Three-Dimensional Characteristics of MCSs East of the Rocky Mountains and Their Large-scale Environments

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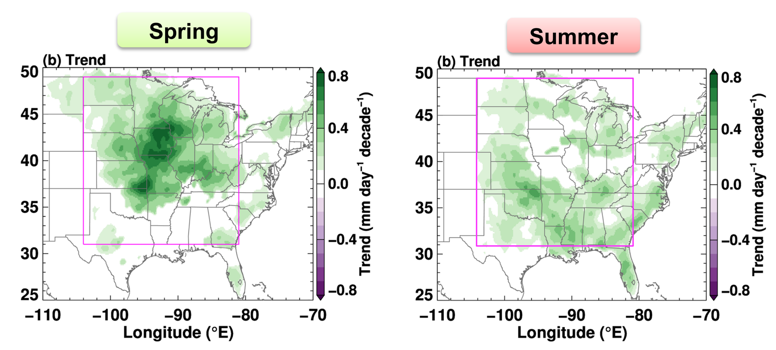
Background

- A mesoscale convective system (MCS) is a contiguous cumulonimbus cloud complex with horizontal dimensions of 100-1000 km and lasts up to ~10-24 h
- Long-term observations showed that MCSs in the central US have become more frequent and produced more extreme precipitation in the past 35 years
- MCSs outside of the central US and beyond the warm seasons have received much less attention
- A systematic survey to characterize 3-D MCS structures and their large-scale environments across CONUS using modern observations is lacking

Observed Trends in MCS Seasonal Rainfall (1979-2014)

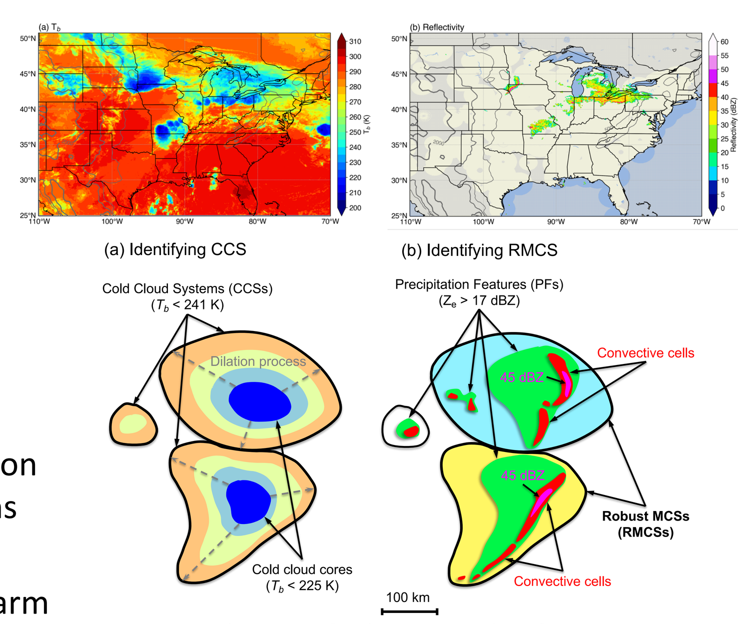


Feng et al. 2016 (*Nature Communications*)

