GEOFIZIKA	Vol. 4	1987

Conference paper
UDC 551.555
551.509

Cold air outbreak and the Adriatic bora*

Alica Bajić

Hydrometeorological Institute of SR Croatia, Zagreb, Yugoslavia

The case studies of twe cold air outbreaks in Zagreb which cause a local wind bora on the eastern Adriatic are presented (17 December 1978 and 7 January 1982).

The cold air outbreak on 17 December 1978 appeared as a shallow zone of large equivalent potential temperature drop (Θ_e) and NE wind with maximum at 800 m above ground. The stable layer which was placed above this zone was more expressed in terms of vertical Θ_e – rather than temperature–-structure which was a consequence of very humid and warm air advected from SW above the cold bora layer. This upstream bora layer characteristics and strengthening of cyclonic activity on the Tyrrhenian Sea caused a longlasting and strong bora associated with precipitation on the northern Adriatic. The strongest bora with maximum gusts of 35.2 m/s and with the longest duration occurred in Senj. At the other locations the duration of bora was 28–40 hours with the maximum gusts varying from 14.9 m/s to 34.7 m/s.

In the case of 7 January 1982, a strong bora, associated with anticyclone strengthening over the middle Europe, occurred along the entire Adriatic coast as a consequence of an expressed cold and dry air outbreak. The main characteristic in this situation was a narrow zone of sudden drop of Θ_e and NE wind with a maximum at 2.5 km altitude. The stability above this zone was smaller than in the first situation and the temperature fall occurred throughout the troposphere. Due to extremely dry air supply, the bora occurred without precipitation lasting from 16 to 31 hours and even 52 hours in Senj. The maximum gusts varied from 17.0 m/s to 35.4 m/s.

Two case studies are not enough for a general conclusion but it should be emphasized that the bora had quite different characteristics in the considered frontal situations.

Prodor hladnog zraka i bura na Jadranu

Prikazane su dvije situacije s prodorom hladnog zraka na područje Zagreba koji je uzrokovao pojavu bure na istočnoj obali Jadrana (17. prosinac 1978. i 7. siječanj 1982.).

* Presented at the Symposium „Observations and Modelling in Geophysics", organized by the Geophysical Institute, Faculty of Science, University of Zagreb. The Symposium was held at Zagreb, Yugoslavia, between 11 and 13 June 1986.

Prodor hladnog zraka 17. prosinca 1978. pojavio se kao plitka zona naglog pada ekvivalentne potencijalne temperature Θ_e i NE vjetra s maksimalnom brzinom na 800 m nad tlom. Stabilni sloj zraka koji se nalazi iznad ove zone jače je izražen u vertikalnoj strukturi Θ_e nego temperature što je posljedica advekcije toplijeg i vlažnijeg zraka sa SW iznad sloja bure. Ovakve karakteristike sloja bure u navjetrini i jačanje ciklonalne aktivnosti nad Tirenskim morem uzrokovali su dugotrajnu i jaku buru na sjevernom Jadranu. Najjača bura s maksimalnim udarom od 35,2 m/s i bura najduljeg trajanja (48 sati) zabilježena je u Senju. Na ostalim lokacijama trajanje bure bilo je 28–40 sati s maksimalnim udarima od 14,9 m/s do 34,7 m/s.

U situaciji od 7. siječnja 1982. jaka bura povezana s jačanjem anticiklone nad srednjom Evropom zabilježena je duž čitave istočne obale Jadrana kao posljedica prodora hladnog i izrazito suhog zraka. Zona pada Θ_e i NE vjetra s maksimumom na 2,5 km visine ovdje je izrazitija nego u prethodnoj situaciji, a stabilnost iznad te zone je manja. Bura uzrokovana ovim prodorom hladnog zraka trajala je 16–31 sat i čak 52 sata u Senju, a maksimalni udari varirali su od 17 do 35,4 m/s.

