ON THE RELATION OF THE DEFORMATION FORCE

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Abstract

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ON THE RELATION OF THE DEFORMATION FORCE

TO DISPLACEMENTS OF THE CENTERS OF ACTION OF THE ATMOSPHERE

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The potential of the deformation force arising as a consequence of the motion of the Earth' s poles, as is known ([1]), may be represented by the expression

$$W_p = -\frac{1}{2}\omega^2 r^2 (X\cos\lambda + Y\sin\lambda)\sin 2\theta,$$

where ω is the angular velocity of the Earth' s rotation, equal to $7.29 \cdot 10^{-5}$ sec^{-1}; r is the Earth' s radius, equal to $6.3712 \cdot 10^{8}$ cm; X and Y are the coordinates of the Earth' s pole of rotation; θ is the colatitude; λ is the longitude of the place.

The vertical component of the deformation force $(\overline{F}_p)_r$ is determined from the equation

$$(\overline{F}_p)_r = \partial W_p/\partial r = -\omega^2 r (X\cos\lambda + Y\sin\lambda)\sin 2\theta.$$

The horizontal component of the force will be the vector sum of two components, one of which is directed along the meridian and the other along the parallel:

$$(\overline{F}_p)_s = (\overline{F}_p)_\varphi + (\overline{F}_p)_\lambda,$$

where

$$(\overline{F}_p)_\varphi = \frac{1}{r}\frac{\partial W_p}{\partial \theta} = -\omega^2 r (X\cos\lambda + Y\sin\lambda)\cos 2\theta,$$

$$(\overline{F}_p)_\lambda = \frac{1}{r\sin\theta}\frac{\partial W_p}{\partial \lambda} = -\omega^2 r (Y\cos\lambda - X\sin\lambda)\cos\theta.$$

Analysis of the expression for the vertical component of the force shows that the nature of its variation is similar to the variation of the potential of the deformation force. The force has maximum magnitudes at 45° north and south latitude and is equal to 0 at the equator and at the poles.

Let us consider the nature of the latitudinal variation of the horizontal component of the deformation force (Fig. 1a). As follows from the figure, the meridional component of the deformation force has maximum and oppositely directed values at the poles and at the equator and is equal to 0 at 45° north and south latitude. The latitudinal component of the force is maximal and oppositely directed at the poles and is equal to 0 at the equator.

As a consequence of this, the resultant horizontal component of the deformation force has a complex character of variation with latitude (Fig. 1b). At the poles the values of the force vector are maximal, and, when rotating counterclockwise, the end of the vector describes a circle. In the latitudinal belt 55–75°, owing to the predominance of the latitudinal component, the trajectory described by the end of the force vector is an ellipse, which becomes increasingly stretched along the parallel as it approaches latitude 45°.

At 45° latitude the force changes only in the zonal direction. The meridional component of the force is absent. Farther south it appears again, but is already directed in the opposite direction. At 30° latitude the end of the resultant force vector, rotating now clockwise, again describes a circle, but of half the radius compared with the trajectory at the pole. As it approaches the equator, this circle increasingly···

more and more transforms into an ellipse elongated along the meridian, and at the equator the horizontal component of the deformation force again reaches maximum values, varying only in the meridional direction.

When considering the influence of the deformation force on atmospheric processes, it should be noted that its vertical component is very small in comparison with gravity; this gives grounds for neglecting its influence on processes in the Earth' s atmosphere. The horizontal component of the deformation force, however, is commensurate with those forces that act in the horizontal plane, and therefore acquires special significance in the study of the dynamics of atmospheric processes.

Earlier we showed ([2]) that the 14-month displacements of the Icelandic minimum of atmospheric pressure are directly connected with the free oscillations of the instantaneous pole of the Earth' s rotation. When the pole is displaced in the direction of the 0° meridian, the center of the Icelandic depression shifts to the southwest, and, conversely, when the pole is displaced in the direction of the 180° meridian, the center of the depression shifts in a northeastern direction. At that time the supposition was expressed that the cause of such displacements is the 14-month changes, associated with the free oscillations of the Earth' s axis of rotation, in the horizontal component of the deformation force $(F_p)_s$. The new data obtained by us make it possible to confirm this supposition.

