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# Long-term airborne measurements of black carbon using a Lufthansa passenger aircraft (IAGOS-CARIBIC)

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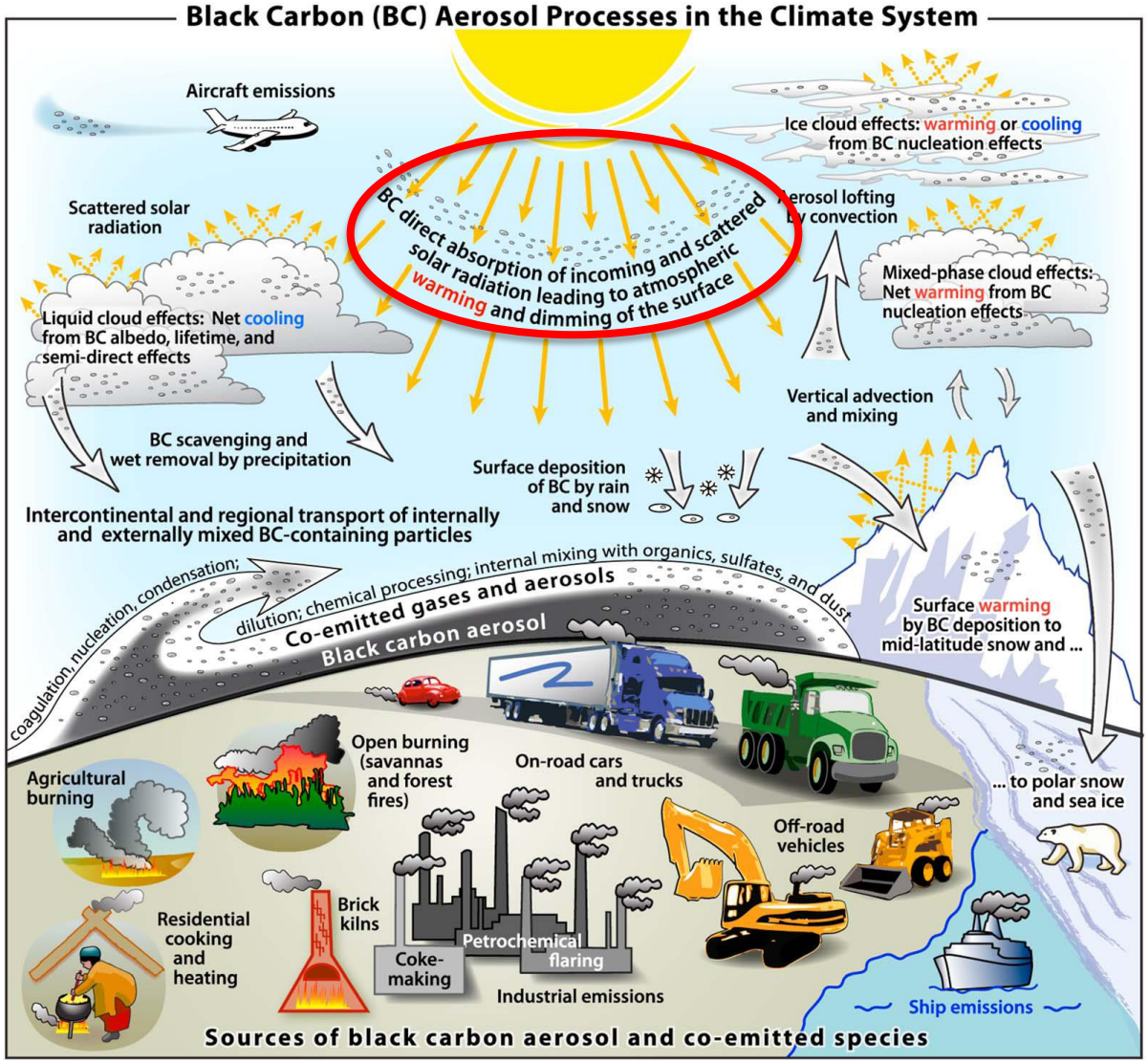
# Black carbon




**Total global emissions of black carbon:**

7500 Gg $yr^{-1}$

+/- factor of 3-4

(Bond et al., 2013)

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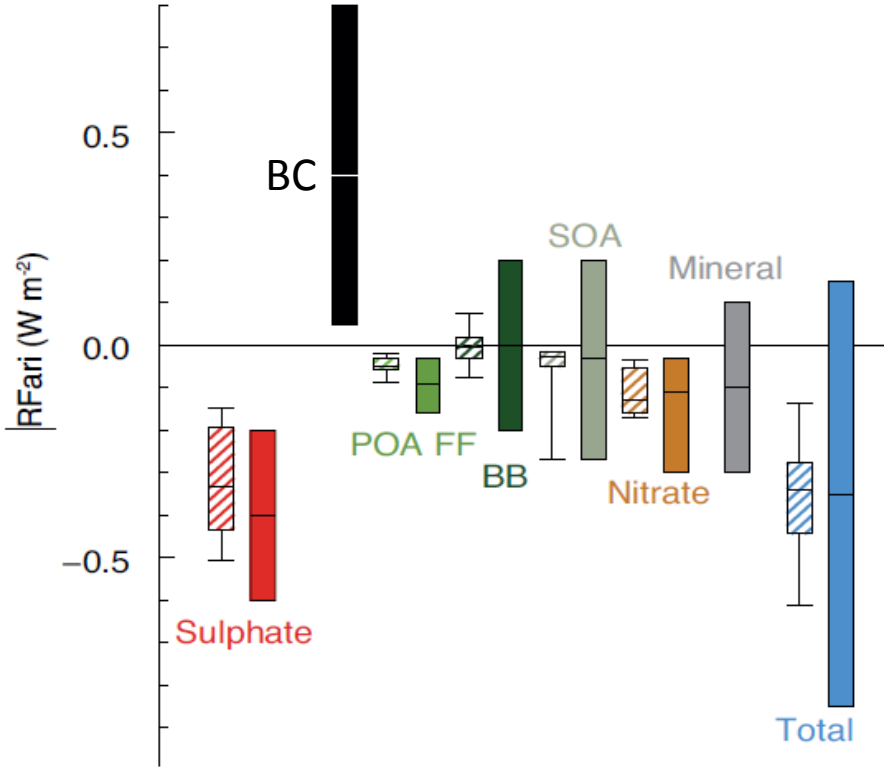
# Direct radiative forcing




Direct radiation forcing of atmospheric black carbon:

+0.4 (0.05 to 0.8) W $m^{-2}$
(IPCC, 2013)

+0.71 W $m^{-2}$ with 90% uncertainty
(+0.08 to +1.27 W $m^{-2}$)
(Bond et al., 2013)

