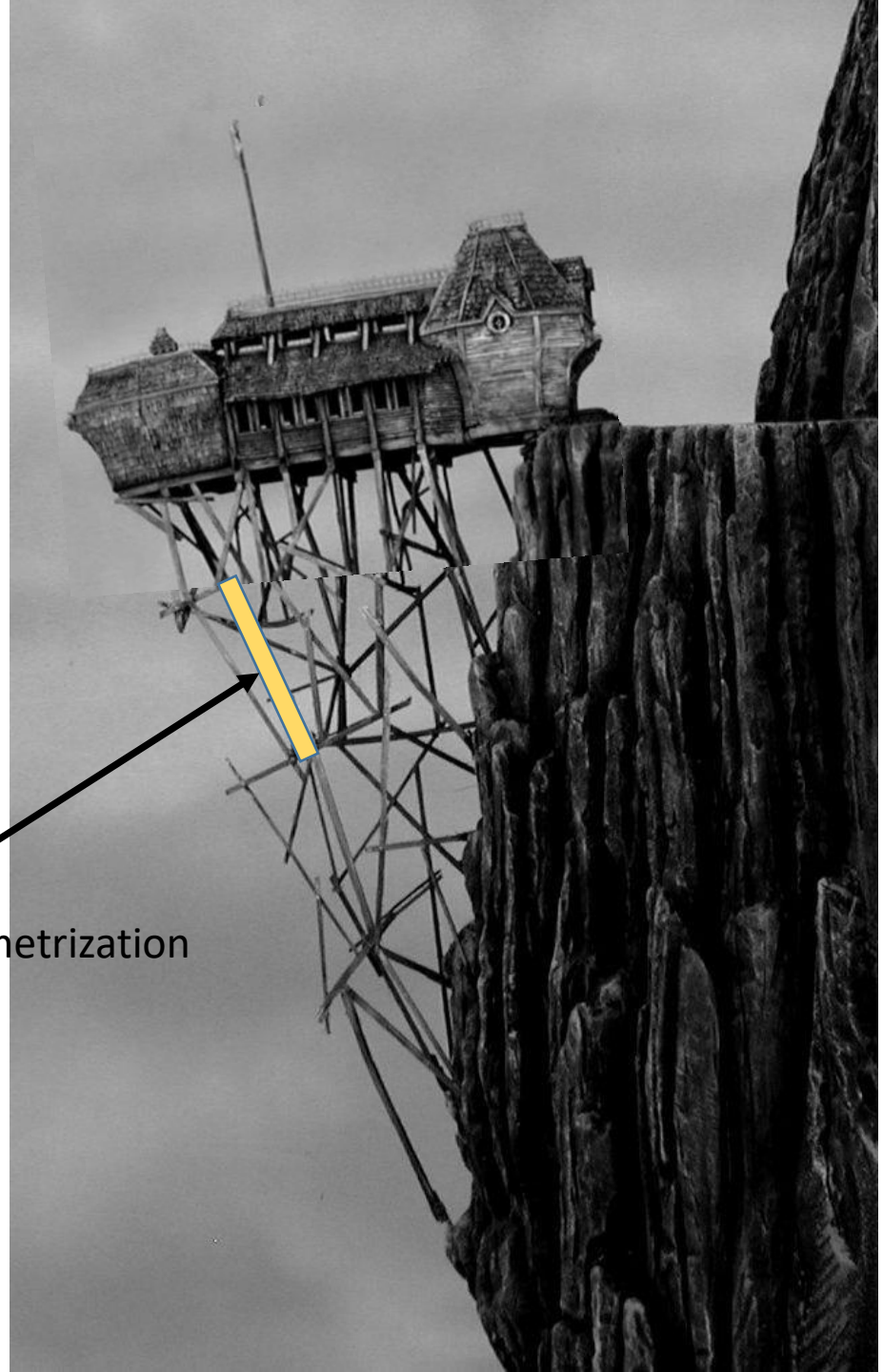
Observations to operations in the Met Office Unified Model

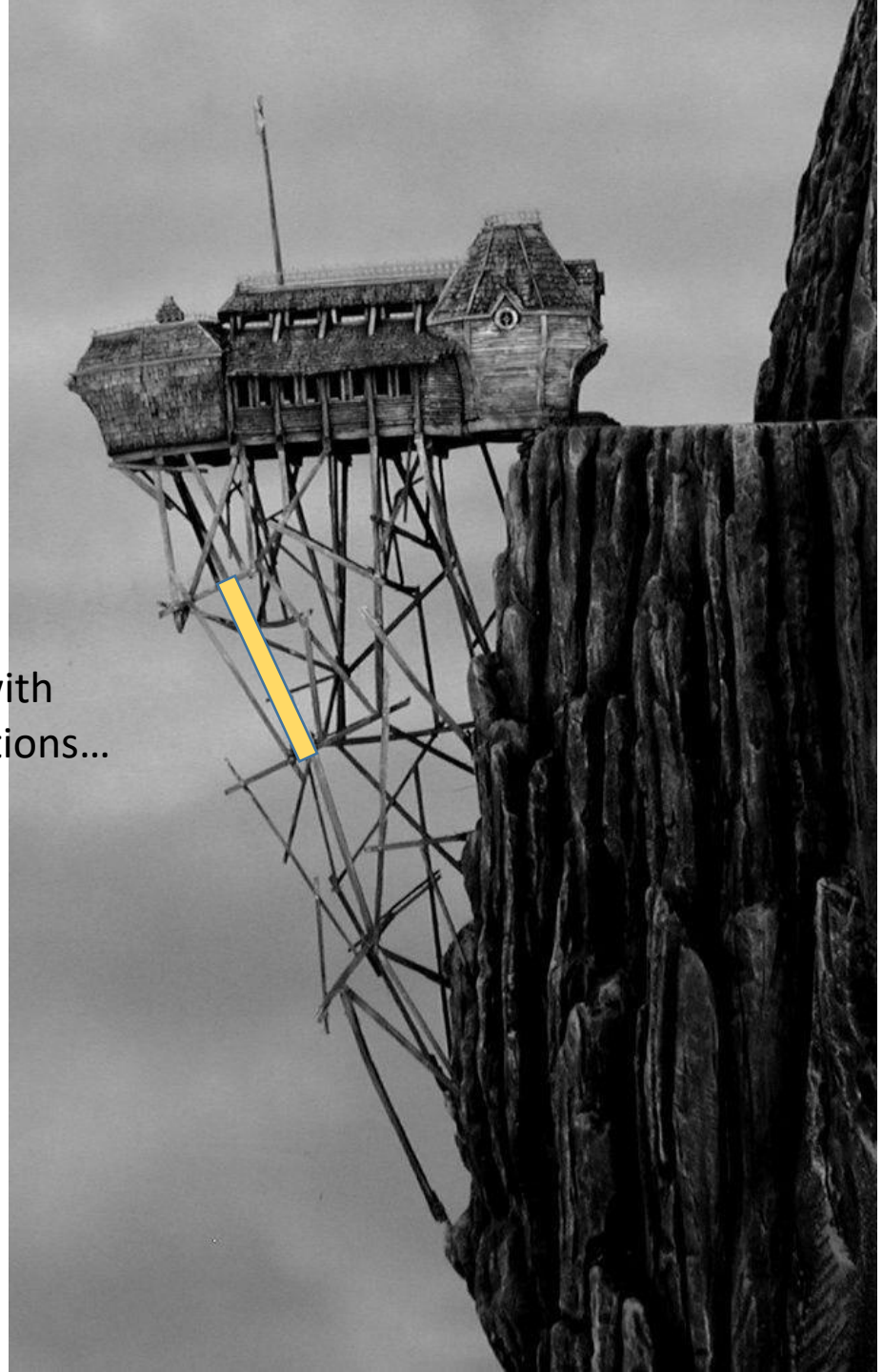
Paul Field

Met Office, Univ. Leeds

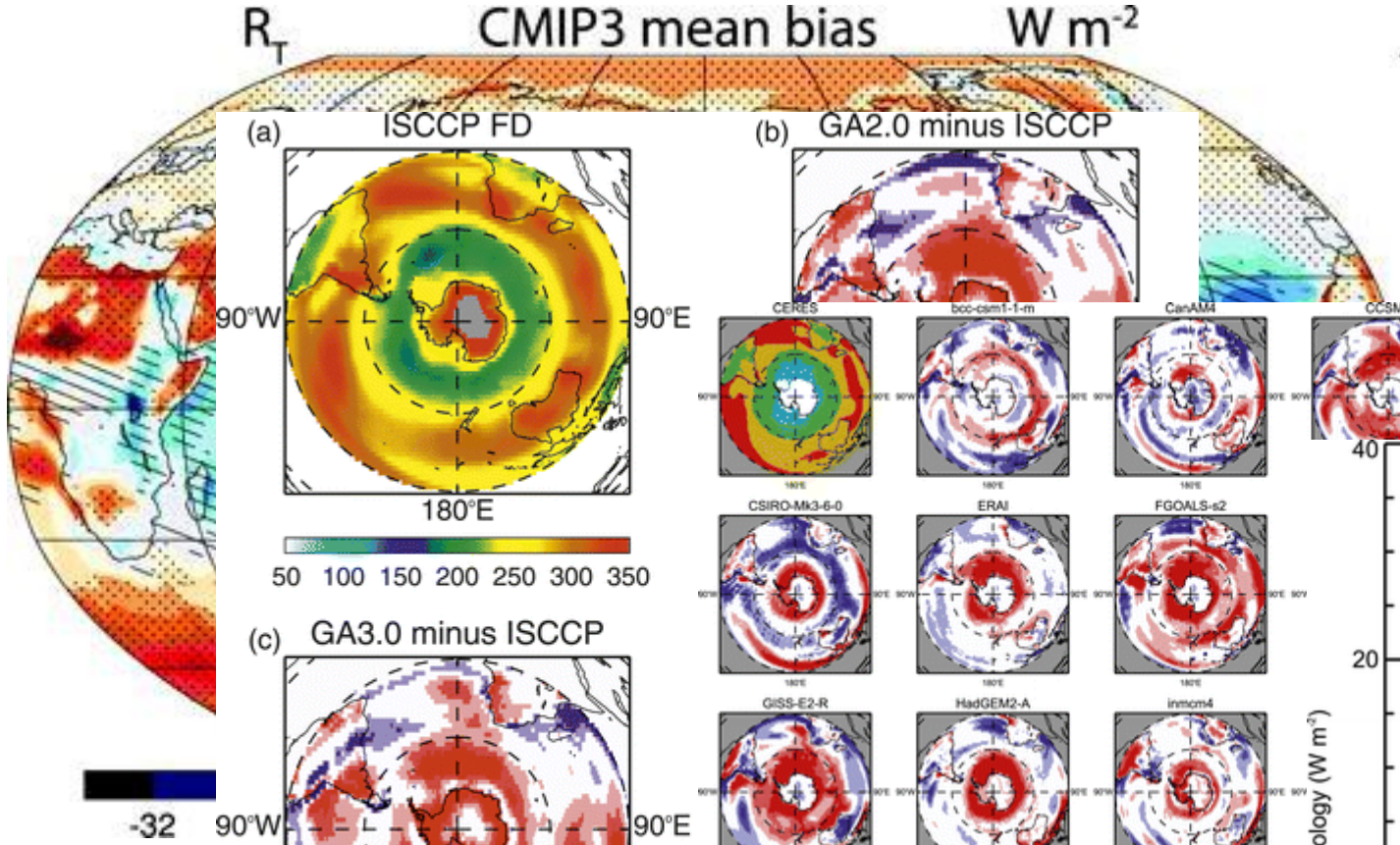
Dan Engle, art department model of Aunt Josephine's house for "Lemony Snicket's a series of unfortunate events"


New improved parametrization

After some work with
other parametrizations…



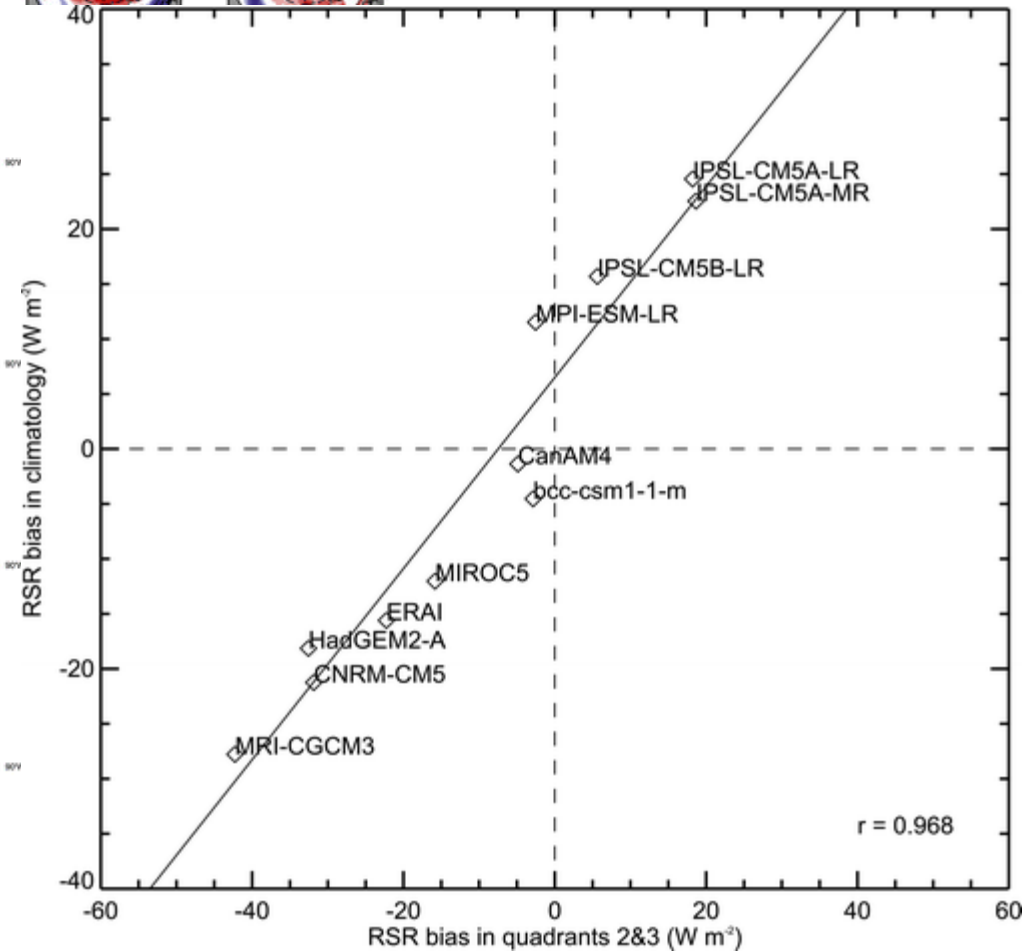
Southern Ocean Bias



Trenberth

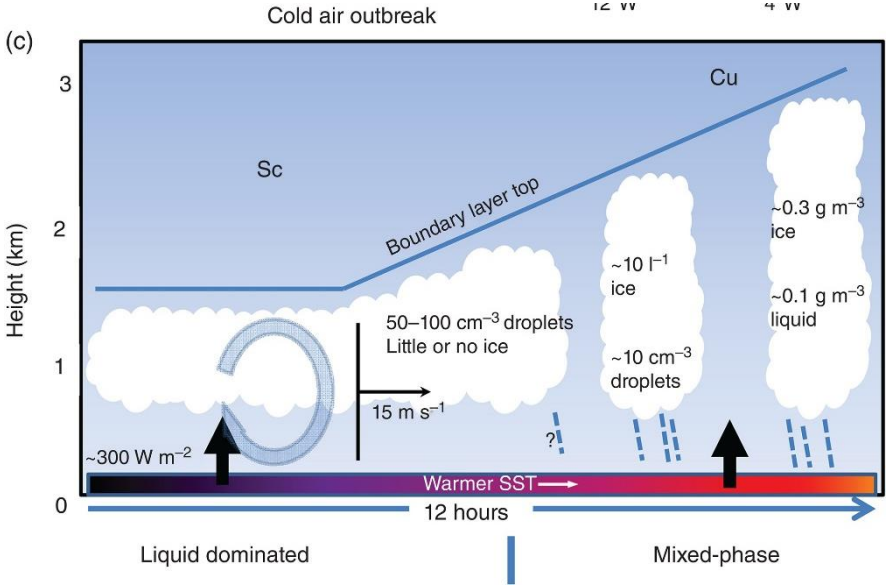
Bodas-Salcedo et al. 20

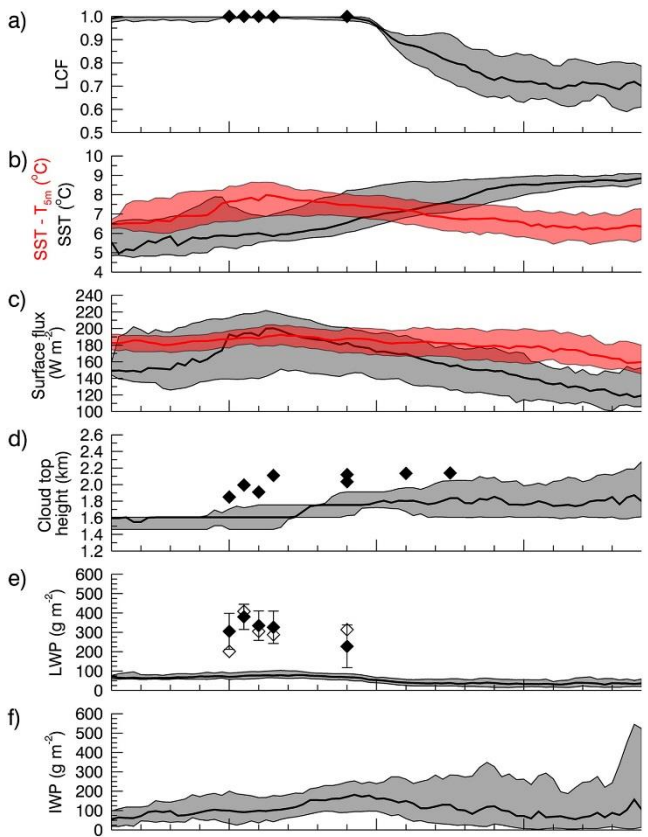
Bodas-Salcedo et al. 2014

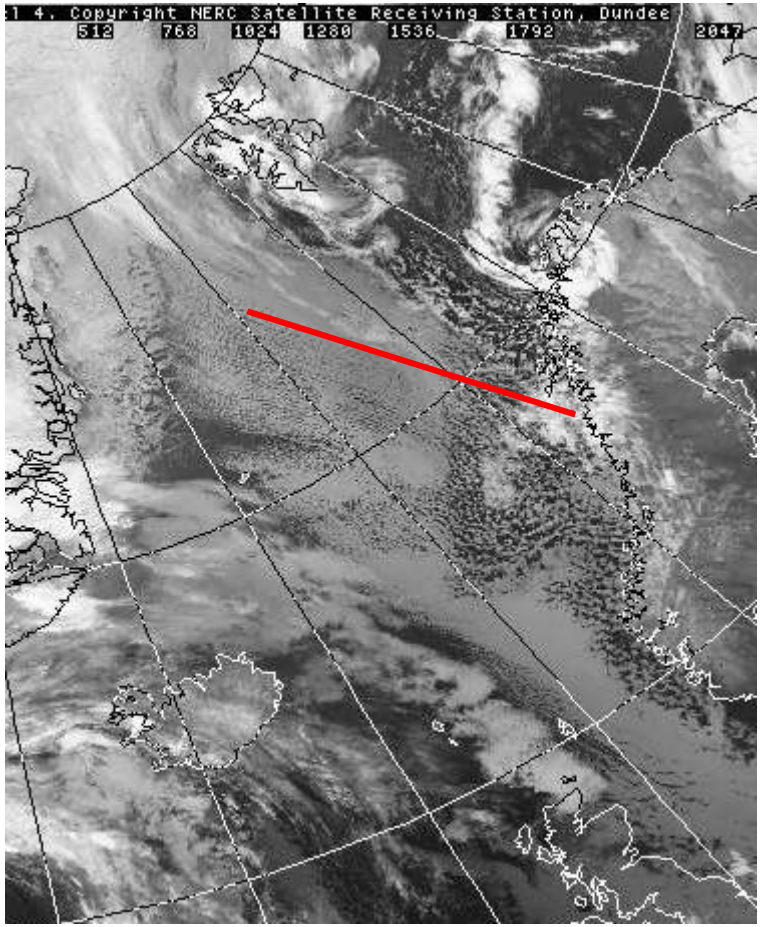


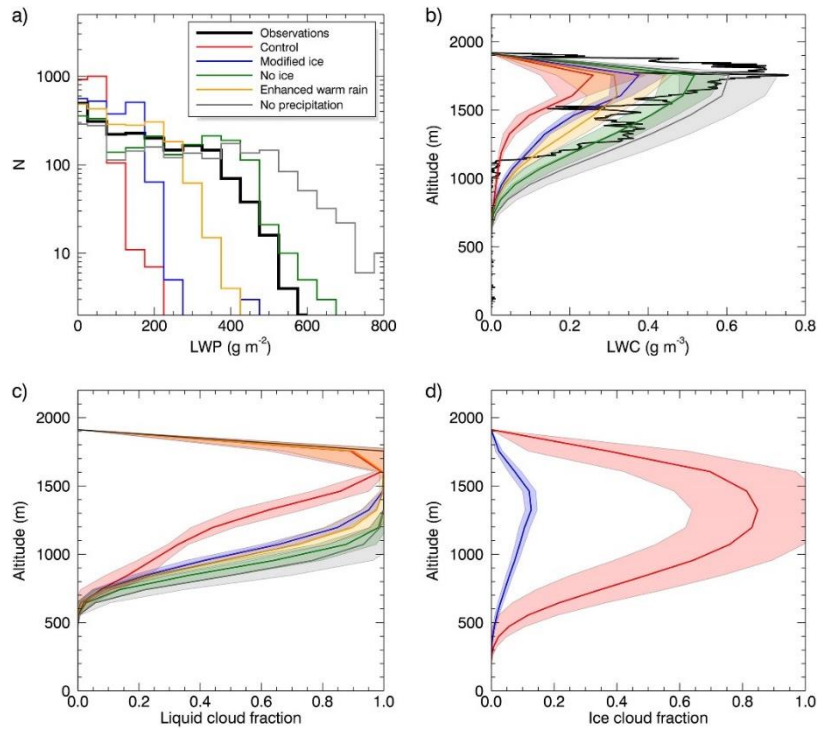
Cold air outbreaks – natural laboratories

