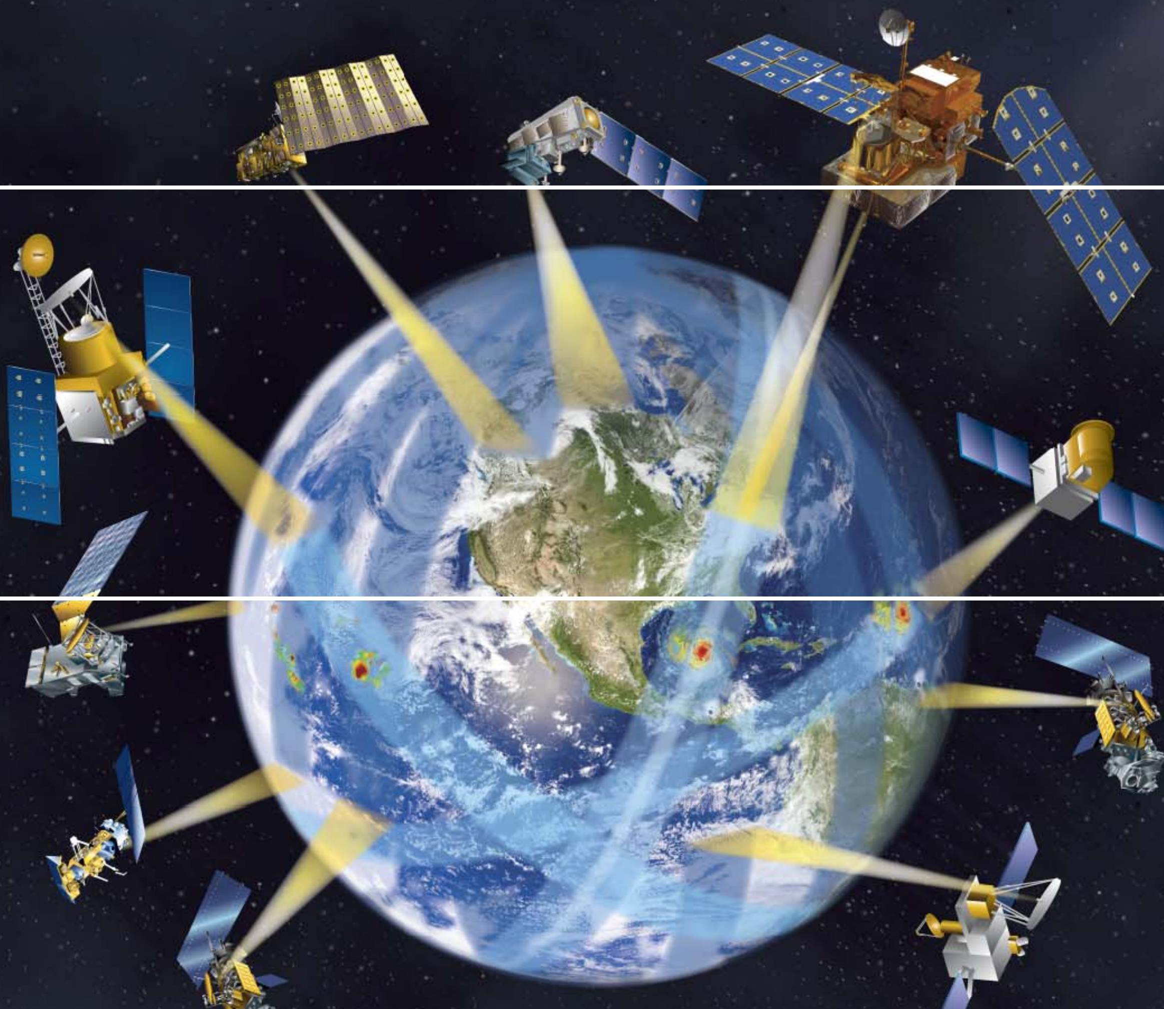
GPM Science Status: Algorithms and Partnerships



Arthur Hou

NASA Goddard Space Flight Center

1st NOAA Workshop on GPM, 18-19 August 2010, College Park, MD

GPM Mission Concept

Unify and advance precipitation measurements from space to provide next-generation global precipitation products within a consistent framework

Low Inclination Observatory (40°)

GMI (10-183 GHz)
(NASA & Partner, 2014)

- Enhanced capability for near realtime monitoring of hurricanes & midlatitude storms
- Improved estimation of rainfall accumulation

GPM Core Observatory (65°)

DPR (Ku-Ka band)
GMI (10-183 GHz)
(NASA-JAXA, LRD 2013)

- Precipitation physics observatory
- Transfer standard for inter-satellite calibration of constellation sensors

Partner Satellites:

GCOM-W1
DMSP F-18, F-19
Megha-Tropiques
MetOp, NOAA-19
NPP, JPSS (over land)

Coverage & Sampling

- 1-2 hr revisit time over land
- < 3 hr mean revisit time over 90% of globe

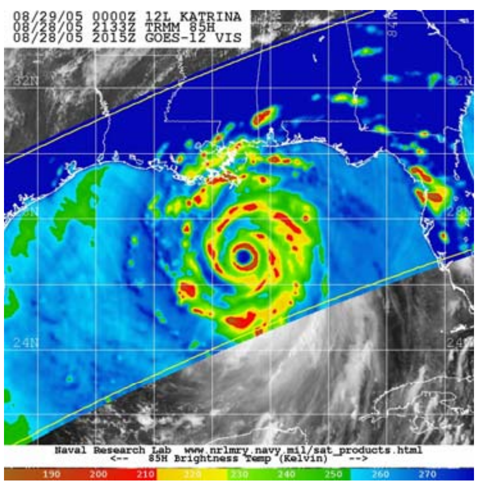
Key Advancement

Using an advanced radar/radiometer measurement system to improve constellation sensor retrievals

