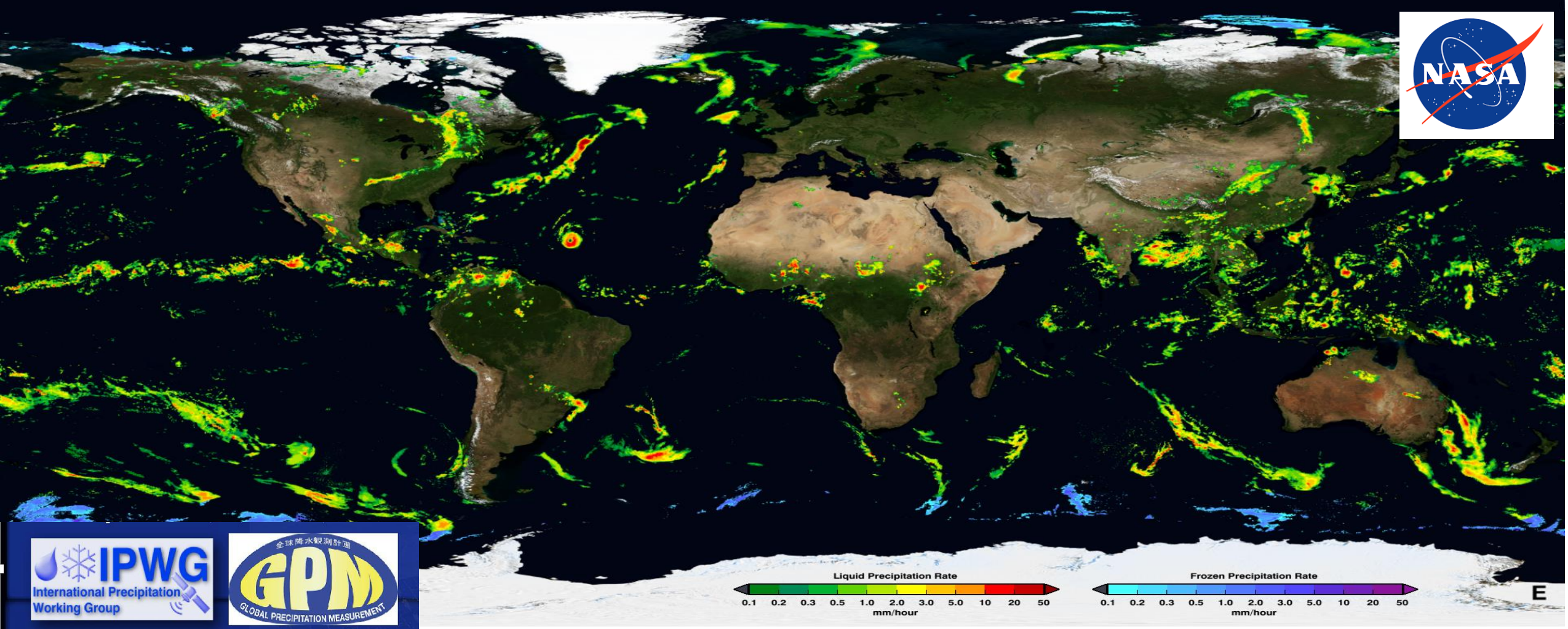

Overview of Precipitation Measurement Missions

Amita Mehta
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8 September 2021

Precipitation Missions

Past and Current Missions:

TRMM: Tropical Rainfall Measuring Mission	11/1997 – 04/2015
GPM: Global Precipitation Measurement Mission	02/2014 – present

Future Mission:

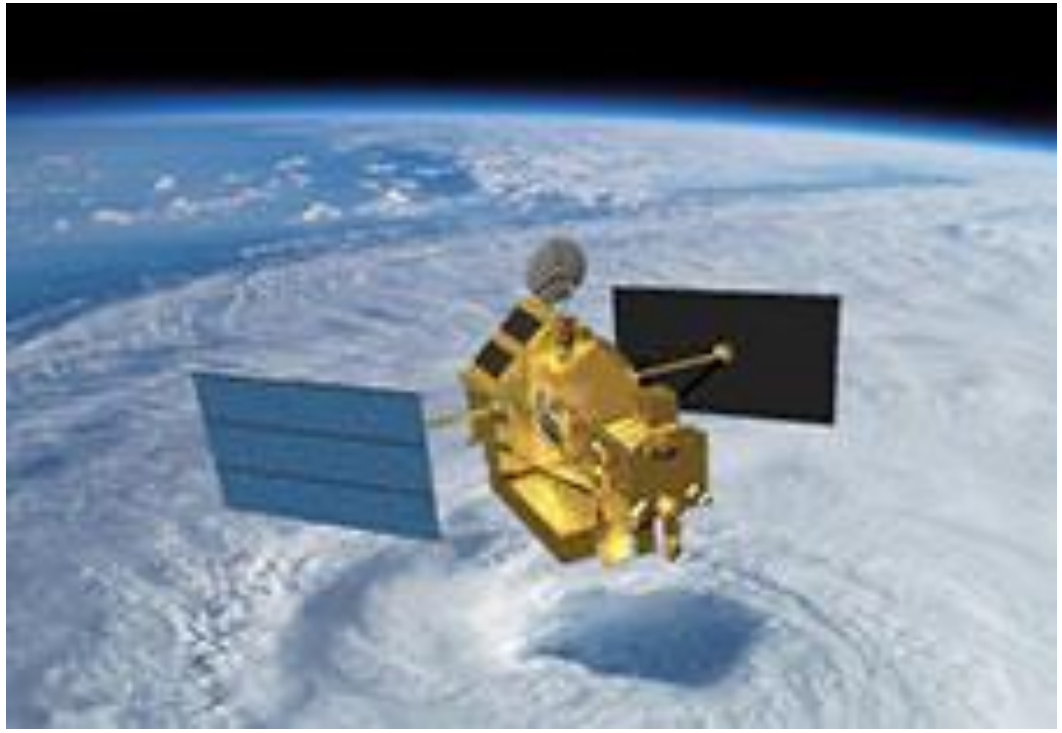
ACCP: Aerosol and Cloud, Convection and Precipitation	Likely Launch 2028
*ESO/AOS: Earth System Observatory/ Atmosphere Observing System	

*The Earth System Observatory/Atmosphere Observing System (ESO/AOS) is the preliminary name for the Constellation of ACCP

TRMM Overview

https://gpm.nasa.gov/missions/trmm

- NASA & JAXA (Japanese Space Agency) Joint Mission
- Designed to provide information about tropical/sub-tropical rainfall and its variability
- Provided critical information about heat release associated with rainfall that plays a key role in driving the atmospheric general circulation – affecting both weather and climate
- Made crucial contribution to the understanding of tropical cyclones and numerical weather prediction
- Led to the development of GPM core satellite



https://earthdata.nasa.gov/learn/articles/tools-and-technology-articles/trmm-to-gpm

