# Quantitative determination of wood smoke and traffic exhaust in ambient concentrations of particular matter

*Fine Dust Congress*

Klagenfurt, 20 June 2012

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Aerosol d.o.o.

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Aerosol

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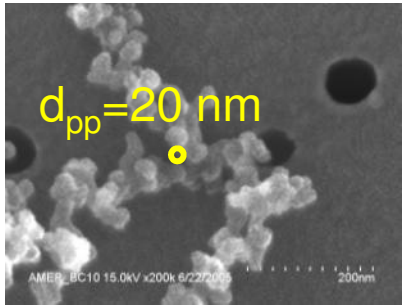
# Aerosol Black Carbon

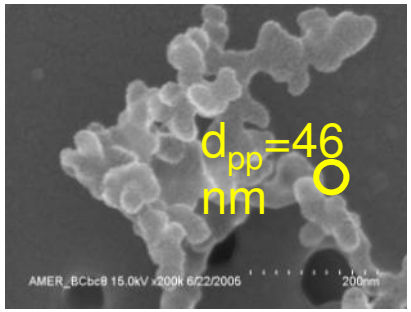
- BC is a product of incomplete **combustion**
- BC not automatically related to $CO_2$ emission
- BC emissions can not be predicted:

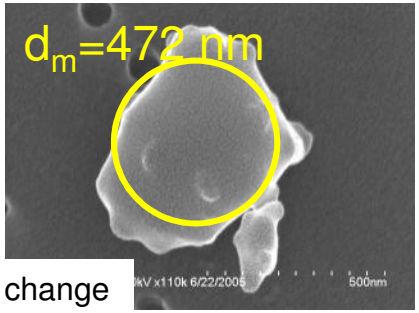
  **must be measured**

- BC particles from different sources can have different characteristics that produce different effects in the atmosphere:

  (Coal/Diesel/Biomass, USA/Asia/Europe)

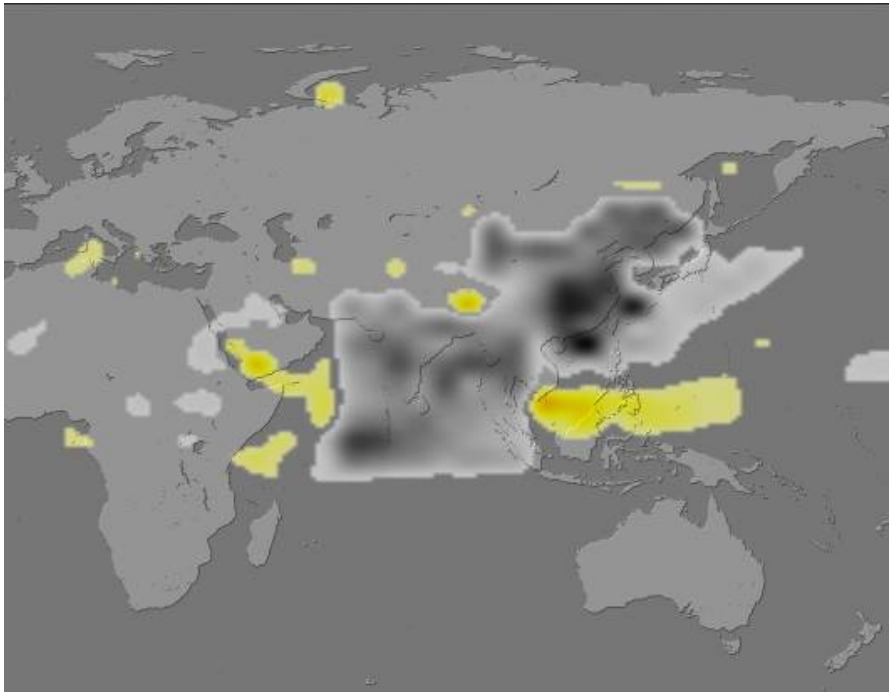


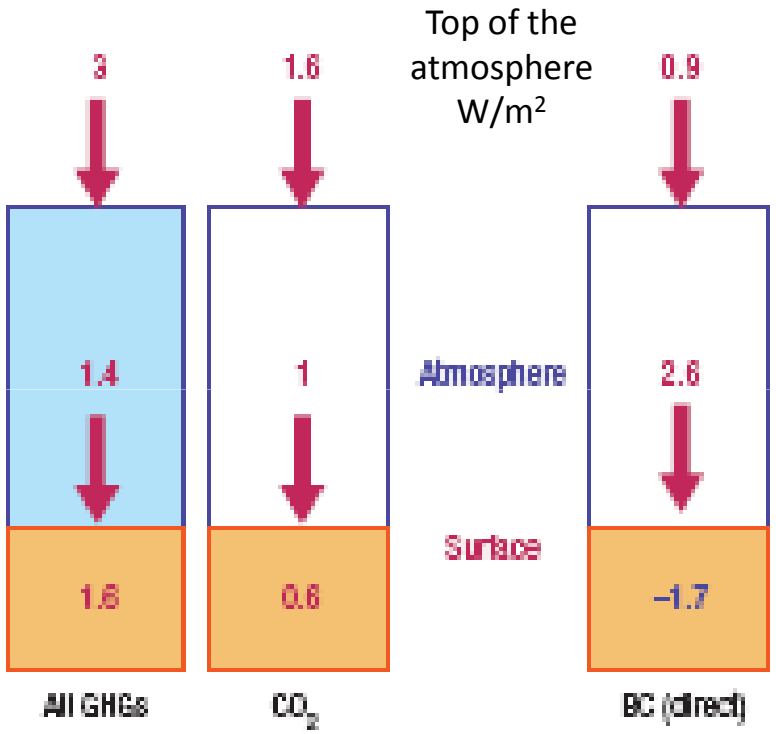




Note change in scale

# Climate Change Effects of Aerosols



S. Menon, J. Hansen et al. *Science* (2002) 2250




V. Ramanathan, G. Charmichael, Nature Geosci (2008) 221

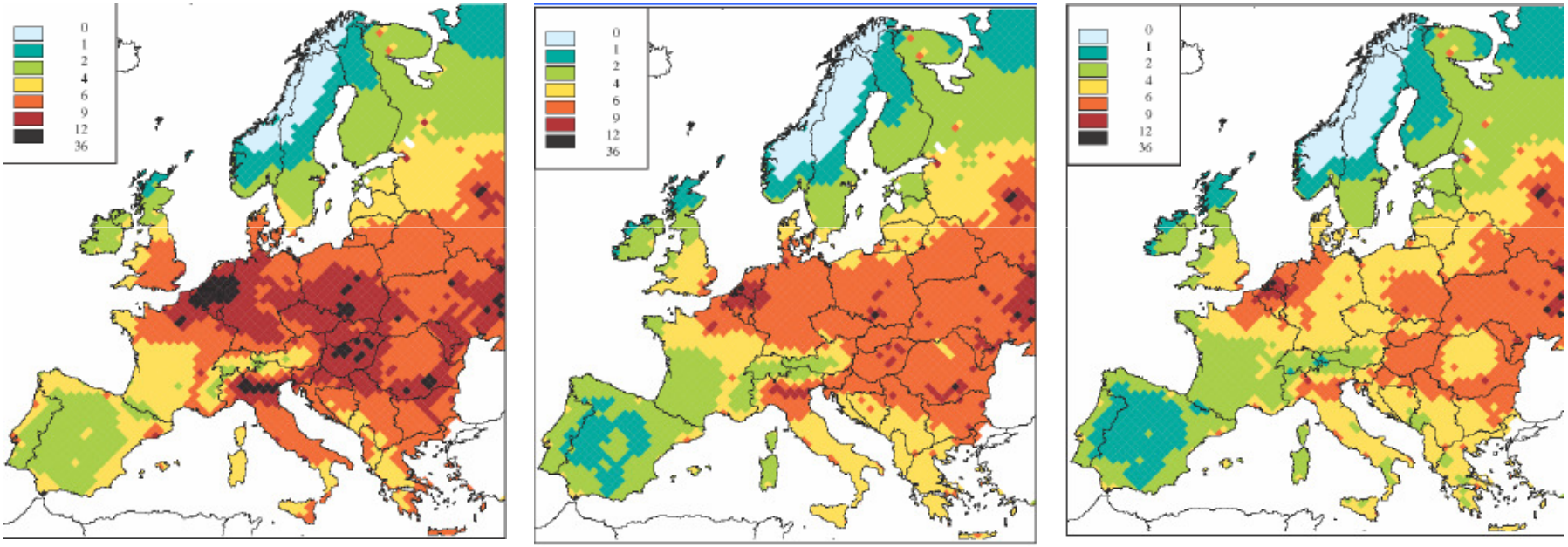
Haze over Asia: up to 40% of sunlight absorbed. Crop yields reduced ; local rainfall changed.

BC forcing is almost 1/3 of the total TOA GHG forcing!
Heat redistribution → weather

# Why are atmospheric aerosols important?

- **Public Health: loss of life** in months due to PM2.5

(CAFE baselines, RAINS 2004)




2000 2010 2020

Even with reduced emissions: statistical life loss still around **5 months average in EU in 2020**!

# Health Effects

## *THE "HARVARD 6-CITIES" STUDY*

**Dockery et al., *N. Engl. J. Med.* 329: 1753 (1993)**

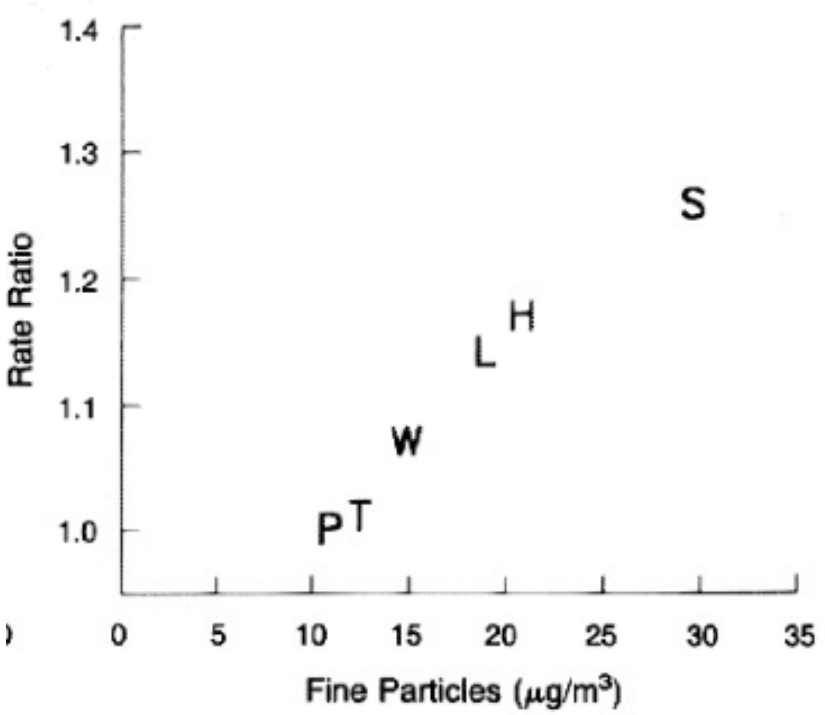
- **Longitudinal cohort study of 8111 adults, 1974 – 1977**

Steubenville, OH (S) Harriman, TN (H) St. Louis, MO (L)
Watertown, MA (W) Topeka, KS (T) Portage, WI (P)

