INTERNATIONAL JOURNAL OF
COASTAL, OFFSHORE & ENVIRONMENTAL ENGINEERING

IJCOE Vol.7/No. 2/Spring 2022 (11-23)

Available online at: www. Ijcoe.org

Science behind global sea level and sea level rise for global warming and polar ice-melt: myths and reality

Aftab Alam Khan

[1] *Professor & Head, Oceanography and Hydrography, BSMR Maritime University, Dhaka, Bangladesh, khan.aftab13@gmail.com*

ARTICLE INFO

Article History:
Received: 06 Jan. 2022
Accepted: 10 May. 2022

Keywords:
Sea level rise
Global warming;
Thermal expansion
Ice-melt
Centrifugal force

ABSTRACT

Global sea level rise of 1.5 meter by 2100 AD due to global warming and polar ice-melt has emerged as a concept and not a science. Ocean thermal expansion responsible for sea level rise has also emerged as a myth. Warming of ocean surface can produce water vapor by evaporation which is not the volumetric expansion of ocean water to raise sea level. More the thermal heating of the ocean surface water more will be the evaporation from the ocean that negates volumetric expansion of the ocean water. Global warming can alleviate ocean temperature not to expand ocean water. Global scale ocean temperature measures 28ºC upto the depth of 40 m only. Below this depth temperature drastically decreases almost to 6ºC at 1000 m depth trending further decrease. Science behind melting of the polar floating ice-blocks supports reoccupation of the same occupied volume of the floating ice without sea level rise. Ice-melting further reduces load from the crust of the Earth to elastically rebound for attaining isostatic equilibrium preventing sea level rise. Paleo-sea level markers in the sediment deposits occur due to the crustal subsidence and uplift for transgression and regression respectively. Prograding delta can result in apparent sea-level drop showing retreat of the sea. Geophysical spheroidal shape of the earth with equatorial bulge and polar flattening maintain a perfect hydrostatic equilibrium condition. Maximum centrifugal force and minimum gravity attraction can allow sea level to occur at about 21 km higher in the equatorial region than in the polar region preventing sea-level fluctuation.

1. Introduction

Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) claims sea level rise by 2100 AD due to fossil fuel burning, global warming and polar ice melt (IPCC, 2013; Church et al., 2013)[1,2]. According to Church and White (2006)3 and Jevrejeva et al (2009)[4], greenhouse gas emission from fossil fuel burning is the main reason for sea level rise that links to the global warming concept. Graph that stormed the world about climate change goes to the publication by Mann, et al (1998)[5] published in the journal Nature (Fig. 1a). However, the graph is proved to be wrong and subsequent update by the authors came in 1999. The temperature graph of Mann, et al (1998)[5] very clear that did not account the record of the medieval warm period and the little ice age shown in the Figure 1b. Removal of medieval warm period and an adjustment of little ice age resulted in the construction of global temperature curve of the last 900 years that shows a distinct cooling trend and abrupt rise in temperature in the last 100 years resembling a 'hockey stick' (Fig. 1a). Three observations are very clear in the temperature anomaly curve (Fig. 1a), a) the 'hockey stick' shape graph of abrupt linear rise in temperature after 1980; b) the absence of global temperature record representing 'Medieval Warm Period' and 'Little Ice Age'; and, c) distinct difference in the pattern of the temperature anomaly curve between year-by-year data from tree rings, corals, ice cores, historical records and year-by-year data from thermometers. In reality, temperature of the present global warming shows lower than the temperature medieval warm period that proves no relation of fossil fuel burning, global warming, thermal expansion and sea level rise. Ocean thermal expansion hypothesis has also been brought out to induce an arbitrary volumetric expansion of the ocean water for global sea level rise (IPCC, 2013)[1]. But, Lombard et al (2005)[6] opined that thermal expansion of the ocean water has declined in recent time due to increased melting of land ice. New ocean temperature data-sets suggests that out of 1.8 mm/year apparently observed sea level rise, thermal expansion contributes only about 0.4 mm/year (Lombard et al., 2006)[7]. The Paris climate conference (COP21) in December 2015 opined that the current global average temperature is 0.85ºC higher than the late 19th century. Paleo-temperature data of 1000 years before present suggest that present global temperature is not more than the temperature of "medieval warm period" (Fig. 1b).

warming, ice-melt and sea-level rise. According to IPCC, sea level is estimated to rise 1.5 metre by 2100, if the countries are not able to restrict CO_2 emission 2ºC "well below" pre-industrial levels as stated in the 2015 Paris climate agreement (according to a new report by the Intergovernmental Panel on Climate Change (IPCC) on September 25, 2019). Global mean sea level (GMSL) from tide gauges and altimeter observations increased from 1.4 mm/yr over the period 1901–1990 to 3.6 mm/yr over the period 2006–2015. Present study is aimed at to find out the science

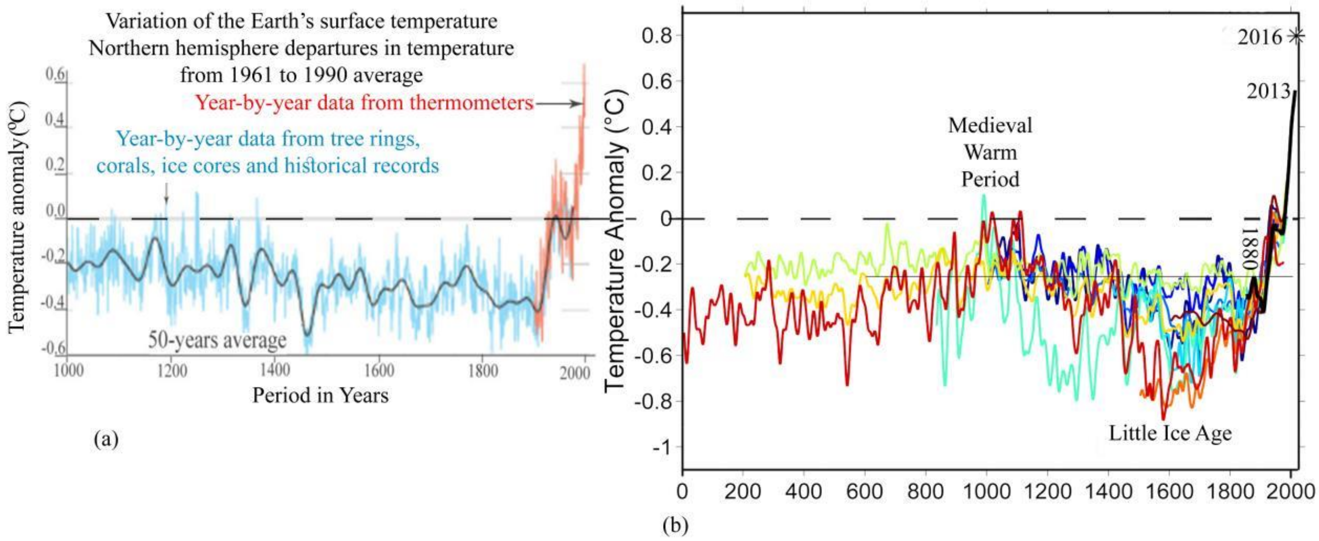


Figure 1. (a) The fake global temperature curve known as 'hockey stick' graph of proxy temperature data from tree rings, lake sediments and ice cores. (b) Global temperature curve that recorded medieval warm 900 years back and little ice age 400 years back. Graph in (a) is posted at the web site below: https://www.theguardian.com/environment/2010/feb/02/hockey-stick-graph-climate-change. Source of the graph in (b) is from the web site below prepared by Robert A. Rohde, the lead scientist for Berkeley Earth, from publicly available data and is incorporated into the Global Warming Art project.
https://commons.wikimedia.org/wiki/File:Holocene_Temperature_Variations.png

Definition of sea-level change states a sea-level change observed with respect to a land-based reference frame. Since, high tide and low tide situation in every twelve hours also measures sea-level change with respect to the land-based reference frame cannot be defined as sea-level change. Hence, sea-level change by rise with respect to the land-based reference frame would occur when land-based reference frame will move downward, and/or sea-level change by fall when land-based reference frame will move upward. The upward or downward movement of the reference frame is possible only when continental crust and oceanic crust will move ups and down. According to Bindoff et al (2007)[8] decade-long satellite altimetry data show that since 1993 sea level has been rising at a rate of around 3 mm/yr. But this measurement has failed to correct data of slow progressive subsidence and uplift of the crust. Global warming phenomenon is linked to the sea-level rise due to polar ice-melting. Fossil fuel burning has been recognized as the culprit for global behind the existing claim of global sea level rise. Further, it is intended to find out that the reality of the claims put forward in favor of rising sea level to issue an alarm of massive submergence of the coastal region of the littoral countries of the world in addition to the large volume of coastal population migration.

