Aethalometer miniaturization for aircraft BC measurements – results from regional, global and Arctic campaigns

Workshop on

Measurement methods and perspectives

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Aerosol

Aerosol Black Carbon

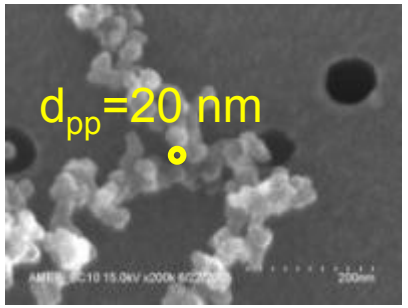
- BC is a **primary** product of incomplete **combustion**
- BC <u>not</u> automatically related to CO_2 emission
- BC emissions can <u>not</u> be predicted:

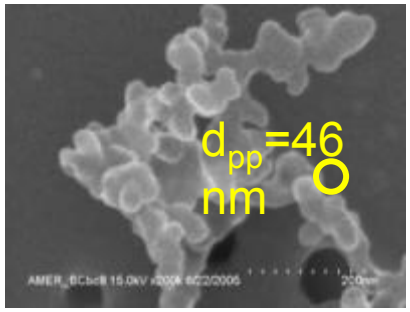
  must be measured

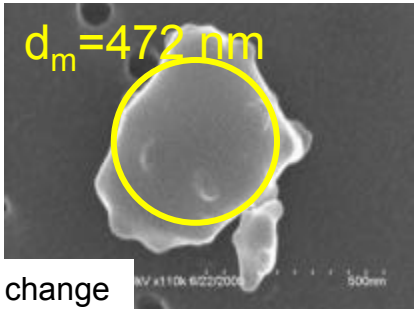
- BC particles from <u>different sources</u> can have <u>different characteristics</u> that produce <u>different effects</u> in the atmosphere:

  Coal/Diesel/Biomass, Asia/Europe/Arctic…

- **relevance**: climate change, health

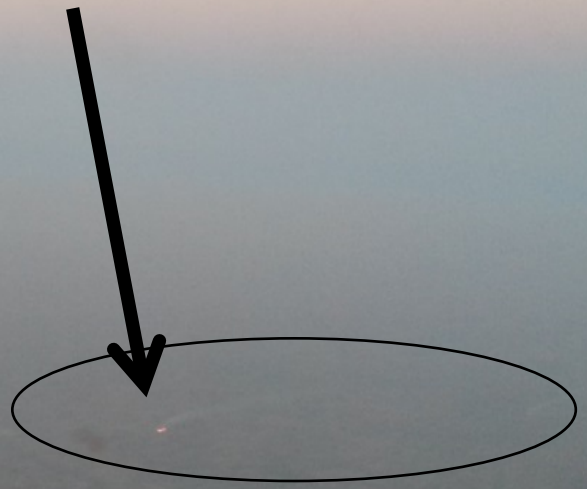






Note change in scale

Aerosol Black Carbon covers large regions

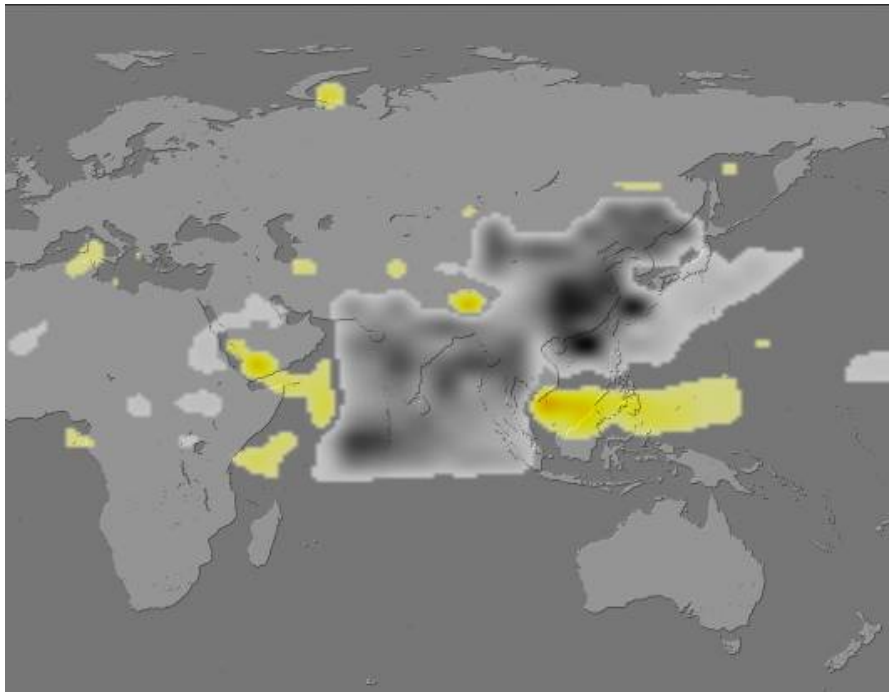


Approx. 1000 m above New Delhi region, India: late afternoon.

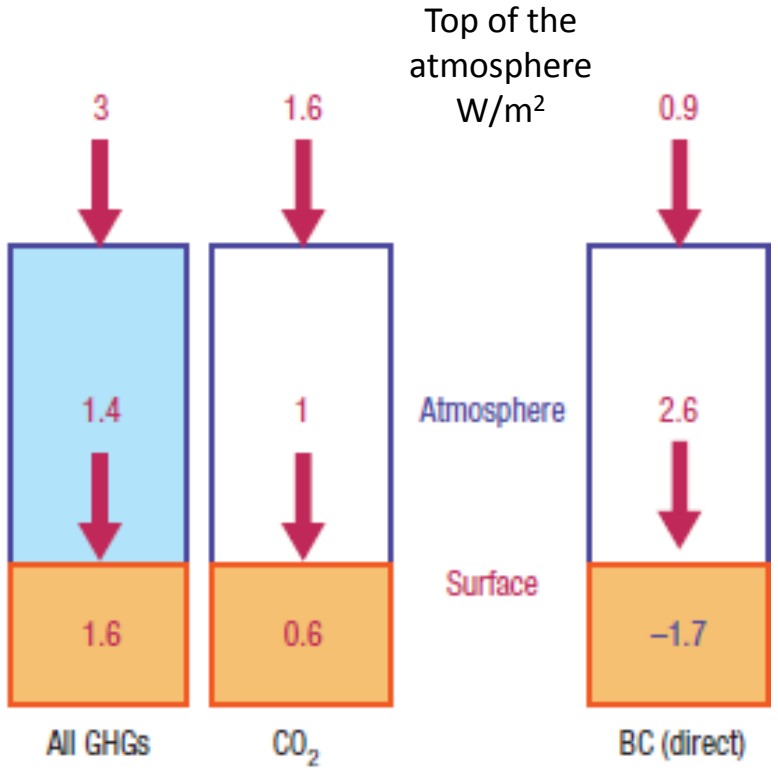
A dense sooty layer: solar radiation reaching the ground is reducing ~ 5% per decade over the entire country. Cause?

Black Carbon and climate change

Total BC forcing: direct + indirect
1,1 W/m²
(Bond et al 2013)



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

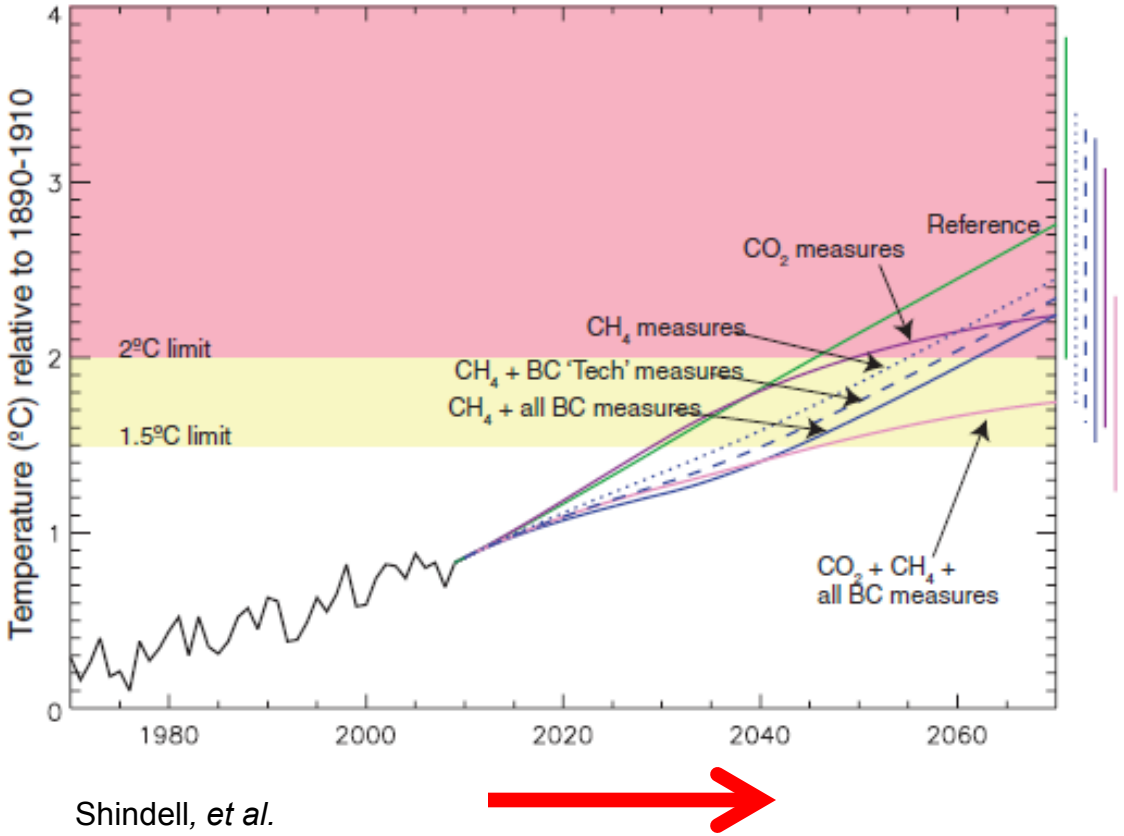


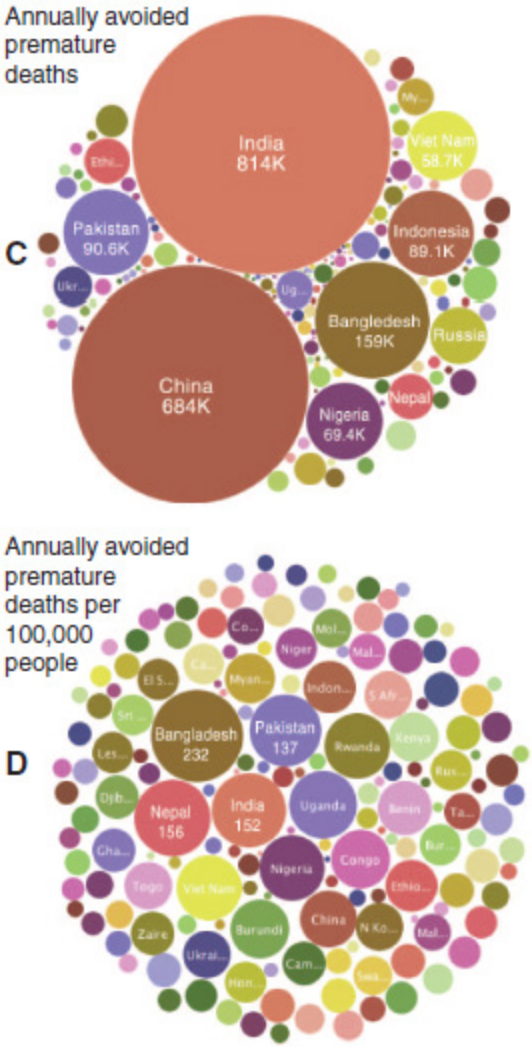
V. Ramanathan, G. Charmichael, Nature Geosci (2008) 221

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

Climate & health!





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

Aerosol Black Carbon : Sources & Emissions

- BC emission factors can be **very different:** emissions depend on **quality of combustion** of different fuels
- Climate forcing depends on **both CO_2 and BC**
- BC concentrations can be highly **variable** locally and regionally
- Knowledge of vertical distribution of BC is essential for calculations of climate forcing, yet data is **extremely sparse**

- BC emissions cannot be predicted: must be **measured**
- **more data** required

BC (x, y, z; t; λ)

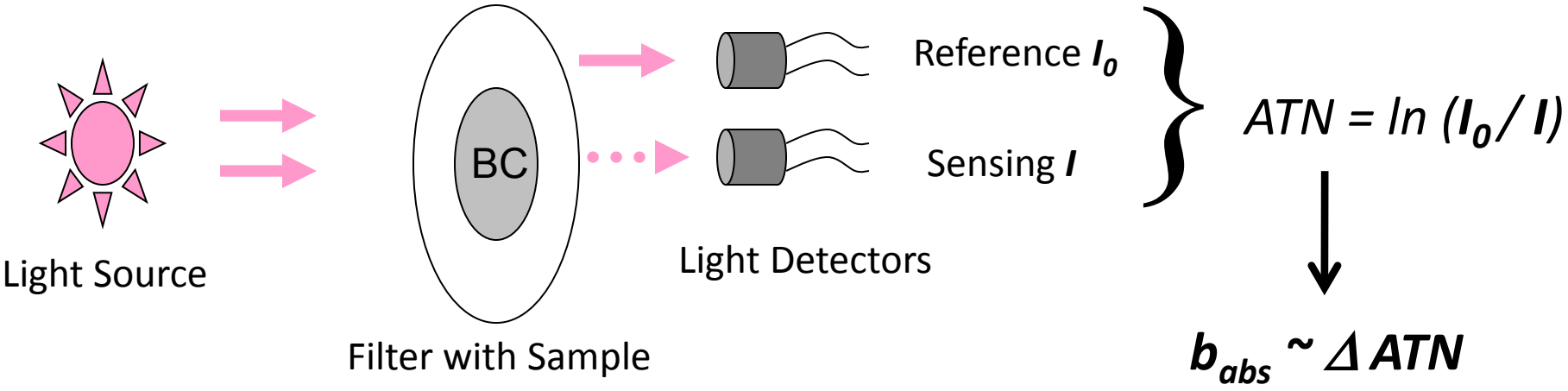
Optical measurement and analysis: advantages

Time resolution of chemical analysis: 1 day!

