Cirrus mean effective ice crystal sizes from Satellite TIROS-N Operational Vertical Sounder (TOVS) Observations

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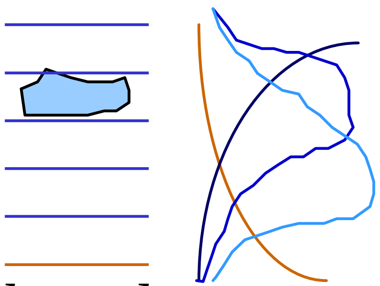
Longterm Satellite Observations

TOVS **vertical sounders** on polar satellites: since 1979

Path-B (*Scott et al., BAMS 1999*, **1987-1995**)

- every 6 hours, 20 km resolution, averaged over 1°
- good spectral resolution (HIRS:19 IR,1VIS, MSU: 4 μw)



3I Inversion (*Chédin, Scott 1985*)

temperature, water vapor profiles

+ *cloud properties*

based on:

radiosonde measurements

4A radiative transfer

R_{clr}, $R_{cld}(\lambda_i,p_k,\theta)$ TOVS Initial Guess Retrieval dataset

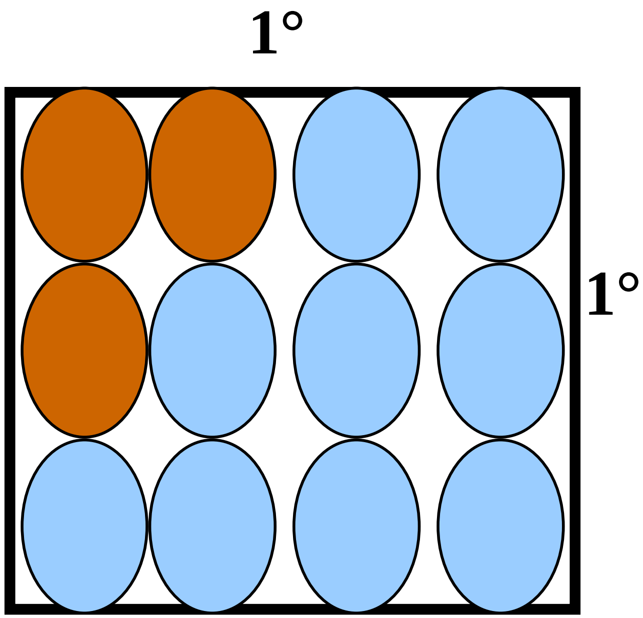
3I Cloud detection

- **at HIRS resolution**

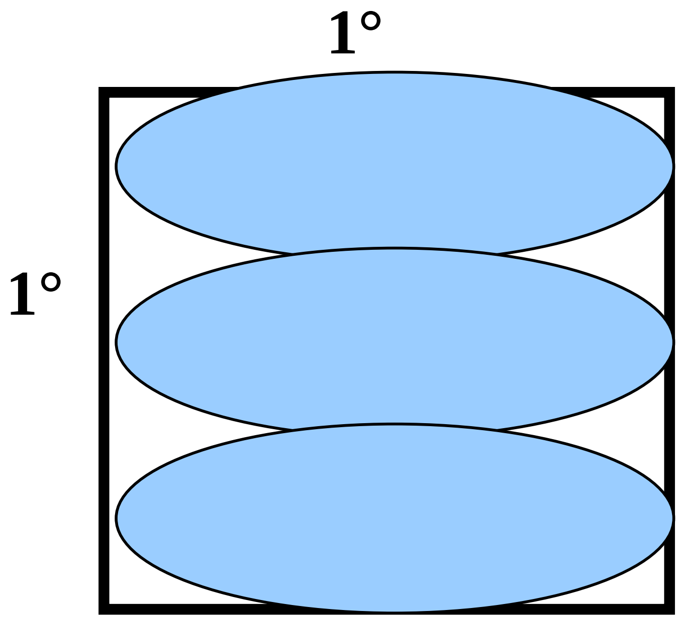
MSU predicts clear sky T_B

7/8 threshold tests

nadir

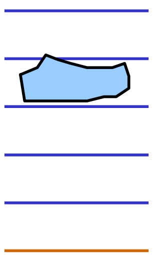


θ_v=58°



3I Cloud property retrieval

♦ **over averaged cloudy pixels**



4 channels in 14µm CO_2-band + 11 µm

max weights: *400-900 hPa* *surface*

<u>coherence of effective cloud amount</u>

$$N\varepsilon\left(p_{cld}\right) \cong N\varepsilon\left(p_k, \lambda_i\right) = \frac{R_m\left(\lambda_i\right) - R_{clr}\left(\lambda_i\right)}{R_{cld}\left(p_k, \lambda_i\right) - R_{clr}\left(\lambda_i\right)}$$ for i=4,8

