Decadal Variations in the Geographical Distribution of Severe Precipitation Features Selected by the Minimum Polarization Corrected Passive Microwave Brightness Temperatures

Andy Meade, Thomas Lavigne, and Chuntao Liu
Texas A&M University at Corpus Christi (cmeade1@islander.tamucc.edu)

Research Questions/Objectives:

- It is a big challenge to examine the long-term variation of the observations from satellites because of the sampling/measurement biases from the differences in the sensitivity, field of view, and frequencies of instruments, as well as the temporal and spatial sampling. The differences between two satellites can be shown using observations in an overlap period between two satellites. Can we use the overlapping period to remove the sampling/measurement biases?
- While there has been a series of satellites collecting passive microwave observations since 1990s, can we determine the most intense convective systems and examine how they vary in tropics in the past three decades?
- At 85/89 GHz, depression of the brightness temperature is due to ice scattering of passive microwave radiance. Therefore, lower brightness temperatures indicate more intense convection lifting for a larger amount of ice particles in the column. Using this general concept, can we determine long-term variations in the geographical distribution of most intense thunderstorms on Earth?

Methodology:

- The lowest 1% of minimum 85/89 GHz Polarization Corrected Brightness Temperatures (PCT) of Precipitation Features (PFs) for F13, TRMM, and GPM in tropics (20°S-20°N) are selected as the most intense convective systems. These satellites are selected because of their long-term operation time span and overlapping periods.
- Between TRMM & F13, the F13 satellite is sun-synchronous and TRMM is non-sun-synchronous. A subsample adjustment to TRMM data is conducted to sample close to local time as the F13 satellite. This allows for a comparison between the two satellites after removing diurnal sampling bias.
- Assuming that the total difference of the global distributions of intense convection between two satellites include the "Sensor+Sampling Differences" and the "Actual Decadal Differences of Convection". Using the time overlap between two satellites, the "Sensor+Sampling Differences" can be estimated. Then after subtracting it from the total difference, we can derive the true decadal differences between two satellites with difference sensor calibrations and time frames.

Note: With this calculation, we normalized the global distribution to 100% in tropics. Therefore, the results only shows "**redistribution**" of the intense convection in tropics under an assumption that total amount of decadal top 1% intense convection in tropics remains constant.

Data:

- 1C PFs are defined by grouping contiguous areas with GPROF precipitation rate > 0.1mm/hr. The minimum 85/89 GHz PCT are calculated following Cecil and Chronis (2018) for each PF. The database are created for most satellite observations carrying 85/89 GHz passive microwave radiometers and open to public at http://atmos.tamucc.edu/trmm/data/.

