Ice Cloud Microphysical properties retrieved from surface and aircraft during MC3E

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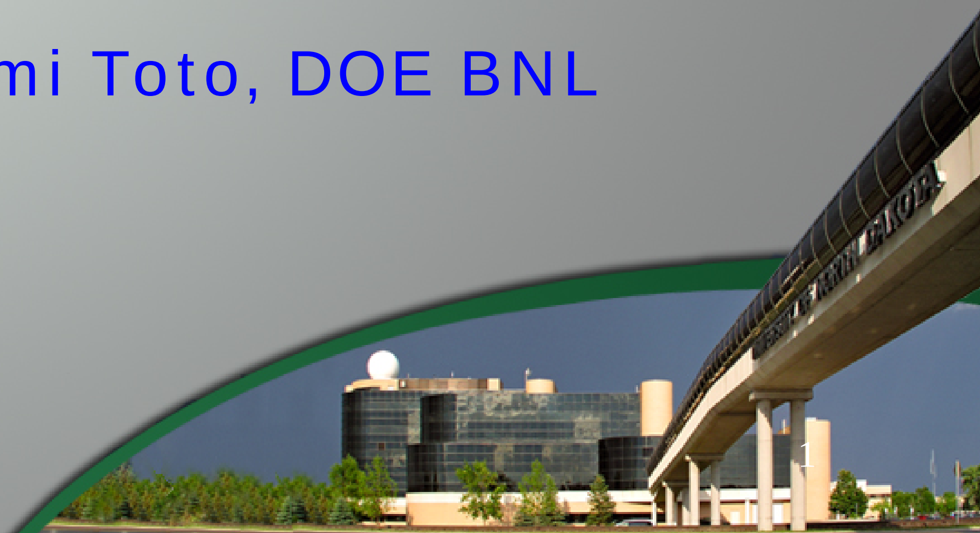
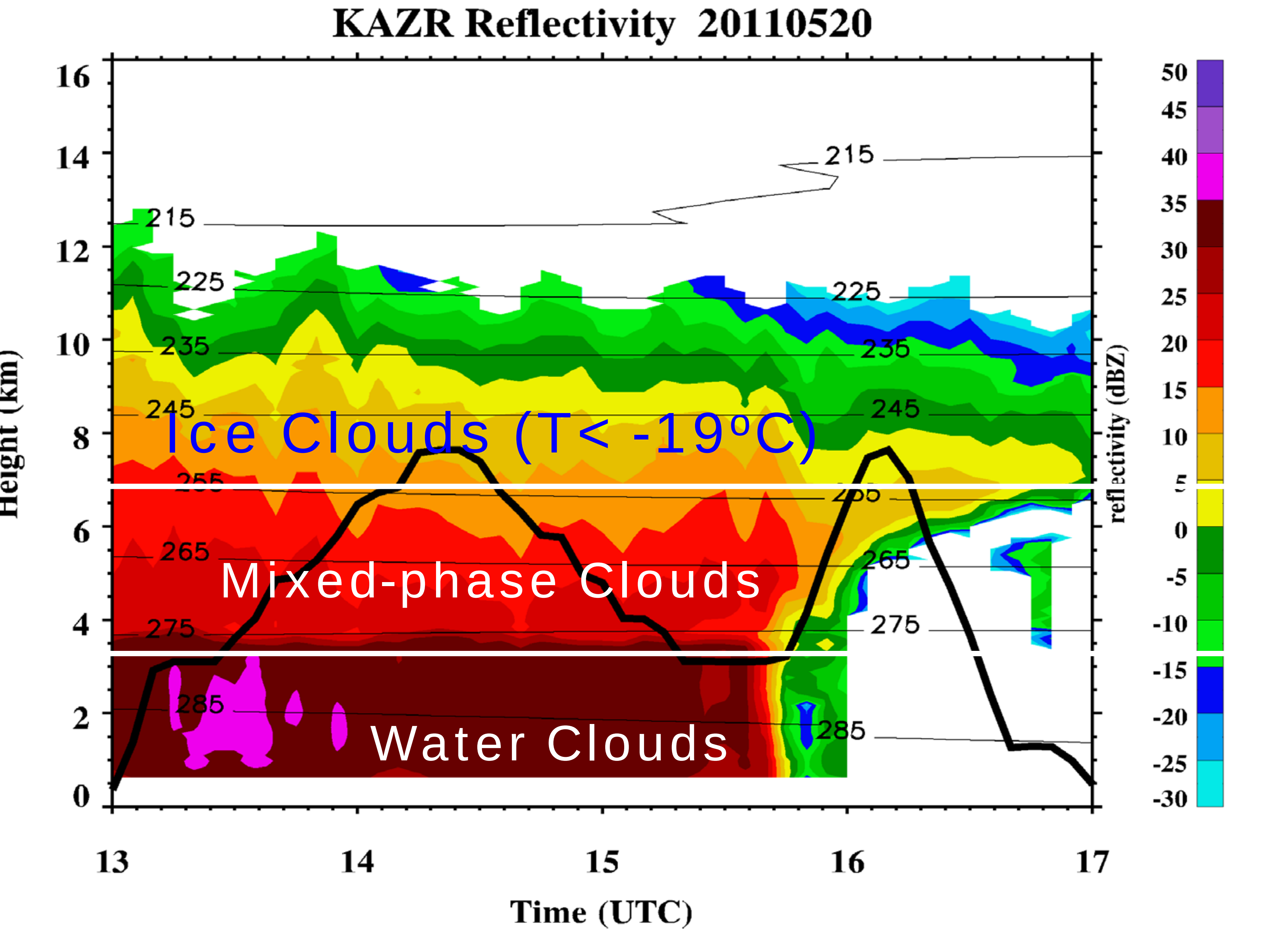
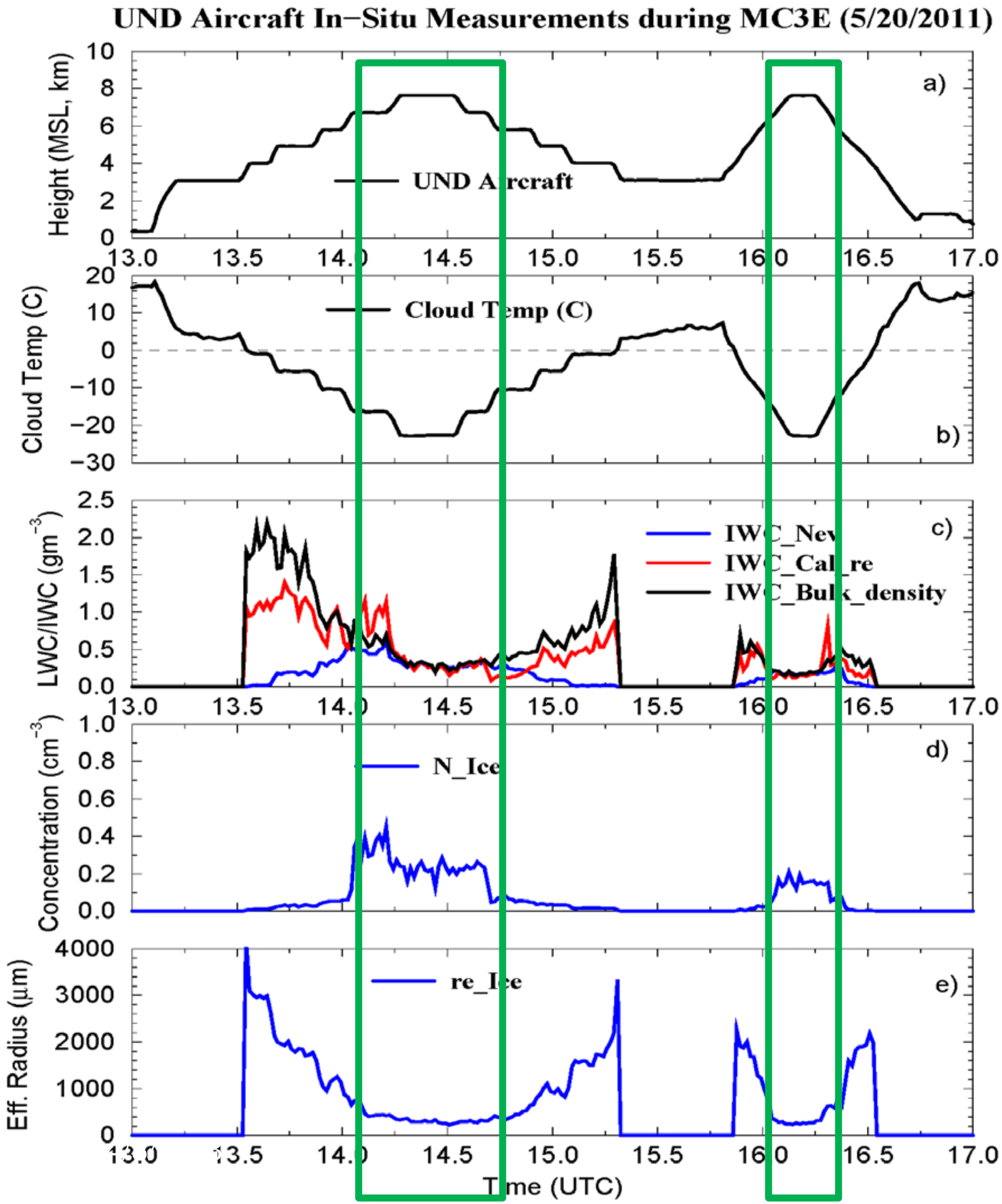



