Evaluation of a New Global Precipitation Analysis at the US Air Force 557th Weather Wing

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Background

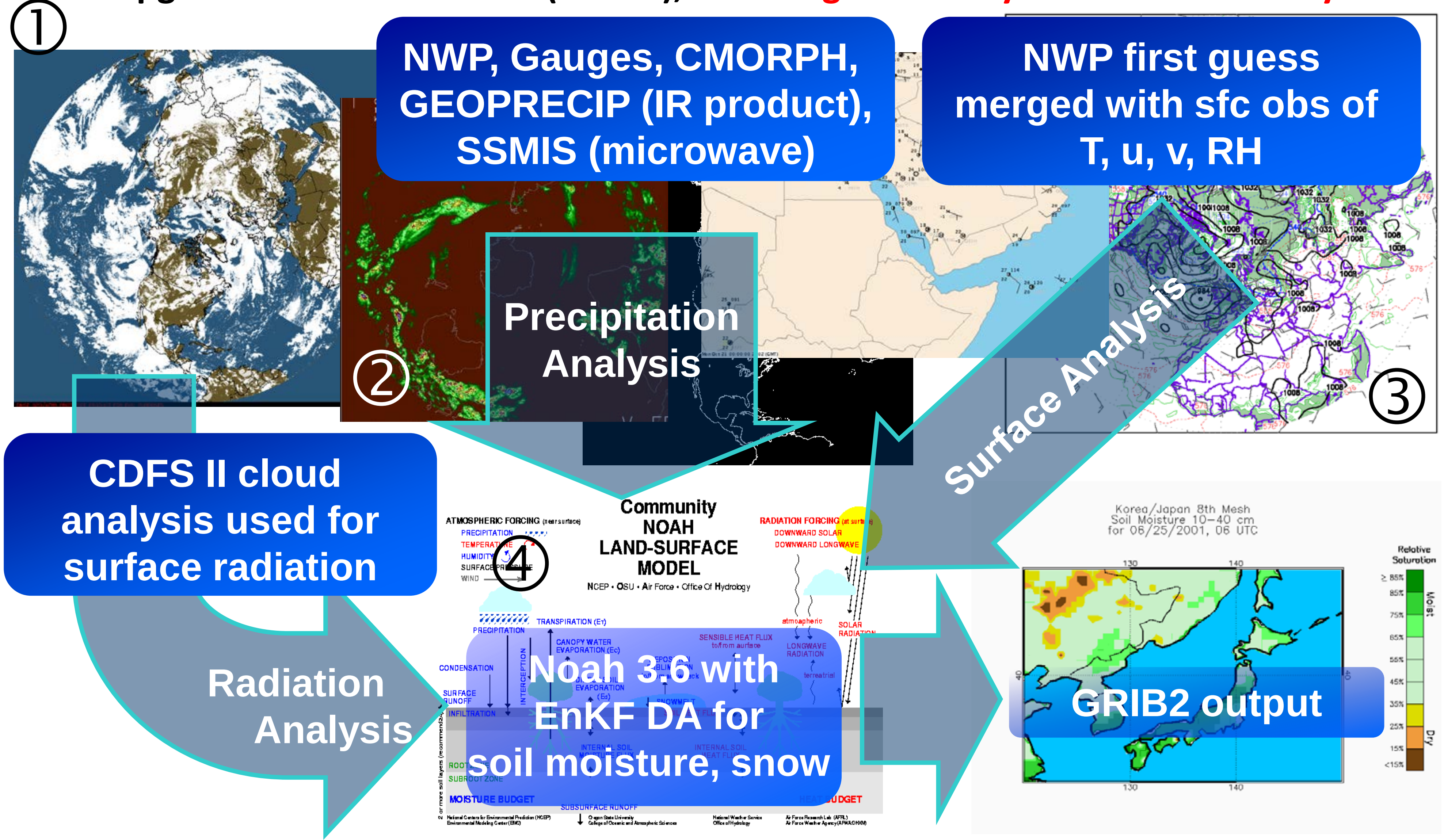
USAF land data assimilation system

- **UNCLASSIFIED, near-real-time system,** multiple applications (military, agricultural, research, …)

Using **NASA Land Information System (LIS)** since 2009

- **Portable software framework** for land surface modeling, data assimilation, and ensembles (lis.gsfc.nasa.gov)

