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ISENTROPIC HIGH RESOLUTION TIME CROSS-SECTION BASED ON POLYNOMIAL HYDROSTATIC ADJUSTMENT

Izentropski vremenski presjek velike rezolucije zasnovan na polinomskom hidrostatičkom prilagođavanju

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Abstract: The objective routine which includes the polynomial hydrostatic adjustment technique has been developed and applied to construct a high resolution time cross-section in the isentropic coordinate system. The mechanism to insure vertical consistency is based on the reciprocal of thermal stability parameter $\partial p/\partial \Theta$ and its derivatives of a higher order. The Hermitian scheme is used to interpolate, but here it is essentially modified and applied with polynomials up to the fifth order. It enables the elimination of any computation in finite difference approximations over the layers of various thickness and uses only the observed values in the vertical interpolation points even in computing their vertical changes.

To obtain a more detailed insight into the prevailing processes the vertical profiles of Brunt-Vaisala frequency, Scorer parameter, vertical acceleration, nonhydrostatic coefficient and the wind are computed. The successfulness and applicability of presented methods are tested in two events of severe weather development.

Key words: objective analysis, time cross-section, polynomial, isentropic, hydrostatic adjustment, vertical initialization, successive interpolation.

Sažetak: Razvijena je objektivna metoda za izradu vremenskih presjeka visoke rezolucije, koja se zasniva na tehnici polinomskog hidrostatičkog prilagođavanja u izentropskom koordinatnom sustavu. Važnu ulogu u osiguranju vertikalne konzistencije računskog postupka ima primjena recipročne vrijednosti parametra terničkog stabiliteta $\partial p/\partial \Theta$ i njegovih derivacija višeg reda. Za interpolaciju se upotrebljava Hermiteova shema, koja je ovdje znatno izmjenjena i primijenjena na polinomima sve do petog stupnja. Na taj je način bilo moguće potpuno izbjeći računanje pomoću aproksimacija u konačnim razlikama na slojevima različite debljine, a u točkama vertikalne interpolacije, čak i za proračun vertikalnih promjena, koristiti samo parametre dobivene sondažom.

Kvalitativni prikaz rezultata uz detaljniji uvid u strukturu aktivnih atmosferskih procesa dobiven je računanjem vertikalnih profila Brunt-Vaisala frekvencije, Scorerovog parametra, vertikalne akceleracije, nehidrostatičkog koeficijenta i vjetra. Uspješnost i primjenljivost razrađenih metoda testirana je u dva slučaja razvoja olujnog nevremena.

Ključne riječi: objektivna analiza, vremenski presjek, polinom, izentropski, hidrostatičko prilagođavanje, vertikalna inicijalizacija, sukcesivne interpolacije

1. INTRODUCTION

For a last 40 years the great significance of the meteorological objective analysis technique is shown not only to eliminate subjectivity and hasten the process of manual analysis, but also to improve the numerical model initialization. In meteorological practice it was first introduced by Panofsky in 1949, and ten years later Cressman gives a suitable definition of the objective analysis as "the procedure of transforming data observations at irregularly spaced points onto points of a regularly spaced grid". Hereafter, a number of objective methods are developed and more or less successfully applied. In the beginning the simple data fitting techniques such as a least-squares fitting method are used, but the resulting fields were quite smooth. Afterwards, more sophisticated statistical and dynamical assimilation methods have been evolved. Gandin (1963), Schatter (1975) and Schlatter et al. (1876) applied statistical interpolation techniques and Flattery (1970) eigenfunction expansions to the hemispheric analysis problem and large scale numerical model application, but the resulting analyses were inappropriate for more detailed investigations of the finer atmospheric processes. In 1976, Schlatter gives a new definition of the objective analysis as "a programmable method for estimating grid point values compatible with a particular numerical prediction model". Further advances are associated with numerical model initialization. In this direction an important contribution is given by Otto-Bliesner et al. (1977) dealing with several meteorological analysis schemes over a data-rich region.

A major stride in the development of objective analysis technique of interest here was made by Shapiro and Hastings (1973; hereafter SH73). They first suggested the use of the Hermite polynomial interpolation scheme between adjacent sounding stations to construct cross-sectional isentropic objective analysis and successfully aplied this routine to interpolate in the horizontal. However, their attempt to perform vertical interpolation by cubic polynomials gave unsatisfactory results such as the entwining of isentropes "resulting in points of infinite stability as well as numerous superadiabatic layers, neither of which were present in the original data". Therefore, they used linear vertical interpolation and caluculated thermal stability information $\partial p/\partial \Theta$ from individual stations by centered and uncentered finite difference approximations. Independently, to construct objective cross-section analysis Whittaker and Petersen (1977) applied overlapping second-order Lagrangian polynomials, but also a linear interpolation in the vertical.

Unlike SH73, objective cross-sectional techniques proposed and developed by Glasnović (1978, 1983; hereafter G78 and G83) enable successful polynomial

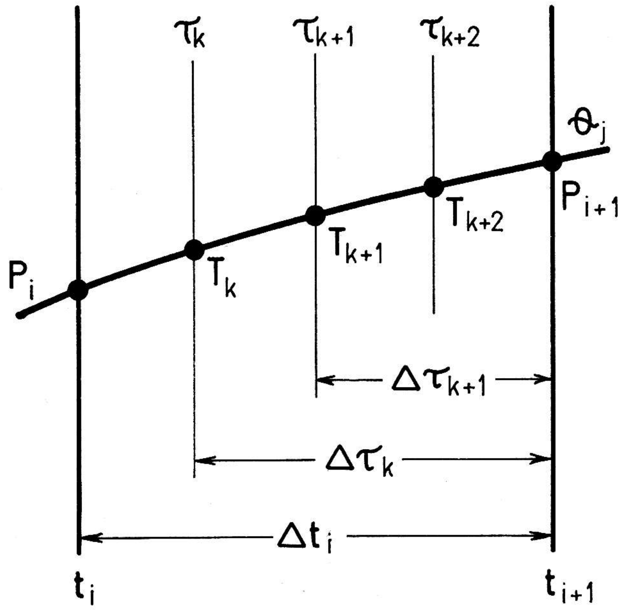

Fig. 1 A simple illustration of the successive interpolation routine with changeable left end-point of the time interval along an isentrope Θ_j = const.

Sl. 1. Pojednostavljeni prikaz primjene sukcesivnih interpolacija s promjenljivom lijevom "krajnjom točkom" vremenskog intervala duž izentrope Θ_j.

