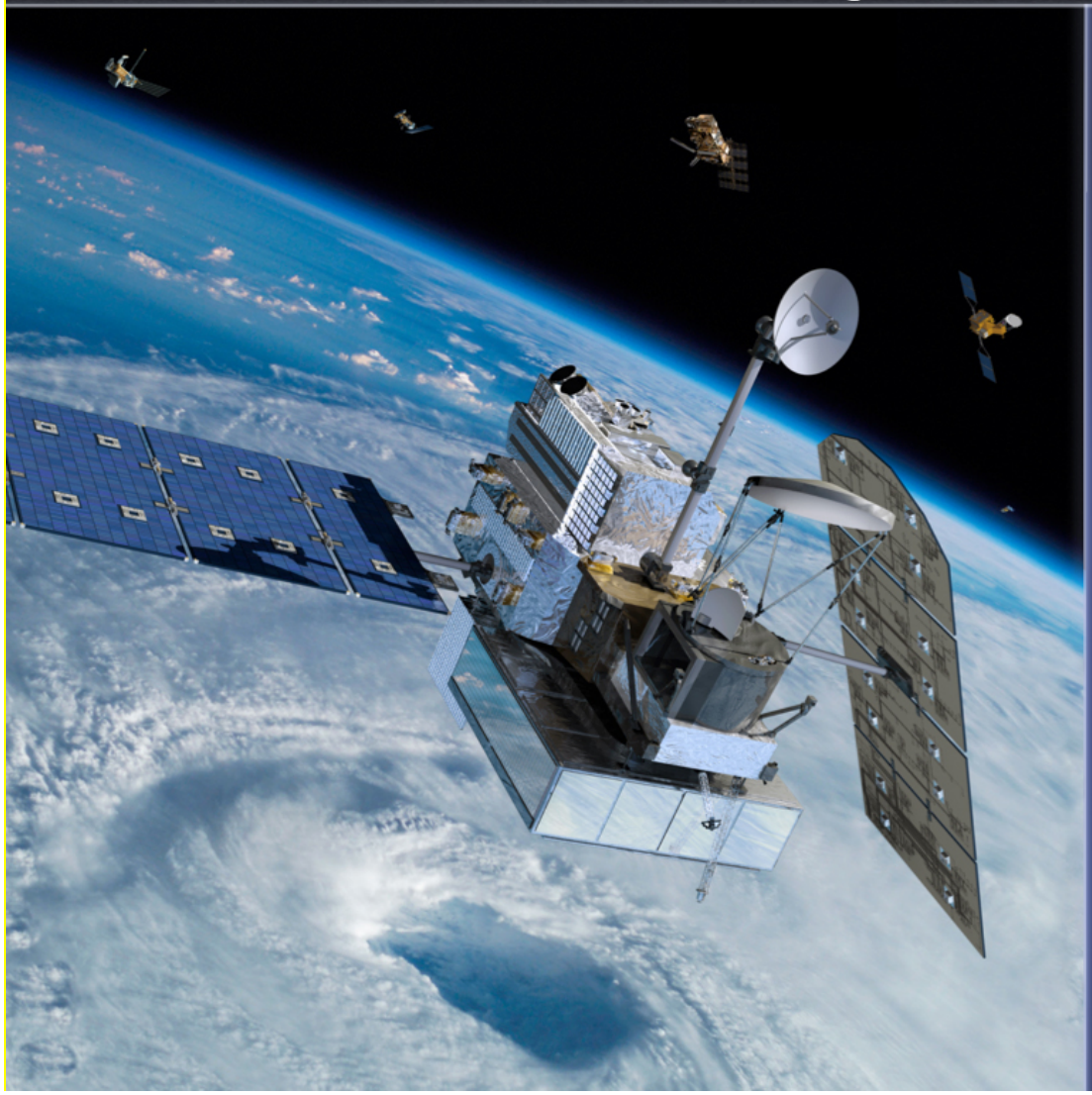
NASA HQ PMM Welcome and Program Status



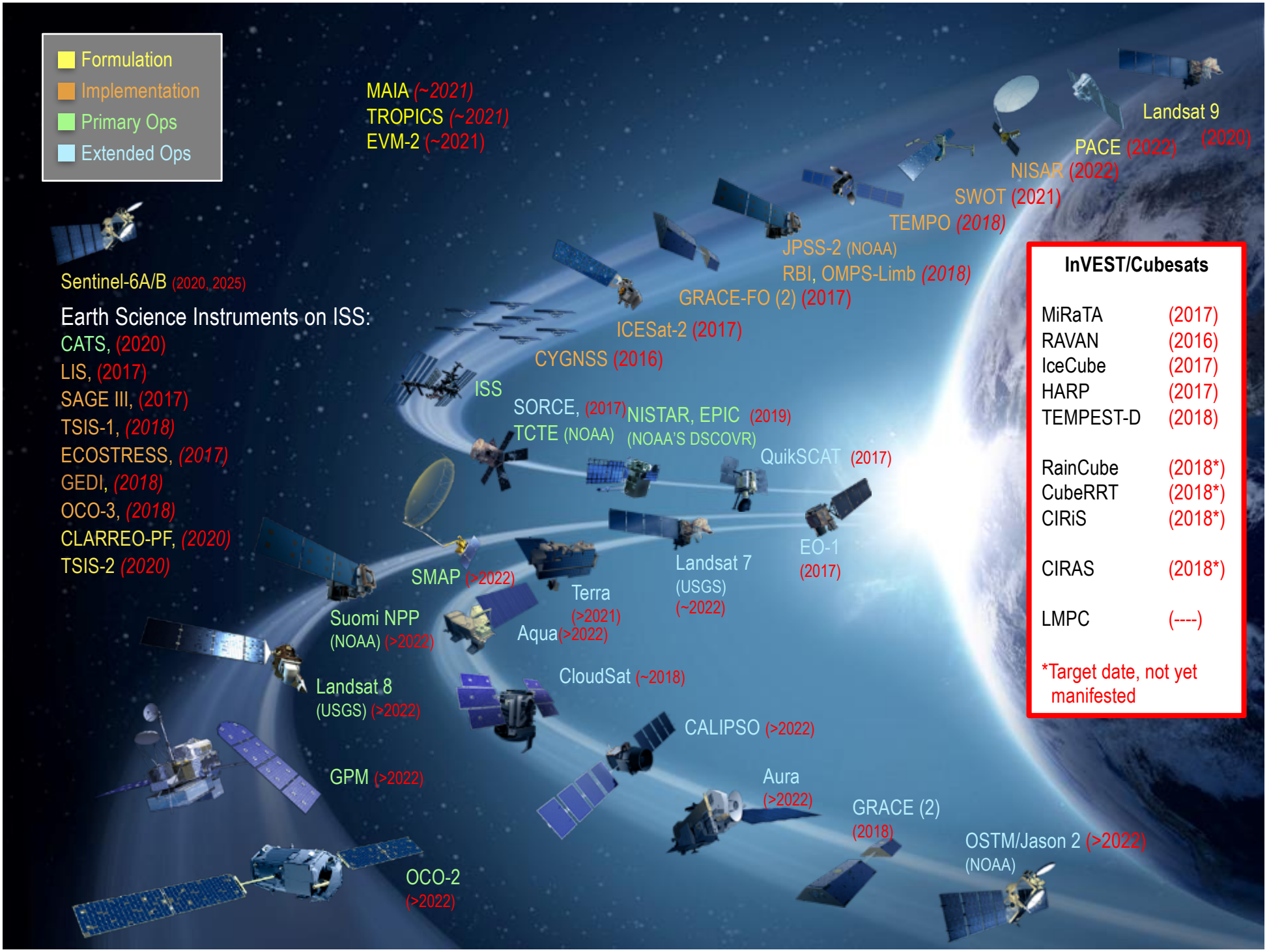
Ramesh Kakar
GPM Program Scientist

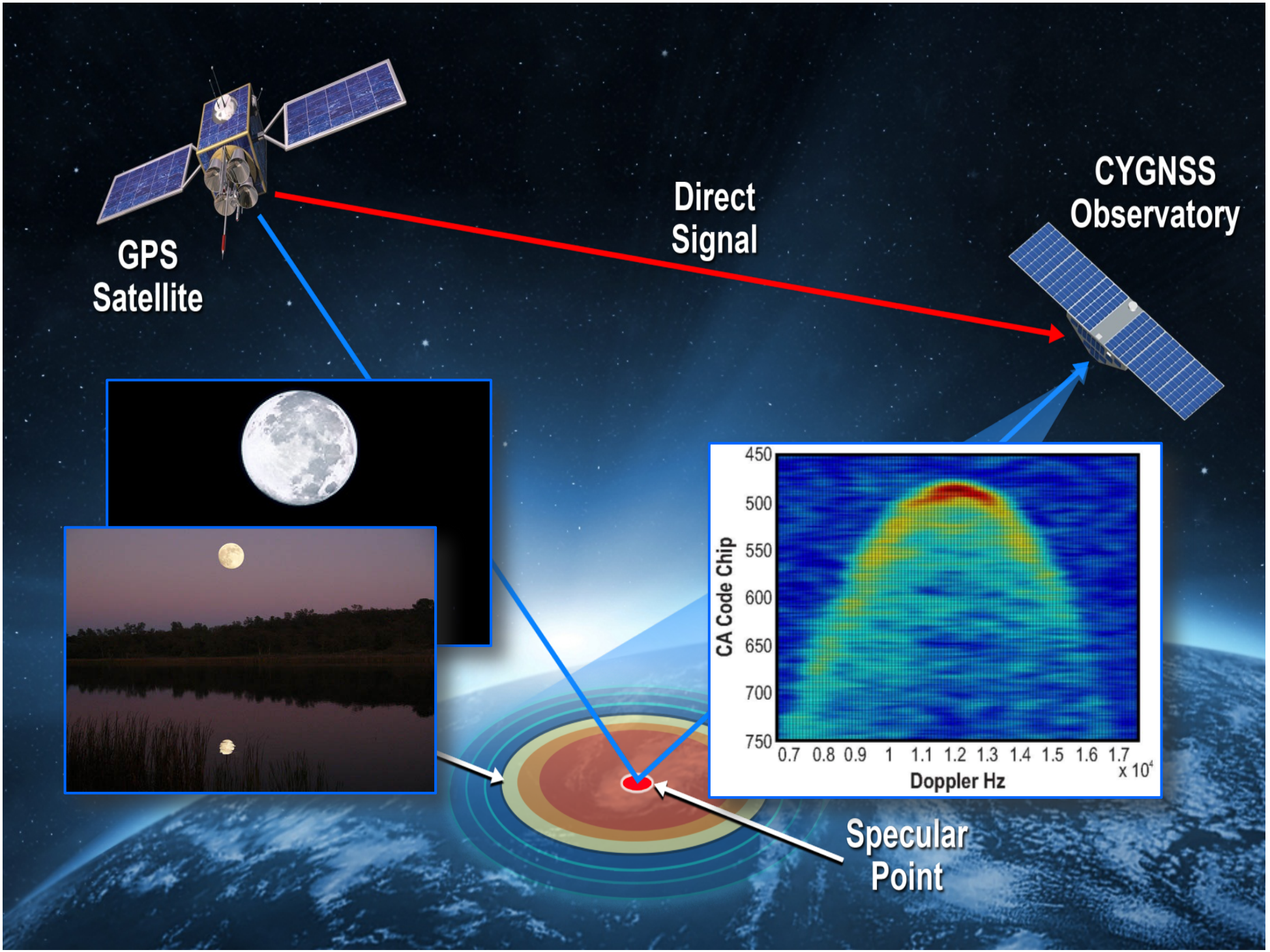
NASA Headquarters

PMM Science Team Meeting
October 24-27, 2016

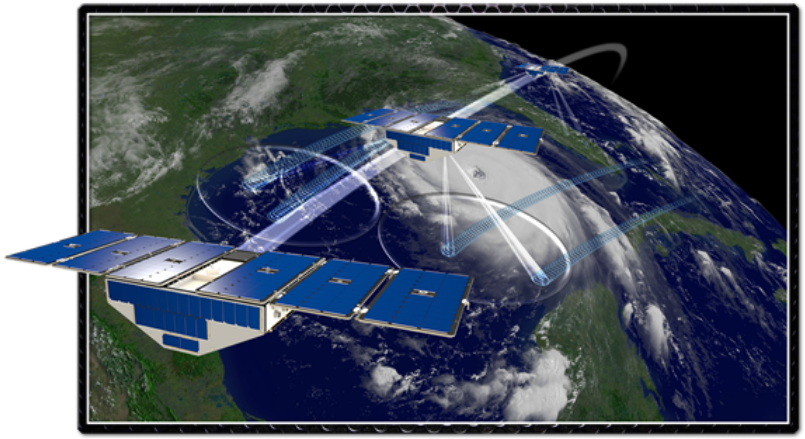
Presentation Plan

- NASA Earth Science Division Satellite Fleet
- Relevant new satellite missions
- GPM Status
- GPM Data Products
- GPM Applications
- GPM field experiments
- Senior Review

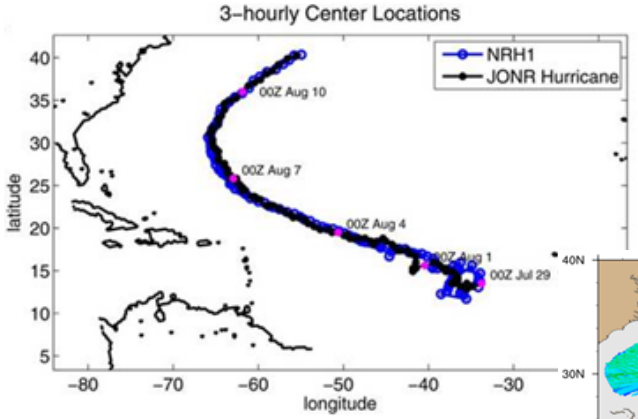

Formulation
Implementation
Primary Ops
Extended Ops
MAIA (~2021)
TROPICS (~2021)
EVM-2 (~2021)
Landsat 9 (2020)
PACE (2022)
NISAR (2022)
SWOT (2021)
TEMPO (2018)
JPSS-2 (NOAA)
RBI, OMPS-Limb (2018)
GRACE-FO (2) (2017)
ICESat-2 (2017)
CYGNSS (2016)
Sentinel-6A/B (2020, 2025)
Earth Science Instruments on ISS:
CATS, (2020)
LIS, (2017)
SAGE III, (2017)
TSIS-1, (2018)
ECOSTRESS, (2017)
GEDI, (2018)
OCO-3, (2018)
CLARREO-PF, (2020)
TSIS-2 (2020)
ISS
SORCE, (2017)
TCTE (NOAA)
NISTAR, EPIC (2019)
(NOAA'S DSCOVR)
QuikSCAT (2017)
EO-1 (2017)
Landsat 7 (USGS) (~2022)