Na osnovi analize spomenutih dviju situacija pokazano je da bura ima posve različite karakteristike u ovisnosti o različitim uvjetima u navjetrini bure.

1. Introduction

Cold air outbreak which causes a local wind bora on the eastern Adriatic coast usually appears after the cold front passage on the upper levels and does not follow the direction of frontal movement above the stable layer. Namely, a part of the frontal system in the lower troposphere is blocked in the upstream Alpine region. As a consequence, the large part of cold air is steered around the lower part of the barrier and reaches the area of Zagreb from NE direction. Such NE cold air outbreaks cause a sudden appearance of the bora wind on the Adriatic.

The aim of this paper is to present two situations with different upstream bora conditions which consequently cause differences in time and space variation of the bora wind along the eastern Adriatic coast. The considered situations are: 17–19 December 1978 and 7–9 January 1982.

2. Synoptic situations

The cold air outbreak in the Zagreb region on 17–18 December 1978 appeared after the passage of the frontal zone associated with a cyclone to the north of the Carpathians, which in a strong W–SW stream moves rapidly to the east. The surface cold air advection in the Mediterranean on 18–19 December regenerated cyclonic activity in the Tyrrhenean Sea and caused the strengthening of the pressure gradient across the Adriatic coast (Fig. 1) and consequently the strong bora wind.

In contrast, the cold air outbreak on the 7 th January 1982 appeared at the same time as a surface front associated with a cyclome which moved along the central Europe to the east (Fig. 1). This quasistationary system enabled a stronger cold air advection from the north to the western part of Croatia and further to the Adriatic.

More detailed analyses of the synoptic situations and vertical atmospheric structure in both considered situations are given in the papers by Bajić and Jurčec (1985), Bajić (1985) and Vučetić (1985).

