Overview of satellite data utilization for preparing extreme precipitation events

US Status

Dr. Mitch Goldberg - Chief Scientist for Satellite and Information Services, NOAA

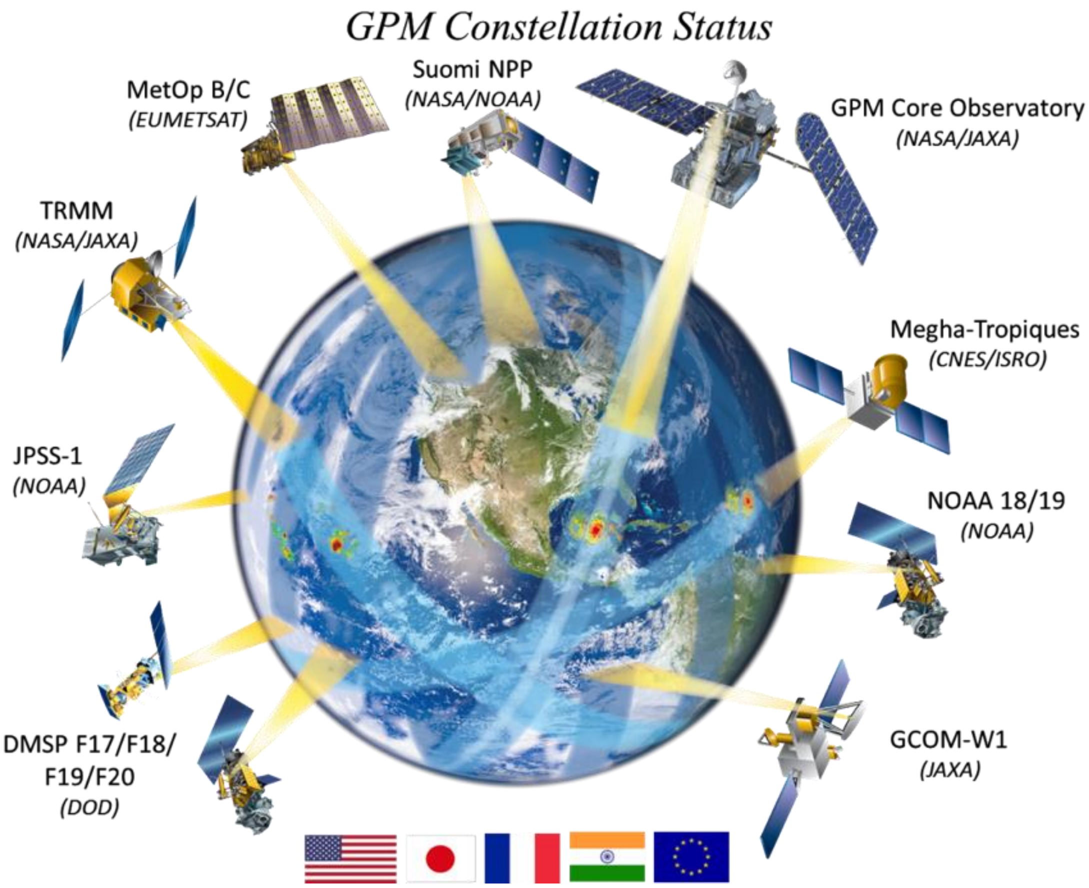
Pingping Xie, NWS/CPC,
Bob Kuligowski, NESDIS/STAR
George Huffman, NASA/GSFC
Joe Turk, JPL (IPWG Rapporteur)

National Environmental Satellite, Data, and Information Service

March 1, 2023

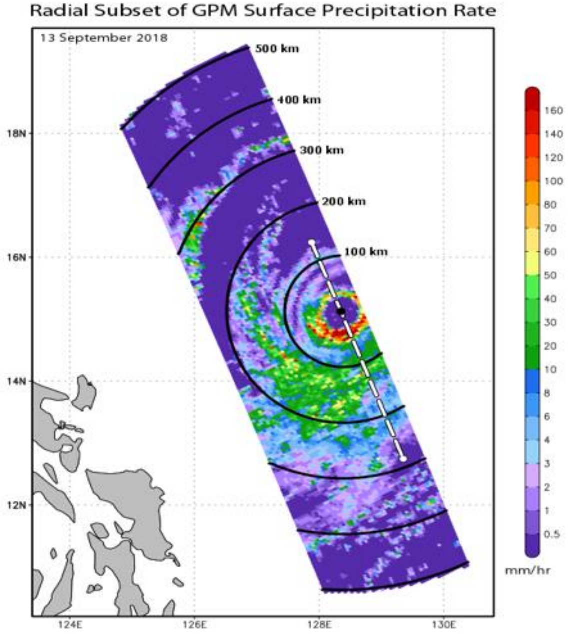
Monitoring extreme precipitation events requires

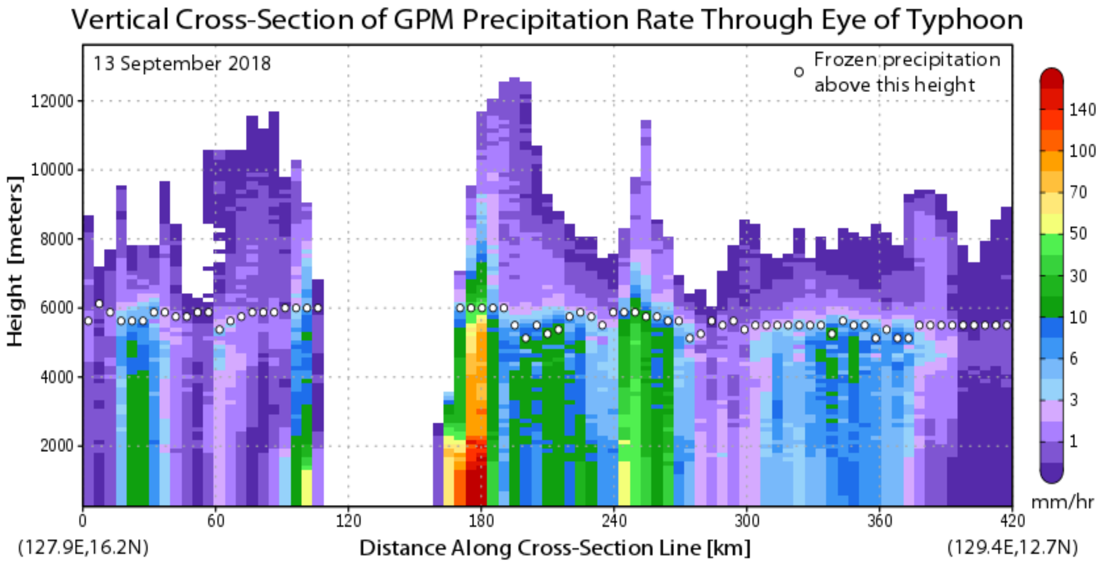
- A healthy constellation of various observing types, including passive microwave (AMSR2, SSMIS, GPM, AMSU, ATMS) and precipitation-capable radars (GPM DPR and CloudSat CPR) and geostationary visible/infrared for high temporal/low latency.
    - Visible / Infrared (IR) only detect cloud tops and cloud-top properties (for clouds thick enough for rain) that does not always relate well to surface rain rate
    - Passive microwave (PMW) is sensitive to vertically integrated cloud water (ocean only) / ice—this is better, but still very indirect
    - Active radar is best (vertical detail) but much more expensive than passive sensors


GPM Constellation Status
MetOp B/C
(EUMETSAT)
Suomi NPP
(NASA/NOAA)
GPM Core Observatory
(NASA/JAXA)
TRMM
(NASA/JAXA)
Megha-Tropiques
(CNES/ISRO)
JPSS-1
(NOAA)
NOAA 18/19
(NOAA)
DMSP F17/F18/
F19/F20
(DOD)
GCOM-W1
(JAXA)

Typhoon Mangkhut - GPM DPR

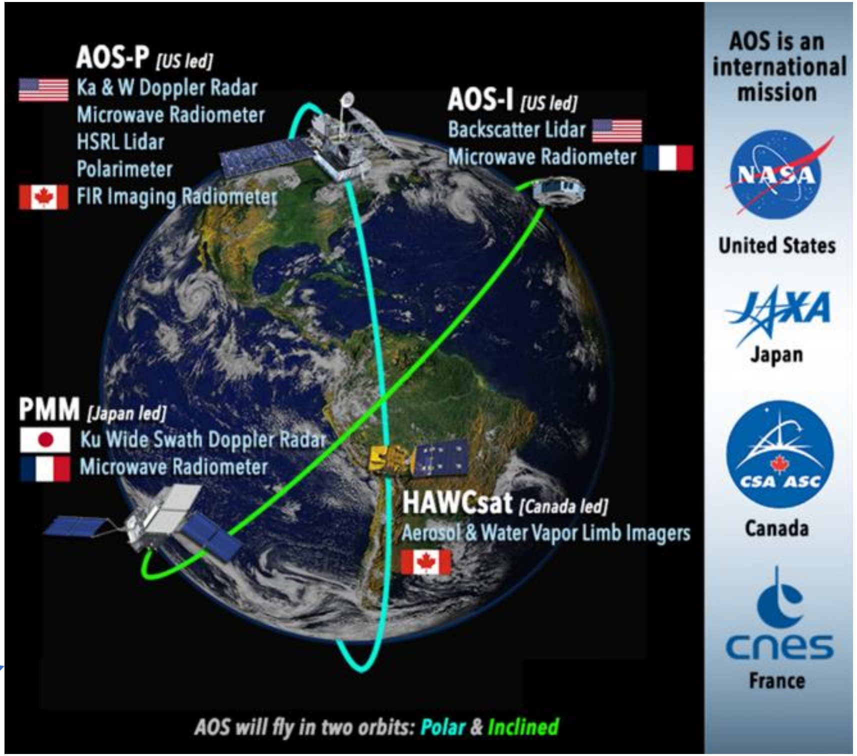
https://gpm.nasa.gov/resources/videos/gpm-captures-super-typhoon-mangkhut-approaching-philippines





PMW Constellation is improving

- Now-2030s: NOAA JPSS, NASA's GPM GMI (along with DPR)
- Now-2025: DoD Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager/Sounder (SSMIS), NOAA AMSU
- 2024 - 2030's: DoD Weather System Follow-on Microwave (WSF-M) Microwave Imager (MWI)
- 2024 - 2030's: JAXA's Advanced Scanning Microwave Radiometer (AMSR-3) on Global Observation SATellite for Greenhouse gasses and Water cycle (GOSAT-GW)
- 2024- 2040's: EUMETSAT MetOp Second Generation Microwave sounder and imager (MWS, MWI)
- 2025- 2030: NOAA QuickSounder (ATMS in 5:30 orbit)
- 2027 NASA INCUS (3 Ka-band radars, 1 radiometer)
- 2029 - 2040: ESA/EUMETSAT Sterna (3 orbits/2 sats)
- Increased Commercial Providers
- 2028 to 2040: Active Radar from NASA /JAXA AOS



GPM Societal Benefit Areas

Disaster risk management

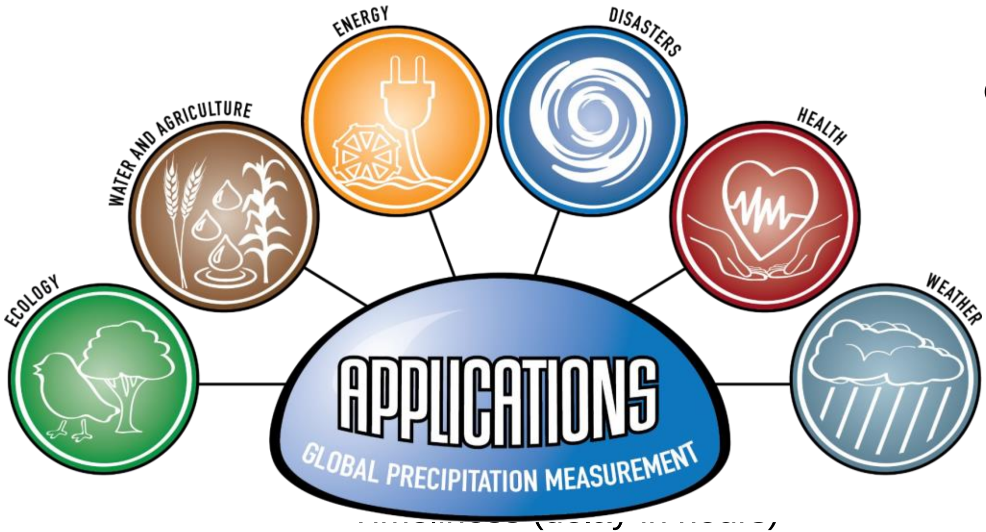
CyStellar; JBA Risk Management, Ltd; Pacific Disaster Center; Monarch Weather Consulting; Information Technology for Humanitarian Assistance (ITHACA); ZonaGeo; United Nations Office for the Coordination of Humanitarian Affairs (UN OCHA)

Reinsurance

Swiss Re; Munich Re; Microinsurance Catastrophe Risk Organisation; CelsiusPro; Agvesto; Syngenta®; Pacific Catastrophe Risk Insurance Company

Agriculture

U.S. Department of Agriculture; Cargill, Inc.; Nutrien™; aWhere, Inc.; PrecisionAg®; Ecoclimasol; BASF Corporation; Embrapa

