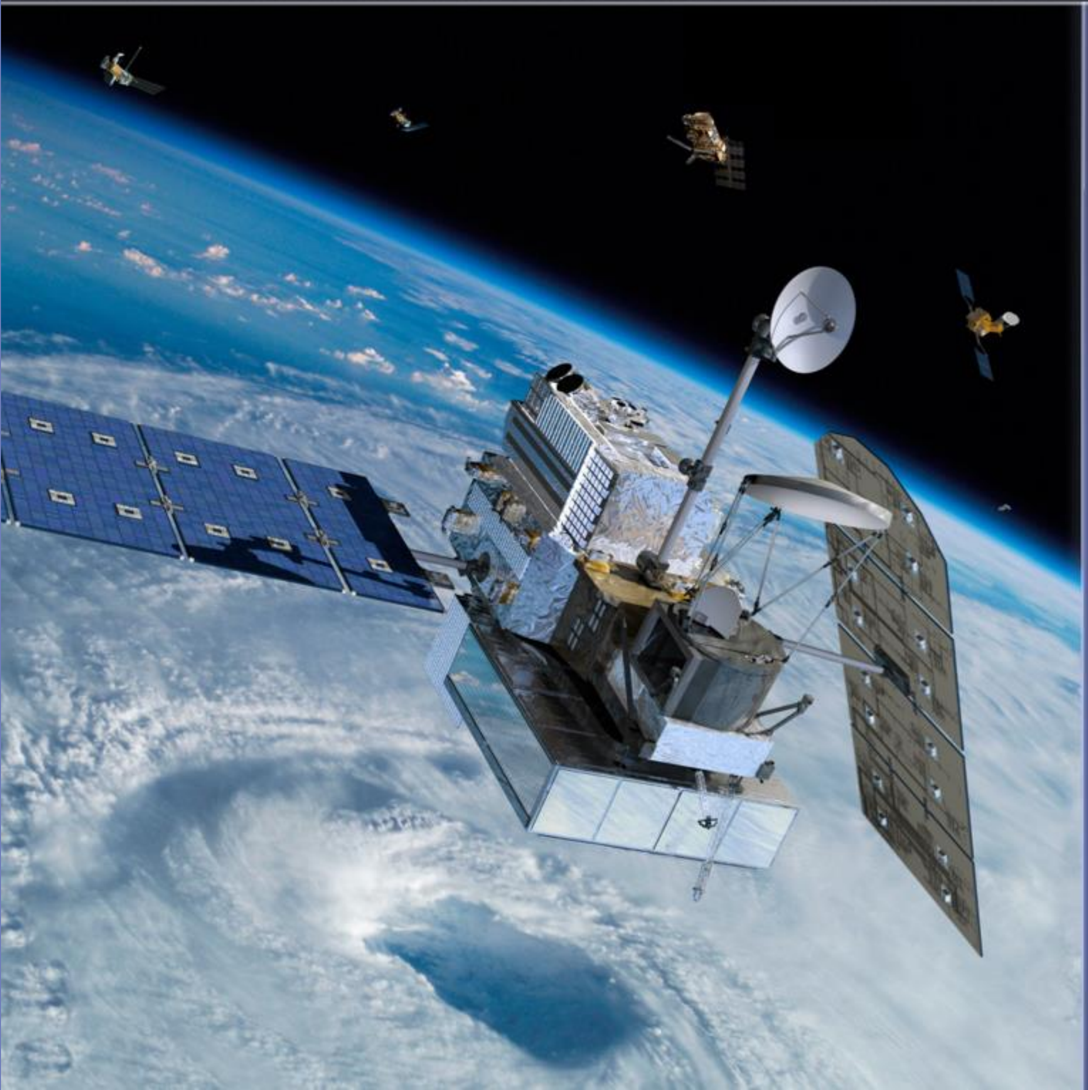
NASA's Global Precipitation Measurement (GPM) Mission: Observing Rain and Snow for Science and Society



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gpm.nasa.gov

EUMETRAIN

25 November 2015

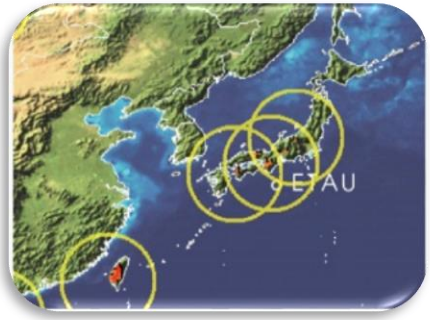
GPM: A Science Mission with Integrated Application Goals

Science Objectives:

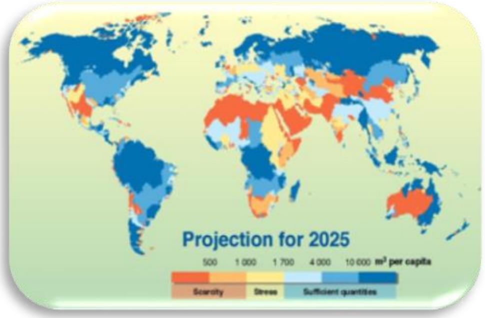
- **New reference standards for precipitation measurements from space**
- **Improved knowledge of water cycle variability and freshwater availability**
- **Improved numerical weather prediction skills**
- **Improved climate prediction capabilities**
- **Improved predictions for floods, landslides, and freshwater resources**

Societal Benefits:

Floods and Landslides

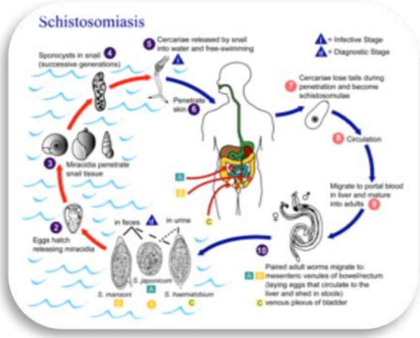


Freshwater Availability/ Agriculture/Famine



Extreme Events

World Health



Applications & Users:

Cyclones, Re-insurance, Famine Warning, Drought, Water Resources, Agriculture, Numerical Weather Prediction, Land System Modeling, Climate Modeling, Disease Tracking, Animal Migration, Food Security

GPM Core Observatory Background

Partnership with the Japanese

- JAXA built the Dual-frequency Precipitation Radar (DPR)
- NASA provided the GPM Microwave Imager (GMI); Ball Aerospace built it under contract
- Integration to the spacecraft bus occurred at NASA Goddard Space Flight Center in 2013
- Launched from Tanegashima Island, Japan on Feb 28, 2014
- Followed successful partnership for the Tropical Rainfall Measuring Mission (TRMM)

Mission Operation

- Fully staffed
- Feathering the Solar Arrays to save fuel; orbit adjust once every two weeks
  - Fuel expectancy 15+ years

Precipitation Processing System (PPS)

- Fully operational and processing precipitation data
  - Rain rates from 0.2-110 mm/hr and detecting/estimating falling snow

Launched 3:37 a.m. JST on Feb. 28, 2014 from Tanegashima Island, Japan

The **GPM Core Observatory** carries **two advanced instruments** that allow us to view precipitation (rain, snow, ice) in new ways and serve as a **connector** between the GPM Core and measurements taken on other partner satellites

GPM Microwave Imager (GMI): 10-183 GHz

13 channels provide an integrated picture of the energy emitted by precipitation, including light rain to heavy rain to falling snow. Like an X-Ray.

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

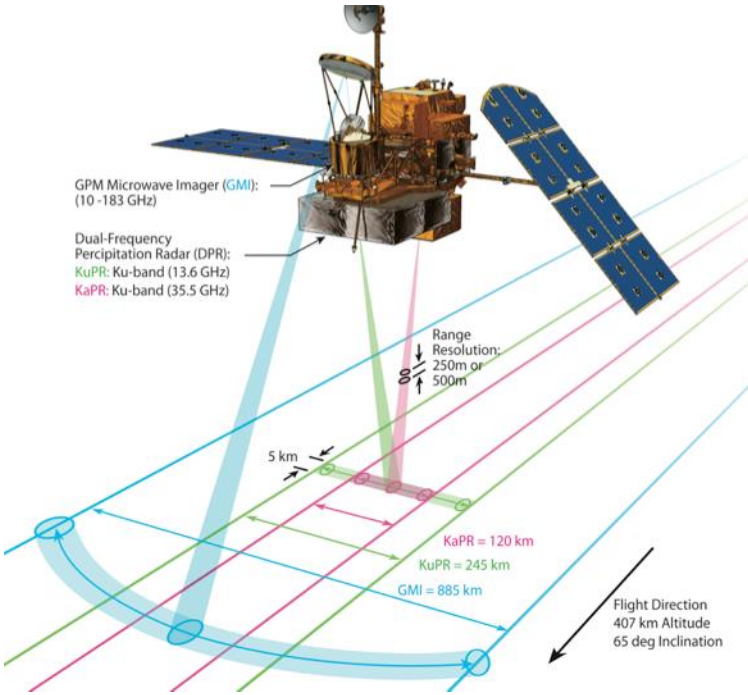
Two different radar frequencies that measure precipitation in 3-D throughout the atmospheric column. Like a CT Scan.

Built by JAXA

Non-Sun-Synchronous orbit at 65^{o} inclination (Arctic to the Antarctic Circle) at 407 km

Core Observatory Geometery and Instruments

0.2-110mm/hr & snow



- Orbit: 407 km; 65 deg inclin.; 3-year life, 15+ year fuel

  GPM Microwave Imager (GMI)
  - Passive microwave radiometer with hot and cold calibration, includes novel calibration engineering
  - Provides measurements of precipitation (rain and snow) intensity and distribution over wide swath (880 km)
  - High spatial resolution (down to ~5km footprints)
  - 166 Kg, 162 W, 34.9 Kbs Science,1.2 m diameter reflector

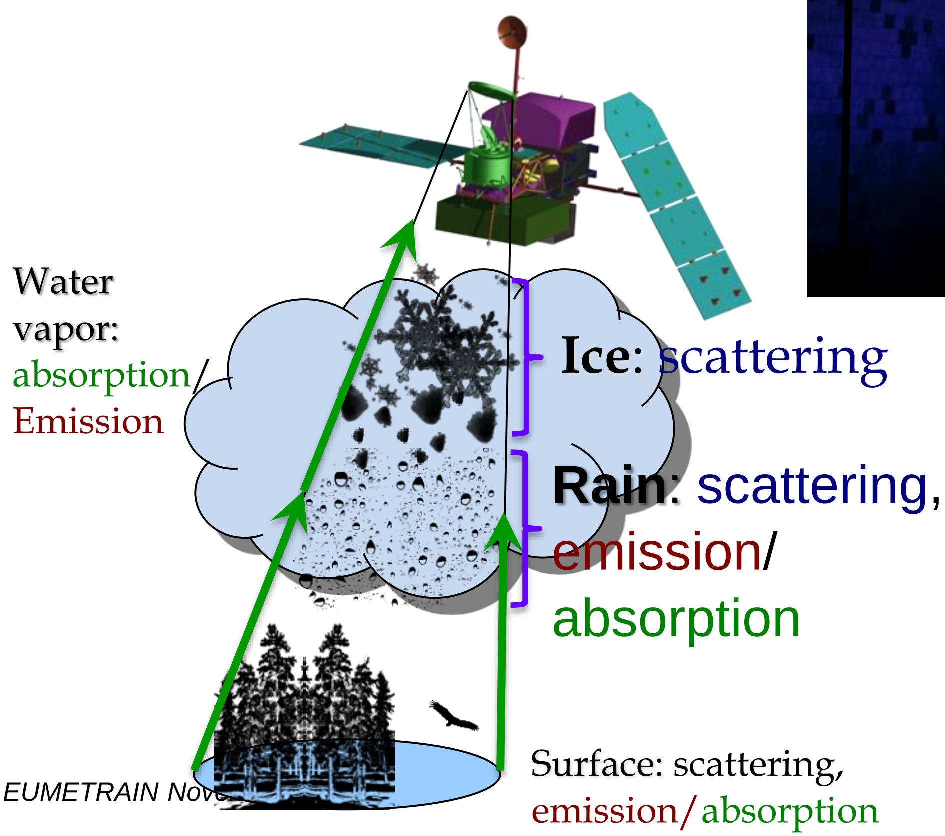
  Dual-frequency (Ku-Ka band) Precipitation Radar (DPR)
  - KuPR similar to TRMM, KaPR added for GPM
  - Provides three-dimensional measurements of precipitation structure, precipitation particle size distribution (PSD) and precipitation intensity and distribution
  - High spatial resolution (5km horizontal; 250m vertical)

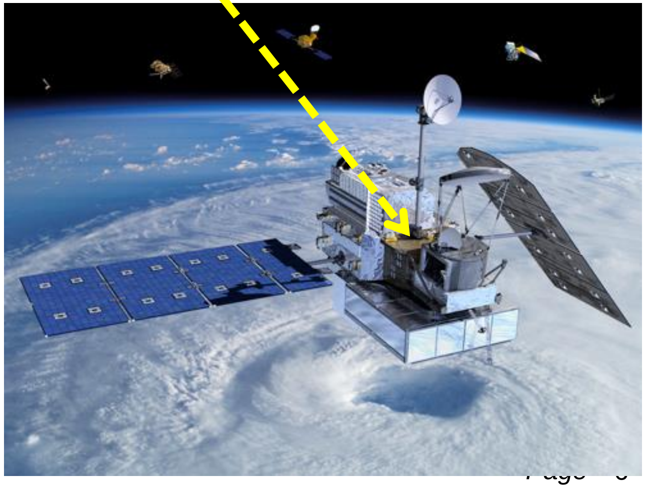
DPR	KuPR	KaPR
Frequency	13.597 , 13.603 GHz	35.547 , 35.553 GHz
Min. detectable rainfall rate	0.5 mm/hr	0.2 mm/hr
Data Rate	< 109 kbps	< 81 kbps
Mass	< 472 kg	< 336kg
Power Consumption	< 446 W	< 344 W
Size	2.5 × 2.4 × 0.6 m	1.2 × 1.4 × 0.7 m

GMI Frequencies	GMI Polarizations
10.65 GHz	V/H
18.7 GHz	V/H
23.8 GHz	V
36.5 GHz	V/H
89 GHz	V/H
166 GHz	V/H
183 GHz	Va/Vb (±3 & ±7)

GPM Microwave Imager

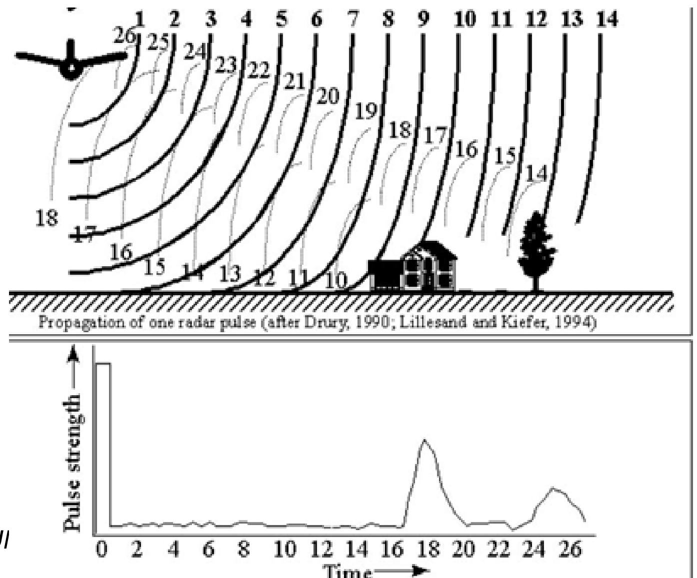
- Different types of precipitation emit energy at different frequencies (GHz). The GMI passively absorbs this energy (and other competing signals) and can decipher what is happening in the cloud (sort of like an x-ray)





