Diurnal variation of particulate matter in the proximity of Rovinari fossil-fuel power plant

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RESEARCH MOTIVATION

Motivation

- economical development is directly connected to energy consumption, and therefore to energy production
- coal reserves are the largest ones and are more evenly distributed worldwide
- burning of fossil fuels produces:
  - around 21.3 gigatones of CO_2 per year
  - nitrogen oxides and sulphur dioxide → fine particulate matter, smog and acid rain

- fine particles are the most dangerous
  - their retention at the source, through appropriate flue gas cleaning technologies is difficult
  - they are entering the free atmosphere, through different points and in different amounts and sizes
  - are transported at distance from the source, disturbing the quality of local air, more or less far or close to the emitting source.
  - they are free to enter the biological barriers and reach easily the lungs and tracheas

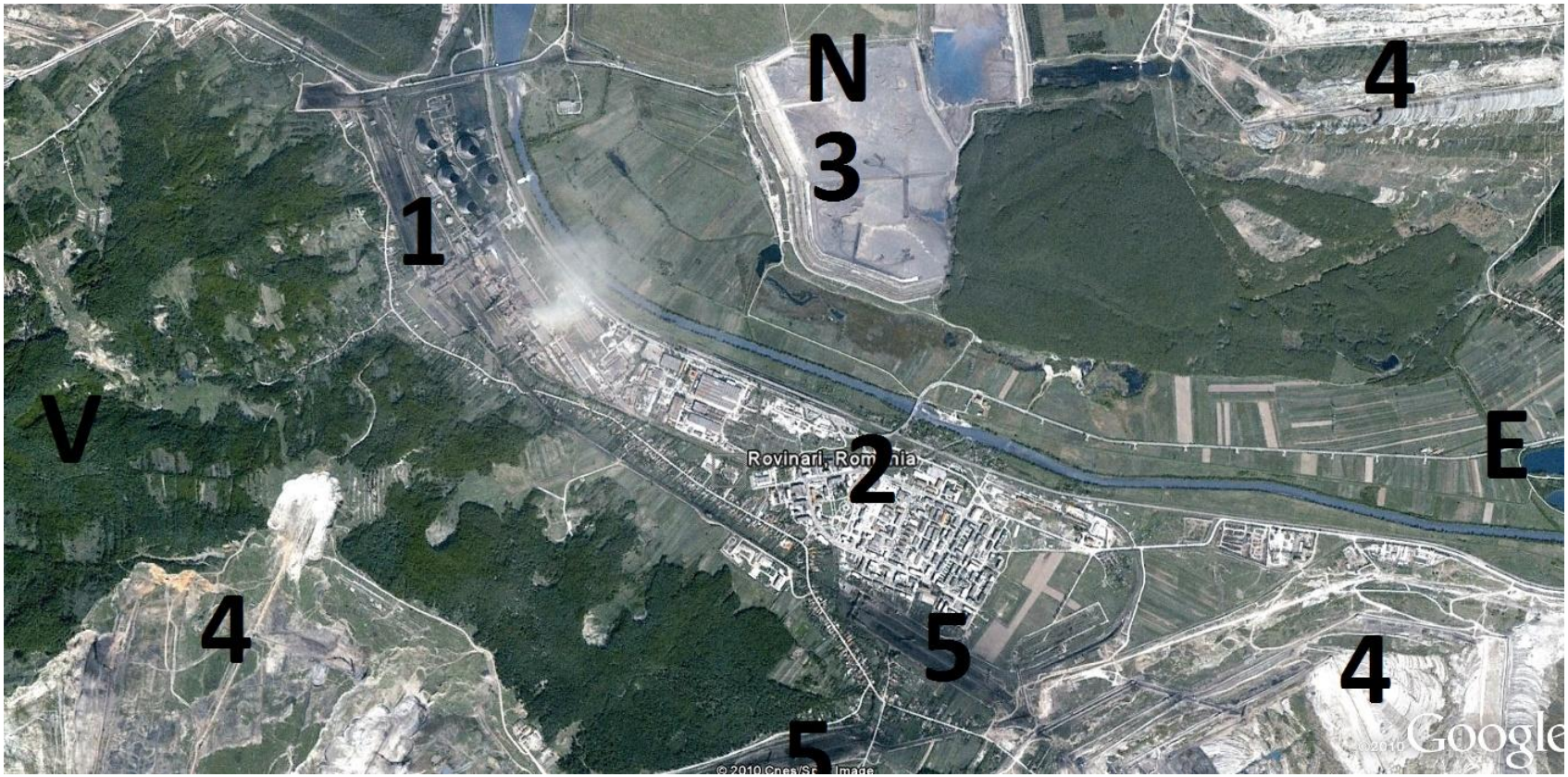
Campaign:
- intercomparison of instruments
- assessment of local pollution with fine particles