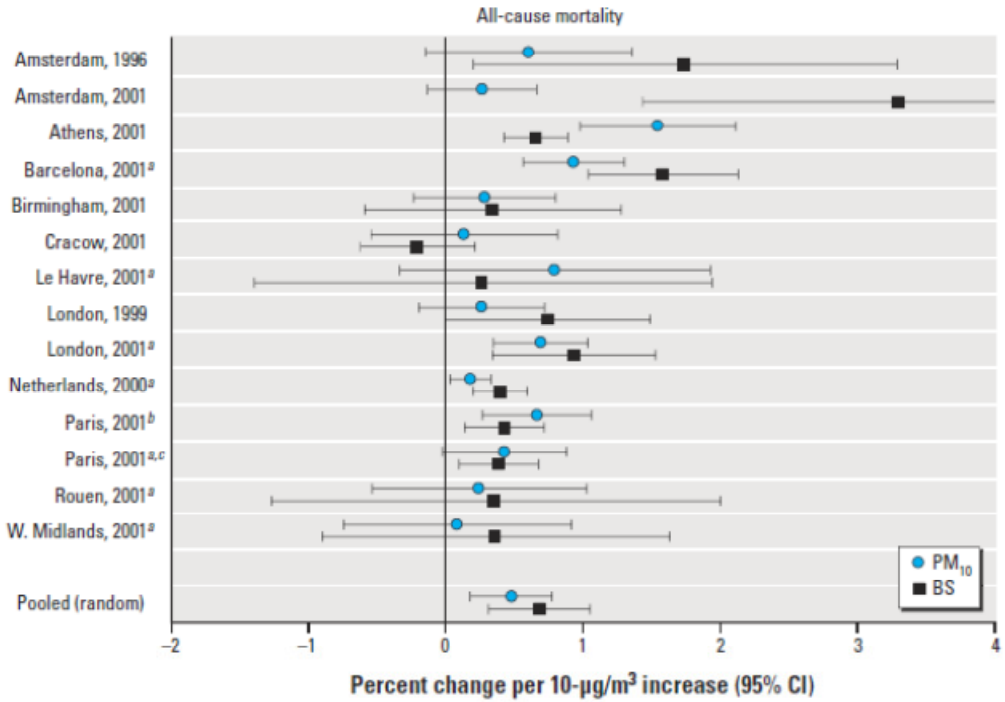
- **1401 death certificates after 14-16 yr follow-up**

**Smoking-adjusted mortality rates (deaths/1000 population)**

| Mortality | Mortality Ratio<br>Highest *vs.* Lowest PM |
|---|---|
| All causes | 1.26 (1.08 – 1.47) |
| Lung cancer | 1.37 (0.81 – 2.31) |
| Other cardiopulmonary | 1.37 (1.11 – 1.68) |
| Non-cardiopulmonary | 1.01 (0.79 – 1.30) |



# Health Effects (2)




**Two-pollutant models in time-series studies suggested that the effect of BCP was more robust than the effect of PM mass.** The estimated increase in life expectancy associated with a hypothetical traffic abatement measure was four to nine times higher when expressed in BCP compared with an equivalent change in PM2.5 mass. Jansen et al, 2011 EHP

# Wood is a major energy source

- wood/biomass is a **sustainable fuel** – trees recycle CO2
- burning biomass is a **major energy source** in the Alps
- various combustion regimes: high-efficiency distric heating ovens – individual wood-stoves
- possible extreme emissions of particulate matter
- local and regional air quality issue – up to **40% of all particulate matter is wood-smoke**
- **woodsmoke is composed of light absorbing carbonaceous aerosols**

Aerosol

# Advantages / Attributes of Optical Analysis

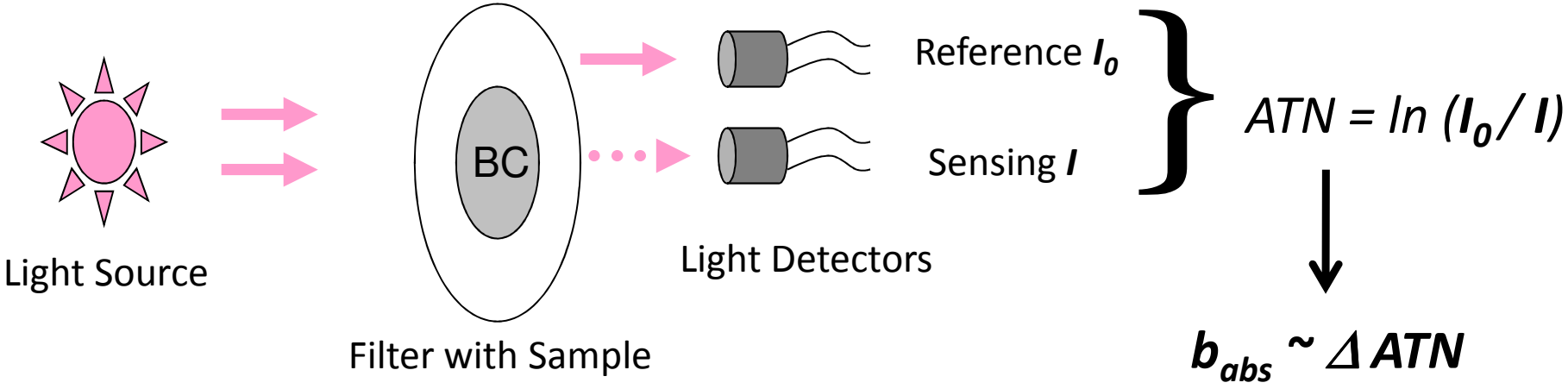
Typical **chemical speciation** time resolution – hours, **day**!

**<u>Optical methods – minute!</u>**

- Instantaneous
- Non-destructive
- Mobile / Portable
- Added dimension - *time*
- Added dimension – *wavelength*

Aerosol

# Analytical Instrument : Aethalometer™

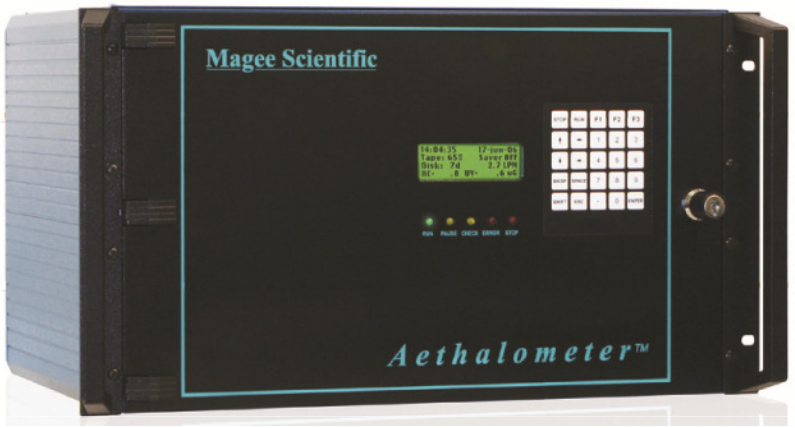



- Collect sample **<u>continuously</u>**.
- ***Optical absorption*** ~ change in ATN.
- Measure optical absorption <u>continuously</u> : λ = 370 to 950 nm.
- Convert ***optical absorption*** to ***concentration of BC:***

$$BC\ (t) = b(t) / \sigma$$

- Real-time data: **5 minutes**
  - *<u>Dynamical, real-time measurement, updated each period</u>*

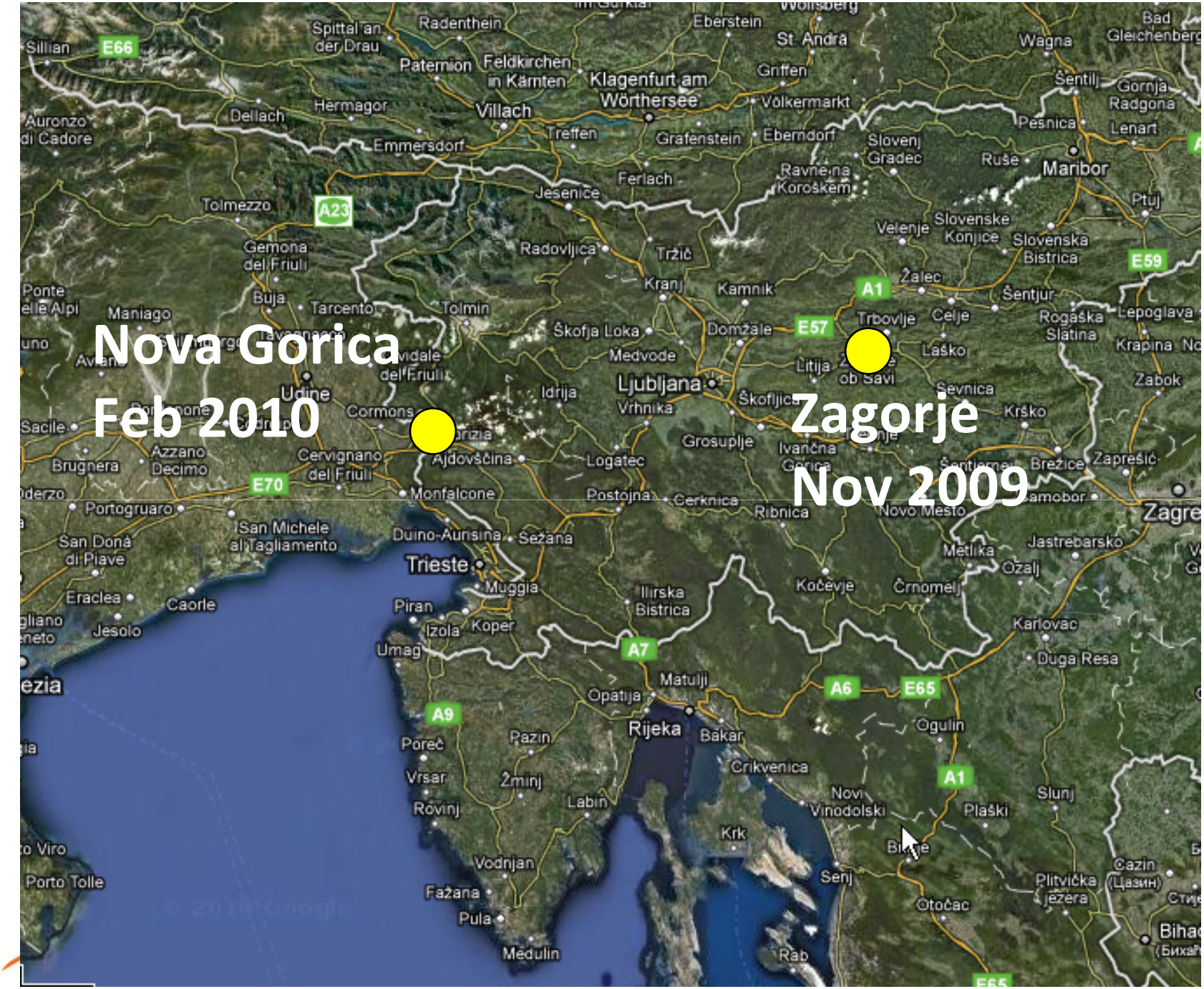
# *Aethalometer* – Continuous rack mount instruments