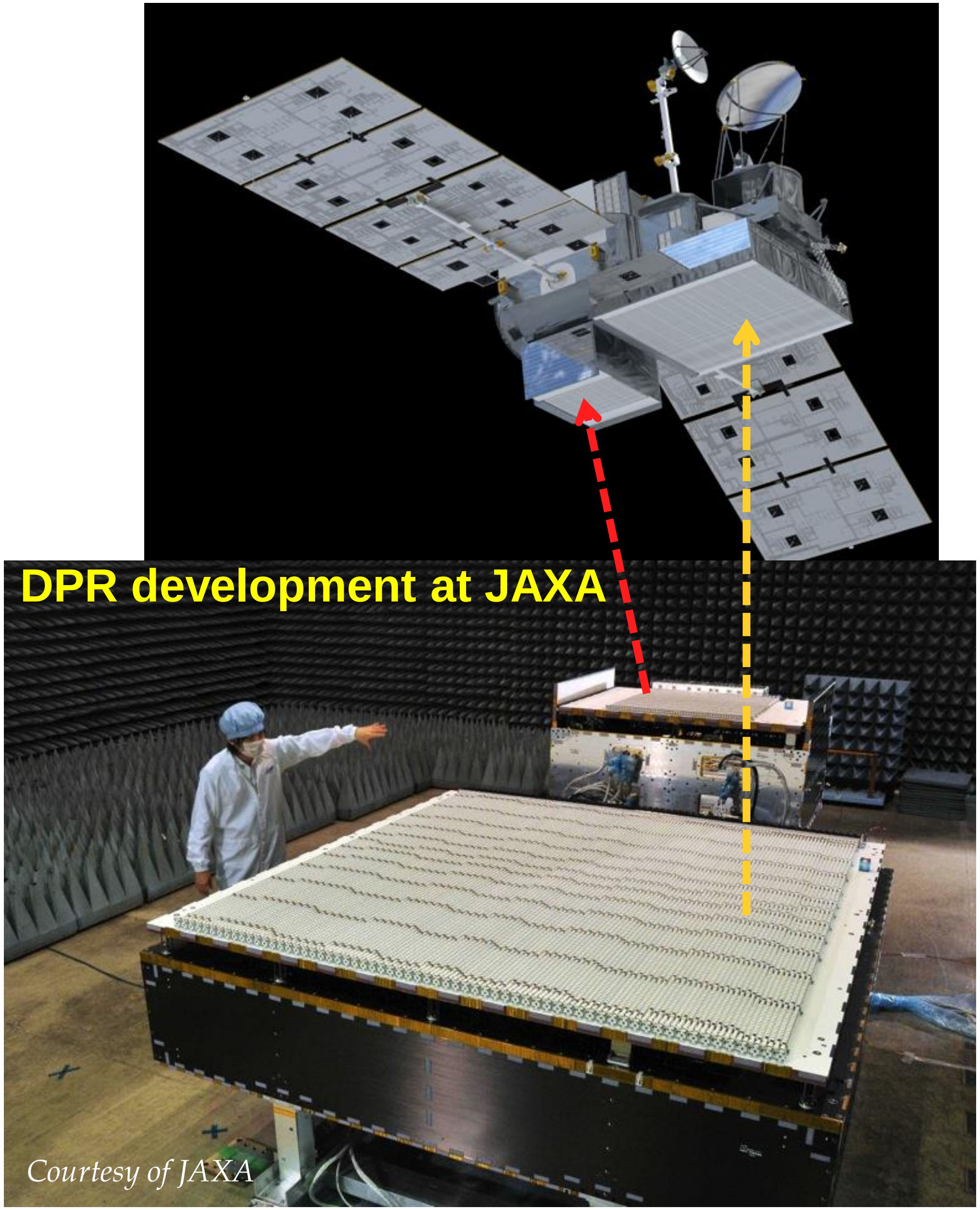
Dual-frequency Precipitation Radar

- The DPR sends out two different frequencies at 35 GHz and 13.6 GHz and can determine the size and distribution of rain, snow, and ice from the strength of the returning signal
- By using two frequencies it enables us to better understand particle distribution and microphysics, which is very important for improving estimates of rain rate on the surface
- Takes 3D data like a CT scan.



Propagation of one radar pulse (after Drury, 1990; Lillesand and Kiefer, 1994)

EUI



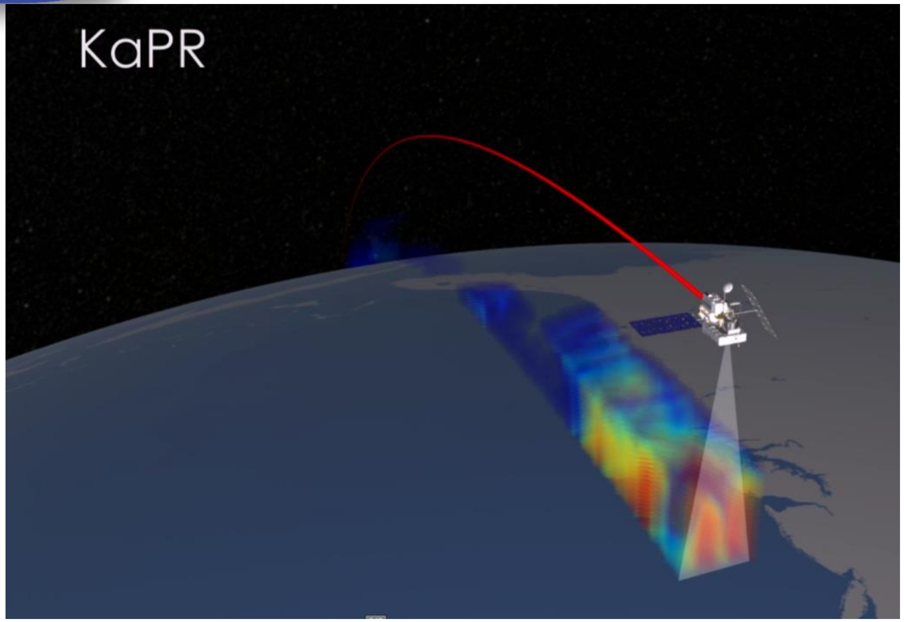
Question

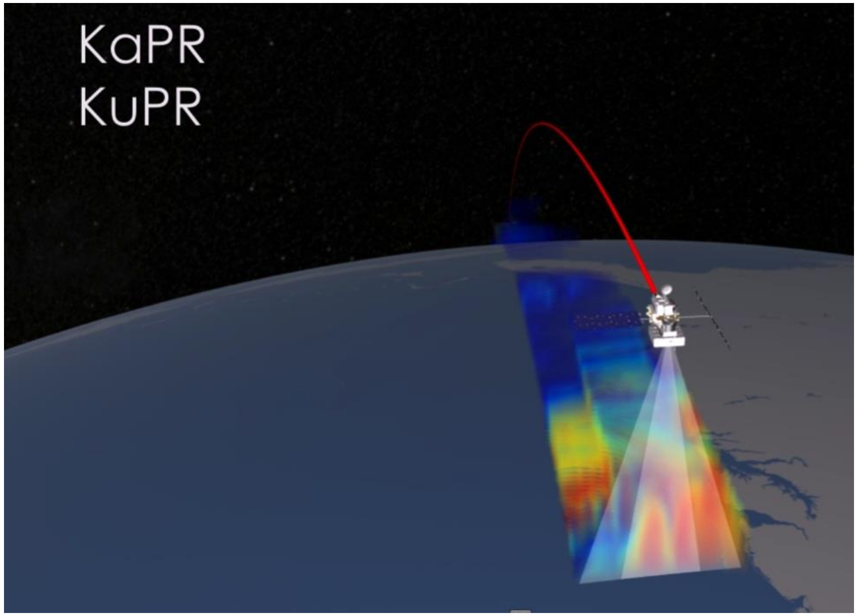
The Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) can sense and retrieve the three-dimensional structure of precipitation within clouds?

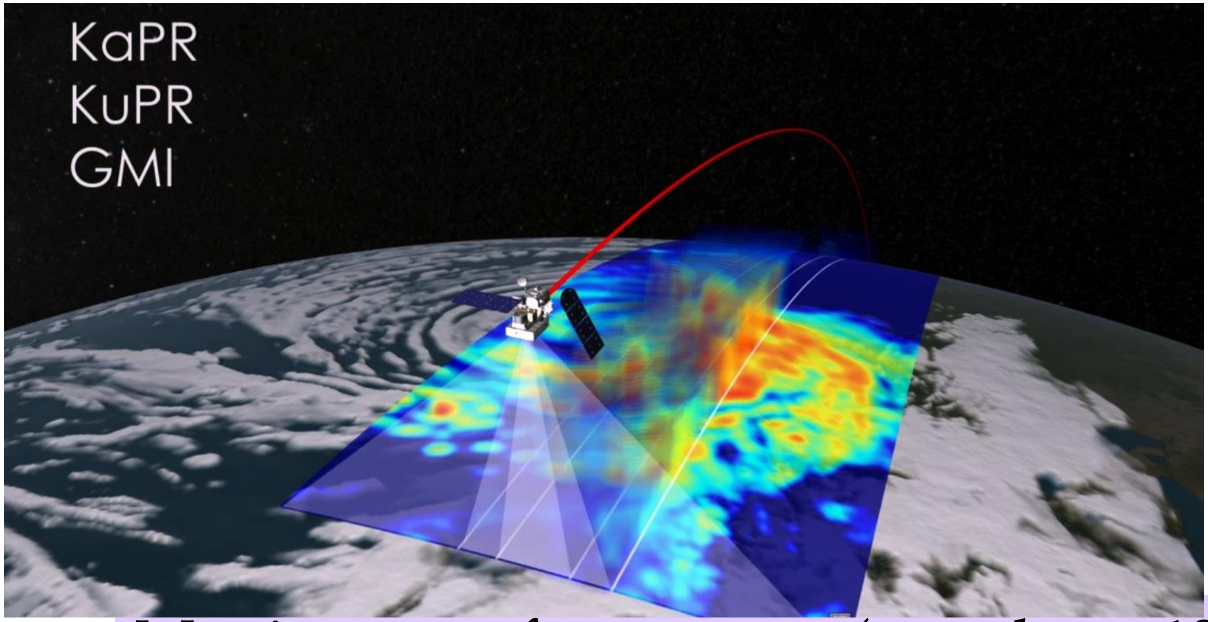
Yes/True?

No/False?

How GPM works:

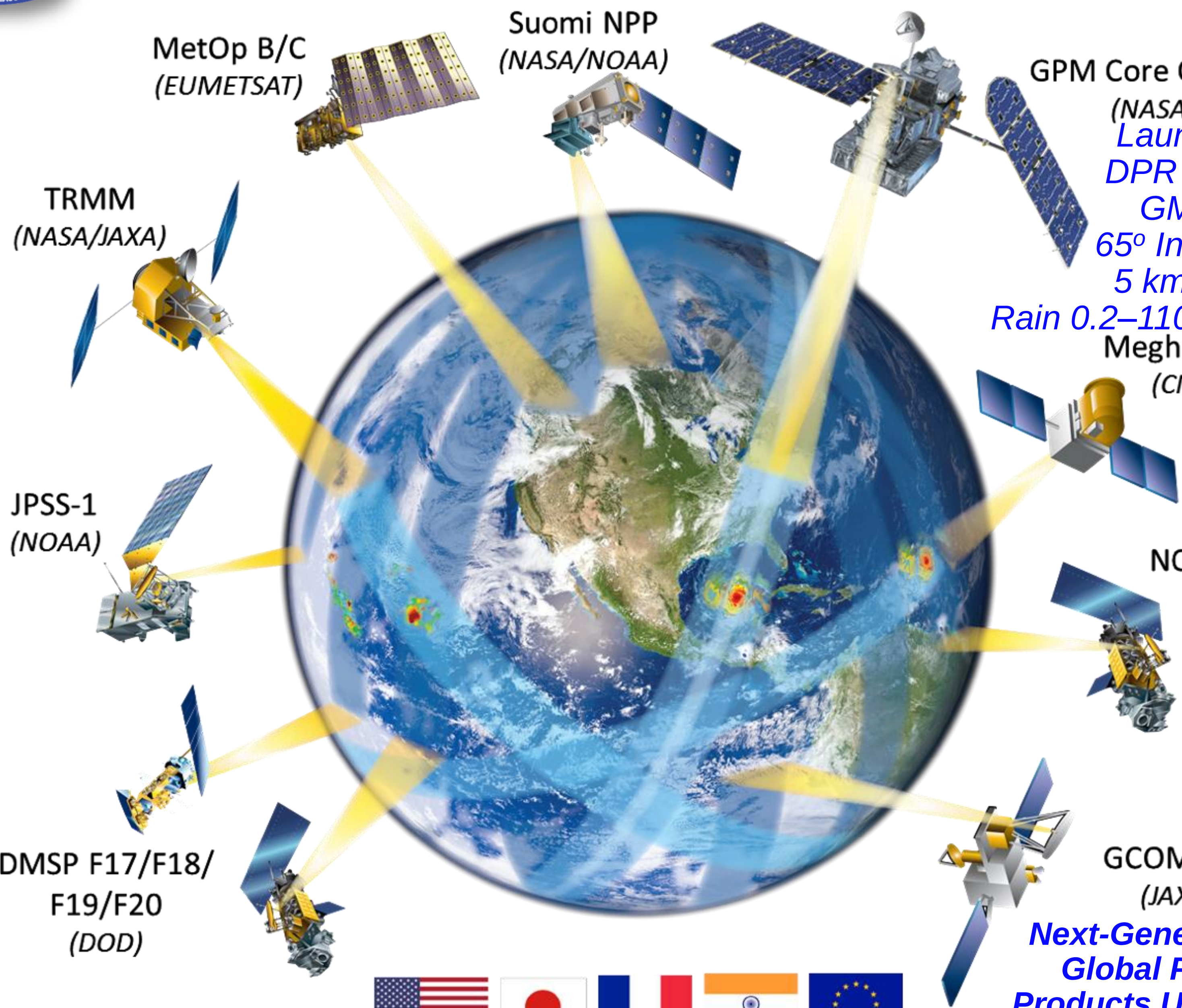






Movie: svs.gsfc.nasa.gov (search on 4016)

GPM Constellation Concept



Launched Feb 2014
DPR (Ku & Ka band)
GMI (10-183 GHz)
65º Incl & 407 km Alt.
5 km best resolution
Rain 0.2–110 mm/hr & snow

Next-Generation Unified Global Precipitation Products Using GPM Core Observatory as Reference

Question

The Global Precipitation Measurement (GPM) Core Observatory spacecraft is used to intercalibrate partner constellation precipitation data to produce next-generation unified precipitation estimates globally?

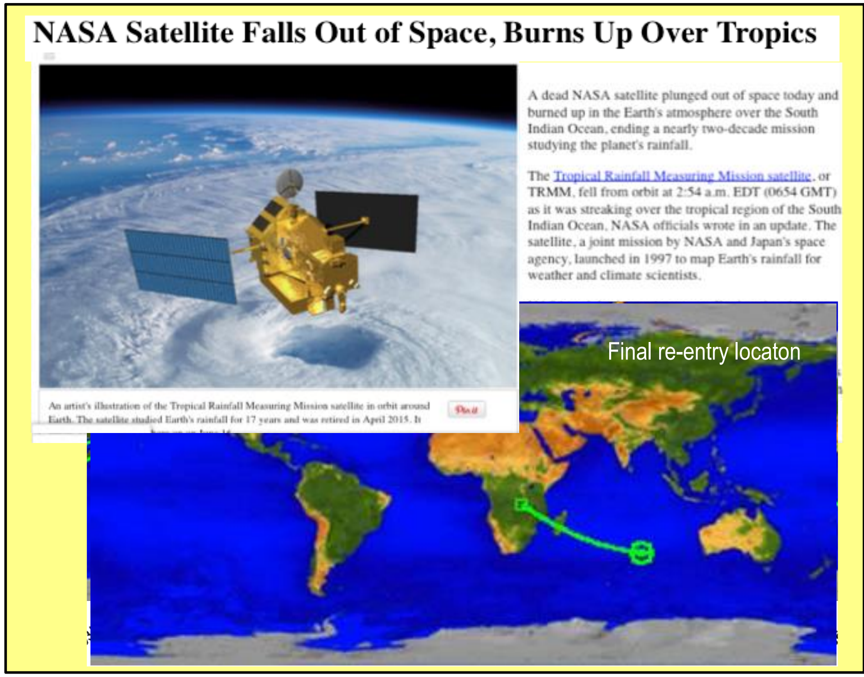
Yes/True?

