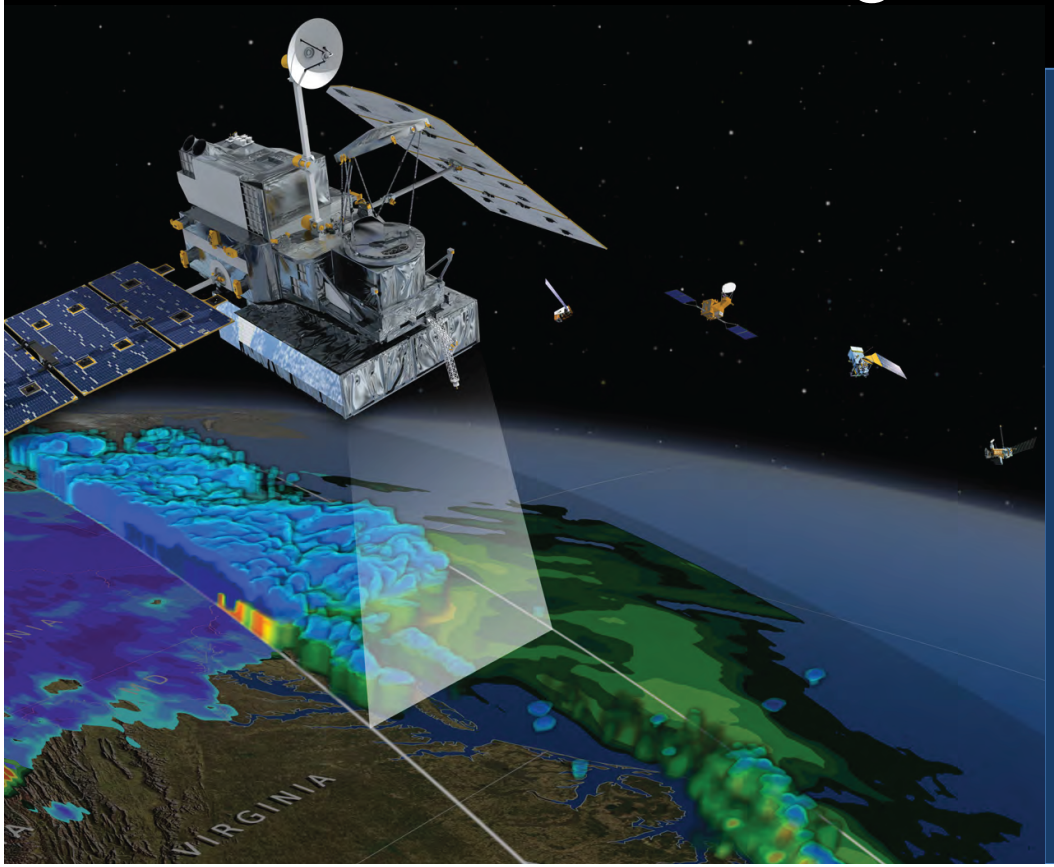
NASA HQ PMM Welcome and Program Status



Gail Skofronick-Jackson
PMM Program Scientist
NASA Headquarters
Gail.S.Jackson@nasa.gov

PMM Science Team Meeting
November 4-8, 2018
Indianapolis, IN


NASA EARTH FLEET
OPERATING & FUTURE THROUGH 2023
LANDSAT-9
NISAR
TROPICS (6)
SENTINEL-6A/B
SWOT
MAIA
PACE
TEMPO
ICESAT-2
GRACE-FO (2)
CYGNSS (8)
NISTAR, EPIC (DSCOVR/NOAA)
SORCE
CLOUDSAT
TERRA
AQUA
AURA
CALIPSO
GPM
LANDSAT 7 (USGS)
LANDSAT 8 (USGS)
OCO-2
SMAP
SUOMI NPP (NOAA)
TSIS-2
PREFIRE (2)
GEOCARB
GLIMR
ISS INSTRUMENTS
EMIT
CLARREO-PF
GEDI
SAGE III
OCO-3
TSIS-1
ECOSTRESS
LIS
JPSS-2, 3 & 4 INSTRUMENTS
OMPS-Limb
INVEST/CUBESATS
RAVAN
RainCube
CSIM
CubeRRT
TEMPEST-D
CIRiS
HARP
CTIM
HyTI
SNoOPI
NACHOS
(PRE) FORMULATION
IMPLEMENTATON
PRIMARY OPS
EXTENDED OPS
10.04.19


NASA EARTH FLEET
OPERATING & FUTURE THROUGH 2023
Related to Precipitation
LANDSAT-9
NISAR
TROPICS (6)
SENTINEL-6A/B
SWOT
MAIA
PACE
TEMPO
ICESAT-2
GRACE-FO (2)
CYGNSS (8)
NISTAR, EPIC (DSCOVR/NOAA)
SORCE
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AQUA
AURA
CALIPSO
GPM
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SMAP
SUOMI NPP (NOAA)
TSIS-2
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GEOCARB
GLIMR
ISS INSTRUMENTS
EMIT
CLARREO-PF
GEDI
SAGE III
OCO-3
TSIS-1
ECOSTRESS
LIS
JPSS-2, 3 & 4 INSTRUMENTS
OMPS-Limb
INVEST/CUBESATS
RAVAN
RainCube
CSIM
CubeRRT
TEMPEST-D
CIRiS
HARP
CTIM
HyTI
SNoOPI
NACHOS
(PRE) FORMULATION
IMPLEMENTATON
PRIMARY OPS
EXTENDED OPS
10.04.19

NASA Earth Science Decadal Survey Report; Released 5 Jan 2018

(https://www.nap.edu/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth)

Recommended NASA Flight Program Elements (NASA HQ can adjust)

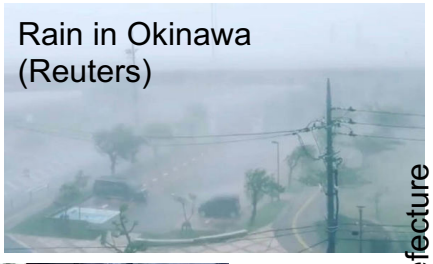
- ***Designated.*** A new program element for ESAS-designated cost-capped medium- and large-size missions to address ***observables essential to the overall program*** and that are outside the scope of other opportunities in many cases. Can be competed, at NASA discretion.
- ***Earth System Explorer.*** A new program element involving competitive opportunities for medium-size instruments and missions serving specified ESAS-priority observations. ***Promotes competition among priorities.***
- ***Incubation.*** A new program element, focused on investment for priority observation opportunities needing advancement prior to cost-effective implementation, including an Innovation Fund to respond to emerging needs. ***Investment in innovation for the future.***
- ***Venture.*** Earth Venture program element, as recommended in ESAS 2007 with the addition of a new Venture-Continuity component to provide ***opportunity for low-cost sustained observations.***

Aerosols;
Clouds, Convection, and Precipitation;
Mass Change; (See Scott's talk)
Surface Biology and Geology;
Surface Deformation and Change

3 of 7 to be selected
Greenhouse gases; Ice elevation; Ocean Surface winds and currents; Ozone and trace gases; Snow depth and snow water equivalent; Terrestrial ecosystem structure; Atmospheric winds

