Second Generation CMORPH: Where We Are and What Challenges We Are Facing

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with
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Precipitation Estimation from LEO Satellites: Retrievals and Applications
1 March, 2023

2nd Generation CMORPH Overview
1) Main Features

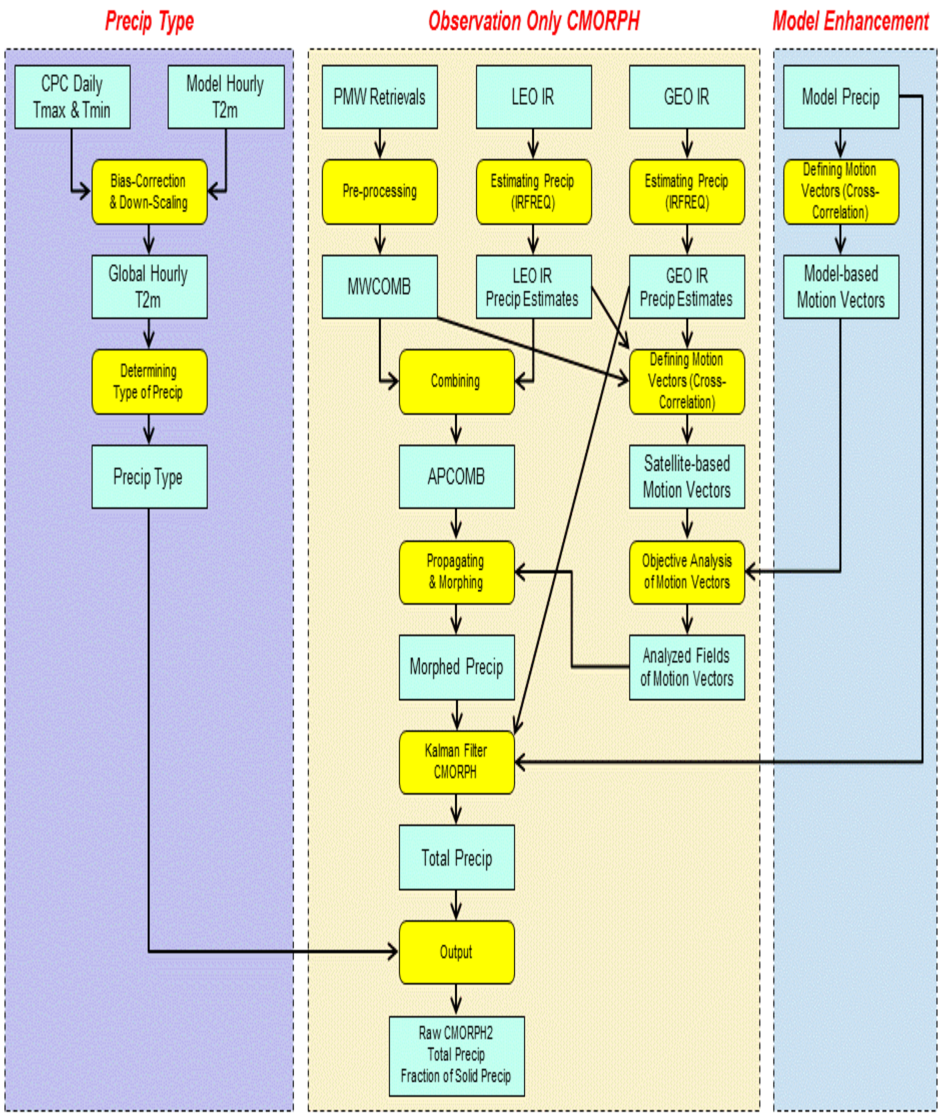
- **CMORPH**
  - *CPC Morphing technique;*
  - *High-resolution global precipitation estimates constructed by integrating information from multiple GEO and LEO satellites*

- **Main Features of CMORPH2**
  - *High spatial / temporal resolution (0.05^{o}lat/lon / 30-min) infused with PMW retrievals from LEO satellites and IR observations from LEO & GEO platforms*
  - *Complete global coverage (90^{o}S-90^{o}N)*
  - *Low production latency (One hour, updated once every 30 minutes until 12-hour latency)*
  - *Greatly improved representation of cold season precipitation (snowfall) thanks to the SFR retrievals from NESDIS/STAR;*
  - *In addition to the total precipitation, fraction of solid precipitation also estimated (quantitative estimation of snowfall)*

