

Importance of measuring Black Carbon

Real-time aerosol analysis of aerosol Black Carbon for over 30 years

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Slovenia

Slovenia has a very strong reputation for the beauty and preservation of our environment.

Our capital city, Ljubljana, was nominated as the “Green Capital of Europe”



Black Carbon and Aethalometer AE33

A. Why measure BC?

What, sources, effects

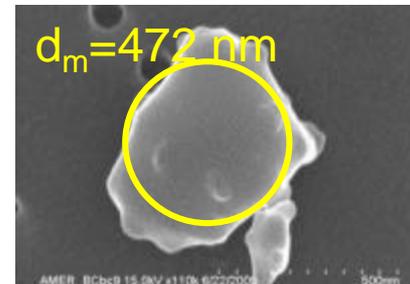
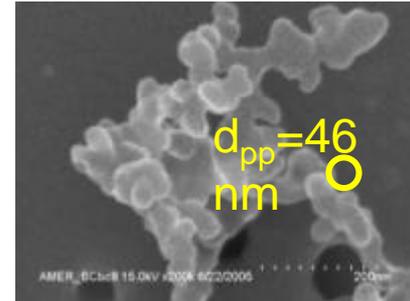
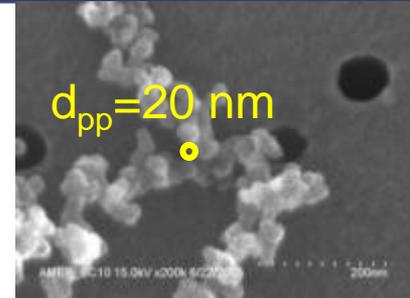
B. Getting good quality data with Aethalometer



Why measure BC?

What is BC

- BC is a **primary** product of incomplete **combustion of carbon fuels**
- **BC** is the **most strongly light-absorbing component** of particulate matter (PM)
- **Inert**: not destroyed in atmospheric processes: removed only by deposition
- **Active Surface** may be highly porous and covered with chemically-active functional groups and/or **toxic compounds**
- May act as a **condensation nucleus** and change the **optical** and **microphysical** properties of **clouds**.
- BC **not** automatically related to CO₂ emission



Note change in scale

Why measure BC?

What is BC

- Quantity of fuel → CO₂
- Quality of combustion → BC
- **BC / (kilogram fuel) is unpredictable * 10³**

BC - MUST BE MEASURED

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



Why measure BC?

Sources

BC and CM – two sides of the same coin

Black Carbon

BC

Primary sources



Carbonaceous matter

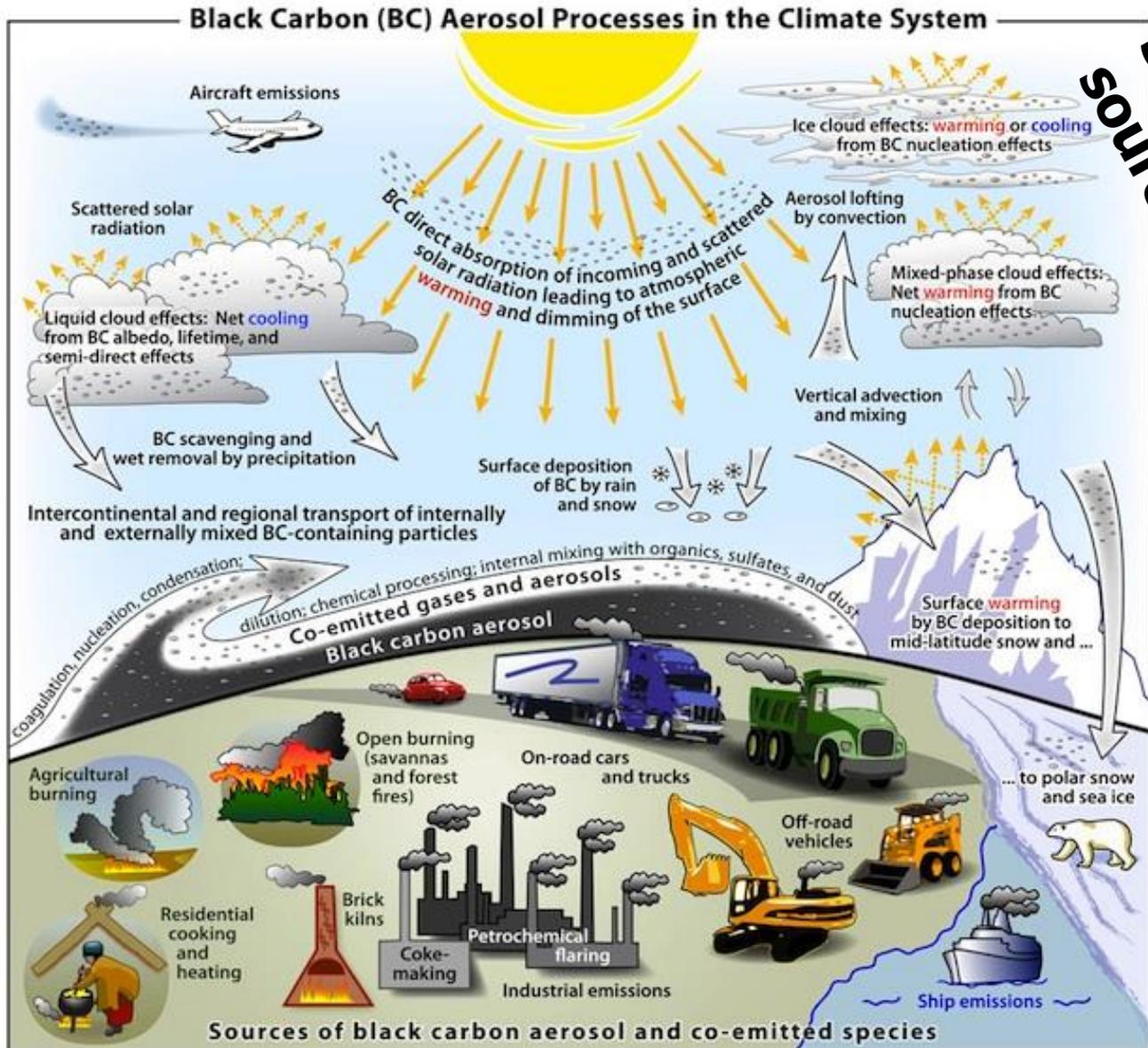
CM

Primary and secondary, contribution to PM2.5



Why measure BC?

