Correlations between microphysical properties of large-scale semi-transparent cirrus

(from TOVS)

and the state of the atmosphere

(from ECMWF ERA-40)

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Effective ice crystal size (D_e) and IWP retrieval of semi-transparent cirrus

based on: spectral difference of cirrus emissivities at 11-8 μm

Observations:

NOAA10 1987 – 1991, 60°N – 60°S , $\theta_v < 25°$

large-scale cirrus: 1°x1° overcast, $p_{cld} < 440$ hPa

$T_{cld} < 263K$, $T_B^{meas}(8\mu m)$, $T_B^{meas}(11\mu m)$, T_{cld}, T_{surf}

ε_{surf}(SARB), closest TIGR H_2O/T profiles

⇨ 3R radiative transfer

⇩

$(\varepsilon_{8\mu m}, \varepsilon_{11\mu m})$

$$\epsilon(\lambda, \Theta_\nu) = \frac{B(T_B^m(\lambda, \Theta_\nu)) - B(T_{surf}(\lambda, \Theta_\nu))}{B(T_{cld}(\lambda, \Theta_\nu)) - B(T_{surf}(\lambda, \Theta_\nu))}$$

Method: simulate $\varepsilon(\lambda, D_e, IWP, \theta)$

hom. cloud, $\beta_{abs}(D_e)$, $\langle\omega_0(D_e)\rangle$, $\langle g(D_e)\rangle$

planar polycrystals (mod. ADA)

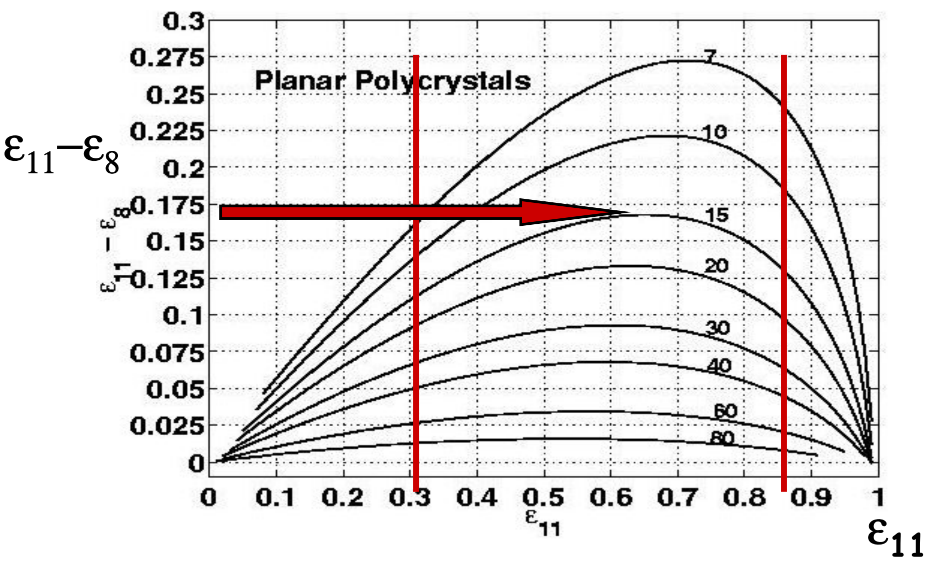
bimodal size distribution

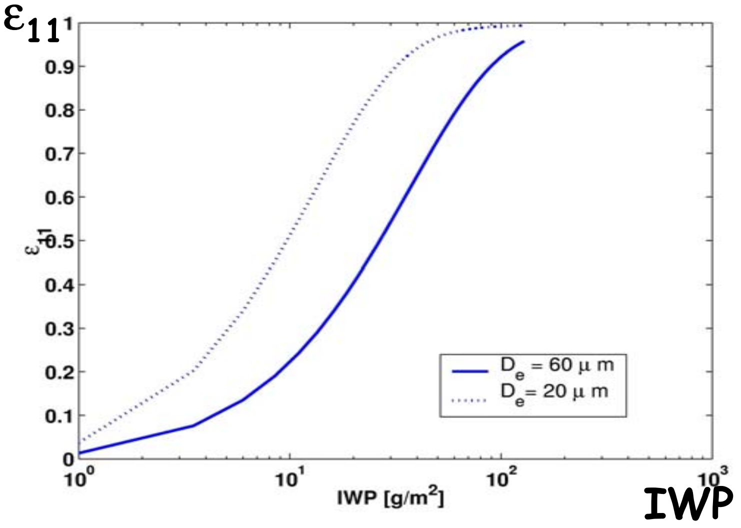
➡ radiative transfer
(Streamer (J.Key))
vary De, IWP