Measurements site

- a small town with 12500 inhabitants
- 25 km south-west from Targu Jiu
- 2Km to the power plant
- Rovinari Power Plant
  - one of the largest electricity producer in Romania
  - 4 groups of 330 MW each
  - installed capacity of 1,420 MW

- main sources for air pollution with particles
  - the coal deposit
  - ash deposit
  - coal transportation system
  - sterile deposit
  - emission from the traffic fleet
- fine particles
  - class C fly ash
  - highly heterogeneous,
  - mixture of glassy particles with various identifiable crystalline phases
  - silicon dioxide (SiO_2) (both amorphous and crystalline), calcium oxide (CaO), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3)

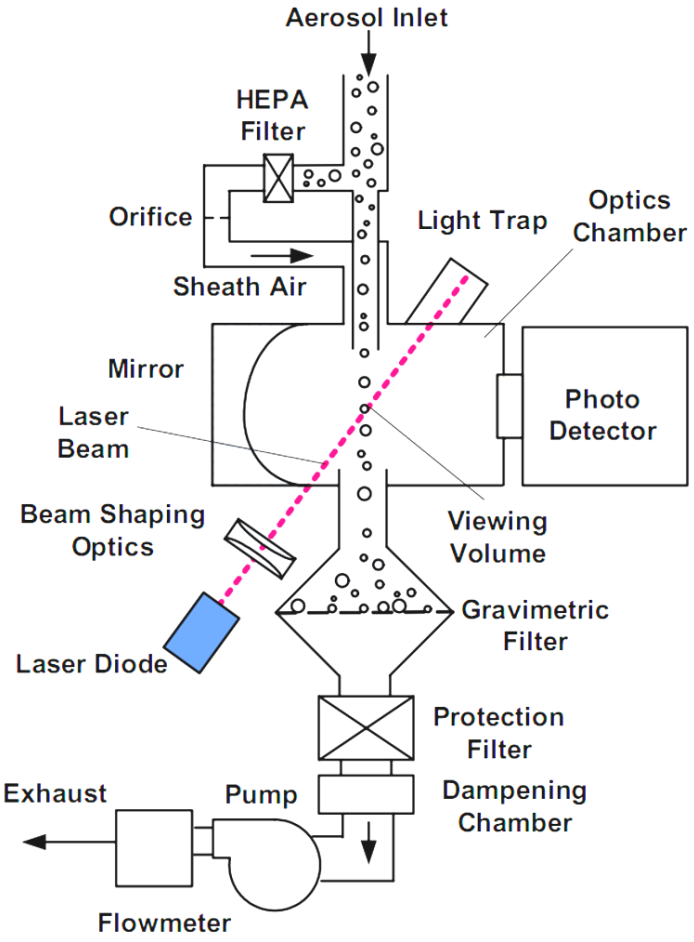
Measurements site



1 – Rovinari power plant, 2 – Mobile laboratory, 3 – Ash deposit, 4 – Sterile deposit, 5 – Coal deposit

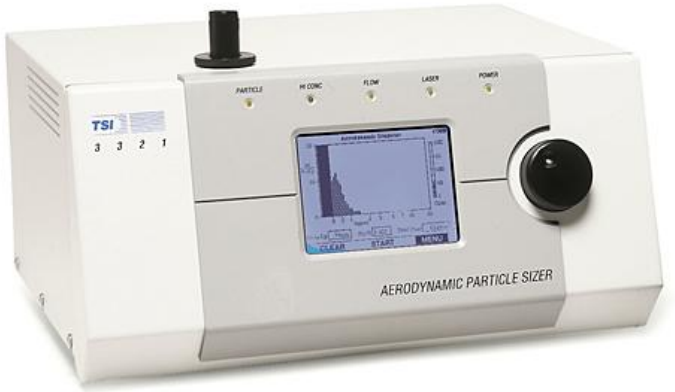
Instruments: DUSTRAK

- measures particle's concentration based on light scattering, for several size classes (inlets!):
  - PM1, PM2.5, PM4, PM10 and total
- light scattering from particles can be mathematically modeled (Mie scattering theory):
  - aerosol's size distribution
  - refractive index
  - shape factor
  - aerosol's density of the aerosol
- the electrical signal response of the PMT is proportional to the mass concentration of the aerosols
- the calibration constant is determined from the ratio of:
  - a known mass concentration of the test aerosol
  - the voltage response of the same photometers that respond linearly to mass concentration.