Sources



Primary sources

Secondary sources

T. Bond et al. JGR (2013)



Sources of black carbon aerosol and co-emitted species

Air pollution effects

- **Public health** – disease & death
- **Climate change** – local, regional and global
- **Precipitation** – reduction of rainfall
- **Visibility** - haze
- **Reduction of sunlight** for agriculture
- Damage to **cultural heritage** (buildings, monuments, art)

Air pollution HEALTH effects

- **Public health** – disease & death

respiratory infections, chronic obstructive pulmonary disease, stroke, heart attack, lung cancer

Diesel Particulate Matter is a listed Air Toxic

4 mio people die due to air pollution globally

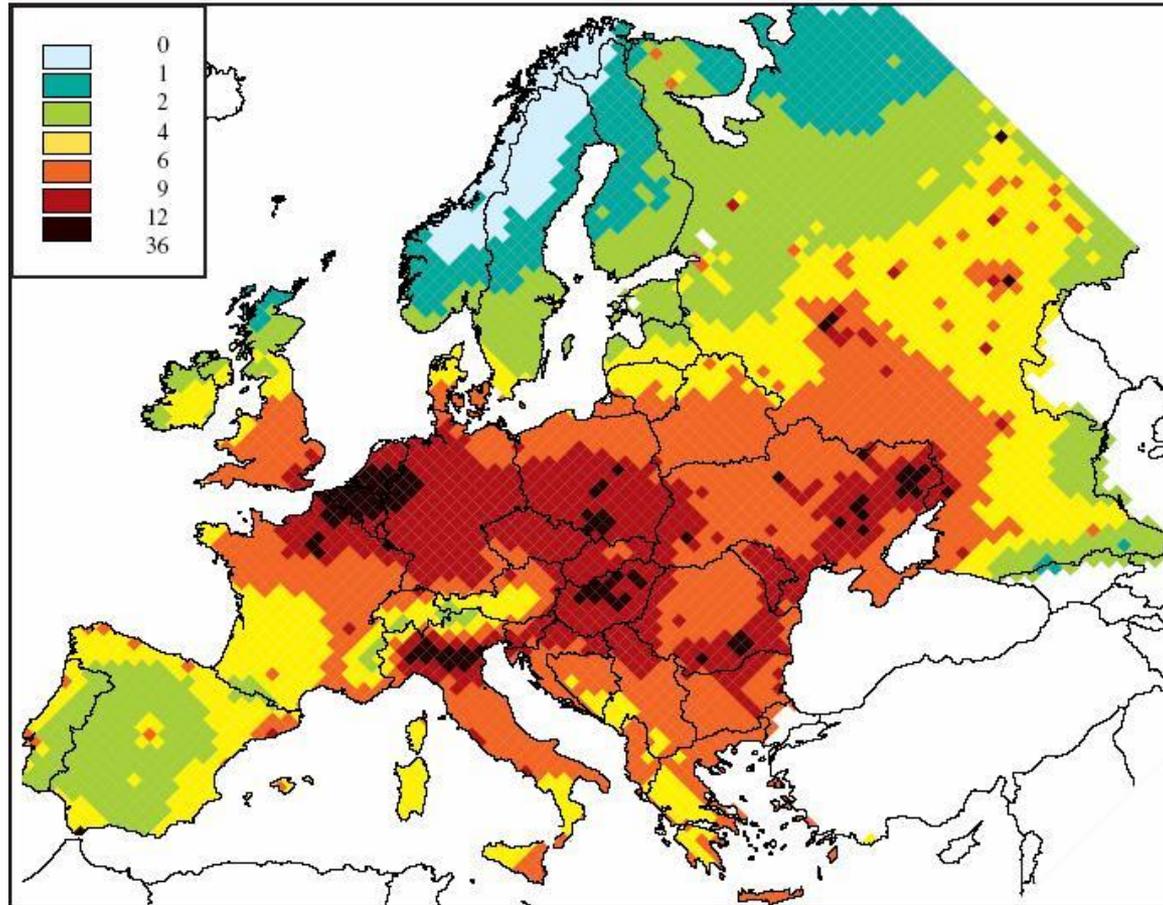


(Sources: WHO, EU, EPA, The Lancet)

Air pollution HEALTH effects

Loss of life expectancy in Europe

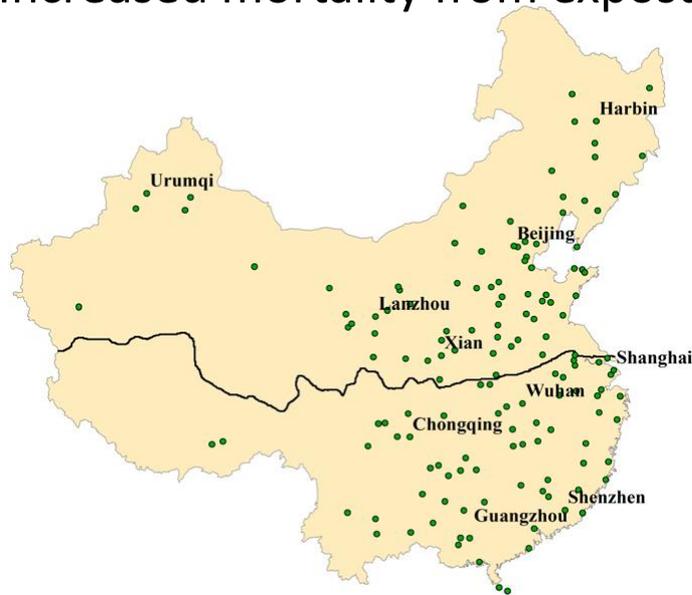
Loss of life expectancy (months)



