OBJECTIVE ANALYSIS OF THE 3-D STRUCTURE OF MESOMETEOROLOGICAL FIELDS BASED ON OPTIMAL INTEGRATION OF ALTERNATIVE METHODS OF SPATIAL INTERPOLATION

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We propose here original approach for solving the problem of objective analysis of the mesometeorological fields based on the procedure of optimal integration of two alternative methods of spatial interpolation (optimal interpolation and the modified method of clustering of arguments). Its methodology and algorithms are explained, and validity tests are analyzed by an example of temperature and wind data.

1. INTRODUCTION

In recent years reuirements to the atmospheric monitoring of local territories became much higher strongly what motivated the development of contemporary and efficient techniues for objective analysis of mesometeorological fields, i.e. fields with the characteristic scales from tens to hundreds kilometers.[1] Here and below by the objective analysis of the mesometeorological fields we mean the procedure of constructing such fields, or, in other words, the procedure of determining meteorological parameters at points of some mesoscale grid using measurement data from stations.

Another motivation for resolution of this problem is in the fact that the objective analysis is a necessary step in processing meteorological information, prior to solving many problems in hydrometeorology and ecology including:

– local numerical weather forecast based on the mesometeorological euations, which calls for a prognostic model with the step from 5 to 50 km (Ref. 1);

– estimation of specialized meteorological parameters (such as area-averaged temperature, its horizontal gradients, analogous gradients of wind velocity components, etc.), generally calculated from data of objective analysis and used to solve many applied problems like diagnosis and prediction of spatial dispersal of industrial pollutants in air basins over local territory (such as big city or industrial zone).

One important circumstance should be mentioned here that unlike the objective analysis of macrometeorological fields which found many practical applications (for examples, see Refs. 2–4), analogous analysis of mesometeorological fields has not been developed properly because of two difficulties present. First difficulty is associated with the poor density of existing aerological network, whose minimum grid spacing is about 300–400 km and is well above the value reuired for the objective analysis of mesometeorological fields; the second difficulty arises from certain drawbacks in the spatial interpolation techniues used in the objective analysis; in particular, the polynomial approximation techniue is characterized by the fact that algebraic polynomials are chosen arbitrary, without any account for meteorological fields properties being studied, while optimal interpolation techniue, though providing better results than the polynomial approximation techniue (the method intercomparison is given in Ref. 5), requires for its implementation a preliminary generalization of large bulk of initial information and calculation of the necessary statistical characteristics (primarily spatial correlation coefficients).

Taking into account all the aforesaid as well as the fact that the quality of the objective analysis of the 3-D mesometeorological fields must be substantially updated (from the viewpoint of practical demands), in the present paper we propose an original approach to solving the problem formulated, which is based on the procedure of optimal combination of two alternative methods of spatial interpolation (method of optimal interpolation and modified method of clustering of arguments (MMCA)). The methodological framework for this approach and its validation using temperature and wind data as an example will be the subject of the below discussion.

2. METHODOLOGICAL FOUNDATIONS OF THE OBJECTIVE ANALYSIS OF MESOMETEOROLOGICAL FIELDS BY THE COMPLEX OF ALTERNATIVE METHODS

Objective analysis of temperature and wind fields based upon alternative methods of spatial interpolation (extrapolation) is accomplished, as in Ref. 5, in two steps. First, optimal interpolation method is used to construct near-ground and free-atmosphere fields of the meteorological parameter and the atmospheric level is chosen where the retrieval error is minimum. Then,

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data from the objective analysis of the meteorological field at the level with the least error of retrieval by the method of the optimal interpolation are used together with data from available stations to construct prognostic MMCA model which then is used to reconstruct vertical profiles of the same meteorological parameter at all points of the chosen regular grid with a step ΔS (being 25 km in our case and, according to Ref. 1, coinciding with the grid spacing required for prediction of mesometeorological processes).

It should noted from the very beginning that this approach to construction of a 3-D mesometeorological field has been described in Ref. 6 dealing with similar (objective analysis) problem of spatial prediction of the same field over the territory with no measurement data available.

