BUILDING THE GV COLUMN: PHYSICAL VALIDATION OF GPM ALGORITHMS

Steve Nesbitt, K. Gleicher, G. Duffy, G. McFarquhar
University of Illinois

With contributions from

V. Chandrasekar, D. Hudak, W. Petersen, A. Bansemer, A. Heymsfield, A. Neumann, M. Poellot, S. Tanelli, C. Williams

Building on TRMM's legacy…

Rain-Profiling Algorithm for the TRMM Precipitation Radar

Toshio Iguchi
Global Environment Division, Communications Research Laboratory, Koganei, Tokyo, Japan

Toshiaki Kozu
Department of Electronic and Control Systems Engineering, Shimane University, Matsue, Japan

Robert Meneghini
NASA Goddard Space Flight Center, Greenbelt, Maryland

Jun Awaka
Department of Information Science, Hokkaido Tokai University, Sapporo, Japan

Ken'ichi Okamoto
Department of Aerospace Engineering, Osaka Prefecture University, Sakai, Japan

(Manuscript received 24 October 1999, in final form 28 April 2000)

"We assume that μ is constant and takes a value of $\mu = 3$."
"The coefficients in the *k–Ze* and *Ze–R* relations are calculated for snow–water mixtures with fractional water contents of 17%, 1.7%, and 1.1%..."

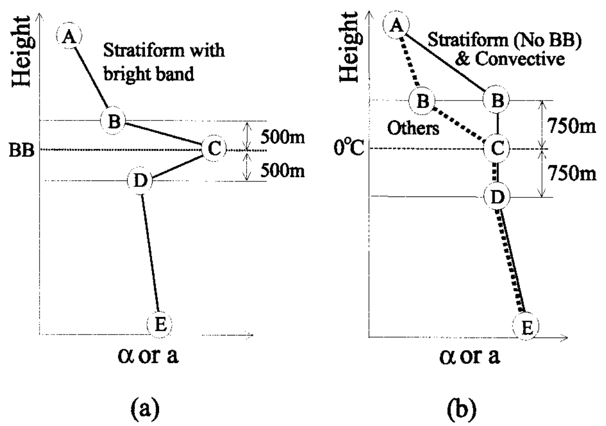
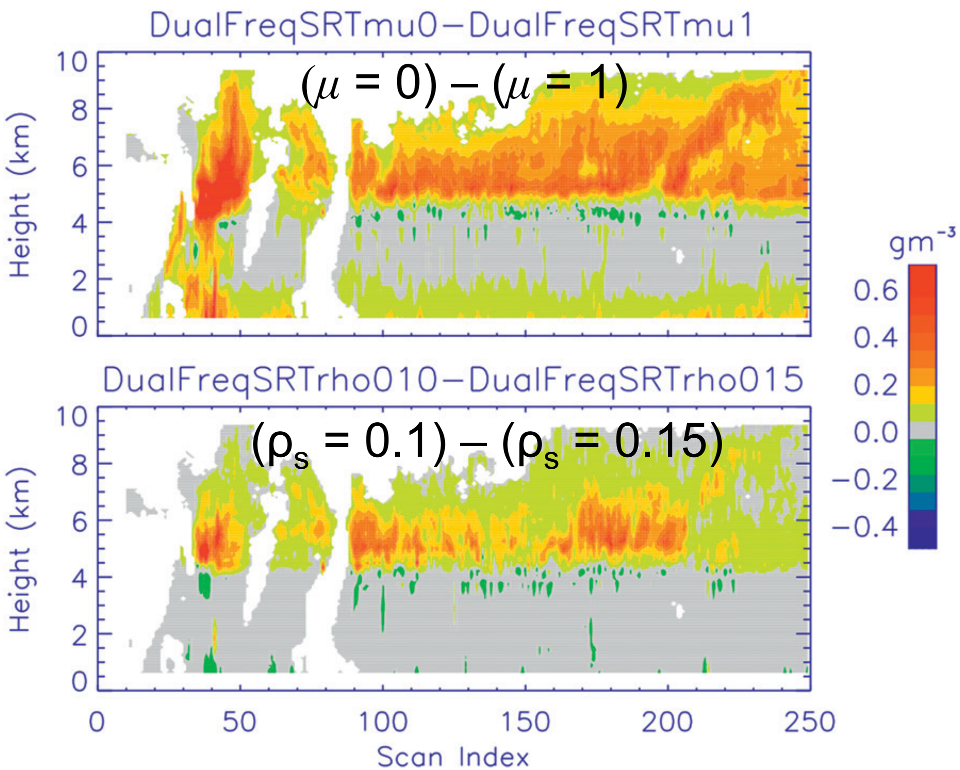


FIG. 4. Schematic presentation of the profiles of α and a. The initial values of a, b, and α are given at five points, A, B, C, D, and E. When a bright band is detected (a), C is chosen at the brightband (BB) center, B is two range bins above C, D is two range bins below C, A is the top of the echo, and E is the lowest valid range bin. If there is no bright band (b), C is chosen at the estimated freezing height, and B and D are 750 m above and below C, respectively. Here A and E are the same as before. Coefficients between these points are calculated by interpolation. Note that the profile for stratiform rain without a bright band is similar to that for convective rain, but their actual values are different.

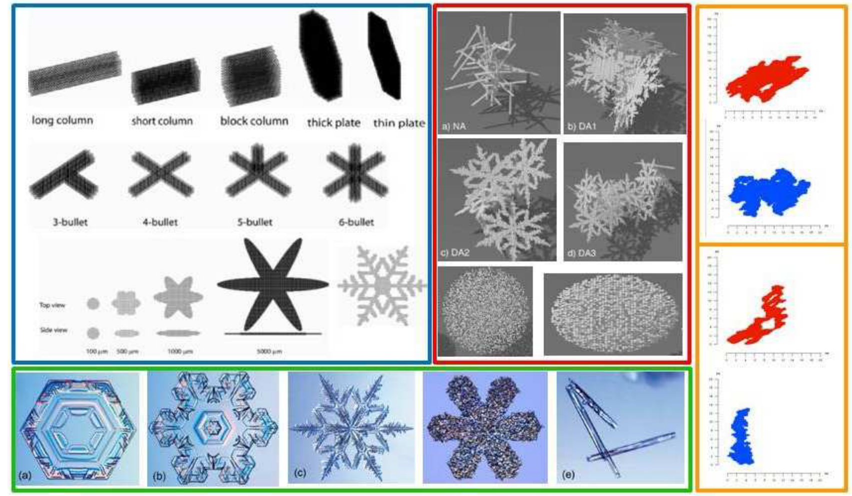
TABLE 1. Initial k–Z_e and Z_e–R parameters ($k = \alpha Z_e^{\beta}$, $R = aZ_e^{b}$, $Z_e = a''R^{b''}$).

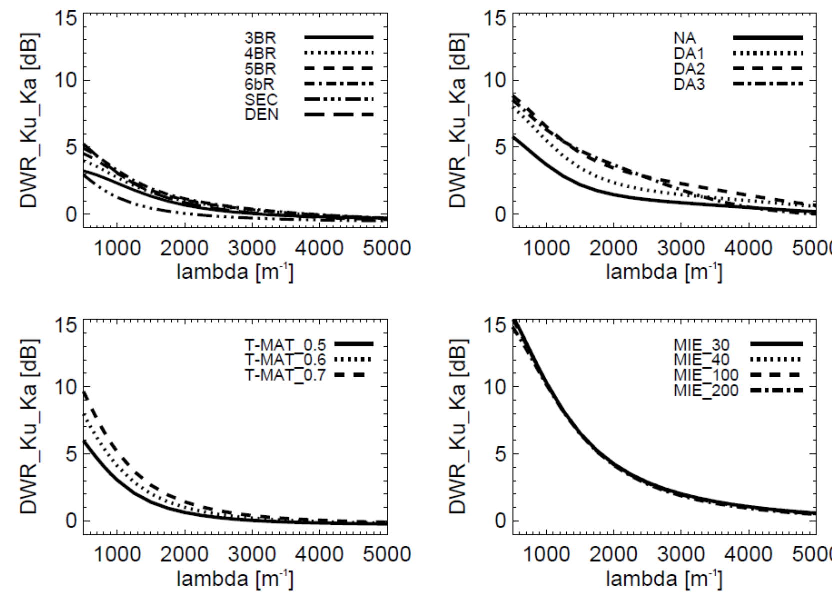
Parameter		Position shown in Fig. 4				
		A	B	C	D (0°C water)	20°C water
Stratiform	α	0.000 086 1	0.000 108 4	0.000 414 2	0.000 282 2	0.000 285 1
	β	0.792 30	0.792 30	0.792 30	0.792 30	0.792 30
	a	0.013 98	0.012 63	0.004 521	0.020 10	0.022 82
	b	0.7729	0.7644	0.7288	0.6917	0.6727
	a''	250.8	304.6	1649.3	283.9	275.7
	b''	1.294	1.308	1.372	1.446	1.487
Convective	α	0.000 127 3	0.000 410 9	0.000 410 9	0.000 410 9	0.000 417 2
	β	0.7713	0.7713	0.7713	0.7713	0.7713
	a	0.020 27	0.034 84	0.034 84	0.034 84	0.040 24
	b	0.7556	0.6619	0.6619	0.6619	0.6434
	a''	174.1	159.5	159.5	159.5	147.5
	b''	1.323	1.511	1.511	1.511	1.554
Others	α	0.000 127 3	0.000 159 8	0.000 410 9	0.000 410 9	0.000 417 2
	β	0.7713	0.7713	0.7713	0.7713	0.7713
	a	0.020 27	0.018 71	0.034 84	0.034 84	0.040 24
	b	0.7556	0.7458	0.6619	0.6619	0.6434
	a''	174.1	207.4	159.5	159.5	147.5
	b''	1.323	1.341	1.511	1.511	1.554

