

Črni ogljik, povzročitelj podnebnih sprememb

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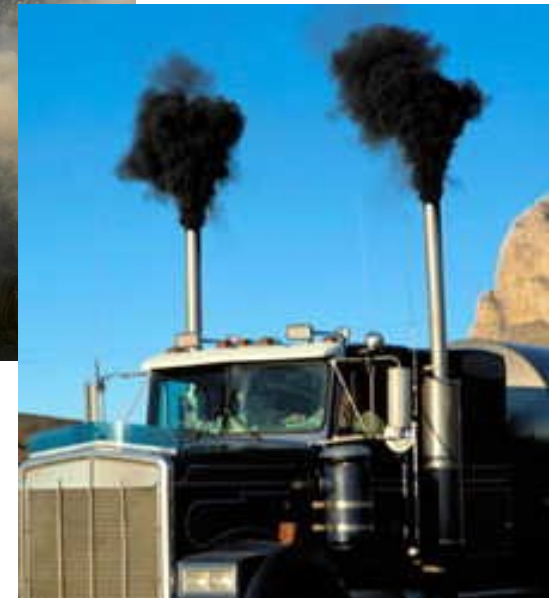


Zahvala sodelavkam in sodelavcem!

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Aerosolizirani črni ogljik

- Kaj je črni ogljik?
- Zakaj je pomemben?
- Kako ga merimo?
- Lokalne, regionalne in globalne meritve in relevanca
- Onesnaženost zraka!
- Kateri viri?
- Podnebne spremembe!



BC in CM – dve strani istega kovanca

Črni ogljik

BC

primaren, viri



Ogljični aerosoli

CM

Primarni in sekundarni, prispevajo k PM2.5



Aerosolizirani črni ogljik

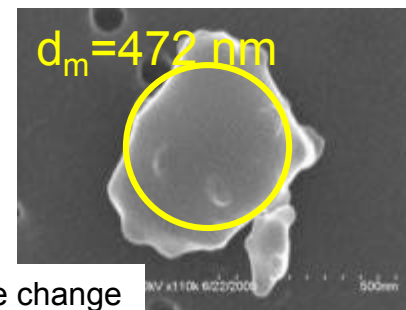
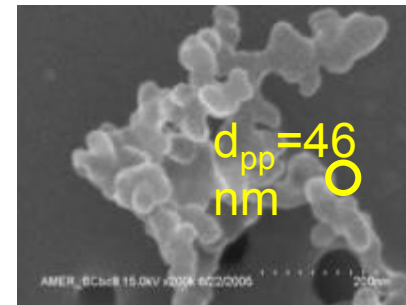
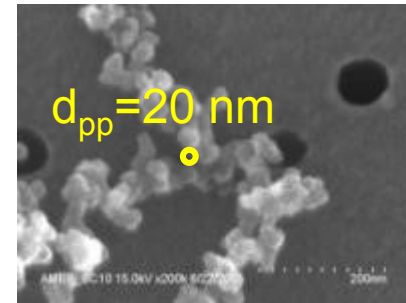
- BC is a **primary** product of incomplete **combustion**
- BC not automatically related to CO₂ emission
- BC emissions can not be predicted:

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)

- **relevance:** climate change, health



Note change
in scale

Črni ogljik je regionalno onesnaževalo



Approx. 1000 m above New Delhi region, India: late afternoon.

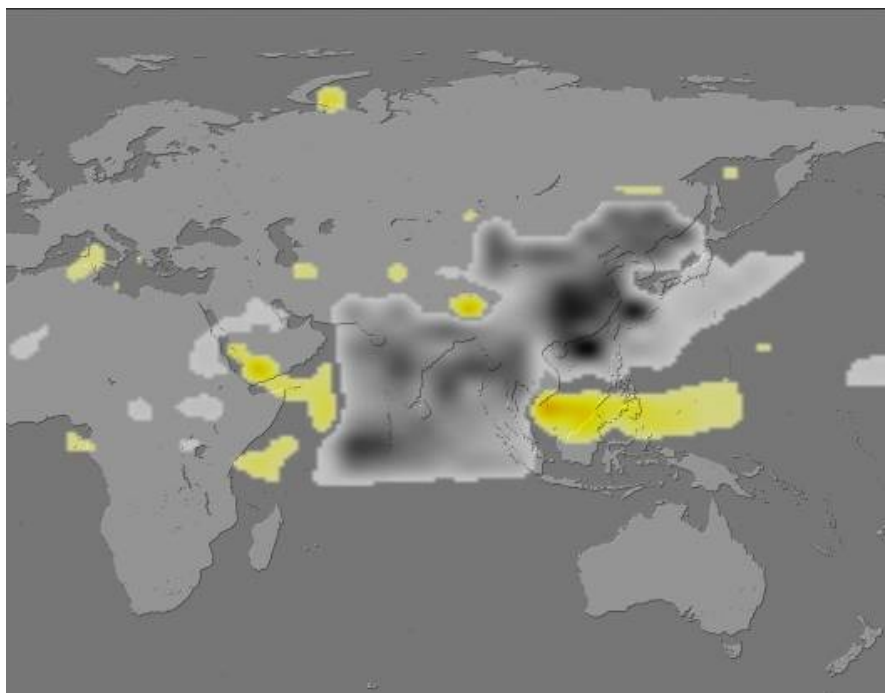
A dense sooty layer: solar radiation reaching the ground is reducing $\sim 5\%$ per decade over the entire country. Cause?

Črni ogljik in podnebne spremembe

Total BC forcing:
direct + indirect

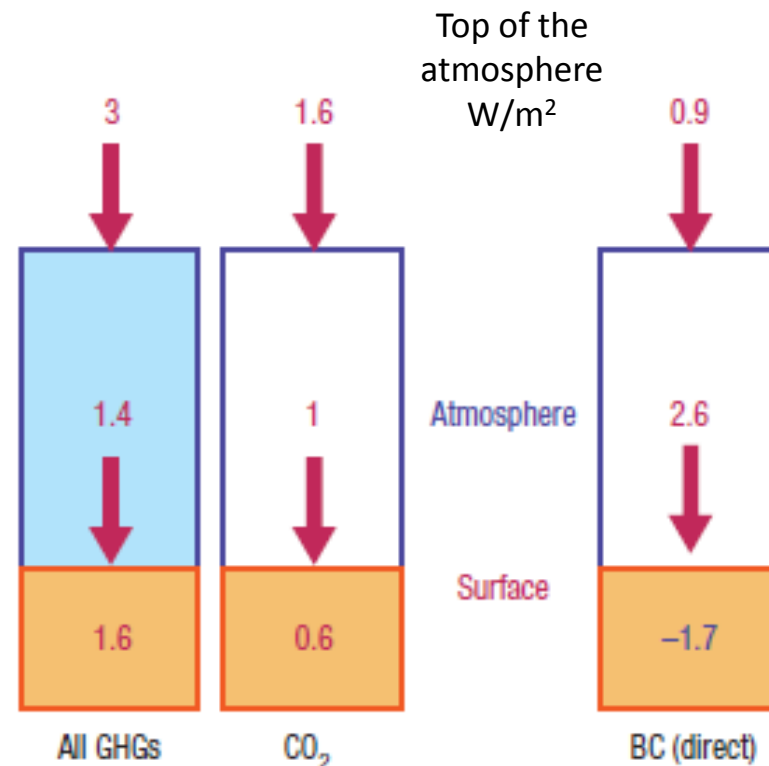
1,1 W/m²

(Bond et al 2013)



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

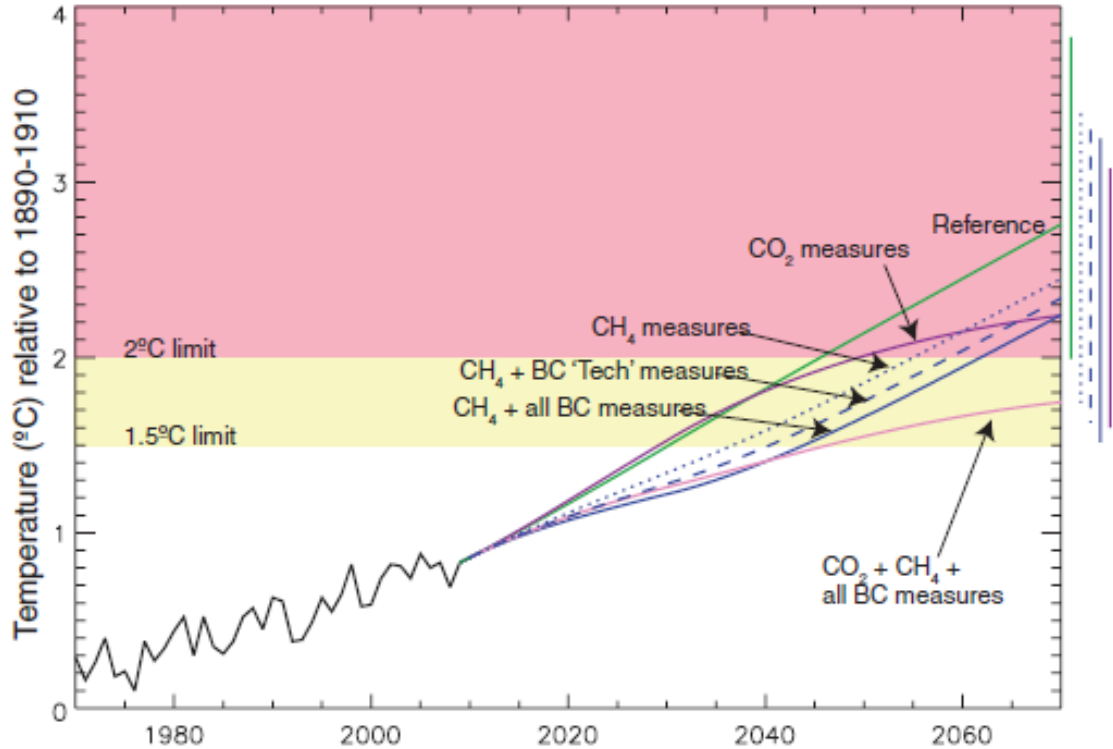
Haze over Asia: up to 40% of sunlight absorbed. Crop yields reduced ; local rainfall changed.



