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Investigation of Mediterranean Cyclones and Their Contribution to Heavy Precipitation in North Africa Using ERA5

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INTRODUCTION & AIM

Mediterranean cyclones play a vital role in shaping rainfall patterns and intensities across North African countries, especially along their Mediterranean coastlines. These cyclonic systems are most active during the winter months and serve as a primary driver of seasonal precipitation in otherwise arid and semi-arid regions. While such rainfall can alleviate drought conditions and replenish essential water resources, it also poses significant risks. When these systems intensify, they can lead to hazardous weather events, including flash floods, infrastructure damage, and agricultural disruption. In the Mediterranean region, a great number of precipitation events were triggered by cyclonic circulation patterns. The extra tropical cyclonic circulation patterns are frequently associated with wind, heavy precipitation and changes in temperature , generating high risk situations such as flash floods and large-scale floods with significant impacts on human life and built environment

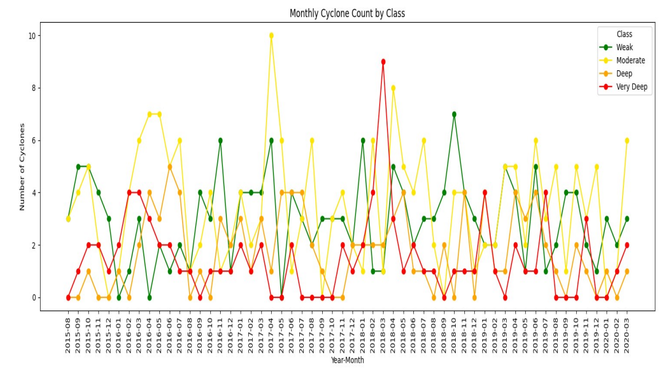
In this study, we analyze several Mediterranean cyclones that have caused extreme precipitation events over North Africa to better understand their characteristics and associated impacts. Specifically, we examine the structural evolution of these cyclones, detecting and tracking cyclonic systems, including their spatial extent, lifespan, and the synoptic-scale pressure systems that accompany them. This integrated approach allows us to identify key meteorological patterns and mechanisms that contribute to extreme rainfall events in the region, providing insights essential for improving future forecasting and climate resilience strategies.

METHOD

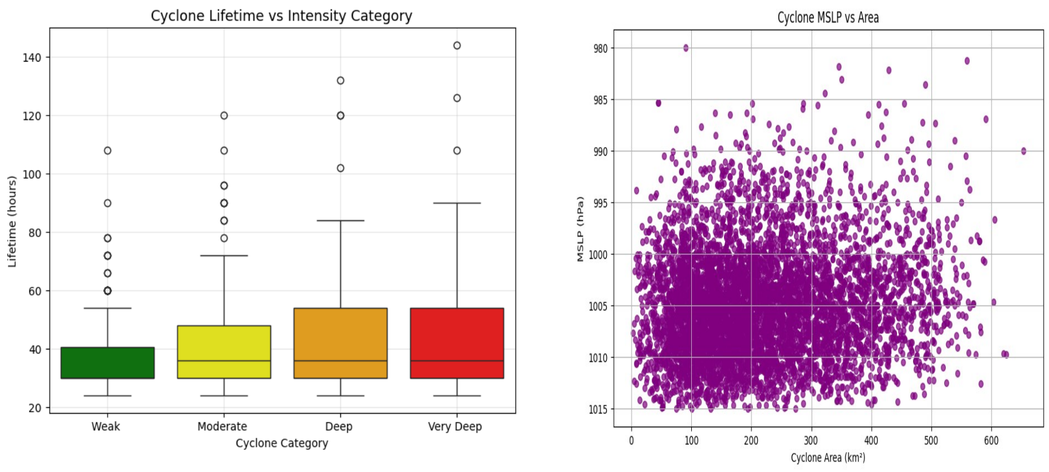
- **Domain:** Mediterranean basin with focus on coastal North Africa (approx. 20°–36°N, 10°W–40°E). The study focused on five North African regions along the north coast, defined by the following latitude and longitude bounds: Morocco (-10° to -1.5° E, 29° to 39° N), Algeria (-1.5° to 8° E, 29° to 39° N), Tunisia (8° to 12° E, 29° to 39° N), Libya (12° to 25° E, 29° to 36° N), and Egypt (25° to 35.5° E, 29° to 36° N).

