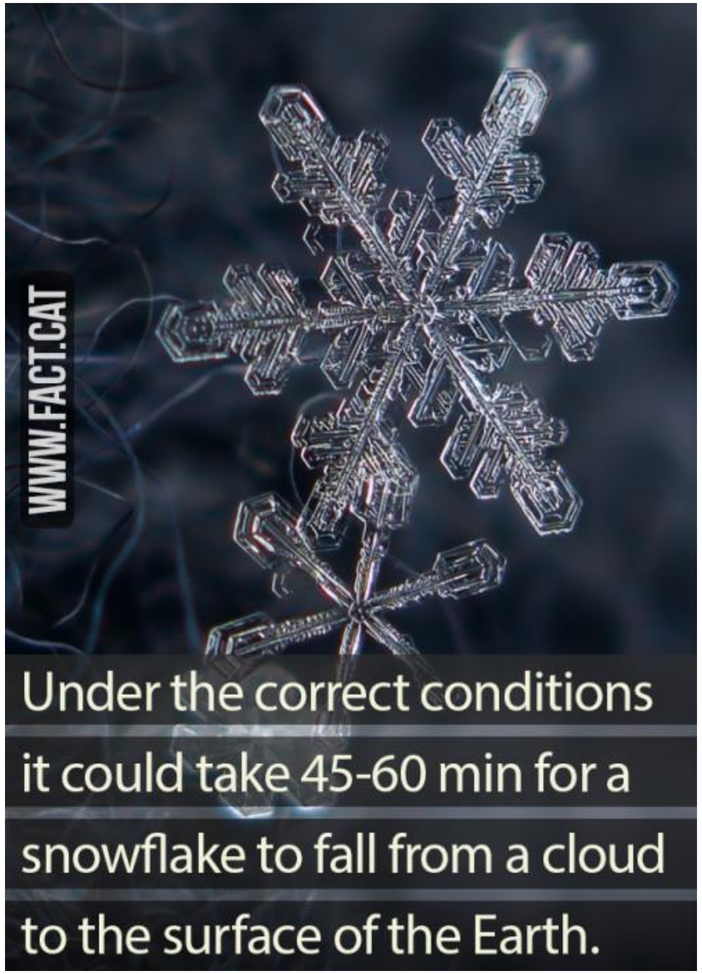
Time-Lag Correlation Between Passive Microwave Measurements and Surface Precipitation and Its Impact on Precipitation Retrieval Evaluation

Yalei You[1], Huan Meng[1,2], Jun Dong[1], Scott Rudlosky[1,2]

[1]Cooperative Institute for Satellite Earth System Studies (CISESS)
Earth System Science Interdisciplinary Center (ESSIC), University of Maryland
[2]National Environmental Satellite, Data, and Information Service (NESDIS)
National Oceanic and Atmospheric Administration (NOAA)

Have you ever wondered how long it takes a raindrop/snowflake to reach the ground?



