Provisional chapter

Dire Consequences Likely to Happen if the Earth's Spinning Angle Gets Little Shifted – A Study Whether Fast Shrinkage of Polar Ice be the Cause?

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Additional information is available at the end of the chapter

1. Introduction

Environmentalist and Scientists are now of the opinion that the entire globe may face threats of: fast shrinkage of polar ice due to its melting and may eventually diminish by 2040, fast rise in the sea level, danger for species like: polar bears, penguins etc., northern portion of Canada, USA and UK may be affected by cold waves, heavy snow falls and storms due to shifting and melting of largest ice sheets in the Atlantic sea.

Permafrost may create further warming which cannot be reversed. Owing to the region becoming warm day by day, there is a potential increase in tundra fires. Scientists warn that these combined factors could turn the Arctic from a vast carbon sink into a potentially lethal source of methane in less than a decade. In view of likely disastrous implications, all the scientists involved, in the research and fieldwork are helping us to understand the growing threat of melting permafrost in the crucial Arctic region.

Our Earth planet is on a dangerous course of passing irreversible tipping points with disastrous consequences due to the melting of green land, polar ice and permafrost which in turn releases toxic methane gases, resulting more warming of the atmosphere.

The ice sheets are the largest potential source of future sea level rise and they also possess the largest uncertainty over their future behaviour. They present some unique challenges for predicting their future response using numerical modelling and, as a consequence, alternative approaches have been explored. One common approach is to extrapolate observed changes to estimate their contribution to sea level in the future.

The findings, published in Nature Geoscience, underscore the need for continuous satellite monitoring of the ice sheets to better identify and predict melting and the corresponding sea-level rise. The ice sheets covering Antarctica is about 90% and Greenland is about 9.5%, thus both contains about 99.5 per cent of the Earth's glacier ice which would raise global sea level by some 63m (about 200 ft.), if it were to melt completely.

This entire action may lead to shift of heavy movement of masses of the Arctic sheets to sea and may likely to have an effect on the spinning angle of the earth due to differential changes in masses apart from the above mentioned threats.

2. Earth planet

The Earth is the third planet from the Sun and the densest planet in the Solar System. It is also the largest of the Solar System's four terrestrial planets. It is sometimes referred to as the Blue Planet [1] the Blue Marble, *Terra* or Gaia as shown in Fig.1. According to evidence from sources, the Earth was formed around four and a half billion years ago. Within its first billion years [2-5] life appeared in its oceans and began to affect its atmosphere and surface, promoting the proliferation of aerobic as well as anaerobic organisms and causing the formation of the atmosphere's ozone layer. This layer and the Earth's magnetic field block the most life-threatening parts of the Sun's radiation, so life was able to flourish on the land as well as in the water [6]. Since then, the Earth's position in the Solar System, its physical properties and its geological history has allowed life to persist.

The Earth's lithosphere is divided into several rigid segments, or tectonic plates, that migrate across the surface over periods of many millions of years. Over 70% percent of the Earth's surface is covered with water [7], with the remainder consisting of continents and islands which together have many lakes and other sources of water that contribute to the hydrosphere. *The Earth's poles are mostly covered with ice that is the solid ice of the Antarctic ice sheet and the* sea ice *that is the polar ice packs*. The planet's interior remains active, with a solid iron inner core, a liquid outer core that generates the magnetic field, and a thick layer of relatively solid mantle.

The Earth gravitationally interacts with other objects in space, especially the Sun and the Moon. During one orbit around the Sun, the Earth rotates about its own axis 366.26 times, creating 365.26 solar days, or one sidereal year. *The Earth's axis of rotation is tilted 23.4°* away from the perpendicular of its orbital plane, producing seasonal variations on the planet's surface with a period of one tropical year (365.24 solar days) [8]. The Moon is the Earth's only natural satellite. It began orbiting the Earth about 4.53 billion years ago (bya). The Moon's gravitational interaction with the Earth's stimulates ocean tides, stabilizes the axial tilt, and gradually slows the planet's rotation.

The planet is home to millions of species life, including humans [9]. Both the mineral resources of the planet and the products of the biosphere contribute resources that are used to support a global human population [10]. These inhabitants are grouped into about 200 independent sovereign states, which interact through diplomacy, travel, trade, and military action.

Figure 1. The Earth Planet

2.1. Shape of the Earth planet

The shape of the Earth approximates an oblate spheroid, a sphere flattened along the axis from pole to pole such that there is a bulge around the equator [11]. This bulge results from the rotation of the Earth, and causes the diameter at the equator to be 43 km (kilometer) larger than the pole-to-pole diameter [12]. For this reason the furthest point on the surface from the Earth's center of mass is the Chimborazo volcano in Ecuador [13]. *The average diameter of the reference spheroid is about 12742 km, which is approximately 40,000 km/π, as the meter was originally defined as 1/10,000,000 of the distance from the equator to the North Pole through Paris, France* [14].

Local topography deviates from this idealized spheroid, although on a global scale, these deviations are small: the Earth has a tolerance of about one part in about 584, or 0.17%, from the reference spheroid [15]. The largest local deviations in the rocky surface of the Earth are Mount Everest (8,848 m above local sea level) and the Mariana Trench (10911 m below local sea level) and formed the equatorial bulge [16-18].

Some important physical and atmospheric characteristics of the Earth are shown in Table 1. From this data, it is evident that the Earth's radii through Polar and Equatorial are different such as 6356.8 km and 6378.1 km respectively. The polar radius is less than equatorial by 21.3 km or 43 km in diameter. The Earth's mass is 5.97219 x 1024 kgs. Circumferences through the equatorial and the meridional are 40075.017 km and 40007.86 km whereas the total surface area is 510072000 sq.km, out of which the land coverage is by 148940000 km^2 (29.2%) and the water coverage is 361132000 km^2 (70.8 %).

