

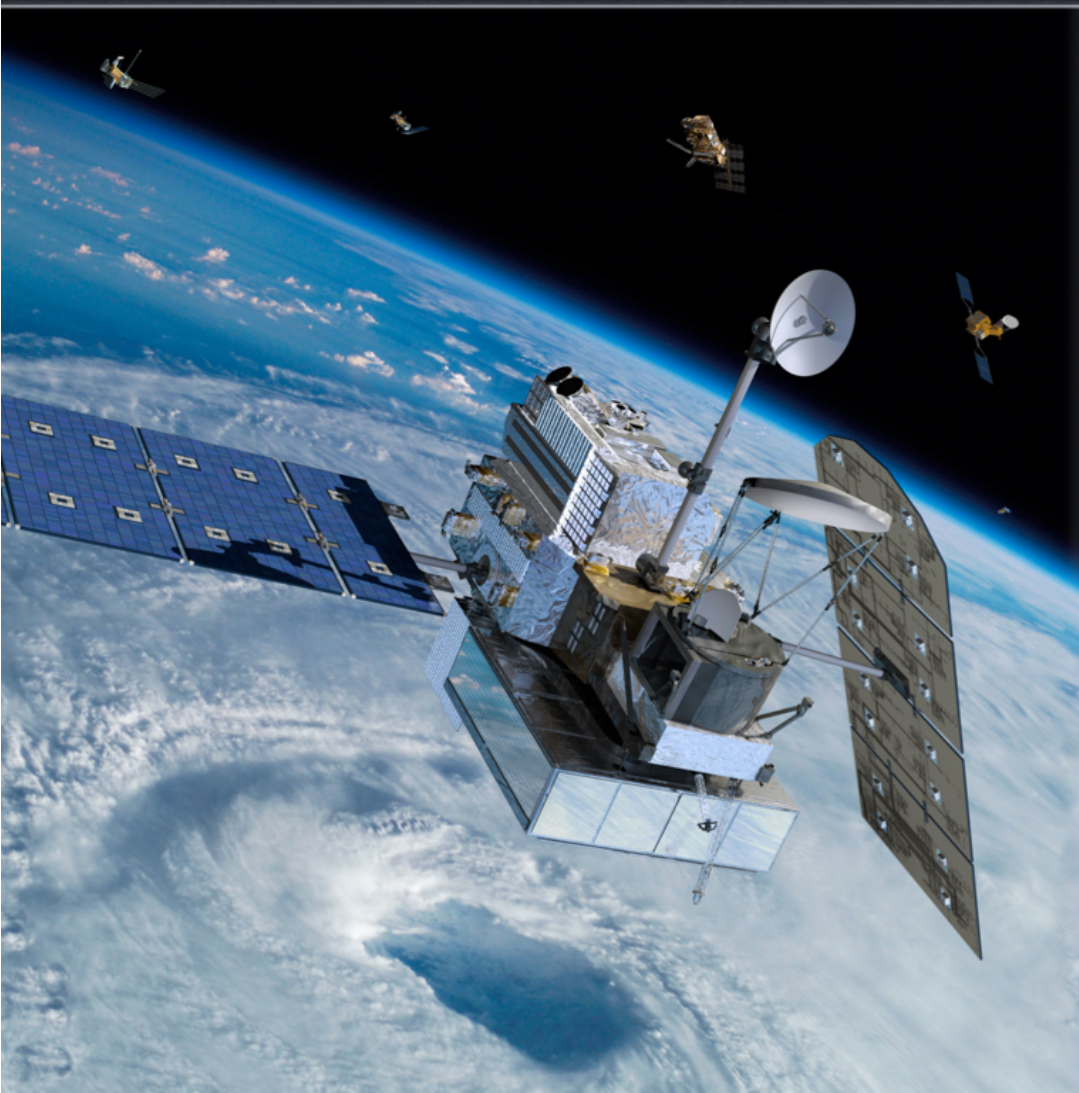


Synthesis of GPM Field Campaign Hydrometeor Datasets for Precipitation Retrieval Algorithms



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Outline

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

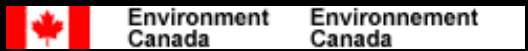
Acknowledgement: Matt Schwaller
NASA GSFC and GPM Flight Project



GPM Ground Validation

Physical Process Validation Drives Collection of “Hydrometeor” Datasets

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



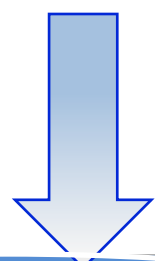
C3VP



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	♦	♦	♦	♦													

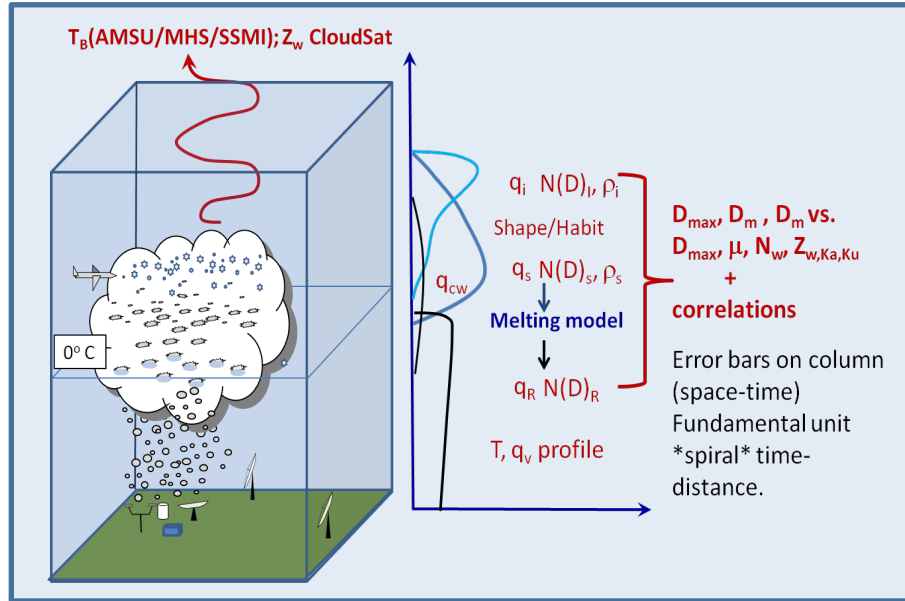
• Define relevant parameters to observe

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_{hyd} , LDR	☒		☒	☒	☒	☒												
	D3R Ka/Ku Dual-Pol	Z, Vr, DFR, W, ZDR, Φ_{DP} , ρ_{hyd} , 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_{hyd} , 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										☒	☒								

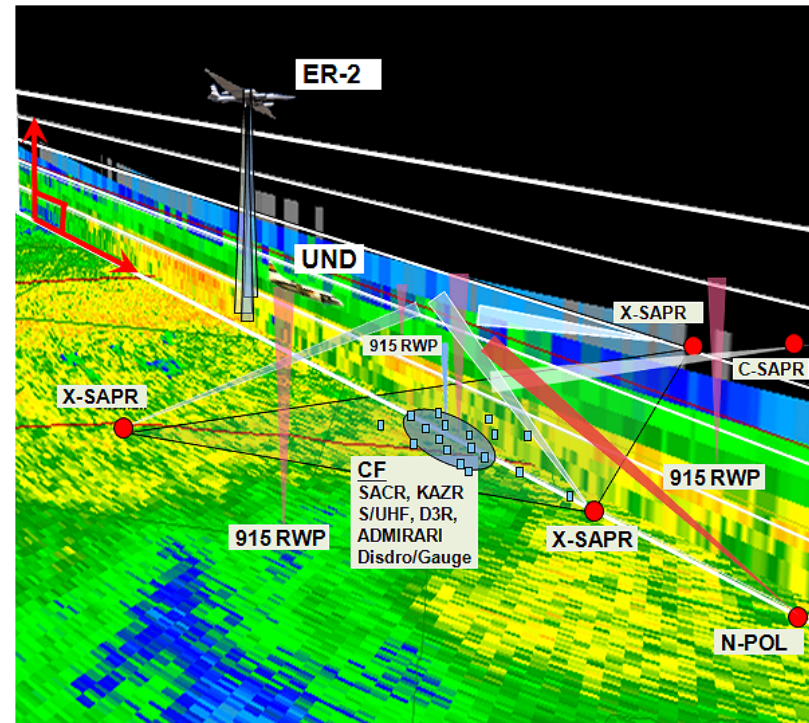


“Building the Column”

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



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)

