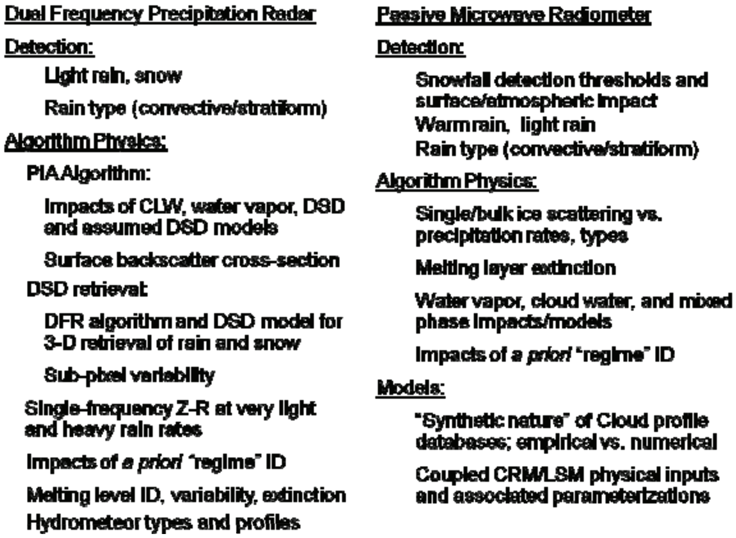
GPM FIELD CAMPAIGNS FOR ALGORITHM PHYSICS

Walter A. Petersen[1], Mathew R. Schwaller[2], Arthur Y. Hou[2]
[1]NASA Marshall Space Flight Center, Earth Sciences Office, Huntsville, Alabama, 35805
[2]NASA Goddard Space Flight Center, Greenbelt, Maryland

1. INTRODUCTION

***Table 1**: Algorithm validation needs*



Dual Frequency Precipitation Radar

- **Detection:**
  - Light rain, snow
  - Rain type (convective/stratiform)
- **Algorithm Physics:**
  - PIA Algorithm:
    - Impacts of CLW, water vapor, DSD and assumed DSD models
    - Surface backscatter cross-section
  - DSD retrieval:
    - DFR algorithm and DSD model for 3-D retrieval of rain and snow
    - Sub-pixel variability
  - Single-frequency Z-R at very light and heavy rain rates
  - Impacts of *a priori* "regime" ID
  - Melting level ID, variability, extinction
  - Hydrometeor types and profiles

Passive Microwave Radiometer

- **Detection:**
  - Snowfall detection thresholds and surface/atmospheric impact
  - Warm rain, light rain
  - Rain type (convective/stratiform)
- **Algorithm Physics:**
  - Single/bulk ice scattering vs. precipitation rates, types
  - Melting layer extinction
  - Water vapor, cloud water, and mixed phase impacts/models
  - Impacts of *a priori* "regime" ID
- **Models:**
  - "Synthetic nature" of Cloud profile databases; empirical vs. numerical
  - Coupled CRM/LSM physical inputs and associated parameterizations

The Global Precipitation Mission (GPM) will employ a constellation of ~8 satellites to measure precipitation between +/-65º latitude[1]. The GPM constellation will fly microwave radiometers accompanied by a core "reference" satellite carrying a Ka-Ku band dual-frequency radar (DPR) and an improved passive microwave radiometer (GMI; frequencies 10-183 GHz). Fundamentally, the improved GPM remote sensing capability is expected to improve measurement accuracy. However, the extended-latitudinal sampling domain of GPM necessitates the development of retrieval algorithms that can reliably estimate precipitation over a larger fraction of the earth's land surface (in comparison to coverage of the Tropical Rainfall Measurement Mission; TRMM), and also accurately measure light precipitation (0.2 mm hr^{-1}) and snowfall. The regime and process complexity (Table 1), number of parameters to be measured, and the science required to make effective use of those measurements in retrieval algorithms requires an extensive validation program. Herein we describe the physical process component of the GPM Ground Validation (GV) program-oriented explicitly toward field campaign plans designed to improve and validate retrieval algorithm physics.