2nd Generation CMORPH Overview

2) Inputs / Algorithms Upgrades

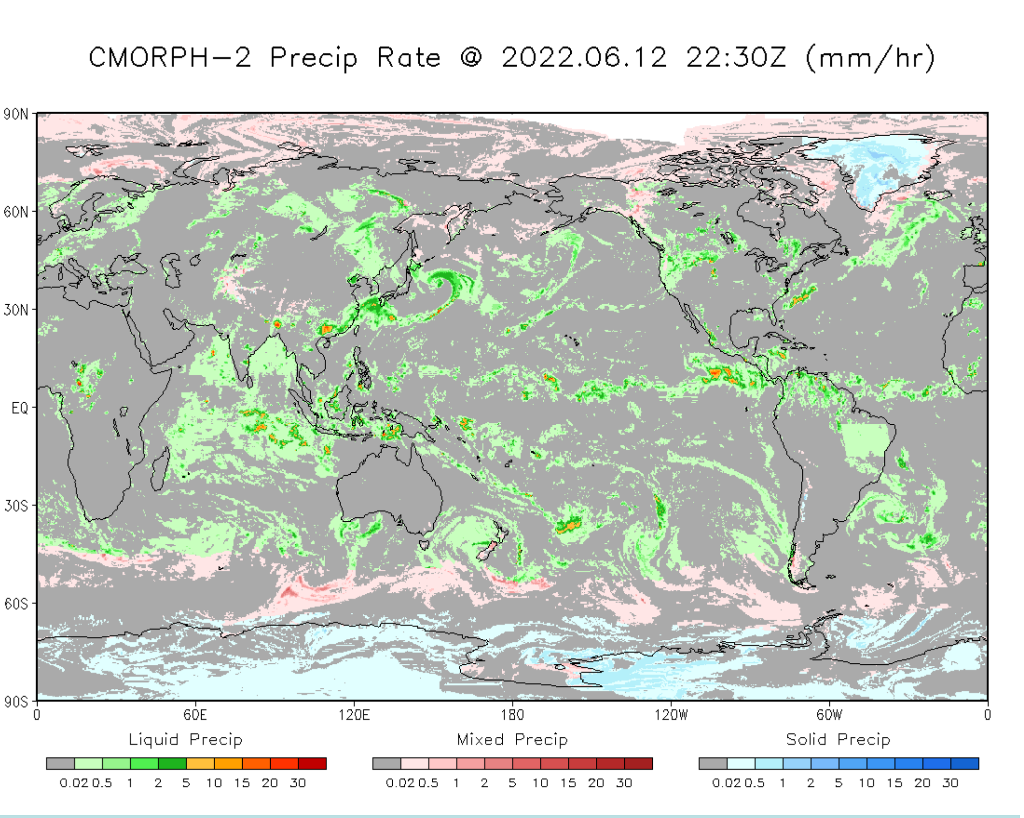
- Improved input Level 2 satellite retrievals of rainfall and snowfall from NASA and NESDIS/STAR
- Satellite IR based precipitation estimates developed / refined at NOAA/CPC
- Greatly refined integration algorithm at NOAA/CPC
  - *Inter-satellite calibration algorithm*
  - *Precipitation motion vectors*
  - *Kalman Filter analysis framework*
- Newly added technique to determine fraction of solid precipitation from surface meteorology (T_{2m} et al) through collaboration with FSU
  - *Global hourly T_{2m} analysis*



CMORPH2 Real-Time Production

1) Overview

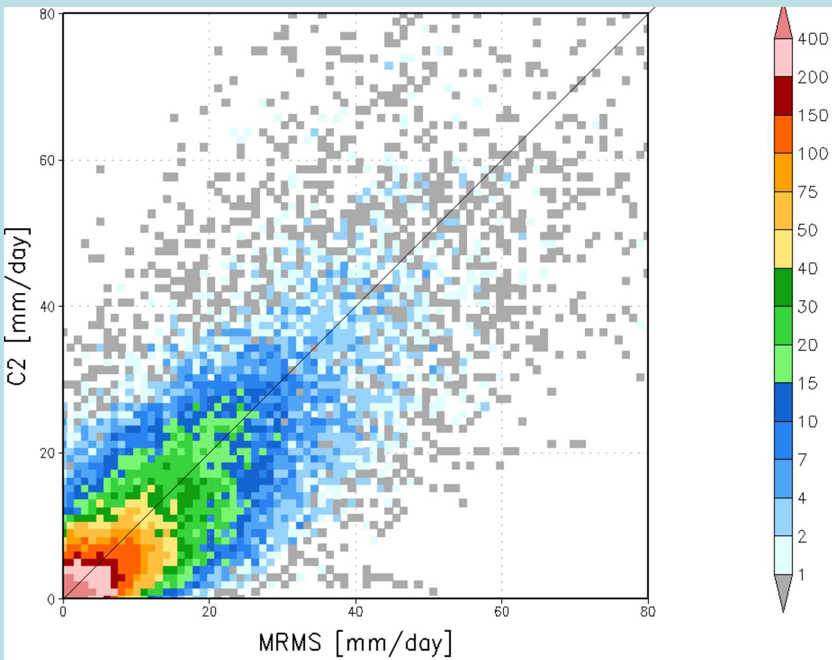
- Started real-time production in April 2017 on development workstations;
- **Migrated to a NWS standard operational environment (Compute Farm, CF) maintained 7/24 by NCEP/NCEP in December 2022;**
- Production Schedule
  - *Generated at a latency of* ***one hour****;*
  - *Updated once every* ***30 min*** *with newly available inputs until* ***12 hours*** *latency;*
- Pushed to:
  - AWC for inputs to the EPOCH;
  - WPC to monitor hurricanes and tropical weather;
  - ESSIC as apart of a JPSS AWIPS package
  - NESDIS/STAR for public release;
  - RealEarth serving various end users;



CMORPH2 Real-Time Production

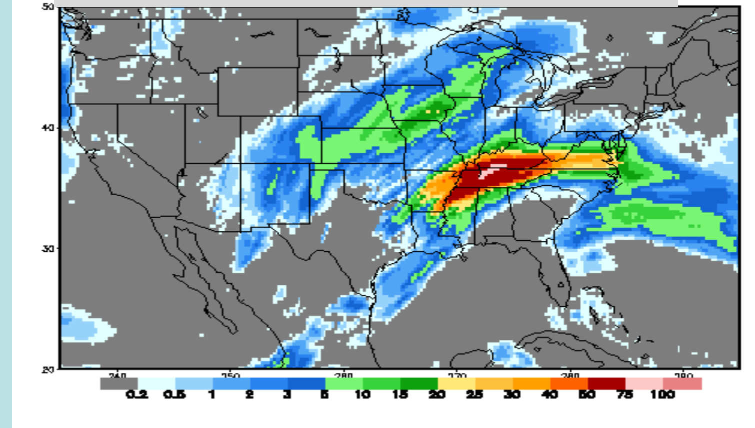
2) Snow Storm Case of Feb., 2019

CMORPH2 NRT captured the precipitation associated with the winter storm of February 2019 very well, with a correlation of **0.753** for daily precipitation over a 0.25^{o}lat/lon grid box.

