Research Article

Cooling down the world oceans and the earth by enhancing the North Atlantic Ocean current

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Abstract
The world is going through intensive changes due to global warming. It is well known that the reduction in ice cover in the Arctic Ocean further contributes to increasing the atmospheric Arctic temperature due to the reduction of the albedo effect and increase in heat absorbed by the ocean's surface. The Arctic ice cover also works like an insulation sheet, keeping the heat in the ocean from dissipating into the cold Arctic atmosphere. Increasing the salinity of the Arctic Ocean surface would allow the warmer and less salty North Atlantic Ocean current to flow on the surface of the Arctic Ocean considerably increasing the temperature of the Arctic atmosphere and release the ocean heat trapped under the ice. This paper argues that if the North Atlantic Ocean current could maintain the Arctic Ocean ice-free during the winter, the longwave radiation heat loss into space would be larger than the increase in heat absorption due to the albedo effect. This paper presents details of the fundamentals of the Arctic Ocean circulation and presents three possible approaches for increasing the salinity of the surface water of the Arctic Ocean. It then discusses that increasing the salinity of the Arctic Ocean would warm the atmosphere of the Arctic region, but cool down the oceans and possibly the Earth. However, it might take thousands of years for the effects of cooling the oceans to cool the global average atmospheric temperature.

Keywords Adaptation to climate change · Arctic ice cover · North Atlantic overturning circulation · Geoengineering

1 Introduction

Many advances in reducing CO_2 emissions have been made over the previous decades with the viability increase in wind and solar energy, and recently with the dissemination of electric cars, it continues to be difficult to achieve the negative emissions required to maintain the world average temperature increase below 1.5 °C as proposed by the Paris Agreement of UNFCCC [1], especially due to the need for negative emissions to reduce the current atmospheric CO_2 concentration. Even if we keep emissions within 1.5 °C, it is expected that the thawing of permafrost will continue to exacerbate the impacts of climate change, with the increase in emissions of CH_4 [2–5].

Reducing CO_2 concentration in the atmosphere is the most important solution to climate change. However, if there is an urgent need to cool down the Earth, several geoengineering proposals exist for emergency cooling. The most discussed of these proposals is the injection of particles in the stratosphere to increase the reflection of solar radiation back into space [6–10]. This is a relatively simple and low-cost solution that could reduce key hazards resulted from global warming [11].

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Other geoengineering solutions propose to reverse the melting of the Arctic sea ice, by pumping seawater from under the Arctic ice cover to the top of it [12, 13]. Figure 1 represents a barge designed to increase the thickness of the Arctic ice cover. However, this alternative might not result in an overall negative energy budget for the Arctic region. This is because the increase in ice formation will increase the temperature of the atmosphere in the Arctic, which will further contribute to melt the ice cover. Thus, the overall energy budget would be similar to the current energy budget. Other geoengineering proposals are presented in [14].

The Arctic sea ice forms an insulating layer impeding that the warmth in the Arctic Ocean (at around − 1 °C) is dissipated to the cold atmosphere (average − 20°) and radiated into space. The ice cover contributes to keeping the heat in the Arctic Ocean from escaping into space, as shown in Fig. 2a.

Recent climate models have shown that the increase in solar radiation absorption with the melted Arctic water is slightly higher than the increased longwave irradiation into space, as shown in Fig. 2b [16]. In other words, heat balance in the Arctic region is reached with or without the ice cover, warming up the atmosphere, cooling down the ocean and maintaining the overall heat balance of the Arctic region at equilibrium.

A study by [17] has calculated the net heat flux of the Arctic region (Fig. 2c). In locations covered by ice, the net heat flux loss is around 8 W/m^2 smaller when compared to areas not covered by ice. The heat lost into space through longwave radiation in areas without ice cover is higher than the shortwave heat reflected due to the albedo effect in areas with ice. In other words, this study shows that the heat loss by the open oceans and into space is higher than the net increase in solar absorption due to the albedo effect, which would result in a slight negative heat balance, having a small cooling effect to the region as a whole. A comparison between the reduction in albedo effect and the increase in radiation into space applying the proposed strategy in the paper is presented in the next section.

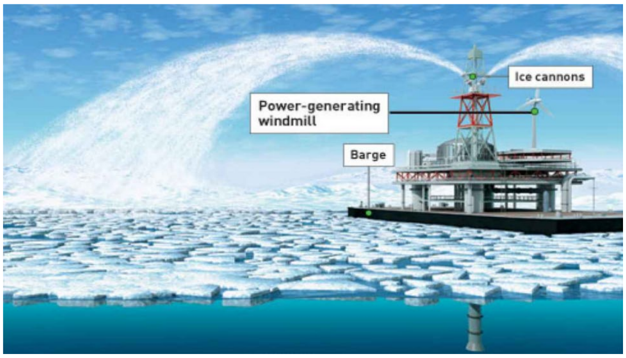


Fig. 1 Method proposed for increasing the thickness of the Arctic ice cover [14, 15]

Considering the analysis of these heat balance climate models, this paper argues that if this equilibrium is broken by allowing the warmer North Atlantic Ocean to flow over the Arctic Ocean, the heat balance of the region will considerably shift and much more heat will be loss into space. The temperature of the Arctic atmosphere would considerably increase and also the amount of heat loss by the Arctic Ocean. This would result in an overall increase in the world's atmospheric temperature and an overall reduction in the world's ocean temperature. However, the combined atmosphere and ocean temperatures would likely reduce. Given that the temperature of the world's oceans would cool from its bottom to the surface, due to the higher density of cool seawater, it could take hundreds or thousands of years for the overall world atmosphere temperature to start reducing. This might not, however, result in an overall cooling of the world atmosphere.

This paper shows that the main contributor to impede the rise of the North Atlantic Ocean currents above the Arctic Ocean surface is its lower salinity superficial layer, and proposes three possible strategies for reducing the salinity of the Arctic Ocean, thus allowing the North Atlantic Ocean to flow above it. An example of strategy to achieve this had proposed in the form of a dam across the Bering Strait with a pumping system to direct the less salty Arctic waters to the Pacific Ocean in 1956 by the Soviet Union. This would have required an 80-km-long dam across the Bering Strait and would block the cold Pacific current from entering the Arctic. By pumping low-salinity cold surface water across the dam to the Pacific, warmer and higher salinity seawater from the Atlantic Ocean would be introduced into the Arctic Ocean [18, 19]. Soviet scientists opposed the idea, stating that the sea in the Pacific side of the dam would freeze and become unnavigable year round, and increase the extent of the Gobi and other deserts to the northern Siberia coastline [18].

This paper is divided into five sections. Section 2 presents the methodology of the paper and proposes innovative strategies to increase the salinity of the Arctic Ocean surface. Section 3 compares the different strategies proposed to increase the salinity of the Arctic Ocean surface. Section 4 discusses the benefits and challenges of the methodology of this paper. Section 5 concludes the paper.