Planetary boundary layer;
Surface topography and vegetation

Typhoon Trami (2018): The Storm and Forecasts



Tropical disturbance observed in Micronesia

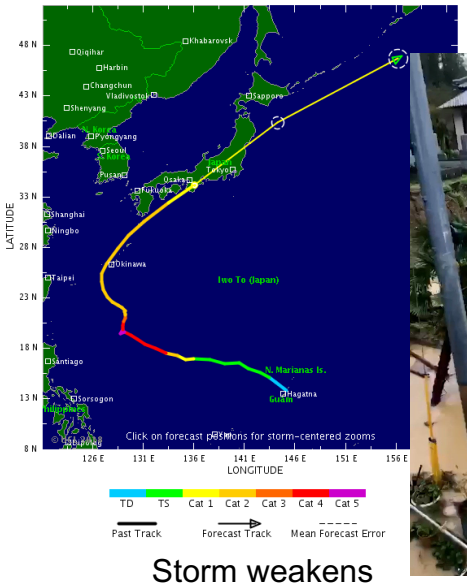
Tropical depression

Tropical Storm status and named Trami

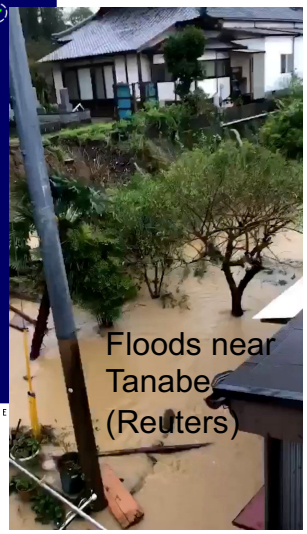
Trami intensified to a Severe Tropical Storm then a Category 1 typhoon

Trami became a Category 3-equivalent typhoon while undergoing an eyewall replacement

Attained Category 4, then Category 5, super typhoon status once it finished its eyewall replacement cycle.



Storm weakens

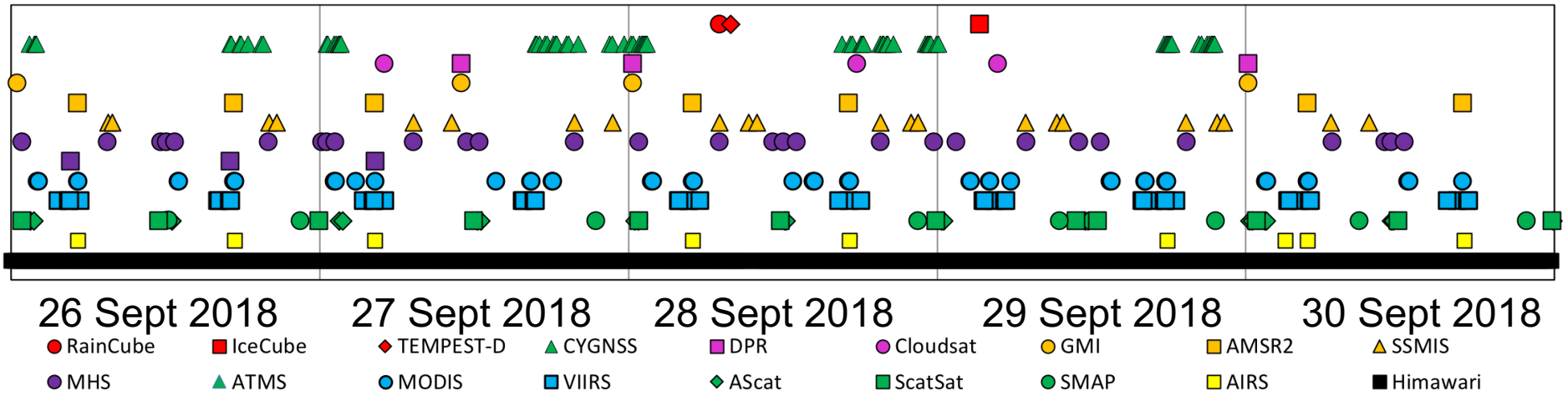


Trami passes Okinawa, Japan

Landfall over Tanabe, Wakayama Prefecture

9/19 9/20 9/21 9/22 9/23 9/24 9/25 9/26 9/27 9/28 9/29 9/30

Typhoon Trami: The Satellite Observations Timeline



Cubesats; Smallsats+ (Winds); Radar (cloud & rain profiling); radiometers (precipitation); sounders (precipitation, T&RH profiles); Vis/IR (T, clouds, etc.); Hyperspectral (atmospheric profiles); geostationary (Vis/IR)

In 5 days:
Observations from 24 satellites
Observations from 39 sensors
Total of 773 observations

NASA Headquarters' Investments in Precipitation – R&A

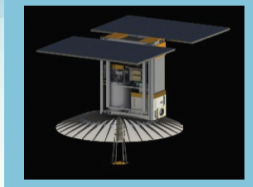
- 2019: Sea Level Change Team (closes Feb 14, 2020, $2.5M/yr for 4 years)
- 2019: Terrestrial Hydrology (closes Nov 14, 2019, $4.75M over 3 years)
- 2019: Ocean Salinity Science Team (closed Aug 29, 2019, $6M over 3 years)
- 2019: Soil Moisture Active-Passive Mission Science Team (closed July 11, 2019, $4.5M over 3 years)
- 2019: Understanding Changes in High Mountain Asia (closed June 12, 2019, $3M over 3 years)
- **2018: NASA Energy and Water Cycle Study (2 of 13, $1.3M over 3 years)**
- **2018: Precipitation Measurement Missions Science Team (40 of 130, $15.5M over 3 years)**
- **2018: Earth Science Applications: Water Resources (13 of 46, $9M over 3 years)**
- 2019: Interdisciplinary Science – interactions between sea ice and the atmosphere; polar ocean/biology/biogeochemical coupling; *lifecycle of snow* (closes Nov 15, 2019, $11.5M over 3 years)
- 2019: Advanced Instrument Technology Transition (closes Oct 24, 2019, $4.4M over 2 years)
- 2019: Weather and Atmospheric Dynamics (closed Sept 16, 2019, $3.1M Yr 1; 2.5M Yrs 2 and 3)
- **2019: Planetary Boundary Layer Incubation Study Team (closed August 1, 2019, 14 of 44, $1.5M over 1 year)**
- 2019: Modeling Analysis and Prediction (closed July 2, 2019, $3M over 4 years)
- **2019: Future Investigators in NASA Earth and Space Science and Technology (closed Mar 11, 2019, up to $135K over 36 months)** 2020 just released this week

For more information, visit:
https://nspires.nasaprs.com

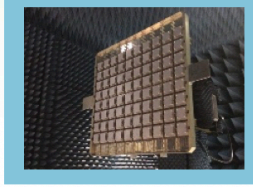
GLOBAL PRECIPITATION MEASUREMENT

Earth Science Technology Program Elements

Advanced Technology Initiatives (ATI)



In-Space Validation of Earth Science Technologies (InVEST)
on-orbit technology validation and risk reduction for small instruments and instrument systems that could not otherwise be fully tested on the ground or airborne systems
(average award: $1-1.8M per year over three years)