AIRCRAFT: PIKnMIX (UKMO)



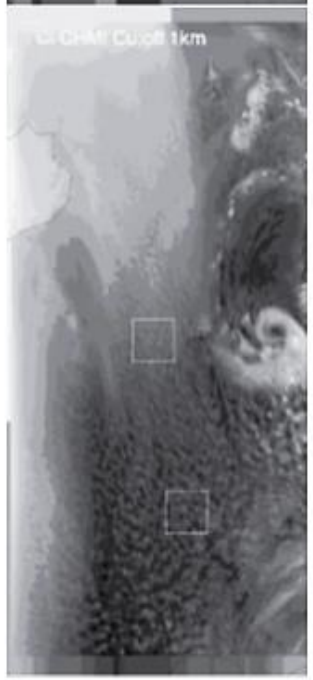


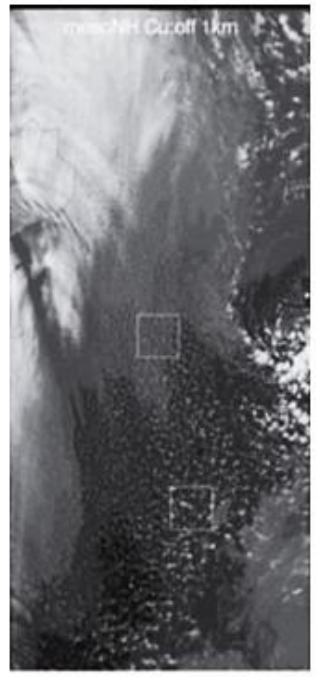


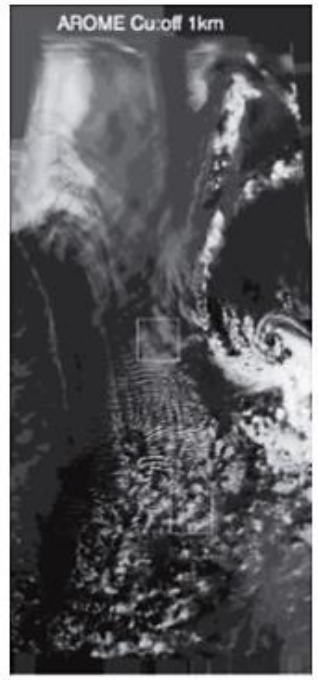


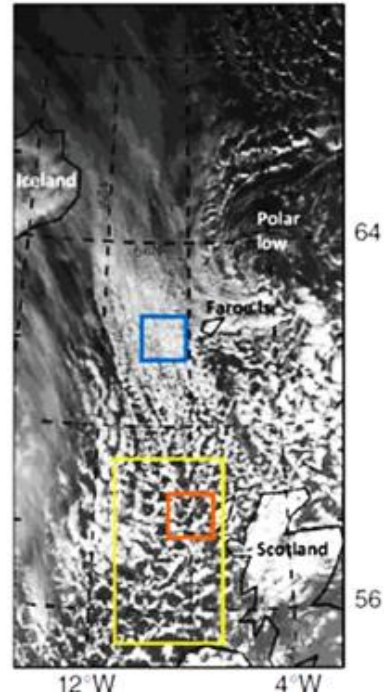
Mixed-phase observations – lack of supercooled liquid water in models

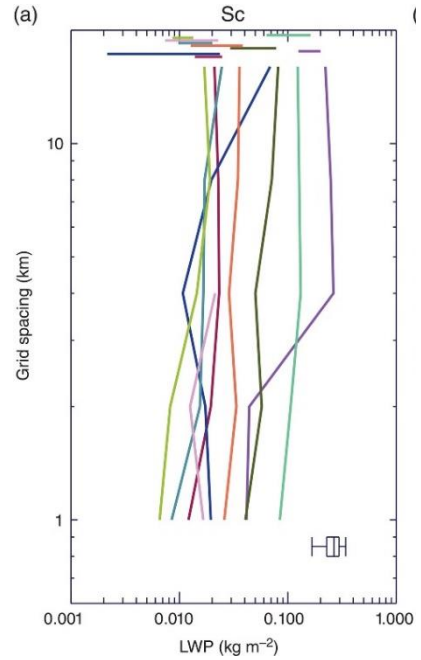
AIRCRAFT: CONSTRAIN (UKMO)

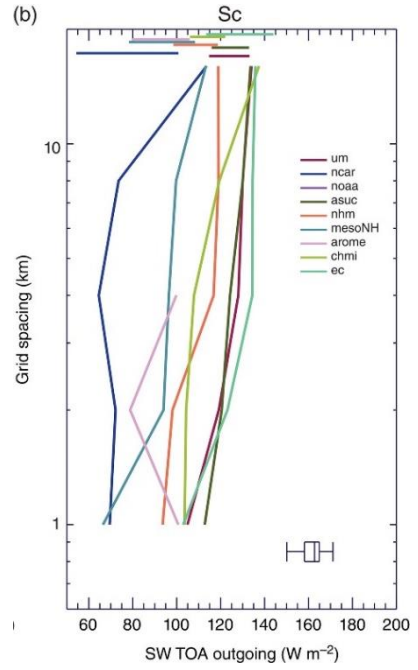




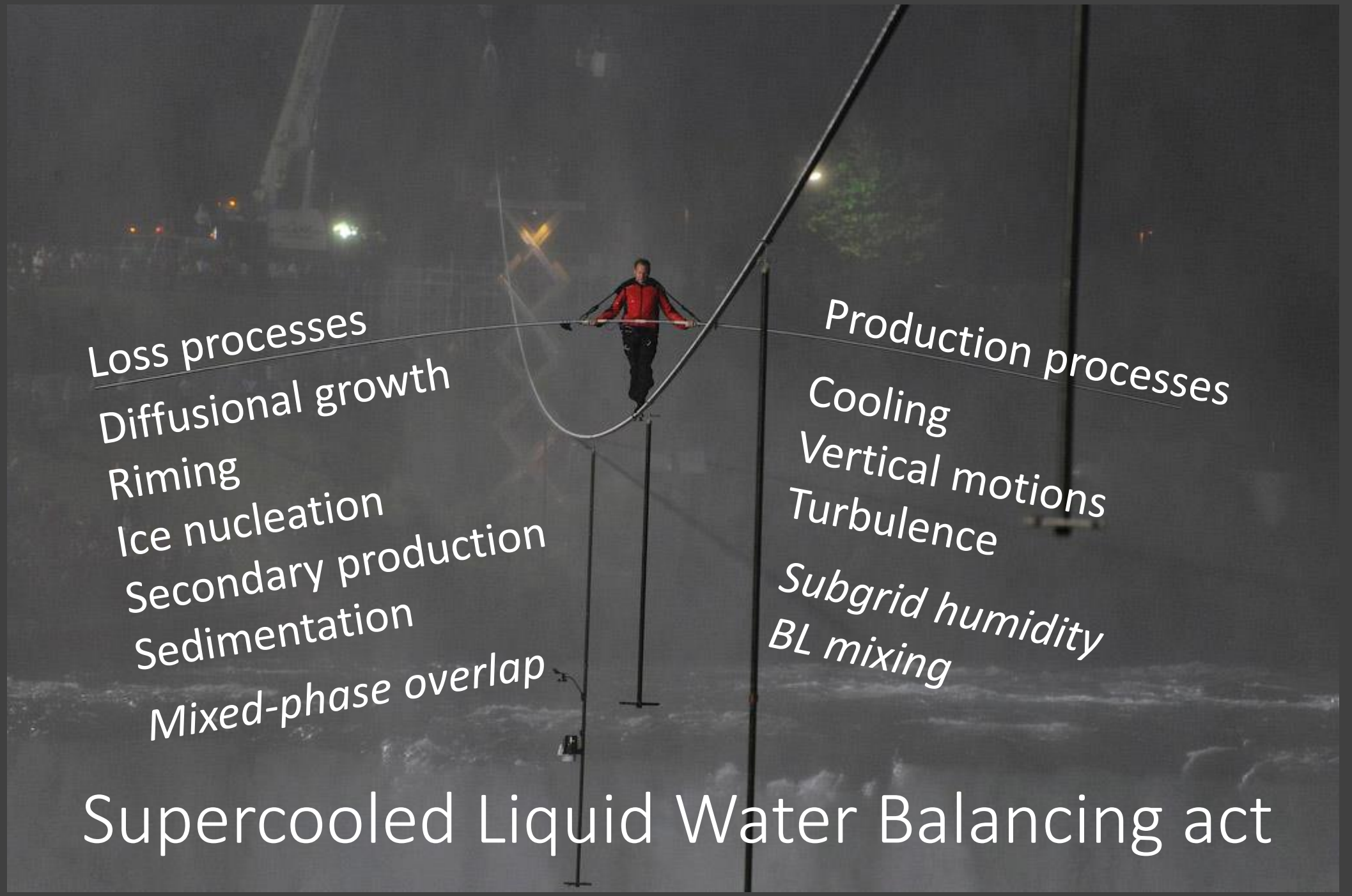








Field et al. 2017 QJRMS

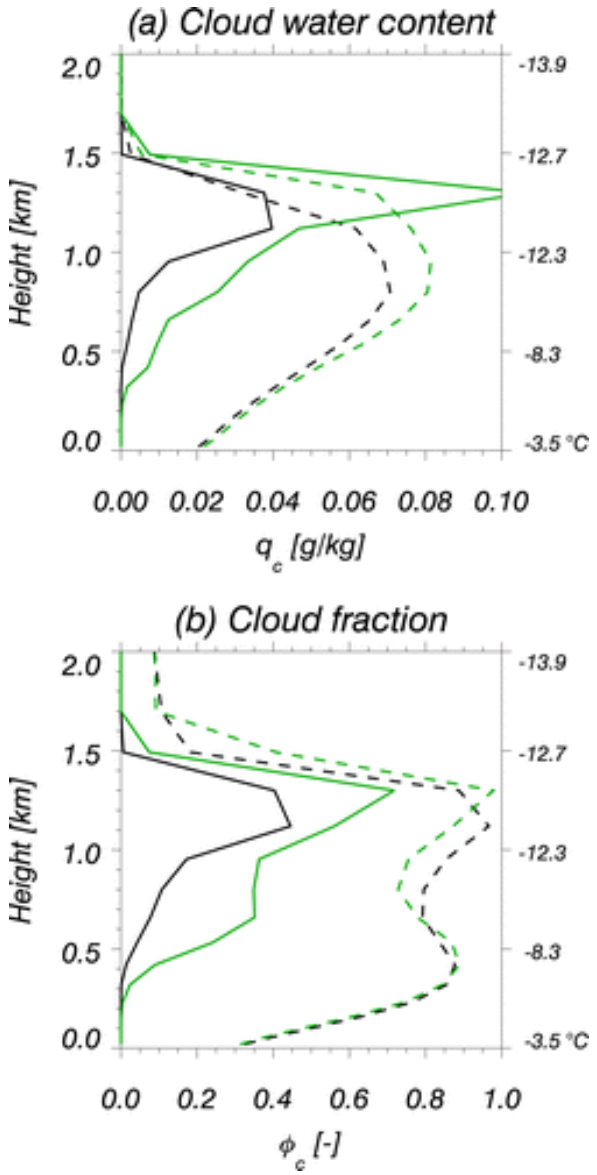


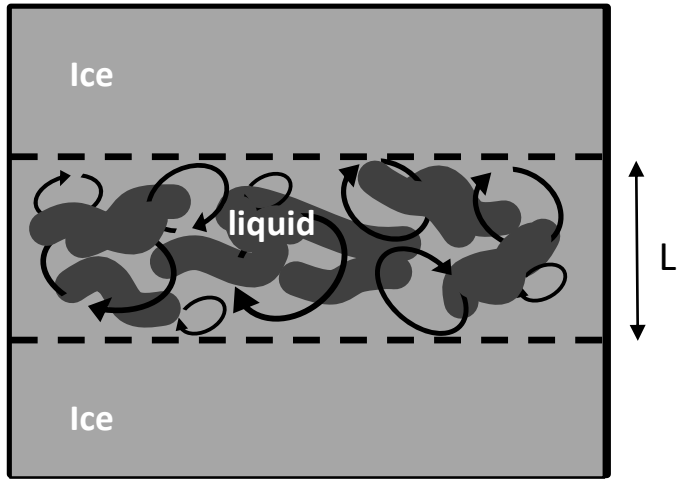
Supercooled Liquid Water Balancing act

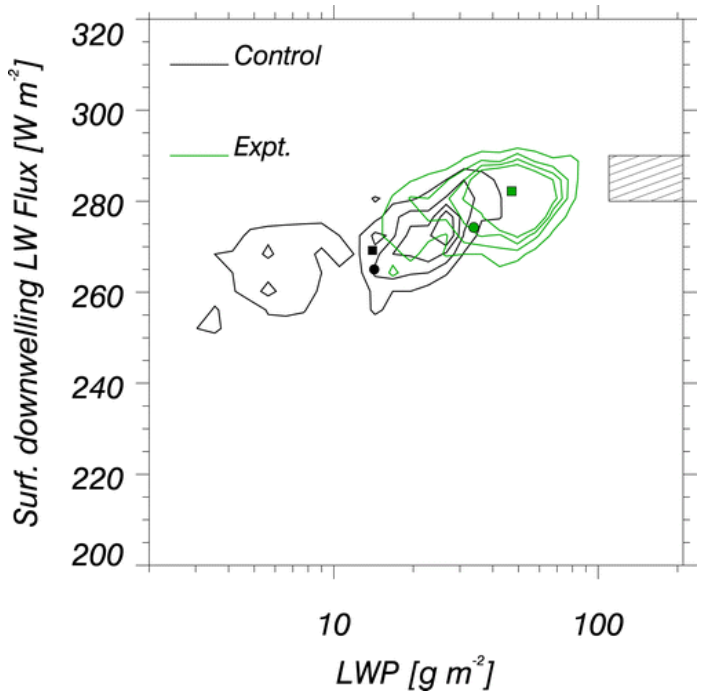
AIRCRAFT: M-PACE (NSF)

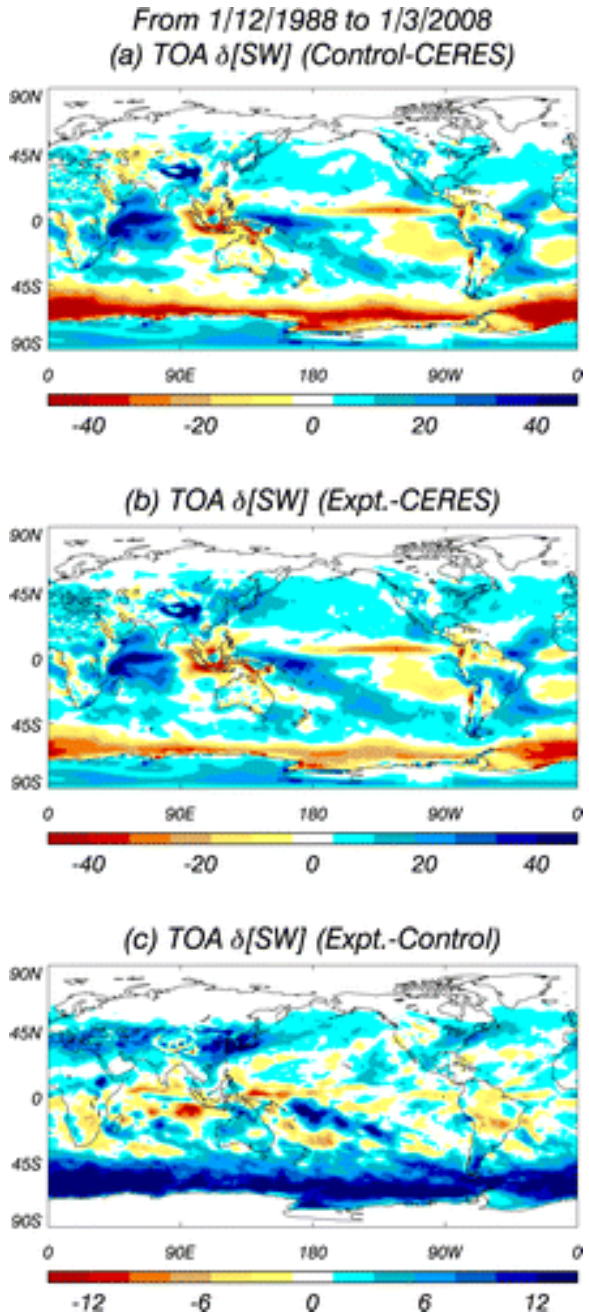
Solve stochastic Squire's equation

New liquid
Old liquid
New ice
Old ice







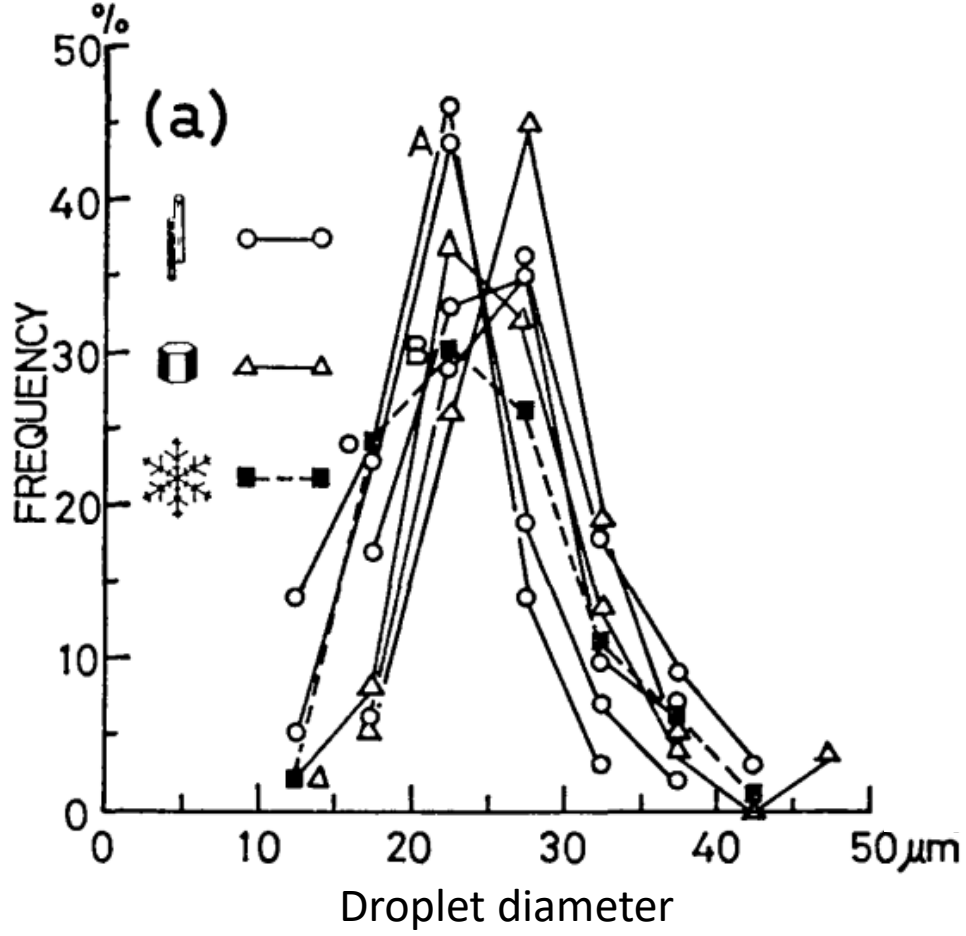


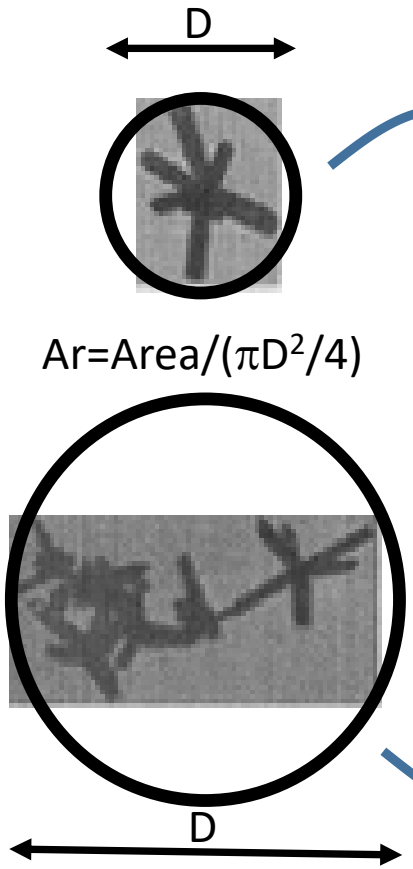
Realistic Riming Rates:

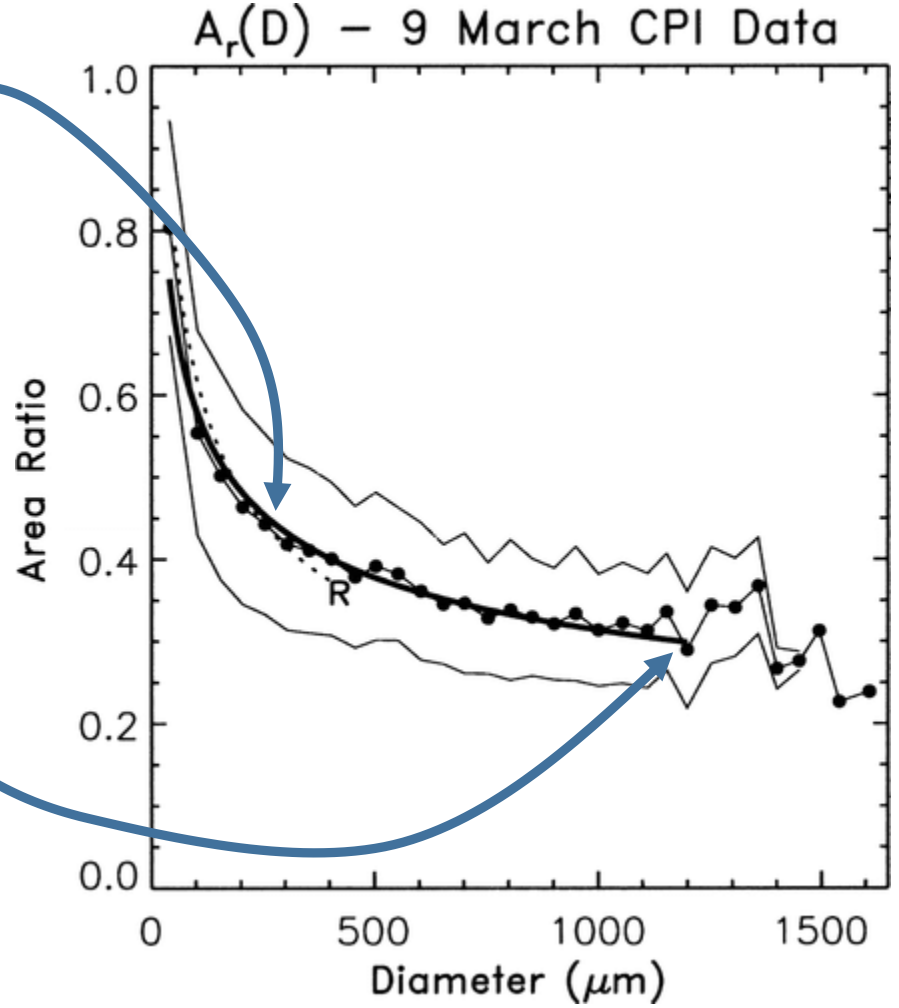
Threshold size of droplets to rime

Accretion area of snow/ice is smaller than circle

AIRCRAFT: CRYSTAL-FACE (NASA)





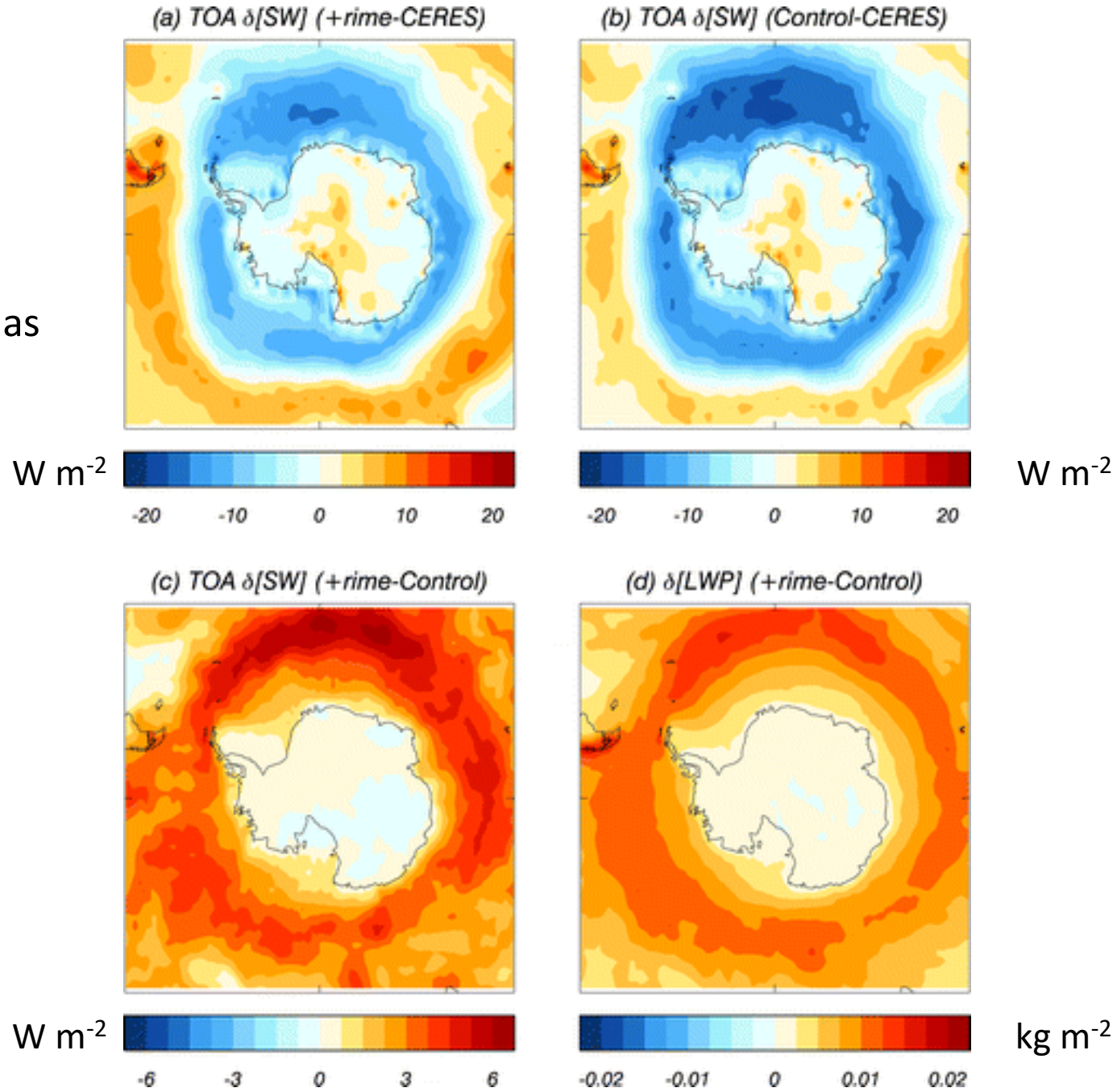


Marimaya, 1975, J. Meteor. Japan

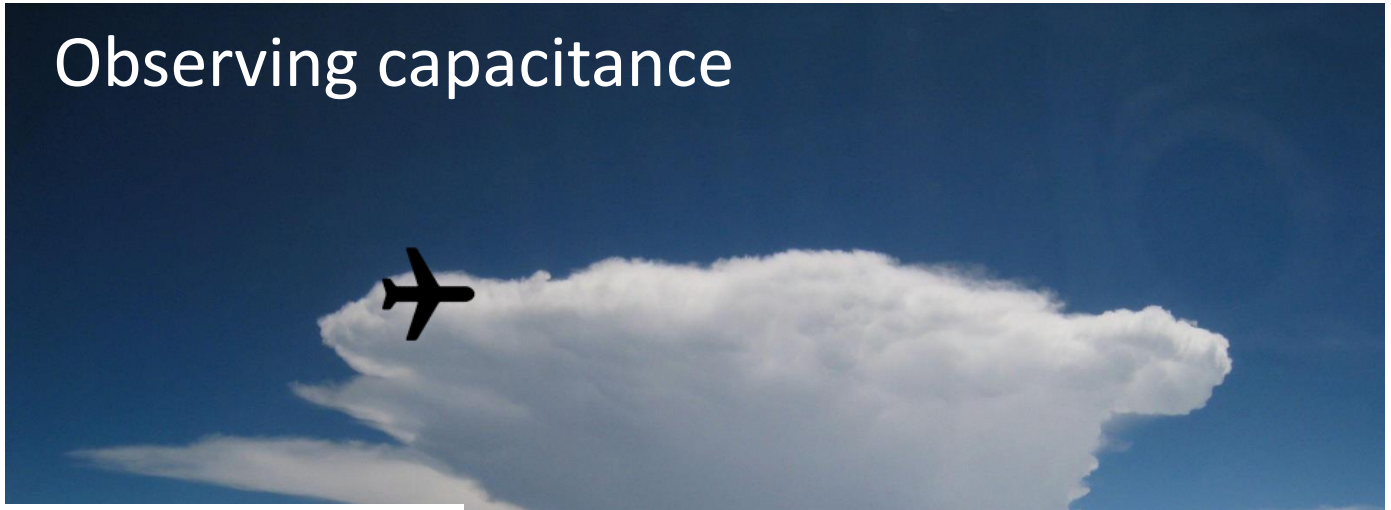
Heymsfield and Miloshevich 2003

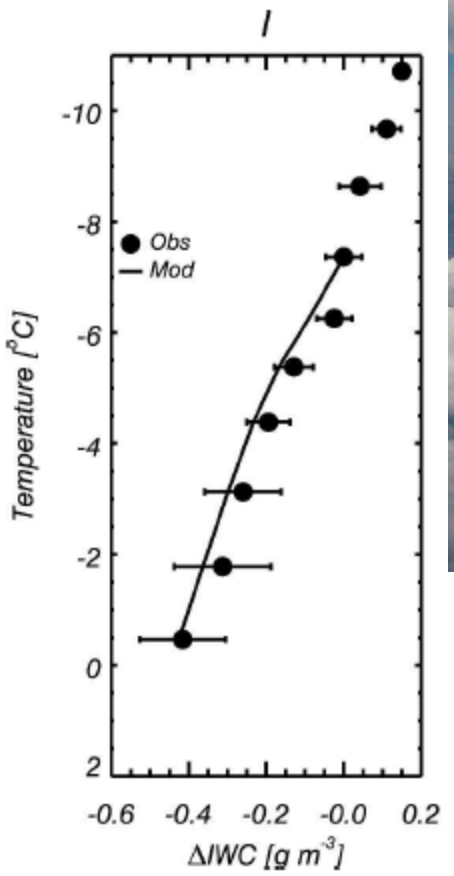
Reduced Riming Rate impact on Southern Ocean Bias

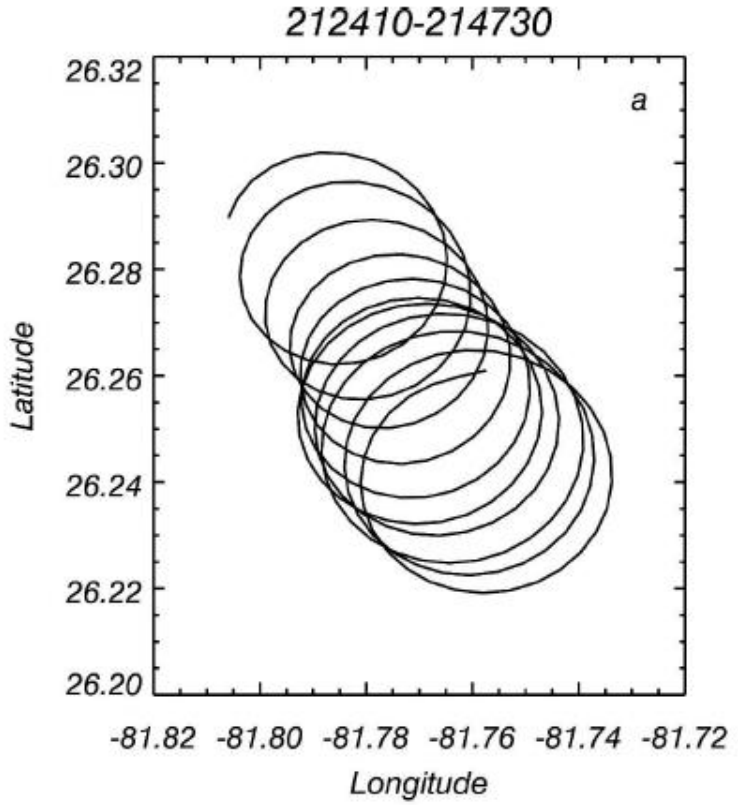
20y AMIP



Observing capacitance



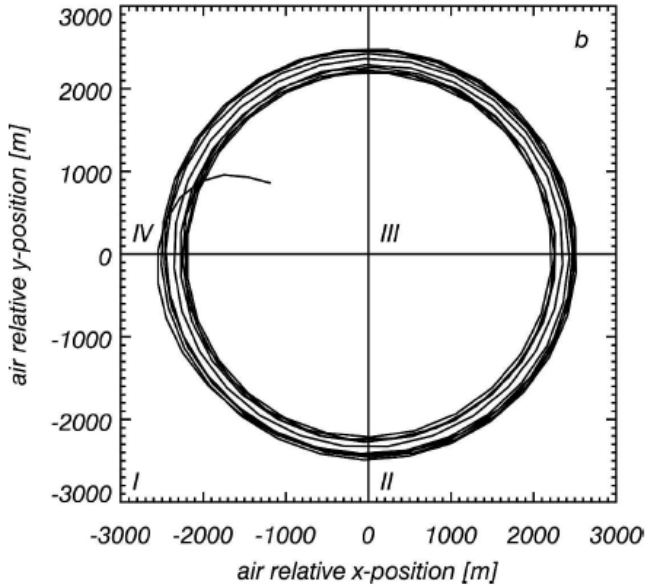




Determine best 'C'

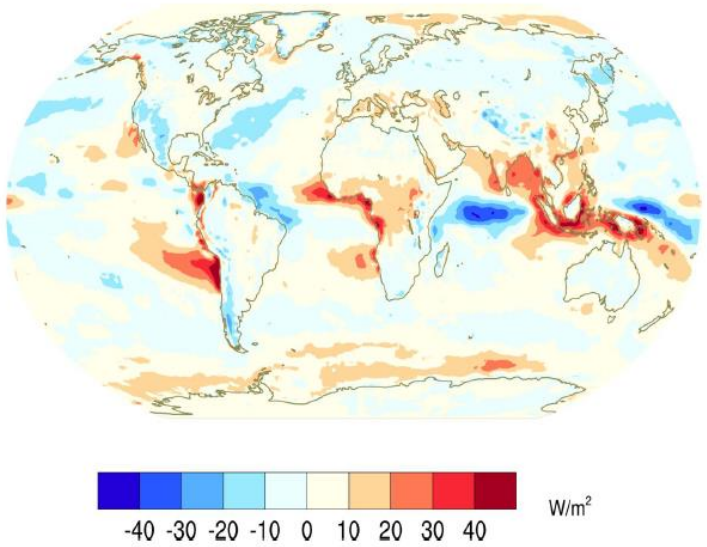
$$\frac{dm(D)}{dt} = \frac{4\pi D f \mathbf{C} S}{A + B}$$

C = ½ sphere value ~plate

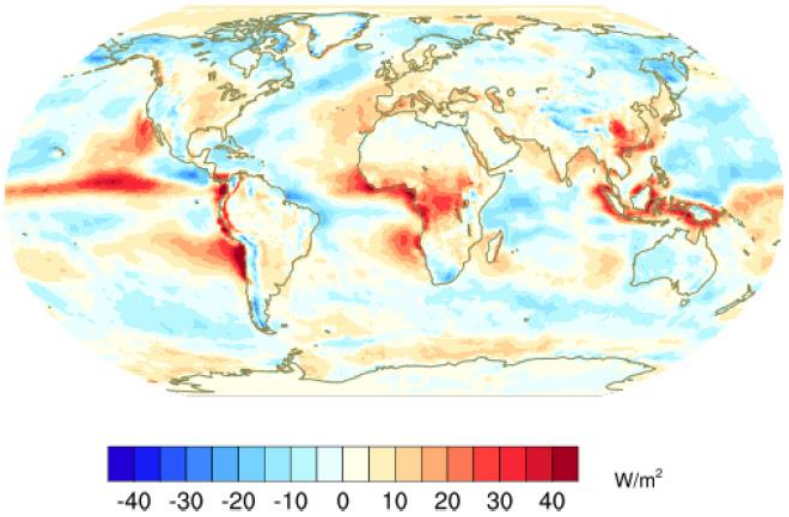


Annual-mean shortwave cloud radiative forcing bias at TOA (W/m2) relative to the CERES-EBAF climatology in GA configurations.

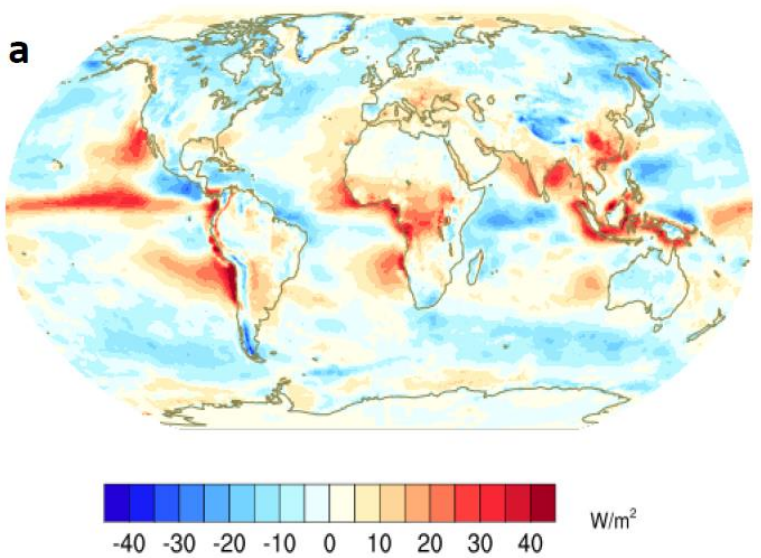
GA7



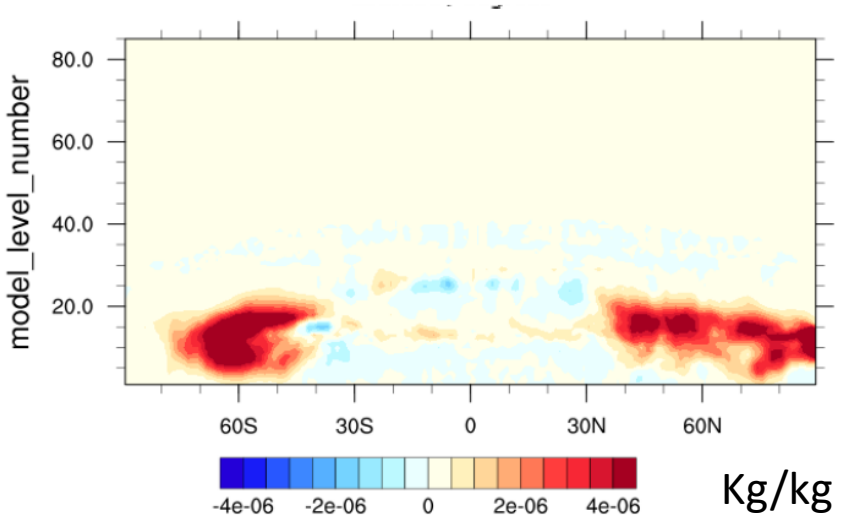
+ riming change



+ capacitance change



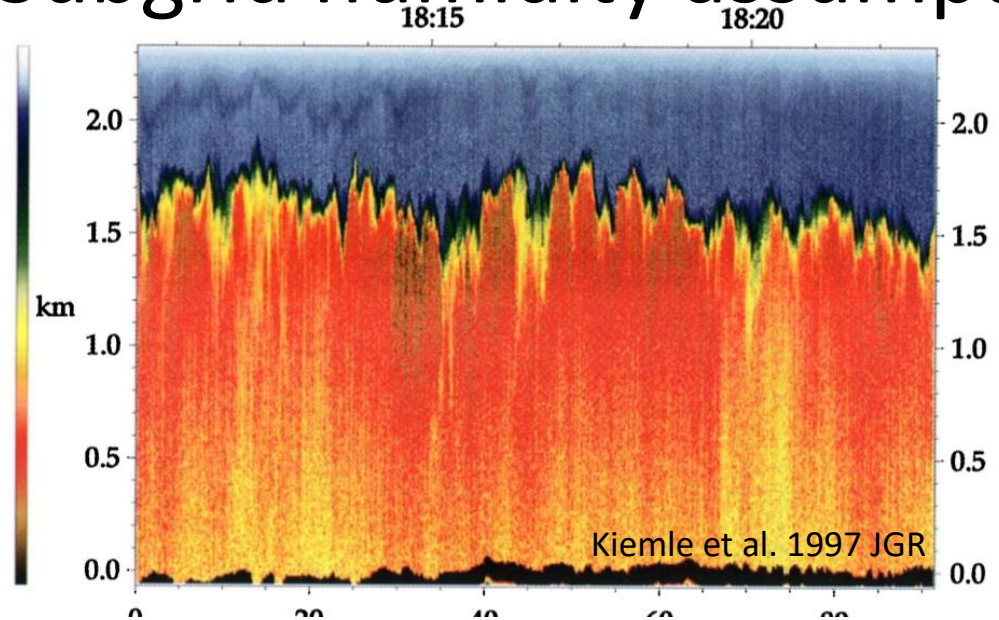
Change in zonal mean Liquid water due to change in capacitance

