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Enhanced light absorption and direct radiative forcing by Black Carbon agglomerates

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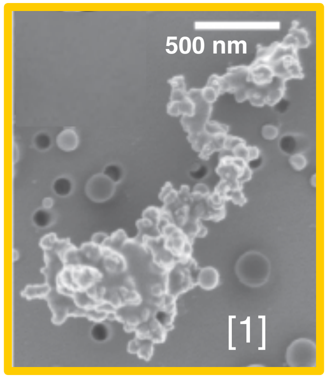
[2]Institute of Atmospheric and Climate Science, ETH Zürich, Switzerland

[3]The Ohio State University, Ohio, USA

Climate models vs. AERONET Observations



Direct Radiative forcing, RF:

$$RF = AAOD\square RFE$$

Absorption Aerosol Optical Depth

RF **efficiency**

[1] S. China, et al., *Nature Comm. 4* (2013) 2122-1-7.

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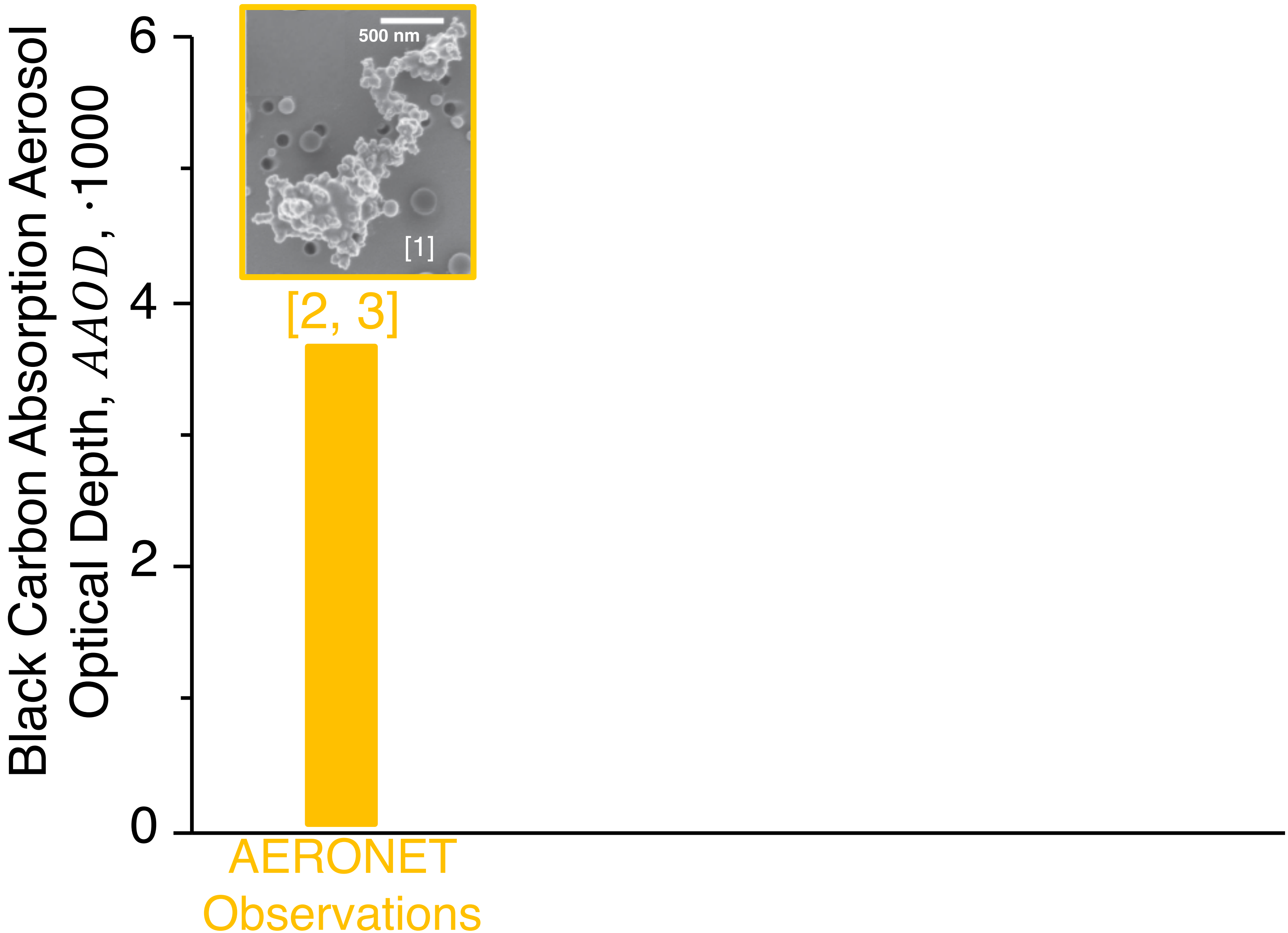

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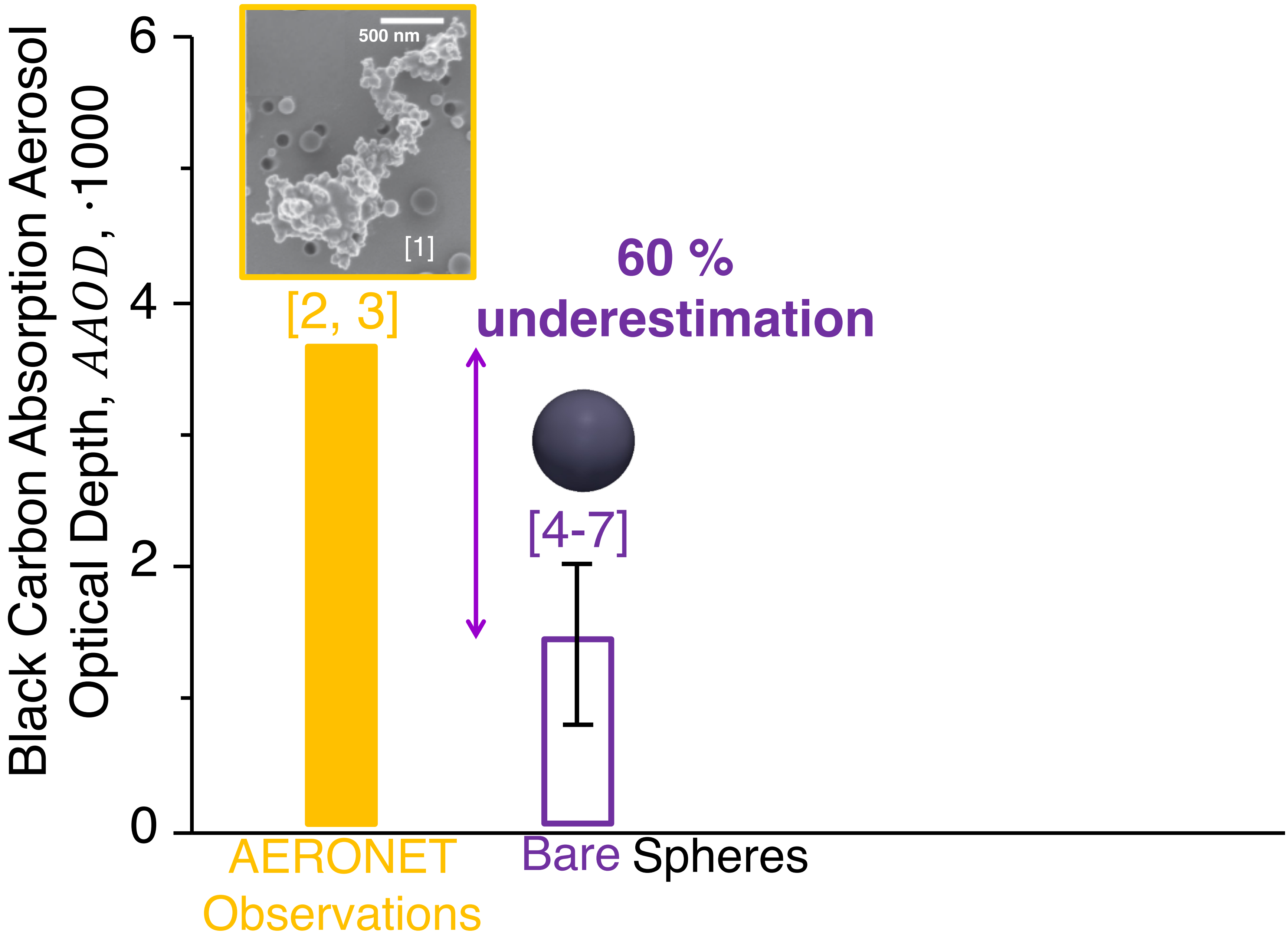

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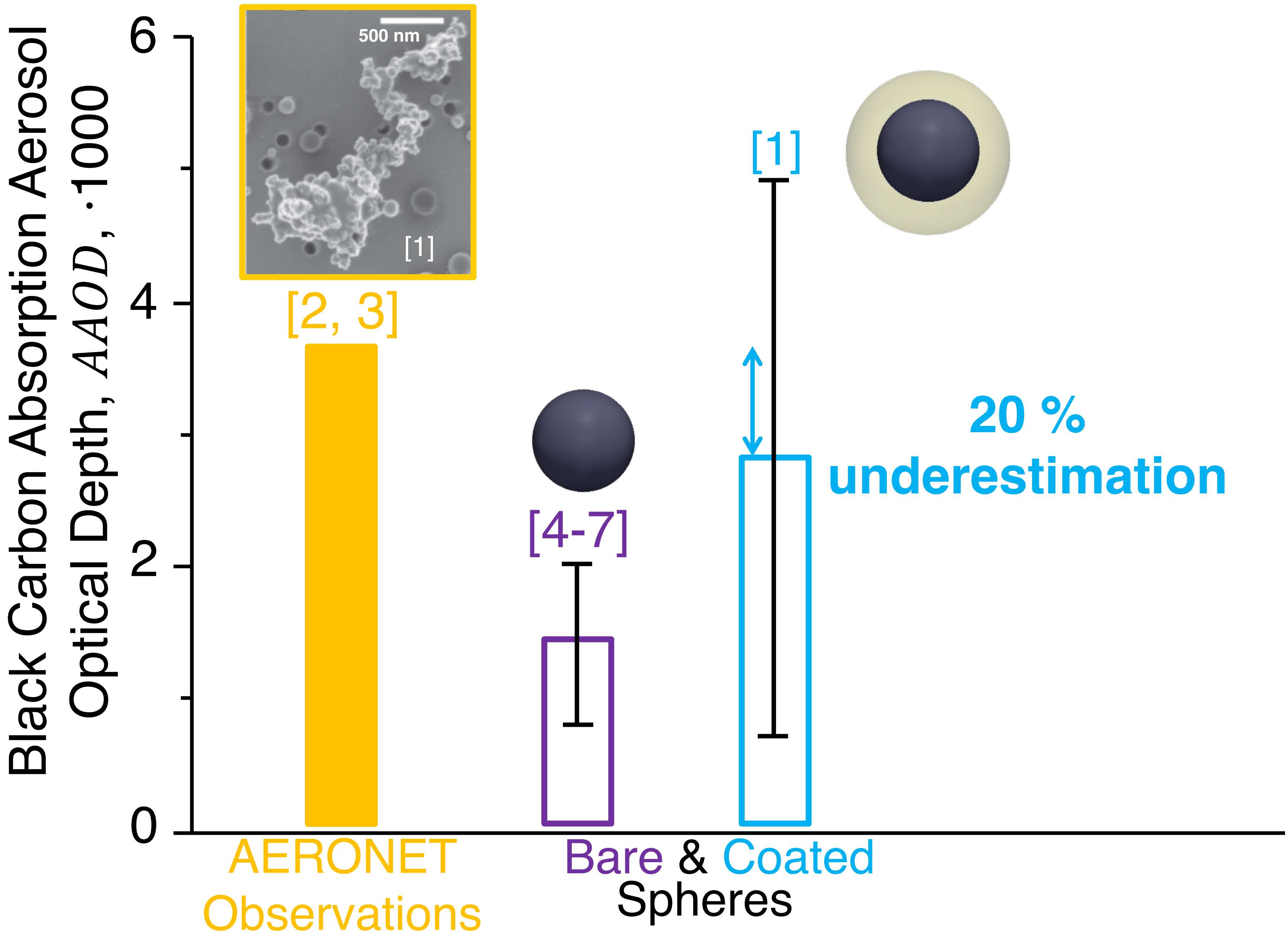

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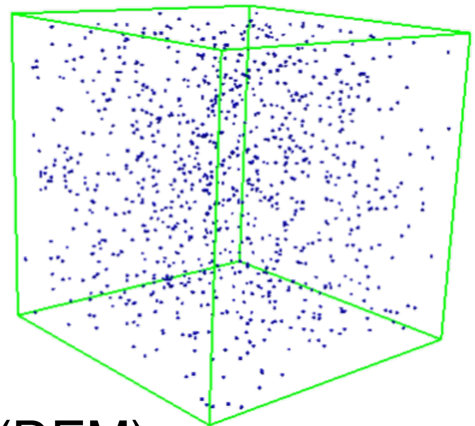
Discrete Element Modeling (DEM)

i) Initial configuration inception has largely ended.