The character considered here of the variation of the total horizontal component of the deformation force makes it possible to suppose that its influence on circulation processes in the atmosphere and, in particular, on the position of centers of action will be most significant in high latitudes, where the latitudinal component of the force has its maximum value. Hence it should be expected that the displacements of the Icelandic pressure minimum, both in latitude and in longitude, should be approximately 1.5 times greater than the displacements of the Azores maximum of atmospheric pressure.

The second, still more important consequence following from the character of the variation of the deformation force is that the displacements of the centers of the Icelandic depression and the Azores maximum under the action of the horizontal component of the deformation force must occur in opposite directions.

Fig. 1. Variation with latitude of the horizontal component of the deformation force: *a*—latitudinal $(F_p)_\lambda$ and meridional $(F_p)_\varphi$ components; *b*—total horizontal component $(F_p)_s$.

To prove these assumptions we used data on the mean monthly coordinates of the position of the center of the Icelandic minimum of atmospheric pressure ([3]) and the mean monthly coordinates of the center of the Azores maximum of atmospheric pressure, determined by V. P. Karklin from mean monthly maps of surface pressure of the Northern Hemisphere of the Earth compiled at the U.S. Weather Bureau ([4]). Seven-year series of data on the latitude and longitude of the indicated centers of action of the atmosphere (relating to the period of considerable amplitude of pole oscillations, 1945–1951) were processed by harmonic analysis. The obtained values of amplitudes and

the phases of the 14-month oscillations of the latitude and longitude of the centers of action were used in calculating and constructing the ellipses of the 14-month displacements of the center of the Icelandic depression and the Azores maximum, presented in Fig. 2.

As follows from Fig. 2, during the period under consideration the 14-month displacements of the indicated centers of action proceeded along ellipses oriented from southwest to northeast in opposite directions. This result is in complete agreement with the character of the spatial variation of the horizontal component of the deformation force.

Indeed, as was indicated, the latitudinal component of the force $(\overline{F}_p)_\lambda$ acts in the Northern Hemisphere in one direction. The meridional component $(\overline{F}_p)_\varphi$, however, in contrast to it, in accordance with the character of its variation (Fig. 1a), displaces the center of the Icelandic depression along the meridian in a direction opposite to the displacement of the Azores maximum of atmospheric pressure. As a consequence, both centers of action of the atmosphere move along identical trajectories, but in different directions.

Fig. 2. Ellipses of the 14-month displacements of the centers of the Icelandic minimum (A) and the Azores maximum (B) of atmospheric pressure, averaged

Fig. 2. Ellipses of the 14-month displacements of the centers of the Icelandic minimum (A) and the Azores maximum (B) of atmospheric pressure, on average for the period from 1945 to 1951. Center of the Icelandic depression $\varphi_{\text{av}} = 61°\text{N}$, $\lambda_{\text{av}} = 18°\text{W}$. Center of the Azores anticyclone $\varphi_{\text{av}} = 35°\text{N}$, $\lambda_{\text{av}} = 31°\text{W}$.

Figure 1: Fig. 2. Ellipses of the 14-month displacements of the centers of the Icelandic minimum (A) and the Azores maximum (B) of atmospheric pressure, on average for the period from 1945 to 1951. Center of the Icelandic depression $\varphi_{\text{av}} = 61°\text{N}$, $\lambda_{\text{av}} = 18°\text{W}$. Center of the Azores anticyclone $\varphi_{\text{av}} = 35°\text{N}$, $\lambda_{\text{av}} = 31°\text{W}$.

over the period from 1945 to 1951. Center of the Icelandic depression $\varphi_{\text{av}} = 61°\text{N}$, $\lambda_{\text{av}} = 18°\text{W}$. Center of the Azores anticyclone $\varphi_{\text{av}} = 35°\text{N}$, $\lambda_{\text{av}} = 31°\text{W}$.

As was to be expected, the amplitude of the 14-month displacements of the center of the Icelandic minimum in latitude proved to be approximately 1.5 times greater than the corresponding displacements of the Azores anticyclone. In longitude this relationship proved to be less pronounced (1.1 times, taking into account the latitude effect).

In general, the results obtained give grounds for asserting that the 14-month displacements of the centers of action of the atmosphere in the Atlantic zone of the Northern Hemisphere of the Earth occur under the action of the horizontal component of the deformation force.

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