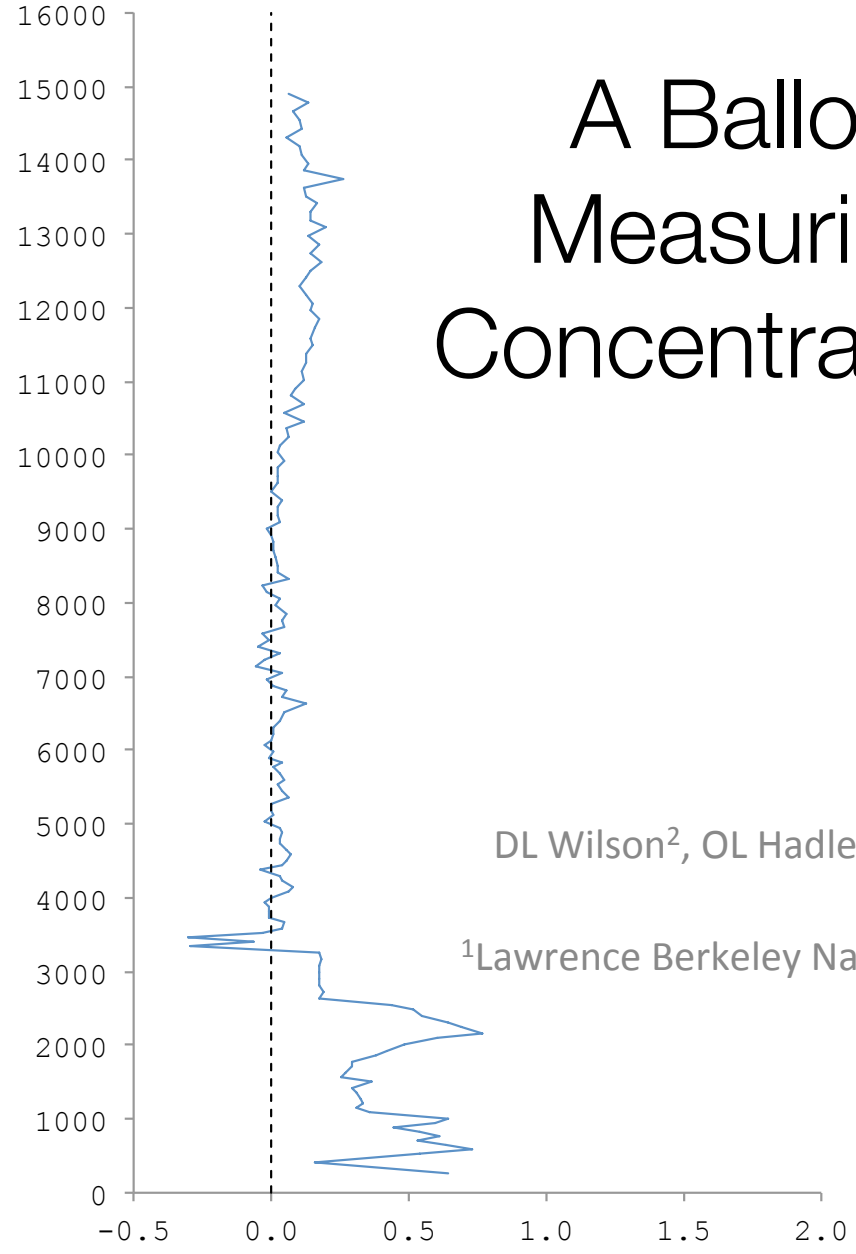

A Balloon-Borne Platform for Measuring Vertically-Resolved Concentrations of Black Carbon in the Troposphere

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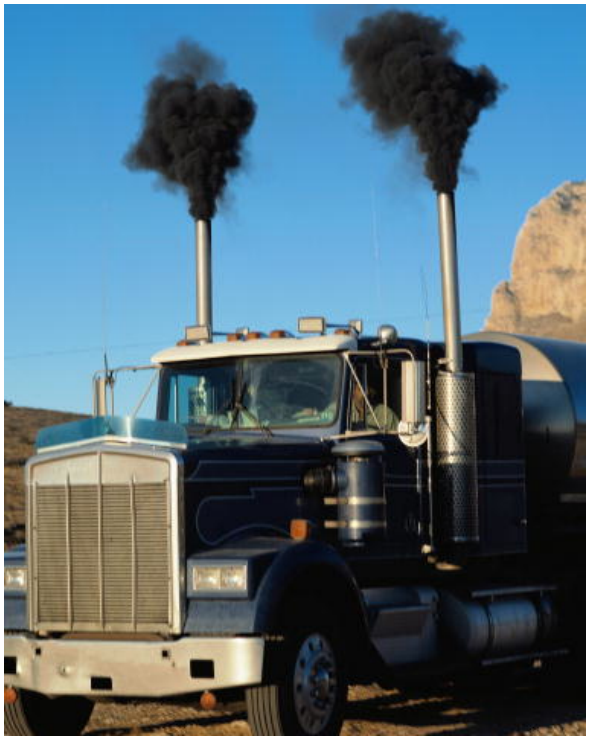
AAAR, 2012 Conference
October 11th, 2012

Black carbon (BC) soot from diesel and biomass combustion negatively impacts health and contributes to climate change.

http://www.cleancookstoves.org/resources/fact-sheets/igniting-change.pdf



http://upload.wikimedia.org/wikipedia/commons/7/79/Diesel-smoke.jpg

TOA forcing from BC estimated 0.9 W/m^2; ~55% of CO_2 forcing (IPPCC and Ramanathan and Carmichael, 2008)

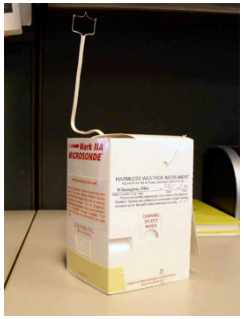
BLACK CARBON

Despite black carbon and other aerosols' importance, there is no routine vertical profiling of aerosols.

- 600,000 radiosondes measuring P, T, and RH are launched worldwide every year. The U.S. NWS launches 75,000 annually.
- 3000-5000 ozonesondes/year worldwide.
- 0 routine aerosol vertical profiles/year.