KAZR Reflectivity 20110520
Ice Clouds (T< -19°C)
Mixed-phase Clouds
Water Clouds
Height (km)
Time (UTC)
reflectivity (dBZ)
215
225
235
245
255
265
275
285
13
14
15
16
17
0
2
4
6
8
10
12
14
16
50
45
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30



➔There are 3 IWCs

a) Measured from Nevzorov. Accurate for re<800 um.

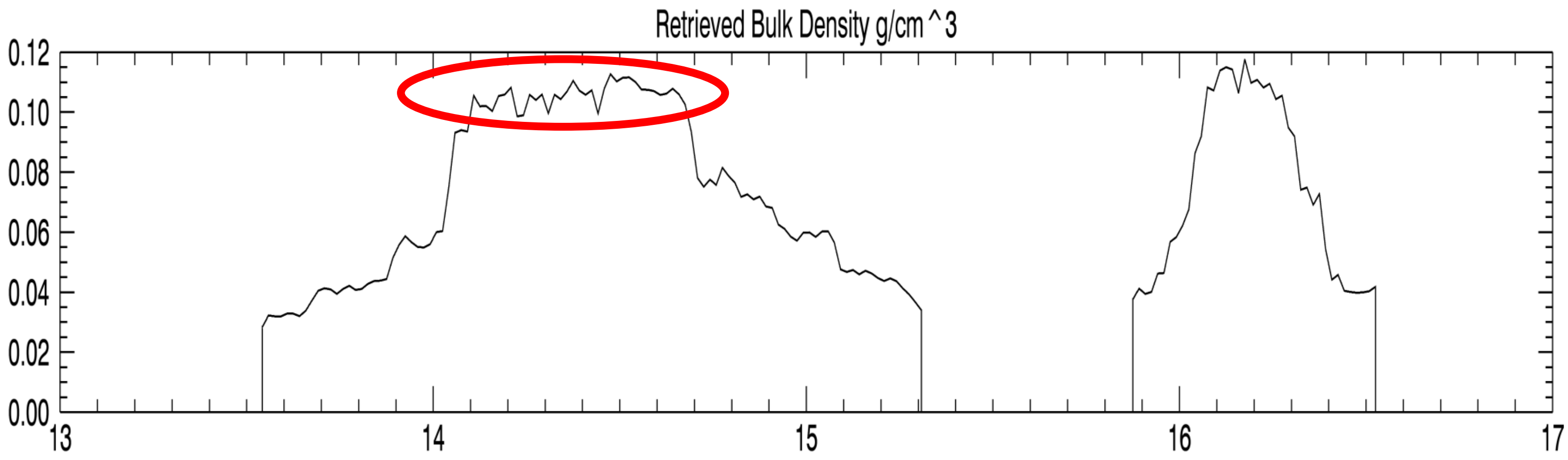
b) Calculate from re and N: IWC~a*De^b N

