Overview: Concept and Approaches

Implementation

- Direct Validation
- Physical Validation
- Integrated Validation
- International Collaboration

Nasa Gpm Gv Science Implementation
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W. Petersen, International GPM Planning Meeting, Paris France, 16-18 June 2009
GPM Ground Validation (GV) Overview

Pre-launch algorithm development & post-launch product evaluation

The GPM GV paradigm moves beyond traditional direct validation/comparison activities by incorporating improved algorithm physics & model applications (end-to-end validation) in the validation process.

Three approaches:

• National Network (surface):
  Operational networks to identify and resolve first order discrepancies (e.g., bias) between satellite and ground-based precipitation estimates

• Physical Process (vertical column):
  Cloud system and microphysical studies geared toward testing and refinement of physically-based retrieval algorithms

• Integrated (4-dimensional):
  Integration of satellite precipitation products into coupled prediction models to evaluate strengths/limitations of satellite precipitation products
GV Science: A System of Feedback

Measurement + Algorithms = Products

National Networks
- Broad statistical evaluation
  - DPR Reflectivity
  - DPR/GMI Rain rate

Validation
- Algorithm Physics:
  - Development
  - Refinement

Physical Process
- Application
  - Water Budget
  - NWP
  - Surface Hydrology

Integrated GV

Supporting Tools

Radar/Rain Gauge Networks
- Reflectivity stats
- Rain rate stats

Disdrometer Arrays
- DSD variability
- Rain rate stats
- GV Radar Cal/Val.
  - Z, D_0

Dual-Pol Radar, Wind Profiler
- Z, Rainfall mapping
- DSD Profile, Particle types
- CRM/LSM Physics/Profiles
- PIA
- Ice physics

Aircraft
- Ice physics, melting layer
- Cloud water
- CRM/LSM Physics/Profiles
- GPM simulator
  - PIA, TBs
GPM GV

3 approaches support
5 cross-cutting science themes:

1. Core satellite error characterization
2. Constellation satellites validation
3. Development of physical models of snow, cloud water, and mixed phase
4. Development of CRM and land-surface models to bridge observations and algorithms
5. Development of coupled CRM-land surface modeling for basin-scale water budget studies and natural hazard predictions
Direct Validation: Validation Network (VN) Architecture

Identify systematic regional or regime issues using a two-tiered approach

Tier 1): DPR Reflectivity- Ground Radar Validation Network (VN)

Reflectivity measurements/profiles of core satellite are *fundamental* to the entire GPM constellation (i.e. DPR serves as a GMI “calibrator”)

- Systematic regime variability in $Z_{GPM} - Z_{Ground}$ can be detected with existing operational radars
- Stable calibration of DPR can also support calibration trending of ground sources
- Future dual-pol radar upgrades (U.S. and elsewhere) will facilitate broad area DSD statistics (D0) to be added- subsequently permits broad scale linking of DSD variability to Z.

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Direct Validation: VN Reflectivity Comparison Methodology

Jacksonville, FL - 31 August 2007 - 6 km AGL

PR Attenuation-Corrected Reflectivity

KJAX WSR-88D Reflectivity

Create TRMM PR and Ground Radar Collocated Linked-Database
GV radar located at central grid point
4 km horizontal resolution, 75 x 75 elements, 300 x 300 km area
13 vertical slices from 1.5 km - 19.5 km, 1.5 km vertical resolution
period of record: August 8, 2006 to present
Example of Reflectivity Comparisons

Well-behaved sites (left) have average reflectivity differences (PR-NEXRAD) between about ±2 dBZ:

- samples taken from above the bright band, within a 100 km radius of the ground radar, stratiform rain cases only
- Enables establishment of gross ground radar bias/error behavior
- Selection of well-behaved radars forms means to evaluate space borne platform (and also enables calibration correction of ground radars).