(1) http://www.ua.nws.noaa.gov/factsheet.htm
(2) Frederick Clowney, President of Intermet Systems (a radiosonde company)

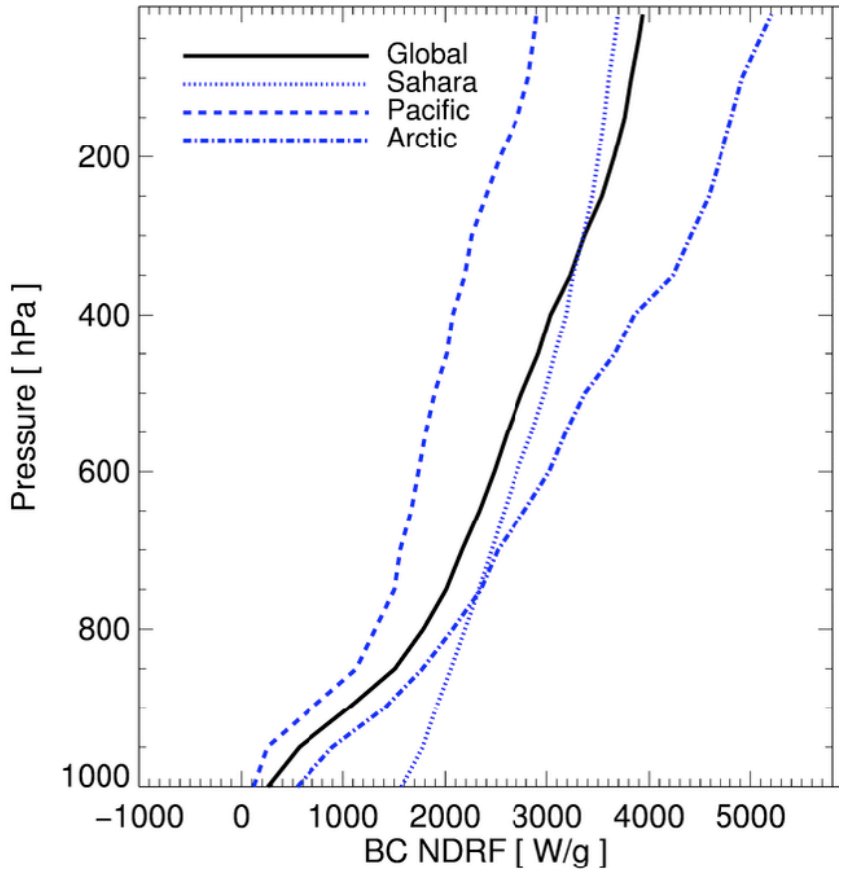
http://www.diel.co.za/images/picture1.png



http://www.ua.nws.noaa.gov/sondes.jpg

Our goal is to develop a technology that will enable routine profiling of tropospheric BC & support campaigns.

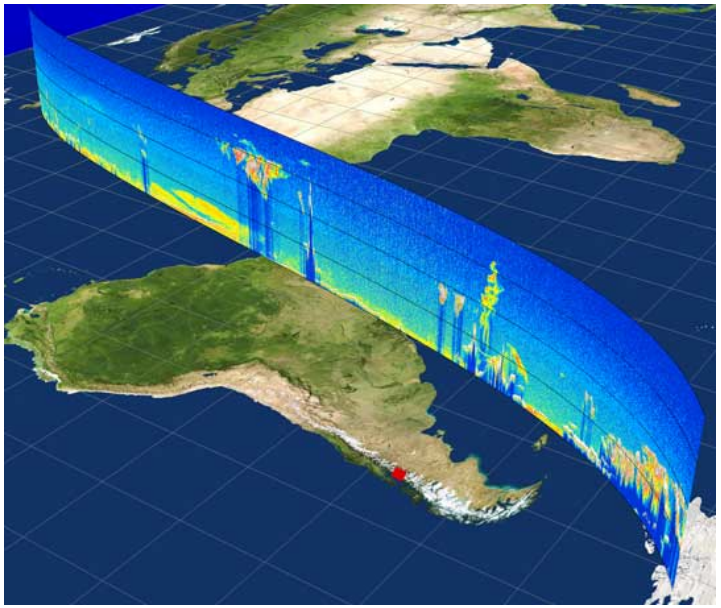
BC direct radiative forcing in Watts per gram of BC increases 10X between ground and upper atmosphere.



Bjørn H. Samset and Gunnar Myhre. "Vertical dependence of black carbon, sulphate and biomass burning aerosol radiative forcing." GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L24802, doi:10.1029/2011GL049697, 2011

BC's impact on climate depends on its position both vertically and with respect to latitude and longitude.

Satellites and large field campaigns measure vertically-resolved aerosols, but satellites carry large uncertainty and field campaigns are expensive and thus rare.



http://earthdata.nasa.gov/featured-stories/featured-research/experiment-sky

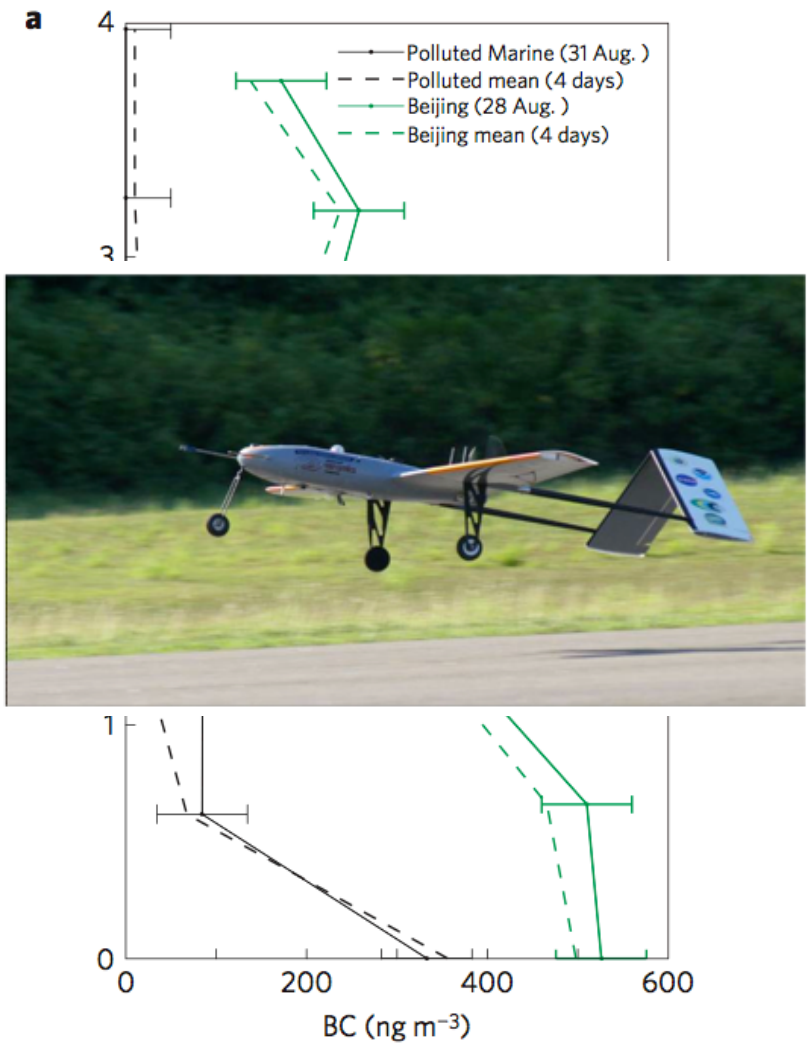
Atmospheric aerosols following a volcanic eruption as measured by CALIOP satellite.

Air quality measurement campaign.

