ON THE LONG-RANGE FORECAST OF ANOMALIES OF THE VERTICAL VELOCITIES OF AIR MOTION OVER THE NORTHERN HEMISPHERE OF THE EARTH

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Abstract

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ON THE LONG-RANGE FORECAST OF ANOMALIES OF THE VERTICAL VELOCITIES OF AIR MOTION OVER THE NORTHERN HEMISPHERE OF THE EARTH

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The problem of the long-range forecast of vertical currents was posed by E. N. Blinova and was considered in papers ([1–3]). In paper ([4]) it was shown how modern aerological data, and in particular the data of the International Geophysical Year, can be used to refine the hydrodynamic long-range forecast of mean monthly temperature anomalies over the Northern Hemisphere of the Earth. In the present work a method is proposed for the hydrodynamic long-range forecast (using modern aerological data) of mean monthly anomalies of vertical currents for the entire Northern Hemisphere of the Earth.

Vertical velocities may be determined from the approximate formula ([5])

$$2\omega a_0^2 \rho v_z \cos\theta = \int_0^z \left[\frac{\partial \Delta\psi}{\partial t} + \frac{1}{a_0^2 \sin\theta} (\psi, \Delta\psi) + 2\omega \frac{\partial \psi}{\partial \lambda} \right] \tilde{\rho}\, dz; \tag{1}$$

λ is the longitude of the place; θ is the colatitude; z is the height above sea level; t is time; ψ is the stream function; a_0 is the mean radius of the Earth; ω is the angular velocity of rotation of the Earth; $\tilde{\rho}$ is the standard density (a function of z alone);

$$\Delta = \frac{1}{\sin\theta} \frac{\partial}{\partial\theta} \left(\sin\theta \frac{\partial}{\partial\theta} \right) + \frac{1}{\sin^2\theta} \frac{\partial^2}{\partial\lambda^2}; \qquad (\psi, \Delta\psi) \equiv \frac{\partial\psi}{\partial\theta} \frac{\partial\Delta\psi}{\partial\lambda} - \frac{\partial\psi}{\partial\lambda} \frac{\partial\Delta\psi}{\partial\theta}.$$

In turn, ψ can be approximately determined through ψ_{cp}—the stream function at the mean level z_{cp}—and through the temperature T by the formula

$$\psi = \frac{g}{2\omega T_1} \int_{|z_{\text{cp}}|}^{z} \tau\, dz + \psi_{\text{cp}}, \tag{2}$$

Fig. 2

Figure 1: Fig. 2

where g is the acceleration of gravity; T_1 is the standard temperature; $T = \tau\cos\theta$. Thus, to determine v_z, it is necessary to know two functions: $\psi_{\text{cp}}(\theta,\lambda,t)$ and $\tau(z,\theta,\lambda,t)$.

We shall consider atmospheric motions as small perturbations superposed on the west-east transfer; for the stream function $\bar{\psi}$ of the west-east transfer we have $\bar{\psi} = -a(z)a_0^2\cos\theta$, where $a(z)$ is a height-dependent "circulation index."

Linearizing (1) and using (2), we obtain the nonstationary nonzonal part v_z'' of the velocity v_z from the equality

$$2\omega a_0^2\cos\theta\cdot\rho v_z'' = \int_0^z \frac{g}{2\omega T_1}\left\{\int_{z_{\text{cp}}}^z \frac{\partial\Delta\tau''}{\partial t}\,dz + a(z)\int_{z_{\text{cp}}}^z \frac{\partial\Delta\tau''}{\partial\lambda}\,dz + 2[a(z)+\right.$$

$$\left.+\omega]\int_{z_{\text{cp}}}^z \frac{\partial\tau''}{\partial\lambda}\,dz\right\}\tilde{\rho}\,dz + \int_0^z\left\{\frac{\partial\Delta\psi''_{\text{cp}}}{\partial t} + a(z)\frac{\partial\Delta\psi''_{\text{cp}}}{\partial\lambda} + 2[a(z)+\omega]\frac{\partial\psi''_{\text{cp}}}{\partial\lambda}\right\}\tilde{\rho}\,dz, \tag{3}$$

a

b

Fig. 1

where τ'' and ψ''_{cp} are the nonstationary nonzonal parts of the functions τ and ψ_{cp}, respectively. We shall take the functions τ'' and ψ''_{cp} from (4); moreover, as in (4), we shall seek a "steady" regime, for which

$$\frac{\partial\Delta\varphi}{\partial t} + \alpha_{\text{cp}}\frac{\partial\Delta\varphi}{\partial\lambda} + 2(\alpha_{\text{cp}}+\omega)\frac{\partial\varphi}{\partial\lambda} = 0, \tag{4'}$$

where φ is either of the functions τ'' and ψ''_{cp}, and $\alpha_{\text{cp}} = \alpha(z_{\text{cp}})$ is the value of the circulation index at the mean level.