Instruments: APS

- measures both aerodynamic diameter and light-scattering intensity
- accelerates particles into a partially evacuated chamber through a nozzle and detects them using two laser beams located at different distances from the nozzle
- measures particles velocities by measuring the time delay between the detection events of the two lasers → aerodynamic diameters
- aerodynamic size range: 0.5 to 20 µm (32 size channels per decade) → optical size range: 0.37 to 20 µm
- measures number-weighted size distributions → converted to mass-weighted size distributions
  - the conversion is based on user input particle density



DUSTRAK vs. APS

- APS provides directly volume size distribution, DUSTRAK is only providing mass-concentration for 5 size-classes
- Both instruments are in situ monitors → affected by very local air fluctuations → not relevant for our study
  - hourly-averaged quantities for PM concentrations
    - relative differences to the mean
    - **Kendall** rank correlation coefficient
  - 6-hours average quantities to calculate the size distribution
    - Kendall rank correlation coefficient
- the uncertainty:
  - normal distribution for data points
  - normal statistics for error propagation

Kendall rank coefficient
- statistical test to establish whether two variables may be regarded as statistically dependent
- non-parametric, as it does not rely on any assumptions on the distributions of *X* or *Y*.

$$n_V(\log D) = \frac{dV}{d\log D}; n_N(\log D) = \frac{dN}{d\log D}$$

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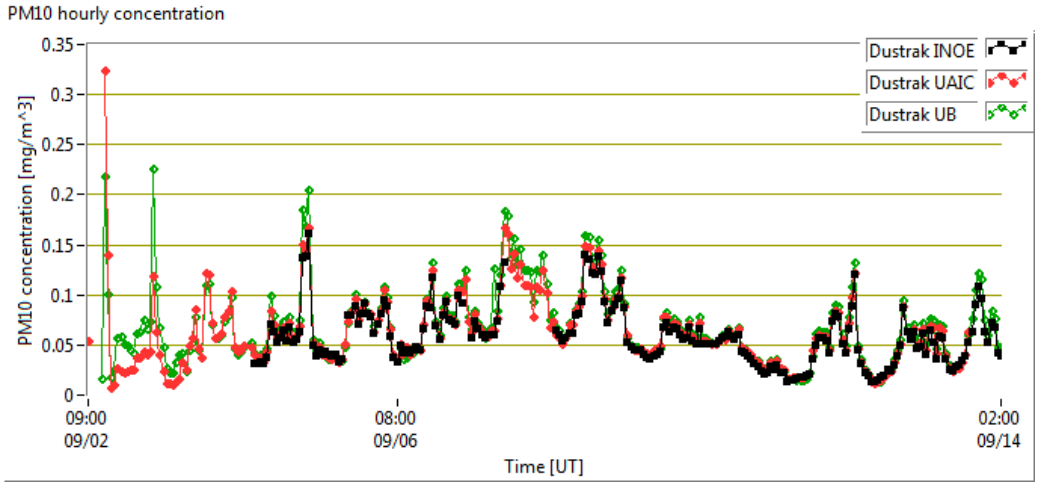
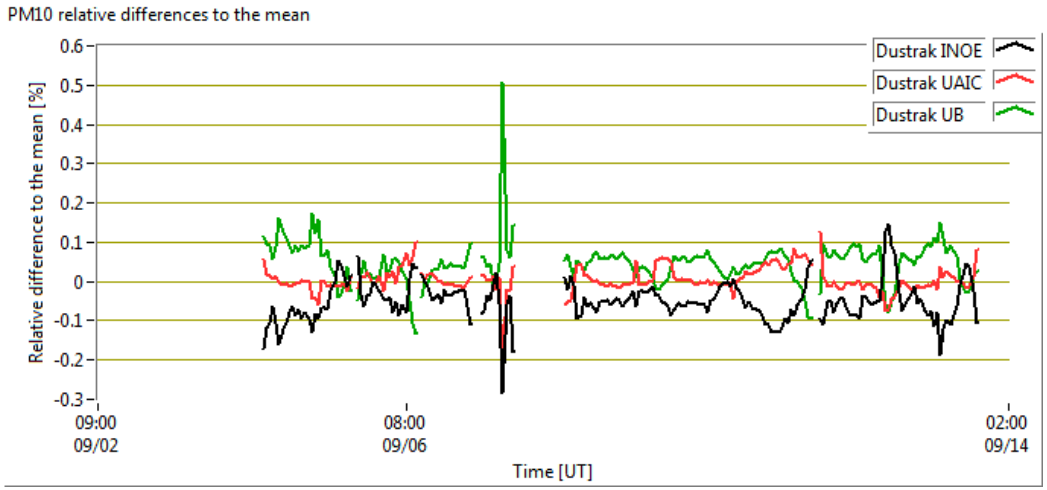
INTERCOMPARISON OF INSTRUMENTS

