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Ice: Sentinel of the Continents

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Abstract

In the last few decades, harmful human activities such as burning fossil fuels have caused a rapid rise in toxic greenhouse gas emissions, trapping Earth's surface heat which raises global temperatures. The issue of global warming is prevalent today as temperatures on Earth are increasing at an alarming rate. This increase causes the ice caps in the Arctic Sea and Antarctica to melt faster which is problematic because cumulative research attests that ice restrains sea levels from reaching cataclysmic levels. The Arctic Ocean and Antarctica exhibit a balancing effect that controls the amount of ice melted and produced as each polar region experiences its summer or winter season. Furthermore, as vaporization levels are extremely low in Polar Regions, these regions utilize ice as a more effective alternative for water retention. In addition, because ice's unique qualities, major volume displacement that would detrimentally damage coastal ports and cities can be evaded.

Keywords:

Sea levels, Icebergs, Antarctica, Arctic sea, Water cycle, Seasons, Density, Buoyancy force, Global warming, Rising temperatures

Introduction

A contemporary issue prevalent today is global warming, the warming caused by the atmosphere's trapping of heat radiating from the Earth to space. According to NASA, the average temperature on Earth's surface rose approximately 1.62 degrees Fahrenheit from the late 1800s [1]. Alarmingly, the majority of the temperature increase occurred in the last 35 years, and the year with the highest average temperature was only recently in 2016 [2]. The principal cause of this detrimental warming is human activities that emit greenhouse gases, gases that trap heat in the Earth's atmosphere. The main greenhouse gases include carbon dioxide, methane, nitrous oxide and fluorinated gases according to the United States Environmental Protection Agency. Carbon dioxide - the most prevalent greenhouse gas - enters Earth's atmosphere in various methods that involve such as emissions from burning materials and chemical reactions (Figure 1).

In the United States, the greatest source of greenhouse gas emissions is the burning of fossil fuels for heat, transportation and electricity. The United States Environmental Protection Agency states that the major economic sectors of greenhouse gas emissions are transportation, electricity production, industry, commercial and residential uses, and agriculture (Figure 2).

The transportation, electricity, and industry sectors similarly each constitute over 20% of the total United States greenhouse gas emissions. The emission of greenhouse gases from the transportation sector is caused as fossil fuels are burnt for usage as fuel for planes, cars, ships, trains and trucks. The emission of greenhouse gases from the electricity sector is caused as electricity is generated for practical daily use. The emission of greenhouse gases from the industry sector is caused as fossil fuels are burnt for manufacturing purposes and other purposes related to industry. Overall, the United States Environmental Protection Agency claims that in

2017, all sources of greenhouse gas emissions produced approximately 6,457 million metric tons of carbon dioxide equivalent [3].

As mentioned before, a large temperature increase occurred in the last 35 years. Consequently, a domino effect occurred of the surface temperature increasing, ice sheets melting, and sea levels rising. In fact, according to data from NASA's Gravity Recovery and Climate Experiment, between the years of 1993 and 2016, Greenland lost approximately 286 billion tons of ice per year on average and Antarctica lost approximately 127 billion tons of ice per year on average. Furthermore, in the last century, the global sea level rose approximately 8 inches, but more importantly, the increase rate in the last 2 decades nearly doubles the increase rate of the last century [2]. Due to the correlation between the cataclysmic losses of ice mass and alarming rise of sea levels, the general public commonly assumes that ice only impacts sea levels by raising them through melting. Contrary to generic belief, however, ice plays a vital role in regulating sea levels through important natural occurrences such as the concept of density, the seasons and the water cycle.

Importance of Ice's Density

In order to fully grasp the beneficial impacts of icebergs, the unique qualities of ice need to be understood. Density is arguably the most pivotal property when defining a substance because each and every substance has a different density that always stays constant. Density is equal to the division of the mass of an object by the volume of that object which can be translated to $D = M/V$ where D represents the object's density, M represents the object's mass, and V represents the object's volume. In essence, density basically defines how concentrated the atoms of the substances are in a specific substance. In addition, if an object has a higher density than the density of the liquid that it is being submerged into, the object will sink. If an object, conversely, has a lower density than the liquid it is being submerged into, the object will float.

