

Concurrent temperature/moisture profile and hydrometeor retrievals from the TROPICS Pathfinder mission

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Overview

- Combining GPM-DPR radar, ERA-5 and TROPICS Pathfinder
- Kd-tree-based retrievals
- Properties of retrieval
- Accuracy based on test dataset
- Global retrievals

Data

- TROPICS data from August 2021 to November 2021 (V02-03_0.4dev3)
- Collocated ERA-5 T/q profiles
- GPM-DPR data from August 2021 to November 2021
(Combined Precipitation L2B 1.5 hours 5 km V06 (GPM_2BCMB))
- ERA-5 T,q profiles
- Ocean only

TROPICS

“Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats”

- 3U-CubeSat mission led by Bill Blackwell MIT
- Tropics Pathfinder operational since August 2021
- Four more spacecraft to be launched hopefully May 2023
- Cross-track scanning 12 channel MW instrument

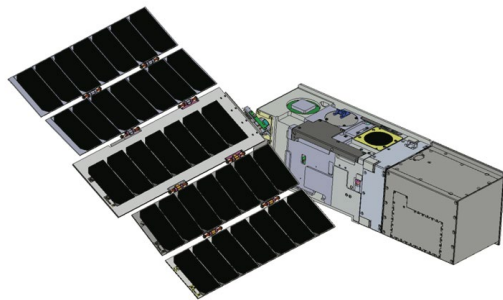


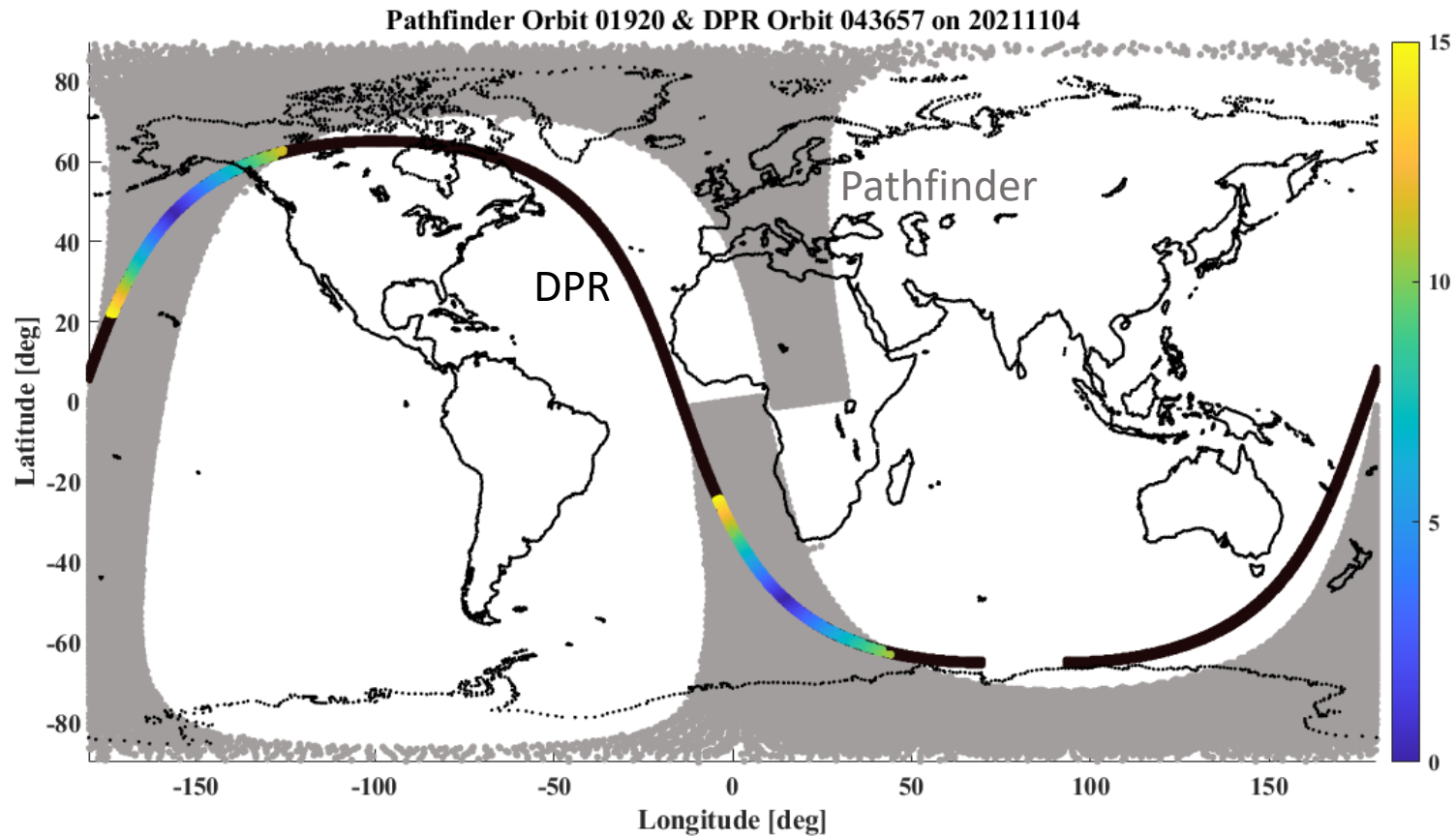
TABLE 2 Description of the TROPICS radiometer channels

Channel	Centre frequency (Ghz)	Bandwidth (MHz)	Beamwidth (°) Down/Cross	ΔT_{rms} (K)	Calibration accuracy (K)
1	91.655 ± 1.4	1000	3.0/3.17	0.7	2.0
2	114.50	1000	2.4/2.62	1.0	1.5
3	115.95	800	2.4/2.62	0.9	1.5
4	116.65	600	2.4/2.62	0.9	1.5
5	117.25	600	2.4/2.62	0.9	1.5
6	117.80	500	2.4/2.62	0.9	1.5
7	118.24	380	2.4/2.62	0.9	1.5
8	118.58	300	2.4/2.62	1.0	1.5
9	184.41	2000	1.5/1.87	1.0	1.0
10	186.51	2000	1.5/1.87	0.6	1.0
11	190.31	2000	1.5/1.87	0.6	1.0
12	204.80	2000	1.4/1.83	0.6	1.0

DPR / TROPICS match database

- Matching how?
 - 0.25 x 0.25 deg 15 min,
 - averaging all DPR measurement in that 0.25x0.25 deg box.
 - Using single L1 observations from TROPICS (no averaging)
 - Quantities we use from DPR:
 - surface rain rate
 - Precipitation Ice Water Path (vertically integrated ice water content derived from DPR)
 - Hydrometeor Water Path (vertically integrated ice +rain water content derived from DPR)
 - Note: Since DPR is not sensitive to cloud ice with small suspended ice particles, e.g. cirrus, we cannot derive cloud ice water path. (TROPICS is also not sensitive to those).
 - Concurrent ERA-5 T,q profiles

- An example of single orbit collocations between Pathfinder & DPR within 15 mins time window
- A total of ~2.1 million collocations obtained for Aug-Nov 2021
- 80% for training and 20% for testing



Calculating DTB

1204

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- In addition to using the 12 TROPICS TBs, we use DTB, defined as observed minus simulated cloud-free TBs.

$$\Delta TB = TB_{\text{obs}} - TB_{\text{sim}}$$

- Cloud-free simulations based on ERA-5 and RTTOV
- Follow 2020 Chen & Bennartz paper (but here no bias correction applied)

