What we have learnt since the European aerosol phenomenologies 1 and 2 (2004)

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Phenomenology – rationale, definition, etc…

- **Rationale**
  - in 2001, PM mass concentration was already monitored at 100's of sites
Phenomenology – rationale, definition, etc…

• Rationale:
  – In 2001, PM mass concentration was already monitored at 100’s of sites.
  – Considering that PM mass concentration:
    – could **probably not totally explain** the health effect of particulate air pollution
    – was **not the right variable** for addressing the climate effect of particulate air pollution
    – was **not sufficient** for validating models

  the JRC initiated a collaboration with (mainly) research institutes to compile aerosol physical and chemical properties across Europe.

• Question:
  What is hidden behind PM mass concentrations?
Phenomenology – rationale, definition, etc…

• Background:
  – No specific project (CREATE started in 2003).
  – The Community was not very enthusiastic.

• A definition:

  *Phenomenology*: the branch of philosophy that deals with what you see, hear, feel, etc., in contrast to what may actually be real or true about the world.
Phenomenology – 1 (2004): physical characteristics of PM

- Sites:
  - 15 natural, rural, near-city, urban and kerbside sites (9 covering 1 year of data or more) with PM mass and particle number data
  - No continuous measurement south of Ispra (IT) and east of Aspvreten (SE)
Results:

- Important impact of the regional background on PM mass concentration
- Particle number concentration does not correlate well with PM mass concentration
Phenomenology – 2 (2004): chemical characteristics of PM

• Sites:
  – 24 natural, rural, near-city, urban and kerbside sites (16 covering 1 year or more) with PM mass and constituent concentration data.
  – No measurement of NH$_4$NO$_3$ and/or carbonaceous aerosol at 13 sites (6 with 1 year of data or more).
Phenomenology – 2 (2004): chemical characteristics of PM

• Results (1):
  – Organic Matter seems to be the major constituent of PM$_{10}$ and PM$_{2.5}$, except at natural and rural background sites, where SO$_4^{2-}$’s contribution can be greater.
  – Elemental Carbon contributes 5-10% to PM$_{2.5}$ (a bit less to PM$_{10}$) at all sites, incl. natural background sites.
Results (2):

- $\text{NO}_3^-$’s contribution increases with PM mass concentration. When $\text{PM10} \geq 50 \, \mu g/m^3$ (winter), $\text{NO}_3^- \geq \text{OM}$

- The lack of harmonization in measurement techniques renders the comparison between sites difficult
Phenomenology –3 (2010): phys. & chem. characteristics of PM

- Sites:
  - 60 natural, rural, near-city, urban and kerbside sites (50 offering 1 year of data or more) with PM mass and constituent data (COST 633 contribution).
  - spatial coverage still heterogeneous but becomes better.
Phenomenology –3 (2010): phys. & chem. characteristics of PM

- Results from Phenomenology 1 and 2 confirmed:
  - There is no general correlation between PM mass and particle number concentration.
Phenomenology –3 (2010): phys. & chem. characteristics of PM

- Results from Phenomenology 1 and 2 confirmed:
  - Organic Matter, $\text{SO}_4^{2-}$ and $\text{NO}_3^-$ are the main constituents of PM$_{10}$ and PM$_{2.5}$, and when moving from kerbside to urban to rural sites:
    - The contribution of carbonaceous aerosol decreases
    - The contributions of $\text{SO}_4^{2-}$ and $\text{NO}_3^-$ increase.
Phenomenology – 3 (2010): phys. & chem. characteristics of PM

• New results from Phenomenology -3:
  – The ratio ultrafine particle number / total particle number decreases as PM mass concentration increases at all sites (29) but 1.
  – Gradients in PM chemical composition when moving from North-western to Southern to Central Europe:
    – The contribution of carbonaceous aerosol is generally greater in Central Europe
    – The contributions of $\text{SO}_4^{2-}$ and $\text{NO}_3^-$ are similar across these 3 sectors.

• Sites:
  – particle number concentration and size distribution data from 24 stations
  – lack of stations in Eastern Europe and in the Mediterranean basin

A. Asmi et al., Atmos. Chem. Phys., 11, 5505–5538, 2011

• Results:
  - high variability in particle number concentration and size distribution, but grouping based on location is possible.

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Results (2):

- high variability in particle number concentration and size distribution, but grouping based on location is possible.
- numbers of particles <100 nm and >100 nm are generally related.
- the week-end effect is weak for particles > 30 nm (see also Asmi, 2012).
- reliable information based on harmonized long-term measurement made freely available on-line for comparison with model outputs:
  - http://ebas.nilu.no/
  - http://www.atm.helsinki.fi/eusaar/

- Sites:
  - 24 sites offering 2 years of harmonised number size distribution data sets
  - ...