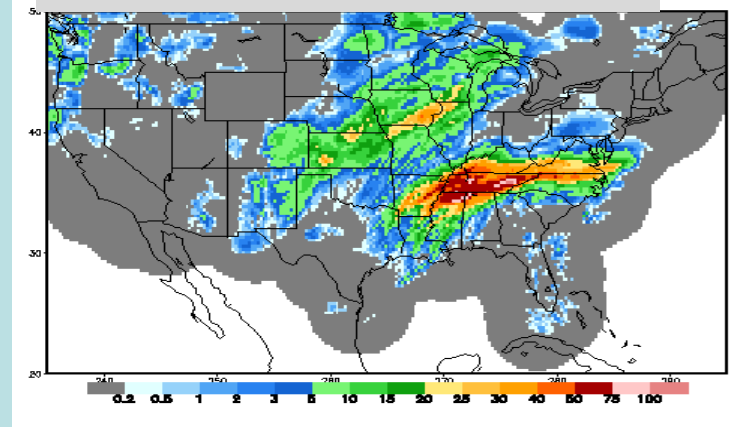


Scatter density plots between the MRMS radar observations (X-axis) and CMORPH2_NRT estimates (Y-axis) of daily precipitation over 0.25^{o}lat/lon grid boxes over the CONUS for 1 – 28 February, 2019.