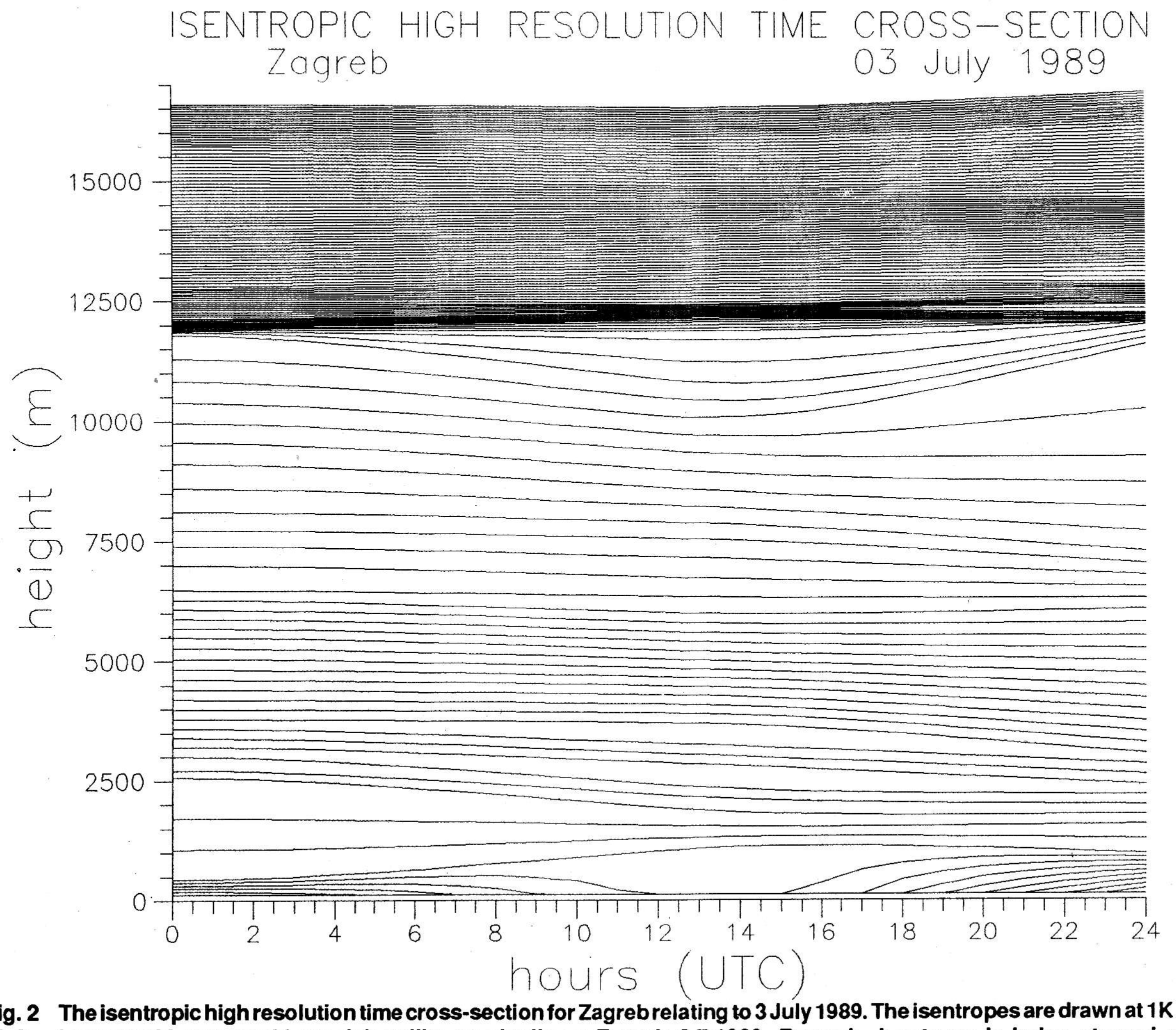

Fig. 2 The isentropic high resolution time cross-section for Zagreb relating to 3 July 1989. The isentropes are drawn at 1 K intervals.

Sl. 2. Izentropski vremenski presjek velike rezolucije za Zagreb 3.7.1989. Razmak izentropa je jedan stupanj apsolutne temperaturne ljestvice.

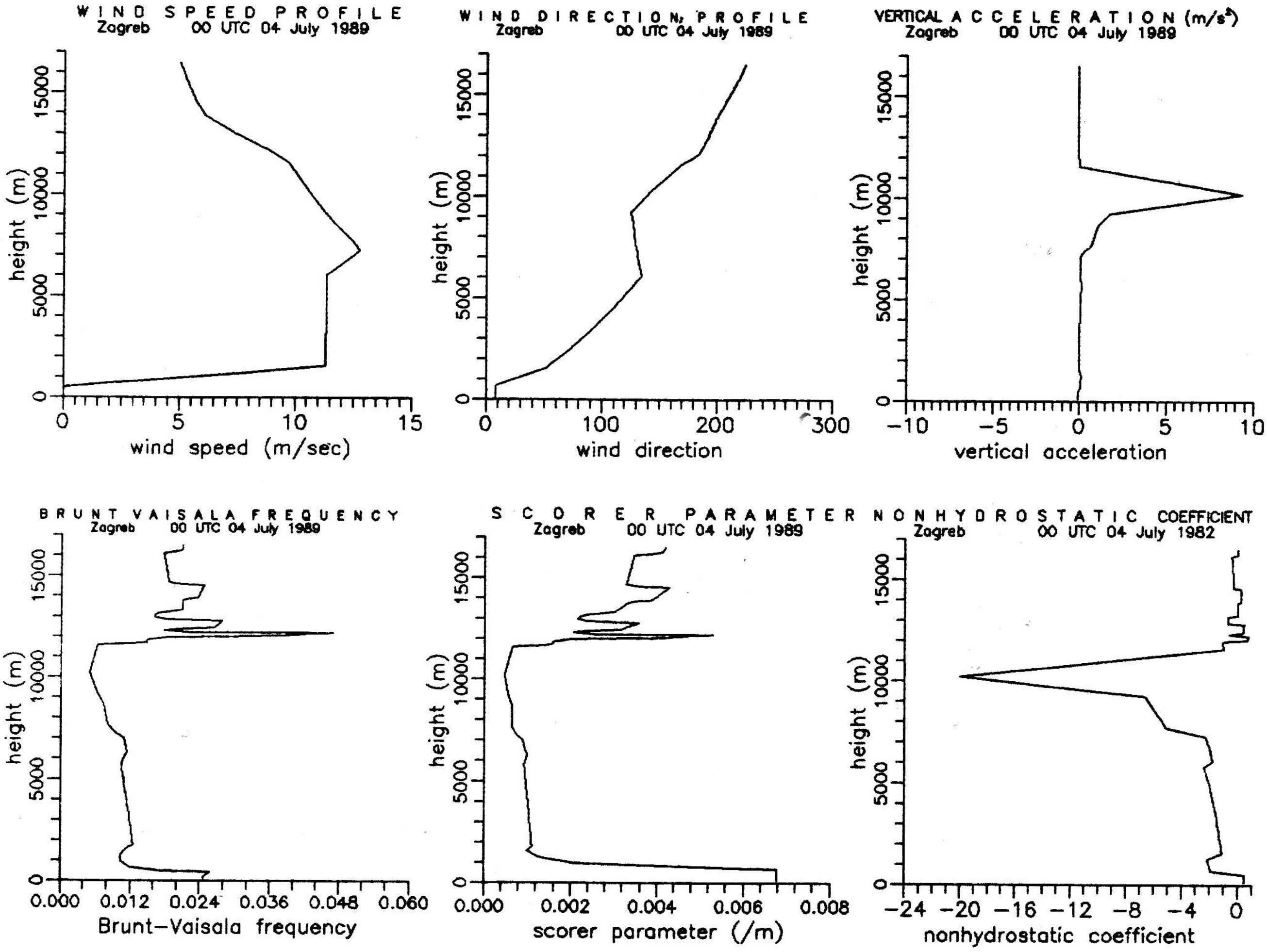

Fig. 3 The vertical profiles of six parameters computed at 1 K potential temperature increments for OO UTC 3 July 1989.
Sl. 3. Vertikalni profili šest parametara računatih na svaki stupanj potencijalne temperature za 4.7.1989. 00 UTC.

vertical interpolation. They include a polynomial hydrostatic adjustment based on the reciprocal of the thermal stability parameter in the form $\partial p/\partial\Theta = -p/\kappa\Theta$ and its derivatives of a higher order. One of the possible applications of such an aproach is shown by Glasnović and Jurčec (1990) to define the objective method for bora layer determination from the stability profile.

The main topic of this study is the theoretical extension of objective analysis technique developed in G83 and its application toward construction of the isentropic high resolution time cros-section. To eliminate the influence of the systematic error caused by conventional computation in the finite difference approximation, emphasis is placed on the polynomial hydrostatic adjustment by use of the various meteorological parameters needed in the objective analysis.