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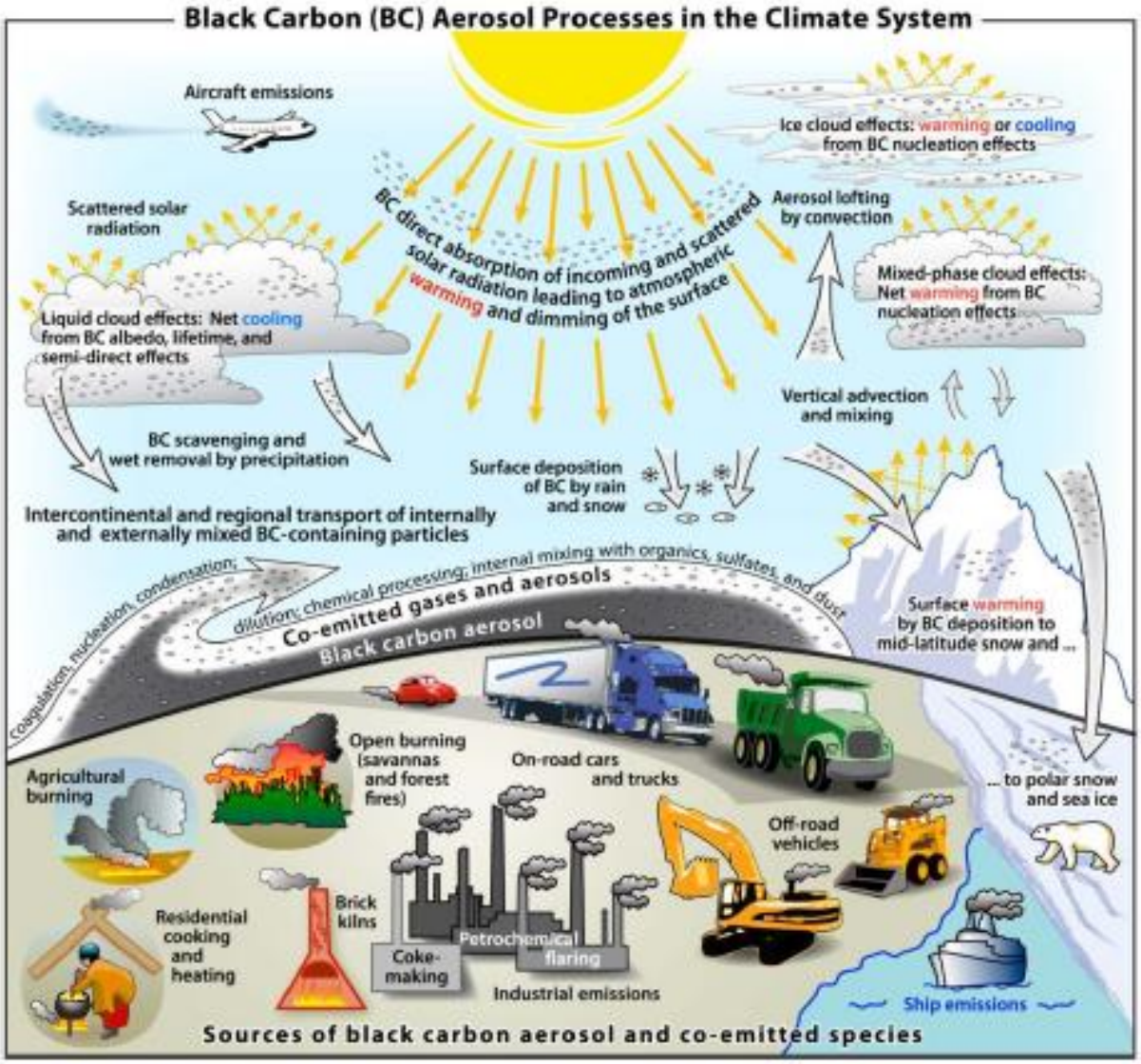
# Model vs. Observation




(Bond et al., 2013)

**Total global emissions of black carbon:**
7500 Gg $yr^{-1}$
(2000 to 29,000 Gg $yr^{-1}$)
(Bond et al., 2013)

**direct radiative forcing differ in literature between:**
0.19 & 0.71 $W/m^2$
(Wang et al., 2013; Bond et al., 2013)

vertically

**BC concentration overestimated by models:**
more severely in the upper troposphere/lower stratosphere (~10x) than at lower altitudes (~3x)
(AEROCOM,CAM5)
(Schwarz et al. 2010 ; Ghan et al., 2012)

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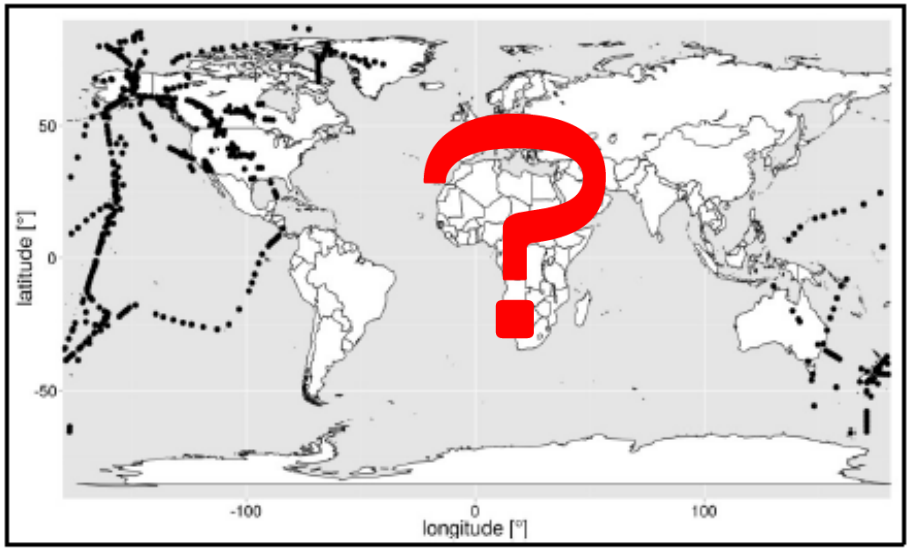
# Global data coverage needed

**Uncertain concentration of black carbon in the UTLS due to:**

- only a few measurements between 8 and 12 km (HIPPO, ARCTAS, ARCPAC, ACRIDICON)
- measurements limited in space and time and mostly performed above the remote area
- different lifetime in the upper troposphere (1 day to 2 weeks) and lower stratosphere (up to 1 year)
  → influence long-range transport, scavenging and aging of black carbon particles




