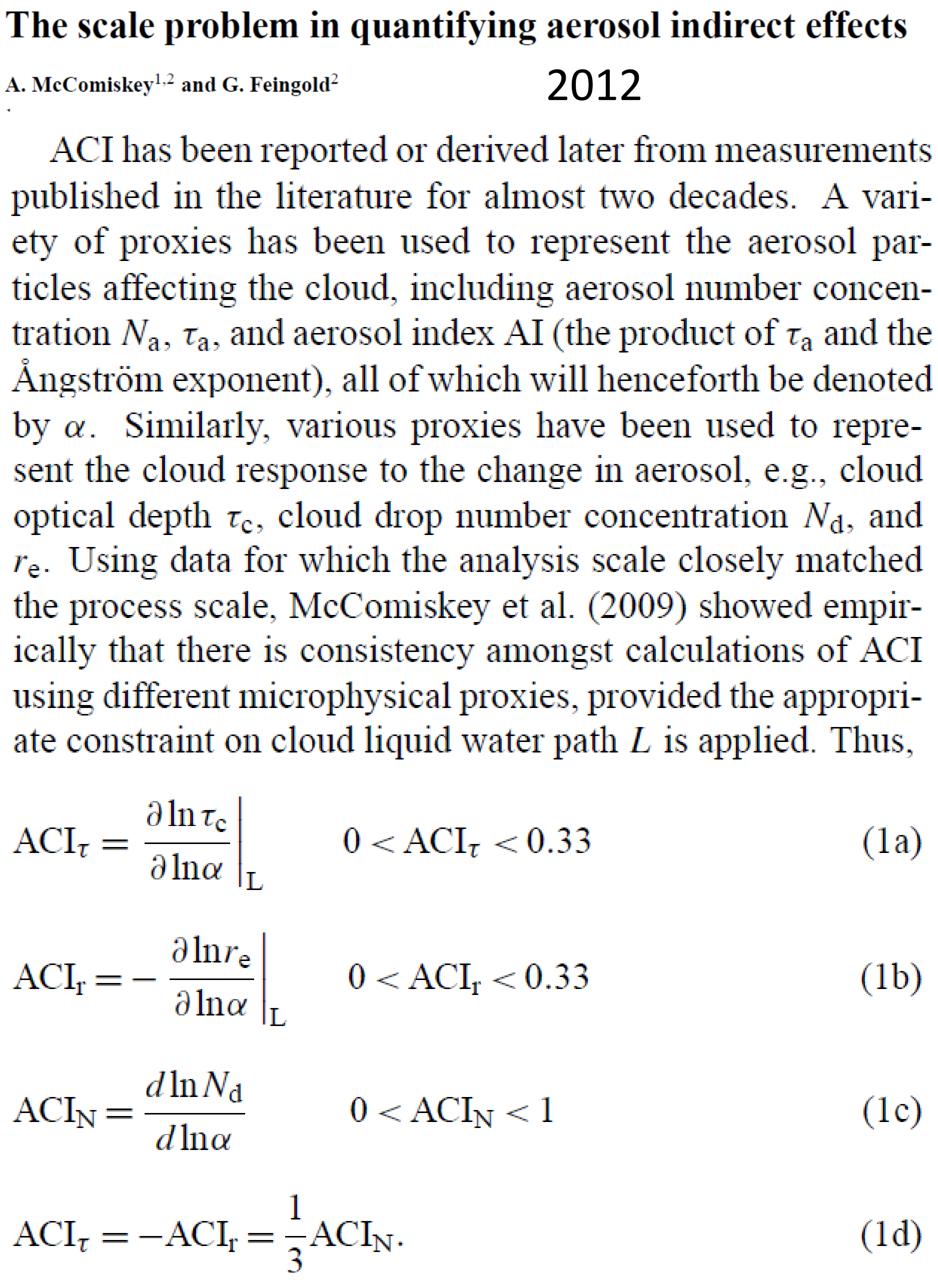
Partial derivatives computed for passive satellite products