First we consider the methodological foundations for the objective analysis in the near-ground mesometeorological field which, as mentioned above, was performed by the method of optimal interpolation using the following relation of the form[3]

$$\xi_0 = \bar{\xi}_0 + \sum_{i=1}^{n} p_i \, \xi_i', \quad (1)$$

where ξ_0 is the meteorological parameter sought at a zero-indexed node of the regular grid; $\bar{\xi}_0$ is the mean (climatic) value of this same meteorological parameter at the sought node of the regular grid, with $\bar{\xi}_0 = \bar{\xi}_i = \bar{\xi}$ for the mesometeorological polygon;[4] $\xi' = \xi_k - \bar{\xi}_k$ is the deviation of meteorological parameter from its normally observed value at the point k; i is the index referring to the on-site observations; n is the number of stations used to calculate meteorological parameter at a grid node, p_i are the weighting coefficients.

According to Ref. 3, the entire procedure of objective analysis is as follows.

From the positions of $n + 1$ points (n stations and one node of the regular grid) located on some meteorological polygon, we calculate the distances

$$l_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (2)$$

for each pair of points (x_i and y_i in Eq. (1) denote coordinates of the point). These distances form the matrix $n(n + 1)$ of the form

$$\begin{Vmatrix} 0 & l_{12} & l_{13} & \dots & l_{1n} & l_{10} \\ l_{21} & 0 & l_{23} & \dots & l_{2n} & l_{20} \\ l_{31} & l_{32} & 0 & \dots & l_{3n} & l_{30} \\ \vdots & \vdots & \vdots & \vdots\vdots\vdots & \vdots & \vdots \\ l_{n1} & l_{n2} & l_{n3} & \dots & 0 & l_{n0} \end{Vmatrix}, \quad (3)$$

where first n columns form symmetrical matrix since $l_{ij} = l_{ji}$, so only $n^2/2$ have to be calculated of $n(n + 1)$ distances.

Then using some analytical expression, obtained for the normalized correlation function, we pass from the distance matrix (3) to the matrix of correlation coefficients r_{ij}

$$\begin{Vmatrix} r_{11} & r_{12} & r_{13} & \dots & r_{1n} & r_{10} \\ r_{21} & r_{22} & r_{23} & \dots & r_{2n} & r_{20} \\ r_{31} & r_{32} & r_{33} & \dots & r_{3n} & r_{30} \\ \vdots & \vdots & \vdots & \vdots\vdots\vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & r_{n3} & \vdots & r_{nn} & r_{n0} \end{Vmatrix}. \quad (4)$$

In accordance with Ref. 6, r_{ij} values are calculated from the following analytical expressions:
for temperature[7]

$$r_T(l_{ij}) = \exp(-0.825(l_{ij})^{0.92}), \quad (5)$$

and for wind velocity components[8]

$$r_u(l_{ij}) = r_v(l_{ij}) = (1 - 0.98\, l_{ij})\exp(-0.98 l_{ij}). \quad (6)$$

After r_{ij} values are evaluated, we write the system of equations to calculate weighting factors p_i under condition that the mean squared deviation from Eq. (1) is minimum,

$$p_1(r_{11} + \eta_1) + p_2\, r_{21} + p_3\, r_{31} + \dots + p_n\, r_{n1} = r_{01};$$
$$p_1\, r_{12} + p_2(r_{22} + \eta_2) + p_3\, r_{32} + \dots + p_n\, r_{n2} = r_{02};$$
$$p_1\, r_{13} + p_2\, r_{23} + p_3(r_{33} + \eta_3) + \dots + p_n\, r_{n3} = r_{03};$$
$$\dots\dots\dots\dots\dots\dots\dots\dots$$
$$p_1\, r_{1n} + p_2\, r_{2n} + p_3\, r_{3n} + \dots + p_n(r_{nn} + \eta_n) = r_{0n},$$

or, in a reduced form

$$\sum_{i=1}^{n} p_i\, r_{ij} + \eta_j\, p_j = r_{0j} \quad (j = 1, 2, \dots, n). \quad (7)$$

Here η_j is the ratio of the mean squared measurement error of meteorological parameter to the mean squared deviation from its norm.

The formulas (1) to (7) make the basis for the calculation technique (Fig. 1) in the method of objective analysis of near-ground and free-atmosphere mesometeorological fields and for a subsequent choice of the level with minimum interpolation (extrapolation) error.

Following the objective analysis made by the objective interpolation (extrapolation) method, next procedure of the objective analysis is executed, but now with a 3-D structure of the mesometeorological field considered (its flowchart is illustrated in Fig. 2). Because the present paper uses for this purpose MMCA algorithm which is similar to that from Ref. 6, below we shall present only its main ideas.

