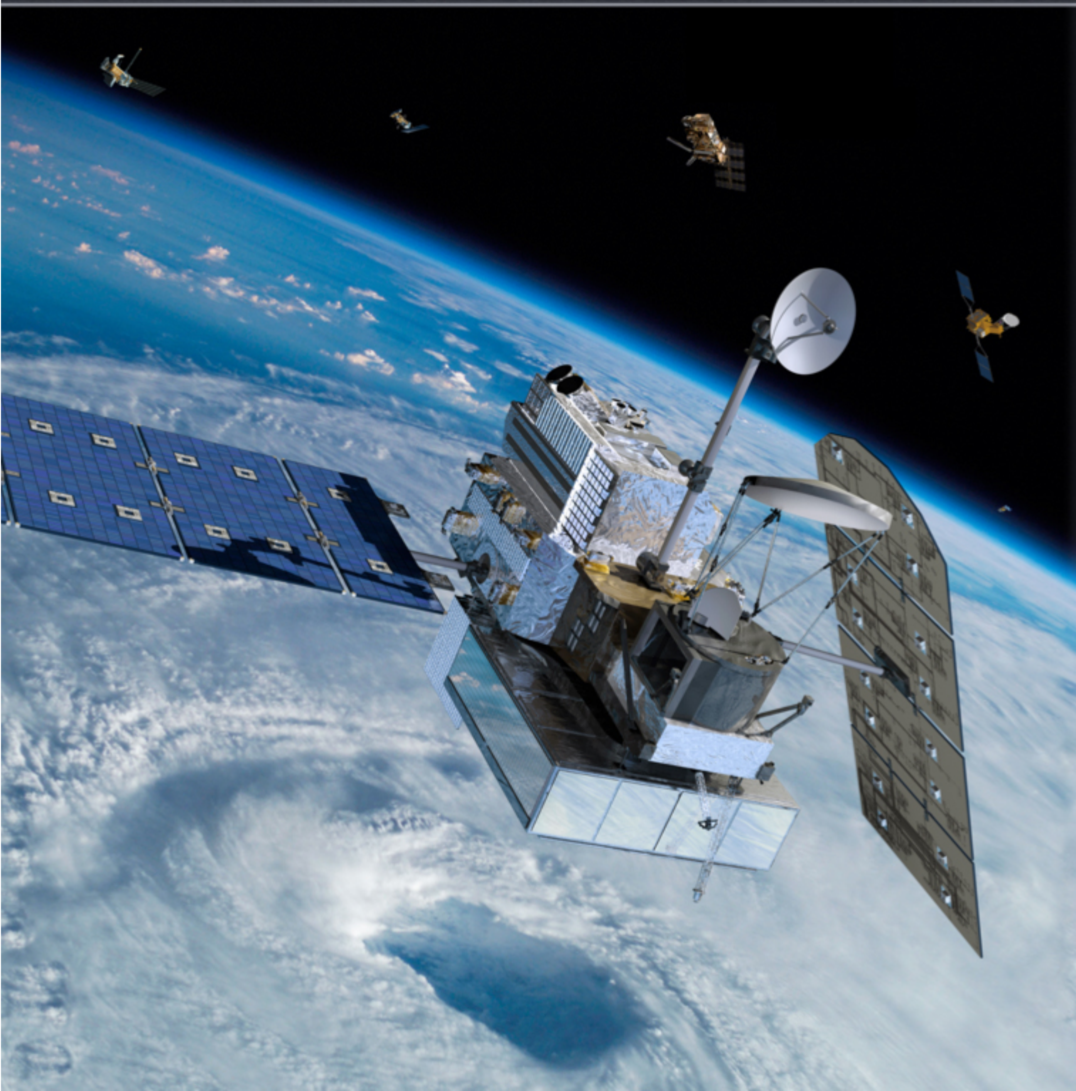
Synthesis of GPM Field Campaign Hydrometeor Datasets for Precipitation Retrieval Algorithms

Walter A. Petersen, NASA GSFC/WFF
walt.petersen@nasa.gov



Outline

- GPM GV Science Framework
- Instruments and Products
- Campaign Examples
- Where to go for datasets
- Summary

Acknowledgement: Matt Schwaller NASA GSFC and GPM Flight Project

Physical Process Validation Drives Collection of "Hydrometeor" Datasets

"Cloud system and microphysical studies geared toward testing and refinement of physically-based retrieval algorithms"

LPVEx

MC3E

GCPEX

WFF

Environment Canada Environnement Canada

C3VP

CHUVA PROJECT

CPTEC

HyMeX

Hydrometeor Datasets Trace to Algorithms

Algorithm component, assumptions, or issue addressed	Applicable Measured and/or Diagnosed Parameters																
	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
Path integrated attenuation approach(es)	◆	◆	◆	◆	◆	◆				◆			◆	◆		◆	
Rain/no rain discrimination	◆	◆	◆	◆	◆	◆			◆	◆			◆	◆	◆	◆	◆
Hydrometeor Identification (3D)	◆	◆	◆	◆	◆	◆	◆		◆				◆	◆	◆		
Melting layer identification	◆	◆			◆	◆			◆						◆		
Hydrometeor melting model	◆	◆			◆	◆	◆	◆	◆				◆		◆	◆	
Convective/Stratiform partitioning	◆	◆	◆	◆	◆	◆											◆
DSD/rain profile, horizontal variability (correlation, beam filling, ε-adjustment)	◆	◆	◆	◆	◆	◆											◆
DSD parameter correlations	◆	◆	◆	◆	◆	◆											
Cloud water profiles	◆	◆	◆						◆	◆		◆	◆	◆	◆		◆
Column/land surface properties	◆	◆	◆						◆	◆	◆					◆	◆
Ice water contents, PSD, density, habit	◆	◆			◆	◆	◆	◆	◆	◆			◆		◆		◆
Ice particle vs. volume extinction	◆	◆			◆	◆	◆	◆	◆	◆					◆		◆
Ice process as coupled to scattering and the rain profile	◆	◆	◆	◆	◆	◆	◆	◆					◆	◆	◆		◆
Regime controls on precipitation	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
CRM/LSM Satellite Simulator Physics	◆	◆	◆	◆													

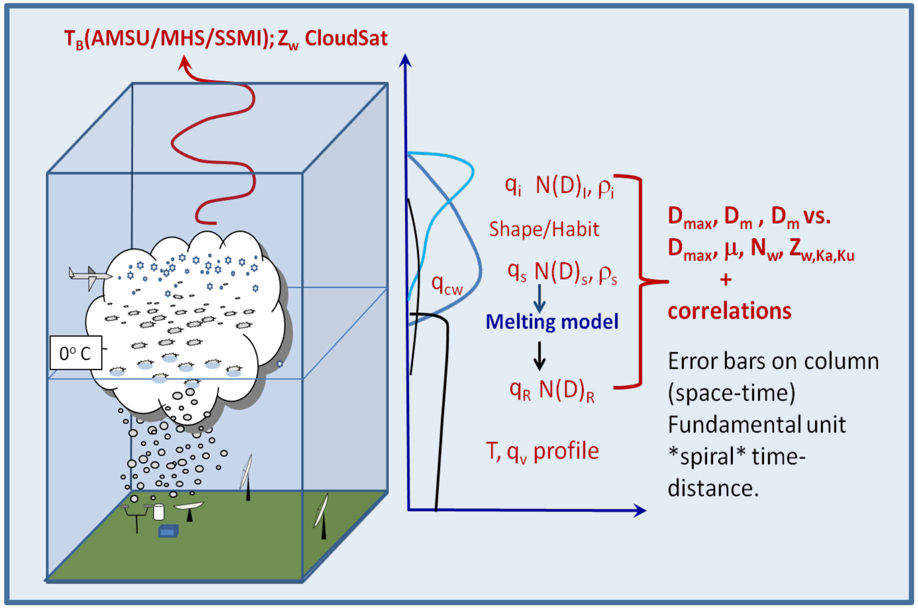
- Define relevant parameters to observe

Then……….

Define and deploy instruments to collect required observations

MC3E 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	NPOL, DOE S/C/X Dual-Pol	Z, Vr, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	⊠		⊠	⊠	⊠	⊠											
	D3R Ka/Ku Dual-Pol	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	⊠	⊠	⊠	⊠	⊠	⊠											
	S/UHF Profiling	Z, Vr, W	⊠		⊠	⊠	⊠	⊠											
	MRR K-band Profiling	Z, Vr, W	⊠		⊠	⊠	⊠	⊠											
	Ka/W-band Radar	Spectra (Z, Vr)	⊠		⊠	⊠										⊠			⊠
Ground Gauge and Radiometer	2DVD/Parsivel Array	DSD, shape, fall spd	⊠		⊠	⊠		⊠											
	Rain gauge array	Rain rate/accum			⊠														
	Sounding Array	P, T, RH, wind									⊠	⊠							
	ADMIRARI Radiometer, MRR	T_B 19, 37 Z 24 GHz	⊠		⊠											⊠			
	DOE/OK Surface Inst.	P,T,RH, soil moisture and aerosols			⊠						⊠	⊠	⊠	⊠					
	AERI Radiometers	T/RH Profile									⊠	⊠							
	DOE Flux tower	Eddy fluxes (T,q,u)									⊠	⊠							
Aircraft	HIWRAP (Ka/Ku Radar)	Z, Vr, DFR, W, ZDR, Φ_{DP}, ρ_{hv}, LDR	⊠	⊠	⊠		⊠	⊠										⊠	
	CoSMIR (Radiometer)	T_B 37,89, 165.5,183 H/V															⊠	⊠	⊠
	AMPR (Radiometer)	T_B 10,19,37,85 H/V															⊠	⊠	⊠
	2D-C/CIP/2D-P, HVPS	Precip. Image	⊠		⊠		⊠	⊠	⊠	⊠					⊠		⊠		
	CDP	Cloud Water/Spectra														⊠			
	Nevzorov	Total water							⊠						⊠	⊠	⊠		
	King Probe	Cloud water bulk														⊠			
	Rosemount Icing Probe	Supercooled water														⊠			
	CN/UHSAS	Aerosol spectra												⊠					
	MAPIR Radiometer	T_B 1.4 GHz H/V									⊠		⊠						

Science Approach to Data Collection

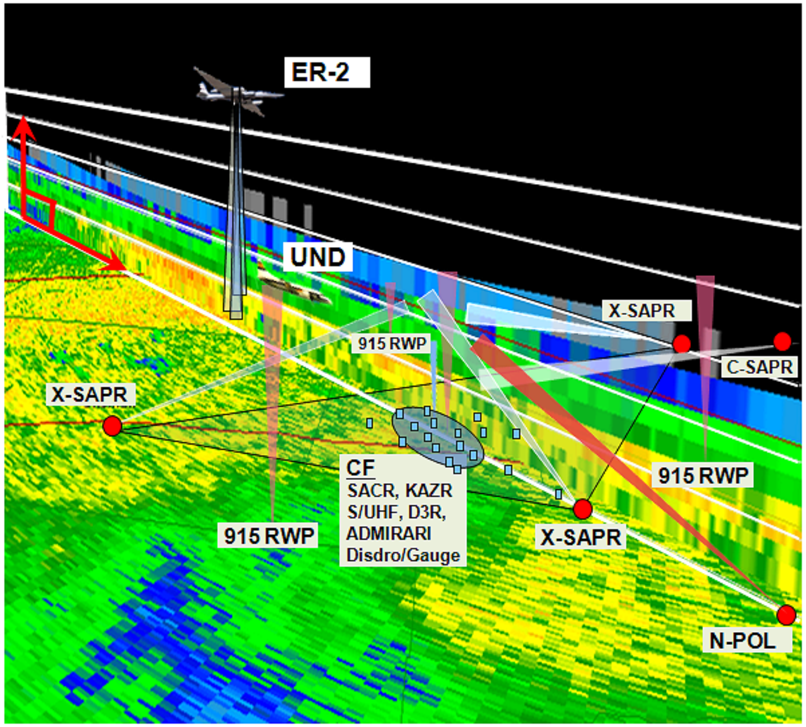


"Building the Column"

Connecting the physical "dots" for precipitation process ground to cloud top, coupled to GPM satellite simulator measurements.