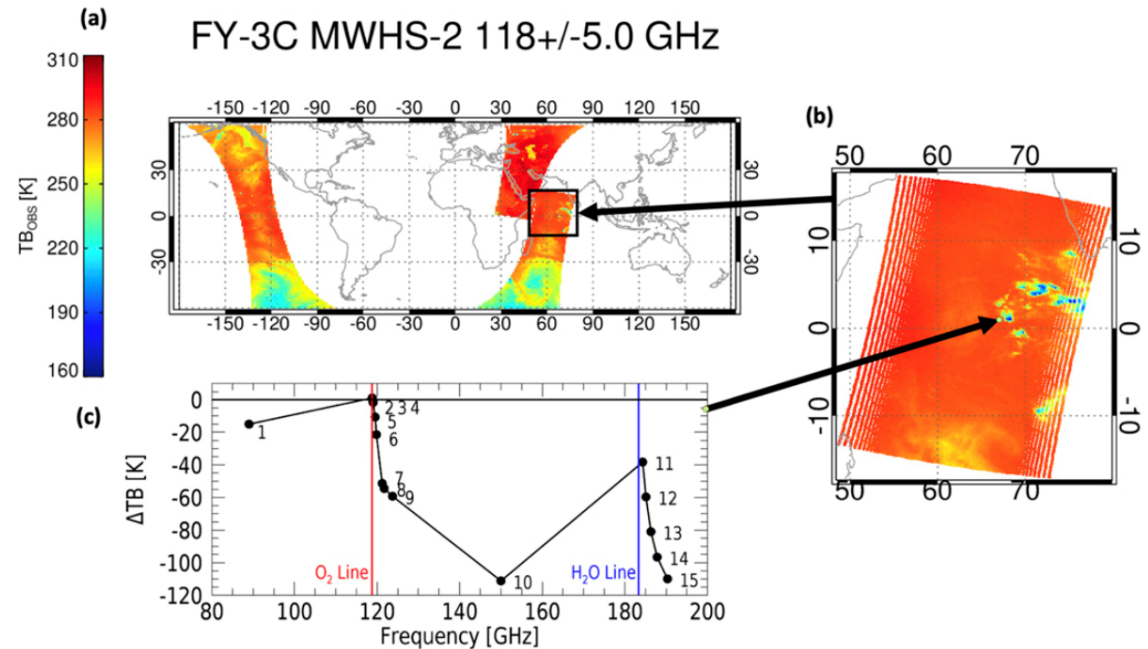
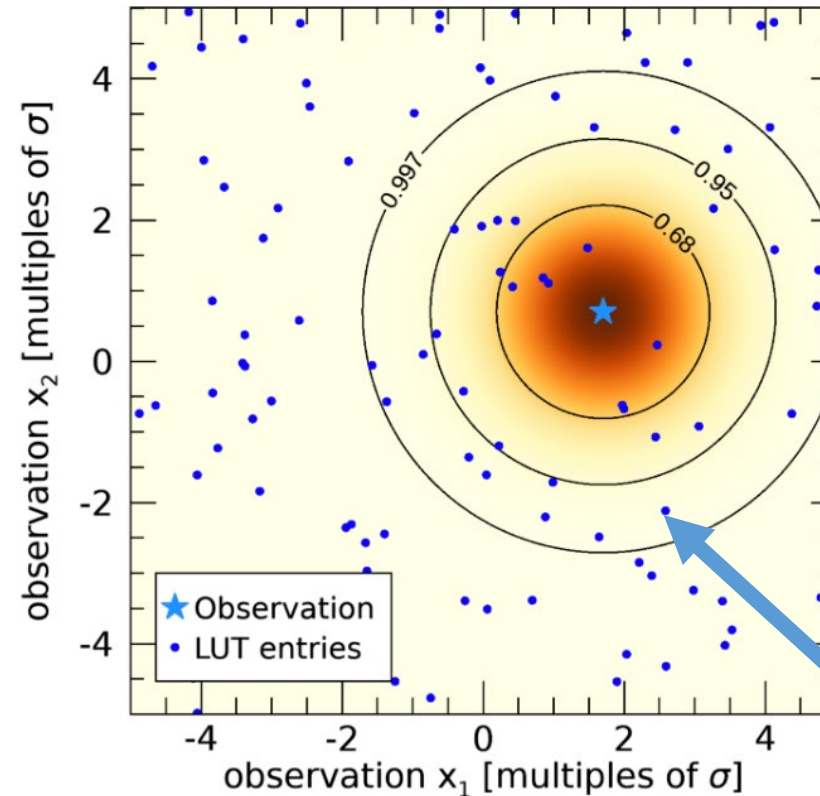


FIG. 4. Example of the scattering signature of deep convective clouds observed by MWS-2. (a) One full orbit of MWS-2 data (channel 9; 22 Aug 2016, with start time 0554 UTC). (b) The same data as in (a), enlarged around an area in the Indian Ocean that contains isolated deep convection, visible as the blue and green dots in the center-right of the panel. (c) The spectral variation of ΔTB for the center of one of the convective cells, as highlighted by the arrow to (b); the plot in (c) also shows the location of the 118.75-GHz oxygen absorption line, the 183.31-GHz water vapor absorption line, and the MWS-2 channel numbers corresponding to Table 1. Note that MWS-2 sounding channels 2–9 and 11–15 are all double sideband (e.g., channel 9 is 118.75 ± 5 GHz). In (b), their corresponding ΔTB are only shown at the location of the upper subband (e.g., $118.75 + 5$ GHz).

Kd-tree retrieval

- Allows finding the nearest neighbor in a lookup table in a multi-dimensional space
- Allows finding all points in a LUT in a hyper-sphere around a given point
- It also allows for various parameters to be retrieved beyond just the values of the nearest neighbor.



- Each LUT entry has:
- DPR IWP
 - DPR RR
 - ERA5 T-profile
 - ERA5 Q-profile

Retrieval:

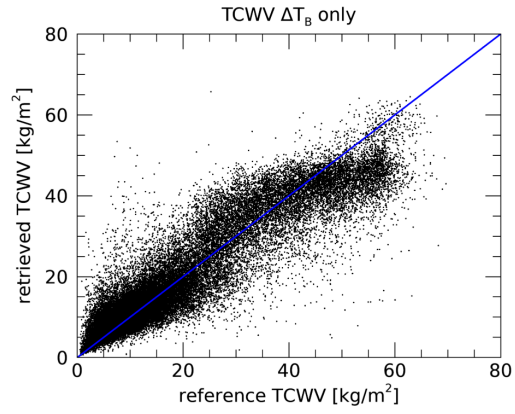
- For each new observation find all LUT entries that fit into e.g. 0.65 likelihood hyper-sphere and average.

Testing different retrievals

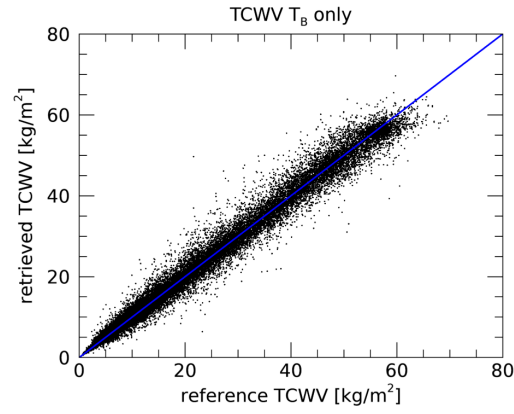
- 12-dimensional kd-tree based on DTB
- 12-dimensional kd-tree based on TB
- 24-dimensional kd-tree based on both, DTB and TB

(Note: actual dimensionality of dataset is lower. One could e.g. perform a PCA before to work in lower dimensions. On to-do list)

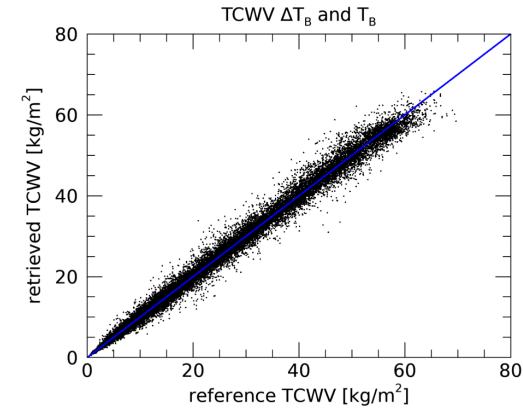
DTB only (12-dim)



