Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 12 Issue 4, April - 2025

Mountains, the Pegs and Anchors of the Earth's Rotation Motion

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***Abstract*— Why is the Earth always stable and in dynamic equilibrium on its orbit?**

Vibration caused by mass imbalance is a common problem in rotating bodies like wheels and rotating machines. It's an important engineering problem to eliminate the vibrations of a rotating body. Imbalance occurs when the principal axis of the body's inertia is not aligned with its geometric axis. The Qur'an talks about mountains and their usefulness several times over 1400 years ago. It presents them as stabilizing pegs and anchors that ensure the dynamic equilibrium of the Earth's globe and its stability. This role isn't explained, although mountains are said to play an important role in this regard. The Qur'an says that it is a great role, greater than the role of stopping the movement of tectonic plates. If the mountains were made like pegs and anchors, it is to ensure the dynamic equilibrium of the Earth's globe, not to stop parts of the Earth as in the theory of plate tectonics. Therefore, the goal of this work is to show how mountains stabilize the Earth's rotation. This is a physical phenomenon that, until now, imperceptible to humans. This work is an introduction to highlight the role of mountains stabilizing corrective weights of the Earth's globe motion.

Keywords*— *Mountains stabilizers; pegs; anchors; Earth's rotation; Earth's irregularities; Moment of inertia; Earth's tensor of inertia; Earth's balancing corrective masses.

I. INTRODUCTION

The Earth's rotation is a fascinating subject that has long attracted the interest of scientists in various fields, including geologists, geodesists, geophysicists, and astronauts. The main studies of the Earth's rotation focus on the study of changes in angular velocity, the determination of the variation of the length of day (LOD), the flattening, and the tilt of the Earth's spin axis relative to the ecliptic plane. The factors that have been most extensively studied about the Earth's rotation include both oceanic and solid tides, atmospheric wind, solar wind, ocean movement, plate motion, earthquakes, and all anthropogenic activities that contribute to global climate change. Research on the effects of these factors on Earth's rotation often uses the tensor of inertia and the conservation of angular momentum theorem to analyze changes. The Euler-Liouville equation is used to describe the Earth's rotation, with the moment of inertia tensor playing a key role [2]. Changes in the Earth's mass distribution, resulting from any process like the melting of ice due to global warming, alter its moment of inertia tensor and thereby affect its rotational motion. Nevertheless, studying the physical mechanisms associated with the Earth's rotation helps us understand the complicated geophysical phenomena that govern its motion, and developing effective strategies to control and predict the Earth's motion requires this knowledge. Research in this field is crucial for developing related scientific disciplines and generating new ideas for research advances and science fiction topics.

II. THE ROLE OF THE MOUNTAINS

Mountains may appear motionless, but they're in constant motion due to the Earth's rotation around itself. The mountains at the Earth's equator, for example, move at a tangential speed of about 1672.5 km/h due to the Earth's rotation. Mountains between the equator and the Earth's rotational axis move at different speeds, but all their speeds are less or equal to the value of 672.5 km/h. A stunning effect is that mountains appear as if they are motionless for us but in reality, they move at the speed of clouds and some airplanes [3] due to the Earth's rotation. These movements are governed, to a first approximation, by the laws of classical mechanics of the material point. The purpose of this study is to show that mountains are pegs and anchors stabilizers that stabilize the Earth's rotational motion. In this paper, we will show that the real function of mountains as corrective masses is to regulate the Earth's motion. We have come to this conclusion because the Qur'an mentions this role several times. Therefore, the other roles should be considered minor. This underscores the significance of mountains in the grand scheme.

III. OBJECTIVES AND RESULTS

This study aims to discover the effect of mountains as pegs and anchors stabilizers on the Earth's rotation motion. The application of Newton's laws to the forces acting on a physical system of the mountain leads us to find out the equation of the rotation of the Earth. Solving this equation we found that the angular acceleration oscillates with an amplitude of $\sim 3.95 \times 10^{-21}$ rad.s^{-2}[4]. The analysis of the results we obtained shows that a single mountain, if it existed alone, would destabilize the Earth and hide all the effects of the tides on the rotation of the Earth causing it to shake. What prevents us from seeing this kind of shaking is the fact that the mountains that exist on

Earth are numerous and properly and fairly distributed in relation to each other, although they seem to have been randomly anchored into the earth's crust to act as stabilizers. There are several thousand mountains and seamounts on the globe, and the Earth's crust also contains many other irregularities. Thus, the effects of the mountains and anomalies and their antipode anomalies on the Earth's motion cancel out each other, and thus its stability is constantly maintained. If it weren't for the mountains, the Earth would have been vibrating from the very beginning of its existence and thus would have long since deviated from its orbit. Ultimately, mountains are to the Earth what counterbalancing small corrective masses are to rotating bodies like vehicle wheels: they stabilize the Earth's rotation. Without mountains, the vibrations of the Earth can cause catastrophic failure, as well as noise and discomfort because the entire Earth's globe will vibrate, and sway (i.e. move away) with us. Thus, the mountains are stabilizing pegs that stabilize the Earth's rotation motion while swimming along its helical trajectory following the Sun through space.

The Qur'an presents the mountains as stabilizing pegs and anchors that ensure the dynamic equilibrium of the whole globe and therefore ensure its stability, but it has not been mentioned anywhere in the Qur'an how they function to accomplish this extremely important role. In fact, according to the Qur'an, the role that mountains play as stabilizing pegs should normally be great, miraculous, incredible, and even very great, far more important than the small role of stopping the movement of tectonic plates. If the mountains are made like pegs, it is to ensure the equilibrium of the whole planet Earth, not to stop parts of the Earth as in the theory of plate tectonics. That is why most of a mountain is embedded in the earth's crust. This means that when the Earth was created 4.5 billion years ago, it was initially created without mountains, that is, it was created unbalanced without corrective small masses; and it began to vibrate, tilting to the right and left, moving forward and backward, vibrating in all directions. These disturbances made the Earth's globe shake and tremble, and it did not allow anyone to stabilize on its back. As a result, life on the Earth was impossible in the beginning. Then mountains were created, and the Earth was anchored by mountains, that is, from the moment the mountains were created and returned to the right places on the Earth's crust, surprisingly, the disturbances were pretty much gone, and at the same time, the Earth was stabilized under their force, like a tent that's stabilized by stakes. This is a reality that is impossible for human beings to perceive without the advancement of science in the last centuries of our era, although it was mentioned in the Qur'an more than 1400 years ago.

The objective of this work is to show that the main role of mountains is to regulate and stabilize the movement of the Earth's globe as corrective small masses.