Measurements during HIPPO, ARCTAS and ARCPAC campaigns between 8-12km

→ **IAGOS-CARIBIC-SP2 Project**

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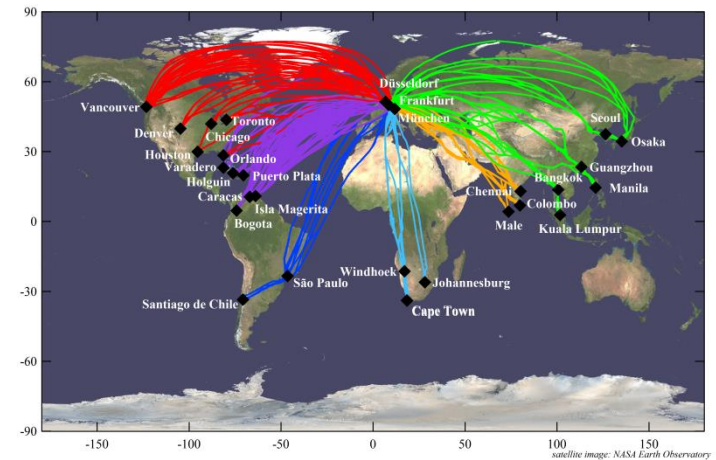
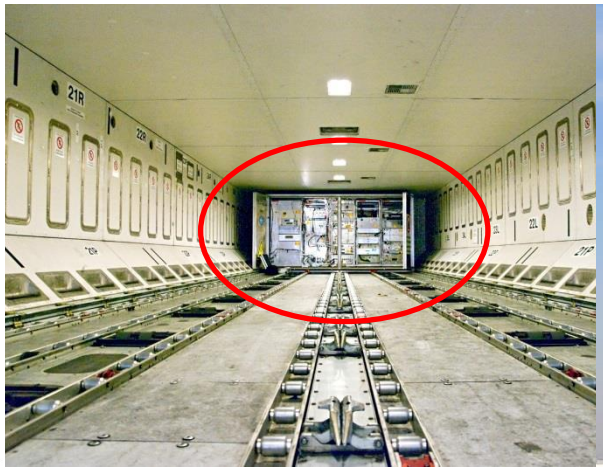
# CARIBIC project

- started in 2004 to regularly measure trace gases in **the tropopause region** with a few aerosol instruments on board
- special air freight **container (1.5 ton)** combines over 15 instruments
- positioned in the cargobay of a Lufthansa passenger aircraft above **a dedicated aerosol, water vapor, trace gas inlet system**
- destinations from **120°W to 120°E and 75°N to 35°S**
- deployment on **a monthly basis (4 flights)** at cruise altitudes of **8 – 12 km (upper troposphere, lower most stratosphere)**



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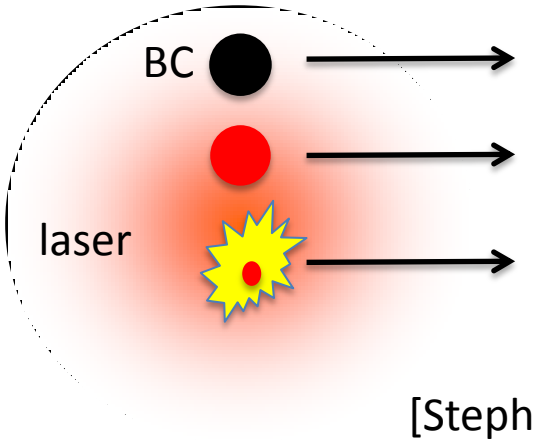
# SP2

- Single Particle Soot Photometer: 10 ng/m3 (**0.3 fg/particle**) BC, ~30 to 50 nm BC



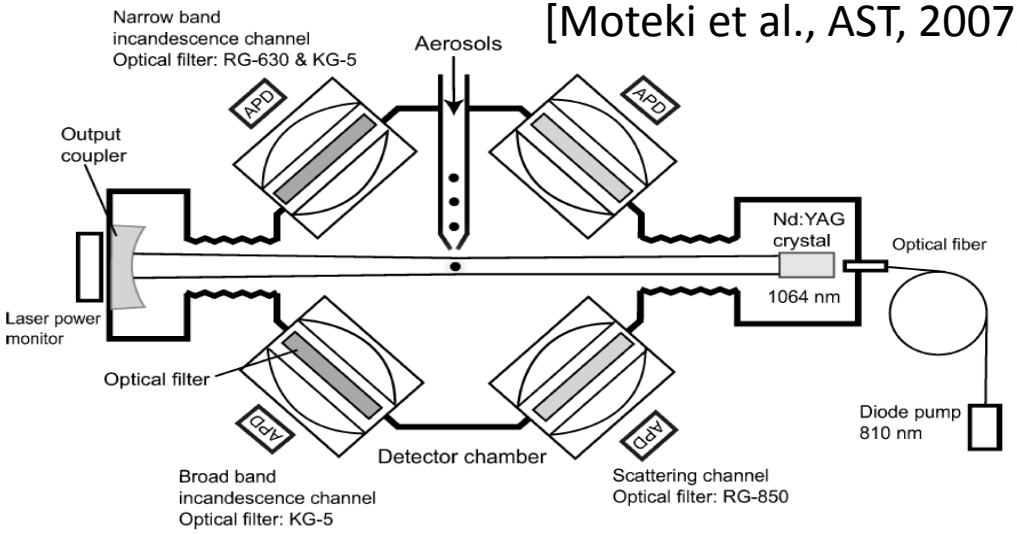

Scatter & absorb light

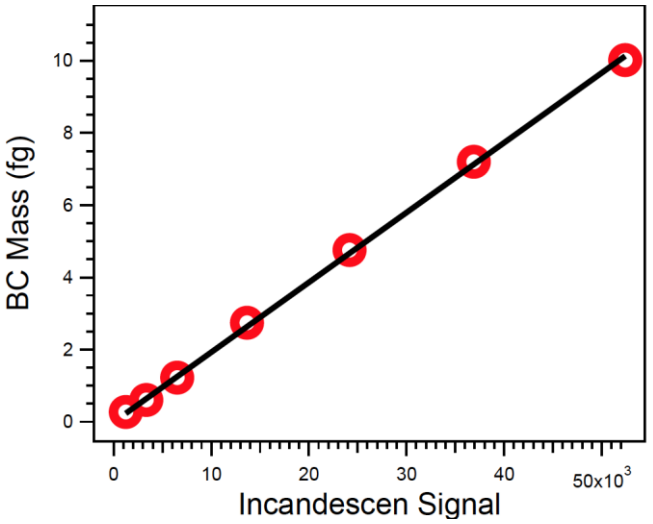
Temperature increases

Incandesce & vaporize

[Stephan et al., Appl. Opt., 2003]