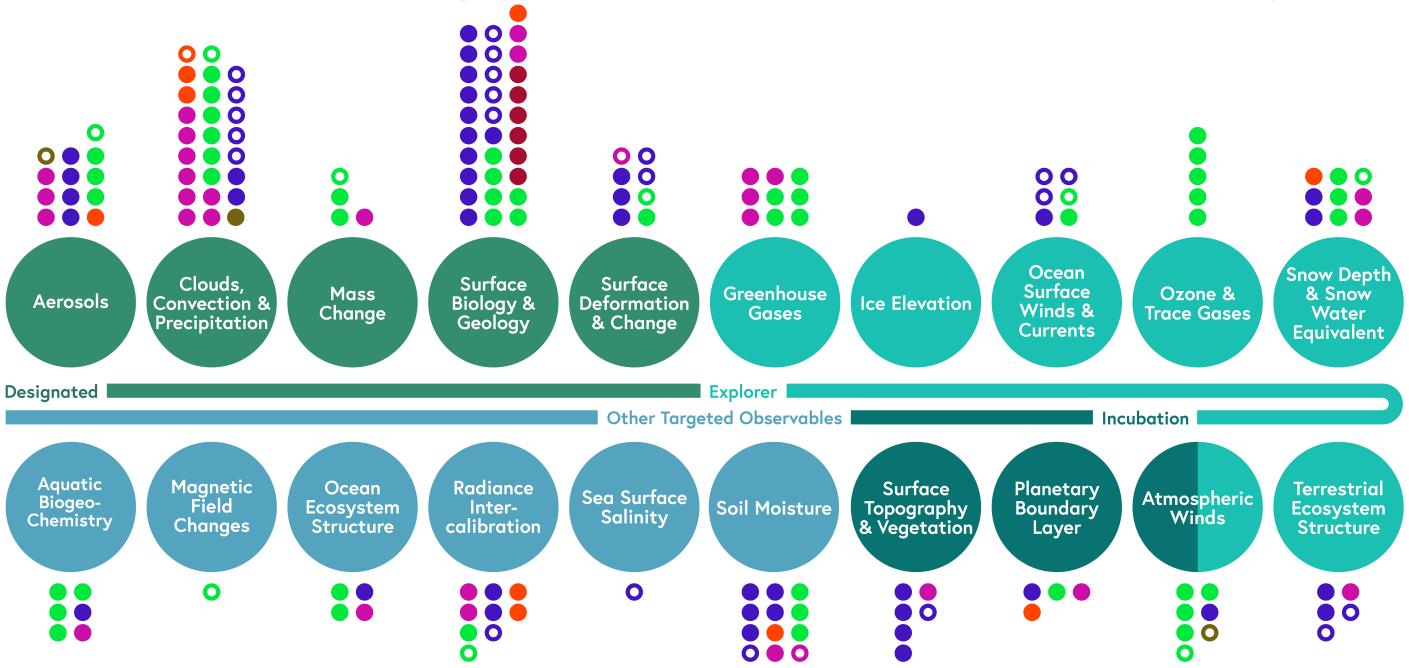
Advanced Component Technologies (ACT)
critical components and subsystems for advanced instruments and observing systems
(average award: $400K/$600K per year over two/three years)

Instrument Incubator Program (IIP)
innovative remote sensing instrument development from concept through breadboard and demonstration
(average award: $1.5M per year over three years and $750K for 18 months for instrument concepts)

Advanced Information Systems Technology (AIST)
innovative on-orbit and ground capabilities for communication, processing, and management of remotely sensed data and the efficient generation of data products
(average award: $600K per year over two years)

ESTO manages, on average, 120 active technology development projects. Most are funded through the primary program lines below. Nearly 800 projects have completed since 1998. **~$100M over the last 6 years for Clouds and Precipitation addressed in 2017 Decadal Survey**

Technologies for New Observations Responding to the 2017 Decadal Survey



- Advanced Component Technologies
- Advanced Information Systems Technology
- Instrument Incubator Program
- In-Space Validation of Earth Science Technologies
- Sustainable Land Imaging - Technology
- Earth Venture Technologies

● Solid circle indicates active project

o Ring shape indicates recently completed project

Upon publication of the 2017 Earth Science Decadal Survey in January 2018, active and recent ESTO investments **already supported all of the recommended targeted observables:**

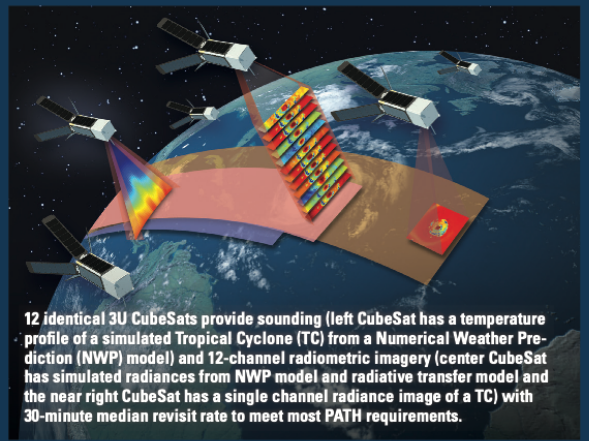
Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats

Science Team

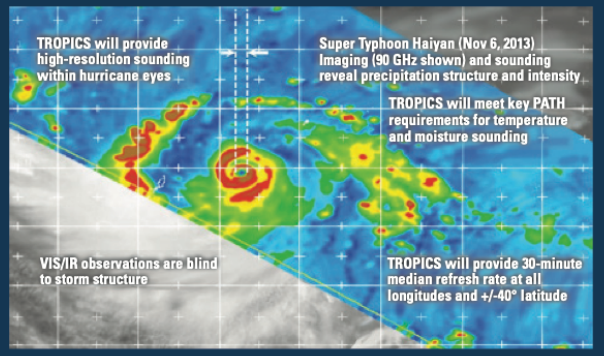
William Blackwell, PI	MIT Lincoln Laboratory
Scott Braun, PS	NASA GSFC
Robert Atlas, Co-I	NOAA AOML
Ralf Bennartz, Co-I	University of Wisconsin
Mark DeMaria, Co-I	NOAA NHC
Jason Dunion, Co-I	University of Miami
Ron Errico, Co-I	NASA GSFC/GMAO
Vince Leslie, Co-I	MIT Lincoln Laboratory
Frank Marks, Co-I	NOAA AOML
Robert Rogers, Co-I	NOAA AOML
Chris Velden, Co-I	University of Wisconsin

Science Objectives

- Relate precipitation structure evolution, including diurnal cycle, to the evolution of the upper-level warm core and associated intensity changes
- Relate the occurrence of intense precipitation cores (convective bursts) to storm intensity evolution
- Relate retrieved environmental moisture measurements to coincident measures of storm structure (including size) and intensity
- Assimilate microwave radiances and/or retrievals in mesoscale and global numerical weather prediction models to assess impacts on storm track and intensity



12 identical 3U CubeSats provide sounding (left CubeSat has a temperature profile of a simulated Tropical Cyclone (TC) from a Numerical Weather Prediction (NWP) model) and 12-channel radiometric imagery (center CubeSat has simulated radiances from NWP model and radiative transfer model and the near right CubeSat has a single channel radiance image of a TC) with 30-minute median revisit rate to meet most PATH requirements.

