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INTERESTS AND APS RELEVANCE

RETRIEVAL OF WARM CLOUD PROPERTIES FROM SATELLITE

AND IMPACT OF AEROSOLS

IS THERE A RELATIONSHIP BETWEEN DROPLET CONCENTRATION AND DROPLET EFFECTIVE RADIUS ?

RATIONALE

$LWC \propto N r_v^3$

$\sigma_{ext} \propto N r_s^2$

→ At a specified LWC, cloud optical properties are modulated by CDNC

APPLICATIONS

→ **CLIMATE CHANGE SIMULATION**

Given LWP from the dynamic module

Given N_{act} from the aerosol activation module

→ Calculate cloud radiative transfer

→ **SATELLITE CLOUD RETRIEVALS**

Given radiance measurements

→ Retrieve LWP and N_{act}

SATELLITE CLOUD RETRIEVALS

From ... cloud
r... ar

CAN WE DERIVE

N_{act} FROM

τ and r_{eff} ??

(λ dep... ectral)
(Droplet M... r angular)

SATELLITE CLOUD RETRIEVALS

Numerous statistical studies of retrieved aerosol optical thickness and droplet effective radius show correlations, but not the expected negative correlation between

τ and r_{eff}

$\tau \propto LWP/ r_{eff}$

Kaufman and Nakajima (1993); Kaufman and Fraser (1997); Han et al. (1994); Han et al. (1998); Wetzel and Stowe (1999); Nakajima et al. (2001); Breon et al. (2002); Harsvardhan et al. (2002); Schwartz et al. (2002)

This is attributed to the variability of LWP

SATELLITE CLOUD RETRIEVALS

Once precipitation starts the relationship between N_{act} and r_{eff} is lost !

SATELLITE CLOUD RETRIEVALS

Identify and reject pixels affected by precipitation

SATELLITE CLOUD RETRIEVALS

In non-precipitating clouds, a smaller effective radius is the signature of a thinner cloud.

$$r_v(H) = A(H/N)^{1/3}$$

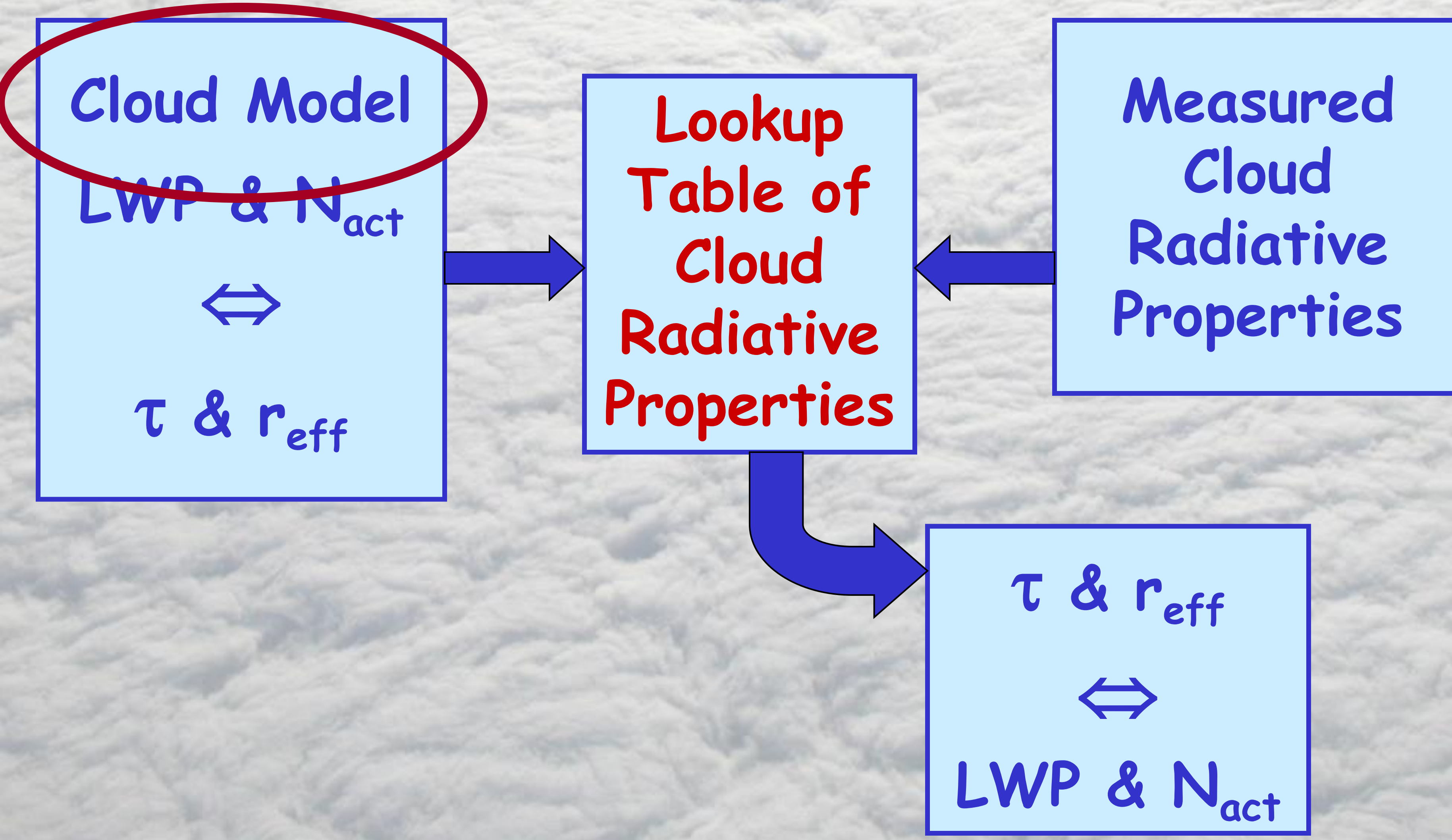
SATELLITE CLOUD RETRIEVALS

If LWP is constant only, then a smaller effective radius is the signature of a greater N_{act}

SATELLITE CLOUD RETRIEVALS

To assess the impact of aerosol on cloud albedo and cloud life cycle, unambiguous & quantitative retrieval schemes of both LWP and N_{act} are necessary

