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ON THE CAUSES OF ADRIATIC *JUGO* WIND VARIATIONS

Uzroci varijacija juga na Jadranu

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Abstract: A brief review is given of some published papers on the S–SE warm and humid *jugo* wind on the eastern coast of the Adriatic Sea. Considering the large scale, *jugo* is connected with deep cyclones approaching from the Atlantic and moving towards the west Mediterranean and the Adriatic Sea, where the coastal and mountain effects induce perturbations and cyclonic activity, resulting in the phenomena of various, mainly unknown, subsynoptic scale features. Thus, depending on the cyclonic activities in the Mediterranean and the Adriatic Sea, the *jugo* speed cannot be predicted easily, particularly considering its maximal gusts reaching locally over 40 ms^{-1}. This paper presents a number of synoptic case studies which indicate that the high speeds and maximal gusts of *jugo* can be identified, and, therefore, also predicted, by the ALADIN forecasting model, together with the appearance of frontal zones and low-level, high wind speeds in the HRID high-resolution vertical time cross-section.

Key words: *jugo* wind, maximal gusts, Mediterranean cyclones, Adriatic fronts, HRID, ALADIN model

Sažetak: Prikazan je pregled nekih publiciranih radova o S–SE toplom i vlažnom jugu na istočnoj obali Jadrana. S obzirom na makrorazmjere, jugo se povezuje s približavanjem duboke ciklone s Atlantika u zapadno Sredozemlje i Jadransko more, gdje planinski i obalni efekti uvjetuju perturbacije tlaka i ciklonalne aktivnosti, koje rezultiraju ciklonama različitih podsinoptičkih razmjera uglavnom nepoznatih uzroka. Prema tome, brzinu juga u ovisnosti o tim ciklonama nije lako prognozirati, naročito kada se uzmu u obzir maksimalni udari juga koji lokalno mogu dostići brzine i preko 40 ms^{-1}. U ovom se radu prikazuju neke sinoptičke situacije koje ukazuju na to da se jako jugo s maksimalnim udarima vjetra može identificirati, pa prema tome i prognozirati prognostičkim modelom ALADIN uz pojavu fronte i velike brzine vjetra u donjim slojevima modela na vremenskom vertikalnom presjeku HRID-u visoke rezolucije.

Ključne riječi: jugo, maksimalni udari vjetra, sredozemne ciklone, fronte na Jadranu, HRID, prognostički model ALADIN

1. INTRODUCTION

There are two main severe winds along the Adriatic Sea: the well known cold *bura* wind of NE direction, and the less known warm and humid S–SE *jugo* wind (“jug” means “south” in Croatian). *Jugo* is associated with the west-Mediterranean cyclonic activity, and its high speed and maximal gusts are influenced by these cyclones and the mesoscale disturbances and fronts over the Adriatic Sea. In contrast to the *bura,* which starts suddenly, *jugo* increases in strength gradually, depending on the approach of the cyclones from the Atlantic. The studies of *jugo* characteristics indicate its great variability in space and time along the Adriatic coast and islands, which makes this wind very dangerous, especially during the active tourist season.

Most of the papers published about *jugo* present its statistical characteristics. Makjanić (1978) calculated the conditional probability of *jugo* appearance at a particular station if it blows at one or more of the other 13 stations along the coast. He found the largest frequency of *jugo* in mid-Adriatic. Trošić (1983) presented the frequencies of *jugo* at Pula, Split and Dubrovnik, using hourly data for a period of five years. For the same three stations, Lisac et al. (1998/99) presented a detailed analysis of *jugo* frequency, introducing a criterion with the conditions a wind vector should satisfy during a *jugo* event. Poje (1992) presented wind persistence on the basis of data from 11 anemographs along the coast indicating that the longest mean duration of strong *jugo* was over 9 hours, as a yearly average. *Jugo* of gale force in the mid-Adriatic island of Palagruža may last up to 23 hours in winter. Vukićević (1991) presented some statistical data for severe *jugo* in Split, for a 30-year period (1961–1990).

From the synoptic point of view, Tutiš and Britvić (1993) presented a case study of severe *jugo* in December 1992 and Jurčec and Vukićević (1995) stressed the connection between *jugo* and the Christmas cyclone activity in the Mediterranean. Jurčec et al. (1996) discussed *jugo* events associated with subsynoptic scale cyclones along the Adriatic Sea. They found a mesoscale orographic perturbation in the area of the Dinaric Alps providing conditions favourable for mesoscale cyclonic generation and the strengthening of *jugo* gusts. Ivančan-Picek and Jurčec (2003) have shown that these mesoscale wind features contain a pronounced ageostrophic component with small-scale vortices of short duration and clearly marked convergence zones. Vukićević and Jurčec (1998) stressed the influence of local effects on the intensity and direction of *jugo*. The numerical simulation results obtained by Brzović (1999) confirm that the direction and intensity of the Adriatic windstorms (*bura* and *jugo*) are strongly influenced by the channelling effect of the Dinaric Alps. From the analyses of 10 synoptic cases with most intense *jugo* wind in the period 1991–2002, Vukićević and Jurčec (2004) showed that severe *jugo* occurs under the influence of the Genoa cyclone with a very deep upper-level trough.

However, the detailed causes and effects of the strength and variations of *jugo* gusts along the Adriatic coast cannot be easily understood since the Mediterranean cyclones and the process of Alpine lee cyclogenesis occurs partly due to the fact that this phenomenon possesses different spatial scales. Gomis et al. (1990) have shown by real data analysis that it is possible to separate the macroscale flow, characterised by barocline waves, and the mountain-induced perturbation resulting from the interaction of these waves with the Alpine barrier. They developed analyses of scale separation and applied this method to 850 hPa fields over the entire Alpine area. Ivančan-Picek (1997) has shown that, using such an objective analysis technique applied with different weight factors, even smaller scale features at surface level in the area of the Adriatic Sea can be isolated.

In this paper, we wish to throw more light on *jugo* conditions along the east Adriatic coast and islands, considering detailed 10-minute variations of wind speed and gusts in special case studies of recent years, their causes and the possibility of their prediction.

2. DATA AND NUMERICAL MODEL

During the selected *jugo* events, standard surface wind measurements were available at 13 meteorological station locations along the east Adriatic coast and islands. These stations have available daily courses of 10-minute variations of wind speed and maximal gusts. The positions of these measuring sites are shown in Figure 1.