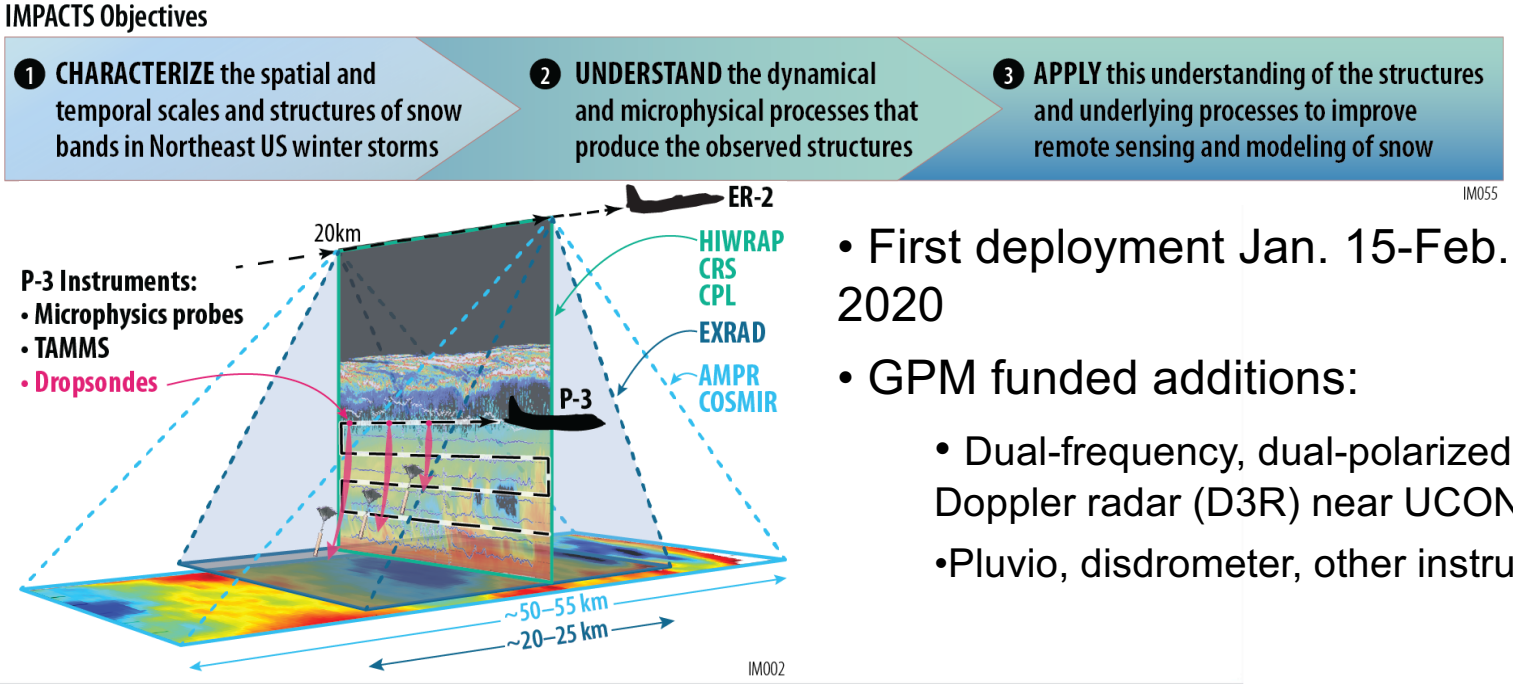


Significance to NASA

- First high-revisit microwave nearly global observations of precipitation, temperature, and humidity
- Fulfills most of PATH Decadal Survey mission objectives using a low-cost, easy-to-launch CubeSat constellation
- Complements GPM, CYGNSS, and GOES-R missions with high refresh, near-all-weather measurements of precipitation and thermodynamic structure
- Increases understanding of critical processes driving significant and rapid changes in storm structure/intensity

Investigation of Microphysics and Precipitation for Atlantic Coast-Threatening Snowstorms (IMPACTS)

– PI Lynn McMurdie, University of Washington, deputy PIs G. Heymsfield (GSFC), J. Yorks, and S. Braun

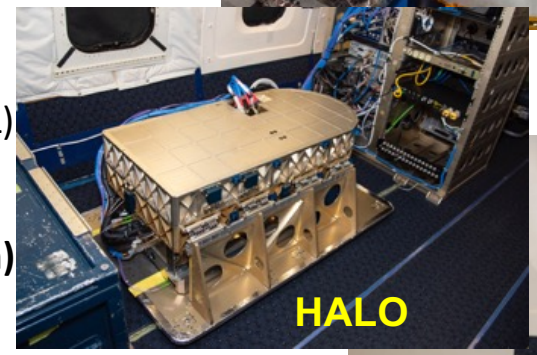


- First deployment Jan. 15-Feb. 29, 2020
- GPM funded additions:
  - Dual-frequency, dual-polarized, Doppler radar (D3R) near UCONN
  - Pluvio, disdrometer, other instruments

Aeolus Cal/Val 2020 – Convective Processes Experiment-Aerosols & Winds (CPEX-AW)

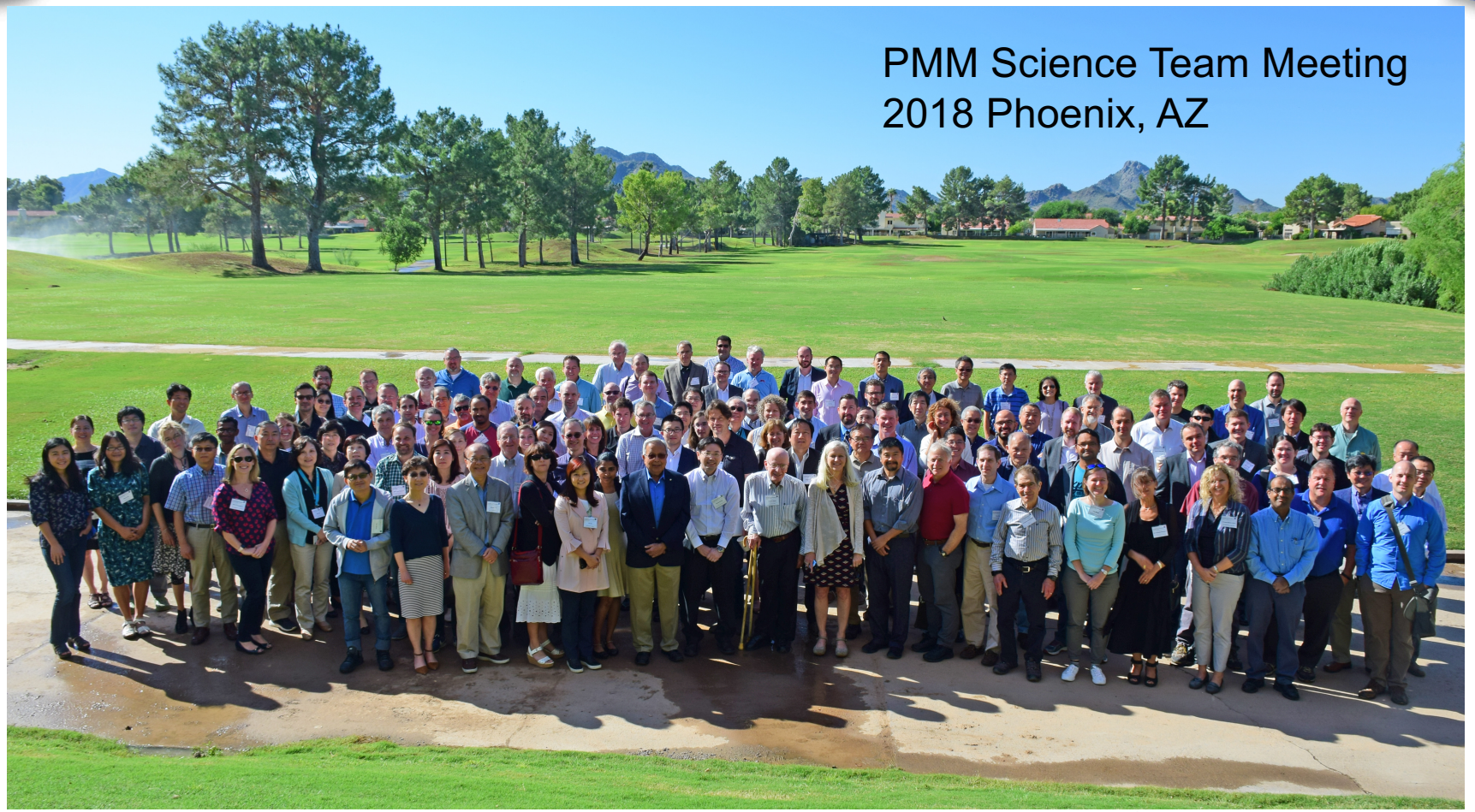
- **DAWN**: (Doppler Aerosol WiNd lidar)** is a pulsed laser, 2-micron, and solid-state. DAWN can provide vertical profiles of u and v components of 3-D wind below the aircraft.
- **HALO****: **(High Altitude Lidar Observatory)** is a multi-function airborne lidar to measure atmospheric H2O mixing ratios and aerosol/cloud/ocean optical properties using the DIfferential Absorption Lidar (DIAL) and High Spectral Resolution Lidar (HSRL) techniques, respectively.
- **Dropsondes****
- **APR-3: (Airborne Precipitation and Cloud Radar 3rd Generation)** APR-3 provides Doppler radar measurements of clouds and precipitation at 3 frequencies (Ku-, Ka- and W-band)
- **Instruments Proposed (and selected) in ROSES 2019:** Weather and Atmospheric Dynamics (closes Sept 16, 2019); instruments funded by Planetary Boundary Layer activities
- ****Confirmed instrument funding for DC-8 flights for summer 2020, also 100 flight hours for the DC-8 aircraft observations**