2 Methodology

A relevant argument in this paper is that if the Arctic sea ice cover is removed by allowing more superficial North Atlantic water to enter the Arctic, it would result in

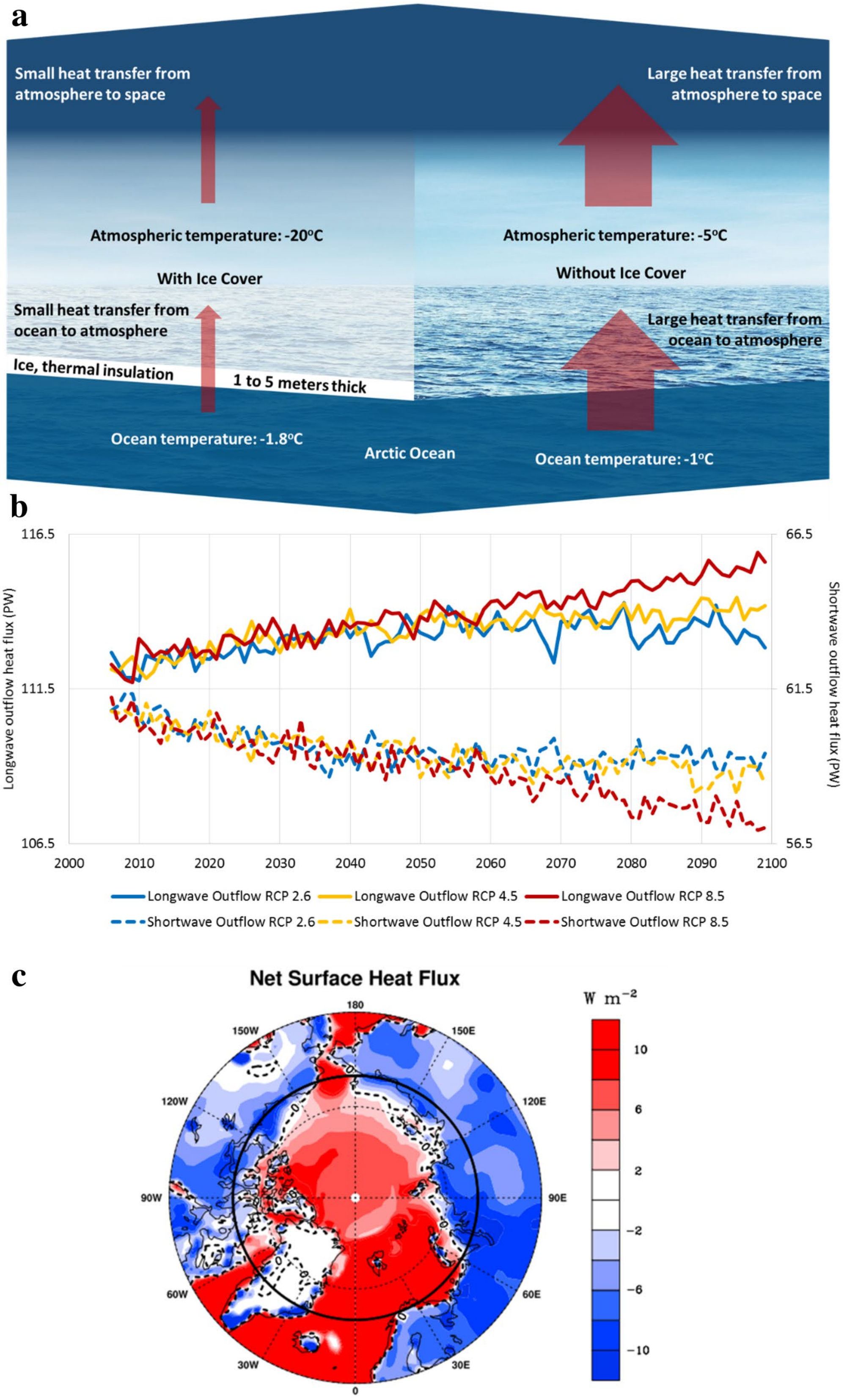


Fig. 2 **a** Thermal insulation potential of ocean ice, **b** climate model results for short and **c** longwave radiation in the Arctic region [16] (variable: TOA incoming/outgoing longwave/shortwave radiation, institute: LASG-CESS, model: FGOALS-g2, experiment: rcp45/60/85, realm: Atmosphere, ensemble: r1i1p1), **c** annual mean net surface heat flux in the Arctic region [17]

an overall negative energy budget for the Arctic Ocean, cooling down the oceans. Even though the albedo of the Arctic Ocean would reduce with the sea ice cover melt, reflecting less heat back to space, the increase in temperature with the Northern Atlantic current and heat radiated into space from the Arctic Ocean would be even higher. This paper does not attempt to prove this concept; it shows a simplified heat balance as a demonstration of the concept and strategies to allow the Northern Atlantic current to reach the Arctic Ocean. Considerable future work is required to prove the negative energy balance proposed in this study.

According to [20], the superficial albedo only contributes a maximum of 30% of the top of atmosphere albedo in the Arctic Ocean. This is due to the curvature of the solar radiation, combined with the reflection of the sunlight by clouds. Assuming a yearly heat reaching the Arctic Ocean surface of 160 W/m^2 per year [21], and a reduction on albedo of 0.15 with the melting of the sea ice cover [20], results in a heat increase of 24 W/m^2. The increase in temperature in the Arctic Ocean increases the heat radiated to space according to Eq. 1 [22].

$$P = \epsilon\sigma AT^4 \quad (1)$$

where P is the longwave radiated heat from heat to space in W/m^2, ϵ is the emissivity, assumed to be 0.99 [22]. σ is the Stefan–Boltzmann constant = 5.67×10^{-8} W m^{-2} K^{-4} [22]. A is the area available for heat radiation of 1 m^2.

T is the average temperature between 1960 and 1970 [23], the temperature required to start cooling the Earth and the temperature of an ice-free Arctic during the winter (suggested by the authors, implementing the solutions proposed in the paper), as shown in Fig. 3.

Figure 3 compares the average monthly temperature of the Arctic Ocean surface between 1960 and 1970 [23] with two scenarios of possible temperature increases in the Arctic Ocean surface, assuming that the North Atlantic Ocean currents enter the Arctic Ocean. The orange line shows the temperature increase required to allow that the contribution to the increase in longwave radiation to space matches the increase in heat absorption due to the change in albedo, as estimated in Table 1. The gray line shows the proposed temperature of the Arctic Ocean surface, assuming that no ice cover is formed in the Arctic Ocean during the winter, due to the increase in North Atlantic current to the Arctic. As estimated in Table 1, the amount of longwave heat radiated to space will be higher than the contribution from the albedo effect, resulting in a negative heat balance in the region.

