Improving Cross-track Scanning Radiometers' Precipitation Retrieval over Ocean by Morphing

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You et al., 2021, JHM, https://doi.org/10.1175/JHM-D-21-0038.1

- **We proposed to add a time dimension into the retrieval process by linking multiple satellites together**

- By doing so, we can
  1. Improve the precipitation retrieval over snow-covered land regions by ΔTB (You et al., 2017, JHM; Turk et al., 2021, JHM)
  2. Use the emissivity temporal variation (Δe) for rainfall retrieval enhancements (You et al., 2018, JGR; 2021, JHM)
  3. Capture the liquid raindrop signature over desert regions (You et al., 2020 GRL)
  4. **Morph precipitation rates from Conical scanning radiometers to cross-track scanning sensors (You et al., 2021, JHM)**

- **Cross-track Scanning Radiometers (Sounder)** :

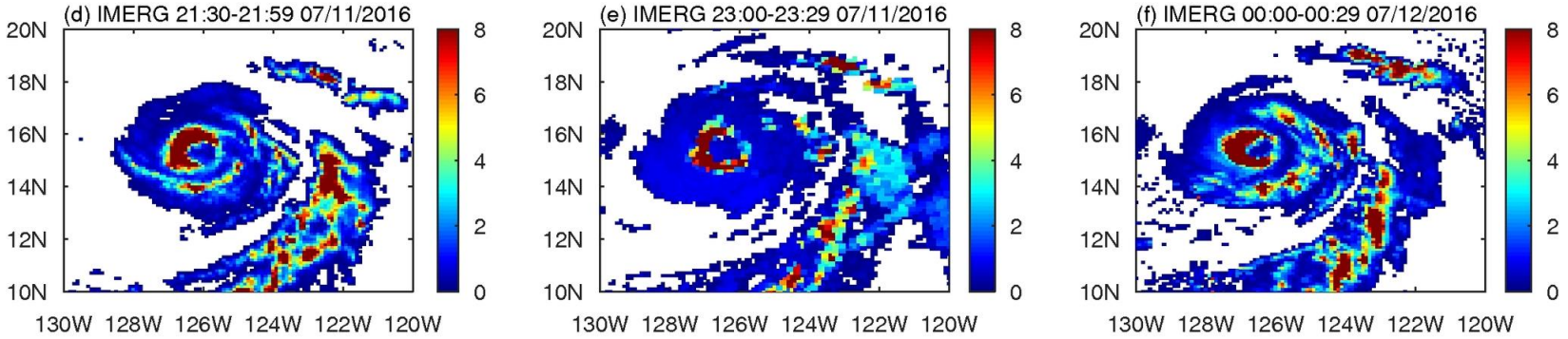
  FOV varies along the scan line, MHS, ATMS, AMSUA/B, SAPHIR

- **Conical Scanning Radiometers (Imager):**

  FOV remains constant along the scan line, AMSRE, AMSR2, TMI, GMI, SSMIS

- This study uses 10 radiometers:
  - **5 Cross track**: MHSs onboard NOAA18, NOAA19, MetOpA, MetOpB, and ATMS onboard NPP
  - **5 Conical**: SSMIS onboard F16, F17, and F18, AMSR2, and GMI

Hurricane Celia to highlight the potential benefits of our method



IMERG

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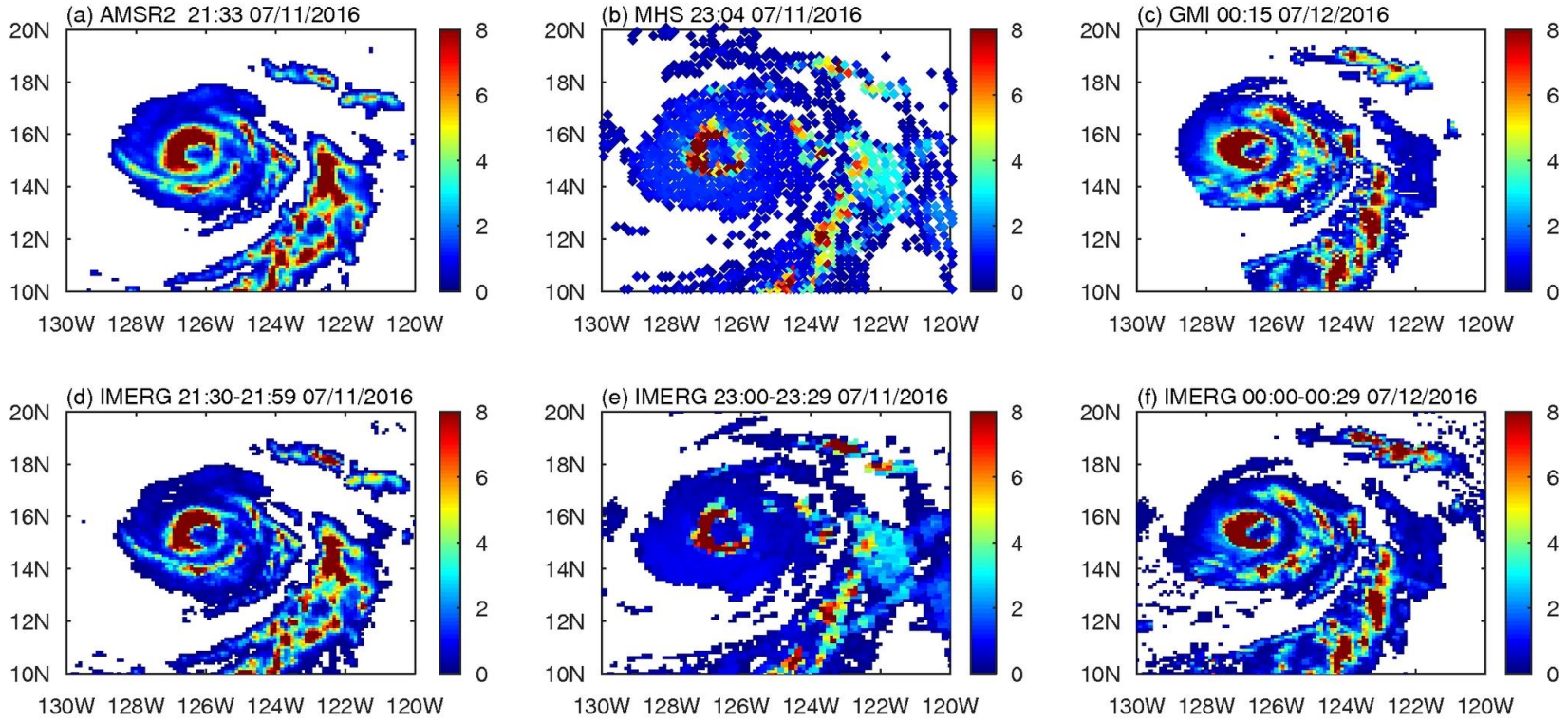

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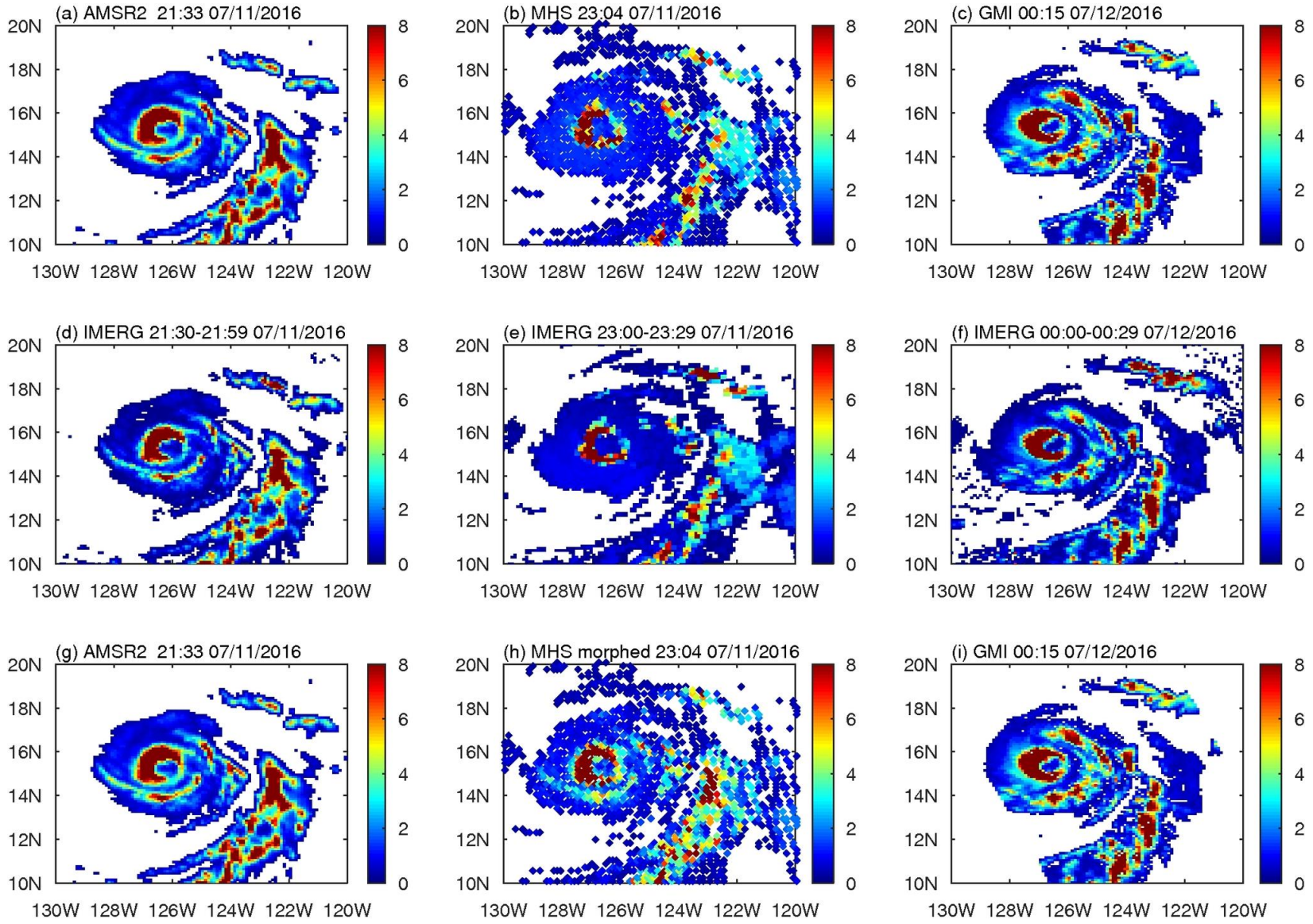

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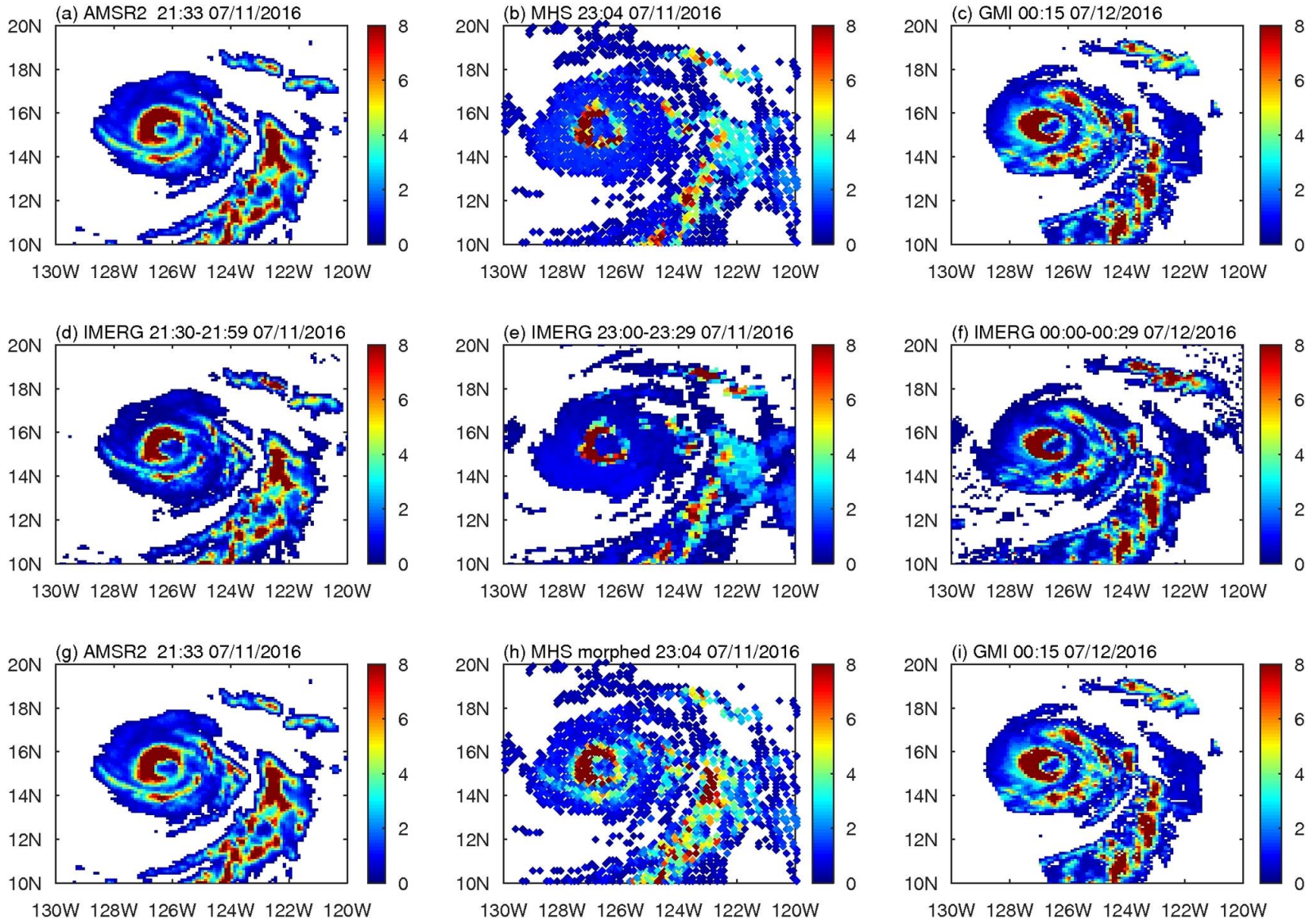