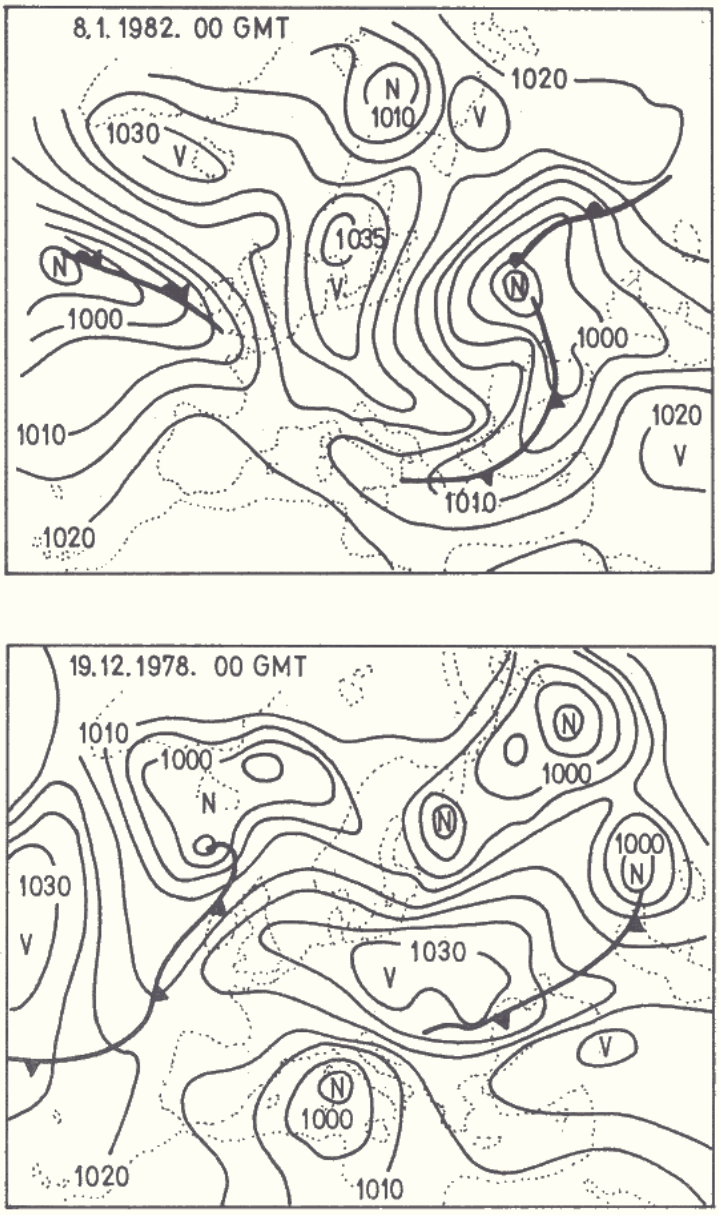

Figure 1. The surface synoptic situations: 19 December 1978 00 (top) and 8 January 1982 00 GMT (bottom).

3. Vertical structure of the upstream bora layer

The cold air outbreaks in both situations appear as a shallow zone of a large equivalent potential temperature (Θ_e) drop and NE wind. However, the height to which this zone extends is quite different. On 7–8 January 1982 the Θ_e drop can be noticed throug-

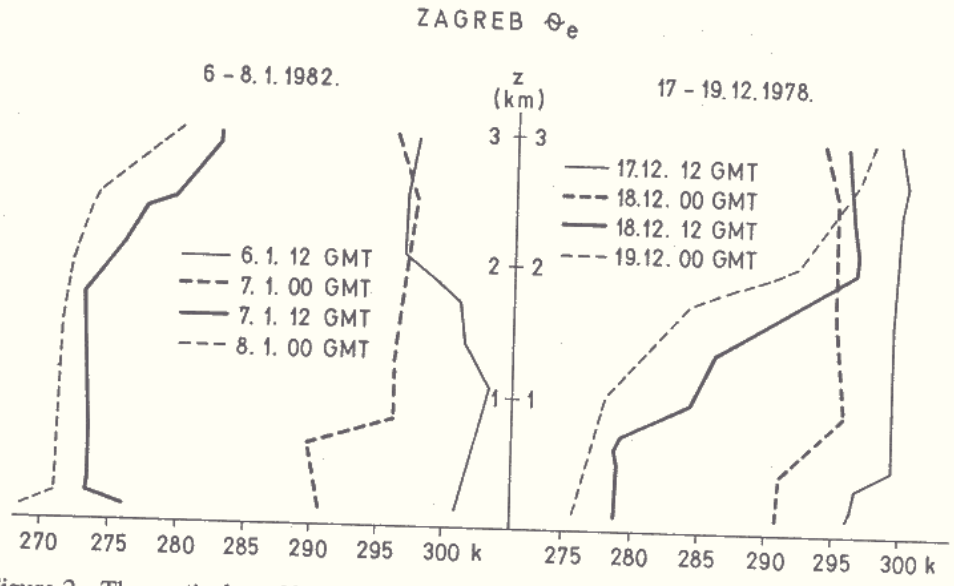

Figure 2. The vertical profiles of equivalent potential temperature (Θ_e) over Zagreb.

