MILANKOVIĆ'S "END OF THE WORLD"

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Abstract. The Milanković's numerical trajectory of secular changes of pole's rotation has shown that its latest positions in positive infinity can be observed on the North Pole of the Siberian plate. Milanković with his discovers "end of the world" or total end of activity in astenosphere. In other words, he discovers plate tectonics of pole's (convergence, divergence, and transform movement), earthquakes, subduction zones, sea floor spreading, etc.

This is not just the end of the atmosphere existence, water or life on the planet, but also a geodynamic, co-mechanic and co-climatological climax. This is the beginning of the ice ages. The pole of rotation, by Milanković, reaches $\varphi = +49^o$ 34'; $\lambda = +65^o$ 16' for the Northern Hemisphere or $\varphi = -130^o$ 26'; $\lambda = -65^o$ 16' for Southern Hemisphere.

Based on this data and according to the pole spreading of lithosphere, it is possible to recognize future climatic zones under geographical latitudes and longitudes. These are also known as the green zones, the most endangered continental places. The entire Europe and the parts of Asia will be under ice. Studying the continent of North America we can observe only a part of Canada is under ice (up to 60 of geographical longitude). This will happen due to continuous Atlantic sea floor spreading, and also due to the counterclockwise rotation of the North American plate. This will cause the continents to move away from the North Pole.

The problem of some time units and numerical secular positions, Milanković calculated and graphically presented, still stands as one of the greatest planetary enigmas. Their close picture is available through geophysical, geodetic, and mathematical methods, satellites, stations on the Earth's surface and also through practicing new technology.

The mentioned "end of the world" does not present the end of the Earth's cosmic phase. It does not correspond to astronomical age determinants and further planetary deviation. Milanković has experienced and mathematically presented cinematic planetary model of continents. He further included the water areas, atmosphere, and living beings.

The Milanković's "end of the world" is just an end of the pole's tectonics, critical temperatures and fluidly fall in the atmosphere. Also, it is the ending of the seismic phase, rift genesis, subdaction, and radioactivity. However, all together will not have any further consequences on the other structures, especially not on the Earth's nucleus. The Milanković's end of the world resembles the minimization of mechanical secular changes of the pole rotation. The Earth's rotation itself stays unchanged or barely changed.

1. INTRODUCTION

Working on the problem of numerical secular rotation pole movements, Milanković came to geographic co-ordinates φ and λ (φ - geographic latitude and λ - geographic longitude). These co-ordinates were used for calculating Earth's trajectory (Milankovitch, 1932a; 1932b; 1933a; 1933b and 1941). The equations are as follows:

a) geographical latitude φ

$$\sin\varphi = \frac{\cos\xi \, \sin(\varphi_1 + \gamma)}{\cos\gamma} \qquad (1)$$

where are:

ξ - part of spherical triangle,
φ_1 - geographic co-ordinates of point 1 and
γ - angle of spherical triangle

b) geographical longitude

$$\sin(\psi - \psi_1) = \frac{\sin\xi \, (\alpha - \beta)}{\cos\varphi} \qquad (2)$$

where are:

ψ_1 - geographic co-ordinates of point 1
α and β - angles of spherical triangle.

The equations (1) and (2) further lead to a composition of table which lists 25 most characteristic points with pole trajectories for both hemispheres. Along with modern meridian and parallels net (see Table 1) polar stereographic projection like displacement trajectory can be presented (see Fig. 1 - Northern Hemisphere and Fig. 2 - Southern Hemisphere). This mathematical calculation leads Milanković to 16 important points from the past that form part of early explorations (*Milićević, 1997a and 1997b*). Also, the same arises importance of 8 points triggering future explorations. These 8 points present the motivation for the following research.

This way Milanković discovers mathematical "end of the world'. Also, he points at ideal continental trajectory, finally free of geodynamic, astronomical, geographical, geodetic, and climatological changes. It is certain to show in the Earth's movement through cosmic paths millions years in the future. Also, it is impossible to determine mathematical changes that fluidal areas will experience. This is due to undetermined area and behavior of upper astenosphere.

