First Aerosol Indirect Effect: Measures and Radiative Forcing

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Theory

$$N_d \propto N_a^{a1}$$

$$IE = \frac{\partial \ln N_d}{\partial \ln \alpha}$$

$$0 \le IE \le 1$$

$$\tau_d \propto N_d^{1/3}$$

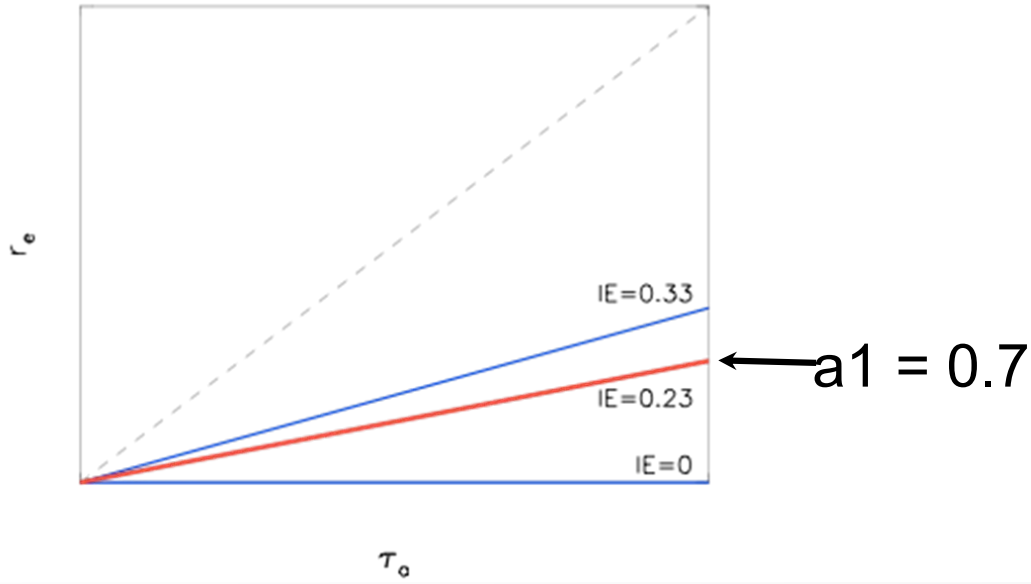
$$IE = \frac{\partial \ln \tau_d}{\partial \ln \alpha}$$