No/False?

TRMM is Done (Nov. 1997-June 2015)

TRMM ACCOMPLISHMENTS

- *Space standard for measuring precipitation*
- *Improved climatologies of rainfall, latent heating and diurnal signals*
- *Improved climate and weather models*
- *Hurricane/typhoon structure/evolution*
- *Multi-satellite (~3-hr) rainfall analyses using TRMM+other satellites*
- *Flood and agricultural applications*
- *Operational use of data by weather agencies.*

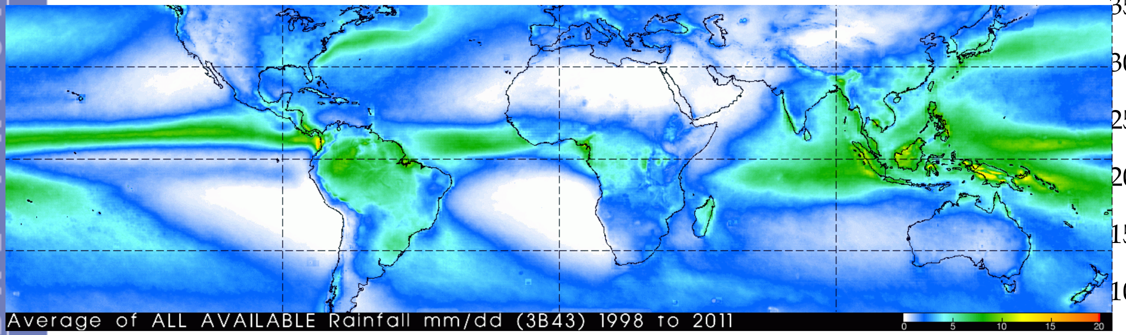

NASA Satellite Falls Out of Space, Burns Up Over Tropics

A dead NASA satellite plunged out of space today and burned up in the Earth's atmosphere over the South Indian Ocean, ending a nearly two-decade mission studying the planet's rainfall.

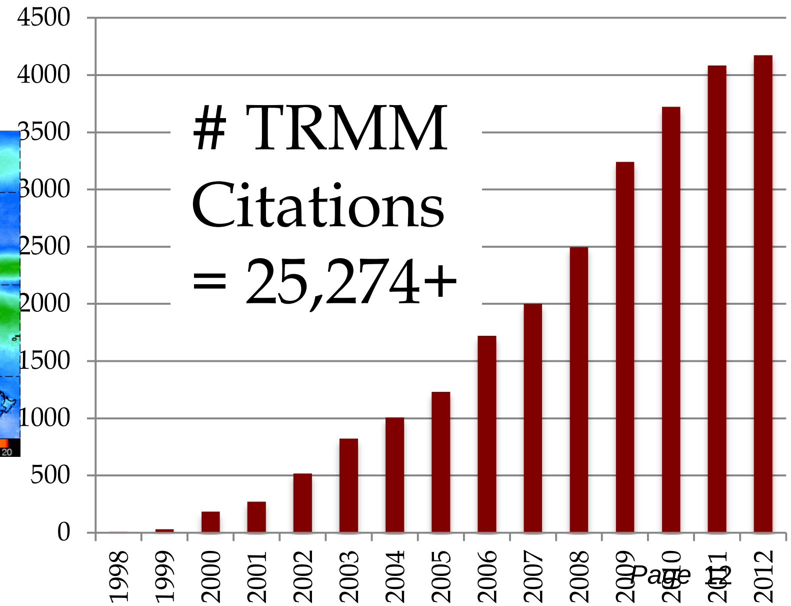
The Tropical Rainfall Measuring Mission satellite, or TRMM, fell from orbit at 2:54 a.m. EDT (0654 GMT) as it was streaking over the tropical region of the South Indian Ocean, NASA officials wrote in an update. The satellite, a joint mission by NASA and Japan's space agency, launched in 1997 to map Earth's rainfall for weather and climate scientists.

An artist's illustration of the Tropical Rainfall Measuring Mission satellite in orbit around Earth. The satellite studied Earth's rainfall for 17 years and was retired in April 2015. It

~1 year overlap with GPM

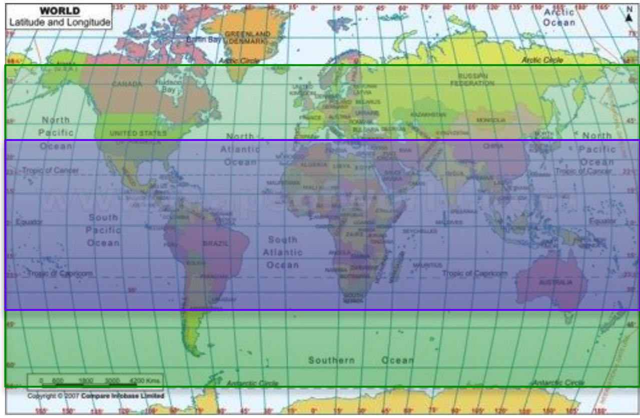


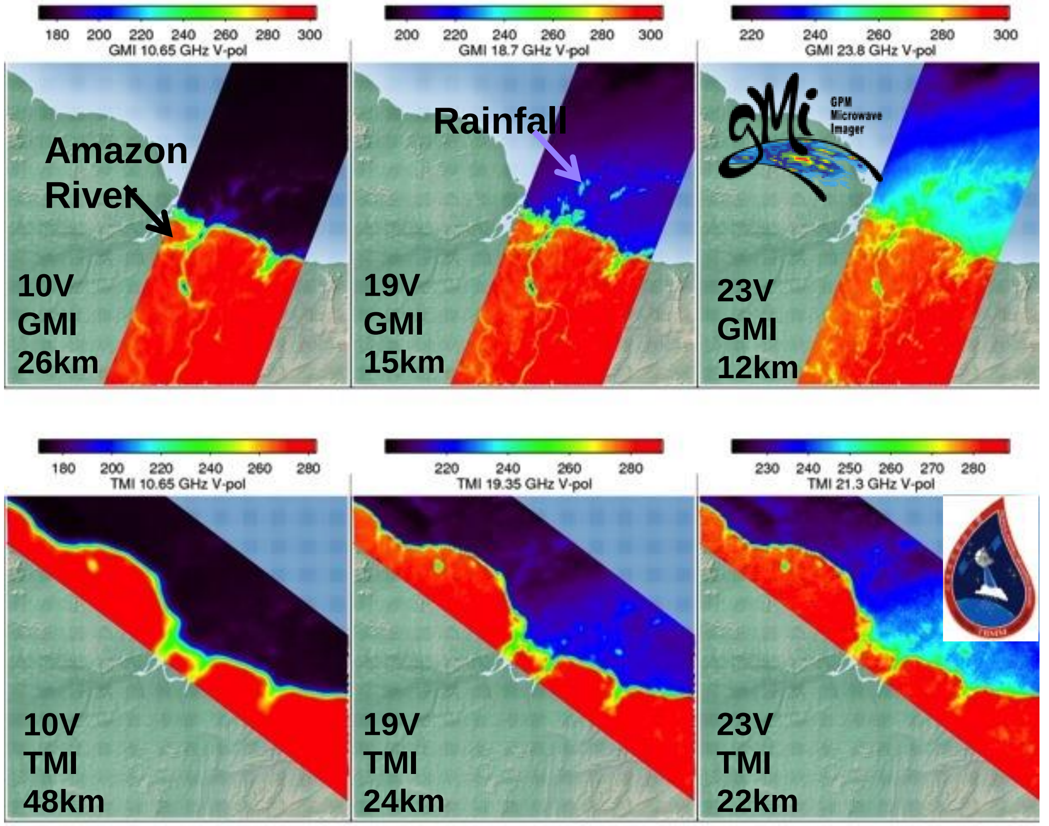
TRMM Rain Average 1998-2011

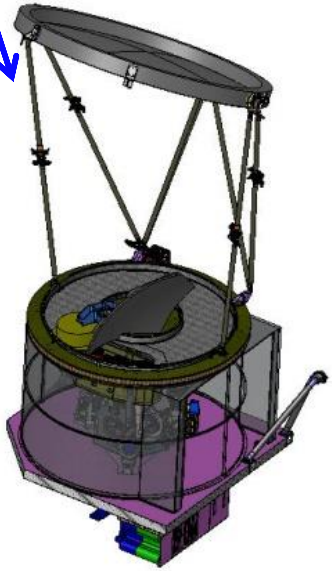


GPM Enhancements Compared to TRMM

- Increased Earth Coverage
- Advanced Instruments
  - Dual Frequency Precipitation Radar
  - Passive Radiometer (10-183 GHz)
- Finer spatial resolution
- Detects falling snow
- Well designed radiometer (unifies partner estimates)







GPM Precipitation Products

GLOBAL PRECIPITATION MEASUREMENT

	GMI	DPR	Combined	Multi-Satellite
Levels	Level 1: Calibrated TB; Level 2: precip rates; Level 3: accumulations	Level 1: Calibrated powers; Level 2: Z & precip rates; Level 3: accum.	Level 2: Combined DPR & GMI; Level 3: accumulations	Level 2: precip rates; Level 3: accumulations
Latency	Latency: Near real time 1 hour ~15 km resolution	Latency: Near real time 3 hours ~5 km resolution	Latency: Near real time 3 hours ~15 km resolution	Latency: Near real time 4-6 hrs ~10 km res., every 30 minutes
Features	Constellation precipitation rates	Ku, Ka, and Ku+Ka products	Greater constraints on estimates; database for GPROF	Uses IR to fill between microwave for 30 min data
Name	Name: GPROF	Name: DPR	Name: CMB	Name: IMERG

EUME

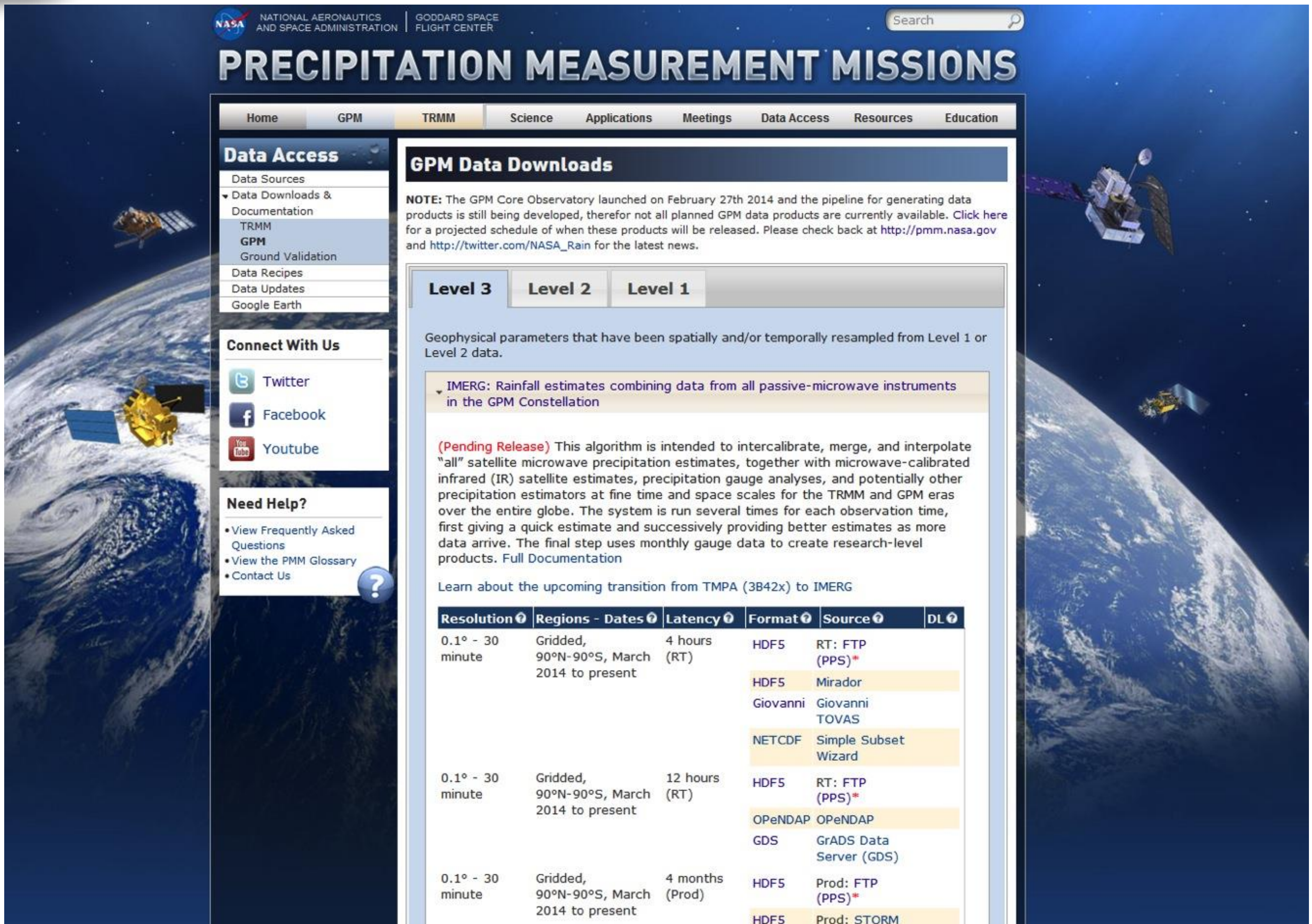
GPM Data Products

- 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, Argentina, Taiwan, Mexico, Australia, Japan, UK, Korea, European Union, China, India, South Africa, Spain
- Data *product reprocessing in early 2016* for updated algorithms
- *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)
May 2015	99.000%	98.875%	97.750%
June 2015	99.958%	99.889%	98.833%
July 2015	99.380%	99.194%	98.405%
August 2015	100.000%	100.000%	97.596%
September 2015	99.609%	99.566%	97.743%
October 2015	99.702%	99.616%	98.884%

Data Access (http://pps.gsfc.nasa.gov)

Data Access (http://pps.gsfc.nasa.gov)



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Search

PRECIPITATION MEASUREMENT MISSIONS

Home | GPM | TRMM | Science | Applications | Meetings | Data Access | Resources | Education

Data Access

- Data Sources
- Data Downloads & Documentation
  - TRMM
  - **GPM**
  - Ground Validation
- Data Recipes
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- Contact Us

GPM Data Downloads

NOTE: The GPM Core Observatory launched on February 27th 2014 and the pipeline for generating data products is still being developed, therefor not all planned GPM data products are currently available. Click here for a projected schedule of when these products will be released. Please check back at http://pmm.nasa.gov and http://twitter.com/NASA_Rain for the latest news.

Level 3 | **Level 2** | **Level 1**

Geophysical parameters that have been spatially and/or temporally resampled from Level 1 or Level 2 data.