[Moteki et al., AST, 2007]

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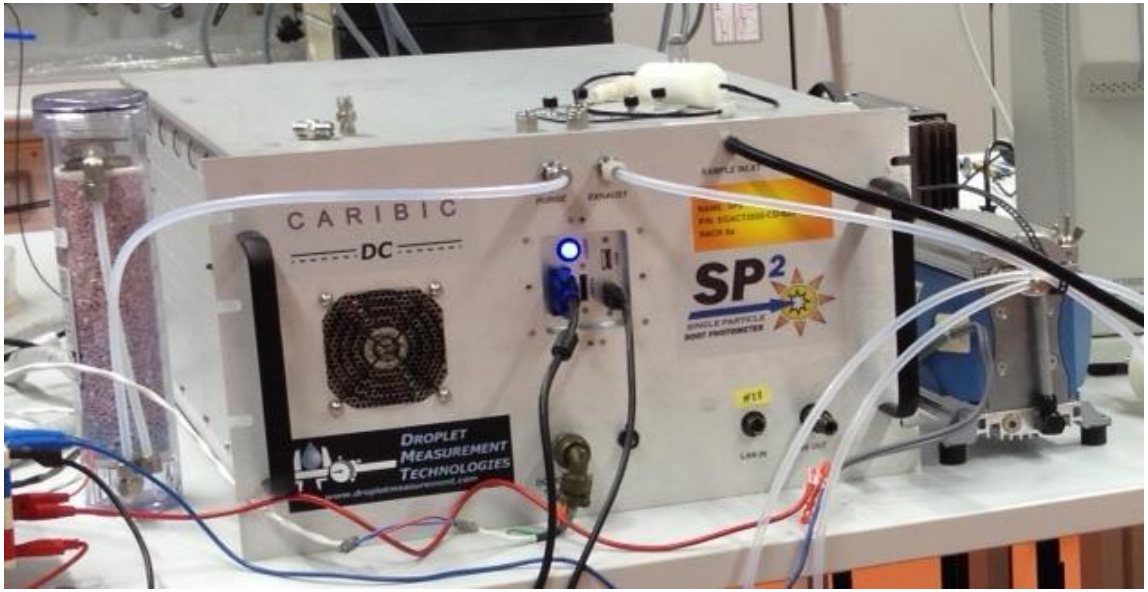
# Modification of SP2

- developed by Stephens et al. 2003 to measure the mass of black carbon and DMT

- smaller dimension
- changed the setup and dimension of the instrument so that all connections are in front
- an additional purge air pump is included in the instrument
- new software interface to operate the SP2 in the CARIBIC container

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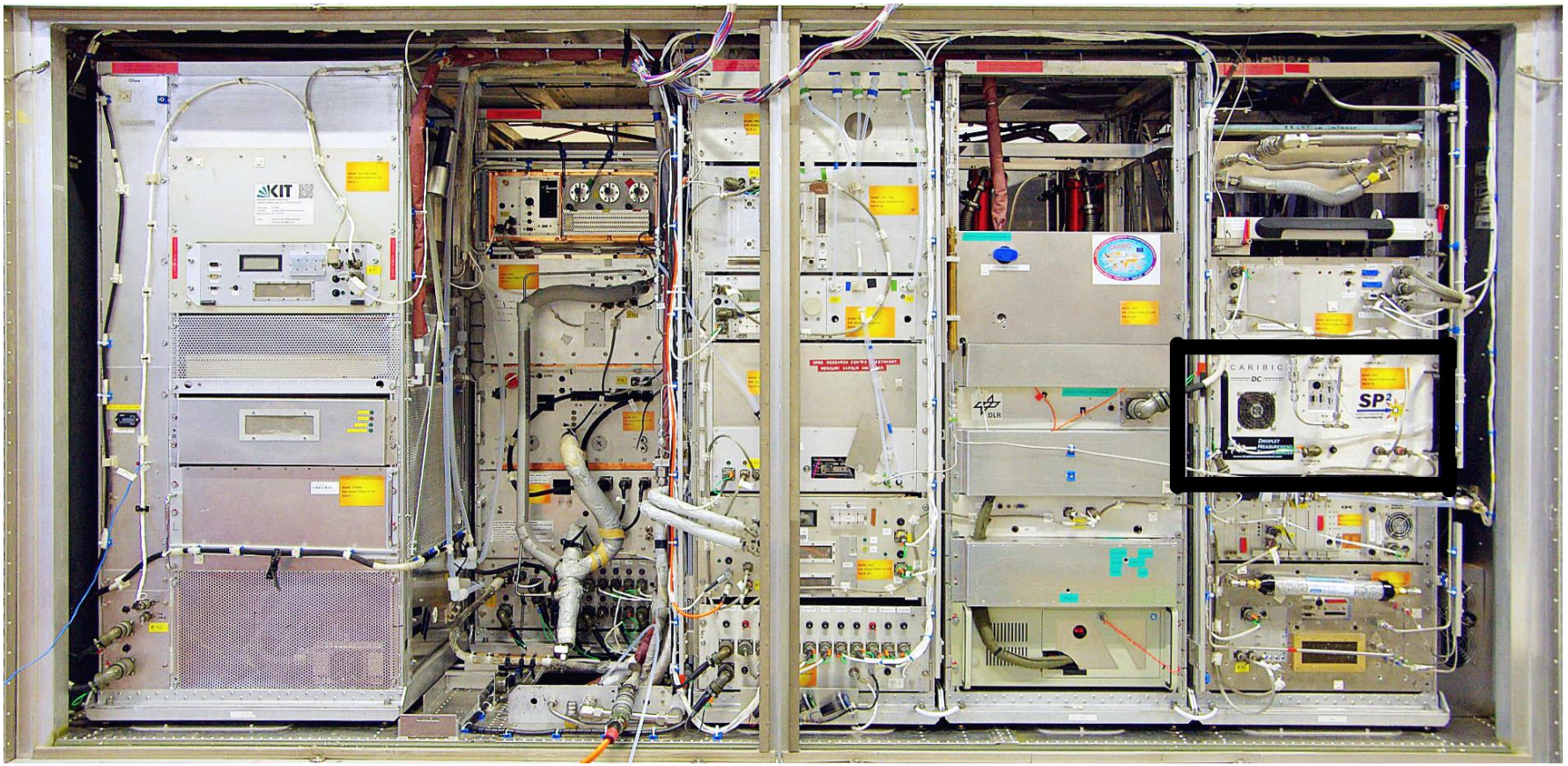
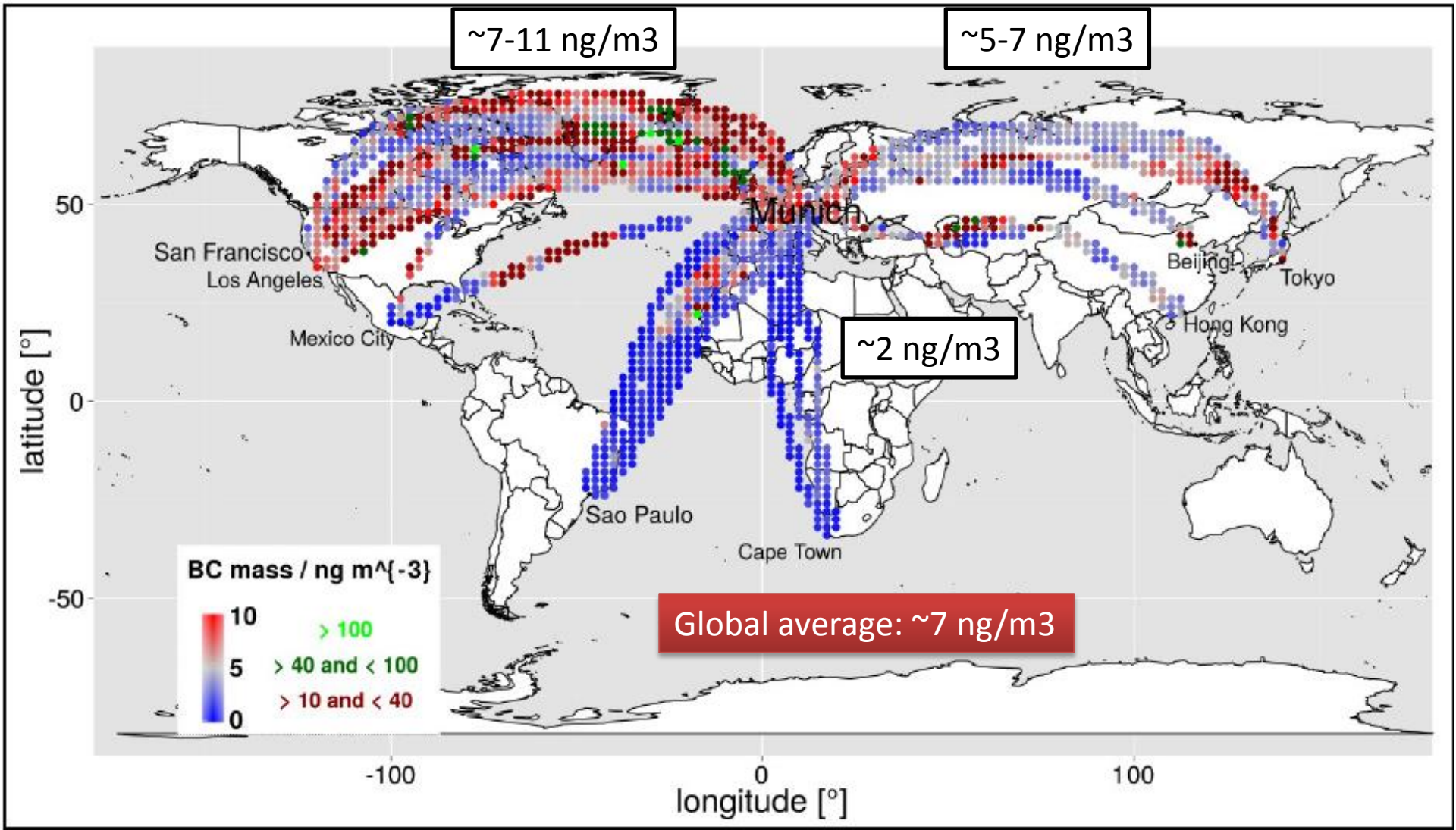
# SP2 in the CARIBIC container