c) Calculate from bulk density: IWC~ $\boldsymbol{\rho}_i \sum \mathbf{D}^3 n$

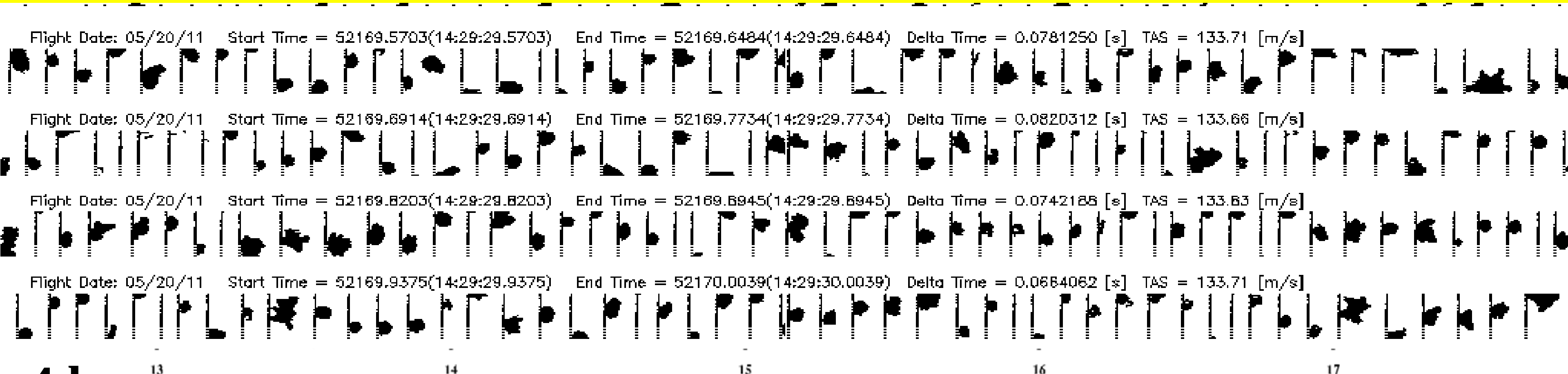
Three IWCs are almost the same at top, but Nev underestimated IWC toward to lower levels.

➔From a combination of CDP (1-50 um), 2DC (30-3,000 um), & HVPS (300-30,000 um), we can calculate ice particle re and N.

➔Re values are about 200-400 um at top, then increase to 4000 um at melting layer (~ 3 km).



Ice particle bulk density retrieved by mean volume diameter.



