Improving microwave precipitation retrieval using total lightning data:

A look into GOES-R and GPM multi-sensor and multi-platform era

Rachel Albrecht[1,2], Kaushik Gopalan[2], Nai-Yu Wang[2], Eric Bruning[3,2], Steve Goodman[4,5], Ralph Ferraro[4]

[1] Instituto Nacional de Pesquisas Espaciais, Brazil
[2] University of Maryland, CICS
[3] Texas Tech University
[4] NOAA NESDIS
[5] NASA GSFC

Lightning and Passive Microwave

- **Blyth et al. (2001), Petersen et al. (2005) and Latham et al. (2007):**
  - ice-scattering is a prerequisite lightning
- **Nesbitt et al. (2001) and Blyth et al. (2001)**
  - thunderstorms with high lightning frequency have the most pronounced scattering signals, and there is a log-linear relationship between lightning optical groups and Tb 85 and 37 GHz.
- **Boccippio (2005) and Boccippio et al. (2005):**
  - trained a neural network of simultaneous Z(PR) profiles, TMI and LIS, and classified in Convective–C, Stratiform–S, and Mixed–M);
  - combined TMI and LIS to retrieve PR rain, improving in 10% the retrieval of convective precipitation.
  - combination of IWP (retrieved from TMI) and lightning occurrence within 15 km from the center of the column cloud separated the “ambiguous” midlevel convective/stratiform cluster pairs in their lightning probabilities.

Boccippio et al. (2005)