Table 1. Mathematical position of poles rotation from current position to the infinity (based on Milanković's mathematical method from 1932 and 1933) including both Earth's hemisphere.

| Time from current position to the infinity (absolute unit is not definite)	Geographic longitudes (φ) and latitudes (λ) of Northern Pole		Geographic longitudes (φ) and latitudes (λ) of Southern Pole	
	φ	λ	φ	λ
0	-	+ 90°	-	- 90°
+ 1	+ 39° 43`	+ 84° 38`	- 140° 17`	-84° 38`
+ 2	+ 40° 46`	+ 80° 22`	- 139° 14`	-80° 22`
+ 3	+ 41° 49`	+ 77° 00`	- 138° 11`	-77° 00`
+ 4	+ 42° 47`	+ 74° 19`	- 137° 13`	-74° 19`
+ 6	+ 44° 25`	+ 70° 44`	-135° 35`	-70° 44`
+ 10	+ 46° 48`	+ 67° 18`	-133° 12`	-67° 18`
+ 15	+ 48° 24`	+ 65° 53`	-133° 36`	-65° 53`
+ ∞	+ 49° 34`	+ 65° 16`	-130° 26`	-65° 16`
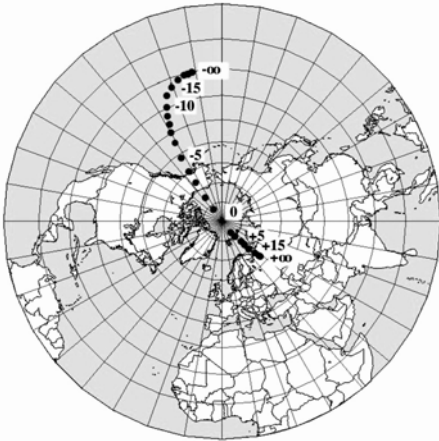
Figure 1: Trajectory of numerical secular Earth's pole position of rotations (based on Milanković's calculation from 1932, 1933, and 1941. for Northern Hemisphere).
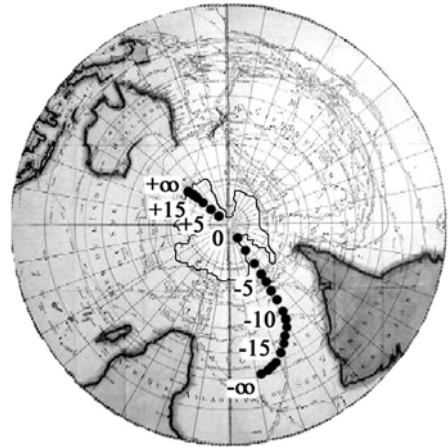

Figure 2: Trajectory of numerical secular Earth's pole position of rotations (based on Milanković's calculation from 1932, 1933, and 1941. for Southern Hemisphere).

2. MATHEMATICAL "END OF THE WORLD"

Looking at the numerical trajectory of pole rotation from 0 to $+\infty$, we will see it is at least three times shorter than the trajectories shown from 0 to $-\infty$ (Fig. 1). Geologically and astronomically looking at this phenomenon this contradicts determined age of planet. Also, it contradicts the research saying planetary development is at its half the predicted existence of the solar system to be another 12 million years. According to given analogy, both trajectories, from $-\infty$ to 0 and from 0 to $+\infty$ should be approximately the same, but that is not true. We can also see the pole trajectory to be linear from 0 to $+\infty$ and distance between poles being very small and practically equal.

Why is Milanković's mathematical calculation simple, trajectory displacement and the value of $+\infty$ on a smaller distance from 30° at northern or southern pole considering from geographical longitude?

A part of the answer to the given question can be found in modern continent systems and measured drift of plates of lithosphere (Fig. 3). According to calculations and measurements (satelite, geodesy, geophysics, mathematics, etc.) the drift of continental plates is greater on plaaces and continents closer to equator. Those are places where seafloor spreading and riftogenesis happened. In addition, there are numerous examples of which the most commons are spreading along East Pacific range. Drift at which this occures ranges from 9 to 15 cm/year. Mid-Atlantic ocean and SE Indian ocean spreading is noted happening from 2.5 to 3.5 cm/year and from 3.5 to 7 cm/year respectively.

The Antarctic plate is moving slower the spead ranges from 1 to 1.5 cm/year. The Mid-oceanic range Gakkel, which is underneeth the North Pole is only drifting from 0.5 to 0.8 cm/year. Antartica is located on the South Pole over 300 million years. The plate is rotating at the maximum of 10°. There are no significant changes as to translation of the current state, but the slow melting.