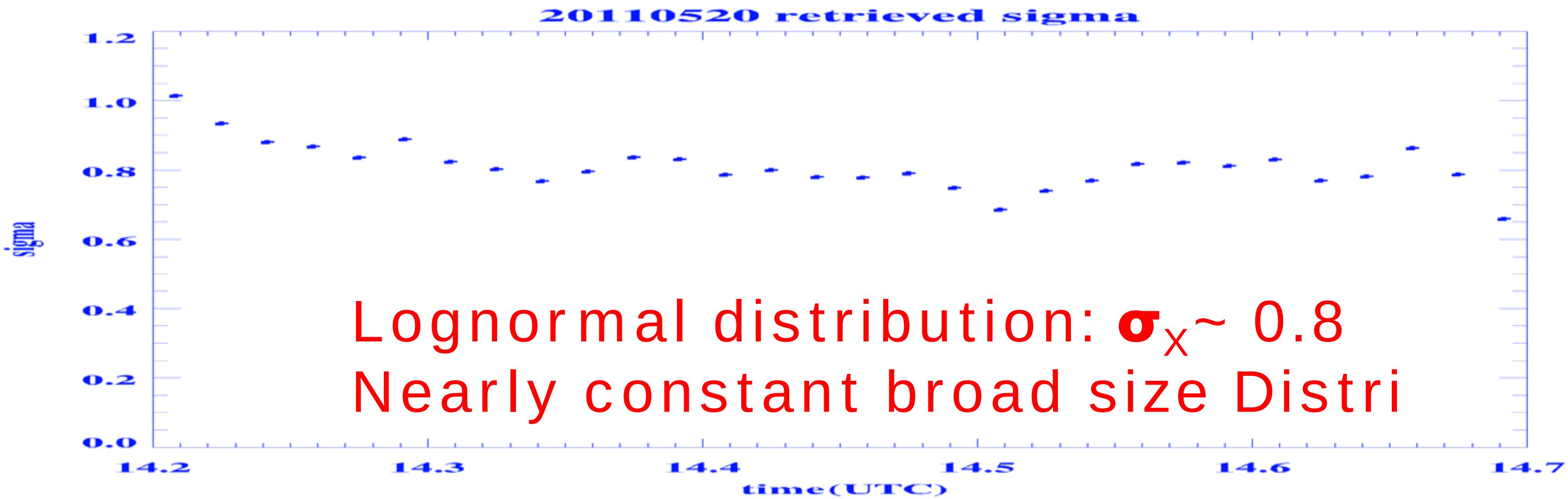
4 km

Applying basic V-r relationship for liquid droplets, the effective radii are 110 to 150 um.

For given fall speed and same water mass ($\rho_L * r_w^3 = \rho_i * r_i^3$),

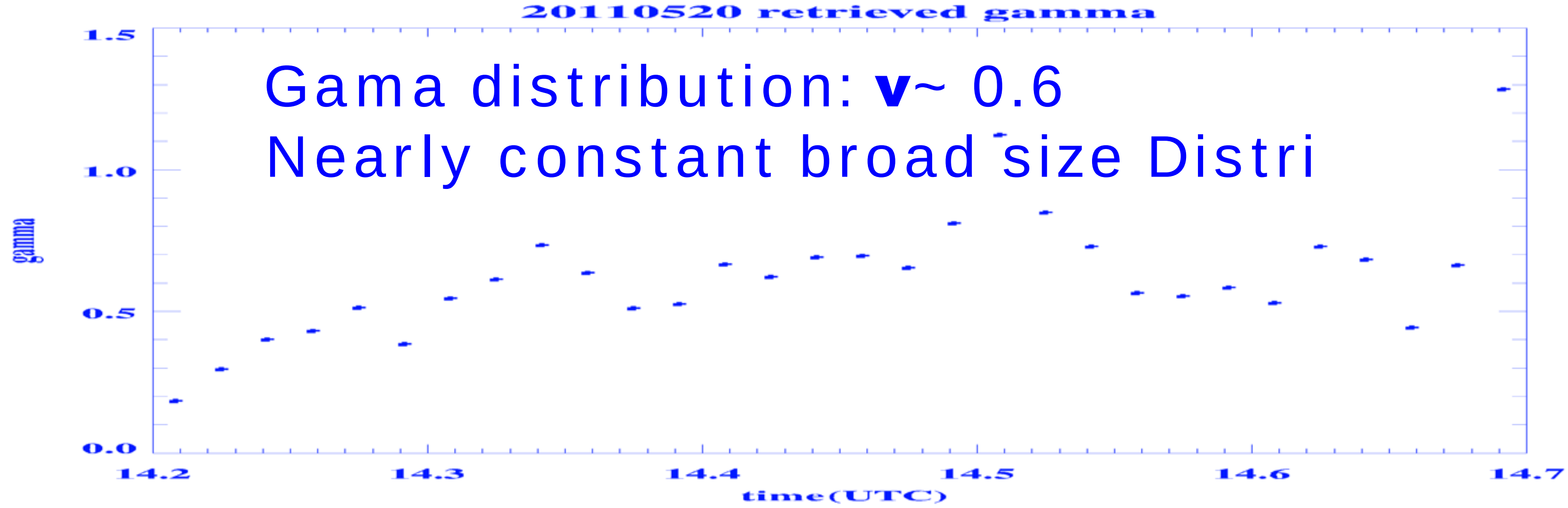
The re=110-150 um (for water droplets) will be equivalent to re=240-340 um for ice particles (ρ_i=0.1 gcm^{-3}), excellent agreement with aircraft in situ measurements.