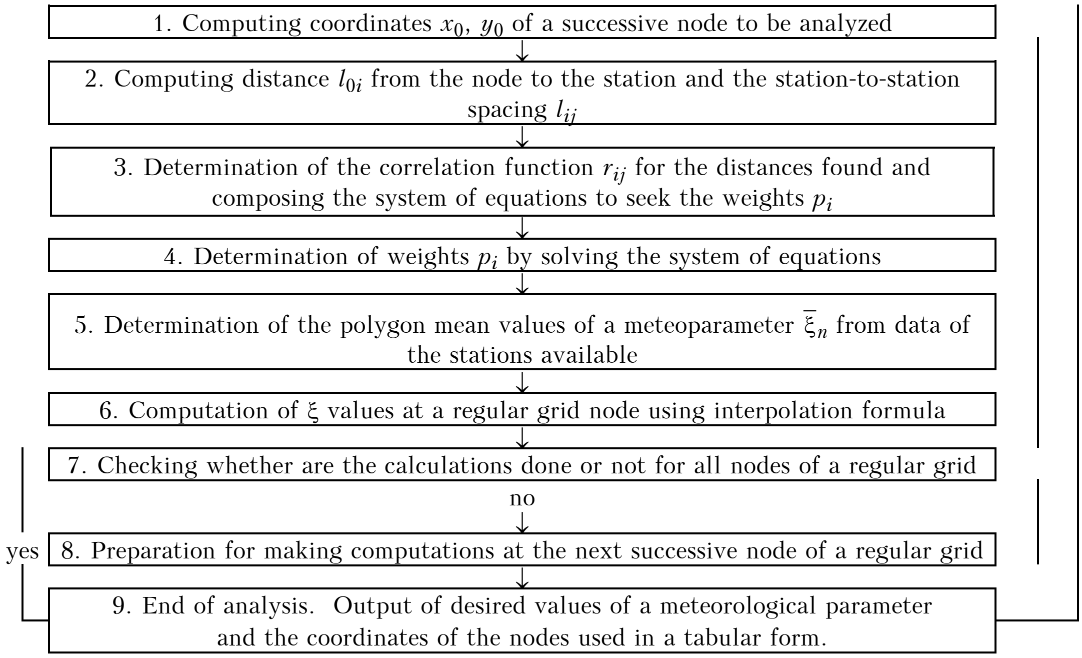

FIG. 1. Flowchart of computing meteoparameters at a regular grid nodes using optimal interpolation formulas.

