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A REVIEW OF SOVIET PUBLICATIONS ON NUMERICAL PREDICTION FOR 1962

by

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A REVIEW OF SOVIET PUBLICATIONS ON NUMERICAL WEATHER PREDICTION FOR 1962

This memorandum contains a collection of 22 reviews or abstracts of Soviet papers in the field of numerical weather prediction. All but three of these were dated 1962. The three exceptions were obtained from a collection of papers edited by E. M. Dobryshman which was published early in 1963. Reviews of Soviet papers for 1961 are contained in NMC Technical Memorandum No. 24, "Abstracts of Recent Soviet Publications on Numerical Prediction, 1961" by John A. Brown, Jr.

For the purpose of discussing them in the following synopsis, the 22 papers will be divided into five groups consisting of:

(a) Six papers on objective analyses and data control;

(b) Three on the solution of the primitive equations;

(c) Six on other short range prognostic methods;

(d) Three on long range prognostic systems;

(e) Four on the development and/or testing of certain basic methods used in numerical forecasting.

A. OBJECTIVE ANALYSIS AND DATA CONTROL

Of the six papers under (a), only one, a paper by M. O. Krichak [16] deals with the problem of checking the raw data received from the teletype circuits. This is the first known Soviet paper on this important phase of numerical weather prediction. The details of Krichak's method are outlined in the attached review. Suffice to say that it is an extremely crude one which is probably intended only for detecting gross errors such as those introduced by hand punching the data cards.

Of the five papers on objective analyses, the most interesting was Chetverikov's [8] in which he describes a scanning system for making an optimum selection of the eight stations to be used in interpolating a value to a grid point. In the optimal interpolation system of L. S. Gandin, the computation of the set of weighting functions to be applied for each grid point involves the inversion of an 8 x 8 matrix. If the same set of eight stations could be used each time, the weights could be computed once and for all. In practice, however, the set varies, so that new weights must be computed for each new analysis. According to Chetverikov, the analysis performed by this method requires as much computing time as the forecasting method. A simpler weighting function which depends only on the distance between the grid point and the station is used by western meteorologists to make objective analyses. A similar function has also been employed by the Soviets and was tested by M. V. Kartashova [13] for the case of dense network of stations. Chetverikov [9] also tested the analyses made with the more complex system described in [8] by comparing numerical forecasts made from them as initial data versus forecasts made from initial data read off from hand analyzed charts. No significant deterioration in the forecasts due to the use of objective analyses was found.

The Soviets do not use wind data in their operational method of computing objective analyses. They are well aware of this defect but, for some reason, have not tried to correct it. A non-operational objective analysis system which uses wind data was described and tested by I. A. Petrichenko [20]. In this method, a second degree polynomial is used to approximate the height field in the vicinity of a grid point. The coefficients are determined using the observed data by the method of least squares. Petrichenko showed that the use of winds improved the analyses but made no hint that his method was intended for operational use.

Another shortcoming in the objective analysis system employed by the Soviets is the lack of any method for using the previous prognosis to influence the current analyses. This defect is especially serious for analyses in sparse data areas. The first known Soviet proposal to remedy this appeared in a 1963 paper by E. M. Dobryshman [10]. Dobryshman presents a method for introducing prognostic values into the analyses but does not mention any actual numerical experiments with it.

B. PRIMITIVE EQUATION MODELS

The most important Soviet work in numerical prediction reported in 1962, is, no doubt, that done in connection with the solution of the primitive equations. Of the three papers on this subject reviewed, the one by S. A. Bortnikov [4] is the most interesting in that he has carried out several numerical experiments. The two-level model used by Bortnikov was described in an earlier paper by Tseng Ching-tsun (Doklady Vol. 137, No. 1, 1961). By introducing several changes in the original implicit time differencing scheme, Bortnikov was able to extend the time step from 30 minutes to three hours. Statistics are given for 12 forecasts.

Two other Soviet papers dealing with the solution of the primitive equations appeared in 1962. In the one by V. M. Kadyshnikov [12], a method of estimating the vertical derivatives by a curve fitting device is described. For the solution of his transformation of the primitive equations, Kadyshnikov proposes what might be called a "quasi-implicit" difference system. There is no mention of any numerical experiments with this system.

Another method for solving the primitive equations was proposed by S. V. Nemchinov and V. P. Sadokov [19] in an English language article in Tellus. Two implicit time schemes for solving the transformed equations were found (thru linear analyses) to be unstable. An explicit method, on the other hand, was found to be stable for a half-hour time step in the case of a four-level model. No mention is made of any numerical experiments with this system which would involve considerable calculation within each time step and may not, therefore, be economically advantageous.

C. OTHER SHORT RANGE PROGNOSTIC SYSTEMS

Of the six papers in this category, the two by P. N. Belov [1] and [3] are probably the most important from an operational point of view. Belov is experimenting with various refinements to a three-level baroclinic model similar to the Dushkin-Lomonosov operational model. He takes into account the variations of the Coriolis parameter and the map scale and has also made some changes in the finite differencing scheme. Of particular interest is the fact that the solution of the vorticity equation is obtained by a relaxation method rather than by using Green's functions. Verification statistics for 22 cases of 24-hour forecasts compare favorably with that from operational numerical forecasts in the United States.

Burtsev and Vetlov [6] have devised a practical scheme for forcasting winds directly from the initial wind field. The method is based on the assumption that the geostrophic deviation of the wind can be represented by a stream function. This probably puts the method in the class of barotropic models. It is nevertheless a very interesting approach and has no known western counterpart. A quasi-Lagrangian iteration method, similar to H. Okland's (Geof. Pub., 1962) is used to perform the time integrations. Experimental forecasts were made and verified for 11 cases at 700 mb.

By assuming a constant lapse rate in the troposphere, isothermal conditions in the stratosphere and taking the troposphere at 250 mb. Gubanova, Khalikova, and Turianskaia [11], first integrate the geostrophic vorticity and thermodynamic equations in the vertical. This together with boundary conditions on the vertical motion, yields a pair of differential equations with the heights at 850 mb and 500 mb as the two unknowns. The authors state that the problem was solved on the BESM-2, but no results of any forecasts were given.

Bykov [7] proposed a method for obtaining a higher (than geostrophic) order estimate of the wind from the height field. This estimate is used in the continuity and thermodynamic equations to develop a very complicated prognostic equation. A method for solving this is outlined for the non-divergent case, but no mention is made of any actual computations. A western counterpart to this paper is the recent one by Arnason, Haltiner and Frawley*.

Thru the use of finite series, Kibel [15] showed how the differential equations of hydrodynamics can be reduced to a system of algebraic equations. No mention is made of any intentions to actually use this method.

D. LONG RANGE PROGNOSTIC SYSTEMS

Of the three papers reviewed on this subject, two were by G. P. Kurbatkin who used a two-level, geostrophic, hemispheric model to compute three-day forecasts in [17] and up to five-day forecasts in [18]. This is an extension of the work of Belousov and Blinova, 1958. The long waves were stabilized by Wolff's method in both experiments. This problem had been over-looked in earlier Soviet models. For the five-day forecasts, Kurbatkin also attempted to control the erroneously predicted northward transport of zonal momentum by smoothing the non-linear terms involved. This is an artificial scheme to compensate for the lack of a vertical transport (of momentum) mechanism in the model.

Kats, Bedrina, and Pozdniahova [14] applied empirically derived influence functions to make forecasts of sea level pressure for periods up to five days. This statistical method involves the solution of four sets of

*"Higher Order Geostrophic Wind Approximations," Monthly Weather Review, May, 1962.

regression equations, each of the 25th order. The solutions were computed on the basis of 280 cases from 1945 to 1957, using the "Pogoda" computer.