2. Materials and Methods

Present study is focused on the geophysical properties of the earth such as spheroidal shape, motion both spinning and rotation, centrifugal force, gravity field and hydrostatic level of the earth. Two third earth's surface is occupied by the ocean that maintains hydrostatic level uniquely coinciding with the spheroidal surface of the earth. Spheroidal mathematical surface is derived from the physical surface of the earth removing materials from elevated region above mean sea level and filling the same in the ocean basin. The spheroidal surface always coincides with the global mean sea level (Fig. 2a). Hence, sea-level rise and/or sea-level drop should be expressed with respect to the spheroidal surface. This is possible when continental crust and oceanic crust moves with respect to each other and shows a measurable displacement (Fig. 2b).

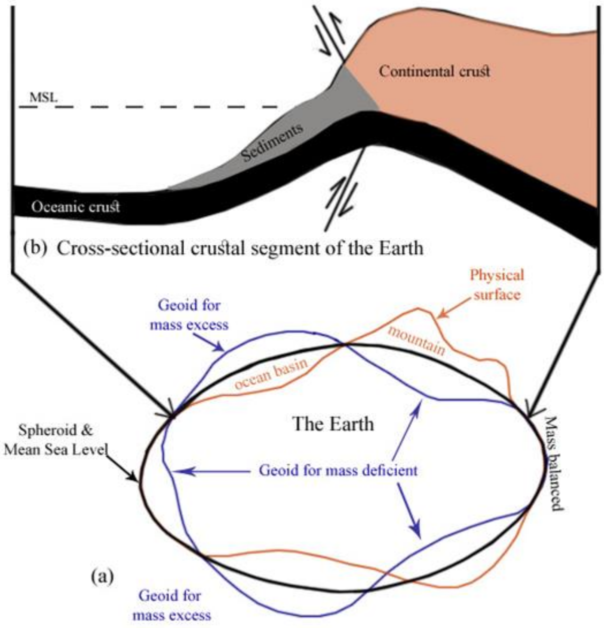


Figure 2. (a) Cartoon display shape of the earth wherein physical surface (brown line) represent ocean basin and mountain with respect to the mean sea level. Materials removed from mountain and filling ocean basin can form a mathematical spheroidal surface coinciding with the mean sea level (black line). Geoid (blue line) is an undulating surface depends on the distribution of mass in the ocean basin.
(b) Cross-sectional view of the crustal segment marked by arrow shows geological positions of the oceanic crust, basin and the continental crust. Sea level change is possible with the relative motion of the crust.

This is a geological process causing earth's crust to move continuously at a very slow rate to cause an apparent sea level change. In reality, sea level does not change rather maintains a hydrostatic equilibrium condition. Sea level observation by satellite altimetry of NASA measures sea surface height (SSH) at a given location, or sea level with respect to the surface of geoid, wherein sea surface always maintains a hydrostatic equilibrium coinciding with the spheroidal surface of the earth. In contrary, geoid is an undulating imaginary surface that occurs above the mean sea level where mass in the ocean basin is excess and occurs below the mean sea level where mass in the ocean basin is deficient (Fig. 2a). Hence, a fluctuating surface cannot be a reference level for the measurement of sea level change. Geoid surface fluctuates with respect to the equipotential surface (mean sea level) which coincides with the spheroidal surface. But for the SSH anomaly is the difference between a fixed satellite altitude and the 'range', which is an undulating sea surface. On the other hand, geoid moves up the mean sea level when internal mass of the ocean basin is excess, while, it goes below the mean sea level when internal mass of the ocean basin is deficient. Hence, under the above conditions determination of 'SSH anomaly' is an anomalous one. One of the most common methods is the tide gauge measurement for observing sea level changes. However, when tide gauges are linked with geographic positioning system (GPS) that records land movements simply cannot differentiate between sea level change and crustal motion. According to Rovere et al (2016)[9] tide gauge has three main disadvantages: (i) uneven distribution globally (Julia Pfeffer and Allemand, 2015)[10]; (ii) missing data associated with sea level signal (Hay et al., 2015)[11]; and (iii) double standard data sets accounting for ocean dynamic changes and land movements (Rovere et al., 2016)[9]. Spheroidal shape of the Earth is attained mainly due to the Earth's spinning on its own axis and the rotation around the Sun. Both the motions i.e., spinning and rotation, caused fluid surface of the ocean covering two third area of the earth to bulge out around the equatorial belt and to flatten around the pole due to the maximum centrifugal force and minimum gravitational attraction along the equator and zero centrifugal force and maximum gravitational attraction in the pole respectively (Fig. 3a). Distribution of centrifugal force and the gravitational attraction between equator and pole associated with angular momentum of the earth is shown in the Figure 3b that maintains an equilibrium position of the hydrostatic level. Because of the spinning, gravitational acceleration of the earth is less at the equator than at the poles. Difference of 0.0178 m/s^2 gravitational acceleration between the pole and the equator signify that the equator is about 21 km away from the center of gravity of the earth than at the poles. Equatorial and polar radius of the earth is 6378 km and 6357 km respectively measured based on the seismic velocity gives a difference of 21 km.

