NASA GPM GV Science Implementation

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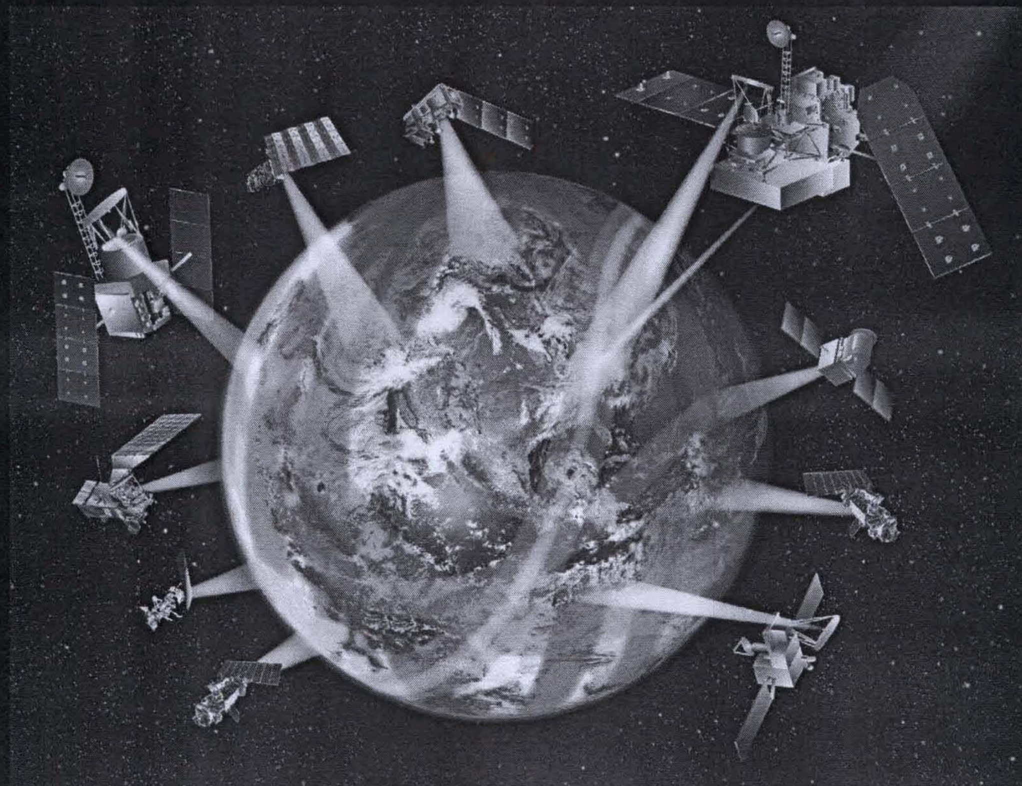

- Overview: Concept and Approaches
- Implementation
  - Direct Validation
  - Physical Validation
  - Integrated Validation
  - International Collaboration

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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):**

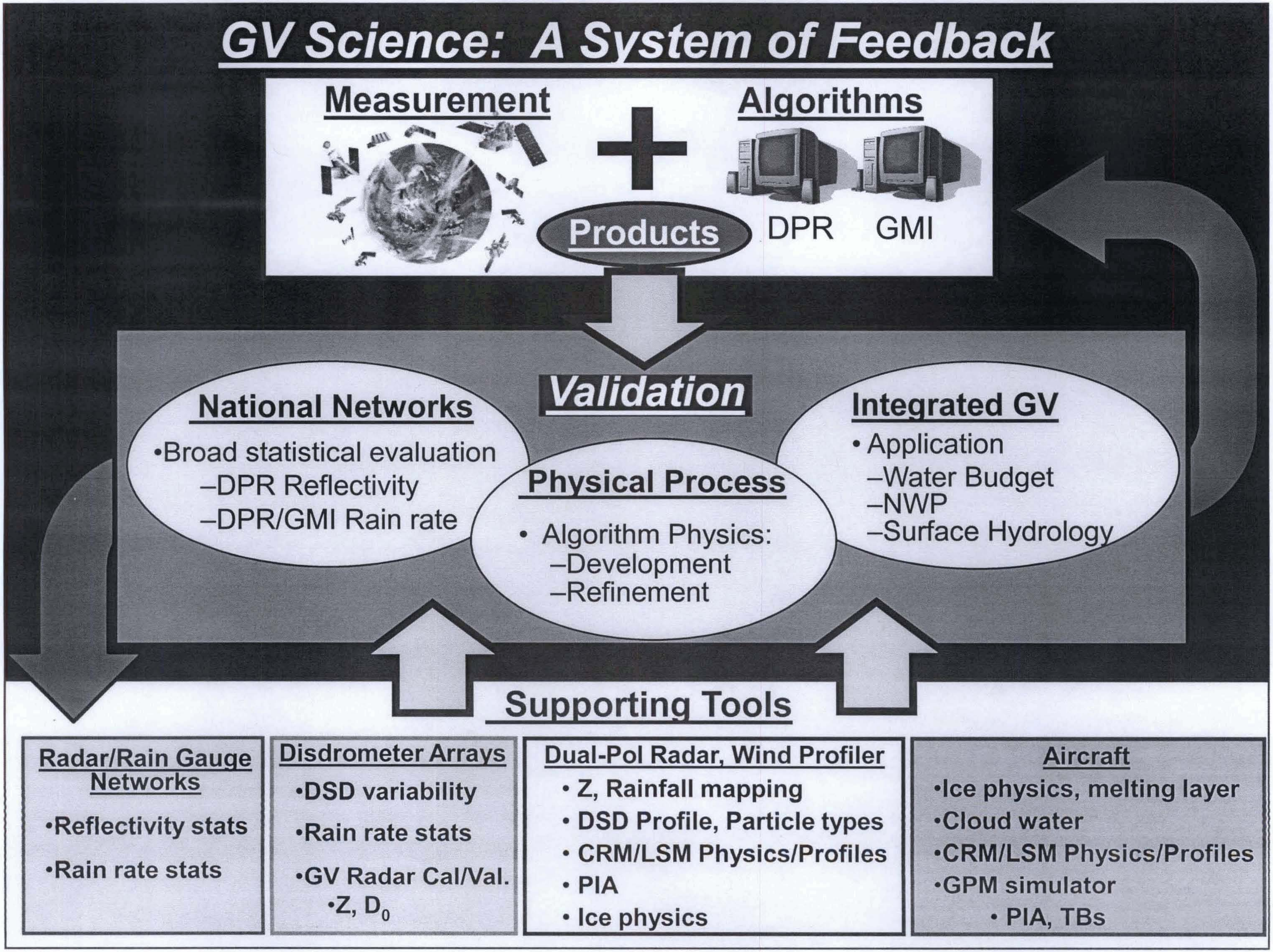
  Operational networks to identify and resolve first order discrepancies (e.g., bias) between satellite and ground-based precipitation estimates

