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

Yuxuan Ren[1], Randall V. Martin[1], Christopher R. Oxford[1], Dandan Zhang[1], Xuan Liu[1], Haihui Zhu[1],
Ann M. Dillner[2], Warren H. White[2], Rajan K. Chakrabarty[1], Sina Hasheminassab[3], David Diner[3], SPARTAN Team
[1]Washington University in St. Louis, [2]University of California Davis, [3]Jet Propulsion Laboratory, California Institute of Technology

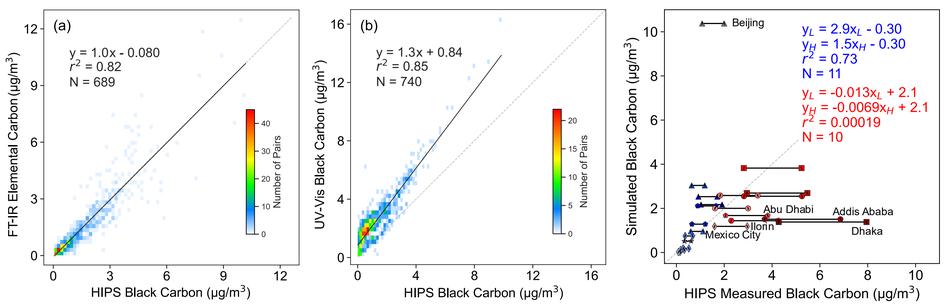
Global characterization of black carbon (BC) is essential but high uncertainty persists in emission inventories and simulations

- 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.
- 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	12/23/2023	113
Addis Ababa	Addis Ababa University	12/7/2022	12/27/2023	116
Bandung	Institute of Technology Bandung	9/6/2019	7/11/2021	23
Beijing	Tsinghua University	3/24/2020	11/28/2023	153
Bujumbura	University of Burundi	12/9/2022	12/26/2023	18
Dhaka	Dhaka University	8/11/2020	10/7/2023	52
Fajardo	Cabezas de San Juan Nature Reserve	3/18/2021	12/24/2023	34
Haifa	Technion Israel Institute of Technology	2/16/2022	6/17/2023	143
Halifax	Dalhousie University	6/14/2019	10/24/2023	112
Ilorin	Ilorin University	7/13/2019	12/1/2021	36
Johannesburg	University of Johannesburg	4/7/2022	12/28/2023	168
Kanpur	Indian Institute of Technology Kanpur	7/14/2021	5/24/2022	14
Kaohsiung	Kaohsiung Medical University	8/20/2022	12/29/2023	123
Melbourne	University of Melbourne	8/9/2022	12/28/2023	34
Mexico City	Universidad Nacional Autónoma de México	2/26/2021	12/24/2023	52
Pasadena	Jet Propulsion Laboratory	11/9/2021	11/15/2023	233
Pretoria	Council for Scientific and Industrial Research	10/22/2020	12/27/2023	233
Rehovot	Weizmann Institute	7/2/2019	6/7/2023	178
Seoul	Yonsei University	9/11/2020	12/30/2023	65
Sherbrooke	Sherbrooke University	8/29/2019	6/21/2023	67
Taipei	National Taiwan University	1/27/2022	12/31/2023	218
Ulsan	Ulsan National Institute of Science and Technology	10/28/2021	12/23/2023	92

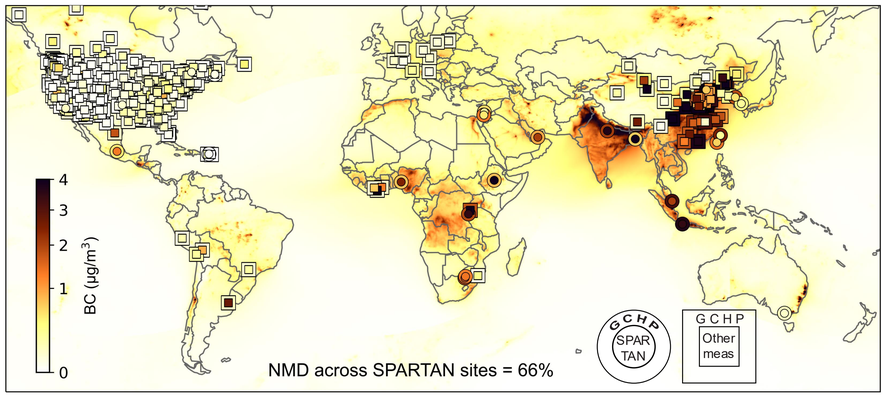
- High consistency in BC concentrations determined by Hybrid Integrating Plate/Sphere (HIPS), Fourier Transform Infrared Spectroscopy (FT-IR), and UV-Visible Spectrophotometer (UV-Vis)