T = 1830 K

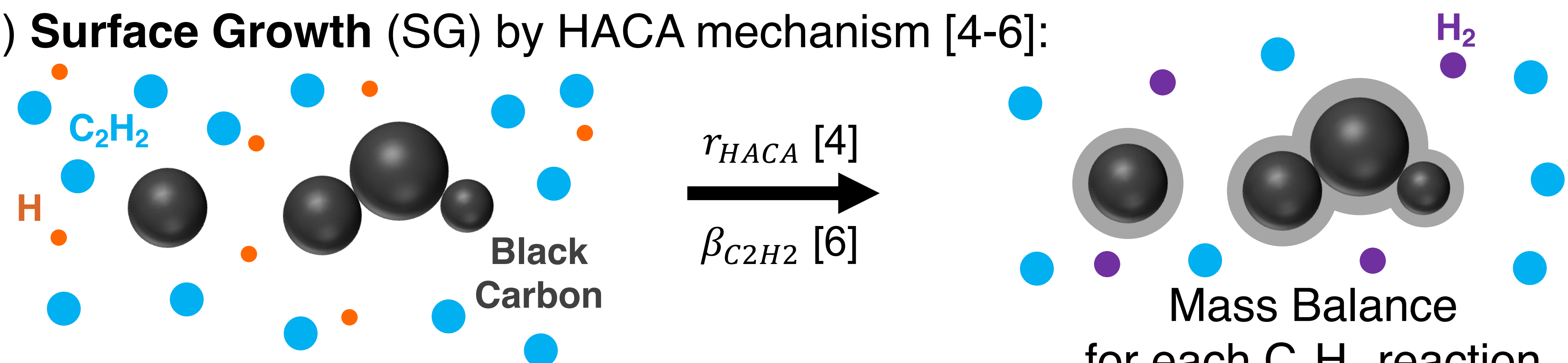
$d_{m,o}$ = 2 nm

$N_{tot,o}$ = $4.5 \cdot 10^{16}$ m^{-3}

[1,2]

ii) Discrete Element Modeling (DEM) of **Particle Motion** and **Coagulation** during Combustion [3]

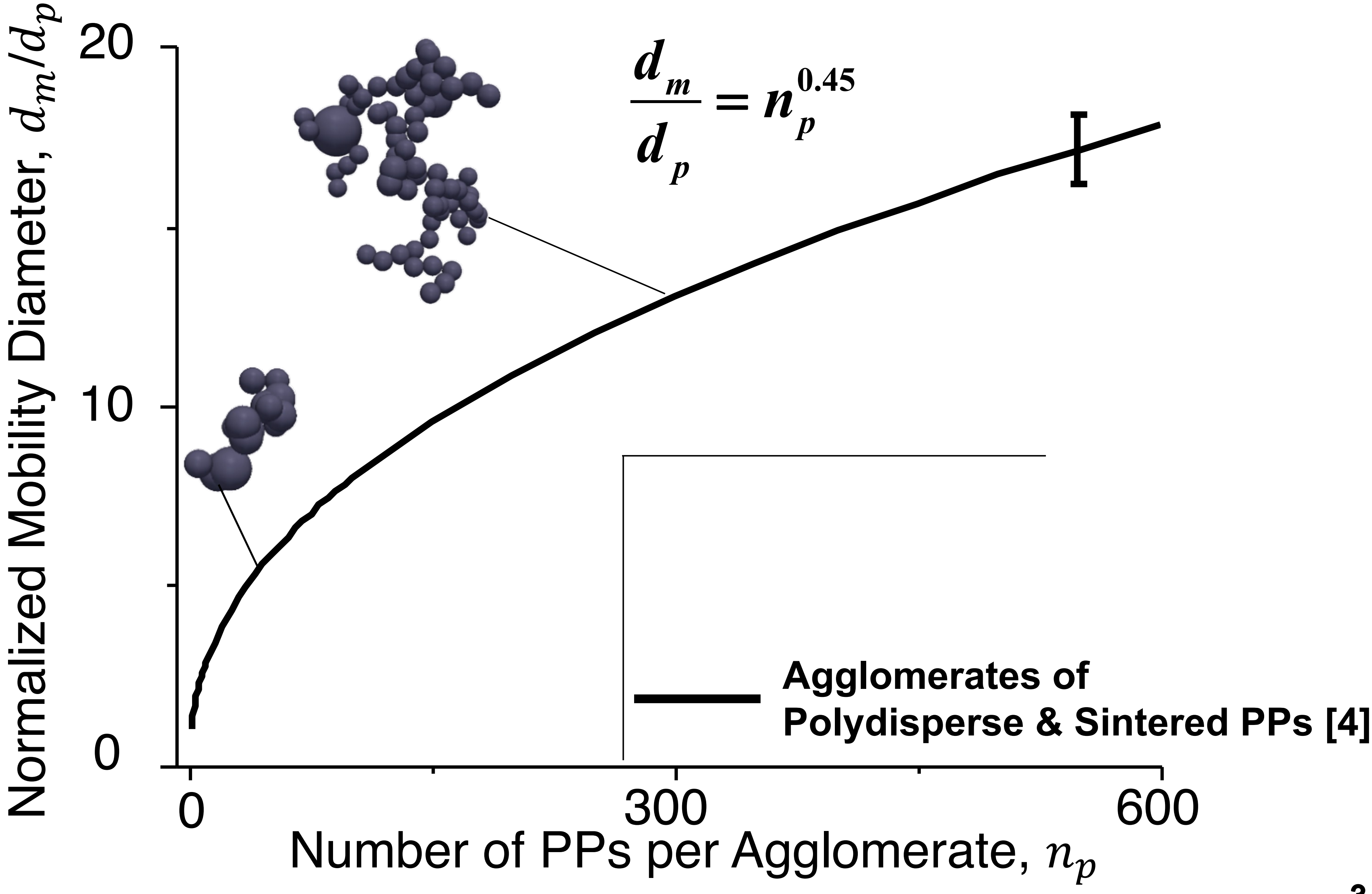
iii) **Surface Growth** (SG) by HACA mechanism [4-6]:



Mass Balance for each C_2H_2 reaction

[1] Abid, A. D.; Heinz, N.; Tolmachoff, E.D.; Phares, D.J.; Campbell, C.S.; Wang, H. Combust Flame 2008, 154, 775.
[2] Camacho ,J.; Liu, C.; Gu, C.; Lin, H.; Huang, Z.; Tang, Q.; You, X.; Saggese, C.; Li, Y.; Jung, H.; Deng, L.; Wlokas, I.; Wang, H. Combust Flame 2015, 162, 3810.
[3] Goudeli, E.; Eggersdorfer, M. L.; Pratsinis, S. E. Langmuir 2015, 31,1320.
[4] Appel, J.; Bockhorn, H.; Frenklach, M. Combust Flame 2000, 121, 122.
[5] Saggese, C.; Ferrario, S.; Camacho, J.; Cuoci, A.; Frassoldati, A.; Ranzi, E.; Wang, H.; Faravelli, T. Combust Flame 2015, 162, 3356.
[6] Kelesidis, G. A.; Goudeli, E.; Pratsinis, S. E. Proc Combust Inst 2017 36, 29.

Black Carbon Morphology



[4] Kelesidis GA, Goudeli E, Pratsinis SE. *Carbon* (2017) 121, 527.

