Spatial distribution of MCSs and their properties over the global tropics

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Motivation

Mesoscale Convective Systems (MCSs)

- Crucial role in global atmospheric circulation and radiation budget
- Severe weather and floods

- Plausible for global tracking
  - Past studies – IR based over a smaller region, and shorter period
  - IMERG precipitation available at finer temporal resolution
  - Computation power
  - Other recent global MCS dataset - Feng et al. 2020.

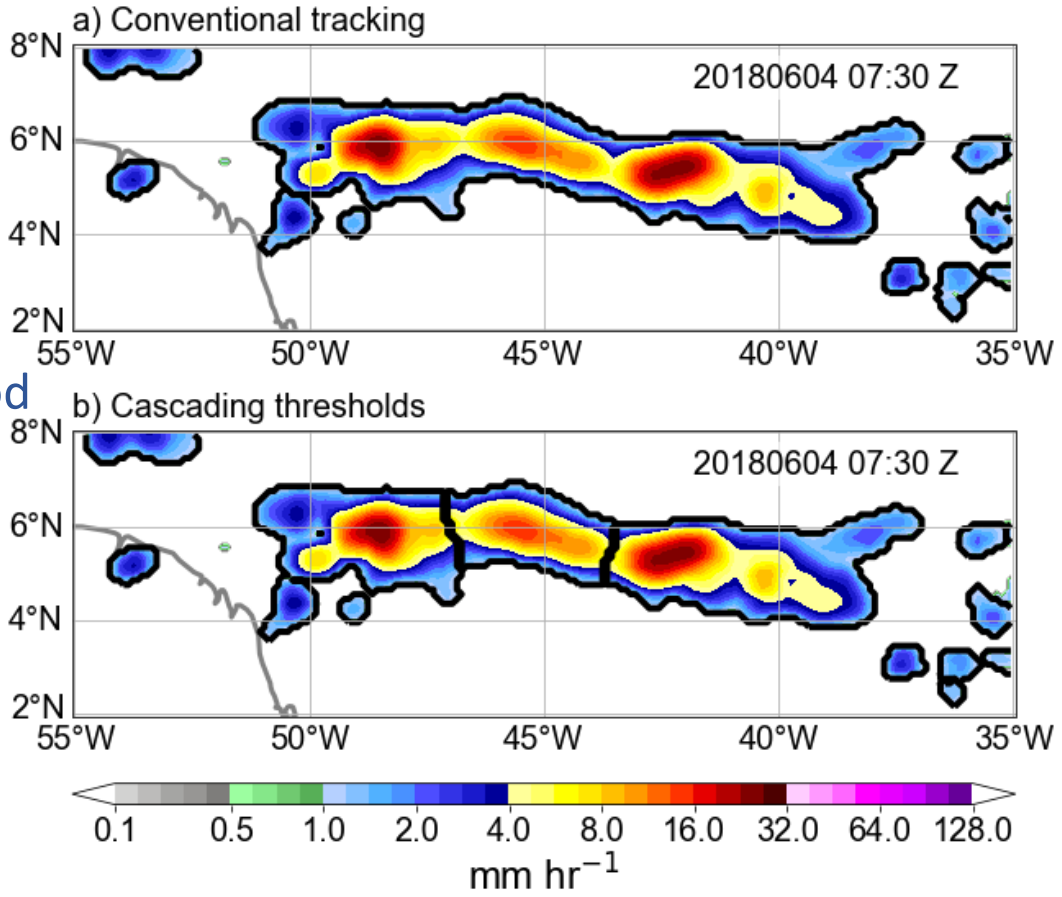
Data and Method

Integrated Multi-satEllite Retrievals for GPM (IMERG)

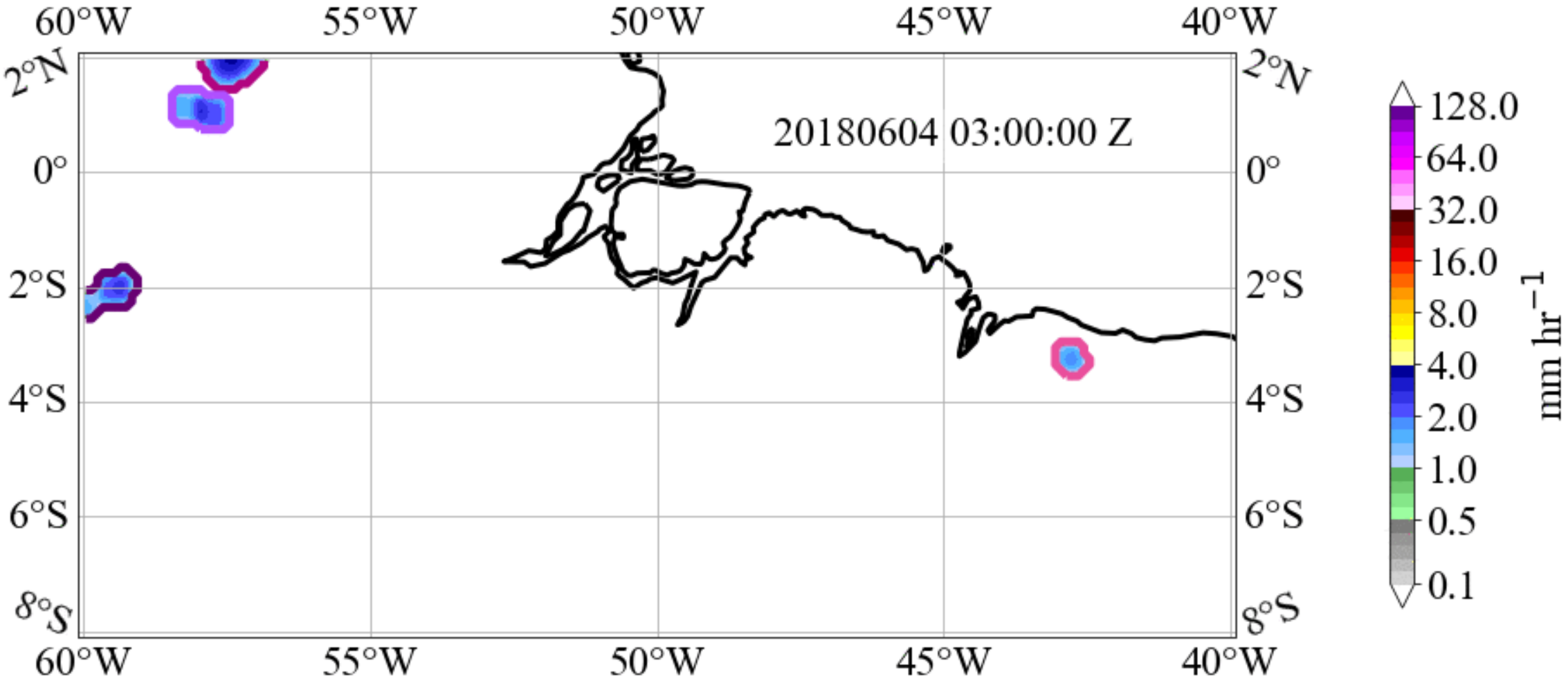
- Final run, available every 30 minutes at 0.1° spatial resolution