IV. Mountains as Stabilizers for the Earth from the Perspective of the Quran

This research grew out of an idea inspired by several verses in the Qur'an that mention mountains as stabilizers of the Earth's globe. The Qur'an, the holy book read daily by 2.5 billion Muslims worldwide, says that mountains were originally created by God to stabilize the Earth's globe and keep it from vibrating. Specifically, the Quran mentions mountains in two different Arabic keywords, "jibal", which is mentioned 39 times, and "rawasiya", which is mentioned 10 times. In the light of these verses [1], God Almighty says regarding the role of mountains on Earth’s globe:

1. And He is the One Who has spread out the earth and made therein firm mountains (as stabilizers) and rivers, . . . (*The Qur’an*, **13**:3)
2. And the earth – We have spread it and cast therein firmly set mountains (as stabilizers), **(***The Qur’an*, **15**:19**)**
3. And He has cast into the earth firm mountains (as stabilizers), lest it should vibrate/sway (i.e., it move away) with you, . . . » (*The Qur’an*, **16**:15)
4. And We have made firm mountains (as stabilizers) in the earth, lest it should oscillate/sway with them, . . . (*The Qur’an*, **21**:31**)**
5. And you see the mountains, thinking them motionless, while they pass as the passing of the clouds, . . . **(***The Qur’an*, **27**:88**)**
6. He has created the heavens without any pillars that you may see, and has cast firm mountains in the earth, lest it should sway (it move away) with you,... **(***The Qur’an*, **31**:10**)**
7. And He set in the earth firmly set mountains over its surface, . . . (*The Qur’an*, **41**:10**)**
8. And the earth – We spread it out and cast therein firmly set mountains and caused to grow therein every kind of delightful thing. (*The Qur’an*, **50**:7)
9. Have We not made the earth as a bed, and the mountains as pegs? **(***The Qur’an*, **78**:6-7**)**.
Note: In this verse, the used interrogative is mean as an affirmative.
10. And the mountains He anchored firmly (as stabilizers). **(***The Qur’an*, **79**:32**)**
11. And We made in it (i.e., in the Earth) lofty firm mountains and provided you with sweet water to drink. **(***The Qur’an*, **77**:27**)**

As can be seen, the Qur'an mentions mountains as the pegs, stakes, and anchors that stabilize the Earth's rotational motion. The key word mentioned in the Qur'an to describe the formation of mountains is "alqa" in Arabic, which means to throw, to cast, and to bring mountains into existence.

According to verses **13**:3, **15**:19, **16**:15, **21**:31, **27**:88, **31**:10, **41**:10, **50**:7, **77**:27, **78**:6-7, and **79**:32 of the Qur'an, the Earth was "spread out" and the mountains served as stabilizers of the Earth. Accordingly, the Qur'an says that the mountains are pegs, stakes, and anchors of the Earth’s globe. God has never said in the Qur'an that mountains have roots; rather, He says that mountains are pegs, anchors as stabilizers of the Earth's globe, like the stakes for a tent.

According to the theories of Isostasy [5-6], Continental drift [7-9], and Plate tectonics; and since the continents move and drift relative to each other, one can believe that the role of the mountains as pegs is to stop the movement of the tectonic plates, or at least to slow it down so that they do not move more, and thus avoid shaking [10-11]. When these theories tell us that the tectonic plates are moving, we say yes, they are; they are moving, and seismological stations record their movement every day. When they move more, earthquakes occur. The problem, however, is that the mountains themselves aren't immobile as we thought; in fact, they move along with the Earth's crust by a few centimeters per year, depending on their continent. This is because the Earth's crust floats on a molten layer, which means that if the crust moves, the mountain will also move. However, the mountains have been there since the beginning of time 4.5 billion years ago, so they have already been created; and these theories are provisional and therefore may disappear in the future. The data in the Qur'an allow us to understand that the main role of the mountains is not only to stop the continental plates from moving or to limit their movements; the real role of the mountains is much greater than that; their role is to stabilize the motion of the of the entire globe. The Quran clearly states that the consequences of an Earth without mountains are described by the Arabic word "an tameeda bikum," which translates as "lest it shakes with you". Contrary to some translations of the cited Quranic verses, mountains do not prevent the Earth from shaking. God never says the word "shake" or "tremble" in these Qur'anic verses [1]. Furthermore, mountains do not prevent earthquakes or reduce their strength. That is, mountains do not prevent earthquakes from occurring, because earthquakes often occur in mountainous regions [12-14]. In general, earthquake occurs in a limited area around the epicenter, which means that earthquakes affect only very limited regions or some parts of the Earth's globe like the powerful 7.7-magnitude Myanmar (Burma) and Thailand earthquake of March 28; 2025. The Arabic phonetic keywords "waalqa fee al-ardi rawasiya an tameeda bikum" mentioned in the Qur'an are much broader because the subsequent reaction which is "an tameeda bikum" affects the entire globe and not just one of its regions or parts. This means that the phrase "an tameeda bikum" in the Qur'an has nothing to do with tremors known to man. Rather, mountains like seamounts act as corrective masses that balance the total moment of inertia of the globe so that the Earth's globe does not vibrate or sway and move away.

V. The Mountains In Science

In 1865, Delaunay published an article on "The effect of the Tides on the Earth's rotation" in which he showed that the cause of the deceleration of the Earth's rotation was the friction of the tides on the oceanic crust [15]. The hypothesis of Tides slowing down the Earth's rotation was also mentioned by Kant in 1754, more than a century before Delaunay [16]. According to Kant, tides exert a slowing friction on the Earth's rotation due to the irregularities of the ocean seabed, principally islands and cliffs. In 1912, Wegener proposed the hypothesis of "continental drift"[7]. In 1915, he published "The Origin of Continents and Oceans" [8-9]. He exhibited a theory based on a new conception of the terrestrial globe: the continents, floating on a more fluid layer, are mobile on the surface of the globe. United into a supercontinent, the continental masses are separated by the interplay of fractures that become oceans, the continents will drift to their current position; the mountains are thus formed. In their books published between 1920 and 1970, Wegener et al. relied on a thin, dense ocean crust and less dense mountains with deep roots to support the theory of continental drift. They also postulated the permanence of the continental drift movement, where the location is not permanently fixed, but this phenomenon occurs over a geological time scale.

Today, plate tectonic models, and geophysical and GPS satellite measurements seem to confirm Wegener's theory. On the contrary, modern geosciences have proven that mountains have deep roots below the surface and that these roots can reach several times their height above the surface. Thus, the appropriate keyword to describe mountains on the basis of this knowledge is the keyword "root," since most of a properly placed root is hidden beneath the surface of the ground. The theory that mountains have deep roots was introduced in the second half of the nineteenth century [17]. The Airy and Pratt models of isostasy are commonly used to explain the formation of mountains [18]. The Airy model of isostasy tells us that mountains have deep roots below the surface of the ground and that these roots can reach several times their height above the surface of the ground, e.g. Frank Press says in his book entitled "Earth" [19] that mountains have deep roots. Also, mountains have deep roots are mentioned again in the Hicks' book [20]. This can also be found in many other sources. These roots are deeply embedded in the earth's crust, which is why mountains have the shape of pegs.