$$0 \le IE \le 0.33$$

$$r_e \propto \tau_d^{-a1/3}$$

$$IE = \frac{\partial \ln r_e}{\partial \ln \alpha}$$

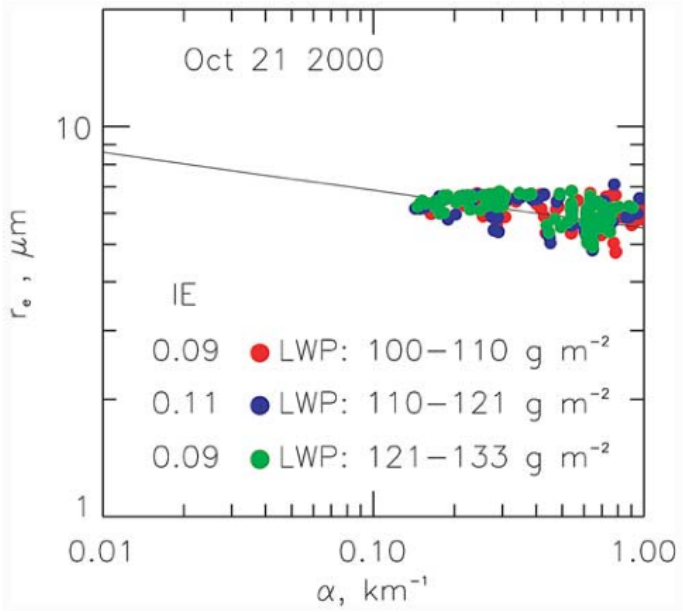
$$-0.33 \le IE \le 0$$



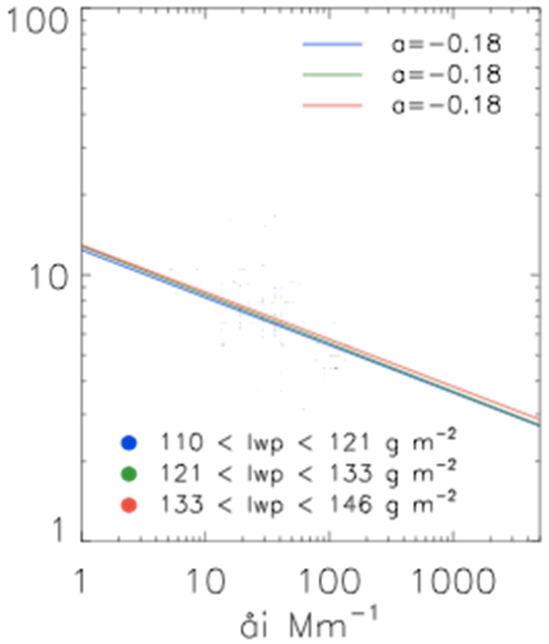
a1 = 0.7

Measures of the first indirect effect from ground-based remote sensing and *in situ* observations at ARM sites

SGP



AMF



Feingold et al., 2003

Literature Survey of Observations of IE

Reference	IE			Platform
	$\partial \ln \tau_d / \partial \ln \alpha$	$\partial \ln r_e / \partial \ln \alpha$	$\partial \ln N_d / \partial \ln \alpha$	
Raga and Jonas, 1993		0.09	**0.26**	in situ airborne
Martin et al., 1994		0.25	**0.75**	in situ airborne
Gultepe, 1996		0.23	**0.67**	in situ airborne
O'Dowd, 1999		0.20	**0.60**	in situ airborne
McFarquhar and Heymsfield, 2001		0.11	**0.34**	in situ airborne
Twohy et al., 2005		0.27	**0.81**	in situ airborne
Ramanathan et al., 2001		0.21 to 0.33	**0.64-1.0**	in situ airborne
Feingold et al., 2003		**0.02 to 0.16***		surface RS
Garrett et al., 2004		**0.13 to 0.19***		surface in situ/RS
Nakajima et al., 2001		0.17	**0.5**	satellite
Breon et al., 2002		**0.085 (ocean) 0.04 (land)**		satellite
Chamiedes et al., 2002	**0.13 to 0.19**	0.13 to 0.19		satellite
Quaas et al., 2004		**0.042 (ocean) 0.012 (land)**		satellite

Questions

- What are the implications in the range of measures on radiative forcing?
- What are the most accurate and robust approaches for observing the first indirect effect?
- Is the range due to physical differences or measurement uncertainty?