CMORPH2_NRT



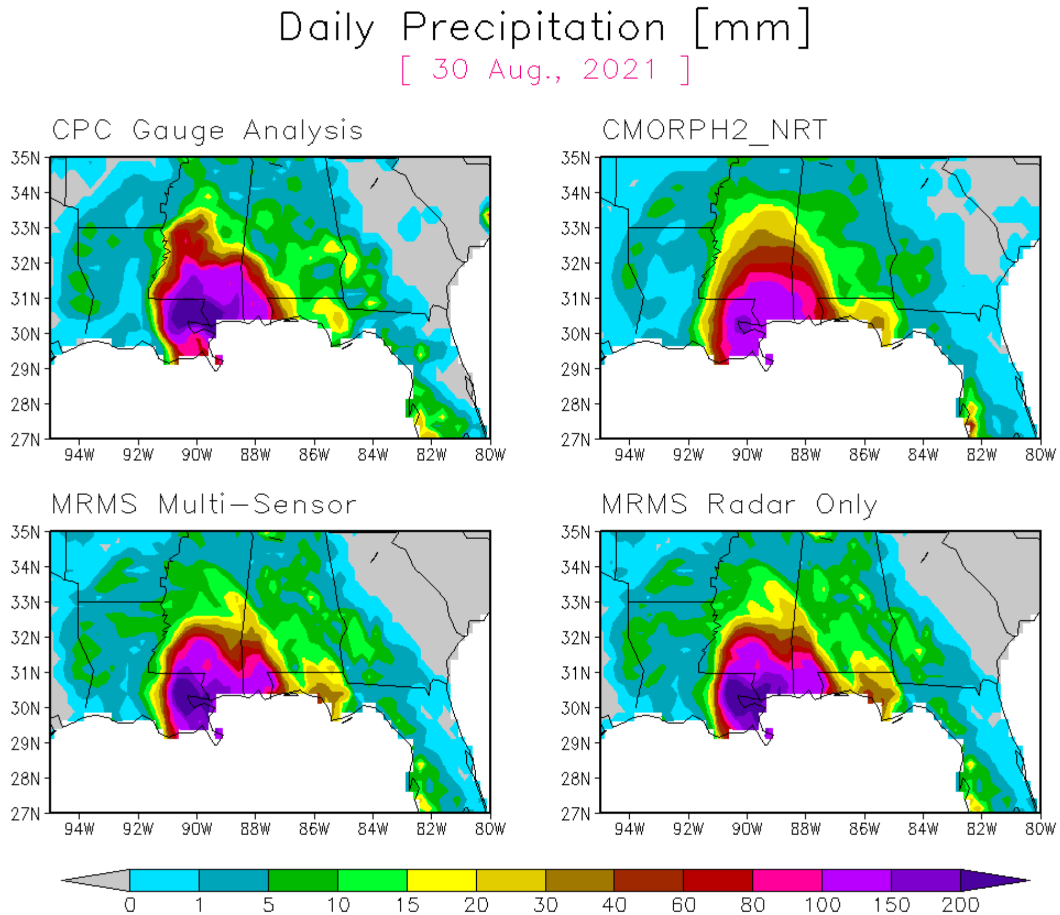
MRMS Radar Estimates

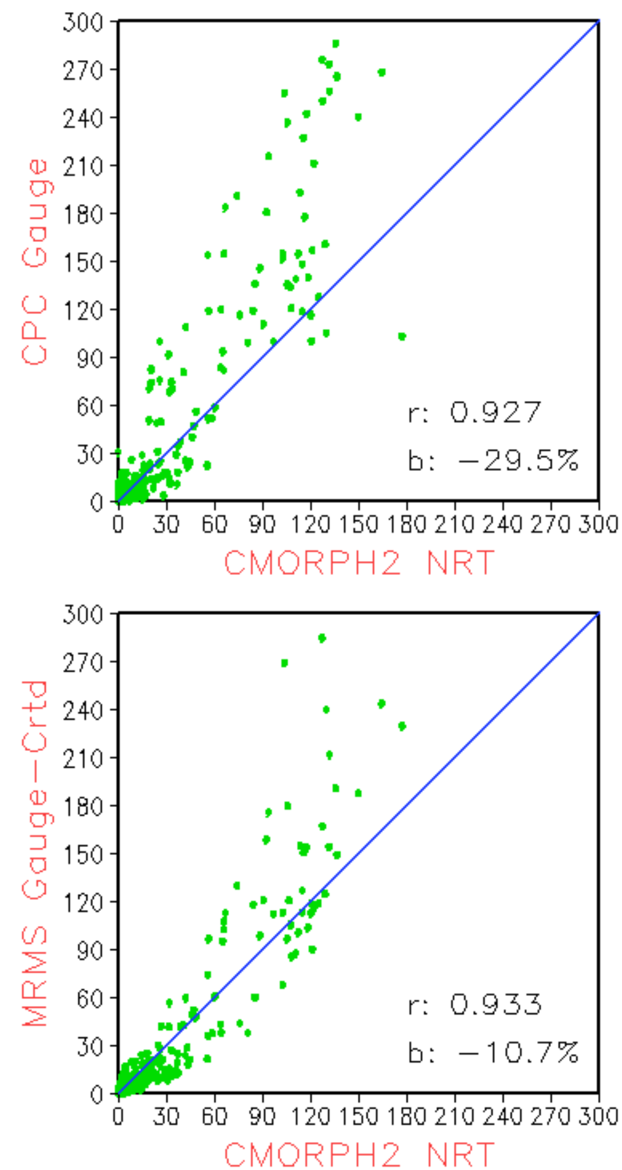


Daily precipitation (mm) for 23 Feb.,2019, derived from CMORPH2 NRT production (top), and MRMS radar observations (bottom)

CMORPH2 Real-Time Production

3) Hurricane Ida: Landing on 30 Aug., 2021





(top) *Da ily precipitation (mm) from (top-left) CPC daily gauge analysis; (top-right) CMORPH2_NRT; (bottom-left) MRMS Multi-Sensor; and (bottom-right) MRMS Radar-Only.*
(Right) *Scatter plots between CMORPH2 NRT and CPC gauge (top) / MRMS Multi-Sensor (bottom) for daily precipitation on a 0.25^{o}lat/lon grid box.*

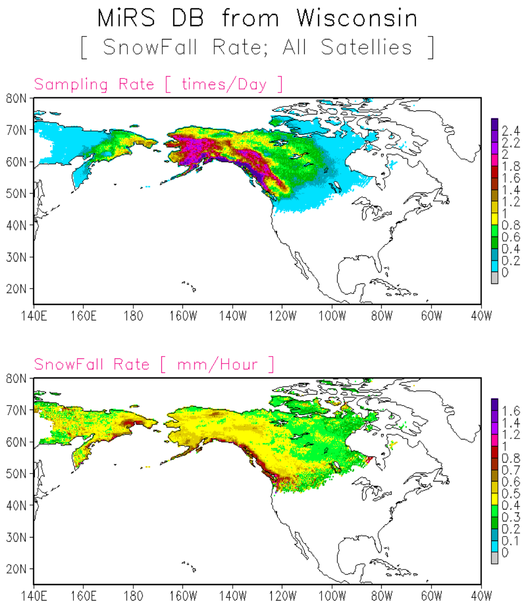
Ongoing Work

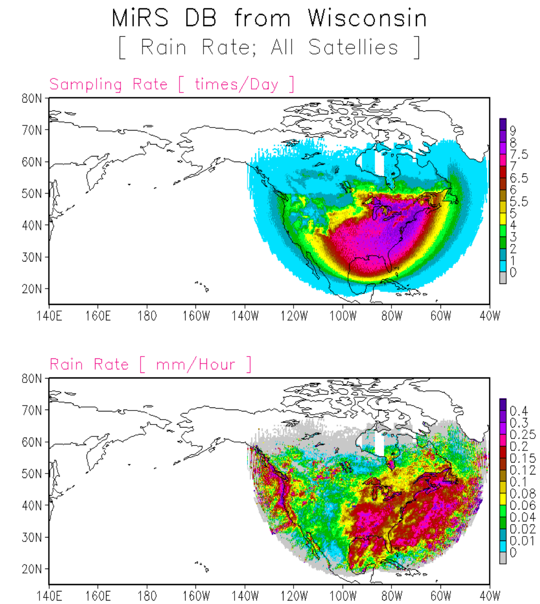
1) Real-Time Production

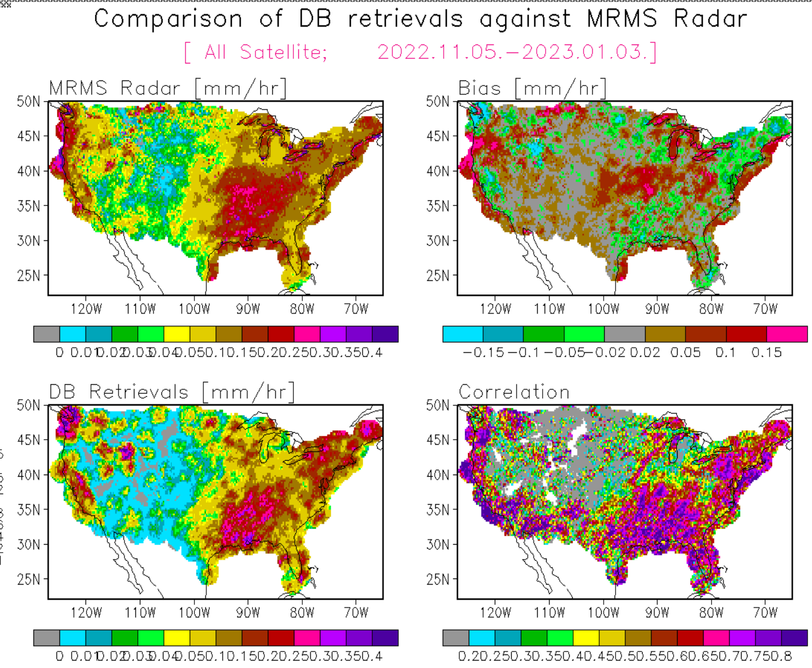
- Migrating the real-time production system to the NOAA super-computer system (WCOSS2) for further enhance production efficiency and stability;
- Infusing Level 2 PMW precipitation retrievals from Direct Broadcast (DB) to further reduce the production latency and improve the quality of the short-latency productions;
- Installing the bias correction procedures to the CMORPH2 real-time production system;
  - *Algorithm developed;*
    - PDF matching against CPC daily gauge analysis over land;
    - Calibration against GPCP V3.2 over ocean;
  - Sub-system constructed offline and tested successfully;