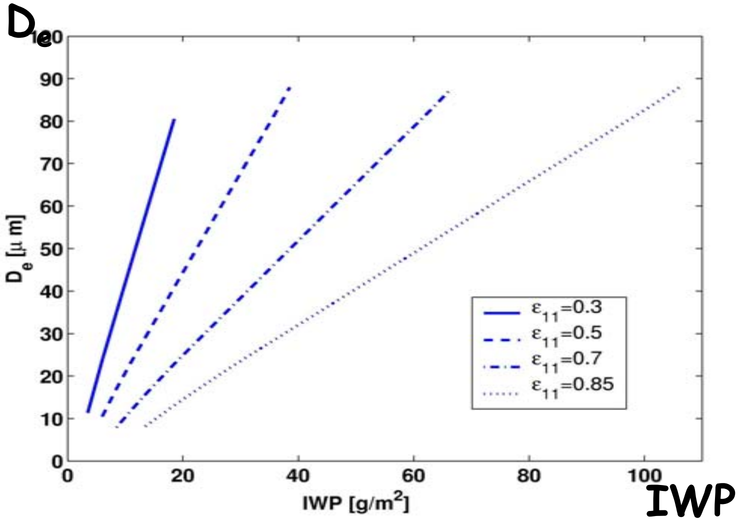
➡ $\varepsilon(\lambda, D_e, IWP, \theta)$

D_e and IWP retrieval (cont.)

produce look-up tables: $D_e = f(\varepsilon_{8\mu m},\varepsilon_{11\mu m})$, $IWP = f(D_e,\varepsilon_{11\mu m})$







$$D_e = 2r_e^{VP} = 2\frac{\int \frac{3V}{4\pi} n(r)\,dr}{\int \frac{P}{\pi} n(r)\,dr} = \frac{3}{2}\frac{IWC}{\rho_i P}$$

for $0.3 < \varepsilon_{11\mu m} < 0.85$
$0.7 < \tau_{VIS} < 3.8$

sensitivity up to $D_e \leq 80\mu m$

Sensitivity study on ice crystal size retrieval

Rädel et al., J. Geophys. Res., May 2003

NOAA10 global average : $\langle D_e \rangle = 55\mu m$

$\langle IWP \rangle = 30\ g/m^2$

possible errors:

Overestimation of D_e: thin Ci with underlying water cloud

partial cover of thick Ci

different crystal shapes, e.g.

hexagonal columns instead of polycrystals

Underestimation of D_e: vertical heterogeneity, i.e.:

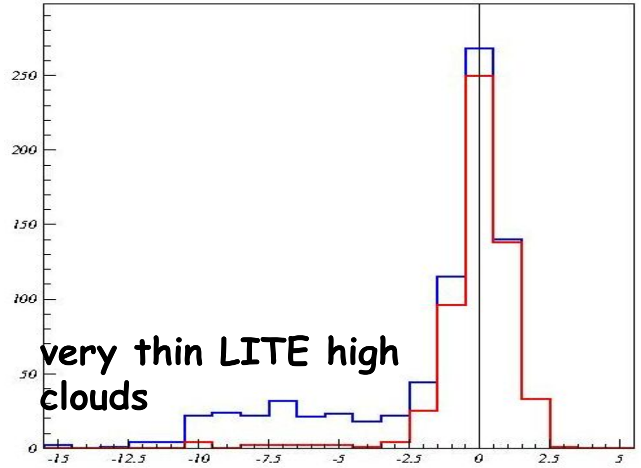
increasing D_e with cloud depth

broader size distribution

Evaluation of TOVS cloud height with LITE

(newest LITE inversion by L. Sauvage)

796 TOVS low clouds
560 LITE single- 236 multi-layer

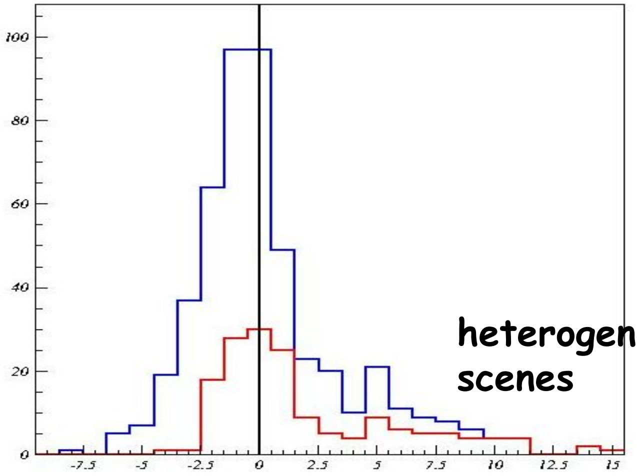


very thin LITE high clouds

$z^{TOVS} - 0.5(z_{top}+z_{base})^{LITE}$ (km)

single layer: $|\Delta z|<1$ km: 70%
peak at 0

495 TOVS high clouds
161 LITE single- 334 multi-layer



heterogenous scenes

$z^{TOVS} - 0.5(z_{top}+z_{base})^{LITE}$ (km)