minimize weighted $\chi_w^2(p_k)$ => Nε, p_{cld}

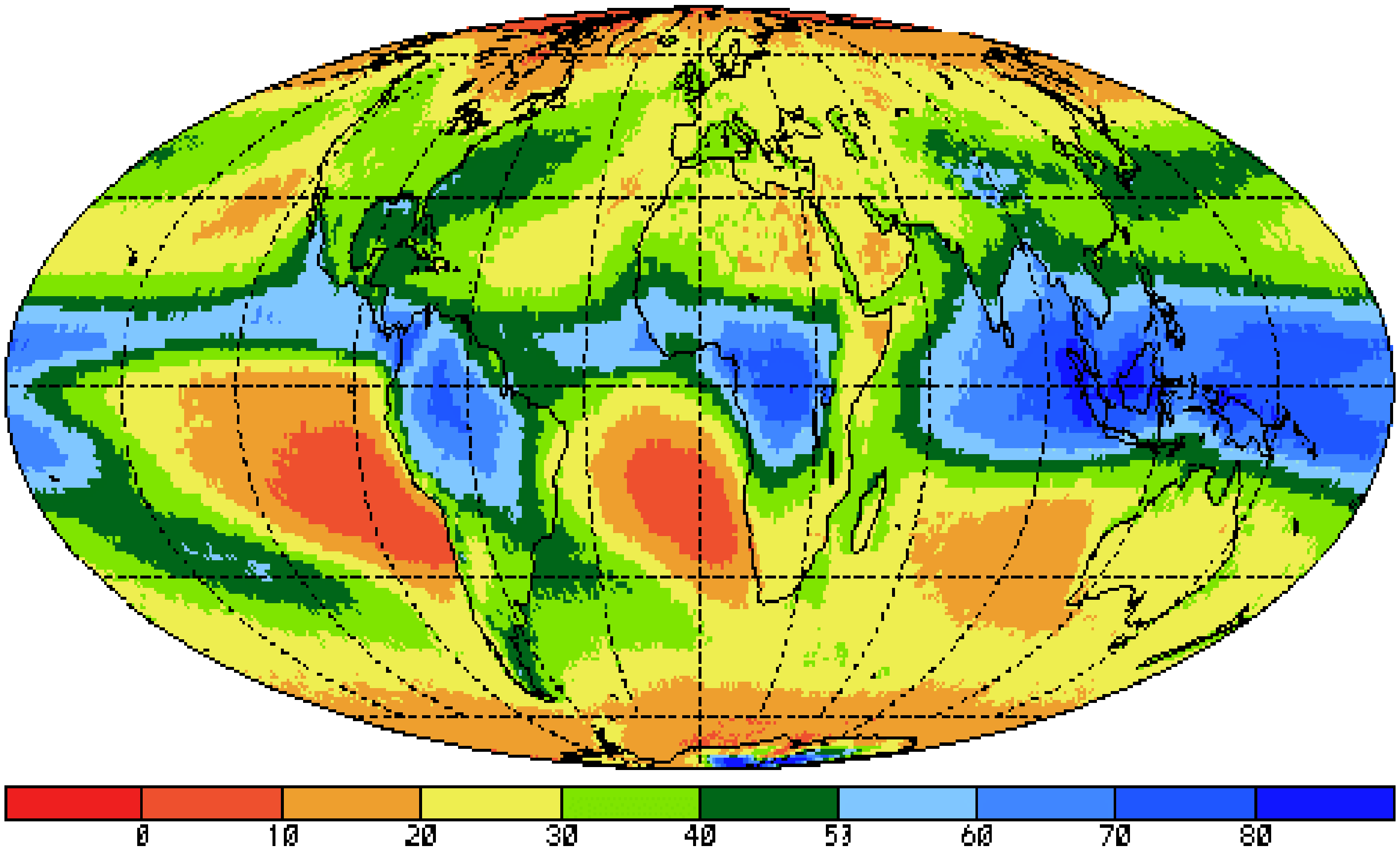
empirical weights <=> T profile uncertainty on R_{cld} - R_{clr}

(Stubenrauch et al., J. Climate 1999)