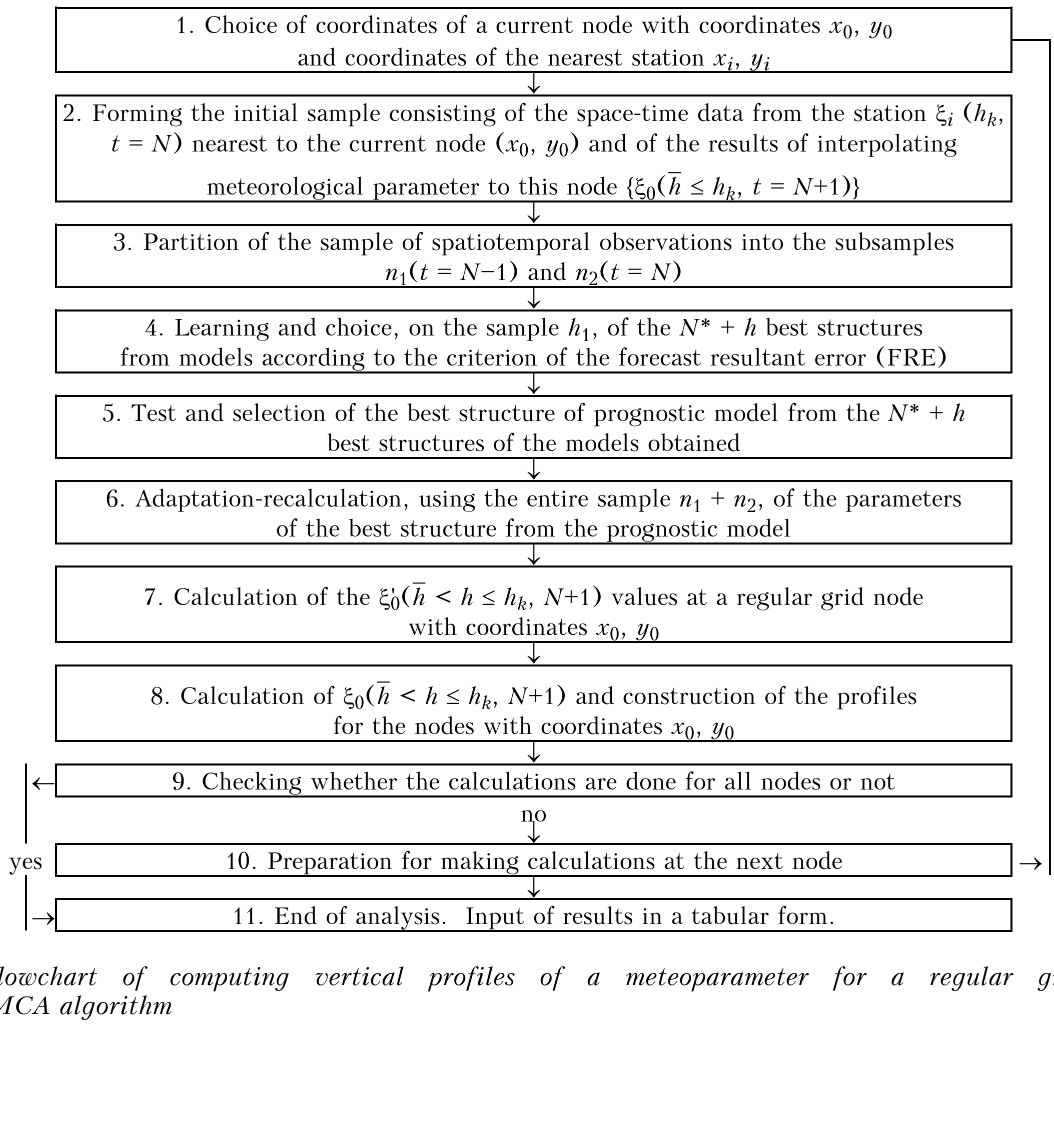

FIG. 2. Flowchart of computing vertical profiles of a meteoparameter for a regular grid node by the MMCA algorithm

First, using the results of reconstructing a meteorological parameter at a regular-grid node with the index "0", together with the data from space-time observations of this parameter

$$\{\xi_i(h,\,t)\ ,\ h = 0,1,\ \dots\ ,\ h_k;\ t = 1,\ \dots\ ,\ N\}$$
$$\{\xi_0(h,\,t)\ ,\ h = 0,1,\ \dots\ ,\ \bar{h} \le h_k;\ t = N + 1\} \qquad (8)$$

(where h is the height, t is the time, and N is the number of profiles), which are obtained from soundings at the nearest (to the node considered) station, we construct the system of linear regression models of the form[6]

$$\xi_0(h,\,N + 1) = \sum_{\tau=1}^{N^*} A(h,\,\tau)\xi_i(h,\,N + 1 - \tau) +$$
$$+ \sum_{j=1}^{h-1} B(h,\,j)\xi_0(j,\,N + 1) + \varepsilon(h,\,N + 1) \qquad (9)$$

at $h = \bar{h} + 1;\ \bar{h} + 2;\ \dots;\ h_k$.

Here N^* is the order of a time lag ($N^* < [N - h - 1]/2$); $A(h,\,1),\ \dots,\ A(h,\,N)$ and $B(h,\,0),\ \dots,\ B(h,\,h{-}1)$ are the unknown parameters, and $\varepsilon(h,\,N{+}1)$ is the model discrepancy.

Then, we select the best model (9). To this end we first perform preliminary separation (according to Ref. 9) of the total sample into the subsamples A (a continuous measurement by the time $t = N - 1$ inclusive) and B (measurements at $t = N$ strictly), and then select the best model using two special techniques.