Top 1% of Precipitation Features classified by for 85/89 GHz MINPCT

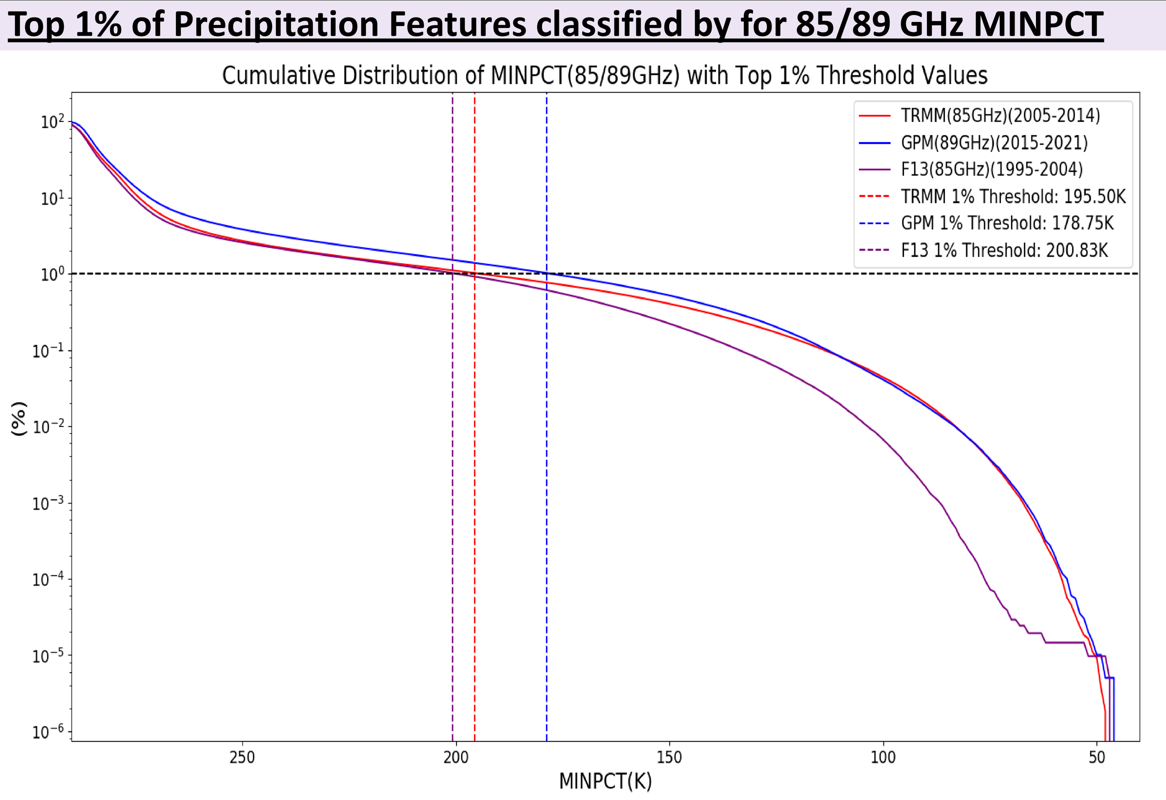

Figure 1. Cumulative distribution of the MINPCT of PFs in tropics from TRMM, GPM, and F13. The top 1 % values of each satellite are shown in dashed lines.

Table 1. The top 1 % values and samples of PFs from each satellite

Satellites	Count#	Threshold(K)
F13(85GHz)(1995-2004)	206843	200.83K
TRMM(85GHz)(2005-2014)	549095	195.50K
GPM(89GHz)(2015-2021)	199417	178.75K

Top 1% thresholds are derived by sorting the MINPCT85-89GHz dataset for PFs in between 20°N and 20°S. Then we find the index of 1% by multiplying the total counts with 0.01. These threshold values are used to select the most intense PFs in the following decadal variations analysis.

Geographical Distribution of top 1% PFs based on MINPCT(85GHz-89GHz)