Forward in Time (FiT) tracking algorithm

- Developed by Gregor Skok (Skok et al. 2013)
  - Step 1: Identify object thru “detect and spread” method
  - Step 2: Area overlap to track across time
- Splits and mergers



Tracking animation



Precipitation System properties

Precipitation system properties

- Area, A
- Volumetric rain rate (Rain volume), VRR
- Maximum rain rate, MaxRR
- Lifetime, L
- Propagation Velocity, PV

Instantaneous vs Lifetime statistic

- Instantaneous Area (A_{inst}) every 30 minutes
- Maximum Area attained during MCS lifetime (A_{Lmax})

TIMPS dataset

Tracked IMERG Mesoscale Precipitation System (TIMPS)

- created by James Russell

Domain: 30 N – 30 S

Years: 2011 – 2020 (10 years!)

MCS definition

- A_{Lmax} >= 3000 km^2 (attain at least once in its lifetime)
- L >= 6 hours
- $MaxRR_{Lmax}$ >= 10 mm hr^{-1} (attain at least once in its lifetime)
- Exclude precipitation systems
  - Near Tropical Cyclones (IBTrACS)
  - Edge systems that touch north/south boundaries.

Results

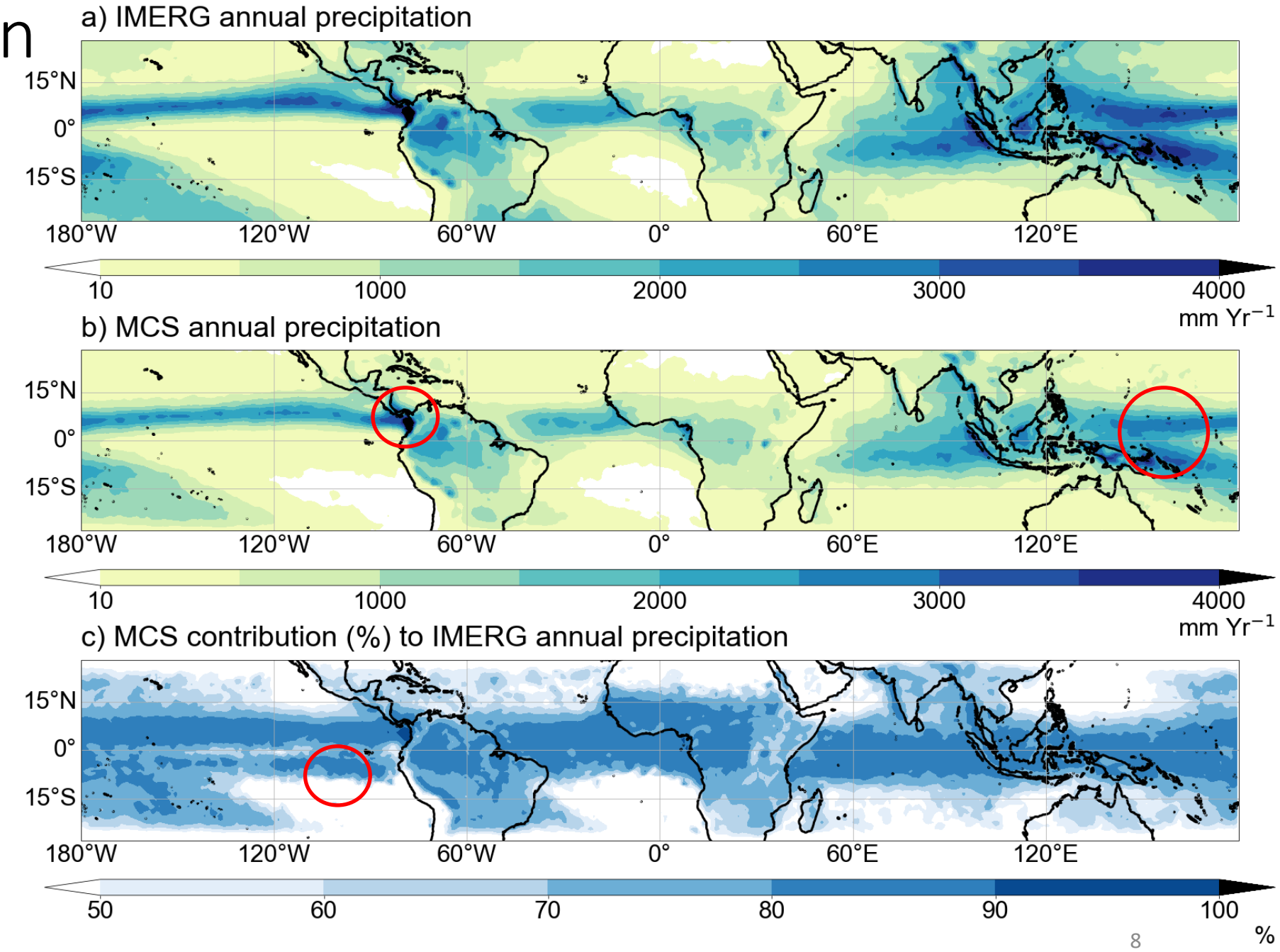
Rain contribution