According to Jessica Fries-Gaither, a past elementary resource specialist in the College of Education and Human Ecology at the Ohio State University, the density of ice is 0.92 g/mL while the density of pure water is 1.0 g/mL [4]. The numbers unequivocally show that ice would float on pure water because its density is lower than pure water's density; however, if ice is made of water, why is the density of ice

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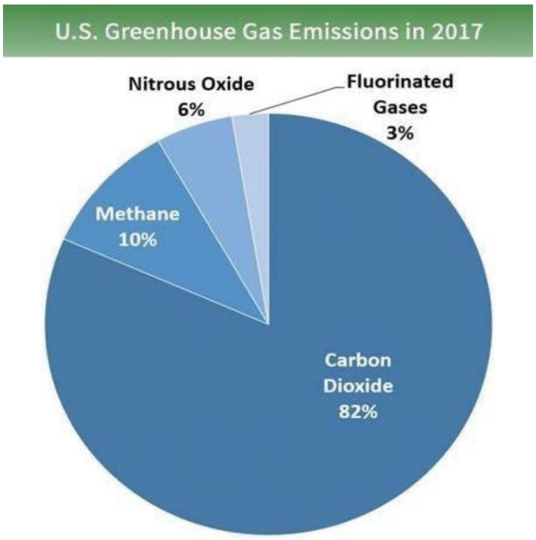

Figure 1: United States Greenhouse Gas Emissions in 2017 by United States Environmental Protection Agency.

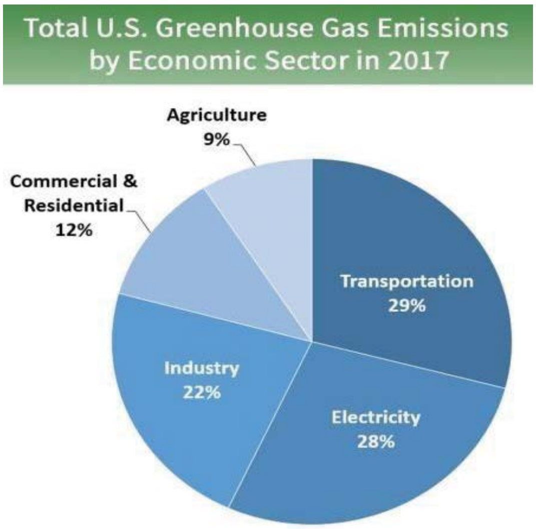

Figure 2: Sources of United States Greenhouse Gas Emissions in 2017: United States Environmental Protection Agency.

lower than the density of water? The answer to this puzzling question can be found when scrutinizing the molecular changes liquid water undergoes during a phase change from its liquid form to its solid form. The molecules of most other substances usually contract when they are frozen which increases the concentration of the molecules, thus elevating the densities of the solid forms of the substances. However, when liquid water freezes, its molecules disperse and expand into a specific crystallized structure [5] (Figure 3).

This specialized alignment leaves more space for the molecules to move around in which lowers the concentration of the molecules, decreasing the density of ice. In addition, this expansion of space makes the volume of the ice greater than the volume of the liquid water. As ice has a lower concentration of molecules and a greater volume, ice's density is lower than the liquid water's density [4]. However, because icebergs are chunks of frozen freshwater floating on seawater, a comparison between the densities of icebergs (0.92 g/mL) and seawater is necessary. Fries-Gaither estimates the density of seawater to be about 1.03 g/mL because of the other minerals that have dissolved into the seawater [4]. This means that ice would still float on the seawater since ice's density is lesser than the sea water's density. In addition to ice, the pure water released from iceberg melting would float above the sea water and form a layer above the seawater because its density of 1.0 g/mL is lower than the sea water's density of 1.03 g/mL.

The concept of density also introduces another way of explaining why icebergs float on seawater. Because the mass that is used in determining the density of a substance is synonymous to the weight of the same substance, density is connected to buoyancy. According to OpenStax, buoyant force, or buoyancy, can be described as the upward force exerted on an object in a fluid that is always present whether the object sinks floats or is suspending in the fluid [6]. An object will float if the buoyant force is greater than an object's weight while the object will sink if the buoyant force is lesser than the object's weight. The strength of the buoyant force can be considered equal to the fluid's weight that is displaced by the object according to the Archimedes Principle. This principle can be shown in equation form as

$$\mathbf{Fb = \rho \times g \times V}$$

where Fb is the buoyant force

ρ is the fluid's density

g is the acceleration due to gravity which is known as 9.8 m/s^2

V is the submerged volume of the object [7, 8].

Using Fries-Gaither's numbers of ice's density(0.92 g/mL) and sea water's density(1.03 g/mL), ice's density is about 90% of the density of water which means that about 90% of the iceberg is underwater and about 10% is above the surface of the seawater. Given this information, a hypothetical situation can be utilized to show how buoyancy supports the floating of icebergs on seawater. For example, an iceberg has a volume of 3000 cubic feet can portray the relationship between buoyancy and icebergs floating on water.

First, the volume of 3000 cubic feet should be converted to milliliters because the densities that will be used later are measured in grams per milliliter. The conversion would look like the following (**Table 1**).

The volume of the total iceberg equals 3000 times 28316.8 mL which produces 8.49504*107 mL.