Radiative Forcing Calculation

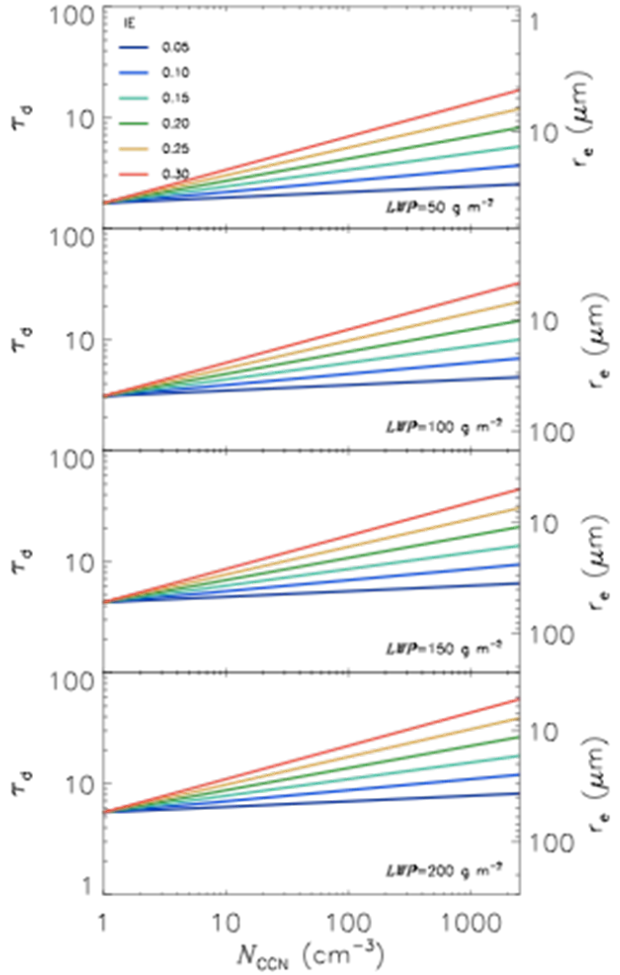
Inputs

$$\tau_{d(0)} = \left[\frac{N_d c^3 LWP^{2.5}}{c^{0.5}} \right]^{0.33}$$

$$\tau_d = \tau_{d(0)} N_{CCN}^{IE}$$

$$r_e = 1.5 \frac{LWP}{\tau_d}$$

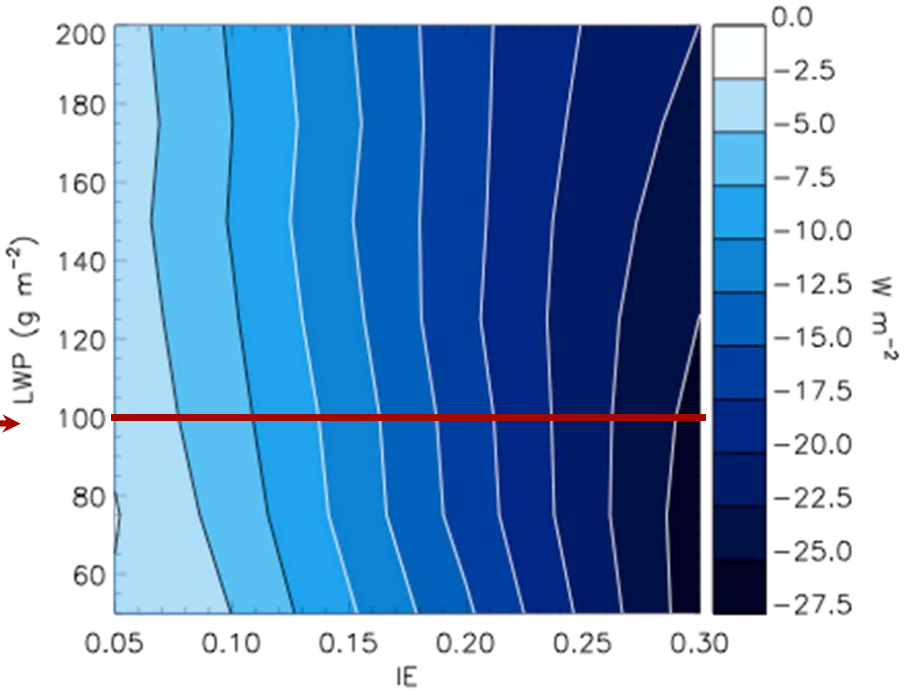
$$H = \left(\frac{2LWP}{c} \right)^{0.5}$$