Moreover, the modern theory of plate tectonics also states that mountains have deep roots and play an important role in stabilizing the Earth's crust [21] because they interfere with the shaking of the Earth. This is also found in many other bibliographic sources [22-23]. In particular, Airy estimated that the density of the crust is largely the same in all continental regions and therefore concluded that topographically higher regions must be compensated by crustal roots at depth. Seismic studies in many mountain belts show that most regions of high surface elevation are indeed compensated by significant deep roots. So many bibliographic resources rightly talk about mountain roots providing balance and stability to the Earth's lithosphere.

Regarding the nomenclature of mountains as pegs rather than roots, it is clear that an object cannot serve as a peg unless it performs the function of a peg by contributing significantly to the stability of another object, such as a tent. The term "peg" becomes superfluous when the object is not used to secure an animal or stabilize an object. Pegs, stakes, and anchors are typically made of materials such as wooden branches, metal rods, concrete, etc. This is different from the roots that naturally grow at the base of trees. This distinction explains the Quran's use of the terms "pegs" and "anchors" to describe mountains as stabilizers of the entire globe.

VI. EARTH'S TENSOR OF INERTIA

The angular velocity and, consequently, the length of the day (LOD) of the solid Earth is subject to change due to the torque generated by forces acting upon it and due to alterations in the mass distribution of the Earth's globe [4]. The length of the day (LOD) can also be determined from the variation of gravity. Before we proceed, it is necessary to provide a brief explanation of the Earth's tensor of inertia. The tensor of inertia is a measure of the mass distribution inside the Earth. The mass distribution with mountains in the Earth's crust that we observe today is not the same as that just after the creation of the Earth 4.5 billion years ago. Initially, the Earth was formed without mountains [1]. So the tensor of inertia of the Earth's globe without mountains had to be very different from that of an Earth's globe with mountains. Nonetheless, the mass distribution is not only the solids, it's also the atmosphere, the terrestrial crust with its mountains, defects, faults, and mine deposits, the ocean, and the hydrosphere, as shown in Fig. 1.

It is evident that anomalies and defects exist in the Earth's crust and the mountains are the corrective small masses that balance the Earth's anomalies and defects. Mountains are for the Earth which are balancing small corrective weights for a vehicle wheel and rotating machinery. In this regard, an analogy between the Earth and the wheel of a vehicle is evident: the Earth's crust is the analog of the tire, the continental mantle of the Earth and its core are the analogs of the wheel's rim, and the mountains are the analog of small wheel balancing masses, and the axis of rotation of the Earth is the analog of the vehicle hub. The role of the wheel balancing corrective small weights is to eliminate vibrations in the vehicle's wheel. Various forces that perturb the Earth's rotation [24-25] are analogous to the friction of the wheel with rolling, asphalt, and air, as shown in Fig. 1.

The study of the Earth always considers mountains as integrated components of the Earth's crust. We believe this approach is incorrect. Mountains must be studied as independent physical systems. The mountains' effect must be considered along with that of the tides, the atmosphere, and all other disturbances. Most studies interested in determining

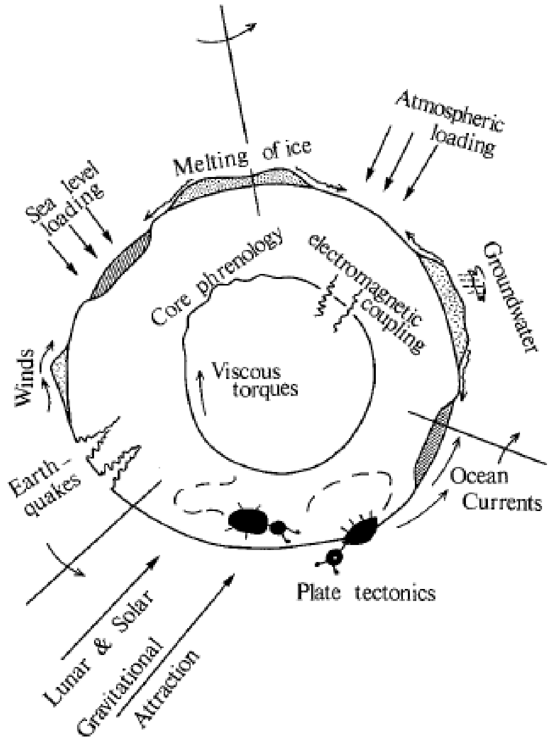


Fig. 1. *Schematic illustrations of the forces that perturb the Earth's rotation (from Lambeck, Nature 286, p. 104, 1980)* [24-25, 42]. *The core topographic refers to R. Hide's model of topographic coupling. The beetles refer to T. Gold's representation of continental drift. Réf. K. Lambeck.*

the change in the length of day (LOD) consider the rotation of the Earth around its axis. These studies consider the Earth, with its mountains and defects, as a single physical system, and this assumption is not correct in our opinion. The angular velocity at which the Earth rotates, and thus the LOD, changes due to the action of torques on the Earth and changes in the Earth's mass distribution. Moment of inertia changes can be studied using the Earth's tensor of inertia in both isotropic and anisotropic cases [26].

In principle, the moment of inertia of the Earth's globe can be calculated with respect to arbitrary axes. Let X, Y, and Z be the coordinate system with its origin in the geocentric reference frame, where axis Z is the orbital axis of the Earth and axis X points to the prime meridian. Let the Earth's principal moments of inertia be A, B, and C, and the corresponding principal axes of inertia be axes a, b, and c. Since the Earth is not a regular sphere, the inclination of the Earth's principal axis of rotation (c) with respect to the perpendicular axis (Z) to the plane of the ecliptic is equal to ~ 23°26', as shown in Fig. 2 & 3 hereinafter. So, the Earth's tensor of inertia that changes in time can be written as,

$$\bar{I}(t)=\begin{bmatrix} I_{11} & I_{12} & I_{13} \\ I_{21} & I_{22} & I_{23} \\ I_{31} & I_{32} & I_{33} \end{bmatrix} \quad (1)$$

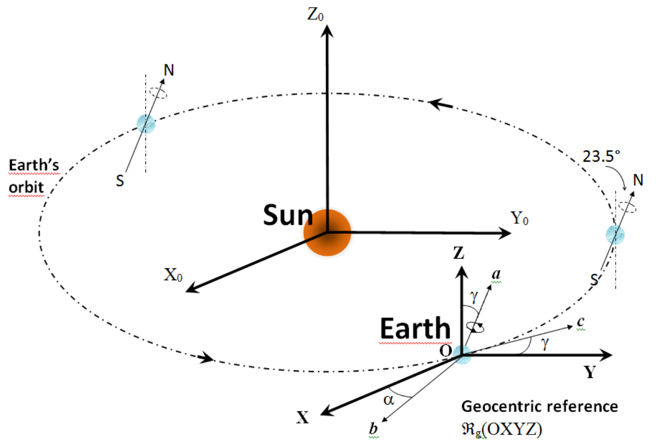


Fig. 2. *The relationship between the Earth's principal axes (a, b, c) and (X, Y, Z) axes system.*