We employed the HRID model (High Resolution Isentropic Diagnosis) for the identification and interpretation of the finest properties of the atmospheric systems, their vertical development and lifetime predicted at some arbitrarily chosen locality (Glasnović et al., 1994). The input data set for HRID contains operational ALADIN/HR model raw data of a number of arbitrarily chosen grid points at every 3 hours in the form of so-called pseudo-TEMP's, which is an alternative name for prognostic TEMP messages. The default vertical resolution is one degree of the absolute temperature scale. The HRID output files are adjusted to the conventional Cartesian co-ordinates so that the cross-section grid points are regularly spaced in the vertical at every hundred meters.

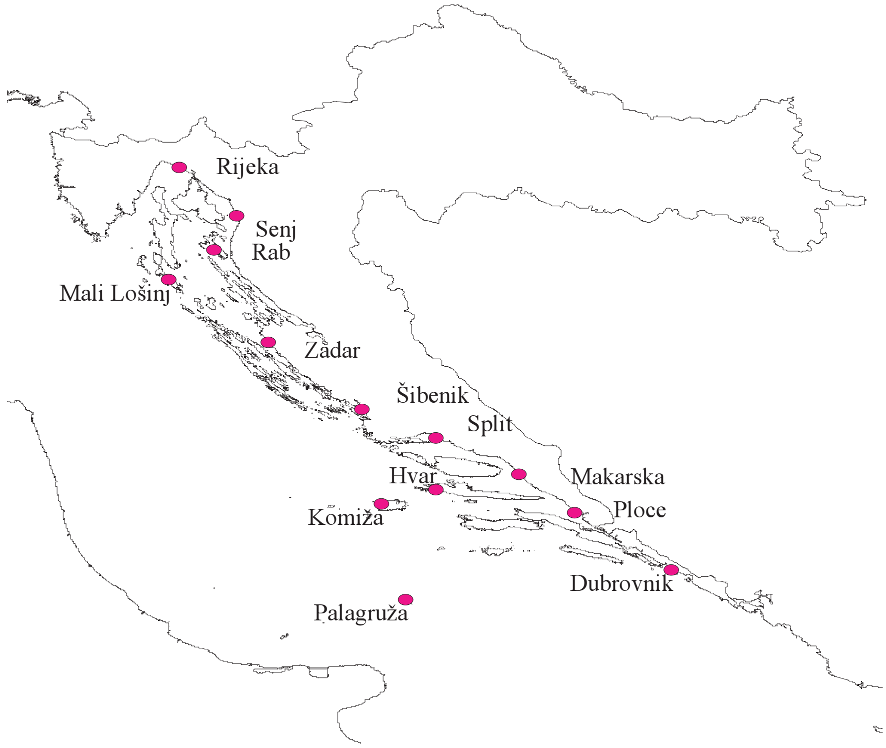

Figure 1. Eastern Adriatic coast with the locations of 13 meteorological stations with available daily courses of 10-minute variations of wind speed and maximal gusts (ms^{-1}).

Slika 1. Položaj 13 meteoroloških postaja na istočnoj obali Jadrana s raspoloživim podacima 10-minutne brzine vjetra i maksimalnih udara (ms^{-1}).

3. THE DAILY COURSES OF WIND SPEED AND GUSTS DURING *JUGO* EVENTS

The results obtained in the previous studies (e.g. Vukičević and Jurčec, 1998; Brzović, 1999) show that the direction and intensity of *jugo* are strongly influenced by local effects. Figure 2 demonstrates an example of such courses of maximum hourly wind data for a special case study of 26 December 2004, illustrating the large differences in speeds on this day. The variations differ greatly from station to station as well as in time at particular stations. Similar characteristics are found on other courses during *jugo* events.

Jugo is usually stronger over the open sea and islands, particularly in southern Dalmatia, but, in some cases, high gusts can also occur over the northern Adriatic. This is seen in Figure 3,

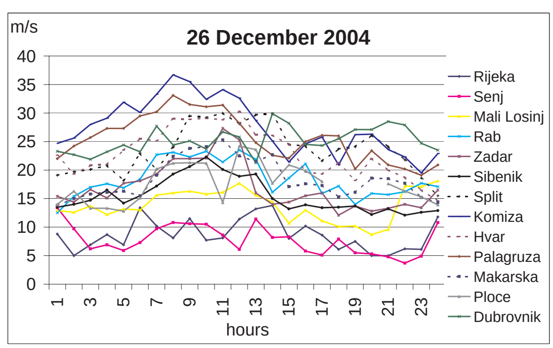

Figure 2. Daily courses of maximal hourly wind speed values (ms^{-1}) for 26 December 2004, for the 13 stations mentioned in Figure 1.

Slika 2. Dnevni hod maksimalne satne brzine vjetra (ms^{-1}) za 26. prosinca 2004. godine za 13 postaja danih na slici 1.

illustrating some examples of courses at several stations (Palagruža, Zadar, Rab and Komiža) in different case studies. Figure 3a shows the course at Palagruža, an island in the middle of Adriatic Sea. It shows that the speed and maximal gusts suddenly increase in the late afternoon, which is unexpected. The direction of *jugo* is 150°, with a slightly bigger variability during maximum speed. Figure 3b for Zadar indicates the maximal gusts during frontal passage when the winds temporarily change to NE direction, which can be due to local conditions, but this feature will be checked by sounding in the next section.

A special characteristic is the course at Rab, in Figure 3c, with very strong gusts, when compared with weaker and less variable wind speeds. This was a real surprise, since it is generally considered that *jugo* is much weaker in the northern than in the southern coast. This phenomenon, therefore, needs to be studied further in the near future, because it could be very dangerous for maritime traffic. Komiža, in mid-Adriatic (Fig. 3d), also indicates larger differences between wind speed and gusts, especially in the morning hours. These variants of the *jugo* wind were not known so far, since most of the studies considered only a few stations along the coast.

In the next section we shall attempt to offer some explanation for the observed variants of *jugo* from the synoptic aspect, with special attention to the problem of forecasting severe *jugo* with gusts.