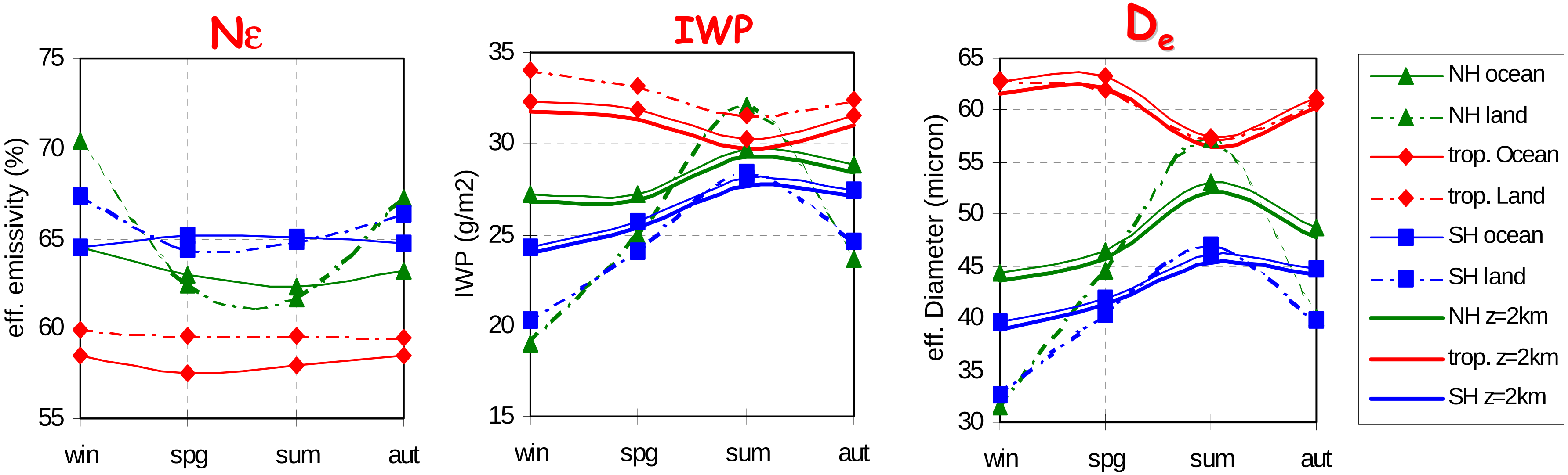
$|\Delta z| < 2$ km : 60 %
peak at –0.5 km

$P_{cld}(TOVS) \approx p_{cld}(\text{mid-cloud})$
better agreement for low large-scale cirrus clouds

LITE:	low clouds	high clouds
$z_{top}-z_{base}$:	1.3 km	2.7 km

Regional and seasonal variations of D_e and IWP

TOVS NOAA10 3-year averages



Nε(SHm) > Nε(NHm) > Nε(trop)

NH land: Nε(sum) < Nε(win)

IWP(trop) > IWP(NHm) > IWP(SHm)

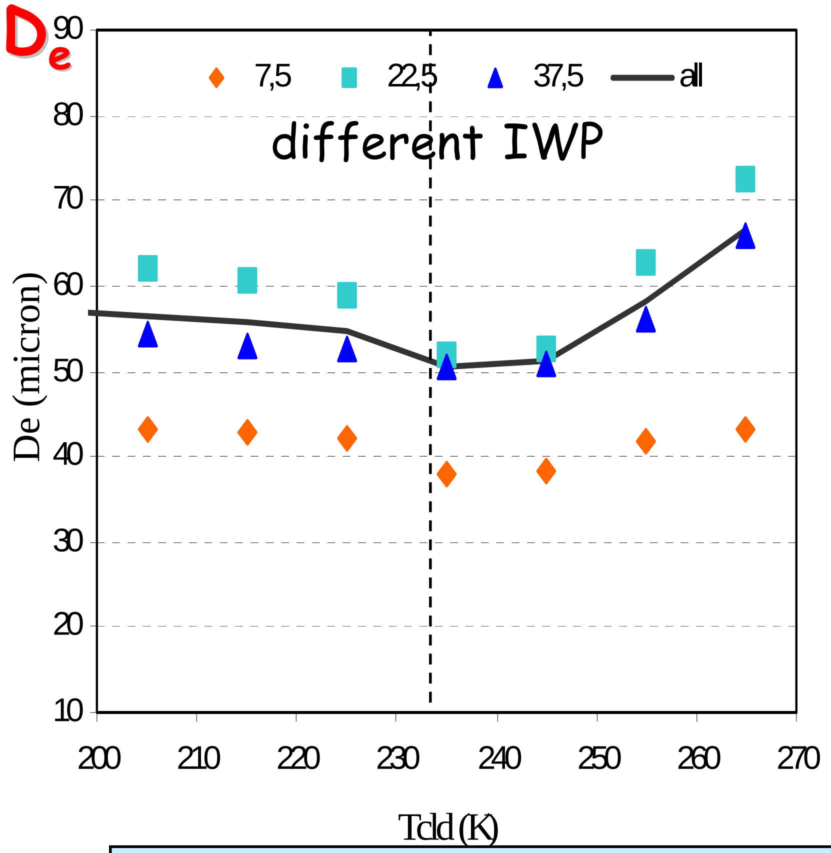
land: IWP(midsum) > IWP(midwin)