IMERG: Rainfall estimates combining data from all passive-microwave instruments in the GPM Constellation

(Pending Release) This algorithm is intended to intercalibrate, merge, and interpolate "all" satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales for the TRMM and GPM eras over the entire globe. The system is run several times for each observation time, first giving a quick estimate and successively providing better estimates as more data arrive. The final step uses monthly gauge data to create research-level products. Full Documentation

Learn about the upcoming transition from TMPA (3B42x) to IMERG

Resolution	Regions - Dates	Latency	Format	Source	DL
0.1° - 30 minute	Gridded, 90°N-90°S, March 2014 to present	4 hours (RT)	HDF5	RT: FTP (PPS)*	
			HDF5	Mirador	
			Giovanni	Giovanni TOVAS	
			NETCDF	Simple Subset Wizard	
0.1° - 30 minute	Gridded, 90°N-90°S, March 2014 to present	12 hours (RT)	HDF5	RT: FTP (PPS)*	
			OPeNDAP	OPeNDAP	
			GDS	GrADS Data Server (GDS)	
0.1° - 30 minute	Gridded, 90°N-90°S, March 2014 to present	4 months (Prod)	HDF5	Prod: FTP (PPS)*	
			HDF5	Prod: STORM	

PPS STORM data ordering and subsetting system

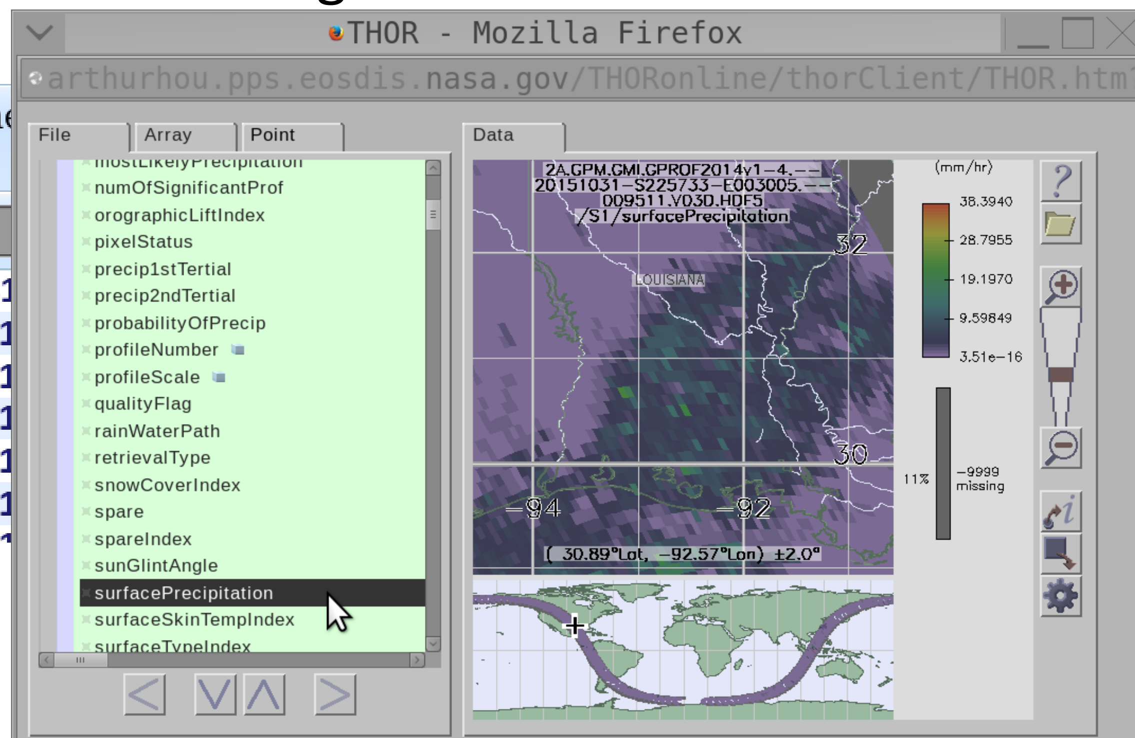
- Select a Data Type and a date range
- Optionally...
  - Specify a geographic region
  - Specify variables of interest within the file
  - Order a custom subset of these variables and region
- Download the HDF5 file via FTP
- Explore the HDF5 file online using THORonline

https://storm.pps.eosdis.nasa.gov/

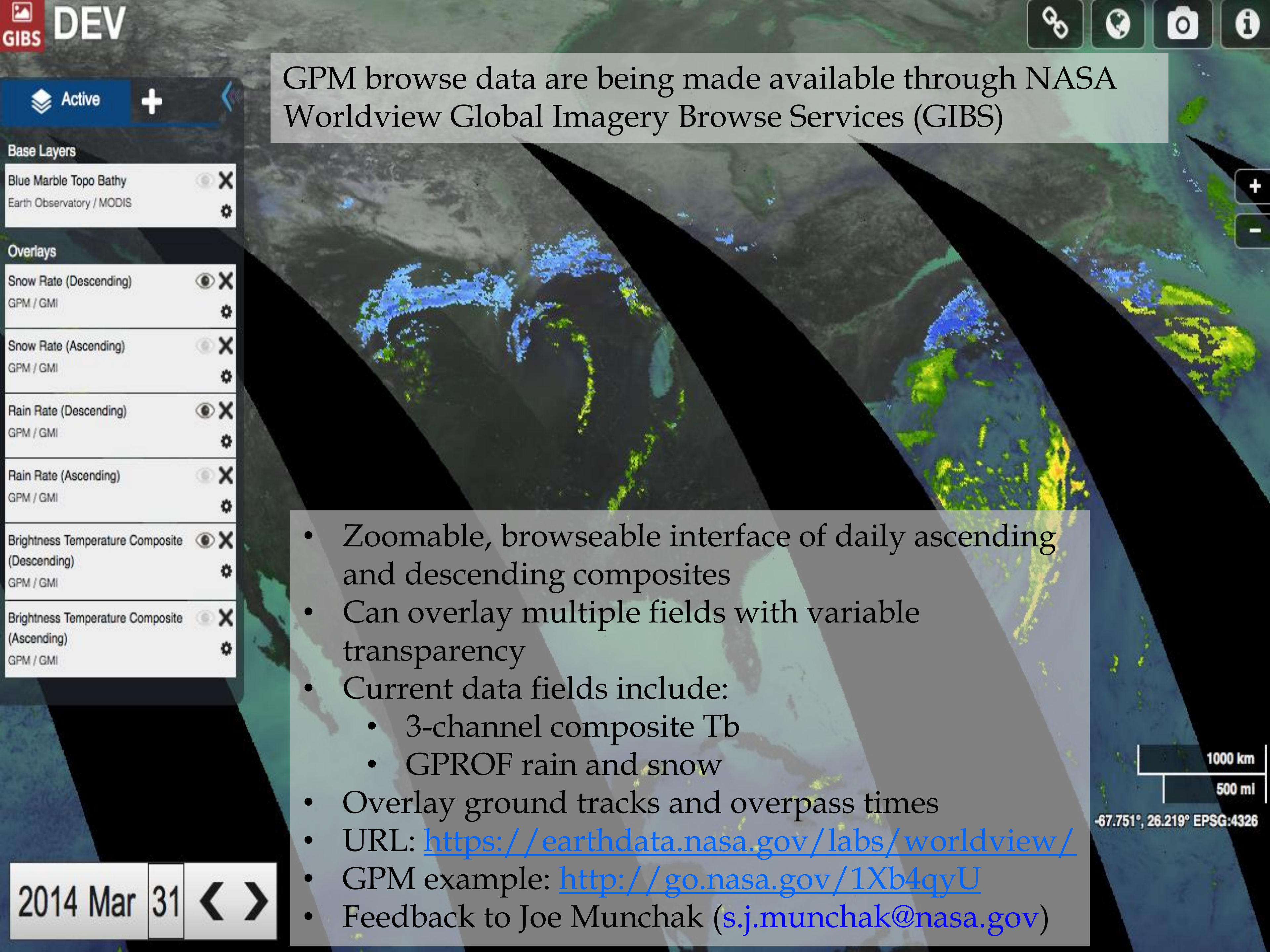
Search Result Table

Algorithm	Download / View	Start Time
2AGPROF	THOR	2015-10-31
2AGPROF	THOR	2015-11-01
2AGPROF	THOR	2015-11-01
2AGPROF	THOR	2015-11-01
2AGPROF	THOR	2015-11-01
2AGPROF	THOR	2015-11-01

FTP Download
Explore HDF5
Browse image



GPM browse data are being made available through NASA Worldview Global Imagery Browse Services (GIBS)



- Zoomable, browseable interface of daily ascending and descending composites
- Can overlay multiple fields with variable transparency
- Current data fields include:
  - 3-channel composite Tb
  - GPROF rain and snow
- Overlay ground tracks and overpass times
- URL: https://earthdata.nasa.gov/labs/worldview/
- GPM example: http://go.nasa.gov/1Xb4qyU
- Feedback to Joe Munchak (s.j.munchak@nasa.gov)

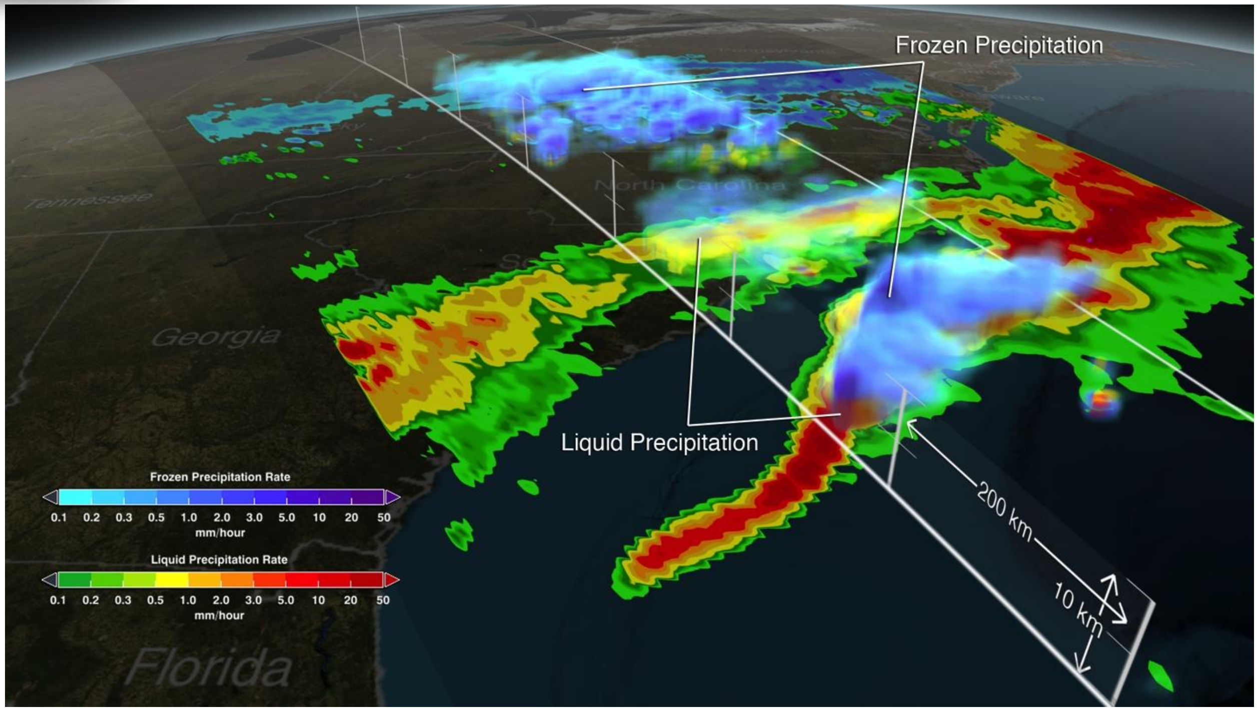
Question

The GPM data (formatted in imagery and as raw data) are available at near real-time for application users and later for higher-quality scientific investigations?

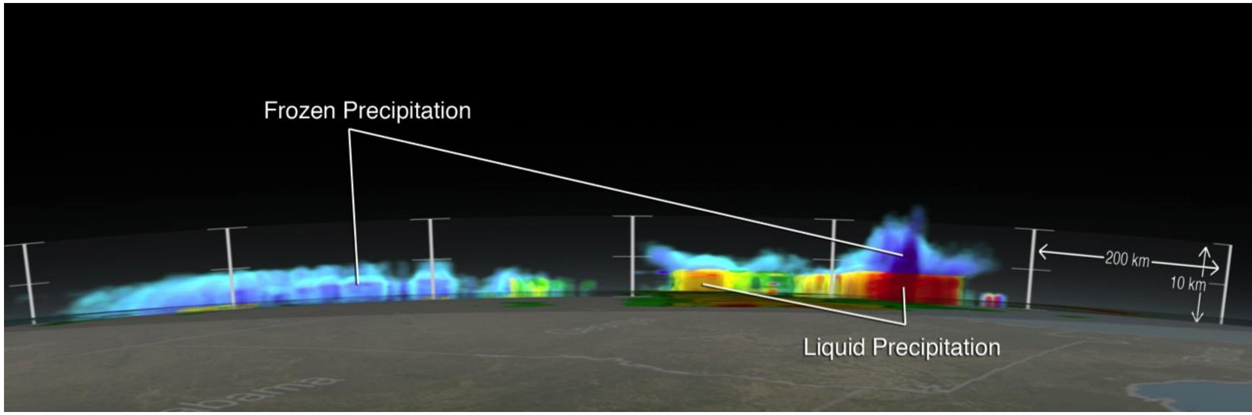
Yes/True?

No/False?

March 17, 2014 Snow Storm



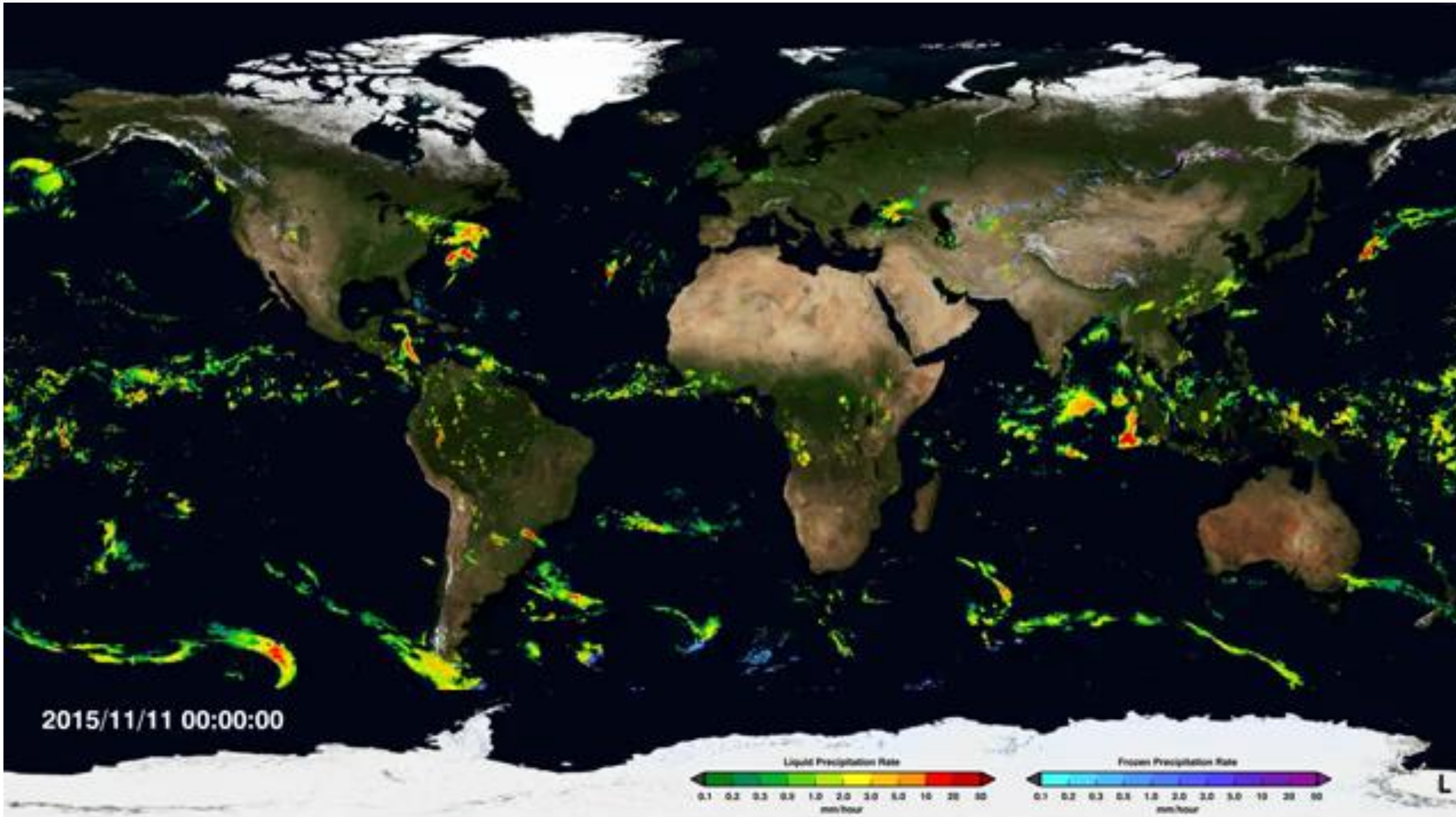
Note melting layer (red to purple dividing line) and cloud top heights



