Improving over land precipitation retrieval by brightness temperature temporal variation

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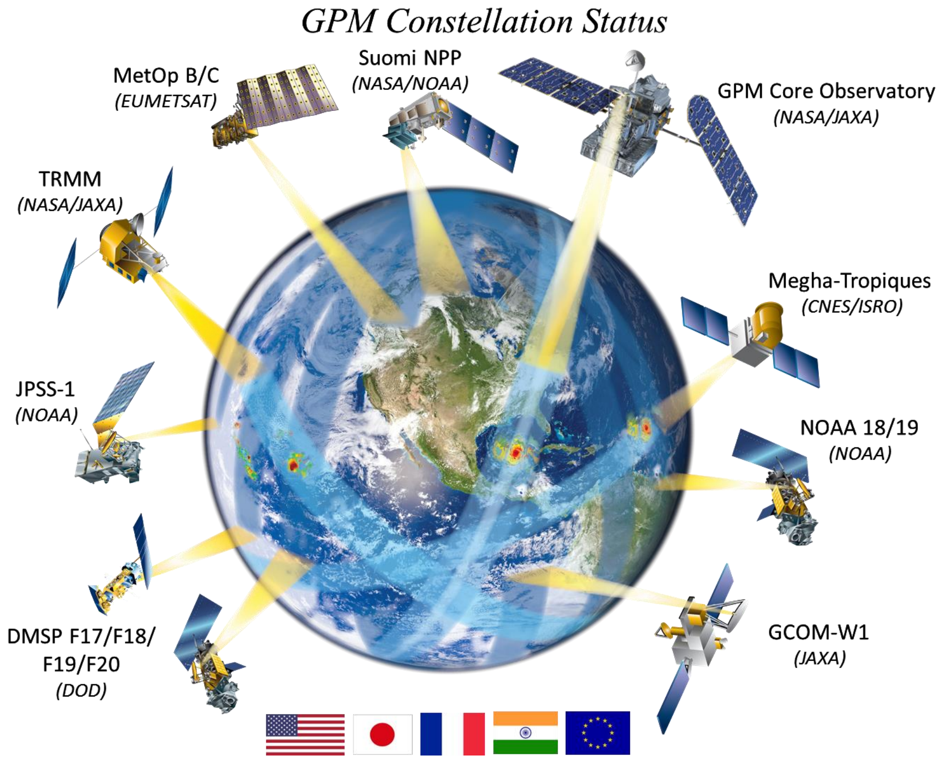
Motivation:

- The primary precipitation signal over land is the brightness temperature (TB) depression at high frequency channels caused by the ice scattering.
- A common and serious issue is the cold land surface contamination (e.g., snow-covered land), which is particularly problematic for rainfall/snowfall retrieval in winter.
- To mitigate this problem, this study proposes to use TB temporal variation (ΔTB), which is derived from eight polar-orbiting satellites, including GPM, F17, F18, S-NPP, NOAA-18, NOAA-19, Metop-A and Metop-B.
- MRMS precipitation data is taken as reference.



Basic idea: Make satellites "talk" to each other. When doing retrieval, one satellite should "consult" what happened previously from another satellite.

Why these 8 satellites:

GPM, F17, F18, S-NPP, NOAA-18, NOAA-19, Metop-A and Metop-B.

Because:

Radiometers onboard these satellites all have frequencies from ~89 GHz to ~183 GHz.

Satellite name	Radiometer name	Frequency	Frequency	Frequency	Resolution	ECT
GPM	GMI	89.0 (V/H)	166.0 (V/H)	183.3±3, ±7 (V)	6 or 7 km	—
F17	SSMIS	91.7 (V/H)	150.0 (H)	183.3±1, ±3, ±6.6 (H)	14 km	1826
F18	SSMIS	91.7 (V/H)	150.0 (H)[a]	183.3±1, ±3, ±6.6 (H)	14 km	1845
SNPP	ATMS*	88.2 (V)	165.5 (H)	183.3±1, ±1.8, ±3, ±4.5, ±7 (H)	14–45 km	1331
NOAA-18	MHS*	89.0 (V)	157.0 (V)	183.3±1, ±3 (H); 191.3 (V)	17–40 km	1833
NOAA-19	MHS*	89.0 (V)	157.0 (V)	183.3±1, ±3 (H); 191.3 (V)	17–40 km	1559
MetOp-A	MHS*	89.0 (V)	157.0 (V)	183.3±1, ±3 (H); 191.3 (V)	17–40 km	2129
MetOp-B	MHS*	89.0 (V)	157.0 (V)	183.3±1, ±3 (H); 191.3 (V)	17–40 km	2132

Previous work showed that high freq. channels provide most information for the light precipitation detection/retrieval.

You, Y., N. Wang, R. Ferraro, and S. Rudlosky, 2017: Quantifying the snowfall detection performance of the Global Precipitation Measurement (GPM) microwave imager channels over land. J. Hydrometeor., doi: http://dx.doi.org/10.1175/JHM-D-16-0190.1

“Convert” TBs from other radiometers to GMI

- Simultaneous Conical Overpass (SCO): simultaneous measurements at a location from two different sensors at a similar frequency should be highly correlated.
  (1) regress SSMIS(F17)-V91.7 against GMI-V89, using SCO pairs between F17 & GPM.
  (2) apply this relation to all pixels.

