Second Generation CMORPH Integrated Satellite Global Precipitation Estimates

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2018.11.20.

Outline

- Objectives
- CMORPH Overview
- Second Generation CMORPH
- Illustrations and Verifications
- Summary

Objectives

- To introduce the second generation CMORPH integrated satellite pole-to-pole global precipitation estimates; and
- To get feedbacks from our CWB peers, and potential users on the CMORPH precipitation products

CMORPH Overview

1) Basic Notion & Flowchart

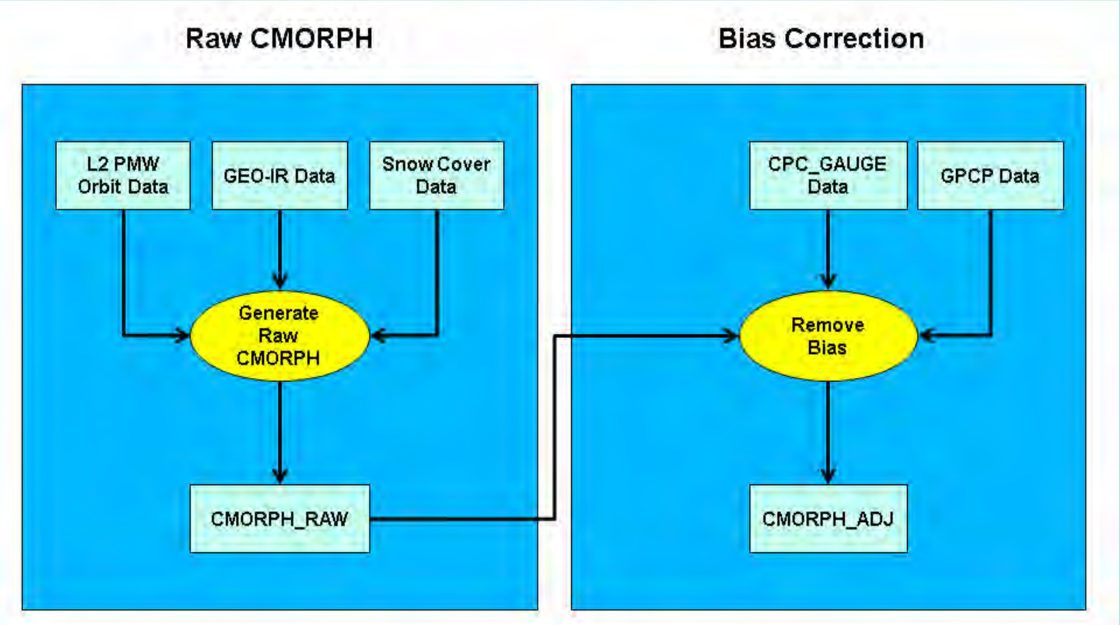
- CPC Morphing Technique

  Joyce et al. (2004),Joyce and Xie (2011), Xie and Joyce (2015), Xie et al. (2017)

- Basic Notion

  to construct a high-quality, high resolution precipitation analysis over the globe through integrating information from satellite observations as well as in situ measurements and model simulations

- Key Elements
  - *Satellite retrievals of instantaneous precip. rates from multi sensors*
  - *Cloud motion vectors to propagate the fields of instantaneous rates*
  - *In situ / long-term data to perform bias correction*



CMORPH Overview

2) First Generation CMORPH

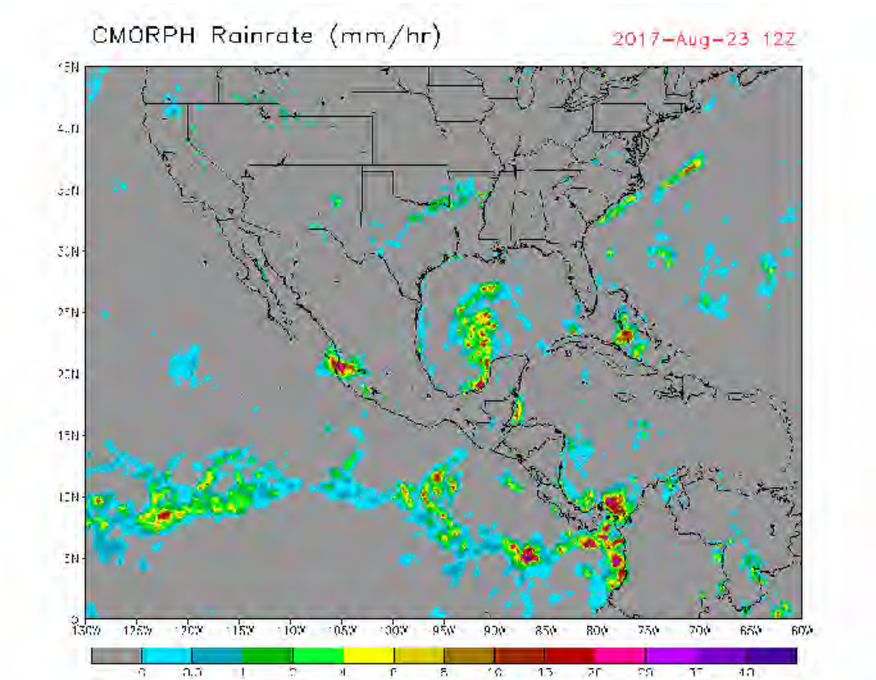
- Chronicle
  - *Real-time production: 2002*
  - *Bias correction: 2011*
  - *Reprocessing: 2014*

- Retrospective Products
  - *8kmx8km resolution over the globe from 60^oS-60^oN*
  - *30-min interval from 1998 to the present*

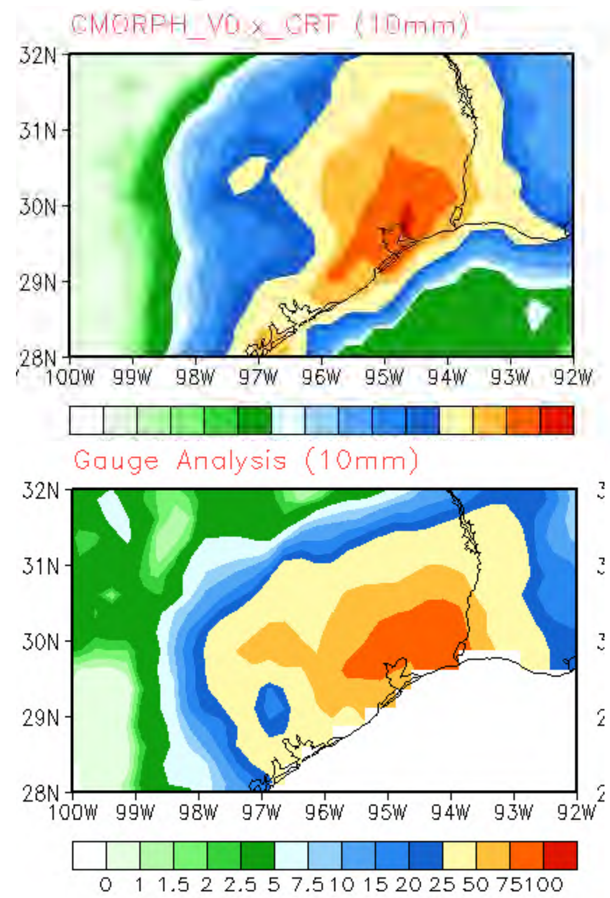
- Real-time Production
  - *Latency reduced to 2 hours*
  - *Updated every 30-min with newly available inputs until at a 12-hour latency*

CMORPH Overview

3) First Generation CMORPH Monitoring Hurricanes



30-min precipitation from the real-time first generation CMORPH



Total precipitation (10mm) accumulated over 23 – 31 August 2017, derived from (top) and the CPC gauge analysis, and (bottom).

CMORPH Overview

4) First Generation CMORPH Shortcomings

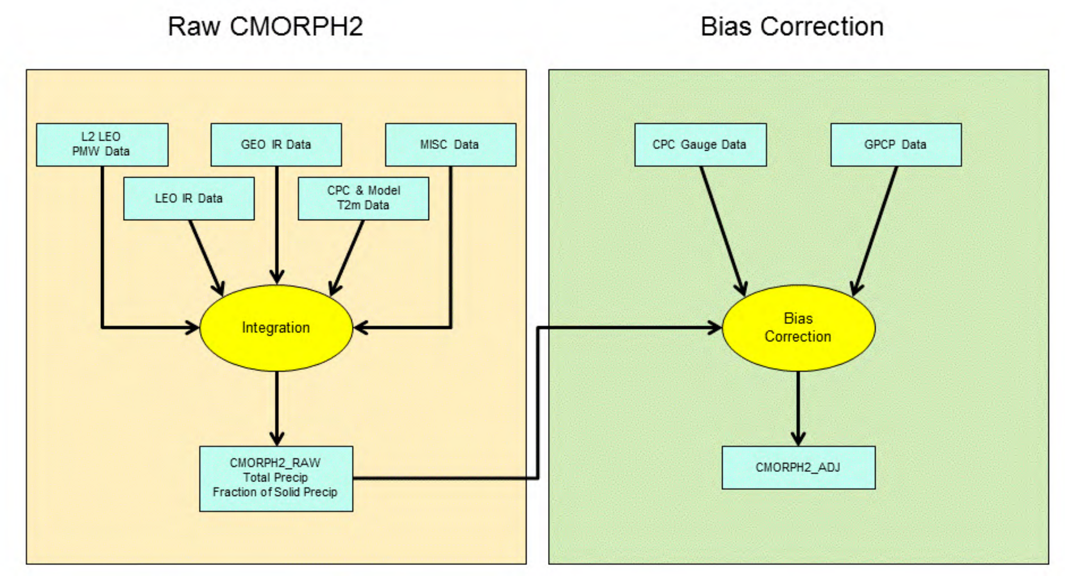
- Incomplete Global Coverage
  - *60°S-60°N*
  - *Restricted by the use of GEO IR to derive motion vectors*
- Compromised Representation of Cold Season Precipitation and Orographic Rainfall
  - *Restricted by poor performance of PMW retrievals*
  - *No inputs from numerical model simulations / forecasts*
- Information from GEO Platforms Not Fully Utilized
  - *Restricted by the ad-hoc integration framework*
  - *Only the IR images used to derive motion vectors*
  - *No GEO IR based precipitation estimates utilized as inputs*

Second Generation CMORPH

1) The Goals

- Pole to Pole Complete Global Coverage
  - *90^oS-90^oN*
  - *0.05^o lat/lon*
- Improved Representation of Cold Season Precipitation
  - *New Versions of PMW retrievals (MiRS et al)*
  - *PMW Snowfall Rate (SFR) retrievals (STAR/Huan Meng)*
  - *LEO IR based precipitation estimates (in-house)*
- Taking Full Advantage of GEO IR
  - *CPC GEO IR based precip est. infused*
- *Improved Presentation of orographic Rain*

