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SEVERE ADRIATIC BORA STORMS IN RELATION TO SYNOPTIC DEVELOPMENTS

Olujne bure na Jadranu u odnosu na sinoptički razvoj

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Abstract: Five typical north Adriatic bora storms are presented from the period 1957-1986. It is shown that severe bora is caused by a very cold air outbreak in a deep upper tropospheric trough which usually develops into a cut-off low in the Mediterranean. This process is often accompanied by a cut-off high in the norheastern Atlantic. Such a blocking type circulation prevents the warmer air from the Atlantic to invade the European continent which is occupied by a broad cold surface anticyclone. The latter builds up a large pressure gradient toward the Mediterranean cyclone which is particularly strong at the northern Adriatic coast. This pressure difference is calculated from the mountain drag according to Smith's (1985) hydraulic model and the results are mainly in good agreement with the observations.
Fast upper level development causes changes in the wind direction above the bora layer. Strongest bora occurs with the reversed upper air flow regardless of the wind intensity, whereas bora ceases under strong unidirectional (NE) current, unless there is a strong temperature inversion in the lower troposphere.

Key words: Adriatic bora, severe downslope wind, blocking type circulation, hydraulic parameters.

Sažetak: Prikazano je pet tipičnih slučajeva olujne bure na Sjevernom Jadranu iz razdoblja 1957-1986. Pokazano je da su ove oluje uzrokovane prodorima vrlo hladnog zraka u dubokim visinskim dolinama, koje se obično razvijaju u odcjepljenu (cu-off) ciklonu u Sredozemlju. Ovaj je proces obično praćen i formiranjem odcjepljene anticiklone u sjeveroistočnom Atlantiku. Takva blokirajuća situacija priječi prodiranje toplijeg zraka s Atlantika na evropsko kopno, koje je okupirano prostranom hladnom anticiklonom. Na taj način nastaje duž obale Sredozemlja izraziti gradijent tlaka, koji je naročito jak na sjevernom Jadranu. Ova razlika tlaka je računata iz Smithovog (1985) hidrauličkog modela i u većini slučajeva se dobro slaže s opaženim vrijednostima. Vrlo brzi razvoj visinske situacije uvjetuje promjene smjera vjetra iznad sloja bure. Najjača bura je povezana sa suprotnim smjerom strujanja na visini bez obzira na intenzitet vjetra, dok u uvjetima jakog jednolikog NE strujanja bura prestaje, osim ako postoji vrlo jaka inverzija temperature u donjoj troposferi.

Ključne riječi: Bura na Jadranu, olujni zavjetrinski vjetar, tip blokirajuće cirkulacije, hidraulički parametri.

1. INTRODUCTION

Analyses of vertical profiles associated with the Adriatic bora events indicate that bora can occur under a variety of upper tropospheric wind directions above the upstream bora region.(Smith, 1987; Jurčec, 1988 b). Smith particularly indicated the possibility of bora occurrence in unidirectional tropospheric (NE) current (as the ALPEX bora case of 25 March), since such a condition could possibly place this type of bora in the same class with the Boulder severe storms or bora-like events in the other parts of the world. Lower speed of the northern Adriatic bora is counteracted by a smaller mountain height in comparison with the Boulder storms. It seems however that it is not only the small directional wind shear in the bora environment which characterizes this bora type, but also the weak upper level winds and strong layered stability in the lower troposphere, which results in a large effective mountain height which may generate wave breaking and lead to a severe wind state.

In the previous issue of this journal (Rasprave-23,1988; papers by Bajić, Jurčec, Vučetić and Tutiš) several ALPEX bora cases were discussed during a special observation period (SOP, March and April 1982) with various bora characteristics. However, although the ALPEX bora cases with an enlarged radiosounding network with greater time resolution, and particularly the first aerial observations of the bora, essentially contributed to better understanding of bora dynamics and its interaction with the larger scale phenomena, the basic deficiency of these »spring-bora cases« was the lack of very cold air outbreaks associated with a pronounced synoptic development leading to severe bora characteristics for the wintertime conditions.

Contrary to the ALPEX cases when severe bora in Senj appeared only for a few hours, archived bora events at this locality indicate that severe bora (with the mean hourly speed greater than 17 m/s) may last for more than 120 hours (see paper on bora by Bajić in this Volume).

The purpose of this work was to show that a characteristic synoptic development exists leading to severe Adriatic bora state. However, the intensity of this process and the location of particular large scale features vary from case to case influencing the velocity and direction of the wind profile above the bora layer. The bora genesis appears to be associated with a strong tropospheric cold air outbreak in the initial stage of a typical cut-off process leading to formation of a deep low in the Mediterranean.This is often accompanied by a cut-off high process in the northeastern Atlantic leading to a known large scale blocking pattern. This prevents warmer air from the Atlantic to reach the European continent which is occupied by an intense cold anticyclone in a shallow tropospheric layer.

It is the location of the upper level trough axis to the east or west of the Alps, and the intensity of the Mediterranean low in a later phase of the process which determine the upper level wind speed and direction influencing the bora behaviour at a particular locality.

Discussed is a summary of a large number of severe bora cases in Senj which occurred during the period 1957-1986. Althoug it is just one sounding in the upstream bora region (Zagreb) and at the time intervals of 12 hours, it seems that they suffice for the study od basic characteristics of these **severe** bora cases from the synoptic aspects.

Five bora cases with particular characteristics will be presented here in more details including the mososcale analysis of the wind and pressure field in the northern Adriatic area.

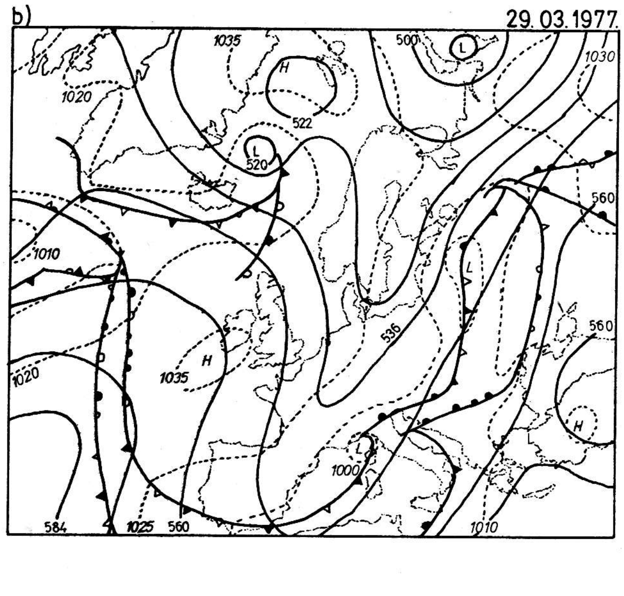
2. FRONTAL BORA TYPE WITH FAST SYNOPTIC DEVELOPMENT

Case of 29 – 31 March 1977 and 1 – 3 January 1979.