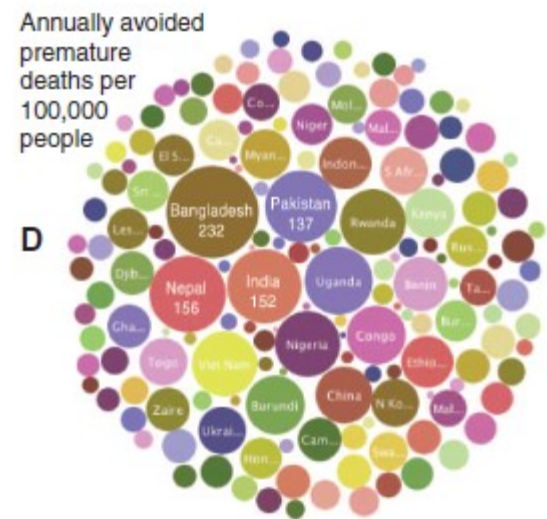
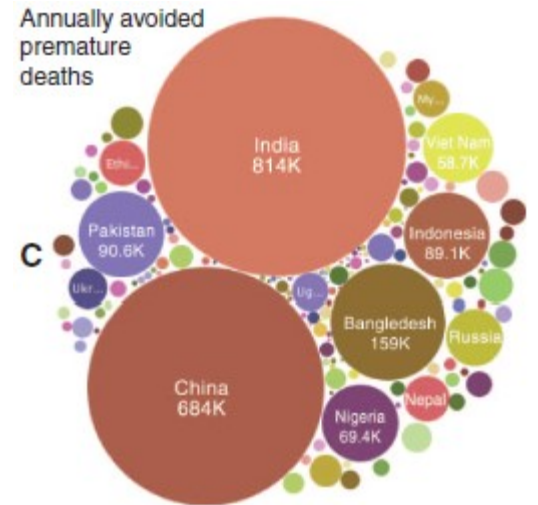
V. Ramanathan, G. Charnichael, *Nature Geosci* (2008) 221

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

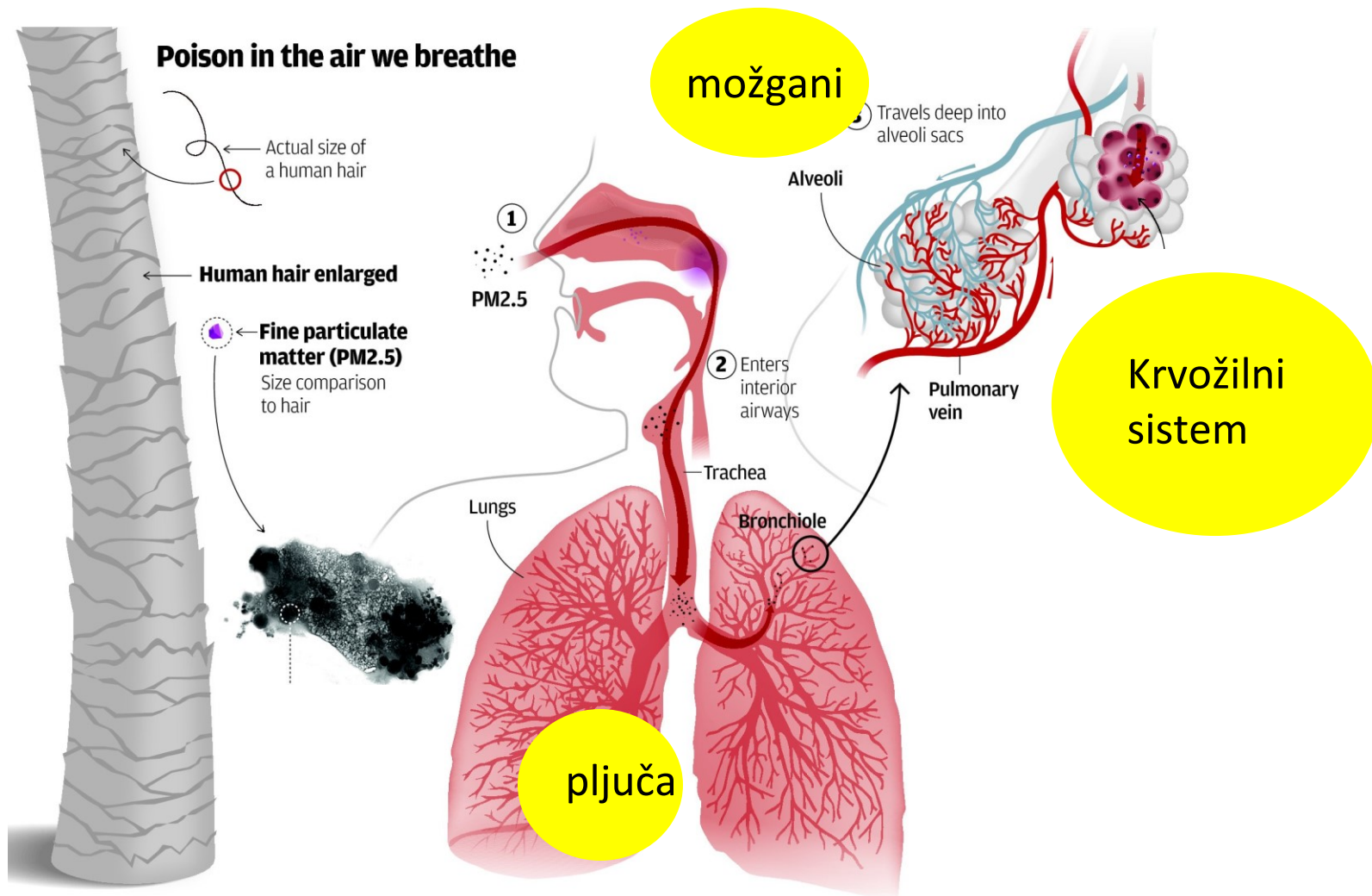
Podnebje in zdravje!



Drew Shindell, *et al.*
Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security
Science 335, 183 (2012);



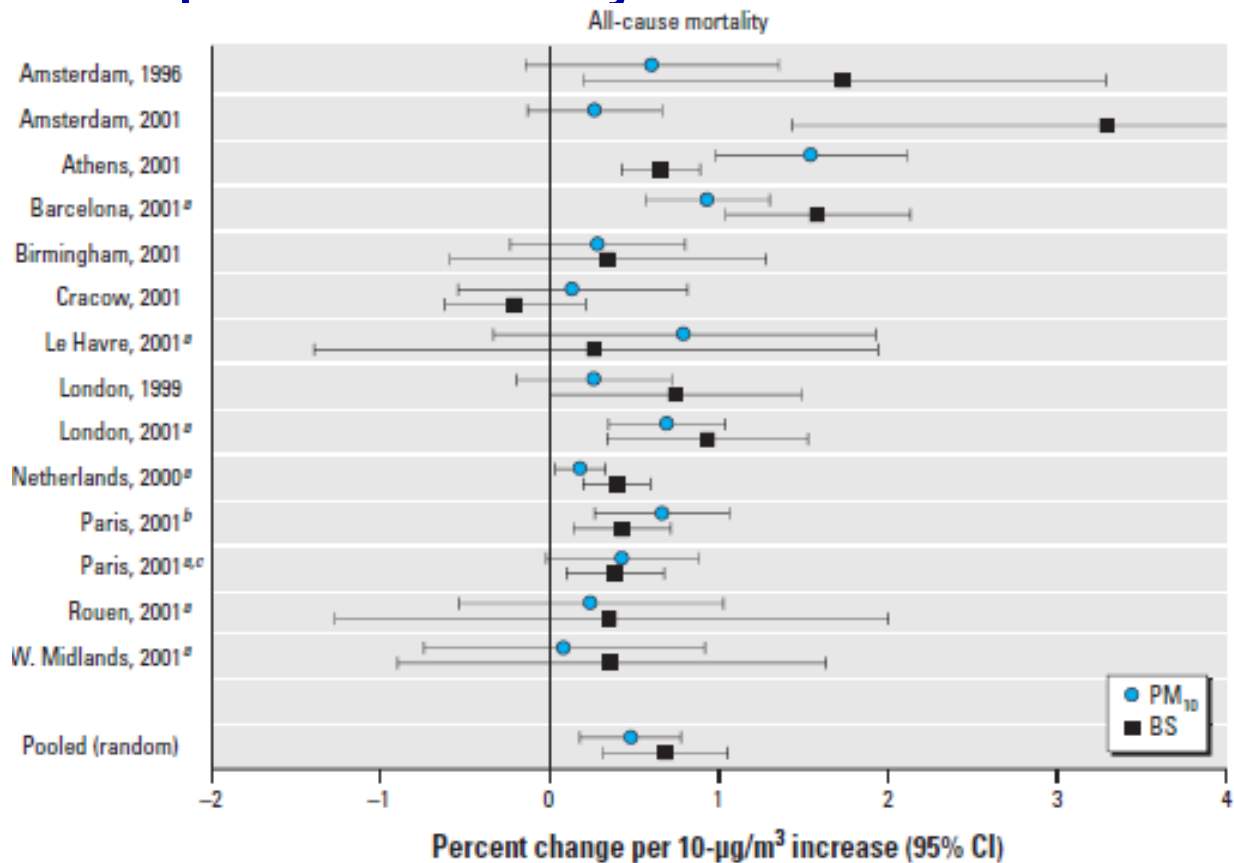
Vpliv na zdravje



Sources: EPA, Environmental Protection Department, Greenpeace.

SCMP Graphic: Adolfo Arranz

Vpliv na zdravje



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

Črni ogljik: prostorska heterogenost in učinki

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

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

- determine **state** of the environment
- **validation** of models
- implement abatement **measures**
- **effectiveness** of abatement measures

Metoda

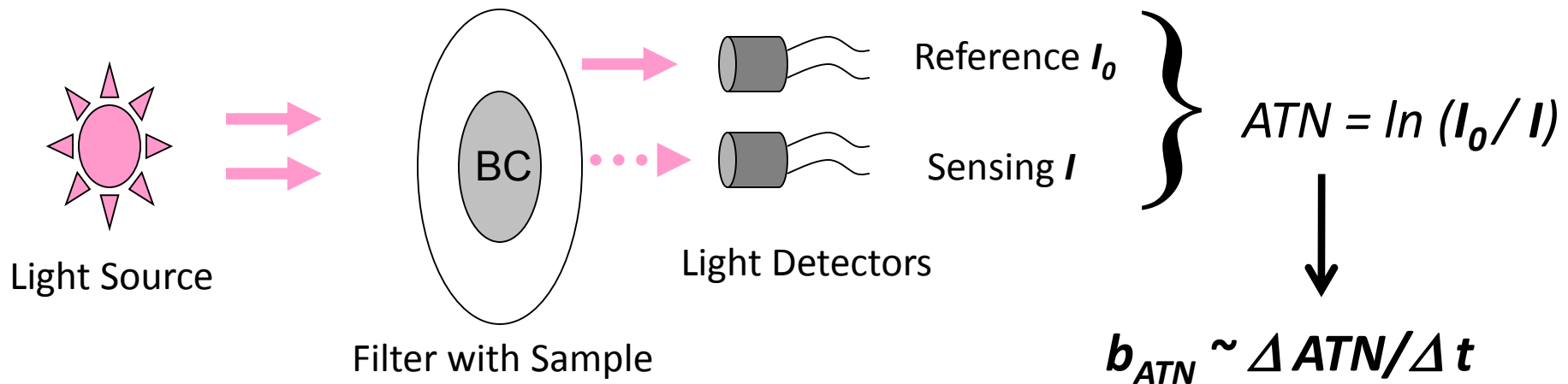
Optično merjenje in analiza: prednosti

Time resolution of chemical analysis: days!

Optical methods – minutes, seconds!