- Sounder (ATMS & MHS): SCO pairs dependent on scan position.

- By doing so, it is as if that we have eight sensors measuring TBs at GMI frequencies, which are 89.0 (V/H) 166.0 (V/H), 183.3±3 (V), and 183.3±7 (V).

You, Y., C. Peters-Lidard, J. Turk, S. Ringerud, and S. Yang, 2017: Improving over land precipitation retrieval with brightness temperature temporal variation. *J. Hydrometeor.* doi:10.1175/JHM-D-17-0050.1.

TB temporal variation (ΔTB):

$$\Delta \boldsymbol{TB} = \boldsymbol{TB}_{\boldsymbol{t_0}} - \boldsymbol{TB}_{\boldsymbol{t_{-1}}}$$

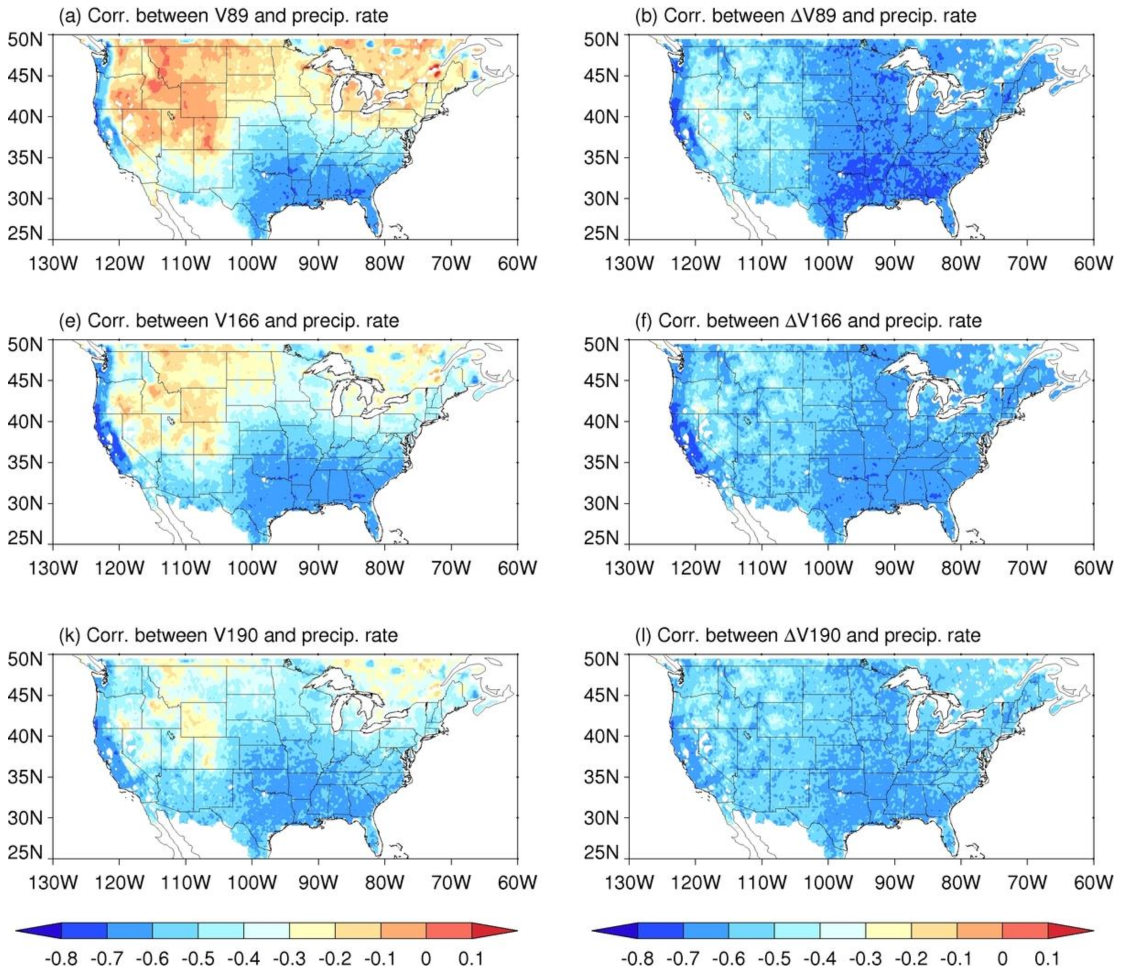
- TB_{t_0} is the current TB associated with precipitation.
- $TB_{t_{-1}}$ is the preceding TB at the same location without precipitation.
- ΔTB is not the difference between two temporally consecutive TB observations

$$\Delta \boldsymbol{t} = \boldsymbol{t_0} - \boldsymbol{t_{-1}}$$

- Δt time difference between these two observations.
- We show later that the shorter the revisit time (Δt), the better the correlation between TB temporal variation (ΔTB) and precipitation intensity is.

