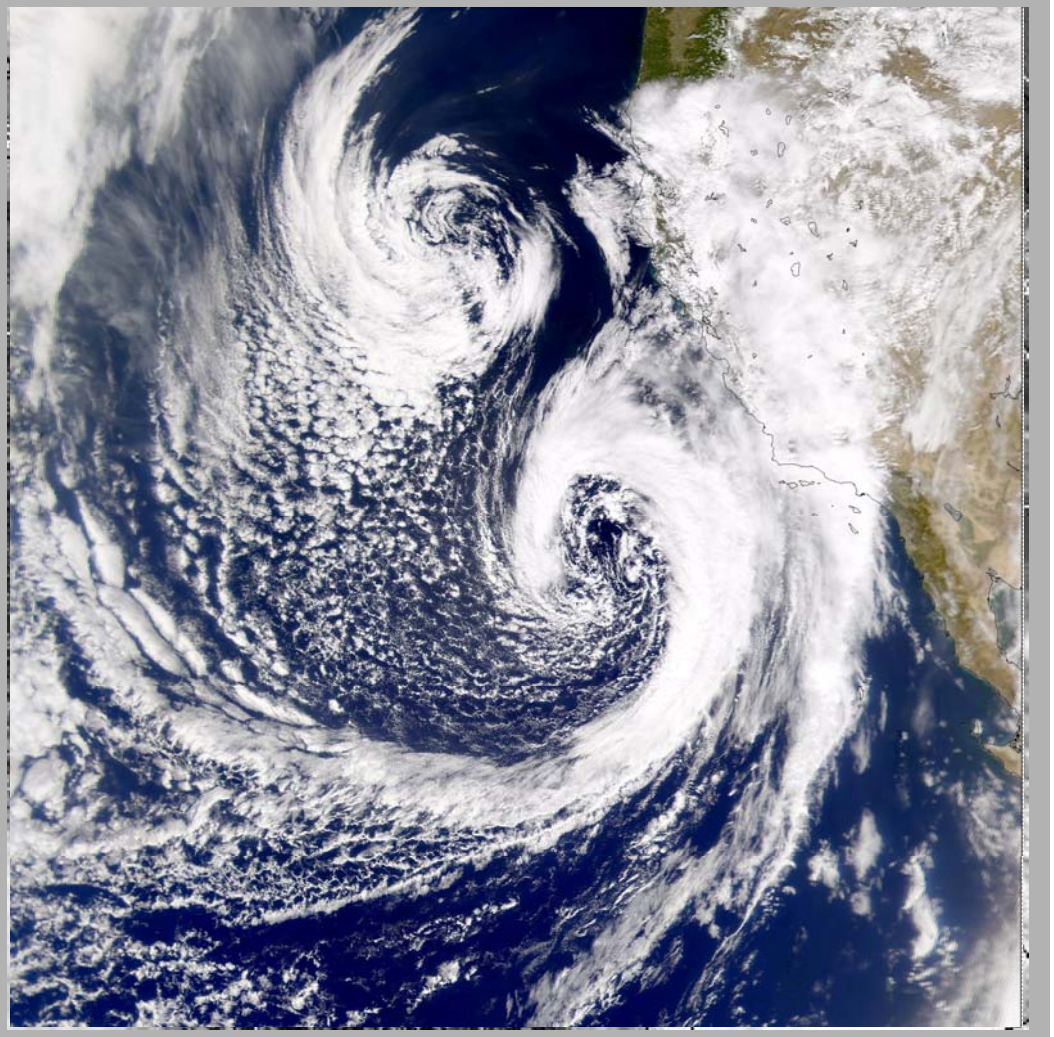
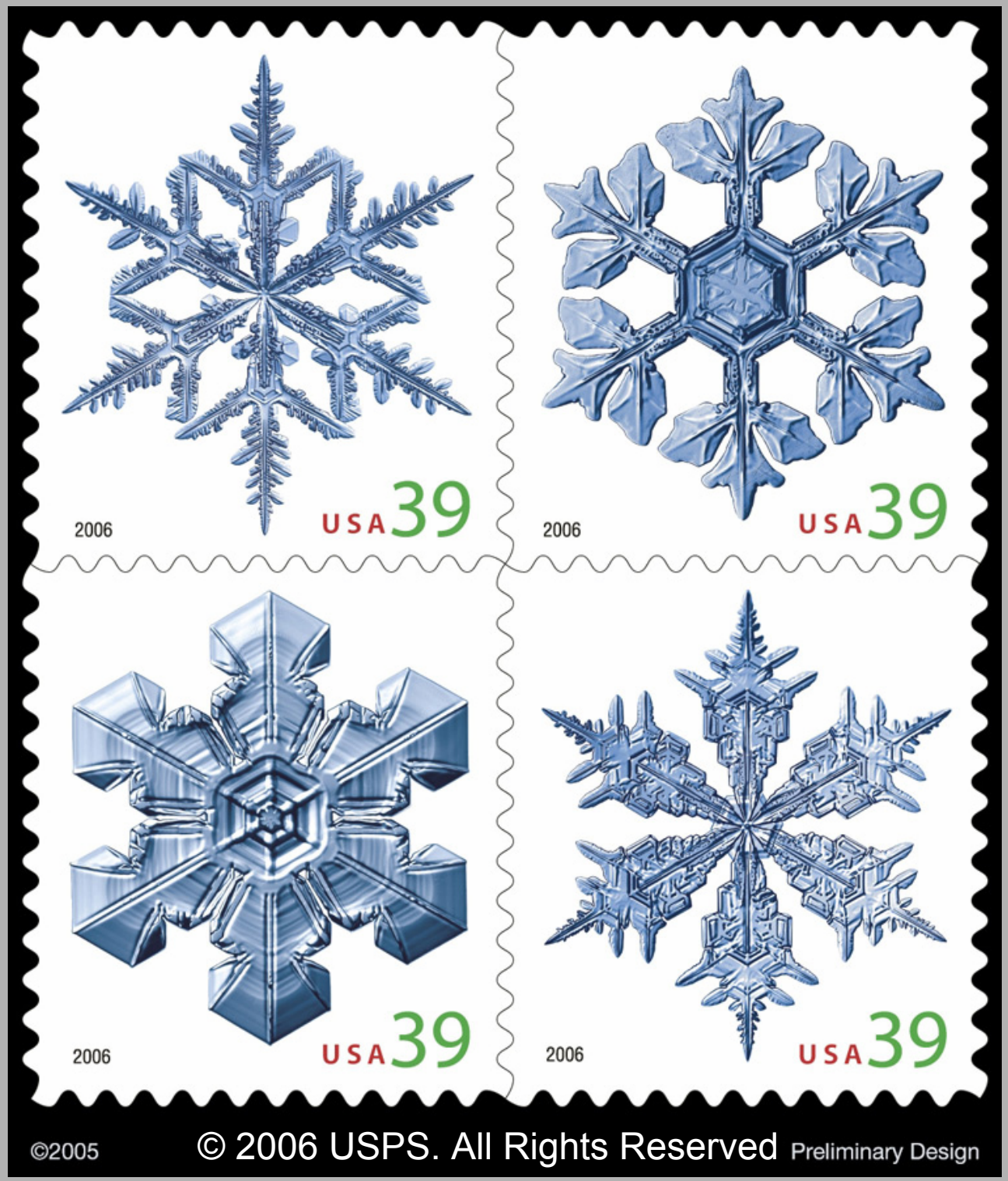
Contrast in ice cloud microphysics between the Tropics and Midlatitudes and its representation in models

Paul Field

Andrew Heymsfield
Aaron Bansemer

Anvils and Stratiform ice cloud

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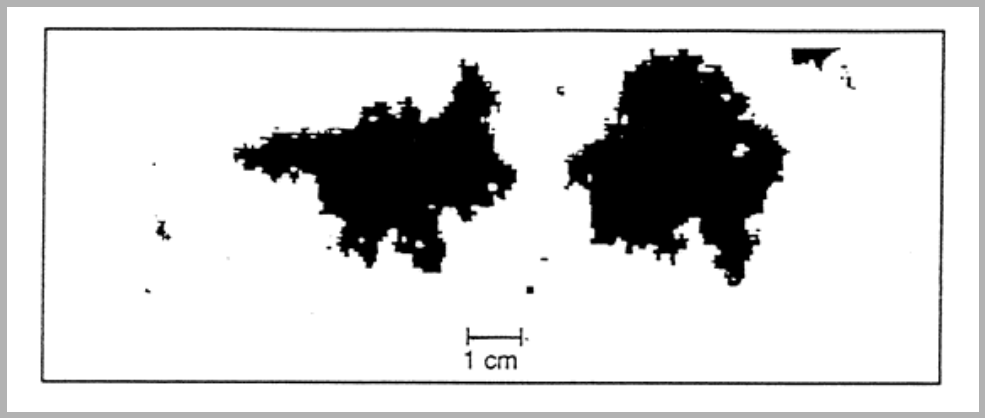
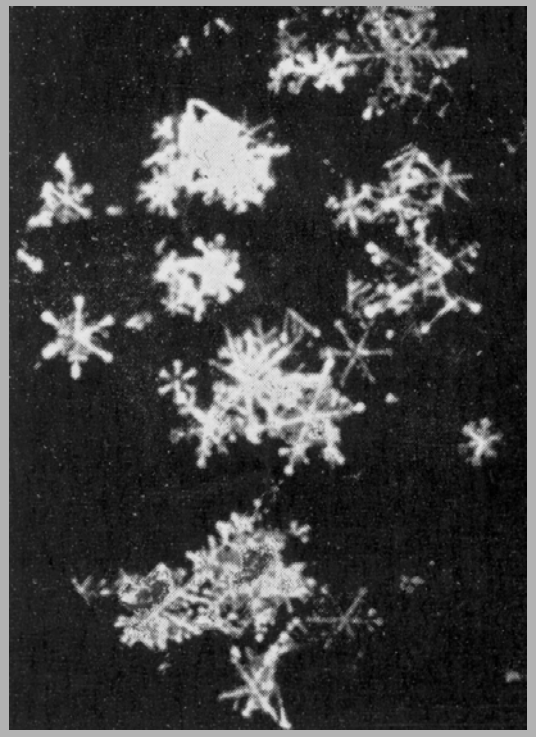
Preliminary Design