Mid-July through mid-August



DC-8 Engine Problems

PMM Science Activities



10th PMM Science Team ROSES Call

- **Proposals Due: 28 June 2018**
- **Total of 130 proposals received**
- **Total Available Funding: ~5.3M/year**
- **Maximum Award Duration: 3 years (2019-2021, FY19-FY21)**
- **Total Number of Awards: 40 Selected + 8 additional PIs as Work Packages through NASA Centers**
  - **Informal notification late December 2018**
  - **US Government furlough resulted in a delay with the official select/decline notifications and for funding of the proposals**

10th PMM Science Team ROSES Call: A.33 Statistics

Type of Institution	# Submitted	# Recommended	Percentage
Universities	86	29	33%
NASA Centers (w/JPL & USRA)	37	11	29%
Other Govt (inc. NCAR)	3	0	0%
Private	4	0	0%
TOTAL:	130	40	31%

NOAA team, selected outside ROSES

Category	# Submitted	#Selected	%inCat	%intotal$Yr1
Applications/Hydrology	22	8	36%	21% (solicitation 30%)
Algorithms	39	17	43%	42% (solicitation 40%)
Science	69	15	22%	37% (solicitation 30%)
TOTAL:	130	40	31%	

Selection	New PIs	%ofselected	Female PIs	%ofselected
	9	22%	12	30%

GLOBAL PRECIPITATION MEASUREMENT

GPM Science Team - Internationals

NASA has **27** no-cost International PI teams; International PI/team Proposals always welcome!

- Argentina (U. Buenos Aires; National University of Córdoba)
- Australia (BOM)
- Austria (U. Graz)
- Belgium (KUL–Antarctica)
- Brazil (INPE)
- Brazil (CPTEC)
- Canada (EC)
- Colombia (U. Nacional de Colombia)
- Cyprus (CMS)
- Finland (FMI, U. Helsinki)
- France (CNRS and partners)
- Germany (U. Bonn)
- HSAF (7 countries, Italy-Leads)
- India (Institute of Tech, Bombay)
- Israel (Hebrew U. Jerusalem)
- Italy (CNR-ISAC)
- Japan
- Netherlands (RNMI)
- South Korea (KMA)
- Spain (UCLM)
- Sweden (Lund University, Chalmers U.)
- Switzerland (EPFL)
- United Kingdom (U. Birmingham)

GPM Management Team

- Program Scientist: Gail Skofronick-Jackson, HQ
- Project Scientist: Scott Braun, GSFC
- Deputy Project Scientists:
  - George Huffman, Science, GSFC
  - Erich Stocker, Data, GSFC/Precipitation Processing System
  - Dalia Kirschbaum, Applications, GSFC
  - Joe Munchak, Ground Validation, GSFC
  - Dave Wolff, Ground Validation Manager, WFF


George


Erich


Dalia


Joe

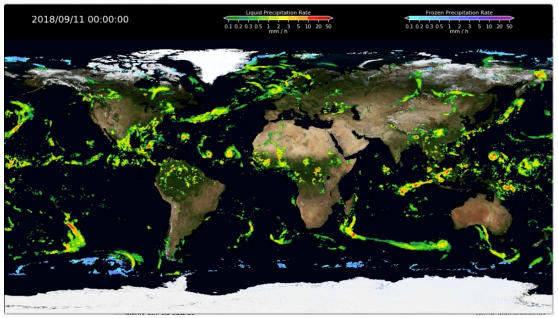

Dave

Share your research & publications

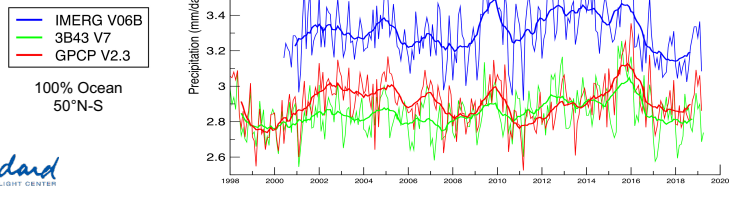
- Send us (Gail/Scott) science highlights and/or paper URL's with a brief summary

Upgraded IMERG Precipitation Data Extended to the TRMM (Year 2000) Era and More Polar Locations

George J. Huffman (Code 612, NASA/GSFC); David T. Bolvin, Eric J. Nelkin (SSAI; Code 612, NASA/GSFC); Jackson Tan (USRA; Code 613, NASA/GSFC)



The Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM) mission (IMERG) precipitation dataset provides precipitation rates for nearly the entire world every 30 minutes, and a long-term time series comparison illustrates how the new Version 06B compares to established datasets.



Name: George J. Huffman, NASA/GSFC, Code 612
E-mail: george.j.huffman@nasa.gov
Phone: 301-614-6308

References: DOI: Early 10.5067/GPM/IMERG/3B-HH-E/06, Late 10.5067/GPM/IMERG/3B-HH-L/06, Final 10.5067/GPM/IMERG/3B-HH/06

Data Sources: The NASA/Japan Aerospace Exploration Agency (JAXA) TRMM and GPM Core Observatory contribute both calibrations of the rest of the constellation (as combined radiometer-radar estimates) and direct microwave precipitation estimates. Passive microwave constellation satellites used during 2000-present include: 1 NASA (JAXA sensor); 1 Centre National d'Études Spatiales/Indian Space Research Organisation; 7 U.S. Department of Defense; 2 European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); 1 JAXA; 7 U.S. National Oceanic and Atmospheric Administration (NOAA). As well, IMERG uses IR data from EUMETSAT, JAXA, and NOAA geosynchronous satellites; global surface gauge analyses from the Global Precipitation Climatology Centre; vertically integrated vapor for feature tracking from the NASA Global Modeling and Assimilation Office; and ancillary analysis/forecast data from European Centre for Medium-range Weather Forecasting, JAXA, and NOAA. Processing is carried out by the NASA Precipitation Processing System (PPS). [Note that all NOAA satellites are built by NASA.] A complete listing is provided in the technical documentation at https://pmm.nasa.gov/sites/default/files/document_files/IMERG_doc_190313.pdf.

Technical Description of Figures:
Upper figure: IMERG provides half-hourly 0.1°x0.1° precipitation estimates that are nearly globally complete, only lacking coverage in polar regions where the surface is snowy/icy. In addition to the calibrated precipitation rate (shown for 00 UTC on 11 September 2018), IMERG contains data fields providing the input datasets, a quality index, and a probability that the precipitation phase is liquid. The last is thresholded at 50% and used to separate the precipitation depiction into rain (bright colors) and snow (blue colors). An animation of the last week of IMERG is available at https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4285, which is updated every hour. This particular figure was chosen because it displays three tropical cyclones in the tropical Atlantic Ocean and two off the east coast of Asia, in addition to the usual Intertropical Convergence Zone (rainfall near the Equator), subtropical highs (rain-free zones at low latitudes), and mid-latitude storm tracks.