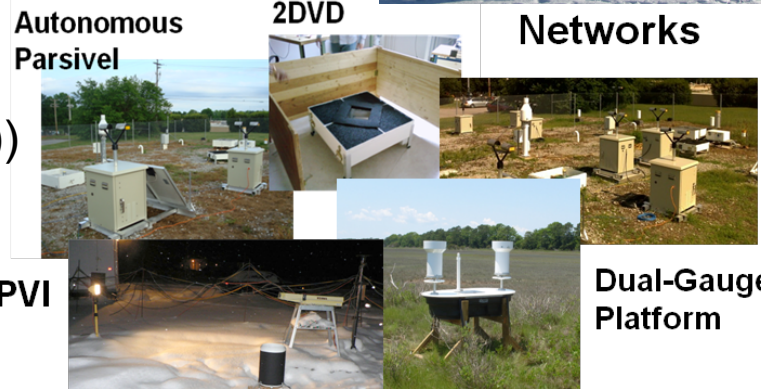
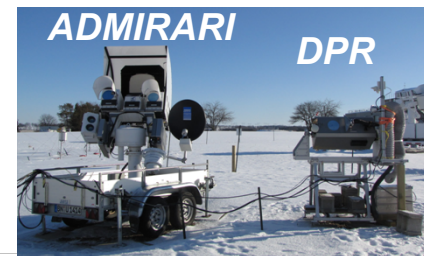
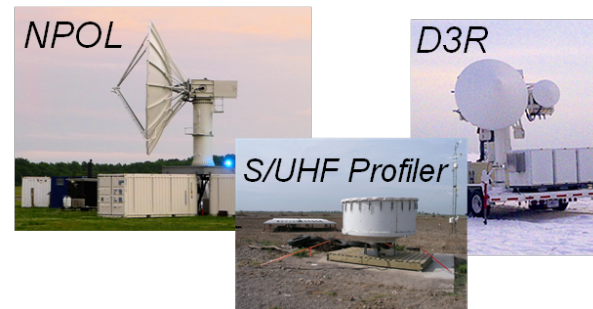
Column TB, Water Path

- 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



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), Δ TB, 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.

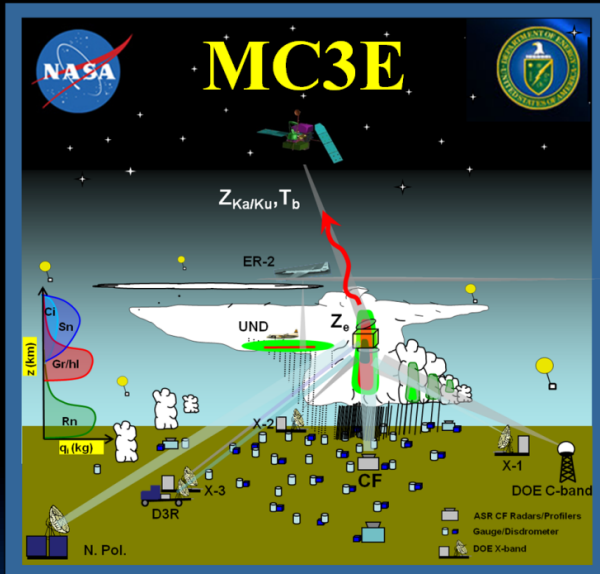
POSS: 1-minute, DSD, rates, DSD moments, Z, dual-pol-moments.....

Precipitation Video Imager: PSD, High-res. imagery



Mid-latitude Continental Convective Clouds Experiment

April 22 – June 6, 2011



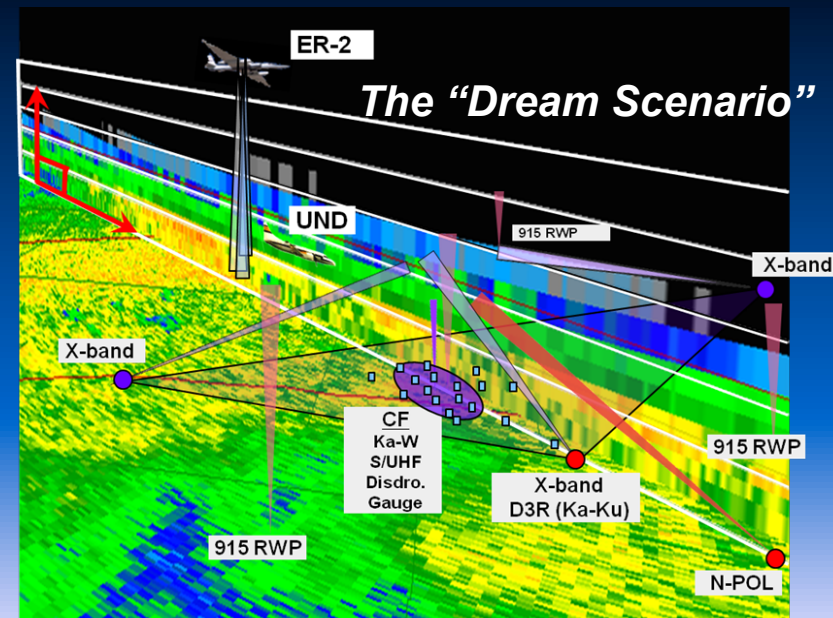
Location: DOE-ARM SGP Central Facility, N. Oklahoma and NE Colorado (CSU CHILL)

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

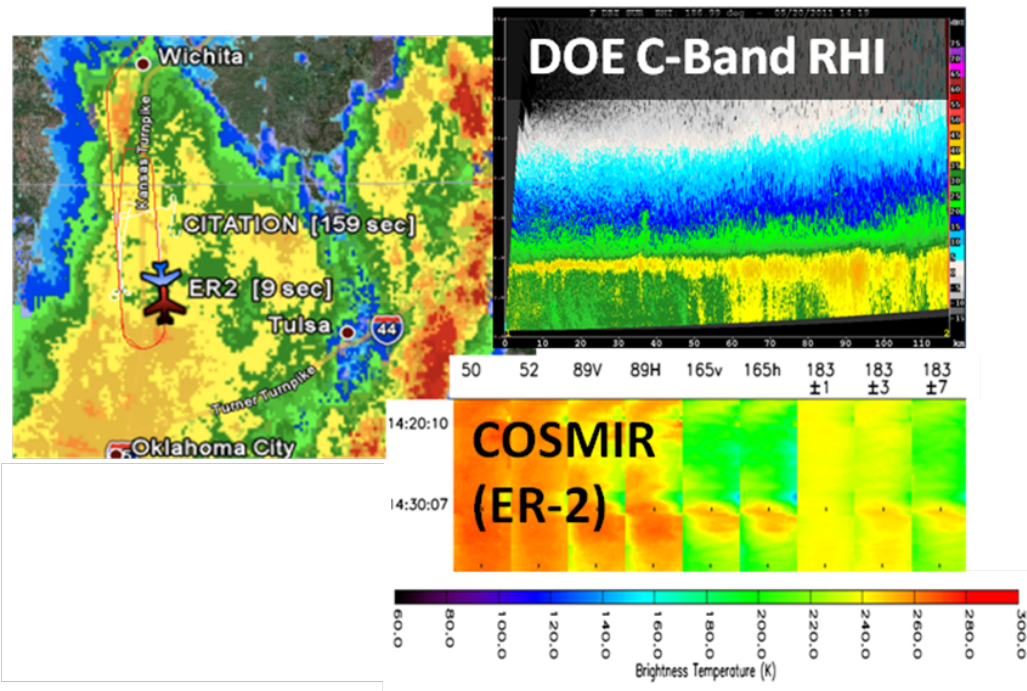




Example Operations and Observations

“Dream Scenario” Event: May 20

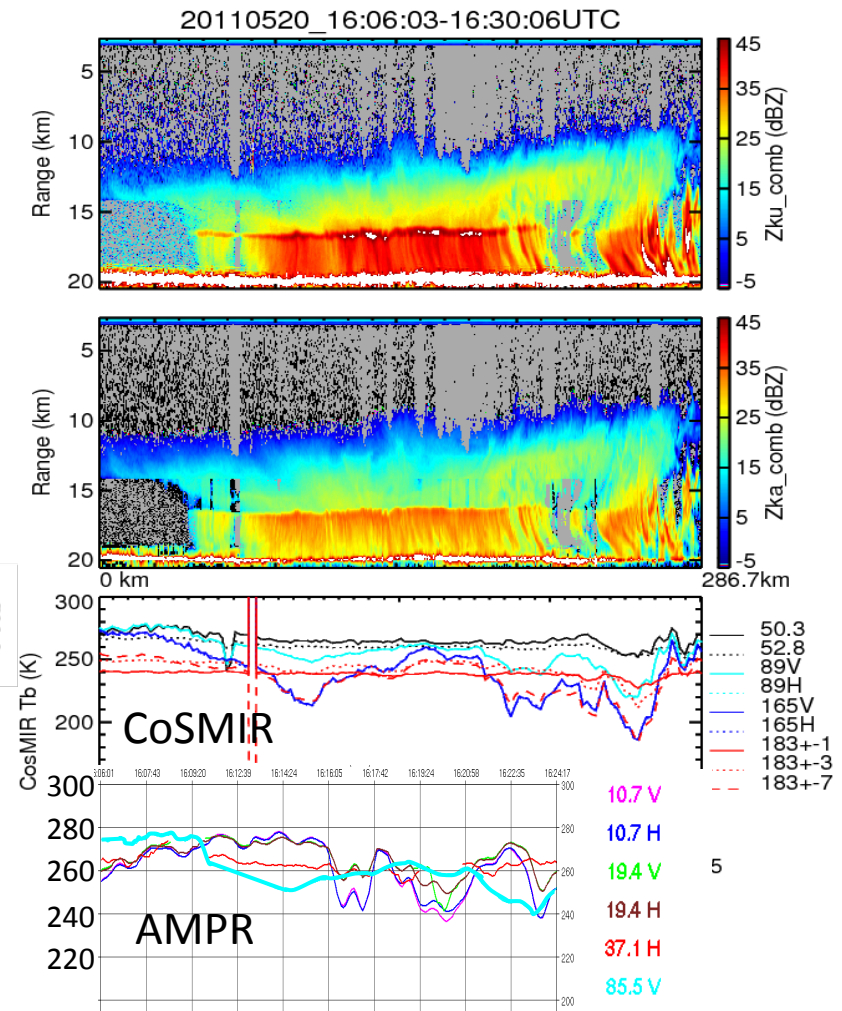
Early: Citation-ER-2 “Dream Scenario” stacks over/near SGP