Jurčec (1988a) described the »frontal bora« case of 9 April 1982 during the ALPEX SOP which was caused by a pronounced cold air outbreak in Zagreb. Two cases selected for the presentation here belong to the group of the 21 strongest outbreaks in the period of 1973-1982 analysed by Bajić (1984, a, b).

The first is a two-day bora case of 29-31 March 1977 associated with a typical fast cut-off process. The sudden bora onset seen in Fig. 1a occurs behind the surface front placed on the advanced side of the upper level trough characterized by a large amplitude and a short wavelength wave known to be dynamically unstable (Fig. 1b). On the next day the upper level cyclone was formed in the western Mediterranean, and the upper level winds above the bora layer remain southerly but weakened. This is the day of continuous severe bora condition along the northern Adriatic coast and islands as seen in Fig. 1 d, which also illustrates a strong pressure gradient across the mountain. Bora decay on the third day was caused by the temperature increase in the layer below the 2 km altitude where the W-SW winds intensified and cyclonic activity faded.

A common feature in the second case (known as the »New Year storm«, Čapka and Jurčec, 1980) is a rapid wind increase at the bora onset, but this time the bora was even more brief. A basic difference in the development of synoptic situation is the fast movement of the upper level trough to the east causing the change of tropospheric winds to the northerly direction (Fig. 2b,c) under which bora rapidly weakened. The temperature drop in the upper troposphere was smaller in comparison with a surface temperature fall of 20° in 12 hours at the bora onset.



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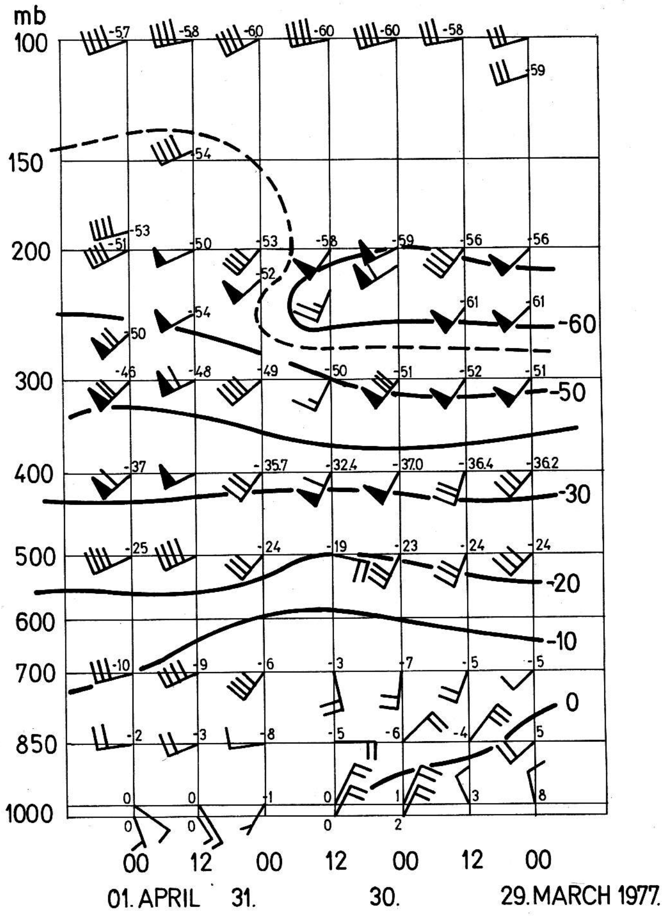


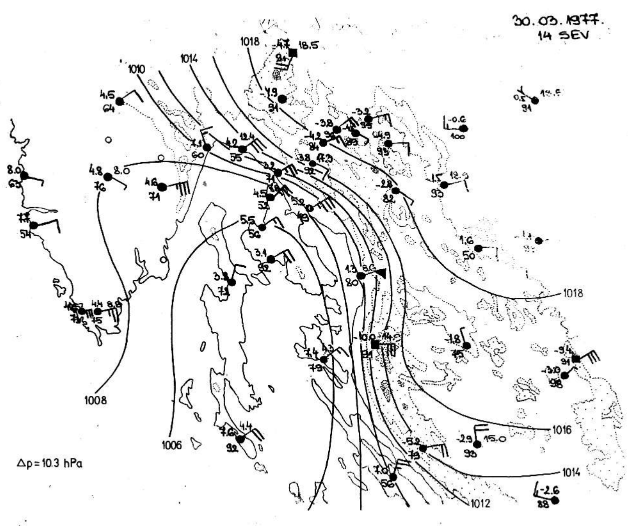
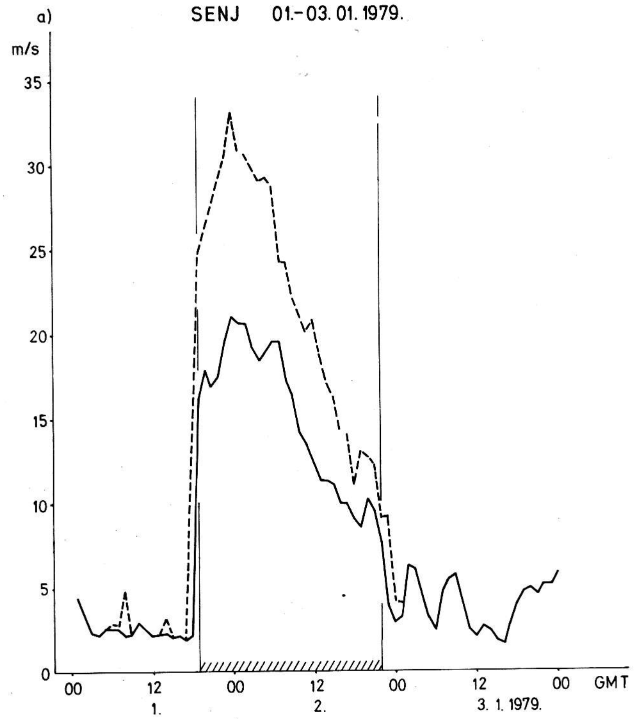


Fig. 1. Case of 29-31 March 1977. a) Mean hourly course of wind speed during bora ENE direction marked on abscisa. Dashed lines indicate the course of the maxima hourly gusts (m s^{-1}); b) Synoptic charts (according to Berliner Wetterkarte) for AT 500 hPa (solid lines) and surface isobars (dashed lines) with fronts for 29 and 30 March; c) Time-height cross section for Zagreb (right to left), wind (in knots), and temperature (with isotherms °C); d) Mesoscale analysis for the northern Adriatic region on 30 March, 14 local time, with isobars. Surface pressure, if available (1000 + hPa) is written in the right upper corner, temperature in the upper left corner and relative humidity (%) is down left. Wind is plotted in knots in conventional way.