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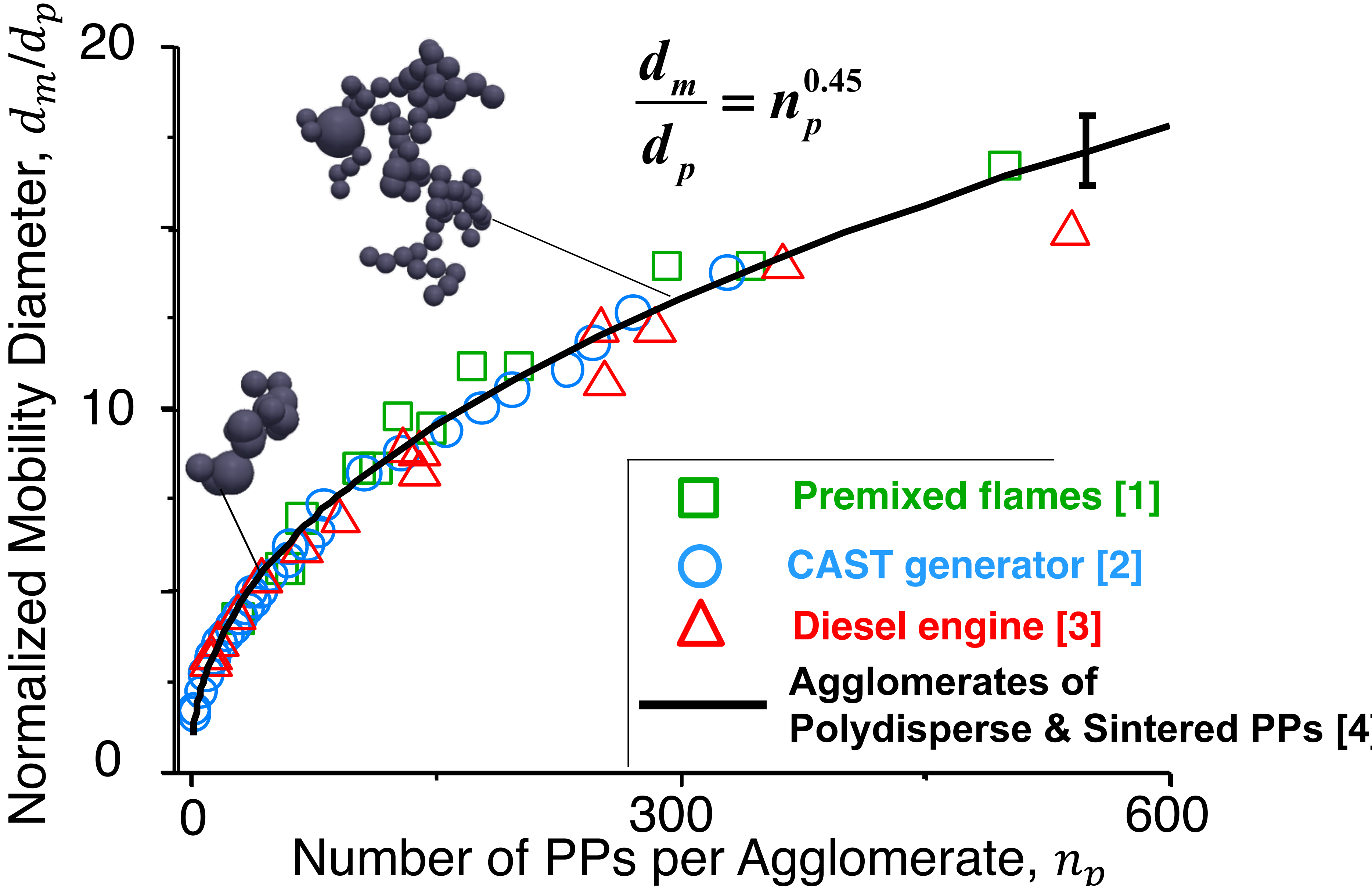
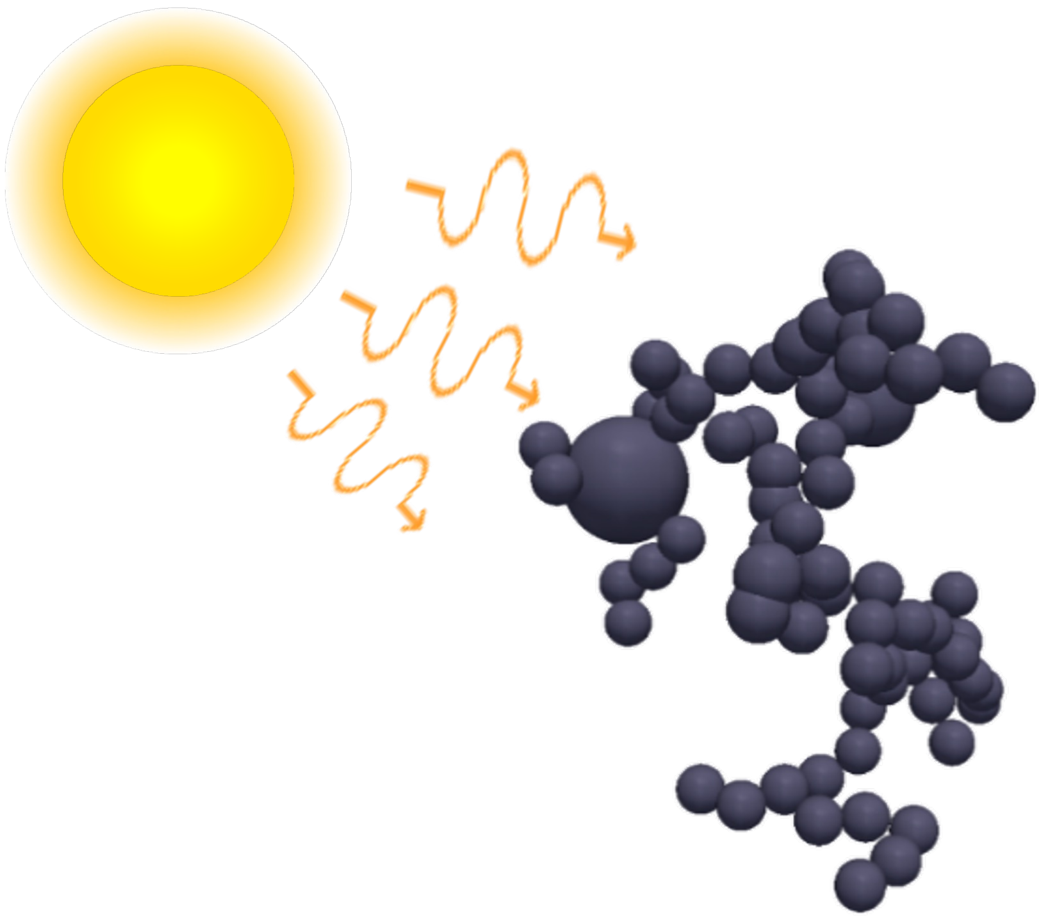


[1] Kelesidis GA, Kholghy MR, Zurcher J, Robertz J, Allemann M, Duric A, Pratsinis SE. (2020) *Powder Technol.* 365, 52.
[2] Yon J, Bescond A, Ouf FX. (2015) *J. Aerosol Sci.* 87, 28.
[3] Rissler J, Messing ME, Malik AI, Nilsson PT, Nordin EZ, Bohgard M, Sanati M, Pagels JH. (2013) *Aerosol Sci. Technol.* 47, 792.
[4] Kelesidis GA, Goudeli E, Pratsinis SE. *Carbon* (2017) 121, 527.

Rayleigh Debye Gans (RDG) theory



C-rich Black Carbon:
RI = 1.66 - 0.76i [1]

[1] Yon, J.; Bescond, A.; Liu, F., J Quant Spectrosc Radiat Transf 2015, 197.

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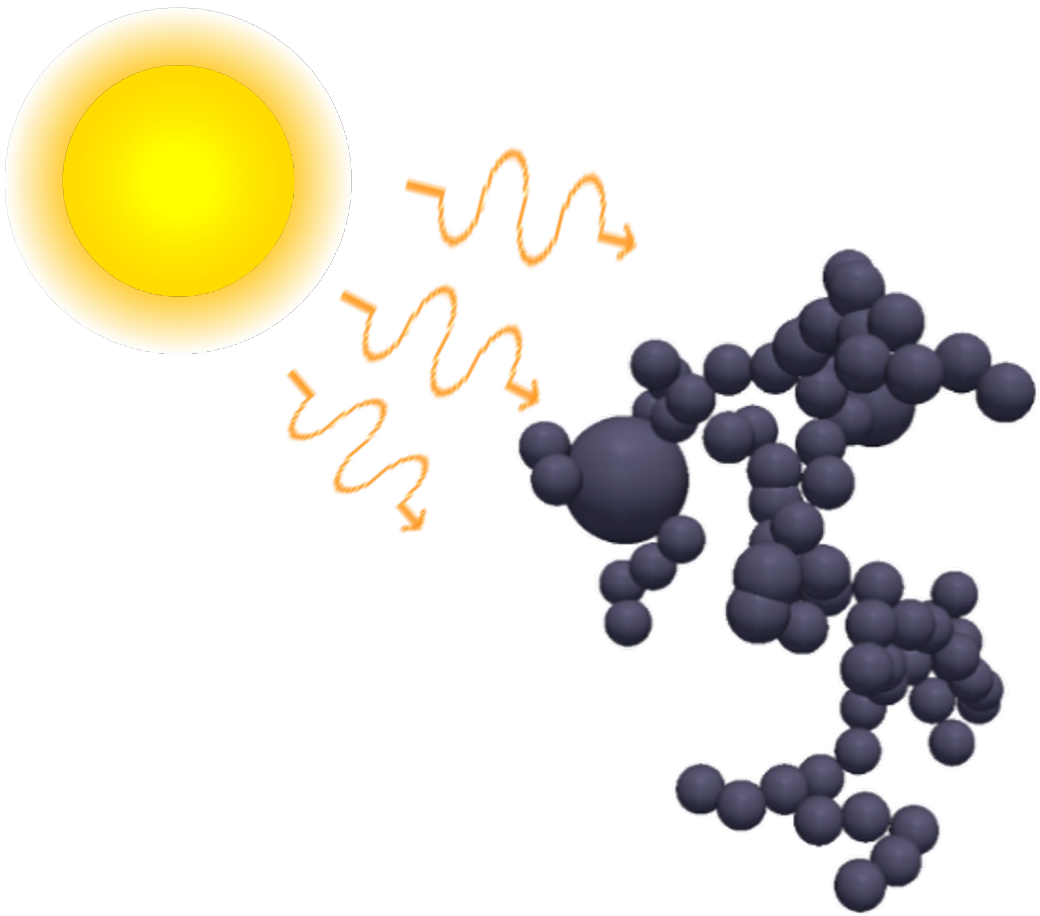

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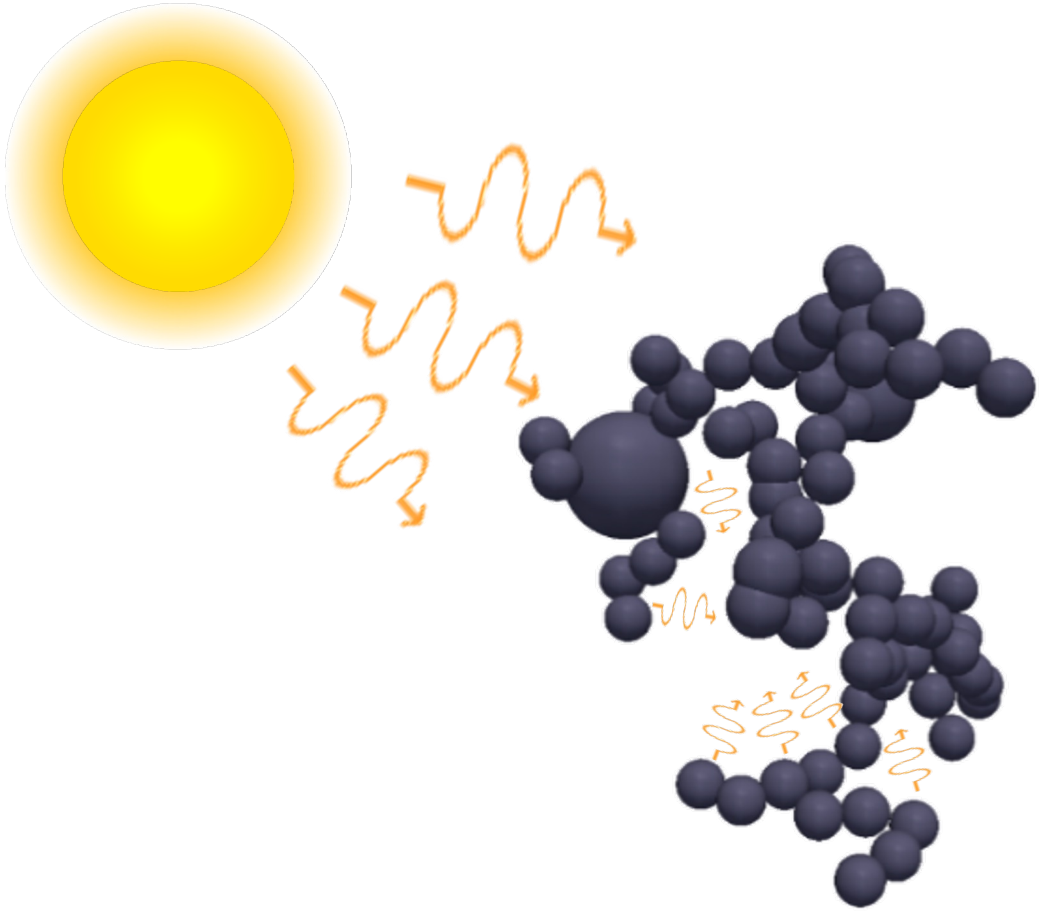