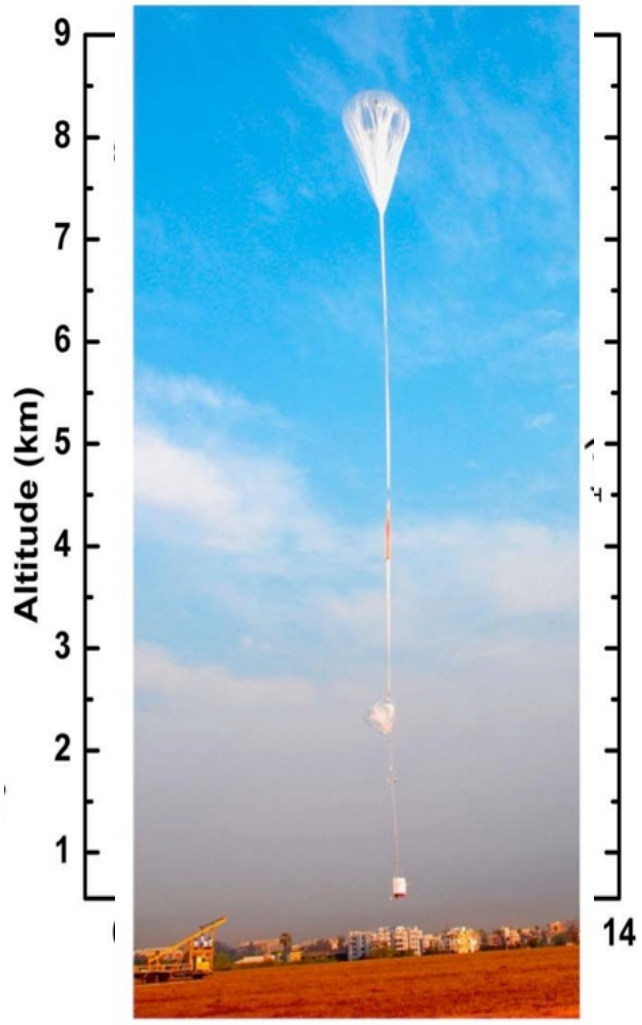
A low-cost and massively-deployable measurement platform will vastly increase amount of data to understand aerosol air-quality and climate impacts.

TRADITIONAL PROFILING

Others have measured BC profiles, but never at low costs or with technologies scalable to 10^5 profiles/year



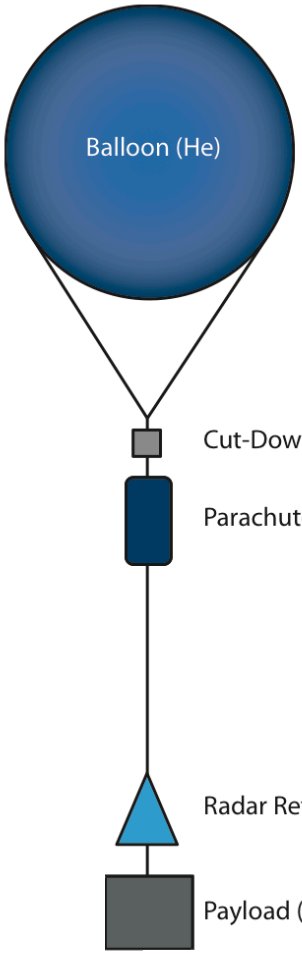
M. V. Ramana et. al. Warming influenced by the ratio of black carbon to sulphate and the black-carbon source. Nature Geoscience 3, 542 - 545 (2010)



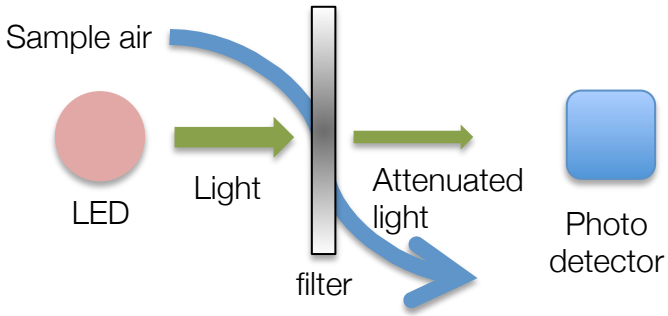
Babu, S. S. et al. Free tropospheric black carbon aerosol measurements using high altitude balloon: Do BC layers build 'their own homes' up in the atmosphere? Geophys. Res. Lett. 38, L08803 (2011).

ATMOSPHERIC HEATING

Berkeley and Aeth Labs have developed a light-weight system that can be carried by a balloon.



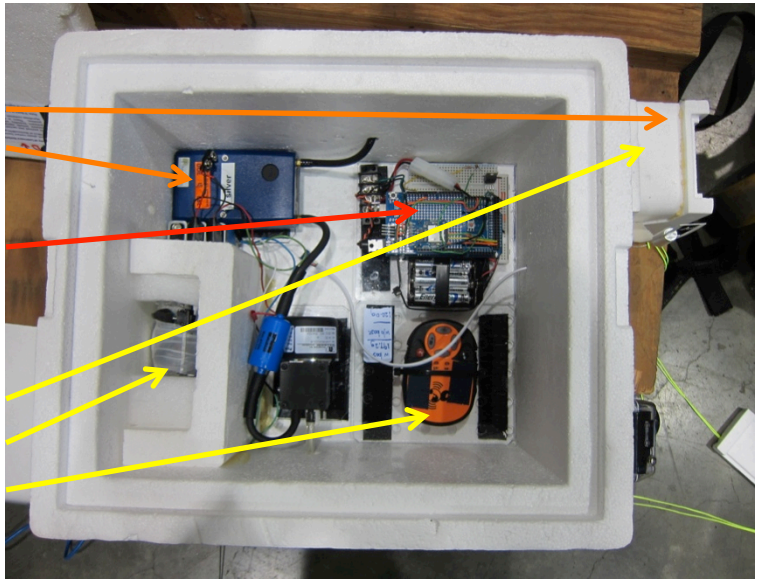
Aethalometer principle



Sensors:
Radiosonde (P, T, RH)
Modified Micro Aeth (BC)