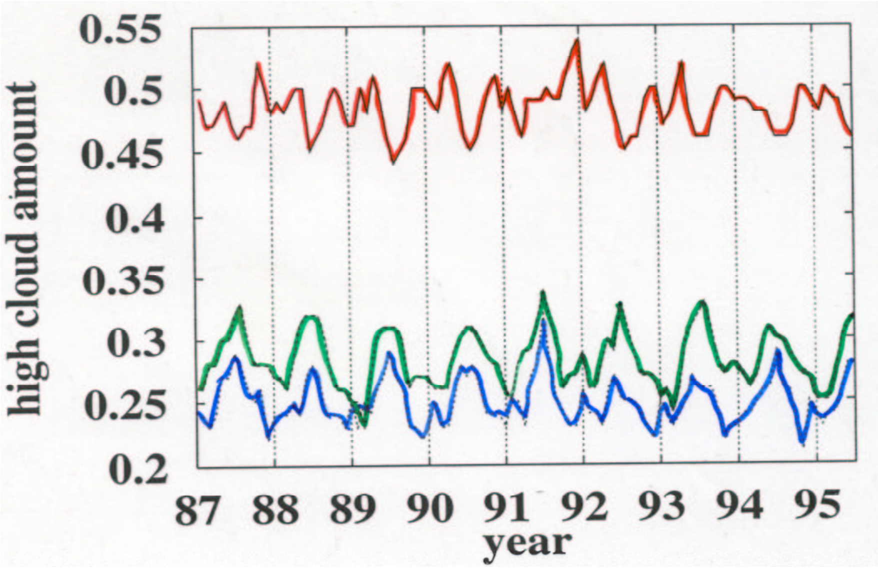
reliable cirrus clouds

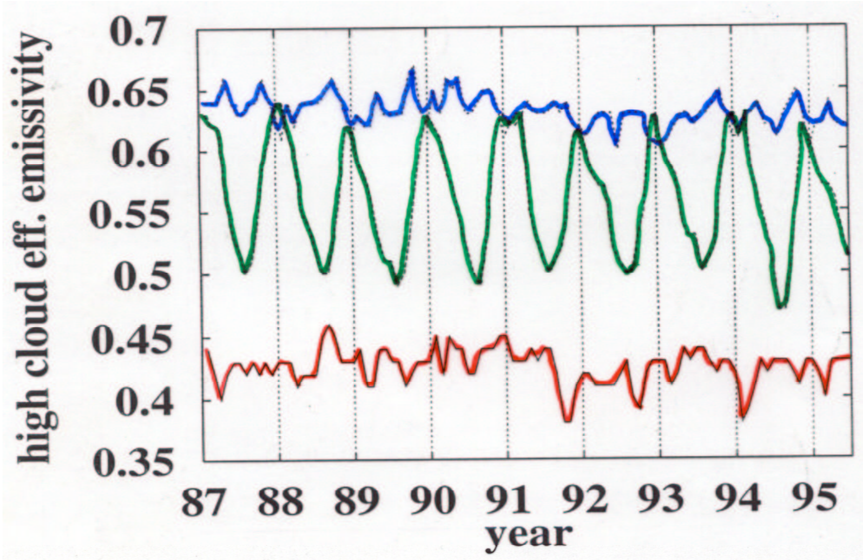
TOVS Path-B high cloud frequency

Pcld < 440 hPa, 1987-1991

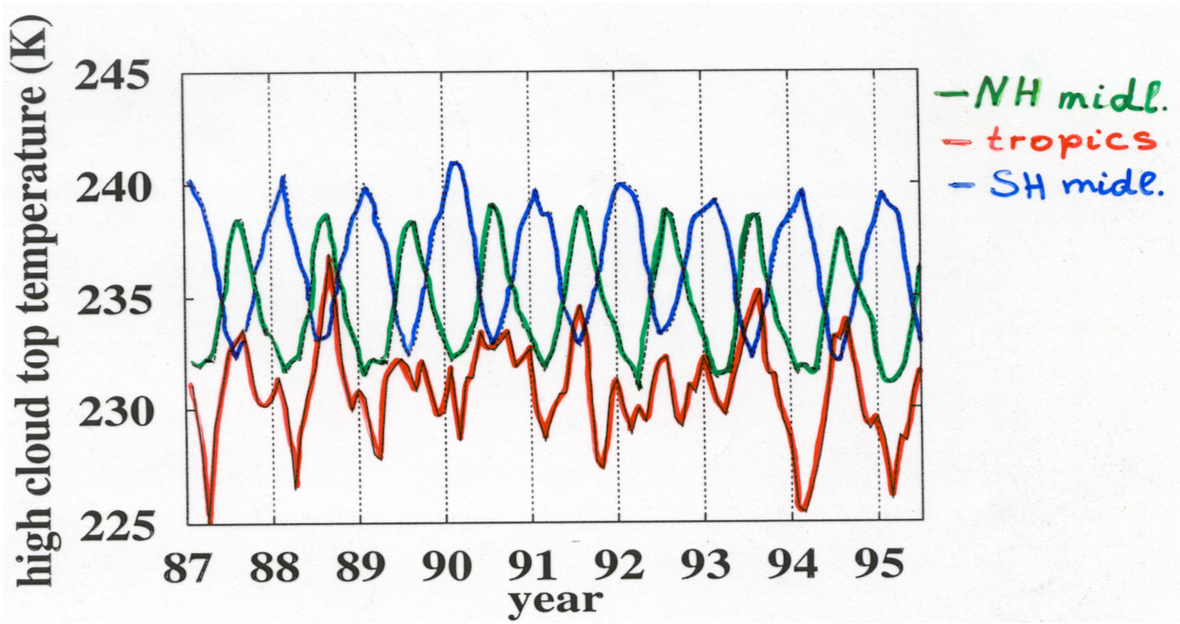


Time series of TOVS Path B high cloud properties



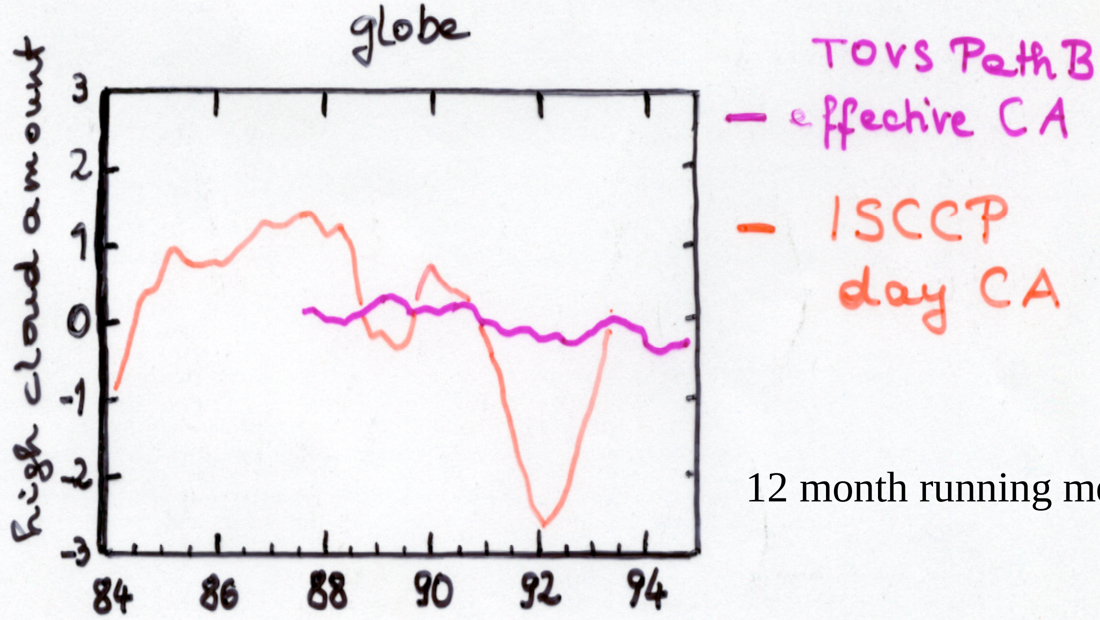


Global CA_{hgh} ~0.3



Study of high cloud amount evolution:

correlation with cosmic rays, volcanic eruptions?



12 month running means

Stubenrauch + Eddounia, CERN Proceedings 2001-007

Workshop on Ion-Aerosol-Cloud Interactions

♦ Satellite observations:

unique possibility to survey cld properties over long period

	ISCCP	TOVS
1983-1995:	**<CA>~67%**	**<eff. CA>~53%**

stable within 2% over globe

Svensmark's 'cosmic ray intensity - CA correlation' analysis could not be confirmed!