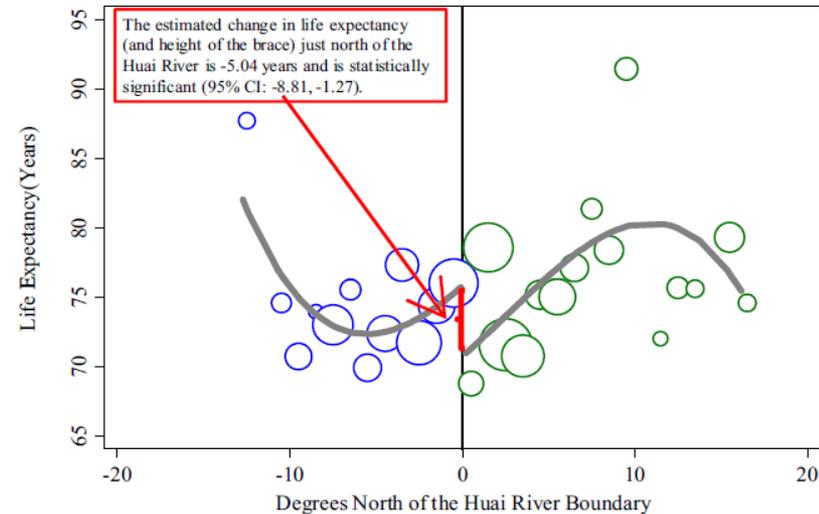
CAFE Report, EU Commission, 2000

Air pollution HEALTH effects

Increased mortality from exposure to coal smoke: China's "Huai River" policy



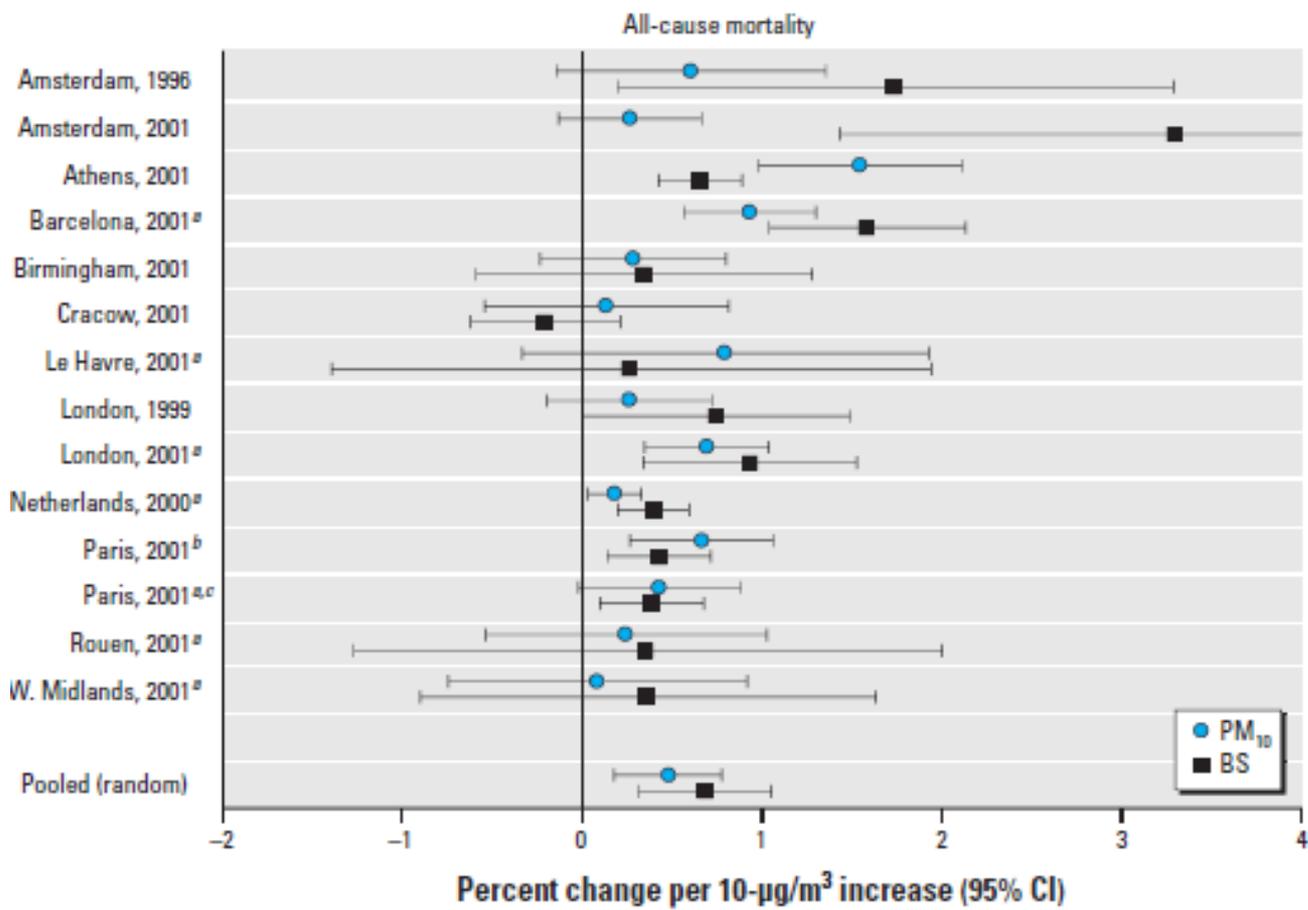
Coal for winter heating was distributed free of charge to all citizens living north of the dividing line



Life expectancy shows a discontinuity of **five years** at the dividing line

'Evidence on the impact of sustained exposure to air pollution on life expectancy from China's Huai River policy', Chen et al., PNAS (2013)

