Precipitation retrievals from passive microwave cubesat and smallsat sensors.

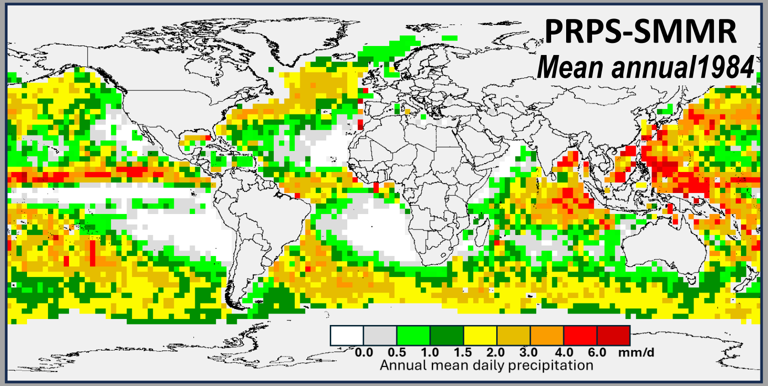
Chris Kidd and Toshi Matsui

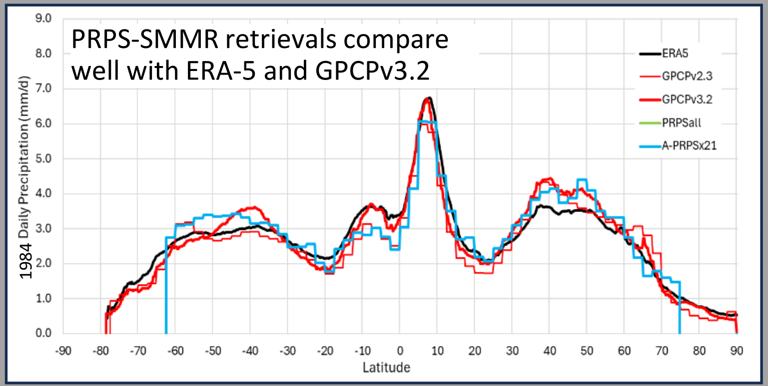
Earth System Science Interdisciplinary Centre, University of Maryland,

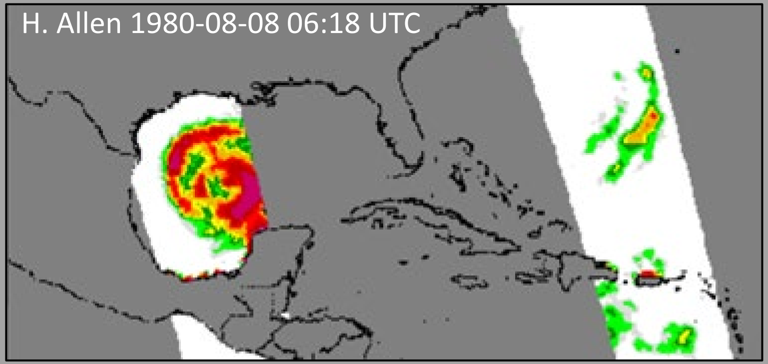
NASA/Goddard Space Flight Center

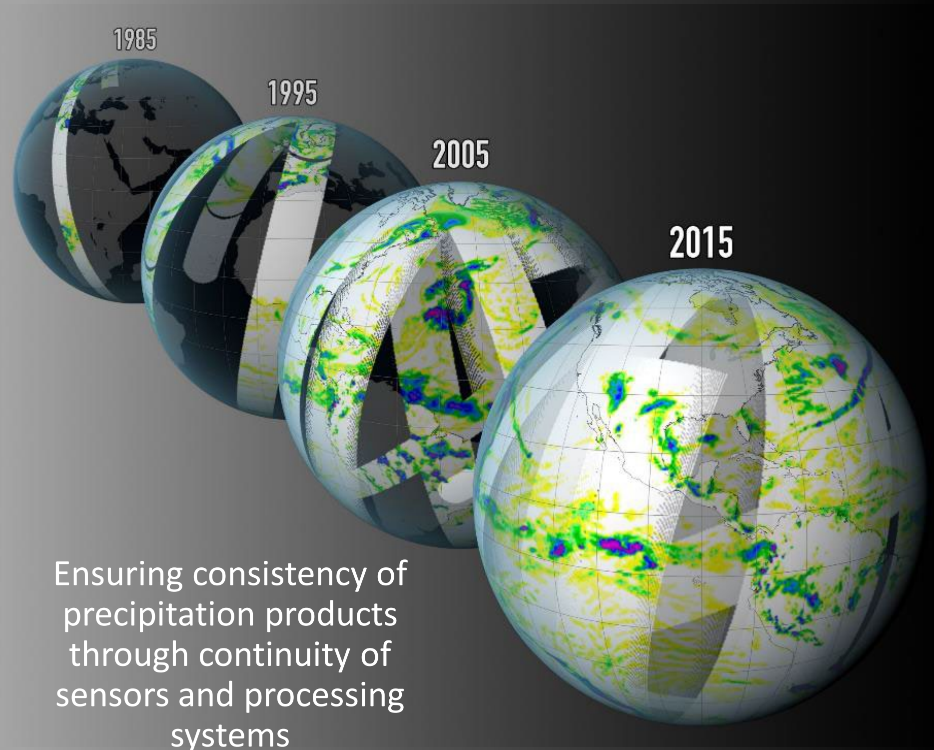
Continuity of Global Precipitation Measurements