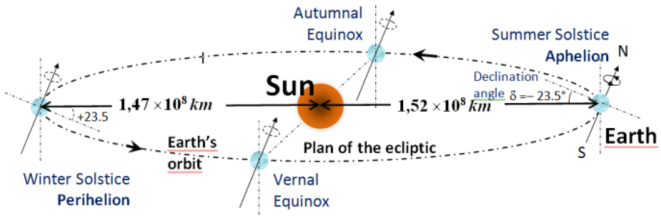


Fig. 3. *Exaggerated Earth's elliptical orbit around the Sun, showing the Aphelion and Perihelion orbital extreme points. Earth is farthest from the Sun when it is summer in the Northern Hemisphere.*

It should be noted that this matrix has nine elements, so in fact, it's there are six elements that are important, we have $I_{12} = I_{21}$, $I_{13} = I_{31}$, and $I_{23} = I_{32}$. The elements of the moment of inertia $I_{i,j}$ (i, j = 1, 2, 3) are computed by these integral over x, y, z coordinates where, $I_{11} = \iint_{yz} (x^2 + z^2) dm$, $I_{22} = \iint_{xz} (x^2 + z^2) dm$ and $I_{33} = \iint_{xy} (x^2 + y^2)\, dm$; and the other elements of the tensor of inertia are $I_{12} = -\iint_{xy} xydm$, $I_{23} = -\iint_{xy} yzdm$ and $I_{13} = -\iint_{xz} xzdm$ where $dm=\rho(r)dV$ [27-28], so these are the theory about the formula for calculating the tensor of inertia of the Earth.

In general, the Earth's tensor of inertia also can be written in terms of two other tensors as,

$$\begin{bmatrix} I_{11} & I_{12} & I_{13} \\ I_{21} & I_{22} & I_{23} \\ I_{31} & I_{32} & I_{33} \end{bmatrix} = \bar{I}(t) = \underbrace{\begin{bmatrix} A & 0 & 0 \\ 0 & B & 0 \\ 0 & 0 & C \end{bmatrix}}_{const\ tensor} + \underbrace{\begin{bmatrix} C_{11} & C_{12} & C_{13} \\ C_{12} & C_{22} & C_{23} \\ C_{31} & C_{32} & C_{33} \end{bmatrix}}_{variable\ tensor} \tag{2}$$

It is imperative to understand the connection between the tensor of inertia and gravity. That's the important question. It is known and proven by **Chen *et al.*** [27-28] that the C_{20} formula of spherical harmonics of the gravitational potential is,

$$C_{20} = (1 + k_2^{'}) \frac{1}{2MR^2} \int_M (2z^2 - x^2 - y^2)\, dm \tag{3}$$

The coefficient $k_2^{'}$ is the second Love number.

So now, that's interesting, we see something in equation (3) which is very similar to the integral formula for the tensor of inertia into the equation (1). Then, this integral relate to the inertia I_{ij}(i, j =1, 2, 3) elements of order 2 according to,

$$C_{20} = (1 + k_2^{'}) \frac{1}{MR^2} \left[\frac{I_{11} + I_{21}}{2} - I_{33} \right] \tag{4}$$

The interesting part here is that the second-order spherical harmonic coefficient of the Earth can be written in terms of elements of the Earth's tensor of inertia. If we want to calculate the third one, $I_{33}(t)$, it's a function of time, it is changing in time. And solve it from equation (4), we can simply write *the* $I_{33}(t)$ axial element as,

$$I_{33}(t) = \frac{I_{11} + I_{21}}{2} - MR^2 \frac{C_{20}(t)}{1 + k_2^{'}} \tag{5}$$

C_{20}(t) a second-degree harmonic of the gravitational potential has a direct relation with *the* $I_{33}(t)$ axial element which is the third moment of inertia around the Z-axis or the third axis. So, if we define the trace of the matrix in equation (1) will be summation of its diagonal elements, then we can simplify writing the axial element $I_{33}(t)$ in terms of this trace by adding and removing the element I_{33} into the right side of equation (5) and making some arrangement calculations, the third moment of inertia becomes,

$$I_{33}(t) = \frac{1}{3} Trace\left(\bar{I}(t) \right) - \frac{2}{3} MR^2 \frac{C_{20}(t)}{1 + k_2^{'}} \tag{6}$$

The Earth's tensor of inertia is decomposed into two tensors, as shown in eq. (2). If we want to get the variation of C_{33}, it's simply we can write $C_{33} = I_{33} - C$, and the constant C goes to the other side. The variation of this term is constant. Thus, the variation of the term C_{33} in eq. (2) is a function of the variation of second-order spherical harmonics C_{20}(t) as,

$$C_{33}(t) = \frac{1}{3} \Delta Trace(\bar{I}(t)) - \frac{2}{3} MR^2 \frac{\Delta C_{20}(t)}{1 + k_2^{'}} \tag{7}$$

So we could find the variation of C_{33} in the variation of the third moment of inertia I_{33}. Why it is the third moment of inertia? The third moment of inertia I_{33} is a somehow rotation around the third axis or the rest rotation axis. If this rotation of rest actually changes, then the length of day (LOD) also changes. According to **Lambeck** [24-25,29], the changes in the length of the day, ΔLOD, in time over the mean length of the day, LOD, are

$$-\frac{\Delta \mathrm{LOD}}{\mathrm{LOD}} = m_3(t) = \frac{-1}{C_m \omega}\left[\Delta h_3(t) + \left(1+k_2^{'}\right)\Omega\, C_{33}(t)\right], \quad (8)$$

where ω is the mean angular velocity of the Earth, ω=7.292115×10^{-5} rad.s^{-1} [30], C_m is the polar moment of inertia of the earth's crust and mantle, and the term h_3(t) is due to motion relative to the rotating reference frame. After simplification of equation (8), we get

$$\frac{\Delta \mathrm{LOD}}{\mathrm{LOD}} = \left(1+k_2^{'}\right)\frac{C_{33}(t)}{C_m} + \frac{\Delta h_3(t)}{C_m \omega} \quad (9)$$

It has proved that the trace is very small. The variation of the trace is almost zero, i.e. ΔTrace(I(t))≈ 0. Thus, the trace is gone in the eq. (7). The, keeping terms to first order in perturbed quantities, the axial component C_{33}(t) changes into eq. (2) can be written in the absence of external torques as (e.g., Munk and MacDonald [31]; Wahr [32]; Barnes et al., 1983 [33]),

$$\frac{\Delta \mathrm{LOD}}{\mathrm{LOD}} = \frac{\Delta h_z(t)}{C_m \omega} - \frac{2}{3C_m} MR^2 \Delta C_{20}(t) \quad (10)$$

DOL = *86400 s*, C_m = 7.1242×10^{37} kg-m^2, ω=5.292115×10^{-5} rad/s, masse of the Earth M=5.9736×10^{24} kg, R is the radii. And after some arrangements, we can easily get

$$\Delta \mathrm{LOD} = \frac{\mathrm{LOD}}{C_m \omega}\left[\Delta h_z(t) + (1+k_2^{'})\,\omega\, \Delta I_{zz}(t)\right], \quad (11)$$

where the coefficient $k_2^{'}$ is the Love number; k^2≈–0.244 [25]. The change ΔLOD in the length of the day is related to m_z(t) by ΔLOD/LOD = – m_z(t), LOD is the nominal length of day of 86400 s, C_m is the polar moment of inertia of the Earth's crust and mantle, and the factor of $1+k_2^{'}$ = 0.756 into the eq. (11) accounts for the yielding of the crust and mantle to imposed surface loads [26].