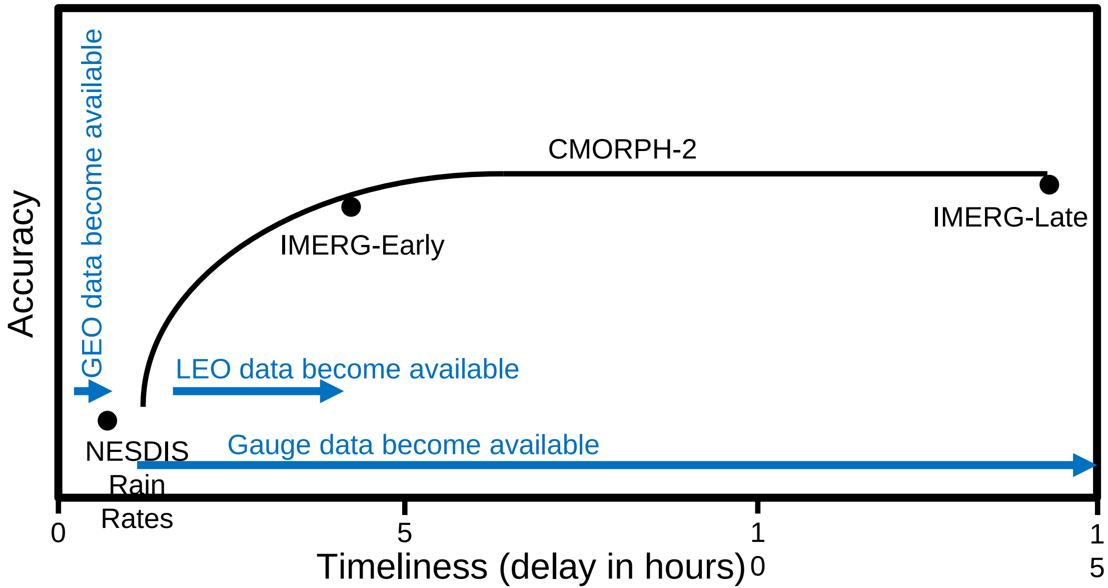


NWP; TC Forecasting; S2S Modeling

NOAA; NRL; U.S. Navy Fleet Numerical Meteorology and Oceanography Center; European Centre for Medium-Range Weather Forecasts; United Kingdom Met Office; Météo France; Australia Bureau of Meteorology; Environment and Climate Change Canada; Indonesia Meteorology, Climatology, and Geophysical Agency; Meteorological Connections, LLC

Precipitation Monitoring

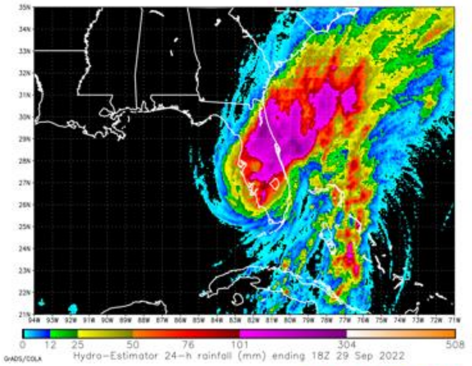
- Why do we have so many products?
- The accuracy vs. timeliness challenge



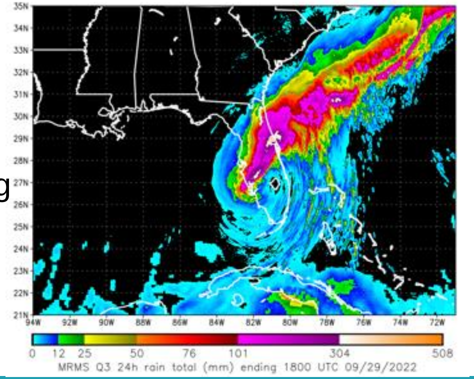
NESDIS' Operational Rainfall Products: GHE

- Global Hydro-Estimator: low-latency "first-look" (5 min after end of IR image time) rate / accumulation based on IR data
- https://www.ospo.noaa.gov/Products/atmosphere/ghe/

GHE 24-h rainfall total ending 18 UTC 9/29/22

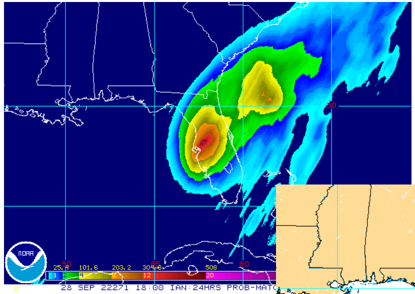


MRMS 24-h rainfall total ending 18 UTC 9/29/22

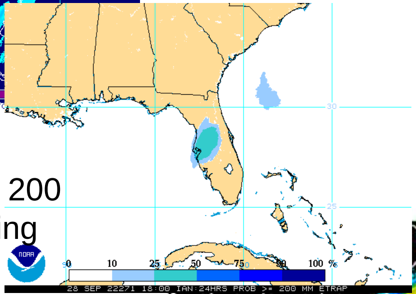


NESDIS' Operational Rainfall Products: eTRaP

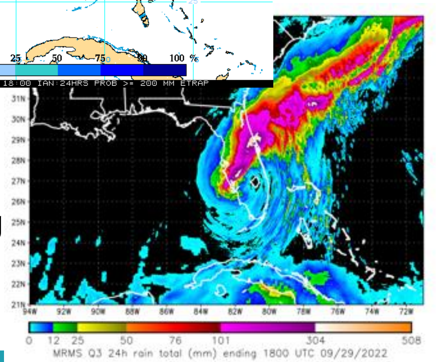
- Ensemble Tropical Rainfall Potential (eTRaP): probabilistic forecasts for tropical systems
- Produced every 6 hours worldwide
- https://www.ssd.noaa.gov/PS/TROP/etrap.html



eTRaP predicted 24-h rainfall accumulation starting 18 UTC 9/28/22



eTRaP 0-24h ¥probability of > 200 mm of rain starting 18 UTC 9/28/22



MRMS 24-h rainfall total ending 18 UTC 9/29/22

SCAMPR

NOAA STAR CENTER FOR SATELLITE APPLICATIONS AND RESEARCH

Search STAR Go

- STAR Satellite Rainfall Estimates Home
- Hydro-Estimator
- Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) >>
- Ensemble Tropical Rainfall Potential (eTRaP)
- Product Validation
- Current Work
- Personnel
- Links

STAR Satellite Rainfall Estimates
Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR)

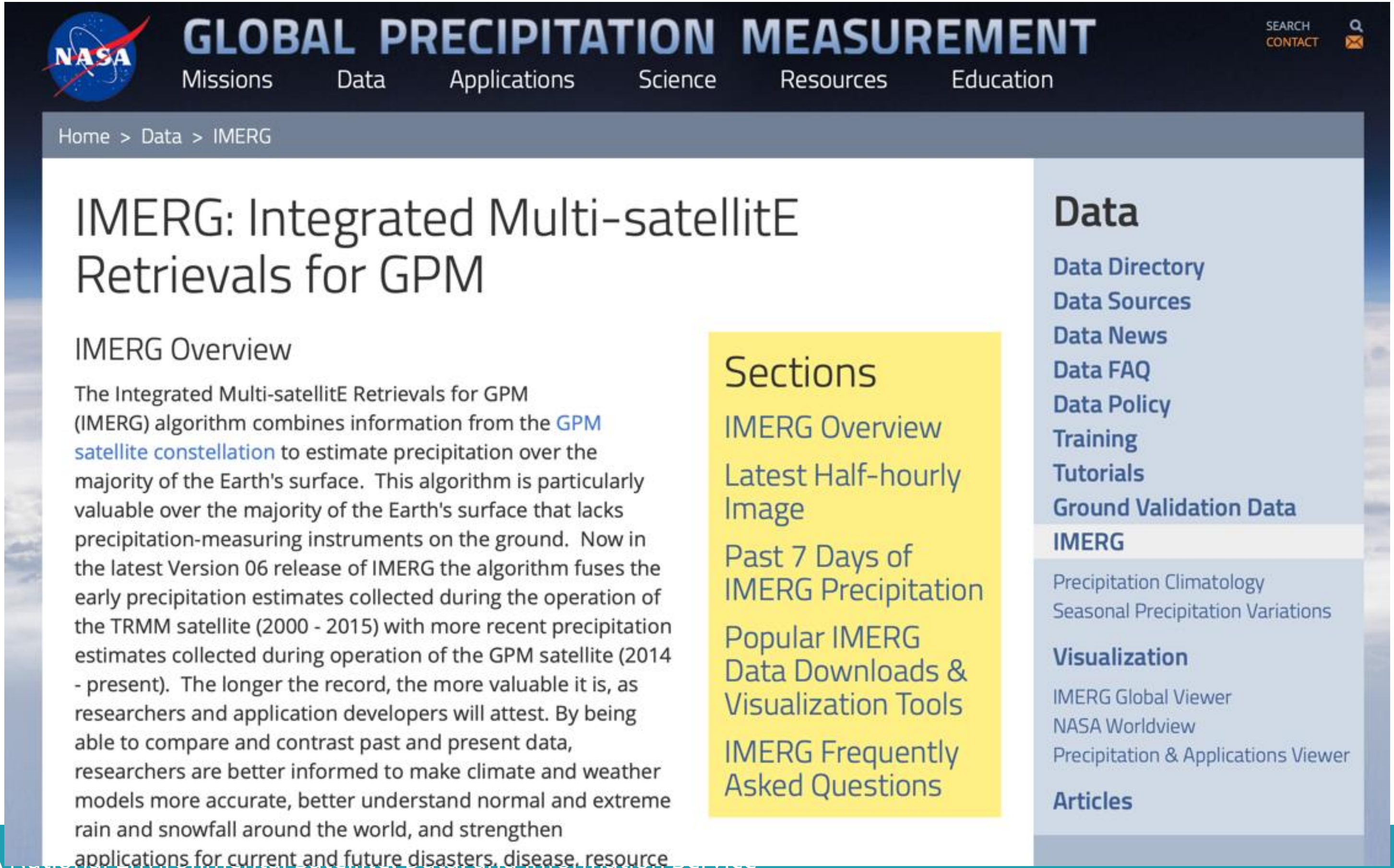
SCaMPR Precipitation Estimates

The Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) algorithm, also called the Enterprise Rainfall Rate algorithm, attempts to effort to combine the separate strengths of infrared (IR)-based and microwave (MW)-based estimates of rainfall. In particular, IR data are available from geostationary Earth orbit (GEO) platforms with high spatial resolution (2 km immediately below the satellite) and very frequent updates (every 10 min over the Western Hemisphere) and the observations are sent to

Enterprise Algorithm (SCaMPR) Precipitation Estimates

Product	Global Images	CONUS Images	DC-area Images
Instantaneous rain rate	Current Images	Current Images	Current Images
1-hour accumulation	Current Images	Current Images	Current Images
3-hour accumulation	Current Images	Current Images	Current Images
6-hour accumulation	Current Images	Current Images	Current Images
12-hour accumulation	Current Images	Current Images	Current Images
24-hour accumulation	Current Images	Current Images	Current Images
48-hour accumulation	Current Images	Current Images	Current Images
72-hour accumulation	Current Images	Current Images	Current Images
Global netCDF files	Download	Global lat/lon file	

IMERG



GLOBAL PRECIPITATION MEASUREMENT

SEARCH CONTACT

Missions Data Applications Science Resources Education

Home > Data > IMERG

IMERG: Integrated Multi-satellitE Retrievals for GPM

IMERG Overview

The Integrated Multi-satellitE Retrievals for GPM (IMERG) algorithm combines information from the GPM satellite constellation to estimate precipitation over the majority of the Earth's surface. This algorithm is particularly valuable over the majority of the Earth's surface that lacks precipitation-measuring instruments on the ground. Now in the latest Version 06 release of IMERG the algorithm fuses the early precipitation estimates collected during the operation of the TRMM satellite (2000 - 2015) with more recent precipitation estimates collected during operation of the GPM satellite (2014 - present). The longer the record, the more valuable it is, as researchers and application developers will attest. By being able to compare and contrast past and present data, researchers are better informed to make climate and weather models more accurate, better understand normal and extreme rain and snowfall around the world, and strengthen applications for current and future disasters, disease, resource

Sections

IMERG Overview

Latest Half-hourly Image

Past 7 Days of IMERG Precipitation

Popular IMERG Data Downloads & Visualization Tools

IMERG Frequently Asked Questions

Data

Data Directory

Data Sources

Data News

Data FAQ

Data Policy

Training

Tutorials

Ground Validation Data

IMERG

Precipitation Climatology

Seasonal Precipitation Variations

Visualization

IMERG Global Viewer

NASA Worldview

Precipitation & Applications Viewer

Articles

GLOBAL PRECIPITATION MEASUREMENT

SEARCH
CONTACT

Missions Data Applications Science Resources Education

Home > Resources > Documents > GPM Level 3 GPROF Version 07 Information

GPM Level 3 GPROF Version 07 Information

Date Last Updated
Friday, June 3, 2022

Author(s)
Precipitation Processing System

Document Description
The L3GPROF algorithm provides monthly and daily mean precipitation and related retrieved parameters from the Level 2 GPROF precipitation profiling algorithm for the GPM core and constellation satellites.

Each L3GPROF product contains global 0.25o x 0.25o gridded monthly/daily unconditional means and pixel counts. Monthly product filenames start with 3A-MO or 3A-CLIM-MO, and daily product filenames start with 3A-DAY or 3A-CLIM-DAY.

