Lifecycle Of Convective Precipitation Systems over the Arabian Peninsula Using Object Tracking

Ahmed Homoudi[1], Klemens Barfus[2], Christian Bernhofer[1], and Matthias Mauder[1]

1. Introduction

Convective precipitation is the primary source of freshwater and groundwater recharge in the arid Arabian Peninsula (AP). Therefore, it is crucial to study convective precipitation systems (PSs) from a Lagrangian perspective using object-tracking methods. These methods can:

a) Provide detailed information on the current state of PSs in the AP.
b) Offers insights into the lifecycle of convective PSs, helping in improving flashflood modelling.
c) Create a reference for evaluating convective-permitting simulations, thereby helping to address the double penalty problem.

2. Methodology

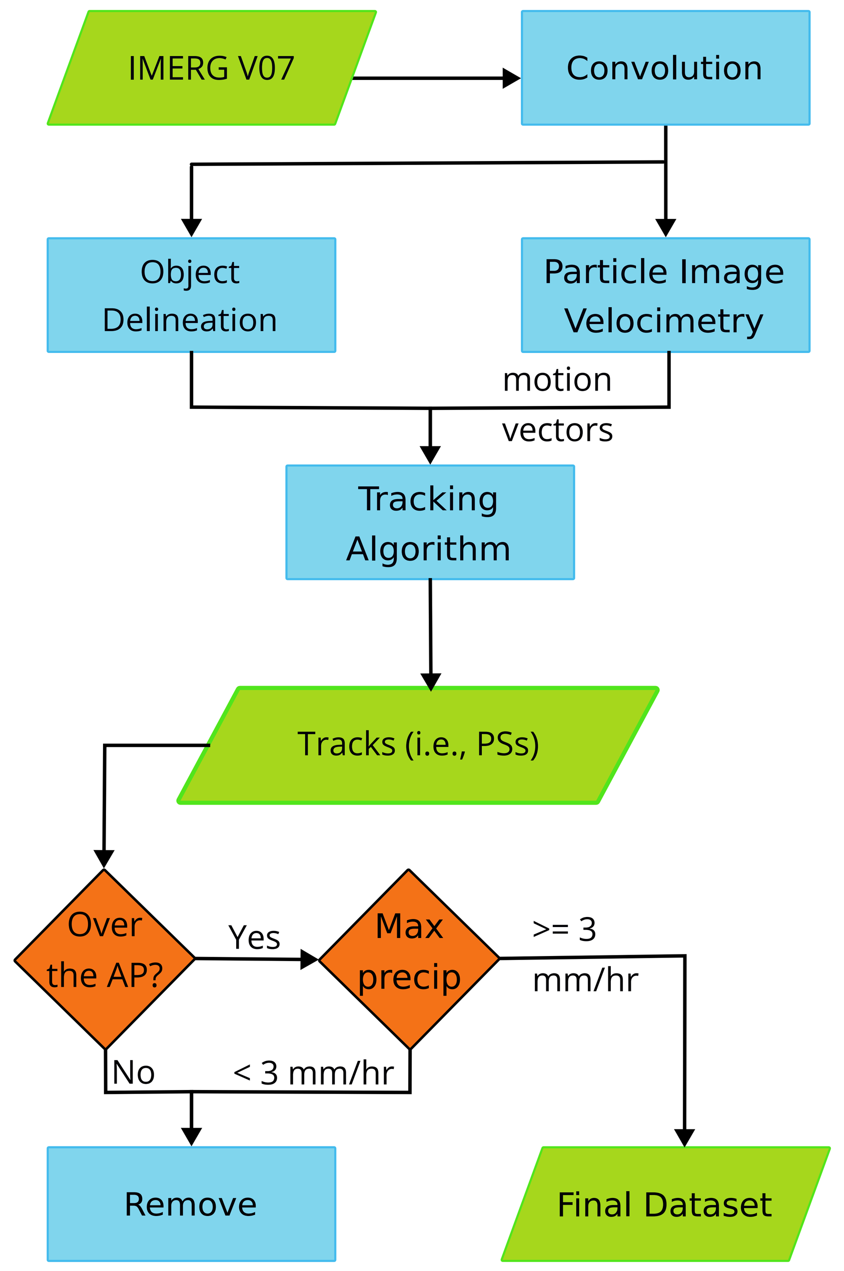

Fig 1: Flowchart of the object-tracking algorithm.

a) The object-tracking method, illustrated in Fig 1, is based on the work of Seelig et al. (2021, 2023), where it combines overlapping and centroid projection techniques. The object's centre is projected at the following timestep using displacement vectors obtained from particle image velocimetry.

b) Objects are delineated using a threshold of 0.5 mm/hr in the convoluted space.

c) The method considers merging and splitting during the system's lifetime.

d) We apply hierarchical agglomerative clustering to the object-based properties of PSs; these properties are averaged along the PS track.

3. Results

By analysing 24 years of the IMERG V07 data, we found three types of convective PSs in the AP.