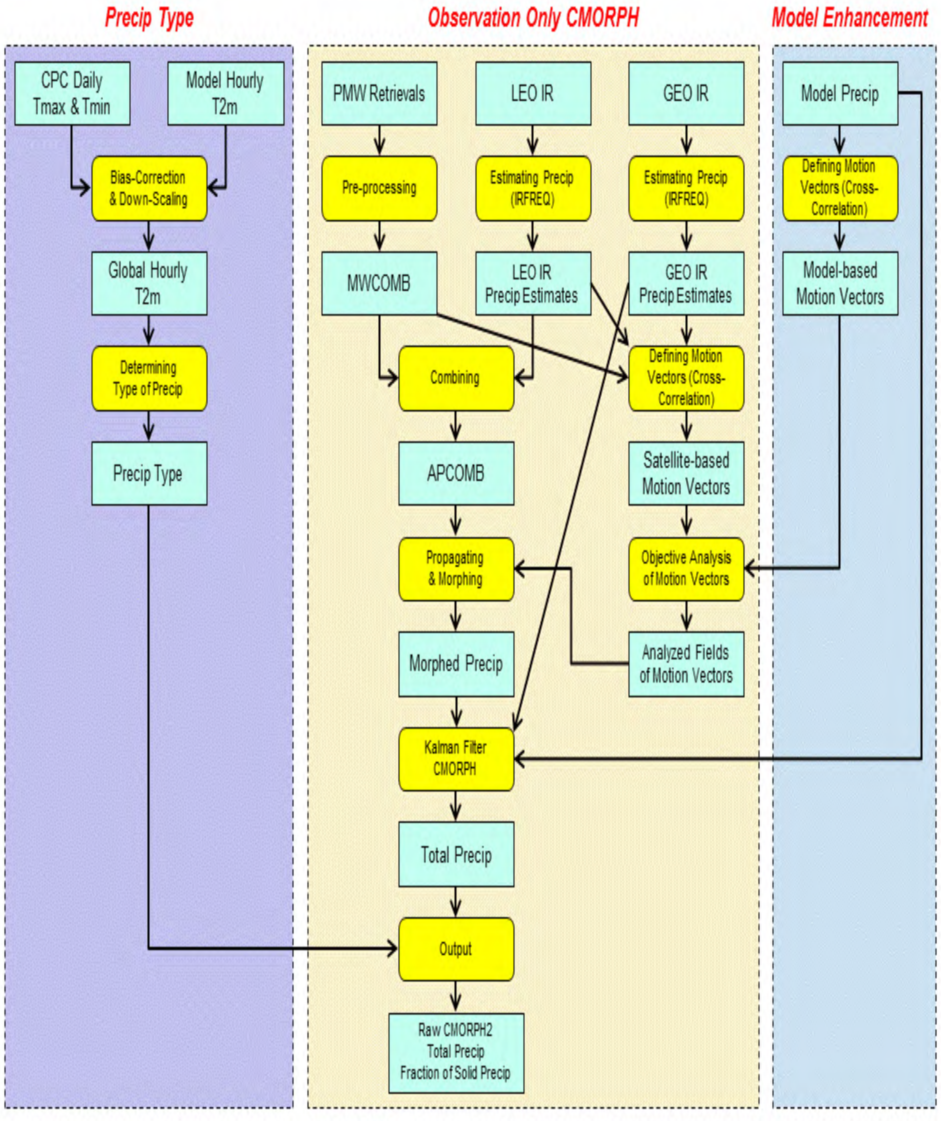
(not yet started working on this)



Second Generation CMORPH

2) Inputs / Algorithms Upgrades

- Improved input 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*



Second Generation CMORPH

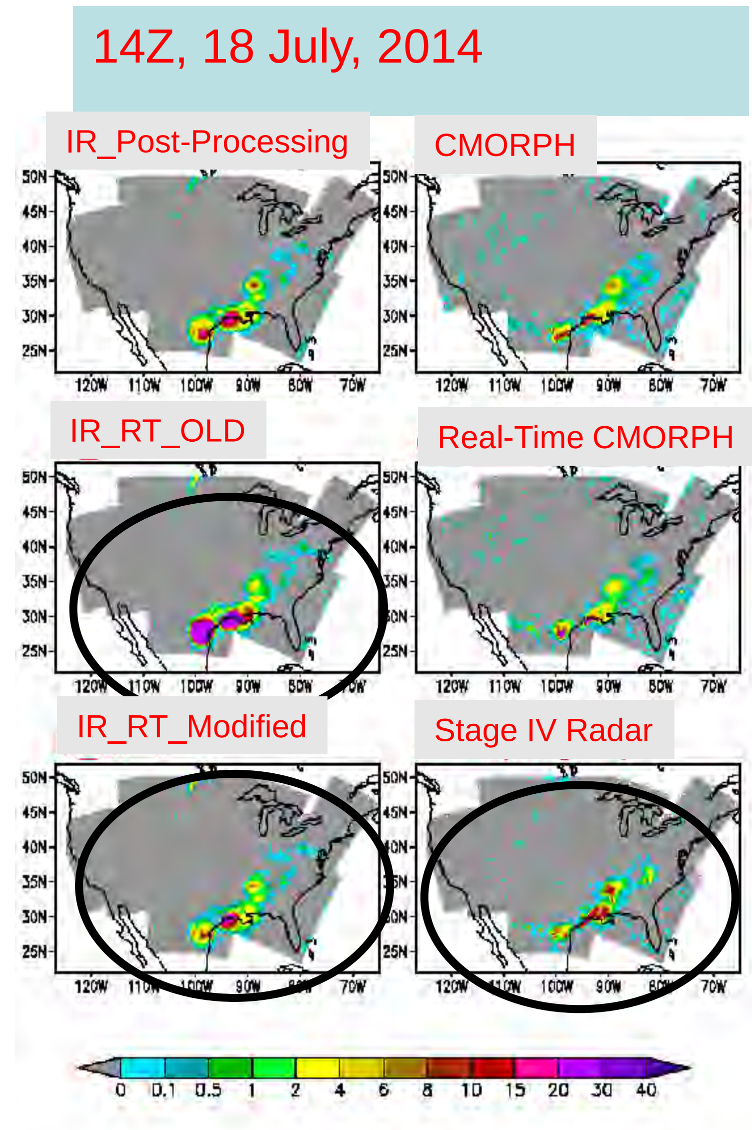
3) Key Algorithm Components Newly Developed

- GEO IR based precipitation estimates
  - *Xie et al. (2014) EGU*
- LEO IR (AVHRR) based precipitation estimates
  - *Joyce et al. (2016) IPWG*
  - *Joyce et al. (2017) AGU*
- Precipitating Cloud Motion Vectors Covering 90^{o}S-90^{o}N
  - *Xie et al. (2015) EGU*
- Kalman Filter based integration algorithm
  - *Joyce and Xie (2011) JHM*
- Determination of fraction of solid precipitation
  - *High-Resolution Global Hourly Surface Air Temperature Analysis*
  - *Fraction calculation algorithm*

Second Generation CMORPH

4) GEO IR based Precipitation Estimates

- **Based on the IRFREQ technique**
  - *PDF calibration against MWCOMB (combined microwave)*
  - *Post-processing PDF establishes using data for a 7-day period centering at the target date;*
  - *Diurnal cycle of precipitation – TBB considered;*
  - *Good performance in post processing **(left-top)***
- **Modifications for real-time**
  - *PDF tables defined using data for recent 7 days*
  - *Un-realistic TBB-precip relationship in real-time applications when weather regimes under rapid changes & MWCOMB for recent hours* not *available **(left-middle)***
  - *Real-time CMORPH for recent hours included to capture the rapid changing weather / precipitation regimes **(left-bottom)***



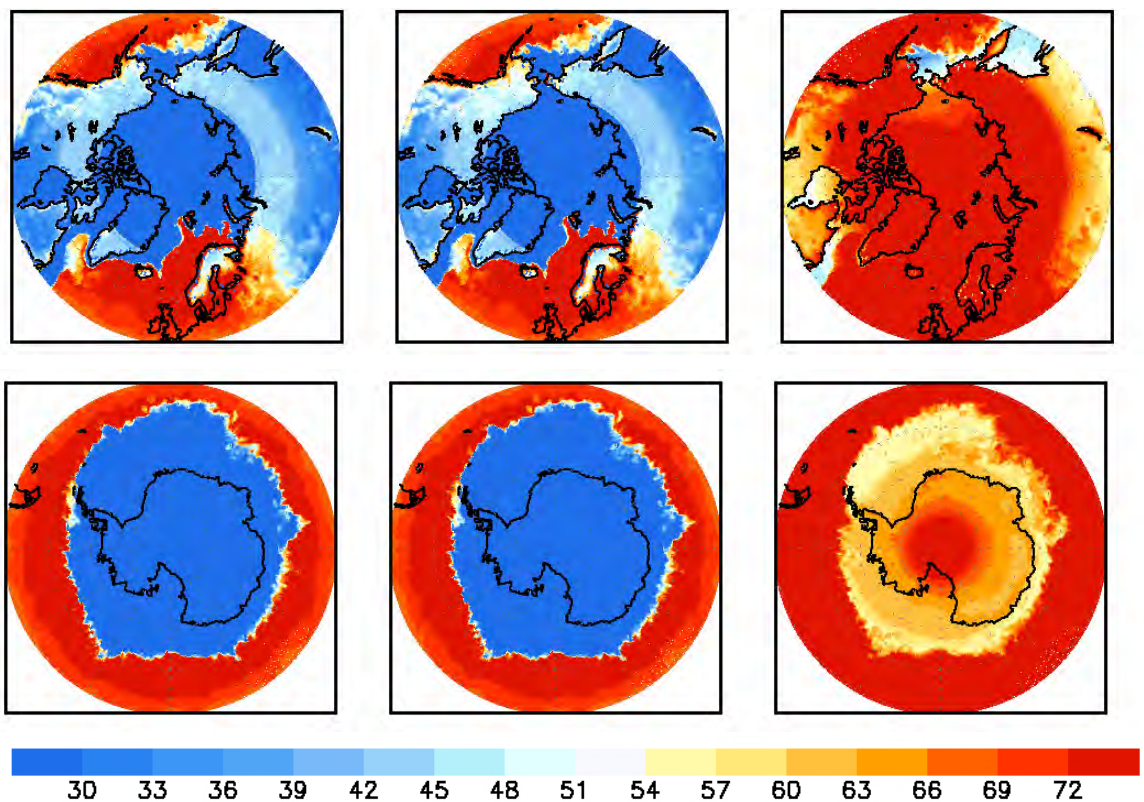
Second Generation CMORPH

5) LEO (AVHRR) IR based Precipitation Estimates [1/2]

Q: Why do we we still need LEO IR based precipitation estimates when we already have PMW retrievals?