TOA Radiative Forcing

mid-latitude (45) diurnal average for the equinox

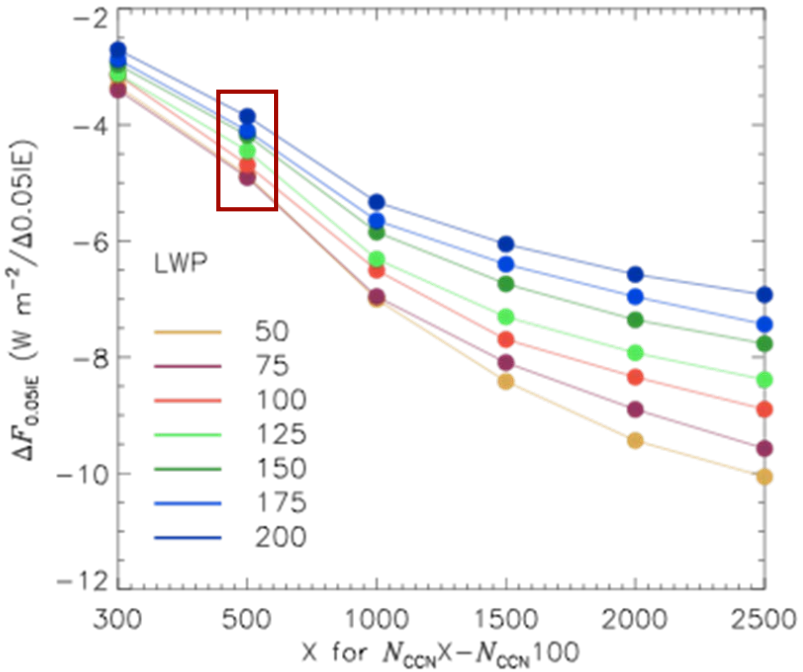
RF for 100 g m^{-2}
~ 5 W m^{-2} / Δ0.05



Range of Error in Radiative Forcing

$$\Delta F_{0.05IE} = \frac{F}{\Delta 0.05IE}$$

"...magnitude of the error in radiative forcing that would result from an error of the magnitude 0.05 in the measurement of *IE*."

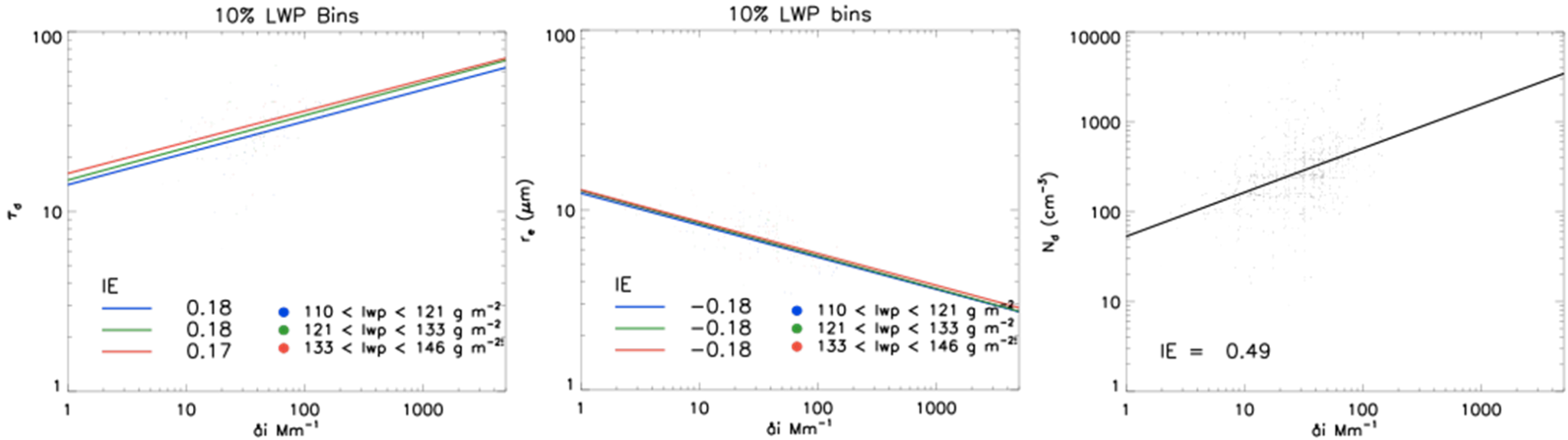


Quantifying Error in the Radiative Forcing of the First Aerosol Indirect Effect, submitted GRL, 06/0