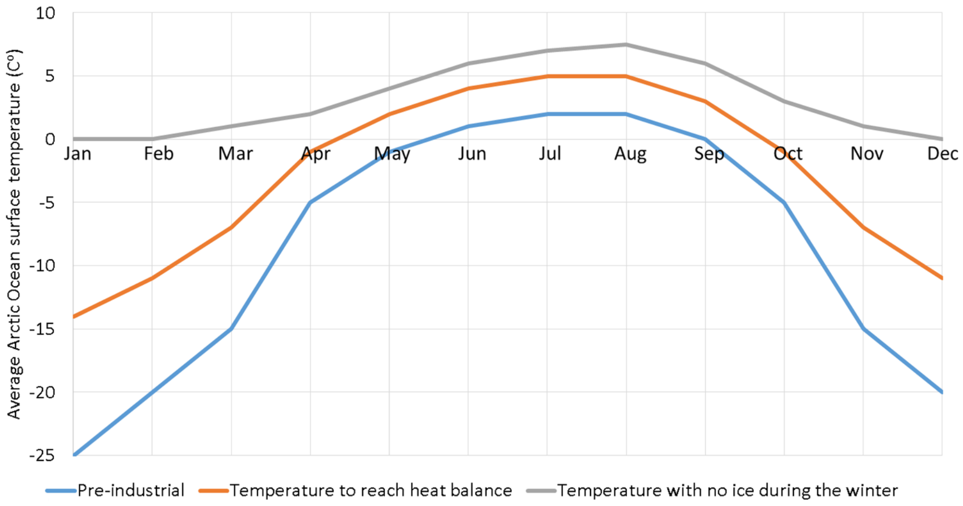


Fig. 3 Average monthly temperature change in the Arctic Ocean in 1960–1970s [23], the temperature required to achieve an equilibrium in heat balance and the temperature assuming no ice cover is formed in the Arctic Ocean during the winter (suggested by the authors, implementing the solutions proposed in the paper) [23]

Table 1 Heat balance of the Arctic Ocean, comparing the albedo effect with the increase in radiation into space

Scenarios	Superficial Arctic Ocean temperature (°C)	Average temperature increase (°C)	Change in albedo contribution	Change in longwave radiation contribution	Simplified heat balance change (W/m^2)
1960–1970 temperatures	− 25 to 2	0	0	0	0
Required temperature to start cooling the Earth	− 14 to 5	+ 5.7	+ 24	− 24	0
Ice-free Arctic during winter	0–7.5	+11.5	+24	− 50	− 26

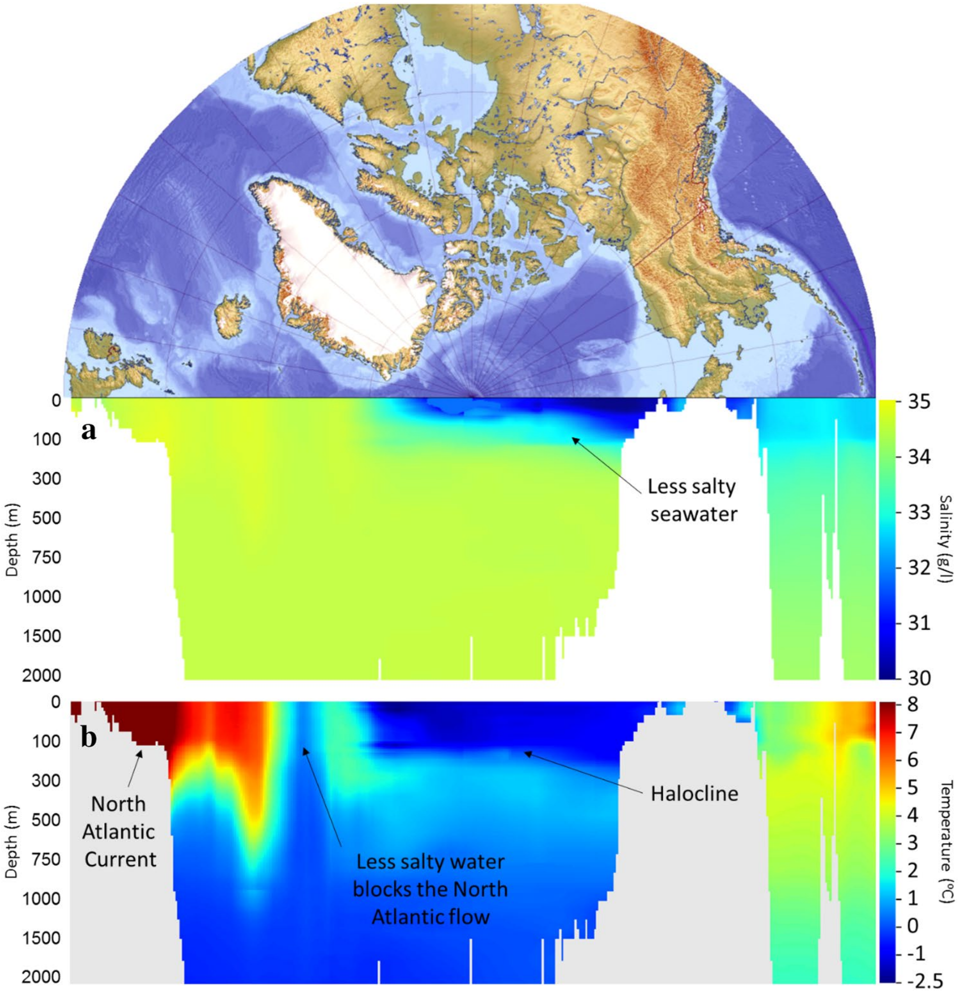
Note that this is just a simple representation of the possible future scenarios compared to historical temperatures. In order to properly analyze the proposed future scenarios, existing models could be modified [24, 25] to examine such scenarios. There are a several feedback phenomena that are not included in the simple representation, such as change in cloud formation, precipitation, climate patterns, ocean currents, and their impact albedo and on longwave irradiation to space. Some of these feedbacks are explored in the discussion section.

A major factor that influences the Arctic climate is the salinity profile of the Arctic Ocean, which is governed by the so-called Halocline phenomenon as shown in Fig. 4b. The surface layer of the Arctic Ocean (about 100 m deep) has a lower salinity (around 25 g/l) and density, and it floats above higher-density waters. The lower salinity happens because the Arctic is constantly fed by freshwater input from large Siberian and Canadian rivers (Ob, Yenissei, Lena, Mackenzie) and Greenland's glaciers. This is combined with the fact that most time of the year, the Arctic Ocean is covered with a layer of ice, which reduces the possibility for the wind on the top of the ice to help mix the less salty surface water with the more salty bottom water.

This layer of less salty cold water has a lower density than that of the North Atlantic Ocean surface water, thus resulting in the warmer currents from the Atlantic to flow below the superficial Arctic Ocean less salty layer. This reduces the potential that the Atlantic Ocean has to warm up the Arctic region, keeping the Arctic ice cover in place. As shown in Fig. 4a, the upper 100 m has a considerably lower salinity than the surroundings, which blocks the warmer Northern Atlantic current to flow above the surface of the Arctic Ocean (Fig. 4b).

Another natural phenomenon that happens in the region is the Halocline, where temperature convection does not happen as the low salinity at the surface does not let the warmer water below to rise (Fig. 4b). Convection eddies caused by the temperature difference between the cold ocean surface and the deep warmer water stop in the Halocline layer, leaving only conduction heat as the upward heat transport mechanism between Atlantic and Surface Arctic waters, which is orders of magnitude smaller

Fig. 4 Cross section of the **a** temperature and **b** salinity of the Arctic Ocean [26, 27]



than heat transfer by convection. Without the Halocline, there would be more heat transfer between the ocean water layers. The salinity and temperature pattern of the Arctic Ocean can be quite complex, being dependent on the different flows into and out of the Arctic region [18].

