Mausam, (1982), **33**, 3, 351-354

551.509.311

12-hour forecasting of horizontal wind components

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(*Received 30 January 1981*)

सार — भ्रमिलता और अपसरण समीकरणों का उपयोग करके 12 घंटों के लिए पवन के क्षैतिज घटकों को ज्ञात किया गया है। इस प्रयोग को 30° और 50° उत्तर अक्षांशों के बीच किया गया है। पूर्वमानित मानों की उनसे संबंधित वास्तविक मानों से तुलना की गई है और ये मान सुझाई गई विधि सत्यापित करते हैं।

ABSTRACT. The horizontal wind components were predicted for 12 hours, using the vorticity and divergence equations. The experiment was carried out in between the latitudes 30 deg. and 50 deg. N. The predicted values were compared with their corresponding ones verifying the suggested method.

1. Introduction

The problem of horizontal wind components forecasting has a special importance because of its necessary for diagnostic study of synoptic stimulations, where the change in pressure, temperature, wind and vertical velocity fields are closely related in each other. There are different numerical models for the prediction by horizontal wind components, they characterize by the physical modelling, the boundary conditions and the method of integration. One of the familiar models for the horizontal wind prediction is the use of concept of an ageostrophic scheme introduced by Burstov (1969). The local variation of horizontal wind components estimated by the formulae:

$$\frac{\partial u}{\partial t} = -\left(u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y}\right) + f v',$$

$$\frac{\partial v}{\partial t} = -\left(u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y}\right) - f u' \quad (1)$$

where, u', v' are ageostrophic wind components. Here the terms $\partial u/\partial p$ and $\partial v/\partial p$ are omitted, these terms express the effect of thermal structure of the atmosphere and the vertical velocity component. Gubin (1965) suggested new varian of the horizontal wind forecasting by the aid of the equations :

$$u = -\frac{1}{2\pi} \iint_{-\infty}^{\infty} \ln \frac{1}{r} \left(\frac{\partial D}{\partial x'} - \frac{\partial \Omega}{\partial y'} \right) dx' \, dy',$$

$$v = -\frac{1}{2\pi} \iint_{-\infty}^{\infty} \ln \frac{1}{r} \left(\frac{\partial D}{\partial y'} + \frac{\partial \Omega}{\partial x'} \right) dx' \, dy' \quad (2)$$

where, $\quad r^2 = (x - x')^2 + (y - y')^2$

In the present work we are dealing to estimate the horizontal components (u and v) from the vorticity and divergence equations using numerical schemes.

2. The governing equations

The vorticity and divergence equations can be written in complete form as :

$$\frac{\partial \Omega}{\partial t} = -A_{\Omega} - \tau \frac{\partial \Omega}{\partial p} - \frac{\partial \tau}{\partial x}\frac{\partial v}{\partial p} + \frac{\partial \tau}{\partial y}\frac{\partial u}{\partial p} - \Omega_a D - v\beta \quad (3)$$

$$\frac{\partial D}{\partial t} = -A_D - \tau \frac{\partial D}{\partial p} - \left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2\right] - 2\frac{\partial u}{\partial y}\frac{\partial v}{\partial x} - \left(\frac{\partial \tau}{\partial x}\frac{\partial u}{\partial p} + \frac{\partial \tau}{\partial y}\frac{\partial v}{\partial p}\right) + (f\,\Omega_{ag} - u\,\beta) \quad (4)$$

where,

$\Omega = \dfrac{\partial v}{\partial x} - \dfrac{\partial u}{\partial y}$ is the relative vorticity

$D = \dfrac{\partial u}{\partial x} + \dfrac{\partial v}{\partial y}$ is the horizontal divergence

$\Omega_a = \Omega + f$ is the absolute vorticity

$= \partial f/\partial y$ is the Rossby parameter

τ is the vertical vorticity

$A_\Omega = u\dfrac{\partial\Omega}{\partial x} + v\dfrac{\partial\Omega}{\partial y}$ is the vorticity advection

$$\Omega_{ag} = \frac{1}{f}\left[\frac{dD}{dt} + \left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \right.$$

$+ 2\left.\left(\dfrac{\partial v}{\partial x}\,\dfrac{\partial u}{\partial y}\right)\right]$ is the ageostrophic vorticity

$A_D = u\,\dfrac{\partial D}{\partial x} + v\,\dfrac{\partial D}{\partial y}$ is the divergence advection