1991 Pinatubo eruption

aerosols -> slight overestimation of ISCCP τ

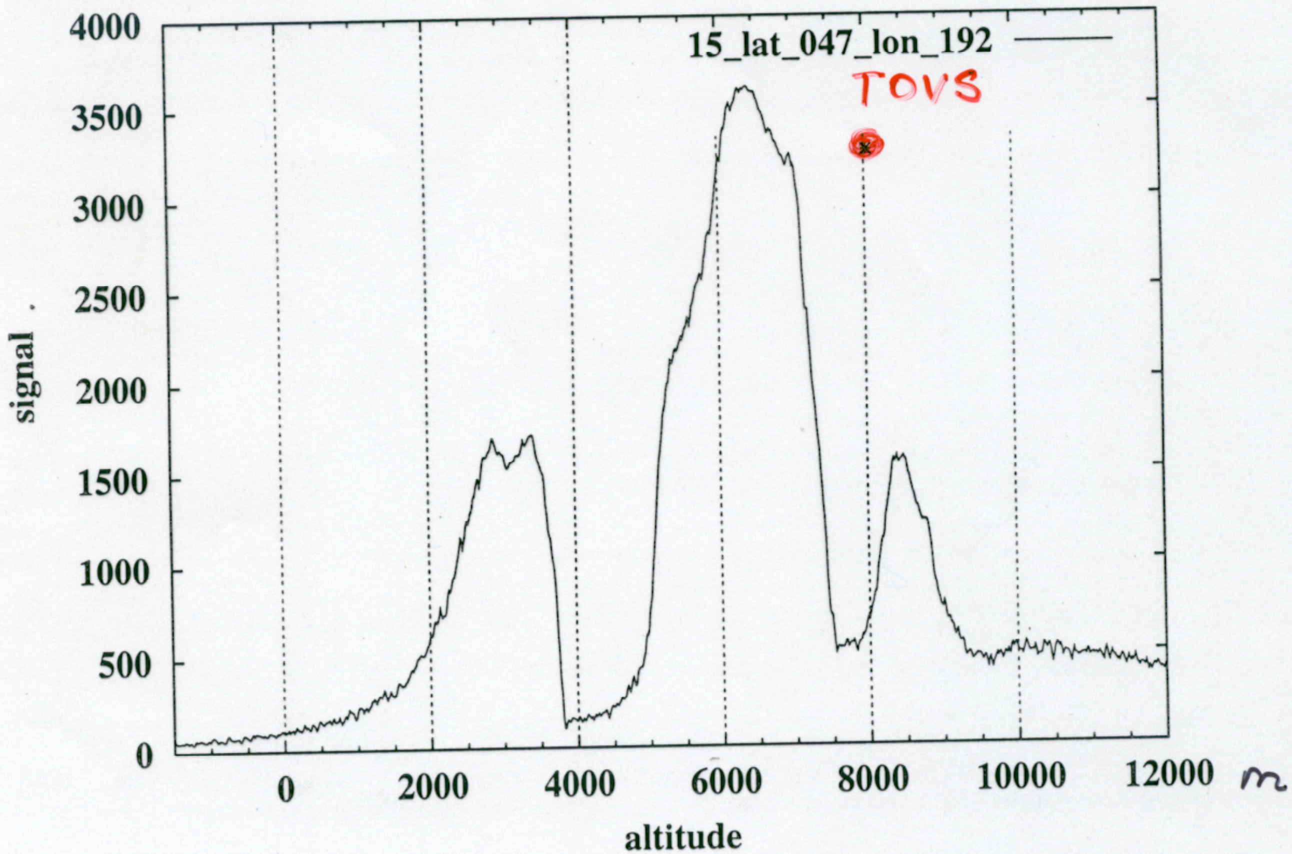
=> slight underestimation of ISCCP high CA (4.5% in tropics)

TOVS high eff. CA stable (IR)

TOVS - LITE comparison 9/94

F. Eddounia

$\Delta t \sim \pm 3$ hours : ~2000 evts



TOVS cirrus ice crystal size retrieval

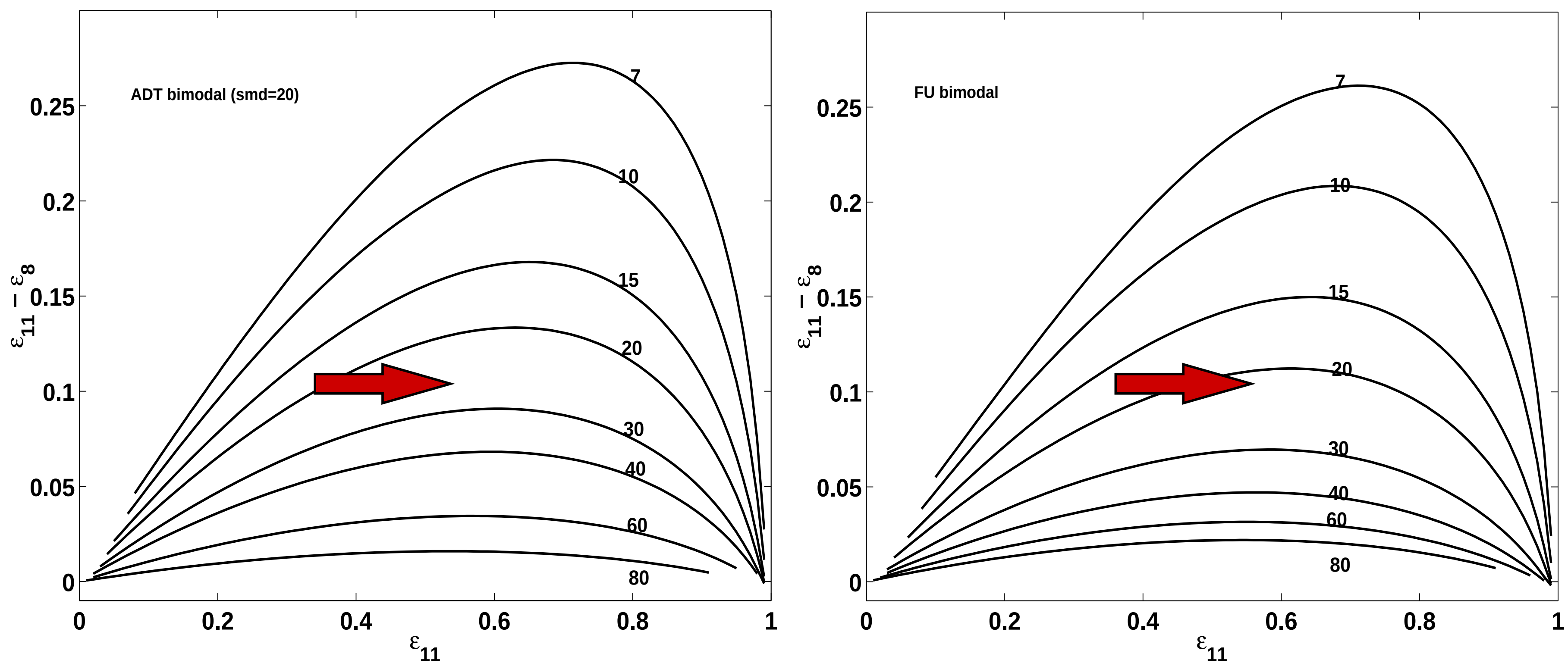
based on spectral difference of cirrus emissivities