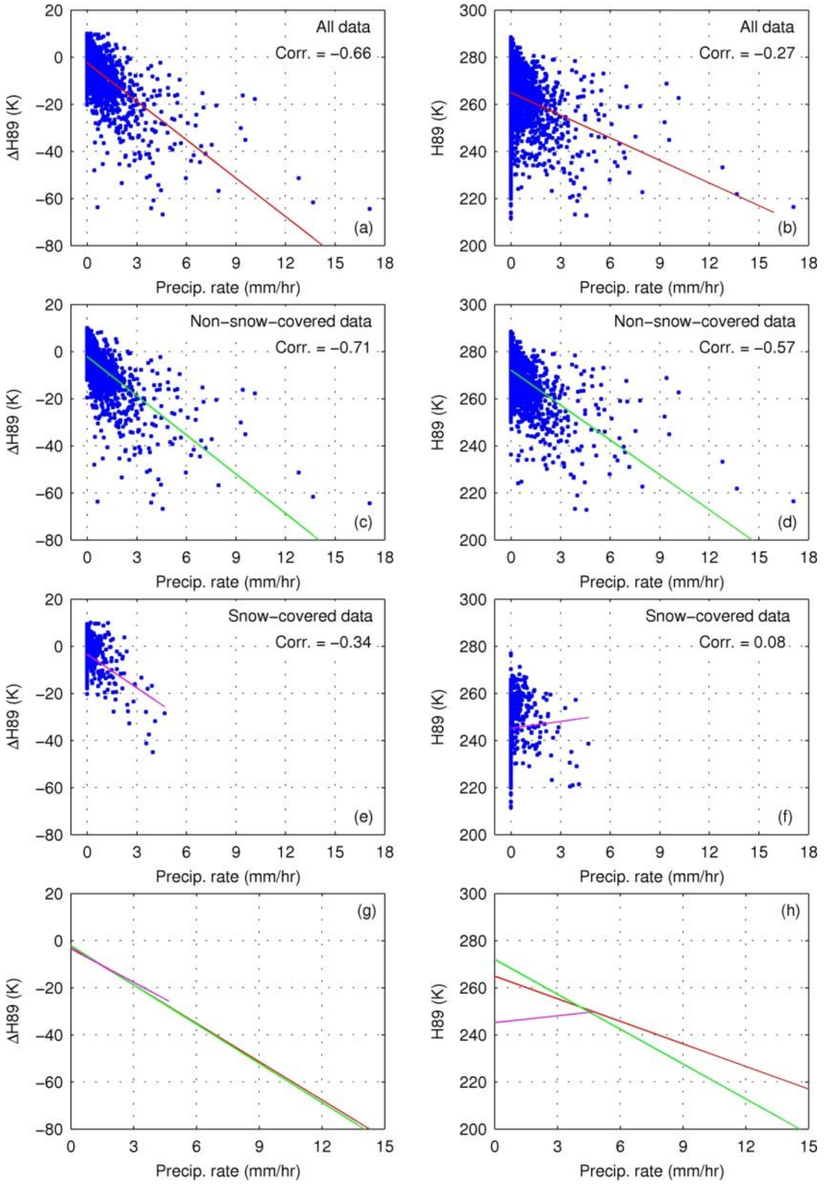
Correlation from TB vs. from ΔTB

Corr. from TB | **Corr. from ΔTB**



- ΔTB correlates more strongly with precipitation rate.
- Especially, over Rocky Mountains and northeast CONUS.

