Jet Propulsion Laboratory
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3D Climatology of Cloud Condensation Nuclei Concentrations Derived from Spaceborne Lidar

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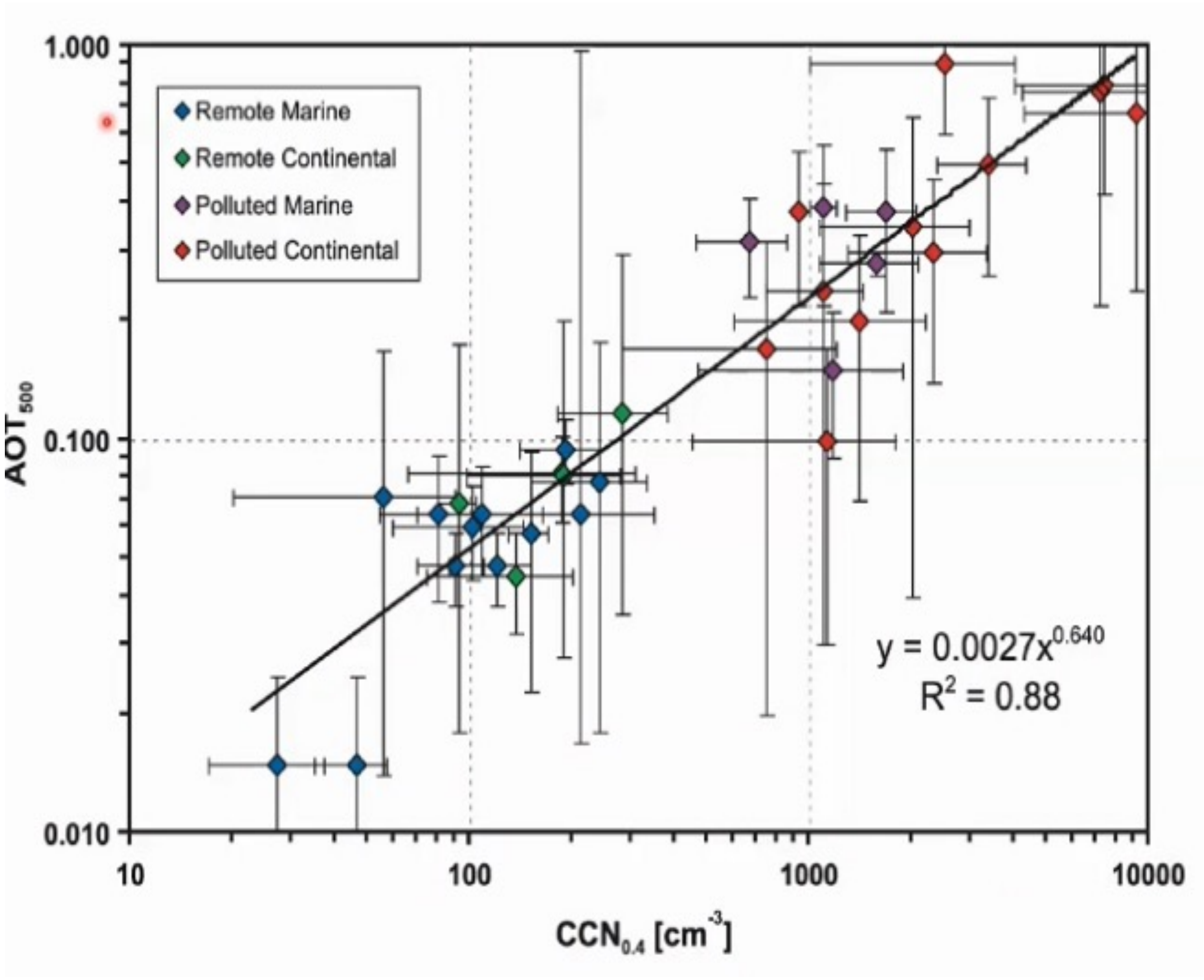
Suitability of AOD as a proxy for CCN

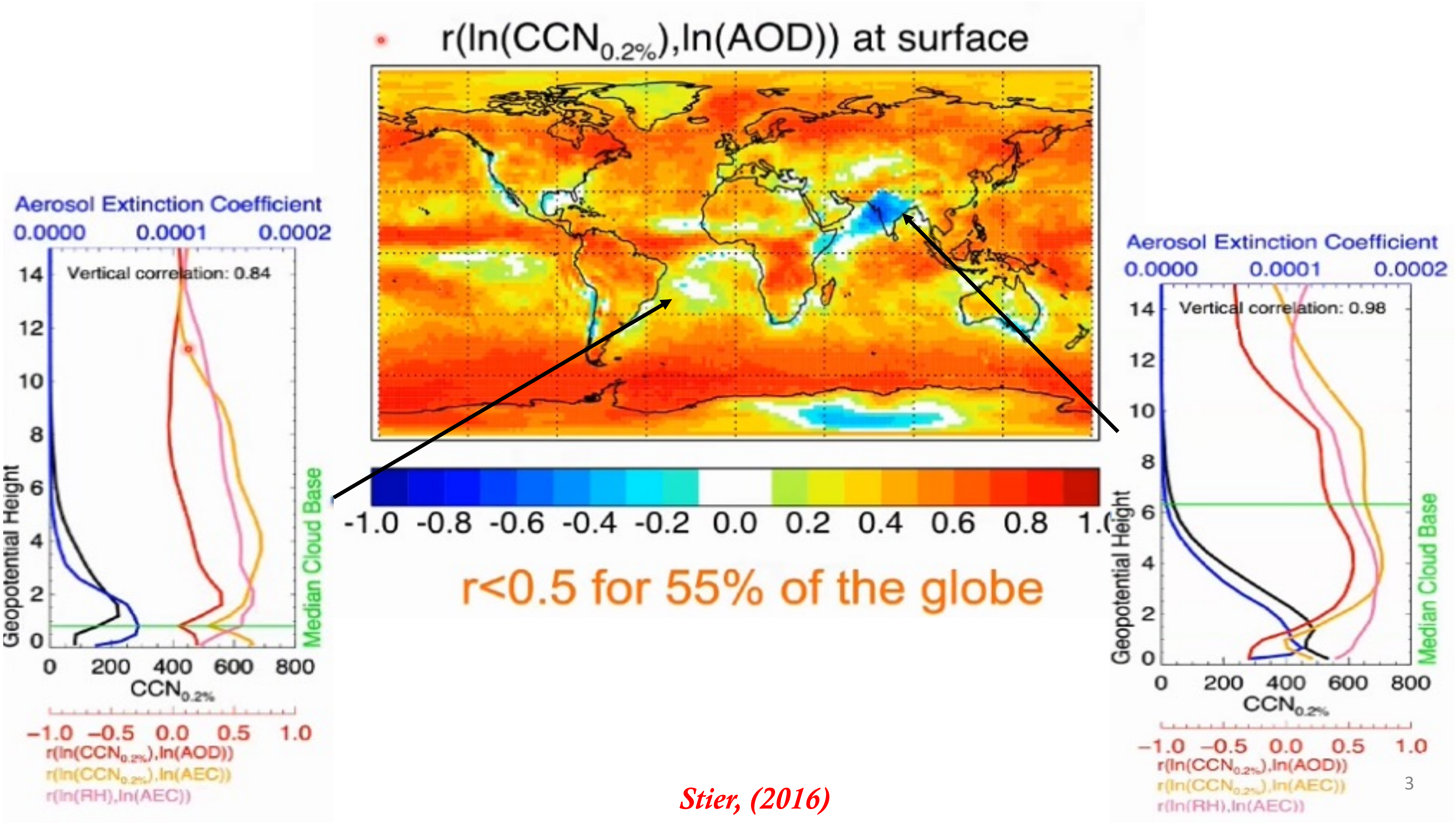


Andreae, (2009)

