Emília Dolgos, Judit Bartholy, Rita Pongrácz*
ELTE Eötvös Loránd University, Institute of Geography and Earth Sciences
Department of Meteorology, Budapest, Hungary

1. INTRODUCTION

Mid-latitude cyclones form an essential part of large-scale atmospheric circulation pattern, and their evolution, intensity, trajectory, and associated weather events (e.g., extreme precipitation, consequent floods, etc.) are all important from a local/regional point of view (e.g., Trigo et al., 1999, Lionello et al., 2006, Bartholy et al., 2009). In this study, we focus on the Mediterranean region where mid-latitude cyclones are fundamental factors in the weather and climate conditions in the region (Flaounas et al., 2016). Since the Mediterranean region is considered as one of the most vulnerable areas to climate change (IPCC, 2021), this region calls for special attention. To mitigate the effects of future climate change and to develop suitable adaptation strategies it is necessary to have a clear and detailed understanding of Mediterranean cyclones and their characteristics. The main goals of this study are as follows:

- Detect changes in cyclone characteristics (frequency, intensity, duration) for the 20th and 21st centuries using reanalysis data.
- Evaluate future trends based on different climate scenarios (RCP and/or SSP scenarios upon availability) using GCM simulation data.
- Evaluate the effects of Mediterranean cyclones over the Carpathian basin with a special focus on precipitation.

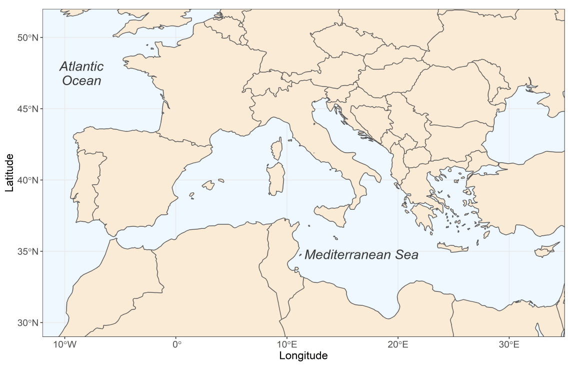

Fig. 1: Study area covering most of the Mediterranean Sea, North Africa, and the southern and middle regions of the continental Europe.

For this purpose, we selected the western part of the Mediterranean region as the target area, namely, the domain covering the region 29°N–52°N and 12°W–35°E (Fig. 1). The data used in this study is the ECMWF reanalysis database ERA-20C (Poli et al., 2016), which provides data from 1900 to 2010 with a spatial resolution of 1°.

2. CYCLONE DETECTION

Cyclone identification is possible by finding local minimum or maximum in meteorological fields (e.g. pressure, relative vorticity, geopotential height, as used in Kelemen et al. (2015) for instance). In this study we search for local minima in the mean sea level pressure (MSLP) field to identify low pressure systems leading to cyclone centers. The temporal resolution of this field is 6-hour. The detection area is covered by 8°×8° sized windows, so altogether 18 detection windows are used with no overlapping areas between them. Within each detection window area, the minimum pressure values and their locations are identified. Additional criteria are as follows:

- the MSLP is lower than 1013 hPa,
- the neighbouring gridcells of the minimum do not have higher values of MSLP.

The second criterion is important when the detected minimum value is located at the edge of the detection window.

If these criteria are not met, then the detected minimum is dismissed as a local minimum as well, as a possible cyclone center.

The algorithm is coded in R, which is an often used tool for statistical analysis (R Core Team, 2022).

3. PRELIMINARY RESULTS

The cyclone detection algorithm is tested for one specific month, namely, January 2010. In this month eight separate low-pressure events are identified over the Mediterranean region. One of them occurred during 7-10 January. According to the ERA-20C reanalysis data the lowest central pressure was 992 hPa during this event. The 72-hour total precipitation exceeded 50 mm in some regions (Fig 2).

* *Corresponding author address*: R. Pongracz, Dept. of Meteorology, Eötvös Loránd University, Pázmány st. 1/a. Budapest, H-1117; Hungary; e-mail: pongracz.rita@ttk.elte.hu

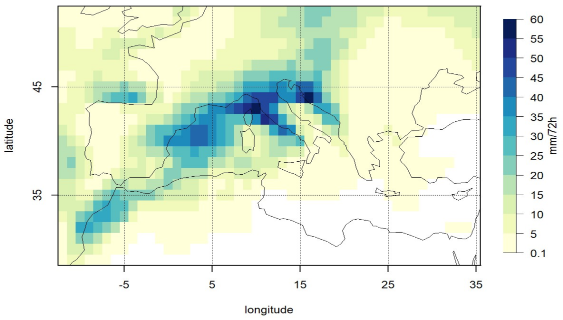

Fig. 2: Total precipitation between 2010-01-07 9 UTC and 2010-01-09 9 UTC during a cyclone event in the study area.