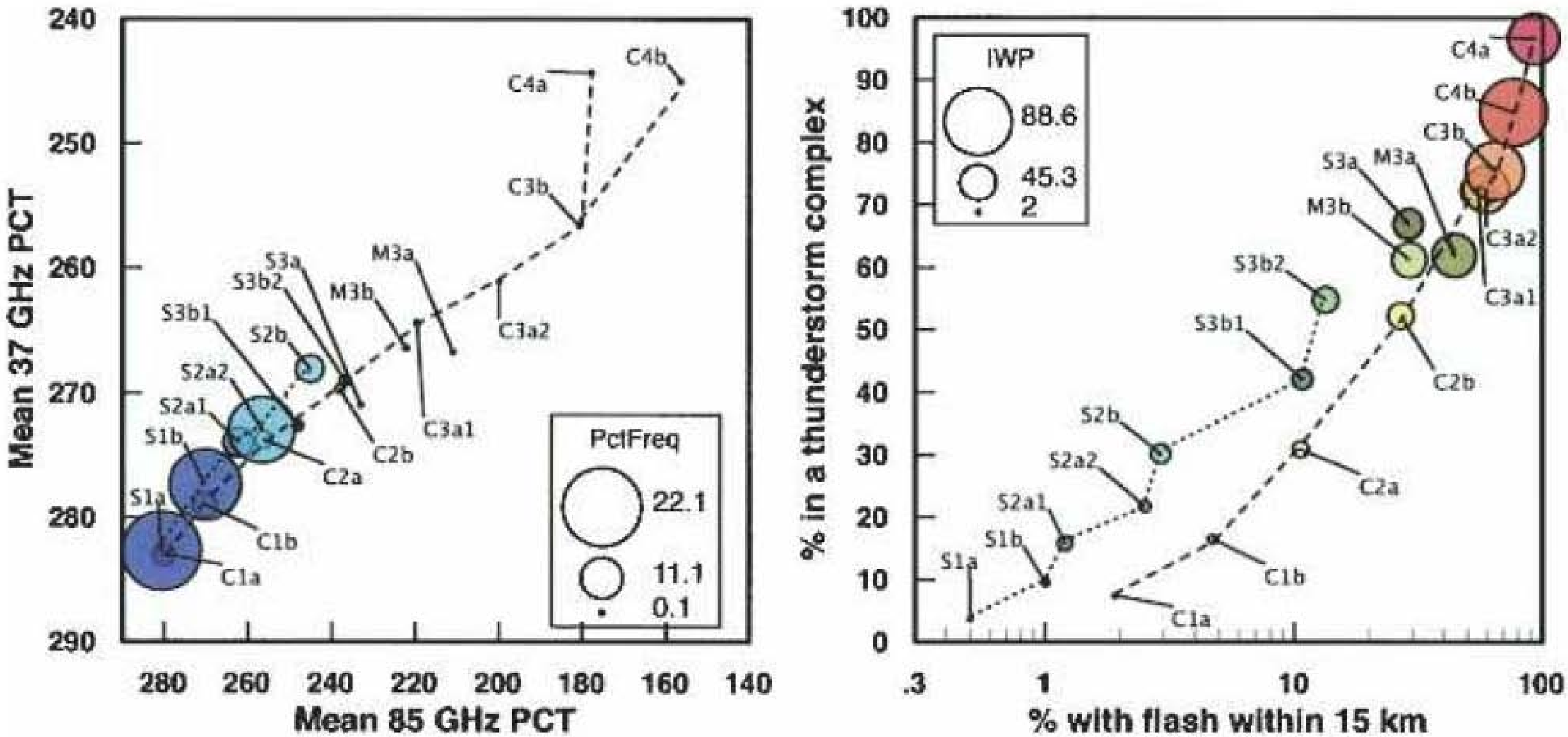
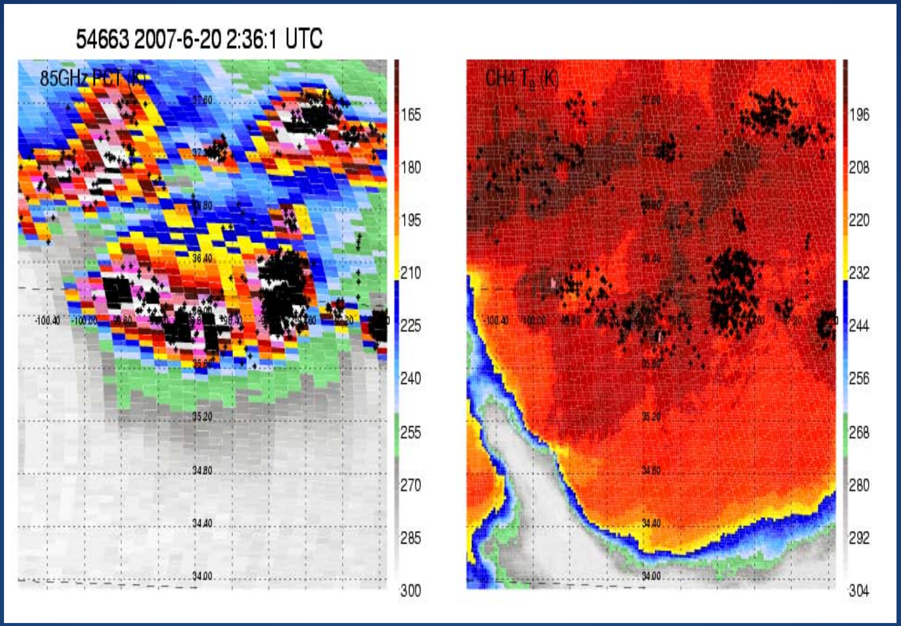


FIG. 15. High-frequency passive microwave and lightning characteristics of the profile clusters. (a) Mean 37- and 85-GHz PCT (bubble size denotes profile frequency in the entire dataset), illustrating significant convective/stratiform ambiguity for important midlevel profiles. (b) Probability that a profile of each type has an LIS-observed lightning flash centroid within 15 km and probability that a profile of each type occurs anywhere in a thunderstorm complex (1Z99 precipitation feature containing lightning). Bubble size denotes IWP, proxied by the 37–85-GHz PCT difference.