Air pollution (BC!) HEALTH effects



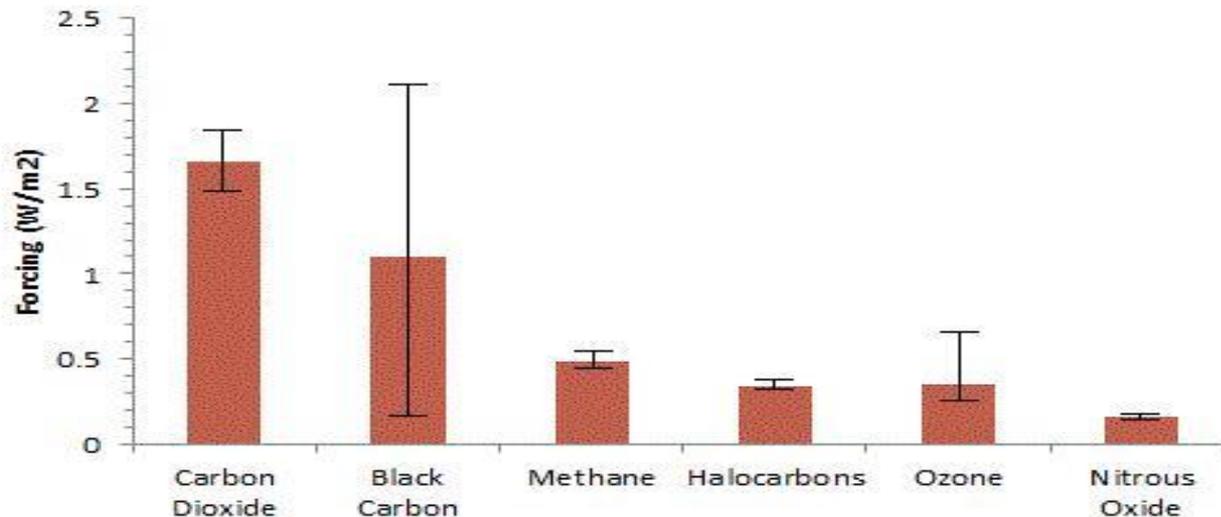
Two-pollutant models in time-series studies suggested that the effect of BCP was more robust than the effect of PM mass. The estimated increase in life expectancy associated with a hypothetical traffic abatement measure was **four to nine times higher** when expressed in BCP compared with an equivalent change in PM_{2.5} mass.

Jansen et al, 2011 EHP

Black Carbon CLIMATE effects

- **Climate change** – local, regional and global

Black Carbon is a listed Greenhouse Agent #2

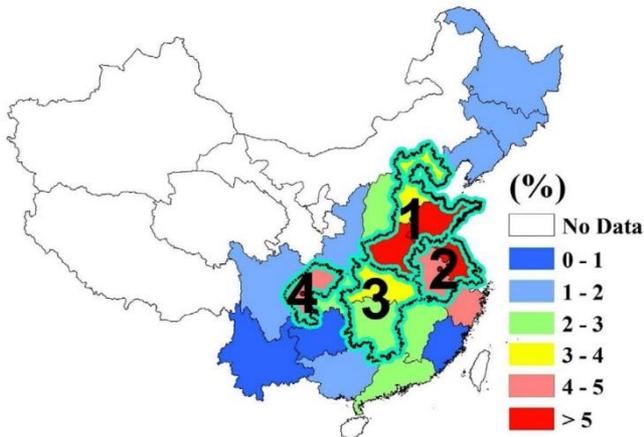


Source: Bounding the role of Black Carbon in the climate system; T. Bond et al. JGR (2013)

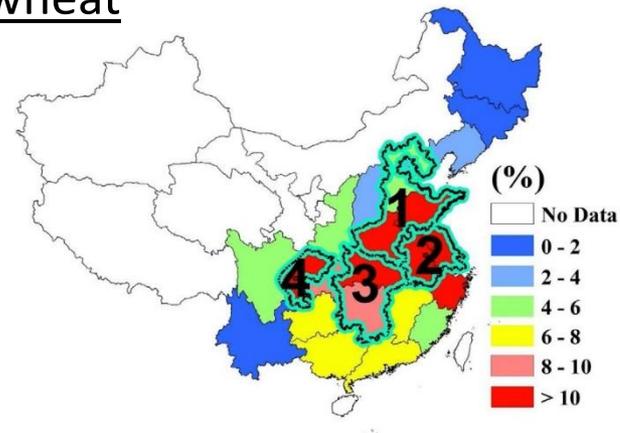
Air pollution RAINFALL ... effects

- **Precipitation** – reduction of rainfall
- **Visibility** – haze; also, reduction of sunlight for agriculture

In China, where air pollution is serious, it may reduce the production of rice and wheat



Rice: up to **5% loss**



Wheat: **over 10% loss**

Effect of heavy haze and aerosol pollution on rice and wheat production in China Tie et al., Nature Sci. Rep. 6, 29612 (2016)

Iran?

Bad
news

PHYS ORG Nanotechnology ▾ Physics ▾ Earth ▾ Astronomy & Space ▾ Technology ▾ Chemistry ▾

f t r e m

Home » Earth » Environment » December 17, 2017

Heavy air pollution shuts schools in Iran (Update)

December 17, 2017

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Iran shut schools around Tehran Sunday and cancelled sporting events as thick smog blanketed the capital despite curbs on road traffic and industrial activity.

The authorities shuttered primary schools in the province of Tehran, home to 14 million residents, before ordering them to remain closed on Monday.

All sports competitions set for Monday were also cancelled, as restrictions on road traffic were stepped up, including a ban on trucks.

Airborne concentration of fine particles (PM2.5) hit 185 microgrammes per cubic metre in the south of Tehran and 174 in its centre on Sunday morning, local authorities said.

That is far above the World Health Organization recommended maximum of 25 microgrammes per m³ over a 24-hour period.

The microscopic particles lodge deep in the lungs and are harmful to human health.