A: Because there are still a lot of missing gaps in the current generation PMW retrievals over the high latitudes. We need something (much) better than nothing to fill in the gaps

PMW RR PMW RR+SFR PMWRR+SFR+AVHRR P



Percentage of hours during DJF of 2017-2018 covered by (left) PMW retrievals of rainfall rate (RR); (middle*) PMW retrievals of rainfall rate (RR) and snowfall rate (SFR), and (right) all precipitation retrievals including PMW based RR, SFR, as well as LEO IR (AVHRR) based estimates.*

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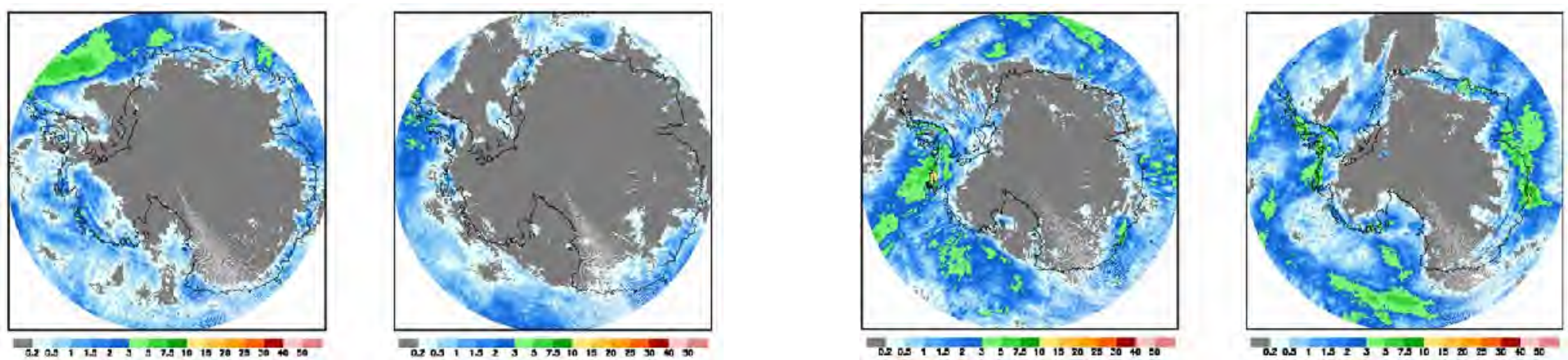
6) LEO (AVHRR) IR based Precipitation Estimates [2/2]

25-29 Jul 2017 | **30 Jul – 3 Aug 2017** | **4–8 Aug 2017** | **9-13 Aug 2017**

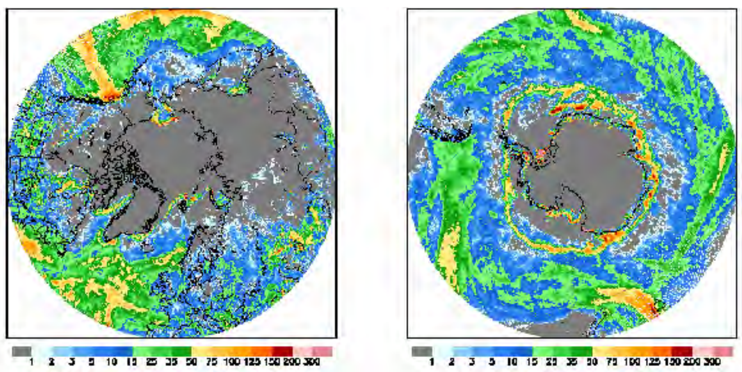


- *AVHRR TB corrected for limb effects (figures skipped)*
- *PDF matching of AVHRR against MWCOMB and CloudSat radar estimates*
- *Calibration tables established as a function of region (1^olat/lon grid), season (pentad), and surface type;*
- *Fine-tuning for optimal performance over polar regions;*

Second Generation CMORPH

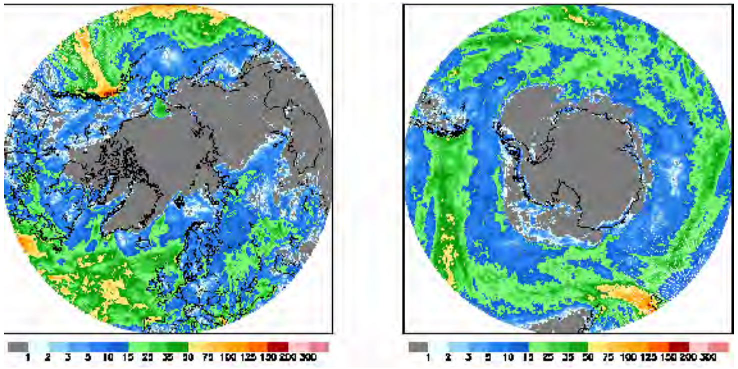
7) Combined Retrievals of Instantaneous Precipitation Rates

MWCOMB PMW RR (mostly NESDIS)
1 - 10 Dec 2017 [accum mm]

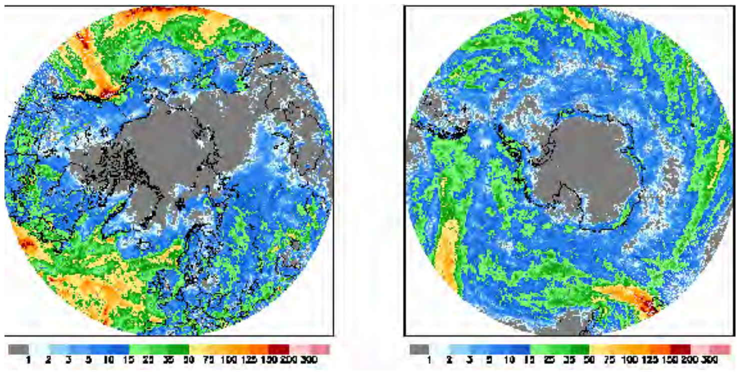


- *Inter-calibrating inputs from various sources against a common reference standard through PDF matching*
- *Constructing composite fields of inter-calibrated precipitation fields, called* ***APCOMB****, on a 0.05ºlat/lon grid and in 30-min intervals*

MWCOMB GPROF-V5 surface precipitation
1 – 10 Dec 2017 [accum mm]



APCOMB (PMW RR+SFR+AVHRR)
1 - 10 Dec 2017 [accum mm]



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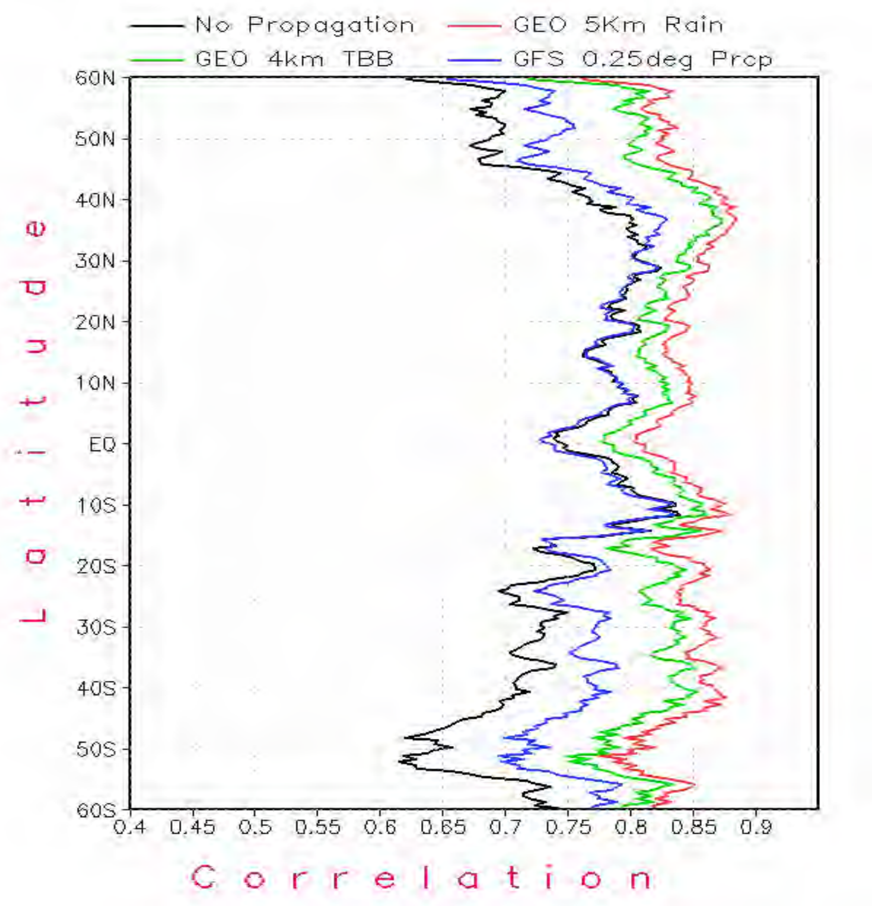
8) Precipitating Cloud Motion Vectors [1/2]

- Based on the Maximum Cross-Correlation (MCC) technique
  - *Determining spatial displacement between two consecutive images resulting maximum local pattern correlation*
- Vectors first derived from GFS 6-12 hour hourly precipitation forecasts and from the GEO-IR based precipitation respectively
- GEO IR precipitation fields for the previous time step are propagated by the GFS and GEO IR precipitation based vectors and compared against the GEO IR precipitation for the current time step to examine the vector performance

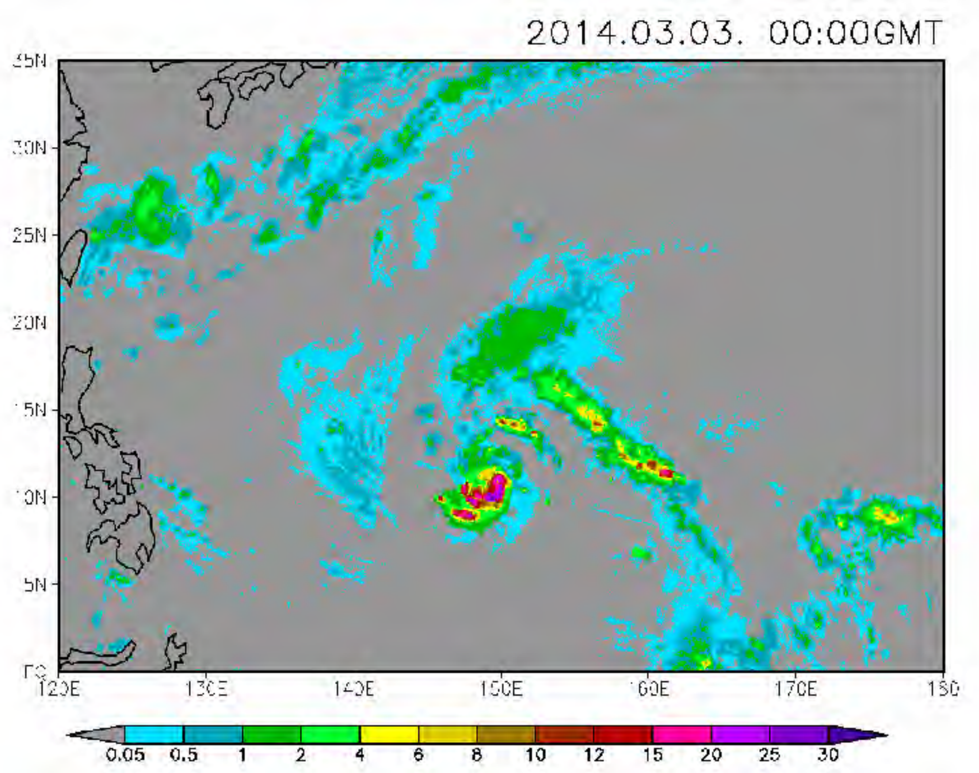
Comparison of propagated precipitation fields against GEO-IR precip estimates for August 2017



Second Generation CMORPH

9) Precipitating Cloud Motion Vectors [2/2]

- GFS and GEO IR precipitation based vectors **combined through 2DVAR** to achieve best possible analysis
- Combination coefficients set as a function of region and season based on the performance of individual vectors
- Vectors are first computed on 0.25ºlat/lon grid following the above mentioned procedures and then down-scaled to 0.05ºlat/lon through bilinear interpolation