TRMM Overview

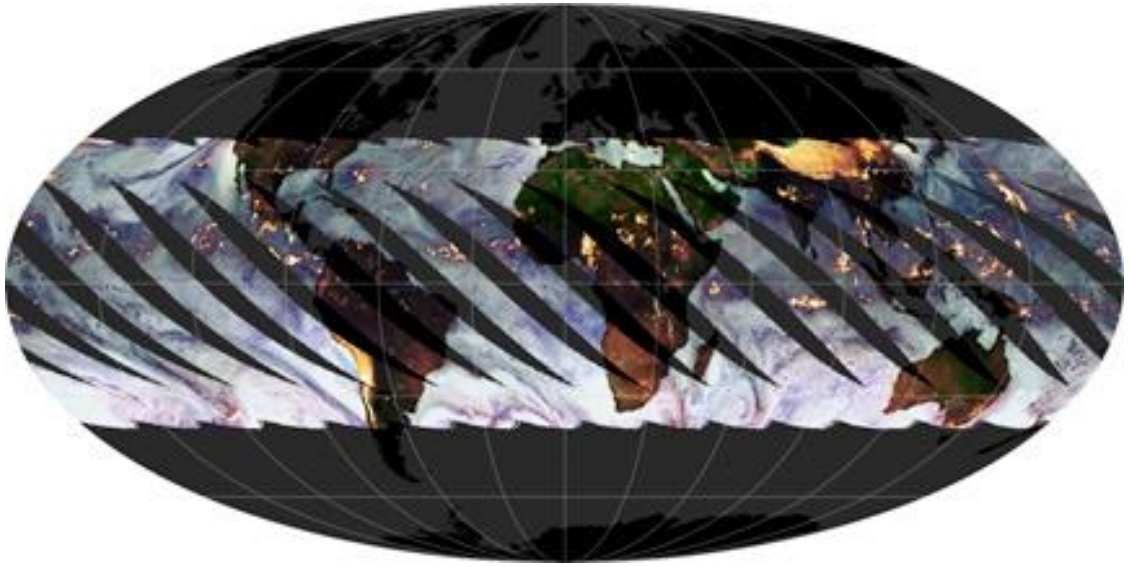
https://gpm.nasa.gov/missions/trmm

- In a non-polar, low-inclination orbit
- Altitude of approximately 350 km, raised to 403 km after Aug 23, 2001
- Spatial Coverage

  16 TRMM orbits a day covering global tropics between 35°S – 35°N latitudes
- Revisit Time: 11-12 hrs

  Time of observation changed daily

TRMM Orbits

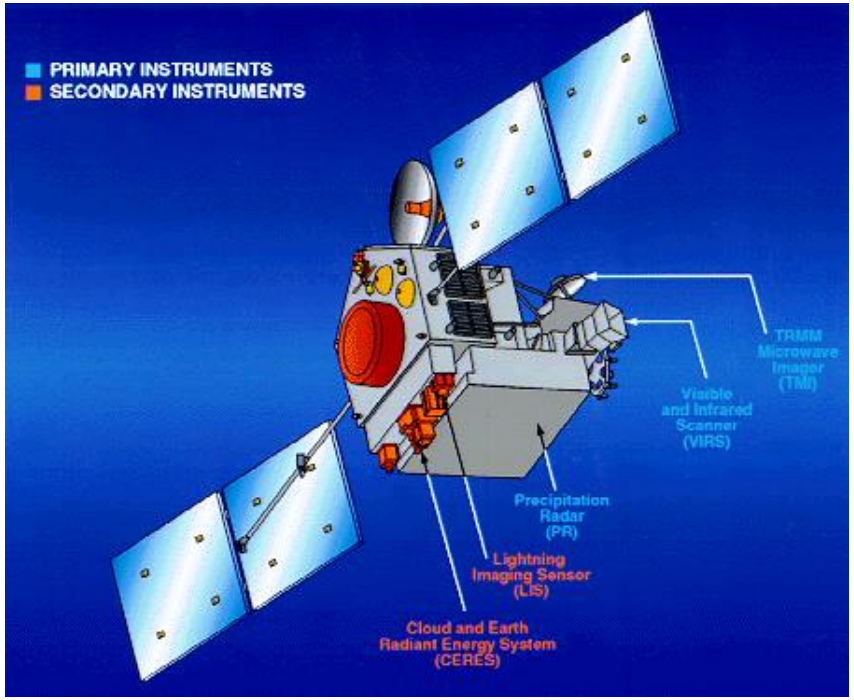


TRMM Sensors

https://gpm.nasa.gov/missions/TRMM/satellite

- **Primary Precipitation Sensors:**
  PR: Precipitation Radar
  TMI: TRMM Microwave Imager
  VIRS: Visible Infrared Radiometer
- The PR and TMI helped quantify the water vapor, the cloud water, and the rainfall intensity in the atmosphere
- Provided 3-dimensional structure of hydrometeors

TRMM Sensors



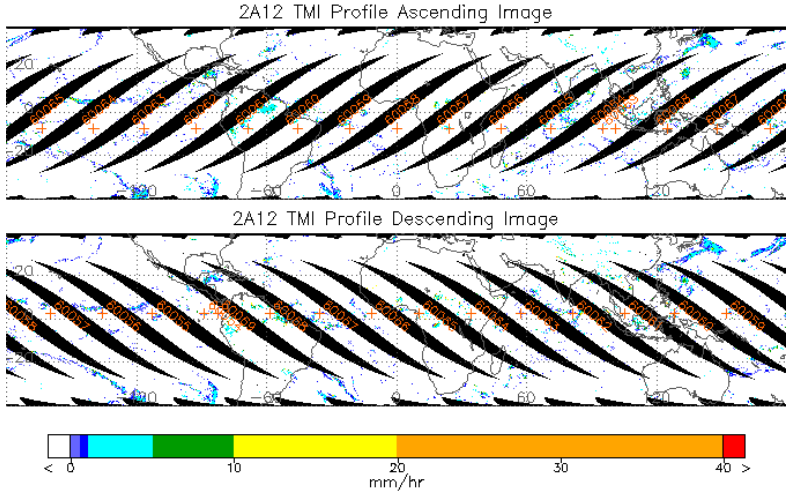
Credit: https://ceres.larc.nasa.gov/instruments/satellite-missions/#trmm

TRMM Sensors

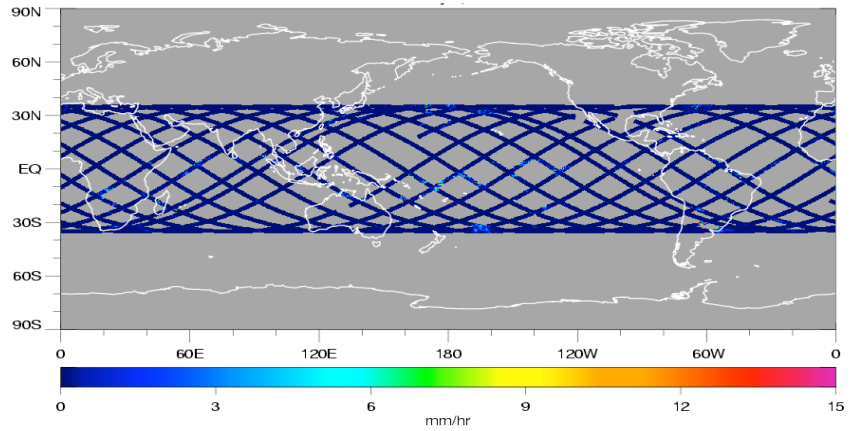
https://gpm.nasa.gov/missions/TRMM/satellite

	Microwave Radiometer (TMI)	Radar (PR)	Visible and Infrared Radiometer (VIRS)
Frequencies	10.7, 19.3, 21.3, 37.0, and 85.5 GHz (dual-polarized except for 21.3: vertical only)	13.8 GHz	0.63, 1.6,3.75. 10.8 , and 12 μm
Resolution (frequency dependent)	63x37, 30x18 , 23x18, 16x9, 7x5 km^2	5-km footprint and 250- m vertical resolution	2.5-km resolution
Scanning	Conically scanning (530 inc.)	Cross-track scanning	Cross-track scanning
Swath Width	880-km swath	250-km swath	830-km swath