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Histogram Comparisons

Vertical Profiles

Scatter Plots

By Precipitation Type

Expanded Number of Global Contributing Sites

- 21 WSR-88D sites in the southeast US
  - Raw data acquired from the NOAA Level-2 archive
  - Automated quality control (TRMM 2A-55 GV algorithms)

- Also used for individual research radars
  - NSSTC/UAH ARMOR Dual polarimetric C-band radar, 1-degree beamwidth
  - Kwajalein Atoll: Historical and on-going QC’d dataset from TRMM GV
  - Automated quality control using polarimetric methods

- International Network Radars
  - Korea (KMA, METRI)
    - Network of 18 S- and C-band radars
    - Automated quality control
    - Option to add additional sites
  - Darwin (Australia)
    - C/S band operational network
    - C-band, research dual polarization radar

- Discussions underway with other international partners
National Network: Direct Validation of Rain Rates

Tier 2): DPR/GMI Rain rates: NOAA Q2 Gridded Product (U.S. NEXRAD Network)

May 12, 2007 @ 22:30 UT

- NOAA Q2 National gridded merged radar-gauge product
- Evaluate GPM Constellation rain rate PDFs against Q2.
- Incorporation of other assets as appropriate (gauge networks, snowfall, Kwajalein GV etc.) into VN architecture

Courtesy: E. Amitai et al., (George Mason University)
Physical Process Validation: Numerous Algorithm Issues/Needs

Dual Frequency Precipitation Radar

Detection:
- Light rain, snow
- Rain type (convective/stratiform)

Attenuation:
- PIA Algorithm: Errors/Accuracy
  Assessing and/or accounting for impacts of CLW, water vapor, DSD and assumed DSD models

Algorithm Physics:
- DSD retrieval:
  DFR algorithm and DSD model for 3-D retrieval of rain and snow as f(regimes, temporal / spatial variability, precipitation rate)
- Z-R at light rain rates
- Sub-pixel variability
- Impact of external a priori regime ID
- Melting level ID, variability, extinction
- Hydrometeor ID and profile

Passive Microwave Radiometer

Detection:
- Snowfall detection thresholds and surface/atmospheric emission characteristics
- Rain no rain (especially 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
Implementation of Physical Process Validation: Field Campaigns

- Designed for:
  - Pre-launch physical algorithm development, post-launch product validation
  - Study of 3-D precipitation process/physics as a function of regime (land emphasis)
  - Improved coupling of Cloud/Radiative Transfer models for satellite simulator

- Algorithm developers explicitly involved in planning, execution and analysis

- Intensive Observations and Extended Observations Programs (IOP, EOP)
  - 5 Field Campaigns
  - Extended data collections to supplement existing operational infrastructure
  - Kwajalein Atoll: PMM-funded (current)
  - "Target of opportunity" IOP/EOP participation when justified and budget permits.

- Completed Winter 2006-2007
  - Canadian CloudSat Calipso Validation Project (C3VP): Canada/U.S. CloudSat/GPM; Initiate priority pre-launch snowfall measurements. Analysis ongoing (WG Talk today)
  - Next up: LPVEX- Finland, Sept-Oct. 2010; Low-level melting layers, snow
## Field Campaign Implementation Planning

<table>
<thead>
<tr>
<th>Objective</th>
<th>Date</th>
<th>Partnership/Location</th>
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<tbody>
<tr>
<td><strong>MC3E:</strong> GMI/DPR rainfall retrievals over land surfaces</td>
<td>Spring/early summer 2011</td>
<td>Mid-Latitude Continental Convective Clouds Experiment (MC3E)- DOE ARM SGP S. Central Oklahoma</td>
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<tr>
<td><strong>Cold-season</strong> retrieval of frozen and mixed precipitation over land surfaces</td>
<td>Winter 2011/2012</td>
<td>TBD</td>
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<tr>
<td><strong>Physical/Integrated</strong></td>
<td>2013</td>
<td>NOAA Hydrometeorological Testbed, Tar/Neuse River Basin, N. Carolina</td>
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<td><strong>Cold season</strong> product validation</td>
<td>2015</td>
<td>TBD</td>
</tr>
<tr>
<td><strong>Physical/Integrated</strong></td>
<td>2016</td>
<td>TBD</td>
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- **Upcoming International FC Collaborations**
  - **Finland (Fall 2010):** Baltic Sea region, **mixed phase/low bright band precipitation**. Collaboration with CloudSat, Finland, ESA [Aircraft + Helsinki Testbed]
  - **Canada (winter 2012):** Cold Season, CARE Site near Great Lakes, Ontario, Canada
GPM 2011 Continental Field Campaign (NASA/DOE)  
Mid-Latitude Continental Clouds and Convection Experiment (MC3E)

Target Location/Date:  S. Central Oklahoma, April-June 2011 (TRMM Coverage)  
Targeted regimes:  Land, late spring transition (baroclinic, MCS, convection)

Yellow pins: CASA Radars, KOUN/OU Prime  
Yellow triangles:  N-POL, Ka-Ku  
Green pins:  DOE Profilers (Disdrometer network)  
Gauges in L. Washita area