RETRIEVALS SCHEMES



RETRIEVALS SCHEMES

Adiabatic Cloud Model

$$LWC = C_w h \Rightarrow LWP = 1/2\ C_w H^2$$

$$N = Cst$$

$$r_v = (C_w h / 4/3 \pi \rho_w N)^{1/3} \ \& \ r_s^2 = k\ r_v^2$$

$$\sigma_{ext} = 2\pi Q_{ext} N r_s^2$$

$$\tau = A H^{5/3} N^{-1/3} = B W^{5/6} N^{-1/3}$$

&

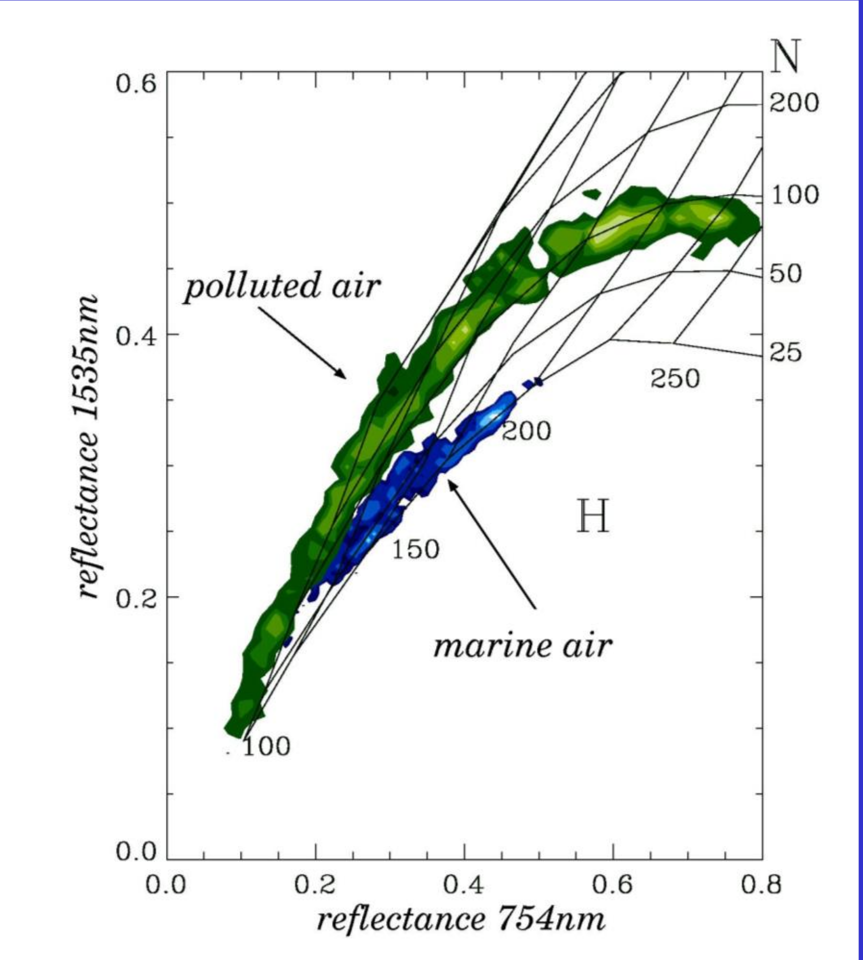
$$r_{eff} = r_v(h^*)/k, \text{ where } 5/6 < h^*/H < 1$$

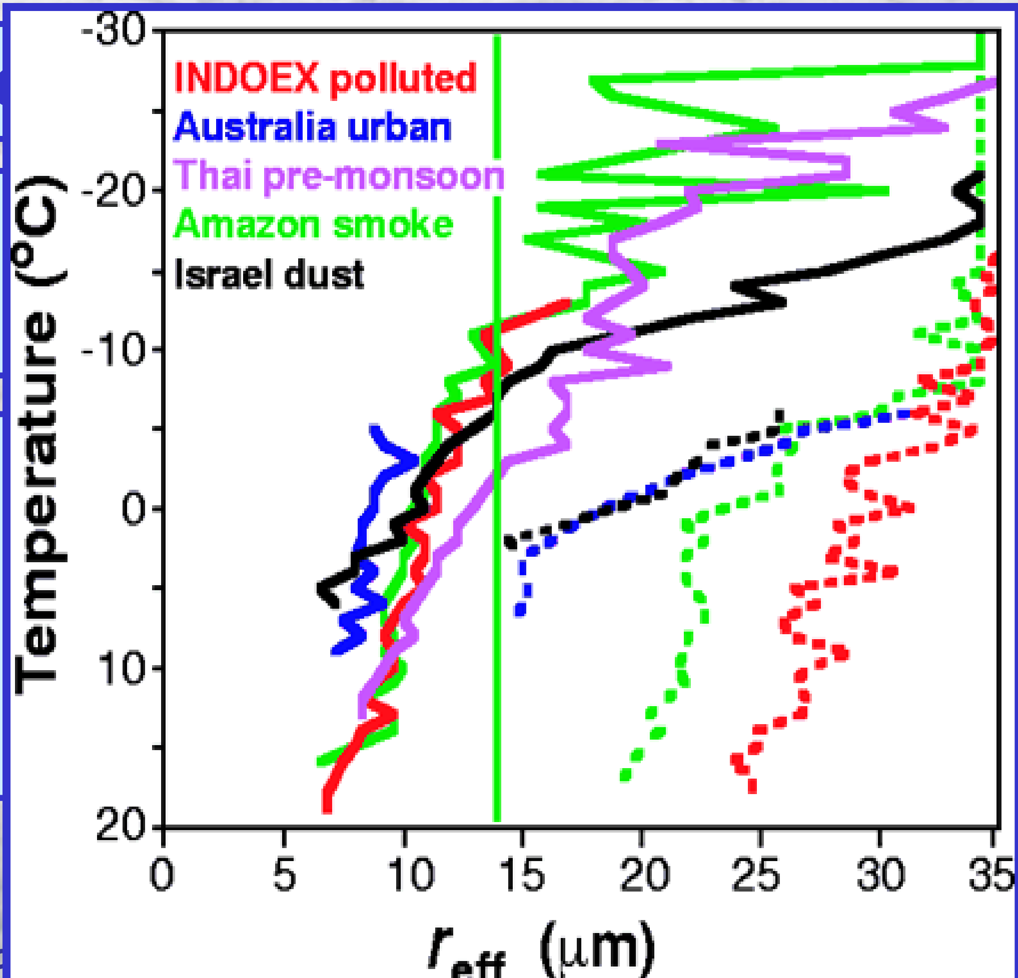
(*Brenguier et al., JAS 2000*)