E. TESTING OF BASIC METHODS

Burtsev and Vetlov [5] tested the so-called "balance equation" by using it to compute the height field corresponding to a given wind field analyzed from wind observations. The calculated height field was then compared with the "actual" based on observed height data. The mean error for interior points of the net was 15 meters at 700 mb. In a second experiment the authors resolved the wind field into its solenoidal and potential components. The mean vector difference between the solenoidal component and the "actual" wind was found to be 3m/sec. at 700 mb. This part of the investigation is very similar to that reported by Brown and Neilon, Monthly Weather Review, March 1961.

N. G. Turianskaia [22] investigated the accuracy and stability of an implicit method for solving the barotropic vorticity equation. The method is based on an expansion of the height field "H" in terms of a polynomial in a small dimensionless quantity "ϵ". The coefficients are obtained by solving a set of Poisson equations. Using four terms only in the expansion of "H", the author shows that the truncation errors are insignificant for a time step of up to five hours. She also concludes that the method is highly stable but has the disadvantages of requiring large storage of data in the computer.

P. N. Belov [2] tested a proposed method of computing vorticity advection which might best be described as a "backward uncentered difference" scheme. This method when applied to the solution of the barotropic vorticity equation gave improved results as opposed to the usual centered difference method. Belov, however, used a "forward" time differencing scheme, rather than the usual "centered" time method.

The last paper in this group, I. G. Sitnikov [21], also deals with some experiments in the basic finite differencing methods used in numerical forecasting. He also made some experimental forecasts using approximate values of the height tendency on the boundary obtained from a local (nine point) solution to the Poisson equation.

For background to this memorandum the reader is referred to a paper by N. Phillips, W. Blumen, and O. Coté, M.I.T., "Numerical Weather Prediction in the Soviet Union", April 1960. This paper gives an excellent review of Soviet work in the field through 1959.

Articles for which full translations are available through the Foreign Area Section, Office of Climatology, USWB, are marked with asterisks in the reference list.

REFERENCES

1. BELOV, P. N. -- Numerical Forecast of Pressure at Various Levels Taking into Account Variations of the Coriolis Parameter and the Map Scale. Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 5, 1962, pp. 453-457 (English Edition).

2. BELOV, P. N. -- On the Increase in Accuracy of Numerical Forecasts by Means of an Improvement in the Method of Computing Vorticity Advection. Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 27-32.

3* BELOV, P. N. -- Results in the Experiment of Numerical Forecasting Method for 850, 500, and 200 mb Contour Charts. Meteor. i. gidrol., No. 10, 1962, pp. 12-21.

4.* BORTNIKOV, S. A. -- Experience with Short-Range Weather Prediction on the Basis of the Solution of a Full System of Thermohydrodynamic Equations. Meteor. i. gidrol., No. 11, 1962, pp. 12-19.

5.** BURTSEV, A. I. and VETLOV, I. P. -- Reconstruction of the Geopotential Field from the Wind Field and the Wind Field from the Vorticity and Divergence. Meteor. i. gidrol., No. 5, 1962, pp. 8-16.

6.** BURTSEV, A. I. and VETLOV, I. P. -- A Scheme for Forecasting Winds in the Free Atmosphere, Meteor. i. gidrol., No. 11, 1962, pp. 3-11.

7. BYKOV, V. V. -- On Taking Account of the Geostrophic Departure in Short-Range Forecasting. Bulletin (Iz vestia) Academy of Sciences, USSR, Geophysics Series, No. 3, 1962, pp. 277-279, (English Edition).

8.** CHETVERIKOV, I. A. -- An Objective Method for the Analysis of Pressure Topography Maps by an Optimal Interpolation. Trudy, Central Institute of Prognosis, Vol. 102, 1962, pp. 3-12.

9.* CHETVERIKOV, I. A. -- Operational Experimental Method of Objective Analysis of the Geopotential Field. Objective Analysis & Forecasting of Meteorological Elements (A Symposium) 1963, pp. 14-20.

10.** DOBRYSHMAN, E. M. -- Certain Problems Related to the Objective Analysis of Meteorological Information According to the Existing Network of Stations. Objective Analysis & Forecasting of Meteorological Elements (Symposium), 1963, pp. 3-13.

11.* GUBANOVA, S. I., KHALIKOVA, G. M., and TURIANSKAIA, N. G. -- On Forecasting the Geopotential in a Polytropic Atmosphere. Trudy Tsent. Inst. Prognozov, No. 102, pp. 53-59, 1962.

12. KADYSHNIKOV, V. M. -- Use of the Method of Integral Relations in Solving Complete Prognostic Equations of Meteorology. Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 8, 1962, pp. 694-699. (English Edition).

13. KARTASHOVA, M. V. -- Some Results of an Objective Analysis of a Pressure Contour Chart with a Dense Network of Stations. Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 13-19.

14. KATS, A. L., BEDRINA, V. S., POZDNIAHOVA, V. A. -- Application of Empirical Influence Functions in Forecasting Pressure Variations for 3-5 Days by Initial Single-Type Macroprocesses. Trudy Tsent. Inst. Prognozov, Vol. 119, 1962, pp. 3-23.

15. KIBEL, I. A. -- Reduction of the System Differential Equations Used Short-Range Forecasting to a System of Algebraic Equations. Doklady Akademii Nauk, USSR, Vol. 143, No. 6, 1962, pp. 1336-1339, (Translation in JPRS 14888 [Dept. of Commerce, Office of Technical Services]).

16.** KRICHAK, M. O. -- An Attempt at the Objective Checking of Initial Data in an Operational Forecast of the Geopotential Field. Objective Analysis & Forecasting of Meteorological Elements (Symposium), 1963, pp. 21-29.

17. KURBATKIN, G. P. -- Forecasting the Pressure Field at Two Levels for the Northern Hemisphere. Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 2, 1962, pp. 159-161, (English Edition).

18. KURBATKIN, G. P. -- Hemispheric Forecasts of the Pressure Field, Temperature, and Vertical Velocities for Periods up to Five Days. Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 12, 1962, pp. 1145-1154, (English Edition).

19. NEMCHINOV, S. V. and SADOKOV, V. P. -- Establishment of a Scheme Stable in Initial Data to Compute Meteorological Elements by Means of Solving Thermohydrodynamic Equations. Tellus, Vol. 14, No. 3, August 1962, pp. 253-260.

20. PETRICHENKO, I. A. -- Use of Geopotential and Wind Speed Data at Several Levels in an Objective Analysis of Pressure Contour Data. Tsent. Inst. Prognozov, No. 102, 1962, pp. 20-26.

21. SITNIKOV, I. G. -- Experiment in the Application of Finite Difference Methods of Numerical Forecasting of the Geopotential. Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 34-46.

22.* TURIANSKAIA, N. G. -- Investigations on a Prognostic Method with Implicit Finite Differences. Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 47-52.

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* Translations available from Foreign Area Section, Office of Climatology, USWB.

** Translations expected to be available from Foreign Area Section by January 1964.

BELOV, P. N.

Numerical Forecast of Pressure at Various Levels Taking Into Account Variations of the Coriolis Parameter and the Map Scale.
Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 5, 1962, pp. 453-457 (English Edition)

Three variants of the vorticity equation (combined with the thermodynamic equation) were tested using a three-level model.* In the first variant, the Coriolis parameter and map scale were considered variables wherever they occur. In the second variant, the map scale variation was neglected and the Coriolis parameter f was assumed constant except that a fixed average value for $\beta = \partial f/\partial y$ was used in the term for the advection of vorticity. In the third variant, the Coriolis parameter and map scale were considered as variables where they appear in the vorticity and temperature advection terms but not in the terms containing time derivatives. The main conclusion of the paper was that the first and third variants gave about the same results and both were significantly better than the second which is similar to the Dushkin-Lomonosov** operational model.

The data levels were at 850, 500, and 200 mbs. The lower boundary condition includes a term in the thermodynamic equation involving the vertical motion due to surface friction. Several forecasts using different values of

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*This equation is discussed by Phillips, Blumen, and Cote, 1960 (pp. 17-18).

