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1. The Global Precipitation Measurement (GPM) Mission: A fundamental role/need for radars and supporting precipitation measurements

Global Precipitation Measurement Mission (GPM)

The GPM "Core" Satellite

- Dual-frequency radar and a multi-frequency radiometer
- Flying "physics laboratory"
- Reference calibration platform for GPM Constellation satellites

An International Mission to Map Global Precipitation

GPM Constellation of Satellites

Improved measurement capability, understanding of global water cycle, detection and forecasting of extreme events, climate and weather prediction

GPM Ground Validation Science

Expand direct validation/comparison activities by incorporating improved algorithm physics & model applications

Warm season Rain/drizzle
Cold season Snow/ice

Identify retrieval errors (Direct validation)
Relate to physical processes and assumptions in the algorithms (Physical Val.)
Benchmark retrieval algorithm and product accuracy/utility (Integrated Val.) via coupled hydrologic, cloud, NWP modeling, data assimilation,.....

Measurements required at multitude of scales

Radar to function as a "BRIDGE" between scales

Gauge (point) $\Delta X \sim 0.1$ to 10 km
Radar (volume) $\Delta X \sim 4$ km
Satellite (global) $\Delta X \sim 0.1$ to 50 km

Desire synergistic and adaptive use of relevant platforms with limited constraints on operation, and quasi-long term sampling (statistics)
Desire sampling in a finite number of "climates"/precip "regimes"
Coupling across dimensions: It is a 4-D problem!!!!

- Radars: Fundamental to GPM algorithm validation for characterizing column precipitation profiles and variability (e.g., DSD, water contents, type), mapping rainfall, and discerning precipitation process physics
- Numerous rich datasets have been collected during current and ongoing GPM GV field efforts

2. Top down: Multi-Parameter Radar, Radiometers and Reference Networks

- 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)
 - Dual-gauge platform dense networks
 - All weather hot-plates
 - OTT Pluvio² weighing gauges
 - Precipitation Video Imager



3. Select GV Field Efforts, Observations, and Results: MC3E and IFloodS

Mid-latitude Continental Convective Clouds Experiment (MC3E)

April 22 - June 6, 2011

Location: Vicinity of DOE-ARM Southern Great Plains Central Facility, N. Oklahoma.

Overarching Objectives:

- GPM: Improved physically-based rainfall retrieval algorithms over mid-latitude land surfaces
- COIN and targeted ground-based multi-frequency/dual-pol radar (S/C/X/Ku-Ka/W), profiler, disdrometer/gauges
- DOE: Improved simulation of convective cloud properties (Initiation, dynamics, microphysics)

Sampling Strategy:

- ER-2 (GPM satellite "proxy") 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

NPOL: Z_h vs. 2DVD ZDR vs. 2DVD

NPOL Z, ZDR data calibration verified with 2DVD network DSD Data

Critical to ongoing rain, DSD variability studies (cf. Bringi et al. paper[s] this conf.)

Rainfall: 2DVDs (blue) vs NPOL (red)

D₀: 2DVDs (blue) vs NPOL (red)

5/11/2011

May 11, 2011 Rain variability

Large drop "tail" in mixed convective-stratiform DSD

Also observed in robust stratiform

1857 UTC 5/11/11: NPOL under echo vault. Pea-sized hail and heavy rain. 2DVDs detect large to giant raindrops in storm. Coincidence? D_{max} = 10 mm rain drop!

NPOL RHI w/CSU Hydrometeor ID

Mid-large drop-size "patches" in MRR at low levels and in 2DVD.

Radar-diagnosed DSD "Regimes"

Ice and coalescence DSD process

Ice dominated DSD process

Ground Estimate

Merged Satellite Estimate

May-June 2013, Iowa

- Assess sources of uncertainty in satellite estimates of rainfall
- Assess / improve satellite data use(s) for hydrologic prediction

NPOL Calibration Comparison with 2DVD-ray 5/20/2013

Within ~0.5 dB of KDP/ZDR/Z_h

Adjust for bias, monitor with Relative Calibration Adjustment (RCA)

Daily RCA for IFloodS (CMAP; 0602)

RCA indicates stable calibration through campaign

Cf. Wolff et al., this conference

NPOL, D3R and U. Iowa XPOL radars operated under multi-satellite coverage and over reference gauge/disdrometer arrays to optimize rain mapping and conduct column microphysical studies.