- **Data:** Mean sea level pressure, Wind at 10-meter, geopotential height(200, 250, 300,350, 400, 450,500, 550, 600,650, 700, 750,800, 850, 900,950) every 6hours and hourly precipitation from ERA5 reanalysis used for 2015–2020.
- **Software:** Cyclone detection & tracking : We used the CyTRACK cyclone-tracking system [1].
- **Methods:**
  - Build a climatology of Mediterranean cyclones affecting North Africa over more than 5 years.
  - Analyze temporal and spatial trends in cyclone frequency, intensity, and size.
  - Hourly ERA5 precipitation was resampled to monthly sums using Python.
  - A Python-based analysis algorithm was developed to process CyTRACK output data, extract ERA5 precipitation, and compute all cyclone statistics.
  - Cyclone classification using MSLP:

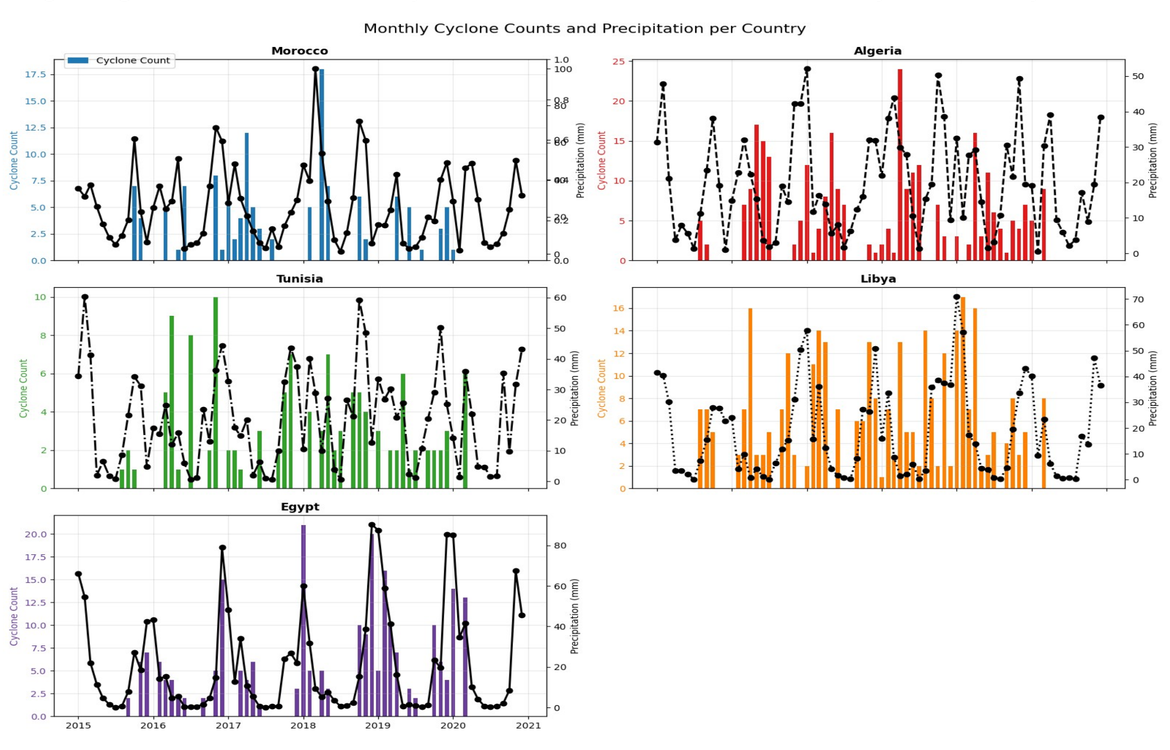
Classification	MSLP threshold
Very Deep	< 995 hPa
Deep	995–1000
Moderate	1000–1005
Weak	>1005



For each month, the total number of cyclones in each intensity category was calculated to examine the seasonal distribution and variability of cyclone activity.

