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Prethodno priopćenje
Preliminary contribution

A PRELIMINARY CASE STUDY OF THE POSSIBLE ADRIATIC TROPICAL-LIKE CYCLONE FROM THE 21ST OF JANUARY 2023

Preliminarna analiza mogućeg slučaja jadranske ciklone tropskih karakteristika od 21. siječnja 2023.

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Abstract: This short article addresses a preliminary study of transient subsynoptic cyclonic behavior over a broader area of the Adriatic Sea. The January 2023 case presented here shows a transition from an extratropical Mediterranean cyclone into a partially tropical-like cyclonic system (TLC) over the south and central Adriatic Sea. The warm barotropic core, cyclonic "eye" and relatively symmetric precipitation bands around the vortex were the main TLC properties of this system. In the short analysis of the event, the assumption is made that size limitations of the Adriatic basin prevented development of the system into a full-strength "medicane". Hence, such vigorous small-scale cyclones just might be named "adricanes". Presentation of this case contributes to the relatively scarce research of these rare Adriatic TLC events. The criteria for cyclonic system classification as TLC or extratropical are also discussed, with the supporting idea of a spectrum between fully tropical and fully extratropical cyclones (instead of binary classification), where the particular system can fall anywhere in between, depending on the ratio of tropical and extratropical properties it possesses.

Key words: TLC, medicane, adricane, adriatic cyclone

Sažetak: Ovaj kratki rad prikazuje preliminarno istraživanje ponašanja podsinoptičkog ciklonalnog sustava nad širim područjem Jadranskog mora. Prezentiran slučaj iz siječnja 2023. pokazuje prijelaz iz izvantropske mediteranske ciklone u ciklonalni sustav djelomično tropskih karakteristika nad južnim i srednjim Jadranom. Topla barotropna jezgra, ciklonalno "oko" i relativno simetrične oborinske pruge oko vrtloga bile su glavne tropske karakteristike ovog sustava. U kratkoj analizi slučaja postavljena je pretpostavka da je ograničen akvatorij Jadranskog mora bio prepreka razvoju sustava u "*medicane*" pune snage. Predlaže se i novi naziv za takve male ali žestoke ciklonalne sustave u Jadranu – engl. "*adricane*". Prezentacija ovog slučaja doprinos je relativno slabo istraženim "mediteranskim tropskim ciklonima" u Jadranu. Razmatrani su i kriteriji za klasifikaciju sličnih sustava u nalik-tropske ili izvantropske, te je podržana ideja o spektru između potpuno tropskih i potpuno izvantropskih ciklonalnih sustava (umjesto binarne klasifikacije), gdje pojedini ciklonalni sustav može biti bilo gdje između ova dva ekstrema spektra, zavisno od omjera njegovih tropskih i izvantropskih obilježja.

Ključne riječi: mediteranski tropski cikloni, medicane, adricane, jadranske ciklone

1. INTRODUCTION

One of the emerging areas of scientific focus in mesoscale meteorology is the morphology and development of Mediterranean Sea cyclonic systems that may partially exhibit tropical-like features. Owing to their similarities with tropical storms and cyclones, they are called medicanes (MEDIterranean hurriCANES, Emanuel (2005)), MTLCs (Mediterranean Tropical-Like Cyclones, Cavicchia et al., 2014), or shorter TLCs (e.g., Horvath et al., 2008; Rizza et al., 2018). Needless to say, the onset, evolution, mature phase, and cessation of such vigorous cyclones, that is, TLCs are not easy to predict, including their (re)transformation to typical extratropical cyclones.