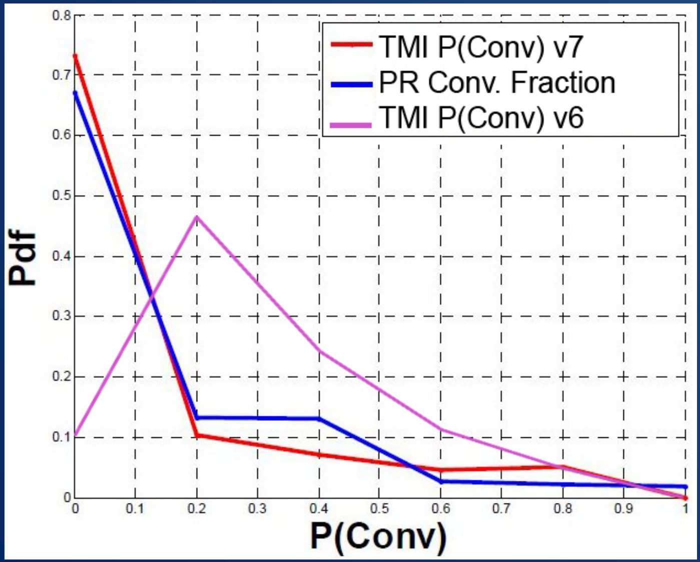
- **There is a physical relationship between lightning and MW:**
  - Both are reflection of ice signatures

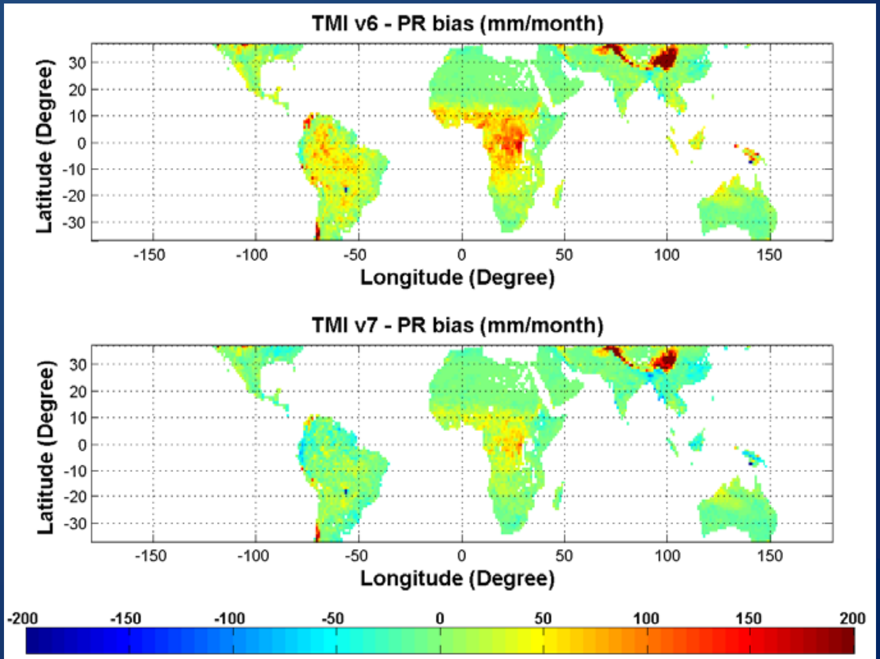


- **Rain rate estimation using Infrared (IR) channels and cloud-to-ground (CG) lightning:**
  - Grecu et al. (2000) showed a reduction of about **15%** in the root-mean-square error of the estimates of rain volumes from IR data defined by convective areas associated by lightning.
  - Morales and Anagnostou (2003) showed that the incorporation of CGs in the rainfall type segregation **~8%** the rain accumulation and 31% in the rain area when estimating rain rates from IR.
  - Chronis et al. (2004) found a **93%** reduction in the root mean square error (RMS) for rain rates at 1^{o} horizontal resolution and **78%** at 5^{o}.