Example "Dream Scenario" from MC3E

- ***Satellite view***: High Altitude ER-2 ("satellite simulator")
- ***Column***: UND Citation Microphysics
- ***3-D Domain***: Multi-frequency/polarimetric radar
- ***Ground reference***: Dense networks of disdrometers (DSD) and rain gauge measurements



Instruments

Airborne

View from the top- Satellite "simulators"

- CoSMIR, AMPR Radiometers
- HIWRAP, APR-2, Ka-Ku Radars

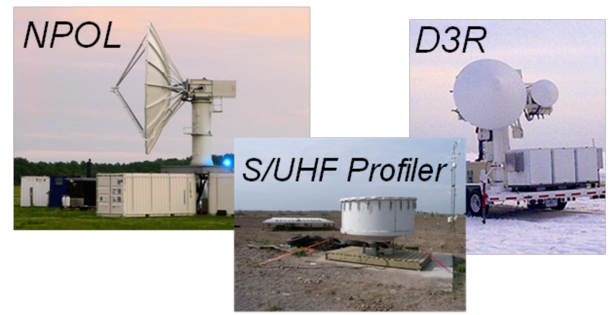
Column microphysics

- Cloud Microphysics Suite (e.g., 2D-C/P/S, CIP,CPI,CDP, HVPS-3, Nevzorov, King)

Ground: Dual-pol/Dual-Freq. Radar

Column precipitation microphysics, rates, DSD

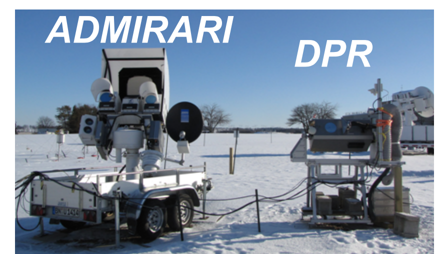
- Scanning: W, Ka, Ku, X, C, S
  - E.g., NPOL, D3R, King City, X/C-SAPR
- Profiling: W, K, X-band, S/UHF



Radiometer (ADMIRARI/DPR)

Column TB, Water Path

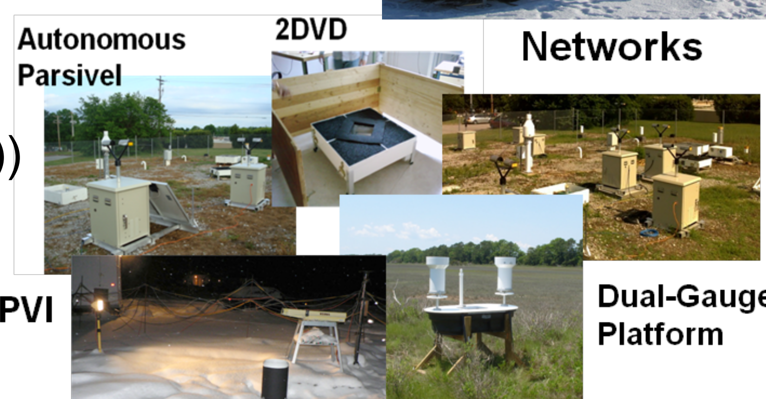
- ADMIRARI (10-37 GHz), DPR (89-150GHz)



Precipitation Rates / DSD

Connect/Reference column to surface

- Disdrometers (2DVD,Parsivel, JW))
- MetOne rain gauges, dual-gauge
- All weather hot-plates
- OTT Pluvio² weighing gauges
- Precipitation Video Imager



Core Data Products: Summary (Sample)

Airborne:

Microphysics: probe raw, ASCII, browse imagery:
Navigation, wind, state params; Liquid/frozen water contents; CN concentration, cloud droplet, cloud ice and precipitation size, concentration, and contents; particle imagery.

Radar: HDF, netCDF, browse imagery
APR-2 [Ka/Ku: Z, V_r, NCP, LDR], HIWRAP [Z_{ka}, Z_{ku}], WCR [Z,V_r, NCP], NAWX[Z]

Radiometer ASCII, browse imagery
CoSMIR (TB, 50-183 GHz H/V), AMPR (TB, 10-85 GHz; H/V)

Ground:

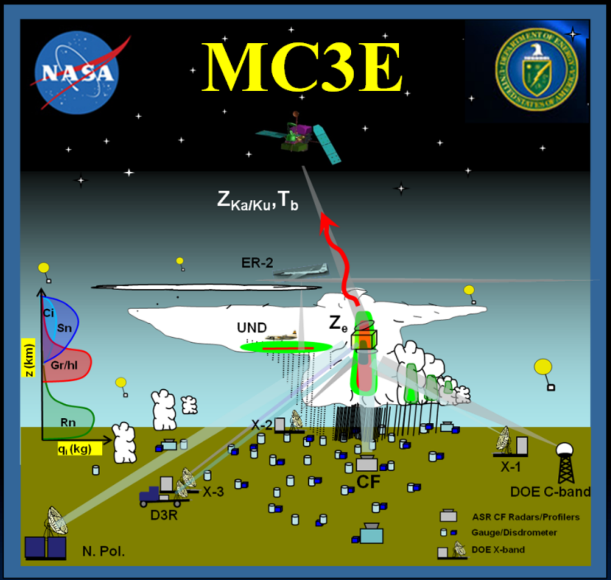
Radar: UF, netCDF, Level-II, ASCII, Browse
E.g., NPOL(S), CHILL(S), D3R (Ka/Ku), Kumpala (C), Kerava (C), Vantaa(C), ARM C/X-SAPR radars (Z, V_r,σ_w + polarimetric variables, HID, DSD, Rain Rates; case-specific), WSR88D (Z, V_r,σ_w, and pol variables if upgraded)…………

Radiometer: ASCII
Sky: TB (H/V), ΔTB, Water Vapor, Temperature, I/LWP; *Ground*: TB (H/V)

Profiler/Profiling: Raw/netCDF/ASCII
Raw/Calibrated/Processed Doppler spectra, moments (Z, V_r, σ_w), DSD (case specific; care must exercised in snow)

Disdrometer/Particle: Raw, ASCII
2DVD: *Drop-by-drop*: Diameters, axis ratios, fallspeeds, volumes, etc.; *1-minute*: N(D), concentrations, numbers, Z, LWC, RR, D_m, D_{min}, D_{max}, σ_m, daily summary and event files.
Parsivel: 1-minute: Similar to 2DVD; but no drop by drop.
POSS: 1-minute, DSD, rates, DSD moments, Z, dual-pol-moments…………
Precipitation Video Imager: PSD, High-res. imagery

Mid-latitude Continental Convective Clouds Experiment
April 22 – June 6, 2011



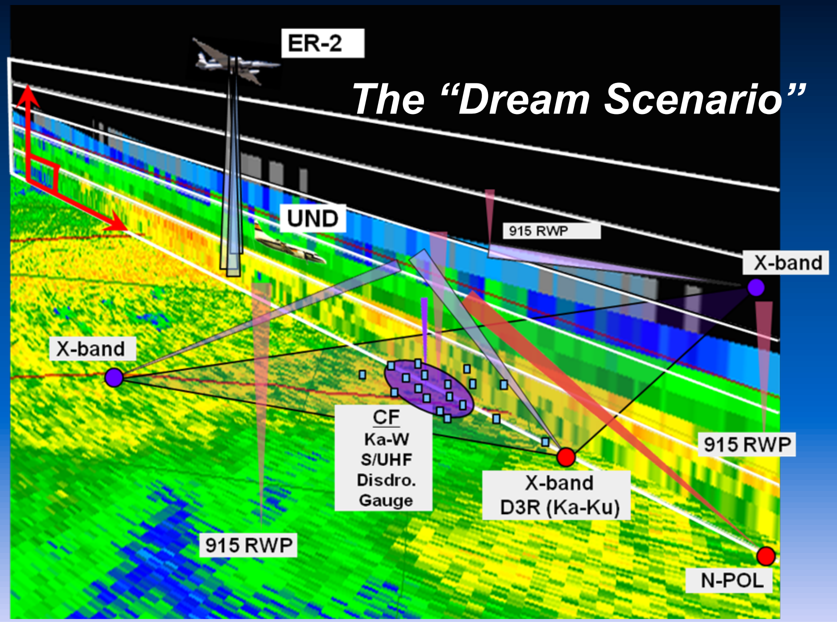
Location: DOE-ARM SGP Central Facility, N. Oklahoma and NE Colorado (CSU CHILL)

Overarching Objectives:

- GPM: Improved physically-based rainfall retrieval algorithms over mid-latitude land surfaces
- DOE: Improved simulation of convective cloud properties (initiation, dynamics, microphysics)