Milanković was not exposed to any research regarding plate movement, when he was calculating numerical secular trajectory of pole rotation. He was helped by his colleagues Vojislav Mišković, Dragoslav Mitrinović and Stanimir Fempl. The discoveries and researches in the area of mathematical and mechanical Earth's model like Jovan Simovljević's states.

The answer to the above question can be found in the following formula that is used for pole change determination, better know as approximate formula.

$$r = r_o \, e^{-\kappa t} \tag{3}$$

where:

      r – amplitude of periodic pole changes or distance between rotational and inertion pole,

      r – modern pole position assuming t = 0, $r_1 = r_o$ and $r_2 = 0$,

      k – coefficient of adaptation calculated from crusial inertial moments in Earth's rotation and
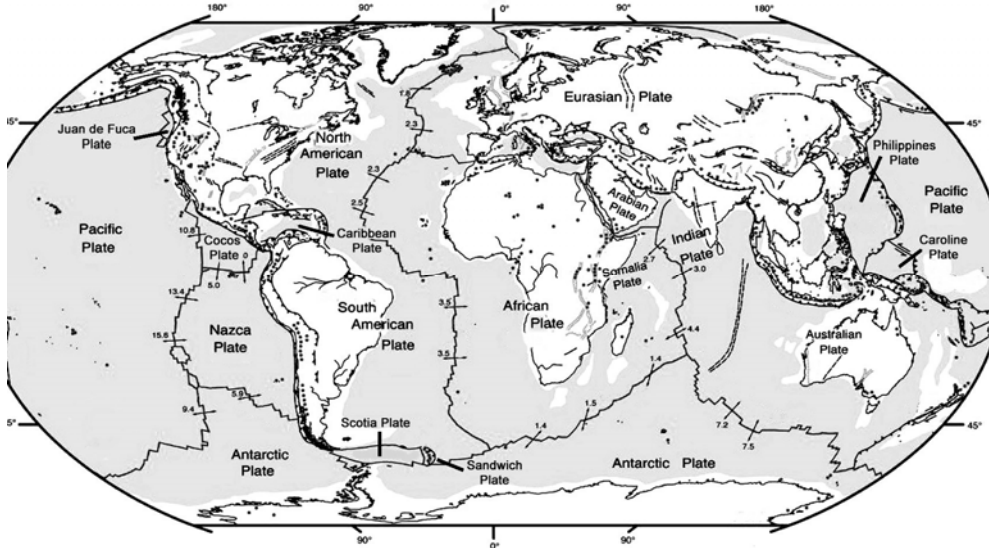
      t – time, from present to future.

Figure 3: Plate tectonics of Earth's litosphere and its drift spreading.

From the above equation (3), the change in position becomes smaller and smaller as time passes. It is happening slowly, due to the coefficient of adaptation having such a small value.

According to calculated positions, Euroasia should be moving SE towards "absolute" future. The same is true for Africa. The direction of continental movement is also SE by most geophysical investigations (paleomagnetism especialy). This suggests that Milanković's mathematical and mechanical model is valid and accepted. North America and Greenland are moving towards W and SW. The spreading at with they are moving from modern North Pole, Greenland is much smaller due to its closeness to the pole and its stable balanced position.

Putting the entire system of continents of the Northern Hemisphere (Euroasia, Africa, and North America) together following Milanković's unit +15 or +∝ we get mathematically balanced planetary system (Fig. 4). The given illustration shown the North Pole ($\varphi = 49^\circ$ 34' and $\lambda = 65^\circ$ 16') being on the continental parts (northern part of Siberia or mouth of the Pechora river in Barents Sea), which assumes changes of planetary climatological zones compared to today's. Milanković has in his early research pointed out to importance of rotation pole location, due to suggestions of Vladimir Köppen and Alfred Wegener. Milanković assumes no rotation pole location can be the same being on continental or oceanic plates.

Today's critical geographic longitude (φ from 65° to 60°) in this case will be drastically moved deeper to Euroasian plate not considering mechanics and Milanković cycles of insolation. This phenomenon will cause more frequent colder ice ages and the border of constant ice will be moved yet below 1500 meters sea level. European plate will be 100% covered with ice, while the Asian plate not, due to influence of ocean, oceanic and sea currents and worm waves.

The mathematical "end of the world" in the sence of forever iced areas will only apply to Europe, Asia, northern part of Greenland and partly of Northern Amrica. Let's have a look to why will this happen?