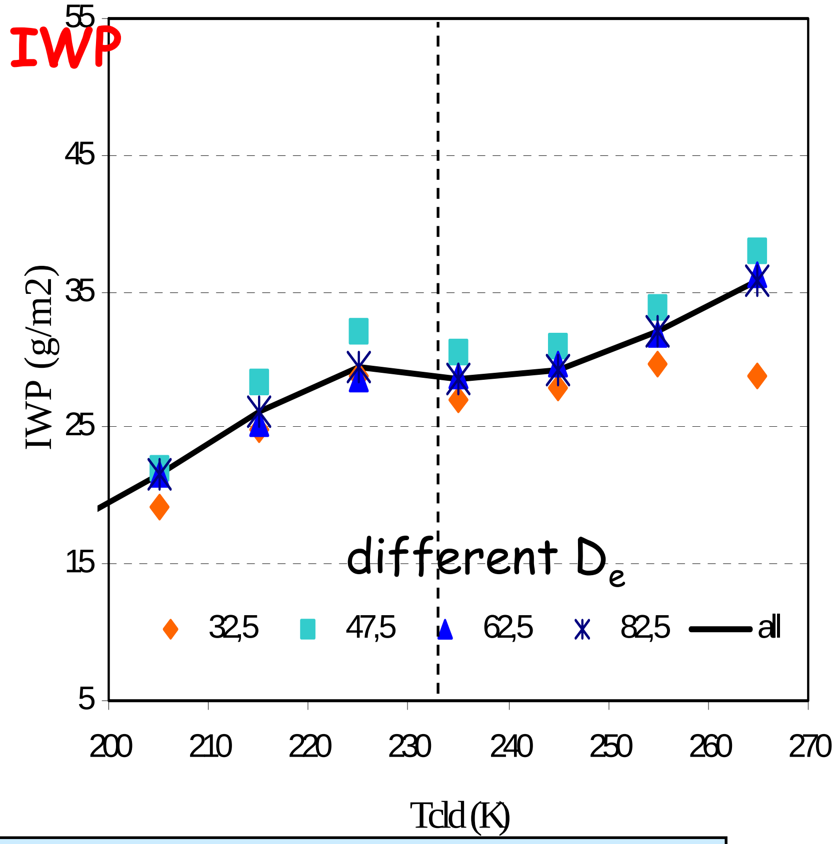
D_e(trop) > D_e(NHm) > D_e(SHm)

land: D_e(midsum) > D_e(midwin)