Flight Computer and DAQ

Tracking systems:
400MHz radio
APRS radio
Iridium GPS

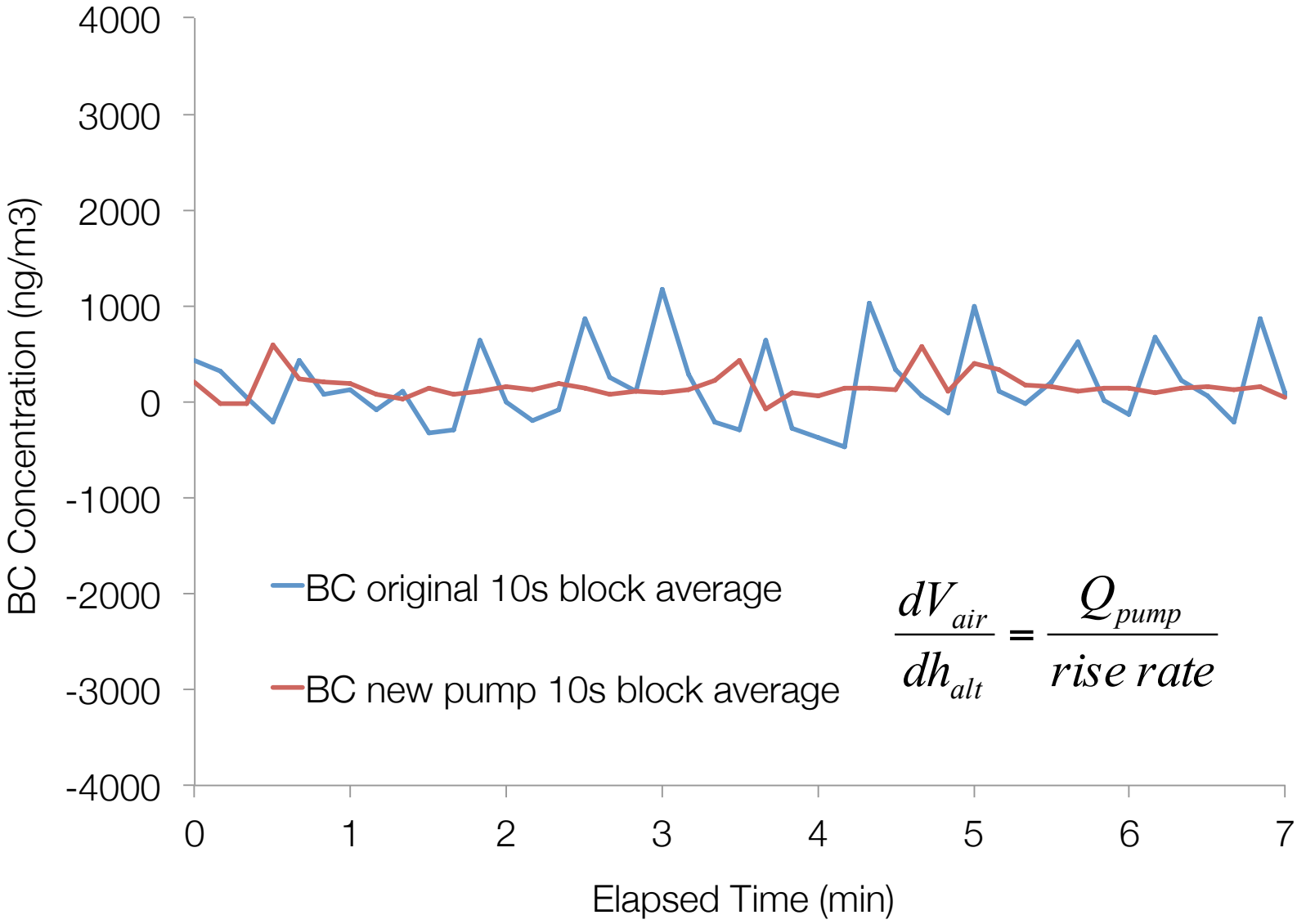


MEASURING BC

Sources of potential aethalometer measurement artifacts include:

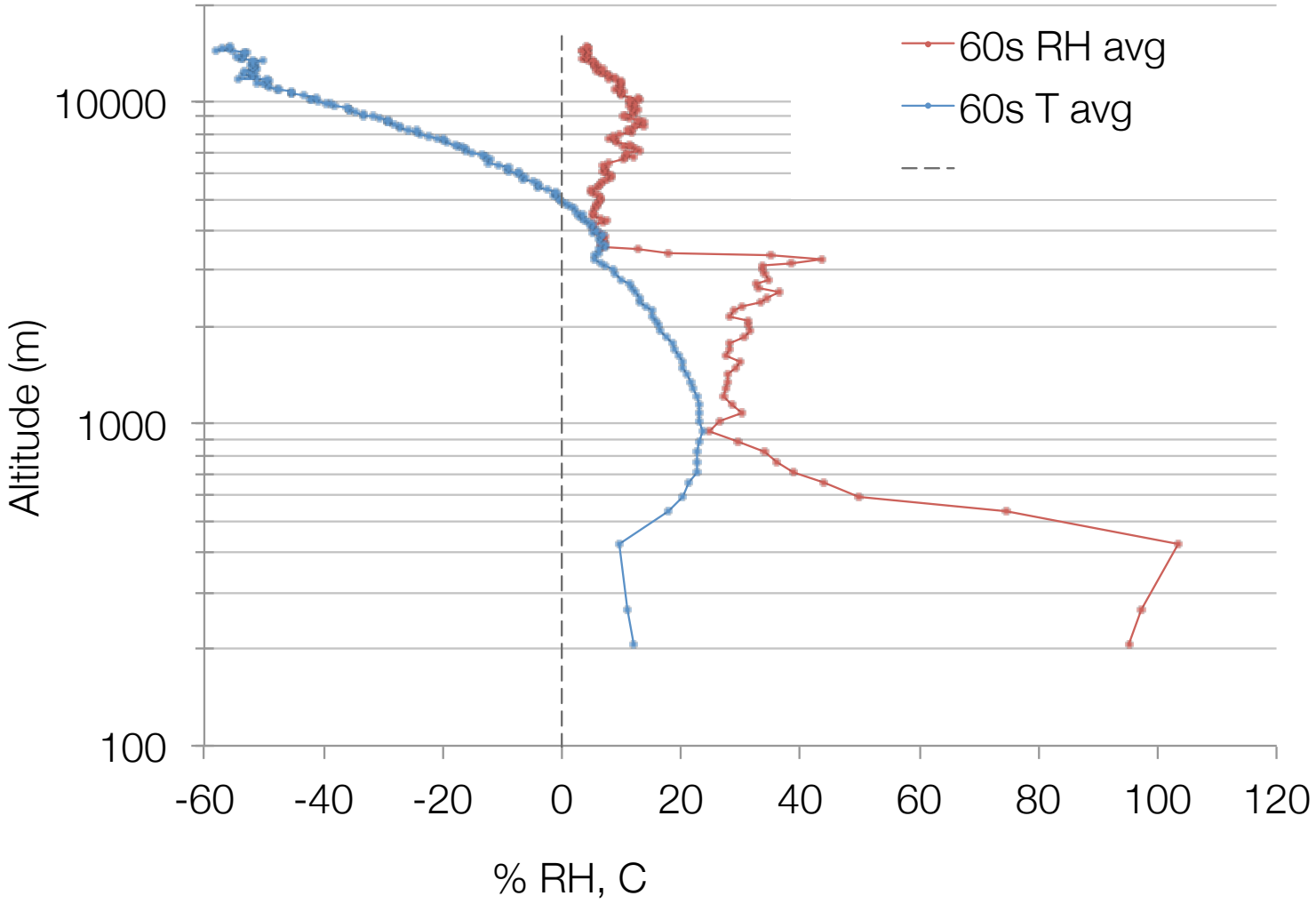
- 1st and 2nd order RH changes (under study)
- Filter material (coupled with RH, under study)
- Filter face velocity (coupled with RH, under study)
- Temperature changes
- Particle loading effects – parameterized by others
- Particle scattering effects – parameterized by others
- Loading of hydroscopic aerosols (coupled with RH)
- Vibration and shock