<u>Various issues and limitations</u>: (*Andrea, 2009; Kapustin et al., 200; Boucher and Quass, 2013; Liu and Li, 2014*)

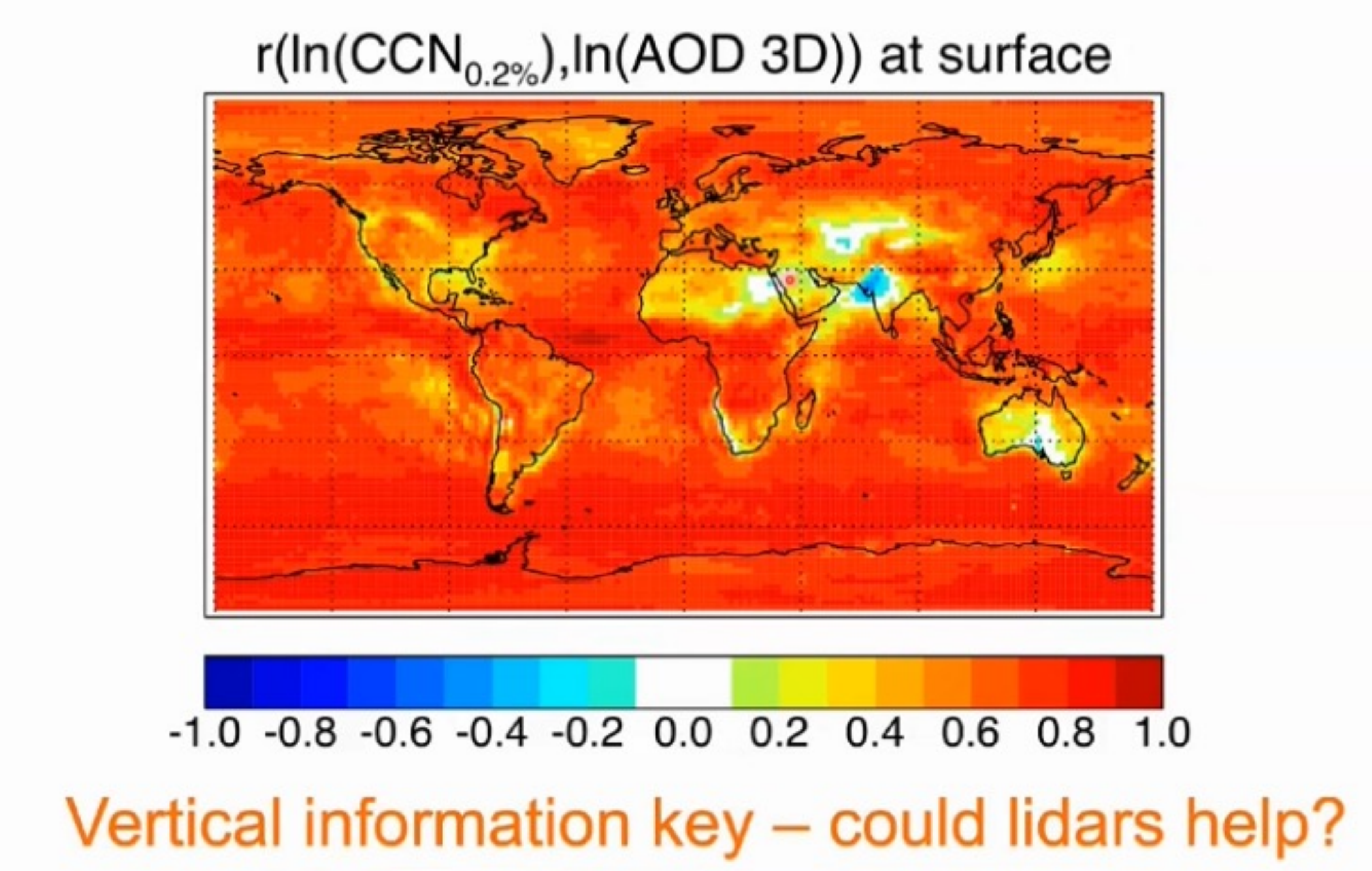
- uncertainty in size distribution and solubility
- aerosol swelling in the humid environment
- AOD/AI does not provide involved aerosol components / chemical compositions
- AOD is a bulk property and doesn't represent the vertical distribution of aerosol
- AOD doesn't provide the information on CCN
- CCN activation controls by particle size and chemical compositions

Suitability of AOD as a proxy for CCN



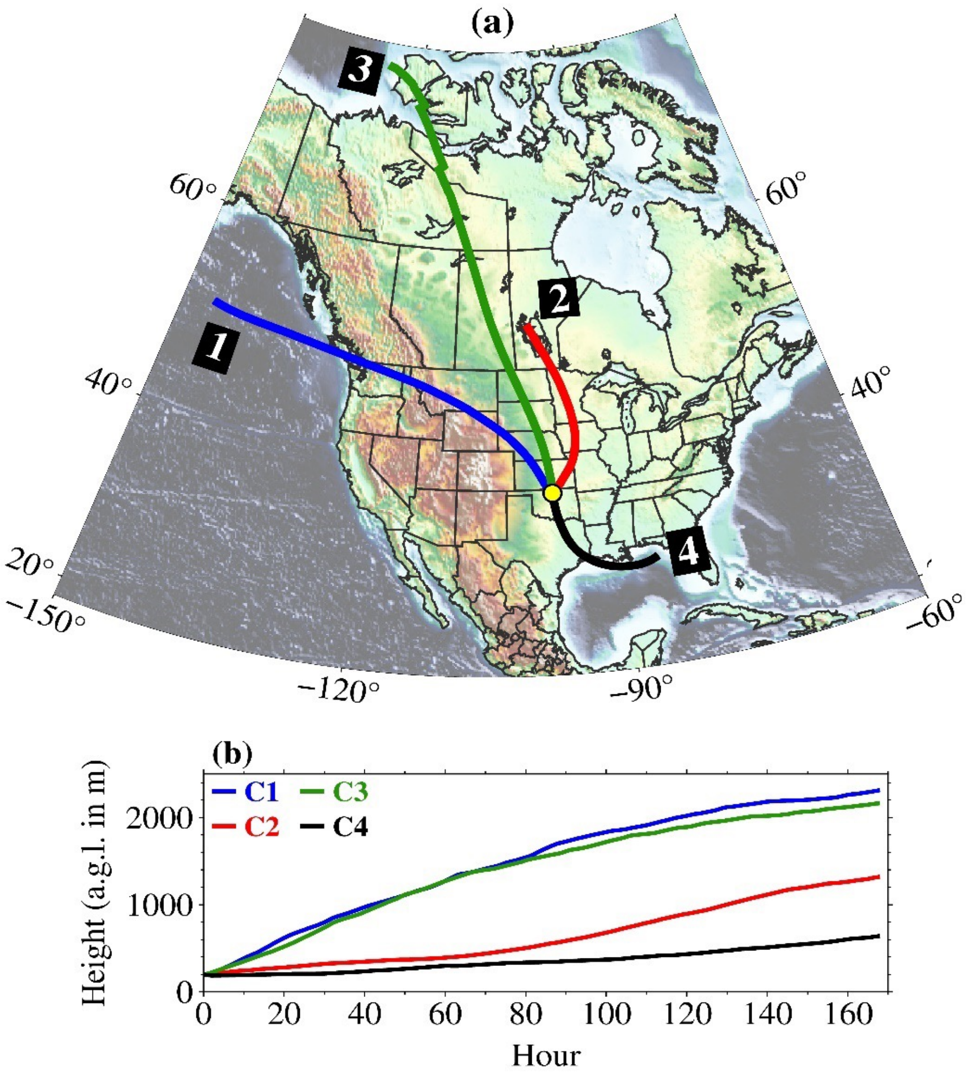
Stier, (2016)