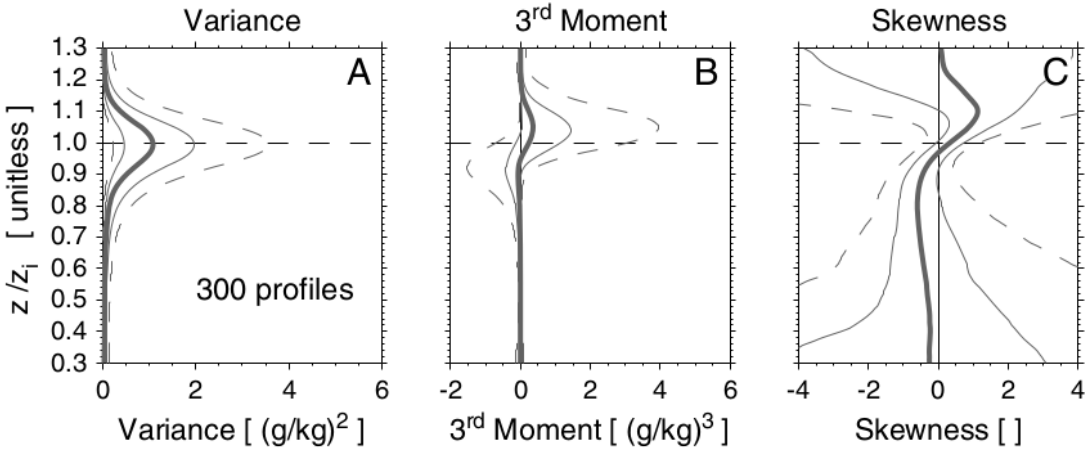


c/o Vidya Varma to be submitted to ACP

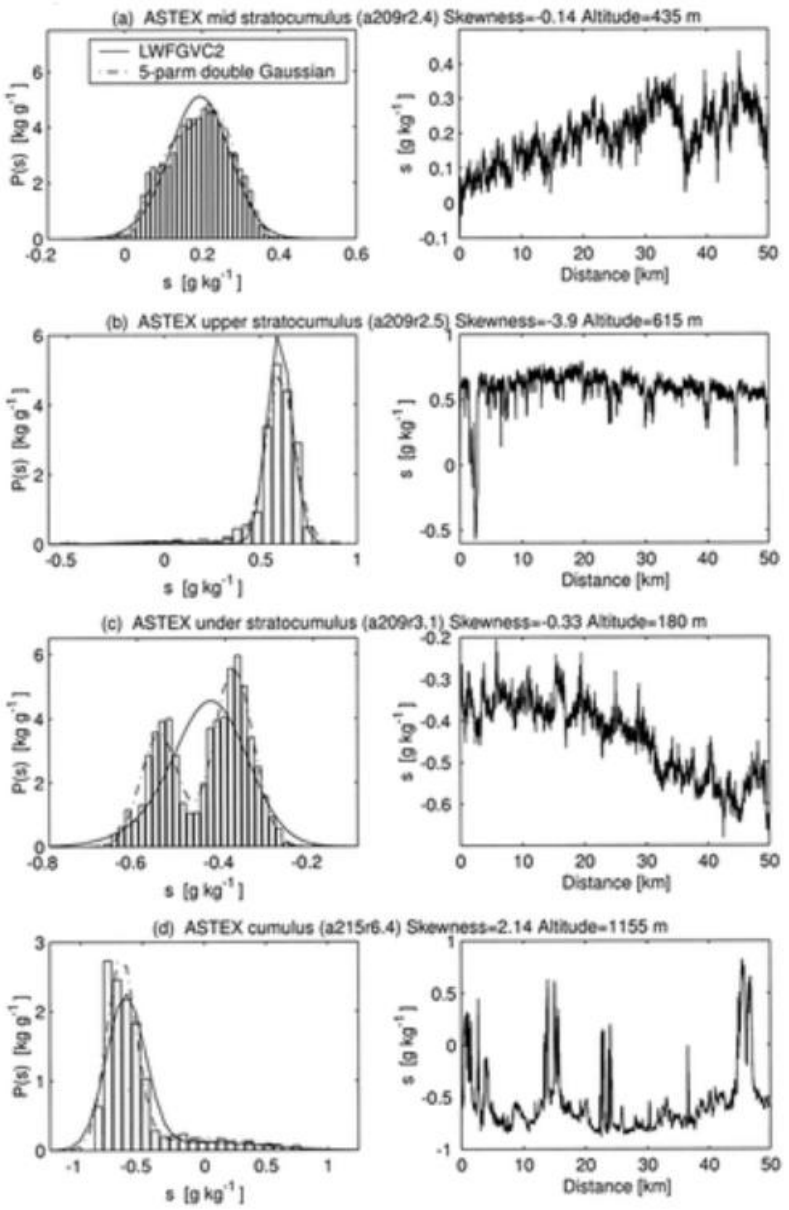
Cloud scheme
Subgrid humidity assumptions

AIRCRAFT: BOREAS, ASTEX (NSF)





Turner et al. 2014 JGR

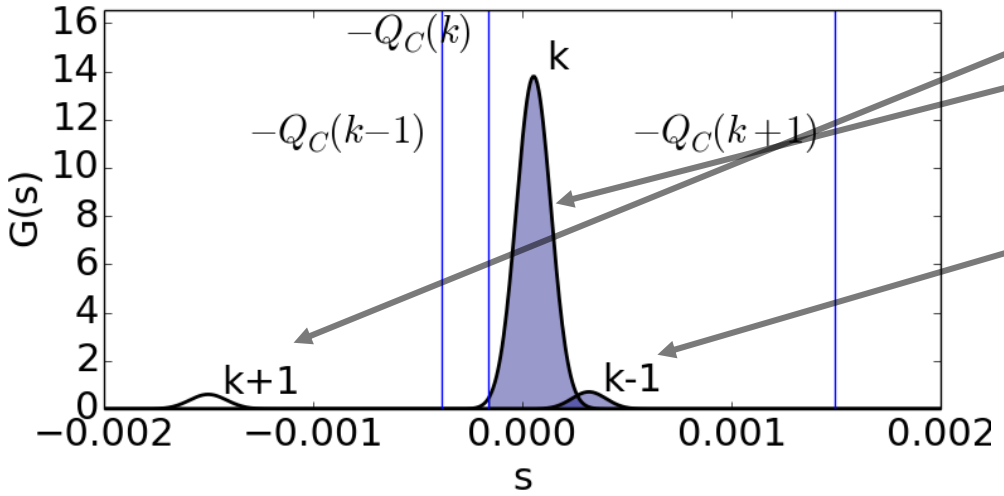


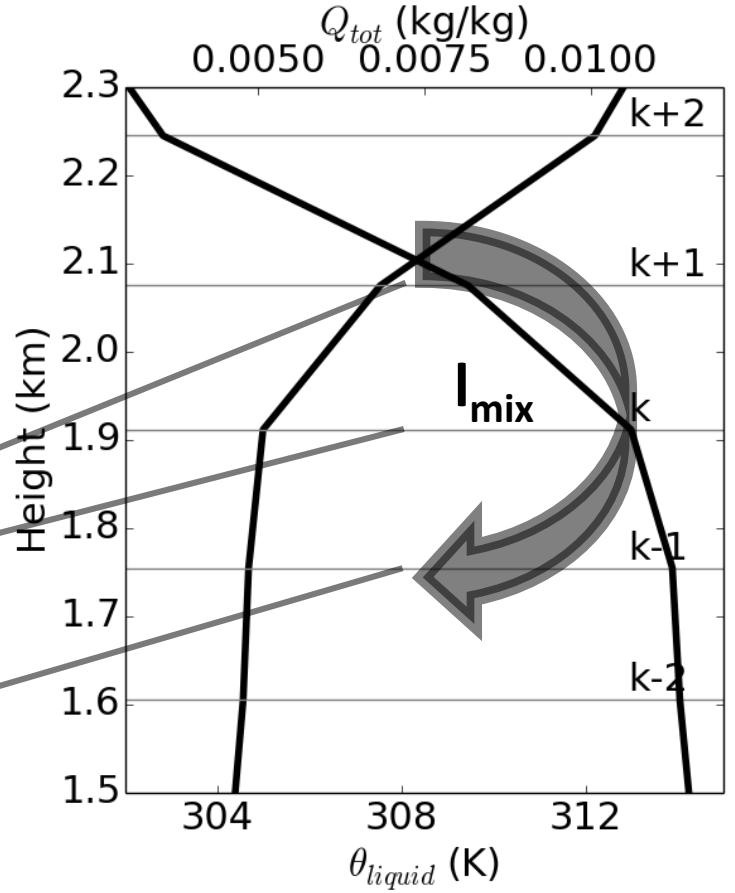
Larson et al. 2001 JAS

Methods: multimodal Smith

→Original Smith: one-modal PDF of subgrid variability, using BL-variance

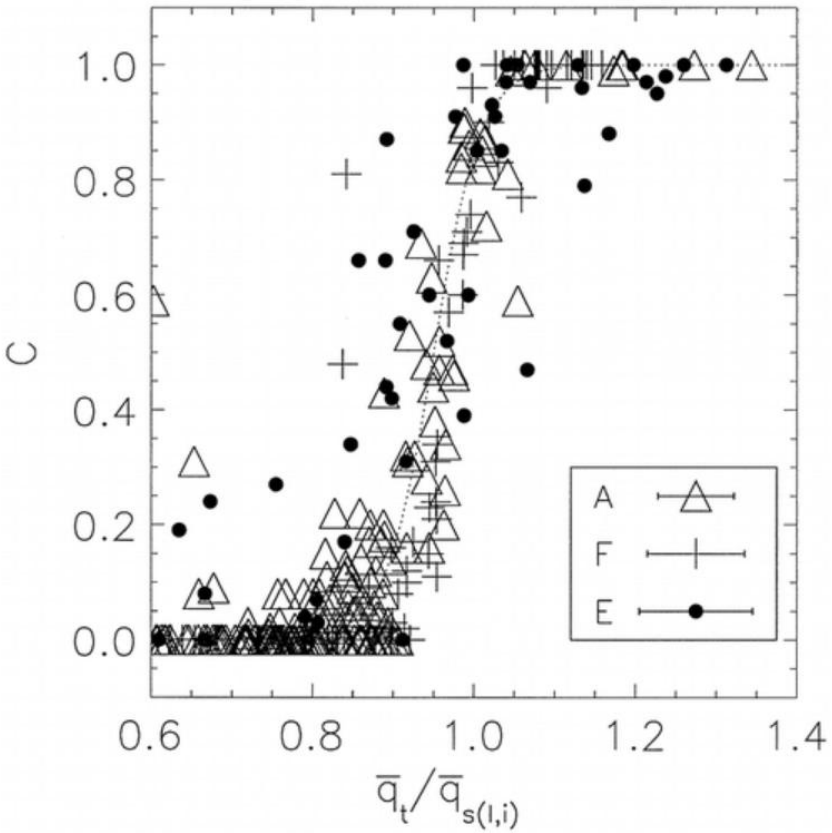
→Use information from below and above this layer to reconstruct multimodal PDF:



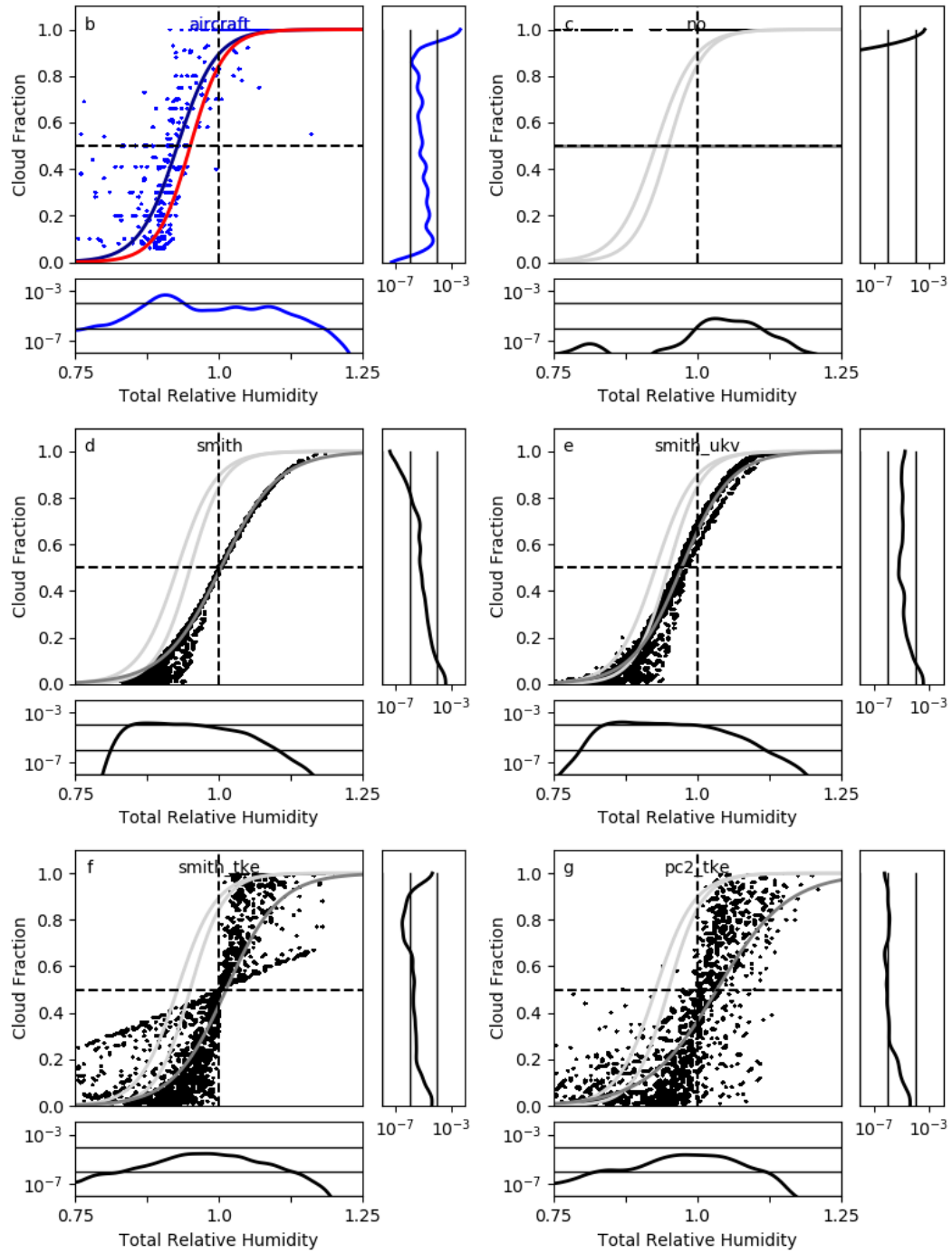


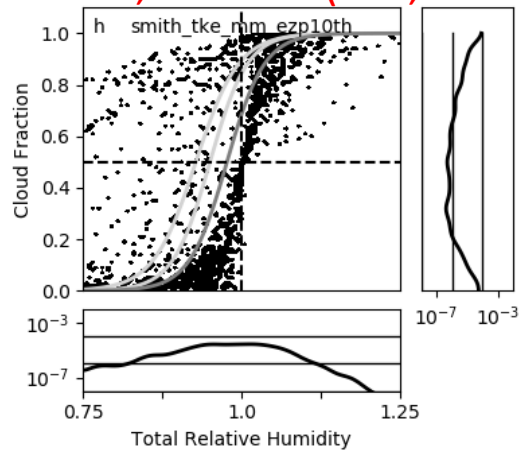
Van Weverberg et al.
Submitted to MWR

AIRCRAFT: FIRE, ASTEX, EUCREX (NSF, UKMO)



