DECADAL FLUCTUATIONS IN EARTH'S ROTATION AS EVIDENCES OF LITHOSPHERIC DRIFT OVER THE ASTHENOSPERE

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ABSTRACT. The decadal instabilities in Earth's rotation (DIER) are thought to be caused by the interactions between the Earth's core and its mantle. This hypothesis successfully explains why there is a close correlation between DIER and the variations in the rate of the westward drift of the geomagnetic eccentric dipole, since it is successfully reproduced by modeling of the redistribution of the angular momentum between the fluid core and the mantle of the Earth. However, the hypothesis can not explain the close correlations of DIER: with the observable variations in the masses of the Antarctic and Greenland ice sheets; with the decade oscillations of the types of synoptic processes (i.e. the epochs of the atmospheric circulation); with the anomalies of the global temperature; and with regional anomalies of the cloudiness, precipitations, and other climatic characteristics. An alternative to the core-mantle interaction hypothesis is presented here. This alternative hypothesis claims that the DIER are actually caused by fluctuations in the angular velocity of lithospheric drift over the asthenosphere. The sliding of the lithosphere over the asthenosphere is possible due to of the vibrational displacement mechanism produced by tidal forces. The lithospheric plates exhibit vibrational displacements over the asthenosphere in the horizontal direction by shear stresses caused by friction, wind, and ocean currents. There is abundant evidence supporting this lithospheric drift model.

1. INTRODUCTION

Nontidal instabilities of Earth's rotation, i.e., variations in the daily rotation rate and polar motion are caused basically by the atmospheric and oceanic circulations. Exchange of angular momentum between the solid Earth and the moving shells occurs due to the friction forces of wind and currents on the lithosphere surface and due to the pressure exerted by the air and water on the mountain ridges. However, the lithosphere is not monolithic, but is split into plates, some of which carry continents. The atmosphere and the ocean affect the lithospheric plates, which then transmit this action to the Earth. What are the consequences of the action experienced by the lithospheric plates? Recall that the lithosphere is underlain by a layer of lower viscosity-the asthenosphere- in which the lithospheric plates are capable of floating. The continents are frozen into the oceanic plates and can also passively move with them (Trubitsyn and Rykov, 1998). Therefore, it is natural to expect that the plates move under the friction force and pressure produced by the atmosphere and the ocean on the plates' outer surfaces. The movement of the plates is impeded by the viscous cohesive force between the asthenosphere and their bases and edges, but the external forces can overcome this resistance, since they are able to accelerate or slow down the Earth's rotation. So why cannot they move relatively thin plates floating on the asthenosphere? It is natural to look for indirect evidence of this phenomenon.

2. INDIRECT EVIDENCES

An illustrative example of what was said above is a situation occurring near the Drake Passage (Sidorenkov, 2009). The westerly winds prevailing in the Roaring Forties (area between latitudes 40^o-50^o th in the Southern Hemisphere) form the powerful Antarctic Circumpolar Current in the ocean (≈ 1 m/s). South America, the Antarctic Peninsula, and the underwater lithosphere represent a barrier to these atmospheric and oceanic flows. They have broken through the lithospheric connection that existed sometime in the past between South America and Antarctica and moved it 1500 km to the east. As a result, the East Scotia Basin was formed, which extends in the streamwise direction and is surrounded by the remains of the connection in the form of the Scotia Arc and numerous islands. The main of the latter is the arc of the South Sandwich Islands, which crushed the oceanic lithosphere in its eastward drift and formed the deep South Sandwich Trench.

Another piece of evidence to support our hypothesis is as follows. The atmospheric circulation has a remarkable feature: at latitudes of 35^o N and 35^o S, the wind direction reverses, i.e., easterlies (trade winds) prevail in the tropical zones between these latitudes, while westerlies dominate in moderate and high latitudes. Accordingly, the shear stresses on the lithosphere surface are oppositely directed. Therefore, maximum shear stresses in the latitudinal direction must concentrate in the lithosphere near latitudes of . These zones must exhibit higher seismic and tectonic activities. Indeed, within this zone in the Northern Hemisphere, there is a continuous chain of mountain systems running through the Mediterranean Sea, Anatolia, Iran, Pamir, Tibet, Japan, and the USA, where earthquakes and volcanic eruptions are observed most frequently. In the Southern Hemisphere, the zone of wind direction reversion passes through the ocean, due to which, possibly, seismic and tectonic processes are not evident.