SMAP (>2022)
Terra (>2021)
Aqua(>2022)
Suomi NPP (NOAA) (>2022)
CloudSat (~2018)
Landsat 8 (USGS) (>2022)
CALIPSO (>2022)
GPM (>2022)
Aura (>2022)
GRACE (2) (2018)
OSTM/Jason 2 (>2022) (NOAA)
OCO-2 (>2022)
InVEST/Cubesats
MiRaTA (2017)
RAVAN (2016)
IceCube (2017)
HARP (2017)
TEMPEST-D (2018)
RainCube (2018*)
CubeRRT (2018*)
CIRiS (2018*)
CIRAS (2018*)
LMPC (----)
*Target date, not yet manifested


GPS
Satellite
Direct
Signal
CYGNSS
Observatory
CA Code Chip
450
500
550
600
650
700
750
0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7
x 10^4
Doppler Hz
Specular
Point

Cyclone Global Navigation Satellite System (CYGNSS)

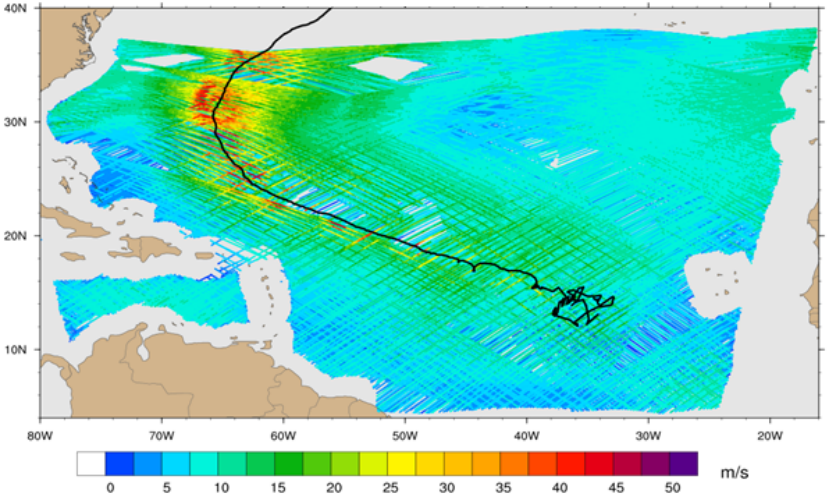


- PI: Christopher Ruf (Univ. of Michigan)
- Rapid sampling of ocean surface winds in the inner core of tropical cyclones; Improved track, intensity and storm surge forecast skill
- 2.8 hr (median) & 7.2 hr (mean) revisit time between ±38° lat; 25 km spatial resolution
- Eight satellites, each carrying a 4-channel receiver capable of bi-static radar measurement of GPS signals reflected by the ocean surface