Nimbus-7 SMMR 1978-1987

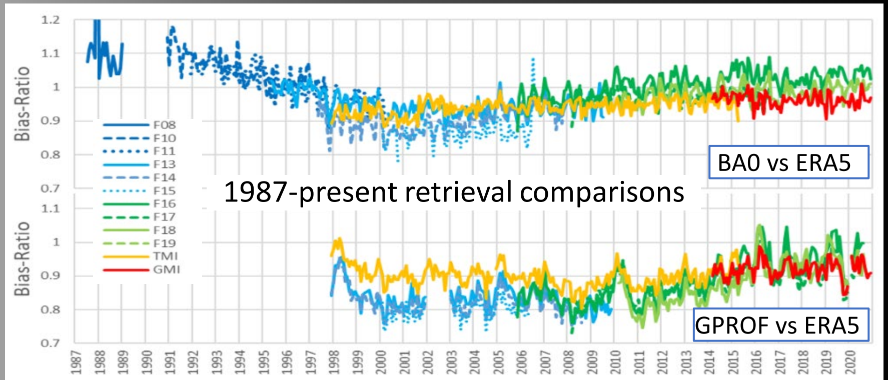




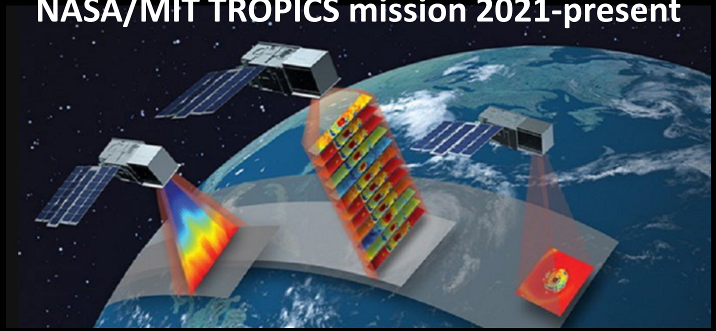


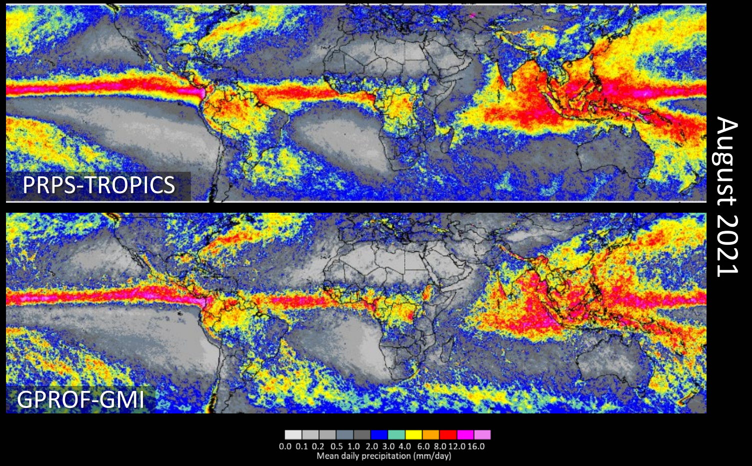


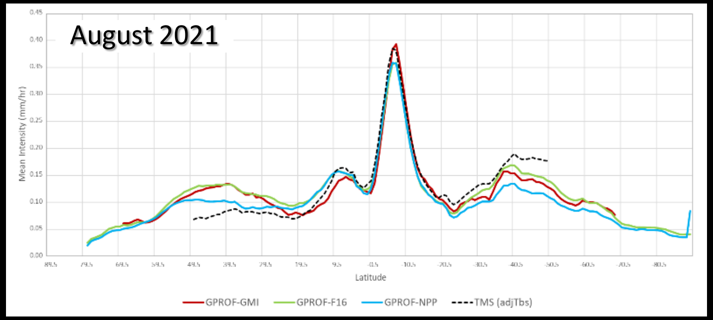
Ensuring consistency of precipitation products through continuity of sensors and processing systems



NASA/MIT TROPICS mission 2021-present







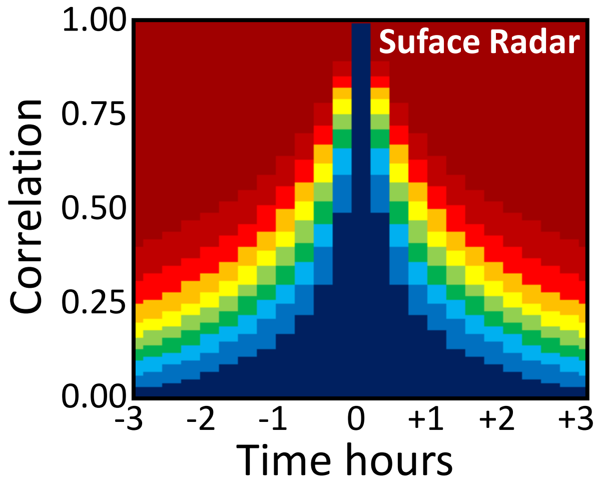
Introduction

Water is a fundamental component of the Earth's energy and water cycle, is essential to life on Earth, critical to our social and economic well being.

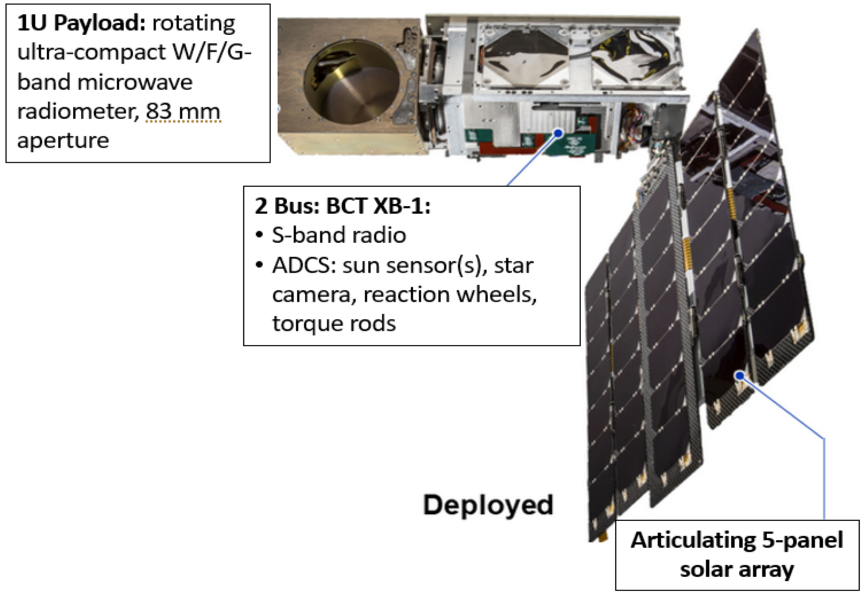
Precipitation (rain or snow) is ultimately the source of all freshwater – but is highly variable both spatially and temporally

The GPM mission, with a constellation of 10 international PMW sensors, provides mean revisit times of ≤3 h – <u>precipitation autocorrelation is ca. 30 mins</u>:

- multiple sensors are required to measure precipitation on a global scale.
- all available capable sensors are to needed capture the variability of precipitation.
- a cost-effective solution was/is needed to improve the temporal sampling – smallsats or cubesats.

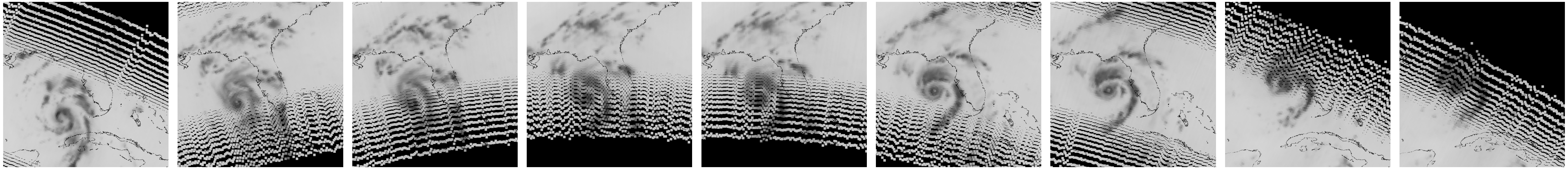


TROPICS & the TROPICS Millimeter-wave Sounder (TMS)