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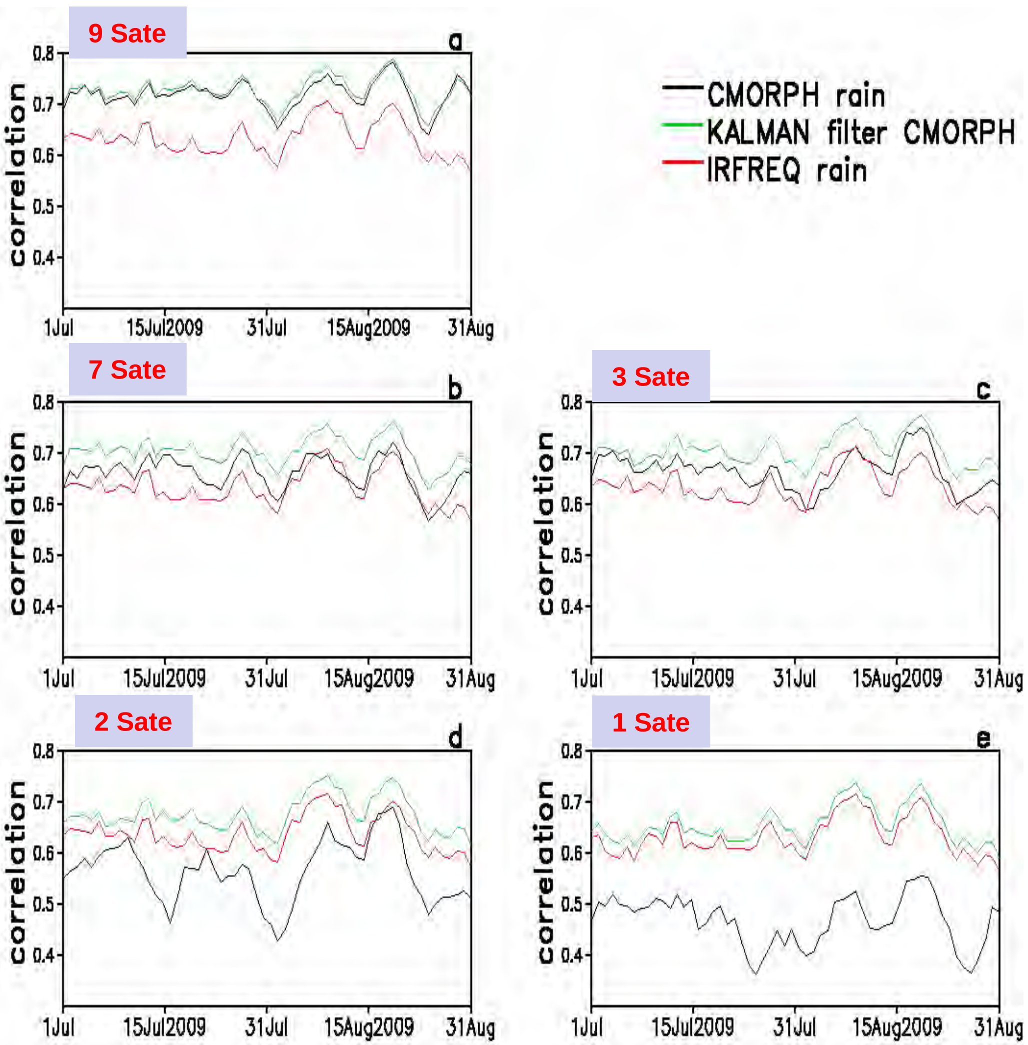
10) KF based Integration Framework



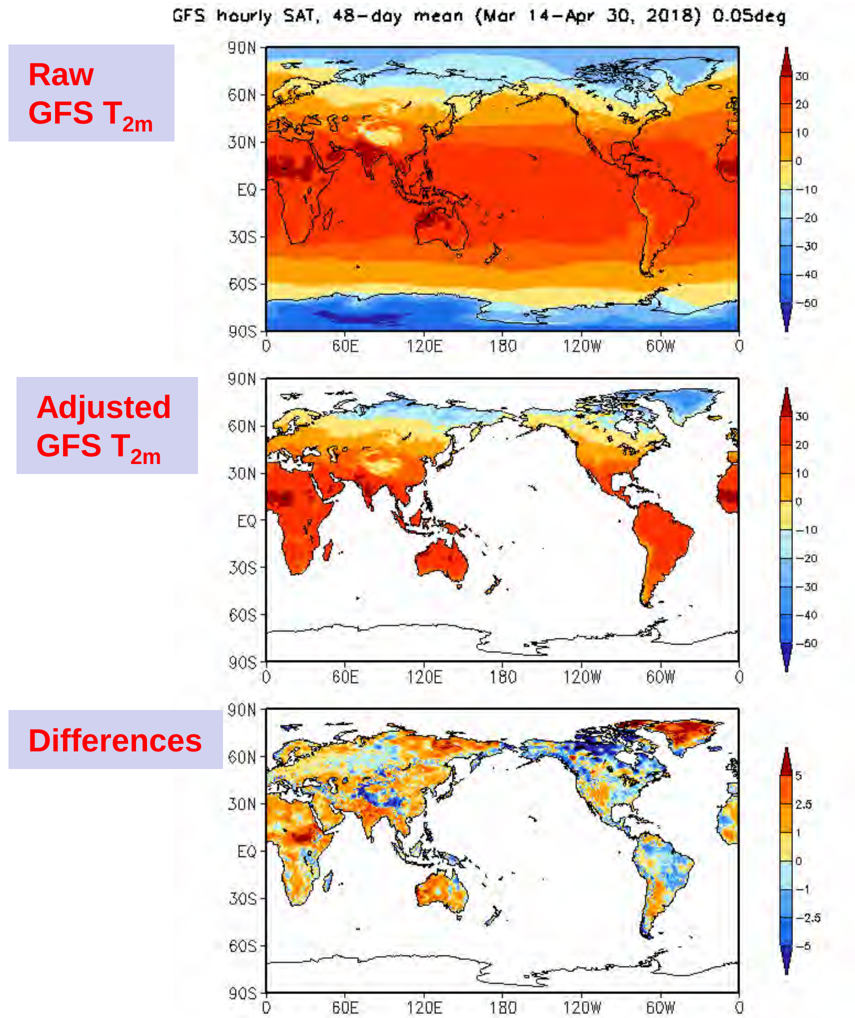
- PMW retrievals propagated from their respective measurement times to the target analysis and used as the ‘first guess’
- GEO/LEO IR based precipitation estimates at (near) the target analysis time used as the ‘observation’ to update / refine the ‘first guess’
- Improvements upon the first generation CMORPH especially significant when fewer platforms carrying PMW sensors are available

← *Time series of correlation between the QRMRS radar-estimated precipitation and IRFREQ (red), the original CMORPH (black), and the KF CMORPH (green). Comparisons are for daily 0.25^{o}lat/lon precipitation over the CONUS for July-August 2009. Results for CMORPH with 9-, 7-, 4-, 2-, and 1-satellite configurations are plotted in panels a)-e), respectively.*

Second Generation CMORPH

11) Fraction of Solid Precipitation

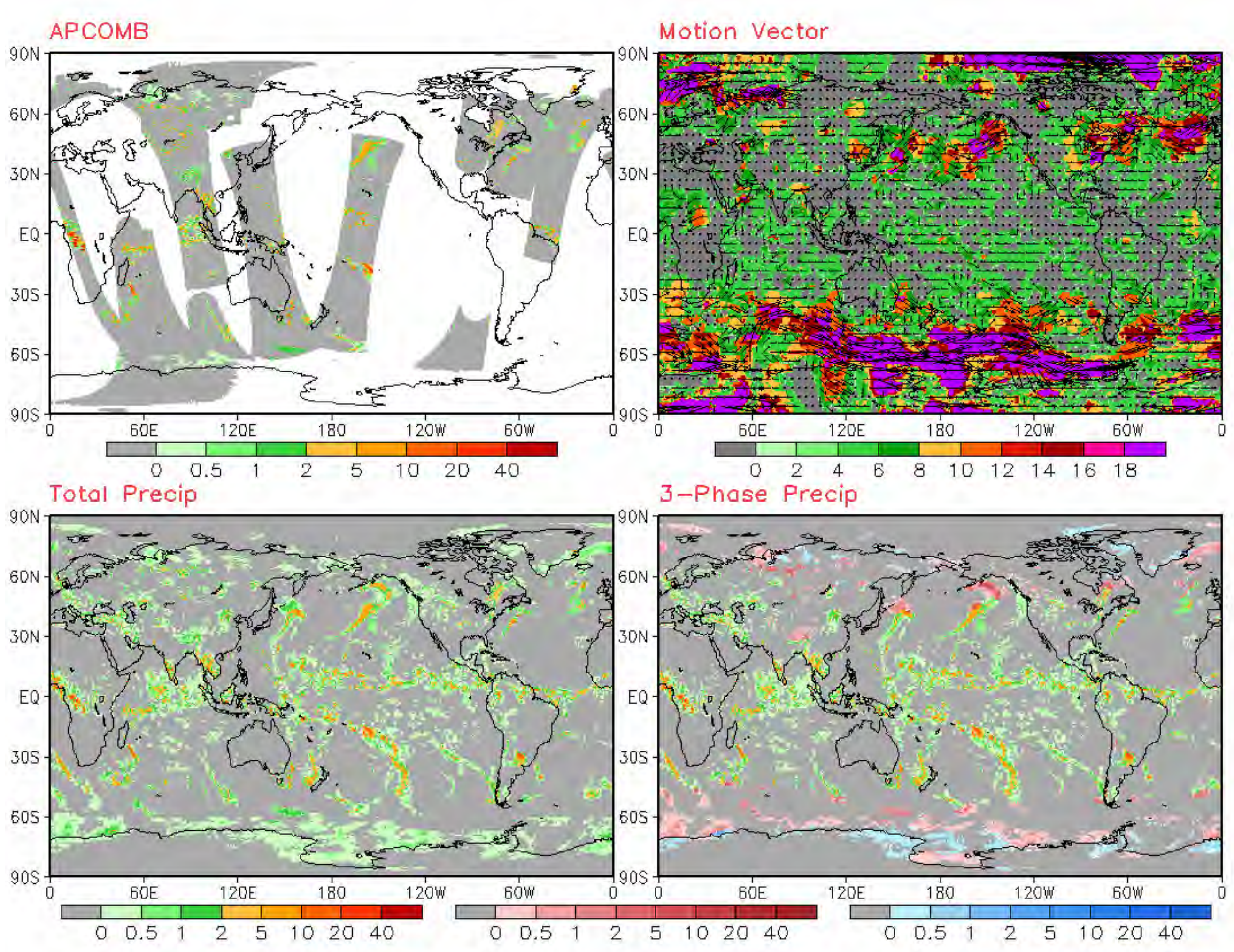
- Fraction of solid precipitation among the total precipitation is determined using the empirical model of Prof. G.-S. Liu of FSU
  - *Function of surface type, surface air temperature (T_{2m}), surface pressure, surface atmospheric humidity et al.*
  - *T_{2m} is the primary predictor*
- Surface air temperature (T_{2m}) defined for each hour on a 0.05ºlat/lon grid over the global land
  - *Adjusting the GFS 6-12 hour forecast of hourly T_{2m} through comparison against CPC analyses of daily maximum and minim temperature*
  - *Adjusted T_{2m} down-scaled to 0.05ºlat/lon with consideration of orographic effects*