Among numerous other similarities, TLCs share one of the main features with tropical cyclones – their dependency on moisture fluxes from the sea surface for the development and sustainability of their life cycle (e.g., Emanuel, 2005; Miglietta et al., 2023). As a result, a sufficiently large body of water with sufficiently high sea surface temperature (SST), compared to the overlying air temperature, is required for the occurrence and presence of TLC. Up to a certain point in the scientific literature, it was not even clear if these systems could appear in smaller basins such as the Black Sea or even the Adriatic Sea (Horvath et. al., 2008). Among the first indications that the genesis of TLCs is possible in the farthest southern part of the Adriatic Sea, dates from Cavicchia et al. (2013), where a 10 km horizontal resolution mesoscale model was used as a basis for the development of a system for automatic detection of TLCs in the period of 1948–2011. It should be noted that the detection of TLCs within the analysis of historical data depends not only on the ability of the numerical model to accurately simulate TLC events, but also on the set of chosen algorithm criteria for their automatic, computer-based detection. Because of this, some TLCs would inevitably be missed, and some false-positive warnings could be expected from the results of such algorithms. For instance, the analysis of Miglietta et al. (2023) shows in a detailed case study how a vigorous cyclonic vortex over the Adriatic, although with a somewhat warm core, was not a type of TLC. In contrast, Cioni et al. (2016), Rizza et al. (2018) and Ricci et al. (2019) unquestionably show by analysing two other separate case studies (September 2006 and January 2014) the presence of the TLC over the southern and central Adriatic Sea.

The aim of this preliminary study was to present immediate and compelling evidence of the most likely recent TLC over the Adriatic Sea, which occurred on January 21, 2023. This study also sets the stage for a follow-up, in-depth analysis of the case and its chain of transitory (sub)events. Some of the effects of this cyclone were severe *jugo* and *bura* winds at the eastern Adriatic coast, strong NE winds inland, precipitation and significant amounts of snow, temporary stop of traffic, etc. Although this is far from a complete scientific study which is to be presented here, the meaning of this short paper is the urgency and timing of analyses and further projects related to such vigorous events. In other words, following the reviewers too, it cannot be overstated that there are at least two things in the related research: fine statistics of similar weather events, and exclusive dynamical analysis about the chain of events – from the preconditioning onwards.

2. SHORT DESCRIPTION OF THE EVENT

On January 18 and 19, 2023, the passage of a large synoptic cold front over Europe induced cyclogenesis on the lee side of the Alpine region. On January 20, the so-called Genoa-low deepened into a fully developed, mature extratropical cyclone with a well-defined frontal system and moved south over the Tyrrhenian Sea. At night, the system crossed the southern part of the Apennine Peninsula and moved out over the southern Adriatic Sea, with its low-pressure center located near the Italian coast, in close proximity to the peninsula of Gargano. During the morning hours on January 21, the system moved rapidly northward and intensified over the central Adriatic region, with a minimum surface pressure of approximately 990 hPa. At that point, the baroclinic nature of the system began to disappear and a warm central part of the vortex formed while isolating itself from the warm sector of its parent extratropical cyclone. The newly isolated low-pressure system, now with a warm core (“eye”), began almost completely independent movement away from the fully

occluded parent cyclone. The newly formed warm-core vortex moved in a northwest direction along the main axis of the Adriatic Sea towards the central part of the basin. At this point, as the system became well developed, it could be safely assumed that it received energy from the warm sea surface's sensible heat and moisture fluxes. We also explored the idea that additional energy may have been gained from the latent heat release caused by convective activity around the warm core.

Embedded under a continent-sized upper-level trough, this small surface low caused sustained wind speeds up to at least 19 ms^{-1} (e.g., hourly mean measurements: Lastovo 19 ms^{-1} E at 06 UTC, Palagruža 17.3 ms^{-1} SW at 11 UTC, source: meteo.hr). On the satellite images, a TLC eye was clearly visible (Fig. 1), while on the radar images, a relatively symmetric structure of precipitation bands was observed around the center of the low pressure (Fig. 2). The barotropic warm core up to a height of 300 hPa was indicated with the aid of different operational forecast mesoscale models (Fig. 3; WRF-ARW model results are presented only for brevity). The presented example forecast of WRF-ARW is the result of a model configuration with a 3 km horizontal grid spacing and 50 vertical levels, cold-initialized by 00 UTC January 21, using ICON-EU forecast lateral boundary conditions, configured with Thompson microphysics, RRTMG radiation, MYNN 2.5 PBL, NOAH-MP LSM, and scale-aware KF convective parameterizations. Note that the simulated height of the warm core is roughly double that of the case studied by Miglietta et al. (2023), who found a warm core depth of up to approximately 650 hPa; namely, the case addressed here extends to the upper troposphere and thus deserves attention as a likely TLC.