Sl. 1. Situacija 29-31. ožujka 1977. a) Hod srednjih satnih vrijednosti brzine vjetra za vrijeme bure ENE smjera označeno na apscisi. Crtkane linije označuju hod maksimalnih udara vjetra (m s^{-1}; sinoptičke karte (prema Berliner Wetterkarte) za AT 500 hPa (pune linije) iprizemne izobare (crtkane linije) s frontama za 29 i 30 ožujak; c) vremenski vertikalni presjek z6a Zagreb (s desna na lijevo), vjetar (u čvorovima) i temperatura (s izotermama u °V); d) mezoanaliza za sjeverni Jadran 30 ožujak, 14 sati, s izobarama. Tlak pri tlu (1000 + hPa) na raspoloživim stanicama crtan je u desnom gornjem uglu, temperatura je u lijevom uglu, a relativna vlaga (%) je dolje lijevo. Vjetar je crtan u čvorovima na uobičajeni način.

The cold air induced a small scale cyclone in the northern Adriatic, and the wind direction was not as uniform as in the first case (Fig. 2d). The pressure difference of Zagreb-Senj following the bora onset was 10 hPa, but rapidly decreased during the next 12 hours.

a)



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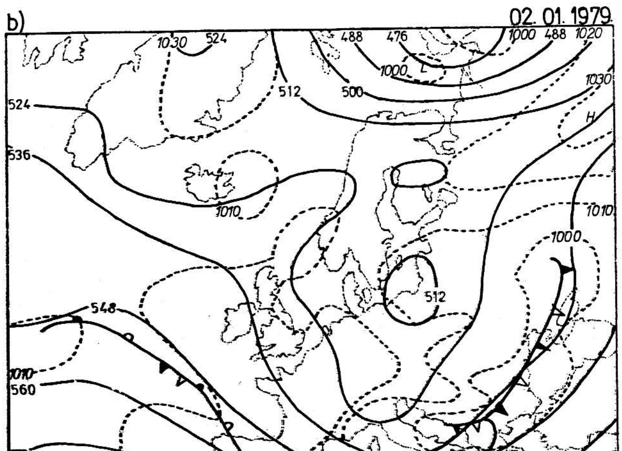


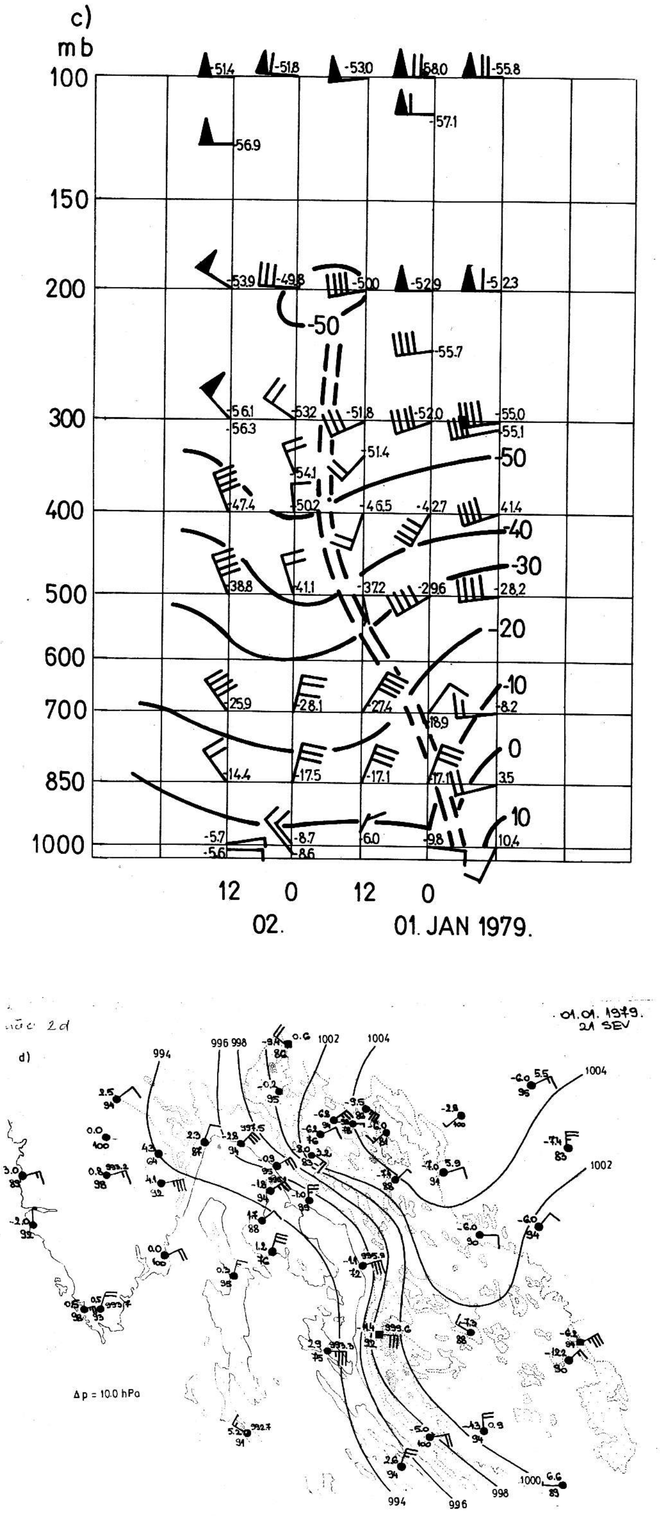


Fig. 2. Case of I – 3 January 1979. a) – d) the same description as in Fig. 1 but for this case.

Sl. 2. Situacija 1 – 3 siječanj 1979. a) – d) imaju isto značenje kao na sl. 1, ali za ovu situaciju.

3. LONG LASTING BORA CASE OF 17-22 JANUARY 1963 WITH A PREFRONTAL TEMPERATURE INVERSION

This is a six-day bora case (Fig. 3a) which remains severe while the upper level flow develops into a typical large scale blocking pattern.

In cases of long lasting severe bora conditions such as this temperature inversion is frequently observed and intensify when a weakening upper tropospheric wind in a prefrontal stage turns to the SW direction. Further change of the upper level wind direction is associated with a narrow trough extending from northeastern Europe to the Adriatic region (Fig. 3b). Figs. 3a and 3c demonstrate that the wind change to the NW direction did not much influence the bora speed which rapidly decays only when the strong NE flow behind the trough reached the upstream bora region. This happens in spite of the temperature fall during the frontal passage on 22 January. Cold air advection and stronger tropospheric NE winds sweeped up the inversion which is obviously an essential feature for a long lasting bora condition in Senj. Thus, **the cold air supply from the east associated with a huge continental anticyclone is not sufficient to oppose the effect of strong unidirectional tropospheric NE flow which apparently restrain otherwise favourable bora conditions** due to cold air supply.