4. CASE STUDIES

4.1. The case on 1–2 November 2003

It is usually considered that *jugo* intensifies gradually. This is only partly correct, as we can see from the daily course of *jugo* in Split and Dubrovnik on 1 November 2003 (Fig. 4). It can be seen that in spite of a gradual intensification this was a relatively rapid process, since at the end of the day the gusts were already 30 ms^{-1}. However, this was a really severe *jugo*

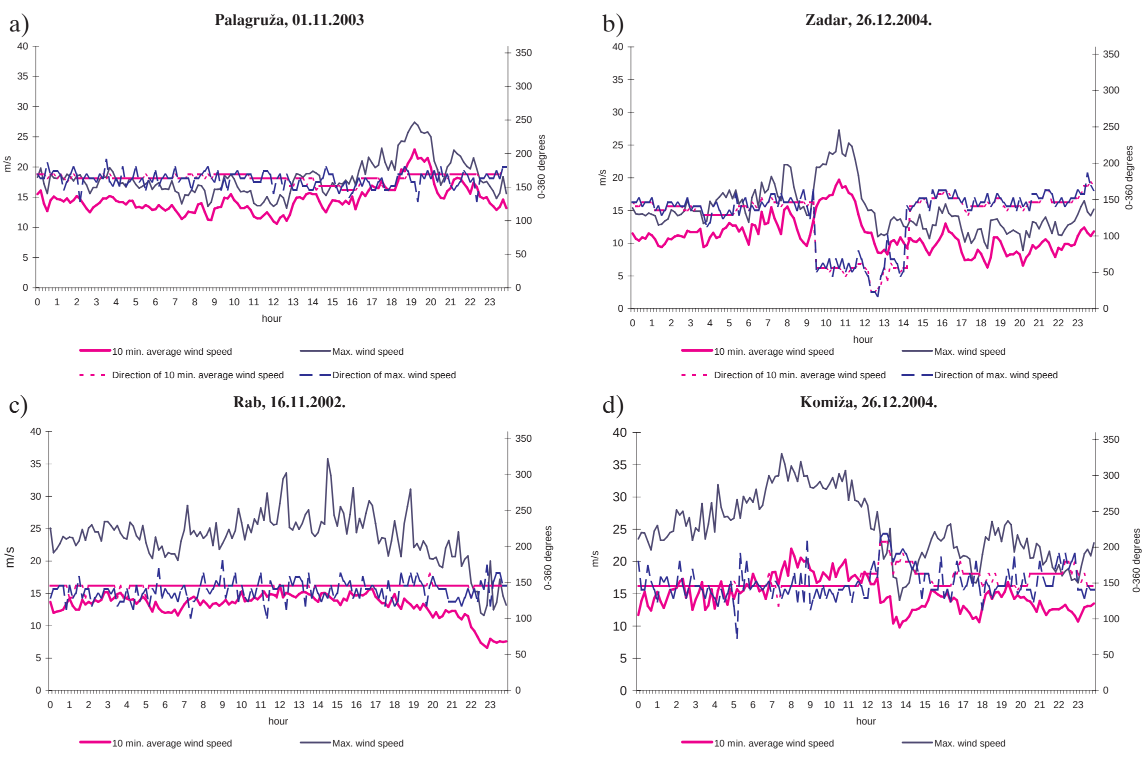

Figure 3. Daily courses of 10-minute variations of wind speed (pink solid lines), maximal gusts (blue solid lines) and wind direction (dashed lines) for the stations: a) Palagruža, 1 November 2003; b) Zadar, 26 December 2004; c) Rab, 16 November 2002 and d) Komiža, 26 December 20004.

Slika 3. Dnevni hodovi 10-minutne srednje brzine vjetra (ružičasta linija), maksimalnih udara (plava puna linija) i smjera vjetra (crtkana linija) za postaje: a) Palagruža 1. studeni 2003.; b) Zadar 26. prosinca 2004.; c) Rab 16. studeni 2002. i d) Komiža 26. prosinca 2004.

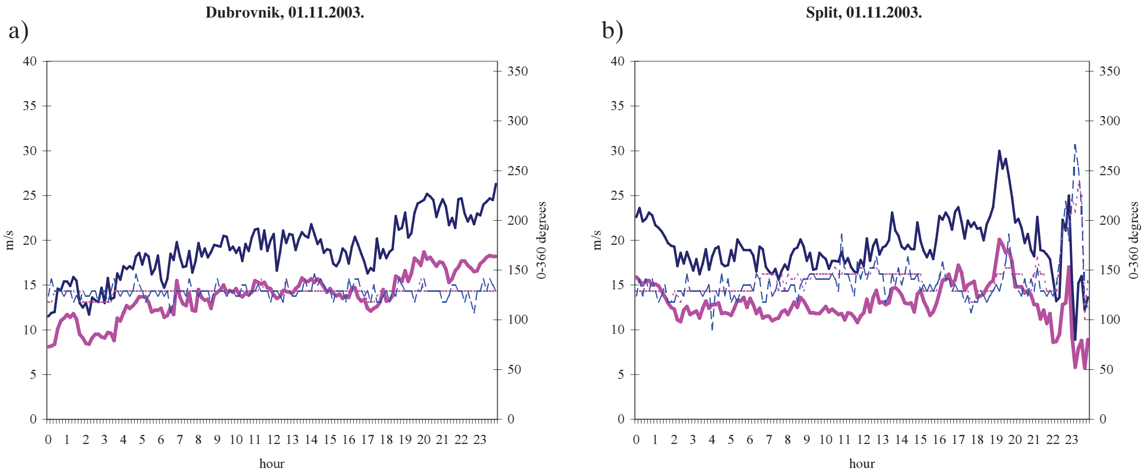

Figure 4. As Figure 3, only for a) Dubrovnik and b) Split, 1 November 2003.

Slika 4. Isto kao na slici 3 samo za postaje a) Dubrovnik i b) Split, 1. studeni 2003.

case, and we shall now consider the reason for such behaviour.

Figure 5 presents the synoptic charts for 1 and 2 November 2003. They show a very deep cyclone over the north Atlantic, with the centre moving rapidly toward Europe already occupied by cyclonic activity and frontal systems in the Alpine area. What supported this fast development is the upper-level trough, associated with the Atlantic cyclone, reaching the western Mediterranean area at 300 hPa level. We could, therefore, probably have predicted the *jugo* occurrence on 1 November 2003, but not the time of the gusts at particular stations. This, however, seems possible by using the HRID vertical cross-section based on the ALADIN/HR model forecast shown in Figure 6, covering for 48 hours, starting at 12 UTC on 31 October 2003, in Zadar. The most pronounced feature on this cross-section is the frontal zone on 1 November, at 18 UTC, characterized by a high relative humidity of over 90%, decreasing temperature in the lower troposphere and increasing temperature in the higher troposphere. The frontal characteristics are also well pronounced as shown by the equipotential temperature lines inside the frontal zone. Convectively unstable area is found below 4 km ahead of the front and at higher levels inside the frontal zone. The wind field shows stronger SW winds and the wind direction changes in the low troposphere. *Jugo* ahead of the front is a shallow weather phenomenon below 2 km, changing direction to W and weakening. The wind changes at 18 UTC when the front passes, followed by minimum pressure and maximum dew point temperature.