The particle details matter…

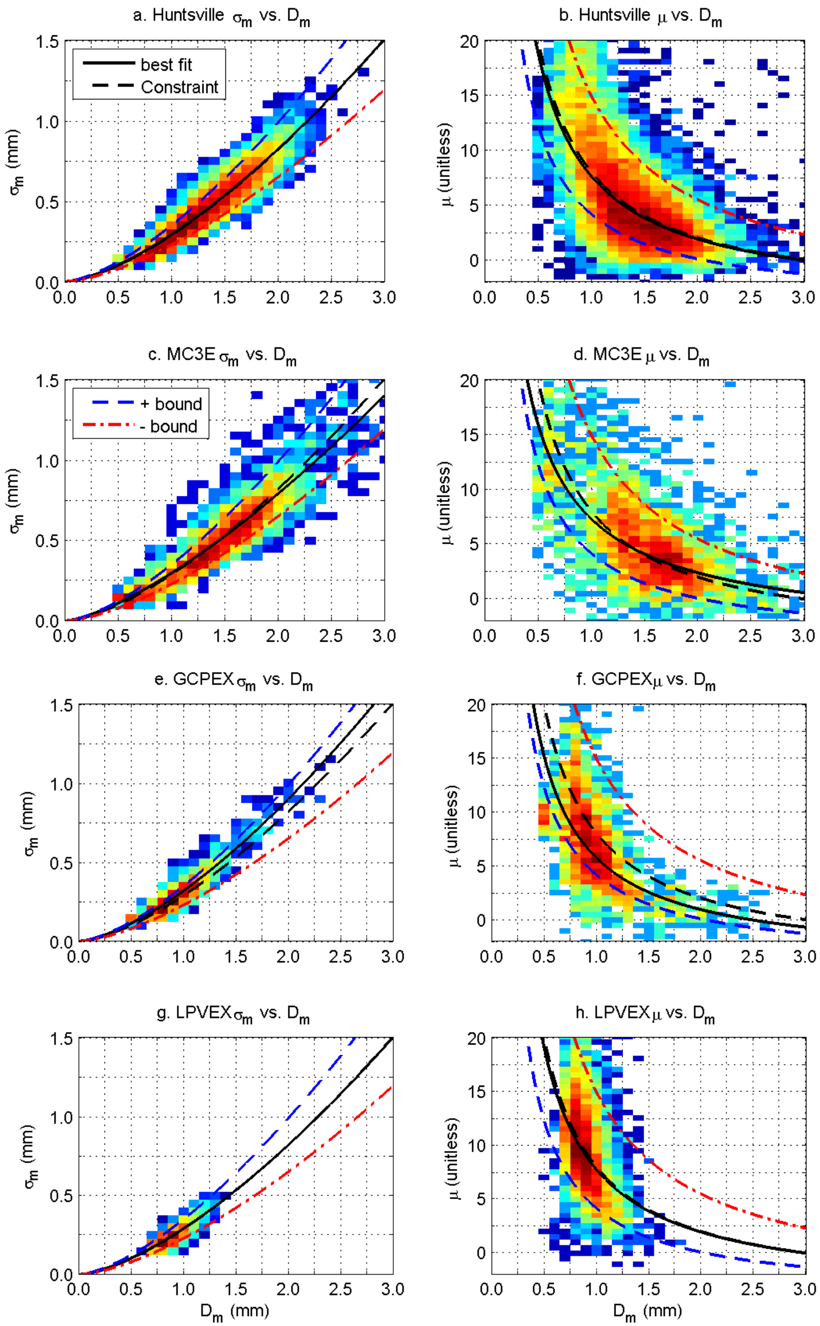


Grecu et al. (2011)
Johnson et al. (2013)





Liu 2008, Petty and Huang (2010), Libbrecht (2005), Kneifel (2011)



Results from the surface DSD WG are encouraging (Williams et al, submitted to JAMC)

Do these results extend up the column into the melting layer, mixed phase, and snow?

GPM Wine Cellar

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$

$$\sigma_m^2 = \frac{\sum_{D_{\min}}^{D_{\max}} (D - D_m)^2 D^{\mu+3} \exp(-\Lambda D)\, dD}{\sum_{D_{\min}}^{D_{\max}} D^{\mu+3} \exp(-\Lambda D)\, dD}$$

$$\sigma_m^2 = \frac{D_m^2}{4+\mu}$$

Actions: GPM-GV Column sub-WG

- Goal: derive unbiased assumptions for parameters such as hydrometeor habit, density, PSD properties, cloud liquid water with uncertainties to constrain algorithm assumptions and scattering and absorption models for GPM algorithms (passive and active frequencies)

- Needs
  - Careful side-by-side analysis of column and surface data that has been and will be collected
  - Understanding of scattering properties of ice, melting particles, selection of appropriate models
  - Retrieval algorithms for ice and mixed phase hydrometeors
  - Vetted cloud-resolving model hydrometeor profiles
  - Relationships between these quantities and “environment” or “regime”
  - Propagation of uncertainties among these quantities

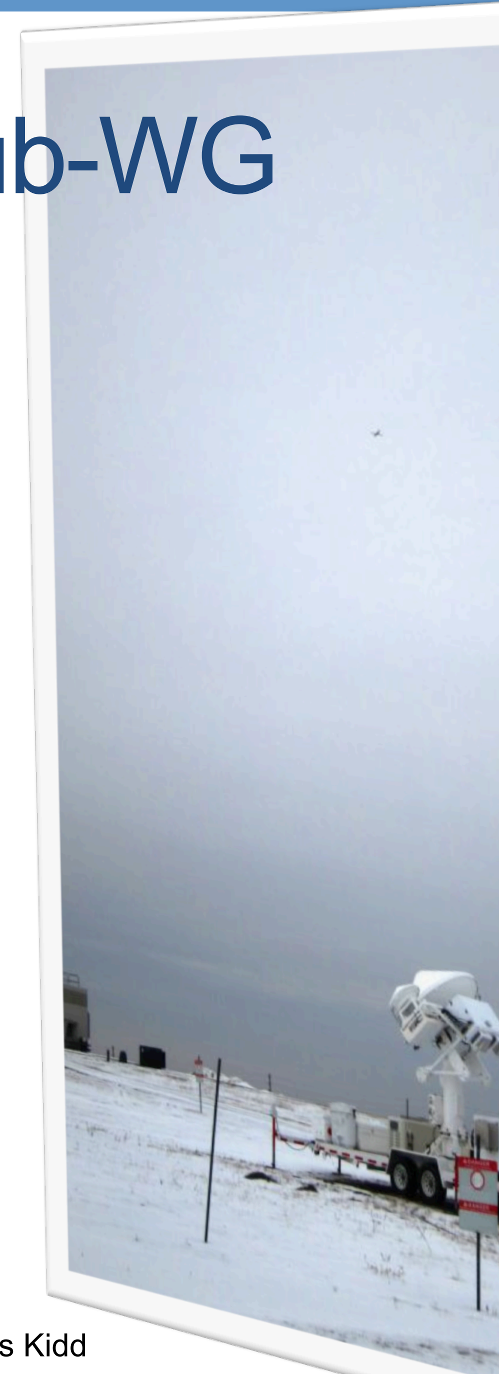


Photo: Chris Kidd

GCPEx GV measurements			Applicable Measured and/or Diagnosed Parameters																
	Instruments	Measurable	Z	Z_{DFR}	R	PSD sfc	PSD col	PID	ρ_b	ρ_p	T	Q_v	Q_{soil}	CN, CCN	TW_c	CW	IW	ε/σ_{sfc}	T_B
Ground Radar and Profiler	C-band Dual-Pol	Z, Vr, W, ZDR, Φ_{DP}, ρ_{hv}	☒		☒	☒	☒	☒											
	D3R Ka/Ku Dual-Pol	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒	☒	☒	☒											
	X-band profiling	Z, Vr, W	☒		☒			☒											
	MRR2 profiling	Z, Vr, W	☒		☒	☒	☒	☒											
	W-band profiling	Spectra (Z, Vr)	☒		☒	☒	☒	☒								☒			☒
	Dual freq. LIDAR	σ					☒												
Ground Gauge and Radiometer	2DVD/Parsivel/POSS	DSD, shape, fall spd	☒		☒	☒		☒											
	Pluvio2 SWE Gauges	SWE Rate			☒														
	TPS 3100 Hot Plate	SWE Rate, Wind, T			☒						☒								
	Soundings	P, T, RH, wind									☒	☒							
	ADMIRARI Radiometer, MRR	T_B 19, 37 Z 24 GHz	☒		☒											☒			
	EC TP3000 Radiometer	TB 23-59 GHz									☒	☒				☒			
	EC Ground-Staring Radiometer	TB 10-89 GHz															☒		☒
	EC Surface Met. Inst.	P,T,RH, wind									☒	☒							
Aircraft	APR2 (Ka/Ku Radar)	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	☒	☒	☒		☒	☒										☒	
	CoSMIR (Radiometer)	T_B 37,89, 165.5,183 H/V															☒	☒	☒
	CPI/2D-C/CIP, HVPS	Precip. Image	☒		☒		☒	☒	☒	☒					☒		☒		
	CDP	Cloud Water/Spectra					☒									☒			
	Nevzorov	Total water							☒						☒	☒	☒		
	King Probe	Cloud water bulk														☒			
	Rosemount Icing Probe	Supercooled water														☒			
	Aircraft T/RH/Gust	Air T, RH, wind									☒	☒							