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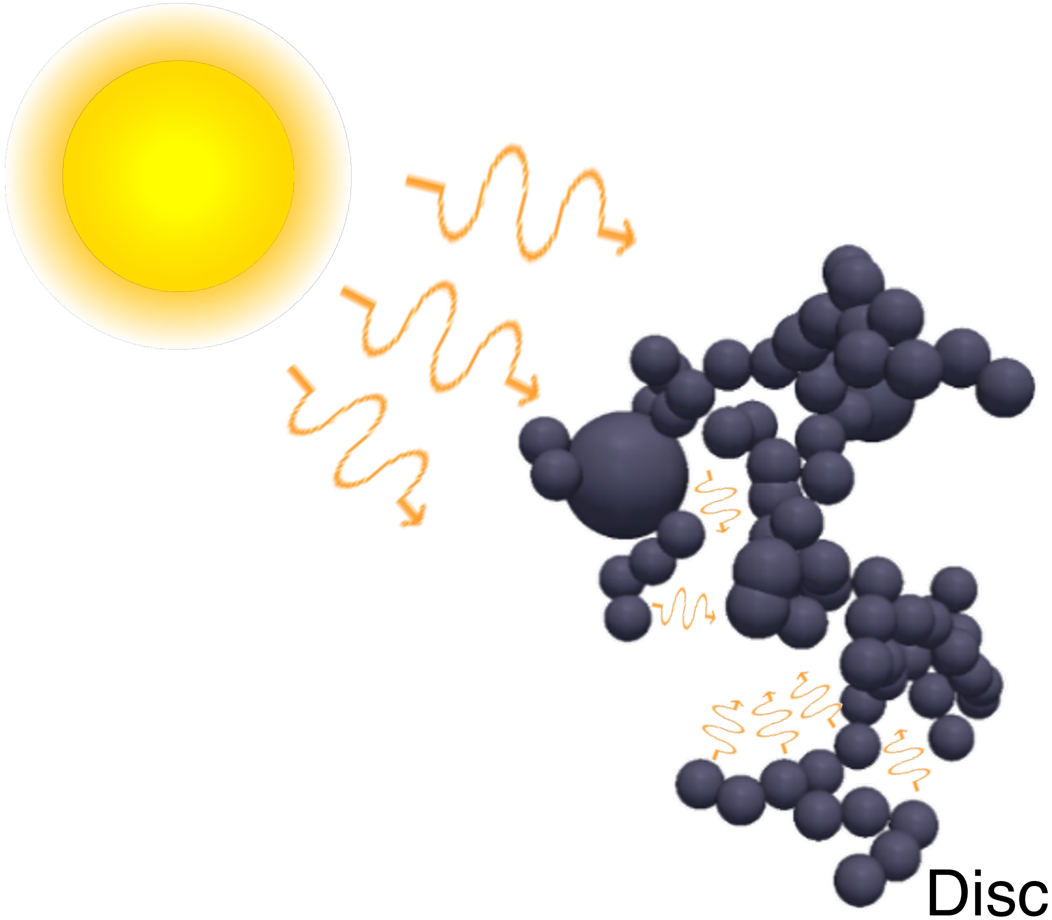

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d_m = 50 - 250 nm; d_p = 7.5 - 40 nm

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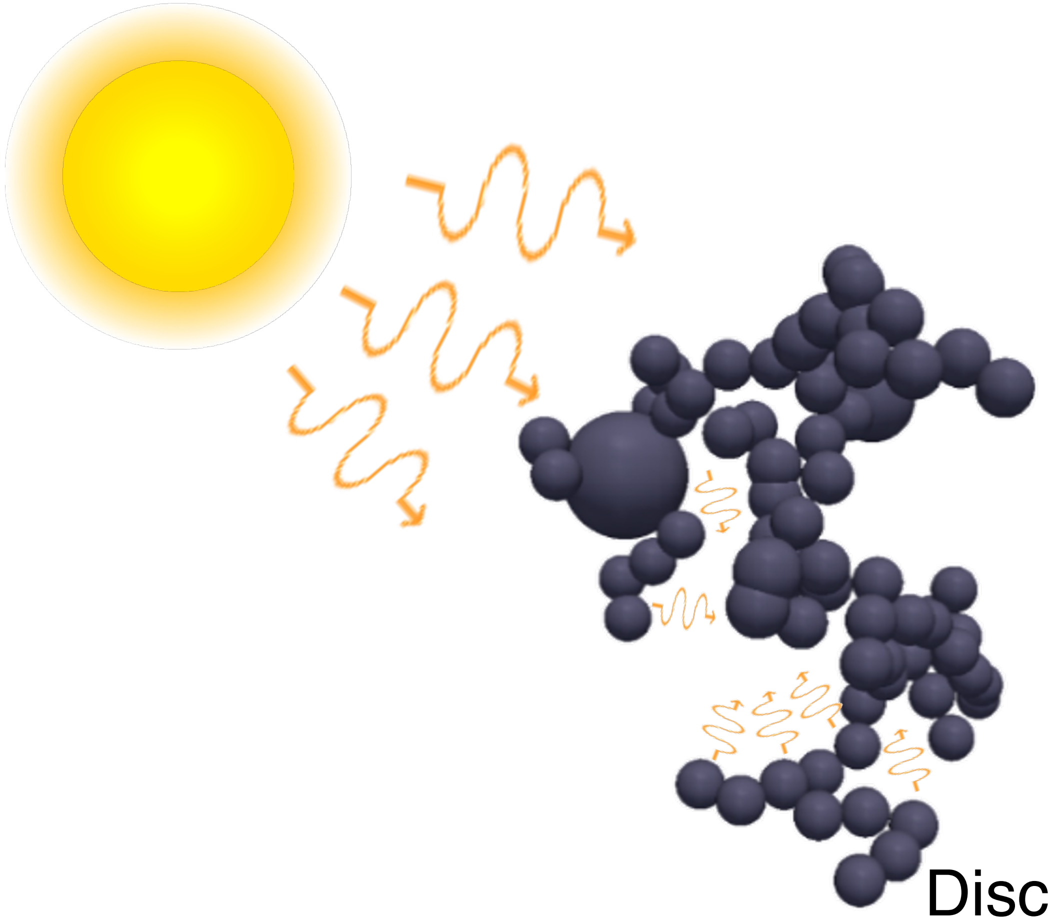

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Light absorption by intra-particle scattering:
$h = 1.18 \pm 0.03$

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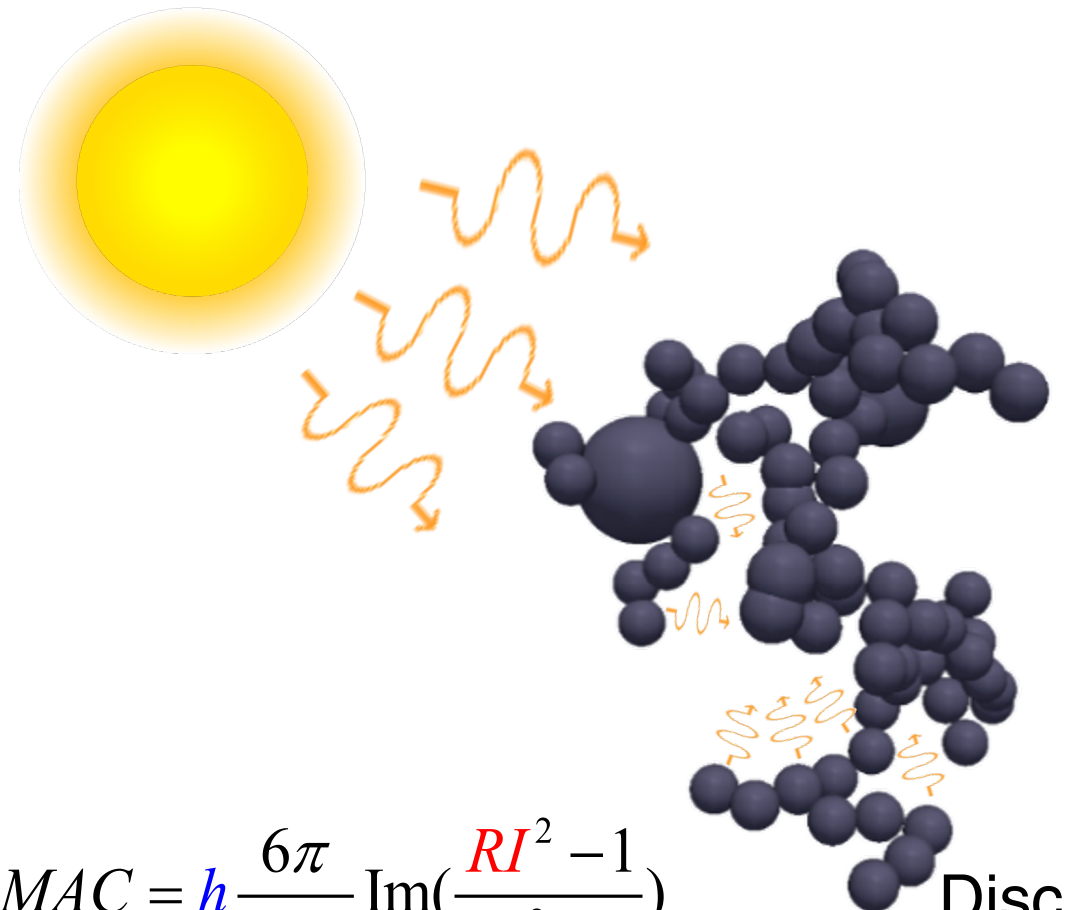

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$$MAC = h \frac{6\pi}{\lambda \cdot \rho} \mathrm{Im}\left(\frac{RI^2 - 1}{RI^2 + 2}\right)$$ [5]

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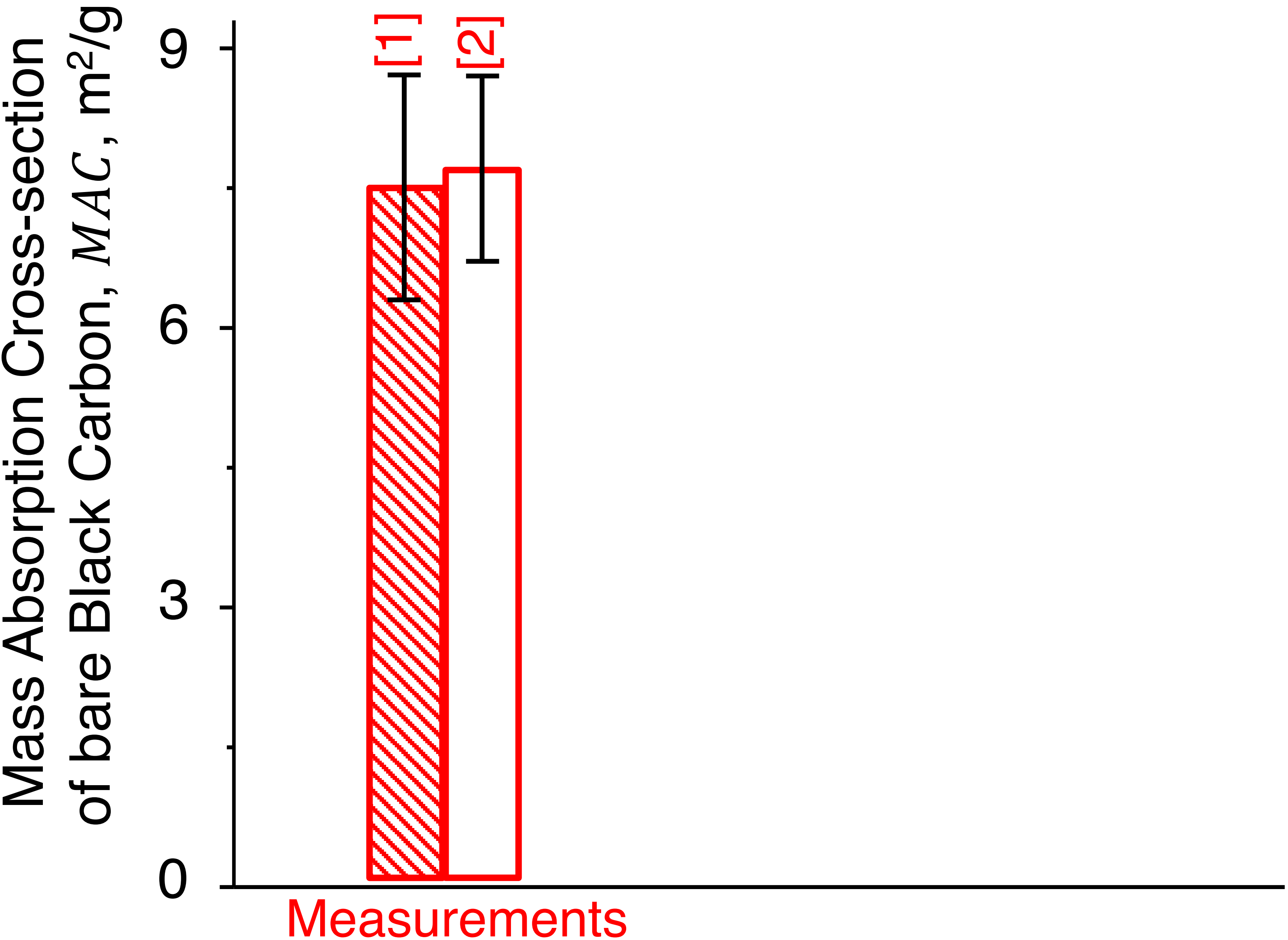
[2] Textor, C.; Schulz, S.; Pratsinis, Guibert, S.; Kinne, S.; Balkanski, Y.; Bauer, S., Berntsen, T., et al. Atmos Chem Phys 2006 6, 1777.
[3] Kelesidis, G. A.; Goudeli, E.; Pratsinis, S. E. Proc Combust Inst 2017 36, 29.
[4] Kelesidis, G.A.; Kholghy, M.R.; Zurcher, J.; Robertz, J.; Allemann, M.; Duric, A.; Pratsinis, S.E. Powder Technol 2020, 365, 52.
[5] Dobbins, R.A.; Megaridis, C.M., Appl Optics 1991, 30, 4747.