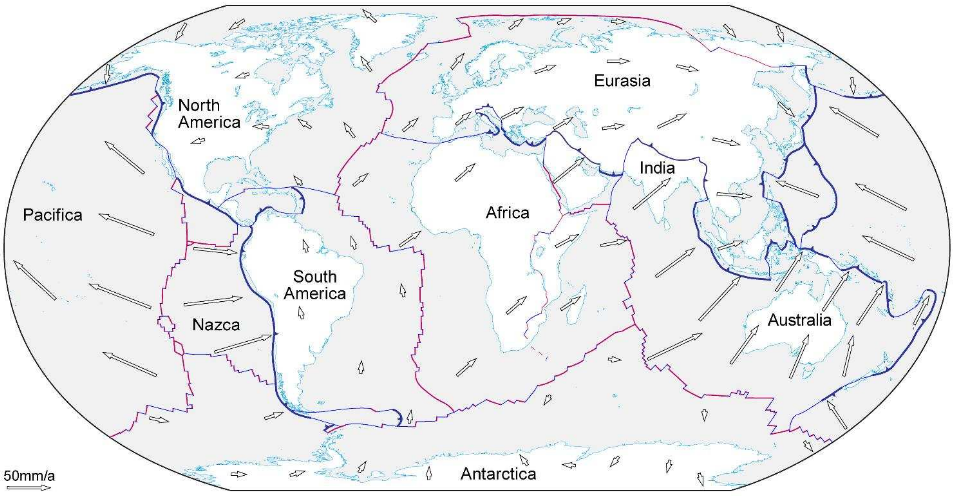

Figure 1: Map of annual mean displacements of GPS receivers over the globe from the data at `http://www.files.ethz.ch/structuralgeology/JPB/files/English/1Introtecto.pdf` (The arrows show the direction and velocity of the receivers' displacements per year)

3. GPS OBSERVATIONS

Now Global Positioning System is used to study moving of the Earth's tectonic plates (Figure 1). Here we can see that plates Europe, Asia, Africa, Australia and Nazca drifts from the West on the East. Only America is moving a little from the East on the West. Plates move as slow as a few centimeters in a year. Here, in subduction zones of "Ring of Fire", the plates collide with each other and sink into the mantle, where they melt. The total effect of the movement of all lithospheric plates is interpreted by geophysicists as the decadal fluctuations of the Earth's rotation.

4. ANTARCTIC ICE MASS DYNAMICS

In (Sidorenkov, 1982) I derived equations relating the Earth's rotation rate and the polar wobble coordinates to variations in the World Ocean water mass and the ice mass in Antarctica, Greenland, and the other Continents. We was found that the variations observed in the Antarctic ice sheet mass qualitative agreed with theoretical mass's variations. As to the quantitative agreement, I believed that the variations observed in the ice masses proved to be 28 times less than the required variations.

Etienne Dionis and Christian Bzouard refined the coefficients in my equations and recalculated specific mass series for the Ocean, Antarctica, Greenland, and Continents. In contrast to my calculations, which relied on the polar wobble series derived by the Ukrainian team of Evgeny Fedorov and Yaroslav Yatskiv (1972), Dionis used series of IERS pole coordinates. The numerical results for Antarctica are shown in the Figure 2. It can be seen that both theoretical curves agree well with each other. By comparing the theoretical curve with Petrov's empirical results, Dionis found an error in my calculations. It turned out that the observation values are less than the theoretical ones roughly by a factor of 100, rather than 28, as I believed. I have corrected this error. The error affected only the scale of the empirical curve, but not its configuration. Therefore, the high correlation coefficient of 0.84 between the theoretical and empirical curves remained unchanged (Figure 2). If the scale of the empirical curve is less than the theoretical one by a factor of 100, then the moment of inertia of the drifting Earth crust layer has to be less than the moment of inertia of the entire Earth by a factor of 100. It is easy to calculate that in this case the thickness of the drifting crust layer is about 20 km.