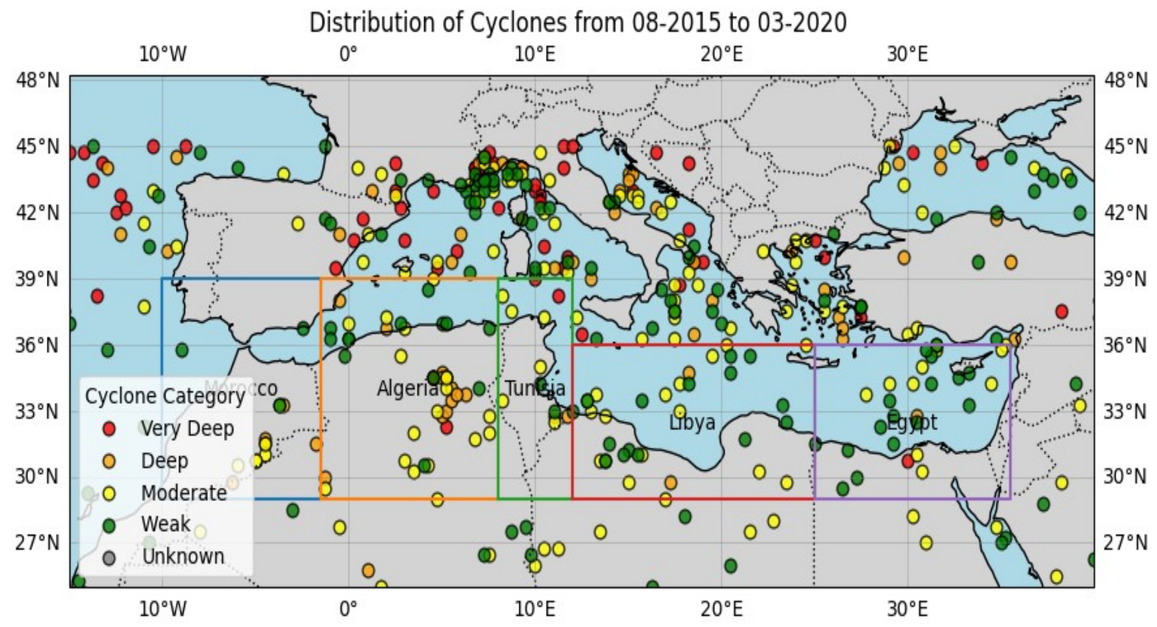


Left Fig.: The lifetime of each Mediterranean cyclone was calculated from its first to last detection in the tracking dataset. The relationship between cyclone lifetime and intensity was then analyzed to assess whether more intense cyclones tend to persist longer.
Right Fig.: The distributions of cyclone area and MSLP were then analyzed for all cyclones



Total number of cyclones each month (colored columns) for each North African country along the Mediterranean coast (Morocco, Algeria, Tunisia, Libya, and Egypt), with the average monthly precipitation (black line) from ERA5 reanalysis data.

RESULTS & DISCUSSION



Distribution of Mediterranean cyclones over North Africa categorized by intensity, with the total count of cyclones indicated for each region during 2015-2020.

CONCLUSION

- Mediterranean cyclones (MCs) are predominantly weak and moderate, while deep and very deep cyclones are rare.
- Most cyclones have a lifetime of less than 140 hours. Weak cyclones exhibit the shortest lifetimes, whereas deep and very deep cyclones generally persist longer.
- Cyclone extent is mostly between 100–400 km. Minimum mean sea level pressure (MSLP) ranges from 1000–1015 hPa, with lower pressures corresponding to higher intensity cyclones.
- Algeria experience more frequent cyclones, while Egypt shows the strongest correlation between cyclone activity and precipitation.

FUTURE WORK

Quantify the rainfall contribution of Mediterranean cyclones during more than 10 years.

REFERENCES

[1]-Albenis Pérez-Alarcón, Patricia Coll-Hidalgo, Ricardo M. Trigo, Raquel Nieto, Luis Gimeno,CyTRACK: An open-source and user-friendly python toolbox for detecting and tracking cyclones, Environmental Modelling & Software, Volume 176,2024,106027,ISSN 1364-8152,https://doi.org/10.1016/j.envsoft.2024.106027