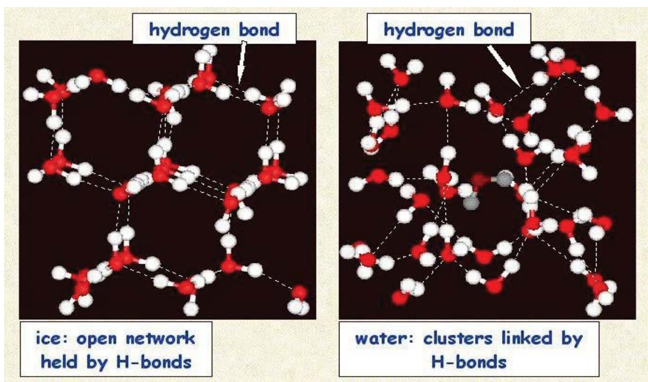

Figure 3: The Molecular Structure of Ice and Liquid Water: University of Wisconsin-Eau Claire.

Next, in order to determine the submerged volume of the iceberg, the total volume needs to be multiplied by 0.9 because about 90% of an iceberg is considered to be underwater; therefore the multiplication's product would represent the volume of the iceberg underwater in millimeters.

8.49504*107 mL x 0.9 = 7.644554 *107 mL

(total volume) (90%) (submerged volume)

Then, the densities of ice and seawater need to be utilized to find the masses of the total iceberg and the submerged iceberg to later determine their weights. Since D = M/V, the mass can be determined by multiplying the volume and density. The density of ice of 0.92 g/mL would be multiplied to the volume of the total iceberg. However, the density that would be multiplied to the submerged volume of the iceberg is the density of seawater not ice because the buoyant force, the weight of the displaced fluid, needs to be determined. The volume of the submerged iceberg is equivalent to the volume of the fluid displaced; consequently the seawater's density of 1.03 g/mL should be multiplied by the volume of the submerged iceberg since buoyant force depends on the weight of the liquid not the solid. Therefore, the mass of the displaced fluid can be determined from the volume of the submerged iceberg and the density of seawater (Table 2).

Next, the weight of the iceberg and the displaced fluid produced by the iceberg must be determined because buoyancy takes into account the weights of the object and the displaced fluid. Weight is defined as the measurement of gravity's pull on an object and can be calculated by multiplying the mass of an object by the acceleration of gravity which is known as 9.8 m/s2 (Table 3).

Because the weight of the displaced fluid is equal to the buoyant force, the buoyant force can be compared to the weight of the total iceberg in order to show how buoyancy relates to the iceberg floating on water in this hypothetical example.

7.65913*108 g<7.7164*108 g

Therefore,

Total weight of the iceberg<Buoyant force

Since the buoyant force is greater than the total weight of the iceberg, the iceberg will float on seawater.

The concepts of density and buoyancy justify why ice floats on water and are applicable to the natural world through an example of icebergs in seawater. Since calculating the precise volumes of all the icebergs is near impossible due to the lack of efficient methodology to measure the colossal sizes of all existing icebergs, the exact volume that would be added to the volume of existing seawater if ice's density was higher than the density of seawater and if the buoyant force was always smaller than the weight of an iceberg cannot be determined. However, the largest known iceberg on Earth, labelled as A68, has an area of nearly 5,800 km^2 and has a volume that doubles the volume of Lake Erie, and according to a team of researchers from the MIDAS Antarctic research project, weighs over one trillion tons [9]. Even if only this behemoth were to completely sink, the sea levels would drastically increase due to volume displacement and detrimentally threaten numerous coastline cities all throughout the world. In addition, according to the National Science Foundation, if the continent of Antarctica, essentially a glacial ice cover, were to sink, the sea levels would increase approximately 200 feet which would leave colossal detrimental effects [10].

Thus, because of the phenomenal floating qualities that ice has because of its low density, overly high sea levels that could bring cataclysmic effects to the world are avoided.

The Ice Balancing Effect of the Arctic Sea and Antarctica

Many people believe that the seasons occur based on Earth's distance from the Sun. They claim that summer occurs when the Earth is close to the Sun while winter occurs when the Earth is far from the Sun. However, according to Dave Kornreich - an assistant professor in the Department of Physics and Physical Science at Humboldt State University - the distance between the Earth and the Sun, en facto, is the greatest in the summer month of July while the distance is the shortest in the winter month of January [11]. Also, he claims that distance has hardly any effect on seasons. Then what actually causes the seasons? The answer to this question is the tilt of the Earth's orbital axis. According to the National Weather Service, the tilt of the axis is 23.5 degrees with respect to Earth's orbital plane, which Makayla Trotter of National Geographic (2012) defines as the disk-shaped space that links the center of the orbiting object to the center of the object that is being orbited around [12]. The ends of this imaginary axis are called the North Pole and the South Pole which are located in the Arctic Sea and Antarctica, respectively [13]. These imaginary poles are always pointed at the celestial poles which are points where the intersection between the celestial sphere and the projection of the Earth's rotation axis occurs [14]. Therefore, the Earth's rotation axis is always pointed in the same direction no matter where the Earth is in its 365.25-day, elliptical orbit.