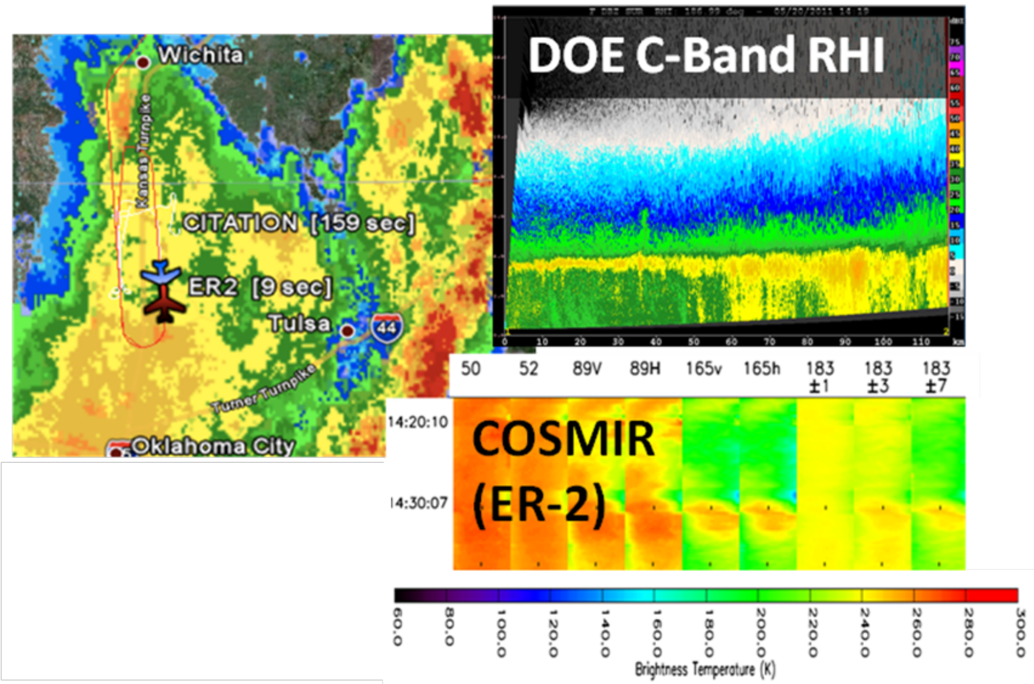
Sampling Strategy:

- ER-2 (satellite "proxy"; HIWRAP, CoSMIR, AMPR) stacked over UND-Citation (in situ microphysics)
- Coincident and targeted ground-based multi-frequency/dual-pol radar (S/C/X/Ku-Ka/W), profiler, disdrometer/gauges
- Column precipitation physics for a variety of precipitation types

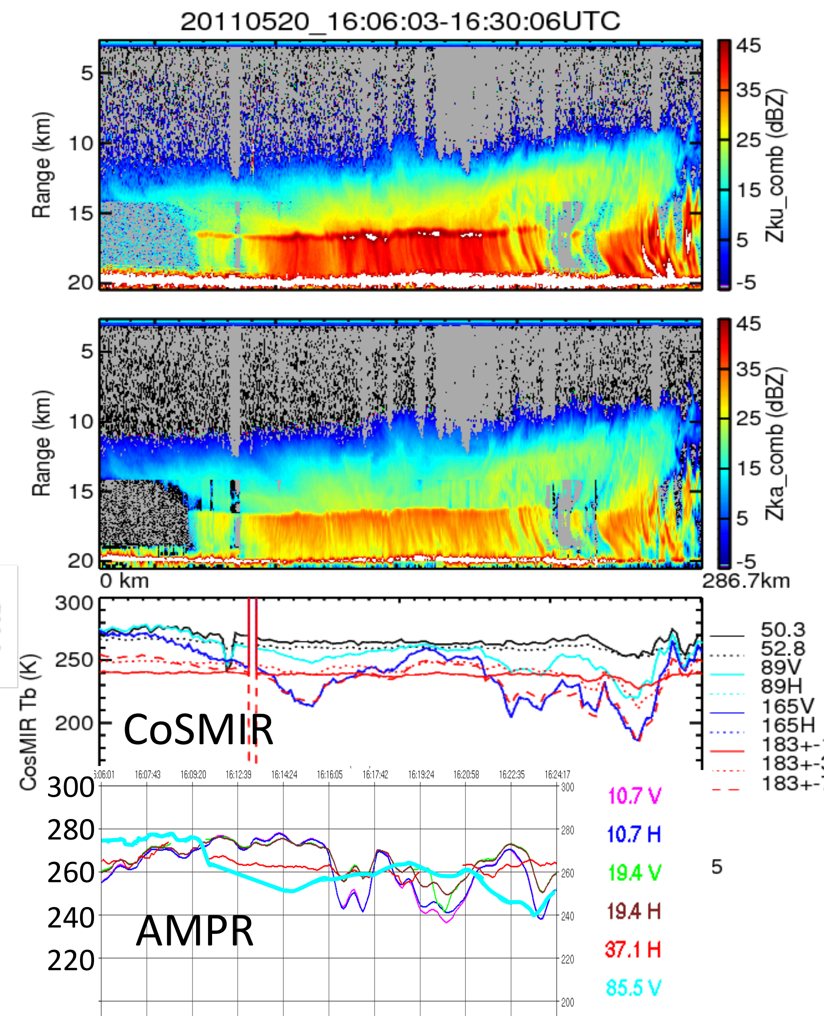


Example Operations and Observations "Dream Scenario" Event: May 20

Early: Citation-ER-2 "Dream Scenario" stacks over/near SGP



A little later: ER-2- Only (HIWRAP, COSMIR, AMPR)



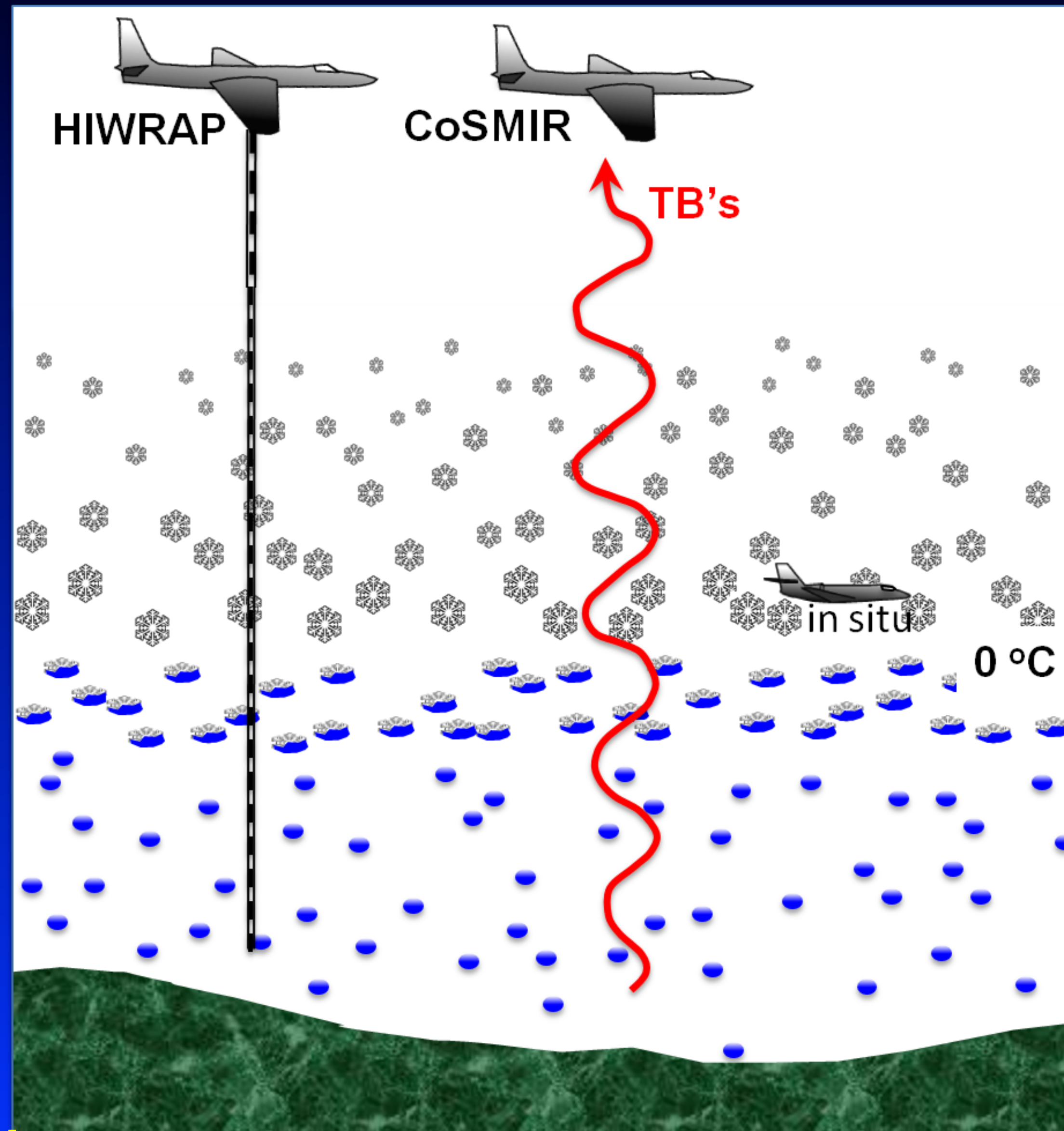
Variety:

- **Early sampling focused on stratiform**
- **Later sampling- ER-2 on deep convective line with trailing stratiform well east of Central Facility.**

5

Evaluating Snow Physics Using HIWRAP and CoSMIR in MC3E
W. Olson et al. (WORK IN PROGESS!!- See Bill's Talk on Wed.)

- Assign scattering model.
- Retrieve precip profile (PSD's) using HIWRAP.
- Compute consistent microwave scattering properties in profile.
- Simulate upwelling brightness temperatures at 89, 165.5 GHz.
- Compare to CoSMIR obs.