Higher flow rate and new firmware decreases sensitivity to motion and vibration



AETH MODIFICATIONS

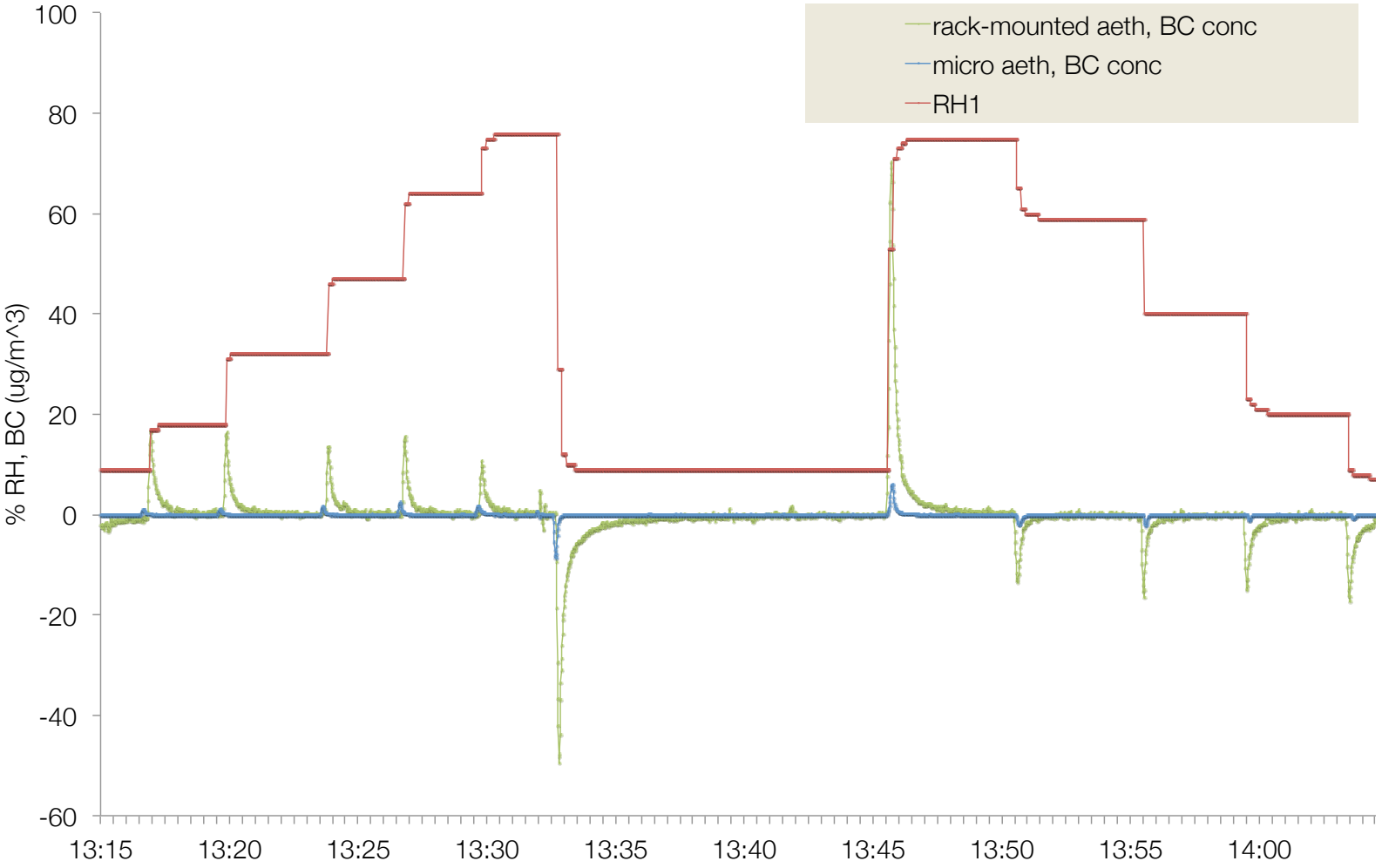
We have observed inversion layers and other phenomenon leading to rapid change in RH



We must consider changing RH's impact on BC signal.

AETH ARTIFACTS

Aethalometer's response to RH changes is due to sorption/desorption of H2O, dependent on filter hydrophobicity and face velocity