Light absorption by bare Black Carbon



[1] T.C. Bond, R. W. Bergstrom, *Aerosol Sci. Technol.* 40 (2006) 27-67.

[2] F. Liu, et al., *Aerosol Sci. Technol.* 54 (2019) 33-51.

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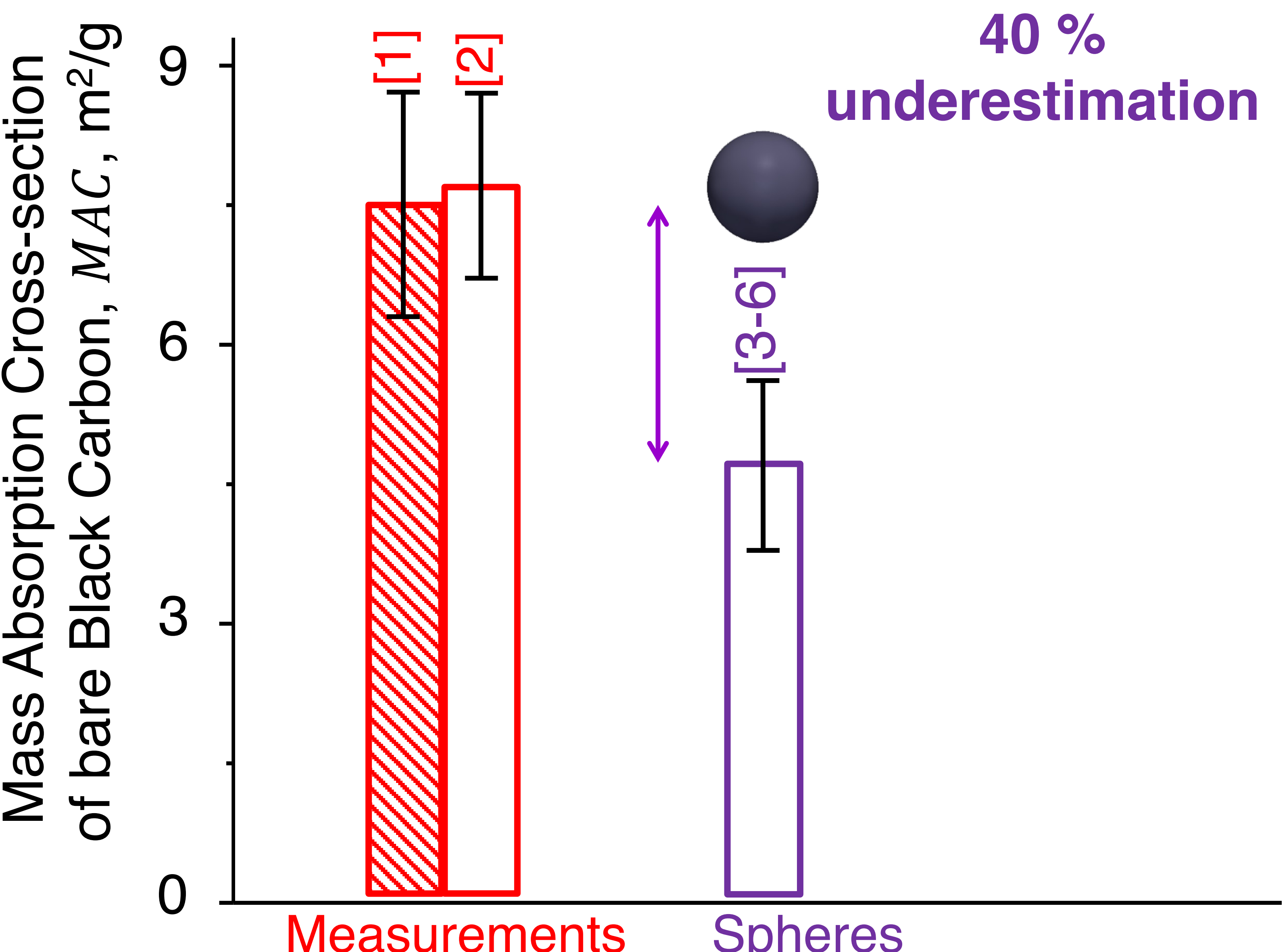

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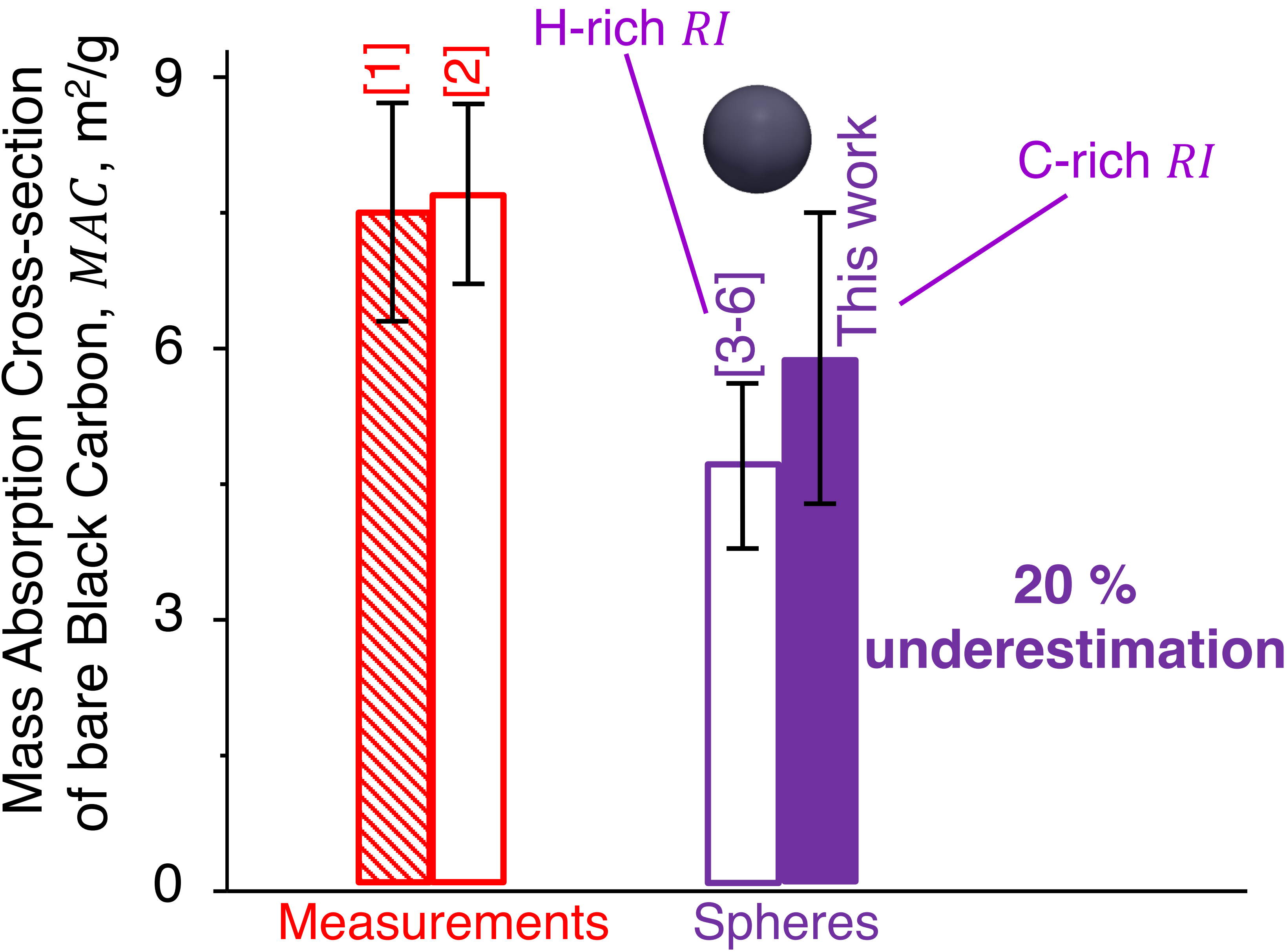