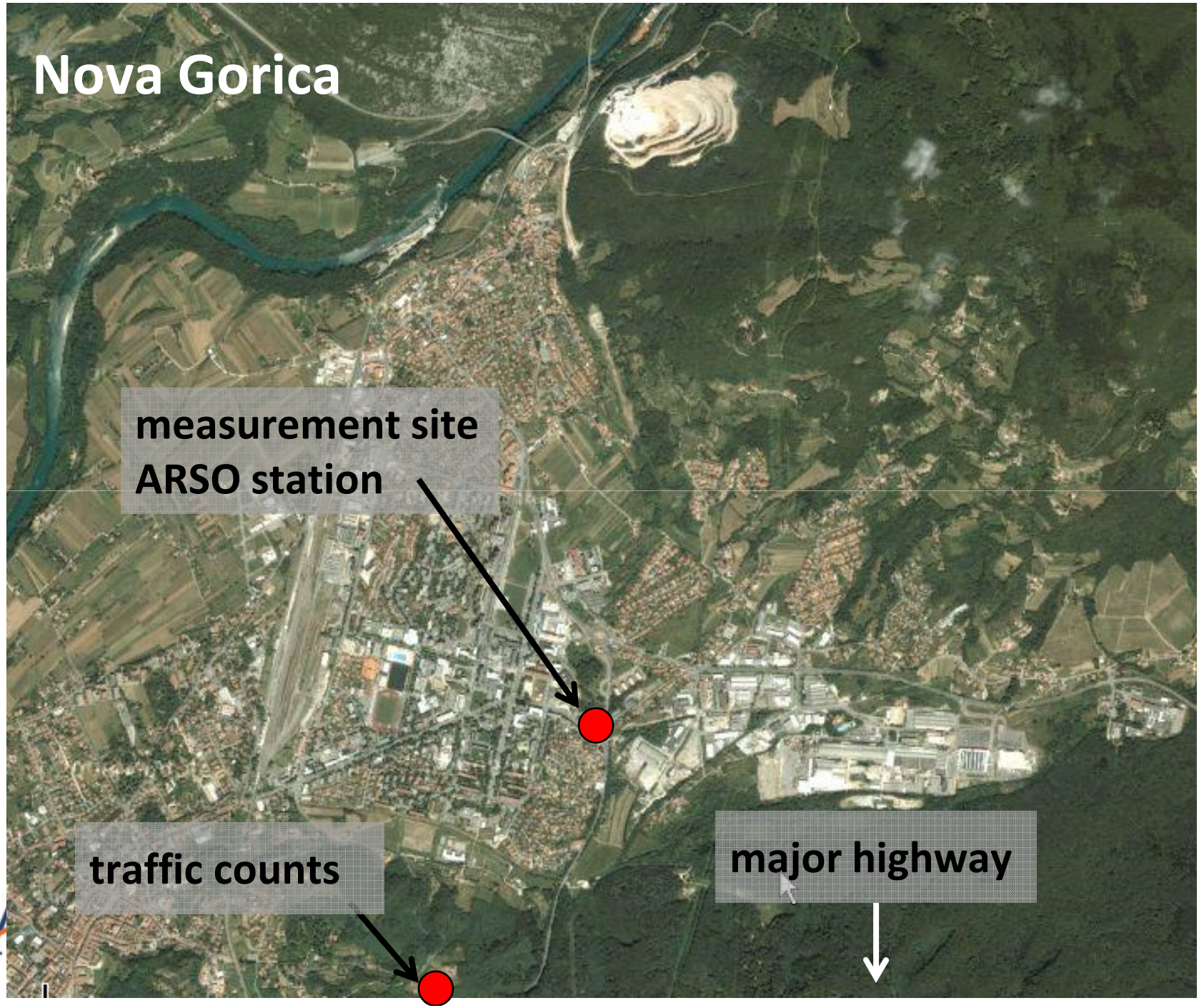



**AE31 Spectrum – Ambient Air Quality Monitoring**

- ✓ ***Seven wavelength (370, 470, 520, 590, 660, 880, and 950 nm)***
- ✓ ***Local source identification***
- ✓ ***Regional, Continental, Global Atmospheric studies***
- ✓ ***Particle size distribution, radiative transfer***
- ✓ ***Climate change, albedo, cloud modification***

Aerosol


Nova Gorica
Feb 2010
Zagorje
Nov 2009
Ljubljana
Trieste
Rijeka
Maribor
Udine
Klagenfurt am Wörthersee
Villach
Jesenice
Kranj
Škofja Loka
Domžale
Trbovlje
Celje
Postojna
Sežana
Koper
Izola
Piran
Pula
Zagreb


Nova Gorica
measurement site
ARSO station
traffic counts
major highway


**measurement site**
**EARS station**

**thermal power plant**
**cement kiln**

# Site and instrumentation

**Aerosol light absorption**:
Aethalometer AE31-ER

- 7 wavelengths: 370, 470, 520, 590, 660, 880, 950 nm
- flow 4 LPM
- absorption coefficient $b_{abs}$ - compensation for loading and scattering
- Angstrom exponent $\alpha$ from $b_{abs}(\lambda)$

**5 min time resolution**

**OC / EC filter analysis**:
Sunset T-O Carbon Aerosol analyzer

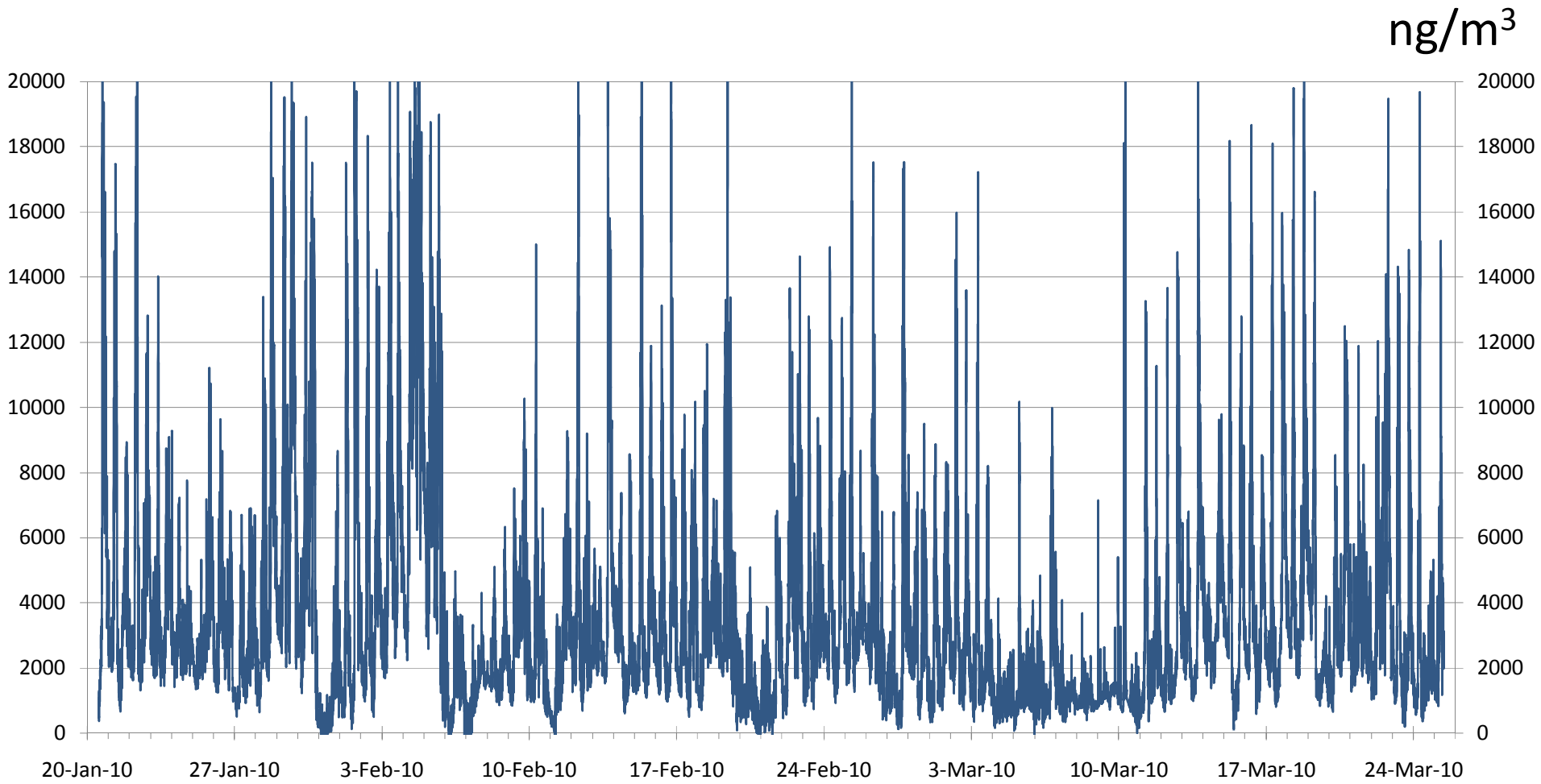
- 24 h quartz filters, 16,7 LPM
- EUSAAR-2 protocol