Table 2 shows the change in seawater density with changes in salinity and temperature. Assuming an Arctic seawater salinity of 30 g/l and temperature 0 °C (i.e., a density of 1067.28 g/l), the temperature of the North Atlantic with a salinity of 35 g/l would need to be higher than 11 °C to be less dense than the Arctic seawater. This is not the case as the seawater loses heat as it approaches the cold Arctic region. Alternatively, assuming a North Atlantic seawater salinity of 35 g/l and temperature 5 °C, the density of the Arctic Ocean will have to be increased from 30 to 32 g/l so that the North Atlantic Ocean will become less dense than the Arctic and flow above it. On average, if the seawater increases 2 °C and salinity reduces 1 g/l, the density of the seawater remains the same. In other words, an increase in 2 °C has a similar impact on the density of seawater as a reduction in 1 g/l in salinity.

As shown in Fig. 5, there are four contributors to salinity reduction in the Arctic Ocean. The Arctic sea ice cover acts in two main ways to reduce superficial salinity. Firstly, it

Table 2 Comparison of the influence of temperature and salinity difference on seawater density [28]

Change in North Atlantic temperature compared to the Arctic salinity of 30 g/l and temperature 0 °C, i.e., a density of 1067.28 g/l			Change in Arctic Ocean salinity compared to the North Atlantic salinity of 35 g/l and temperature 5 °C, i.e., a density of 1067.91 g/l		
North Atlantic temperature (°C)	Density (g/l) with salinity 35 g/l	Difference in density compared to 1067.28 g/l (g/l)	Arctic salinity (g/l)	Density (g/l) with temperature 0 °C	Difference in density compared to 1067.91 (g/l)
20	1062.54	4.71	30	1067.28	2.22
20	1064.43	2.85	31	1068.01	1.47
15	1066.22	1.06	32	1068.75	0.74
10	1067.91	−0.63	33	1069.49	0.004
5	1069.49	−2.21	34	1070.22	−0.73
0	1070.96	−3.68	35	1070.96	−1.47

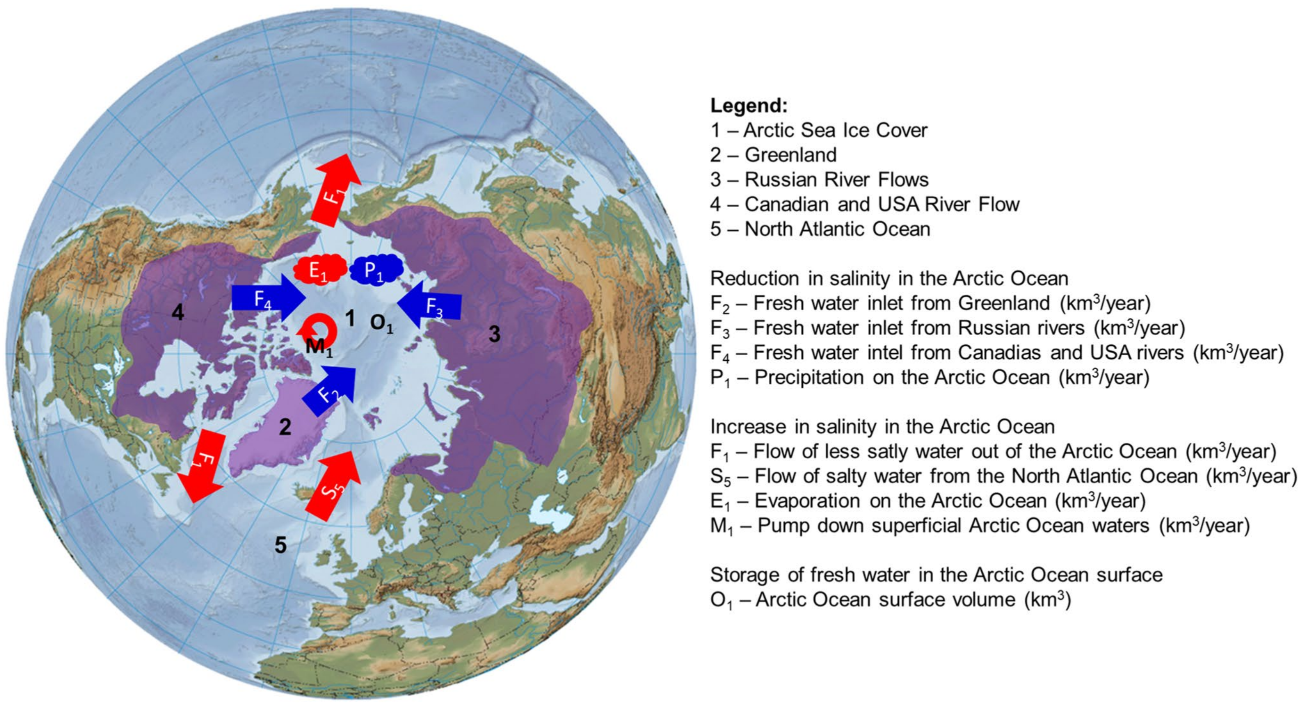


Fig. 5 Northern hemisphere topographic map highlighting the area that contributes to reduce the salinity in the Arctic Ocean, showing the flow balance in the region [29]

impedes that the seawater below the ice evaporates, which would increase the salinity of the surface water. Secondly, the ice cover blocks the wind/water interface and, thus, reduces the mixing of the surface waters with the deeper saltier waters. Greenland's melting contributes to reducing the temperature of the North Atlantic currents and to the reduction in salinity of the Atlantic Ocean. The rivers of Russia, Canada and the USA contribute directly to the reduction of the salinity in the Arctic Ocean due to the dilution of the surface ocean waters.

Equation 2 presents the mass balance of the different flows in and out of the Arctic Ocean surface, as described in Fig. 5. Equations 3 and 4 present the seawater salt concentration of the Arctic Ocean surface. These equations are applied to estimate the effectiveness of the proposed strategies to increase the salinity of the Arctic Ocean.

$$F_2 + F_3 + F_4 + P_1 - E_1 - F_1 + S_5 - M_1 = 0 \qquad (2)$$

$$C_{1f} = \frac{O_1 \times C_{1i} + (F_2 + F_3 + F_4 + P_1 - E_1) \times C_{fw} - F_1 \times C_{1i} + S_5 \times C_5 - M_1 \times C_{1i}}{O_1 + F_2 + F_3 + F_4 + P_1 - E_1 - F_1 + S_5 - M_1} \qquad (3)$$

$$C_{1f} = \frac{O_1 \times C_{1i} - F_1 \times C_{1i} + S_5 \times C_5 - M_1 \times C_{1i}}{O_1 + F_2 + F_3 + F_4 + P_1 - E_1 - F_1 + S_5 - M_1} \qquad (4)$$

where flows and volumes are presented in Fig. 5. C_{1i} is the initial average salt concentration of the Arctic Ocean surface (100 meters deep), assumed to be 30 g/l. C_{1f} is the average salt concentration of the Arctic Ocean surface (100 meters deep) after sometime of implementing the strategies proposed in this paper in g/l. C_{fw} is the salt concentration of freshwater, equal to 0 g/l. C_5 is the salt concentration of the North Atlantic current, assumed to be 35 g/l.