When geographical latitude of North Pole is +15 or +∞ then its place is on continental plates. The zones of permafrost can spread south more then they are able to do today. The critical borders or critical geographical latitudes around 50 to 55° for Northern Hemisphere stay the same they were defined by Vladimir Köppen and later used by Milanković in his calculations to define insolation curve (Milanković, 1920, 1930). However, the snow and ice in this case easier move towards south, due to no barriers in terms of ocean and sea water heating.
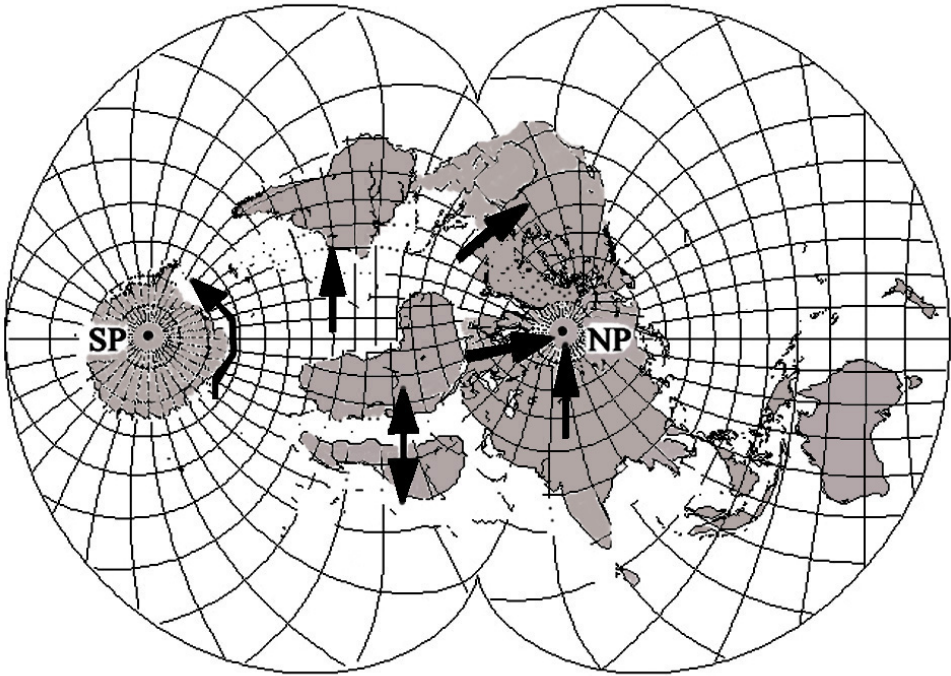

Figure 4: Continental drift and rotations of plates and its arrangement in the future (based on Milanković calculation and numerical secular pole rotations).
NP – North Pole, SP – South Pole.

The mathematical ice ages of "the end of the world" will be even more expressed due to all of the above stated. It will be reflexed in low temperature and defined ignoring celestial mechanics laws, i.e. changes in astronomical precession, obliquity, and eccentricity.

Two continents from Northern Hemisphere (Europe and larger part of Asia) will disappear. They will covered by ice and their roots will sink deep towards the upper part of astenosphere. Northern parts of North America, Greenland and partly Africa will constantly be under the influence of "permanent" ice cover.

On the other hand, the place of South Pole in "the end of future" will not undergo considerable changes; it will stay on Antarctica continental plate. Antarctica will slightly move toward NW, undergoing small counterclockwise rotation (maximum of 10°), while the pole approaches NW part of the continent. Finally, according to mathematical balanced position ($\varphi = -130^o 26'$ and $\lambda = -65^o 16'$) no changes will happen and snow and ice will permanently cover this part of the world.

3. THE AGE POLE MOVEMENT PROBLEM
(CHANGES IN GEOGRAPHICAL COORDINATES)

Milanković (1941) touched only a fragment of pole rotation movement and its time periods in his book "Canon of insolation and the ice-age problem". He stated the changes happen in the interval of 5 millions of years (minimum) to 30 millions of years (maximum). This leads him to relatively "good" time period of pole movements. The movement value in the second last point (+15) from the Table 1 means it presents minimal time of 75 millions of years, or maximum of 450 millions of years.