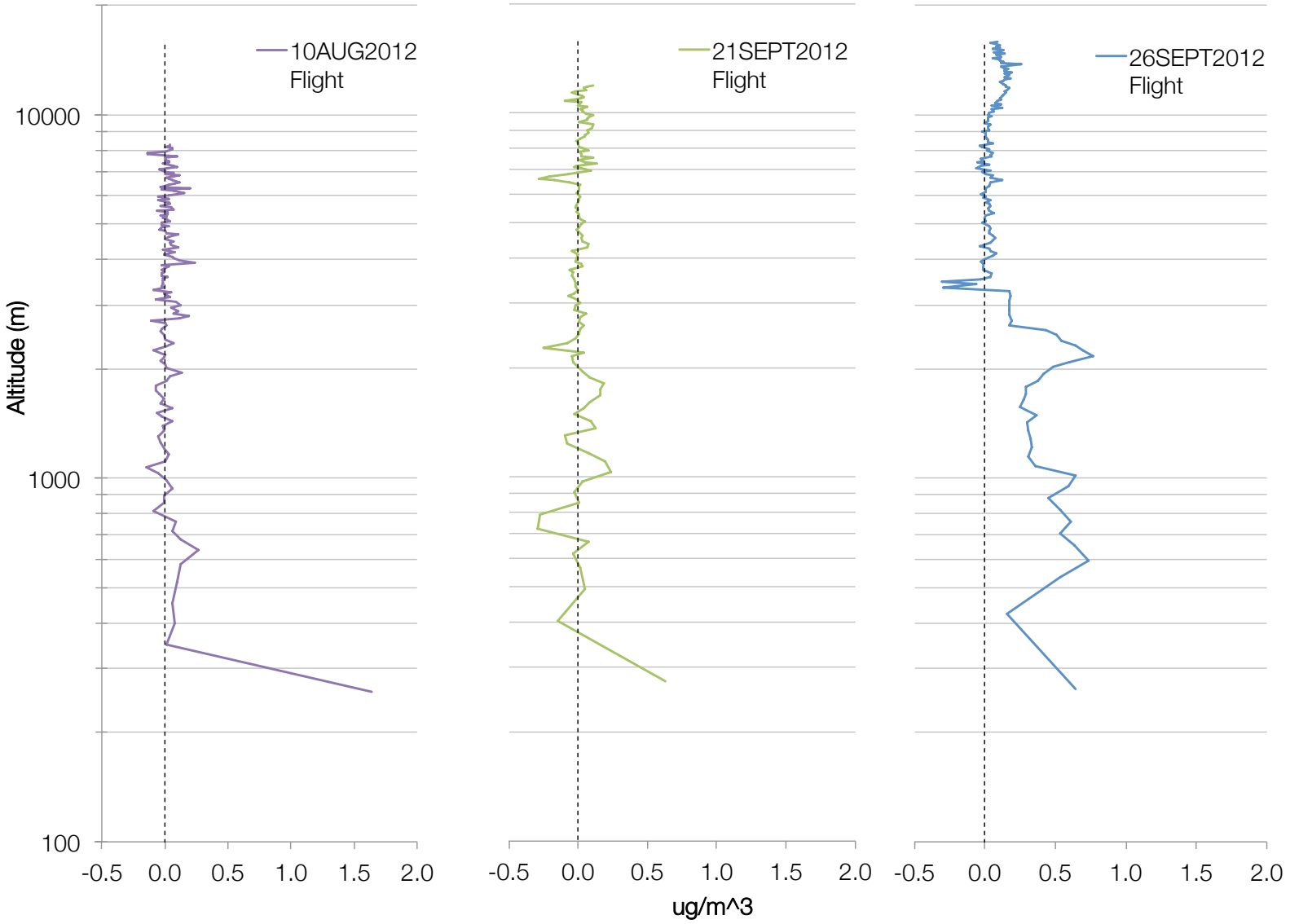


RH AND BC

After significant testing, we have launched three payloads containing the aethalometer.

LAUNCH VIDEO

We have obtained three vertical profiles of black carbon concentration.



VERTICAL PROFILES

Conclusions:

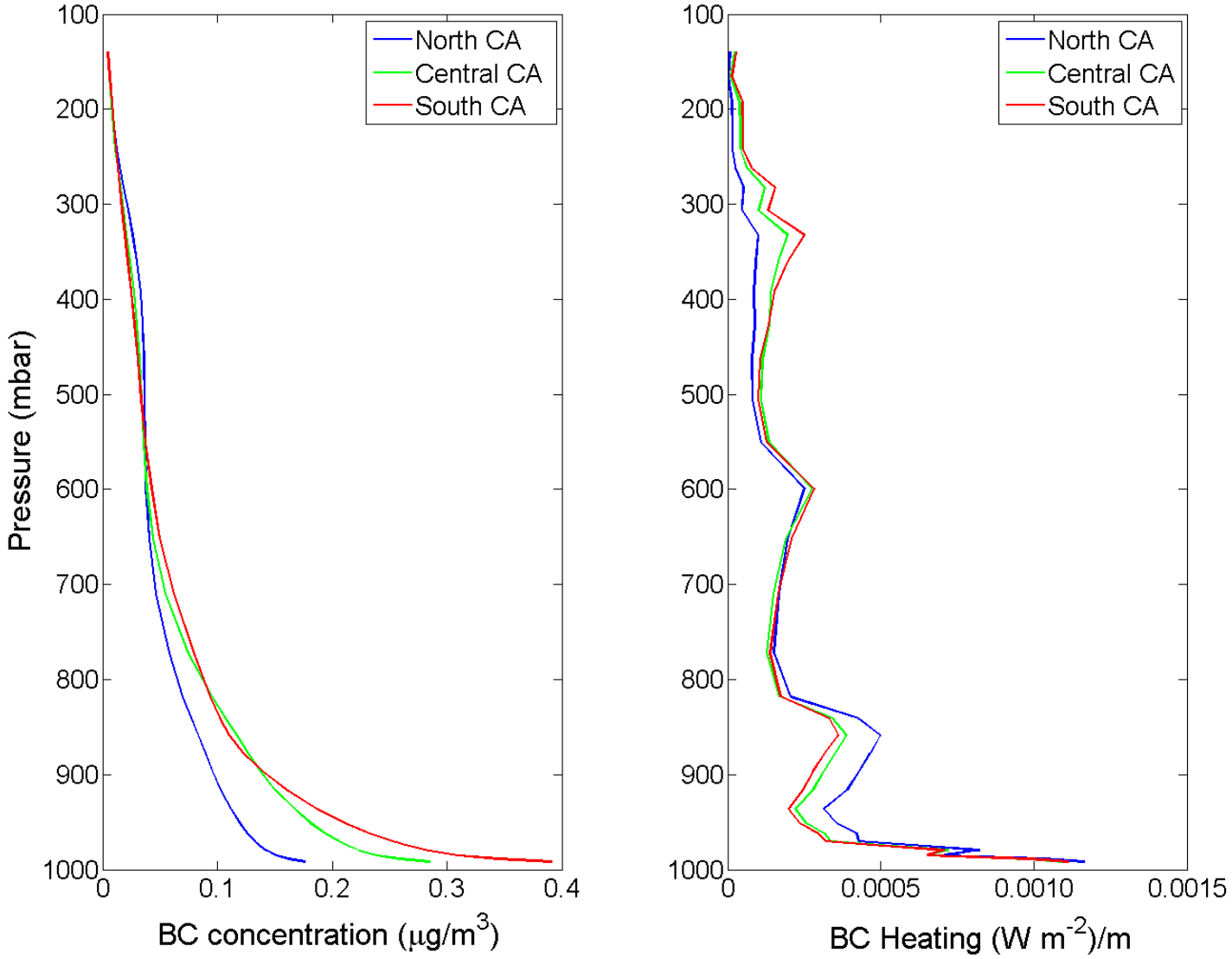
- We have demonstrated that small/lightweight technology exists to make vertical measurements of meteorological parameters and aerosol concentrations without FAA restriction.
- The modified commercial micro-aethalometer has provided reasonable data.

On-going research:

- Continue to examine BC sampling artifacts
- Continue modifying aethalometer design to increase signal/noise and lower cost, each by an order of magnitude
- Measure vertical profiles throughout California and elsewhere to demonstrate value of project

EXTRA SLIDES

Spatial considerations are important when considering the global impact of BC.



Hadley et. al. WRF-Chem model of BC forcing (in prep)

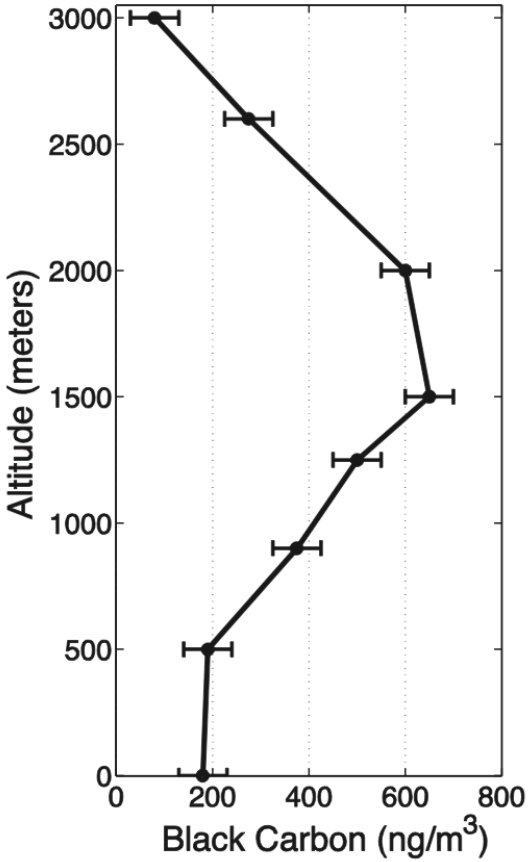
ATMOSPHERIC HEATING

In order to get quality BC data at a given altitude, we need to rise as slow as possible and draw as much air as possible.