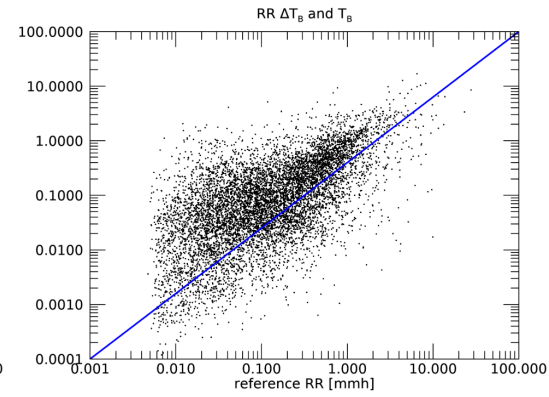
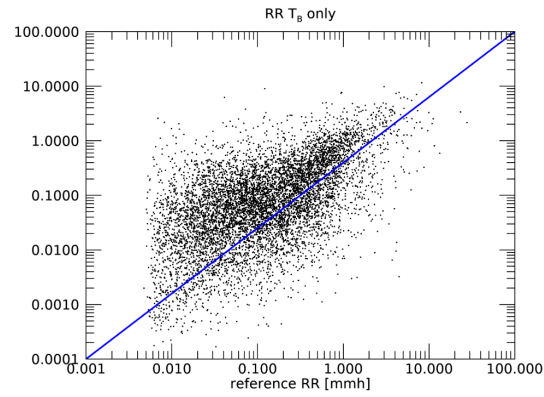
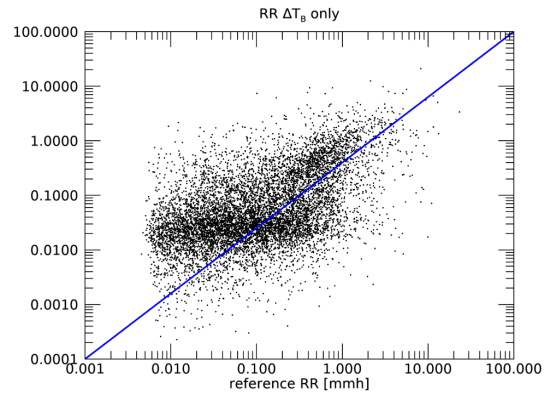
TB only (12-dim)



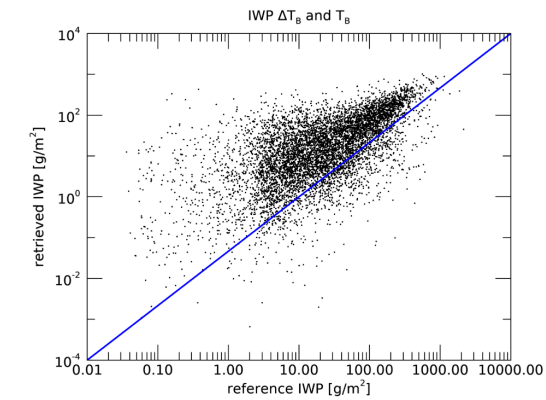
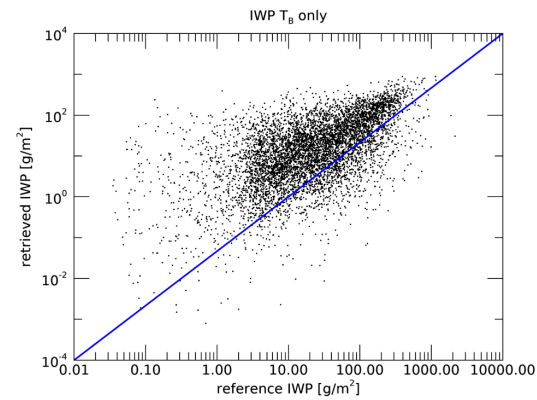
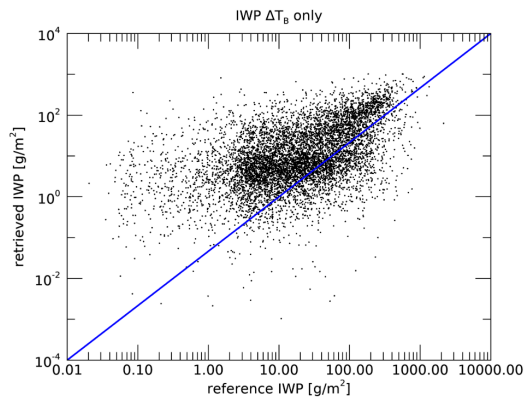
Both (24-dim)



TCWV



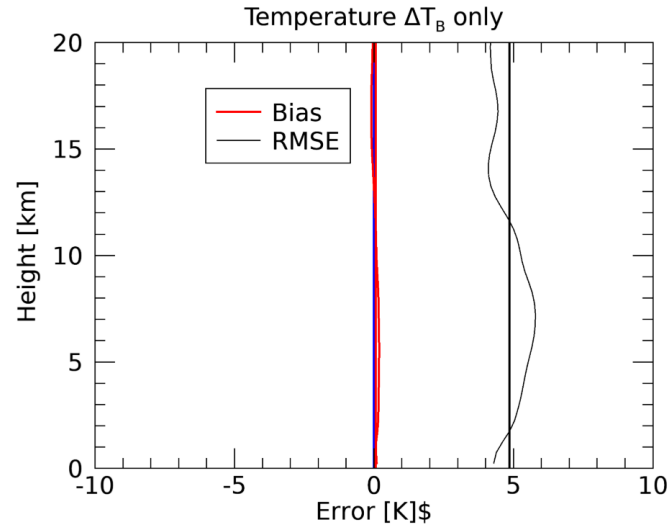
IWP



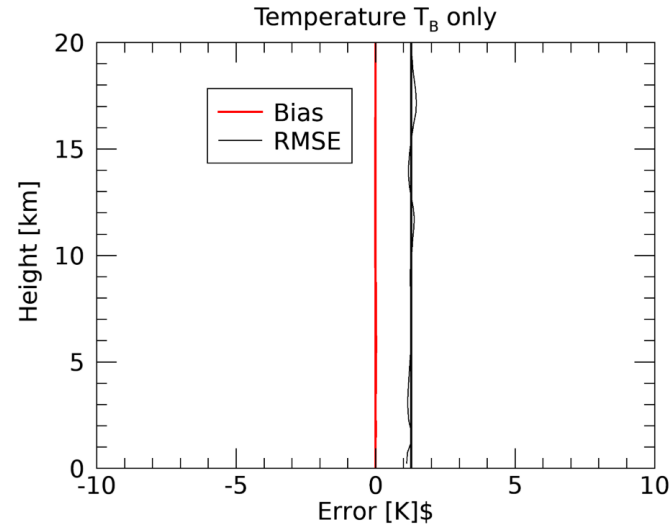
RR

DTB only (12-dim)

