

From LWP to COT: k coefficient

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Parameterization of Cloud Radiative Transfer in GCM

Cloud Module $\Rightarrow$ LWP
Aerosol Module $\Rightarrow$ N_{act} $\Rightarrow$ **COT**

$\Rightarrow$ **Radiative transfer module**

Parameterization of Cloud Radiative Transfer in GCM

$$W = \frac{4}{3} \pi \rho_w \int_0^H N(h) r_3^3(h) dh = \frac{4}{3} \pi \rho_w \int_0^H M_3(h) dh$$

$$\tau = \int_0^H \pi Q_{ext}(\bar{x}) N(h) r_2^2(h) dh = \int_0^H \pi Q_{ext}(\bar{x}) M_2(h) dh$$

$$k = \left(\frac{r_2}{r_3} \right)^6 = \left(\frac{r_3}{r_e} \right)^3$$

Martin et al. 1994

$$\tau = A(kNH)^{1/3} W^{2/3} \quad \text{or} \quad r_e = \left(\frac{3W}{4\pi\rho_w kNH} \right)^{1/3}$$

$$k = M_2^3 / N M_3^2$$

Martin et al. 1994, ... and many others since

During the course of this work it was found that the most suitable parameterization for effective radius of droplets in layer clouds is

$$r_e [\mu\text{m}] = 10^3 \left(\frac{3L [\text{g m}^{-3}]}{4\pi\rho_w k N_{\text{TOT}} [\text{cm}^{-3}]} \right)^{1/3}, \quad (14)$$

where the values of k and N_{TOT} are

(i) in maritime airmasses:

$$k = 0.80 \pm 0.07 \text{ (1 standard deviation)}$$

$$N_{\text{TOT}} = -1.15 \times 10^{-3} A^2 + 0.963 A + 5.30, \quad (15)$$

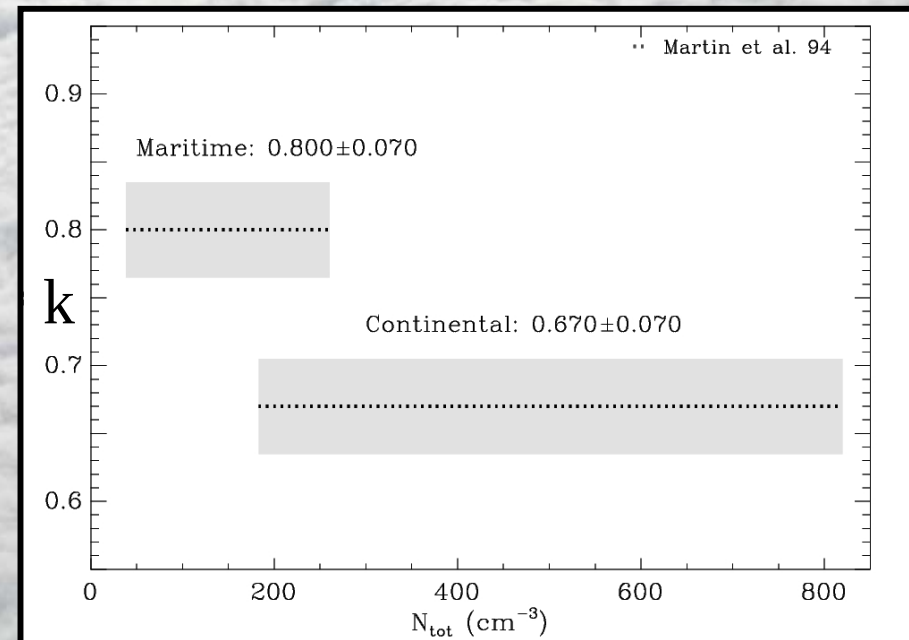
where A is the aerosol concentration in the range ($36 \leq A \leq 280 \text{ cm}^{-3}$) and

(ii) in continental air masses:

$$k = 0.67 \pm 0.07 \text{ (1 standard deviation)}$$

$$N_{\text{TOT}} = -2.10 \times 10^{-4} A^2 + 0.568 A - 27.9 \quad (16)$$

Chen et al. Global climate response to anthropogenic aerosol indirect effects: Present day and year 2100. J. Geophys. Res.