GPM Observations from Non-Sun-Synchronous Orbits

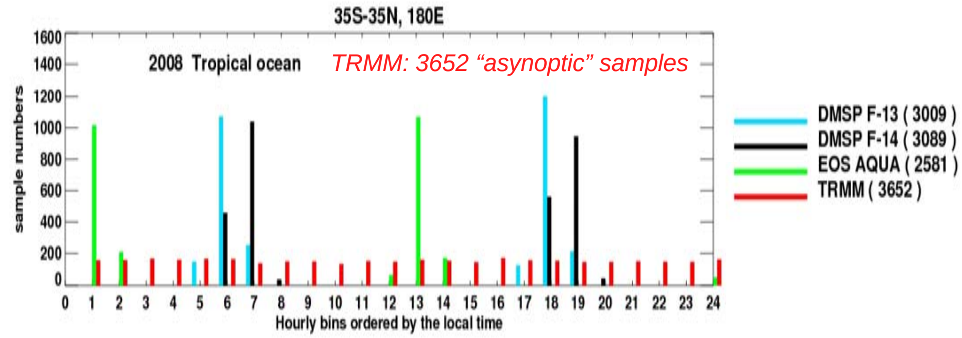
Near real-time observations filling gaps between those of polar orbiters at fixed time of the day for:

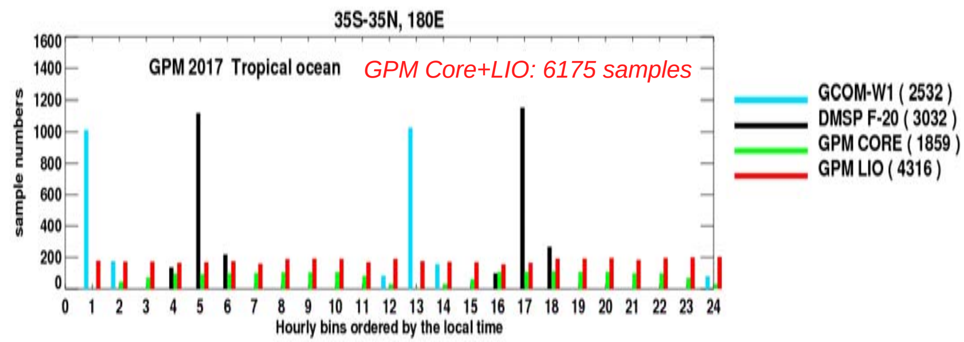
- Intercalibration of polar-orbiting sensors over wide range of latitudes
- Near real-time monitoring of hurricanes & midlatitude storms
- Improved accuracy of rain volume estimation
- Resolving diurnal variability in rainfall climatology

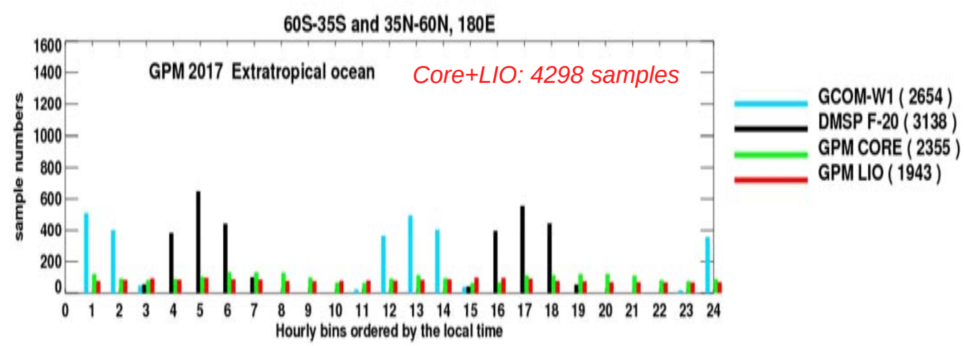


Monthly Samples as a Function of the Time of the Day

(1º x 1º Resolution)





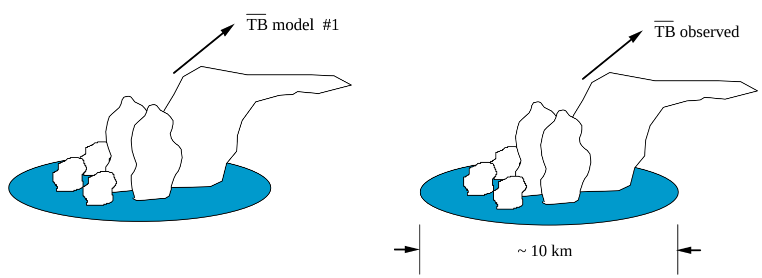


Next-Generation Global Precipitation Products

- Intercalibrated constellation radiometric data reconciling differences in center frequency, viewing geometry, resolution, etc.
  - Converting observations of one satellite to virtual observations of another using non-Sun-synchronous satellite as a transfer standard
  - GMI employs an encased hot load design (to minimize solar intrusion) and noise diodes for nonlinearity removal to attain greater accuracy & stability
- Unified precipitation retrievals using a common cloud database constrained by DPR+GMI measurements from the Core Observatory

Optimally matching observed T_b with simulated T_b from an a priori cloud database