Therefore, the above analysis clearly shows that *jugo* occurs ahead of a cyclonic activity in the Alpine area with maximal gusts related to the frontal zone.

4.2. The case on 16–17 November 2002

There was another case on November 2002, which has a large statistical frequency of *jugo* storms. It was a case of strong *jugo* on the island of Rab on the northern Adriatic coast. As Figure 3 shows, instead of a relatively weaker wind speed the maximal gusts reached about 35 ms^{-1}.

Figure 7 shows the surface synoptic charts for 16 and 17 November 2003. A deep cyclone is visible over the north Atlantic on 16 November, and weaker cyclonic activity with fronts occupies the Alpine area, central Europe and the west Mediterranean. The front is found over the Adriatic Sea on 17 November 00 UTC.

Figure 8 shows the HRID vertical cross-section for Rab, obtained by the ALADIN/HR model as in the previous case. The ALADIN prediction indicates that late in the evening of 16 November a frontal surface appeared in the middle troposphere and reached ground level only the next day, as indicated by the field of equipotential temperature. However, the frontal surface was weak at that time and winds were also weak at surface level. This can

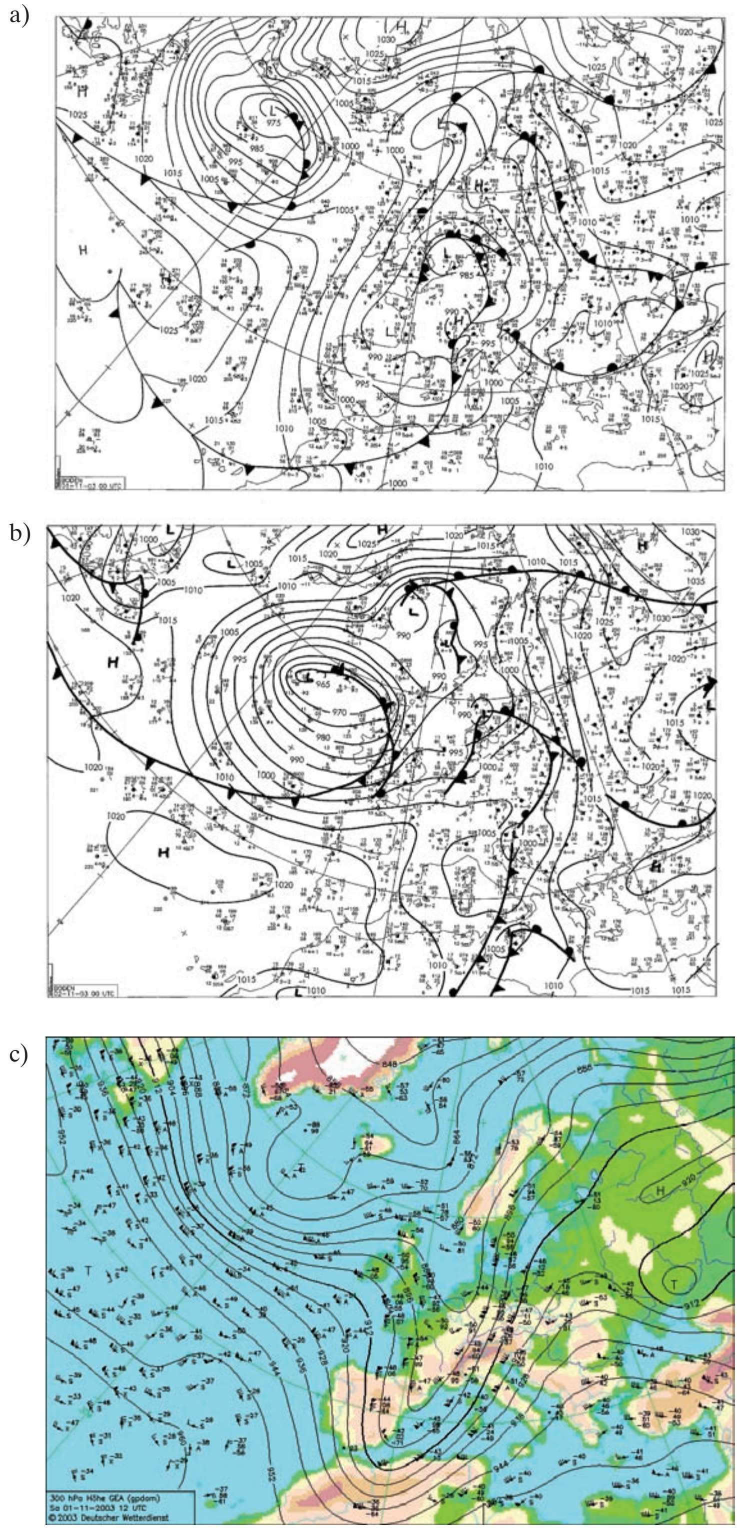

Figure 5. Analysis of the mean sea level pressure over Europe on 1 November 2003, 00 UTC (a), 2 November 2003, 00 UTC (b) and the 300 hPa geopotential height on 1 November 2003, 00 UTC (c). (From the Wetterbericht der Deutscher Wetterdienst).

Slika 5. Analiza prizemnog polja tlaka zraka nad Europom za 1. studeni 2003, 00 UTC (a); 2. studeni 2003, 00 UTC (b) i geopotencijala na AT 300 hPa za 1. studeni 2003, 00 UTC (c). (prema Wetterbericht der Deutscher Wetterdienst).

