Addressing the difficulties in quantifying the Twomey effect from satellite observations

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Contents

Twomey effect

- increase in CCN -> increase in in N_d
- decrease in R_e (LWP ~ constant)
  - -> increase in cloud albedo
  - -> negative radiative forcing
  - -> offset the warming by GHGs

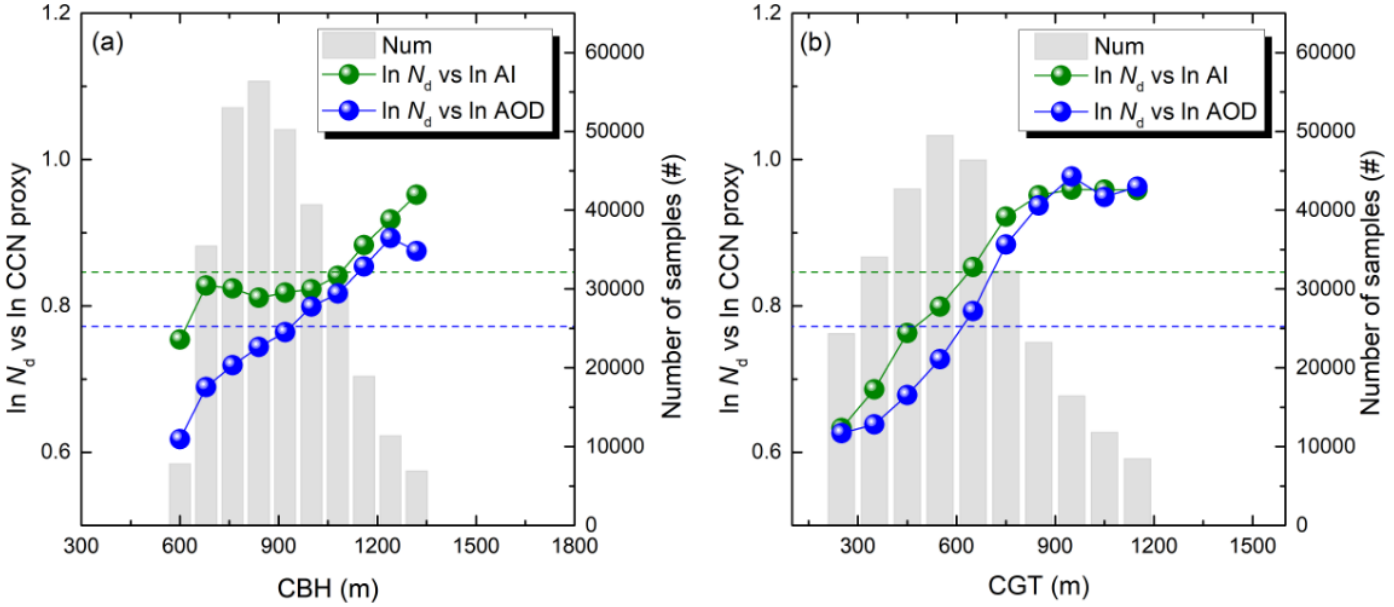
$$\mathcal{F}_{aci} = F_s^{\downarrow} \cdot \frac{\partial \alpha_c}{\partial \ln N_d} \cdot \frac{\partial \ln N_d}{\partial \ln a} \cdot \Delta \ln a_{ant}$$

S

- updraft
- precipitation
- retrieval biases
- vertical co-location of aerosol and cloud