- ice crystal single scattering properties Q_{abs}, ω_0, g

aggregates: modified ADA *(Mitchell 1996)*

hexagonal columns: FDTD *(Fu 1998)*

radiative transfer based on discrete ordinate method (Streamer, *J. Key)*



Simulation of look-up tables

- ADA: $Q_{abs} = 1 - \exp\left(\frac{-4\pi n_i D_e}{\lambda}\right)$, ω_0 g from FDTD
- $D_e = 2r_e^{VP} = 2\frac{\int \frac{3V}{4\pi} n(r)dr}{\int \frac{P}{\pi} n(r)dr} = \frac{3}{2}\frac{IWC}{\rho_i P}$
- Bimodal-Γ size distribution $N(D)=N_{0s}e^{-\lambda_s D}+N_{0l}D^{\nu_l}e^{-\lambda_l D}$
- $D_e(\varepsilon_{11\mu m},\varepsilon_{8\mu m})$, for 8 surfaces and 4 θ_v's

  SARB surface emissivities
- for $0< \varepsilon_{11\mu m}-\varepsilon_{8\mu m}<0.01$ -> $D_e(\varepsilon_i)=D_e(\varepsilon_{i-1})+2.5\mu m$

Sensitivity study on ice crystal size retrieval

Homogeneous cloud, z_{cld} = 10 km, z = 1 km, T_{surf} = 300 K,
polycrystals, bimodal-Γ size distribution

		15µm D_e	60µm
crystal shape	spheres	+ 15%	+30%
	hexagonal columns	+ 15%	- 10%
size distribution	tropical	- 20%	- 28%
	midlatitude	+ 5%	- 20%

		thin clouds		thick clouds	
		15µm D_e	60µm	15µm D_e	60µm
z_{cld}	> 4km	- 4%	- 2%	- 6%	- 2%
T_{surf}	< 15 K	+ 3%	+ 2%	+ 5%	+ 2%
Δz	> 1 km	+ 4%	+ 6%	+ 8%	+ 10%
horizontal heterogeneity	90% cloud cover	+ 7%	+ 2%	+ 27%	+12%
vertical heterogeneity	IWC(2) = 1.5 IWC(1)	+ 0.5%	+ 1.0%	+1.2%	+ 0.7%
	$D_e(2) = 2\ D_e(1)$	-15%	- 20%	-15%	- 20%
+ water cloud	r_e=10µm, LWC=0.03g/m^3	+ 10%	+ 15%	+ 9%	+ 9%
	r_e=7µm, LWC=0.20g/m^3	+ 25%	+ 25%	+ 15%	+ 15%

TOVS cirrus ice crystal size retrieval

(*Stubenrauch et al., JGR 1999, CIRAMOSA*)

1°x1° overcast 3I high clouds (p_{cld}<440 hPa)

T_B^{meas}(8µm), T_B^{meas}(11µm), T_{cld}, T_{surf}
closest TIGR atmosph. H_20/T profile, SARB surf. emissivities

↓ **3R radiative transfer**

cirrus effective emissivities

$$\varepsilon(\lambda,\theta_v) = \frac{B\left(T_B^m(\lambda,\theta_v)\right) - B\left(T_{surf}(\lambda,\theta_v)\right)}{B\left(T_{cld}(\lambda,\theta_v)\right) - B\left(T_{surf}(\lambda,\theta_v)\right)}$$