- 1st row: AMSR2, MHS, GMI
- 2nd row: IMERG final-run in the corresponding half-hour
- 3rd row: AMSR2, Morphed-MHS, GMI

Innovation:

- Improve MHS precipitation rates at the MHS observation time by morphing
- In contrast, MHS precipitation rates remain unchanged in IMERG

Objective: Improving cross-track scanning radiometers' retrievals by morphing conical scanning radiometers' retrieval

Motivation: Conical > Cross-track over ocean

Innovation:

- Improve cross-track scanning radiometers' retrieval
- In contrast, precipitation rates from cross-track radiometers remain unchanged in Level3 datasets (IMERG, CMORPH, and GSMaP).
- Motion vector derived from precipitation rate directly, instead of IR TB or MERRA2 TPW

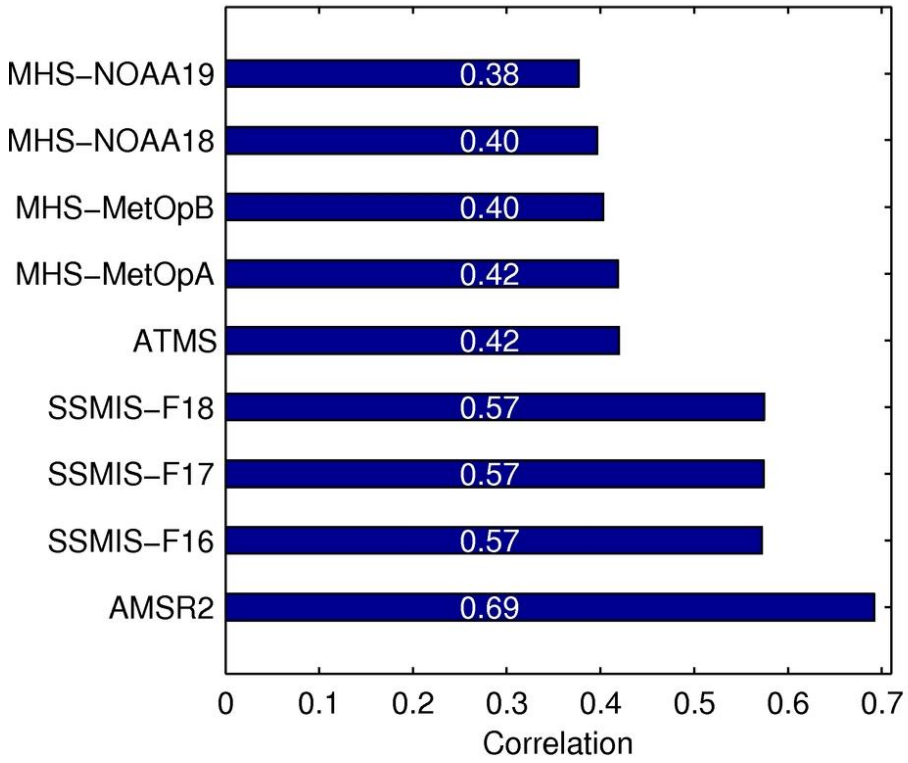
Methodology:

- Morphing
- Average (equal weight)

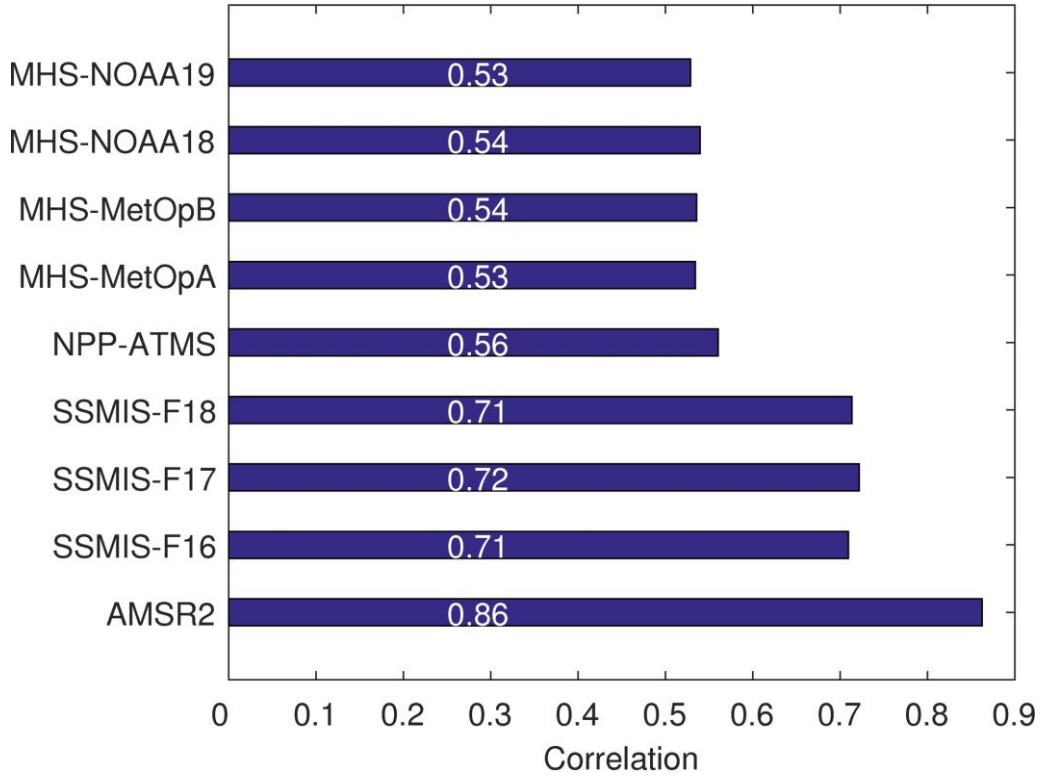
- Take GMI as the reference (i.e., GMI and cross-track radiometers observe the same event)
- KuPR also used for reference, but not for the motion vector calculation

Motivation: **Conical** > **Cross-track** over ocean

KuPR as the reference (JHM, You et al. 2020)

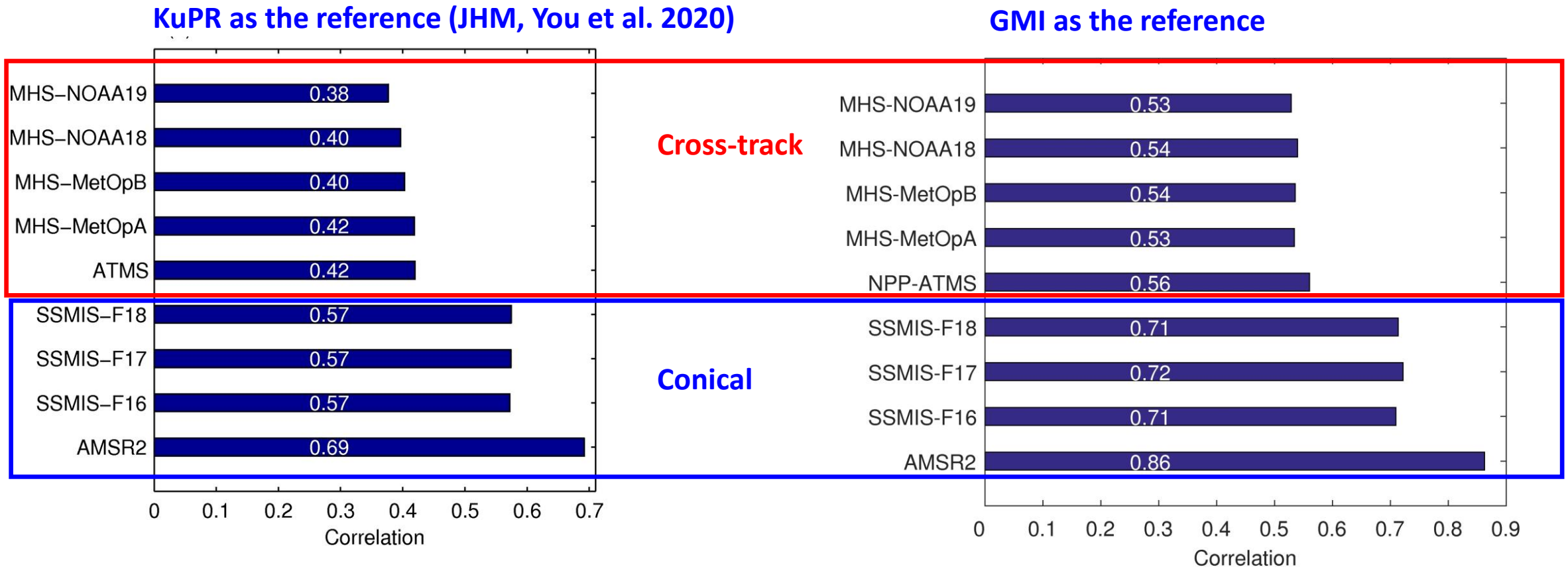


GMI as the reference



- **Coincident observations between KuPR (GMI) and each sensor**

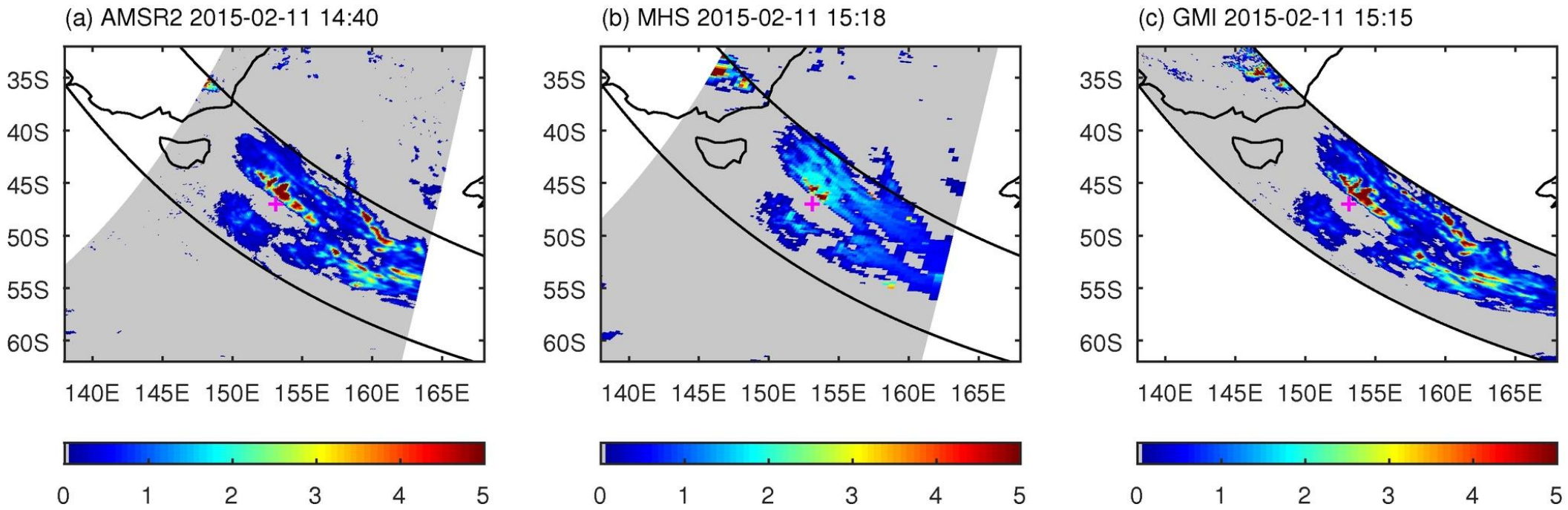
Motivation: **Conical** > **Cross-track** over ocean



- **Coincident observations between KuPR (GMI) and each sensor**

Case1: Morphing AMR2 forward to NOAA19-MHS

- **Because Conical > Cross-track, so we can morph conical's result to Cross-track' observation time**



- NOAA19-MHS and GMI < 5 minutes (take as coincidently)
- Morph AMSR2 to NOAA19-MHS
- Get the morphed precipitation rates (MHS/2+morphed AMSR2/2)
- Compared with GMI

