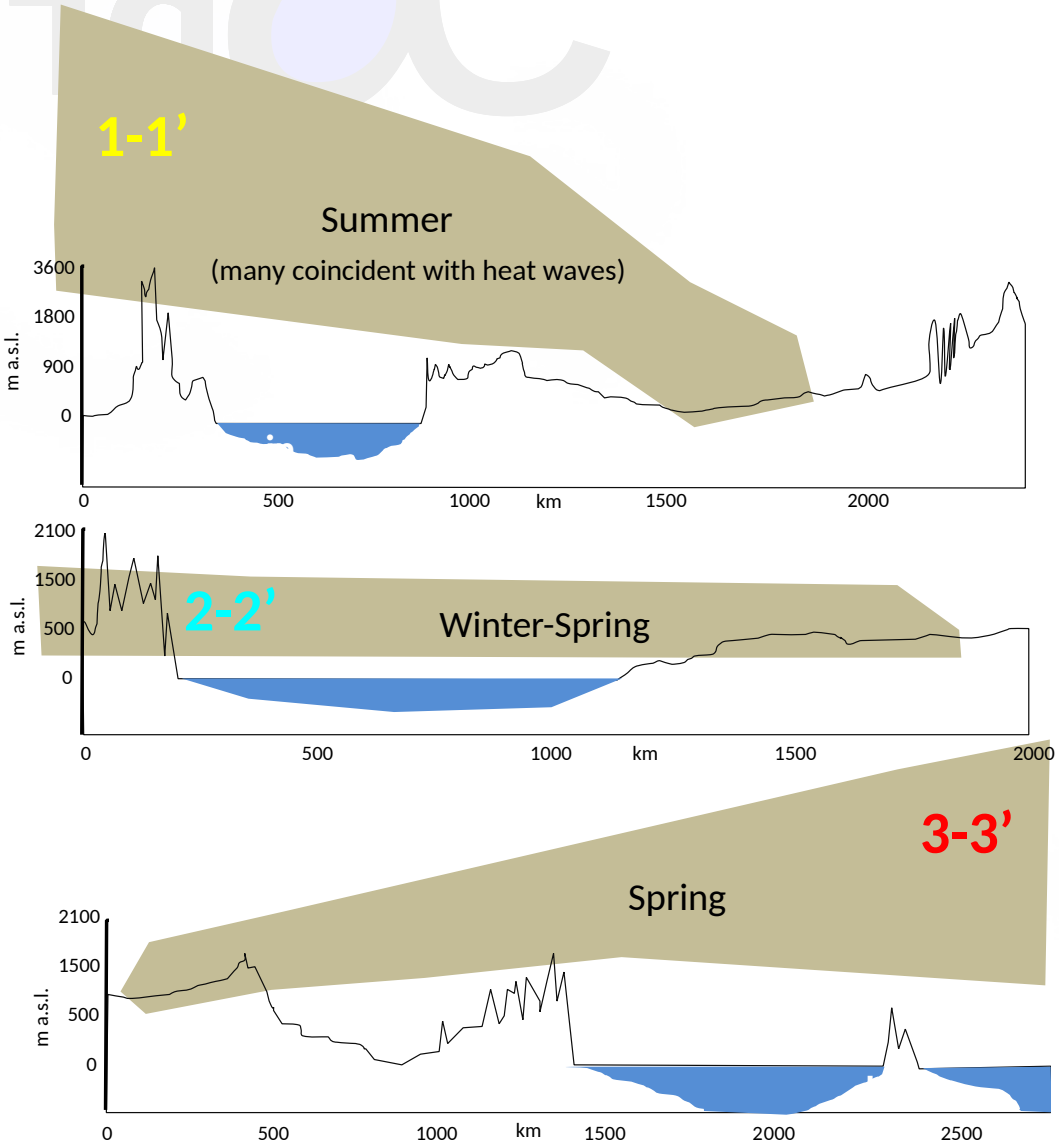
Increased PM concentrations during AODs are caused by:

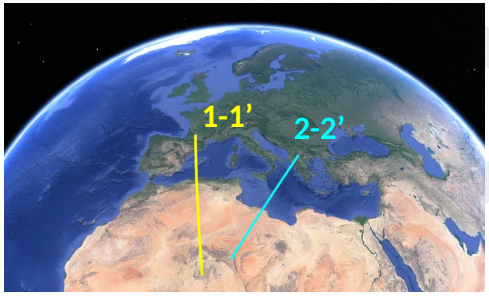
1. Obviously the transport of mineral matter from desert dust
2. The co-transport of anthropogenic pollutants with dust, both emitted at the source areas or entrained during dust transport
3. The accumulation of locally emitted anthropogenic PM pollutants by:
   - 3.1. A relatively low mixing layer height accumulate local pollutants
   - 3.2. Dust favouring the formation of secondary pollutants (such as $nssSO_4^{2-}$)
   - 3.3. If ADOs frequency is higher in spring/summer: higher secondary PM pollutants

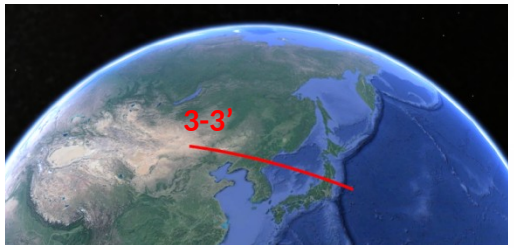
Considering also bioaerosols

- <u>These might strongly vary from one region to other</u>
- Patterns of PM during ADOs that might influence human health are very complex
- These might strongly vary from one region to other
- Not only PMx levels have to be quantitatively contrasted with potential health effects
- ADOs also favour the occurrence of individual or synergistic effects that might involve:
  - Meteorology
  - Anthropogenic co-pollutants
- The impact of this complex mix of PM compounds on human health should be assessed in health assessment analysis of ADOs, if possible independently for anthropogenic and mineral dust loads
- It is not only mineral dust that matters for air quality during dust episodes

# PM and atmospheric relevant patterns

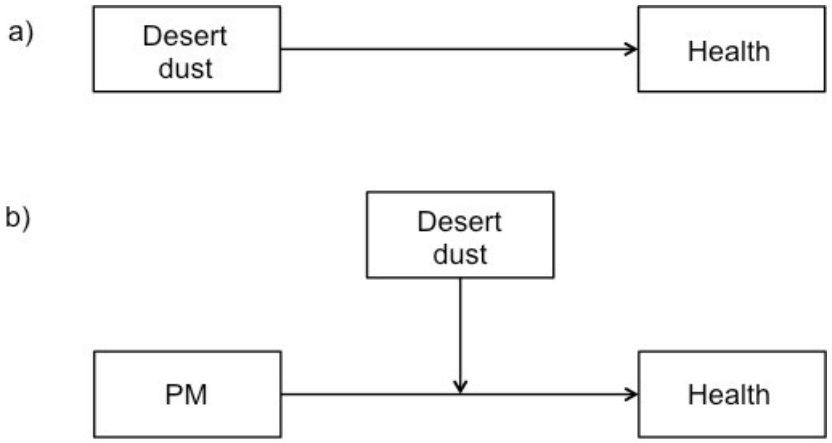


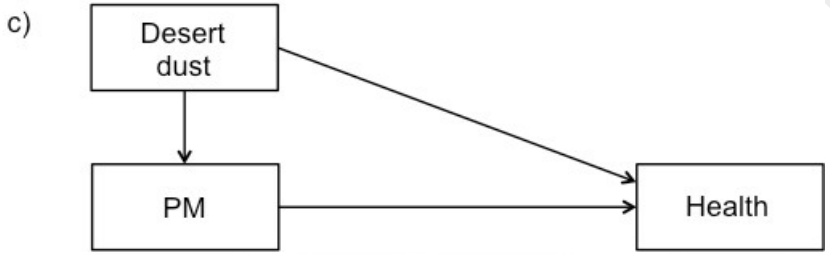



# Design of epidemiology studies

- What should be monitored in dust events to evaluate health effects?
  - Dust load of PMx
  - Anthropogenic load of PMx
  - Meteorological parameters
- Dust and PM parameters to be used in epidemiological (time-series) studies
  - PMx
  - PMx (dust)
  - PMx (non-dust)



# Dust-air quality evaluation system (EU)

http://ec.europa.eu/environment/air/quality/legislation/pdf/sec_2011_0208.pdf

EUROPEAN COMMISSION

Brussels, 15.02.2011
SEC(2011) 208 final

**COMMISSION STAFF WORKING PAPER**

**establishing guidelines for demonstration and subtraction of exceedances attributable to natural sources under the Directive 2008/50/EC on ambient air quality and cleaner air for Europe**