Upgraded November 2019 (LIS 7.2), ~10-km global analyses four times a day



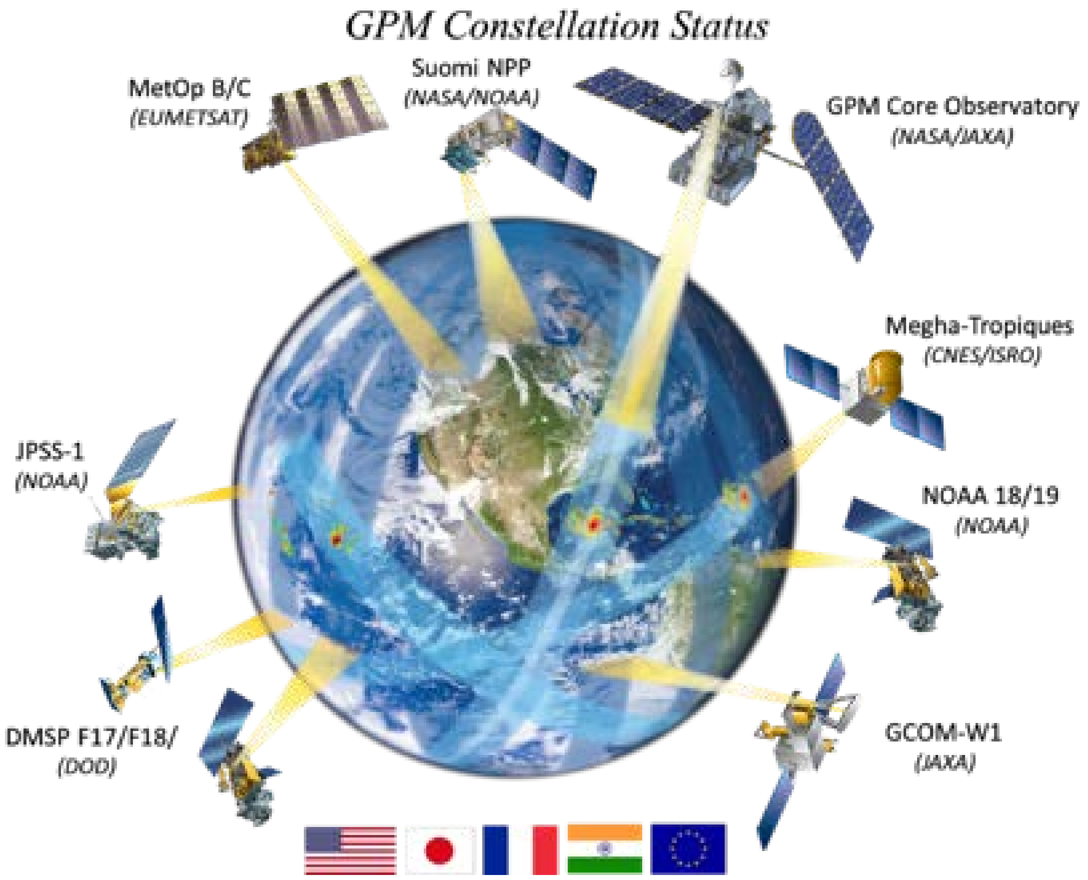
Precipitation Algorithms At a Glance

Legacy Air Force Analysis: Pre-LIS 7.2	Bratseth Analysis: LIS 7.2
Designed to use best available data source in each grid box, largely following decision tree approach	**Minimizes mean square error of field** based on error characteristics of all available data **Converges to Optimal Interpolation** but avoids direct matrix inversion
Two steps: **(1) Direct insertion** of highest quality datum in grid box (Gauge, CMORPH, SSMIS, Bogus report, GFS, GEOPRECIP, or climatology) **(2) Lateral interpolation of surface reports** to low quality neighbors (modified Barnes analysis)	**Two steps:** **(1) Use USAF GALWEM 6-12hr NWP forecast** as first guess **(2) Statistically adjust first guess** toward gauges, CMORPH, SSMIS, GEOPRECIP
Observations are thinned (single datum per grid box in step 1, other reports are purged)	**All observations used** (after quality control checks)
Weights use distance, observation source hierarchy	Weights use **error covariances, local data density**

Bratseth, A M, 1986: Statistical interpolation by means of successive corrections. *Tellus*, **38A**, 439-447, https://doi.org/10.1111/j.1600-0870.1986.tb00476.x

Evaluation Goals

- Immediate questions:
  - **How does the new Bratseth analysis improve upon the Legacy Air Force analysis?**
  - **How does Bratseth compare to other high-quality alternatives?**
- To answer**, we evaluate a multi-year Bratseth reanalysis produced by NASA from LIS 7.2rp6**
- Further question:
  - **Would assimilating NASA's IMERG-Early Run NRT satellite retrievals improve Bratseth?**
- IMERG assimilation is supported in LIS 7.3—**we evaluate short data assimilation experiments with this version of LIS**



GPM Constellation as of 31 Jan 2017 (used in IMERG)
From NASA PMM
See: ppm.nasa.gov/data-access/downloads/gpm

Evaluated Products

Name	Producer	Data Sources	Bias Correction	Projection	Spatial Limits	Temporal Resolution
IMERG-Final Run V06B[&]	NASA	Microwave, IR, Gauges	Yes	Lat/Lon, 0.1° x 0.1°	60S60N	30-min
Bratseth 7.2rp6	NASA/USAF	Microwave, IR, Gauges, NWP	No	Lat/Lon, 0.14° x 0.9°	90S90N	3-hourly
Legacy USAF	USAF	Microwave, IR, Gauges, NWP, Bogus Reports, Climatology	No	Lat/Lon, 0.25° x 0.25°	60S90N	3-hourly
CHIRPSv2[@]	UC-Santa Barbara	IR, Gauges	Yes	Lat/Lon, 0.05° x 0.05°	50S50N	Daily