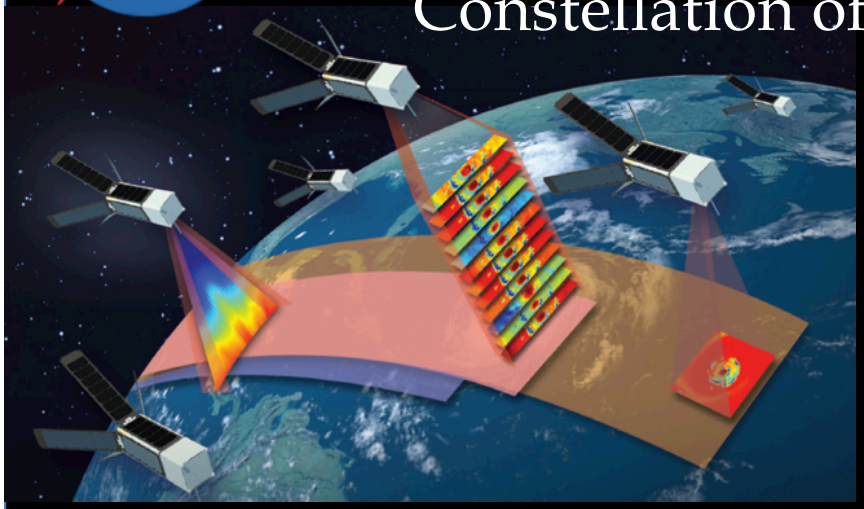


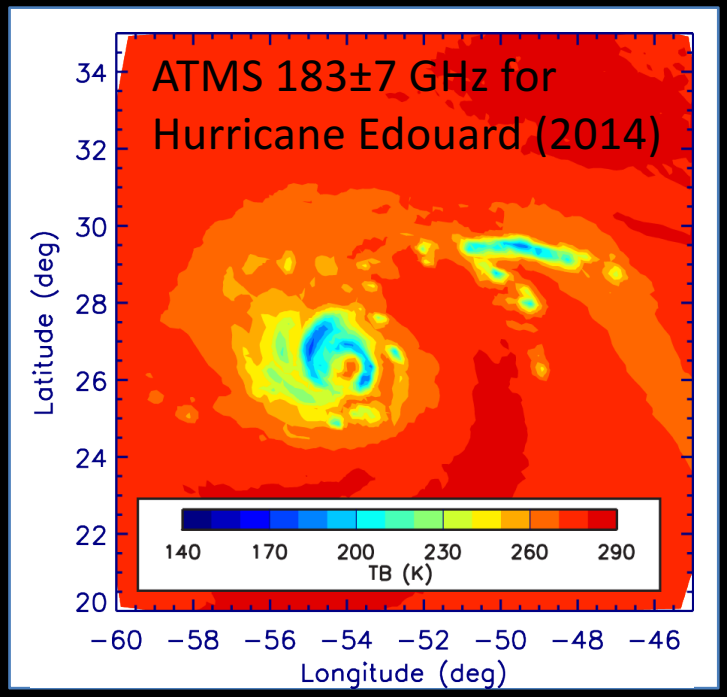
(top) Storm track of Nature Run simulated tropical cyclone

(right) Surface wind speed sampled by CYGNSS throughout its 13-day life cycle



Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS)



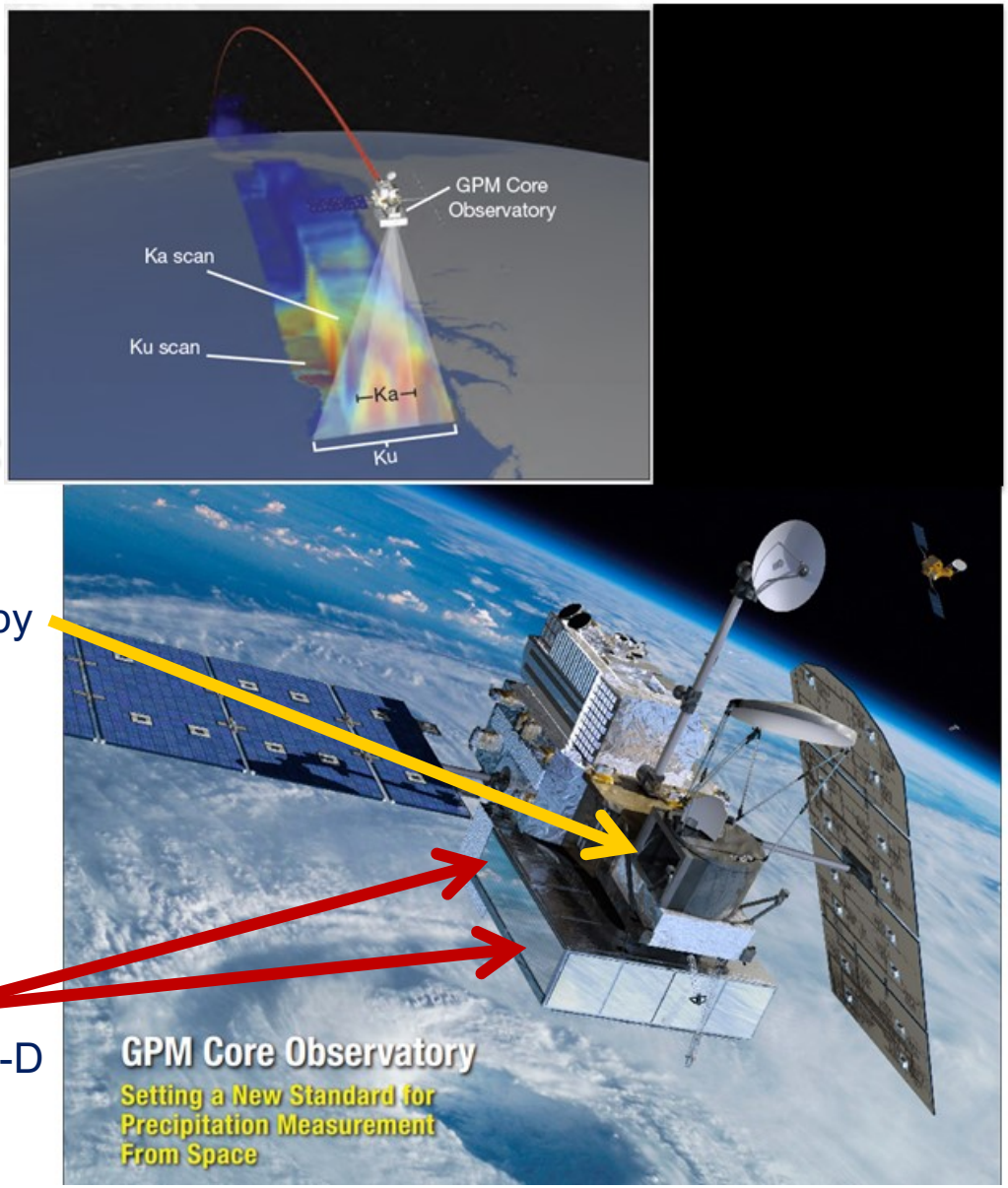


- PI: William Blackwell (MIT/Lincoln Labs)
- Project Scientist: Scott Braun (NASA/GSFC)
- 7 temperature channels near 118 GHz, 3 moisture channels near 183 GHz, and imaging at 90 and 206 GHz
- 12 CubeSats, 4 in each of 3 orbital planes
- TROPICS will provide 21-min median refresh rates between ±40° latitude, horizontal resolution similar to ATMS
- TROPICS will provide rapid-refresh temperature, humidity, and precipitation structure data
- Launch ~June 2019 for 1-yr mission

See poster 209 by S. Braun on Tuesday, 10/25

GPM's "Flagship" Core Observatory

Carries **two instruments** that can view precipitation (rain, snow, ice) in new ways; serves as a standard to calibrate measurements made from partner satellites