TMI Swaths



PR Swaths



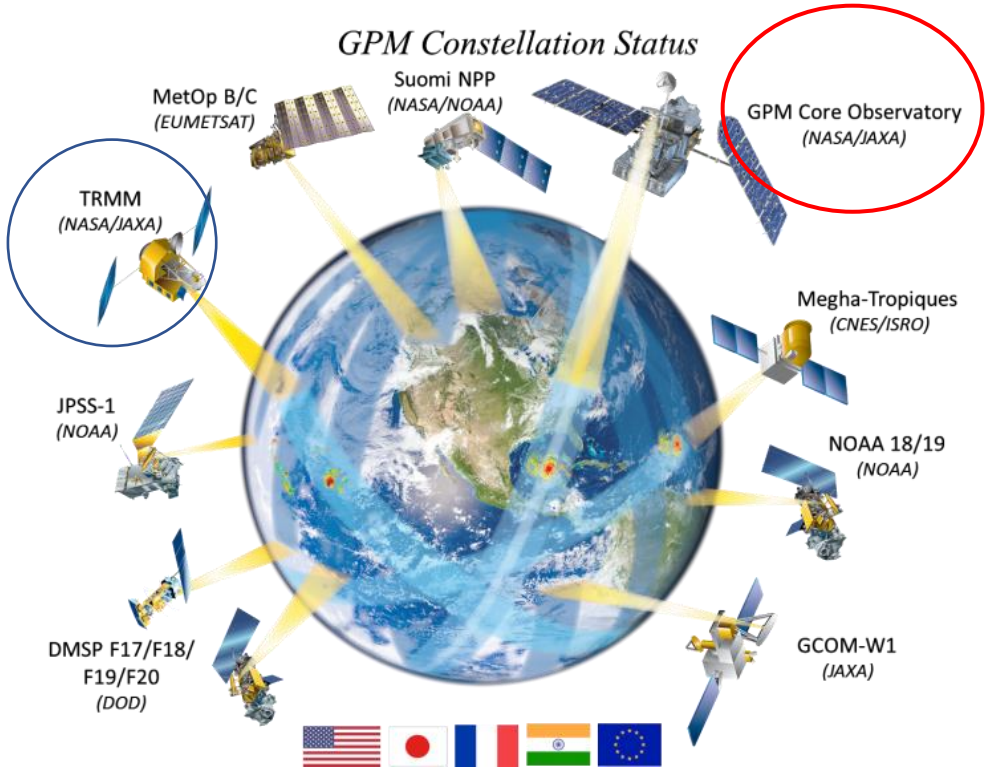
Kummerow, C., et. al, 1998: The tropical rainfall measuring mission (TRMM) sensor package, J. Atmos. Oceanic Technol., 15, 809-817.

GPM Overview

https://www.nasa.gov/mission_pages/GPM/overview/index.html

- Just as TRMM, GPM also is a NASA and JAXA Joint Mission
- Designed as an international satellite mission to provide improved observations of **rain and snow worldwide every three hours**
- Significant contribution to
  - understanding of Earth's water and energy cycles
  - forecasting of extreme events
  - advancing societal applications of precipitation data

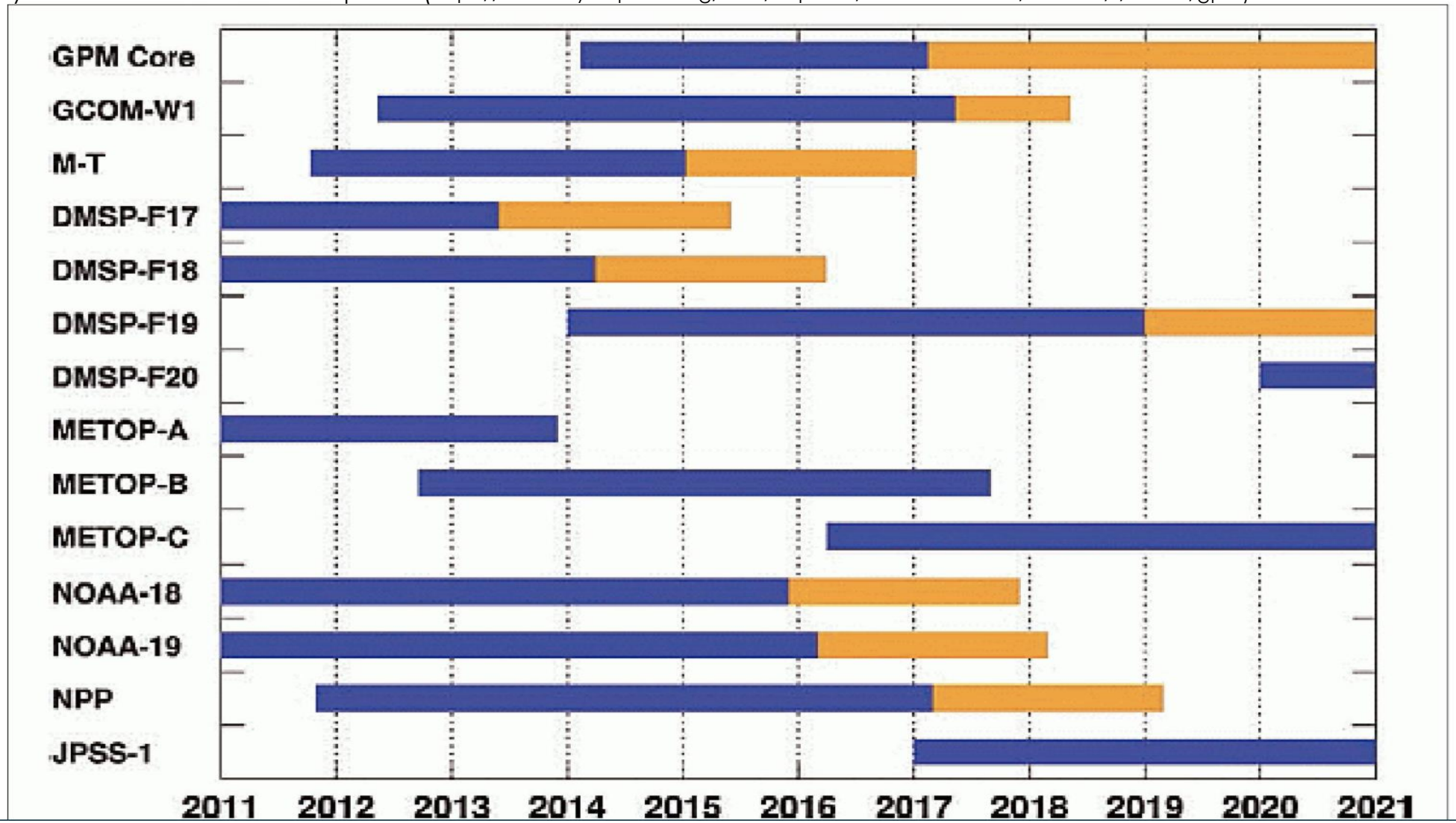
GPM Core Satellite
Launched Feb 27, 2014



GPM Overview

https://www.nasa.gov/mission_pages/GPM/overview/index.html

Estimated launch schedules and life spans of GPM constellation satellites, with blue denoting the primary mission phase and yellow the extended mission phase (https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/gpm)