Ice Particle Size Distributions (PSD) calculated from UND aircraft (5/20)



Lognormal distribution: $\boldsymbol{\sigma}_X$~ 0.8

Nearly constant broad size Distri



Gama distribution: $\boldsymbol{v}$~ 0.6

Nearly constant broad size Distri

Some Notes on Fall Speed Estimation

- **At present, apply only a cursory Z-based method to estimate 'ice / aggregate' classification fall speeds at altitude.**
- **Current behavior is similar to Hexogonal Column / Bullet Rosette curves (right, e.g., Protat and Williams 2011)**
- **Working towards improved methods that may capitalize on additional KAZR / UAZR moments, MicroARSCL inputs.**

The Accuracy of Radar Estimates of Ice Terminal Fall Speed from Vertically Pointing Doppler Radar Measurements

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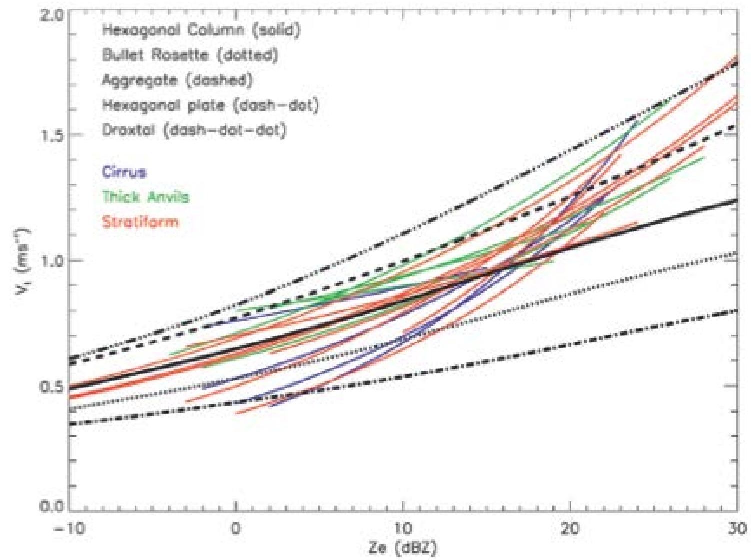


FIG. 5. The variability of the V_t–Z_e relationship in ice clouds. Color code is as in Fig. 3. Five relationships derived using typical particle habits (see text for details) are also given: hexagonal columns (solid), bullet rosettes (dotted), aggregates (dashed), hexagonal plates (dash–dotted), and droxtals (dash–dot–dot). The terminal fall speeds are referenced to ground level in this figure.