Equation (11), which is called here the length of day equation, will be used to compare the observed length of day changes with modeled variations computed using the products of atmospheric and oceanic general circulation models. The gravitational potential of the Earth is the result of different perturbing acceleration phenomena. Therefore, you have to somehow consider ΔC_{20} as the change due to the gravity, you need to consider the solid tide, atmospheric pressure, and ocean tides. You have to calculate these effects and you know how to compute these things and remove them from the determined ΔC_{20} coefficient. Then what you get is residual is the corrected one. Then, you will come to the variation of the length of day (ΔLOD). The atmospheric pressure should be added back because it is some part of this Earth system. Atmospheric pressure is always around the Earth but the solid tide is the thing that comes and goes so there are periodic variations so this is permanent. The pressure of the mountains that are firmly fixed to the Earth should be added buck.

It should be noted that without the existence of mountains on the earth's crust, the Earth's rotation will deviate strongly from a state of uniform rotation, the globe will move back and forth around the axis of rotation (c), causing this axis to vibrate, and it will also tilt to the right and left around one of its axes A and B, see Fig. 2 and 3 above. The study of the Earth's moment of inertia tensor becomes more complex due to the absence of mountain disturbances. Here we have deliberately limited ourselves to the ellipse model to further clarify the effect of the mountains on the stability of the Earth's motion.

In general, the variation of the LOD can be the measure of the deceleration of the rotation of the Earth around its axis (c) due to various disturbances such as surface pressure due to Earth tides, ocean tides, ocean currents, atmospheric winds, friction of ocean water with undersea mountains, climate change effect, melting of the north pole, etc. These studies always involve the rotation of the Earth around a single axis, the axis (c). The role of mountains as stabilizing anchors of the Earth's rotation has never been on the agenda. In the studies of the Earth, mountains have always been confused with the Earth's crust, even more often they have been considered as a homogeneous solid body.

The phenomenon that concerns us in this work is completely different; it involves the vibration of the Earth in all directions as if it were swaying as if there were no mountains before the achievement of its dynamic equilibrium. To understand this, we must be able to imagine the terrestrial globe with and without mountains 4.5 billion years ago!

The mountains play the role of stabilizing small corrective masses of the rotation of the Earth, and to modulate this crucial role, we can continue the calculation using a concept similar to the geoid model [34]. Geophysicists and geodesists generally use the ellipsoid model [35-36] to study the Earth's globe and thus avoid the problems of irregularities of the earth's crust. This makes it easy, for example, to calculate the elements of the Earth's tensor of inertia. However, since the Earth's ellipsoid is only strictly valid on a large scale, it is as smooth as a billiard ball and does not take into account any irregularities such as mountains or valleys. From this point of view, the ellipsoid is the shape closest to the true shape of the Earth, because the Earth is slightly flattened at the poles and bulges at the equator [37]. Nevertheless, the ellipsoid is only a mathematical model, and we must take into account the real shape of the earth's crust as it is. Therefore, we should use a concept like the geoid to see how the Earth behaves without mountains and with mountains.

VII. THE GEOID VERSUS THE ROLE OF THE MOUNTAINS

The aim is to highlight the effect of the existence - or not- of mountains as stabilizers of the Earth as a physical system. It is known that the Earth is an oblate spheroid [37-40]. Moreover, it should be noted that the greatest difference in height of the solid Earth is about 11 km (Marianas) + 8 km (Everest) = 20 km. Compared with 6371 km, the average radius of the planet seems barely perceptible to the eye, but the mountains is so important that they stabilize the entire Earth's globe. Today, the "real" shape of the Earth is approximated by the geoid. The geoid is a model of the global mean sea level that is used to measure precise surface elevations (z=U/g where U is the potential and g is the acceleration of gravity, g=9,82 m/s^2 at Casablanca city) with a high degree of accuracy. According to an animation published by the European Space Agency, which simulates the real shape of the geoid's rotational motion in space [41], although the geoid appears to have a smooth, regular shape, this is not the case; it shows how the geoid represents deviations from the Earth's ellipsoid. Although it has 'highs' and 'lows', it is a surface of equal gravitational potential U, as shown in Fig. 4.

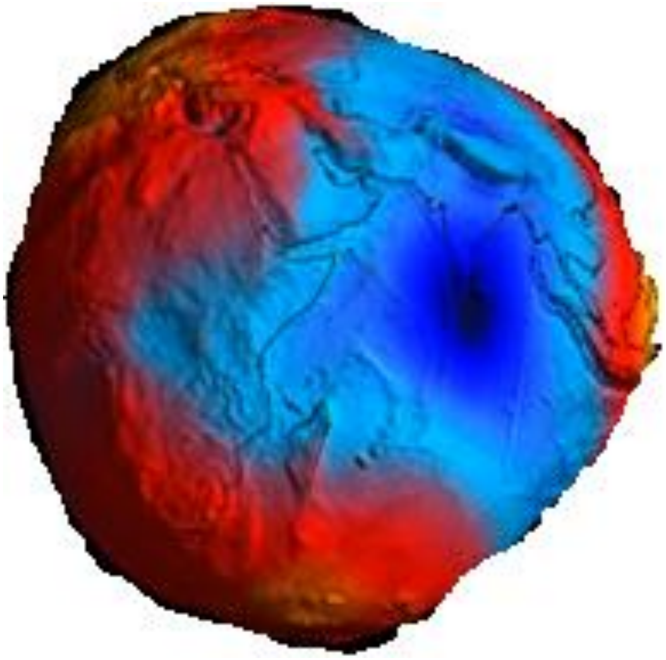


Fig. 4. *This geoid view is from the video in [41]. Yellow/red color is where gravity is the strongest and blue is the weakest. It shows how the geoid represents deviations from the Earth's ellipsoid. The lighter the area "yellow" would have a higher elevation than orange or red.*

It is evident that the dark deep blue area, which appears as a hole in Fig. 4 in Sri Lanka, South India, corresponds to the lowest gravity on the globe. However, the geoid is a surface where the gravitational potential, denoted U, is the same everywhere, see Fig. 5. It best corresponds to the mean sea level. Place a ball anywhere on the geoid surface and it will not roll. The irregular shape of the geoid shows that the density of the Earth is not uniform; it is unevenly distributed both on the surface and in the volume, meaning that some areas of the planet experience a greater gravitational "pull" than others. The Earth's gravity varies in different areas of the planet because of the different densities of the various materials that make up the planet. Much of this mass is in a state of flux, and the geoid can change over geologic time scales. Because of these variations in gravitational force, the height, N, of different parts of the geoid is constantly changing, moving up and down in response to gravity, as shown in the rotating geoid in the animation in Ref. [41].