1) Method of directed area search for optimization of model structure through the use of a two-step model selection in terms of

– forecast resultant error (H. Akaike) of the form

$$\mathrm{FRE} = \frac{(N - N^* - 1) + s}{(N - N^* - 1) - s}\,\mathrm{RSS}(s), \qquad (10)$$

where $\mathrm{RSS}(s) = \sum_{j=1}^{N-N^*-1} \left[(\xi^{(i)}_{h,N-j} - \hat{\xi}^{(i)}_{h,N-j}(s)\right]^2$ is the residual sum of squares for the current model $\hat{\xi}^{(i)}_{h,N-j}(s)$ containing s nonzero parameter estimates. The $\hat{\xi}^{(i)}_{h,N-j}$ estimation is performed by the expression

$$\hat{\xi}^{(i)}_{h,N-j} = \mathrm{X}\hat{\Theta},\quad \mathrm{X} \in M_{(N-N^*-1)\times(N^*+h)},\quad \Theta \in R^{N^*+h}, \qquad (11)$$

where $\hat{\Theta} = [\hat{A}_{h,1},\ \dots,\ \hat{A}_{h,N^*},\ \hat{B}_{h,0},\ \dots,\ \hat{B}_{h,N-1}]^{\mathrm{T}}$ is the minimax estimate of the parameters from the sample A, which is calculated using special formulas (see Ref. 6), and T indicates transposition; R is the Euclidean space of k-dimensional vectors; $M_{m\times p}$ is the space of matrices with the dimensions $m\times p$;

– the rms error of prediction on the control sample (sample B)

$$\left|(\xi^{(i)}_{h,N} - \hat{\xi}^{(i)}_{h,N}(s)\right|^2 \to \min, \qquad (12)$$

where the minimum is taken over all $N^* + h$ structures, each representing a model $\hat{\xi}^{(i)}_{h,N}(s)$.

2) Method of minimax estimation of the model parameters ensuring the quality of the corresponding forecast that can be estimated by the inequality

$$E\left|E(\xi^{(0)}_{h,N+1} - \hat{\xi}^{(0)}_{h,N+1}\right|^2 \le \delta_{h,N+1}$$
$$(h = \bar{h} + 1,\ \dots,\ h_k), \qquad (13)$$

where $E(\cdot)$ is the operator of mathematical expectation to take averages over all possible realizations of observation errors, while $\xi^{(0)}_{h,N+1}$ and $\delta_{h,N+1}$ are minimax estimates that depend on the variance of observation errors σ^2 and on the *a priori* information on the maximum admissible deviations of forecasts given by the condition

$$\Delta_{h,N+1} = \max_{t = 1,\ \dots,\ N} \left|\xi^{(i)}_{h,t}\right| \quad (h = 0,\ 1,\ \dots,\ h^*), \qquad (14)$$

or set by a user.

Final step of the data interpolation to the grid node with the index 0 is finding the missing components of the vertical profile $\xi_0(\bar{h} < h \le h_k,\ N{+}1)$ from formulas of the form

$$\xi_0(\bar{h} < h \le h_k,\ N{+}1) = \bar{\xi}_0(\bar{h} < h \le h_k) +$$
$$+ \xi_0'(\bar{h} < h \le h_k,\ N{+}1), \qquad (15)$$

where $\bar{\xi}_0(\bar{h} < h \le h_k)$ is the vertical profile of the mean (climatic) values of a meteorological parameter, which is obtained for the grid node provided that $\bar{\xi}_0 = \bar{\xi}_i = \bar{\xi}$ on the territory of the mesometeorological polygon[4]; $\xi_0'(\bar{h} < h \le h_k,\ N{+}1)$ is the profile of the random deviations of the same value at the grid node, under study reconstructed using the MMCA algorithm, and construction of the complete profile with allowance for data for the level with minimum forecast error $\xi_0(h \le h_k,\ t = N{+}1)$.

The integrated method described above was used to solve the problem of objective analysis of mesometeorological field of temperature and wind velocity components, that is, to determine profiles of the said parameters at the regular mesoscale grid nodes from measurements at the neighboring aerological stations.

3. THE RESULTS OF STATISTICAL ESTIMATION OF THE OBJECTIVE ANALYSIS QUALITY

The objective analysis itself and its validation were performed using special radiosonde data from five aerological stations representing a mesometeorological polygon (its scheme is presented in Fig. 3 as well as the corresponding regular grid) located in the West Ukraine and " elorussia. For this case, the radiosonde observational record spans from November 24 to December 7, 1991, while the data themselves, as in

Ref. 5, are tied to the geometric system of 10 levels: $h = 0$, 200, 400, 800, 1200, 1600, 2000, 4000, 6000, and 8000 m.

