Rainfall accumulation estimation using clear-sky brightness temperature temporal variation from a satellite constellation

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1. Background and Objectives

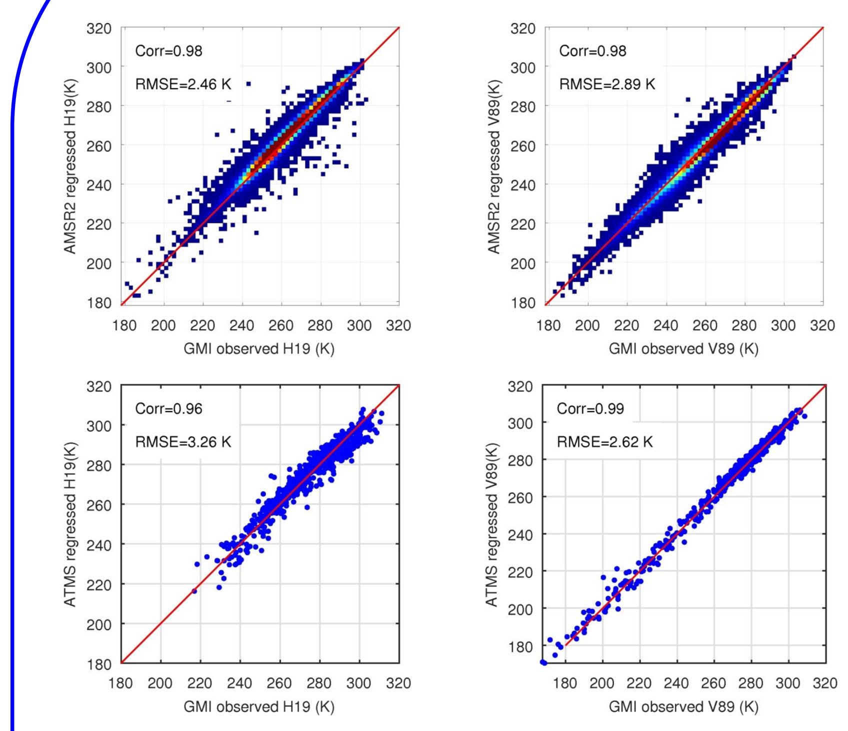
- Clear-sky brightness temperatures (TBs) account for over 80% of total satellite observations. Previous studies (e.g., You et al., 2014) showed that clear-sky TBs, especially the TBs at the low frequencies (e.g., 19 GHz), can memorize the previous rainfall events' effect. In other words, rainfall can lead to the surface emissivity decrease and therefore a TB depression at low frequency channels, due to the soil moisture increase.

- Such a relation (emissivity decrease due to the previous rainfall events) provides an alternative way to estimate the rainfall accumulation using the clear-sky TBs. In essence, this method is similar to using the soil moisture for rainfall accumulation estimation (e.g., Brocca, 2014). Currently, the rainfall retrieval results from clear-sky TBs (or soil moisture) have not been used in the level-3 gridded rainfall products.

- This study proposes to use TB temporal variation (ΔTB) at 19 GHz **under clear-sky condition** to retrieve the rainfall accumulation. We compute the ΔTB at 19 GHz (horizontally polarized) from 10 passive microwave radiometers, including GMI onboard GPM, SSMIS onboard F16, F17 and F18, ATMS onboard S-NPP, AMSR2 onboard GCOM-W, and AMSUA onboard NOAA-18, NOAA-19, Metop-A and Metop-B.

- To this end, we first convert TBs from other sensors to the GMI channels (section 2); Then, we quantify the soil memory time (MT) over CONUS using Stage IV hourly rainfall dataset (section 3). Finally, section 4 presents the rainfall accumulation estimate results from ΔTB over CONUS. We also discuss the future work in section 4.

2. Data and Methodology



- This study uses the microwave radiometer observations from GPM, GCOM-W, F16, F17, F18, S-NPP, NOAA-18, NOAA-19, Metop-A and Metop-B. We use frequencies from ~19 GHz to 89 GHz from each sensor.
- We first use Simultaneous Conical Overpass (SCO) technique and Principal Component Analysis (PCA) to "convert" all TBs to GMI frequencies.
- By doing so, it is as if that we have 10 sensors measuring TBs at GMI frequencies, which are 19.0 (V/H) 23.8 (V), 37.0 (V/H), and 89.0 (V/H).
- Figure on the left shows the conversion results from AMSR2 and ATMS (near nadir pixels). **In general, the correlation coefficients are larger than 0.95 and RMSE are less than 3.5 K for all channels and all sensors.**

