Modeling the influence of the Earth rotation axis position on the global climate variations

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Abstract. This study presents the results of numerical experiments to determine the Earth’s climate when its rotation axis is displaced without changing the axis tilt to the ecliptic plane. There is some evidence of the possibility of this shift in the past. The calculations were carried out using a hydrodynamic three-dimensional global climate model, including blocks of atmosphere, thermohaline large-scale ocean circulation and sea ice. Numerical experiments demonstrate a significant temperature changes throughout the world. A large area of Antarctica warmed up to temperatures above 15 °C. This is reason of intense melting of glaciers for a long time. Significant warming of the Arctic Ocean will lead to sea ice melting in the Arctic. Strong changes in temperature and ice cover lead to significant changes in horizontal ocean circulation. A procedure is proposed for calculating wind speed in atmosphere energy - moisture balance model. It is based on the geostrophic approach, taking into account the thermal component of the wind, and introducing the mechanism of friction on the underlying surface. A technique has been developed for the formation of the necessary maps and the relationships between them when turning the Earth rotation axis or using new cartographic data.

1. Introduction

There are some assumptions and evidence of a warm climate in Northeast Siberia 12-24 thousand years ago [1-3]. Perhaps this is due to a change in the location of the north geographic pole at this time [4, 5].

In accordance with the opinion of the founder of the continental drift theory A. Wegener [4], the northern geographic pole at the Late Valdai or Ostashkov glaciation epoch (12-24 thousand years ago) was located almost in the center of Greenland, about 15 degrees south of its current position. In this case, the location of the climatic zones in the Arctic region at that time should have been different.

It follows that the main part of the northeast Asia and Alaska territory was supposed to be in a temperate region with coniferous and deciduous forests and steppes.

The American geophysicist A. O’Kelly puts forward an even more radical assumption about of the northern geographic pole location of this glaciation era - in the area of Akpatok Island in the Hudson Strait, which separates the Labrador Peninsula from Baffin Island, at a point whose geographical latitude is now 60°N [5].

The reason for the change in the position of the north geographical pole may be a change in the position of the Earth rotation axis [6]. In recent years, a theory has been proposed that explains the
mechanism of global climate change and catastrophic changes on Earth, developed in 1984 by the NASA astronomer and geophysicist P. Schulz: This is a slippage of the lithosphere, leading to a displacement of the Earth geographic poles, for example, under a tangent impact of a 20 km diameter asteroid, flying at a speed of 50 km / s without any noticeable change of the Earth rotation as gyroscope. The inclination of the Earth rotation axis with respect to the ecliptic plane does not change.

In this paper, based on this theory, numerical experiments are carried out to determine the Earth’s climate when the rotation axis is shifted without changing its inclination to the ecliptic plane. The calculations were carried out using the climate model described below and the developed methodology for the maps formation during shift of the Earth’s rotation axis.

2. The climate model description

The main elements of the global climate system are the oceans, atmosphere, sea ice and soil layer.

The ocean model equations are considered in the geostrophic approximation with the friction term in the horizontal momentum equations. The temperature and salinity values satisfy the advection-diffusion equations, which allow us to describe the thermohaline circulation of the ocean. Convective processes are also taken into account in an approximate manner [7–9].

Thus, the basic equations system written in local Cartesian coordinates \((x, y, z)\), where \(x, y\) are horizontal coordinates and \(z\) is the height directed upwards, has the following form:

**horizontal momentum equations**

\[
-lv + \lambda u = -1 \frac{\partial p}{\partial x} + 1 \frac{\partial \tau_x}{\partial z}, \quad lu + \lambda v = -1 \frac{\partial p}{\partial y} + 1 \frac{\partial \tau_y}{\partial z},
\]

**continuity equation**

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0,
\]

**hydrostatic equation**

\[
\frac{\partial p}{\partial z} = -\rho g,
\]

**sea water state equation**

\[
\rho = \rho(S, T),
\]

**transport and diffusion equation for tracers \(X\) (temperature and salinity)**

\[
\frac{d}{dt} X = k_v \nabla^2 X + \frac{\partial}{\partial z} (k_v \frac{\partial X}{\partial z}) + C.
\]

in which \(u, v, w\) are components of the velocity vector, \(\lambda\) is the friction term, variable in space, increasing towards the coastal boundaries and the equator, \(T, S, p\) are temperature, salinity, pressure, respectively; \(\tau_x, \tau_y\) - components of the wind friction stress; \(\rho\) - water density; \(l\) is the Coriolis parameter, \(g\) is the gravity acceleration, \(\kappa_v, \kappa_h\) are respectively the vertical and horizontal turbulent diffusion coefficients of the tracers, \(C\) are the sources.