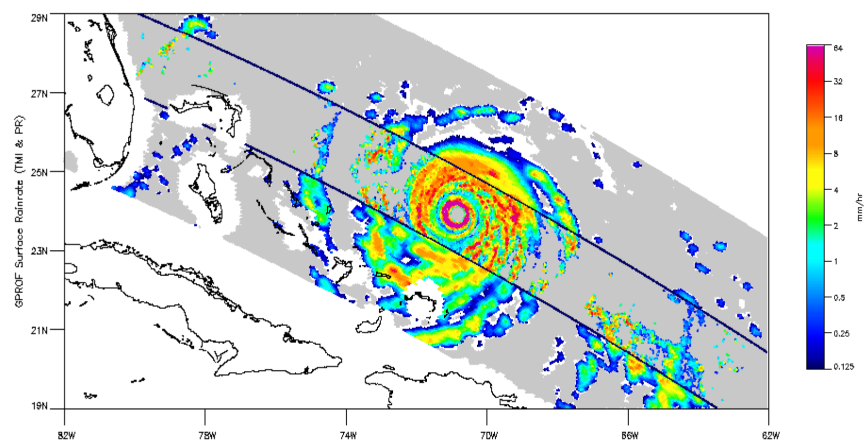
Simulated T_b *Observed T_b*



TRMM uses a model-generated cloud database

GPM uses a DPR/GMI-constrained database

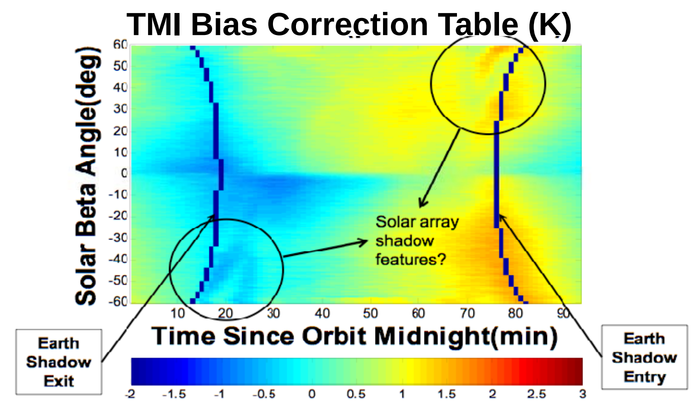
Prototype GPM Radiometer Retrieval



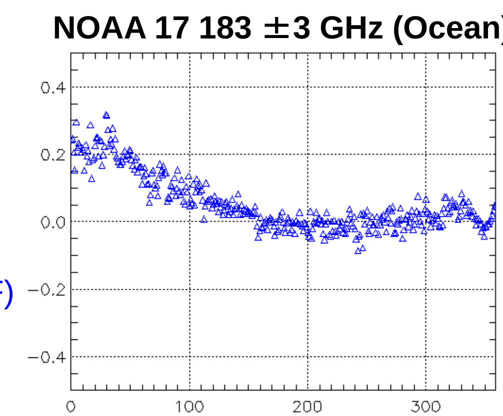
Comparison of TRMM PR surface rain with TMI rain retrieval using an cloud database consistent with PR reflectivity and GMI multichannel radiances

Inter-Satellite Calibration of Microwave Radiometers

- *Objective:* Quantify and reconcile differences between similar but not identical microwave radiometers to produce self-consistent global precipitation estimates
- *X-Cal (Imagers):* Convert observations of one satellite to virtual observations of another using non-Sun-synchronous satellite as a transfer standard (*e.g*. TMI or GMI)
  - Develop corrections for recurring instrument errors and implementation strategy for routine intercalibration of constellation radiometers
  - Bias correction a function of orbital phase and solar beta angle
  - Agreement between different methods ~ 0.3 K



- *X-Cal (Sounders):*
  - Double differencing using forecast residual as primary transfer standard to provide a basis for calibration consistency
  - Collaboration with NWP centers



Courtesy of Hanna, Weng, & Yan (NOAA)

GPM International X-Cal Working Group (NASA, NOAA, JAXA, CNRS, EUMETSAT, CMA, CONAE, GIST, & universities) in coordination with WMO/CGMS GSICS

GPM Ground Validation

Pre-launch algorithm development & post-launch product evaluation

- Refine algorithm assumptions & parameters
- Characterize uncertainties in satellite retrievals & GV measurements

Three complementary approaches:

- *Direct statistical validation (surface):*

  - Leveraging off operational networks to identify and resolve first-order discrepancies between satellite and ground-based precipitation estimates

- *Physical process validation (vertical column):*

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

- *Integrated hydrologic validation/applications (4-dimensional):*

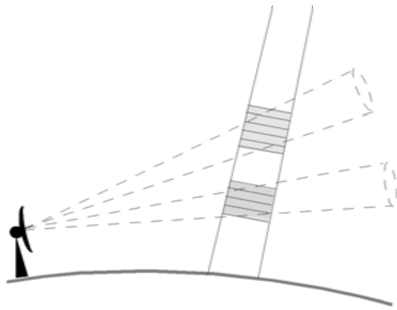
  - Identify space-time scales at which satellite precipitation data are useful to water budget studies and hydrological applications; characterization of model and observation errors

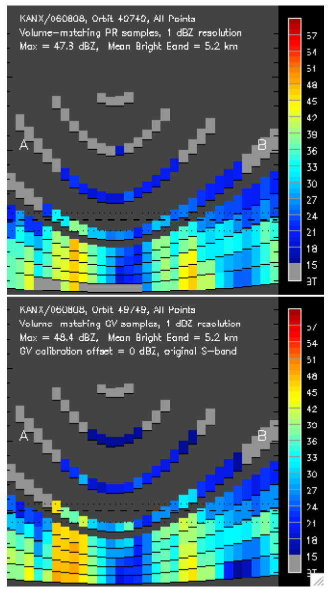
"Truth" is estimated through the convergence of satellite and ground-based estimates

Direct Statistical Validation

Identify systematic regional or regime issues

Geometrically matches ground and spaceborne radar volumes (TRMM PR used as pre-launch proxy for GPM DPR)





Horizontal/vertical cross-section comparisons

Volume statistics on radar reflectivity

- Surface rain-rate comparison

– Compare satellite rain products with NOAA National Mosaic & QPE (NMQ) data at 0.01° resolution updated every 5 min.