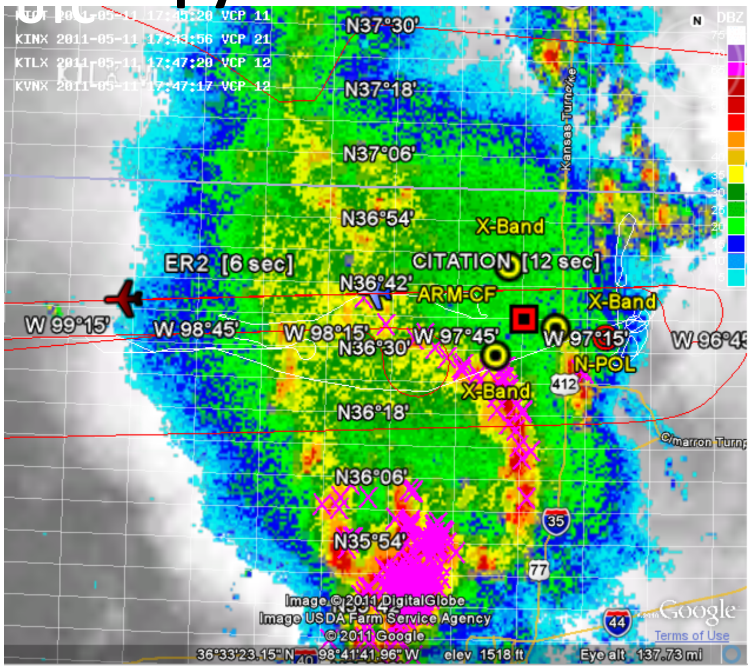


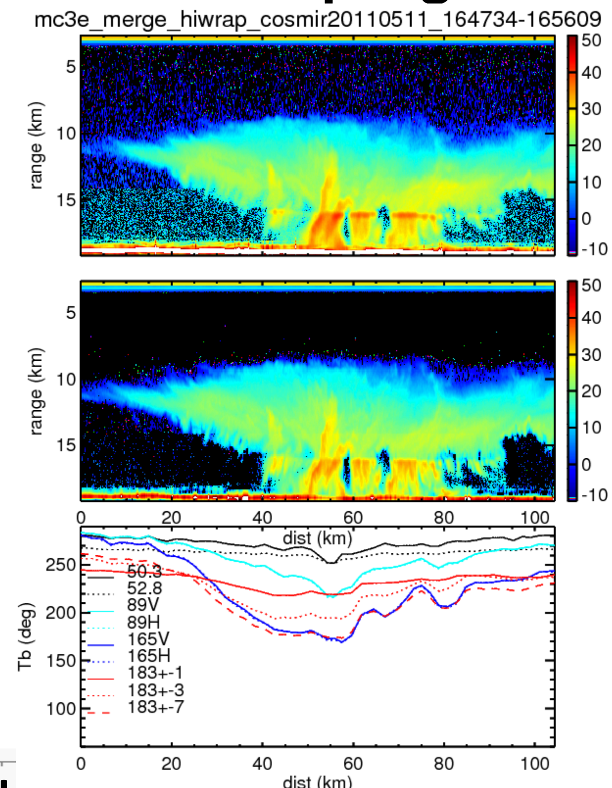
Note: brightness temps aren't sensitive to variations of surface emission and liquid precip if light rain is present => **scattering signatures discriminate snow particle models.**

See Olson et al. talk for result!!

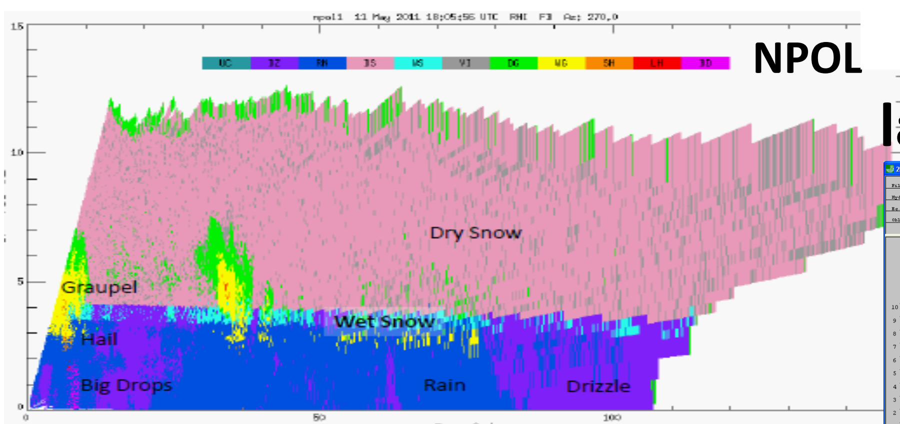
Example Operations and Observations: 11 May 2011

"Lumpy" mixed stratiform-convective sampling…………..



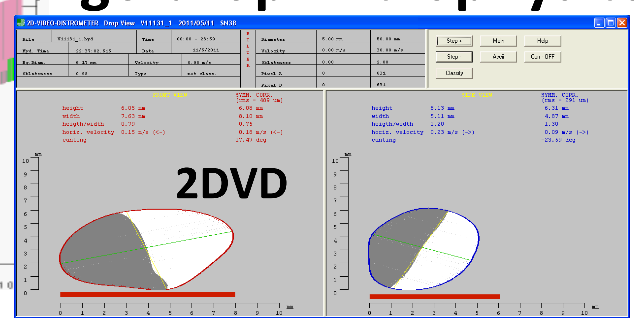


HIWRAP
CoSMIR
AMPR
Ka-Ku and
10-183 GHz



NPOL

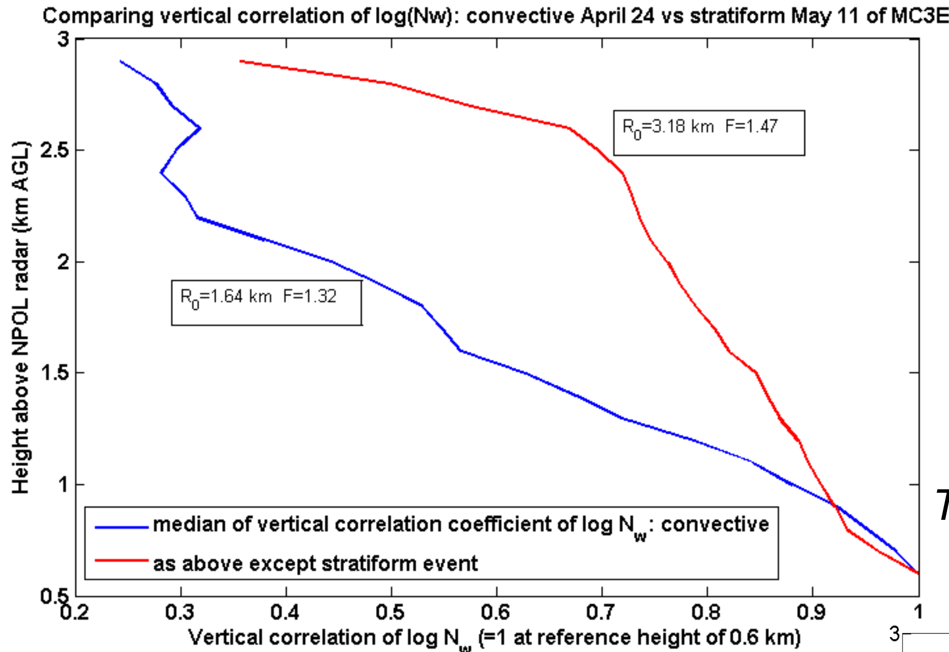
large-drop microphysics



8mm 6 mm

Regime physics and D_{max}?

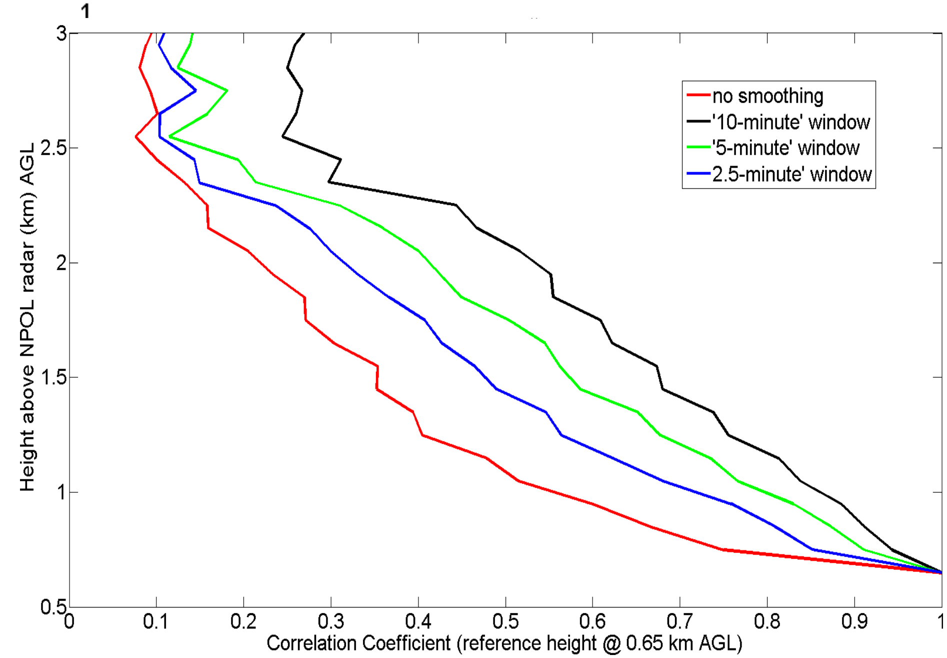
DSD Correlation (ρ) in the Vertical Column



N_w in Convective and Stratiform

Convective N_w decorrelates far faster than stratiform.