Iran ... خبر خوب (good news)

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Tue January 23, 2018

TEHRANTIMES
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Restricting diesel engine trucks eases Tehran's air pollution

December 30, 2017

Society



Summary : BC is important pollutant

- **BC emissions vary** by orders of magnitude
- **Local effects:** health
- **Regional effects:** transport of pollutants
- **Global effects:** climate
- Need to measure **emission factors**
- **Ambient concentrations** show extreme **heterogeneity**

Need to **measure** – **local, regional and global:**

- determine „**zero state**“
- Design abatement: **goals, measures**
- implement abatement **actions**
- **measure effectiveness** of the abatement; adapt if necessary

BC – Need for Data

- **Climate impact** of BC is second only to CO₂
- Ground-level BC concentrations that affect **public health** are **highly variable**
- BC emissions can not be predicted: must be **measured**
- To manage **Climate** and **Health** impacts, we need **data** :

BC (X, Y, Z, t)



How to obtain good BC data

Real-time aerosol analysis of aerosol **Black Carbon** for almost **40 years**



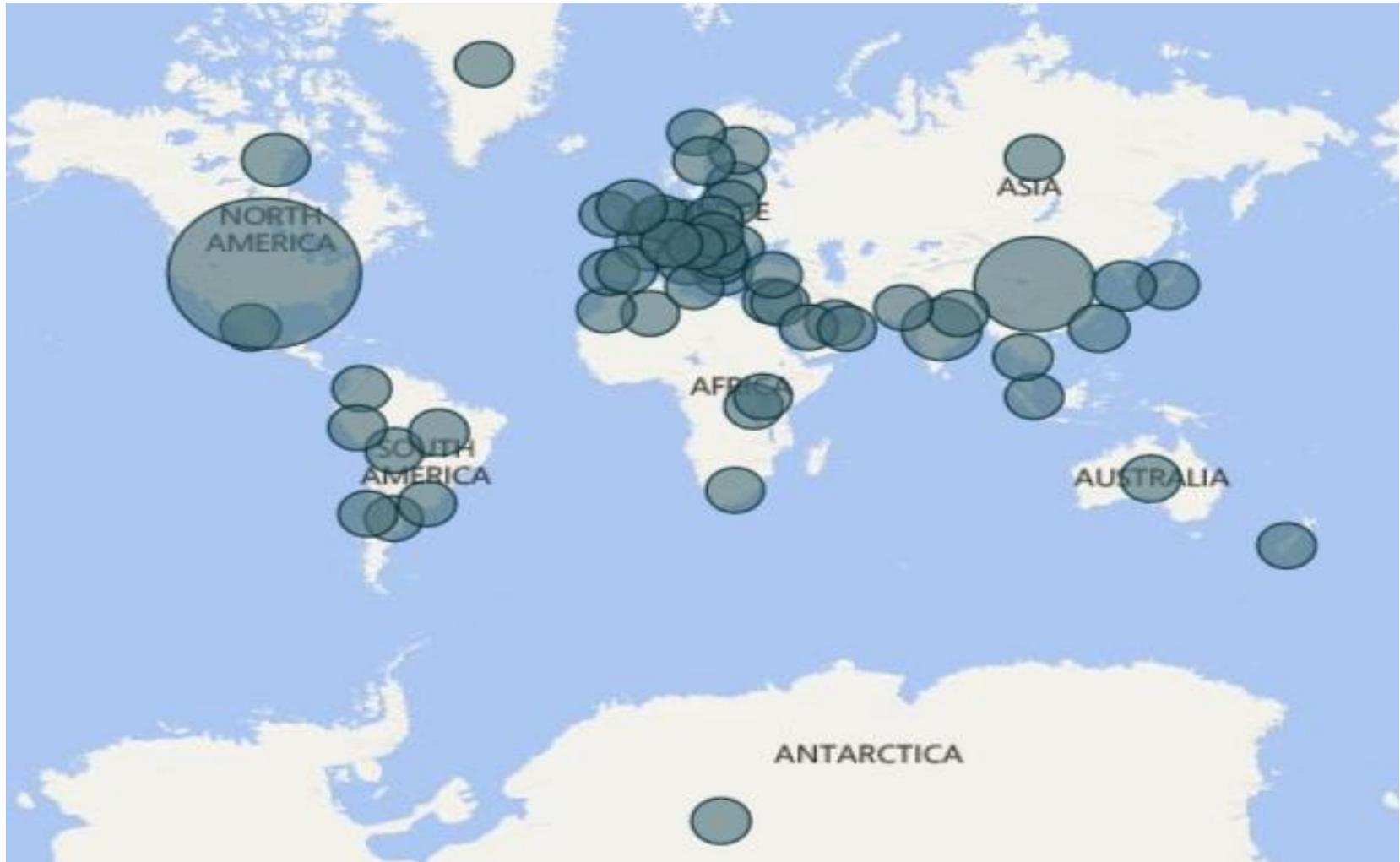
Magee Scientific Aethalometer AE33



The Eurostars Programme is powered by EUREKA and the European Community



Magee Scientific Aethalometer



Aethalometer AE33 : Key features & benefits

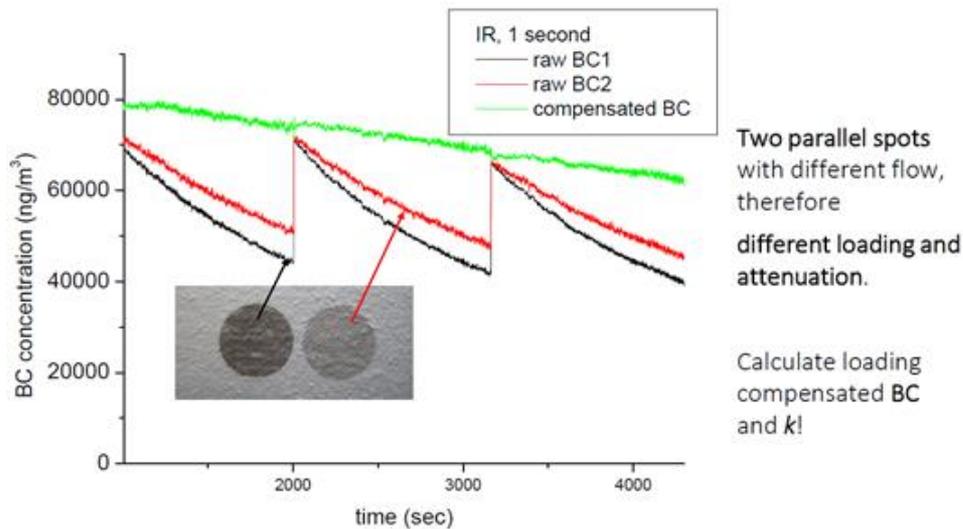
1. **Fully automatic** operation, **rugged**, reliable
2. **High time resolution** (1-Hz) analytical response
3. Real-time **Source Apportionment** †
4. Real-time **Filter Loading Compensation** (Dual Spot™) †
5. **QA/QC** procedures
6. Combine with TCA-08 for “**OC/EC**” determination †