Mesoscale analysis in Fig. 3d shows that the wind increase was accompanied by an enlarged pressure difference across a mountain of 10 hPa which well agrees with the theoretical estimation as will be discussed in section 6.

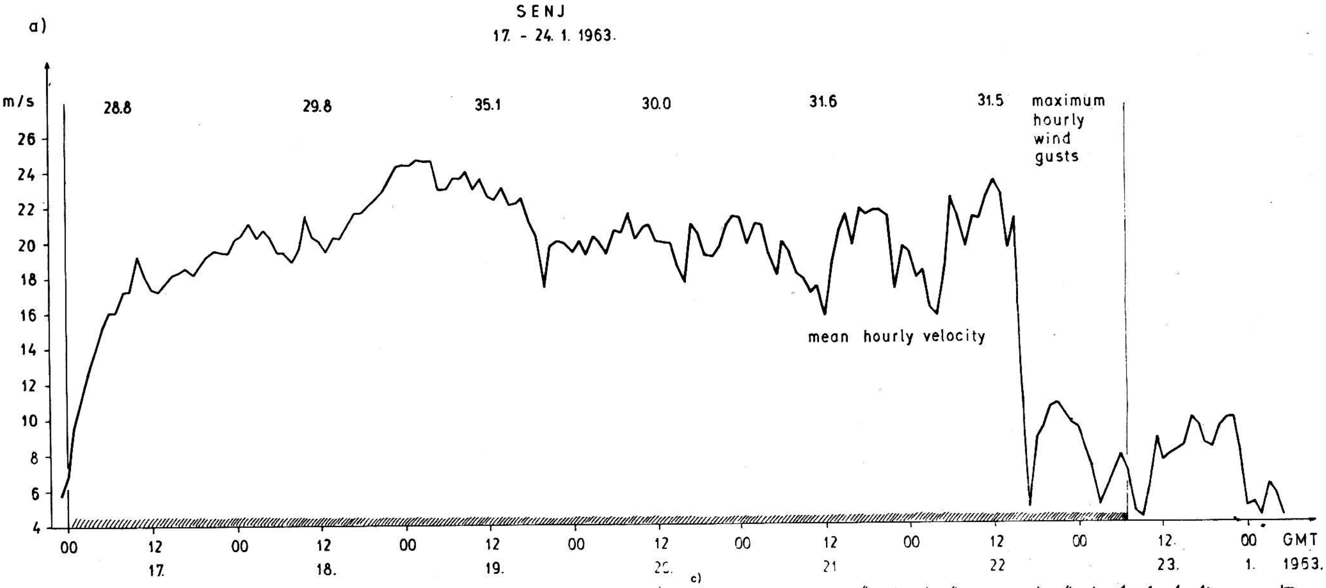
4. CASE OF 27 NOVEMBER TO 5 DECEMBER 1962 IN WHICH SURFACE FRONT PASSAGE CAUSES BORA WEAKENING

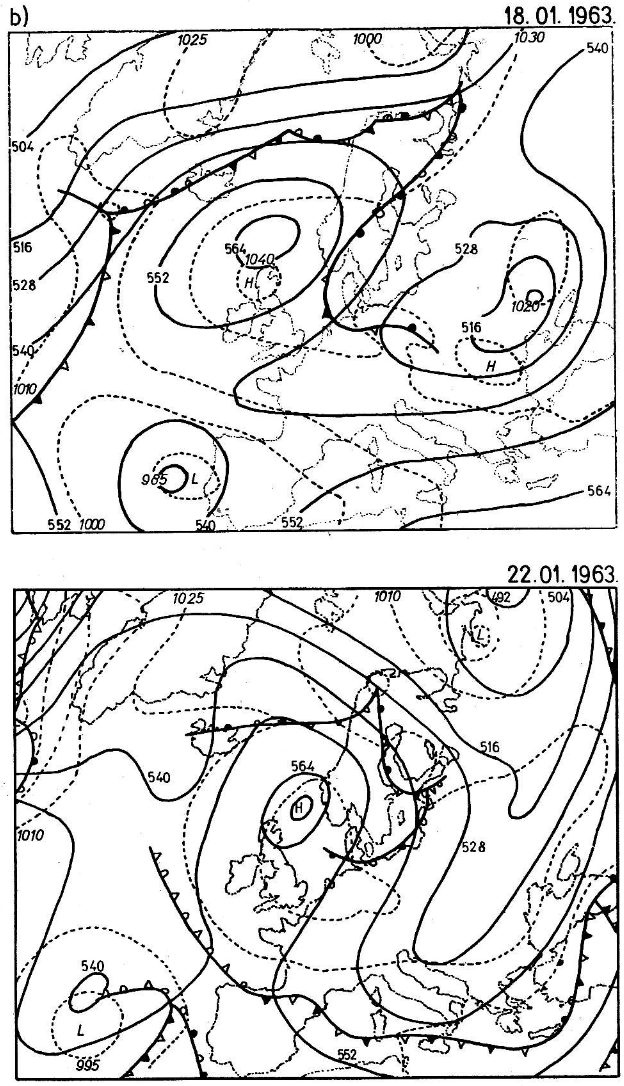
In the first two cases (Section 2) we have shown that the front arrival causes a fast bora speed increase. This will also be the case in the last selected example in section 5.

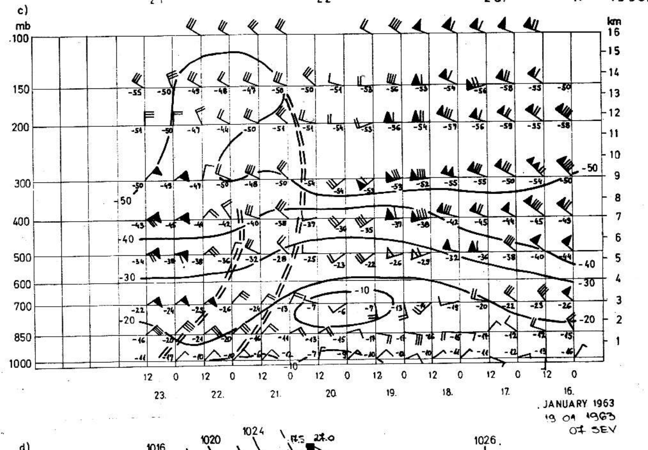
On the contrary here we consider the case in which bora experiences temporary weakening on 2 December (Fig. 4a) just at the time when the surface front with the temperature fall arrives in the bora region (Figs. 4b and 4c).

Increase of the bora speed during the initial three day period is associated with a common synoptic development characterized by a deep trough in western Europe. The axis of this trough with a frontal zone passes the upper troposphere on 30 November and the wind changes to the NW. The frontal zone moves relatively undisturbed above the Alpine tops, whereas cold air in the lower layer is blocked at the northern windward side of the Alps and gradually moves around the mountain.

