SPATIO-TEMPORAL CHARACTERISTICS AND INTENSIFICATION OF MESOSCALE CONVECTIVE SYSTEMS IN SOUTH ASIA OVER THE PAST TWO DECADES

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Introduction

- Towering cumulonimbus clouds are common in many regions and are associated with intense updrafts and downdrafts.
- They frequently interact and form organized lines, clusters or complexes of convective storms: Mesoscale Convective Systems (MCSs).
- These organized convective systems extend over a length scale of more than 100 km in one or more direction and persists for at least 4 hours or longer.
- MCSs produce over 50% of the annual rainfall in some regions and often cause deadly and destructive flash flooding. They are also known to trigger tropical cyclones.

Background

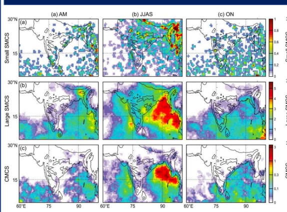


Fig 1. Seasonal-mean density of (top) small Separated MCSs (SMCS), (middle) large SMCSs, and (bottom) Connected MCSs (CMCS) during (a) AM, (b) JJAS, and (c) ON

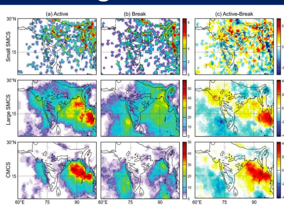


Fig 2. Density of (top) small SMCSs, (middle) large SMCSs, and (bottom) CMCSs, for (a) active and (b) break BSISO1 periods during JJAS and (c) the difference between (a) and (b).

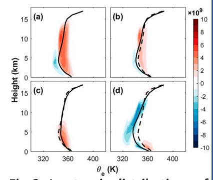


Fig 3. Isentropic distributions of the WRF simulated vertical mass transports (kg s^{-1} K^{-1}) associated with (a) MCS, (b) non-MCS deep convection, (c) congestus, and (d) shallow + clear averaged over 2009 JJA.

- Explored the seasonal and intraseasonal distribution of MCS classified in terms of sizes.
- During the active phase more number of large and connected MCS are seen over BoB associated with monsoon depressions [Virts and Houze, 2016].
- Transports by MCSs are at least 1.5 times stronger throughout the troposphere [Chen et al., 2021].

Objective

Understand the spatio-temporal characteristics of Mesoscale Convective Systems (MCS) over South Asia as observed from high resolution satellite observations.

Methodology and Data

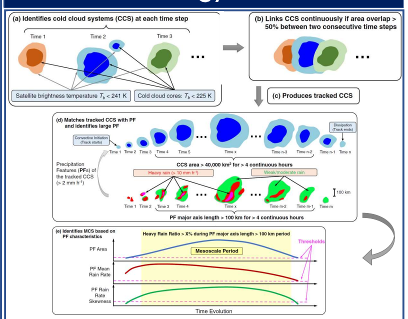
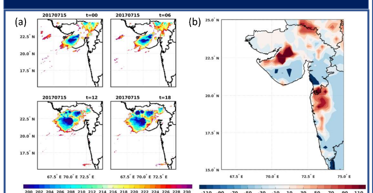


Fig 4. Workflow of the PyFLEXTRKR [Feng et al., 2021]

Data	Source	Δx	Δt	Period
Brightness Temperature (T_b)	GPM	0.1°	1 hour	2001-2020
Precipitation	GPM	0.1°	1 hour	2001-2020
Meteorological Parameters	ERA5	0.25°	1 hour	2001-2020

Validation



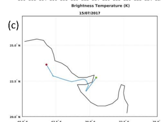
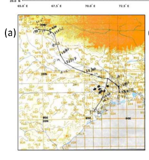


Fig 5. (a) Brightness Temperature (K) at 6 hourly intervals on 15th July 2017; (b) Anomalous rainfall on 15th July 2017; (c) MCS Track from PyFLEXTRKR



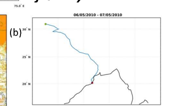
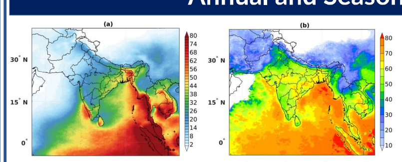


Fig 6. (a) Track of the convective cell [Goyal et al., 2014]; (b) Track of the MCS from PyFLEXTRKR

Annual and Seasonal Characteristics



- Multiple hotspots over South and Southeast Asia.
- More than 50% of annual rainfall contributed by MCS.
- Higher contribution to rainfall over ocean compared to land.
- Clear seasonality.
- Land and coasts contribute more to seasonality.

Fig 7. (a) Mean annual number of the mesoscale convective systems (MCS); (b) Annual mean fraction of precipitation produced by MCS (units: %), over the past two decades (2001-2020).

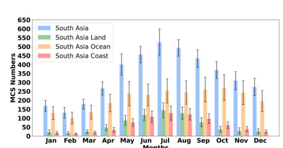


Fig 8. Monthly distribution of mean MCS numbers.