- **TROPICS pathfinder launched 30 June 2021** in near polar orbit
- **Four cubesats launched May 2023** into a low inclination orbit ca. 35N-35S.
- **Operating at 91.655, 118(x7), 183(x3), 204.8 GHz**

TROPICS 205 GHz imagery of Hurricane Idalia, 29/30 August 2023

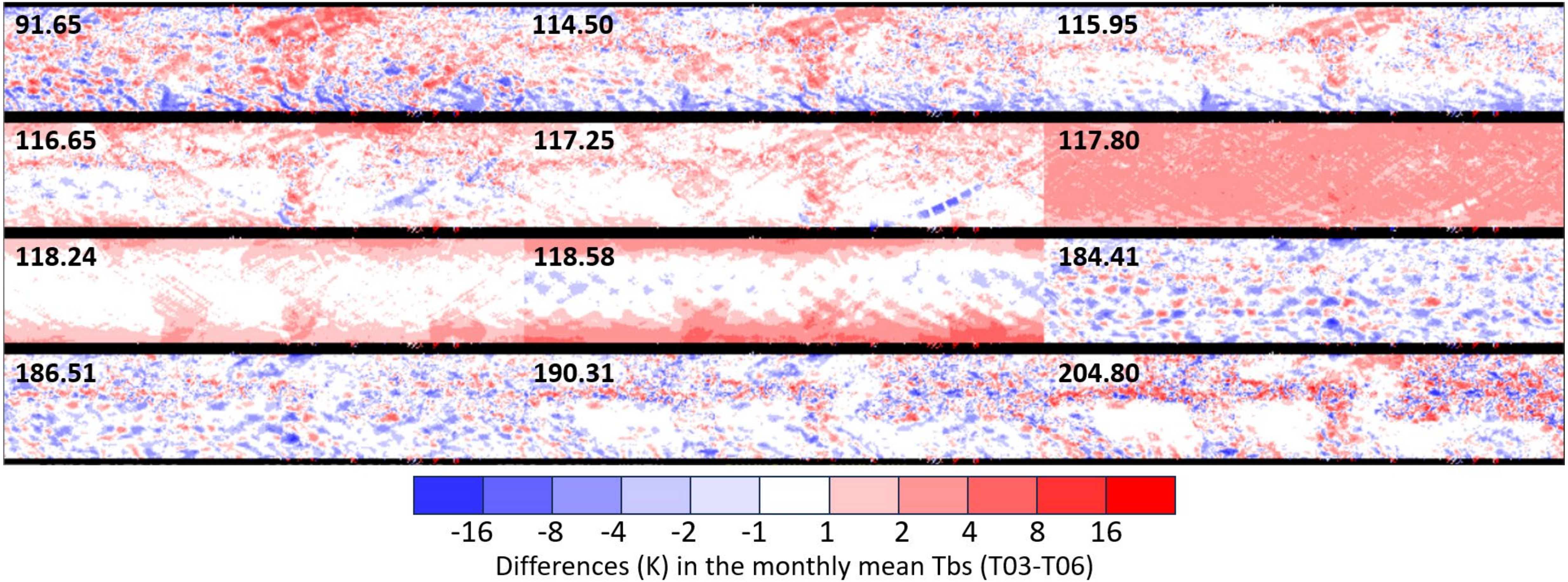


T03 13:59	T06 21:47	T05 22:14	T06 23:23	T05 23:50	T06 00:58	T05 01:25	T06 02:33	T05 03:00

27 mins | 67 mins | 27 mins | 68 mins | 27 mins | 68 mins | 27 mins

TROPICS inter-sensor comparisons

TROPICS-03 minus TROPICS-06 differences *Jul-Sep 2023; ctr swath 27-54*



Calibration of the TROPICS's TMS sensors has not be without difficulties

<u>The Precipitation Retrieval and Profiling Scheme (PRPS)</u>

PRPS Concept: *Simplicity, Efficiency, Flexibility*

Precipitation is determined <u>through association</u> with observed brightness temperatures - in common with most retrieval schemes

- Relies upon an indexed, observational *a priori* database.
- Uses no external dynamic ancillary data.
- Constant retrieval resolution across all scan angles, *ca.25x25 km for TMS*
- Provides measures of 'fit' and error *& surface type, most-likely precipitation.*

An *a priori* database (and index file) is built using sensor-reference data to associate the observed brightness temperatures with precipitation rates.

NOTE: the TMS at-launch retrievals used a surrogate ATMS database; current PRPS-TMS V04-01 uses a database based on TMS vs GMI GPROF.