www.fact.cat

- **Raindrop often takes less than 5 minute.**

- **Snowflake can take between 30 and 60 minutes.**

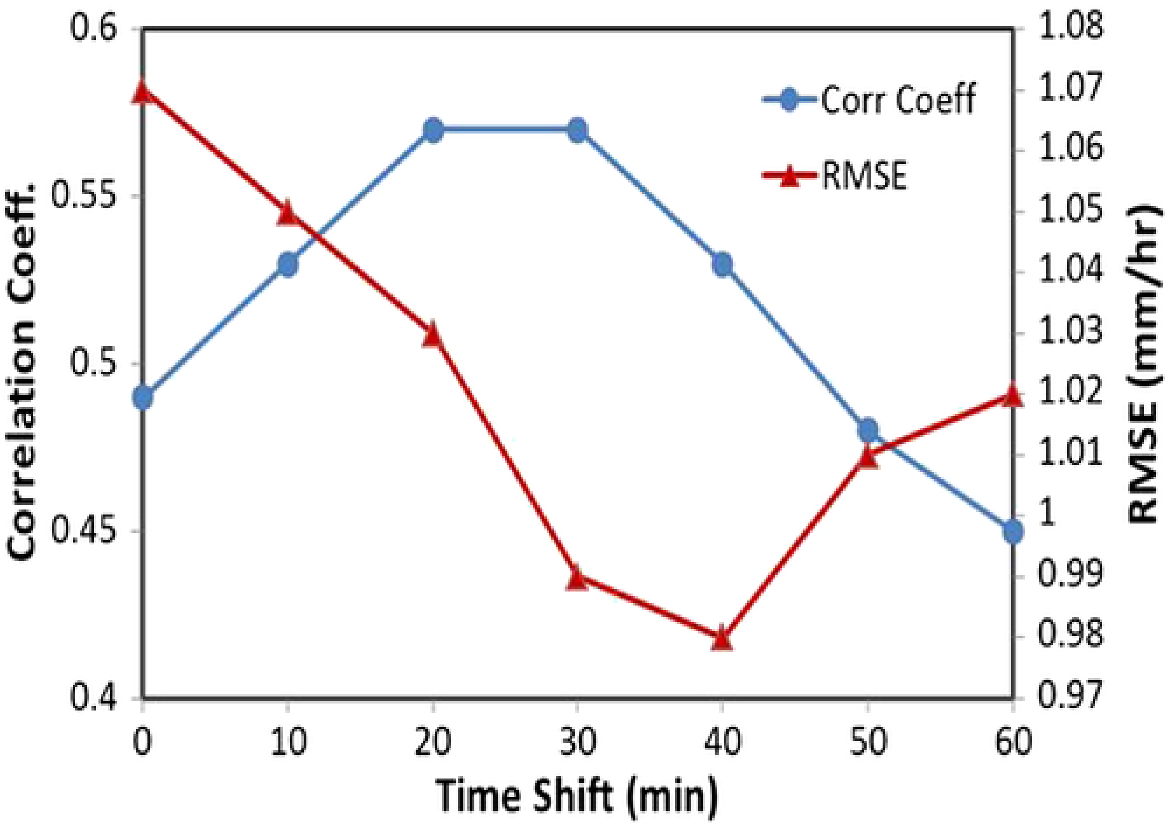
www.bestfunforall.com

Why the time matters

- Remote sensing instruments used for global precipitation measurements do NOT directly measure rainfall at the ground level.
- Passive microwave radiometer (PMW) observations serve the basis for generating the widely used global precipitation datasets (e.g., IMERG and CMORPH).
- Passive microwave radiometer measures the integrated effects from the hydrometeors in the entire precipitation column (water path), not the surface precipitation rate.
- More than 15 passive microwave radiometers are currently operational.

Satellite	PMW Sensor
NPP	ATMS
NOAA18	AMSUA/MHS
NOAA19	AMSUA/MHS
NOAA20	ATMS
MetOp-A	MHS
MetOp-B	MHS
MetOp-C	MHS
GPM-core	GMI
F16	SSMIS
F17	SSMIS
F18	SSMIS
GCOM-W	AMSR2
FY-3,4	MWRI/MWHS
Megha-Tropiques	SAPHIR
Follow-on missions	…

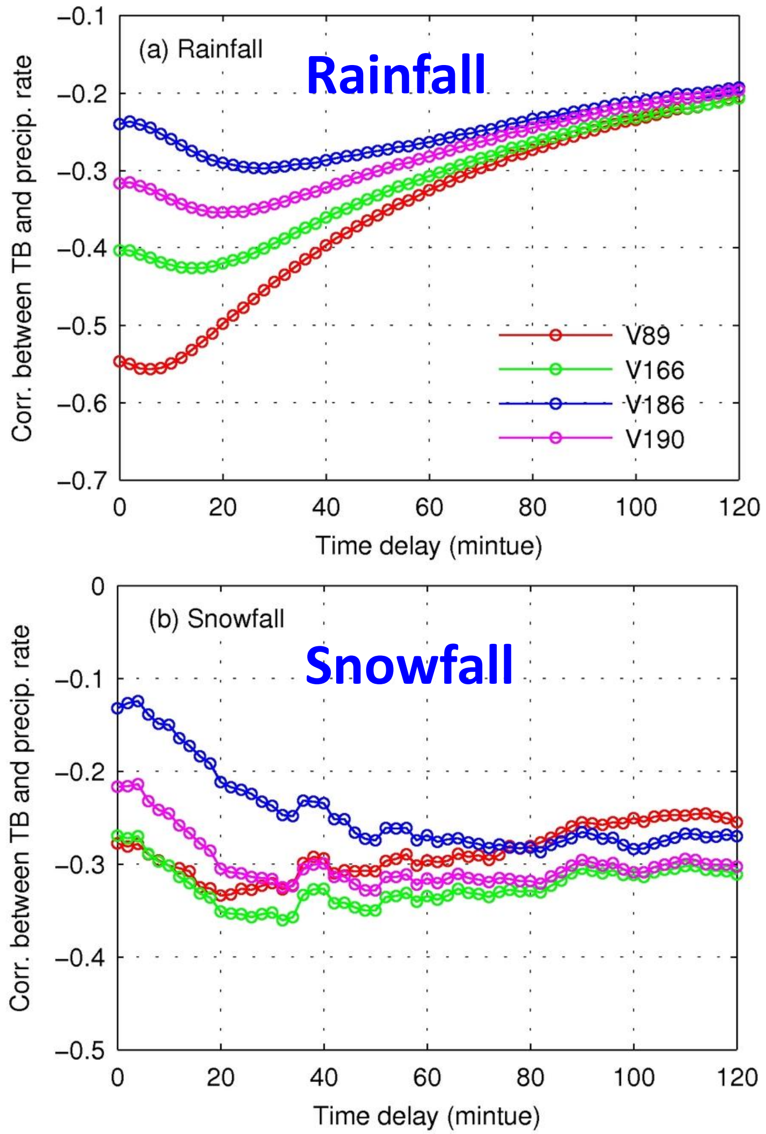
Lag-time between ATMS snowfall and ground radar observations