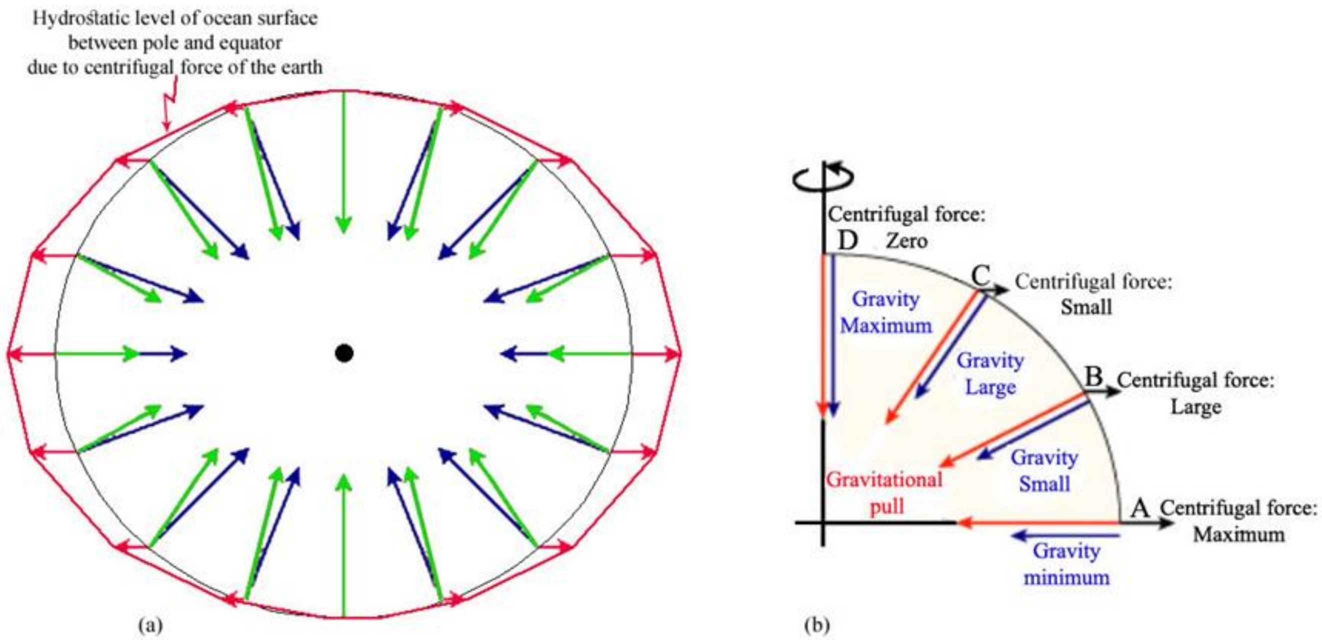


Figure 3. (a) The shape of a sphere by pulling the mass of the earth close to the center of gravity. Blue arrows point from Earth's surface toward its center. Their lengths represent local gravitational field strength. (b) Gravity is strongest at the poles because they are closest to the center of mass. This difference is enhanced by the increasing density toward the center. Red arrows show the direction and magnitude of the centrifugal force. At the equator, it is large and straight up. Near the poles, it is small and nearly horizontal. Vector addition of the blue and red arrows gives the net result of gravity plus centrifugal effect. This is shown by the green arrows in (a). Rotation of the earth produces more centrifugal force at the equator, less as latitude increases, and zero at pole shown in (b).

Difference in equatorial and polar radii signify that the earth is of spheroidal shape having equatorial bulging and polar flatting. Fluid mass of a disc under spinning and rotation can form a shape of an oblate due to maximum outward vector along its major axis and zero outward vector along its minor axis. Earth's equatorial plane where centrifugal force is maximum and gravity attraction minimum can bulge the ocean surface such that its external form is an equipotential of its own attraction and the potential of the centripetal acceleration. Further, water in volume from the polar region in all time cannot flow towards equatorial region since the surface of the equatorial region is 21 km more elevated than the polar region and horizontal gravity gradient is directed to both the poles. The average water surface level of high tide and low tide in a coastal belt is defined as the mean sea level and zero reference surface. Mean sea surface conforms to the earth's spheroidal surface. Since geoid surface fluctuates in accordance with the distribution of the earth's internal mass distribution, the measurement of sea level change with respect to the geoid surface is erroneous.

Water level in the oceans can rise and fall not due to the addition and removal of water rather due to the uplift and subsidence of the crustal block in the continental margin. Formation of the oceans can initiate the formation of the continental margin both as the converging and the diverging plate margins. The continental margin is the junction between the continental crust and the oceanic crust (Fig. 4). Since, continental break and continental drift away from each other is responsible for the opening and the formation of the oceans, zero elevation sea-level occur on to the continental margin. With the progressive sedimentation the continental margin is covered by the influx of sediments developing continental shelf and slope.

There are four different scenario of fault movements two in the converging and two in the diverging plate margin those control the status of sea-level.
Case 1 and 4 exhibit an uplift of the continent and subsidence of the ocean basin resulting in sea-level drop.
Case 2 and 3 exhibit a subsidence of the continent and uplift of the ocean basin resulting in sea-level rise.

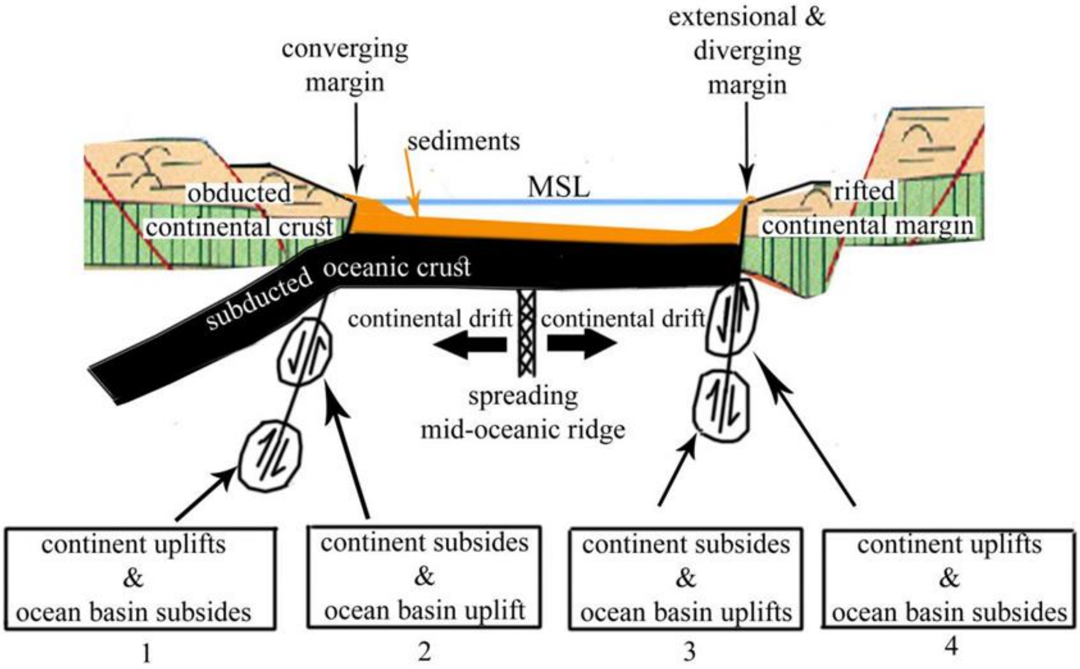


Figure 4. Model representing drifted continents, formation of an ocean by sea floor spreading from mid-oceanic ridge underlain by oceanic crust, and plate margins associated with various types of faults for crustal movement in order to signify apparent sea-level rise and fall.

On the other hand, global sea-level always maintains a hydrostatic equilibrium condition of equipotential surface. So, we call sea-level rise when sea enters the coastal belt and sea-level fall when sea moves away from the coastal belt. The entrance and exit of sea is directly linked to the fault movement of the continental and oceanic crust. Figure 4 explains very clearly the fault mechanism for determining the status of sea-level. There exists a definite fault margin between the continental crust and newly formed ocean basin underlain by the oceanic crust. These faults can occur in the both converging and diverging plate margins. In both the margins, sea-level can either enter inside the continental block or it can retreat from the continental block without causing sea level rise or sea level drop, and maintains an unique hydrostatic equilibrium level. When continental crust moves down (subsidence) with respect to the oceanic crust, sea-level can enter inside the continent, in contrary, when oceanic crust moves down with respect to the continental crust, sea-level can retreat from the continent. When both continental and oceanic crust move simultaneously (geologically non-existence) either by subsidence or by uplift, sea (level) may enter inside the continental block or retreat from the continental block without causing actual sea level rise or sea level drop respectively. It is essential to consider: a) crustal movement as above may occur in a very small coastal region of the earth surface measuring only few square kilometers, b) ocean occupies more than 170 million square kilometers surface area of the earth. So volumetric displacement of ocean water either for subsidence or by uplift will not cause any detectable sea level change. Similarly, neither sea transgression is a sea level rise, nor sea regression is a sea level drop.