**Belskaya, N. N., Dushkin, P. K. and Lomonosov, E. G., 1961 the frictional coefficient were made to find an optimum value corresponding to a turbulent viscosity coefficient of $16 m^2/sec$. Integration was performed by a relaxation method. By increasing the maximum allowable discrepancy in geopotential height from 0.3 meters to 1 meter, the speed of convergence was doubled with no ill effects apparent for a 24-hour forecast which takes 7-8 minutes on the URAL II machine used. The mean error of the 500 mb 24-hour height forecasts for eight test cases was 3.2 decameters corresponding to an average observed height change of 5.2 decameters.

A "forward" time differencing scheme was used with smoothing after each time step. Belov's 9-point smoothing operator while effective for cellular type irregularities has no response for 2 and 4 grid increment waves in one direction (Reviewer).

BELOV, P. N.

On the Increase in Accuracy of Numerical Forecasts by Means of an Improvement in the Method of Computing Vorticity Advection
Trudy Tsent. Inst. Prognozov, No. 102, 1962
pp. 27-32.

A new method for computing the vorticity advection is described and tested. In place of the usual finite difference Jacobian, centered at the grid point in question, a linear combination of this and a Jacobian centered in the "up-wind" quadrant is proposed. The relative weight given to the up-wind Jacobian is made proportional to the strength of the geostrophic wind. A "forward" time difference scheme is used with this method.

This method was evidently used by Belov in work reported in an earlier paper. (Trudy Tsent. Inst. Prog., No. 111, 1961) In this later paper, he tests the method on the simplest type barotropic model possible. Ten examples of 24-hour, 500 mb, prognostic charts were computed with and without the proposed improvement. Smoothing was applied after each time step for both methods. The "improved" version gave a mean error of 4.4 decameters compared to 5.9 decameters for the conventional Jacobian method. The mean algebraic error for the new method was only 1 meter whereas the conventional gave a "pillow" error of 45 meters.

It is well known that the use of forward time difference scheme with a centered distance scheme for computing the Jacobian should lead to computational instability. The use of a backward uncentered distance scheme with forward time differencing however should result in some dampening. This probably accounts for the improvements Belov obtained. (Opinions in this paragraph are Reviewers.)

BELOV, P. N.

Results in the Experiment of Numerical Forecasting Method for 850, 500, and 200 mb Contour Charts. Meteor. i. gidrol., No. 10, 1962, pp. 12-21.

This paper is a continuation of an earlier one by Belov, "Numerical Forecast of Pressure at Various Levels Taking into Account Variations of the Coriolis Parameter and the Weather Map Scale." (Bull. Izvestia No. 5, 1962). Since the first paper, he has calculated 14 more 24-hour forecasts for a total of 22 cases. The same 3-level geostrophic baroclinic forecasting model was employed. Verification results for the full set of forecasts are shown and discussed. Belov states that, pressure patterns were generally forecast to move with the correct speed. Small pressure systems, however, tended to be eliminated, probably because of the smoothing applied after each time step. In certain cases, the development of new highs and lows were predicted but most new developments were not predicted. He attributes some of these errors to the neglect of the vertical motion terms in his forecast equations.

The author comments concerning the advantages in time and effort expended of objective (machine) analyses over subjective analyses. He computed five (5) forecasts each starting with the two different analyses and shows in a table that the forecasts from the subjective analyses were slightly better than those from objective analyses. He states, however, that the differences are small and could probably be eliminated by improving the objective analysis technique (I. A. Chetverikov's)* through the use of wind data.

The forecasting model employed by Belov is similar in principle to the three-level filtered baroclinic models used by Western meteorologists. The average absolute errors in height of his forecasts compare favorably in magnitude with root mean square height errors available for comparable levels and seasons from forecast models employed operationally in the U. S. (Reviewer's opinion). The mean height error for 500 mb 24-hour forecasts was 3.4 dkm. This gave a mean relative error (error/change) of 61%.

*Trudy T. S. I. P., No. 102, 1962.

BORTNIKOV, S. A.

Experience with Short-Range Weather Prediction on the Basis of the Solution of a Full System of Thermohydrodynamic Equations.
<u>Meteor. i. gidrol</u>, No. 11, 1962, pp. 12-19.

Bortnikov describes the testing of a two-level primitive equation forecasting system which was set forth in an earlier paper by Tseng Ching-ts'un (Doklady, Vol. 137, No. 1, 1961). A 300 km mesh length in a 22 x 18 grid was used. The two levels were 700 and 300 mb.

Several changes in the implicit time integration scheme proposed by Tseng Ching-ts'un were introduced. For example, the non-linear terms were computed as a combination (?)* of their values at the beginning and the end of time step rather than by taking the value at the beginning only. In the equation for the mean height change, the non-linear terms were taken at the end of the time step instead of at the beginning as in Tseng Ching-ts'un's method. These changes imply an iterative scheme but no mention of this is made. The time integration is performed over <u>3-hour</u> time steps. A "slight" smoothing was applied at each step to the equations for determining the wind shears and the thickness of the layer. According to this report, the model performed stably out to 48 hours, which is as far as any calculations were made.

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*The author states that they were computed "partially for the initial time, partially for the time interval δt".

No mention is made of the horizontal finite-difference system used and the number of iterations required in each time step is not indicated.

An example of a successful forecast is shown with figures. Verification statistics based on 12, 24 hour forecasts are also given. The mean relative error (error/change) for the geopotential height was 77%.

BURTSEV, A. I. and VETLOV, I. P.

Reconstruction of the Geopotential Field from the Wind Field and the Wind Field from the Vorticity and Divergence
Meteor. i. gidrol., No. 5, 1962, pp. 8-16

In this paper the authors test some of the basic equations and methods commonly used in numerical weather prediction. They first tested the balance equation in the form:

$$(1)\quad \nabla^2 H = f\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) - \left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + 2\frac{\partial u}{\partial y}\ \frac{\partial v}{\partial x}\right]$$

(in which the so called "beta" term has been neglected)* and, for comparison, in the approximate form:

$$(2)\quad \nabla^2 H = f\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) = f\Omega$$

where f is the Coriolis parameter, Ω is the relative vorticity and H is the geopotential.

The wind components u and v were taken from analyses of 700 mb RAWIN reports for five observation times (1-5 February 1960). A 21 x 17 rectangular net with a grid interval of 300 km was used. Equation (1) and (2) were treated as Poisson equations and solved for H where the boundary values

*Although the neglected "beta" term is relatively small it is systematic and therefore usually retained in Western applications. For a small grid at high latitudes (where beta is small), however, its contribution is probably not significant (Reviewer).

were set equal to the actual values obtained from the 700 mb height analyses. The calculated charts of H were then compared with the "actual" ones based on observed height data. It was noted that the calculated values were too high in cyclones and too low in anticyclones, the differences amounting to as much as 5 decameters for the solution of equation (1). Mean errors for both solutions were evaluated over 117 interior grid points. For equation (1), the mean error was 15 meters compared to 19 meters for those calculated using equation (2).

In the second portion of the paper the winds are divided into a solenoidal and a potential component using the equations:

$$\nabla^2 \Psi = \Omega \quad \text{and} \quad \nabla^2 \Phi = \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) = D$$

The boundary conditions used, were

$$\Psi_B = \frac{1}{f} H \qquad \text{and} \qquad \Phi_B = 0$$

Comparisons were made of the calculated solenoidal part versus the actual wind and the differences in these were then compared with corresponding differences between the geostrophic and actual winds. In all cases, the mean vector difference (3m/sec) between the solenoidal and actual was less than the geostrophic and actual (about 3.5 m/sec.).

Finally, a comparison was made of the vector sum of the computed solenoidal and potential components versus the actual wind. The mean vector difference here was found to be about 2.62 m/sec. In general, the calculated wind fields were smoother than the actual. In regions of extreme wind speeds they were generally too weak.

The investigations reported in this second portion of the paper are quite similar to those reported by J. A. Brown and J. R. Neilon in their paper, "Case Studies of Numerical Wind Analyses", Monthly Weather Review, March 1961, which was not referenced.

BURTSEV, A. I. and VETLOV, I. P.