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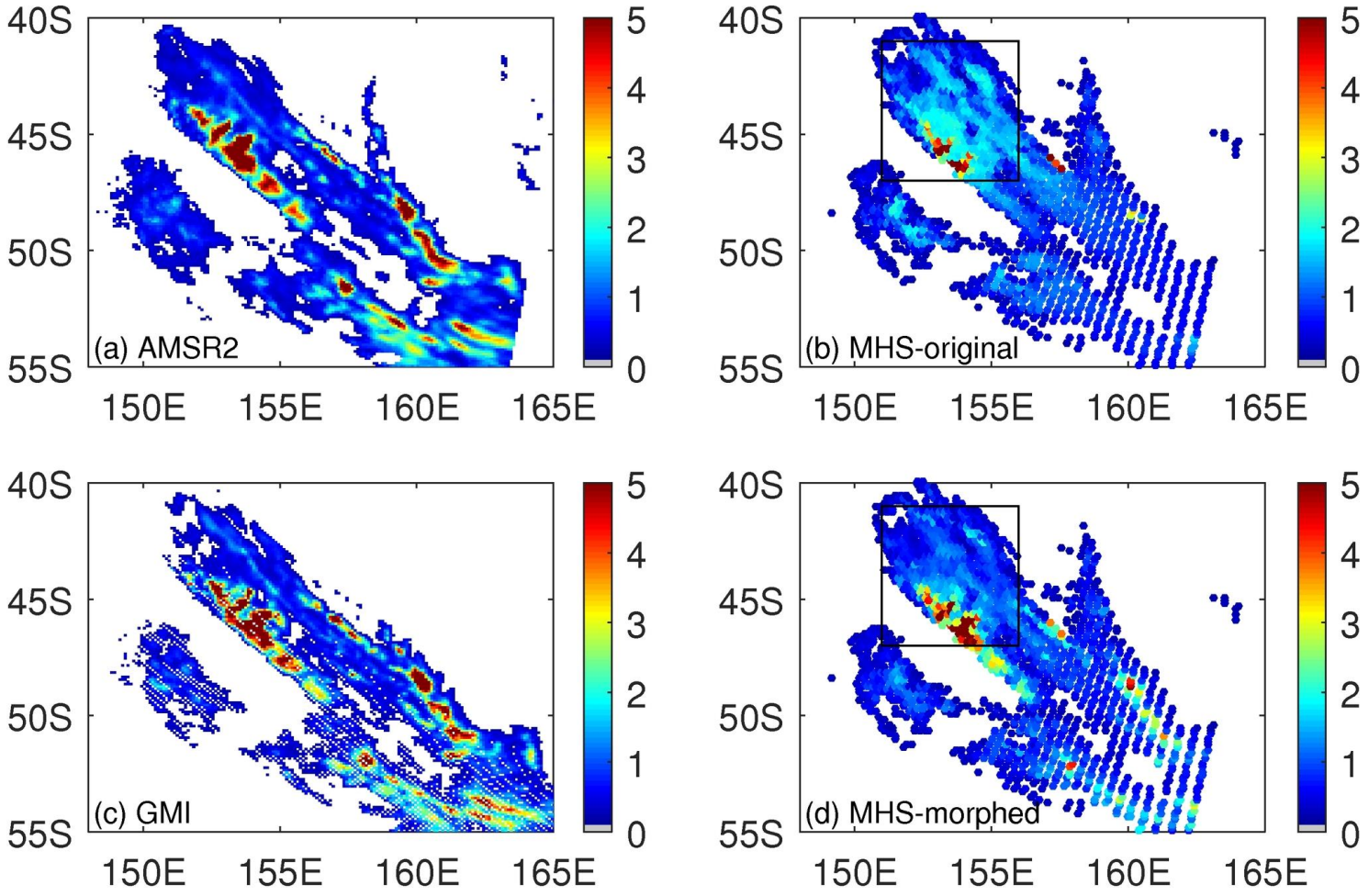

- Morphed result (d) agree with much better with GMI (c), especially in the highlighted region indicate by the black box
- Heavy rainfall in a larger area
- Light rainfall around 1 mm/hr is largely resolved.

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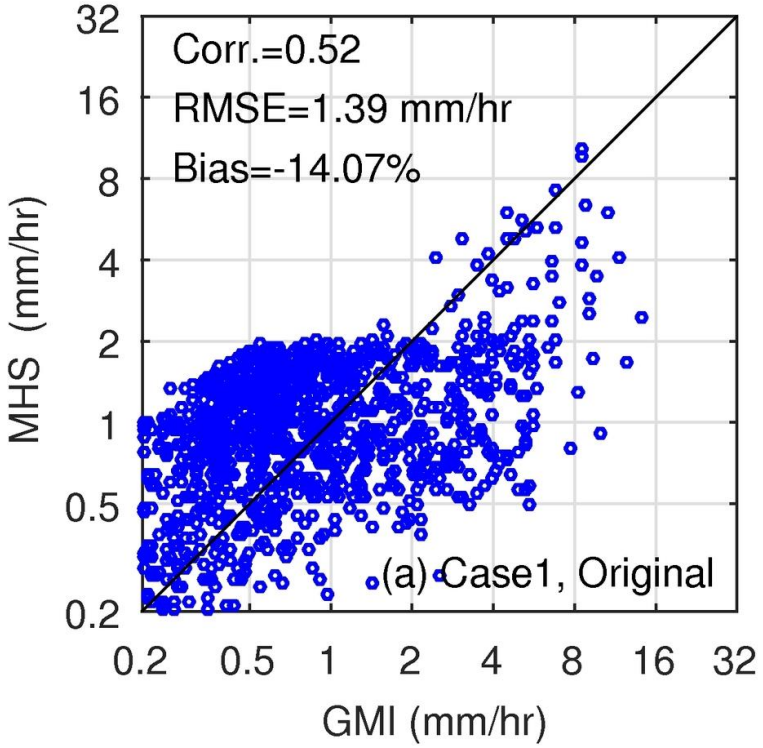

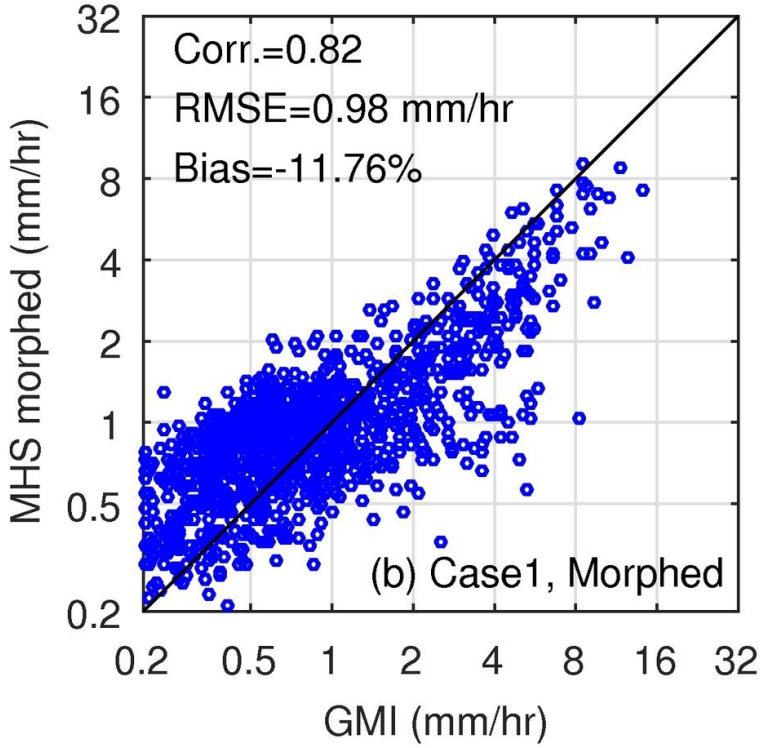

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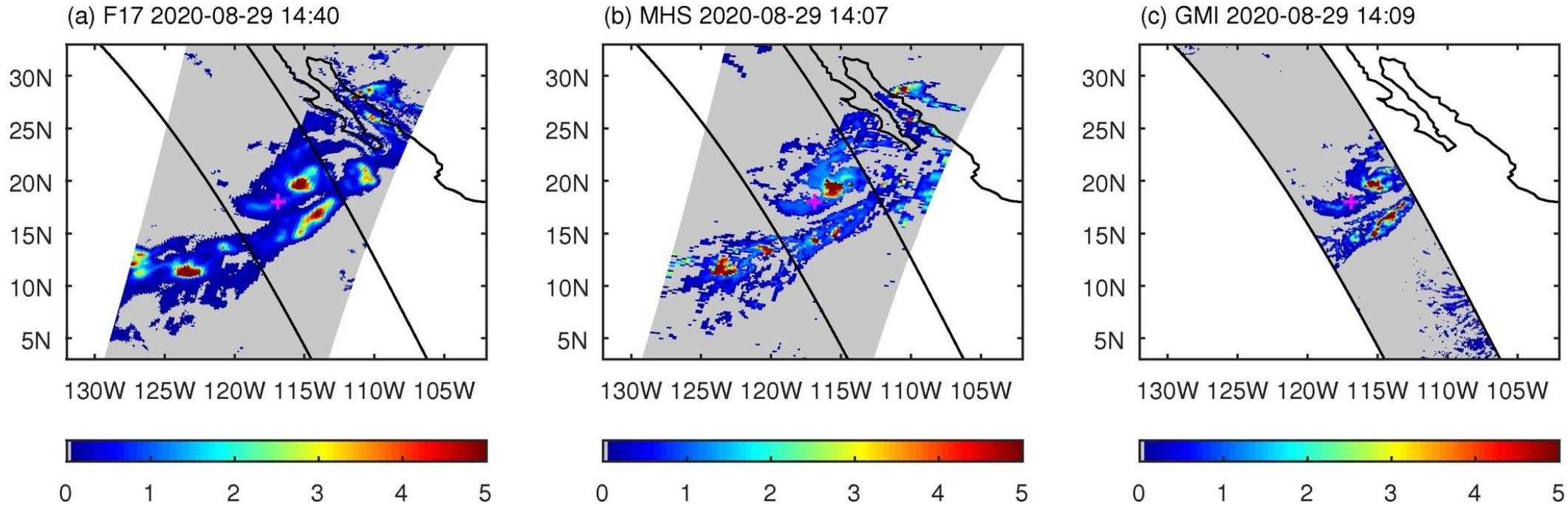

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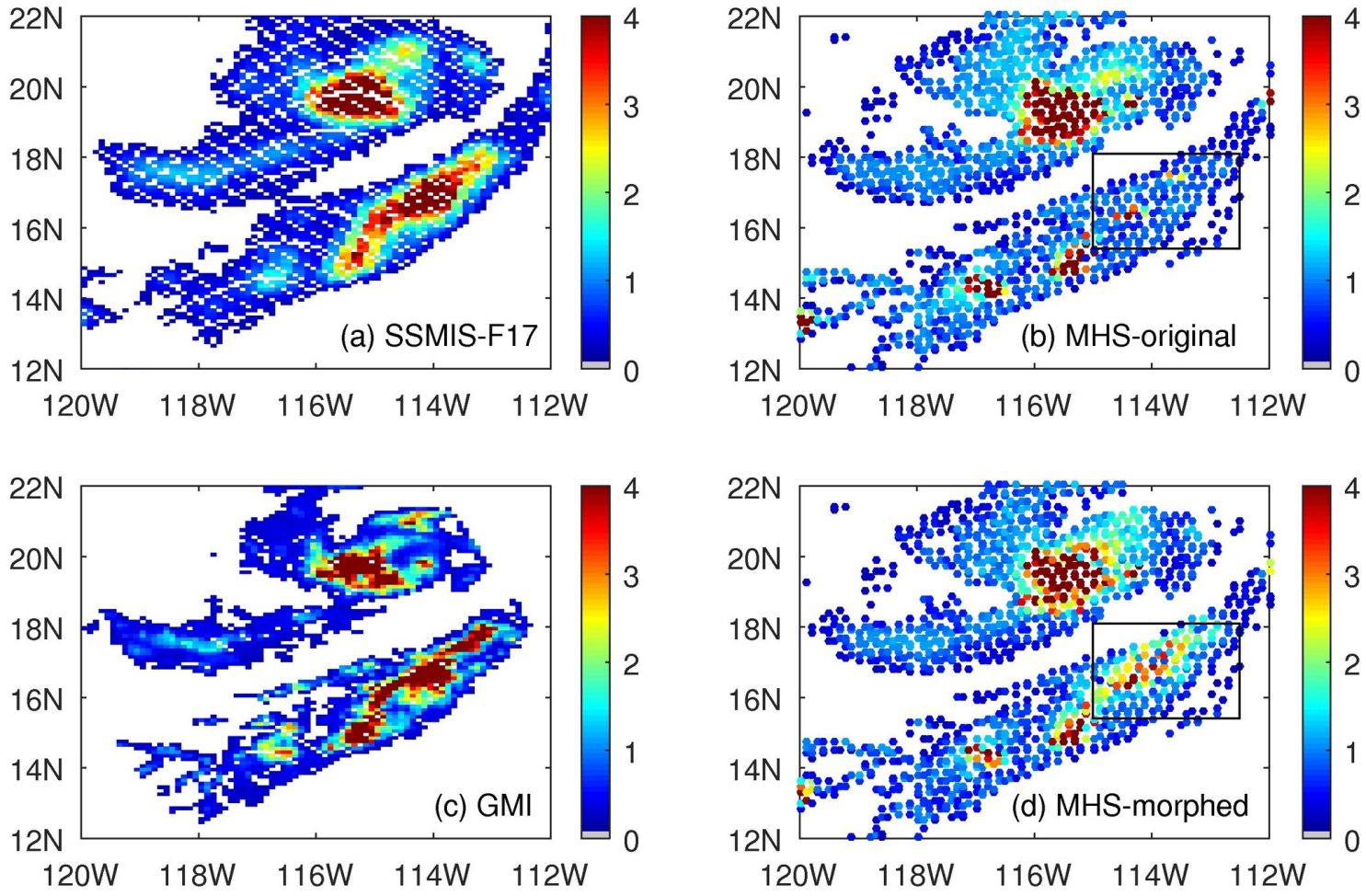
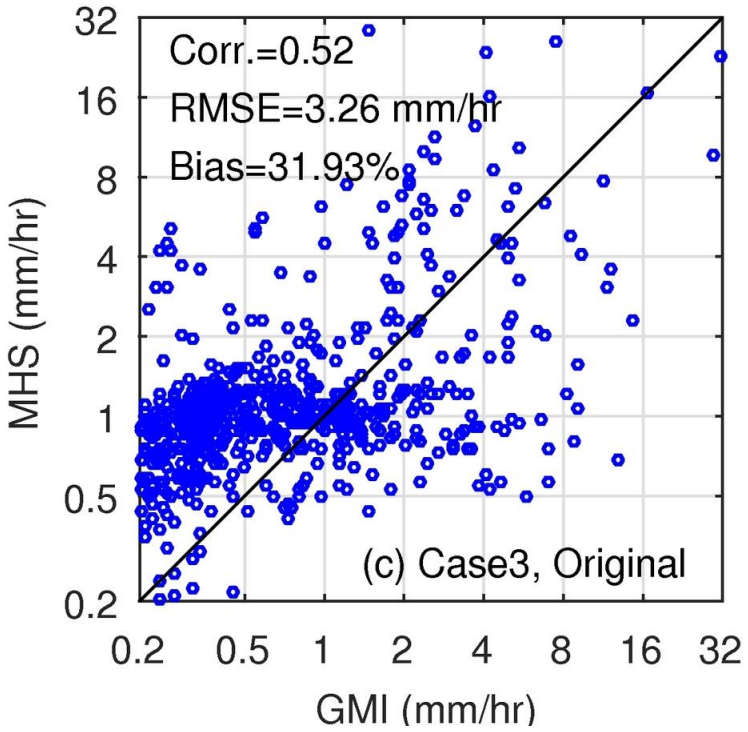
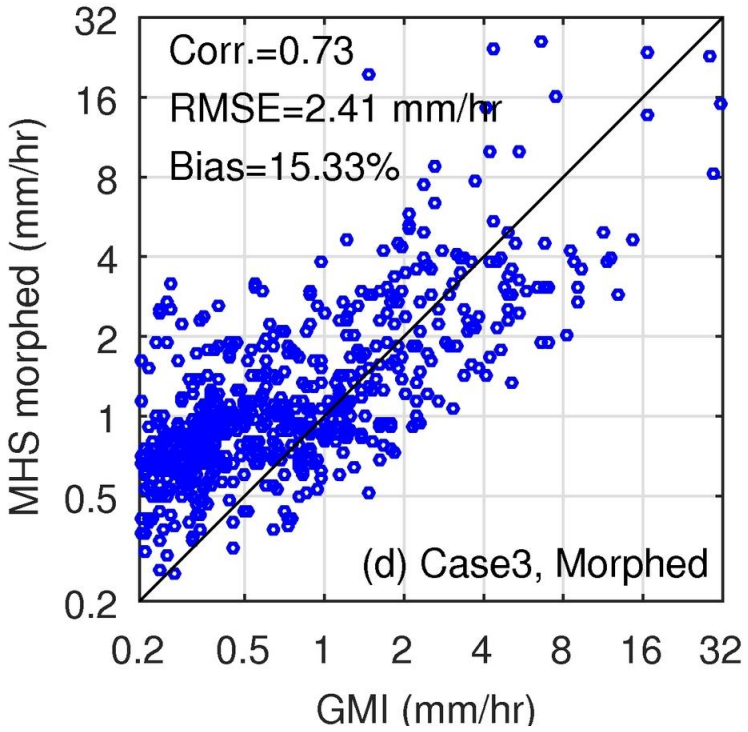