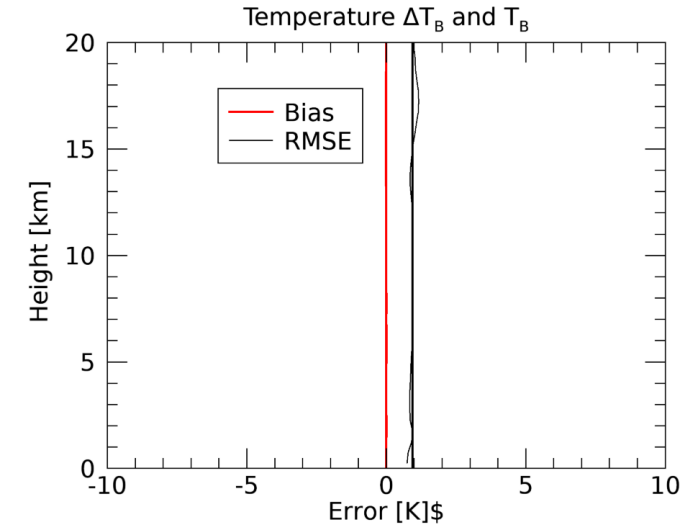
Temperature



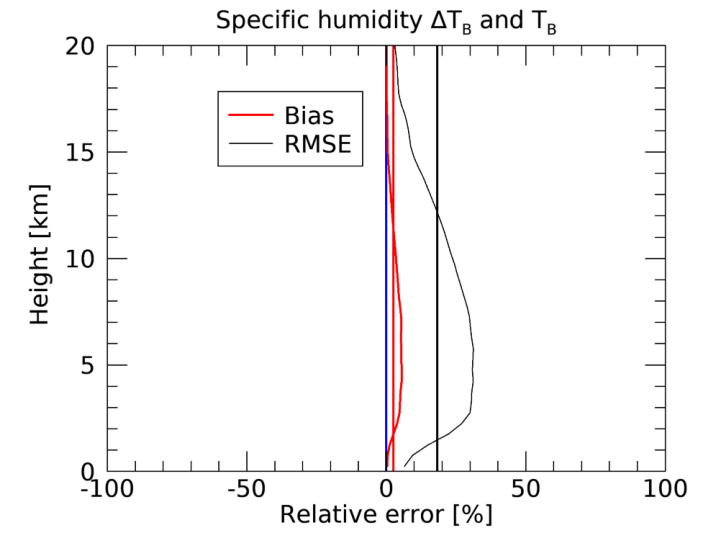
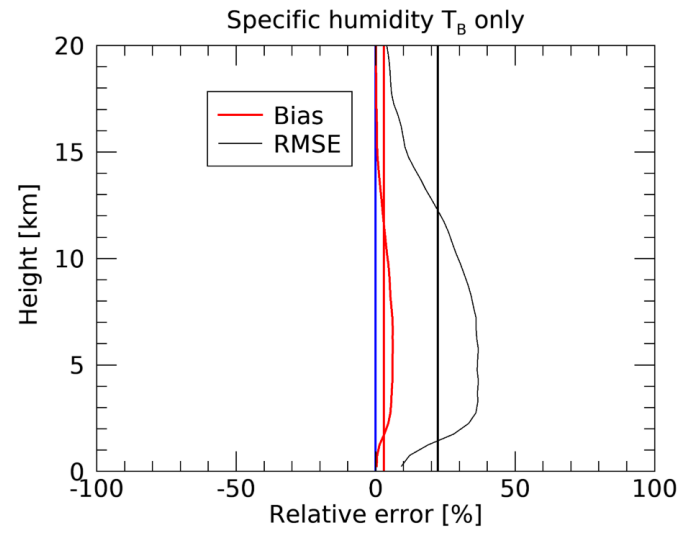
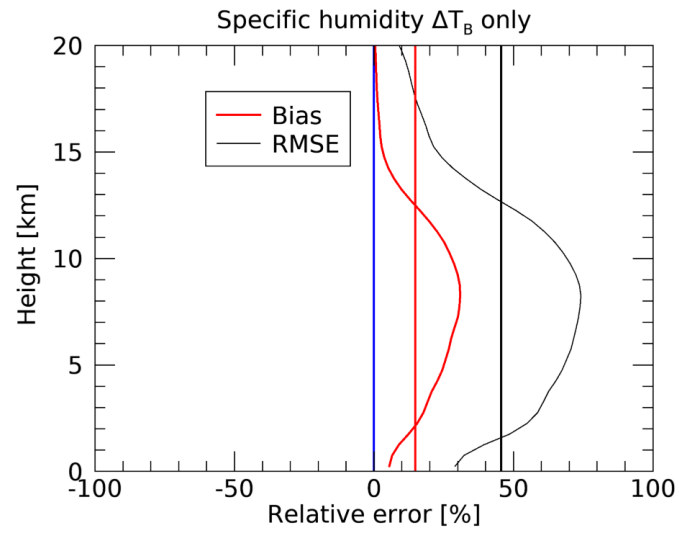
TB only (12-dim)



Both (24-dim)



Moisture



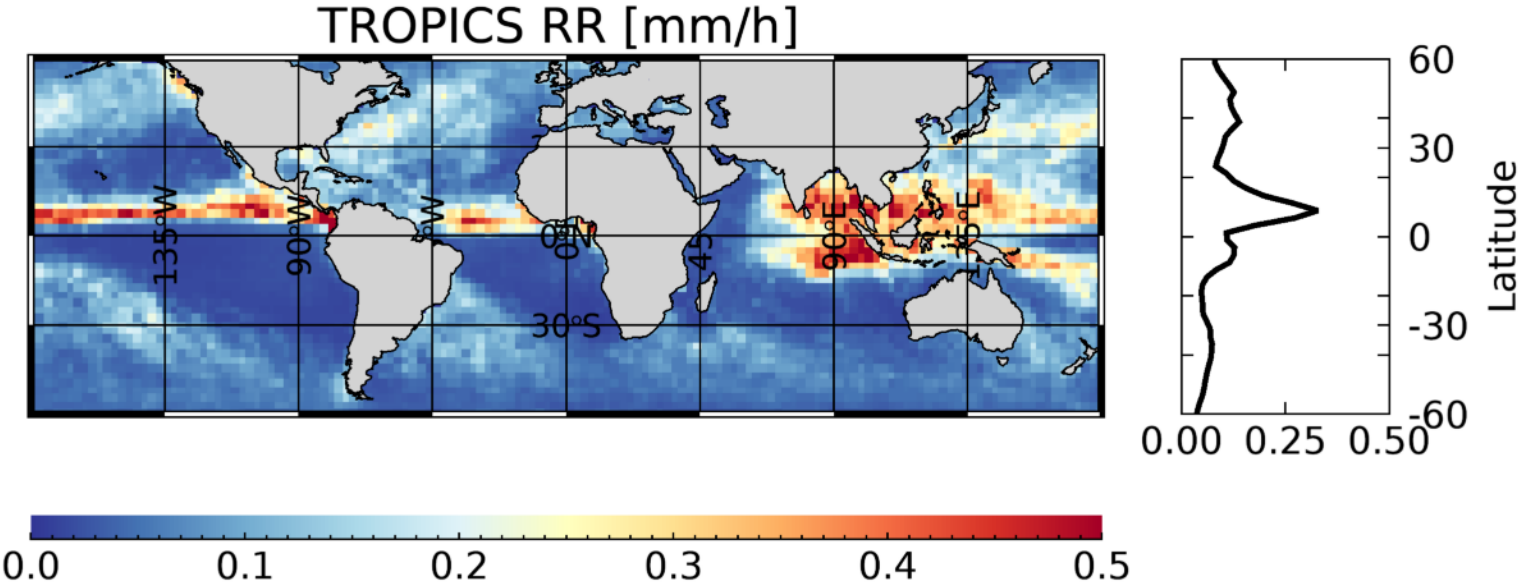
Summary of performance

T-only (12-dimensional)		Bias	RMSE
TCWV	[kg/m ²]	-0.04	1.70
IWP	[g/m ²]	0.09	35.9
RR	[mm/h]	0.02	0.34
T-profile	[K]	-0.01	1.27
q-profile	[relative %]	2.91	22.22