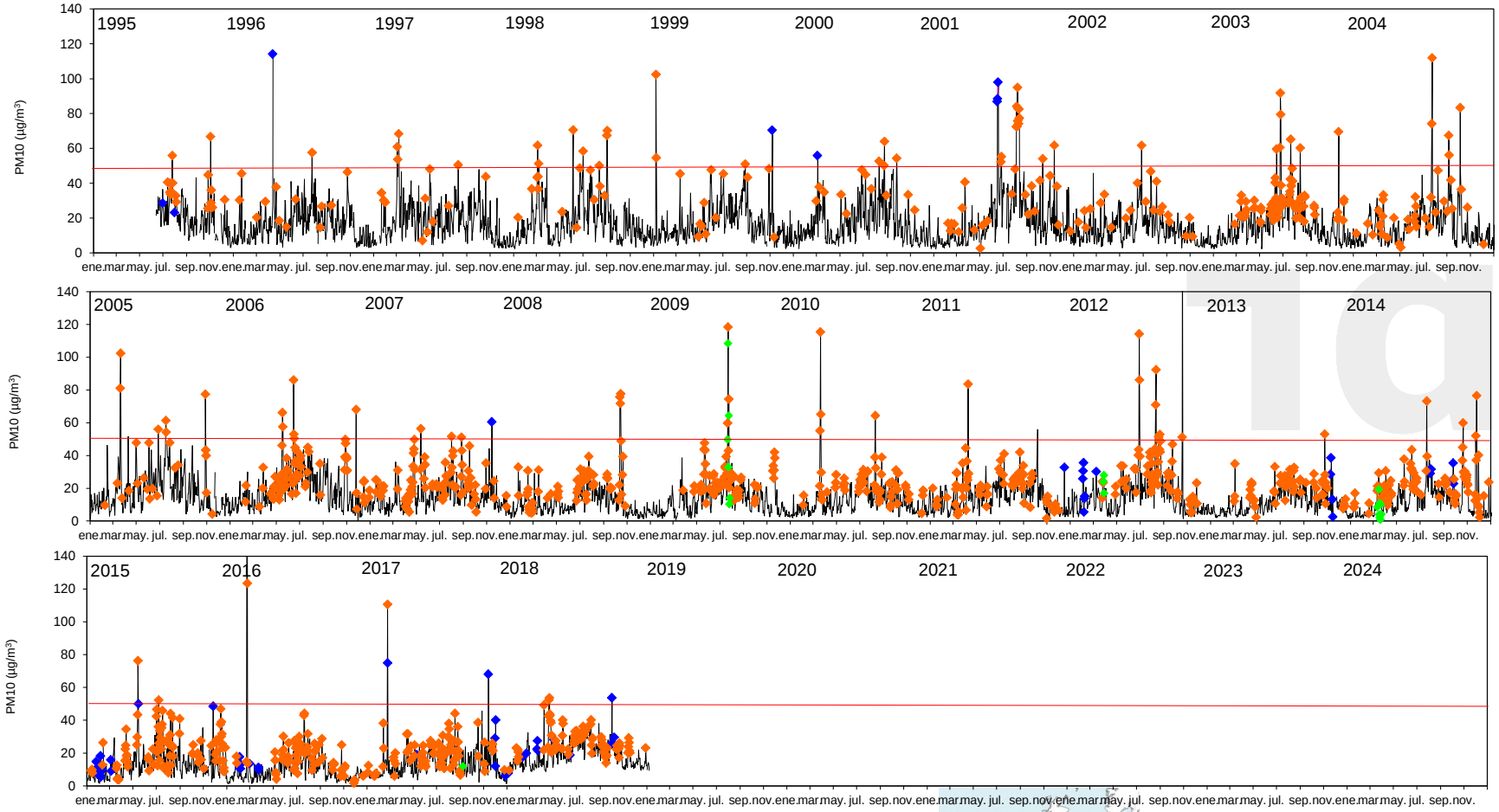
**4.1. Methodology for the determination of re-suspended and transported Saharan dust**

The following describes a procedure to determine the African origin of the exceedances of the daily mean concentration of 50µg/m$^3$. The procedure is based on a method developed in Spain and Portugal (Querol et al., 2006) for application in both countries[10]. It focuses on the daily limit value; discounting the contributions by re-suspended and transported natural Saharan dust episodes in the calculation of the annual average of $PM_{10}$ may however also have a

# Dust-air quality evaluation system (EU)

## African dust, regional background NE Spain

**Daily PM10 (µg/m³)**




**Daily limit value $PM_{10}$ 2008/50/CE (50 µg $m^{-3}$)**

**87 out of 96 exceedances registered in 21.5 years are caused by African dust outbreaks**

- African dust outbreaks
- Local dust from Monegros
- Forest fires

# Dust-air quality evaluation system (EU)

1. **Reporting on the detection of episodes and measurement PM10 levels in EMEP-type sites:**

**1.1. Modelling outputs, meteo and satellite imagery tools**

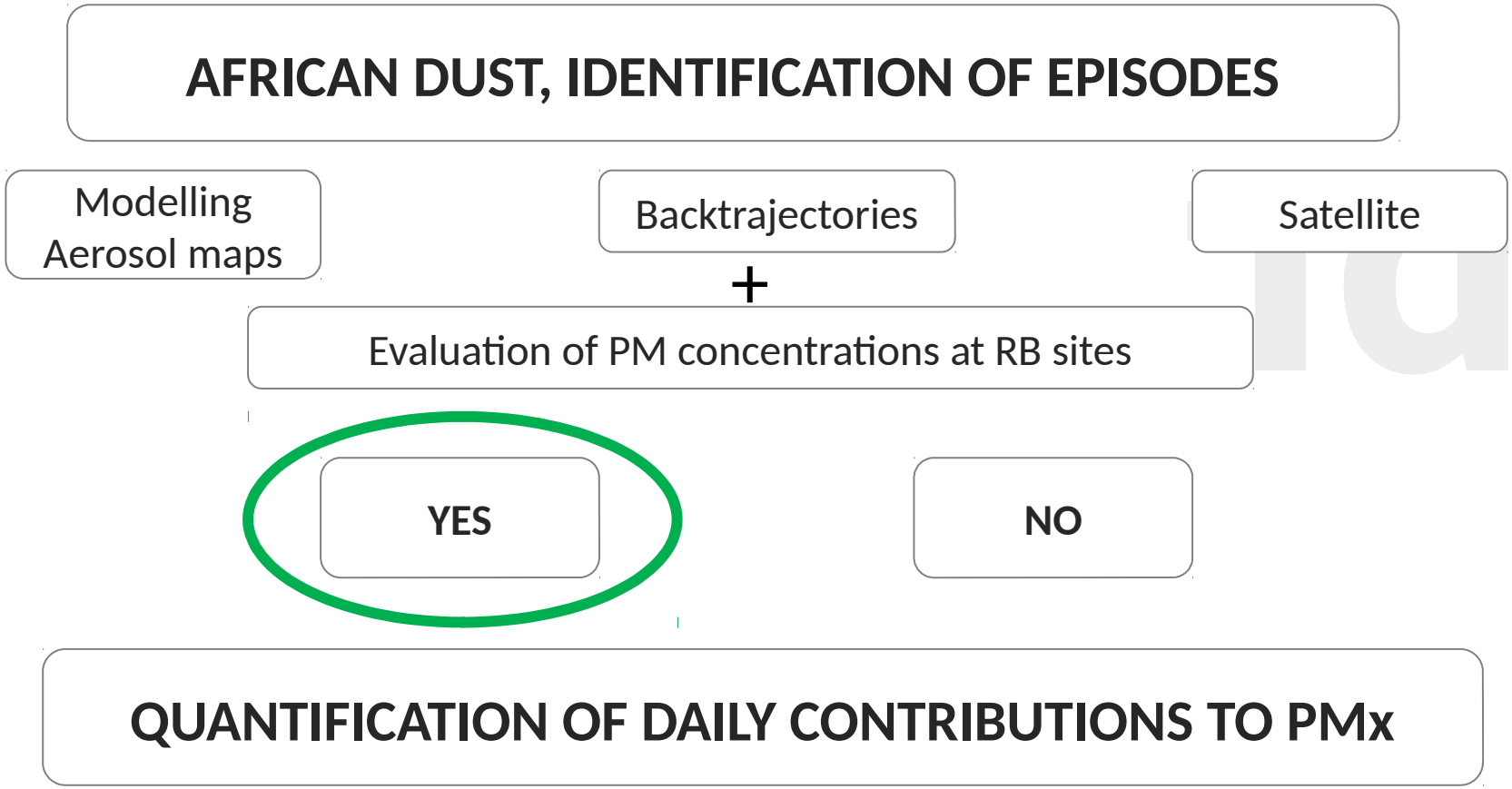
**1.2. Daily evaluation of PM ambient concentrations recorded in a specific regional background monitoring network made of around 25 remote monitoring sites (Spain and Portugal)**

**1.3. Reporting on episodes detected and daily $PM_{10}$ levels for each station of the regional background network**

**1.4. Three months after the end of the year a reporting on scientifically support the occurrence of each episode included in the list**

# Dust-air quality evaluation system (EU)

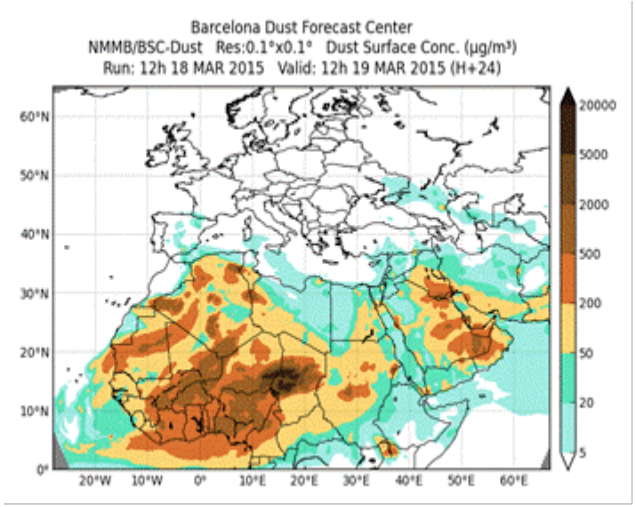
## The percentile method



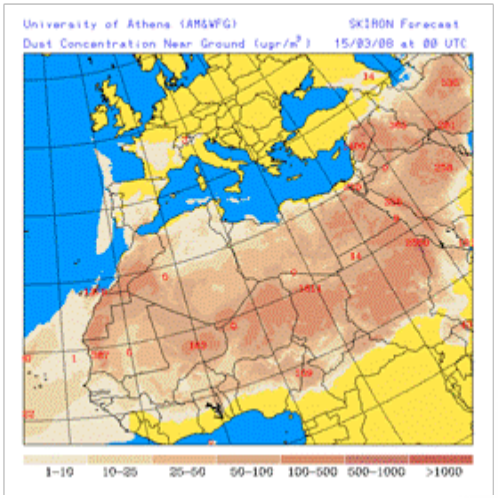
# Dust-air quality evaluation system (EU)