Jia et al. (2022) ACP, accepted

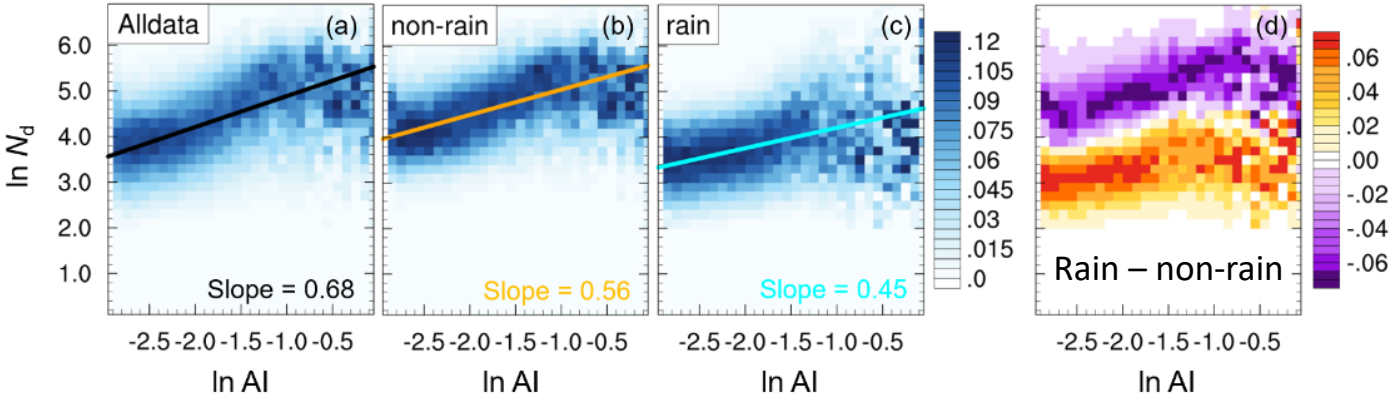
Dependence of *S* on updraft

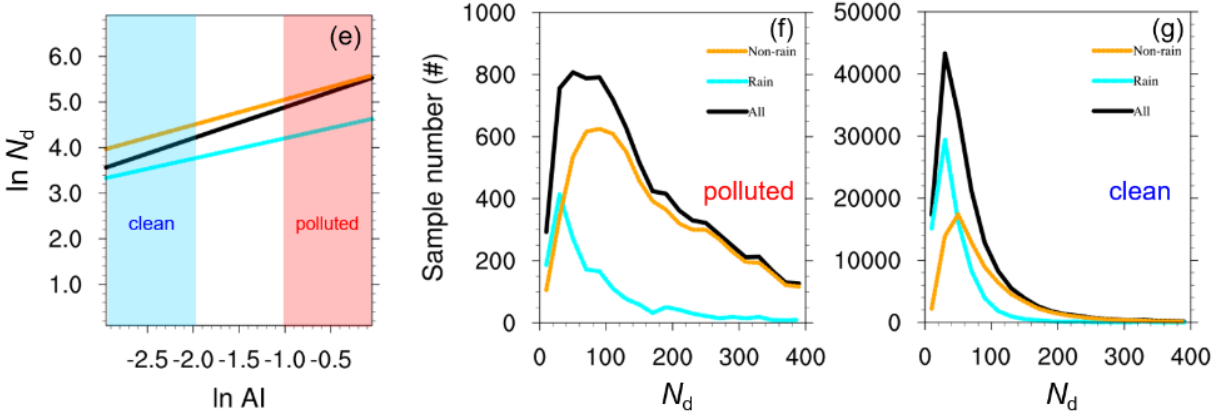


* Nd from MOD06
* *AOD/AI from MOD08*
* CBH &CGT from MISR observation
(Böhm et al,AMT, 2019)

- Cloud base height (CBH) and cloud geometric thickness (CGT) as proxies of updraft
  (Zheng and Rosenfeld, GRL, 2015)
- Stronger aerosol-cloud interactions at larger updraft velocity

Dependence of *S* on precipitation





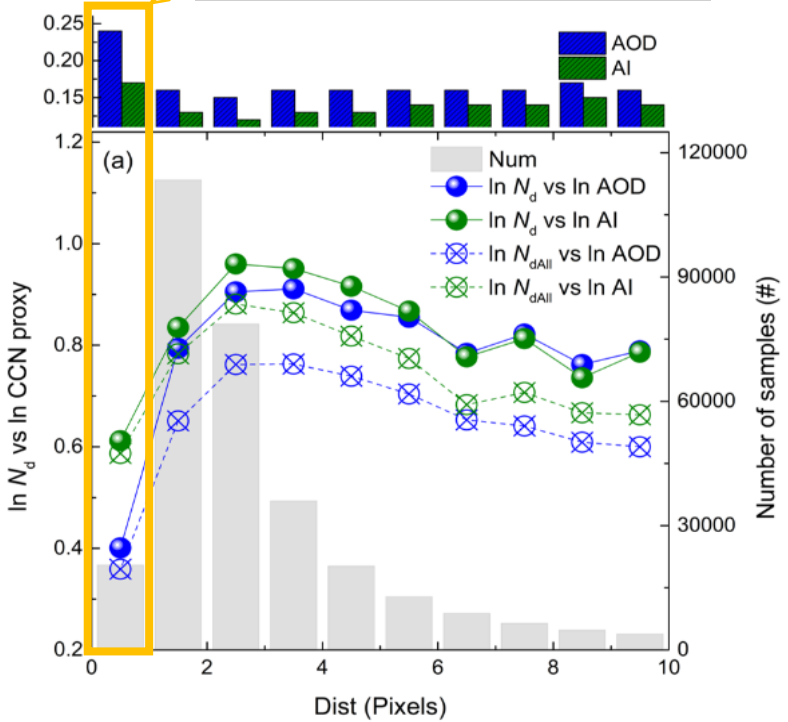
* Nd from MOD06
* *AOD/AI from MOD08*
* Precipitation info from CloudSat