Cubic Feet (ft^3)	Volume (mL)
1 ft^3	28316.8 mL
3000 ft^3	$8.49504*10^7$ mL

Table 1: Conversions of Iceberg.

	Volume(mL)		Density(g/mL)		Mass(g)	
Total Iceberg	$8.49504*10^7$ mL	x	0.92 g/mL	=	$7.81544*10^7$ g	Total Iceberg
Submerged Iceberg	$7.644554*10^7$ mL	x	1.03 g/mL	=	$7.87388*10^7$ g	Displaced Fluid

Table 2: Mass of the displaced fluid.

	Mass(g)		Acceleration of gravity(m s^2)		Weight(g)
Total Iceberg	$7.81544*10^7$ g	x	9.8 m/s^2	=	$7.65913*10^8$ g
Displaced Fluid	$7.87388*10^7$ g	x	9.8 m/s^2	=	$7.7164*10^8$ g

Table 3: Weight of the iceberg and the displaced fluid.

Since the North and South Pole are located opposite of each other, the seasons that the poles experience are opposite of each other as well. In months June through August, the Northern Hemisphere is experiencing summer because the North Pole is pointed towards the Sun; however, the Southern Hemisphere would be experiencing winter since the South Pole would be facing away from the Sun. During the months of December, January and February, the Southern Hemisphere would experience summer because the South Pole would be facing towards the Sun while the Northern Hemisphere experiences winter since the North Pole would be facing away from the Sun (Figure 4).

In June, July, and August, the Arctic Sea - where the North Pole is located - experiences summer and receives sunlight for all 24 hours of the day unless there are clouds in the air [15]. Because of this constant exposure to the sun, the average temperature shoots up to approximately 32°F, according to Michon Scott of the National Oceanic and Atmospheric Administration (NOAA) [16]. And, since 32 degrees Fahrenheit is ice's melting point, a substantial amount of ice melts during the summer.

According to scientists at the National Snow and Ice Data Center (NSIDC), about 100,000 square kilometers of ice is lost during the first half of July only, and more ice melts through the rest of the summer due to the high pressure at sea level in the Arctic Sea which leads to clearer skies that expose the ice to more sunlight [17]. During this season, the average minimum sea ice extent drops 9 million square kilometers to 6.5 million square kilometers from the average maximum extent of 15.6 million square kilometers - according to the NSIDC - due to the constant exposure to sunlight and high temperatures ("Arctic vs Antarctic", n.d.). Since water is produced when ice melts, the approximate 9 million square kilometers that melts during the Arctic Sea's summer would add a significant amount of water into the sea, elevating sea levels. However, the concurrent winter occurring in the South Pole alleviates this potential increase. Antarctica, where the South Pole is located, is in the season of winter and becomes the coldest location on Earth. During the entire 3 month period, Antarctica receives no sunlight for all 24 hours of the day which drops the average temperature to -72 degrees Fahrenheit, according to the U.S. Antarctic Program [18]. Thus, because the average temperature is significantly lower than the freezing point of water of 32°F, a considerable amount of seawater around Antarctica freezes. According to National Geographic, Antarctica adds approximately 16 million km^2 of ice to the average minimum extent of 3.1 million km^2, reaching the average maximum extent of 18.8 million km^2 [19]. Although the Antarctic produces about 7 million square kilometers more than the Arctic (16 million gained by the Antarctic subtracted by 9 million lost by the Arctic), the thickness of the Arctic Sea ice accounts for this difference. The NSIDC finds that the average thickness of the Arctic sea ice is 1.89 meters while the Scientific Committee on Antarctic Research (SCAR) and Antarctic Sea Ice Processes and Climate (ASPeCt) programs find that the mean level sea ice thickness of Antarctica is 0.62 meters. Using the average maximum/minimum extents in summer/winter of the Arctic Sea and Antarctic ice, the mean Arctic Sea sea ice thickness, and the mean Antarctic sea ice thickness, a basic calculation can be completed to portray that the Arctic Sea loses more ice than the Antarctic gains during the months of June, July and August.

First, the surface area of the ice gained in Antarctica can be determined by subtracting the average maximum ice extent by the average minimum ice extent.

18,800,000 km^2 - 3,100,000 km^2 = 16,700,000 km^2

(Average max ice extent) (Average min ice extent) (Amount of ice gained)

Subsequently, the amount of ice lost in the Arctic Sea can be determined by subtracting the average maximum ice extent by the average minimum ice extent.

15,600,000 km^2 - 6,500,000 km^2 = 9,100,000 km^2

(Average max ice extent) (Average min ice extent) (Amount of ice lost)

Thirdly, the mean thickness of the Arctic sea ice and Antarctic sea ice need to be converted to kilometres because the amounts of ice lost/gained are measured in km^2 (Table 4).