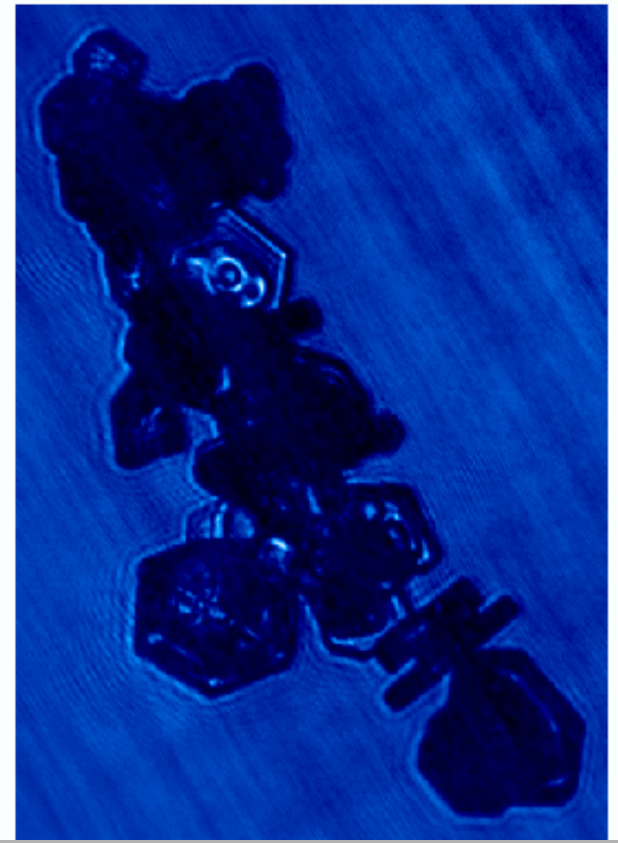


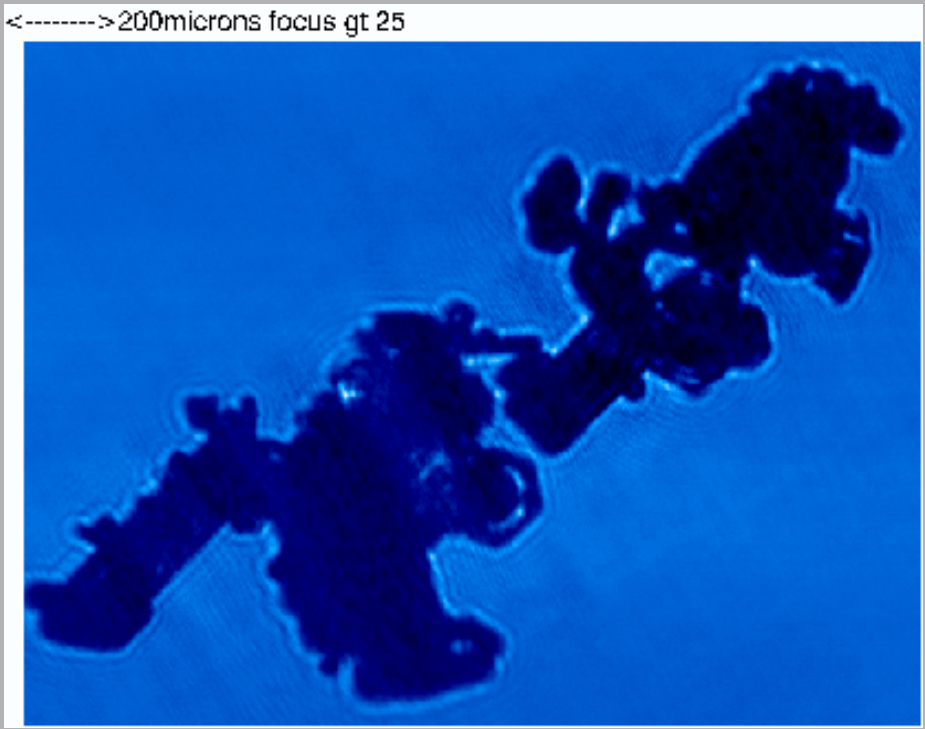
Paul Lawson, JAS'99

Emerald2
Paul Connolly
UMIST

Mason
POC



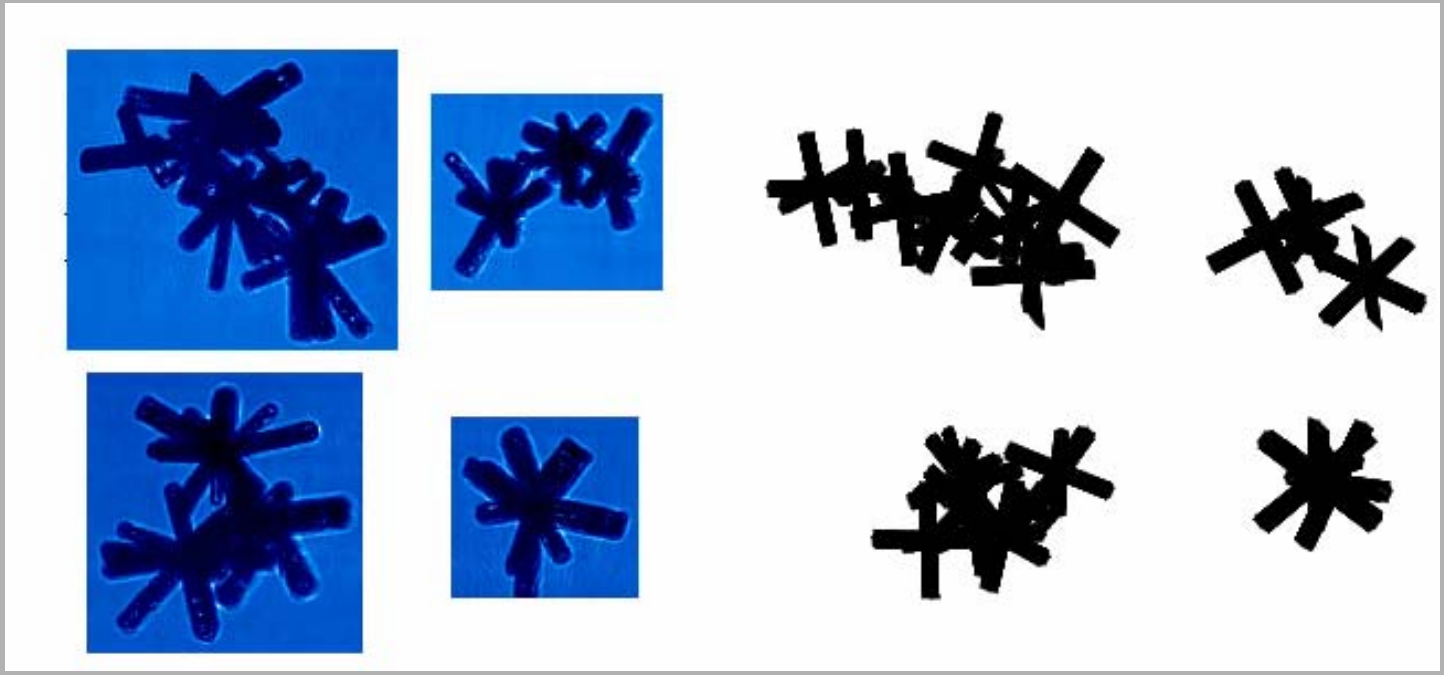




Carl Schmitt, CRYSTAL

Real and modelled aggregates

CPI **Model**



500 μm

T=-46°C

Westbrook et al. GRL 2004

Mass ~ D^2

(independent of monomer habit)

Aggregates

- Emergent self similarity
- Similar power laws for:
  - Mass-dimension
  - Fallspeed-dimension
  - Capacitance
- Independent of monomer habit – and hence regime

Tropics and Midlatitudes

‘a’=(tropics ‘a’ + midlat ‘a’) ‘b’=(tropics ‘b’ + midlat ‘b’)

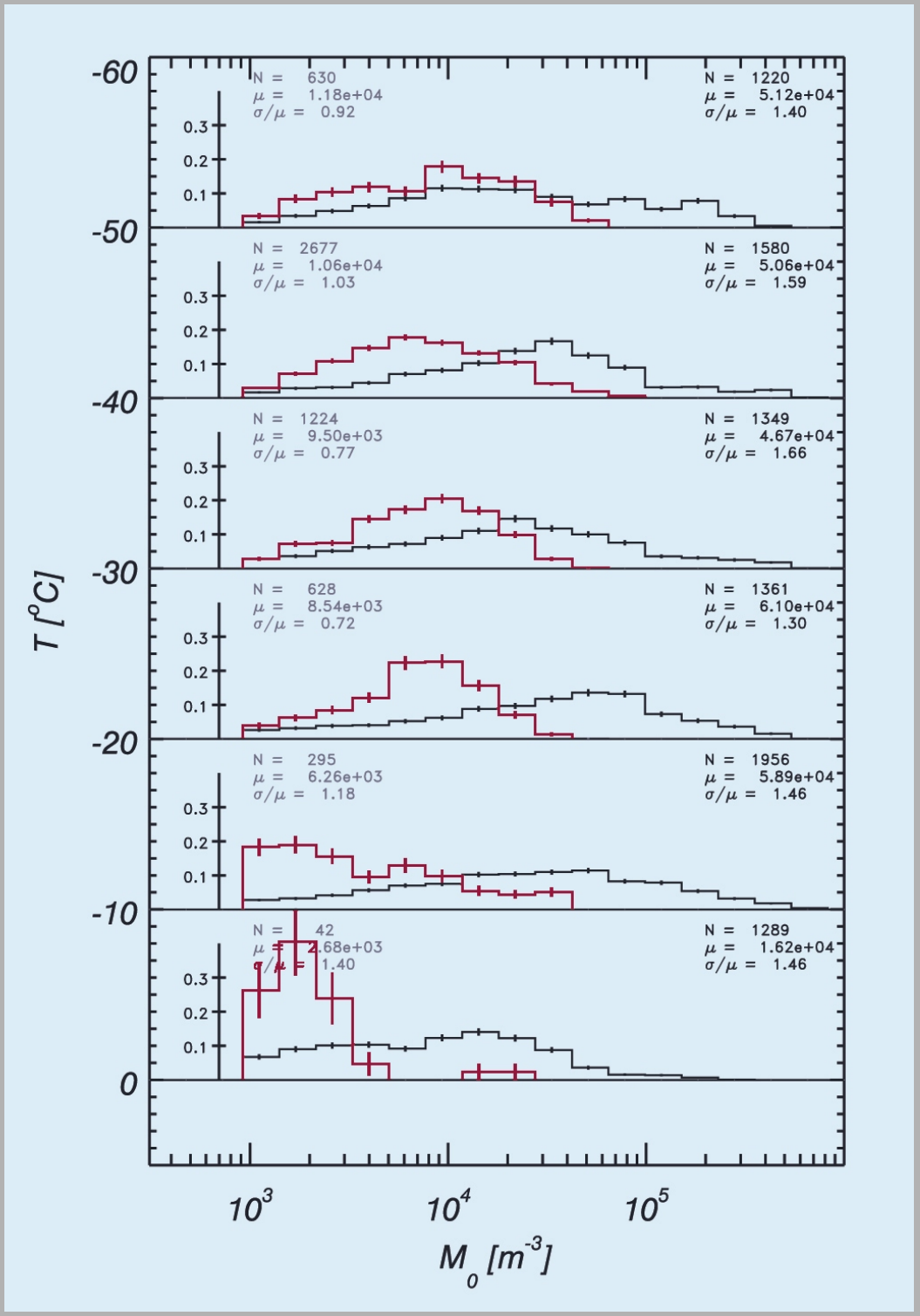
Aircraft data

- Problem with measuring small particles. Only look at particles D>100μm

- Computing moments (truncated)

$$M_n = \sum_{D=100\,\mu m}^{\infty} D^n N_D$$

- Time period for averaging ? (10 s ~ 1 km)