**PM10**:
EN 12341
reference gravimetric method

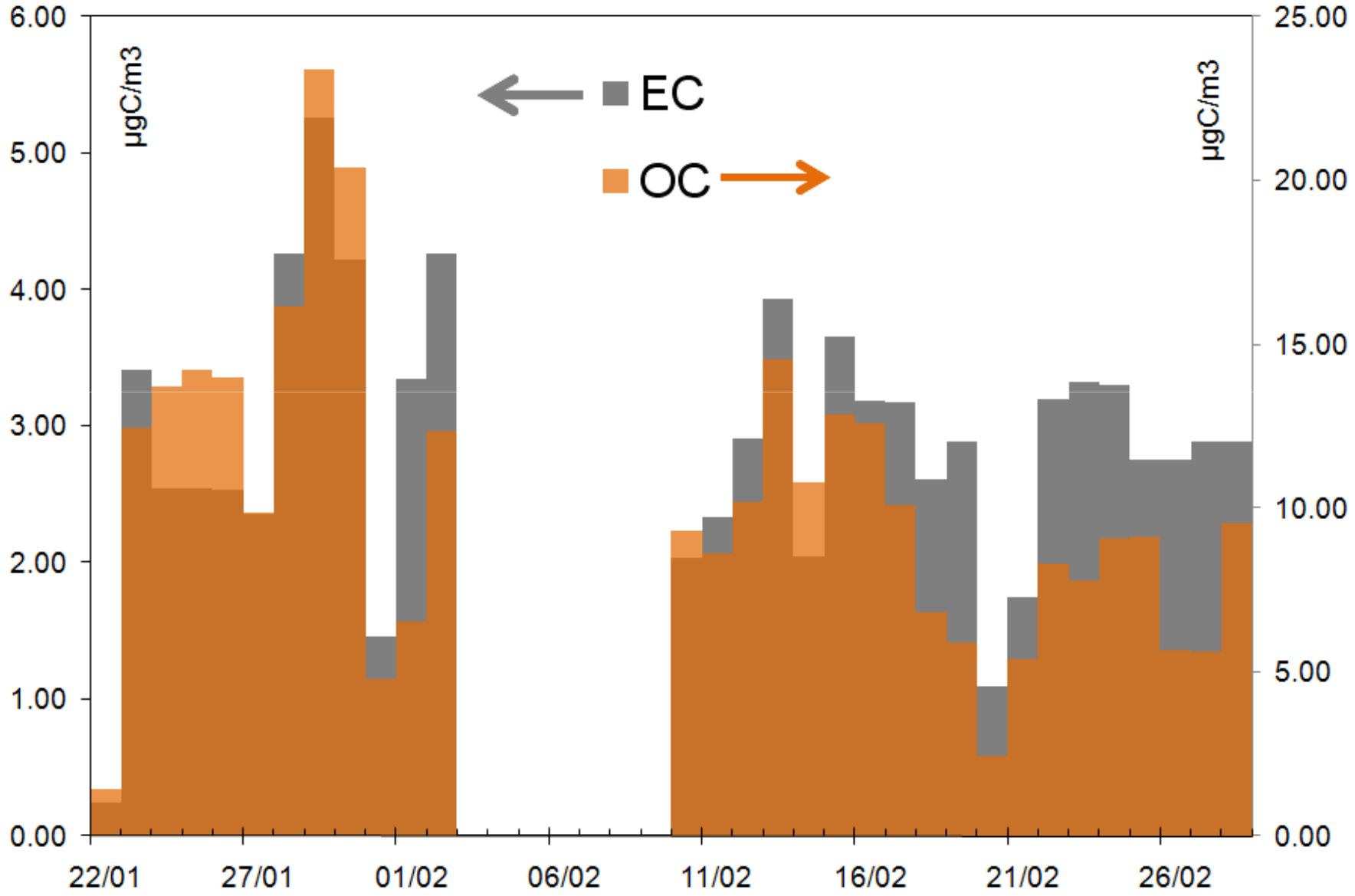
**1 day time resolution**

Aerosol

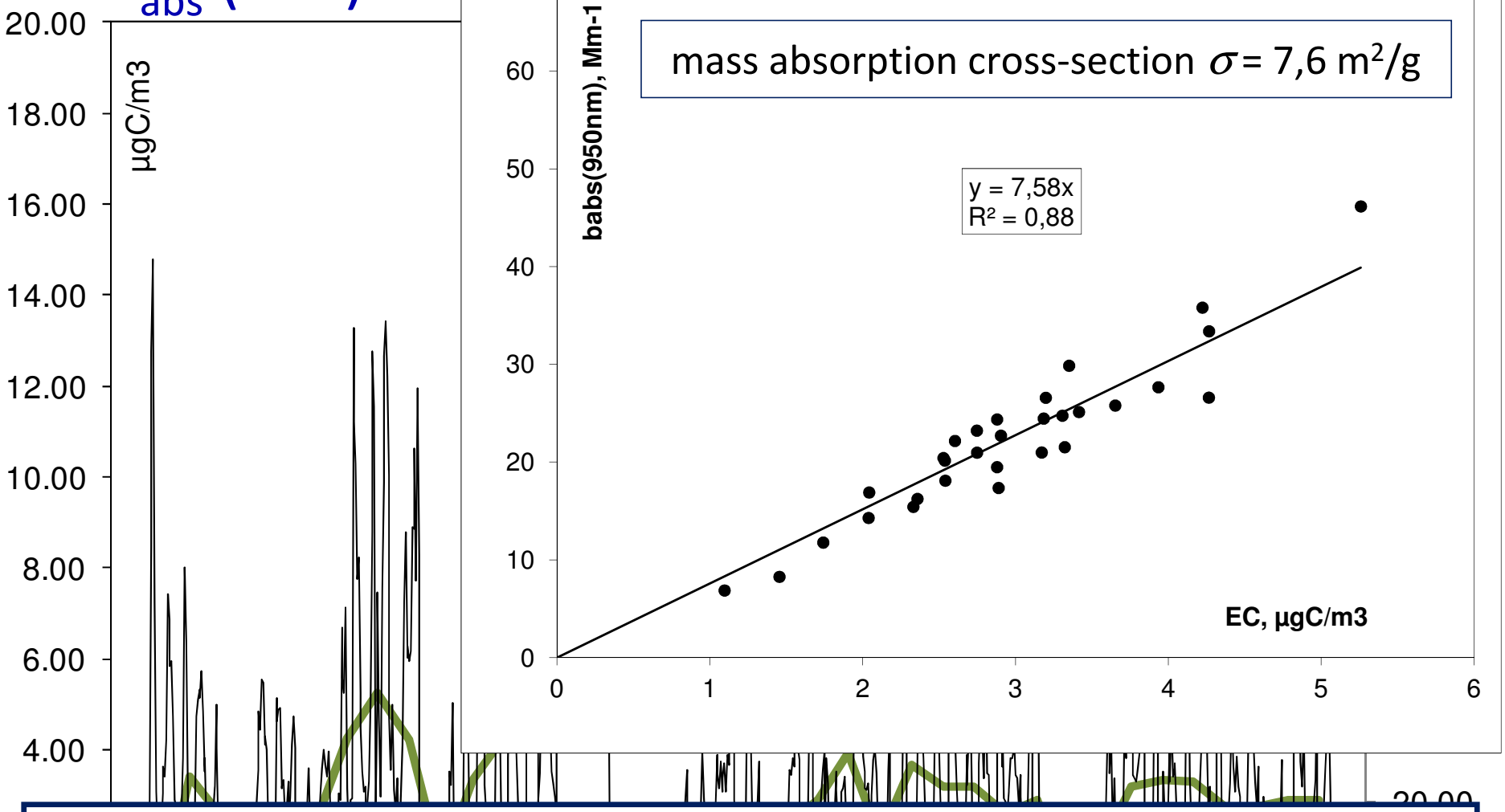
# BC time-series, Nova Gorica



# OC, EC time-series, Nova Gorica

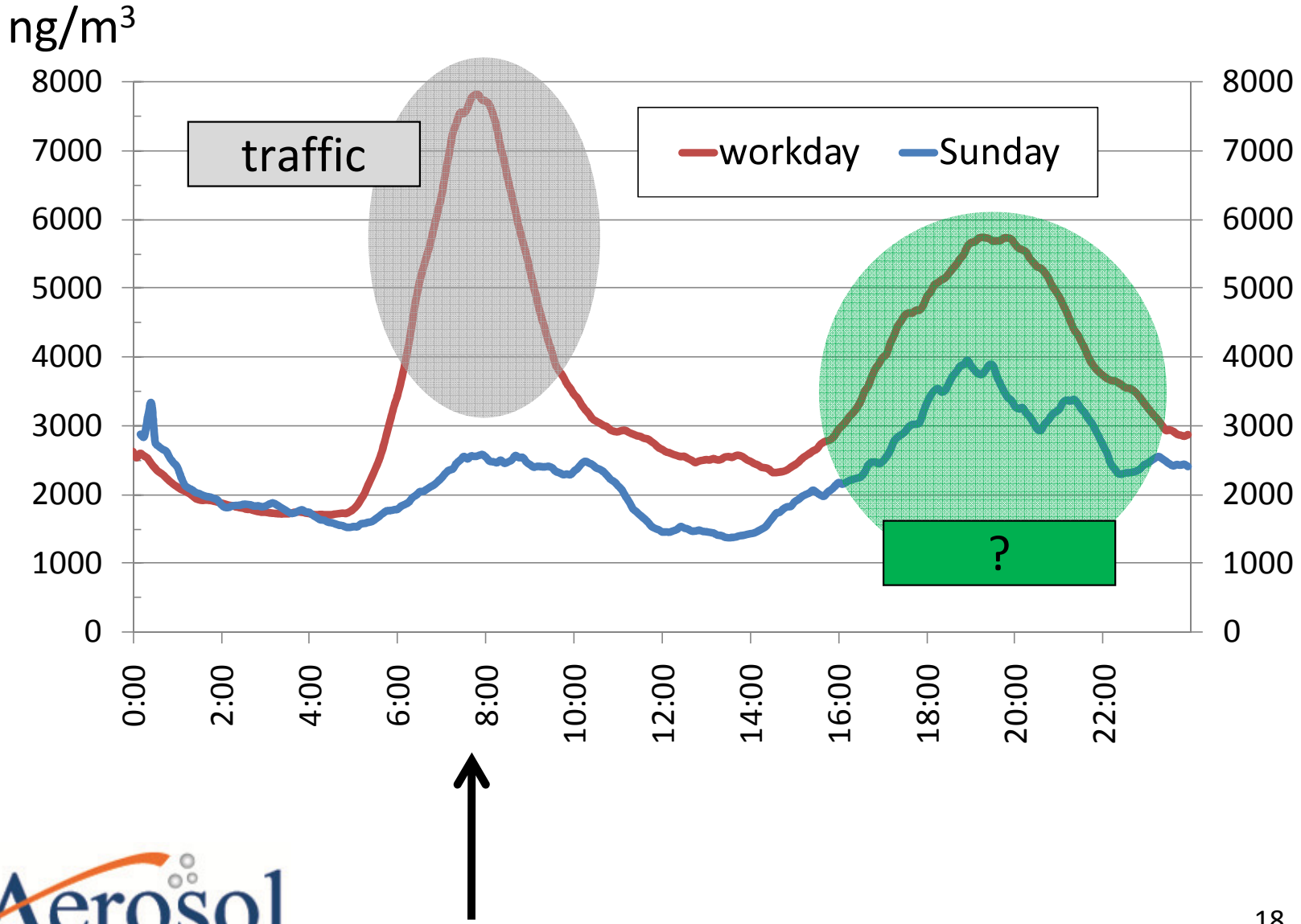


# $b_{abs}$ (950) ~ B




Good agreement between thermal EC and optical BC!

# BC in Nova Gorica – diurnal variation



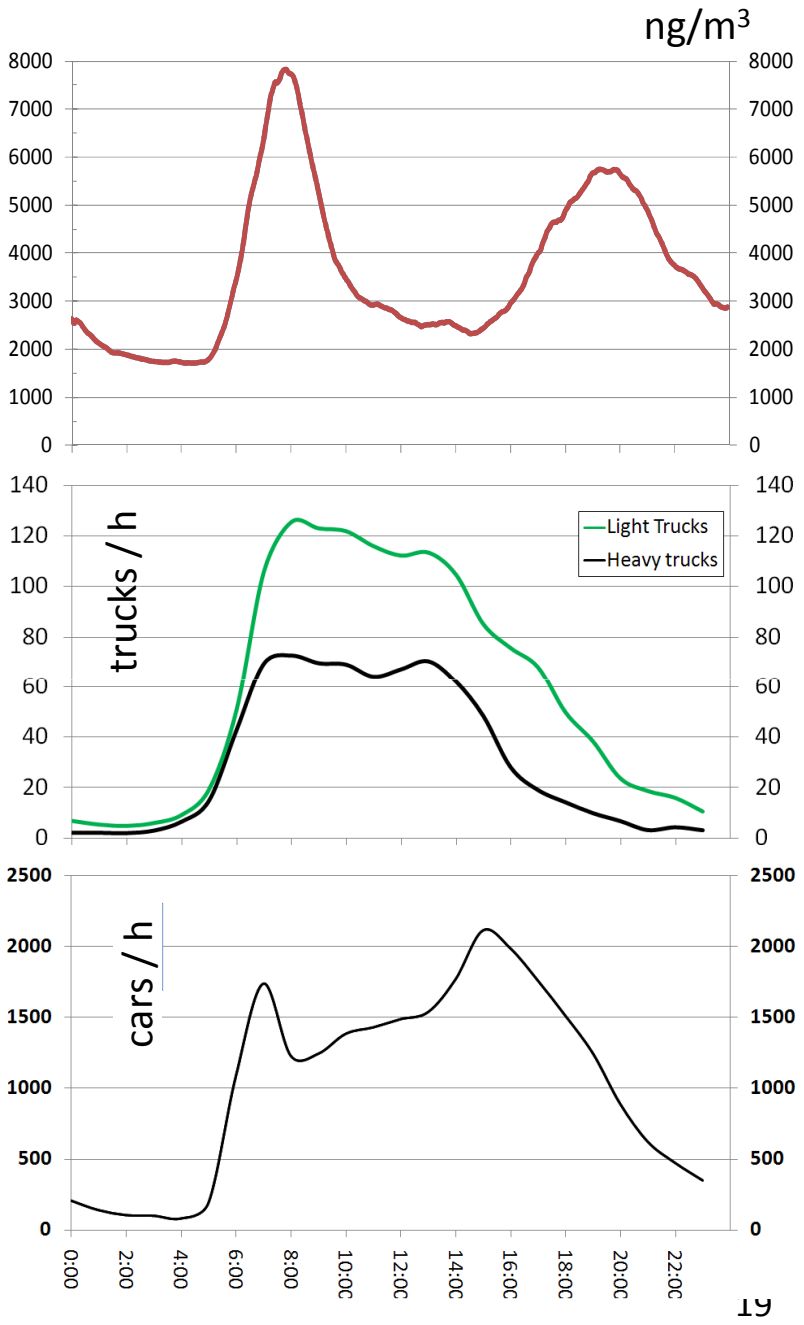
# Traffic

Does traffic diurnal pattern match the BC pattern?

Trucks are all diesel and emit more than other vechicles.

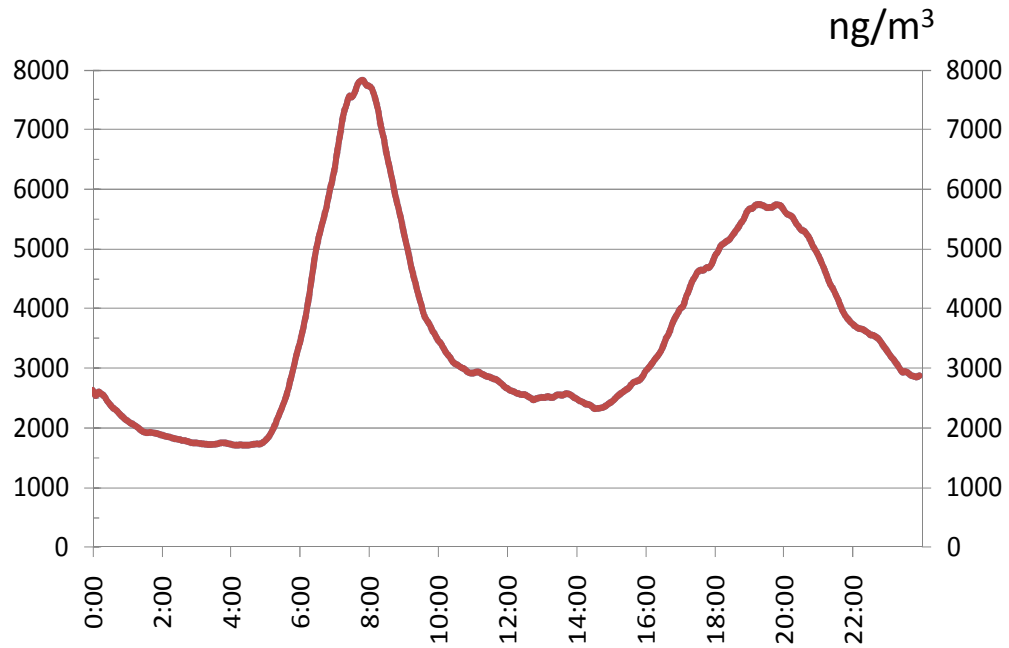
What about cars?