Physical characteristics				
Mean radius				6371.0 km
Equatorial radius				6378.1 km
Polar radius				6356.8 km
Flattening				0.0033528
Circumference				40075.017 km (**equatorial**) 40007.86 km (**meridional**)
Surface area				510072000 $km^2$148940000 km^2 (29.2%) **land** 361132000 km^2 (70.8 %) **water**
Volume of the Earth				1.08321×10^{12} km^3
Mass				5.97219×10^{24} kg 3.0×10^{-6} Suns
Mean density				5.515 g/cm^3
Surface gravity				9.780327 m/s2 0.99732 *g* (**Earth gravity**)
Moment of inertia factor				0.3307
Escape velocity				11.186 km/s
Equatorial rotation velocity				1,674.4 km/h (465.1 m/s)
Axial tilt				23°26′21.4119″ (23.43°)
Albedo				0.367 (**geometric**) 0.306 (**Bond**)
Surface temp.	**min**	**mean**	**max**	
Kelvin	184 K	288 K	330 K	
Celsius	–89.2 °C	15 °C	56.7 °C	
Atmosphere				
Surface pressure				101.325 kPa (at MSL)
Composition				78.08% nitrogen (N_2) (**dry air**) 20.95% oxygen (O_2) 0.93% argon 0.039% carbon dioxide About 1% water vapor (varies with climate)

Table 1. Physical and Atmospheric Characteristics of Earth

3. Geomorphology

It is known fact that the surface of the Earth is a combination of surface processes that sculpt landscapes, and geologic processes causing tectonic upliftment and subsidence. *Surface processes comprise the action of water, wind, ice, fire, and living things on the surface of the Earth,* along with chemical reactions that form soils and alter material properties, the stability and rate of change of topography under the force of gravity, and other factors, such as (in the very recent past) human alterations of the landscapes. Many of these factors are strongly mediated by climate. Geologic processes include the upliftment of the mountain ranges, the growth of volcanoes, isostatic changes in the land surface elevation (sometimes in response to surface processes), and the formation of deep sedimentary basins where the surface of the Earth drops and is filled with material eroded from other parts of the landscape. The Earth's surface and its topography therefore are an intersection of climatic, hydrologic, and biologic action with geologic processes.

The broad-scale topographies of the Earth illustrate this intersection of its surface and the subsurface actions. *Mountain belts are uplifted due to geologic processes. Denudations of these high uplifted regions produce sediment that is transported and deposited elsewhere within the landscape or off the coast* [19]. On progressively smaller scales, similar ideas apply where individual landforms evolve in response to the balance of additive processes (upliftment and deposition) and subtractive processes (subsidence and erosion). Often, these processes directly affect each other: ice sheets, water, and sediment are all loads that change topography through flexural isostasy. Topography can modify the local climate, for example through orographic precipitation, which in turn modifies the topography by changing the hydrologic regime in which it evolves. Many geomorphologists are particularly interested in the potential for feedbacks between climate and tectonics mediated by geomorphic processes.

An early popular geomorphic model was the *geographical cycle* or the *cycle of erosion* model of broad-scale landscape evolution developed by William Morris Davis between 1884 and 1899. It was an elaboration of the uniformitarianism theory that had first been proposed by James Hutton (1726–1797). In 1920s, Walther Penck developed an alternative model to Davis's. Penck thought that the landform evolution was better described as an alternation between ongoing processes of upliftment and denudation, as opposed to Davis's model of a single upliftment followed by decay. Penck's ideas were not recognised until many years after his death, perhaps because his work was not translated into English, he was involved in disputes with Davis, and he died young.

Both Davis and Penck have tried to place the study of the evolution of the Earth's surface on a more generalized, globally relevant footing than it had been previously. In the early 19th century, authors-especially in Europe-had tended to attribute the form of the landscapes to local climate, and in particular to the specific effects of glaciation and periglacial processes. In contrast, both Davis and Penck emphasized the importance of evolution of landscapes through time and the generality of the Earth's surface processes across different landscapes under different conditions.

3.1. Processes of geomorphology

Modern geomorphology focuses on the quantitative analysis of interconnected processes. Modern advances in geochronology, in particular cosmogenic radionuclide dating, and optically stimulated luminescence dating and low-temperature thermochronology have enabled us for the first time to measure the rates at which geomorphic processes occur on geological timescales [20, 21]. At the same time, the use of more precise physical measurement techniques, including differential GPS, remotely sensed digital terrain models and laser scanning techniques, have allowed quantification and study of these processes as they happen [22]. Computer simulation and modeling may then be used to test our understanding of how these processes work together and through time. Geomorphically relevant processes generally fall into:

i. the production of regolith by weathering and erosion,

ii. the transport of that material, and

iii. its eventual deposition.

3.2. Glacial processes

Glaciers, while geographically restricted, are effective agents of the landscape change. The gradual movement of ice down a valley causes abrasion and plucking of the underlying rock. Abrasion produces fine sediment, termed glacial flour. The debris transported by the glacier, when the glacier recedes, is termed as **'moraine'**. Glacial erosion is responsible for U-shaped valleys seen in Fig.2, as opposed to the V-shaped valleys of fluvial origin [23].

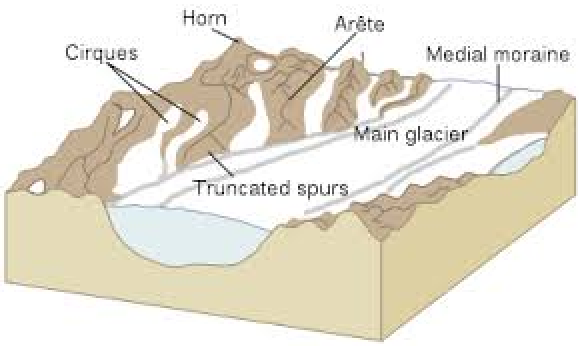


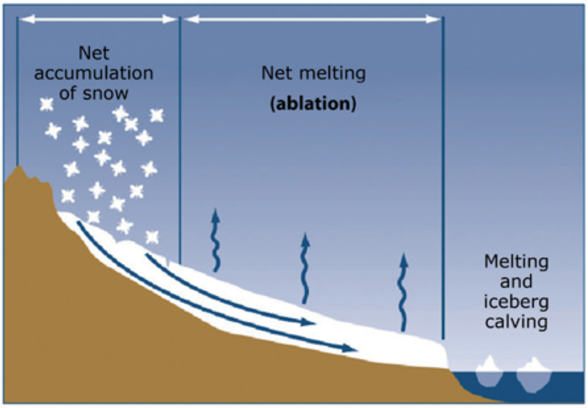
Figure 2. Features of a glacial landscape