Variety:

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

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



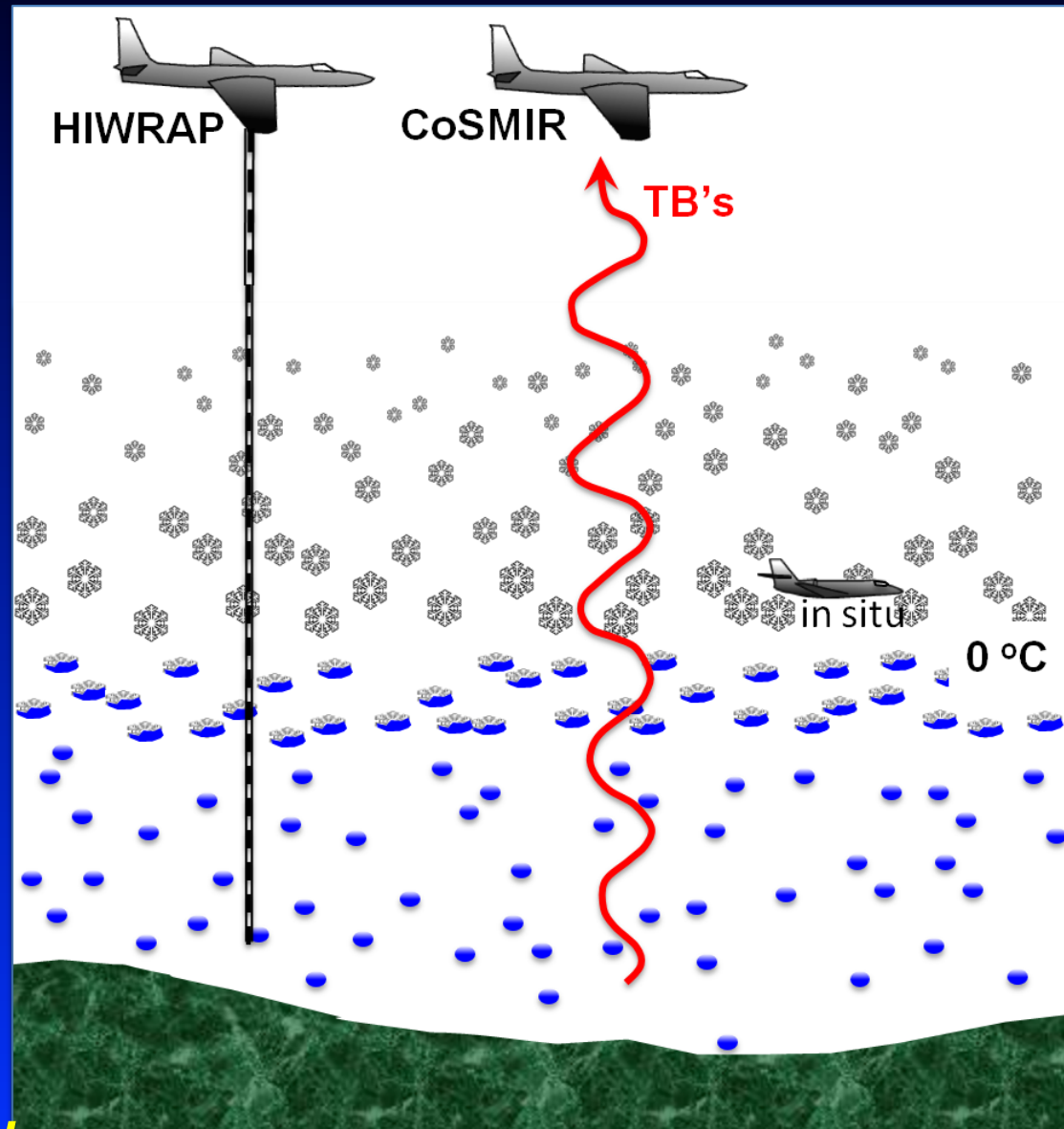
Evaluating Snow Physics Using HIWRAP and CoSMIR in MC3E

W. Olson et al. (WORK IN PROGRESS!!- 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.**

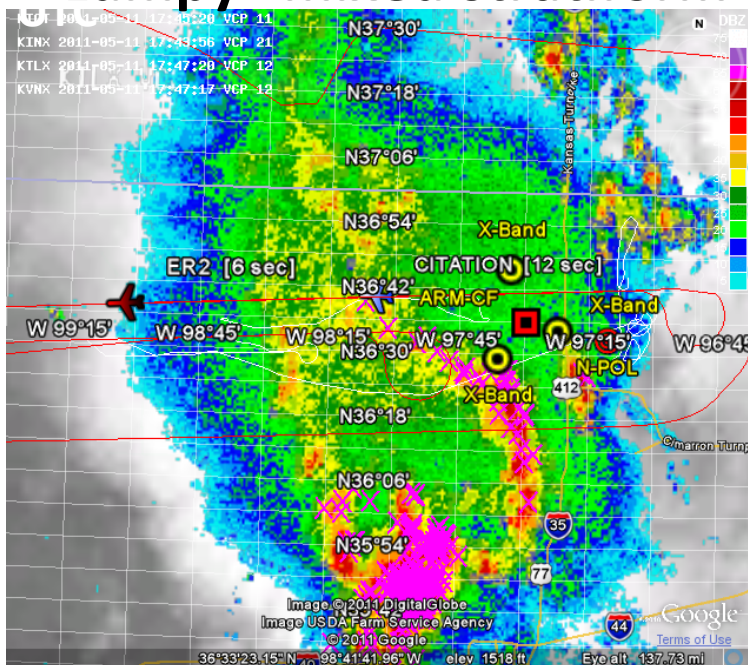
See Olson et al. talk for result!!



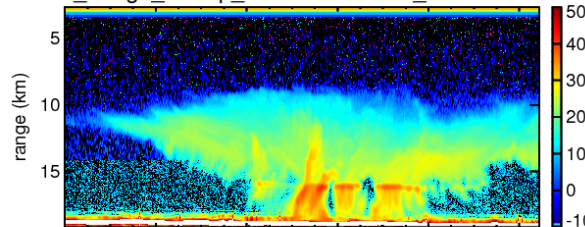


Example Operations and Observations: 11 May 2011

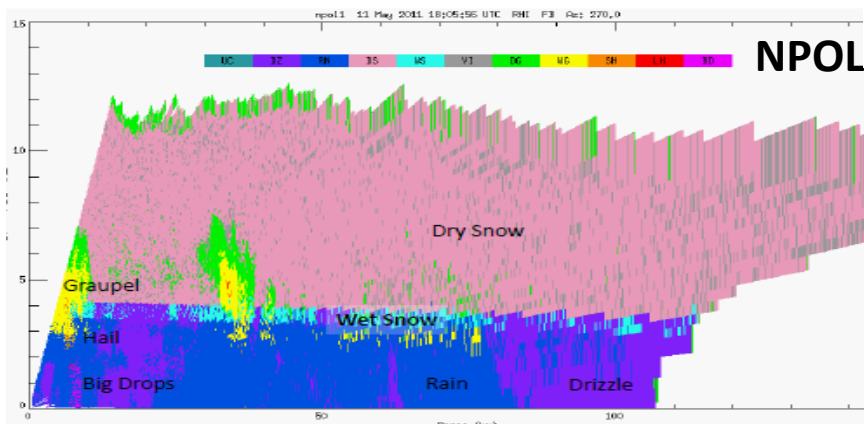
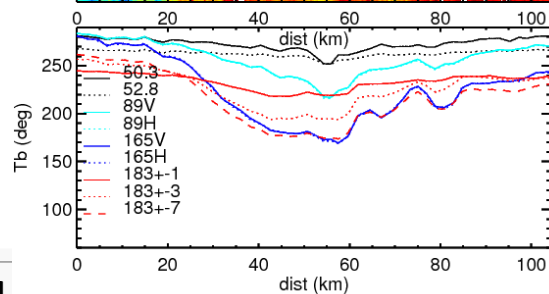
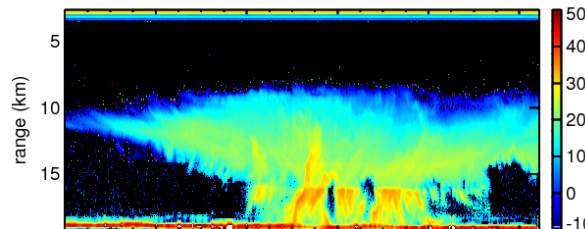
“Lumpy” mixed stratiform-convective sampling.....