MCS precipitation is computed at each 0.1° x 0.1° pixel

Heavy MCS rainfall regions

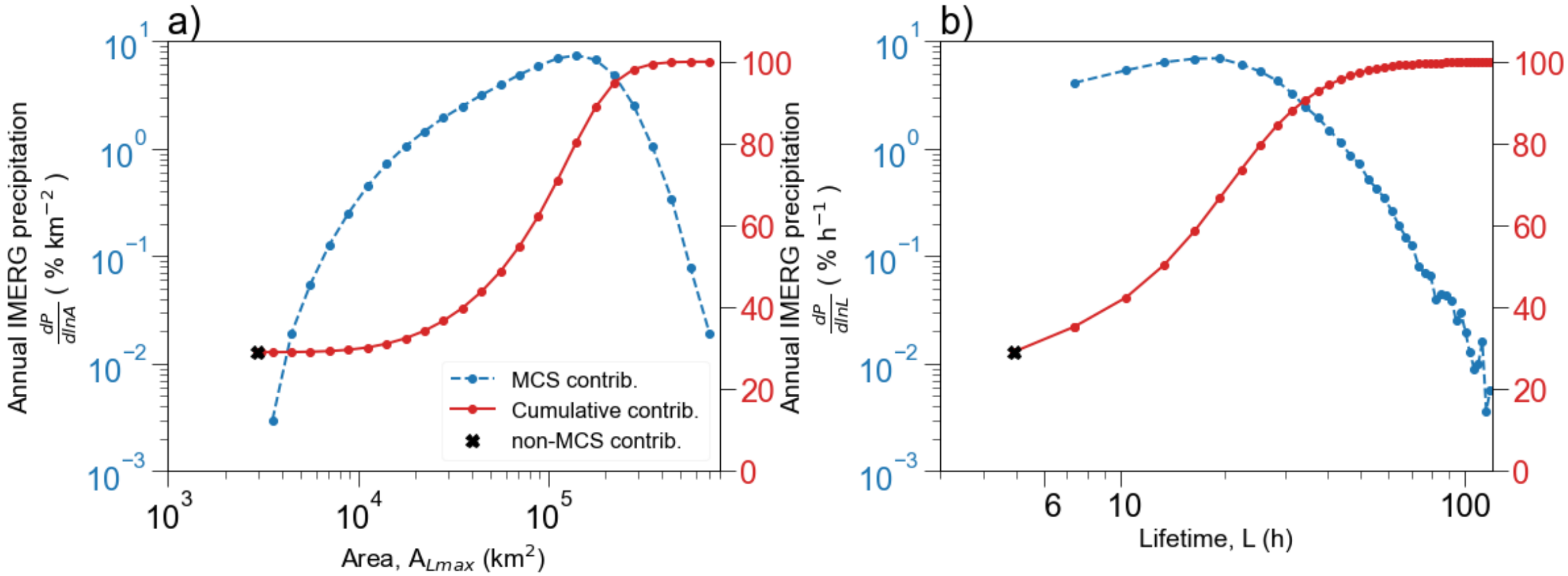
70-90% of IMERG annual precipitation near equatorial regions.

Double ITCZ in eastern pacific



Rain contribution

- MCSs contribute ~ 70% of annual precipitation, though they are ~ 7% of all tracked systems
- Rain contribution reaches maximum at MCS size of ~10^5 km^2
- MCSs with lifetime > 24 hours contribute ~ 20%



Track based statistics

- Calculating statistics at each IMERG pixel (0.1° x 0.1°) is computationally expensive. Hence for figures on the following slides, I do these steps

1. Divide the domain in to 1° x 1° grid cells

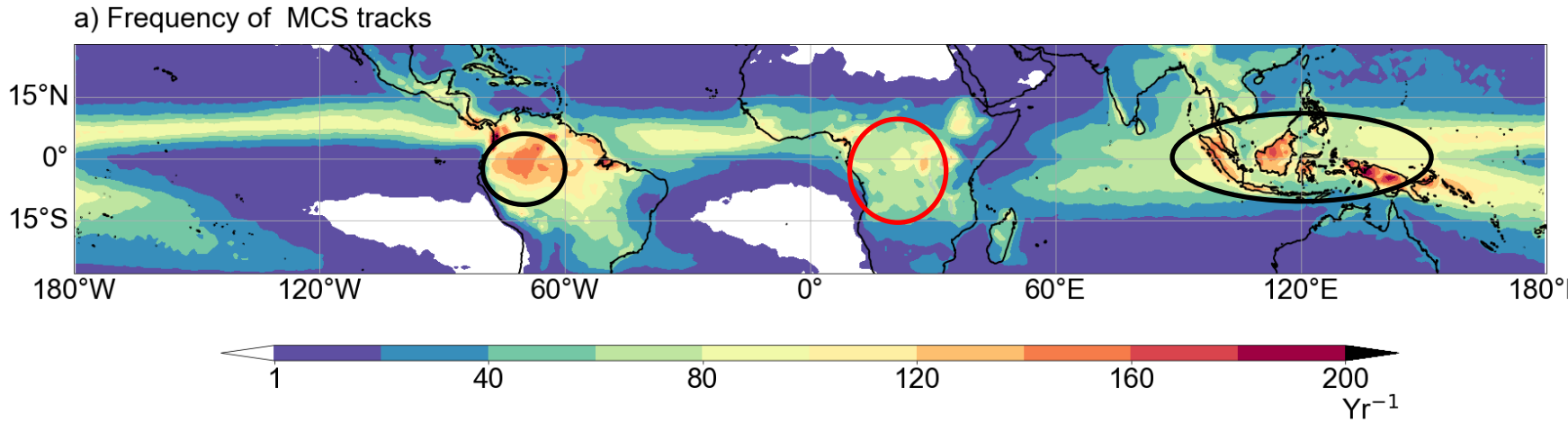
2. Attach the MCS properties to a grid cell along the MCS track (based on instantaneous weighted-centroid).

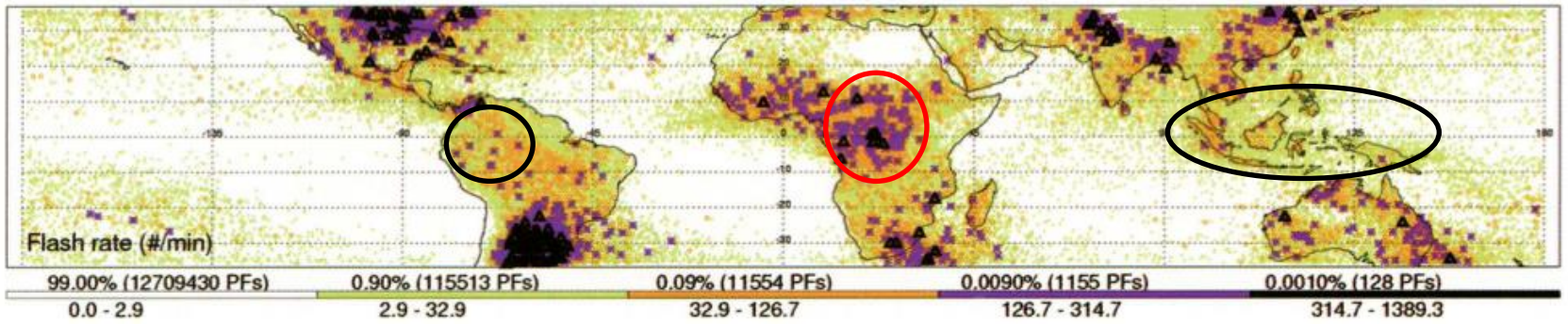
MCS track frequency

Amazon and MC have relatively more MCSs than central Africa.

Though central Africa has fewer MCSs but many thunderstorms.

Lightning frequency out of phase with MJO precipitation over MC (Virts et al. 2015;).