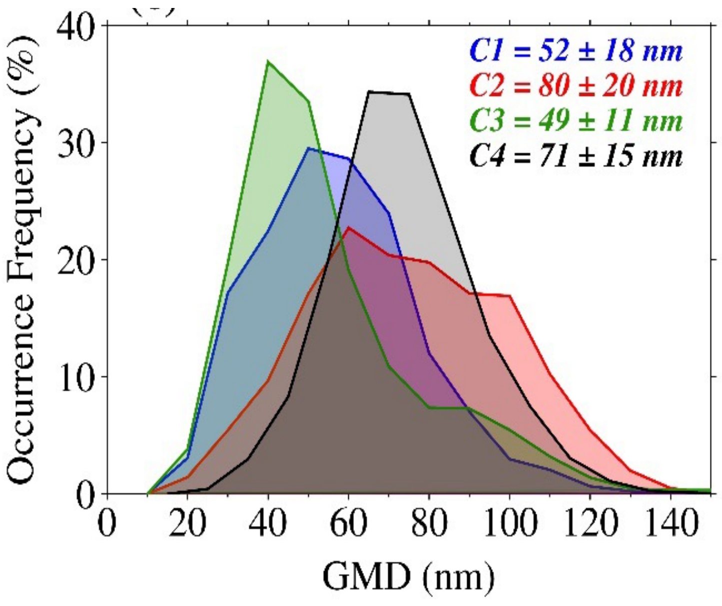
Suitability of AOD as a proxy for CCN

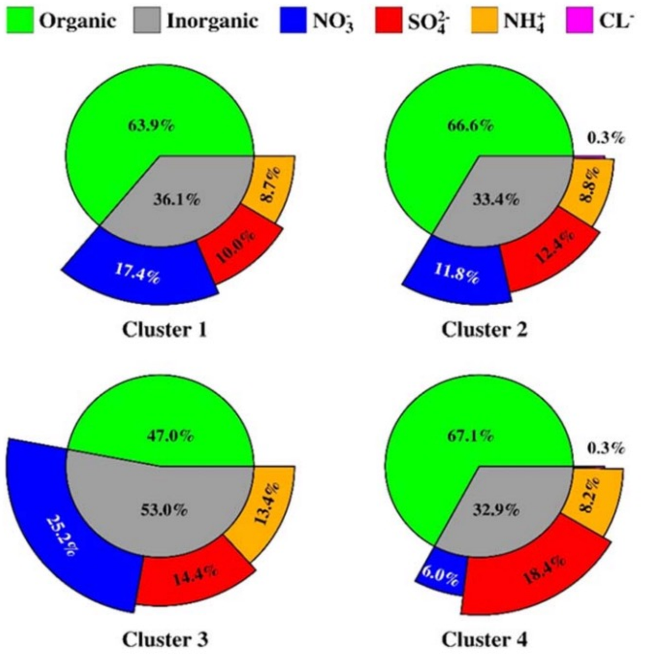


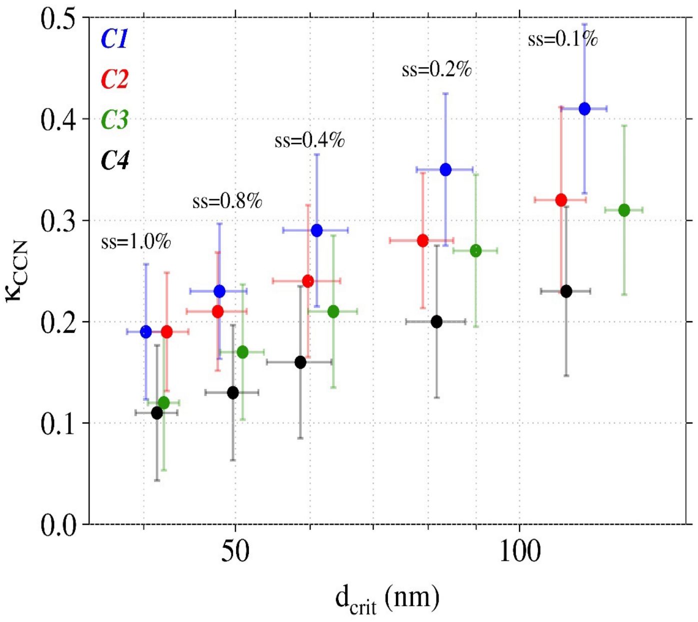
Stier, (2016)