*† this feature is unique to the Aethalometer,
and is not offered in any other instrument*

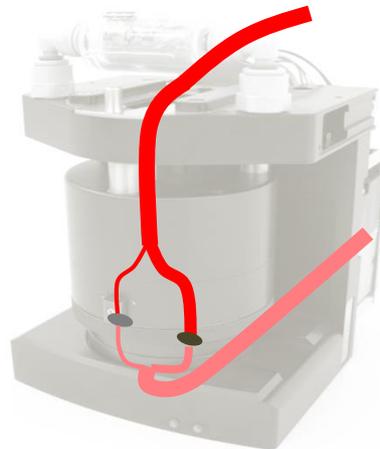


**RELIABLE DATA, MORE DATA,
LESS POST-PROCESSING**

Filter Loading Compensation - Dual Spot™



- Automatically: out of the box (AE33)
- No need for postprocessing
- Real-time „good data“
- „More data“ : indication of age of aerosols (k-values)



AE33 : 7 λ – separating diesel from biomass...

Real-time source apportionment

7 λ : 370, 470, 520, 590, 660, 880, 950 nm

- “Black” materials absorb uniformly across the spectrum: the 880 nm analysis is quantitative for ‘**Black Carbon**’.

/traffic; diesel; liquid fuel/



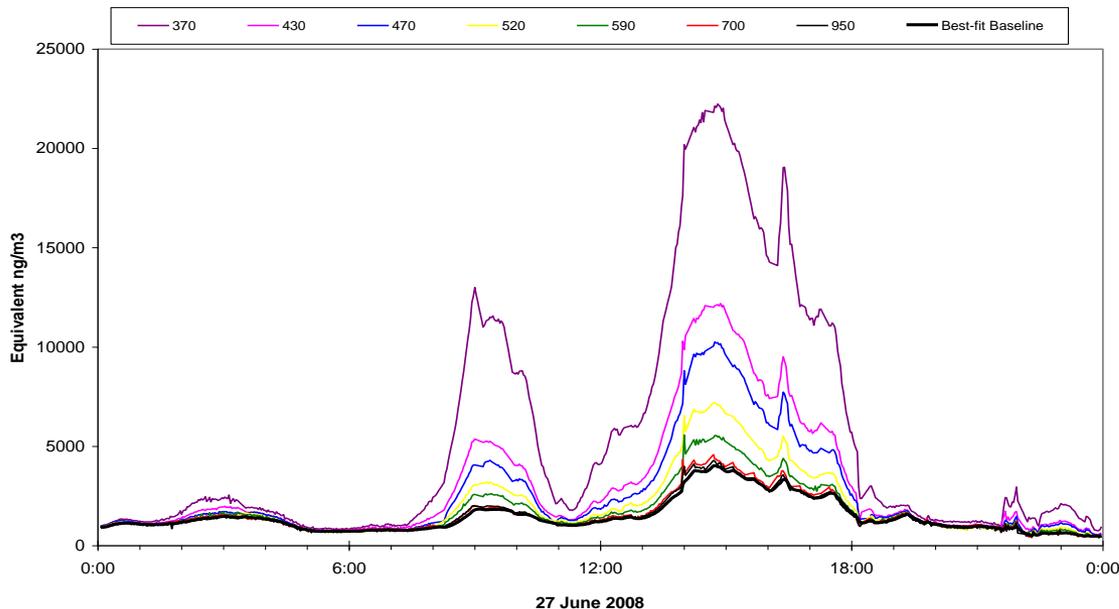
- Other species – aromatic organic compounds – sometimes called “**Brown Carbon**” - can show increased absorption at shorter wavelengths.

/biomass; woodsmoke; coal; solid fuel;
aromatic compounds; organic vapors/

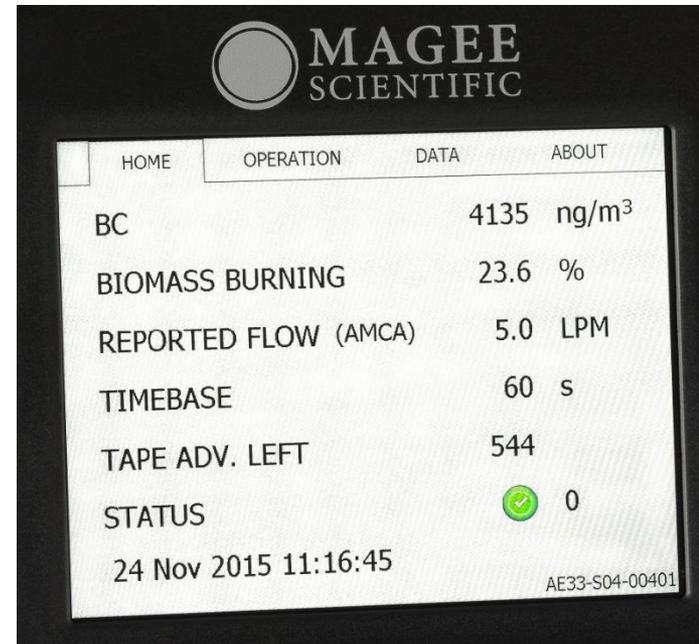


AE33 : 7 λ – separating diesel from biomass

7-wavelength Aethalometer data - biomass burning plume impact at remote site.
Data as recorded



Data courtesy of Bryan Fabbri, NASA 'COVE' program, 2008



- Automatically: out of the box (AE33)
- No need for postprocessing
- Real-time „good data“ and „more data“

Aerosol Black Carbon : Global Measurements

WORST : S. & E. Asia, 2×10^9 people. BC = 10 ~ 100 $\mu\text{g}/\text{m}^3$.