Rain/Stream Gauge Networks

Focus Hydrologic Basins

Radars

Platforms:

- Satellite (PMM GPROF, TMPA rain products), Polarimetric/multi-frequency radar, precipitation, soil moisture, and streamflow measurement networks.
- Coupled NWP/Cloud/Land-Surface/Hydrologic modeling

5/20/13: Squall Line Case

NPOL Radar Reflectivity

NPOL Pol-Hybrid 24-Hour Rain Map

Ice-phase impacts DSD

2DVD

NPOL Rain mapping

15 KM Range

25 KM Range

47 KM Range

1-minute Rain Rate Parsivel-2 vs. NPOL Hybrid algorithm with range

4. Select GV Field Efforts, Observations, and Results: GCPEX and NASA Wallops

GCPEX: GPM Cold Season Precipitation Experiment (Jan-Feb. 2012)

- "Satellite proxy": DC-8- APR-2 radar and CoSMIR radiometer
- UND Citation, NRC C580 aircraft
- Ground radar (C, X, Ka-Ku, W), radiometers, disdrometer/gauge net

01/31/2012: Moderate snow; relatively weak signature in brightness temps.

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

Station Airborne (cloud) Snow microphysics profiles

Grnd. Instruments (surface) Regional to Particle Scale

DC-8 APR-2 Radar

DC-8 CoSMIR Radiometer

King City C-band Radar

D3R Radar Ku-Band

SVI Size Distributions and Images

U. Manitoba Imaging Camera

Event 1

Event 2

Station

Station	Rainfall	Pluvio	Pluvio
CARE	54.311	7.7	0.8
Event 1	1.1	1.1	1.1
Event 2	36.311	1.0	0.2
Monter	27.334	0.6	0.2
Stearnsboro	51.350	1.0	0.3
Event 1	1.1	1.1	1.1
Event 2	1.1	1.1	1.1
Skylive	51.350	1.0	0.3
Event 1	1.1	1.1	1.1
Event 2	1.1	1.1	1.1
Huron	86.341	0.4	0.8
Event 1	1.1	1.1	1.1
Event 2	1.1	1.1	1.1

King City radar SWE map computed from 2DVD Z-S: 355.88°S1.78 (courtesy, G. Huang, D. Hudak); Compare to Pluvio 200/400-reference on right.

Verified consistency of reference SWE (Pluvio₂ 200 vs. 400)

Small drop detection in cold rain

1/17/2012: POSS (red) vs. 2DVD (blue) DSD. 2DVD Small-drop counts increase using single camera methods.

GPM-WFF Validation Network

Area mean precipitation at GPM Fields of View

Measurement error/uncertainties

Rain physics and spatial variability

25 dual-gauge platforms in 25 km²

Mean Error in Rainfall Rate [%] Convective Cases

Mean Error in Rainfall Rate [%] Stratiform Cases

cf. P. Domaszczynski, et al., this conference.

How do vertical profile variability and microphysical process couple to produce satellite sub-pixel to pixel scale spatial variability in rain properties?

4-D Variability Maps to the Physics of Precipitation Process

Reflectivity

Hydrometeor ID

Wet Snow/Graupel/Sm. Hall "Big" Drops

Dry Snow/Graupel/Hall

Large Rain Drops

2DVD

Profile variability/character on sub-pixel scales

- How much Z₀, DSD spatial/temporal profile variability is there within a 5 km Pixel?
- Rapid-scan RH's sectors more useful than reconstructed x-sects from full volumes

25 June 2012 NPOL Wallops

Individual columns (1.0 x 0.5 x 0.5) (x2 RHIs) within a 5 km "FOV"?

Z₀ profile changes evident, significant D₀ change in liquid responding to pulses of melting ice- also coupled to horizontal variability!

Summary: GPM has collected myriad high quality multi-parameter radar, gauge, and disdrometer field datasets to support pre-launch GPM physical validation efforts. Collection and analysis efforts will continue into post-launch era.

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