TMI version 7 rain rate algorithm 2A12 (Gopalan et al., 2010)

- **Heuristic method that artificially removed pixels with high disagreement between RR_{TMIv6} and RR_{PR}:**
  - 1) Re move RRTMIv6 >1.50 RR_{PR} from the convective training ($P(C)_{PR}$>= 0.75)
  - 2) Remove RR_{TMIv6} <0.50 RRPR from the stratiform training ($P(C)_{PR}$= 0)
  - 3) Adjust a curve to RR_{PR} and T85V for convective and stratiform RR
  - 4) Find a $P(C)_{v7}$ probability of distribution that matches the PR convective fraction (CF).





- However, the TMI P(Conv) version 7 (Gopalan et al., 2010) is purely heuristic.

- Therefore, our **objective** is to take advantage of this physical relationship between MW and lightning to improve the partition between Convective and Stratiform precipitation:
  - Insert lightning parameters measured by TRMM LIS into TMI convective portion equation following **McCollum and Ferraro (2003)**:

$$\text{CPI} = 1.24(\text{STDEV}) + 1.11(\text{T10V}) + 0.22(\text{NPOL}) + 0.14(\text{PIWD}) - 1.25(\text{POL}) - 1.24(\text{T37V}) + 0.45(\text{T85V}) - 84.3.$$

GOES-R and GPM

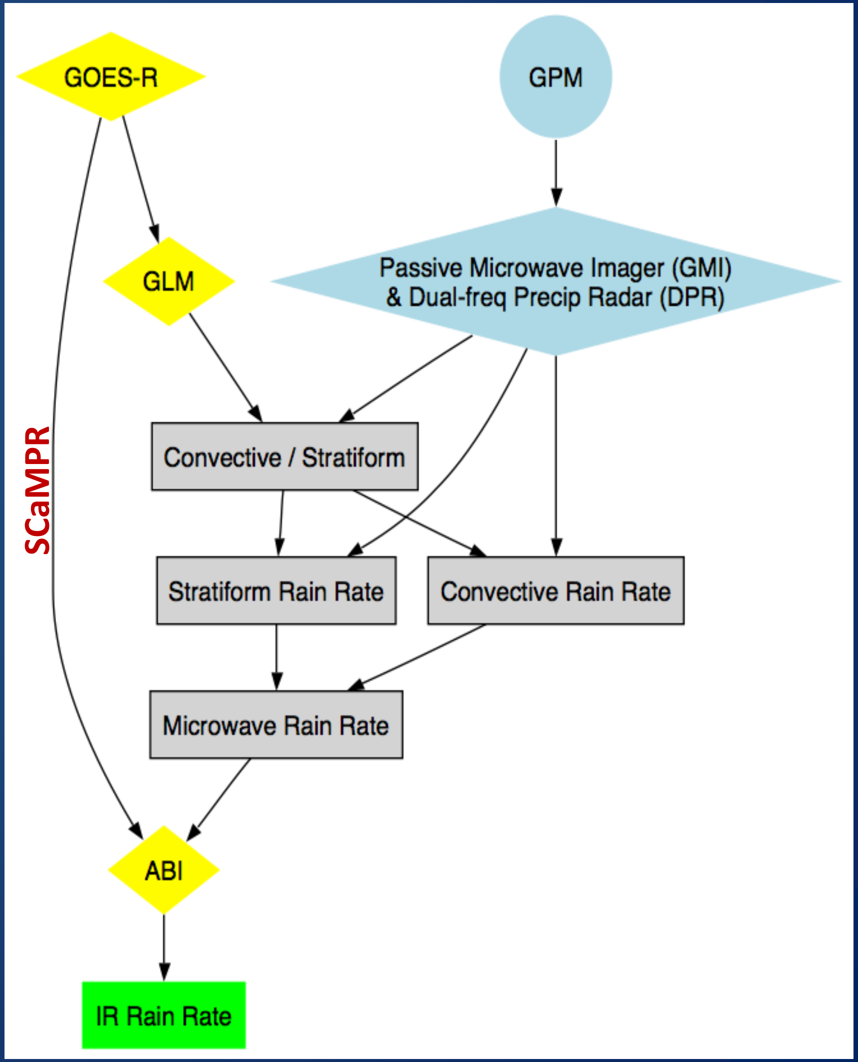
- **GOES-R rain rate algorithm is Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) (Kuligowski, 2002)**
  - an effort to combine the relative strengths of infrared (IR)- based and microwave (MW)-based estimates of precipitation.
  - uses GOES IR data as a source of predictor information and calibrates them against MW-based rain rates