Milanković also used values of International Services of Latitudes presented at that time to come to the conclusion. He said the secular pole movement in the million of years from $1^o 20'$. However, when Milanković takes the value to his calculations and pole position from -1 to +1, he found the time period to yield only 4.5 million years. This essentially was linear positioning of pole rotation trajectory, and as such unsatisfactory.

Numerous measurements performed in the second half of the 20th century up until today show the above mentioned time division cannot be linear. These measurements show the time division is circular or semi-circular with continental spreading from centre, i.e. rotation pole. This type of movement slows down the pole, but does not affect spread of continental movement (Eubanks et al., 1988). Considering African plate, it is spreading towards west with average speed of 3 cm/year, and toward east from 4 cm/year. Its movement away from South America in next few millions of years will increase for about 30 km or it will double from current in next 100 million years. This will cause the continuous spreading of eastern part of African plate, namely Indian ocean. The size of the spread will increase by at least 1% of it current size.

The African plate like rudiment of ancient Gondwanaland will continue further disintegrate through processes of divergent, collision, transform movement, etc. This will especially be the case in zones of Red Sea, Mediterranean Sea and along Eastern African plate (Eastern African Trench). Considering as a base origin and the age of these processes, then their further growth needs to accelerate (especially divergent and transform movement). The African and European plates will drastically decrease its translations, but increase plate rotations. African plate will be moving in the counterclockwise direction, while Euroasian plate moves clockwise.

Apart from idealized presentation, Milanković's pole rotation trajectory suggests final continental increase in geodynamics and migratory free of continental collision. This implies no new mountain chain formation or big subduction zones (Fig. 4). This process makes sense correlating future planetary development with already seen Mars' history assuming absence of tectonic plates. The Earth and its current global location of continental mass, however does not reflect tendency for its decrease in movement. The only exception is the zone of mid-oceanic range Gakkel under the North Pole which creates natural barrier between Nansen Basin and Fram Basin. The phenomenon happens due to keeping of current state or even increasing the speed of spreading in the rift valley zone.

Also, frequent volcanic and seismic activity can push the slow movement half rotation out of the balance. The unbalanced effect can even happen in the zones of Antarctica and also in the close vicinity of South Pole with unbelievable magnitude of 8.2°, close to the end of 20th century (Hutton, 2001). The lesser important effects would be the astronomical once; wondering of cosmic masses, changes in Milanković orbital elements, ice age triggers, etc.).

Every dominant geodynamical change on the planet will reflect on the pole rotation trajectory and its position. Milanković also sees this. His prediction is there will be many unexpected changes from calculated locations, even drastic differences and increased distances between rotation poles. This will happen over a long time period.

Assumed reasons of plate and rotation pole movements Besse and Courtillot (1991, 2002) find in temperature changes and critical temperature points on the border between mantle and Earth's crust. The two scientists use these facts to say the Earth's interior is more stable. On the other hand, the same facts cause the unstableness of continents, axis of rotation and planet's position in space.

Apart from mathematical (Rangarajan & Barreto, 2000), astronomical way, it is possible for the problem of more accurate time units to be found we could use geophysical (Greiner-Mai, 1989) and geodetic methods (Seidelmann & Wilkins, 1992). International Laser Ranging Service's data (Dickman, 1977) like paleomagnetism (Richards et al., 1977; Gordon et al., 1984; Scotese & Barrett, 1990) play an important role. They offer a way to see former (million years old) changes in rotation pole location allowing also research for regular development of these changes that can be taken to the future. The equations used in paleomagnetism to find pole location in the Earth's geological past, for example, are identical to Milanković's equations (1) and (2). We can get more accurate values using paleodeclination average values like time internal critical values (Van der Voo, 1990).

A better correlation and even more accurate pole location age can be obtained using absolute age methods (radioactivity age). Milanković points these methods to be priceless (namely K-Ar, Rb-Sr, $^{238}U/^{206}Pb$, $^{235}U/^{207}Pb$, Sm-Nd, Re-Os, etc.).

Finally International Earth Rotation Services (IERS) gives outstanding data on rotation pole changes.

