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Synoptic case study of cyclone Yvette – May 2014

Synoptyczne studium ewolucji cyklonu Yvette – Maj 2014

Abstract This paper analyzes the trajectory of the Mediterranean cyclone Yvette, pressure changes in its center and the evolution of selected meteorological fields during the life cycle of the cyclone. Geopotential, wind and divergence fields in the upper troposphere, vertical velocity, relative vorticity and wind fields in the middle troposphere as well as sea level pressure fields were analyzed. The cyclone lasted 6 days. The central pressure dropped to a minimum of 996 hPa. The biggest deepening rate reached −7hPa/12h. The impact of upper and mid-tropospheric circulation on the cyclone activity could be observed especially during cyclogenesis and maximum deepening stage.

Keywords Balkans, Mediterranean cyclone Yvette, upper and middle troposphere, sea level pressure.

Zarys treści Opracowanie przedstawia analizę trajektorii śródziemnomorskiego cyklonu Yvette, zmian ciśnienia w centrum niżu oraz wybranych pól meteorologicznych zmieniających się w cyklu życiowym niżu. Środowisko synoptyczne związane z niżem opisano, wykorzystując pola geopotencjału, wiatru i dywergencji w górnej troposferze, rozkłady prędkości pionowej, wirowości względnej i wiatru w środkowej troposferze, a także pola ciśnienia na poziomie morza. Cyklon trwał 6 dni. Ciśnienie w centrum układu osiągnęło wartość minimalną 996 hPa. Największa ujemna tendencja ciśnienia wyniosła −7hPa/12h. Wpływ cyrkulacji w górnej i środkowej troposferze na aktywność niżu zaobserwowano szczególnie wyraźnie podczas fazy cyklogenezy oraz maksymalnego pogłębiania.

Słowa kluczowe Bałkany, cyklon śródziemnomorski Yvette, górna i dolna troposfera, ciśnienie na poziomie morza.

A chance for the occurrence of the Mediterranean cyclone, which later moves toward central and eastern Europe, increases in spring and peaks in April–May season (Degirmendžić, Kożuchowski 2014). Yvette cyclone, named „Tamara" in Bosnia and Herzegovina, Croatia and Serbia, serves as an example of such a system. Yvette affected the weather over the Balkans and Central Europe during the period of 12–18th May 2014. Flooding in Serbia, Bosnia and Herzegovina caused the greatest damage, as the rainfall was the heaviest in 120 years of weather measurements.

1. Data and methods

The evolution of the cyclone was characterized on the basis of the following maps (2x daily) spanning the period from 12th May (00 UTC) to 18th May (12 UTC), 2014:

- divergence field [s^{-1}], wind vectors and isotachs [$m\,s^{-1}$] at 200 hPa level,
- geopotential field [m] at 300 hPa level,
- relative vorticity [s^{-1}], vertical velocity [$Pa\,s^{-1}$] and wind field [$m\,s^{-1}$] at 500 hPa level,
- sea level pressure field [hPa].

Maps were generated with the help of Godfrey Reanalysis Plotter (NCEP Reanalysis Plotter) – http://www.atms.unca.edu/cgodfrey/reanalysis/reanalysis.shtml. Data for the plotter was obtained from the NCEP–NCAR Reanalysis (Kalnay et al. 1996). Because of the large number of maps, only those were presented, which provide the key to understanding the evolution of Yvette. Cyclone Central Pressure (CCP) and the positions of the low were determined on the basis of SLP maps plotted with 0,5 hPa interval.

The purpose of the study is to characterize the trajectory and the life cycle of Yvette expressed in CCP changes and to assess the role of upper-tropospheric circulation in cyclone activity during cyclogenesis, maximum deepening and cyclolysis phase.

2. Evolution of cyclone Yvette

On 12th May, 00 UTC the trough developed over the central Adriatic associated with low from the Ukraine. Zone of upper-level positive divergence in the delta region of PFJ jet streak from France spanned over the Balkan Peninsula.

12th May (12 UTC) (1st point of the trajectory – Fig. 1).

For the first time closed isobar of 1013 hPa could be seen on the SLP map – it contoured the region of the northern Italy and the northern Adriatic. Near the incipient low the region of positive divergence (at 200 hPa, max. $+1{,}5 \times 10^{-5}\ s^{-1}$) expanded in the LF sector of the jet streak (max. 60 $m\,s^{-1}$) situated above the northern Italy. Cyclone Yvette was formed under the LF quadrant, beneath peripheral area ($<+1{,}2 \times 10^{-5}\ s^{-1}$) of the positive divergence region (Fig. 2). The axis of the trough was already negatively tilted and extended from Denmark, the Czech Republic to Romania. Cyclogenesis took place beneath the LF sector and on the lee-side of the Alps, therefore, it serves as an example of the type B of cyclogenesis by Petterssen and Smeybe (1971). Moreover, it is likely that the Alps weakened low-level cold advection from the north, what favored cyclone formation.