Development of a 13-year 3-D MCS Database

1. Dataset and Methodology

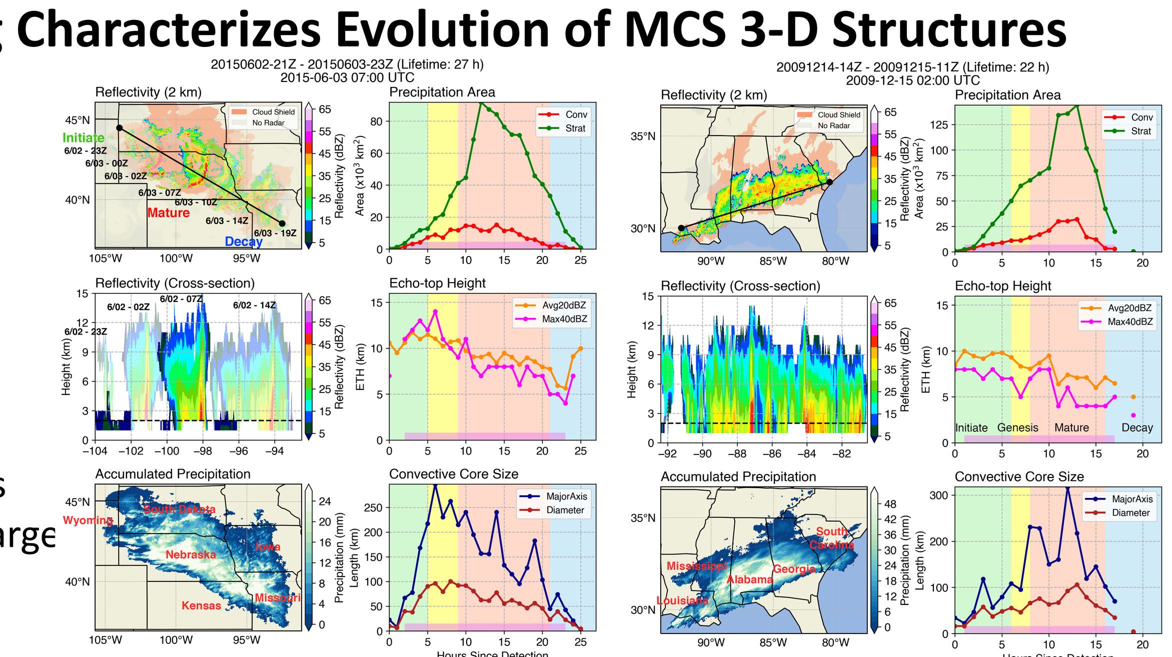
- **Dataset (2004-2016)**
  - **MergedIR** global satellite infrared brightness temperature: Δx=4 km, 30 min
  - **GridRad**: Δx=2 km, Δz=1 km, hourly
  - Stage IV precipitation: Δx=4 km, hourly
  - NARR: Δx=32 km, 3 hourly
- **MCS Tracking**
  - Robust MCS definition: lifetime > 6 h, Precipitation Feature (PF) major axis length > 100 km, contains 45+ dBZ convective echoes
  - Tracking for each year is done in two lengths: warm season (Mar-Oct), cold season (Nov-Feb)



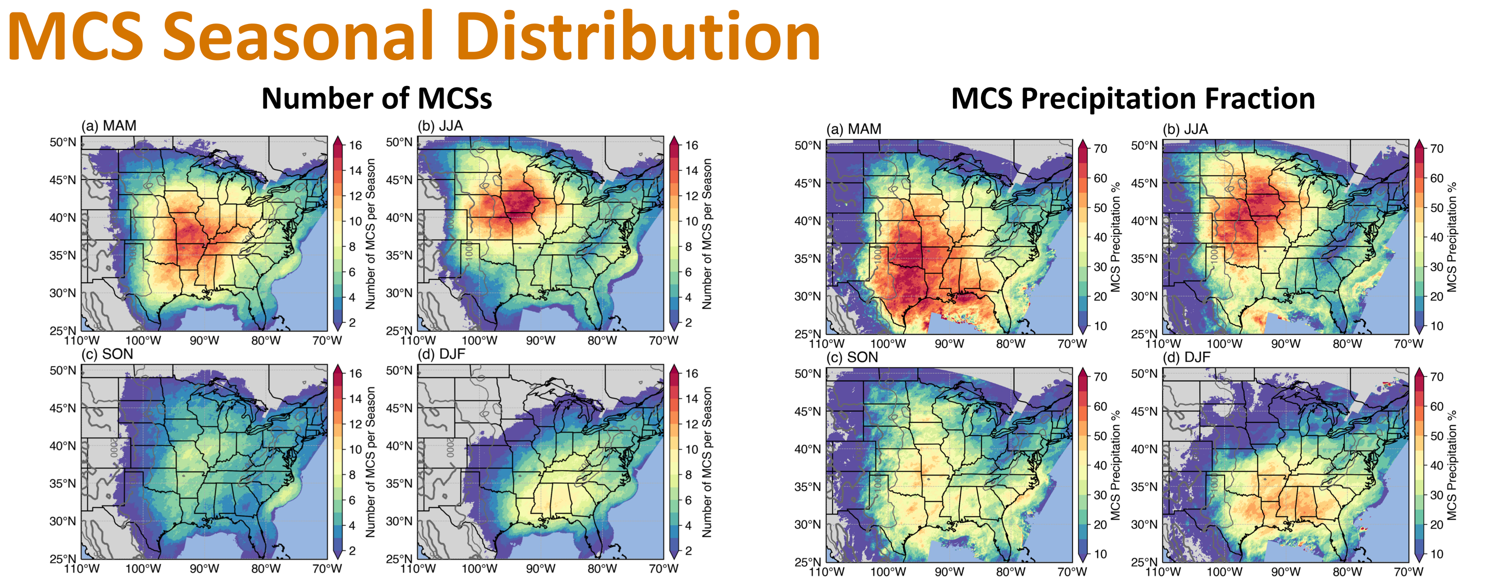
Schematic of Robust MCSs Identification
Feng et al. 2018 (*JAMES*)