Lower figure: The long-term time series for the new Version 06 IMERG Final Run (blue), both as monthly and smoothed time series, is both a key test of its stability and a scientifically interesting product. The current Version 2.3 Global Precipitation Climatology Project Satellite-Gauge (GPCP SG) product (red) and Version 7 TRMM Multi-satellite Precipitation Analysis (TMPA; green) are shown for comparison. The global ocean is chosen for display since all three datasets have a similar surface gauge-dominated performance over land, and the area is limited to the latitudinal extent of the TMPA dataset (50°N-S). Each dataset has a long-term average characteristic of its calibrator, and the higher value for IMERG is considered reasonable based on diagnostics that show the GPCP SG to be 5-8% low. All three datasets show similar interannual peaks and minima, but there are slight, systematic phase shifts that appear to be related to the use or not of satellite radar data in the intercalibration of the various satellites within each product.

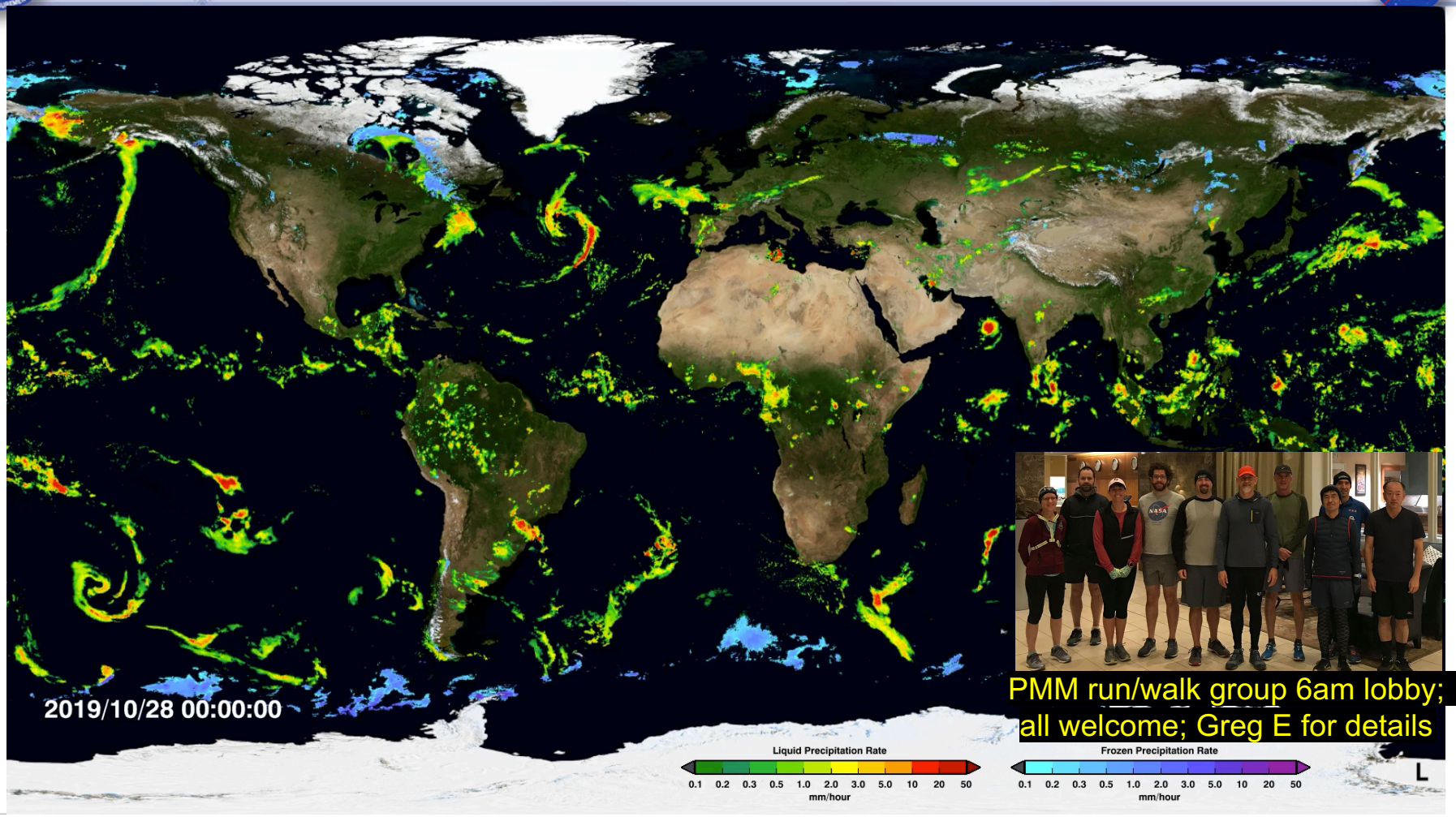
Scientific significance, societal relevance, and relationships to future missions: IMERG is the most-requested GPM dataset; it integrates the entire GPM constellation and generates a relatively fine-scale, long-term record with three different latencies that addresses a wide range of expert and non-expert uses and societal benefit areas. Examples include flood and landslide analysis, drought analysis, agricultural forecasting, climatological statistics (including extreme precipitation case analyses), micro-insurance, water-related disease tracking, wildfire analysis in boreal forests, global water cycle studies, and numerical model validation. IMERG depends critically on high-quality retrievals from individual sensors, so continued progress on improving these retrievals for "difficult" situations is important, particularly the retrieval of solid precipitation, particularly when the surface is snowy/icy. In turn, improved quality in these retrievals will improve the quality of IMERG products and materially affect the research and societal benefit areas listed. The upcoming Aerosols, Clouds, Convection and Precipitation concept, which is being developed out of the Decadal Survey, should provide key process insights for these retrievals and subsequent improvement of IMERG quality for users.

Earth Sciences Division - Atmospheres

Please send accepted GPM related publications (in any journal) to Lisa Nalborczyk for inclusion on the GPM webpage listing https://pmm.nasa.gov/resources/gpm-publications

Questions?