ε(11µm)-ε(8µm) < - > simulated look-up tables

↓

D_{eff}

TOVS cirrus ice crystal size retrieval

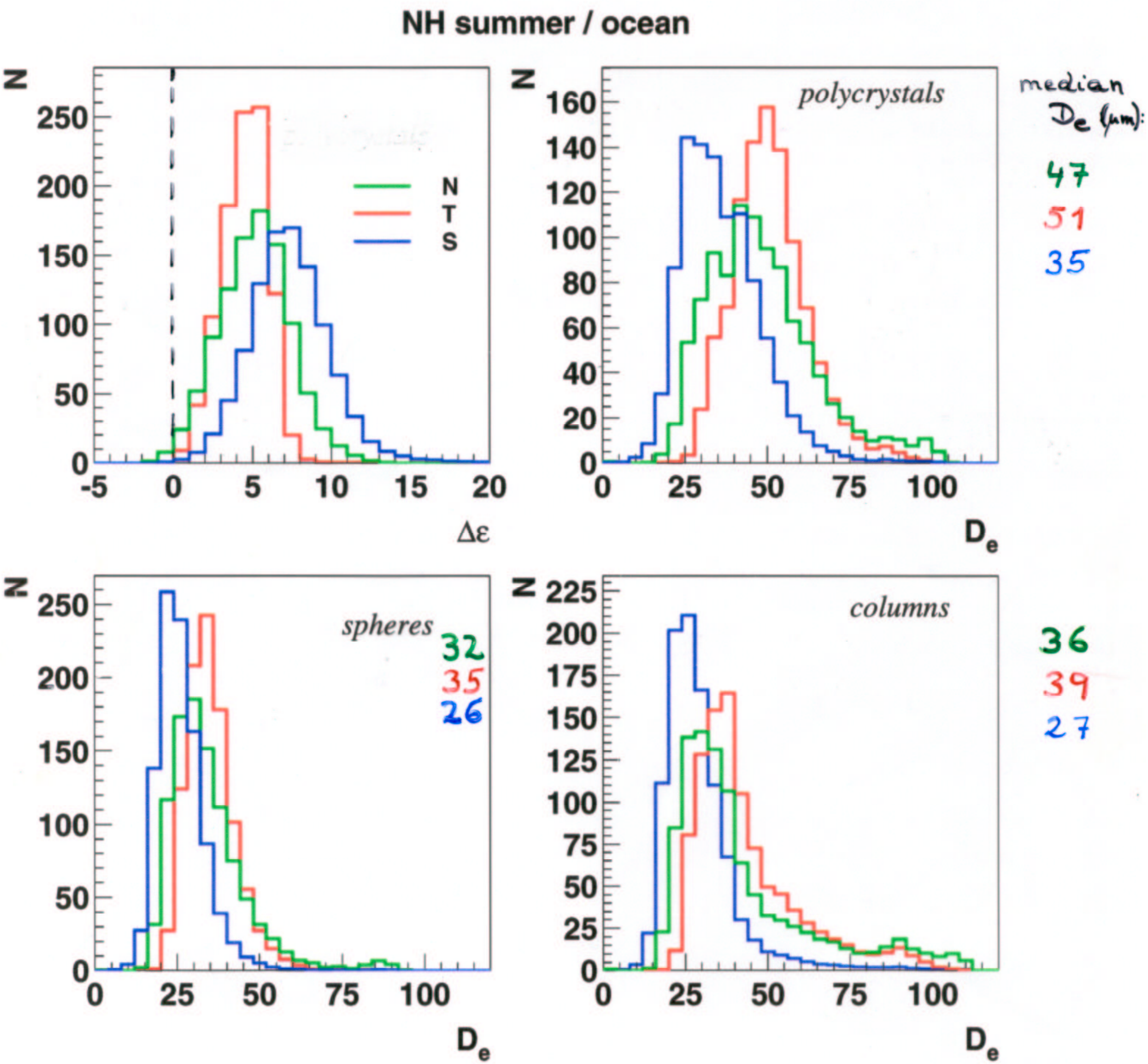
- NOAA10 satellite observations: 1/1987 - 9/1991
  (NOAA12: 8 μm channel problem at low temperatures!)

- $0.3 < \varepsilon(11\mu m) < 0.85$, sensitivity: $D_e \leq 90\mu m$
  $0.7 < \tau_{VIS} < 3.2$