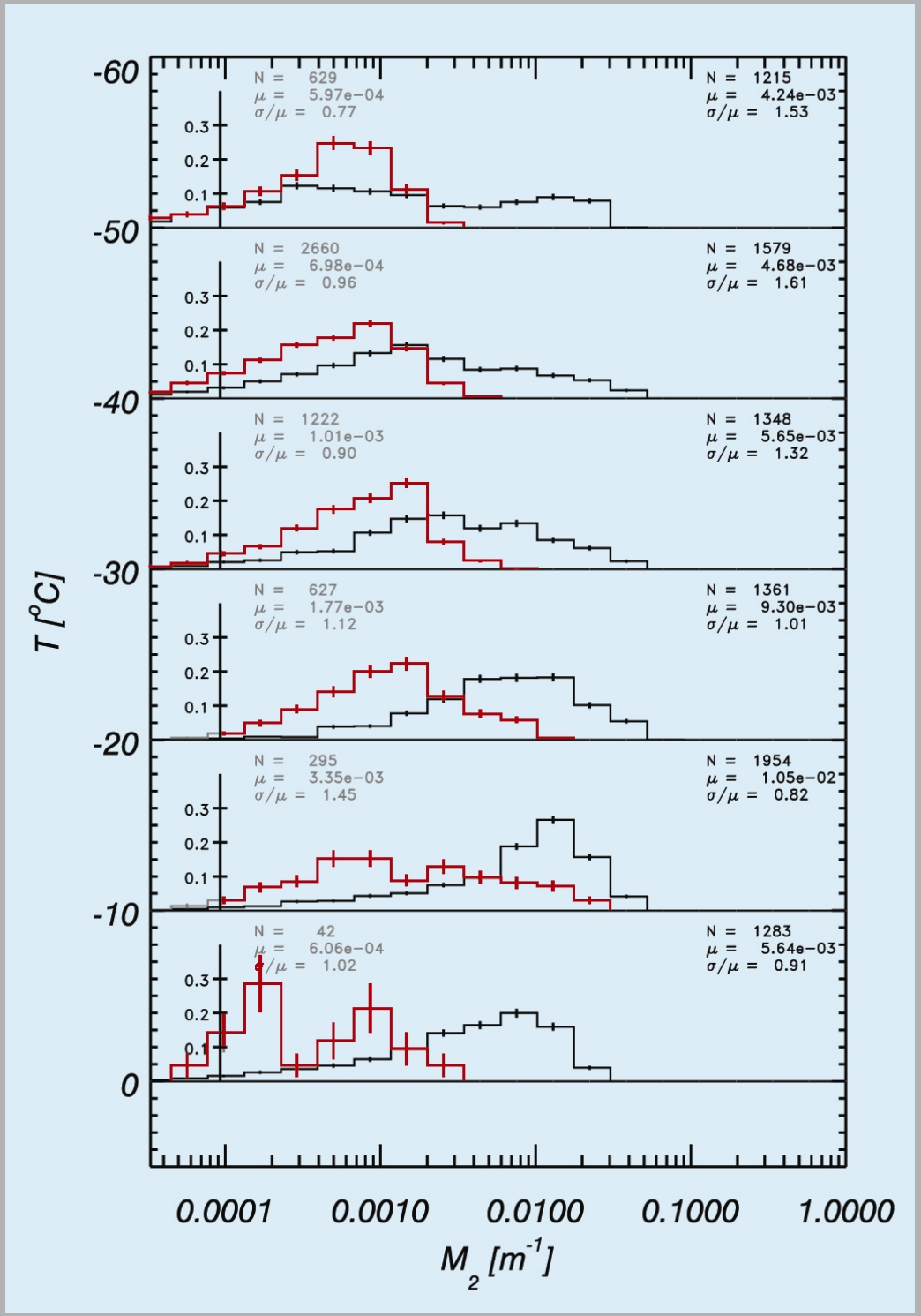
Moment histograms

M_0

Concentration for D>100μm

Tropical

Midlat



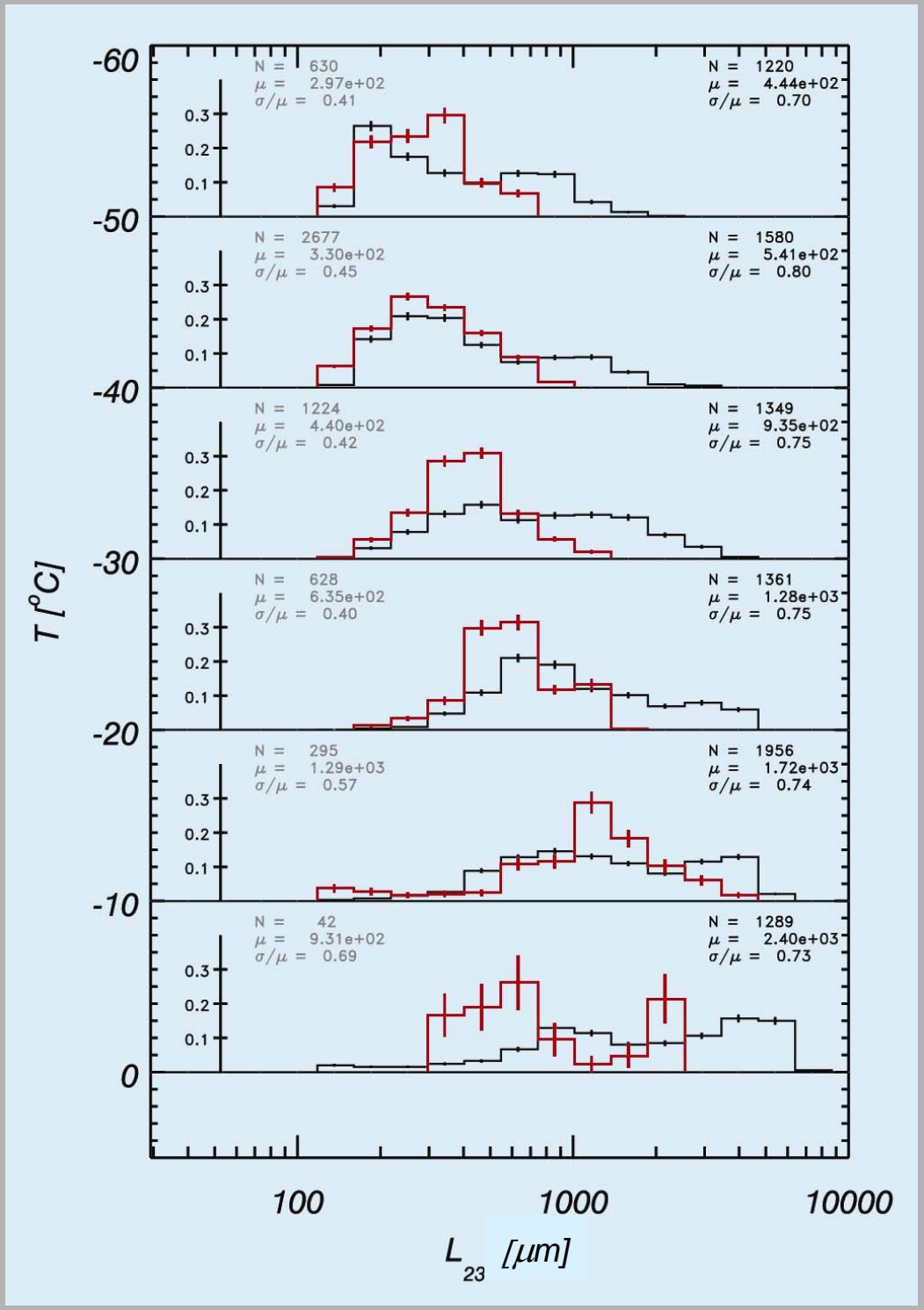
Moment histograms

M_2

Proportional to IWC for D>100μm

Tropical

Midlat



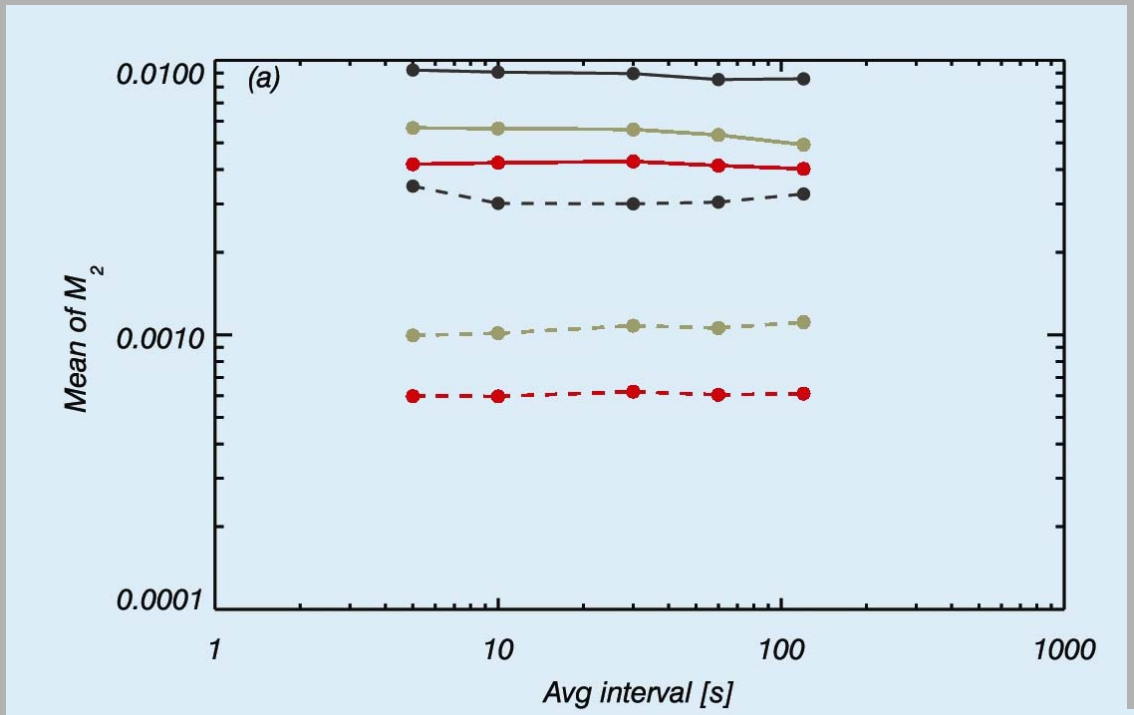
Moment histograms

L_{23}

Characteristic size M_3/M_2 D>100μm

Tropical

Midlat



Time averaging

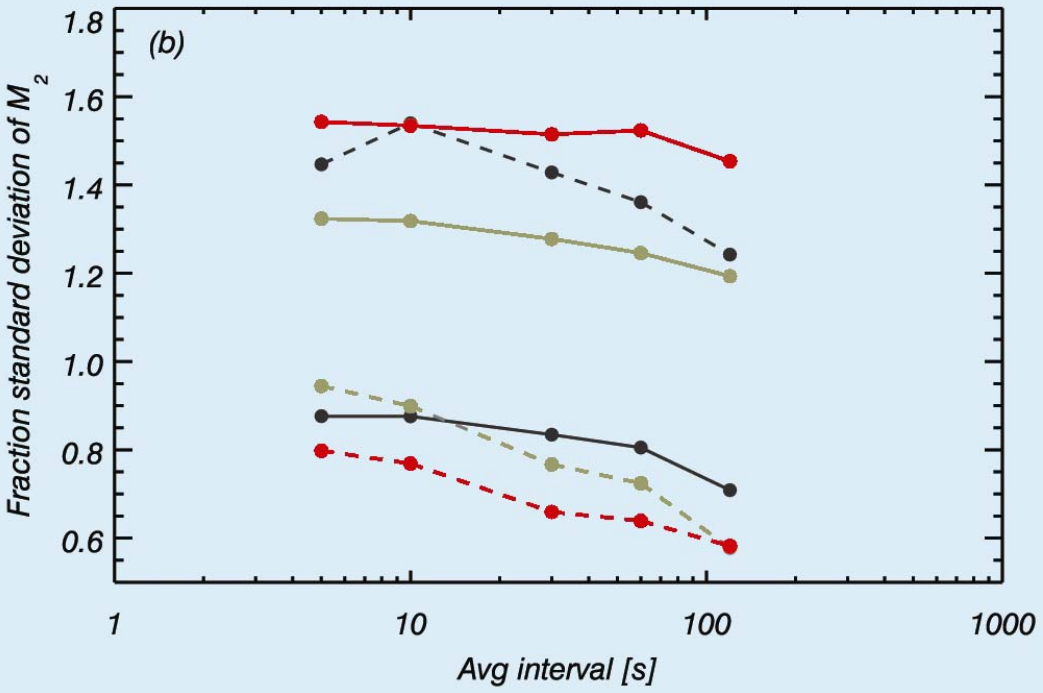
2nd Moment

-10C

-30C

-50C

Midlat



Rescaling particle size distributions