2. OBJECTIVE CROSS-SECTIONAL TECHNIQUE

2a. General aspects and polynomial hydrostatic adjustment

One of the most obvious differences between the present study and the cited works (SH73, G83) is in the selection of the interpolation function and its degree. Although the Hermitian interpolation scheme is used as previously, here it is essentially modified and applied with polynomials not only of the third, but also of the fourth and fifth order. In general, over an interval, between the two points $P_1(x_1,y_1)$ and $P_2(x_2,y_2)$ defined as "end-point conditions", this objective routine is formed by pairs of polynomials

$$y_n(x) = \sum_{k=0}^{n} a_{nk} x^k \qquad (2.1)$$

with derivatives which for certain m<n may be written as

$$y_n^{(m)}(x) = \sum_{k=m}^{n} a_{nk} k(k-1)\ldots\ldots(k-m+1)x^{k-m} \qquad (2.2)$$

and which are needed to construct an appropriate algebraic equation system. For example, in the case of fifth-order polynomials it gives six algebraic equations with six unknown coefficients a_{nk} (from a_{50} to a_{55}) to be determined.

In the meteorological aplications, the essential and very sensitive part of this method is how to incorporate the observed thermal features into analysis at every level of a given sounding station. An adequate mathematical and physical mechanism is required to insure the vertical consistency of the applied numerical procedure. Here, "the polynomial hydrostatic adjustment technique" is developed to satisfy that requirement.

It eliminates any computation in finite difference approximations over the layers of various thickness and takes into account at the end-points of each interpolation interval the observed values only, **even in computing their vertical changes**. This is the key-element of considered technique which enables the conservation and building of the finest thermal properties into analysis.

Thus in order to determine the coefficients a_{nk} it is very important how one computes the derivatives $y_n^{(m)}(x)$ from the observed values. In isentropic coordinates it means to compute $p_n^{(m)}(\Theta)$, i.e. derivatives of pressure p as a function of potential temperature Θ. Using polynomial hydrostatic adjustment suitable relations are derived from the isentropic hydrostatic equation in the alternative form of the reciprocal of the hydrostatic thermal stability parameter

$$\frac{\partial p}{\partial \Theta} = -\frac{1}{\kappa}\frac{p}{\Theta} \tag{2.3}$$

and its derivatives which can be expressed by means of multiple differentiations as a general relationship

$$p_n^{(m)} = (-1)^m \frac{\prod_{k=1}^{m}\left[1+(k-1)\kappa\right]}{\kappa^m}\frac{p}{\Theta^m} \tag{2.4}$$

where $\kappa = R/c_p$. This differential equation, which may be written in a programmable form

$$\frac{\partial^m p}{\partial \Theta^m} = -\frac{1+(m-1)\kappa}{\kappa\Theta}\frac{\partial^{m-1} p}{\partial \Theta^{m-1}}, \tag{2.5}$$

possesses some very useful properties needed to accomplish successful vertical initialization. First, it is applied locally at the point (p,Θ) omitting any computation over the layers. Secondly, the highest derivative comprises every preceding derivative of lower order and its physical meaning.

To complete this numerical procedure the Hermite polynomial scheme is modified in the construction of the algebraic equations system. To perform this, the interpolation function and every even of their higher derivatives in two vertical interpolation points are used, respectively. It does not mean that the first and every odd

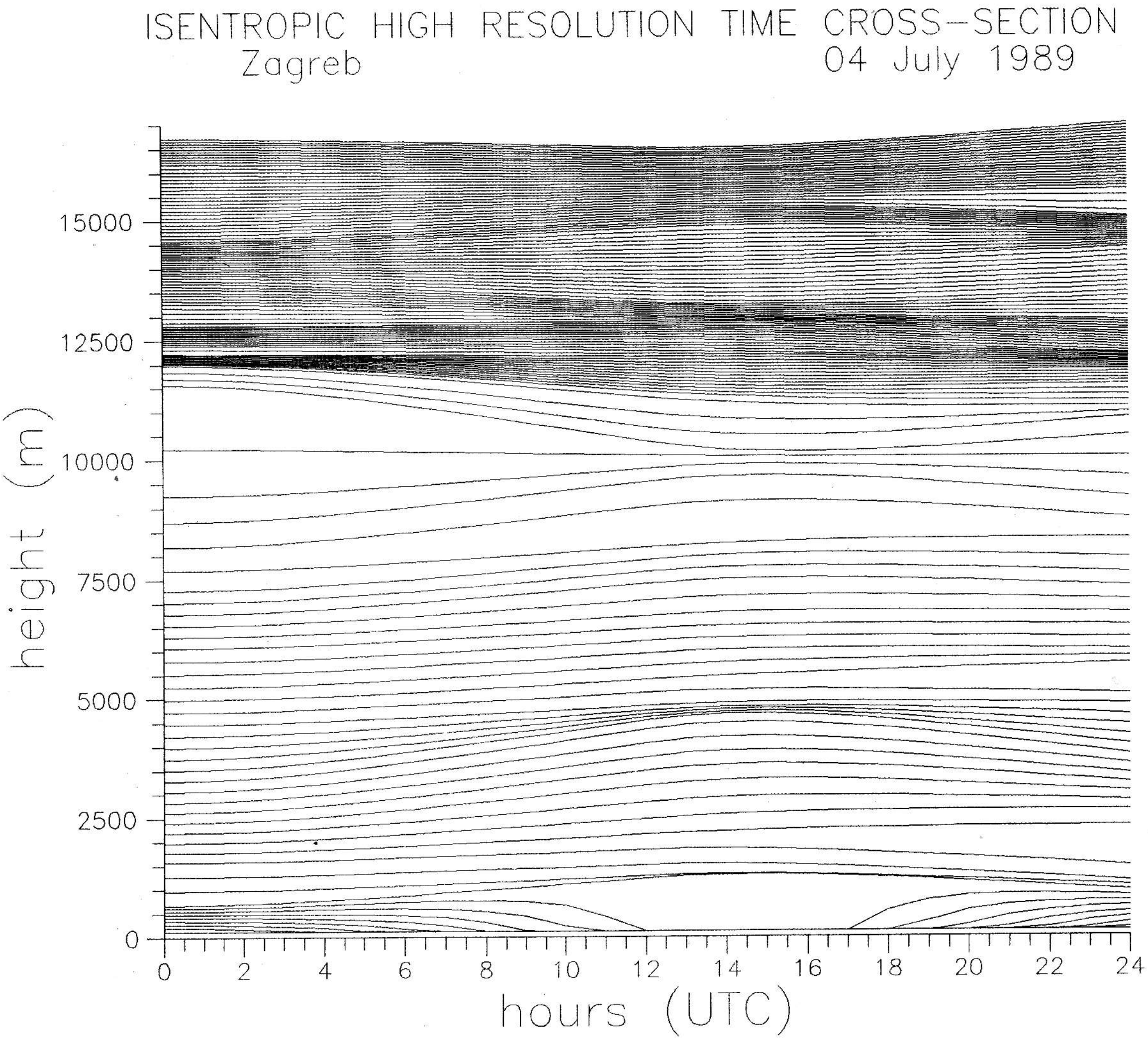

Fig. 4 The same as in Fig. 2, but relating to 4 July 1989.
Sl. 4. Isto kao na Sl. 2, ali za 4.7.1989.