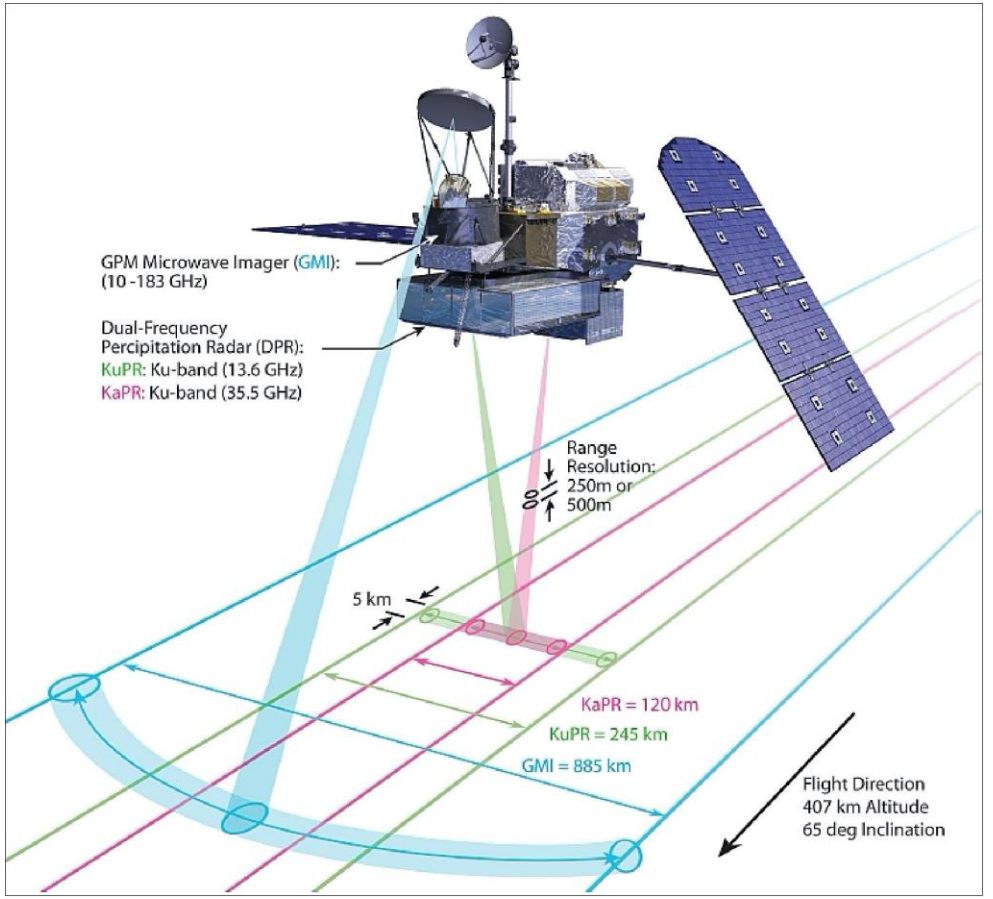


GPM Sensors

https://directory.eoportal.org/web/eoportal/satellite-missions/content/-/article/gpm

- DPR: Dual Precipitation Radar
  - more sensitive to light rain and snow compared to the PR
  - Because of Ka and Ku bands, provides additional information about particle drop size distribution

- GMI: GPM Microwave Imager
  - optimized frequencies to obtain light, moderate, and heavy precipitation



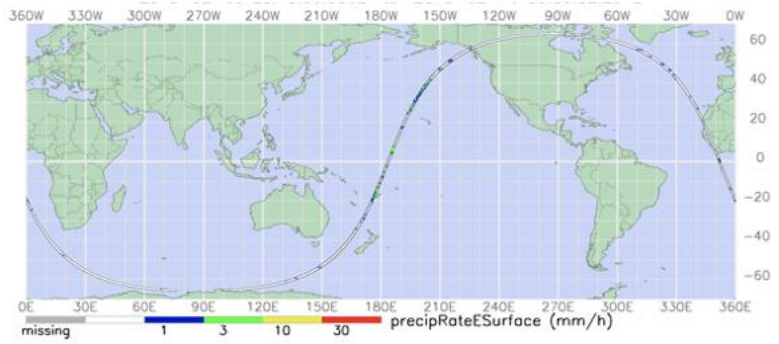
Dual Precipitation Radar

https://gpm.nasa.gov/missions/GPM/DPR

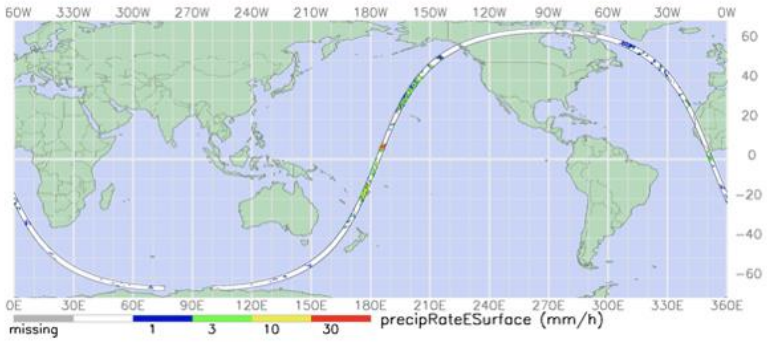
	KuPR	KaPR
Swath Width	245 kilometers (km)	245 kilometers (km) as of May 2018 (previously 120km)
Range Resolution	250 meters (m)	250/500 meters (m)
Spatial Resolution	5 km (Nadir)	5 km (Nadir)
Beam Width	0.71 degrees	0.71 degrees

DPR Swaths

Ka 35.5 GHZ



Ku 13.6 GHZ



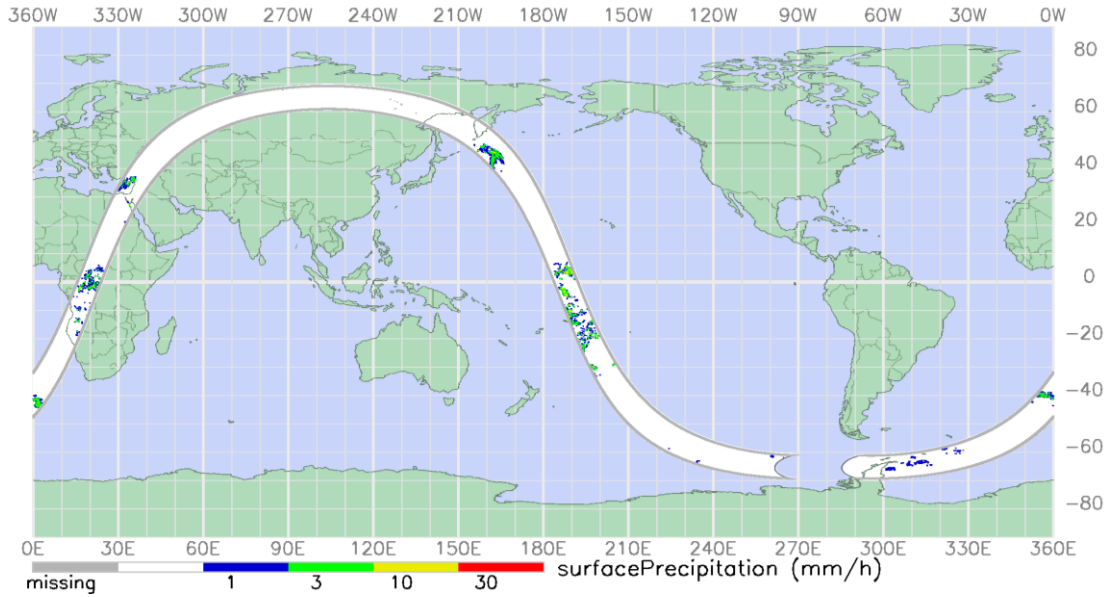
GPM Microwave Imager

https://gpm.nasa.gov/missions/GPM/GMI

Band [GHz]	Polarization	Spatial Resolution (3-dB footprint size) [km x km]
10.65	V,H	32 x 19
18.7	V,H	18 x 11
23.8	V	16 x 10
36.5	V,H	15 x 9
89.0	V,H	7 x 4
165.5	V,H	6 x 4
183.31+/-3	V	6 x 4
183.31+/-7	V	6 x 4