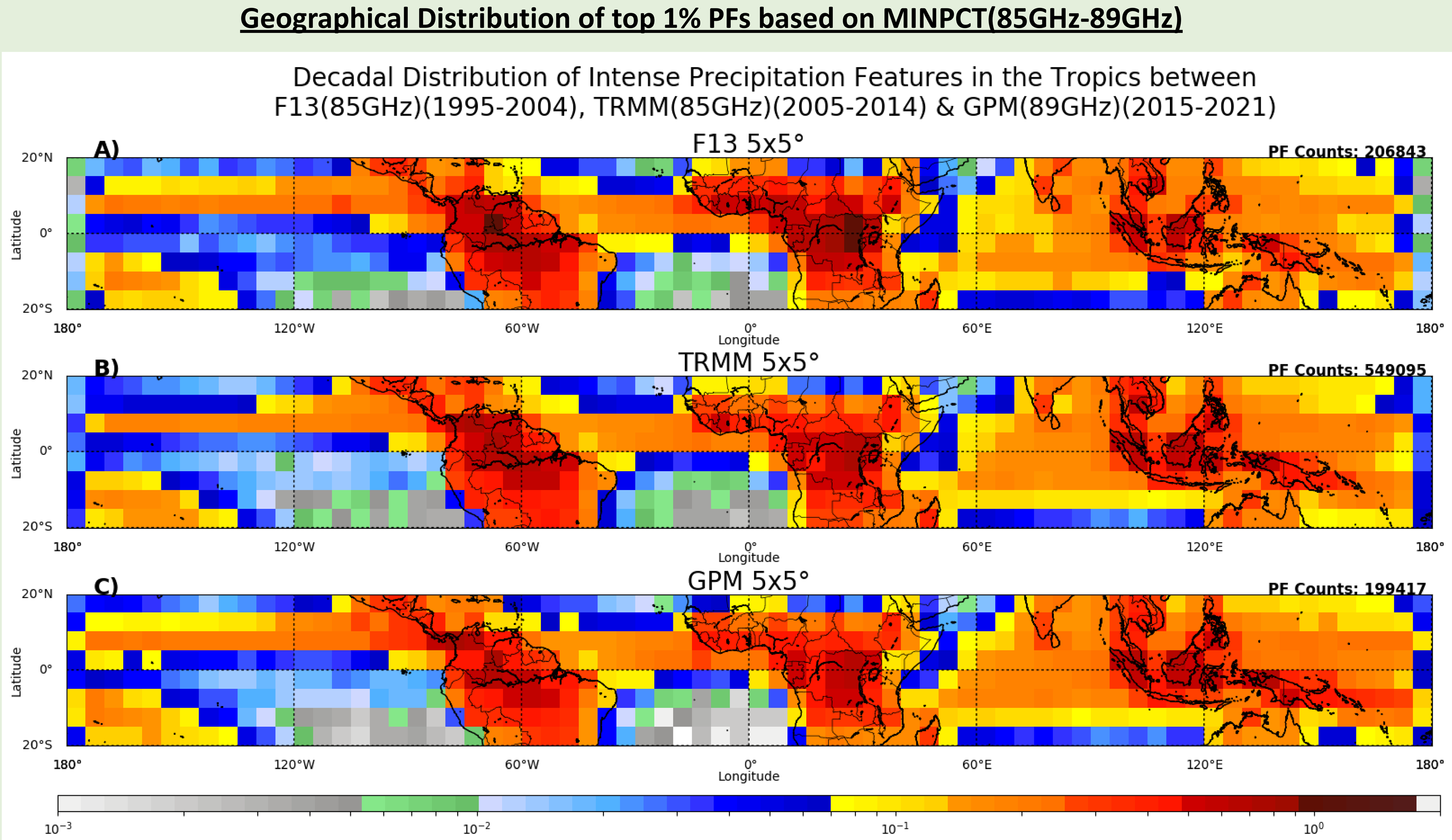

Figure 2. The geographical distributions of top 1% Intense Precipitation Features for F13, TRMM, and GPM. First, the counts of top 1% of PFs on 5°x5° grid are derived in 20°S-20°N. Then the distribution is divided by the total number of PFs in tropics to derive the percentage distribution of the top 1% of PFs. Note that the distribution is quite close to each other with subtle differences. These differences include both the sensor/sampling difference and the decadal variation of intense convection.

Decadal Variations of Intense Precipitation Features

(TRMM-F13)