In the meantime the upper level flow develops into a common cut-off process and behind the upper tropospheric front ridge intensified with the NE current above the bora layer. Thus, again in spite of the surface front arrival and cold air outbreak particularly pronounced in Zagreb on 2 December at 850 and 700 hPa, the bora was weakening. However on the next day with decreasing wind speed in the upper troposphere which changes to the southerly direction, the bora speed again increased with gusts reaching 41 m/s. At this stage bora is under the influence of a cut-off cyclone in the Mediterranean and a surface strong anticyclone which occupied most of middle and southern Europe.







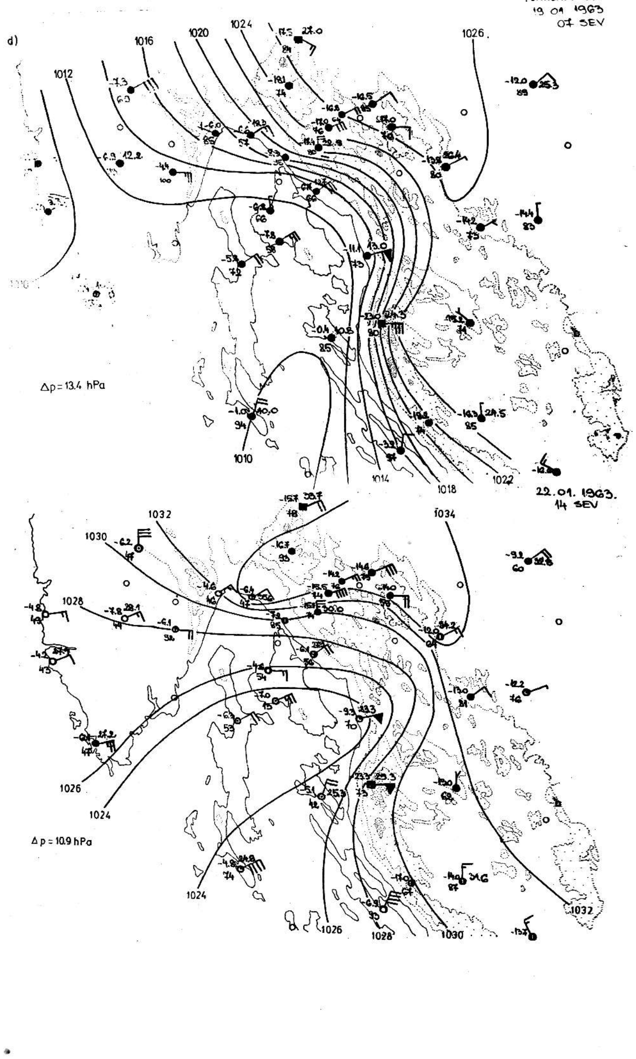
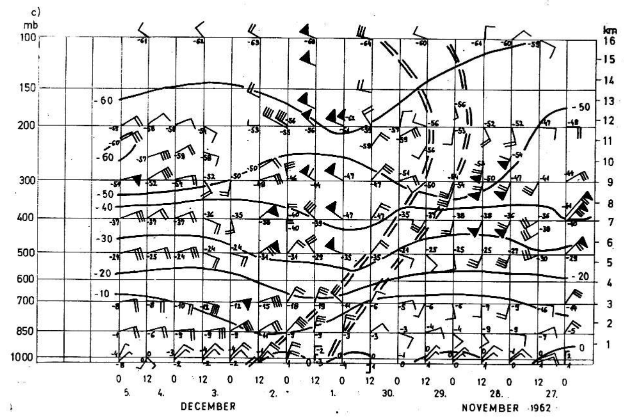
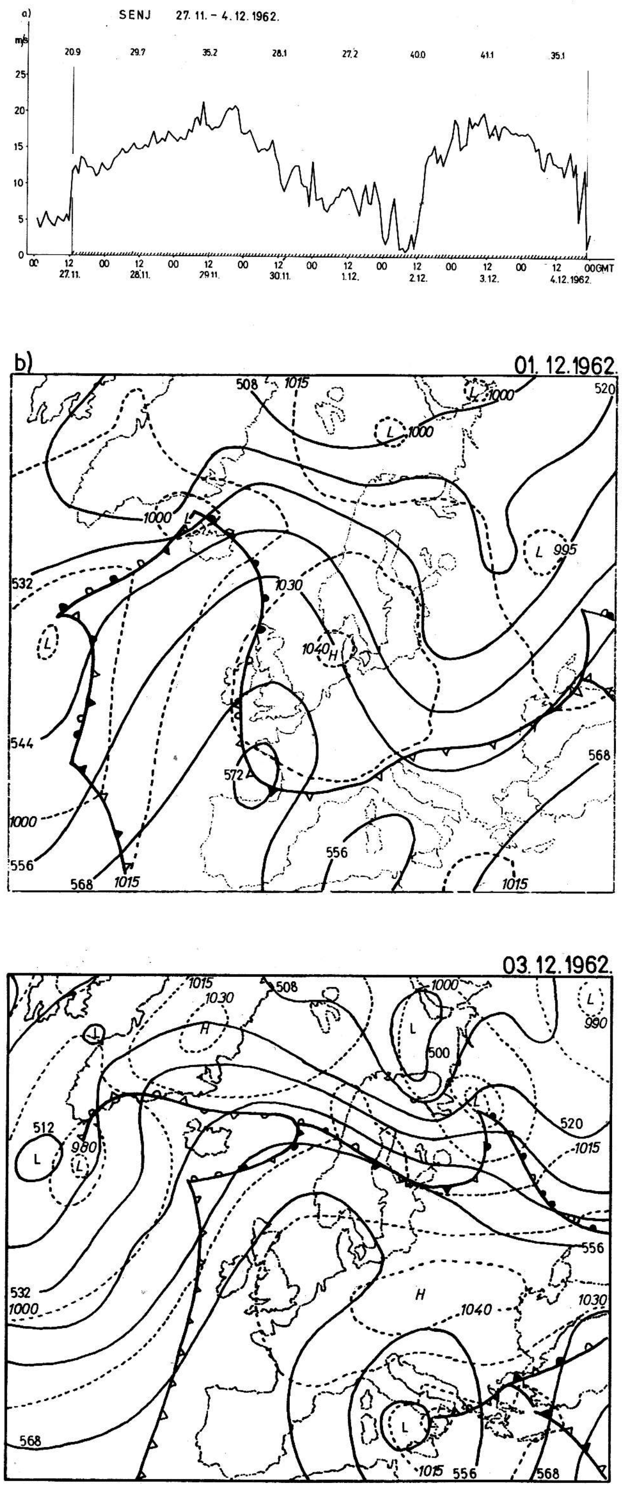


Fig. 3. Case of 16 – 23 January 1963. a) – d) the same description as in Fig. 1 for this case.

Sl. 3 Situacija 16 – 23 siječanj 1963. a) – d) imaju isto značenje kao na sl. 1. ali za ovaj slučaj.