W & N RETRIEVALS SCHEMES

Adiabatic Cloud Model

$$\tau = BW^{5/6}N^{-1/3} \;\&\; r_{eff} = (W^{*1/2} / 4/3\pi\rho_w N)^{1/3}$$

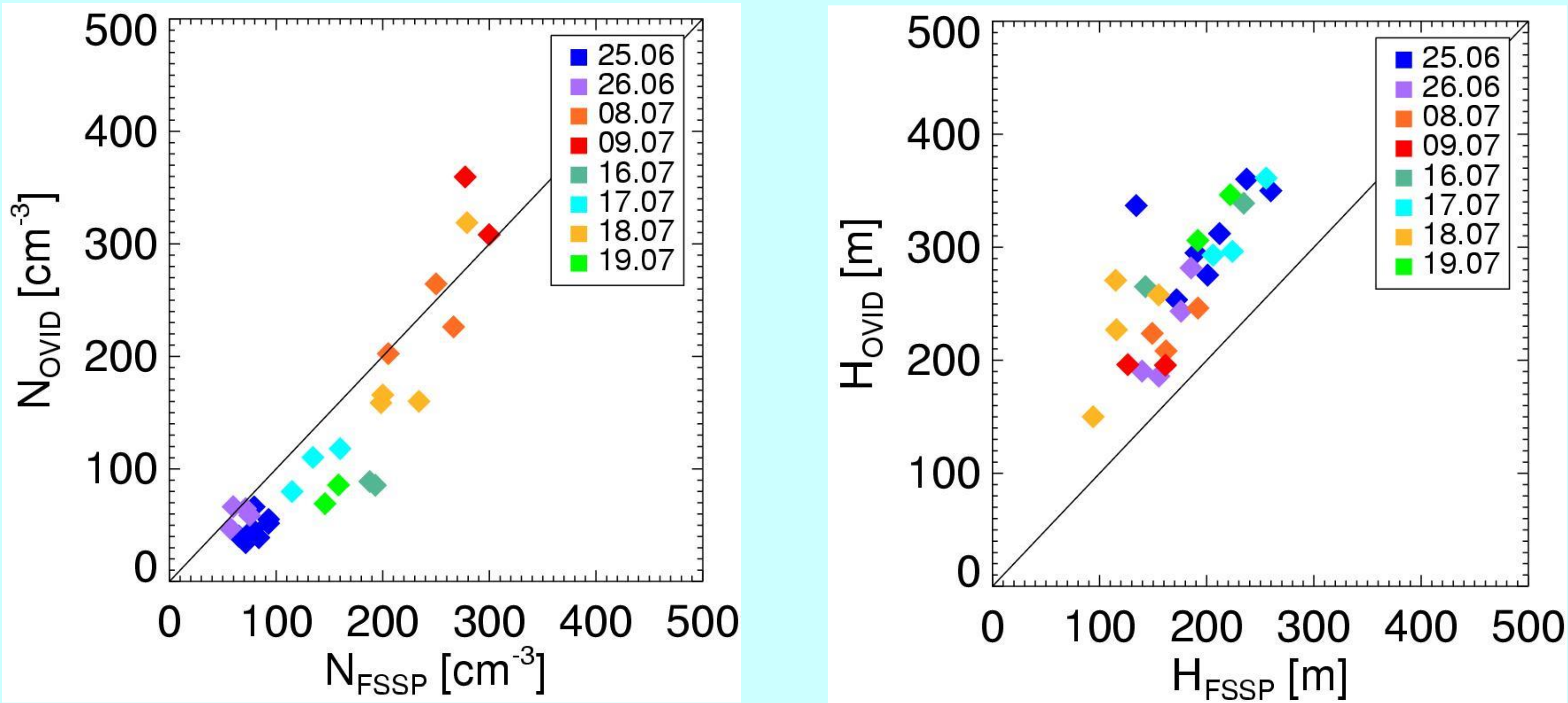




RETRIEVALS SCHEMES VALIDATION

The Brenguier-Schüller scheme has been validated against in situ measurements (ACE-2)

(*Schüller et al. 2000, 2003*)

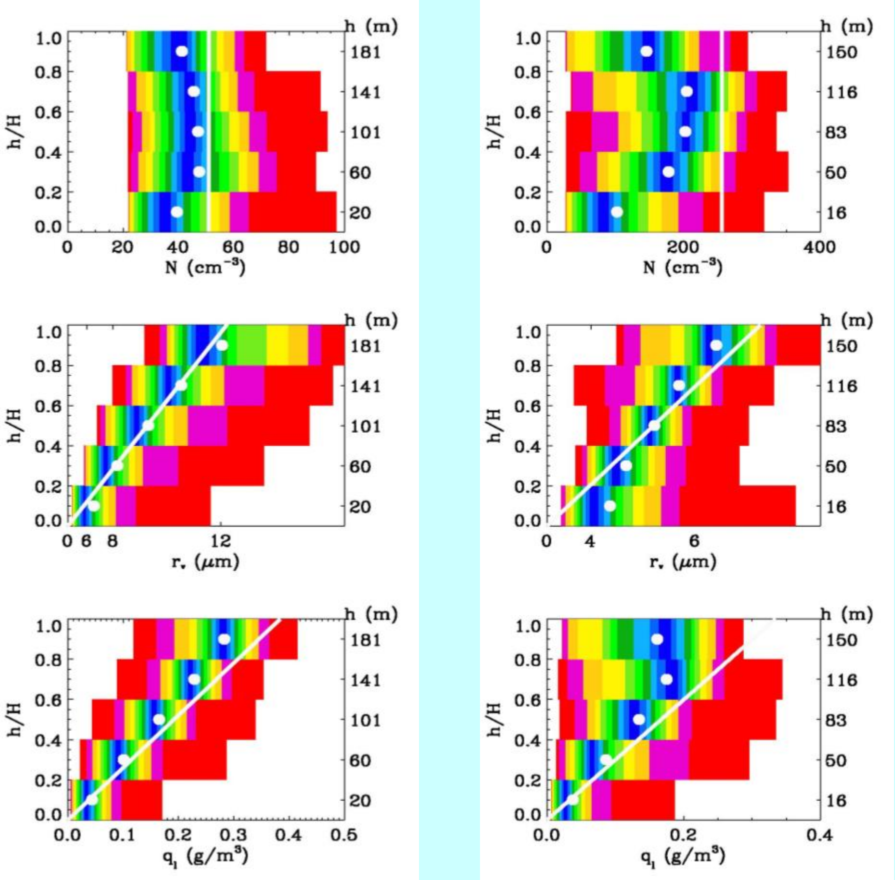


N correctly retrieved

H & W overestimated

SUB-ADIABATICITY

When the pixel resolution gets coarser, the W / N biases increase



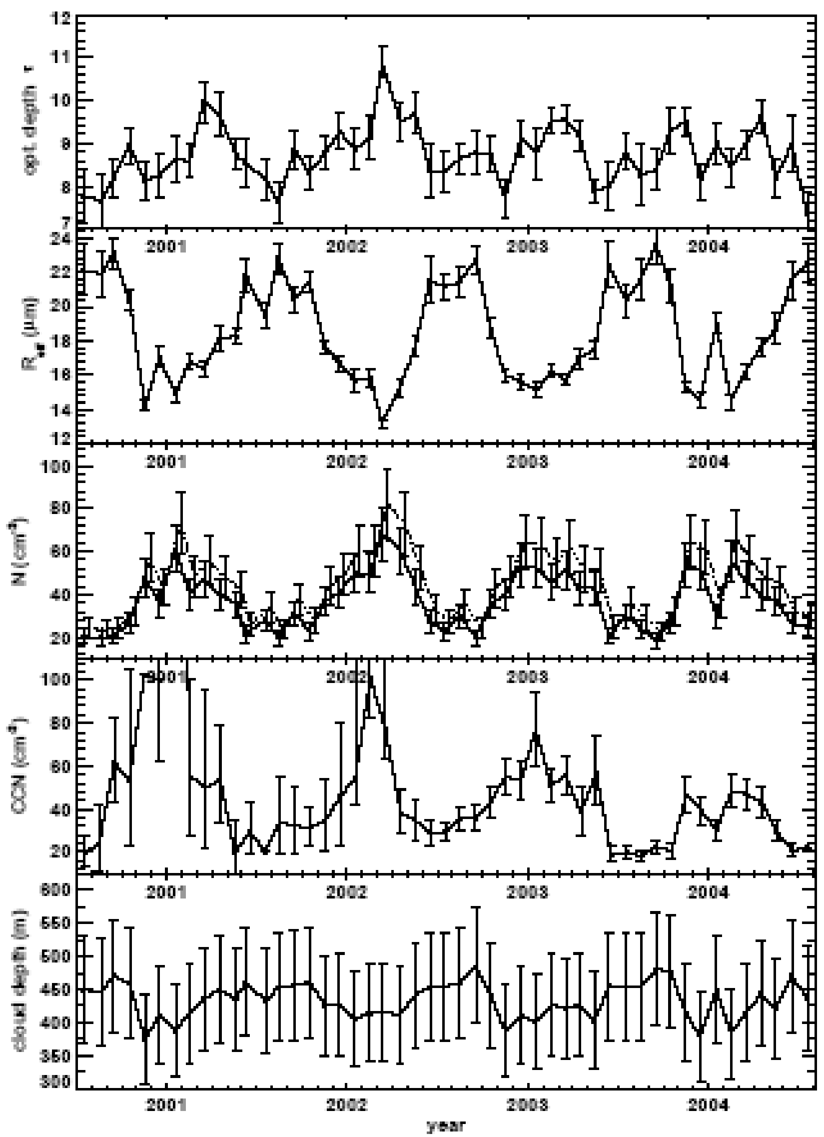
Pawlowska and Brenguier (2000) ; Brenguier et al. 2003

Real clouds are not adiabatic!