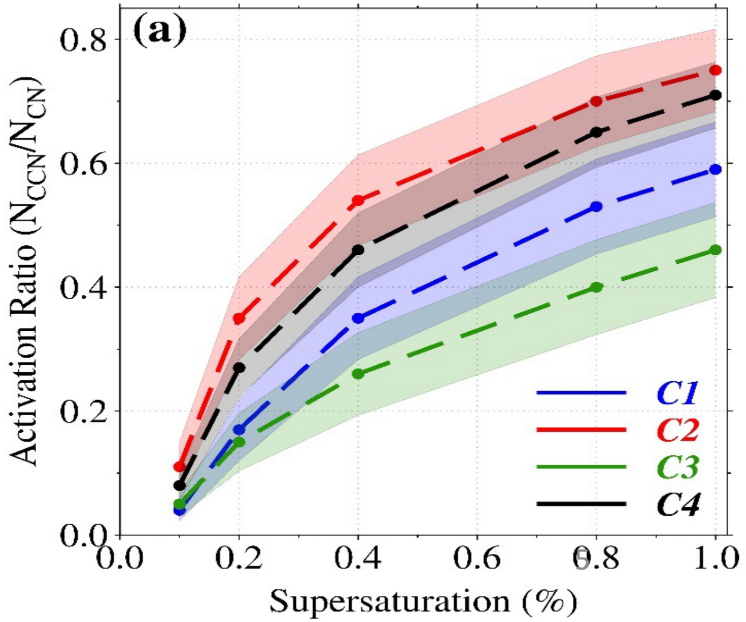
aerosol–CCN activity at SGP





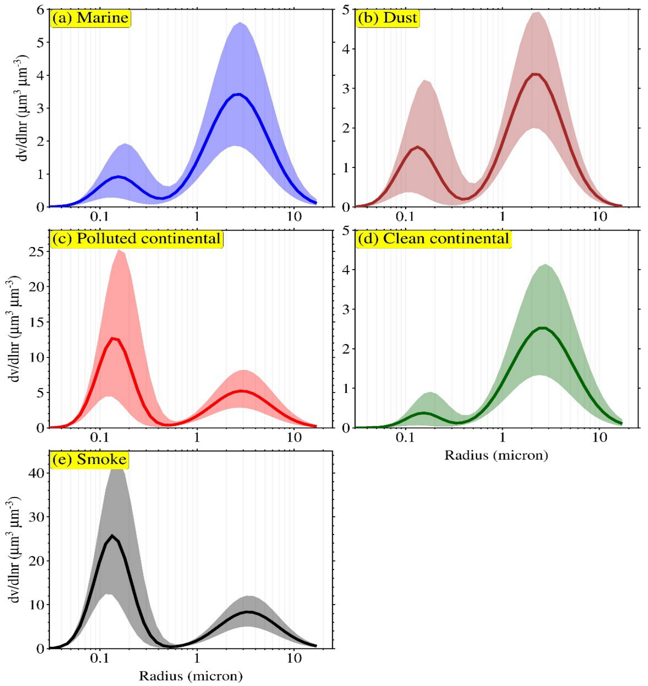






Patel and Jiang, (2021), ERC

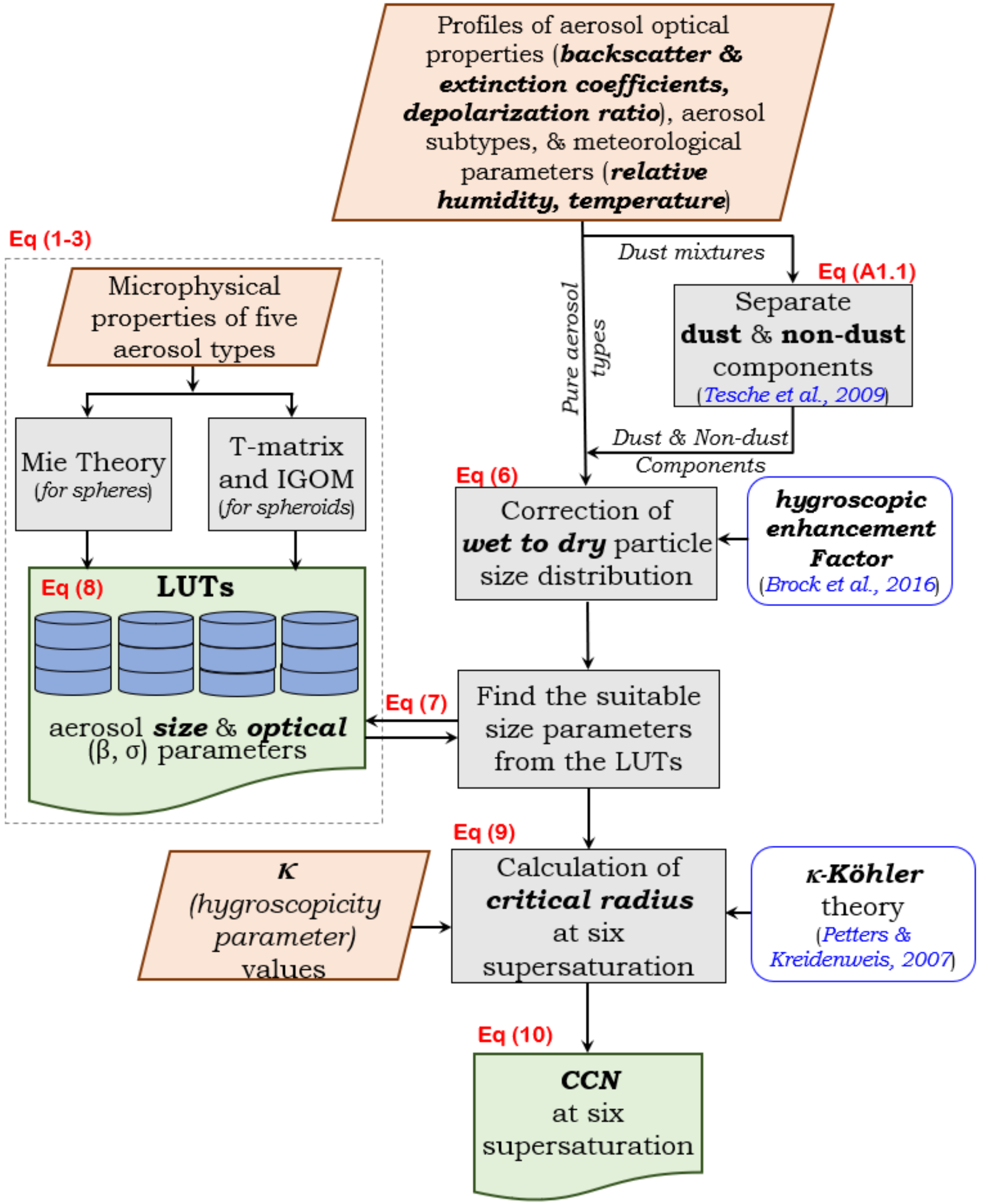
CCN retrieval from lidar observations



$$\frac{dn(r)}{d\ln(r)} = \sum_{i=f,c} \frac{N_{ti}}{(2\pi)^{1/2}\ln\sigma_i}\exp\left[-\frac{(\ln r - \ln r_i^n)^2}{2(\ln\sigma_i)^2}\right]$$

- Radius of PSD : 0.01-10 µm with a fixed bin size of 0.002
- Intervals of σ_f, σ_c, r_f and r_c are fixed at 0.01, 0.01, 0.002 and 0.01 µm
- Intervals are set as a compromise between accuracy and computation time

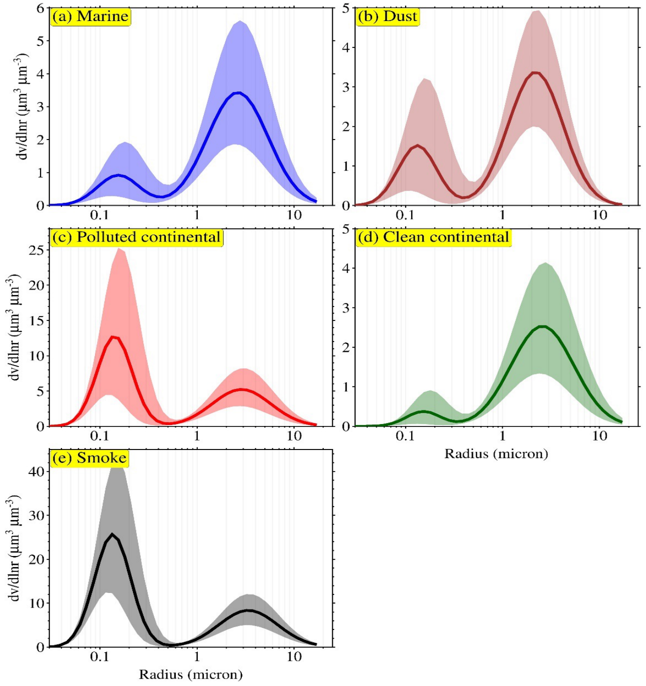
Patel et al., 2023, ACP, under review



$$\beta_d = \beta_p \frac{(\delta_p - \delta_2)(1+\delta_1)}{(\delta_1 - \delta_2)(1+\delta_p)}$$

- δ_1 (0.24, 0.31 and 0.06) and δ_2 (0.03, 0.05, and 0.02) at 355, 532 and 1064 nm
- ratio $\boldsymbol{\delta_p} > \boldsymbol{\delta_1}$ ($< \boldsymbol{\delta_2}$) then aerosol mixture is considered as **pure dust** (**non-dust**).
- lidar ratio of 44 for dust and 23 for marine
- 58, 70 and 30 at 355, 532 and 1064 nm for polluted continental