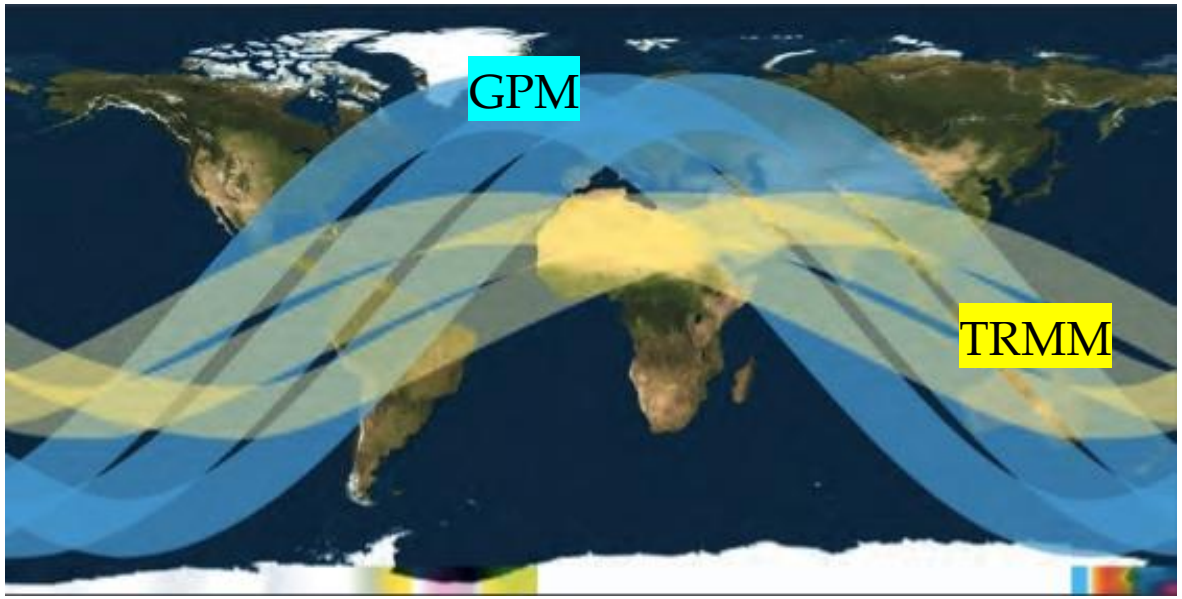
https://www.remss.com/missions/gmi/

GMI Swath: 885 km



TRMM and GPM

https://gpm.nasa.gov/missions/GPM/GMI



TRMM measurements are limited to tropics; GPM measurements span middle and high latitudes

- GMI and DPR provide improved reference standard for inter-calibration of constellation precipitation measurements compared to TMI/PR
- Better accuracy of measurements for GMI & DPR
- GMI has higher spatial resolution than TMI
- Improved light rain and snow detection in GPM (<0.5mm/hr)
- DPR has better identification of liquid, ice, mixed—phase precipitation particles

TRMM and GPM Data Products

https://gpm.nasa.gov/data/directory

Level 3 | Level 2 | Level 1 | Related Datasets

Level 1A: Reconstructed, unprocessed instrument data at full resolution, time referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (i.e., platform ephemeris), computed and appended, but not applied, to Level 0 data.

Level 1B: Radiometrically corrected and geolocated Level 1A data that have been processed to sensor units..

Level 1C: Common intercalibrated brightness temperature (Tc) products using the GPM Microwave Imager (GMI) Level 1B as the reference standard.

1C
- Calibrated brightness temperature for GPM GMI, TRMM TMI, and constellation microwave radiometers

1B
- Brightness temperatures for GPM GMI, and TRMM TMI, PR and VIRS

1A
- Reconstructed, unprocessed instrument data at full resolution for GPM GMI and TRMM TMI

Level 3 | Level 2 | Level 1 | Related Datasets

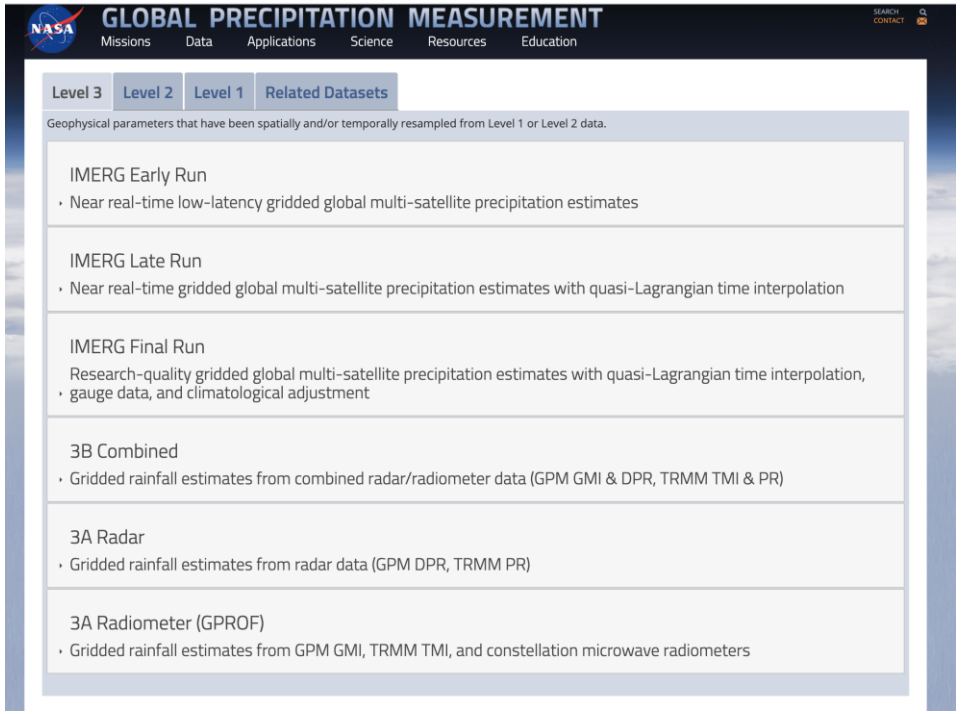
Derived geophysical parameters at the same resolution and location as those of the Level 1 data.

As of the GPM Version 6 reprocessing cycle, the radars on both the TRMM and GPM satellites have their data products written in the HDF5 file format. Also as of Version 6 the research products are stored in the same FTP archive for both satellites, ftp://pps.gsfc.nasa.gov/. The FTP archive is organized into directories whose names are "yyyy/mm/dd/radar/" where yyyy, mm, and dd are the four-digit year and the two-digit month and day of month, respectively. In prior reprocessing cycles, TRMM and GPM data products were stored in different FTP archives. As of May 2020, PPS distributes near-realtime GPM data via FTPS and HTTPS rather than FTP. A similar switch is expected to occur with research data products later in 2020.