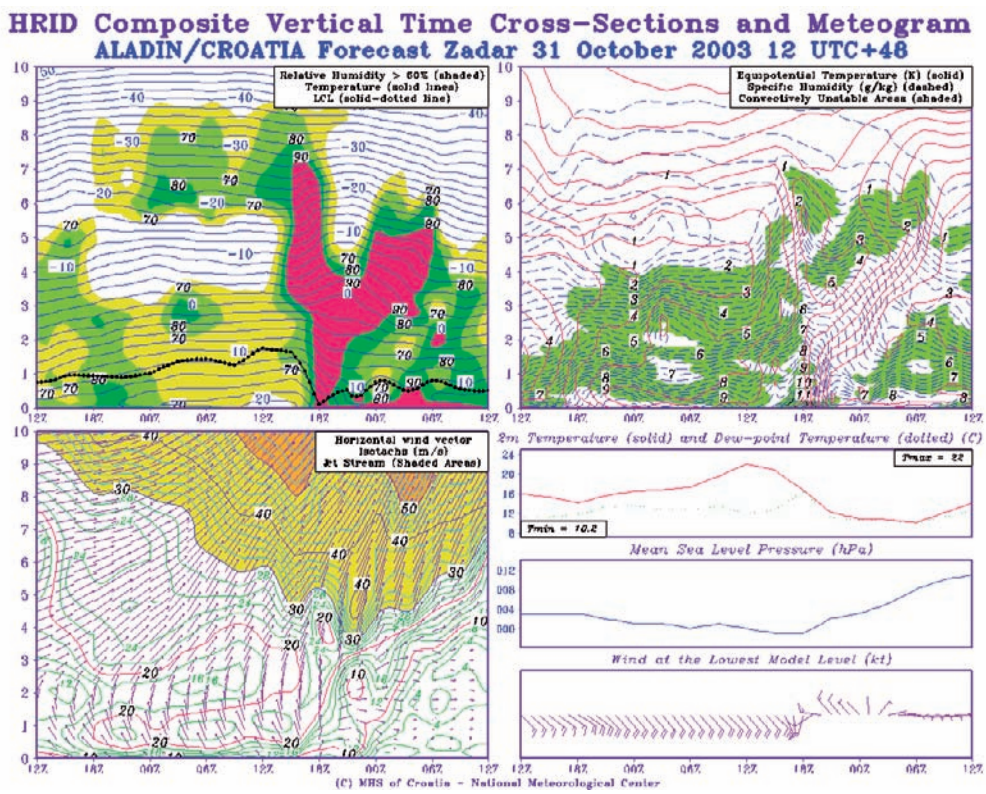

Figure 6. HRID composite vertical time cross-sections, ALADIN/HR forecast for Zadar, 31 October 2003, 12 UTC + 48. Top left – relative humidity >60% (shaded area), temperature (solid lines), LCL (dotted line). Top right – equipotential temperature (K) (solid), specific humidity (gkg^{-1}) (dashed), convective unstable areas (shaded). Down left – horizontal wind vectors and isotachs (ms^{-1}). Down right – temporal evolution of surface temperature and dew-point temperature, mean sea level pressure and wind at the lowest model level (kt).

Slika 6. HRID vertikalni vremenski presjek temeljen na izračunu modela ALADIN/HR za Zadar, 31. listopada 2003, 12 UTC + 48. Gore lijevo – relativna vlažnost >60% (osjenčano područje), temperatura zraka (pune krivulje), konvektivna kondezacijska razina LCL (crtkana krivulja). Gore desno – ekvivalentno potencijalna temperatura (K) (pune krivulje), specifična vlaga (gkg^{-1}) (crtkane krivulje), konvektivno nestabilna područja (sjenčano). Dolje lijevo – vektori horizontalne brzine vjetra i izotahe (ms^{-1}). Dolje desno – dnevni hodovi prizemne temperature zraka i rosišta, prizemnog tlaka zraka i vjetra na najnižem nivou modela (čv).

also be seen in the lowest model level. Pressure rapidly increased next day, after reaching its lowest value on 16 November after 12 UTC. At that time, temperature decreased and the dew point temperature rose.

This case shows that winds were relatively weak, since the front was not pronounced at surface level, but this time, strong *jugo* was characterised by high gusts caused by the upper-level front predicted by the HRID and ALADIN/HR model forecast.

4.3. The case on 25–27 December 2004

Jugo is associated with the «Christmas cyclone», which statistically frequently appears at this time in Adriatic area (Jurčec and Vukićević, 1997). Such an extremely strong *jugo* episode occurred during 26 December 2004. It can be seen in Figure 3 that in Zadar and Komiža wind speeds and maximal gusts reached high values in the morning hours of 26 December 2004.

Figure 9 shows the sea-level synoptic charts for 26–27 December 00 UTC with a deep cyclone in the western Mediterranean. It was caused by the northerly cold flow ahead of the Atlantic high and by a cyclone which was, at this time, located much more to the north over the Atlantic. The frontal system was found on 27 December, 00 UTC, over the north Adriatic a)

b)

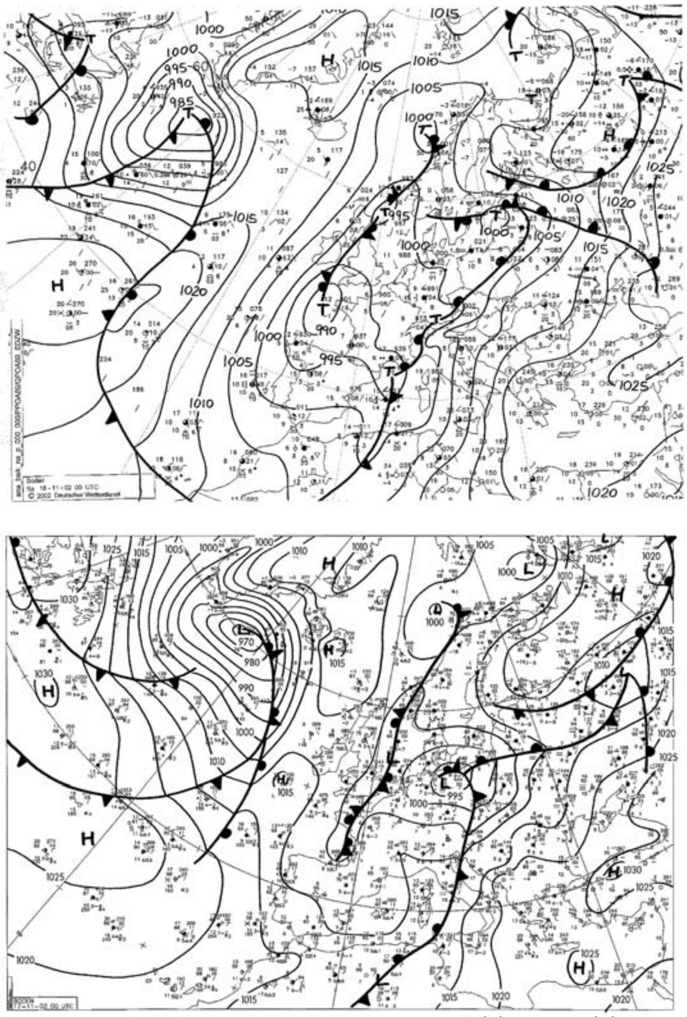

Figure 7. Analysis of the mean sea level pressure over Europe on 16 (a) and 17 (b) November 2002, 00 UTC . (From the Wetterbericht der Deutscher Wetterdienst).