Ongoing Work

2) Preliminary Work on DB Infusion



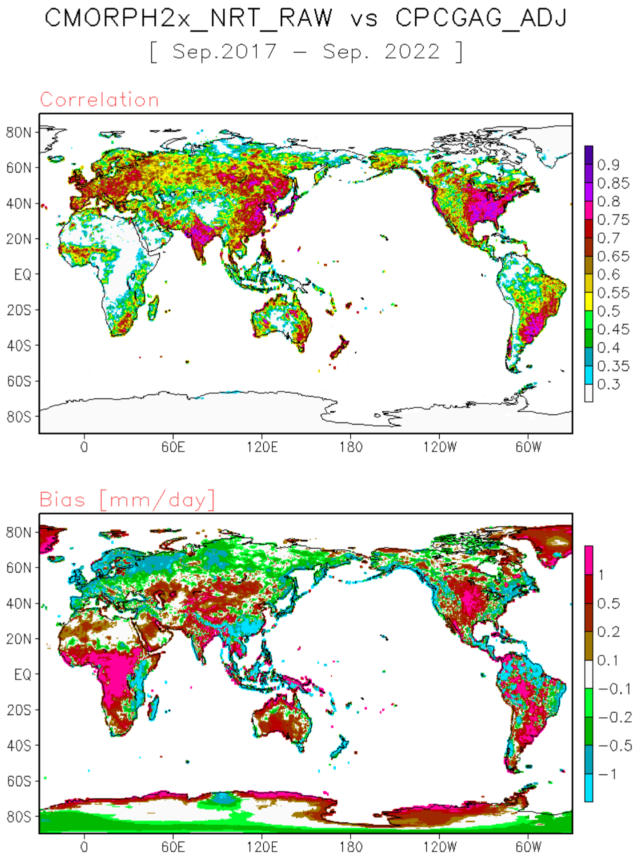


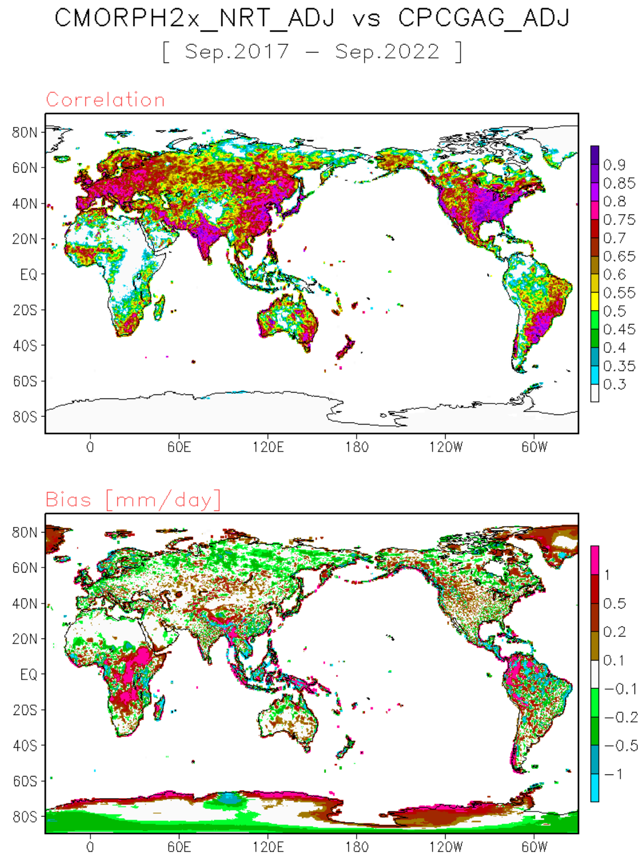


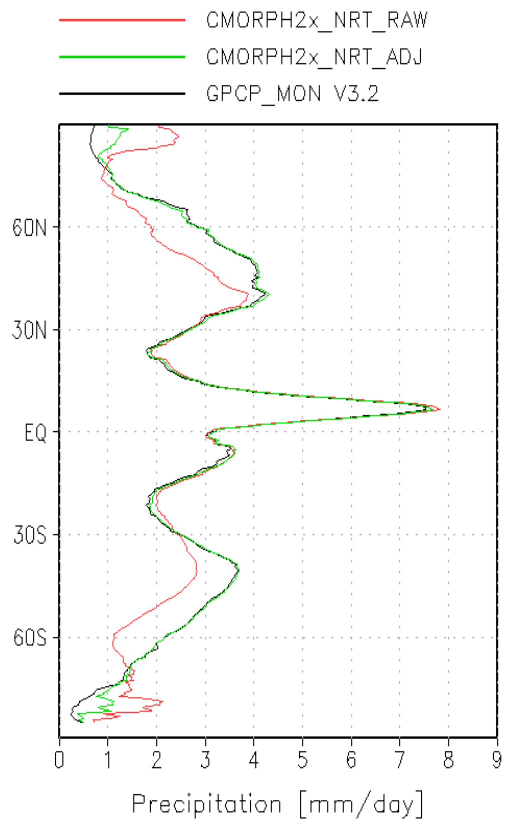
- *(Left) Spatial coverage of DB SFR retrievals from GINA;*
- *(Middle) Spatial coverage of DB RainRate retrievals from SSEC;*
- *(Right) Correlation between DB rain rate retrievals and MRMS radar 30-min precipitation over a 0.25^{o}lat/lon grid box;*
- ➔
- *DB Level 2 retrievals available from 5 satellites at a latency of 10-20 minutes;*
- *Quality of DB retrievals are similar to those of regular productions;*
- *Quite promising to reduce the CMORPH2 production latency to ~45 minutes (if computational resources appropriate) and substantially improve the quality of short-latency CMORPH2;*