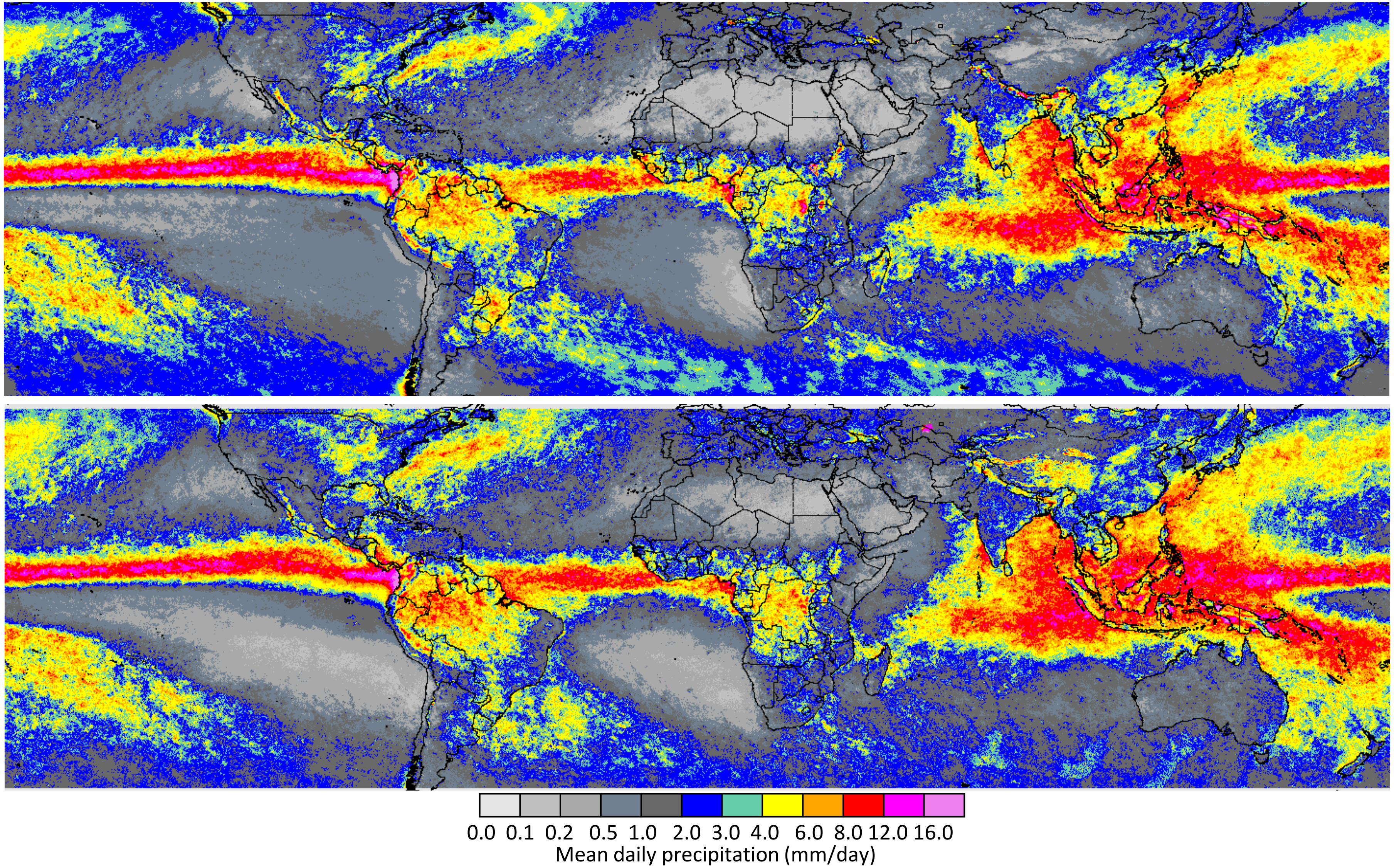
Mean annual precipitation

GPROF
NOAA-19
MHS

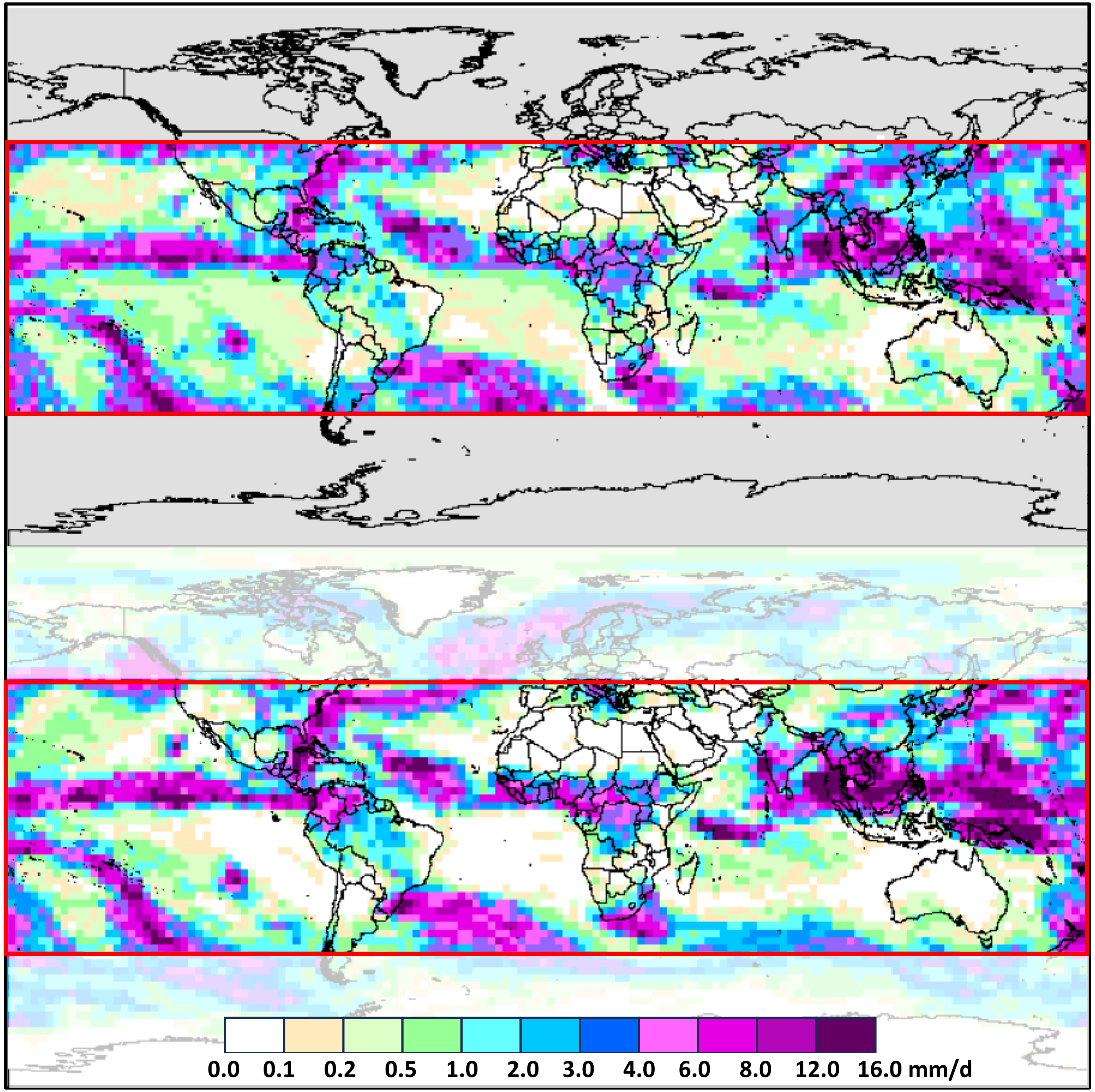
2021.08.01
-
2022.07.31

PRPS
TROPICS
TMS

2021.08.08
-
2022.07.31



Both instantaneous and monthly PRPS-TMS in good agreement with the GPROF retrievals



Case:

TROPICS-03, PRPS V04-01*

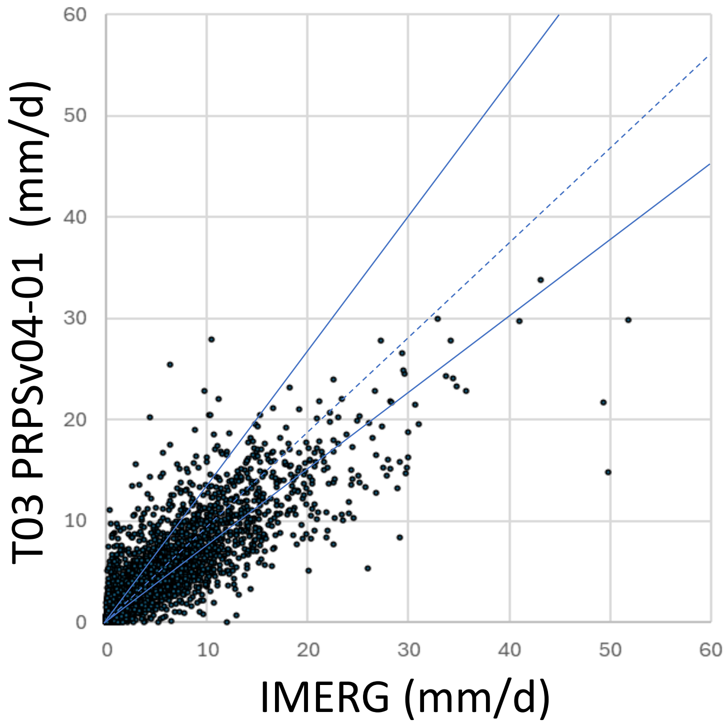
2023-09-16 to 2023-09-22

7-day accumulation, 2.5-degree resolution

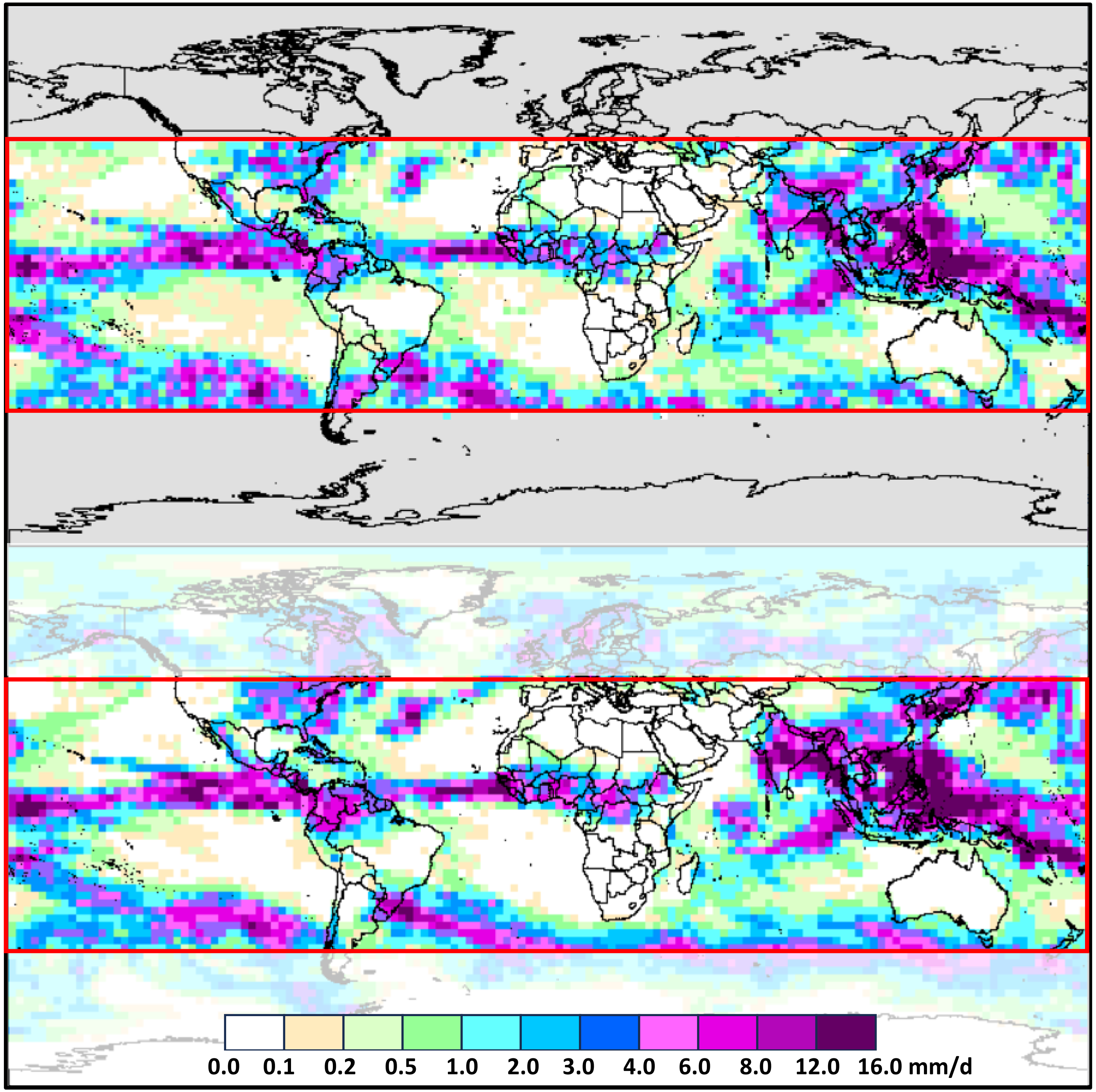
Mean error = -0.229 mm/d

Bias/ratio = 0.932

Correlation = 0.871



*channels 111100001111



Case:

TROPICS-06, PRPS V04-01*

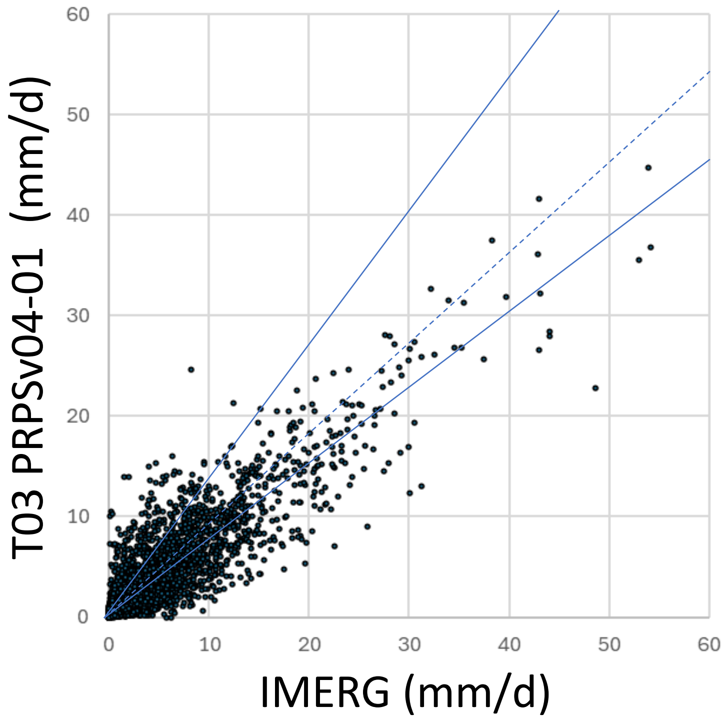
2023-07-06 to 2023-07-12

7-day accumulation, 2.5-degree resolution

Mean error = -0.358 mm/d

Bias/ratio = 0.885

Correlation = 0.899



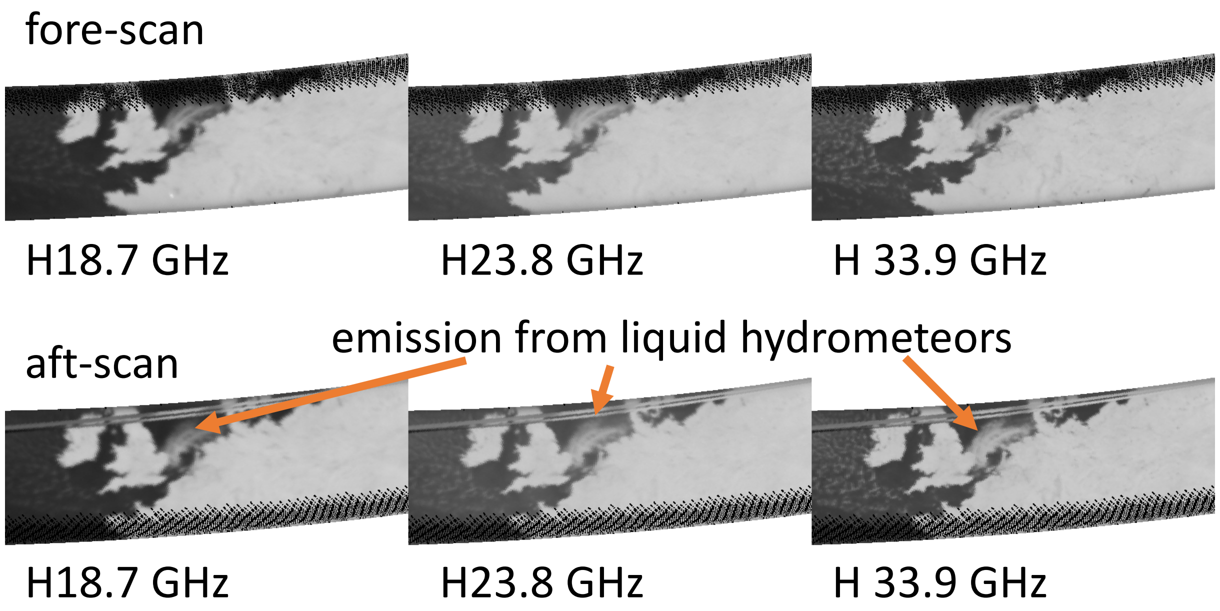
*channels 111100001111

International Space Station **STP-H8 mission**

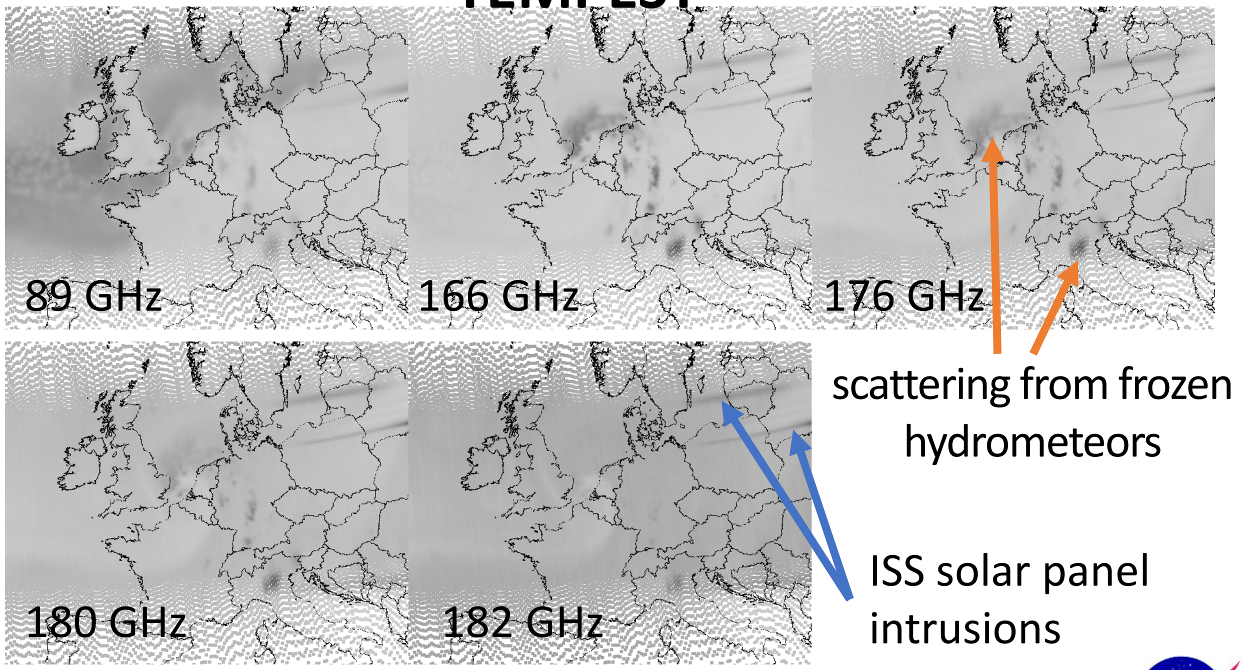
Two instruments *attached to the International Space Station (ISS) (52N-52S):*

- **Compact Ocean Wind Vector Radiometer (COWVR)** - fore/aft conical imaging at three frequencies (18.7, 23.8, and 33.9 GHz) with six (full) polarizations for each frequency.
- **Temporal Experiment for Storms and Tropical Systems (TEMPEST)** - cross-track scanning at five frequencies (89, 166, 176, 180, and 182 GHz).