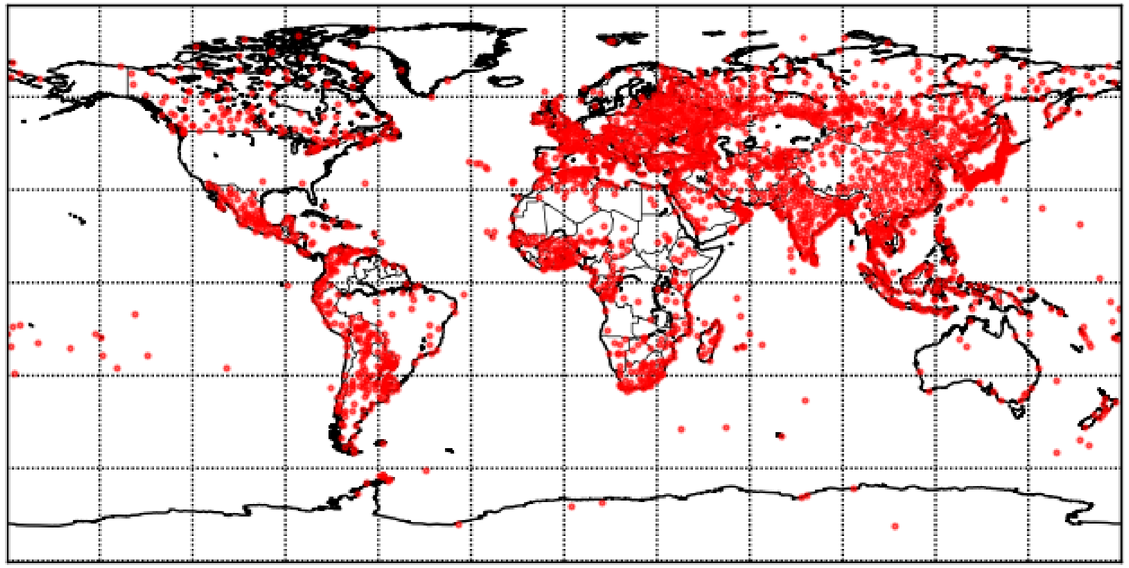
[@]**Funk, C, and Coauthors, 2015**: The Climate Hazards Infrared Precipitation with Stations—A new environmental record for monitoring extremes. *Sci Data*, **2**, 150066, https://doi.org/10.1038/sdata.2015.66

[&]**Tan, J, G J Huffman, D T Bolvin, and E J Nelkin, 2019**: IMERG V06: Changes to the morphing algorithm. Accepted to *J Atmos Oceanic Technol*, https://doi.org/10.1175/JTECH-D-19-0114.1

Reference Observations

- **Need to evaluate analyses outside CONUS**, preferably against gauge data
- Best available data is **Global Summary of the Day (GSOD)** subset of Global Historical Climate Network-Daily (GHCN-D) v3.26 (**Menne et al 2012**)
  - Only source of daily observations at NOAA NCEI for South America, Africa, parts of Asia
  - Are supposed to reflect daily totals ending at 00Z
- Reject GSOD datum if:
  - Failed QC test administered by NOAA NCEI; or
  - Precipitation data was missing and assumed to be "zero"

GSOD GHCN-D Stations Reporting Precipitation in 2018



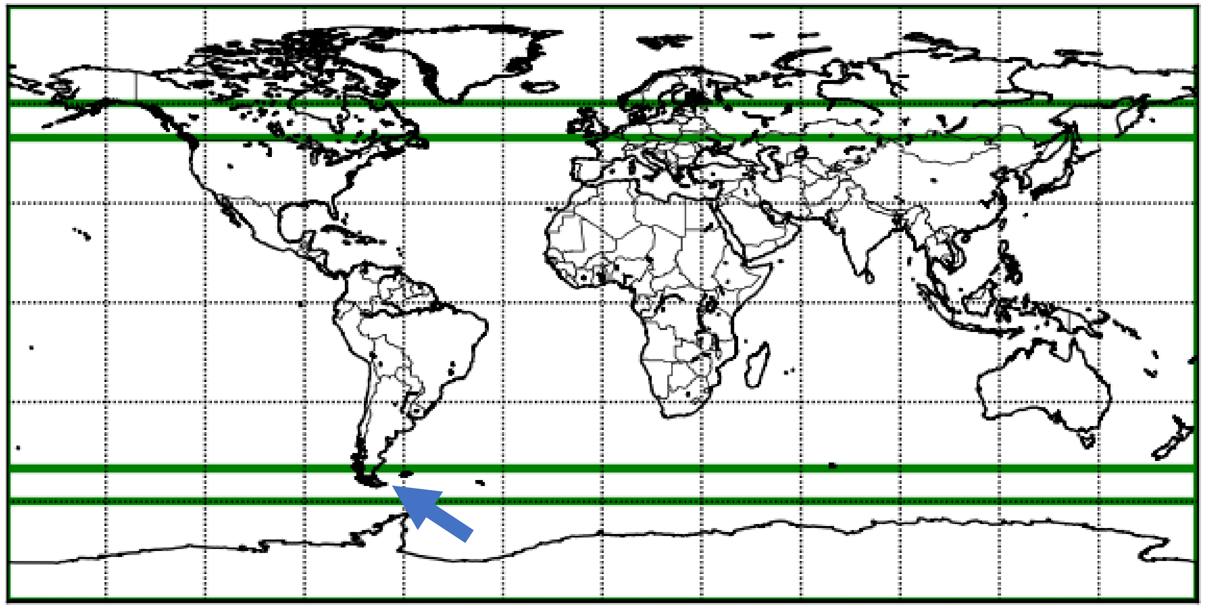
For this work**, precipitation products are aggregated to daily (00Z-00Z) values**, compared to GSOD for **December 2011 through November 2018 (7 full years)**

Menne, M J, and Coauthors, 2012: Global Historical Climatology Network-Daily (GHCN-D), Version 3.26. NOAA NCEI. http://doi.org/10.7289/V5D21VHZ [accessed 10 Aug 2019]