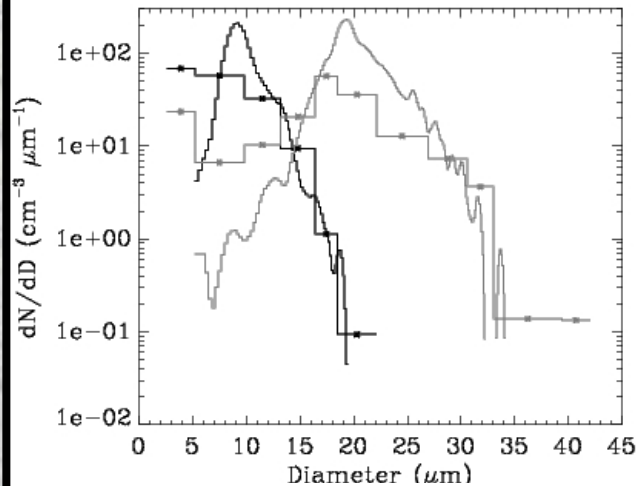


When entrainment effects become important, the relationship between r_e and r_v breaks down and such data have been ignored in the analysis.

Data Base

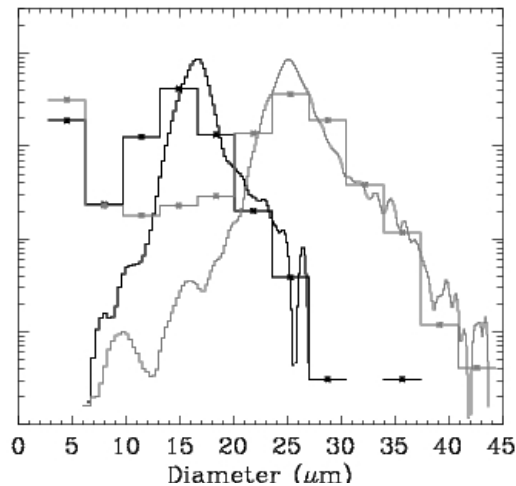
Project	Location	Aircraft	Date	Flight	Cloud type	F-100 15 cl	F-100 40 cl	Fast-F
SCMS	Florida	C-130	22/07/95	RF04	Cu	x		x
SCMS	Florida	C-130	24/07/95	RF05	Cu	x		x
SCMS	Florida	M-IV	04/08/95	me05	Cu	x		x
SCMS	Florida	M-IV	05/08/95	me06	Cu	x		x
SCMS	Florida	M-IV	06/08/95	me07	Cu	x		x
SCMS	Florida	M-IV	07/08/95	me08	Cu	x		x
SCMS	Florida	M-IV	08/08/95	me09	Cu	x		x
SCMS	Florida	M-IV	09/08/95	me10	Cu	x		x
SCMS	Florida	M-IV	10/08/95	me11	Cu	x		x
SCMS	Florida	M-IV	11/08/95	me12	Cu	x		x
SCMS	Florida	M-IV	12/08/95	me13	Cu	x		x
ACE2	Canary islands	M-IV	25/06/97	me20	Sc			x
ACE2	Canary islands	M-IV	26/06/97	me21	Sc			x
ACE2	Canary islands	M-IV	08/07/97	me28	Sc			x
ACE2	Canary islands	M-IV	09/07/97	me30	Sc			x
ACE2	Canary islands	M-IV	16/07/97	me31	Sc			x
ACE2	Canary islands	M-IV	17/07/97	me33	Sc			x
ACE2	Canary islands	M-IV	18/07/97	me34	Sc			x
ACE2	Canary islands	M-IV	19/07/97	me35	Sc			x
DYCOMS-II	northeast Pacific	C-130	13/07/01	RF03	Sc		x	x
DYCOMS-II	northeast Pacific	C-130	24/07/01	RF07	Sc		x	x
DYCOMS-II	northeast Pacific	C-130	25/07/01	RF08	Sc		x	x
DYCOMS-II	northeast Pacific	C-130	27/07/01	RF09	Sc		x	x
RICO	Caribbean	C-130	16/12/04	RF06	Cu		x	x
RICO	Caribbean	C-130	17/12/04	RF07	Cu		x	x
RICO	Caribbean	C-130	19/12/04	RF08	Cu		x	x
RICO	Caribbean	C-130	20/12/04	RF09	Cu		x	x
RICO	Caribbean	C-130	07/01/05	RF10	Cu		x	x
RICO	Caribbean	C-130	11/01/05	RF11	Cu		x	x
EUCAARI	Netherlands	ATR-42	13/05/08	as49	Cu			x
EUCAARI	Netherlands	ATR-42	14/05/08	as50	Cu			x
EUCAARI	North Sea	ATR-42	15/05/08	as51	Sc			x
EUCAARI	North Sea	ATR-42	15/05/08	as52	Sc			x