3. Science behind Mean Sea Level

In view of the fact that the spheroidal surface of the earth is a mathematical surface, while, global mean sea level is a physical surface of the earth that always coincides. Further, the mathematical surface is calculated based on the theoretical gravity values of the earth at all points is known as the reference spheroid. It is related to the mean sea-level (MSL) determined from the average values of high tide and low tide conditions equivalent to a surface made by removing excess mass of the land to fill the ocean depressions. The force of gravity (g_z) or the plumb line on an equipotential surface is everywhere normal directed to the center of the earth. Based on the calculations of gravity using formula (equation 1 below) of the International Association of Geodesy, the mathematical spheroidal surface of the earth is determined (Telford et al., 1976)[12]. The formula expresses 'g' value at any point on the latitude as:

$$g = g_o(1 + \alpha \sin2\phi + \beta \sin2 2\phi) \qquad (1)$$

where g_o = equatorial gravity = 978.0318 Gals, ϕ = latitude, and the constants α and β are equals 0.005324 and -0.0000058 respectively.

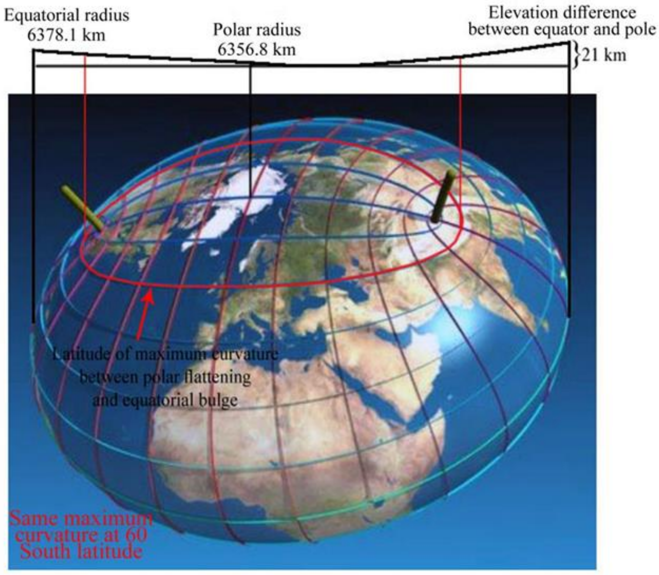


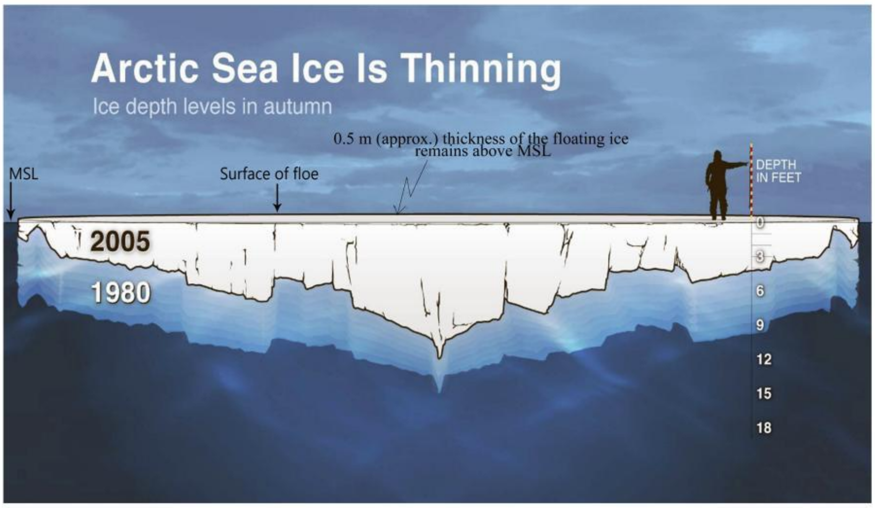
Figure 5. Projection of polar and equatorial radius on to the horizontal plane shows elevation difference 21 km between equator and pole with higher at the equator. Maximum curvature of the spheroidal surface of the Earth coincides approximately with 60°N latitude preventing bulk water movement across 60°N latitude from Arctic. Similarly, floating ice from Antarctica can freely move upto 60°S latitude where spheroidal surface has maximum curvature.

The value of gravity thus determined by this relation is the measure of the values at the sea level that coincides with spheroidal surface of the earth. The spheroidal surface is characterized by the gravity attraction at the equator equal 978.0318 Gals and at the poles equal 983.3318 Gals. The difference of gravity between the poles and the equator is 5.3 Gals (5300 milliGals) more at the poles. Thus, the gravity field around the earth can represent an equatorial bulge of minimum gravity attraction and polar flattening of maximum gravity attraction. Equatorial bulge is attributed to the volumetric expansion due to lower density and and lower gravity attraction at the equator, while, polar flattening is attributed to the volumetric contraction at the poles due to higher density and maximum gravity at the poles.

Horizontal gravity gradient (component of g_z) is also significantly less in the equatorial region which can prevent sea water to move to the equatorial region from the higher latitudes. On the otherhand maximum curvature of the earth at around 60°N and 60°S latitudes and the occurrence of equatorial surface at about 21 km higher elevation than the polar region can definitely prevent ocean water movement and circulation (Fig. 5). The spheroidal shape of the earth depends on: (i) greater gravity attraction of the polar region for polar flattening and lesser gravity attraction of the equatorial region for equatorial bulging, and, (ii) the centrifugal force of earth's spinning and rotation. The centrifugal force causes the mass (ocean water) to move away from the earth located at the equatorial region. The outward normal of the centrifugal force acts on the surface of the ocean-fluid surface is maximum at the equator and zero at the poles (Fig. 3b). It is the centrifugal force due to the Earth's spin and rotation cause polar flattening and equatorial bulge. The polar flattening ratio (eccentricity) of 1/298 implies that sea-level at the equator occurs about 21 km higher than at the poles. Ocean water surface would occur in equilibrium hydrostatic level which is curvilinear, and this level is influenced by the gravity as well as centrifugal force of the earth. Centrifugal force acts on water of the oceans more than it does on the solid Earth. Any addition of water to the ocean water cannot flow up the hill towards equator from the poles to cause global sea level rise. Hence, although ocean water at the equator makes a level difference of 21 km higher than at the poles, it is the centrifugal force maximum at the equator and zero at the poles restricts ocean water to move down-hill toward poles. Shape of the earth established from geodetic measurements and more recently by satellite tracking, is practically spheroidal, bulging at the equator and flattened at the poles, such that the difference between equatorial 'a' and polar 'b' radii, divided by the former 'a', is 1/298. This ratio is known as the polar flattening ratio. The surface of the theoretical shape is the surface of the centripetal acceleration which is equivalent to an equipotential surface of gravity field. Centripetal acceleration is the rate of change of tangential velocity. The direction of the centripetal acceleration is always inwards of an object along the radius vector of the circular motion. The magnitude of the centripetal acceleration is related to the tangential speed and angular velocity. In general, a particle moving in a circle experiences accelerations both angular and centripetal velocity. The circumference of the Earth along the equator (equatorial circumference) is 40,075 km and along longitude (polar circumference) is 40,008 km. Difference of 67 km also larger at the equator than at the pole which poses an upward gradient 1 in 149.28 (equivalent 0.602°) towards equator. Hence, an upward slope directed to the equatorial region and downward slope directed to polar region makes conditions very clear for volumetric water circulation of the oceans. Inflection point of the curvature in the slope coincides with the spheroidal surface at around 60° latitudes. This makes higher level at the equator and lower level at the poles that prevents ocean-waters flowing to lower level from higher level.