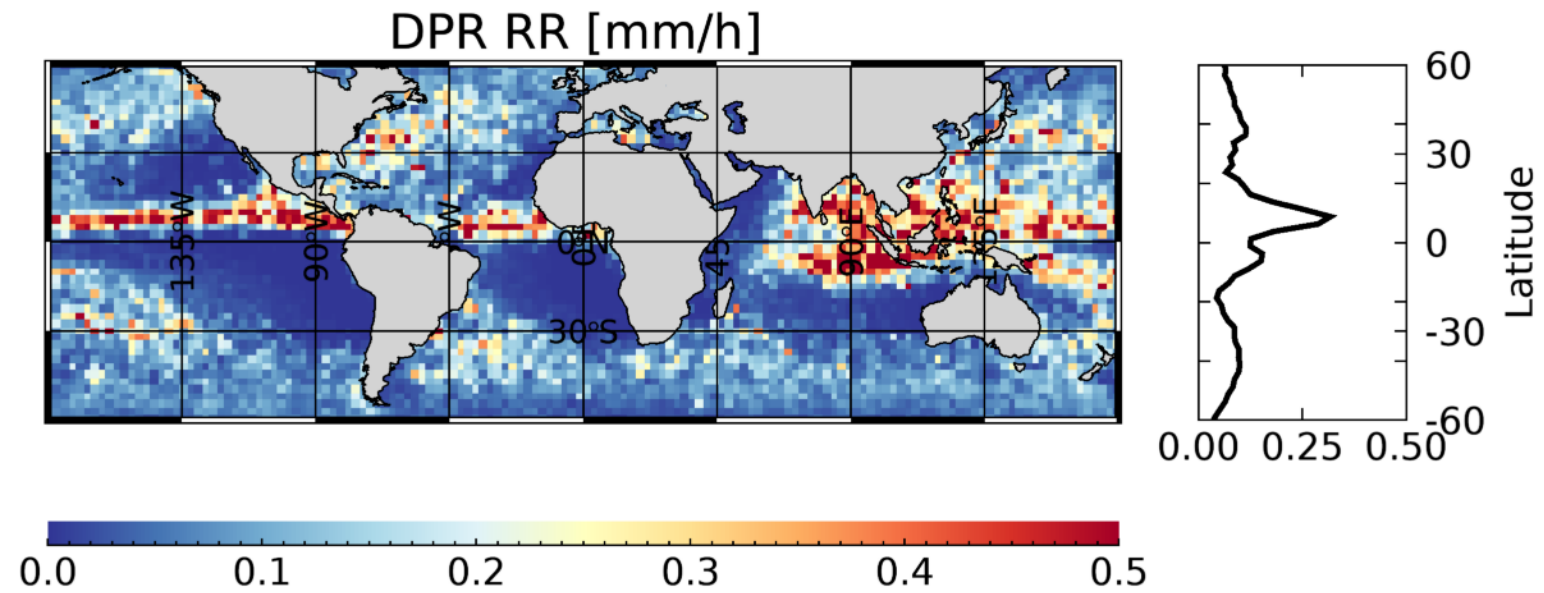
dT-only (12-dimensional)		Bias	RMSE
TCWV	[kg/m ²]	-0.08	5.19
IWP	[g/m ²]	0.11	37.5
RR	[mm/h]	0.01	0.32
T-profile	[K]	0.05	4.85
q-profile	[relative %]	14.82	45.64

dT+T (24-dimensional)		Bias	RMSE
TCWV	[kg/m ²]	0.00	1.16
IWP	[g/m ²]	0.03	32.3
RR	[mm/h]	0.01	0.29
T-profile	[K]	-0.01	0.94
q-profile	[relative %]	2.51	18.23