A Scheme for Forecasting Winds in the Free Atmosphere
Meteor. i. gidrol., No. 11, 1962, pp. 3-11.

The authors propose and test a scheme by which upper winds are forecast directly from the initial wind field. The basic method was suggested by M. I. Yudin (1957) in a paper mentioned by Phillips, Blumen and Cote (1960, pp. 23, 24). Burtsev and Vetlov have extended the method and made it adaptable for computation with an electronic computer.

The derivation of the equations begins with the equations for horizontal motion in the form:

(1) $\frac{du}{dt} = fv'$ and (2) $\frac{dv}{dt} = -fu'$

where u' and v' are the components of the geostrophic deviation.

The scheme is to find u' and v' for each time step and to assume that they remain constant during the step, so that the equations (1) and (2) can be integrated in time; once, to obtain new values for u and v, and once again to obtain the new coordinates (x, y) of a parcel which was initially at (x_0, y_0). For example:

(2) $u(t_0 + \delta t) = u(x_0, y_0, t_0) + fv' \delta t$

(3) $x(t_0 + \delta t) = x(t_0) + u(x_0, y_0, t_0) \delta t + 1/2\, fv' (\delta t)^2$

New values for u' and v' are then computed from the computed wind field for $(t + \delta t)$ and the process is repeated for the next time step, etc.

The initial and subsequent values of u' and v' are determined from the balance equation written in the form:

$$(4) \quad \nabla^2 \psi' = \frac{1}{f} \left\{ \left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + 2 \frac{\partial u}{\partial y} \frac{\partial v}{\partial x} \right\}$$

where ψ' is the stream function of $\mathbb{V}'$ which has been assumed to be non-divergent. The Poisson equation (4) is solved by the Liebman relaxation method.

An iteration method is used to find the initial points whose one hour trajectories terminated at each intersection of the 17 x 21 rectangular grid. The scheme here is similar to the quasi-Langrangian method used by H. Okland (Geofys. Publikasjoner, Jan. 1962) to integrate the barotropic forecast equation.

Experimental 24-hour forecasts were made for 11 cases at 700 mb using a URAL II electronic computer. For each case, two or three forecasts were made corresponding to: (a) initial wind field determined from observed wind data [11 forecasts], (b) initial winds taken as geostrophic using the 700 mb height field [11 forecasts] and, (c) initial winds same as in (a) but where u' and v' are assumed to be zero throughout the forecast period (5 cases). The numerical forecasts with initial winds (a) were slightly better than those made with (b). Those made under the assumption (c) gave 12% greater mean relative vector error than when u' and v' were determined at each time step from the balance equation (4).

The 11 numerical forecasts (a) were also found to be slightly better (about 4%) than those made from synoptic prognoses at the Central Forecasting Institute.

An important assumption, basic to the method, is that the motion is horizontal (or isobaric). This is implied but not emphasized. The method would probably be more applicable to forecasting the wind field on an isentropic surface under the assumption of adiabatic motion.

This interesting scheme of forecasting winds has no known counterpart in Western meteorology. The neglect of the irrotational part of the geostrophic deviation probably puts this forecasting method in the barotropic class. A comparison of wind forecasts made with this method versus a barotropic model which uses a stream function determined initially from the balance equation, would be most interesting. (The opinions expressed in the last two paragraphs are those of the Reviewers.)

BYKOV, V. V.

On Taking Account of the Geostrophic Departure in Short-Range Forecasting
Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 3, 1962, pp. 277-279, (English Edition)

A method is proposed whereby a higher order estimate of the wind than the geostrophic is obtained in terms of derivatives (up to 3rd order) of the geopotential or height field "H". This estimate is used in the continuity and thermodynamic equations which are combined to eliminate the terms involving the vertical motion. The resulting prognostic equation is a second order linear differential equation with variable coefficients for $\partial H/\partial t$ in terms of x, y, and p/p_0, the relative pressure. No method is proposed for solving this extremely complicated equation. Instead the author proceeds to the consideration of a simpler model by setting the horizontal divergence equal to zero and by neglecting terms in the expansions for the wind components which involve vertical motion. The resulting prognostic equation is a linear (with respect to $\partial H/\partial t$) second order differential equation with variable coefficients. A numerical solution is proposed and a scheme for performing the necessary computations is outlined but no mention is made of any actual numerical experiments.

The method of obtaining the higher (than geostrophic) order estimates of the wind components u and v was based on Kibel's method of expanding them in powers of a small dimensionless parameter "ϵ". Dimensionless quantities are introduced into the equation of motion, the x component, for example, of which then takes the form:

$$\epsilon \left(\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} \right) + \epsilon^2 \omega \frac{\partial u}{\partial p} = \frac{-\partial H}{\partial x} + \frac{f}{f_c} v$$

where u, v, ω, x, y, and p are non-dimensional quantities and the parameter ϵ is about 10^{-1} for a characteristic time scale of 10^5 seconds.

Substituting the series expansion of u and v (e.g. $u = u_0 + u_1 \epsilon + u_2 \epsilon^2 + ---$) into the non-dimensionalized equations of motion and grouping terms with the same power of ϵ, provides expressions for the coefficients u_0, u_1, etc.

A Western counterpart of this paper by Bykov is the one by Arnason, Haltiner, and Frawley, "Higher Order Geostrophic Wind Approximations", Monthly Weather Review, May 1962. Like Bykov, these authors derive and use a different non-geostrophic wind approximation than that obtained from the balance equation. The advantages to be derived from this substitution, however, appear doubtful. Bykov states that the barotropic vorticity equation and the balance equation require "simultaneous integration", whereas his proposed method results in a single prognostic equation. Actually, the balance equation needs to be solved only once to obtain the initial stream field. The barotropic vorticity equation is self-sufficient for integration with respect to time. (Opinions in this paragraph are Reviewer's).

CHETVERIKOV, I. A.

An Objective Method for the Analysis of Pressure Topography Maps by an Optimal Interpolation
Trudy, Central Institute of Prognosis, Vol. 102, 1962, pp. 3-12.

This is an extension of the work of L. S. Gandin (Trudy GGO, No. 114, 1960). Due to the limited capabilities of the computer being used, Gandin had assumed that the observational network was fixed and 100% reliable, so that data from the same 8 stations selected around a grid point would always be available. Under this assumption the weighting functions could be computed once and for all.

Chetverikov has devised a scanning system (suggested by A. S. Belousov) which makes an optimum selection of the eight stations to be used in interpolating a height value to a grid point. The method assures that the stations selected are both symetrically distributed about the grid point and as near as possible. In this system, however, the weighting function for each of the eight stations must be computed corresponding to each grid point each time a new analyses is made.

The solution of the resulting eight equations in eight unknowns is solved thru matrix inversion. This was evidently not a simple problem to program since much difficulty was experienced with round-off errors. The procedure must also require considerable computing time since the author states that the objective analysis by this method requires as much time as the method of numerical forecasting.

Objective 500 mb analyses by this method were made for six days in June 1959. Comparisons with hand analyzed charts were made. The results in sparse data areas were poor. Even in good data areas, the central values of highs and lows are generally smoothed out so that the lows, for example, are not analyzed as deep as they should be. This is probably due to the neglect of the available wind data which, of course, are used by an experienced analyst. The best feature of this system is the method of selecting a distribution of stations about the grid point in such a way that too many stations do not fall in the same quadrant. (The opinions in this and the following paragraph are the Reviewer's).

In the introduction to the paper, the author stated that examples of his objective analyses system "indicated the possibility of a practical application." Evidently, it was not considered an operational model at that time. In a later article by the same author he stated that "experimental operational forecasts" had been made since May 1961 using the objective analysis system described in this earlier article.

CHETVERIKOV, I. A.

Operational Experimental Method of Objective Analysis of the Geopotential Field
Objective Analysis & Forecasting of Meteorological Elements (A Symposium) 1963, pp. 14-20.

