Lightning enriched global precipitation feature database

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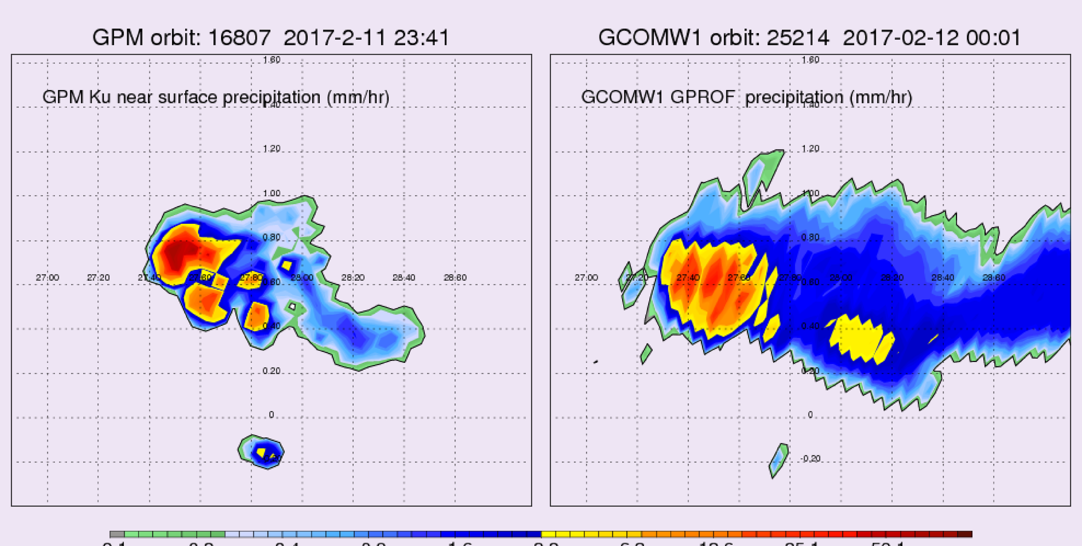
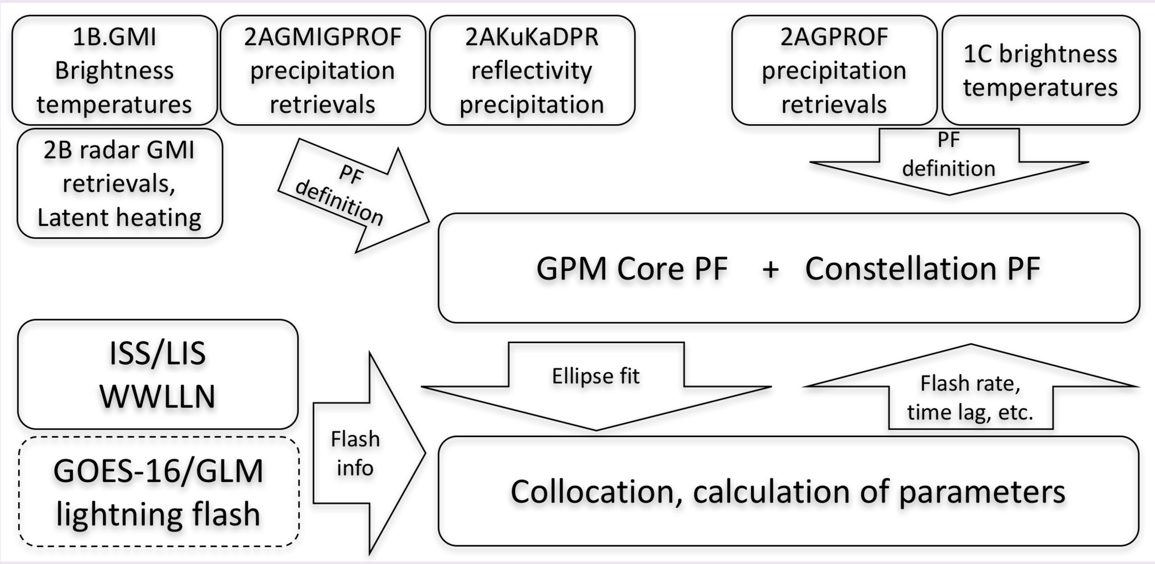
Objectives:

The Tropical Rainfall Measurement Mission (TRMM) has provided a wealth of insight about lightning and precipitation in the tropics. However TRMM did not provide coverage outside the tropics and sub-tropics (i.e., beyond ±38° latitude), and hence it was unable to sample the lightning activity and precipitation features over a large fraction of mid-latitude continents and oceans, including extratropical cyclone storm tracks. The Global Precipitation Measurement (GPM) mission picks up where TRMM left off in that it provides information on precipitation features in the mid- and high latitudes (up to 65°N/S). However, GPM lacks a lightning instrument that can provide additional insights into mid-latitude thunderstorm activity and distribution. Hence we integrate observations from coincident the ISS Lightning Imaging Sensor (LIS) and the World Wide Lightning Location Network (WWLLN) observations with measurements from the GPM constellation of satellites, in particular to extend the existing GPM Precipitation Feature (PF) database so its data parameters are similar to that of the TRMM PF database (i.e., precipitation + lighting). Currently, WWLLN and ISS-LIS lightning have been collocated into precipitation features defined from GPM core satellite and constellation satellites observations.

GPM and Constellation Precipitation Features (PFs):



Examples of Precipitation Features (PFs). Left panel shows PFs defined by grouping the near surface precipitation area detected by GPM Ku precipitation radar; Right panel shows same systems observed by GCOMW1 passive microwave radiometers 20 minutes later. The PFs are grouped by contiguous surface precipitation area based on GPROF retrieval product.

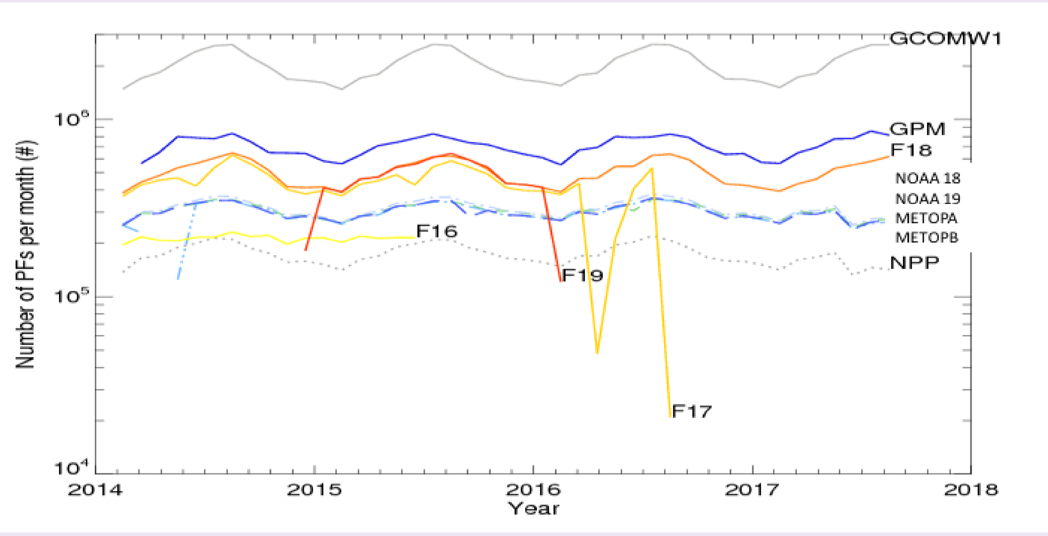


- Schematic diagram of constructing precipitation feature (PF) database using products from GPM core and constellation satellites, and collocation of lightning datasets from the ISS-LIS, the WWLLN, and the GOES-16/GLM.

Passive microwave radiometers on constellation satellites

Satellite	Sensor	Swath (km)	Center Channel Frequency in GHz (Resolution in km)
GPM	GMI	850	10.65 (26), 18.7 (15), 23.8 (12), 36.5 (11), 89.0 (6), 165.5 (6), 183.31±[3,7] (6)
F16 / *F18*	SSMIS	1700	19.35 (45x74), 22.235 (45x74), 37.0 (28x45), 91.665 (13x16), 150 (13x16), 183.311±[1,3,7] (13x16)
GCOMW1	AMSR2	1450	6.925/7.3 (10), 10.65 (10), 18.7 (10), 23.8 (10), 36.5 (10), 89.0 (5)
METOPA / *METOPB* / *NOAA18* / *NOAA19*	MHS	2180	89 (16), 157 (16), 183.311±[1, 3] (16), 190.31 (16)
MT1	SAPHIR	1700	183.31± [0.2, 1.1, 2.7, 4.0, 6.6, 11] (10)
SNPP	ATMS	2200	23.8 (75), 31.4 (75), 50.3 (32), 51.76 (32), 52.8 (32), 53.596±0.115 (32), 54.4 (32), 54.94 (32), 55.5 (32), 57.290344 (32), 88.2 (32), 165.5 (16), 183.31±[1, 1.8, 3, 4.5, 7] (16)