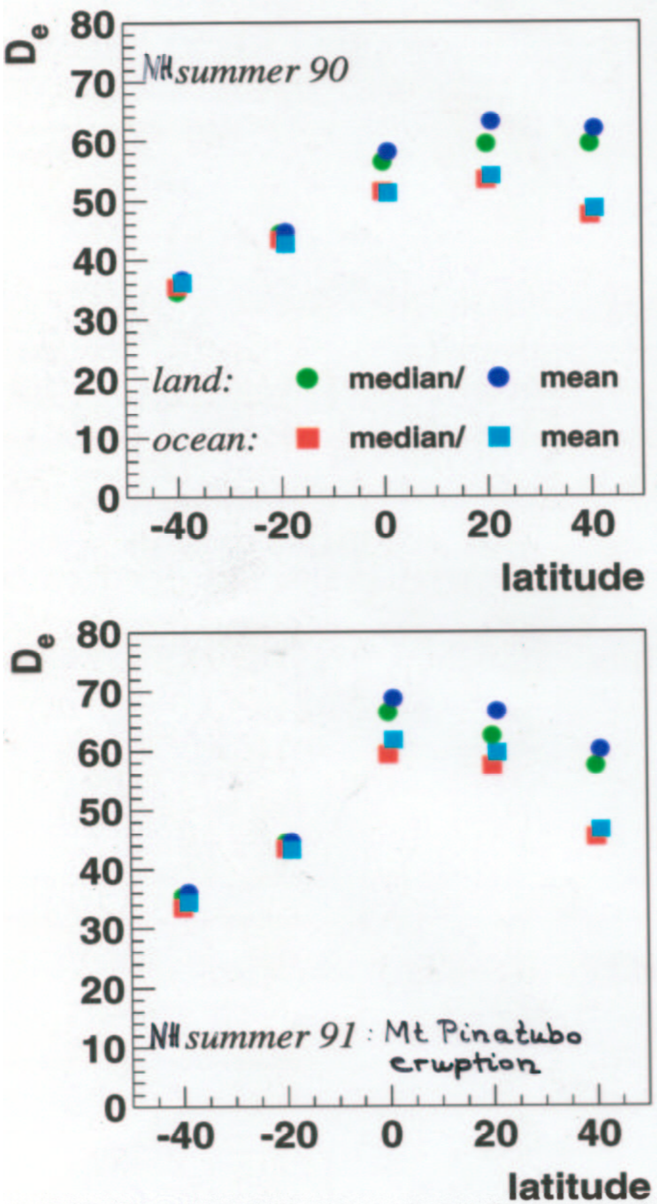
- $\theta_v < 25°$

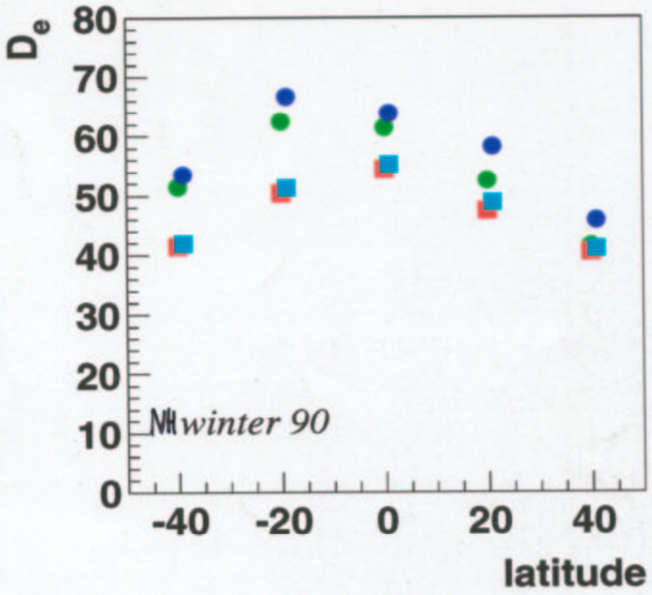
- D_e uncertainties increase with D_e :

- calculate median values of distributions


NH summer / ocean
N
Δε
N
T
S
polycrystals
D_e
median D_e (μm):
47
51
35
spheres
32
35
26
columns
36
39
27

D_e as function of latitude





midlatitudes:

$D_e(\text{sum}) > D_e(\text{win})$

$D_e(\text{tropics}) > D_e(\text{midlat.})$

Conclusions and Outlook

- Retrieval of *Cirrus mean effective ice crystal size* feasable *at a global scale* using TOVS Path-B satellite data
- *aggregate assumption*: D_e between 35 and 65 μm

  D_e(*tropics*)>D_e(*midlatitude*),
  D_e(*summer*)> D_e(*winter*)

  D_e=f(H_2O,ε, dynamics)
- *hex. column assumption*: D_e about 8 to 11 μm smaller
- recent NOAA satellites: no 8 μm channel -> 4μm channel
- study other theoretical approaches (*Yang*, *Mishchenko*, *Baran*)
- check coherence with combined LW/SW fluxes (ScaRaB)

CIrrus microphysical properties and their effect on RAdiation:

L I L L E

Met Office

CIRAMOSA

Kickoff: 9/2/2001

survey and integration into climate MOdels using combined SAtellite observations

Coordinator: Claudia Stubenrauch (C.N.R.S.-LMD)

Web-site: **http://www.lmd.polytechnique.fr/CIRAMOSA/Welcome.html**

CIRAMOSA Objectives

- long-term survey of cirrus physical and microphysical properties (1987-1995)
- correlations between cirrus properties and the state of the atmosphere
- study their effect on the reflection and absorption of solar and thermal radiation
- improvement of cirrus radiative transfer in GCMs

Observations: **TOVS, ATSR, POLDER, in-situ**

state of atmosphere

Cirrus

macrophysics ***microphysics***

correlations

GCM radiative transfer model

ScaRaB observed - simulated

TOA LW, SW fluxes