The condition of normal flow absence is required at all boundaries. The normal components of heat and salt fluxes are also taken equal to zero at the continent borders. The ocean is exposed to wind stress on the surface. The flows \(T\) and \(S\) are assumed to be zero at the bottom, and they are determined by the interaction with the atmosphere on the surface.

The equations are discretized on the Arakawa grid using simple central differences in space for diffusion and a scheme with weights upstream for advection. Explicit finite time differences schemes provides the required accuracy, and have sufficient efficiency. At each time step, the velocity field is determined diagnostically from the density field. Mathematical and numerical modeling is a powerful tool for studying the climate system and predicting climate change. Modern modeling is carried out
using powerful software tools, including domestic ones, for example, to solve the problems of unsteady gas dynamics of multicomponent gas by various numerical methods [10-14].

Dynamic equations of the sea ice thermodynamic model [9, 10] are solved for ice compactness and for the average ice thickness. The ice growth and melting in the model depends only on the difference between the heat flux from the atmosphere to sea ice and the heat flux from ice to the ocean. The diagnostic equation is solved for the ice surface temperature.

The energy and moisture balance model or the atmospheric general circulation model is used to describe the atmosphere processes [15].

All model blocks are coupled by the exchange of momentum, heat and moisture. The real continents configuration and the ocean depths distribution are used [7-9]. The vertical levels of the ocean model are evenly distributed in logarithmic coordinates so that the upper layers are thinner than the lower ones. The horizontal grid is uniform in the coordinates of longitude and sine of latitude, determining cells of the same area in space. This model uses 8 vertical levels for density. The maximum depth is assumed to be 5000 m.

The equations in a spherical coordinate system are solved by a numerical finite-difference method. To calculate one time step for the ocean, sea ice, and surface currents, several time steps for the atmosphere are required. The initial state of the climate system is characterized by constant temperatures of the ocean, atmosphere and zero speeds of ocean currents. Calculations show that the model reaches equilibrium over a period of about 2000 years. The predictive equations of the model are solved by the method of central second-order differences in space and simple forward-time differences. The model uses a finite-difference grid of 72 × 72 cells uniform in longitude and sine of latitude. The longitude resolution of the model is 5°, and in latitude it changes from approximately 1.5° at the equator to approximately 10° at the poles.

3. The procedure for calculating wind speed in the energy - moisture model of the atmosphere

Here, we propose a procedure for determining the wind velocities field from the atmosphere temperature field, based on the geostrophic approach, taking into account the thermal component of the wind, and introducing the mechanism of friction on the underlying surface. This method allows in general describe the wind speeds field depending on the state of the climate system.

The following relationships are used to calculate wind speeds:

\[ -2\Omega \sin \theta \cdot V = -\frac{1}{\rho r \cos \theta} \frac{\partial p}{\partial \phi} - \lambda U \]

\[ 2\Omega \sin \theta \cdot U = -\frac{1}{\rho r \cos \theta} \frac{\partial p}{\partial \phi} - \tilde{\lambda} V \]

\[ \frac{\partial p}{\partial r} = -\rho g \]

\[ p = \rho RT \]

where \( \Omega \) is the angular velocity of the Earth's rotation, \( \theta \) is the latitude, \( s = \sin \theta \), \( c = \cos \theta \), \( \rho \) is the density, and \( p \) is the pressure.

The coefficients \( \lambda \) and \( \tilde{\lambda} \) characterize the processes of friction on the underlying surface and are selected empirically. Eliminating the density and pressure from these equations, after integration over the thickness of the atmospheric boundary layer \( H \), assuming a standard stratified atmosphere, we obtain the zonal and meridional components of wind speeds:

\[ V_H = \frac{gH}{rT_0(4\Omega^2 s^2 + \lambda \tilde{\lambda})} \left( \frac{2\Omega s}{c} \frac{\partial T_0}{\partial \phi} - c\lambda \frac{\partial T_0}{\partial s} \right) \]