An example is shown for the first part of this event with 6-hr timesteps in Fig. 3. The cyclone entered the Mediterranean region from the Atlantic Ocean through the Strait of Gibraltar. From here, the cyclone deepened while moving in a north-easterly direction. The snowstorms brought on by the cyclone caused disruptions in several European countries. Flights had to be cancelled in Switzerland and Germany, while in Poland the snow caused power cuts (https://www.ncei.noaa.gov/access/monitoring/monthly-report/hazards/201001). It caused snowfall, sleet, rain in Hungary. In the western part of Hungary some synoptic stations detected 17 mm of precipitation within 24 hours (https://www.met.hu/idojaras/aktualis_idojaras/napijelentes_2005-2019/).

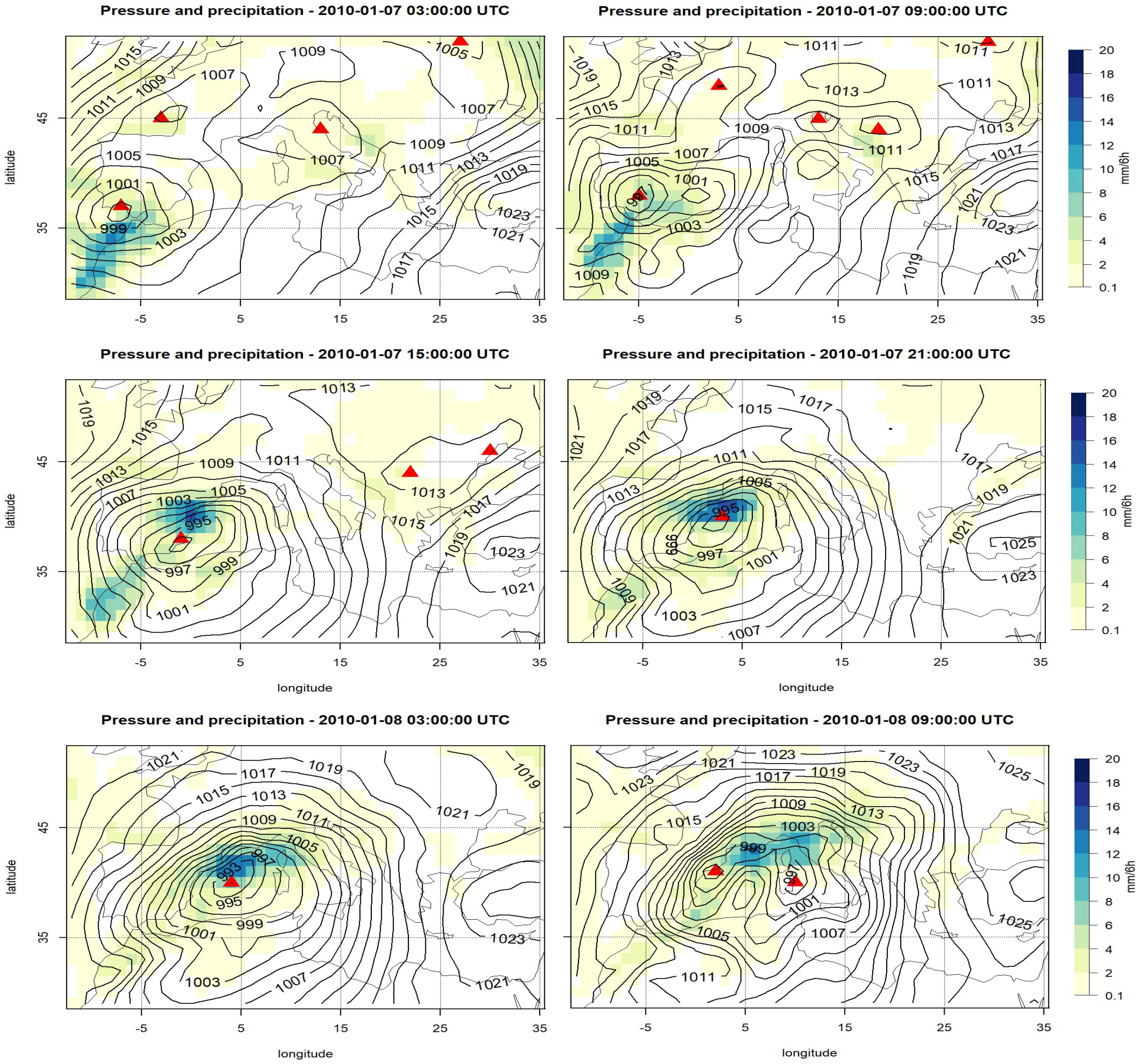

Fig. 3: Isobars (black lines), 6-hour precipitation (color scale) and detected potential cyclone centers (red triangles) for a Mediterranean cyclone event between 2010-01-07 3 UTC and 2010-01-08 9 UTC.

Based on the isobars not all of the detected minima can be considered as cyclone centers. It is very apparent in the first three time steps. After completing the development of the tracking algorithm, it is possible to eliminate such „false” cyclone centers.