Meng H., et. al., 2017, JGR.

- Correlation and RMSE between ATMS snowfall rate (SFR) and ground radar snowfall observations.
- Two sets of data are best correlated by shifting ATMS snowfall forward ~ 30 minutes.

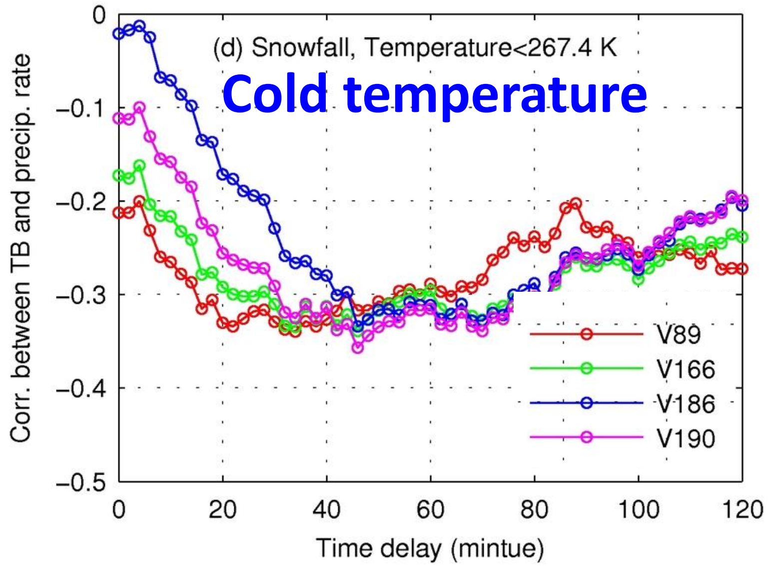
Lag-time between brightness temperature (TB) and ground radar observations

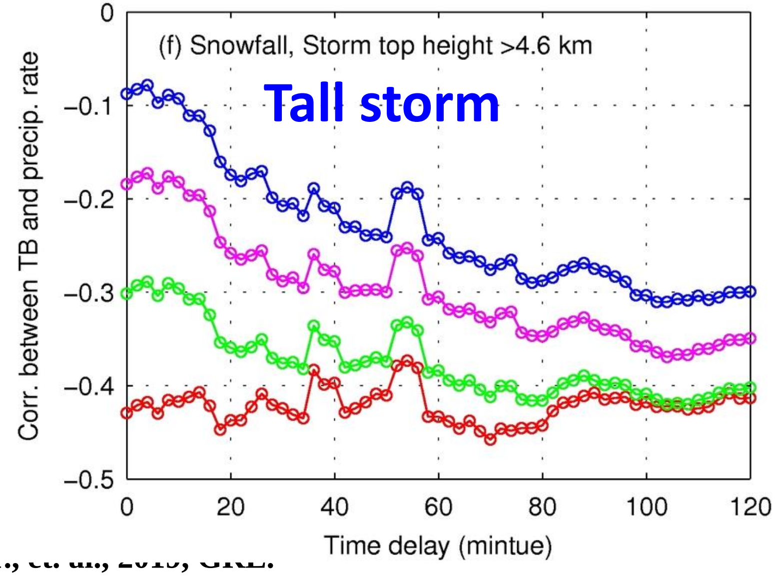


You Y., et. al., 2019, GRL

- TBs are from GMI 89, 166, 186, and 190 GHz, and ground radar observations are over CONUS.
- Lat-time is defined as the time where the correlation peaks.
- Different channels is (more) sensitive to particles at different height. (V89 close to the ground, V186 close to the cloud top, V166 & V190 in between).
- **Rainfall: varying from 8 to 30 minutes**, depending on channels
- **Snowfall: varying from 20 to 80 minutes**, depending on channels.