Intercomparison: PM concentration



Time series of PM10 hourly concentration for 3 DUSTRAK particle counters

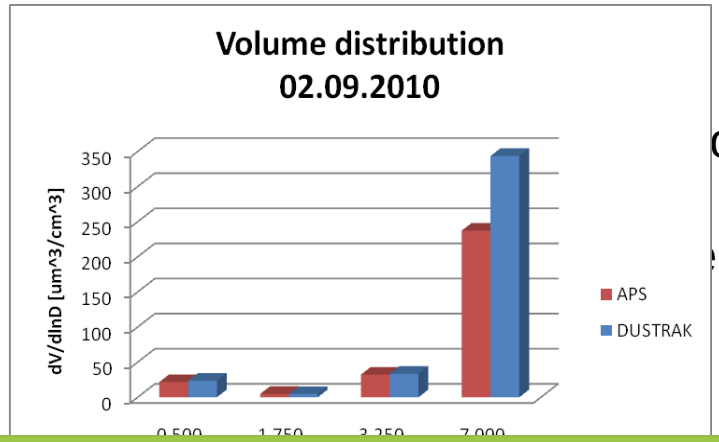


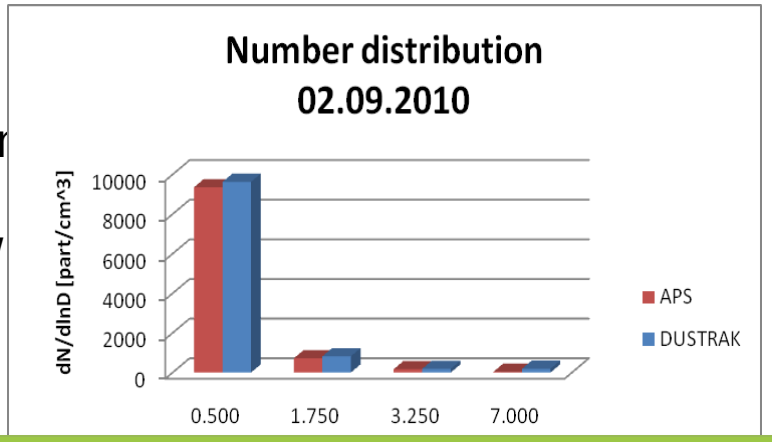
- Max. difference to the mean: 18% < 20% measurements uncertainty
- Kendall: 0.7 – 0.81
- Max. difference = for unstable atmosphere

PM10 hourly concentration relative differences to the mean

Very good correlation!