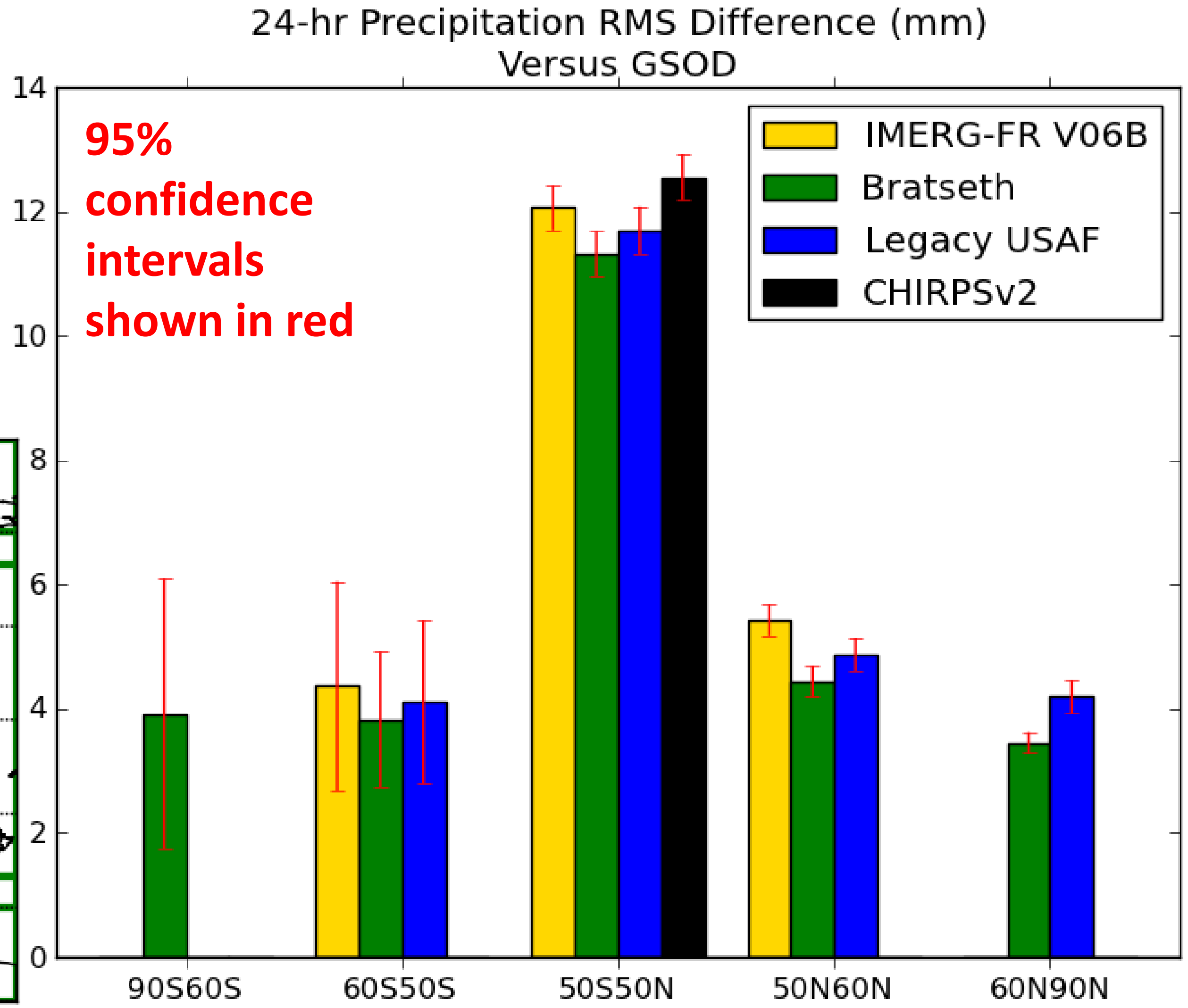
RMSD Summary (Dec 2011 – Nov 2018)

Bratseth has best mean RMSD in 50S50N, 50N60N, and 60N90N strips

Differences in 60S50S band not significant due to small sample size (southern South America)



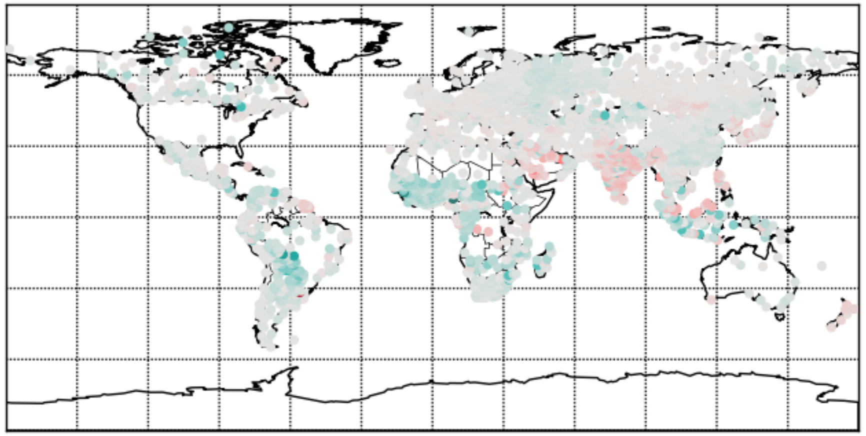
Mean of station RMSD values by latitudinal band