Instrumental Biases



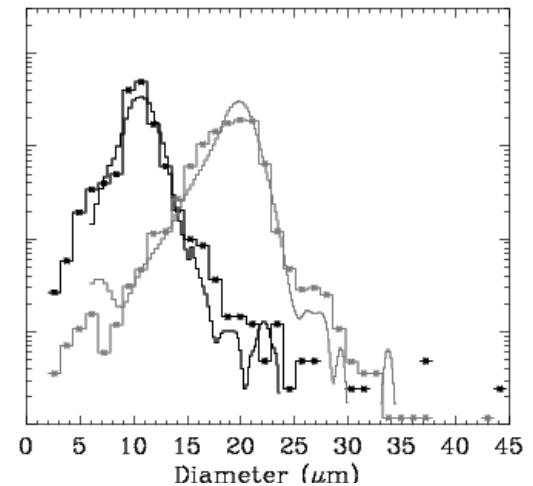
SCMS-1995

C130-FSSP & Fast-FSSP



SCMS-1995

ME-FSSP/Fast-FSSP

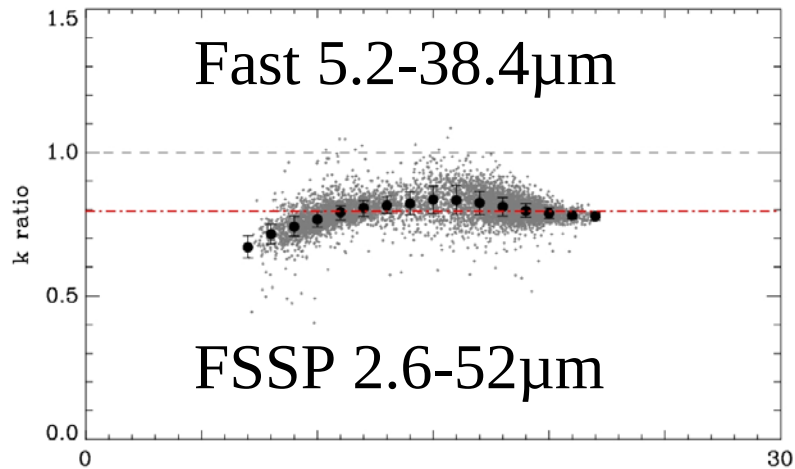


DYCOMS-2001

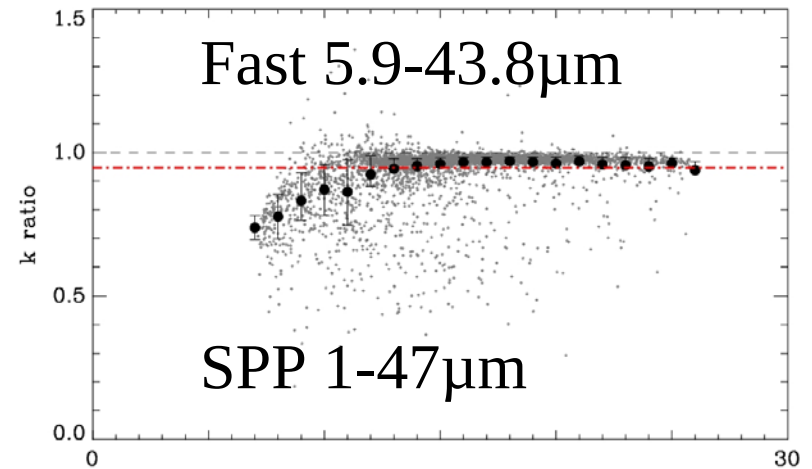
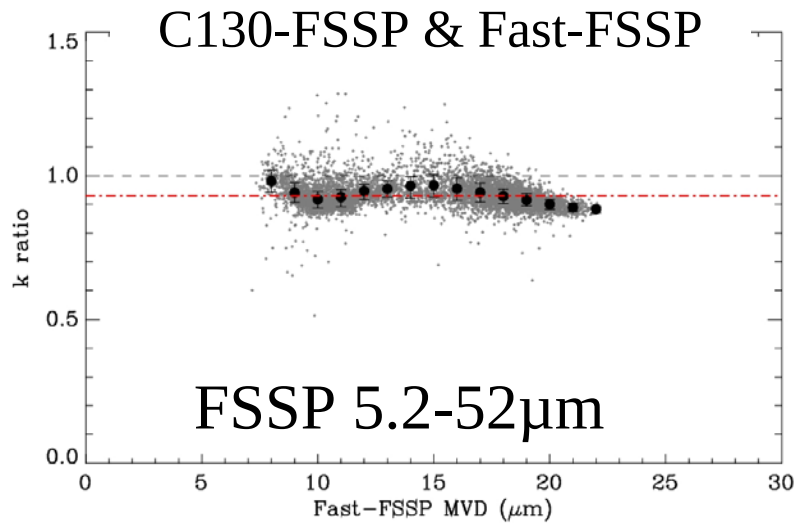
C130-SPP/Fast-FSSP

The FSSP-100 provides accurate measurements of the mean droplet diameter, but it significantly overestimates the width of the spectrum, hence underestimates the k coefficient. This is especially true when droplets are smaller, i.e. in high concentration clouds