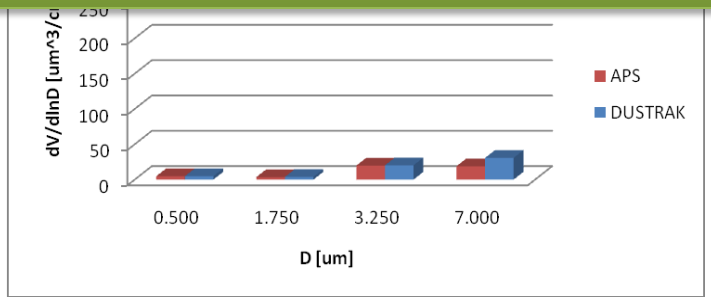
Intercomparison: size distribution

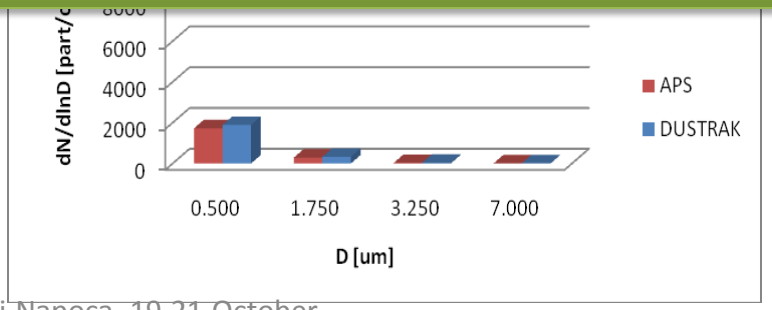




- the 2 instruments agree well for small particles, but disagree for large particles (>4um),
  - APS is less sensitive because is close to its detection limit
  - DUSTRAK was collecting aerosols near the ground, while the APS was collecting aerosols from 2m above the ground.
- Kendall rank correlation coefficient
  - 0.66 for number distribution
  - 0.57 for volume distribution

Good correlation!





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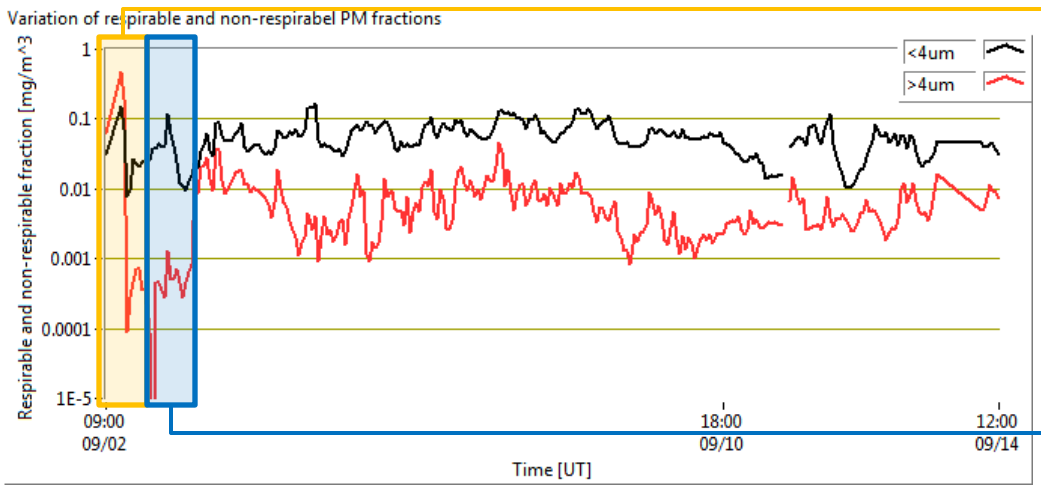
CHARACTERISTICS OF LOCAL AIR: PM VARIABILITY

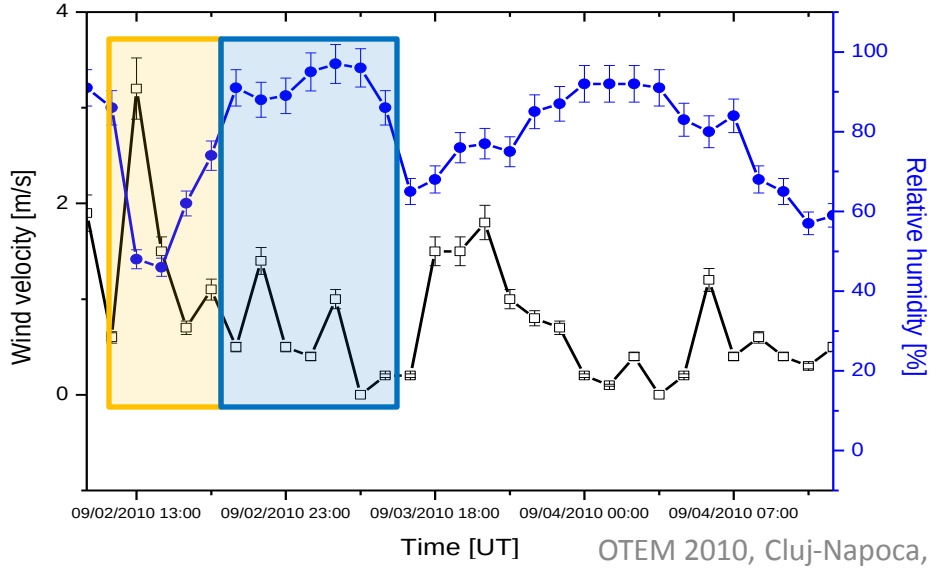
Diurnal variations of particulate matter



turbulence & dry air: large particles lifted from the ground (sources from the vicinity)