Large pressure differences across the mountain is also seen from the mesoscale analysis presented in Fig. 4d. In section 6 it is shown that the pressure difference of Zagreb-Senj is well predicted on this day in contrast to the previous day when it was largely overestimated. Comparison of this analysis with the one on 29 November (in the same Fig. 4d) well illustrates the good correlation between the bora speed and pressure gradient across the mountain.





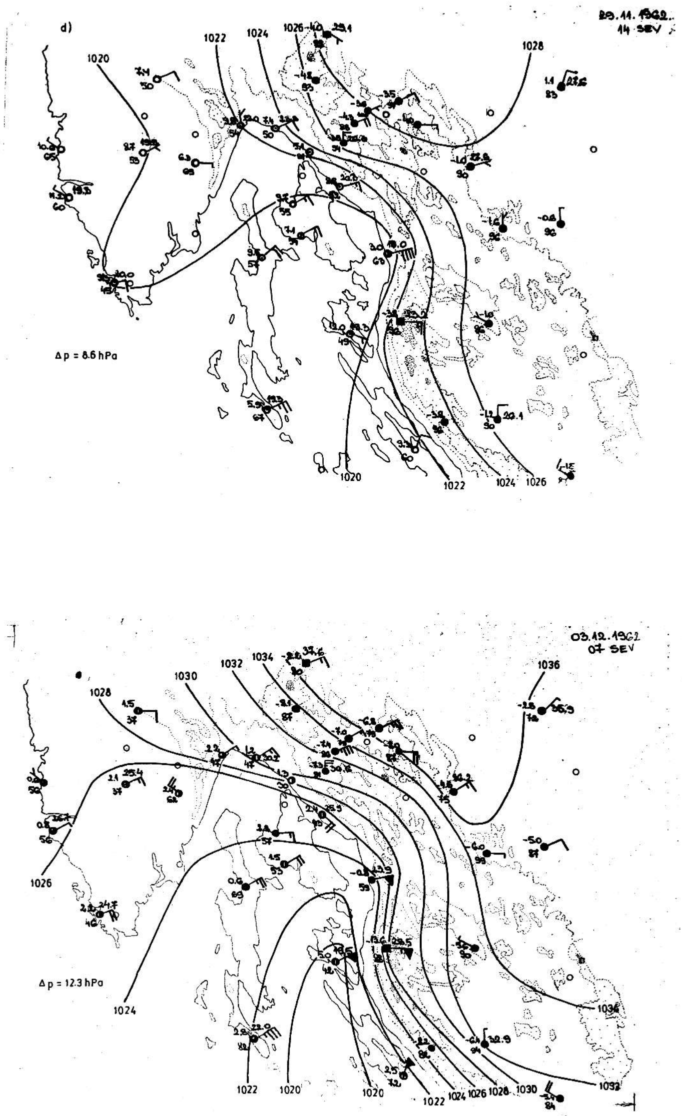


Fig. 4. Case of 27 November – 5 December 1962. a) – d) the same description as in Fig. 1 for this case.

Sl. 4. Situacija 27 studeni – 5 prosinac 1962. a) – d) imaju isto značenje kao na sl. 1 ali za ovaj slučaj.

5. CASE OF 7–14 DECEMBER 1967 – THE STRONGEST FRONTAL BORA ASSOCIATED WITH STRONGEST WESTERLY FLOW IN THE UPPER TROPOSPHERE

This is one of the most interesting cases from the archived data in the considered 30 year period when the absolute maximum gust of 46 m/s occurred in Senj (Fig. 5a).

The onset of this bora is uncommon since the wind speed is low in the lowest 2 km layer and increases in the higher troposphere to the absolute maximum observed in the considered radiosounding data set from Zagreb. Moreover, the direction is not as the usual NE immediately from the surface but turns briefly into this direction around the altitude of 1 km, as seen in Fig. 5e. In respect to the wind direction there was not much difference the following day but the upper level wind speed somewhat decreased.

Synoptic development at the beginning of this situation is marked by a cold air outbreak and a deepening trough in western Europe. This could be followed by the changes of wind direction in Zagreb to a more southerly direction until the passage of the trough axis on 9 December (Fig. 5c). Strengthening of the westerly flow on the next day again did not have much influence on the bora speed in Senj (Fig. 5a) although maxima gusts were increased.

A pronounced bora intensification occurred on 12 December apparently as a consequence of weakening upper tropospheric flow associated with the second passage of the trough axis seen over the Alps in Fig. 5b.

Further large scale development had a usual sequence characterized by a cut-off process and displacement of the upper level ridge from western Europe eastward. Bora again rapidly weakened when the NE wind occupied the entire troposphere with increasing wind speed on 14 December.

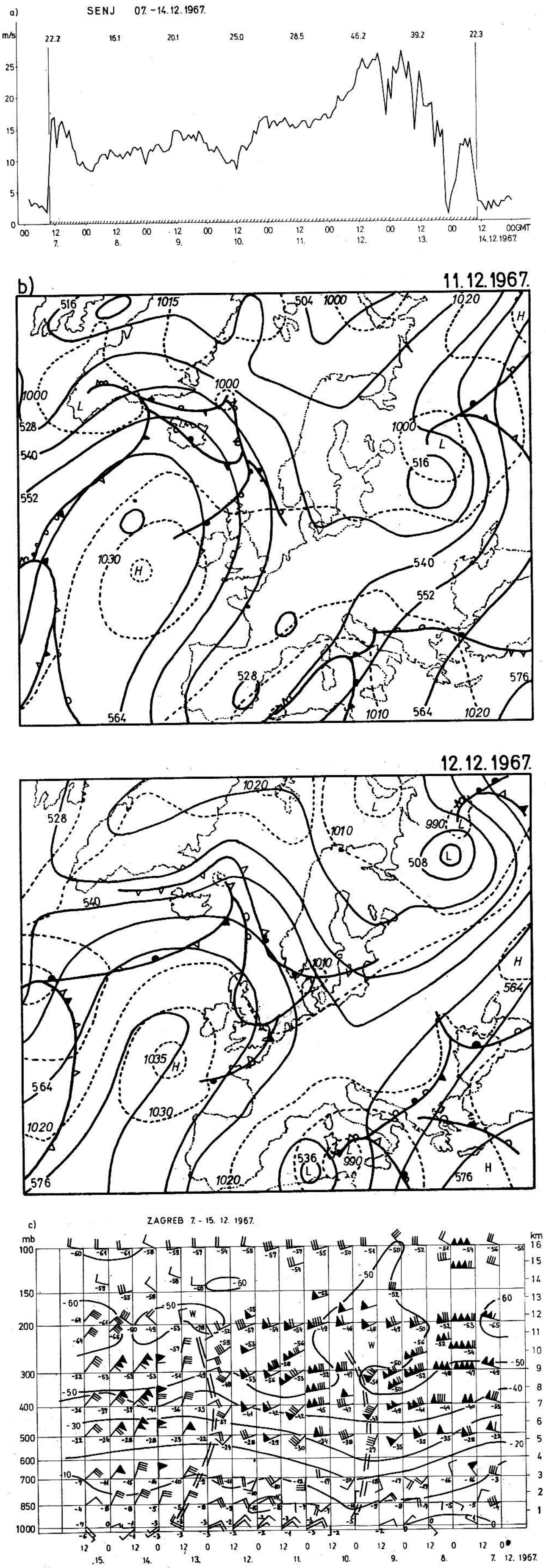
At the surface deep Mediterranean cyclone and a high pressure over southern Europe built up a very large pressure gradient over the Adriatic. On a smaller scale Fig. 5d indicates on December 12 the maximum pressure difference among the considered bora cases in the 30-years over the northern Adriatic.

