ISSN 1512-1461

DOC 551.513.511.509

CLASSIFICATION OF SYNOPTIC PROCESSES OCCURRING IN THE EARTH'S ATMOSPHERE

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Annotation

On the basis of physical properties, an analytical and methodological work is presented, which concerns the analysis of the classification of processes generated and developed in the lower layers of the earth's atmosphere. The classification is made taking into account space-temporal scales, characteristics of wave motions, energy estimates and peculiarities of physical orography. The influence of the relief on the development of regional atmospheric motions has been theoretically established by estimating the corresponding parameters. The determination of the vertical velocity of the air flow using the orographic Jacobian is also analyzed. The work is relevant, timely and has practical value.

Keywords: *Cyclonic movements, spatial-temporal scale classification, Rosby waves*

Introduction

In the earth's atmosphere, the origin, development and disappearance of processes with different properties are constantly taking place. Most of them are useful for public life, but, unfortunately, there are a number of undesirable processes that are brought with them great material damage and even human casualties. Atmospheric processes occurring in our air sphere are described by the fundamental laws of physics. All these laws are described mathematically and, in principle, it is possible to solve them, in extreme cases, using modern computer technology. And this gives us the opportunity to model and predict the desired processes. The atmosphere is in perpetual motion, the cause of which is the uneven distribution of solar energy. Such a "machine" operates: an uneven influx of heat from the sun causes an uneven distribution of temperature, density, pressure, which causes various movements. Today, and especially for tomorrow, the study of these processes, the establishment of their dynamics, modeling and forecasting is of great theoretical, practical and vital importance. It is desirable and useful to know the size, frequency, power of atmospheric phenomena that arise, exist and disappear in certain time intervals. For this purpose, in this work, a spatial, temporal, force and energy classification of different types of atmospheric motions has been developed.

Spatial-temporal scale classification

The generated and subsequently developed atmospheric processes and phenomena are characterized by different ranks of spatial and temporal scales. The magnitude of the scales mainly, as a rule, determine the physical and geographical nature of these processes. It is known that atmospheric processes, beginning with the rustling of leaves and ending with cyclonic movements, should be described by a system of hydro thermodynamics equations. Naturally, the description of all processes is impossible and is not required. It is clear that the weak process that has arisen in Brazil, for example, a draft, thunder, lightning, will not be able to influence the powerful process in

ISSN 1512-1461

Georgia. Therefore, atmospheric processes must be divided into spatial areas and time periods. Therefore, this makes it possible to study in more depth the physical meaning of individual phenomena and to carry out their modeling and forecasting using the appropriate approach. Based on the analysis of long-term observations, world-famous scientists have proposed the following space-temporal classification of atmospheric movements.

A) microscale movement. The characteristic propagation length is tens of meters; a period of ten seconds (draft).

B) Mesoscale movement - horizontal propagation of several tens of kilometers, the characteristic time is one - two hours. For example, cumulus clouds, local movements on the ocean, surf and ebb of water. This process, due to its complexity, is also divided into: meso ∝ - scale (200 - 2000) km; meso β - scale (20 - 200) km; meso γ - scale (2 - 20) km. The first processes include atmospheric fronts, tropical cyclones, etc. The second ones are orographic disturbances, cloud flows, etc., the third ones are the formation of cumulus clouds, several types of gravitational waves, etc. [1.8].

D) Macroscale movements - the length of the process (1000 - 2000) km. Period 1 - 2 days. Examples are cyclones and anticyclones.

The following processes are significant in terms of time: the global period of a week, a month; seasonal processes - months, year; annual - several years; for economic and scientific interests, centuries are also important - several centuries; geological - periods of warming and cooling. The internal physical nature of all these movements, processes is determined by the so-called. applying the analogy method [1.4.].

Due to the complexity of the physical nature of atmospheric processes, it is natural to isolate and study all individual movements, it is necessary to evaluate the main leading factor in it. Therefore, there is a need to simplify the system of corresponding mathematical equations. It has been established that the equations of hydrothermodynamics, which describe atmospheric dynamic processes, contain mainly two types of forces, and just they provide all types of motions in the atmosphere. These forces are: mass-volume (gravitational, Coriolis, centrifugal) and surface (pressure gradient and internal friction). The necessary requirement for the system of equations [1-7] is that from the possible types of solution of the system of equations, processes (waves) that are not essential for a given situation should be identified - "filtered out". This purpose is mainly served by the classification of synoptic processes.