## Identification of Saharan dust outbreaks

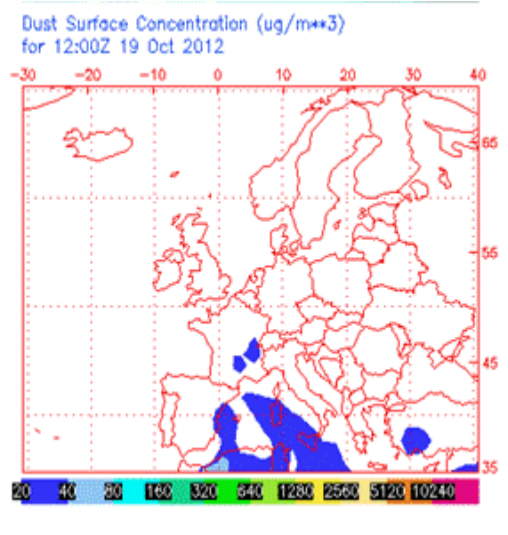
### MMMB-BSC-dust




### SKIRON simulations




### NAAPS - NRL

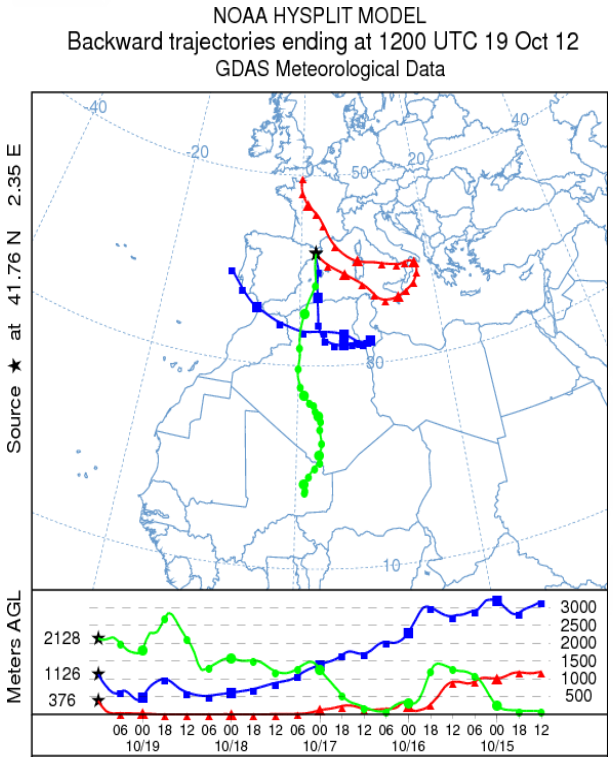


# Dust-air quality evaluation system (EU)

## Identification of Saharan dust outbreaks

## HYSPLIT back-trajectories

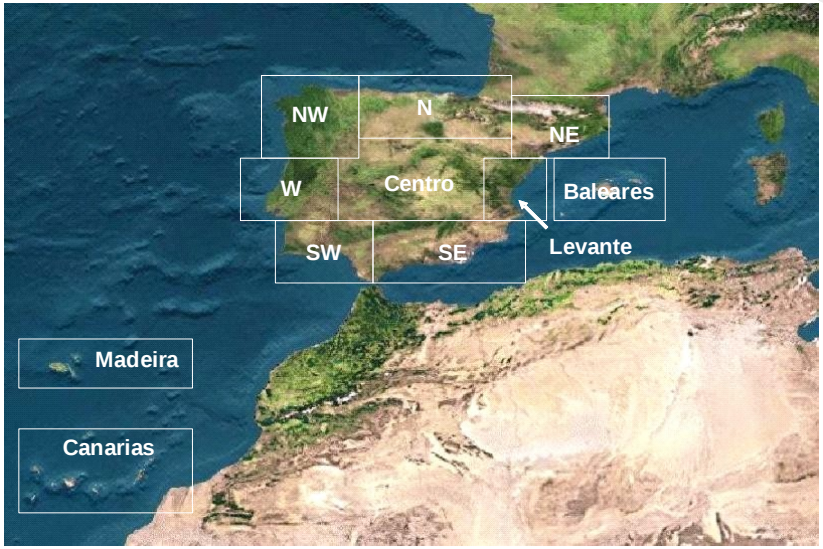
**Calculated for 120 hours at 3 heights: 750, 1500 and 2500 m a.s.l.**



# Dust-air quality evaluation system (EU)

## Reporting on episodes

## Impact on surface PMx concentrations: experimental

# Dust-air quality evaluation system (EU)

Dirección General de Calidad y Evaluación Ambiental

## Reporting on episodes

ENERO 2008

| ENERO 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE |
|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | |
| EUROPEO SULFATOS | | | | | | |
| AFRICANOS | 19-29 | 23 | 23 | 22-23 | 22-24 | 22-23 |

FEBRERO 2008

| FEBRERO 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE |
|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | |
| EUROPEO SULFATOS | | | | | | |
| AFRICANOS | 6-12<br>21-23<br>27-29 | 12-19<br>22-28 | 13-20<br>22-28 | 14-20<br>24-29 | 14-17<br>26-27 | 14-17<br>23-26 |

MAYO 2008

| MAYO 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE |
|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | |
| EUROPEO SULFATOS | | | | | | |
| AFRICANOS | | 2-6 | 2-6 | 3-6 | 2-6 | 3-6 |

MARZO 2008

| MARZO 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE | NORTE | NORESTE | BALEARES |
|---|---|---|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | | | | |
| EUROPEO SULFATOS | | | | | | | | | |
| AFRICANOS | 5<br>13-16 | 2-3<br>15 | 1-3<br>14-16 | 1-3<br>14-15 | 14-15 | | | 15 | 1-3 |

ABRIL 2008

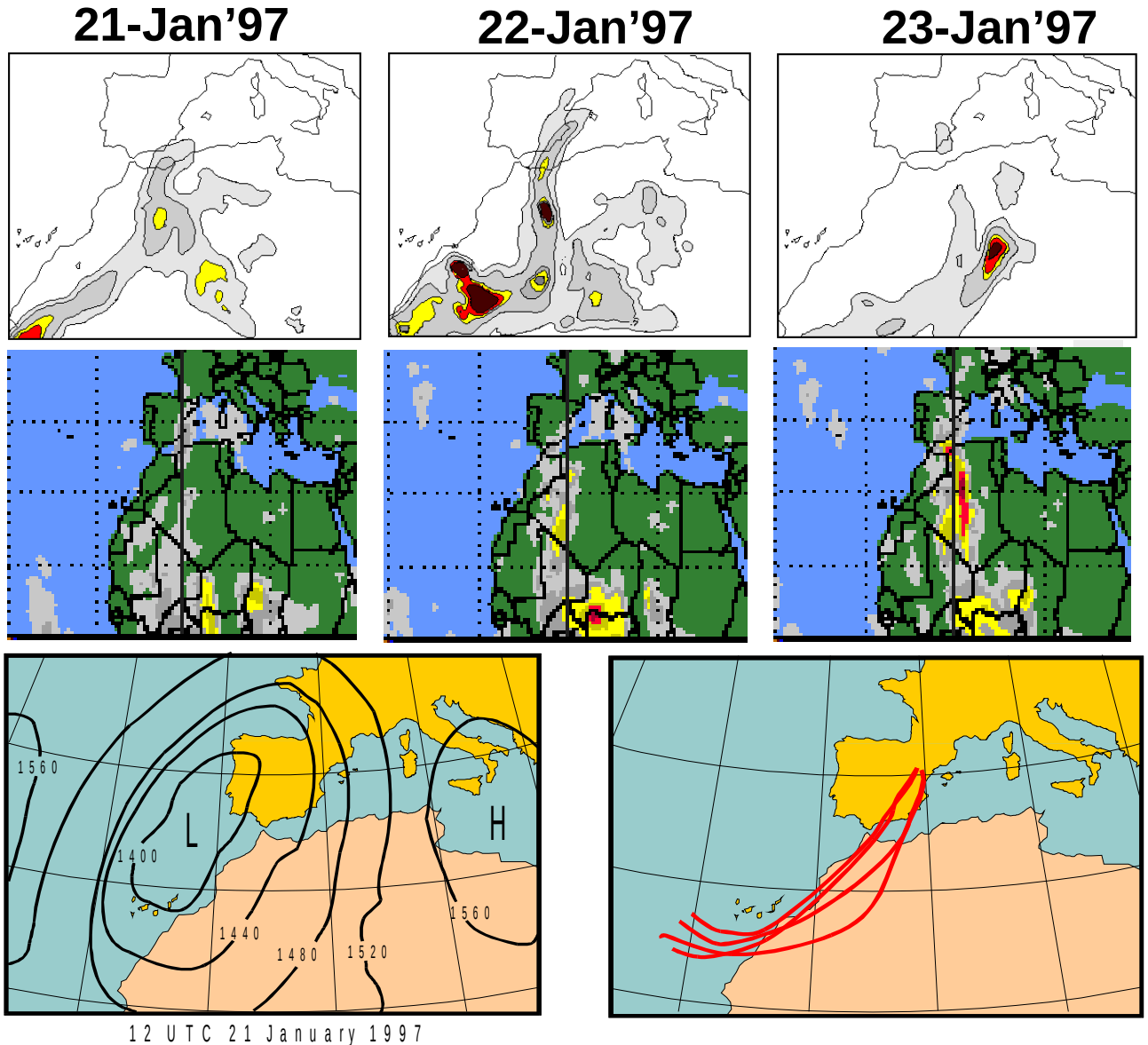
| ABRIL 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE | NORTE | NORESTE | BALEARES |
|---|---|---|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | | | | |
| EUROPEO SULFATOS | | | | | | | | | |
| AFRICANOS | 2-5<br>14-15<br>24-29 | 7<br>16-17 | 7<br>16 | 7<br>16 | 7<br>16 | 7<br>16 | 16 | 16-17<br>27-28 | 16-17<br>28 |

MAYO 2008

| MAYO 2008 | CANARIAS | SUROESTE | SURESTE | LEVANTE | CENTRO | NOROESTE | NORTE | NORESTE | BALEARES |
|---|---|---|---|---|---|---|---|---|---|
| COMBUSTIÓN BIOMASA | | | | | | | | | |
| EUROPEO SULFATOS | | | | | | | | | |
| AFRICANOS | | 2-6 | 2-6 | 3-6 | 2-6 | 3-6 | 3-6 | 2-6 | 2-6 |