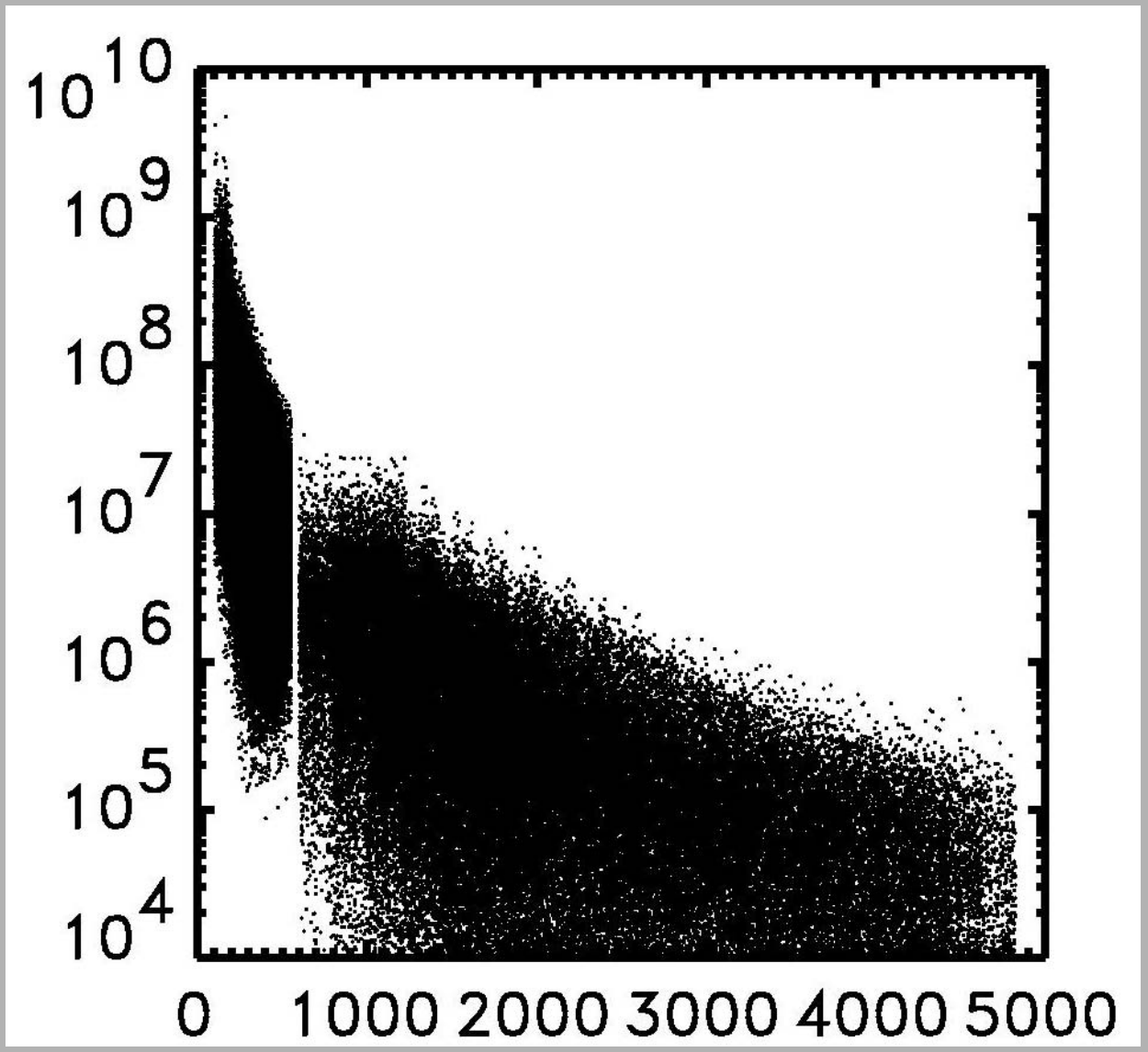
$$N(D) = M_2^4 M_3^{-3} \phi_{23}(x)$$

Measured PSD

Rescaled Distribution

Dimensionless size $x = D\left(\frac{M_2}{M_3}\right)$

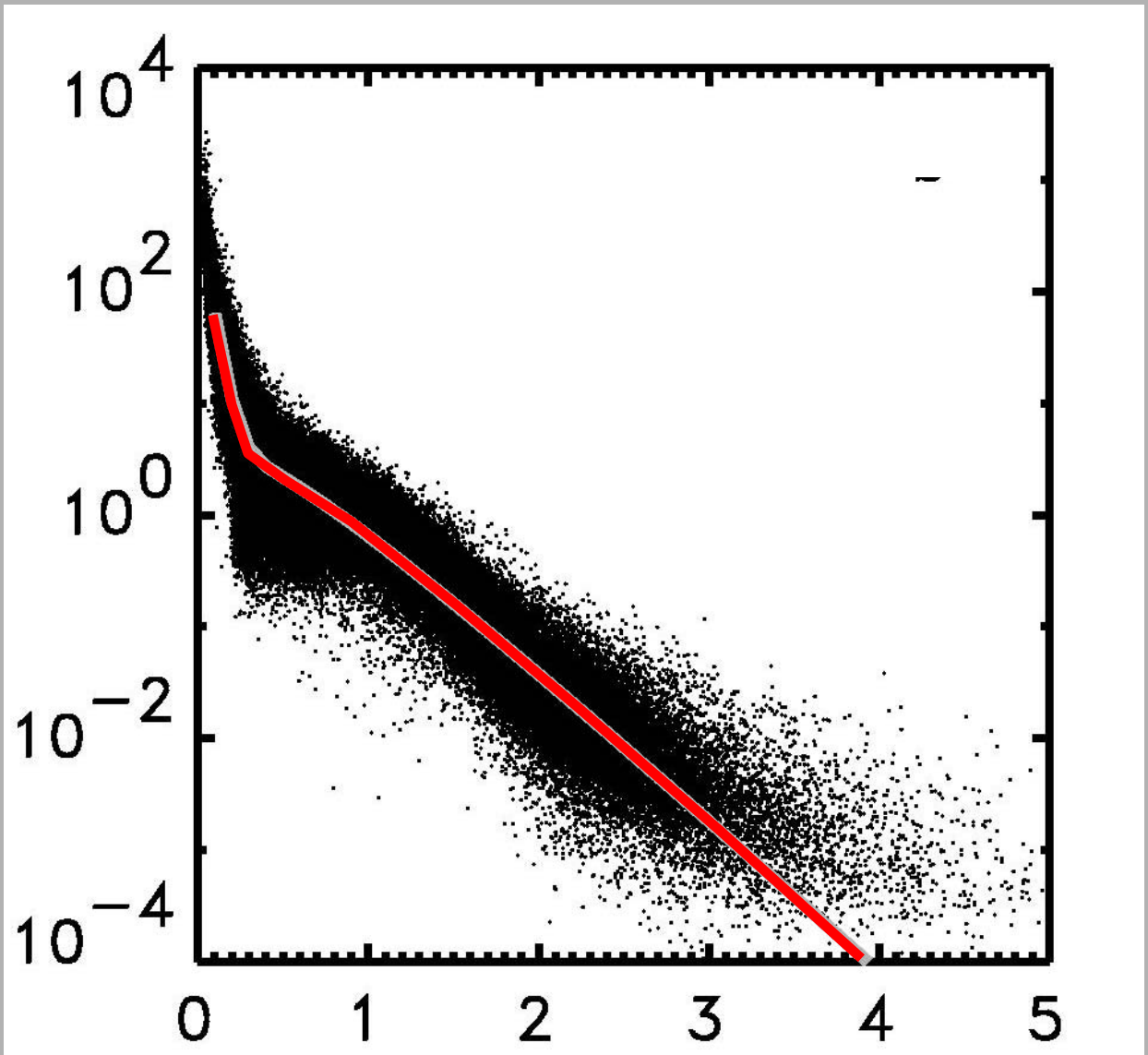
Measure ice particle size distributions



Field et al.2005

Rescaled size distributions: M_2, M_3

$$\frac{N(D)M_3^3}{M_2^4}$$



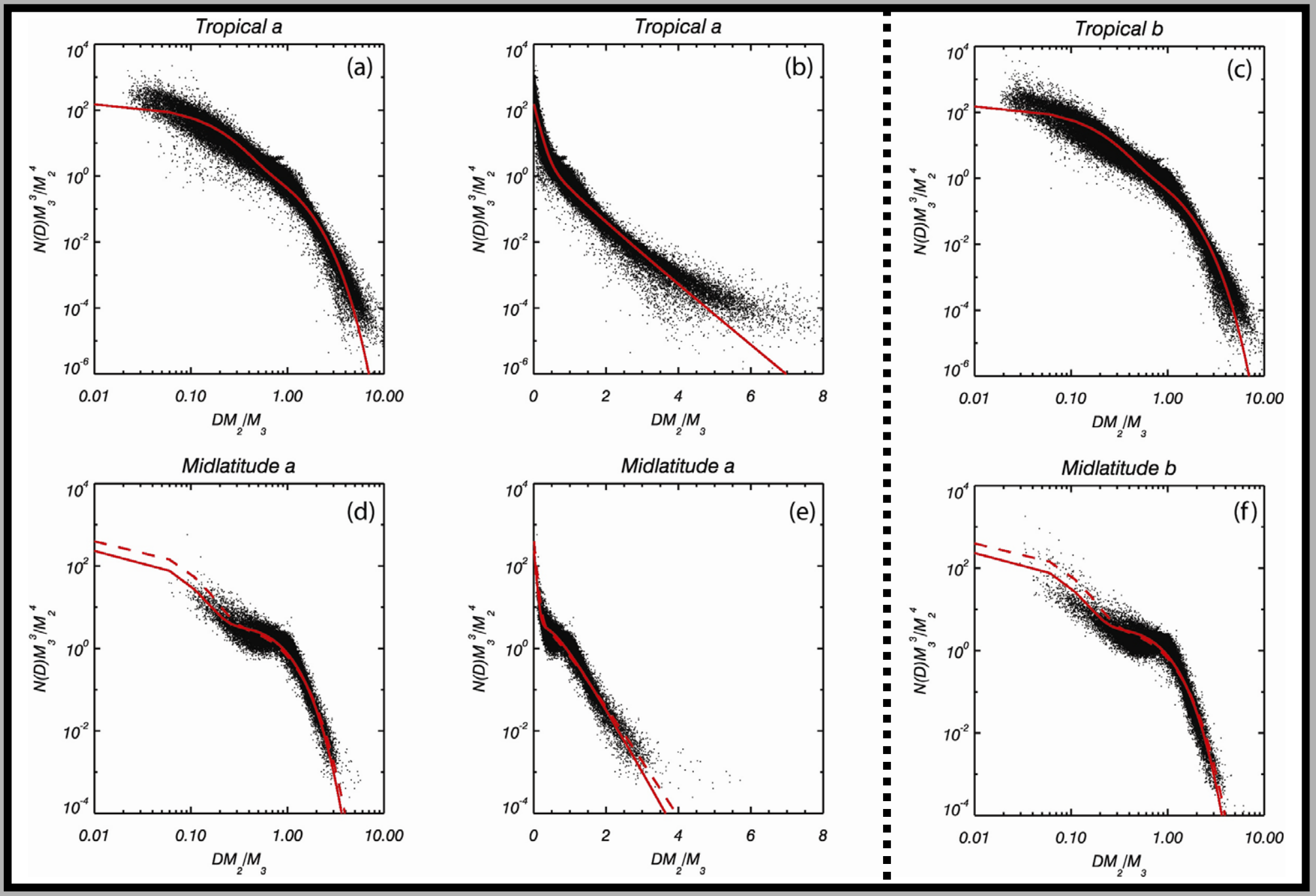
$D\ M_2/M_3$

Field et al.2005

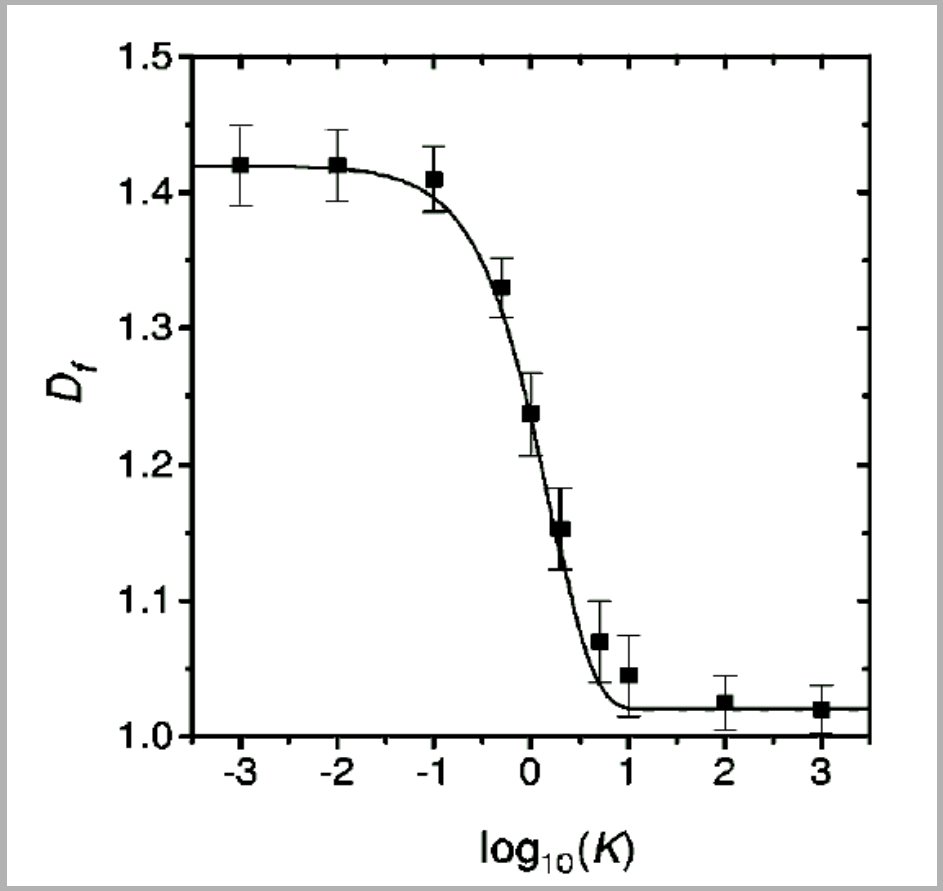
Properties of fit to rescaled distribution

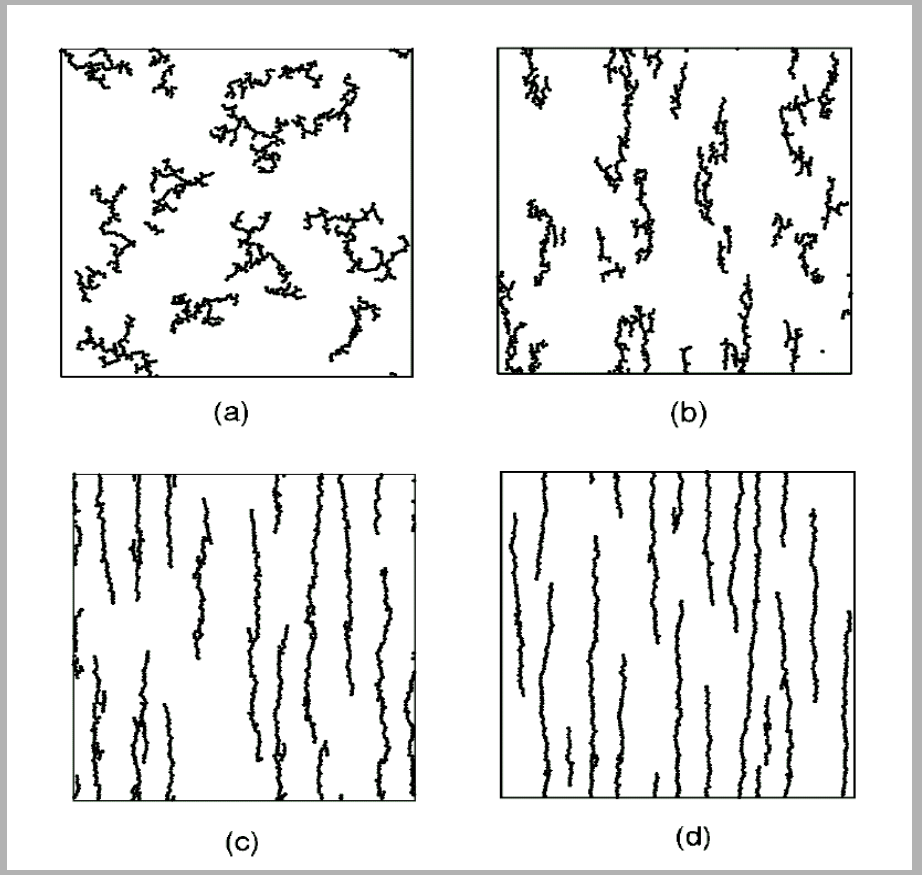
- All moments of fitted rescaled distribution ($n \geq 0$) should be finite
- Large x behaviour should be exponential
- 2nd and 3rd moments of fit to rescaled distribution=1

PSD Rescaling



Aggregation in E-fields





Tan et al. 2000 Phys Rev E

Saunders and Wahab 1975

The nature of ice particles

- Aggregates
- $M=aD^b$ (b~2)
- $V=cD^d$ (d~0.4)

NWP requirements

Forecasting

- Sedimentation (Precip rate) $M_{2.4}$
- Diffusional growth M_1 to $M_{1.7}$
- Riming $M_{2.4}$
- IWC M_2