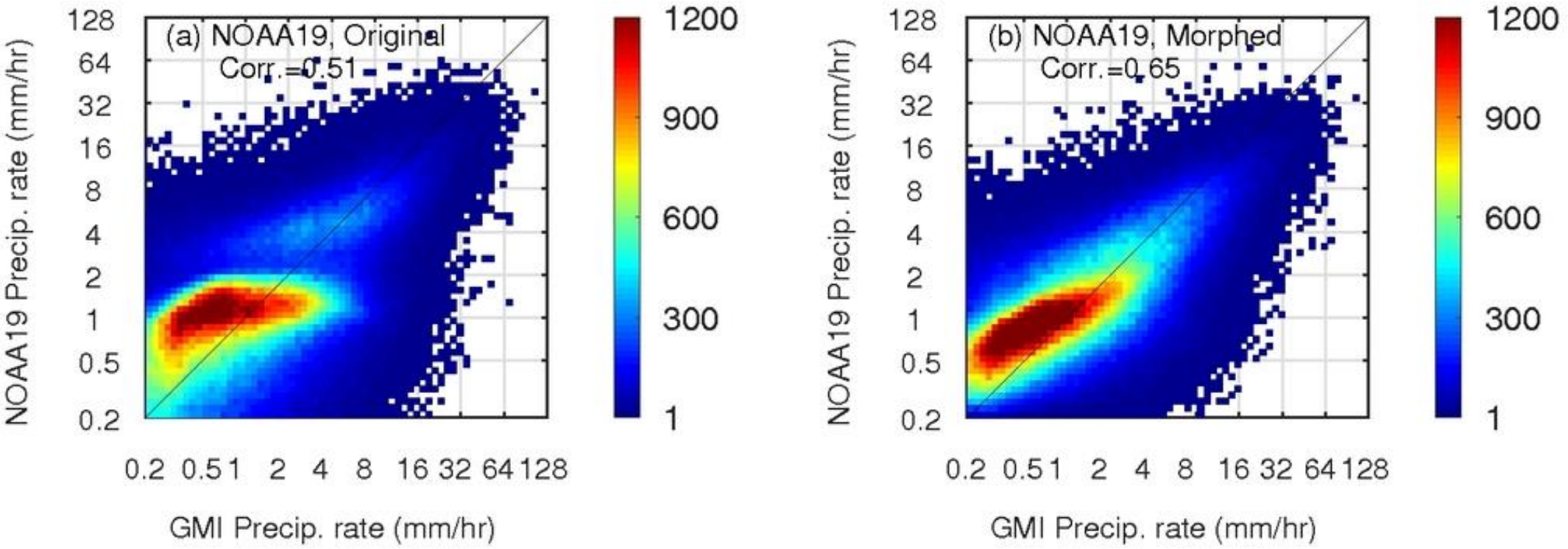
Case2: Morphing F17-SSMIS backward to NOAA19-MHS

- **Because imagers > sounders, so we can morph conical's result to sounder observation time**





Overall performance for all sounders



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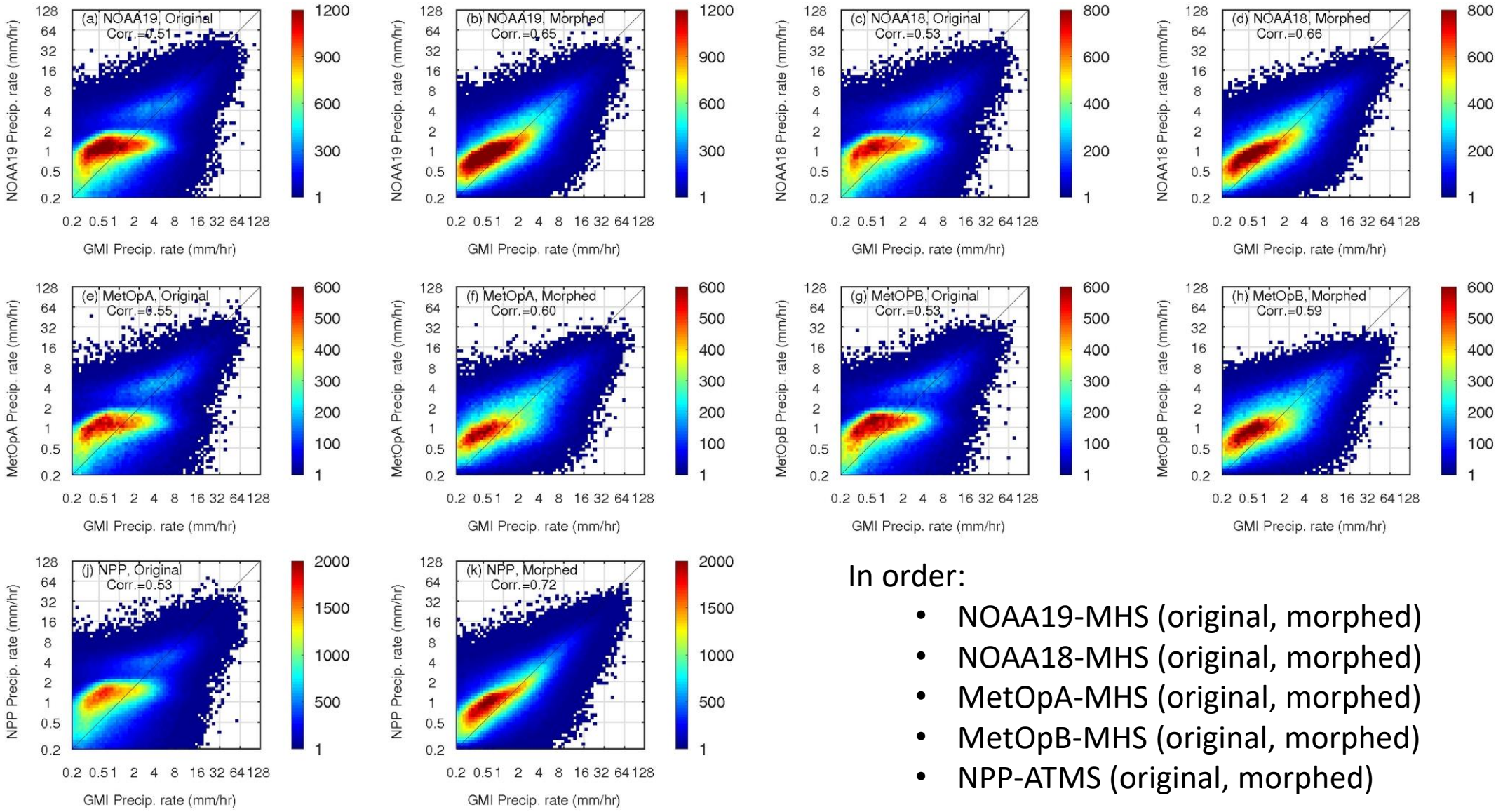


In order:

- NOAA19-MHS (original, morphed)
- NOAA18-MHS (original, morphed)
- MetOpA-MHS (original, morphed)
- MetOpB-MHS (original, morphed)
- NPP-ATMS (original, morphed)

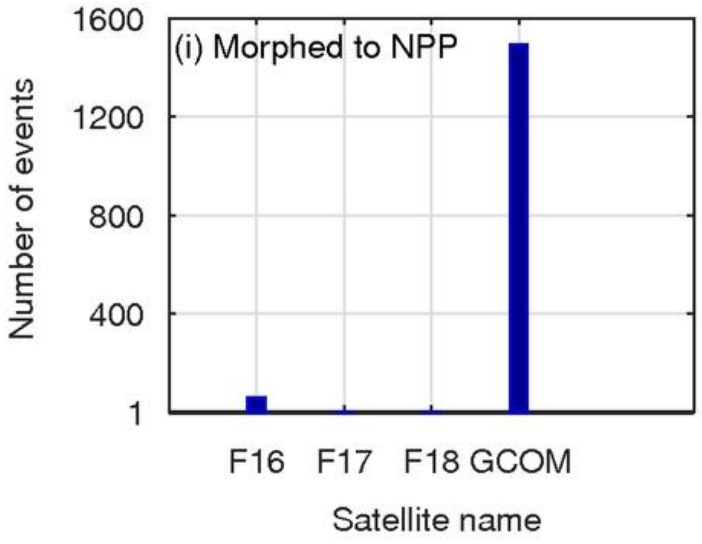
Improvement degree differs:

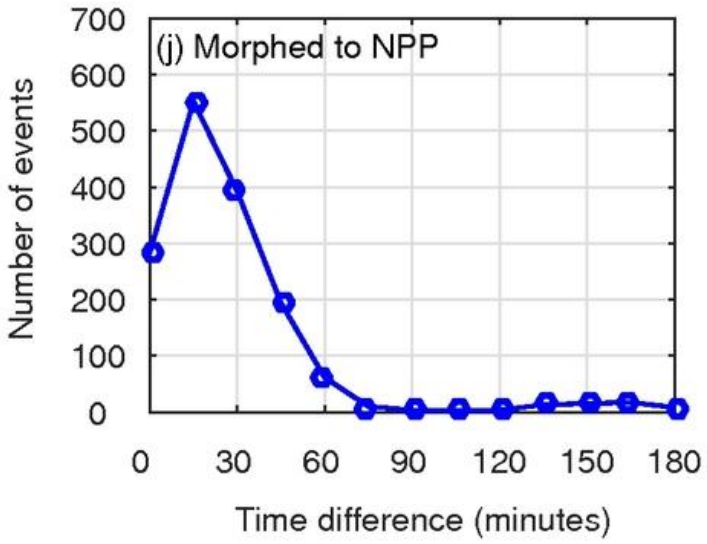
	Correlation	RMSE (mm/hr)	Bias (%)	Sample size
NOAA19-MHS original	0.51	2.64	-15.23	486,606
NOAA19-MHS morphed	0.65	2.45	-13.44	486,606
NOAA18-MHS original	0.53	2.82	-16.83	302,527
NOAA18-MHS morphed	0.66	2.66	-17.70	302,527
MetOpA-MHS original	0.55	2.96	-18.06	221,869
MetOpA-MHS morphed	0.60	3.04	-19.63	221,869
MetOpB-MHS original	0.53	2.71	-16.94	227,126
MetOpB-MHS morphed	0.59	2.81	-18.71	227,126
ATMS original	0.53	2.49	-12.27	613,913
ATMS morphed	0.72	2.08	-7.84	613,913