2B Combined
- Single-orbit rainfall estimates from combined radar/radiometer data (GPM GMI & DPR, TRMM TMI & PR)

2A Radar
- Single-orbit radar rainfall estimates for GPM DPR, Ka, Ku and TRMM PR

2A Radiometer (GPROF & PRPS)
- Single-orbit radiometer rainfall estimates from GPM GMI, TRMM TMI, and constellation microwave radiometers



TRMM and GPM Data Products

https://gpm.nasa.gov/science/precipitation-algorithms

Precipitation Algorithms:

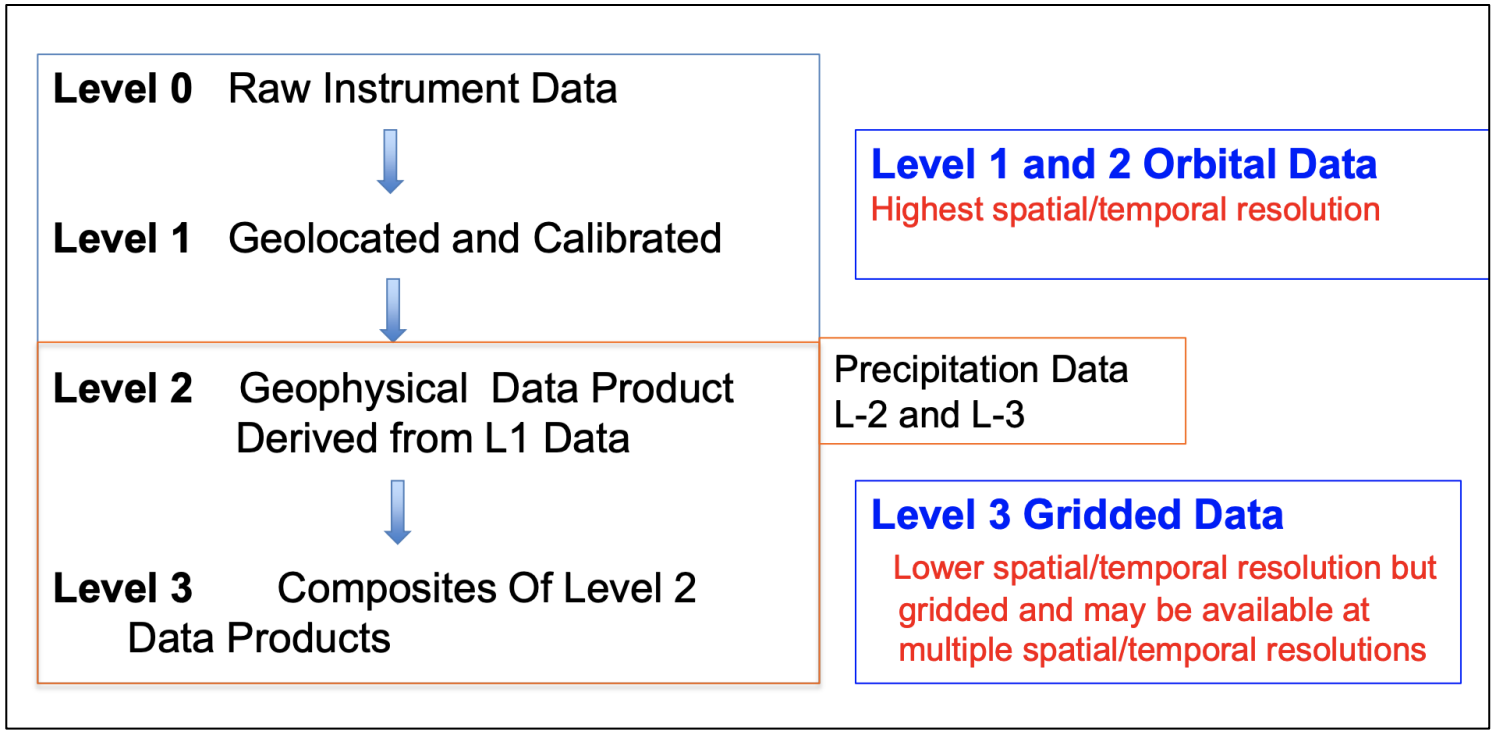
[Radar Algorithms]

[Radiometer Algorithms]

[Combined Algorithms]

[Multi-Satellite Algorithms]

Data Product Levels



https://gpm.nasa.gov/sites/default/files/imce/GPM_Apps_Webinar1_2015-12-08.pdf

TRMM and GPM Multi-satellite Products

https://gpm.nasa.gov/science/precipitation-algorithms#multi-satellitealgorithms

- TRMM and GPM Core satellites are used to calibrate microwave observations from a constellation of national and international satellites
- These multi-satellite algorithms allow improved spatial and temporal coverage of precipitation data
- TRMM Multi-satellite Precipitation Analysis (**TMPA**) and Integrated Multi-satellitE Retrievals for GPM (**IMERG**)have been widely use for research and applications
- Current **IMERG Version 6** combines multi-satellite products from TRMM and an extended precipitation time series (20+ years) is now available at 0.1x0.1 degree spatial resolution and 30 minute temporal resolution

Future Mission: Aerosol and Cloud, Convection Precipitation (ACCP)

https://science.nasa.gov/earth-science/decadal-accp

- The National Academies of Sciences, Engineering and Medicine (NASEM) 2017 Decadal Survey *Thriving on Our Changing Planet: A Decadal Strategy for Earth Observation from Space highlighted Earth System Science themes, science and application questions
- Several high priority objectives led to the inclusion of ACCP mission in the Decadal Survey
- Currently in the system design phase
- Plans to launch in 2028

*https://www.nationalacademies.org/our-work-decadal-survey-for-earth-science-and-applications-from-space

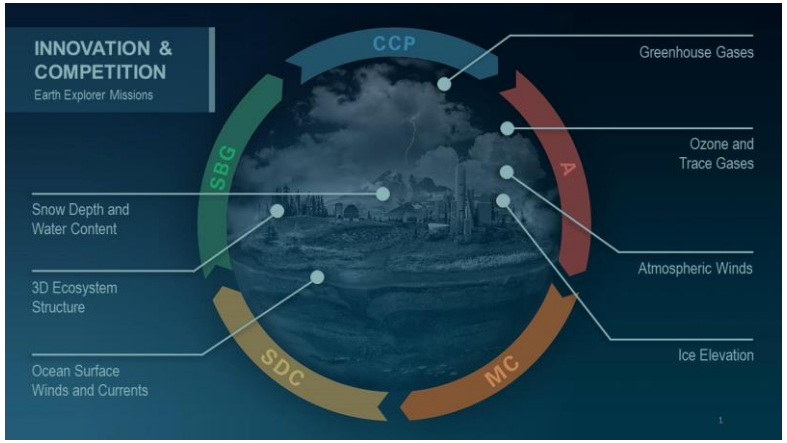
ACCP: A Part of NASA Earth Observatory

https://science.nasa.gov/earth-science/earth-system-observatory

NASA will design a new set of Earth-focused missions to provide information to guide efforts related to **climate change, natural hazard mitigation, fighting forest fires, and improving real-time agricultural processes**