In stratocumulus clouds, the top is strongly affected by entrainment of free tropospheric, dry and hot air, hence LWC is substancially reduced.

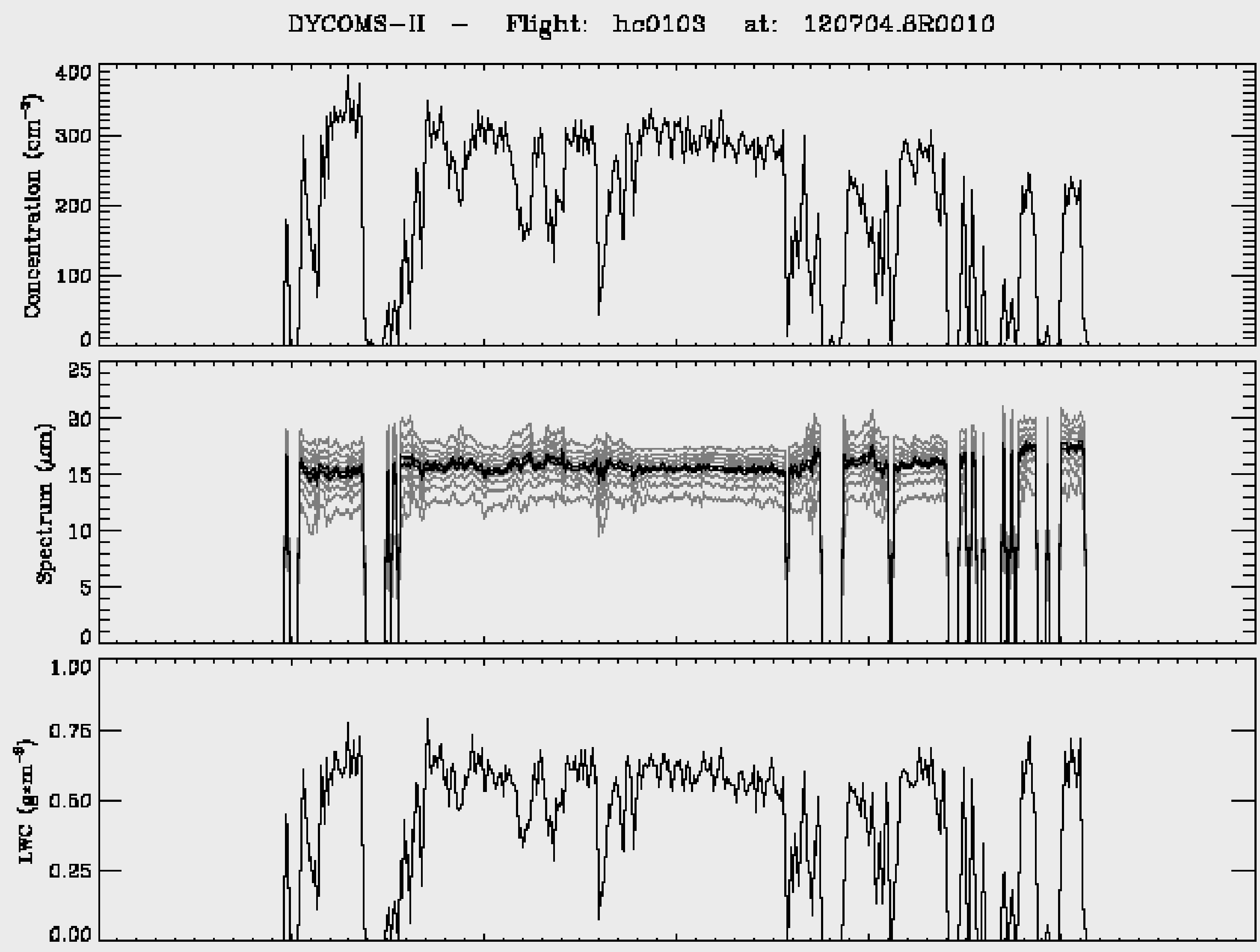
The cloud top also governs most of the cloud radiative properties

RETRIEVALS SCHEMES VALIDATION



Boers et al. (2006) improved the scheme to account for sub-adiabaticity and applied it to Cape Grimm data

SUB-ADIABATICITY



ENTRAINMENT-MIXING

When dry air is entrained and LWC is reduced, is it

- by homogeneous evaporation of all the droplets i.e. N is constant and r_v decreases ?

(homogeneous mixing)

OR

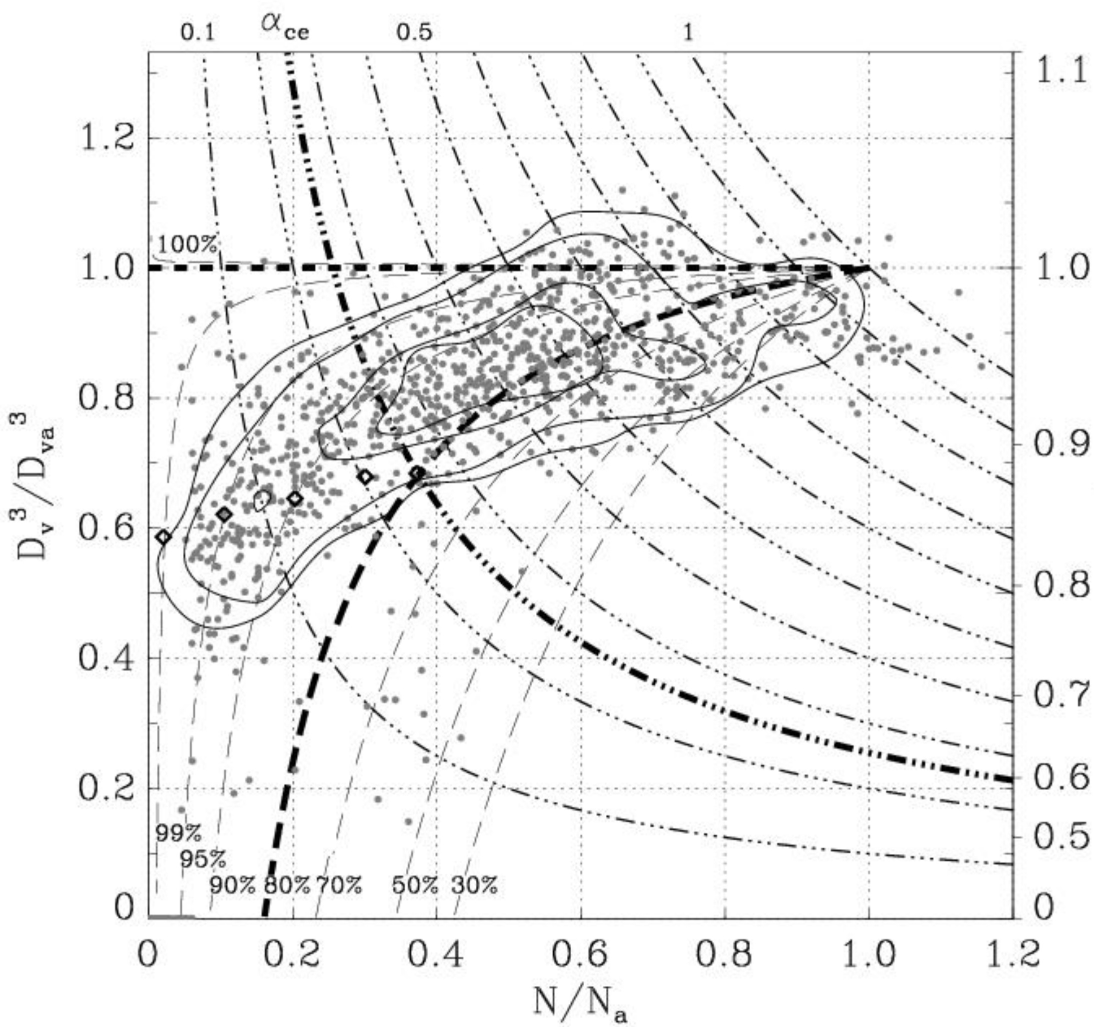
- by total evaporation of some droplets while others are not affected, i.e. r_v constant and N decreases ?