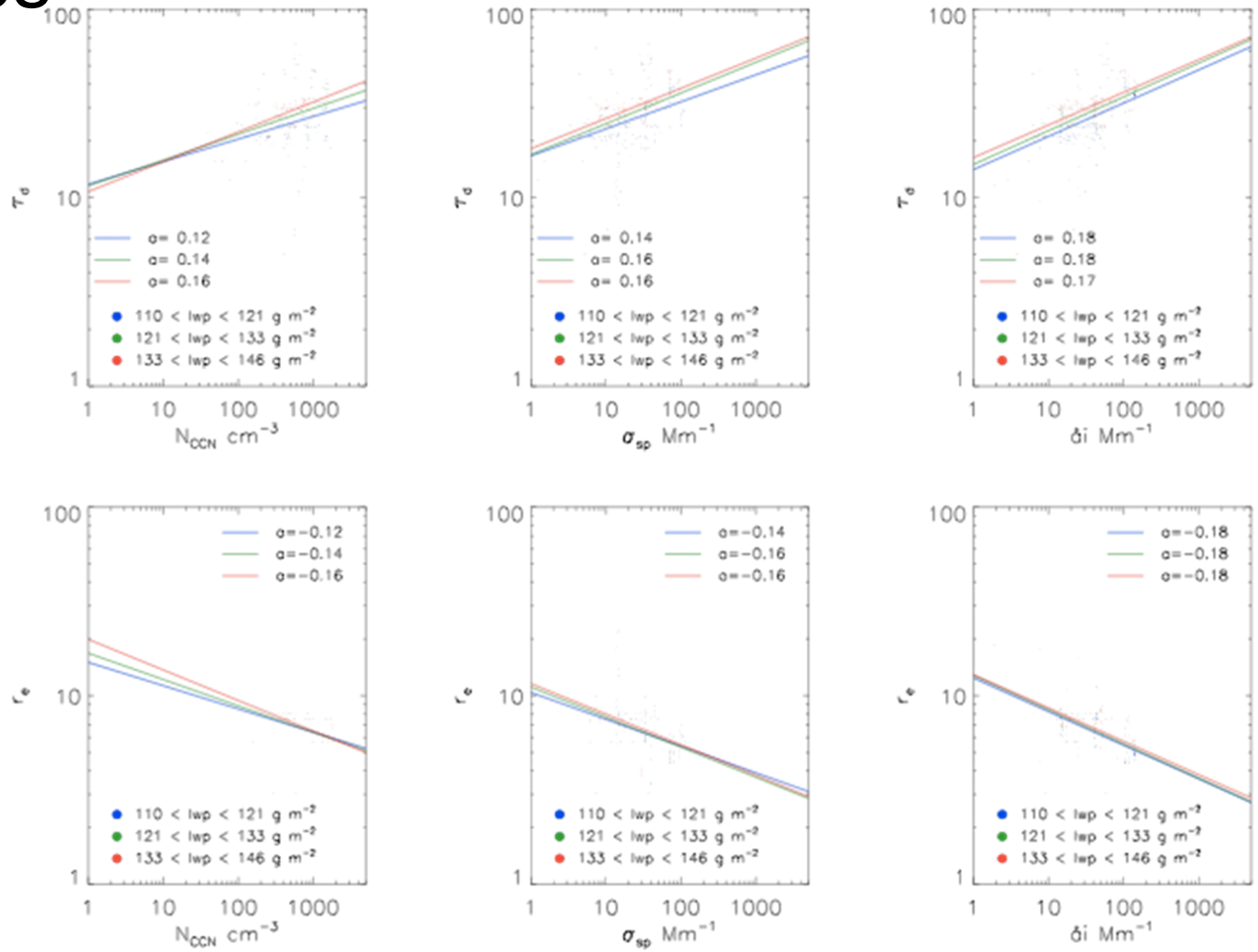
Theoretical relationships are consistent