GLOBAL PRECIPITATION MEASUREMENT



PMM run/walk group 6am lobby; all welcome; Greg E for details

NASA Center Work Package Support

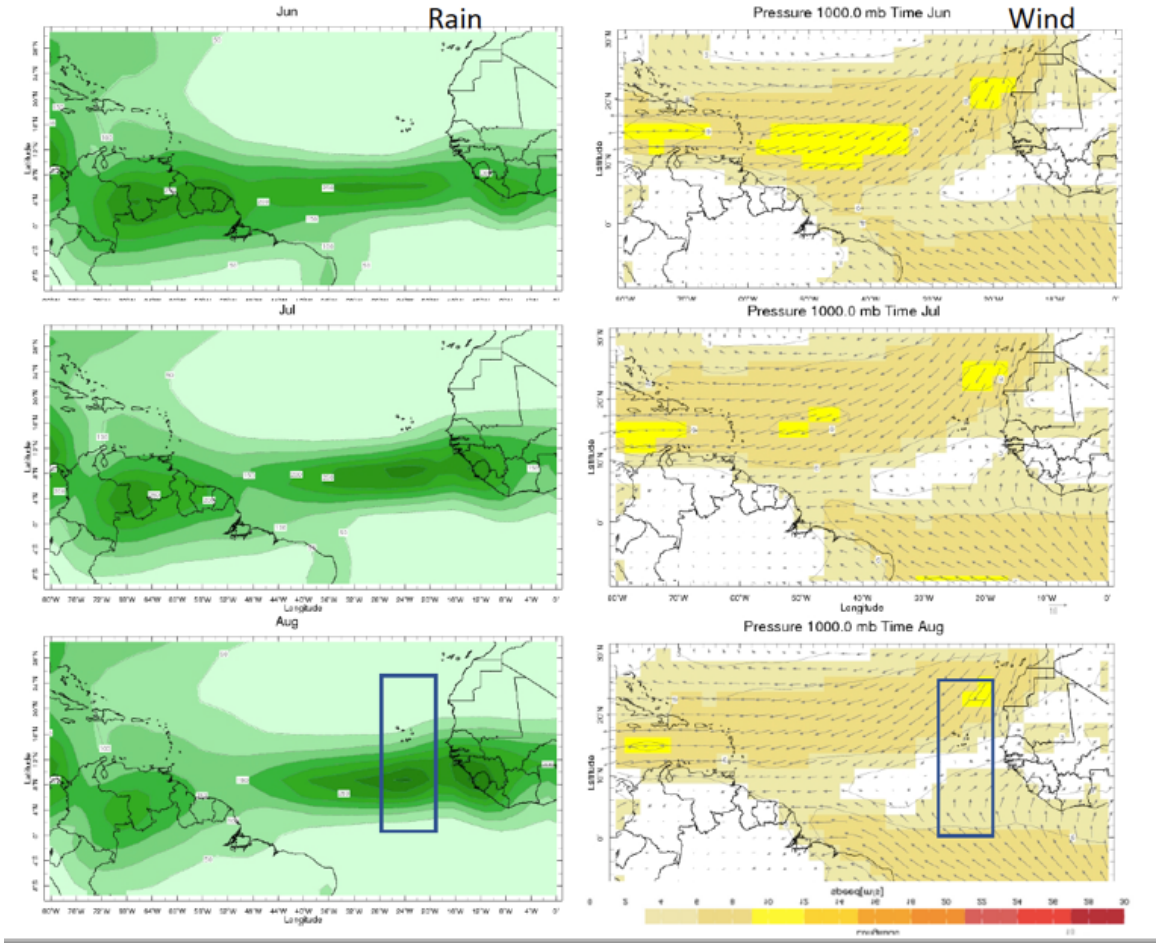
NASA implemented a Work Package Internal Scientist Funding Model (ISFM) at NASA Centers during FY18.

Under ISFM, NASA Center scientists are covered for a portion of their time for FY19, FY20, & FY21.

Cecil, Daniel (MSFC)	Better Understanding GPM Radiometer Measurements Using Ground-Based Radar
Huffman, George (GSFC)	Extending the IMERG Multi-Sensor Level 3 Precipitation Product into Polar Regions
Meneghini, Robert (GSFC)	Path Attenuation Estimates from the Dual-Frequency Precipitation Radar
Munchak, Stephen (GSFC)	Improved Representation of Active and Passive Surface Characteristics in the GPM DPR-GMI Combined Precipitation Algorithm
Olson, William (GSFC/JCET)	Continued Development and Validation of Ice- and Mixed-Phase Precipitation Models for the GPM Combined Radar-Radiometer Algorithm
Petersen, Walter (MSFC)	Validation of GPM Precipitation Retrieval Algorithms across the Precipitation Continuum
Peters-Lidard, Christa (GSFC)	Dynamic Emissivity Estimates to Support Physical Precipitation Retrievals for GPM (continued)
Tao, Wei-Kuo (GSFC)	Advancing the Retrieval of Latent Heating for PMM with Improved Simulations of Convective, Synoptic, and Cold Season Systems and their Associated Microphysical and Precip. Processes

CPEX-AW Climatology June. July, August

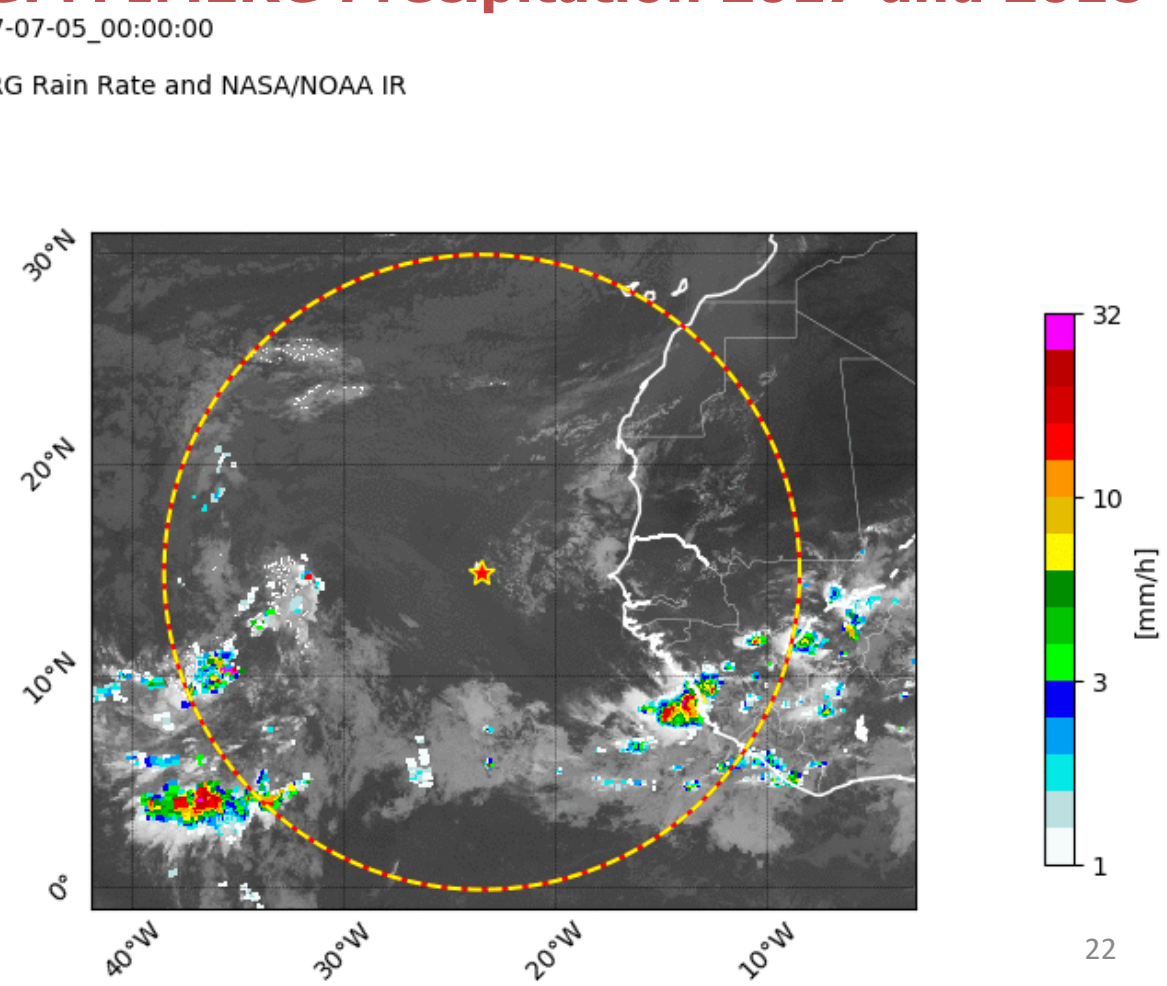
Figure: Climatology of rainfall (left panels) and wind (right panels) for June, July, and August (credit: IRI). Blue box indicates the domain for DC-8 flights.