2. GPM FIELD CAMPAIGN SCIENCE

A lesson learned from the TRMM is that algorithm retrieval errors have a strong dependence on meteorological regime and physical processes specific to those regimes. As such, field campaign (FC) strategies supporting the development and validation of GPM retrieval algorithms must target regime physical processes where large uncertainties are known to exist a priori (i.e., land, snow, light precipitation). Accordingly, GPM Ground Validation (GV) FC strategy incorporates the following objectives:

(1) Coordinated airborne and ground-based observations of precipitation rates, numbers, shapes and size distributions (PSD), melting-layer physics, and CCN/IN aerosol characteristics.
(2) Quantification of PSD and rain rate decorrelation over sub-satellite pixel scales.
(3) Observations of surface microwave emission as a function of the land surface state/type.
(4) Collection of high-quality large-scale forcing and microphysical validation datasets for testing the fidelity of coupled cloud resolving, land surface, and radiative transfer models (CRM/LSM/RTM).
(6) Establishment of CRM space-time integrating and data assimilation capability for QPE.

To ensure that the GV measurements successfully support algorithm needs these objectives will be pursued in a wide variety of relevant regimes (Sec. 3), constantly reevaluated for relevance to algorithm application, and implemented with algorithm developers participating in the planning and execution loops of the FCs.

3. FIELD CAMPAIGN ARCHITECTURE, SCHEDULE AND INFRASTRUCTURE

The reference architecture for GV physical process studies is based on a series of Intensive Observation Periods (IOPs; Table 2) bracketed by Extended Observation Periods (EOPS). EOPs are best interpreted as scaled-down FCs operating for an extended period- e.g., 6-12 months. EOPs leverage existing operational network and/or PI-owned research instrumentation and datasets (e.g., radar, gauge). Select GV instrumentation is added to expand sampling duration. IOPs are 4-6 week, FCs (Table 2) conducted with a dense complement of ground and airborne instruments that may or may not occur in conjunction with an EOP. Notwithstanding the shorter operations period and dense ground instrumentation, the distinguishing characteristic of an IOP is the inclusion of aircraft sampling (high-altitude radar/radiometer + in-situ microphysics aircraft).

Table 2. GPM field campaign schedule

Objective	Date/Location
Snowfall retrievals	C3VP, winter 2006-7, Ontario Canada.
Detection and retrieval of Warm-rain over land Deep convection over land	Pre-CHUVA, Mar. 2010, Alcantara, Brazil
Retrievals of high latitude light precipitation	LPVeX, Sept.-Oct. 2010, Finland/Baltic;
Physical basis for GMI DPR retrievals over land	MC3E; Apr-June 2011, DOE ASR Central Facility, OK
Snowfall retrievals	Winter 2012, Ontario Canada
Hydrologic/Physical validation	2013, Hydromet. Testbed, N. Carolina; joint with NOAA
Cold season validation	2015, TBD
Hydrologic validation	2016, TBD

3.1 IOP Infrastructure

In order to satisfy measurement requirements across the full spectrum of precipitation rates, types and regimes, a core complement of transportable GPM GV instrumentation is being employed. The nominal instrument complement (Table 3) includes a mix of airborne radar/radiometers operating at DPR and GMI frequencies, insitu microphysical and radar instruments, transportable multi-frequency (S, Ka-Ku, W) dual-polarimetric (DP) radars, dense networks of video/optical disdrometers and rain gauges, and S-band/UHF wind profiler pairs.

Table 3. NASA-funded IOP instruments

Air/ground instrument	**Purpose**
Air: NASA ER-2/DC-8 HIWRAP/APR2 Ka-Ku band radars	DPR/GMI algorithm simulator datasets
Air: NASA ER-2/DC-8 10-183 GHz radiometers	Combined DPR/GMI simulator dataset
Air: In situ microphysics aircraft (1D, 2D particle probes, water content etc.)	Microphysics for RT modeling, ground radar sampling.
Ground: NASA N-POL S-band DP radar	Precipitation rate, type, and DSD
Ground: NASA dual-frequency (Ka-Ku band) DP doppler radar (D3R)	DPR PIA and DSD retrievals. Precipitation physics in light rain, snow.
Ground: NASA disdrometer network [nominally 5- 2D-video, 16-optical, 2-5 impact, 20 rain gauges].	DSD/Precip. Variability at pixel scale, extension to radar sampling domain
Ground: NOAA ESRL S-band/UHF profiling radar.	DSD profile retrievals.