← *Time series of respirable (<4um) and irrespirable (>4um) particulate matter measured by DUSTRAK*

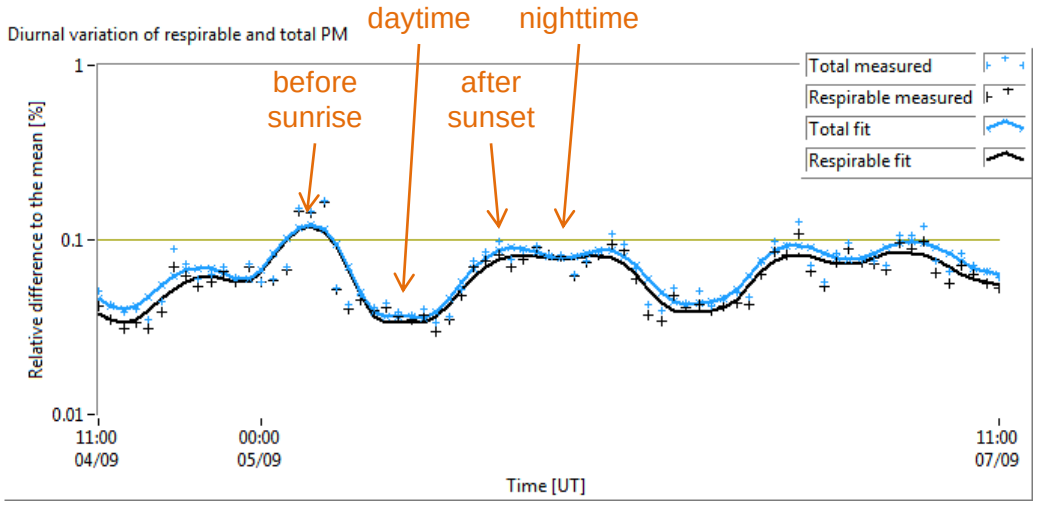
calm & humid air: large particles deposited on the ground (sources from the vicinity)



← *Wind velocity and relative humidity on Sept. 02-04, 2010*

- the amount of small particles is constant over the time → emissions: fine particles, almost constant
- large particles are highly variable, depending on the turbulence and wind direction.

Diurnal variations of particulate matter

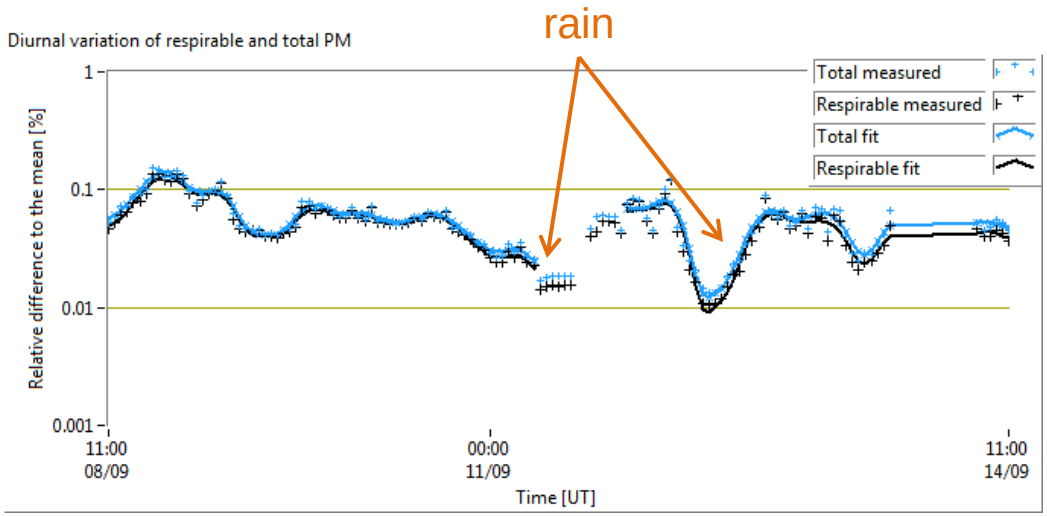


← *Diurnal variations of respirable (<4um) and total particulate matter measured by DUSTRAK*

Sept 04-07

PM concentration near the ground is following a daily pattern:

- Maximum concentration = after the sunset (20-23 PM local time) up to early in the morning (3-6AM local time)
- PBL is contracting → pushes particles from the higher layers to the ground.