The geoid has an irregular shape with a wavy appearance; there are elevations in some areas and valleys in others. The colors of the image in Fig. 4 represent the height of the geoid surface above or below the WGS84 ellipsoid surface. Red is high, blue is low. When we measure heights, they must be relative to some zero level, usually sea level; but even sea level can change. The geoid is a global height plane that approximates sea level throughout the planet. The geoid, as measured by satellites, makes it possible to distinguish the flattening of the Earth, the equatorial ridge, the undulations of the geoid, and the shape the Earth would have if it were uniformly covered by oceans at rest.

Figures 6 and 7 show possible shapes of the terrestrial globe and equipotential surfaces of the geoid on a large scale. In Fig. 6, points A and B are on two different equipotential surfaces, i.e. they are not at the same height, since one has to work against gravity to move from point A to point B. On the contrary, points A and C are on the same equipotential surface. If an object were placed on the geoid at any two points A or C, it would not move.

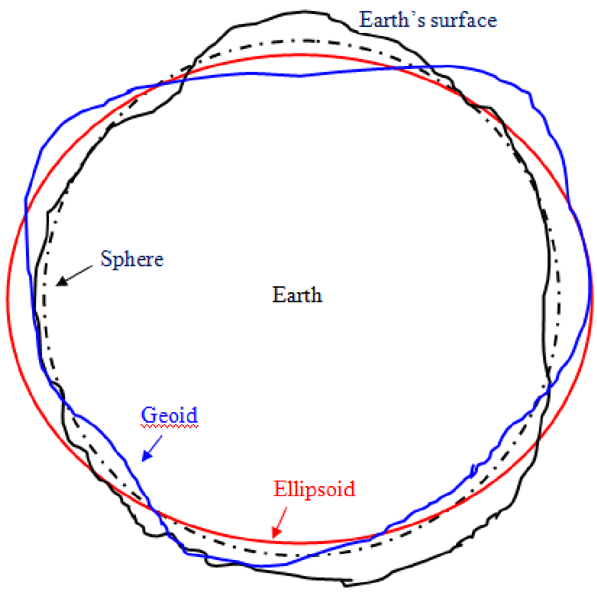


Fig. 5. *Earth's surface, sphere, ellipsoid, and geoid on a large scale.*

As for the causes of geoid elevations, there must be lateral variations in the density of the Earth. The presence of a local excess of mass at a point above the reference ellipsoid, especially mountains, as shown in Fig. 8, must warp the surface outward to keep the total gravitational potential constant. Variations in geoid height, N, relative to a reference ellipsoid represent undulations that vary by about ± 100 m. For comparison, the contribution of changes in continental water stocks at geoid height, N, is only a few centimeters. A trough especially the valleys, leads to a geoid lowering, see Fig. 8. And, at a smaller scale, there is topography — mountains have more mass than a valley and thus the pull of gravity is regionally stronger at mountains.

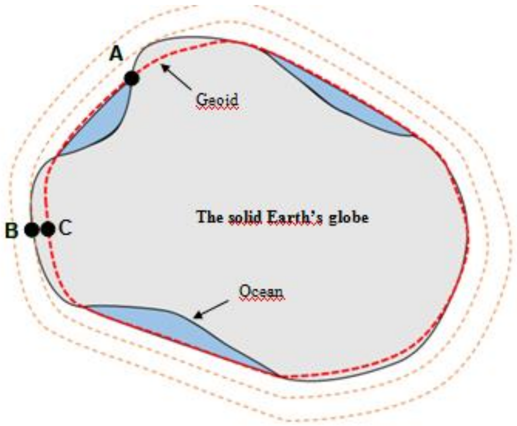
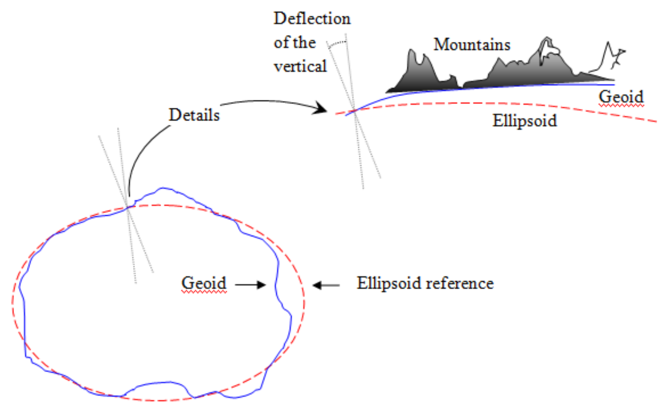
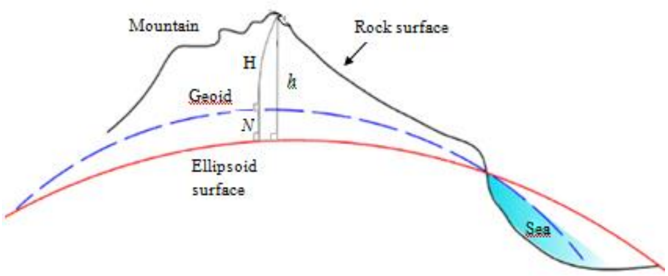


Fig. 6. *The dashed lines represent the large-scale equipotential surfaces of the Earth's gravity. The equipotential surface coinciding with the mean sea level is the geoid* [42-44].



(a) Large-scale depiction.



(b) Smaller scale details.

Fig. 7. *Shapes of the Earth's surface, the geoid surface, and ellipsoid surface reference. Variations in geoid height, N, relative to a reference ellipsoid represent undulations*.

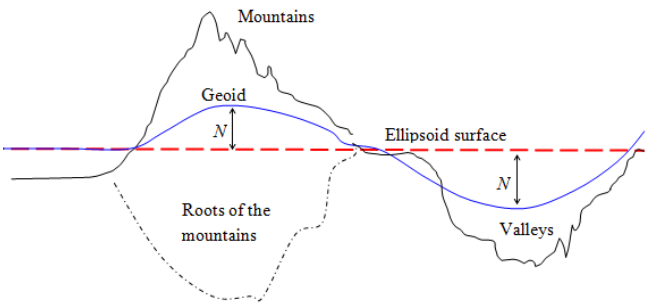


Fig. 8. *On the left, mass excess (mountains and their roots) on the reference ellipsoid surface. On the right, mass defect (valleys) beneath the reference ellipsoid surface.*

Also, the presence of a high-density mass below the ellipsoid surface reference, such as the roots of mountains, deposits of mine such as iron mines, etc., causes an elevation of the geoid. On the contrary, a hollow of lower density, e.g. the dark deep blue area appearing as a hole in Sri Lanka, South India in Fig. 4, or the Canadian shield level, causes a lowering of the geoid. As we can see, the geoid is the irregularly shaped "ball" that scientists use to more accurately calculate the depth of earthquakes or other deep objects beneath the Earth's surface. Satellites such as GRACE and LAGEOS are widely used to measure the temporal variations of the geoid.