4. Polar Ice Melt and the Sea Level Rise

Scenario of ice melting and ice growth alongwith ocean water response are different in two polar regions. Arctic Ocean in the north is surrounded by the land mass thus can restrict the movement of the



(a)

(b)

Figure 6. (a) Profile shown here depict roughly what fraction of sea ice fell within different thickness ranges for the years shown, within the area of the Arctic Ocean where the Navy has declassified its soundings. Data provided by NASA scientist Ron Kwok, based on research Kwok, R. and Rothrock, D. A., (2009)[13]. Decline in Arctic sea ice thickness from submarine and ICESat records: 1958 - 2008. Geophysical Research Letters 36, L15501.
http://www.climatecentral.org/gallery/graphics/arctic_sea_ice_thinning_fall.
(b) Cartoon depict floating ice submerged in the ocean displacing more than 95% of water volume. On melting the same volume of ice would re-occupy the displaced volume of water without adding water to the surrounding ocean justifying no-sea level rise on ice melting.

floating ice, while, Antarctic in the south is surrounded by the open oceans thus can allow floating ice to move freely. Nonetheless, the movement of the floating ice is likely to be maximum up to 60°S latitude where maximum curvature occurs (Fig. 5). Further, the attraction of gravity can play an important role to the flow of water which is always to the downward gravity. Similarly, water cannot flow from higher gravity to lower gravity wherein higher gravity of the polar region would attract water from moving towards equatorial region. This condition would necessarily make ocean water static at every 'g_z' position directed to the centre of gravity of the earth. Since, greater horizontal gravity gradient is toward poles that would also help melt-water to remain attracted towards polar region. Polar flattening and equatorial bulge both are intrinsically related to the maximum curvature of the Earth's spheroidal surface that occur between 45°N and 60°N latitudes in the northern hemisphere and, 45°S and 60°S latitudes in the southern hemisphere. In reference to the mapping of geoid height between 60°N and 60°S it is inferred that the maximum curvature of the spheroidal surface occurs between 60°N and 60°S (Dobrin, 1976)[14]. Hence, ice-melt water from polar region cannot flow beyond 60°N and 60°S. Sea-level can rise due to ice melting if the melt water is added to the ocean water. But in reality, ice-melt water does not add to the ocean water rather only replaces the entire volume of the submerged ice on melting. Further, freezing volume generally is larger than the volume of the same quantity of water on melting. So, floating and submerged ice blocks when melt, it can reoccupy more volume than the volume it does. Hence, on melting the ice block can easily replace the occupied volume without adding extra melt to the ocean water. Simple scientific analogy confirms that floating ice-blocks that occupy volume of the displaced water will re-occupy same volume on melting without adding water to the surrounding oceans (Fig. 6).

According to an article "Third dimension: new tools for sea ice thickness", it is revealed that the average thickness of sea-ice in the Arctic Ocean is about 3 m. This measurement was performed between March 29, 2015 to April 25, 2015 by the Center for Polar Observation and Modeling, UCL London (Lindsay and Schweiger, 2015)[15]. http://nsidc.ogr/arcticseaicenews/2015/05/newtools-for-sea-ice-thickness. The month of April ice extent for 1979 to 2015 shows a decline of 2. 4% per decade relative to the 1981 to 2010 average. A decline in the ice extent between 1979 and 2015 is about 1,208,000 km2 in its areal extent. But, overall ice extent decreased to about 862,000 km^2. Lindsay and Schweiger (2015)[15] found that ice thickness over the central Arctic Ocean has declined. Reduction of ice thickness in the central Arctic Ocean from an average of 3.59 m to 1.25 m during 1975 to 2012, a reduction of 65%, is observed.

In April 2015, Arctic sea-ice covered about 14,000,000 km^2. An average of 3m thickness of the floating ice and the maximum areal extent of Arctic floating-ice about 14,500,000 km^2 can occupy volume equivalent to 43,500 km^3. Areal extent of the floating ice is reduced to 7,000,000 km^2 equivalent to 17,500 km3 volumetric space at the end of summer-melt season. Hence, out of total 39,000 km^3 of floating ice in the Arctic Ocean, about 31000 km^3 ice-melt would occupy same volume of the displaced water by the submerged ice-sheets and no-sea-level rise occurred. Khan (2019)[16] calculated an equivalent volumetric quantity of 65% thickness reduction of ice sheets in the Arctic Sea over the period 1975 to 2012 and opined that more than 2,500,000 km^3 in volume of ice-melt water must have been added to the ocean water by now over an area more than 14,500,000 km^2 in the central Arctic Ocean. The added water, by now, should have raised sea level in the Arctic Sea more than 178 mm which is much much greater than what IPCC has claimed. However, until now (as of April 2021) there is no record of such sea level rise, not even 66 mm at the rate of 3 mm/yr predicted by IPCC 22 years ago.

5. Isostasy and the Sea Level

Ice melting from oceanic heat flux decreases faster than the ice growth in the weakly stratified Southern Ocean, leading to an increase in the net ice production and hence an increase in ice mass.

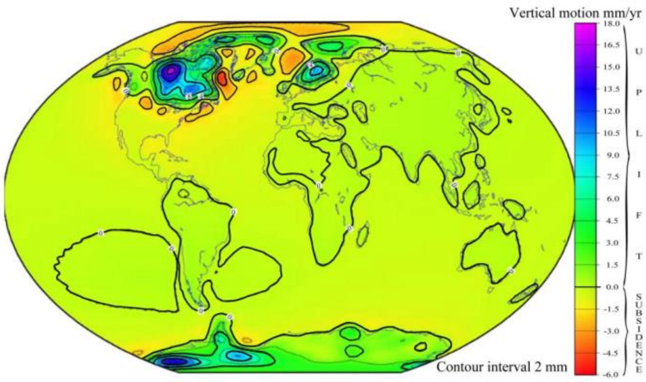


Figure 7. Crustal isostatic balancing (modified from https://commons.wikimedia.org/wiki/File:PGR_Paulson2007_Rate_of_Lithospheric_Uplift_due_to_PGR.png. Both Arctic and Antarctic polar region exhibit significant vertical motion in terms of uplift and subsidence. Uplift term is much greater than subsidence represented by color code. Because of the greater uplift than subsidence polar region never shows sea level rise. Both Arctic and Antarctic polar region are isostatically unbalanced while all the lower latitudes areas are relatively balanced isostatically (source: Erik Ivins, 2010 of NASA's Jet Propulsion Laboratory in Pasadena, California USA alongwith his article entitled "Rate of lithospheric uplift due to Postglacial Rebound", posted in the website https://en.wikipedia.org/wiki/ Post-glacial_rebound.

Both the polar region exhibit reduction in ice-load in the crust due to melting and removal of ice-cover from the continental blocks every year. Reduction in weight of the continent can activate isostatic mechanism and continent uplifts to maintain isostatic equilibrium and prevents sea level rise. Figure 7 exhibits vertical motion of the crust in the two polar region applying glacial isostatic adjustment (GIA) theory prepared by Erik Ivins, 2010 of NASA's Jet Propulsion Laboratory in Pasadena, California USA alongwith his article entitled "Rate of lithospheric uplift due to Postglacial Rebound", posted in the website https://en.wikipedia.org/wiki/Post-glacial_rebound. The map (Fig. 7) showing vertical motion of the crust is based on the work by Paulson et al (2007)[17].

According to Khan (2019)[16], quote "both the polar region exhibit noticeable uplift and subsidence of the crust in order to attain its isostatic equilibrium. In the north polar region, crust is characterized by the maximum 18 mm/yr uplift surrounded by the region of maximum 6mm/yr subsidence. Difference of 12 mm/yr is attributed for the uplift that should result in an apparent sea-level drop. In reality, it is not a sea level drop rather sea moves away from the continent exposing the land, while sea will move inside the continent submerging land when continent will subside due to the over-burden load of the the growing ice cover in yearly basis. In the south polar region, Antarctica shows maximum uplift 12 mm/yr and maximum subsidence 2 mm/yr with a difference of 10 mm/yr assigned to uplift that would also result in an apparent sea-level drop means regression of sea from the continent. Reverse would occur due to the overburden load for ice growth over the continent. There are good number of publications about the post glacial isostatic rebound of the polar region", unquote.