The way glacial processes interact with other landscape elements, particularly hillslope and fluvial processes, is an important aspect of Plio-Pleistocene landscape evolution and its sedimentary record in many high mountain environments. Environments that have been relatively recently glaciated but are no longer may still show elevated landscape change rates compared to those that have never been glaciated. Nonglacial geomorphic processes which nevertheless have been conditioned by past glaciation are termed paraglacial processes. This concept contrasts with periglacial processes, which are directly driven by formation or melting of ice or frost [24].

3.2.1. Glacial mass balance

How do glaciers move? A glacier is a pile of ice, and as such, deforms under the force of gravity. Glaciers flow downslope because they *accumulate* mass (ice) in their upper portions (from precipitation and from wind-blown snow) and *ablate* (melt, sublimate and calve ice bergs) in their lower portions as shown in Fig. 3.

This means that a glacier in a steady state (equilibrium) will not change in steepness or size, because accumulation=ablation. The altitude with zero net accumulation or ablation on the glacier is the *equilibrium line altitude*. Changes in rates of accumulation or ablation will lead to glacier advance or recession; if the accumulation area of a glacier shrinks, for example, and the equilibrium line altitude rises, then the glacier will recede [25].

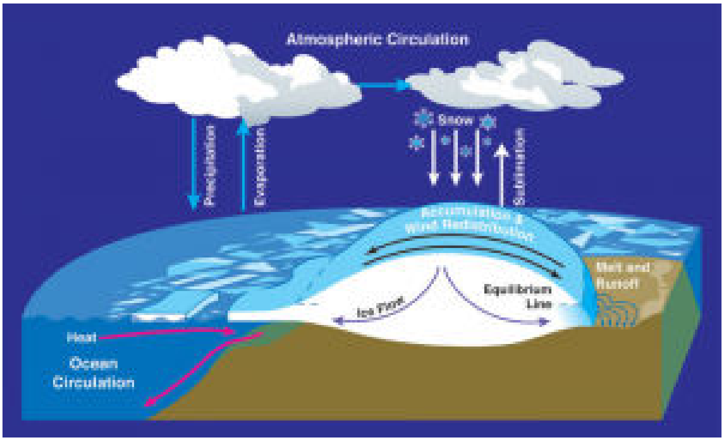


(Source: From the USGS Link: http://pubs.usgs.gov/fs/2009/3046/)

Figure 3. Components of mass balance of a glacier

Glacier mass balance is the difference between accumulation and ablation. It is therefore controlled by both temperature and precipitation. If accumulation is greater than ablation, then the glacier has positive mass balance and will advance. If ablation is greater than accumulation, then the glacier has negative mass balance and will recede.

Glaciers always flow downslope under the weight of their own gravity. A receding or shrinking glacier still flows (although it might flow very slowly!); it's just that it's melting faster than its acquiring snow in its upper reaches. As a result, the glacier will thin and the snout position will recede backwards.



(Source: From Wikimedia Commons)

Figure 4. Glacier mass balance and atmospheric circulation by NASA.

In theory, glaciers discharge ice from the accumulation area to the ablation area and maintain a steady-state profile. The velocity, the *balance velocity*, is controlled by glacier mass balance and glacier geometry. Some glaciers have dynamic flow driven by other factors, for example, surging glaciers, tidewater glaciers, ice streams or ice-shelf tributary glaciers.

3.2.2. Glaciers flow through ice deformation and sliding

Glaciers always flow downslope, through the processes of deformation and sliding (see Fig. 4). Glacier flow, velocity and motion are controlled several factors, including those listed below:

- Ice geometry (thickness, steepness),
- Ice properties (temperature, density),
- Valley geometry,
- Bedrock conditions (hard, soft, frozen or thawed bed),
- Subglacial hydrology,
- Terminal environment (land, sea, ice shelf, sea ice), and
- Mass balance (rate of accumulation and ablation).

When glaciers flow downslope, gravitational driving stresses are resisted (resistive stress). The driving stress is controlled by gravitational acceleration, ice density and temperature, ice thickness and ice surface slope. Resistive stresses mainly operate at the glacier bed, and comprise *basal drag*, or *lateral drag* against valley walls.

This driving stress means that glaciers move in one of three ways:

i. Internal deformation (creep)

ii. Basal sliding

iii. Soft bed subglacial deformation.

All glaciers flow by creep, but only glaciers with water at their base (temperate or polythermal) have basal sliding, and only glaciers that lie on soft deformable beds have soft sediment deformation. If all three factors are present, one can have the ingredients to contribute to fast ice flow.

4. Ice melt fuels sea level rise concerns

4.1. Satellites monitoring of ice sheets for better prediction about sea level rise

Since 2002, the satellites of the Gravity Recovery and Climate Experiment (GRACE) detect tiny variations in the Earth's gravity field resulting from changes in mass distribution, including movement of ice into the oceans. Using these changes in gravity, the state of the ice sheets can be monitored at monthly intervals.

Dr Bert Wouters, currently a visiting researcher at the University of Colorado, said: "In the course of the mission, it has become apparent that ice sheets are losing substantial amounts of ice-about 300 billion tonnes each year-and that the rate at which these losses occurs is increasing. Compared to the first few years of the GRACE mission, the ice sheets' contribution to sea level rise has almost doubled in recent years."

Yet, there is no consensus among scientists about the cause of this recent increase in ice sheet mass loss observed by satellites. Besides anthropogenic warming, ice sheets are affected by many natural processes, such as multi-year fluctuations in the atmosphere (for example, shifting pressure systems in the North Atlantic, or El Nino and La Nina events) and slow changes in ocean currents.