$$\frac{dV_{air}}{dh_{alt}} = \frac{Q_{pump}}{rise\ rate}$$

$$conc = \frac{mass}{Volume}$$

Need to maximize dV/dh
Slow the ascent rate



Capturing vertical profiles of aerosols and black carbon over the Indian Ocean using autonomous unmanned aerial vehicles
C. E. Corrigan, G. C. Roberts, M. V. Ramana, D. Kim, and V. Ramanathan
Atmos. Chem. Phys., 8, 737-747, 2008

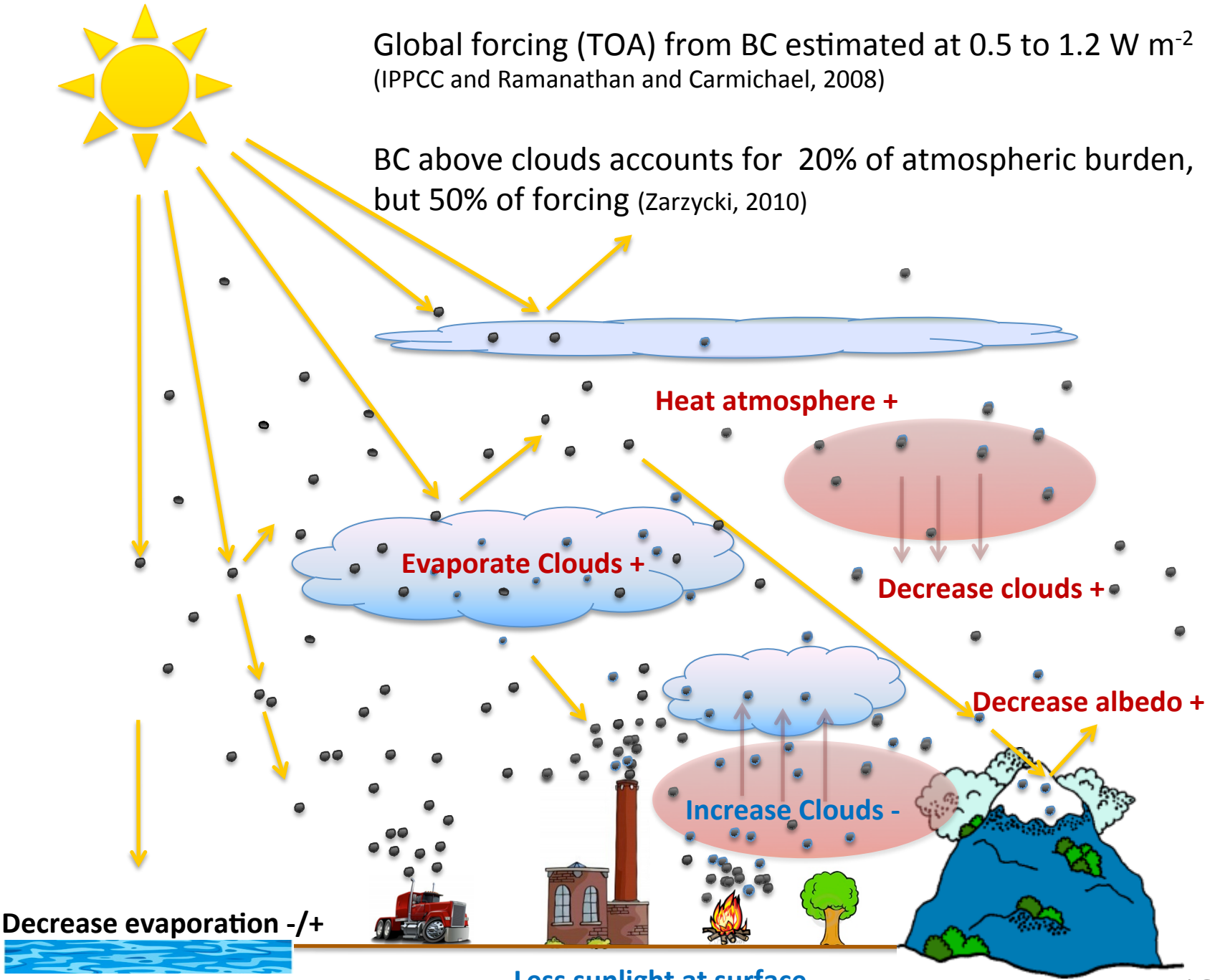
17

- Slow ascent rate maximizes the signal : noise
  - Balloon travels farther in horizontal direction
  - Balloon may reach neutral buoyancy before reaching target altitude
    - Could float to Africa
  - Need to install a cut-down device that activates
    - When payload reaches 12km, or
    - After 3 hours of flight time
  - Have tested cut-down device 9 times
    - Five and a half successes, with last 4 flights flawless
    - Failures informed troubleshooting and prevention procedures

CUT-DOWN

Global forcing (TOA) from BC estimated at 0.5 to 1.2 W m^{-2}
(IPPCC and Ramanathan and Carmichael, 2008)

BC above clouds accounts for 20% of atmospheric burden, but 50% of forcing (Zarzycki, 2010)



WARMING OR COOLING?