File Downloads

L3GPROF_Information_V07.pdf 173.82 KB

Data Product Type(s)
3A Radiometer (GPROF)

Document Category
Algorithm Information

Resources

- Frequently Asked Questions
- Image Gallery
- Video Gallery
- Documents
- GPM Refereed Publications
- TRMM Refereed Publications
- 3D Printed GPM
- Precipitation Data
- Media & Press Resources
- Glossary
- All Articles

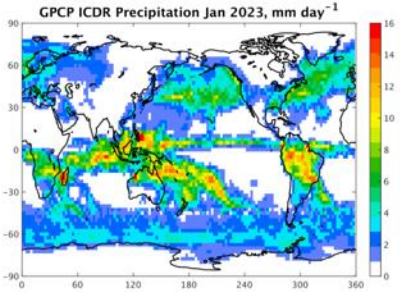
GPCP

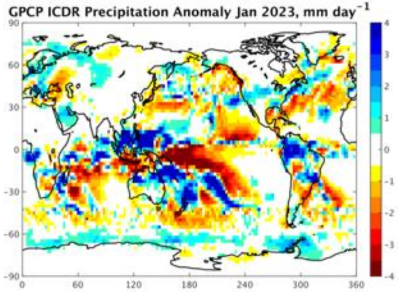
Global Precipitation Climatology Project (GPCP)

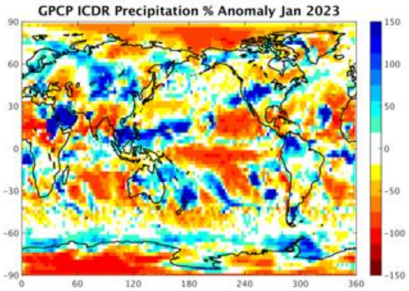
University of Maryland College Park
Earth System Science Interdisciplinary Center (ESSIC) and Cooperative Institute for Climate and Satellites (CICS)

GPCP Monthly Analysis (GPCP-Interim)--Latest Month

Interim GPCP estimates are provisional estimates of GPCP available ~10 days after the end of the month. They can be used for the most recent months for which GPCP is unavailable.







GPCP Background
Description

GPCP V2.3 Monthly
Description & Download

GPCP-Interim V2.3 Monthly
Description & Download

https://www.nws.noaa.gov/ost/climate/STIP/44CDPW/44cdpw-PXie.pdf

Science and Technology Infusion Climate Bulletin
NOAA's National Weather Service
44th NOAA Annual Climate Diagnostics and Prediction Workshop
Durham, NC, 22-24 October 2019

A Preliminary Examination of the Second Generation CMORPH Satellite Precipitation Estimates

Pingping Xie[1], Robert Joyce[1, 2], Shaorong Wu[1, 2], Li Ren[1, 2], and Bert Katz[1, 2]
[1]*Climate Prediction Center, NOAA/NWS/NCEP*
[2]*Innovim, Inc.*

1. Introduction

Blending information from multiple sensors and multiple satellites has demonstrated an effective way of producing analyses for improved monitoring and quantitative analysis of weather, climate and water. At NOAA Climate Prediction Center (CPC), a technique is developed to construct high-quality, high-resolution global precipitation estimates through integrating retrievals from passive microwave (PMW) and infrared (IR) measurements from low Earth orbit (LEO) as well as geosynchronous equatorial orbit (GEO) satellites. Called CPC Morphing (Joyce *et al.* 2004; Xie *et al.* 2017), this technique constructs high-resolution precipitation estimates in two steps, *i.e.* a) to define purely satellite-based precipitation estimates (the raw CMORPH) with complete spatial coverage; and b) to remove the bias in the raw CMORPH through comparison against concurrent gauge observations.

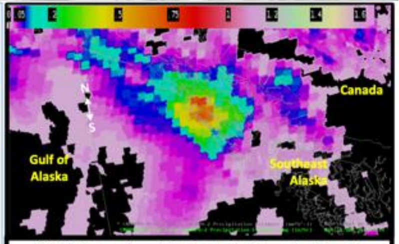
Two versions of the CMORPH have been developed. The first version (CMORPH1) produces estimates of 30 minute precipitation on an 8 km × 8 km grid over a quasi-global domain (60°S-60°N). The CMORPH1 is reprocessed for a 22-year period from 1998 to the present to form a Climate Data Record (CDR) (Xie *et al.* 2019b). CMORPH1 is updated on a near real-time basis at a latency of two hours. The second generation CMORPH (CMORPH2) is developed in recent years to provide full global coverage (90°S-90°N) at a refined spatial resolution (0.05°lat/lon) with improved quality especially for cold season precipitation (Xie *et al.* 2018).

JPSS NOAA NASA

CMORPH-2 Precipitation Rates Quick Guide

What are CMORPH-2 Precipitation Rates?

The second-generation Climate Prediction Center (CPC) MORPHing (CMORPH-2) technique employs microwave precipitation estimates that interpolate precipitation features from geostationary (i.e., GOES) and Low-Earth Orbiting (LEO) infrared data. The merged satellite product encompasses the magnitude guidance of precipitation rates from microwave sensors integrated with the movement of precipitation features from geostationary satellites. CMORPH-2 is a global product and is accessible in AWIPS for Alaska users.



CMORPH-2 observations of high rain rates (~1 inch per hour) along the southeastern Alaska coastline at 1100 UTC, 26 October 2020.

Algorithm: Microwave – LEO/GOES Morphing Process	Attributes & Resolutions
Microwave precipitation rates from all available satellites are combined into a single global field that governs the magnitude and shape of precipitation at each time step. Precipitation estimates derived from GOES and LEO infrared brightness temperatures are calibrated with the microwave data, and used to fill gaps where microwave retrievals are not available. GOES wind vectors are used to propagate this precipitation field in time.	***Unit:*** inches per hour ***Spatial:*** 0.05° ***Latency and Availability:*** AWIPS product latency is 1-4 hours and is available every 30 minutes.

Impact on Operations

Primary Application

Satellite Derived Precipitation: LEO and GEO satellites are combined together to estimate the shape, magnitude and movement of precipitation regions over land and offshore.

Satellite versus Radar Precipitation estimates: Satellite derived precipitation can be advantageous over radar-based precipitation estimates (i.e., Multi-Radar Multi-Sensor, MRMS). CMORPH-2 can provide better coverage of precipitation compared to MRMS since satellite sampling is more uniform, especially over areas of high terrain and data-sparse regions (e.g. offshore precipitation) where radar coverage and precipitation gauge networks are poor and or limited.

Limitations

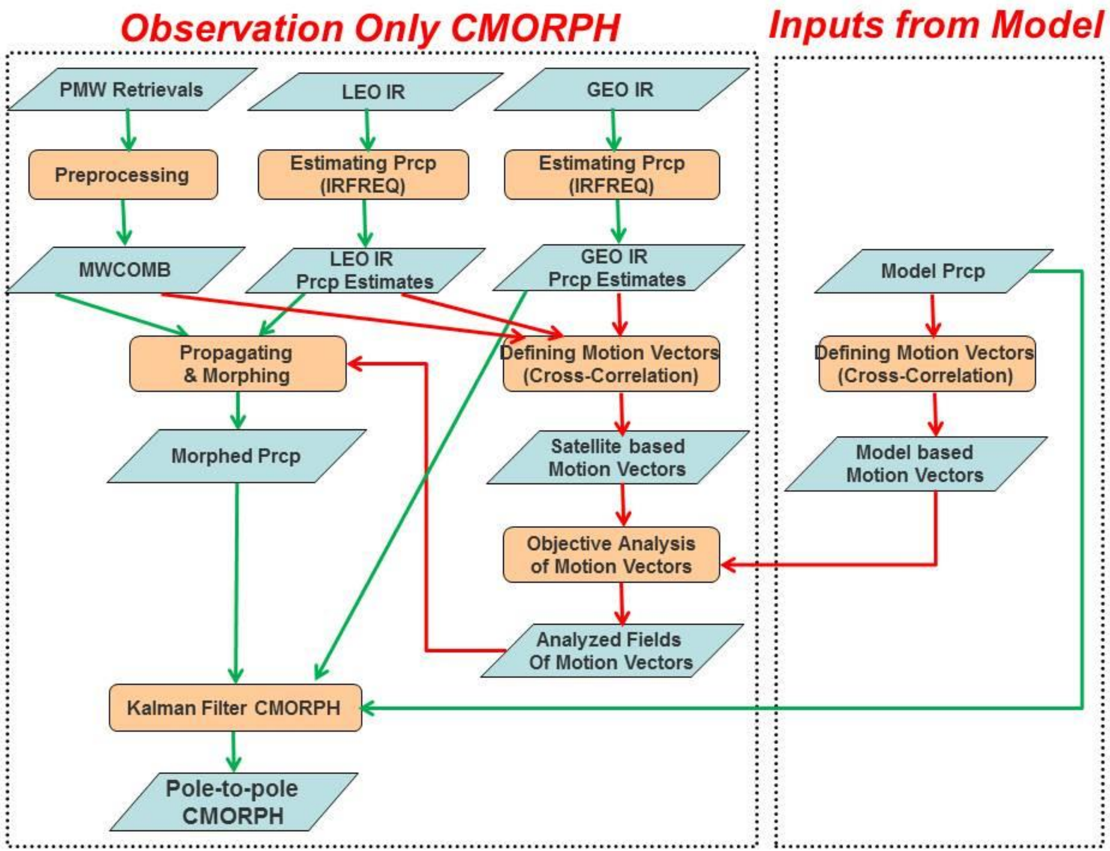
Snow: Snow covered ground results in precipitation underestimation due to difficulty in differentiating cloud ice from surface snow.

Liquid Clouds: Microwave precipitation rates over land is dependent on the presence of ice clouds. Observations mainly comprised of liquid clouds (i.e., warm rain processes) increases likelihood of underestimates of precipitation.

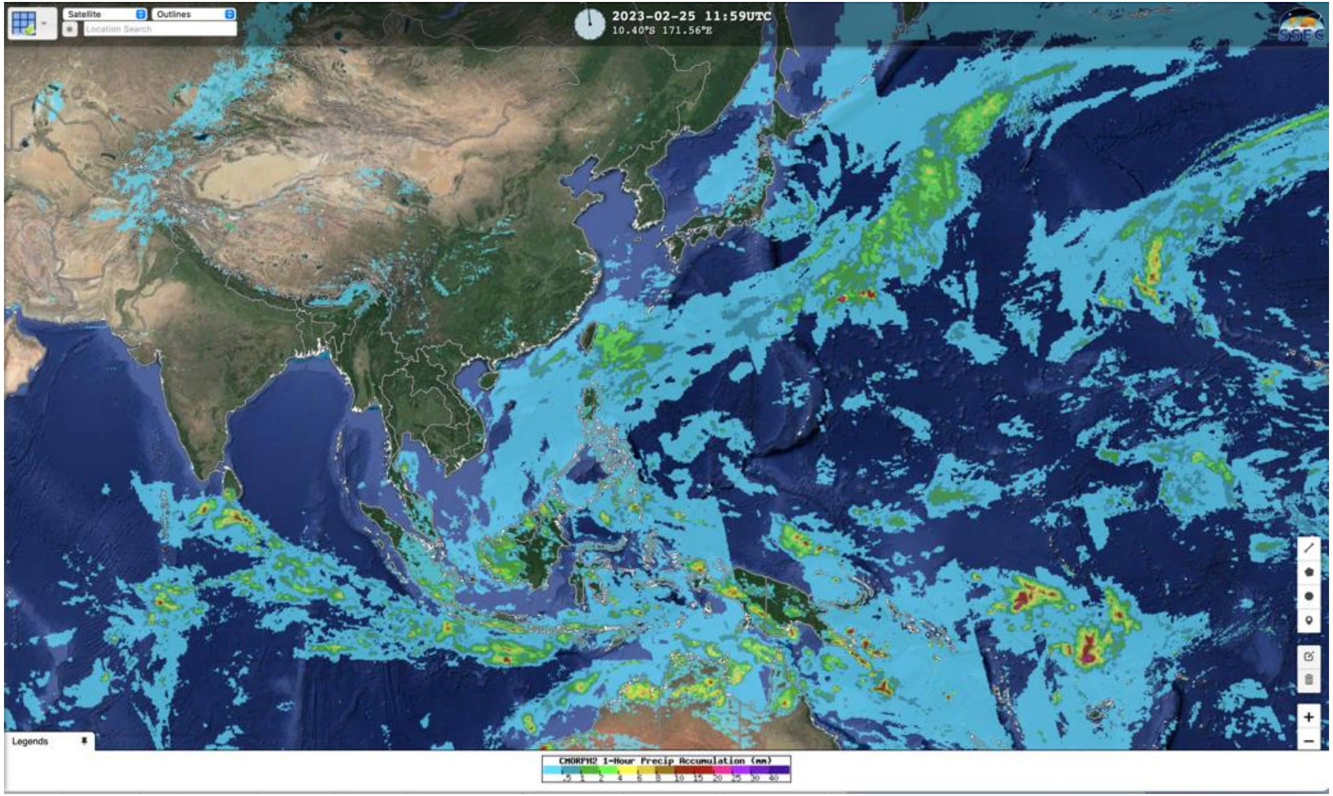
Precipitation Mode: Stratiform, shallow convection, and deep convection precipitation modes can affect CMORPH-2 accuracy due to differences in cloud ice concentration that influence precipitation rates.

Bias Correction: The current CMORPH-2 version is not bias corrected. An updated version with magnitude of CMORPH-2 adjusted against gauge observations is coming soon.