Fourthly, the average volume of the sea ice gained by Antarctica can be determined by multiplying the average amount of ice lost, which is surface area since it is measured in km^2, and the mean thickness of the Antarctic sea ice.

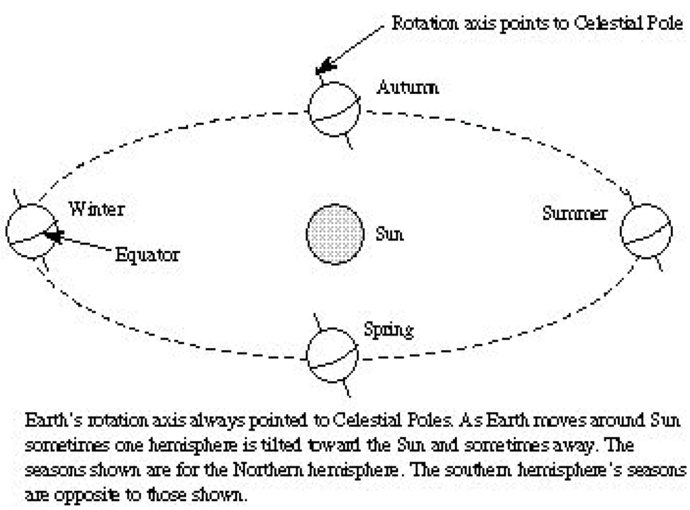

Figure 4: The Earth's Seasonal Rotation: NOAA's National Weather Service.

16,700,000 km^2 × 0.00062 km = 10,354 km^3

(Amount of ice gained) (Thickness) (Volume of ice gained)

Finally, the average volume of sea ice lost by the Arctic Sea can be determined by multiplying the average amount of ice gained by the mean thickness of Arctic sea ice.

9,100,000 km^2 × 0.00189 km = 17,199 km^3

(Amount of ice lost) (Thickness) (Volume of ice lost)

The average volume lost by the Arctic Sea (17,199 km^3) is greater than the average volume of sea ice gained by Antarctica (10,354 km^3) during June, July, and August. Thus, approximately 7,000 km^3 water is added into the oceans, elevating sea levels despite the formation of ice in Antarctica. Although it's seemingly uselessness against the substantial additions of water into the ocean by the Arctic Sea, the creation of ice in Antarctica is critical to sea level moderation because were the creation not occur, approximately 17,000 km^3 of water would be added to the ocean which would raise sea levels drastically (Figures 5 and 6).

In contrast to the sea level increases during June, July and February, sea levels are actually lowered during December, January and February. In these months, Antarctica experiences summer because the Southern Hemisphere is faced towards the Sun. According to the U.S. Antarctic Program, the average temperature increases to -18°F which is still significantly lower than the freezing point of water [16]. Due to this fact, many people hold the misbelief that more ice is produced during the summer instead of the ice melting.

However, the NSIDC reports that the average minimum ice extent in the summer is about 16 million km^2 less than the average maximum extent in the winter of 18.8 million km^2, signalling a loss. This drastic loss occurs because Antarctica receives 24 hours of sunlight exposure and because the medium surrounding the continent aids in the melting

	Thickness(meters)		Conversion(m to km)	Thickness(kilometers)
Antarctica	0.62 m	÷	1000	0.00062 km
Arctic	1.89 m	÷	1000	0.00189 km

Table 4: Sea ice thickness.

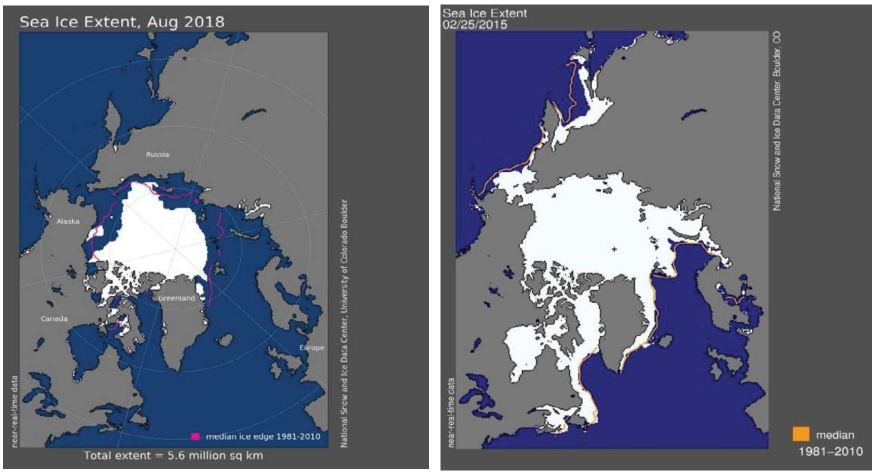

Figure 5: Arctic Sea Ice Extent in August 2018(left) and February 2015(right).