In this paper the author compares verification statistics from experimental numerical forecasts in which the initial grid data were obtained from: (a) machine computed objective analyses, on the one hand, and (b) hand analyzed charts, on the other. He also compares the analyses (a) and (b) directly for eight of the twenty cases used in the forecast verification study.

The method of objective analysis used was described in an earlier paper by Chetverikov (Trudy Tsent. Inst. Prog., No. 102, 1962). Analyses were made for 850, 500, and 300 mbs corresponding to the three levels used in the numerical forecasting model designed by S. L. Belousov (Trudy, Tsent. Inst. Prog. Vol. 126, 1962).*

Hand analyses were used as the verification standard. The results showed that the use of objective analyses gave no significant deterioration in the quality of the forecasts. The 850 mb forecasts made with the objective analyses were, if anything, slightly better. For the 500 and 300 mb forecasts, however, the mean relative error (i.e. ratio of error to change) was 2% greater for the forecasts made with the objective analyses. This tendency

*This reference was not available to the Reviewer.

may be due to the fact that the Soviets do not use wind data in their objective analyses scheme (Reviewer's opinion). The additional information contained in the wind data is more important at higher levels where the height data is both less accurate and less plentiful (Reviewer).

In the direct comparisons between objective and hand analyses, the mean absolute height differences of 1.53, 2.12, and 3.32 decameters were found corresponding to the 850, 500, and 300 mb analyses. These differences, according to the author, do not exceed the errors to be expected considering the errors in the observations themselves and the errors due to interpolation in reading off the verification data from the charts.

DOBRYSHMAN, E. M.

Certain Problems Related to the Objective Analysis of Meteorological Information According to the Existing Network of Stations
Objective Analysis and Forecasting of Meteorological Elements (Symposium), 1963, pp. 3 - 13.

In the first part of this paper the author discusses the density problem of the network of observing stations. He reasons that about 10 upper air stations per 10^6 km^2 would constitute an optimal density for numerical weather prediction purposes. He then points out that the existing world wide network falls far short of this ideal and that the stations are extremely unevenly distributed. He presents a world map showing average densities (per 10^6 km^2) for regions such as North America and Greenland (4.1), Europe (14.0), Asia (7.0), the Pacific (0.2), etc. Taking into account the fact that the network could probably be less dense in polar and equatorial regions, Dobryshman estimates that it would still be necessary to have 1400-1500 sounding stations in each hemisphere.

In the second and last part of this paper, the author discusses the problem of numerical objective analysis in the case of sparse or "empty" data regions. He proposes the idea that the previous forecast should influence the analysis in sparse data area to an extent depending mainly on the interpolation error corresponding to the distribution of observing stations about the grid point in question. He expresses this mathematically in the equation:

$$H = \bar{H} + \Sigma q_i H_i' + (1 - \Sigma q_i \mu_i) \pi$$

where H is the analyzed values

$\bar{H}$ is the normal value

q_i is the weight, according to Gandin's optimal interpolation scheme

H_i' is the observed deviation from normal

μ_i is the value of the normalized correlation function corresponding to the distance between the grid point and the "i th" station

π is the prognostic value of H

This paper by Dobryshman represents the first known attempt by Soviet meteorologists to introduce the use of prognostic values as an aid to the objective analyses in sparse data regions. Such a procedure has been in operation in Western countries for many years. No mention is made in the paper of any numerical experiments with this proposed method.

GUBANOVA, S. I., KHALIKOVA, G. M., & TURIANSKAIA, N. G.

On Forecasting the Geopotential in a Polytropic Atmosphere
Trudy Tsent. Inst. Prognozov, No. 102, pp. 53-59, 1962.

A two-parameter model with basic input levels of 850 mb and 500 mb is described along with the details of the method of solution. The derivation of the prognostic equations begins with the vorticity equation and the first law of thermodynamics under adiabatic conditions. Surface friction is introduced through the lower boundary condition on the vertical velocity. The authors state that the methods of introducing friction and of solving the equations were those of Blackburn and Gates.*

The distribution of geopotential with pressure is determined in the troposphere and stratosphere by two separate formulae relating the height variable to the input heights of 850 and 500 mbs and to the tropopause pressure. These formulae are derived by assuming a constant lapse rate in the troposphere and an isothermal stratosphere. The tropopause is taken as 250 mb.

The prognostic equations are first integrated with respect to pressure utilizing the derived distributions of geopotential. These integrations together with the boundary condition on vertical velocity result in two differential equations in two unknowns (i.e., the geopotentials at 850 and 500 mb). The corresponding difference equations are solved using the extrapolated Liebman over-relaxation technique. The time extrapolation is the usual centered

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*Journal of Met., Vol. 13, No. 1, 1956. The reference given by the authors was to "A Collection of Translated Articles," 1960.)

difference except for the initial hour where the forward difference is used.

An interesting detail of the computing scheme is that where gradients of the map factor and Coriolis parameters are needed, they were calculated by differentiating their analytical expression and then finding their values rather than differencing the values themselves. A rectangular grid of 28 x 42 = 1176 points on a polar stereographic projection was used. The mesh length was 350 km at 60° N.

No results were published in this paper. The authors merely state that the solution of the problem was performed on the "high speed" BESM-2.

KADYSHNIKOV, V. M.

Use of the Method of Integral Relations in Solving Complete Prognostic Equations of Meteorology
Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 8, 1962, pp. 694-699.
(English Edition)

In this article the author proposes a computational system for solving the primitive (hydrostatic) equations. He begins by writing the five primitive equations in the x, y, $\zeta = {}^{p}/_{P}$ (relative pressure) coordinate system. The equations of motion are then transformed so as to contain terms like $\frac{\partial uv}{\partial x}$ and $\frac{\partial v^2}{\partial y}$. For example, one of these is written:

$$\frac{\partial (u\omega)}{\partial \xi} = \frac{\partial u}{\partial t} + \frac{\partial u^2}{\partial x} - \frac{\partial uv}{\partial y} + \frac{\partial \Phi}{\partial x} - fv = F^1 \qquad \xi = (1 - \zeta)$$

This form is desired in order that the vertically differentiated quantities in these equations will vanish at p = 0. This is necessary to avoid carrying a history of the dependent variables at the top of the atmosphere. (Reviewer) The hydrostatic, continuity, and thermodynamic equations are arranged so that the vertically differentiated terms are $(1 - \xi)\Phi$, $(1 - \xi)\,\omega$ and $(1 - \xi)\omega T$ which also vanish at $p = 0$ $(\xi = 1)$.

The author next assumes that the vertical derivative of a quantity Z^i can be expressed as a polynomial in the vertical coordinate ξ. Thus,

$$(1) \quad \frac{\partial Z^i}{\partial \xi} = F^i = \sum_{k=0}^{n} a_k^i \, \xi^k$$

Integrating (1) from $\xi = 0$ to $\xi = \xi_k$, he obtains:

$$(2) \qquad Z_k^i - Z_0^i = a_0^i \xi_k + 1/2\, a_1^i \xi_k^2 + \ldots\ldots + \frac{1}{n+1} a_n^i \xi_k^{n+1}$$

where Z_0^i is the value at sea level and i = 1, 2 ...5 (i.e., one for each primitive equation).

Dividing the vertical into n layers (i.e., letting k = 1, 2 ...n), he obtains five sets of n equations (2) in (n + 1) unknowns (i.e., a_0, a_1 ...a_n). Regarding $a_0 = F_0$ as known, the a's and therefore the F's may be expressed in terms of the Z's.

The set of F_0^i 's, one for each primitive equation, are evaluated by neglecting terms of the type $\omega_0 \frac{\partial}{\partial \xi}$ in the expansion of such expressions as $\frac{\partial (u\omega)_0}{\partial z}$. The derivative $\left(\frac{\partial \omega}{\partial \xi}\right)_0$ is related to D_0 (divergence) by means of the continuity equation.