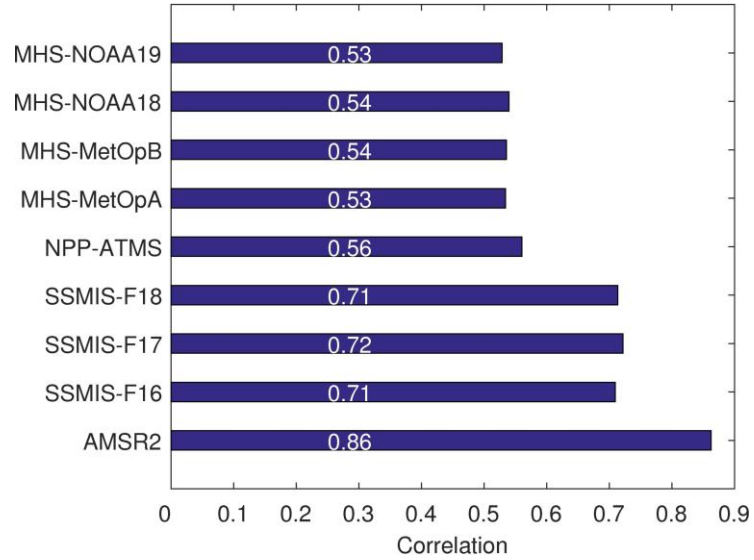
Degree of the improvement can be grouped into three categories:

1. **ATMS**
2. **MHSs from NOAA18 and NOAA19**
3. **MHSs from MetOpA and MetOpB**

Improvement degree differs:





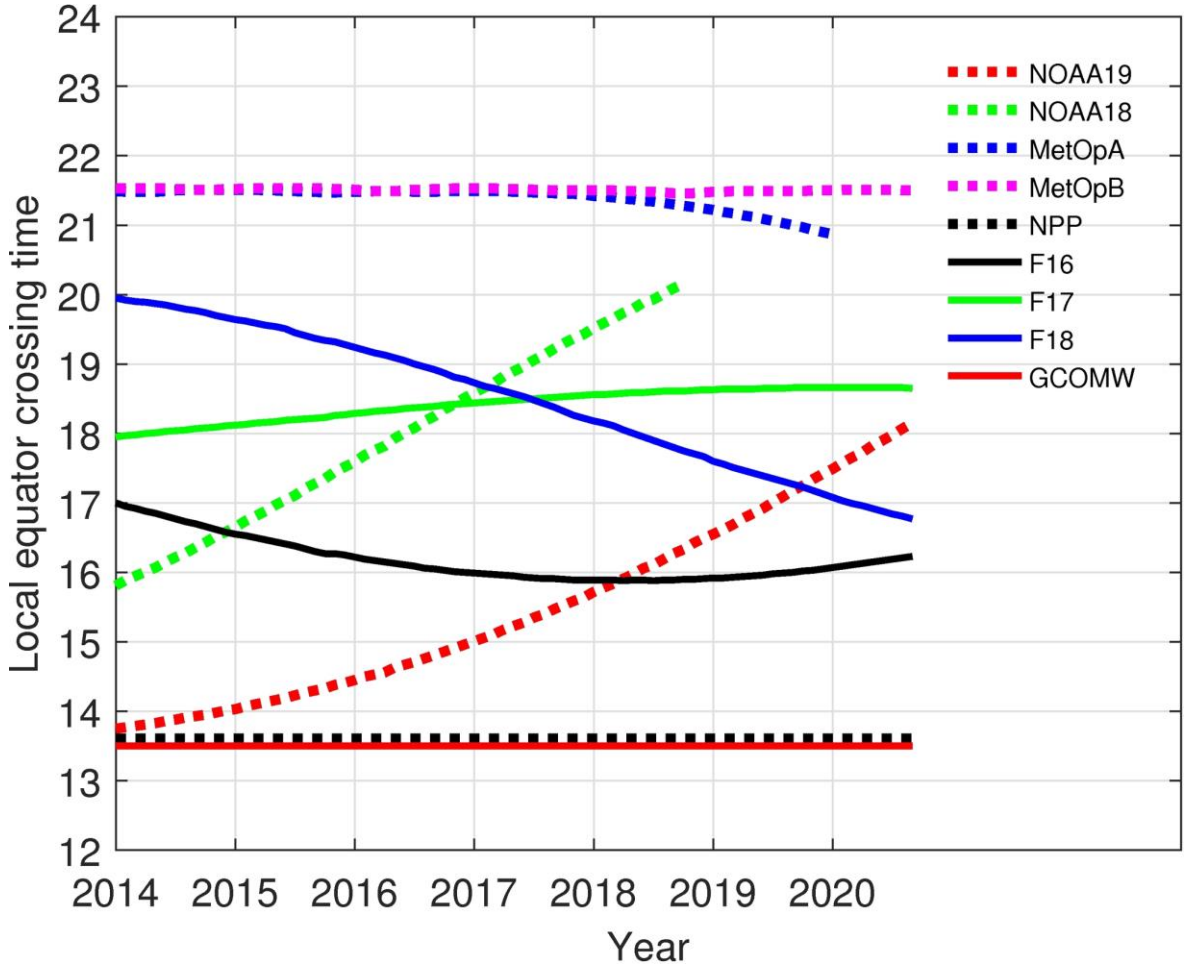


Why ATMS improves the most:

- Almost all the morphed precipitation rates are from AMSR2 (**precipitation sources**)
- Almost all the time differences between ATMS and AMSR2 < 60 minutes (**time interval**)

- We also analyzed three other factors: **precipitation type (convective vs. stratiform), precipitation event size (large vs. small), and region (tropics vs. subtropics)**

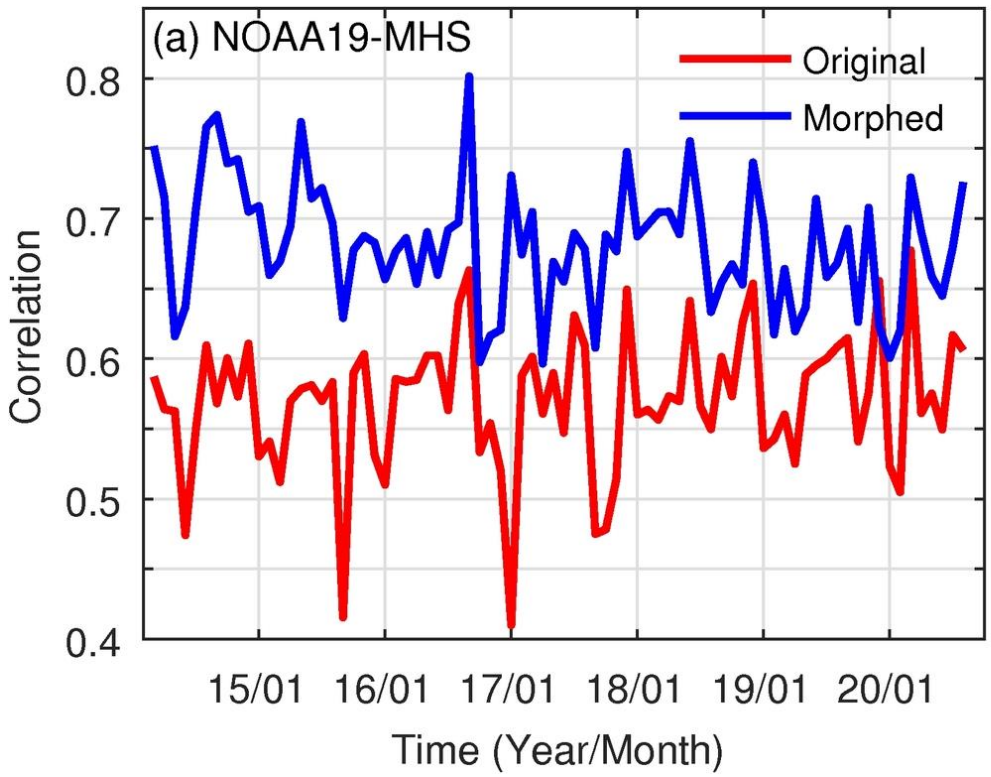
Improvement degree differs:

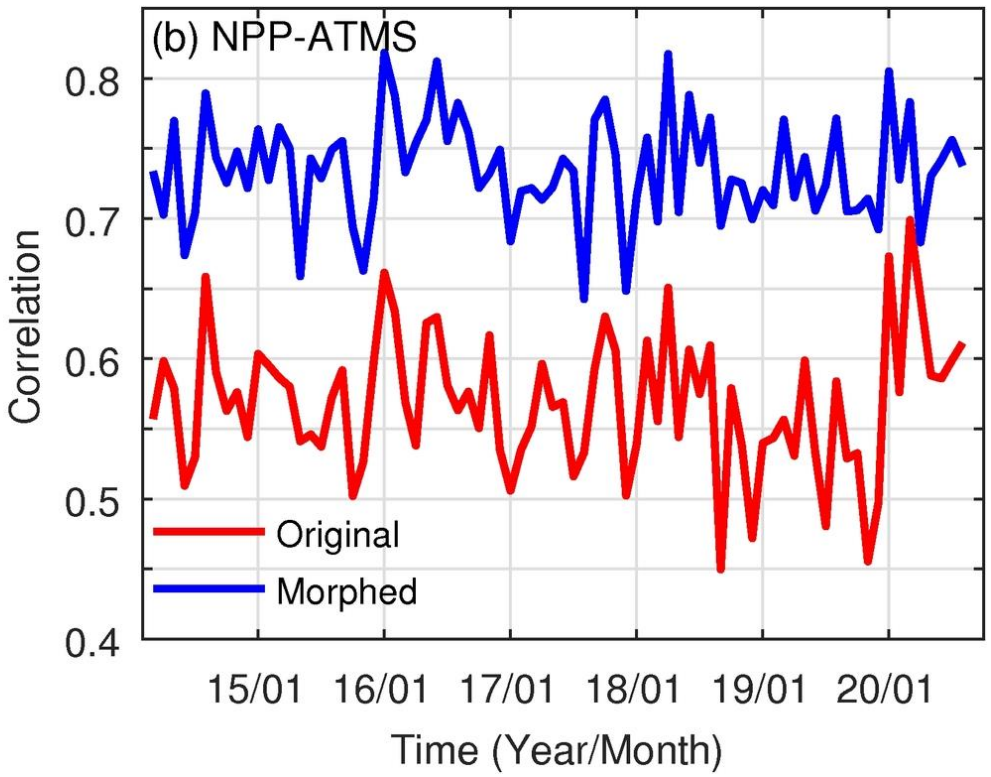


Whether or not a cross-track scanning sensor can meet a conical scanning sensor depends on their orbital features

- ATMS and AMSR2 are close to each other (keep in mind this ECT at nadir).
- MetOpA and B do not meet F16 in a +/- 3 hr window

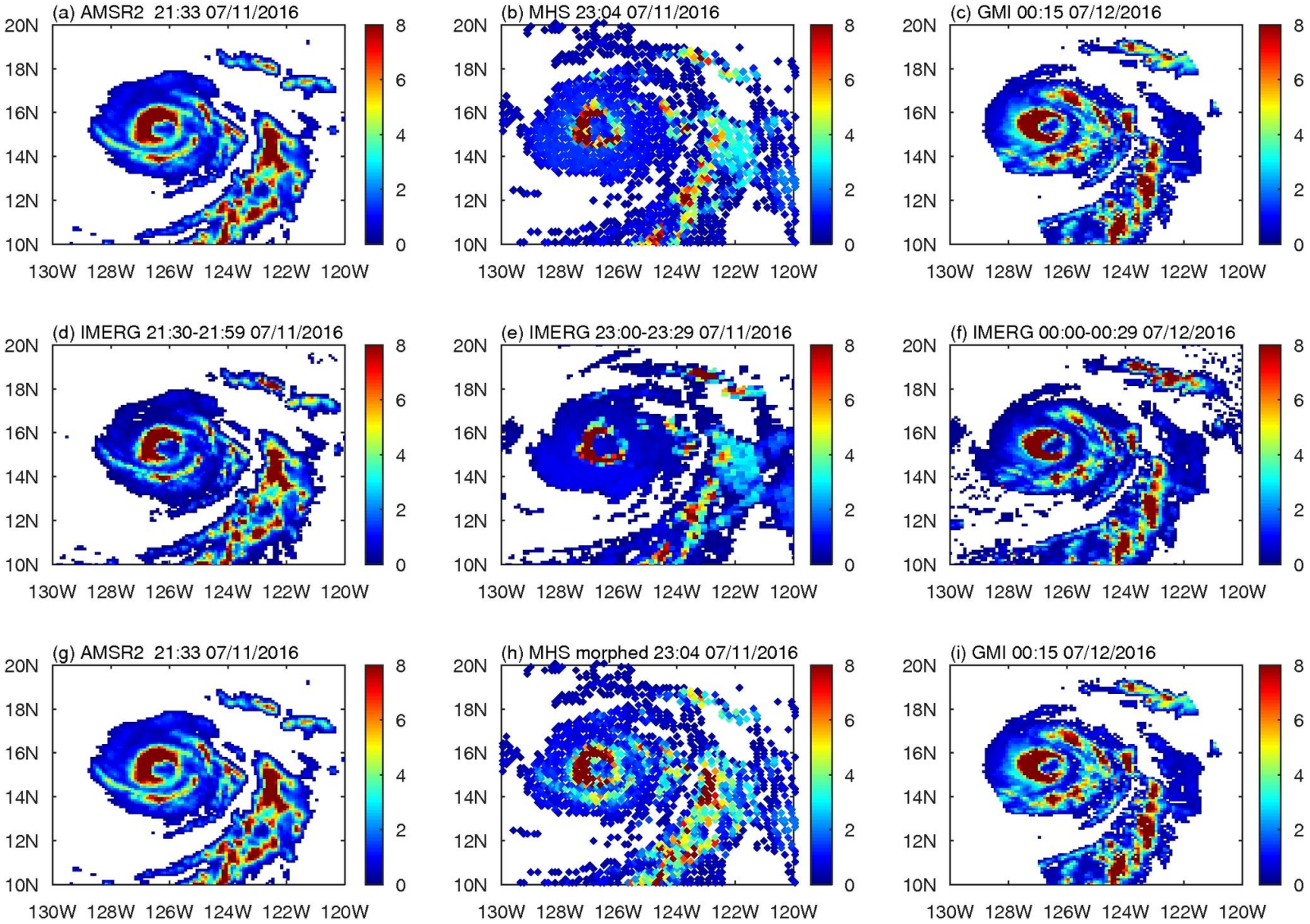
Correlation time series





- **Correlation increase from 0.57 to 0.68**
- **Correlation increase from 0.57 to 0.74**

Hurricane Celia to highlight the potential benefits of our method



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Innovation:

- Improve MHS precipitation rates at the MHS observation time by morphing
- In contrast, MHS precipitation rates remain unchanged in IMERG

Conclusions and Discussions:

- We can improve the cross-track scanning radiometers' retrieval by morphing conical scanning radiometers' retrieval to cross-track scanning radiometers' time.