- Instantaneous, high sensitivity
- Non-destructive
- Mobile, small
- Added dimension – *time*
- Added dimension – *wavelength*

Inštrument: Aethalometer™



- Collect sample **continuously**.
- ***Optical attenuation*** \sim change in ATN. Convert to **absorption**.
- Measure optical absorption **continuously** : $\lambda = 370$ to 950 nm.
- Convert ***optical absorption*** to ***concentration of BC***:

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

- Real-time data: **minutes**
 - *Dynamical, real-time measurement, updated each period*

Aethalometer AE33

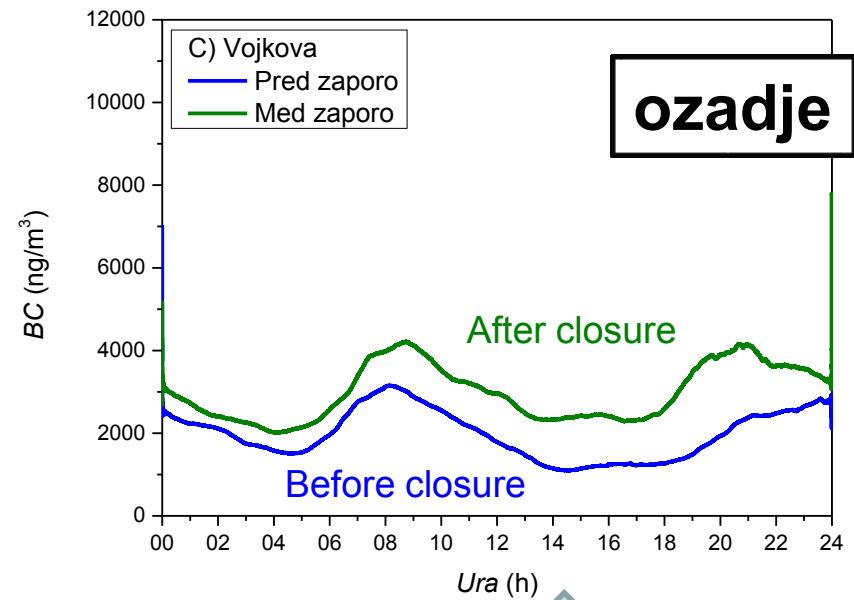
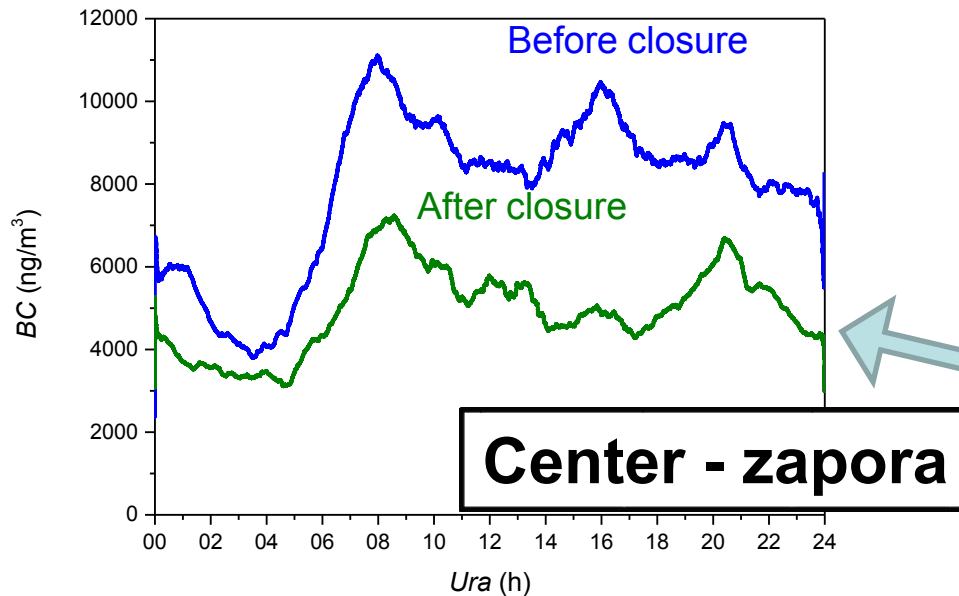
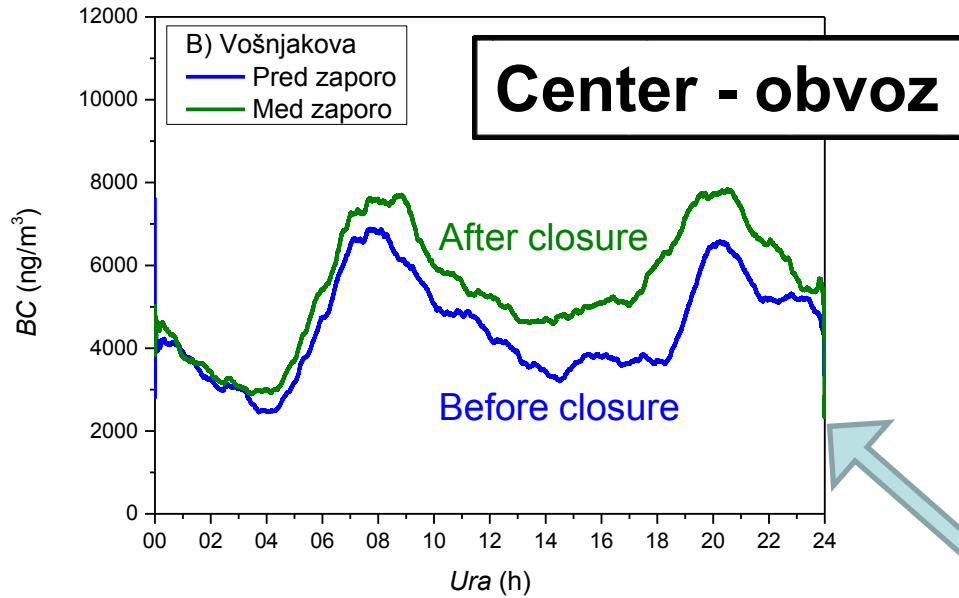