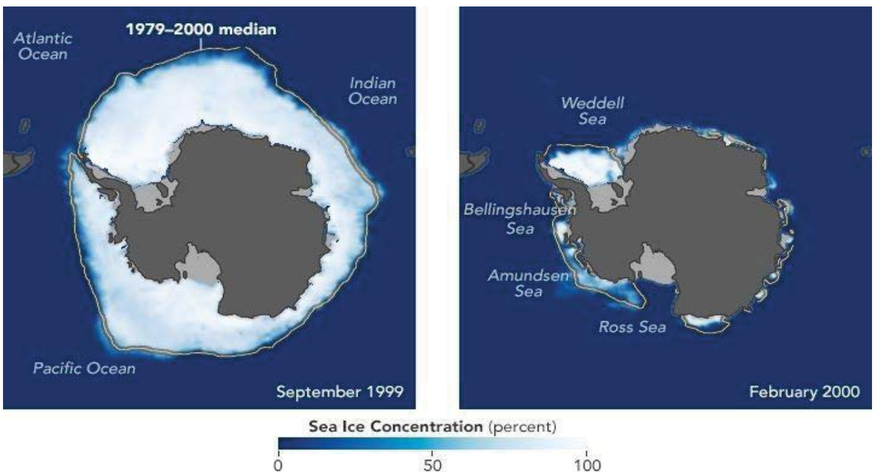

Figure 6: Antarctic Sea Ice Extent in September 1999(left) and February 2000(right).

of ice [19]. Unlike the Arctic Sea that is nearly completely surrounded by land, Antarctica has no surrounding land boundary since it is completely encompassed by the Southern ocean, a collective name for the Pacific, Indian and Atlantic Oceans. This causes a vast amount of Antarctic ice drifts to northern waters that have lower latitudes. According to the University of California in Santa Barbara's ScienceLine program, lower latitude waters receive more sunlight due to the tilt of the Earth's axis, leading to warmer waters overall; thus, as the Antarctic ice float towards the lower latitude waters, the higher temperatures of those waters causes the Antarctic ice to melt [20] (Figure 7).

Since an extensive amount of ice is melting in Antarctica, one would expect an increase in sea level. Contrary to belief, akin to the counter to the melting of the Arctic Sea ice in the months of June, July and August by the freezing of the Southern Ocean's water, the winter occurring in the Arctic Sea regulates the sea levels. The Arctic Sea is deprived of sunlight for approximately 6 months between early October and early March, according to the NOAA [16]. Because of the lack of sunlight for an extended period of time, the Arctic Sea's temperature drops extremely to -40°F [16]. This causes the Arctic Sea to gain an immense amount of ice as any temperature under 32°F causes water to freeze into ice. According to Maria Jose Vinas of NASA's Earth Science News Team, the 2019 maximum ice extent in the Arctic Sea peaked at 14.78 million km^2 [21]. Usually, however, the maximum extent is usually reached sometime between late February and early April at an extent of 15.6 million km^2, according to the NSIDC [22]. This average maximum extent is approximately 9 million km^2 more than the average minimum extent of 3.1 million km^2. The base of the calculation completed before for the average volume of ice gained and lost by the Arctic Sea and Antarctica during June, July and August can also be used to determine that increased volume of water in the oceans during the months of June, July and August is decreased by the production of ice during the months of December, January, and February.

Once again, firstly, the surface area of the ice lost in Antarctica can be determined by subtracting the average maximum ice extent by the average minimum ice extent.

$18{,}800{,}000\ km^2 - 3{,}100{,}000\ km^2 = 16{,}700{,}000\ km^2$

(Average max ice extent) (Average min ice extent) (Amount of ice lost)

Subsequently, the amount of ice gained in the Arctic Sea can be determined By subtracting the average maximum ice extent by the average minimum ice extent.

$15{,}600{,}000\ km^2 - 6{,}500{,}000\ km^2 = 9{,}100{,}000\ km^2$

(Average max ice extent) (Average min ice extent) (Amount of ice gained)

Thirdly, the mean thickness of the Arctic sea ice and Antarctic sea ice need to be converted to kilometres because the amounts of ice lost/gained are measured in km^2 (Table 5).

Fourthly, the average volume of the sea ice lost by Antarctica can be determined by multiplying the average amount of ice lost, which is surface area since it is measured in km^2, and the mean thickness of the Antarctic sea ice.

$16{,}700{,}000\ km^2 \times 0.00062\ km = 10{,}354\ km^3$

(amount of ice lost) (thickness) (volume of ice lost)

Finally, the average volume of sea ice gained by the Arctic Sea can be determined by multiplying the average amount of ice gained by the mean thickness of Arctic sea ice.