mc3e_merge_hiwrap_cosmir20110511_164734-165609

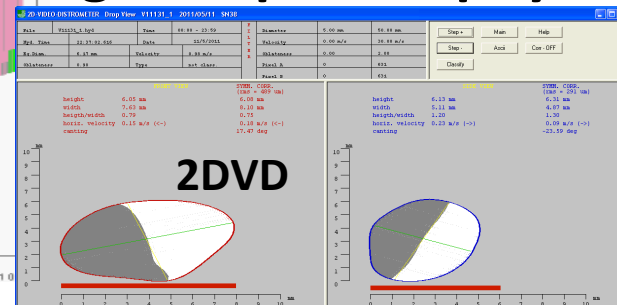


HIWRAP
CoSMIR
AMPR
Ka-Ku and
10-183 GHz



Regime physics and D_{max} ?

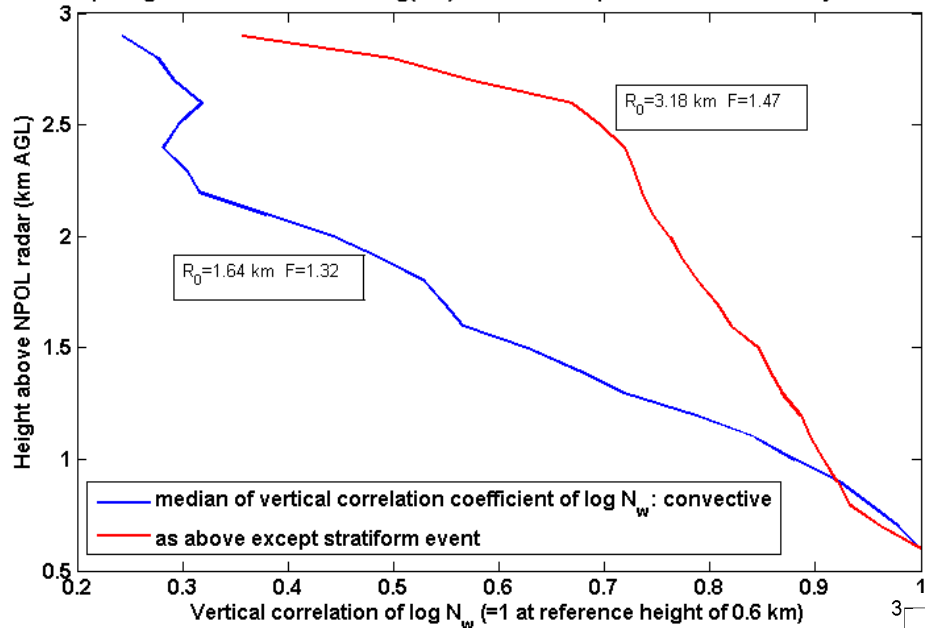
large-drop microphysics



8mm

6mm

Comparing vertical correlation of $\log(N_w)$: convective April 24 vs stratiform May 11 of MC3E



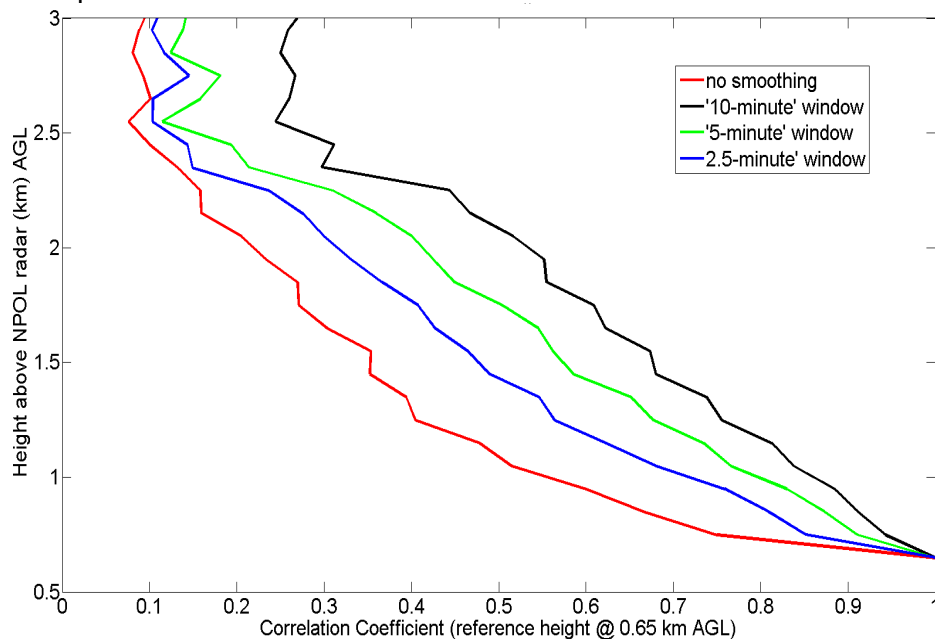
N_w in Convective and Stratiform

Convective N_w decorrelates far faster than stratiform.

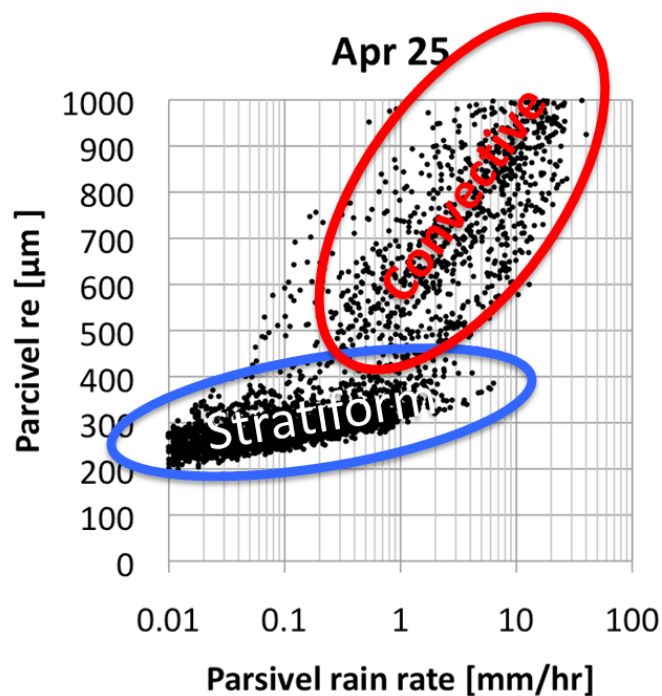
Tolstoy, Bringi, Thurai

Result sensitive to “smoothing”
.....what is best approach?