CCN retrieval from lidar observations



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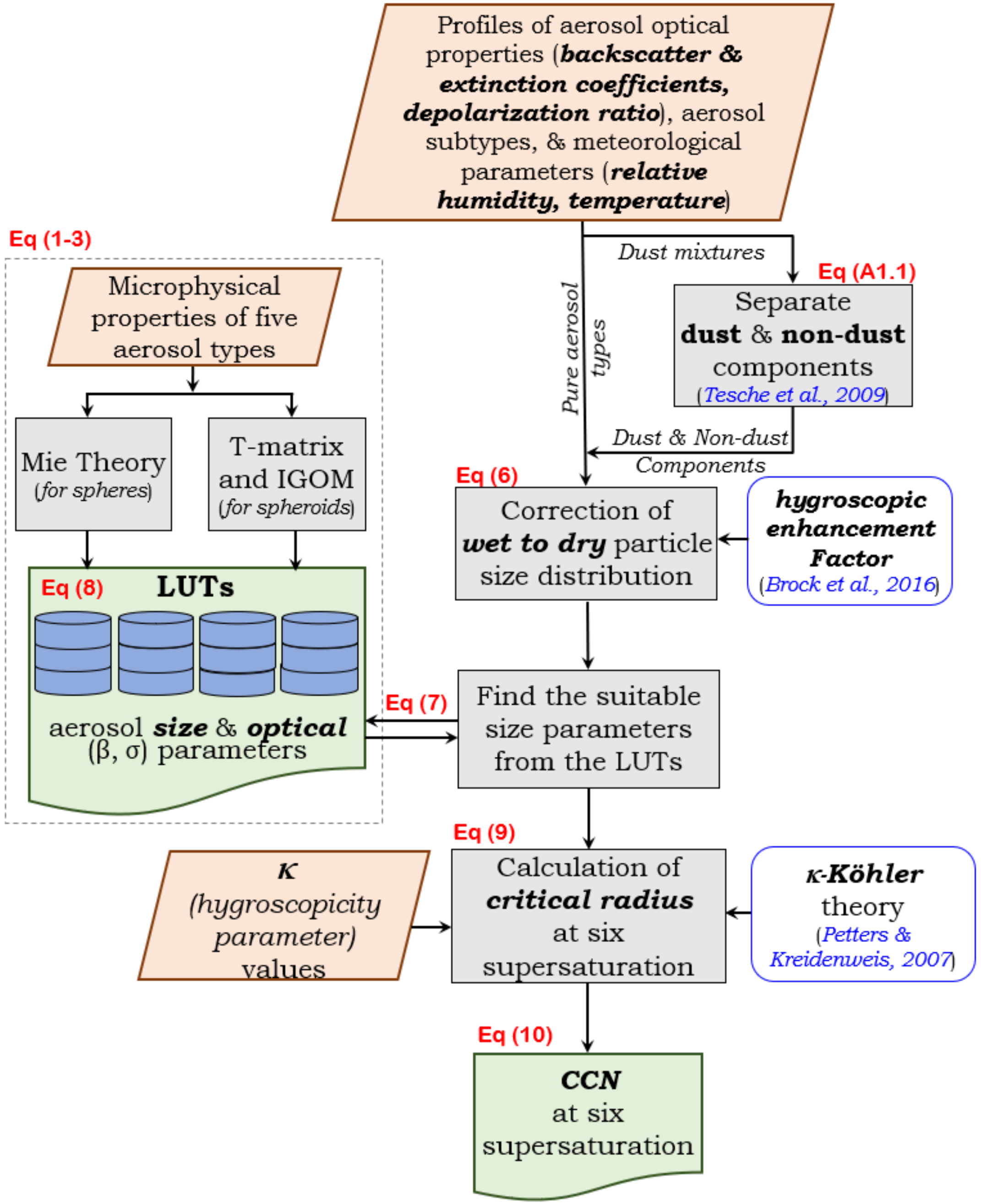
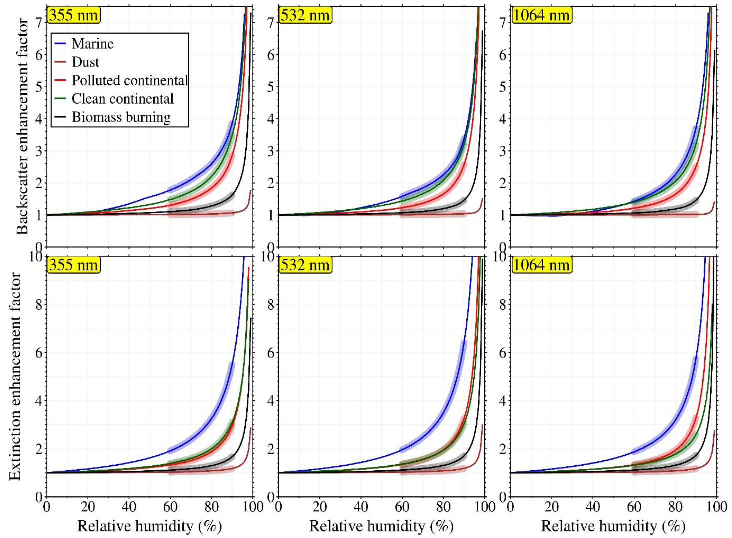




$$\xi(RH,\lambda) = \xi_{dry}(RH,\lambda)\,.\,f_\xi(RH)$$

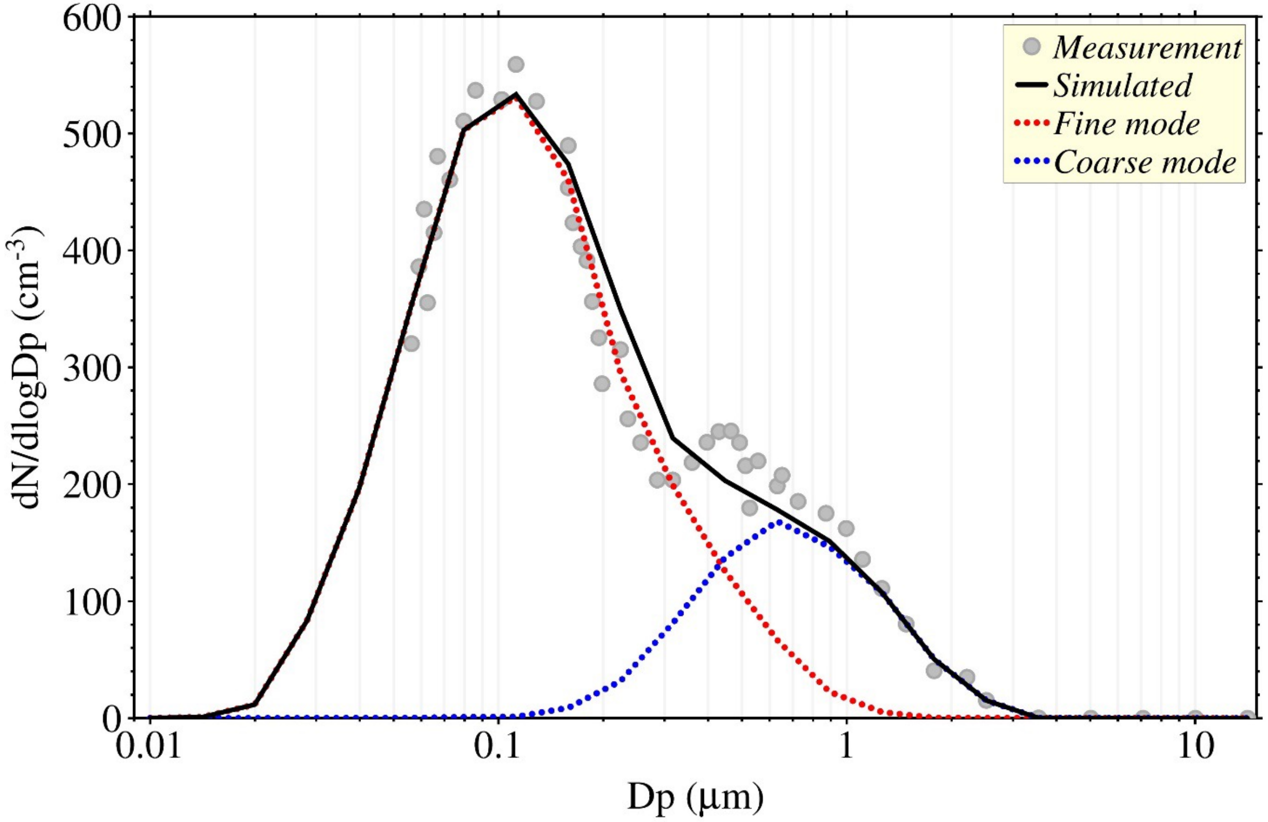
$$= \xi_{dry}(RH,\lambda)\,.\,\left[1 + \kappa_\xi(\lambda)\frac{RH}{100 - RH}\right]$$

$$D_{crit} = \left(\frac{4A^3}{27 * \kappa * \ln(S_c)^2}\right)^{1/3}; \quad A = \frac{4\sigma_{s/a}M_w}{RT\rho_w}$$