2. MCS Tracking Characterizes Evolution of MCS 3-D Structures

- **Summer MCS:**
  - Deep intense convection, propagate ~1000km
- **Winter MCS:**
  - Shallower convective cells embedded in large stratiform area



MCS Seasonal Distribution

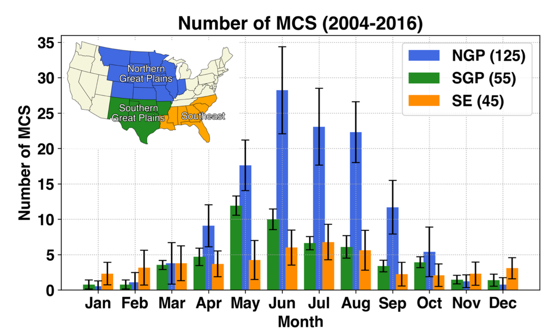


- Besides spring and summer, MCSs also occur frequently in southeast during winter
- A dozen MCSs accounts for 40-70% total rainfall across all seasons in various regions

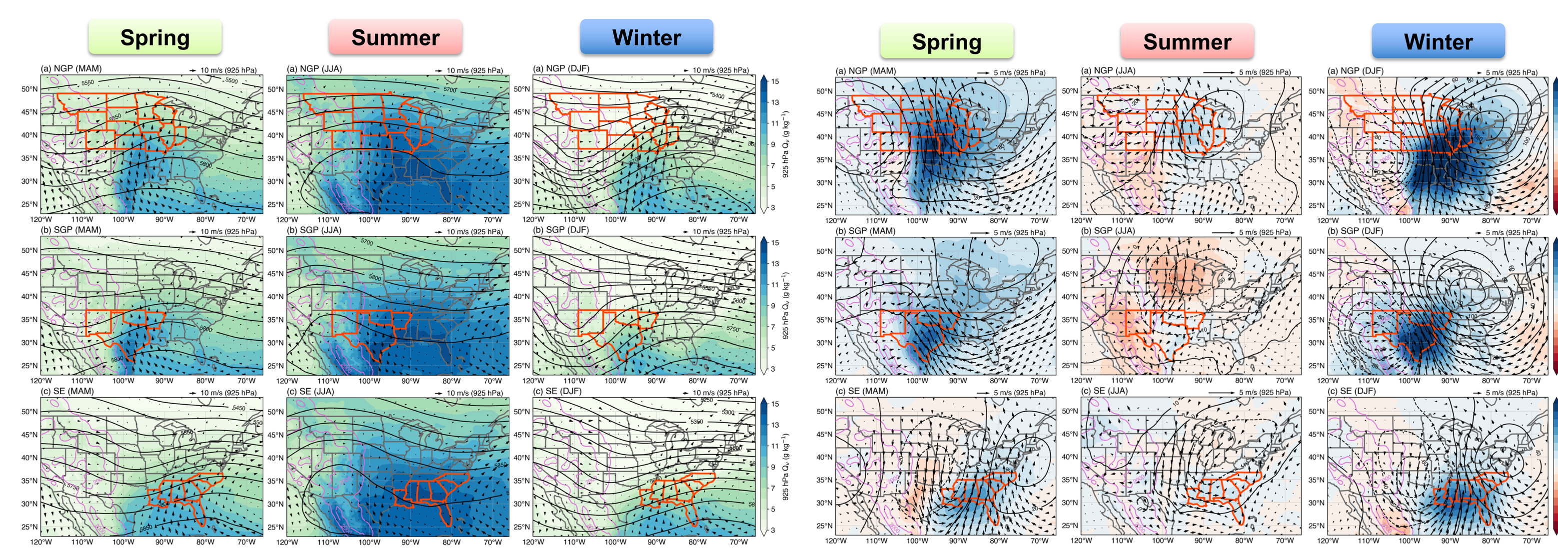
MCS Large-Scale Environments

1. MCS Seasonal Cycle in 3 Key Regions