GPM IMERG Precipitation 2017 and 2018

Circle represents a 2-hour flight distance from Capo Verde. NASA's DC-8 can fly for about 10 hours maximum.

For convective process observations, NASA will want to fly into the ITCZ and would like to continue flights into August.



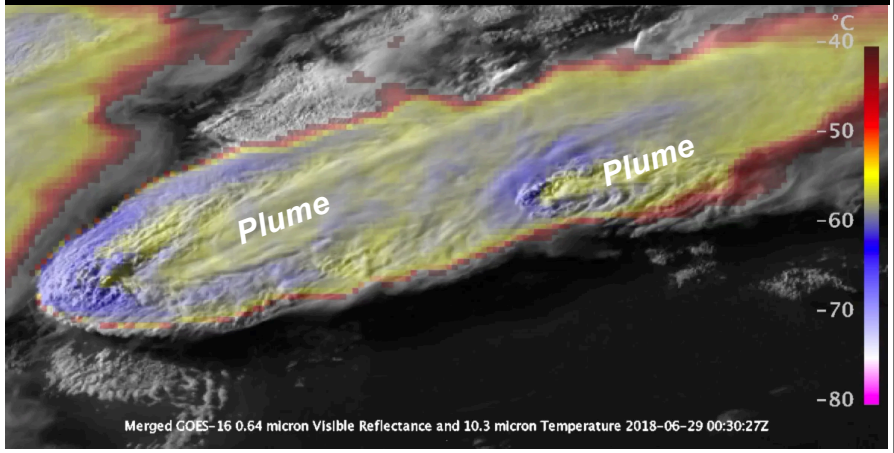
GOES Severe Thunderstorm Research

In Collaboration With U. Oklahoma, U. Alabama in Huntsville, NOAA/CSU CIRA, and NASA MSFC

We are using model analyses, ground-based remote sensing observations, and GOES satellite imagery to:

- **Characterize severe hail, wind, and tornadic storm evolution**
- **Recognize unique storm behavior that occurs in advance of severe weather**
- **Develop and demonstrate satellite-derived methods that could improve severe storm detection and warnings**

GOES-16 1-Minute Visible + Infrared Composite Imagery of Supercell Storms That Produced Above Anvil Cirrus Plumes and Up To Baseball-Sized Hail Over North Dakota



Learn More: https://climate.nasa.gov/news/2782/severe-storms-show-off-their-plume-age/

http://www.dcotss.org

https://satelliteliaisonblog.com/2019/06/24/use-of-goes-16-imagery-during-

RECENT FINDINGS AND APPLICATIONS

1) **The most severe storms have the strongest updrafts that can be detected via pattern recognition in GOES visible, infrared, and lightning imagery**
2) **Severe storm updrafts inject cirrus plumes into the stratosphere that have unique patterns which can be identified by forecasters to improve warnings**
3) **NASA research on above-anvil cirrus plumes was leveraged by NOAA to issue a tornado warning in Colorado when a weather radar malfunctioned**
   - **GOES-16 satellite imagery was the only real-time dataset available to monitor the severe storms**
   - **This tornado warning provided 14 minutes of lead time, which potentially saved lives and property** (see link, lower left)
4) **Plume impacts on stratospheric chemistry will be studied with the NASA ER-2 during the "Dynamics and Chemistry of the Summer Stratosphere" (DCOTSS) EV-S campaign, which will begin in Spring 2020**

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Please contact: kristopher.m.bedka@nasa.gov and william.l.smith@nasa.gov
to learn more about DCOTSS!

GOES Satellite Imagery Benefits NASA Airborne Science

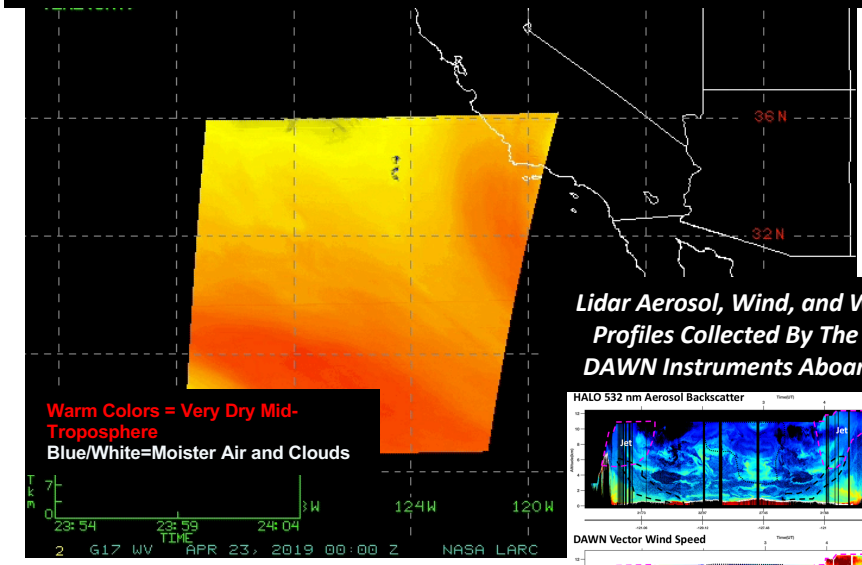
- We upload GOES data to the NASA DC-8 in near-real time, providing mission scientists with valuable situational awareness during flight
- NOAA NESDIS provided GOES 1-minute resolution "Mesoscale Domain Sectors" for eight DC-8 flights during two recent NASA field campaigns:
  - NASA ARMD High Ice Water Content – Radar II (August 2018)
  - Aeolus Cal/Val Test Flight Campaign (April 2019)
- This extremely high temporal resolution GOES imagery provides significant benefit to NASA research, allowing us to observe weather processes with unprecedented detail
- DC-8 in-situ data has been combined with GOES observations to develop a new satellite-derived aircraft icing detection product that could improve aviation safety
  - In collaboration with the SPoRT Center at NASA MSFC,

Learn More: https://climate.nasa.gov/news/2867/nasa-testing-airborne-lasers-to-touch-the-wind/

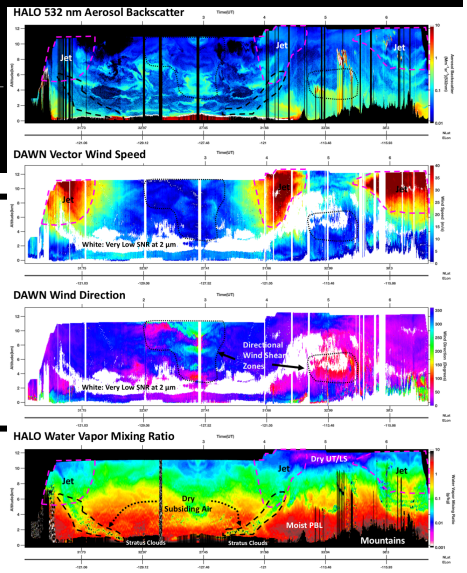
https://www.youtube.com/watch?v=UyFhTjkJTZA

https://www.nasa.gov/aero/nasa-completes-high-ice-water-content-radar-flight-campaign-in-

22-23 April 2019 DC-8 Flight Track Atop 1-Minute GOES-17 7.3 micron Water Vapor Absorption Channel Imagery



Lidar Aerosol, Wind, and Water Vapor Profiles Collected By The HALO and DAWN Instruments Aboard The DC-8



Data Collected During the April 2019 Aeolus Cal/Val Test Flight Campaign

Mission Scientist: Kristopher Bedka (LaRC)
DAWN PI: Michael Kavaya (LaRC)
HALO PI: Amin Nehrir (LaRC)

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