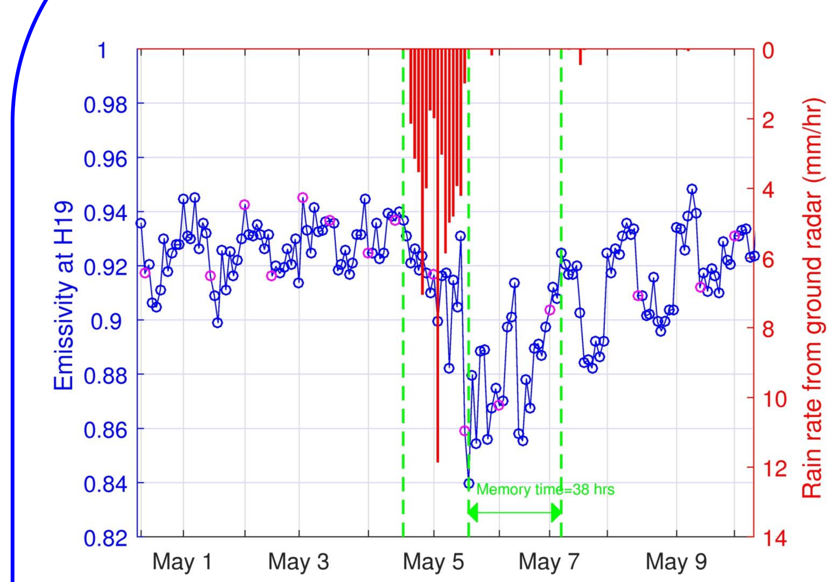
- Precipitation observations are from MRMS (2-minute, 0.01 degree) over CONUS, Stage IV (hourly, 4km) over CONUS, and IMERG final run (half hour, 0.1 degree) from 60S to 60N. All data (TBs and precipitation) are from 03/2014-12/2016 over land, which are averaged to 0.5 degree resolution.

- **TB temporal variation (ΔTB) is defined as:**

$$\Delta TB = TB_{t_0} - TB_{t_{-1}}$$

Where TB_{t_0} is the daily mean clear-sky TB, with rainfall events on that day, and $TB_{t_{-1}}$ is the preceding daily mean clear-sky TB at the same location, without rainfall events.

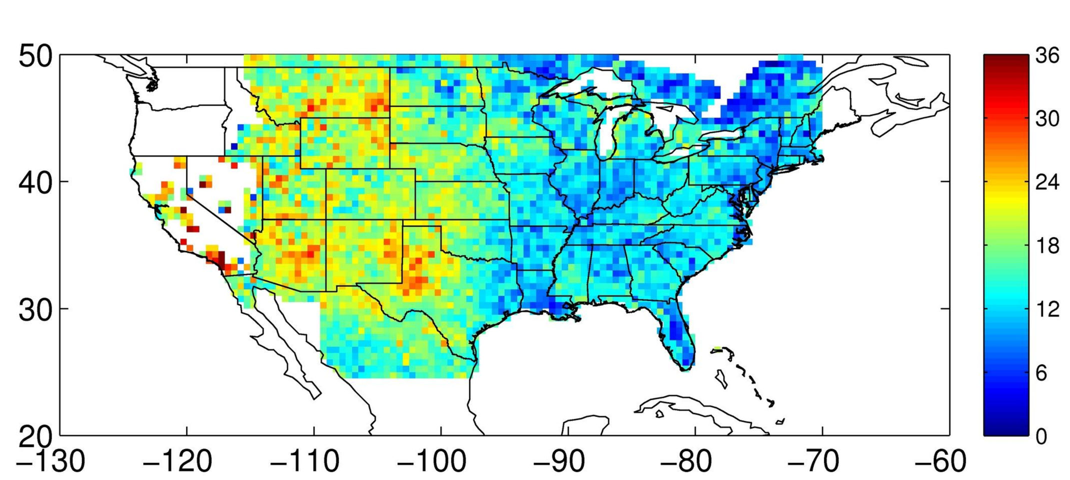
3. Soil Memory Time and Retrieval Performance



Definition of the Soil Memory Time:
The time difference between the time immediately after a rainfall event and the time when the surface emissivity "bounces back" to the emissivity prior to this rainfall event (difference < 0.02).

As an example, the figure on the right shows how to compute the soil memory time.

- surface emissivity prior to this rainfall event: 0.94 (at the first green dashed vertical line)
- time immediately after this event (second green dashed vertical line): 05-05-2015 12:00
- time when surface emissivity "bounces back" (third green dashed vertical line): 05-07-2015 2:00.
- the time difference (memory time): 38 hours



Following this memory time (MT) computation method, we compute MT for all rain events over CONUS in 2015 using hourly Stage IV data, in each 0.5 degree grid box. In this process, AutoSnow is used to filter out pixels associated with the snow/ice cover. All MT values in each grid box is averaged.

