The Impact of Iceberg Melting on the Climate of the Arctic Circle

Yiran Fang(✉)

University of Liverpool, Liverpool L6 1BA, UK
15858216636@163.com

Abstract. The main manifestation of iceberg melting is global warming, and the most intuitive manifestation of global warming is the temperature of the Arctic circle. This study discusses the relationship between the total heat released by iceberg melting and the temperature of the Arctic circle. The total heat is roughly the sum of the three values of heat transfer, heat radiation and heat convection. Since the value of heat radiation is smaller than that of the other two factors, it can be ignored, that is to say, the total heat released by iceberg melting is heat transfer plus heat convection. This study will roughly calculate and estimate the total heat released by iceberg melting, and obtain the research results by comparing the highest temperature in the Arctic Circle from 2017 to January 2021. The purpose of this study is to show that iceberg melting has a direct impact on global warming, and at the same time, to summarize the importance of mitigating global warming.

Keywords: Iceberg · Heat transfer · First law of thermodynamics · Thermal convection

1 Introduction

In recent years, due to a large number of greenhouse gas emissions, slowing down global warming has become a top priority for environmental protection. At the same time, due to global warming, the melting rate of icebergs is also accelerating, and the temperature of the Arctic Circle is also affected.

There may be two reasons for the rising temperature in the Arctic circle. The first is that low latitude regions carry a large number of warm currents into the Arctic circle. The second is that icebergs have melted in recent years.

For calculate the heat conduction, the heat conduction formula is needed. This study mainly expounds the relationship between glacier melting and various forms of heat transfer. Since global warming is now known as one of the biggest environmental problems facing the world, this paper wants to explore the relationship between glacier melting and thermodynamics in this study. At present, the known heat conduction modes include heat transfer, heat convection and heat radiation. Therefore, the total heat absorbed by the glacier is obtained by combining the formulas of these three physical quantities. During the simulation experiment, this study uses ice instead of glacier

G. Ali et al. (Eds.): ISEMSS 2022, ASSEHR 687, pp. 190–195, 2022.
https://doi.org/10.2991/978-2-494069-31-2_23

and water instead of ocean. In this process, the size of thermal radiation is much smaller than that of heat transfer and convection, so it can be ignored. Next, through this simulation experiment, the theme of this exploration is how much heat can be released by glacier melting. Through the change of the approximate volume of glaciers in recent years, we can get the approximate amount, so as to further help investigate and obtain approximate results. This study can compare the degree of global warming with the degree of glacier melting over the years, so as to determine whether glacier melting is an important cause of global warming. This study hopes to explore the relationship between iceberg melting and climate warming in the Arctic Circle and point out the importance of reducing greenhouse gas emissions to environmental protection.

2 Calculation and Estimation of Total Heat Produced by Iceberg A68A'S Melting

2.1 The Formulae Used in Calculation

The heat conduction formulae of glacier melting [1] is:

$$\mathrm{Q} = \frac{\Delta T}{R} = \frac{\Delta T \lambda S}{L} \tag{1}$$

where ΔT is the change of temperature, R is the thermal resistance, Q is the heat released by iceberg, S is the area of the iceberg, λ is the thermal conductivity of iceberg and L is the thickness of iceberg.

The Newton's law of cooling [2]:

$$q = h\Delta T = \frac{Q}{S} \tag{2}$$

where q is heat flux per unit area, h is convective heat transfer coefficient.

2.2 Analysis of the Formulas

Based on above two formulas, the heat flux for iceberg melting is ~400 to ~2830 $m^3\ s^{-1}$ (which is depending on the runoff). The ice-water heat transfer coefficient h is 1.1×10^{-3} [3].

After simplifying the formula, $\mathrm{Q} = \mathrm{s}\, h\Delta T = qs$. As research during the 2020/2021 for the megaberg A68A, the amount of iceberg reduced for 141 m and 150 m deep, so the area is 21150 m^2 [4]. Assume the heat flux is the average of the biggest and the smallest value, q = 1615. $Q = 1615 \times 21150 = 3.4 * 10^7$.

For heat conduction formula of glacier melting, first of all use the value $3.4 * 10^7 \div (s \times h) = \frac{3.4\times10^7}{23.3} = 1.46 \times 10^6$. And then this number is taken into the first formula,

$$\mathrm{Q} = \frac{\Delta T}{R} = \frac{\Delta T \lambda S}{L} \tag{3}$$

$\Delta T = 1.46 \times 10^6$, this value is obtained from the previous calculation, R (thermal resistance) = 11.25 W/m K [5], assume that the cooling rate is at a normal value. $Q = \frac{1.46 \times 10^6}{11.25} = 1.3 \times 10^5$ J.