factor of -1

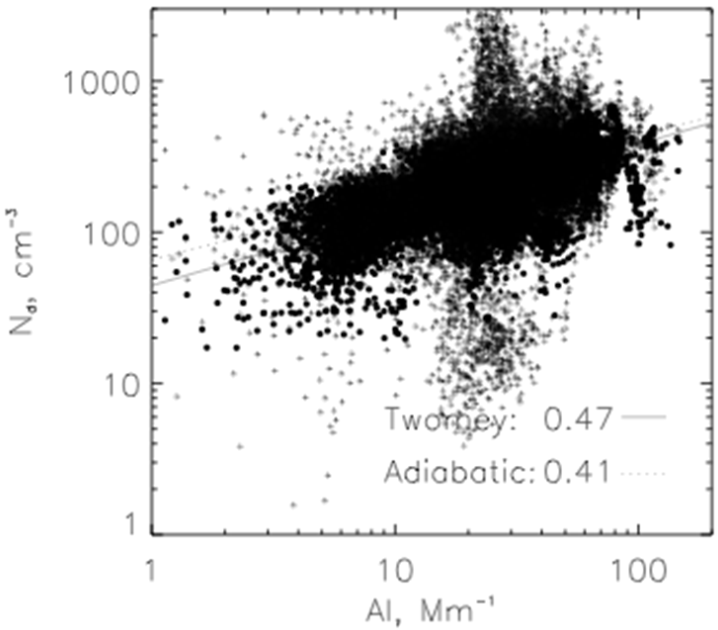
factor of 3



IE is sensitive to aerosol index at Pt. Reyes

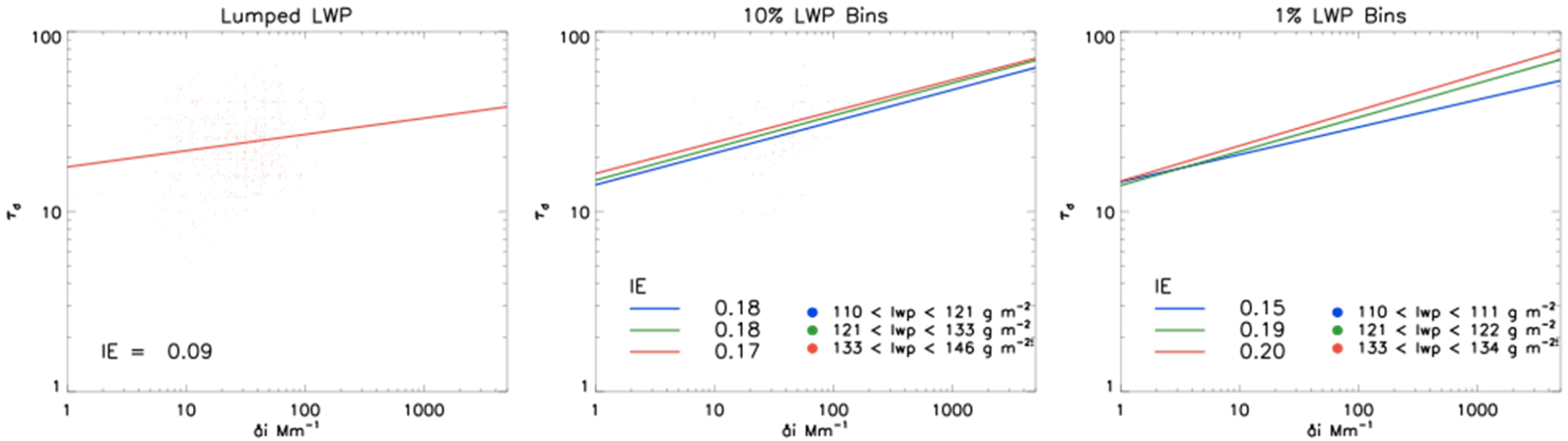


Drop Number Retrievals



MASE IE=0.56

Averaging reduces the sensitivity of IE



Conclusions/Future Directions

- Uncertainty in measures of IE must be improved for accurate radiative forcing estimates

- Sensitivity of IE is lost with averaging

- Variation in IE with aerosol amount, microphysical, and optical properties
  - further examination of IE at other ARM sites
    SGP, BRW, AMF?