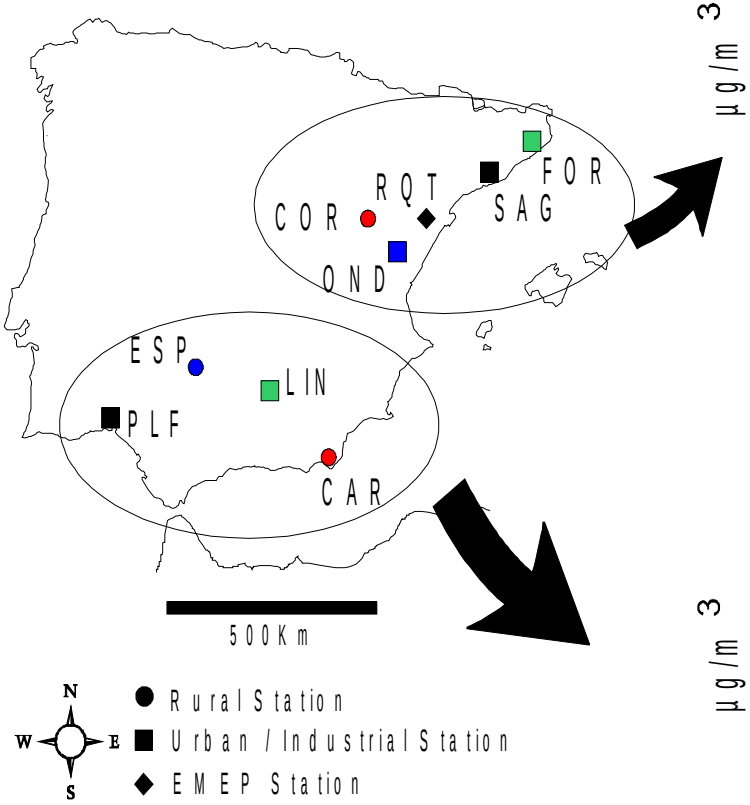
# Dust-air quality evaluation system (EU)

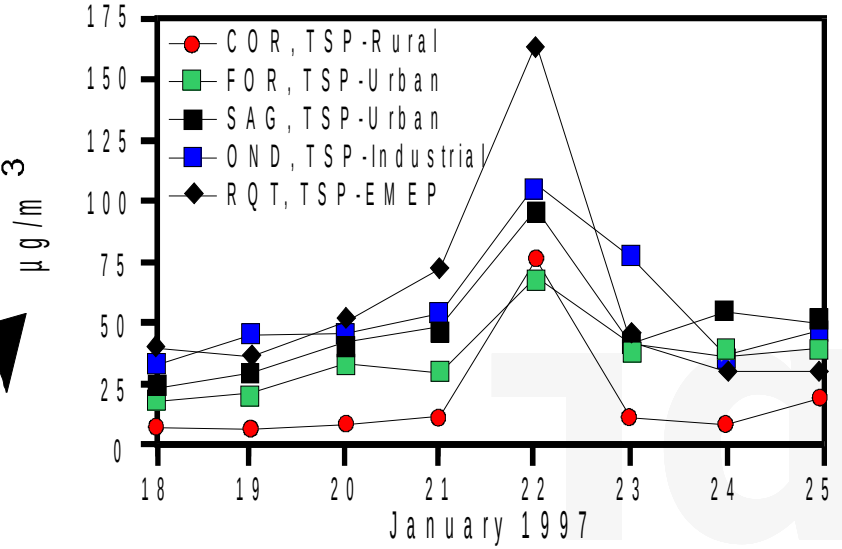
**Example of detection and support information in reporting**

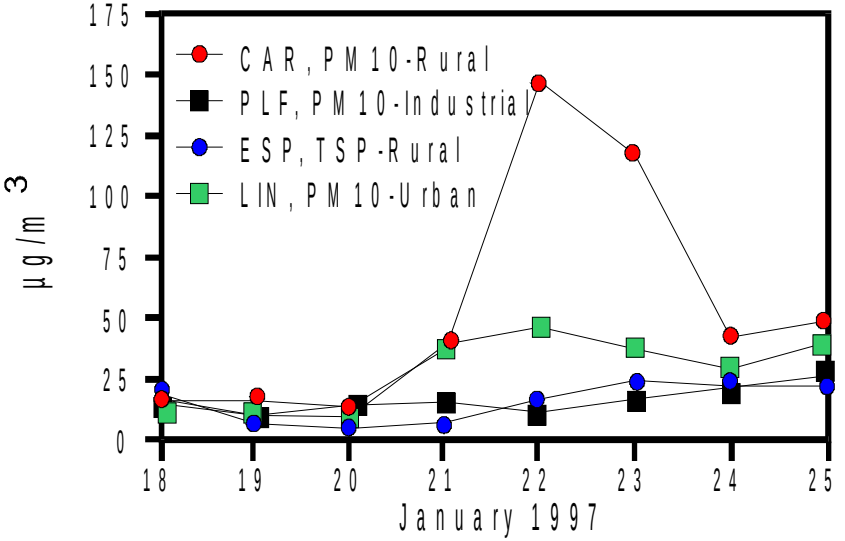


# Dust-air quality evaluation system (EU)

## Reporting on episodes



# Dust-air quality evaluation system (EU)

## The quantitative approach

**Procedure for the quantification of natural contribution to ambient levels of PM**

2. Determining the natural contribution **'net dust load'** for each day of the list of African episodes

2.1. **Local-regional $PM_{10}$ contribution (LRC, without African origin)** determined to be subtracted to the bulk $PM_{10}$ levels during the episode

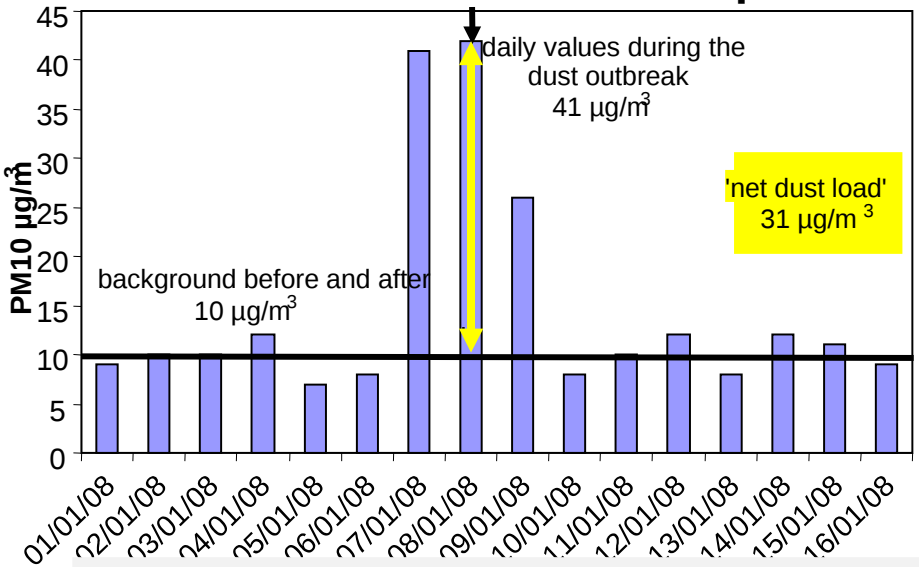
2.2. LRC daily calculated from monthly mobile **40 percentile** (centring the considered day in the middle of the month period) of the $PM_{10}$ levels excluding the African days

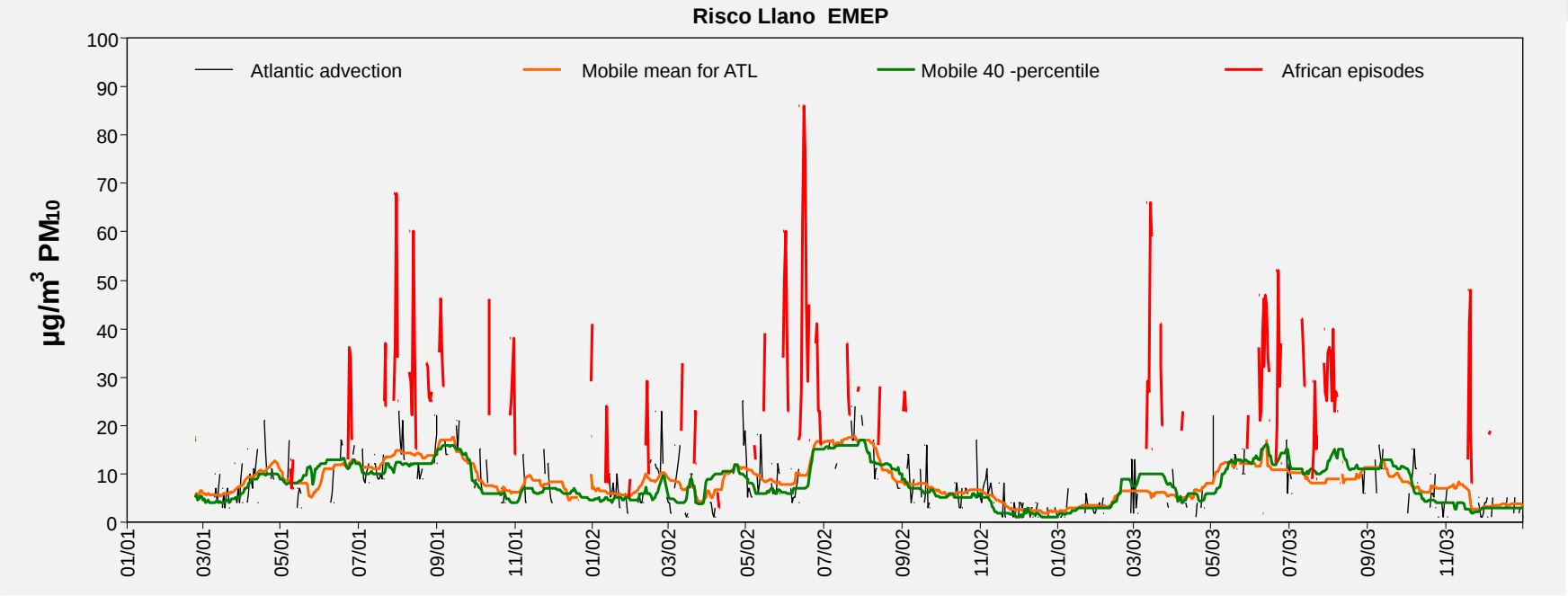
2.3. Then '**net dust load**' for a given day with African dust influence in one regional background station is determined: $PM_{10}$-LRC