Lokalne meritve

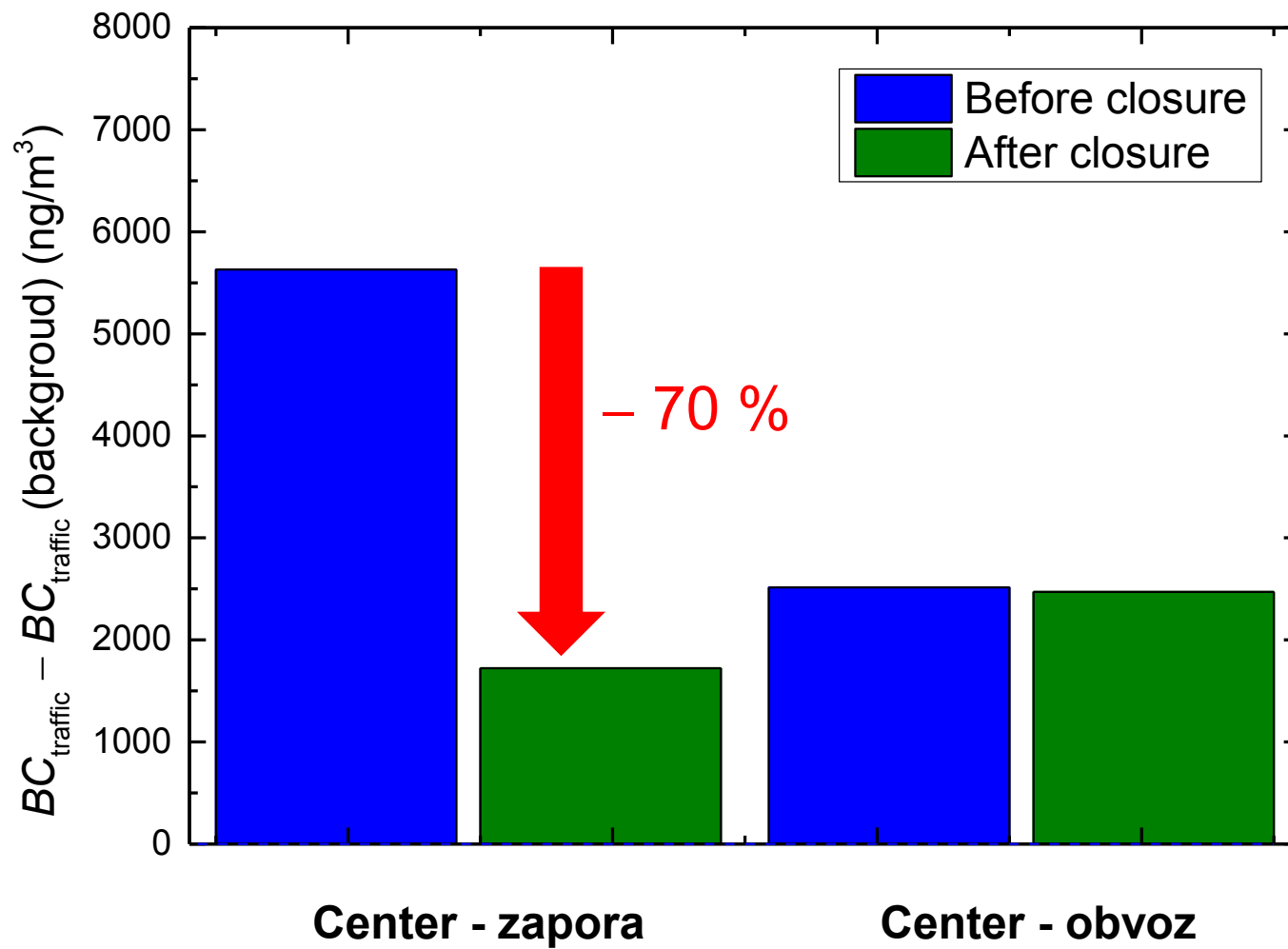
Lokalno onesnaženje zraka – promet



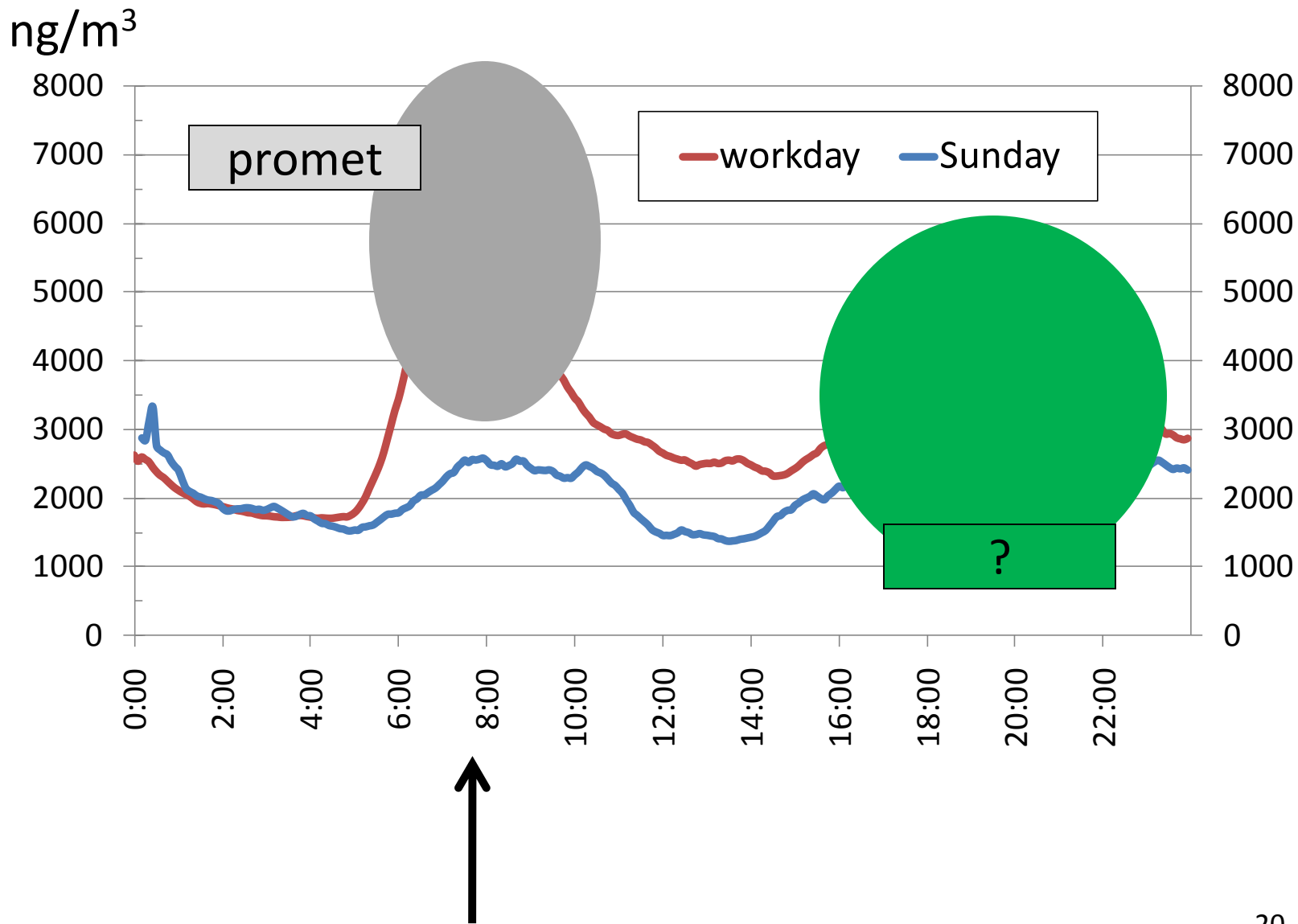
Ljubljana (avgust – oktober 2013)



Ljubljana (BC_{traffic} center – ozadje)



BC v Novi Gorici – spremembe čez dan



Biomasa je globalno pomemben vir



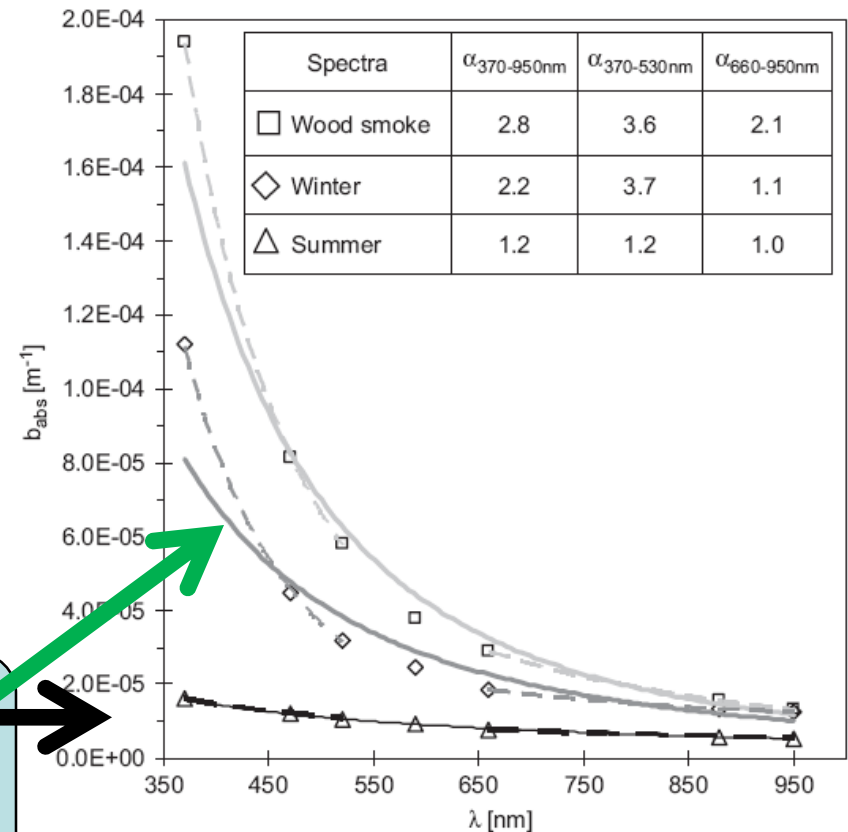
Lesni dim vs. diesel - 7λ

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

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

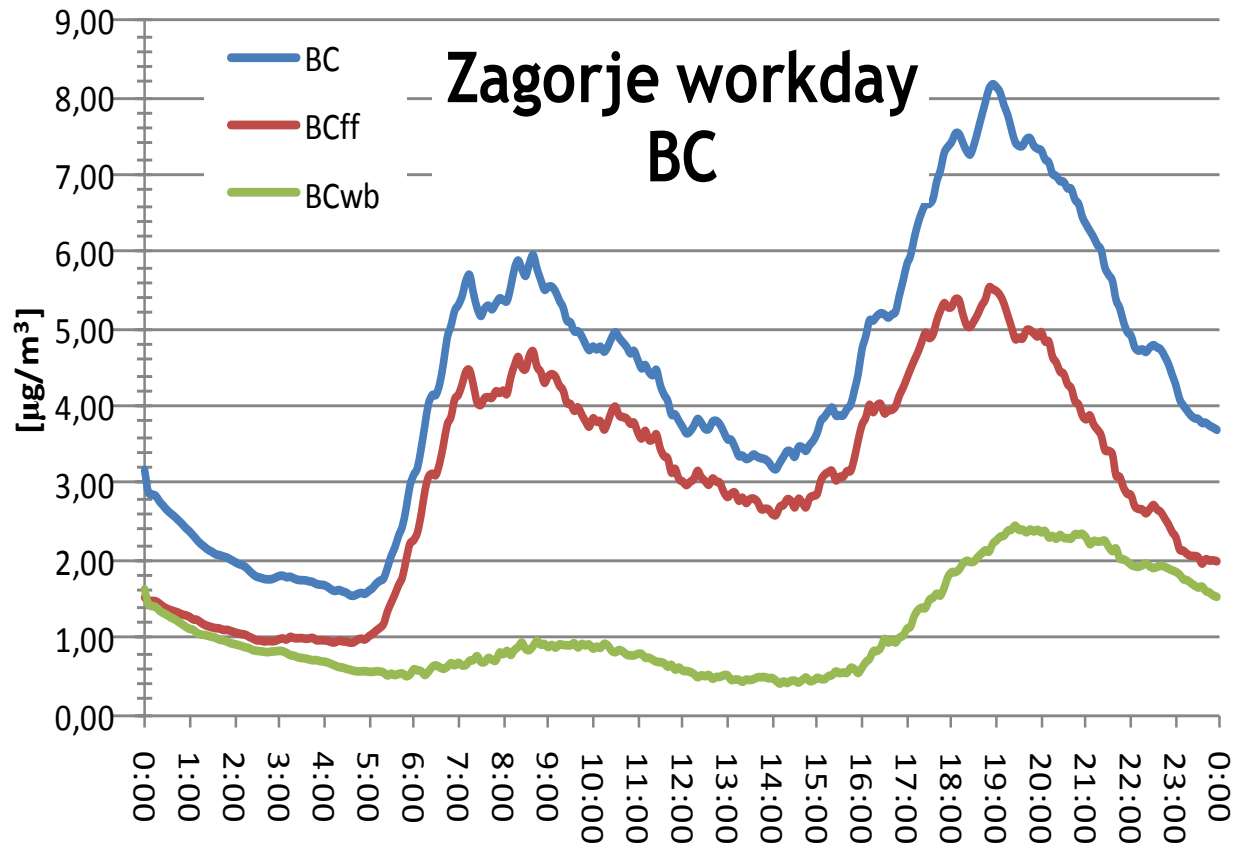
diesel: $\alpha \approx 1$

biomass-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

Določanje virov: katere vire omejevati?




promet

73% ± 8%

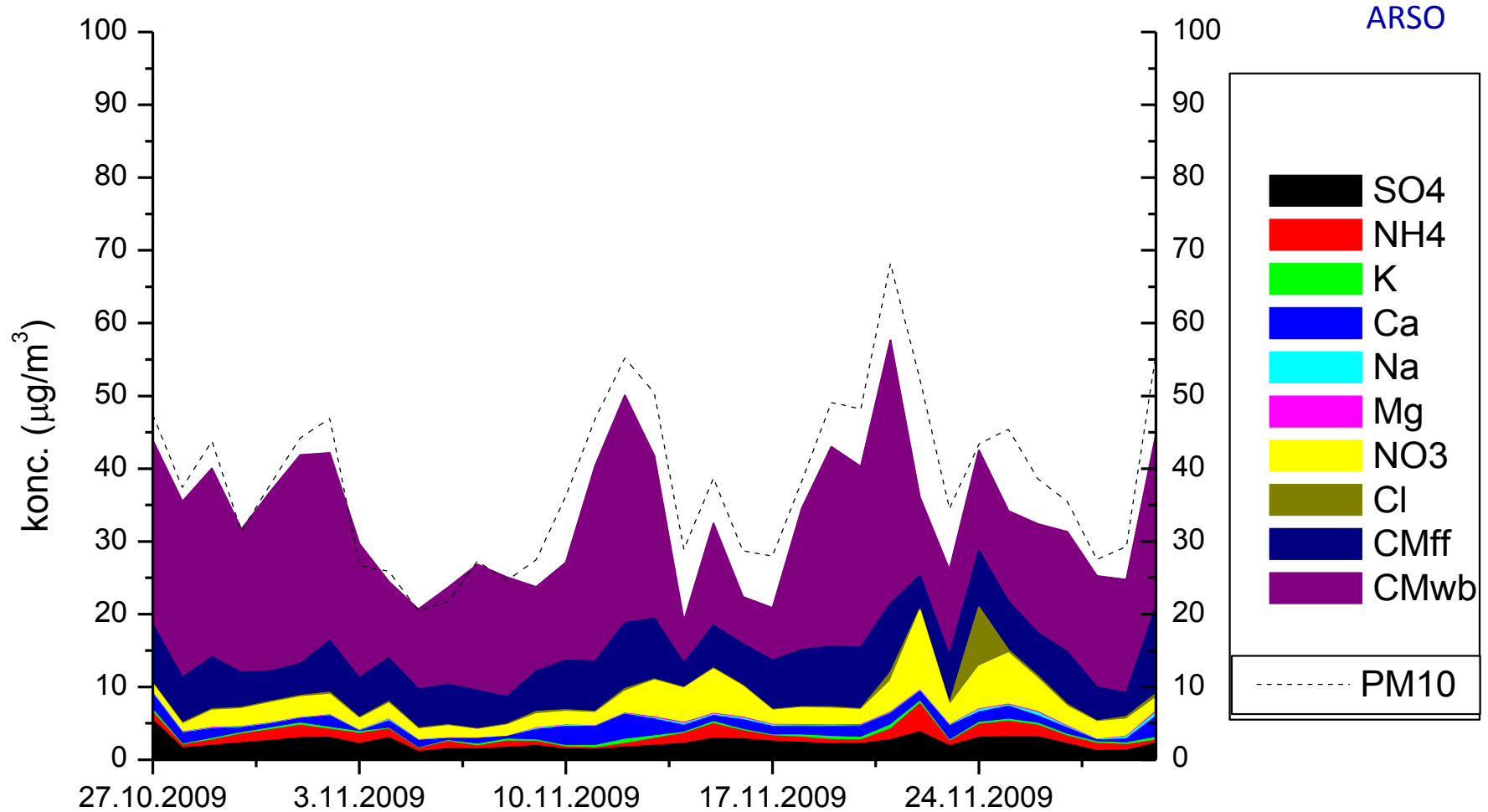
27% ± 8%

**zgorevanje
lesa**

HOME	OPERATION	DATA	ABOUT
BC		4536	ng/m ³
BIOMASS BURNING		7.6	%
REPORTED FLOW (AMCA)		5.0	LPM
TIMEBASE		60	s
TAPE ADV. LEFT		152	
STATUS			0
18 Oct 2015 15:07:06			
AE33-S02-00138			