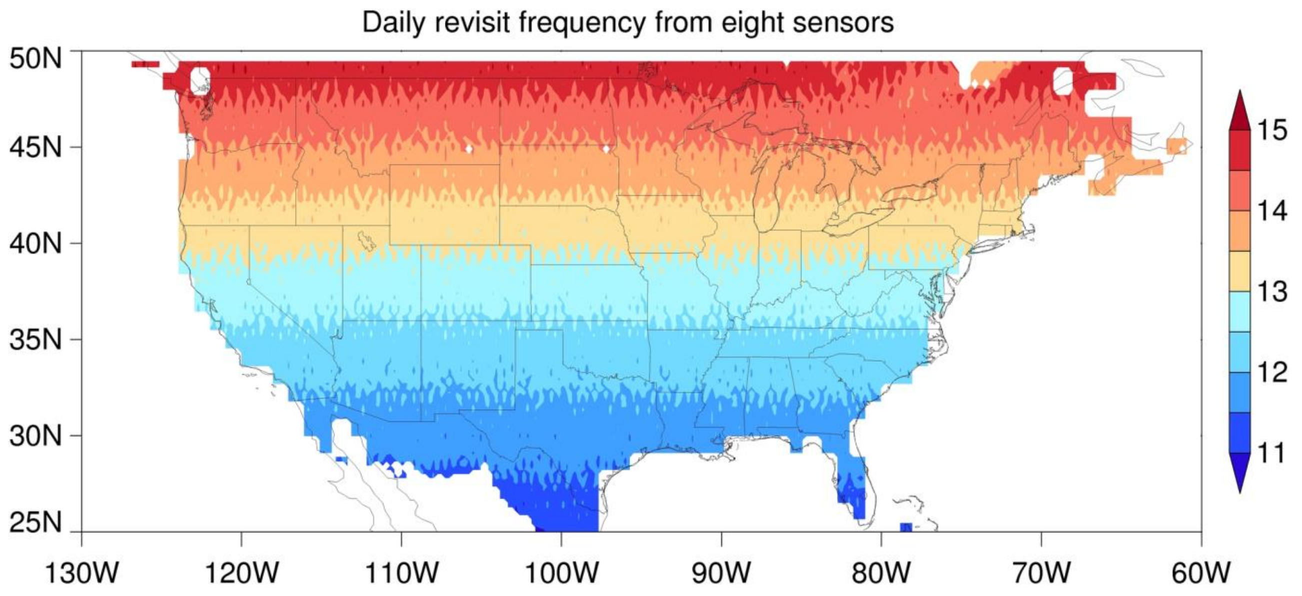
Why ΔTB is better



Because:

Surface contamination from snow cover is greatly mitigated by ΔTB due to the frequent re-visit (every 2hr) from these eight satellites.