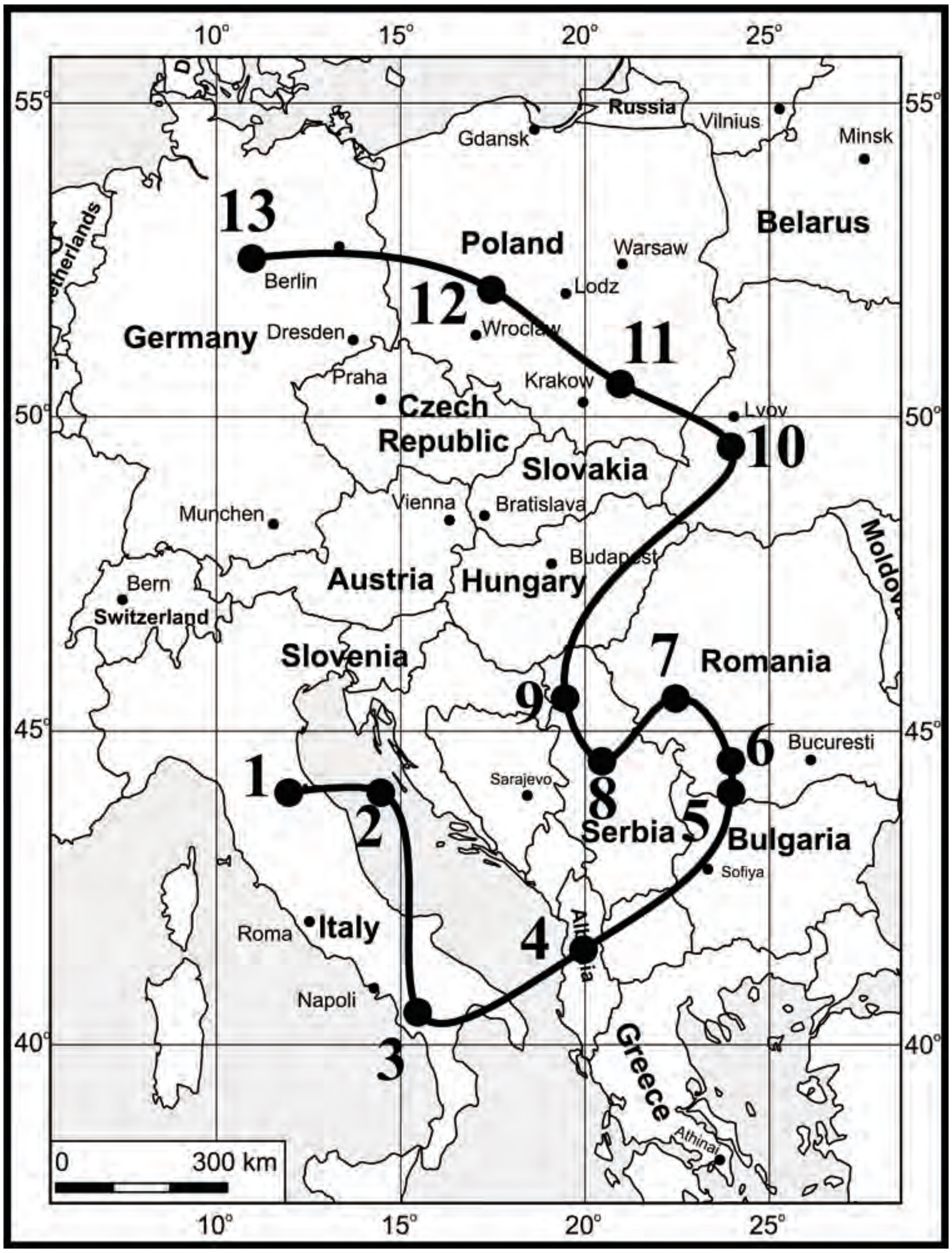

Fig. 1. Trajectory of cyclone Yvette in the period between 12th May, 12 UTC (1st point) and 18th May, 12 UTC (13th point), 2014. Points along trajectory are numbered every 12 hours

Rys. 1. Trajektoria cyklonu Yvette w okresie od 12 maja, 12 UTC (punkt) do 18 maja, 12 UTC (punkt 13) 2014 r. Punkty na trajektorii ponumerowano co 12 godzin

13th May (00 UTC) (2nd point)

Cyclone moved over the northern Adriatic and slightly deepened (−1 hPa/12h). Jet streak (max. 55 m s^{-1}) shifted further east toward the Apennine Peninsula. Two regions of positive divergence existed within LF sector – the first, to the west of the northern Italy, the second, over Romania, Bulgaria and Serbia (the weaker one). Between these two zones, below the region of positive divergence aloft, Yvette continued to develop. Above the incipient low the zone of the ascending motions with maximum −0.3 Pa s^{-1} was formed.

13th May (12 UTC) (3rd point)

At that time cyclone began to deepen rapidly due to the trough (shortwave) developing to the west of the low pressure system. That trough was situated west of the Apennine Peninsula. Another trough over Romania was still present (Fig. 3). Vort max formed in the vicinity of the trough axis (to the west of the Alps), which generated PVA (Positive Vorticity Advection, 500 hPa) above the low-level cyclone. Yvette was situated below the delta region of the jet streak (max. 55 m s^{-1}) and below the region of positive divergence stretched latitudinally from Sardinia to the Black Sea (Fig. 4).