- The Great Plains has the strongest MCS seasonal cycle, particularly the NGP
- MCS occurrence peaks in May in SGP, then in June shifting north to NGP
- Southeast MCSs have weak seasonal cycle: peak in July, least frequent in the fall; Southeast has the most MCSs among all regions in winter



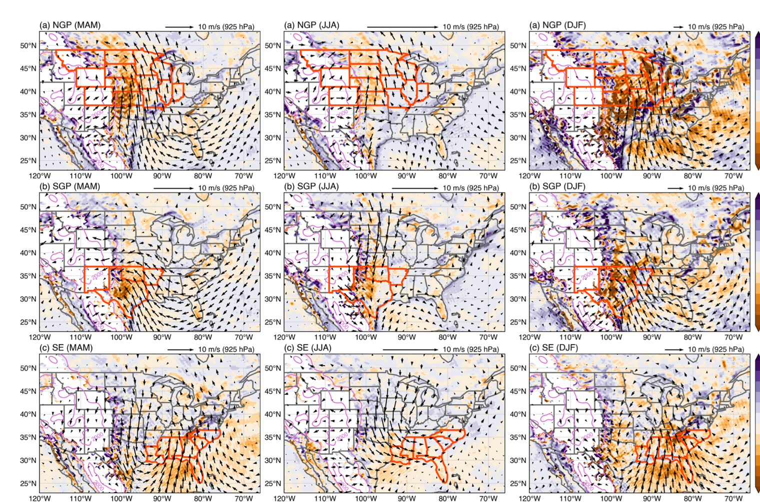
2. MCS Large-scale Environments by Seasons



Contours: 500hPa height, shading: 925hPa humidity, vectors: 925hPa wind

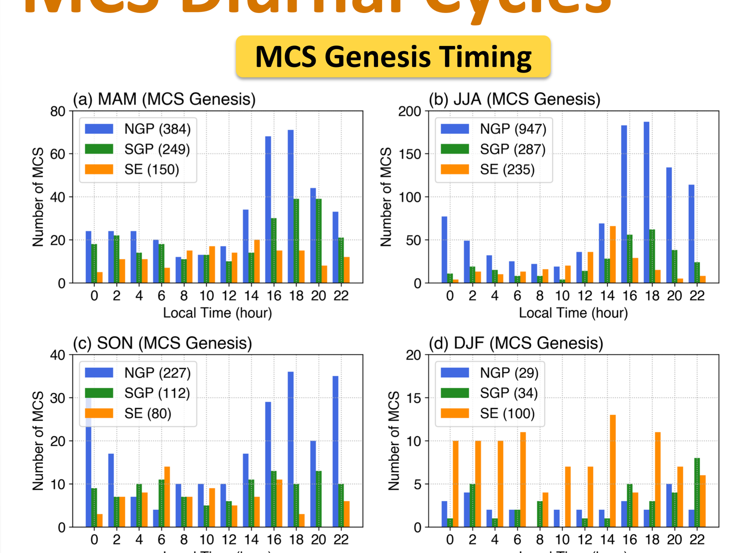
Same as the left figures except the anomalies are plotted