The scale problem in quantifying aerosol indirect effects

A. McComiskey[1,2] and G. Feingold[2]

2012

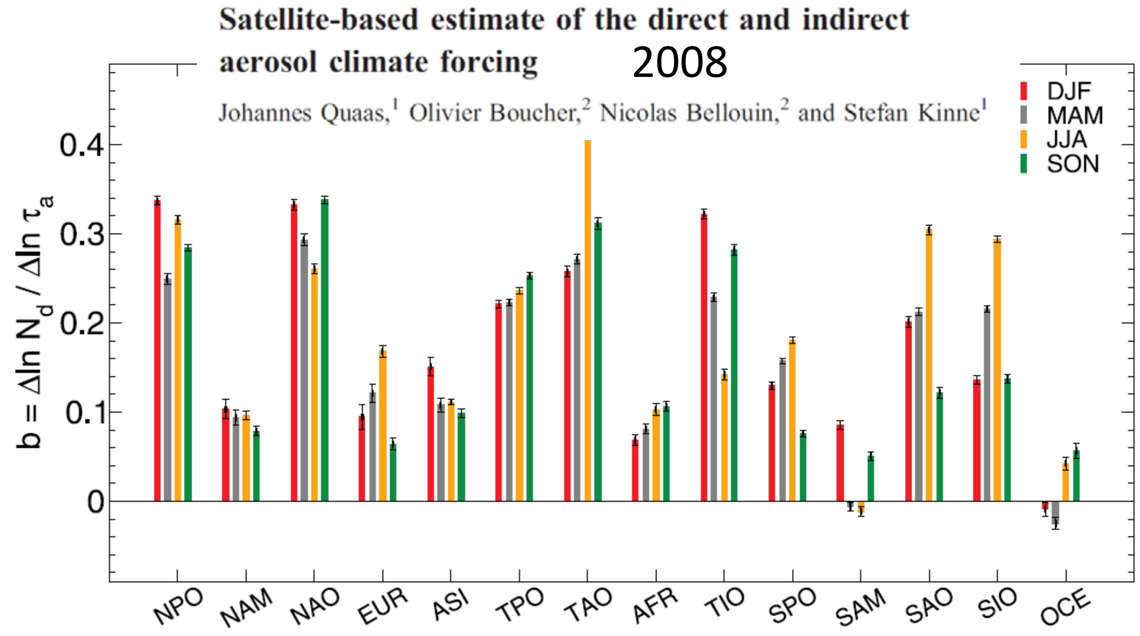
ACI has been reported or derived later from measurements published in the literature for almost two decades. A variety of proxies has been used to represent the aerosol particles affecting the cloud, including aerosol number concentration N_a, τ_a, and aerosol index AI (the product of τ_a and the Ångström exponent), all of which will henceforth be denoted by α. Similarly, various proxies have been used to represent the cloud response to the change in aerosol, e.g., cloud optical depth τ_c, cloud drop number concentration N_d, and r_e. Using data for which the analysis scale closely matched the process scale, McComiskey et al. (2009) showed empirically that there is consistency amongst calculations of ACI using different microphysical proxies, provided the appropriate constraint on cloud liquid water path L is applied. Thus,

$$\mathrm{ACI}_\tau = \left.\frac{\partial \ln \tau_c}{\partial \ln \alpha}\right|_L \qquad 0 < \mathrm{ACI}_\tau < 0.33 \tag{1a}$$

$$\mathrm{ACI}_r = -\left.\frac{\partial \ln r_e}{\partial \ln \alpha}\right|_L \qquad 0 < \mathrm{ACI}_r < 0.33 \tag{1b}$$

$$\mathrm{ACI}_N = \frac{d \ln N_d}{d \ln \alpha} \qquad 0 < \mathrm{ACI}_N < 1 \tag{1c}$$

$$\mathrm{ACI}_\tau = -\mathrm{ACI}_r = \frac{1}{3}\mathrm{ACI}_N. \tag{1d}$$



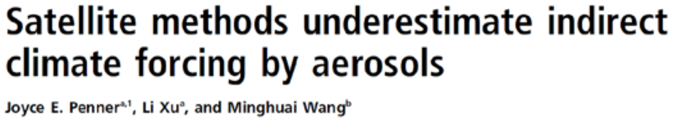
Satellite-based estimate of the direct and indirect aerosol climate forcing

2008

Johannes Quaas,[1] Olivier Boucher,[2] Nicolas Bellouin,[2] and Stefan Kinne[1]