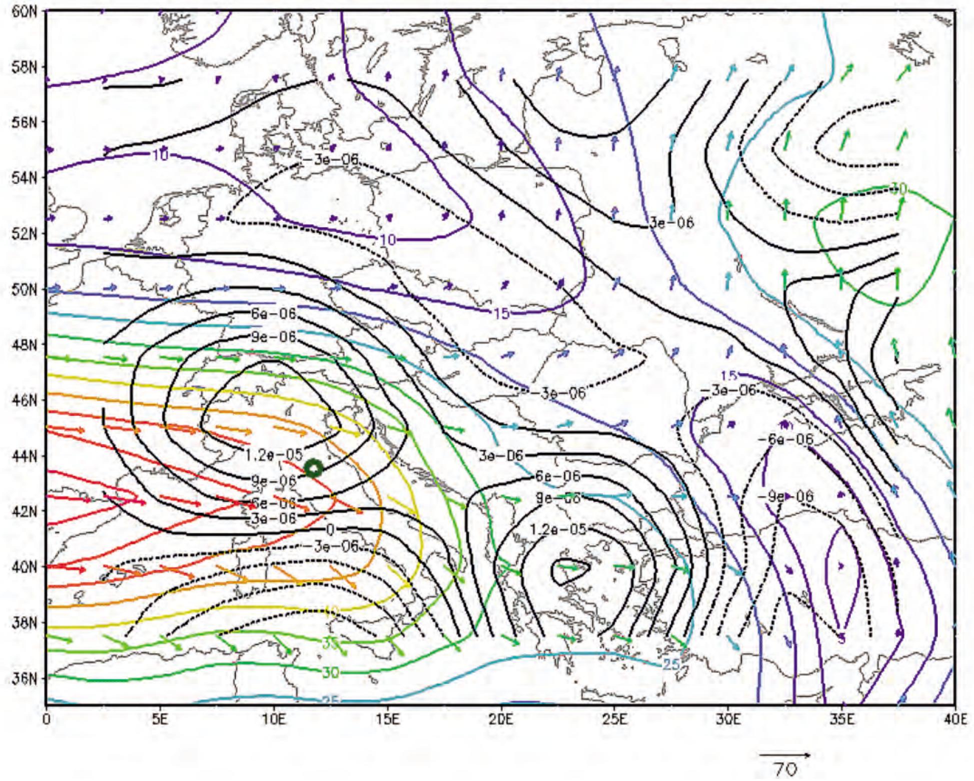

Fig. 2. Izotachs [m s⁻¹], wind vectors (color) and divergence fields [s⁻¹] (black) at 200 hPa level on 12th May, 12 UTC, 2014. Green circle indicates the position of Yvette center (ed. by J. Degirmendžić)

Rys. 2. Izotachy [m s⁻¹], wektory wiatru (kolor) i pole dywergencji [s⁻¹] (czarny) na powierzchni 200 hPa w dniu 12 maja, 12 UTC, 2014 r. Okrąg w kolorze zielonym wskazuje położenie środka niżu Yvette (opr. J. Degirmendžić)

The zone of ascending motions spanned over the Apennine Peninsula and the Adriatic Sea. Digging trough to the west of the low-level cyclone resulted in CCP falling by −3.5 hPa/12h. The deepening rate continued to increase till 14th May 12 UTC (Fig. 5).

14th May (00 UTC) (4th point)

The trough over the Apennine Peninsula deepened. Distinct vort max center associated with trough axis existed over northern Italy. This center was situated to the west of the surface low which indicated that Yvette vertical axis tilted to the west and PVA was present above the system. Such displacement of upper and low-level vort maxima enhances the activity of a surface cyclone (eg. Elsberry, Kirchoffer 1988). Wide zone of positive divergence stretched from Italy to the Black Sea (max. 9×10^{-6} s^{-1}). Upward drafts (ca. −0.6 Pa s^{-1}) were observed above the low. Cyclone Yvette shifted from over Italy to Albania in the past 12 hours due to simultaneous propagation of wave and jet streak in that direction and deepened by further 5,5 hPa.

14th May 12 UTC (5th point)

Between 4th and 5th point of the trajectory (from Albania to the border of Bulgaria and Romania) cyclone Yvette deepened significantly – by as much as 7 hPa (Fig. 5). Summing up, since cyclogenesis event (12th May, 12 UTC) till 14th May (12 UTC), i.e. during 2 days, CCP has fallen by a total value of 17 hPa. The lowest value of CCP (996 hPa) was observed for 12 hours (14th May, 12 UTC – 15th May, 00 UTC). Vorticity max at 500 hPa level was still located upstream of Yvette (to the south-west of the low center) – wind vectors crossed at a large angle isolines of relative vorticity indicating large PVA present above the low (Fig. 6). Center of cyclone was situated under strong positive divergence, ca. $+2.5 \times 10^{-5}$ s^{-1}. Such strong divergence was related to both: the jet streak (max. 40 m s^{-1}) and the right branch of the trough located over the Adriatic Sea and the Balkans (Fig. 7).

The trough was already negatively tilted which resulted in divergence increase from $+9 \times 10^{-6}$ s^{-1} to $+2{,}5 \times 10^{-5}$ s^{-1}. The region of low-level cyclonic circulation precisely coincided with the zone of ascending drafts at 500 hPa isobaric level. The maximum of vertical velocity (ca. −0.6 Pa s^{-1}) could be seen above the center of low.

15th May (00 UTC) (6th point)

The vorticity max aloft was catching up (approaching from the south) with the center of surface cyclone. The jet streak weakened and moved away from the low pressure system. Upper-level divergence also diminished. Cut-off low emerged within upper-level trough. As a result PVA above the cyclone minimized. The upper troposphere ceased to play a significant role in Yvette development. Since that moment cyclone began to fill systematically (Fig. 5).