4. FUTURE PLANS AND STEPS

The next step in the study will be to develop the tracking of the identified potential cyclones using the nearest neighbour algorithm (Kelemen et al., 2015). A possible cyclone center will be chosen and compared to the centers detected in the following timestep. With the finalized tracking algorithm, we will be able to filter out cyclones with too short lifespans. The cyclone tracking is still under development, several methods are being tested with different conditions. This is necessary because the conditions chosen will have a major influence on the results of future statistical analysis (Neu et al., 2013). After the cyclone detection and tracking algorithms are finalized, we will carry out a thorough statistical analysis for past events, and also for the future. For this purpose GCM simulations will be selected from the CMIP6 database (Eyring et al., 2016). To get the most accurate results the following criteria will be used during the selection of the GCM simulations:

- availability of historical and RCP/SSP scenario simulations,
- spatial resolution: at least 100 km,
- total precipitation data: at least with daily resolution,
- horizontal wind components data: at least with 6 hourly temporal resolution,
- MSLP: at least 6 hourly temporal resolution.

The ultimate goal of the whole research is to connect frontal systems and precipitation zones to the Mediterranean cyclones. Hence to get a clearer picture how precipitation patterns will change in the future depending on the scenario, in the target region, and especially in the Carpathian basin.

Acknowledgements. The study contributes to the COST CA19109 action (MEDCYCLONES). Research leading to this study has been supported by the following sources: the Hungarian National Research, Development and Innovation Fund (under grants K-120605 and K-129162), and the National Multidisciplinary Laboratory for Climate Change (RRF-2.3.1-21-2022-00014).

HUNGARIAN NATIONAL LABORATORY
NATIONAL RESEARCH, DEVELOPMENT AND INNOVATION OFFICE
MINISTRY FOR INNOVATION AND TECHNOLOGY

REFERENCES

Bartholy, J., Pongrácz, R., Pattantyús-Ábrahám, M., 2009. Analyzing the genesis, intensity, and tracks of western Mediterranean cyclones. *Theoretical and Applied Climatology,* 96(1-2), 133–144. https://doi.org/10.1007/s00704-008-0082-9

Eyring, V., Bony, S., Meehl, G.A., Senior, C.A., Stevens, B., Stouffer, R.J., Taylor, K.E., 2016. Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization, *Geoscientific Model Development,* 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016

Flaounas, E., Di Luca, A., Drobinski, P., Mailler, S., Arsouze, T., Bastin, S., Beranger, K., Brossier, C.L., 2016. Cyclone contribution to the Mediterranean Sea water budget. *Climate Dynamics,* 46(3-4), 913–927. https://doi.org/10.1007/s00382-015-2622-1

IPCC, 2021. *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391p. https://doi.org/10.1017/9781009157896

Kelemen, F.D., Bartholy, J., Pongrácz, R., 2015. Multivariable cyclone analysis in the Mediterranean region. *Quarterly Journal of the Hungarian Meteorological Service Időjárás*, 119(2), 159–184. https://doi.org/10.28974/idojaras.2015.2.3

Lionello, P., Bhend, J., Buzzi, A., Della-Marta, P., Krichak, S.O., Jansà, A., Maheras, P., Sanna, A., Trigo, I., Trigo, R., 2006. Cyclones in the Mediterranean Region: Climatology and Effects on the Environment (Chapter 6). In: Lionello, P., Malanotte-Rizzoli, P., Boscolo, R. (eds.) *Mediterranean climate variability*. – Developments in earth & environmental sciences: Vol. 14 Elsevier, Amsterdam, The Netherlands. 325–372.

Neu, U., Akperov, M.G., Bellenbaum, N., Benestad, R., Blender, R., Caballero, R., Cocozza, A., Dacre, H.F., Feng, Y., Fraedrich, K., Grieger, J., 2013. IMILAST: A community effort to intercompare extratropical cyclone detection and tracking algorithms. *Bulletin of the American Meteorological Society*, 94(4), 529–547. https://doi.org/10.1175/BAMS-D-11-00154.1

Poli, P., Hersbach, H., Dee, D.P., Berrisford, P., Simmons, A.J., Vitart, F., Laloyaux, P., Tan, D.G.H., Peubey, C., Thépaut, J., Trémolet, Y., Hólm, E.V., Bonavita, M., Isaksen, L., Fisher, M., 2016. ERA-20C: An Atmospheric Reanalysis of the Twentieth Century. *Journal of Climate*, 29(11), 4083–4097. https://doi.org/10.1175/JCLI-D-15-0556.1

R Core Team, 2022. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Trigo, I.F., Davies, T.D., Bigg, G.R., 1999. Objective climatology of cyclones in the Mediterranean region. *Journal of climate*, 12(6), 1685–1696. https://doi.org/10.1175/1520-0442(1999)012<1685:OCOCIT>2.0.CO;2