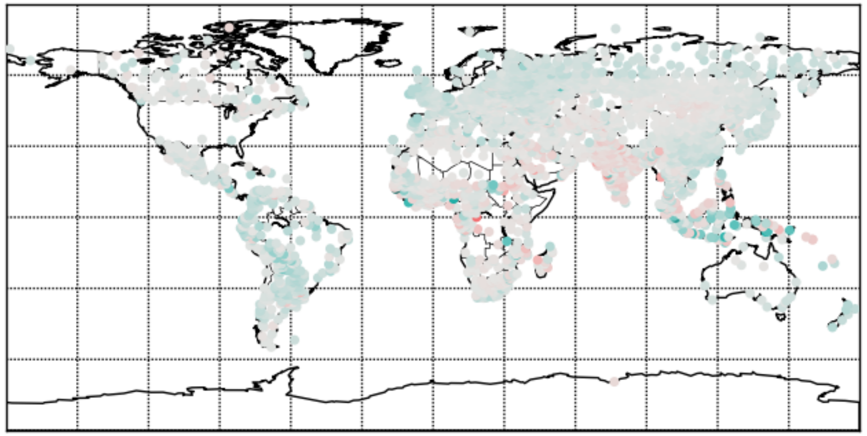
RMSD Reduction By Station (Dec 2011 – Nov 2018)

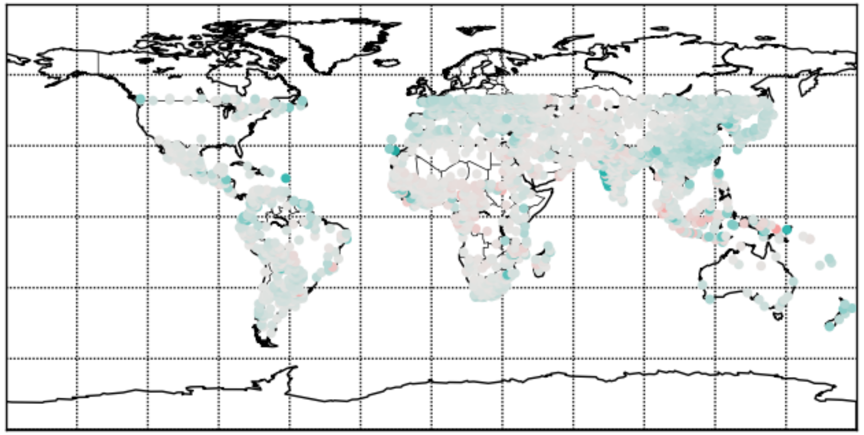
Bratseth improves agreement over Legacy Air Force product in parts of Africa, South America, western Russia;
worsens in India, Saudi Arabia

Bratseth has somewhat better agreement than IMERG-Final Run in South America, western Russia, western Europe;
somewhat worse in India



Bratseth has better agreement than CHIRPS in eastern China, southwest Europe





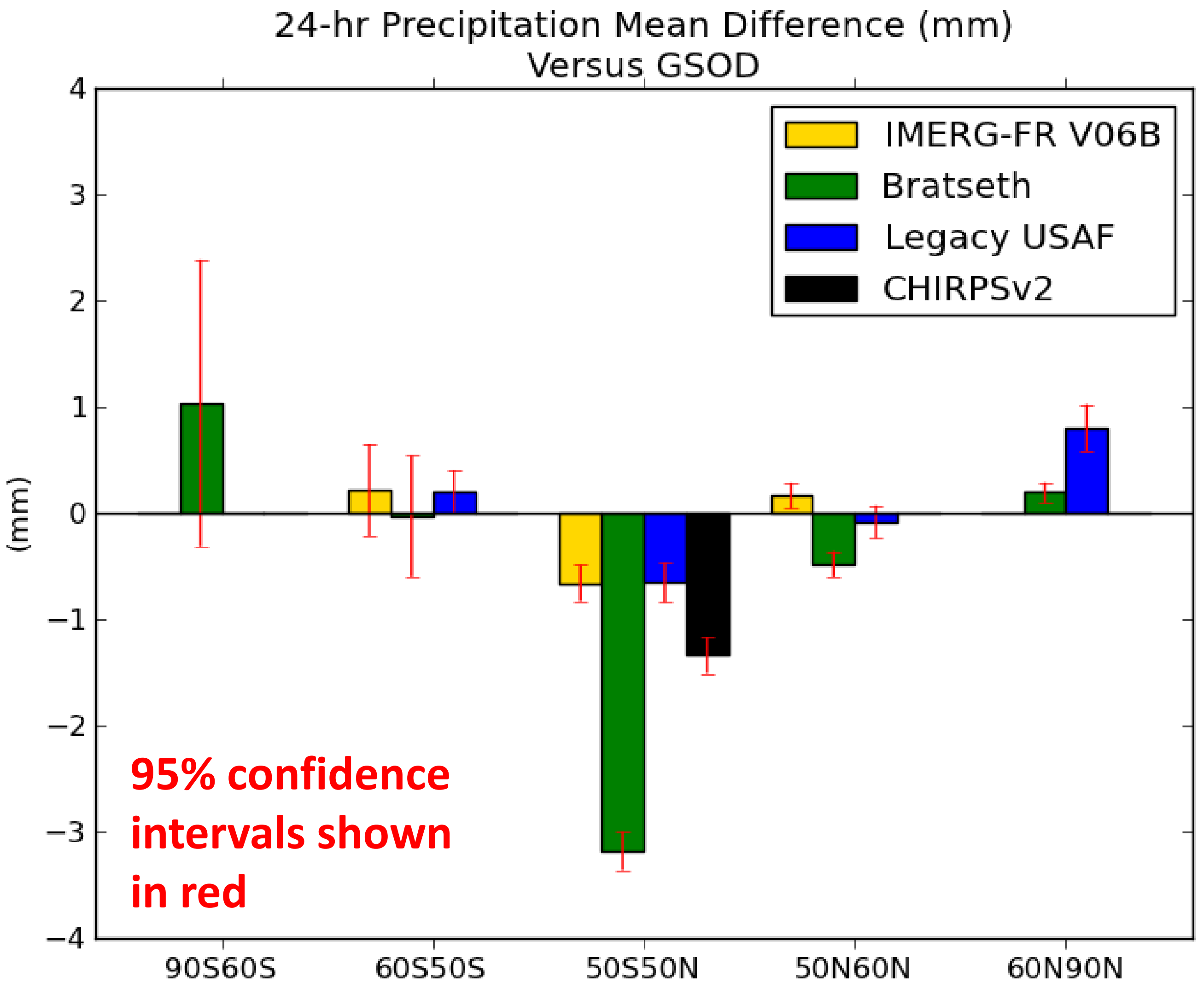
Mean Difference Summary (Dec 2011 – Nov 2018)