We argue that if these contributions to salinity reduction of the Arctic Ocean are stopped, increasing the salinity of the Arctic surface from 30 to 34 g/l, the North Atlantic Ocean will flow over the superficial Arctic Ocean, warm up the Arctic region and remove the Arctic ice cover, even through the winter. However, this will depend on the strength of the newly formed currents, which without the less salty seawater blockage could reach all the way to the Beaufort Sea and submerge due to its loss in temperature and flow back to the Atlantic Ocean beneath the warmer current. Note that seawater has a volumetric heat capacity of around 3000 times larger than that of air. In order to increase the salinity of the Arctic Ocean surface, three proposals are detailed below.

2.1 Increasing the salinity of the Arctic Ocean surface

This section presents three strategies to increase the salinity of the Arctic Ocean, and these are presented below. These strategies are then compared with each other in aspects such as amount of freshwater contribution and the amount of energy consumption.

1. Reduce the river flow to the Arctic.
2. Reduce Greenland ice sheet melting.
3. Mix the Arctic Ocean waters.

2.1.1 Reduce the river flows to the Arctic

This is the most straightforward approach to increase the salinity of the Arctic Ocean surface. It consists of reducing the flow of water from the Russian, Canadian and USA Rivers to the Arctic Ocean, as shown in Fig. 6a and b respectively. The most appropriate approach to stop the flow of water in these rivers is to divert the water to water scarce regions, where it could bring financial returns to Russia, Canada and USA, and pay the required infrastructure to transport the water. Fig. 6c presents the water stressed regions of the world that would be benefited from the diversion of water that would be discharged in the Arctic Ocean. The Results section presents a study comparing the flow of major rivers and the energy required to transpose the water to southern basins, where water is scarce.

Engineering projects that have already been proposed are the North American Water and Power Alliance (NAWAPA), a vast series of dams, tunnels and reservoirs designed to move 150 km^3 of Arctic meltwater to southern Canada, USA and Mexico [31–33]. Soviet engineers and administrators have contemplated diverting some of the water of the Ob and Irtysh to Kazakhstan, Soviet Central Asian republics and to replenish the Aral Sea. During the 1980s, there were considerable discussions between Western and Soviet researchers about the impact of the Siberian river diversion to the Arctic Ice cover, local, regional and global climate [34–39]. Social and media pressure contributed to the project's dissolution, due to the substantial social and environmental impacts resulting from the project [40]. Recently, Russian scientists proposed to reduce the flow of Siberia's Rivers that have increased (due to the melting of the permafrost) and could upset the salt balance and circulation of the Arctic Ocean, leading to the shutdown of the Gulf Stream that would trigger colder winters across Europe and Siberia [39]. This is exactly what the paper wants to avoid while reducing the flow of Siberian Rivers to the Arctic.

In order to estimate the energy consumption to transpose the water from a basin to another, Eq. 5 is applied. The energy requirement estimate for the transposition

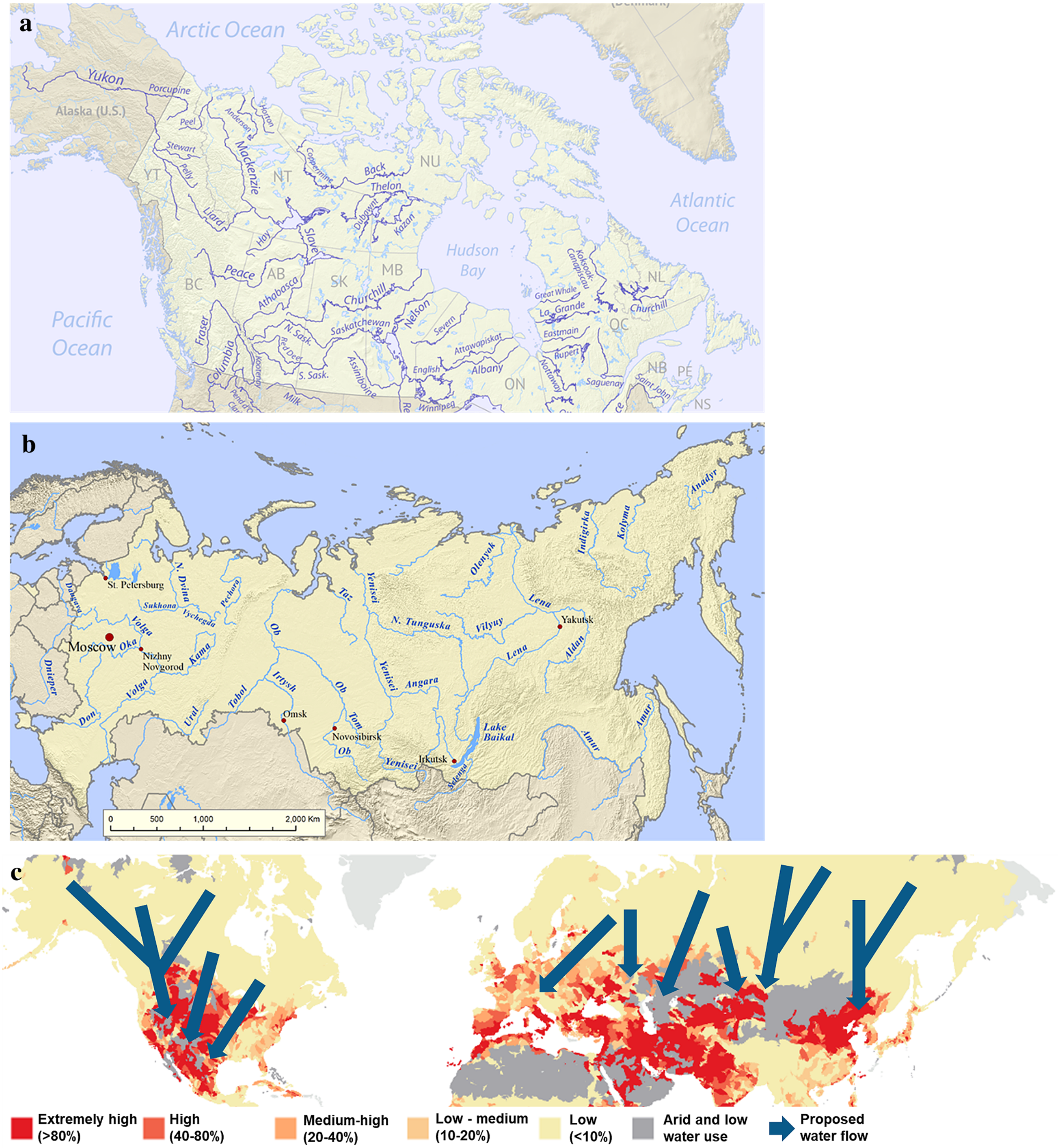


Fig. 6 Proposed supply of water from Canada and Russia to projected water-stressed regions of the world in 2030 [30]

assumes the half of the maximum pumping head. This is because the water precipitation is distributed at different heights in the basin. The total pumping head assumes the difference in height between the Arctic Ocean (0 m) and the minimum required head to transpose water to the basin in the South. The data utilized in this analysis are taken from [41]. The average river flow discharged to the Arctic Ocean was taken from [42]. Note that there is the possibility that some of the water transposed could generate electricity in the basin to where the water was transposed to; however, this is not considered in this paper.