Note the change in scale!

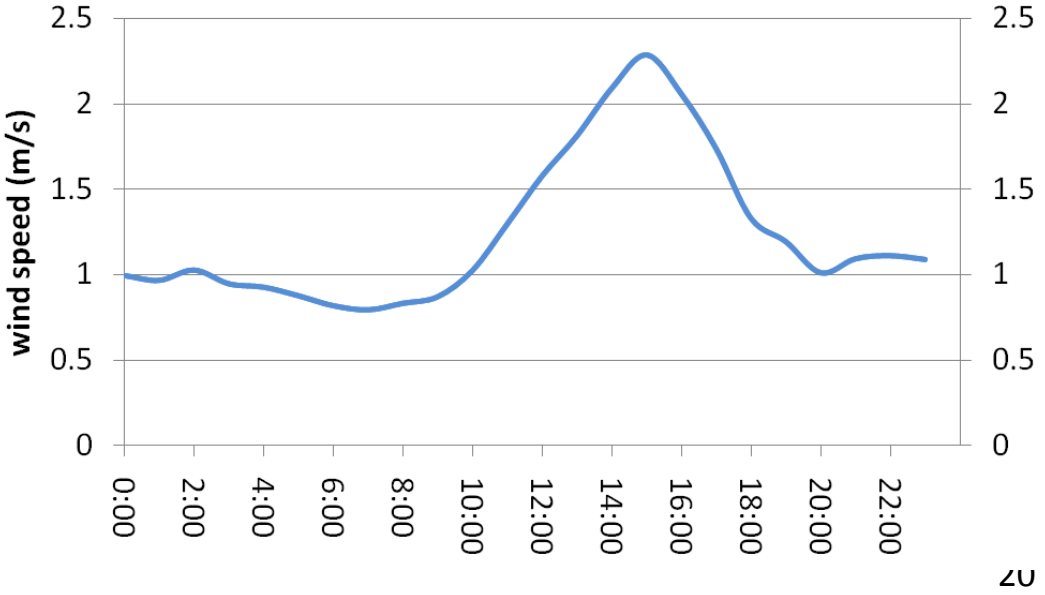


# Wind

Does the wind diurnal pattern influence the BC pattern?




Wind does disperse the primary air pollution!




Aerosol

# From Black&White to Color

# Renewable fuels: wood

- wood/biomass is a **sustainable fuel** – trees recycle CO2
- burning biomass is and has been a **major energy source**
- various combustion regimes: high-efficiency distric heating ovens – individual wood-stoves
- possible extreme emissions of particulate matter

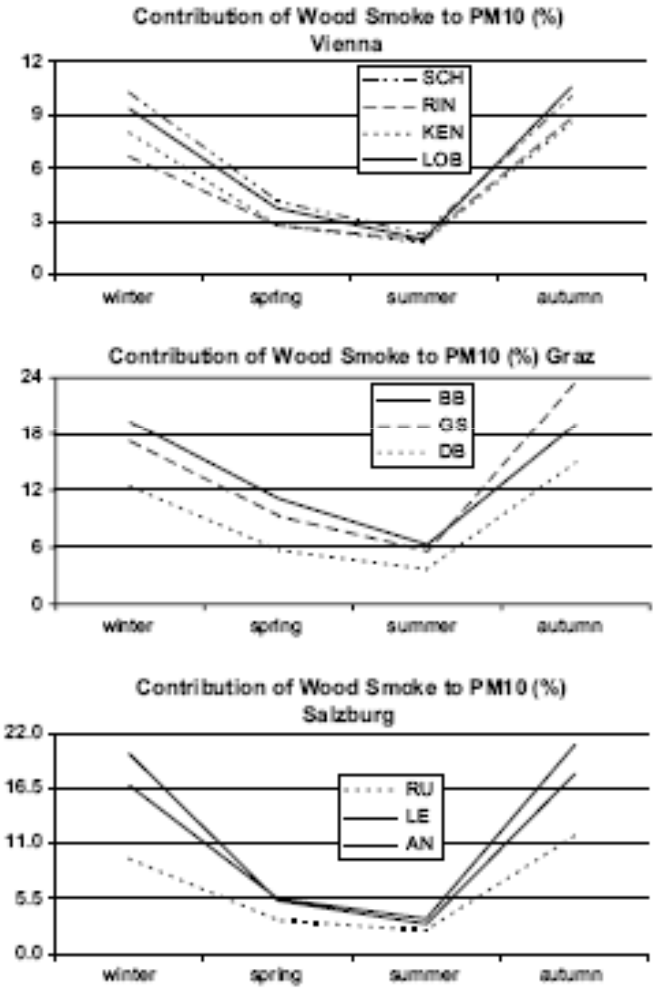
# Wood-smoke – part of PM10

- **rural areas** (small villages in Lower Austria, Styria, Carinthia, Burgenland and Salzburg):

| | WS | WS + HULIS |
|---|---|---|
| annual average | 8 - 21%; | 15 - 28% |
| winter | 14 - 32% | 19 - 42% |

- **urban areas** (Vienna, Graz, Salzburg, Klagenfurt):

| | WS | WS + HULIS |
|---|---|---|
| annual average | 5 - 16% | 9 - 20% |
| winter | 8 - 22% | 13 - 28% |




Aquella, TUW; A. Caseiro et al. / Atmospheric Environment 43 (2009) 2186–2195

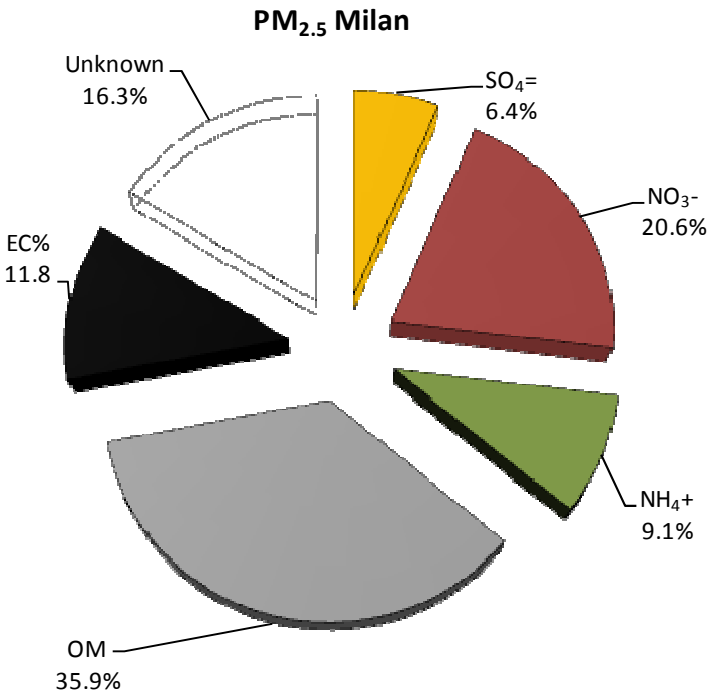
# *Woodsmoke in cities?!*

| PM2,5 | | |
|---|---|---|
| Paris, winter | 20% | Favez 2009 |
| Grenoble, winter | 35% | Favez 2010 |

similar for Vienna, Graz, Salzburg (Caseiro 2009),
Zurich (Lanz 2008, Szidat 2006)...

and also:

| | | |
|---|---|---|
| Milano, fall | 30% | Perrone 2012 |
| Milano, winter | 25% | Perrone 2012 |



# Wood-smoke vs. diesel

- measure attenuation with the Aethalometer: UV-IR
- calculate absorption coefficient $b_{abs}(\lambda)$
- for completely **black sample**: $b_{abs} \sim 1/\lambda$
- woodsmoke contains aromatic substances – increased absorption: more at **lower wavelengths**!

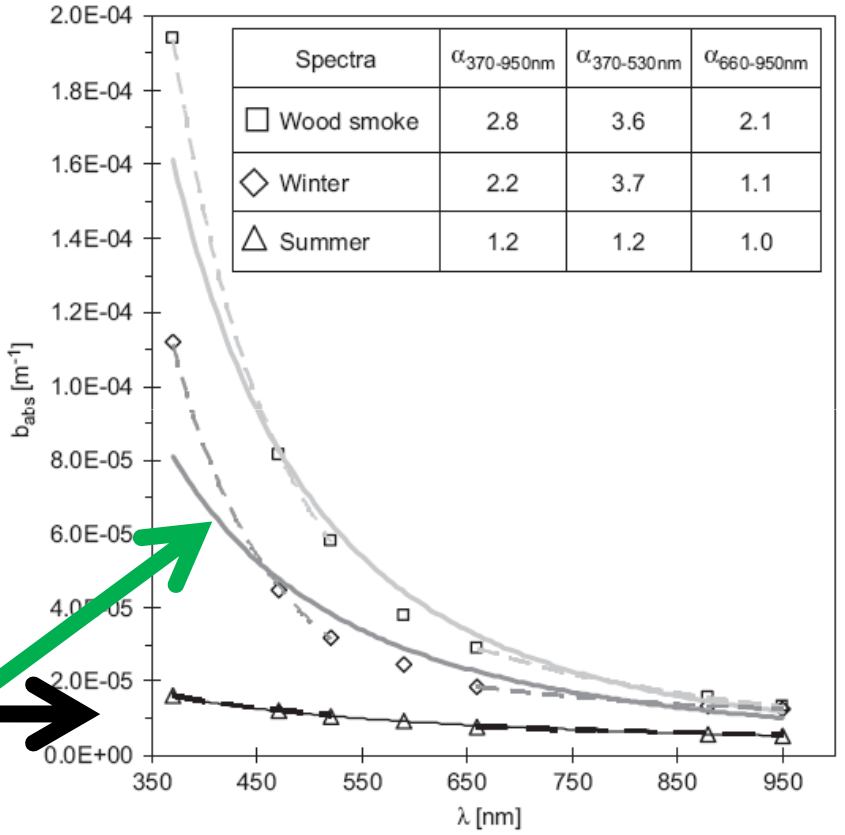
# Wood-smoke vs. diesel - 7λ

- measure attenuation with the Aethalometer
- absorption coefficient - $b_{abs}$
- for pure black carbon: $b_{abs}$ ~$1/\lambda$
- generalize **Angstrom exponent**:

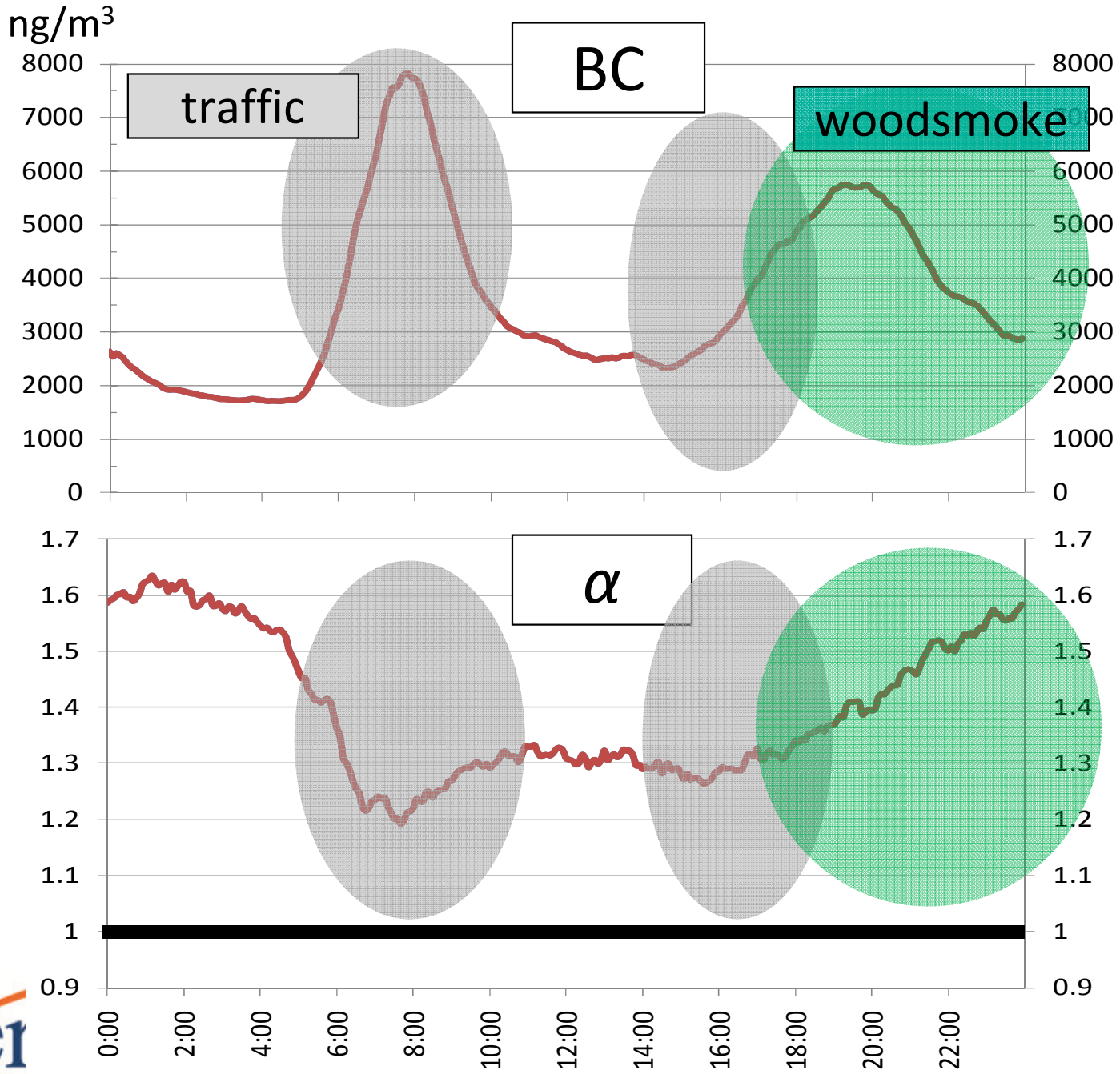
$$b_{abs} \sim 1/\lambda^{\alpha}$$

**diesel**: $\alpha \approx 1$

**wood-smoke**: $\alpha \approx 2$ and higher




J. Sandradewi et al., A study of wood burning and traffic aerosols in an Alpine valley using a multi-wavelength Aethalometer, Atmospheric Environment (2008) 101–112


ng/m3
BC
traffic
woodsmoke
8000
7000
6000
5000
4000
3000
2000
1000
0
α
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00

# Quantification

$b(\lambda) = b_{wb}(\lambda,\text{wood}) + b_{ff}(\lambda,\text{fossil})$ $\lambda = 470\ nm,\ 950\ nm$

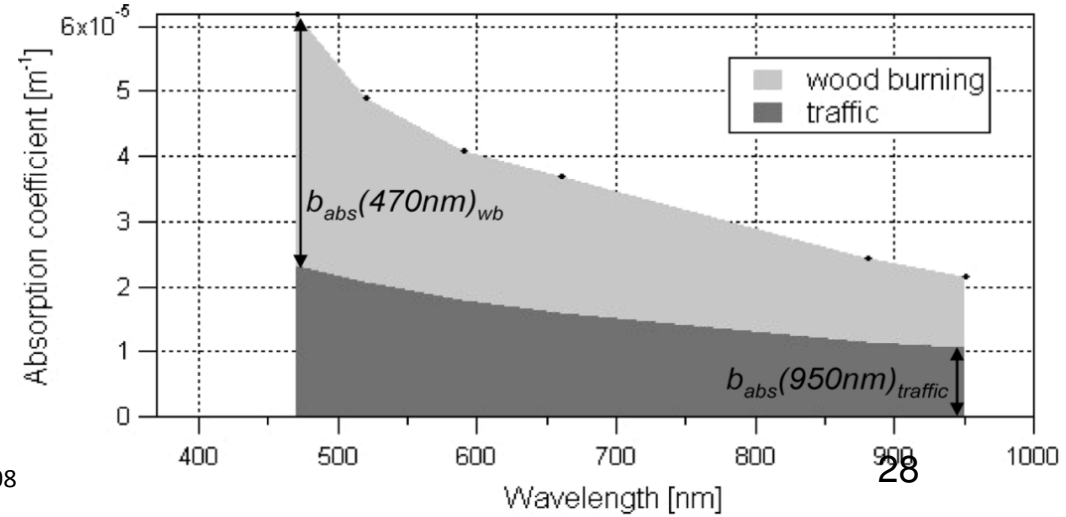
$b_i(470\ nm) / b_i(950\ nm) = (470\ nm / 950\ nm)^{-\alpha}$

$\alpha = 1{,}0 \pm 0{,}1$ (fossil) Bond & Bergstrom 2004 .

$\alpha = 2{,}0\ -0{,}5/+1{,}0$ (wood) Kirchstetter 2004, Day 2006, Lewis 2008

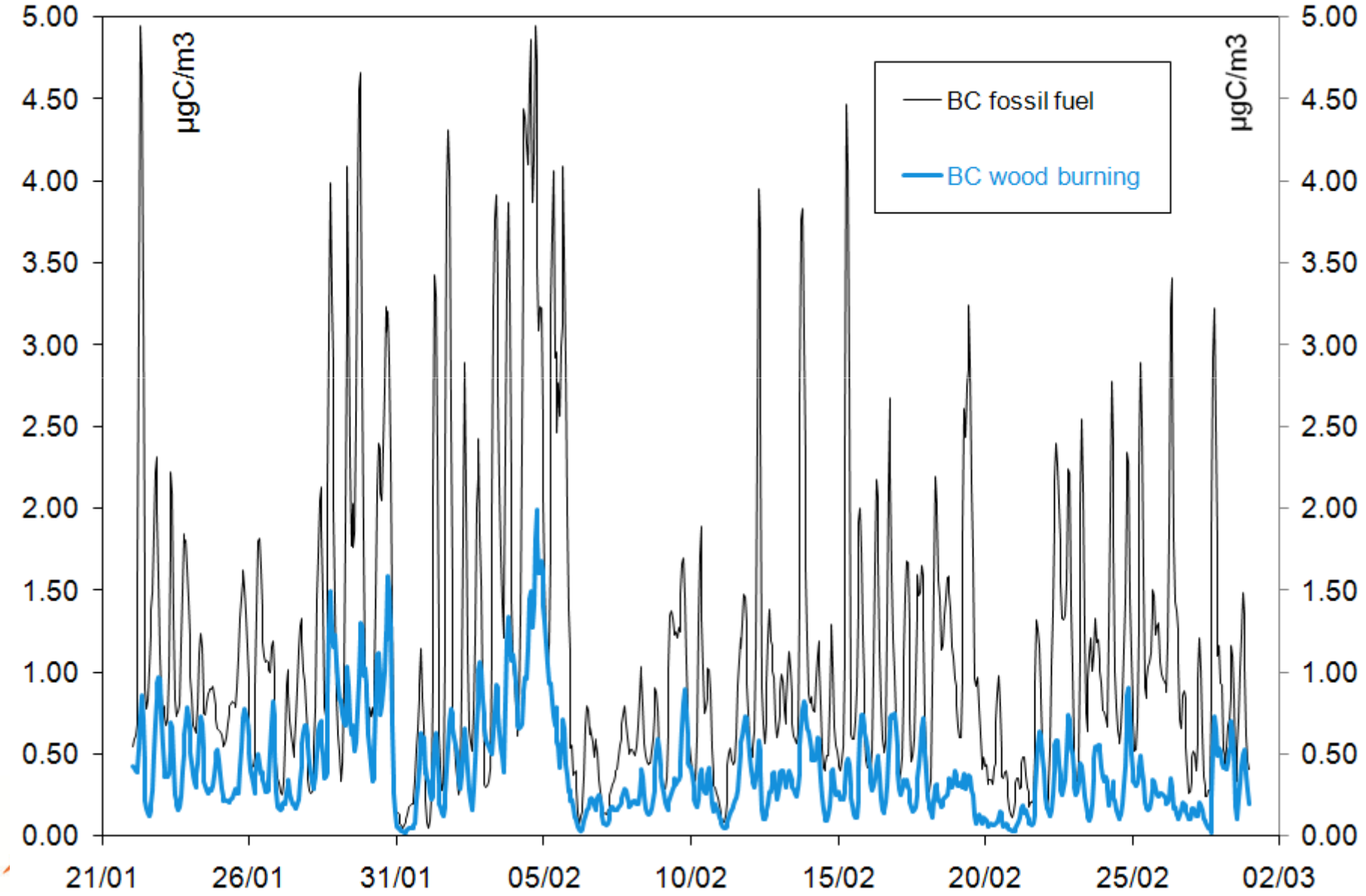
$BC_{ff} = BC\ b_{ff}(950\ nm) / b(950\ nm)$