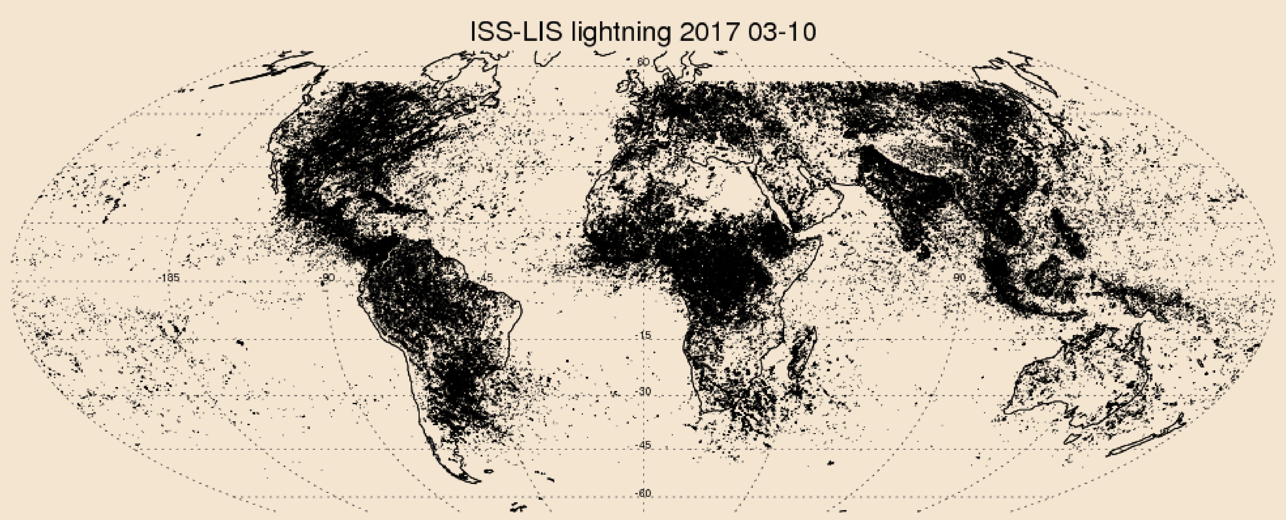
Number of PFs per month from different satellites



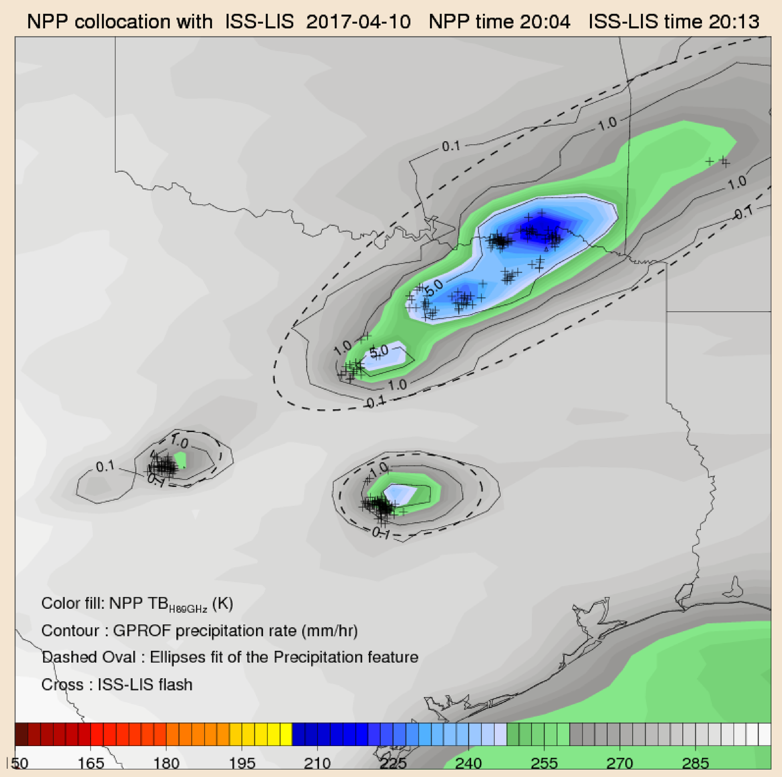
From 2014-03 to 2017-08

	Samples	Total size of data
GPM Pixel level data	~18920 orbits	1,800 GB
Precipitation Feature (GPM Ku Radar)	~ 23 million PFs	75 GB
Precipitation Feature (constellation satellites)	~220 million PFs	11 GB