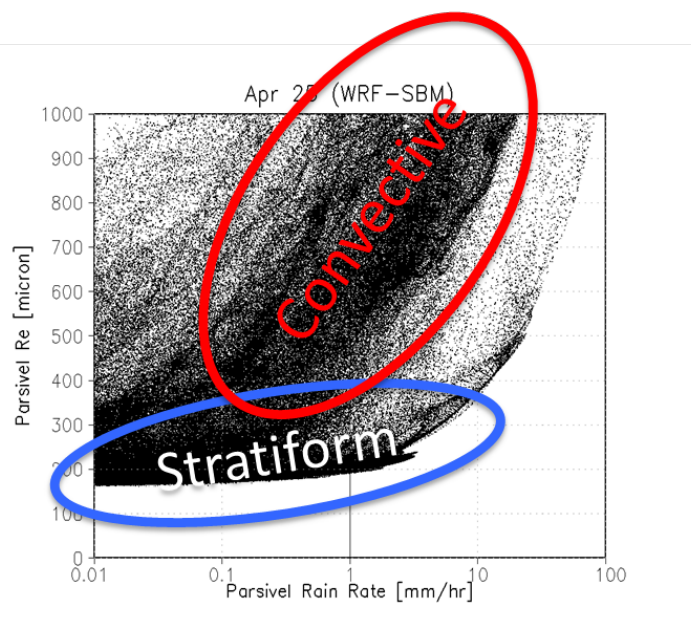
Domaszynski, Petersen, Wolff



Parsivel



WRF-SBM

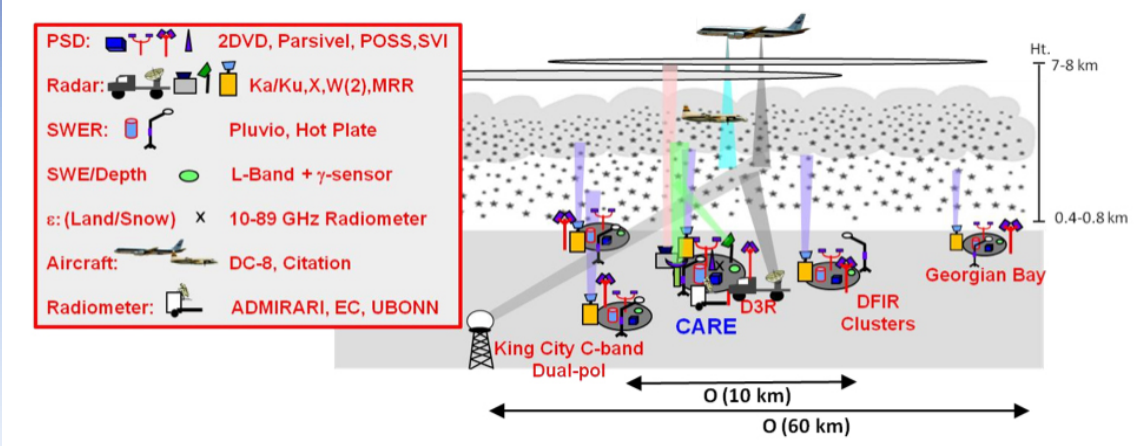


- MC3E April 25th MCS Case: DSD network observations vs. WRF-SBM
- Approximate agreement- increases confidence in model simulation(at least in liquid phase).



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



- “Top down” Approach**
- 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



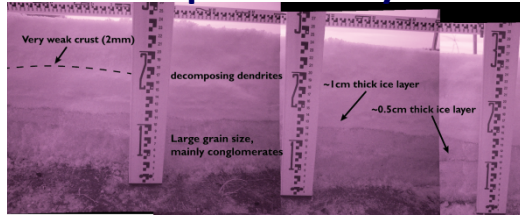
Ground: NASA/EC Disdrometers, gauges, and Micro Rain Radars



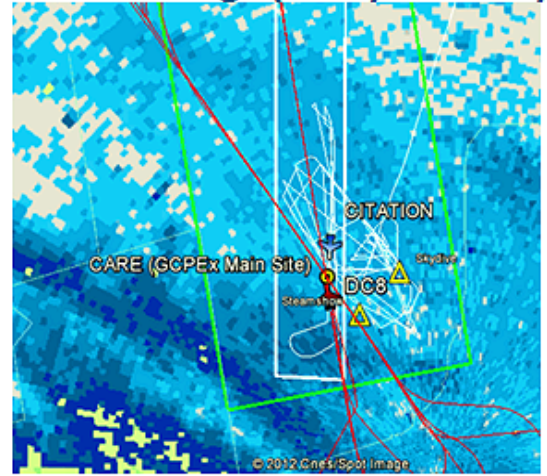
NASA Snow Video Imager



EC Snowpack Survey



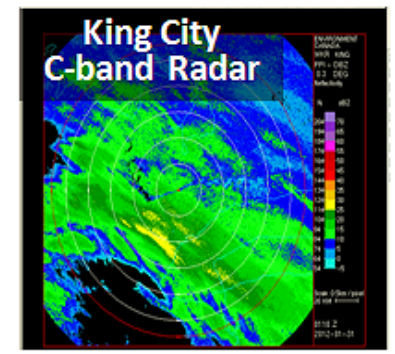
DC-8 Airborne (satellite)
Stacked Legs (DC-8/Citation)



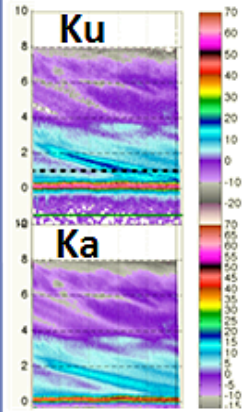
Citation Airborne (cloud)
Snow microphysics profiles



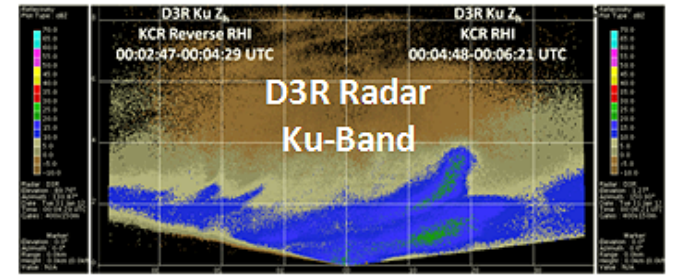
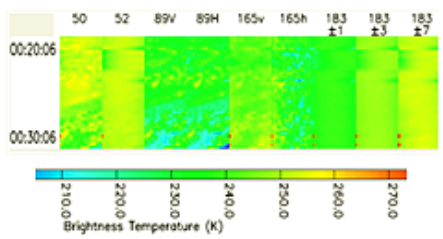
Grnd. Instruments (surface)
Regional to Particle Scale



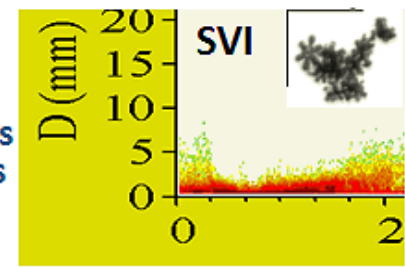
DC-8 APR-2 Radar



DC-8 CoSMIR Radiometer



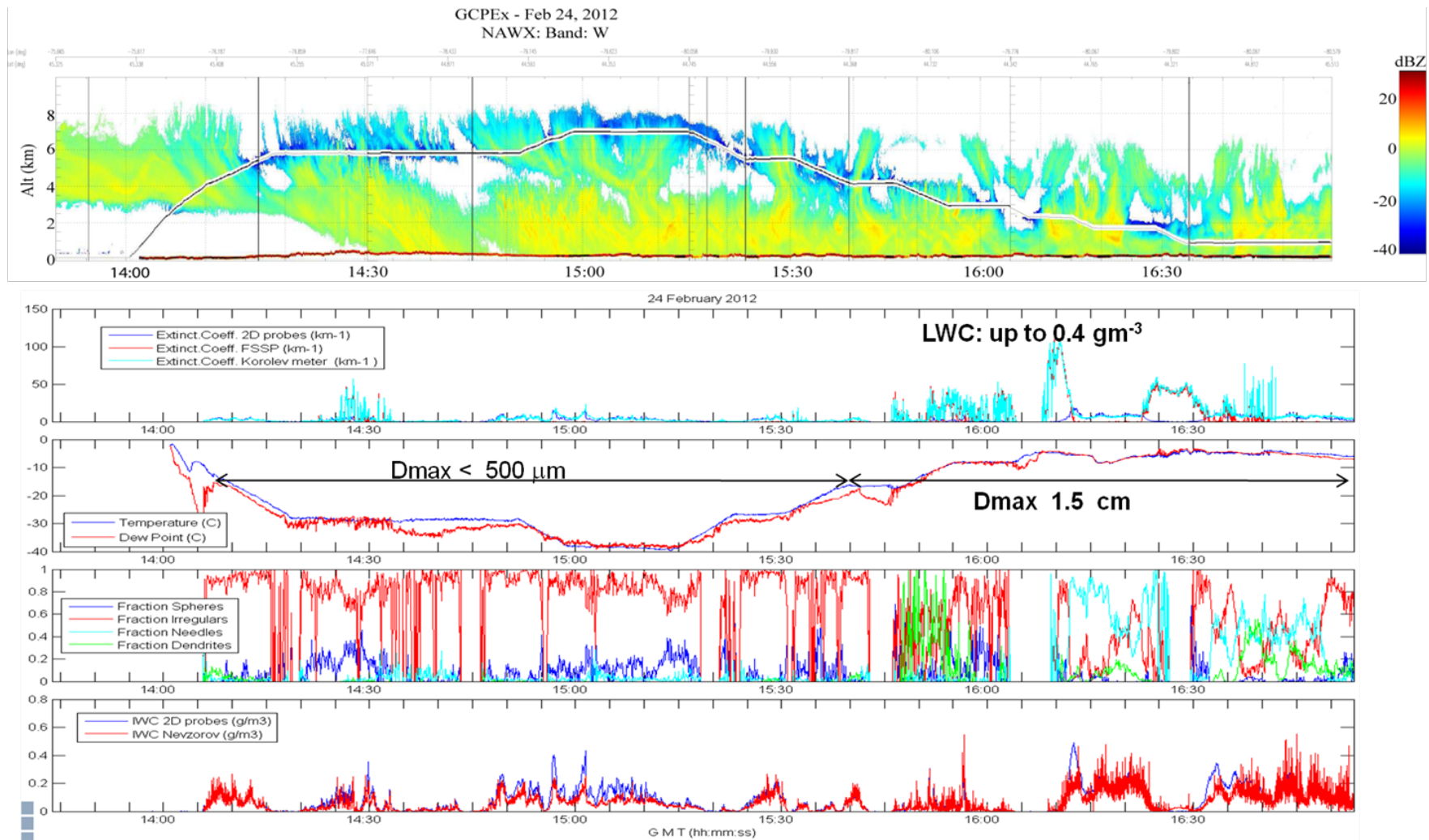
SVI Size Distributions And images



U. Manitoba Imaging Camera



GLOBAL PRECIPITATION MEASUREMENT



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

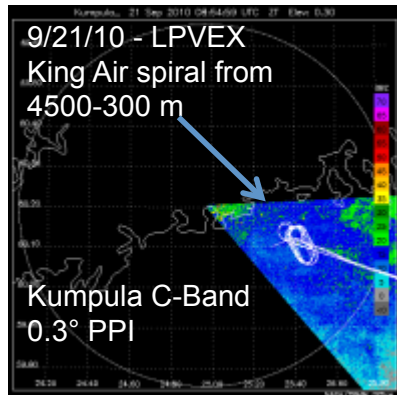
Matched aircraft in situ – aircraft radar/radiometer – ground radar products