CMORPH2 system. (Pingping Xie, CPC)



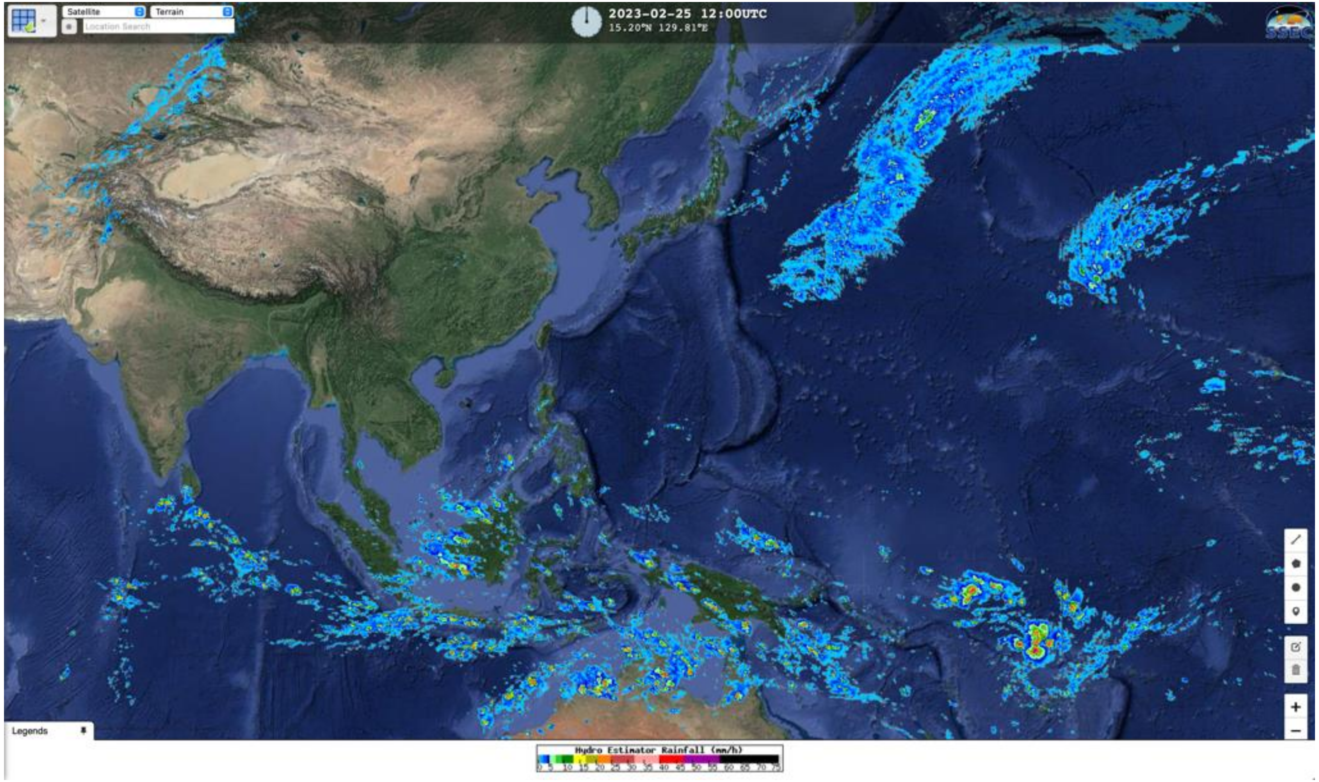
NOAA Flood Proving Ground Website



https://www.ssec.wisc.edu/flood-map-demo/precipitation-and-ice-products/

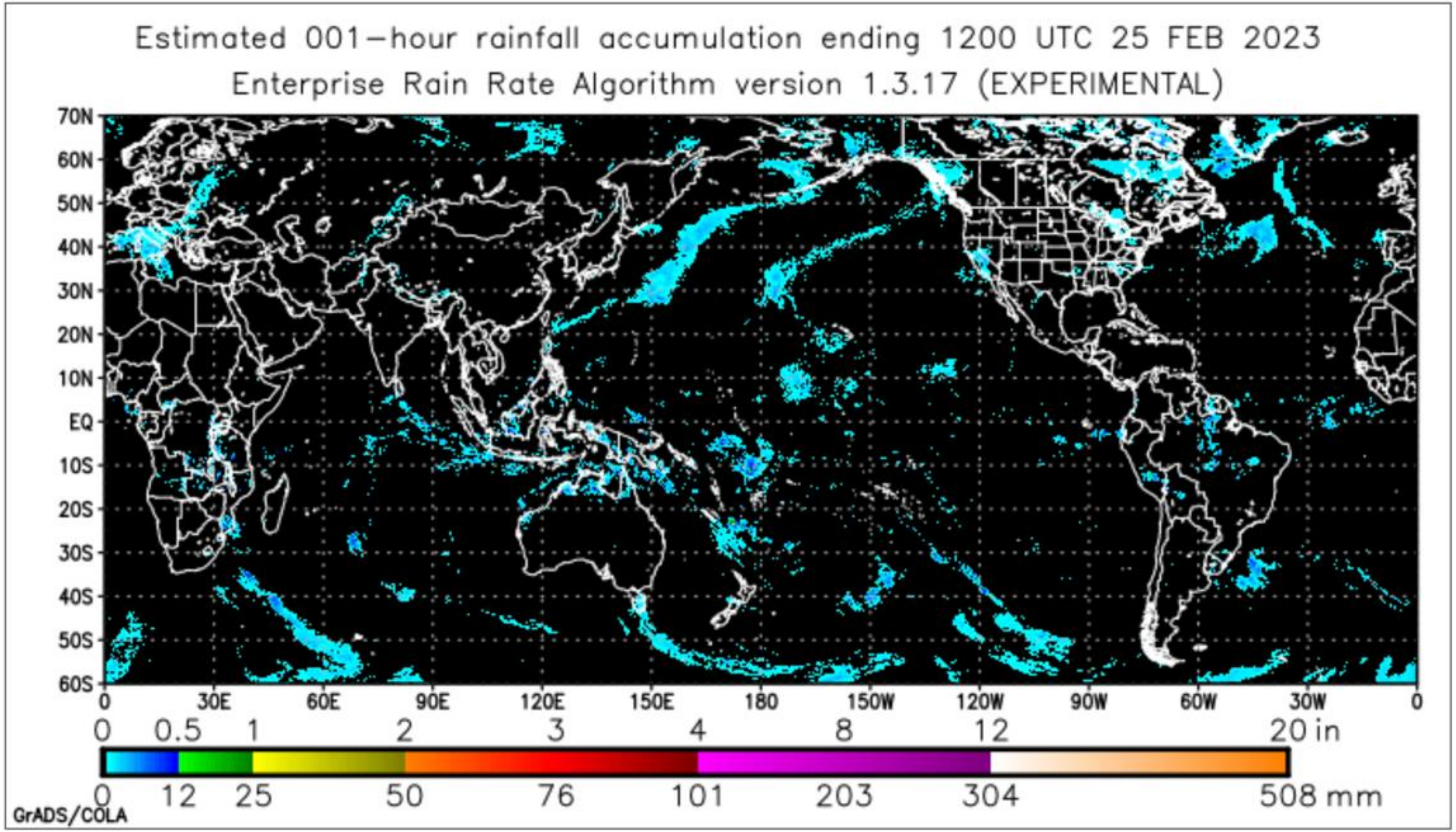
GHE using the Real Earth Interface

https://realearth.ssec.wisc.edu/.

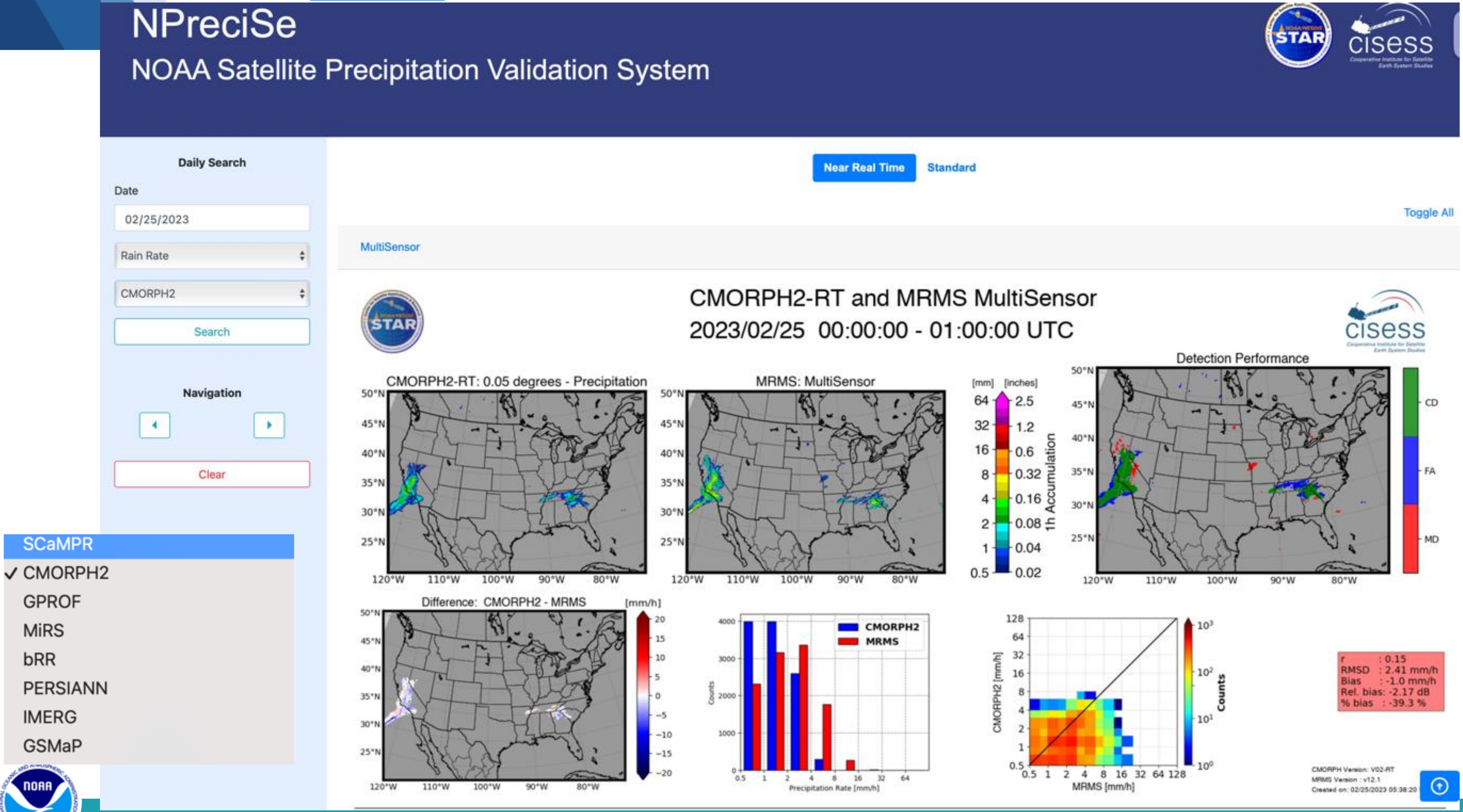


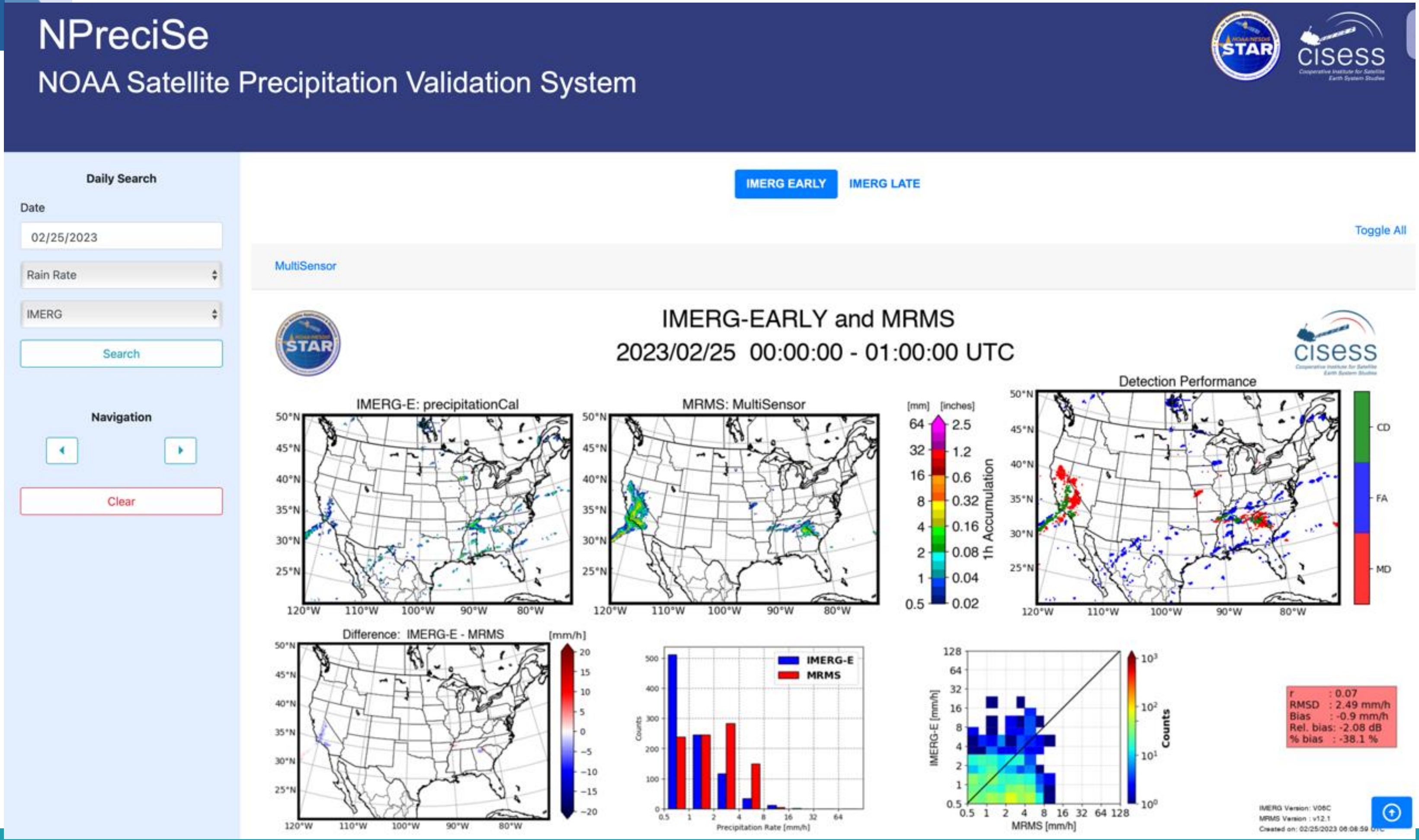
SCAMPR – Self-Calibrating Multivariate Precipitation Retrieval