Zipser et al. 2006

Precip. Intensity

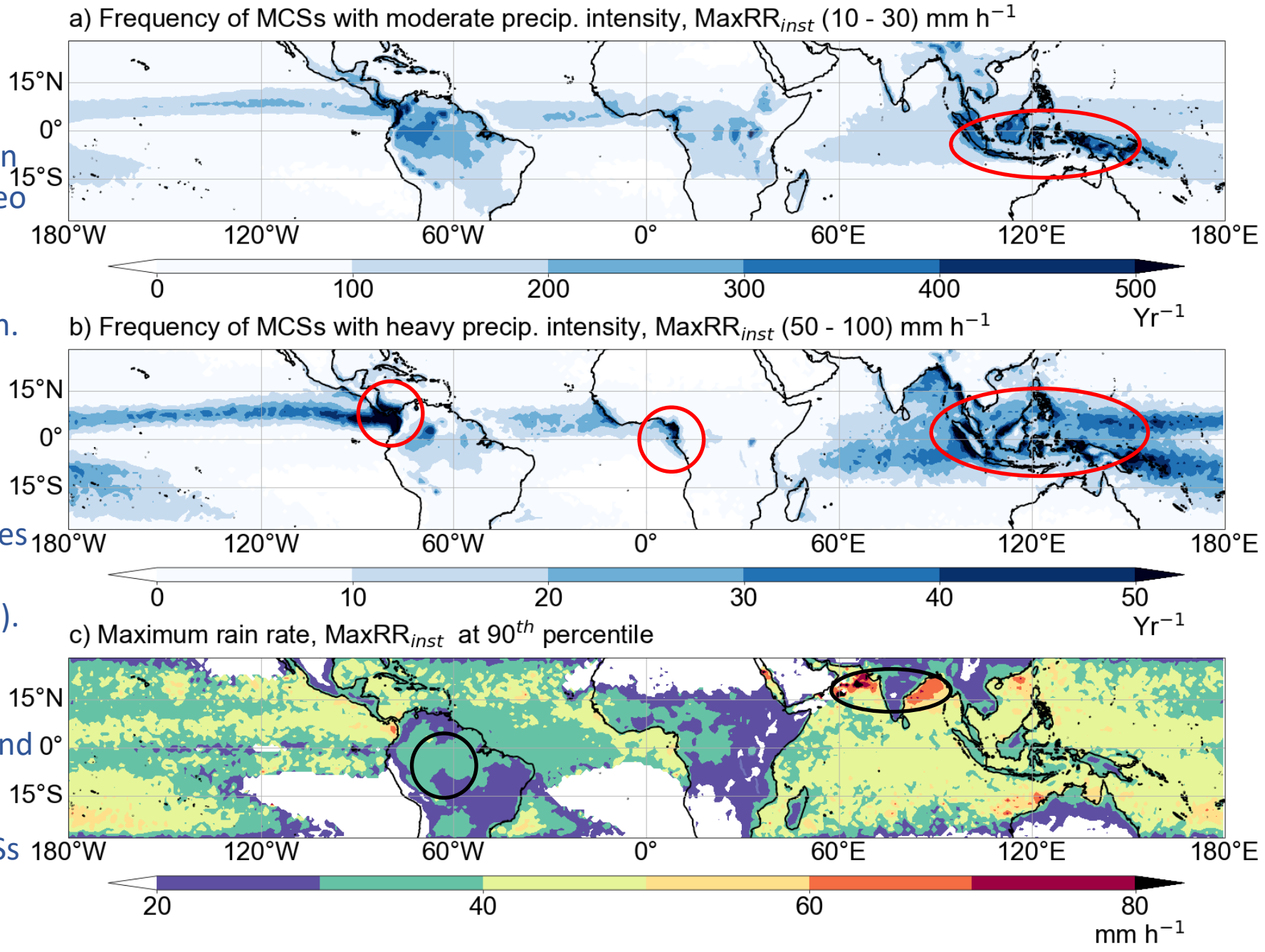
Coastal regions have heavy precipitation – Colombia, Cameroon, Sumatra, Borneo

Land < Ocean < Coastal/Offshore region. Why?

- Maybe difference between land vs ocean PMW retrieval
- Maybe more subtle – Heavy rain rates over land from thunderstorm or smaller systems (Hamada et al.2014).

Amazon similar to other tropical land and ocean.

In North Indian ocean , top 10% of MCSs have heavy rain rates.



Lifetime

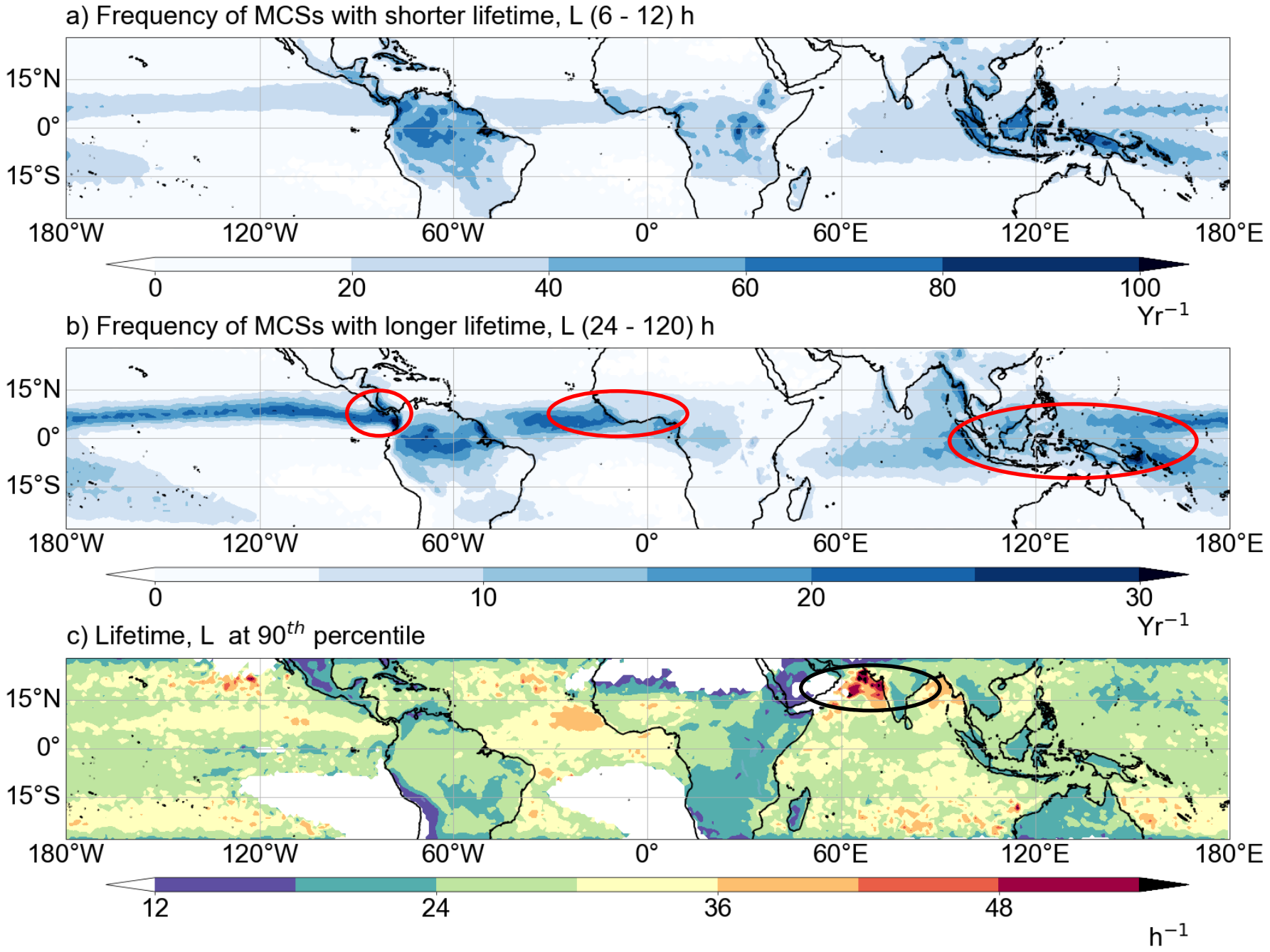
Land vs Ocean:

Long lived systems are more frequent over all three ocean basins, and Amazon.

Pacific coast of Colombia

W. Africa vs E. Atlantic

North Indian Ocean



Propagation Velocity

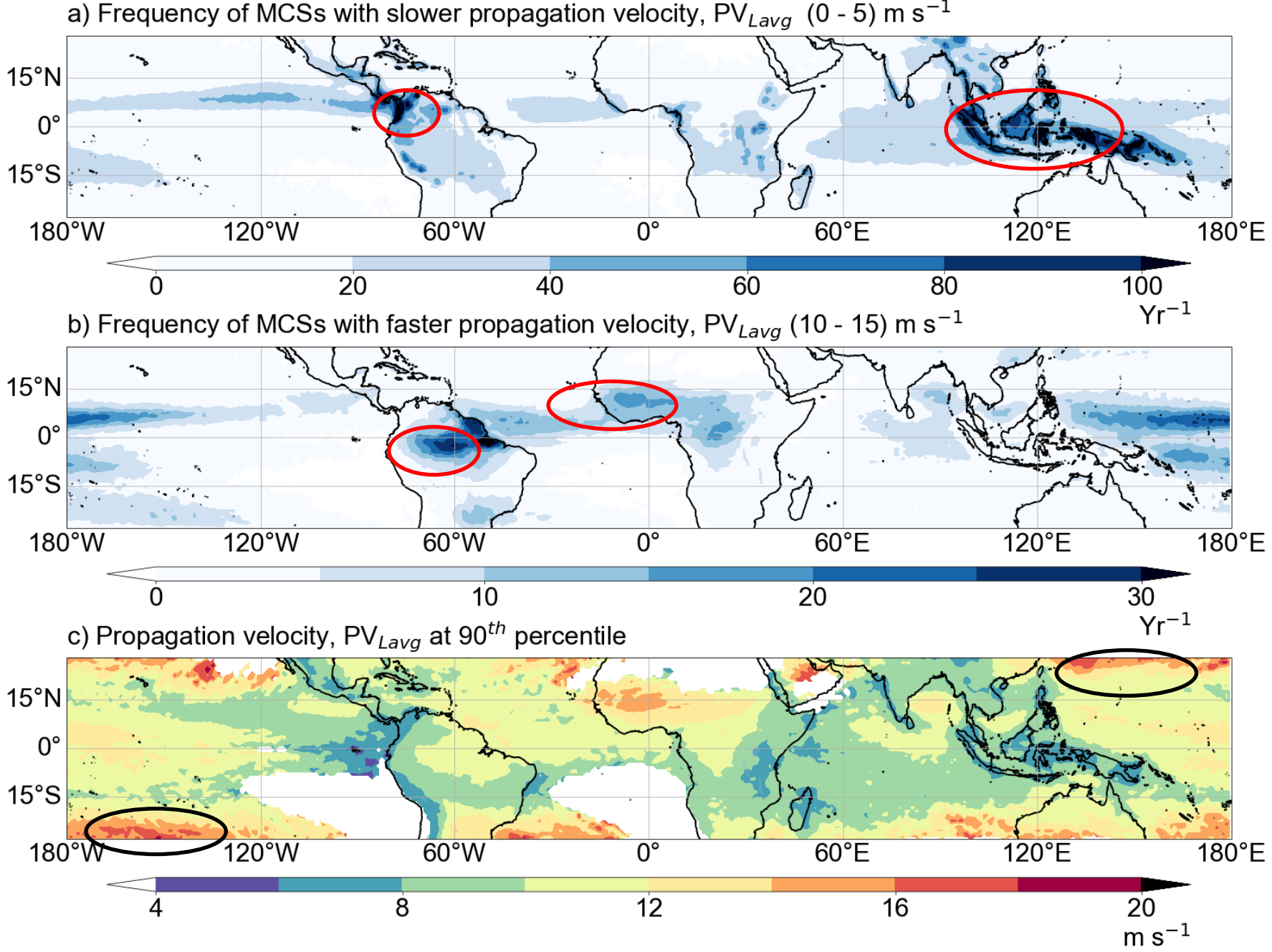
Slow moving MCSs are found over maritime continent, W. Coast of Panama, and Colombia

Fast moving systems are found over Amazon, Africa, and West Pacific.

