VOL. 1

MARCH 3, 2020

KIDS DISCOVERY

ARCTIC EDITION

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2020

Learn about the cutting-edge science and research behind Thermokarst lake formations

Thermokarst Lakes

Thermo-what? How bubbling lakes in the Arctic have bcome the focus of Arctic climate research

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FEATURE ARTICLE

Words by Adam Warner
Photos by John Reed

Plants older than your grandparents

Before we dive into what thermokarst lakes are and why they are important, let's talk about plants in the Arctic. While polar bears, penguins and seals might be the first thing that comes to your mind when we talk about life in the Arctic, there are actually an abundance of species that live in the Arctic. Most surprisingly, there are plants older than your grandparents that still exist in the Arctic and have played an important role in climate oscillations in the past (Wooller et al, 2012).

These plants are not exactly the type of plants that first come to mind. Rather, they are plants that lived long ago and now take the form of frozen organic matter, a form of carbon. In fact, scientists have recently discovered an enormous sink, meaning source, of carbon that dates back to the Holocene; this carbon sink mainly comes in the form of frozen organic matter in the Siberia region below thermokarst lakes (Anthony et al, 2014). Thermokarst lakes played an important role in stabilizing the climate by capturing and storing a large amount of carbon (Anthony et al, 2014).

Dynamics of greenhouse gas sequestration (example: frozen permafrost in Siberia), and release (example: bubbling methane from thermokarst lakes) are important because greenhouse gasses play the most significant role in understanding climate change: Essentially, greenhouse gasses -- like water vapor, carbon dioxide and methane-- trap heat into our environment and have been increasingly been released by anthropogenic (people) emissions and feedbacks from anthropogenic climate change. Because greenhouse gasses like methane are especially potent, scientists should research different environmental processes and features that interact with the global greenhouse gas budget.

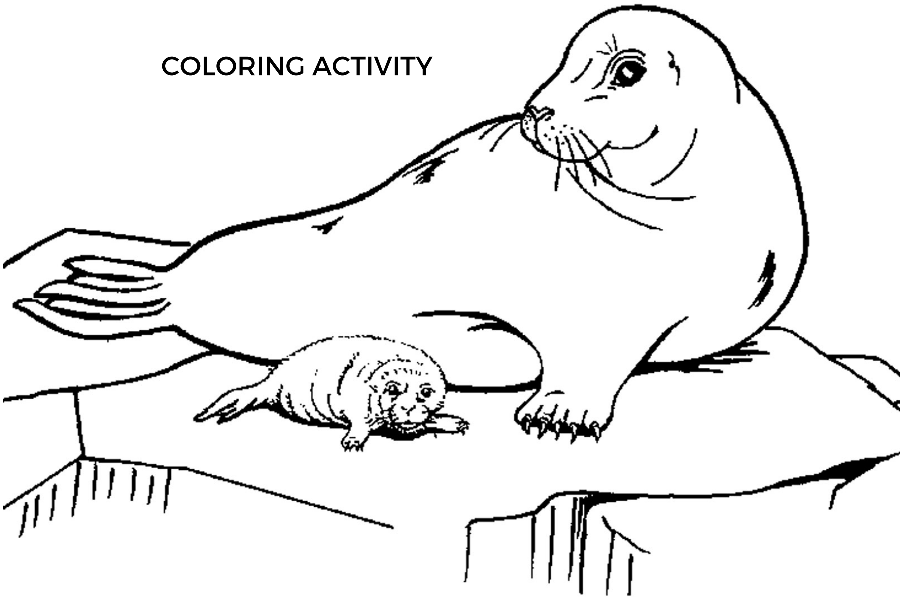
The Arctic geophysical properties, like the existence of year-round frozen ground, are subject to destabilization because of climate change. Destabilization of certain Arctic environmental features like the melting of permafrost have significant implications for our global climate system as a whole. In order to get a better picture of what of these processes, we have to talk about permafrost. Most plants in the Arctic now exist in a frozen, organic matter state, called permafrost. Scientists consider permafrost to be anything that has been frozen in the ground for more than two years, and permafrost interacts with other aspects of the our warming environment in dynamic ways(Rowland et al, 2010). However, with our warming climate, that permafrost is becoming a little less permanent.

So what's the big deal?

Not so permanent permafrost...