6. Thermal Expansion and the Sea Level Rise

During the winter, area up to 18,000,000 km^2 of ocean is covered by sea-ice, but by the end of summer it is reduced to about 3,000,000 km^2. Hence, about 23,000 km^3 sea-ice of Antarctica can freely float northward into the warmer water where it eventually melts every year without showing any sea level rise in the lower latitudes. Further, melting of such a huge volume of floating sea-ice of Antarctica not only can reoccupy volume of the displaced water but also can cool ocean-water in the lower latitudes of the southern oceans preventing so-called sea level rise due to thermal expansion. Further, thermal expansion of the ocean surface water is never a volumetric expansion of the ocean water which is suggested for sea level rise. According to Zhang (2007)[18] thermal expansion in the lower latitude is unlikely because of the reduced salt rejection and upper-ocean density. Enhanced thermohaline stratification tend to suppress convective overturning leading to decrease ocean heat transport in the upward ocean. Ocean temperature measures 28ºC upto only 40 m depth. Below this depth temperature drastically decreases almost to 6ºC at 1000 m depth trending further decrease. Atmospheric temperature rise may heat the surface of the ocean water that only develops ocean water circulation and evaporation not a thermal / volumetric expansion of the ocean water. Due to warming of surface water of the ocean density may decrease and the cold water from below is up-welled and a surface circulation can start. According to the IPCC executive summary of sea level rise in chapter 09 it is admitted that the observational data are scant, both in time and space (Barnett, 1985)[19]. Further, the inter-annual variability creates too much noise to cause error in the estimation.

The ocean currents are generated from the forces acting upon the water such as earth's rotation, wind, temperature, salinity difference and gravitation. Depth contours, shoreline configurations, and interactions with other currents influence a current's direction, amplitude and strength. Ocean currents are primarily horizontal water movements known as 'wind wave'. At Calm Ocean with no or little wind wave amplitude of the current is much less than at the condition of storm generated 'wind wave'. Sea surface height (SSH) measurements would be different at two conditions. This may lead to wrong estimate of sea level condition. Sea level does not rise due to thermal expansion of the ocean water as there is no real thermal expansion due to global warming. Temperature of sea water has no direct impact on sea-level. According to Hegerl, et al (2007)[20] of IPCC Fourth Assessment Report, it is clearly expressed quote, "*consistency with surface air temperature alone does not guarantee a realistic simulation of thermal expansion, as there may be compensating errors among climate sensitivity, ocean heat uptake and radiative forcing*", unquote.

7. Geological Factors and the Sea level

Geologically, global (eustatic) sea level change is not possible. In order to have eustatic sea level change the entire oceanic crust that makes the floor of all the oceans need to subside or uplift uniformly at the same time. According to Kemp et al (2015)[21] "land uplift or subsidence" can result in, respectively, a fall or rise in sea level that cannot be considered eustatic as the volume or mass of water does not change. There are numerous geological factors and processes that can change ocean floor configuration nonetheless tectonism, volcanism, visco-elastic deformation, trench-slope deposits, sub-marine fan deposits and prograding delta system are the most important. However, these factors and processes do not occur simultaneously everywhere around the earth and hence no impact on the volume change of the ocean basin occur for sea level change. In case of prograding delta with high sedimentation rate, an overlap condition on to the contact margin of the continental and oceanic crust, the scenario of sea level change is different. A variety of processes drive configuration-change of the ocean floor, and not the ocean surface, resulting in distinct spatial patterns at local to regional scale by transgressions and regressions of the sea but the hydrostatic level of the ocean water remains unchanged. Palaeo-sea level changes have been identified from the geological records wherein data from the Late Triassic (≈227 Ma) until the present time are reasonably well documented but not the amplitude of the eustatic changes of the sea level. Eustatic change may occur when the sea level changes due to an alteration in the volume of water in the entire oceans or, alternatively, a change in the shape of the entire ocean basins and hence a change in the amount of water the entire oceans can hold. Eustatic change is always a global effect and only approximations (Vail et al., 1977)[22].

The Phanerozoic history of North America from the Late Triassic or Early Jurassic, corresponds to the Pangea breakup phase, during which North America drifted westwards. The eastern continental margin became the modern extensional Atlantic margin basins, while the western margin underwent tectonism and accretionary prism development leading to the assembly of the Cordilleran orogen. Similar extensional basins and sedimentary accretionary prism leading to orogens developed along the eastern margin of the Atlantic Ocean in Africa and Europe, and in some region of Asia. These mega events of the earth led to major sea-level rise and fall in terms of tens to hundreds of meters as oceans have undergone regional transgressions and regressions. Hence, transgressions occur when a region undergoes major subsidence of the continental crust or uplift of the oceanic crust can cause sea to enter inside the continent showing relative sea level (RSL) rise with respect to the existing sea level. Example of mid-Holocene (about 8000 years ago) subsidence in the Bengal Basin floor of continental crust caused a major marine transgression to signify sea level rise to the tune of more than 10m (Khan et al., 2000)[23]. Similarly, regressions can occur when continental crust uplifts and oceanic crust subsides. Geological processes are responsible of two types of major crustal movements viz., uplift and subsidence. Relation of such crustal movement with respect to the global and regional sea level is explained in the Figure 4. Mörner (2020)[24] recorded relative sea level drop from Holocene until the Recent at Ouvéa Island in New Caledonia and documented distinct two terraces representing paleo-shores at +22m high and +4m high respectively (Fig. 8).

Figure 8. The spectacular Lekiny sea cliff on Ouvéa Island including 3 distinct sea levels: an upper +22 m shore, a huge under-cut shore with rock-cut platform at +4 m, and Holocene to present under-cut shore. Picture taken at high-tide level on November 2018 (Source: Mörner, 2020)[24].

Both the paleo-shores show distinct tidal under-cut terraces representing the Holocene Interglacial period terraces graded to present sea level. This documentation could be a unique example of land uplift and sea subsidence for relative sea level drop. Oceans maintain hydrostatic equilibrium level without truly sea level change in every geological events. Prograding delta system in the coastal region and other geological events may cause local/relative sea-level fall as new sedimentary deposition advances as accretion pushing sea further down the coast irrespective of global warming and polar ice-melt. Hence, both regional and local apparent sea-level rise and fall is related to the geological events and not related to global warming and polar ice melt.

8. Examples of Sea Level of the Littoral Countries

Mörner (2019a)[25] observed geomorphological facts from Maldives, Goa and Bangladesh in the Indian Ocean and from Fiji and New Caledonia in the Pacific Ocean to record sea level condition and found it to be stable since the last 50-70 years. He further observed a very clear and distinct rock-cut platform on Ouvéa Island leveled at +70 cm above the present high tide level (HTL). The platform is fresh and un-weathered and cut into the older strongly weathered reef masses that evident definite relative sea level drop (Fig. 9a). In the coast north of Saint Joseph on Ouvéa Island of New Caledonia it is found that the tidal washing limit has moved 2m seaward and about 5 cm down. The new coastal zone is now in the process of becoming over-grown. This lends support that sea level is not rising on Ouvéa Island (Fig. 9b; Mörner, 2018)[26]. Bangladesh coast to the west at Kotka, trees reveal that the tree trunks have horizontal root systems hanging some 80 cm above the shore surface. Such root systems are found just below the mud surface indicating stable sea level despite strong erosion (Fig. 9c; Mörner, 2010)[27]. Landsat image of 1990 and 2019 depict the emerging of new islands of about 1500 sq km area in the coastal belt of Bangladesh proving major sea regression and extensive land accretion (Fig. 9d; present study). A common view of the shores of the atoll islands of the Maldives has been documented by Mörner (2019b)[28]. Figure 9e exhibits three distinct features: (a) a prominent notch from the sea level position prior to the 20 cm fall at about 1970, (b) the abandoned shore segment in the process of being overgrown by creepers, and (c) post-1970 at present, washing limit (Mörner, 2019b)[28]. Coastal morphology data of the last 400 years in the beach in Goa, India show three shore-lines representing three successive sea-level positions such as the present shore at +10.0 cm (red line), the pre-1960 shore at +20 cm (blue line), and the 17th century +60-cm shore (yellow line)(Fig. 9f). The dead cliff and double rock-cut platform is marked by white line. Loveson et al. (2014)[29] noted that the subsequent shoreline growth from 1957 to 2012 fits the present sea-level reconstruction perfectly well just before the 20-cm sea level fall at about 1960 (Mörner, 2017)[30]. The tide gauges in Mumbai, India as well as in Visakhapatnam, India show a sudden fall in the sea level from 1955 to 1962, followed by virtually stable sea-level conditions in the last 50 years. Coral mortality induced by the 2015–2016 El-Niño in Indonesia: the effect of rapid sea level fall is shown in the Figure 9g (Ampou et al., 2017)[31]. In the late 20th century sea level fell killing many corals (the centre in the image) and forcing corals to grow as microatolls (Fig. 9h).