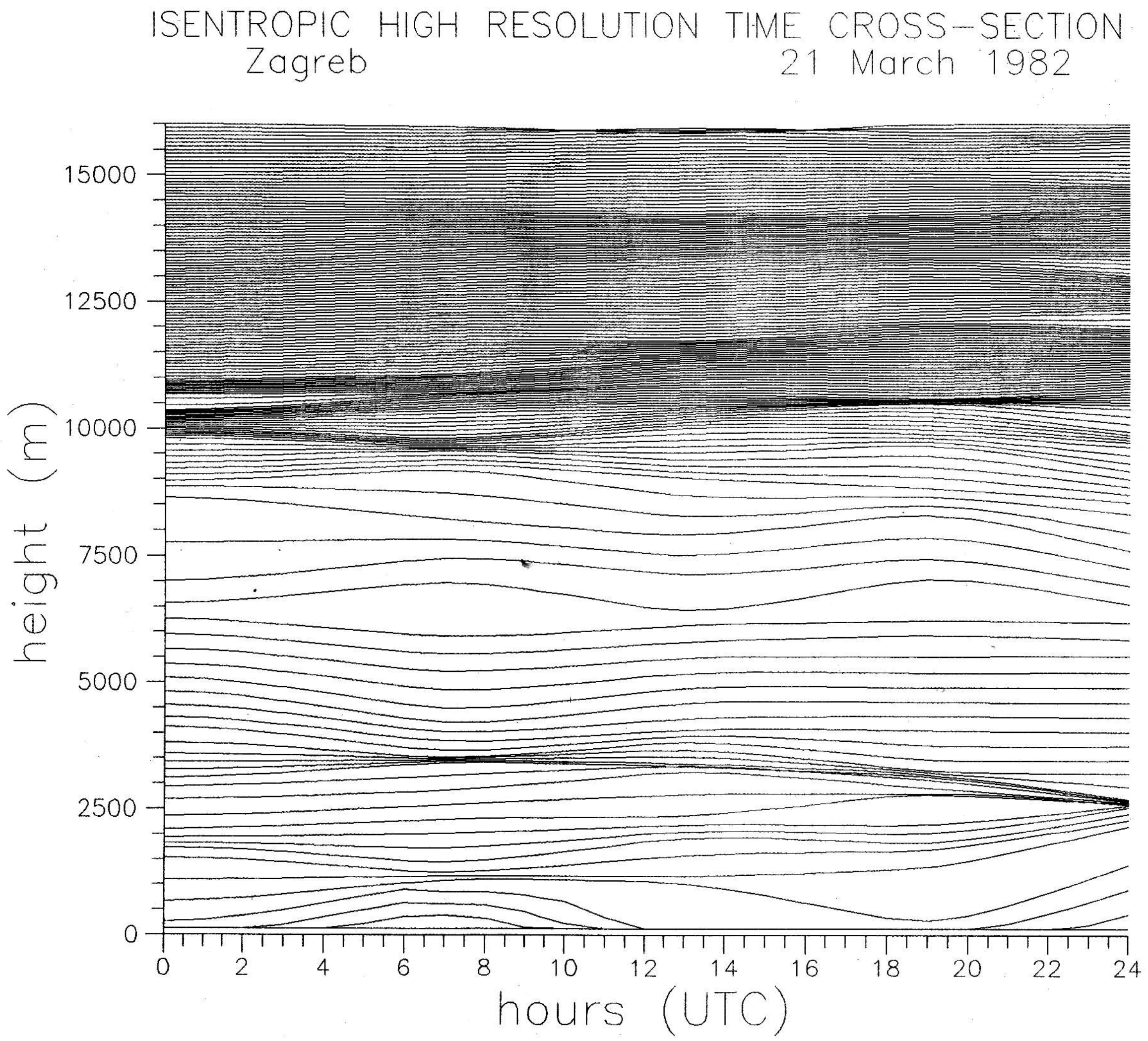

Fig. 5 The same as in Fig 2, but relating to 21 March 1982. It is based on five successive Zagreb soundings from ALPEX SOP at every six hours.

Sl. 5. Isto kao na Sl. 2, ali za 21.3.1989. Vremenski presjek je konstruiran na temelju pet uzastopnih sondaža stanice Zagreb iz ALPEX SOP.

derivative is neglected, since according to (2.5) this is included in the highest one. In the above mentioned example of fifth-order polynomials the algebraic system contains six equations and has a form

$$p_i = \sum_{k=0}^{5} \Theta_i^k a_k$$

$$p_{i+1} = \sum_{k=0}^{5} \Theta_{i+1}^k a_k$$

$$p_i^{II} = \sum_{k=2}^{5} k(k-1)\Theta_i^{k-2} a_k \qquad (2.6)$$

$$p_{i+1}^{II} = \sum_{k=2}^{5} k(k-1)\Theta_{i+1}^{k-2} a_k$$

$$p_i^{(4)} = \sum_{k=4}^{5} k(k-1)(k-2)(k-3)\Theta_i^{k-4} a_k$$

$$p_{i+1}^{(4)} = \sum_{k=4}^{5} k(k-1)(k-2)(k-3)\Theta_{i+1}^{k-4} a_k$$

using the derivatives of second and fourth order over an interval with end-points (p_i, Θ_i) and (p_{i+1}, Θ_{i+1}). After the values of coefficients a_k have been determined their substitution in the interpolation polynomial

$$p_j(\Theta) = \sum_{k=4}^{5} a_k \Theta_j^k \quad , \text{for } i \leq j \leq i+1 \qquad (2.7)$$

gives the corresponding solution curve for arbitrarily chosen Θ_j. Polynomial vertical interpoaltion can be successfully performed in such a way even for potential temperature increments lower than 1K and it offers the basis for construction of a high resolution cros-section. Also, an additional improvement of this numerical procedure is the application of successive interpolations with changeable first end-point value, since this enables the use of the information valid in the preceding interpoaltion interval.

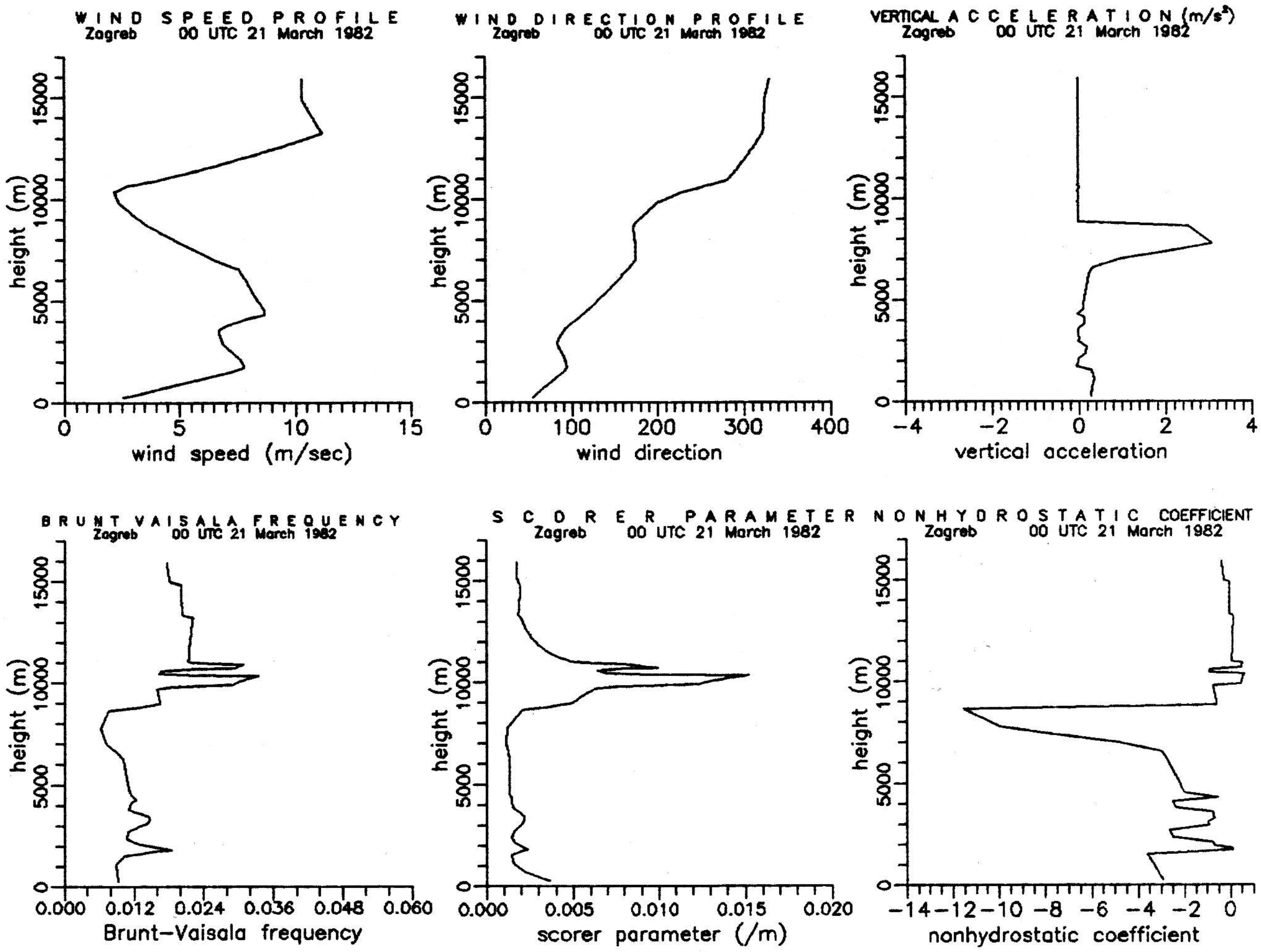

Fig. 6 The same as in Fig. 4, but for 00 UTC 21 March 1982.
Sl. 6. Isto kao na Sl. 4., ali za 21.03.1981., 00 UTC.