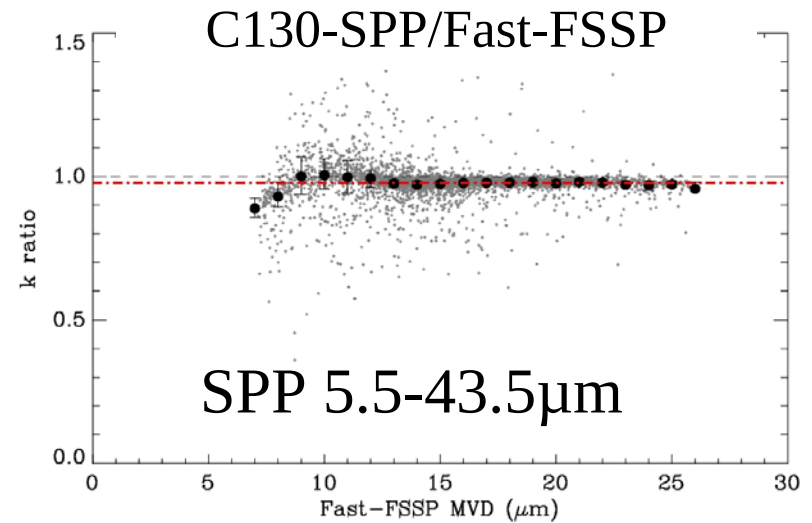
Instrumental Biases



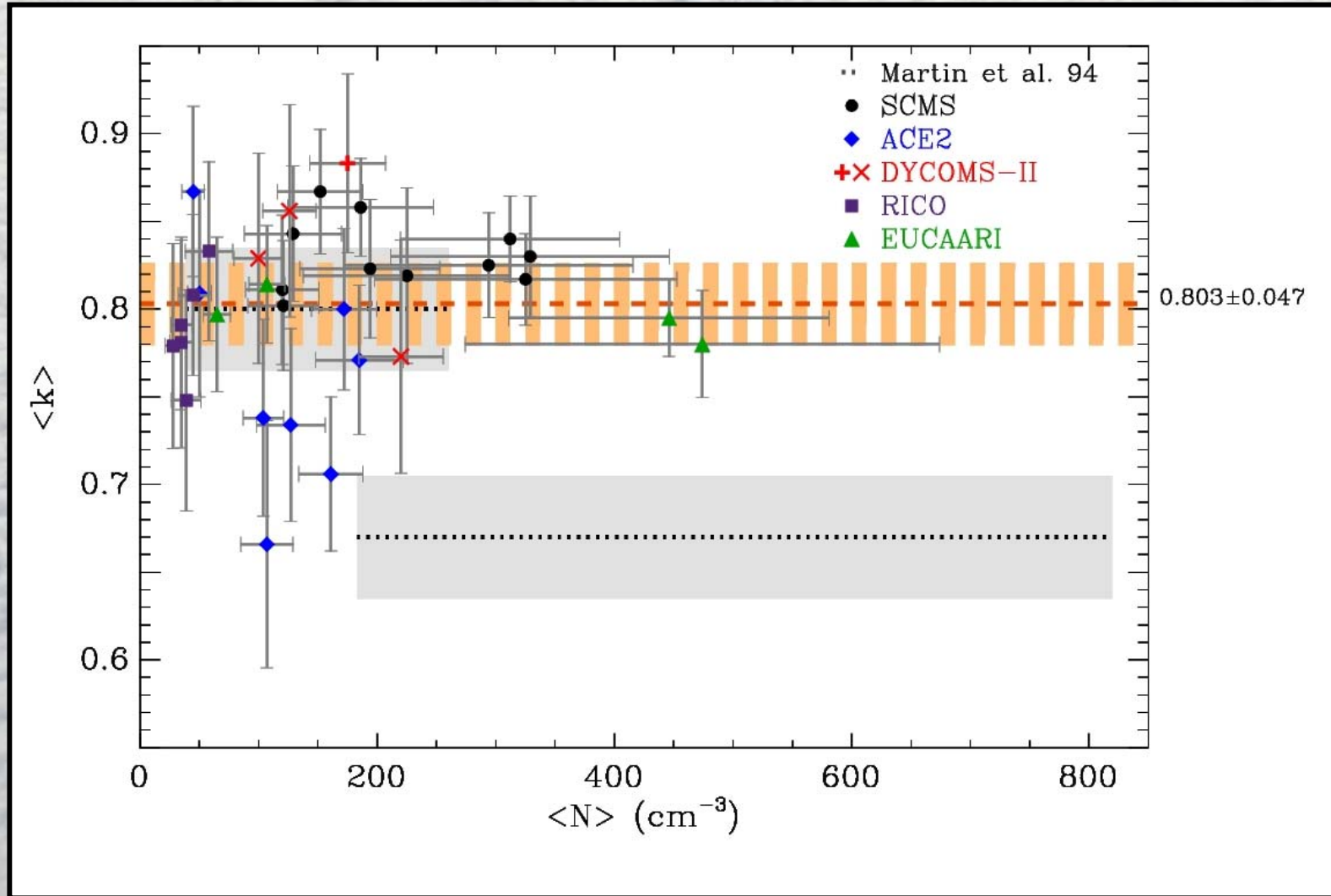
SCMS-1995



DYCOMS-2001



Results



Vertical Integration

$$W = \frac{4}{3} \pi \rho_w \int_0^H N(h) r_3^3(h) dh = \frac{4}{3} \pi \rho_w \int_0^H M_3(h) dh$$

$$\tau = \int_0^H \pi Q_{ext}(\bar{x}) N(h) r_2^2(h) dh = \int_0^H \pi Q_{ext}(\bar{x}) M_2(h) dh$$

$$\tau = A(kNH)^{1/3} W^{2/3} \quad \text{with} \quad k = M_2^3 / N M_3^2$$

Is true only in vertically uniform clouds !

Vertical Integration

In convective clouds, that are vertically stratified, with LWC increasing from cloud base to top : $q_c = C_w h$