- modified instrument integrated in the CARIBIC container in **July and August 2014**
- sample flow 0.12 L/min
- measurements at pressures below the 670 hPa level

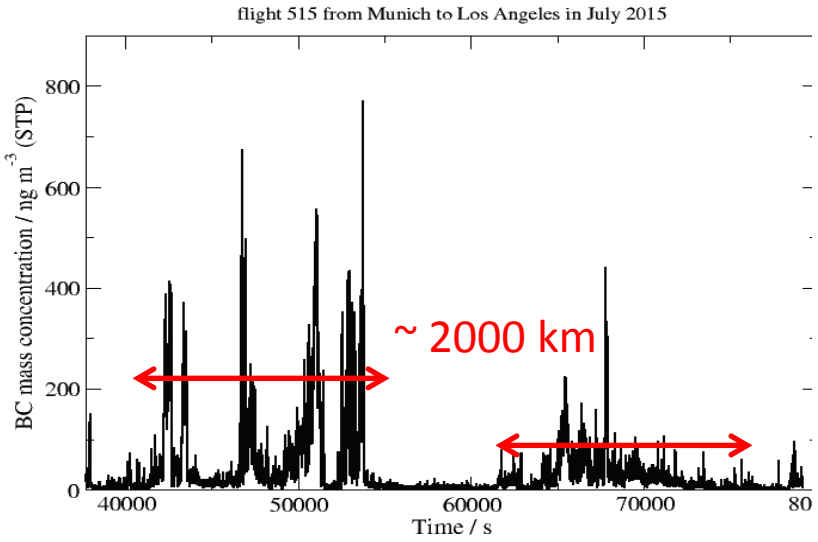
# Black carbon measurements: August 2014 to February 2016

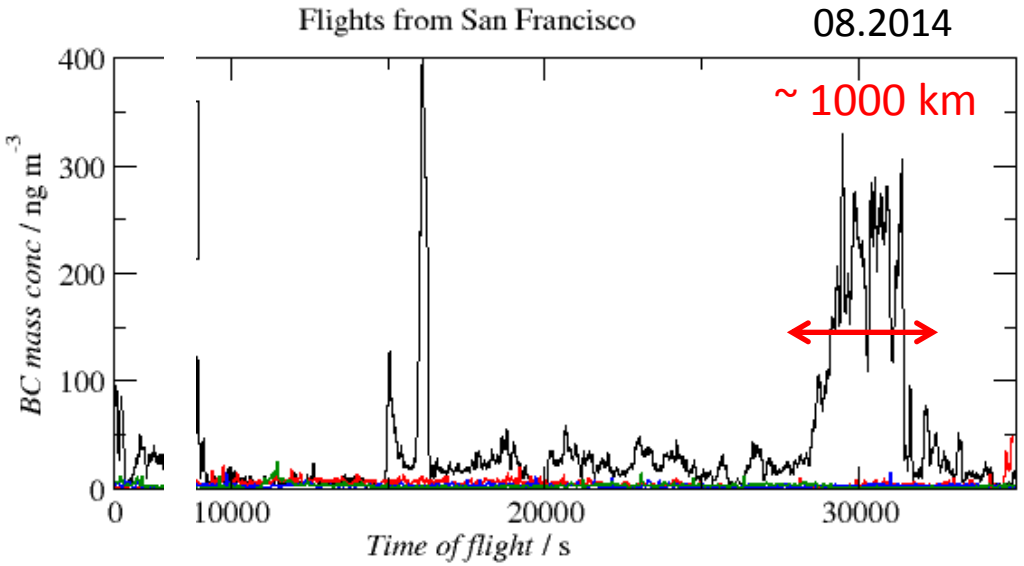
660 measurement hours, with 8 different destinations over four continents