- **SCaMPR will be calibrated against GMI, and total lightning measurements will be made by GOES-R Geostationary Lightning Mapper (GLM).**

- **Moreover, NOAA new focus is on multi-sensor and multi-platform algorithms (sensors and platforms complete each other)**

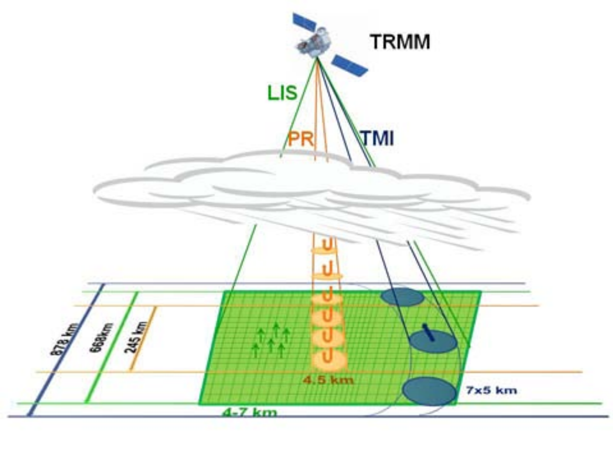
- **We propose to use total lightning to help Passive Microwave on Convective/Stratiform partition:**
  - GMI proxy data → TRMM Microwave Imager (TMI)
  - GLM proxy data → TRMM Lightning Imaging Sensor (LIS)