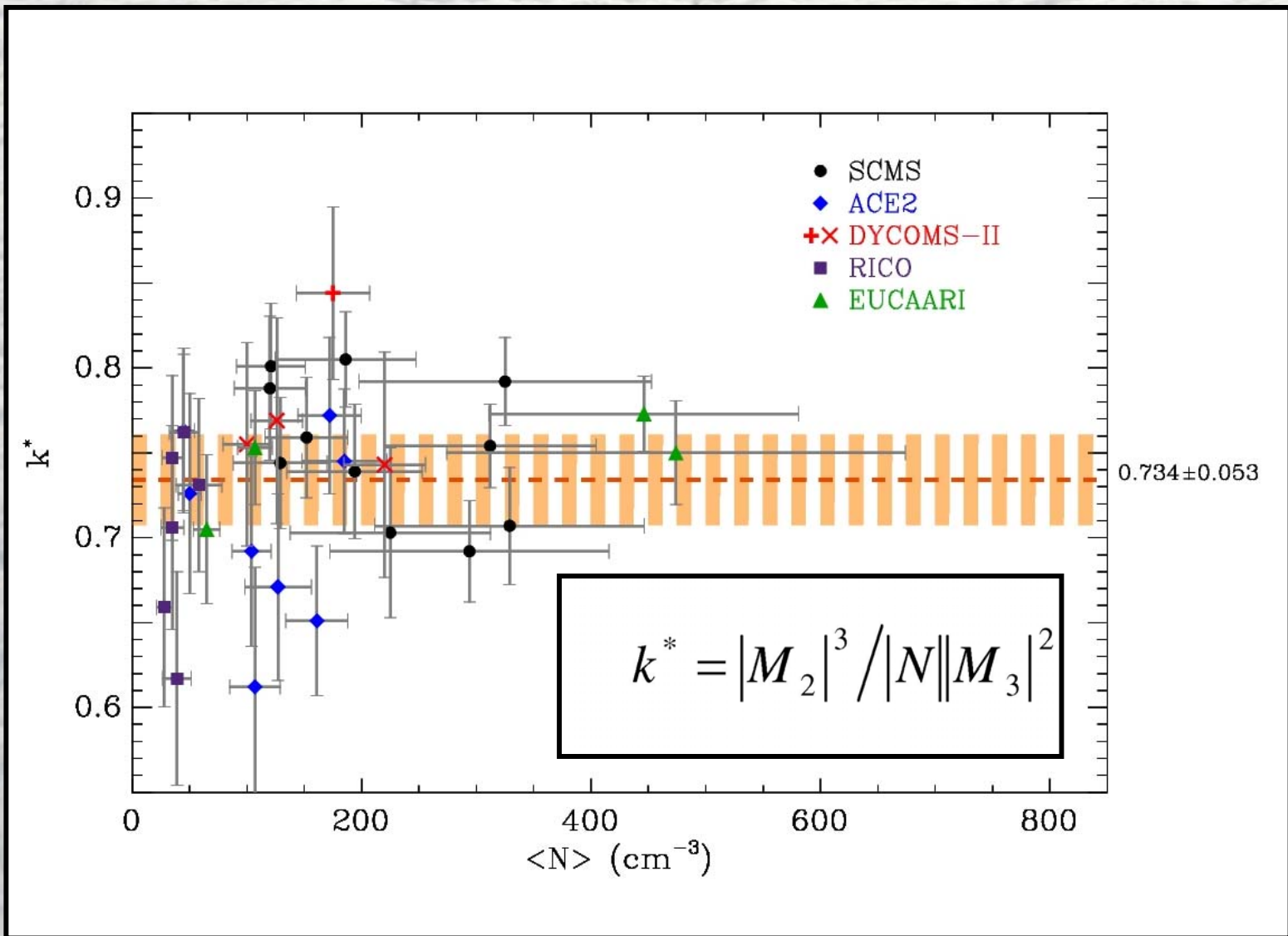
$$k^* = |M_2|^3 / |N| |M_3|^2, \quad \text{where } |x| = \int_0^H x(h) dh.$$

Assuming k is constant throughout the cloud, $r_2^2 = k^{1/3} \alpha^{2/3} h^{2/3}$, where $\alpha = C_w / (4/3 \pi \rho_w)$.

It follows that $|M_2| = 3/5 k^{1/3} \alpha^{2/3} N H^{5/3}$, and $|M_3| = 1/2 \alpha N H^2$, and finally:

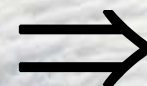
$$k^* = (3/5)^3 (1/2)^{-2} k = 0.864 k$$

Results



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Aerosol Module $\Rightarrow$ N_{act}