Slika 7. Analiza prizemnog polja tlaka zraka nad Europom za 16. (a) i 17. (b) studeni 2002, 00 UTC. (prema Wetterbericht der Deutscher Wetterdienst).

Sea, where it was already on the previous day. The ALADIN/HR model correctly predicted the frontal position. Figure 10 shows the ALADIN/HR forecast presented in the time cross-sections for Zadar for 48 hours, with the initial time on 25 December 2004 at 12 UTC. It can be seen that the lifting condensation level (LCL), i.e. the height where air would become saturated, drops to a height below 0.5 km, when relative humidity increases above 90% throughout the troposphere with a slightly decreasing temperature. This occurred at the time when the frontal zone reached Zadar, between 06 and 12 UTC on 26 December. This can be especially well seen in the equipotential temperature field, where the steeply inclined equivalent potential temperature lines together with the crowding lines of specific humidity clearly indicate the frontal zone. However, this front is not so pronounced as in the case of 1 November 2003 (in Fig. 7). The meteogram also registers the minimum pressure and maximum temperature on 26 December at 12 UTC during frontal passage.

The predicted low-level winds in Zadar did not change direction during frontal passage. A very strong wind of over 30 ms^{-1} occupied the low layer at around 1 km altitude. The model results are not in agreement with the observed

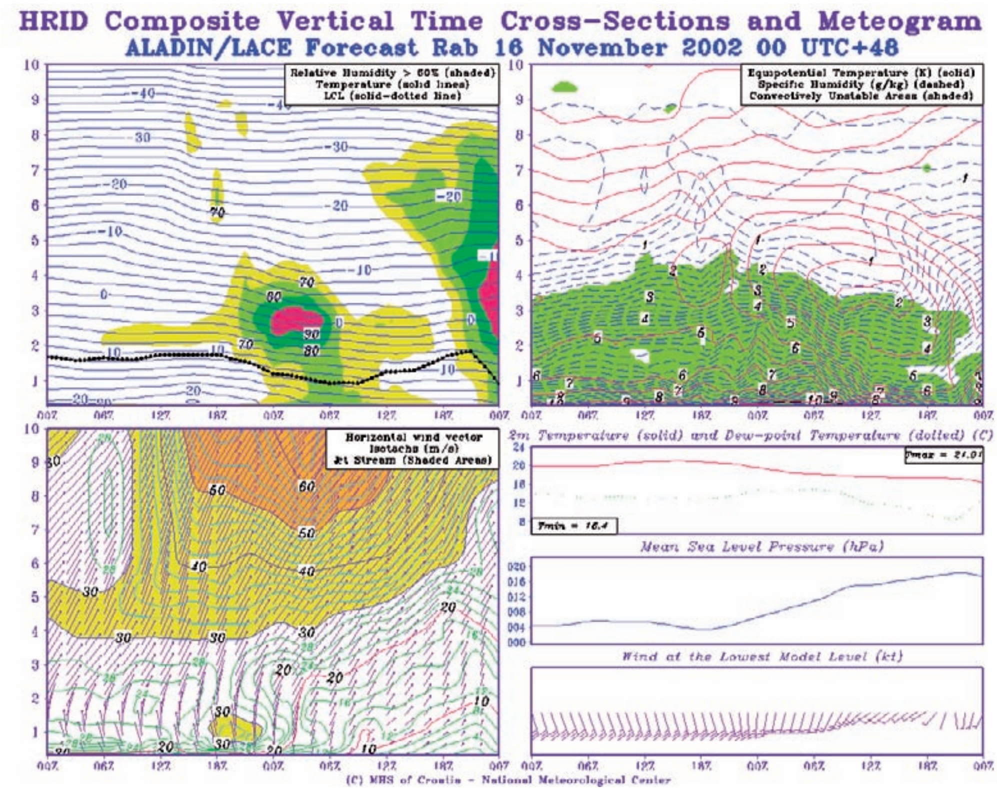

Figure 8. HRID composite vertical time cross-sections, ALADIN/HR forecast for Rab, 16 November 2002, 00 UTC + 48. Top left – relative humidity >60% (shaded area), temperature (solid lines), LCL (dotted line). Top right – equipotential temperature (K) (solid), specific humidity (gkg^{-1}) (dashed), convective unstable areas (shaded). Down left – horizontal wind vectors and isotachs (ms^{-1}). Down right – temporal evolution of surface temperature and dew-point temperature, mean sea level pressure and wind at the lowest model level (kt).

Slika 8. HRID vertikalni vremenski presjek temeljen na izračunu modela ALADIN/HR za Rab, 16. studenog 2002, 00 UTC + 48. Gore lijevo – relativna vlažnost >60% (osjenčano područje), temperatura zraka (pune krivulje), konvektivna kondenzacijska razina LCL (crtkana krivulja). Gore desno – ekvivalentno potencijalna temperatura (K) (pune krivulje), specifična vlaga (gkg^{-1}) (crtkane krivulje), konvektivno nestabilna područja (sjenčano). Dolje lijevo – vektori horizontalne brzine vjetra i izotahe (ms^{-1}). Dolje desno – dnevni hodovi prizemne temperature zraka i rosišta, prizemnog tlaka zraka i vjetra na najnižem nivou modela (čv).

values which indicate temporary changes of wind directions in Zadar (Fig. 3). This might have been caused by some local influence(s) and should be further investigated in detail.

To conclude, this case indicates that strong *jugo* is related to low-level cyclonic activities in the Mediterranean, whereas the gusts depend on the intensity and structure of the frontal zone. Such a conclusion should be, of course, proved by additional cases, which are already planned for our future investigations of the *jugo* project and also as our contribution to the WWRP MEDEX project – the MEDitarranean EXperiment on cyclones that produce high impact weather in the Mediterranean (http://medex.inm.uib.es/).

5. THE RELATION OF JUGO TO SCIROCCO

Until recently, *jugo* was considered to be a wind which belongs to the family of *scirocco* winds. In the paper by Jurčec et al. (1996) we suggested that the definition of *scirocco* should be corrected if *jugo* is to be considered a local variation of the *scirocco* wind system in the Mediterranean.