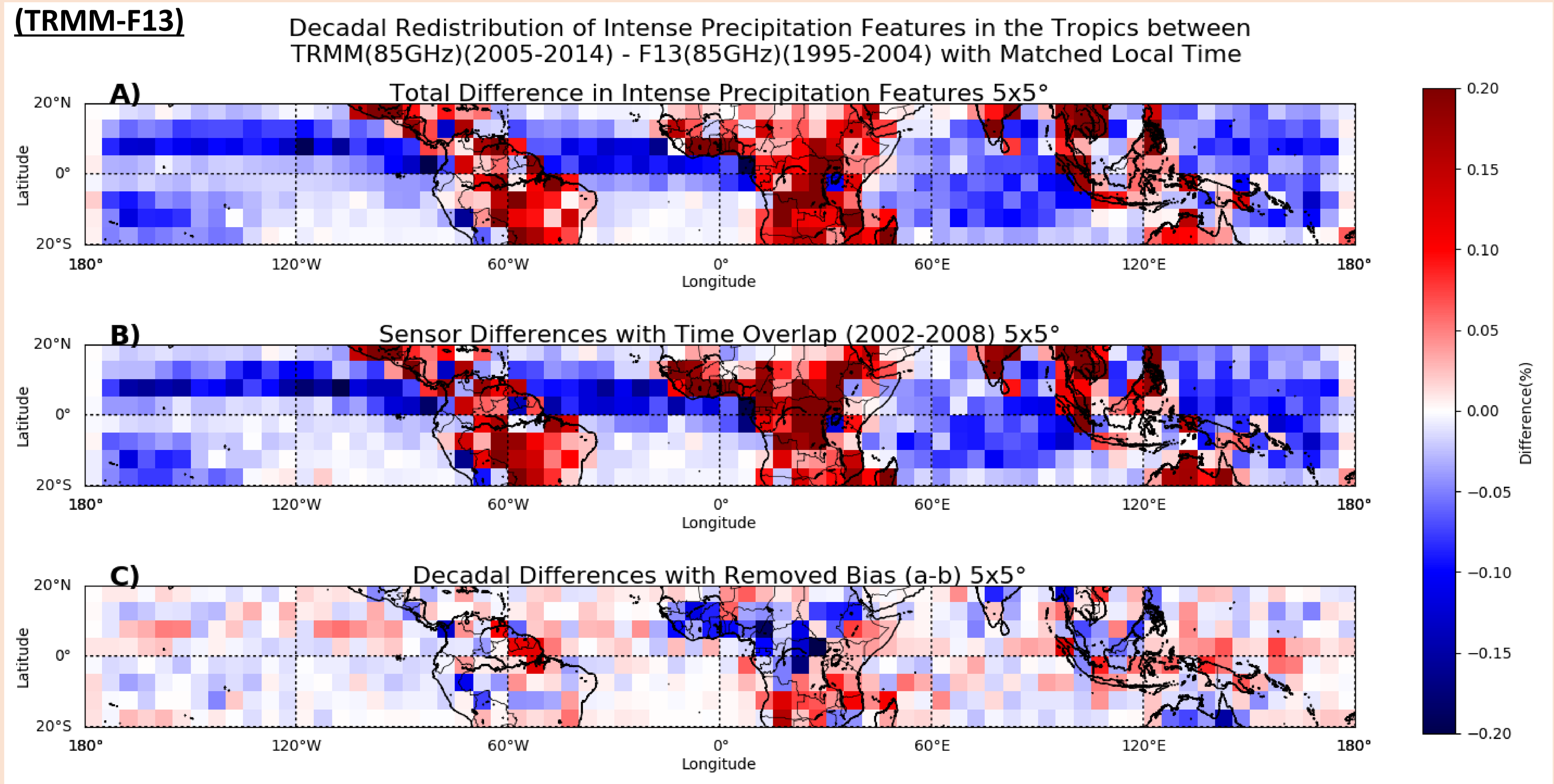

Figure 3. A) Decadal total difference in top 1% distributions of tropical intense PFs for TRMM (2005-2014) – F13(1995-2004). The distributions for both satellites are determined using the 85GHz passive microwave channel. **B)** The difference in the top 1% ratios of intense PF's between TRMM-F13 during the only overlap period of 2002-2008, which represents the sensor/sampling differences. **C)** The decadal difference of intense convection between TRMM and F13, that is derived by subtracting the sensor/sampling difference (Panel B) from total differences (Panel A)

(GPM-TRMM)