Second Generation CMORPH

12) Sample APCOMB, Motion Vectors, & CMORPH2

12:00Z, 10 May 2018



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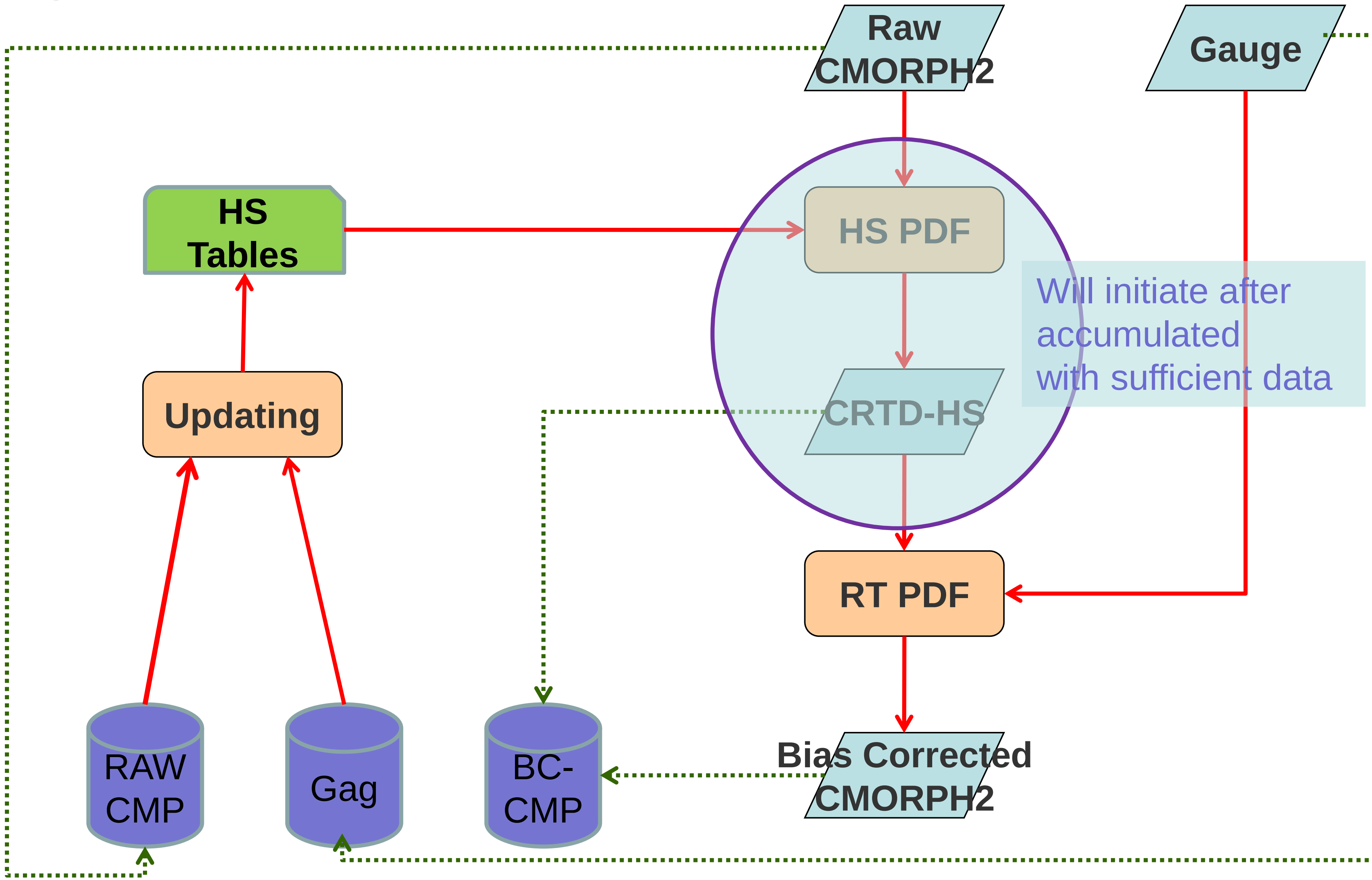
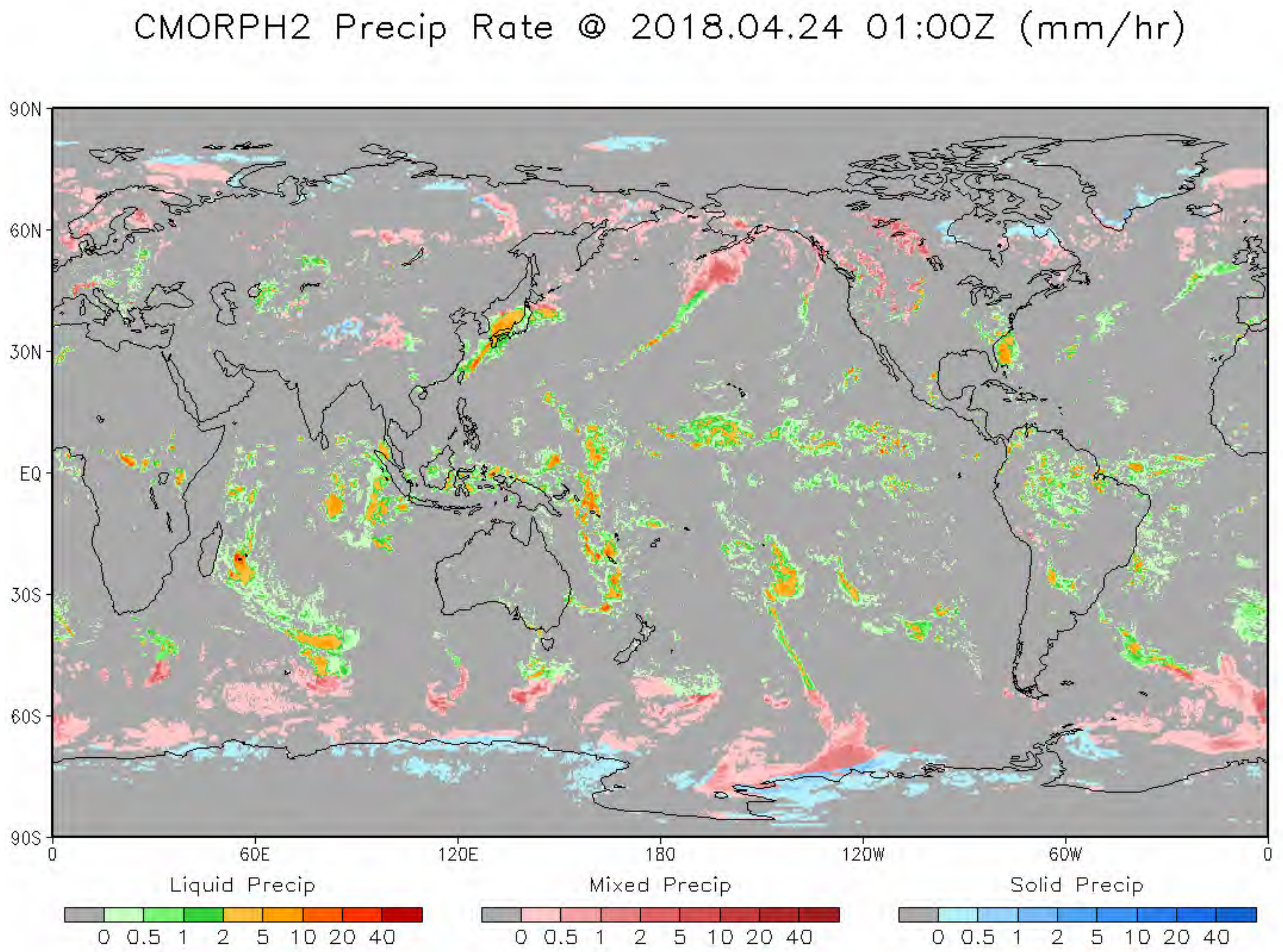
14) Bias Correction



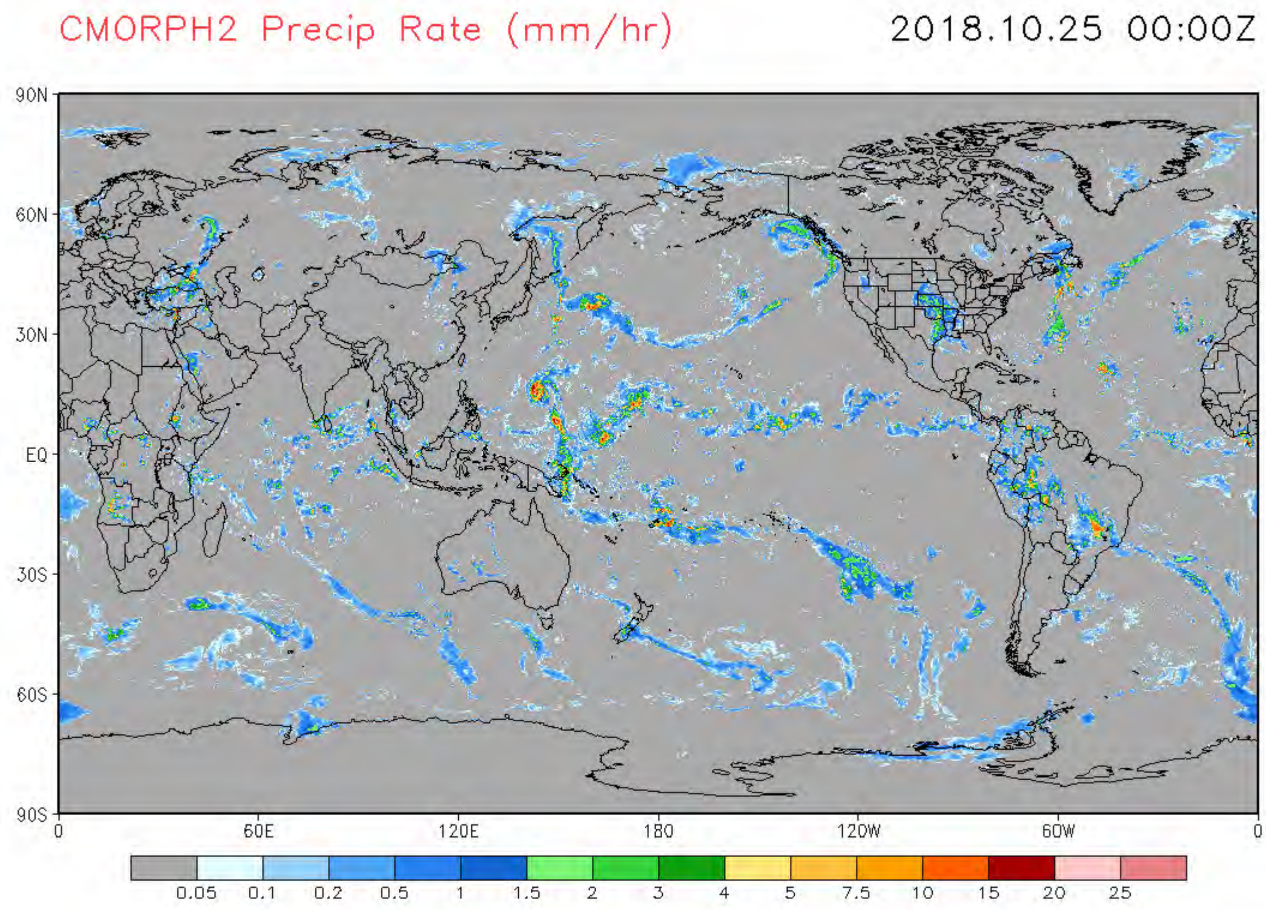
Illustrations and Verifications

1) Global View (3-phase)