The coral died due to sea level drop dated younger than 1955 (red dot gives position of dated sample) and since then the coral has not been able to grow upwards due to stable sea level conditions forcing the coral to grow laterally into a microatoll. The limit for coral growth seems to be 40 cm below low tide level as measured at the site (Mörner, 2019b)[28]. Some of the most dramatic uplift is found in Iceland. Much of modern Finland is former seabed or archipelago that shows sea level immediately after the last ice age. Massive coral (Pavona clavus) exposed in 1954 by tectonic uplift in the Galapagos Islands, Ecuador. Beach ridges on the coast of Novaya Zemlya in arctic Russia. Such ridges are formed by pushing of sea ice as a result of Holocene glacio-isostatic rebound. A 8000-year old-well off the coast of Israel now submerged is a land mark of crustal subsidence giving relative measure of sea level rise. The "City beneath the Sea" near the Port Alexandria on the Nile delta fits with the drowned well off the coast of Israel. Both subsided due to subduction-pull of the downgoing African crustal slab as it enters the Hellenic trench in the Mediterranean. Apparent sea level rise in Venice lagoon is due to the tectonic subsidence of the basin floor caused by subduction rollback of Adriatic slab wherein down-going crust causing subsidence of Venice rather than sea level rise.

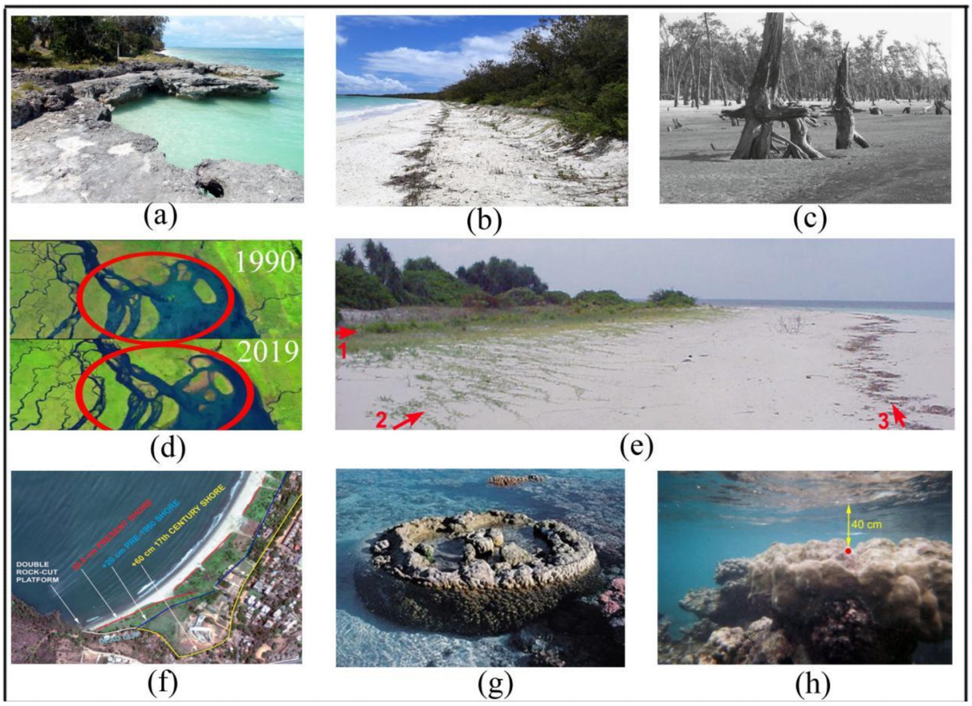


Figure 9. Examples of sea levels at different littoral countries. Explanation of each example is available in the text.

9. Conclusions

Global sea level is continuously being maintained its hydrostatic level due to the Earth's angular momentum, spinning and rotation. Dominance of oceans and the maximum centrifugal force at the equatorial region between 30°N and 30°S caused the spheroidal shape of the Earth characterizing equatorial bulge and polar flatten along which global sea level is maintained hydrostatic equilibrium condition. Global mean sea level is an equipotential surface that fits uniquely with the spheroidal surface of the Earth. Hydrostatic equilibrium condition of the mean sea level is continuously being maintained by the centrifugal force and the orbital angular momentum of the Earth. Under such physical law, mean sea level will not change unless a change in the centrifugal force and orbital angular momentum occurs.

Global warming and the subsequent thermal expansion due to increased sea surface temperature shall not enhance sea level because thermal expansion does not apply to the entire water volume of the ocean and volumetric expansion of the ocean water is not possible by the rise in sea surface temperature (SST) except increased evaporation of the sea surface. An increased evaporation add more water vapor to the atmosphere that helps heat trapping to enhance global warming in turn forming intense rainfall, cyclone, storm surge, coastal flooding.

Polar ice melting due to global warming shall not contribute to the ocean water for sea level rise rather the entire submerged ice sheets on melting shall reoccupy the same displaced volume by the submerged ice sheets. Polar ice cover of Greenland and Scandinavia in the northern hemisphere and

Antarctica in the southern hemisphere on melting shall not cause sea level rise rather an apparent drop because of the isostatic rebound of the Earth's crust to attain isostatic equilibrium wherein the residual uplift is more than the residual subsidence. Higher gravity attraction of the poles and lower gravity attraction at the equator also play an important role in preventing bulk volume displacement of the ocean water.

Crustal uplift and subsidence shall allow sea water to enter inside the continent or retreat from the continent without showing an actual sea level rise or drop. Sea level marker are preserved in the deposited sediments that have undergone sedimentation in the marine environment of deposition in the ocean basin. Instead of sea level rise and fall, the terms such as "sea transgression for rise" and "sea regression for fall" should be used. All the littoral countries of the world are safe from sea level rise phantasy except the countries are situated in the active tectonic regime, especially in the active plate collision margin where continuous crustal deformation is progressing due to the plate subduction and obduction. Study revealed that no "sea-level rise" will occur to the littoral countries of the earth due to global warming and polar ice-melt.

10. Acknowledgement

Entire study is done by the sole author of this article. The work is not supported by any institute or organization. There is no conflict of interest since no organization or institute sponsored this study. I do acknowledge all the authors of all the published and unpublished papers used in this study and those have enlightened my ideas and views, and helped to enrich this article.

11. References

[1] IPCC Climate Change, 2013. The physical science basis. In: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[2] Church, J.A., Clark, P.U., Cazenave, A., Gregory, J., Jevrejeva, S., Levermann, A., Merrifield, M., Milne, G., Nerem, R., Nunn, P., Payne, A., Pfeffer, W., Stammer, D., Unnikrishnan, A., 2013. Sea level change. Climate change 2013: the physical science basis. In: Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., Midgley, P.M. (Eds.), Contribution of Working Group I to the Fifth Assessment Report of the IPCC. Cambr. Univ. Press, Cambridge, pp. 1137-1216. https://doi.org/10.1017/CBO9781107415324.026.