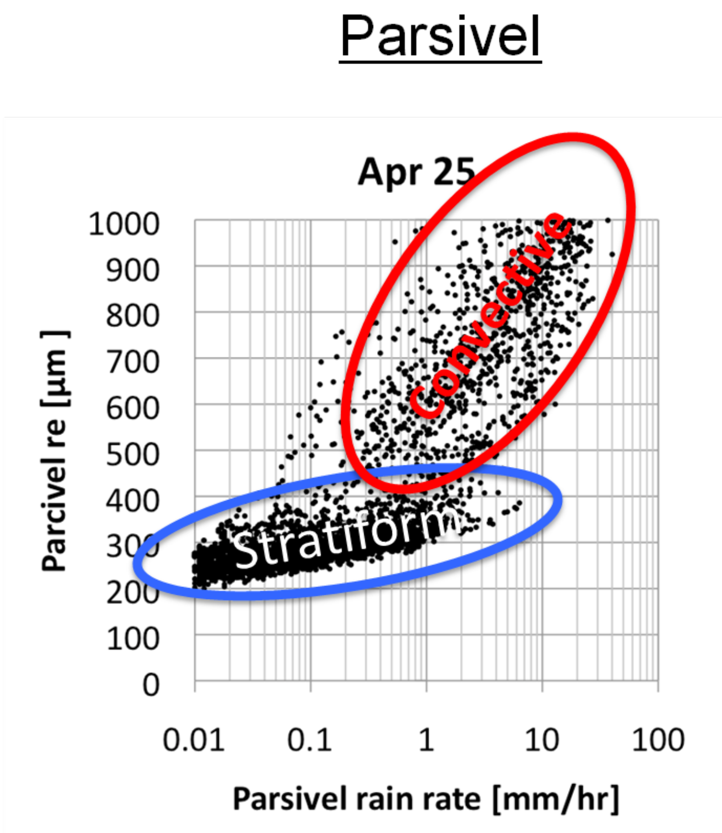
Tolstoy, Bringi, Thurai

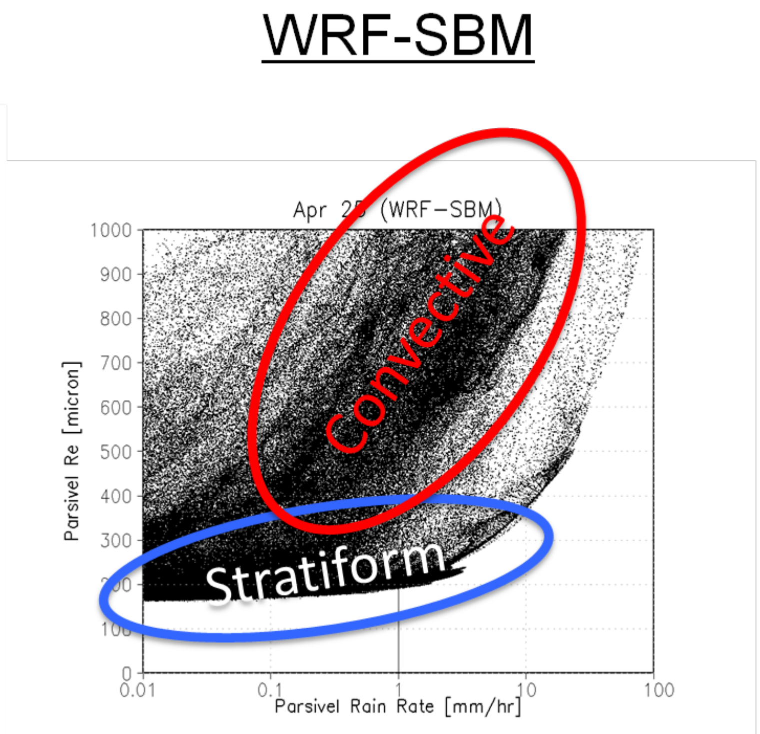


Result sensitive to "smoothing" ……what is best approach?

Domasczynski, Petersen, Wolff

DSD Data Use: Satellite Simulator (WRF-SBM) Validation



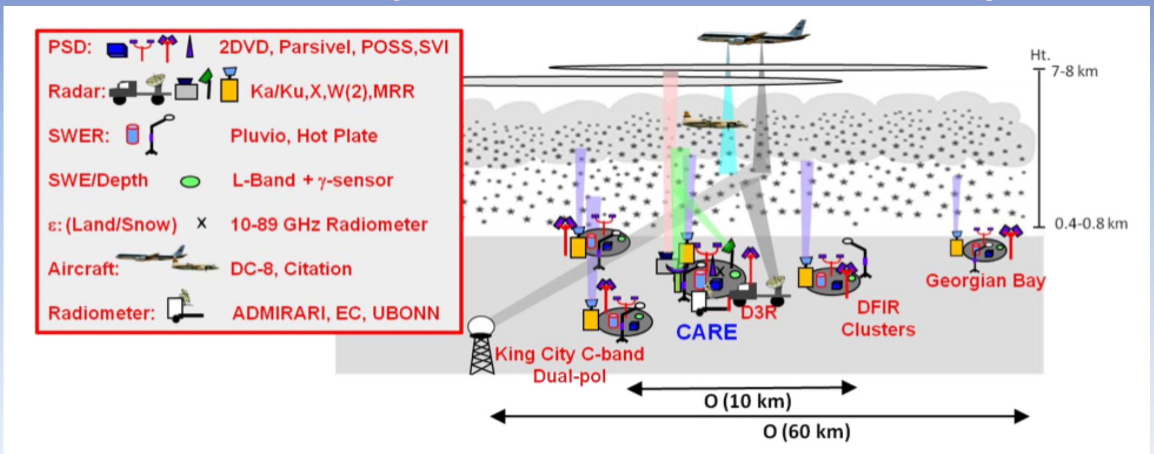


- MC3E April 25th MCS Case: DSD network observations vs. WRF-SBM
- Approximate agreement- increases confidence in model simulation(at least in liquid phase).

T. Matsui

Global Precipitation Measurement Mission (GPM) Cold Season Precipitation Experiment (GCPEX) 1/17/12 – 2/29/12 Egbert, Ontario, Canada

Observations to Improve GPM Satellite Methods for Detecting and Measuring Falling Snow



<u>“Top down” Approach</u>

- DC-8 “satellite” instrument view
- UND Citation aircraft: in cloud snow particle measurements
- Ground-based remote sensing – snow and snowpack at surface

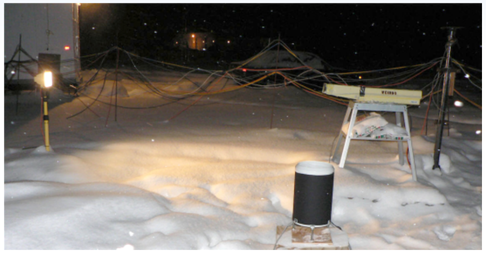
From the Top (NASA DC-8) APR-2 and CoSMIR

In-situ microphysics: UND Citation, NRC C-580

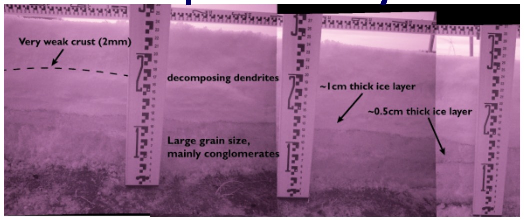
Ground-based Remote Sensing: EC King City Radar NASA D3R Radar, McGill Verti-X, W-band

Ground: NASA/EC Disdrometers, gauges, and Micro Rain Radars

NASA Snow Video Imager



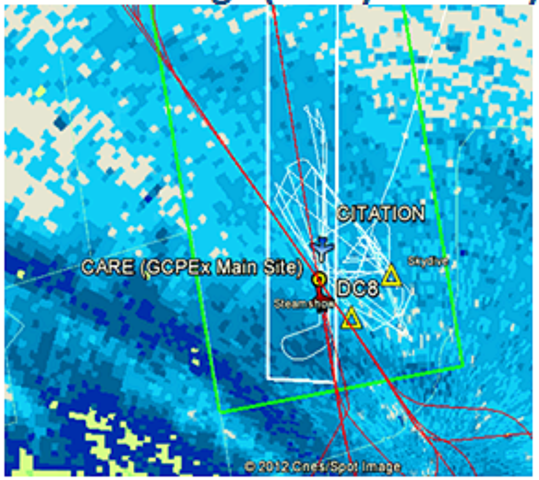
EC Snowpack Survey



GPM: Example of Collective Measurements 1/30-31 Case

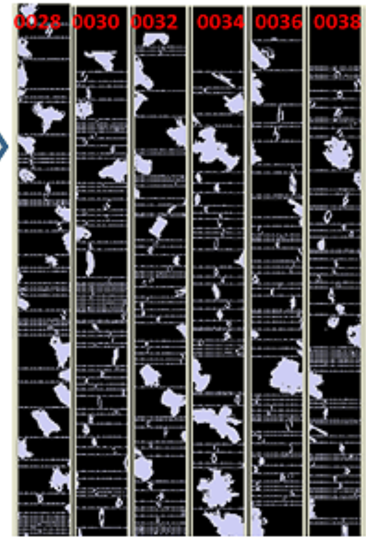
DC-8 Airborne *(satellite)*

Stacked Legs (DC-8/Citation)



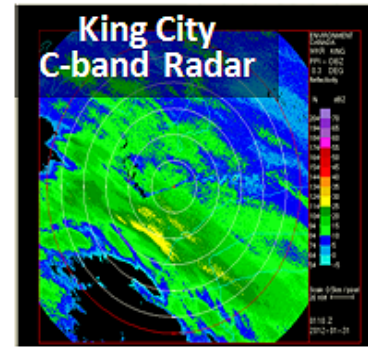
Citation Airborne *(cloud)*

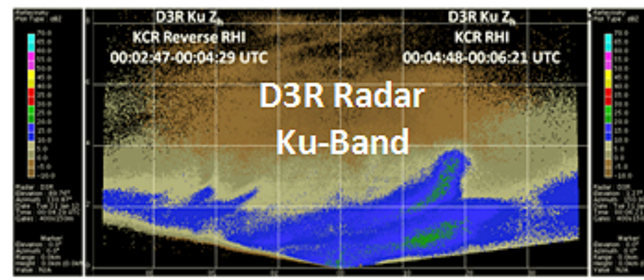
Snow microphysics profiles



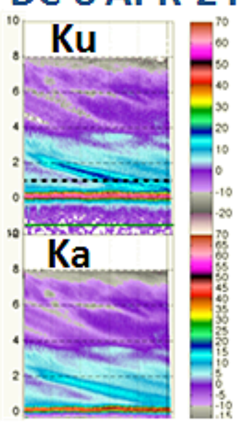
Grnd. Instruments (surface)