Washington, DC Snow event, 18 cm March 17, 2014

Movie: svs.gsfc.nasa.gov (search on 4173)

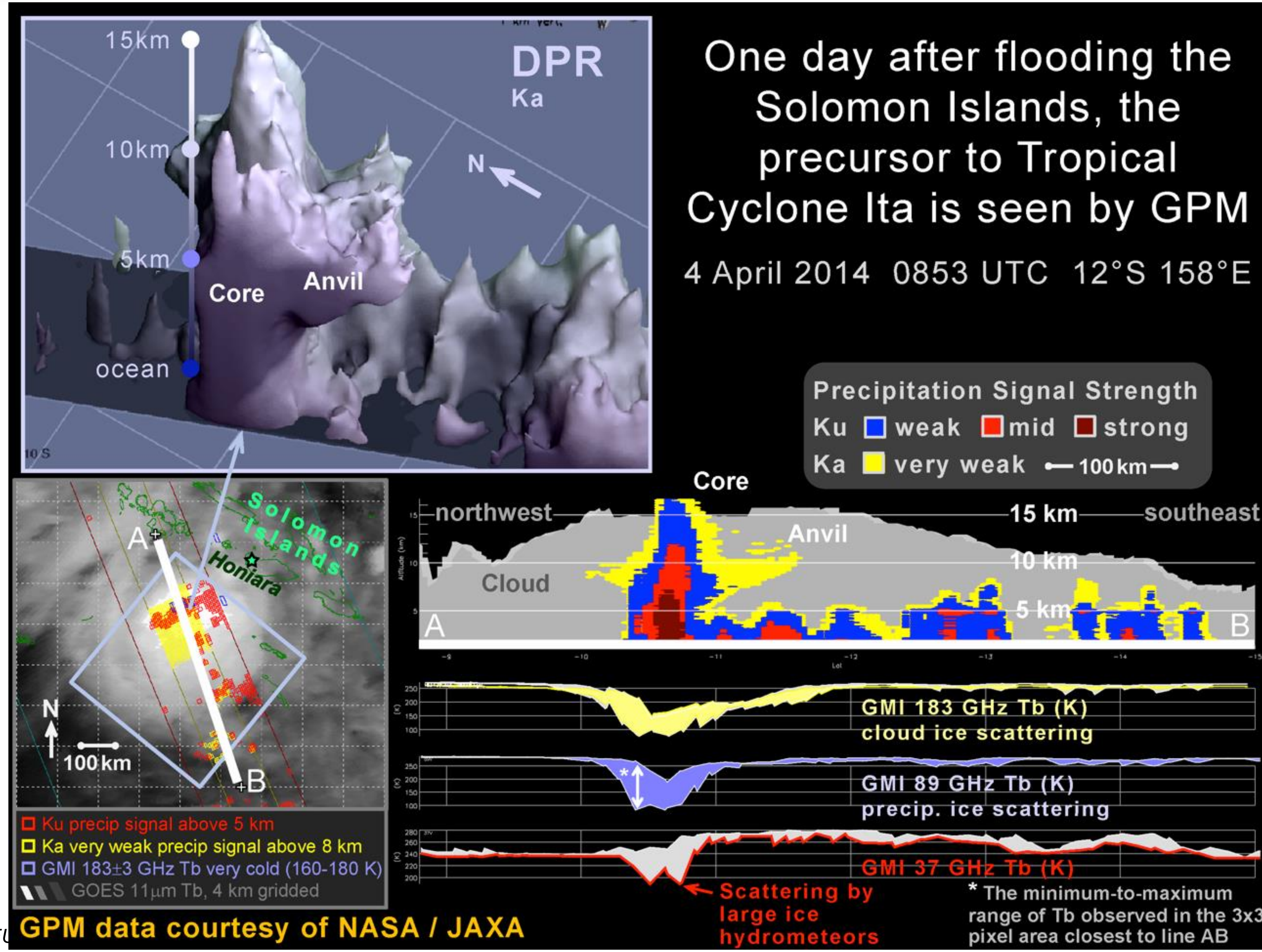
IMERG Rain (Nov 11-18, 2015)



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

Movie: svs.gsfc.nasa.gov (search on 4285)

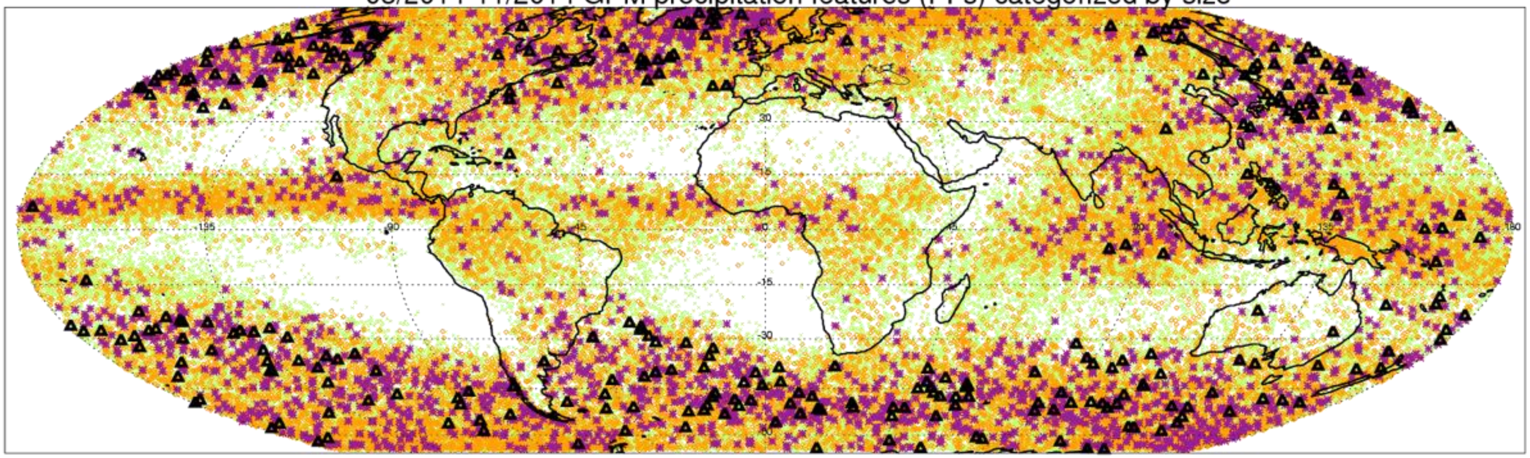
GPM Core Observatory: New Scientific Capabilities



GPM's Largest & Strongest Precipitation Systems

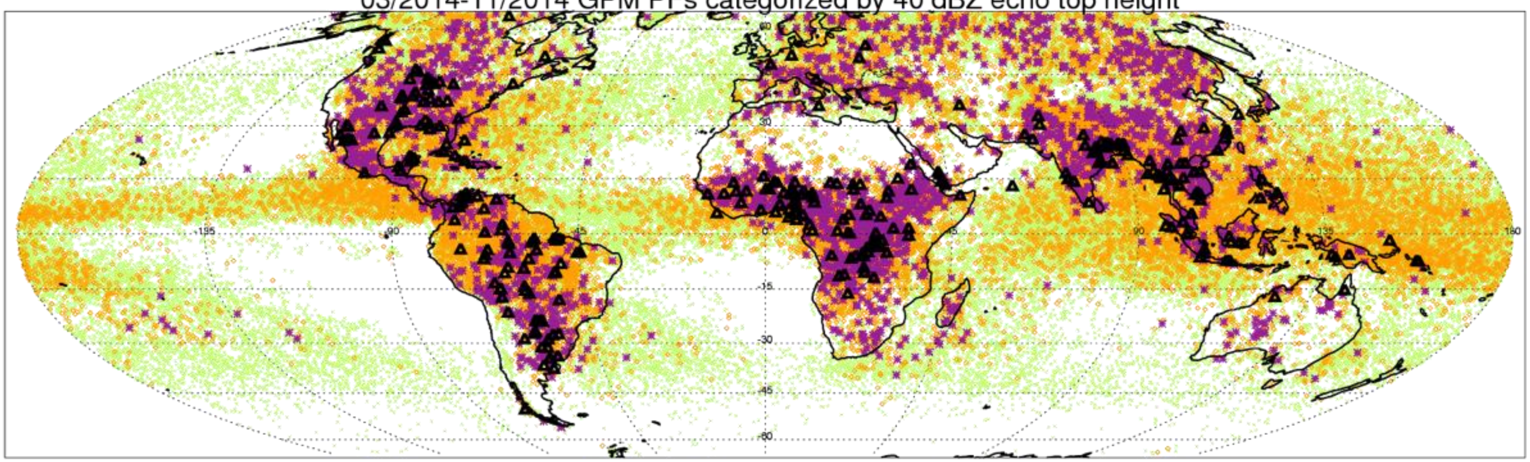
The most ***extensive*** precipitation systems are found over mid and high latitude ocean

03/2014-11/2014 GPM precipitation features (PFs) categorized by size



The ***strongest*** storms such as hailstorms and lightning storms are dominant over land

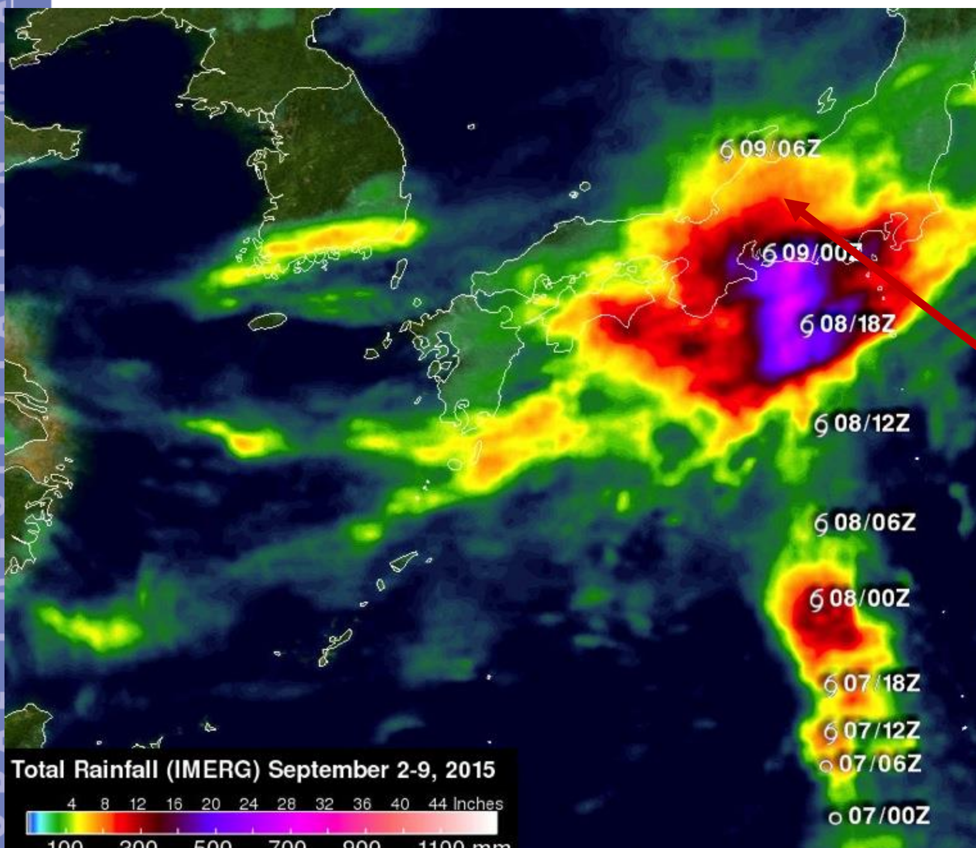
03/2014-11/2014 GPM PFs categorized by 40 dBZ echo top height

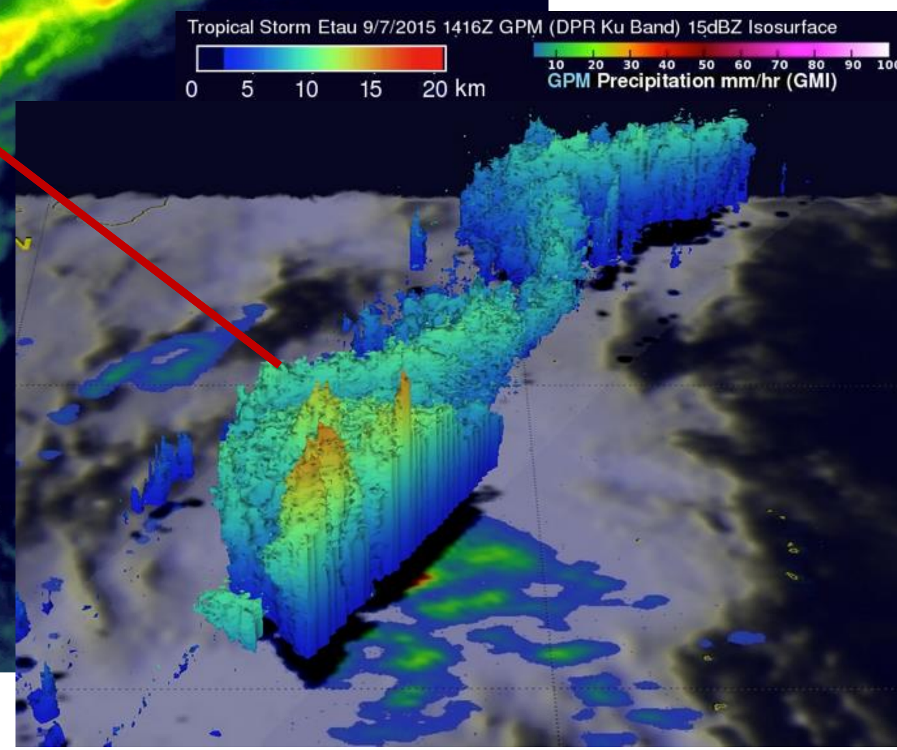


Credit: Chuntao Liu, Texas A&M – Corpus Christi

GPM Observes TS Etau & Flooding Rains in Japan

In early September 2015, Japan experienced extreme rainfall that resulted in flooding, landslides and many injuries. A nearly stationary front that was already moving over Japan caused much of the rain but tropical storm Etau also interacted with the front and magnified the scale of the deluge. The images show rainfall accumulations from Sept. 2-9 from the Integrated Multi-satellite Retrievals for GPM (IMERG) data (left). The inset image shows GPM's DPR and GMI rainfall measurements of Etau when the satellite passed over the center of the tropical storm on September 7, 2015 at 1416 UTC.