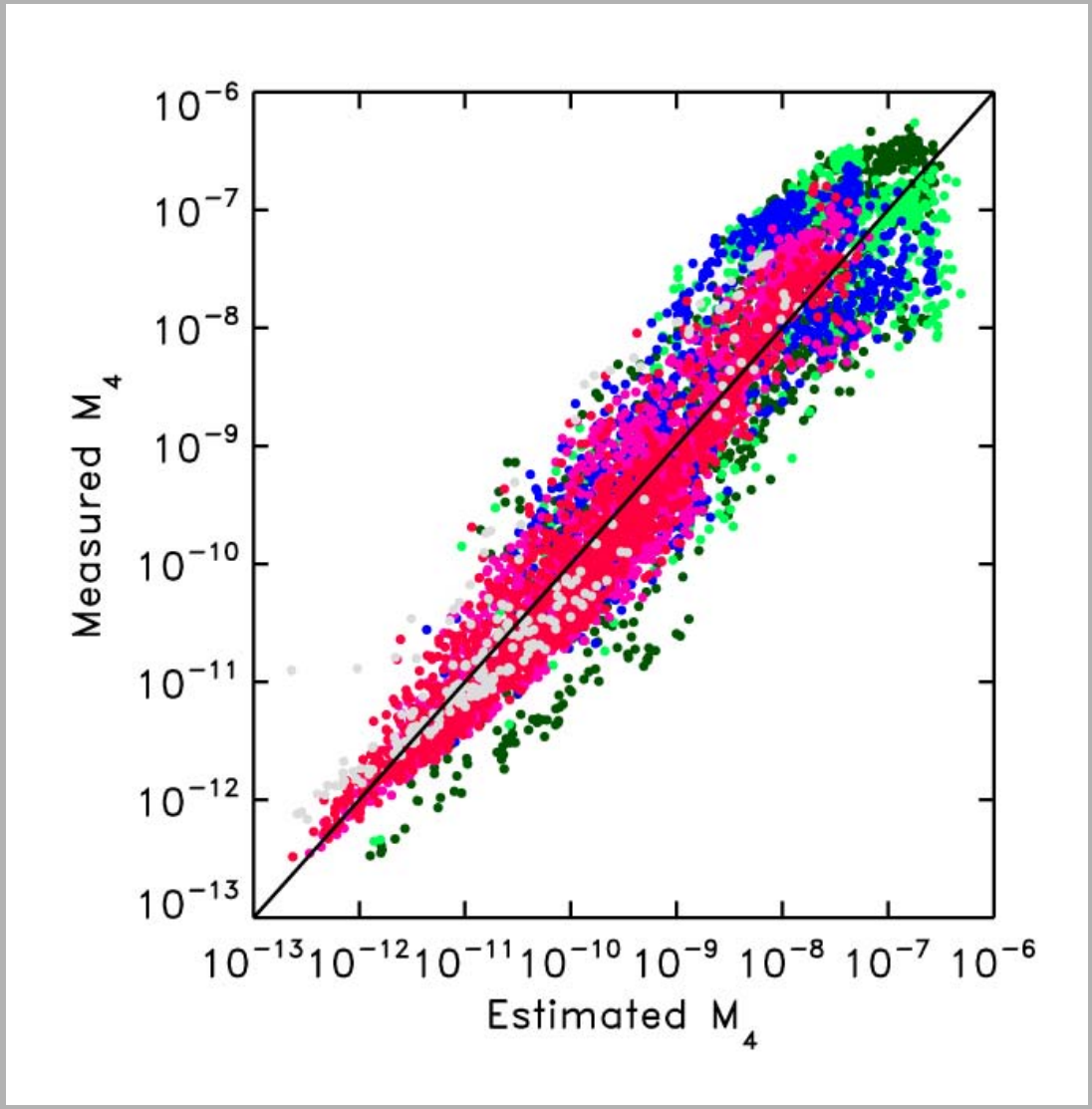
Moments 1 to 2.4 need to be estimated

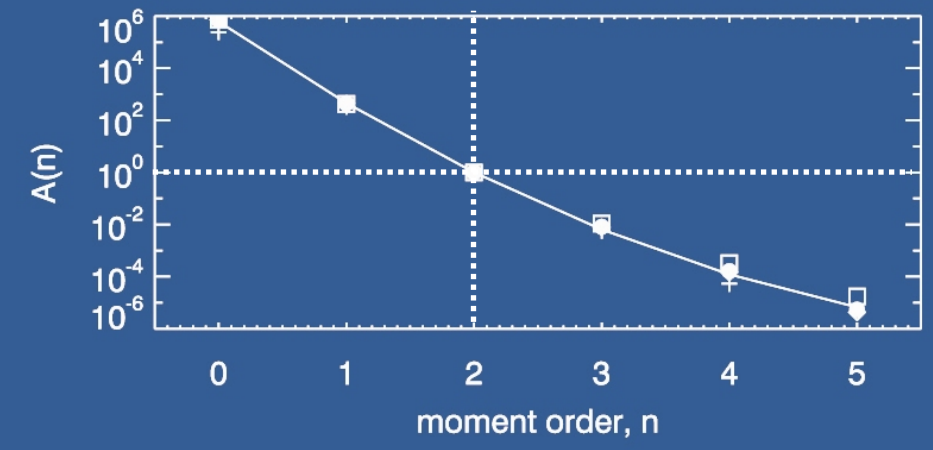
Radar assimilation – higher moments

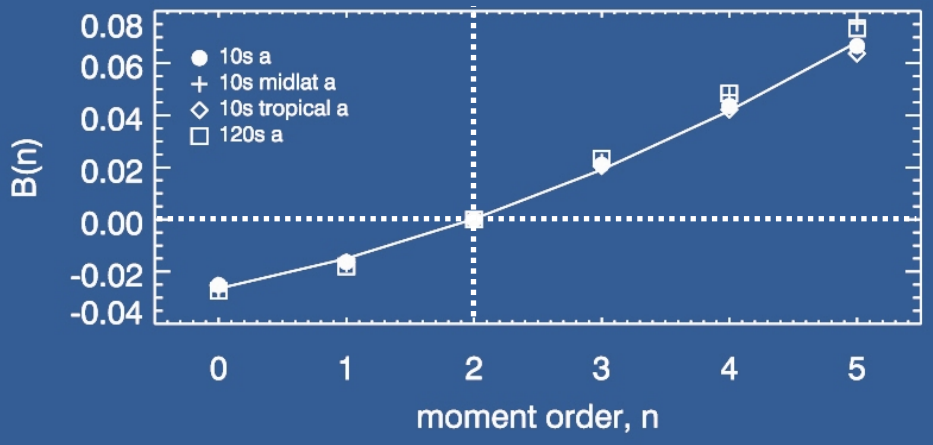
Moment estimation param.

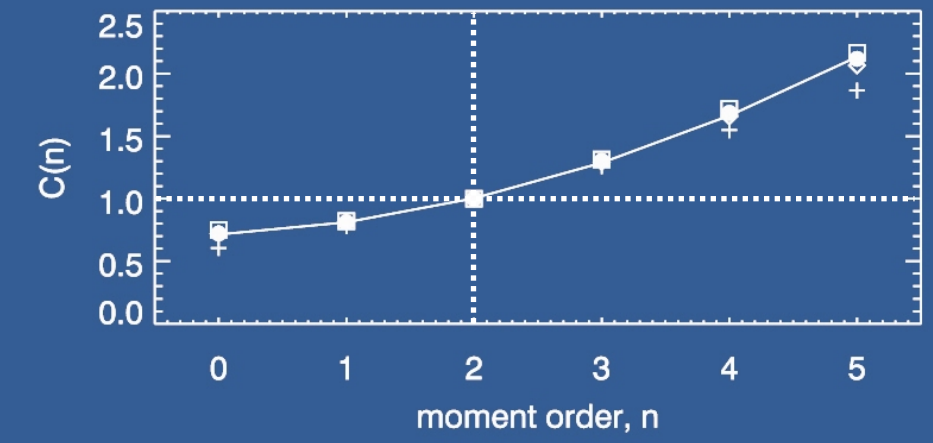
$M_n = A(n) \exp[B(n)T] M_2^{C(n)}$

Field et al. 05 used
$M_n = a(n,T) M_2^{b(n,T)}$





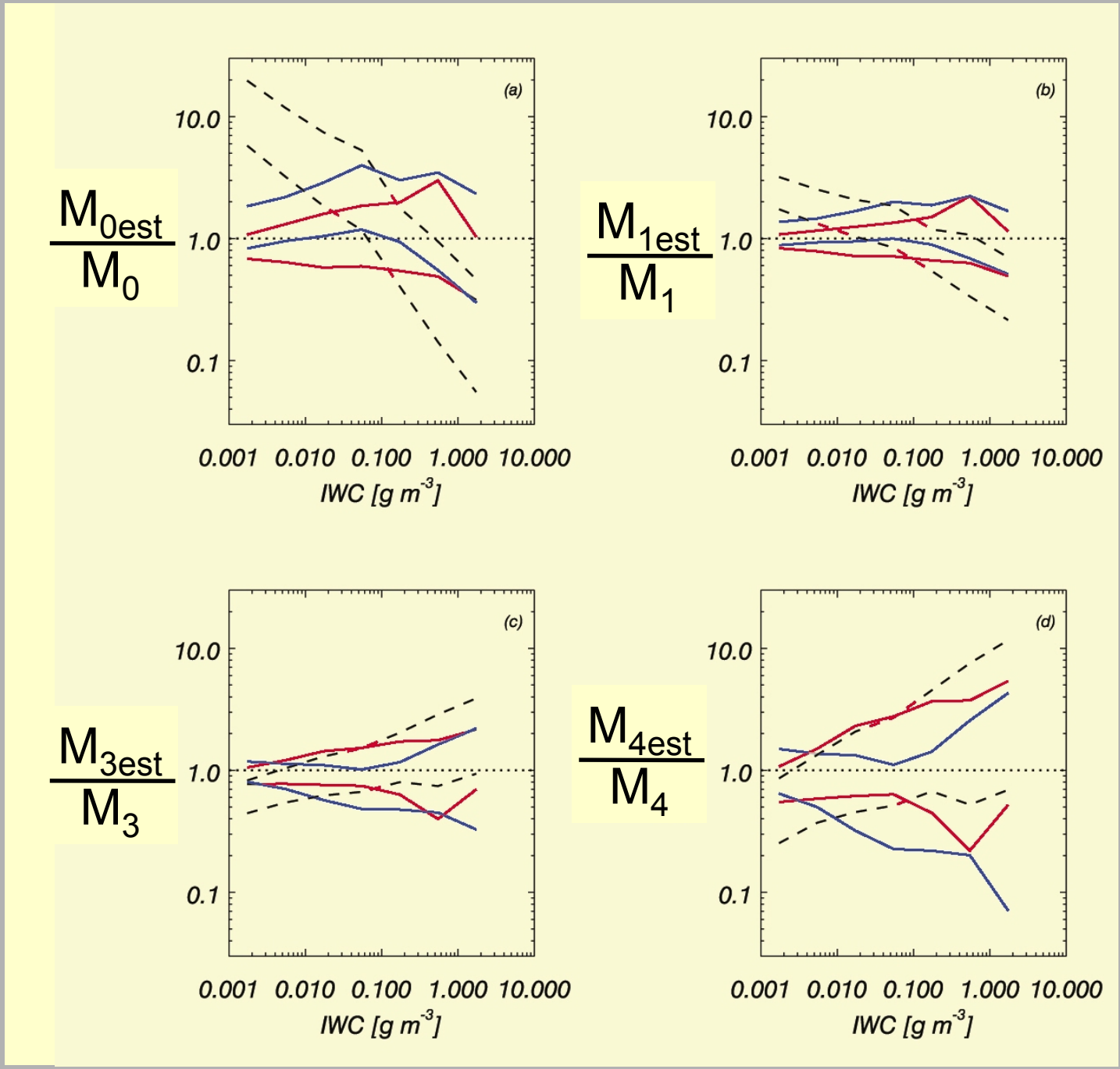




Quadratic fits to A(n),B(n),C(n)

$$M_n = A(n) \exp[B(n)T] \, M_2^{C(n)}$$

Testing the parameterization



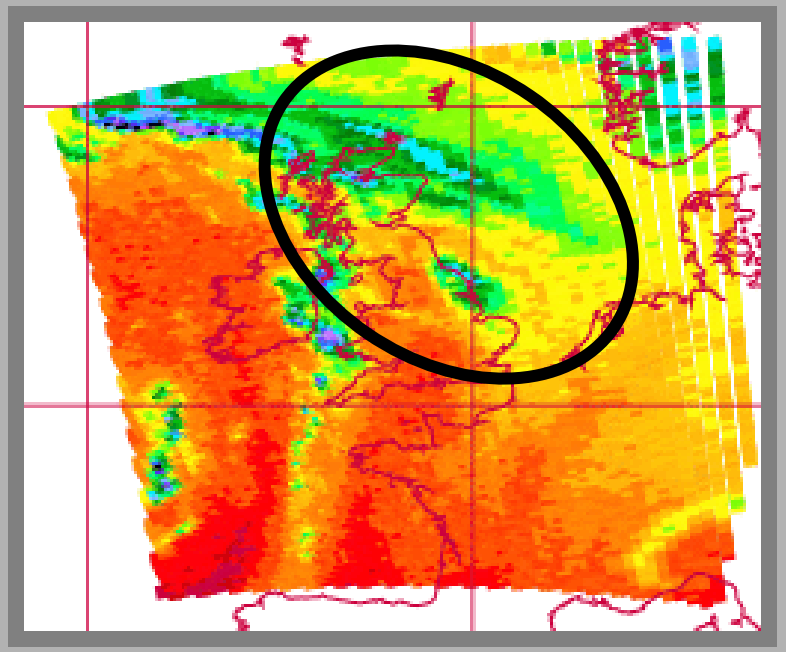
One parameterization?