Courtesy Walt Petersen

Matched aircraft in situ – aircraft radar/radiometer – ground radar products

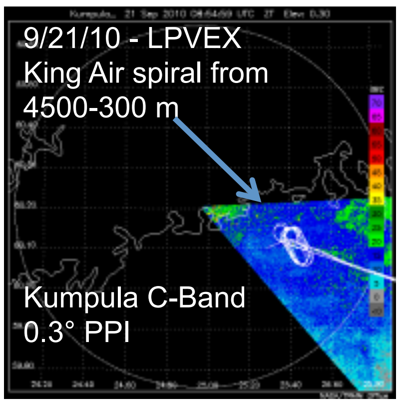
➔ Easy to use hypothesis-testing tools for algorithm developers and cloud resolving modelers

in collaboration with CSU/B. Dolan (radar QC & HID), NCAR/A. Heymsfield, A. Bansemer (microphysics)

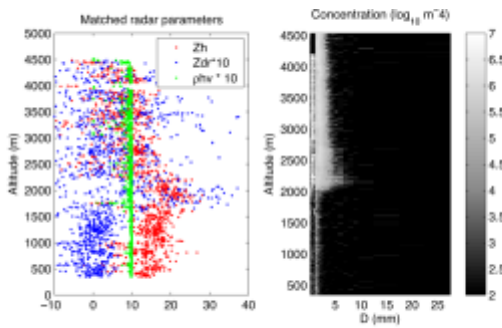
MGRAD – Merged Ground-based Radar-Aircraft Data

Space-time matching of ground-based polarimetric scanning radars with aircraft microphysics (C3VP, LPVEX, MC3E, GCPEX,…)

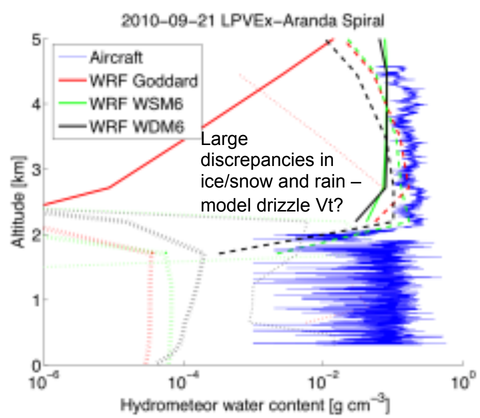
MGRAD in action – LPVEX 9/21 Spiral



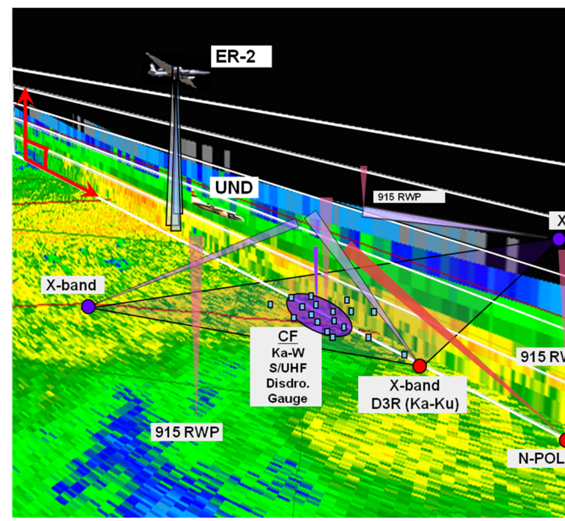
(below) Matched radar and aircraft show aggregation, lgt. rain/drizzle



Prelim. comparisons of 1 km WRF simulations (using Goddard, WSM6, and WDM6 microphysics) of Qi (soild), Qs (dashed), Qc (dots), Qr (wide dash) with UWKA/Heymsfield/ Bansemer TWC retrievals



SatSimRAD – Satellite Simulator Radar-Aircraft Data



Make the "Dream Scenario" a reality

Match ER-2 HIWRAP, DC-8 APR-2, AMPR, COSMIR with:

- ground based radar volumes
- aircraft *in situ* measurements

LPVEX MGRAD 1.0 available for Sept 21, Oct 20

MC3E MGRAD 1.0 is processing en masse

MC3E SatSimRAD beta (today's discussion)

UND Probes in MC3E and GCPEX

Probe	Characteristics
Cloud Droplet Probe	0.9 to 50 μm
Cloud Imaging Probe	25 μm to 1.55 mm
Cloud Particle Imager	2.3 μm to 100 μm
2-D Cloud Probe	50 μm to 1.6 mm
HVPS	150 μm to 1.92 cm
LWC Probe	Bulk LWC
Nevzorov Total Water	Bulk TWC
Nevzorov Ice Water	Bulk IWC

MGRAD details

Aircraft location
(t,x,y,z – GPS)

Ground-based
radar data
cf radial format
(t,r,ϕ,θ – PPI, RHI)

Convert spatial coordinates to common Cartesian coordinates relative to ground-based radar (x,y,z) using 4/3R beam propagation model

R_h=R_z=500 m T_h=5 min

At each aircraft point, apply a Cressman filter to the radar data in space and time

$$d_s^2 = \left(\frac{x_r - x_a}{R_h}\right)^2 + \left(\frac{y_r - y_a}{R_h}\right)^2 + \left(\frac{y_r - z_a}{R_z}\right)^2$$

$$d_t^2 = \left(\frac{t_r - t_a}{T_h}\right)^2$$

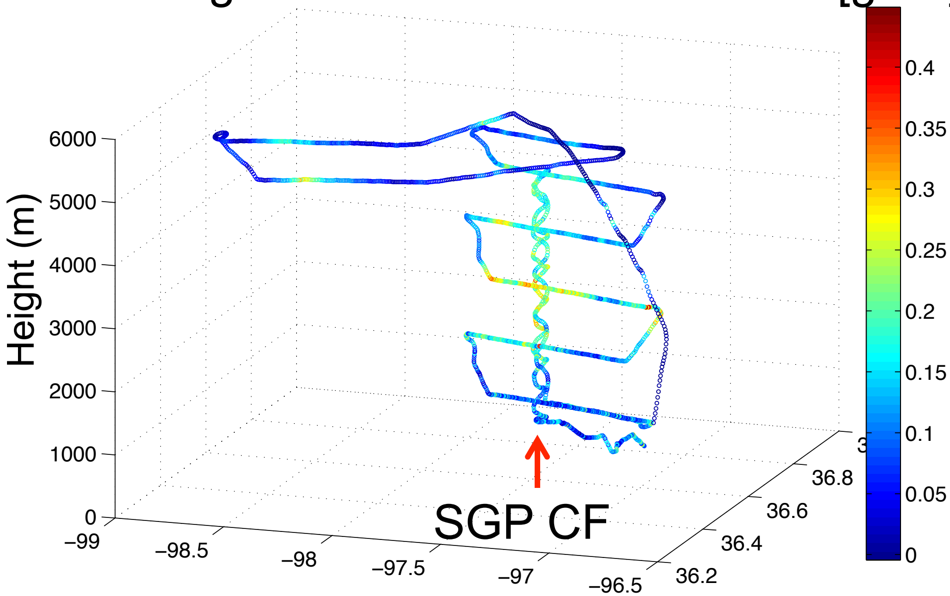
$$X = \frac{\sum_{i=0}^{n} \omega_s \omega_t X_i}{\sum_{i=0}^{n} \omega_s \omega_t}$$

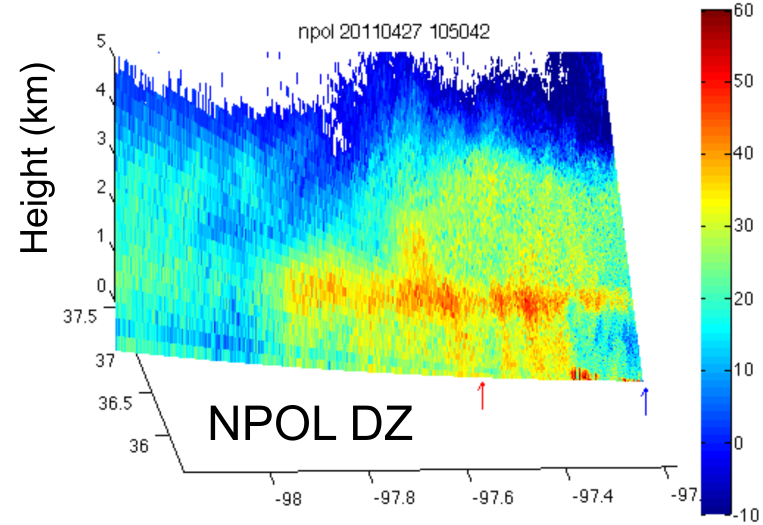
Experimenting with other methods, such as Discrete Fourier Transform in t