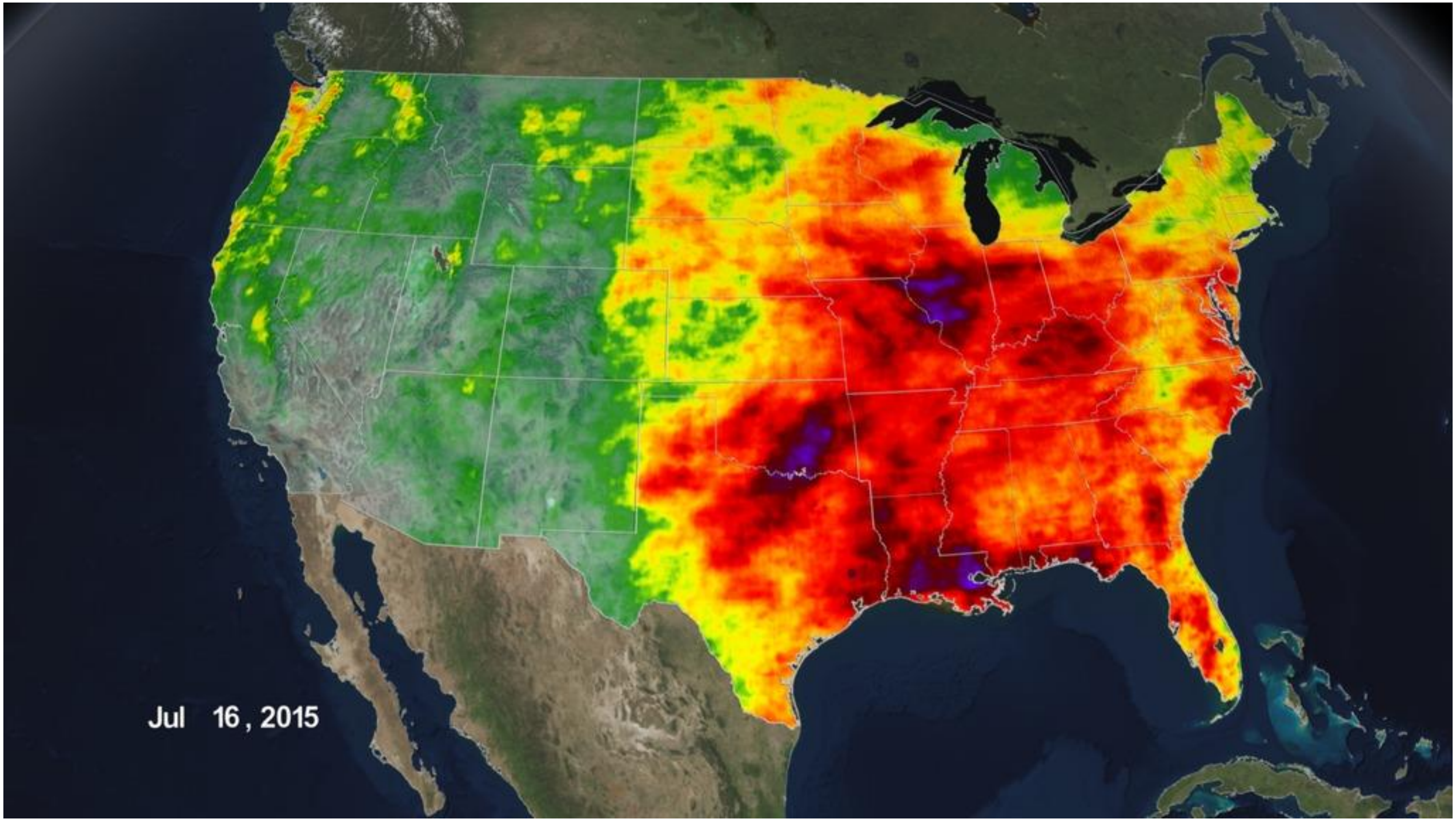


EUMETRAIN November 2015

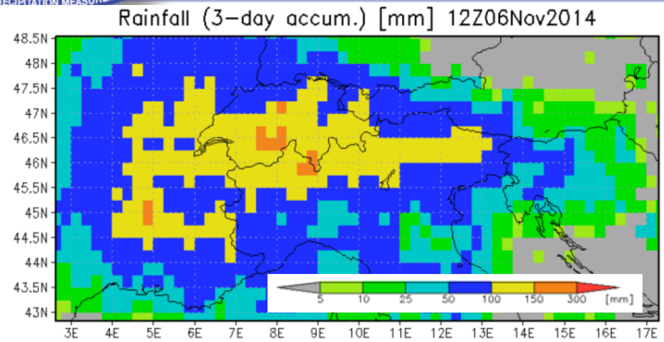
Image Credit: Hal Pierce, Caption Credit: Steve

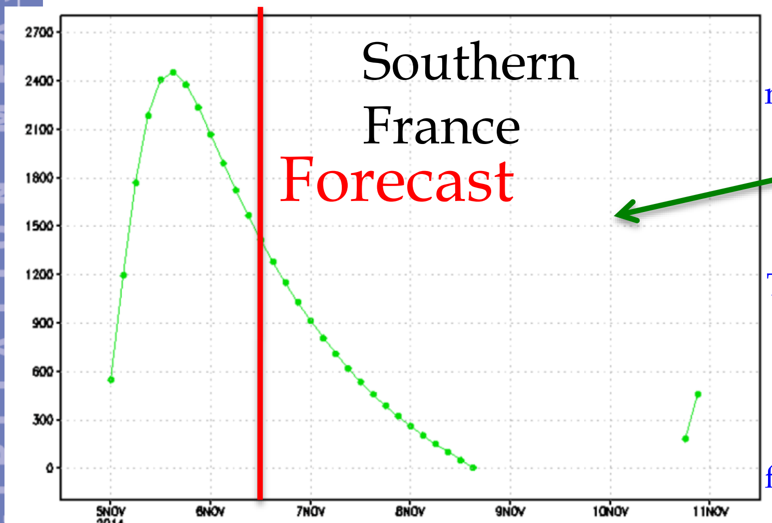
Water Resources

The United States has seen a tale of two extremes in 2015, with drenching rains in the eastern half of the country and persistent drought in the west. A new visualization of rainfall data collected from space shows the stark contrast between east and west for the first half of 2015.

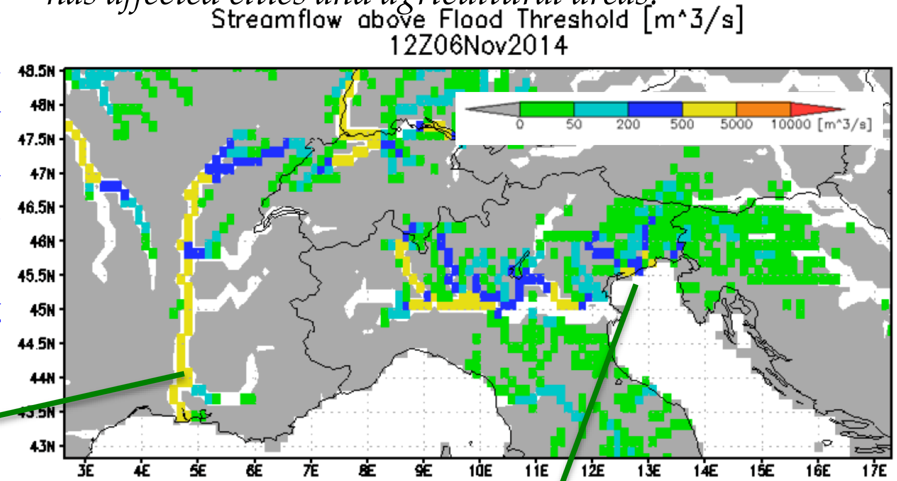


Flooding in Southern Europe (November 6, 2014)



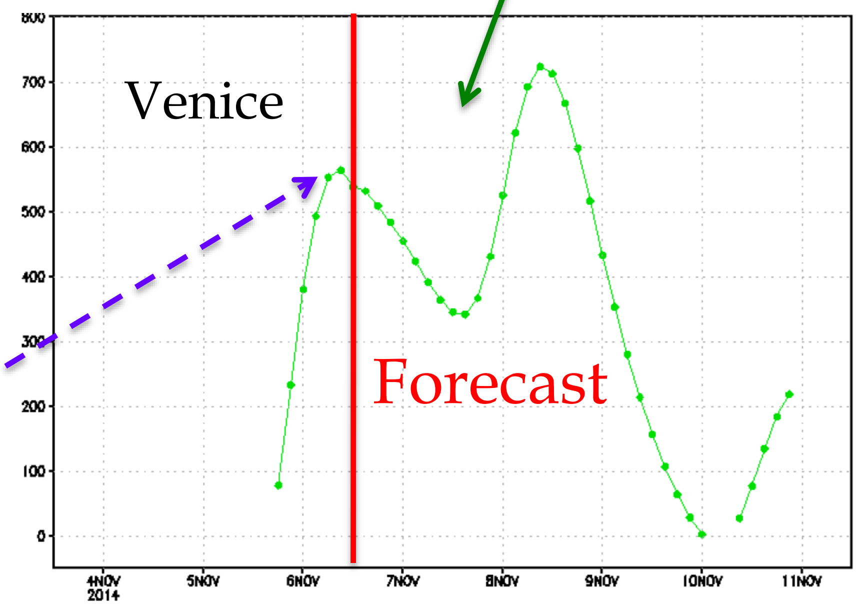


Flooding, first in France and in parts of northern Italy, has affected cities and agricultural areas.



Heavy rains struck southern France (peaking Tuesday-Wednesday) and then parts of northern Italy

Calculations based on TRMM/GPM rainfall are extended in time using GEOS-5 rain forecasts with a second peak forecast for Venice for Saturday.



St Marks Square, Venice

Global Flood Monitoring System (GFMS) Adler/Wu U. of Maryland

NASA's Integrated Multi-satellitE Retrievals for GPM (IMERG) data were used to estimate the historic amount of rain that fell during Sept 29-Oct 5, 2015 in the US Carolinas. A "fire hose" of moisture was pumped into this region from hurricane Joaquin resulting in widespread flooding. Over two feet of rain were reported in South Carolina. This analysis indicated that major hurricane Joaquin also dropped over 700 mm (27.5 inches) in the Bahamas.

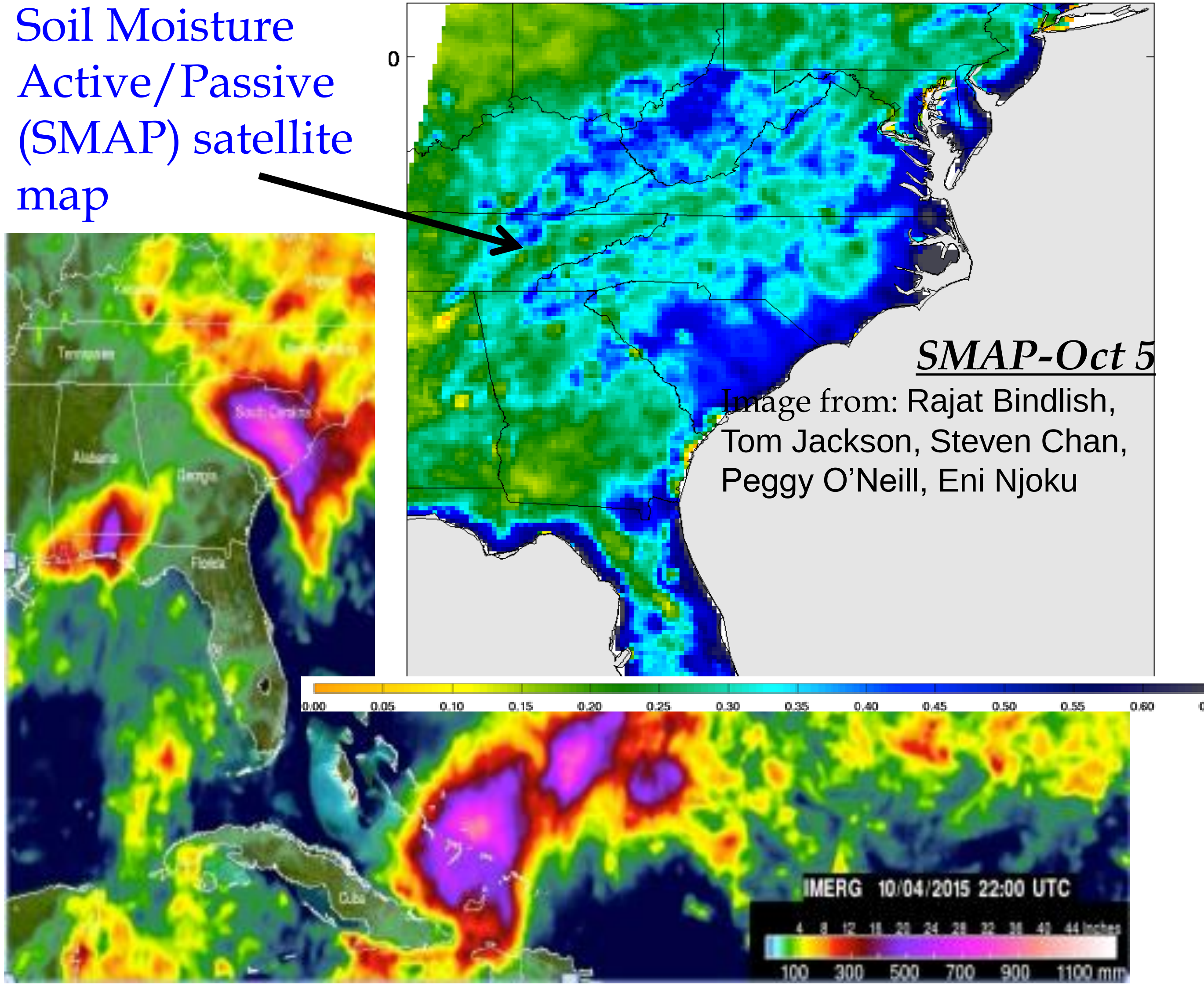
Hurricane Joaquin
Accumulated rain 9/27-10/4/2015

Visualization and caption credit: Hal Pierce/GSFC

GPM Observes Historic Rainfall Totals for Nor'easter and H. Joaquin

NASA's Integrated Multi-satellitE Retrievals for GPM (IMERG) data were used to estimate the historic amount of rain that fell during Sept 29-Oct 5, 2015 in the US Carolinas. A "fire hose" of moisture has been pumped into this region from hurricane Joaquin resulting in wide spread flooding. Over two feet of rain have been reported in South Carolina. This analysis indicated that major hurricane Joaquin also dropped over 700 mm (27.5 inches) in the Bahamas.

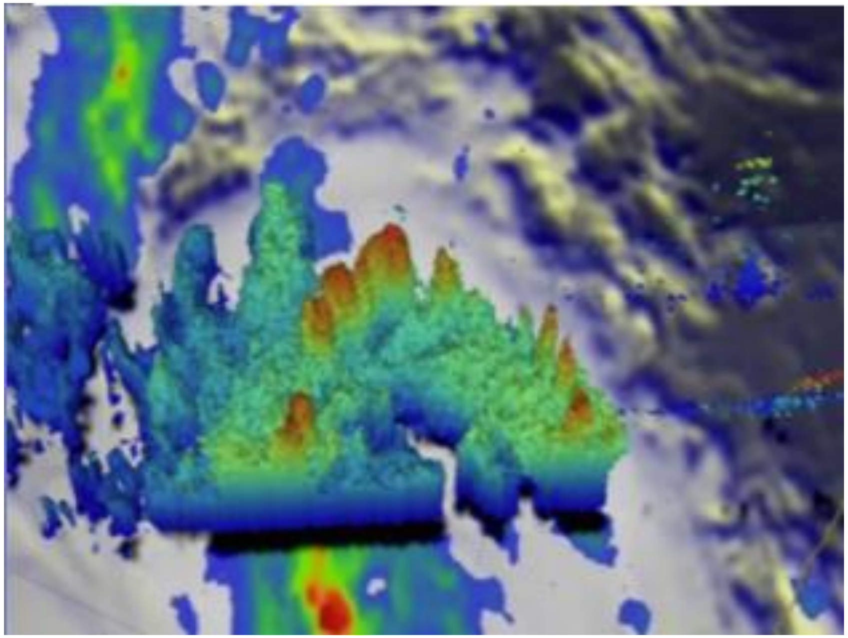
Soil Moisture Active/Passive (SMAP) satellite map



Visualization and caption credit: Hal Pierce/GSFC

GPM Observes Hurricane Patricia

The GPM Core Observatory satellite flew above the intensifying tropical cyclone on October 22, 2015 at 0401 UTC. Patricia was still a tropical storm with winds estimated at 55 kts (63 mph). Rainfall derived GMI and DPR showed that an eye was forming with intense rainfall just to the southeast of the forming eye. GPM's DPR measured rain falling at the extreme rate of almost 110 mm (4.3 inches) per hour within an intense feeder band west of Patricia's center.