Ongoing Work

3) Bias Correction Offline Test Results





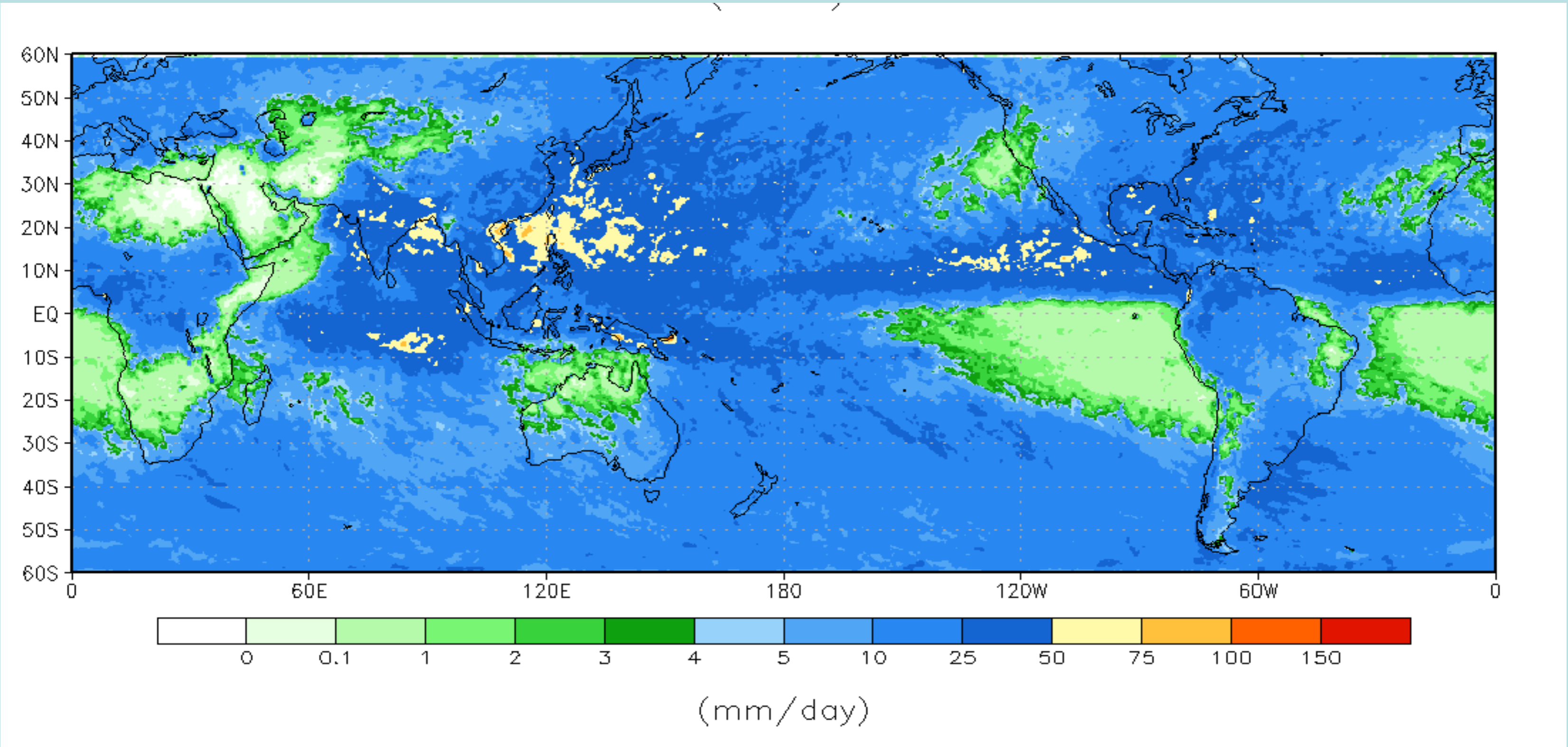


- *Large-scale bias in the raw CMORPH2 (left) is removed almost completely after PDF matching against daily gauge analysis (middle);*
- *Correlation with daily gauge analysis is improved after the bias correction (left and middle figures, top panels);*
- *Over ocean, magnitude of precipitation is very close to GPCP 3.2 after the calibration (bottom);*

Ongoing Work

4) Constructing Retrospective Analysis from 1991

- Construction of a retrospective analysis is of critical importance to many applications:
  - *Weather / climate monitoring;*
  - *Extreme intensity (heavy / droughts) quantifications;*
  - *Weather / hydrology models trainings;*
- Construction for 1998 to the present started;
- Preliminary investigation for 1991 to 1997;
- *Sample 99 percentile pentad mean precipitation for pentad 44 (24-28 August) using CMORPH1;*



Challenges

1) Issues with the Input Level 2 PMW

- Purely from Level 3 products developers' selfish point of view;

- Saturation for heavy rainfall;

- Under-estimation for orographic rainfall / snowfall;
  - Should we solve this problem at Level 2 or Level 3 stage?

