Black Carbon Emissions Underestimated in the Global South as Revealed by Globally Distributed Measurements

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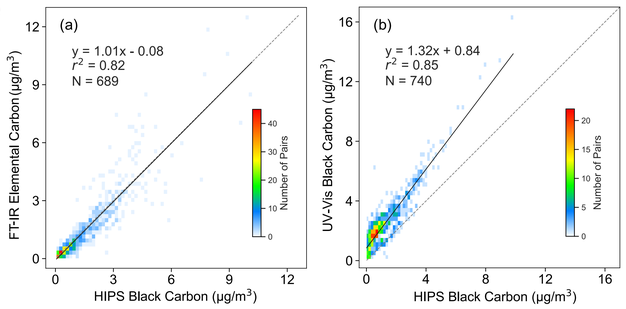
Global characterization of black carbon (BC) is essential but high uncertainty persists in emission inventories and simulations

- BC affects climate forcing (absorbs solar radiation, influences cloud processes, reduces snow albedo after deposition) and human health (cardiovascular and respiratory morbidity and mortality, cancer).
- Estimates of global anthropogenic BC emissions in bottom-up inventories are highly uncertain due to data paucity, particularly for residential and industrial sectors in developing regions[1].
- Considerable inconsistencies in model-measurement comparisons have been observed in developed regions, while model evaluation in the Global South remains limited.

Surface PARTiculate mAtter Network (SPARTAN) offers long-term consistent BC measurements across globally distributed sites

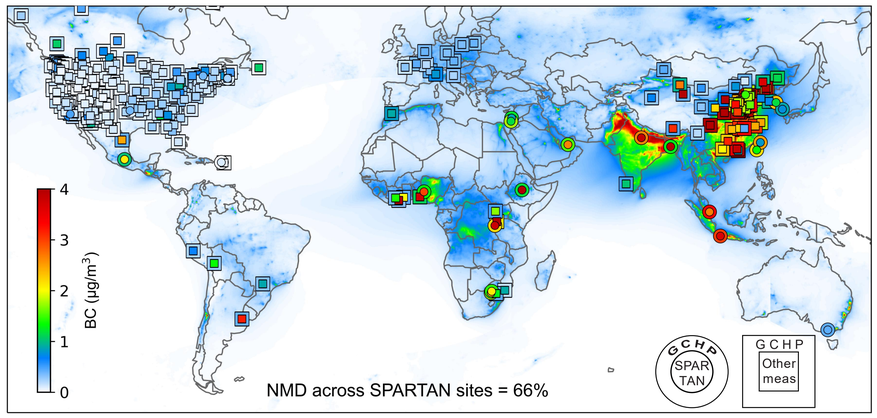
Site	Host Institute	Start Date	Most Recent Sample Date	*N*
Abu Dhabi	Masdar Institute	4/26/2019	8/14/2023	112
Addis Ababa	Addis Ababa University	1/21/2023	8/9/2023	76
Bandung	Institute of Technology Bandung	9/6/2019	7/11/2021	23
Beijing	Tsinghua University	3/24/2020	9/21/2023	128
Bujumbura	University of Burundi	12/9/2022	8/26/2023	14
Dhaka	Dhaka University	8/11/2020	7/16/2023	50
Fajardo	Cabezas de San Juan Nature Reserve	3/18/2021	8/27/2023	39
Haifa	Technion Israel Institute of Technology	2/16/2022	6/17/2023	143
Halifax	Dalhousie University	6/14/2019	3/14/2023	110
Ilorin	Ilorin University	7/13/2019	12/1/2021	37
Johannesburg	University of Johannesburg	4/7/2022	9/2/2023	137
Kanpur	Indian Institute of Technology Kanpur	7/14/2021	5/24/2022	14
Kaohsiung	Kaohsiung Medical University	8/20/2022	8/23/2023	112
Melbourne	University of Melbourne	8/9/2022	9/2/2023	32
Mexico City	Universidad Nacional Autónoma de México	2/26/2021	5/7/2023	49
Norman	University of Oklahoma	6/8/2023	8/11/2023	3
Pasadena	Jet Propulsion Laboratory	11/9/2021	9/13/2023	216
Pretoria	Council for Scientific and Industrial Research	10/22/2020	9/4/2023	199
Rehovot	Weizmann Institute	12/15/2019	4/28/2023	171
Seoul	Yonsei University	9/11/2020	7/1/2023	60
Sherbrooke	Sherbrooke University	8/29/2019	4/27/2023	64
Singapore	National University of Singapore	8/23/2019	12/17/2019	12
Taipei	National Taiwan University	1/27/2022	9/1/2023	176
Ulsan	Ulsan National Institute of Science and Technology	10/28/2021	10/3/2023	67