- **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

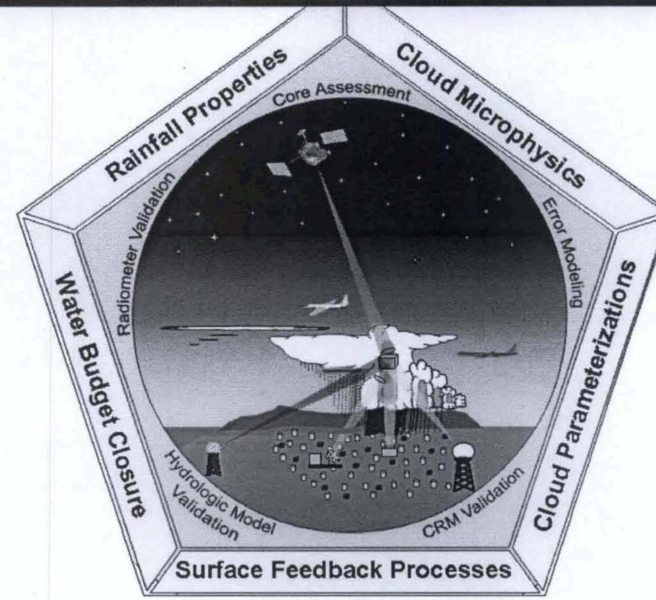

GV Science: A System of Feedback
Measurement
Algorithms
Products
DPR
GMI
Validation
National Networks
•Broad statistical evaluation
–DPR Reflectivity
–DPR/GMI Rain rate
Physical Process
• Algorithm Physics:
–Development
–Refinement
Integrated GV
• Application
–Water Budget
–NWP
–Surface Hydrology
Supporting 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

Cross-cutting themes

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

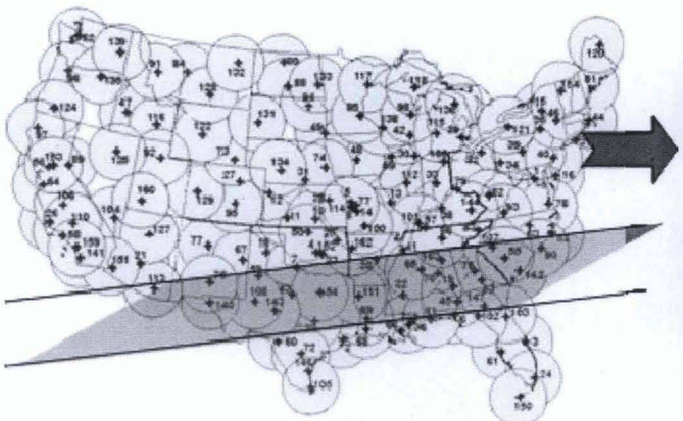
Direct Validation: Validation Network (VN) Architecture

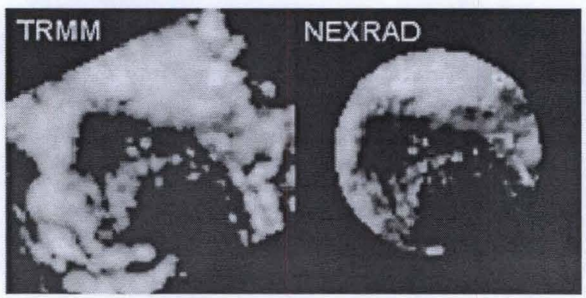
Identify systematic regional or regime issues using a two-tiered approach

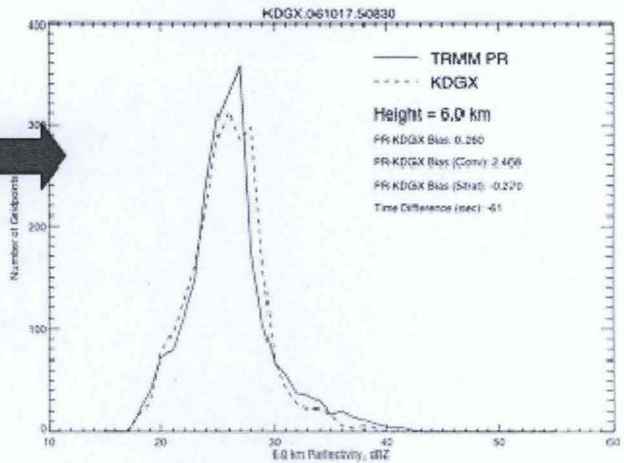
Tier 1): DPR Reflectivity- Ground Radar Validation Network (VN)

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.