D_e and IWP as function of cloud temperature

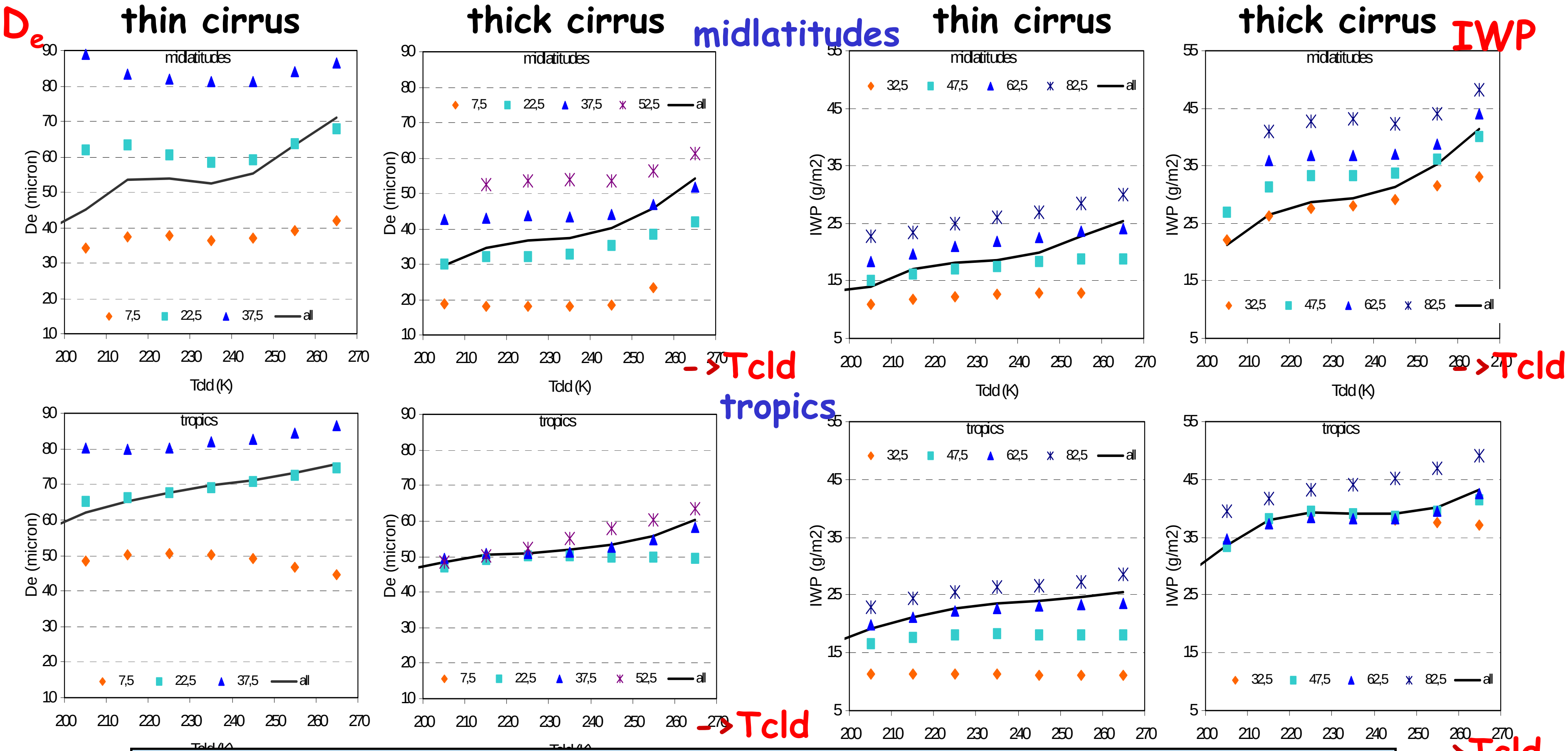
Large-scale semi-transparent cirrus 60°N -60°S





cold cirrus: D_e depends more on IWP than on T_{cld}
IWP increases with T_{cld}

Regional dependence for thin and thick Cirrus



different behaviour in midlatitudes and tropics

thick Ci in tropics: D_e and IWP do not depend strongly on T, almost no scatter due to different IWP or D_e

Atmospheric properties accompanying large-scale cirrus

ERA-40 ECMWF reanalyses:

- humidity, U, V and W for 23 pressure levels
- Every 6 hours, 1.125° x 1.125° spatial resolution

Co-location with TOVS observations: (1989, 1990)

	Water vapour (cm)		Horizontal wind (m/s)		Frequency of situations with		
	mean	RMS	mean	RMS	strong updraft	no wind	strong downdraft
NH midlatitude summer	**3.0**	1.2	**14.5**	10.9	**9%**	**38%**	**3%**
NH midlatitude winter	**1.4**	0.8	**26.1**	15.8	**13%**	**29%**	**7%**
tropics	**5.0**	0.9	**7.6**	6.0	**7%**	**44%**	**0.1%**
SH midlatitude summer	**2.3**	1.0	**23.4**	13.8	**6%**	**42%**	**4%**
SH midlatitude winter	**1.5**	0.8	**22.3**	15.2	**10%**	**34%**	**4%**