Regional to Particle Scale

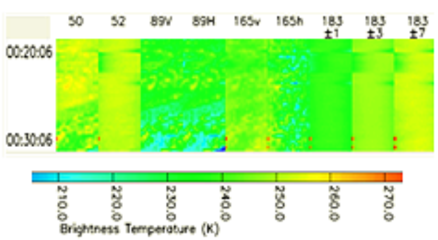




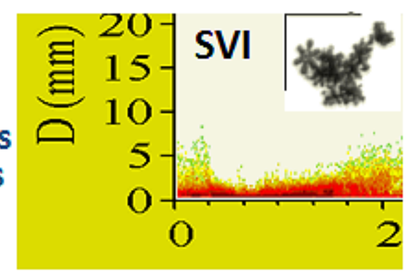
DC-8 APR-2 Radar



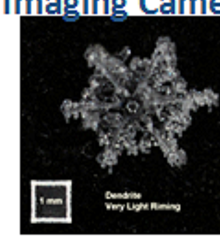
DC-8 CoSMIR Radiometer



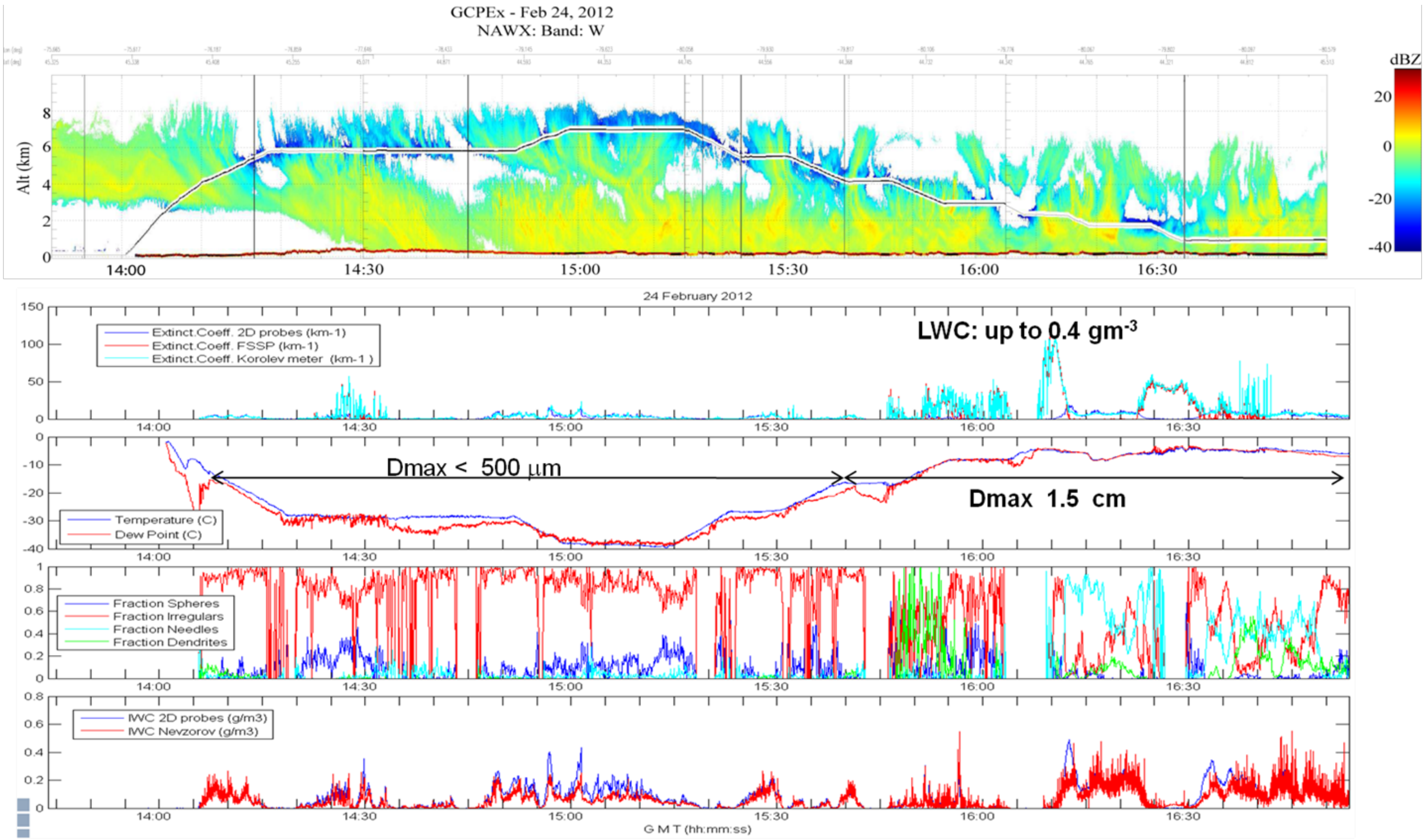
SVI Size Distributions And images



U. Manitoba Imaging Camera



GCPEX C580 Data 2/24/2012 Case



Consistent measurements by the different in-situ probes. The Particle classification result shows change in particle type and phase with altitude.

Courtesy: Mengistu Wolde, NRC

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

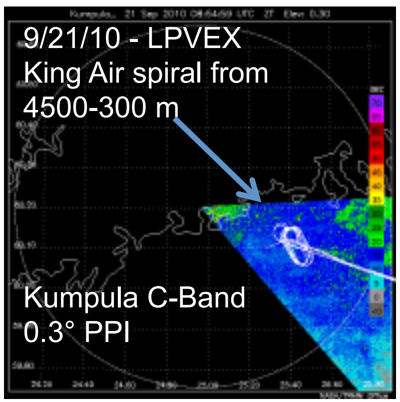
➔ Easy to use hypothesis-testing tools for algorithm developers and cloud resolving modelers

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

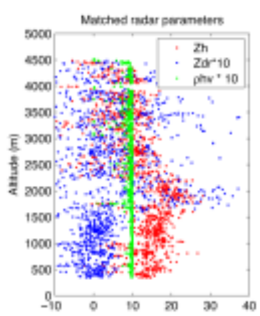
MGRAD – Merged Ground-based Radar-Aircraft Data

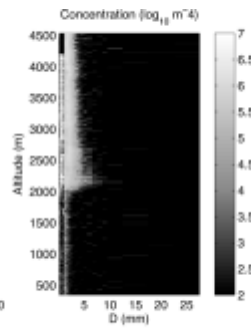
Space-time matching of ground-based polarimetric scanning radars with aircraft microphysics (C3VP, LPVEX, MC3E, GCPEX,…)

MGRAD in action – LPVEX 9/21 Spiral

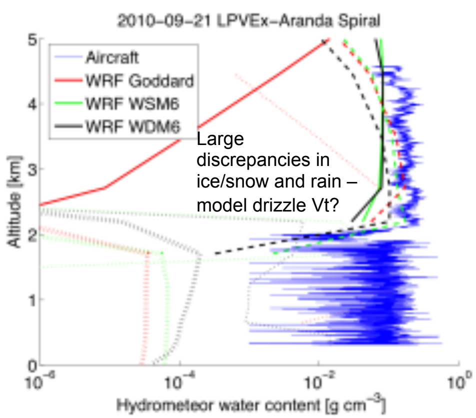


(below) Matched radar and aircraft show aggregation, lgt. rain/drizzle

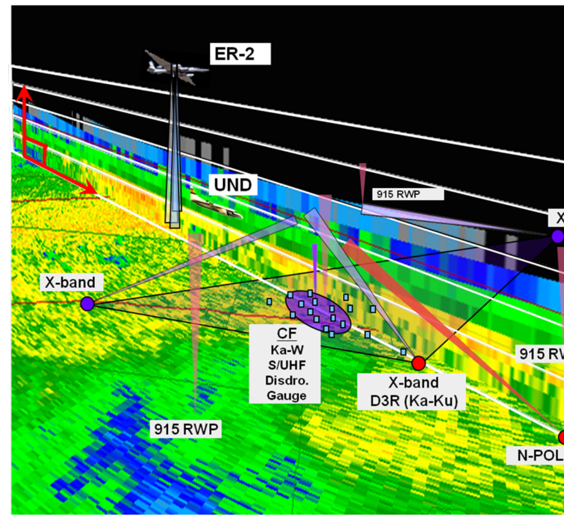




Prelim. comparisons of 1 km WRF simulations (using Goddard, WSM6, and WDM6 microphysics) of Qi (soild), Qs (dashed), Qc (dots), Qr (wide dash) with UWKA/Heymsfield/ Bansemer TWC retrievals



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

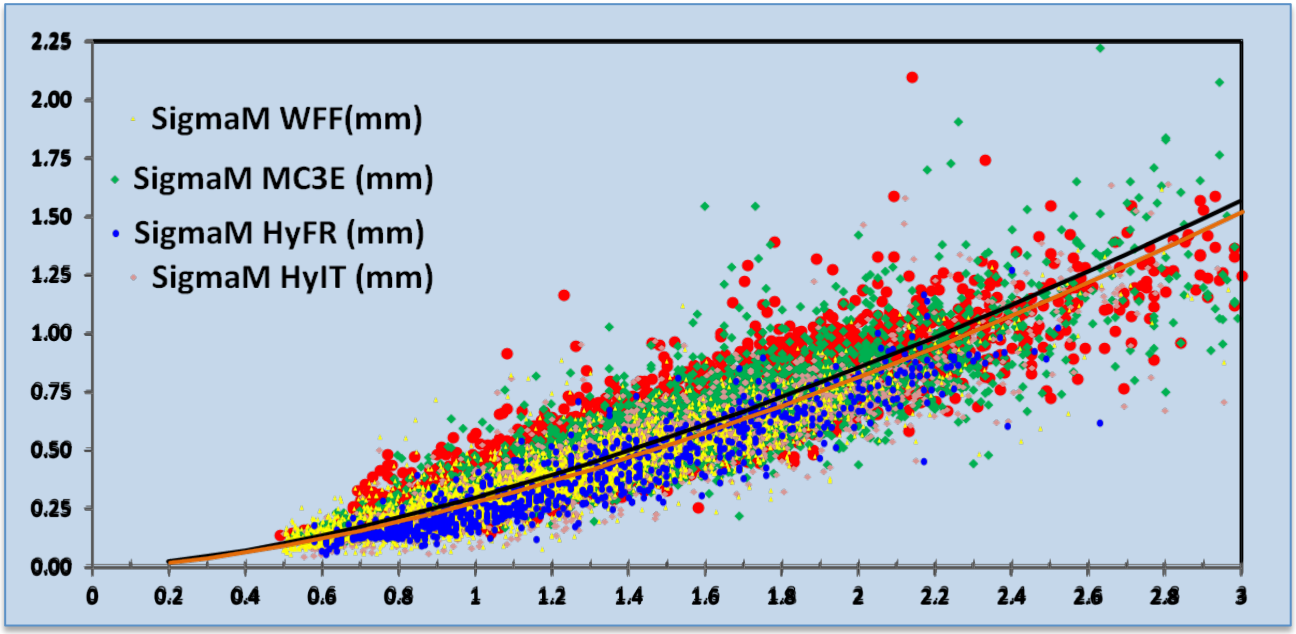
LPVEX MGRAD 1.0 available for Sept 21, Oct 20

MC3E MGRAD 1.0 is processing en masse

MC3E SatSimRAD beta …..working….