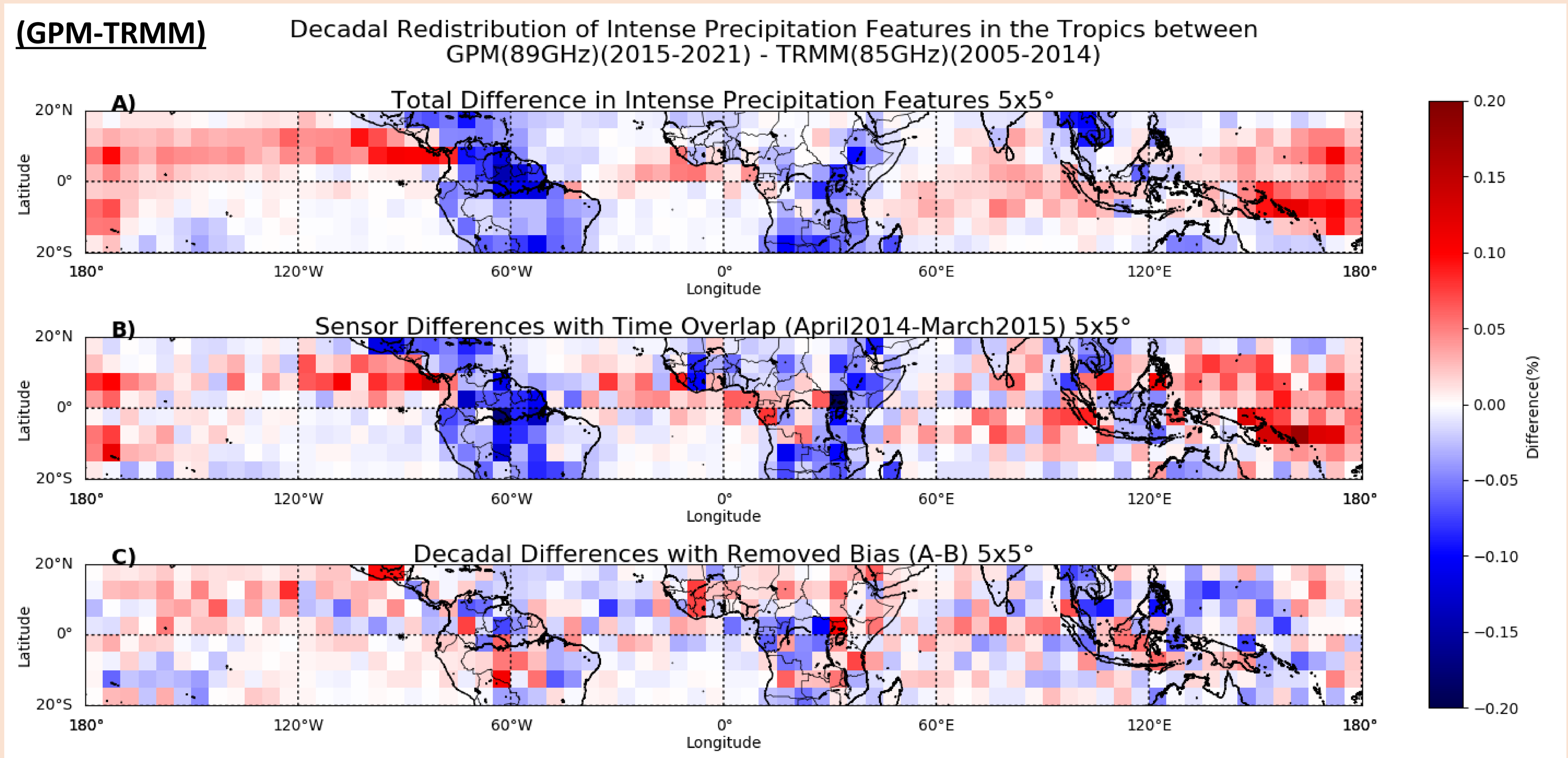

Figure 4. Same as Figure 3 but represented for GPM(2015-2021) – TRMM(2005-2014) with overlap in (2014-2015)

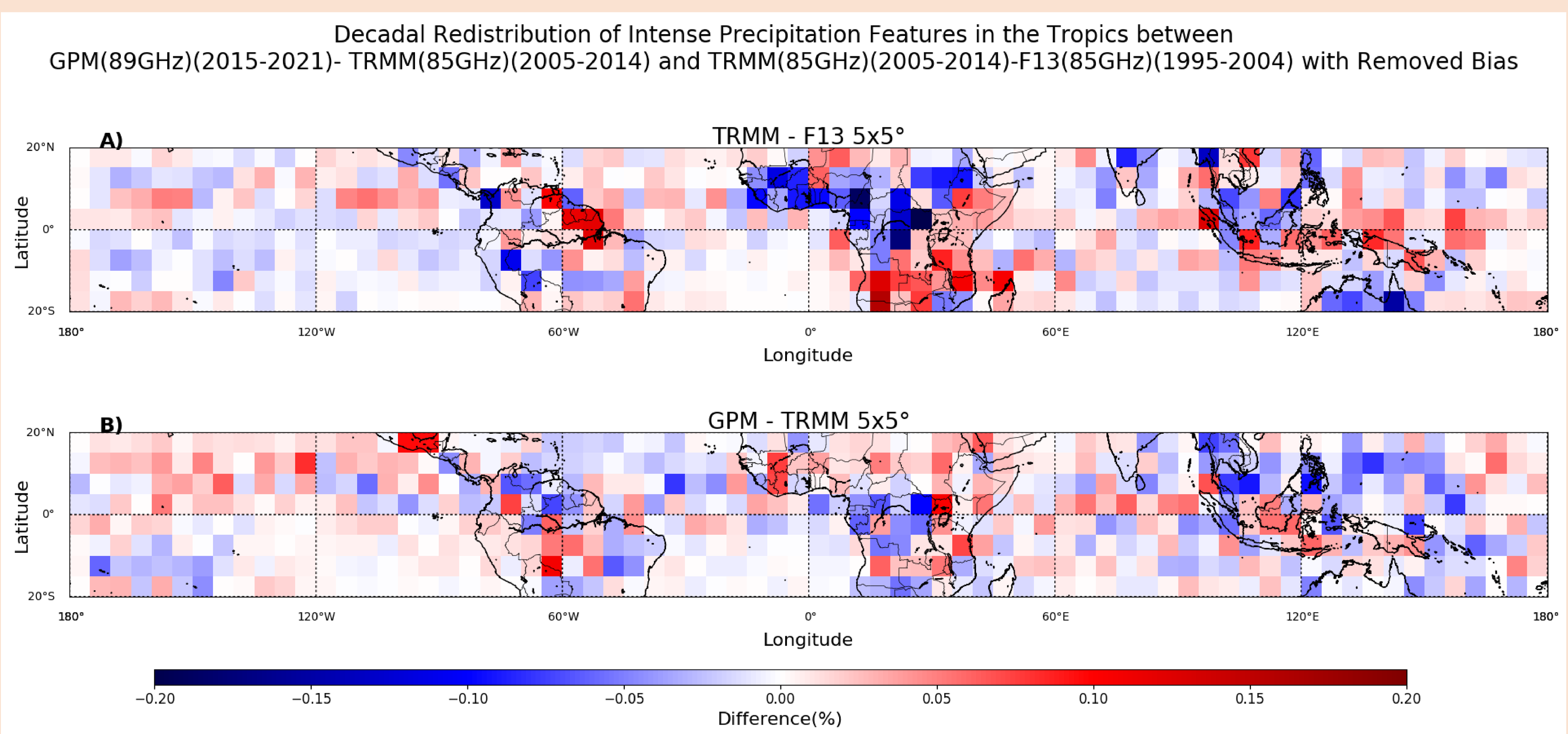

Figure 5. Comparison between Figure4C and Figure5C, which is the decadal differences in the top 1% of intense PFs after removing sensor/sampling biases. A) TRMM-F13; B) GPM-TRMM.