- **Bratseth has strongest apparent dry bias in 50S50N, second strongest in 50N60N**
  - Suggests need for bias correction

- **Bratseth improves over legacy Air Force product in 60N90N**

- Note: Apparent dry bias for IMERG-FR and CHIRPS (both bias-corrected) may indicate GSOD reports are too wet

Mean of station bias values by latitudinal band

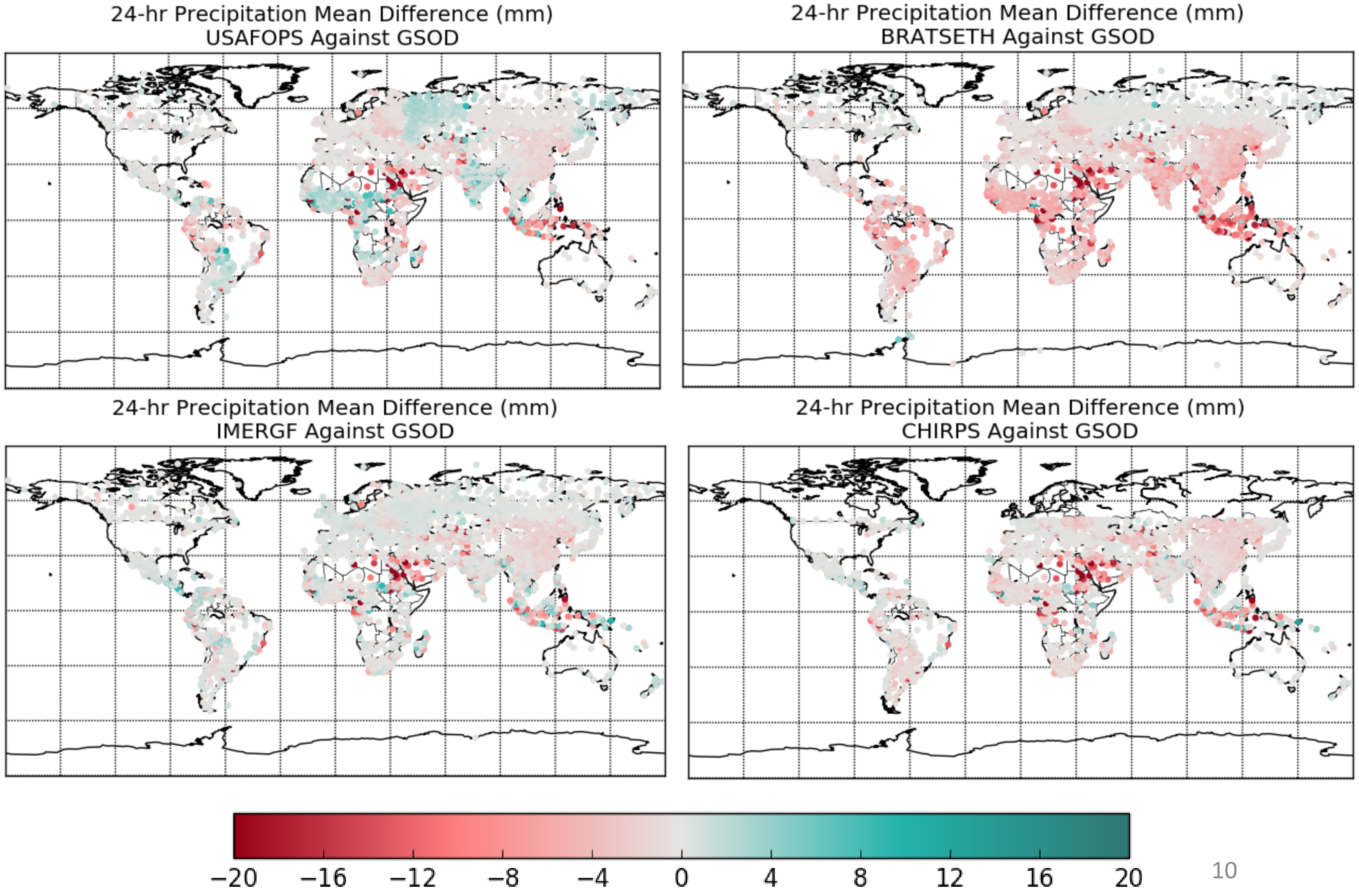


Mean Difference By Station (Dec 2011 – Nov 2018)

Bratseth removes apparent wet bias in parts of Russia compared to Legacy Air Force product