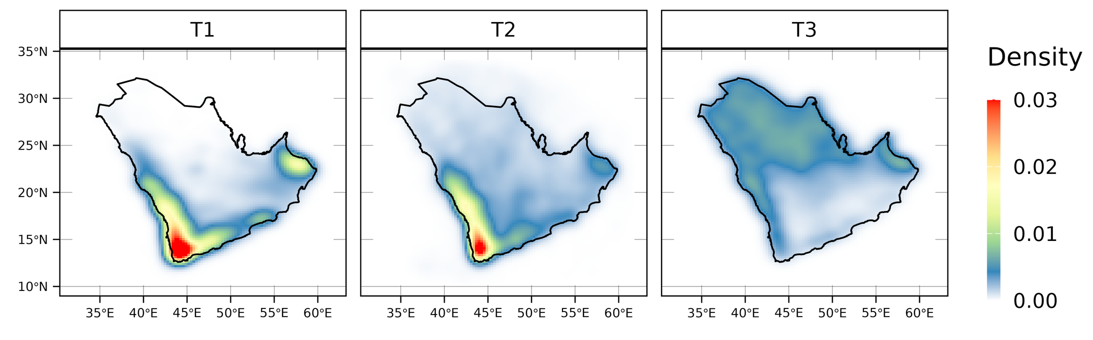

Fig 2: Spatial distribution of the types of convective precipitation systems in the AP.

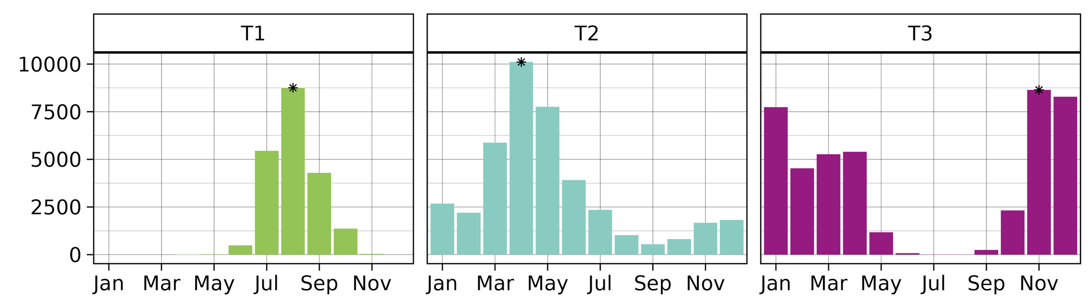

Fig 3: Monthly distribution of convective precipitation systems for different types. The asterisk indicates peaks.

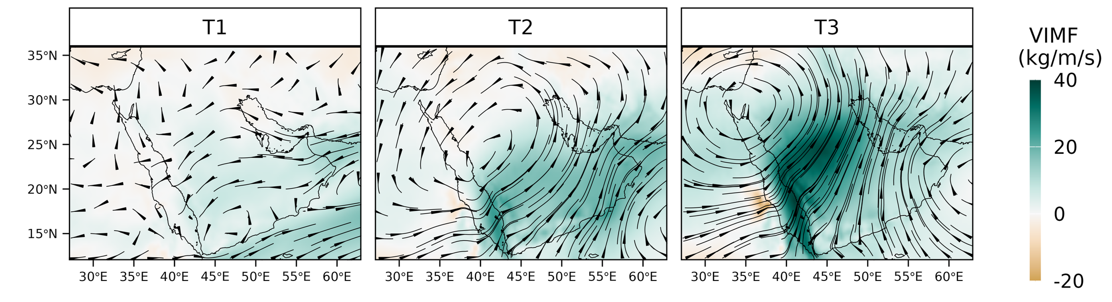

Fig 4: Composite daily anomalies of vertically integrated moisture flux (1000 hPa to 300 hPa) for the convective precipitation systems.

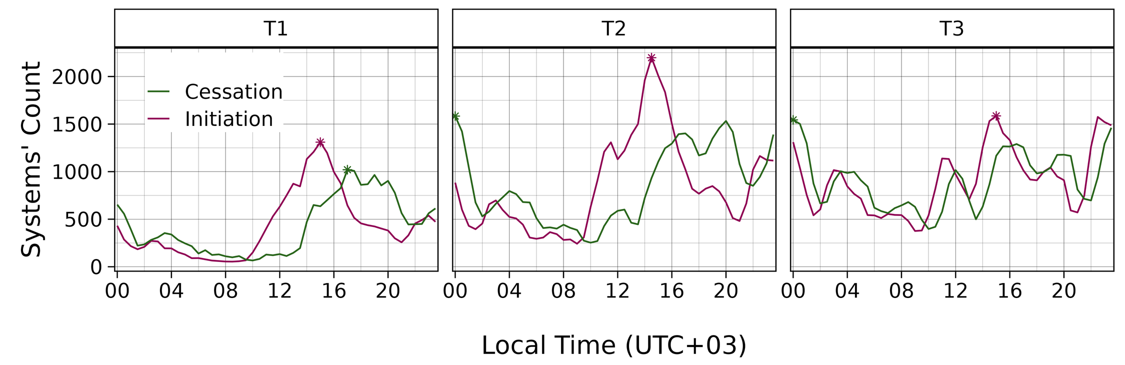

Fig 5: Diurnal cycle of convection initiation and cessation for the convective precipitation systems in the AP. The asterisk indicates the peaks.