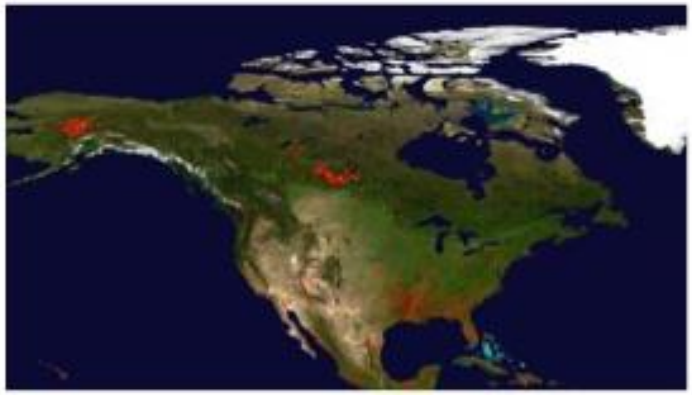


# Biomass burning

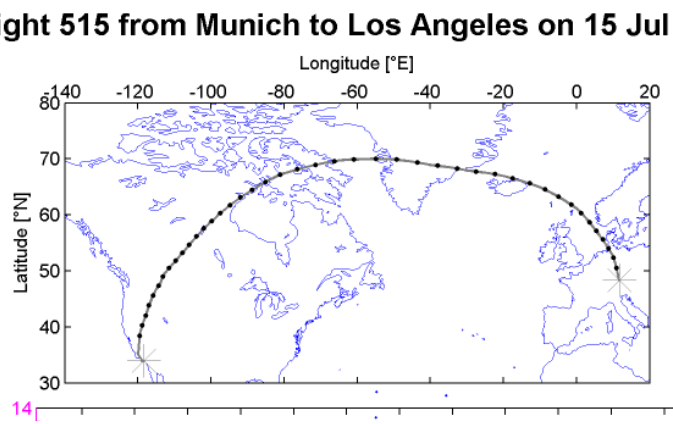
- Up to 800 ng/m3, compared with the ~7 nm/m3 back ground average
- Huge air mass covering for a few hundreds to thousands kilometer