(inhomogeneous mixing)

The process is governed by two characteristic time scales

- Homogeneisation time scale : $\tau_T \sim L/U \sim (L^2/\varepsilon)^{1/3}$
- Droplet evaporation time scale: $\tau_d \sim -(D^2 / AS)$,

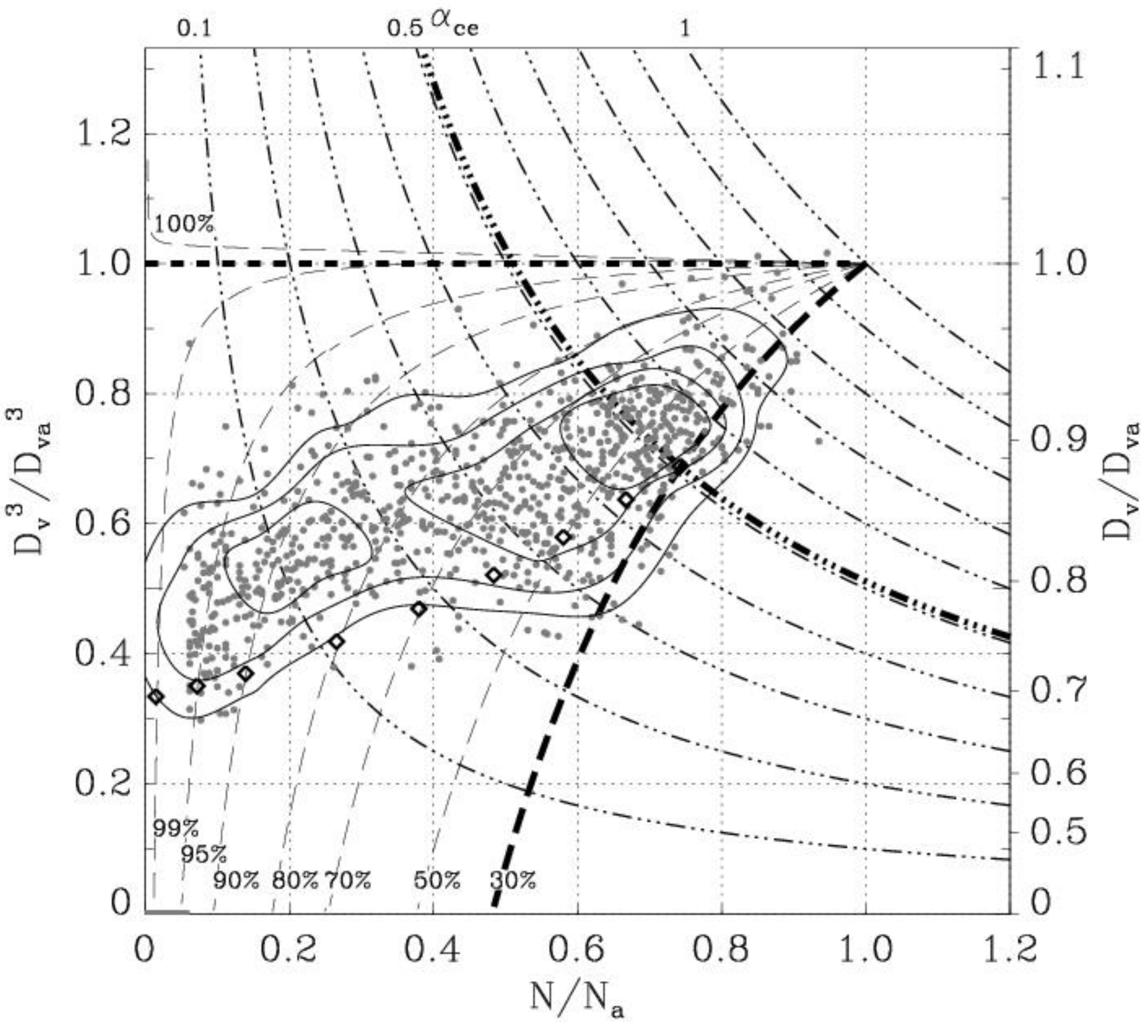
ENTRAINMENT-MIXING



Burnet & Brenguier, JAS 2006

$\tau_d / \tau_T = 6.6$

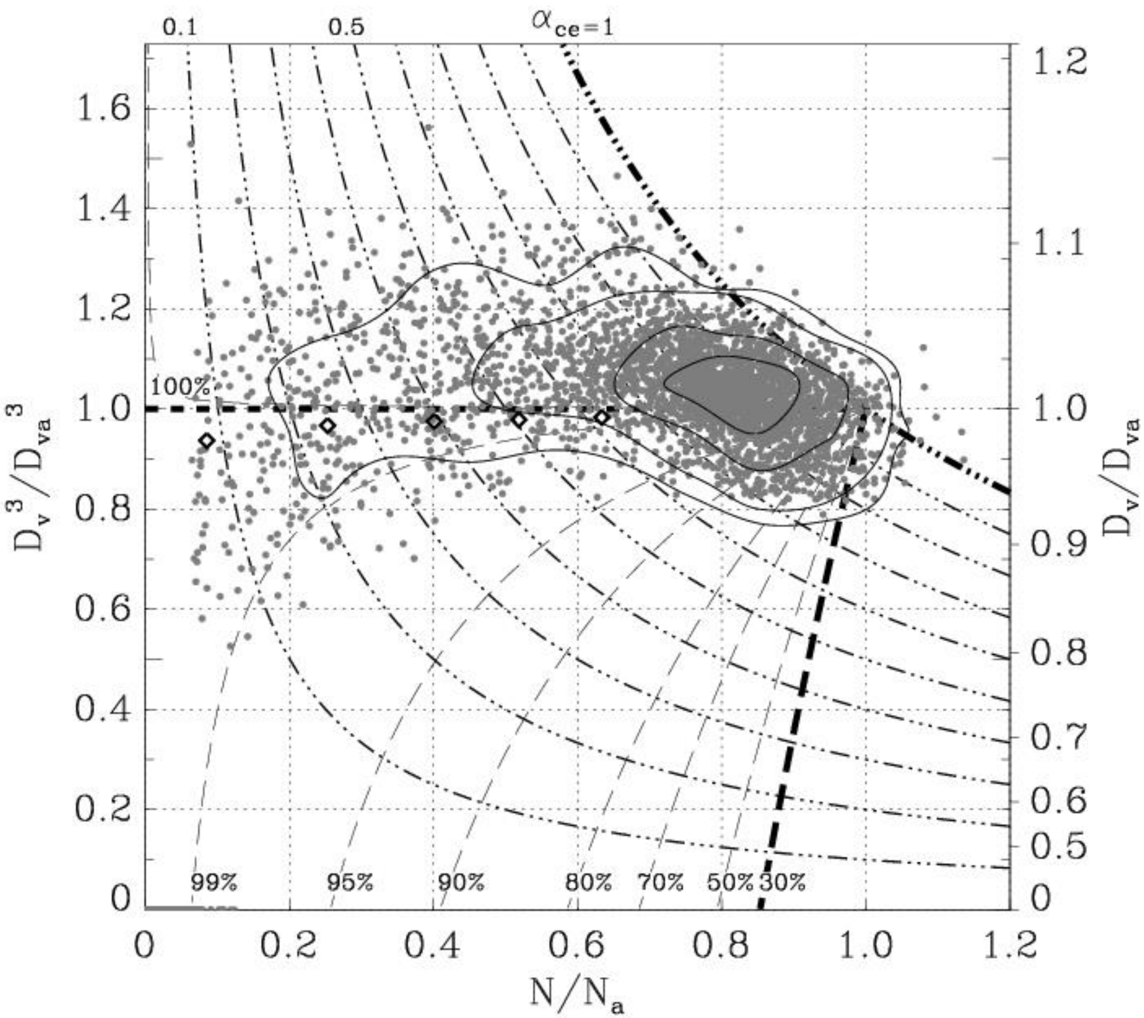
ENTRAINMENT-MIXING



Burnet & Brenguier, JAS 2006

$\tau_d / \tau_T = 1.9$

ENTRAINMENT-MIXING



Burnet & Brenguier, JAS 2006

$\tau_d / \tau_T = 0.05$

ENTRAINMENT-MIXING