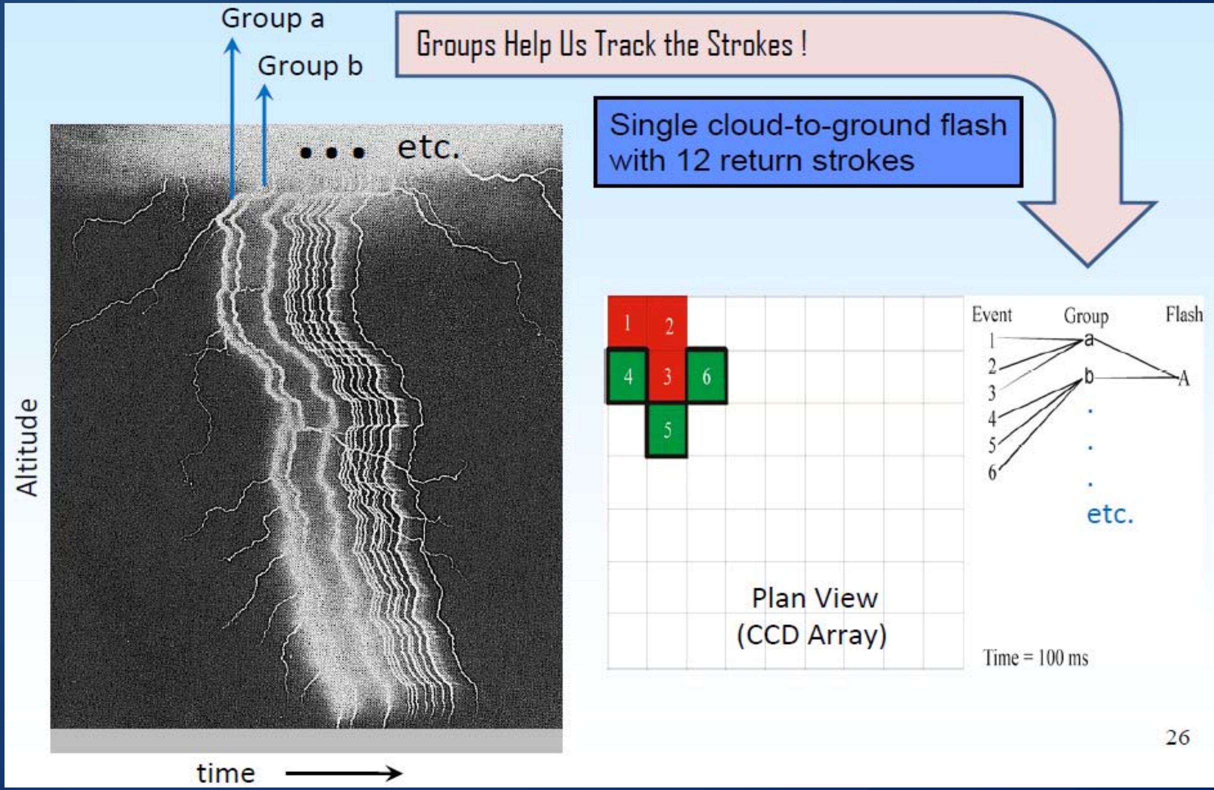
- **Improving MW rain rate we improve SCaMPR calibration.**



Data
(proxies TMI and LIS)

- University of Utah Precipitation Feature database (**http://trmm.chpc.utah.edu/**) (Liu et al., 2008) collocated with several LIS (**http://thunder.msfc.nasa.gov/)** parameters:
  - » flashes
  - » groups
  - » events