- Increase of intense PFs in south African and Sahel region, but a decrease in central Africa during past three decades.
- Increase of intense convection over the north of Pacific ITCZ in three decades. There is a decrease of intense convection over the south of the Pacific ITCZ in the first two decades.
- Increase of intense PFs in the maritime continent in general. However, there is also a shift from increase to decrease over west Pacific ocean north of Indonesia.
- Increase of intense PFs in central South America which is seen in Panel B in comparison to Panel A where there is a lower ratio of intense PFs

Note: Many of the differences shown here are probably related to the ENSO cycles. Further investigation is needed.

Summary

A decadal comparison is conducted using the top 1% MINPCT values of PFs for F13, TRMM, and GPM satellites. An overlap periods between satellite are used to reduce the sensor/sampling bias between satellites. Though significant regional changes are found in the past three decades, there is still a big challenge to separate the long-term decadal changes from the interannual variations.

Seasonal Variations Differences between TRMM-F13

Table 2. threshold 85 GHz MINPCT values of top 1% PFs from TRMM and F13 in difference seasons

Satellites	DJF	MAM	JJA	SON
F13(85GHz)(1995-2004)	207.33K	199.52K	204.31K	198.65K
TRMM(85GHz)(2005-2014)	171.86K	161.87K	170.95K	160.08K