- The improvement degree depends on
    - Morphed precipitation sources (e.g., SSMIS vs. AMSR2)
    - Time interval (1-hr vs. 3-hr)
    - Precipitation type (convective vs. stratiform)
    - Precipitation size (large vs. small)
    - Region (tropics vs. sub-tropics)

- Future work includes:
    - Optimal weights
    - SAPHIR (both land and ocean)
    - Morphing KuPR to radiometer's observation time over both land and ocean
    - Apply to the TROPICS
    - Link with IMERG (blended Level2 product)

You et al., 2021, JHM, https://doi.org/10.1175/JHM-D-21-0038.1

Acknowledgments:

- Dr. PingPing Xie for the discussions of the morphing concept
- NASA grant 80NSSC20K0903 from the Weather and Atmospheric Dynamics program
- NASA's PMM science team via the Internal Scientist Funding Model awarded to Drs. Peters-Lidard and Munchak
- All projects are under the management of Dr. Skofronick-Jackson

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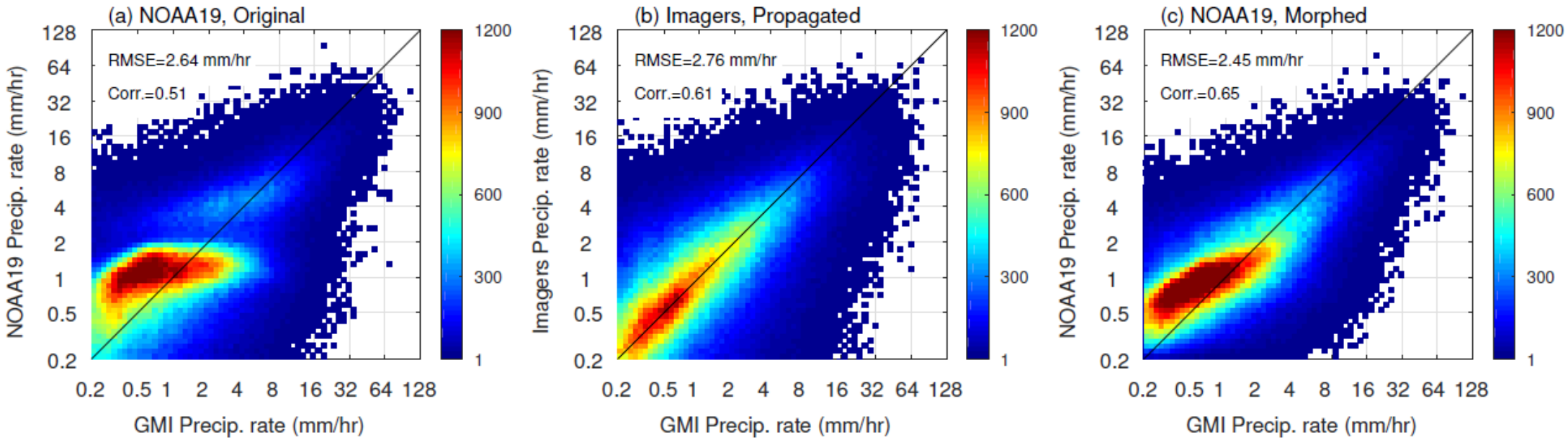
Backup slides

Overall performance for all sounders



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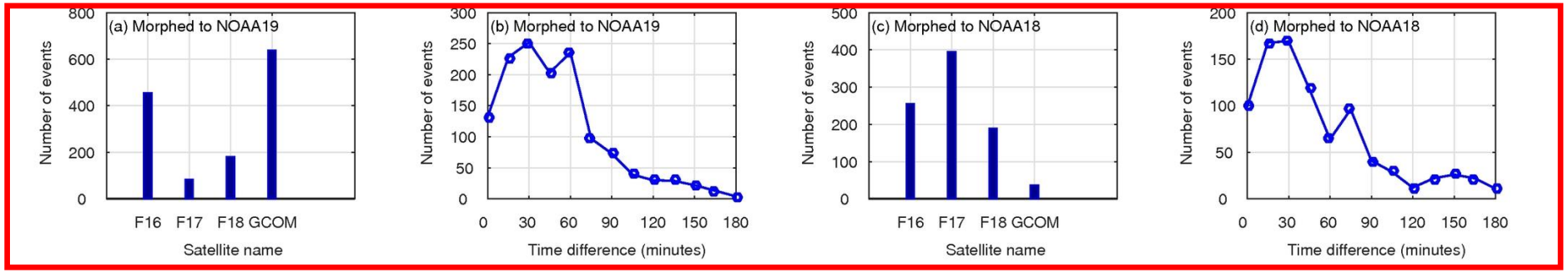

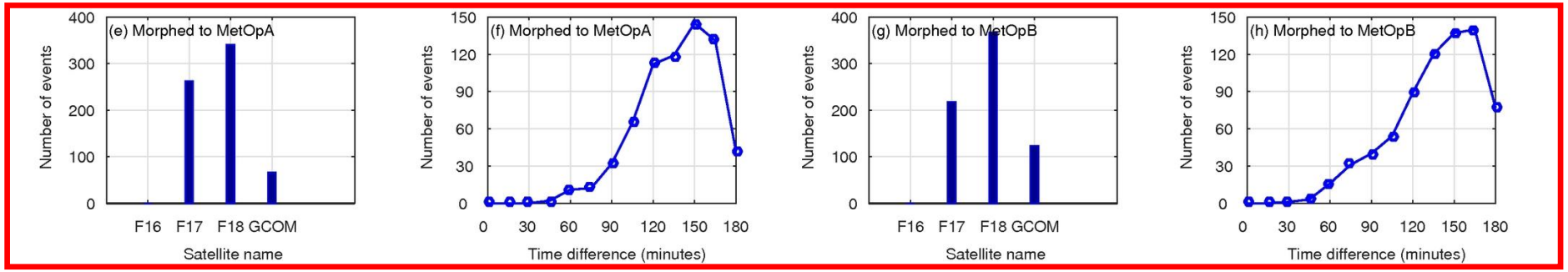

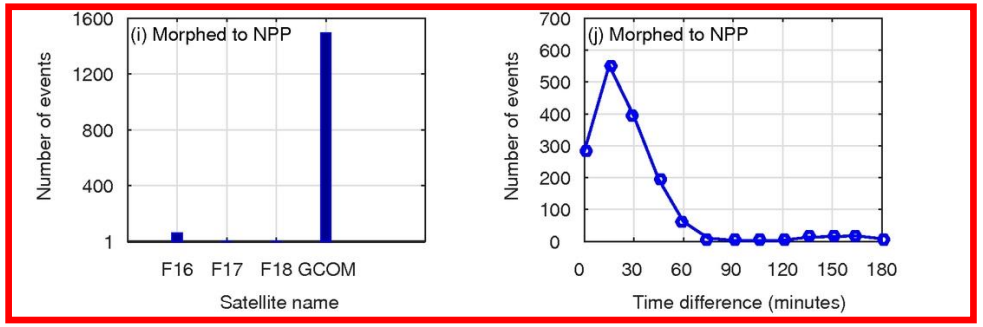

Compared with ATMS:
- More contributions from SSMISs
- Time differences are larger

Compared with ATMS:
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- Time differences are much larger

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- Almost all the morphed imagers results are from AMSR2
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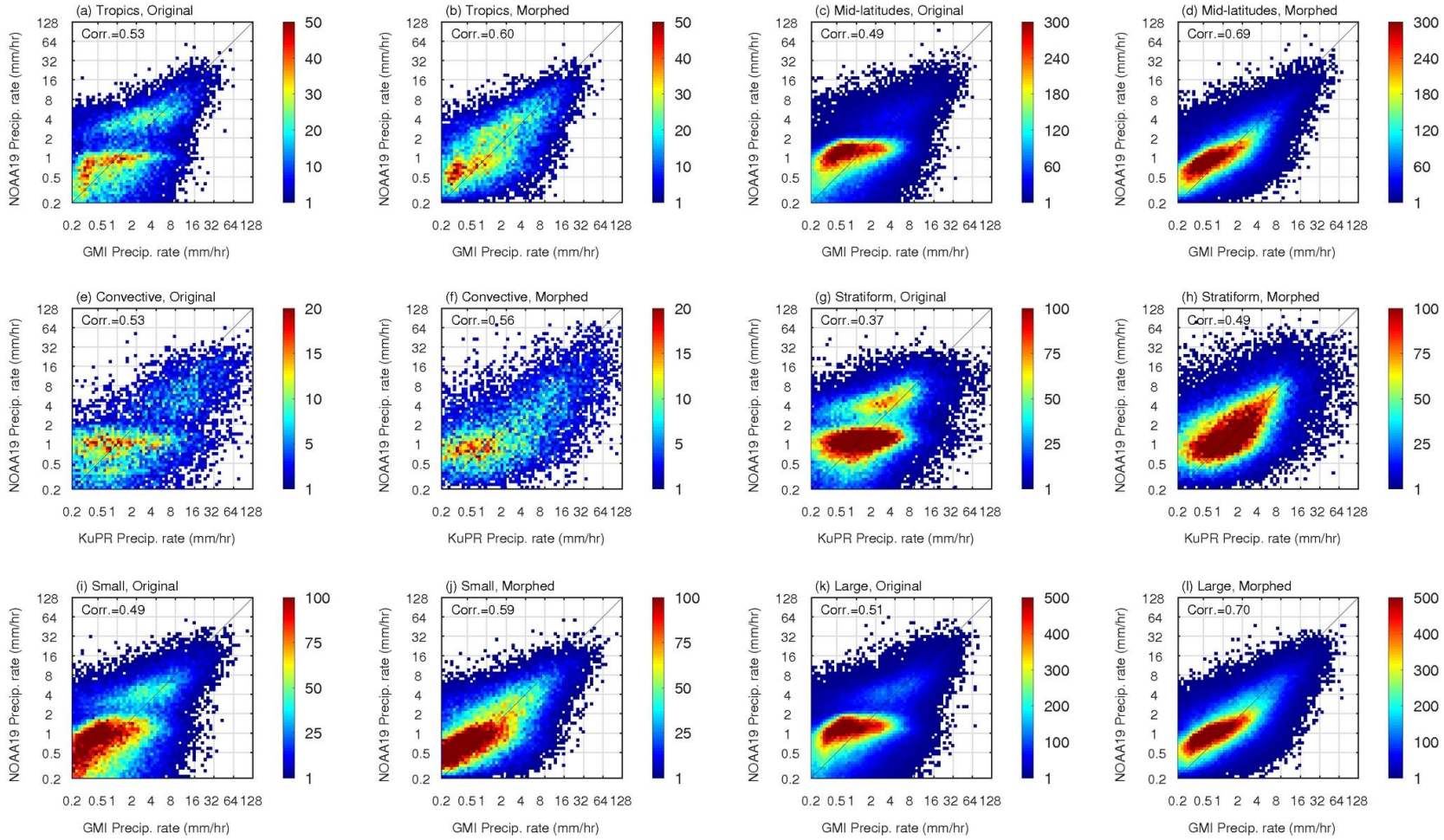
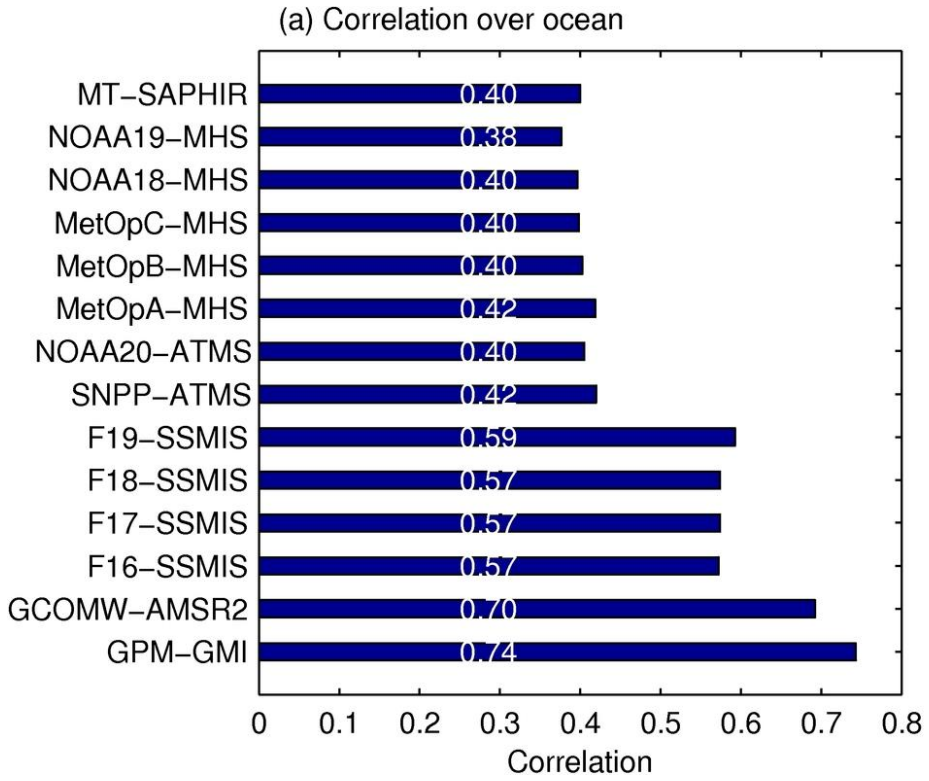
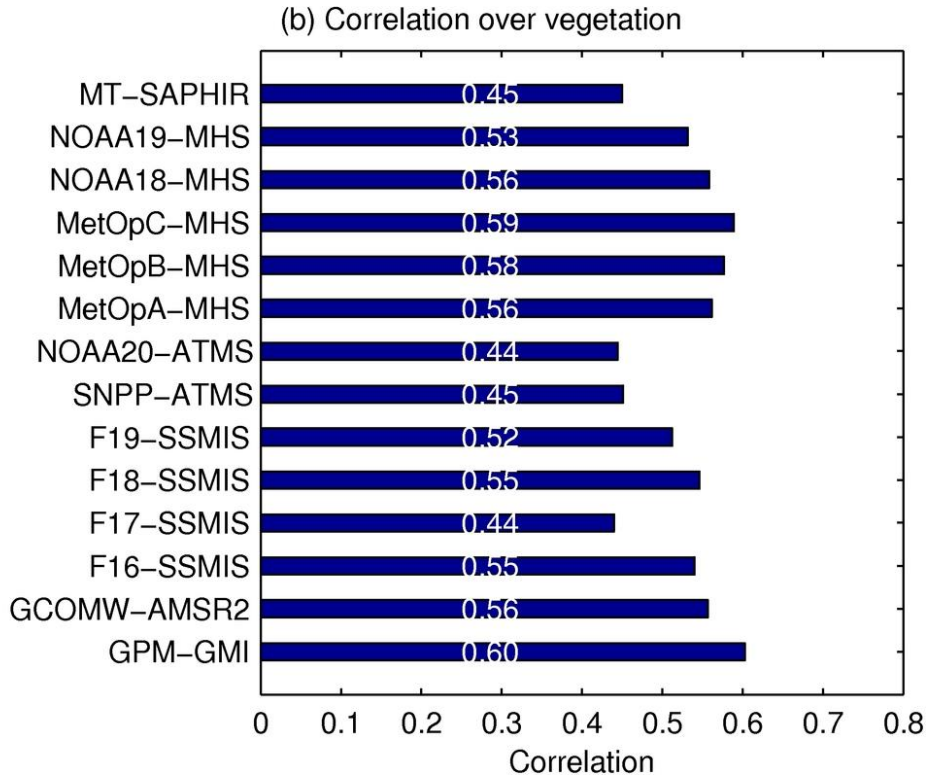