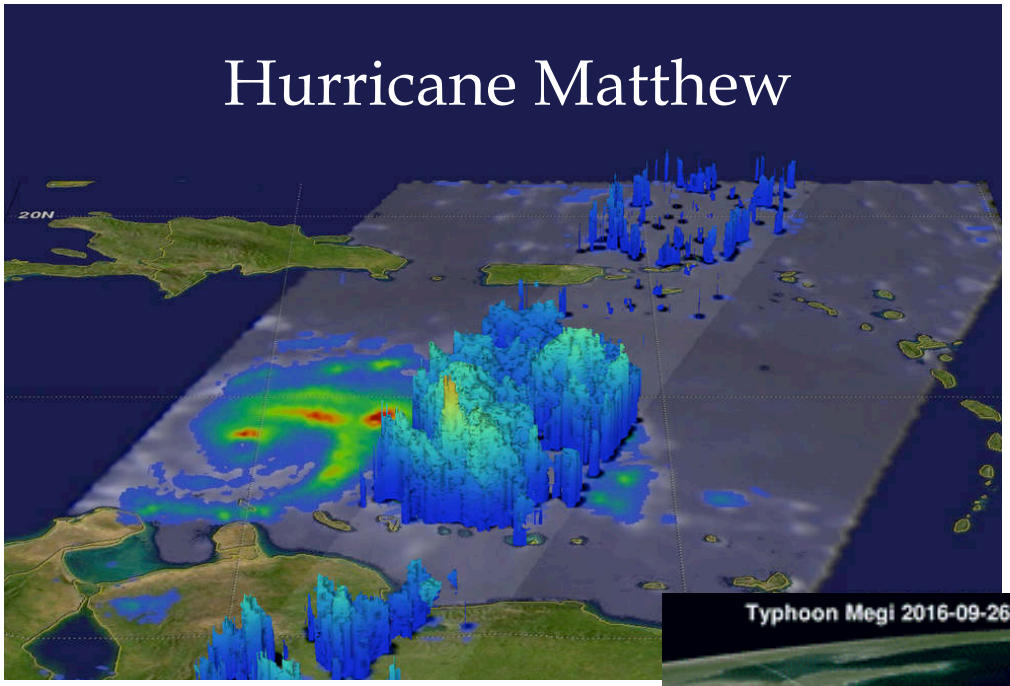
GPM Microwave Imager (GMI): 10-183 GHz

13 channels that provides an integrated picture of energy emitted and scattered by precipitation

Dual-frequency Precipitation Radar (DPR): Ku-Ka bands

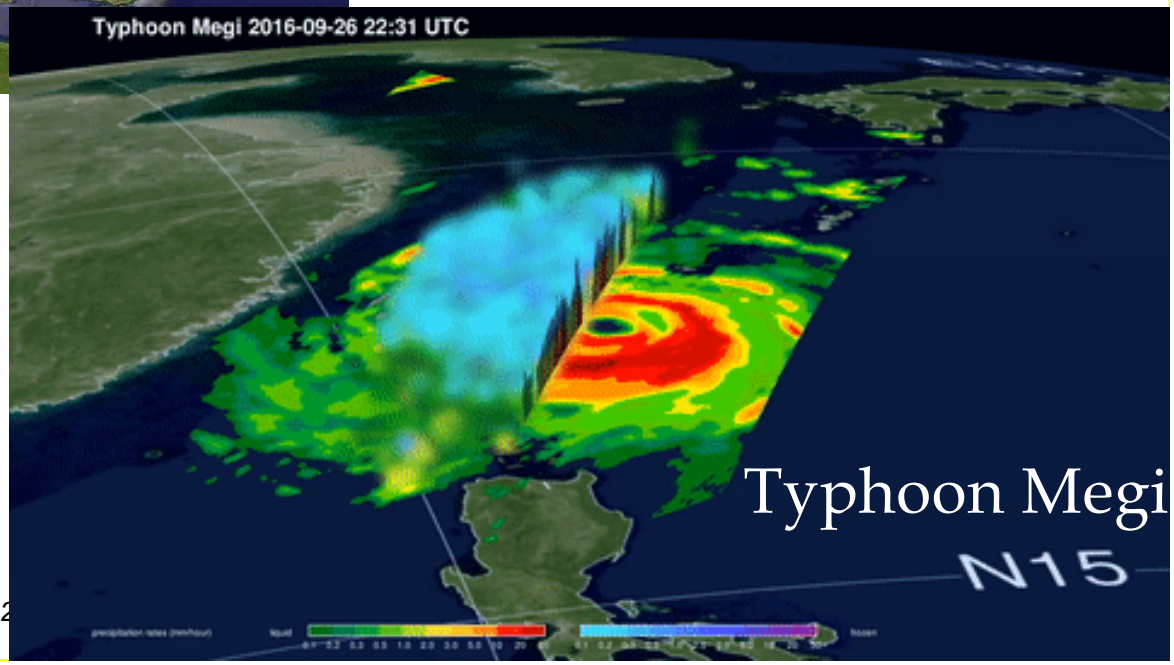
Two different radars with different frequencies that look at precipitation in 3-D throughout the atmospheric column

Hurricane Matthew on 30 Oct 2016

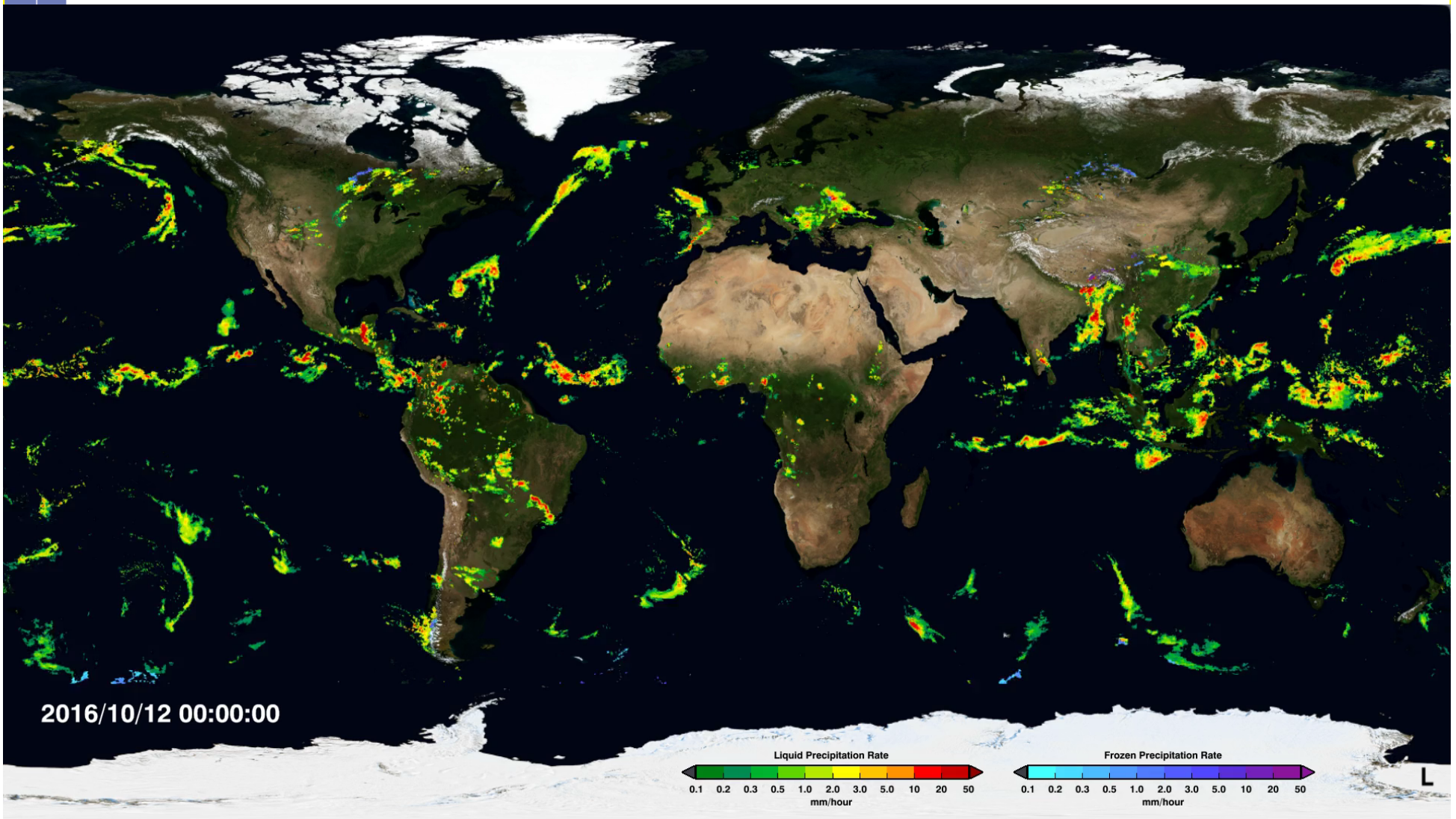


The GPM core observatory flew over Hurricane Matthew on Sept. 30, 2016 at 0946Z (5:46 a.m. EDT) with rate rates > 9 in/hr and storm top heights above 16 km (9.9 miles).

The GPM core passed over Typhoon Megi near Taiwan on September 26, 2016 at 2231 UTC with rain at 250 mm per hour.