<u>Optical methods – minutes, seconds!</u>

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

Optical measurement of Black Carbon: Aethalometer™

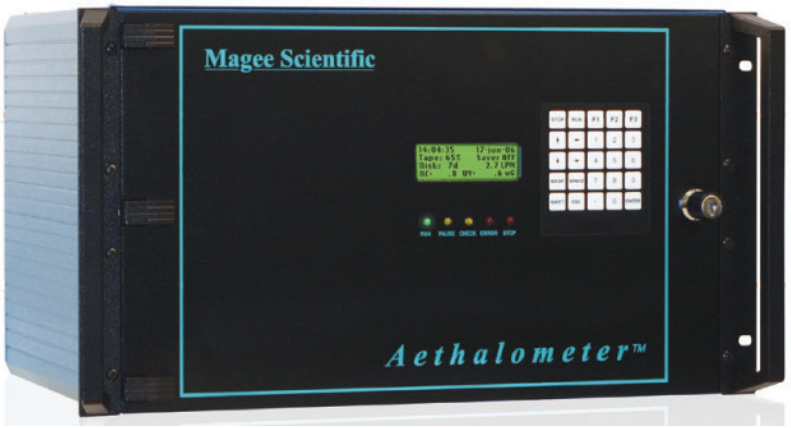


- Collect sample **continuously**.
- ***Optical absorption*** ~ change in ATN.
- Measure optical absorption continuously : λ = 370 to 950 nm.
- ***Optical absorption*** to ***mass equivalent BC concentration:***

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

- Real-time data: **1 minute**

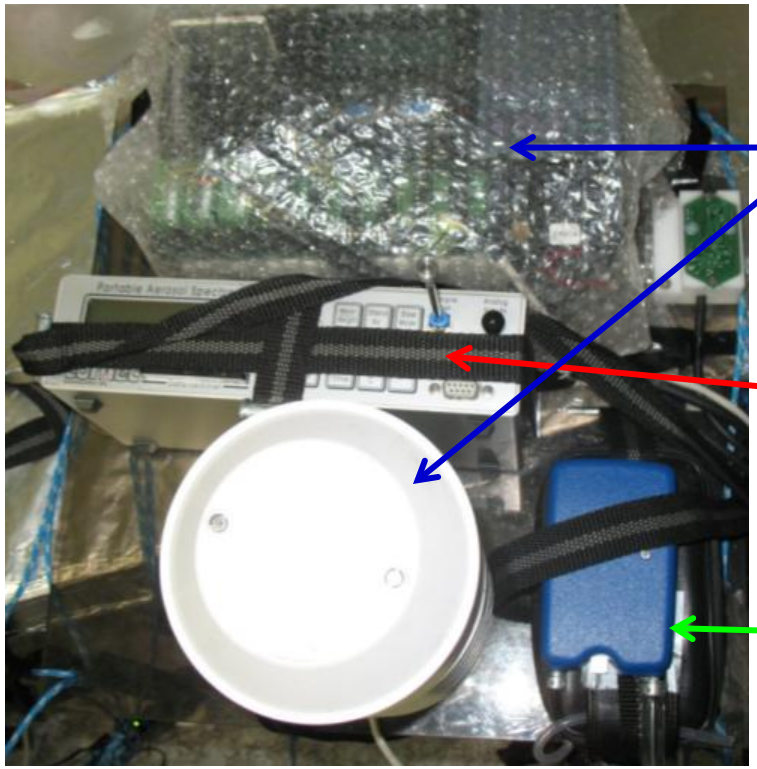
Aethalometer



AE31 & AE33 – 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***

Too big? YES!!



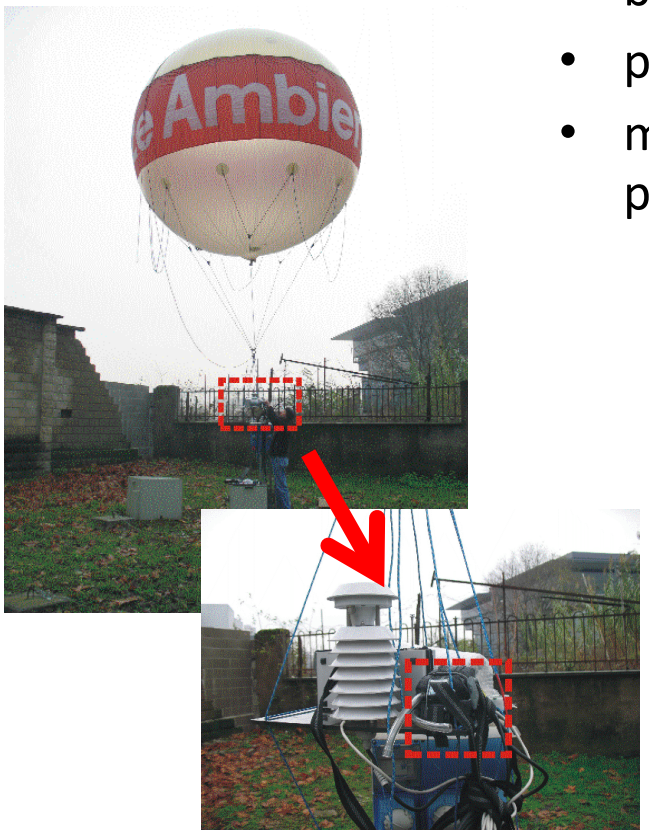
- **Torre Sarca, Milano (University of Milano - Bicocca)**;
- 2 and 3 December 2008,
- ascent and descent rate: **30.0 ± 0.1 m/min**;
- time resolution: 6 sec - **3.0 m of vertical resolution**
- maximum height during launch was **510 m AGL.**

Meteorological Station (LSI-Lastem)

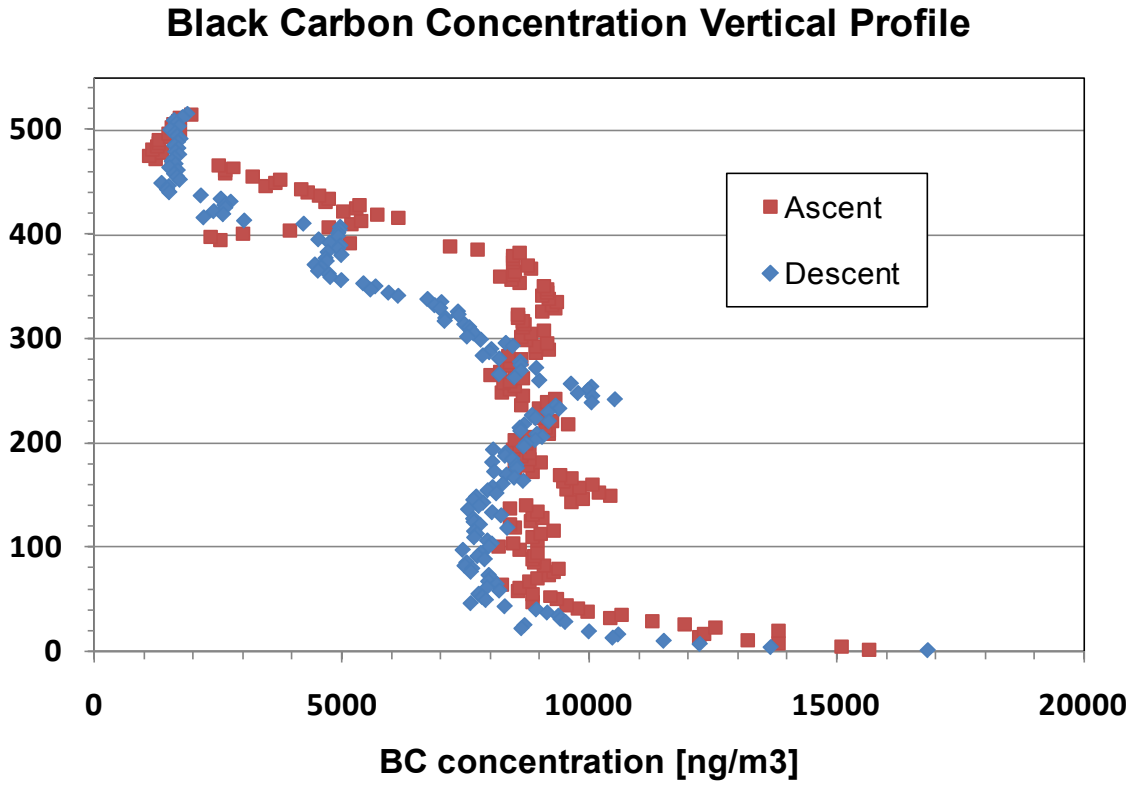
OPC Grimm *1.108*

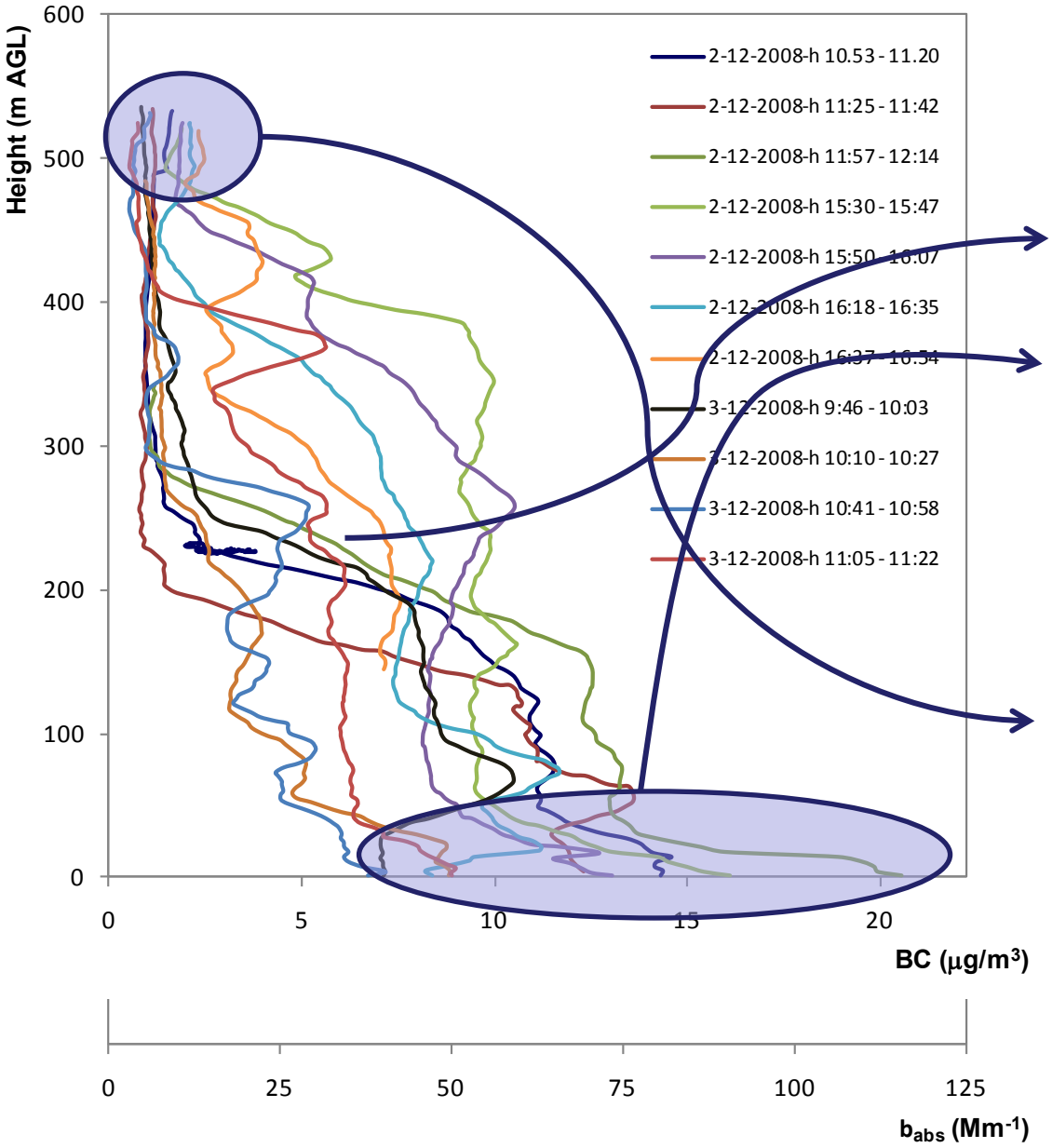
Prototype AE5x

BC vertical profiles over Milano



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





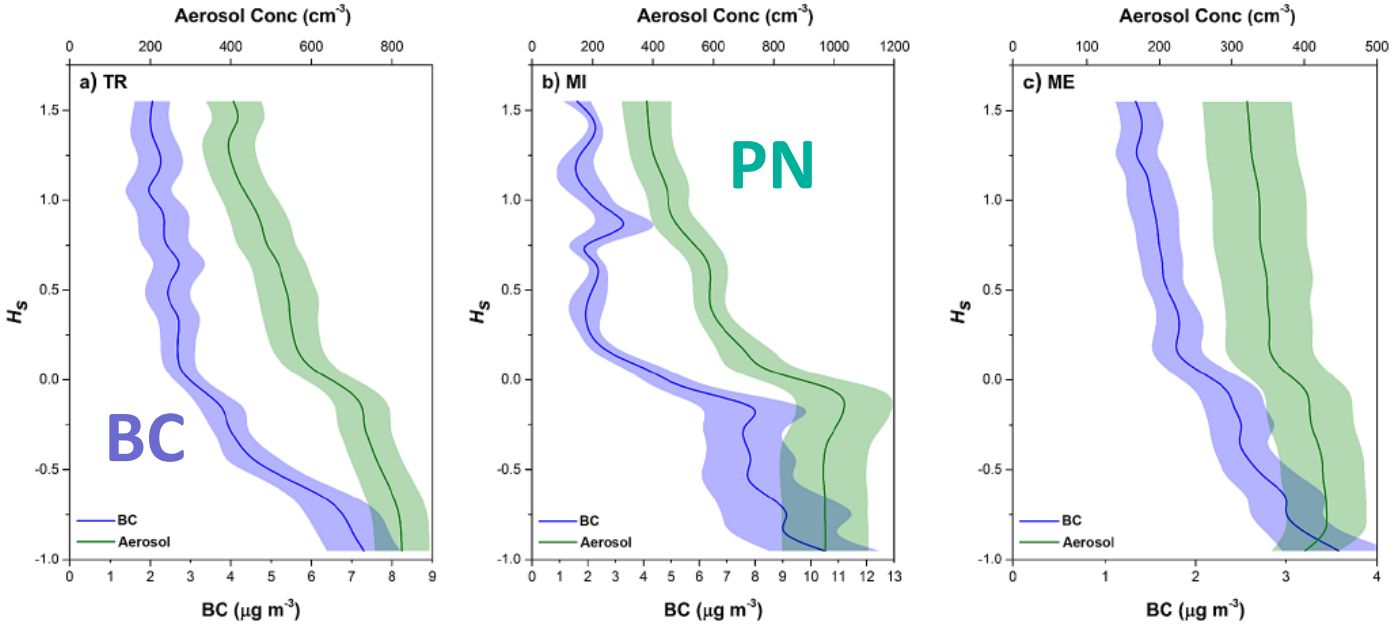
1) **Stable mixing layer** of variable depth.