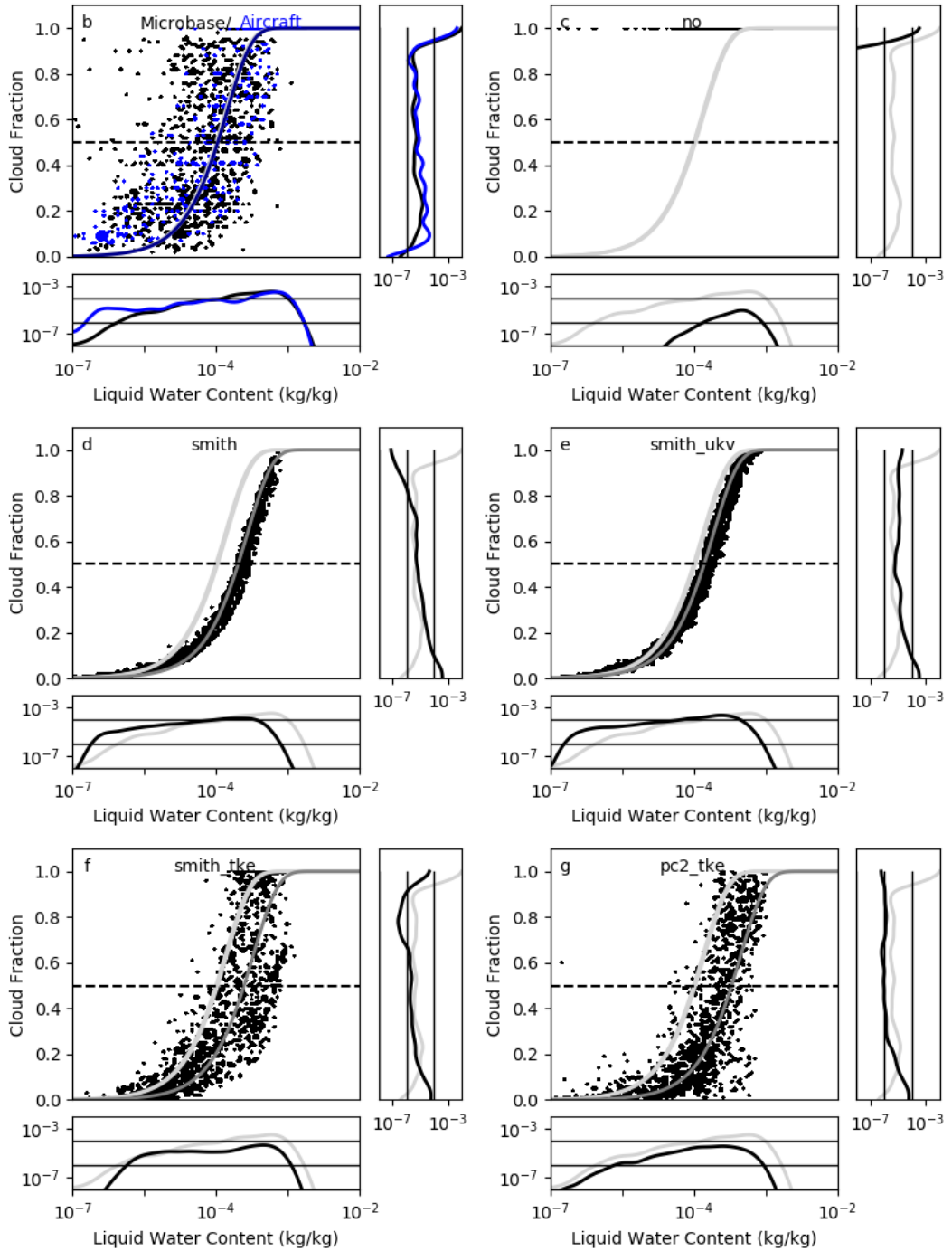
Wood and Field 2000 JAS





Van Weverberg et al.
Submitted to MWR

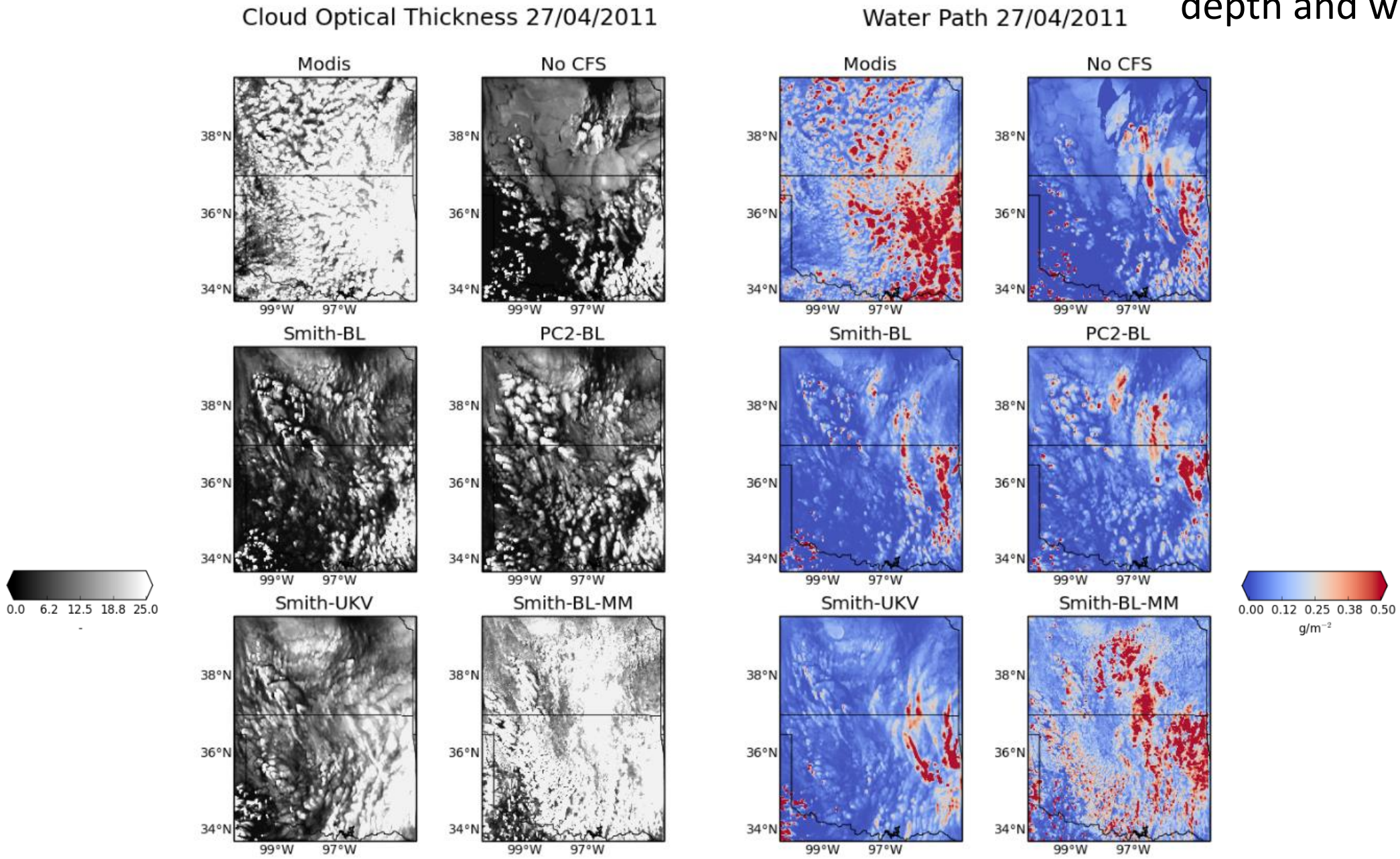
ARM SITE DATA



Van Weverberg et al.
Submitted to MWR

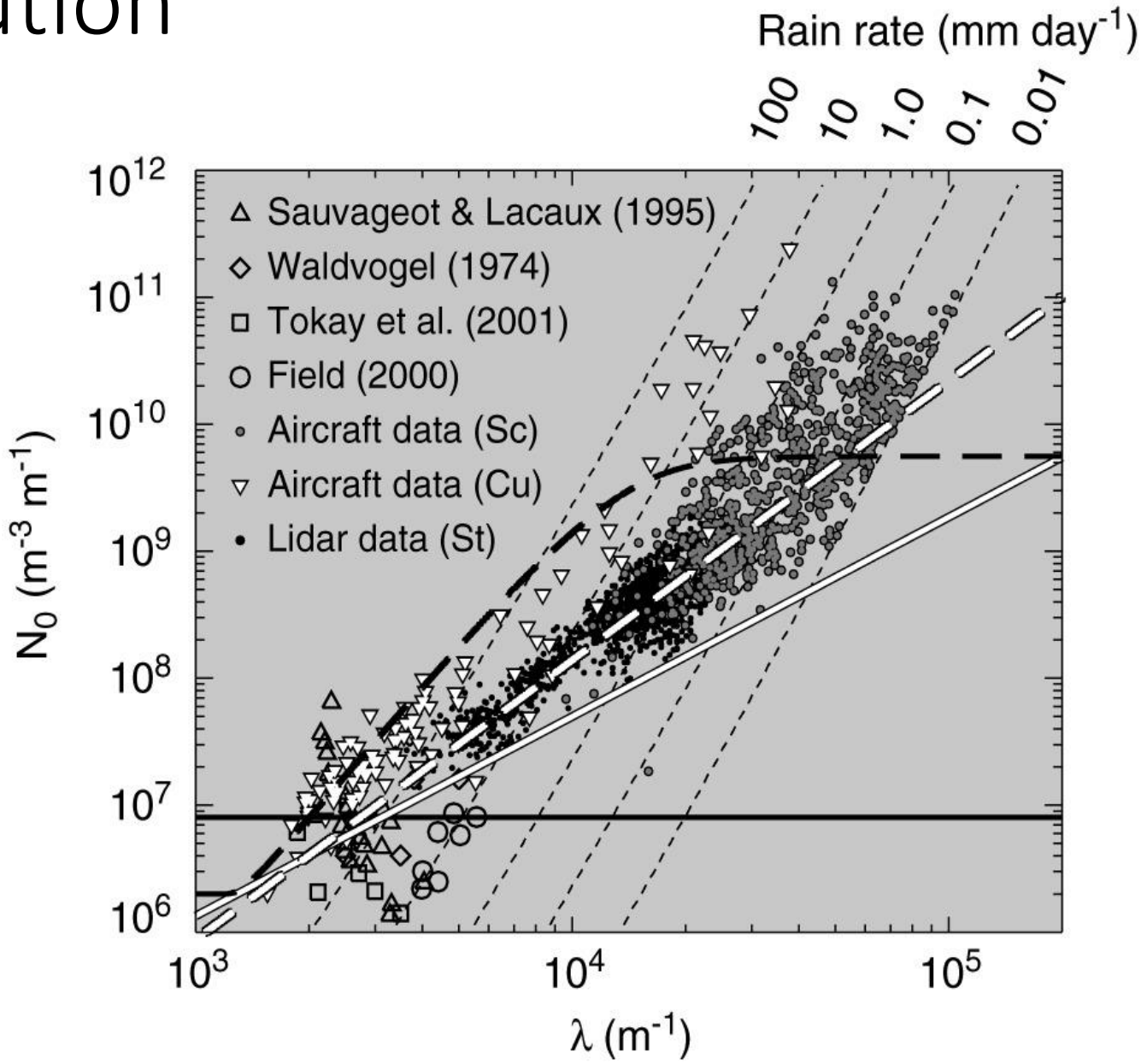
Cloudscheme stratocumulus case

MODIS-COSP optical depth and water path



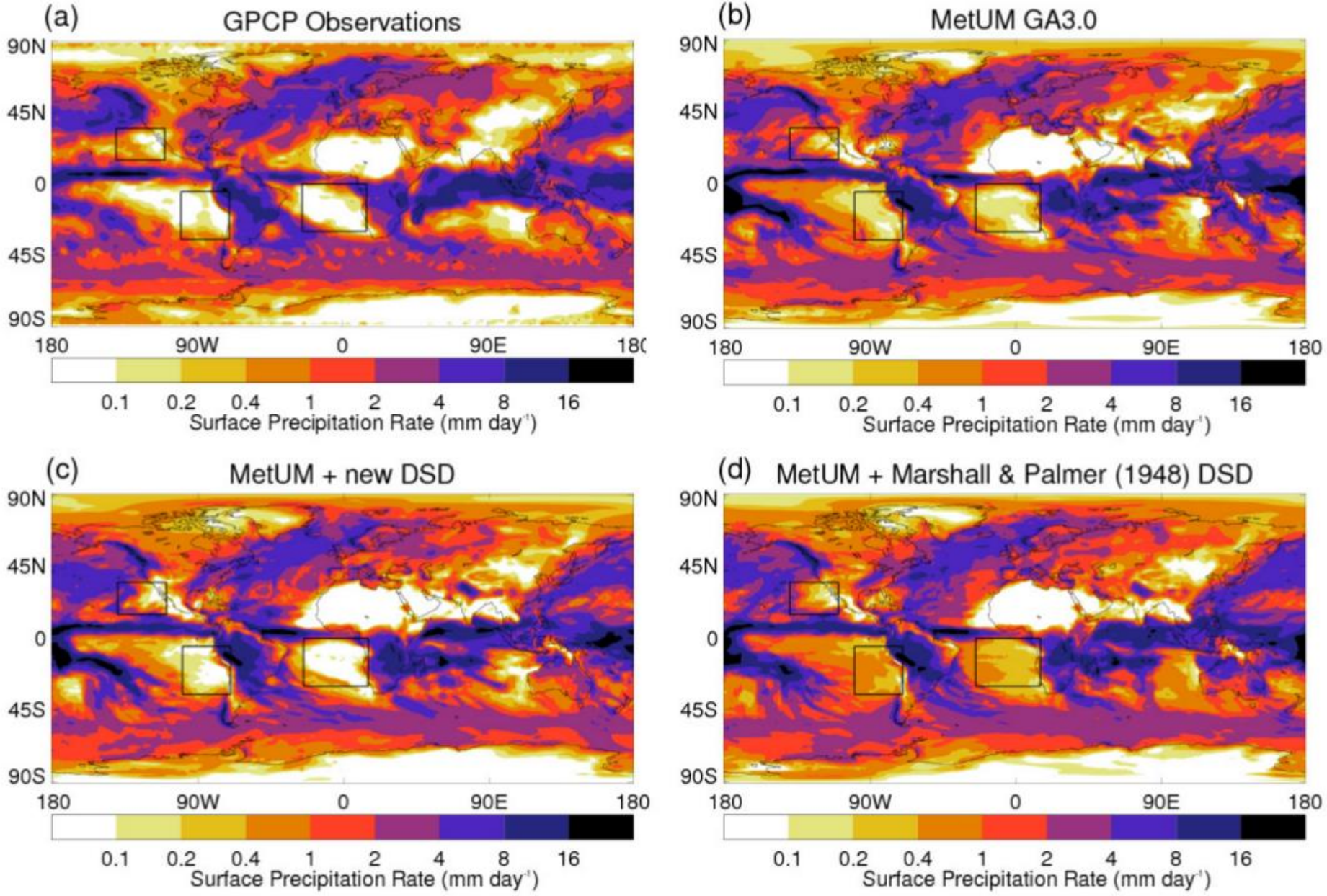
Droplet size distribution

- VOCALS field program motivated re-evaluation of DSD representation

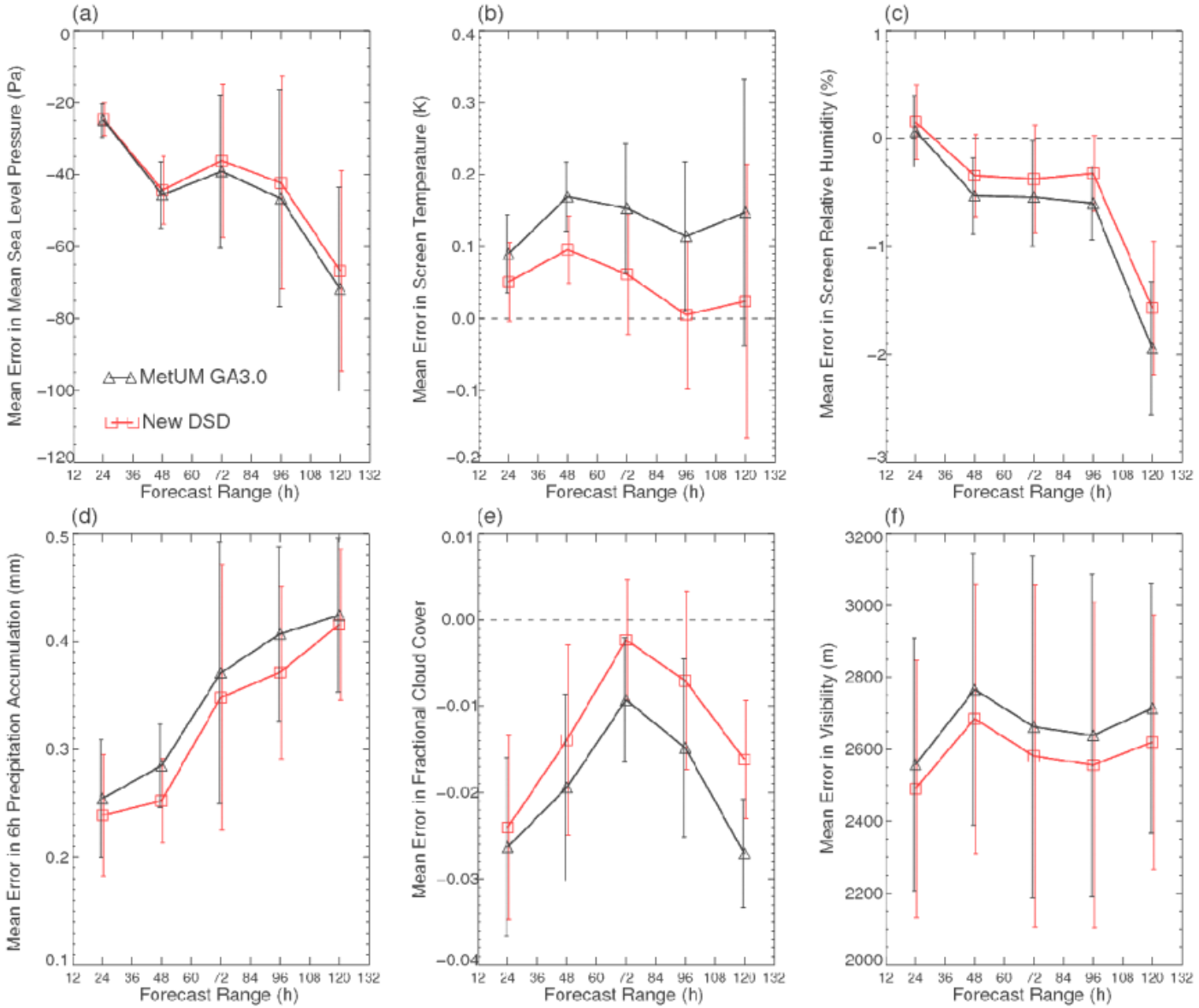


Abel and Boutle 2012

Impact of new rain DSD representation:
improved, reduced precip rates in stratocu decks

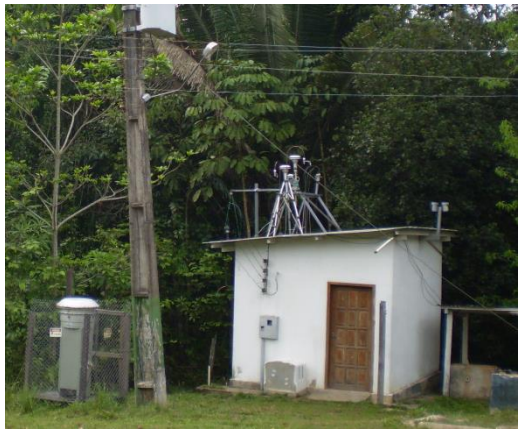


Impact of new rain DSD representation: Improved forecast weather metrics



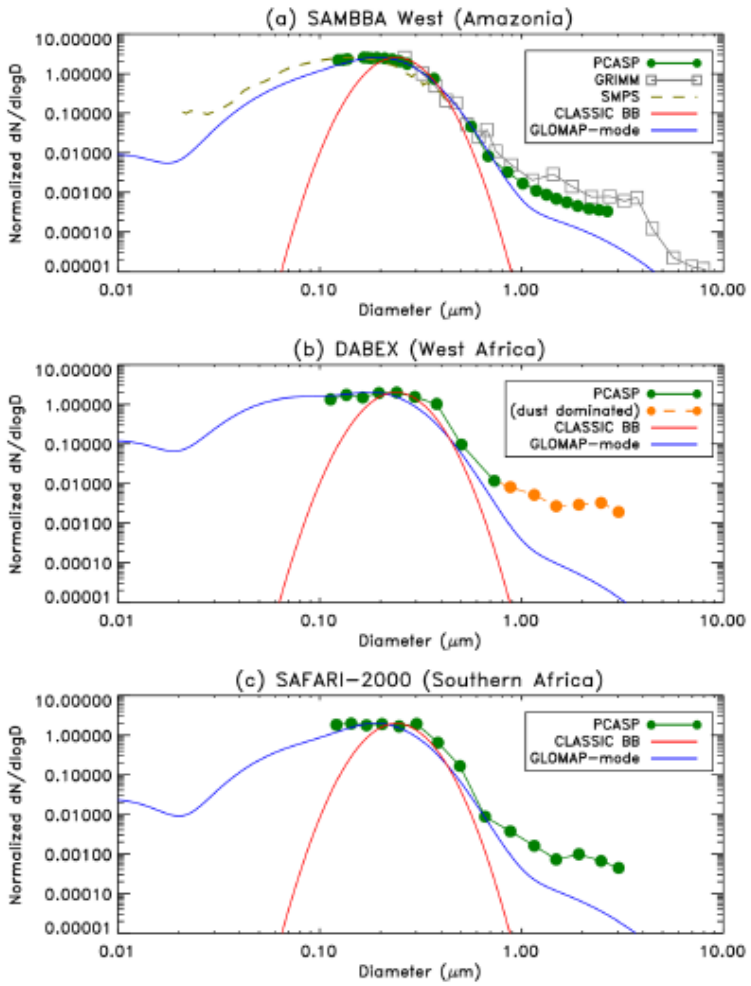
SAMBBA observations

(South American Biomass Burning Analysis) – Sept/Oct 2012



Campaign coordinators: Karla Longo, Ben Johnson, Paulo Artaxo, Hugh Coe, Jim Haywood, Will Morgan

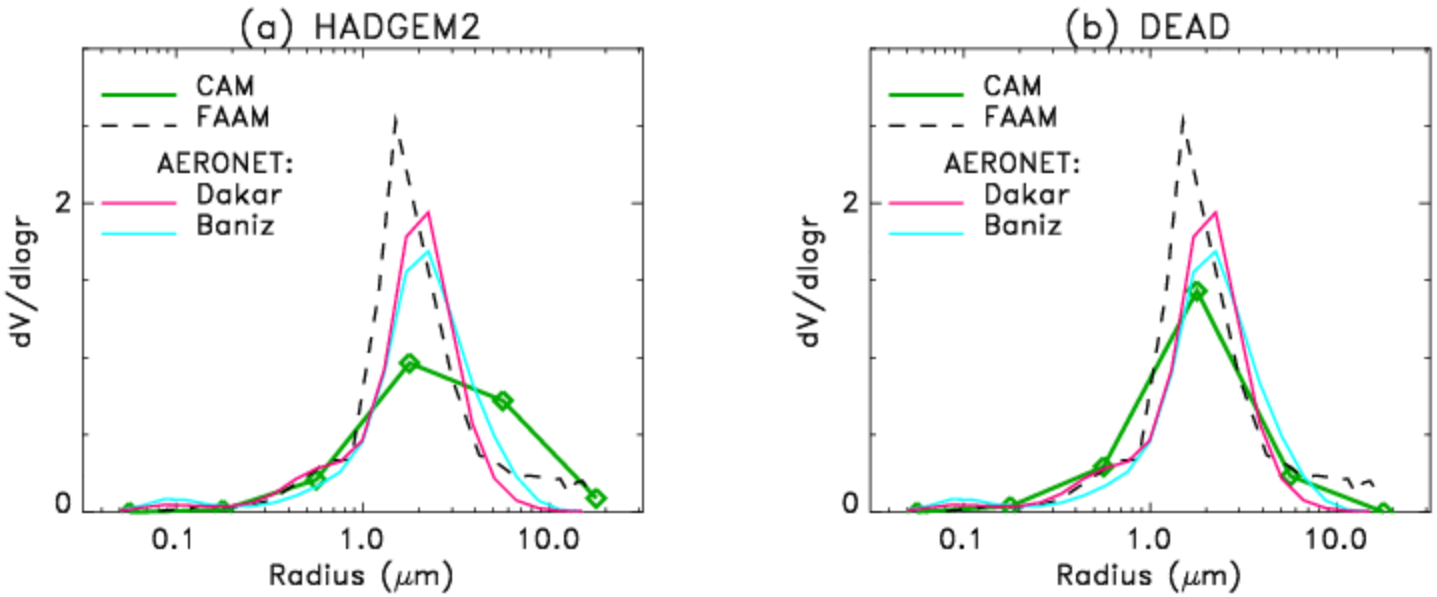
Biomass burning aerosol size distributions (campaign-means) versus HadGEM



- Observed BB aerosol size distributions similar across tropical source regions
- GLOMAP-MODE represents full size distribution very well
- CLASSIC represents only accumulation mode for optical properties
- Shows the benefit of including aerosol microphysical processes

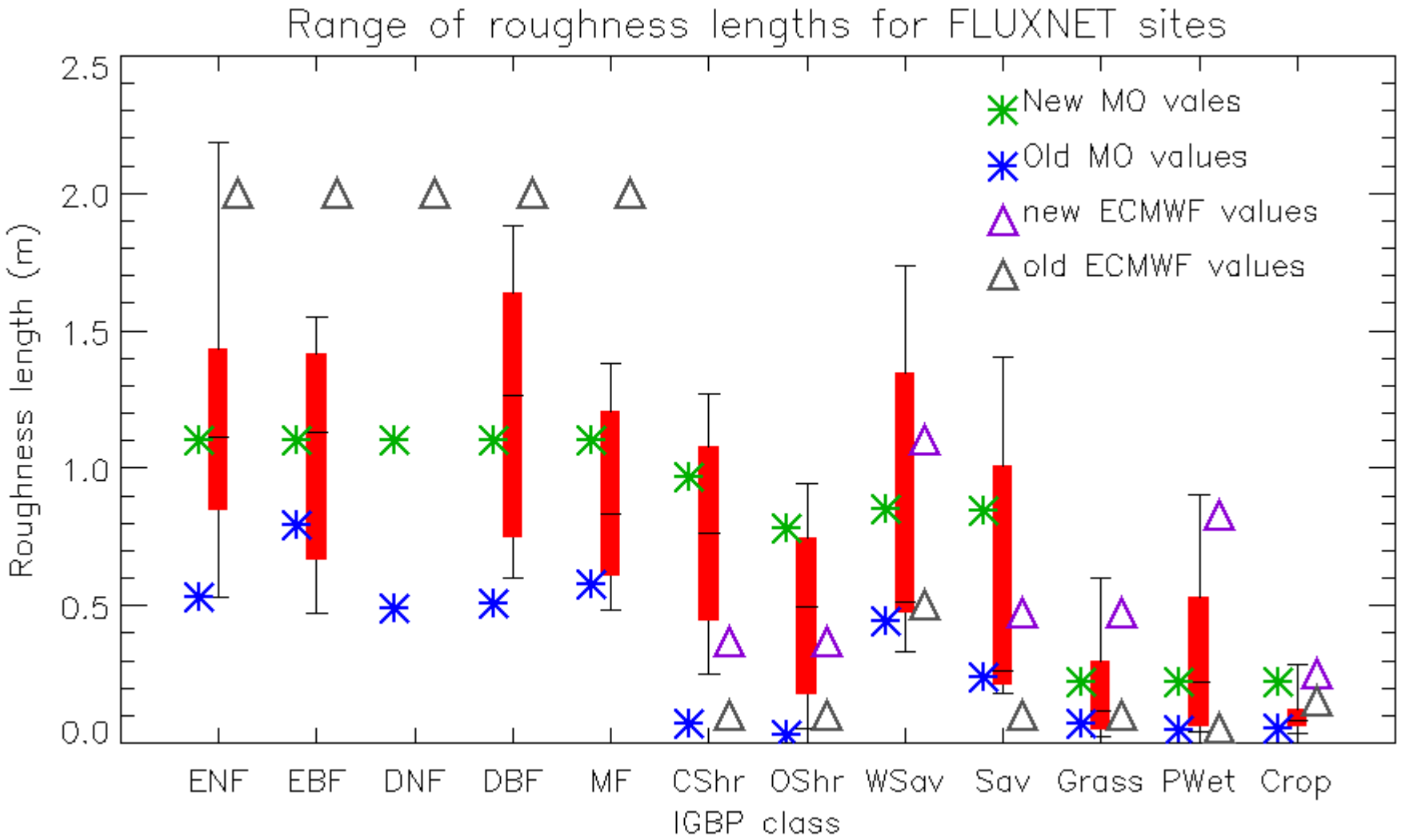
Johnson et al. (2016): https://www.atmos-chem-phys.net/16/14657/2016/

Comparing measured aerosol size distribution from GERBILS campaign with UM (CAM)



- Experimental dust schemes trialled in CAM limited area model. DEAD scheme used specified emission size distribution and agreed best with FAAM and AERONET.
- The NWP 2-bin dust scheme was developed with similar approach to DEAD with initial distribution based on multiple dust campaigns.