- But, **introduces apparent dry bias** in South America, Africa, India

IMERG-FR, CHIRPS have less apparent bias than Bratseth

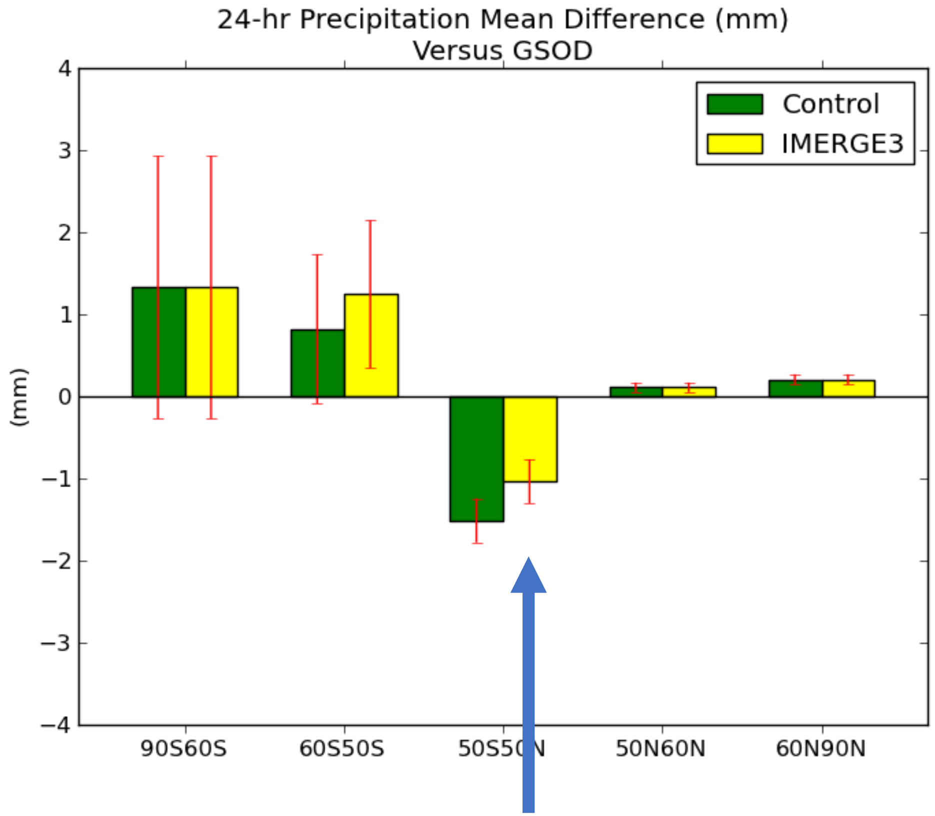


Bratseth Assimilation of IMERG-Early Run

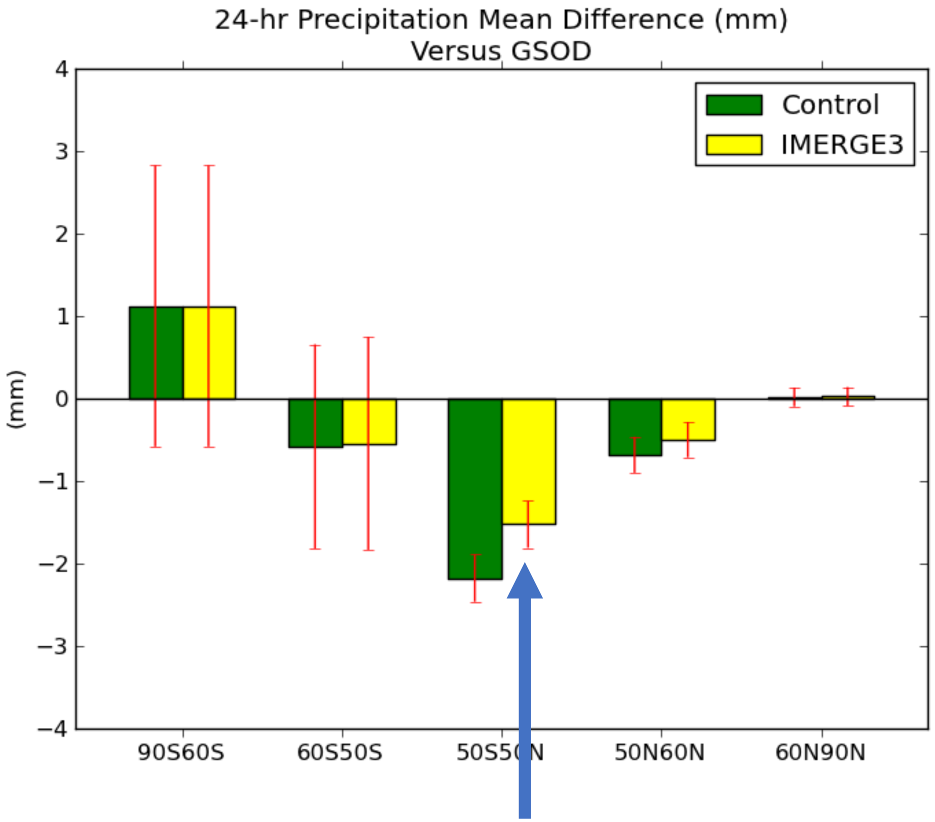
- **LIS 7.3 adds support for IMERG in Bratseth scheme**, and we run two experiments:
  - CONTROL: Normal data assimilation
  - IMERGE3: Add IMERG-ER, remove other satellite inputs
- Target two time periods:
  - December 2017 – February 2018 (**DJF 2018**)
  - June 2018 – August 2018 (**JJA 2018**)
- Results:
  - **No significant change in RMSD between experiments**
  - **Significant reduction in MD (bias) for 50S50N with IMERGE3**
  - **Significant difference in hemispheric RMSD and MD per season**