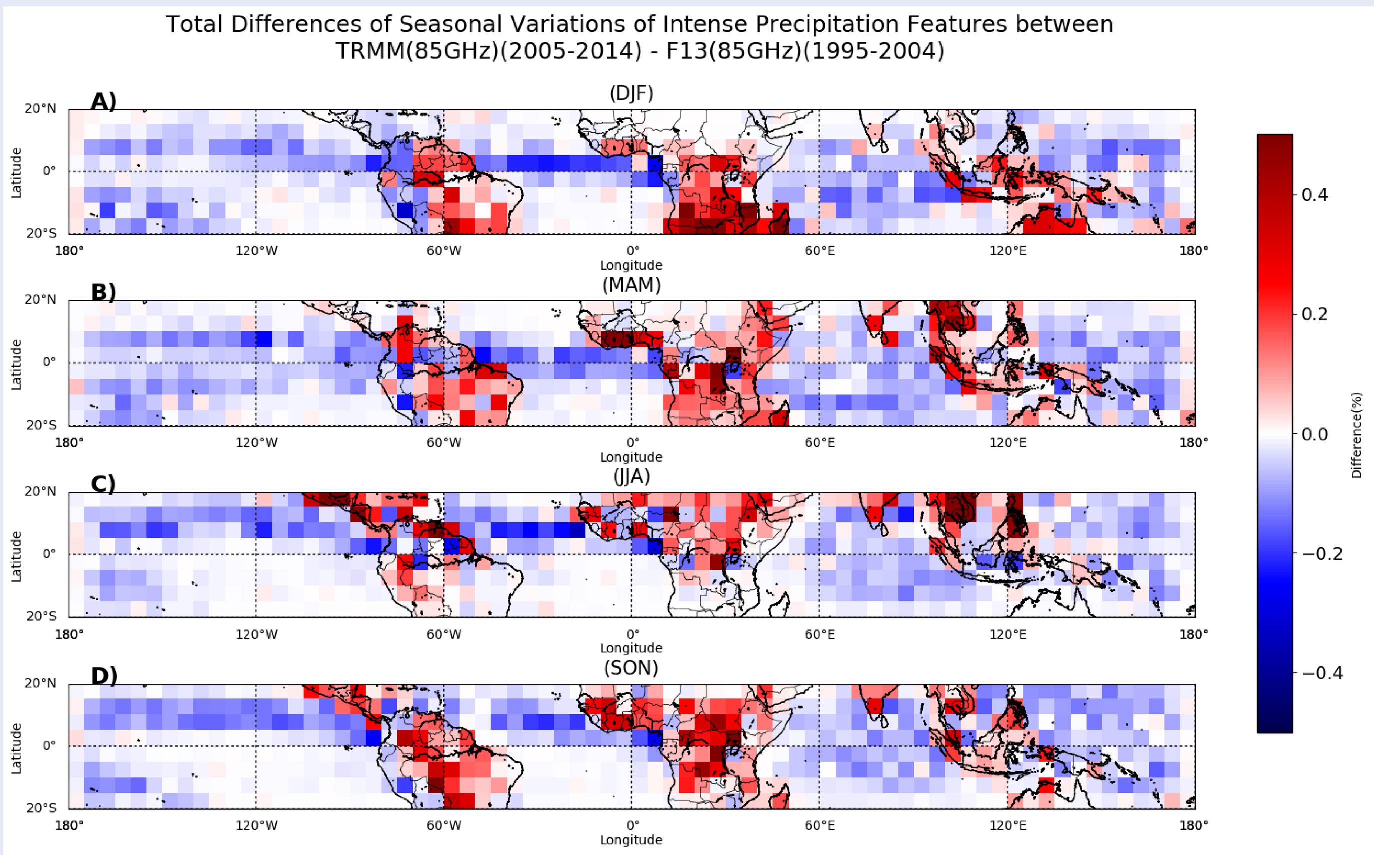

Figure 6. Total differences in the distribution of top 1% intense PFs between TRMM (2005-2014) and F13 (1995-2004) in DJF (A), MAM B(), JJA (C), and SON (D).

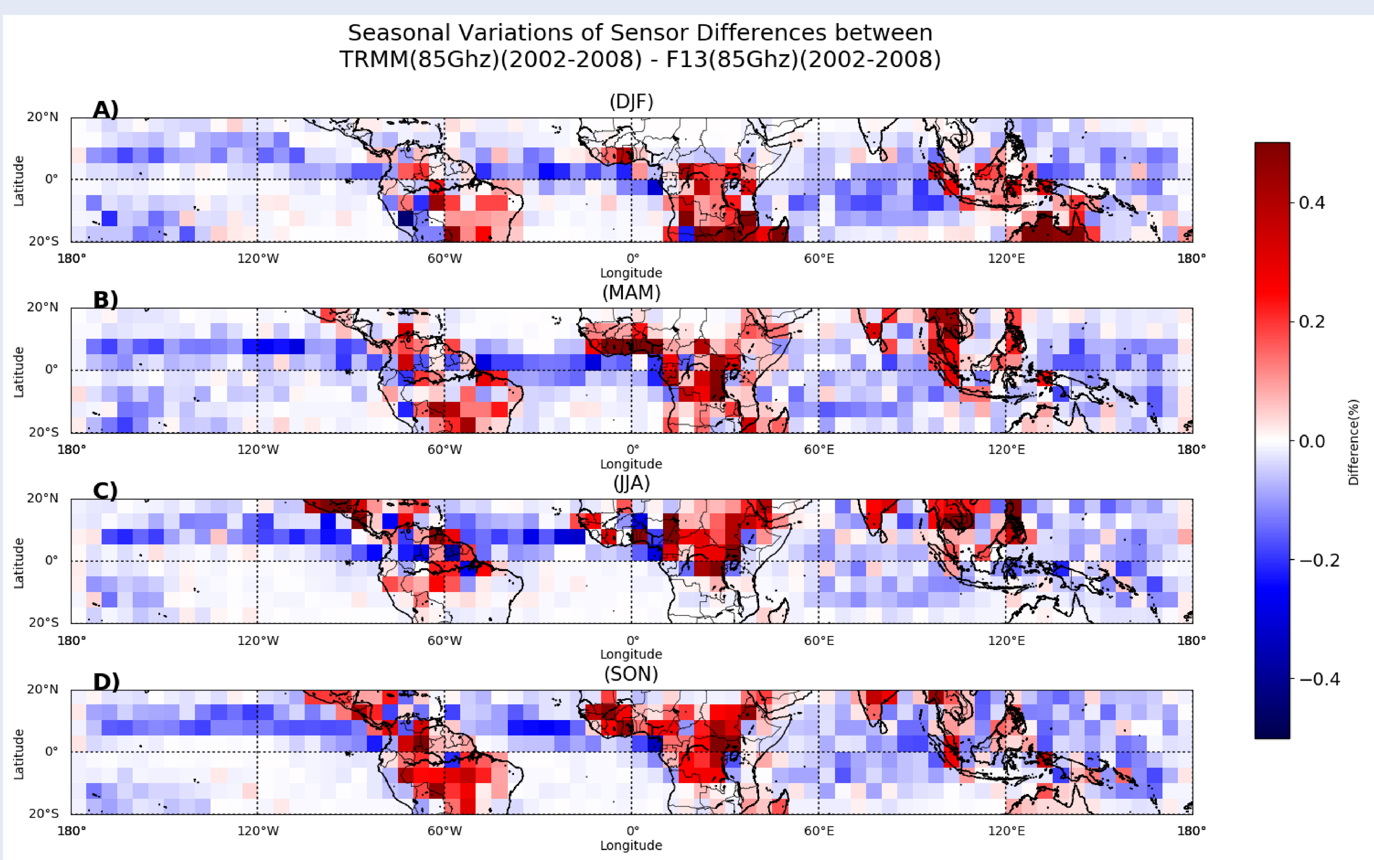

Figure 7. The sensor/sampling difference in distribution of top1% PFs during the overlapping period between TRMM-F13 (2002-2008) which starts at Jan(2002) to Nov(2008).