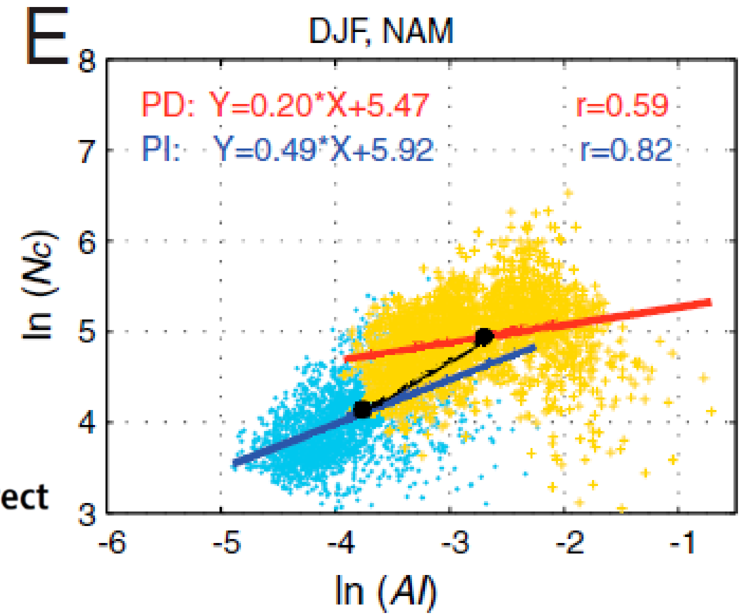
Figure 3. Slopes of the linear regression ln CDNC versus ln AOD for the different regions and seasons. Error bars show 10 times the standard deviation (a list of abbreviations is given in Table 1).

Penner, Xu and Wang, 2011

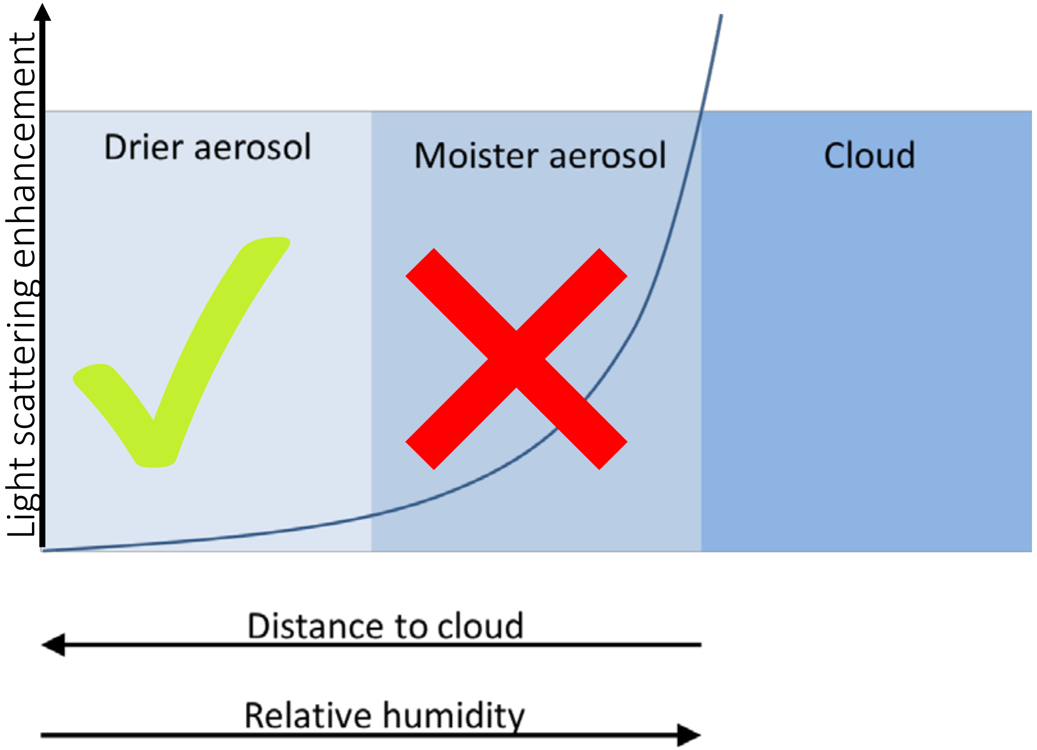


Satellite methods underestimate indirect climate forcing by aerosols

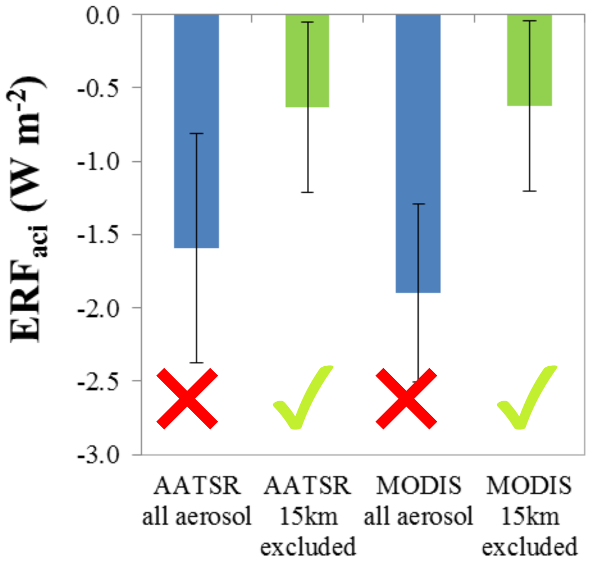
Joyce E. Penner[a,1], Li Xu[a], and Minghuai Wang[b]