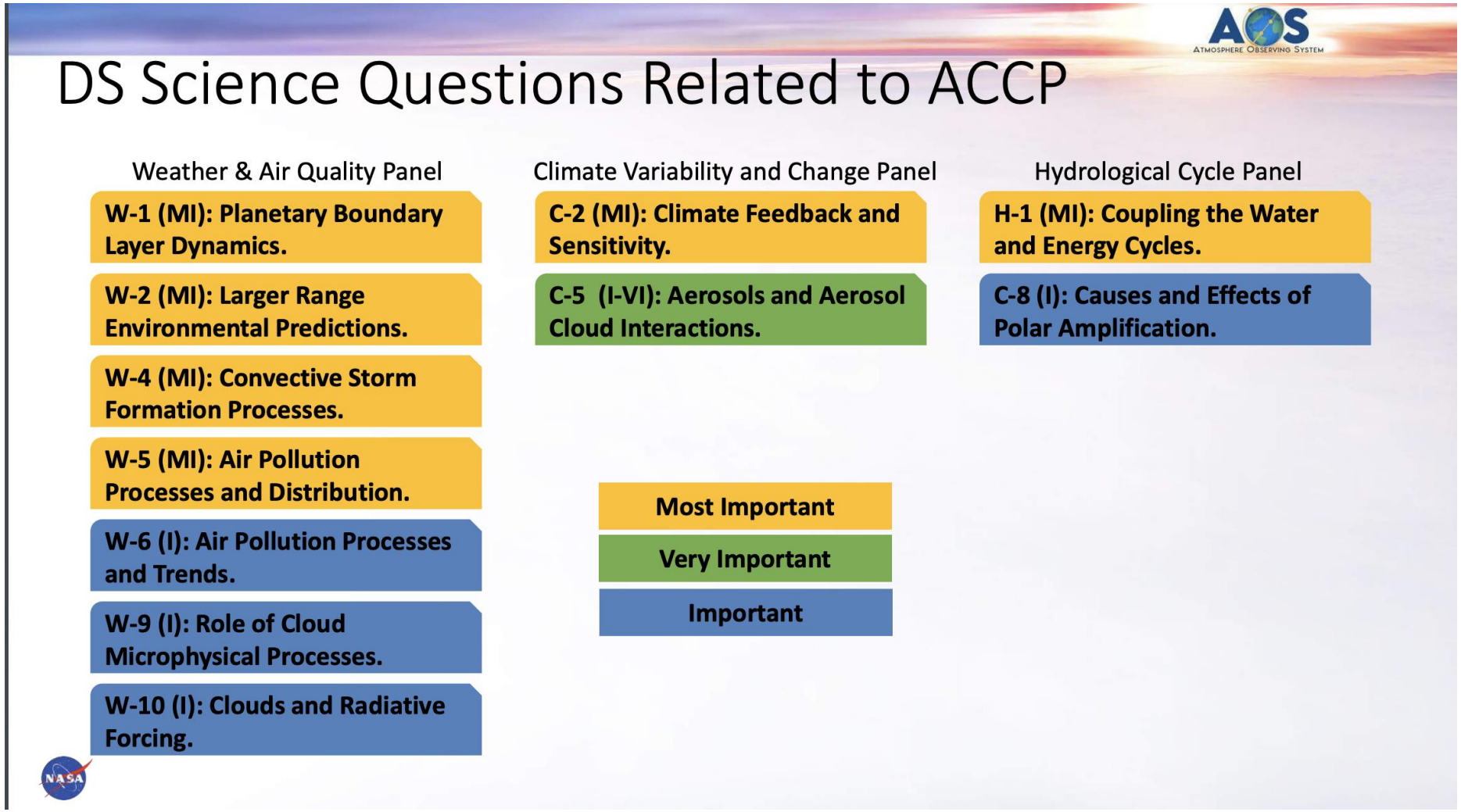
Areas of focus for Earth system observatory include:

- Aerosols
- Cloud, Convection, and Precipitation
- Mass Change
- Surface Biology and Geology
- Surface Deformation and Change



ACCP: Science Questions

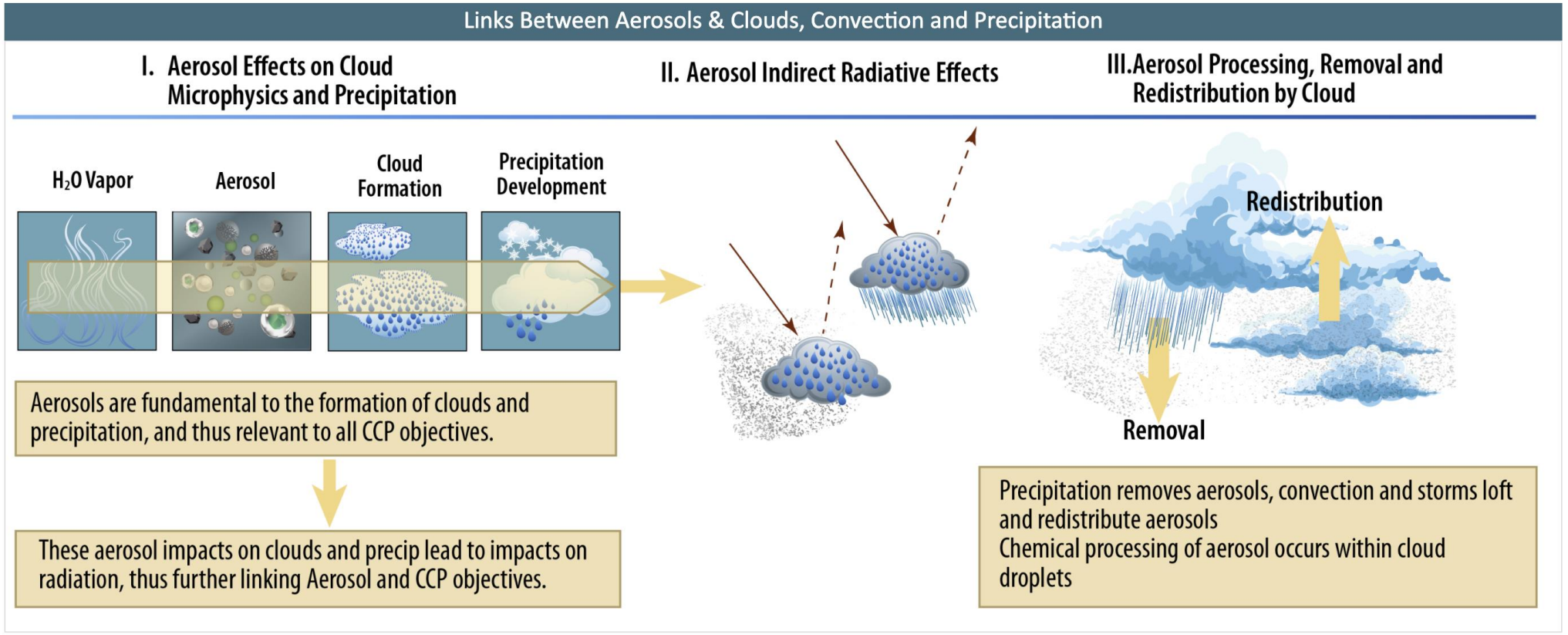
https://vac.gsfc.nasa.gov/accp/docs/ESO_AOS_Community_Forum_072921.pdf