Scirocco is defined as (Huschke, 1959): "A warm south wind in advance of a depression moving eastward across the southern Mediterranean or North Africa. The air comes from the Sahara (as a desert wind), it is dry and dusty, but the term is not used in North Africa where the natives call it *chom* (hot) or *arifi*

a) b)

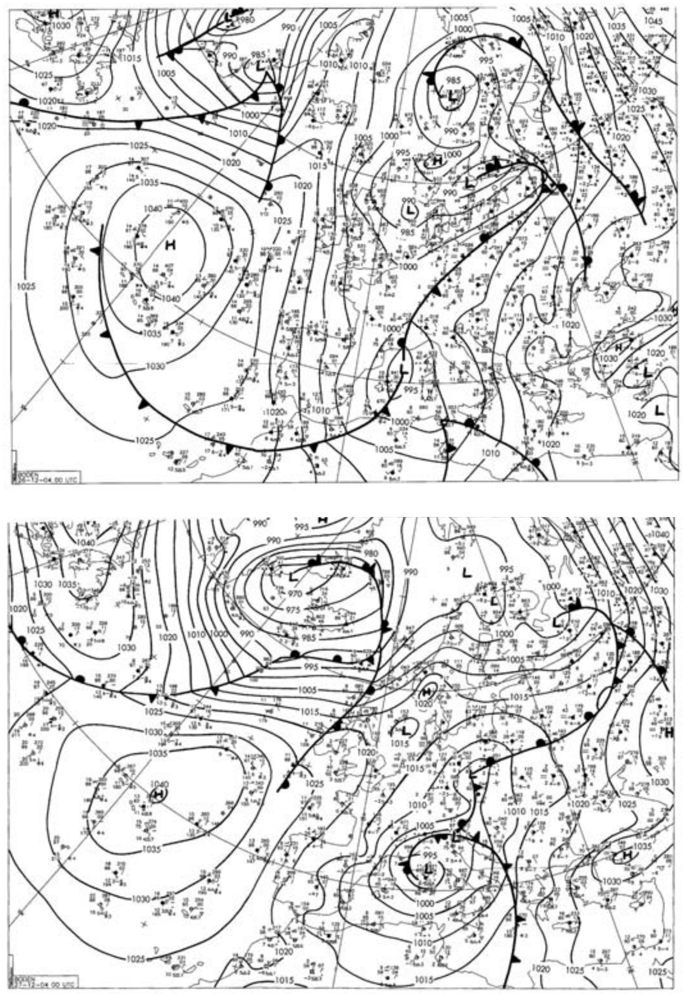

Figure 9. Analysis of the mean sea level pressure over Europe on 26 (a) and 27 (b) December 2004, 00 UTC (From the Wetterbericht der Deutscher Wetterdienst).

Slika 9. Analiza prizemnog polja tlaka zraka nad Europom za 26. (a) i 27. (b) prosinca 2004, 00 UTC. (prema Wetterbericht der Deutscher Wetterdienst).

(thirsty). In crossing the Mediterranean, the *scirocco* picks up a lot of moisture because of its high temperature, and reaches Malta, Sicily and southern Italy as a very enervating, hot and humid wind. As it moves northward, it causes fog and rain."

Since this description is not satisfactory for severe *jugo* in the Adriatic, we suggested that the origin of the depression could be also the western Mediterranean and the description of *scirocco* in the Adriatic should satisfy the local *jugo* wind. This suggestion was not accepted, hence we concluded that ***jugo* is not *scirocco*.** This does not mean that *scirocco* can not reach the Adriatic and even the continental part of Croatia. As indicated by Reiter (1975), *scirocco* contains dust and produces a thick haze that reduces visibility and causes "muddy rain" which has been detected in the continental part of Croatia. This is *scirocco*, **but not *jugo* wind!**

6. CONCLUSION

Jugo is a warm and humid wind of S–SE direction along the eastern Adriatic Coast and islands. It is a shallow weather phenomenon usually extending not more than 2 km in height, where it rapidly changes to SW winds on the advanced side of an upper-level trough.

On macroscale, the origin of *jugo* is related to deep cyclones moving from the Atlantic to the western Mediterranean, where they are influ-

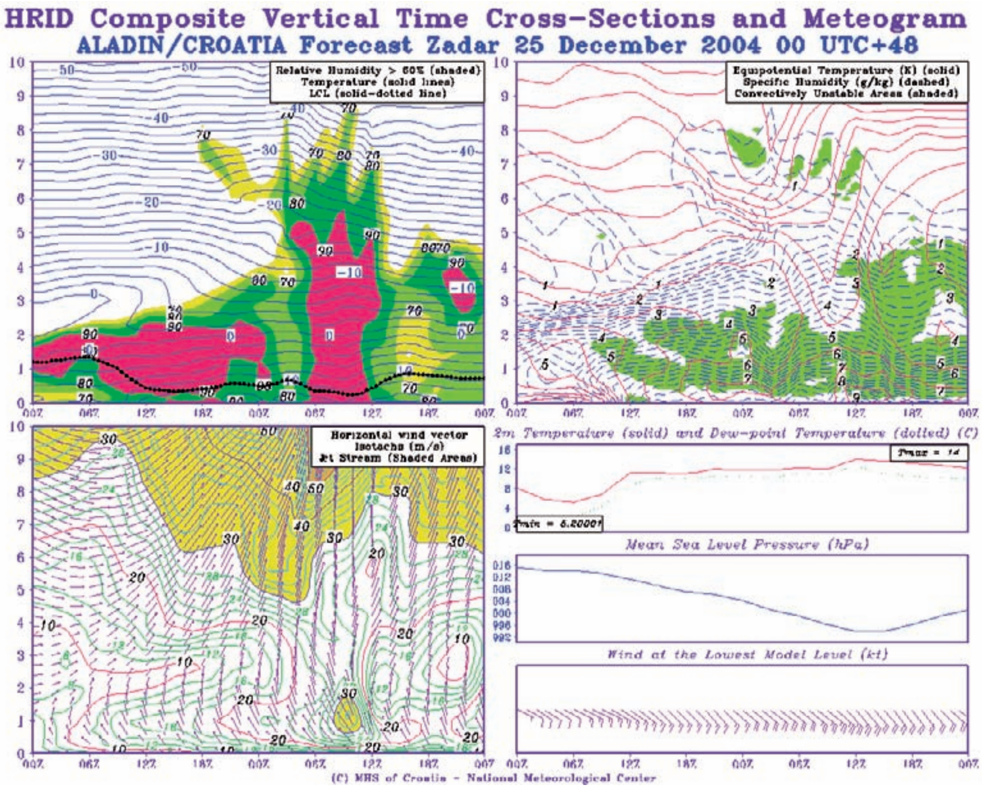

Figure 10. HRID composite vertical time cross-sections, ALADIN/HR forecast for Zadar, 25 December 2004, 12 UTC + 48. Top left – relative humidity >60% (shaded area), temperature (solid lines), LCL (dotted line). Top right – equipotential temperature (K) (solid), specific humidity (gkg^{-1}) (dashed), convective unstable areas (shaded). Down left – horizontal wind vectors and isotachs (ms^{-1}). Down right – temporal evolution of surface temperature and dew-point temperature, mean sea level pressure and wind at the lowest model level (kt).