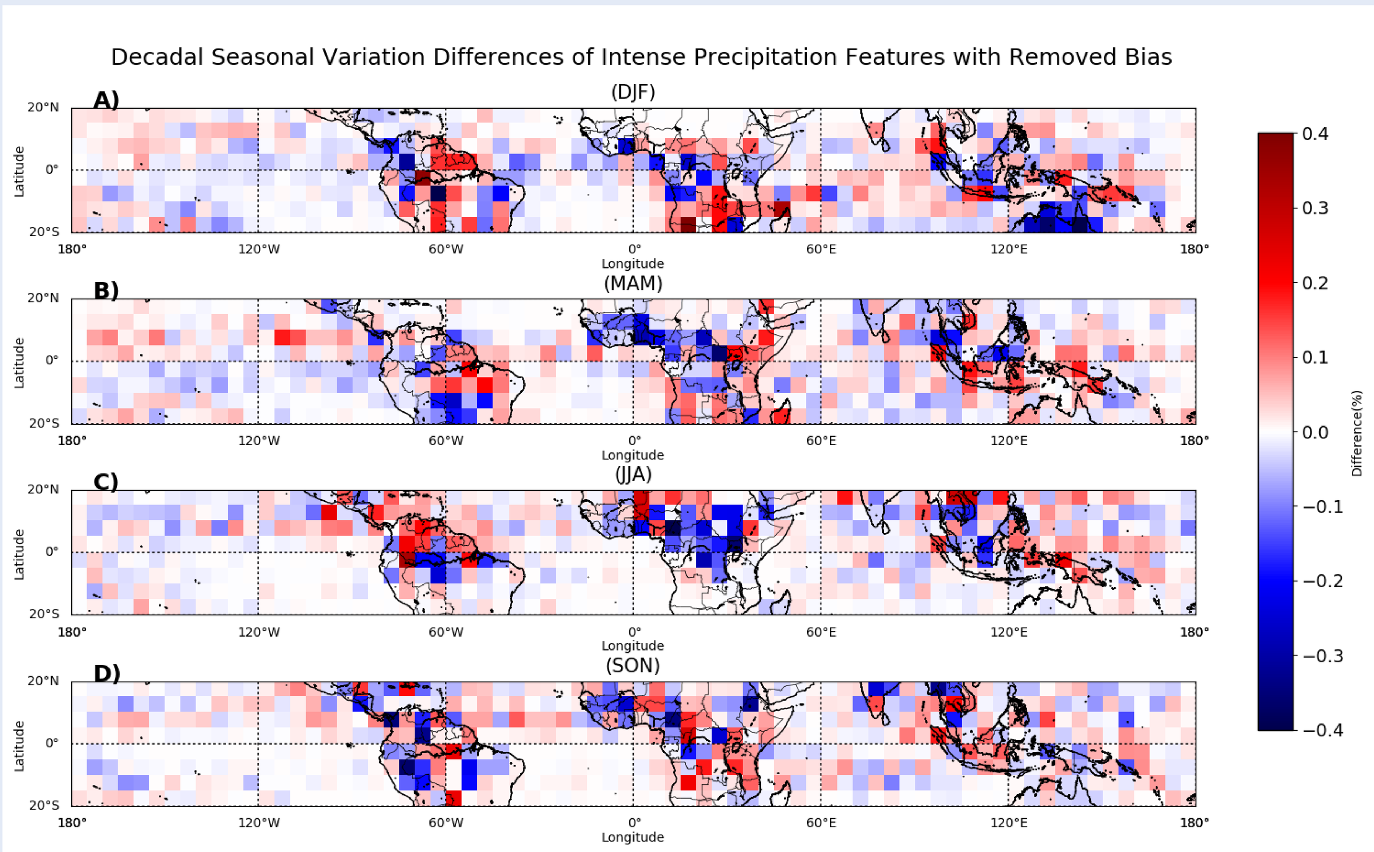

Figure 8. Decadal differences after removing the sensor/sampling difference from Figure 7 in four seasons, including (A) DJF, (B) MAM, (C) JJA, and (D) SON.

- Increases of Intense PFS in DJF in Central South America as well in MAM
- Decrease in central Africa present for JJA & MAM with increases in DJF & SON.

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