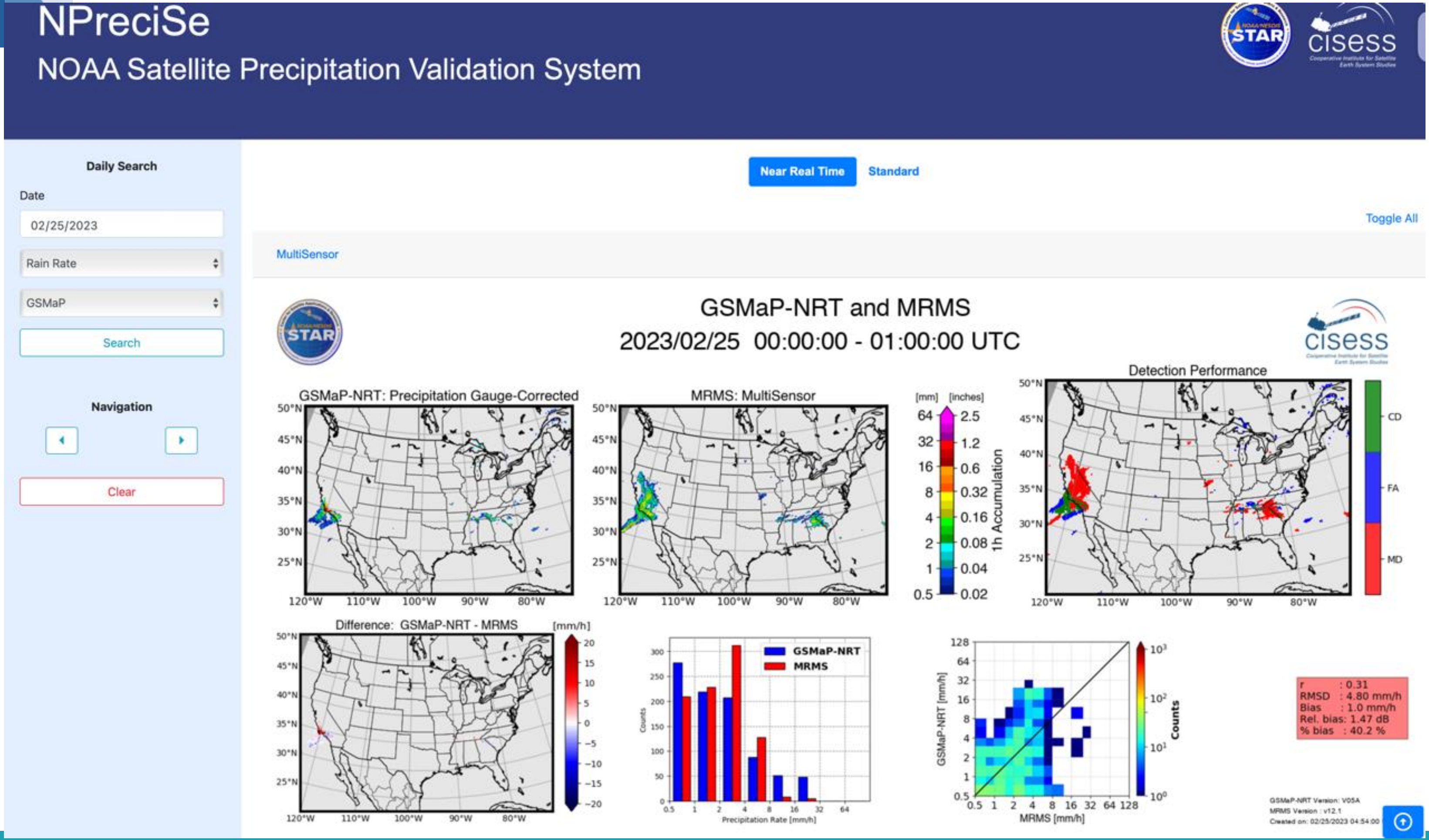
https://www.star.nesdis.noaa.gov/smcd/emb/ff/SCaMPR.php

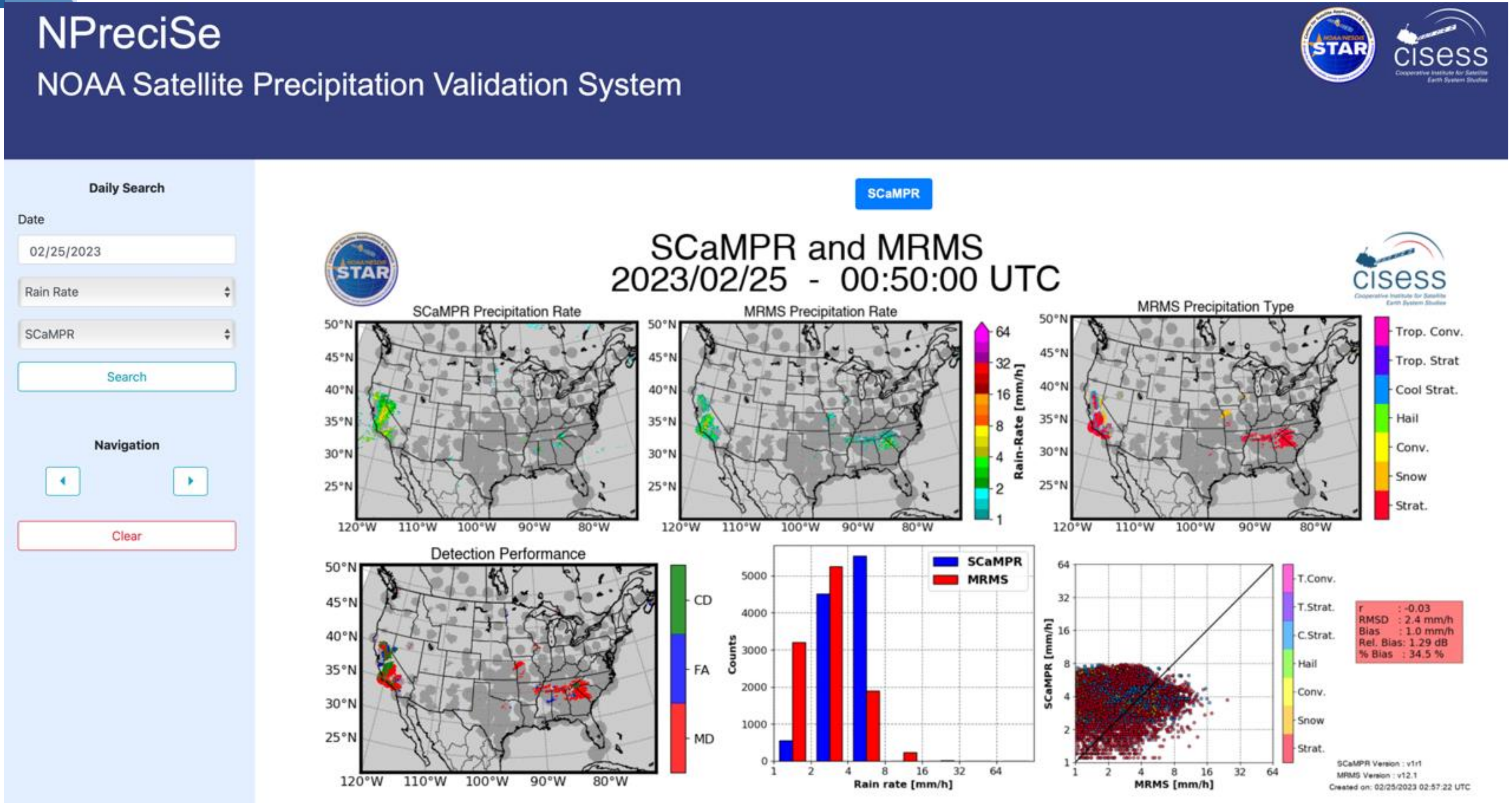


NPreciSE


NPreciSe
NOAA Satellite Precipitation Validation System
STAR
cisess
Daily Search
Date
02/25/2023
Rain Rate
CMORPH2
Search
Navigation
Clear
Near Real Time
Standard
Toggle All
MultiSensor
CMORPH2-RT and MRMS MultiSensor
2023/02/25 00:00:00 - 01:00:00 UTC
CMORPH2-RT: 0.05 degrees - Precipitation
MRMS: MultiSensor
Detection Performance
1h Accumulation
[mm] [inches]
CD
FA
MD
Difference: CMORPH2 - MRMS
[mm/h]
CMORPH2
MRMS
Counts
Precipitation Rate [mm/h]
CMORPH2 [mm/h]
MRMS [mm/h]
r : 0.15
RMSD : 2.41 mm/h
Bias : -1.0 mm/h
Rel. bias: -2.17 dB
% bias : -39.3 %
CMORPH Version: V02-RT
MRMS Version : v12.1
Created on: 02/25/2023 05:38:20
SCaMPR
✓ CMORPH2
GPROF
MiRS
bRR
PERSIANN
IMERG
GSMaP

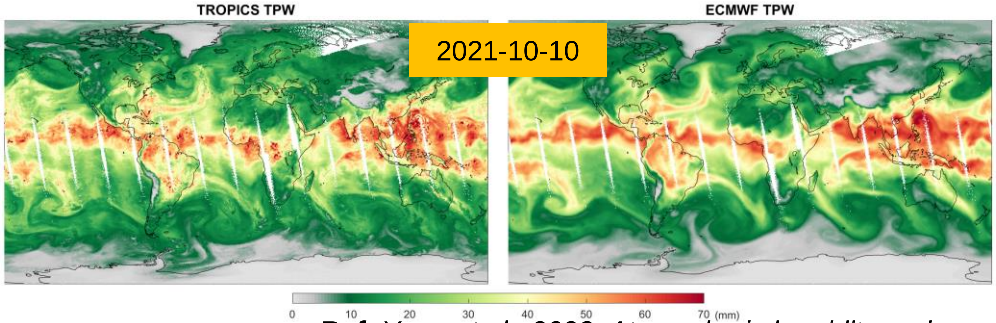

NPreciSe
NOAA Satellite Precipitation Validation System
Daily Search
Date
02/25/2023
Rain Rate
IMERG
Search
Navigation
Clear
IMERG EARLY
IMERG LATE
Toggle All
MultiSensor
IMERG-EARLY and MRMS
2023/02/25 00:00:00 - 01:00:00 UTC
IMERG-E: precipitationCal
MRMS: MultiSensor
Detection Performance
1h Accumulation
[mm] [inches]
CD
FA
MD
Difference: IMERG-E - MRMS
[mm/h]
IMERG-E
MRMS
Precipitation Rate [mm/h]
Counts
IMERG-E [mm/h]
MRMS [mm/h]
r : 0.07
RMSD : 2.49 mm/h
Bias : -0.9 mm/h
Rel. bias: -2.08 dB
% bias : -38.1 %


NPreciSe
NOAA Satellite Precipitation Validation System
STAR
cisess
Daily Search
Date
02/25/2023
Rain Rate
GSMaP
Search
Navigation
Clear
Near Real Time
Standard
Toggle All
MultiSensor
GSMaP-NRT and MRMS
2023/02/25 00:00:00 - 01:00:00 UTC
GSMaP-NRT: Precipitation Gauge-Corrected
MRMS: MultiSensor
Detection Performance
[mm] [inches]
1h Accumulation
CD
FA
MD
Difference: GSMaP-NRT - MRMS
[mm/h]
GSMaP-NRT
MRMS
Counts
Precipitation Rate [mm/h]
GSMaP-NRT [mm/h]
MRMS [mm/h]
r : 0.31
RMSD : 4.80 mm/h
Bias : 1.0 mm/h
Rel. bias: 1.47 dB
% bias : 40.2 %
GSMaP-NRT Version: V05A
MRMS Version : v12.1
Created on: 02/25/2023 04:54:00

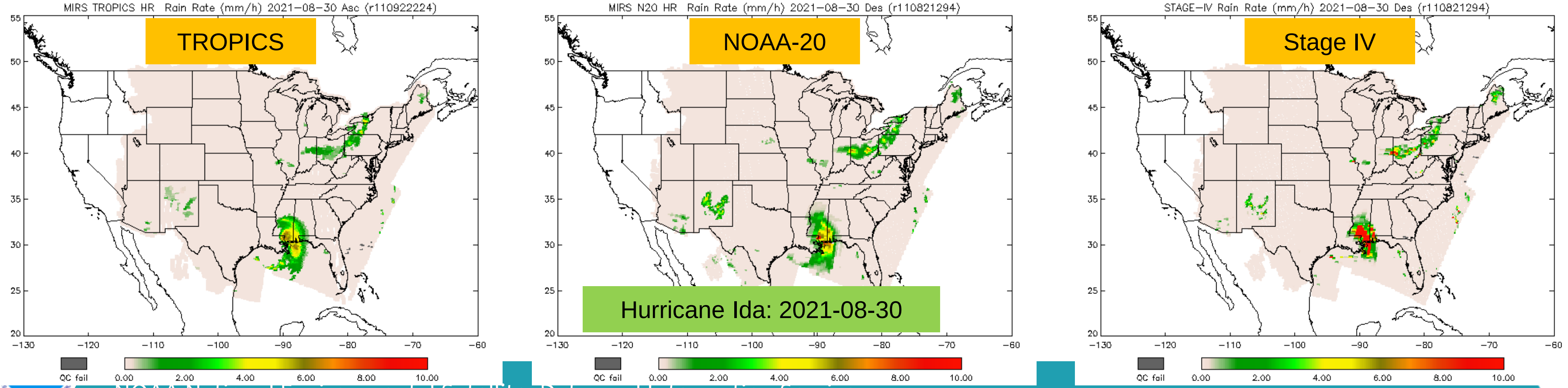

NPreciSe
NOAA Satellite Precipitation Validation System
STAR
cisess
Daily Search
Date
02/25/2023
Rain Rate
SCaMPR
Search
Navigation
Clear
SCaMPR
SCaMPR and MRMS
2023/02/25 - 00:50:00 UTC
SCaMPR Precipitation Rate
MRMS Precipitation Rate
MRMS Precipitation Type
Rain-Rate [mm/h]
Trop. Conv.
Trop. Strat
Cool Strat.
Hail
Conv.
Snow
Strat.
Detection Performance
CD
FA
MD
SCaMPR
MRMS
Counts
Rain rate [mm/h]
SCaMPR [mm/h]
MRMS [mm/h]
T.Conv.
T.Strat.
C.Strat.
Hail
Conv.
Snow
Strat.
r : -0.03
RMSD : 2.4 mm/h
Bias : 1.0 mm/h
Rel. Bias: 1.29 dB
% Bias : 34.5 %
SCaMPR Version : v1r1
MRMS Version : v12.1
Created on: 02/25/2023 02:57:22 UTC