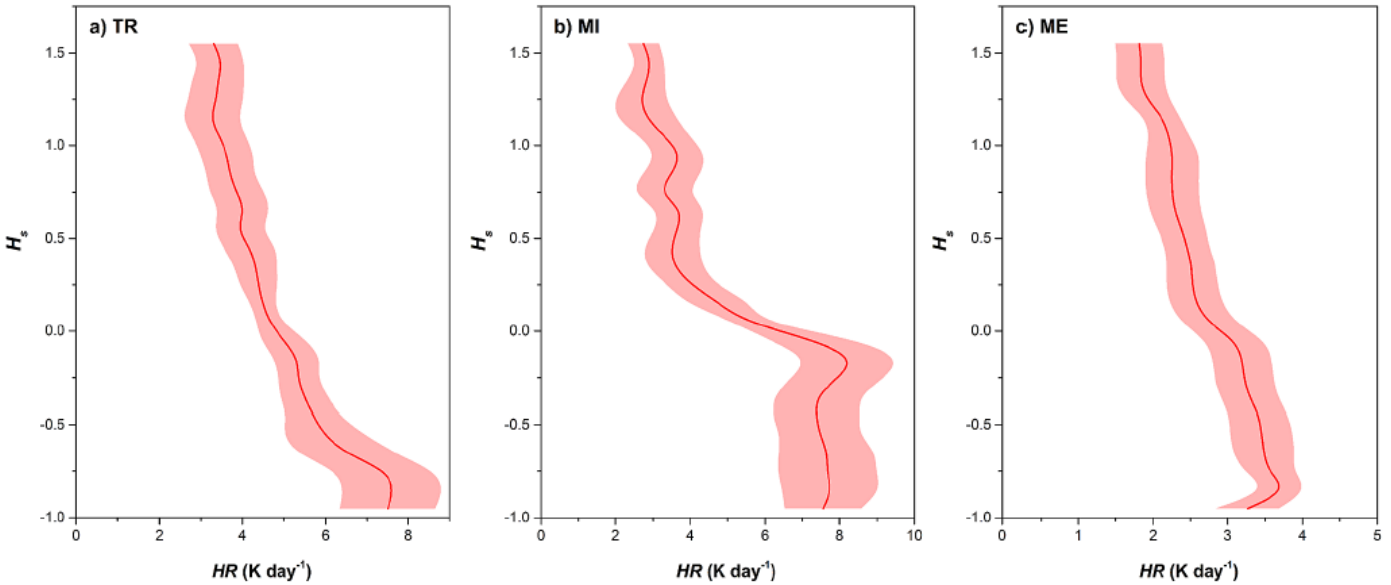
2) **Sharp decrease at the MH**

3) **Higher values b_{abs} (and BC) near ground** +24±4% higher than average BC measured within whole mixing layer.

4) **Lower degree of variance above the MH**,
fairly constant values of b_{abs} (and BC) 17±2% of those within the mixing layer.

Terni (TR) Milano (MI) Merano (ME)



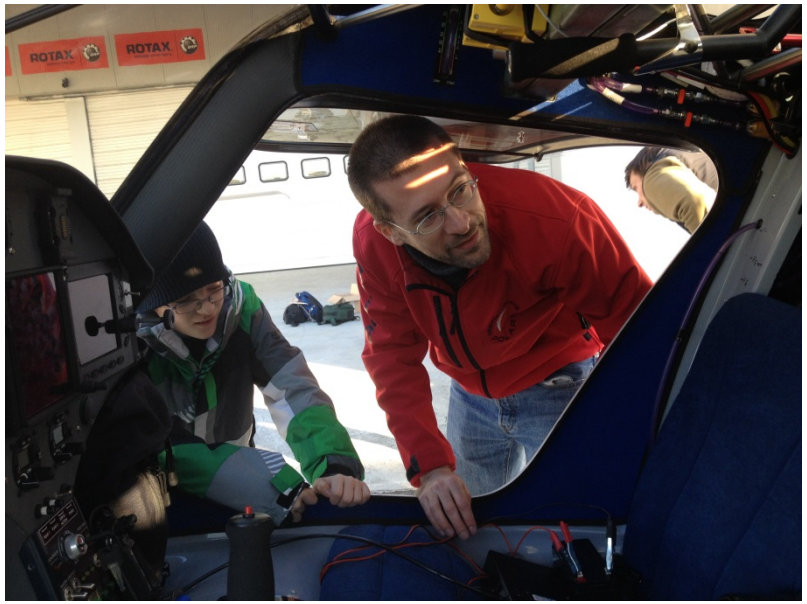


heating rate (K/day)

Aircraft and sampling: Aethalometer measurements @ 3 km and 200 km/h

Aircraft and sampling: Aethalometer measurements @ 3 km and 200 km/h

Small and light – not much space in the cockpit!

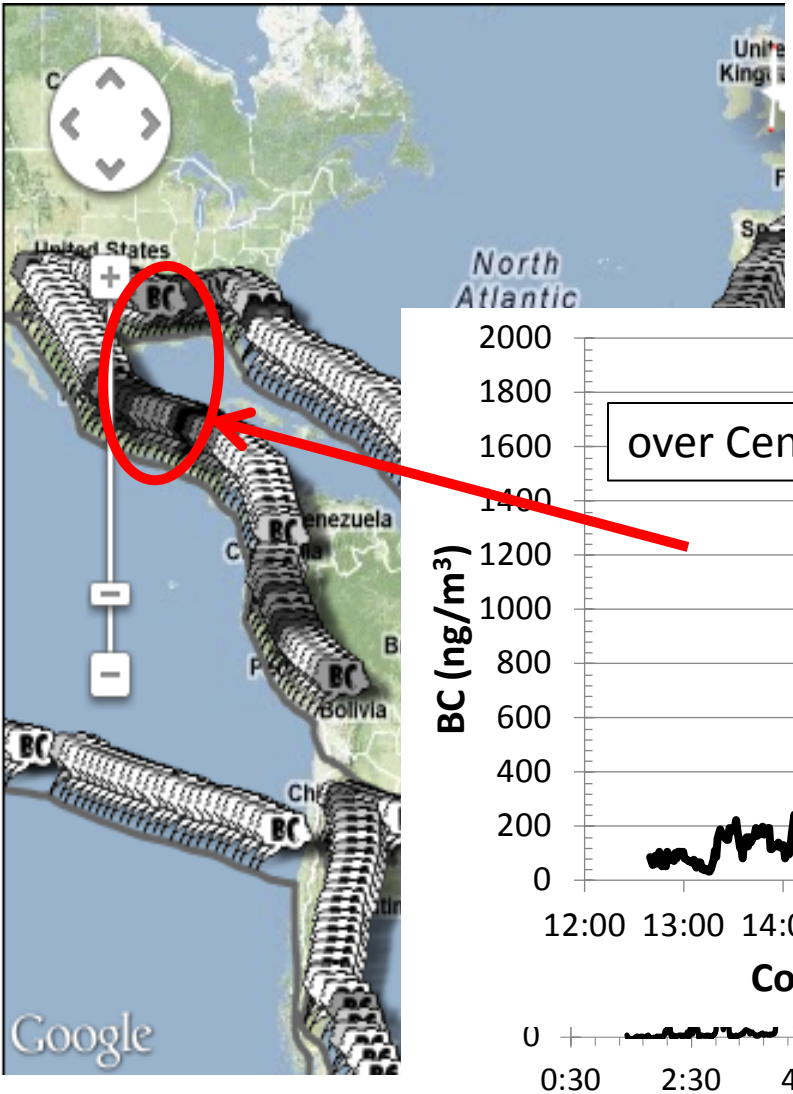


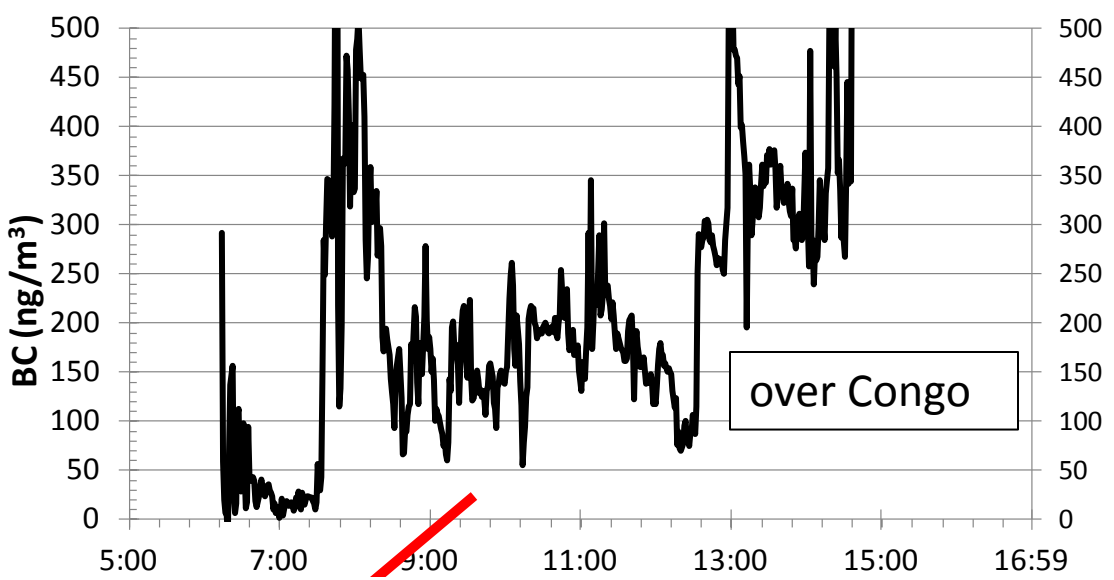
Inlet on the starboard wing:

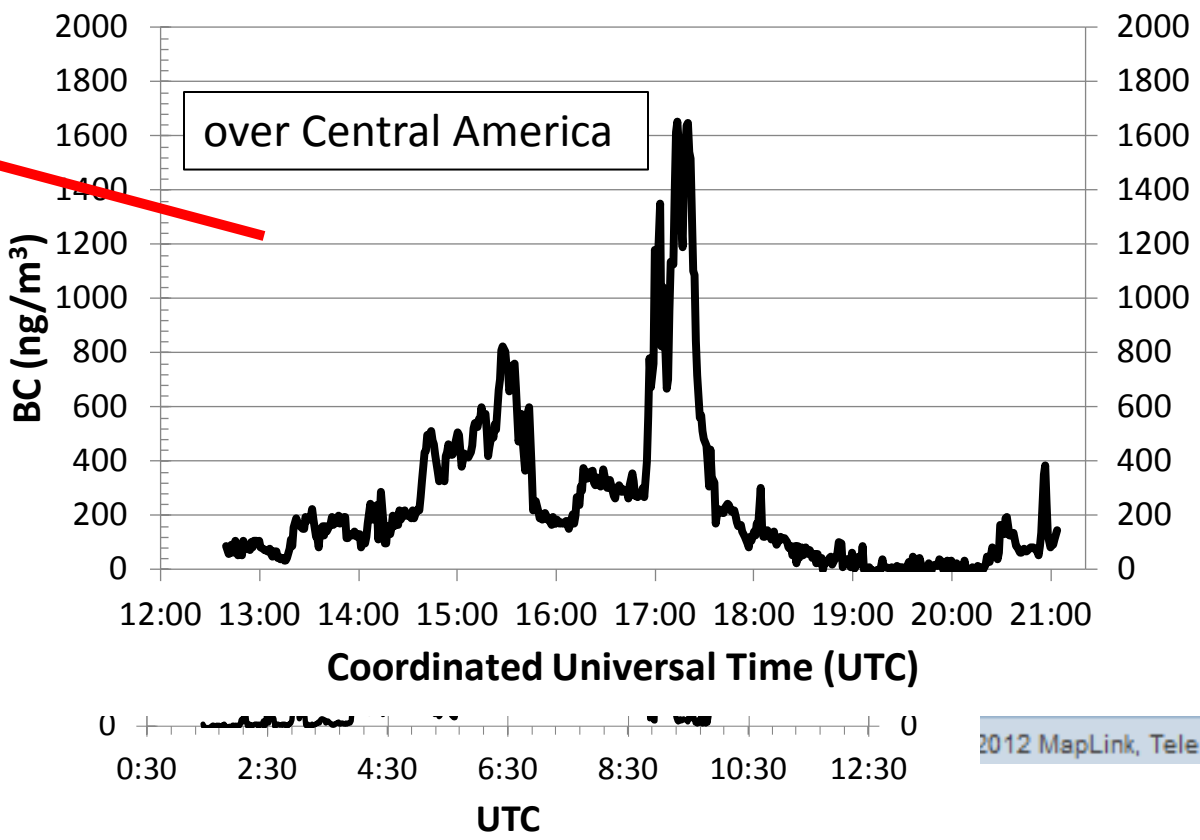
Different sources: point vs. distributed