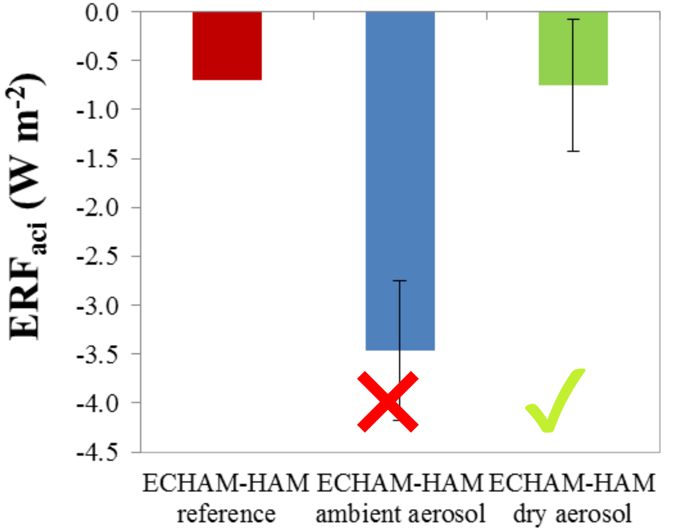
Sampled/dry aerosol CCN proxies



Christensen et al. (2017) ACP



Neubauer et al. (2017) ACP



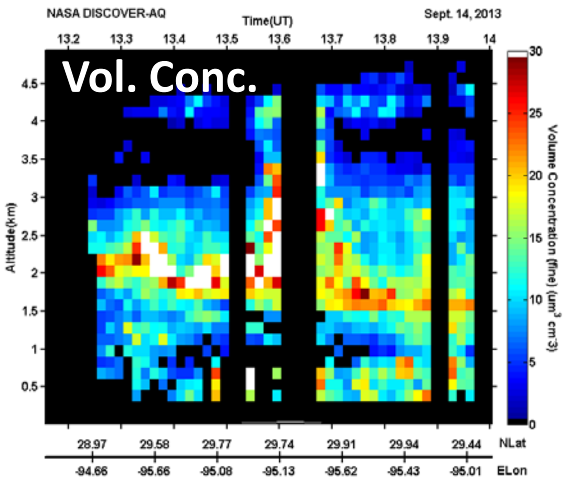
- AOD/AI as CCN proxies overestimate CCN due to water uptake near clouds
- Dry aerosol (model) and excluding near cloud aerosol (satellite) give better CCN proxies
- Large impact on radiative forcing

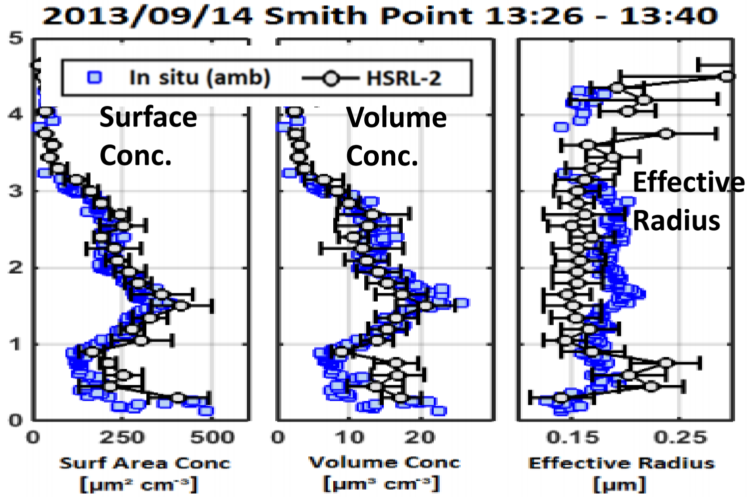
Inferring CCN Concentrations from Remote Sensing

- Stier (ACP, 2016) examined used global model to examine relationships between CCN and aerosol radiative properties
  - Poor correlation between CCN and column retrievals of AOD, fine mode AOD, and Aerosol Index
  - Constraints from passive sensors are particularly limited in key areas of aerosol-cloud radiative forcing
  - Correlations of CCN with local aerosol extinction significantly exceed correlations with column AOD
  - Satellite-based HSRL has large potential for global monitoring of CCN
- Lidar profiles provide a means to remotely infer CCN locally (i.e. at the altitude of clouds*)*
- Backscatter lidar (basic) – provides attenuated backscatter and an estimate of aerosol extinction at cloud altitude
- HSRL (better) – provides calibrated backscatter and accurate extinction at cloud altitude