tropics: largest water vapour, smallest winds

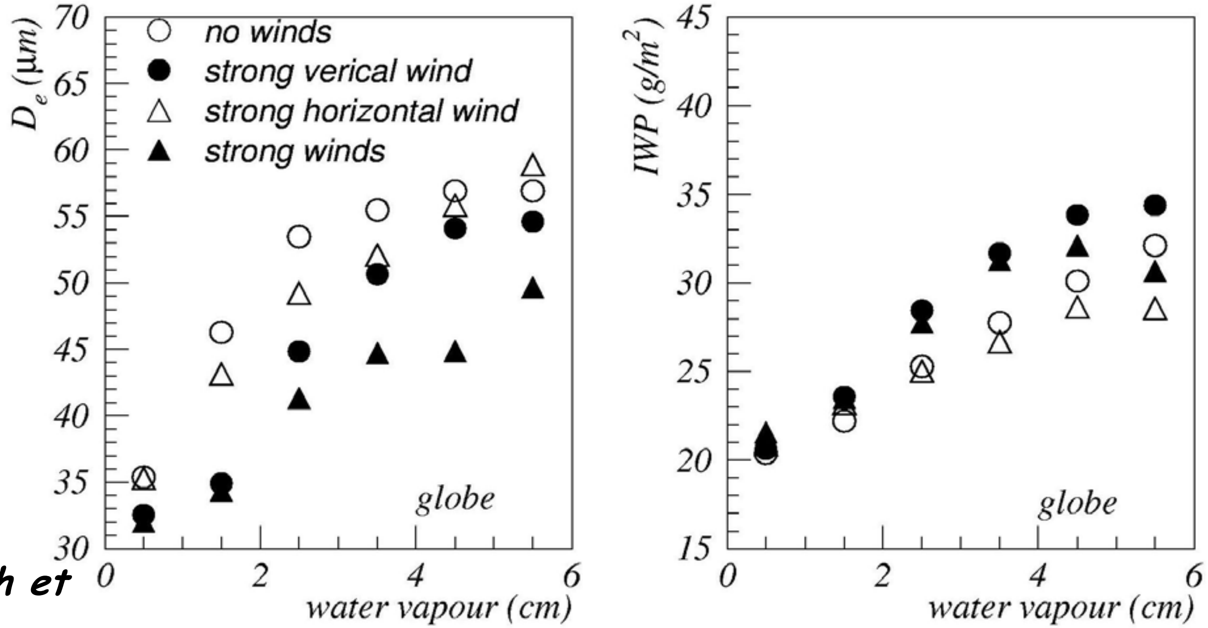
midlat. winter: strongest winds

SH: horizontal winds always strong

most large-scale semi-transparent cirrus in situations with no vertical wind

D_e and IWP as function of humidity and wind

Large-scale semi-transparent cirrus 60 N – 60 S, T_{cld} < 233K



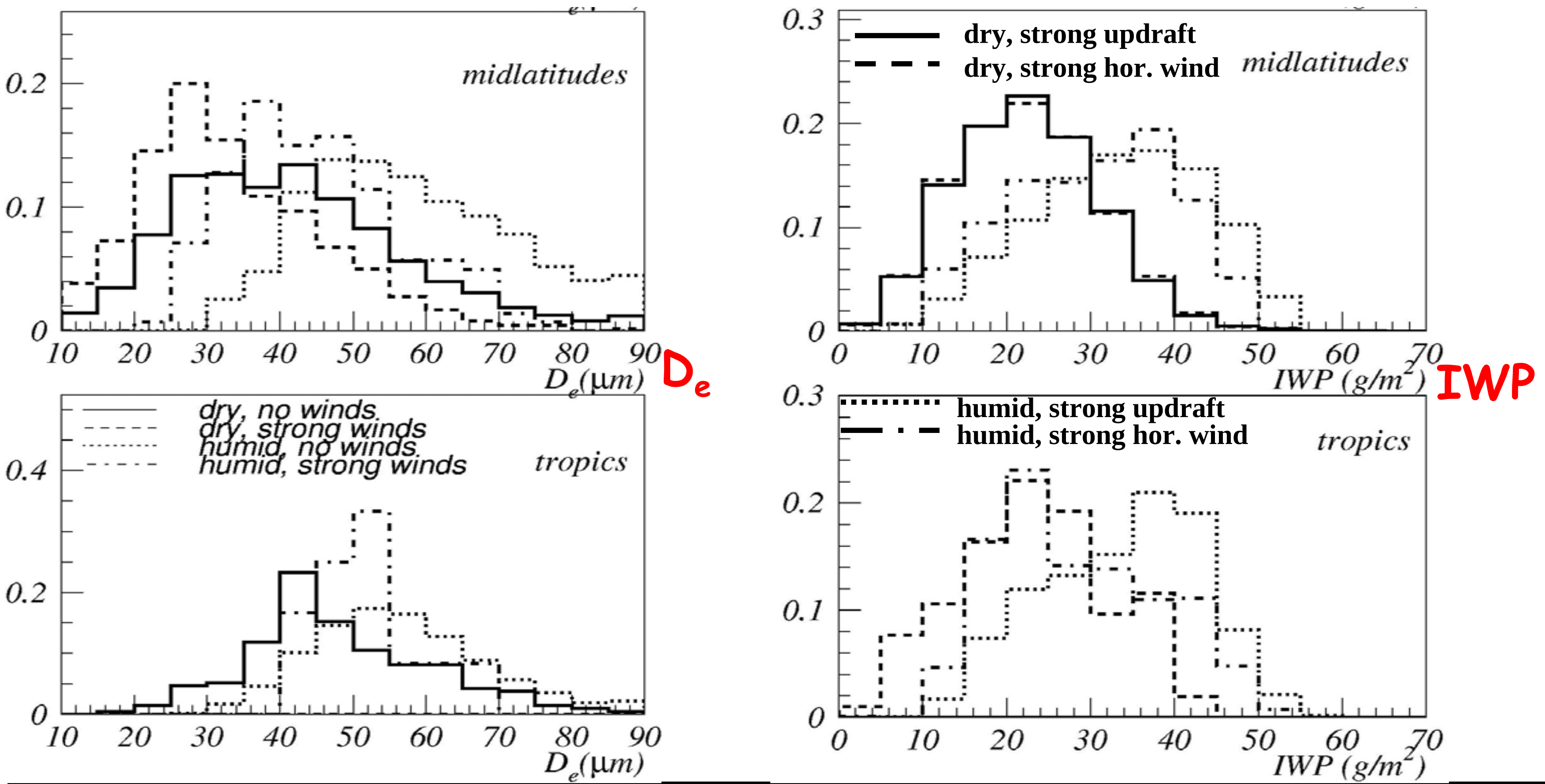
Stubenrauch et al. 2003, submitted to Atmos.Res.