Lag-time **dependence on temperature and storm height** for Snowfall

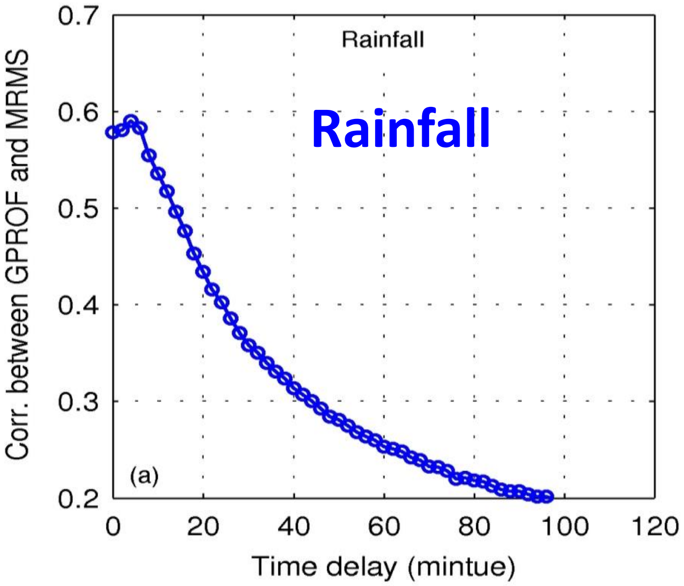


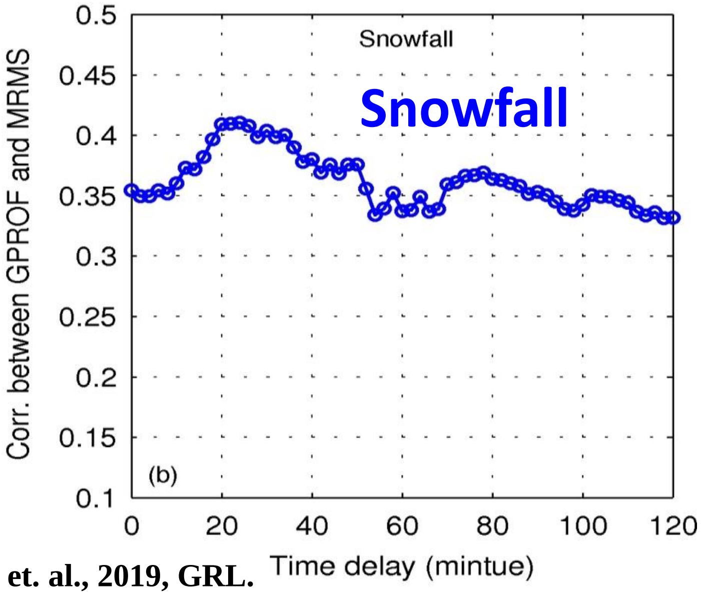


You Y., et. al., 2015, GRL.

- Lag-time depends on fall speed (particle size) and height.
- Snowfall: varying from 20 to 82 minutes, depending on channels.
- **Under cold environment** (<267.4 K, 25th percentile), **lag-time is more apparent**, and the magnitude of the correlation increase is larger.
- **For tall storm** (> 4.6 km, 75th percentile), **lag-time is more apparent**, and the magnitude of the correlation increase is larger.
- No clear dependence is found for rainfall.