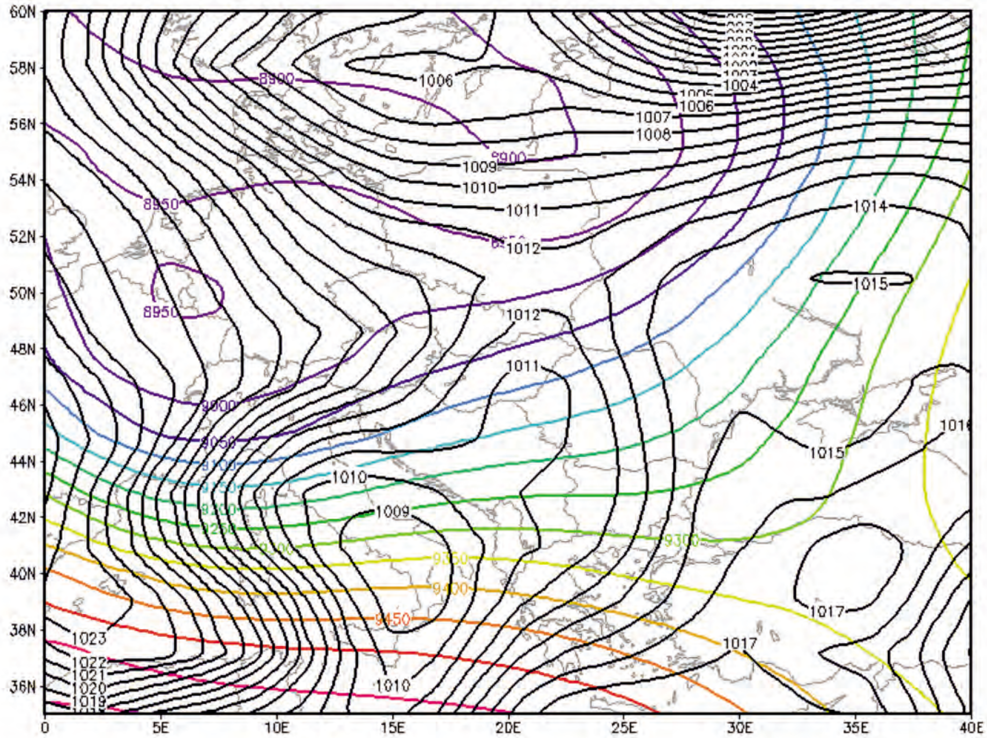

Fig. 3. SLP field [hPa] (black) and 300 hPa geopotential height (color) on 13th May 2014, 12 UTC
(ed. by J. Degirmendžić)

Rys. 3. Pole ciśnienia na poziomie morza [hPa] (czarny) i geopotencjału powierzchni 300 hPa (kolor) w dniu 13 maja 2014 r., 12 UTC
(opr. J. Degirmendžić)

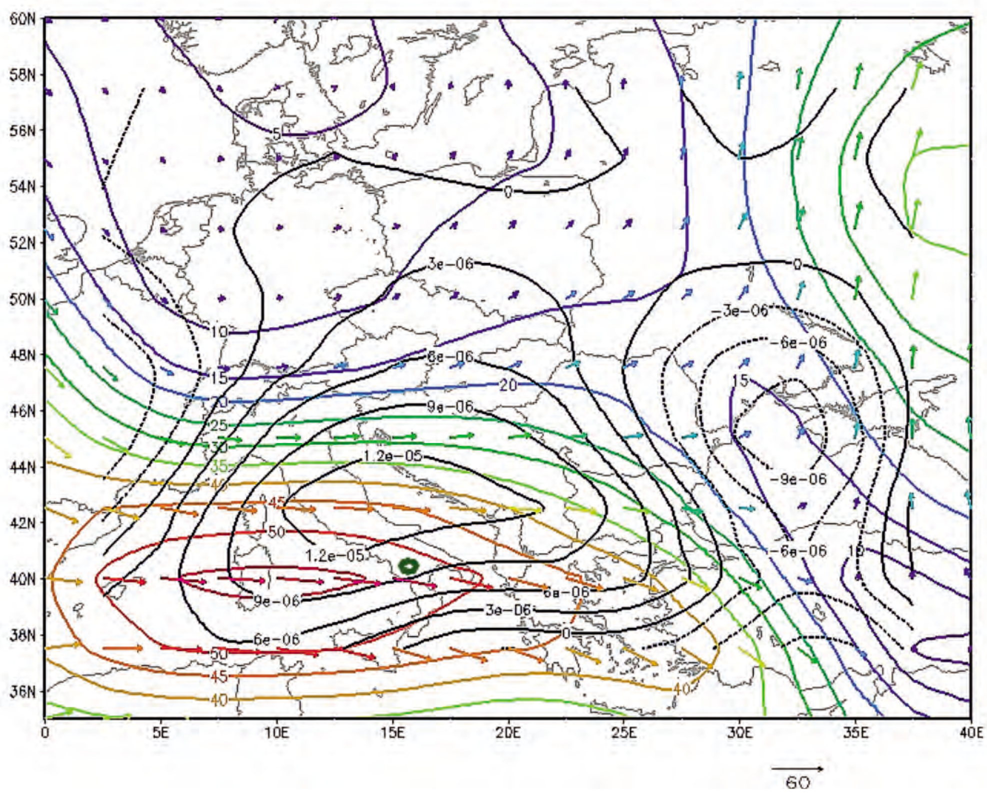

Fig. 4. Same as Fig. 2 except for 13th May 2014, 12 UTC
Green circle indicates the position of Yvette center (ed. by J. Degirmendžić)

Rys. 4. Jak na rys. 2 tylko w dniu 13 maja 2014 r., 12 UTC
Okrąg w kolorze zielonym wskazuje położenie środka niżu Yvette (opr. J. Degirmendžić)