The objective analysis of mesometeorological fields was considered here in application to the problem of diagnosis and prediction of the spatial spread of industrial pollutants, and so, as in Ref. 5, layer-average values of temperature and wind, rather than individual level observations, were used for the layers between $h = 0$ and h. In practice such characteristics are usually called the mean temperature and wind and denoted as $\langle T\rangle_h$, $\langle U\rangle_h$, and $\langle V\rangle_h$, respectively.

Here we should like to note that, because of the instrumentation chosen, the 200-m height, rather than the station level, was used as the lowermost atmospheric layer boundary in the wind velocity measurements. Furthermore, due to the limited number of stations used for objective analysis, extrapolation was applied in combination with the interpolation, though only in those cases when the regular grid nodes are beyond or near the radius R of the station (see Fig. 3).

FIG. 3. Map of the mesometeorological polygon 300 km by 300 km which was used to validate the algorithm of the objective analysis.

TABLE I. Standard deviations (□) and the probabilities (P) of error, below a preset value, in the objective analysis of the field of temperature, zonal and meridional winds: for station Kremenets (1) by the optimal interpolation techniue, and for station Nesterov (2) by the optimal extrapolation techniue.

Layer, km	δ		Probability, P									
			< ±1		< ±2		< ±3		< ±4		> ±4	
	1	2	1	2	1	2	1	2	1	2	1	2
a) temperature, T, °C												
0	0.8	1.0	0.75	0.63	0.94	0.94	1.00	0.94	1.00	0.94	0.00	0.06
0–0.4	1.1	1.5	0.73	0.50	0.94	0.81	1.00	0.81	1.00	1.00	0.00	0.00
0–0.8	1.0	2.0	0.69	0.19	0.94	0.69	1.00	0.88	1.00	0.94	0.00	0.06
0–1.2	1.0	2.2	0.69	0.25	0.94	0.63	1.00	0.88	1.00	0.88	0.00	0.13
0–1.6	1.1	2.3	0.64	0.19	0.94	0.50	0.94	0.88	1.00	0.88	0.00	0.13
0–2.0	1.4	2.3	0.61	0.19	0.94	0.56	0.94	0.88	0.94	0.88	0.06	0.13
0–4.0	1.5	2.4	0.61	0.25	0.88	0.38	0.94	0.75	0.94	0.88	0.06	0.13
0–6.0	1.7	2.6	0.50	0.13	0.81	0.44	0.94	0.69	0.94	0.81	0.06	0.19
0–8.0	1.9	2.7	0.44	0.13	0.81	0.44	0.94	0.69	0.94	0.81	0.06	0.19
B) zonal wind, U, m s^{-1}												
0.2–0.4	0.8	1.9	0.75	0.56	1.00	0.75	1.00	0.88	1.00	0.88	0.00	0.13
0.2–0.8	1.6	4.3	0.44	0.38	0.75	0.56	0.94	0.63	1.00	0.69	0.00	0.31
0.2–1.2	2.4	6.4	0.25	0.38	0.63	0.38	0.75	0.56	0.94	0.56	0.06	0.44
0.2–1.6	2.6	7.4	0.13	0.31	0.44	0.38	0.75	0.50	0.88	0.50	0.13	0.50
0.2–2.0	2.9	8.4	0.19	0.25	0.38	0.31	0.69	0.38	0.81	0.50	0.19	0.50
0.2–4.0	3.2	9.2	0.19	0.19	0.38	0.25	0.69	0.31	0.81	0.44	0.19	0.56
0.2–6.0	3.7	10.8	0.19	0.13	0.38	0.19	0.56	0.25	0.81	0.25	0.19	0.75
0.2–8.0	3.9	11.4	0.25	0.06	0.38	0.13	0.56	0.19	0.75	0.25	0.25	0.75
c) meridional wind, V, m s^{-1}												
0.2–0.4	0.5	0.5	0.63	0.56	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00
0.2–0.8	1.3	2.0	0.44	0.25	0.75	0.50	0.94	0.69	1.00	1.00	0.00	0.00
0.2–1.2	2.4	3.2	0.38	0.13	0.56	0.31	0.75	0.56	0.94	0.69	0.06	0.31
0.2–1.6	2.8	3.7	0.25	0.13	0.44	0.31	0.75	0.44	0.88	0.69	0.12	0.31
0.2–2.0	3.4	3.9	0.19	0.06	0.38	0.31	0.69	0.44	0.81	0.63	0.19	0.38
0.2–4.0	3.6	4.0	0.19	0.06	0.38	0.19	0.69	0.38	0.81	0.63	0.19	0.38
0.2–6.0	4.5	14.4	0.19	0.00	0.38	0.13	0.56	0.44	0.75	0.69	0.25	0.31
0.2–8.0	5.2	14.5	0.13	0.00	0.31	0.19	0.44	0.31	0.69	0.63	0.31	0.38