Wave classification of air flow movement

Multiple movements in the Earth's atmosphere can be considered as a system of superimposed waves. These waves have different length, amplitude and speed. Wave motion in the atmosphere can be caused by "external" factors (the influence of the Moon's gravity, the impact of rock masses, etc.). Such oscillations are called forced, and oscillations that are not related to external factors and exist for a long time are called internal oscillations. Internal oscillations are divided into three main types: large-scale, gravitational and acoustic.

1. Large-scale synoptic - Rosby waves are characterized by wavelengths from tens of kilometers to several thousand kilometers, speeds up to tens of m / s, periods of several days, and a pressure amplitude of (20-30) millibars. A typical scale of such synoptic processes is according to A. Obukhov and Monin [9] L = 3000 km ($L = \frac{c}{l}$, where c is the speed of sound propagation in air, l is the Coriolis parameter.

2. "Internal", inertial-gravity waves are due to the existence of the Earth's gravitational field and arise when the density changes with height. The particles vibrate and mix in the vertical plane. The

ISSN 1512-1461

period of oscillations is (300-350) seconds, the speed is from tens of m/s to hundreds of m/s, the amplitude is small, but at the moment of superposition of waves it can reach wind speeds of (5-10) m/s.

3. Acoustic or compression waves are caused by compression-expansion of the medium. The period does not exceed 300 seconds, the speed is (300-350) m/s, the pressure amplitude is only a few tenths of a millibar. These waves are ordinary sound waves.

A wide circle of scientists refers to large-scale, gravitational and acoustic waves: -first, longitudinal, second, transverse-vertical, where particles move up and down, and the wave propagates horizontally; third, transverse-horizontal, where the particles move perpendicular to the propagation of the wave from south to north, and the wave itself moves to the east [1.3.].

In the atmosphere, which is a contracting baroclinic medium, there are also intra-acoustic and gravitational three-dimensional waves. There are also low-frequency oscillations generated by Rosby waves. These waves make it possible to determine the speed, taking into account the advantage of horizontal displacement [1.2.3]. Rosby waves are frequently observed and play an important role in oceanology and meteorology. The Rossby wavelength is determined by the formula [1.5.6.].

$$L = 2\pi \sqrt{\frac{u}{\beta}}, \tag{1}$$

Where u is the zonal flow velocity ≈ (10-15) m/s, the β - Rosby parameter is related to the latitudinal variation of the Coriolis parameter [5.6]. In the study of individual processes, the wave equation obtained from the system of equations of thermohydrodynamics is solved in certain approximations in this way, the corresponding wave characteristics are determined - the length, frequency and speed of wave propagation [1.2.3.6.8]. For the first type of waves, that is, for large-scale motion, Ω the equation of potential torque-vortex is valid [1.2.5.6.7.8.9].

$$\frac{d}{dt}(\Omega + l) = -lD\,, \tag{2}$$

Where l is the Coriolis parameter, $\frac{d}{dt}$ is the total derivative, D is the flat velocity divergence. For a barotropic medium, where the density is a function of pressure only, the absolute velocity vorticity is preserved and (2) is written as [5.6.7].

$$\frac{d}{dt}(\Omega + l) = 0\,, \tag{3}$$

The solution is given in the form of the following plane wave [1.5.7.];

$$V = Ae^{\iota\alpha(x-\sigma t)} \tag{4}$$

Where A is the amplitude, σ - is the frequency, ∝ - is the wavenumber.

The solution of equation (3) for the first type of flows is the already given (1) Rossby formula. In the case of the second type of current, the dependence for σ of the wave frequency is obtained [2.3]:

$$\sigma = U \pm \sqrt{gH}\,, \tag{5}$$

Here H is the height between the levels at hydrostatic equilibrium. For the third case:

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$$\sigma = U \pm \sqrt{\gamma RT} \qquad (6)$$

Where R is the universal constant, T is the absolute temperature, $\gamma = \frac{c_p}{c_v}$. Specific heat of gas c_p at constant pressure and specific heat c_v at constant volume. The above formulas (1) - (6) have of great theoretical and practical importance, especially in numerical weather forecasting.

In the 1950s of the last century, world-renowned meteorologists showed that large-scale motion is characterized by the balancing of two important forces acting in the atmosphere - the baric force and the Coriolis force arising from the rotation of the Earth around its axis. For various reasons, if this condition is violated, the wind and pressure fields are transformed (adapted) in such a way that after a few hours the equilibrium is restored. It is this circumstance that contributes to the existence of the geostrophic wind [1.2.3.], which plays an important role in the classification and study of synoptic processes. The components of the geostrophic wind with respect to the coordinate axes u and v are given by the formula [2.5.6.8.].

$$U = -\frac{1}{lp}\frac{\partial p}{\partial y}\ ;\ V = \frac{1}{lp}\frac{\partial p}{\partial x}$$

Where P is the atmospheric pressure, ρ is the air density. Under geostrophic conditions, when the centrifugal force is also taken into account, we have a geocyclostrophic movement that determines the origin and movement of cyclonic and anticyclonic regions [2].