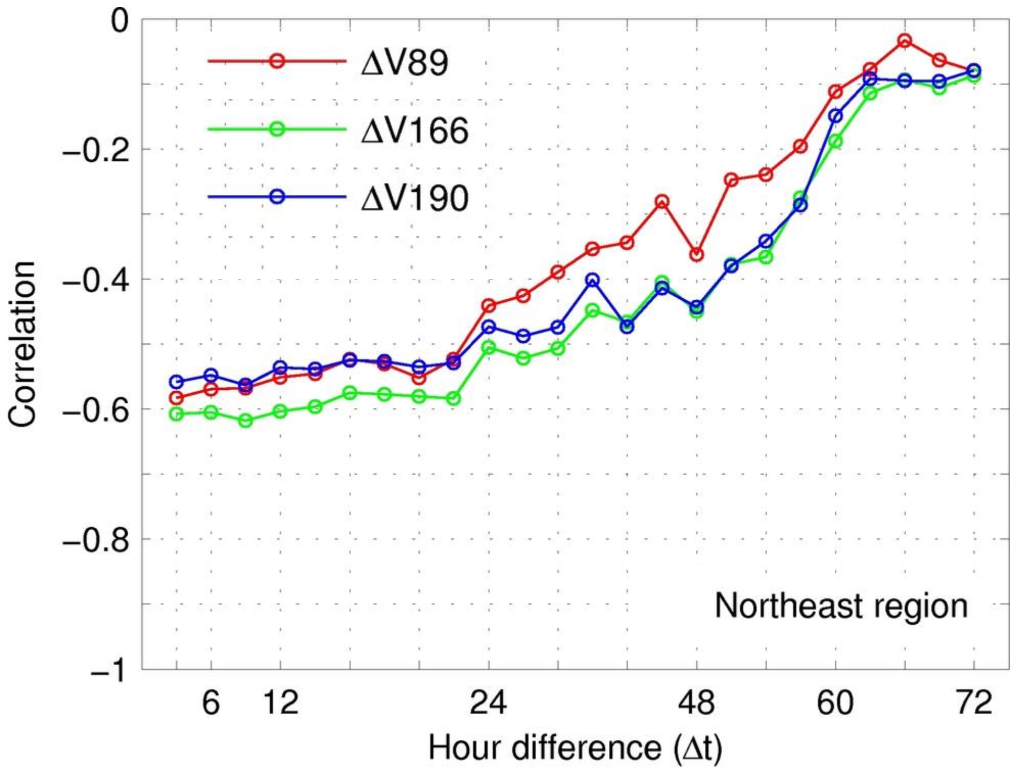
Daily re-visit frequency

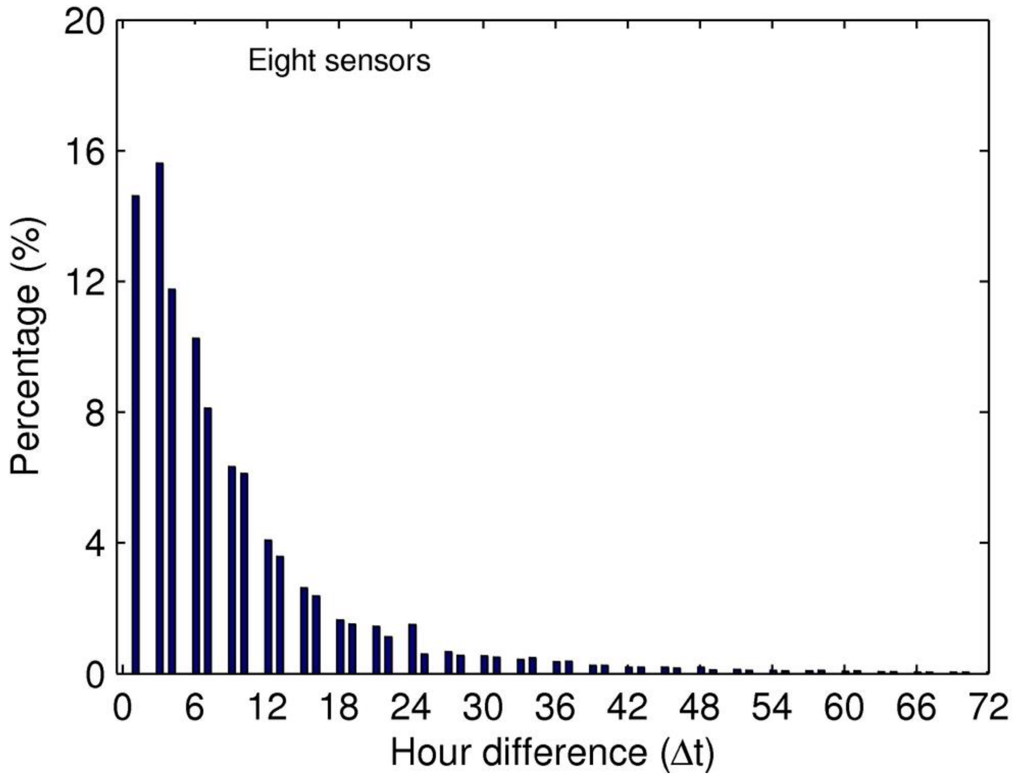


- Over the targeted region, the daily re-visit frequency is from 10 to 16 times (on average, every ~2-hr), depending on latitudes.

- The frequent revisit for a certain location enables us to find a non-cloudy background accurately, therefore ΔTB mostly contains the precipitation information, instead of surface and environmental contamination.