– Integrate satellite rainfall data into NMQ

- Radar reflectivity comparison

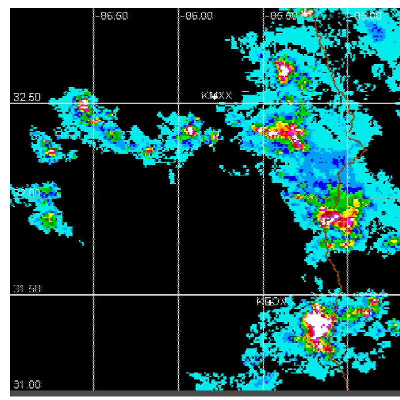
– Systematic regime variability in reflectivity between space and ground radars can be detected with existing operational networks

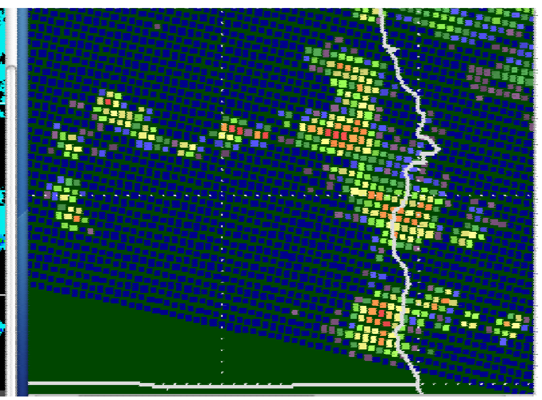
– Stable PR supports ground radar calibration

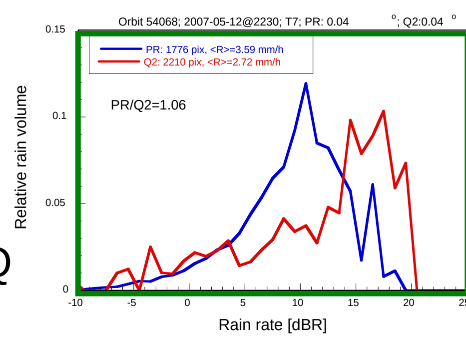
– Scalable and Platform-Adaptive Matching Software available as open source

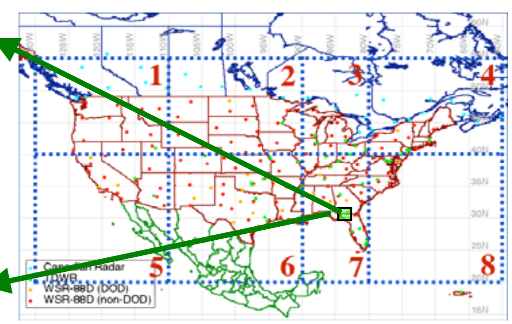
(In use in Korea, Taiwan, Australia, & Europe)

NOAA Q2 ***TRMM PR***

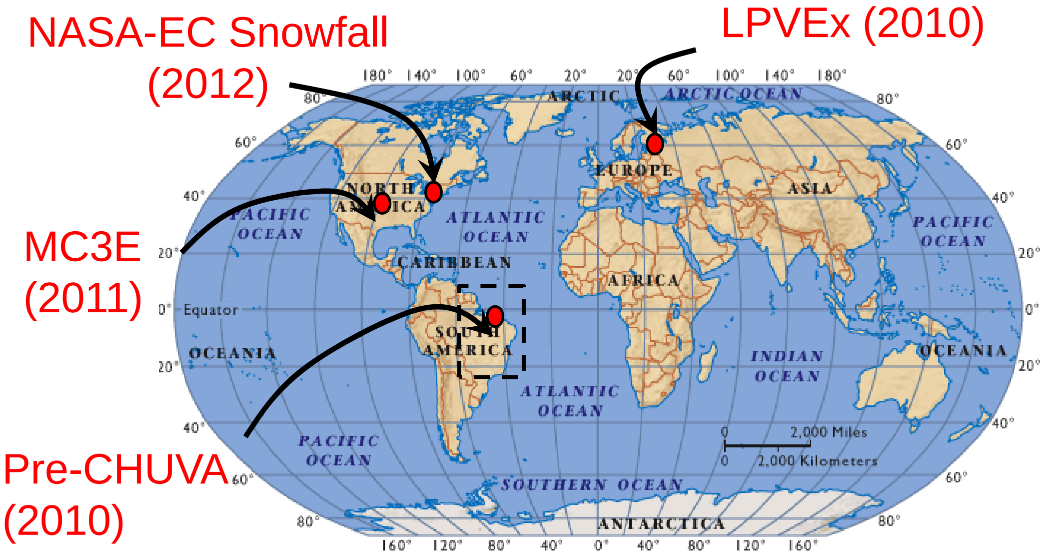


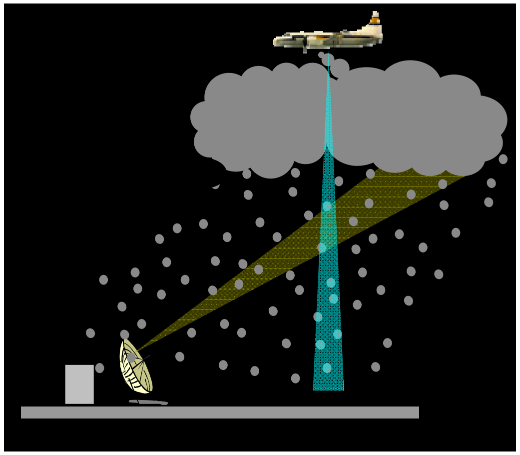






Physical Validation: Field Campaigns (2010-2012)