➔ 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)

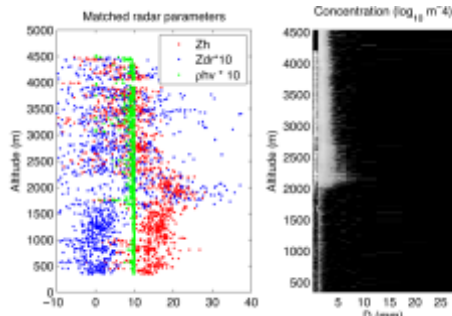
MGRAD – Merged Ground-based Radar-Aircraft Data

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

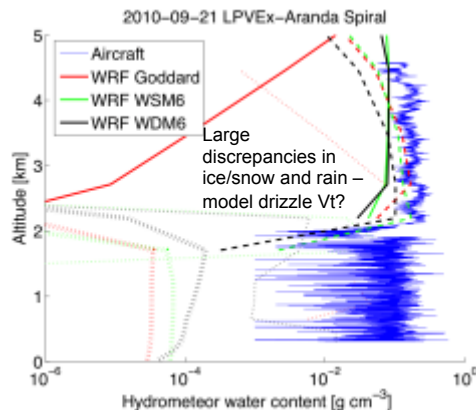
MGRAD in action – LPVEX 9/21 Spiral



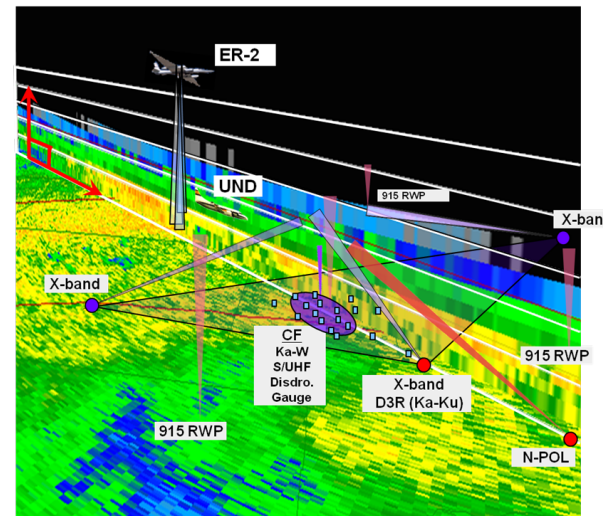
(below) Matched radar and aircraft show aggregation, lgt. rain/drizzle



Prelim. comparisons of 1 km WRF simulations (using Goddard, WSM6, and WDM6 microphysics) of Q_i (soild), Q_s (dashed), Q_c (dots), Q_r (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:

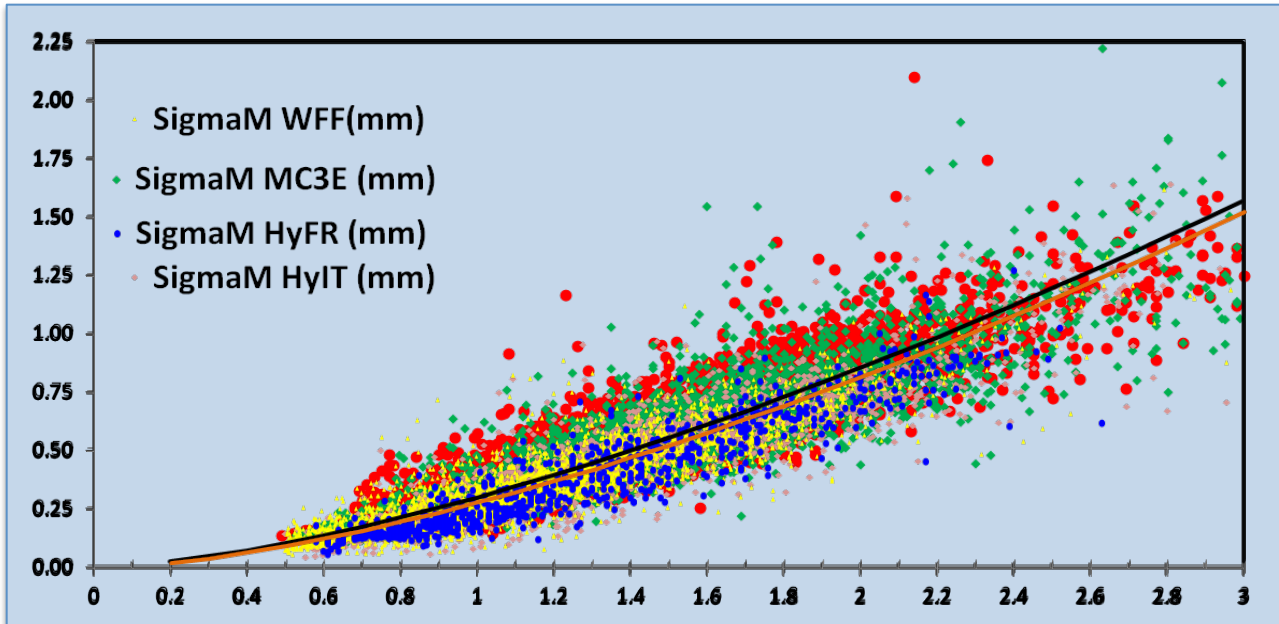
- ground based radar volumes
- aircraft *in situ* measurements

LPVEX MGRAD 1.0 available for Sept 21, Oct 20

MC3E MGRAD 1.0 is processing en masse

MC3E SatSimRAD betaworking....

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



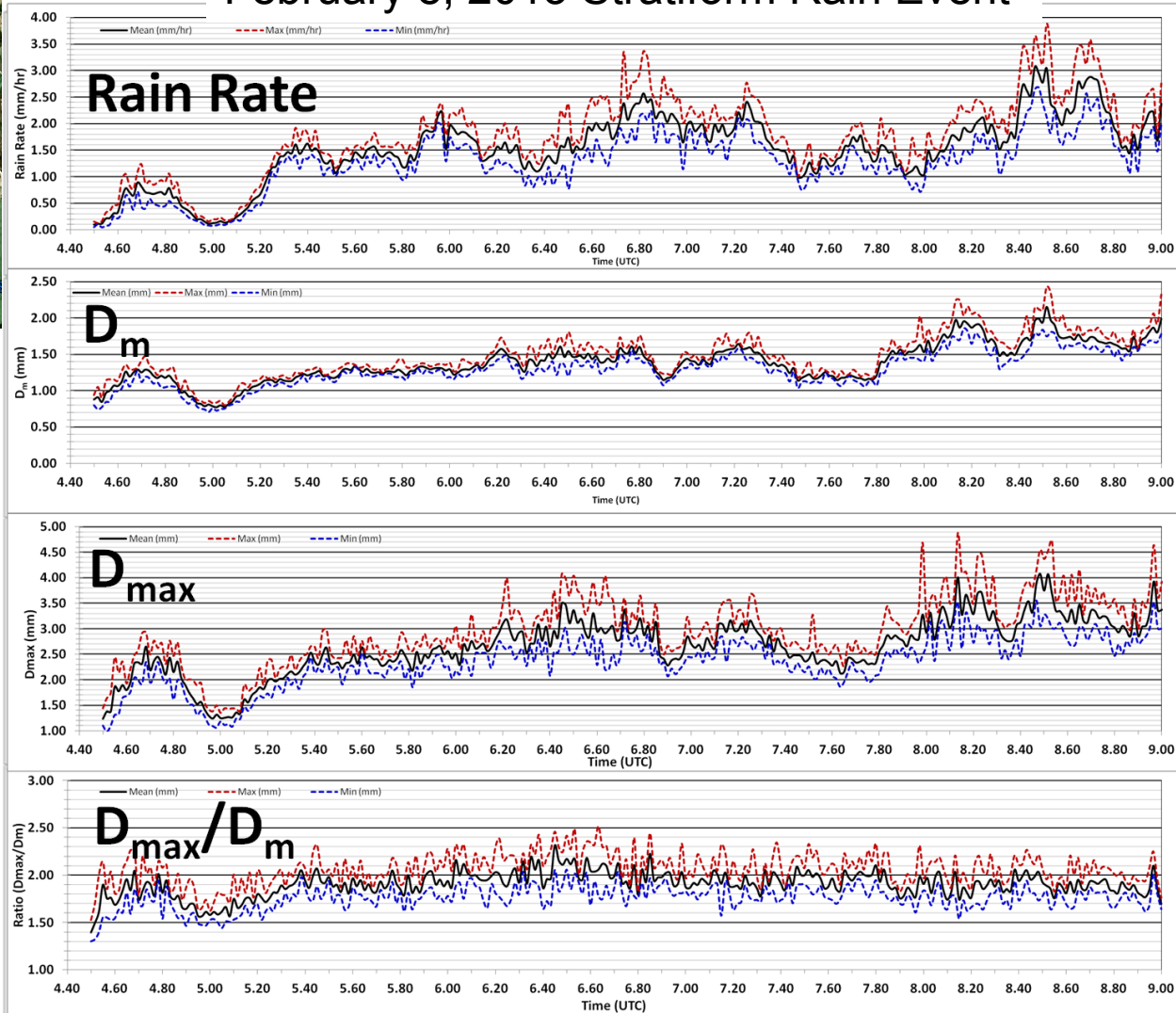
For a Gamma DSD and *no truncation*: $(\sigma_m/D_m)^2 = 1/(4+\mu)$
 Observational fit (orange line): General power law: $\sigma_m \approx 0.3 * D_m^{1.5}$
 $(\sigma_m \approx \sigma_y * D_m^b)$