6. THEORETICAL ESTIMATION OF THE PRESSURE DIFFERENCE ACROSS THE MOUNTAIN FROM THE HYDRAULICS

Earlier papers on bora in the last issue of »Papers« as well as that by Grubišić in this Volume discussed the application of Smith's (1985) hydraulic theory for the calculation of mountain drag and the pressure difference across the mountain. Most of them have indicated good results compared to the observations. However, due to commonly complex layered stratifications the mean static stability N (Brunt-Väisälä frequency) was rather subjectively determined.

Here we employ in N the expression for the thermal stability derived hydrostatically by Glasnović (1983):

$$\frac{\partial p}{\partial \theta} = -\frac{1}{\varkappa}\frac{p}{\theta} \quad , \quad \varkappa = R/c_p \qquad (1)$$



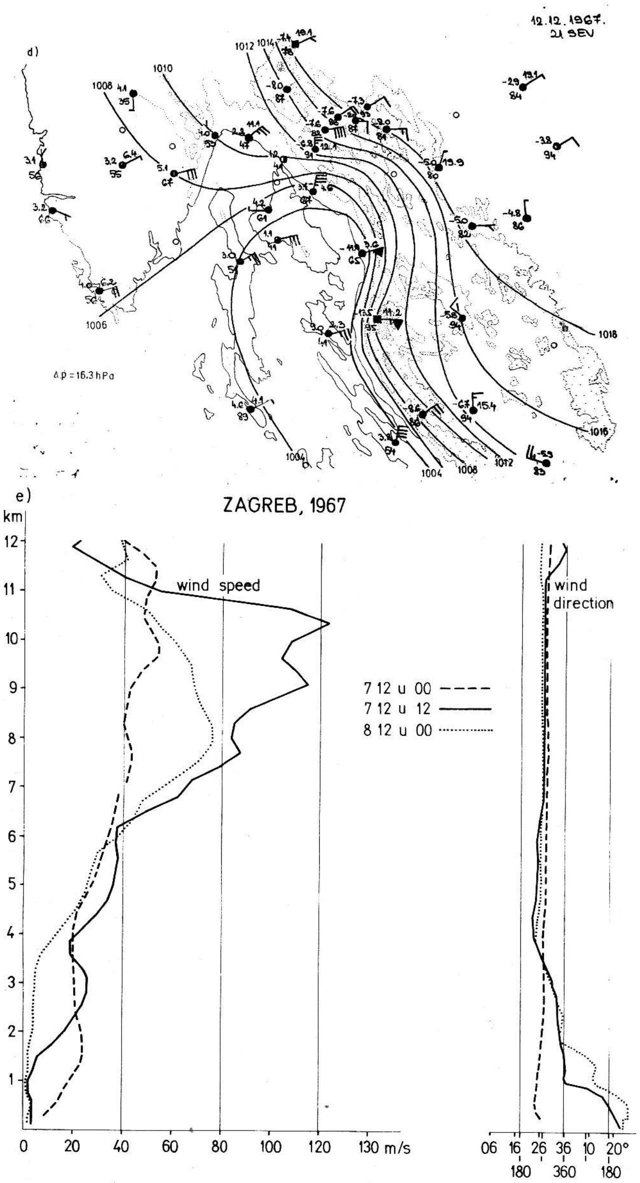


Fig. 5. Case of 7 – 15 December 1967. a) – d) the same description as in Fig. 1; e) represents the vertical wind profiles for 7 and 8 December for Zagreb.

Sl. 5. Situacija 7 – 15 prosinac 1967. a) – d) imaju isto značenje kao na sl. 1, ali za ovaj slučaj; sl. 5e) predstavlja vertikalni profil vjetra za 7 i 8 prosinac za Zagreb.

While this relation is consistent with the hydrostatic modelling approximation of Smith, it gives a very large value of N in comparison with the earlier estimation from the actual vertical profile of potential temperature θ in the sounding. Therefore it results in a very large value of effective mountain height $\hat{h} = h\ N/U$. This is seen from the results of the five presented cases given in Table 1 for $\hat{h} \leq 1.57$ if the mountain height $h = 800$ m. It is seen that for these cases the limited value of $\hat{h} = 1.0$ would allow the mountain heights 500 to 1050 m (the inverse of the Scorer parameter $l^{-1} = U/N$). The latter value over 1000 m concerns the case of 2 December 1962 when the bora layer extended troughout the troposphere, with a weakening surface bora speed. At this particular time theoretically estimated pressure difference largely overestimates the actual value presented in the last column in Table 1. On the next day 3 December with the lower H_0 (bora layer height) and a decreased wind speed U, the pressure difference is very close to the observed value, which is the case in most of the presented estimates, and it can be interpreted that the lowering of the critical isentrope related to the pressure difference under the hydrostatic equilibrium, is very realistic.

The empirical values of H are defined here according to the positive bora component, i.e. $u_B = 45° \pm 90°$ which becomes zero at H_0 representing the environmental »critical« (zero-) level for the u_B component.

It is interesting to note that the »hydrostatic bora layer« determined in this way is mainly between the altitude of 3 and 4 km which could be considered as equilibrium heights for further studies of nonhydrostatic effects on the perturbation velocity.

7. CONCLUSIONS

Analyses of synoptic events for the cases of severe bora stoms in the northern Adriatic show that bora is associated with a strong cold air outbreak leading to a cut-off process in the Mediterranean. The basic feature prior to this process is a deep trough in western Europe and a pronounced ridge in northeastern Atlantic leading sometimes to the cut-off high process and the well known blocking situations. Since these cases are quasi-stationary and allow the cold air supply over central Europe with a shallow but strong anticyclone at the surface layer, this causes long lasting temperature inversions and the longest bora condition. If the ridge axis has the position from the SW to NE Europe, the NE flow may intensify in the upper troposphere above the low level bora flow which suddenly decays. We do not know whether this strong NE flow is directly responsible for such a decay or it influences the temperature inversion which is simultaneously destroyed with the bora flow.