Tropics vs. Sub-tropics

Convective vs. Stratiform

Small vs. Large





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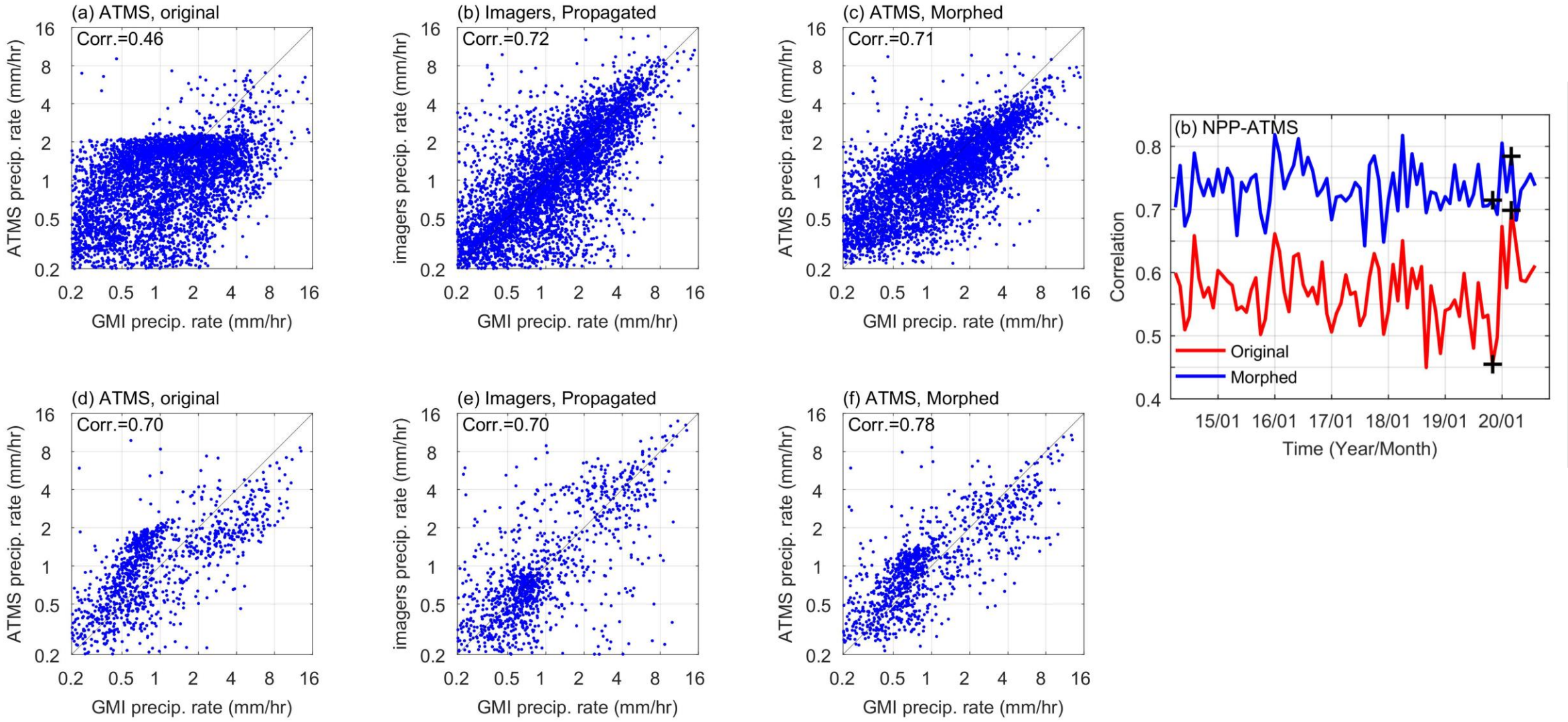
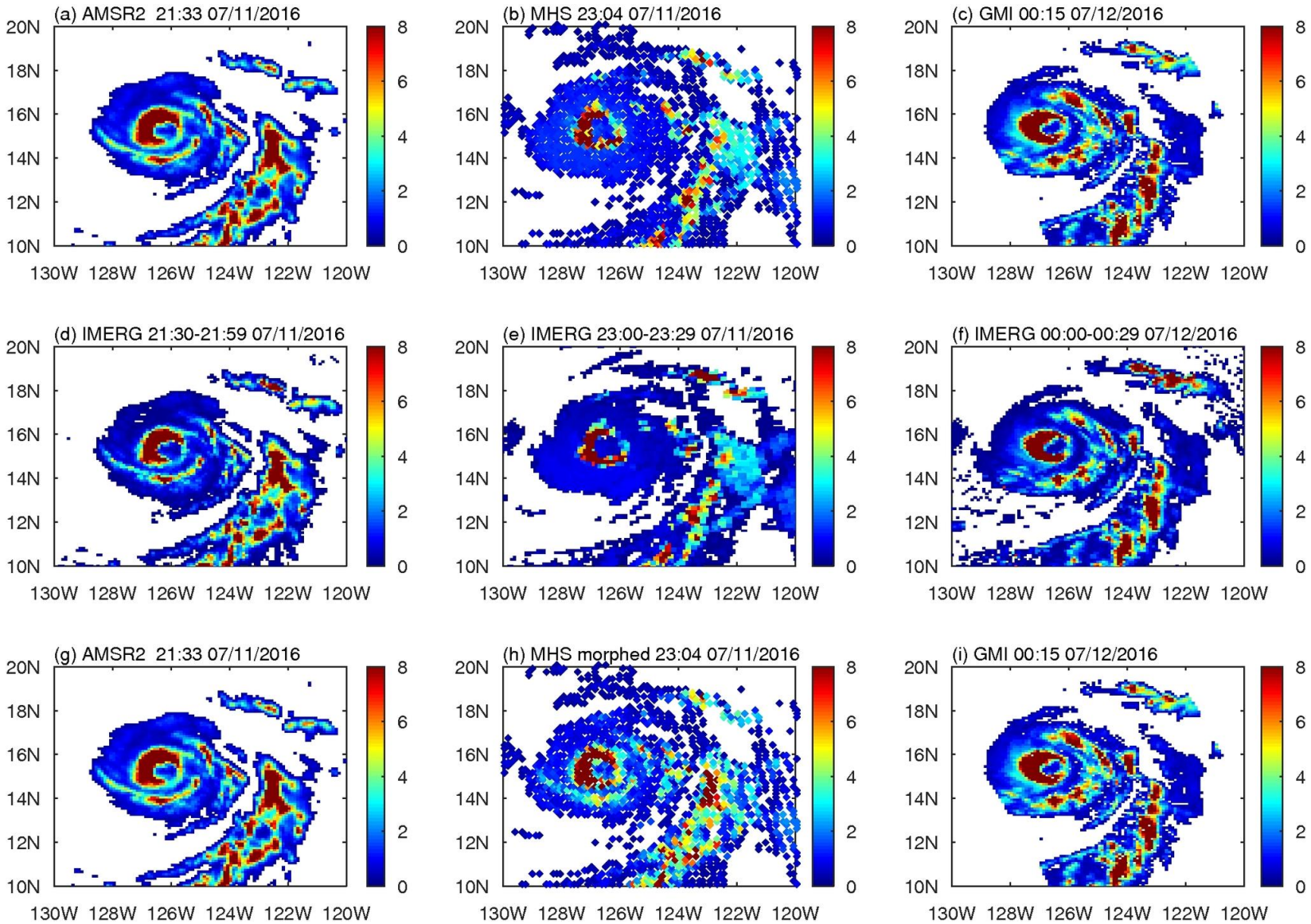
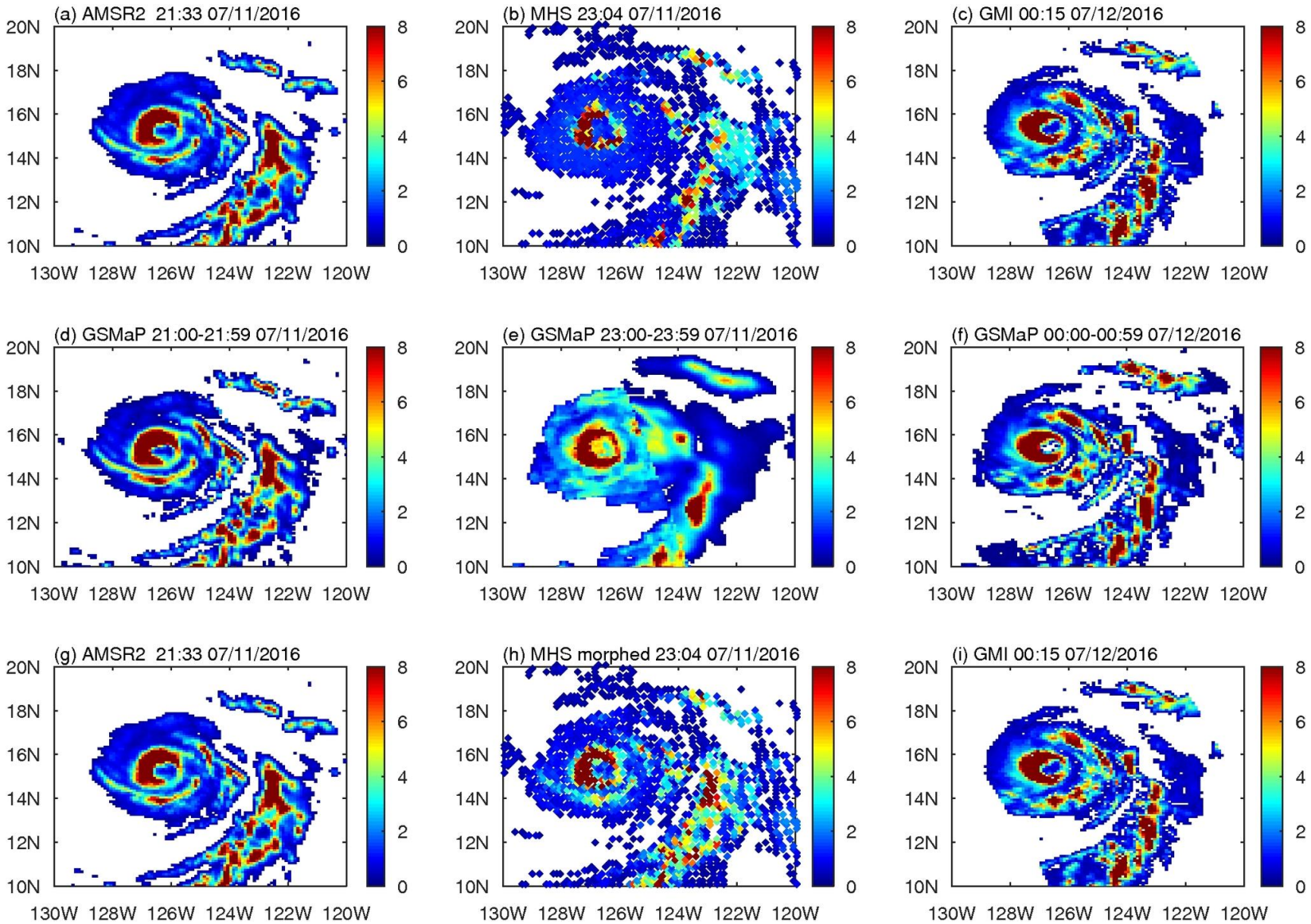