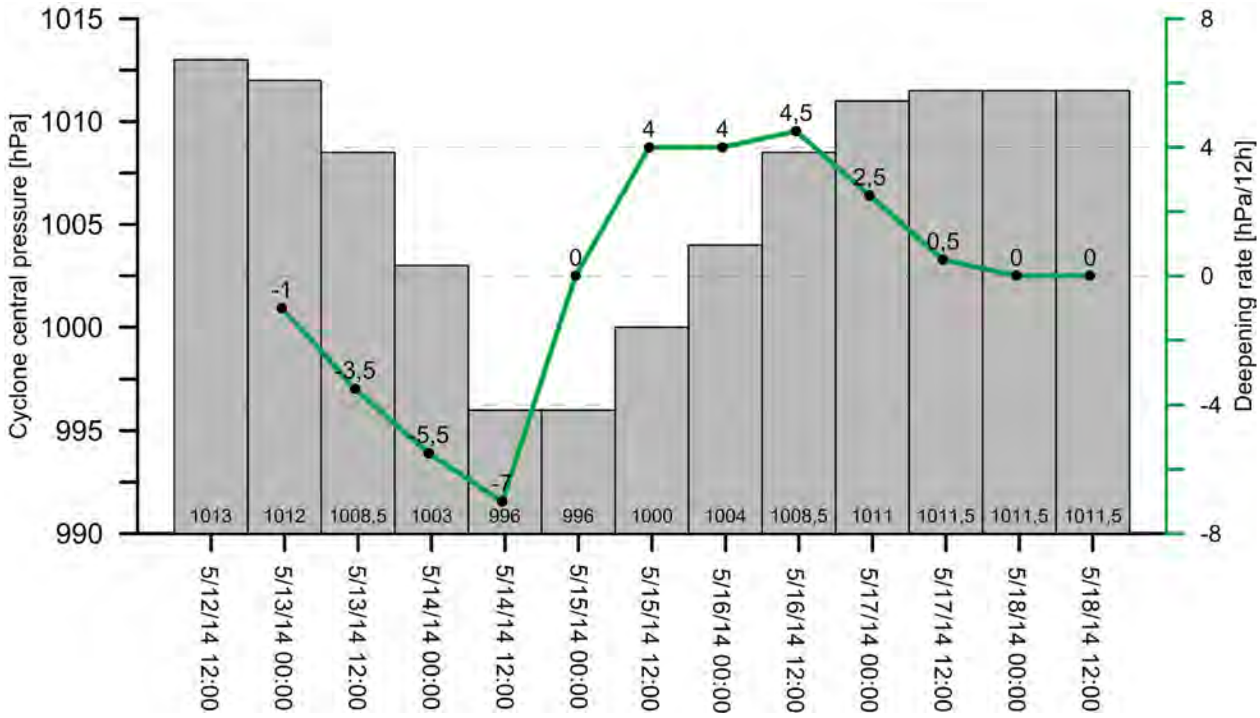

Fig. 5. CCP [hPa] and deepening rate [hPa/12h] of cyclone Yvette (ed. by J. Degirmendžić)

Rys. 5. Ciśnienie w centrum niżu [hPa] i tendencja ciśnienia [hPa/12h] (linia) cyklonu Yvette (opr. J. Degirmendžić)

It is worth mentioning that the highest rainfall in Serbia was recorded on 14–15th May 2014 (Degirmendžić, Walisch 2014). In this period cyclone's center was moving along 4–5–6–7 segment of its track, i.e. Yvette was on its way from Albania to the east and north-east of Serbia, therefore over this country the northerly and north-easterly wind prevailed, possibly increasing orographic precipitation. On 13th May the highest rainfall was noted in Bosnia and Herzegovina – at that time cyclone was traveling between points 2–3 (Fig. 1). Most likely southern advection of moist air induced elevated rainfall totals over BiH. Cyclone positions from 5 to 9 are fairly close to each other which indicated slowdown of cyclone speed. In addition, at points 5 and 6 Yvette reached the lowest central pressure – 996 hPa. These two factors: intense cyclonic vortex and quasi-stationary nature of low situated at 5–6–7 segment of trajectory contributed to the maximum values of rainfall in Serbia.

15th May 12 UTC (7th point)

Mid-tropospheric vorticity max shifted close to the cyclone core – surface system became vertically stacked. The divergence values above the cyclone decreased and the max divergence region (+1,2 × 10^{-5} s^{-1}) was located north-east of the system center. That divergence region was associated with delta of cyclonically curved („banana-shaped") jet streak (max. 40 m s^{-1}). In the next 12 hours cyclone Yvette returns over Serbia. The cut-off low developed in the upper troposphere and the surface low became separated from the steering current. As a result cyclone did not move further to the north-east. Over the past 12 hours the system shallowed by ca. 4 hPa.

16th May (00 UTC) (8th point)

The center of cyclone Yvette, over northern Serbia, was superimposed with upper-level divergence close to zero. The region of divergence max and intensive upward drafts shifted far to the north, close to the eastern border of Poland. The upper wave completely cut off and the axis of the system remained vertical. As a consequence, in the next 12 hours, cyclone Yvette moved only slightly, toward northern Serbia. The system was constantly filling up.

16th May (12 UTC) (9th point)

Upper tropospheric support for the development of surface cyclone ceased to exist. Upper-level divergence over Yvette low approached zero. At the same time the value of divergence increased to +2,1 × 10^{-5} s^{-1} east of Polish border. It was the most likely factor triggering further propagation of the storm to the north-east (see 10th point of the trajectory, Fig. 1).

17th May (00 UTC) (10th point)

The cyclone moved under weak positive divergence region and the zone of weak ascending motions. As a result its dissipation rate decreased (Fig. 5). Center of surface low was situated north of the upper vortex. Since that time Yvette started to circle around the upper cut-off system beneath its northern sector. Its movement was steered by the upper-level cyclonic circulation therefore surface cyclone was traveling from over the eastern Poland to the west (10–13th trajectory points, Fig. 1, Fig. 8).