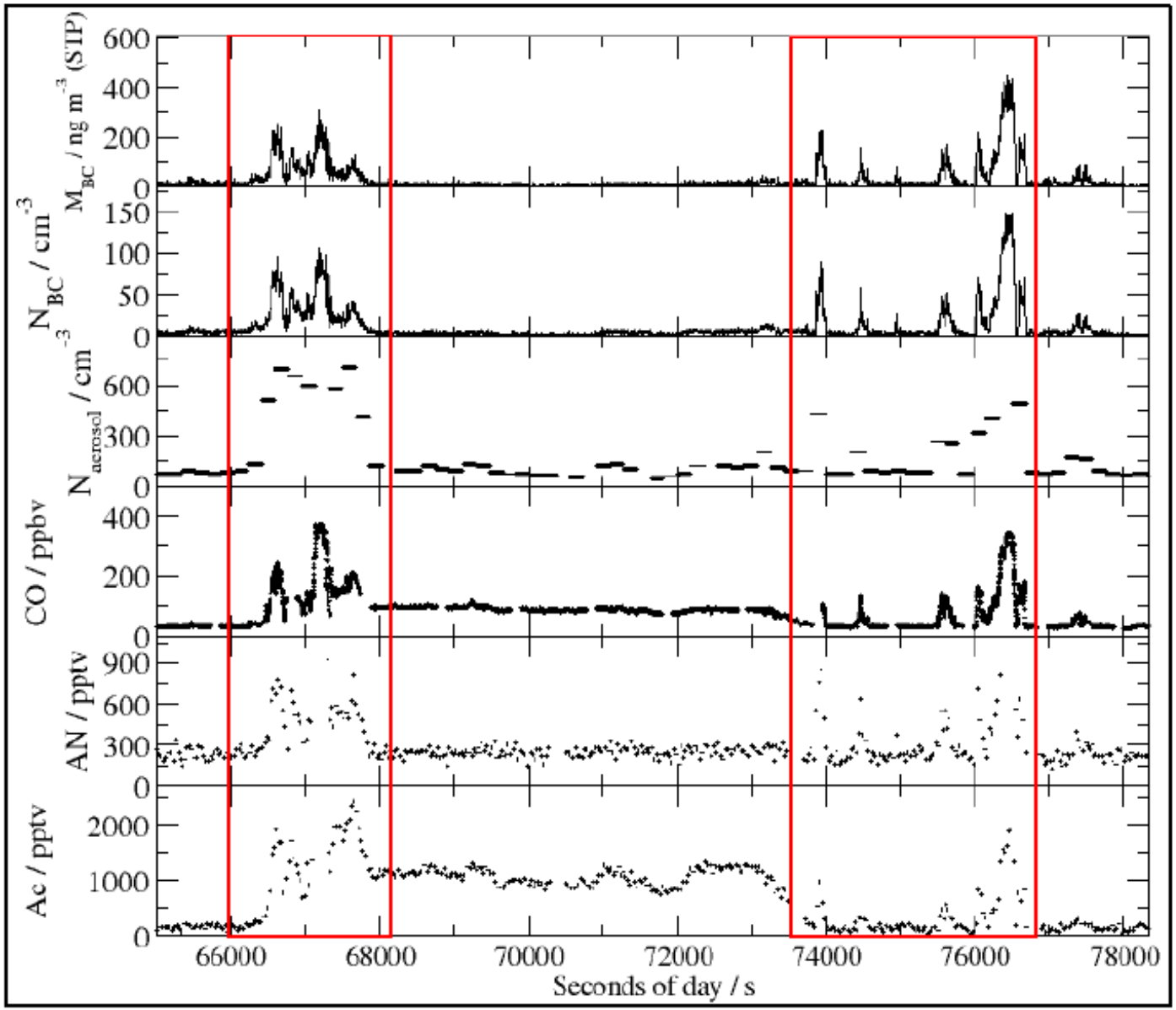



MODIS fire map, North America, 10-19. July 2015



# biomass burning emission

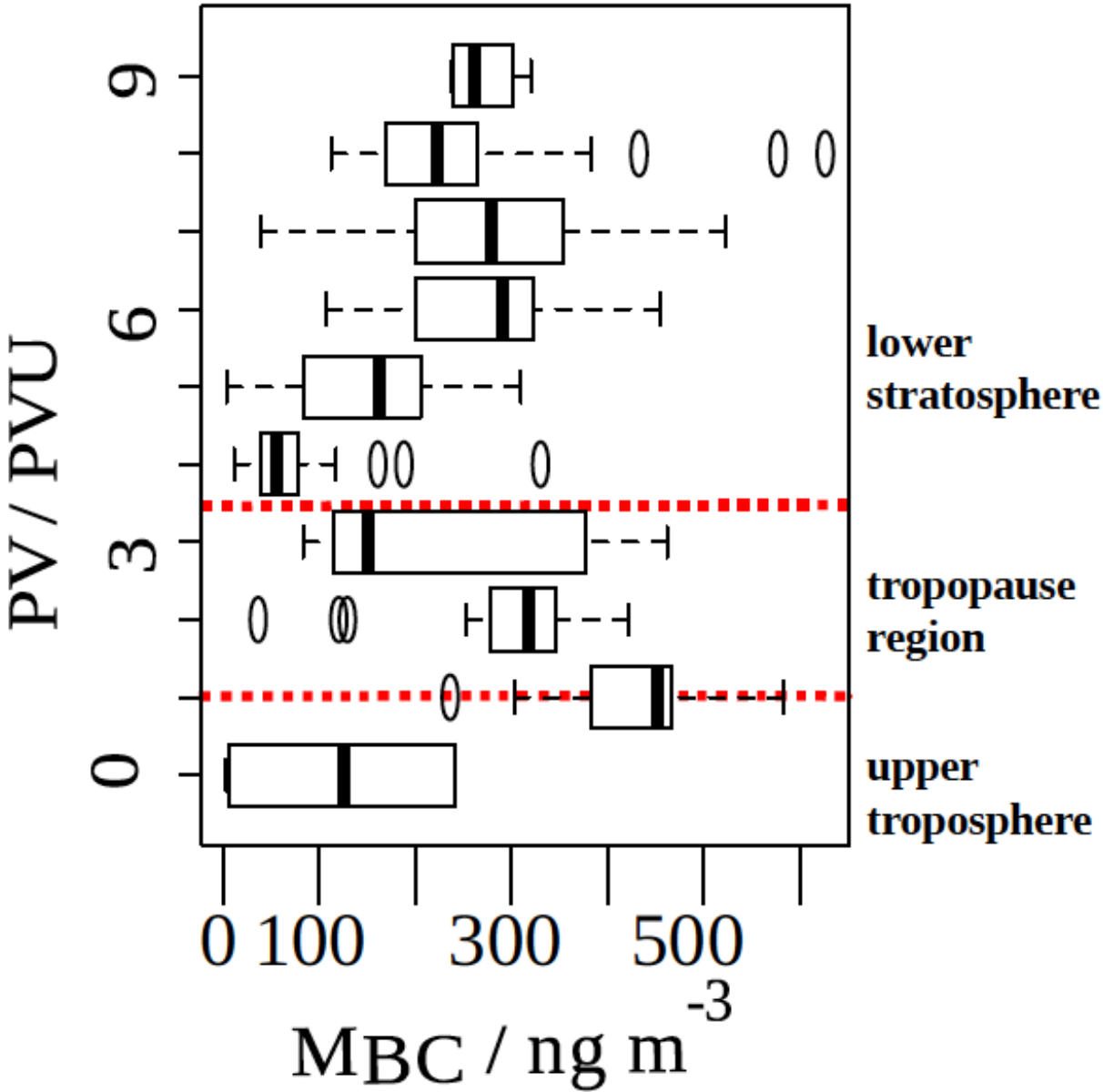



**Biomass burning emission:**

- analyzed by CO, AN and Ac values
- can lead to a **30x higher black carbon mass concentration** compared to background
- **Number concentration** can be **up to 20x higher** than background