From the definition of vorticity and divergence fields, it is easy to estimate the equations :

$$\nabla u = \frac{\partial D}{\partial x} - \frac{\partial\Omega}{\partial y},$$

$$\nabla v = \frac{\partial D}{\partial y} + \frac{\partial\Omega}{\partial x} \qquad (5)$$

where, $\nabla = \dfrac{\partial^2}{\partial x^2} + \dfrac{\partial^2}{\partial y^2}$

Eqns. (3) and (4) can be expressed as :

$$\frac{\partial\Omega}{\partial t} = A^t \text{ and } \frac{\partial D}{\partial t} = B^t \qquad (6)$$

where A^t and B^t the right hand side of Eqns. (3) and (4) which contain terms independent upon time. Using the Adams integration scheme we can compute the terms Ω and D after time step $\triangle t$ by the following way :

$$\Omega_{t+\triangle t} = \Omega_t + \left(\frac{3}{2}A^t - \frac{1}{2}A^{t-\triangle t}\right)\triangle t$$

$$D_{t+\triangle t} = D_t + \left(\frac{3}{2}B^t - \frac{1}{2}B^{t-\triangle t}\right)\triangle t$$

The vertical motion τ, evaluated as shown in (2) by the aid of the following expression :

$$\tau_p = -\frac{1}{e^{\bar{x}\,\triangle p}}\left[\int_{p_0}^{p} K\,e^{x\,\triangle p}\,dp - \tau_0\right] \qquad (7)$$

where, $\bar{x} = -\dfrac{c_v\,g}{c_p\,R}\,\dfrac{1}{\bar{T}}$

$$K = D - \frac{Q}{c_p\,T}$$

$T, \bar{T}$ are the temperature and mean layer temperature at any grid point

D is the horizontal divergence

Q nonadiabatic effects

g is the acceleration due to gravity.

R is the constant of air.

c_p is the specific heat at constant pressure

c_v is the specific heat at constant volume

3. Method of computations

System of Eqn. (5) having the representation of Poisson type can be solved by Liembann relaxation method :

$$R^{\nu+1}_{i,j} = X_{i,j+1} + X^{\nu+1}_{i,j-1} + X_{i+1,j} + X^{\nu+1}_{i-1,j}$$
$$- 4X^{\nu}_{i,j} - (\triangle S)^2 \times F_{ij}$$

and

$$X^{\nu+1}_{i,j} = X^{\nu}_{i,j} + \alpha R^{\nu+1}_{i,j}$$

The coefficient α had been chosen at different levels as shown in Eqn. (3) which can give a rapid convergence.

$\alpha_{700} = .258$, $\alpha_{500} = .237$, $\alpha_{300} = .241$.

As a mathematical consequence of the existence of several types of wave families, the initial data were the horizontal wind field and geopotential heights. The terms A and B computed at time interval $t-\triangle t$ and t, using the central finite difference on horizontal and vertical coodinates. Then using the above difference scheme we can have Ω and D at time $t+\triangle t$. The predicted values of D and Ω can be smoothed by the formula :

$$(X)_{ij} = \cdot 904\,X_{ij} + .016\,(X_{i,j+1} + X_{i+1,j} +$$
$$+ X_{i-1,j} + X_{i+1,j}) + \cdot 008\,(X_{i-1,j+1} +$$
$$+ X_{i-1,j-1} + X_{i+1,j-1} + X_{i+1,j+1})$$

where X denotes D or Ω

The process of smoothing is carried out after every time step prediction of D and Ω. The resulting values of D and Ω, must be taken as initial data in the right hand side of Eqn. (5).

4. Results and discussion

The results of this experiments, are the horizontal wind components at 700, 500 and 300 mb after 12 hours. The initial wind field components are shown in Figs. 1 (a) & (b). Figs. 2 (a) & (b) show the predicted values of u and v components at 500 mb and Figs. 3 (a) & (b) show the actual wind field in the same day.