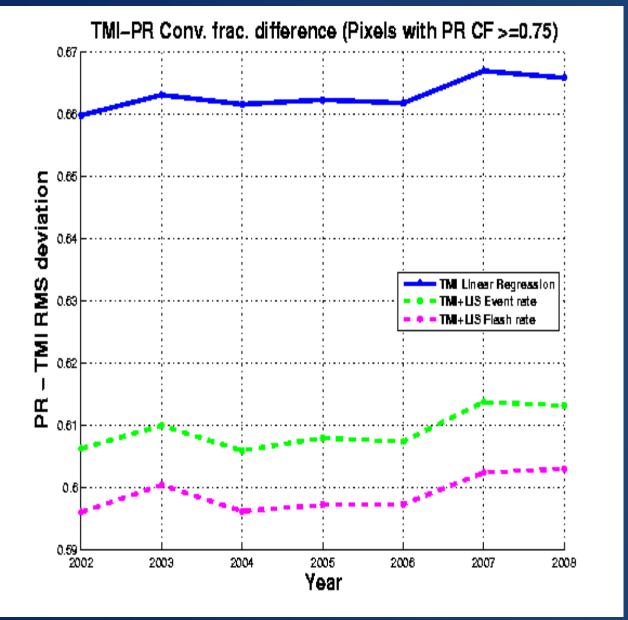




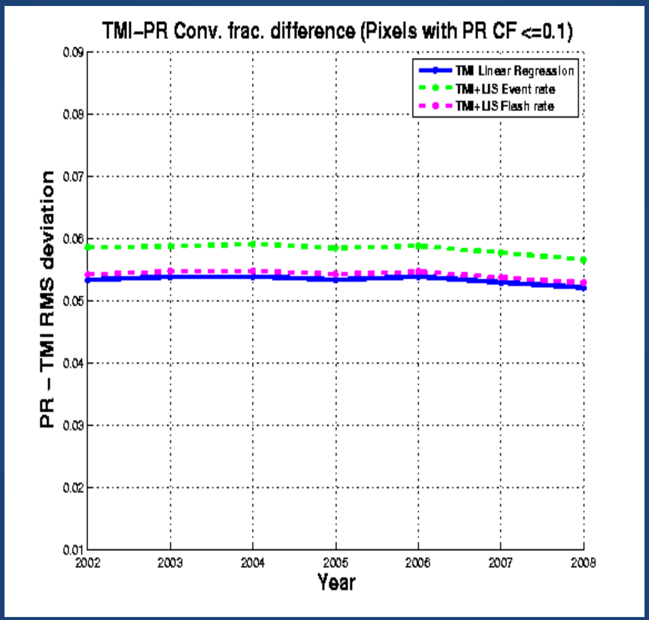
Preliminary results

TMI CPI = A (STDEV) + B (T10V) + C (NPOL) + D (PIWD) + E (POL) + F (T37V) + G (T85V) + H (LIGHTNING PARAMETERS) + I

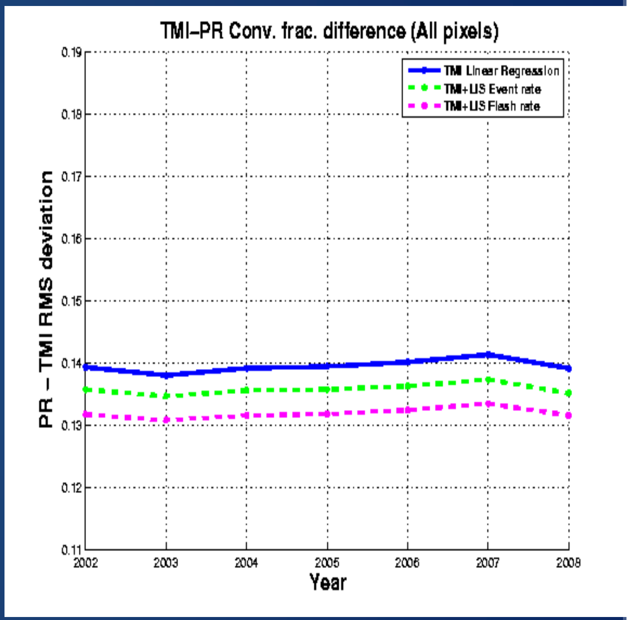
Convective



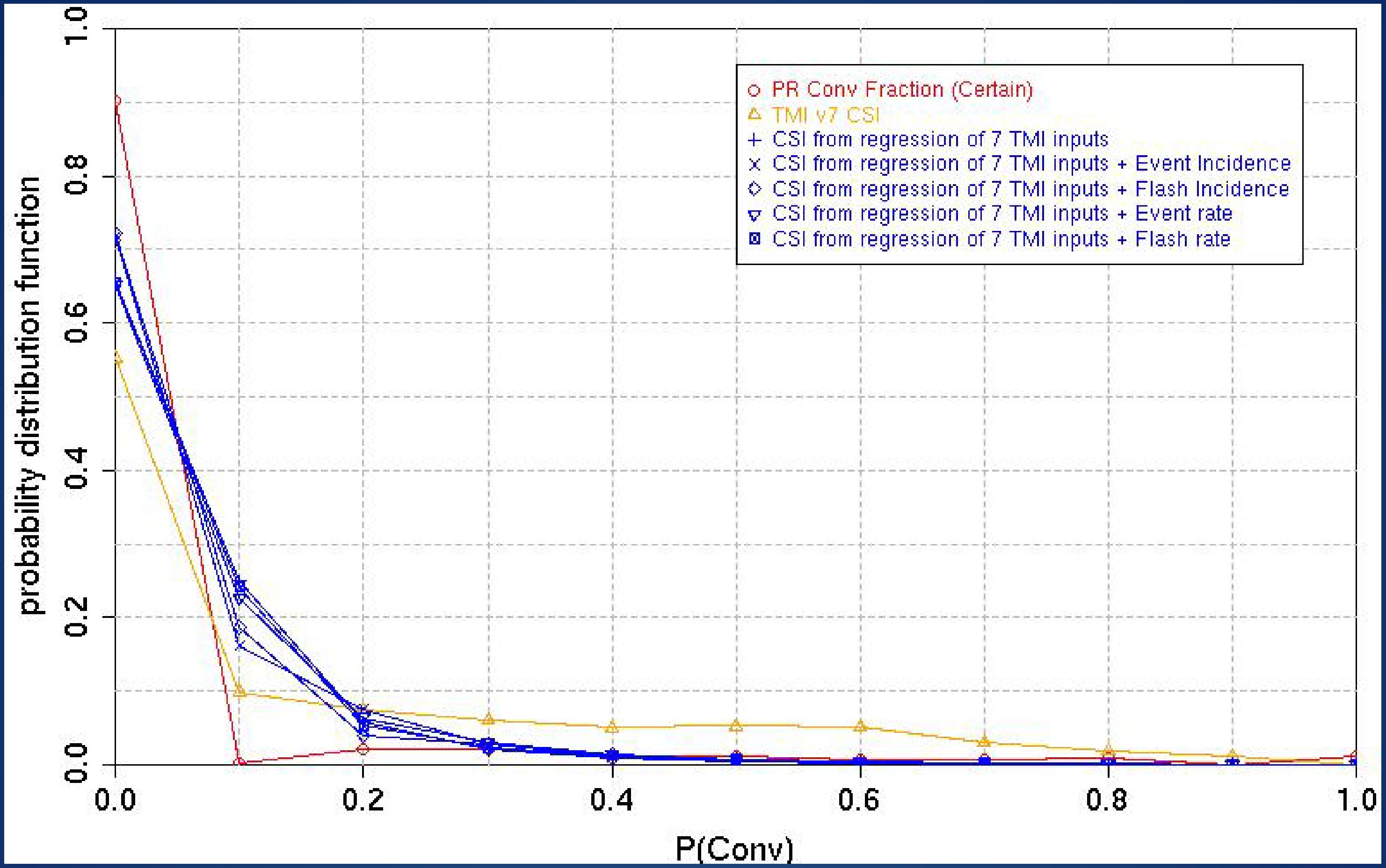
Stratiform



All



- Clearly the presence of lightning is prominent in convective rain:
  - 10% RMS error improvement in microwave convective rain identification when using lightning data
- Virtually no improvement from lightning in C/S in startiform rain
- Overall (all rain) 5% error reduction in microwave C/S identification with lightning data



- All lightning parameters improve P(Conv) for P(Conv) >= 0.3 (Convective) and P(Conv)=0 (purely Stratiform) compared to TMI v7.

- But it worsen P(Conv) for 0.3 < P(Conv) < 0 compared to TMI v7.

Conclusions

- Preliminary analysis indicated that lighting data can help microwave convective/stratiform partition, especially over convective rain regime (10% convective, 5% overall)

- As expected, the method did not work well over the stratiform region. Work in progress to identify stratiform features in the some lightning derived parameters, for example, lightning "centroid" and "extent" density, flashes within 15 km, etc.:
  - Lightning "centroid" and "extent" are related to the ice-phase microphysical precursors to lightning, and may therefore have explanatory power in precipitation estimation settings.
  - Flash initiation rate ("centroid") is related to the recharging rate of a local electric field. This happens most readily where active inter-hydrometeor charge separation is taking place, i.e., in deep convective cores where updrafts are providing abundant supercooled water and hydrometeor growth.
  - The "extent" of flash propagation indicates the extent of charged regions defined primarily by advective processes that redistribute the charged precipitation formed in the storm updraft.