It is found that:

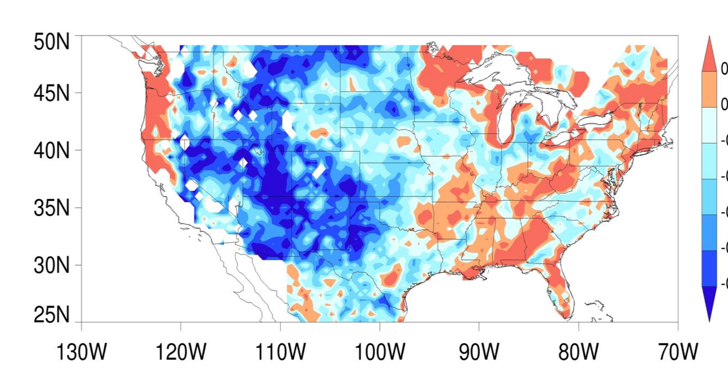
- **MT over the western US (less vegetation) are mostly around 24 hours, while MT over the eastern US are much smaller.**
- **This result indicates that the rainfall effect, on average, can propagate into the next day. Therefore, we retrieve the 2-day rainfall accumulation.**

4. Retrieval Results and Future work

We first compute the correlation between 2-day rainfall accumulation and ΔTB at H19, using 2015 data.

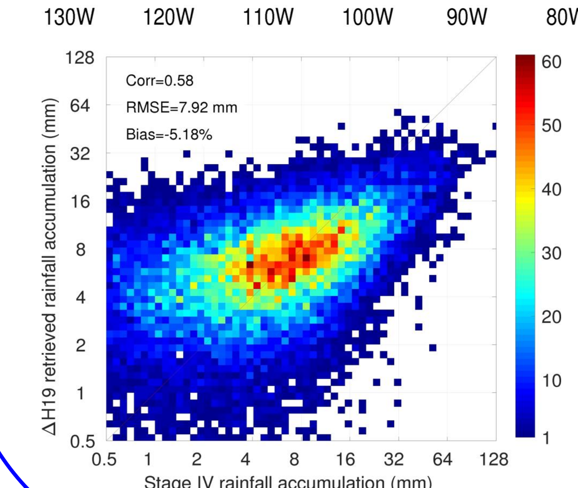
Then, a simple linear regression method is used to retrieve the 2-day rainfall accumulation.

We use the 2014 and 2015 data as the training dataset, and 2016 data as the validation dataset. Note that only grid boxes with correlation coefficients > 0.4 are included.



It is found that:

(1) The 2-day rainfall accumulation correlates well with the clear-sky surface emissivity variation, over the less vegetated region (western US), with the majority of correlation < -0.4.

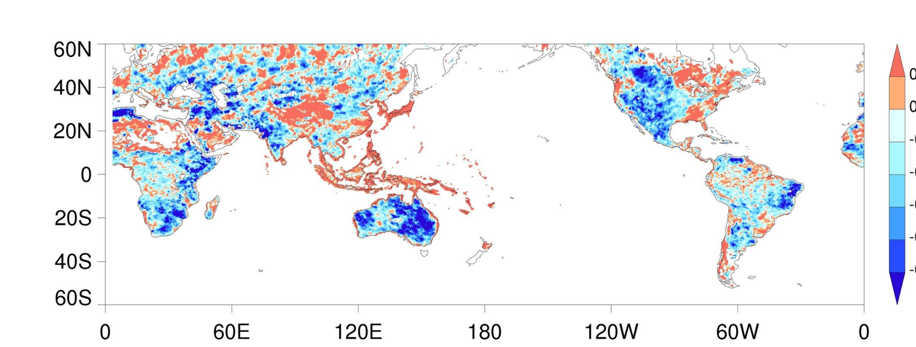


(2) The retrieval results from ΔH19 over western US agree well with the Stage IV rainfall data, with correlation, RMSE, and bias at 0.58, 7.92 mm and 5.18%, respectively.

We further compute the correlation between 2-day rainfall accumulation and ΔTB at H19, using IMERG final run data between 60N and 60S.

Results show that about 32% of grid boxes have correlation coefficients < -0.4.

These strong negative correlations are over less vegetated regions, e.g., south Africa, the majority of Australia, and the western US.



Future work includes:

(1) Screen out the "dense vegetation" region, where the surface does not respond strongly to rainfall.
(2) Retrieve the "event" rainfall accumulation, besides the 2-day rainfall accumulation
(3) Use emissivity, instead of TB, in the retrieval process, to minimize the environmental influences (e.g., temperature and water vapor).

References:

You, Y., C. Peters-Lidard, N. Wang, J. Turk, S. Ringerud, S. Yang, and R. Ferraro, 2018: The Instantaneous Retrieval of Precipitation Over Land by Temporal Variation at 19 GHz. *J. Geophys. Res.*, https://doi.org/10.1029/2017JD027596

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.*, https://doi.org/10.1175/JHM-D-17-0050.1

You, Y., J. Turk, Z. Haddad, L., Li and G., Liu, 2014: Principal Components of Multi-frequency Microwave Land Surface Emissivities. Part II: Effects of Previous-time Precipitation. *J. Hydrometeor.*, **15**, 20–37.