- Introducing the confounding effect of aerosol–precipitation interaction can artificially amplify Nd-to-aerosol sensitivity by 21 %
  - from 0.56 to 0.68

Jia et al. (2022) ACP, accepted

Dependence of *S* on retrieval biases

- cloud contamination
- cloud adjacency (or 3-D) effect
- aerosol swelling effect



*distance to nearest cloudy pixel from clear pixels for aerosol retrieval

Nd: quality-assured Nd

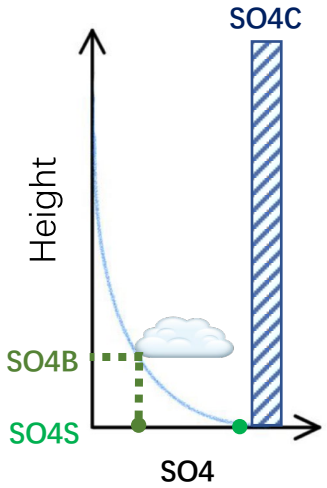
(Grosvenor et al., Rev. Geophys, 2018)

Nd_{All} : no cloud screening applied

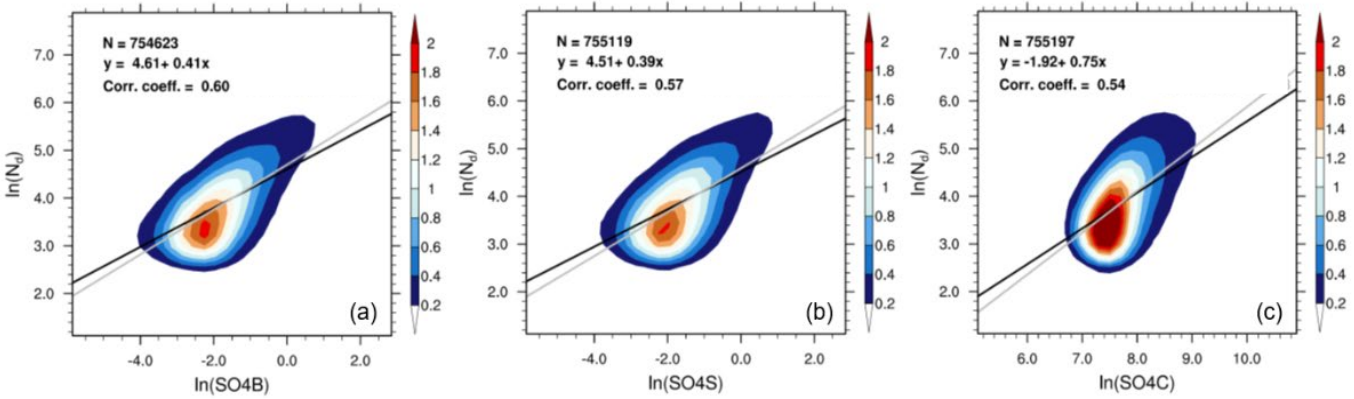
- Retrieval biases in both aerosol and cloud appear to underestimate the strength of the Twomey effect

Dependence of *S* on vertical co-location of aerosol and cloud

* Nd from MOD06
** SO4 from MERRA-2*



Two-dimensional probability density functions



sulfate mass concentrations near cloud base

sulfate surface mass concentrations

sulfate column mass density

Corr. Coeff.	0.60	0.57	0.54
Slope	0.41	0.39	0.75

- **Use of SO4C can result in a nearly twofold enhancement of the estimated *S***
- **Use of near-surface aerosol measurements is promising**

Jia et al. (2022) ACP, accepted

Conclusions

- Sources of the uncertainty in *S* from satellite-based method:
  - ? - updraft
  - ↑ - precipitation
  - ↓ - retrieval biases
  - ↑ - vertical co-location of aerosol and cloud

- What's next?
  - an 'optimal' estimate of RFaci

Jia, H., Quaas, J., Gryspeerdt, E., Böhm, C., and Sourdeval, O.: ***Addressing the difficulties in quantifying the Twomey effect for marine warm clouds from multi-sensor satellite observations and reanalysis****, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2021-999, in review, 2022.*