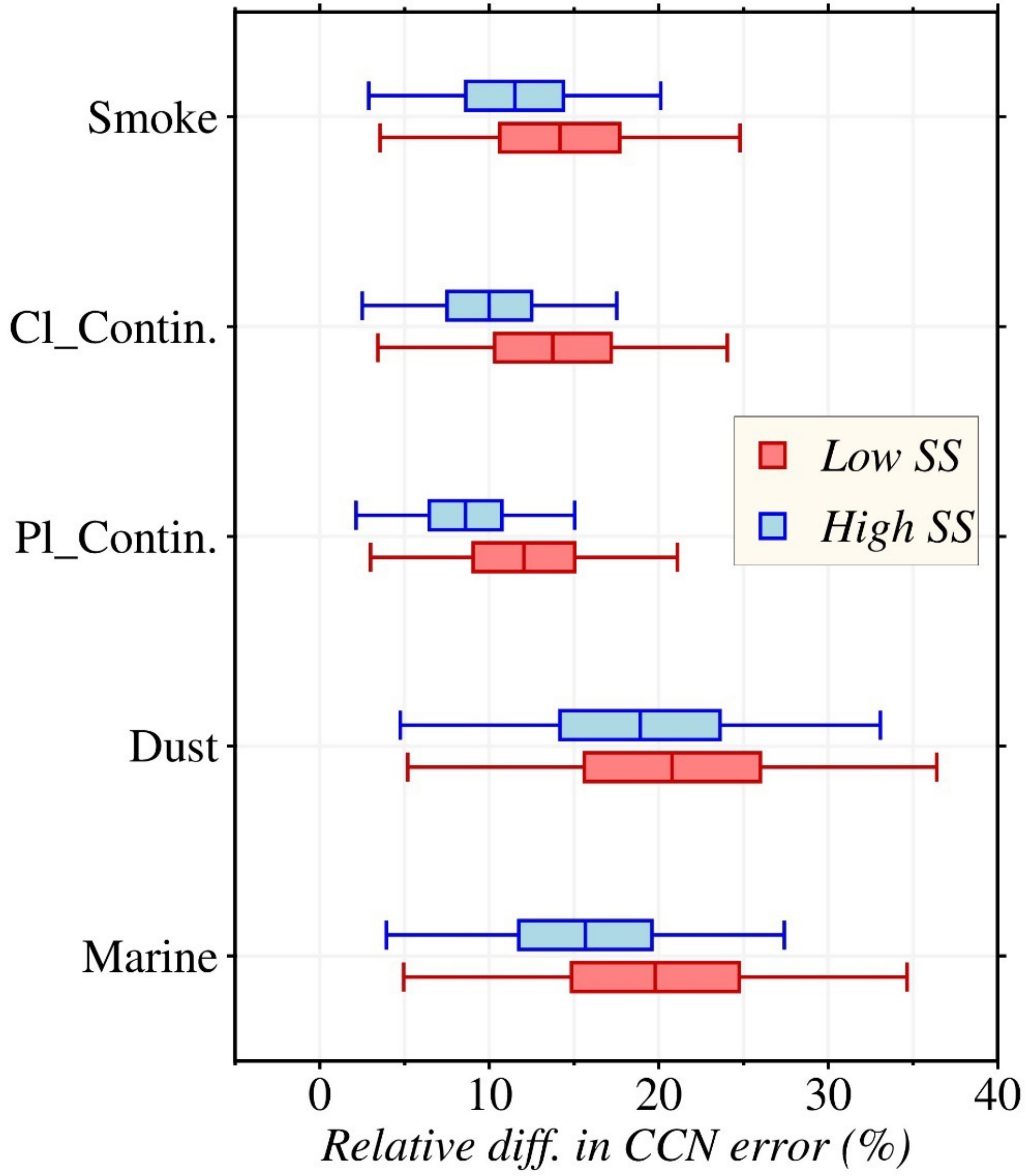
$$N_{ccn} = \int_{\ln r_c}^{\ln r_{max}} \frac{dn(r)}{d\ln(r)}\, d\ln(r)$$

Patel et al., 2023, ACP, under review

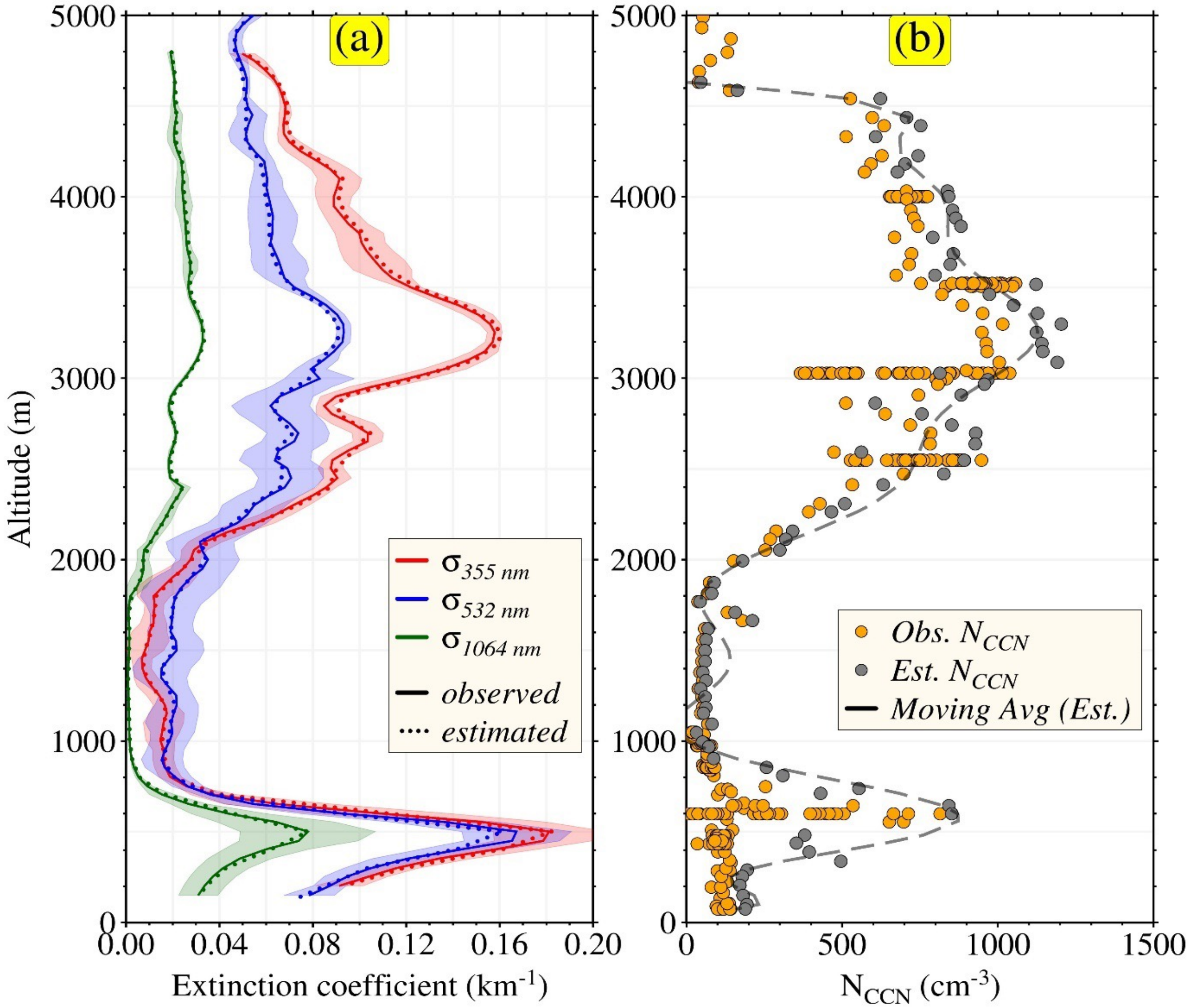
The observed aerosol size distribution and the corresponding bimodal fits.