Aerosol Black Carbon : Global Measurements

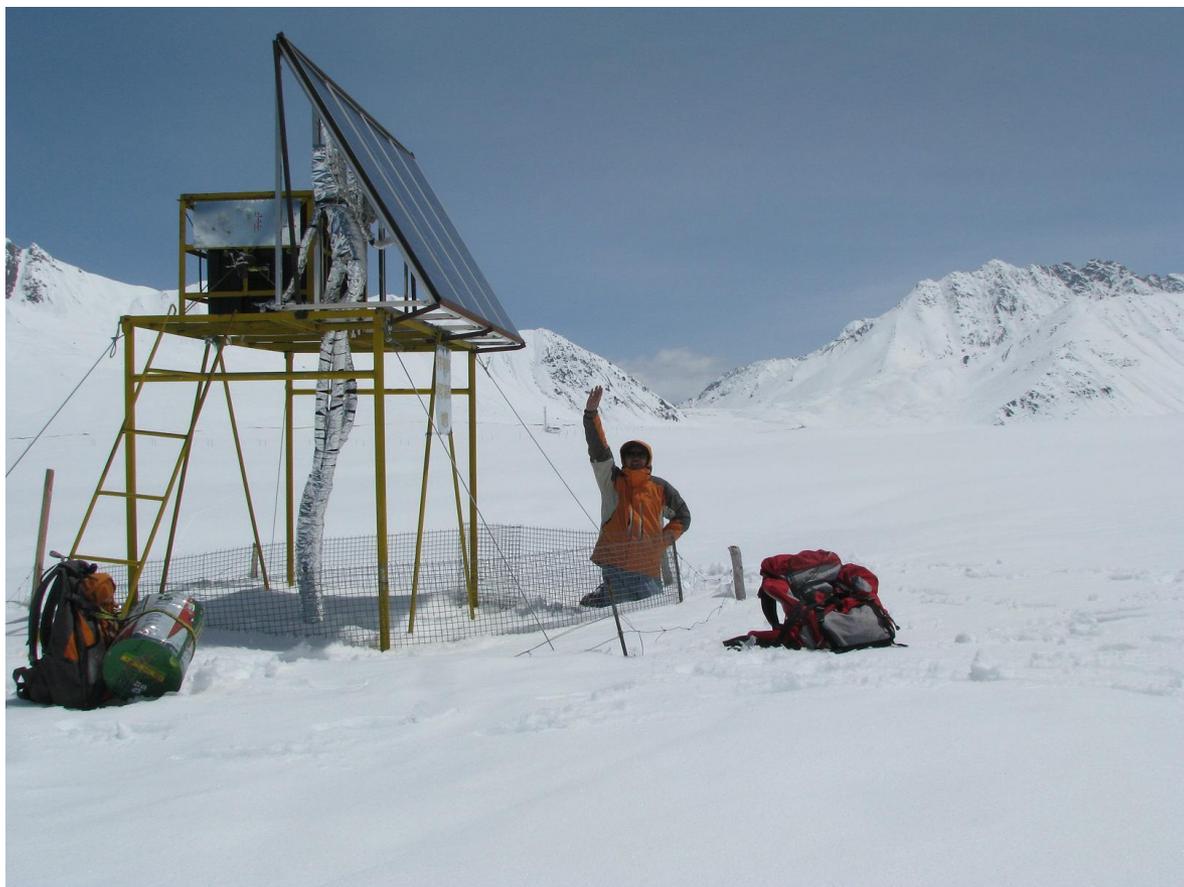
BEST : Antarctica, 200 people. BC < 1 ng/m³, -55°C

Dr. Tony Hansen
The Inventor &
Owner/CEO MageeSci



Aerosol Black Carbon : Global Measurements

Tibet, China : Altitude 5200 m.



Picture courtesy of J. J. Cao, Xi'an, China

Aerosol Black Carbon : Global Measurements

Amazonian rain forrest, Brazil: extreme T and RH conditions.



Picture courtesy of Prof .Paulo Artaxo

Aerosol Black Carbon : Global Measurements

Mojave Desert, California, USA : +45°C

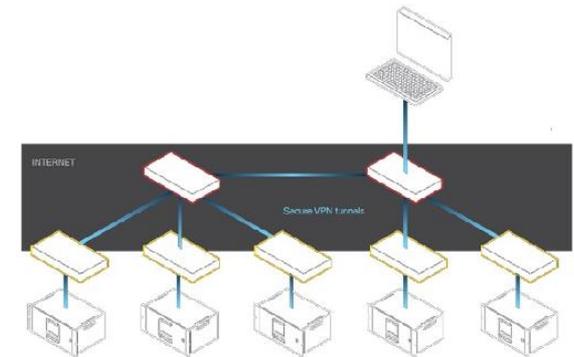


Picture courtesy of E. Winegar, California

The Magee Scientific Aethalometer AE33 Global acceptance

1. EMPA, Swiss Federal Laboratories for Materials Science and Technology, Switzerland
2. US Environmental Protection Agency, USA
3. Paul Scherrer Institute, Switzerland
4. California Air Resources Board, USA
5. CMA, China Meteorological Administration, Beijing, China
6. INERIS, National Institute for Environment, France
7. CNEMC, China
8. IMD, India Meteorological Department, Delhi, India
9. NESCAUM, Northeast States for Coordinated Air Use Management, Boston, USA
10. CIEMAT, Center for Research in Energy/Ambient/Technology, Spain
11. Port of Long Beach, USA
12. Institute for Advanced Sustainability Studies, Germany
13. National Institute of Optics, Romania
14. AARI, The Arctic and Antarctic Research Institute, Russia
15. IIT (Indian Institute of Technology), various campuses, India
16. South Coast Air Quality Management Dist., Los Angeles, California, USA
17. Rwanda Climate Observatory (MIT), Rwanda
18. NOAA Global Monitoring, National Oceanic and Atmospheric Administration, USA
19. ICIMOD, Intl Centre for Integrated Mountain Development Kathmandu, Nepal
20. TROPOS, Leibniz Institute for Tropospheric Research, Germany
21. AIRPARIF, Air Quality network in Paris, France
22. Flemish EPA, Belgium
23. Bay Area Air Quality Management Dist., San Francisco, California, USA
24. CDER, Centre de Recherche dans le domaine des Energies Renouvelables, Algeria
25. NILU, Norwegian Institute for Atmospheric Research, Norway
26. CNRS-CEA, National Center for Scientific Research, France
27. LANUV, State Agency for Nature, Environment and Consumer Protection, Germany
28. Air Quality Control Company, Tehran, Iran

Small country, great products



Variety of applications

Evaluating transport air quality measures



Motivation

Atmospheric pollution represents a risk factor for respiratory health. Traffic emissions are of particular concern in urban related pollutants have been associated with overall mortality of respiratory health.