ACCP: Science Objective

https://vac.gsfc.nasa.gov/accp/science.htm

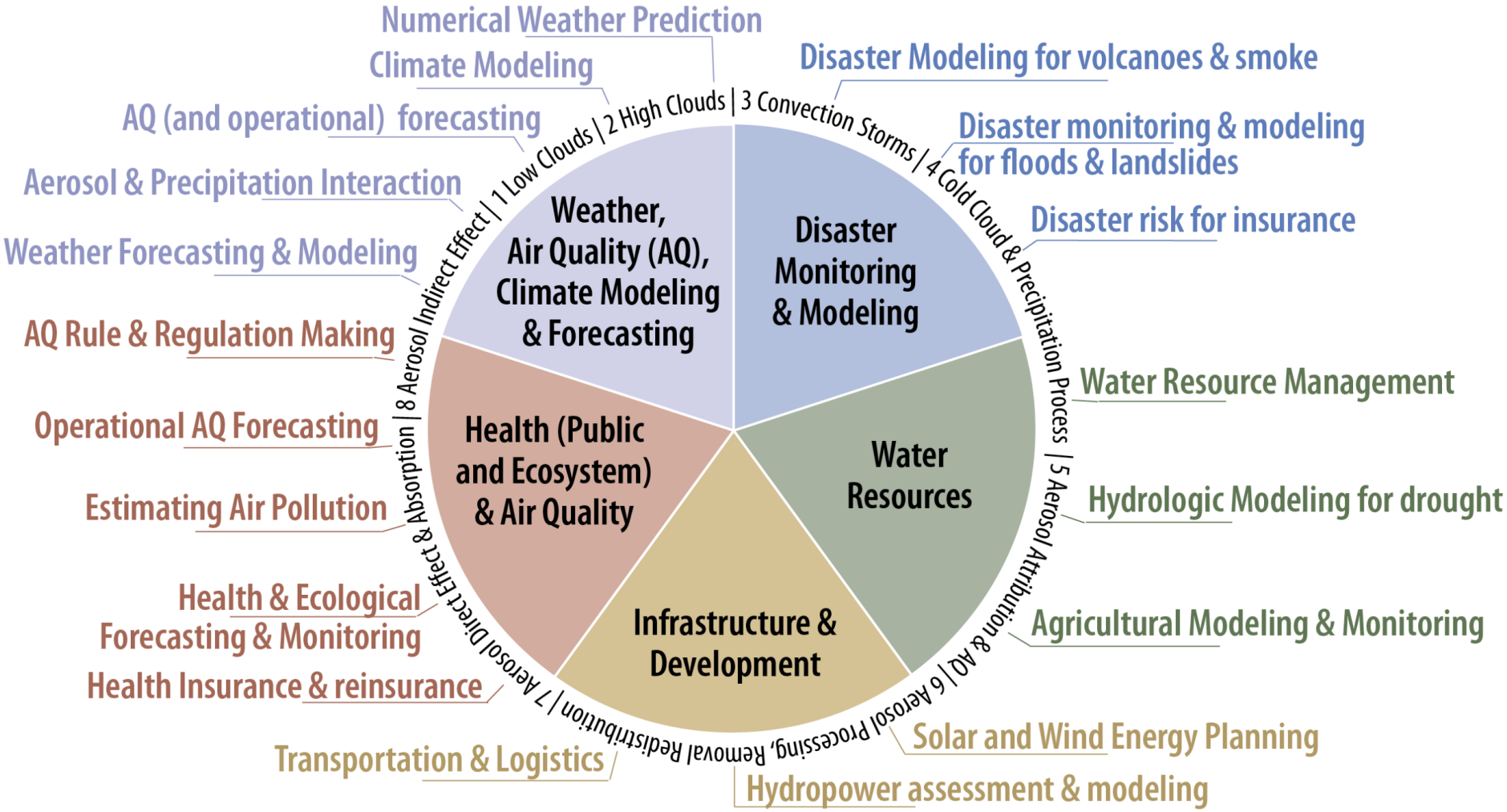
- ACCP will explore cloud feedbacks, storm dynamics, cold cloud and precipitation processes, and aerosol processes



ACCP: Application

https://vac.gsfc.nasa.gov/accp/applications.htm

ACCP Products will be used to benefit society in Five Thematic Areas

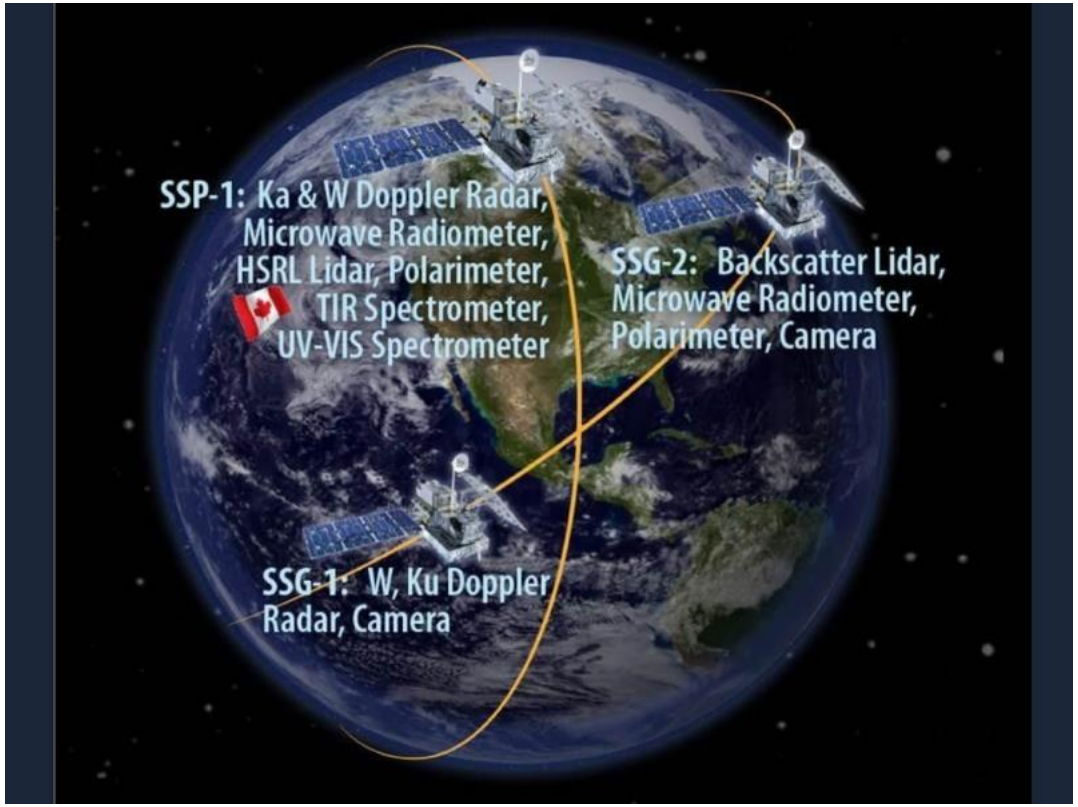


ACCP: Architecture

https://vac.gsfc.nasa.gov/accp/arch.htm?

- International partnership with Canada, France, Germany, and Japan

- Three satellite constellation
  SSP-1, SSG-1, SSG-2
  SSP-1: Space Segment Polar
  98° inclination (i.e., polar) orbit
  Sun synchronous
  1:30 AM/PM equatorial crossing
  SSG (-1 and -2): Space Segment GPM
  65° inclined orbit, similar to GPM



ACCP: Instruments

https://vac.gsfc.nasa.gov/accp/arch.htm?

Radar, Lidar, Radiometer, polarimeter

Instrument	Size	Description
SSP-1		
Ka + W Doppler Radar	Medium satellite radar	W band Doppler, Ka band Doppler, 15km swath
Microwave Radiometer	Small satellite radiometer	118, 183, 240, 310, 380, 660, 880 GHz
HSRL Lidar	Medium satellite lidar	532nm HSRL, 1064nm backscatter
Polarimeter	Small-medium satellite polarimeter	550km swath, 0.5km resolution
TIR Spectrometer	Small satellite spectrometer	Long wave infrared
UV-VIS Spectrometer	Small satellite spectrometer	Short wave infrared
SSG-1		
W, KU Doppler Radar	Small satellite radar	W band Doppler, Ku band Doppler
Camera	Small satellite camera	Stereo camera visible imaging
SSG-2		
Backscatter Lidar	Small satellite lidar	532nm, 1064nm backscatter
Microwave Radiometer	Small satellite radiometer	118, 183, 240, 310, 380, 660, 880 GHz
Polarimeter	Small satellite polarimeter	1130km swath, 1km resolution
Camera	Small satellite camera	Stereo camera visible imaging

ACCP: Benefits

https://vac.gsfc.nasa.gov/accp/arch.htm?

In addition to the science research and applications benefits, ACCP will be

- the first-ever global measurements from space to show how ice and water move vertically within clouds, influence of natural and human-made aerosols [vertical motion, rain and snow in storms, weather and air quality]
- the first-ever global measurements that directly link clouds' physical properties to how they transfer heat [radiation budget, climate feedback]
- an International collaboration

Next : IMERG Version 6

Dr. Georg Huffman