Since the value of thermal radiation is small in the calculation of total heat of glacier melting, the heat generated by thermal radiation will be ignored. To sum up, the average heat released under the ideal state of glacier melting is the heat released by glacier melting plus the heat released by conductive heat transfer. So in an ideal state, the total heat released by glacier melting is $Q_{total} = 3.4 \times 10^7 + 1.3 \times 10^5 = 3.42 \times 10^7$.

Assume that the runoff speed does not change during 2017–2021. After roughly calculating the heat released by a68a iceberg melting in 2020–2021, it is necessary to compare the total heat of glacier melting in 2017–2021 with the total heat of iceberg melting in 2021–2021, and then compare it with the Arctic temperature in recent years to get a rough link between iceberg melting and global warming.

In the data survey, the author found that since the a68a iceberg had split and melted into fragments in April 2021, the data after that could not be counted, so the reserved area would end in January 2021. The total iceberg area of a68a in 2017 was 5800 square kilometers. By December 2020, it will shrink to 4200 square meters in three years [6].

$Q = 1615 \times 1.6 \times 10^9 = 2.6 * 10^{12}$. In the above calculation, it can be known that the value of heat transfer is relatively small for heat convection, so the total heat is similar to that of heat convection. Therefore, between 2017 and January 2021, the total heat generated by the melting of a68a iceberg is $2.6 * 10^{12}$ J.

After calculating the approximate value of the total heat released by iceberg melting, the highest temperature in the Arctic over the years since 2017 is obtained through investigation. As research, the highest temperature through 2021 June is 38 °C (100.4 °F). A high temperature of 4.7 °C, roughly 40 °F, was reported Wednesday at Qaanaaq Airport, along the far northwest coast of Greenland at a latitude of about 77.5° north, about 750 miles north of the Arctic Circle. Maximum temperatures (°F) on Nov. 29, 2017. The red arrow denotes Qaanaaq Airport [7].

By comparing the above data, it can be seen that the temperature of the Arctic circle has increased by 33.3 °C between 2017 and January 2021. The highest temperature in the Arctic has risen sharply, including air pollution (i.e. greenhouse gas emissions), the number of deforestation and so on. If assuming that the melting of icebergs has an impact on global warming, the global maximum temperature should be proportional to the heat released by the melting of icebergs. From the above calculations and data phones, it can be found that the maximum temperature of the Arctic circle has increased at an extremely rapid rate in recent years. At the same time, the heat generated by the melting of icebergs is also much higher than before because of the melting of glaciers.

However, there is a problem here. Because the temperature of 38 °C is measured in June 2021, when the a68a iceberg has melted and split, the heat released will be significantly higher than that in previous years. Therefore, the following discussion is conducted to determine whether this result is true if the a68a iceberg does not split.

3 Discussion

For thermal radiation, Boltzmann's law is used. The formulae is: $Q = \alpha T^4$.

Where Q is the total energy is the total energy affected by thermal radiation, α is the Boltzmann constant. And T is the absolute temperature which is end by unit K. Since the absolute temperature of icebergs is relatively low for other objects, the total amount of thermal radiation can be roughly ignored.

For a68a iceberg, the total heat released by iceberg melting is related to the melting area and temperature difference. When different icebergs melt, the temperature difference is roughly the same, but the a68a iceberg is not melting, but splitting, which cannot be regarded as complete melting, because it may also split into dozens or even hundreds of small icebergs without melting at the same time. At the same time, for the key data of a68a iceberg, there is only complete splitting in April 2021, but there is no relevant record before that. Therefore, there is some doubt whether the a68a iceberg has completely melted in January 2021. At the same time, for the key data of a68a iceberg, there is only complete splitting in April 2021, but there is no relevant record before that. Therefore, there is some doubt whether the a68a iceberg has completely melted in January 2021. If the a68a iceberg is completely split before 2021 (it is assumed that it is completely melted here), the maximum temperature measurement in the Arctic circle will be higher, because after the a68a iceberg melts, other icebergs will melt and release heat under the influence of thermal convection, so the impact of the same iceberg melting will be smaller. In the same case, if the a68a iceberg has not completely melted in January 2021, the impact of heat released by iceberg melting on the Arctic temperature may be relatively inaccurate, because if the remaining a68a iceberg melts, more heat will be released, and the Arctic temperature may become higher.

The rest is actually a very small part of the iceberg exposed on the sea, this will involve a problem, that is, what is the approximate volume of the iceberg exposed to the sea surface. And that's using Archimedes' buoyancy formula. The buoyancy of an object immersed in a liquid is equal to the gravity of the liquid it displaces. This is the famous Archimedes' principle [8]. Use the formulae

$$F_b = G \tag{4}$$

At the same time,

$$\rho_{sea} g V_{Drained\ water} = \rho_{iceberg} g V_{iceberg} \tag{5}$$

We know the density of ice is approximately nearby 0.9×10^3 kg/m^3, And the density of the sea is nearby 1.03×10^3 kg/m^3.