2.4. A list of 'net dust load' values for each day and regional background station is produced to be used to subtract the natural dust contribution to $PM_{10}$ during days with exceedances of the DLV recorded at the AQ monitoring sites close to this specific regional background station. The **list** is **produced by the Ministries of the Environment from Portugal and Spain**

# Dust-air quality evaluation system (EU)

## The quantitative approach



# Dust-air quality evaluation system (EU)

## Quantification of Saharan dust

| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | España FR | España EMEP | | SIN NAF | SIN NAF | | PERC 40 | PERC 40 | | Bellver | Mahón | |
| 2 | | Bellver | Mahón | | Bellver | Mahón | | Bellver | Mahón | | Descuentos | Descuentos | NA |
| 3836 | 01/07/2011 | 22 | 15 | | 22 | 15 | | 17 | 14 | | | | |
| 3837 | 02/07/2011 | 15 | 11 | | 15 | 11 | | 17 | 14 | | | | |
| 3838 | 03/07/2011 | 20 | 16 | | | | | 17 | 14 | | 3 | 2 | |
| 3839 | 04/07/2011 | 32 | 20 | | | | | 17 | 14 | | 15 | 6 | |
| 3840 | 05/07/2011 | 22 | 15 | | 22 | 15 | | 17 | 14 | | | | |
| 3841 | 06/07/2011 | 26 | 16 | | 26 | 16 | | 17 | 14 | | | | |
| 3842 | 07/07/2011 | 22 | 21 | | 22 | 21 | | 17 | 14 | | | | |
| 3843 | 08/07/2011 | 28 | 19 | | 28 | 19 | | 16 | 14 | | | | |
| 3844 | 09/07/2011 | 26 | 16 | | 26 | 16 | | 16 | 14 | | | | |
| 3845 | 10/07/2011 | 22 | 20 | | | | | 15 | 13 | | 7 | 7 | |
| 3846 | 11/07/2011 | 31 | 25 | | | | | 15 | 13 | | 16 | 12 | |
| 3847 | 12/07/2011 | 45 | 26 | | | | | 15 | 13 | | 30 | 13 | |
| 3848 | 13/07/2011 | 24 | 17 | | | | | 14 | 13 | | 10 | 4 | |
| 3849 | 14/07/2011 | 17 | 17 | | 17 | 17 | | 13 | 13 | | | | |
| 3850 | 15/07/2011 | 17 | 10 | | 17 | 10 | | 13 | 11 | | | | |
| 3851 | 16/07/2011 | 13 | 11 | | 13 | 11 | | 13 | 11 | | | | |
| 3852 | 17/07/2011 | 21 | 14 | | 21 | 14 | | 13 | 10 | | | | |
| 3853 | 18/07/2011 | 17 | 14 | | 17 | 14 | | 13 | 11 | | | | |
| 3854 | 19/07/2011 | 20 | 19 | | 20 | 19 | | 13 | 11 | | | | |
| 3855 | 20/07/2011 | 11 | 13 | | 11 | 13 | | 13 | 10 | | | | |
| 3856 | 21/07/2011 | 13 | 9 | | 13 | 9 | | 13 | 10 | | | | |
| 3857 | 22/07/2011 | 13 | 13 | | 13 | 13 | | 13 | 10 | | | | |
| 3858 | 23/07/2011 | 14 | 14 | | 14 | 14 | | 13 | 10 | | | | |
| 3859 | 24/07/2011 | 13 | 15 | | 13 | 15 | | 12 | 10 | | | | |
| 3860 | 25/07/2011 | 11 | 10 | | 11 | 10 | | 12 | 10 | | | | |

LEYENDA | OESTE | CANARIAS | SUROESTE | SURESTE | ESTE | CENTRO | NOROESTE | NORTE | NORESTE | BALEARES | MADI

# Dust-air quality evaluation system (EU)

## The quantitative approach

**Determining the anthropogenic and natural contributions to PM in an urban site**

3. **The AQ monitoring networks** compile a list of dates with exceedances of the DLV coinciding with the African dust outbreaks from the report by the **Ministry of the Environment**.

4. The 'net PM10 dust contribution' for the closest regional background site is subtracted from the $PM_{10}$ levels of list produced in task 3 to discount the natural contribution

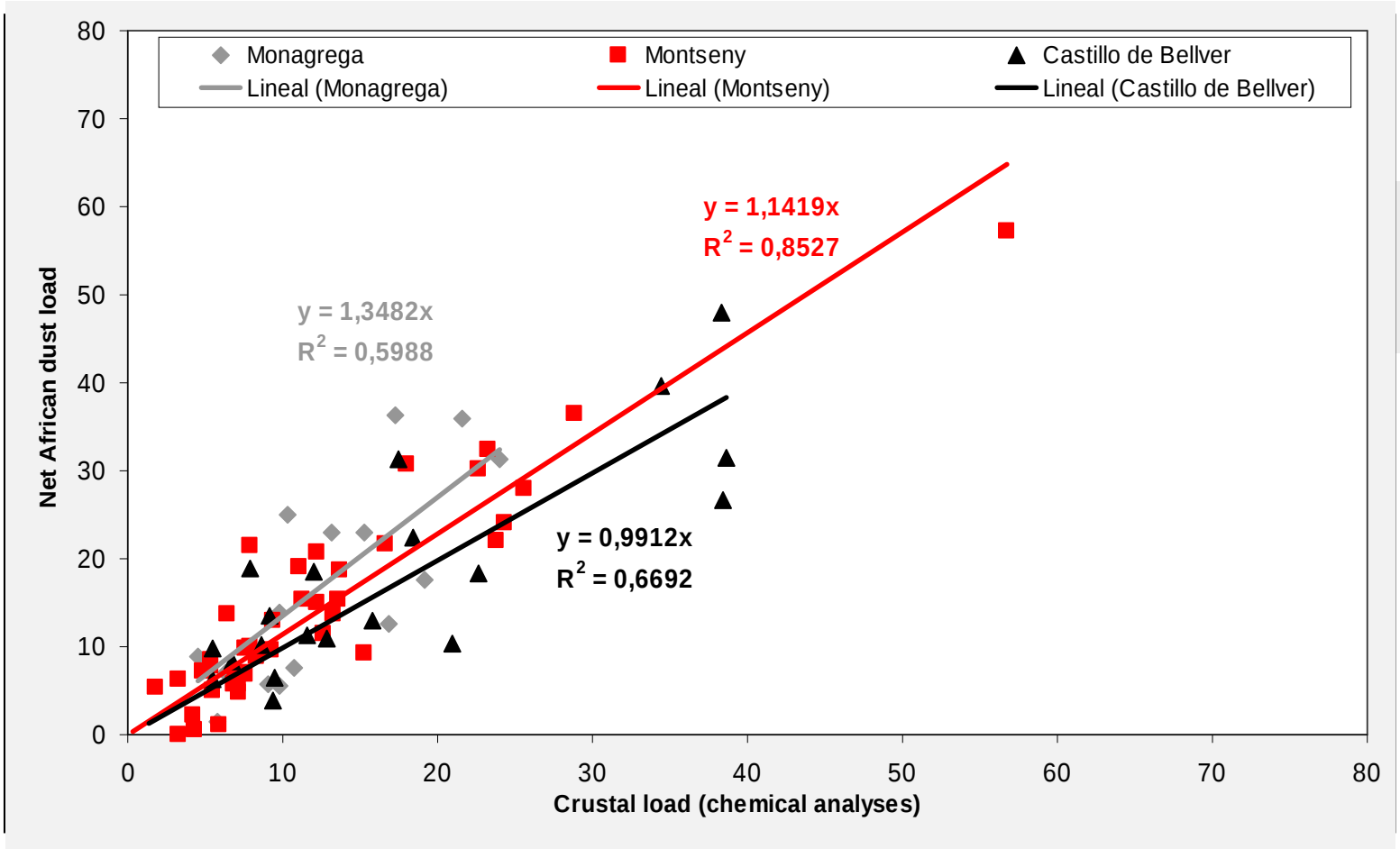
5. If after subtraction, the $PM_{10}$ levels are < DLV (50 µg/m$^3$) then the exceedance will be attributed to the natural contribution, otherwise will be attributed to anthropogenic causes

6. PM10 levels of the days where the exceedances was attributed to natural contributions are not included in the annual average.

7. The AQ monitoring networks reports on:
7.1. Mean average and total number of exceedances
7.2. List of exceedances attributed to natural contributions (exceedances are not deleted!!!)
7.3. Calculated dust contribution to the annual mean (from the difference of the annual mean-annual mean with the subtractions of the calculated daily net dust loads).