2b. High resolution time cross-section

The objective time cross-section is two-dimensional and relating to the (t,Θ) - coordinate system with time t as the horizontal axis and with potential temperature Θ in the vertical. The high resolution of the analysis is achieved by vertical interpolation in 1 K increments of potential temperature and is described in the previous section.

In the second step of the presented cross-sectional technique Hermitian cubic polynomials are used as in SH73 to perform the horizontal interpolation in time and applied on the constant Θ - surfaces. The initial system of algebraic equations takes the form

$$
\begin{aligned}
p_i &= t_i^3A + t_i^2B + t_iC + D\\
\left(\frac{\partial p}{\partial t}\right)_i &= 3t_i^2A + 2t_iB + C\\
\left(\frac{\partial p}{\partial t}\right)_i &= 3t_i^2A + 2t_iB + C\\
p_{i+1} &= t_{i+1}^3A + t_{i+1}^2B + t_{i+1}C + D\\
\left(\frac{\partial p}{\partial t}\right)_{i+1} &= 3t_{i+1}^2A + 2t_{i+1}B + C
\end{aligned}
\qquad (2.7)
$$

which for $t_i = 0$ with $C = (\partial p/\partial t)_i$ and $D = p_i$ available from observations may be reduced and rearranged to give

$$
\begin{aligned}
t_{i+1}^3A + t_{i+1}^2B &= (p_{i+1} - p_i) - \left(\frac{\partial p}{\partial t}\right)_i t_{i+1}\\
3t_{i+1}^2A + 2t_{i+1}B &= \left(\frac{\partial p}{\partial t}\right)_{i+1} - \left(\frac{\partial p}{\partial t}\right)_i
\end{aligned}
\qquad (2.8)
$$

as the system of two equations with two unknowns A and B, defined over an interval along Θ_j = const between end-points $P_i(t_i,p_i)$ and $P_{i+1}(t_{i+1}, p_{i+1})$. When system (2.8) is solved and the coefficients determined, the interpolated values p_k for arbitrarily T_k may be calculated by substituting A and B in the interpolation polynomial

$$p_k = A\tau_k^3 + B\tau_k^2 + C\tau_k + D \quad ,\text{for } \Theta_j = \text{const.} \qquad (2.9)$$

and its changes with time can be obtained according to

$$\left(\frac{\partial p}{\partial t}\right)_k = 3A\tau_k^2 + B\tau_k + C \quad ,\text{in } \Theta_j = \text{const.} \qquad (2.10)$$

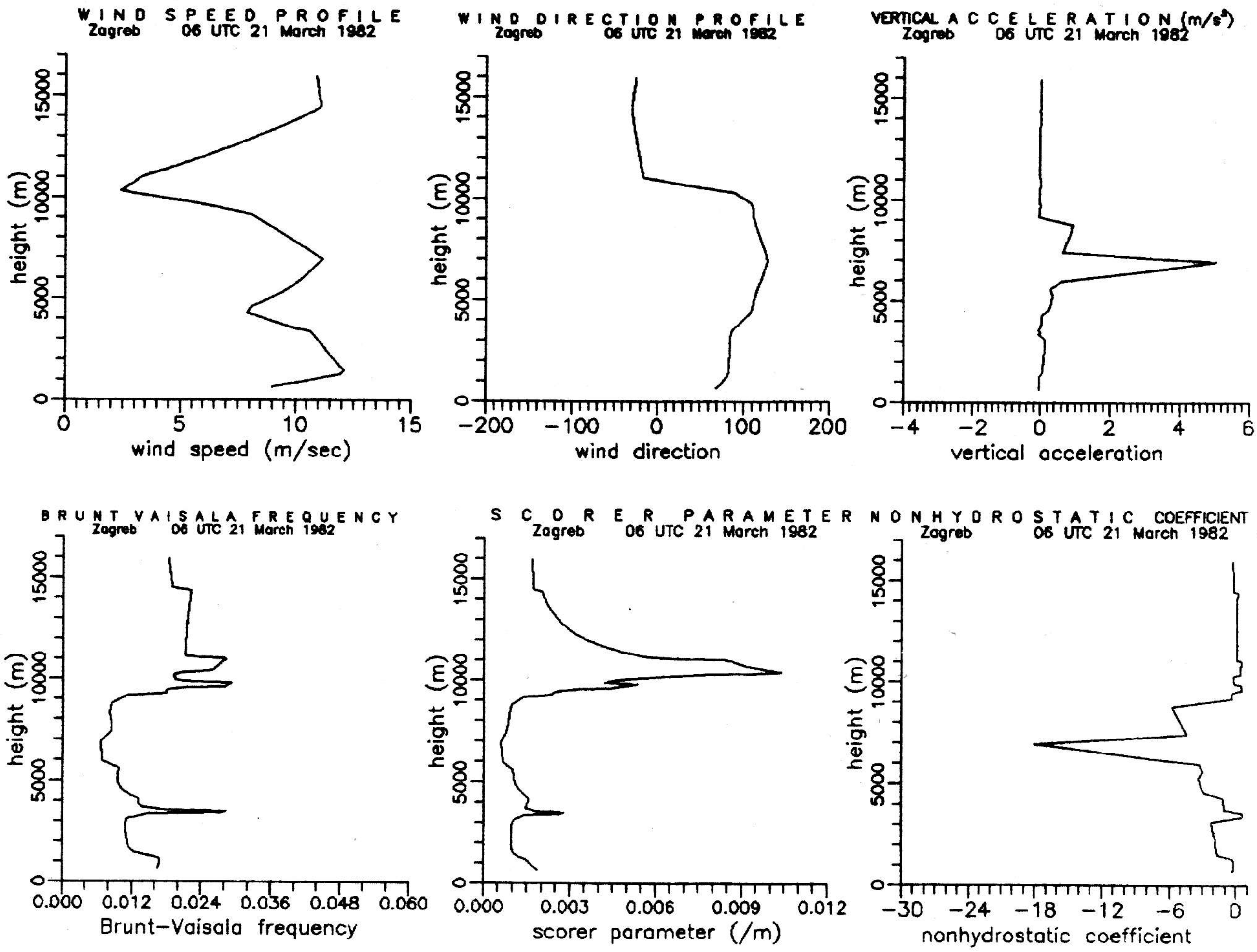

Fig. 7 The same as in Fig. 6, but for 06 UTC 21 March 1982.
Sl. 7. Isto kao na Sl. 6., ali za 06 UTC.

The successive interpolations are used in the following steps of interpolation and instead of $P_i(t_i,p_i)$ as the first or left end-point, $T_k(\Theta_k,p_k)$ is taken into account. As illustrated in Fig. 1, this means the replacement of p_i and t_i with previously interpolated values p_{k-1} and τ_{k-1}, where in system (2.7) $D = p_{k-1}$ and $C = (\partial p/\partial t)_{k-1}$ are valid.