Melting permafrost plays a significant role in the release of methane into the atmosphere, which is an extremely potent greenhouse gas (Walter et al, 2007b). However, scientists have been slow to include permafrost methane bubbling from lakes into their models because it is extremely difficult to accurately quantify the amount of methane released from bubbling (Walter et al, 2007b). Because of the potency of methane as a greenhouse gas, scientists now and in the future will continue to pay closer attention to mechanisms that amplify methane release from permafrost because that release has the potential to enormously impact warming, especially in the Arctic. Polar amplification captures the idea that climate warming will have a much more severe impact on the polar regions.

COLORING ACTIVITY



CONNECTING THE DOTS?

What do seals have to do with thermokarst lakes?

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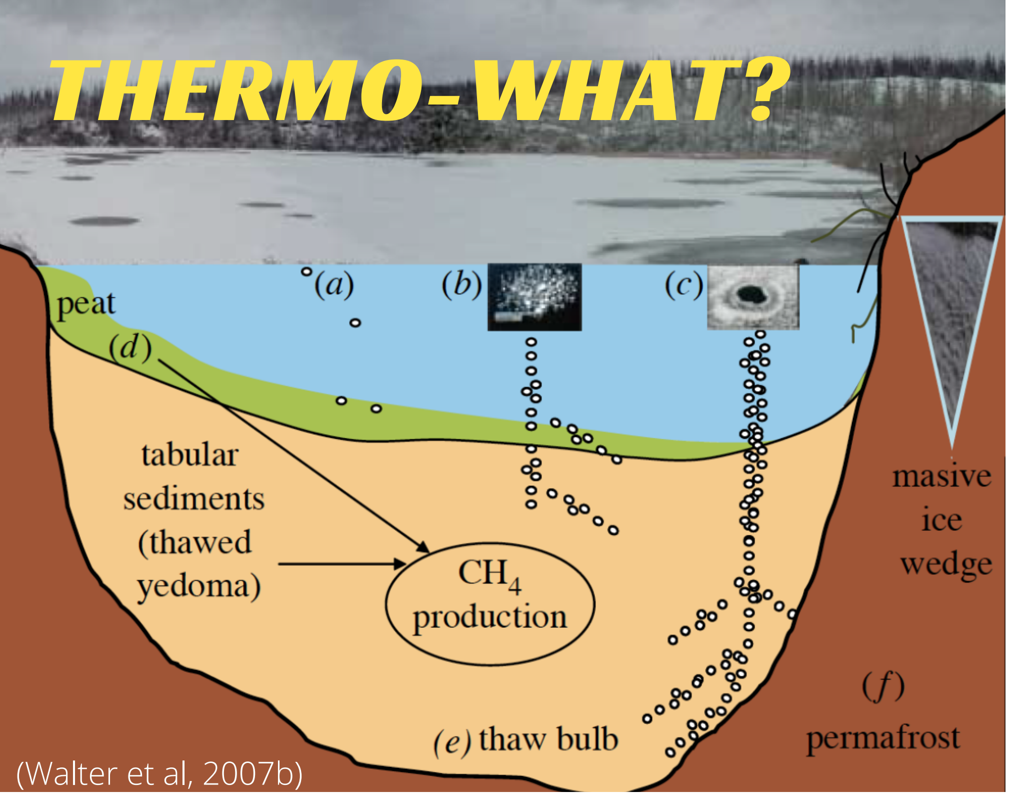
Hint: Thermokarst lakes --> global warming --> sea ice decline --> less seal habitat

THERMO-WHAT?



(Walter et al, 2007b)

Now that we have talked a bit about permafrost, and why the relationship between climate change and permafrost has important implications for our environment, let's dive a little deeper to learn about a unique geophysical structure in the Arctic called thermokarst lakes. Thermokarst lake formation follows a few general steps: The structure and characteristics of the ground below thermokarst development influences the capacity for thermokarst lakes to develop because thermokarst lakes generally develop atop melting permafrost (Hinkel et al, 2012). As the thaw bulb extends downward, permafrost continues to melt and result in the bubbling of methane to the surface of the lake (Figure 1) (Hinkel et al, 2012). Thermokarst lakes are expanding with our warming climate and do so through the process of thermal-erosion and thaw slumping (Grosse et al, 2008).