IMERG Rain (12-19 Oct 2016)



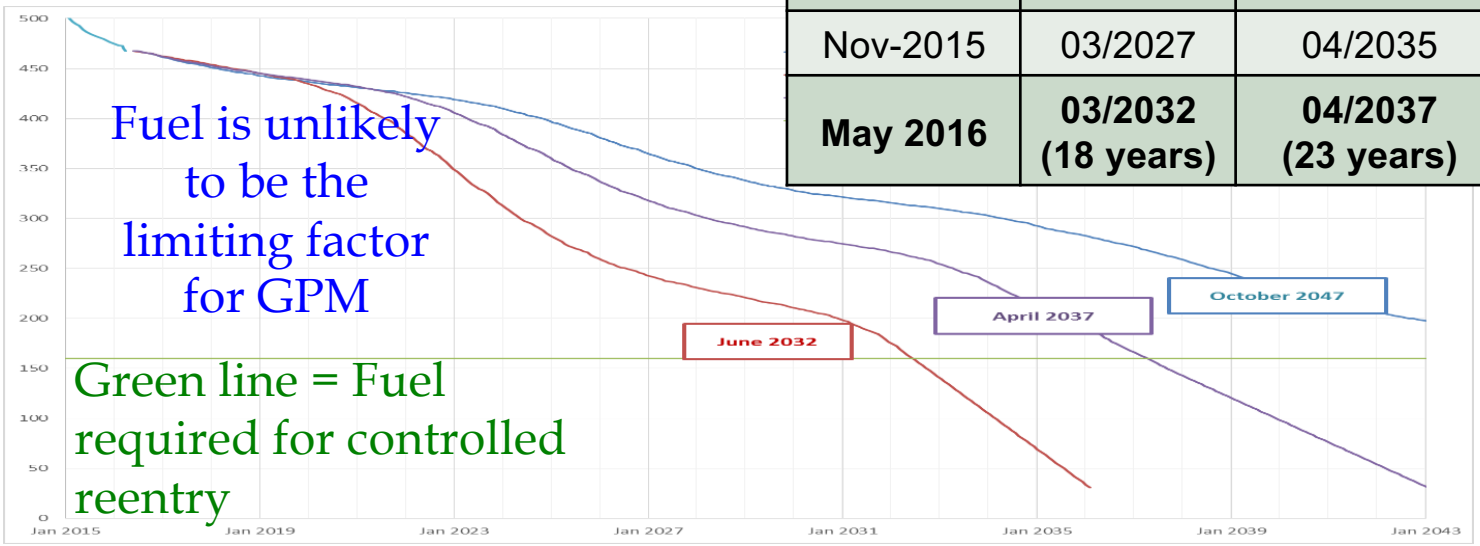
30 minute by 0.1deg by 0.1deg; available ~ 4-6 hours after obs.

GPM Instruments & Spacecraft Status

- DPR is performing well
- GMI is an extremely well calibrated imager
  - GPM GMI is calibrated and stable. Comparisons with other well calibrated sensors and with radiative transfer models indicate absolute GMI calibration accuracy within 1K (likely < 0.25K).

- Fuel Predictions

Prediction	Plus/Early	Mean/Nominal	Minus/Late
June-2015	06/2029	11/2039	06/2043
Nov-2015	03/2027	04/2035	08/2039
May 2016	**03/2032 (18 years)**	**04/2037 (23 years)**	**08/2047 (33 years)**



- Wentz and Draper, "On-Orbit Absolute Calibration of the Global Precipitation Mission Microwave Imager," *J. Atmos. Oceanic Tech.,*, 2016.

Precipitation Products and Version Status

	Product Level	Description	Coverage	Latency* & Version
L1	Level 1B GMI Level 1C GMI	Geolocated Brightness Temperatures (TBs) and intercal TBs (1C)	Swath, instrument field of view (IFOV)	*1 hour for near real time products for applic. users*; **Version 04**
L1	Level 1B DPR	Geolocated, calibrated radar powers	Swath, IFOV (produced at JAXA)	**Version 04**
L1	Level 1C, partner radiometers	Intercalibrated TBs	Swath, IFOV	**Version 04**
L2	Level 2 GMI (GPROF2014)	Radar enhanced (RE) precipitation retrievals	Swath, IFOV	*1 hour* **Version 04**
L2	Level 2 partners	RE precip retrievals from 1C	Swath, IFOV	**Version 04,** (MHS @ V03)
L2	Level 2 DPR	Z, σ_0, Characterization, DSD, Precipitation w/ vert. structu.	Swath, IFOV (Ku, Ka, combined Ku/Ka)	*3 hours;* **Version 04**
L2	Level 2 Combined GMI/DPR	Precipitation retrievals constrained with DPR & GMI	Swath, IFOV	*3 hours;* **Version 04**
L3	Level 2, 3 LH	Latent Heating (LH) products	0.25 x 0.25 monthly grid	**Version 04;** TRMM Lat only
L3	Level 3 Instrument Accumulations	GMI, partner radiometers, combined and DPR	0.25 x 0.25 daily and monthly grid	**Version 04**
L3	Level 3 Merged Product (IMERG)	Merger of GMI, partner radiometer, and IR	0.1 x 0.1 at a 30 minute grid	*4-5 hrs;* **Version 03**

*All algorithms have additional latencies from 4 hours to 2 months after data collection for producing higher quality precipitation products for scientific investigations and climate studies

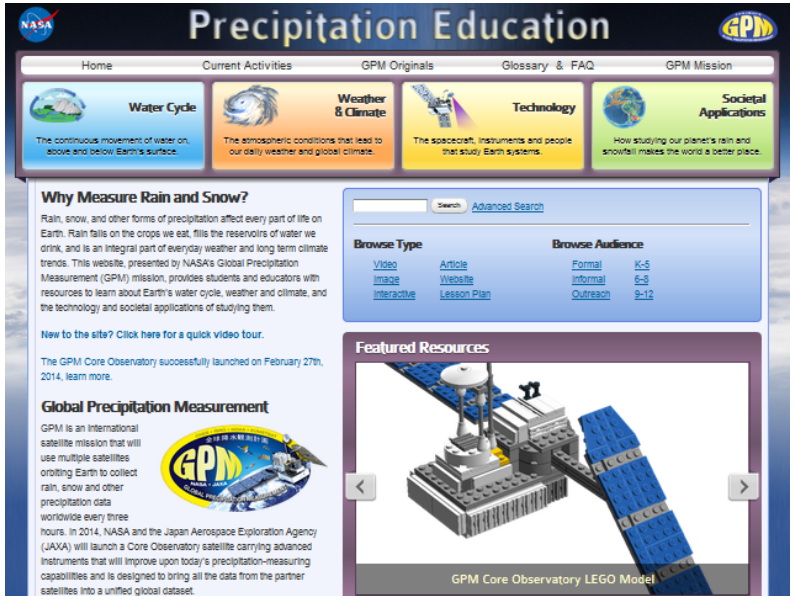
GPM Data Products

- Want GPM data from NASA? gpm.nasa.gov
  - Products Available from: http://pps.gsfc.nasa.gov
    - Precipitation from DPR, GMI, Combined, IMERG, constellation partners
    - Levels 1 (calibrated instr data), 2 (instantaneous swath), 3 (gridded)
- NASA/GPM Data Usage Statistics:
  - Average monthly downloads on the order of **64TB in >6 million files/month**
  - Daily downloads from ***users and agencies all over the world***: EUMETSAT, ECMWF, UK Met Office, United Nations, Brazil, Netherlands, Finland, Argentina, Taiwan, Mexico, Australia, Japan, UK, Korea, European Union, China, India, South Africa, Spain, and others
- **Data *product updated algorithm reprocessing March-June 2016*** for Version 04 (V04), Version 05 expected Spring 2017
- ***Meeting Data Latency Requirements of 1-3* hours** for GPM Core Products > 97% of the time

Month	1c (GMI Brightness)	GPROF (GMI Precipitation)	Combined (DPR/GMI Precipitation)
October 2015	99.702%	99.616%	98.884%
November 2015	99.502%	99.444%	98.681%
December 2015	**99.944%**	**99.910%**	**97.723%**

Applications/Education & Public Outreach

GLOBAL PRECIPITATION MEASUREMENT



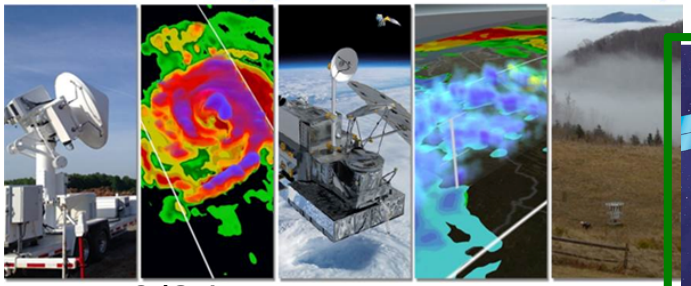
Social Media (June'16 Stats)