"So, if observations span only a few years, such 'ice sheet weather' may show up as an apparent speed-up of ice loss which would cancel out once more observations become available," Dr Wouters said [26].

The team of researchers compared nine years of satellite data from the GRACE mission with reconstructions of about 50 years of mass changes to the ice sheets. They found that the ability to accurately detect an accelerating trend in mass loss depends on the length of the record.

At the moment, the ice loss detected by the GRACE satellites as shown Fig.5 is larger than what we would expect to see just from natural fluctuations, but the speed-up of ice loss over the last years is not.

The study suggests that although there may be almost enough satellite data to detect a speed-up in mass loss of the Antarctic ice sheet with a reasonable level of confidence, another ten years of satellite observations is needed to do so for Greenland.

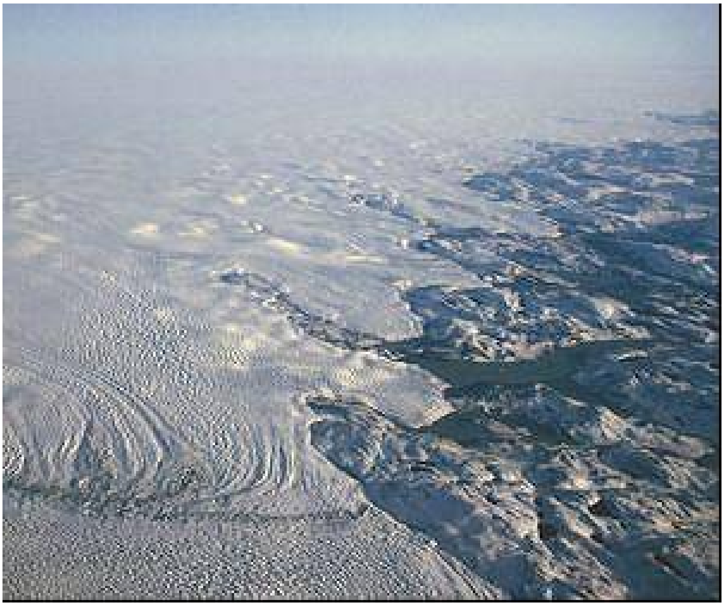


Figure 5. The Satellite Monitoring about Sea Level Rise

The findings suggest the need for continuous satellite monitoring of the ice sheets to better identify and predict melting and the corresponding sea-level rise. The ice sheets covering Antarctica and Greenland contain about 99.5 per cent of the Earth's glacier ice which would raise global sea level by some **63m** if it were to melt completely.

As a result, extrapolation of the current contribution to sea-level rise of the ice sheets to 2100 may be too high or low by as much as **35cm**. The study, therefore, urges caution in extrapolating current measurements to predict future sea-level rise.

4.2. Polar ice caps melt raises the oceans rise?

In the last 100 years the Earth's temperature has increased about half a degree Celsius, creating **Global Warming**. This may not sound like much, but even half a degree can have an effect on our planet. According to the U.S. Environmental Protection Agency (EPA) the sea level has risen **6** to **8 inches** (15 to 20 cm) in the last 100 years [27]. This higher temperature may be causing some floating icebergs to melt, but this will not make the oceans rise. Icebergs are large floating chunks of ice. In order to float, the iceberg displaces a volume of water that has a weight equal to that of the iceberg. Submarines use this principle to rise and sink in the water, too.

But the rising temperature and icebergs could play a small role in the rising ocean level. Icebergs are chunks of frozen glaciers that break off from landmasses and fall into the ocean.

The rising temperature may be causing more icebergs to form by weakening the glaciers, causing more cracks and making ice more likely to break off. As soon as the ice falls into the ocean, the ocean rises a little.

(Source: by Tom Brakefield)

Figure 6. Antarctica accounts for about 90 percent of the world's ice

If the rising temperature affects glaciers and icebergs, could the polar ice caps be in danger of melting and causing the oceans to rise? This could happen, but no one knows when it might happen.

The main ice covered landmass is Antarctica at the South Pole, with about 90 percent of the world's ice (and 70 percent of its fresh water) as shown in Fig.6. Antarctica is covered with ice an average of 2,133 meters (7,000 feet) thick. If all of the Antarctic ice melted, sea levels around the world would rise about 61 meters (200 feet). But the average temperature in Antarctica is (-) 37°C, so the ice there is in no danger of melting. In fact in most parts of the continent it **never** gets above freezing.

The ice is not nearly as thick on the North Pole as that of the South Pole. The ice floats on the Arctic Ocean. If it melted, sea levels would not be affected.

There is a significant amount of ice covering on Greenland, which would add another 7 meters (20 feet) to the oceans if it melted. Because Greenland is closer to the equator than Antarctica, the temperatures there are higher, so the ice is more likely to melt.

Water is most dense at 4 degrees celsius. Above and below this temperature, the density of water decreases (the same weight of water occupies a bigger space). So as the overall temperature of the water increases, it naturally expands a little bit making the oceans rise.

In 1995 the Intergovernmental Panel on Climate Change issued a report which contained various projections of the sea level change by the year 2100. They estimate that the sea will rise 50 centimeters (20 inches) with the lowest estimates at 15 centimeters (6 inches) and the highest at 95 centimeters (37 inches). The rise will come from thermal expansion of the ocean and from melting glaciers and ice sheets. Twenty inches is no small amount, it could have a big effect on the coastal cities, especially during storms.

4.3. New Greenland ice melt

New data published on March 16th, 2014, Sunday in 'Nature Climate Change' reveals that over the past decade, the region has started rapidly losing ice due to a rise in air and ocean temperatures caused in part by climate change (see Fig.7). The increased melt raises grave concerns that sea level rise could accelerate even faster than projected, threatening even more coastal communities worldwide [28].

"North Greenland is very cold and dry, and is believed to be a very stable area," said Shfaqat Khan, a senior researcher at the Technical University of Denmark who led the new study. "It is surprisingly to see ice loss in one of the coldest regions on the planet."