- **Spring** and Fall (not shown):
  - Ahead of deep trough, LLJ transports large anomalous moisture
  - Consistent low-level convergence
- **Summer:**
  - Weakest baroclinic forcing
  - High pressure, large mean low-level humidity but small humidity anomaly, weak LLJ
- **Winter:**
  - Small mean low-level moisture
  - Strongest baroclinic forcing and convergence of large moisture anomaly

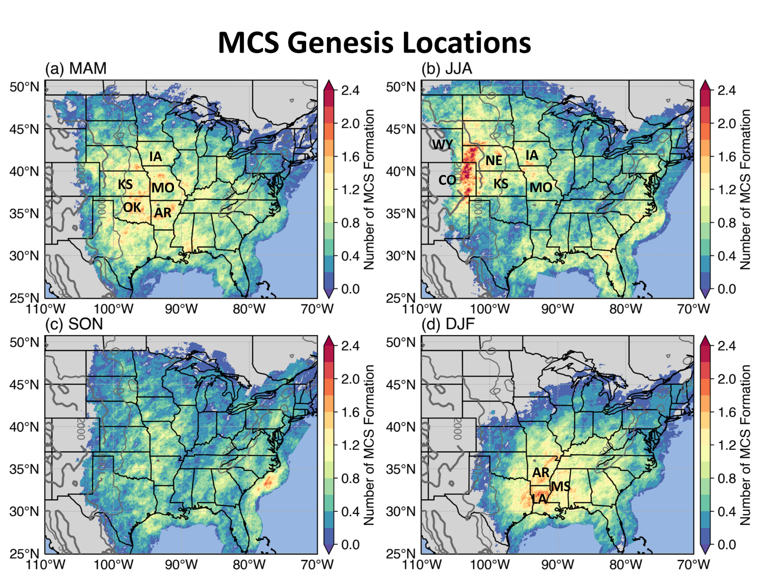


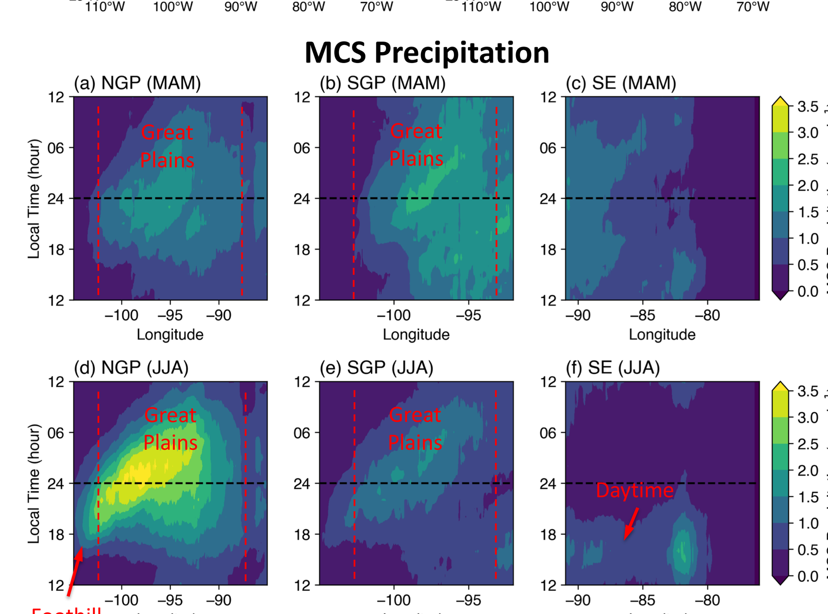
Shading: 925hPa anomalous divergence, vectors: 925hPa anomalous wind

MCS Diurnal Cycles



- Great Plains spring/summer: peak convective initiation (2-4PM) generally leads peak MCS genesis by 4-6 hours
- Southeast MCSs have weak diurnal cycle throughout the year except for summer