Furthermore, an elevated surface temperature field around the system center appears in measurements by the official weather stations located at the Croatian outermost islands (12 UTC; °C; Palagruža 10.8, Vis-Komiža 10.8, Lastovo 10.0), opposed to surrounding area (same time; Split-Marjan 5.5°C, Šibenik 6.0, Makarska 7.8, Ploče 7.5, Hvar 8.9; also Italian coast – Vieste 6.1, S. Giovanni Teatino 2.4, Termoli 6.2). This is another important indicator of the existence of the warm central part of the vortex. The SST in the central and southern Adriatic Sea was approximately 14°C. The final "landfall" of the system occurred on the Italian coast near Ancona in the late evening hours of January 21. The characteristics mentioned above indicate that this system exhibited most of the TLC properties; thus, it is tentatively propo-

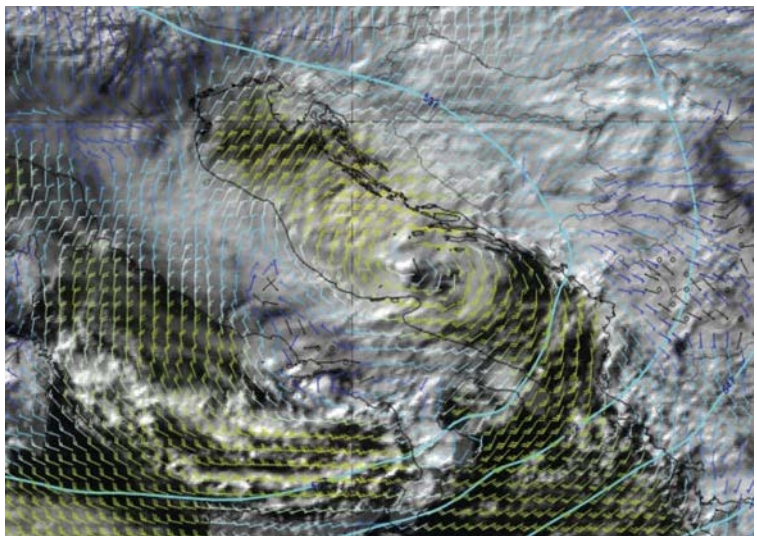

Figure 1. Satellite image in the visible spectrum at 09 UTC on January 21 (EUMETSAT); barbs show 10 m wind speed and direction; blue lines are geopotential at 500 hPa (ECMWF analysis). The cyclonic eye near the center of rotation was clearly visible. Source: eumetrain.org

Slika 1. Satelitska slika u vidljivom spektru za 21. siječnja u 9 UTC (EUMETSAT); zastavice pokazuju brzinu i smjer vjetra; plave linije predstavljaju visinu izobarne plohe 500 hPa (ECMWF analiza). Ciklonalno oko blizu centra rotacije bilo je jasno vidljivo. Izvor: eumetrain.org

sed that this was indeed a TLC. The elapsed time from the beginning of the Genoa-low cyclogenesis up to the "landfall" and dissipation of the TLC was approximately 50 h. Out of those, TLC properties were observed during the last 24 h. The total length of the track over the Adriatic Sea was approximately 450 km. The radius of the system with continuous precipitation bands was approximately 170 km at the time of its largest size (see Fig. 2).