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

μ constraint: Reducing the range of possible solutions

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%)

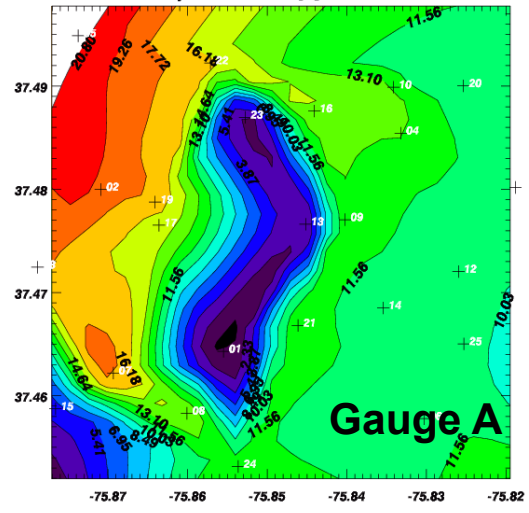
$$D_{max} = 1.6-2.0 \cdot D_m$$

Add- σ_m -D_m spatial
 variability

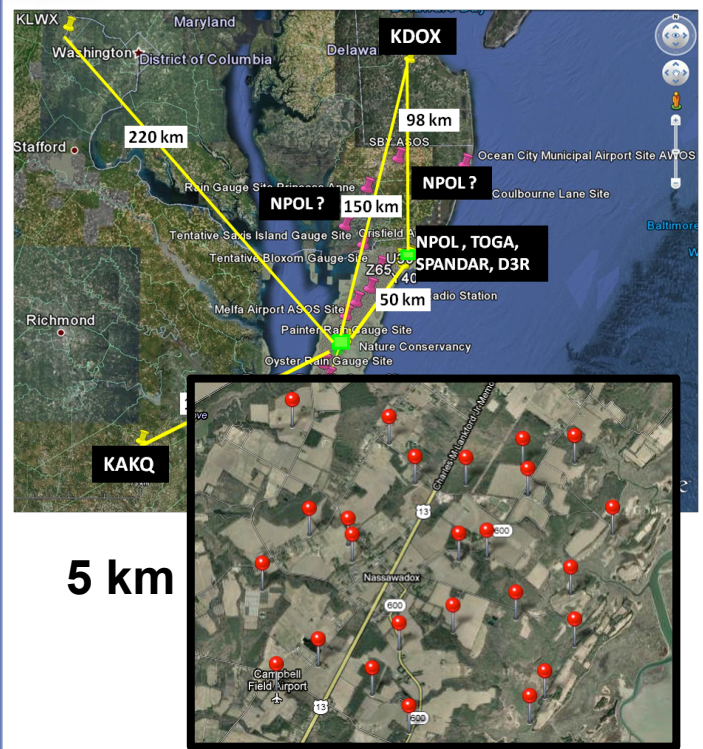
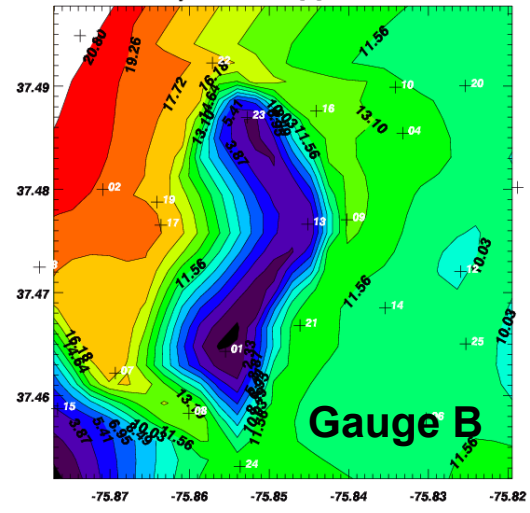
← One minute intervals →

Rainfall 27 Feb. 2013: Nassawadox Grid

Daily Accumulation [A]: 02/27/2013



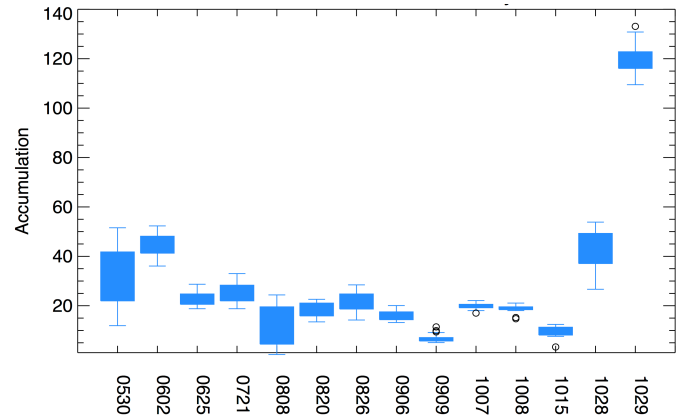
Daily Accumulation [B]: 02/27/2013



5 km

25 km² (DPR footprint; GMI HF footprint)

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



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



GPM Ground Validation

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).

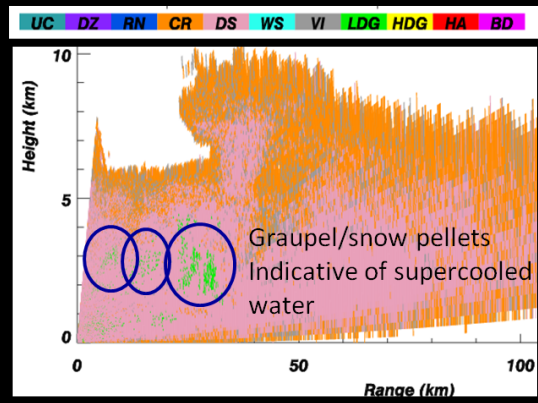
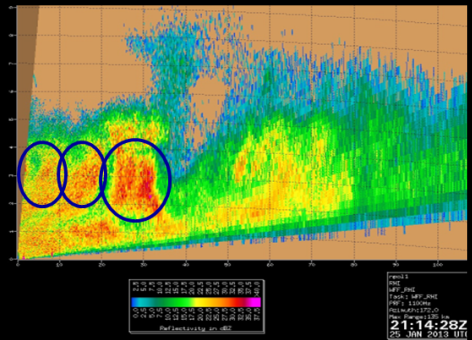


Liquid – mixed phase – Snow



NPOL Data Collection Snow

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



Cold Front Passage Shows Fall-speed Variability.

Rain Images are 64x48 mm. L's are 10x10 mm.