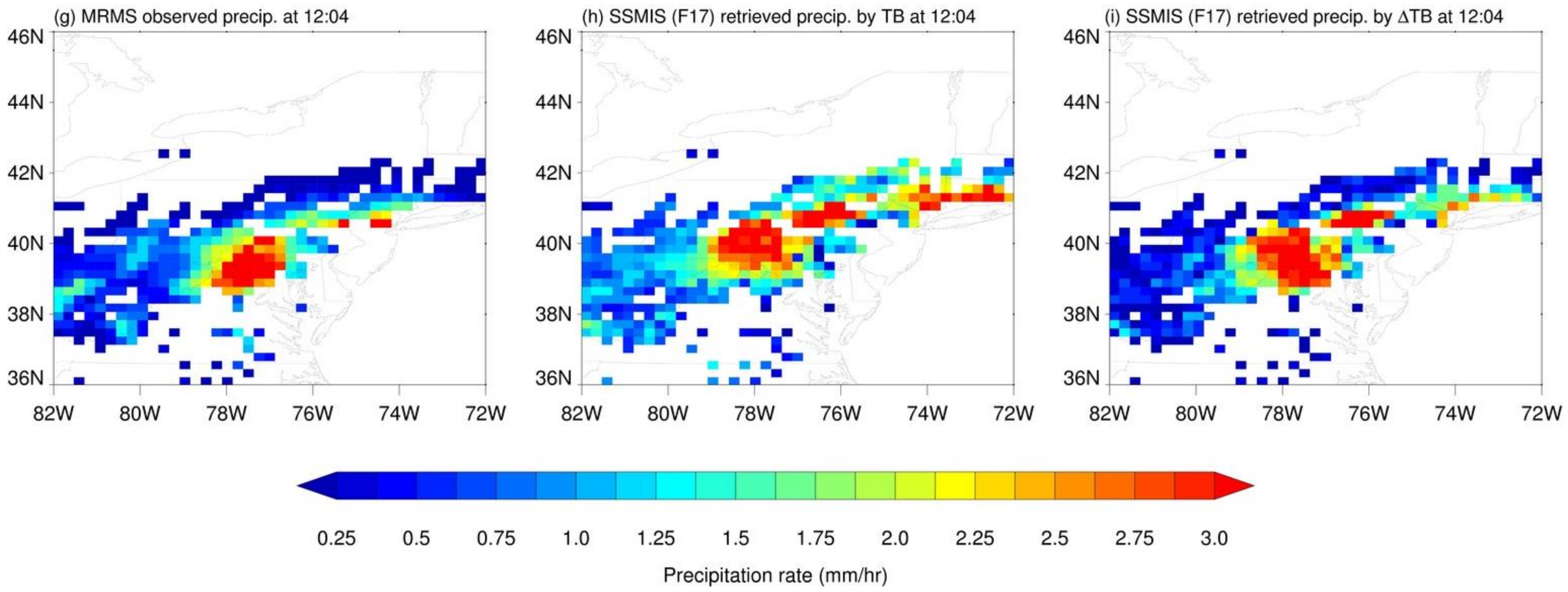
Shorter ΔT , better correlation





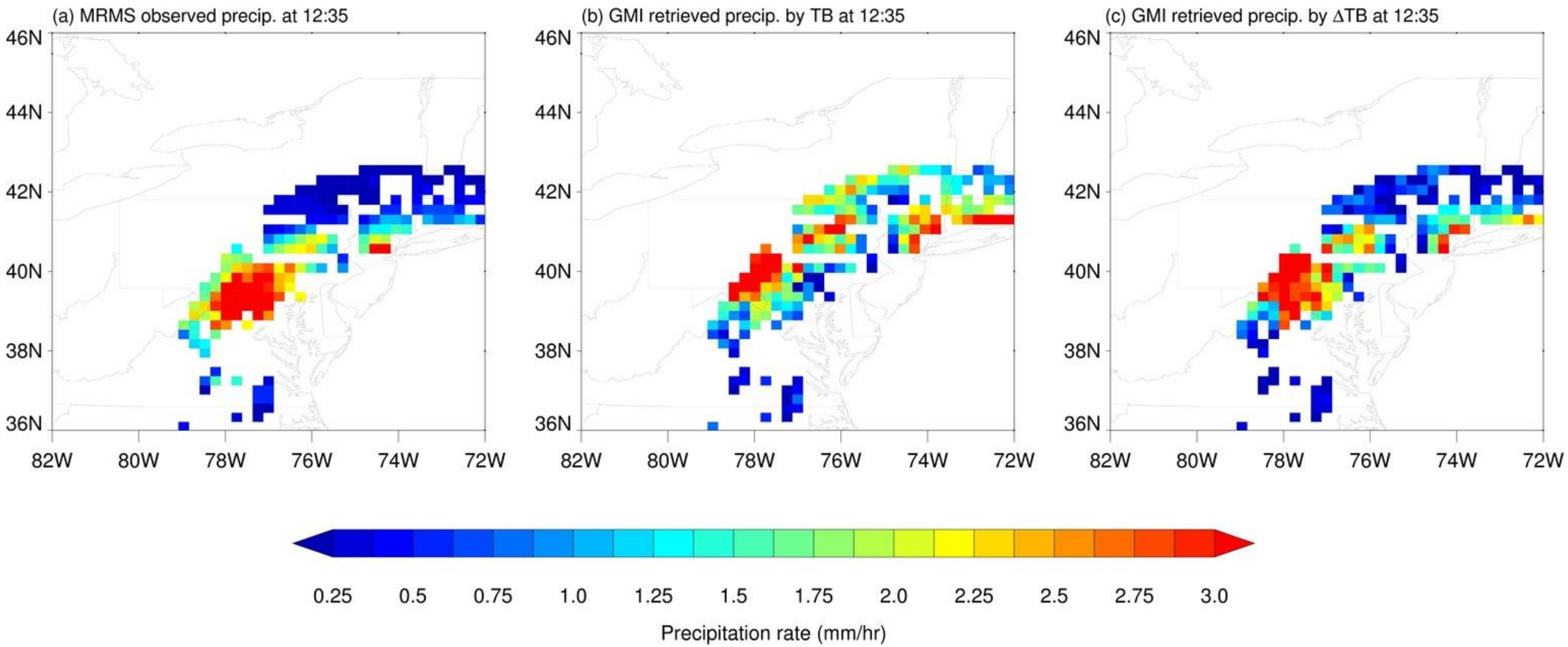
- Correlation substantially weakens with longer ΔT over the Northeast region (37-47N, 65-80W).
- With these 8 satellites, almost all ΔT (94.6%) is less than 24 hrs.

A blizzard case: Mid-Atlantic and Northeast on 23 Jan 2016



- **Over-estimation for light precipitation is greatly alleviated for all sensors.**