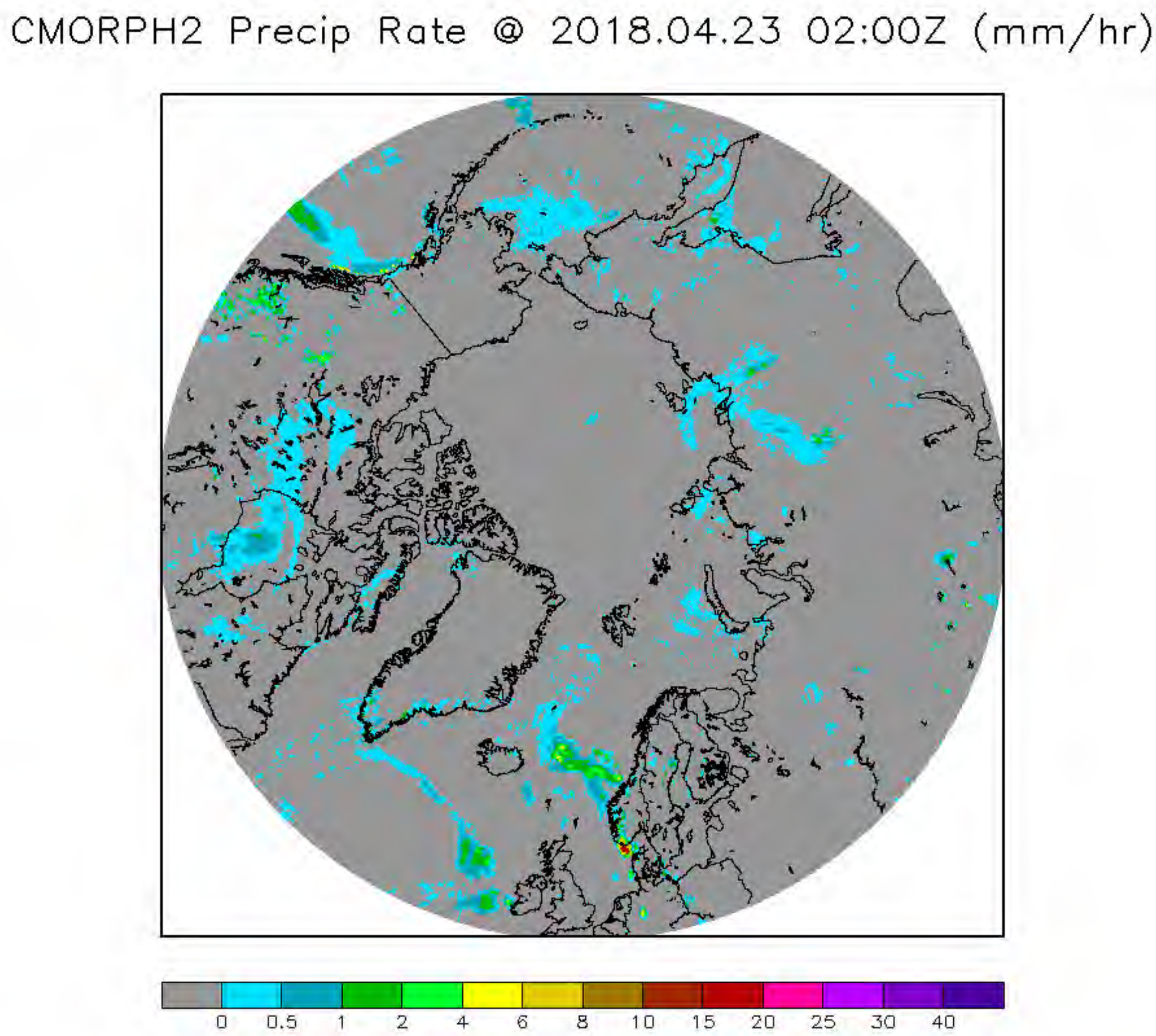
Illustrations and Verifications

2) Global View   (animation)

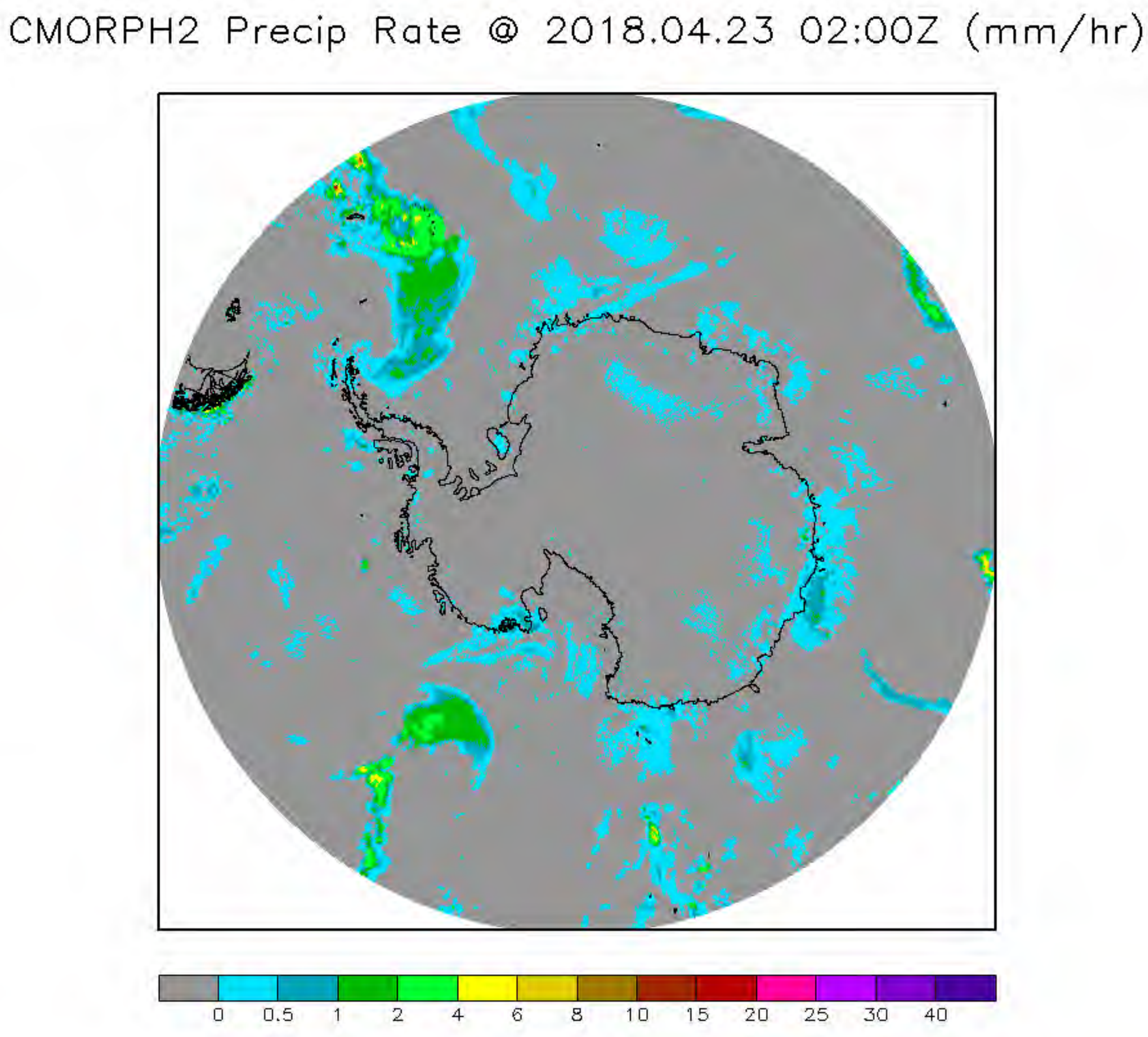


Illustrations and Verifications

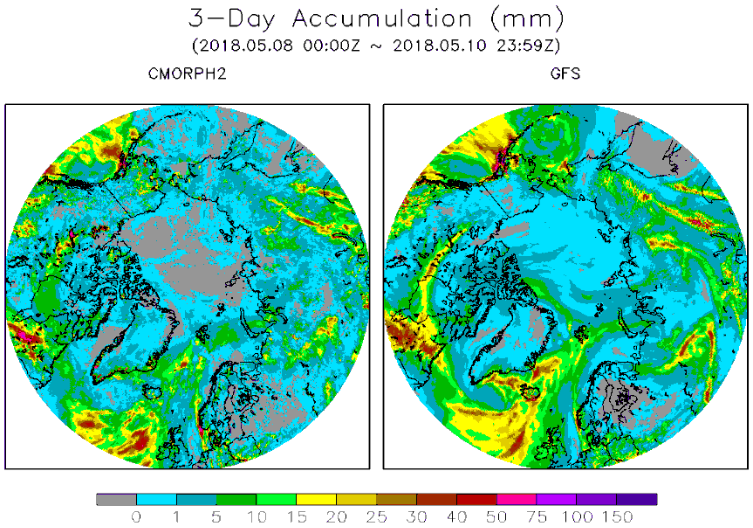
3) North Pole Animation

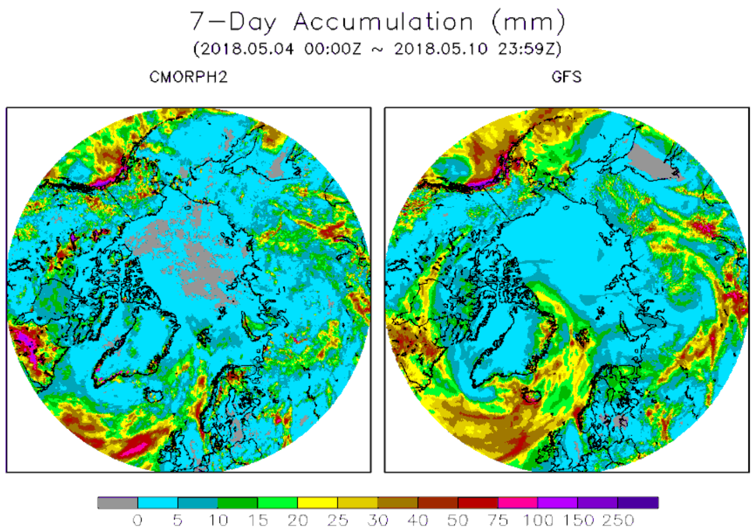


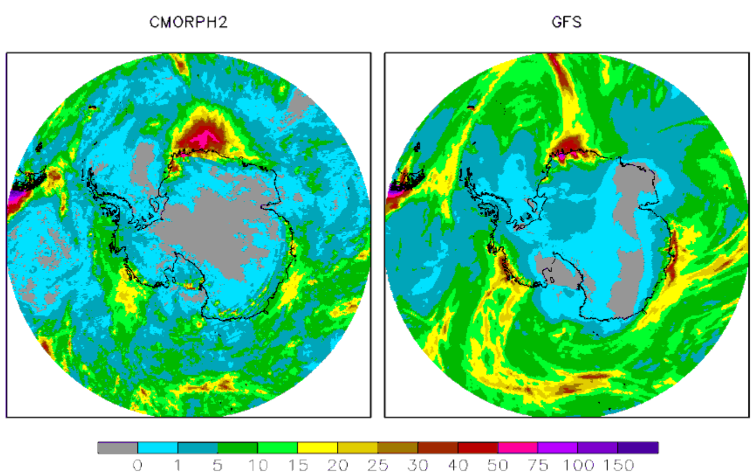
Illustrations and Verifications
4) South Pole Animation