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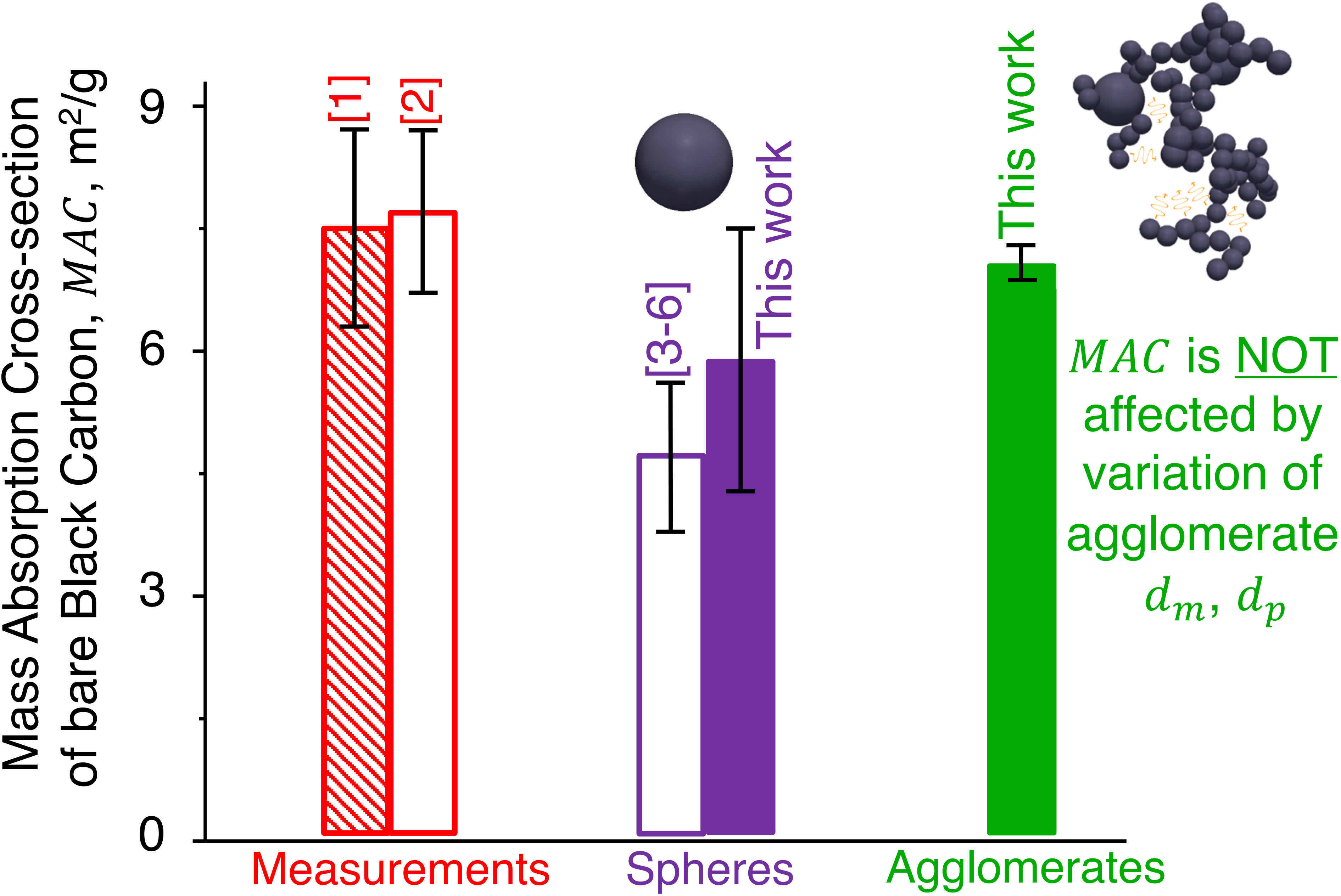

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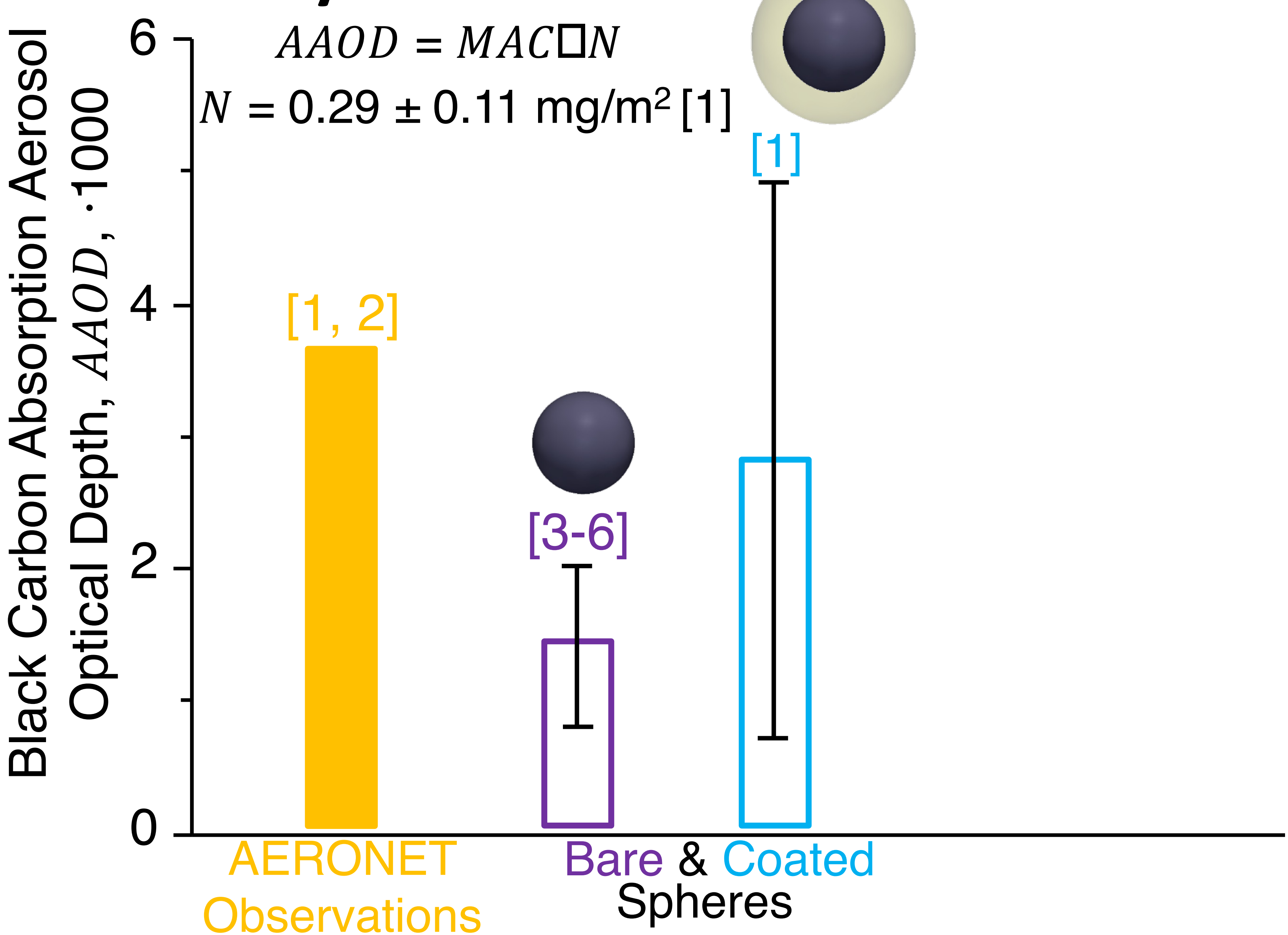
AAOD by Black Carbon



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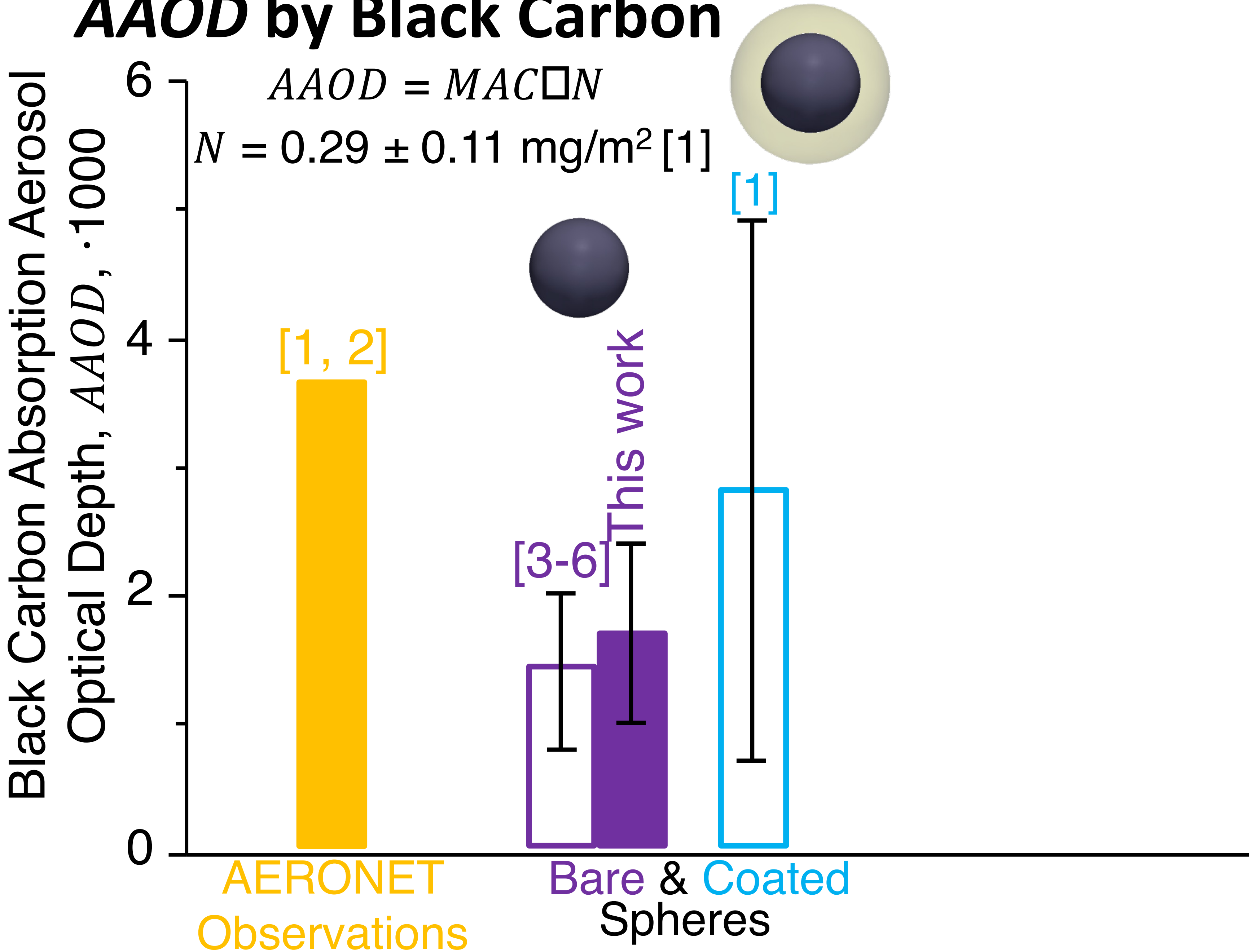