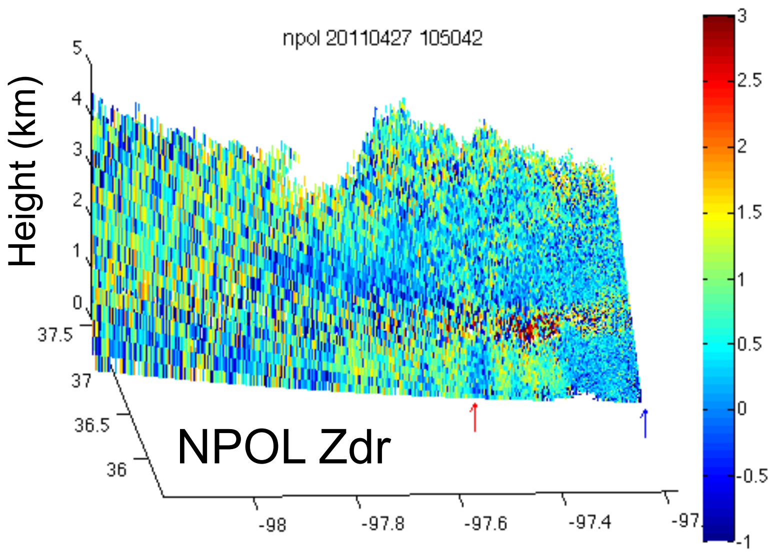
$$\omega_{s,t} = \begin{cases} \frac{1 - d^2}{1 + d^2} & \text{if } d^2 \leq 1 \\ 0 & \text{if } d^2 > 1 \end{cases}$$

MC3E 20110427

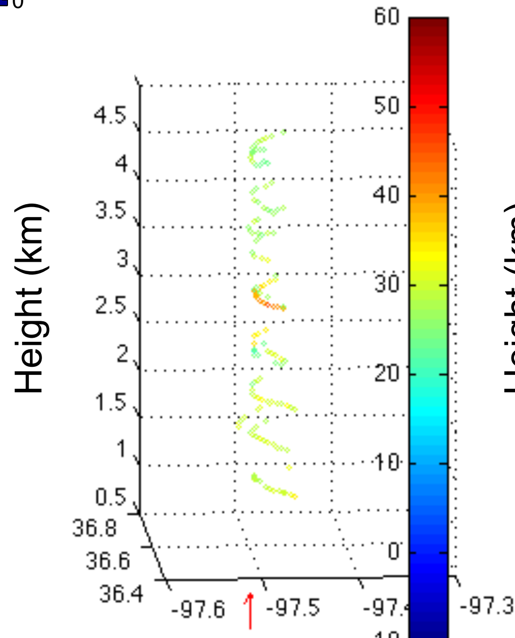
Citation flight track and Nevzorov TWC [g/m^3]