BACKUP

Cloud droplet terminal fall speed

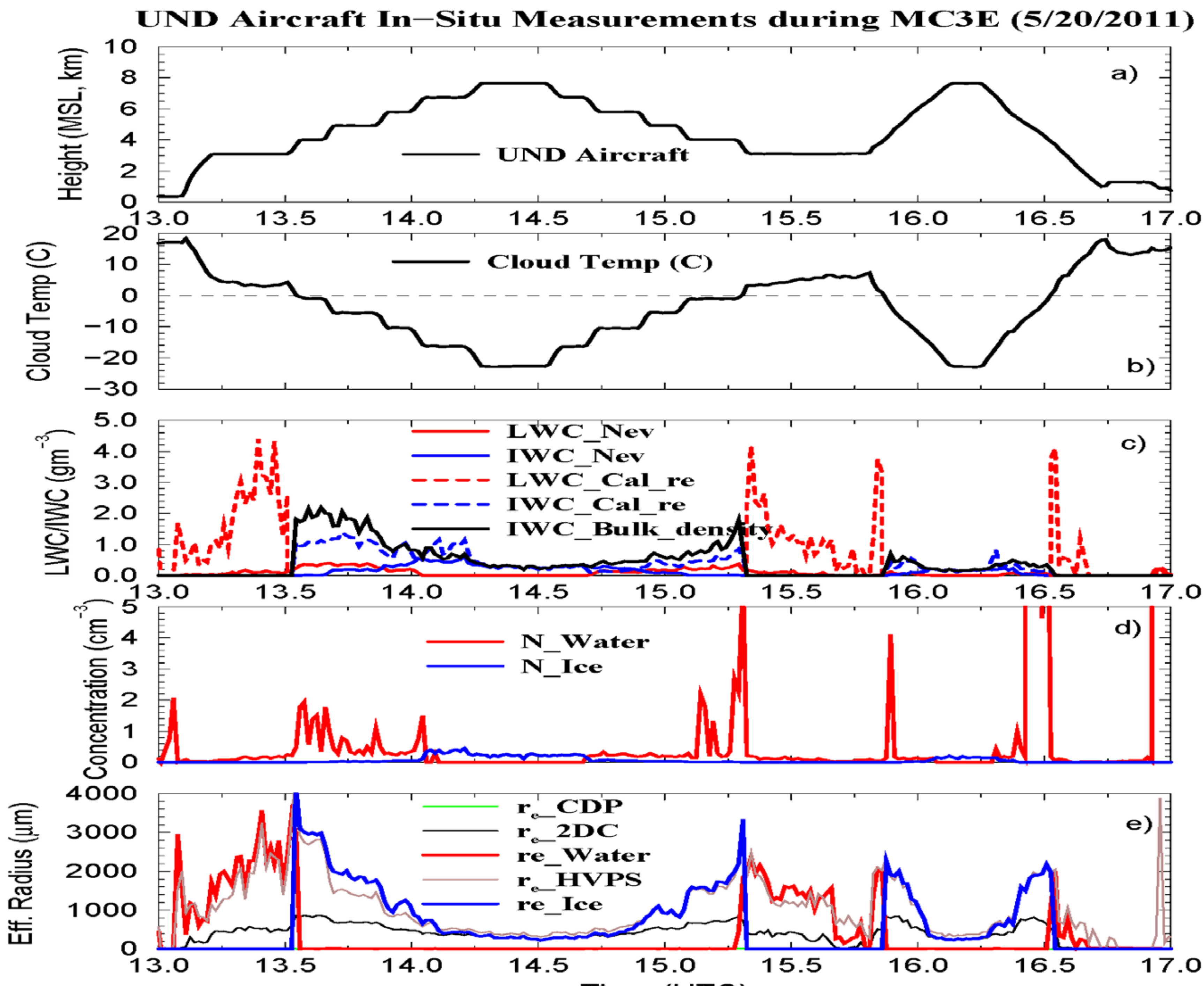
TABLE 8.1. *Terminal Fall Speed as a Function of Drop Size (equivalent spherical diameter) (From Gunn and Kinzer, 1949)*

Diam. (mm)	Fall speed (m/s)	Diam. (mm)	Fall speed (m/s)
0.1	0.27	2.6	7.57
0.2	0.72	2.8	7.82
0.3	1.17	3.0	8.06
0.4	1.62	3.2	8.26
0.5	2.06	3.4	8.44
0.6	2.47	3.6	8.60
0.7	2.87	3.8	8.72
0.8	3.27	4.0	8.83
0.9	3.67	4.2	8.92
1.0	4.03	4.4	8.98
1.2	4.64	4.6	9.03
1.4	5.17	4.8	9.07
1.6	5.65	5.0	9.09
1.8	6.09	5.2	9.12
2.0	6.49	5.4	9.14
2.2	6.90	5.6	9.16
2.4	7.27	5.8	9.17

1) 0< r<40 um, $V_f=K_1r^2$, Stokes' law, $K_1=1.19*10^6$ cm^{-1} S^{-1}

2) 40<r<0.6 mm, $V_f=K_2r$, linear law, K2=$8*10^3$ S^{-1}

3) 0.6<r<2 mm, $V_f=K_3r^{1/2}$, Square root law, $K_3=2.2*10^3$ $(\rho/\rho0)^{1/2}$ cm^{-1} S^{-1}. ρ is air density, ρ0 is a reference density of 1.2 kg/m3. (Rogers and Yau book, P124-126)



UND Aircraft In−Situ Measurements during MC3E (5/20/2011)
Height (MSL, km)
UND Aircraft
a)
Cloud Temp (C)
Cloud Temp (C)
b)
LWC/IWC (gm^-3)
LWC_Nev
IWC_Nev
LWC_Cal_re
IWC_Cal_re
IWC_Bulk_density
c)
Concentration (cm^-3)
N_Water
N_Ice
d)
Eff. Radius (μm)
re_CDP
re_2DC
re_Water
re_HVPS
re_Ice
e)