$$E_T = F_T \times d \times h/2 \times a \tag{5}$$

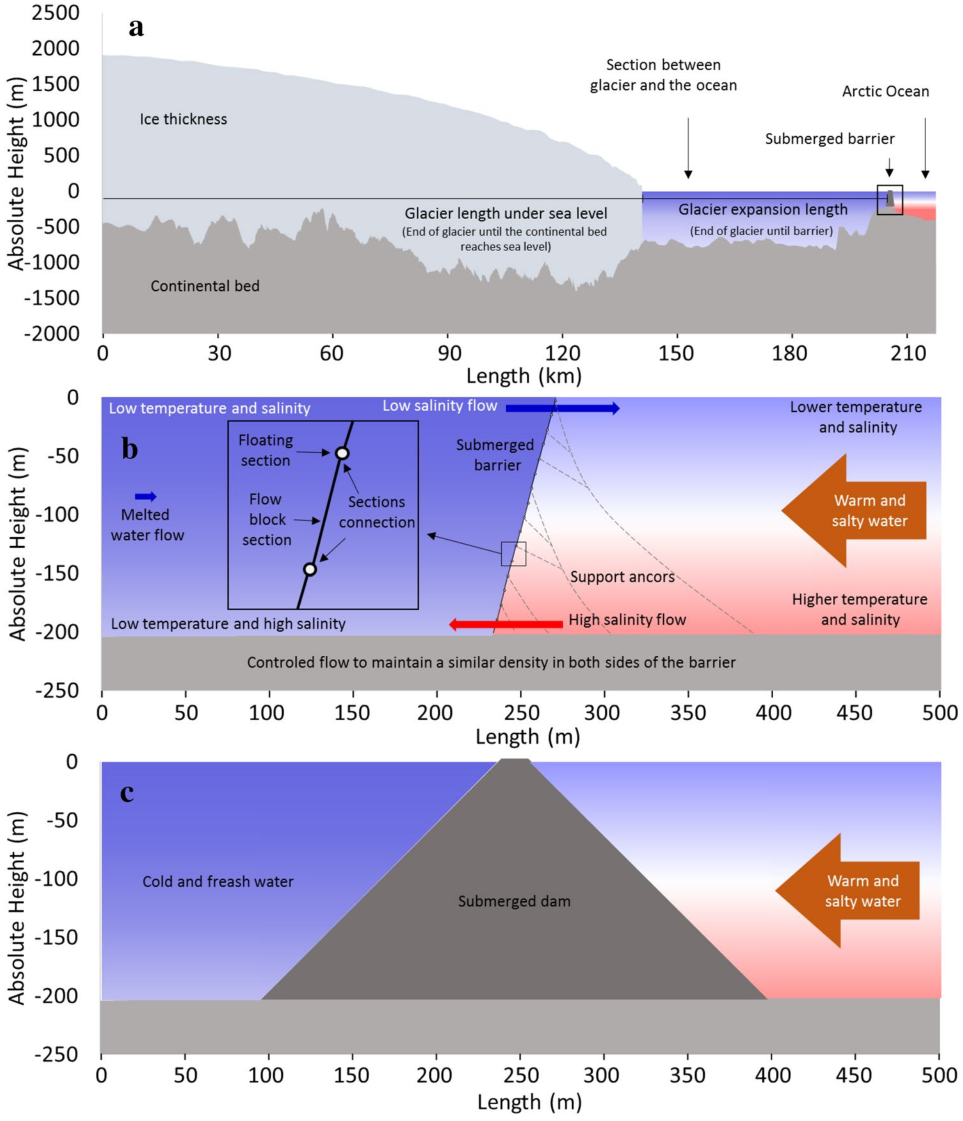


Fig. 7 **a** Longitudinal representation of the barriers and dams in front of Greenland glaciers and proposed **b** barriers and **c** dams to reduce ice melting in Greenland [43]

where E_T is the energy required to mix the superficial and deep Arctic Ocean waters (J). F_T is the average river flow to be transposed (m^3/s). *d* is the density of water (1.000 kg/m^3). *h* is the height required to transpose the water to the basin in the South (in meters). *a* is the acceleration of gravity (9.81 m/s^2).

2.1.2 Reduce Greenland ice sheet melting

An important step to increase the salinity of the Arctic Ocean surface and the temperature of the North Atlantic current is to reduce the Greenland ice sheet melting. Approaches to accomplish this have been proposed in [43–45]. Moore et al. [45] and Wolovick and Moore [44] propose three approaches to reduce Greenland ice sheet melting, reducing the flow of water under the ice sheets, so that it will reduce its speed, build structures to contain the flow of the ice sheets and create dams to restrict the flow of warmer seawater to contact the ice sheet. Hunt and Byers 2018 proposes the creation of floating barriers instead of dams and estimate the costs of them and their impact on ice melting and sea level rise. The most convenient approaches for this project are the dam and barriers as represented in Fig. 7. The estimated Greenland ice sheets melting rate was taken from Romanovsky et al.

One issue to notice is that with the increase in the North Atlantic current entering the Arctic Ocean will considerably increase the temperature of the Arctic atmosphere. This could increase the melting of Greenland ice contributing to reduce the salinity of the Arctic Ocean and cooling down the North Atlantic current, weakening it and increasing sea level rise. However, without the barriers, Greenland would melt much faster than if barriers are added.

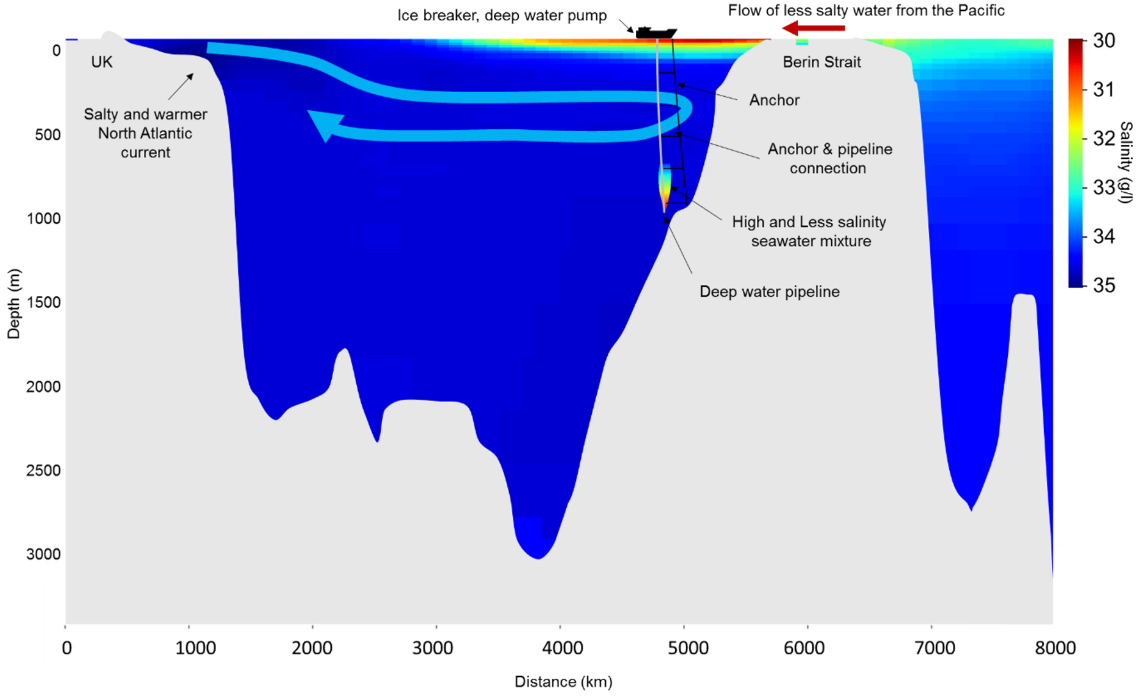


Fig. 8 Diagram of the Arctic Ocean mixer proposed in this paper

Even if it is possible to considerably reduce the melting of Greenland ice, this is not a long-term solution, given that Greenland would not be able to store all inlet ice forever. Even with the barriers, after several hundred or thousand years, the glaciers will overflow the Greenland coast and reach the Arctic Ocean and contribute to more freshwater to the Arctic Ocean surface.