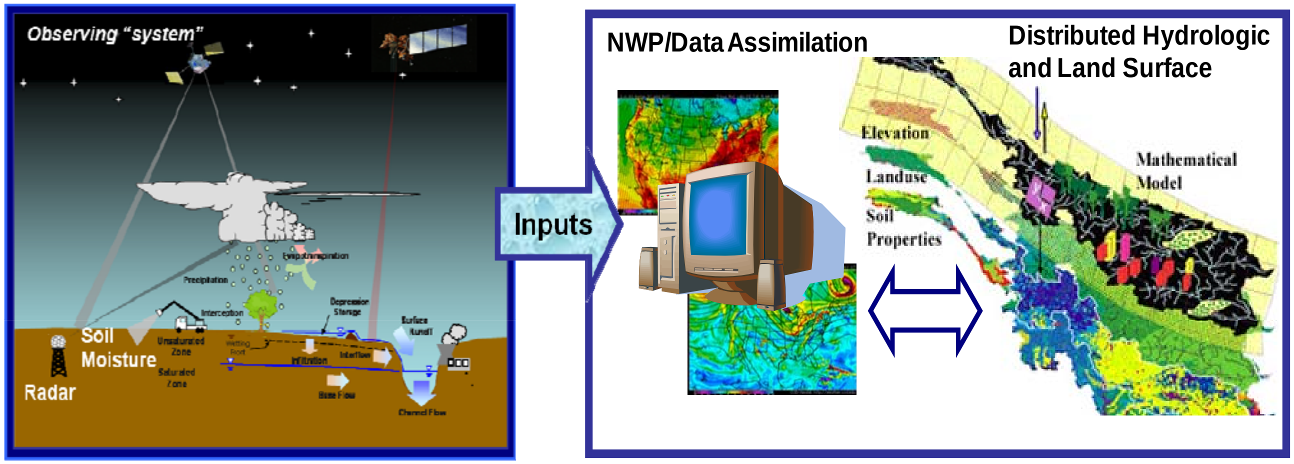


- 2010: Pre-CHUVA: GPM-Brazil & NASA field campaign targeting warm rain retrieval over land, Alcântara Launching Center, 3-24 March.
- 2010: Light Precipitation Validation Experiment (LPVEx): CloudSat-GPM light rain in shallow melting layer situations, Helsinki Testbed & Gulf of Finland, Sept-Oct.
- 2011: Mid-Latitude Continental Convective Clouds Experiment (MC3E): NASA-DOE field campaign at DOE-ASR Central Facility in Oklahoma, Apr-May.
- 2012: High-Latitude Cold-Season Snowfall Campaign: GPM-Environment Canada campaign on snowfall retrieval, Ontario, Canada, Jan-Feb.

Algorithm developers directly engaged in design, execution, & analysis

Integrated Hydrological Applications/Validation

Identify space-time scales at which satellite precipitation data are useful to water budget studies and hydrological applications



- Characterization of uncertainties in satellite and ground-based (radar, dense gauge networks) rainfall estimates over a broad range of space/time scales
- Characterization of uncertainties in hydrologic models and understanding propagation of input uncertainties into model forecasts
- Assessing performance of satellite rainfall products in hydrologic applications over a range of space-time scales
- Using data from synergistic missions (e.g. SMOS, SMAP, GRACE) to refine hydrologic model parameters and improve predictions driven by GPM input data

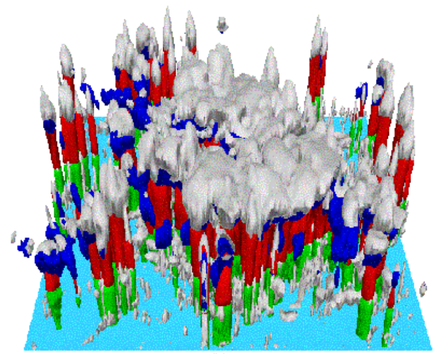
Joint field campaign with NOAA HMT-SE under planning for 2013

GPM Dynamically-Downscaled High-Resolution Product

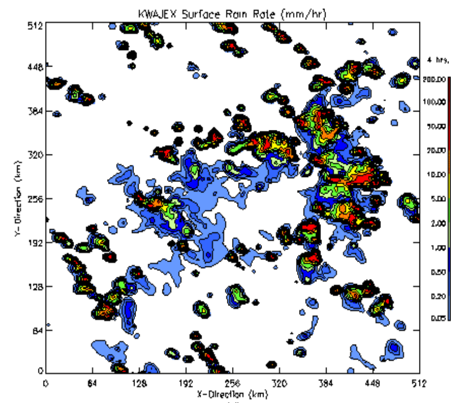
Using CRM to downscale satellite precipitation observations

GPM Observations

Assimilate satellite precipitation data into cloud-resolving model to produce observation-constrained dynamically-balanced precipitation analysis at 1-2 km for hydrological applications