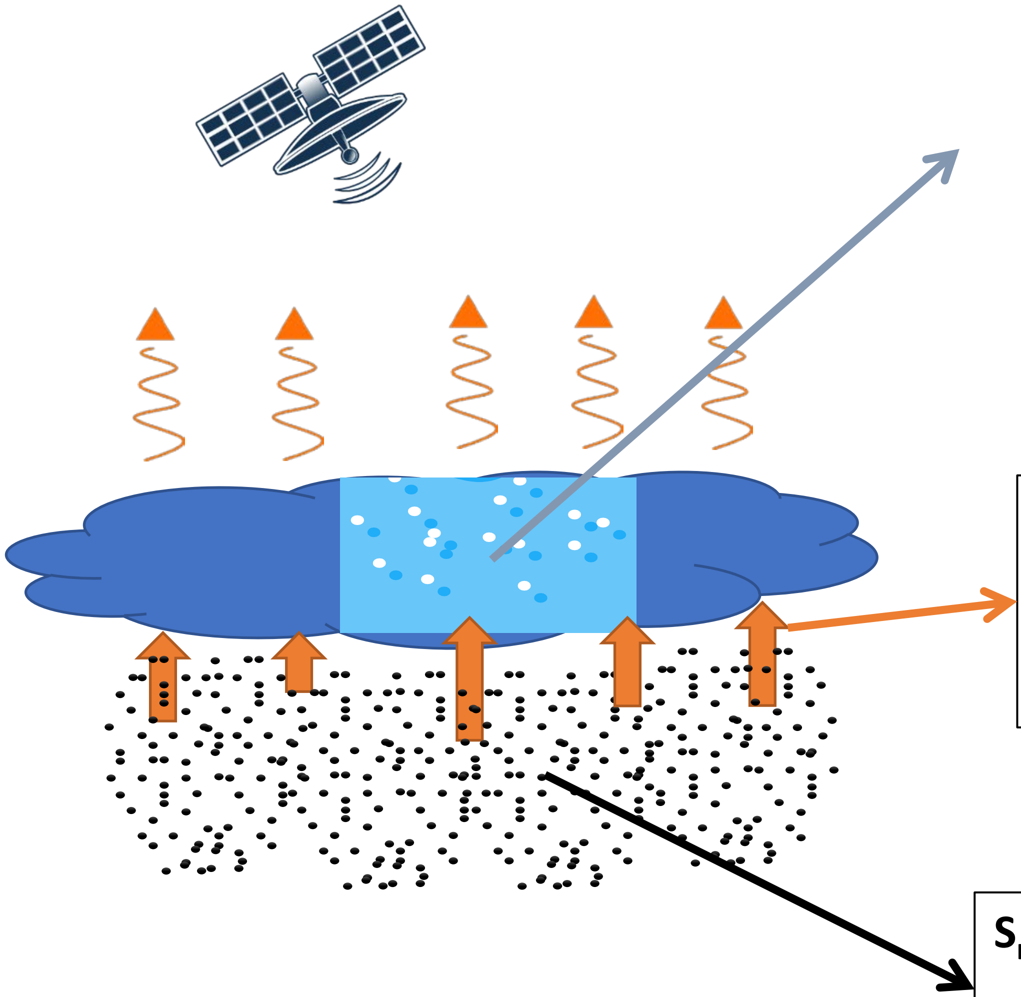
- Multiwavelength HSRL (best) – provides:
  - Calibrated backscatter and accurate extinction at cloud altitude
  - Aerosol Index at cloud altitude
  - Retrievals of aerosol concentration at cloud altitude

Müller et al., 2014, AMT; Sawamura et al., 2017, ACP





CCN(S) retrieval for marine stratocumulus



$$N_d = \frac{2\sqrt{10}}{k\pi Q^3}\left(\frac{c(T,P)\tau}{\rho_w r_e^5}\right)^{1/2}$$

τ = Cloud Optical Thickness (Depth)
r_e = Effective radius

W_b = 0.44 × **CTRC** + 22.3 (cm/s)

W_b =cloud-base updrafts
CTRC = cloud top radiative cooling

S_{max} = C(T,P)$W_b^{3/4}N_d^{-1/2}$

S_{max} = cloud-base maximum supersaturation

CCN retrieval for convective clouds

1. Retrieve N_d based on T-r_e
2. $W_b = 0.9H_b$ (W_b=cloud base updraft) (H_b=cloud base height)
3. $S_{max} = C(T,P)W_b^{3/4}N_d^{-1/2}$