D. Beddows et al., Atmos. Chem. Phys., 14, 4327–4348, 2014

• Results:
  – all types of particle number size distributions (clusters) can be detected at almost all sites
  – the particle number size distribution clusters can be combined in 2 groups
    - Central Europe: afternoon nucleation, and growth from south to north → Arctic
    - Outer Europe: regional nucleation at coastal sites and growth from west to east

• Sites:
  – data from 24 stations covering ≤2003 to 2009 - 2010
  – 17 stations in North-America, 5 in Europe, 2 in Antarctica

• Results:
  – No significant trend for European continental sites, opposite trends for others
  – Mostly decreasing trends in continental USA, increasing at Mauna Loa
Aerosol decadal trends - Part 2: number concentrations (2013)

- Sites:
  - data from 16 stations covering ≤2001 to 2010 - 2011
  - 8 stations in Europe, 4 in continental North-America, 2 in the Pacific Ocean, 2 in Antarctica
Aerosol decadal trends - Part 2: number concentrations (2013)

- Results:
  - clear decreasing trends in particle number at most sites, especially in winter
  - generally consistent with trends in CCN proxies in Europe
Phenomenology – 4 (2016): harmonized concentrations of carbonaceous aerosol at regional background sites

- Sites:
  - 10 regional background sites providing data from at least 2 full years between 2008 and 2011.
  - Harmonized data, but sampling artifacts continuously addressed at 4 sites only.
Phenomenology – 4 (2016): harmonized concentrations of carbonaceous aerosol at regional background sites

• Results:
  – TC/PM$_{10}$ annual mean ratios range from 0.11 at a Mediterranean site to 0.34 at the most polluted continental site, and TC/PM$_{2.5}$ ratios are slightly greater at all sites (0.15 – 0.42).

Error bars show one mean absolute deviation around corrected averages.
Phenomenology – 4 (2016): harmonized concentrations of carbonaceous aerosol at regional background sites

• Results:
  − TC/PM$_{10}$ annual mean ratios range from 0.11 at a Mediterranean site to 0.34 at the most polluted continental site, and TC/PM$_{2.5}$ ratios are slightly greater at all sites (0.15 – 0.42).
  − EC/TC annual mean ratios range from 0.10 to 0.22, and do not depend much on PM concentration levels, especially in winter.
Phenomenology – 5 (2016): black carbon optical properties at regional background sites

• Sites:
  – 9 regional background sites providing data from 1-4 years between 2008 and 2011.
  – harmonized elemental carbon and aerosol light absorption data
Phenomenology – 5 (2016): black carbon optical properties at regional background sites

• Results:
  - The annual mean mass absorption cross-section (MAC) of elemental carbon is quite similar across all sites (geometric mean = 10.0 m²/g, range 7.5 - 13.3)

Box plots show the 10th, 25th, 50th, 75 and 90th percentiles
Red markers show the geometric mean values.
Green error bars show the uncertainty of the geometric mean value.
Results:

- The internal mixing of elemental carbon with other components enhances light absorption (lensing effect)
Phenomenology –Y (201X): high-time resolution chemistry of submicron particulate matter

• Sites:
  – 21 sites with data covering 1 - 3.5 years between 2011 and 2015.
  – 15 ACTRIS and/or GAW sites, 4 national air quality network sites
  – harmonized data processing (collection efficiency, ionization efficiency, relative ionization efficiency)

M. Bressi et al, in prep.
Phenomenology –Y (201X): high-time resolution chemistry of submicron particulate matter

• Results:
  – Organics’ contributions are substantial in all regions and at all types of site (32-68%).
  The highest contribution is observed in northern Europe (61% on average).
Phenomenology – Y (201X): high-time resolution chemistry of submicron particulate matter

• Results:
  – The highest $\text{SO}_4^{2-}$ contributions are found in southern Europe, and at remote and coastal sites (27-29%).
Phenomenology –Y (201X): high-time resolution chemistry of submicron particulate matter

• Results:
  – The highest NO$_3^-$ contributions are primarily observed in mid-latitudes, and at urban and regional sites (24-25%).
  
  NO$_3^-$ contributions increase with PM mass concentrations at 14/24 sites.

ACTRIS-2 Science Meeting – Granada, Spain – 01 February 2017
What have we learnt since the European aerosol phenomenologies 1 and 2?

1. There’s kind of a relationship between PM mass and particle number concentrations, but the variability is big.
2. The variability in particle number size distribution can be explained by the combination of a few processes.
3. Particle number have decreased over 2000 - 2010, but the WE effect is low.
4. PM chemical composition (intensive) is much less variable than concentrations (extensive).
5. Carbonaceous matter is the main constituent of PM in all size fractions at almost all sites.
6. Nitrate contribution increases with PM concentration at most sites.
7. The mass absorption cross-section (MAC) of elemental carbon is similar at all regional background sites across Europe.
What have we learnt since the European aerosol phenomenologies 1 and 2?

- We have learnt to work together (open access to data), and that it is worth processing and discussing data from others (European dimension).

- We have learnt what “phenomenology” means (meant), and how to shift from “measured” to “true” values for a set of atmospheric variables thanks to standardisation and data quality control.