There are significant differences in the way entrainment-mixing proceeds in convective clouds, depending on the turbulence intensity, the droplet sizes and the saturation deficit in the environment.

BUT

Is that so important for radiative transfert ?

LES MODELLING

The Meso-NH LES model is used
50x50x10m grid resolution ; 10 km domain
with bulk microphysics

4 different cloud scenes

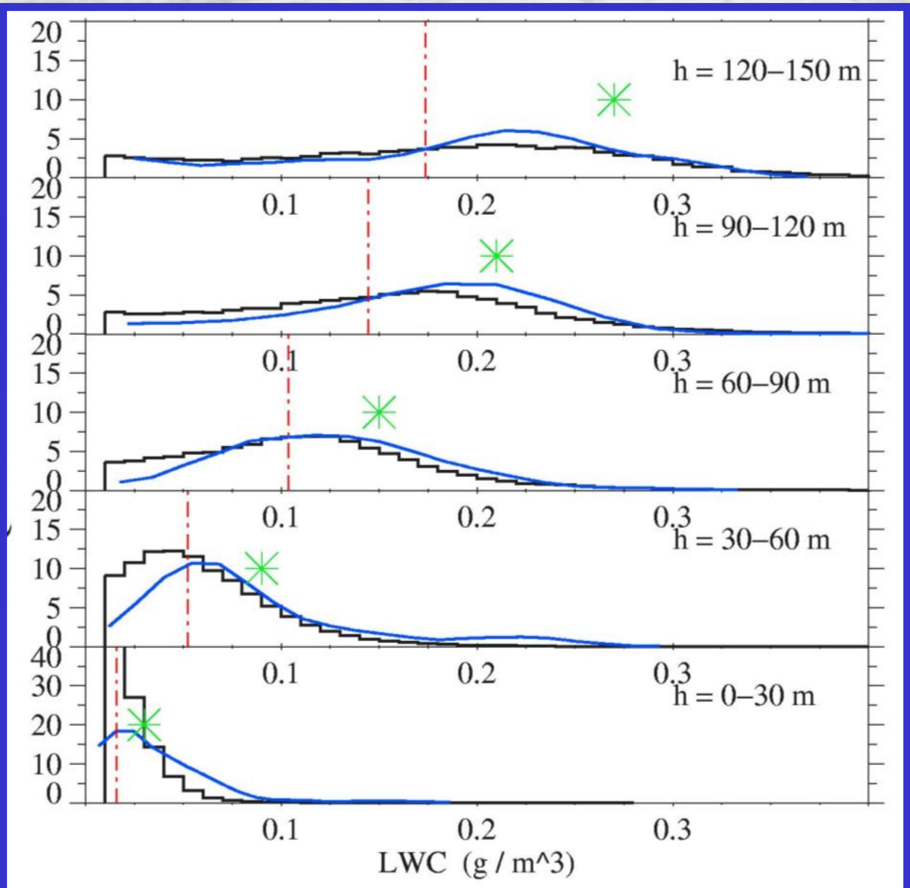
In sub-adiabatic grids, the LWC deficit is accounted for by either
reduced r_v at constant N: homogeneous mixing
or
reduced N at constant rv: inhomogeneous mixing

3 different initial N values (50, 256, 400 cm^{-3})