"Global" Gamma DSD Parameter Constraints

- ***Observations: Similar σ_m vs. D_m in GV datasets from Huntsville, MC3E, France, Italy, Finland, Wallops……***



For a Gamma DSD and *no truncation:* $(\sigma_m/D_m)^2 = 1/(4+\mu)$

Observational fit (orange line): General power law: $\sigma_m \approx 0.3 * D_m^{1.5}$

$(\sigma_m \approx \sigma_y * D_m^{b})$

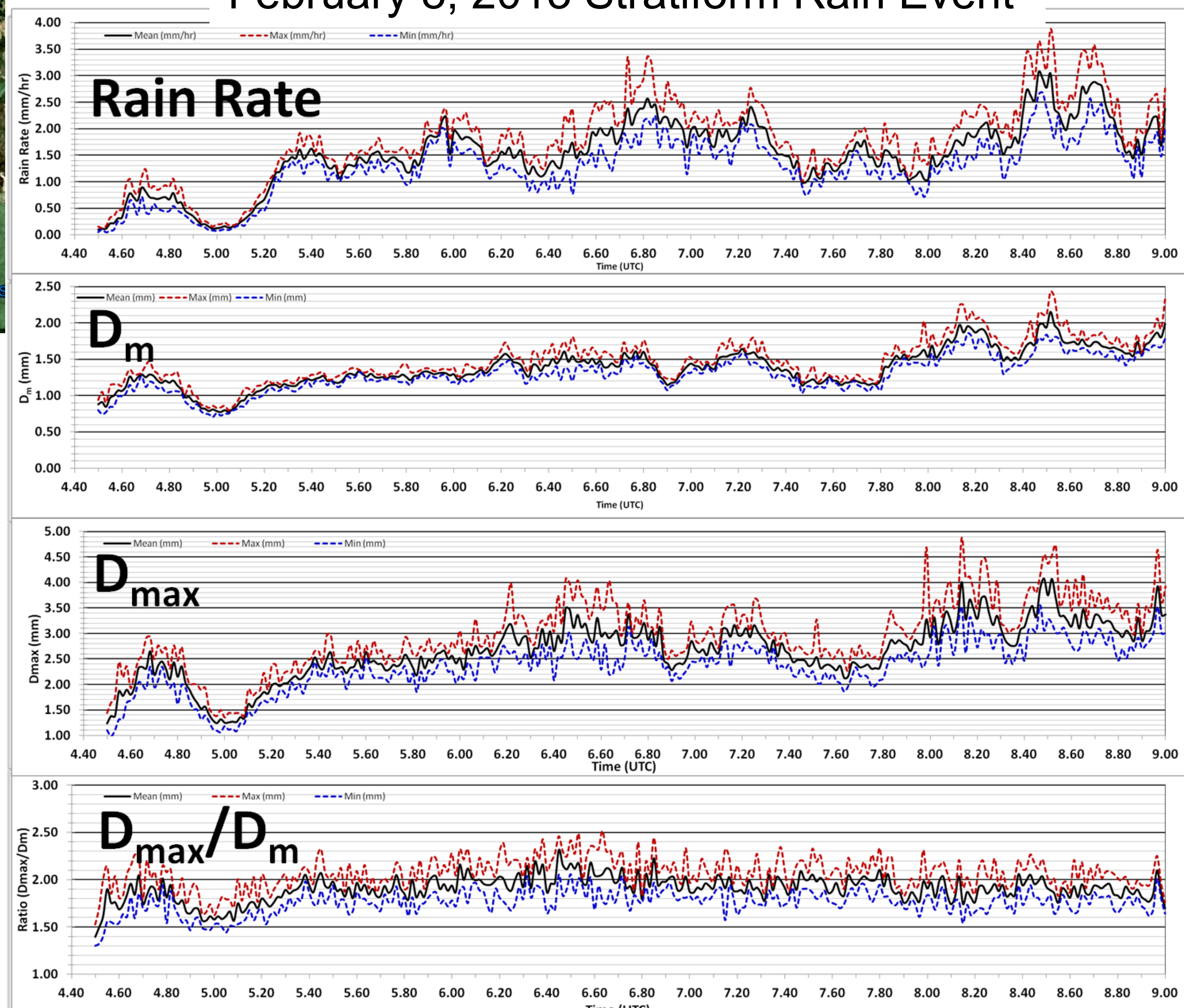
$\mu = 11/D_m - 4$ (black line)

μ constraint: Reducing the range of possible solutions

WFF: Sub-Pixel Precip/DSD "Texture"

5-site disdro, 4 km²

February 8, 2013 Stratiform Rain Event



Multiple 2DVD 1-min.
mean, max, min values

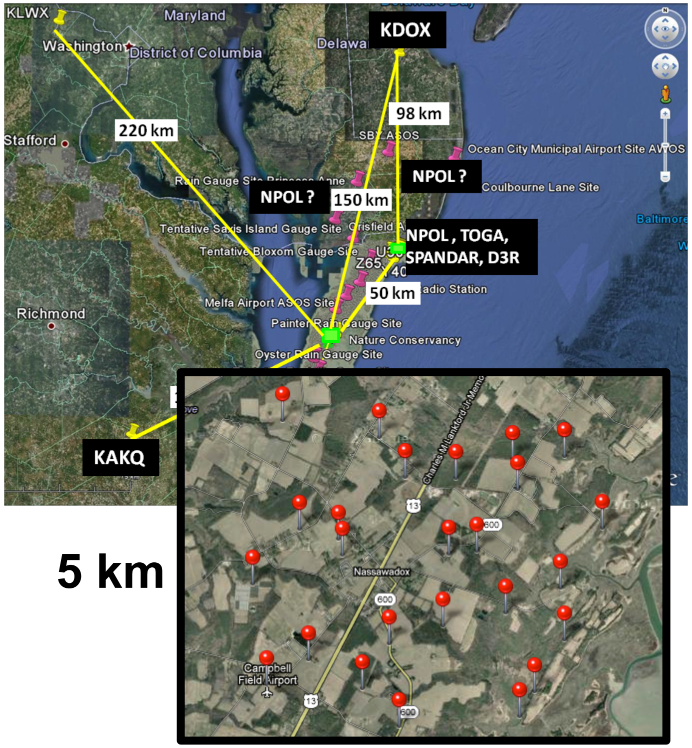
Rain (~20%)
D_m (5%-10%)
D_{max} (15%) D_{max}/D_m(10%)

$D_{max} = 1.6\text{-}2.0 * D_m$

Add- σ_m-D_m spatial variability

One minute intervals

WFF-Nassawadox Dense Gauge Network: Rainfall “Granularity”



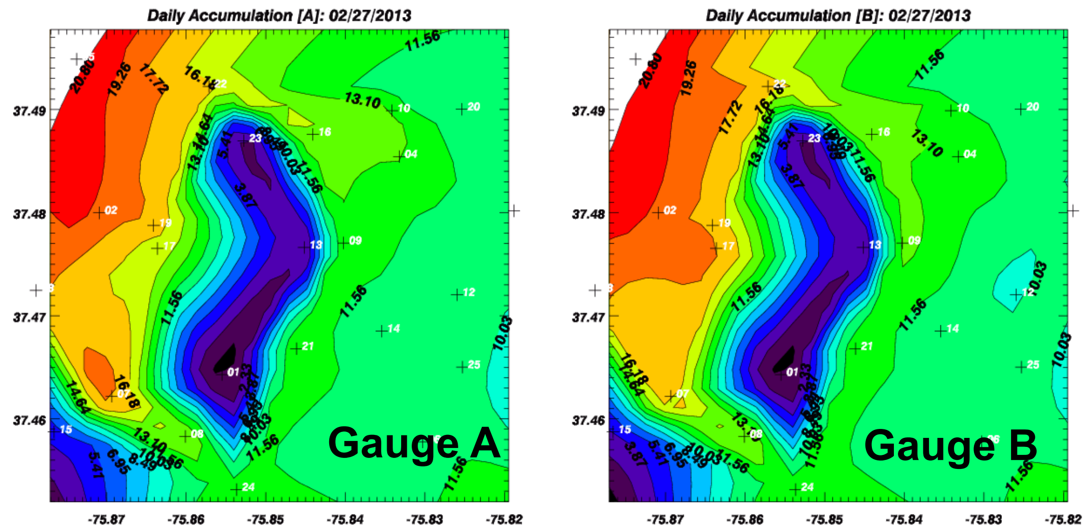
5 km

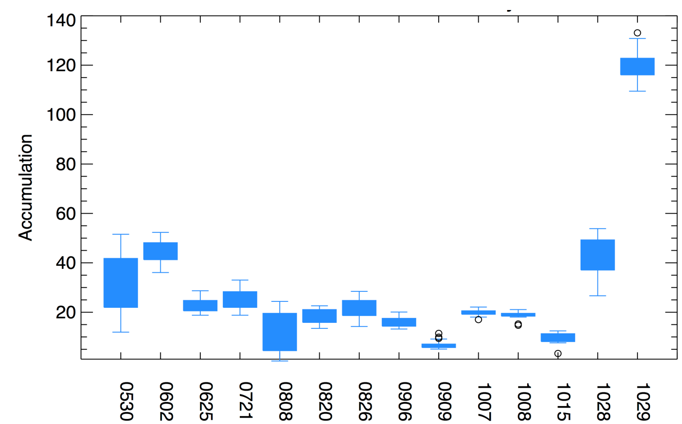
5 km

25 km2 (DPR footprint; GMI HF footprint)

50 gauges, installed on 25 **dual-gauge** platforms- **Gauge redundancy is critical**

Rainfall 27 Feb. 2013: Nassawadox Grid





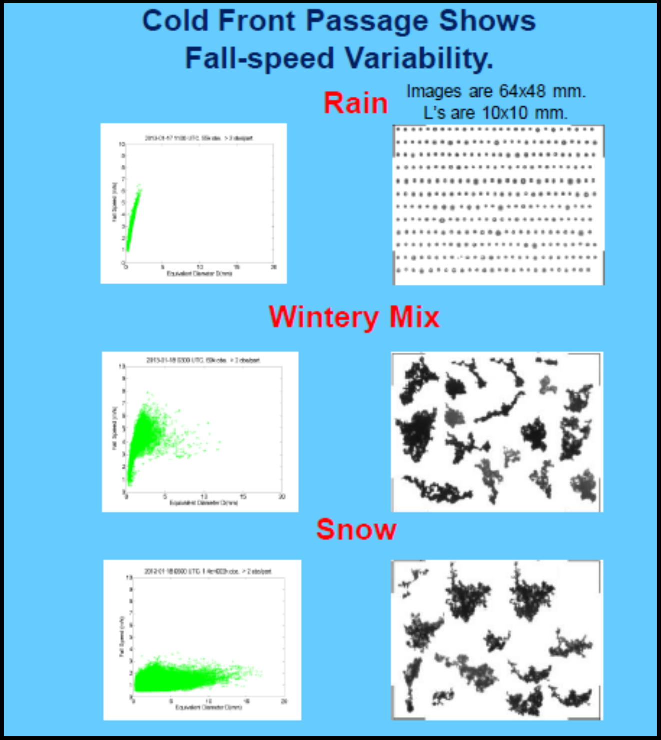
- Variability often large on daily time scales!
- Enough data for NMQ study now………

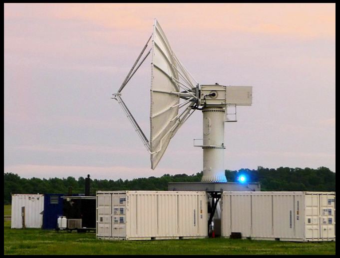
WFF-PRF: Recent Winter Liquid, Mixed Phase and Snow

PVI-2: Upgrade- PSD, imagery, fall speeds

- Identify, track, size, count each snow crystal/flake
- Integrate to create distributed targets as "seen" by radars/radiometers
- Current work: Mass estimate via diameter, fall speed and grey-scale
- Systems for Canada, Finland (SPICE sites).