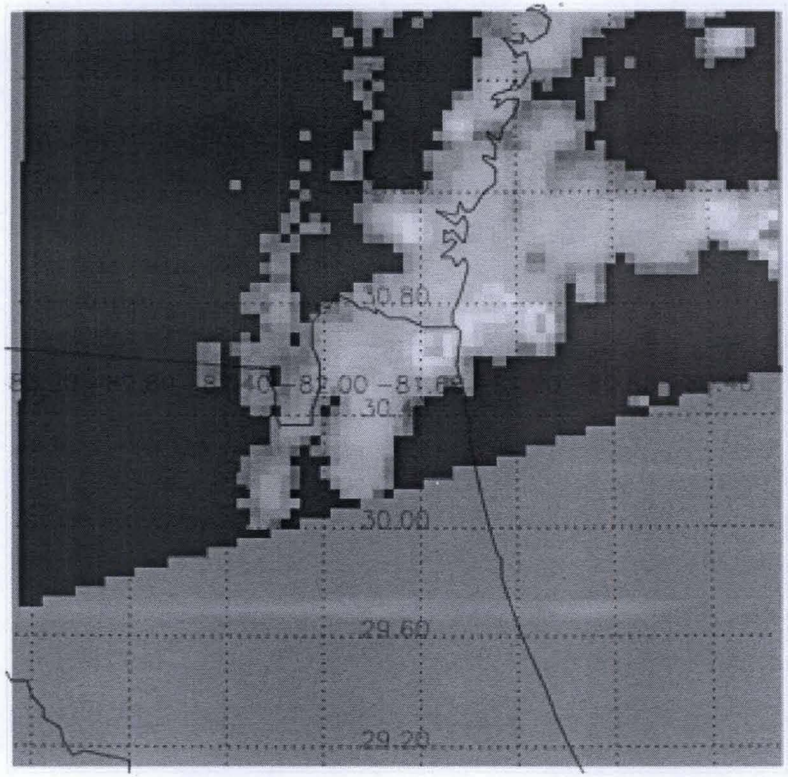




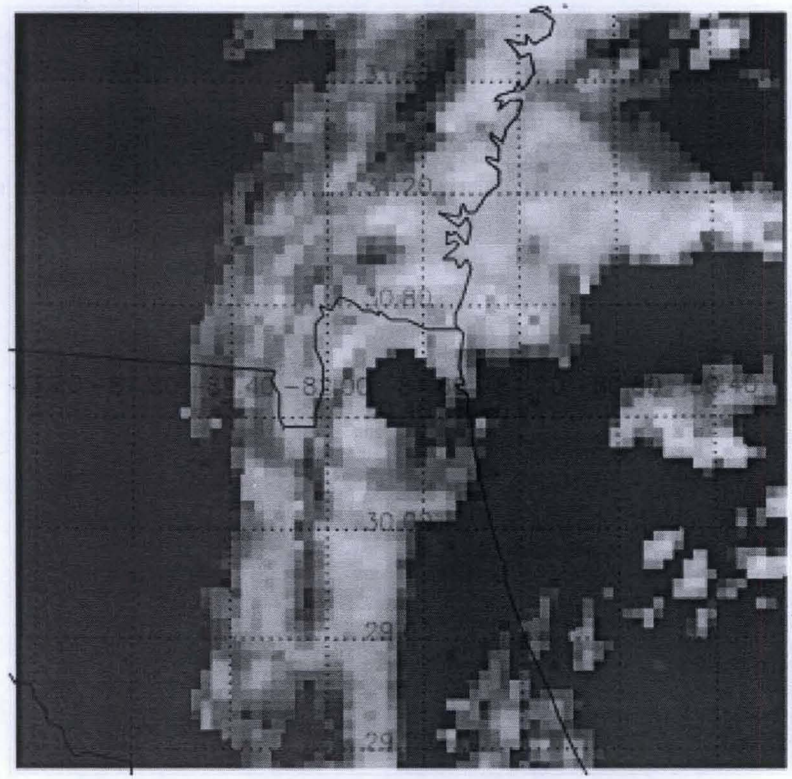
Direct Validation: VN Reflectivity Comparison Methodology