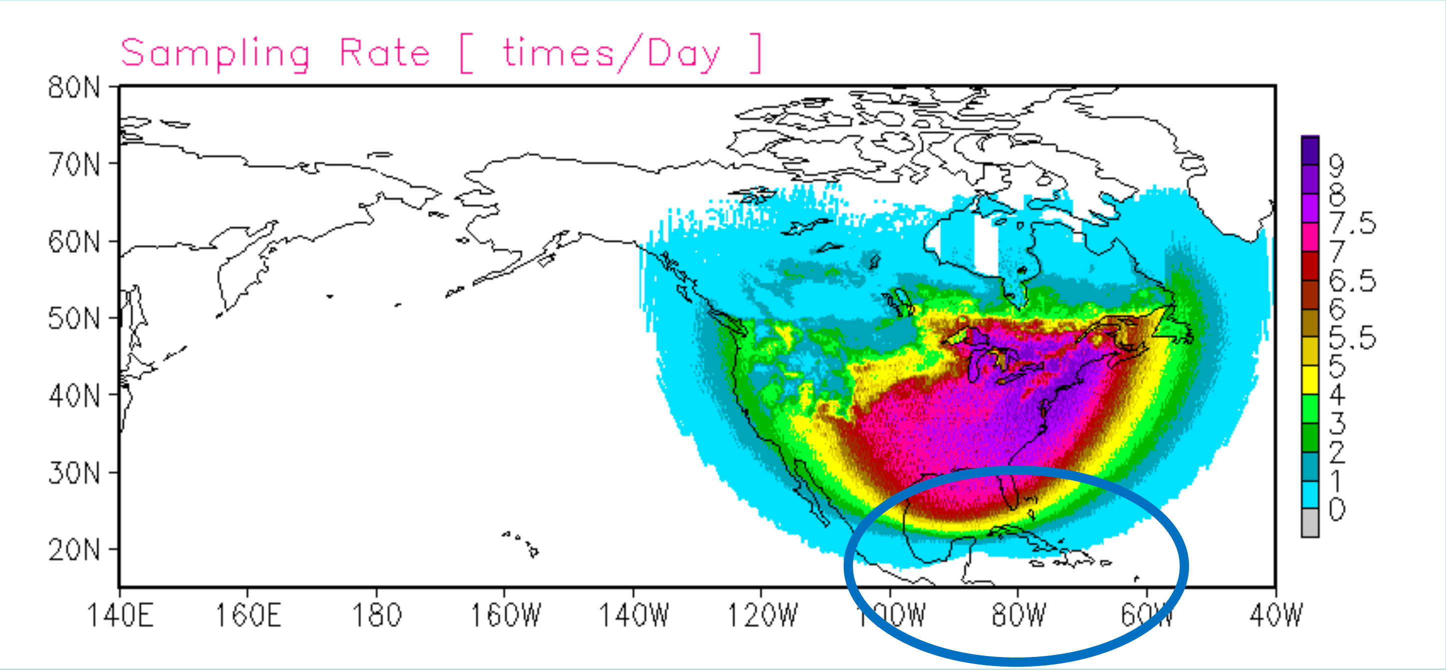
- Snowfall and mixed precipitation retrievals
  - Further improved quality;
  - Consistent retrievals of rain rate, snowfall rate, and mixed precipitation

- Light rain detectability / estimation for probability of zero rain
  - *Some algorithms already include such an estimation for zero rain retrievals;*
  - *Level 3 processing needs the probability information to perform inter-calibration (converting zero rain to a non-zero value);*

Challenges

2) Reducing Real-time Production Latency for L2 Retrievals

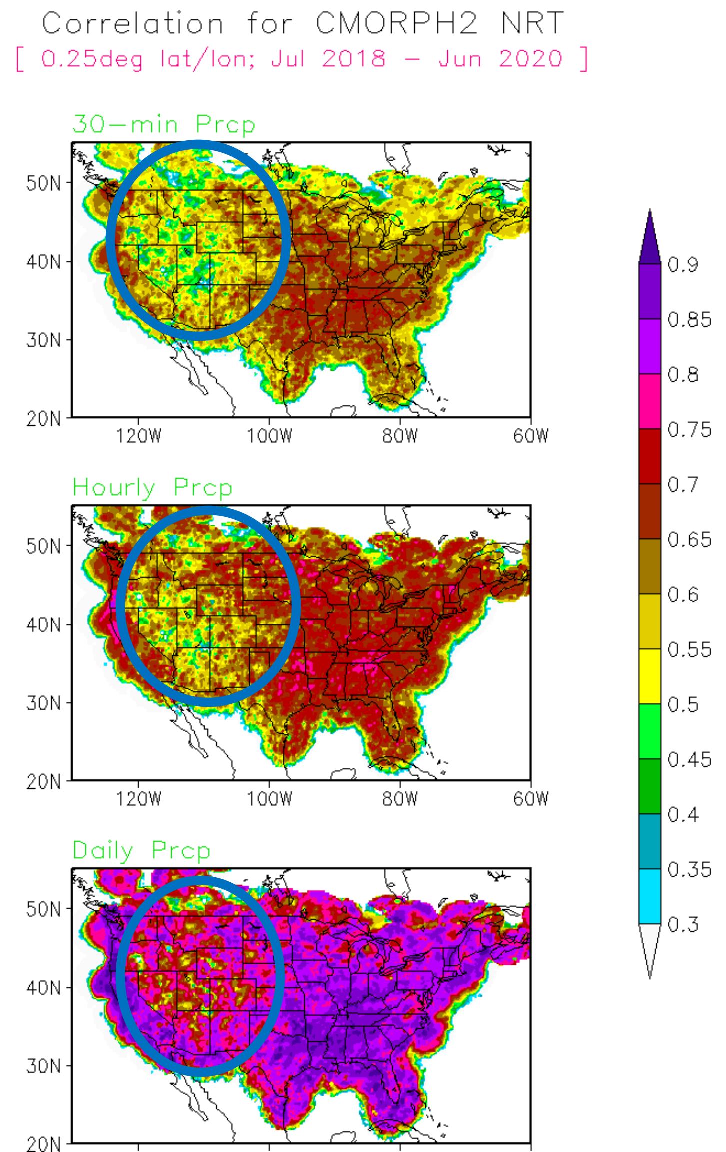
- Many applications of satellite precipitation products requires a latency of < one hour;
- Ensuring availability of DB retrievals for key regions is of critical importance;
- Seamless transition from observation-based short-latency monitoring to (mostly model-driven) nowcasting?