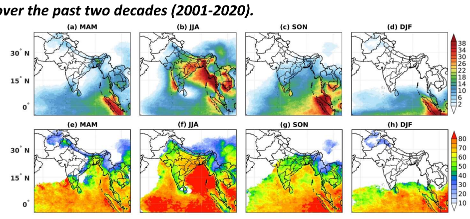


Fig 9. (a-d) Mean number of the mesoscale convective systems (MCS) in different seasons; (e-h) Mean fraction of precipitation produced by MCS (units: %) in different seasons over the past two decades (2001-2020).

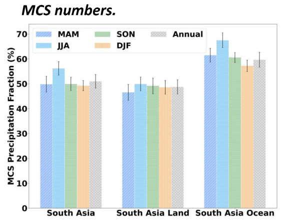


Fig 10. Mean rainfall fraction over different regions in different seasons.

- During pre-monsoon season, MCSs mostly form over land (along IGP, eastern and north-eastern India, and parts of Southeast Asia).
- During monsoon season, most parts of South Asia is under the influence of MCS.
- All the regions receive more than 50% of rainfall.
- The fraction is highest during the monsoon.
- In all the seasons, ocean receive higher fraction of rainfall.

Land vs Ocean

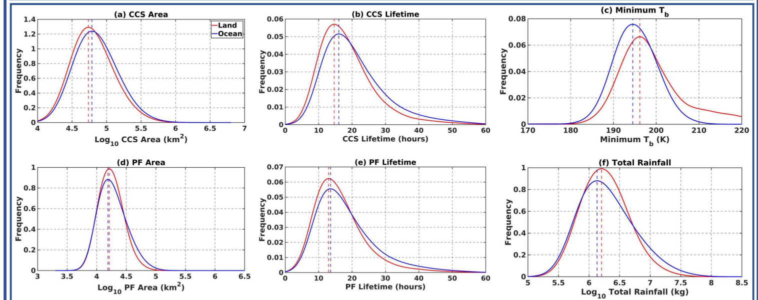
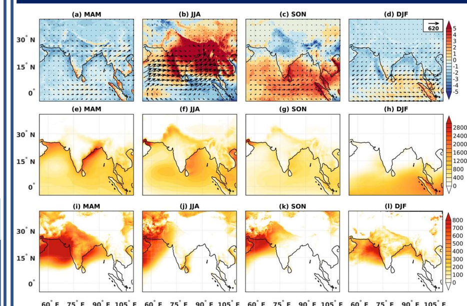


Fig 11. Kernel density distribution of the MCS characteristics over land and ocean.

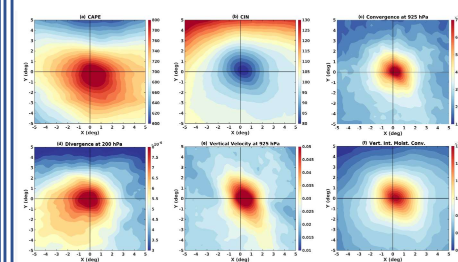
- Oceanic systems are generally larger, longer lived, grows vertically deeper and probability of higher rainfall is significantly higher over ocean.

Large Scale Environment



- Strong positive anomaly of VIMC, strong CAPE and low CIN are collocated, favouring the genesis.

Fig 12. Composites of atmospheric conditions at the time of MCS genesis. (a) Anomaly of vertically integrated moisture convergence (VIMC, kg m^{-2} s^{-1}) and vertically integrated water vapor flux (kg m^{-1} s^{-1}) are represented by shadings and vectors, respectively; (b) Composite of CAPE (J kg^{-1}); (c) Composite of CIN (J kg^{-1}).

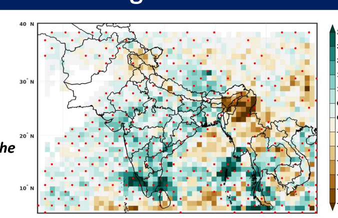


- Close to the genesis location, we observe higher intensity of favourable conditions.
- The influence of large-scale environment decreases with distance from the point of genesis.

Fig 13. Composites of environmental conditions averaged over a period of 3 hours prior to the genesis of MCS as a function of the position relative to location of MCS. (a) CAPE (J kg^{-1}); (b) CIN (J kg^{-1}); (c) Convergence at 925 hPa (s^{-1}); (d) Divergence at 200 hPa (s^{-1}); (e) Omega (Pa s^{-1}); (f) VIMC (kg m^{-2} s^{-1}).

Changes in Number

Fig 14. Changes in MCS numbers from 2001-2020. The red stippling represent the significance at 95%.



- Numbers have increased over South Asia.

Conclusions

- Developed the MCS database over South Asia for the past two decades (2001-2020).
- MCS has clear seasonality with higher activity and higher contribution to mean rainfall observed during JJA.
- MCS contribute the major fraction of rainfall in each season.
- More intense characteristics are observed over ocean.
- The favourable conditions (high CAPE, low CIN, higher VIMC, high vertical velocity) are collocated close to the MCS genesis.
- Increased numbers.

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