Potential Opportunities: SmallSats and Future Operational Sensors (e.g. TROPICS)

- MiRS extended to TROPICS TMS data (collaboration with TROPICS science team).
- NOAA QuickSounder/EDU (2025-2026)
- MiRS planned for EPS-SG/MWS (Q1 2025)
- Other opportunities:
  - TEMPEST-D (INCUS, 2026)
  - tomorrow.io (active PR constellation > 2025)
  - EPS-SG/MWI+ICI (Q4 2025)
  - Sterna (MW constellation ~ 2025 +)



Ref: *Yang et al., 2023: Atmospheric humidity and temperature sounding from the CubeSat TROPICS mission: Early performance evaluation with MiRS. Remote Sensing of Environment*



CMORPH1 Applications

Extreme Precipitation Climatology

- *Construction of extreme precipitation climatology enables the monitoring of extreme precipitation events (both heavy rainfall and drought) from a climate perspective.;*
- *Extreme precipitation climatology (99-, 95-, 90-pct, mean, % of raining days) constructed for each 0.25ºlat/lon grid and for each pentad period using CMORPH1 data from 1998 to 2017;*

Sample CMORPH1 1-day (left) and 7-day precipitation climatology for pentad 37 (June 30-July 04)

Top:

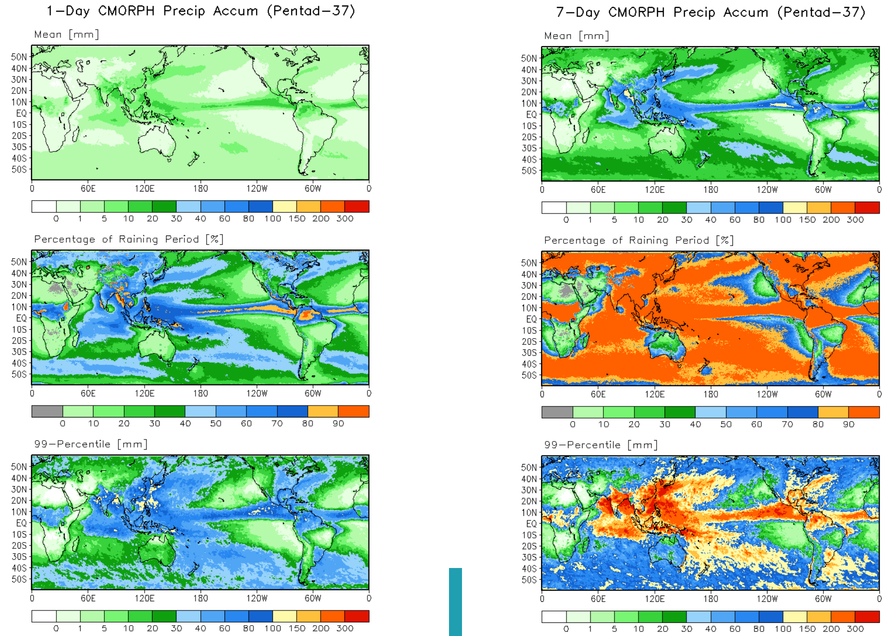
Mean precip;

Middle:

% of raining

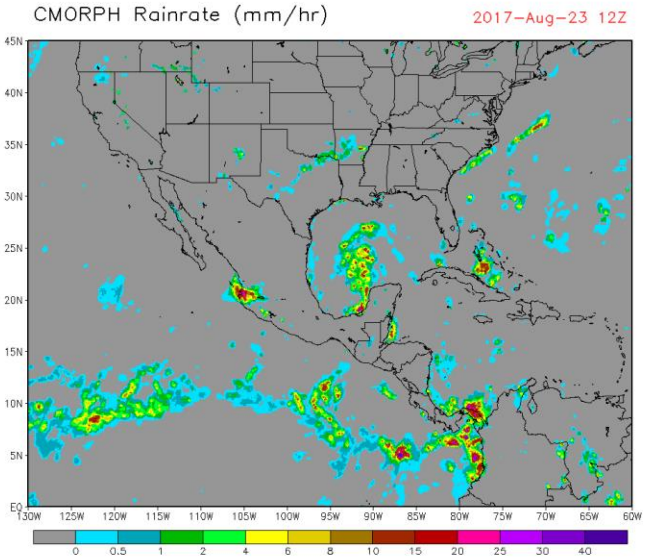
Bottom:

99 percentile

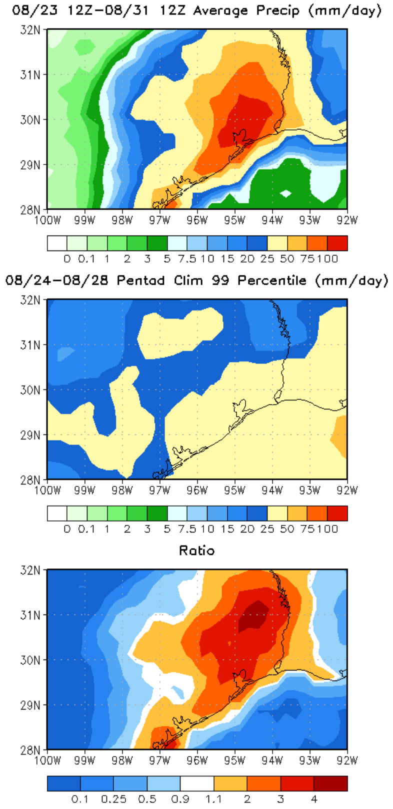


CMORPH1 Applications

Monitoring Hurricane Harvey



- *CMORPH captured Harvey precipitation and its evolution very well, over both land and ocean;*
- *Historical precipitation with the mean rate averaged over a 8 day period more than twice of the 99 percentile over a wide area over southern Texas*

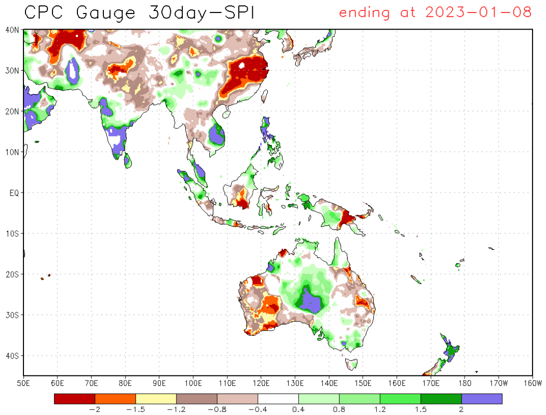


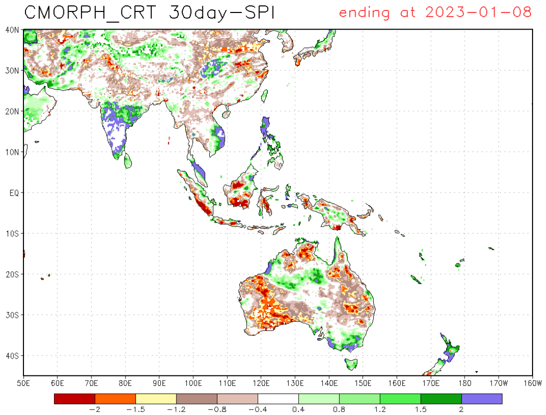
CMORPH1 Applications
Applications in the WMO / SWCEM Program

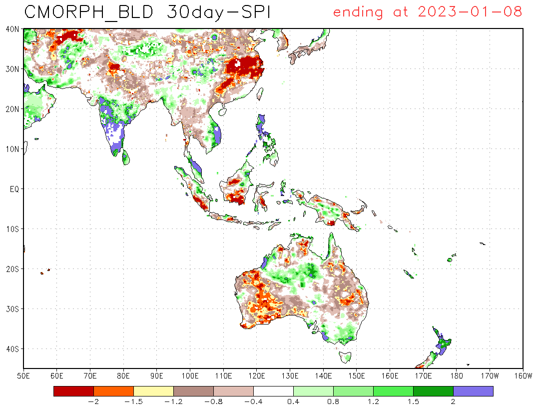
SPI 30-day ending at 2023.01.08

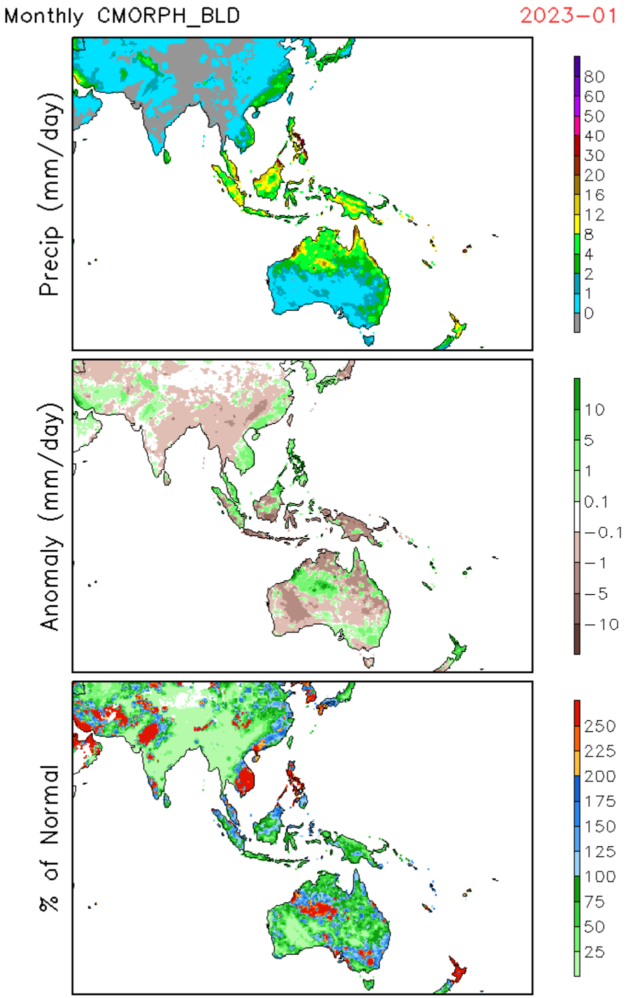
(left)
Derived from CPC Daily Gauge Analysis
(center)
Derived from CMORPH_CRT
(right)
Derived from CMORPH_BLD

- CMORPH1 satellite precipitation products provided to the WMO Space based Extreme Weather and Climate Extremes Monitoring (SWCEM) program for the monitoring of precipitation over Southeast Asia;
  - Weekly / Monthly summaries of precipitation extremes (heavy rainfall and drought)
  - https://ftp.cpc.ncep.noaa.gov/precip/PORT/SEMDP

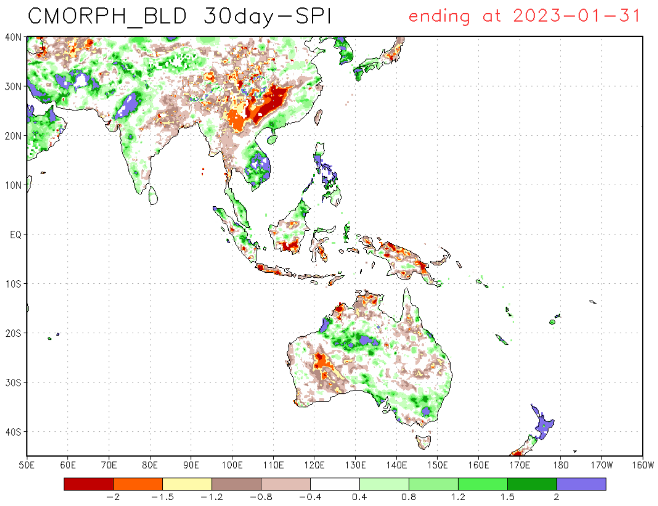




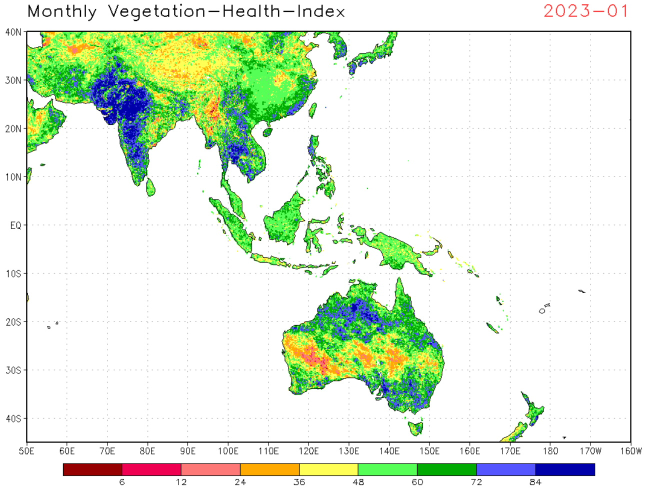




Monthly CMORPH_BLD
2023-01
Precip (mm/day)
80
60
50
40
30
20
16
12
8
4
2
1
0
Anomaly (mm/day)
10
5
1
0.1
-0.1
-1
-5
-10
% of Normal
250
225
200
175
150
125
100
75
50
25