Cloud Resolving Model

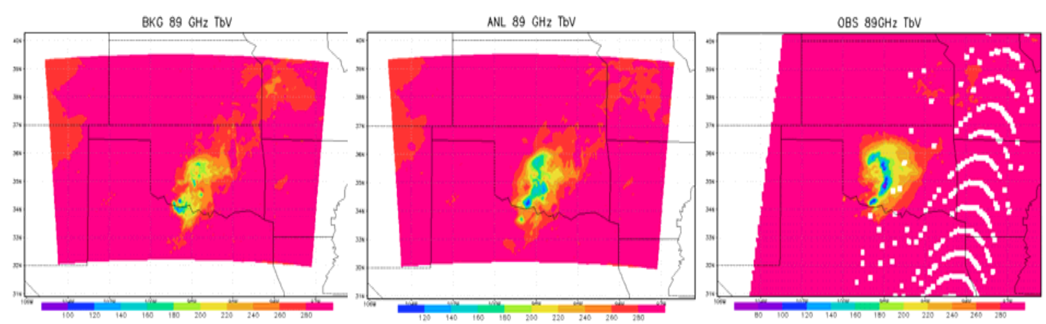


Level-4 Precipitation Analysis

NASA-CSU prototype WRF EnsDAS assimilating AMSR-E Tb

- *NASA Unified WRF model (9-3-1 km nesting)*
- *NOAA conventional observations (radiosonde, aircraft) and operational clear-sky satellite data*
- *Precipitation-affected satellite radiances*
- *NASA Satellite Data Simulation Unit*
- *CSU Maximum Likelihood Ensemble data assimilation scheme*

Background (3-h fcst) Analysis (Conv+AMSR-E) Observed Tb 89v



Zupanski et al.

GPM Data Products

Product Level	Description	Coverage
Level 1B GMI, GMI-2 Level 1C GMI, GMI-2 *Latency ~ 1 hour*	Geolocated Brightness Temperature and intercalibrated brightness temperature	Swath, instrument field of view (IFOV)
Level 1B DPR	Geolocated, calibrated radar powers	Swath, IFOV (produced at JAXA)
Level 1C, partner radiometers	Intercalibrated brightness temperatures	Swath, IFOV
Level 2 GMI, GMI2 *Latency ~1 hour*	Radar enhanced (RE) precipitation retrievals	Swath, IFOV
Level 2 partner radiometers	RE precipitation retrievals from 1C	Swath, IFOV
Level 2 DPR *Latency ~3 hours*	Reflectivities, Sigma Zero, Characterization, DSD, Precipitation with vertical structure	Swath, IFOV (Ku, Ka, combined Ku/Ka)
Level 2 combined GMI/DPR *Latency ~3 hours*	Precipitation	Swath, IFOV (initially at DPR Ku swath and then at GMI swath)
Level 3 Latent Heating (GMI, DPR, Combined)	Latent Heating and associated related parameters	0.1 x 0.1 monthly grid
Level 3 Instrument Accumulations	GMI, partner radiometers, combined and DPR	0.1 x 0.1 monthly grid
Level 3 Merged Product	Merger of GMI, partner radiometer, and IR	0.1 x 0.1 hourly grid
Level 4 Products	Model assimilated data	Fine temporal and spatial scale TBD

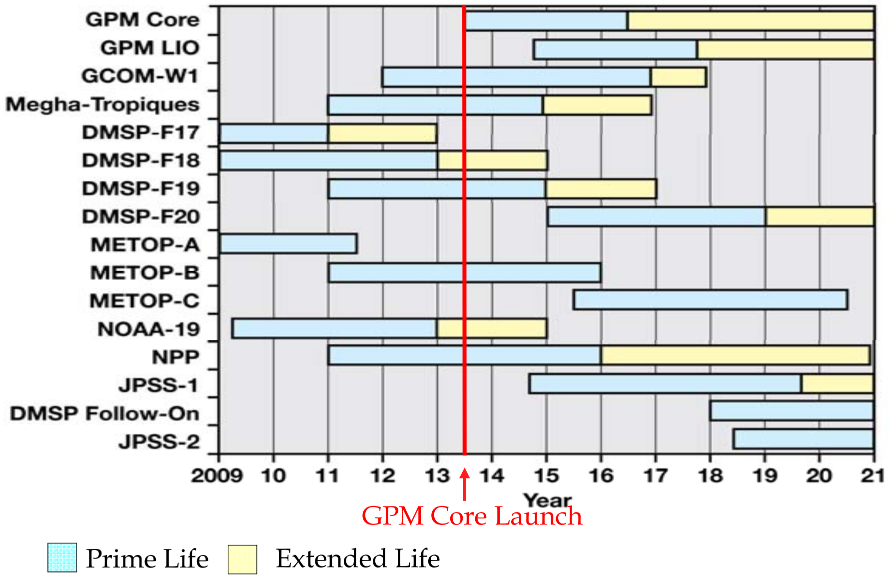
Science Partnership with NOAA on GPM

- Level 1 radiometer intercalibration (partnership through GSICS & PMM)
  - Using NWP forecast residuals for sounder intercalibration
- Level 2 precipitation algorithms (NOAA PI's on PMM Science Team)
  - Land surface characterization for physically based retrieval
  - Precipitation microphysical properties
- Statistical validation
  - Collaboration with NOAA NMQ for validation and product enhancement
- Hydrological applications/validation
  - Joint field campaigns with NOAA HMT (e.g. HMT-SE)
- Level 3 multi-satellite product development
  - Moving towards U.S. national products (global & regional)
  - Combined satellite & ground-based measurements
- Level 4 dynamic downscaling
  - WRF ensemble data assimilation using NOAA operational data streams