← *Diurnal variations of respirable (<4um) and total particulate matter measured by DUSTRAK*

Sept 08-14

Variations in particle size

Sept. 02 = windy but dry day

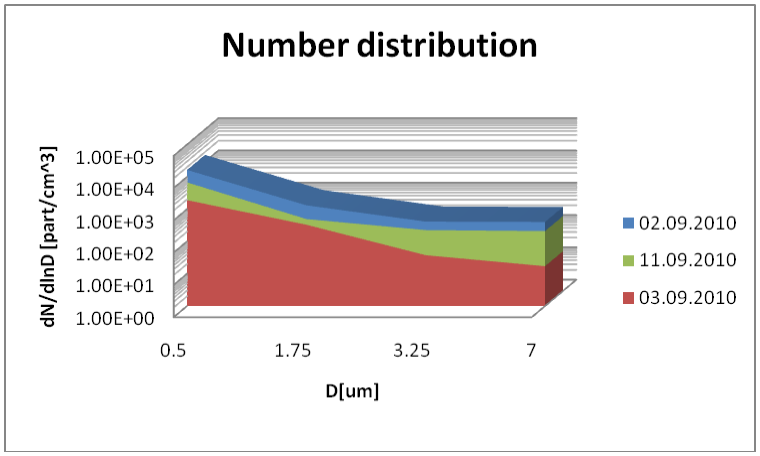
- **Small and large particles in high concentrations**

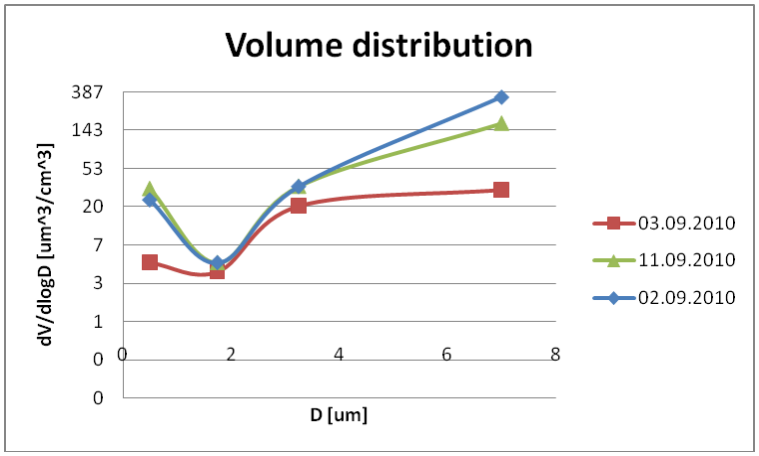
Sept. 03 = calm and sunny day

- **concentrations are much lower**
- **less contribution from large particles, due to gravitational deposition in calm atmospheric conditions**

Sept. 11 = calm and dry day after the rain

- **Small and large particles in high concentrations**
- **Less proportion of particles above 7um, due to the wet deposition (rain the day before)**





Comparison of number (left) and volume (right) size distribution measured with DUSTRAK, for Sept. 02, 03 and 11

Conclusions

- Campaign's interest
  - to assess the measurement accuracy of several instruments by direct intercomparison
    - very good correlation for all 3 instruments for the PM10 channel (Kendall rank correlation coefficient of 0.7 ... 0.81)
    - good correlation for the number and volume distribution calculated from APS and DUSTRAK (0.57 ... 0.66).
  - to identify the characteristics of local air in the proximity of Rovinari fossil-fuel plant, focusing on aerosols
    - ash concentration at ground but also the size distribution depend strongly on the wind direction and intensity, and on the time of the day
    - during a 24 h activity in the Rovinari city, a lot of polluting events (with particles) are occurring.
    - maximum concentration is found after the sunset up to early in the morning
    - when wet deposition is involved, the envelope of time series curves changes, although the daily pattern still remains.
- The pollution caused by Rovinari power plant is high and it exceeds the admissible limits, especially for particles
- The power plant is not the only polluting source

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Thank you!