[3] Church, J.A., White, N.J., 2006. A 20th century acceleration in global sea-level rise. Geophy. Res. Lets., 33 (1). https://doi.org/10.1029/2005GL024826. L01602.

[4] Jevrejeva, S., Grinsted, A., Moore, J.C., 2009. Anthropogenic forcing dominates sea level rise since 1850. Geophy. Res. Lets., 36, L20706.

[5] https://doi.org/10.1029/2009GL040216.

[6] Mann, M.E., Bradley, R.S., Hughes, M.K., 1998. Global-scale temperature patterns and climate forcing over the past six centuries. NATURE 392, 779-787.

[7] Lombard, A., Cazenave, A., Le Traon, P.Y., Ishii, M., 2005. Contribution of thermal expansion to present-day sea level rise revisited. Glob. Plane. Chan., 47, 1-16.

[8] Lombard, A., Cazenave, A., Le Traon, P.Y., Guinehut, S., Cabanes, C., 2006. Perspectives on present-day sea level change: a tribute to Christian le Provost. Ocean Dynamics 56 (5-6), 445-451. https://doi.org/10.1007/s10236-005-0046-x

[9] Bindoff, N.L., J. Willebrand, V. Artale, A, Cazenave, J. Gregory, S. Gulev, K. Hanawa, C. Le Quéré, S. Levitus, Y. Nojiri, C.K. Shum, L.D.Talley and A. Unnikrishnan, 2007: Observations: Oceanic Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge Univ Press, Cambridge, United Kingdom and New York, NY, USA.

[10] Rovere, A., Stocchi, P., Vacchi, M., 2016. Eustatic and Relative Sea Level Changes. Cur. Clim. Change Rep. https://doi.org/10.1007/s40641-016-0045-7.

[11] Julia Pfeffer, J., Allemand, P., 2015. Contribution of vertical land motions to relative sea level variations: a global synthesis of multisatellite altimetry, tide gauge data and GPS measurements. Eart. Plane. Sci. Lets. 439, 39-47.

[12] Hay, C.C., Morrow, E., Kopp, R.E., Mitrovica, J.X., 2015. Probabilistic reanalysis of twentieth-century sea-level rise. NATURE 517, 481-484.

[13] Telford, W.M., Geldart, L.P., Sheriff, R.E., Keys, D.A., 1976. Applied Geophysics. Camb. Univ. Press, 860 pp

[14] Kwok, R. and Rothrock, D. A., 2009. Decline in Arctic sea ice thickness from submarine and ICESat records: 1958–2008. Geophys. Res. Lett., v. 36, L15501, doi:10.1029/2009GL039035

[15] Dobrin, M.B., 1976. Intro. Geophy. Pros., 3rd ed. McGraw-Hill, New York. 630pp.

[16] Lindsay, R., Schweiger, A., 2015. Arctic sea ice thickness loss determined using subsurface, aircraft, and satellite observations. The

Cryosphere 9, 269-283. https://doi.org/10.5194/tc-9-269-2015.
[17] Khan, A.A., 2019. Why would sea-level rise for global warming and polar ice-melt?. Geoscience Frontiers 10, 481- 494.
[18] Paulson, A., Zhong, S., Wahr, J., 2007. Inference of mantle viscosity from GRACE and relative sea level data. Geophy. J. Int., 171, 497-508. https://doi.org/10.1111/j.1365-246X.2007.03556.x.
[19] Zhang, J., 2007. Increasing Antarctic sea ice under warming atmospheric and oceanic conditions. Am. Met. Soc., 20, 2515-2529.
[20] Barnett, T. P., 1985. Long term climatic change in observed physical properties of the oceans In Detecting the Climatic Effects of Increasing Carbon Dioxide (Eds. MC MacCracken and FM Luther) US DOE/ER 0235 pp 91-107
[21] Hegerl, G.C., F. W. Zwiers, P. Braconnot, N.P. Gillett, Y. Luo, J.A. Marengo Orsini, N. Nicholls, J.E. Penner and P.A. Stott, 2007: Understanding and Attributing Climate Change. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the FAR of the IPCC [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambr. Univ. Press, Cambridge, United Kingdom and New York, NY, USA.
[22] Kemp, A.C., Dutton, A., Raymo, M.E., 2015. Paleo constraints on future sea level rise. Curr. Clim. Chan. Rep., 1, 205-215.
[23] Vail, P.R., Mitchum Jr., R.M., Thompson III, S., 1977. Seismic Stratigraphy and Global Changes of Sea Level: Part 4. Global Cycles of Relative Changes of Sea Level: Section 2. Application of Seismic Reflection Configuration to Stratigraphy Interpretation. AAPG Mem. Spec. Vol., p. 83-97.
[24] Khan, A.A., Akhter, S.H., Alam, S.M.M., 2000. In: Hosani, Mohamed and Al (Ed.), Evidence of Holocene Transgression, Dolomitization and the Source of Arsenic in the Bengal Delta. Geoengineering in Arid Lands. Balkema, Rotterdam, pp. 351-355.
[25] Mörner, N.-A., 2020. Sea Level Records on Ouvéa Island in New Caledonia. Nat. Sci., 2020, Vol. 12, (No. 6), pp: 329-359. https://www.scirp.org/journal/ns
[26] Mörner, N.-A., 2019a. Rotational Eustasy as Observed in Nature. Int. J. Geos., 10, 745-757. https://doi.org/10.4236/ijg.2019.107042
[27] Mörner, N.-A., 2018. Absolute Evidence of the Absence of an on-Going Sea Level Rise on Ouvéa Island of New Caledonia. SSRG Int. J. Geoinf. Geol. Sci. (SSRG – IJGGS) – Volume 5, Issue 3, p. 30-33
[28] Mörner, N.-A., 2010. Sea level changes in Bangladesh: New observational facts. Ener. Env., 21(3), 235–249.
[29] Mörner, N.-A., 2019b. Biology and Shore Morphology: Keys to proper reconstruction of sea level changes, J. Marn. Biol. Aquas. Doi: http://dx.doi.org/ 10.31579/ 26415143/JMBA.2019 /020
[30] Loveson, V.J.; Gujar, A.R.; Iyer, S.D.; Udayaganesan, P.; Luis, R.A.A.; Gaonkar, S.S.; Chithrabhanu, P.; Torodkar, G.M., and Singhvi, A.K., 2014. Beach dynamics and oscillations of shoreline position in recent years at Miramar Beach, Goa, India: A study from GPR survey. Nat. Haz., 73(3), 2089–2106. doi:10.1007/s11069-014-1175-7.
[31] Mörner, N.-A., 2017. Coastal morphology and sea-level changes in Goa, India during the last 500 years. J. Coastal Res., 33(2), 421–434. Coconut Creek (Florida), ISSN 0749-0208.
[32] Ampou, E.E., Johan, O., Menkes, C.E., Niño, F., Birol, F., Ouillon, S., and Andréfouët, S., 2017. Coral mortality induced by the 2015–2016 El-Niño in Indonesia: the effect of rapid sea level fall. Biogeosciences, 14, 817-826.

Internet sources:
https://en.wikipedia.org/wiki/ Post-glacial_rebound.
https://commons.wikimedia.org/wiki/File:PGR_Paulson2007_Rate_of_Lithospheric_Uplift_due_to_PGR.png.
http://nsidc.org/arcticseaicenews/2015/05/
http://www.climatecentral.org/gallery/graphics/arctic_sea_ice_thinning_fall.
https://commons.wikimedia.org/wiki/File:Holocene_Temperature_Variations.png
https://www.theguardian.com/environment/2010/feb/02/hockey-stick-graph-climate-change.