Black carbon layers @ 3 km

Results


North Atlantic
United States
Bolivia
Google

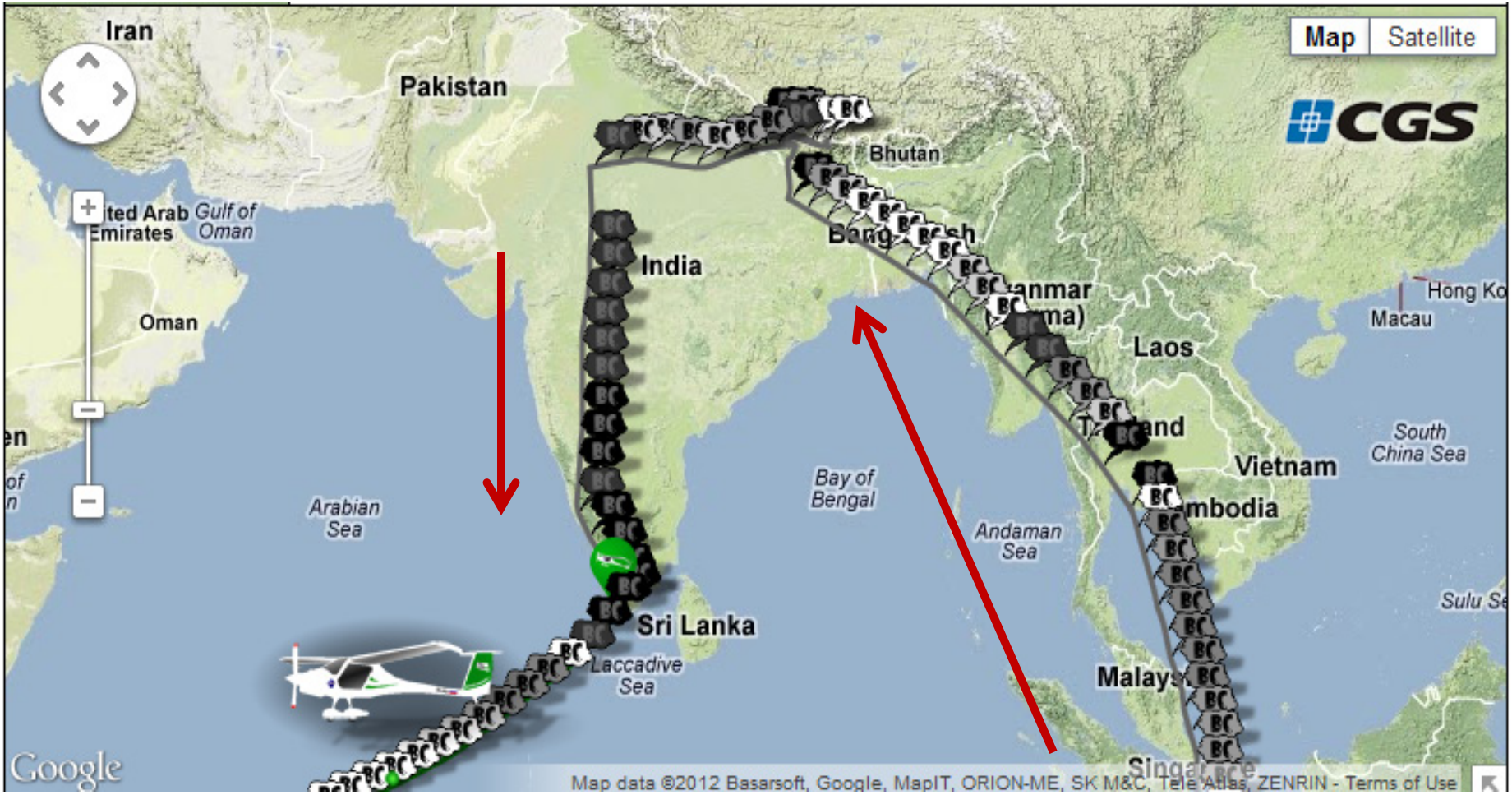

BC (ng/m³)
over Congo
5:00
7:00
11:00
13:00
15:00
16:59


BC (ng/m³)
over Central America
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
Coordinated Universal Time (UTC)


Papua New Guinea
2012 MapLink, Tele Atlas - Terms of Use

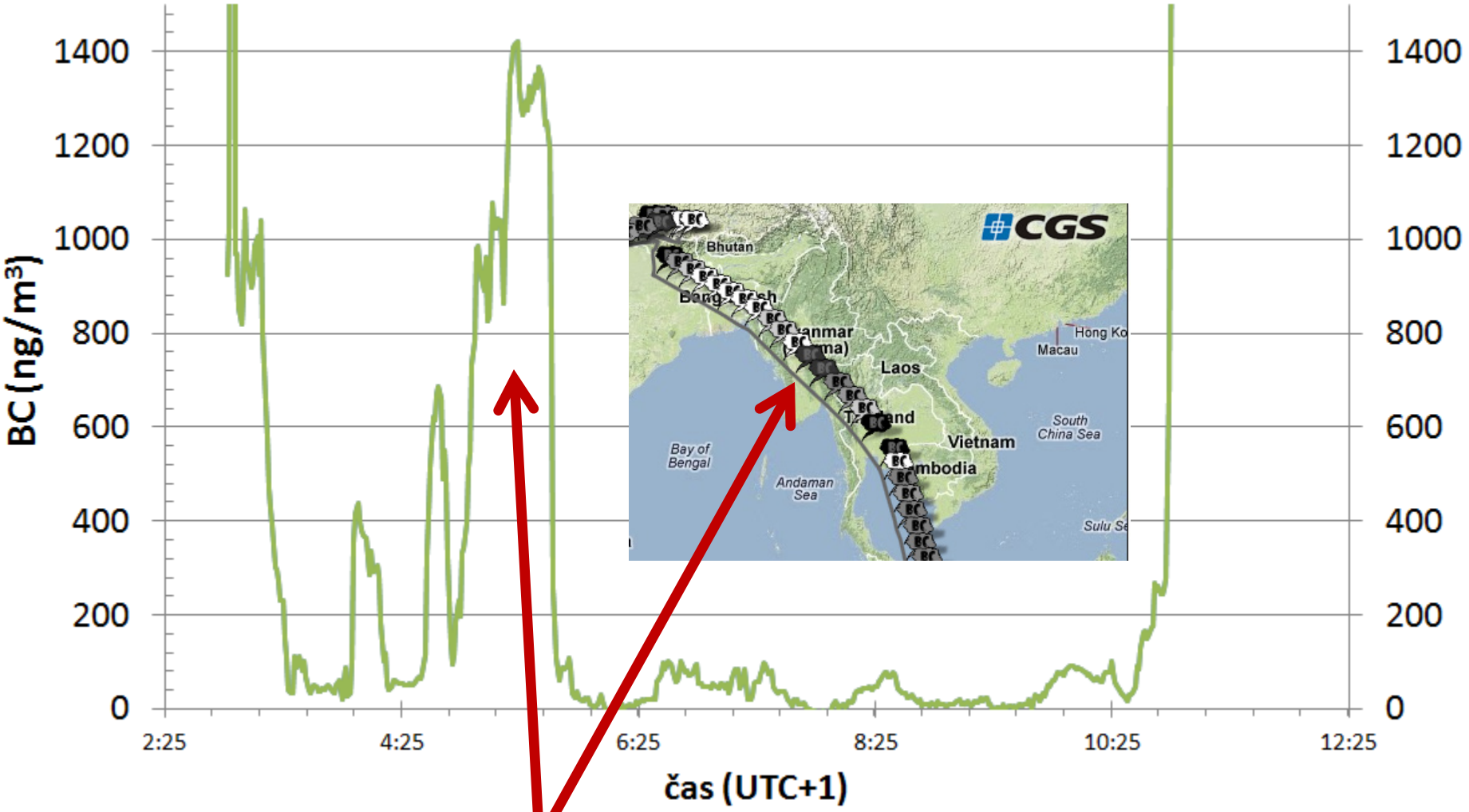
0:30
2:30
4:30
6:30
8:30
10:30
12:30
UTC

Results: SE Azija, India



Take-off: Thailand

Landing: India



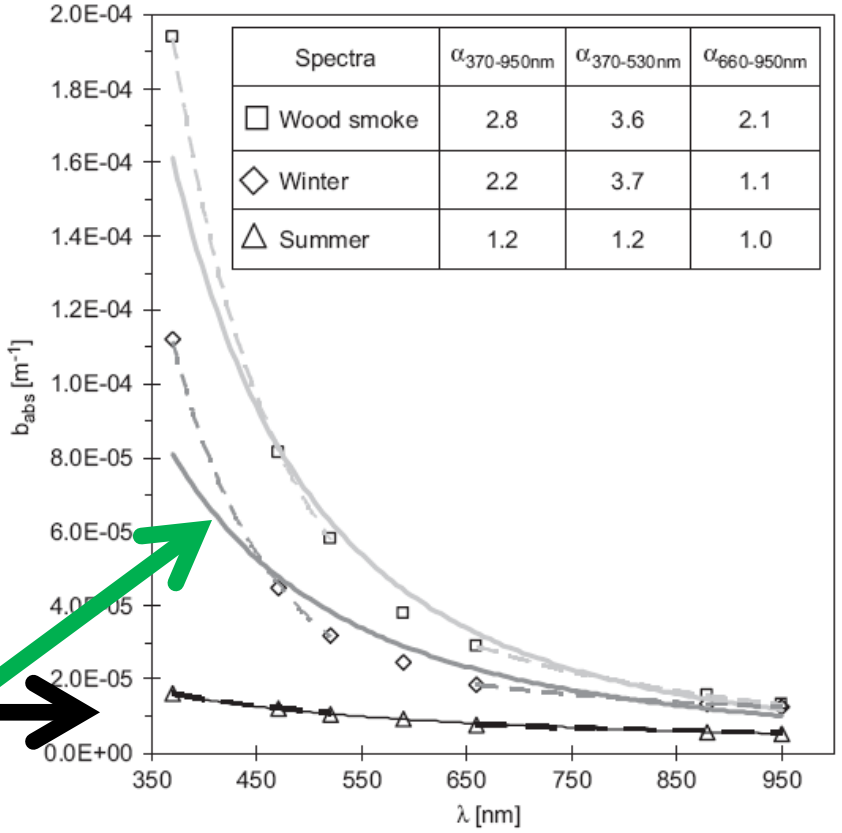
Biomass-smoke vs. diesel – wavelength dependence