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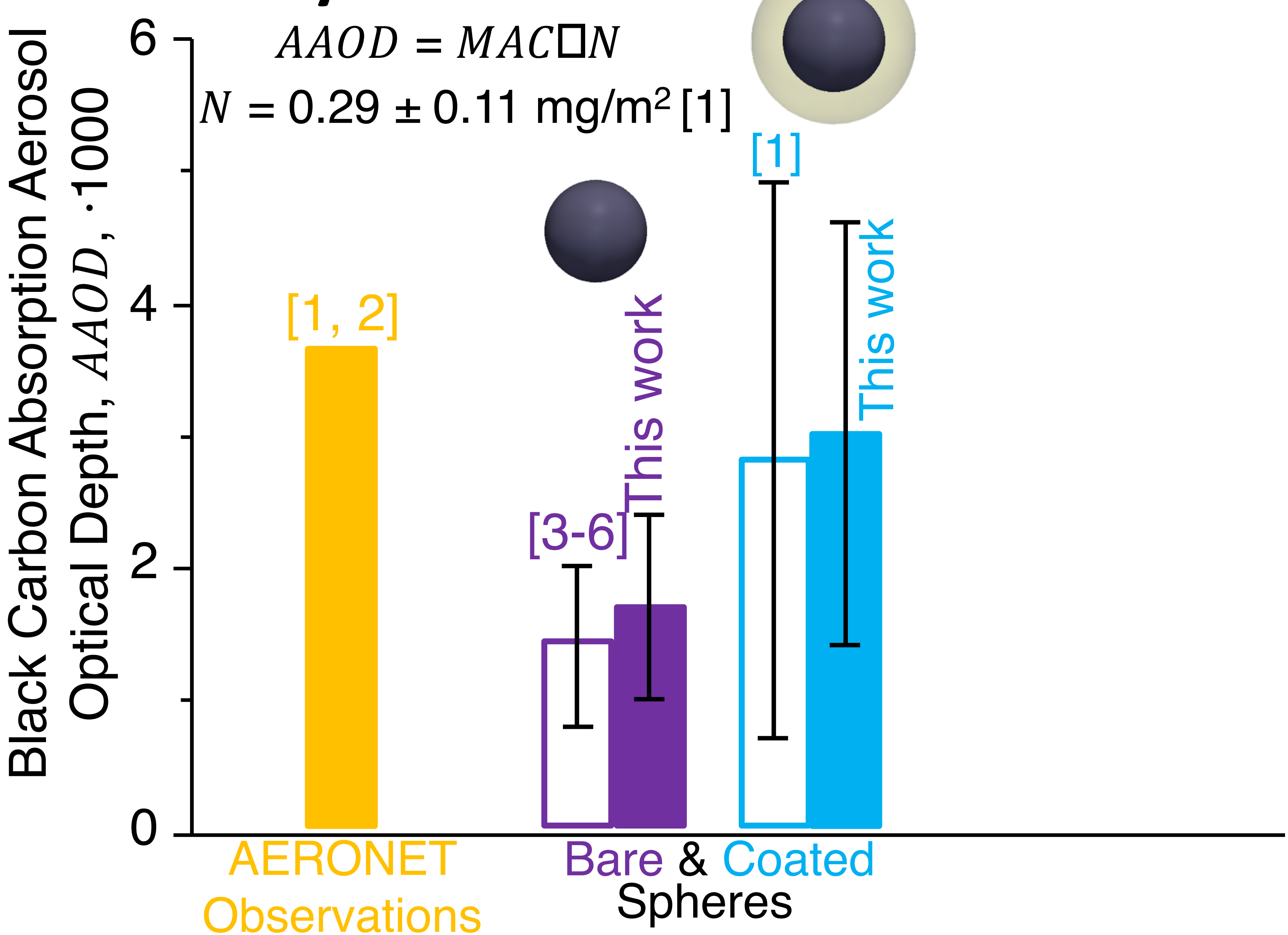
***AAOD* by Black Carbon**



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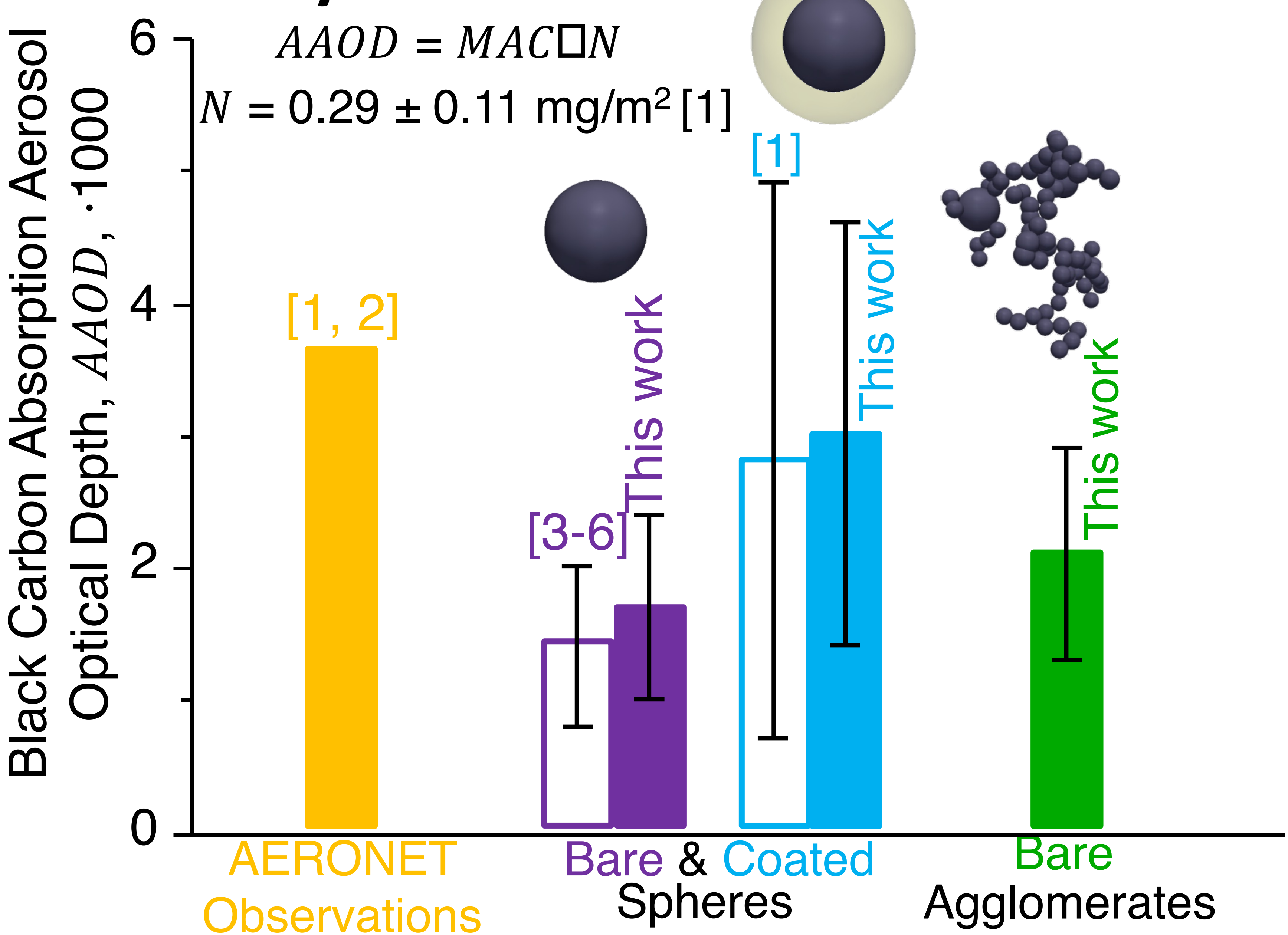
AAOD by Black Carbon



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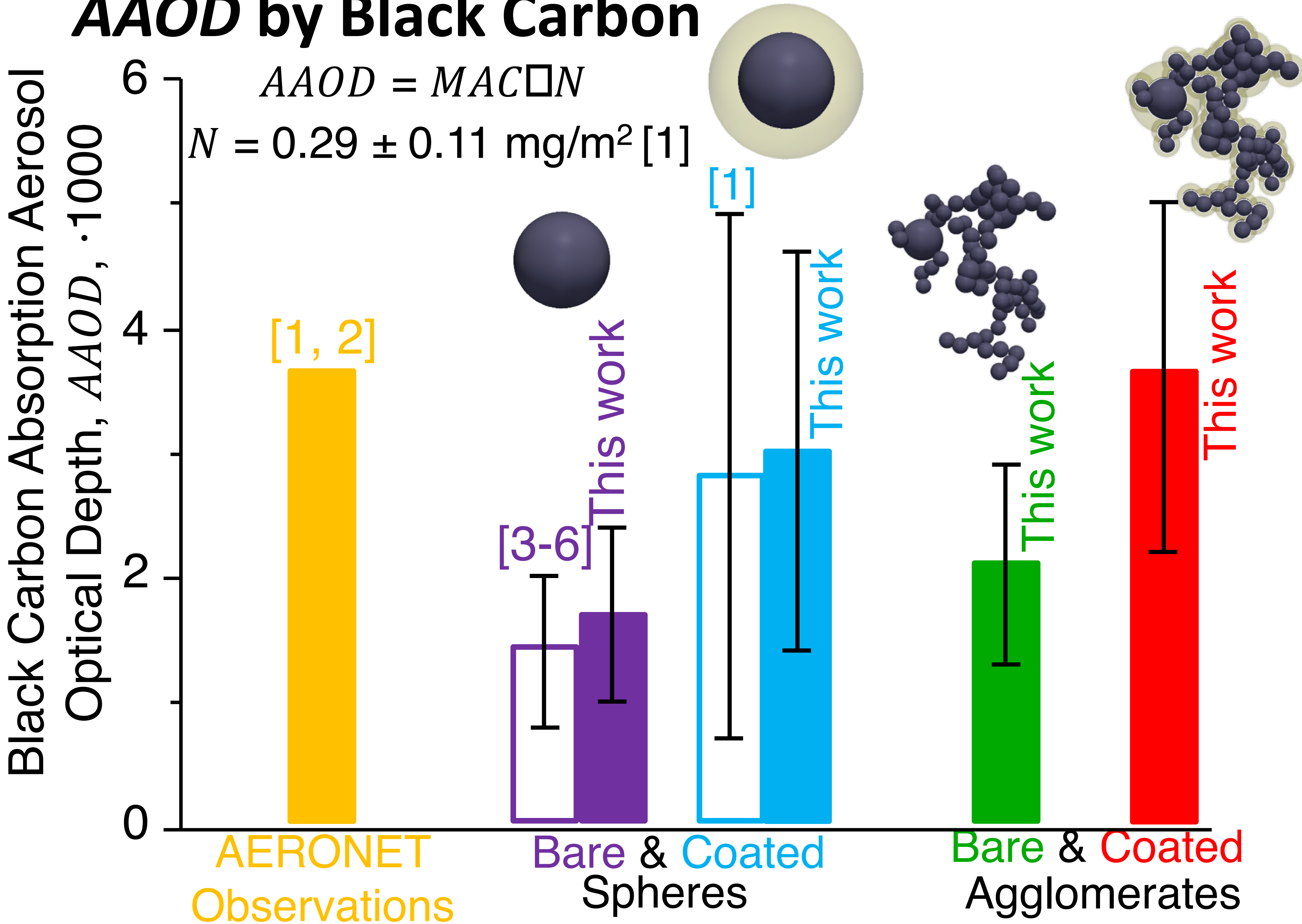