With the aid of (4) we can now eliminate from (3) the derivatives with respect to time–

Fig. 2

···time and write

$$2\omega a_0^2 \cos\theta \cdot \tilde{\rho} v_z'' = \frac{\partial}{\partial\lambda}(\Delta+2)\int_0^z [\alpha(z)-\alpha_{\text{cp}}]\left\{\int_{z_{\text{cp}}}^z \frac{g}{2\omega T_1}\tau''\,dz + \psi_{\text{cp}}''\right\}\tilde{\rho}\,dz. \quad (5)$$

Let us write the working formula, taking $\alpha(z) = \alpha_{\text{cp}} z/z_{\text{cp}}$ and replacing τ'' by its value τ_0'' for sea level. We finally obtain

$$v_{z\text{cp}}'' \cos\theta = \frac{g\alpha_{\text{cp}} z_{\text{cp}}^2}{-i\omega a_0^2 T_1}\frac{\partial}{\partial\lambda}(\Delta+2)\left(\tau_0'' - \frac{3\omega T_1}{g z_{\text{cp}}^2}\psi_{\text{cp}}''\right). \quad (6)$$

By (4)

$$\psi_{\text{cp}}'' = \sum_{n=1}^{\infty}\sum_{m=1}^{n}\left[D_n^m \cos(m\lambda+\sigma_n^m t) + D_n'^m \sin(m\lambda+\sigma_n^m t)\right] P_n^m(\cos\theta), \quad (7)$$

$$\tau_0'' = \sum_{n=1}^{\infty}\sum_{m=1}^{n}\left[\tau_{1n}^m(0)\cos(m\lambda+\sigma_n^m t) + \tau_{2n}^m(0)\sin(m\lambda+\sigma_n^m t)\right] P_n^m(\cos\theta), \quad (8)$$

where D_n^m and $D_n'^m$ are determined through the coefficients of the expansion of the initial height field of the 600-mb surface,

$$\tau_{1n}^m(0) + i\tau_{2n}^m(0) = \frac{2Mm}{a_0^2\sqrt{\tilde{\sigma}_n^m}}\frac{D_n^m + iD_n'^m}{a_n^m + \sqrt{\tilde{\sigma}_n^m}}; \qquad \sigma_n^m = \frac{2(\alpha_{\text{cp}}+\omega)m}{n(n+1)} - \alpha_{\text{cp}} m;$$

$$\tilde{\sigma}_n^m = \sigma_n^m + \alpha_{\text{cp}} m - \frac{k'' n(n+1)}{a_0^2} i; \qquad a_n^m = \frac{\lambda^*}{\lambda'}\sqrt{\frac{k'}{k^*}\sigma_n^m} + \mu\frac{\sqrt{k'}}{\lambda'}\sqrt{i}$$

(the remaining notation, see (4)). Therefore, if $v_{z_{\text{cp}}}'' \cos\theta$ is represented in the form

$$v_{z_{\text{cp}}}'' \cos\theta = \quad (9)$$

$$= -\frac{g\alpha_{\text{cp}} z_{\text{cp}}^2}{12\omega^2 a_0^2 T_1}\sum_{n=1}^{\infty}\sum_{m=1}^{n}\left[W_n^m \cos(m\lambda+\sigma_n^m t) + W_n'^m \sin(m\lambda+\sigma_n^m t)\right] P_n^m(\cos\theta),$$

then

$$W_n^m = -[n(n+1)-2]\, m \left(\tau_{2n}^m - \frac{3\omega T_1}{g z_{\text{cp}}^2} D_n'^m \right),$$

$$W_n'^m = [n(n+1)-2]\, m \left(\tau_{2n}^m - \frac{3\omega T_1}{g z_{\text{cp}}^2} D_n^m \right).$$

On the basis of (9), working formulas were prepared for vertical-velocity anomalies averaged over time. The averaging extended over the period from 40 to 70 days (from the initial time). Using these formulas, in the Laboratory of Planetary Atmospheric Dynamics and Hydrodynamic Long-Range Weather Forecasting of the Institute of Applied Geophysics of the Academy of Sciences of the USSR, a series of forecasts of vertical-current anomalies for the entire Northern Hemisphere was issued using old material.

In Figs. 1a and 2a two examples are given of forecasts of mean monthly anomalies of vertical currents for March and June 1959. An indirect check of the validity of these forecasts may be provided by comparison with the actual distributions of precipitation. In Figs. 1b and 2b actual data on precipitation over the regions of Eurasia are presented.

At present, forecasts of anomalies of vertical currents for the entire Northern Hemisphere are being regularly prepared in an operational manner.

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CITED LITERATURE

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Note: Figure translations are in progress. See original paper for figures.