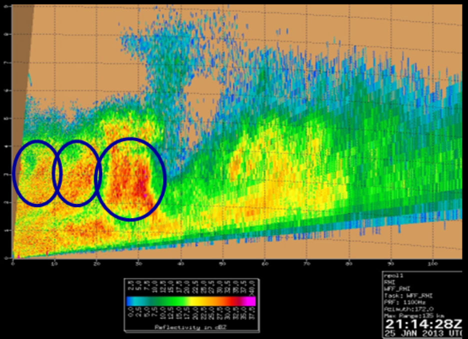
Liquid – mixed phase – Snow

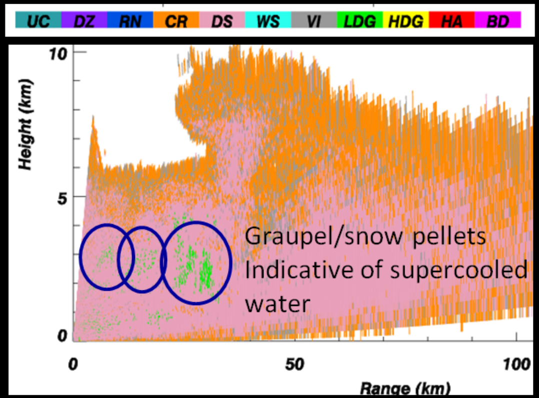




NPOL Data Collection Snow

Snow generated in elevated embedded "turbulent" cells – seeder-feeder!

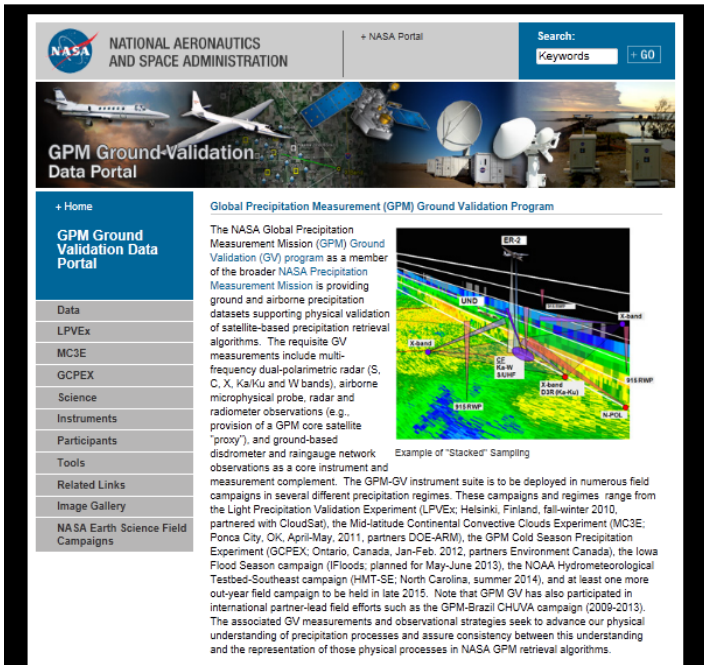


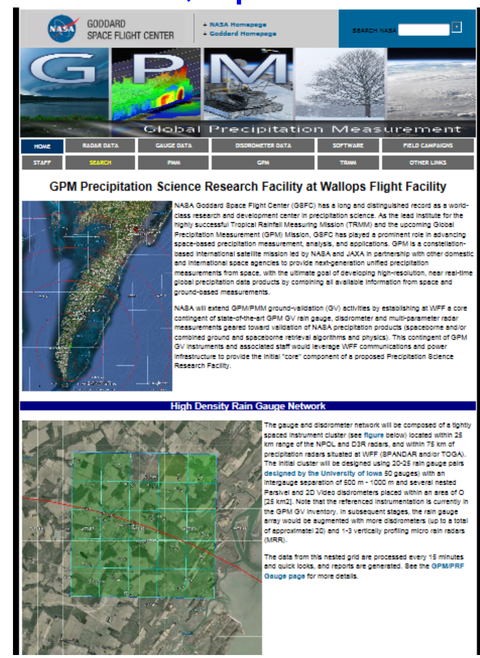


Data Location and Case Summary

Main NASA GV Field Campaign Data Portal: http://gpm.nsstc.nasa.gov/

Follow links to NASA Campaign data (includes campaign logs and summaries etc.) there are subsequent links to partner data sites, special datasets





Partner and associated field data links:

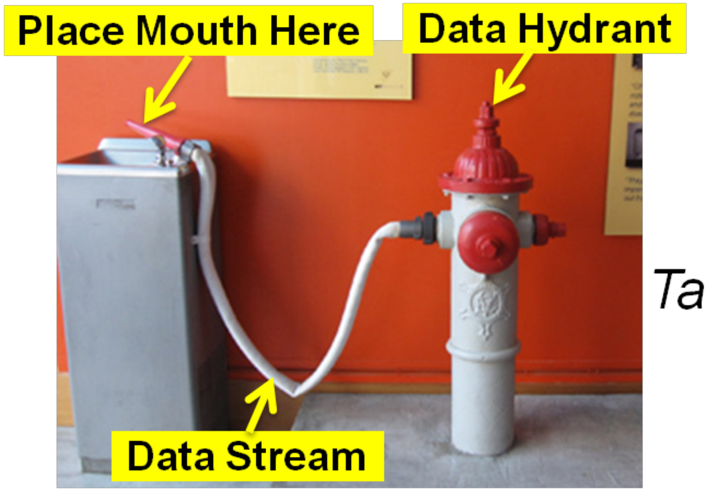
LPVEX: http://lpvex.atmos.colostate.edu/
DOE-ARM/MC3E: http://www.arm.gov/campaigns/sgp2011midlatcloud
CHUVA: http://chuvaproject.cptec.inpe.br/portal/noticia.ultimas.logic
HyMEX: http://mistrals.sedoo.fr/HyMeX
WFF GV Precip Facility: http://wallops-prf.gsfc.nasa.gov/

Summary

- "Hydrometeor" datasets collected to support physical validation in pre-launch era (C3VP, LPVEX, CHUVA, MC3E, GCPEX, HyMEX…..WFF)
- Large volume of quality datasets across multiple-regimes (cold/warm season); more available via partner-led field campaigns and data-servers.

http://gpm.nsstc.nasa.gov/

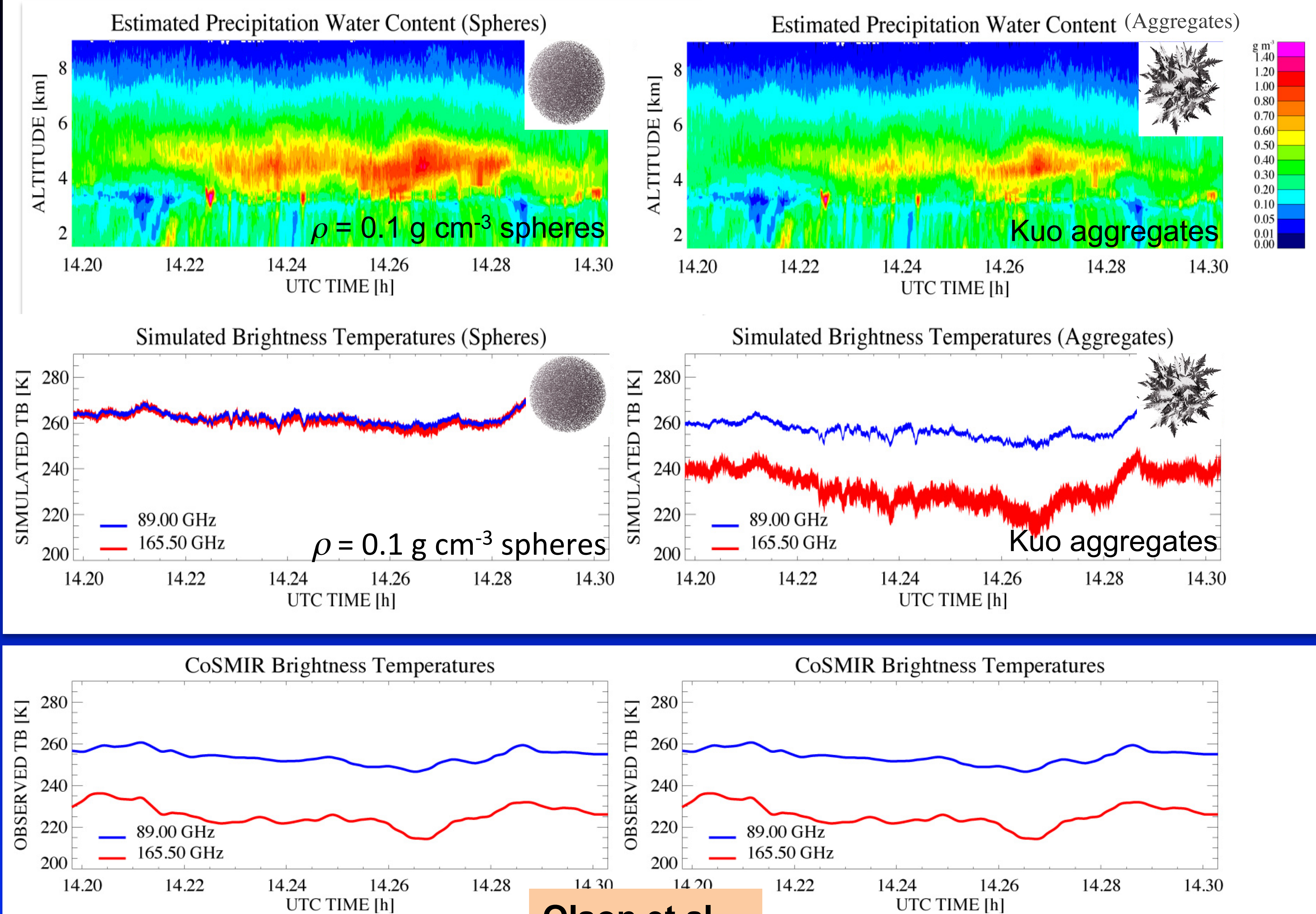
- Some progress on campaign case analyses; DSD studies across campaign spectrum
- "Building the column" MGRAD/SatSimRad products should facilitate analysis
- Value-added datasets can be archived on GPM GV data portal
- More to come……, IFloodS, IPHEX, ……………………….
- Need more analysis coordination, dataset prep/input, analysis "density" still problematic.



Take a sip!

EXTRAS

Radar Retrieval and Simulation of TB's Using Spherical/Aggregate Ice



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