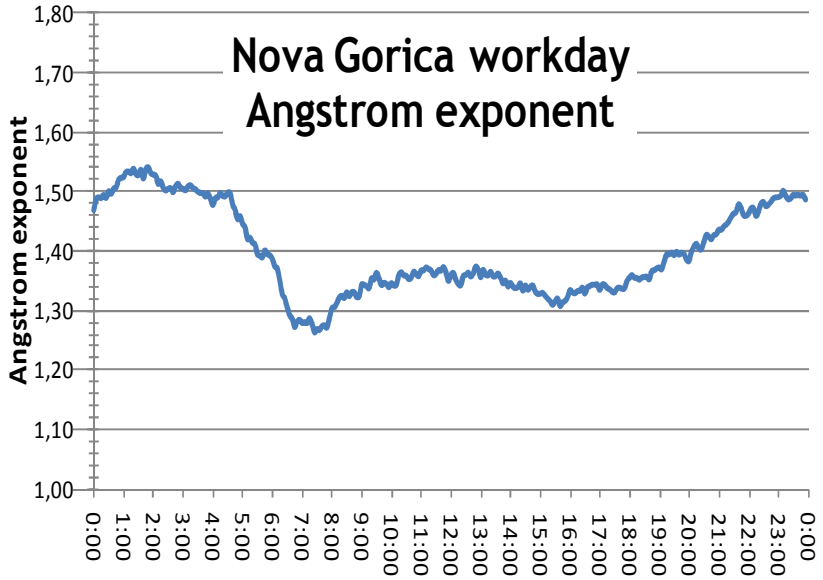
$BC_{wb} = BC - BC_{ff}$




Sandradewi 2008

# $BC_{ff}$, $BC_{wb}$ time series, Nova Gorica




Nova Gorica workday
Angstrom exponent
Angstrom exponent
1,80
1,70
1,60
1,50
1,40
1,30
1,20
1,10
1,00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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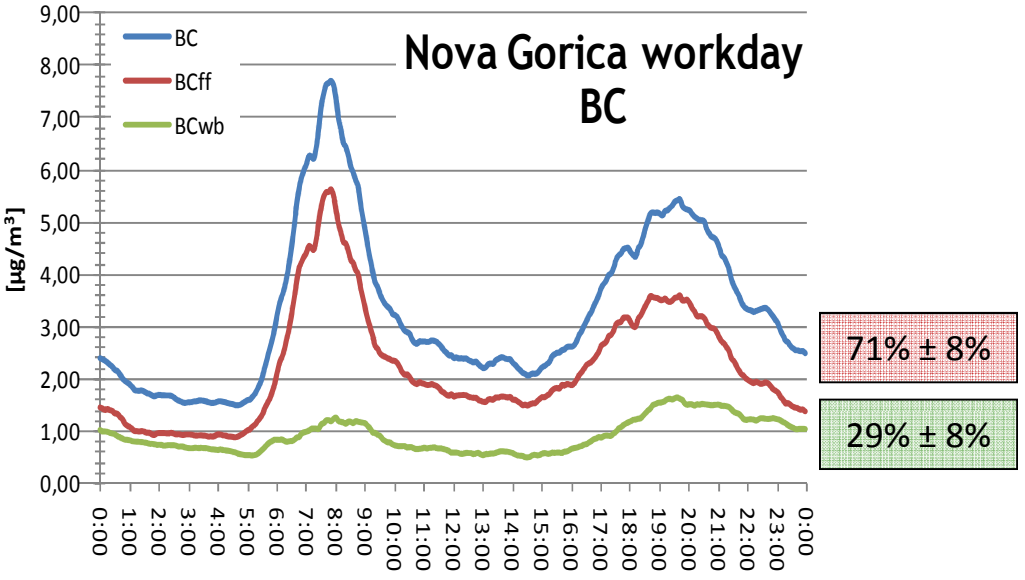
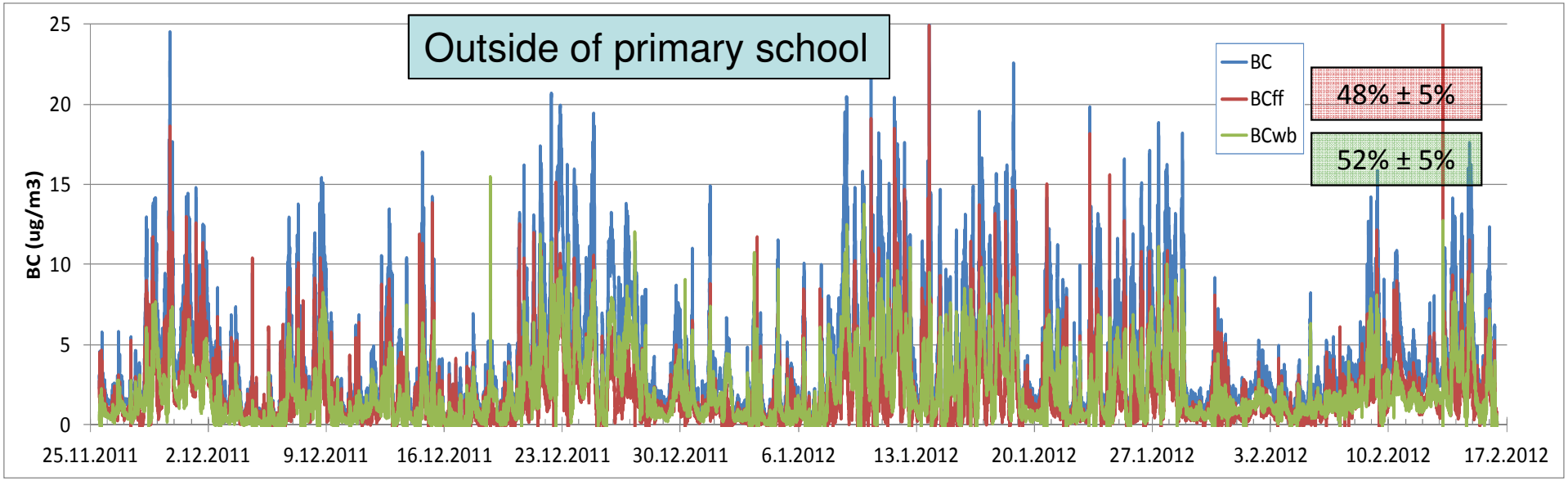
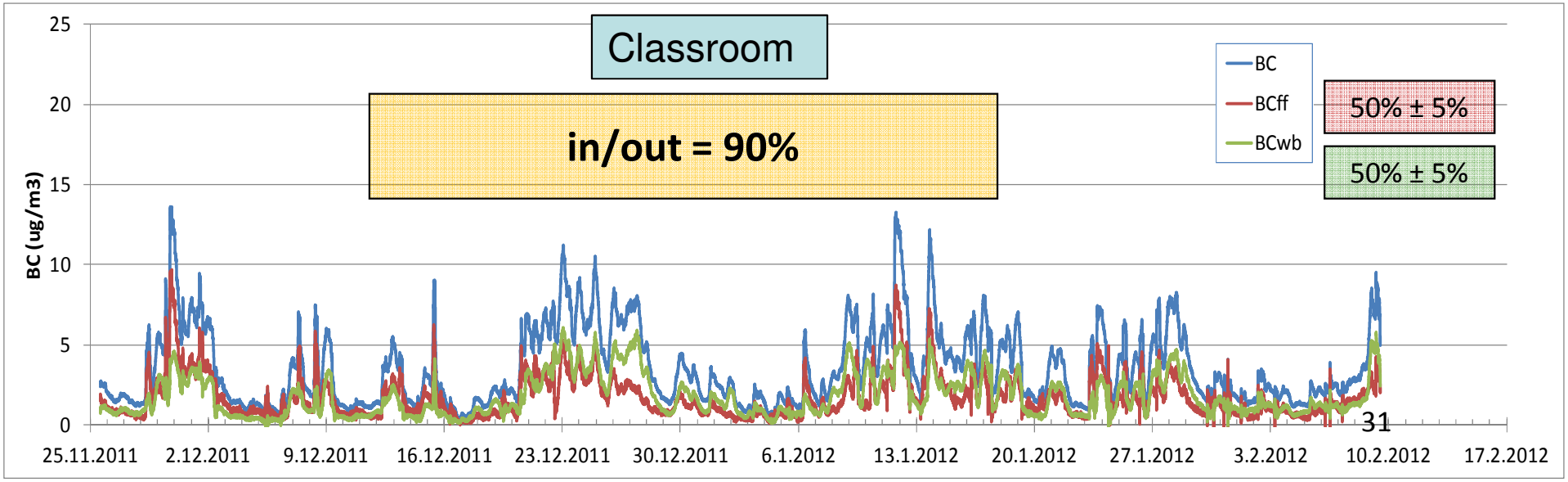
19:00
20:00
21:00
22:00
23:00
0:00


Nova Gorica workday
BC
BC
BCff
BCwb
[µg/m³]
9,00
8,00
7,00
6,00
5,00
4,00
3,00
2,00
1,00
0,00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
71% ± 8%
29% ± 8%