Slika 10. HRID vertikalni vremenski presjek temeljen na izračunu modela ALADIN/HR za Zadar, 25. prosinca 2004, 12 UTC + 48. Gore lijevo – relativna vlažnost >60% (osjenčano područje), temperatura zraka (pune krivulje), konvektivna kondezacijska razina LCL (crtkana krivulja). Gore desno – ekvivalentno potencijalna temperatura (K) (pune krivulje), specifična vlaga (gkg^{-1}) (crtkane krivulje), konvektivno nestabilna područja (sjenčano). Dolje lijevo – vektori horizontalne brzine vjetra i izotahe (ms^{-1}). Dolje desno – dnevni hodovi prizemne temperature zraka i rosišta, prizemnog tlaka zraka i vjetra na najnižem nivou modela (čv).

enced by the coastal mountain ranges, particularly by the Alpine lee side effects. This synoptic forcing mainly causes a gradual intensification of *jugo* over the Adriatic Sea, but the subsynoptic effects of mesoscale cyclones and fronts lead to a rapid increase in wind speed and maximal gusts, which can reach a speed of over 40 ms^{-1}.

Deep Mediterranean cyclones can intensify the strong southern flow from the north of Africa to the Adriatic Sea and this was the reason for the misleading interpretation that *jugo* belongs to the family of *scirocco* winds. Although *scirocco* can, on rare occasions, reach the Adriatic Sea, its arrival is recognized by its containing vast quantities of dust from Africa and causing “muddy rain” in the continental part of Croatia. Thus, according to their origin and structure, *jugo* and *scirocco* can be easily distinguished.

High *jugo* speeds and, particularly, maximal gusts are found during frontal passages, which are clearly predicted by the HRID vertical time cross-section based on the ALADIN/HR 48-hours prediction model with high resolution. Very strong *jugo* wind is shown to be related to strong cyclonic activity in the Mediterranean, and this is also successfully predicted by the strong SE winds in the low layer of the ALADIN model. Some observed temporary changes of wind direction during *jugo* events should be further investigated.

The presented curves of maximal gusts indicate that the highest values of gusts usually appear over the open sea, but they are also found at the coastal stations.

It is expected that intensive studies of Mediterranean cyclones and their structure in the MEDEX scientific project will contribute to the knowledge about Adriatic cyclones and their influence on the *jugo* wind behaviour.

REFERENCES

Brzović, N., 1999: Factors affecting the Adriatic cyclone and associated windstorms. *Contr. Atmos. Phys*., **72**, No. 1, 51–65.

Glasnović, D., I. Čačić and N. Strelec, 1994: Application of High Resolution Isentropic Diagnostic Model. *Osterreichische Beitrage zu Meteorologie und Geophysic*, 109–136.

Gomis, D., A. Buzzi and S. Alonso, 1990: Diagnosis of mesoscale structure in cases of lee cyclogenesis during ALPEX. *Meteo. Atmos. Phys*., **43**, 49–57.

Huschke, R. E. (ed). 1959: Glossary of Meteorology, A.M.S., 638 pp.

Ivančan-Picek, B., 1997: Adriatic cyclogenesis – Mesoscale structures. *Inter Symposium on cyclones and Hazardous Weather in the Mediterranean,* 14–17 April 1997, Palma de Mallorca, 267–272.

Ivančan-Picek, B. and V. Jurčec, 2003: Mesoscale atmospheric vortex generation over the Adriatic Sea. *Idojaras*, **197**, 67–83.

Jurčec, V., B. Ivančan-Picek, V. Tutiš and V. Vukićević, 1996: Severe Adriatic jugo wind. *Meteor. Zeitschrift,* **5**, 67–75.

Jurčec, V. and V. Vukićević, 1996: Olujno jugo na Palagruži 28–30. lipanj 1996. *Jadranska meteorologija*, **41**, 251–256.

Jurčec, V. and V. Vukićević, 1997: Božićna ciklona 1996. godine. *Izvanredne meteorloške i hidrološke prilike u Hrvatskoj*, **20,** 33–39.

Lisac, I., B. Zelenko, A. Marki and Ž. Trošić, 1998/99: Wind direction frequency analysis for the jugo wind in the Adriatic. *Croatian Meteor. Journal*, **33/34**, 19–37.

Makjanić, B., 1978: Bura, jugo etezije. Prilozi poznavanju vremena i klime SFRJ, SHMZ, 73 str.

Poje, D., 1992: Wind persistence in Croatia. *Inter. J. Climatology*, **12**, 569–586.

Reiter, E.R., 1975: Handbook for forecasters in the Mediterranean. *Tech. Paper* **No. 5** – 75. Naval Postgraduate School Monterey, CA. 344 pp.

Trošić, Ž., 1983: Statistička obilježja juga na Jadranu. Magistarski rad Sveučilišta u Zagrebu, 112 str.

Tutiš, V. and S. Britvić, 1993: Olujno jugo 5–10 prosinac 1992. *Izvanredne meteorološke i hidrološke prilike u Hrvatskoj,* **16**, 27–34.

Vukićević, V., 1991: Statistička analiza olujnog vjetra u Splitu. *Vijesti PMS*, **37**, 7–18.

Vukićević, V. and V. Jurčec, 1998: Olujno jugo 1997. u Splitu i varijacije brzine prizemnog vjetra. *Izvanredne meteorološke i hidrološke prilike u Hrvatskoj*, **21**, 29–33.

Vukićević, V. and V. Jurčec, 2004: Jugo na Jadranu. *Jadranska Meteorologija*, **49**, 52–58.

WWRP MEDEX project: MEDitarranean EXperiment on cyclones that produce high impact weather in the Mediterranean (http://medex.inm.uib.es/).