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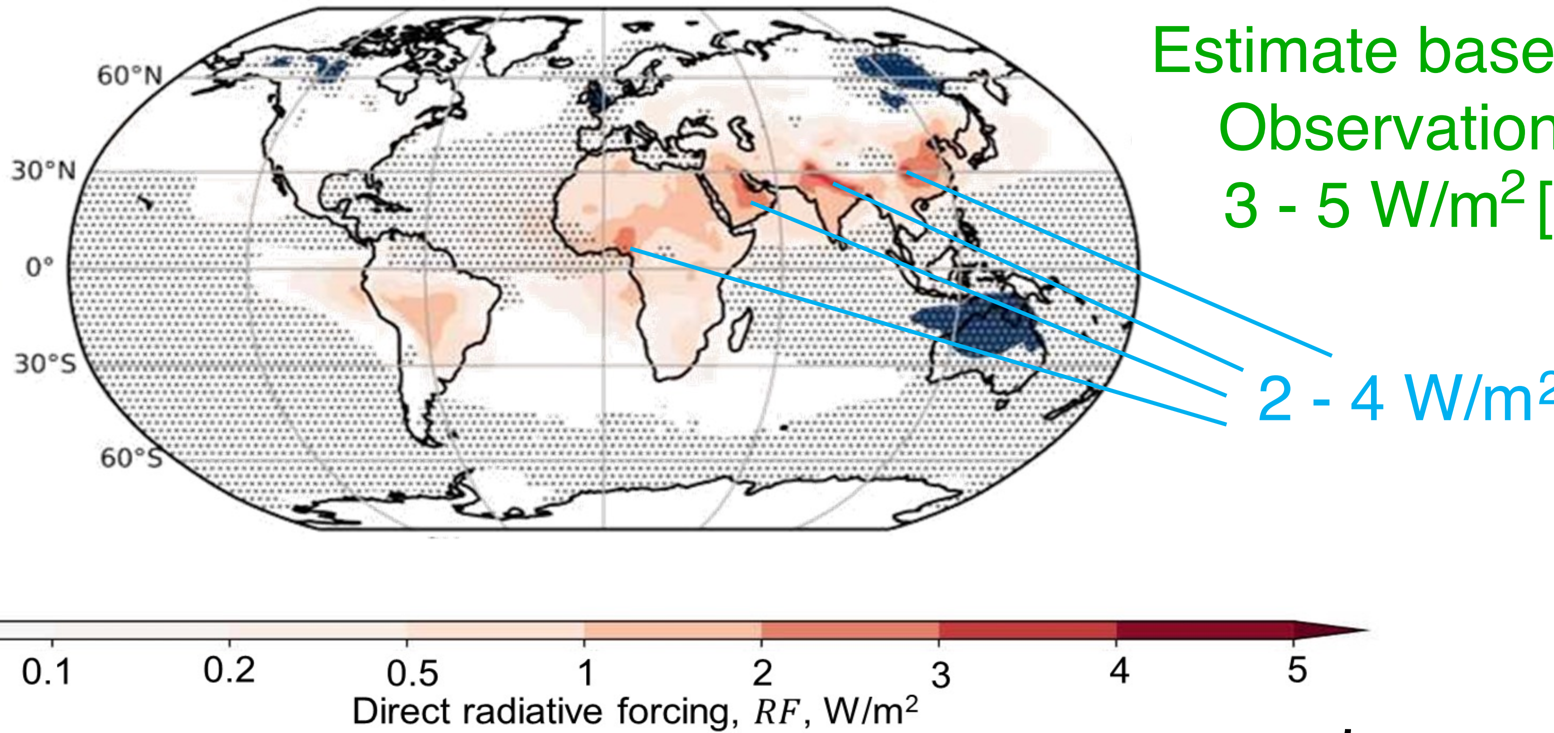
Climate impact of Black Carbon



Estimate based on Observations: 3 - 5 W/m^2 [2]

ECHAM6.3-HAM2.3 [1]

[1] D. Neubauer, et al. *Geosci. Model Dev.* 12 (2019) 3609-3639.

[2] T.C. Bond, et al. *J. Geophys. Res.* 118 (2013) 5380-5552.

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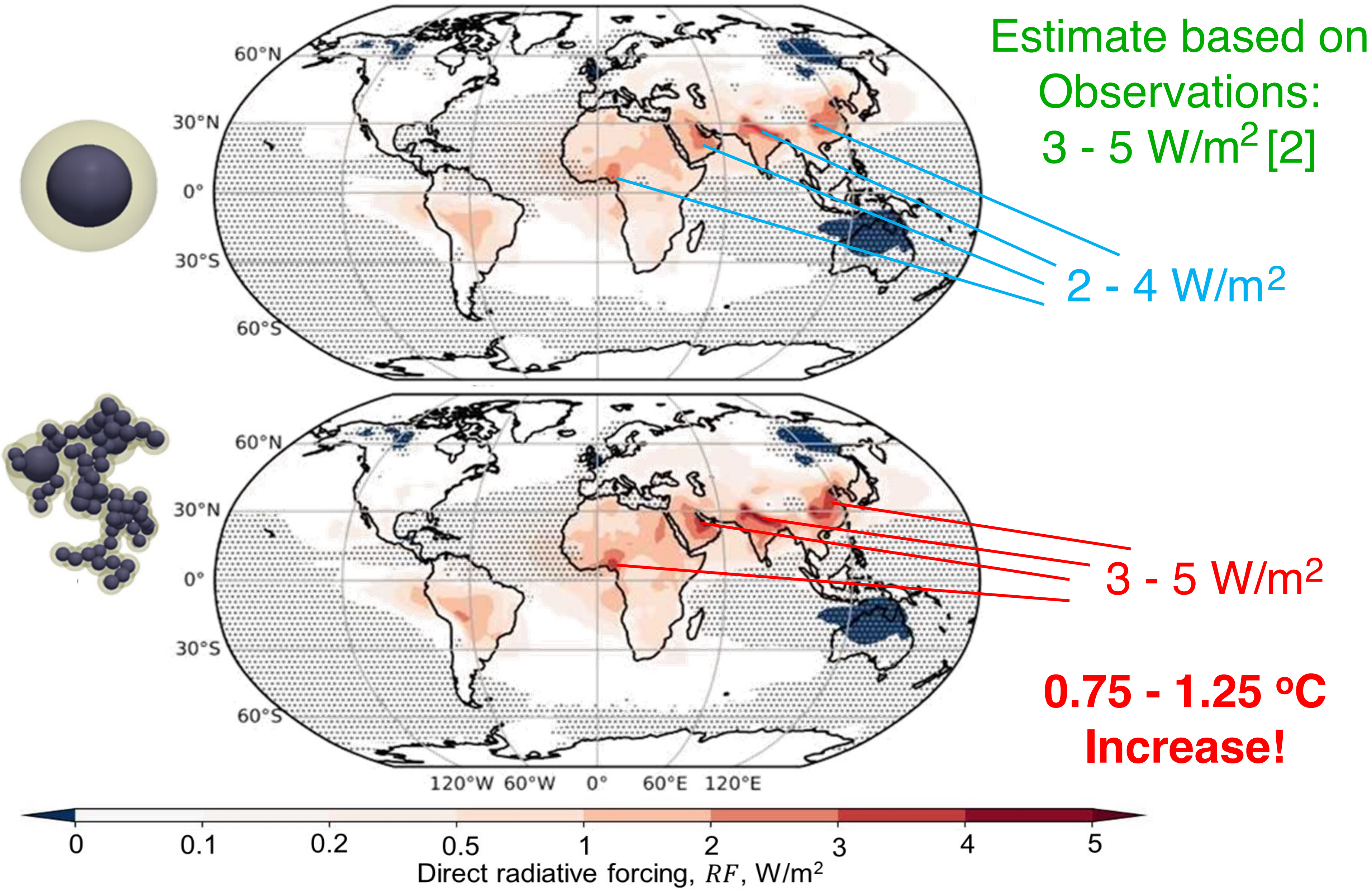

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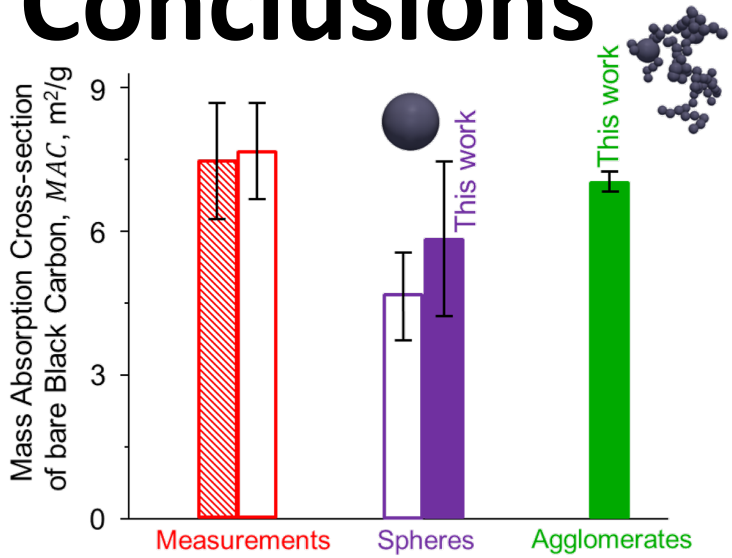
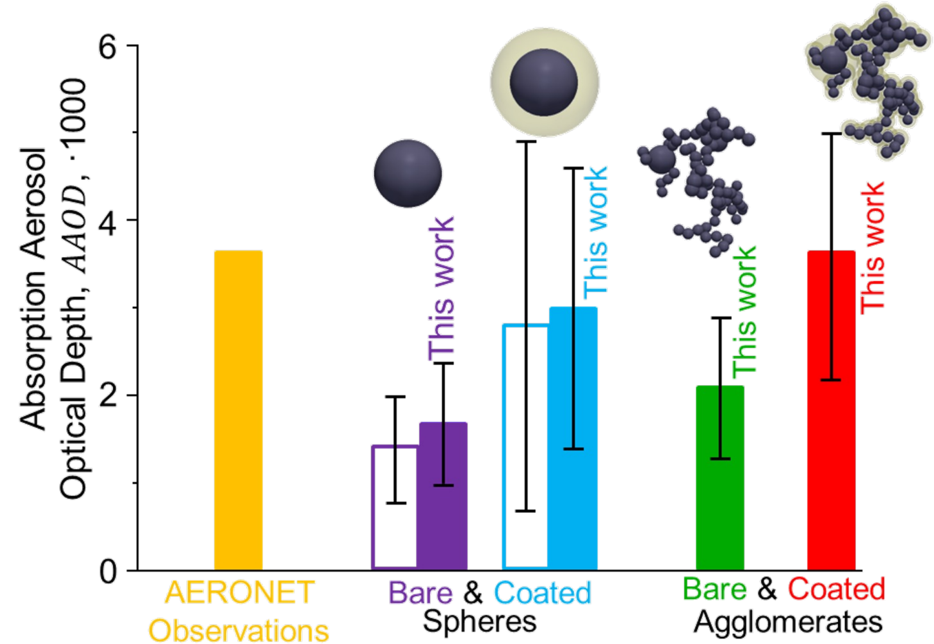
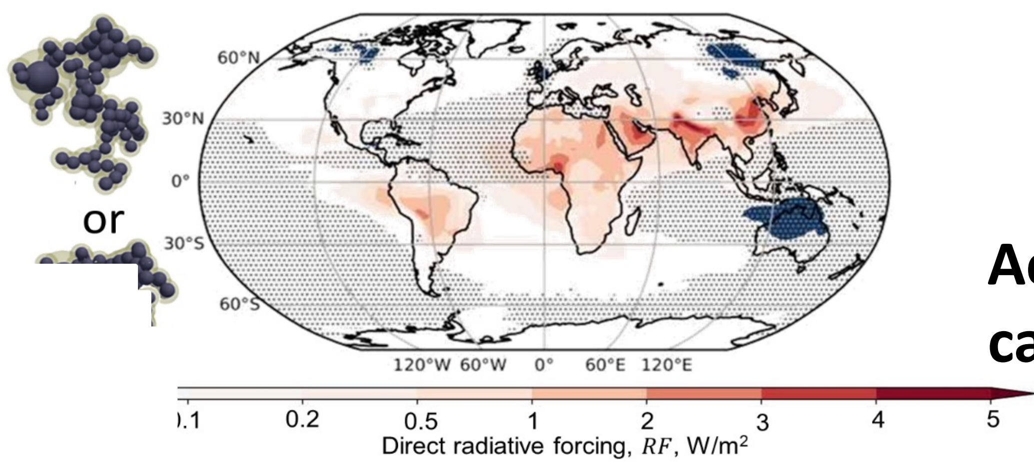
Conclusions



Light absorption of Black Carbon is enhanced by PP light scattering due to the agglomerate structure and NOT d_m, d_p!



Black Carbon agglomerate $AAOD$ in excellent agreement with AERONET observations.



Accounting for the realistic black carbon morphology enhances its direct RF by 25-50 %!

G.A. Kelesidis, D. Neubauer, L.-S. Fan, U. Lohmann, S.E. Pratsinis, *Environ. Sci. Technol.* (2022) in press: doi.org/10.1021/acs.est.2c00428.

Thank you for listening