We have shown that the frontal bora has a characteristic onset with a sudden velocity increase which is therefore of particular importance for proper forecasting in such a fast developing synoptic situation.

The »hydrostatic bora layer« at the altitude of 3-4 km for the mountain height of 800 m is very interesting as an equilibrium layer but requires further study of non-hydrostatic effects, the height and intensity of the temperature inversion, as well as the proper mountain height for each case which need not be 800 m as considered here and in most studies of the bora from the hydraulic viewpoint.

Smith's model requires the undisturbed atmosphere above the critical streamline and the »dead region« with a strong turbulence. In the real atmosphere this seems to be correct for the bora component, i.e. the flow perpendicular to the mountain ridge. Very strong flow in the opposite direction or perpendiculiar to the bora component does not seem to disturb the bora state.

However, under unidirectional (NE) incoming flow bora ceases unless there is a strong low level temperature inversion, but it is unlikely that the inversion would persist in the condition of strong northerly flow in the upper troposphere.

The preliminary study of bora in the middle and southern Adriatic which has much higher and broader mountains on the upstream region than the north Adriatic area, seems to indicate that bora occurs with a greater bora

	GMT	H_o (m)	U (ms^{-1})	N 10^{-2} (s^{-1})	l^{-1} (m)	$\hat{h}$ (m)	H* (m)	∇p^* (hPa)	p_{ob} (hPa)
1962									
2. 12.	00	9580	12.3	1.97	624	1.28	3350	10.8	5.1
2. 12.	12	10220	20.9	1.98	1056	0.76	4400	17.2	8.8
3. 12.	00	5690	17.6	1.92	917	0.87	4100	14.2	14.1
1963									
22. 1.	00	6770	10.7	1.98	540	1.48	3150	9.8	8.2
22. 1.	12	11410	12.5	2.o1	622	1.29	3350	11.2	10.4
1967									
13.12.	00	10160	11.9	1.96	607	1.32	3300	10.5	10.5
1977									
30.3	00	2110	9.6	1.86	516	1.55	3050	8.6	8.3
1979									
2. 1.	12	4080	13.5	1.95	692	1.16	3550	11.5	3.7

Table 1. Hydraulic parameters for selected cases in which the effective mountain height $\hat{h} \leq 1.57$. H_o is the bora layer height according to the positive bora component $u_B = 45° \pm 90°$, N denotes hydrostatically calculated stability (Brunt-Väisälä frequency), l^{-1} is the inverse of Scorer parameter ($l = N/U$), U is wind velocity u_B in m s^{-1}, h (=800 m) is the mountain height. Values with stars are prognostic (theoretical according to Smith's model, 1985) indicating bora layer height H, and pressure difference across the mountain calculated from the drag formula of Smith. ∇p_{ob} is the observed pressure difference Zagreb-Senj at the surface in hPa.

Tabela 1. Hidraulički parametri za odabrane situacije u kojima je efektivna visina planine $\hat{h} \leq 1.5$. H_o je visina sloja bure prema pozitivnim vrijednostima komponente bure definirane kao $u_B = 45 \pm 90°$, N označuje izračunatu hidrostatsku stabilnost (Brunt-Väisälä frekvenciju u $10^{-2}s^{-1}$) l^{-1} je recipročna vrijednost Scorerovog parametra (l=N/U). U je brzina vjetra komponente bure u_B u m s^{-1}, h (=800 m) je visina planine. Vrijednosti sa zvijezdicom su prognostičke (teoretske prema modelu Smitha, 1985) i pokazuju visinu sloja bure H i razliku tlaka preko planine izračunatu iz Smithove relacije za drag. ∇p_{ob} je opažena razlika tlaka Zagreb-Senj pri tlu u hPa.

layer depth. We expect that these studies will lead to further understanding of bora dynamics in relation to other downslope winds in different parts of the world.

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KRATAK SADRŽAJ

Analize sinoptičkih situacija u slučajevima s olujnom burom na sjevernom Jadranu pokazuju da bura nastaje pri vrlo jakom prodoru hladnog zraka u dubokoj visinskoj dolini, koju karakterizira velika amplituda i mala dužina vala. Ovakav val je dinamički nestabilan i dovodi do procesa odcjepljenja ciklone u Sredozemlju. Istovremeno se u sjeveroistočnom Atlantiku javlja izraženi greben, koji se često razvija u odcjepljenu anticiklonu i na taj način nastaje poznati tip blokirajuće cirkulacije. S obzirom da su ovakva stanja kvazi-stacionarna i omogućavaju dovod hladnog zraka u srednju Evropu uz formiranje plitke, ali vrlo snažne i prostrane anticiklone, to uzrokuje dugotrajne inverzije temperature i uvjete za dugotrajnu buru na sjevernom Jadranu. Ako os grebena ima položaj od SW prema NE Evropi, onda NE struja može ojačati i u višoj troposferi iznad sloja bure koja naglo slabi. Mi za sada ne znamo da li je ova jaka NE struja direktni uzrok za prestanak bure ili ona utječe na inverziju temperature koja istovremeno nestaje s iščezavanjem bure.

Pokazano je da frontalna bura ima karakterističan početak s naglim porastom vjetra što je posebno važno za pravovremenu prognozu u situaciji s tako brzim razvojem.

Iz hidrauličkih parametara prema Smithovoj (1985) teoriji računate su razlike tlaka iz planinskog otpora, pri čemu je korištena relacija (1) prema Glasnoviću (1983) za određivanje termičke stabilnosti iz koje se računa Brunt-Väisälä frekvencija i Scorerov parametar (Tabela 1). Na taj način je izračunat »hidrostatički sloj bure« koji za planinu visine od 800 m uglavnom ima visinu između 3 i 4 km. Međutim ovakav ravnotežni sloj zahtjeva proučavanje nehidrostatskih efekata, visinu i intenzitet inverzije temperature, kao i prikladnu visinu planine koja ne mora biti 800 m, što je za sada uobičajena visina za proučavanje bure s hidrauličkog aspekta.

Smithov model zahtjeva neporemećenu atmosferu iznad kritične strujnice i »mrtvog« područja s jakom turbulencijom. U realnoj atmosferi to je izgleda slučaj s komponentom bure, tj. strujanjem okomitim na planinski greben. Pokazuje se da vrlo jako strujanje u obrnutom smjeru od bure ili okomito na taj smjer ne utječe na stanje bure u Senju. To bi trebalo uzeti u obzir kada se razmatra ideja Smitha o zajedničkim karakteristikama bure na Jadranu i oluja u Boulderu pri istosmjernom strujanju u navjetrini. Preliminarna proučavanja bure na srednjem i južnom Jadranu uz mnogo višu i širu planinsku prepreku u navjetrini pokazuju veći sloj bure i čini se da bi mogli više pridonijeti razumijevanju dinamike bure u odnosu na druge zavjetrinske vjetrove u različitim krajevima svijeta.