2.1.3 Mix Arctic ocean waters

If the two alternatives above do not prove to be technically, economically and/or environmentally viable, a further alternative would be to pump the less salty water from the Arctic Ocean surface to 1 km depth in the Arctic Ocean, particularly in the Beaufort Sea, whose surface waters have one of the lowest salinity. The less salty and less dense water at 1 km depth will rise; however, the less dense water will mix with the deep water and will not return to the surface. The depth in which the surface is released should vary from below the Halocline (500 meters deep, Fig. 4b) to around 1 km deep.

This will eventually remove the thin, less salty seawater layer from the top of the ocean and thus increase bottom-up the salinity of the Arctic surface seawater layer. This increase in salinity will increase the density of the superficial seawater and thus allow more water from the Atlantic to enter the Arctic Ocean surface. Such project would require an ice breaker ship with a pumping system attached to a pipelines at least 1 km deep and attached to the ocean bed, as shown in Fig. 8. The energy utilized to operate the pumps could be generated by offshore floating wind turbines or brought from Canada or Russia via underwater transmission lines.

The advantage of this approach is that the system always pumps the least salty water to the deep ocean. The water pumping from the surface attracts more of the less salty water from the surface close to the pumping inlet. This will continue until the salinity of the pumped water is similar to the salinity of the deep ocean layer. Thus, this solution could extinguish the halocline layer of the whole Arctic, with only one large ship. On the other hand, if high-salinity water was pumped onto the surface of the Arctic Ocean, it would sink due to its higher density and would not mix with the thin layer of superficial seawater.

The energy requirement for pumping the water from the surface to the bottom of the Arctic Ocean is calculated using Eq. 6.

$$E_M = F_M \times \left(D_d - D_s\right) \times d \times a \qquad (6)$$

where E_M is the energy required to mix the superficial and deep Arctic Ocean waters (J). F_M is the average flow

Table 3 Arctic Ocean superficial salinity mass balance

Scenarios	Storage (km^3)	Flow/concentration that reduces salinity in the Arctic Ocean (km^3 per year)				Flow/concentration that increases salinity in the Arctic Ocean (km^3 per year)			
	O_1/C_{1f}	F_2/C_{fw}	$F3/C_{fw}$	F_4/C_{fw}	P_1/C_{fw}	F_1/C_{1i}	S_5/C_5	E_1/C_{fw}	M_1/C_{1i}
Estimate of current flows and volumes mass balance in the Arctic Ocean									
Flows and volumes	703,000	200	1545	325	3500	35,490	30,420	500	0
Salt concentration (g/l)	30	0	0	0	0	30	35	0	30
References	[26, 27]	[46]	[42]	[42]	[47]	Calculated Eqs. 2 and 4	Calculated Eqs. 2 and 4	[48]	No pumping
Estimate of flows and volumes mass balance in the Arctic Ocean after 50 years of operation of strategies									
Flows and volumes	703,000	150	772	112	5250	55,813	51,029	1500	0
Salt concentration (g/l)	32	0	0	0	0	32	35	0	32
Estimate of flows and volumes mass balance in the Arctic Ocean after 25 years of operation of strategies									
Flows and volumes	703,000	100	772	112	4375	39,345	40,725	750	5988
Salt concentration (g/l)	31	0	0	0	0	30.9	35	0	30.9

of superficial Arctic seawater to the deep Arctic Ocean (m^3/s). D_d is the density of seawater at a depth of 1 km (1070.673 kg/m^3). D_s is the density of seawater at the surface (1067.551 kg/m^3). d is the pumping depth (1.000 m). a is the acceleration of gravity (9.81 m/s^2).

A challenge of this alternative is that the water from the Pacific, which is considerable less salty than the water from the North Atlantic Ocean will flow through the Bering Strait and contribute to reducing the salinity of the Arctic ice. Thus, a partial restriction of the Bering Strait current with submerged floating barriers might be required [18, 19].

3 Results

This section intends to compare the proposed strategies to increase the salinity of the Arctic Ocean estimating the flows and salinity concentration mass balances, energy requirements and estimated costs. The assumptions made in this section intend to create a conservative estimate of future scenarios operating the different strategies to increase the salinity of the Arctic Ocean. In order to estimate the current flow and salinity concentration balances of the superficial Arctic Ocean, the values with reasonable estimates were taken from the literature and presented in Table 3 and the unknown flows were estimated using the mass balances Eqs. 2 and 4. Note that these are just preliminary scenarios with the intent of giving an overall idea of a possible outcome of implementing the proposed

Table 4 Comparison of strategies to reduce the input of freshwater to the Arctic Ocean

	Average Flow (m^3/s)	Drainage area (km^2)	Outflow	Pumping head (m)	Energy requirement (GW)[a]	Energy requirement per freshwater contribution (MW/m^3)	Investment costs
Reduce the river flows to the Arctic							
Mackenzie	10,300	1,790,000	Beaufort Sea	270	14	1.377	Medium
Ob	12,475	2,990,000	Gulf of Ob	130	8	0.663	Low
Yenisei	19,600	2,580,000	Kara Sea	320	32	1.632	Medium
Lena	16,871	2,490,000	Laptev Sea	520	45	2.652	High
Reduce Greenland ice sheet melting							
Greenland	22,000	2,166,000	Around Greenland	–	–	–	Medium [43]
Mix the Arctic Ocean waters							
Pumping water	190,000	4,000,000	Arctic Ocean at 1 km depth	23	17.5	0.461	Low
Total energy	–	–	–	–	116.5	–	–

[a] The energy requirement for reversing the river flows assumes half average flow presented in the table

strategies to increase the salinity of the Arctic Ocean superficial seawater.

After the salinity of the Arctic reaches a threshold of 32 g/l salinity, as proposed in Table 2, the Superficial North Atlantic current will move into the Arctic Ocean. This will thus increase the mixing of the superficial seawaters of the Arctic, and the salinity of the Arctic Ocean will considerably increase. At this point, the amount of energy required to reduce the salinity of the Arctic Ocean could then be reduced. However, the capital intensive river reverser systems continue operational due to its mutual benefits or also providing water to drought prone regions. It is also assumed that after the targeted salinity of the Arctic Ocean is reached, the rain patterns in the Arctic ocean will increase by 50% (due to the increase in temperature and upward wind pattern over the Arctic Ocean), the evaporation will increase by 150% (due to the melting of the Arctic sea ice cover), the melting of Greenland with barriers will increase 50%, and the river flows is reduced to half of their current flow.