# Dust-air quality evaluation system (EU)

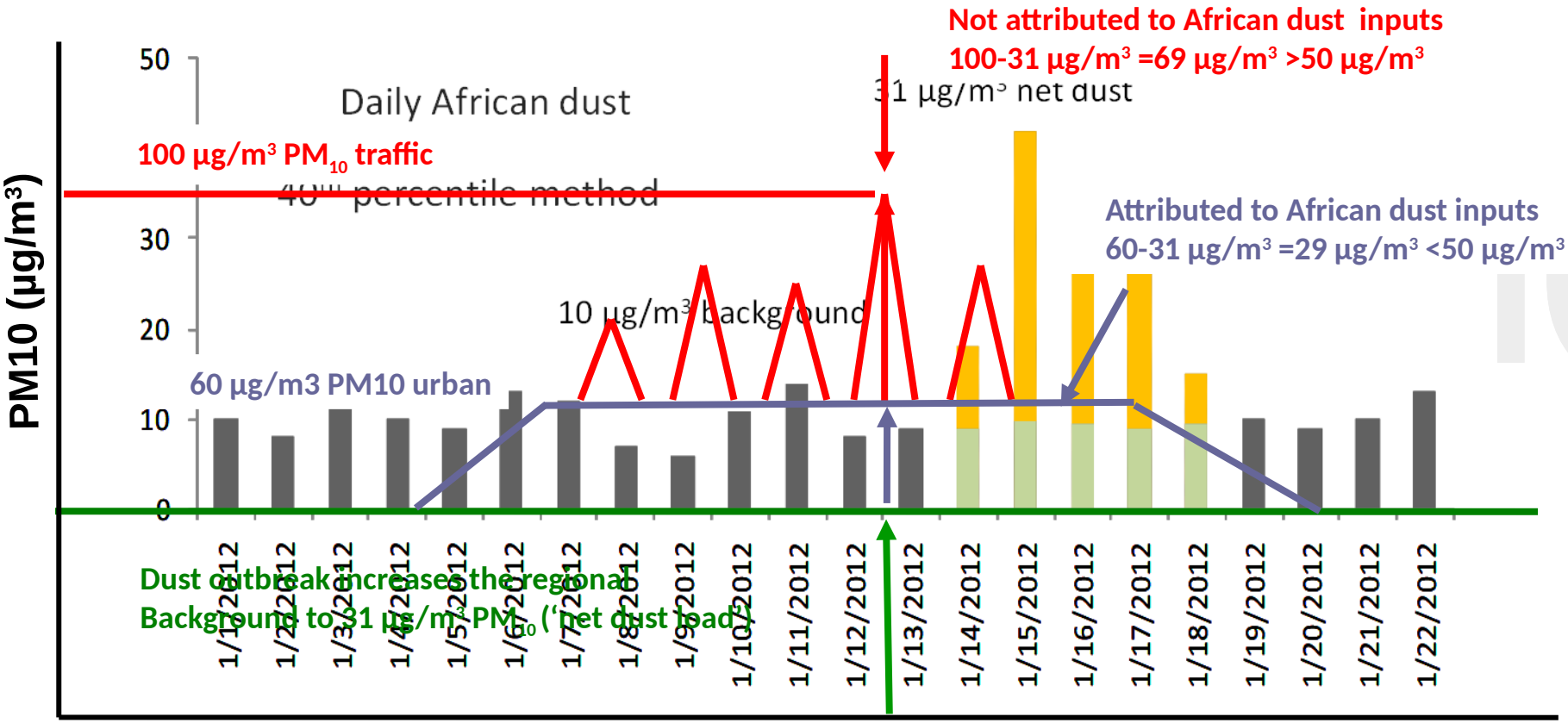
## Validation of the procedure by chemical analysis of PM10



# Dust-air quality evaluation system (EU)

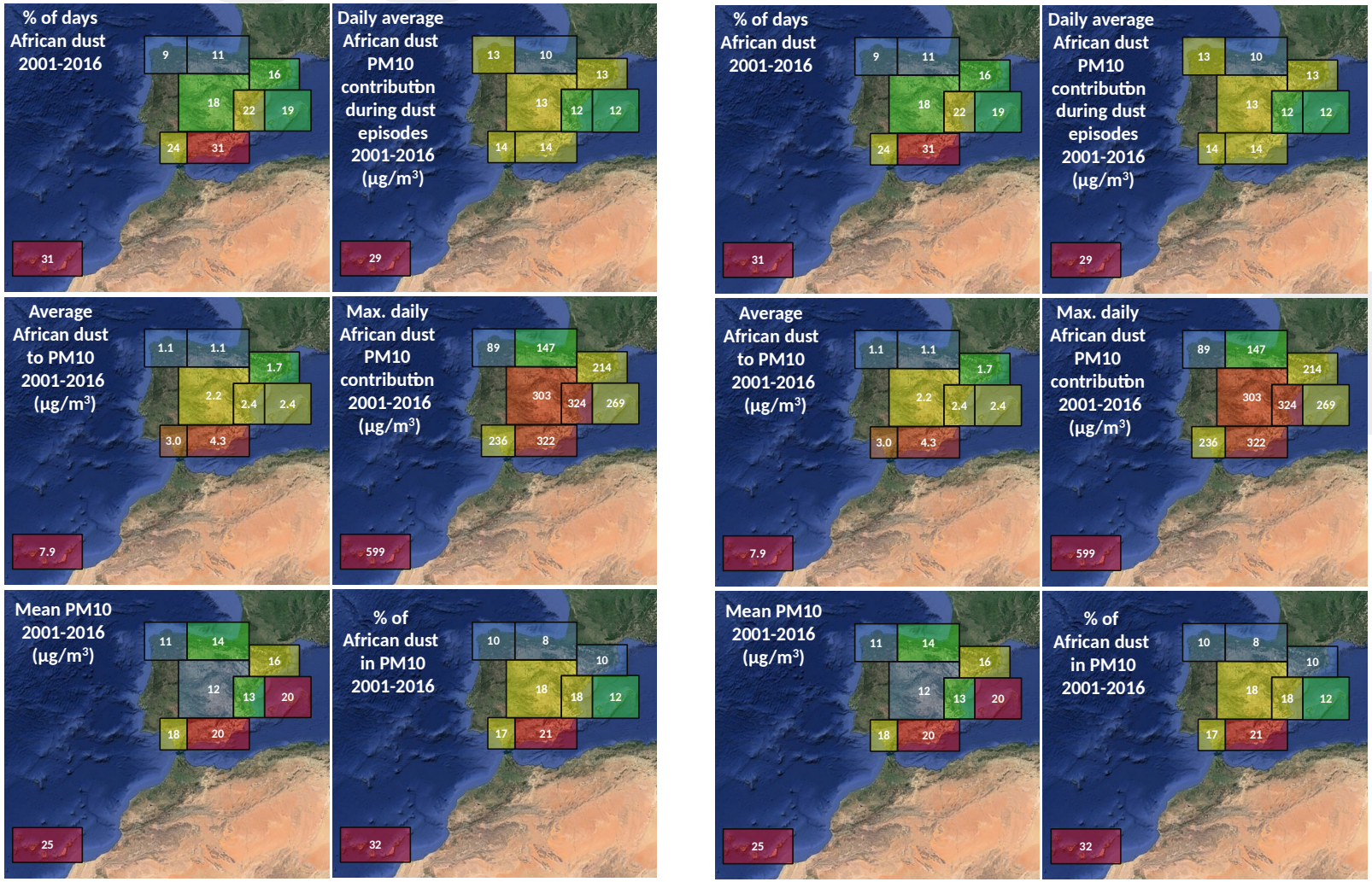
**Determining the anthropogenic and natural contributions to PM in an urban site**

**EXAMPLE**




# Examples of applications

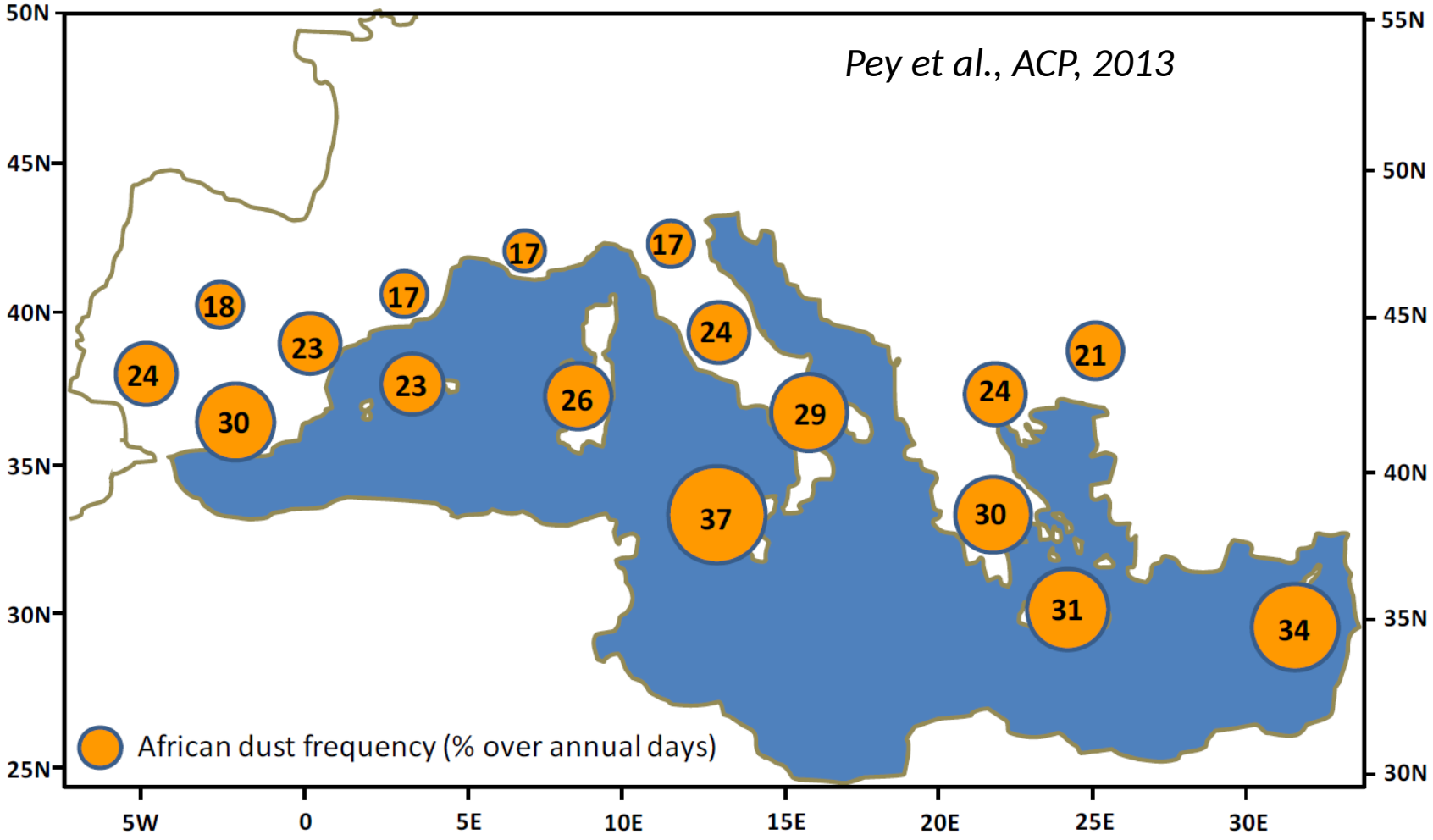
PM10 and PM2.5 Saharan dust loads over Spain 2001-2016