If the globe were a perfect sphere, then calculations of depth and distances would be easy because we know the equations for these calculations on a sphere. However, the Earth is more like an ellipsoid. Ellipsoid calculations aren't as easy as spherical calculations, but they're still known and doable. Anyway, we all know that the Earth is not really an ellipsoid, because there are oceans, mountains, roots of mountains, deposits of mines, cliffs, faults, valleys, etc. that are not part of an ellipsoid. The geoid is an imaginary sea level surface that undulates (has a wavy surface) over the entire globe; it's not just for the oceanic areas; it extends through the solid land masses as well.

Locally and on very small scales, i.e. regional scales, based on the concept of the geoid; the moment of inertia relative to the center of the Earth of an area occupied by a mountain, for example, is greater than the moment of inertia of a valley. Therefore, their moments of force are also incomparable. So the Earth's moment of inertia tensor is not uniform. Calculating the moments of inertia of mountains on smaller scales, mountain by mountain, square meter by square meter, will allow us to obtain a tensor of moments of inertia more complex than that of an ellipsoid shape. It will be a colossal task to be accomplished. It is therefore the tensor of inertia of such mountains that ensures the stability of the rotation of the Earth. First of all, mountains are heavier than waves of tides and the atmosphere.

To obtain a swaying Earth, simply remove the mountains in the simulation software. Without the mountains, you will see the planet Earth swaying and vibrating. In the simulation shown in the animation in Reference [41]; if the mountains are removed, then the planet Earth will sway and vibrate. The Earth turns in dynamic equilibrium because of the existence of the mountains. Thus, the mountains play the role of corrective masses, as in rotating machines.

The Earth's rotation is perturbed by mass redistributions and relative motions within the Earth's system, as well as by torques from the Earth's interior and from celestial bodies [45]. The GRACE satellite mission has been measuring the Earth's gravity field and its temporal variations since 2002. Although these variations are mainly due to mass transfer within the geofluid envelopes, they also result from mass displacements associated with phenomena such as glacial isostatic adjustment and earthquakes [46-47]. However, the calculation we have performed in this paper is highly simplified. For a complete calculation, it is necessary to consider changes in the Earth's inertia tensor due to mountains, faults, and irregularities [48]. We do not know what all the physical quantities we have calculated will be when the calculation is complete and more in-depth.

As a perspective, using an accurate 3D model of the Earth's globe, one can run some simulations that simulate the actual shape of the Earth's globe, both with and without mountains. As we try to visualize what the planet might have looked like 4.5 billion years ago, we expect an Earth without mountains to shake and vibrate.

Conclusion

The mountains and their usefulness for the terrestrial globe are mentioned several times in The Holy Qur'an [1]. Especially, The Qur'an presents the mountains as stabilizing pegs and anchors that ensure the dynamic equilibrium of the entire globe while swimming on its helical trajectory around the Sun, and therefore they ensure its stability but it has not been mentioned anywhere in The Quran how they function to accomplish this extremely important role. That is, when the Earth was created 4.5 billion years ago, it was created initially without mountains, i.e. it was created unbalanced; and it began to vibrate tilting to the right and left, going forward and moving backward, i.e. the Earth "vibrates" in all directions. These disturbances made the Earth shake and tremble, and it did not allow anyone to stabilize on its back. As a result, life was impossible on the Earth at the beginning. Then, mountains were created and the Earth became gravitationally anchored by mountains, that's to say from the moment when the mountains were created and returned to the right places on the Earth's crust surprisingly, the disturbances were pretty much gone and the Earth simultaneously was stabilized under their strength effect like a tent stabilized by stakes. It is a reality impossible for humans to perceive without the advancement of Sciences during the last centuries of our era despite the fact that it was mentioned in The Qur'an more than 1400 years ago. In this article, based essentially on some calculations of moments of inertia for the rotating bodies, we have shown how mountains play the role of stabilizing anchors of the Earth's rotational motion and this is one physical phenomenon, up to date, imperceptible to humans. Therefore, this work is an introduction to understanding the role of the mountains as stabilizing pegs and anchors of the Earth's rotation motion.

Acknowledgment

We would like to acknowledge the generous support from Cadi Ayyad University for this work.

References

[1] The Quran, **13**:3, **15**:19, **16**:15, **21**:31, **27**:88, **31**:10, **41**:10, **50**:7, **78**:6-7, **77**:27, **79**:32.

[2] Zhang, W. and W. Shen (2020) New estimation of triaxial three-layered Earth's inertia tensor and solutions of Earth rotation normal modes. Geod. Geodyn. **11**(**5**), 307–315.

[3] Saâd, B. (2024) Mountains and Clouds Motion Similarity and Their Dependencies on the Observer's Reference. M. Ezziyyani et al. (Eds.): AI2SD 2023, LNNS 931, pp. 1–12.

[4] Saad, B. (2023) Earth rotates on itself, the revelation of the Qur'an more than 1400 years ago. Emirati J. Space Astron. Sci. **1**(**2**), 14–37.

[5] Watts, A. B. (2023) Isostasy and Flexure of the Lithosphere. Cambridge University Press.

[6] Dutton, C. (1882) Physics of the Earth's Crust; Discussion. Am. J. Sci. **s3-23**(**136**), 283–290.

[7] Wegener, A. (1912) The formation of continents. Geol. Rundsch. **3**(**4**), 276-292.

[8] Saigeetha, A. F. and R. Banyal (2005) Alfred Wegener—From continental drift to plate tectonics. Reson. **10**(**6**), 43–59.

[9] Chander, R. (1999) Wegener and his Theory of Continental Drift. Reson. 4**,** 24–41.

[10] Ibrahim, M. A. (2019) The mountains as stabilizers for the Earth from Quranic perspective. Proc SOCIOINT 2019 Istanbul, Turkey, pp. 1231–1237.

[11] Ibrahim, M. A. (2020) Mountains as stabilizers for Earth from the Quranic and modern science perspectives. IJASOS- Int. J. Adv. Social. Sci. **5**(**15**), 1287–1292.

[12] Saâd, B. (2024) On the Causes of EarthQuake Lights. In M. Shelley & O. T. Ozturk (Eds.), Proc of ICRES'2024, Antalya, Turkiye, pp. 951–965.