COT

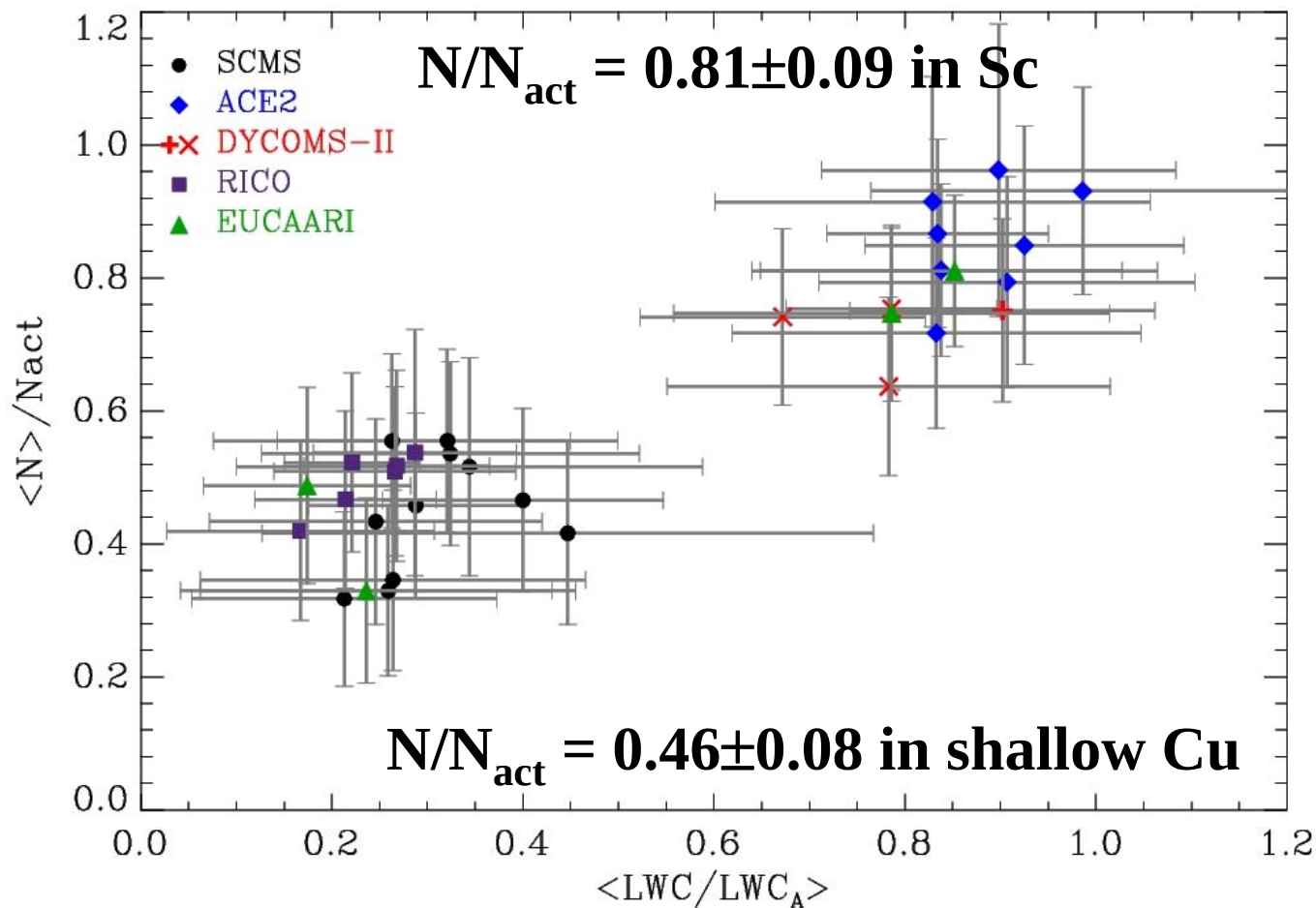


Radiative transfer module
COT & N

But $N \neq N_{\text{act}}$

because of entrainment-mixing

Results



Conclusion

$$\tau = A(k_{act}^* N_{act} H)^{1/3} W^{2/3} \quad \text{where} \quad k_{act}^* = k^* N / N_{act}$$

$N/N_{act} = 0.81 \pm 0.09$ in stratocumulus clouds

$N/N_{act} = 0.46 \pm 0.08$ in shallow cumuli

$$k_{act}^* = 0.73 \times 0.81 = 0.59 \quad \text{in stratocumulus clouds}$$

$$k_{act}^* = 0.73 \times 0.46 = 0.34 \quad \text{in shallow cumuli}$$

Thank you

for your attention