- Tropical and midlatitude rescaled distributions are different

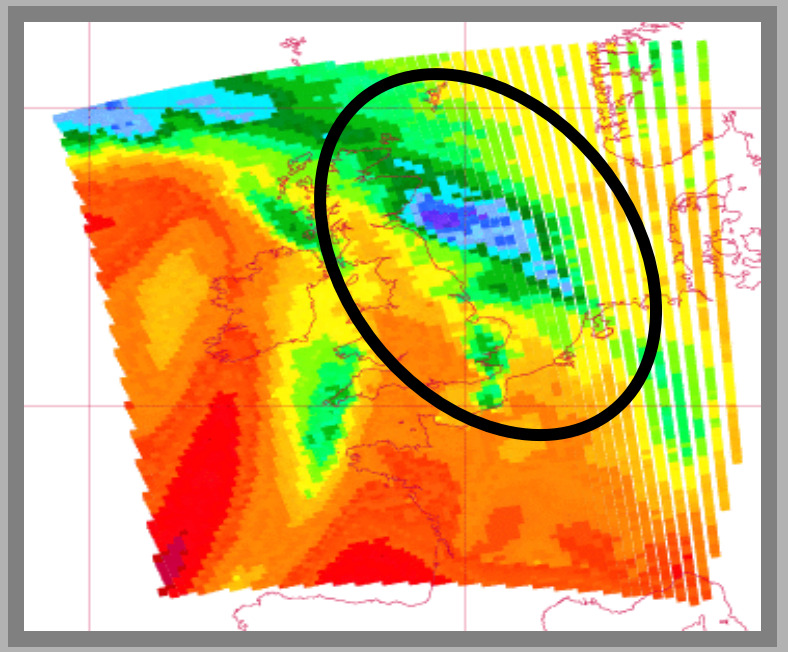
$$M_n = M_2^p M_3^q \int x^n \phi_{23} dx$$

	n	0	1	2	3	4	5
$\int x^n \phi_{23} dx$	tropical	20	2.3	1.0	1.0	1.7	3.7
	midlat	19	1.8	1.0	1.0	1.3	2.0

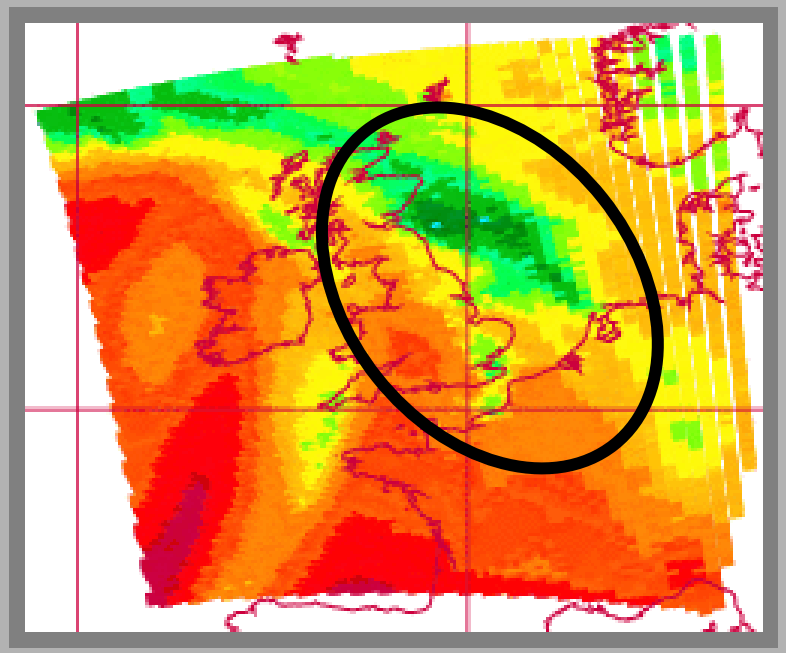
AMSU-B Ch20(180GHz) BT



Obs

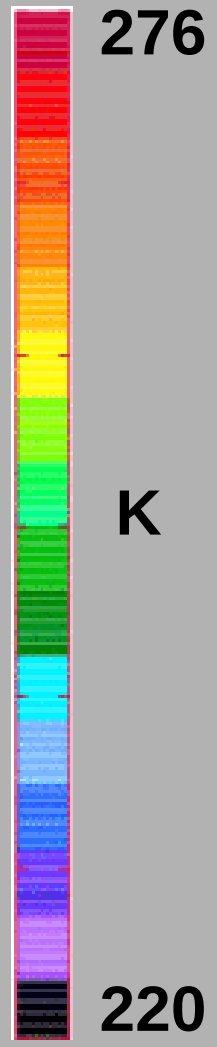


ARTS



UKMO

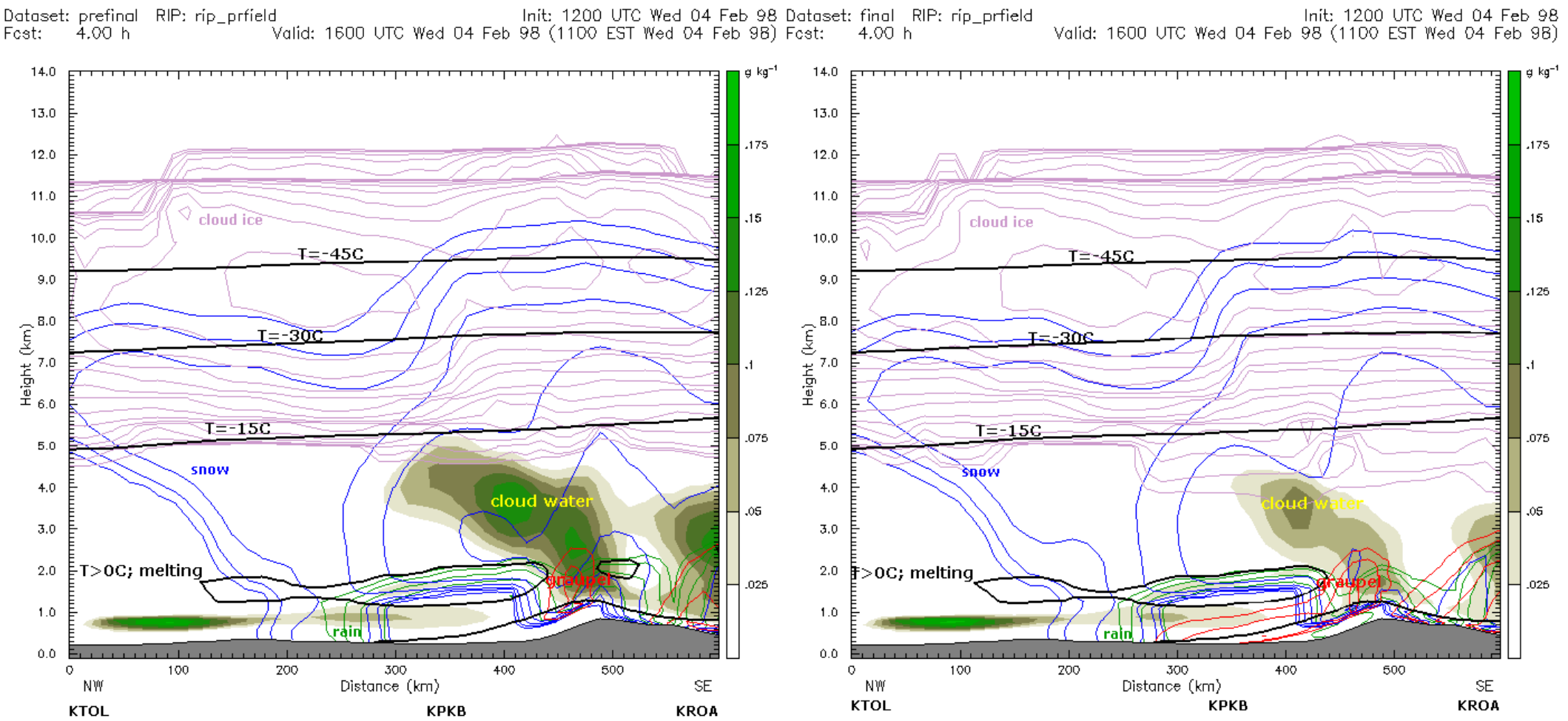
(Doherty et al. 2007 QJ)



Application to WRF/MM5

- Currently (for snow)
  - Exponential size distributions
  - $N_0(T)$
  - Spherical geometry
  - Constant snow density
- Change to
  - Obs. based PSDs
  - $N_0^*(T,IWC)$
  - Non-spherical geometry
  - Density varies with size