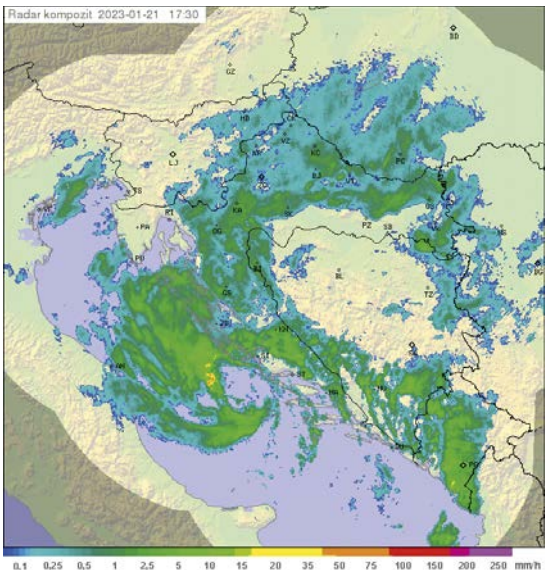

Figure 2. Composite radar image from the DHMZ radar network for January 21, 16:30 UTC. Relatively symmetric precipitation bands were noticeable around the clear cyclonic eye. Source: meteo.hr

Slika 2. Kompozitna radarska slika iz radarske mreže DHMZ-a, za 21. siječnja u 16:30 UTC. Uočljive su relativno simetrične oborinske pruge oko jasnog ciklonalnog oka. Izvor: meteo.hr

There are no exact criteria established yet for the system to be classified as TLC (Horvath et al., 2008; Miglietta et al., 2023). Moreover, in an actual world of intensive climate change, such a set of criteria is even more difficult to define and maintain. Hence, this work warns of the need for similar studies and dedicated projects. Different authors have set their own criteria to best suit the methods used in their research. For example, Tous and Romero (2011) used the criteria of cyclone eye clarity, symmetric shape, continuous cloud cover, radius < 300 km, and lifetime > 6 h for classification based on the infrared satellite images. According to this set of criteria, the system described in this study is TLC. However, according to Cavicchia et al. (2013), the maximum wind speed in a circle of radius 50 km around the pressure minimum should be higher than 29 ms^{-1} for a time longer than 4 h. According to these criteria, the described system is not a fully developed TLC, as it most likely lacks strength, judging from the maximum wind speeds recorded by the weather stations. However, we argue that the criteria used for objectively classifying systems as medicanes should not necessarily be the same for closed basins such as the Adriatic Sea compared to the more open waters such as the Mediterranean Sea. If a particular cyclonic system does not meet all the quantitative criteria previously used in the literature for Mediterranean Sea TLCs but meets most or all the qualitative criteria required, we argue that it should still be classified as a TLC. Should subsequent, more comprehensive studies substantiate our assertions regarding the TLC nature of the system, if not classified as a medicane, the term "adricane"[1] could potentially be introduced as a new nomenclature for such a cyclonic TLC system.

Based on our preliminary study, it can be assumed that, in a hypothetical scenario with a larger body of water available, the particular cyclonic system would eventually evolve into a full-strength medicane. Nevertheless, for such a claim to be truly strong, our findings should be supported by more in-depth research. Another argument for lowering certain quantitative thresholds, such as the required wind speed for intra-Adriatic TLC classification, comes from the fact that, as the Adriatic Sea has smaller dimensions, such systems generally affect a larger percentage of the basin compared to the Mediterranean Sea, and there is a much greater probability of coastal areas being affected by adverse weather conditions. Miglietta et al. (2023) argued that there is a continuum between fully tropical and fully extratropical systems, and that particular cyclones can be anywhere in that spectrum, possessing fewer or more tropical-like properties; hence, this statement fully supports our preliminary study.

[1] Petar Golem, a PhD student, was the first to suggest, i.e., coin this name, adricane, for this type of cyclonic storm.