Many large cities all over the world have recognized the need for an encouragement of public transportation usage, traffic flow improvement, speed limit reduction, traffic restrictions are an unpopular tool to mitigate improvement in air quality is needed to demonstrate the benefits of such measures.

Among traffic-related pollutants, black carbon (BC) has been shown to be a particularly important pollutant. BC concentrations vary proportionally with those of CO, NO₂ and NO. BC can therefore be considered a good emission because it is primarily and directly emitted by diesel engines.



Evaluating Residential wood combustion abatement



Motivation

Residential wood combustion contributes significantly to the total aerosol mass at various rural and urban sites throughout the world. Residential wood combustion is the largest source of aerosol mass at various rural and urban sites throughout the world. Residential wood combustion is the largest source of aerosol mass at various rural and urban sites throughout the world.

Smoke from wood stoves is generated primarily by incomplete combustion of wood. The number of different factors related to the wood stove's operation, including the type of wood, the stove's design, the heating method, and the building's insulation, all affect the amount of smoke emitted. The use of wood stoves is a common heating method in many rural and urban areas. The use of wood stoves is a common heating method in many rural and urban areas.



Mine ventilation optimization



Motivation

Mines use large ventilation systems to maintain a safe and healthy working environment. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

As mines go deeper it becomes more difficult to supply air. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Regional vs. Black Carbon pollution



Motivation

Once emitted into the atmosphere, the BC aerosol can be transported over long distances. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Understanding the range and timing of global concentrations may enable new ventilation on demand fan and filtration technologies to be developed. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Fossil fuel vs. Biomass burning Black Carbon



Motivation

Atmospheric pollution represents a risk factor for respiratory health. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Wood combustion in residential areas is commonly used for heating. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Global Black Carbon pollution



Motivation

Black carbon (BC) has a unique and important role in the Earth's climate system. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Comparisons with remote sensing observations indicate that the use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Spacial scale contributions to Black Carbon pollution



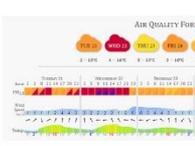
Motivation

Fixed-site air quality monitors used for compliance monitoring and to declare air quality alerts are intended to represent outdoor population exposures of people living in an approximately 50-100 km radius around the monitoring site. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

A method that resolves contributions from different spatial scales allows particle measurements from all monitoring sites to be better interpreted. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Black Carbon Pollution Alerts



Motivation

Exposure to air pollution, especially at high concentrations, is a major cause of respiratory problems, heart disease, cancer, and adverse effects on children's health. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Issuing high pollution alerts and offering forecasts can raise awareness, encourage people to take protective actions, and provide information to help them plan their activities. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Black Carbon car emissions



Motivation

One of the main sources of air pollution is traffic. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Two methods can be used to determine the so-called 'real world' emissions of a vehicle. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Vertical profiles of Black Carbon Pollution



Motivation

Detailed vertical profiles of aerosol parameters are needed to assess the impact of air pollution on human health and the environment. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

BC profiles are globally scarce compared to ground level data. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Stove characteristics Based on Black Carbon



Motivation

Smoke from wood burning stoves and fireplaces can be a significant source of air pollution. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

The U.S. Environmental Protection Agency (EPA) set standards for the certification of wood-burning stoves. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Fenceline Monitoring of Black Carbon



Motivation

In industrial fence line communities the environmental and public health impacts of air pollution are a major concern. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

The detectors can be positioned permanently inside the fence line. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Marine vessel Black Carbon Pollution



Motivation

The duration of use is usually significantly longer for marine vessels than for land-based vehicles. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Ship emissions contribute both to global warming. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



Urban Black Carbon Monitoring



Motivation

Aerosols affect the climate due to their ability to scatter and absorb sunlight, and to act as cloud condensation nuclei, thus modifying the lifetime of clouds, droplet size and precipitation rate. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.

Measurements of the vertical distribution of aerosol properties provide essential information for generating more accurate model estimates of radiative forcing and atmospheric heating rates. The use of large ventilation systems is essential for the safety and health of miners. The use of large ventilation systems is essential for the safety and health of miners.



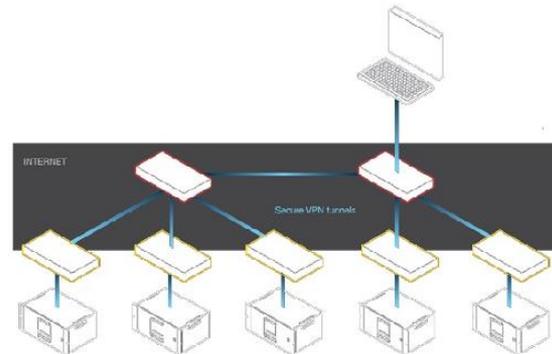
Aerosol d.o.o.

- **Aethalometer AE33**
- **Accessories:**
 - ND filter validation kit
 - Met station
 - CO2 sensor
- **Consumables:**
 - filter tape



Aerosol d.o.o.

- **Aerosol Inlet Dryer**
- **Optical transmissometer OT21**
- **Networking solutions:**
 - AethNET
 - AethAlerts
 - AEccessor



Aerosol d.o.o.

The R&D group at Aerosol d.o.o.

- is the leading group in Europe which concentrates entirely on topics of Carbonaceous Aerosols
- 57 peer reviewed articles + 130 conference presentations

Developed

New Method and Instrumentation to Measure and Characterize Aerosolized Carbon

TC-BC : TOTAL CARBON ANALYZER TCA08