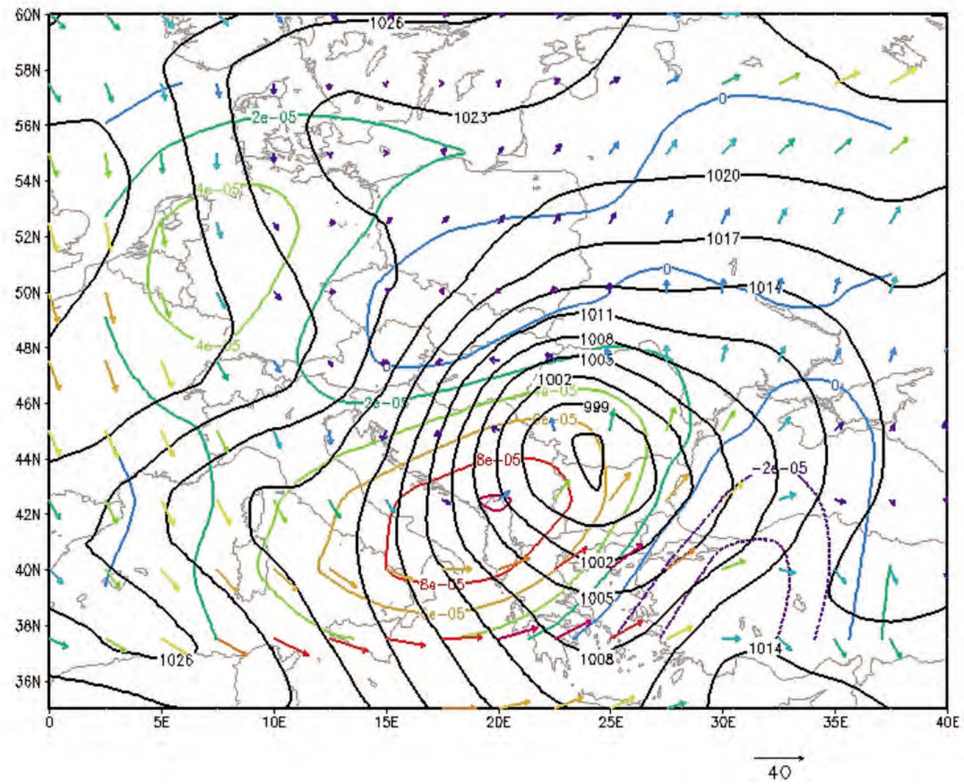

Fig. 6. Relative vorticity field [s^{-1}], wind vectors at 500 hPa level (color) and SLP [hPa] (black) on 14th May 2014, 12 UTC (ed. by J. Degirmendžić)

Rys. 6. Pole wirowości względnej [s^{-1}], wektory wiatru na powierzchni 500 hPa (kolor) oraz rozkład ciśnienia na poziomie morza [hPa] (czarny) w dniu 14 maja 2014 r., 12 UTC (opr. J. Degirmendžić)

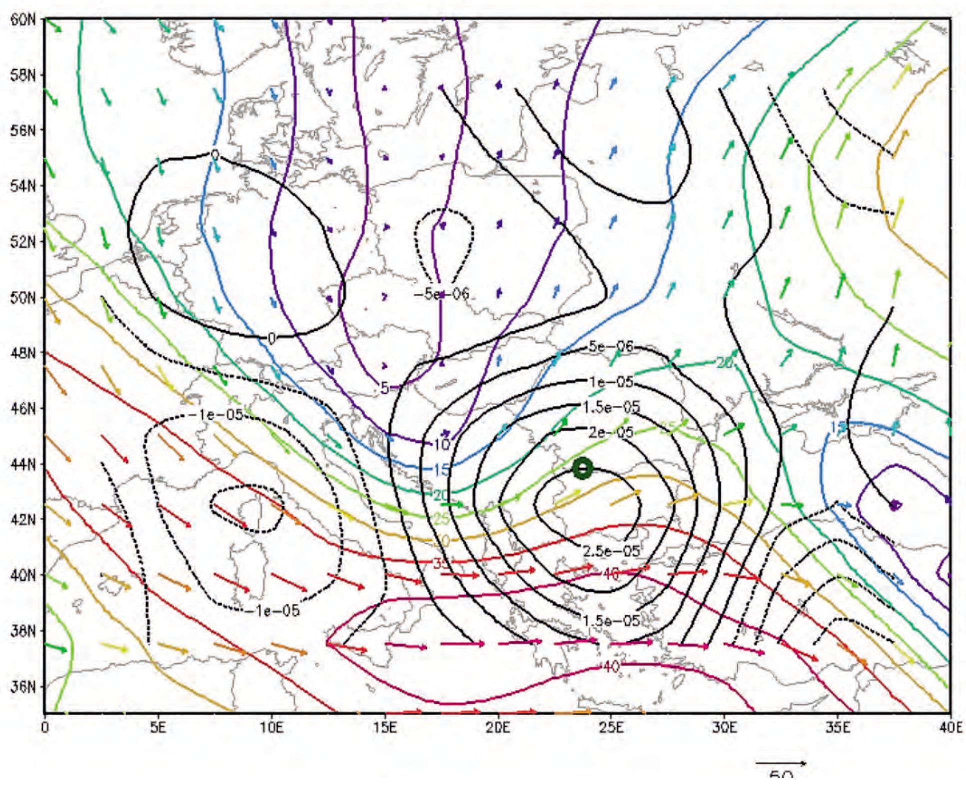

Fig. 7. Same as Fig. 2 except for 14th May 2014, 12 UTC
Green circle indicates the position of Yvette center (ed. by J. Degirmendžić)

Rys. 7. Jak na rys. 2 tylko w dniu 14 maja 2014 r., 12 UTC
Okrąg w kolorze zielonym wskazuje położenie środka niżu Yvette (opr. J. Degirmendžić)

17th May (12 UTC) (11th point)

Cyclone Yvette was still located beneath weak positive divergence, south-west of the divergence max. Maximum of the vertical velocity (−0.25 Pa s^{-1}) occurred directly above the surface low. Yvette was no longer filling up – CCP values remained at 1011,5 hPa till the end of its life cycle (Fig. 5). Cut-off low became stagnant over the Balkans while surface low circulated eastward in the sector of eastern flow in the upper troposphere.

In the period 15–17th May 2014 (6–11th point of the trajectory, Fig. 1) high rainfall totals were recorded in Poland (Degirmendžić, Walisch 2014). During the first two days maxima occurred in south-eastern Poland. Cyclone Yvette located between 10th and 11th point of track maximized rainfall sums over south-western Poland. Precipitation maxima moved westward, following simultaneous shift of the region of northern and north-eastern advection associated with surface low.

18th May (00 UTC) (12th point)

Cyclone Yvette was located over western Poland, south-west of the region of divergence max in the upper troposphere. Weak positive divergence associated with quasi-meridional jet streak localized east of Poland was still present above the center of low. At mid-tropospheric level weak ascending motion (ca. −0,2 Pa s^{-1}) was observed. Yvette displaced to the north of the center of the upper cut-off low. The system central pressure remained stable.