Illustrations and Verifications
5) Comparison with GFS 3-day/ 7-day Accum







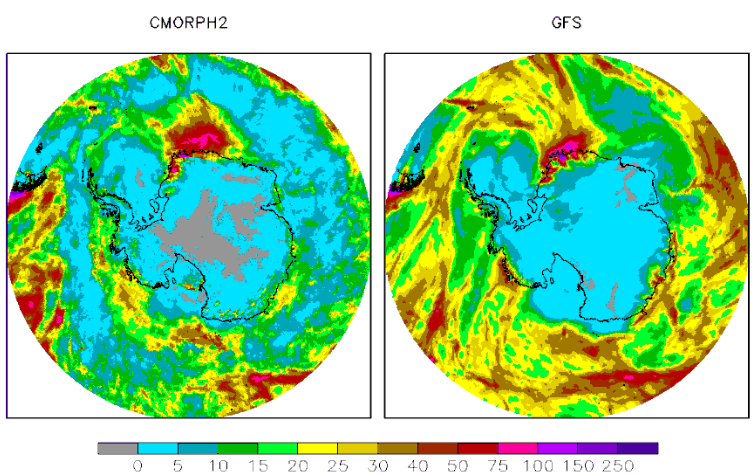
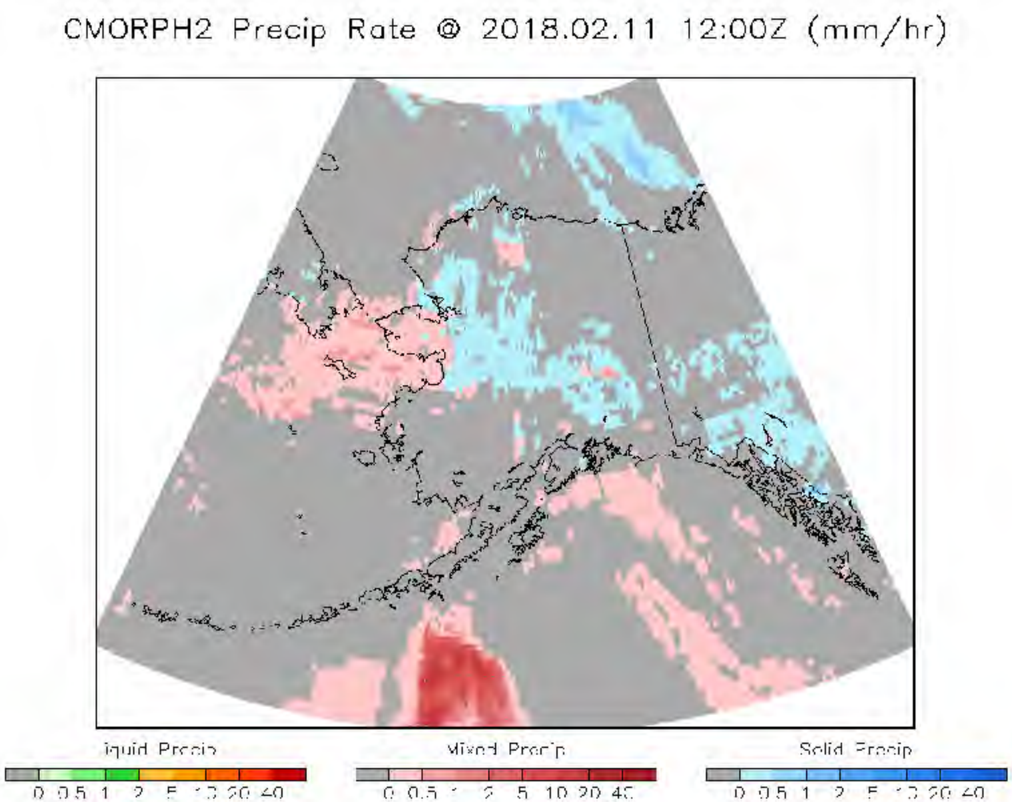
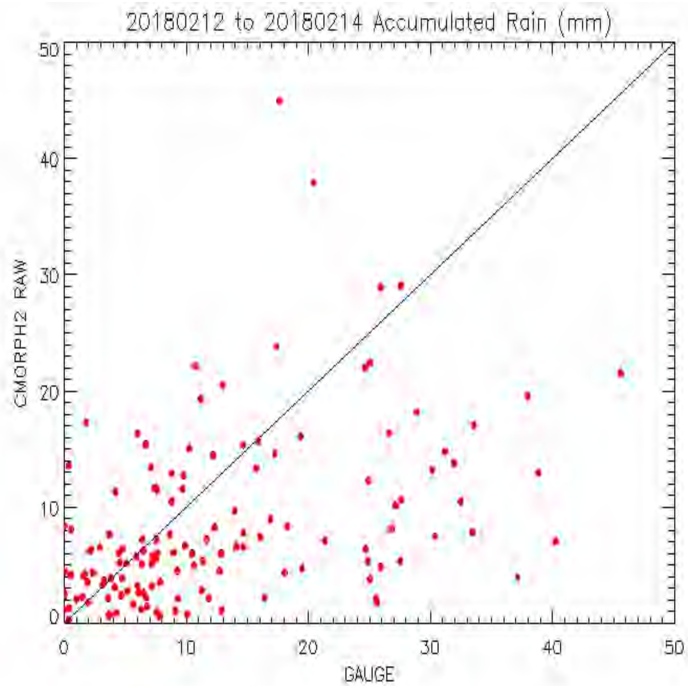


Illustration and Verifications

6) Alaska Snow Storm of Feb., 2018



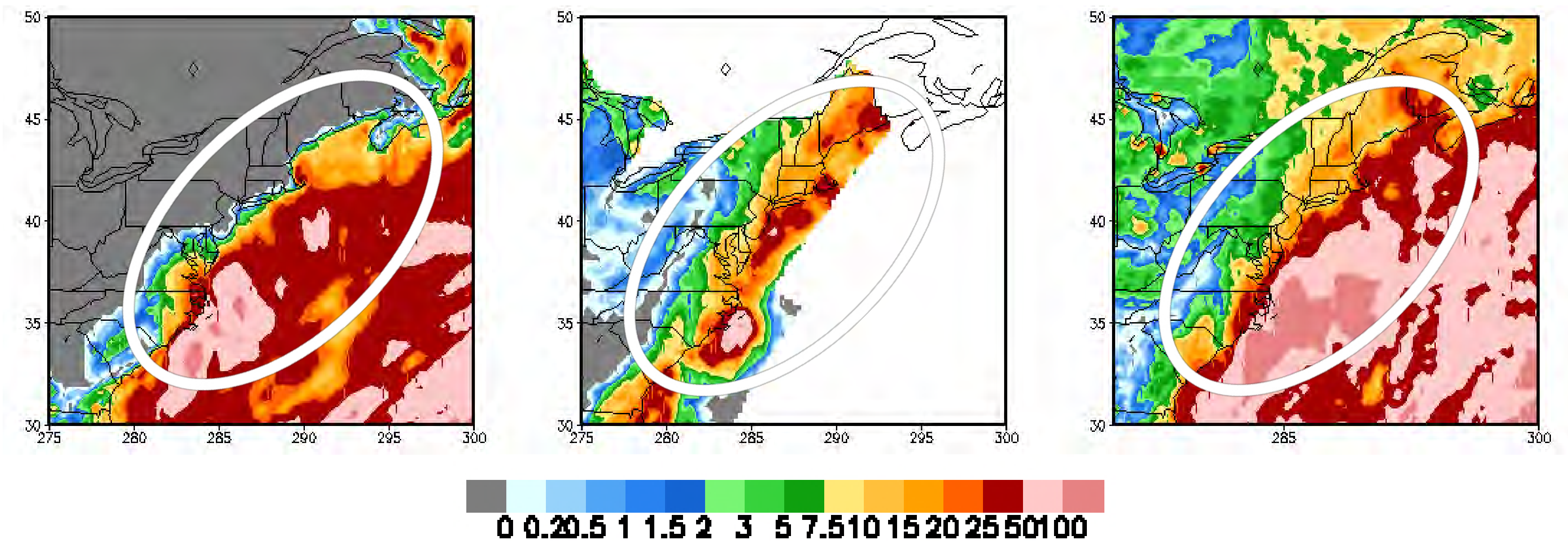


Scatter plots between 3-day accumulated precipitation from the RAW CMORPH2 and the CPC gauge based analysis on 0.25^{o}lat/lon grid boxes over Alaska

Illustrations and Verifications

7) Winter Storm Grayson 3-5 January 2018

CMORPH | Stage IV Radar | CMORPH2



- *Accumulated precipitation (rainfall, snowfall, mixed) from the Stage IV radar observations (middle), the currently operational CMORPH (left) and the second generation CMORPH (CMORPH2, right);*
- *The operational version CMORPH missed / under-estimated snowfall over most of the regions covered with surface snow;*
- *CMORPH2 is capable of capturing snowfall along the path of Grayson over the east coast.*

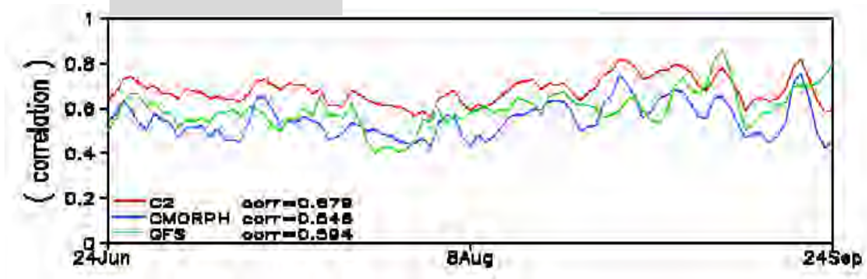
Illustrations and Verifications

8) Comparison against CPC Gauge Analysis

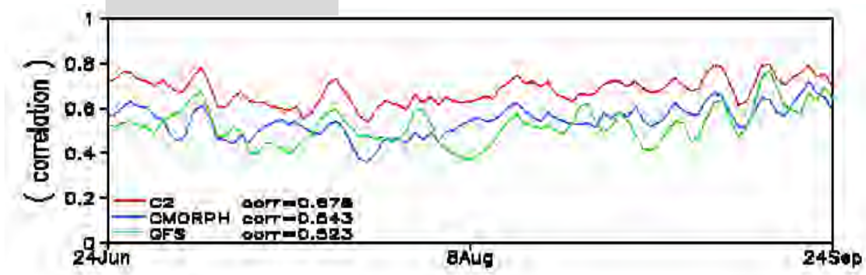
- Comparison to CPC gauge analysis of daily precipitation on 0.25ºlat/lon for JAS of 2018