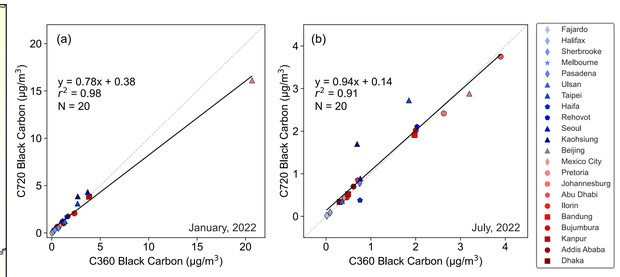


- Mass absorption cross section (MAC): 10 m^2/g at 633 nm for HIPS; sensitivity test range 7–13 m^2/g

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

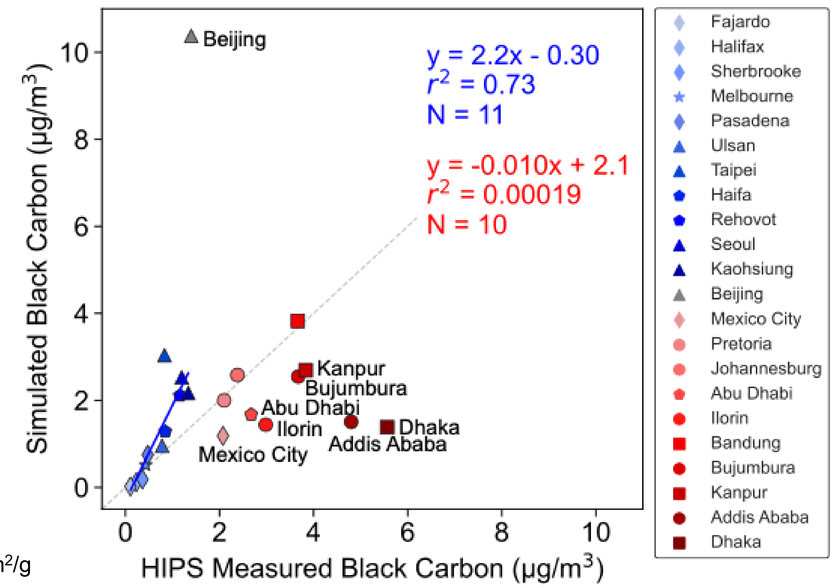
We use the GEOS-Chem chemical transport model in its high-performance implementation (GCHP) version 13.4.1 at cubed-sphere resolutions of C360 (~25 km) using the Community Emissions Data System (CEDS) emission inventory. The simulations and emissions are for 2019.



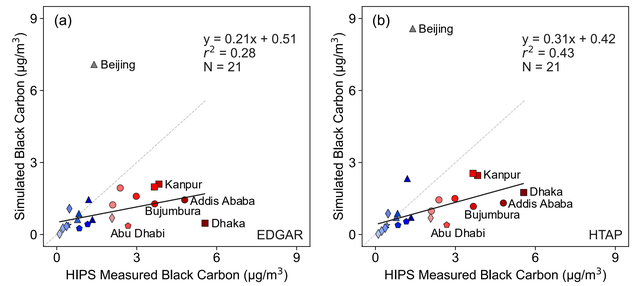


Consistency between C360 and C720 (~12 km) supports comparing grid-averaged model outputs with measurements.

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 = 0.73) but pronounced discrepancy across the Global South (r^2 = 0.00019).
- These findings motivate renewed attention to the challenging task of characterizing BC emissions from developing countries.

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ren.yuxuan@wustl.edu