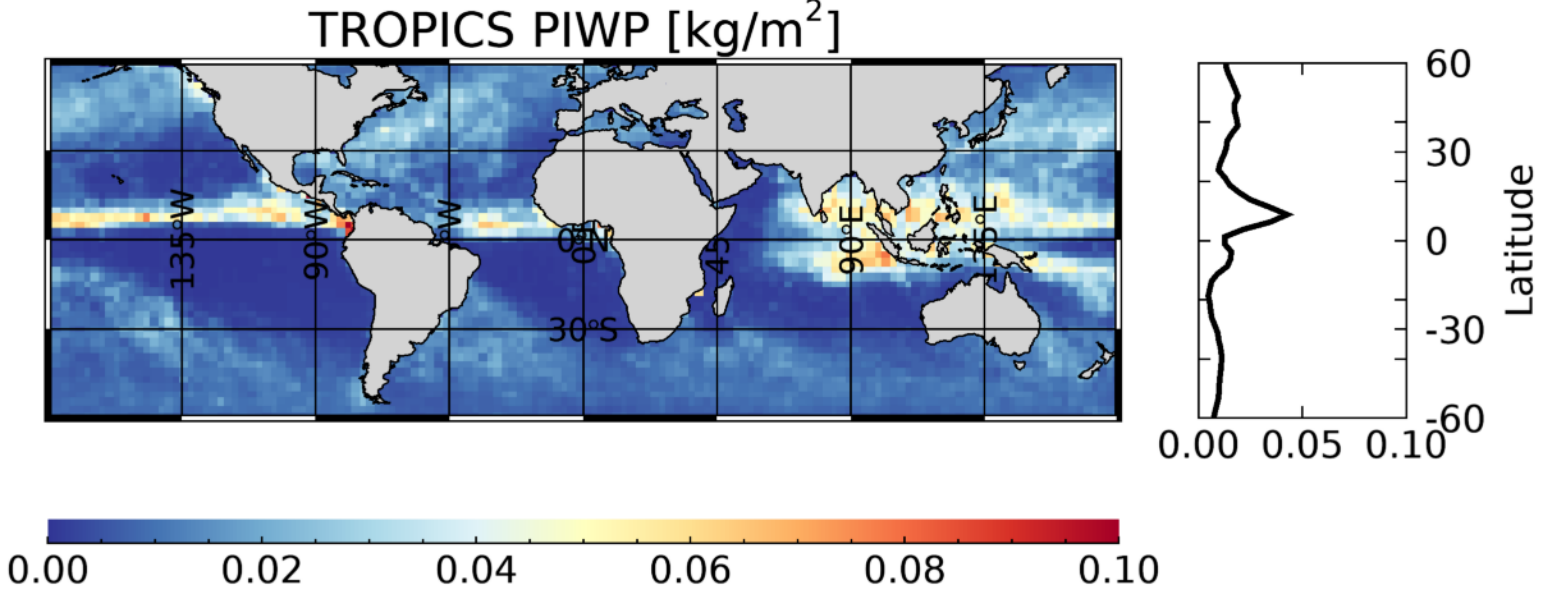
TROPICS Rain Rate



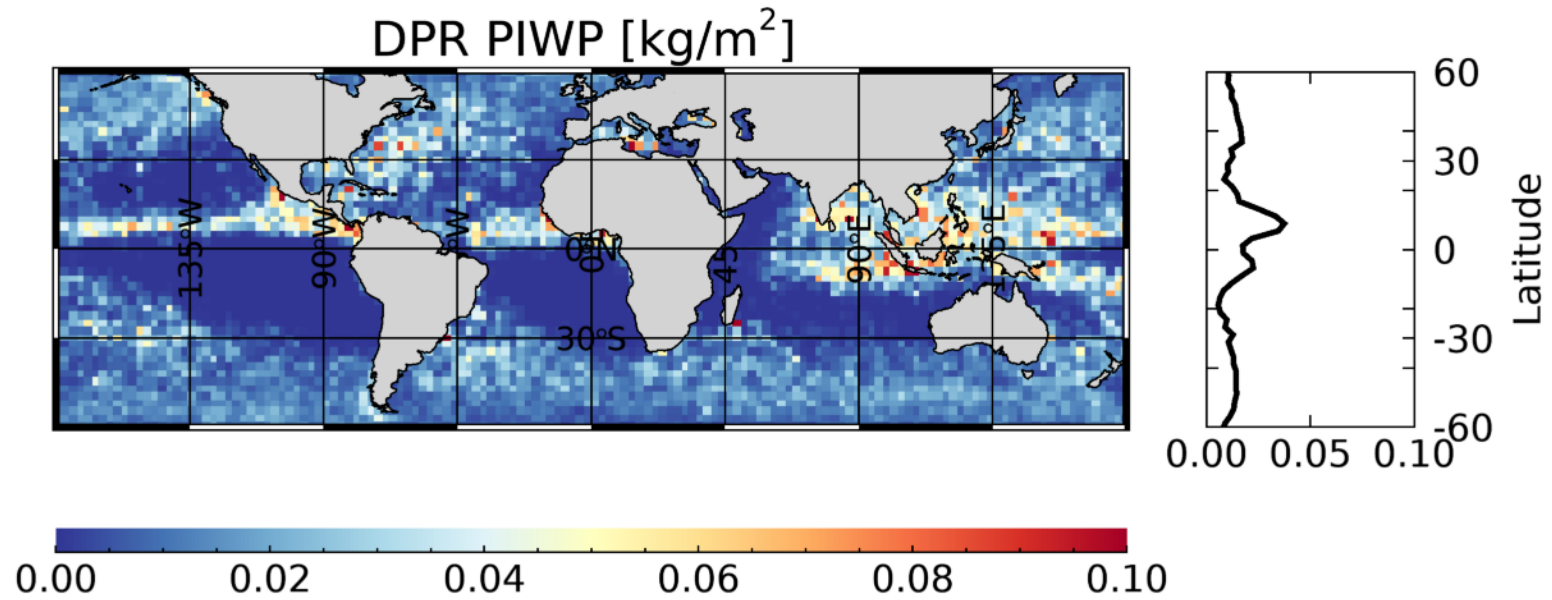
DPR Rain Rate



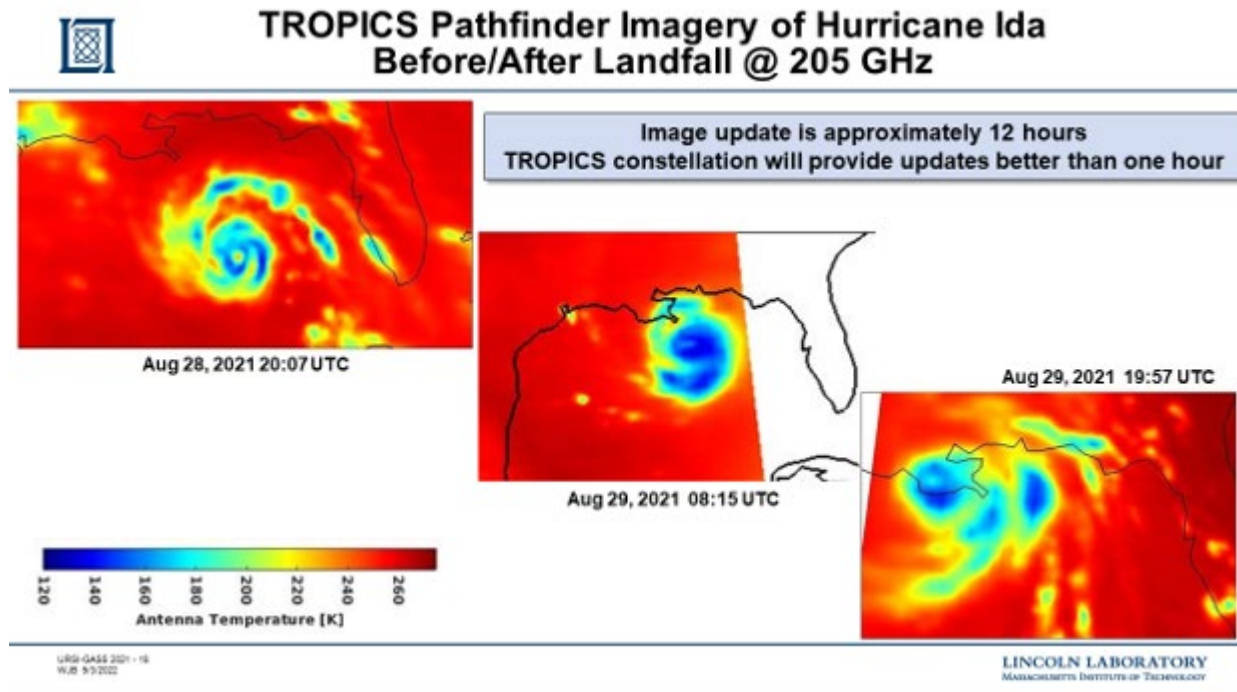
TROPICS Precip Ice Water Path



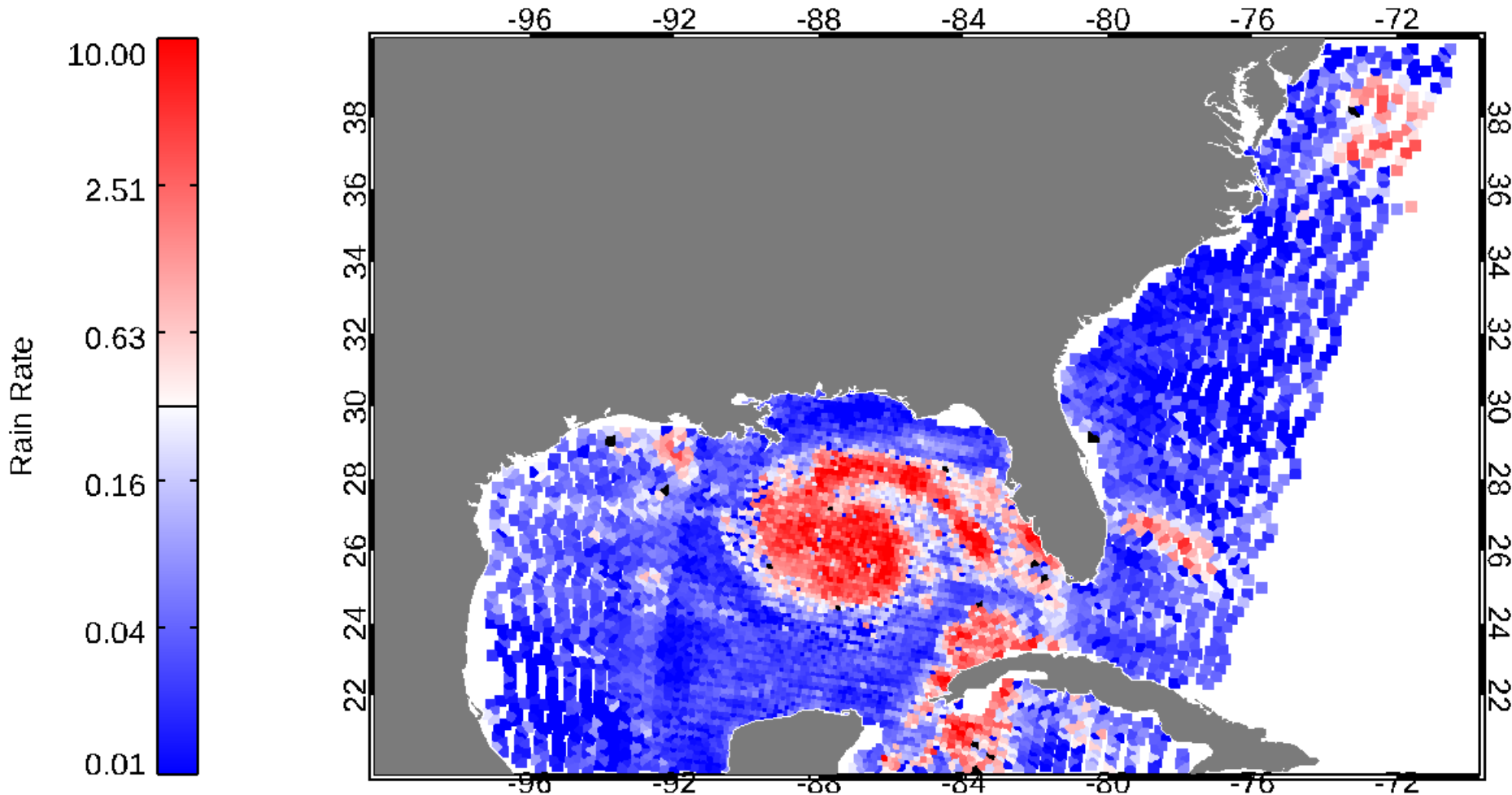