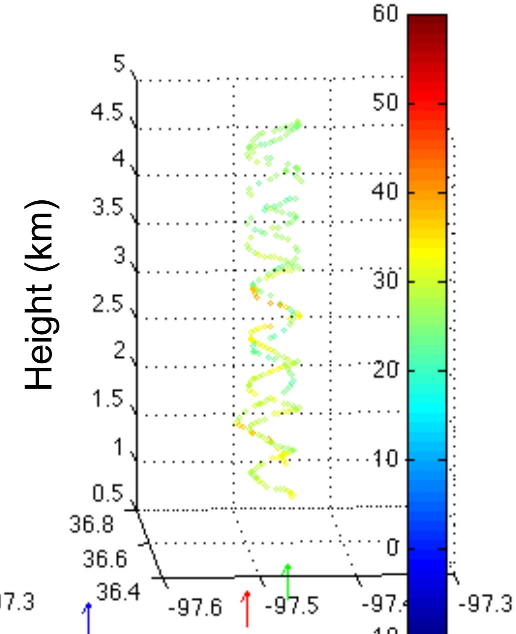




NPOL DZ



CSAPR DZ-2 dBZ

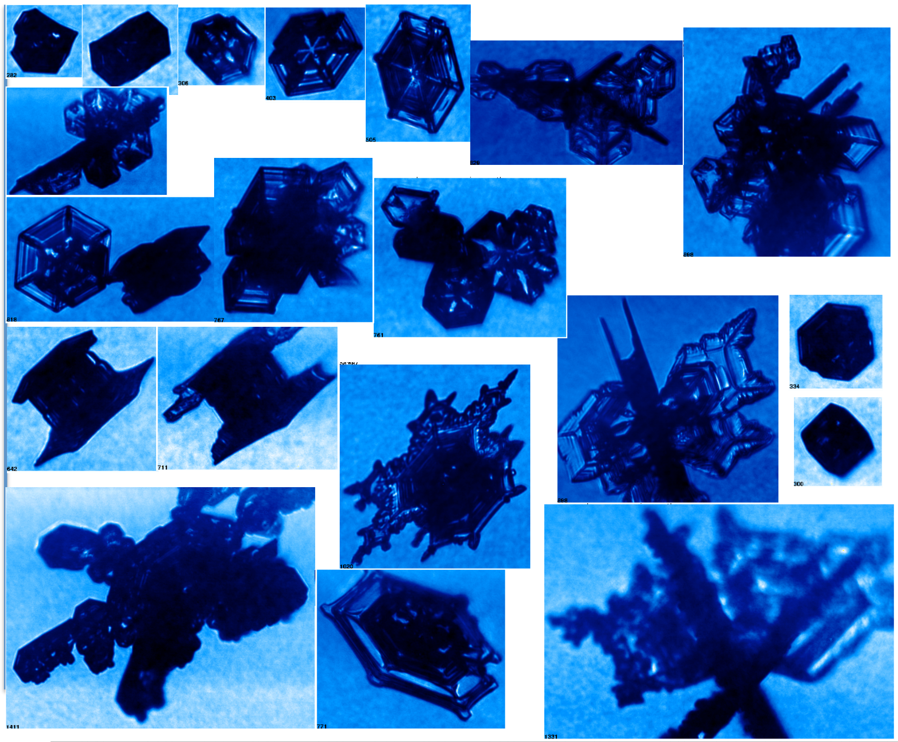


Also see talk by A. Heymsfield

4 KM

3.5 KM

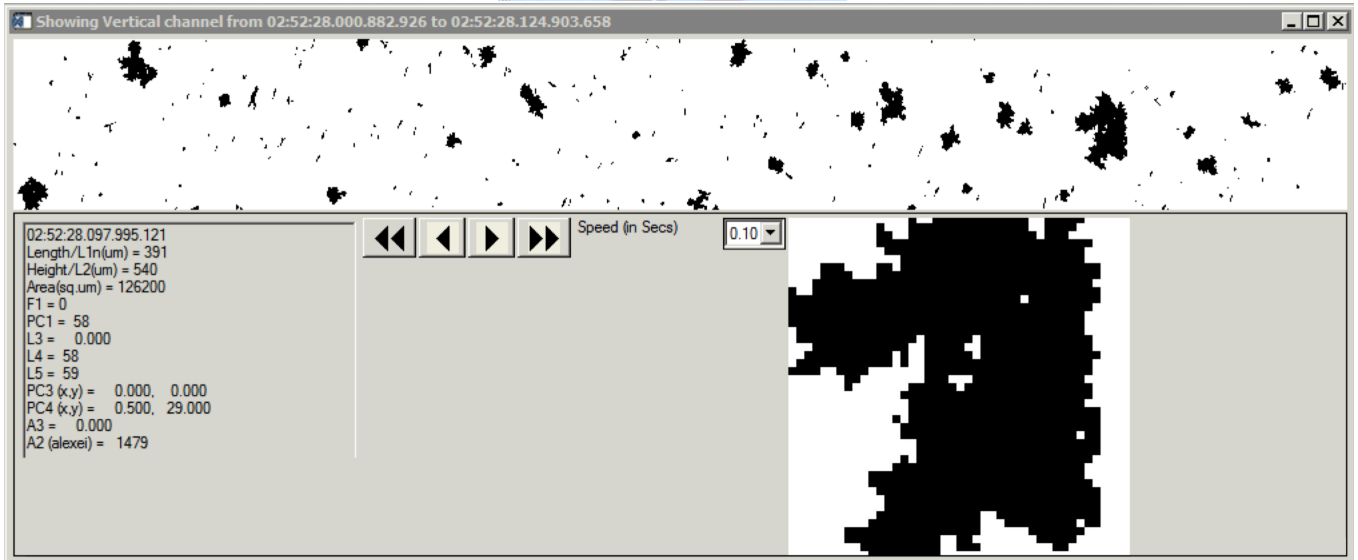
3 KM



0.2 mm

27 Jan 2012 CPI Images

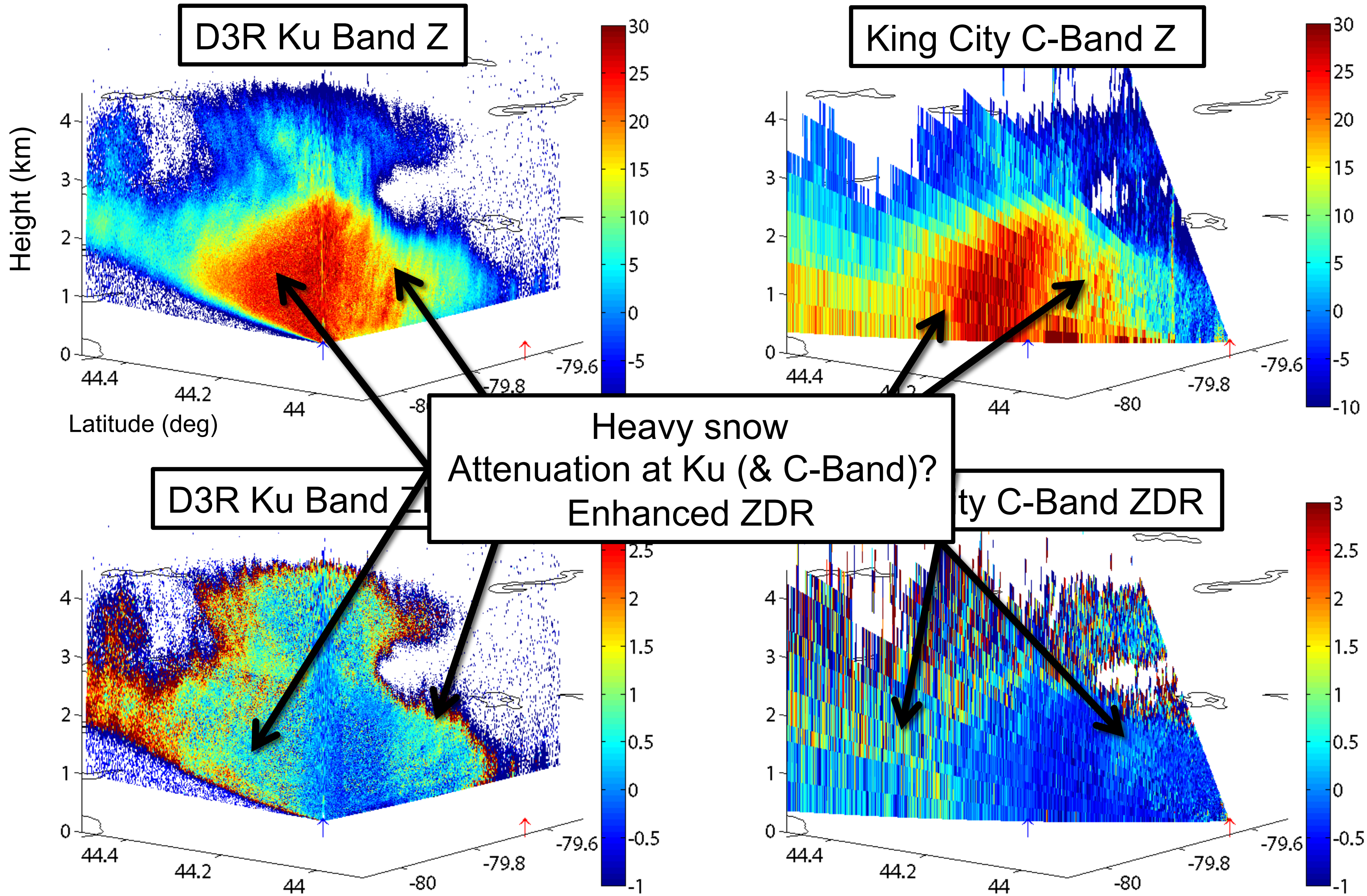
27 Jan 2012 HVPS3 Images



1.9 cm

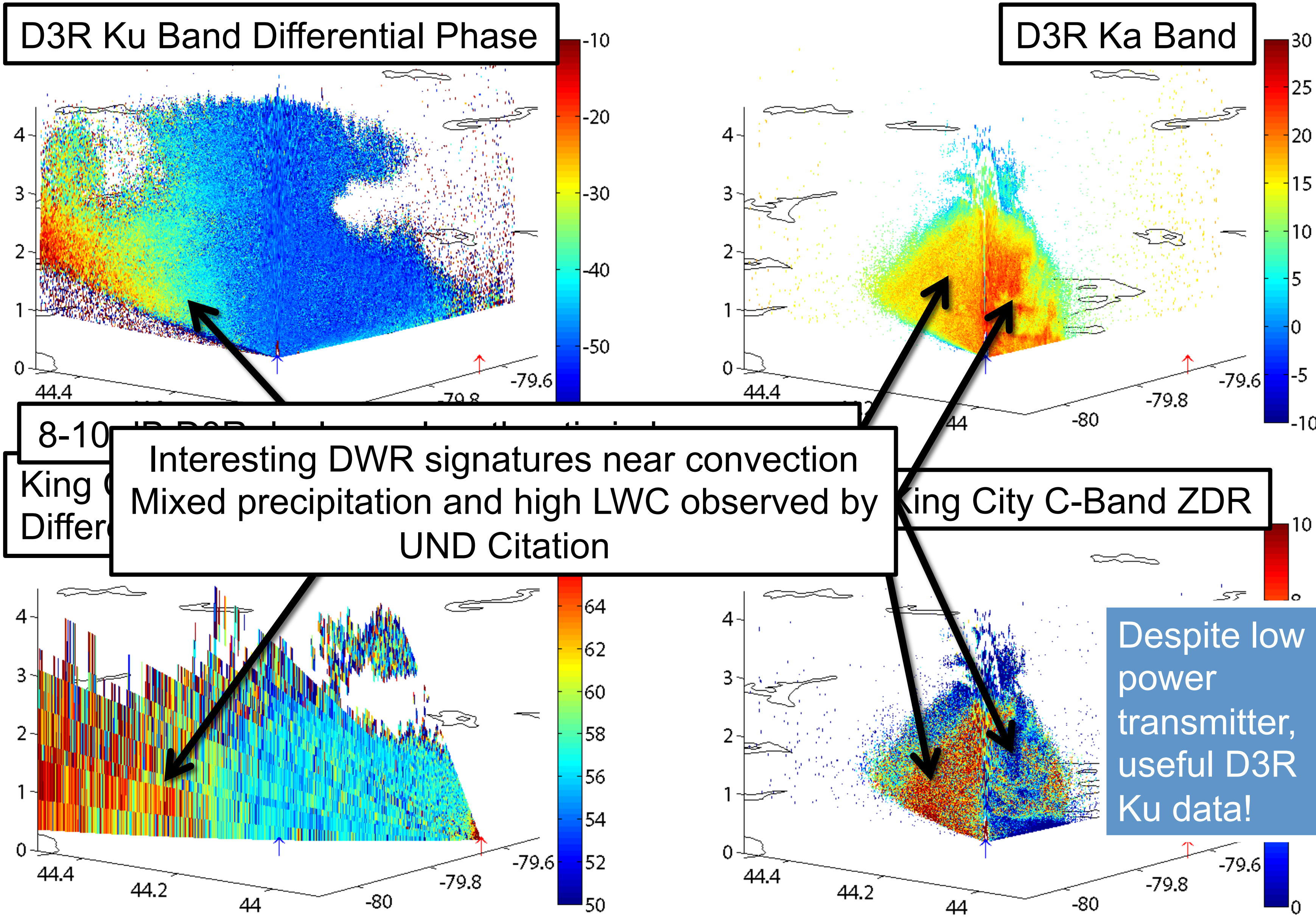
1.5 km

18 Feb '12 GCPEX – EC King City/NASA D3R comparisons



(Data - D. Hudak & Chandra)

GCPEX – EC King City/NASA D3R comparisons (Data - D. Hudak & Chandra)