18th May (12 UTC) (13th point)

Relative vorticity max at 500 hPa level reached position east of the surface low, which means that the vorticity max encircled Yvette storm by 180° during its life cycle. Surface low dissipated beneath the area of weak positive divergence but vertical motions over a cyclolysis region vanished (Fig. 9). Progressing cyclolysis could be partially forced by the northerly low-level cold advection originated from the Scandinavian Peninsula.

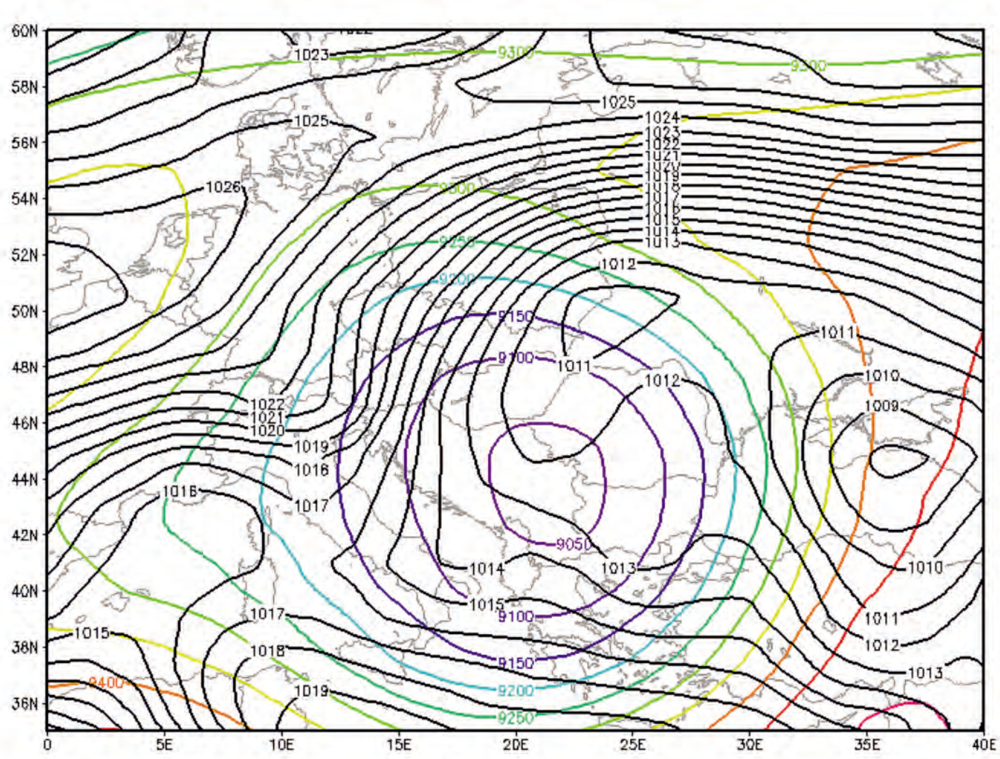

Fig. 8. 300 hPa geopotential height [m] (color) and SLP [hPa] (black) on 17th May 2014, 00 UTC
(ed. by. J. Degirmendžić)

Rys. 8. Geopotencjał powierzchni 300 hPa [m] (kolor) i rozkład ciśnienia na poziomie morza [hPa] (czarny) w dniu 17 maja 2014 r., 00 UTC
(opr. J. Degirmendžić)

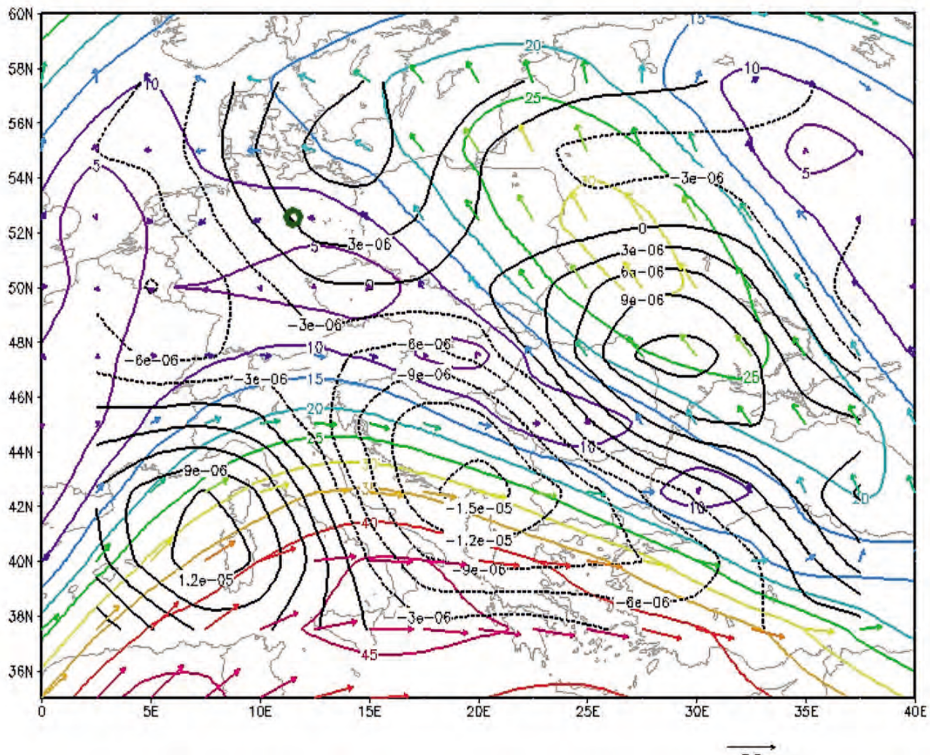

Fig. 9. Same as Fig. 7 except for 18th May 2014, 12 UTC
Green circle indicates the position of Yvette center (ed. by J. Degirmendžić)

Rys. 9. Jak na rys. 7 tylko w dniu 18 maja 2014 r., 12 UTC
Okrąg w kolorze zielonym wskazuje położenie środka niżu Yvette (opr. J. Degirmendžić)

3. Conclusions

Cyclone Yvette developed in spring 2014 – season when meridional circulation types prevail. Its life cycle lasted for 6 days (12th May, 12 UTC – 18th May, 12 UTC). The minimum CCP dropped to 996 hPa and the maximum deepening rate reached −7 hPa/12h (Fig. 5). The cyclone experienced cyclogenesis over Italy and the Adriatic, than traveled across central Europe and Poland. Cyclolysis was observed over Germany.