ISS-LIS and collocation to PFs

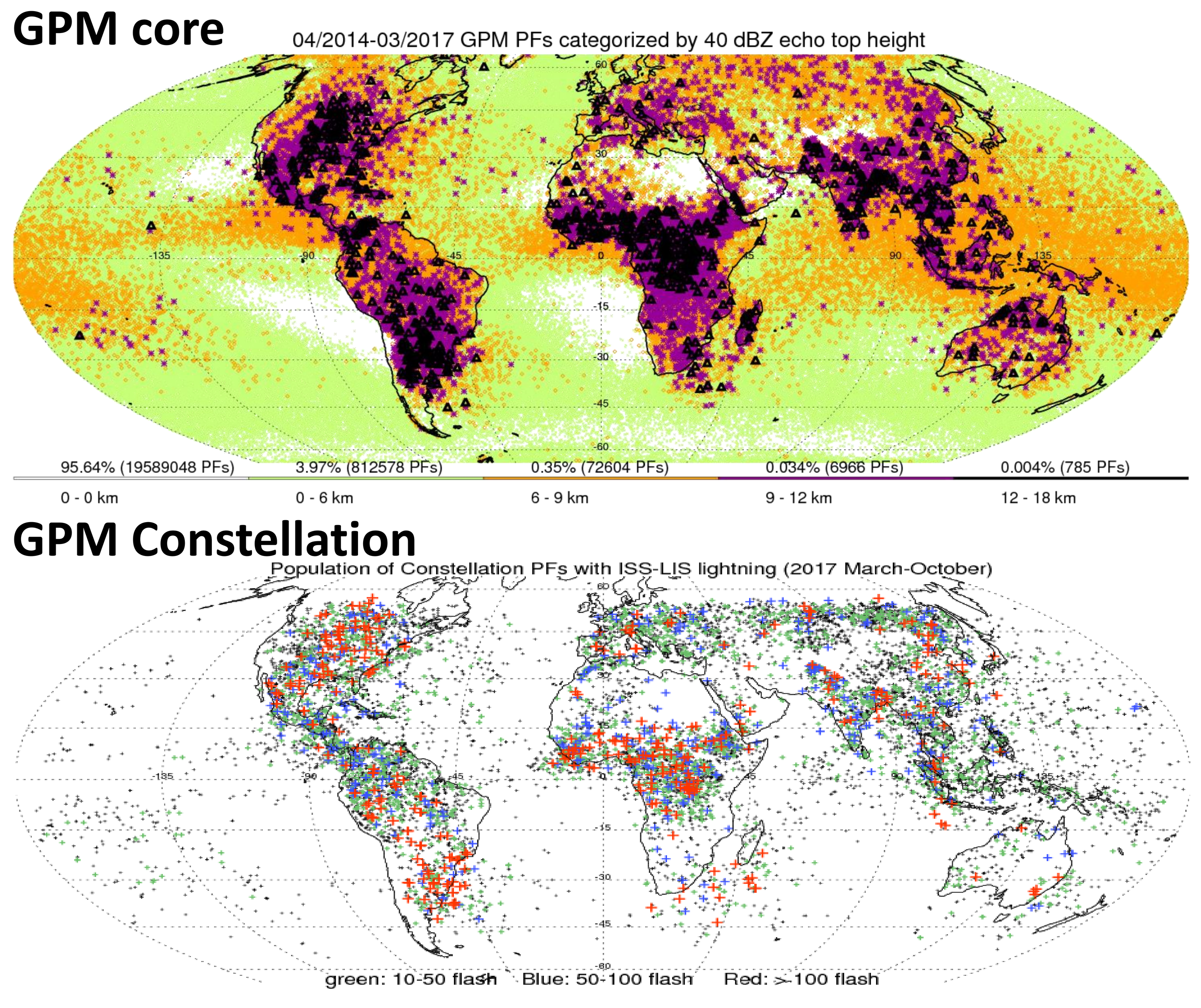


- Launched on February 19, 2017, the Lightning Imaging Sensor (LIS) instrument onboard International Space Station (ISS) is an instrument similar to the TRMM LIS.
- Benefiting from ISS's 54° inclination orbit, the ISS-LIS provides a wider global coverage than the TRMM LIS and continues the long term optical observation of lightning since 1990s.
- ISS-LIS has observed 622,912 lightning flashes between March and October, 2017.
- It confirms the previous knowledge of dominant lightning activity over land and known hotspots of lightning (e.g., central Africa, Himalayan region, South America)