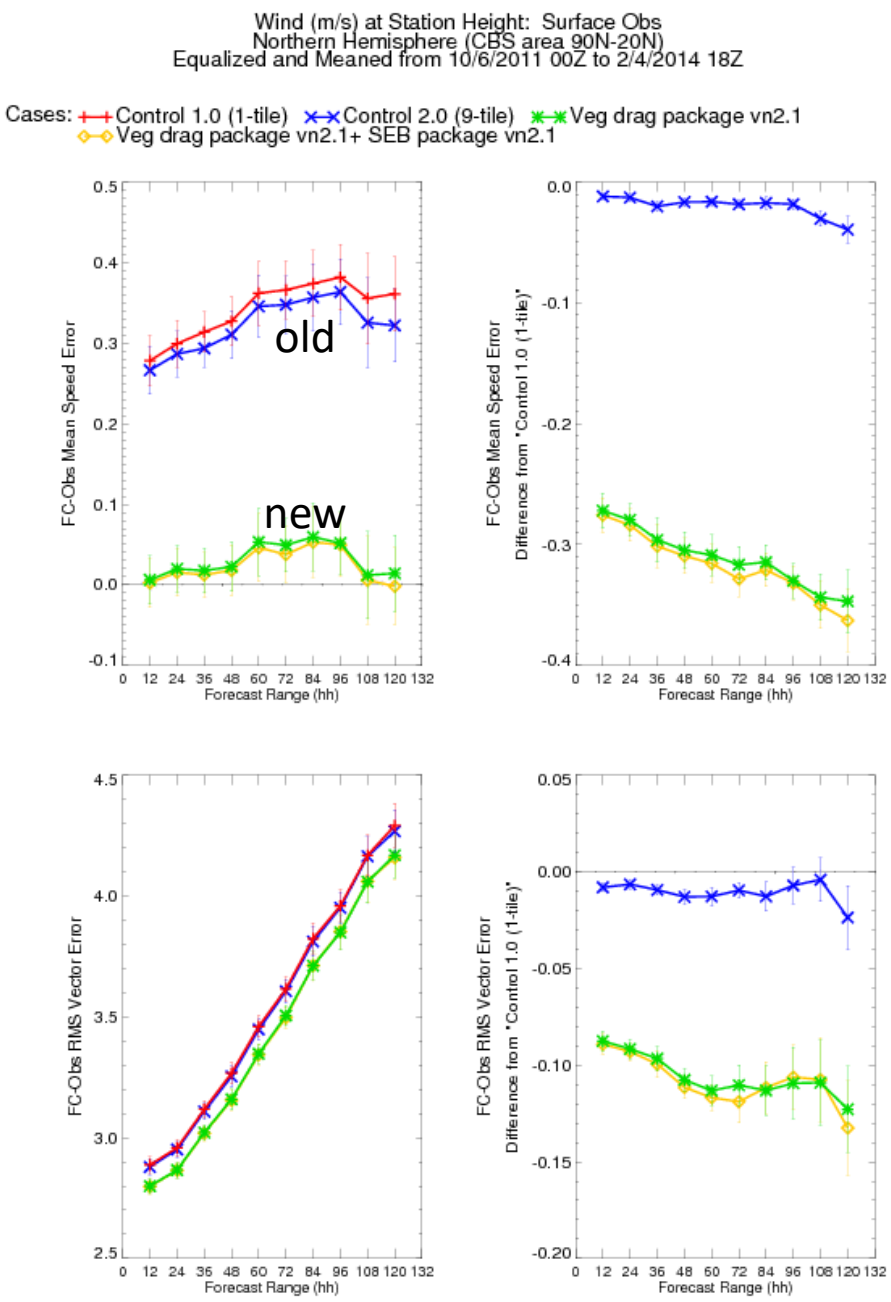
Surface Scheme

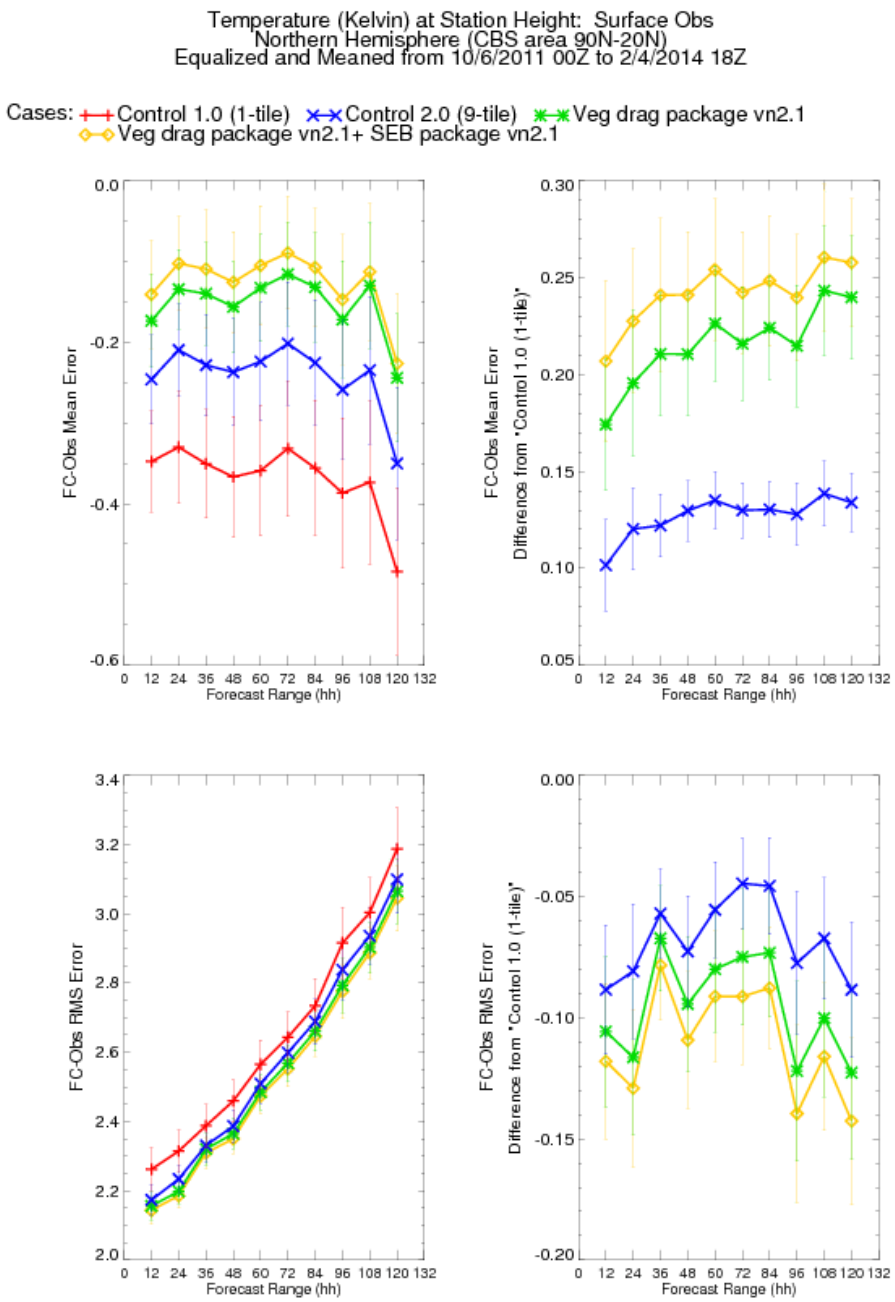


For large Obukhov length (shear driven turbulence) in neutral conditions
roughness length backed out from $U_* \ln(z/z_{rough}) = kU$

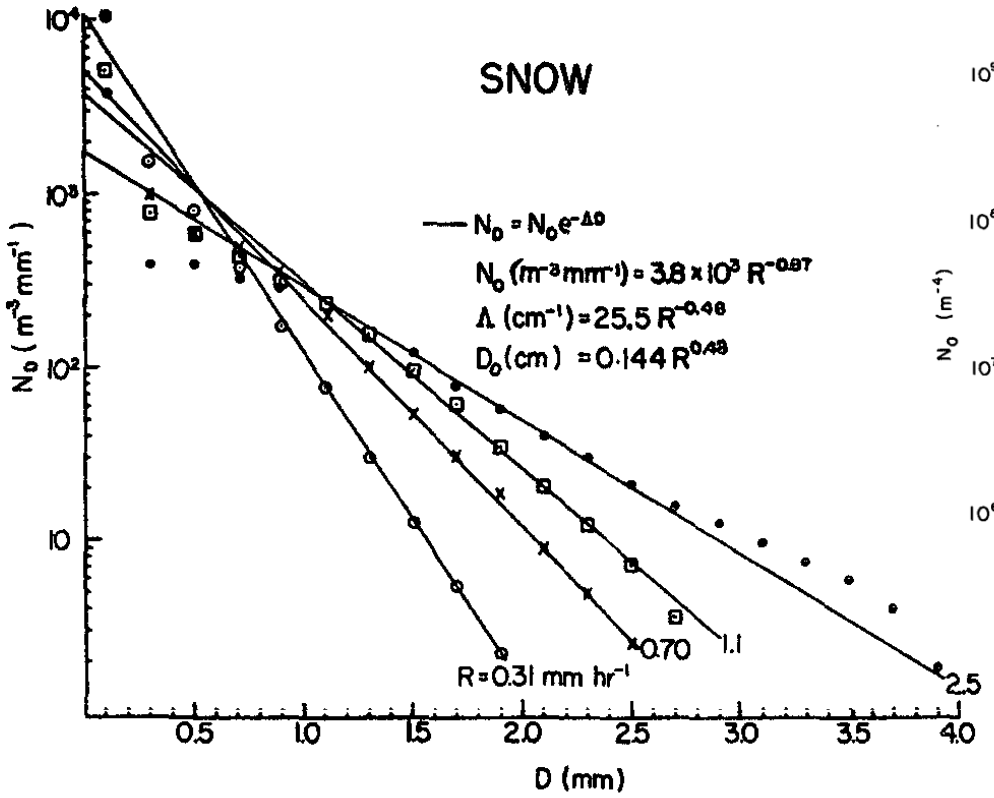
c/o Martin Best

Surface scheme Improvements to forecast weather metrics

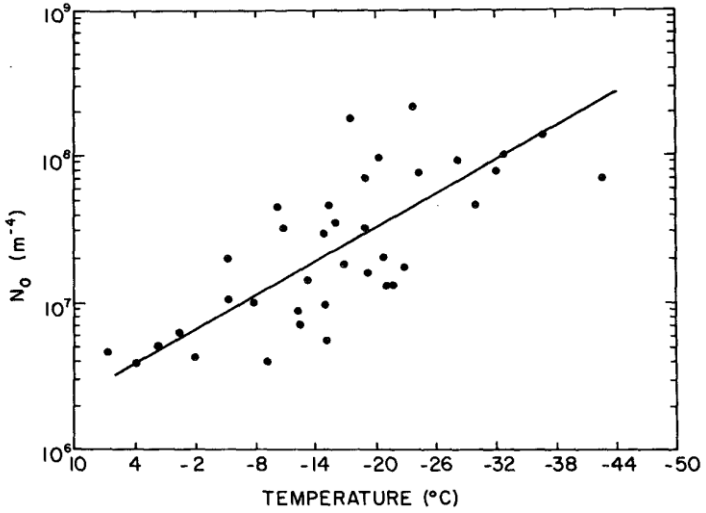




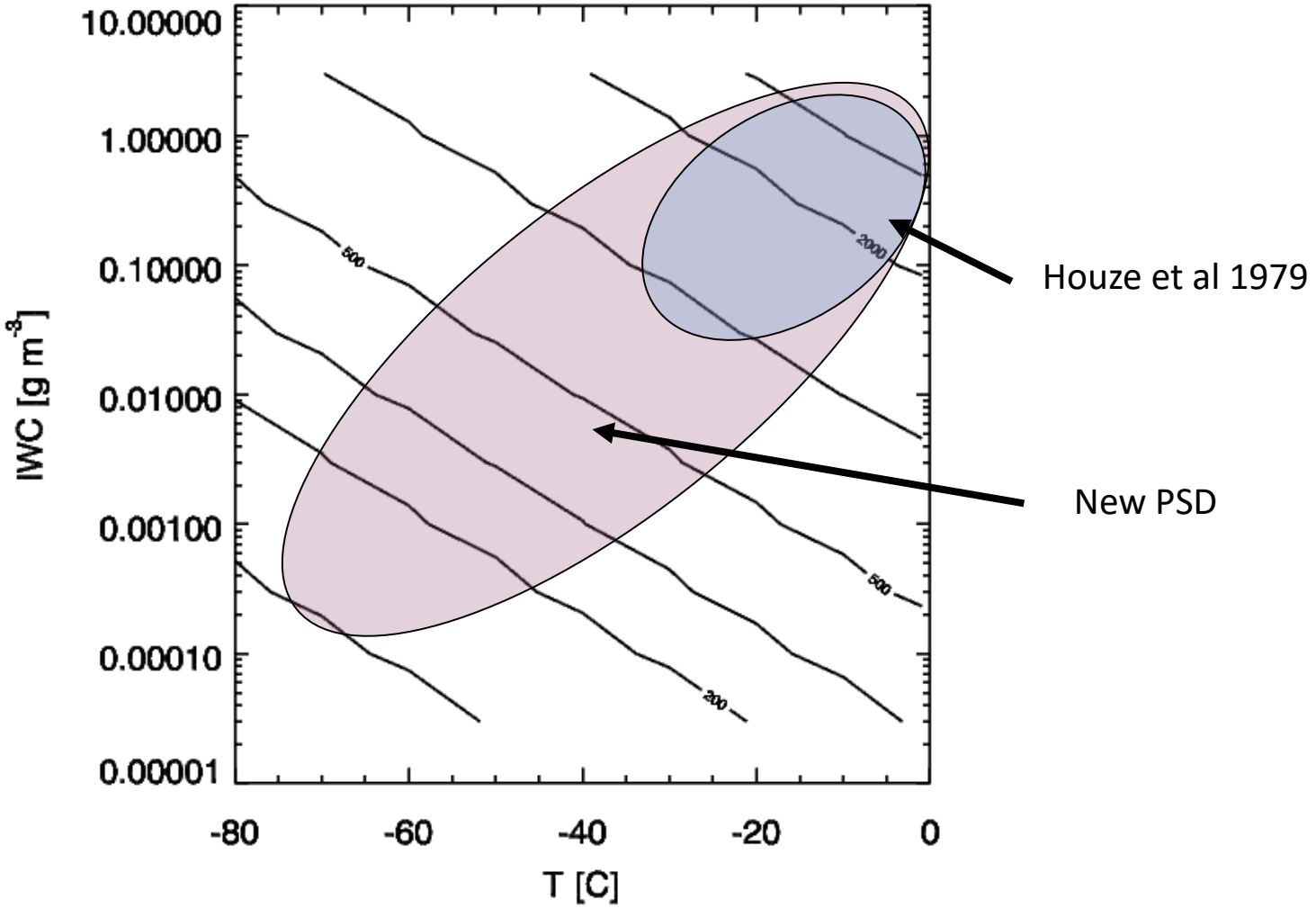
Snow particle size distributions



Gunn and Marshall 1958

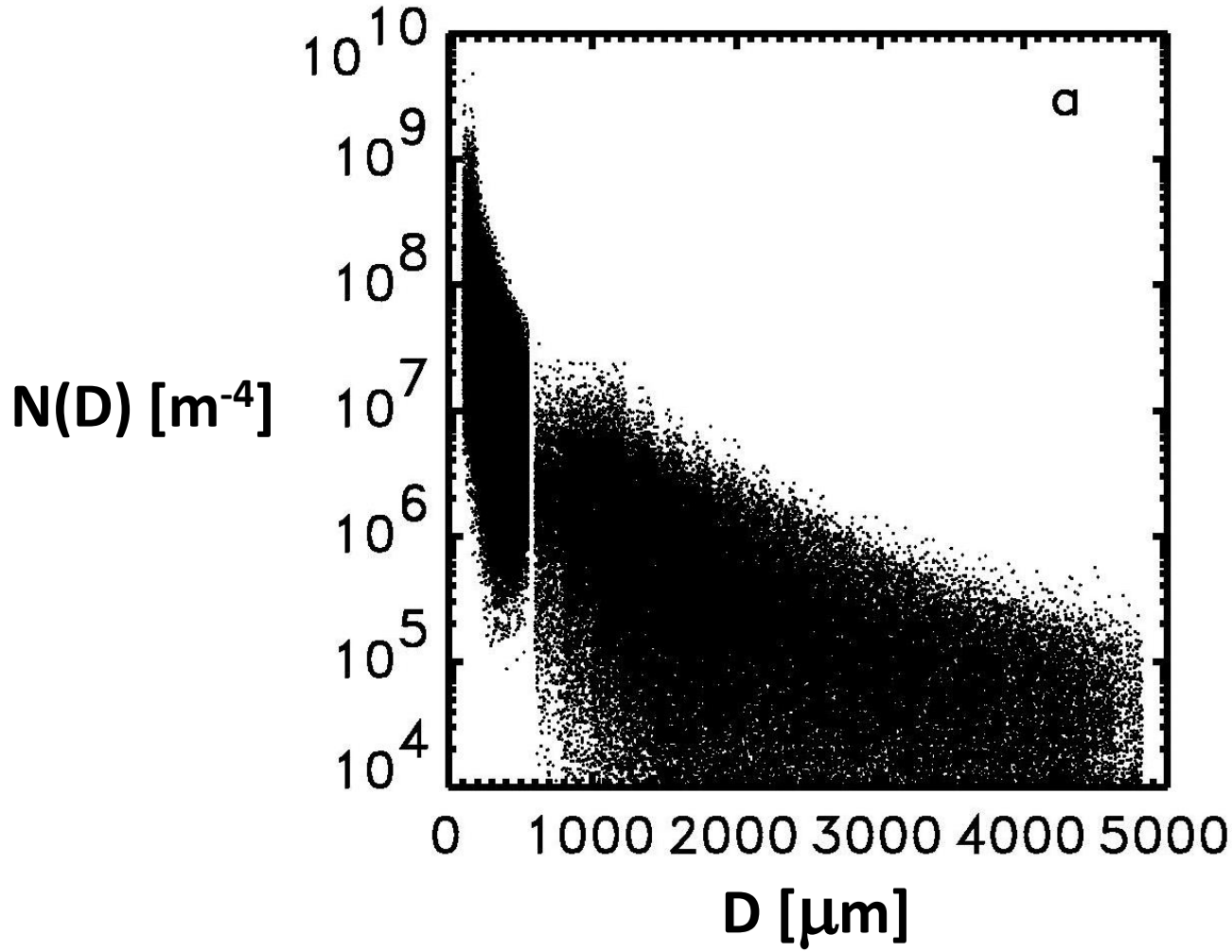


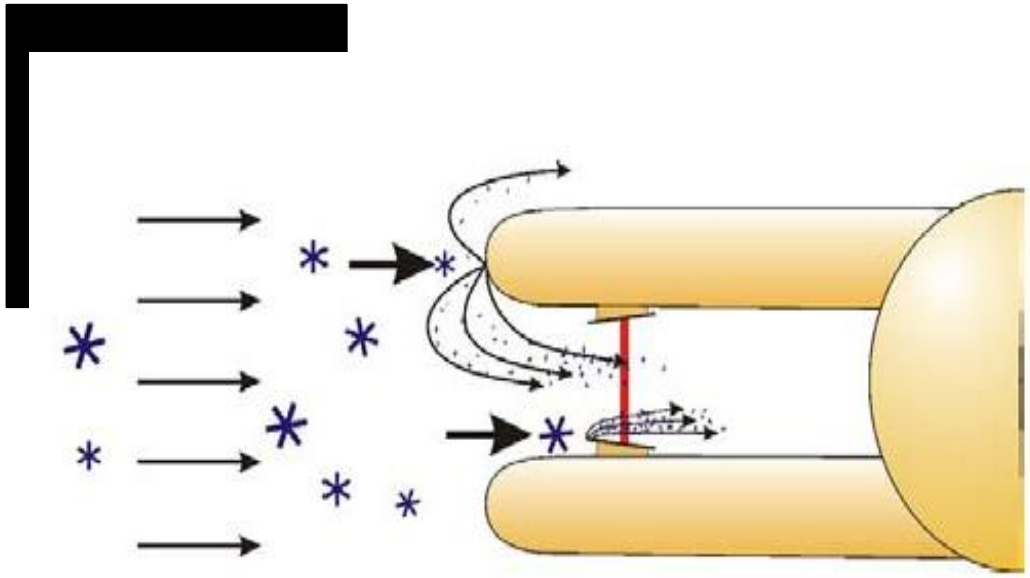
Houze et al. 1979

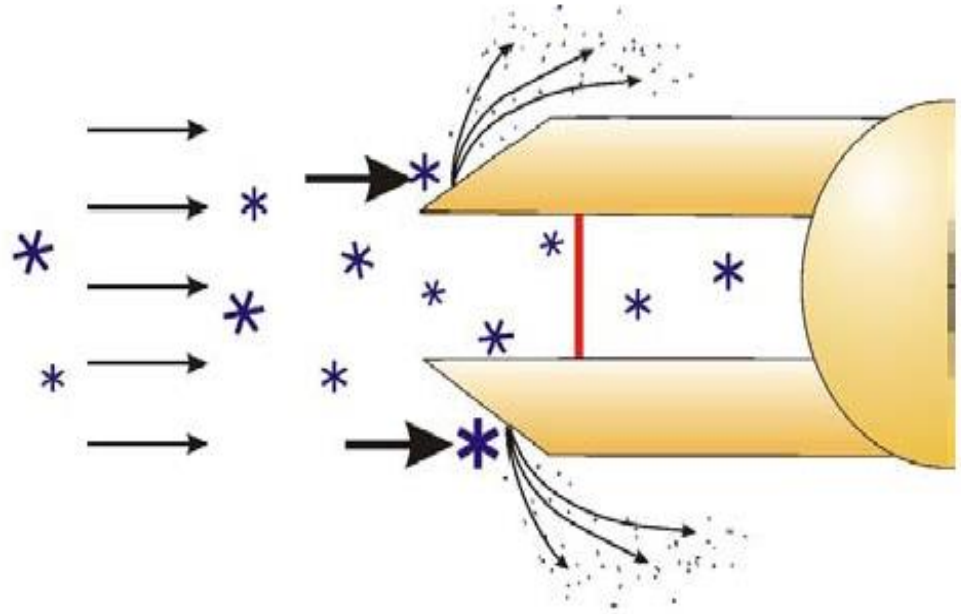


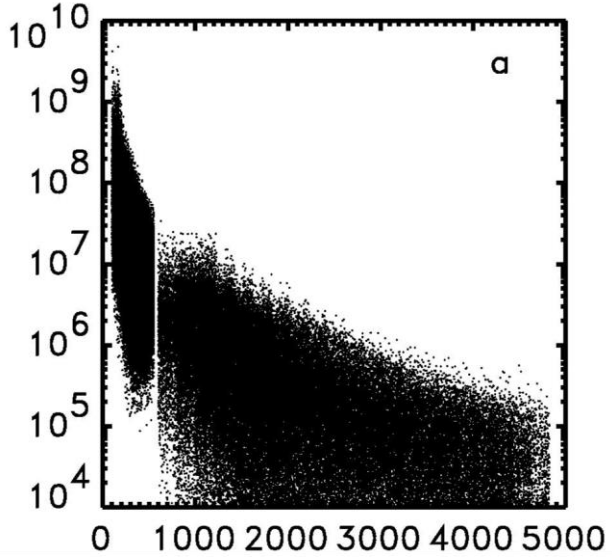
Aircraft projects:

Project	Location	Date	Cloud probes	Aircraft	Number of 10-s intervals
TRMM	9°N, 167°E	August–September 1999	2D-C/HVPS	UND Citation	4100
CRYSTAL-FACE	26°N, 81°W	July 2002	2D-C/HVPS	UND Citation	4600
FIRE	37°N, 96°W	November 1991	2D-C/2D-P	NCAR King Air	2700
ARM	37°N, 97°W	March 2000	2D-C/HVPS	UND Citation	2600

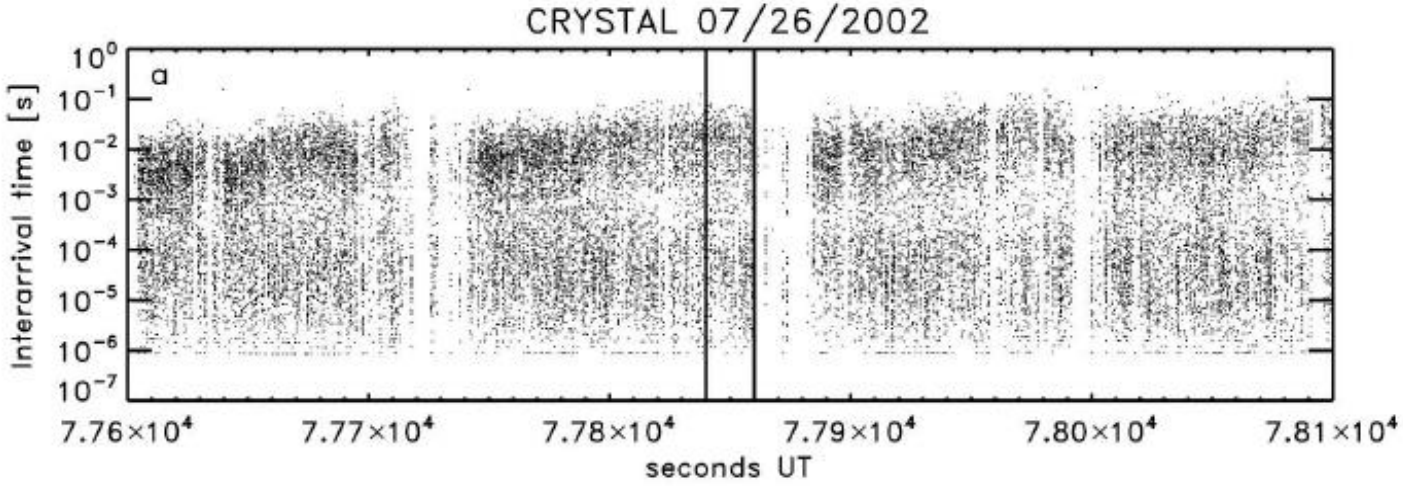

a
N(D) [m-4]
10^10
10^9
10^8
10^7
10^6
10^5
10^4
0
1000
2000
3000
4000
5000
D [μm]

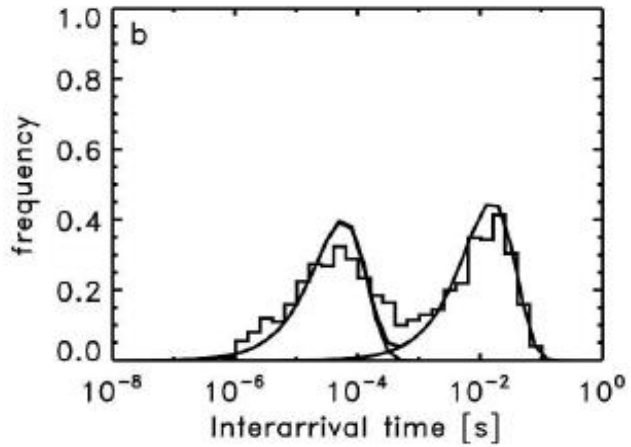


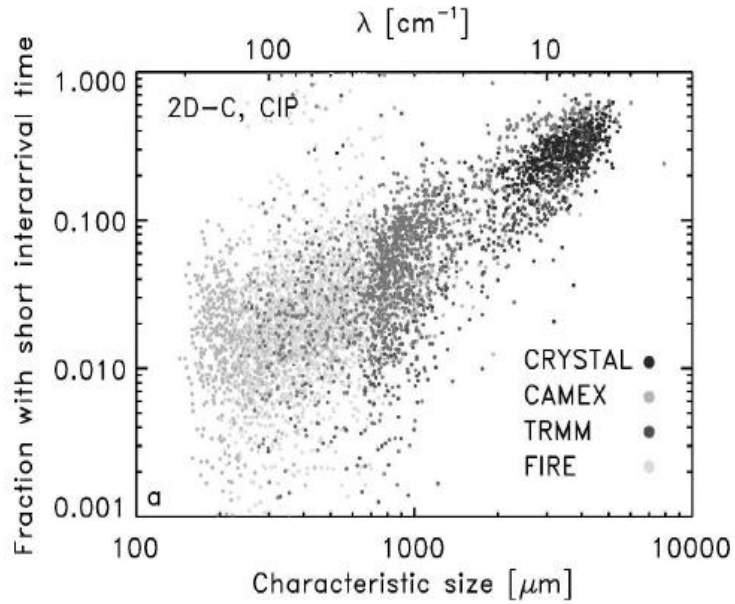


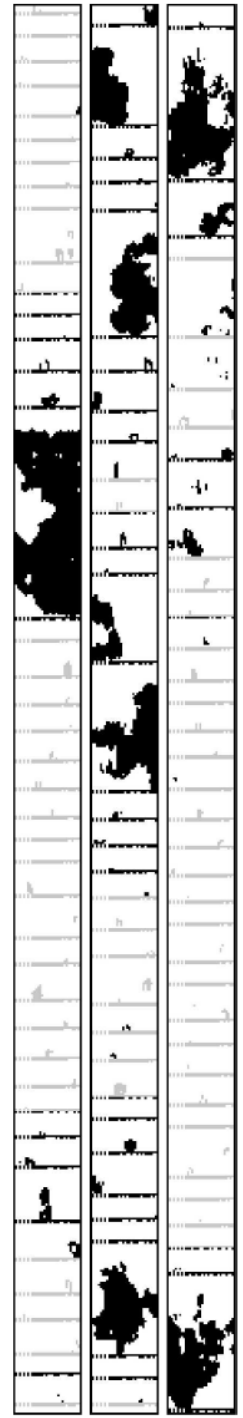


Korolev tips – from DMT site


CRYSTAL 07/26/2002
a
Interarrival time [s]
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
7.76×10^{4}
7.77×10^{4}
7.78×10^{4}
7.79×10^{4}
7.80×10^{4}
7.81×10^{4}
seconds UT


b
frequency
1.0
0.8
0.6
0.4
0.2
0.0
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
Interarrival time [s]


λ [cm^{-1}]
100
10
2D-C, CIP
a
Fraction with short interarrival time
1.000
0.100
0.010
0.001
CRYSTAL
CAMEX
TRMM
FIRE
100
1000
10000
Characteristic size [μm]



Rescaling particle size distributions

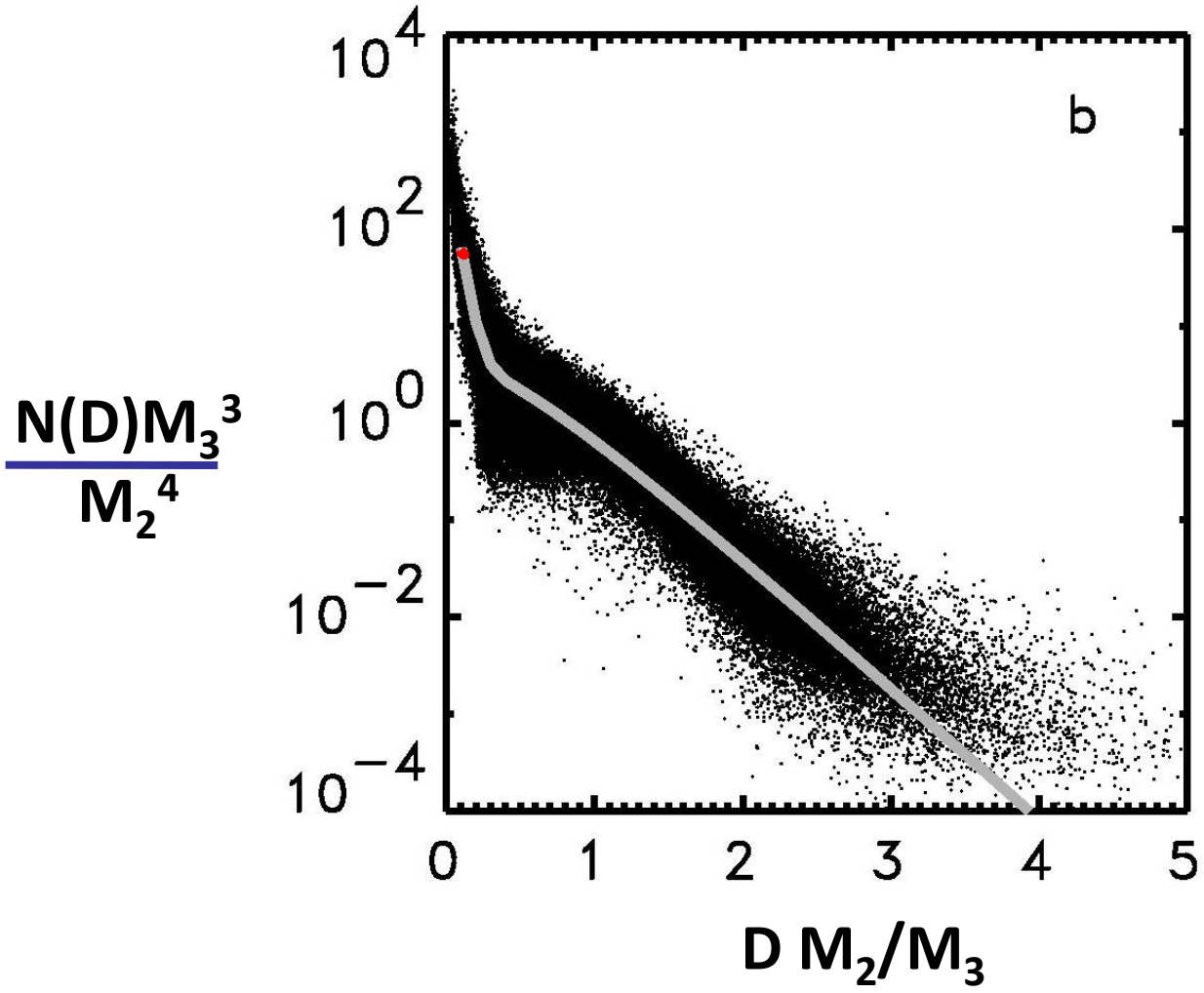
$$N(D)=M_2^4\, M_3^{-3}\psi_{23}(x)$$

Measured PSD

Rescaled Distribution

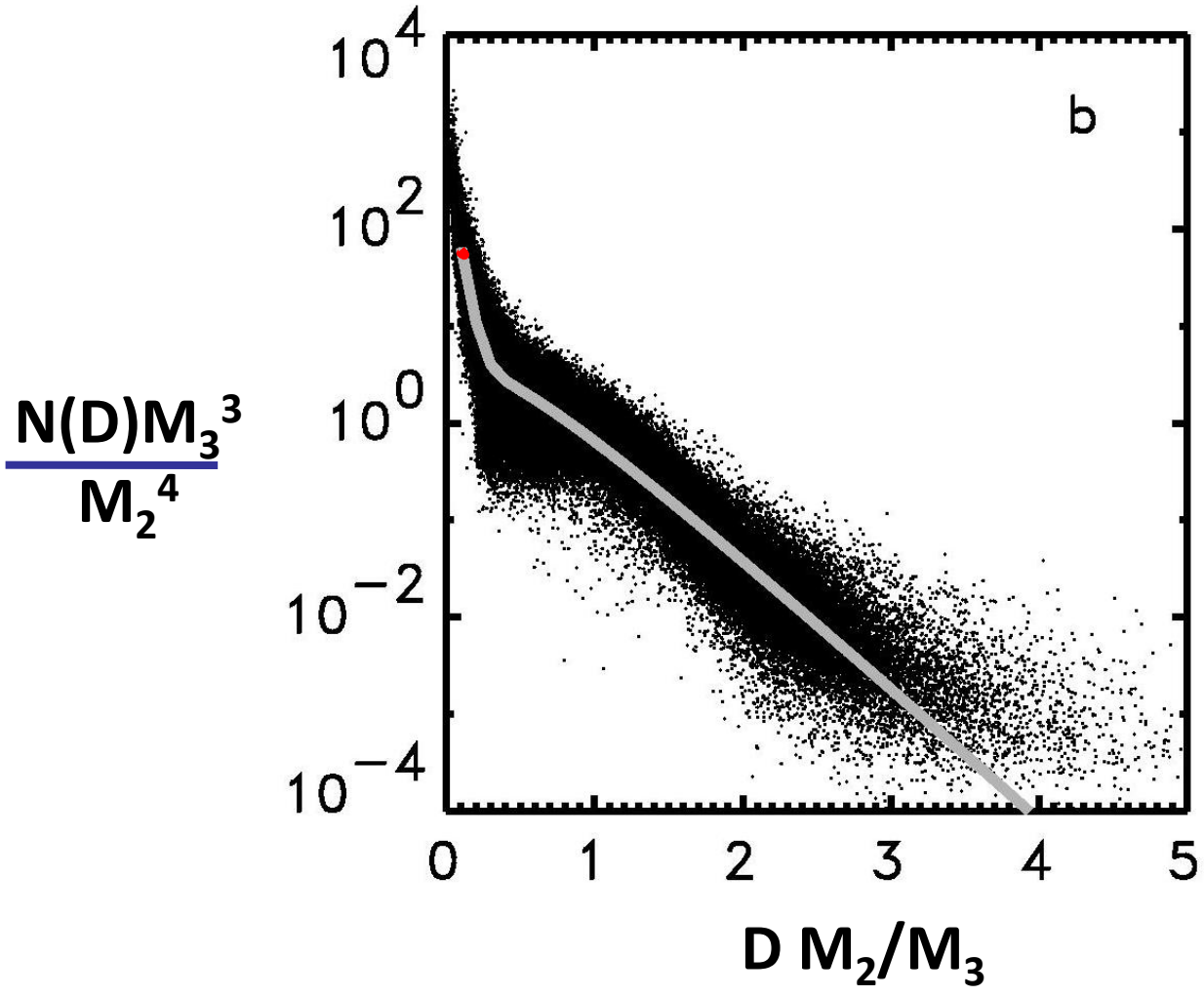
Dimensionless size $x=D\,(M_2/M_3)$

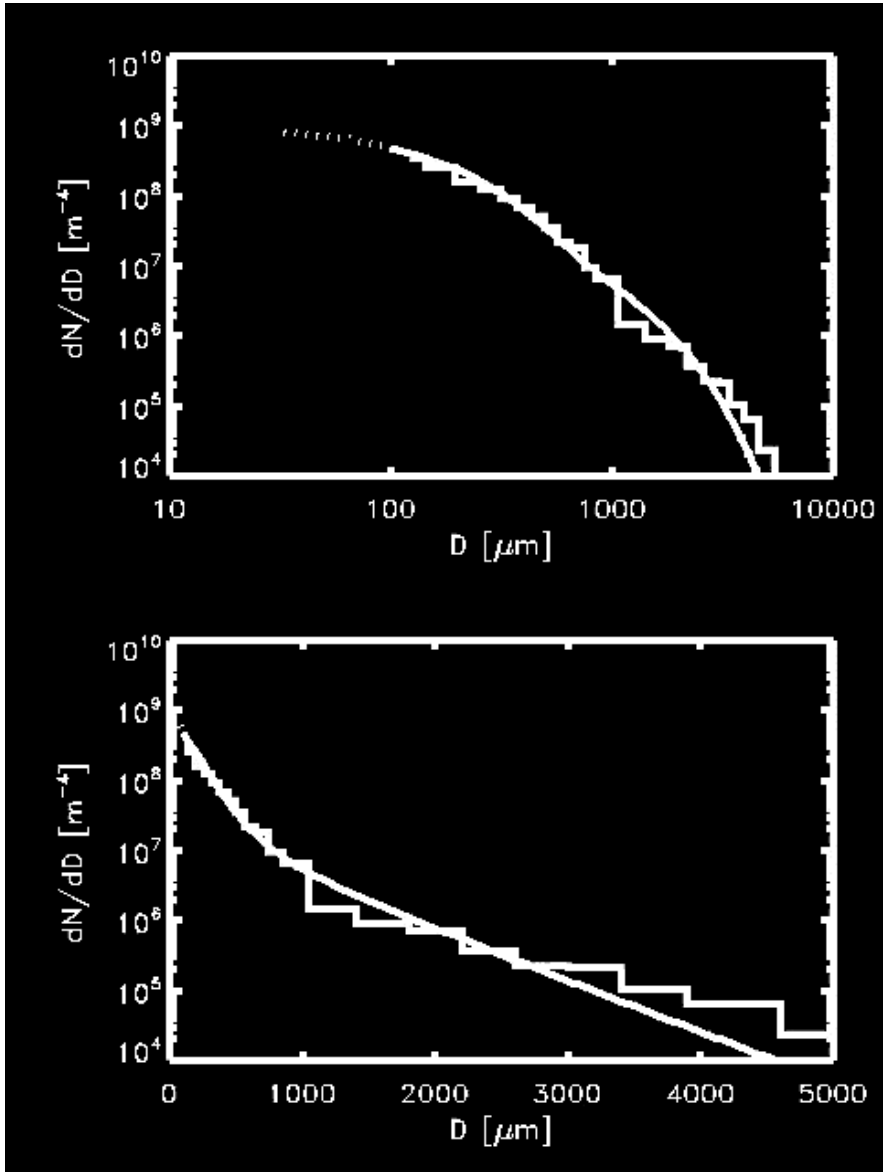
Sekhon+Srivastava 1971, Willis 1984, Sempere-Torres et al 1998, Testud et al. 2001, Lee et al. 2004 (Generalised framework) – raindrop dist re-scaling
Field+Heymsfield 2003, Westbrook et al. 2004ab, Delanoë et al. 2005, Field et al. 2005, 2007



Parametrize moments of distribution as function of IWC and T

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

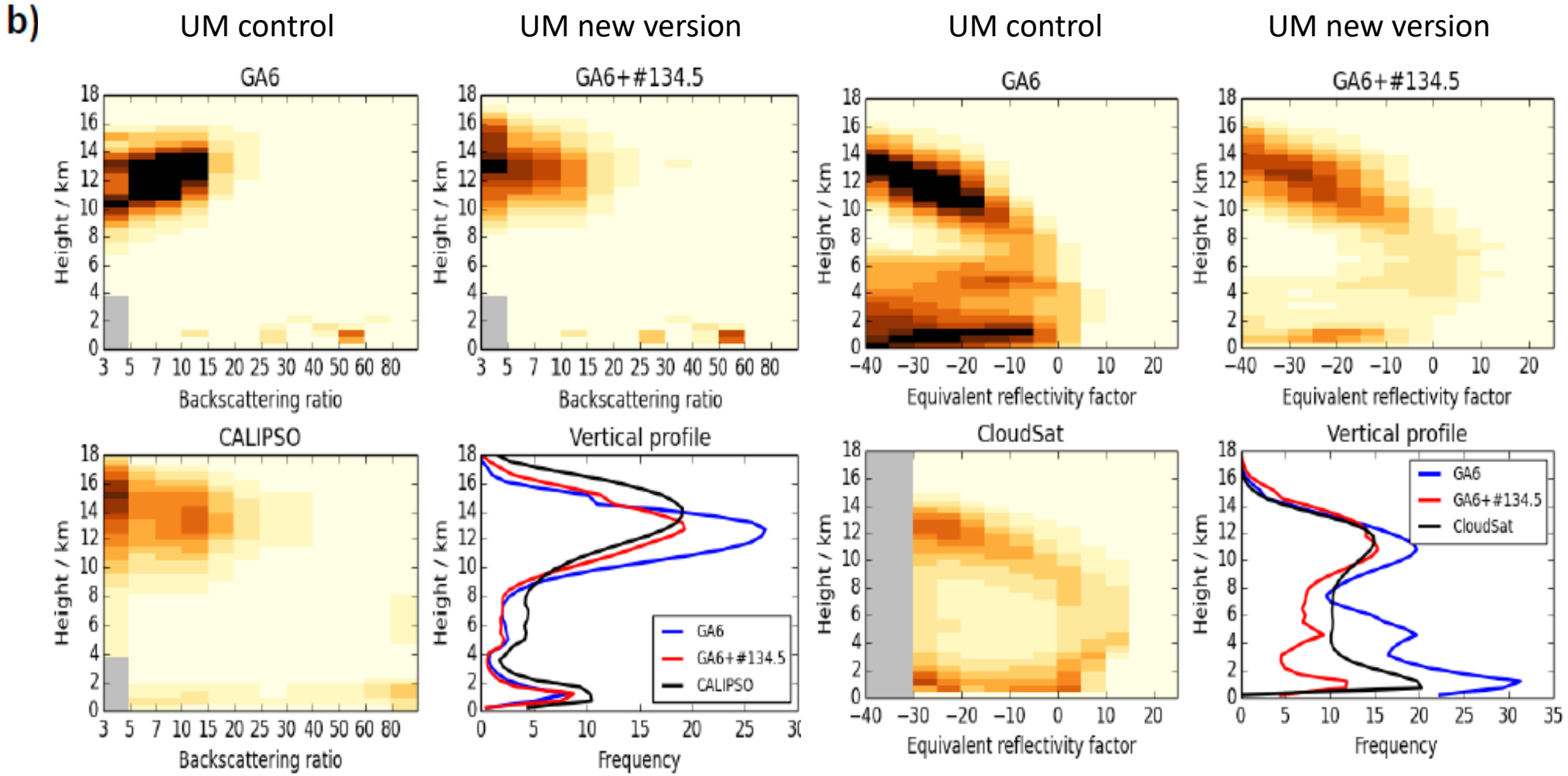




Parametrize moments of distribution as function of IWC and T

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

Improvements in cirrus cloud



Calipso comparison

Cloudsat comparison

Keith Williams et al.