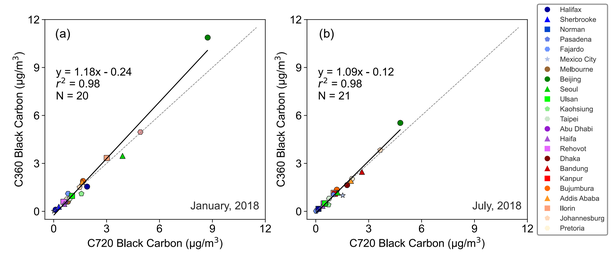
- Hybrid Integrating Plate/Sphere (HIPS)[2] with a mass absorption cross section (MAC) of 10 m^2/g at 633 nm
- Fourier Transform Infrared Spectroscopy (FT-IR)[3]
- UV-Visible Spectrophotometer (UV-Vis)[4]
- Fixed and varying MAC values complicate intercomparison of measurements



High-resolution GEOS-Chem modeling capability enables better connections between global emissions and localized point measurements

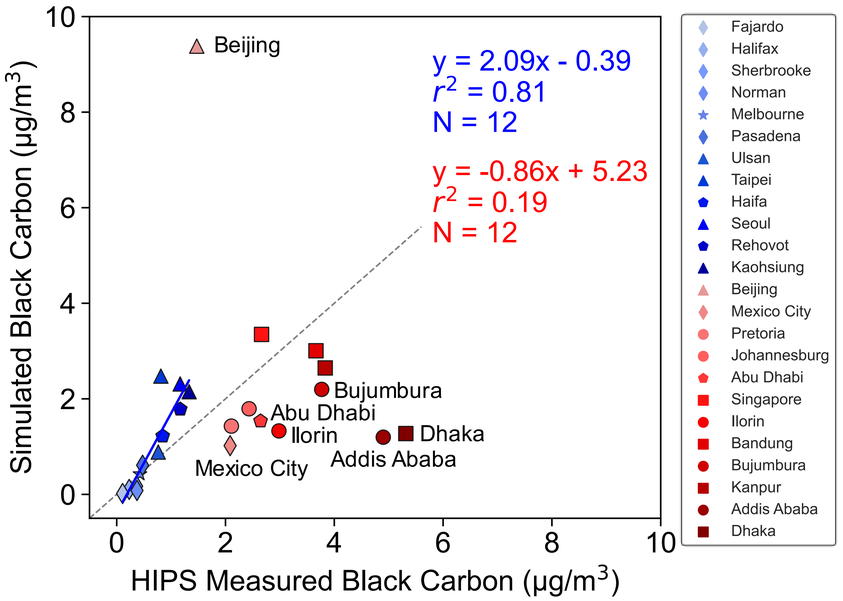
We use the GEOS-Chem chemical transport model in its high-performance implementation (GCHP) version 13.4.1 at cubed-sphere resolutions of C360 (~25 km) using the Community Emissions Data System (CEDS) emission inventory. The simulations and emissions are for 2019.



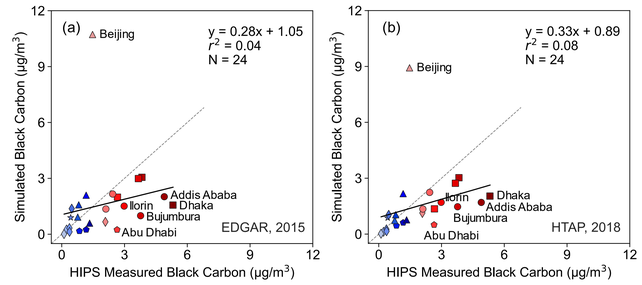


Consistency between C360 and C720 (~12 km) supports comparing grid-averaged outputs with measurements.

Model evaluation highlights the need for improved emission characterization in the Global South



- High consistency across primarily developed regions in northern midlatitudes and Australia
- Pronounced discrepancy across the Global South



Sensitivity analyses using the Emissions Database for Global Atmospheric Research (EDGAR) inventory and the Task Force on Hemispheric Transport of Air Pollution (HTAP) inventory yield similar results.

Summary

- We apply a novel dataset of globally distributed BC measurements from SPARTAN and other available measurements to evaluate widely used BC emission inventories.
- High-resolution GCHP simulations are used to relate BC emissions to ambient concentrations for comparison with measurements.
- Results using CEDS inventory indicate high model-measurement consistency across primarily developed regions (r^2 = 0.81) but pronounced discrepancy across the Global South (r^2 = 0.19).
- These findings motivate renewed attention to the challenging task of characterizing BC emissions from developing countries.

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[1] Bond *et al*., 2013. *J. Geophys. Res.*, *11*8, 5380–5552. [2] White *et al*., 2016. *AS&T*, 50, 984–1002. [3] Dillner and Takahama, 2019. *Atmos. Meas. Tech.*, 8, 4013–4023. [4] Pandey *et al*., 2019. *Atmos. Meas. Tech.*, 12, 1365–1373.

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