2c. Intersection line of the isentropes at the ground

One of the striking features of the isentropic cross-sections are sloping isentropes which may intersect the ground. Since this intersection is an important characteristic for the dynamics of cyclones and frontal zones, it must be considered with special attention.

Before numerical treatment of the gridpoints near the ground, the pressure and potential temperature distribution at the surface which in a time cross-section is always straight line z_s = const, must be available. To provide this, interpolation in time, as in section 2b., at z_s = const is made for p and Θ, respectively. Afterwards, to fill up a possible deficiency of isentropes between the ground and the first isentrope above it which crosses all of the time intervals the polynomial vertical interpolation, as in the section 2a., is performed at T_k = const.

2d. The alternative selection of interpolation function

In the sections above, pressure p in dependence of potential temperature Θ is used as the interpolation function in objective time cross-section analysis. Note that another selection of the interpolation funetion is also possible to perform the vertical interpolation at t_i = const. For example, it may be the geopotential or geometrical height calculated as in G83 by means of relation

$$z_{j+1} = z_j + \frac{c_p}{2gp_0^{\kappa}}\left(\Theta_j + \Theta_{j+1}\right)\left(p_j^{\kappa} - p_{j+1}^{\kappa}\right) \qquad (2.11)$$

where in the first step the subscript j denotes the corresponding values at the ground. Further procedure is the same, but in (2.7) - (2.10) the substitution of z instead of p is needed.

To complete such an analysis it is necessary to compute not only the other meteorological fields and derived parameters, but also the geometrical heights of their isolines. It requires the additional time and vertical interpolations in (t,z) - space and an extension of the polynomial hydrostatic adjustment technique. Here, as an example, is presented one of the adjustment parameters used which can be derived from the alternative form of the isentropic hydrostatic equation

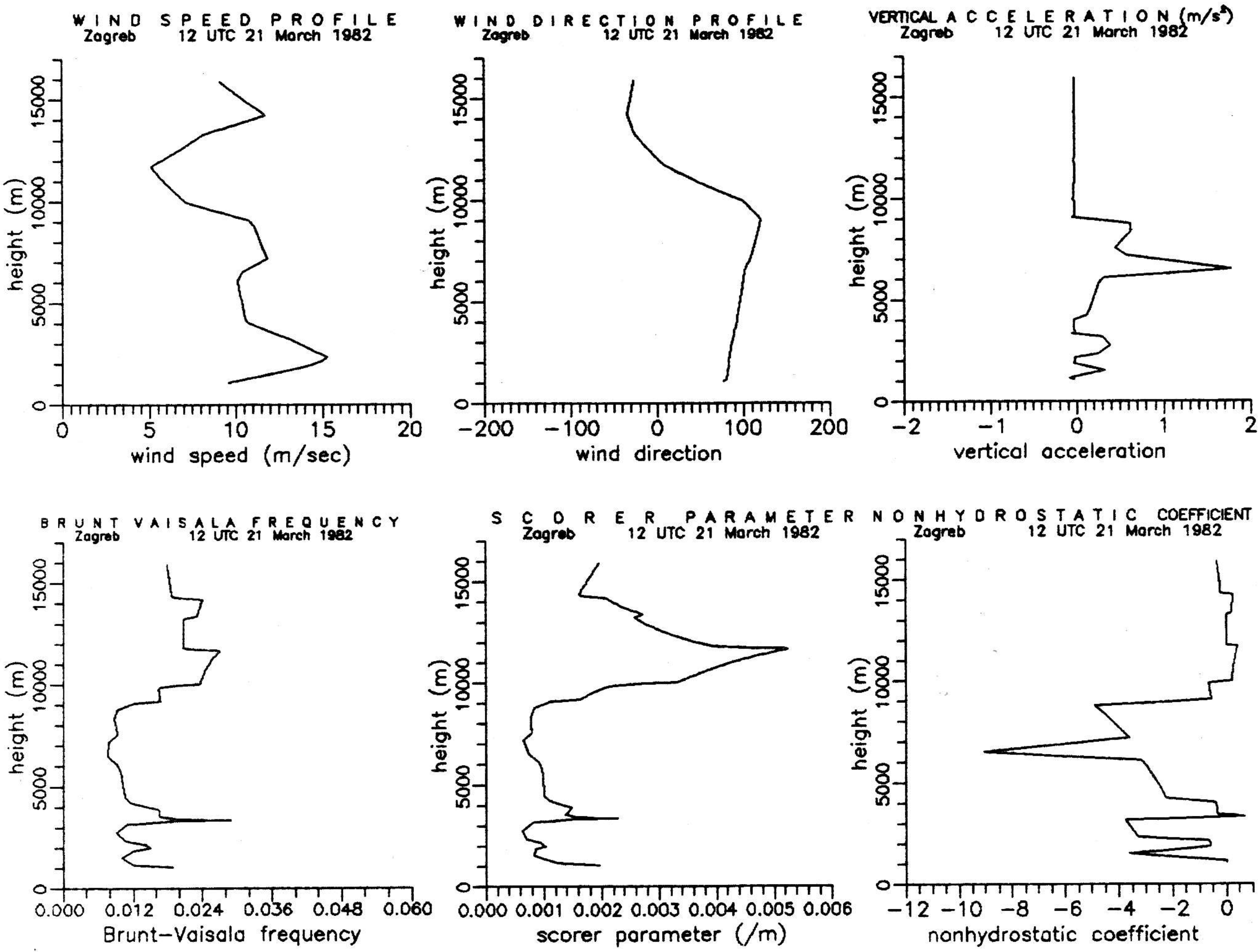

Fig. 8 The same as in Fig. 6, but for 12 UTC 21 March 1982.
Sl. 8. Isto kao na Sl. 6., ali za 12 UTC.

$$\frac{\partial z}{\partial \Theta} = \frac{\varepsilon}{g} \qquad (2.12)$$

where $\varepsilon = c_p(p/p_o)^{\kappa}$ is the Exner function. By succesive differentiation its n-order derivative, for n>1, may be written as

$$\frac{\partial^n z}{\partial \Theta^n} = (-1)^{n-1} \frac{\prod_{k=1}^{n-1}\left[1+(k-1)\kappa\right]}{\kappa^{n-1}\Theta^{n-1}} \frac{\partial z}{\partial \Theta} \qquad (2.13)$$

or in the programmable form

$$\frac{\partial^h z}{\partial \Theta^n} = -\frac{\left[1+(n-2)\kappa\right]}{\kappa\Theta} \frac{\partial^{n-1} z}{\partial \Theta^{n-1}} \qquad (2.14)$$

3. RESULTS

Since the topic of this work is in the domain of the development of the high resolution objective analysis technique, the main result here is the evidence of its successfulness and applicability.

To provide this, high resolution time cross-sections in the isentropic coordinates are constructed relating to particular synoptic events such as frontal passage and cyclogenesis. From the surface level up to 100 hPa they contain between 140 and 150 isentropes, plotted as functions of time and geometrical height in 1 K potential temperature increments for the 24-hour interval. As can be seen in the presented figures, there is a great number of the characteristic details which can be used to reveal and examine the time-evolution of the finest processes comprehended in such an analysis. For this purpose just the use of isentropic surfaces, as it is well known, has a considerable advantage. In the first place, the atmospheric motions are mostly adiabatic and in the absence of diabatic effects the isentropic surfaces may be considered as "material surfaces". This means that the mass flux through each surface must be zero and the air will tend to flow along them. On the other hand, one of the most useful properties of such an analysis which can be easily identified in the cross-section is that they tend to crowd up in stable layers. Therefore, while a horizontal crowding of the isentropes indicates the frontal zone their vertical crowding denotes a thermal inversion. On the contrary to the stable regions with crowded isentropes, their wide vertical spacing can be found in relatively unstable atmospheric conditions.