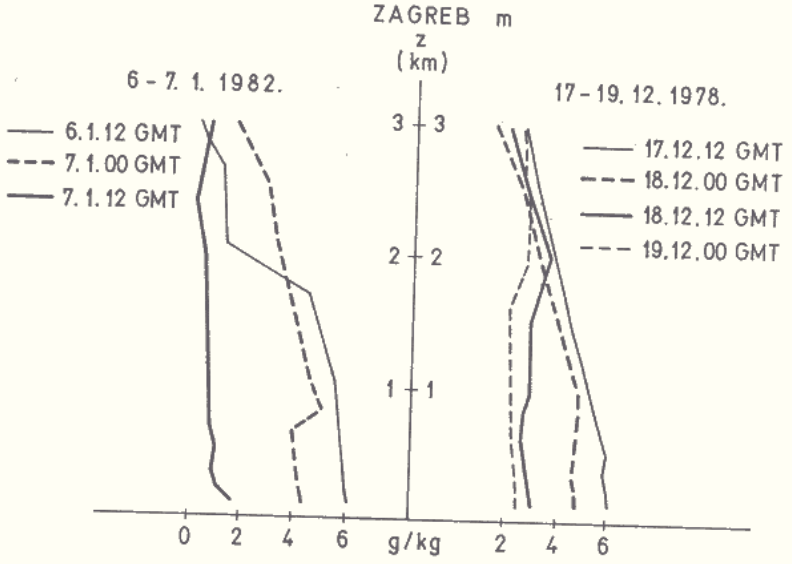

Figure 3. The vertical profiles of mixing ratio (m) over Zagreb.

hout the entire considered layer (Fig. 2). This was a consequence of a temperature drop which occurred throughout the troposphere, and of moisture decrease due to strong sinking motion of dry air originating in the stratosphere. The low humidity in the troposphere can be seen on the vertical mixing ratio profile (m) (Fig. 3), which was responsible for dryness of the front and the absence of precipitation in the bora region.

On 18th December 1978, a drop of Θ_e and m was measured just in the lowest 2 km. The temperature inversion layer appeared in this situation first below 1 km and later on it moved to higher altitudes (Fig. 4). This layer was more expressed in terms of vertical Θ_e structure, rather than temperature, a consequence of very humid and warm air advected from the SW above the cold bora layer.

The stability above the upstream bora layer on 7–8 January 1982 was smaller than in the previous situation and it appeared on 7th January at 12 GMT above the 2 km height.

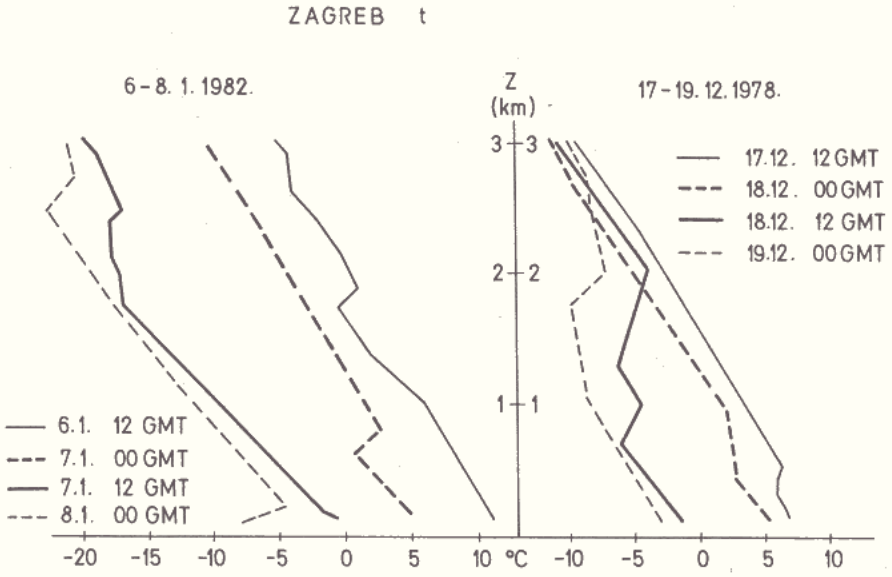

Figure 4. The vertical profiles of temperature (t) over Zagreb.

The upper boundary of Θ_e increase was at the same time the altitude where the wind had the NE component in both situations (Fig. 5). The maximum of the NE wind component (v) appeared just below the stable layer expressed in terms of Θ_e. The stronger and lower stable layer on 18–19 December 1978 was accompanied by a stronger wind than the one in January 1982.