Wintery Mix

Snow

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

Global Precipitation Measurement (GPM) Ground Validation Program

The NASA Global Precipitation Measurement Mission (GPM) Ground Validation (GV) program as a member of the broader NASA Precipitation Measurement Mission is providing ground and airborne precipitation datasets supporting physical validation of satellite-based precipitation retrieval algorithms. The requisite GV measurements include multi-frequency dual-polarimetric radar (S, C, X, KaKu and W bands), airborne microphysical probe, radar and radiometer observations (e.g., provision of a GPM core satellite "proxy") and ground-based disdrometers and rain gauge network observations as a core instrument and measurement complement. The GPM-GV instrument suite is to be deployed in numerous field campaigns in several different precipitation regimes. These campaigns and regimes range from the Light Precipitation Validation Experiment (LPVEx; Helsinki, Finland, fall-winter 2010, partnered with CloudSat), the Mid-latitude Continental Convective Clouds Experiment (MC3E; Ponca City, OK, April-May, 2011, partners DOE-ARM), the GPM Cold Season Precipitation Experiment (GCPEX; Ontario, Canada, Jan-Feb, 2012, partners Environment Canada), the Iowa Flood Season campaign (IFloods; planned for May-June 2013), the NOAA Hydro-meteorological Testbed-Southeast campaign (HMT-SE; North Carolina, summer 2014), and at least one more out-year field campaign to be held in late 2015. Note that GPM GV has also participated in international partner-lead field efforts such as the GPM-Brazil CHUVA campaign (2009-2013). The associated GV measurements and observational strategies seek to advance our physical understanding of precipitation processes and assure consistency between this understanding and the representation of those physical processes in NASA GPM retrieval algorithms.

GPM Precipitation Science Research Facility at Wallops Flight Facility

NASA's Goddard Space Flight Center (GSFC) has a long and distinguished record as a world-class research and development center in precipitation science. As the lead institute for the highly successful Tropical Rainfall Measuring Mission (TRMM) and the upcoming Global Precipitation Measurement (GPM) Mission, GSFC has played a prominent role in advancing state-of-the-art precipitation measurement, analysis, and applications. GPM is a continuation of this international scientific mission led by NASA and JAXA in partnership with other domestic and international space agencies to provide re-generation unfilled precipitation measurements from space, with the ultimate goal of delivering high-resolution, near-real-time global precipitation data products by combining at a global information from space and ground-based measurements.

NASA will extend GPM/GPM's ground-validation (GV) activities by establishing at WFF a core contingent of state-of-the-art GPM GV rain gauge, disdrometer and multi-parameter radar measurements geared toward validation of NASA precipitation products (spaceborne and/or combined ground and spaceborne retrieval algorithms and physics). This contingent of GPM GV instruments and associated staff would leverage WFF communications and power infrastructure to provide the initial "core" component of a proposed Precipitation Science Research Facility.

High Density Rain Gauge Network

The gauge and disdrometer network will be composed of a tightly spaced instrument cluster (see figure below) located within 25 km range of the WFF and GSFC sites, and within 75 km of precipitation radar situated at WFF (SPANDAR and/or TQDA). The initial cluster will be designed using 20-25 rain gauge cells designed by the University of Iowa (UGI) gauges with an inter-gauge separation of 500 m - 1000 m and several nested gauges and 200+ disdrometers (cells) within an area of 0 - 25 km². Note that the referenced instrumentation is currently in the GPM GV inventory. In subsequent stages, the rain gauge array would be augmented with more disdrometers (up to a total of approximately 20) and 1-3 vertically pointing micro rain radar (MRR).

The data from this nested grid are processed every 15 minutes and quick looks, and reports are generated. See the GPM/PRF gauge page for more details.

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/>

- “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!

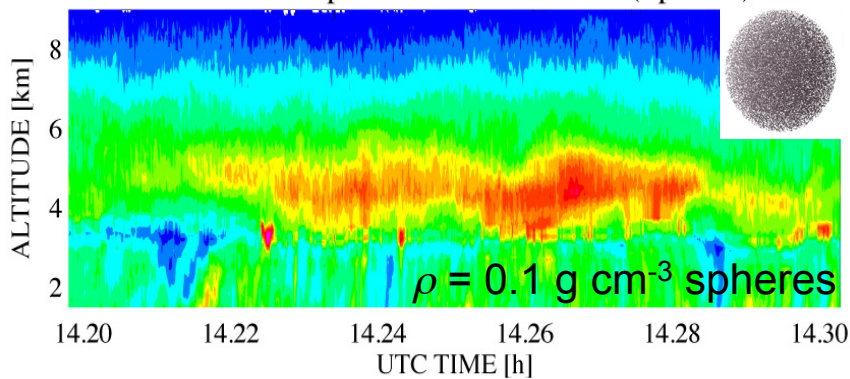


GLOBAL PRECIPITATION MEASUREMENT

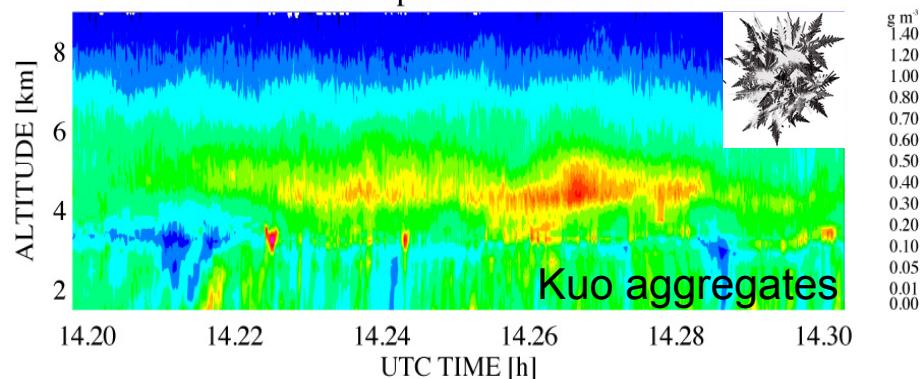
EXTRAS

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

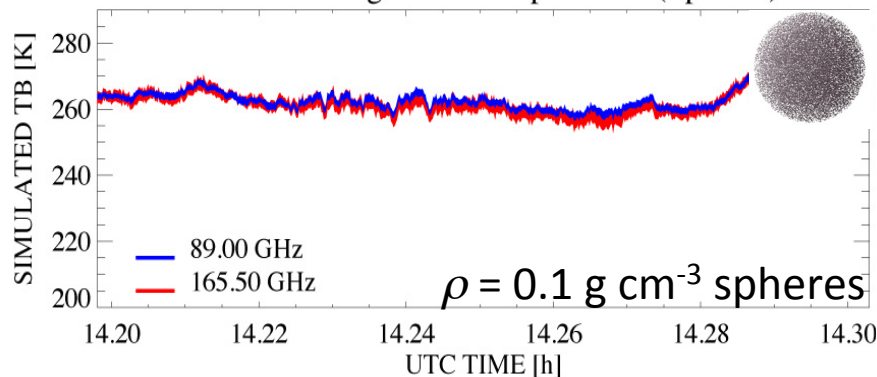
Estimated Precipitation Water Content (Spheres)



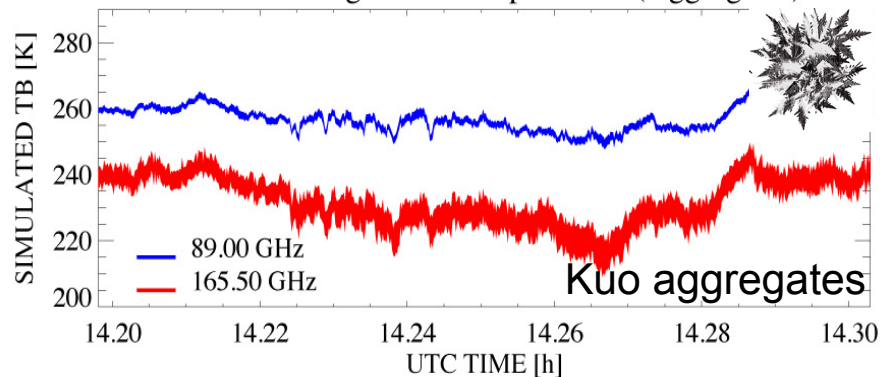
Estimated Precipitation Water Content (Aggregates)



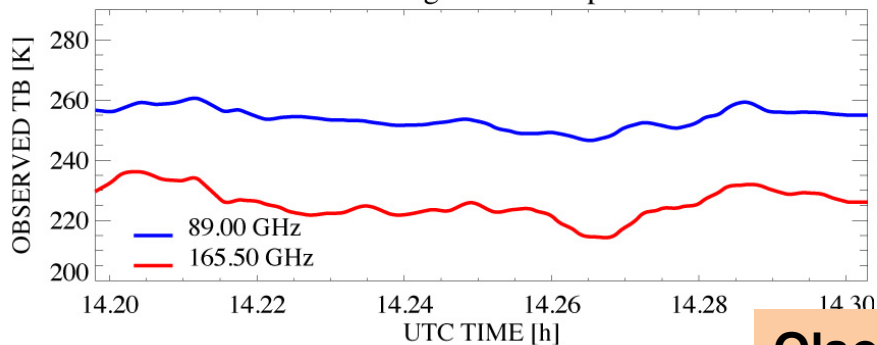
Simulated Brightness Temperatures (Spheres)



Simulated Brightness Temperatures (Aggregates)



CoSMIR Brightness Temperatures



CoSMIR Brightness Temperatures