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

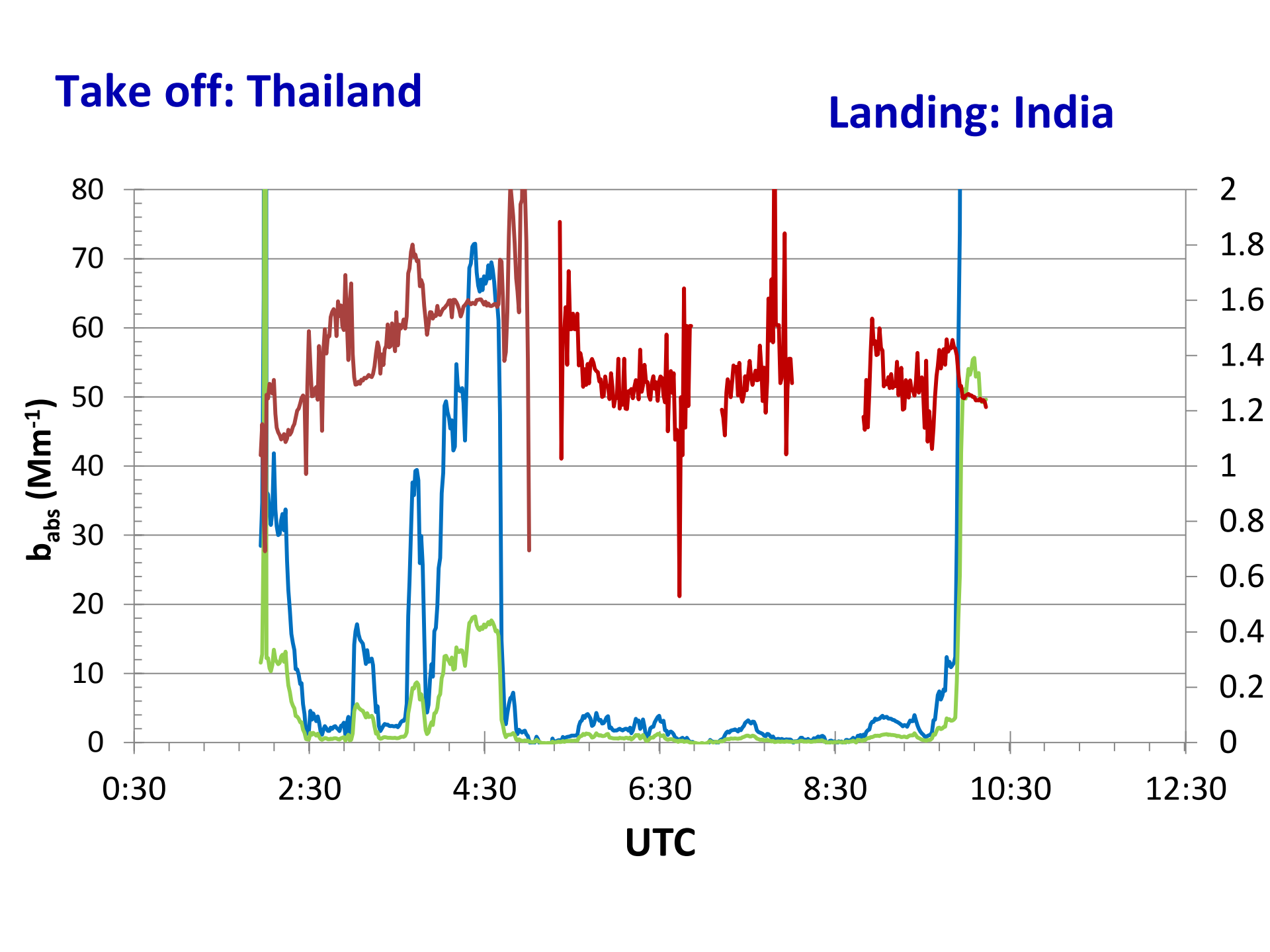
$$b_{abs} \sim 1/\lambda^{\alpha}$$

diesel: $\alpha \approx 1$

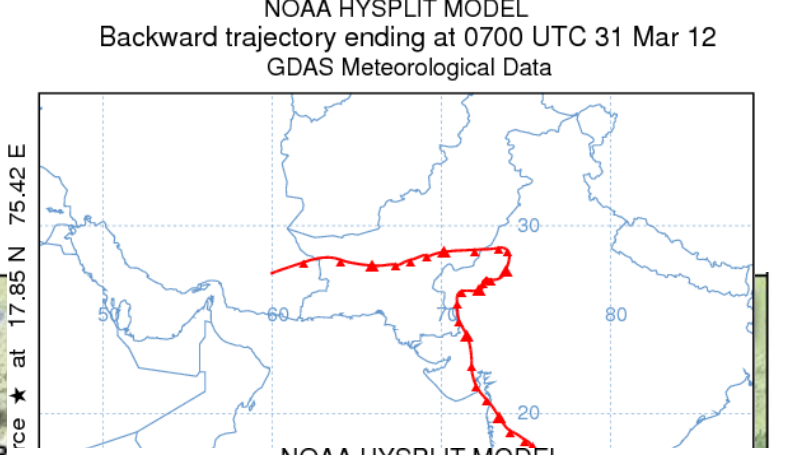
biomass: $\alpha \approx 2$ and higher

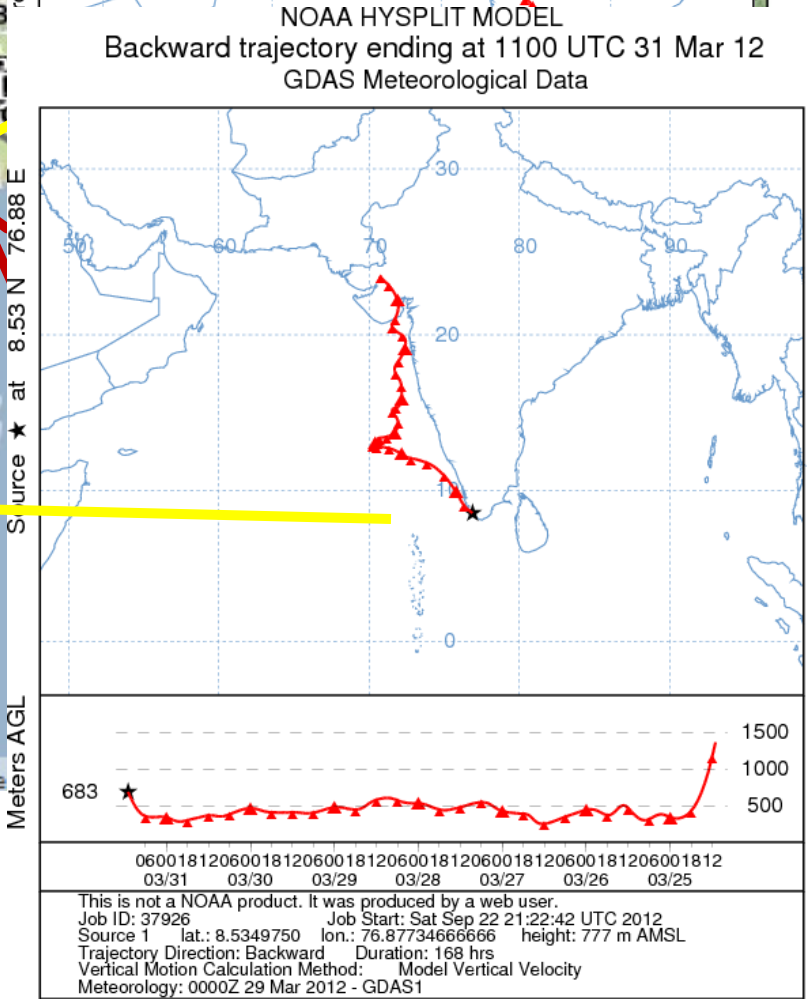


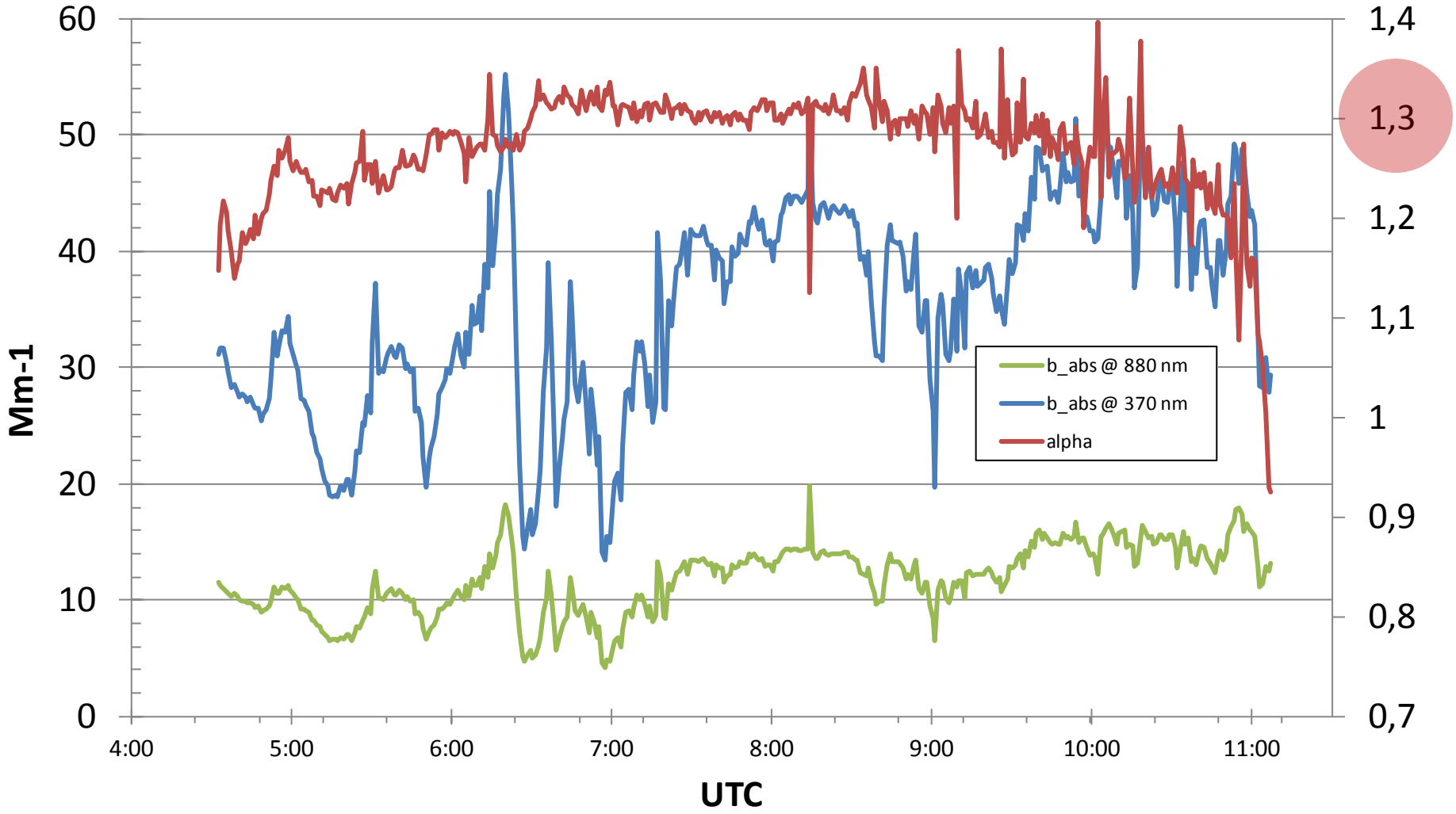
J. Sandradewi et al., A study of wood burning and traffic aerosols in an Alpine valley using a multi-wavelength Aethalometer, Atmospheric Environment (2008) 101–112


Take off: Thailand
Landing: India
80
70
60
50
40
30
20
10
0
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
b_{abs} (Mm^{-1})
0:30
2:30
4:30
6:30
8:30
10:30
12:30
UTC

Results: SE Asia, India



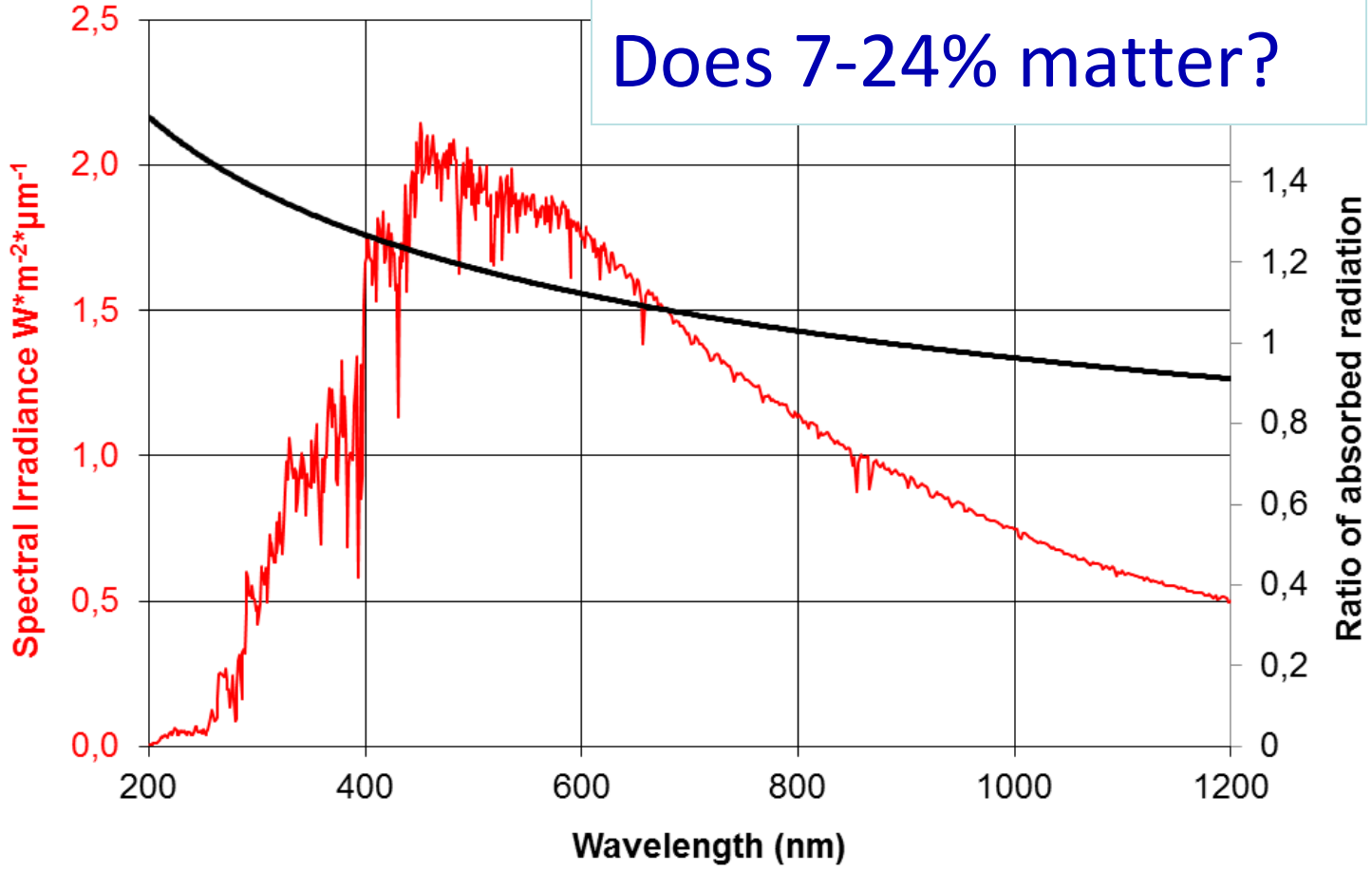


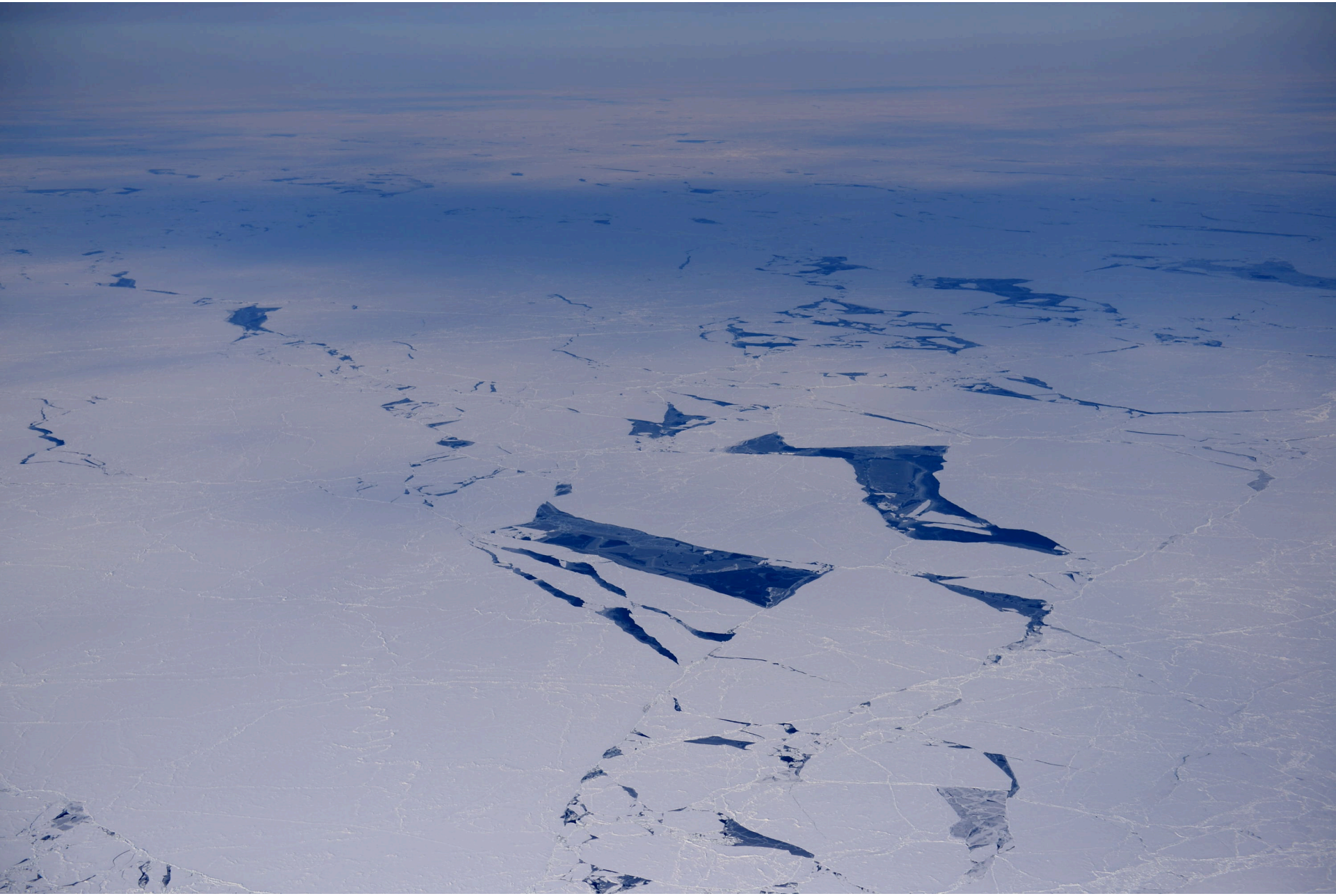

60
50
40
30
20
10
0
Mm-1
1,4
1,3
1,2
1,1
1
0,9
0,8
0,7
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
UTC
b_abs @ 880 nm
b_abs @ 370 nm
alpha

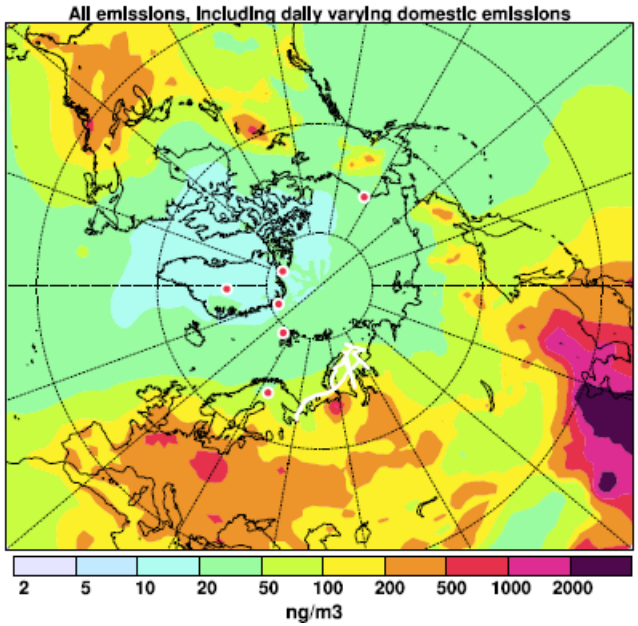
Climate implications – increase of Angstrom exponent

α=1 → 1.3

Does 7-24% matter?