Above the zone of NE wind, the wind direction changed in both situations. On 17–18 December 1978 the direction turned from NE to the SW, and on 7–8 January 1982 from NE to NW. This wind above the cold bora layer was perpendicular to the

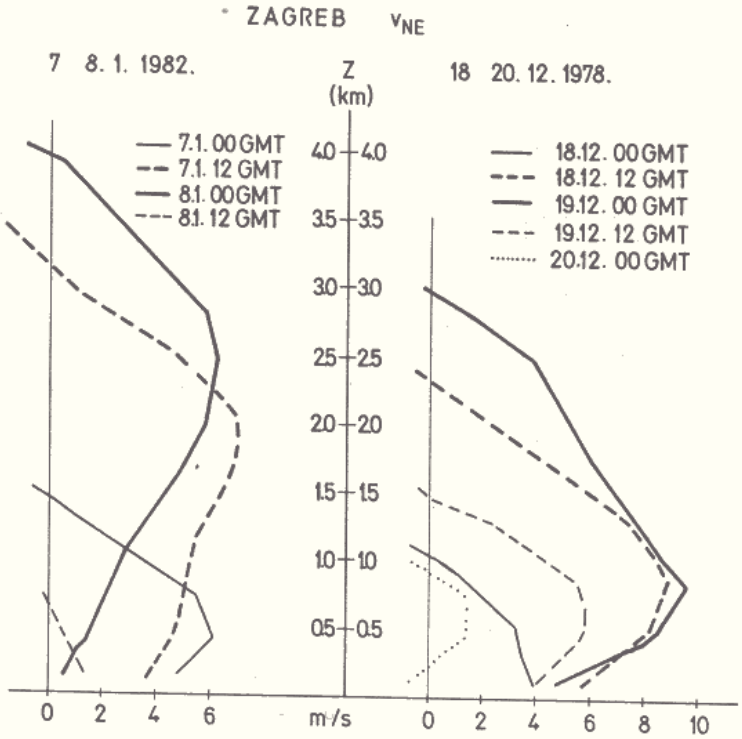

Figure 5. The vertical profile of NE wind component (v) over Zagreb.

lower layer wind. According to this, the upper and lower airflow layers were separated and the disturbances could not propagate aloft. The upper fluid then imposed no pressure gradients on the lower fluid to accelerate according to hydraulic laws (Smith, 1984).

4. Bora characteristics

On 7 January 1982 the bora occured rapidly and without precipitation due to the extremely dry air supply. The maximum bora gusts varied from 17 m/s (Mali Lošinj) to 35.4 m/s (Senj) as seen in Fig. 6. On 7 January the bora occurred almost at the same time along the entire Adriatic coast (2–6 hours after the beginning of the cold air outbreak at Zagreb). Its duration was from 16 hours (Pula and Omišalj) to 31 hours (Dubrovnik) and even 52 hours in Senj.

On 18–19 December 1978, strong bora associated with precipitation occurred on the northern Adriatic. The maximum 24 hourly precipitation amount (40.9 mm) was noticed in Senj on 19 December. Longer cold air advection in this situation caused the long-lasting bora (28–48 hours). The maximum gusts varied from 14.9 m/s (Pula) to 34.7 m/s (Omišalj) and 35.2 m/s (Senj), as seen in Figure 7. The onset of the bora in this situation was not so rapid as in January 1982.

Thus, the characteristics of the bora in the two presented situations are quite different.

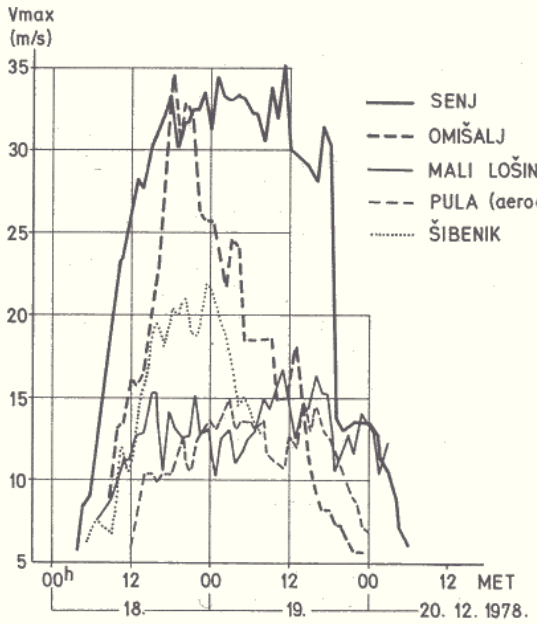

Figure 6. Daily courses of maximum bora gusts: 18–20 December 1978.