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GPM Priorities for Sampling

1. DPR/GMI **simulator** observations
   a. Most likely target- stratiform with ER-2 sample of convection
   b. Microphysics AC legs at various depths and within melting layer
   c. Pre and post storm sampling of surface backscatter cross-section

2. 3-D **Particle type/size variability**:
   a. High density 2DVD measurements
   b. Collocated multi-frequency and polarimetric radar (4-D extension)
   c. Collocated/coincident with aircraft

3. Satellite **simulator CRM/LSM/RTM** Development:
   a. Sounding data sets
   b. Datasets 1, 2 above
   c. Multi-Doppler kinematics

**Planned Instruments**:
- **Aircraft**: ER-2 GPM simulator, microphysics
- **Radars**: NASA N-POL, NASA Ka-Ku, CASA X-band, ARM Ka/W, wind profilers
- **Surface**: Disdrometer/rain gauge network; soil moisture/fluxes/hydrologic
- **Soundings**: DOE SGP array 6 – 8 launches/day

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**Physical Process Studies: Infrastructure Development**

Calibrated measurements across the full spectrum of precipitation rates/types

**Ka/Ku-Band Transportable Scanning Dual-Polarimetric Radar**
- Match DPR frequencies, more direct link to PIA and dual-wavelength methods
- Extension to clouds, light precipitation, and improved sampling of ice, snow, mixed phase
- Mobility enables placement in variety of network configurations/regimes with relative ease

**N-POL S-band Transportable Scanning Dual-Polarimetric Radar**
- Transportable radar platform for study of heavy/moderate precipitation regimes
- Retrieval of 3-D particle size distribution (DSD) information and qualitative ice microphysics
- Receiver and antenna system upgrade ongoing; deployment summer 2010.

**Disdrometer/Gauge D-Scale Array ([2-4 km separation over 100 km²])**
- Validation of GV ground radar DSD retrievals/precipitation rates and type
- Spatial/temporal covariance of particle size distributions and precipitation rates

**Wind Profiler**
- Vertical profiles of Z, DSD under coverage umbrella of radar

**Aircraft Instrumentation/Operations**
- In situ cloud microphysical sampling
- High-altitude GPM (DPR/GMI) Simulator (HIWRAP, AMPR, COSMIR etc.)
End-to-end utility of retrieval algorithms: Pre-launch algorithm physics linked to hydrologic/water budget application, and hydrologic GV methods

HMT Southeast: "mountain to coast"
Summer flooding, Hurricane Landfall, Winter mixed events........

Extensive QPE and hydrologic instrumentation, hydrologic modeling

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NASA welcomes international participation in PMM Program GV activities to improve GPM products for the benefit of all nations

3rd International GPM GV Workshop held March 2008 in Buzios, Brazil

Numerous international investigators invited to submit (and are in the process of submitting) no-cost proposals to PMM to establish joint GV projects complement existing activities

19 Countries, 24 different activities targeting aspects of 3 core approaches

Scientific collaboration, data sharing, and leveraged field resources/efforts in joint projects as members of the PMM Science Team

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• Providing **stable, calibrated surface precipitation measurements** for independent assessment of satellite-based precipitation estimates.

• Providing **useful** "microphysics laboratories" for improving performance of satellite algorithms and the quality of GPM data products.

• Providing **information for improving error characterization** of satellite precipitation products for NWP, multi-satellite precipitation analysis, climate re-analyses, and hydrological applications.

• Providing or supplementing **test beds for improving satellite precipitation data usage** in hydro-meteorological modeling and prediction.
Summary

U.S. GV Science Implementation

- Stresses involvement of algorithm teams in planning

• Three Approaches
  • Direct Validation (Reflectivity, Rainrate)
    - VN Architecture being steadily enhanced/expanded
    - U.S. and international radar datasets being incorporated
    - Expand to accommodate widespread rain rate validation for radiometers
  • Physical Process (Land Focus)
    - Core infrastructure development underway: Ka-Ku, N-POL, Disdrometers
    - Field campaigns: 5 Planned GPM/PMM
  • Integrated (Hydrologic)
    - NOAA HMT Southeast focus/collaboration underway (2010-2014)

International activities and collaboration (Required)

- Rapidly gaining momentum
- Encourage Joint Research Proposals with NASA PMM Science Team along focusing on three GV approaches