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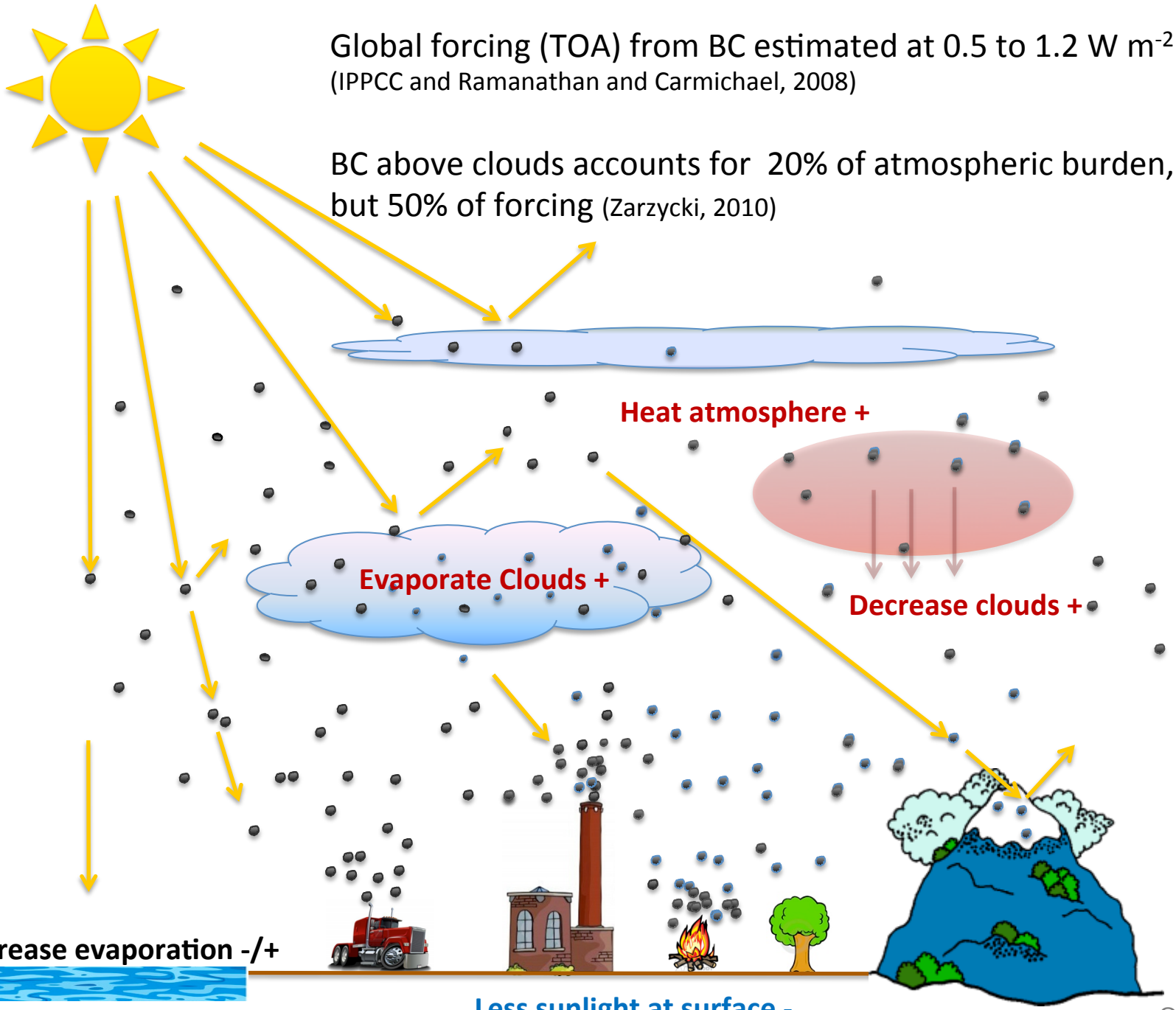
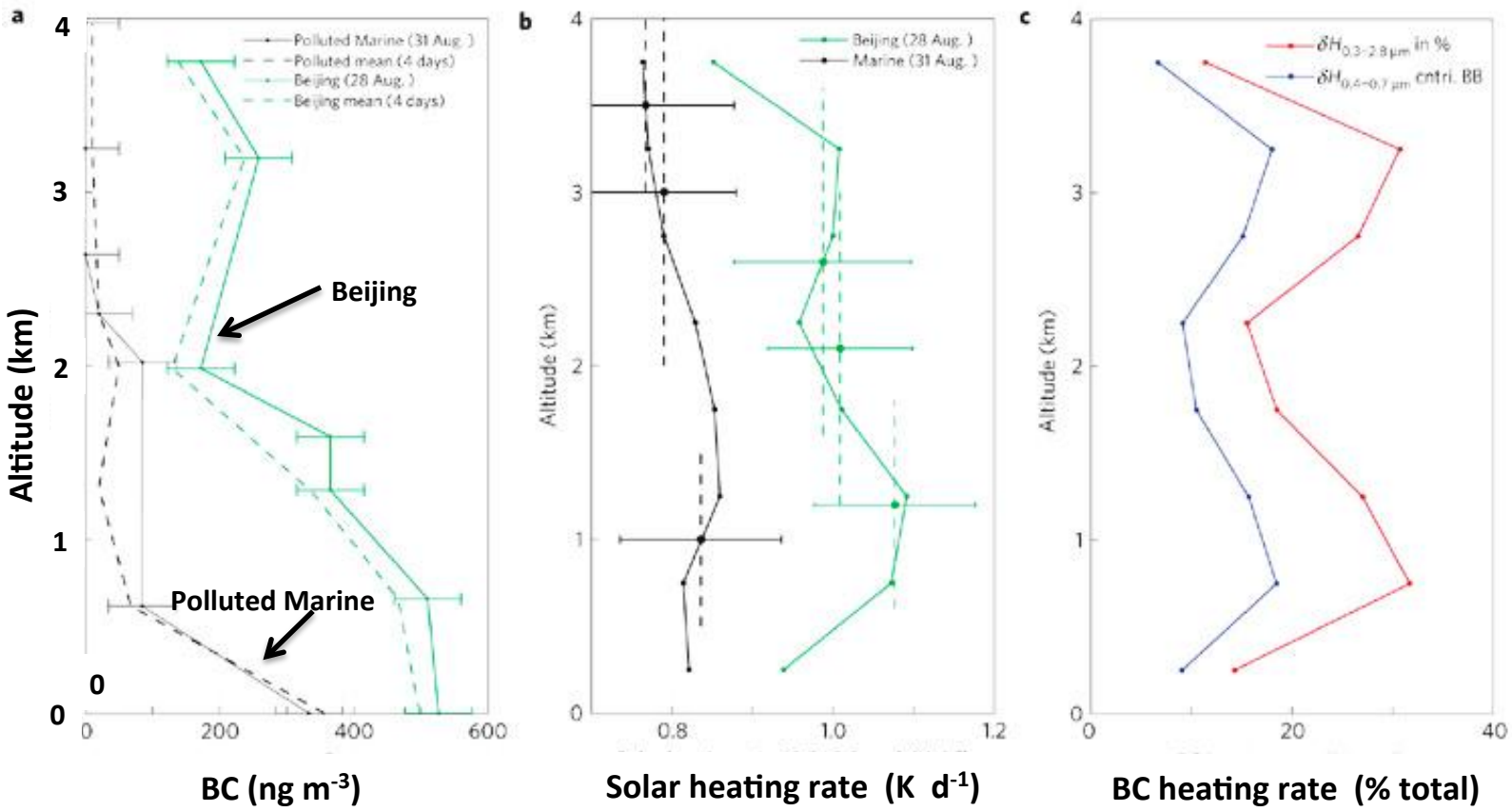


WARMING OR COOLING?

In-situ data from UAVs show climate-relevant concentrations of BC in the troposphere.



M. V. Ramana, V. Ramanathan, Y. Feng, S-C. Yoon, S-W. Kim, G. R. Carmichael & J. J. Schauer. "Warming influenced by the ratio of black carbon to sulphate and the black-carbon source." Nature Geoscience 3, 542 - 545 (2010) Published online: 25 July 2010 doi:10.1038/ngeo918

BC is more effective at heating the higher it is in the atmosphere

VERTICAL PROFILES OF BC