Correlation coefficient between the predicted deviation and the actual deviation about the initial values at the same time interval :

$$\frac{\sum_{i=1}^{N}\left(\partial v_{pr}\right)_i^1\left(\partial v_{act}\right)_i^1}{N\,\sigma_{pr}\,\sigma_{act}}$$

where,

$\partial v_{pr} = v_{pr} - v_{in}$ $\qquad \partial v_{act} = v_{act} - v_{in}$

$(v_{pr})_i = (v_{pr})_i - \partial\bar{v}_{in}$ $\quad (\partial v_{act})_i' = (\partial\bar{v}_{in})_i - \partial\bar{v}_{in}$

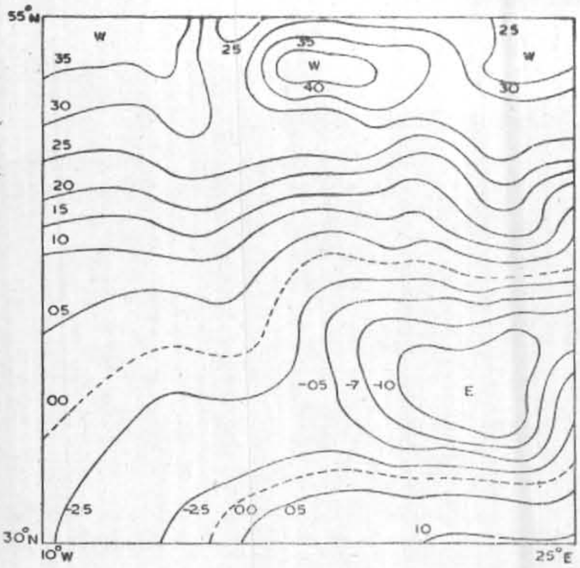

Fig. 1 (a). The initial zonal component of horizontal wind field at 500 mb on 00 U.T. of day 23 March 1967

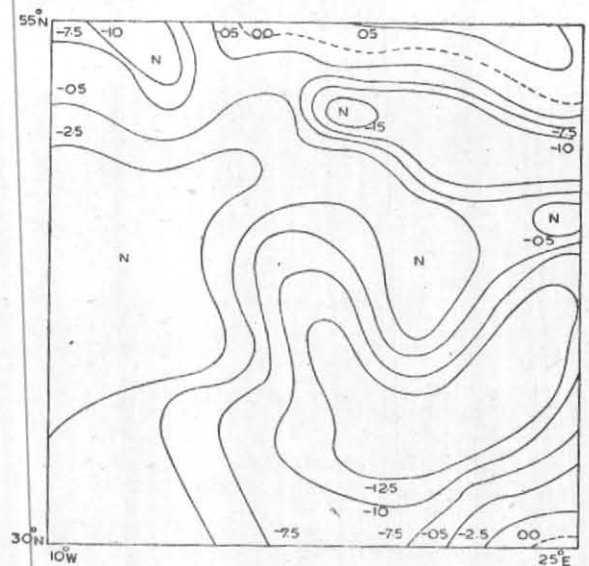

Fig. 1 (b). The initial meridional component of horizontal wind field at 500 mb on 00 U.T. of day 23 March 1967

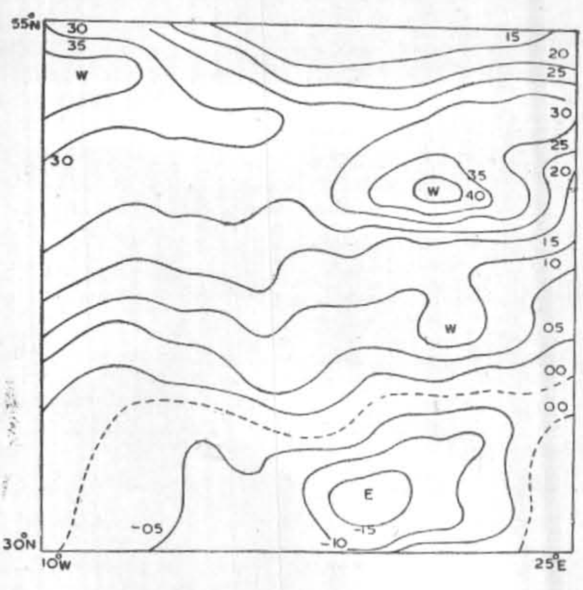

Fig. 2 (a). The predicted zonal component of horizontal wind field at 500 mb on 1200 U.T. of day 23 March 1967