Complementary international/interagency partner contributions not listed in Table 3, but to be deployed during the IOPs include X-band DP and vertically pointing Ka and W-band radars, ground-based scanning multi-frequency radiometers, micro-rain radars, and operational meteorological network data.

4. IOP ARCHETYPES

Two currently planned IOPs nominally serve as “archetypes”: the Mid-latitude Continental Convective Clouds Experiment (MC3E); and the 2012 Cold-Season snowfall project. MC3E, is designed to address algorithm physics for moderate to heavy continental rain and is a NASA and the DOE Atmospheric System Research (ASR) Program collaboration. The IOP will be located at the ASR Central Facility in N. Oklahoma, during April-June, 2010. GPM Science priorities for MC3E include:

1) Airborne high altitude and in-situ remote sensing of cloud systems, surface backscatter properties, ice physics and relation to precipitation rate as remotely sensed by the radiometers; testing of path integrated attenuation and DSD retrievals at Ka-Ku band.
2) Ground based retrieval of Drop Size Distribution (DSD) and hydrometeor profiles in a “unified” framework (e.g., combined disdrometer, profiler, and multi-parameter radar); sampling of sub-pixel scale DSD and rain rate variability using a dense disdrometer network (0.5–5 km spacing). The multi-sensor approach will enable cross validation and error analysis of DSD retrievals and methods.
3) Refinement of satellite simulator models (CRM/LSM/RTM) anchored by high-quality forcing datasets.

The IOP instrumentation will also include the DOE-ASR X-band DP radar network, DOE C-band DP radar, surface radiometer, DOE flux and aerosol measurements, and an array of six DOE radiosonde launch sites.

The 2012 cold season FC is focused on snowfall retrieval algorithms and builds on the C3VP experience. The campaign will take place at the Centre for Atmospheric Research Experiments (CARE) located in Egbert, Ontario, Canada. In contrast to C3VP, this FC will add a high altitude radar/radiometer aircraft (NASA DC-8) for collection of coincident Ka-Ku band radar and multi-frequency radiometer data. The science will focus on:

1) Quantification of column snow physics including snow crystal habit, density (water content) and PSD, cloud environment properties such as liquid water content, and multi-frequency microwave scattering/extinction.
2) Study of methods to isolate and remove microwave surface emission from the radiometer retrievals.
3) Development of snow microphysical databases for radiative transfer forward models.

High-altitude Ka-Ku band radar (APR2) and multi-frequency radiometer (CoSMIR) data will be collected from the NASA DC-8 in coordination with an in-situ microphysical aircraft. Approximately five ground-instrument clusters will be created at or near the CARE site and each will consist of a snowfall liquid water equivalent gauge (e.g., Geonor), 2D Video Disdrometer[2], a Parsivel Disdrometer, an L-band snow water equivalent sensor (developed by A. Barros, Duke U.), and a snow video imager [3]. These clusters will operate within double fence international reference (DFIR) enclosures surrounding an S-band/UHF profiler pair, X band radar, and a W-band radar located at CARE. Scanning Ka-Ku band (D3R) and C-band DP (King City) radars will overlook the CARE site. Several surrounding sites will be outfit with disdrometers, MRR (where possible), and snow gauges to enable broader validation of radar-estimated snowfall rates.

5. CONCLUSION

Physical Validation of NASA GPM algorithms will rely on five land-based field campaigns, and several more international collaborations targeted to specific DPR and GMI retrieval algorithm issues. The campaigns will employ an extensive complement of ground and airborne multi-parameter/frequency radars and in situ microphysical instrumentation to collect datasets facilitating improved algorithm physics.

6. ACKNOWLEDGMENT

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7. REFERENCES

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