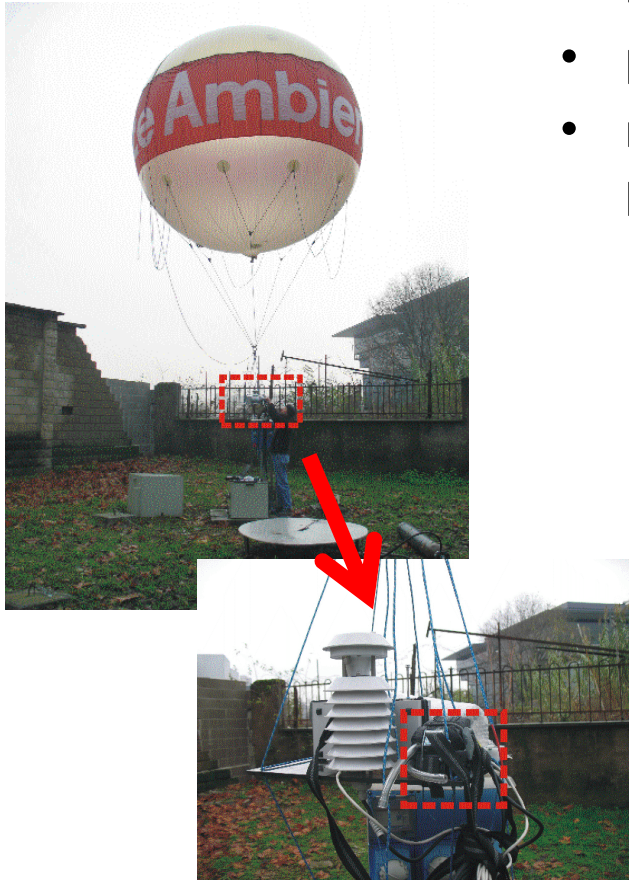


Koncentracije PM10 Zagorje

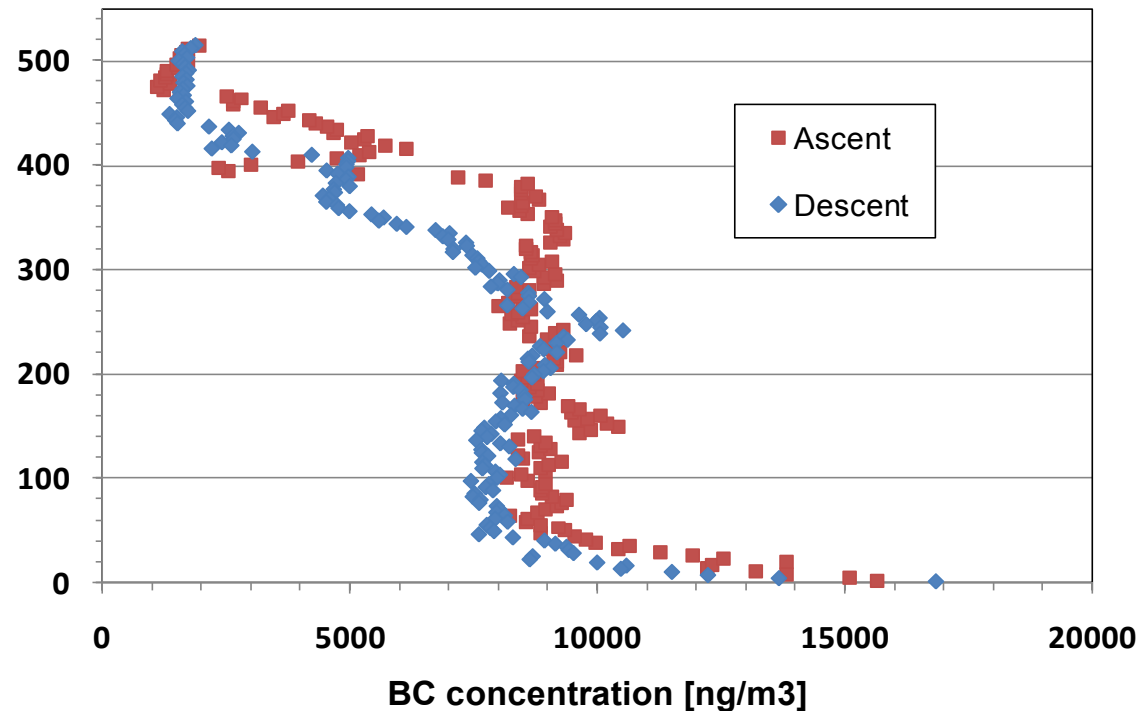


Vertikalni profili – Milano

- ballon with prototype **Aethalometer**
- profiles up to 500 m, 2 days of measurements
- measurements compared to calculation of optical properties



Black Carbon Concentration Vertical Profile



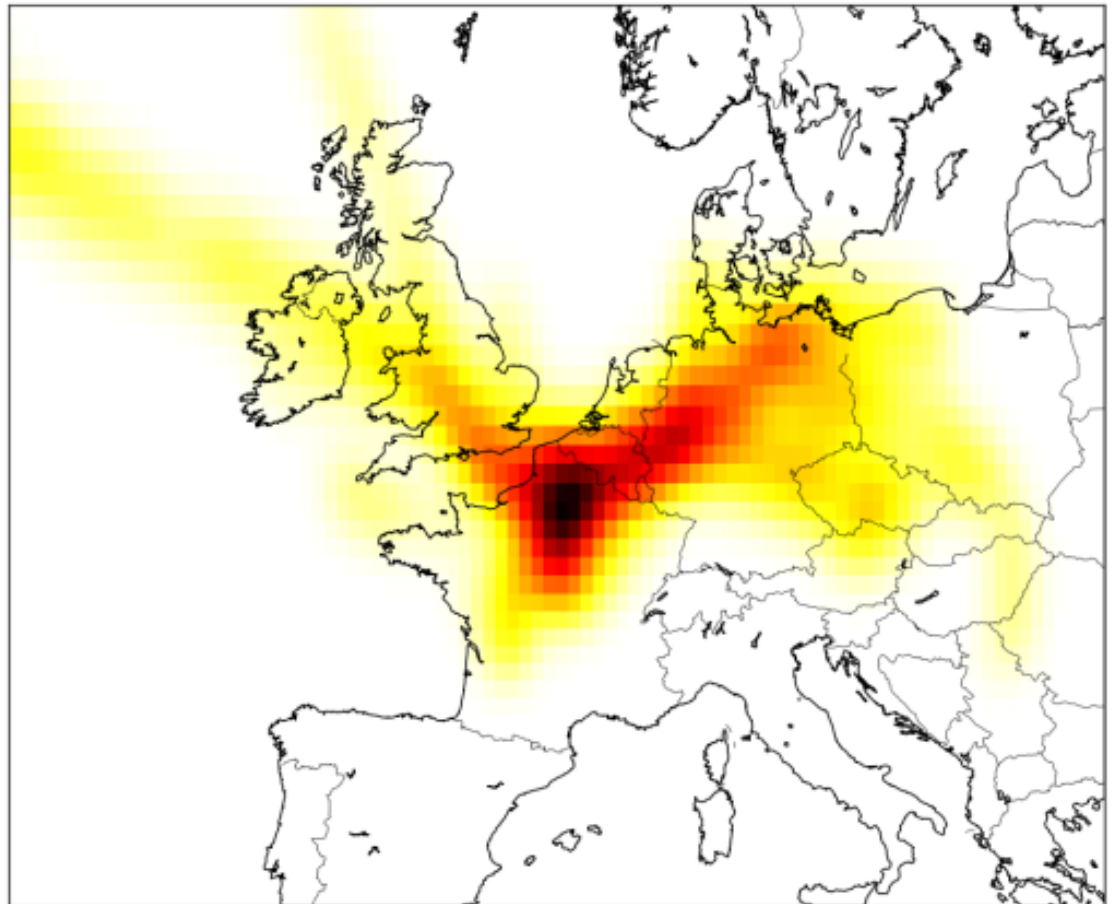
Regionalne meritve

Analiza trajektorij

Back trajectory analysis: Potential Source Contribution Function (PSCF)

- probability an air parcel may be responsible for concentrations at receptor site
- 72h back trajectories – HYSPLIT v4.9
- starting at 500m AGL

PSCF analysis of **BC**
Paris winter 2013

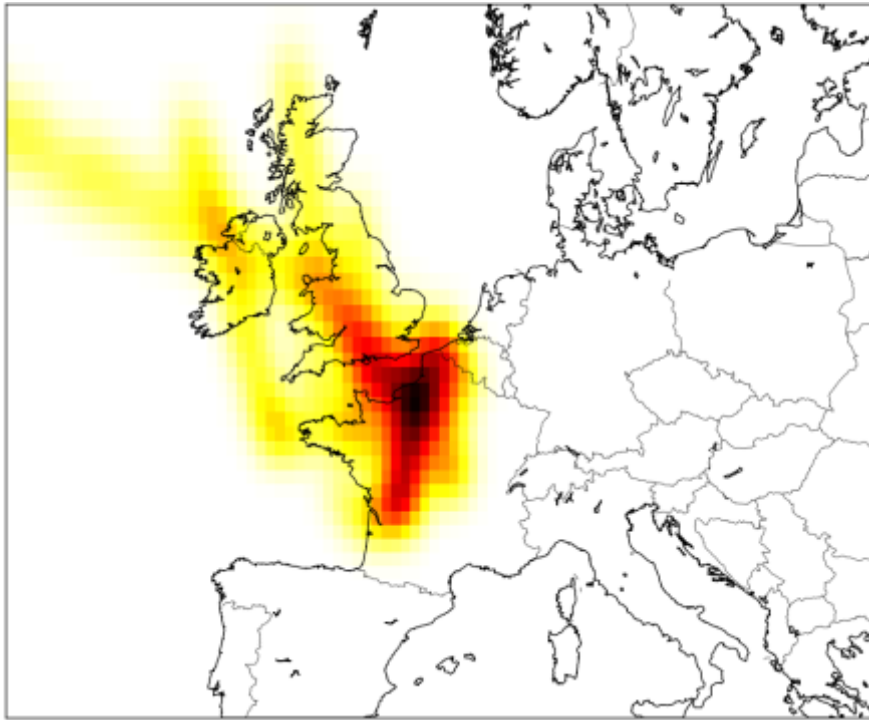


Kje so viri?