Jacksonville, FL - 31 August 2007 - 6 km AGL

PR Attenuation-Corrected Reflectivity

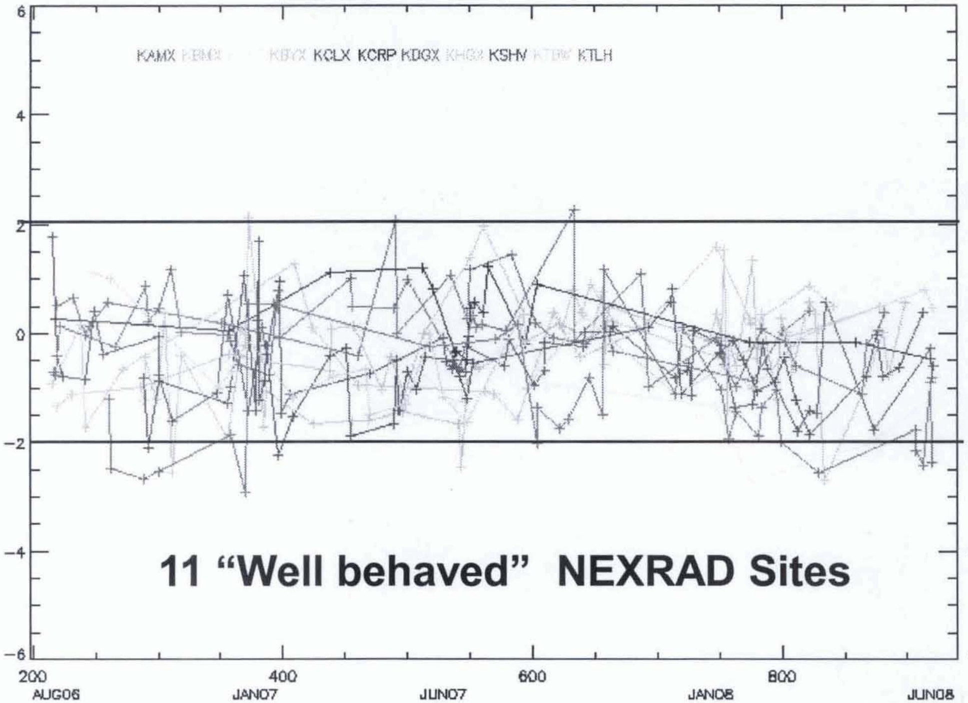


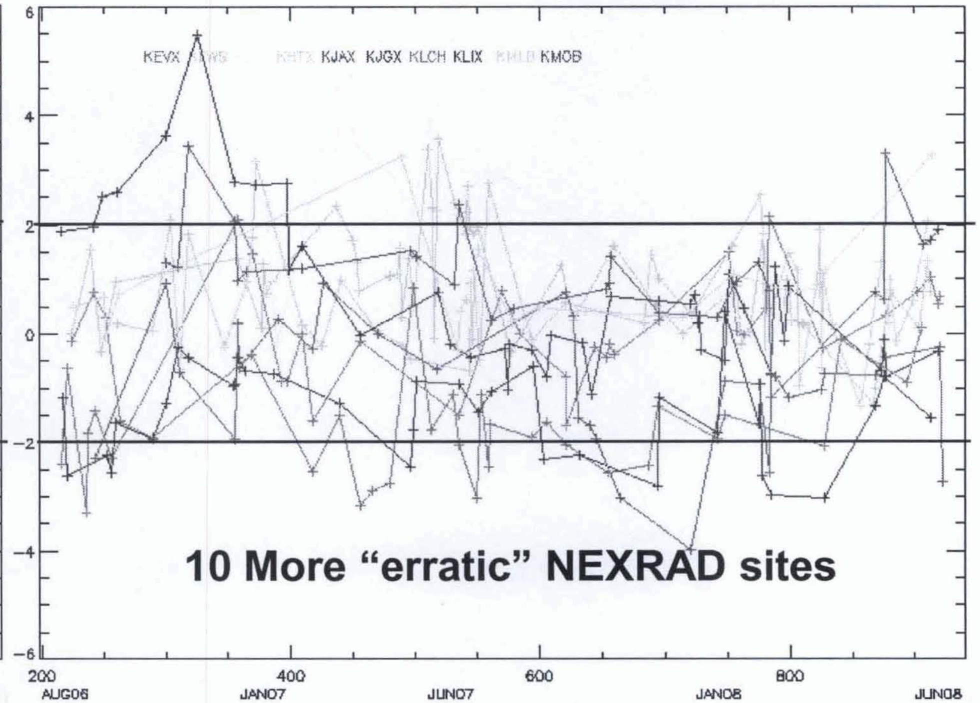
KJAX WSR-88D Reflectivity



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

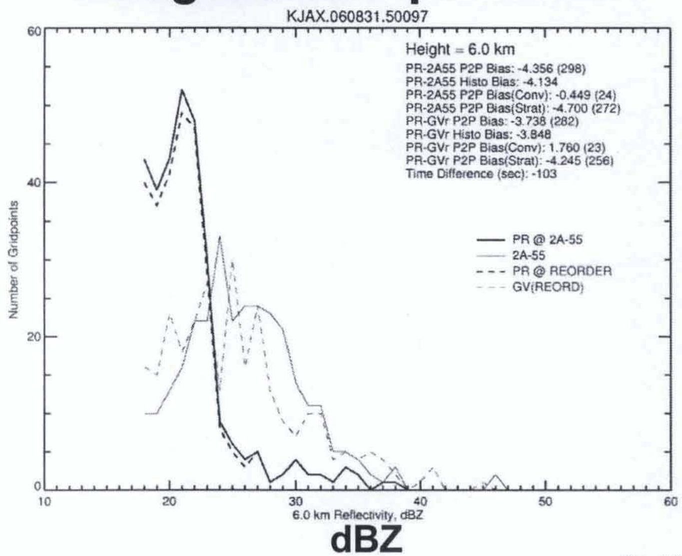




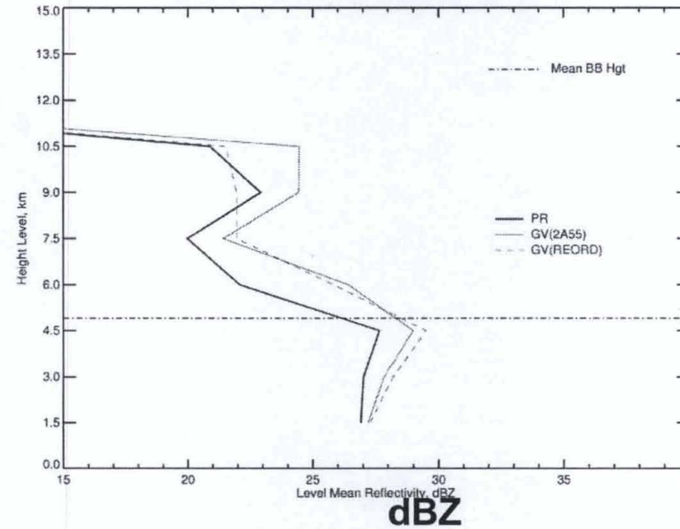
- **Well-behaved sites (left) have average reflectivity differences (PR-NEXRAD) between about ±2 dBZ**
  - **samples taken from *above* the bright band, within a 100 km radius of the ground radar, stratiform rain cases only**
  - **Enables establishment of gross ground radar bias/error behavior**
  - **Selection of well-behaved radars forms means to evaluate space borne platform (and also enables calibration correction of ground radars).**