[13] Cheloni, D., N. A. Famiglietti, C. Tolomei, R. Caputo and A. Vicari (2024) The 8 September 2023, Mw 6.8, Morocco earthquake: A deep transpressive faulting along the active high Atlas mountain belt. Geophys. Res. Lett. **51**(**2**), 1–10.

[14] Huang, K., G. Wei, K. Chen, N. Zhang, M. Li, and L. Dal Zilio (2024) The 2023 M_w 6.8 Morocco Earthquake: A Lower Crust Event Triggered by Mantle Upwelling? Geophys. Res. Lett. **51**(**12**), 1–9. https://doi.org/10.1029/2024GL109052

[15] Delaunay, M. (1865) On the existence of a new cause having a significant influence on the secular equation of

the Moon. J Pure Appl Math, Series 2, 10, 401–411. (in French).

[16] Hastie, W. [tr. & ed. I. Kant, 1754] (1900) Examination of the Question whether the Earth has undergone an Alteration of its Axial Rotation. Kant's Cosmogony, Glasgow: James MacLehose and Sons. 1–11. (in French)

[17] Bowie, W. (1926) Notes on the Airy or "Roots of Mountains" Theory. Science **63**(**1632**), 371–374.

[18] Gutenberg, B. (1943) Seismological evidence for roots of Mountains. GSA Bull. **54** (**4**), 473–498.

[19] Cailleux, A. (1968) Anatomy of the Earth. New York, McGraw-Hill Book Company, 1968.

[20] Skinner, B. J. and S. C. Porter (1992) The Dynamic Earth: An Introduction to Physical Geology. John Wiley & Son, New York 1992.

[21] Stuwe, K. (2007) Geodynamics of the Lithosphere. Springer-Verlag Berlin Heidelberg 2007.

[22] Hills, G. (1944) The Roots of Mountains. Geol. Mag. **81**(**2**), 77–80.

[23] Whitchurch, A. (2013) Dense mountain roots. Nature Geosci*.* **6**, 85.

[24] Lambeck, K. (1980) Changes in length-of-day and atmospheric circulation. *Nature* **286**, 104–105.

[25] Lambeck, K. (1980) The Earth's variable rotation: geophysical causes and consequences. Cambridge Univ. Press.

[26] Gross, R. S., I. Fukumori, D. Menemenlis and P. Gegout (2004) Atmospheric and oceanic excitation of length-of-day variations during 1980–2000". JGR Solid Earth **109** (B01406), 1–15.

[27] Zhou, Y. H., J. L. Chen, D. A. Salstein (2008) Tropospheric and stratospheric wind contributions to Earth's variable rotation from NCEP/NCAR reanalyses (2000–2005). Geophys. J. Int. **174**(**2**), 453–463.

[28] Chen, W. and W. B. Shen (2010) New estimates of the inertia tensor and rotation of the triaxial nonrigid Earth. JGR Solid Earth **115** (B12419), 1–19.

[29] Lambeck, K. (1988) Geophysical Geodesy: The Slow Deformations of the Earth. Oxford Univ. Press.

[30] Groten, E. (2004) Fundamental Parameters and Current (2004) Best Estimates of the Parameters of Common Relevance to Astronomy, Geodesy, and Geodynamics. J. Geod. **77**, 724–797.

[31] Munk, W. and G. MacDonald (1960) The rotation of the Earth: A Geophysical Discussion". Cambridge Univ. Press 1960.

[32] Wahr, J. M. (1982) The effects of the atmosphere and oceans on the Earth's wobble, I, Theory, Geophys. J. R. Astron. Soc., **70**, 349–372.

[33] Barnes, R.T.H., R. Hide, A.A. White, and C.A. Wilson (1983) Atmospheric angular momentum fluctuation, length-of-day changes and polar motion. Proc. R. Soc. London Ser. A, **387**, 31–73.

[34] Reguzzoni, M., D. Carrion, C. I. De Gaetani, A. Albertella, L. Rossi, G. Sona, K. Batsukh, J. F. Toro Herrera, K. Elger, R. Barzaghi, and F. Sansó (2021) Open access to regional Geoid models: the International Service for the Geoid. Earth Syst. Sci. Data, **13**(**4**), 1653–1666.

[35] Li, X. and H.-J Götze (2001) Tutorial: Ellipsoid, Geoid, gravity, geodesy, and geophysics. Geophysics, **66**(**6**), 1660–1668.

[36] Li, X. and H.-J Götze (1996) Topography and Geoid effects on gravity anomalies in mountainous areas as inferred from the gravity field of the Central Andes. Phys. Chem. Earth. **21**(**4**), 295–297.

[37] Fan, H. (1998) On an Earth ellipsoid best-fitted to the Earth surface. J. Geodesy. **72**(9), 511–515. doi.org/10.1007/s001900050.

[38] Anderle, R. J. (1980) Accuracy of mean earth ellipsoid based on Doppler, laser and altimeter observations. Bulletin Géodésique **54**(4), 521–527.

[39] Pavlis, N. K., S. A. Holmes, S. C. Kenyon and J. K. Factor (2012) The development and evaluation of the Earth Gravitational Model 2008. JGR Solid Earth **117**, B04406, 1–38.

[40] Rapp, R. H. and N. K. Pavlis (1990) The development and analysis Geopotential coefficient models to spherical harmonic degree 360. JGR Solid Earth **95**(B15), 21885–21911.

[41] The European Space Agency. The Geoid. Retrieved January 05, 2025 from https://www.esa.int/ESA_Multimedia/Videos/2021/03/The_Geoid

[42] Lambeck, K. (2017) The Earth's Variable Rotation: Geophysical Causes and Consequences. Symposium - International Astronomical Union, **128**, 1–20.

[43] Chambat, F.; Lemasquerier, D. Ellipsoids and the Geoid., Retrieved January 05, 2025 from https://culturesciencesphysique.ens-lyon.fr/ressource/Terre-ellipsoidale-Geoide.xml

[44] Aero Propeller Geoids vs. Ellipsoids: What' the difference? Retrieved March 27, 2025 from https://www.propelleraero.com/blog/Geoids-vs-ellipsoids-whats-the-difference/

[45] Hu, X., C. K. Shum, and M. Bevis (2023) A triaxial reference ellipsoid for the Earth. *J. Geod.* **97**(29)

[46] Chen, W. and W. B. Shen (2010) New estimates of the inertia tensor and rotation of the triaxial nonrigid Earth. JGR Solid Earth **115** (B12419), 1–19.

[47] Panet I., V. Mikhailov, D. Diament, F. Pollitz, G. King, O. Viron, M. Holschneider, R. Biancale, and JM Lemoin (2007) Coseismic and post-seismic signatures of the Sumatra 2004 December and 2005 March earthquakes in GRACE satellite gravity. Geophys. J. Int. **171**(**1**), 177–190.

[48] Rice, J. R. and M. A. Chinnery (1972) On the Calculation of Changes in the Earth's Inertia Tensor due to Faulting. *Geophys. J. Int.* **29**(**1**), 79–90.

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