Querol et al., 2019. In prep

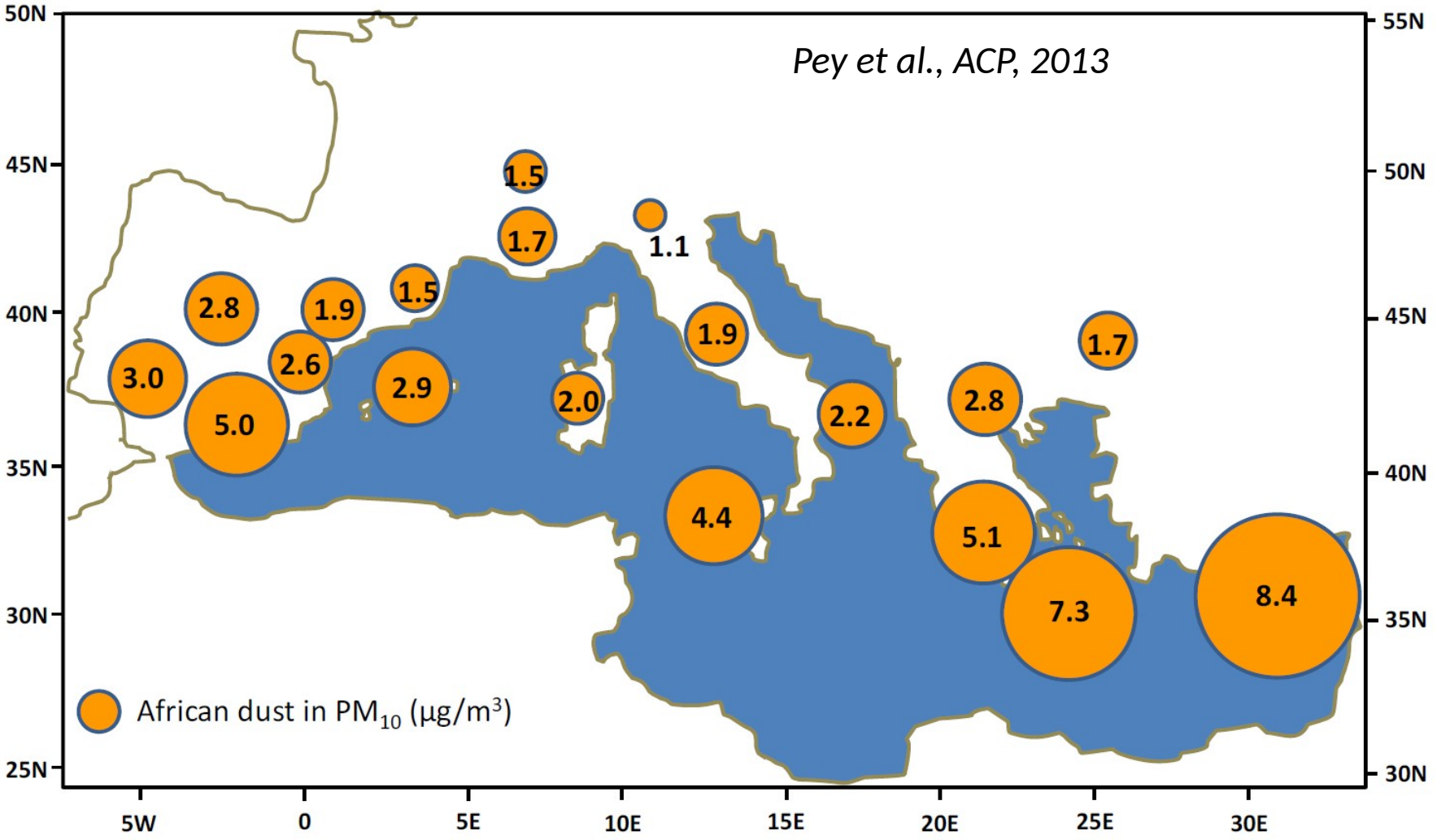
# Examples of applications

**African dust outbreak frequency**



# Examples of applications

**African dust contribution to PM10 in REGIONAL BACKGROUND sites**



# Examples of applications

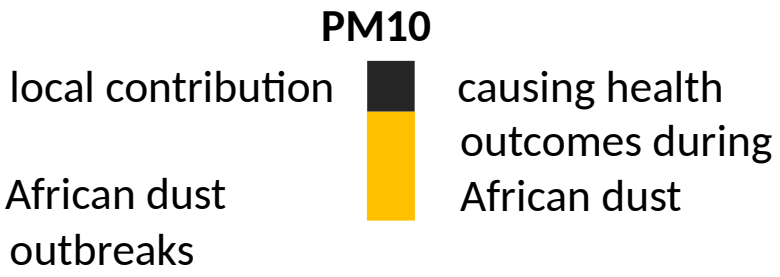
## Dust origin areas and study areas with health effects

- Epidemiological studies: *Perez et al., 2008; Jimenez et al., 2010; Mallone et al., 2011; Tobías et al., 2011; Sajani et al., 2011; Samoli et al., 2011a; Diaz et al., 2012; Perez et al., 2012a, 2012b*
- Toxicological studies: *Polimenakou et al., 2008*
- Inhalation dose: *Mitsakou et al., 2008*
- Pregnancy complications: *Dadvant et al., 2011*
- Pediatric asthma: *Samoli et al., 2011b*
- Meningococcal meningitis: *Tobias et al., 2011b*

**TABLE.** Levels of $PM_{10}$ and Percentage Increase in Risk of Cardiovascular Mortality 10 $\mu g/m^3$ During Non-Saharan Dust Days (Contributing Total $PM_{10}$ Levels) and Saharan Dust Days (Contributing Local and Saharan Contributions to $PM_{10}$ Levels)

| | | | Percentiles | | | | Short-term Effects | |
|---|---|---|---|---|---|---|---|---|
| | Mean (sd) | Minimum | 25 | 50 | 75 | Maximum | Lag | %IR (95% CI) |
| Non-Saharan dust days (n = 1317) | | | | | | | | |
| $PM_{10}$ | 38.6 (15.7) | 7.0 | 27.0 | 35.9 | 47.1 | 107.6 | Lag 0 | 1.1 (−0.1 to 2.4) |
| | | | | | | | Lag 1 | 2.8 (1.6 to 4.1) |
| | | | | | | | Lag 2 | 1.7 (0.5 to 2.9) |
| | | | | | | | Lag 3 | 0.3 (−0.9 to 1.6) |
| Saharan dust days (n = 145) | | | | | | | | |
| Local contributions to $PM_{10}$ | 27.7 (10.7) | 0.0 | 20.6 | 27.5 | 34.6 | 53.0 | Lag 0 | 4.9 (−0.3 to 10.3) |
| | | | | | | | Lag 1 | 9.7 (4.3 to 15.3) |
| | | | | | | | Lag 2 | 6.3 (1.1 to 11.8) |
| | | | | | | | Lag 3 | 7.3 (2.0 to 12.8) |
| Saharan contributions to $PM_{10}$ | 16.5 (12.0) | 0.0 | 8.0 | 13.0 | 23.0 | 57.0 | Lag 0 | 3.0 (−1.5 to 7.6) |
| | | | | | | | Lag 1 | 4.0 (−0.4 to 8.7) |
| | | | | | | | Lag 2 | 2.2 (−2.2 to 6.8) |
| | | | | | | | Lag 3 | 3.5 (−1.0 to 8.1) |

***Perez et al., 2012. Epidemiology***

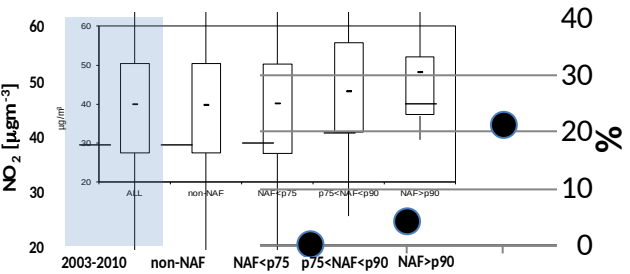


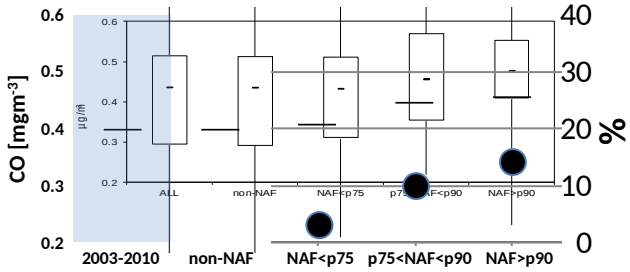
# Examples of applications

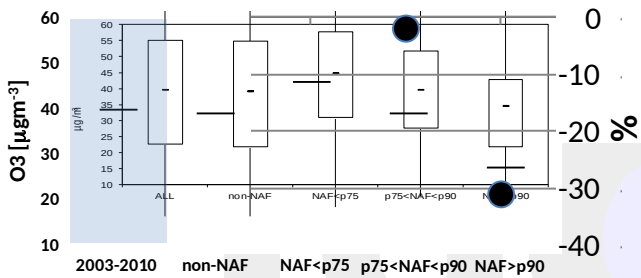
*Pandolfi et al., 2014, STOTEN*

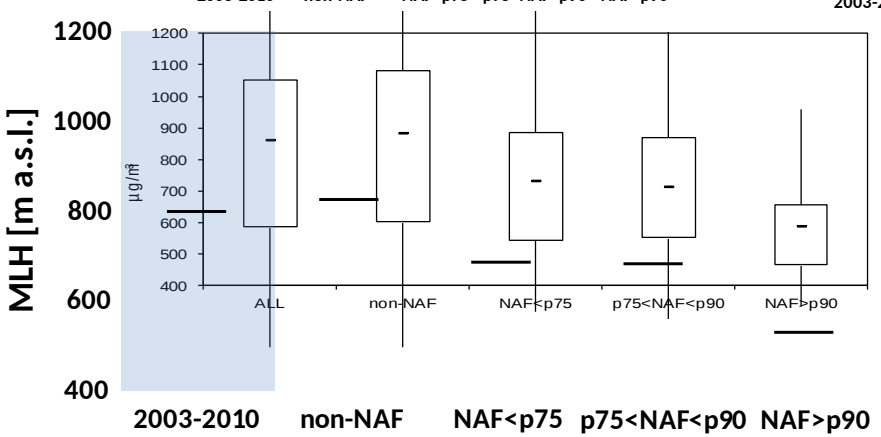
**BARCELONA 2003 – 2010: 2513 MLH days from radiosounding at 12:00 UTC**