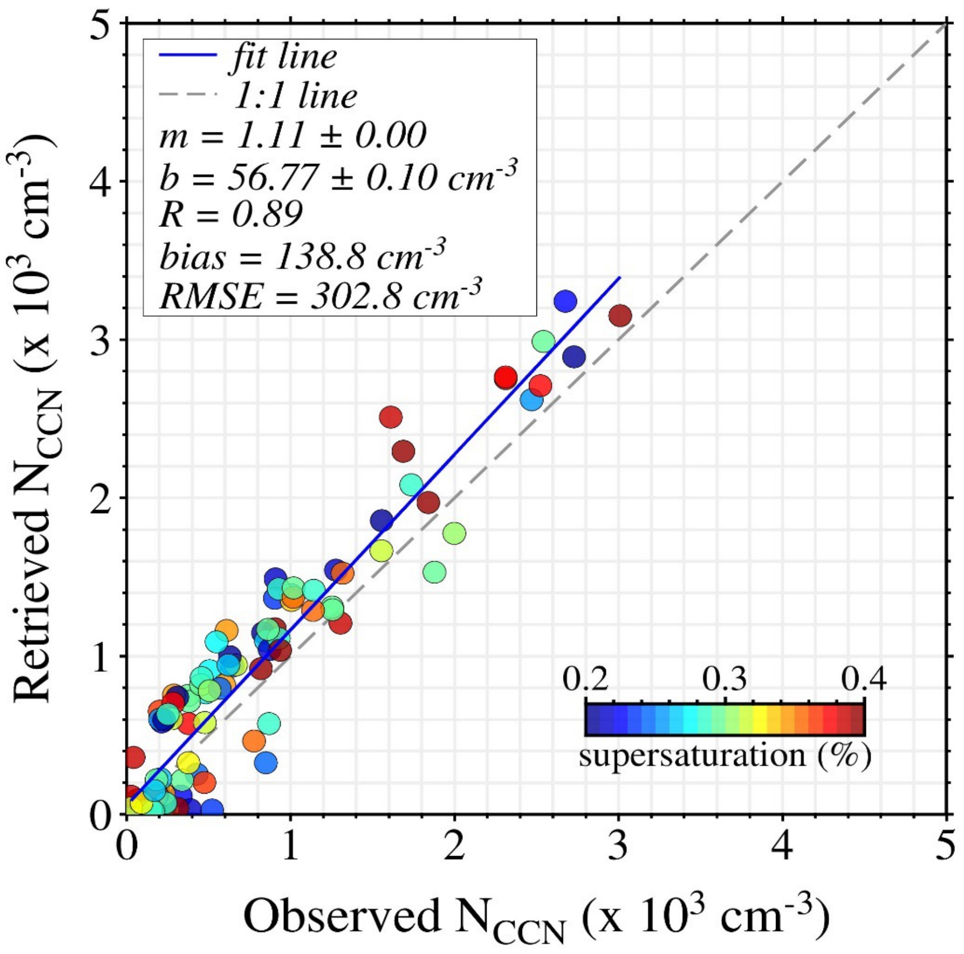


Relative difference in CCN error between 3β+2α and 3β+3α.



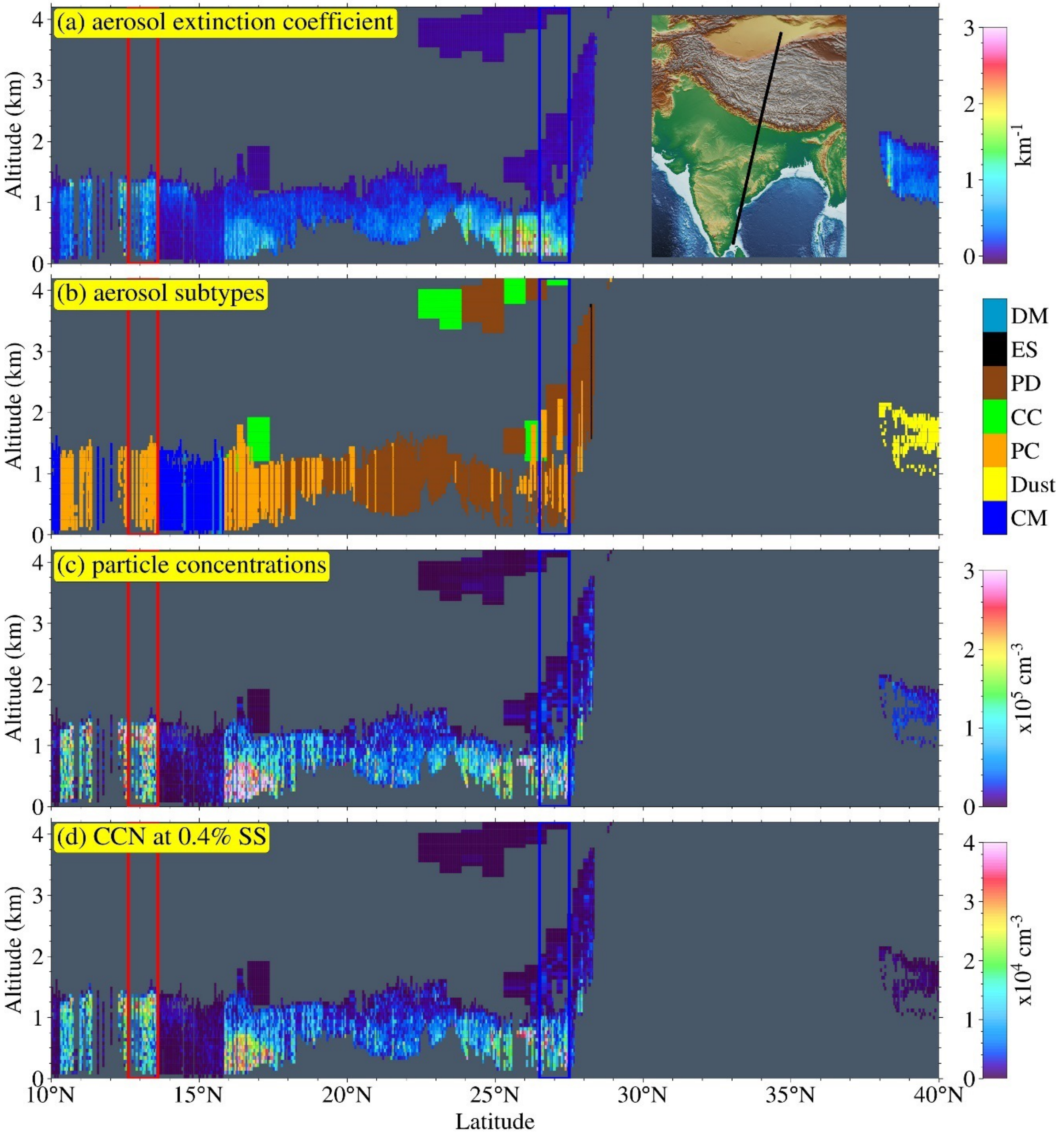
Comparison with airborne observations (NASA ORACLES)