The middle of the way scenario to reach the ultimate goal of 2 g/l increases in superficial Arctic Ocean salinity using Eqs. 2 and 4 and assuming an average North Atlantic Ocean current compared to the current flow and targeted flow, reduction in river flows to a half, reduction in Greenland melting by a half, increase in precipitation by 25% compared to current values, increase in evaporation by 50% result in a required pumping of superficial

Table 5 Advantages, disadvantages and unknown impacts of strengthening the North Atlantic current

Advantages	The water that would have been discharged into the Arctic Ocean would be directed to water-scarce regions, benefiting Canada and Russia, for the creation of a new commodity market, and benefiting North American and Asian countries that suffer from water scarcity The possibility of using the Arctic ocean as a maritime route for shipping throughout the year The increase in surface salinity and sea ice cover in the Arctic will enhance the Atlantic meridional overturning circulation (AMOC) [49, 50], increasing the temperature of the UK, Norway, Iceland, Russia, USA, Canada, the Arctic region and Europe as a hole Allow for the extraction of natural resources in the Arctic region The reduction in Arctic sea ice during the winter will considerably increase the absorption of CO_2 by the Arctic Ocean. This is because there will be more ocean surface in contact with the atmosphere, which will allow more CO_2 to be adsorbed by the ocean. Additionally, the lower temperature of the ocean will increase the capacity for storing CO_2 in the world's oceans. This would reduce the atmospheric CO_2 concentration Apart from providing water to locations that suffer from water scarcity, these river transfer projects will require several dams and reservoirs, which could be used as strategy for energy storage to support the dissemination of intermittent renewable energy sources such as wind and solar Reducing the temperature of the Mid Atlantic Ocean, as more of the warm waters flowing to the Arctic will reduce the probability of hurricanes in the Atlantic Ocean. It might, however, reduce precipitation in locations surrounding the Atlantic Ocean The reduction in temperature of the world's oceans will reduce the melting of Antarctica, which could reduce sea level rise. The potential of cooling down the oceans, the Earth and eventually the atmosphere
Disadvantages	Considerable increase in permafrost thawing, which will have a devastating impact on Canada and Russia landscape and contribute to the increase in methane emissions. However, this paper assumes that permafrost thawing would happen even if this project does not go ahead, due to global warming The changes in temperature in the world's atmosphere would happen faster than expected, particularly in the Arctic region, which would increase the number of droughts and floods The Polar weather cell could change direction with the melting of the Arctic ice during the winter. This is because the air temperature at the North Pole would be higher than the air temperature in Canada and Russia; thus, air would rise in the North Pole and descend in Canada and Russia. The Ferrel cell might disappear in the Northern Hemisphere, and the Polar cell will be directly in contact with the Hadley cell in the winter in the Northern hemisphere. This would likely result in an increase in rain in the Arctic Region and have an extensive impact on the weather of Europe, America and Asia. It is, however, difficult to predict the impact of these changes The Arctic sea ice loss might not only warm the atmosphere over the Arctic but also cause a mini global warming [51, 52]. The large increase in temperature in the Arctic could result in melting Greenland ice from its surface, even considering that submerged barriers are implemented Potential impact on the habitat of Arctic animals, such as polar bears, seals, fish, plants, bacteria and others. However, if climate change is not addressed, there is a potential for many other species extinguish around the world The cooling of the oceans will happen from the bottom of the ocean until it reaches its surface. It might take thousands of years for the effects of the cooling to the realized in the world's atmosphere
Unknown	It is difficult to predict if the melting of the Arctic Ocean will increase or reduce sea level rise. The increase in temperature in the Arctic would increase the melting of Greenland during the summer; however, it could contribute to more snow on Greenland, due to the increase in humidity in the region. The ice-free Arctic will considerably cool the world's oceans, due to the removal of the ice layer in the Arctic. This will reduce the melting of the Antarctic ice sheets. Overall, it is difficult to predict if sea levels will rise of fall This change of ocean circulation will alter global temperature patterns on decadal time scales [53, 54]

Arctic Ocean water to the deep Arctic Ocean of 5988 km^3/year over 50 years. After these 50 years, the Arctic Ocean superficial salinity will reach the threshold in which the North Atlantic Ocean current can naturally enter the Arctic Ocean.

The energy requirement for operating the proposed strategies, as suggested in Table 3, is presented in Table 4. Equation 5 is applied to estimate the energy requirement for reversing the Canadian and Russian rivers, and Eq. 6 is applied to estimate the energy requirement for pumping the superficial Arctic Ocean seawater to the deep ocean. It can be seen that the estimated total energy requirement for operation of the proposed solutions is 116.5 GW for 50 years in which 99 is to reverse the USA, Canadian and Russian rivers, and 17.5 to pump water from the Arctic Ocean surface to the deep ocean. This is equivalent to around five Three Gorges Dam (generation capacity of 22.5 GW) operating at full capacity throughout the year.

4 Discussion

Given the numerous relevant impacts of the approaches to allow the North Atlantic current to reach the Arctic, these impacts are described in Table 5.

Global warming could contribute in two ways to the dynamics in the Arctic Ocean. It increases the temperature of the North Atlantic Ocean, however, it also increases the melting of Greenland ice, which cools down the surface temperature of the North Atlantic current and reduces the salinity of the surface water of the Arctic Ocean [55]. In other words, global warming might not contribute to the North Atlantic Ocean to flow above the Arctic Ocean. At least until there is ice to be melted in Greenland.

5 Conclusion

This paper has shown that increasing the salinity of the surface water of the Arctic region would allow the North Atlantic Ocean to flow above the superficial Arctic layer, thus transporting heat from the Atlantic Ocean into the Arctic and increasing the amount of heat radiated into space and overall cooling the Earth's oceans and possibly the Earth as a whole. The cooling of the oceans will happen from the bottom of the ocean until it reaches its surface. It might take hundreds or thousands of years for the effects of the cooling to the detected in the world's atmosphere.

Three strategies were discussed to increase the salinity of the Arctic Ocean surface waters so that the North Atlantic current can flow above the Arctic Ocean. These strategies involve reducing the river flow to the Arctic, reducing Greenland ice sheet melting and mixing the Arctic Ocean waters. In other words, these alternatives would be convenient of the Arctic region, with the increase in temperature and convenient for the world as a whole due to the reduction in ocean temperatures. Regarding the energy requirements, the most attractive projects in a descending order are the Greenland submerged barriers, Arctic water mixing, Ob transposition, Mackenzie transposition, Yenisei transposition and Lena transposition. Regarding the investment costs, the most interesting projects in a descending order are the Arctic water mixing, Ob transposition, Mackenzie transposition, Yenisei transposition, Greenland submerged barriers and Lena transposition. It is estimated that after implementing the proposed solutions, it would take around 50 years to allow the North Atlantic Ocean current to flow above the Arctic Ocean.

Human intervention is already having serious impacts on the Earth's climate, biosphere, land and oceans. Different proposals of how these impacts should be managed, and possible strategies to reduce these impacts are being considered to preserve life on Earth. This paper argues that comparing the advantages and disadvantages of allowing the North Atlantic current to enter the Arctic Ocean, this alternative should be further studied and considered for tackling global warming.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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