W. Pacific vs E. Pacific

W. Africa vs E. Atlantic

Mid-latitude influence

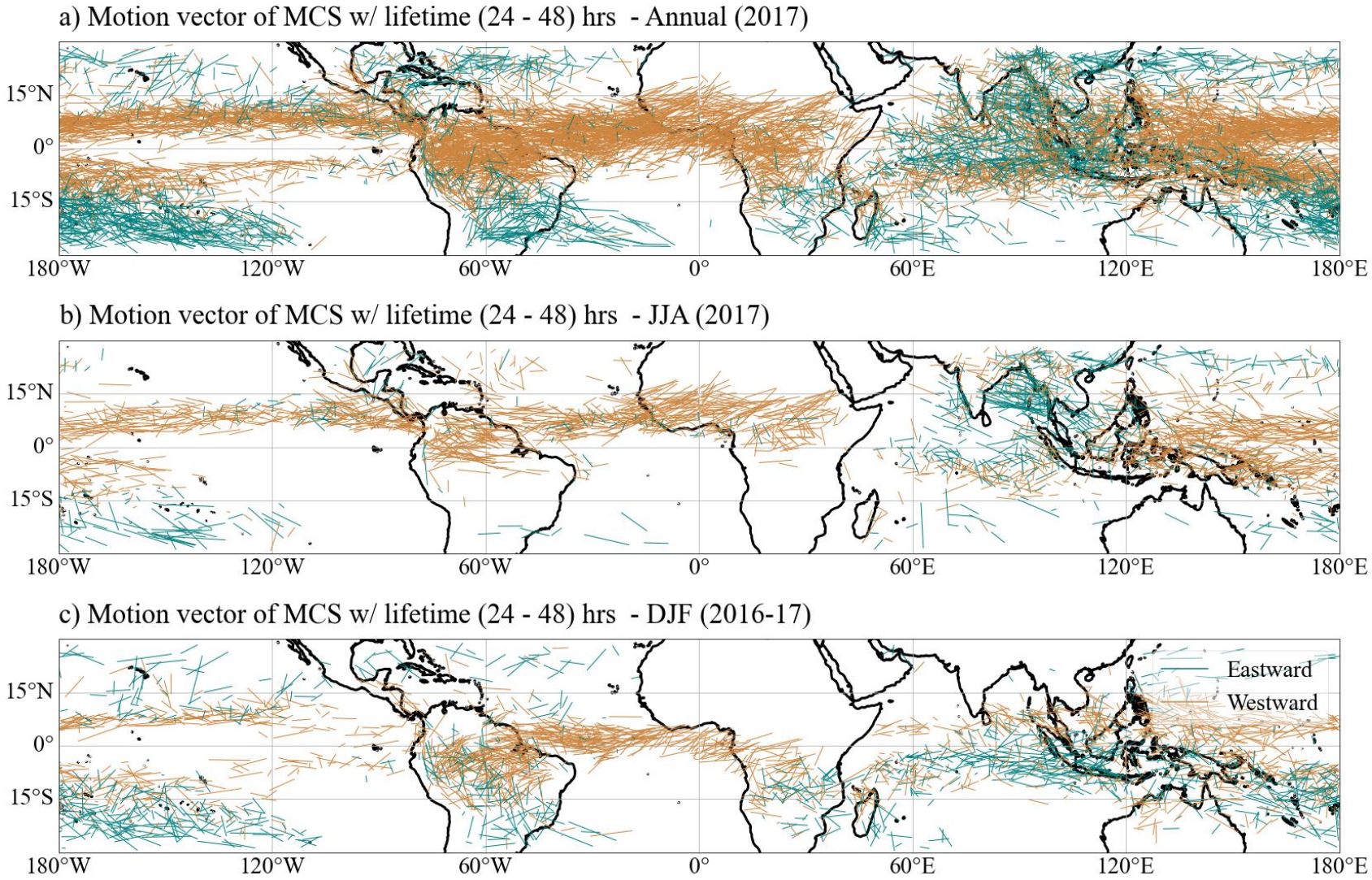


Motion vector

Atlantic and Pacific ITCZ vs Indian Ocean

Asian and Australian monsoon circulations

Double ITCZ over eastern Pacific in DJF.



Summary

Rain contribution

- MCSs contribute 70-90% of IMERG annual precipitation near equatorial regions. Though MCSs are ~7% of tracked systems.

MCS frequency

- Amazon and MC have relatively more MCSs than central Africa which has more thunderstorm.

Heavy precipitation frequency

- Land < Ocean < Coastal region. Is it due to differences in PMW retrieval or in the convection

Long lived MCSs over Ocean

- Land had fewer MCSs that are long lived possibly due to diurnal cycle and barrier effect of complex terrain

Propagation velocity

- Fast moving systems over W. Africa and Amazon are probably squall lines

Summary of regional differences

Land Vs Ocean

- Ocean have higher frequency of MCS that are large, heavy rain producers, and long-lived.

W. Coast of Colombia:

- Large, heavily precipitating, but slow moving MCSs might cause frequent floods.

Amazon as green ocean

- Larger, long-lived and heavy rain producing MCSs similar to ocean.
- Higher frequency of MCSs similar to other land areas due to strong diurnal cycle.

W. Pacific vs E. Pacific

- East pacific has smaller, long-lived and slow moving MCSs compared to west pacific

W. Africa vs E. Atlantic

- E. Atlantic has slightly larger and long-lived MCSs than W. Africa but MCSs over W. Africa are fast moving.

Percentile plot show that Central America, Peru, Arabian Peninsula and N. Africa have fewer MCSs but most of them are smaller, short-lived and moderate rain producers. Similarly Bay of Bengal and Arabian Sea have fewer MCSs but most of them are large, long-lived and heavy rain producers.

Questions?

Precip. Intensity

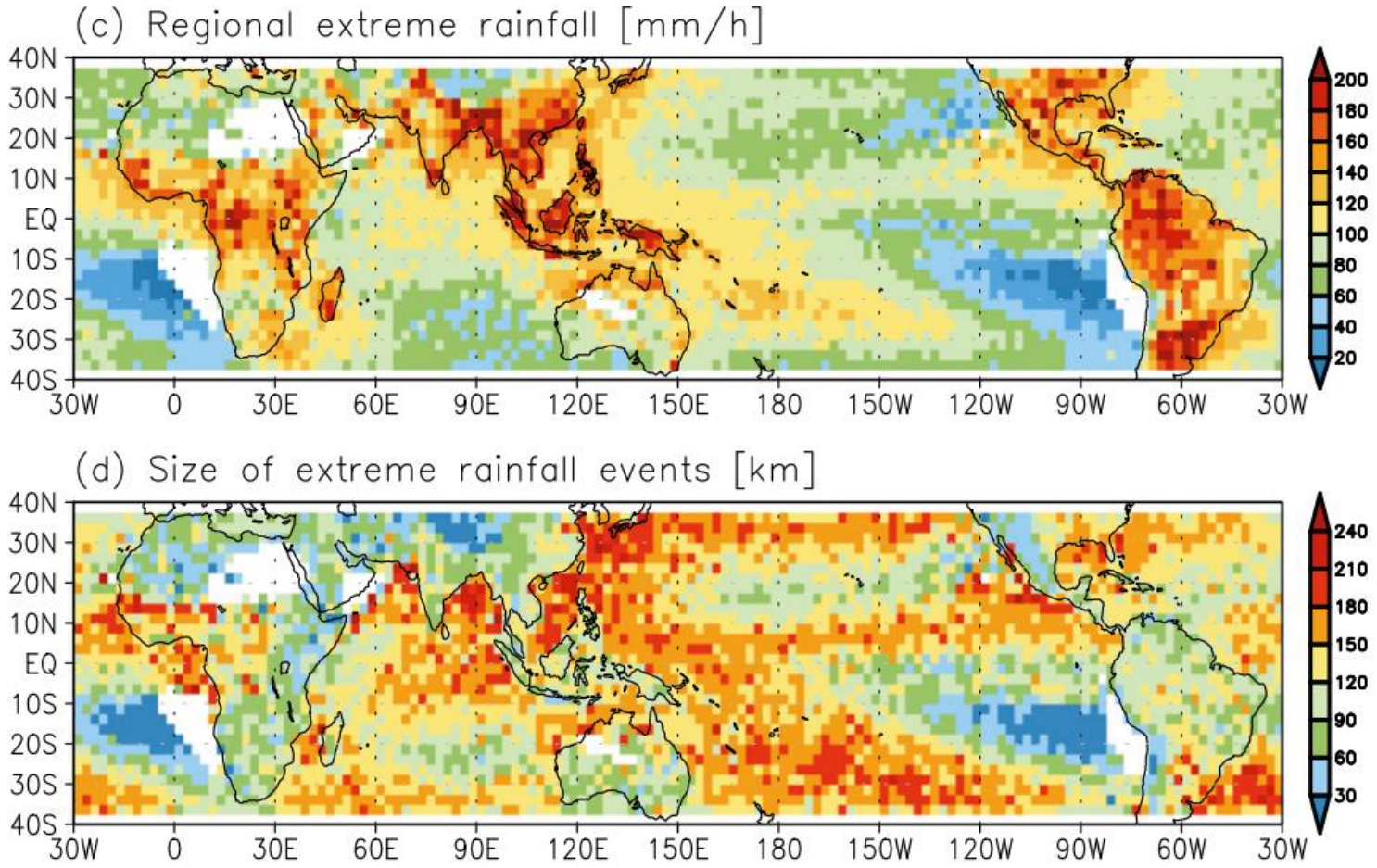
Rain rate over land regions > 100 mm hr^{-1}