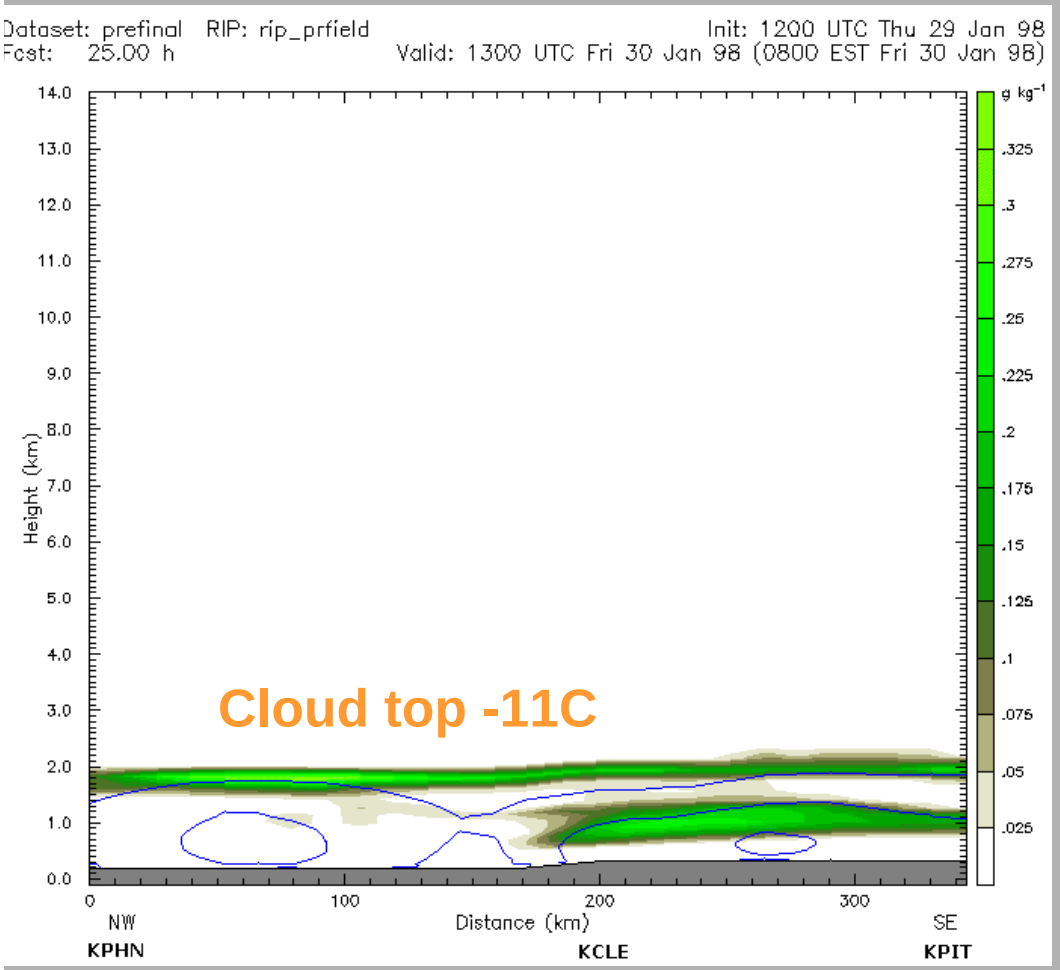
Freezing rain – W. Virginia 4 Feb 1998

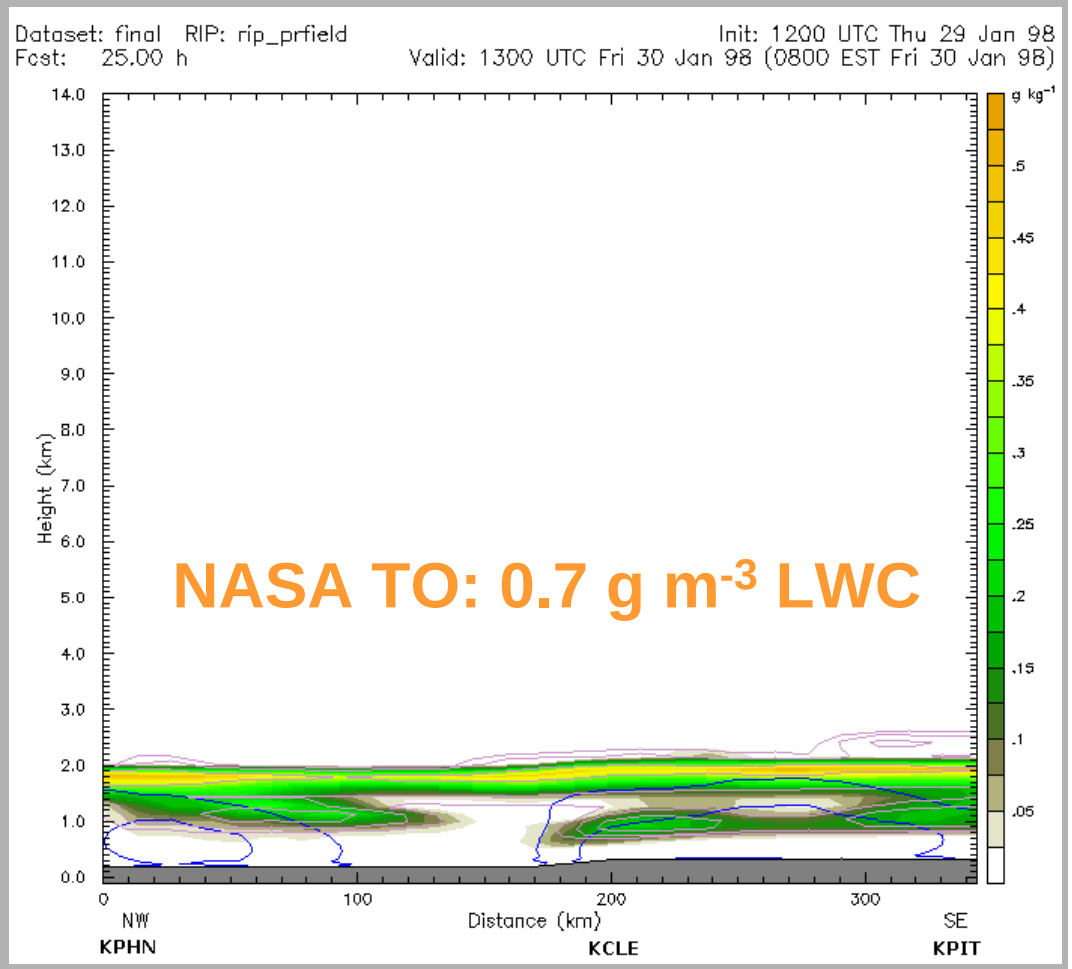


Old **New**

Modified MM5/WRF microphysics, 20km (Thompson et al. 2007)

Cleveland supercooled Sc – 30 Jan 1998



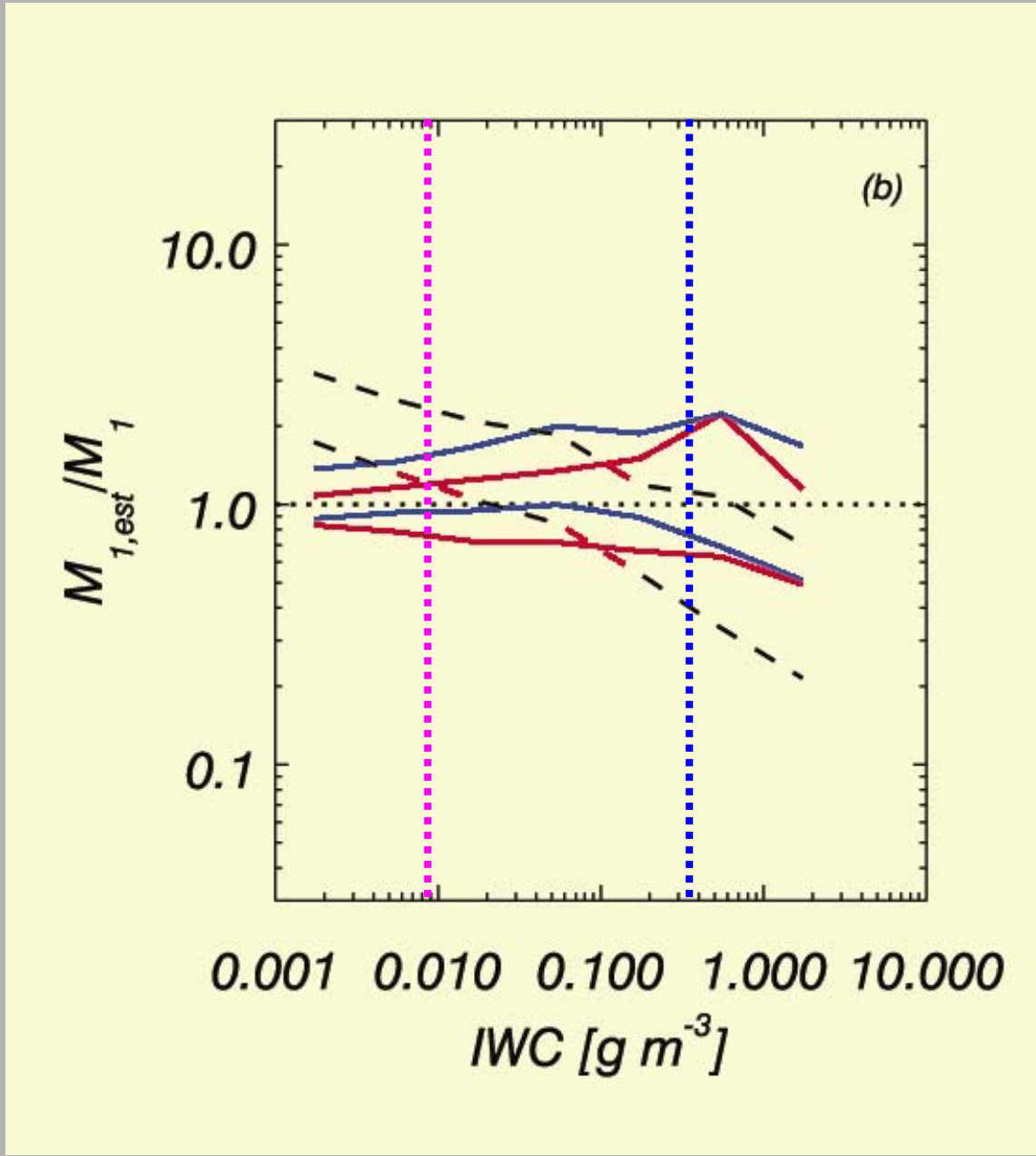


Old

New

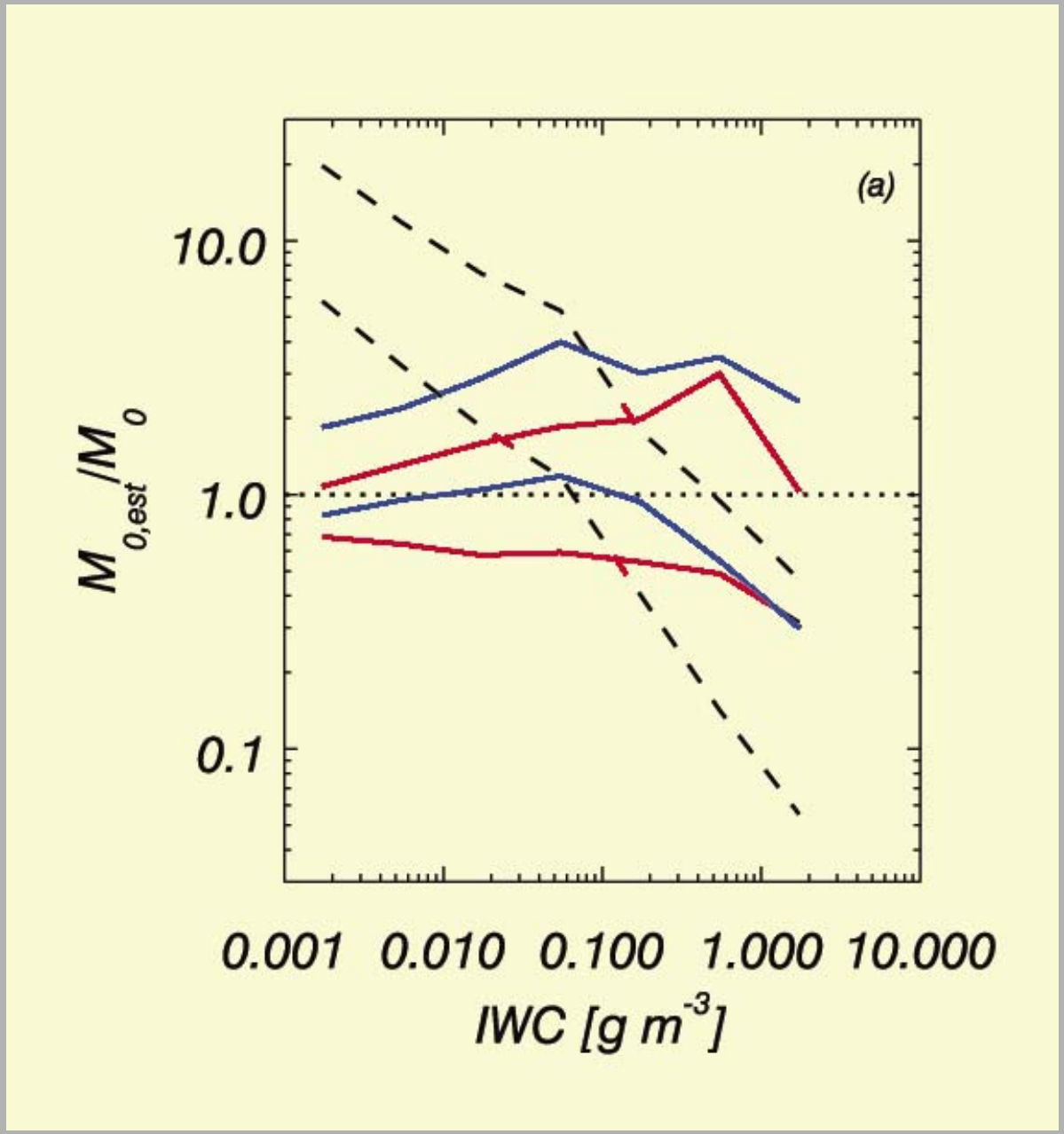
Implementation of moment scheme

- Deep snow clouds – REDUCED embedded SLWC
- Deep snow clouds – REDUCED RHice
- Shallow layer clouds – INCREASED SLWC



One moment or two?

- Lin et al. (2002, JAS) show factor 25 in N_{ice} from hom freezing
- Uncertainty in Nice prediction needs to be better than ±factor ~2



Summary

- Use aggregate geometry for snow
- Rescaled PSDs are different for midlat and tropical ice cloud….
- But, one moment estimation parameterization based on T, IWC works for midlat and tropical ice cloud works well
- For NWP, do we need two moment snow schemes?