In the first part of section 2, the above scheme for estimating vertical derivatives is illustrated by applying it to a 3-level model with levels at 1000, 500, and 250 mbs. Up to this point, the author has dealt primarily with the problem of obtaining estimates of the vertical derivatives by a curve fitting device. In the rest of the paper he discusses a proposed scheme for solving his transformation of the primitive equations. In this connection he outlines what might be called a "quasi-implicit" difference system which is carried out in the following manner:

(a) The time step is first taken by estimating the non-linear terms explicitly (using values at the beginning of the time-step) and the linear terms at the end of the time step (implicitly). As part of the calculation, it is necessary to simultaneously solve a set of Helmholtz equations (one for each level) each of which involve the unknown geopotentials at the other levels.

(b) After provisionally taking the time step as above, he uses the new values obtained for the end of the step in the non-linear terms and takes the time step again. The second set of values is accepted as final.

In the third and last section, the author discusses the simultaneous solution of the set of Helmholtz equations referred to above. Certain conditions involving the vertical temperature distribution are necessary for this solution. He concludes these will always be fulfilled in practice. There is no discussion anywhere in the paper concerning the computational stability of the proposed method and no mention is made of any numerical experiments with it.

KARTASHOVA, M. V.

Some Results of an Objective Analysis of a Pressure Contour Chart with a Dense Network of Stations
Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 13-19.

The author tests a simplified version of Gandin's (Trudy, GGO, No. 114, 1960) method of optimal interpolation for computing objective analyses. In the complete method of optimal analysis the weights applied to the observations depend on the autocorrelation functions between all of the stations involved in the interpolation. For a dense network of stations, however, Kartashova assumes that the weighting coefficient can be estimated as a function of the distance "r" between the grid point and the point of observation. Her interpolation formula can then be written:

$$H = \frac{\Sigma\mu\,(r_i)\,H_i}{\Sigma\mu\,(r_i)}$$

where

$$\mu(r) = \frac{1}{1 + .066r^2} - .232 \qquad \text{(r in 100's km)}$$

The above expression for $\mu(r)$ was obtained by L. S. Gandin* by fitting a regression curve to his calculated optimal weighting functions.

To test this simplified method, ten 500 mb contour charts were

*"On the Objective Analysis of Meteorological Fields", Materials of the Conference of the Coordinating Commission of Numerical Forecast Methods, 1961.

analyzed objectively and compared with hand prepared analyses. A 20 x 24 grid with a 250 km mesh length was used. Computation of the analyses for the 480 grid points requires about 7 minutes on the BESM-2.

An overall mean deviation of 1.4 decameters was found between the objective and hand analyses. The mean of the maximum deviations for each of the 10 cases was 6.9 decameters. Two sample objective analyses and their corresponding hand analyzed charts are shown in figures 1-4. The quality of the objective analyses are judged (by the Reviewer) to be inferior to that obtained in Western countries. This is probably due mainly to the fact that wind observations are not used in this Soviet method of objective analyses (Reviewer's opinion).

KATS, A. L., BEDRINA, V. S., POZDNIAHOVA, V. A.

Application of Empirical Influence Functions in Forecasting Pressure Variations for 3-5 Days by Initial Single-Type Macroprocesses
Trudy Tsent. Inst. Prognozov, Vol. 119, 1962
pp. 3-23.

This paper is essentially a review and extension of Soviet work similar to that of Robert White and his colleagues reported earlier in the AMS Journal of Meteorology for October, 1955, and for October, 1957. The paper begins by reviewing work on hydrodynamic theory and showing that forecasts of pressure change can be expressed as the sum of the products of theoretical influence functions and the functions of the original meteorological fields such as pressure, temperature, thickness, and vorticity. In view of the difficulties of deriving the influence functions theoretically, the authors derive them empirically by applying the method of least squares to past observed data. The values thus obtained are called empirical instead of theoretical influence functions. They are equivalent to linear multiple regression coefficients derived by standard methods which the authors, nevertheless, describe in great detail.

A review is made of several Soviet papers in which the above described method has been tried since 1956 for forecasting heights at several levels from 1000 to 300 mb. In some cases the number of variables has been reduced by use of Chebyshev polynomials. It is noteworthy, however, that the Soviets have evidently never used any of the newer techniques of statistical forecasting such as screening or multiple discriminant analysis. (Reviewer)

The authors recognize the importance of considering the entire Northern Hemisphere for a long-range weather forecast and still not having too many predictors. They therefore characterize the circulation in terms of zonal and meridional indices computed separately in each of six sectors of the hemisphere, giving a total of 12 variables. In addition they compute a space mean pressure at each of 11 points from Newfoundland to Lake Baikal. This gives a total of 25 predictors which they then use in linear multiple regression equations for predicting sea level pressure at each of these 11 points for 2, 3, and 5 days in advance.

In order to introduce some non-linearity, the data is separated into winter and summer seasons and into two types of initial circulation patterns corresponding to cyclonic or anticyclonic conditions over European Russia. Four sets of regression equations of the 25th order corresponding to each of the above four categories on the basis of 280 cases from 1945 to 1957 are then computed using a high speed ("Pogoda") machine. The regression coefficients or empirical influence functions in these equations are presented in maps and tables and discussed. One of the more interesting conclusions is that seasonal differences are less important than the circulation type in the determination of the regression coefficients.

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The authors fail to present the results of any test on independent data. Such a test would be crucial to judging the success of their method since there is reason to question the stability of regression equations which contain as many as 25 terms.

KIBEL, I. A.

Reduction of the System Differential Equations Used for Short-Range Forecasting to a System of Algebraic Equations
Doklady Akademii Nauk, USSR, Vol. 143, No. 6, 1962, pp. 1336-1339.

This is a theoretical paper which outlines the approximations and mathematical procedures involved in making the reduction indicated by the title. The author begins by defining a three-dimensional grid in x, y, and ζ (where $\zeta = p/p_0$). He then proposes to approximate meteorological functions as "terminal sums" (finite series) of the form:

$$F(x, y, p, t) = \sum_{m=0}^{p} \sum_{n=0}^{q} \sum_{s=0}^{h} \bar{F}(t) \left(\frac{x}{L_1}\right)^m \left(\frac{y}{L_2}\right)^n \zeta^s$$

where p, q, and h correspond to the (p + 1) by (q + 1) by (h + 1), three-dimensional grid, L_1 and L_2 are the horizontal dimensions of the grid, and the values of $\bar{\bar{F}}(t)$ are determined so that the sums will fit the values of F(x, y, p, t) at each grid point. It is assumed that not only the wind components u and v, but also their derivatives, can be expressed as terminal sums of the above form. With these assumptions and some complex mathematics, Kibel is able to write the two horizontal equations of motion, the continuity equation and the thermodynamic equation as a system of p x q x h equations each in the form of the sum of three finite series (one for each dimension).

He next assumes that any of the functions of time needed can be approximated in the form of a polynomial as follows:

$$f(t) = f(0) + \sum_{\lambda=1}^{\theta} \bar{f}_{\lambda} \left(\frac{t}{T}\right)^{\lambda} ,$$

where θ is the number of time steps in the forecast period T.

With this device the four basic equations which had been placed in the form of finite series can be integrated with time to obtain a system of algebraic equations for the determination of u, v, $\omega = {}^{dp}/_{dt}$ and Φ (the geo-potential) provided these fields are known initially. It is pointed out that the equation of continuity in its terminal sum form must be satisfied initially as well as at any time; thus, providing a means for determining the initial field of ω.

The system of derived equations are very complex and lengthy. Many serious problems would undoubtedly arise if one were to actually try to apply them. Kibel, however, gives no hint that he considers the method a practical numerical forecasting scheme. The paper is probably intended mainly to show that the reduction is theoretically possible.

KRICHAK, M. O.

An Attempt at the Objective Checking of Initial Data in an Operational Forecast of the Geopotential Field
Objective Analysis and Forecasting of Meteorological Elements (Symposium), 1963, pp. 21-29.

The author describes a proposed method for automatically checking the reported radiosonde data used in making numerical objective analyses. It is significant that the only references given to previous work in this area were to Bedient and Cressman (1957) and to Cressman (1959).