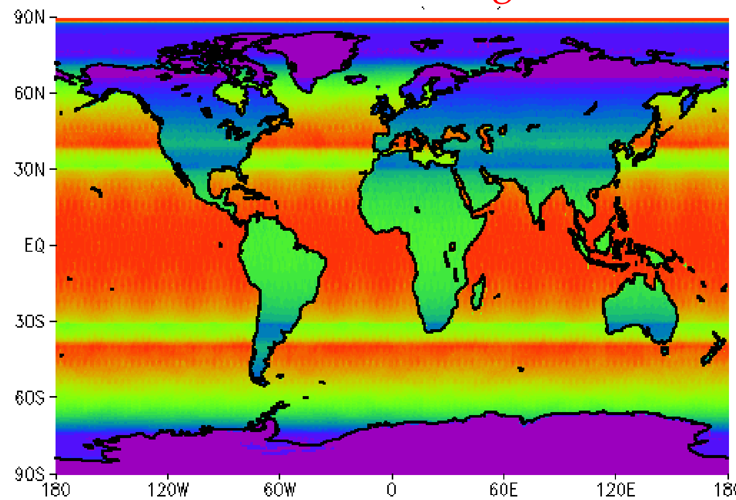
Additional Slides

GPM Constellation Sampling and Coverage

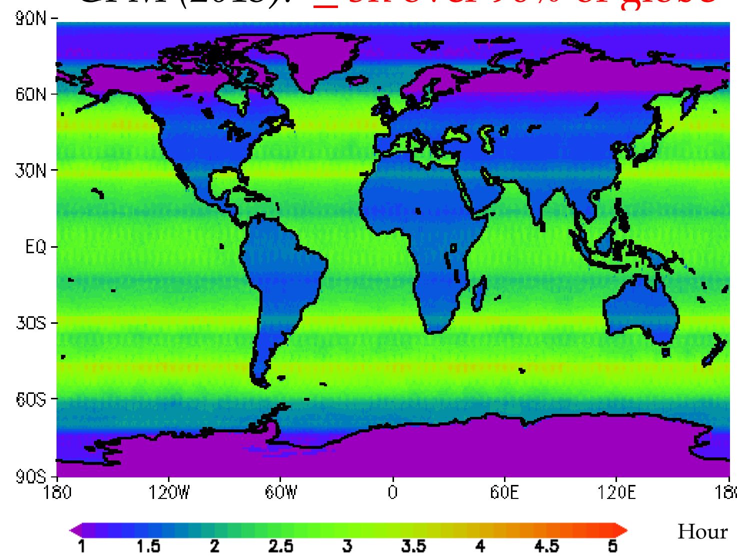
Baseline Constellation Schedule



Current Capability:
≤ 3h over 45% of globe



GPM (2015): ≤ 3h over 90% of globe



	Average Revisit Time (hr)				
Year	**2013**	**2014**	**2015**	**2016**	**2017**
			Land		
Tropics	1.9	1.5	1.5	1.6	2.4
Extratropics	1.3	1.0	1.0	1.2	1.4
Globe	1.6	1.2	1.2	1.4	1.8
			Ocean		
Tropics	3.2	2.6	2.6	2.6	4.9
Extratropics	3.3	2.6	2.6	2.6	3.4
Globe	3.2	2.6	2.6	2.6	4.2
			Land and Ocean		
Tropics	2.8	2.3	2.3	2.3	4.2
Extratropics	2.6	2.1	2.1	2.1	2.7

1-2 hr revisit time over land with inclusion of sounders

LPVEx Field Campaign (Sept. 15 – Oct. 24, 2010)

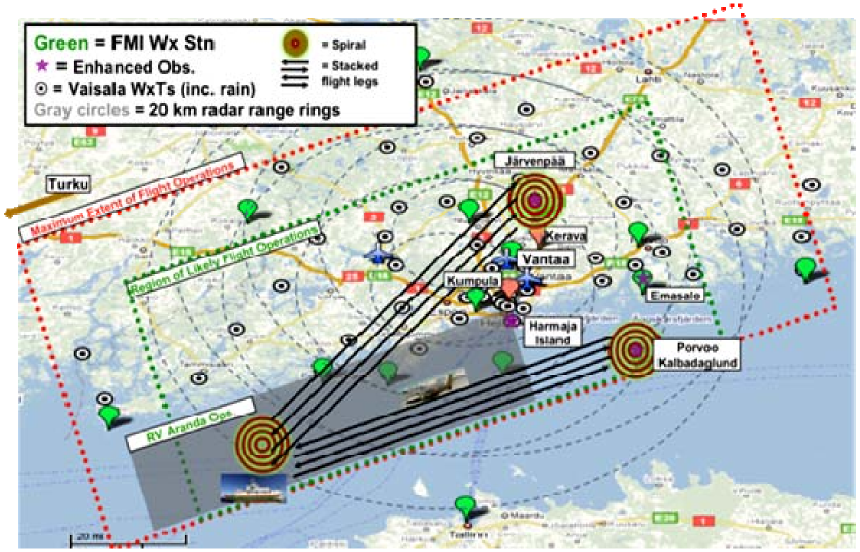
Target: Light rain in cold low altitude melting layer environment

GV Science:

a) Quantify column DSD/precip variability over inland, coastal, sea regimes
b) Melting layer physics coupled to water below and ice above
c) Reconstructed Ka-Ku band (DPR) data for DFR algorithm testing
d) Observationally-validated model databases for radiometer algorithms

Approach:

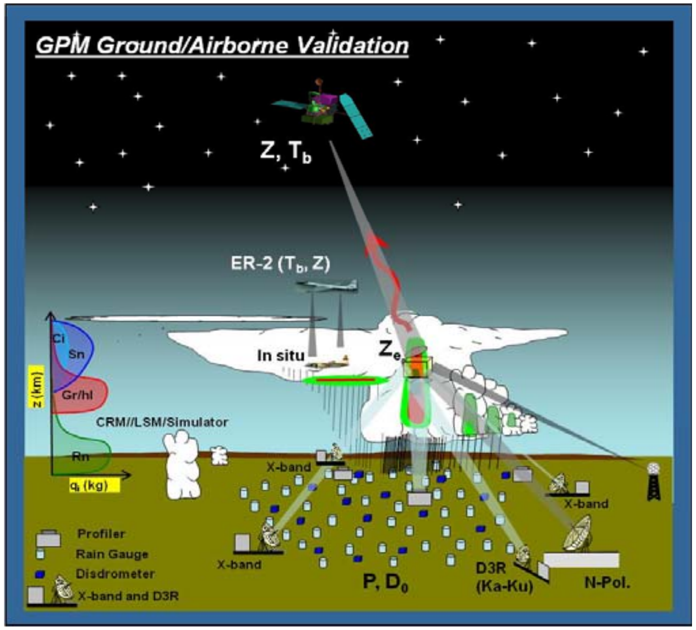
- Heavily instrument surface sites + 1 Ship under radar/aircraft/satellite coverage at Järvenpää (*inland*), Harmaja (*Island)*, Emasalo (*coast*), and R/V Aranda (*sea*)
- 3 Dual-pol radars, 6-8 disdrometers/4-MRRs/ADMIRARI radiometer/3 POSS U. Wyoming King Air Airborne microphysics + W-band radar



Helsinki-Testbed & Gulf of Finland

MC3E Field Campaign (April 15 – May 31, 2011)

Target: Mid-latitude convective and stratiform rainfall over land



Confirmed Instruments:

- Aircraft: ER-2, UND Citation (microphysics)
- Radars: NPOL, D3R, DOE X-band(s), C-band, Ka/W, S/UHF profiler
- Surface: Dense disdrometer/gauge net. ASR surface met, radiometer, flux and, aerosol instruments
- Soundings: ASR array 6 – 8 launches/day

Location: DOE-ASR Central Facility, Oklahoma

GV Science Priorities

1. **Coordinated Airborne [high altitude/in situ]**
   a. High altitude Ka/Ku-band radar, multi-freq. radiometer with in-situ ice microphysics
   b. Pre/post storm surface properties
2. **3-D Mapping of *hydrometeor distribution/type***
   a. Unified framework for retrieving 3-D DSD
   b. Sub pixel scale DSD variability
   c. Cross validation/comparison of multi-frequency (Ka-Ku) and dual-pol. retrievals
3. **Satellite *simulator models (CRM/LSM/RT)***
   a. High quality sounding-based forcing data
   b. Microphysical and kinematic validation.
   c. Land surface impacts

Status: Pre-field deployment sampling and logistics planning

NASA-EC Snowfall Campaign (Jan.-Feb. 2012)

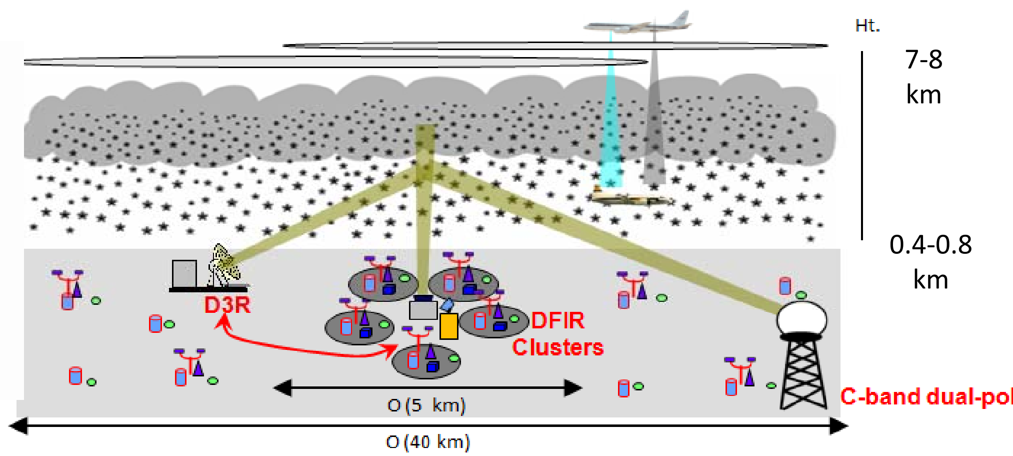
Target: Snowfall retrieval algorithms

GV Science

1. Radiometer/DPR Snowfall measurement sensitivities to snow type, rate, surface and tropospheric characteristics
2. Physics of snowfall in the column and relation to extinction characteristics
3. Model databases for forward modeling and retrieval development.

Approach

- Network observations of SWE and PSD
- In-situ and high-altitude airborne sampling
- Ground-based radar/profiling components
- Soundings for column T and Water Vapor



Status: Planning phase

Site chosen: Environment Canada CARE site in Ontario, Canada

Instruments planned: DC-8 (Ka-Ku band radar, CoSMIR radiometer), microphysics aircraft (TBD), D3R Ka-Ku radar, C-band dual-pol radar, numerous snow-gauge/disdrometer clusters, profiling radars at S/UHF, X, K, and W-bands.