COWVR



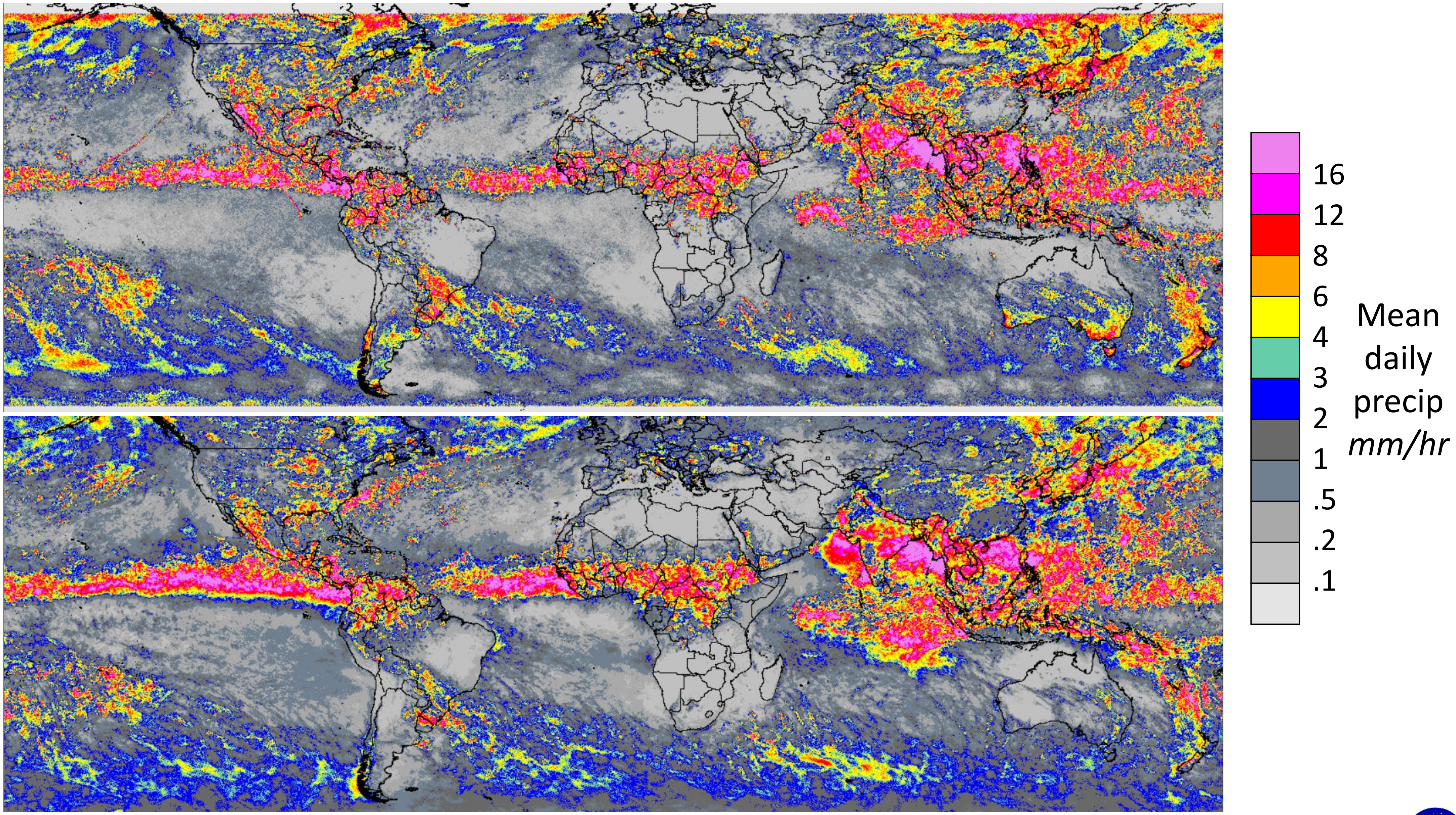
TEMPEST



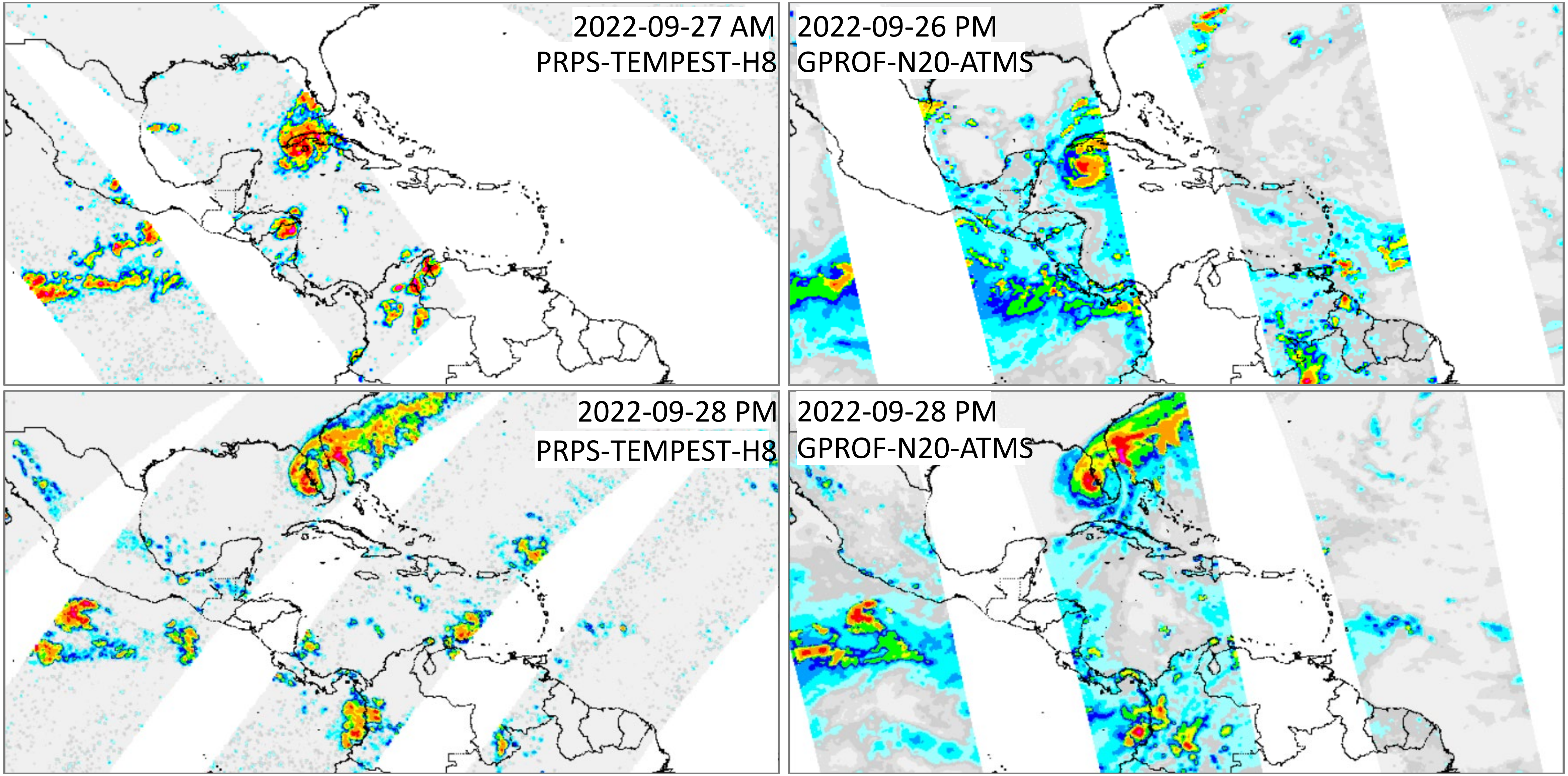
PRPS-TEMPEST-H8 monthly precipitation: August 2022