$9{,}100{,}000\ km^2 \times 0.00189\ km = 17{,}199\ km^3$

(amount of ice gained) (thickness) (volume of ice gained)

The average volume gained by the Arctic Sea (17,199 km^3) is now greater than the average volume of sea ice lost by Antarctica (10,354 km^3) during December, January, and February. Thus, approximately 7,000 km^3 water is now taken from the oceans to yield ice, lowering sea levels despite the melting of ice in Antarctica. This production of Arctic sea ice negates the increased sea levels that were produced in the months of June, July and August and returns the sea levels back to normality.

Through the balancing effect by the Arctic Sea and Antarctica over between different seasons and within seasons as one geographic area gains as the other loses, overall sea levels are moderated from extreme increases due excessive ice meltings. However, overall sea levels are increasing even with the regulating effects of the balancing effect as a result of the increased temperatures produced by global warming.

Replacement of Vaporization with Ice in Polarized Regions

The water cycle, also known as the hydrologic cycle, depicts the

Figure 7: A piece of ice melting as it floats away from the Antarctic mainland: Video blocks.

	Thickness(meters)		Conversion(m to km)	Thickness(kilometers)
Antarctica	0.62 m	÷	1000	0.00062 km
Arctic	1.89 m	÷	1000	0.00189 km

Table 5: Mean sea ice thickness.

Reservoir	Volume (cubic km x 1,000,000)	Percent of Total
Oceans	1370	97.25
Ice Caps and Glaciers	29	2.05
(..iroundwater	10.	0.68
Lakes	0.125	0.01
Soil Moisture	0.065	0.005
Atmosphere	0.013	0.001
Streams and Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004

Table 6: Inventory of water on earth's surface.

continuous movement of water on Earth [23,24]. According to a basic summarization by the United States Geological Survey (USGS), there is no distinct starting point in the cycle, but the cycle consists of three essential steps [25]. Evaporation, the process where liquid water changes phases to gas or water vapor, is the first step in the water cycle. Because the bonds that bridge the water molecules together need to be broken for water vapor to be created, heat energy is needed and provided by the sun. As the temperature reaches the boiling point of 212° F or 100° C, water quickly evaporates, but water also slowly evaporates at the freezing point of 32° F or 0°C.

The water vapor produced through evaporation rises up to the cooler atmosphere through air [26]. Subsequently, clouds are formed through a process known as condensation where water vapor is converted into liquid water [23]. In the clouds, water droplets combine and grow larger until the clouds cannot hold them any longer which causes precipitation - solid or liquid water released from clouds. Finally, the precipitation returns water back to Earth's surface [27].

According to a 1989 Scientific American Article by J.W.M La Riviere, approximately 425,000 cubic kilometers of sea water is converted into water vapor every year [28]. Because of recent increases in temperatures due to global warming, a reasonable assumption can be made that in recent years, more than the approximate reported in 1989 is evaporated per year. The large-scale evaporation subsequently causes a decrease in water levels, according to National Geographic [29]. All of the water that was evaporated is later returned back to the Earth's surface as precipitation due to the continuous nature of the water cycle. However, Leeanne Hazzard and Fabrice Veron of the Air-Sea Interaction Laboratory in the College of Marine and Earth Studies at the University of Delaware find that most of the precipitation falls onto land because more clouds are formed over land than over oceans [30]. Because approximately 80% of all evaporation comes from the oceans according to the Department of Atmospheric Sciences at the University of Illinois at Urbana-Champaign and because the majority of precipitation falls onto land, evaporation has an overall positive effect of lowering sea levels [31].

However, not all sea and ocean regions on Earth reap the benefits of evaporation significantly. Two regions that minimally experience the decrease of sea levels through evaporation are the Arctic Sea and Antarctica due to the deficiency of evaporation in those areas. According to Michon Scott of the NOAA, the lack of evaporation in the Arctic Sea is justified by the average temperatures of that region: the average winter temperature is -40 degrees Fahrenheit while at most 32 degrees Fahrenheit during the summer season [16]. The low temperatures lead to lower heat energy - the fuel for evaporation - which equates to less evaporation. In addition, another reason for the lack of evaporation is the layer of sea ice that covers the ocean waters according to the NSIDC [32]. This means that the sea ice above the ocean water must melt first in order for the evaporation process to occur, requiring a greater amount of heat and exposure to sunlight that the Arctic Sea does not provide especially in the winter season. Antarctica's deficiency of evaporation is attributed to the same causes as the Arctic: extreme temperatures and blockage of ocean water by sea ice [32]. The average temperatures in the winter and summer of Antarctica are even lower than those of the Arctic Sea. The U.S. Antarctic Program reports the average monthly temperature in the winter at -76 degrees Fahrenheit and the average monthly temperature in the summer at -18 degrees Fahrenheit [16]. Additionally, the average maximum sea ice extent of 18.8 million square kilometers during the winter season in the Antarctic - according to the NSIDC - impedes evaporation from occurring on a substantial amount of water.