Conclusions

- Examples of observations have been ‘pulled through’ to model and improve its performance
- Single flights/campaigns can highlight problems – multiple campaigns good for generalised parametrizations
- Obs are good for informing assumed size distributions (e.g. droplets, ice, aerosol)
- If individual processes can be isolated then important parameters can be backed out from observations (e.g. veg drag, capacitance)
- Healthy scepticism of observations…(e.g. artifacts and potential biases…)

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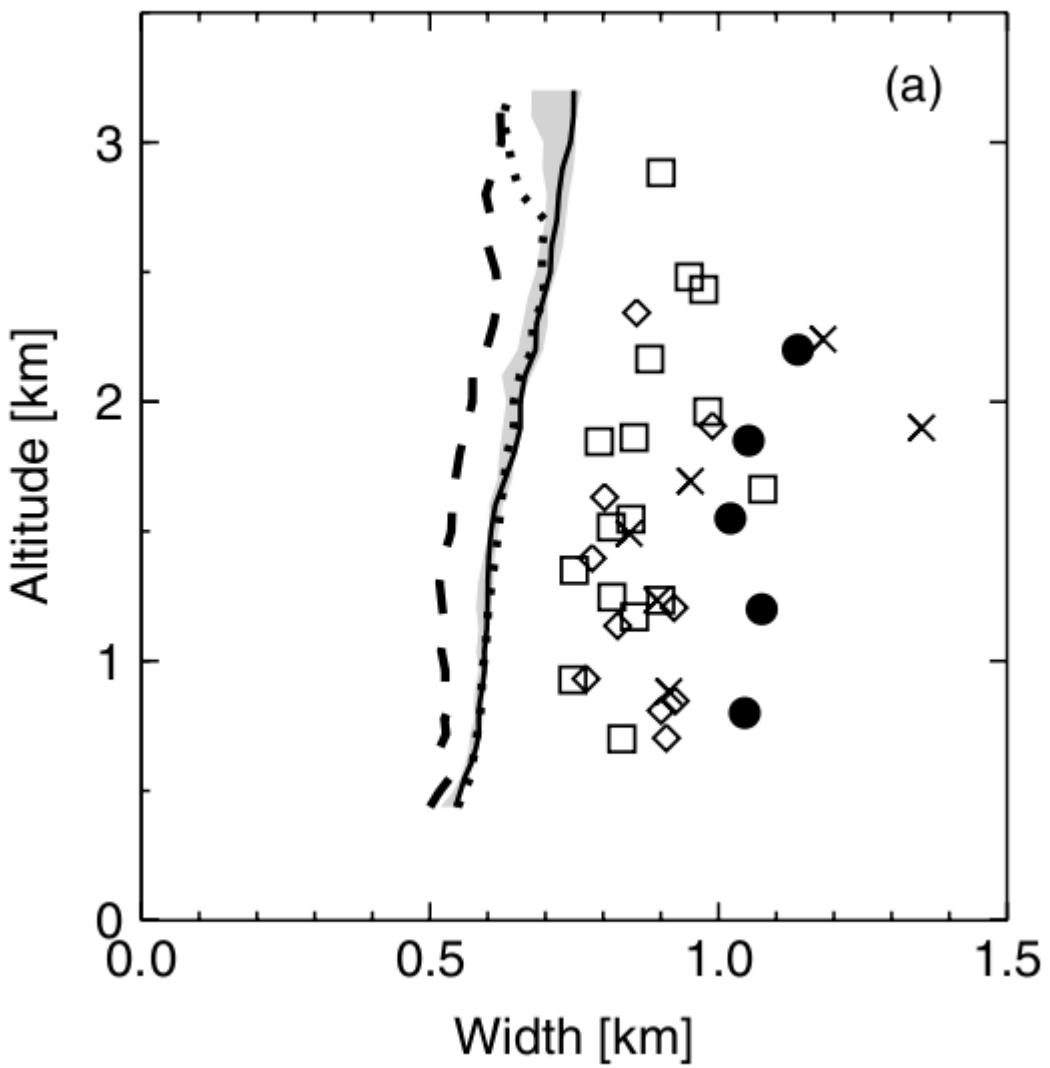

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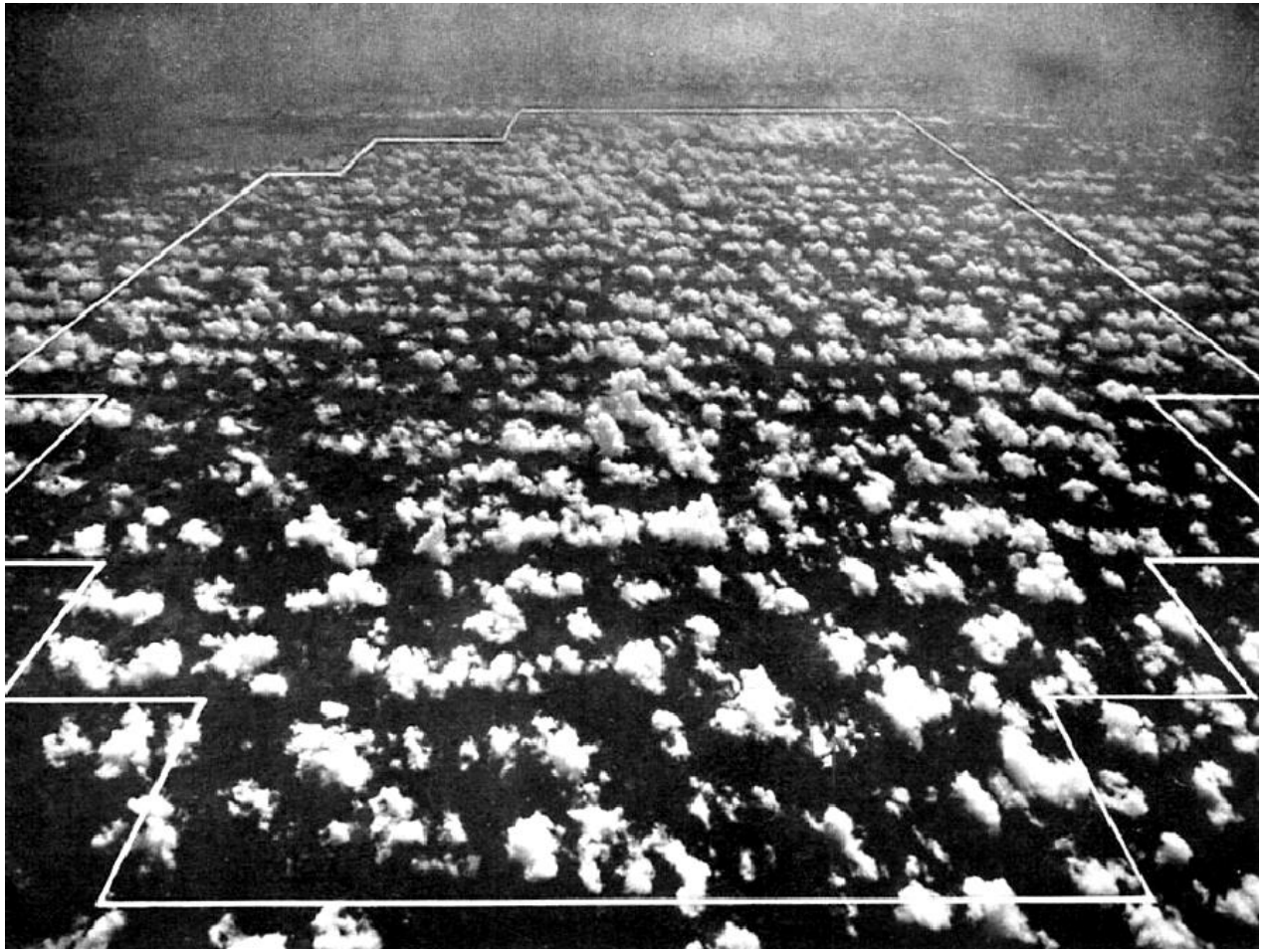
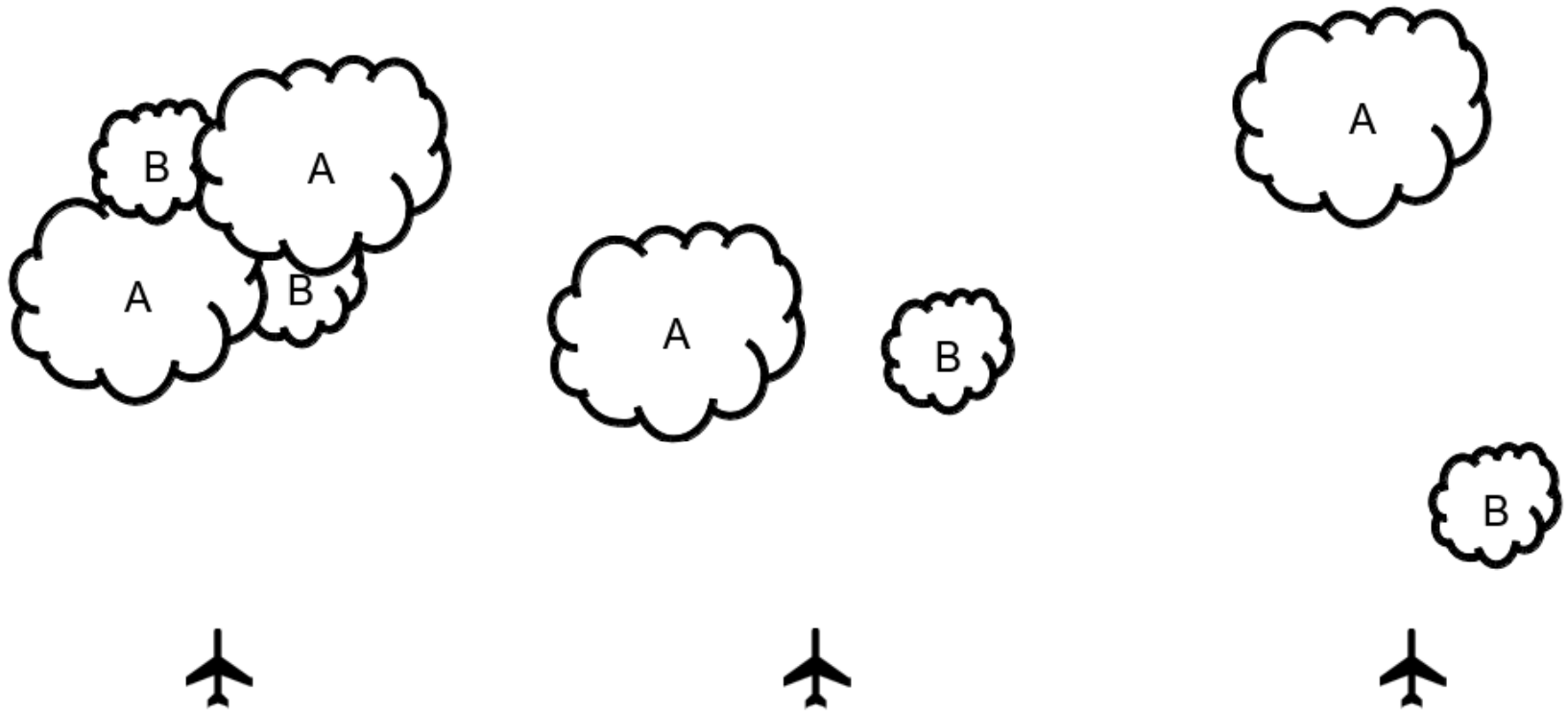
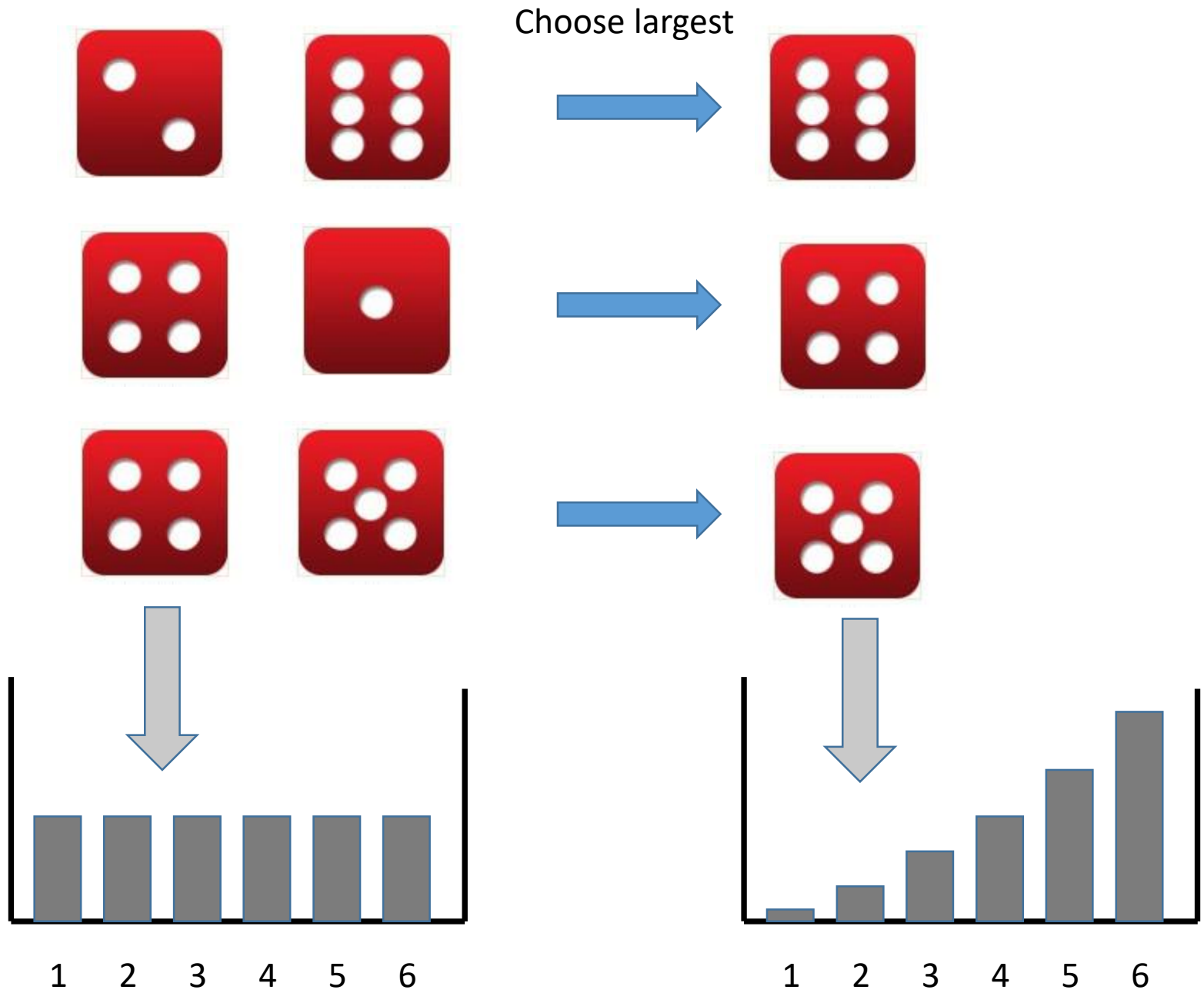
2000).





I II III


Choose largest
1 2 3 4 5 6
1 2 3 4 5 6

$$B = \max\{ \text{  } \}.$$

$$B = \max\{X_1, X_2, \ldots, X_n\}.$$

B is a random variable equal to the maximum of the independent identically distributed random variables X1, X2, Xn

$$P_{B2}(y) = P(X1=y)P(X2<y) + P(X2=y)P(X1<y) + P(X1=y)P(X2=y)$$

Probability of choosing a value *y* as the largest of the two random variables (*X1,X2*) = probability that *X1* is *y* AND *X2* is smaller than *y* + probability that *X2* is *y* AND *X1* is smaller than *y*. + probability that *X1* is *y* AND *X2* is *y*

$$B = \max\{ \text{  } \}.$$

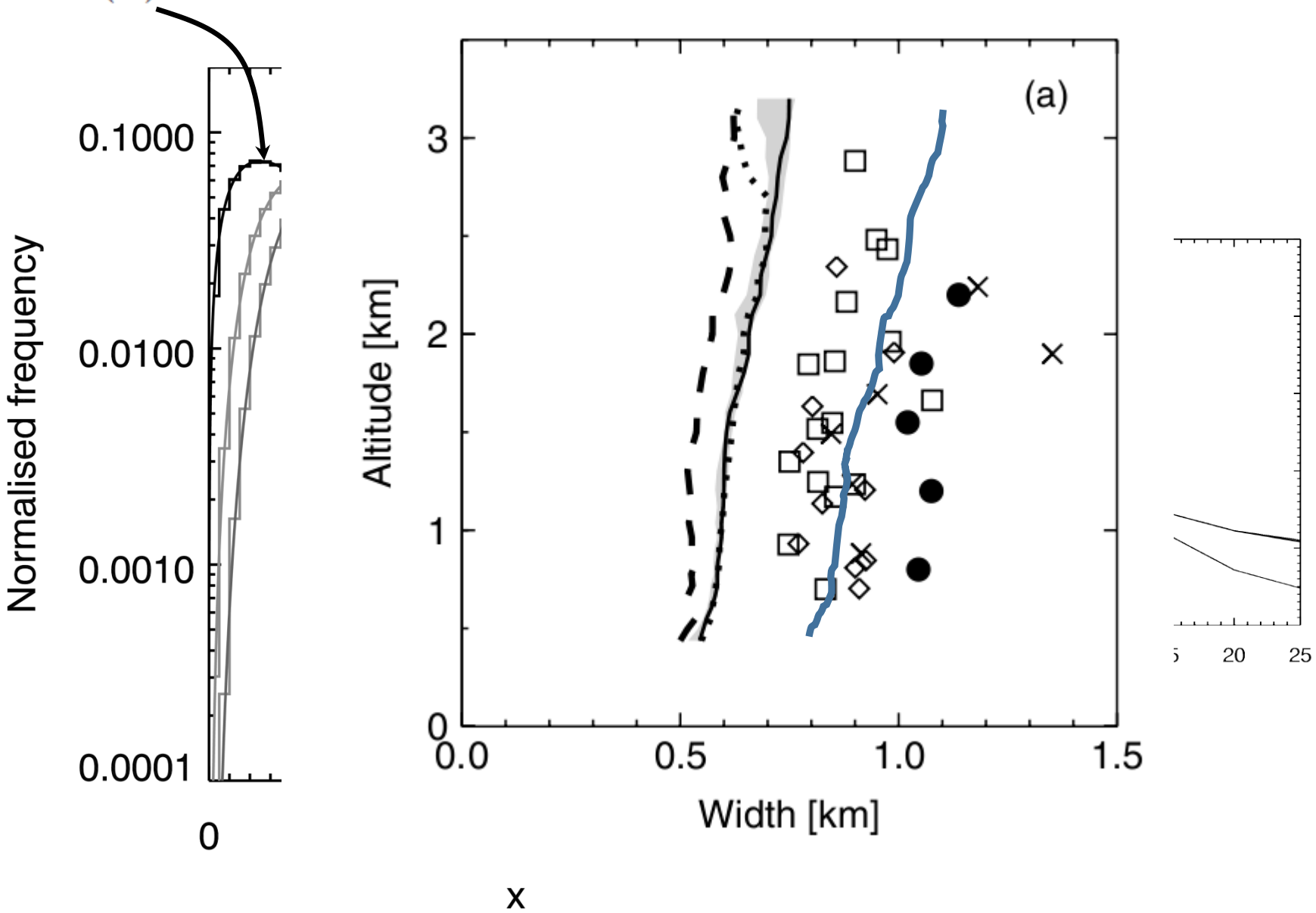
$$B = \max\{X_1, X_2, \ldots, X_n\}.$$

B is a random variable equal to the maximum of the independent identically distributed random variables X1, X2, Xn

$$P_{B_2}(y)\mathrm{d}y = P(X_1 \in [y, y+\mathrm{d}y])P(X_2 < y) + P(X_1 < y)P(X_2 \in [y, y+\mathrm{d}y])$$

Probability of choosing a value between *y* and *y*+d*y* as the largest of the two random variables (*X1,X2*) = probability that *X1* lies between *y* to *y*+d*y* AND *X2* is smaller than *y* + probability that *X2* is lies between *y* to *y*+d*y* and *X1* is smaller than *y*.

$$N(x) = ax^b exp(-cx)$$


Normalised frequency
0.1000
0.0100
0.0010
0.0001
0
x
Altitude [km]
0
1
2
3
0.0
0.5
1.0
1.5
Width [km]
(a)
20
25

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