Challenges

3) Leveraging Strength of the Radar, Satellite, (and even) Numerical Modeling Technology

- Enhancing the collaborations among the communities of radar observations, satellite estimations and numerical modeling;
- Working on topics beyond inter-comparison and verifications to improve the QPE / QPF over challenging regions such as mountainous areas over the western CONUS;
- **Should we create a mechanism under the JPSS to facilitate the collaborations?**
- *Right figure: Correlation between CMORPH2 and MRMS radar precipitation;*

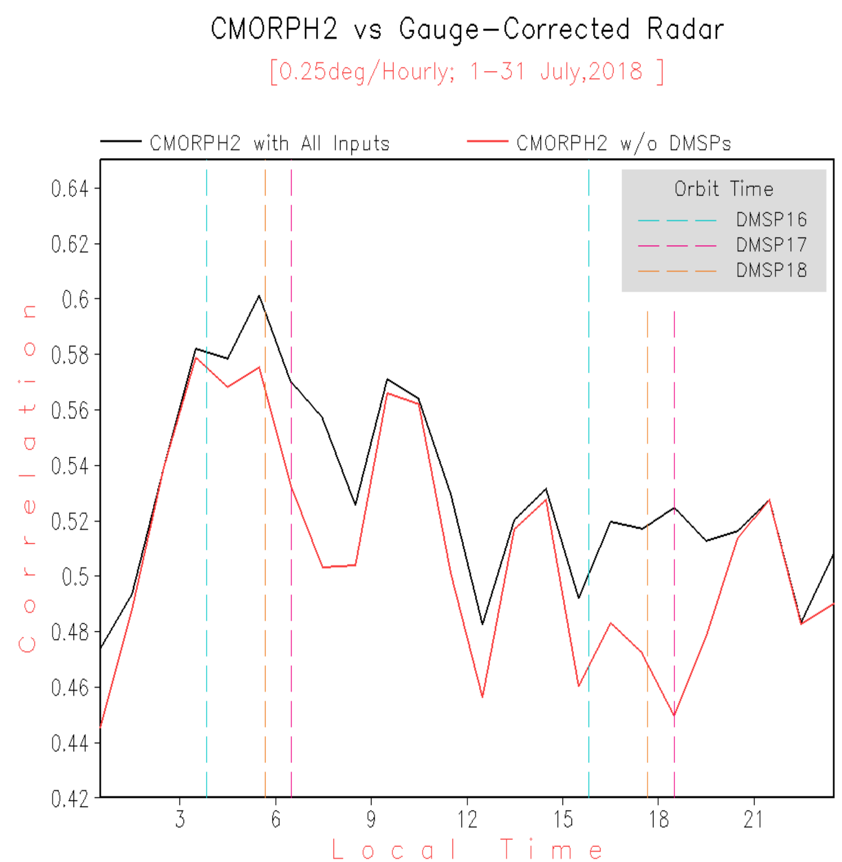


Challenges

4) Long-Term Stability of a Evenly Spacing 5+-GEO System and a PMW Sensor Carrying LEO Constellation

- At least 5 geostationary satellites are needed to provide seamless coverage of cloud and water vapor measurements over the tropics and sub-tropics in an temporal interval no longer than one hour (ideally 30 minutes or less);

- A constellation of >=10 PMW sensor carrying LEO platforms needs to capture the rapidly evolving storms and other disaster causing weather precipitation systems;
  - *At least one core satellite on a precessing orbit with a suite of advanced active and passive instruments serving as the calibrator;*
  - *Gaps between two satellite visits should be less than 2 hours (ideally <1 hour);*
  - *Enhanced observations for hours of expected strong convections (local later afternoon / early evening)*



When PMW retrievals from the three DMSP satellites are dropped (red line), correlation for CMORPH2 satellite precipitation estimates degraded substantially over and around the hours of DMSP satellite orbit times;

Challenges

5) Establishing CDRs of Stable Versions

- Climate applications require the creation of a long-term homogeneous record for an extended period (ideally >= 30 years);

- Such applications are often based on a set of climatology fixed for many years (e.g. WMO updates its official 30-year climate normal period once every 10 years);

- ***While it is important to continuously improving the retrieval algorithms, it is also crucial to maintain the production of a matured version of algorithm level for an extensive period before the base period switches;***

Challenges

6) Interactions with Users

- User interface (web page and ftp site) is poor, especially for CMORPH;

- Need to coordinate our efforts to better serve our users:

  - *Improved web pages / data portals;*
  - *Prompt reactions to significant ongoing weather / climate / hydrology events;*
  - *Easy-to-access archives of historical data;*
  - *Collection of prominent historical cases and their analysis;*
  - *Looking at a event from multiple angles (not just precipitation);*