In order to make up for the lack of evaporation, the Arctic Sea and Antarctica have an alternative to lower their sea levels: ice caps and glaciers. Due to the consistent, extreme cold temperatures of these two regions, the ice caps and glaciers are constantly formed, extracting water from the ocean and lowering sea levels. An advantage ice caps and glaciers have over the evaporation process is that the evaporation process has to return the water extracted from the oceans back to Earth's surface while ice caps and glaciers retain the converted water unless melted (Table 6).

Because of their reservoir qualities, ice caps and glaciers hold the second highest percentage of total water at 2.05%. In addition, ice caps and glaciers hold 28,987,000 cubic kilometres of water more than the atmosphere which is where the evaporated water rises to [33-35]. Clearly, ice caps and glaciers provide a sound alternative to evaporation that is considerably more beneficial than the evaporation process itself when regarding the decreasing of sea levels.

Conclusion

During the modern time period when global warming is a major issue, ice is a critical factor in regulating sea levels so that detrimental effects will not impact the globe's influential coastal cities and their populations. Catastrophic sea levels that would raze numerous trading ports, cities and towns are avoided because of the lower density ice possesses relative to water which allows ice to float on top of water. The two polar regions on Earth exhibit a balancing effect between different seasons and within seasons, in which as a polar region loses ice through melting under the heat of the summer season, the opposite polar region balances the loss by producing ice due to the winter cold, in order to evade hazardously high sea levels. Moreover, ice offers the polar regions of Earth, where vaporization levels are extremely low, a better alternative to lower sea levels. Now, common misconceptions that the general public have long held can be overturned through the extensive knowledge of ice provided in this research. In addition, the research above aids in raising awareness about the importance of preserving ice as global temperatures surge due to the emission of greenhouse gases. However, in order to gain an even deeper understanding of the impacts of ice on the moderation of sea levels, further research in the future should be conducted.

References

1. NASA (2019) The Causes of Climate Change.
2. NASA (2019) Climate Change Evidence: How Do We Know?
3. United States Environmental Protection Agency (2019) Overview of Greenhouse Gases.
4. Fries-Gaither J, Lockman AS (2009) All About Icebergs - Icebergs and Glaciers. Beyond Penguins and Polar Bears.
5. Eau C (2019) Physical Properties & Intermolecular Interactions Elaboration - States of Matter. University of Wisconsin
6. OpenStax (2019) Physical Properties & Intermolecular Interactions Elaboration - States of Matter.
7. Scholberg K (2015) How Do You Calculate Volume Displaced in a Fluid?
8. National Institute of Standards and Technology (2019) Fundamental Physical Constants.
9. Phys.org (2019) Trillion-Tonne Iceberg Breaks off Antarctica.
10. Vilar M (2000) Antarctica Melts. Science World 56: 16
11. Kornreich D (2019) What Causes Seasons? Beginner. Curious About Astronomy? Ask an Astronomer.
12. Trotter M (2012) Orbital Plane.
13. National Weather Service (2019) Why Do We Have Seasons?
14. Swinburne University of Technology (2019) Celestial Poles.
15. PMEL Arctic Zone (2019) Daylight, Darkness and Changing of the Seasons at the North Pole.
16. Scott M (2019) Antarctica Is Colder than the Arctic, but It's Still Losing Ice. NOAA Climate.gov
17. National Snow and Ice Data Center (2018) Approaching autumn, pace slows.
18. Evers J (2019) South Pole. National Geographic Society.
19. Boudreau D, McDaniel M, Sprout E, Turgeon A (2012) Antarctica. National Geographic Society.
20. UCSB Science Line (2016) 20. I wonder why the water is warmer in certain parts of the world.
21. Blumberg S (2019) Arctic Sea Ice 2019 Wintertime Extent Is Seventh Lowest.
22. National Snow and Ice Data Center (2019) Arctic vs Antarctic.
23. United States Geological Survey (2019) Condensation and the Water Cycle
24. Precipitation Education (2019) The Water Cycle.
25. United States Geological Survey (2019) The Fundamentals of the Water Cycle.
26. United States Geological Survey (2019) Evaporation and the Water Cycle.
27. United States Geological Survey (2019) Precipitation and the Water Cycle.
28. Maurits JW (1989) Threats to the World's Water. *Scientific American 261*: 80-97.
29. National Geographic Society (2019) Evaporation.
30. Hazzard L, Veron F (2017) Water Anyone. Marine and Earth Studies University.
31. University of Illinois (2019) Evaporation over Oceans.
32. National Snow and Ice Data Center (2019) Factors Affecting Arctic Weather and Climate.
33. Pidwirny M (2006) The Hydrologic Cycle. Fundamentals of Physical Geography
34. Worby AP, Geiger CA, Paget MJ, Van WM, Ackley MSF et al (2008) Thickness distribution of Antarctic sea ice, J. Geophys. Res 113: C05S92
35. Earth Observatory (2020) World of Change: Antarctic Sea Ice.