- 2nd generation CMORPH compares well to CPC daily gauge analyses relative to both operational CMORPH and GFS precipitation for all latitudes

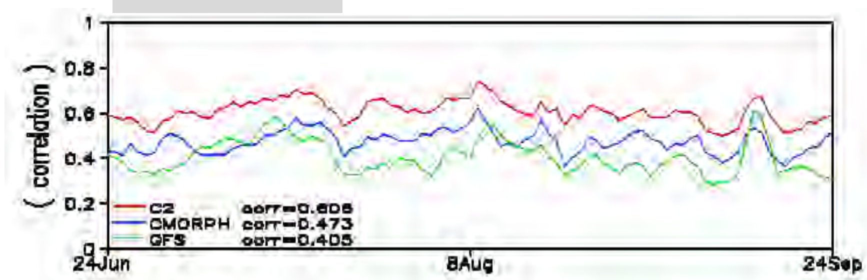
40N-60N



20N-40N



20S-20N



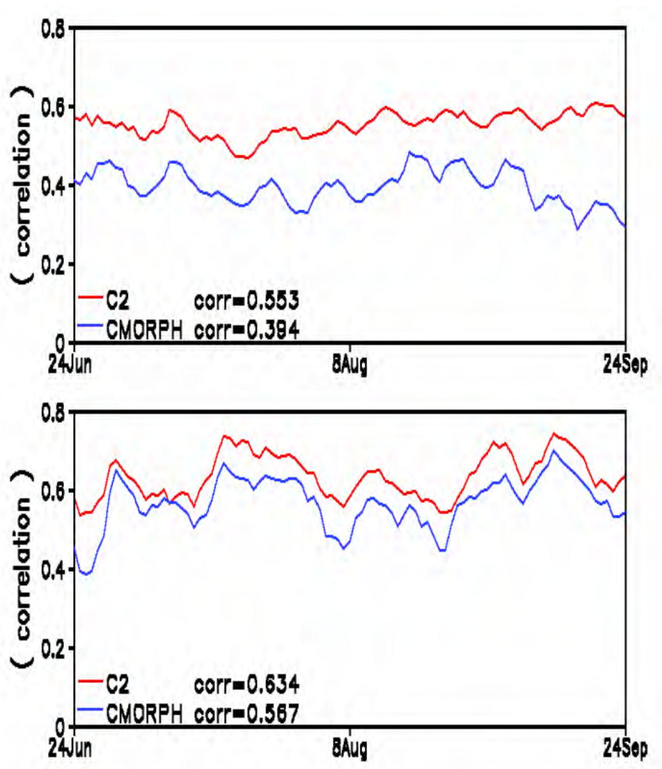
Illustrations and Verifications

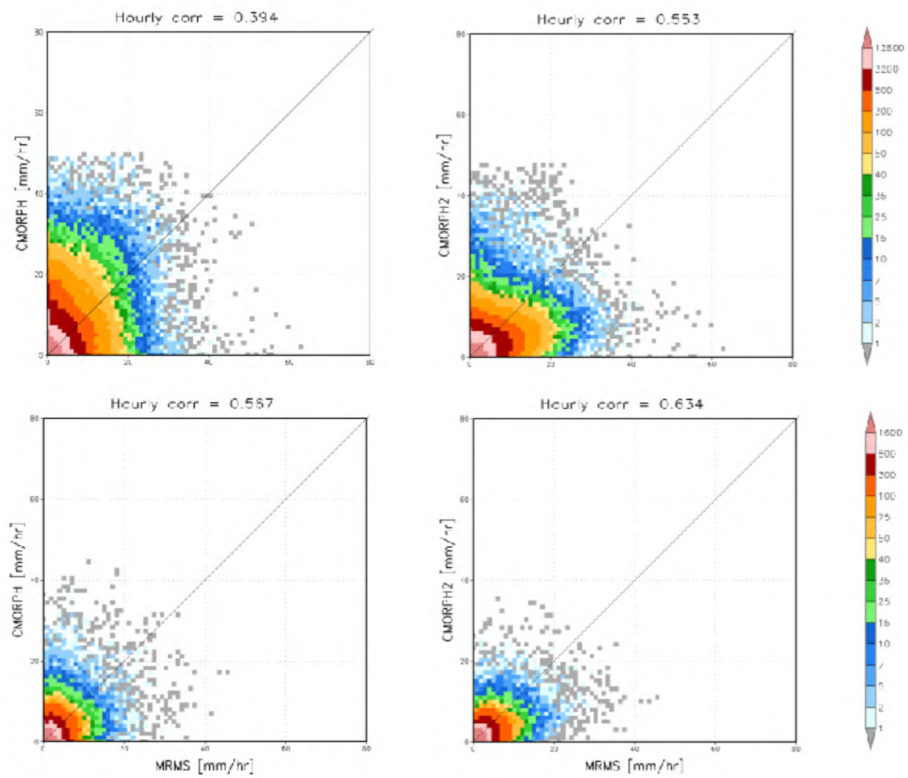
9) Hourly comparison against MRMS Radar Precipitation

Time Series of Correlation | **CMORPH** | **CMORPH2**

LAND

OCEAN





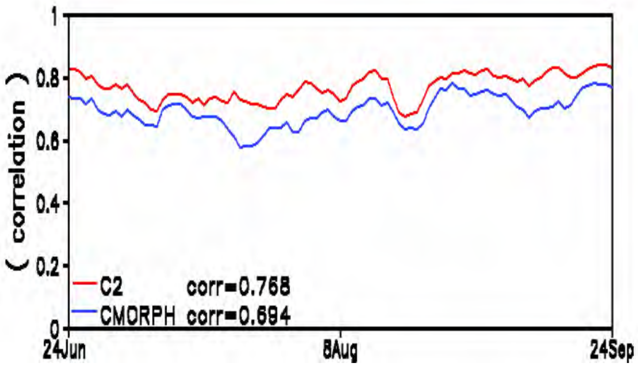
- *Comparison between CMORPH and MRMS radar daily precipitation on 0.25ºlat/lon grid boxes over land east of 110ºW (top) and over ocean 20-150Km off the coasts (bottom) for JAS of 2018.*
- *Significantly improved performance for the second generation CMORPH upon its predecessor (CMORPH).*

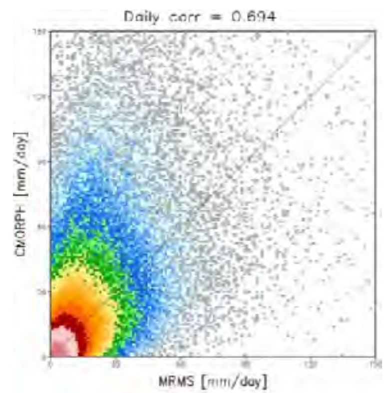
Illustrations and Verifications

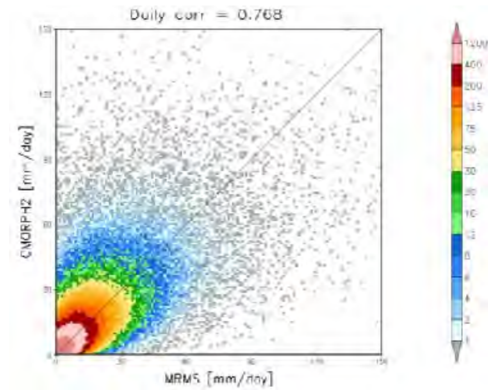
10) Daily comparison against MRMS Radar Precipitation

Time Series of Correlation | **CMORPH** | **CMORPH2**

LAND







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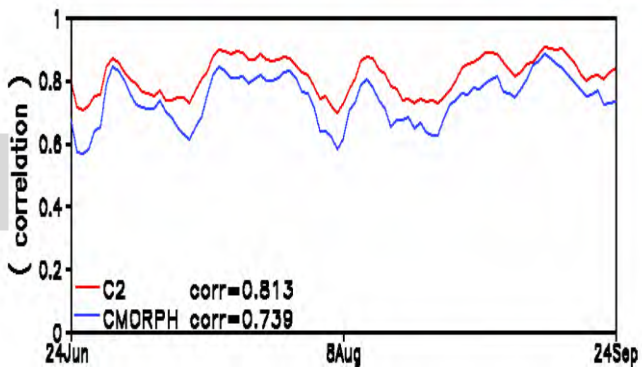

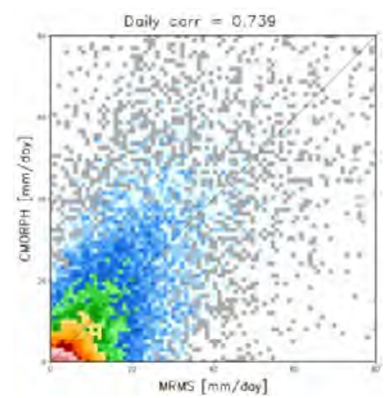

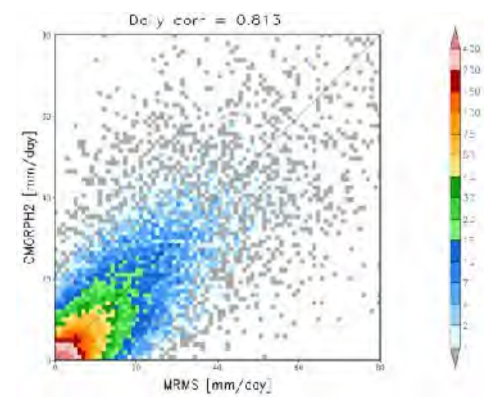

- *Comparison between CMORPH and MRMS radar daily precipitation on 0.25ºlat/lon grid boxes over land east of 110ºW (top) and over ocean 20-150Km off the coasts (bottom) for JAS of 2018.*
- *Significantly improved performance for the second generation CMORPH upon its predecessor (CMORPH).*

Summary and Future Plan

- What we have done
  - *Put the CMORPH2 processing system into the (parallel run) real-time production at a CPC work station*
  - *The second generation CMORPH:*
    - *Covering the entire globe from pole to pole on a fine resolution of 0.05^{o}lat/lon*
    - *in a 30-min interval and updated on a real-time basis*
    - *With much improved representation of snowfall and cold season precipitation*
- What are on the way
  - *Comprehensive examinations for May 2017 to the present*
  - *Reducing the latency to one hour*
  - *Pushing the CMORPH2 into NWS/AWIPS II*
  - *Fine-tuning and finalizing the system*
  - *Interactions with users*
- In the upcoming 2-3 years
  - *Reprocessing CMORPH2 for 1991 to present*
  - *Generating associated product (gauge-CMORPH blended) for the same period*
  - *Constructing precipitation climatology for 1991 – 2020*
  - *Regional enhancements to CMORPH*
  - *Refined representation of orographic effects*

- Sample Real-Time CMORPH2 (Globe)
- Sample Real-Time CMORPH2 (Antarctica)
- Sample Real-Time CMORPH2 (Arctic)