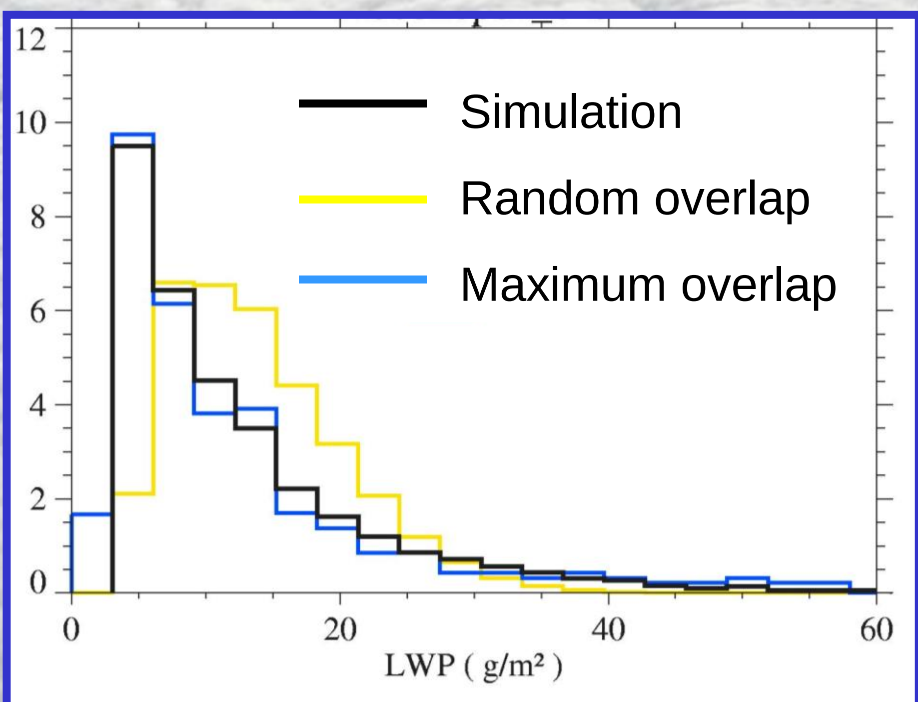
24 cloud scenes

3D radiative transfer with SHDOM

VALIDATION OF LES SIMULATIONS



Vertically stratified LWC statistics
Chosson & Brenguier 2006

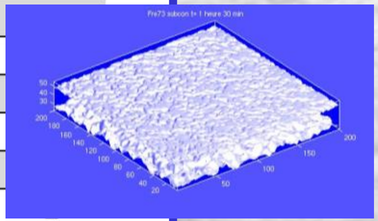


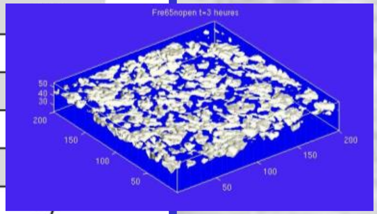
LWP statistics
Chosson & Brenguier 2006

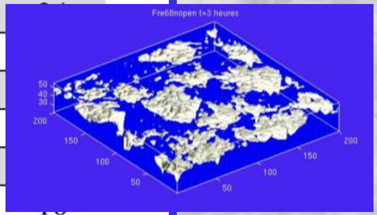
RADIATIVE TRANSFER CALCULATIONS

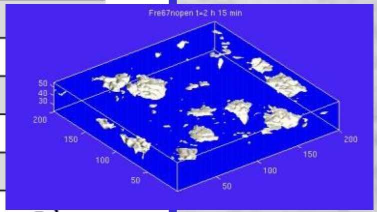
$$PP\ bias = 100*(A_{3D}-A_{PP})/A_{PP}$$

Cloud scene	N_{ad}	Mixing scheme	*CF* %	A_{Vis} %	*LWP* g/m²	*H* m	*PP bias* %
1	50 cm^{-3}	heterogeneous	100	43	83	286	[illegible]
		homogeneous	100	46	83	286	[illegible]
	256 cm^{-3}	heterogeneous	100	61	83	286	[illegible]
		homogeneous	100	65	83	286	[illegible]
	400 cm^{-3}	heterogeneous	100	67	83	286	[illegible]
		homogeneous	100	70	83	286	[illegible]
2	50 cm^{-3}	heterogeneous	35	5	12	105	[illegible]
		homogeneous	54	7	10	95	[illegible]
	256 cm^{-3}	heterogeneous	57	9	10	93	[illegible]
		homogeneous	72	14	8	86	[illegible]
	400 cm^{-3}	heterogeneous	62	11	9	91	[illegible]
		homogeneous	76	16	8	84	[illegible]
3	50 cm^{-3}	heterogeneous	28	4	19	129	[illegible]
		homogeneous	44	7	14	110	[illegible]
	256 cm^{-3}	heterogeneous	42	8	15	112	[illegible]
		homogeneous	58	13	11	97	[illegible]
	400 cm^{-3}	heterogeneous	45	9	14	108	[illegible]
		homogeneous	62	16	11	94	[illegible]
4	50 cm^{-3}	heterogeneous	10	2	19	123	[illegible]
		homogeneous	15	3	15	106	[illegible]
	256 cm^{-3}	heterogeneous	15	3	15	106	[illegible]
		homogeneous	20	5	11	91	[illegible]
	400 cm^{-3}	heterogeneous	16	4	14	102	[illegible]
		homogeneous	22	6	11	87	-5









Chosson & Brenguier 2006

RADIATIVE TRANSFER CALCULATIONS

$$\text{PP bias} = 100*(A_{3D}-A_{PP})/A_{3D}$$

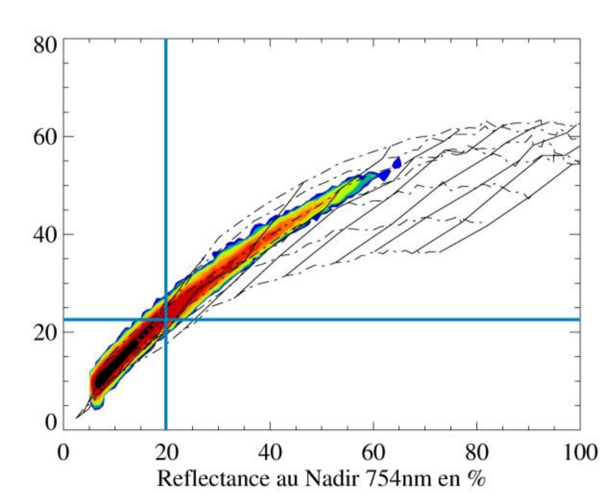
Cloud scene	N_{ad}	Mixing scheme	CF %	A_{Vis} %	LWP g/m²	H m	PP bias %
1	50 cm^{-3}	heterogeneous	100	43	83	286	-9
		homogeneous	100	46	83	286	-2
	256 cm^{-3}	heterogeneous	100	61	83	286	-8
		homogeneous	100	65	83	286	-2
	400 cm^{-3}	heterogeneous	100	67	83	286	-7
		homogeneous	100	70	83	286	-2
2	50 cm^{-3}	heterogeneous	35	5	12	105	-23
		homogeneous	54	7	10	95	0
	256 cm^{-3}	heterogeneous	57	9	10	93	-30
		homogeneous	72	14	8	86	-5
	400 cm^{-3}	heterogeneous	62	11	9	91	-34
		homogeneous	76	16	8	84	-7
3	50 cm^{-3}	heterogeneous	28	4	19	129	-34
		homogeneous	44	7	14	110	-1
	256 cm^{-3}	heterogeneous	42	8	15	112	-40
		homogeneous	58	13	11	97	-7
	400 cm^{-3}	heterogeneous	45	9	14	108	-40
		homogeneous	62	16	11	94	-10
4	50 cm^{-3}	heterogeneous	10	2	19	123	-23
		homogeneous	15	3	15	106	7
	256 cm^{-3}	heterogeneous	15	3	15	106	-31
		homogeneous	20	5	11	91	-1
	400 cm^{-3}	heterogeneous	16	4	14	102	-33
		homogeneous	22	6	11	87	-5