Land vs Ocean vs Coastal region (Ogino et al. 2016)

Maybe difference between land vs ocean PMW retrieval

Amazon similar to other tropical land.

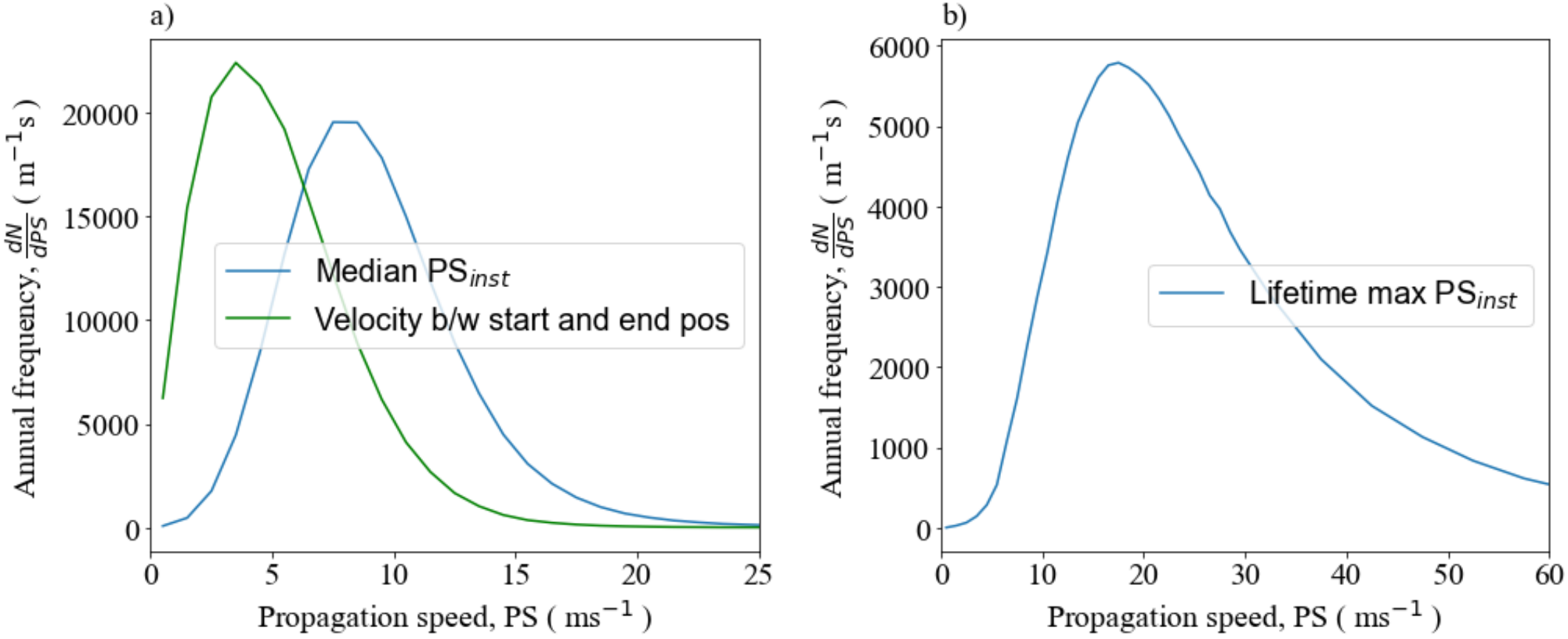
Top 10% MCSs of north Indian ocean have heavy rain rates.



Hamada et al. 2014

1. Propagation velocity

- Instantaneous propagation speed (PS_{inst}) vs propagation velocity (PV_{avg})
- Maximum propagation speeds (PS_{inst}) of 50 m/s (subplot b) - unrealistic in tropics
- Propagation velocity peaks at 5 m/s - reasonable for tropics