To obtain not only a more qualitative insight into the prevailing processes, but also to provide an additional verification of the results, the vertical profiles of some appropriate parameters are calculated. Since the change of potential temperature with height is a measure of static stability and it is proportional to the crowding of the isentropes, the Brunt-Vaisala frequency according to

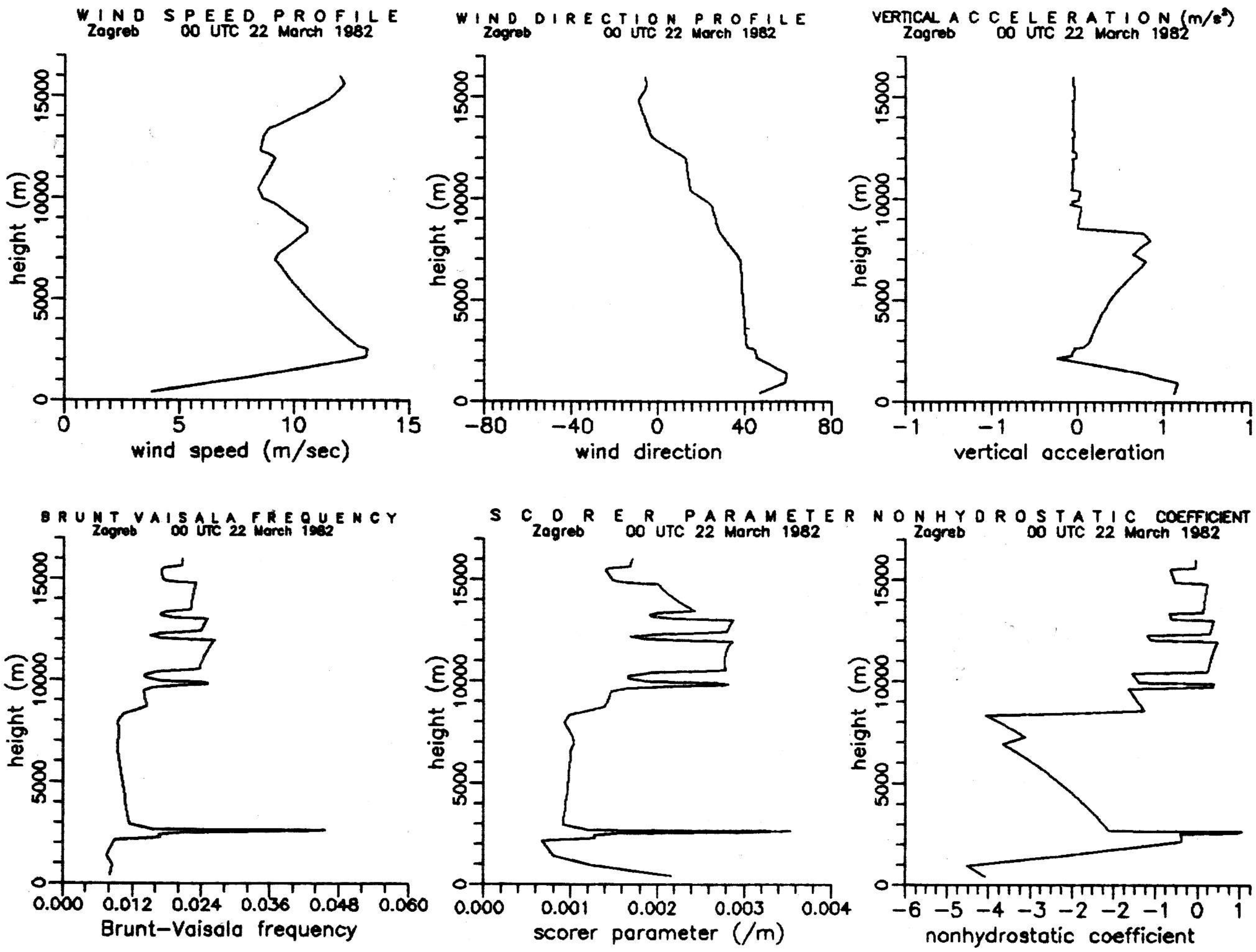

Fig. 9 The same as in Fig. 6, but for 00 UTC 22 March 1982.
Sl.9. Isto kao na Sl. 6., ali za 22.03.1982., 12 UTC.

$$N = \left(\frac{g}{\Theta} \frac{\partial \Theta}{\partial z} \right)^{1/2} \qquad (3.1)$$

in 1K potential temperature increments is computed at an arbitrary time. To complete the stability analysis and to include the wind information the Scorer parameter ℓ, one of the governing terms in the wave motion equation, as the ratio of Brunt-Vaisala frequency and wind speed is calculated. In addition, the vertical acceleration and nonhyudrostatic coefficient E_a profiles are obtained according to relations defined in G83 and applied in GJ90. Note that the nonhydrostatic coefficient E_a is a nondimensional number giving the measure of energetic changes across the isentropic surfaces. Also, it has the meaning of the deviation from the hydrostatic equilibrium and may indicate the increase of the air temperature with height. By using its alternative form

$$E_a = 1 + \kappa \frac{\partial \ln p}{\partial \ln \Theta} \qquad (3.2)$$

it can be applied to define the additional stability crtierion in a nonhydrostatic atmosphere. Mathematically, by inclusion of requirement $\partial p / \partial \Theta < o$, the coefficient E_a is defined in the interval $(-\infty, +1)$ and is limited on the right. Physically, a part of this interval from -1 to +1 indicates the stable state and for $E_a > O$ the internal energy of the unit mass increases with potential temperature as a vertical coordinate. In the case of $E_a = -n$, where n is any real number, the state is relatively unstable and its intensity depends on n.

The results of described objective technique are illustrated and discussed below relating to the sounding data in two events of severe weather development.

3a. A strong upper-level cyclogenesis on 3 and 4 July 1989 with severe precipitation in Zagreb

Data source to construct the isentropic time cross-sections shown in Fig. 2 and Fig. 4 are the successive Zagreb soundings at OO and 12 UTC. All earlier mentioned characteristics inherent to such an analysis can be easily seen in these cross-sections. In both of them the striking feature is the wide vertical spacing of sloping isentropes aloft indicating the strong high-level cyclogenesis. This process begins at 3 July p.m., rapidly develops up to 4 July at OO UTC and hereafter gradually weakens. Compared with considerable crowding of the isentropes in the very stable stratosphere, this pronounced instability is the most impressive at 4 July OO UTC, where the unstable layer is nearly 4.5 km deep, extending from 7.3 up to 11.7 km. Qualitatively, it can be considered in Fig. 3 in which six vertical profiles of various parameters are shown. All of them confirm the existence of cyclogenesis. The lowest value of Brunt-Vaisala frequency lower than 0.005 s^{-1} is found near 10.1 km, where the nonhydrostatic coefficient has a minimum reporting the largest deviation from the hydrostatic equilibrium and the vertical acceleration becomes unusually large. This unstable region of the sharp gradients is placed beneath the very stable tropopause which is defined by the strong peak of Brunt-Vaisala frequency profile with N greater than 0.045 s^{-1}. At the same time, the vertical acceleration curve indicates that in the middle and lower troposphere the stagnation of vertical motions is the prevailing process. Another notable feature in Fig. 2 and Fig. 4 is relating to the frontal passages at the ground and can be recognized by horizontal crowding of the isentropes. Note that the severe surface cold front arrived in Zagreb at 15 UTC on 3 July 1989.