The stability of the region is particularly important because it has much deeper ties to the interior ice sheets than other glaciers on the island. *If the entire ice sheet were to melt--which would take thousands of years in most climate change scenarios--sea levels would rise up to 23 feet, catastrophically altering coastlines around the world.*

Sea levels have risen 8 inches globally since the start of the 1900s, and current projections show that figure could rise another 3 feet by the end of this century i.e. 2100.

Greenland houses 680,000 cubic miles of ice in its ice sheet, which stretches up to 3 miles thick in some places and covers roughly three-quarters of the island. Glaciers stretch from this frozen mass in all directions, eventually meeting the sea. In the past 20 years, some of these glaciers, particularly in the southeast and the northwest, have dumped ever increasing amounts of ice into the ocean. That water has accounted for more than 15 percent of global sea level rise over that period.

"This implies that changes at the margin can affect the mass balance deep in the centre of the ice sheet," said Dr Khan. Sea levels are creeping up at the rate of *3.2 mm a year*. Until now, Greenland had been thought to contribute about *half a mm*. The real figure may be significantly higher. They calculate that between April 2003 and April 2012, the region was losing ice at the rate of 10 billion tonnes a year.

(Source: Henrik Egede-Lassen)

Figure 7. Helheim glacier in the southeast Greenland.

4.4. East Antarctic melting could raise sea levels by 10 to 13 feet

The study, published in the journal 'Nature Climate Change', by Katie Valentine looked at the 600-mile Wilkes Basin in the East Antarctica as shown in Fig.8, which, if melts, has enough ice to raise sea levels by 10 to 13 feet [29]. Researchers found that the region was vulnerable to melting because it held in place by a small "ice plug" that may melt over the next few centuries, meaning East Antarctica could "become a large contributor to future sea-level rise on time-scales beyond a century," according to the article.

(Source: by Katie Valentine)

Figure 8. A region of East Antarctica is more vulnerable than previously thought to a massive thaw that could result in world's sea levels rising for thousands of years, a study on Sunday, May 4, 2014 at 9:25 am.

"East Antarctica's Wilkes Basin is like a bottle on a slant. Once uncorked, it empties out," Matthias Mengel, lead author of the study, said in a statement that uncorking, however, is a relatively distant threat. The researchers conducted simulations under scenarios with waters that were 1 to 2.5°C warmer than what they are today, and the study's authors said there was still time to limit warming enough to keep the plug in place. However, the planet is on a track to hit 2°C if major steps to curb climate change aren't taken, and already much of the globe's warming has been absorbed by the oceans. And although the East Antarctic threat is distant, yet it's a major finding; the study is the first to look at the Wilkes Basin to determine how the East Antarctic region might contribute to sea level rise [30-35].

"This is unstoppable when the plug is removed," Anders Levermann told National Geographic. The speed [of removal] we don't know, but it's definitely a threshold.

If all of Antarctica were ever to melt, it could raise sea levels by about 188 feet. A 2012 study found that Antarctica's ice loss had gone up by 50 percent over the past decade, and this year, a study found a massive Antarctic glacier has entered an irreversible melt, which could lead to a rise in sea levels of 1 centimeter. That glacier "has started a phase of self-sustained retreat and will irreversibly continue its decline," one of the study's authors said earlier this year.

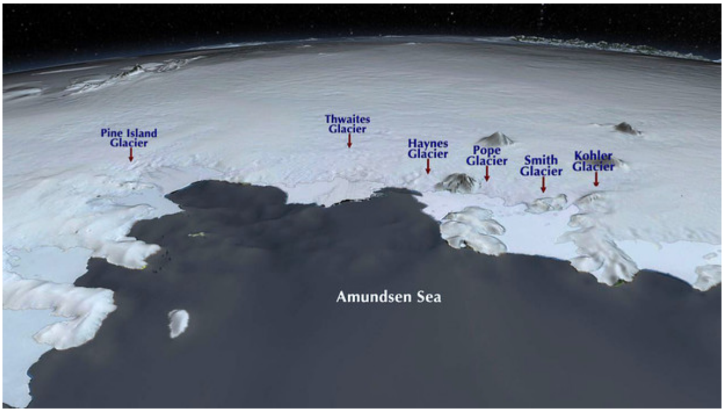
Another study from this year found that the shrinking of Antarctic glaciers can be "highly dependent" on climate variability [36-46].

"These new results show that the degree of melting experienced by the Antarctic ice sheet can be highly dependent on climatic conditions occurring elsewhere on the planet," Eric Steig said.

As for the Arctic, the National Snow and Ice Data Center in Boulder, Colorado announced in March 2014 that the region experienced the fifth-lowest winter sea ice cover extent since 1978.

4.5. Antarctic glaciers melting 'passed point of no return'

The vast glaciers of western Antarctica are rapidly melting and losing ice to the sea and almost certainly have "passed the point of no return," according to new work by two separate teams of scientists.



(Photo: NASA via AFP)

Figure 9. Getty Images by Traci Watson, Special for USA; May 13, 2014; 9:14 a.m.

The likely result: a rise in global sea levels of 4 feet or more in the coming centuries, says research made public on May 12, 2014, Monday by scientists at the University of Washington, the University of California-Irvine and NASA's Jet Propulsion Laboratory as shown in Fig.9.

"It really is an amazingly distressing situation," says Pennsylvania State University glaciologist Sridhar Anandakrishnan, who was not affiliated with either study. "This is a huge part of West Antarctica, and it seems to have been kicked over the edge."

The researchers say the fate of the glaciers is almost certainly beyond hope. One study shows that a river of ice called Thwaites Glacier is probably in the early stages of collapse. Total collapse is almost inevitable, the study shows. A second study shows that half-dozen glaciers are pouring ice into the sea at an ever-greater pace. That will trigger 4 feet of sea-level rise, says study author Eric Rignot, a glaciologist at the University of California-Irvine, and NASA's Jet Propulsion Laboratory.