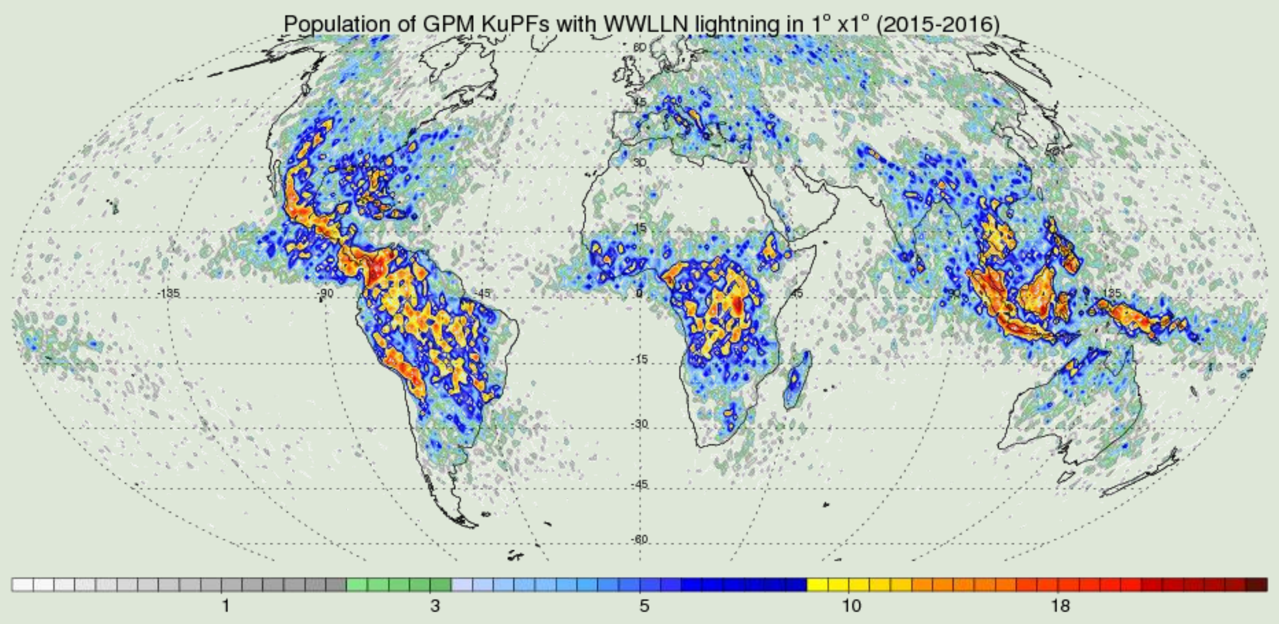
- Due to different orbits, it is difficult to make exact pixel by pixel collocations between ISS-LIS lightning and precipitation observed by GPM constellation satellites. Therefore, a feature level collocation algorithm is designed:
  1. An ellipse is fitted to each PF based on the area of precipitation.
  2. ISS-LIS lightning flashes are searched within the ellipse for a given time period relative to the PF snapshots
- Left: An example of collocation between ISS-LIS lightning flashes and NPP observed 89 GHz brightness temperature and derived surface precipitation with about 9 minute time lag

