In situ measurements of the mixing state and light-scattering properties of black carbon in the troposphere and lower stratosphere

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Overview

- A single-particle soot photometer (SP2) was flown six times in January/Feburary, 2006 from San Jose, Costa Rica, onboard the NASA WB-57F aircraft. Air was sampled between the Equator and 11 degrees North latitude from the lower tropospere to the lower stratosphere.
- A simple algorithm has been developed to identify the mixing state of individual black carbon (BC) particles processed by the SP2.
- Measurements of light-scattering off of individual BC before they are perturbed by the laser have been interpreted in a Mie theory shell-and-core framework. The equivalent coating thicknesses of internally mixtures, as well as their associated absorption enhancement have been calcluated.

These results represent first steps down a new path towards more complete understanding of the role of BC, and internal mixing of BC, in global climate change.

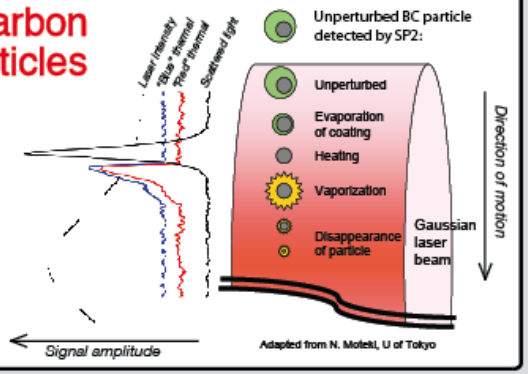
Characterizing black carbon particles

Mixing state

Individual BC particles are identified as internally mixed if there is clear evidence for the scattering size of the particle decreasing as it penetrates into the laser.

Optical size

The scattered light information aquired before the particles experience more than 5% of the full intensity of the laser, is used to optically size the unperturbed particle.



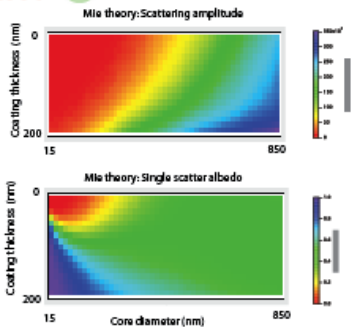
Mie theory: shell-and-core model

Spherical core -- diameter specified by a density of 2 g/cc and detected refractory mass. Calculations made for complex indices of refraction from (1.8, 0.8)-(2, 0)
Concentric spherical coating -- with indices of refraction from 1.4-1.6.
Wavelength of 1064 nm (laser) and limited calculations at 550 nm

Calculated quantities:

- *Theoretical optical size* -- as detected by the SP2
- *Absorption enhancement* of BC core due to coating
- *Single-scattering albedo*

Coating thickness is determined by matching the experimentally determined optical size of the particle with the Mie theoretical optical size.

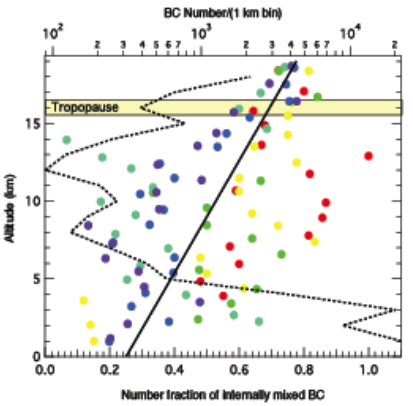


Black carbon mixing state

- The number fraction of internally mixed BC is extrapolated from our measurements over the range of BC core diameter of 100-250 nm.
- Colored points represent individual flight averages of internally mixed fraction over 1 km vertical bins.
- The solid black line is a linear fit to 1 km averages over all flights.
- The dashed line represents the total number of BC measured in each 1 km interval (top axis).

Primary Result

- The number fraction of internally mixed BC tends to increase with altitude.
- At least 70% of BC in the UT/LS is internally mixed
- At lower altitudes, but extending well into the troposphere, the mixing state of BC is strongly dependent on the source or history of the air parcel.



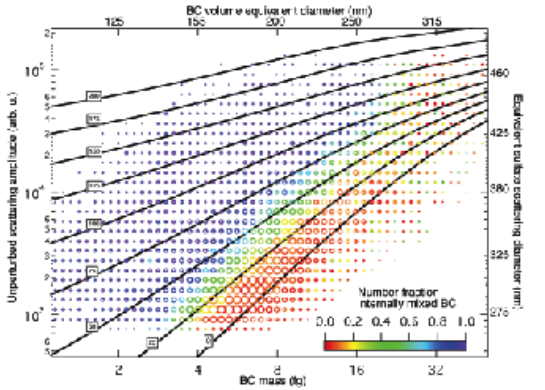
Black carbon optical size

Scattering size of unperturbed BC

- Graph represents ~66,000 BC particles sampled above 1km.
- Grid point size is proportional to BC number.
- Grid point color indicates the number fraction of internally mixed BC observed with associated locus values.
- Black lines represent Mie theory

Primary Result

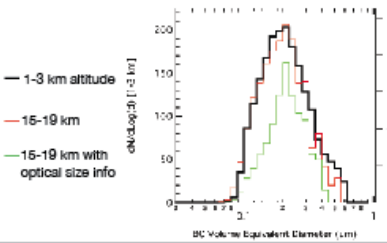
- Mie theory scattering amplitude values are within a factor 2 of measurements off BC assumed to be bare.
- Internally mixed fraction of BC consistant with light-scattering measurements.
- Maximum coating thicknesses of 200nm observed in all air samples.



Enhancement of light absorption by coatings

Mie theory calculations of the absorption enhancement of BC due to coatings are constrained by our measurements for two altitude ranges: 1-3 km and 15-19km. The uncertainty value includes two terms: the uncertainty due to coating index of refraction, and the range due to assumptions about unperturbed BC that are optically too small or large to be sized.

Mass distributions



Primary Result

Altitude	*Average absorption enhancement*
1 - 3 km	1.36 ± 0.1
15-19 km	1.5 ± 0.1

Acknowledgements

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