\[ U_H = \frac{-gH}{rT_0(4\Omega^2 s^2 + \lambda \tilde{\lambda})} \left( \frac{\partial T_0}{c \partial \phi} + 2\Omega sc \frac{\partial T_0}{\partial s} \right) \]
4. Numerical experiments
Numerical experiments conceptually correspond to A. O’Kelly’s theory described above. It is assumed that the Earth rotation axis is shifted in such a way that the north pole is at 60 ° N and 90 ° west. Figure 1 shows the continents configuration (gray color) on the computational grid for this case, obtained using the developed map conversion system and computational grid. The model continents configuration has undergone significant changes in the used cartographic projection. So, for example, Antarctica has shifted to the equator. Circles indicate the previous position of the rotation axis (i.e., geographical poles) in this figure and further.

![Figure 1](image.png)

**Figure 1.** The continents configuration (gray color) on the computational grid when the Earth rotation axis is situated 30 ° in latitude and -90 ° in longitude.

The calculations were carried out from the initial state until the stationary regime was achieved. The initial state is characterized by a uniform field of ocean and atmosphere temperatures and zero current velocities in the ocean. The calculated distribution of atmospheric temperature (°C) for January is shown on a modern global map in figure 2. There has been a significant temperature increase throughout northern Asia. In January, the zero isotherm runs along the coast of the Arctic Ocean. Warming also affected Scandinavia. Along with this, significant air cooling is observed throughout North America. Temperature contours have a concentric structure, grouping around a new north pole. The zero isotherm drops to 30 ° N in this region. Noticeable changes have also occurred in the southern hemisphere, where summer is in January. A significant area of Antarctica warmed up to temperatures above 15 ° C. This should lead to intense melting of glaciers for a long time.
Figure 2. The atmosphere temperature distribution (°C) for January when the Earth rotation axis is situated 30 ° in latitude and -90 ° in longitude.

For comparison, the calculated distribution of atmospheric temperature (°C) for January and the current position of the rotation axis and continents configuration is shows in figure 3. It is easy to see a significant difference compared to figure 2.

Figure 3. The atmosphere temperature distribution (°C) for January at the current position of the Earth rotation axis.

Significant warming of the Arctic Ocean will lead to sea ice melting in the Arctic. Figure 4 shows the time variation of the process of reaching the steady state mode of the total sea ice area for two calculation options. The solid line corresponds to the current state, and the dashed line corresponds to the shift of the Earth's rotation axis by 30 ° in latitude and -90 ° in longitude. A 2-times decrease in the sea ice area is observed in the second case.

The sea ice area distribution (dark areas) for January is shown in figure 4 at the indicated above shift of the Earth's rotation axis. A significant part of the Arctic Ocean is ice-free during winter.
months. Ice cover (ice thickness does not exceed 1.5 m) is present only near the northern coast of North America. The entire water area of this ocean along Europe and Asia is free of ice right up to the North Pole. This situation is associated with the movement of the North Pole to the region of mainland America. In the southern hemisphere, only a small area in the south of the Indian Ocean near Antarctica in the area of south pole localization is covered with ice in winter and summer.

![Figure 4](image-url)  
**Figure 4.** Distribution of sea ice area (dark areas) for January when the Earth rotation axis is situated 30° in latitude and -90° in longitude.

Strong changes in temperature and ice cover lead to significant changes in horizontal circulation, characterized by a barotropic stream function (figure 5). Traditional circulation rings are either weakened (Pacific Ocean) or absent (Atlantic Ocean). There are only two areas of powerful circulation in different directions in the South Pacific Ocean in the region of the new South Pole.

![Figure 5](image-url)  
**Figure 5.** Barotropic current function for July when the Earth rotation axis is situated 30° in latitude and -90° in longitude.
5. Conclusions
This paper presents the results of numerical experiments to determine the Earth’s climate when its rotation axis is displaced without changing the axis tilt to the ecliptic plane. There is some evidence of the possibility of such a shift in the past. The calculations were carried out using a hydrodynamic three-dimensional global climate model, including blocks of atmosphere, ocean, sea ice. The procedure is proposed for calculating wind speed in the energy - moisture balance atmosphere model. A technique has been developed for the formation of the necessary maps and the relationships between them when turning the Earth rotation axis or using new cartographic data. The calculations confirm the assumptions and evidence of a warm climate in northeastern Siberia 12-24 thousand years ago with a change in the location of the northern geographic pole at this time.

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