3b. The 21 March 1982. low-level cyclogenesis followed by severe cyclonic bora on northern Adriatic

In the case presented in Fig. 5 five successive Zagreb soundings every six hours from ALPEX SOP are used to compute the high resolution time cross-section. Unlike the above summer events, in spite of relatively unstable layers with the wave structure of the isentropes between 6.5 and 8.5 km all of the important processes take place beneath 5 km. By horizontal crowding of the isentropes it is easy to identify the passage and time-evolution of the frontal system at a.m. and surface warm front in the evening. The essential feature of this analysis responsible for severe bora on the northern Adriatic is the existence of elevated inversion. Namely, it is well known that such an inversion close to the mountain top upstream of the barrier is the neccessary condition for the occurrence of severe downslope winds and essentially depends on its intensity and the layer depth just below it. The evolution in time of this elevated inversion obviously indicates the considerable enlargement of its intensity, but its height decreases. The qualitative evidence of this conclusion is clearly documented in Fig. 6 - Fig. 9. First, the strongest peak value in the profile of Brunt-Vaisala frequency is found near 2.8 km at OO UTC on 22 July 1982 in Fig. 9, where N is greater than 0.045 s^{-1}.

It is a very important characteristic of this inversion, since its intensity is two times stronger than the others at the multiple tropopause levels. Similar properties can be seen in the Scorer parameter profile. According to vertical acceleration and nonhydrostatic coefficient curves, its pronounced peak values indicate the greatest deviation from hydrostatic equilibrium and the unstable layer just below in version in the region of ascending motions along sloping isentropes.

Secondly, the geometrical height of considered elevated inversion has a maximum near 3.4 km between 06 i 12 UTC on 21 July and its intensity is approximately equal to that in the tropopause. Note that during this interval the strongest bora gusts on the northern Adriatic are observed. These objective results may be compared with the synoptic analysis presented by Ivančan-Picek and Vučetić in this Volume.

4. SUMMARY AND CONCLUSIONS

In this study the objective methods for computation of the isentropic high resolution time cross-section are defined and their applicability is verified in two strong cyclogensis events. To achieve the high resolution of the analysis in 1 K potential temperature increments the polynomial hydrostatic adjustment technique is developed. Instead of conventional computation in the finite difference approximations, the isentropic hydrostatic relations and its derivatives of a higher order have been involved in the numerical procedure. In such a way, in the vertical interpolation it enables not only to minimize the influence of the systematic error, but also to incorporate the physics of the finest atmosperic processes into the analysis. Note that a great number of difficulties reported in SH73 by this approach are quite removed.

From discussion in the previous section a considerable number of possibilities for application of the high resolution time cross-section is evident. In the first place, it may be a very useful diagnostic tool for forecasters. On the other hand, it may be used as the output of any numerical model and to provide a detailed local weather forecast for an arbitrarily chosen gridpoint.

Finally, the polynomial hydrostatic adjustment technique, successfully used here, may be applied to improve the vertical initialization of the numerical model in any coordinate system. This is obviously suggested by the application of the presented methods. Their striking result indicates that this computational technique which is strictly hydrostatic can by successfully aplied in the pronounced nonhydrostatic atmosphere. It is realized by th localization of mathematics at every point (p,Θ), which in such an analytic approach according to (2.3)-(2.7) allows the possibility of building the physics in the considered objective routine and to conserve it in the analysis.

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KRATKI SADRŽAJ

Premda je krajnji cilj rada objektivna konstrukcija vremenskog presjeka visoke rezolucije u izentropskom koordinatnom sustavu, njegovo je ostvarenje tek potvrda uspješnosti i opće primjenljivosti objektivnih metoda koje je pri tom bilo neophodno definirati i testirati. U odnosu na uobičajenu tehniku računanja, koja se primjenjuje u presječnoj objektivnoj analizi, u ovom je radu predložen i razrađen kvalitativno potpuno različit pristup razmatranoj problematici, osobito u dijelu koji se bavi problemom vertikalne inicijalizacije. Njegov je ključni element rutina polinomskog hidrostatičkog prilagođavanja, čijom se primjenom osigurava vertikalna konzistencija računskog postupka. Temelji se na recipročnoj vrijednosti parametra termičkog stabiliteta $\partial p/\partial\Theta$ i njenim derivacijama višeg reda $\partial^m p/\partial\Theta^m$ u obliku relacija (2.3) do (2.5), što su izvedene iz izentropske hidrostatičke jednadžbe. S obzirom na to da se ove relacije u točkama vertikalne interpolacije (p,Θ) primjenjuju lokalno, dakle u njihovoj infinitezimalnoj okolini, te da najviša derivacija u sebi sadrži sve derivacije nižeg reda i njihovu fiziku, razmatranom se problemu moglo prići analitički. Time je u postupku vertikalne interpolacije potpuno eliminirano računanje pomoću aproksimacija u konačnim razlikama na slojevima različite debljine, kao i sistematske pogreške koje se takvim računom nužno javljaju.

Tehnika polinomskog hidrostatičkog prilagođavanja u ovom je radu ugrađena u Hermiteovu interpolacijsku shemu, koju je zbog primjene polinoma višeg stupnja prethodno trebalo modificirati. Pri tom kao vrlo značajnu prednost razmatranog postupka treba izdvojiti njegovu ekonomičnost, budući da su čak i za proračun viših derivacija pojedinih meteoroloških parametara dovoljni osnovni podaci mjerenja u samo jednoj točki. Pokazalo se da je takvom "lokalizacijom" matematike moguće ne samo postići visoku rezoluciju analize uz međusobni razmak izentropa manji od jednog stupnja apsolutne temperature ljestvice, već i sačuvati postojeću fiziku strukturalnih promjena u danoj točki atmosfere. U prilog tome govori podatak da je razmatrane objektivne metode bilo moguće uspješno primijeniti u izrazito nehidrostatičkoj atmosferi s vrlo burnim ciklogenetičkim razvojem, što kvalitativno dokazuje proračun vertikalnih profila Brunt-Vaisala frekvencije, Scorerovog parametra, vertikalne akceleracije i odstupanja od hidrostatičke ravnoteže. Čini se također da je važan korak naprijed u poboljšanju računskog postupka i primjena sukcesivnih polinimskih interpolacija što se koriste i duž vertikale i na vremenskoj osi, prije svega zato što preuzimaju informaciju iz prethodnog računskog intervala.

Treba naglasiti da je takvim objektivnim tretmanom utemeljenim na tehnici polinomskog hidrostatičkog prilagođavanja bilo moguće ukloniti velik broj poteškoća o kojima pri sličnim pokušajima, pa čak i u primjeni linearne vertikalne interpolacije izvještavaju Shapiro i Hastings (1973), te Whittaker i Petersen (1976), čiji su radovi na tom području i danas temeljna literatura. Riječ je prije svega o stvaranju velikog broja nerealnih superdijabatičkih slojeva gotovo beskonačne stabilnosti, kojih u stvarnim podacima nije bilo, a nije ni moglo biti. Takvo iskrivljenje objektivne analize vertikalnih presjeka, što je dovelo do ispreplitanja i zatvaranja pojedinih izentropa, spomenuti su autori pripisali nedostatku mehanizma koji bi mogao osigurati vertikalnu konzistenciju. Stoga su postupak vertikalne interpolacije izvodili linearno, a superadijabatičke slojeve iz analize uklanjali osrednjavanjem temperature.

Glavni, a čini se i najvrjedniji rezultat ovog rada je upravo uspješna primjena tehnike polinomskog prilagođavanja u objektivnoj konsturkciji vremenskih presjeka visoke rezolucije. To ujedno navodi na zaključak da bi takav pristup mogao donijeti znatna poboljšanja vertikalne inicijalizacije numeričkih prognostičkih modela u bilo kojem koordinatnom sustavu.

Nadalje, na temelju opširne diskusije rezultata provedene u ovom radu i dobro poznatih analitičkih svojstava izentropske analize jasno je da postoji niz različitih mogućnosti primjene razmatranih vremenskih presjeka. Prije svega, oni mogu poslužiti prognostičarima u operativnom radu kao vrlo moćno dijagnostičko oruđe. U drugu ruku, čini se da bi takav način prezentiranja izlaznih polja iz numeričkog prognostičkog modela za određeni broj proizvoljno odabranih točaka mreže mogao dati mnogo detaljniji uvid u prognoziranu dinamiku procesa na danom lokalitetu nego što ih je moguće dobiti uobičajenim načinom prikazivanja.