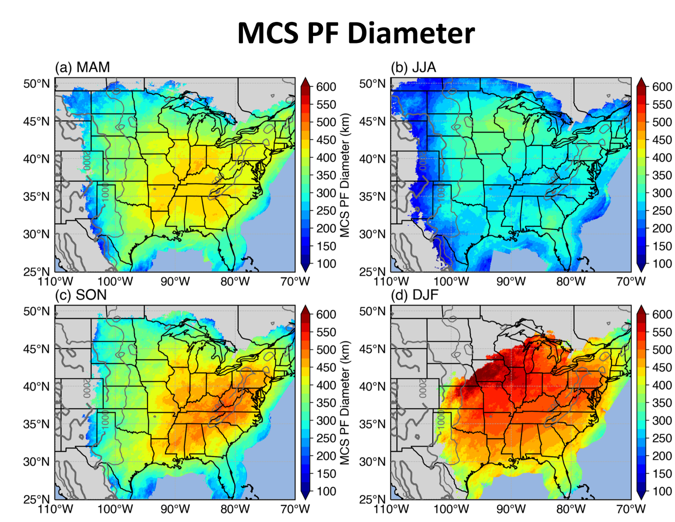
- Nocturnal peak MCS precipitation dominates the Great Plains in MAM/JJA
- Southeast MCSs in JJA peak at daytime, are much less frequent and do not propagate zonally

Summary

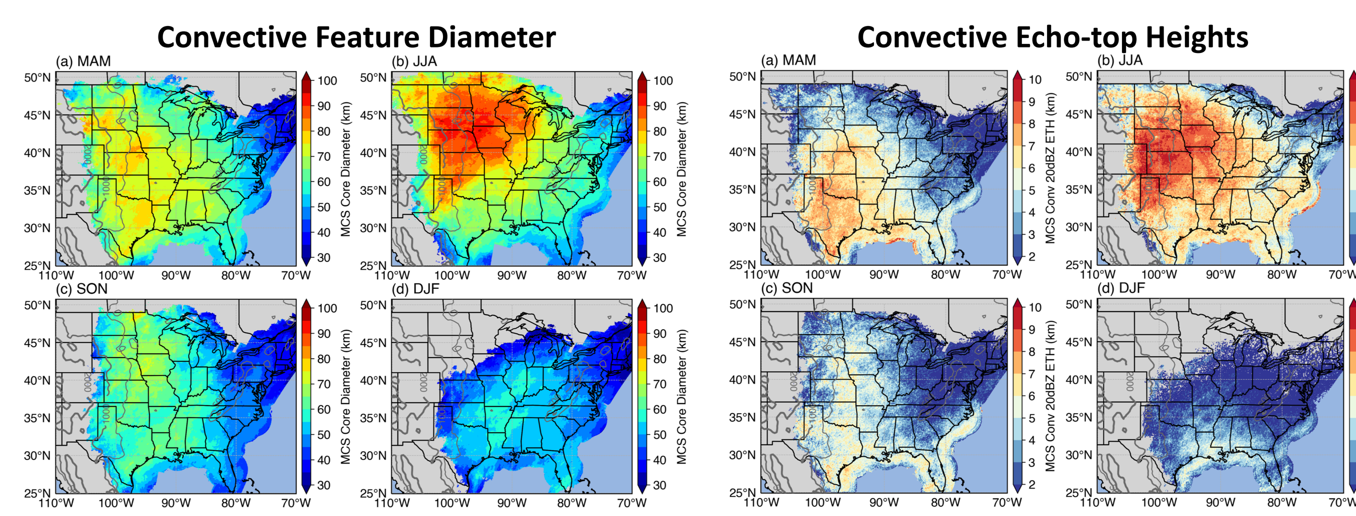
- Long-lived and intense MCSs 3-D characteristics and their large-scale environments are summarized below:

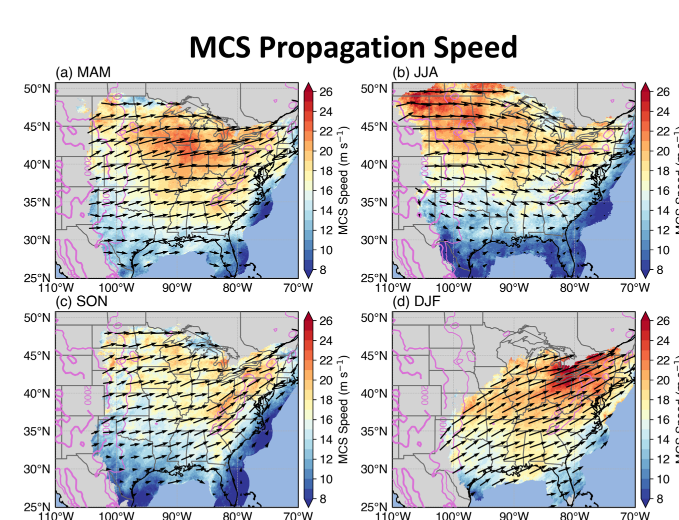
	Large-scale Environments	MCS Diurnal Cycle	Key MCS Characteristics
Spring / Fall	Strong dynamics + thermodynamics: deep trough, strong LLJ moisture transport, low-level convergence	Nocturnal maximum rainfall, but convection not always surface triggered	Rain volume: high Conv. features: large & deep Strat. area: large
Summer	Weakest baroclinic forcing: weak convergence acts on warm and humid environment	Strongest nocturnal maxima rainfall, surface triggering in afternoon	Rain volume: low Conv. features: largest & deepest Strat. area: smallest
Winter	Strongest baroclinic forcing: Strong low-level convergence brings large moisture anomaly to overcome weak thermodynamic support	No diurnal cycle	Rain volume: highest Conv. features: smallest & weakest Strat. area: largest

3-D MCS Characteristics

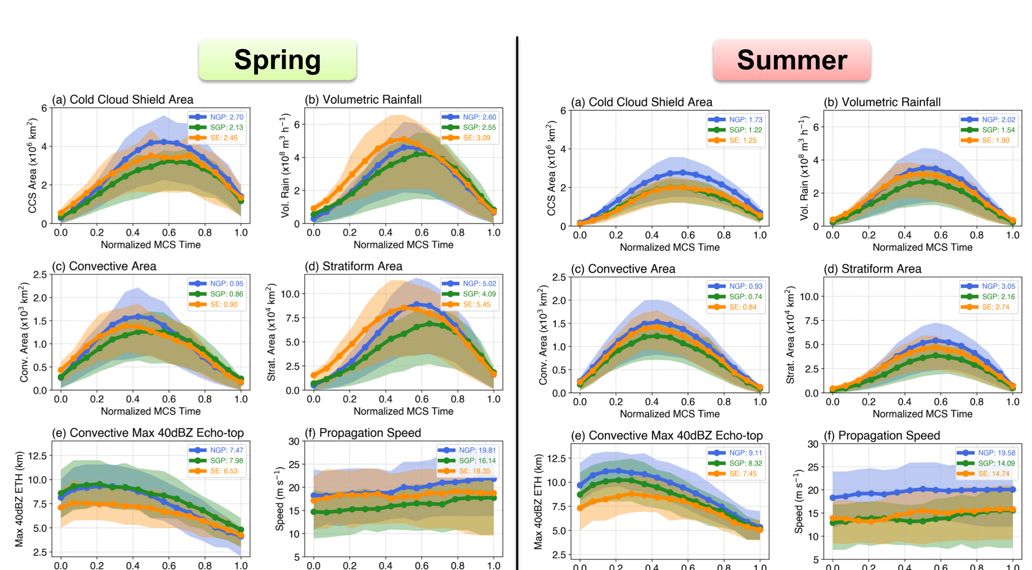


- **Summer:**
  - Smallest PF (stratiform rain), largest & deepest convective features
- **Winter:**
  - Largest PF (stratiform rain), weakest convective features
- **Spring and Fall:**
  - In between, larger PF east of 90°E





- NGP region has fastest propagation speed (15-20 m/s) in warm seasons
- Propagation direction likely correlates with mid-level winds (400~500 hPa)
- Winter MCSs also have fast propagation speed north of 35°N, consistent with strong frontal system background winds



- Spring MCSs are larger and produce more vol. rain, have larger stratiform area than summer
- SE MCSs are more rainy in spring, but NGP MCSs are larger and more rainy in summer

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