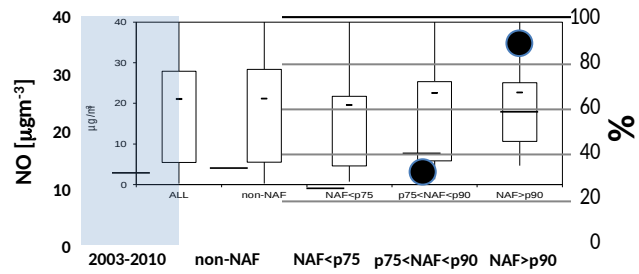
- Effects of Saharan dust outbreaks on MLH
- Effects of MLH oscillation on air quality during Saharan dust outbreaks

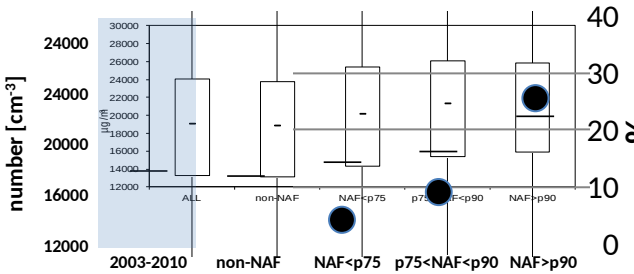


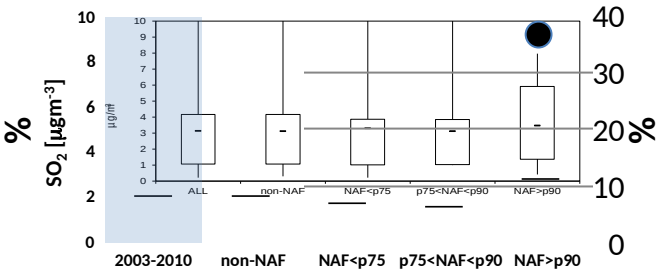



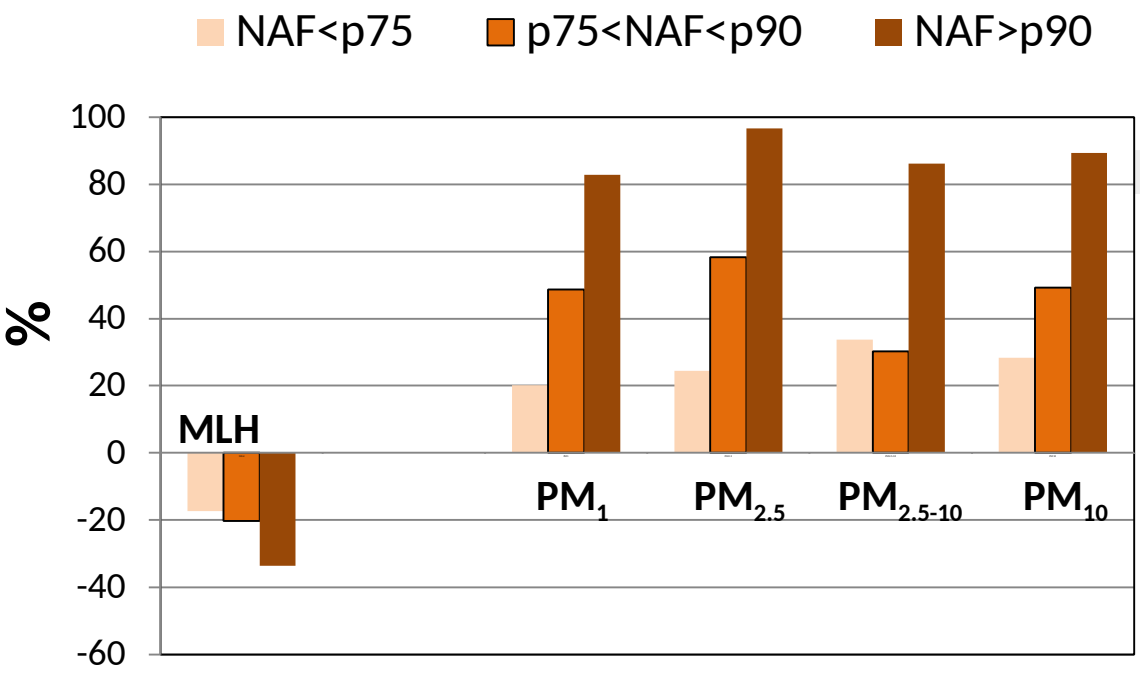



# Examples of applications

*Pandolfi et al., 2014, STOTEN*

**BARCELONA 2003 – 2010**

Relative decrease [%] of MLH and relative increases [%] of PMx concentrations during different NAF episodes intensities compared to non-NAF days




**Comparison >p90NAF with no-NAF**

Local contribution >30-50%

African dust

**PM1>81%**

Local contribution

African dust

**PM10 >85%**

# Examples of applications

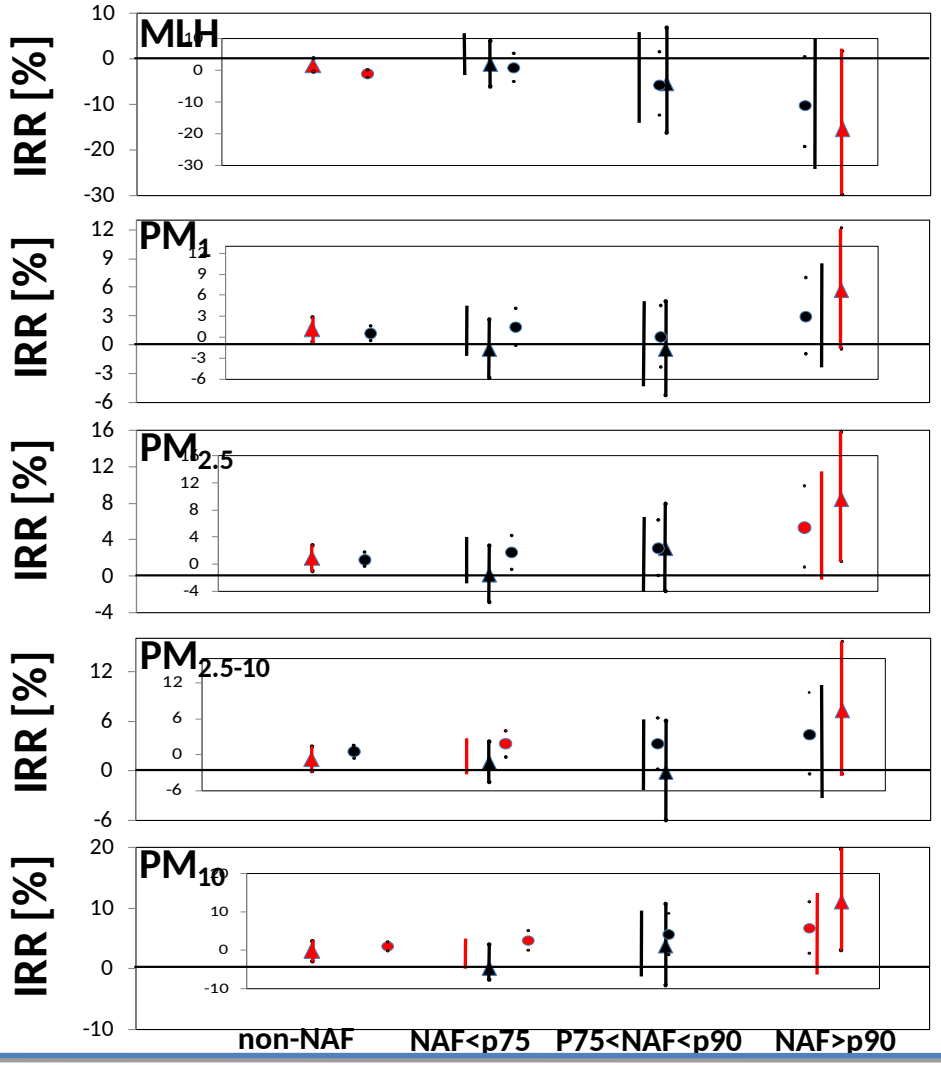
*Pandolfi et al., 2014, STOTEN*

**BARCELONA 2003 – 2010**

**Effect of MLH oscillations on health during Saharan dust outbreaks**

2003 - 2010

2003 - 2007



# Final considerations

**Major questions still not replied**

What causes health effects?

- Temperature increase
- Dust
- Non-dust fraction
- Microorganisms
- Mixed anthropogenic PM
- Other

Why in some studies we find health outcomes and not in others?

- **Do methods yield some outputs concerning PM contributions?**
- A temperature increase much pronounced in some regions
- Microorganisms
- Different source or mix (with anthropogenic PM)
- Other

Need for harmonization of study designs and exposure control

How might we reduce population exposure to PMduring dust outbreaks?

- Abate resuspension after episodes
- Decrease emissions of local pollutants
- Informing sensible population (How? When?)
- Other ???

# Acknowledgements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- Also to the Ministry of the Environment of Spain for supporting this research since 1999


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