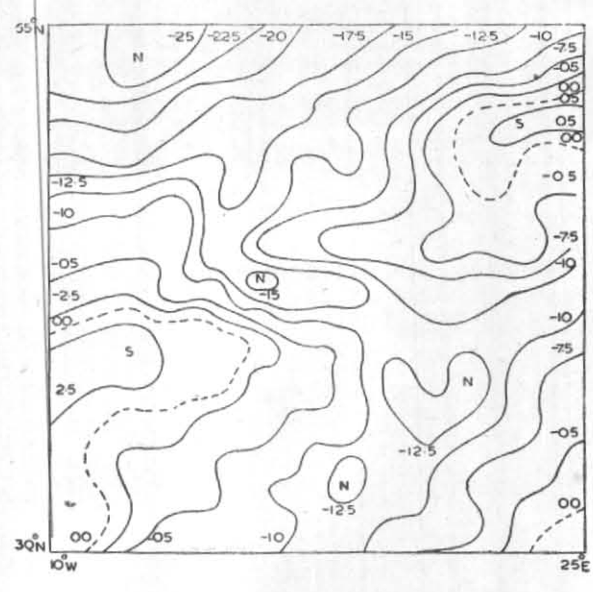

Fig. 2 (b). The predicted meridional of horizontal wind field at 500 mb on 1200 U.T. of day 23 March 1967

TABLE 1

Standard level (mb)	*R*
700	.79
500	.87
300	.74

σ_{pr} and σ_{act} are the standard deviation for the predicted and actual values respectively.

It is clear from Table 1 that the correlation factor reaches its maximum value at 500 mb level.

The kinetic energy distribution estimated from the predicted wind components at every time integration is shown in Fig. 4.

The proposed model gives a good enough result as by verification by statistical methods and by the energy conservation behaviour. As shown above that the respective disagreement occurs only on 300 mb probably for the occurrence of high wind speed which cannot be predicted by this model. Some improvements in the method of computation and by taking into consideration some mathematical and dynamical factors and initial data problem, surely will give the expected results at the 300 mb level.

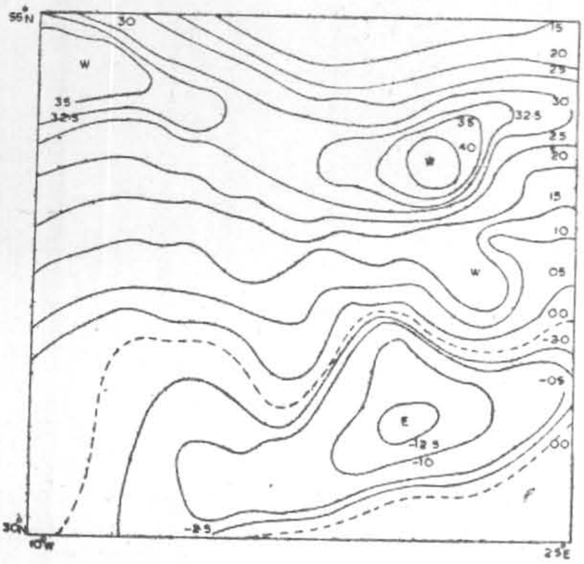

Fig. 3 (a). The actual zonal component of horizontal wind field at 500 mb on 1200 U.T. of day 23 March 1967

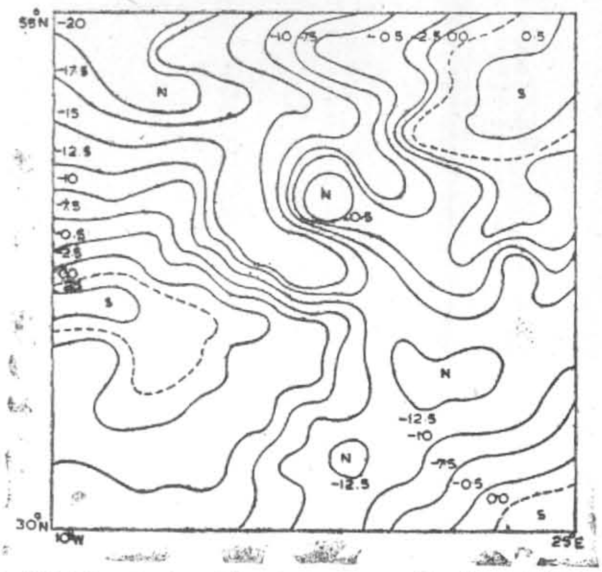

Fig. 3 (b). The actual meridional component of horizontal wind field at 500 mb on 1200 U.T. of day 23 march 1967

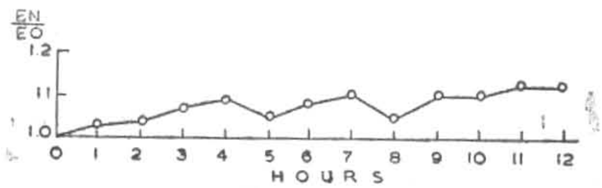

Fig. 4. Kinetic energy variation through the period of forecasting

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