Essentially, as the ground in the Arctic gets warmer because of climate change, what was once permafrost now becomes thawed organic matter that microbes begin to break down which releases a significant amount of methane (Hinkel et al, 2012). In addition to contributing to the greenhouse gas effect, and expanding thermokarst lake will have a larger thaw bulb that will then cause bubbling of methane to rise to the surface of the lake and into the atmosphere, which will then cause even more warming in process called a runaway effect or positive feedback loop (Grosse et al, 2008). In fact, researchers have discovered that the deeper the lake and the thaw bulb, the more carbon dioxide and methane released through thawing (Mateev et al, 2016). This linear relationship suggests the importance of studying the geography of a landscape to gain a better picture of some of the geophysical interactions occurring.

Another important feedback loop, meaning relationship that either amplifies or stabilizes a process, is the role of ice melt in thermokarst lakes. As ice in thermokarst lakes continues to melt with the warming climate, there is even more of a potential for heat to flux into the lakes which then causes additional methane release, resulting in further warming (Arp et al, 2012). An important part of the positive feedback loop between thermokarst lakes and methane emissions is the decrease in surface albedo, meaning that as ice melts and exposes darker ground or water, more solar radiation will be absorbed and leading to further warming (Hinkel et al, 2012).

THE BIGGER PICTURE

As we mentioned earlier, the past can tell us a lot about the future. Scientific research continues to support the importance of studying methane release from the Arctic regions because methane released from the polar regions has made a significant contribution to the total atmospheric methane concentration during the last deglaciation event (Walter et al, 2007a). In fact, thermokarst lake contributions to atmospheric methane are projected to increase by 15-25% by the time the year 2100 arrives (Tan and Zhuang, 2015).

A CLOSER LOOK: SCIENTIFIC METHODS

How do scientists know what they know? Scientists studying the Arctic use a combination of different methods in order to get clues about what is going on the Arctic so that they are able to support or reject their hypothesis. For example, scientists exploring the impact of methane release on the last deglaciation event used ice cores, meaning really long tubes of ice extracted, to measure and date gas content in the tiny air bubble trapped in the ice to get a better picture of atmospheric concentrations long, long ago (Walter et al, 2007a). Another important method for studying the changing Arctic landscape is the use of remote sensing and radar (Arp et al, 2012).

Additionally, scientists commonly use climate models and mathematical algorithms to predict into the future. For example, Tan and Zhuang employed the use of climate models to predict how thermokarst lake and methane release dynamics would react under different climate change scenarios (Tan and Zhuang, 2015). While modeling works well for large scale understanding, methods to explore thermokarst lakes at a local level can involve studying tree rings from trees that grow near the lakes to get a more accurate picture of when certain thermokarst lakes formed (Burn and Smith, 1990). The bottom line: scientific research in the Arctic requires creativity, out-of-the-box thinking, and an understanding of global and local scales.