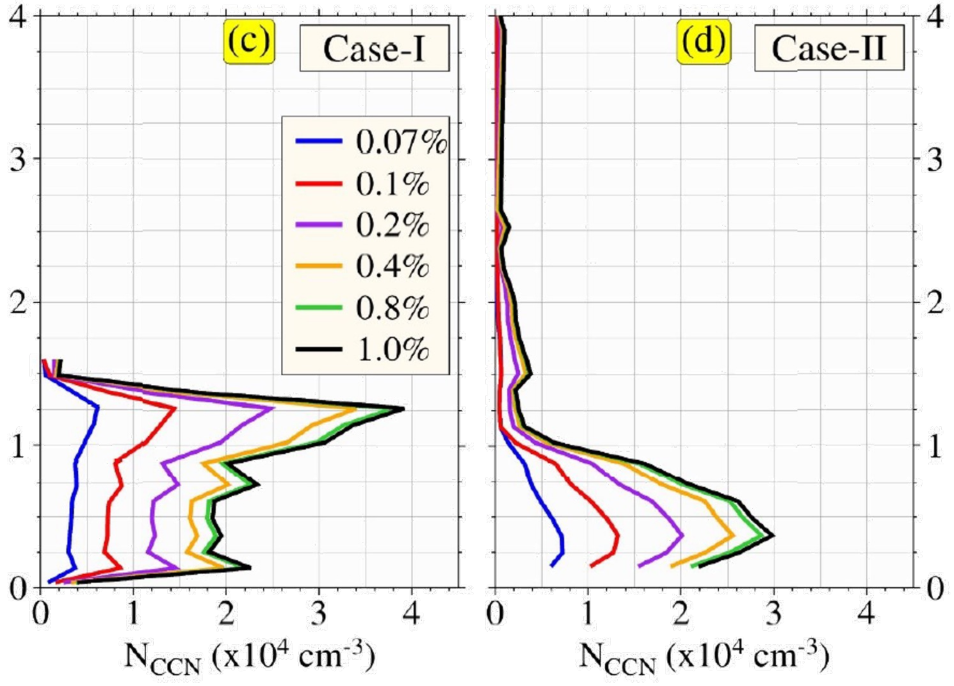


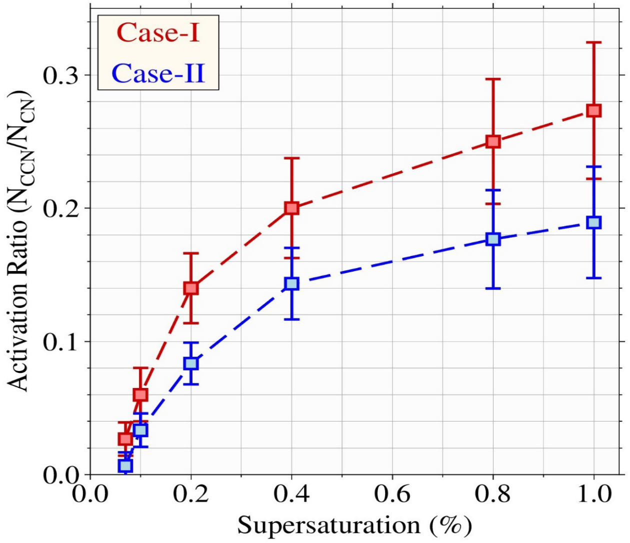


Patel et al., 2023, ACP, under review

Satellite retrieved CCN (CALIOP-CALIPSO)







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Conclusion

- We presented an emergent remote sensing-based analytical algorithm based on the physical law to retrieve the vertically resolved N_{CCN} from aerosol optical properties measured by the multiwavelength lidar system.
- The results demonstrate that the N_{CCN} retrieved by our algorithm is highly influenced by the variability of aerosol particle size and composition based on aerosol subtypes and also captures the meteorological influence.
- The ability of CALIOP to detect the aerosol subtypes has facilitated the retrieval of aerosol type-specific 3D N_{CCN} climatology on a global scale. These datasets from spaceborne lidar measurements will be beneficial for evaluating models and other satellite products, opening a new window to investigate the region and regime-wise detailed ACI studies and better constraining anthropogenic contributions to the climate forcing in the climate model.

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Extreme Smog Challenge of India Intensified by Increasing Lower Tropospheric Stability

Ritesh Gautam and Piyushkumar N. Patel contributed equally to this work.

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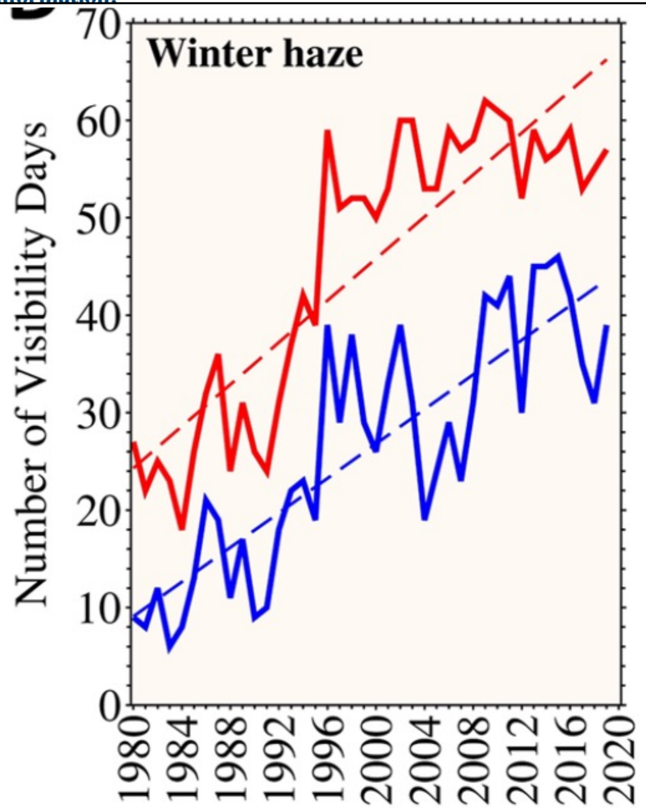
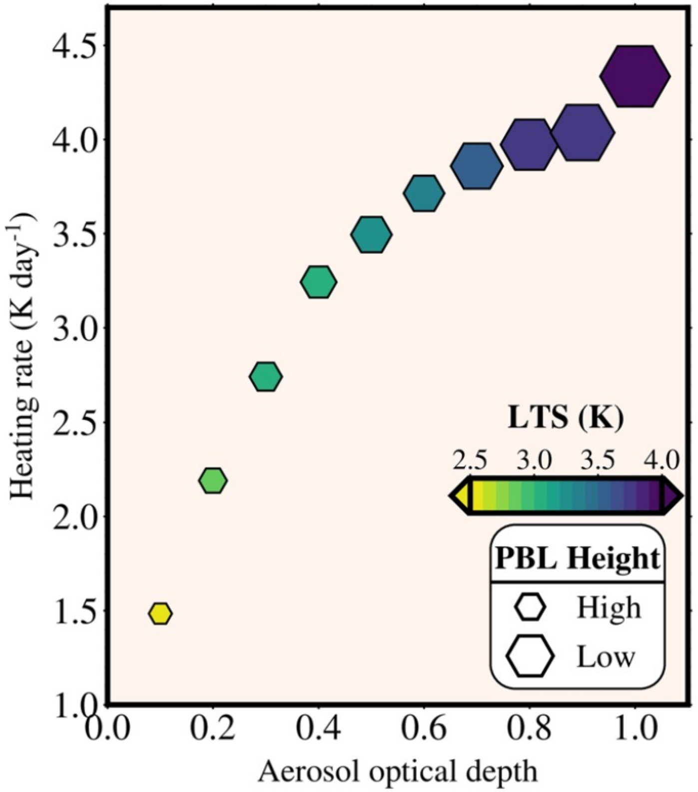
Key Point:

- Past 40-year observations reveal aerosol-induced radiation-meteorological feedbacks have intensified extreme smog in India

Supporting Information:






Thank you