→ clear influence on the amount of black carbon in the UTLS

# biomass burning emission



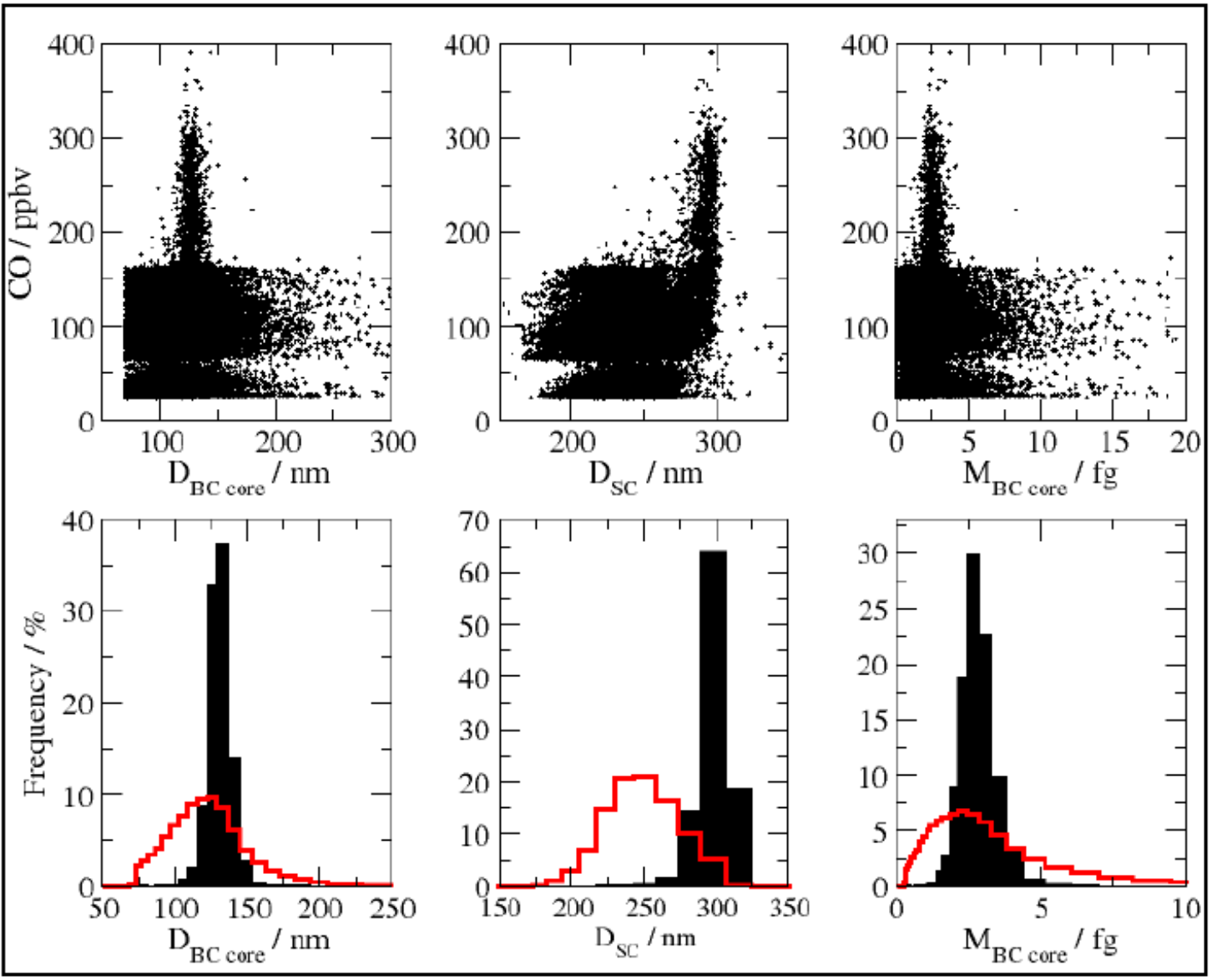

**Vertical distribution of biomass burning black carbon particles:**

- Biomass burning black carbon particles can reach the upper troposphere and lower stratosphere
- even in the lower stratosphere black carbon mass concentration up to 500 ng $m^{-3}$

  → significant for the lifetime of black carbon particles in the atmosphere

  → influence long-range transport, mixing state and scavenging

# biomass burning emission




**Biomass burning plumes:**

- *black carbon particles:*
  low CO:
  size: 70 - 500 nm
  mass: 0.3 – 25 fg
  **high CO**:
  size: 110 - 150 nm
  mass: 2 – 4 fg

- *scattering particles:*
  low CO:
  size: 150 - 310 nm
  **high CO**:
  size: 270 - 310 nm

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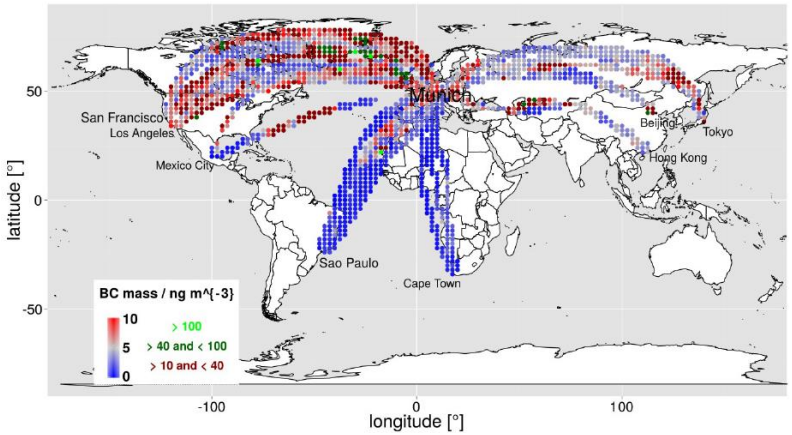
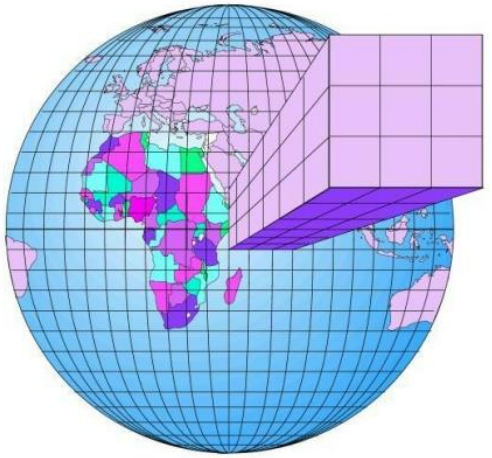
# Outlook



- Global long-term BC mass concentration at UT/LS
  - Mean back ground
  - Extreme events, biomass burning
- BC mixing state

- BC scavenging and transformation
- BC emission
  - Total
  - Biomass burning
  - Aircraft emission
- BC direct radiative forcing
- Influence on the cirrus cloud formation at UT/LS (ice nucleation)
- Deep convection

… …

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DROPLET MEASUREMENT TECHNOLOGIES
OUR INSTRUMENTS ACCURATELY MEASURE CLOUD & AEROSOL PARTICLES

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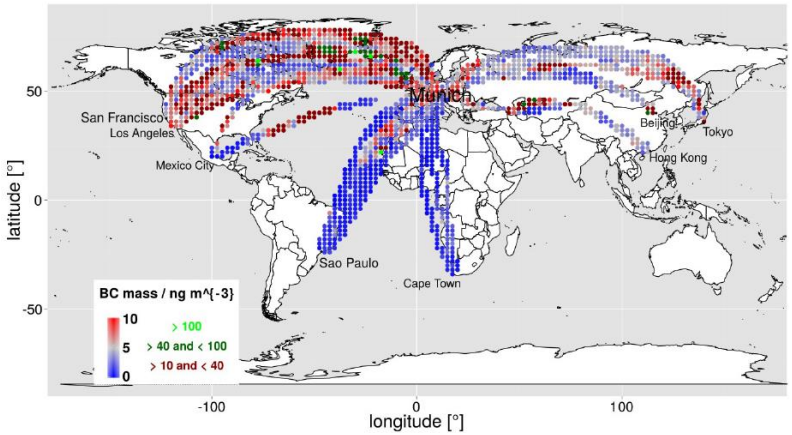
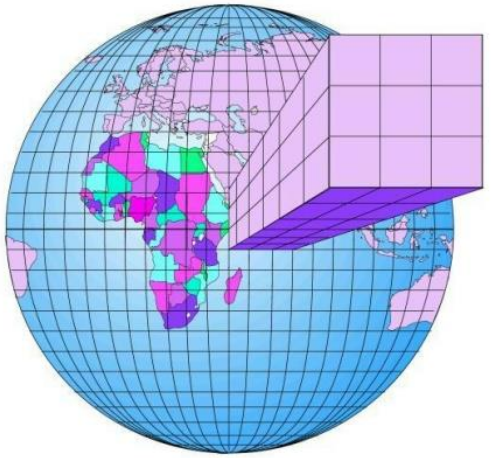
# Outlook



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