PRPS-TEMPEST-H8

GPROF NOAA20 ATMS



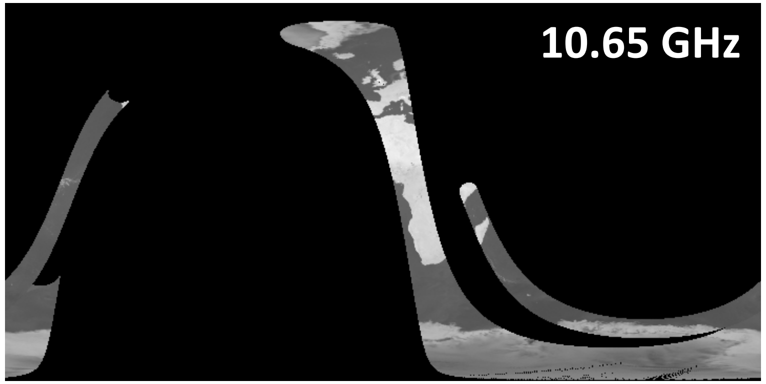
Hurricane Ian 2022



Passive Microwave frequencies

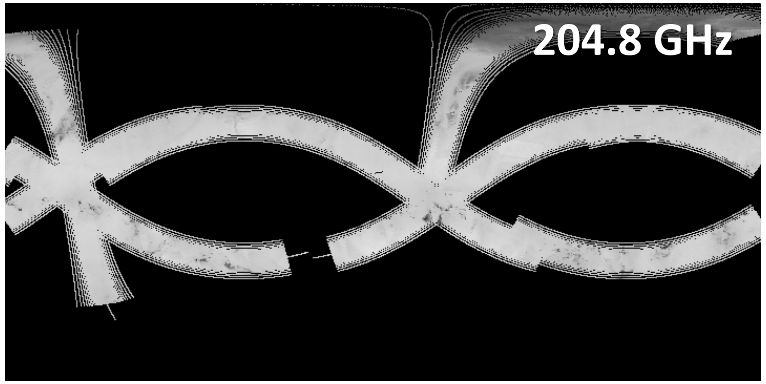
Frequency	**TROPICS TMS**	**STP-H8 COWVR**	**STP-H8 TEMPEST**	GPM GMI	*GOSAT-GW AMSR-3*	NOAA ATMS	WSF-M MWI	*EPS MWS*	*EPS MWI*	*EPS ICI*
6					*6.925/7.3*					
10				10.65	*10.25/10.65*		10.85			
18		**18.7**		18.7	*18.7*		18.85		*18.7*	
23		**23.8**		23.8	*23.8*	23.8	23.8	*23.8*	*23.8*	
37		**33.9**		36.5	*36.42*	31.4	36.75/37.3	*31.4*	*31.4*	
50-60						50-57 (13)		*50-57(14)*	*50-54 (4)*	
90	**91.655±1.4**		**89**	89.0	*89.0*	88.2	89	*89*	*89.0*	
118	**114-118 (7)**								*118 (4)*	
150/165			**165**	166.5	*165.5*	165.5		*164-167*	*165.5*	
183	**184-190 (3)**		**174-181 (3)**	183.31 (2)	*183.31(2)*	183.31 (5)		*183.31 (5)*	*183.31 (5)*	*183.31 (3)*
200+	**204.8**							*229.0*		*243.2*
300+										*325 (3)*
400+										*448 (3)*
600+										*664*

1-hour Global Coverage by PMW frequency

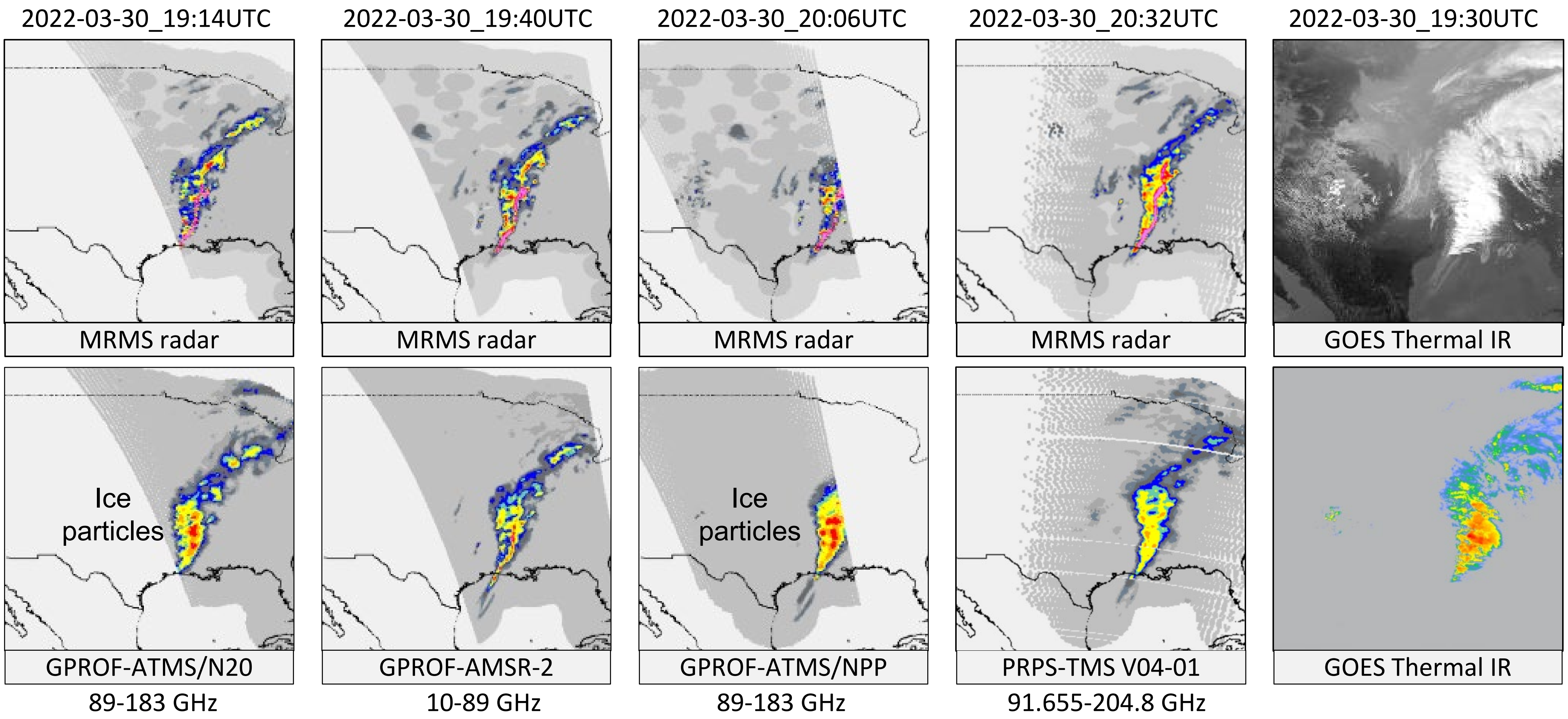


12:00 to 13:00 05-Jul-2023

Higher frequency channels (sensitive to ice) are better sampled than the lower frequency (liquid) channels



Imager vs sounder precipitation retrievals



High-frequency PMW retrievals tend to be more similar to the cloud-top Thermal IR

Future challenges

Fundamental is an understanding of the properties and characteristics of what you are measuring.

- **observations are needed at scales that reflect the natural variability of precipitation** *(spatial and temporal scales are intrinsically linked)*
- **Need for 'baseline' sensors** *(such as AMSR/GMI), augmented by smallsats/cubesats to improve temporal sampling.*

However:

- **not all observations for retrievals are the same** *- different channel availability, spatial resolution, noise/accuracy levels, etc… .*
- **Integration of new, commercially-collected data** – *new challenges and opportunities*