Output Graphical Comparisons

Histogram Comparisons

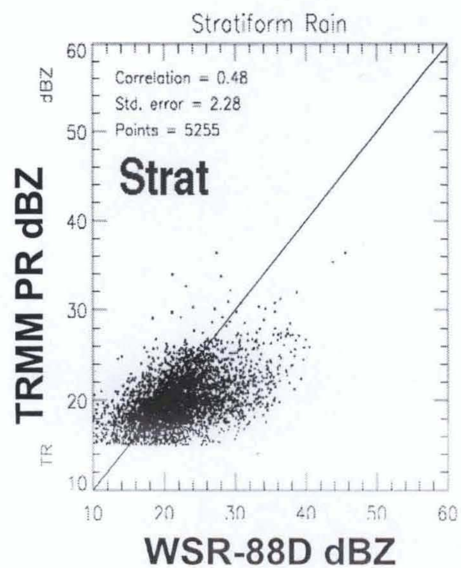


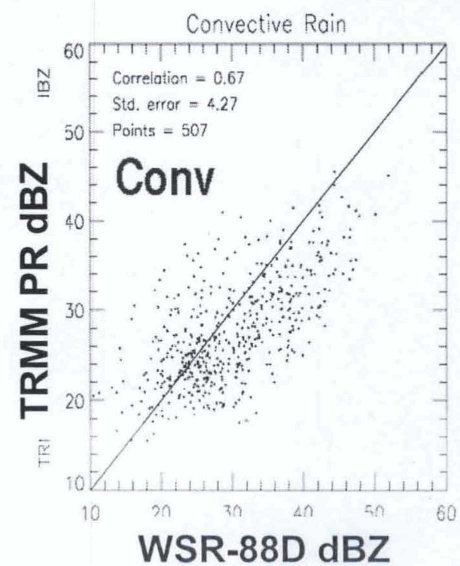
Vertical Profiles



Scatter Plots

By Precipitation Type





Expanded Number of Global Contributing Sites

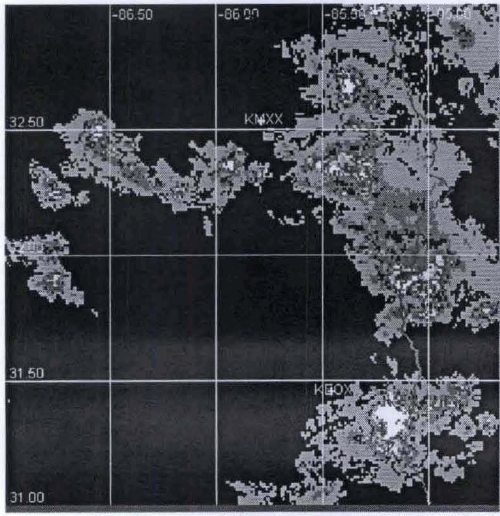
- **21 WSR-88D sites in the southeast US**
  - Raw data acquired from the NOAA Level-2 archive
  - Automated quality control (TRMM 2A-55 GV algorithms)
- **Also used for individual research radars**
  - NSSTC/UAH ARMOR Dual polarimetric C-band radar, 1-degree beamwidth
  - Kwajalein Atoll: Historical 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

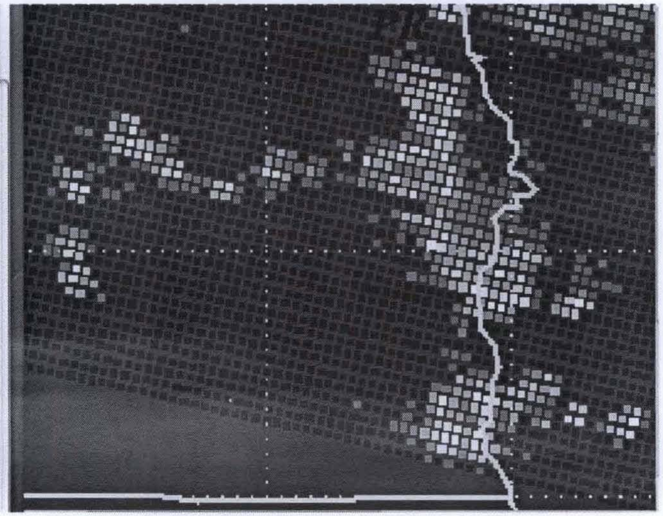
Tier 2): DPR/GMI Rain rates: NOAA Q2 Gridded Product (U.S. NEXRAD Network)

May 12, 2007 @ 22:30 UT

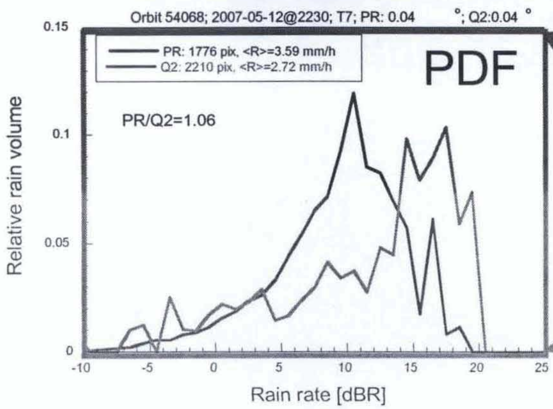
NOAA



TRMM



- 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: Numerious 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

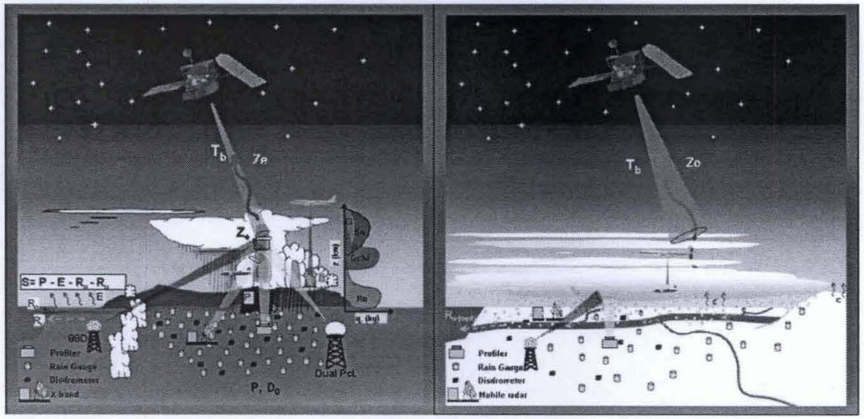
Models:

"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

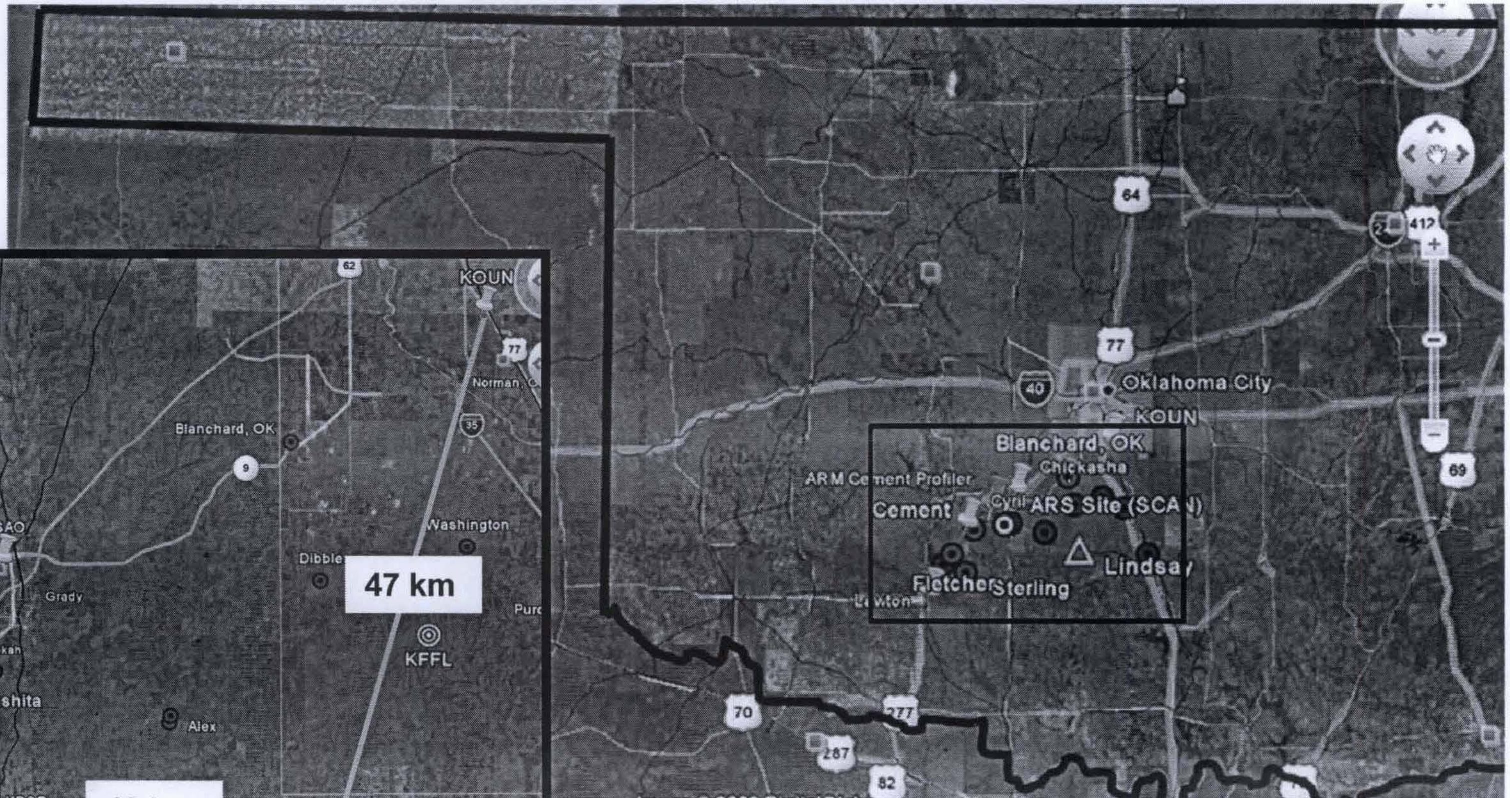
Field Campaign Implementation Planning

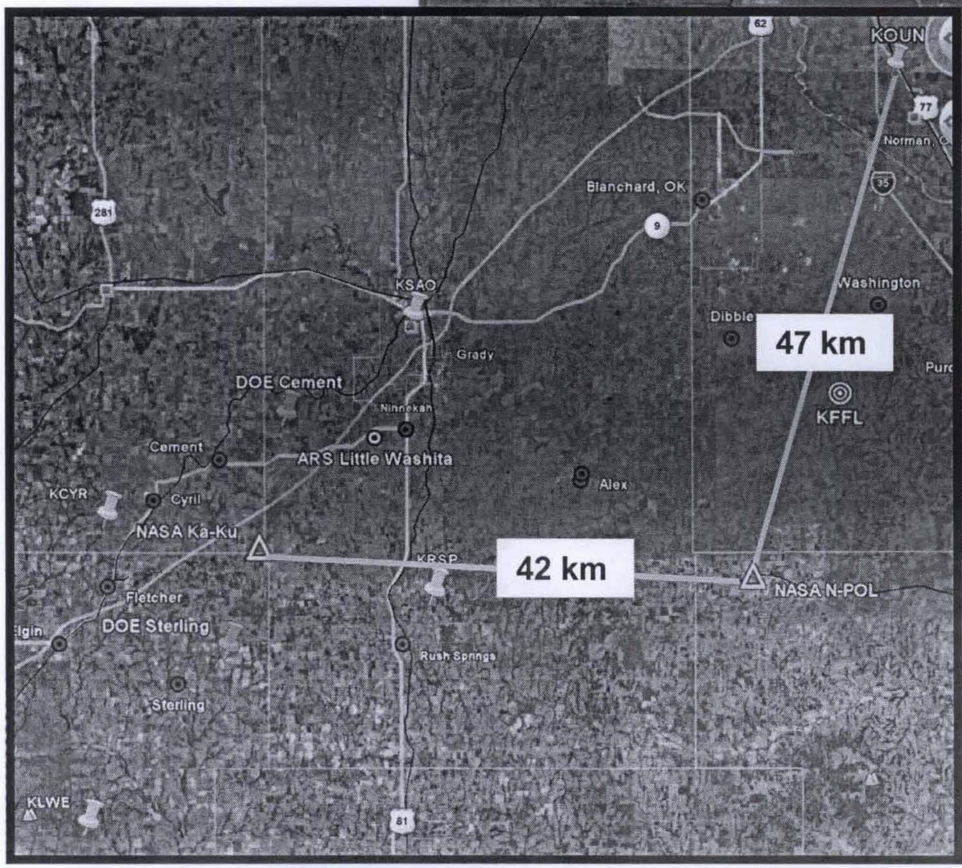
Objective	Date	Partnership/Location
MC3E: GMI/DPR rainfall retrievals over land surfaces	Spring/early summer 2011	Mid-Latitude Continental Convective Clouds Experiment (MC3E)- DOE ARM SGP S. Central Oklahoma
Cold-season retrieval of frozen and mixed precipitation over land surfaces	Winter 2011/2012	TBD
Physical/Integrated	2013	NOAA Hydrometeorological Testbed, Tar/Neuse River Basin, N. Carolina
Cold season product validation	2015	TBD
Physical/Integrated	2016	TBD