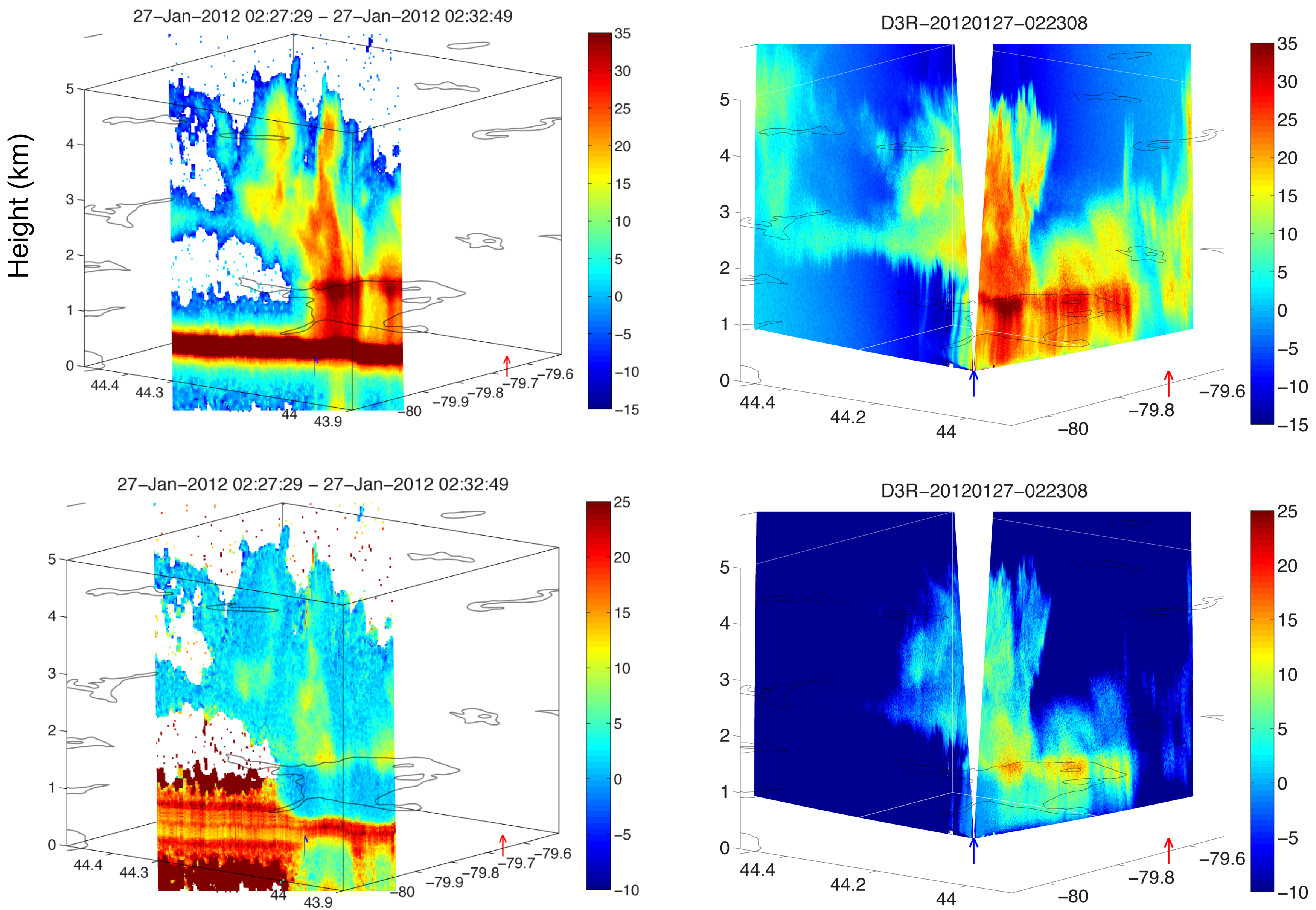
8-10

King C
Differ

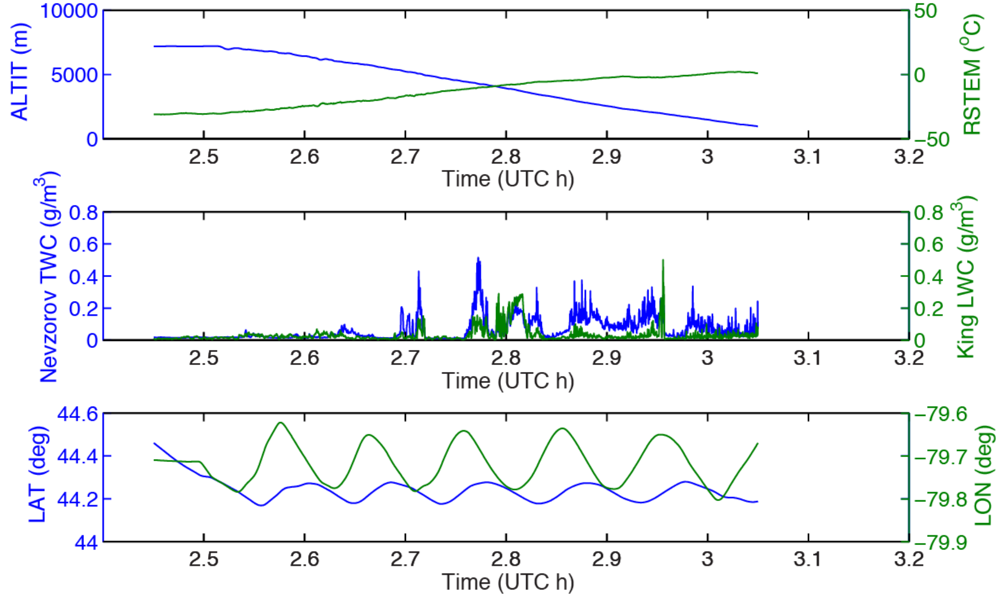
Interesting DWR signatures near convection
Mixed precipitation and high LWC observed by
UND Citation

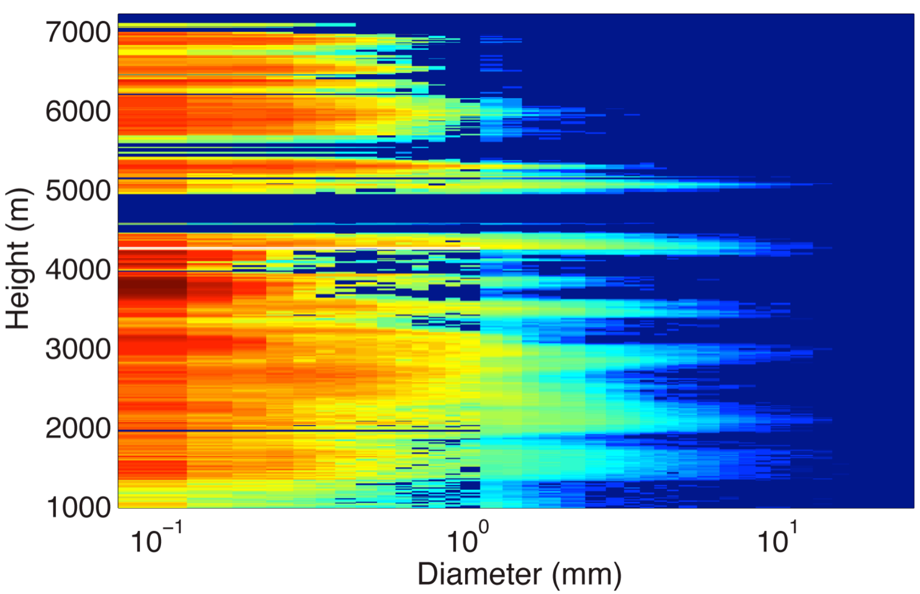
Despite low power transmitter, useful D3R Ku data!

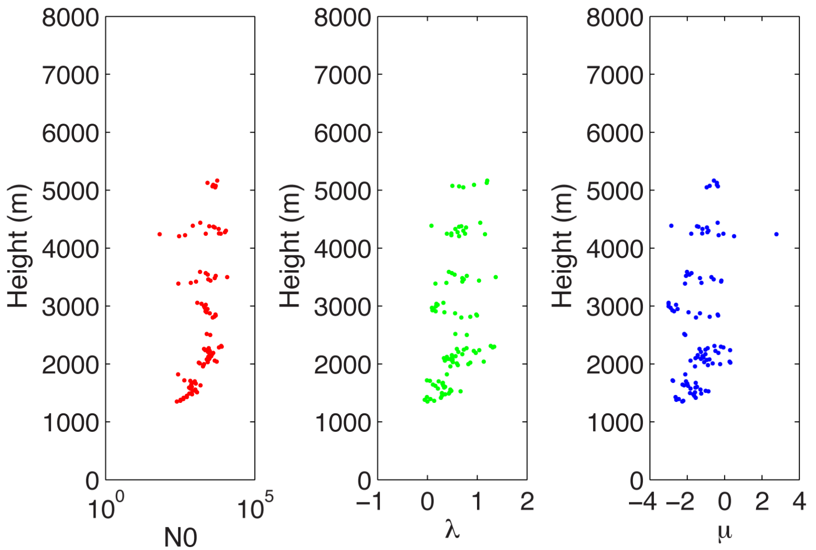
GCPEX – JPL APR-2/NASA D3R comparisons (Data – S. Tanelli & Chandra)



GCPEX 27 Jan 2012 Spiral UND-NCAR Time series and DSDs from CIP+HVPS







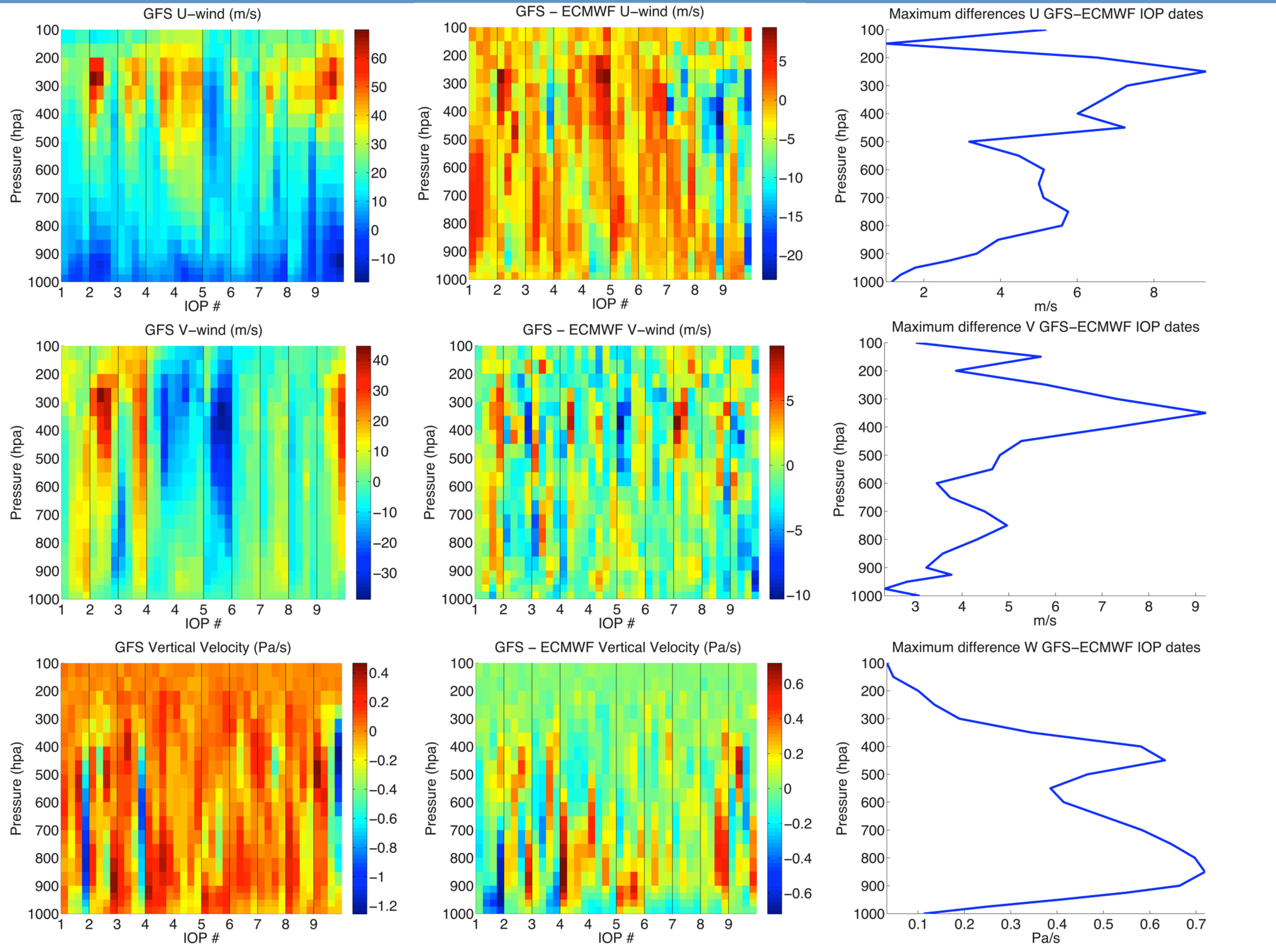
We have variety – and lots of it!