In the paper the Cuality of the objective analysis was estimated in terms of two statistics: standard (rms) interpolation error (δ) and the probability P of errors below some value being ±1,...,±4°C and more than ±4°C for near ground and free-atmosphere mean temperature, and less than ±1,...,±4 m s^{-1} and larger than ±4 m s^{-1} for the wind velocity components.

Let us consider in more detail the Cuality control techniCue employed in the objective analysis, since several techniCues are used in practice. Recently two techniCues have become most common, the first one is based on comparing results of the objective and synoptic analyses (see Refs. 10 and 11 for details), and the second relies on determining the meteorological parameter for the control station from data available from surrounding ones without calculating their values at the regular grid nodes (e.g., see Ref. 4). We used the second, more objective, method to estimate the Cuality of the objective analysis of a 3-D structure of the wind and temperature fields within the mesometeorological polygon considered.

Now let us discuss the results of numerical experiments for estimating Cuality of the objective analysis of mesometeorological fields, evaluating first the performance of the objective analysis based on the optimal interpolation (extrapolation) techniCue. That will be done using Table I containing, for two stations of the chosen mesometeorological polygon, standard (rms) errors (δ_ξ) and probabilities (P) of the objective analysis errors below or above some preset value (the said analysis was performed for the fields of the near-ground (T) and free-atmosphere ($\langle T\rangle_h$) temperatures, as well as for the mean zonal ($\langle U\rangle_h$) and meridional ($\langle V\rangle_h$) winds).

TABLE II. Standard deviation (δ) and the probabilities (P) of errors, below a preset value, of the objective analysis of the temperature and zonal and meridional wind fields, using combination of the optimal interpolation (extrapolation) techniue and MMCA for the Kremenets (1) and Nesterov (2) stations.

Layer,	δ		Probability, P									
			< ±1		< ±2		< ±3		< ±4		> ±4	
km	1	2	1	2	1	2	1	2	1	2	1	2
a) temperature, T, °C												
0–0.4	1.0	1.9	0.75	0.55	0.95	0.85	1.00	0.90	1.00	0.95	0.00	0.05
0–0.8	1.6	2.1	0.50	0.45	0.75	0.75	0.90	0.80	0.95	1.00	0.05	0.00
0–1.2	1.8	2.2	0.40	0.40	0.70	0.70	0.75	0.80	0.95	0.95	0.05	0.05
0–1.6	2.1	2.3	0.35	0.35	0.60	0.60	0.85	0.85	0.95	0.95	0.05	0.05
0–2.0	2.4	2.3	0.25	0.35	0.55	0.60	0.70	0.85	0.85	0.90	0.15	0.10
0–4.0	3.1	2.8	0.20	0.30	0.55	0.60	0.65	0.75	0.70	0.80	0.30	0.20
0–6.0	3.3	2.8	0.20	0.20	0.45	0.55	0.60	0.75	0.65	0.80	0.35	0.20
0–8.0	3.4	2.7	0.20	0.20	0.45	0.55	0.60	0.75	0.65	0.85	0.35	0.15
B) zonal wind, U, m s^{-1}												
0.2–0.8	1.8	1.9	0.65	0.60	0.85	0.85	0.90	0.90	0.95	0.95	0.05	0.05
0.2–1.2	1.8	1.7	0.55	0.60	0.85	0.80	0.85	0.95	0.95	0.95	0.05	0.05
0.2–1.6	1.7	1.3	0.55	0.70	0.75	0.85	0.90	1.00	1.00	1.00	0.00	0.00
0.2–2.0	1.9	1.1	0.50	0.65	0.85	0.90	0.90	1.00	0.90	1.00	0.10	0.00
0.2–4.0	1.6	1.5	0.55	0.70	0.90	0.80	0.90	0.90	0.95	1.00	0.05	0.00
0.2–6.0	2.0	1.1	0.55	0.65	0.80	0.95	0.85	1.00	0.90	1.00	0.10	0.00
0.2–8.0	2.3	1.2	0.60	0.80	0.75	0.85	0.80	0.95	0.90	1.00	0.10	0.00
c) meridional wind, V, m s^{-1}												
0.2–0.8	1.7	2.2	0.55	0.45	0.80	0.75	0.95	0.80	1.00	1.00	0.00	0.00
0.2–1.2	2.0	2.1	0.30	0.40	0.60	0.70	0.75	0.80	0.85	0.95	0.15	0.05
0.2–1.6	1.7	2.0	0.40	0.35	0.75	0.60	0.80	0.85	1.00	0.95	0.00	0.05
0.2–2.0	1.5	2.0	0.25	0.35	0.75	0.60	1.00	0.85	1.00	0.90	0.00	0.10
0.2–4.0	2.2	2.2	0.25	0.30	0.65	0.60	0.90	0.75	1.00	0.80	0.00	0.20
0.2–6.0	2.7	1.9	0.15	0.20	0.40	0.55	0.75	0.75	0.85	0.80	0.15	0.20
0.2–8.0	2.7	2.3	0.15	0.20	0.35	0.55	0.70	0.75	0.00	0.85	0.15	0.15