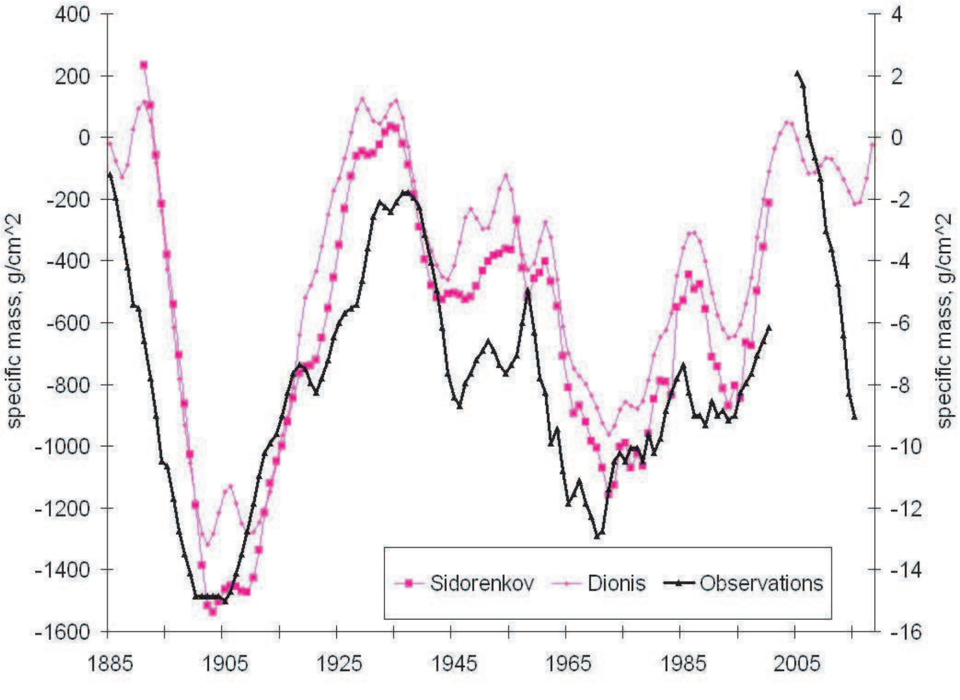

Figure 2: Temporal variations the specific mass of ice in Antarctica obtained from theoretical calculations and observations (r=0,84)

Relying on GRACE satellite data, Dionis computed series of specific mass variations in Antarctica (from 2005 to 2015) and Greenland (from 1993 to 2016). The scale of the series of specific mass variations in Antarctica is less than the theoretical value by a factor of 28. In this case, the thickness of the drifting crust layer has to be about 70 km.

The scale of the series of specific mass variation in Greenland as inferred from GRACE satellite data is less than the theoretical scale by a factor of 4.

These contradictory results also indicate that the observed decadal-long fluctuations in the Earth's rotation rate are not due to the rotation and polar motion of the whole Earth but rather to changes in the speed of drift of the lithosphere over the asthenosphere. The Earth's layers that are deeper than the asthenosphere don't take part in the formation of the observed decadal fluctuations.

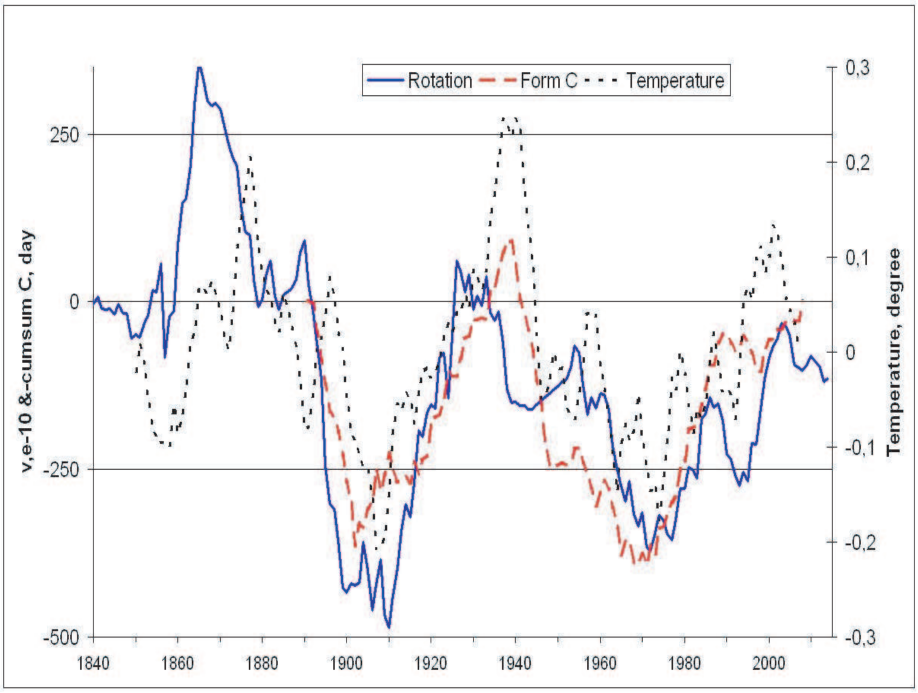

Figure 3: Synchronous changes in the Earth's rotation angular velocity v (blue line), atmospheric circulation forms C (red line) and of five year running anomalies of the Northern Hemisphere's air temperature