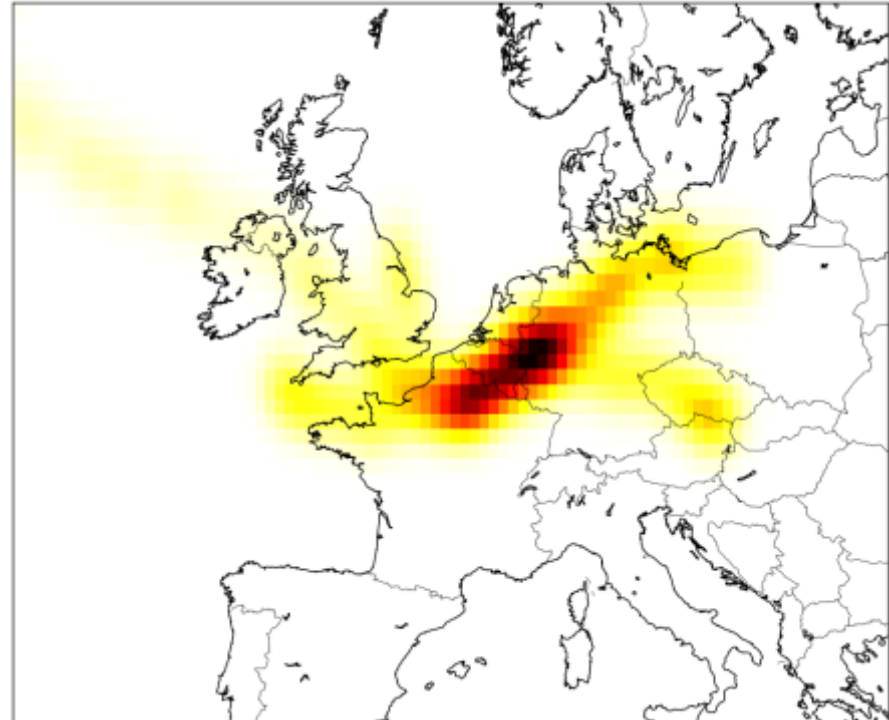
- Angstrom exponent α from AE33 spectral data
- PSCF (Back trajectory analysis using Potential Source Contribution Function)

Paris – **winter** campaign 2013

$\alpha < 1.3$ **traffic emissions**



$\alpha > 1.3$ **biomass burning**



Globalne meritve

Letalo in vzorčenje: meritve na 3 km in pri 200 km/h



Letalo in vzorčenje: meritve na 3 km in pri 200 km/h



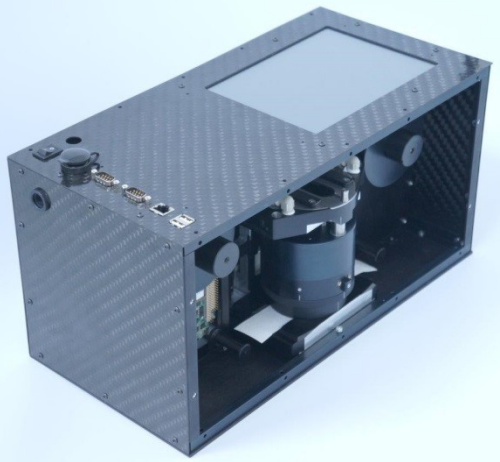


Različni viri:
točkovni in
porazdeljeni

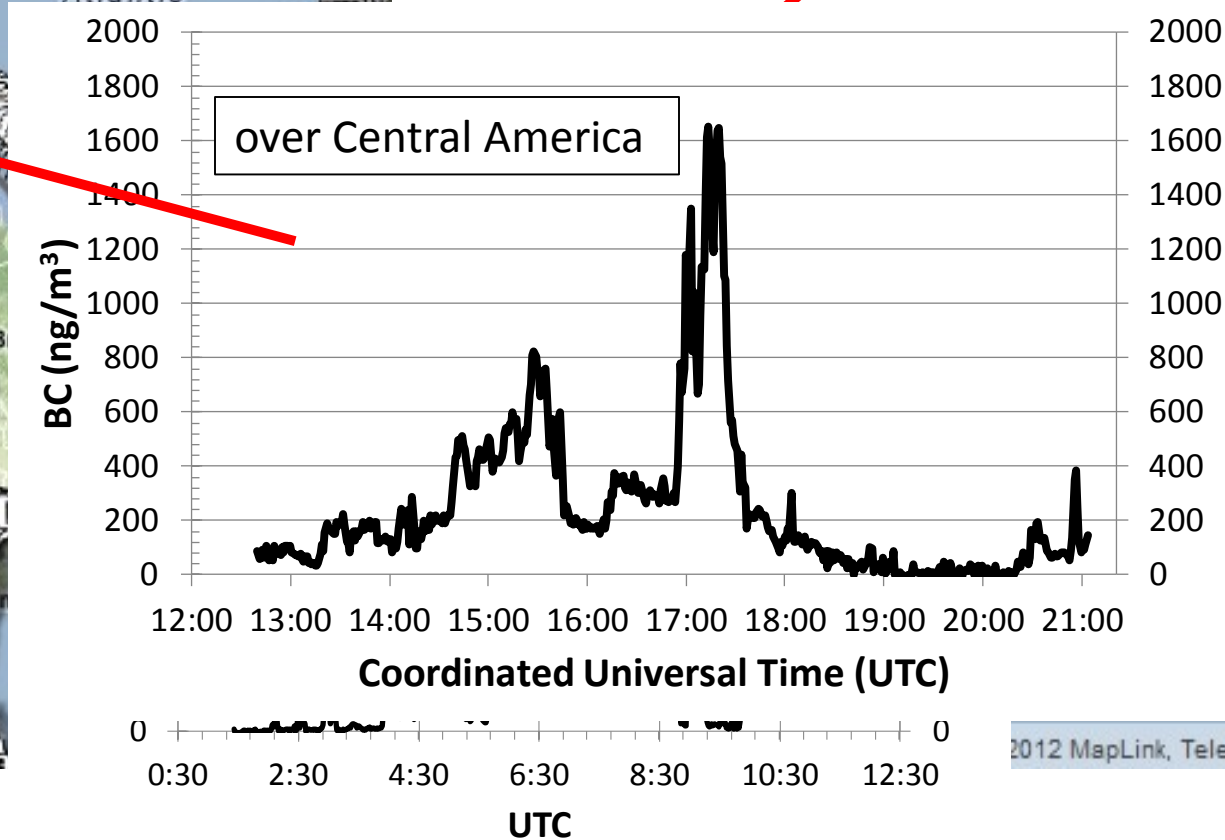
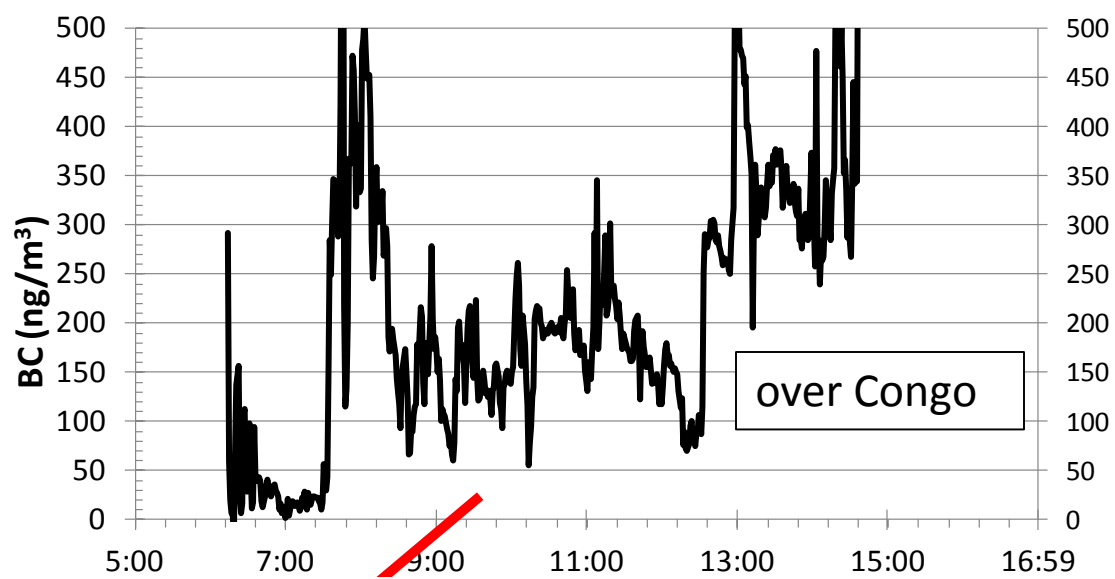
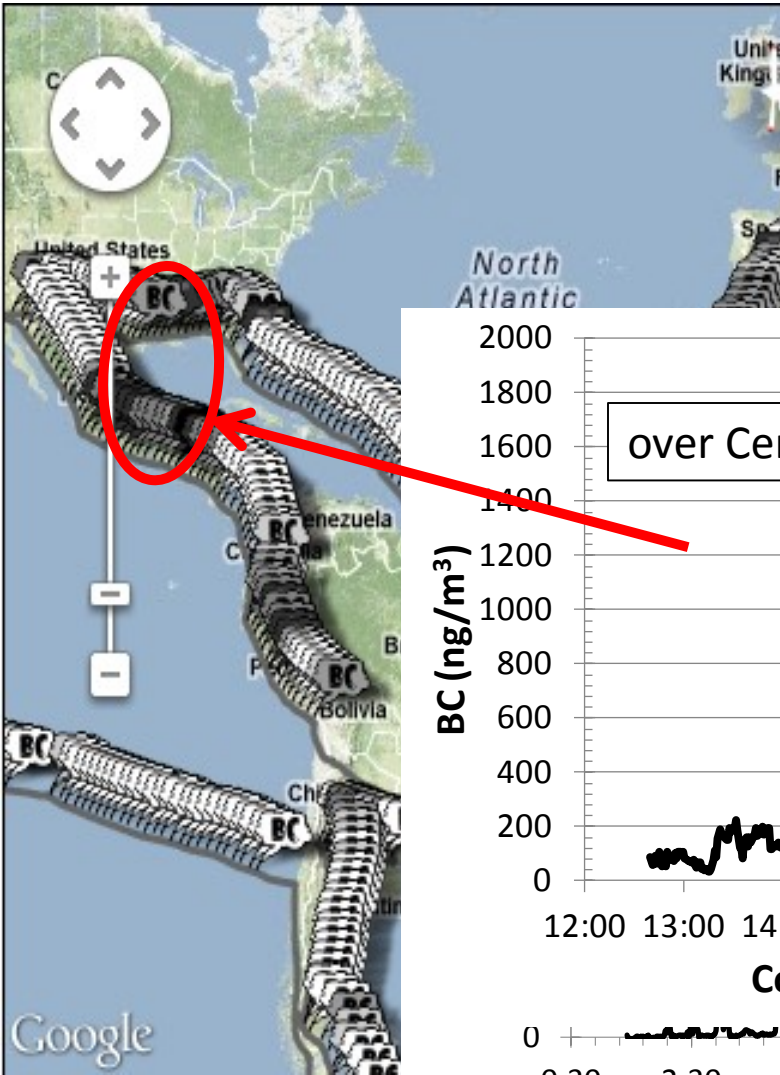