Table I shows that: (1) when using optimal interpolation (or extrapolation) techniue, the objective analysis of temperature and wind velocity fields yields the best results in the near-ground (or 200 to 400-m) layer. For example, the probability of optimal interpolation (extrapolation) of near-ground temperature even with the accuracy better than ±1°C (the value comparable to standard error of radiosonde temperature measurement) is about 0.75(0.63); and (2) when using optimal interpolation, the objective analysis operates at other atmospheric levels as well but only for mean temperature ($\langle T\rangle_h$) fields (for the fields of zonal and meridional winds this analysis completely fails and thus different interpolation techniues have to be used).

The uality of the objective analysis of the mesometeorological fields, although performed by the complex of alternative techniues (optimal interpolation (extrapolation) techniue and modified MCA version) can be judged from data of Table II containing the same statistical uality estimates as Table I. Table II shows that

(a) in contrast to temperature field, application of integrated algorithm to objective analysis of wind field yields significantly better results (as compared to the optimal interpolation). Indeed, whereas the probability (P) of errors of, say, less than ± 2 m s^{-1} amounts to 0.75–0.90 for zonal and 0.60–0.80 for meridional mean winds (and for all or the majority of atmospheric layers used) by using the integrated method, the same probability of the errors of the objective analysis but now on the basis of optimal interpolation only is achieved (regardless of the component of the mean wind) for the lowermost layers, those restricted to less than 0.8–1.2 km altitudes, and

(b) the objective analysis based on the procedure of optimal combination of two alternative extrapolation techniues (optimal extrapolation and MMCA) yields much better results than the optimal extrapolation analysis does, for all considered mesometeorological fields, that is, those of temperature, zonal, and meridional winds. The admissible accuracy of the objective analysis (with less than 0.60 probability of less than ± 2 m s^{-1} errors) shows for much of the tropospheric depth (up to 4-km altitude for temperature and to 6–8 km for the mean wind velocity components).

4. CONCLUSION

The results of numerical experiments conducted on statistical estimation of the uality of objective analysis of the 3-D mesometeorological fields, by example of temperature and wind fields, allow us to draw the following, meteorologically important conclusions:

(1) objective analysis of temperature field (given that the regular grid nodes fall within the interpolation radius R as shown in Fig. 3) is recommended to be done using optimal interpolation techniue giving practically acceptable accuracy of constructing such a field, while the objective analysis of wind velocity field, meeting the same reuirements, should be carried out on the basis of an integrated algorithm including optimal interpolation techniue and MMCA since the latter is more accurate than the former;

(2) in cases when the regular grid nodes lie beyond the interpolation radius R, the objective analysis of temperature and wind fields strongly needs for application of the integrated algorithms as providing reasonably accurate spatial prediction impossible with the optimal extrapolation techniue.

In conclusion it should be noted that the results obtained reuire further verification against a more complete statistical material covering longer aerological observations and representing different mesometeorological polygons with diverse physical and geographical conditions.

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