Vertical movement in the atmosphere

The vertical movement of atmospheric air has different scales and character. The speed of the vertical movement of air particles (the vertical component of the air flow velocity) $W = \frac{dz}{dt}$ (m/s) characterizes the change in the height of a stationary particle over time. It is positive when air rises and negative when it descends. In the practice of synoptic processes, a pressure coordinate system is used, where $W_1 = \frac{dP}{dt}$ (mb/h) and characterizes the change in particle pressure when it moves vertically. This speed is negative for upstream and positive for downstream. The numerical ratio between them is $W = -13.8\ W_1$ for the 500 MB level. Vertical air velocities can be caused by the influence of various factors - turbulence and air convection, large-scale air currents in the surface layer, orography, etc. Vertical velocities can be calculated using the equations of rotation velocity, continuity, heat flow, as well as the orographic Jacobian [10].

Relief waves and their role

Most of the physical and geographical surface of the Earth is mountainous. In addition to the air flow in these areas, the so-called. orographic waves. They have a number of features, the study of which clarifies the circulation mechanism of air movement and improves the quality of predicting their changes. Since the kinetic energy of the motion of the atmosphere is concentrated mainly in its lower layers, it is natural to assume that the main part of wave disturbances originates and develops precisely in these layers. At the same time, the atmosphere is stratified (divided into layers) due to the dependence of temperature, density and wind on altitude. We also have an orographic vertical wave distribution. Dozens of scientific papers devoted to the interaction of the relief with atmospheric flows indicate that even simple physical models describe well the stable-

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equilibrium solutions of the Rossby-type equations for the local relief. The results obtained can be applied to specific mountain ranges, such as the Caucasus, the Rocky Mountains in the USA, the Andes in South America, etc.]. To study the influence of a mountain range on the movement of an air flow, it is necessary to use the Friedman equation for mountainous terrain [1.2.3.5.6].

$$\left(\frac{\partial}{\partial t}+u\frac{\partial}{\partial x}+v\frac{\partial}{\partial y}\right)\left(\Delta\Psi+a\Psi_x+b\Psi_y\right)=l\eta\left(a\Psi_x-b\Psi_y\right) \quad (7)$$

Here, Ψ is a function of the current, u and v are the horizontal velocities along the coordinate axes ox and oy. $\eta=\frac{p_z}{p_o}$ ageostrophy parameter, p_z - pressure at mountain height, p_o - standard pressure value, Δ - flat Laplace operator, $a=-\frac{\partial ln\eta}{\partial_x}$;$a=-\frac{\partial ln\eta}{\partial x}$; $b=-\frac{\partial ln\eta}{\partial_y}$; $b=-\frac{\partial ln\eta}{\partial y}$; The characteristic parameters of the mountain influence, respectively, relative to the coordinate axes Ψ_x and Ψ_y of the current direction function parallel to the earth and the meridian. The solution of this equation is in the form of the following plane wave [1.2.5.]:

$$\Psi=\Psi_o e^{i(mx+ny-\sigma t)} \quad (8)$$

Insert (8) in the (7) its existence by the following dependence [5.6.].

$$am+bn=0\ , \quad \text{so} \quad \frac{a}{b}=-\frac{n}{m} \quad (9)$$

Here m and n are wave numbers. Relation (9) is a very important result for mountainous areas. Its implementation leads to the existence of two-dimensional waves of the neutral type. The ratio of the characteristic lengths of these waves along the meridian and the parallel is proportional to the average slope of the mountain in the same direction. Stationary waves will also be observed, for the existence of which the following conditions are necessary and sufficient [1.2.5.6]:

$$\frac{n}{m}=\frac{1}{a}\left(b+\frac{\beta}{l}\right) \quad (10)$$

Comparison of (9) and (10) shows that the β effect does not affect neutral waves, but is essential for waves of the stationary type. Based on these theoretical results, very important practical conclusions were made: a) the ratio of wavelengths to the average slope of the terrain is different for neutral and standing waves; b) The fact recognized by synoptic practice was theoretically substantiated. Most of the atmospheric processes propagate across the Caucasus in the form of a zonal current along the parallel (processes account for 70%), there is practically no meridional intrusion from the north, and the result is the opposite for the American Rocky Range [2.6].