All the above suggests several processes will certainly see in the future. They could impact calculated mathematical trajectory of rotation poles. This geodynamical development is as follows:

☼ continuation of East Pacific and Mid-Atlantic ocean spreading; especially their increased or decreased translation and rotation;

☼ decay of some parts of lithosphere, especially along African and Eastern African rift, and continuation of its movements towards north, thinning Mediterranean, further growth of Alps, Red Sea spreading and seismic reaction along Anatolian fault;

☼ lift of cordilleran system along the border of North American and South American plate with Pacific plate, disappearing of micro plate Huan de Fuca further reduction of Cocas plate and seismic activity along San Andreas fault and Alps systems;

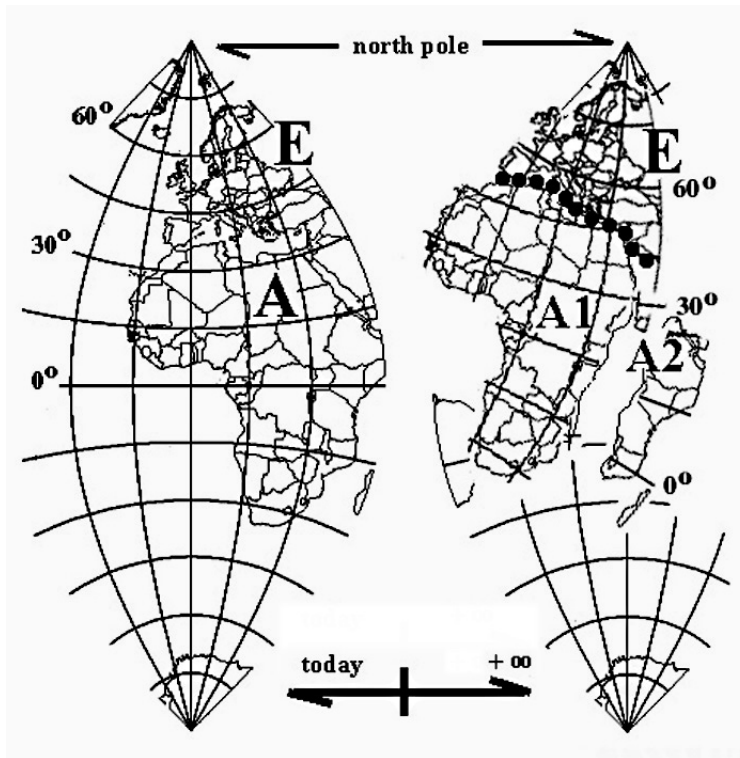☼ activation of "ring of fire" through volcanic activity, earthquakes and subduction.

Figure 5: Modern disposition of continental areas of African and western part f Euroasian plate (left) and arrangement of the same areas in the infinity future (right). African plate will separate into two parts through East African Trench (A1 and A2) and Mediterranean Sea will be smaller for 80% (mark with dots). Glacier zone will reach 30° north of equator and it will cover northern part of African plate A1.

Considering all of the above stated, we can shaw continental locations in infinite future (Fig. 5). Assuming Northern Hemisphere to be the place where most continents will be gives it more importance then southern. Also, it will directly determine future climatic zones.

Also, the most continental margin, collision, volcanic activity, earthquake, glacier phases, etc. belongs to Northern Hemisphere. This makes Northern Hemisphere dominant in geodynamics and geohistorical development and importance, and also secular rotation pole movement.

4. CONCLUSION

Milanković "end of the world" presents final phase in geological stages of planet's development of its geodynamical – mechanical - climatological conversion. Milanković's "end of the world" could bring Earth to sterile phase today seen on Mars. Milanković unfortunately could not define time of same rotation pole locations (impossible to be done today, too). It was necessary to will know state and development processes in Earth's nucleus, changes in magnetic field intensity, and main cause of these changes, basic characteristics geodynamo and relation with reserve changes in Earth's magnetic field. Also, necessary to understand was the stage in astenosphere (especially geothermal and geochemical processes), seismic, riftogenesis, total mass and speed of half-decay of radioactive elements in the Earth's interior and many other factors.

The described "end of the world" doesn't present the end of cosmic phase of the Earth hence in that sense does not support astronomical determinations. Milanković presented mathematically kinematic planetary model of continents, but assuming further survival of water, atmosphere and life on the planet.

According to Milanković's "end of the world" is only the end of tectonically plates, final temperature and fluidal fall in the astenosphere, final stage of seismic phase, riftogenesis, subduction and probably radioactivity. All of these together will have no further consequences especially not on Earth's nucleus and Earth's magnetic field.

Finally, Milanković's "end of the world" presents minimum of mechanical secular rotation pole movement. The planar rotation like space body stays unchanged or slightly changed.

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