D_e and IWP increase with water vapour

D_e 12 μm smaller in case of strong winds

IWP 10 gm^{-2} larger in case of strong vertical updraft

Regional distributions of D_e and IWP as function of humidity and wind



D_e larger in case with no winds than strong winds

humid tropics: IWP larger in case of strong w than strong u+v

Cirrus horizontal extent

determine horizontal extent of cirrus clouds (ε > 0.3):

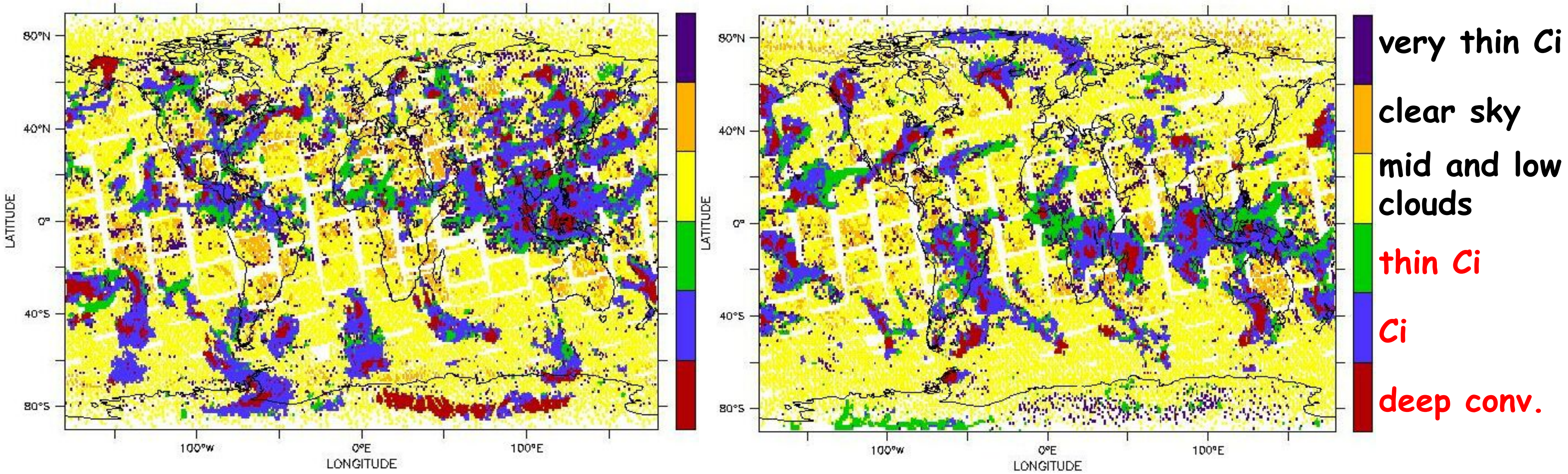
a. empty boxes are filled with 'most likely' information on cirrus type

b. simple clustering algorithm groups adjacent boxes containing

deep convection (ε>0.95 🟥), cirrus (0.95>ε>0.5 🟦)

or thin cirrus (0.5>ε>0.3 🟩)