The author begins by pointing out that the checking system described by Bedient and Cressman would require handling large amounts of data which would not otherwise be used in the Soviet operational forecast model.

In the system proposed by Krichak the only data used are the 850, 500, and 300 mb heights. These heights are combined to obtain three parameters, i. e., the mean temperatures of the 850 - 500 mb and the 500 - 300 mb layers and the lapse rate (γ) corresponding to the difference between these two mean temperatures.

For each of these three parameters, the means and extremes for all stations are determined. The assumption is then made that, for correct data, the difference between maximum positive and negative departures should fall within certain limits (i. e. the departures should be distributed symetrically). In the case of γ, for example, the difference between the maximum departures is given by:

$$(1) \quad \delta_\gamma = \left| (\gamma_{max} - \bar{\gamma}) - (\bar{\gamma} - \gamma_{min}) \right|$$

If the prescribed limit for any of the parameters δ is exceeded, the data is assumed to be erroneous. For example if $(\bar{\gamma} - \gamma_{min})$ exceeds $(\gamma_{max} - \bar{\gamma})$ by more than 1.5° per km, the data which yielded the minimum lapse rate, in this case, would be discarded. The limits for δ_γ and $\delta_{\bar{T}}$ were originally determined from climatological data. By experimenting with a range of values and noting whether or not each rejection was justified, it is possible to establish optimum values for these limits. On this basis the value of δ_γ was lowered to 0.8°/km and $\delta_{\bar{T}}$ was raised to 10°C. Use is also made of the fact that an error in one of the two mean temperatures will cause an error in the lapse rate. Thus, any station which exhibits both an extreme in lapse rate and either of the two mean temperatures is assumed to be in error.

When a stations is rejected, another one moves to the head of the list as having an extreme value. New differences between maximum departures are then computed and the process is repeated. The cycling is continued until none of the critical values δ are exceeded and no station represents an extreme in both $\bar{T}$ and γ.

The author mentions that many of the errors detected are due to incorrect punching of the data. In the United States, the teletype punched tape is fed directly into a computer which transfers the data to magnetic tape. No hand punching is involved. Evidently, the Soviets do not have such a system.

This would explain why they do not want to handle any more than the minimum amount of data required for their operational forecast model and have, therefore, resorted to this crude method which is evidently intended only for detecting gross errors such as those due to incorrect punching.

KURBATKIN, G. P.

Forecasting the Pressure Field at Two Levels for the Northern Hemisphere
Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 2, 1962, pp. 159-161, (English Edition)

The author describes a two-level model which is used to make hemispheric forecasts for periods up to three days. The model is one in which the divergence terms cancel when the vorticity equations for the two-levels (700 and 300 mbs) are added. A second equation is obtained by subtracting the vorticity equations and eliminating a term involving the vertical velocity at 500 mb thru the thermodynamic equation. The equations are written with reference to spherical coordinates and data is obtained at intervals of 5° latitude and 10° longitude.

The space derivatives were computed as in the work of Blinova and Beloussov (1958)*. Horizontal derivatives were taken over an interval of 555 km and the time step was four hours. The two equations (a Poisson and a Helmholtz) were solved using two dimensional Green's functions for the sphere. The stream function was replaced by the isobaric height times $g/\bar{f}$, where $\bar{f}$ is a mean value of the Coriolis parameter. This procedure seems highly questionable considering the fact that the grid extends from the pole

*This method is described by Phillips, Blumen, and Coté, 1960, pp. 36-37.

to 10° of latitude. The author makes no excuses for it, but is careful to verify the forecasts only from 20° to 65° latitude. (Reviewer)

Verification statistics are presented based on four forecasts made with and without long wave stabilization using P. Wolff's method. Both methods gave poor results but the forecasts with long wave stabilization (especially the two and three day forecasts) were definitely better than those without stabilization. The large grid interval and long time step used is no doubt partly responsible for the poor verification scores. Substitution of the height for the stream function, however, must also have had serious consequences which could have easily been avoided. (The opinions in this paragraph are the Reviewer's.)

KURBATKIN, G. P.

Hemispheric Forecasts of the Pressure Field, Temperature and Vertical Velocities for Periods Up to Five Days
Bulletin (Izvestia) Academy of Sciences, USSR, Geophysics Series, No. 12, 1962, pp. 1145-1154, (English Edition)

This paper represents an extension of a previous study by Kurbatkin in which he investigated the behavior of a two-level model based on the geostrophic system of equations. (Bulletin (Izvestia) A/S Geophysics Series, No. 2, 1962) In the previous paper, Kurbatkin concerned himself with forecasts up to three days. In the present paper he deals with problems encountered when the forecast period is extended to five days.

The vorticity and thermodynamic equations are expressed in terms of spherical coordinates and solved by means of appropriate Green's functions following Blinova (1956) and Blinova and Belousov (1958). The levels used were 700 and 300 mb. The long waves were stabilized by Wolff's method.

The primary difficulties encountered by Kurbatkin in the longer range forecasts are problems which have been studied extensively by Western meteorologists, namely, the accumulation of angular momentum in middle latitudes and the erroneous retrogression of long waves. The first problem is characteristic of models which do not include frictional effects together with vertical transport of momentum through turbulent motions. Kurbatkin does not attempt to correct the problem by introducing these effects into his model. Instead, he artificially reduces the northward flux of momentum by smoothing the non-linear terms which are involved in the process. In doing this, he is supressing a natural occurrence which may be important in bringing about local changes in the zonal circulation. Kurbatkin is aware of this and therefore regards the method as a "tentative approximation".

From a verification point of view, the two examples of five-day forecasts shown by Kurbatkin do not seem too impressive. (Reviewer's opinion) There is a tendency for excessive anticyclogenesis at low latitudes, and several important areas where troughs are predicted in regions where ridges are observed and vice-verse. Verification statistics, based on five experimental forecasts, were given only in terms of relative-errors (presumably the ratio of error to change). These decreased at 700 mb from about 100% for a one-day forecast to about 70% for a five-day forecast.

NEMCHINOV, S. V. and SADOKOV, V. P.

Establishment of a Scheme Stable in Initial Data to Compute Meteorological Elements by Means of Solving Thermohydrodynamic Equations
Tellus, Vol. 14, No. 3, August 1962, pp. 253-260.

The authors develop a scheme for solving the primitive equations which is theoretically stable for a 30-minute time step corresponding to a 250 km mesh length. In this scheme, the horizontal equations of motion are integrated in time analytically over the time step to obtain u and v components (wind) as functions of time (1. 3)*. This is done by assuming that the non-linear (advective) and pressure force terms can be considered invariant during the time step interval. From the analytic expressions thus derived for the wind components, the authors obtain the horizontal divergence as a function of time. Substituting this into the continuity equation yields an expression for the vertical motion which is then substituted into the thermodynamic equation to obtain a differential equation in which the geopotential is given as a function of time (1. 7). This equation involves a vertical integration which is represented and transformed through the use of matrices.

As a result of the above transformations and integrations within the time step, the authors arrive at a system of four equations (2. 1) consisting

*Since Tellus is readily available in the United States, only the equation numbers will be given in this review.

of the two equations of motion (involving analytic time integration) the thermodynamic equation (transformed as described above) and finally, the continuity equation in the form of an integral expression for the vertical motion. Three methods of solving this system are proposed. The two implicit methods, in which the pressure force (for example) in the equations of motion would be calculated from values at the end of the time step, were found, thru linear analyses, to be unstable. The explicit method, in which values at the beginning of the time are used, was found to be computationally stable and also to have a less stringent instability criteria (time step relative to mesh length) than the Courant, Friedrichs, Lewy criteria for the usual centered time and space differencing system. Thus, for a four-level model with a 250 km mesh length, a time interval $\Delta t = 1939$ secs is theoretically stable under this system.

The CFL criteria for the usual system with the same mesh length on the other hand, would require Δt to be less than 850 secs. In view of the fact that the calculations to be carried out per time step are more complicated than in the usual primitive equation system, the economic advantages of the shorter time step required in this method are doubtful. No mention is made of any plans to carry out actual computations using this system. (Opinions expressed in this paragraph are the Reviewer's.)