(a) ATMS, original
Corr.=0.46
ATMS precip. rate (mm/hr)
GMI precip. rate (mm/hr)
(b) Imagers, Propagated
Corr.=0.72
imagers precip. rate (mm/hr)
GMI precip. rate (mm/hr)
(c) ATMS, Morphed
Corr.=0.71
ATMS precip. rate (mm/hr)
GMI precip. rate (mm/hr)
(b) NPP-ATMS
Correlation
Original
Morphed
15/01
16/01
17/01
18/01
19/01
20/01
Time (Year/Month)
(d) ATMS, original
Corr.=0.70
ATMS precip. rate (mm/hr)
GMI precip. rate (mm/hr)
(e) Imagers, Propagated
Corr.=0.70
imagers precip. rate (mm/hr)
GMI precip. rate (mm/hr)
(f) ATMS, Morphed
Corr.=0.78
ATMS precip. rate (mm/hr)
GMI precip. rate (mm/hr)



GPROF

IMERG

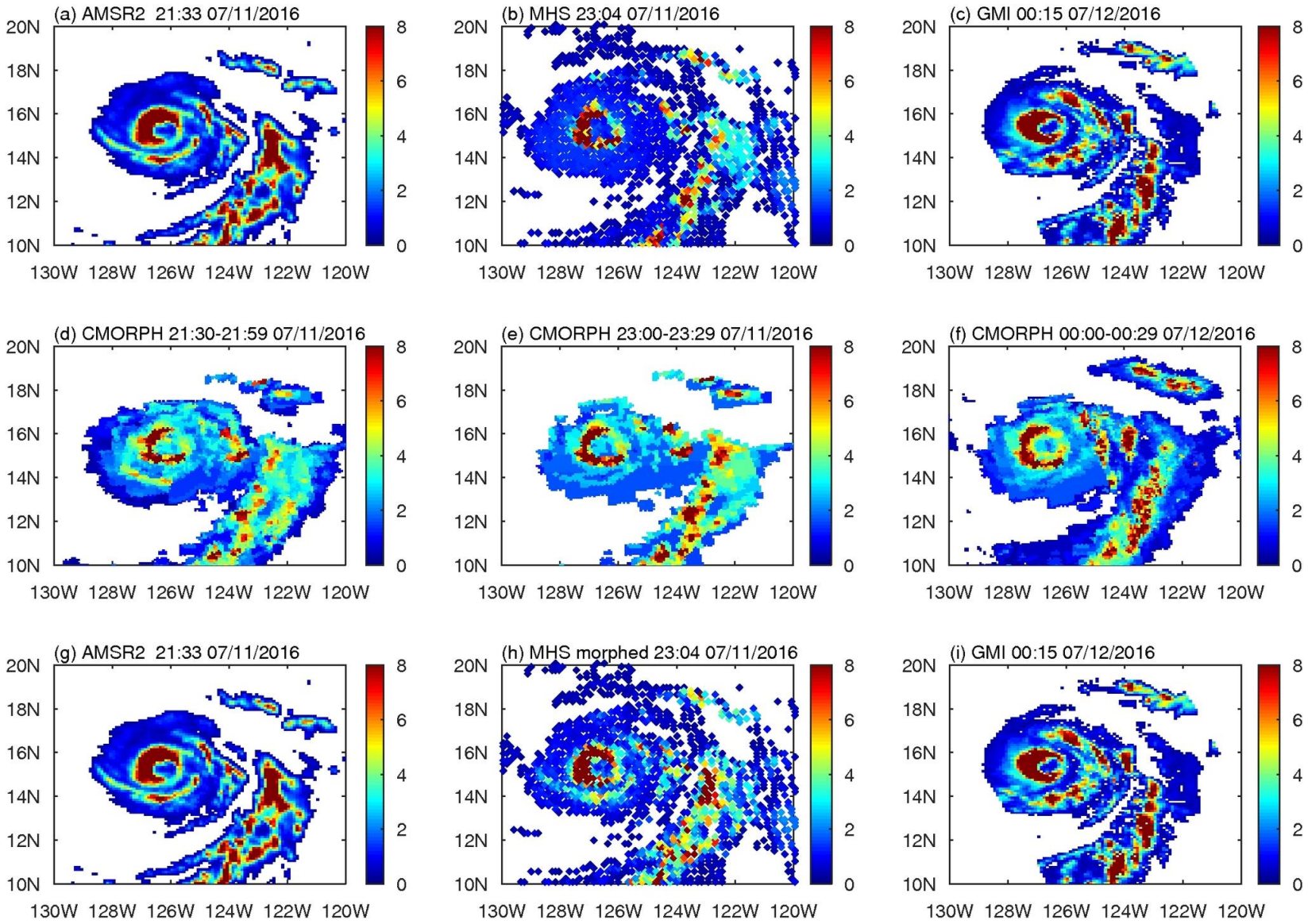
Our method



GPROF

GSMaP

Our method



GPROF

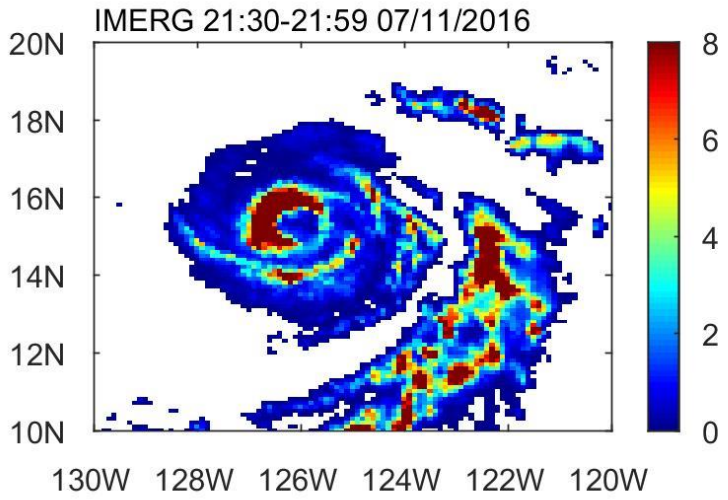
CMORPH

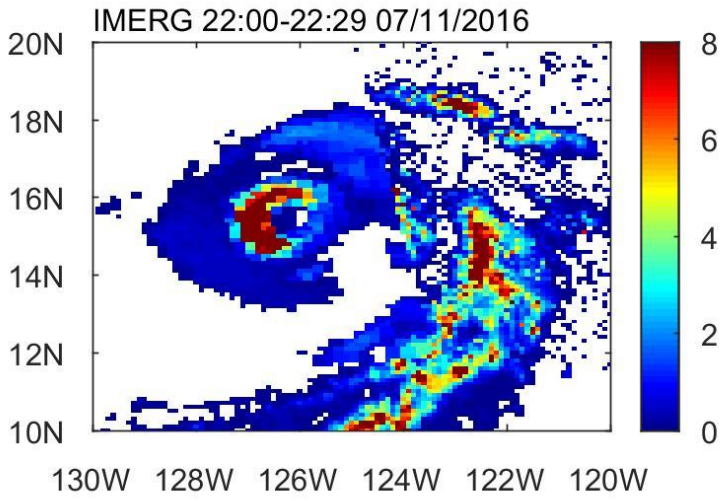
No AMSR2/GMI

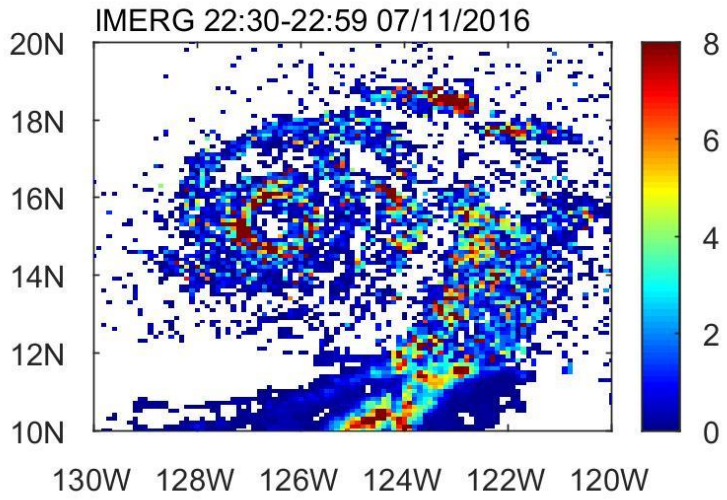
Our method

TABLE 2. Quality ranking of PMW precipitation retrievals from various sensors aboard various platforms.

Quality ranking	PMW sensor (decreasing quality from top to bottom)	LEO platforms (decreasing quality from left to right)
1	TMI	TRMM
2	AMSR	*Aqua*
3	MWRI	*FY-3B*
4	SSMIS	*F-18*, *F-17*, and *F-16*
5	SSM/I	*F-15*, *F-14*, and *F-13*
6	MHS	*MetOp-B*, *MetOp-A*, *NOAA-19*, and *NOAA-18*
7	AMSU	*NOAA-17*, *NOAA-16*, and *NOAA-15*


IMERG 21:30-21:59 07/11/2016
20N
18N
16N
14N
12N
10N
130W 128W 126W 124W 122W 120W
8
6
4
2
0


IMERG 22:00-22:29 07/11/2016
20N
18N
16N
14N
12N
10N
130W 128W 126W 124W 122W 120W
8
6
4
2
0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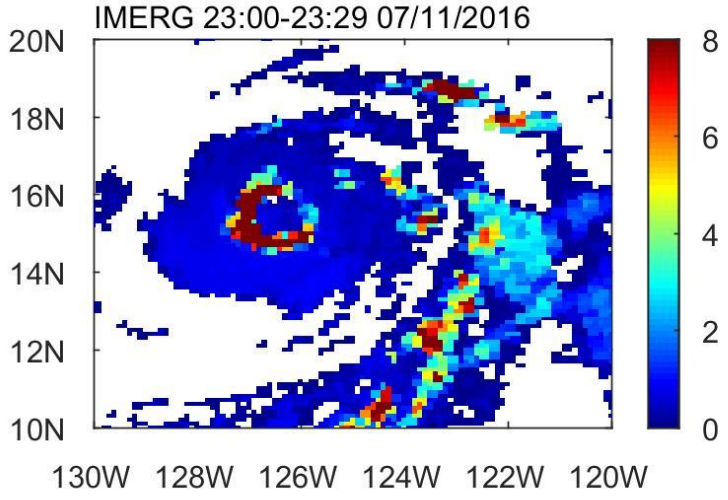
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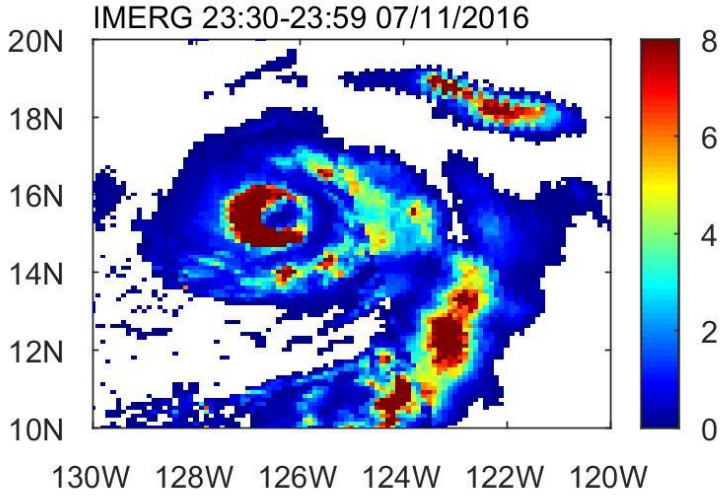
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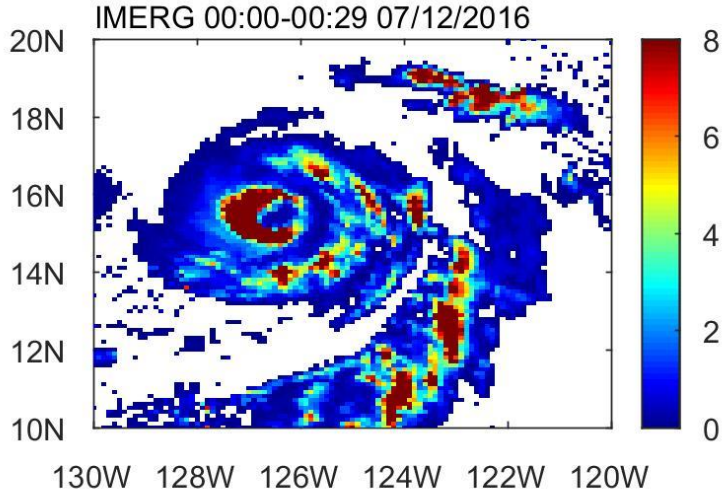
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