Then the formula is obtained through simplification [9],

$$\frac{V_{Exposed\ to\ the\ sea}}{V_{iceberg}} = \frac{\rho_{sea} - \rho_{iceberg}}{\rho_{sea}} \tag{6}$$

So according to the calculation, the volume of the iceberg above the sea surface is about $\frac{13}{103}$.

Since it is impossible to calculate the melting of icebergs below the sea surface, and the volume above the sea surface is known to be a small part of the total volume of the station, the total heat released by the melting of icebergs at the sea surface must be smaller than the heat released by all the melting parts of a whole iceberg.

4 Conclusion

This study mainly explores whether there is a link between the total heat released by iceberg melting and the rising temperature in the Arctic circle. Through the calculation and analysis of some data, it is concluded that with the melting of a68a iceberg, the temperature in the Arctic Circle is gradually rising. Therefore, it can be speculated that the heat released by the melting of iceberg is in direct proportion to the rise of the temperature in the Arctic circle. There are some problems in this speculation.

For example, there are many factors for the rise of temperature, and the melting of icebergs is only a small part of them. For this problem, a simulation experiment can be carried out to verify whether this guess is correct by placing an appropriate amount of ice and water in the confined space and measuring the melting size of the ice and the temperature in the confined space before, after and during the melting process.

Another problem is that as the a68a iceberg mentioned above has been completely split before April 2021, there will be errors in the experiment when the specific melting date cannot be guaranteed. In this case, since the data I calculated is January 2021, the research results will be larger or smaller when the iceberg is completely split before April 2021 and melts or splits but does not melt. The solution is to advance the year of measuring the reduction of iceberg area by one year, so as to avoid the impact of iceberg splitting on the research results. Or another method is to measure icebergs other than a68a that have shrunk rapidly in recent years. In this way, the research error can also be reduced. For example, the iceberg A-76. The area when it has been discovered is 4320 km^2 in 2021 [10].

The Atlantic warm current flows to the north polar circle at low latitudes, which is called thermohaline circulation in the Atlantic. It can be assumed that if greenhouse gas emissions in low dimensional regions are reduced, the warm current carried to the Arctic circle will also be reduced. For environmental protection, as long as humans try the best to reduce greenhouse gas emissions, we can gradually slow down the rising temperature of the Arctic Circle.

Acknowledgements. I am very grateful to the teachers for checking the omissions and filling the gaps in my paper. I am also grateful to the teachers for timely correcting my mistakes and guiding me to revise them.

Authors' Contributions. This paper is independently completed by Yiran Fang.

References

1. Kosky, P., Balmer, R.T., Keat, W. and Wise, G. Exploring engineering an introduction to engineering and design. London Acad. Press, Elsevier, 2016.

2. Connor, N. Newton's Law of Cooling | Convection & Calculation | nuclear-power.com. [online] Nuclear Power, 2019. Available at: https://www.nuclear-power.com/nuclear-engineering/heat-transfer/convection-convective-heat-transfer/newtons-law-of-cooling/ [Accessed 25 Jun. 2022].
3. Li, N., Tuo, Y., Deng, Y., Li, J., Liang, R. and An, R. Heat transfer at ice-water interface under conditions of low flow velocities. [online] Research Gate, 2016. Available at: https://www.researchgate.net/publication/307621016_Heat_transfer_at_ice-water_interface_under_conditions_of_low_flow_velocities [Accessed 24 Jun. 2022].
4. ScienceDaily. Satellites reveal world's most famous "mega iceberg" released 152 billion tons of fresh water into ocean as it scraped past South Georgia, 2022. [online] Available at: https://www.sciencedaily.com/releases/2022/01/220119194240.htm.
5. Ahmad, N. (1994). Thermal Conductivity of Ice. physica status solidi (b), 181(1), pp.37–44. doi:https://doi.org/10.1002/pssb.2221810104.
6. Amos, J. Split signals end for remnant of Antarctic iceberg A68a. BBC News, 2021. [online] 28 Jan. Available at: https://www.bbc.co.uk/news/science-environment-55843384 [Accessed 25 Jun. 2022].
7. Belles, J. Freak Warm Spell Surges Temperatures 50+ Degrees Above Average in Greenland. [online] The Weather Channel, 2017. Available at: https://weather.com/news/weather/news/2017-11-30-greenland-temperature-above-average-heat-wave [Accessed 24 Jun. 2022].
8. White, F.M. Fluid mechanics. New Delhi, India: Mcgraw-Hill Education, 2017.
9. Sánchez, G. What fraction of an iceberg shows above water? [online] Quora, 2015. Available at: https://www.quora.com/What-fraction-of-an-iceberg-shows-above-water.
10. European Union. Iceberg A-76 | Copernicus, 2021. [online] www.copernicus.eu. Available at: https://www.copernicus.eu/en/media/image-day-gallery/iceberg-76 [Accessed 25 Jun. 2022].