DPR Precip Ice Water Path



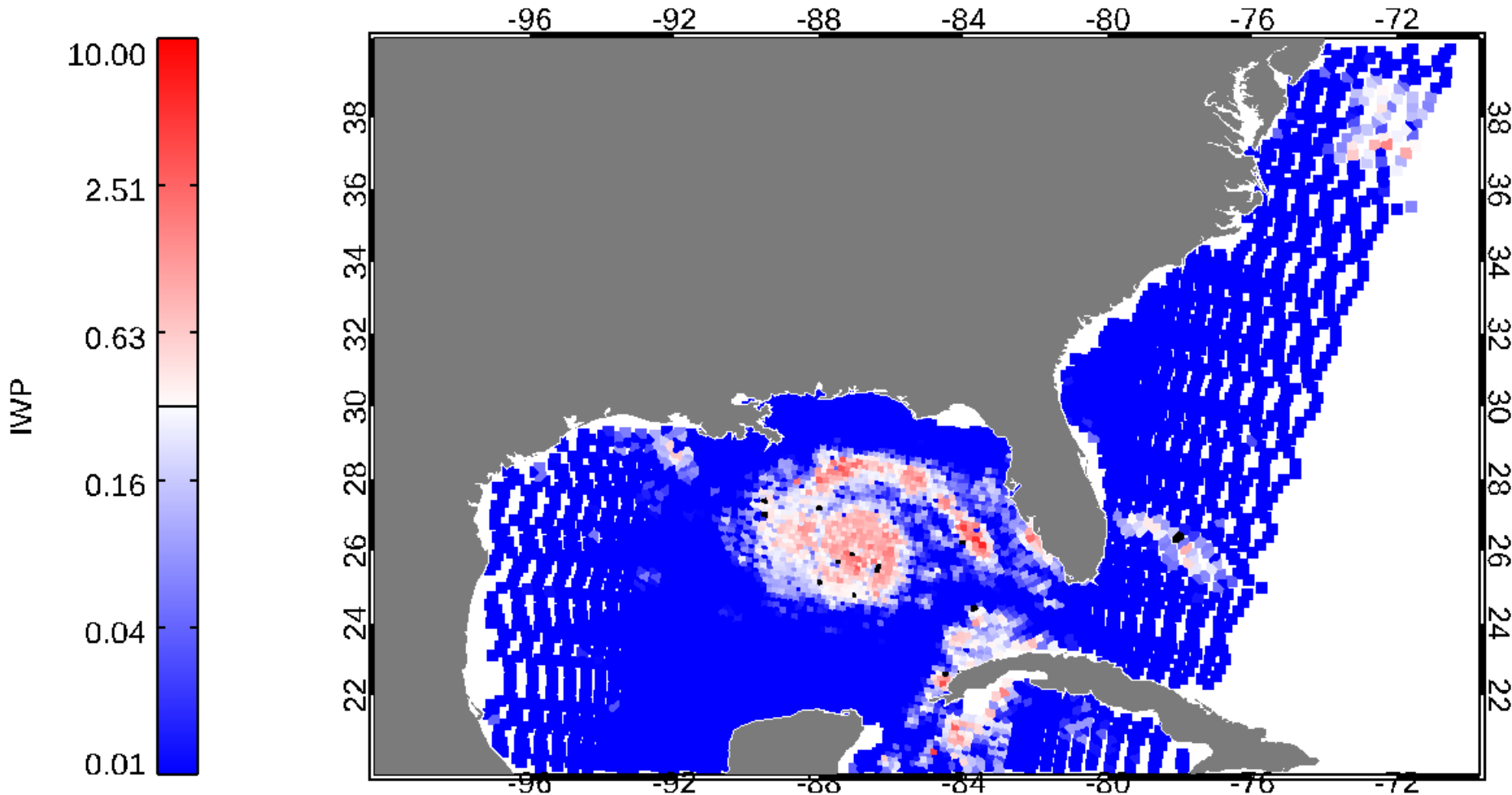
Hurricane Ida 8/28/21c 20:07 UTC



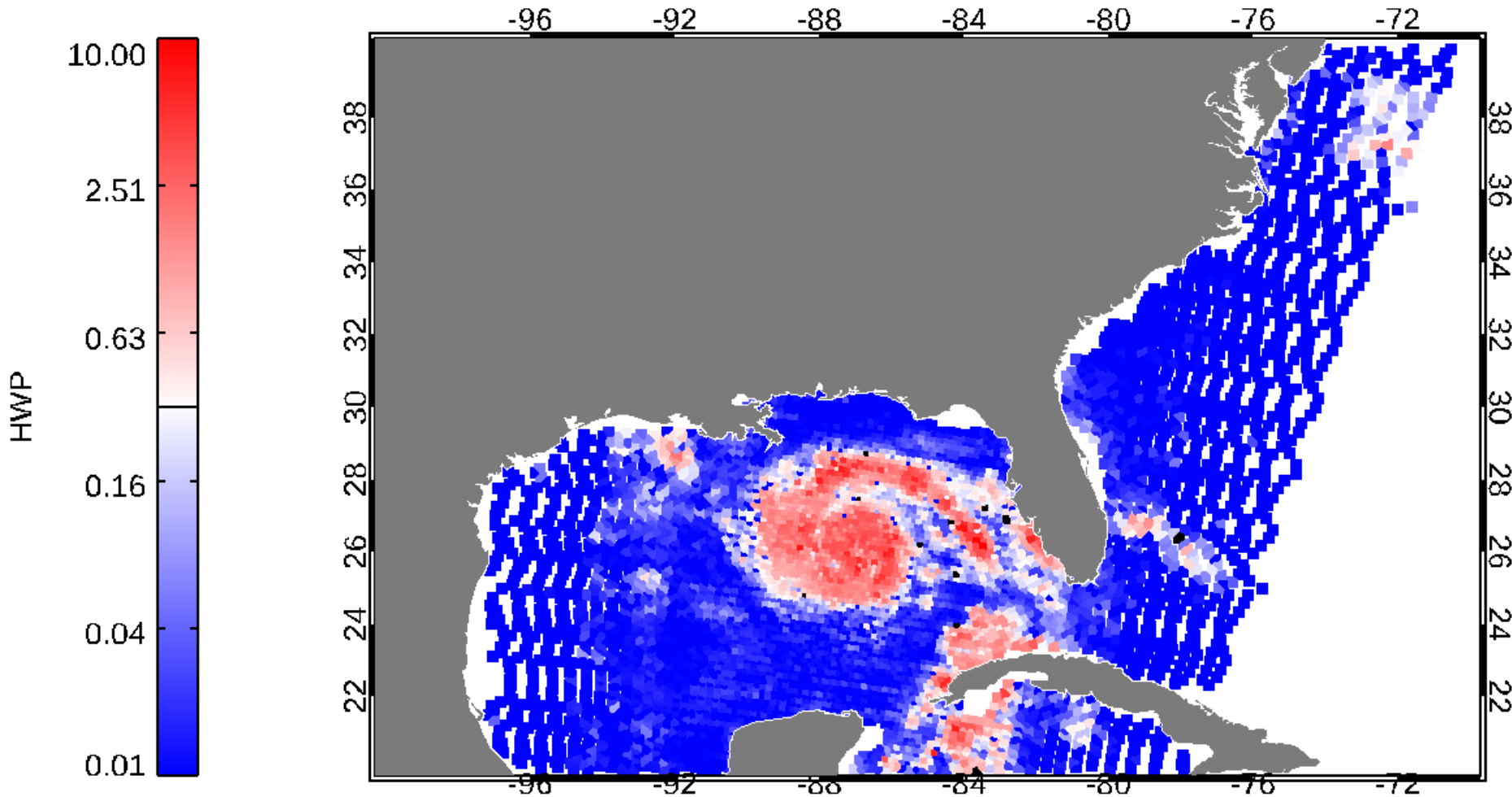
Hurricane Ida 8/28/21c 20:07 UTC – RR [mm/h]