Impact for rainfall/snowfall evaluation

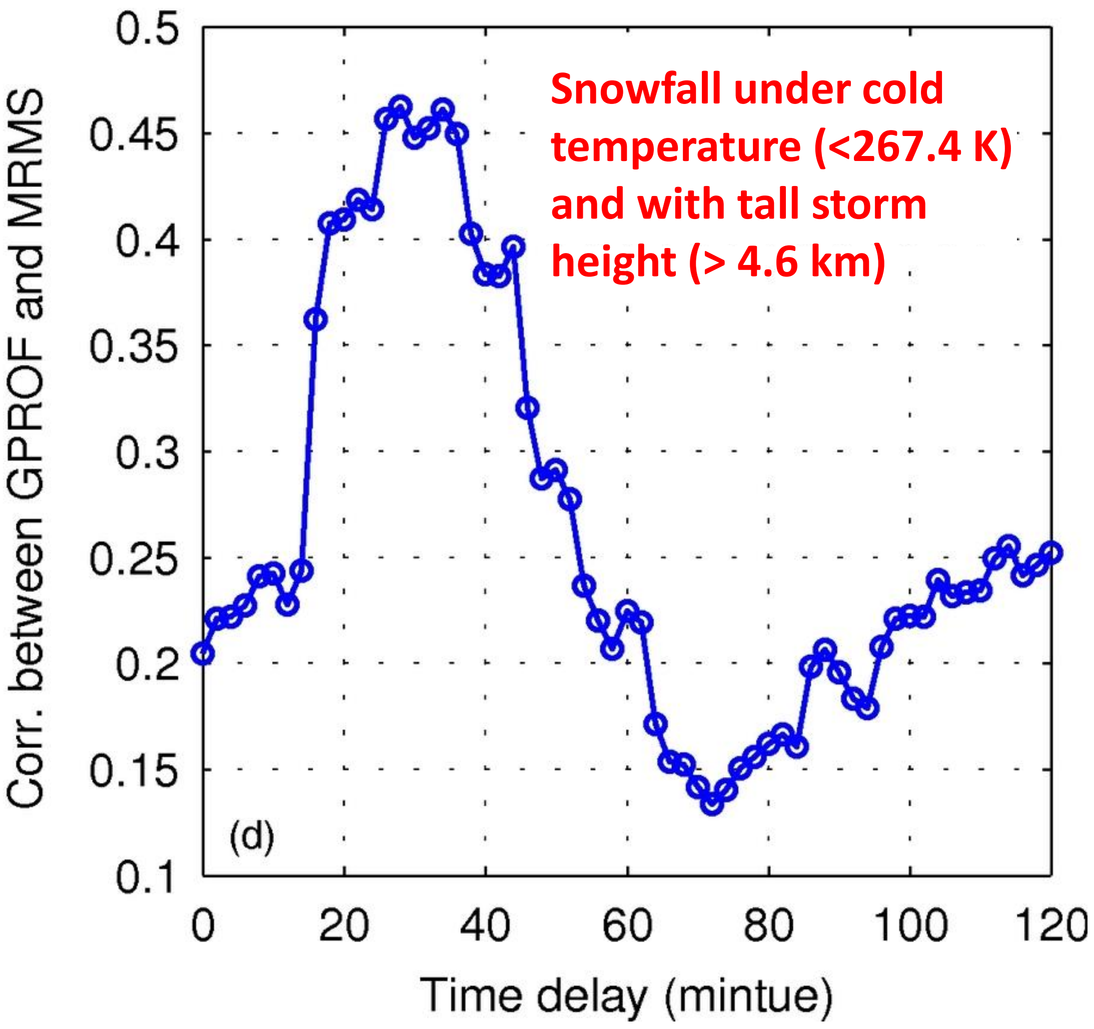




You Y., et. al., 2019, GRL.

- Correlation between GPROF-retrieved rainfall/snowfall from GMI and MRMS ground radar estimates. (MRMS: Multi-Radar/Multi-Sensor System, GPROF = Goddard Profiling Algorithm).
- **For rainfall**: the correlation increases marginally up to a ~6-min lag time. Therefore, the correlation between the simultaneous satellite-retrieved rainfall rate and surface rainfall rate is safe to use as a performance indicator.
- **For snowfall:** the correlation peaks around 30 minutes.

Impact for rainfall/snowfall evaluation



You Y., et. al., 2019, GRL.

- **For snowfall:** the correlation peaks around 30 minutes. **The weak correlation at the simultaneous time may not indicate poor snowfall retrieval performance** (especially in cold environments and for tall storms).
- The commonly used global precipitation products (IMERG and CMORPH) is at 30-minute resolution.
- This result implies that the **radiometer-retrieved snowfall rates may need to shift forward (e.g., 30 min)**, especially in cold environments and for tall storms, before integrating the retrieval results into the level-3 merged products.

Summary:

- The lag time between brightness temperature and the surface snowfall rate ranges from 30 to 60 min, while the lag time is much smaller for rainfall.

- Weak correlation between satellite-retrieved snowfall rate and surface observations may not indicate poor retrieval performance.

- A 30-min time lag is recommended when incorporating the level 2 swath snowfall rate into the level 3 gridded products.

- **Meng, H., Dong, J., Ferraro, R., Yan, B., Zhao, L., Kongoli, C., Wang, N.-Y., and Zavodsky, B. (2017), A 1DVAR-based snowfall rate retrieval algorithm for passive microwave radiometers, *J. Geophys. Res. Atmos.*, 122, 6520– 6540, doi:10.1002/2016JD026325.**
- **You, Y., Meng, H., Dong, J., & Rudlosky, S. (2019). Time-lag correlation between passive microwave measurements and surface precipitation and its impact on precipitation retrieval evaluation. *Geophys. Res. Lett.*, 46, 8415– 8423. https://doi.org/10.1029/2019GL083426.**

Comments/Questions