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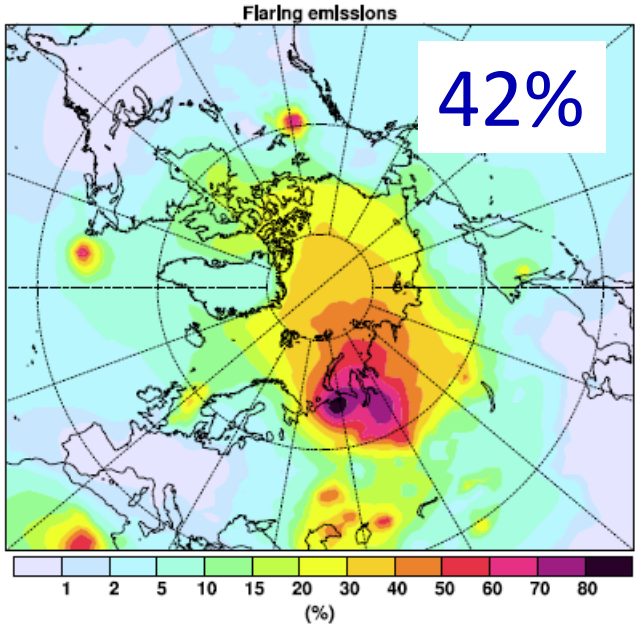
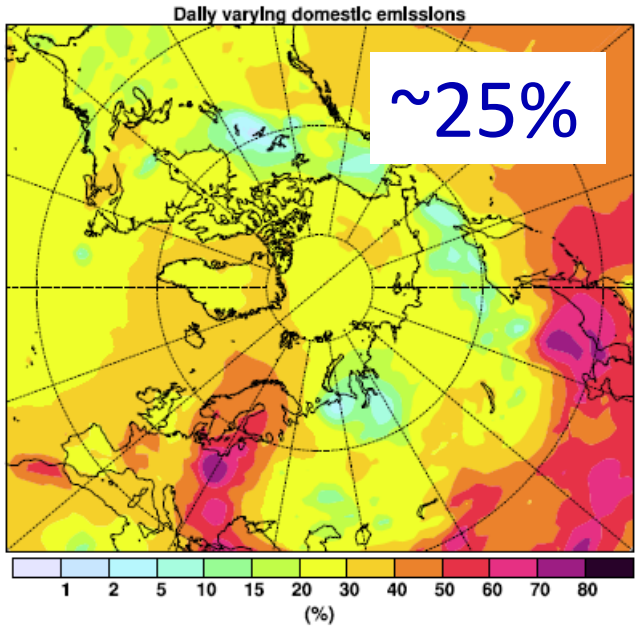


flaring

+



domestic heating

+ …

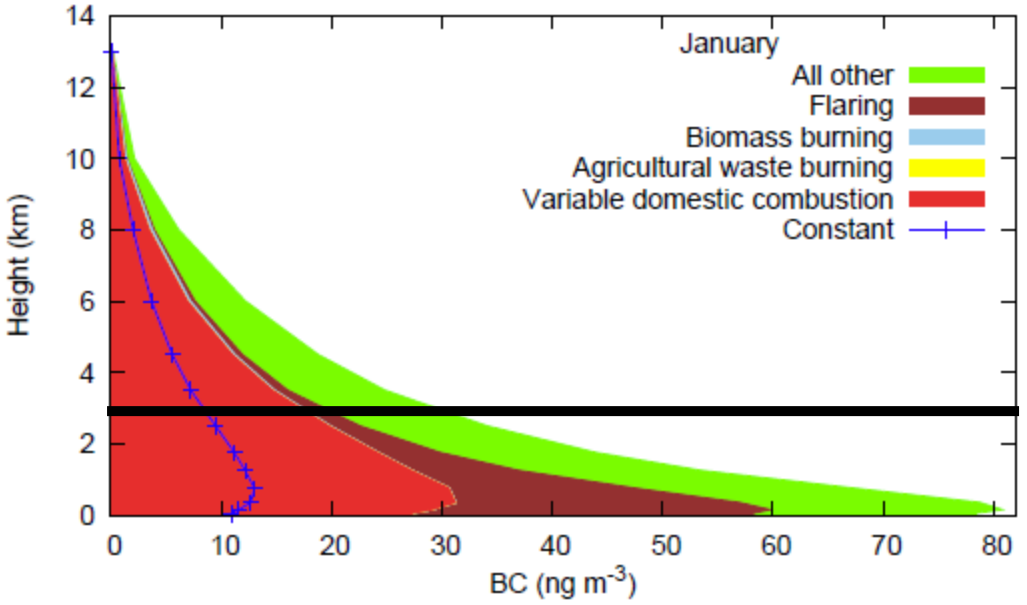
10 100 1000

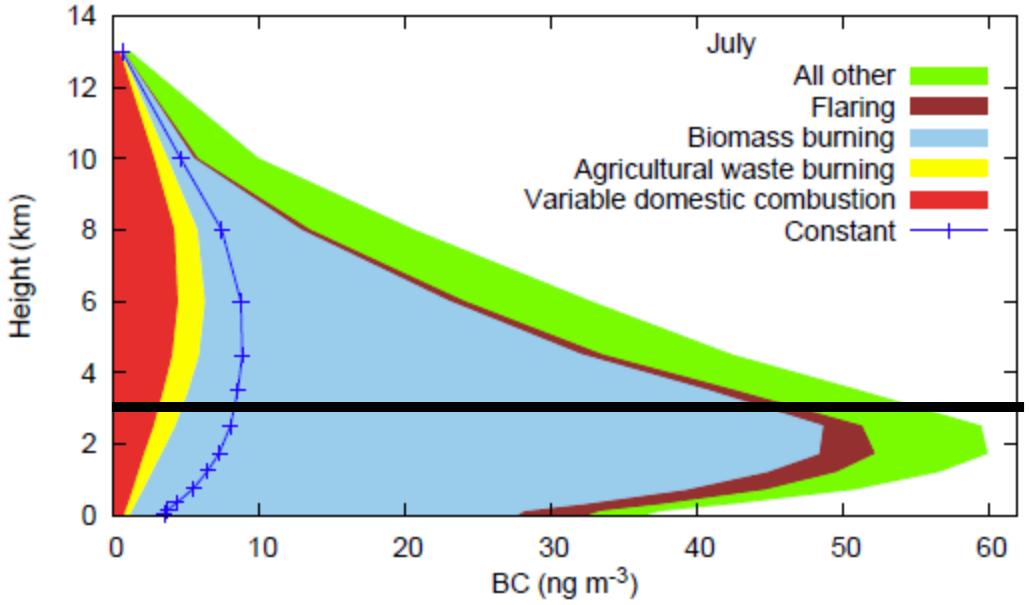
Modeled ground concentrations

(Stohl, 2013)

Modeled BC vertical profiles (jan, jul)

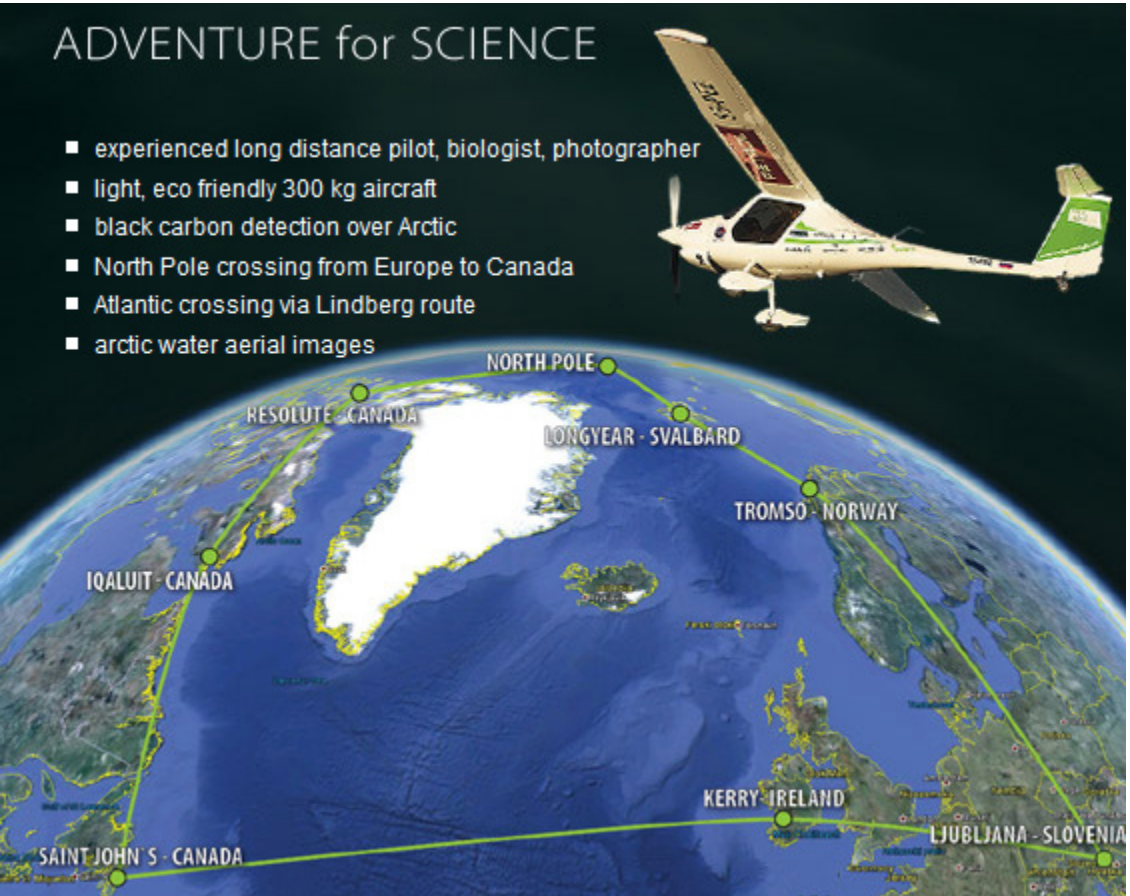
Concentrations: max 100 ng/m^3

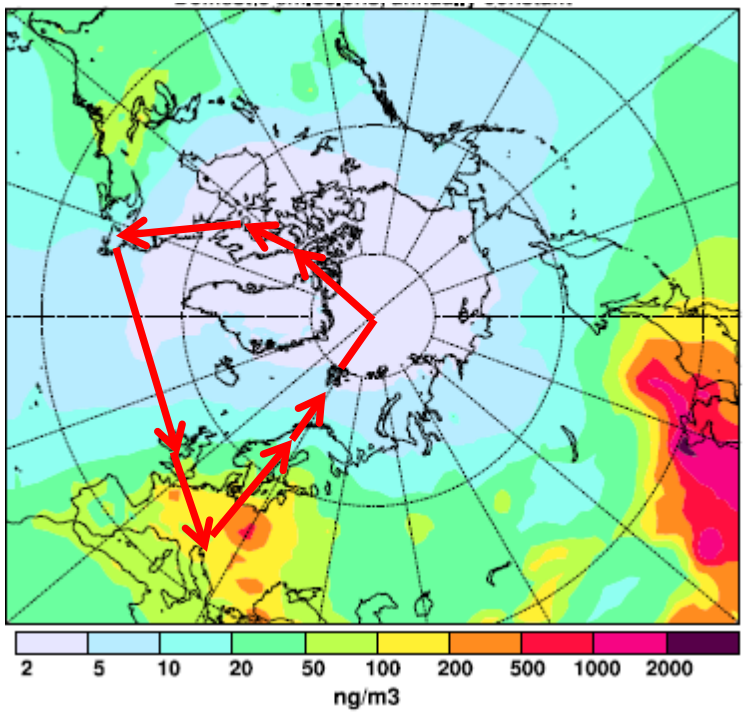




(Stohl, 2013)

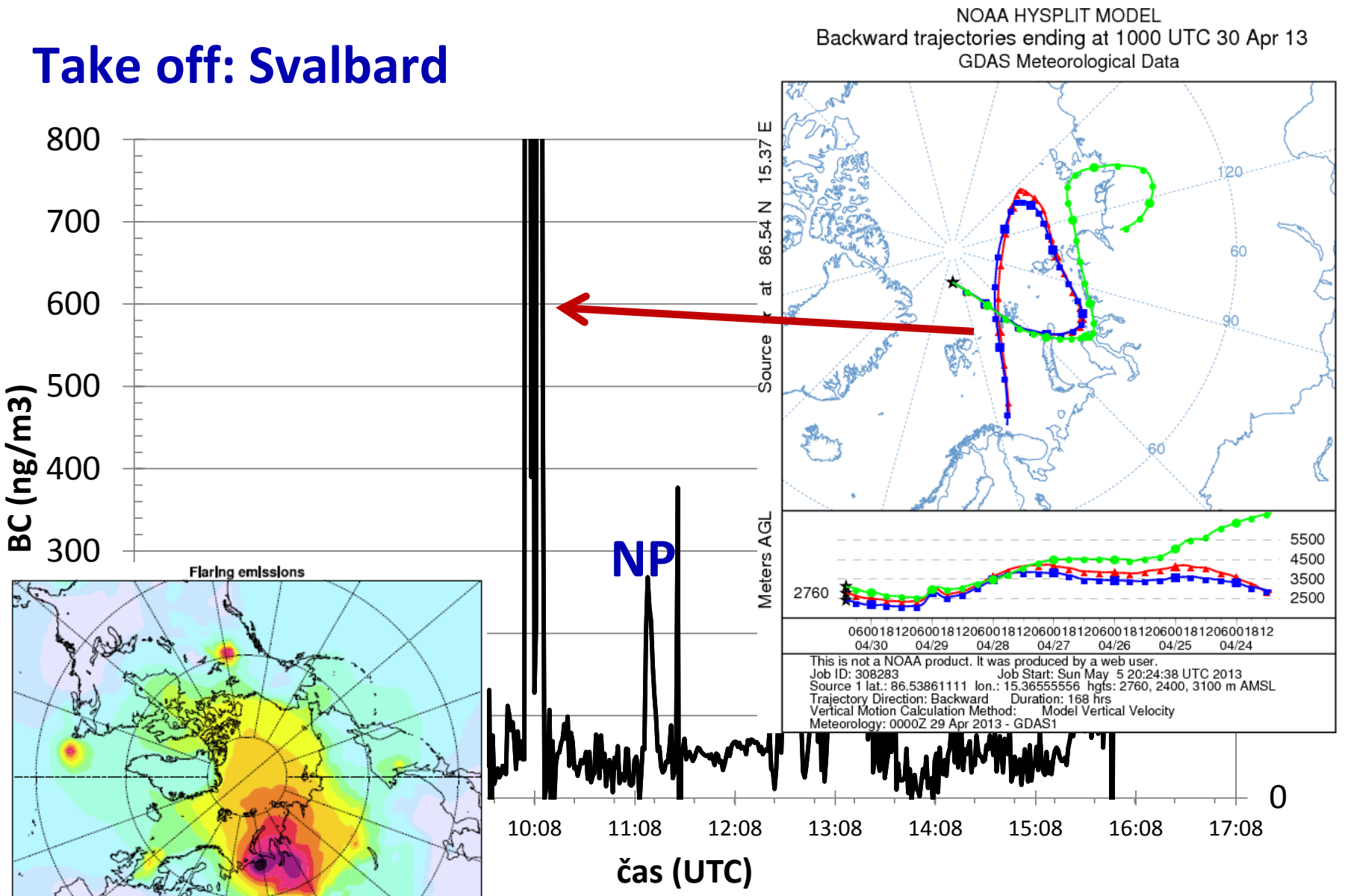
Measurements?