"The retreat of ice in that area is unstoppable," Rignot said at a briefing on May 12, 2014, Monday, adding that the glaciers have "passed the point of no return."

Rignot and his team used data from satellites and aircraft to map changes in six West Antarctic glaciers and the terrain underlying these massive ice floes. The data show the glaciers are stretching out, thinning and shrinking in volume. They're also flowing faster from the continent's interior to the sea, dumping larger quantities of ice into the ocean than before and thereby raising sea levels.

Figure 10. Collapse of Thwaites Glacier

At the same time, the portion of each glacier projecting into the sea is being melted from below by warm ocean water as shown in Fig. 10. That leads to a vicious cycle of more thinning and faster flow, and the local terrain offers no barrier to the glaciers' retreat, the researchers report in an upcoming issue of Geophysical Research Letters.

A report in the mid of May 2014 Week's Science says the Thwaites Glacier will collapse, perhaps in 200 years. The paper doesn't specify the amount of sea-level rise associated with Thwaites' demise.

4.6. No way back for west Antarctic glaciers

The study of 19 years of data, due to be reported in the journal Geophysical Research Letters, confirms the ominous news that the southern hemisphere is not just warming? it is that it is warming in a way that speeds up the melting of the West Antarctic glaciers.

Long ago, glaciologists began to wonder whether the West Antarctic ice sheet was inherently unstable. The water locked in the ice sheet in the Amundsen Sea region—the area the Nasa researchers examined—is enough to raise global sea levels by more than a metre. If the whole

West Antarctic ice sheet turned to water, sea levels would rise by at least five metres as shown in Fig.11.

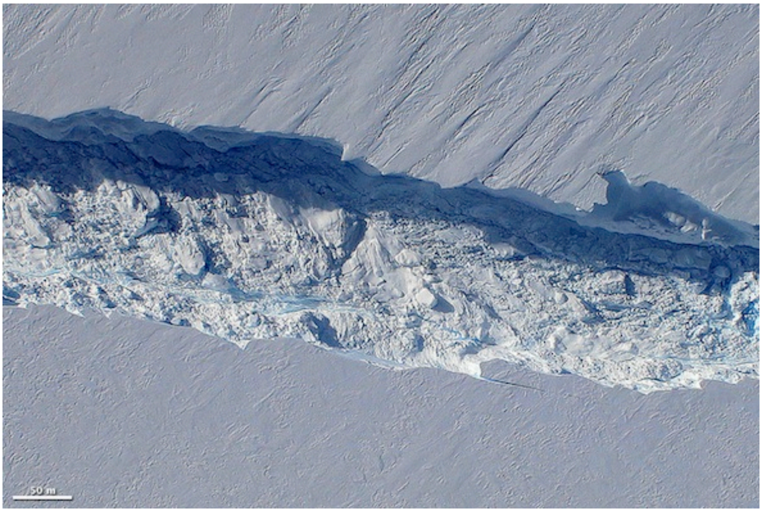


Photo: *by NASA (Source: Earth Observatory via Wikimedia Commons).*

Figure 11. Birth of an iceberg: a massive crack in West Antarctica's Pine Island glacier.

4.6.1. Steady change

What the latest research has revealed is a steady change in the glacial grounding line, which is the point in a glacier's progress towards the sea where its bottom no longer scrapes on rock but starts to float on water. It is in the nature of a glacier to flow towards the sea, and at intervals to calve an iceberg that will then float away and melt. The puzzle for scientists has been to work out whether this process has begun to accelerate.

Eric Rignot, a glaciologist at the Nasa Jet Propulsion Laboratory and the University of California, Irvine, thinks it has. He and his research partners believe that European Space Agency satellite data has recorded the points at which the grounding lines can be identified in a series of West Antarctic glaciers monitored between 1992 and 2011, as the glaciers flexed in response to the movement of tides.

All the grounding lines had retreated upstream, away from the sea—some by more than 30 kilometres. The grounding lines are all buried under hundreds of metres of ice, and are difficult to identify.

The shift of ice in response to tidal ebb and flow provides an important clue. It also signals an acceleration of melting, because it is the glacier's slowness that keeps the sea levels static. As it inches towards the sea, there is time for more snow and ice to pile up behind it.

4.6.2. Speeds up

But if the water gets under the ice sheet, it reduces friction and accelerates the passage of frozen water downstream. So the whole glacier speeds up, and the grounding line moves yet further upstream. Something similar has been reported from the glaciers of Greenland. And once the process starts, there is no obvious reason why it would stop. The melting will still be slow, but the latest evidence indicates that it seems to be inexorable.

"We've passed the point of no return," Prof Rignot says. "At current melt rates; these glaciers will be history within a few hundred years.

"The collapse of this sector of West Antarctica appears to be unstoppable. The fact that the retreat is happening simultaneously over a large sector suggests it was triggered by a common cause, such as an increase in the amount of ocean heat beneath the floating sections of the glaciers. At this point, the end of this sector appears to be inevitable."

5. Antarctic mass variation on account of ice melt

Antarctica is melting, not growing. In fact the ice mass is dropping at an accelerating rate due to multiple factors including accelerated glacial ice calving rates. The loss of sea based ice allows the Antarctic ice to move faster towards the ocean resulting in an increased rate of loss of the Antarctic ice.