- **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)

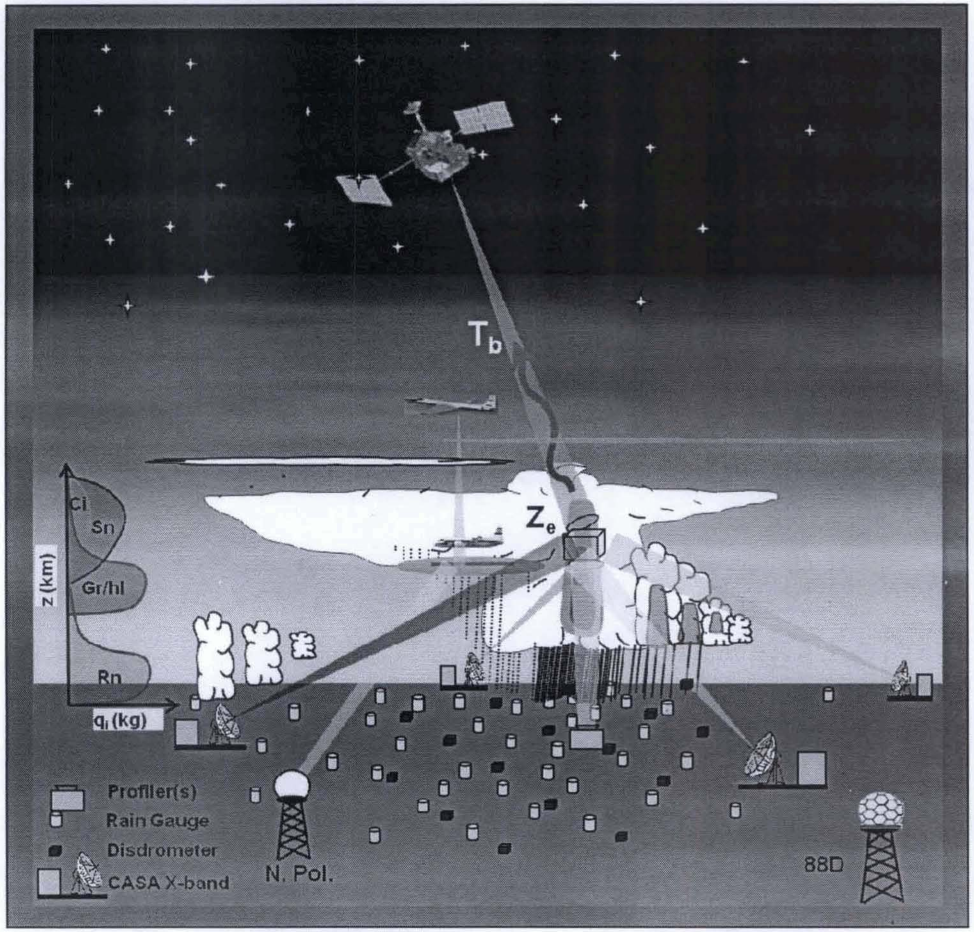
Target Location/Date: S. Central Oklahoma, April-June 2011 (TRMM Coverage)
Targeted regimes: **Land,** late spring transition (baroclinic, MCS, convection)





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

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

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 (O[2-4 km separation over 100 km^2]

- Validation of GV ground radar DSD retrievals/precipitation rates and type
- Spatial/temporal covariance of particle size distributions and precipitation rates