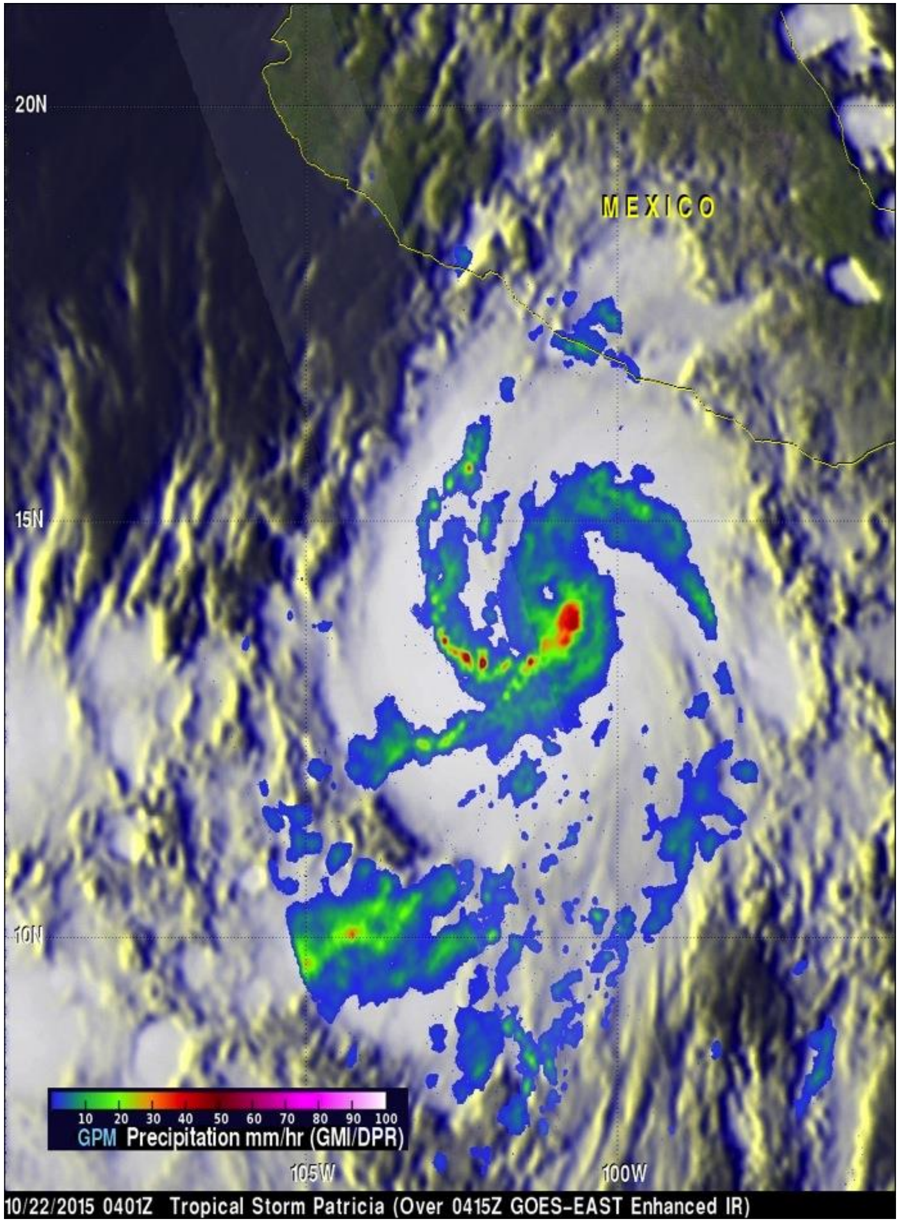
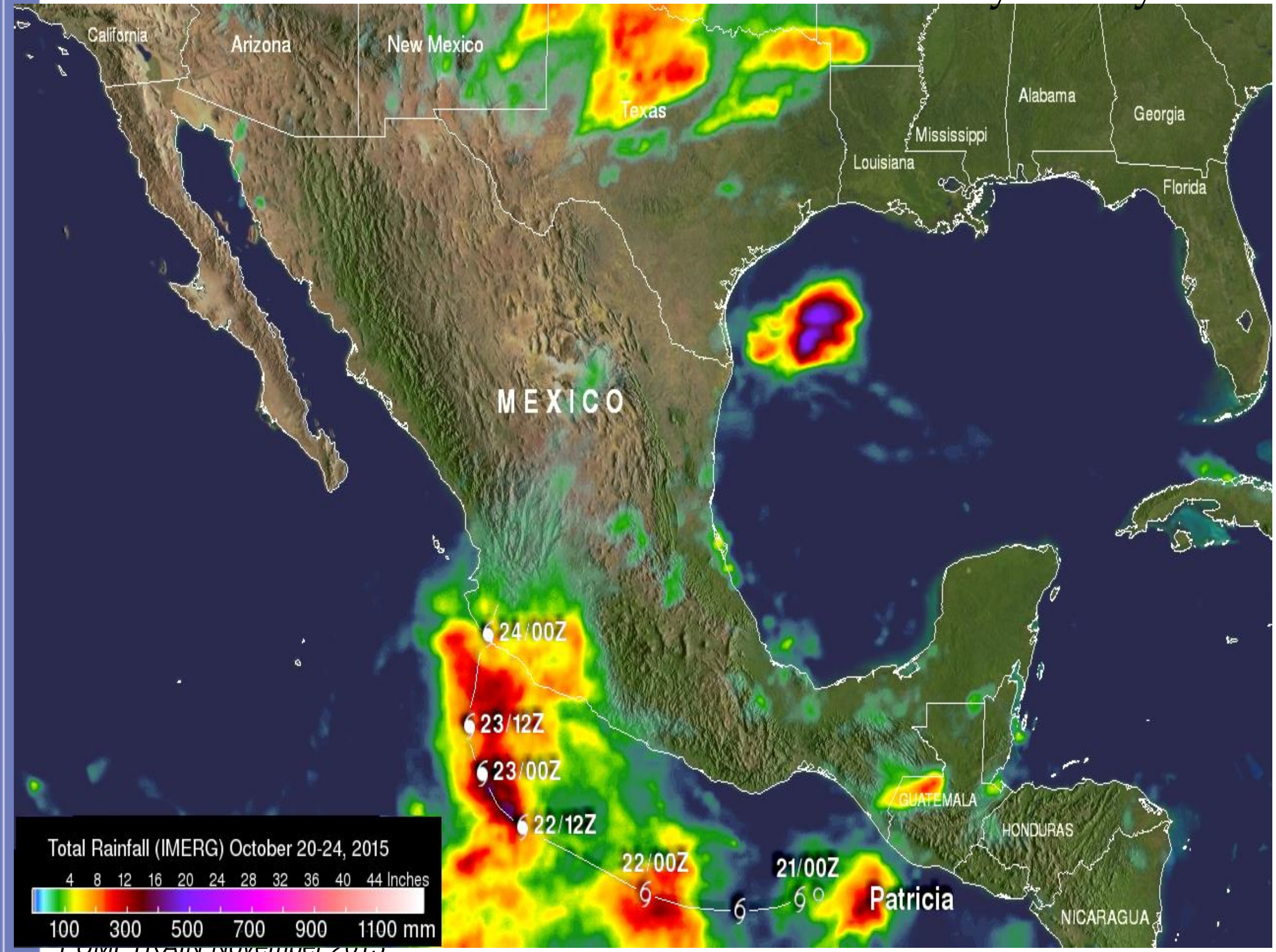


Image and Caption Credit: Hal Pierce and Steve Lang/GSFC

GPM Tracks Rainfall Accumulation for Hurricane Patricia

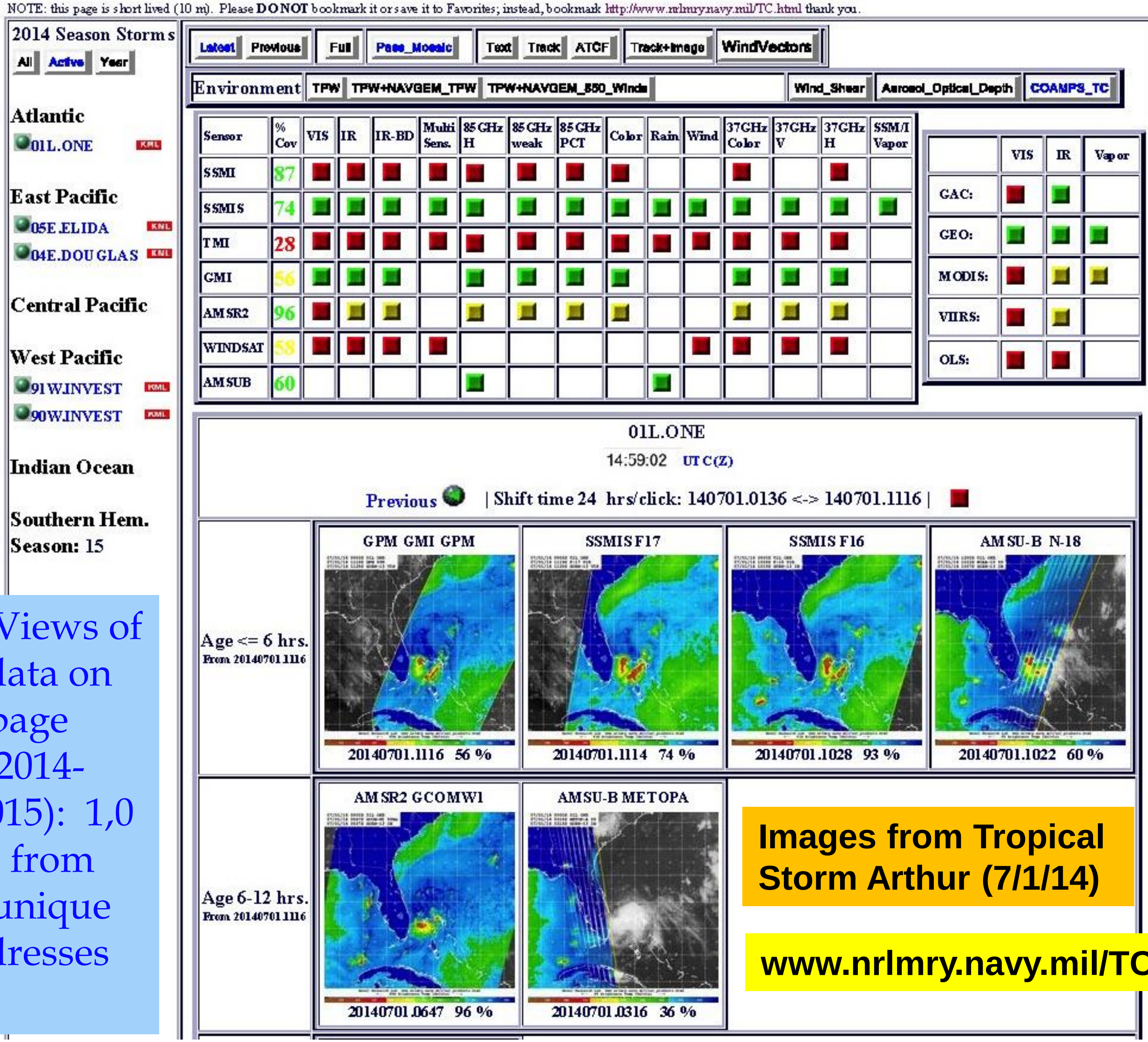
Hurricane Patricia (10/20-24/2015), the most powerful hurricane on record in the Western Hemisphere, quickly lost power as it moved over Mexico. Then an upper-level low pressure system and the remnants of Hurricane Patricia combined to cause very heavy rain in Texas.



Data from NASA's Integrated Multi-satellitE Retrievals for GPM (IMERG) were used to estimate the accumulation of rain from October 20-24, 2015.

Credit: Hal Pierce, SSAI/NASA GSFC

Naval Research Laboratory Tropical Cyclone Page



Total Views of GMI data on NRL page (June 2014-Feb.2015): 1,0 11,234 from 424K unique IP addresses

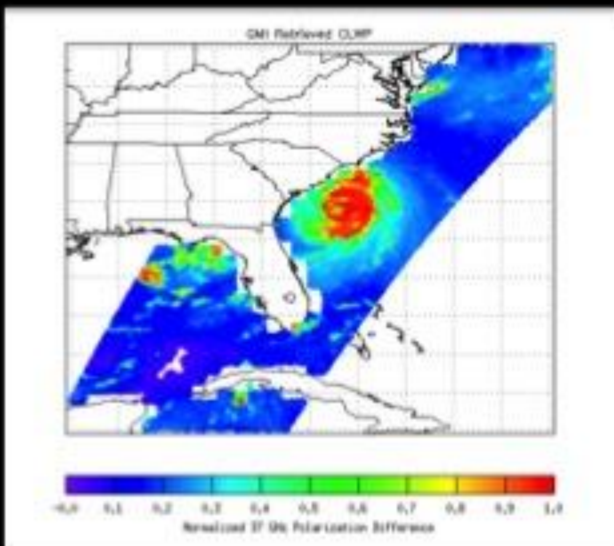
Images from Tropical Storm Arthur (7/1/14)

www.nrlmry.navy.mil/TC.html

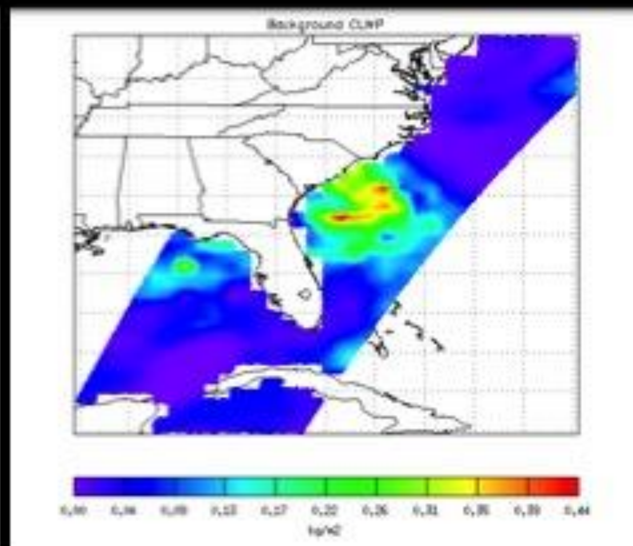
Using GPM Data for Cloud and Precipitation Analyses

Global Modeling and Assimilation Office

GPM Microwave Imager Observations
Hurricane Arthur (3 July 2014)



GEOS-5 6hr Cloud Water Forecast
before assimilating GPM Microwave Imager data



GEOS-5 Cloud Analysis Increment
after assimilating GPM Microwave Imager data

The GPM satellite was successfully launched on February 27th, 2014. GMAO is currently developing the all-sky radiance data assimilation system to utilize GPM Microwave Imager (GMI) radiance data in GEOS-5 to improve global cloud and precipitation analyses. This will contribute to improve near-real time weather forecasts including severe storms like hurricanes.

Figure Credit : Min-Jeong Kim, Jianjun Jin, Will McCarty, Ricardo Todling, and Ron Gelaro

Question

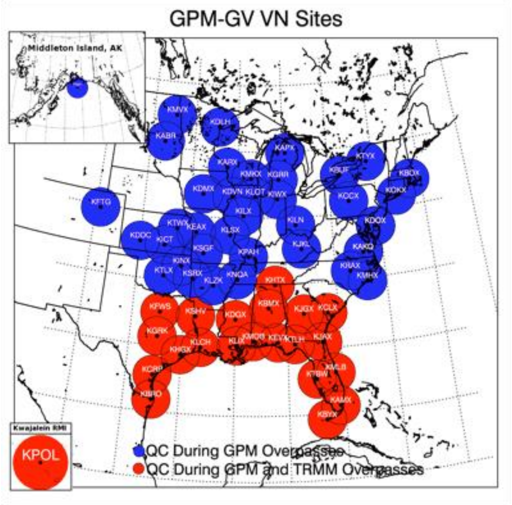
The Global Precipitation Measurement (GPM) data is already proving useful for science and society?

Yes/True?

No/False?