Aerosol

# Outdoor -> indoor BC concentrations

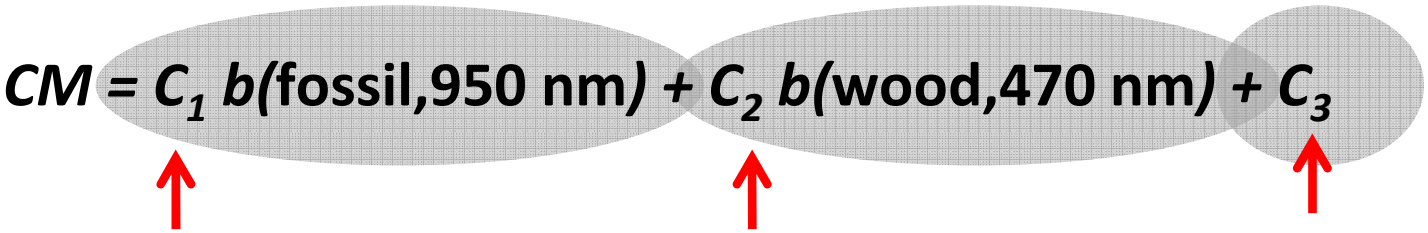


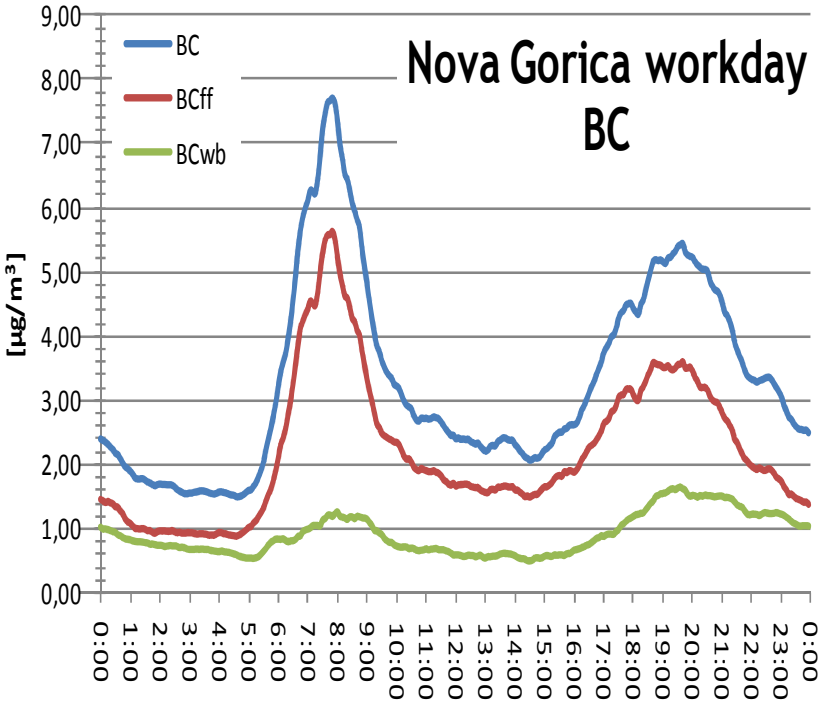
# Carbonaceous matter

measure Total Carbon – 24 h resolution

*TC = OC + EC* → *carbonaceous matter CM*

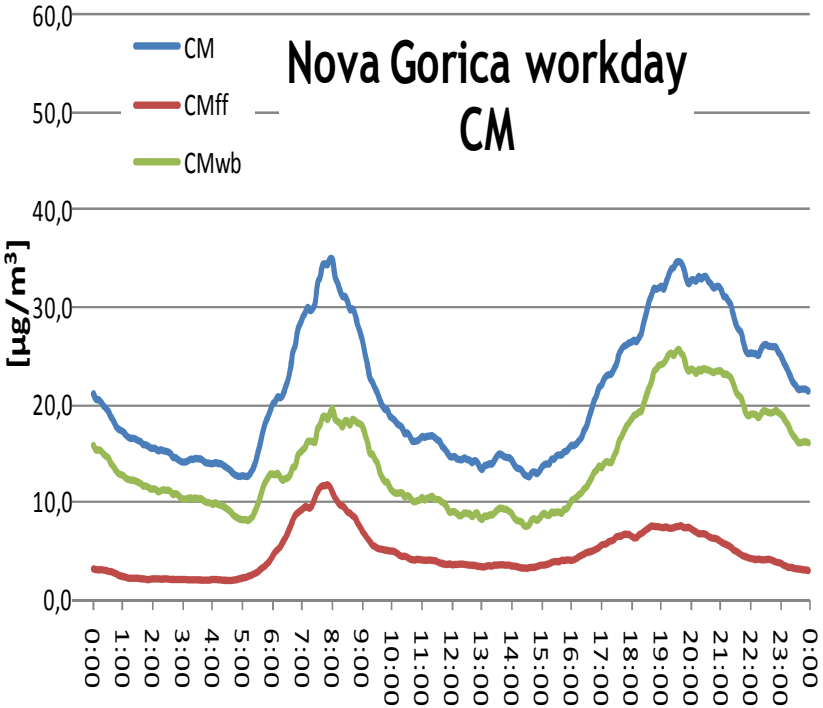



***CM = BC + OM***




71% ± 8%

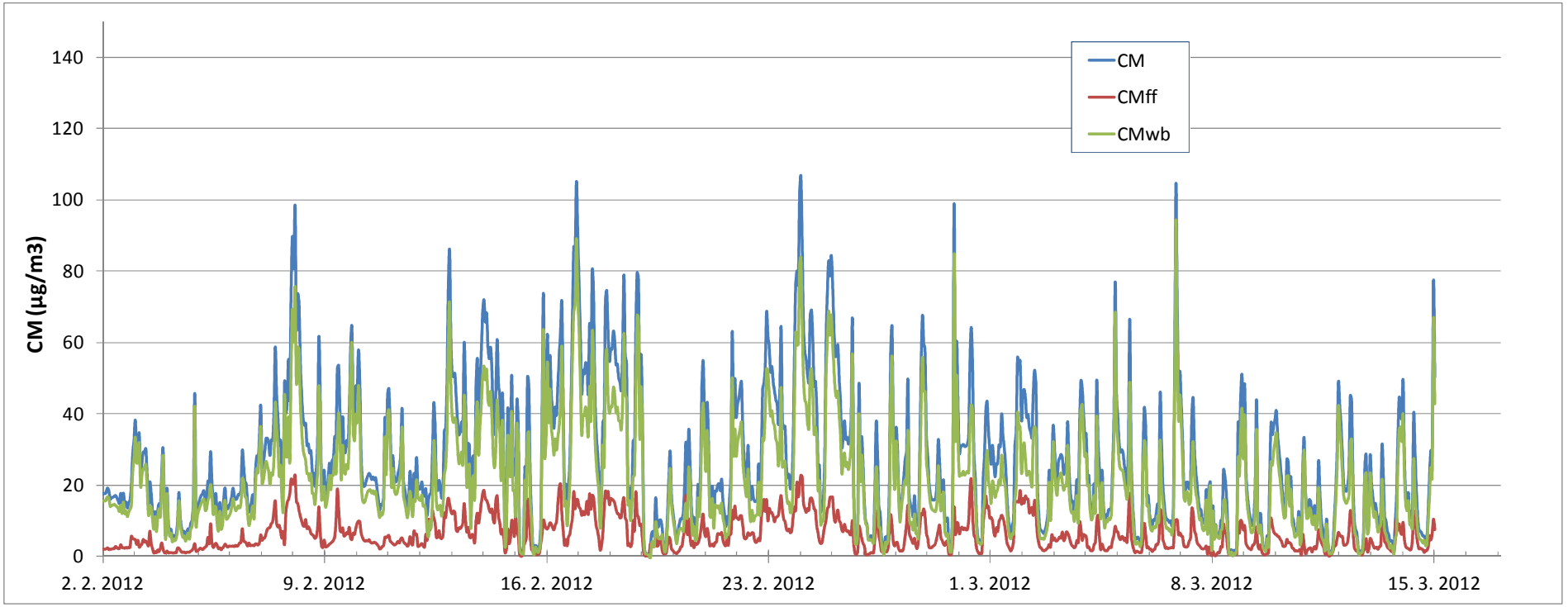
29% ± 8%




71% ± 15%

22% ± 15%

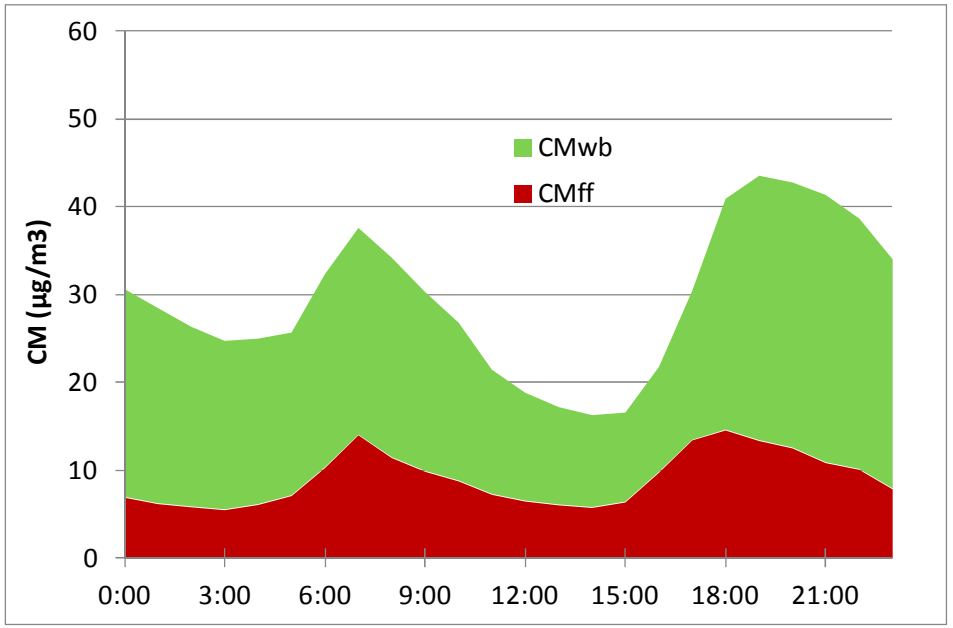
Aerosol




# Klagenfurt

OC/EC TUW

Aerosol

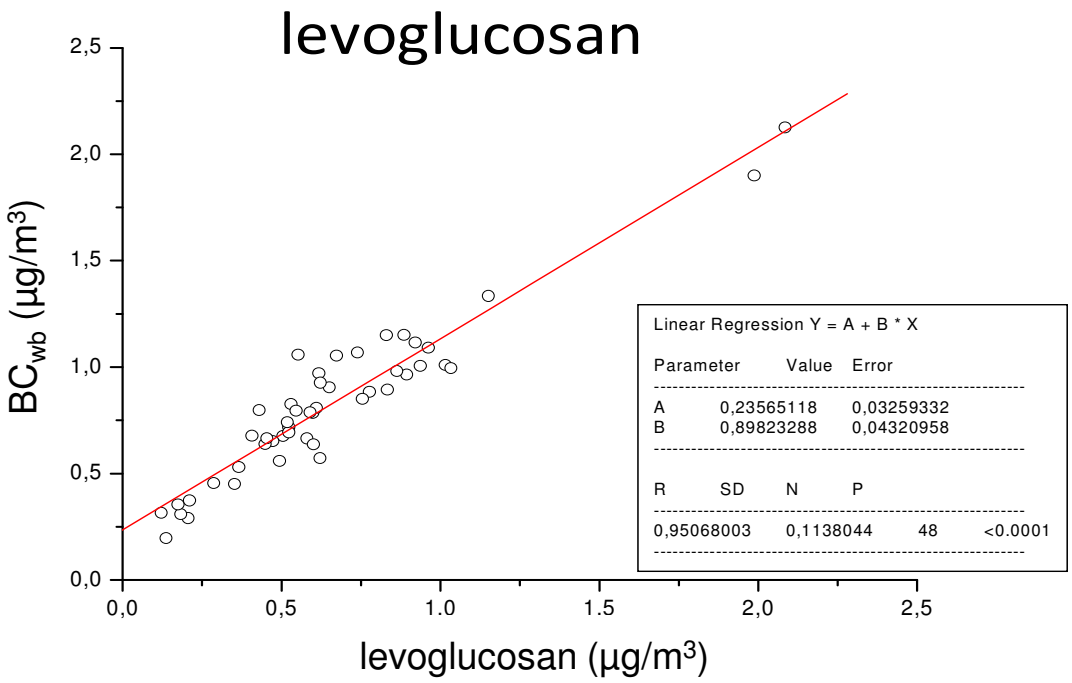



69% ± 22%

31% ± 10%

# Wood-smoke markers – levoglucosan

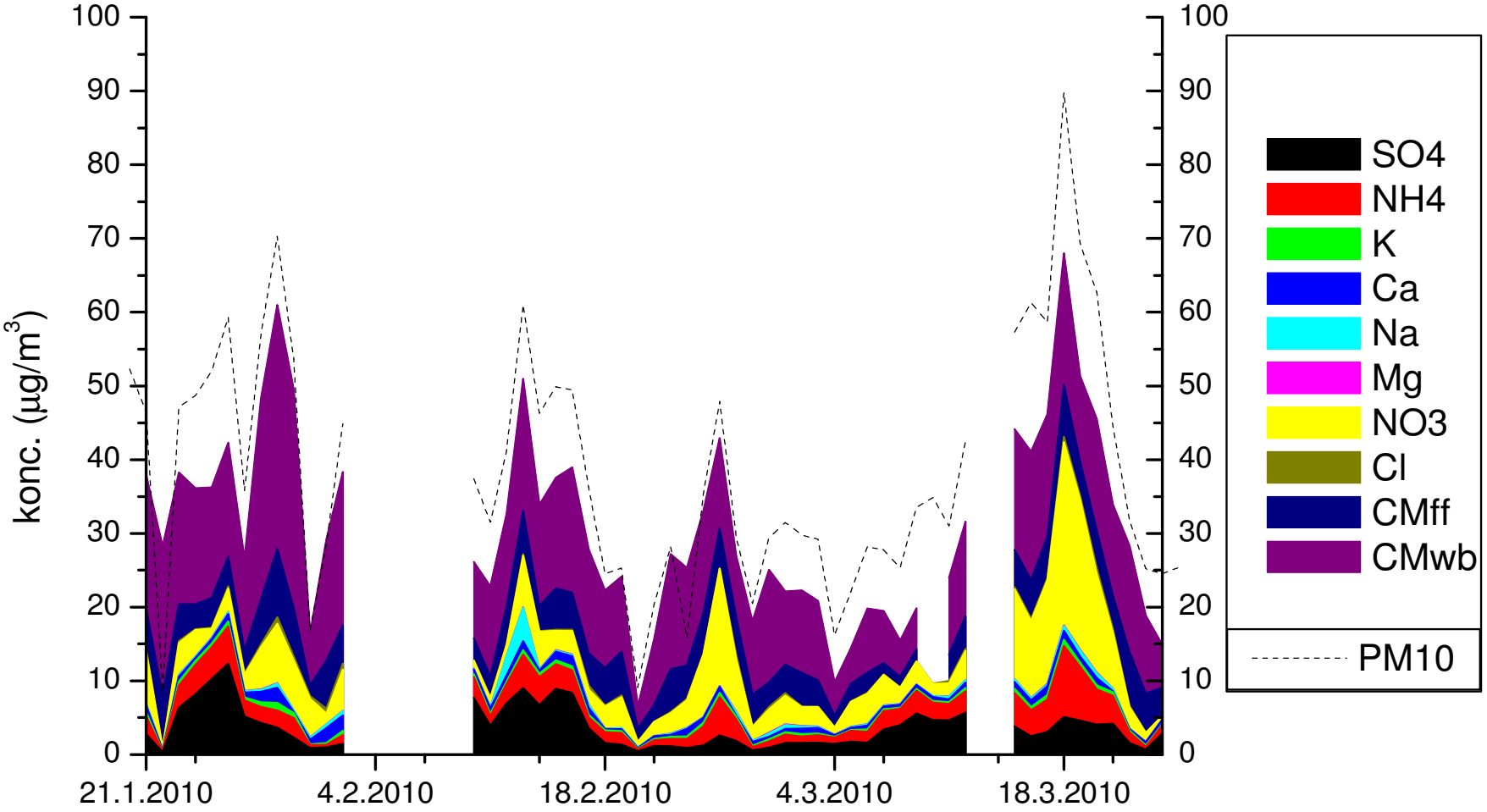
**Nova Gorica**




Levoglucosan - ion chromat. EARS

# Mass closure – Nova Gorica

Filter chemical analysis- EARS




Aerosol

# Conclusions

- we can measure **Fossil Fuel** and **Wood-Smoke Black Carbon** with the Aethalometer: less BC from wb than ff
- time resolution is **5 min**
- we can investigate **time evolution** of BC and WS during the day, excellent correlation with markers, PAH source
- **quantitative Wood-Smoke determination** – 24 h TC, yet still high time resolution (15-30 min): more carbonaceous aerosol from wb than ff!

Aerosol

# Conclusions (2)

- all this and more - automatically in AE-33 and TC module, under development

| AE-33 | + | TC |
|---|---|---|
| 1 min | | ~ 20 min |

**Thank you for your attention!**
**Questions?**

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Aerosol

# INTERNATIONAL CONFERENCE

of the project **PMinter** on

# AIR QUALITY

## 15th and 16th of May 2013
## Maribor, Slovenia

for environmental experts, administration authorities, transport specialists, academia ...

**about monitoring and modelling of**

PM10, fossil and non-fossil organic carbon, traffic emissions&wood combustion: measures to reduce them, regional air quality management plans and cross border co-operation

Naložba v vašo prihodnost
Operacijo delno financira Evropska unija
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Investition in Ihre Zukunft
Operation teilfinanziert von der Europäischen Union
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REPUBLIKA SLOVENIJA
MINISTRSTVO ZA GOSPODARSKI RAZVOJ IN TEHNOLOGIJO

KÄRNTEN

Umwelt. Klagenfurt am Wörthersee
Die Landeshauptstadt

TU Graz

Das Land Steiermark

Univerza v Mariboru

MESTNA OBČINA MARIBOR