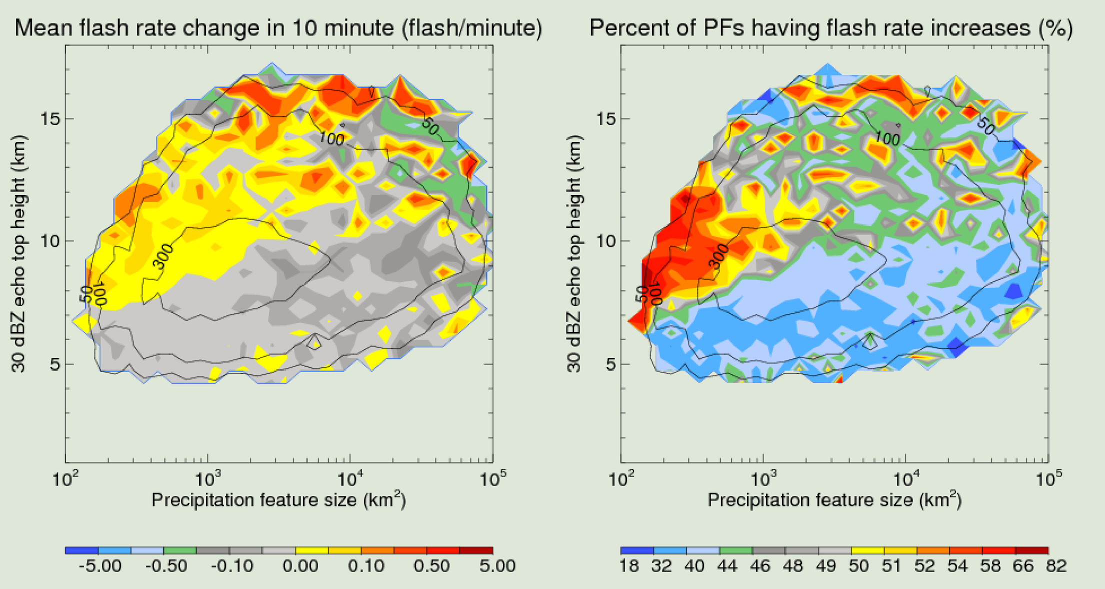
PFs + ISS-LIS:



- Using three year observations from GPM core satellites, the global distribution of intense convective storms can be shown with PFs having 40 dBZ Ku radar echo reaching high altitudes. As shown in top left panel, the PFs are categorized by their rarity based on the maximum height of 40 dBZ radar echo. The strongest storms are over Africa, Argentina, Central plain of North America, Bangladesh, Kashmir, South Europe etc. Many of these are associated with hail and high lightning rates.
- Using one hour window (+- 30 minutes) within PF ellipse, ISS-LIS data are collocated to constellation PFs. During first 8 months (March-Oct 2017), there are total 41.8 million PFs defined with passive microwave observations from multiple constellation satellites. Only 11,776 were found having an ISS-LIS flash within the PF ellipse and one hour time window. *This leads to 0.028% collocation rate, which is much lower than ~1% based on TRMM PF+LIS collocations.* This low collocation rate is mainly due to the different orbits between ISS and constellation satellites.
- There are cases having partial overlaps between the constellation satellite swath and ISS-LIS swath. These cases have been recorded as LIS sample area in each PFs. The left panel shows all collocations, including those partially collocated ones.
- Though with low collocation rate, the global thunderstorm distributions still show a consistent distribution with past studies of more intense thunderstorms over land than over ocean, and those known hotspots within Africa, South America and Himalayan regions.
- This collocated dataset will serve as a foundation for understanding the global thunderstorm properties, especially for those in mid-high latitudes.

PFs + WWLLN:





- Collocation between PFs and WWLLN (and GOES-16/GLM) is quite different from ISS-LIS and PFs because WWLLN (GOES-16/GLM) has continuous observations. Therefore, the time window of collocation can be much smaller, such as 5-10 minute compared to 30 minutes for ISS-LIS.
- Using 10 minute (5 minute before and after) time window, thunderstorms can be identified by PFs with WWLLN lightning within an ellipse as shown in the panel above.
- Because spatial variation of WWLLN detection efficiency due to the density/locations of ground stations, we have to be cautious using this dataset to interpret the geographical distribution of thunderstorms.
- Because the information of lightning rates before and after PF snapshots can be obtained by continuous observations of WWLLN (or GLM), we could examine the relationships between development of the thunderstorms and their instantaneous properties.
- The panel above shows that *small PFs with high reflectivity at high altitudes tend to have more increases of lightning flash rate in next five minute than those PFs with larger sizes*. This is consistent with the charge separation due to large ice particles in the early stage of convective systems.

Summary:

- We have significantly extended the TRMM and GPM Precipitation Feature database by inclusion of the passive microwave observations made with the other members of the GPM Constellation.
- We developed an algorithm to associate lighting observations from the ISS-LIS as well as from a stationary platform (e.g. WWLLN or GOES-GLM) to the properties of precipitation systems identified by passive microwave observations.
- The new lighting-enriched PF database builds upon the knowledge attained with TRMM to further facilitate our investigations of thunderstorms in the mid-latitudes.
- The constellation PFs and ISS-LIS collocated PFs are available online at: http://atmos.tamucc.edu/trmm/data/gpm/

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