PETRICHENKO, I. A.

Use of Geopotential and Wind Speed Data at Several Levels in an Objective Analysis of Pressure Contour Data
Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 20-26.

This work is an extension of that reported in an earlier paper by Petrichenko and Kartashova (Trudy Tsent. Inst. Prognozov, No. 111, 1961). The author describes and tests an objective analyses scheme in which the geopotential field in the vicinity of a point is approximated by a second degree polynomial in x, y and p (pressure). The coefficients are determined by the method of least squares. In the earlier paper, height data only for the three-levels 850, 700, and 500 mbs were used from six stations surrounding the point. In this newer work, the author extends the method by using wind data from the three levels in addition to the height data. Data from eight surrounding stations were used in determining the required coefficients of the polynomial by minimizing the expression:

$$F = \frac{1}{\sigma_H} \Sigma (H - H_{ob})^2 + \frac{1}{\sigma_W} \Sigma [(u - u_{ob})^2 + (v - v_{ob})^2]$$

where H is the analyzed (or computed) height,

H_{ob} are the observed height values,

u and v are the analyzed geostrophic wind components,

and u_{ob} and v_{ob} are the observed actual wind components.

The author followed Gilchrist and Cressman (1954) in taking the ratio $\sigma_H / \sigma_W = 3$. The method requires the solution of a system of ten equations in ten unknowns. Only three of the unknowns need to be determined, however, for the grid point where $x = y = o$. Each determination of a single height involves 72 predictors corresponding to eight stations, three levels, and the three observed quantities H, u and v. The author exhibits the 72 term expression used for determining the height at 500 mb for a single grid point. He also presents the corresponding 24-term expression involving only the heights at three levels for eight stations as predictors. Computations based on daily data for January and June 1959 were made using the geopotential plus winds method, on the one hand, and the geopotential only, on the other. The results showed that the introduction of wind data generally lowers both the maximum and the mean errors. The maximum errors for all three levels were lowered for both months. The mean error at 700 mb, however, was not affected for either month. The author did not comment on this curious fact.

The method of fitting polynomials to obtain objective analyses was abandoned years ago by Western meteorologists. The scheme described here is obviously impractical for operational use. The paper is significant, however, in that it is the first known attempt by Soviet meteorologists to use wind data in their objective analyses.

SITNIKOV, I. G.

Experiment in the Application of Finite Difference Methods of Numerical Forecasting of the Geopotential
Trudy Tsent. Inst. Prognozov, No. 102, 1962,
pp. 34-46.

In this paper, the author compares the results of using finite difference techniques and boundary specifications to solve the geostrophic barotropic vorticity equation:

$$(1) \quad \nabla^2 \left(\frac{\partial H}{\partial t}\right) = -\frac{g}{f} J(H, \nabla^2 H) - \beta \frac{\partial H}{\partial x}$$

The extrapolated Liebman (relaxation) method is used to solve the Poisson equation (1). The author states that the initial data were taken from a map containing 30 x 26 grid points with a mesh length of 300 km. Later in describing the differencing method used, he shows a diagram with a 250 km mesh length. Still later he introduced $\delta s = 300$ km as an "improvement", over the original interval of 250 km. (This paper falls well below the average quality of other Soviet articles in the field in both content and presentation.)

Experimental forecasts were made by varying the space interval used in computing the Laplacians which occur on either side of equation (1). In the first variant the interval was taken as $\sqrt{2}\delta s$ for both sides. In the second variant, only the interval for the Laplacian on the right hand side was increased to double the mesh length which was also the interval for the Jacobian in both variants. According to the author, the first variant was unstable whereas the second, "as a rule" was not. The reviewer suspects that the observed instability may have been caused by either a too long time step or by the forward time differencing system*.

A further reduction in the instability was obtained by decreasing the time step from 1-1/2 hours to 45 minutes indicating that it was probably due to the CFL effect (Reviewer's opinion). The author did not specify the type of time differencing system used in the experiments with various space intervals. Later, however, he mentions as another improvement "introduced by us", the use of a centered time difference scheme in place of the "forward" method.

Sitnikov also experimented with the use of a nine point or "local" solution of the Poisson equation to obtain approximate values of $\partial H/\partial t$ near the boundary for the initial time. This approximate method of solving Poisson's equation was discussed by Phillips, Blumen, and Coté, 1960, (pp. 32-34). Two variants of this type of boundary specification were tried. In the first, the values of $\partial H/\partial t$ obtained by the nine-point method were held constant throughout the forecast period. In the second they were gradually reduced after each time step so that by 12 hours they would be equal to zero. With the first

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*The use of different space intervals for computing ∇^2, as in the second variant, probably damped this instability which could have been avoided in the first place. Western experience has shown that the second variant should give inferior results provided the proper time step and differencing methods are used (Reviewer).

variant, considerable distortion and noise waves often occurred near the boundary. Presumably these did not occur in the second variant. In "most instances" the use of the non-zero condition on the boundary improved the quality of the forecast. An example of a forecast made with and without zero conditions on the boundary is illustrated with charts. Neither forecast is very impressive (Reviewer's opinion). The disappearance of two lows in western Europe in the case of forecast with non-zero conditions was attributed to "excessive smoothing" for this case. The case with zero boundary conditions and less smoothing retained the lows but failed to forecast a low in the Norwegian sea.

TURIANSKAIA, N. G.

Investigations on a Prognostic Method with Implicit Finite Differences
Trudy Tsent. Inst. Prognozov, No. 102, 1962, pp. 47-52.

The author investigates the accuracy and stability of a numerical solution of the barotropic vorticity equation. The method which was originally developed by V. P. Sadokov (Doklady, Vol. 134, No. 3, 1960) is something as follows:

Consider the following implicit form of the barotropic equation*:

$$(1) \quad \nabla^2 H_{\tau+1} + \epsilon J\,(H_{\tau+1}, \nabla^2 H_{\tau+1}) = \nabla^2 H_\tau - \epsilon J(H_\tau, \nabla^2 H_\tau)$$

where $\epsilon = \dfrac{g\,(\Delta\tau)\,\Delta H}{2fL^2}$

In this equation, dimensionless quantities have been introduced. For example, ΔH is the characteristic variation of geopotential height over the distance L, the mesh length. ($\Delta\tau$ is the time step interval and f, the Coriolis parameter.)

For the choice of parameters the author uses, ϵ is less than 1, provided $\Delta\tau$ is less than eight hours. A solution in the form:

$$(2) \quad H_{\tau+1} = H_0 + \epsilon H_1 + \epsilon^2 H_2 + \cdots + \epsilon^n H_n \qquad (\epsilon < 1)$$

is sought. Introducing (2) in (1), and grouping together terms of the same

*The derivation in the paper included the β - term which has been omitted here for simplicity.

126 551

power in ε, the following set of Poisson equations for the unknown fields H_n, is obtained:

$$(3) \quad \nabla^2 H_0 = \nabla^2 H_\tau \qquad \text{(i.e., } H_0 = H_\tau\text{)}$$

$$\nabla^2 H_1 = -2J(H_0, \nabla^2 H_0)$$

$$\nabla^2 H_n = -\sum_{k=0}^{n-1} J(H_k, \nabla^2 H_{n-1-k})$$

The author then proceeds to discuss the solution for a sinusoidal wave disturbance superimposed upon a uniform flow. She already knows the exact solution for this case, and is also able to derive an analytic solution of (2) and (3). For $\Delta\tau$ equal to <u>four-five</u> hours, and with four terms in (2), the truncation errors are shown to be insignificant.

Also presented are the results of a test computation using the same sinusoidal initial conditions but in which a finite difference scheme is used for solving the Poisson equations. The results are compared to the exact solution and also to a solution with only two terms in equation (2).

The author concludes that the advantage of the method is high stability and small truncation errors. The disadvantages are that much data have to be stored in the computer.