Just from GCPEX:

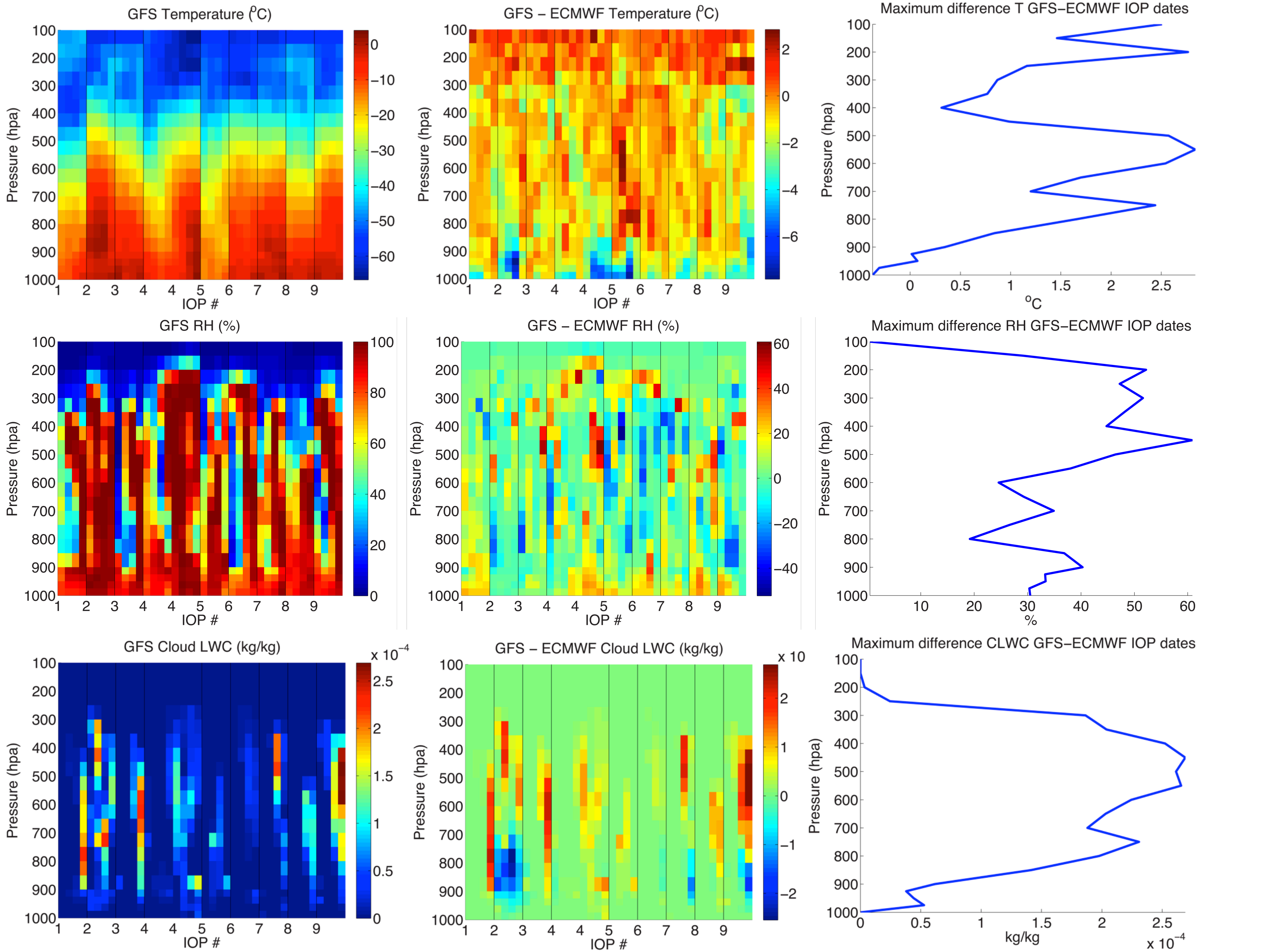
	January 19	January 27	January 28	January 30-31
Precip Type	Snow	Freezing Rain	Snow	Snow
# of Citation Spirals	4	2	7	1
Ground sites w/in spirals	CARE(4) Steam Show(4) SkyDive(4)	CARE(2) Steam Show (2) SkyDive(2)	CARE(4) Steam Show(4) SkyDive(4) Huronia(3)	CARE(1) Steam Show(1)

February 12	February 14	February 16	February 18	February 24
Lake Effect Snow	Snow	Snow	Snow	Snow/Mixed Phase
1	3	0	**12**	7
Steam Show(1) SkyDive(1)	CARE(2) Steam Show(1) SkyDive(1) Huronia(1)		CARE(12) Steam Show(12) SkyDive(12)	CARE(4) Steam Show(4) SkyDive(4) Huronia(3)

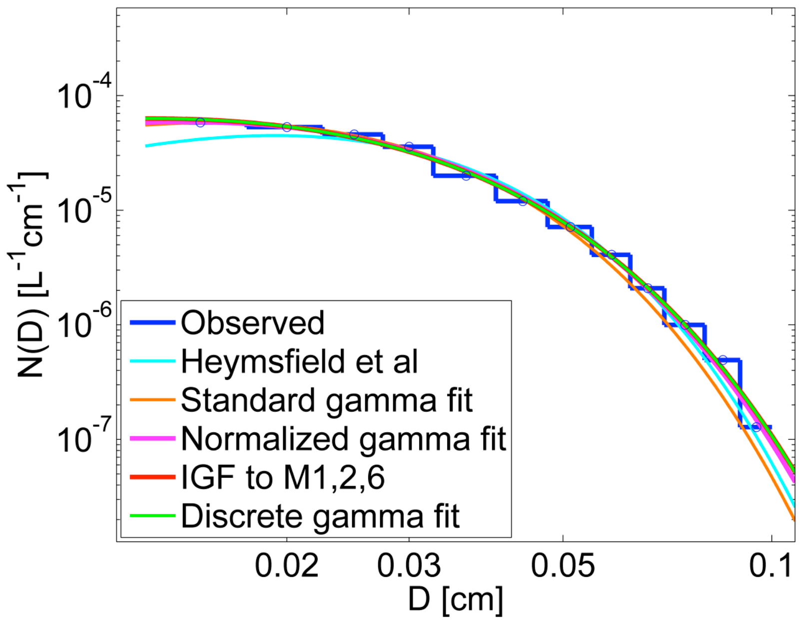
Building the GV column

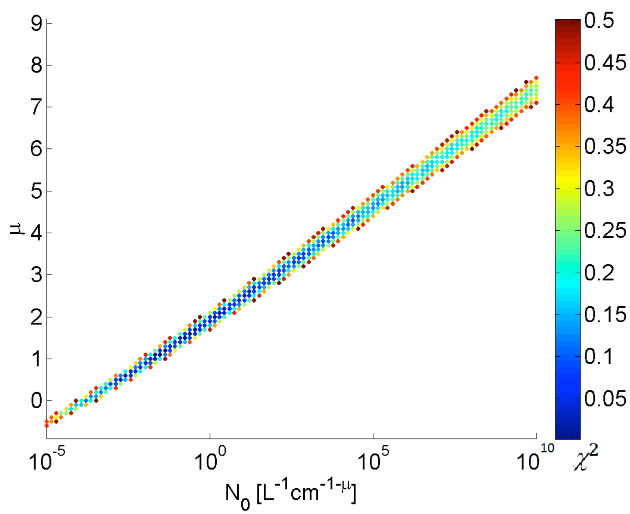


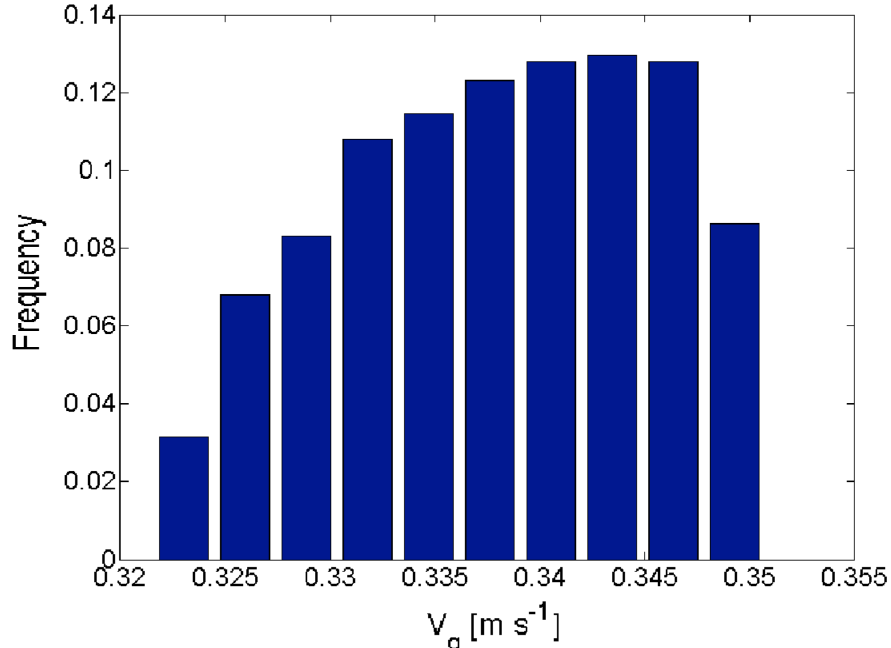
Building the GV column



Propagation of uncertainties
Necessary to quantify phase space for Gamma SD parameters
-and-
determine how the three-dimensional volume in N_0-λ-μ phase space depends on cloud or environmental parameters