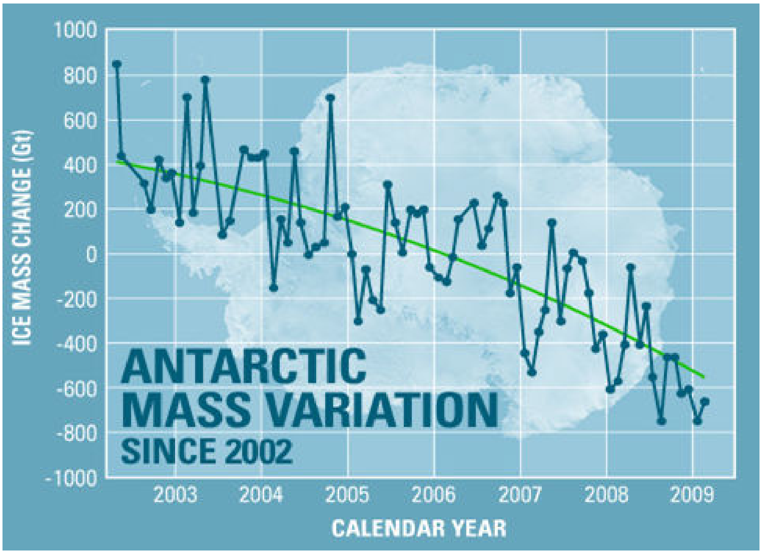
5.1. Antarctica warming

Antarctica is losing ice mass while gaining ice extent. This is a confusing point to some. There are a few keys that can help us understand what this means in the context of global warming. Land ice is different than sea ice. Antarctica is losing ice as illustrated below in the ice mass chart from the GRACE satellite as shown in Fig.12 and Fig.13.

The sea ice-extent is increasing as expected based on observations and model studies. Context is important here. While it is warming in the Southern Hemisphere (SH), there are other things changing that influence Antarctic Sea Ice Extent, while it is warming in and around the Antarctica. It remains cold during winters which allow ice extent to grow each winter. The growth of the Antarctic Sea Ice is likely due to changes in ocean and wind circulation combined with changes in moisture levels and related factors that are related to the ice extent increase. There is indication that changes in stratospheric ozone may also play a role.

Some models and studies hypothesized this would occur, so the observations are in a line with such expectations. Further attribution studies will help confirm the degree of connectivity to current climate change. The key to understanding simultaneous warming in the Antarctic region and increase sea ice extent is well explained in Zhang 2007 [47].

The model shows that an increase in the surface air temperature and downward longwave radiation results in an increase in the upper-ocean temperature and a decrease in sea ice growth, leading to a decrease in salt rejection from ice, in the upper-ocean salinity, and in the



(Source: http://www.nasa.gov/topics/earth/features/20100108_Is_Antarctica_Melting.html)

Figure 12. Antarctic Ice Mass Loss [manual update]

upper-ocean density. The reduced salt rejection and upper-ocean density and the enhanced thermohaline stratification tends to suppress convective overturning, leading to a decrease in the upward ocean heat transport and the ocean heat flux available to melt sea ice. The ice melting from ocean heat flux decreases faster than the ice growth does in the weakly stratified Southern Ocean, leading to an increase in the net ice production and hence an increase in ice mass. This mechanism is the main reason why the Antarctic sea ice has increased in spite of warming conditions both above and below during the period 1979–2004 and the extended period 1948–2004 [48, 49, 50].

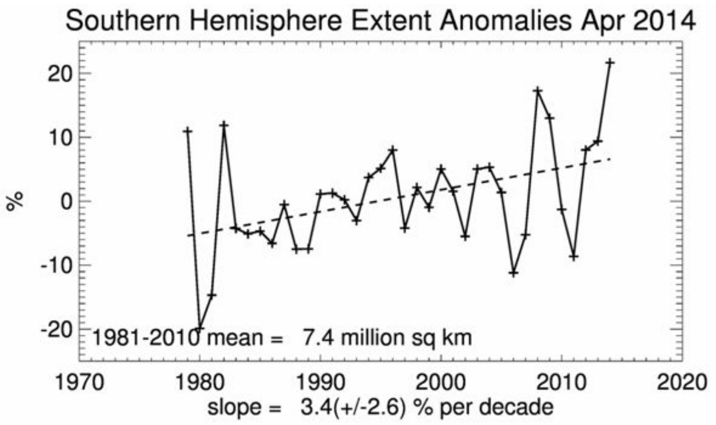
Generally, in SH winter, ice extent can grow more than usual, while in summer the overall satellite observations show that ice mass of Antarctica is decreasing.

With more snow precipitation in the Antarctica, one might expect that the ice mass would grow as well, but at this time the ice discharge (calving) rates are increasing.

Data confirms these three factors:

- Antarctica is warming
- Antarctic sea ice extent is increasing
- Antarctic land Ice mass is decreasing

A warmer world seems to translate to more snow but faster loss of that snow in the spring/summer months.

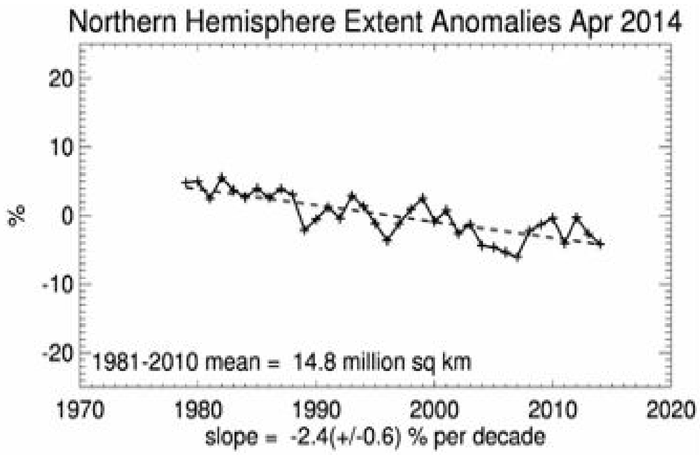


(Source: http://nsidc.org/data/seaice_index/)

Figure 13. Antarctic Ice Extent Increase updates annually

5.2. Arctic warming

The Arctic, in the Northern Hemisphere (NH) acts in the opposite direction regarding ice .....extent, and is also losing ice mass as shown in Fig. 14 The main reason that the NH is not gaining ice extent like Antarctica is the Northern or Polar Amplification Effect. This is due to the fact that the NH is mostly land, while the SH is mostly water and ice. So the two hemispheres behave quite differently.