Black carbon
layers @ 3 km



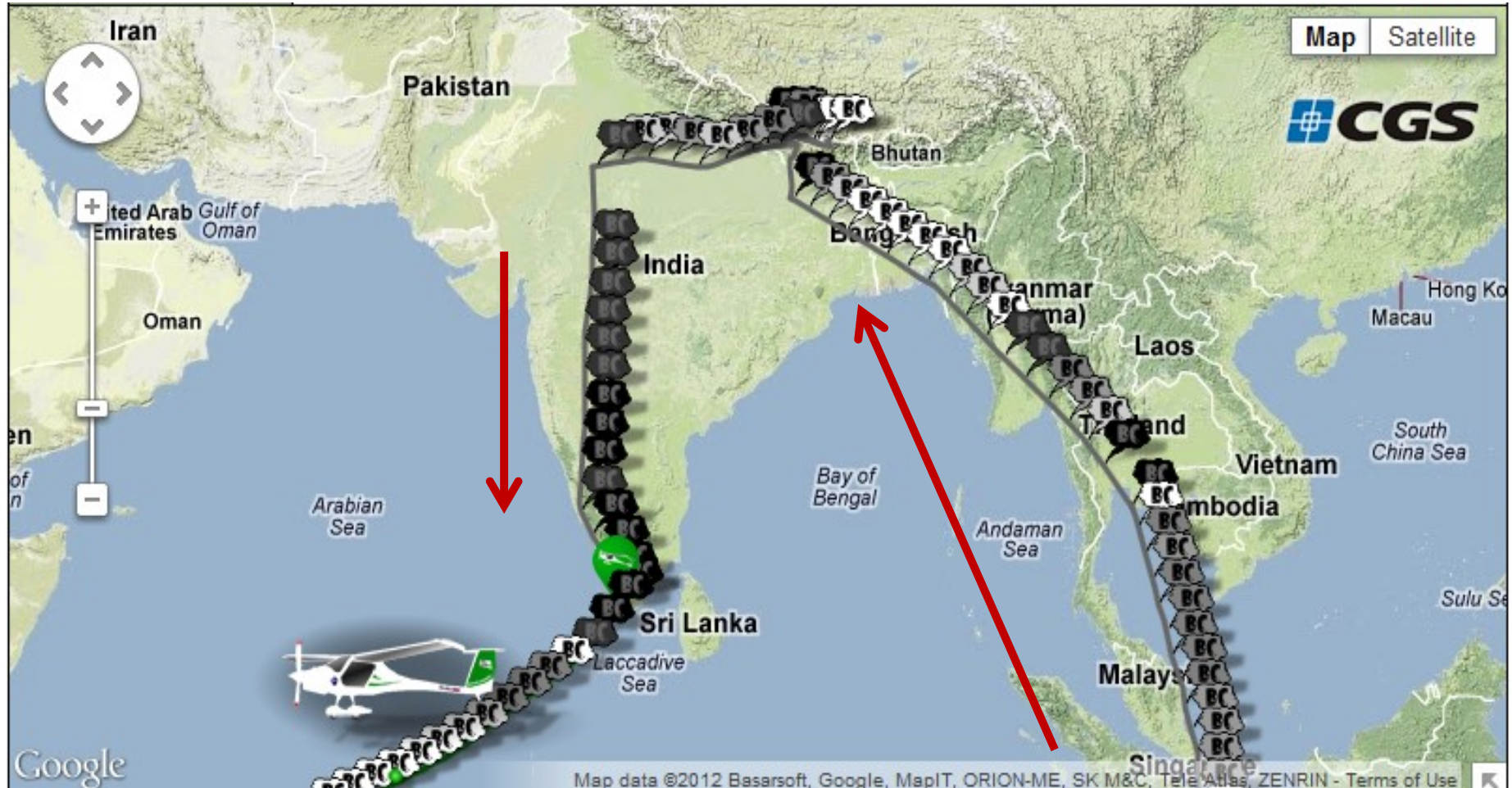
Rezultati 2012



Rezultati 2016

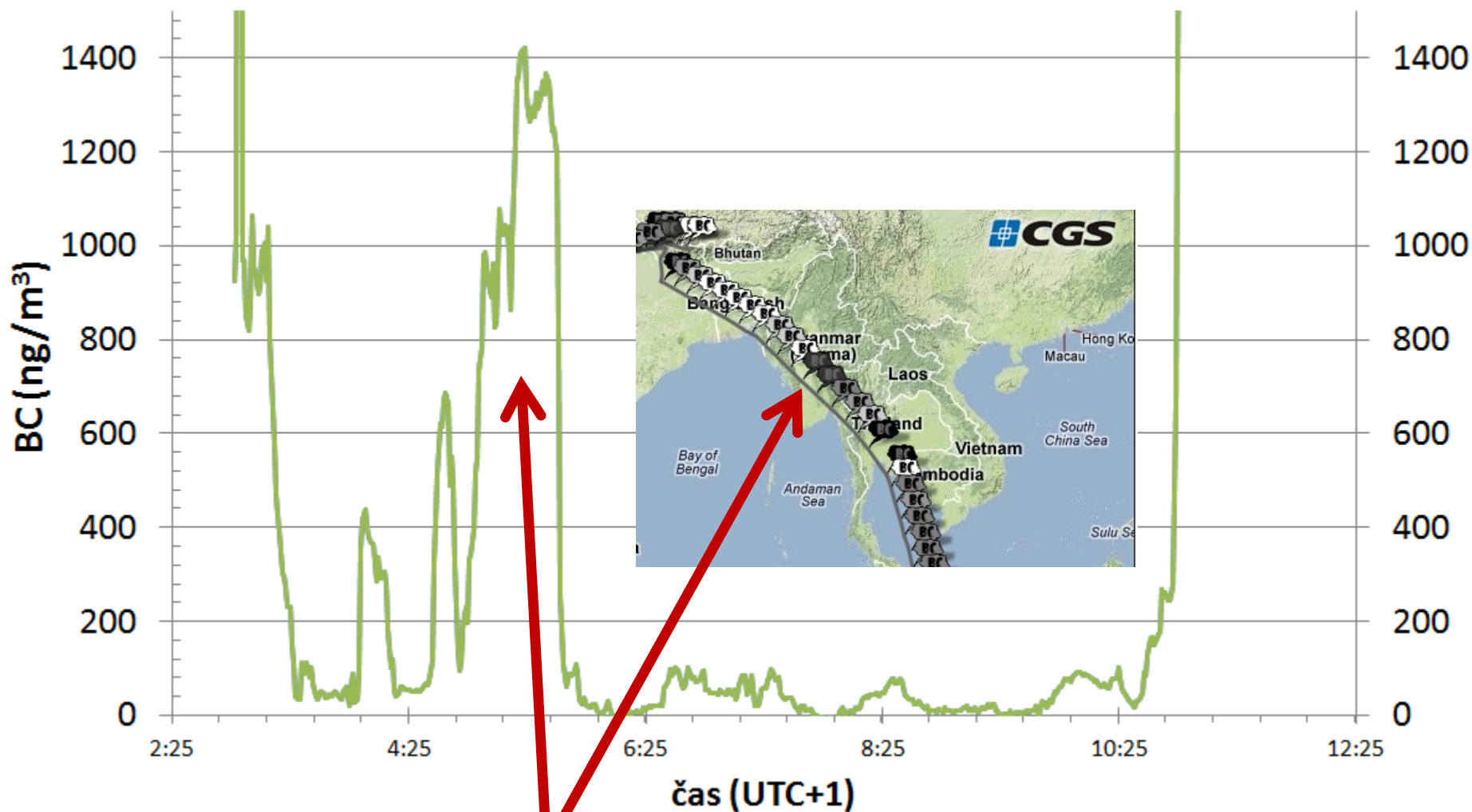


Primer: Azija



Vzlet: Tajska

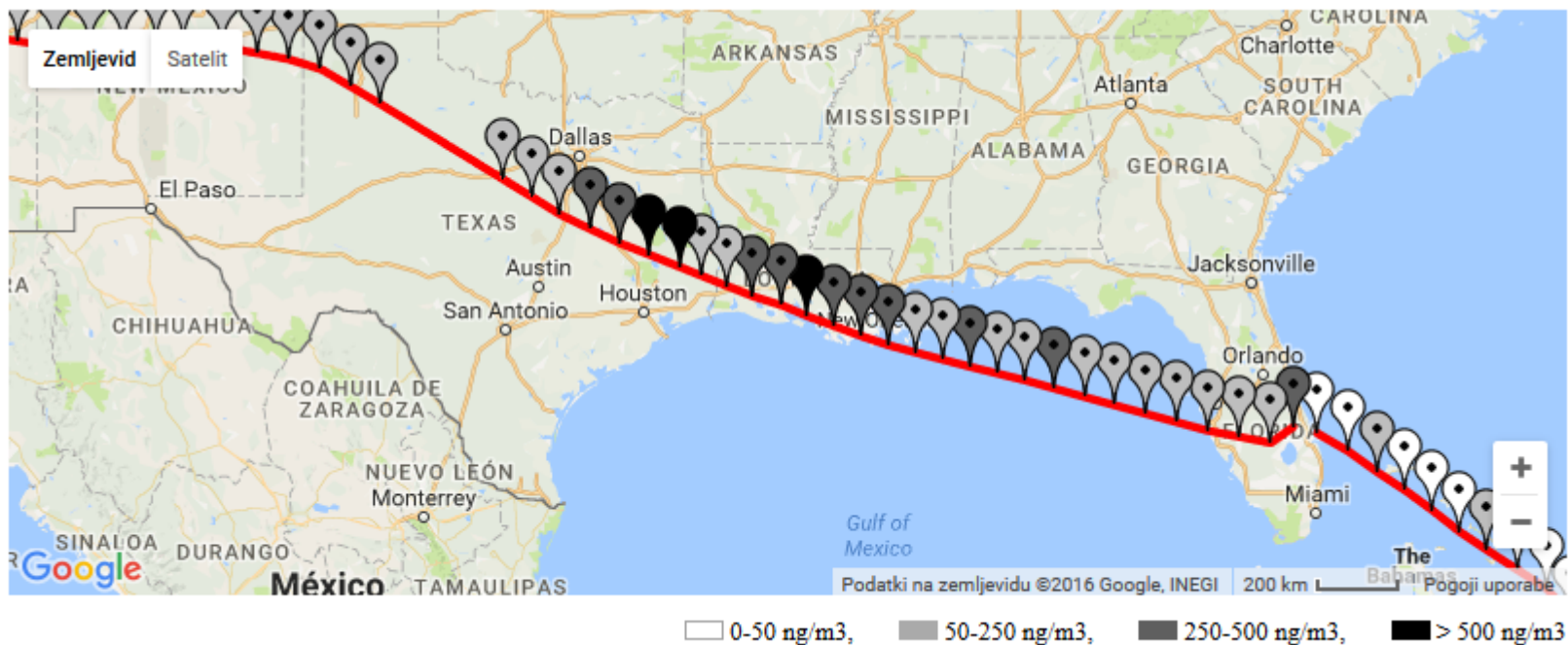
Pristanek: Indija



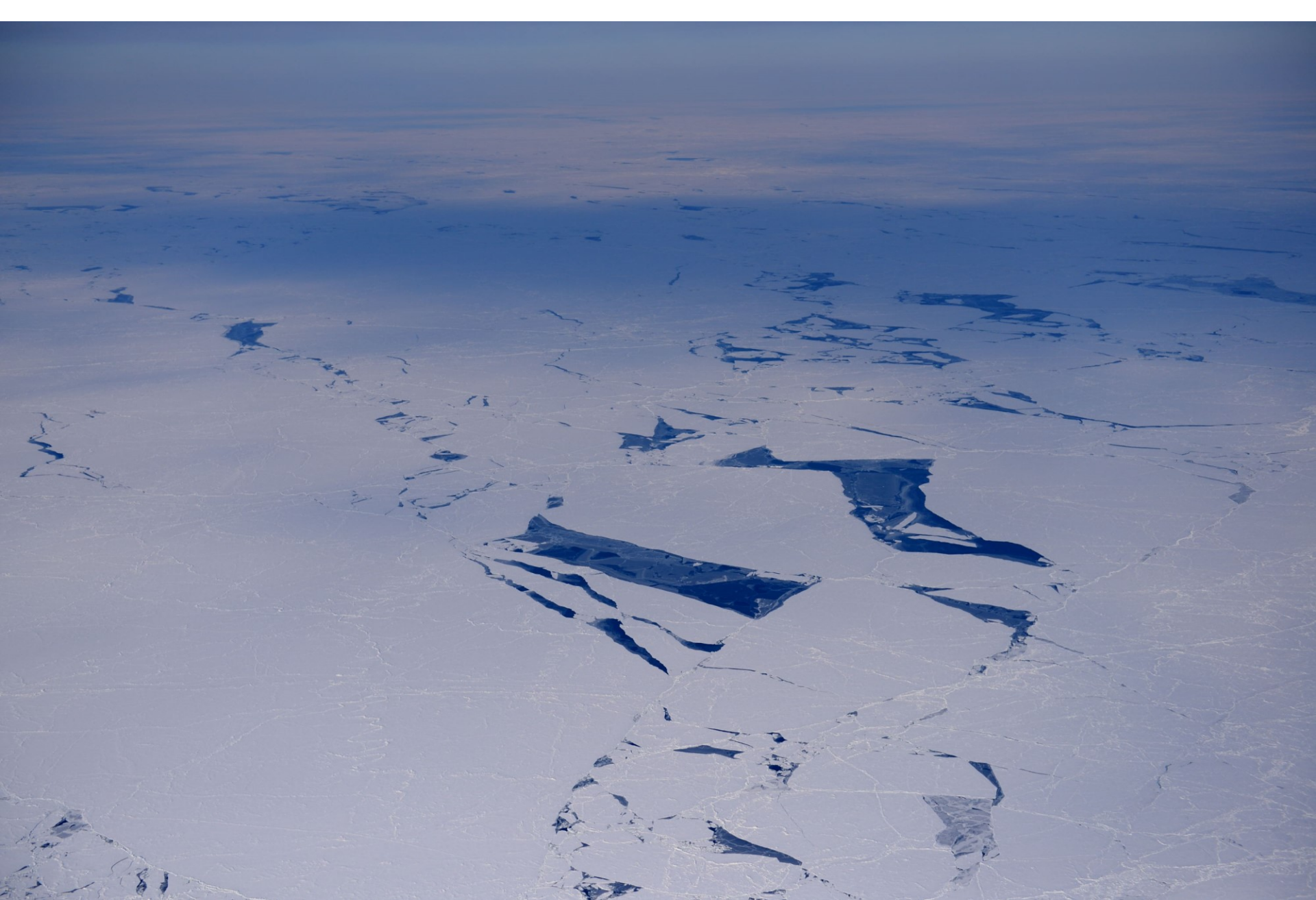
Povečane koncentracije črnega ogljika



Industrija v razvitem svetu



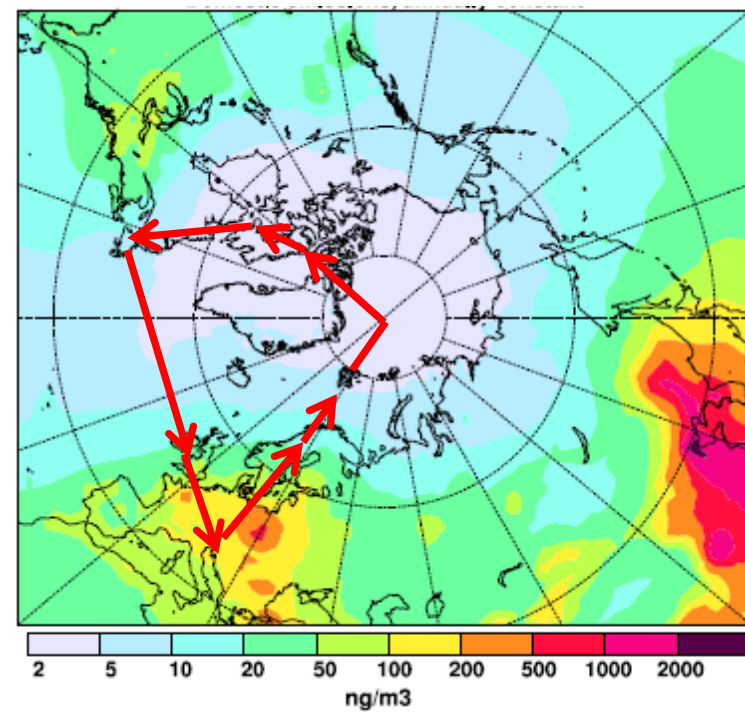
Industrijski viri – črpanje in predelava nafte, so v razvitem svetu še vedno pomemben **regionalen vir črnega ogljika**.



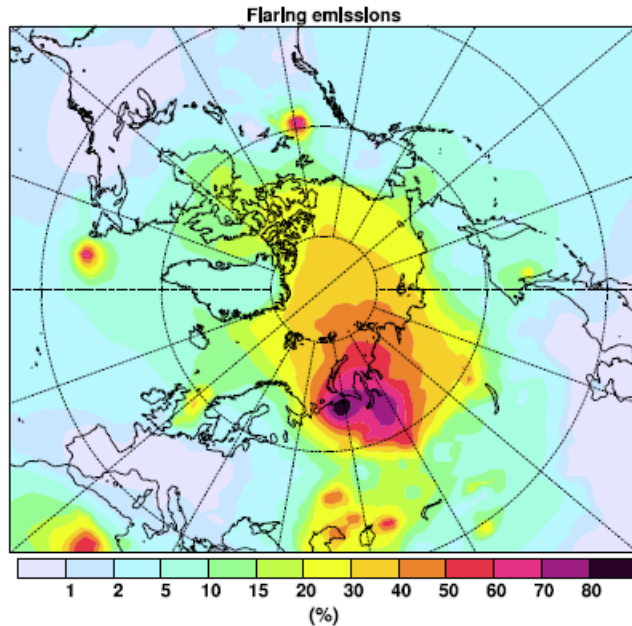
Meritve?

ADVENTURE for SCIENCE

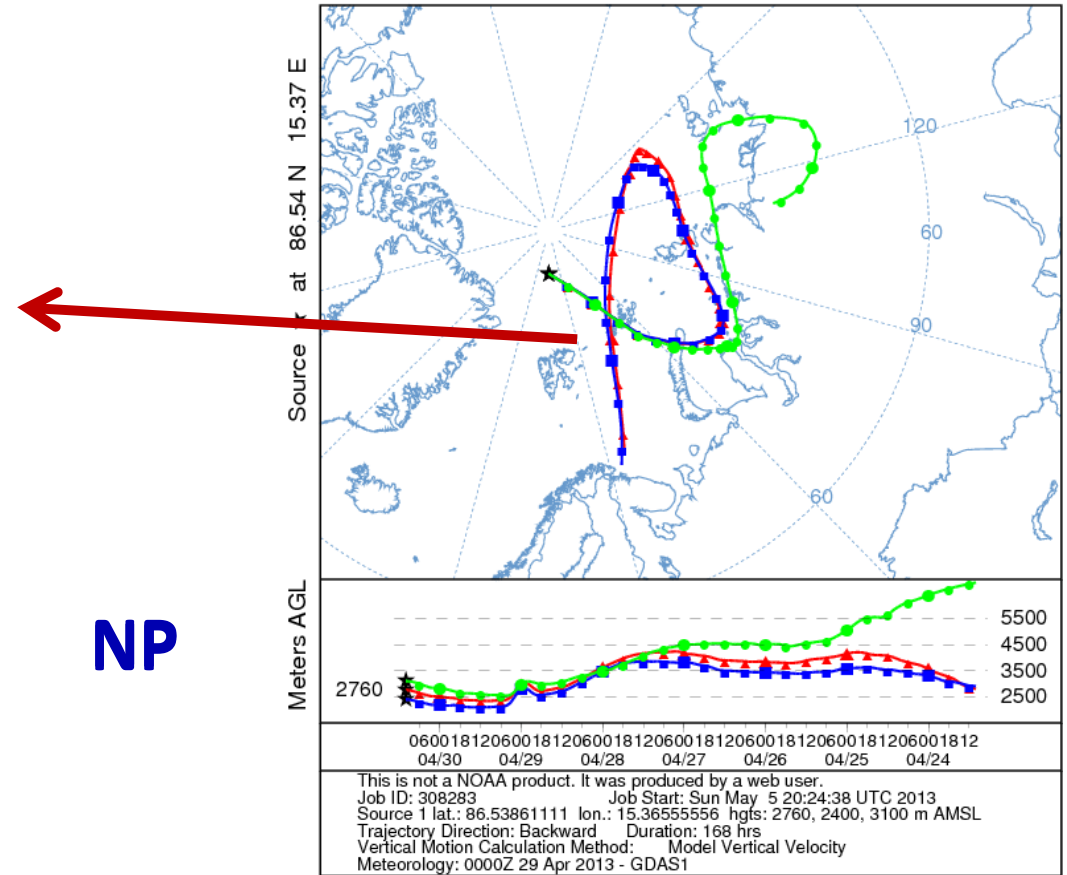
- experienced long distance pilot, biologist, photographer
- light, eco friendly 300 kg aircraft
- black carbon detection over Arctic
- North Pole crossing from Europe to Canada
- Atlantic crossing via Lindberg route
- arctic water aerial images



Vzlet: Svalbard



NOAA HYSPLIT MODEL
Backward trajectories ending at 1000 UTC 30 Apr 13
GDAS Meteorological Data



NP

Conclusions 1/2

- source apportionment, “Aethalometer model”: **biomass vs. diesel**, excellent correlation with markers
- time resolution is **1 min**
- we can investigate **time evolution, spatial distribution**: BC, CM
- **correlation** between different pollutants: **PAH source**
- **quantitative Wood-Smoke determination** – “Aethalometer model” CM time resolution: 15 min
- the new dual-spot Aethalometer AE33 with **real-time loading compensation** was developed, online source app.
- technical improvements facilitate **monitoring**
- **quantitative** estimation of **abatement measures**

Conclusions 2/2

- Local, regional and global relevance of BC and other light absorbing aerosols
- **Local** – air pollution and health
- **Regional** – transport of pollutants
- **Global** – climate
- **Measurements** are needed for all types of effects
- Examples and co-benefits

Hvala!
Vprašanja?

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