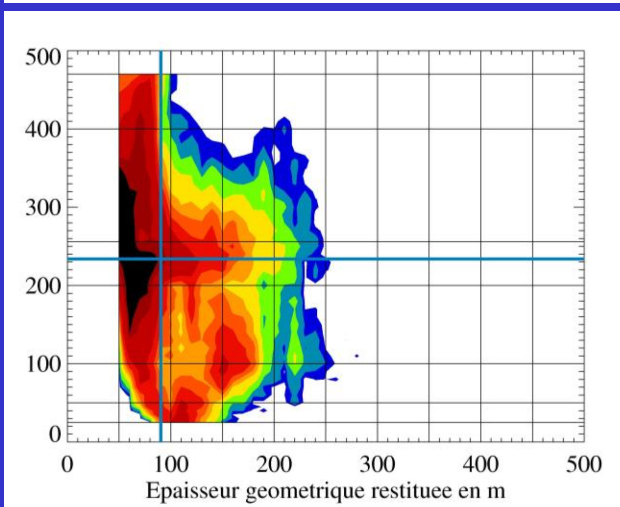
Chosson & Brenguier 2006

If mixing is of the homogeneous type, the PP bias is in the range
+7 to –10

If mixing is rather inhomogeneous, the PP bias is in the range
–7 to -40

RETRIEVAL OF CLOUD PROPERTIES





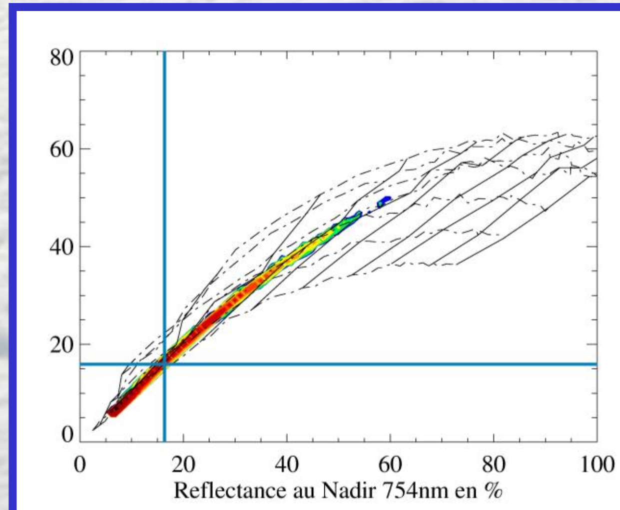
HOMOGENEOUS

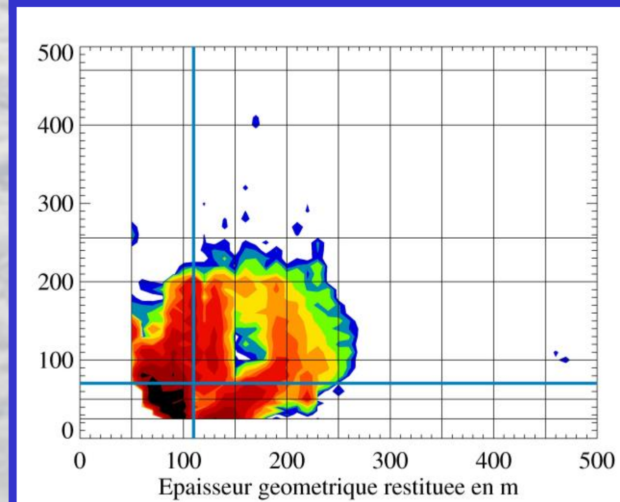
H=90 m N=235 cm^{-3}

ALL CLOUDY PIXELS

H (205 m) is underestimated (90-110 m) but not sensitive to the mixing type

N (256 cm^{-3}) is underestimated (70 cm^{-3}) when mixing is of the inhomogeneous type



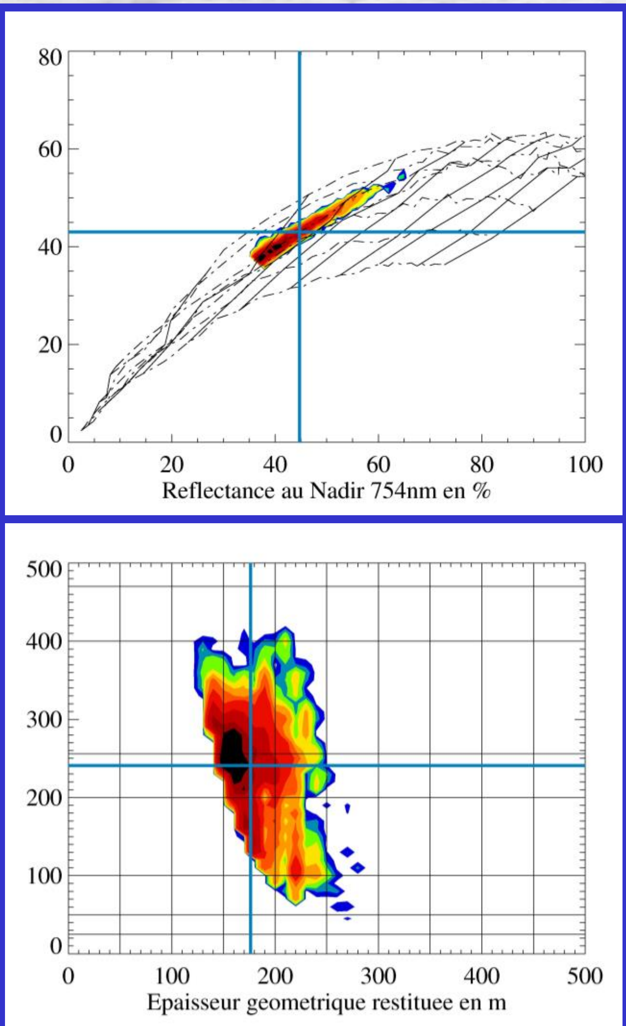


INHOMOGENEOUS

H=110 m N=70 cm^{-3}

Chosson & Brenguier 2006

RETRIEVAL OF CLOUD PROPERTIES



HOMOGENEOUS

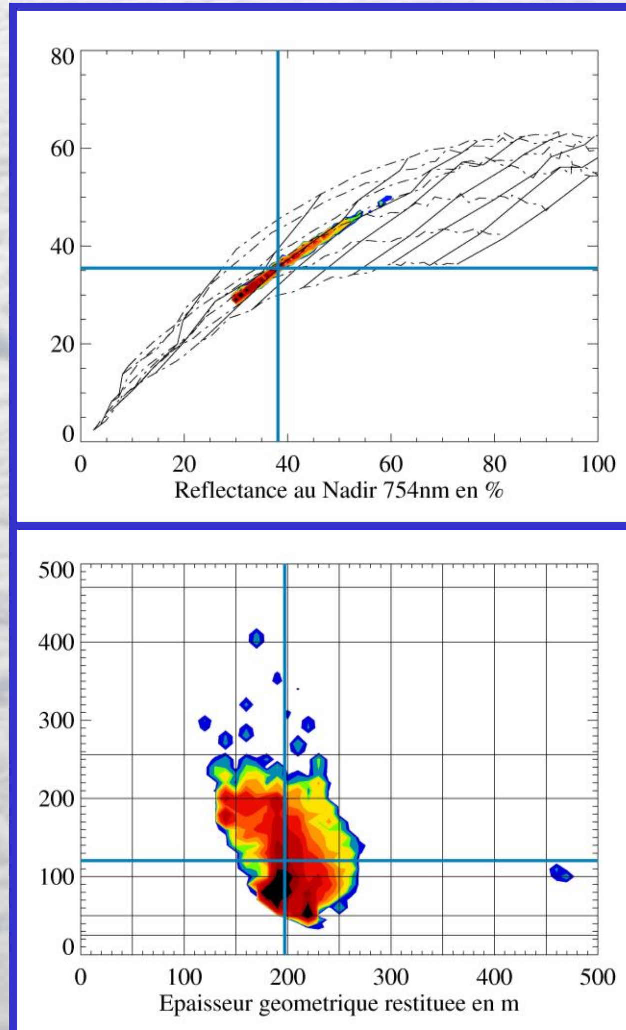
H=180 m N=240 cm^{-3}

10 % BRIGHTEST PIXELS

H (205 m) is well retrieved (180-200 m) and not sensitive to the mixing type

N (256 cm^{-3}) is underestimated (120 cm^{-3}) when mixing is of the inhomogeneous type

Chosson & Brenguier 2006



INHOMOGENEOUS

H=200 m N=120 cm^{-3}

CONCLUSIONS

In convective clouds, the droplet effective radius at cloud top depends on LWP (cloud thickness) and N_{act}

When precipitation starts this relationship is lost : Precipitating clouds look like pristine clouds

In non-precipitating convective clouds, the retrieved droplet effective radius may be used to derive N_{act}

The droplet effective radius at cloud top however may be strongly affected by entrainement-mixing processes

When mixing is of the inhomogeneous type, N_{act} is substantially underestimated

CONCLUSIONS

The impact of entrainment-mixing processes on the droplet size distribution depends on the turbulence intensity, on the saturation deficit in the environment, and on the initial droplet size

Entrainment-mixing processes mainly affect cloud top

If these parameters cannot be documented, the vertical profile of r_{eff} may help at solving the ambiguity