Twitter: NASA_Rain
Total Twitter Followers: 16,711

Facebook: NASA.Rain
Total Facebook Followers: 44,975
Most popular post: Facebook Live event 6/24
(with Reach: ~2M, Likes: 12K, Shares: 2K)

gpm.nasa.gov Pageviews: 36,920
gpm.nasa.gov/education Pageviews: 26,318

Movie webpage: svs.gsfc.nasa.gov



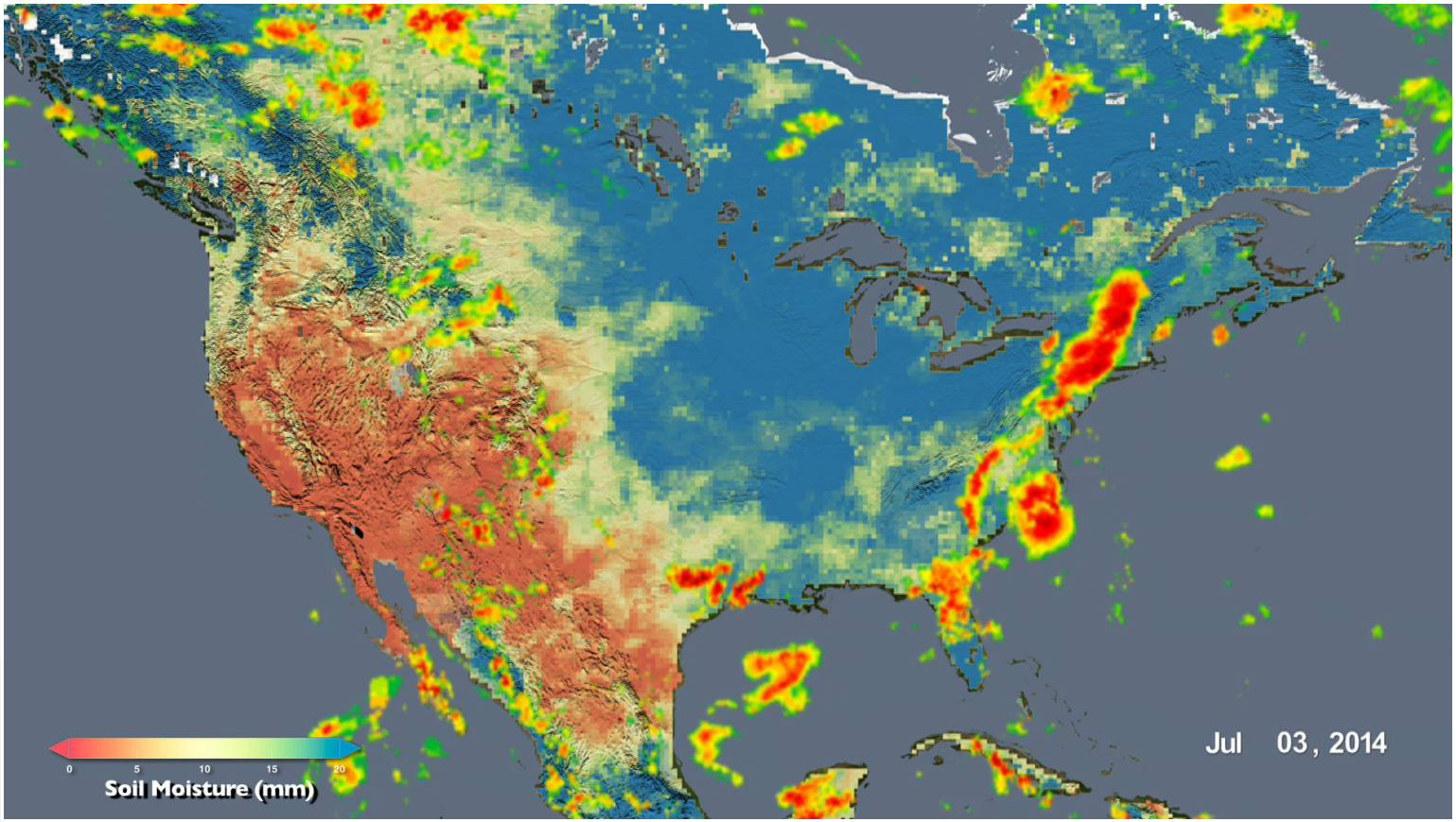
Educational Comic Book

Contact Information: Gail.S.Jackson@nasa.gov

GPM Info: gpm.nasa.gov Data: pps.gsfc.nasa.gov

Social Media: *Twitter*: NASA_Rain *Facebook*: NASA.Rain

Teacher Page: pmm.nasa.gov/education Movies: svs.gsfc.nasa.gov

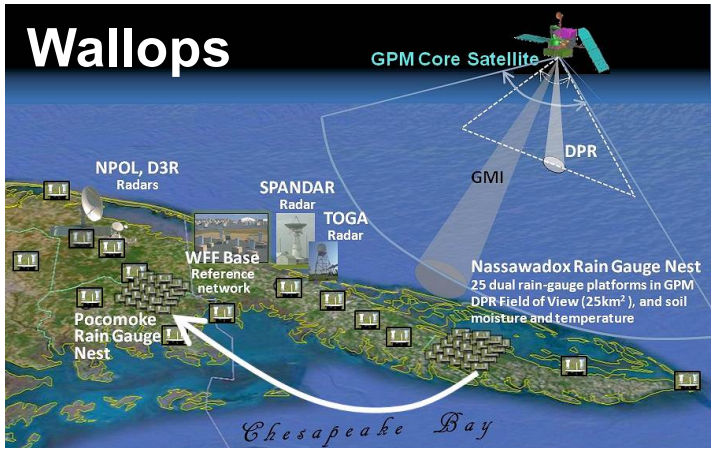


GET DATA
New Users Start Here

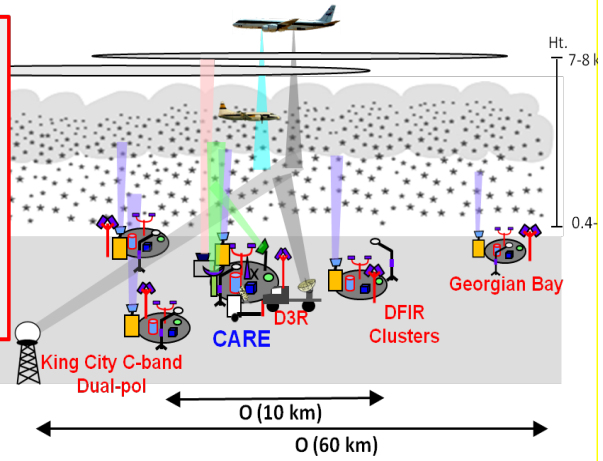
IMERG Rain and Soil Moisture movie

Ground Validation Activities

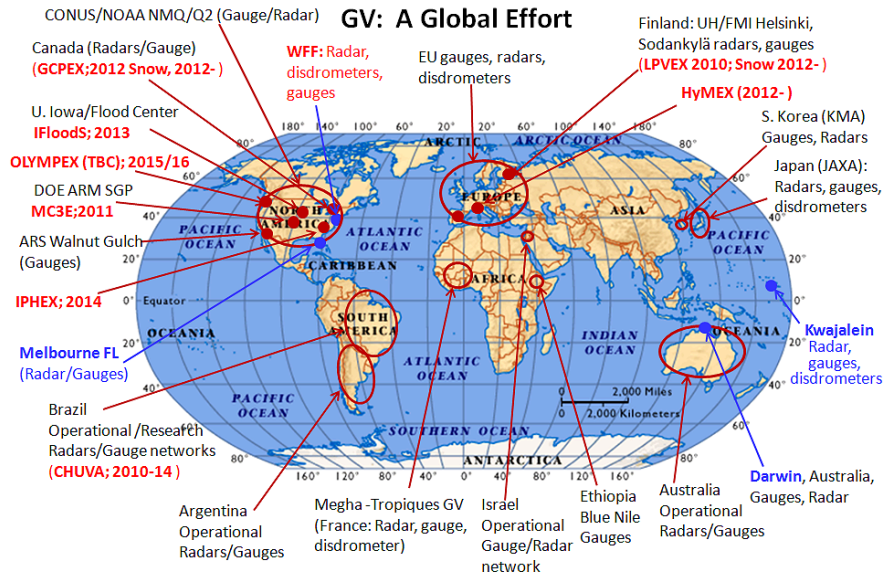
1. **Direct validation** (Satellite retrievals compared to ground observations)
2. **Physical validation** (Understanding remote sensing principles)
3. **Integrated hydrological validation** (Linking to drainage basins)



PSD:	2DVD, Parsivel, POSS,SVI
Radar:	Ka/Ku,X,W(2),MRR
SWER:	Pluvio, Hot Plate
SWE/Depth	L-Band + γ-sensor
ε: (Land/Snow)	X 10-89 GHz Radiometer
Aircraft:	DC-8, Citation
Radiometer:	ADMIRARI, EC, UBONN



Field campaign sampling strategy

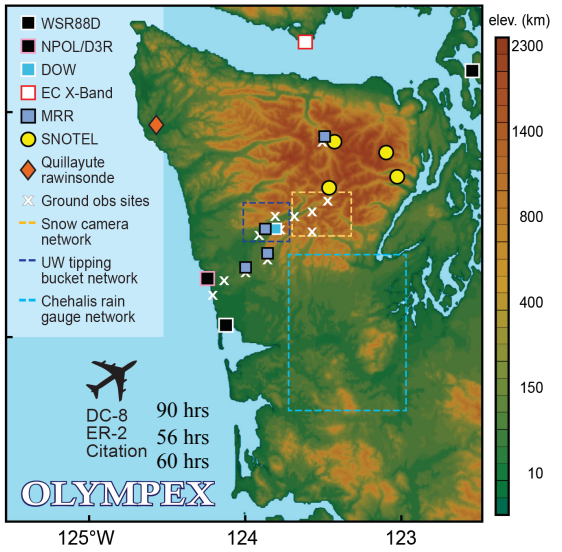


2015/16 GPM Olympic Mountains Experiment (OLYMPEX)