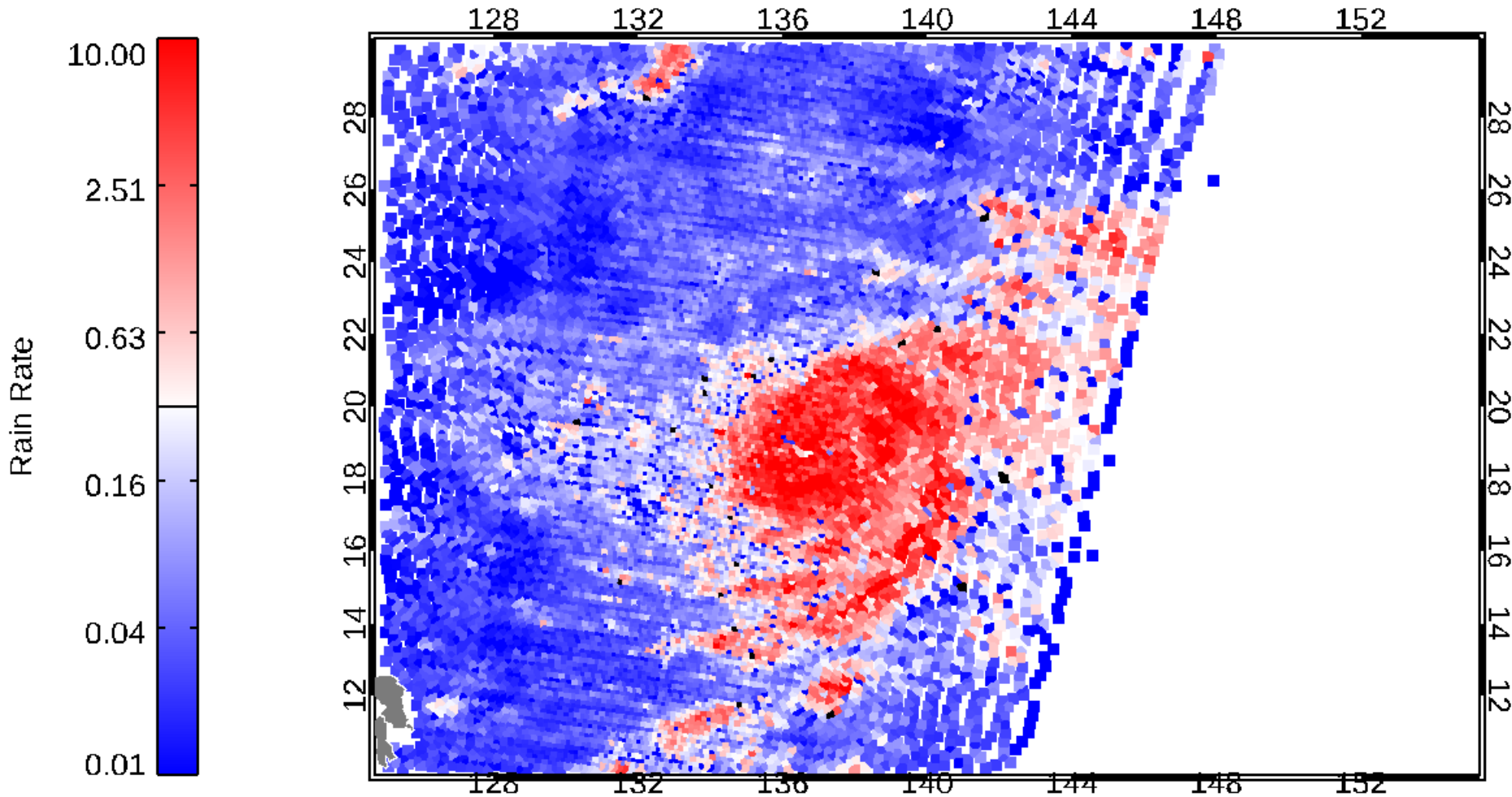
Hurricane Ida 8/28/21c 20:07 UTC – IWP [kg/m²]



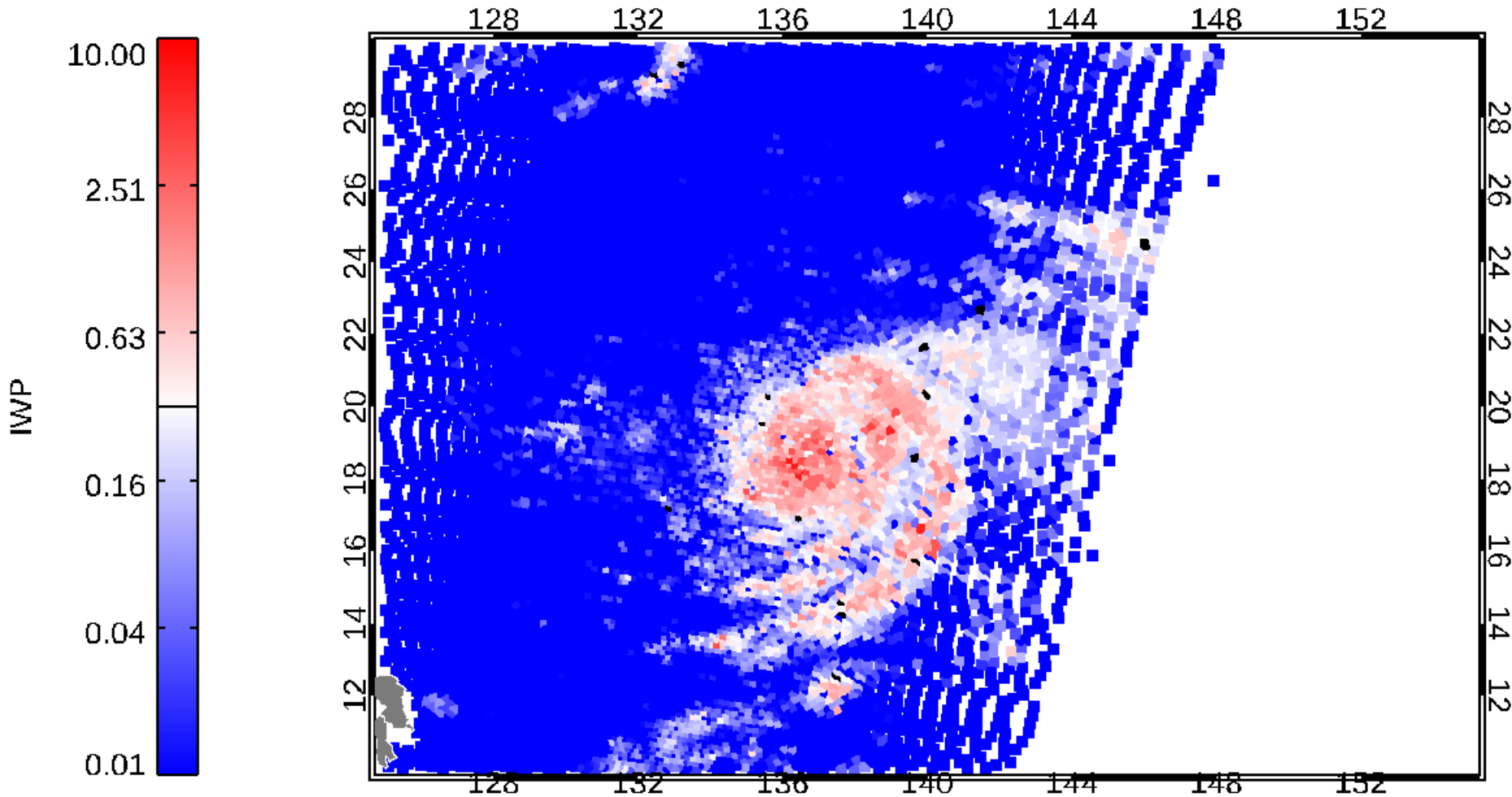
Hurricane Ida 8/28/21c 20:07 UTC – HWP [kg/m²]



Hurricane Mindulle 9/26/21 5:45 UTC – RR [mm/h]



Hurricane Mindulle 9/26/21 5:45 UTC – IWP [kg/m²]



Outlook

- TROPICS Pathfinder retrievals of IWP, HWP, RR, T, q look good compared to DPR and ERA5 as reference.
- Note that the comparisons against DPR or ERA5 are not strictly a independent validation. (Comparisons against ground-based precip and radiosondes needed).
- However, results are promising. Kd-tree might provide efficient way to retrieve concurrent profiles and IWP, RR...
- There are a set of interesting features associated with the kd-tree LUTs that we want to exploit further. These include the ability derive the data density, the likelihood of precipitation, and other features.