- T1 systems can last up to 24 hours.

- T3 systems have a maximum duration of 20 hours.

- Both T1 and T3 show similar development to T2 systems, as shown in Fig 6.

- Maximum precipitation, area, and volume of the systems rapidly develop until they reach a peak around the system's mid-life; afterwards, they degenerate gradually.

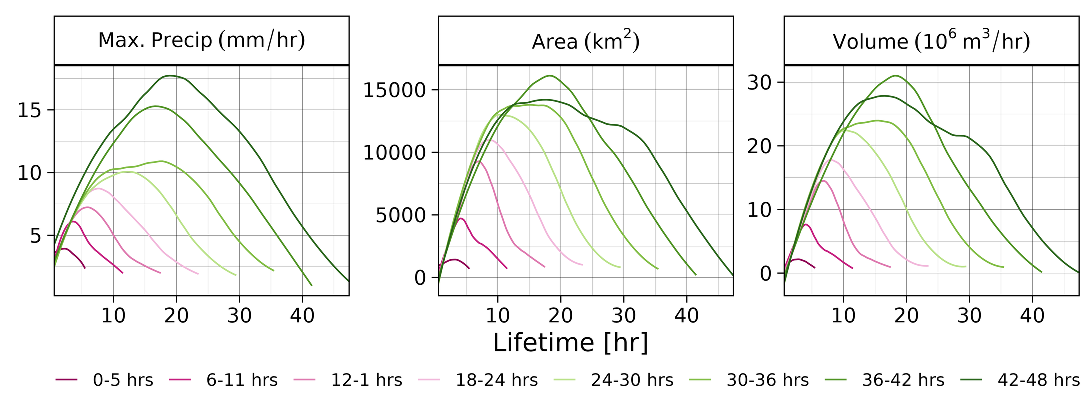

Fig 6: Evolution of T2 systems maximum precipitation, area, and volume sorted by different durations of a lifetime.

4. Conclusions

a) The Indian monsoon influences T1 systems, while T2 systems are modulated by extratropical-tropical moisture transport.

b) T3 systems are mainly affected by midlatitude cyclones entering the AP in the colder months.

c) Convection initiation peaks during the afternoon for T1 and T2 systems, while T3 systems show multiple peaks during the day.

d) T2 systems are characterised by the longest lifetimes, most extensive spatial coverage, highest intensities, and the greatest total rain volume compared to other types. They can bring up to 60% of the annual rainfall in Saudi Arabia (Loung et al., 2020).

e) Systems lasting less than 24 hrs show a peak in precipitation, followed by volume, then an area, agreeing with Takahashi et al. (2021), Inoue et al. (2009), and Moseley et al. (2013).

f) Further investigation of the underlying thermodynamic condition of the convective systems is recommended.

5. References

Inoue, T., Vila, D., Rajendran, K., Hamada, A., Wu, X. & Machado, L.A.T. (2009) Life Cycle of Deep Convective Systems over the Eastern Tropical Pacific Observed by TRMM and GOES-W. *JMSJ*. Ser. II, 87A, 381–391. DOI:10.2151/jmsj.87A.381.

Luong, T.M., Dasari, H.P., Doan, Q.V., Alduwais, A.K. & Hoteit, I. (2024) Organized precipitation and associated large-scale circulation patterns over the Kingdom of Saudi Arabia. *Int. J. Climatol.*, 44(10), 3295–3314. DOI: 10.1002/joc.8524.

Moseley, C., Berg, P. & Haerter, J.O. (2013) Probing the precipitation life cycle by iterative rain cell tracking. *J. Geophys. Res. Atmos.*, 118(24), 13,361–13,370. DOI:10.1002/2013JD020868.

Seelig, T., Deneke, H., Quaas, J. & Tesche, M. (2021) Life Cycle of Shallow Marine Cumulus Clouds From Geostationary Satellite Observations. *J. Geophys. Res. Atmos.*, 126(22). DOI:10.1029/2021JD035577.576.

Seelig, T., Müller, F. & Tesche, M. (2023) Do Optically Denser Trade-Wind Cumuli Live Longer? *Geophys. Res. Lett.*, 50(13), 1–8. DOI: 10.1029/2023GL103339.

Takahashi, H., Lebsock, M., Luo, Z.J., Masunaga, H. & Wang, C. (2021) Detection and tracking of tropical convective storms based on globally gridded precipitation measurements: Algorithm and survey over the tropics. *J. Appl. Meteorol. Climatol.*, 60(3), 403–421. DOI:10.1175/JAMC-D-20-0171.1.

Affiliation:

1 TUD Dresden University of Technology, Institute of Hydrology and Meteorology, Meteorology, Dresden, Germany

2 Independent Researcher, Dresden, Germany

Contact:

Ahmed Homoudi
ahmed.homoudi@tu-dresden.de

https://orcid.org/0000-0001-6906-5986