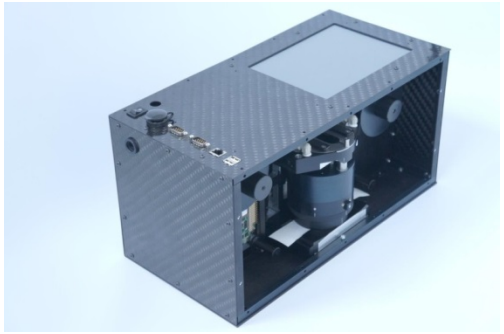
Same plane, same pilot – new journey!

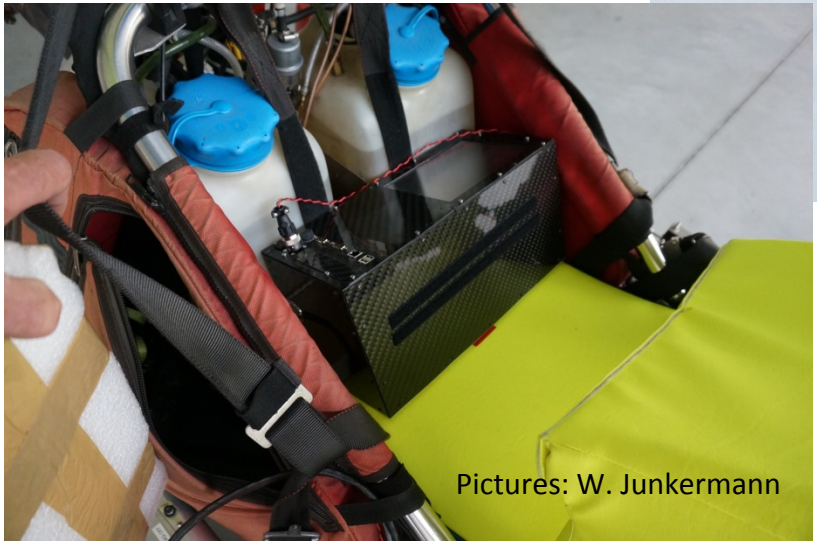
Take off: Svalbard



Norilsk?

On-going campaigns – new: AE33-avio

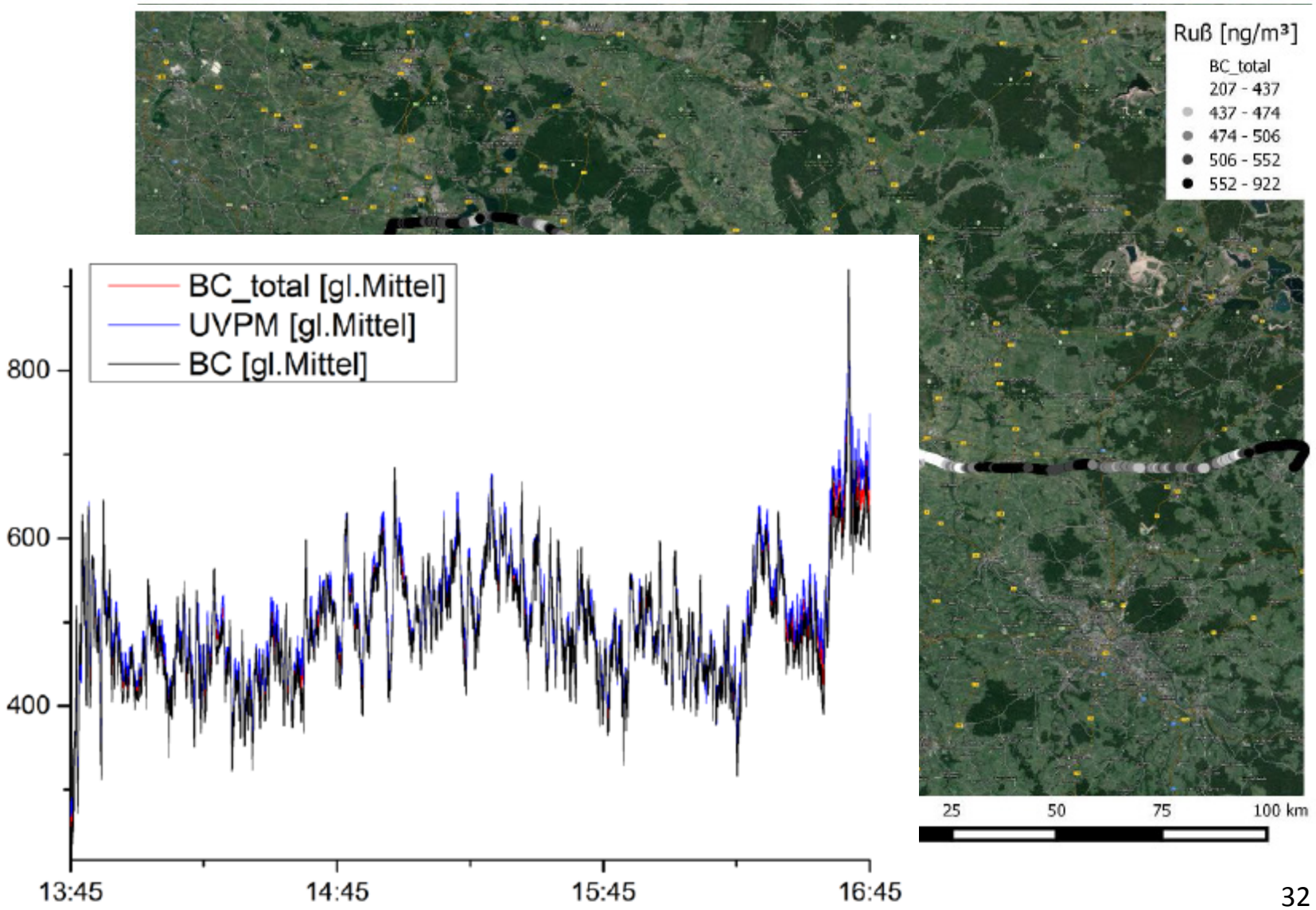




Picture: L. Ferrero

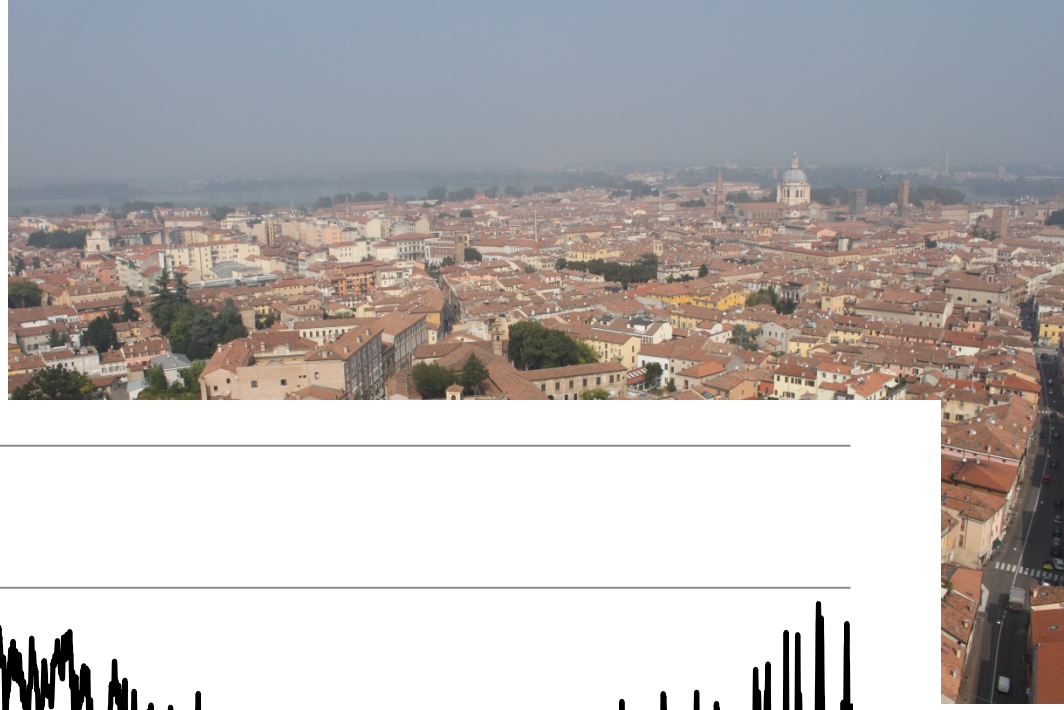
Picture courtesy of K. Weber

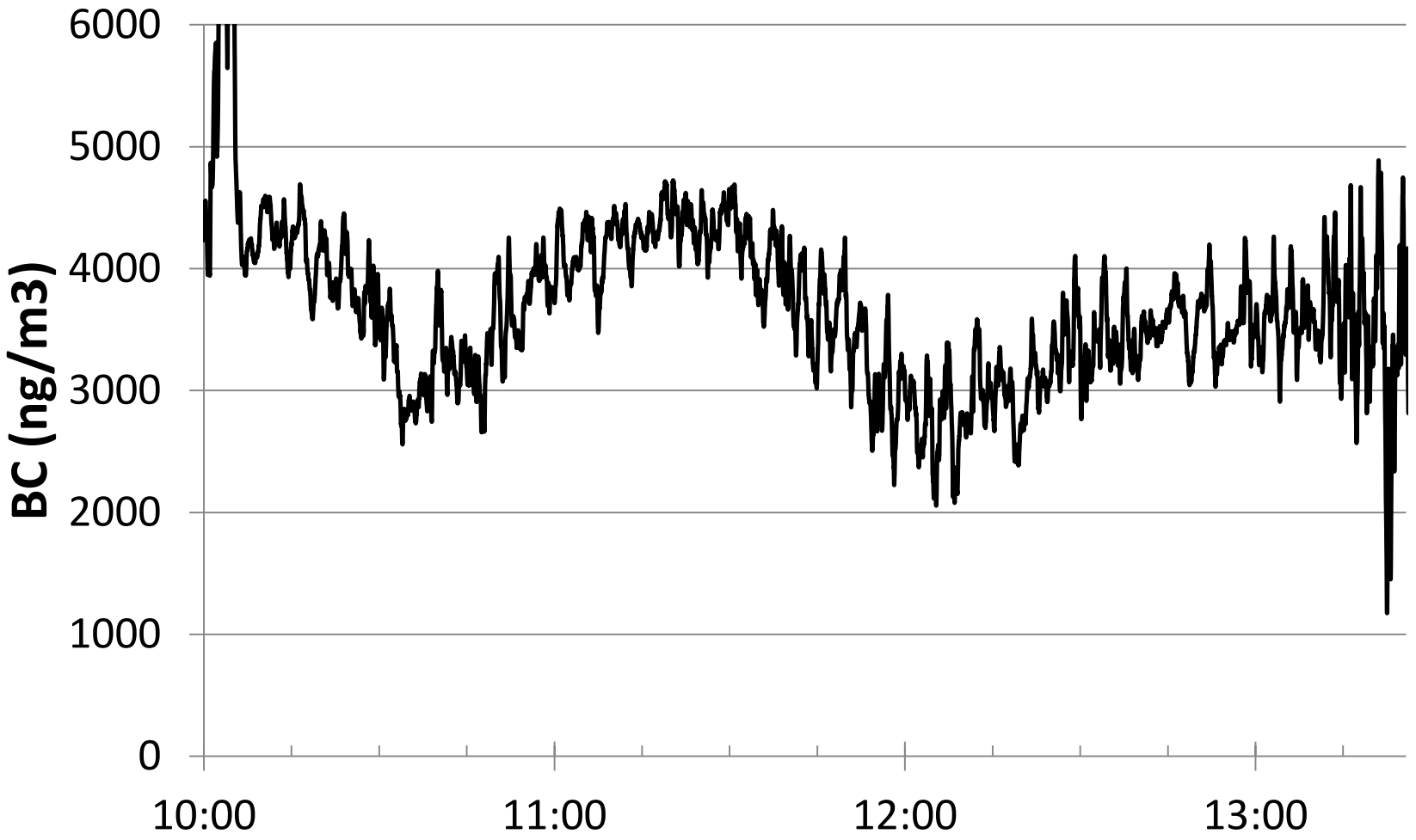
On-going Saxonia campaign – preliminary results



Flights and data processing courtesy of K. Weber .