(Source: http://nsidc.org/data/seaice_index/)

Figure 14. Arctic Ice Extent updates annually

6. Results and discussion

From the above study, it is seen that the Earth's land [51-53] covers by 148940000 km^2 (29.2%) and water by 361132000 km^2 (70.8 %) that means every mm rise in sea will have a shift of melting ice into water around:

a. Assuming average sea level rise of 0.5mm per year due to greenland Icemelt, then additional water will be added to sea water as under:

- Volume of Water=361132000 km^2x 1000 x1000=361132x10^9 sqm per year
- Rise of water per year=(0.5mm/1000)=5x10^{-4} m
- Total water added per year=(361132x10^9 sqm) x (5x10^{-4} m)=1805660x10^5 cum (i.e. 180.566 billion tonne)

b. By year 2100, when sea rise is likely to be raised to minimum 3.6 feet (1.1 metre) due to melting of polar ice sheets and green land ice, then additional water will be added to sea water:

- Multiplier=(1.1m x 1000/0.5mm)=2200
- Water will be added=(180.566 billion tonne x 2200)=397.245 trillion tone

c. By year 2100, when sea rise is likely to be raised to maximum 10-13 feet (3.3-4.0 metre), then additional water will be added to sea water: (397.245x3=1191.735)≈1200- 1450 trillion tonne

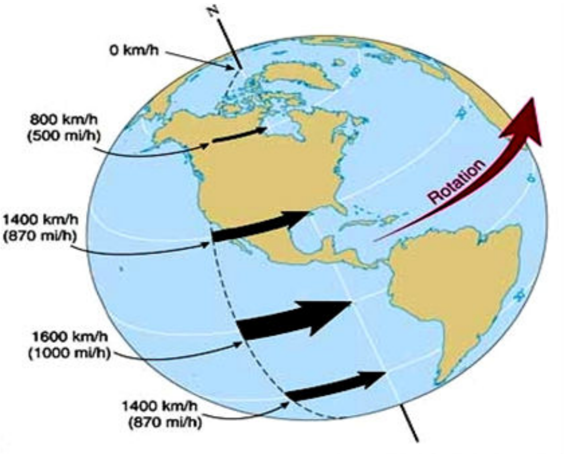


Figure 15. Earth Rotational Angle 23.43^0

Thus, such heavy weight shifting of (approx.) 400 trillion tonnes minimum or (approx.) 1200-1450 trillion tonnes maximum from polar ice-sea or Northern / Southern coast and green land to sea water, might force to the change in spinning angle of the earth from 23.43 degree to 23.43^0 (+or-) as seen in Fig. 15. Further detailed analysis is still required or model is to be prepared to find out the exact date and time as to when such situation may arise.

What would be the fate of the Earth and its living creatures, when it happens?

7. Conclusions

From the study, it is very much clear that Global Warming is happening and Polar Ice melt / Green land ice melt is continuing fast. This will not only affect our living and developments but have dire impacts on:

i. The Earth's poles are mostly covered with ice that is the solid ice of the Antarctic ice sheet and the sea ice that is the polar ice packs.

ii. Fast shrinkage of the polar ice will diminish by 2040, fast rise in the Sea Level, danger for species like: polar bears, penguins etc., northern portion of Canada, USA and UK may be affected by cold waves, heavy snow falls and storms due to shifting and melting of heaviest ice sheets in the Atlantic sea. Permafrost may create further warming which cannot be reversed.

iii. The surface of the Earth is a combination of surface processes that sculpt landscapes, and geologic processes that cause tectonic upliftment and subsidence. Surface processes comprise the action of water, wind, ice, fire, and living things on the surface of the Earth.

iv. Glaciers, while geographically restricted, are effective agents of the landscape change. The gradual movement of ice down a valley causes abrasion and plucking of the underlying rock. Abrasion produces fine sediment, termed glacial flour.

v. According to the U.S. Environmental Protection Agency (EPA) the sea level has risen about 6 to 8 inches (15 to 20 cm) in the last 100 years due to Global Warming.

vi. Antarctica is covered with ice an average of 2,133 meters (7,000 feet) thick. If all of the Antarctic ice melted, sea levels around the world would rise about 61 meters (200 feet). But the average temperature in Antarctica is (-) 37°C, so the ice there is in no danger of ice melting.

vii. Sea levels are creeping up at the rate of *3.2 mm a year*. Until now, Greenland had been thought to contribute about *half a mm*. The real figure may be significantly higher.

viii. Sea level change by the year 2100, estimates a rise of 50 centimeters (20 inches) with the lowest estimates at 15 centimeters (6 inches) and the highest at 95 centimeters (37 inches). The rise will come from thermal expansion of the ocean and from melting glaciers and ice sheets. Twenty inches is no small amount, it could have a big effect on coastal cities, especially during storms.

ix. Greenland houses 680,000 cubic miles of ice in its ice sheet, which stretches up to 3 miles thick in some places and covers roughly three-quarters of the island. In the past

20 years, some of these glaciers, particularly in the southeast and northwest, have dumped ever increasing amounts of ice into the ocean. That water has accounted for more than 15 percent of global sea level rise over that period.

x. The planet is on a track to hit 2°C rise in the temperature if major steps to curb climate change aren't taken, and already much of the globe's warming has been absorbed by the oceans.

xi. Glacier has started a phase of self-sustained retreat and will irreversibly continue its decline. There may be a chance to grow glaciers at northern portion of Canada, USA, UK and may create venerable conditions of snow fall and cold waves in these regions.

xii. A calculation shows that between April 2003 and April 2012, the region was losing ice at the rate of 10 billion tons a year.

xiii. By year 2100, if a minimum of 3.6 feet (1.1 metre) or maximum 10-13 feet (3.3-4 metres) sea level rise occurs, then it will have a shift of ice melt into water by 397.245 trillion tonnes or maximum 1200-1450 trillion tonnes respectively.

Thus, looking into the weight shift from polar (Northern / Southern coast) to sea, it might create change in the spinning angle of the Earth from 23.43 degree to further (+) or (-). The day may be a dark day on the beautiful planet when the entire living creatures may face dire consequences of their end up, provided things are checked and not to go beyond our control today. Try to imagine the consequences, act fast to "Save Earth; Save Life".

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