Wind Profiler

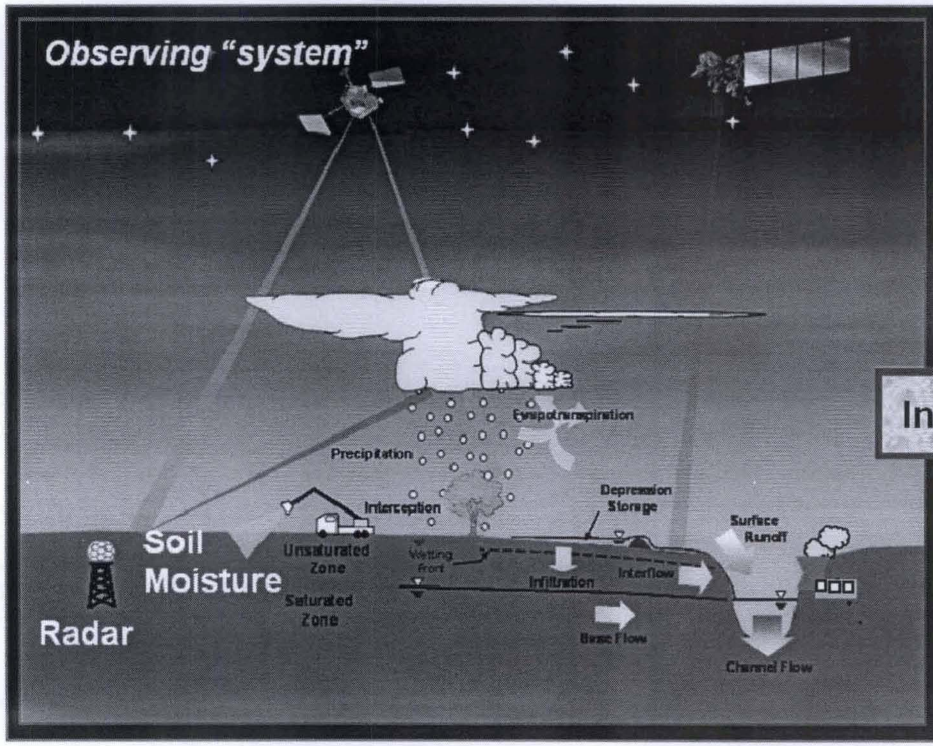
- Vertical profiles of Z, DSD under coverage umbrella of radar

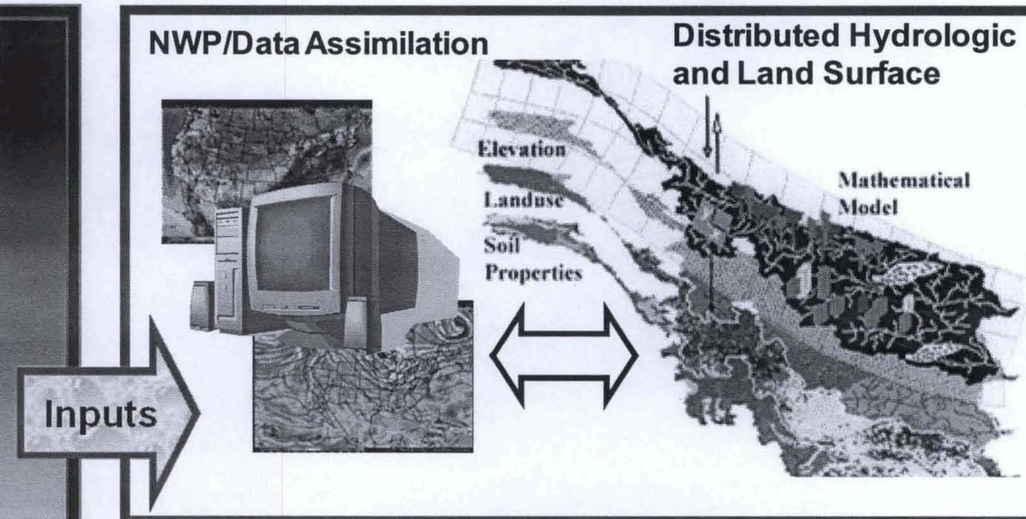
Aircraft Instrumentation/Operations

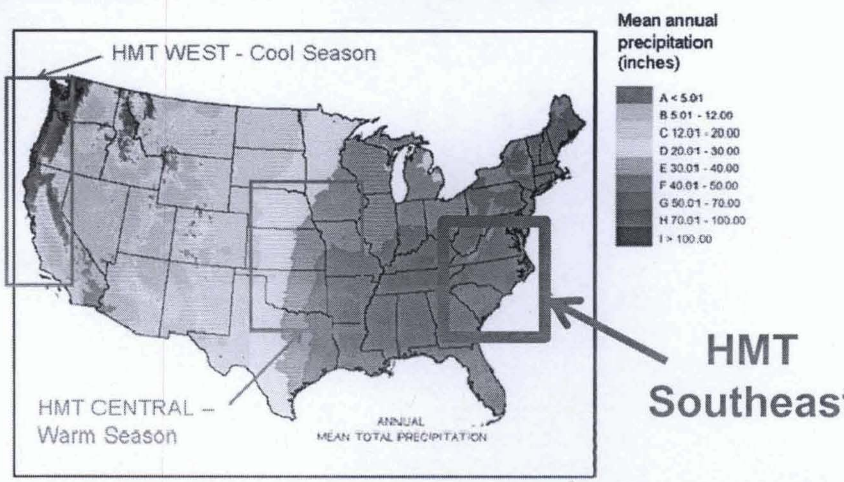
- In situ cloud microphysical sampling
- High-altitude GPM (DPR/GMI) Simulator (HIWRAP, AMPR, COSMIR etc.)

Integrated Validation: Collaboration- NOAA Hydrometeorology Testbed (HMT)

End-to-end utility of retrieval algorithms: Pre-launch algorithm physics linked to hydrologic/water budget application, and hydrologic GV methods





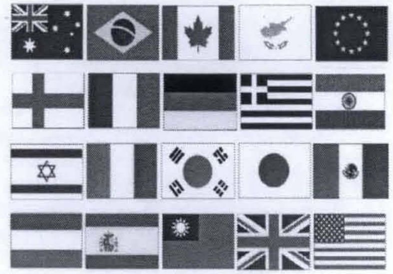


HMT Southeast: "mountain to coast"

Summer flooding, Hurricane Landfall, Winter mixed events……..

Extensive QPE and hydrologic instrumentation, hydrologic modeling

International partnership: A Key to GPM GV success



Potential GPM GV Sites and Partners

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***

GPM GV Success Criteria

- 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 analyses, 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
    - Near term field campaigns: Finland (2010), MC3E (2011), Cold Season (2012)
  - 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