Cyclone Yvette formed under the LF quadrant of the jet streak, beneath the region of positive divergence, therefore it can be classified as B type of cyclogenesis by Petterssen and Smeybe (1971). B type is triggered by the dynamic forces connected with upper-tropospheric circulation.

Surface low strengthened its activity on 13th May 12 UTC. Two factors energized the cyclone: 1) trough developed west of Yvette and 2) jet streak sited in the right branch of the trough. In connection with those two features characteristic for the upper-level wind field, large zone of positive divergence spread over the Balkans and the northern part of the Mediterranean Sea – this observation is consistent with the results of Cammas and Ramond (1989), who revealed the complete lack the areas of convergence and descending motions in the vicinity of the jet streak embedded in the right branch of the trough.

On May 14th 12 UTC the cyclone reached its maximum activity (minimum CCP) – the center of low was situated under strong divergence (ca. $+2{,}5 \times 10^{-5}\ s^{-1}$). This divergence was associated with the jet streak (max. 40 $m\,s^{-1}$) and the right branch of the trough located over the Adriatic Sea and the Balkans. Trough was negatively tilted. Such shape of the trough formed in the last 12 hours – Lagouvardos et al. (2006) pointed that negatively tilted trough often produces a severe weather outbreak. Prezerakos et al. (2006) presented the case study of cyclogenesis in the eastern Mediterranean basin. Cyclone analyzed by the authors underwent strong deepening southwest of the upper-level divergence max. ($+14 \times 10^{-5}\ s^{-1}$). The values of divergence above the low amounted to approx. $+2 \times 10^{-5}\ s^{-1}$. It is worth noting that the maximum value of divergence aloft situated close to a cyclone's core over Europe and the North Atlantic was recorded in spring (period 1958-2001) and equaled to $+9{,}2 \times 10^{-5}\ s^{-1}$ (Degirmendžić 2011) – it was nearly four times as much as the maximum divergence associated with Yvette.

The divergence max at 200 hPa remained to the north-east of the center of the surface low during most of its life cycle. Sauer (1995 – Fig. 19, 52, 53), Wash at al. (1992), MacDonald and Reiter (1988) observed similar spatial relationship – cyclones are usually positioned to the south-west, west and north-west of divergence max regions. The greater the activity of cyclone the smaller the distance between upper divergence max and center of surface low (meteorological bombs feature the shortest distance).

Yvette dissipated beneath the zone of weak positive divergence aloft and weak ascending motions in the middle troposphere. The sample of lows experiencing cyclolysis, even though the positive divergence aloft is present, includes 50% of all cyclolysis events (Degirmendžić 2011). The events similar to Yvette cyclolysis occure mostly due to the low-level cold advection (Rolfson, Smith 1996).

4. Summary

Synoptic evolution of cyclone Yvette is presented in this paper. Analysis is based on different low-, mid- and upper--tropospheric maps (SLP; relative vorticity, wind and vertical velocity fields at 500 hPa; geopotential heights at 300 hPa; divergence and wind fields at 200 hPa). The trajectory and CCP changes along the track were determined.

Cyclone Yvette formed under the LF quadrant of the jet streak, beneath peripheral area (<+1,5 × 10^{-5} s^{-1}) of the positive divergence region on 12th May 2014, 12 UTC (Fig. 2) – it is an example of the type B of cyclogenesis by Petterssen and Smeybe (1971).

On 13th May, 12 UTC the cyclone began to deepen rapidly due to the trough developing to the west of the surface low. Vort max formed near the trough axis (to the west of the Alps), which generated PVA above the cyclone. Since cyclogenesis event (12th May, 12 UTC) till 14th May, 12 UTC, i.e. during 2 days, CCP has fallen by a total value of 17 hPa. The lowest value of CCP (996 hPa) was observed twice – on 14th May, 12 UTC and on 15th May, 00 UTC. On the first day cyclone center was situated under strong positive divergence region, ca. +2.5 × 10^{-5} s^{-1}.

On 15th May (00 UTC) the vorticity max aloft caught up with the center of the surface cyclone. As a result PVA above the cyclone minimized. Between 16th May, 12 UTC (9th point – Fig. 1) and 17th May, 00 UTC (10th point, Fig. 1) Yvette jumped from Serbia over Ukraine – it was the longest distance traveled during 12 hours. On 17th May, 00 UTC surface low situated again under, though weak, but positive divergence region and the zone of weak ascending motions and started to circulate eastward beneath the sector of eastern flow of the upper-tropospheric cut-off low.

On 18th May, 12 UTC the surface low dissipated below the area of weak positive divergence (Fig. 9). According to Rolfson and Smith (1996) Yvette cyclolysis could occur mostly due to the low-level cold advection.

Summing up, the cyclone lasted for 6 days. The central pressure dropped to a minimum of 996 hPa. The biggest deepening rate reached −7hPa/12h. The upper and mid--tropospheric forcing on the cyclone activity was particulary evident during cyclogenesis and maximum deepening stage.

Acknowledgments

This research was conducted on the basis of maps of different meteorological parameters generated by Godfrey Reanalysis Plotter provided by Dr. Christopher Godfrey, the University of North Carolina, Asheville. Database for the plotter was obtained from the National Centers for Environmental Prediction/National Center for Atmospheric Research 40-Year Reanalysis Project.

I would like to express my great appreciation to Dr Aleksander Szmidt for preparing map of Yvette trajectory.

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