Bratseth Assimilation of IMERG-ER Change in Mean Difference

DJF 2018



JJA 2018



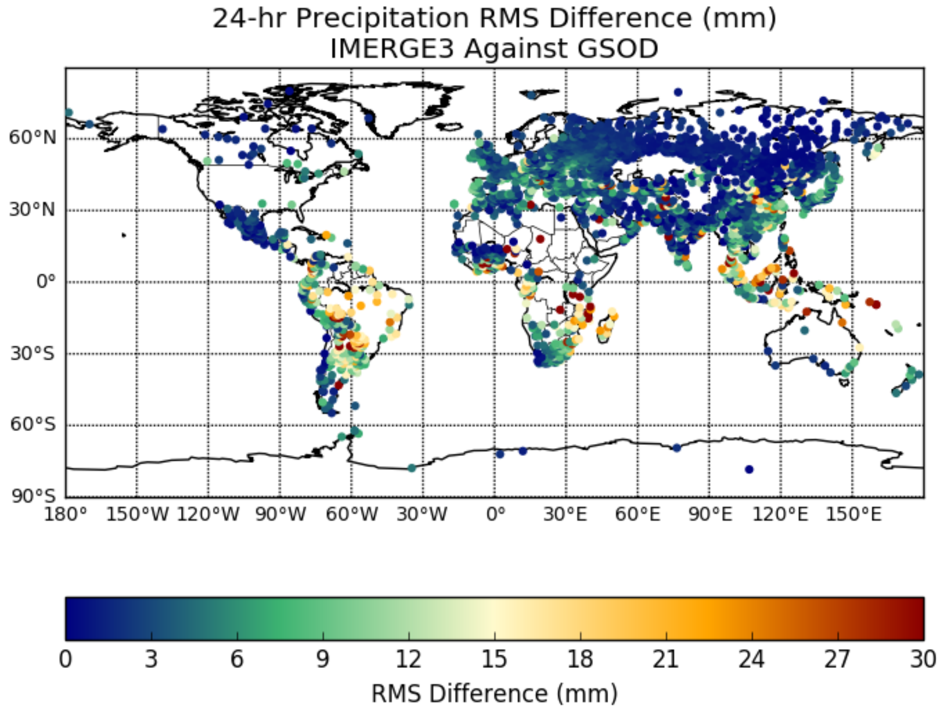
Mean of station bias values by latitudinal band

95% confidence intervals shown in red

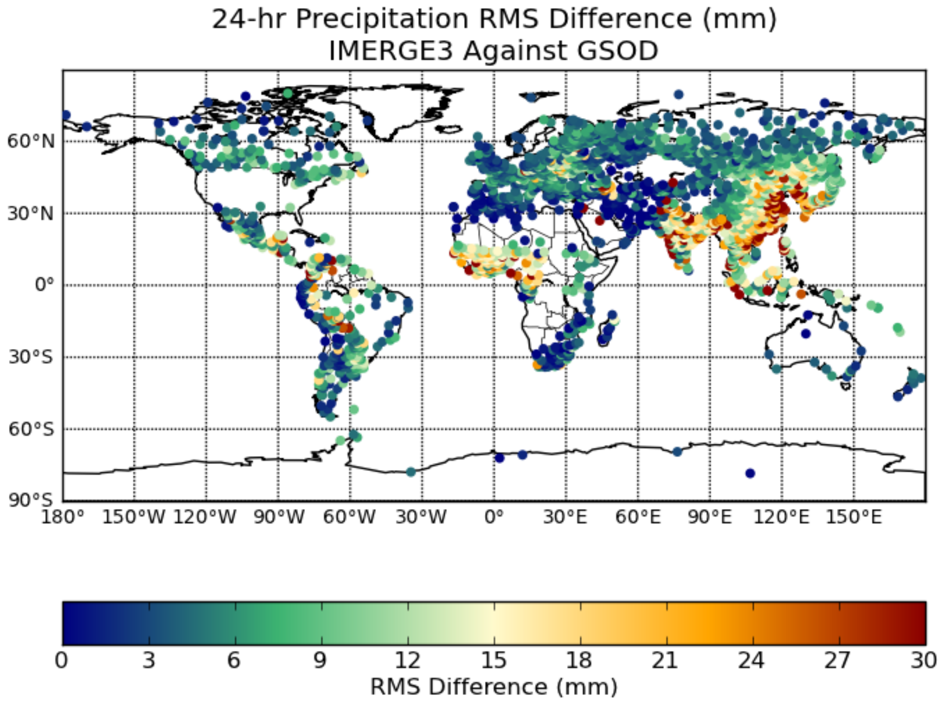
Significant reduction of bias for 50S50N when assimilating IMERG-ER for both seasons, but adds wet bias from 60S50S in DJF 2018

Bratseth Assimilation of IMERG-ER RMSD Results By Station

DJF 2018



JJA 2018



NOTE: Bratseth currently uses **single set of global error covariances** based on **several months** of ”tuning” against input observations

Northern Hemisphere RMSD lower/better in DJF2018 compared to JJA2018; opposite true in Southern Hemisphere – weaker signal also appears with bias (not shown)

Suggests need for hemispheric, time-of-year error covariances

Summary

USAF LIS 7.2 Bratseth precipitation analysis is a high-quality product

- **Appears to have superior accuracy** to Legacy Air Force product, IMERG-Final Run, and CHIRPSv2; however, dry bias is evident
- **UNCLASSIFIED NRT analyses now produced four times a day by 557th Weather Wing at 10-km global resolution**

Assimilating NASA IMERG-Early Run NRT retrievals into Bratseth appears to reduce dry bias

- **Capability exists with LIS 7.3, available for future USAF operations**

Hemispheric results differ by season:

- **Suggests need for developing hemispheric, time-of-year error covariances to further improve analysis [LIS 7.4?]**