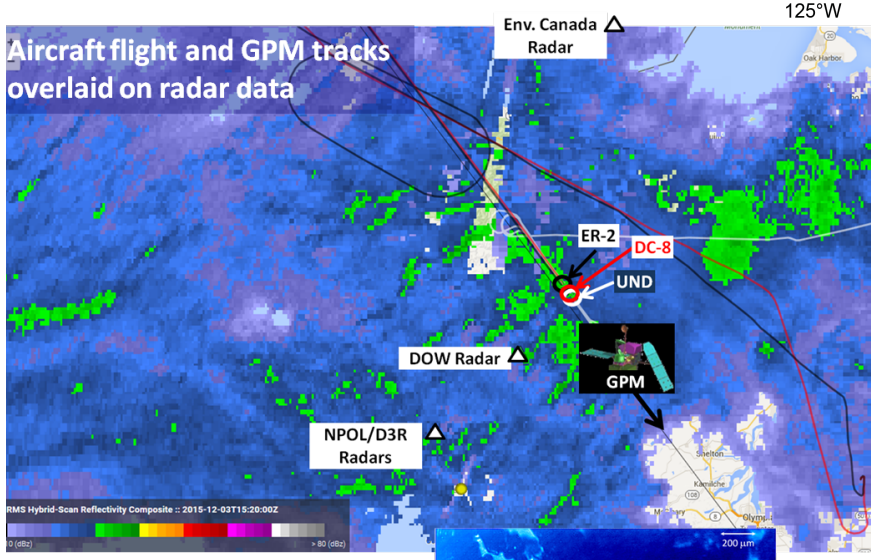
GLOBAL PRECIPITATION MEASUREMENT

- Validation of GPM in Pacific Northwest region (11/15 – 1/16)
- Multiple-aircraft, ground radars and supporting gauge networks in heavy rain and snow data collection over ocean and complex terrain
- Participants: NASA, U. Washington, Colorado State U., U. Utah, Environment Canada, Quinault Nation, NPS, USFS, NOAA-NWS

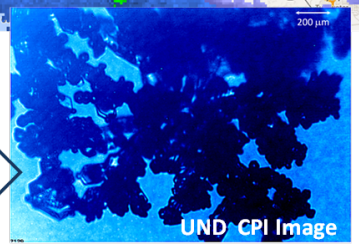
Ground and airborne measurements to connect the physical "building blocks" of precipitation to GPM space-based observations and hydrologic response



1 meter of Rain in 10 days!
Flooding ensued…….



UND Citation cloud particle imager (CPI) observation, 4 km altitude. Indications of rimed (supercooled liquid water), branched and aggregated snow.



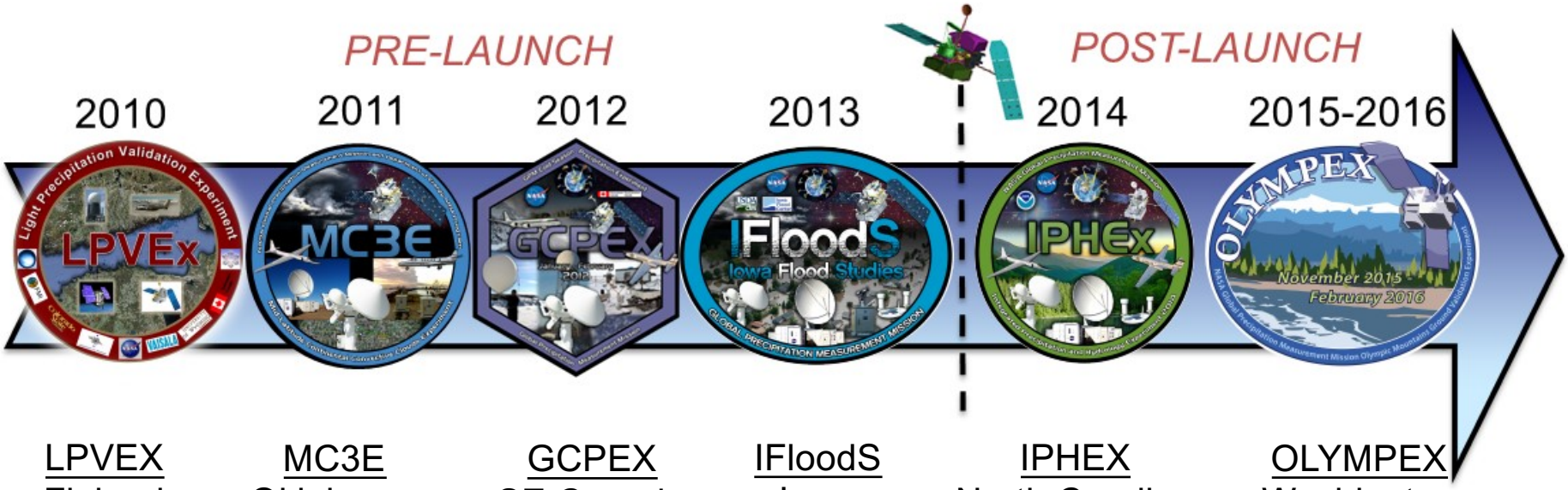
First triple-aircraft "stack" flying under the GPM satellite and over an intensive ground radar network!

NASA GPM Ground Validation Field Efforts

GLOBAL PRECIPITATION MEASUREMENT

GPM GV Lead / Co-Lead

PRE-LAUNCH | POST-LAUNCH



LPVEX	MC3E	GCPEX	IFloodS	IPHEX	OLYMPEX
Finland	Oklahoma	SE Canada	Iowa	North Carolina	Washington
High latitude light rain	Mid-latitude Deep Convection	Mid-Latitude Synoptic and Lake effect Snow	Mid-Latitude Warm season MCS Rain, Hydrology	Mid-Latitude Warm-Season Orographic rain Hydrology	Mid-Latitude Cold Season Orographic, ocean rain, snow Hydrology

GV Contributions to International Partner Campaigns

Environment Canada

C3VP

2006/07 Canada
Lake effect and synoptic snow

CHUVA PROJECT

2010, Brazil, INPE/CPTEC
Tropical warm rain

HyMeX

2012 EU- France/Italy,
orographic rain

ICE-POP

2018, KMA- Korea
orographic snow

NASA Research Announcement

- **Science Mission Directorate**
- **New NASA Research Announcement Expected**
- **Precipitation Science Team**
- **Solicitation: NNH15ZDA001N**
- **Date Released** February 2015
- **NOIs Due** April 15, 2015
- **Proposals Due** June 30, 2015
- Selection Made November 2015
- Funds available: ~ $7.0 M/year for 3 years
- Number of Awards: 60 out of 135 proposals

- This solicitation was for the selection of the 9th Precipitation Science Team
- No-cost research proposals can be accepted from international investigators to complement existing science team activities
- We need to come to an agreement on a procedure to extend already selected international proposals

ROSES Research Categories

2.1. Algorithm/Product Validation and Enhancement (50% of available funding)

2.2 Utilization of Satellite/GV Products for Process Studies and Model Development (25% of available funding)

2.3. Methodology Development for Improved Applications of Satellite Products (25% of available funding)

NASA TRMM/GPM Science Team

NASA GPM Science team has **60** new PI teams

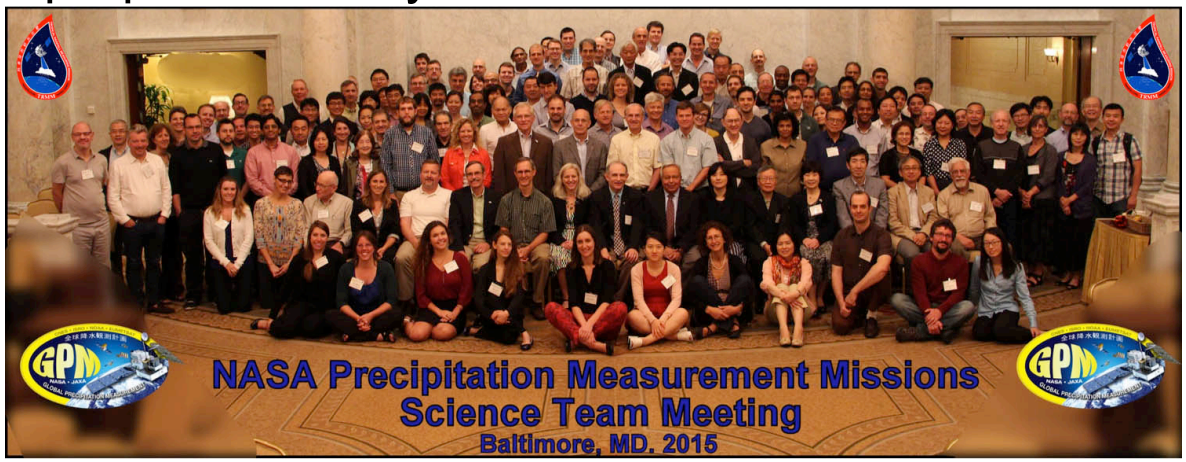
- Selected Dec 2015 for 3-yrs, next Science Team mtg Oct 24-27, 2016