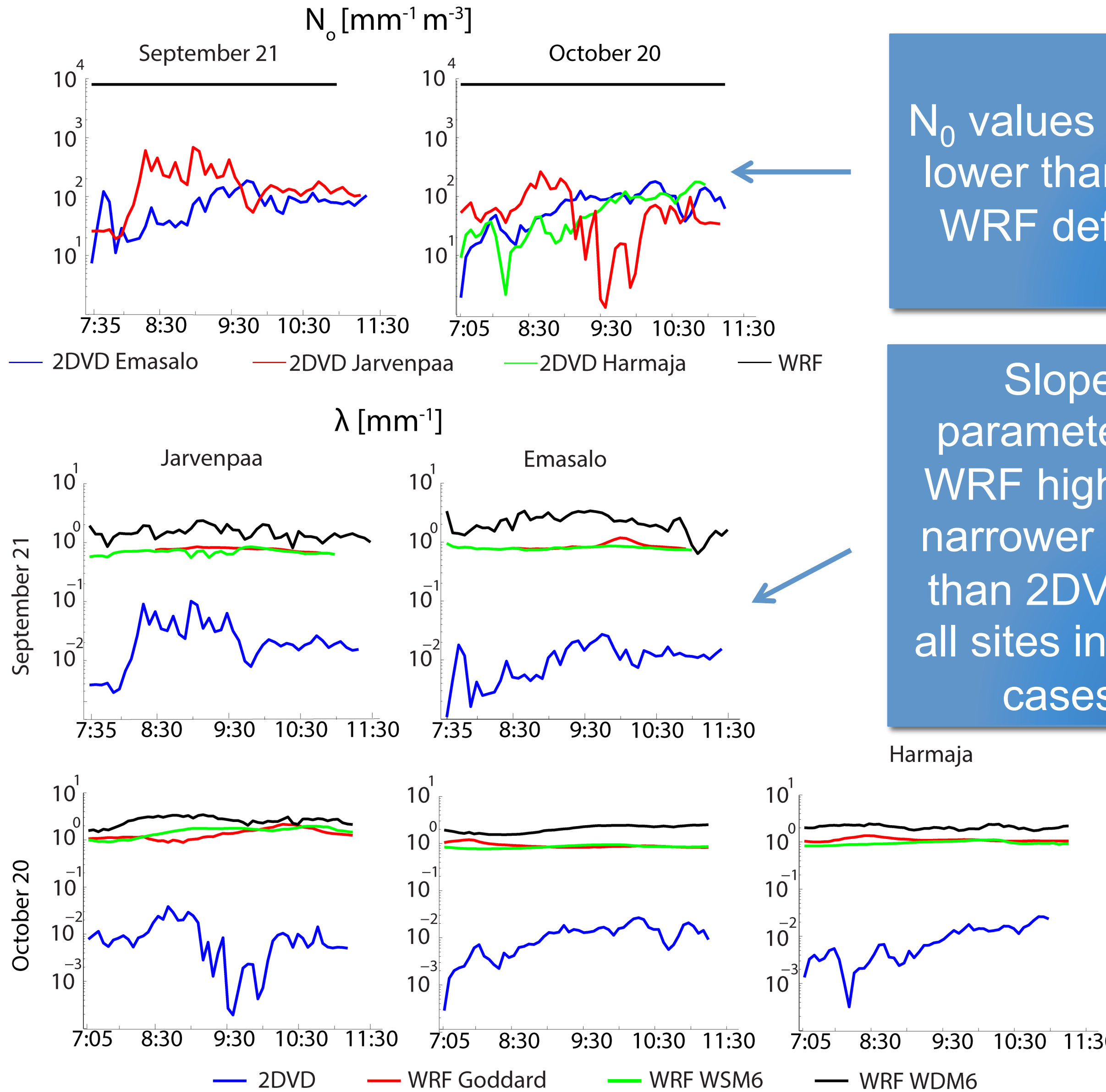
$$V_q = \frac{\int_{D_{\min}}^{D_{\max}} V(D) m(D) N(D)\, dD}{\int_{D_{\min}}^{D_{\max}} m(D) N(D)\, dD}$$

McFarquhar et al. (2013), in prep.

Weather Research and Forecasting Model (v3.4) runs (1 km inner nest) were conducted using Goddard, WSM6, and WDM6 microphysics for 21 Sept and 20 Oct cases

Exponential DSD properties compared with aircraft in situ, 2DVD, and C-Band dual pol observations.
➔Here 2DVD observations are compared

Gleicher et al. (2013), *in prep.*



N_0 values much lower than the WRF default

Slope parameter in WRF higher – narrower DSD than 2DVD at all sites in both cases

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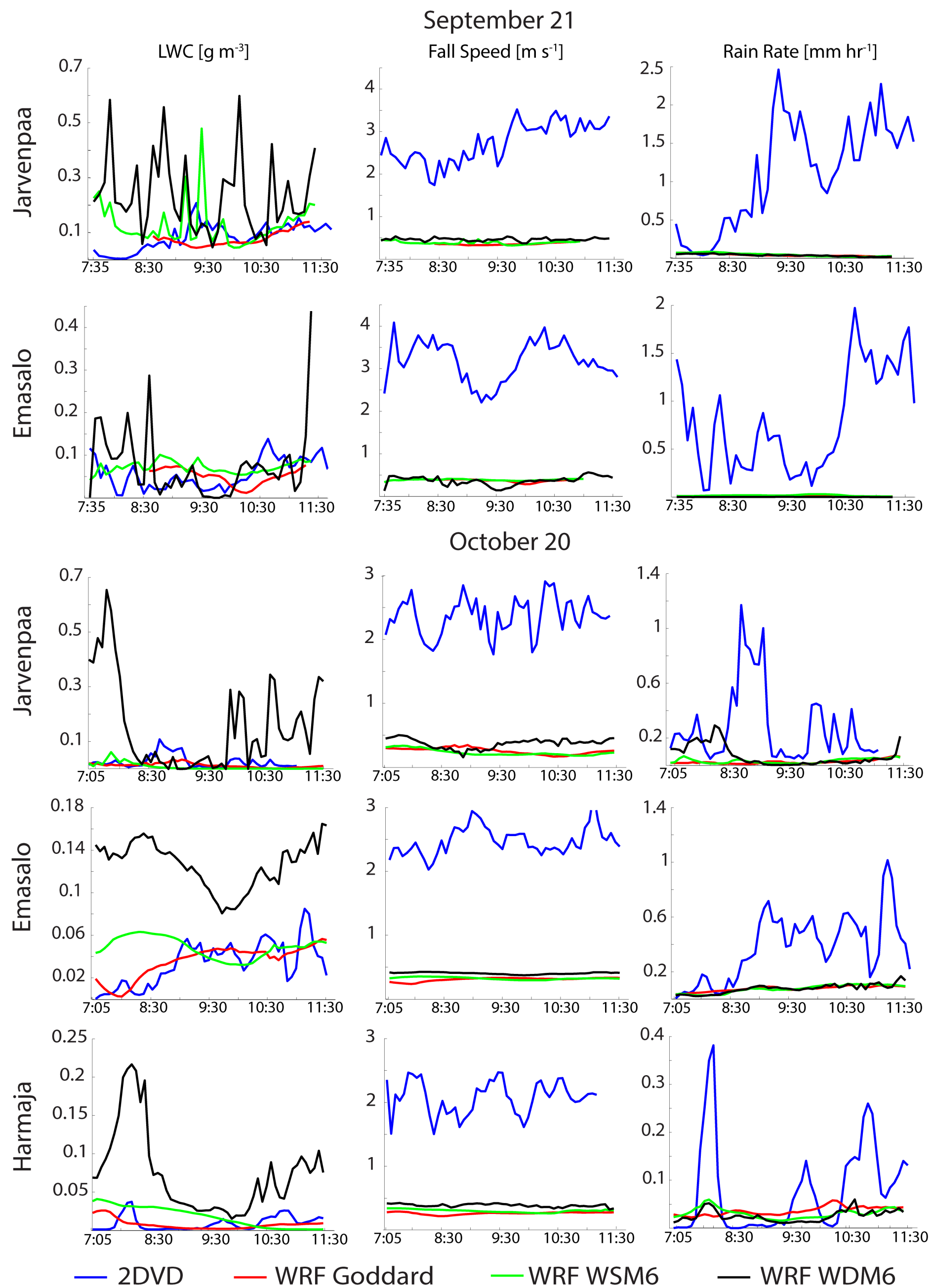

Disagreements in rain rate driven by improper fall speeds in WRF more than LWC
↓
WRF assumes drops too small (large λ) thus fall too slowly

Conclusions

- Lots of work to do; need to leverage DSD working group (radar+DSD+algorithm scientists) to maximize analysis to improve algorithms and models
- Team members: participate in the DSD working group!
- Future field campaign observational strategies will include column profiling and use lessons learned (GPM + others) come to Hydrology session and see Dan Cecil's poster about a new South American field campaign)

Comments?

- Contact:

Steve Nesbitt

snesbitt@illinois.edu

+1 217 244 3740