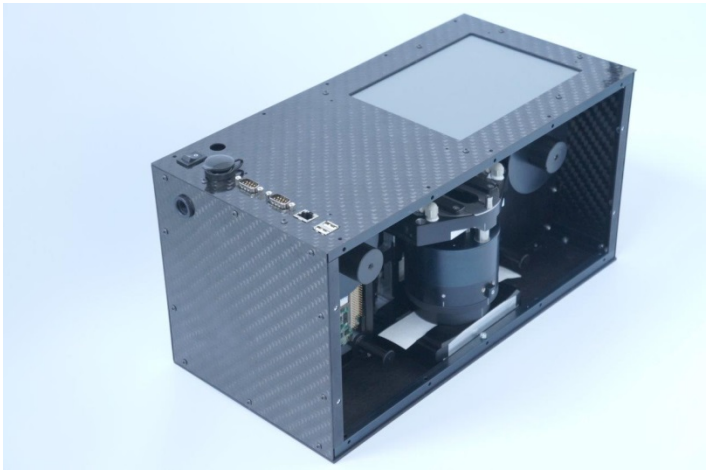
On-going Italian campaign – preliminary results





Conclusions

- Round the world & Arctic campaigns generated a big **dataset**
- **Hotspots** identified, **long range /regional** transport
- **Measured values higher than modeled**
- **Altitude range** important for weather, climate
- **Discrimination** between sources
  - **Biomass vs. Diesel** emissions have different effects on cloud formation
- **New instrument** development
- Tests ongoing – Germany, Italy



Thank you for your attention!
Questions?

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fax: +386 59 191 221

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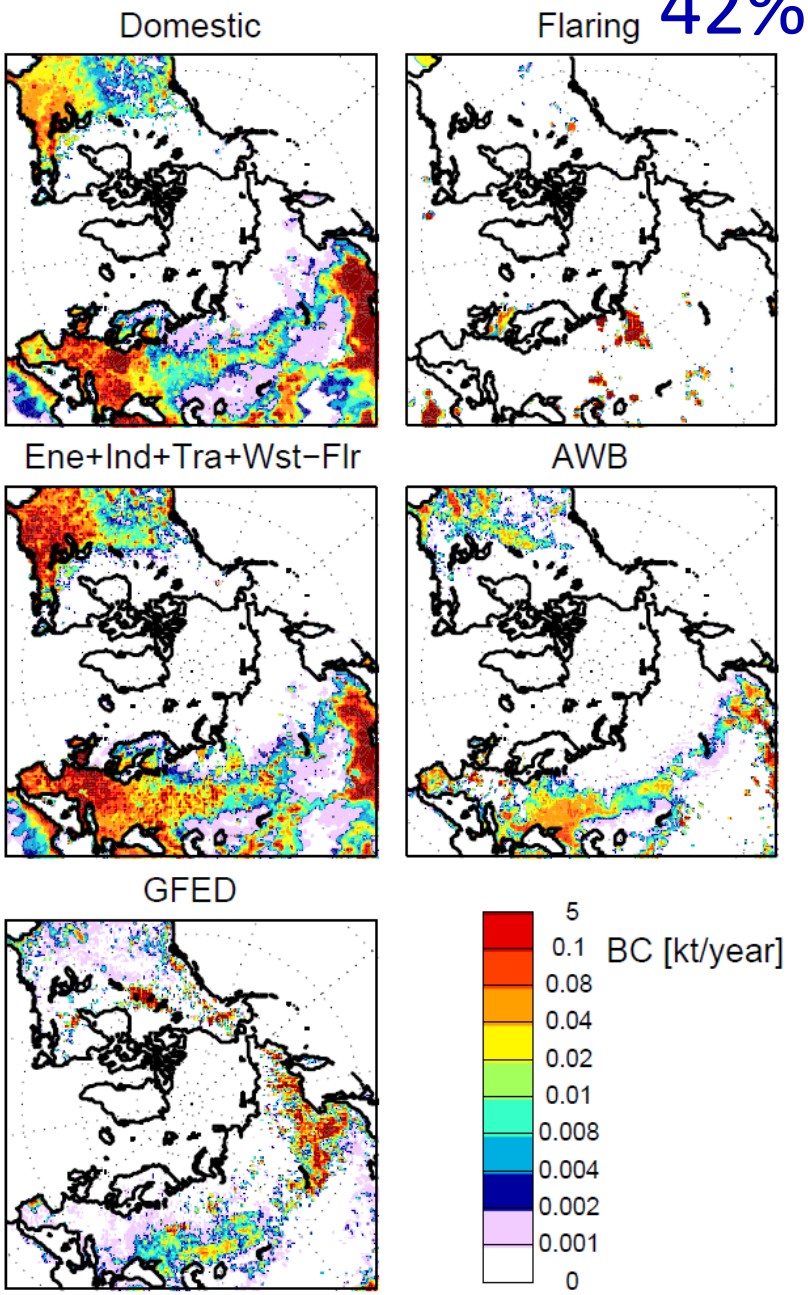
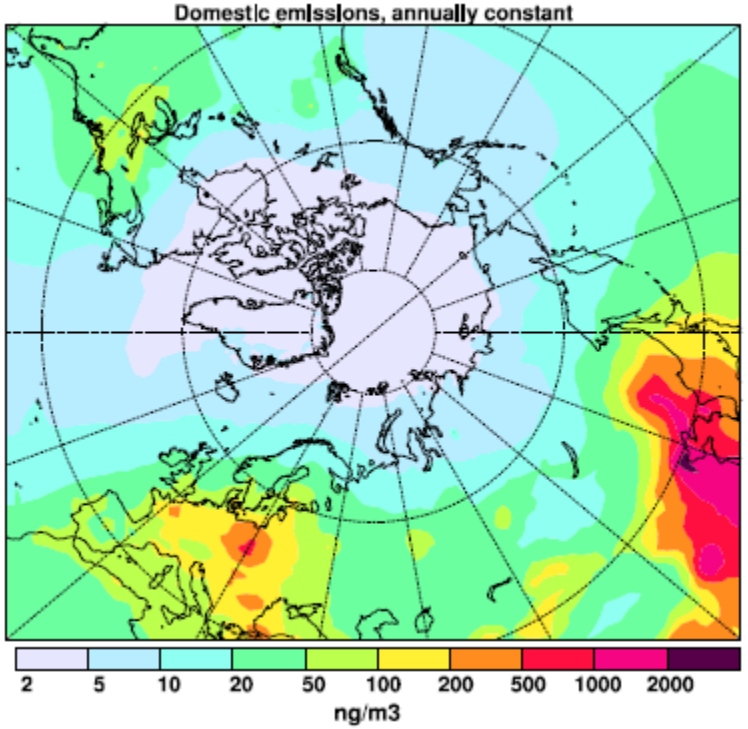
Aerosolized Black Carbon

- **What is Black Carbon?**
- **Why is it important?**
- **Regional and global measurements – influence on the climate?**
- **How do we measure it?**
- **Black Carbon around the world and over the Arctic**
- **Which sources?**

Emissions



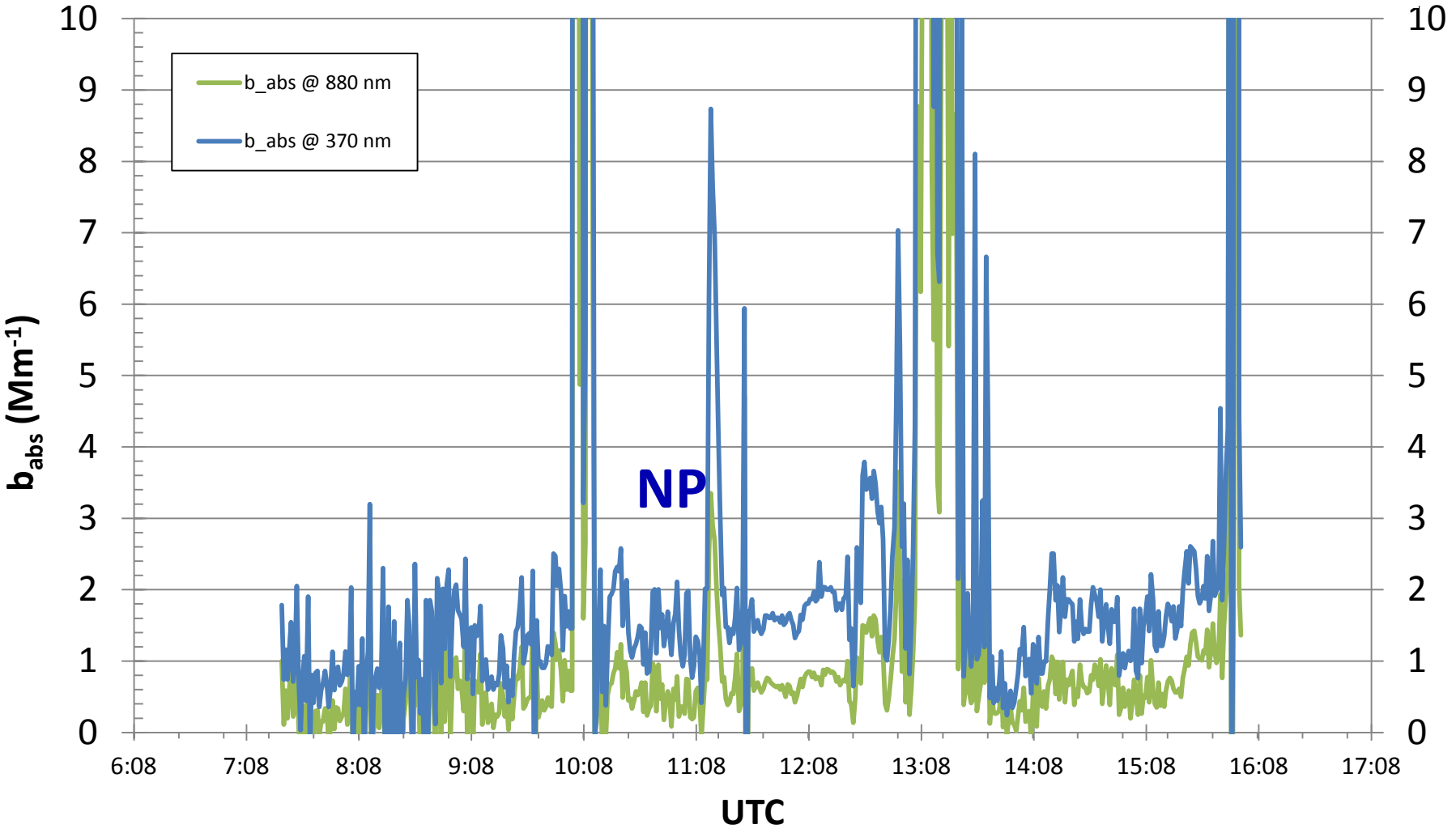
Impact - concentrations



So far so good – models.
What about measurements?

Take off: Svalbard

Landing:Canada

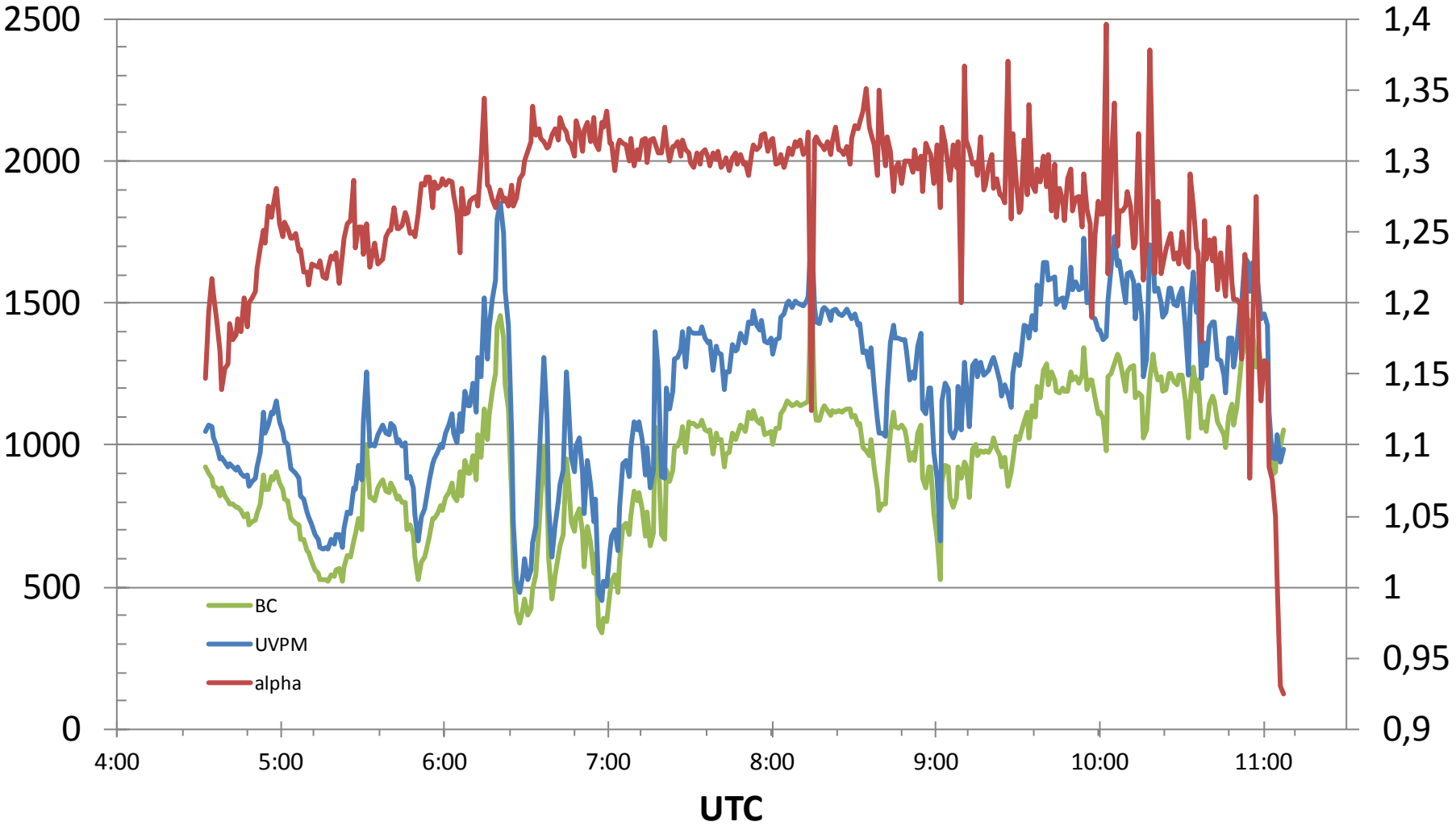


Conclusions

- 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**

Aerosol

BC (ng/m^3)



Aerosol