In fact, daily atmospheric processes, including weather, in any particular area in most cases differ markedly from the general background. This feature is primarily due to the features of the Earth's layer, mesoscale radiation surface and orography. All this causes a deviation of the wind from the vertical direction, a change in the background value of precipitation and other meteorological elements. Orographic clouds and micro-local weather are forming. The existence of such clouds and waves is confirmed by daily operational data and many satellite images. In the

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formation of these processes of mesoscale movement, an essential role is played by the orographic vertical velocity, which is determined by using the Jacobian obtained by us [1.7.]

$$W_h = \frac{1}{l\eta\rho}(p, ln\eta)H = \frac{1}{l\eta\rho}\left(\frac{\partial p}{\partial x}b - \frac{\partial p}{\partial y}a\right)H \quad (11)$$

Where H = 1000 m is the height of the surface layer of the atmosphere. Determination-estimation of the Values a, b, W_h for a particular local region is one of the main goals of scientific research by many specialists. Obviously, these parameters should be estimated from the orography of the study area. To do this, we need to know the extent of the mountain in the direction of the parallel and meridian and the average height of the mountain. For example, if we take the average height of the Main Caucasus as 4000 m, the length along the parallel as 1500 km, and the width as 120 km, we get that $a = 0{,}68 \cdot 10^{-6}$1/m; b=6,4$\cdot 10^{-6}$1/m; i.e. a=0,1b. Such a relationship between the parameters confirms dependence (9), in particular, that atmospheric processes pass through the Caucasus mainly along the zonal parallel of the current.

Energy assessment of the dynamics of atmospheric processes: Naturally, the predicted duration of changes in processes of different spatial scales in the Earth's atmosphere is estimated by the time of generation of the corresponding kinetic and potential energies. It has been estimated and determined that the energy of atmospheric motion $(10^{21} - 10^{22})$ is of the order of joules. The power of solar energy coming to the Earth's surface is $1{,}8 \cdot 10^{17}$ w [9]. About 40% of this energy is reflected back into the atmosphere, so the output remains 10^{17}w. That is, on average $2 \cdot 10^{10}$ J/s per unit area. sq. M. The quadratic velocity of the air flow in terms of kinetic energy (per unit mass) is a maximum of 200 sq.m/sq.s. St. Therefore, the so-called leading flow speed c = (10-15) m/s. It is estimated that 70% of the kinetic energy of the atmosphere comes from the flow of these zonal currents at mid-latitudes. The remaining 30% is used for meridional movement [1.2.9]. According to a long-term empirical estimate, the rate of transition of potential energy into kinetic energy in the atmosphere is $2 \cdot 10^{10} \frac{\partial E}{\partial t} = 2 \cdot 10^{15}$ w [9]. Based on the physical opinion, obviously, the average value of dissipation $\frac{1}{M}\frac{\partial E}{\partial t} = 4$ sq.c./sq.s. (transition of kinetic energy into heat due to existing friction) should be of the same order. The characteristic energy conversion time $\tau = \left(\frac{1}{E}\frac{\partial E}{\partial t}\right)^{-1} = 5 \cdot 10^5$ s, about one week, coincides with the duration of synoptic processes observed by Voeikov [1].

It is essential that the time of generation of kinetic energy coincides with the duration of the conception-existence (energy dissipation) of synoptic processes. This is one of the classic examples of the coincidence of the observed and noted material with the reality of theoretical results. The difference between the time of energy generation t and the change t_0 of the time of change of synoptic situations determines the duration of the existence of atmospheric processes. If the condition $(t - t_0) < \tau$ is met, then the atmospheric situation will be short-term 1-3 days. When we have $(t - t_0) > \tau$, then the processes are long (15 days or more). These include medium-range forecasts, ranging from 5 days to 15 days. It is clear that in the short term, the energy flux and dissipation will be negligible, and the adiabatic approach is valid. This is one of the options used in almost all types of numerical weather forecasting schemes.

ISSN 1512-1461

Conclusion

The work is methodical in nature and establishes a multifaceted classification of processes occurring in the lower layers of the Earth's atmosphere. Based on various physical conditions, an explanation of all atmospheric currents has been carried out. The space-time, orographic and energy scale properties of dynamic processes observed in the atmosphere are considered. The proposed technique is of great practical and applied importance mainly for meteorologists, researchers, students of relevant industries. It will also be useful for those interested in studying and forecasting the dynamics of atmospheric movements.

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Article received 2022-05-17