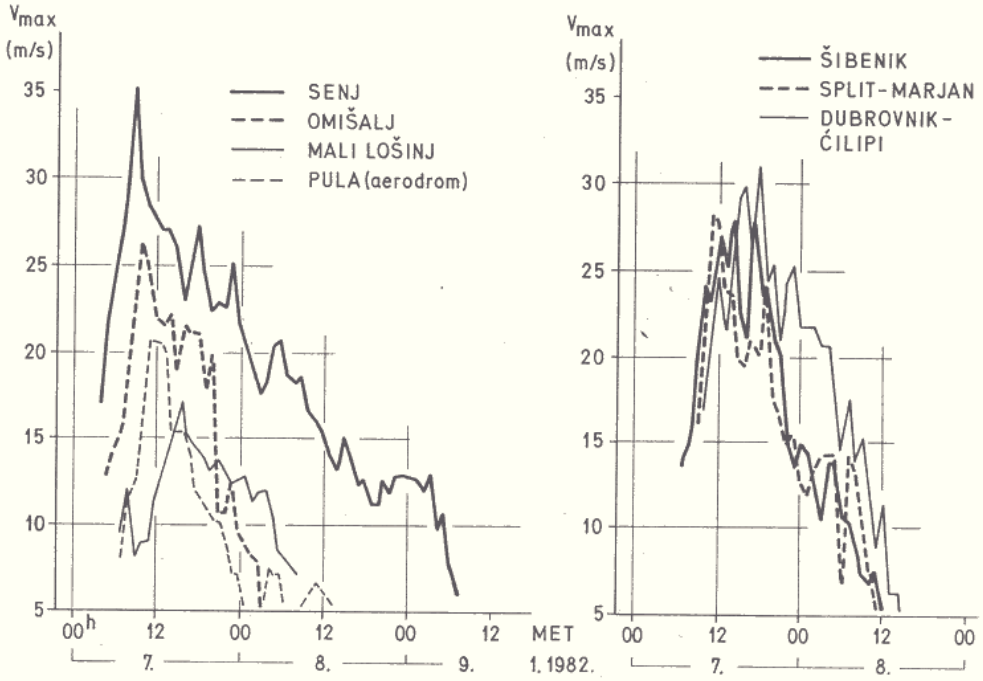

Figure 7. Daily courses of maximum bora gusts: 7.–9 January 1982.

5. Conclusion

The presented case studies of two cold air outbreaks in Zagreb demonstrate that the bora characteristics are dependent on the upstream atmospheric conditions.

A shallow upstream bora layer, with strong NE wind, capped with a very stable layer on 18–19 December 1978, caused the bora which was spatially restricted to the northern Adriatic. In this situation the bora associated with precipitation was of longer duration.

In contrast, rapid cold and extremely dry air outbreak on 7 January 1982 caused the short-lasting bora which extended over the entire Adriatic coast.

The two case studies are inadequate for a general conclusion, but it follows that the bora strength and duration greatly depend on the frontal system characteristics.

References

Bajić A. (1985): Karakteristike suhe fronte nad Zagrebom i njezini uzroci, Rasprave **20**, 3–10.

Bajić A. and V. Jurčec (1985): Orographic influence on synoptic development and associated local weather, Zbornik meteoroloških i hidroloških radova **12**, 37–40.

Smith R. B. (1984): Aerial observations of the Yugoslav bora, Zbornik meteoroloških i hidroloških radova **10**, 127–130.

Vučetić V. (1985): Karakteristike bure u lokalnim i mezorazmjerima, Rasprave 20, 11–20.