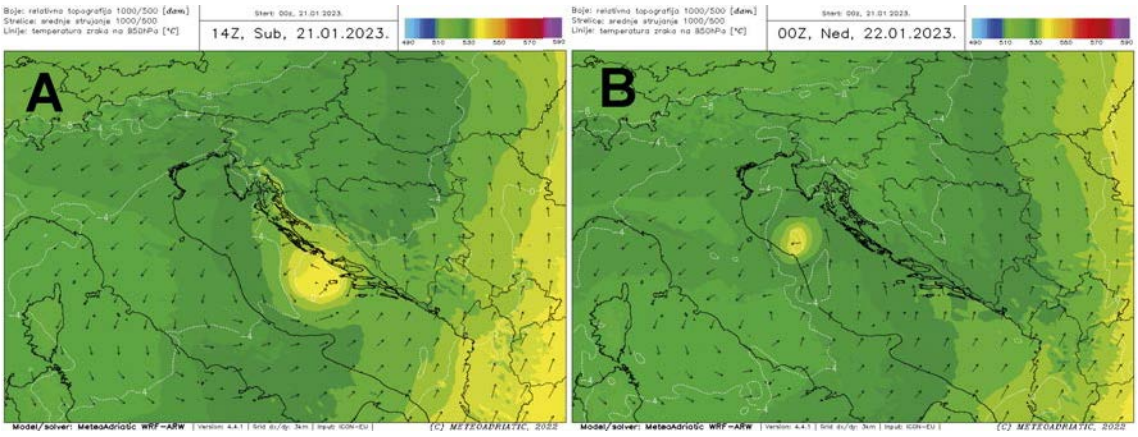

Figure 3. Example output of WRF-ARW model. The predicted field of 1000 to 500 hPa thickness (i.e., the relative topography, color shading) for January 21 at 14 UTC (A) shows a well-isolated warm core of the vortex embedded within the cold air mass inside a larger upper trough. The track of the system led to "landfall" and dissipation around the city of Ancona during the night hours of January 22 (B). Source: meteoadriatic.net

Slika 3. Primjer izračuna numeričkog modela WRF-ARW. Prognozirano polje relativne topografije 500/1000 hPa (prikazano bojama) za 21. siječnja u 14 UTC (A) pokazuje dobro izoliranu toplu jezgru vrtloga unutar hladne zračne mase koja se nalazi u sklopu prostorno veće visinske doline. Modelirana staza sustava dovela je do izlaska na kopno i raspadanja oko grada Ancone tijekom noćnih sati, 22. siječnja (B). Izvor: meteoadriatic.net

3. DISCUSSION AND CONCLUSION

Explosive transitions from a relatively small baroclinic extratropical cyclone into an almost barotropic warm-core TLC beyond the (sub)tropics have been reported in recent literature (Kouroutzoglou et al., 2021; Cioni et al., 2016; Ricchi et al., 2019), but no prominent case, such as that presented here, has yet been documented over the Adriatic basin. There is also a generally low number of well-documented TLC systems in the Adriatic Sea basin, and certainly an even lower number that moved that far north into the central Adriatic area. This set the presented case among the relatively rare, yet vigorous, mesoscale events. Due to the relative lack of high-resolution, multi-method research[2] on the long-term climatology of TLCs within the Adriatic basin, it is unclear how often systems like this evolve in the area and which tropical properties they typically possess.

There is also uncertainty regarding the degree to which TLCs within the Adriatic Sea resemble TLC systems in other parts of the Mediterranean Sea due to basin size limitations, SST, and coastal terrain. Namely, for the full development of tropical-like cyclonic properties, that is, TLC, a sufficiently large surface of relatively warm water is required. This calls for future research to determine the extent to which the size of the Adriatic basin presents a limitation for the full maturity of a TLC.

Even more urgent questions regarding this topic still need to be addressed. What is the possible maximum strength of a TLC over the Adriatic basin, and how much of a threat could it pose to sea and air traffic, agriculture, fisheries, and overall coastal properties, especially considering the expected sea-level rise in the coming decades? Which particular synoptic conditions in the area favor the development of Adriatic TLCs and the potential occurrence of an adricane? How might the expected future climate change within the area alter the frequency, duration, and strength of the Adriatic TLCs? These questions form compelling topics for future research efforts in Adriatic meteorology, oceanography, and geophysics.

[2] An example of an effective approach would be to integrate high-resolution, convection-allowing mesoscale model downscaling of historical global datasets with the analysis of satellite imagery and weather radar system observations. This collaborative method could substantially enhance our understanding of the nature of TLCs and consequently improve the accuracy of their operational predictions.

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