5. ESTIMATIONS

According to a classical estimate, the lithosphere can slide over the asthenosphere if the forcing period T is much longer than the stress relaxation time τ in the asthenosphere. As is well known, the relaxation time τ is determined by the ratio of the viscosity η to the shear modulus μ. According to a variety of estimates, the viscosity of the asthenospheric substance lies in the range 10^{18}-10^{23} P (Poise). The shear modulus μ is 10^{12} dyn/cm^2. Then we have $\tau = \eta/\mu \approx 10^6$-$10^{11}$ s or 0.03 - 3000 years. Thus, for the lower limit of η, our hypothesis is acceptable. For the upper limit of viscosity, lithospheric drift is unlikely.

However, this classical estimate does not take into account the effects of lithospheric vibrational displacements. Indeed, the lithospheric plates constantly vibrate in the vertical direction (roughly

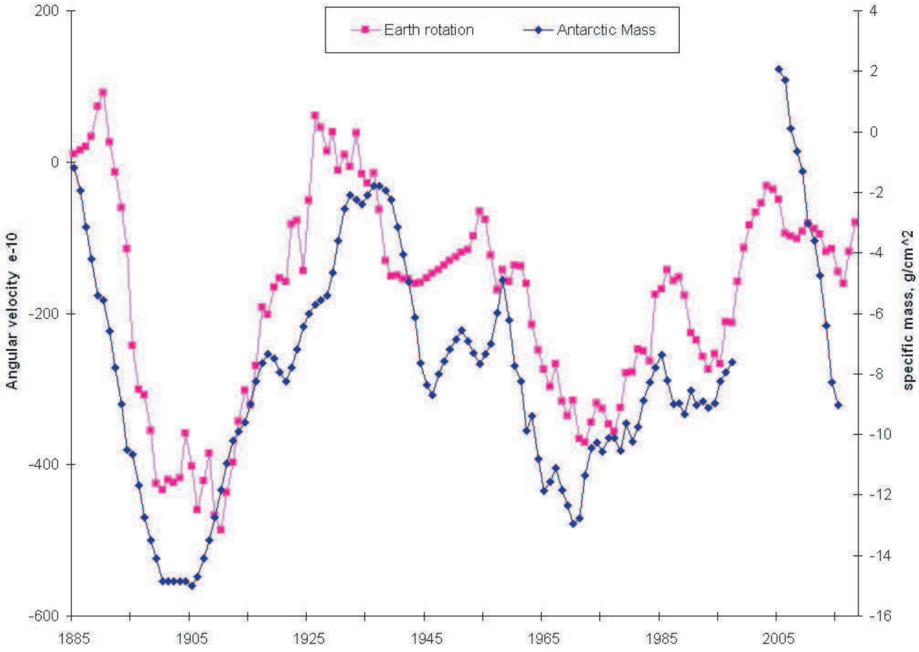

Figure 4: Variations in the specific mass of ice in Antarctica and in the Earths rotation angular velocity (red line). Correlation's coefficient r=0,85.

by 50 cm) under the action of lunisolar tides. On the other hand, the lithospheric plates are permanently affected in the horizontal direction by shear stresses caused by wind and ocean currents. As a result, the lithospheric plates must exhibit vibrational displacements over the asthenosphere in the direction of the acting tangential forces. Vibrational motions dominate in nature (especially, in biosphere)!

6. CLIMATE VARIATIONS

The state of the ice sheets in the Antarctic and Greenland depends on the climatic variations. Therefore, the decadal fluctuations in the Earth's rotation may also correlate with the fluctuations in the climatic characteristics and indices. This relationship has been found in many papers. There is a close correlation between the Earth's rotation fluctuations and the frequencies of the atmospheric circulation forms, the anomalies of the global and hemisphere-averaged air temperature (Figure 3), accumulation ice mass in Antarctica (Figure 4), and many another climate characteristics. These relationships are explained given the assumption that the lithosphere drifts along the asthenosphere.

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