Frequency distributions

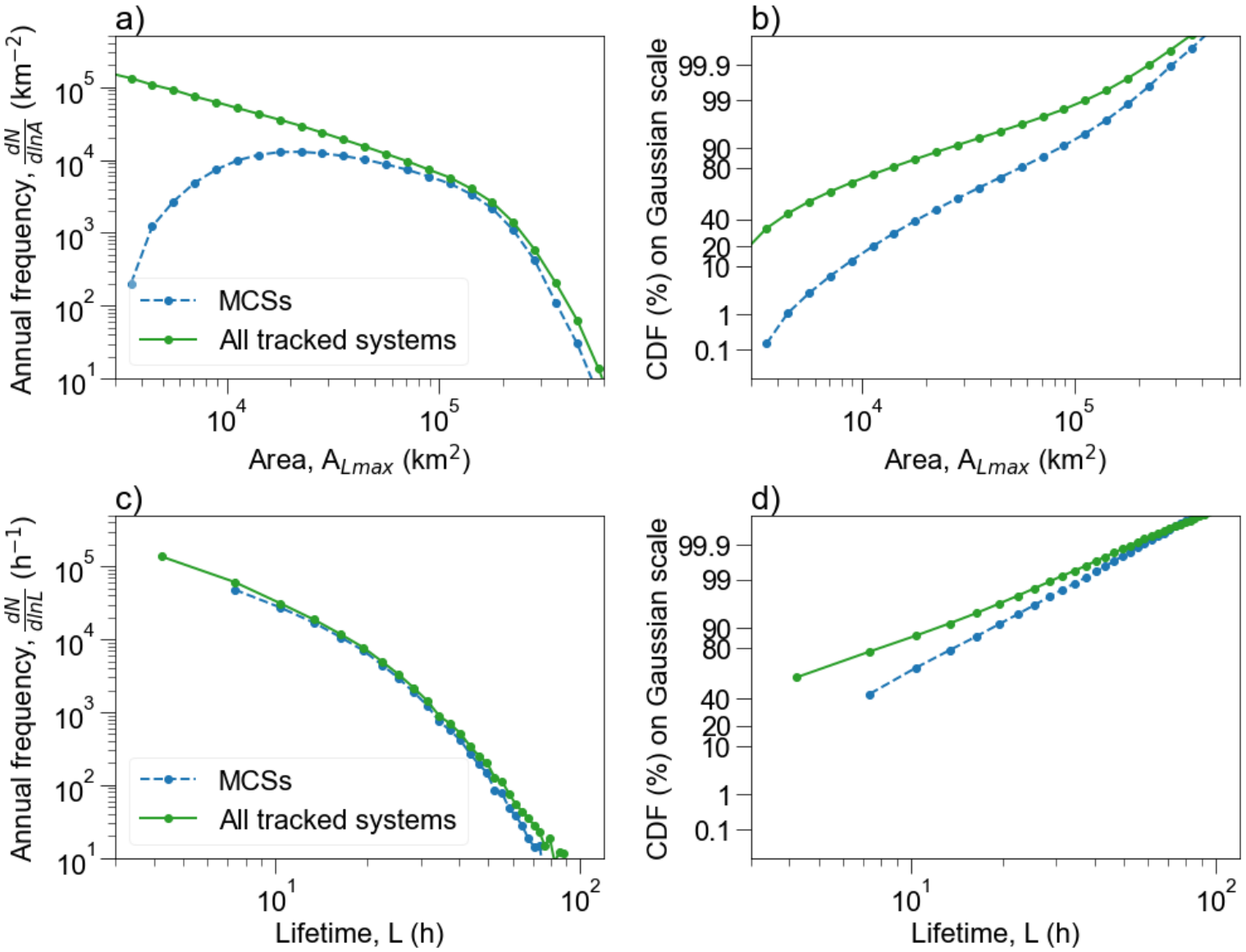
What parametric distribution do they follow?

- Size distribution -> Power law?
- Lifetime distribution -> Log-normal

- Only 7% of all tracked systems are MCSs

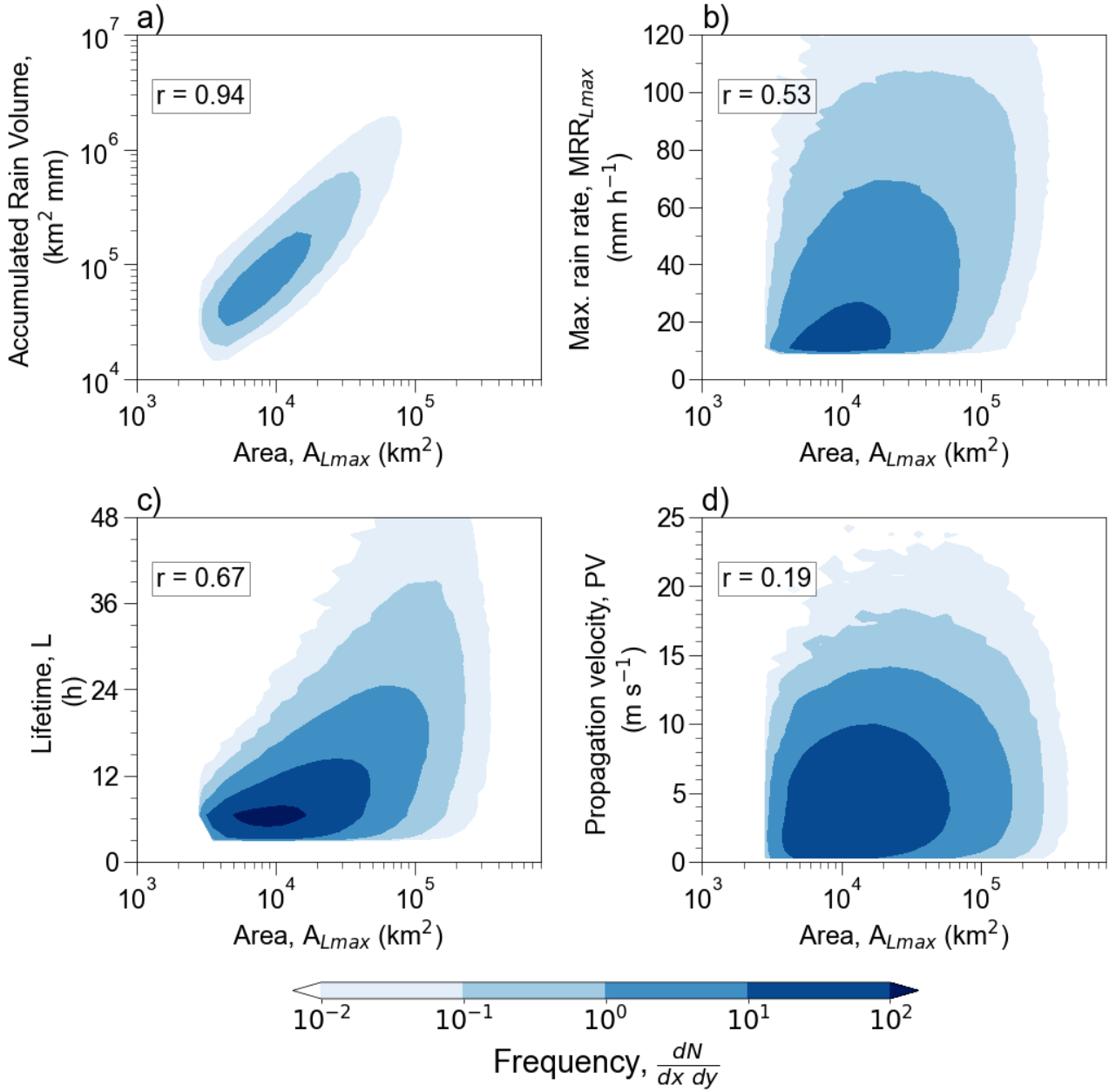
- 99% of MCSs are smaller than $2x10^5$ km^2 (~400 km equivalent diameter)

- 90% MCS have lifetime < 24 hours



Relationship between MCS properties

- Size and Accumulated rain volume (VRR_{inst}) have highest correlation(r) of 0.94
- MCS lifetime increase with size
- Large MCSs seem to have heavy rain rates but the relationship is weak.
- Poor correlation between MCS size and propagation speed.



7. $Area_{inst}$

Land vs ocean:

Land has higher frequency of smaller MCSs whereas oceans has higher frequency of large MCS.

Amazon vs Africa

W. Pacific vs E. Pacific

W. Africa vs E. Atlantic

Percentile subplot shows that most MCSs in Peru, Central America, Arabian peninsula, and North Africa are small