A blizzard case: Mid-Atlantic and Northeast on 23 Jan 2016



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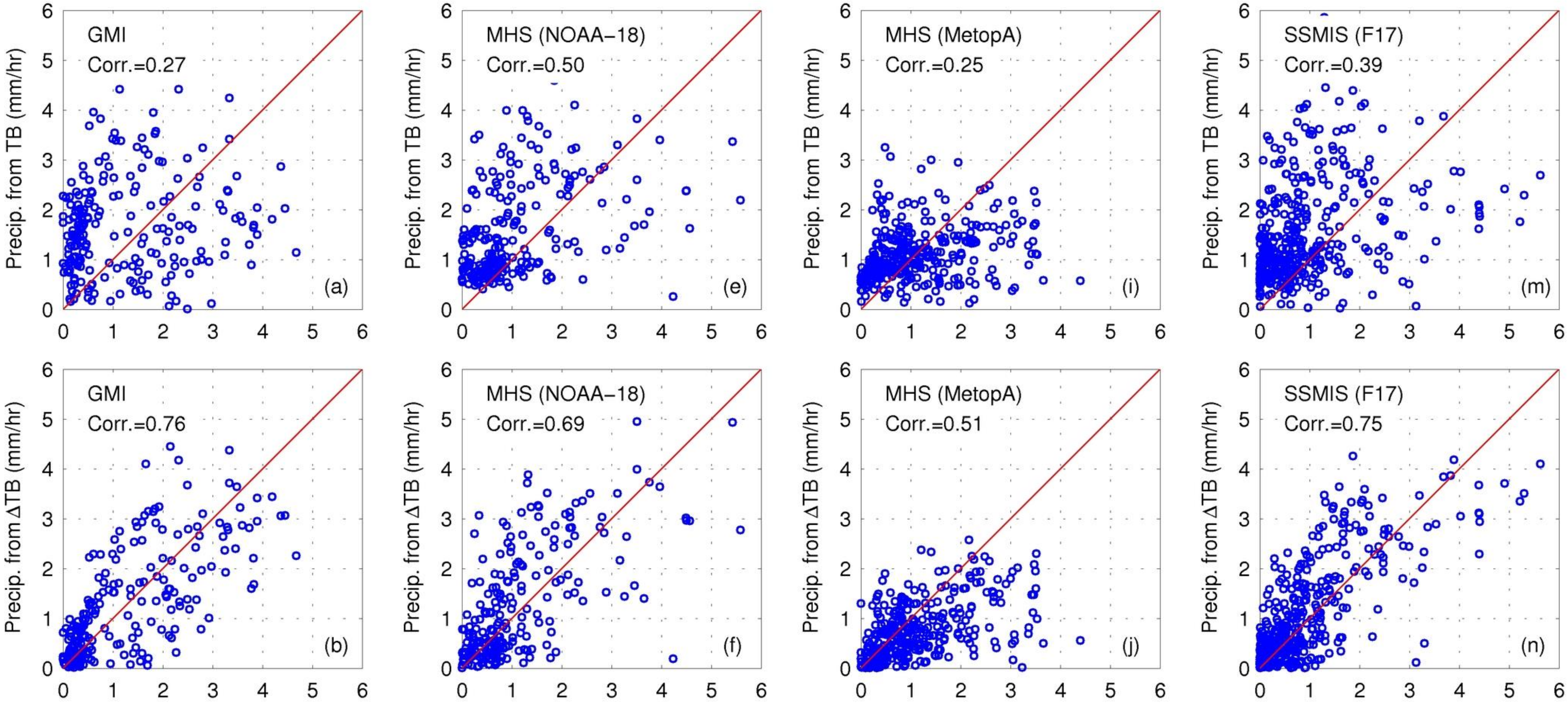
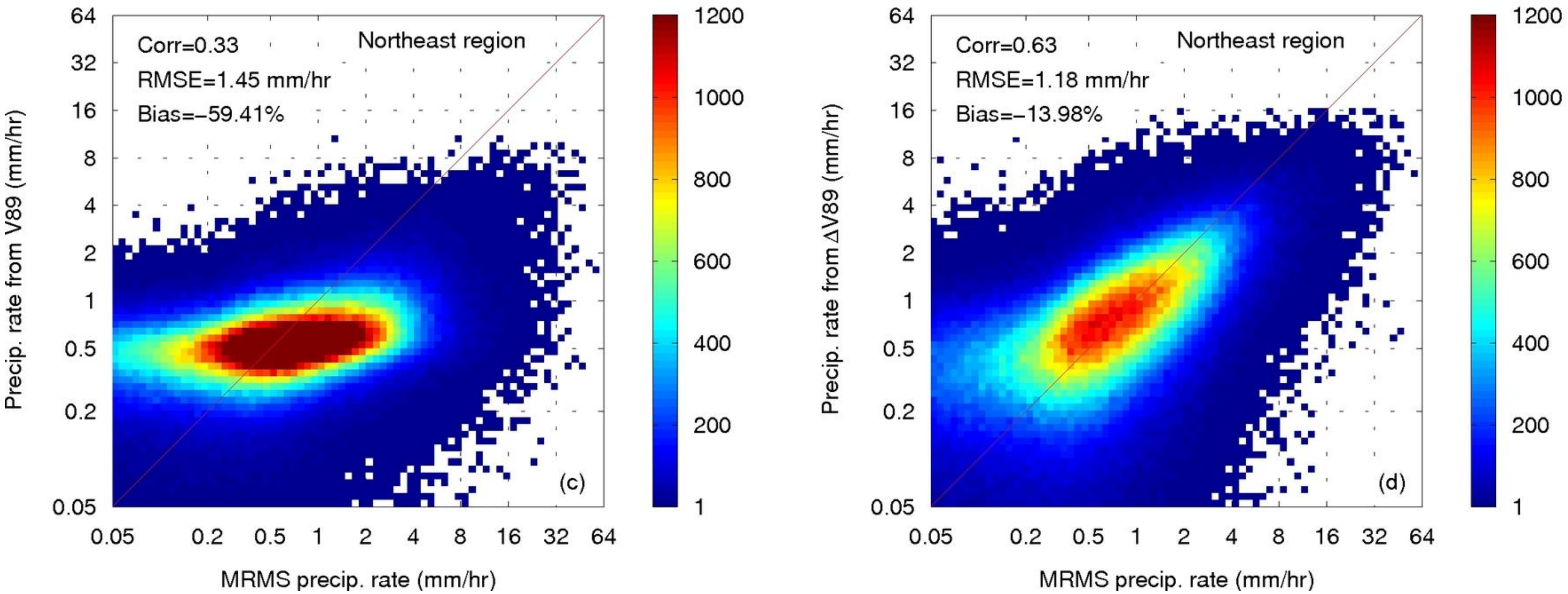


- **Over-estimation for light precipitation (<2 mm/hr) is greatly alleviated for all sensors.**
- **Because: if ΔTB is 0, the retrieval can only be 0.**

Retrieval results:

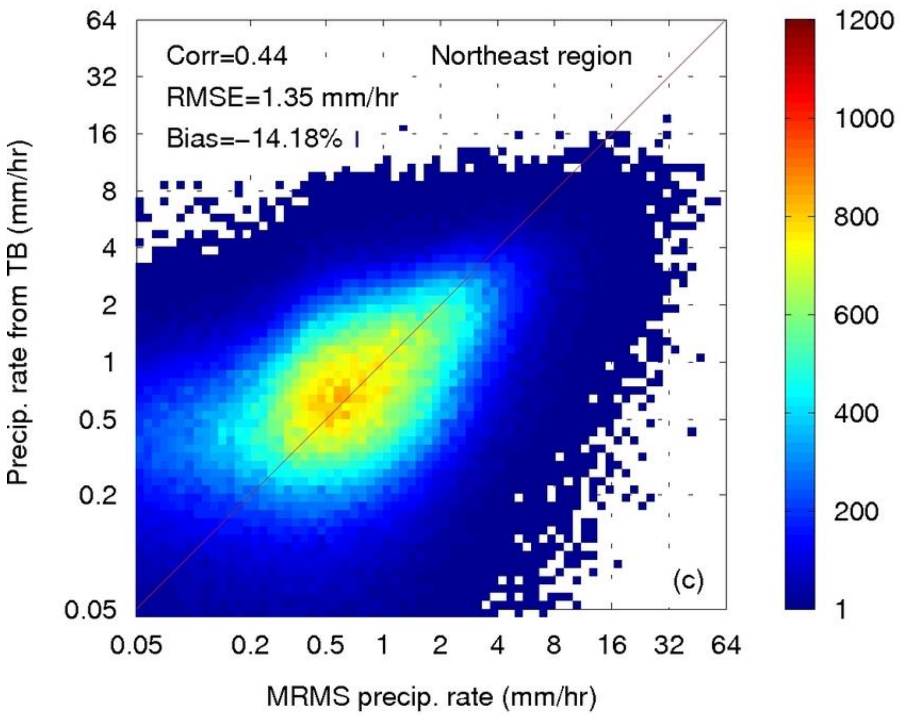
- Only using 89 GHz channel, AMSR2-type sensor (highest freq. ~89 GHz).
- Simple linear regression (2014-2015 training; 2016 validation).

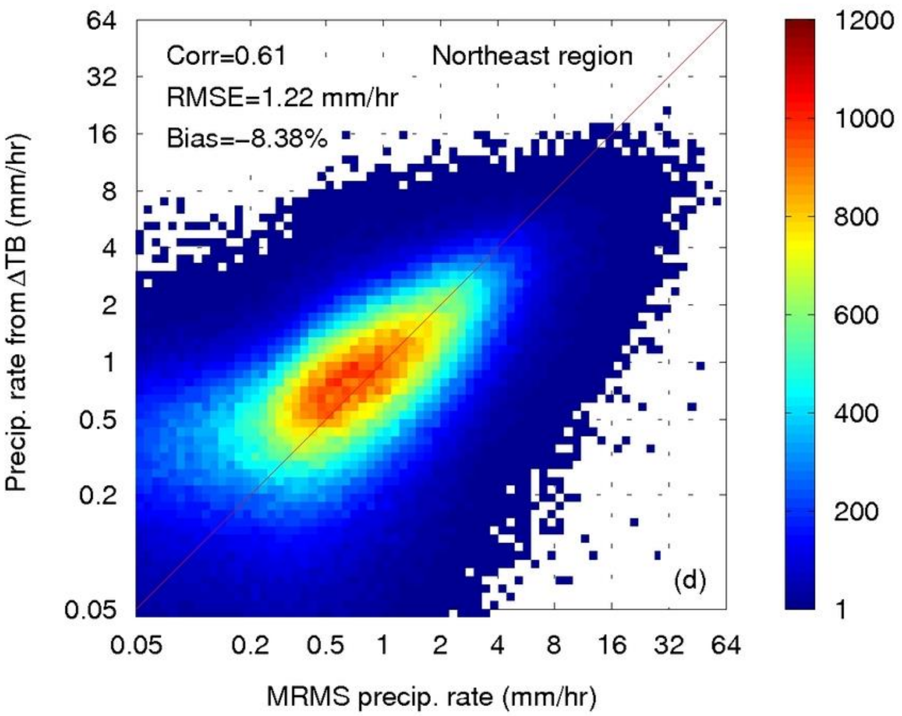


- **Largest improvement is at the lower end of the precipitation intensity.**

Retrieval results:

- **Using all channels from 89 to 183 GHz.**
- **Simple linear regression (2014-2015 training; 2016 validation).**





- **Largest improvement is at the lower end of the precipitation intensity.**

Summary:

- ΔTB correlates more strongly with precipitation rate than TB itself.
- ΔTB greatly mitigates snow-cover contamination.
- Largest improvement is found for the cold season precipitation.

Acknowledgement:

- Dr. Wesley Berg for SSMIS data status.
- Dr. Joe Munchak for reading/discussing the original draft.
- Dr. Eric Nelkin for providing the equatorial crossing time.