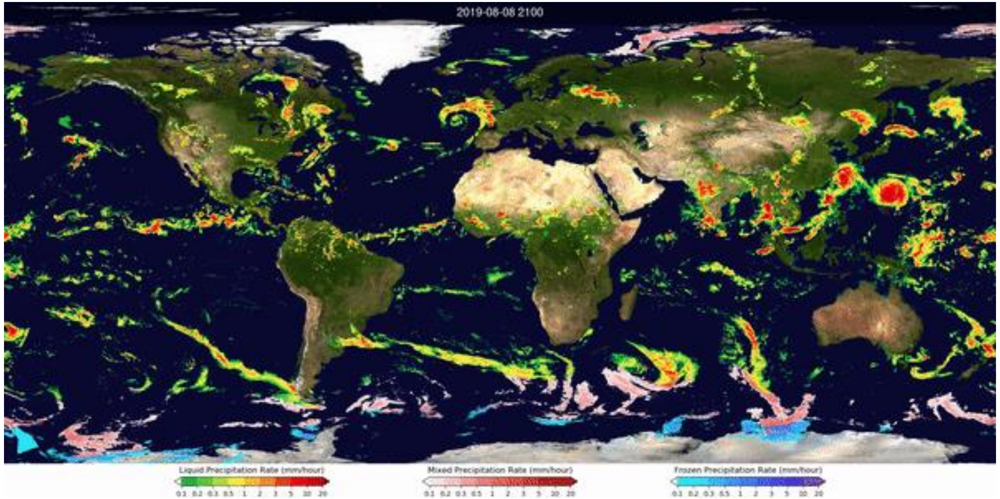


CMORPH_BLD 30day-SPI
ending at 2023-01-31
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50E 60E 70E 80E 90E 100E 110E 120E 130E 140E 150E 160E 170E 180 170W 160W
-2 -1.5 -1.2 -0.8 -0.4 0.4 0.8 1.2 1.5 2

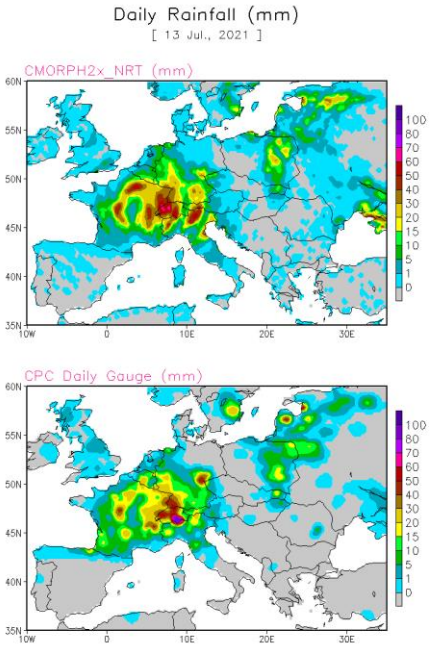


Monthly Vegetation-Health-Index
2023-01
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50E 60E 70E 80E 90E 100E 110E 120E 130E 140E 150E 160E 170E 180 170W 160W
6 12 24 36 48 60 72 84

Accumulated Precipitation Applications



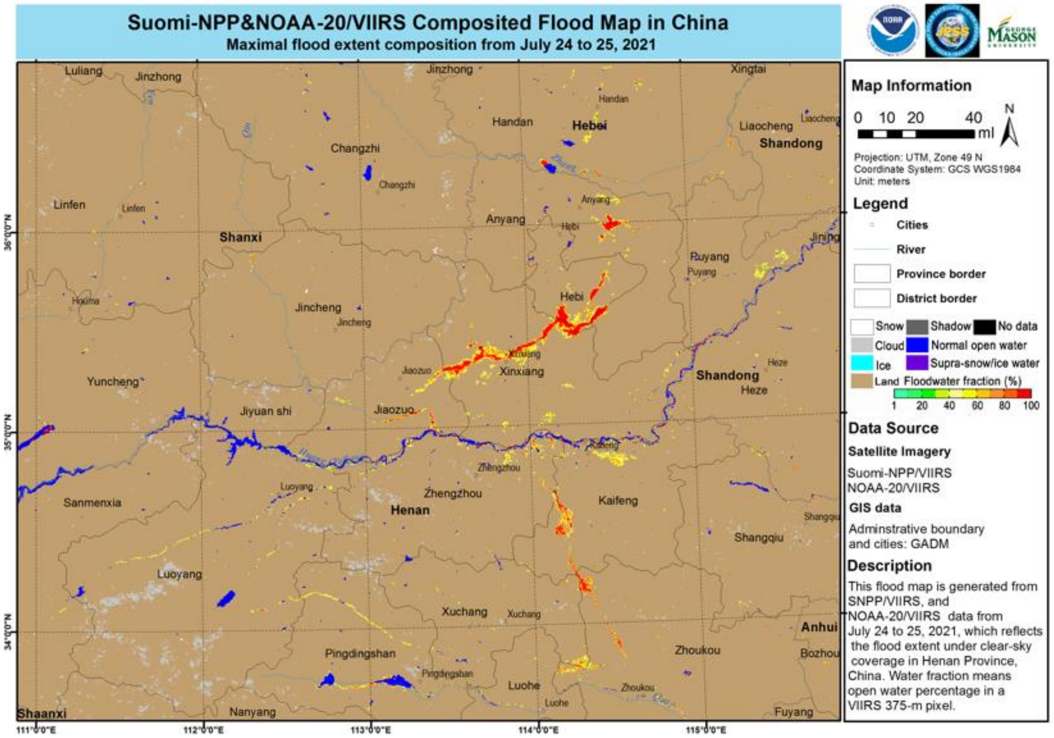
NOAA CPC CMORPH2 Precipitation Rate Product - 5 GEO and 12 LEO satellites – providing 30-minute temporal precipitation rates.

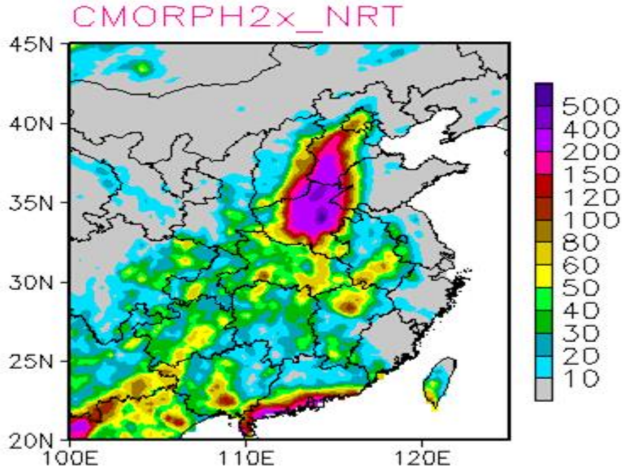


Europe Heavy Rain Event – July 13, 2021

Central China Heavy Rainfall

Accumulation over 17 – 21 July, 2021 (mm)

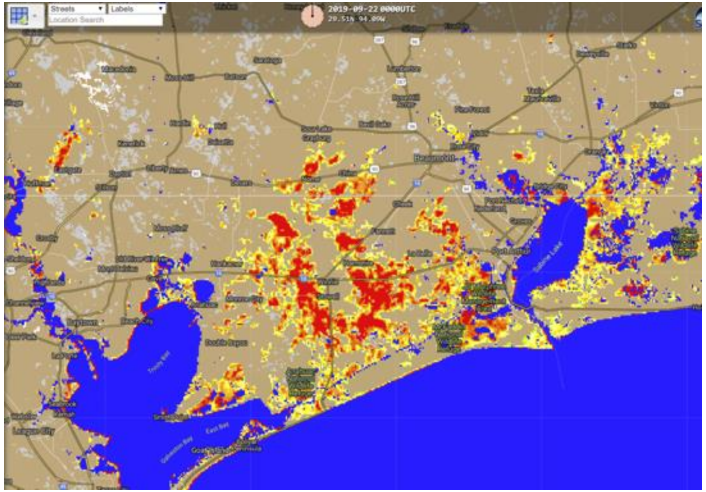


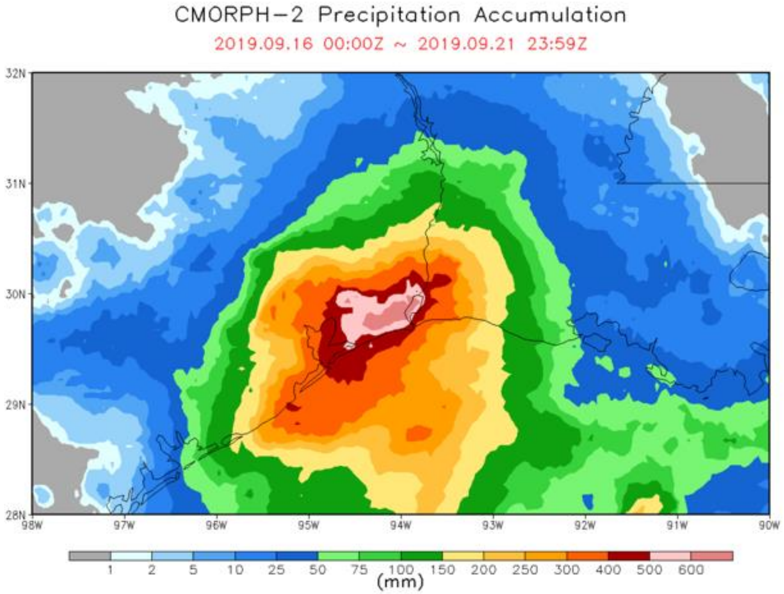


Zhengzhou, China

VIIRS 5-day flood composite vs 6-day accumulated precipitation from satellite-based CMORPH2

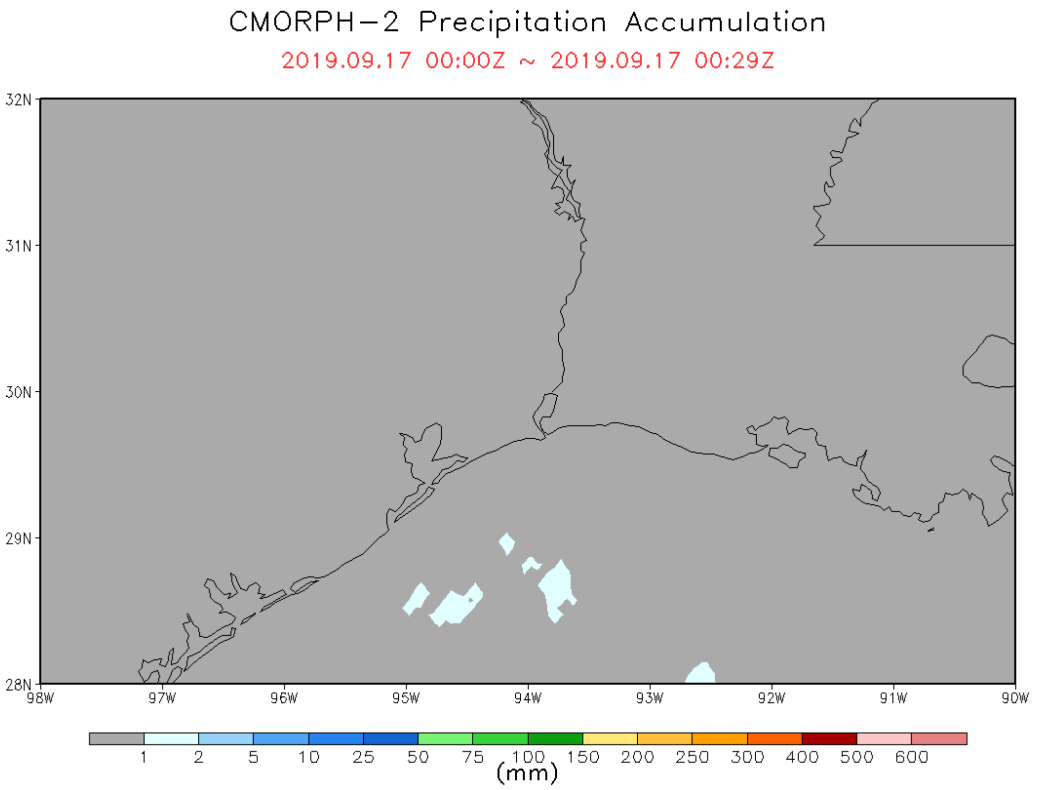
Tropical Storm Imelda



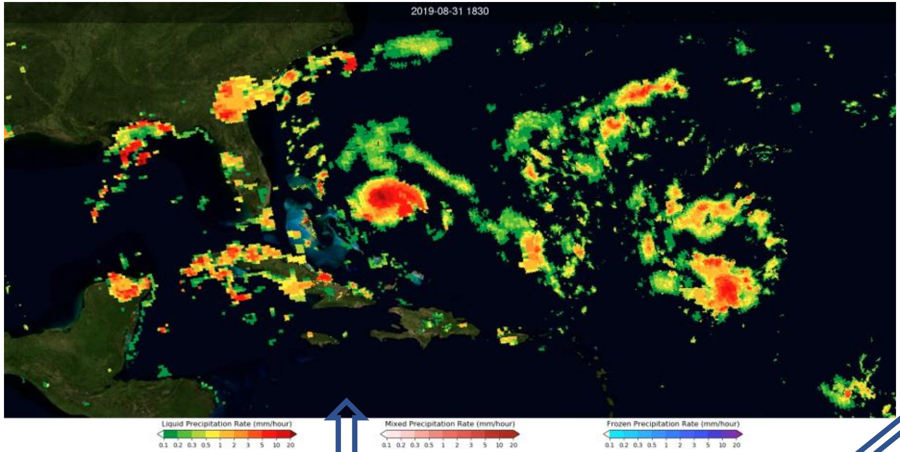


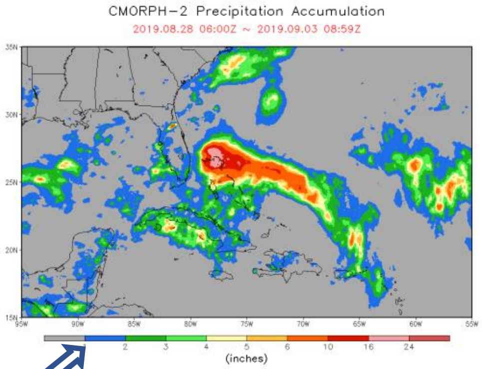
CMORPH2 Captured TS Imelda

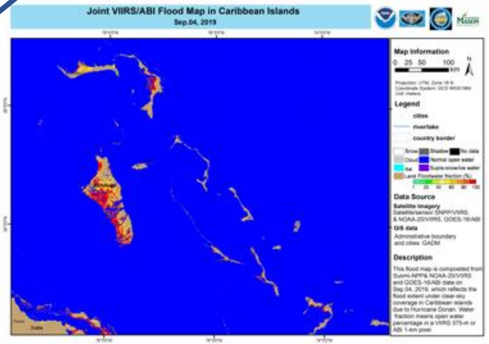
Accumulated Precipitation Since 00:00UTC, 17 Sept., 2019