NASA has **22** no-cost International PI teams

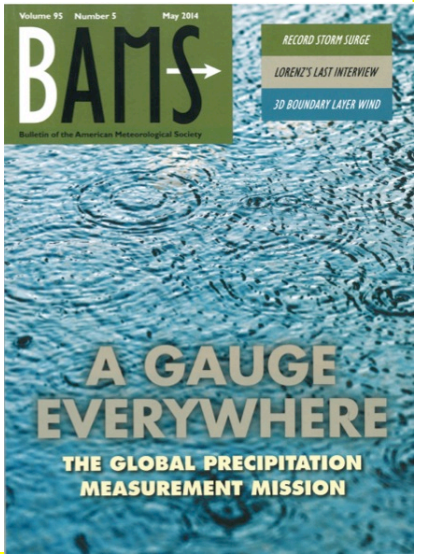
- International PI/team proposals always welcome

- Argentina (U. Buenos Aires)
- Australia (BOM)
- Austria (U. Graz)
- Belgium (KUL–Antarctica)
- Brazil (INPE)
- *Brazil CEMADEN)*
- Canada (EC)
- *Columbia UNAL, IDEAM)*
- Cyprus (CMS)
- *Ethiopia (AAU/NMA)*
- Finland (FMI)
- France (CNRS and partners)
- Germany (U. Bonn)
- HSAF (7 countries, Italy-Leads)
- *India (ISRO)*

(Italics = not finalized)



- Israel (Hebrew U. Jerusalem)
- Italy (CNR-ISAC)
- Japan
- South Korea (KMA)
- Spain (UCLM)
- Switzerland (EPFL)
- United Kingdom (U. Birmingham)

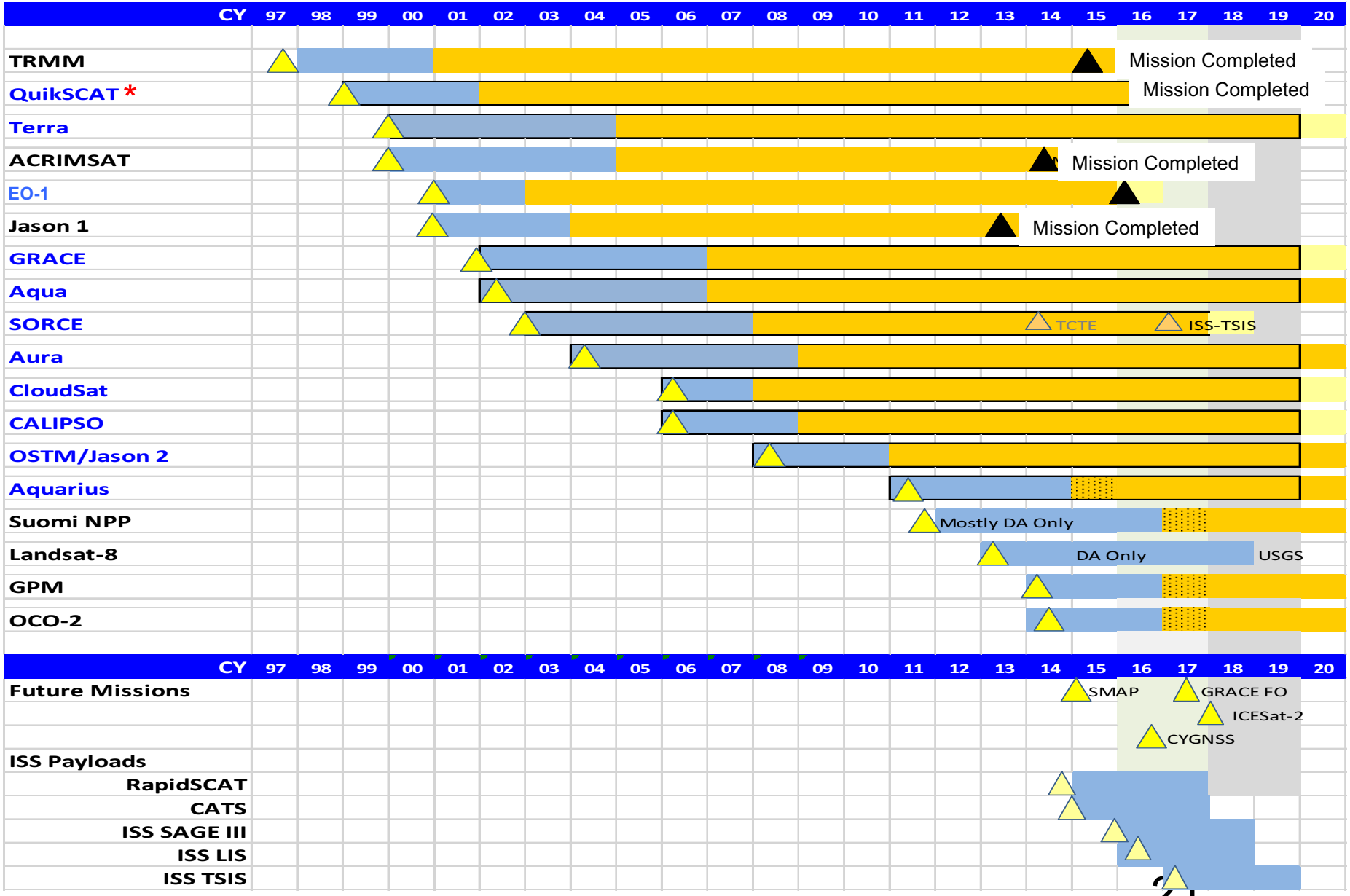


GPM Article in BAMS May 2014: The Global Precipitation Measurement Mission by Arthur Hou, et al.

Post Launch GPM Article in review with minor edits

ED 2015 Senior Review Mission Set

Prime
Extension
Phase F



ESD 2017 Senior Review

- The NASA HQ Science Mission Directorate 2017 Senior Review process, as implemented by the Earth Science Division, will be used for mission extensions FY18 and beyond:
  - This is a comparative review in which the primary evaluation factor is the scientific value of the dataset, with attention to the value of science that will be enabled by the extension of the dataset. All missions which have completed prime operations (including GPM) will be reviewed.
  - Science evaluation factors:
    - ***Scientific merit of the mission datasets***, based on their intrinsic value in research investigations by the community, relevance to ESD science goals, and data product maturity;
    - ***Quality trends of the standard data products***, value of long term data records and overall data continuity, and projected quality based on continuing mission performance, including any degradation of sensor or platform;
  - Secondary evaluation factors include operational utility, technical health & status and cost efficiency.
  - Operational utility is evaluated by an interagency team in an independent subpanel which reports to the Science Panel.
  - Extension is assumed unless the mission is clearly underperforming.

Major Requirements for Direct Validation

GPM Mission NASA HQ Level 1 Science Requirements

1. DPR: **quantify rain rates** between ***0.22*** and ***110*** millimeter (mm) per hour (hr) and demonstrate the *detection of snowfall* at an effective resolution of 5 km.

2. GMI: **quantify rain rates** between ***0.2*** and ***60*** millimeter (mm) per hour (hr) and demonstrate the *detection of snowfall* at an effective resolution of 15 km.

3. Measurements from the Core observatory, shall estimate the **D_m of precipitation particle size distribution to within +/- 0.5 mm.**

4. Instantaneous rain rate estimate with bias and random error **<50% at 1 mm hr^{-1} and <25% at 10 mm/hr at 50 km resolution** between Core Observatory & calibrated ground validation data.

ESD 2017 Senior Review Schedule

- Mission Team Q&A @ AGU — December 11, 2016
- Call Letter — December 20, 2016
- Proposals Due — March 3, 2017
- National Interests, Technical & Cost Panels — April 10-14, 2017
- First Science Panel Meeting — April 18, 2017
- Questions from Panel to Missions — April 21, 2017
- Science Panel/Mission Presentations — May 9-11, 2017
- Final Report — June 30, 2017

Summary

- NASA Earth Science Division Satellite Fleet (very vigorous plan in place)
- Relevant new satellite missions (several new missions will complement GPM)
- GPM Status (excellent shape)
- GPM Data Products (very popular)
- GPM Applications (extremely useful)
- GPM field experiments (tremendously helping GPM validation)
- Senior Review (an important gate but we are ready)