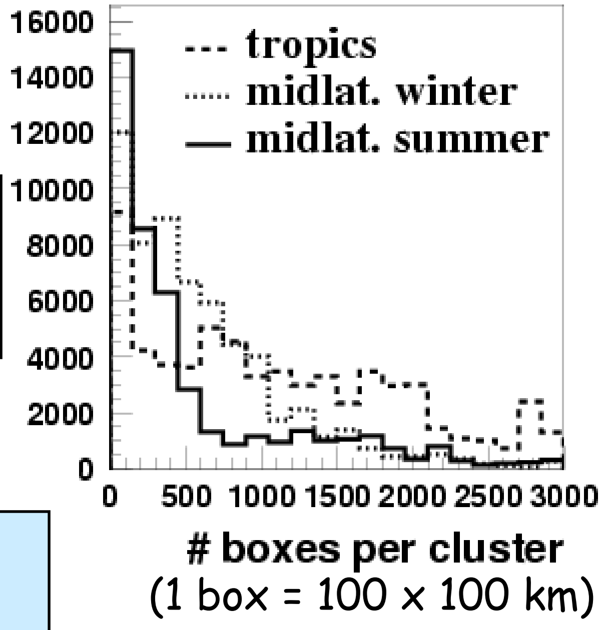
Examples: 18/07/1989 and 30/12/1989 7h30 PM



Cirrus horizontal extent

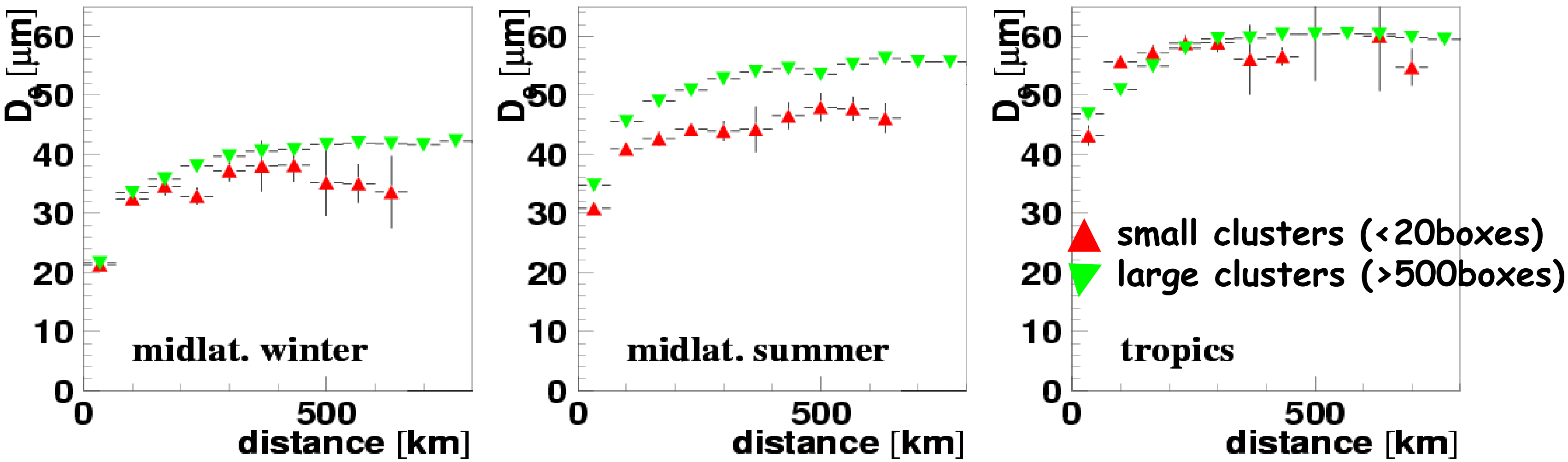
cirrus clusters: largest in tropics

smallest in ML summer



D_e as fct. of **distance** to convective centre:

D_e small if very close to convective centre
and in smaller clusters -> dynamics?



Conclusions and Outlook

- Large-scale semi-transparent cirrus: $\langle D_e \rangle = 55 \mu m$ $\langle IWP \rangle = 30 g/m^2$
- IWP increases with T_{cld}
- TOVS Path-B & ECMWF reanalyses →

  D_e and IWP increase with atmospheric water vapour,

  increase depends on vertical updraft, hor. wind,

  formation processes?

★

- Study D_e as function of cirrus size and location to convective center for different dynamic situations
- Find parameterizations IWP $= f\,(q,w,T)$, $D_e = f\,(IWP,q,w,u+v,T)$ using also cluster information