Mesoscale Convective Systems in Northeastern North America: identification and evaluation with the Canadian Regional Climate Model (CRCM6)

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Introduction

- Mesoscale Convective Systems (MCSs) contribute significantly to warm-season precipitation, accounting for 30-70% of total and extreme rainfall in parts of the central and eastern United States [2, 3].
- Responsible for meteorological hazards at regional and local scales in the mid-latitudes and the tropics.
- Research on MCS has been limited in northeastern Canada, resulting in a lack of comprehensive knowledge of their characteristics, contribution to precipitation, and associated extreme events.

Objective: Evaluation of the CPM CRCM6-2.5km model to represent the characteristics and patterns of MCS in northeastern North America.

Data and Methods

The Python-based MCS tracking algorithm, developed by [4] and modified by [1], integrates brightness temperature (BT) and precipitation (PR) data. The algorithm applies thresholds requiring PR ≥ 5 mmh^{-1}, BT ≤ 241 K, an area ≥ 1,000 km^2, and a lifetime ≥ 4 hours to define an MCS. A major axis length of 100–1,000 km ensures systems are mesoscale rather than synoptic. These criteria identify spatially and temporally connected systems with robust precipitation and cloud-top signatures.

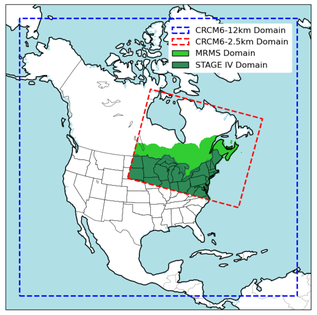


Figure 1. CRCM simulation domains for the 12 km (blue line) and the 2.5 km (red line) versions. Observed data availability is shown in green regions.

Table 1. Description of the data used over STAGE IV domain from 2015-2022.

Data	Δx (km)	Δt	Variables
CRCM6-12 km	≈ 12 km	1-h	PR, OLR
CRCM6-2.5 km	≈ 2.5 km	1-h	PR, OLR
ERA5	≈ 31 km	1-h	PR, OLR
IMERG	≈ 11 km	30-min	PR
MERGIR	4 km	30-min	BT
STAGE IV	4 km	1-h	PR
MRMS	1 km	1-h	PR

Results

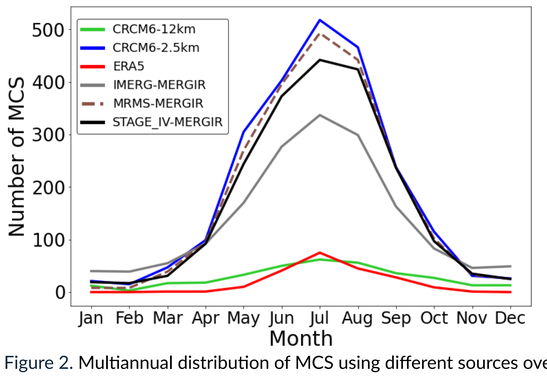


Figure 2. Multiannual distribution of MCS using different sources over STAGE IV domain (dark green area in Fig. 1). The first name in the source represents the origin of the PR data, while the second name indicates the source of the BT data.

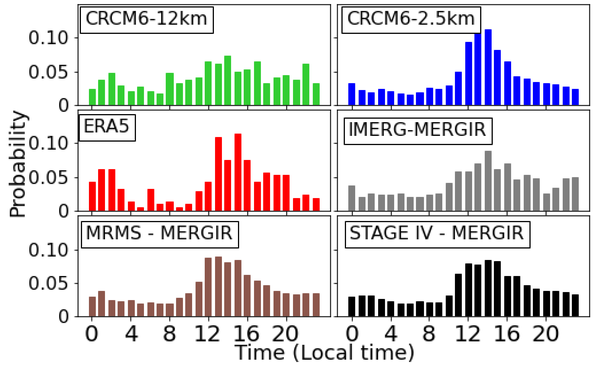


Figure 3. Histogram of MCS initiation time frequencies (relative to total events) over STAGE IV domain (dark green area in Fig. 1) using different data sources.

Results

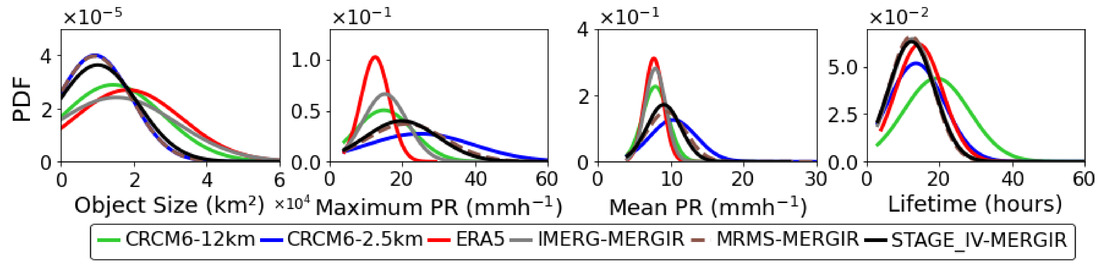


Figure 4. Probability Density Functions (PDF) for the hourly size (a), maximum and mean precipitation, and lifetime of the MCS over STAGE IV domain (dark green area in Fig. 1).

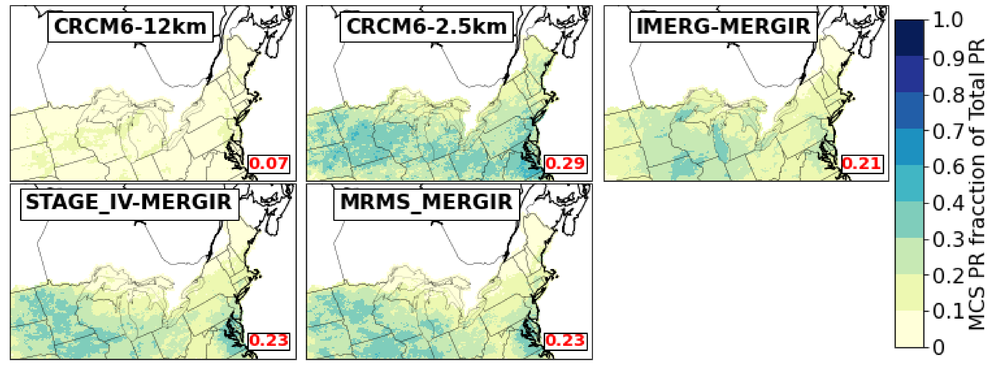


Figure 5. Fraction of total precipitation from MCS during summer (JJA) over STAGE IV domain (dark green area in Fig. 1).

Conclusions

- Radar observations data (MRMS AND STAGE IV) shows that MCS events are most frequent from June to September, accounting for an average of 23% of summer precipitation. It also highlights a clear diurnal cycle in initiation times and a relatively large proportion of small, short-duration systems, with high precipitation rates.
- Lower-resolution products, such as ERA5 and CRCM6-12km, struggle to accurately simulate the fine-scale details of weather phenomena like MCS events, particularly their intense precipitation, resulting in a poor representation of key MCS characteristics.
- The CRCM6-2.5km model agrees well with radar data regarding the frequency, size, and intensity of MCSs, including the diurnal cycle of their initiation times. However, CRCM2.5 slightly overestimates the mean and maximum precipitation intensity of MCSs.

Next Steps: Further investigation into the relationship between MCSs, extreme precipitation, and wind events. Under various climate scenarios, assess the future in MCS dynamics, including precipitation and wind patterns.

References

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