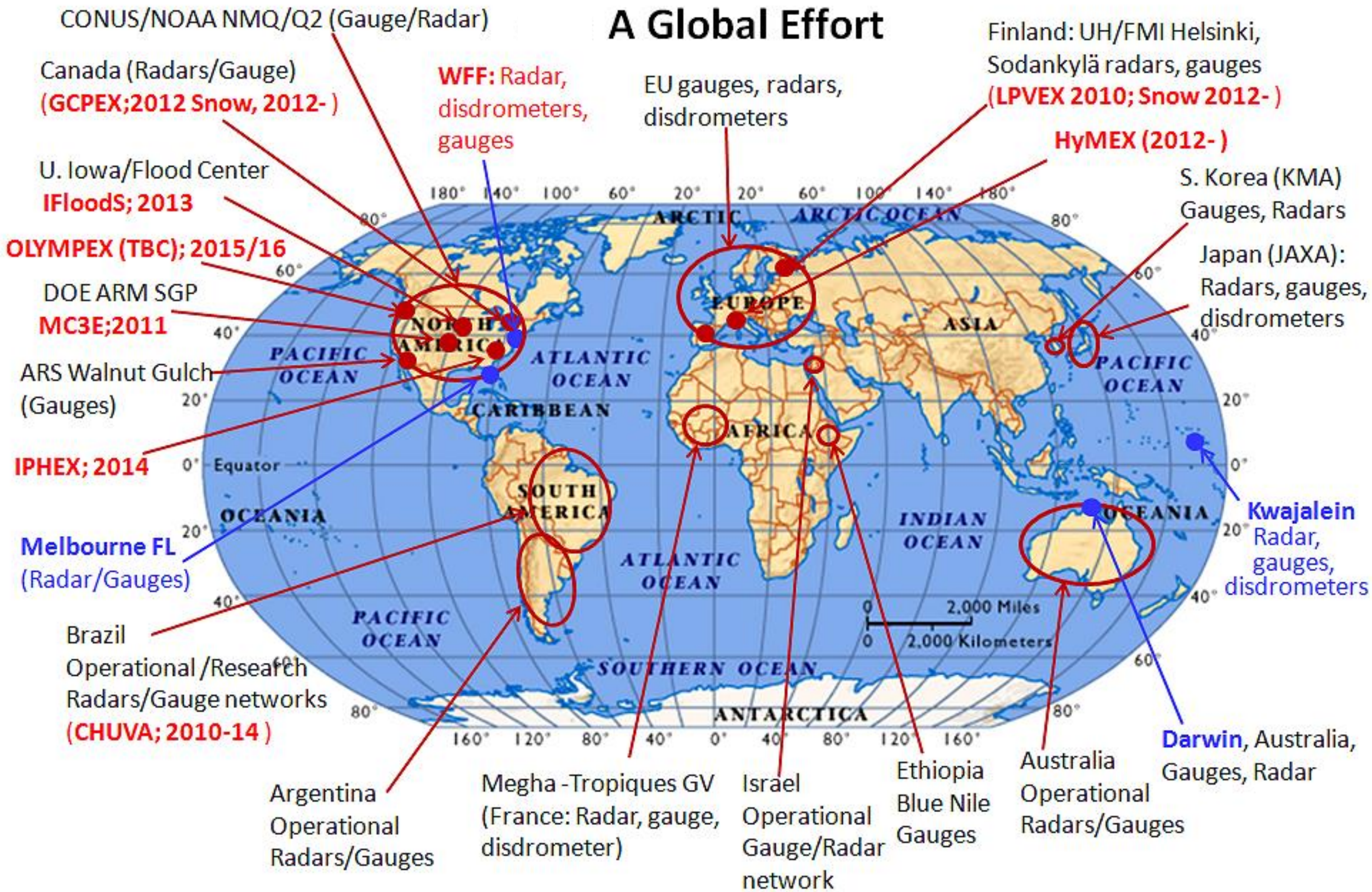
Ground Validation Activities

1. **Direct validation** (Satellite retrievals compared to ground observations)
   - Precipitation GV Research Facility at NASA Wallops
   - Operational Validation Network (VN) providing ground radar and coincident satellite overpass data over CONUS and some international partners.
   - Automated NMQ rain rate data stream over CONUS.



2. **Physical validation** (Understanding remote sensing principles)
3. **Integrated hydrological validation** (Linking to societal benefits)

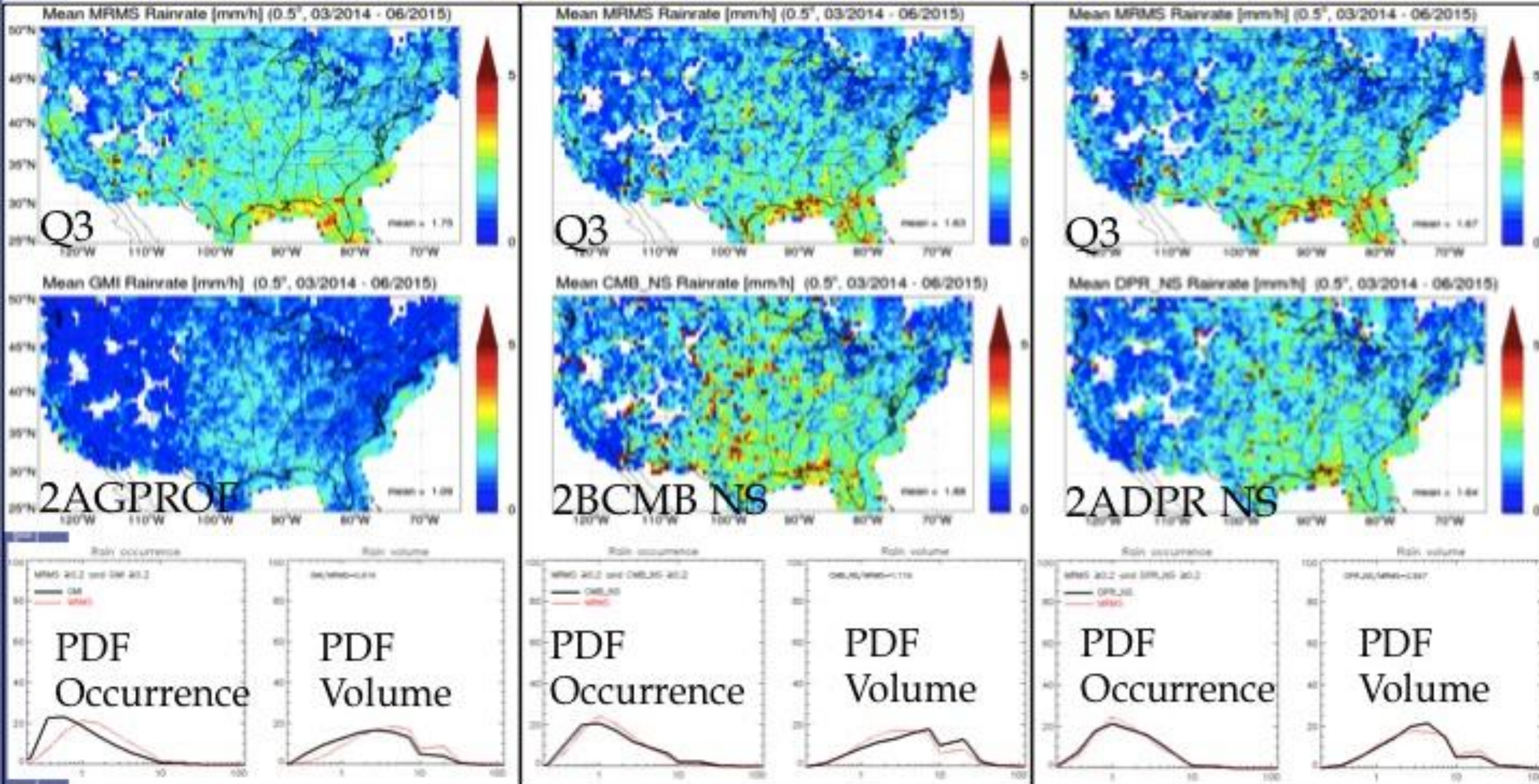
A Global View of Precipitation with a Global Team



Post Launch Direct GV: What are we seeing? Product Consistency?

http://gpm-gv.gsfc.nasa.gov/

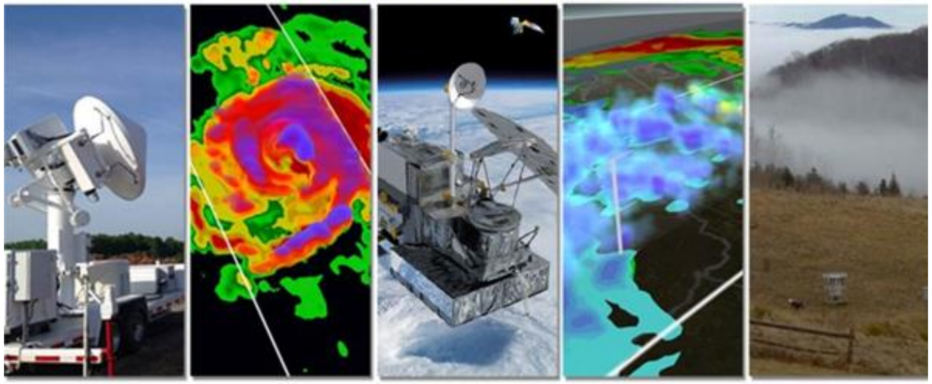
MRMS (Q3) and GPM: 03/14 to 06/2015 : 0.5° grid; Liquid only; > 0.2 mm/hr; RQI > 0.9



- Considering *liquid only* and *constraining GV* (MRMS/Q3)
  - GPROF low relative to DPR, CMB and MRMS Products. CMB, DPR, MRMS similar- CMB a bit higher in mean; ***How will things change with V4 of DPR/V2 of GPROF?***
- ***Level 1 Requirements:*** *Mean* relative error generally falls within requirements; RMSE……

Applications/Education & Public Outreach

2015 GPM Applications Workshop



Workshop: 9-10 June 2015
(~150 participants)

Extreme Events and Disasters

- Landslides
- Floods
- Tropical cyclones
- Re-insurance

Water Resources and Agriculture

- Famine Early Warning System
- Drought
- Water Resource management
- Agriculture

Weather, Climate & Land Surface Modeling

- Numerical Weather Prediction
- Land System Modeling
- Global Climate Modeling

Public Health and Ecology

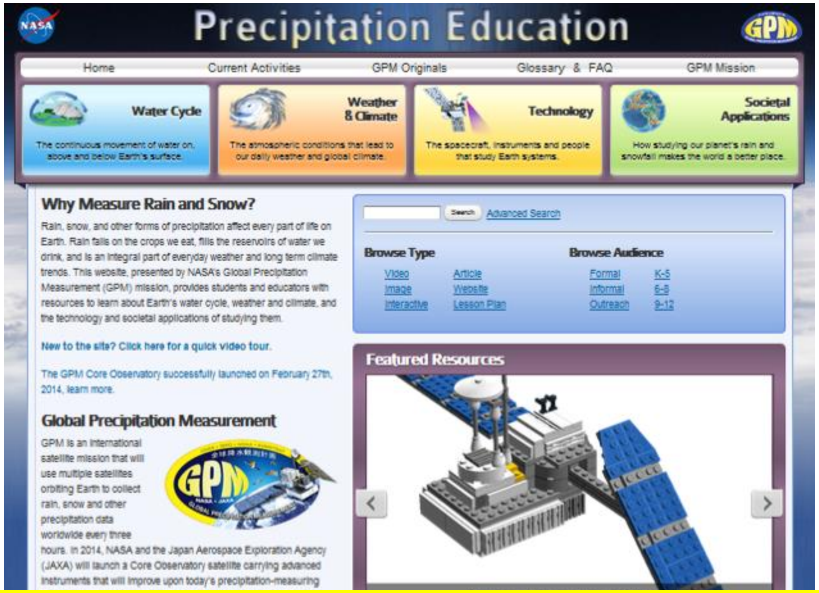
- Disease tracking
- Animal migration
- Food Security

<u>Social Media (Oct. 2015 Stats)</u>

Twitter: NASA_Rain
Total Twitter Followers: > 14.7K

Facebook: NASA.Rain
Total Facebook Followers: > 23.7K

gpm.nasa.gov Pageviews: 43291
gpm.nasa.gov/education Pageviews: 49297
Movie webpage: svs.gsfc.nasa.gov

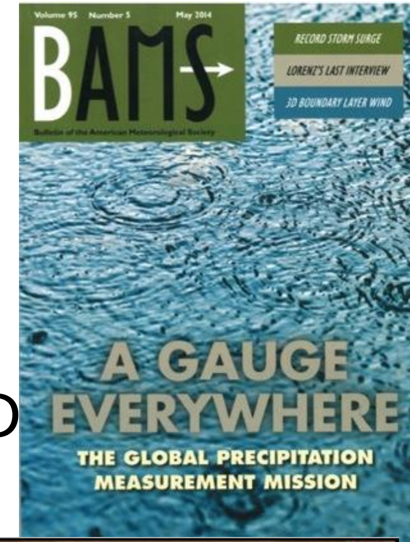


http://gpm.nasa.gov/education

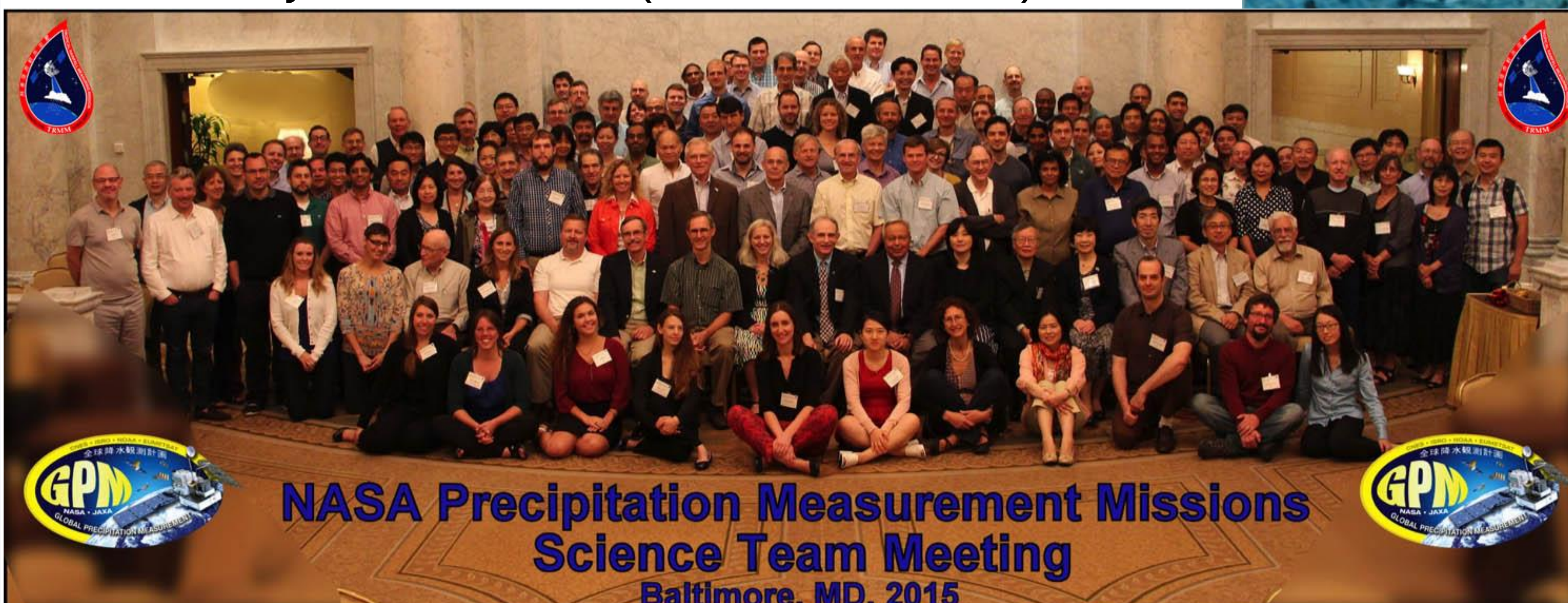
TRMM/GPM Science Team Meetings

- The GPM Science team has 60 NASA funded PI teams
- GPM has 25 no-cost International PI teams

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



- 2015 Science Team Meeting in Baltimore, MD
  - Nearly 200 attendees (from 14 countries)



For more information on the TRMM and GPM Missions:

http://gpm.nasa.gov; Movies at: http://svs.gsfc.nasa.gov/

Twitter: NASA_Rain Facebook: NASA.Rain

Gail.S.Jackson@nasa.gov