Hydrology & Flood Proving Ground Initiatives Supporting Hurricane Dorian







Precipitation rate estimates (@ 30 minutes interval, 2-hour latency) derived from 12 LEO and 5 GEO satellites

Accumulated precipitation, nearly 2 feet of rainfall over Bahamas

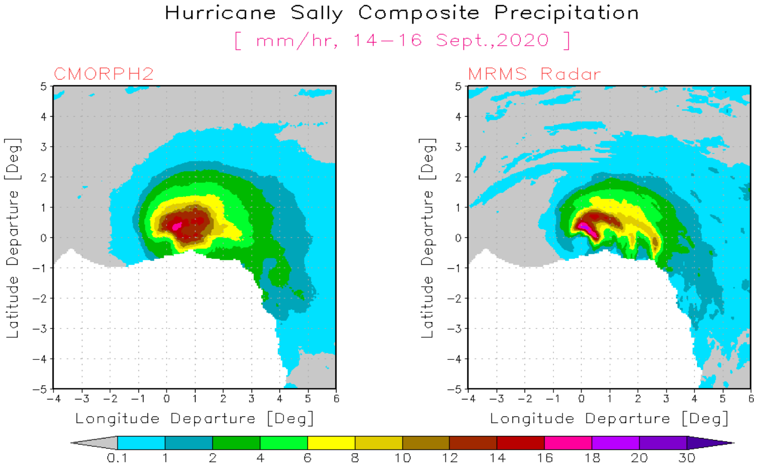
NOAA NESDIS response to International Disaster charter flood information for the Bahamas

17 Satellites!!

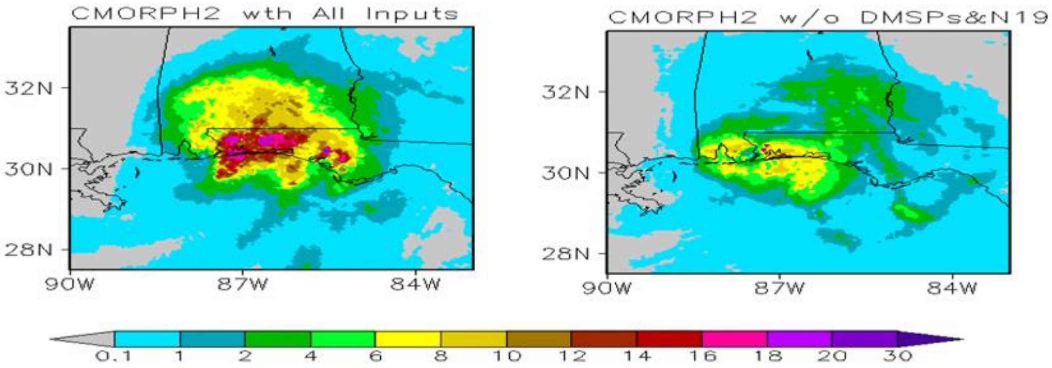
LEO Satellites: DMSP-16/17/18, NOAA-15/18/19/20, SNPP, METOP-A/B, GCOM-W1, and GPM

GEO Satellites: Himawari-8 (141E), GOES-17 (137W),GOES-16 (75W),Meteosat-11 (0-deg), Meteosat-8 (41.5E)

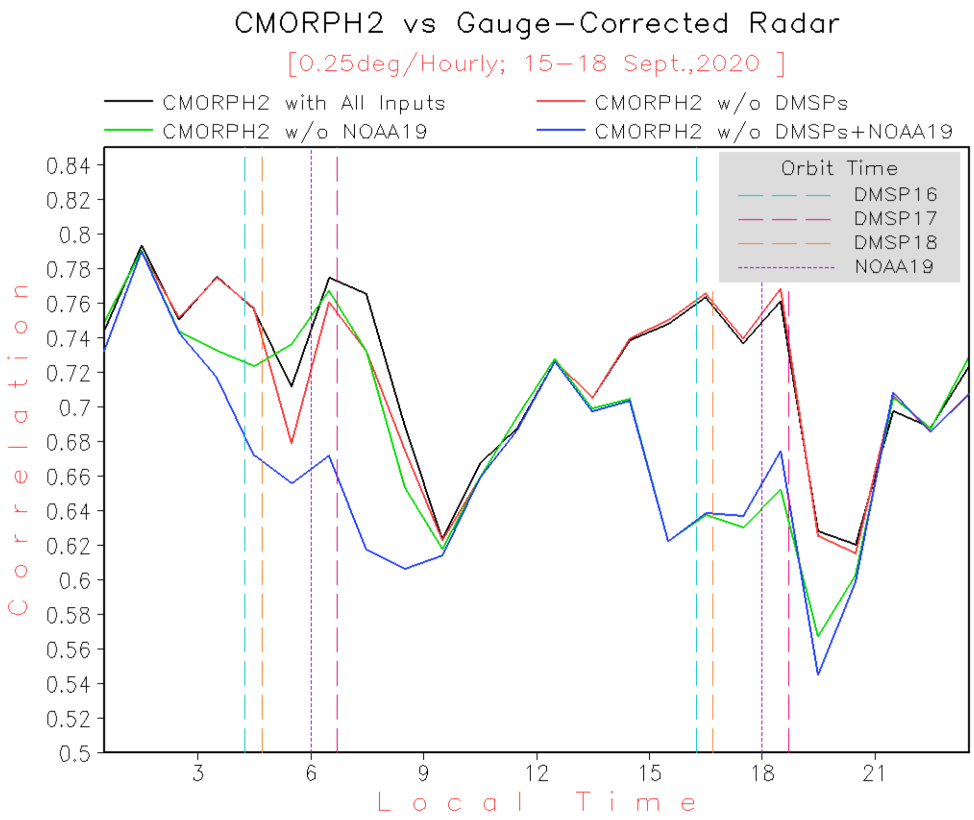
Temporal Coverage from PMW is important. Hurricane Sally example:



CMORPH2 for 11Z, 16 September 2020. ~ 6 AM



CMORPH2 – Stage IV 6-Hourly Precipitation Correlation

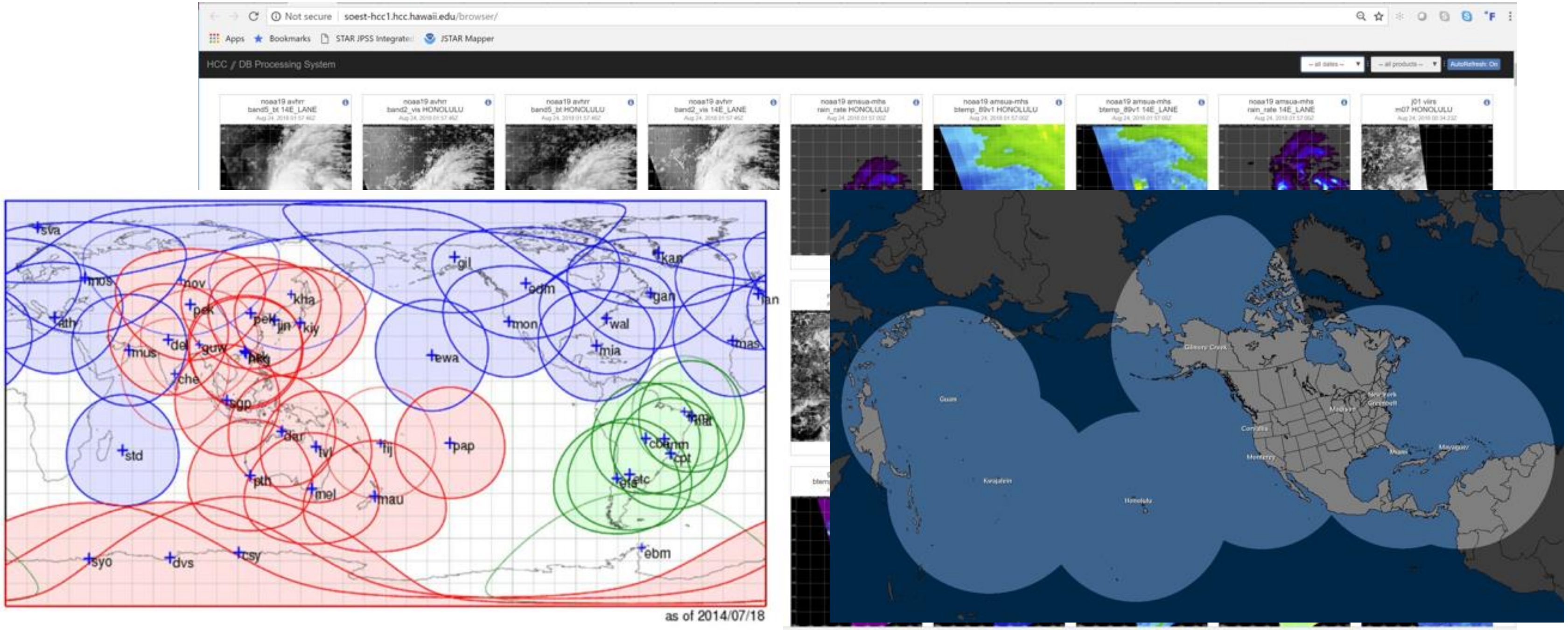


Dropping satellites with PMW sensors would cause substantial degrade in the quantitative accuracy of CMORPH satellite precipitation estimates, compromising capacity to monitor the heavy precipitation.

Concluding remarks

- According to current plans the constellation looks healthy.
- Need to increase our efforts in user engagement and user understanding – we need to develop the applications that will mitigate impacts of weather and climate on societies.
- We need to improve our access to real-time products for emergency response. Different applications have different latency requirements.
- We need to continue to provide training and we need to continue to learn from our users.
- Ultimately latency will always be a driving need, therefore new approach like space data relays should be considered to reduce latency from LEO satellites, or existing approaches such as direct broadcast should continue. LEO missions should include a low latency (< 15 minutes) option.

Direct Broadcast Provides Real-time Information



From International Precipitation WG

Key Point 1: Constellation Continuity

Maintaining a constellation of satellite sensors is fundamental to provide the necessary temporal and spatial sampling to properly capture the variability of precipitation. To address this requirement:

- Missions that provide core, high-quality passive microwave observations across a wide range of frequencies (e.g. AMSR-2/3, GMI category), to act as standard references for:

- Contributing missions, that augment passive microwave observations between the core missions, each providing well-calibrated, multi-channel observations;

- Satellite-based precipitation-capable radars (e.g. GPM DPR and CloudSat CPR) to provide a calibration source for the above passive microwave radiometers, and a climate data record for extreme events and precipitation types that are inherently difficult for passive microwave sensors to detect.

- The organisation of these sensors into complementary syn-synchronous orbits is crucial to provide observations across the diurnal period to avoid duplication of observations, or observation-poor periods.

-Continuity of observations from deprecated, but still functioning sensors: The IPWG recognizes the value of these continued observations to augment the prime constellation at different times of day as their orbits drift.

Key point 2: Value of Geostationary Observations

The contribution of information from Infrared observations, primarily from Geostationary sensors, is invaluable for providing regular information on cloud development and movement which can be combined with passive (and active) microwave retrievals to provide high spatial and temporal resolution precipitation products.

- The contribution and continuation of the global infrared composite product, derived from all available geostationary sensors, is crucial for providing the infrared data for the above combined precipitation products.

- As an input to the above, the provision of observations over the Indian Ocean is a crucial component of the global infrared product: IPWG recognises the challenges and appreciates the achievements of providing continuing observations over this region.

- The expansion of the global infrared data set to include the geostationary water vapour channel is deemed extremely important for further improving the combined products: the IPWG supports the inclusion of this information.

Key Point 3: New technologies

Development of new technologies provides exciting new opportunities, although the full impact of these upon global precipitation estimates have yet to be fully determined: initial results from missions, such as the TROPICS pathfinder cubesat are very promising. However,

- integration of such missions into the greater constellation needs to be fully analysed, (e.g. related to impacts on temporal sampling);

- calibration and long termlong-term stability of such sensors and their derived products, particularly in climate data records;

- impact of channel selection: cubesats typically exploit the high-frequencies due to the need for smaller antennas – this impacts their response to precipitation.