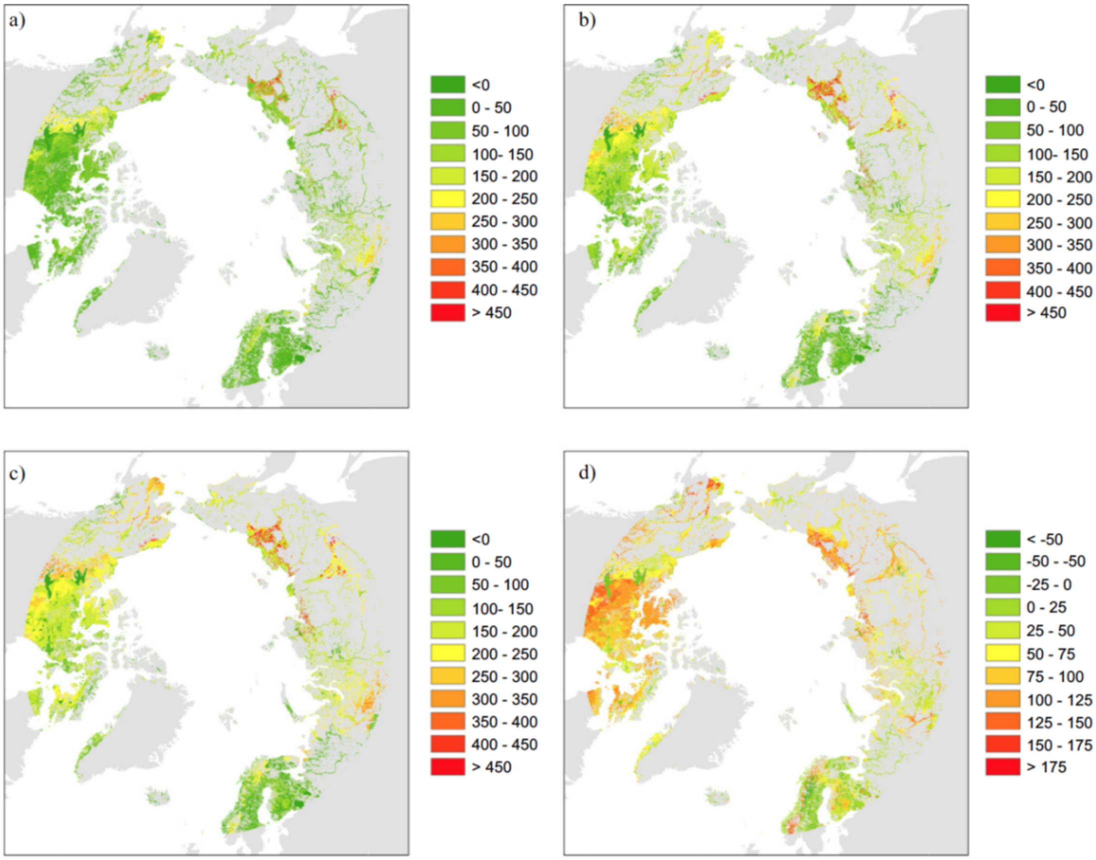


Figure 2. Distribution of CH_4 emissions from arctic lakes (units: mg CH_4 m^{-2} day^{-1}). (a) CH_4 emissions averaged from 2005 to 2008, (b) CH_4 emissions averaged from 2096 to 2099 (RCP 2.6), (c) CH_4 emissions averaged from 2096 to 2099 (RCP 8.5), and (d) the difference of future and present CH_4 emissions.

(Tan and Zhuang, 2015)

FUTURE RESEARCH

Initial interest in exploring methane dynamics started to catch spark in the late 20th century as scientists began to realize the potential of methane's role in positive climate feedback (Christensen, 1993). Over the years, as scientists developed a better understanding of methane feedback, they began to look towards sources of methane release like thermokarst lakes. Now, with extensive research on thermokarst lake formation and dynamics, scientists have a better understanding of the role of thermokarst lakes:

1. In relation to methane release: with climate change, permafrost will continue to melt leading to land subsidence and the formation of thermokarst lakes which will foster the exchange of methane gas from frozen ground to the atmosphere.
2. In contributing to positive feedback loops relating to changing albedo and greenhouse gas emissions.
3. As landforms that have existed through the ages: the studying thermokarst formations from the Holocene help scientist understand their role in past warming.

A big part of the research that is going on now is accurate model making to better understand thermokarst lake dynamics and make predictions about the future. Because scientists' primary focuses when researching thermokarst lakes are to gain a better understanding of the lakes' functions and the role in the global ecosystem and carbon cycle, a lot of research centers around modeling feedback and interactions that involve thermokarst lakes. For example, researchers often have to look to the past to better understand today and tomorrow. Teams of scientists have recently developed an estimate that much of the carbon from the Holocene era now exists in frozen ground in Siberia. They estimate that there are close to 160 petagrams (10^15 grams!) of organic carbon frozen in Siberia (Anthony et al, 2014). Research that involves predictions helps to shape future scientific endeavors and model making.

In addition to research focusing on the past to model for the future, scientists studying the Arctic are exploring how to quantify the amount of methane is actually being released. Because bubbling is the primary pathway for methane release from lakes to the atmosphere, there exists a large discrepancy in our ability to accurately measure how much methane is being released from that bubbling (Walter et al, 2006). In other words, scientists are just now beginning to realize the magnitude of carbon that has the potential to be released with our warming climate.

Furthermore, scientists are working hard to gain a more complete picture of the variety of methane release sources. While it is clear that thermokarst lake formations play a crucial role in the cycling methane from frozen permafrost to potent greenhouse gases in the atmosphere, there are also large lakes and ponds that contribute a significant amount of methane into the atmosphere (Wik et al, 2016). Classification of water bodies in the Arctic, like the difference between thermokarst lakes, glacial/post-glacial lakes, and ponds, depends largely on the formation process (Wik et al, 2016). Additionally, methane in ocean sediments trapped beneath permfrost plays an important role in methane release into the ocean and the atmosphere; in fact, researchers have found that a significant amount of ocean water in the Arctic is already saturated with methane (Shakova et al, 2010).

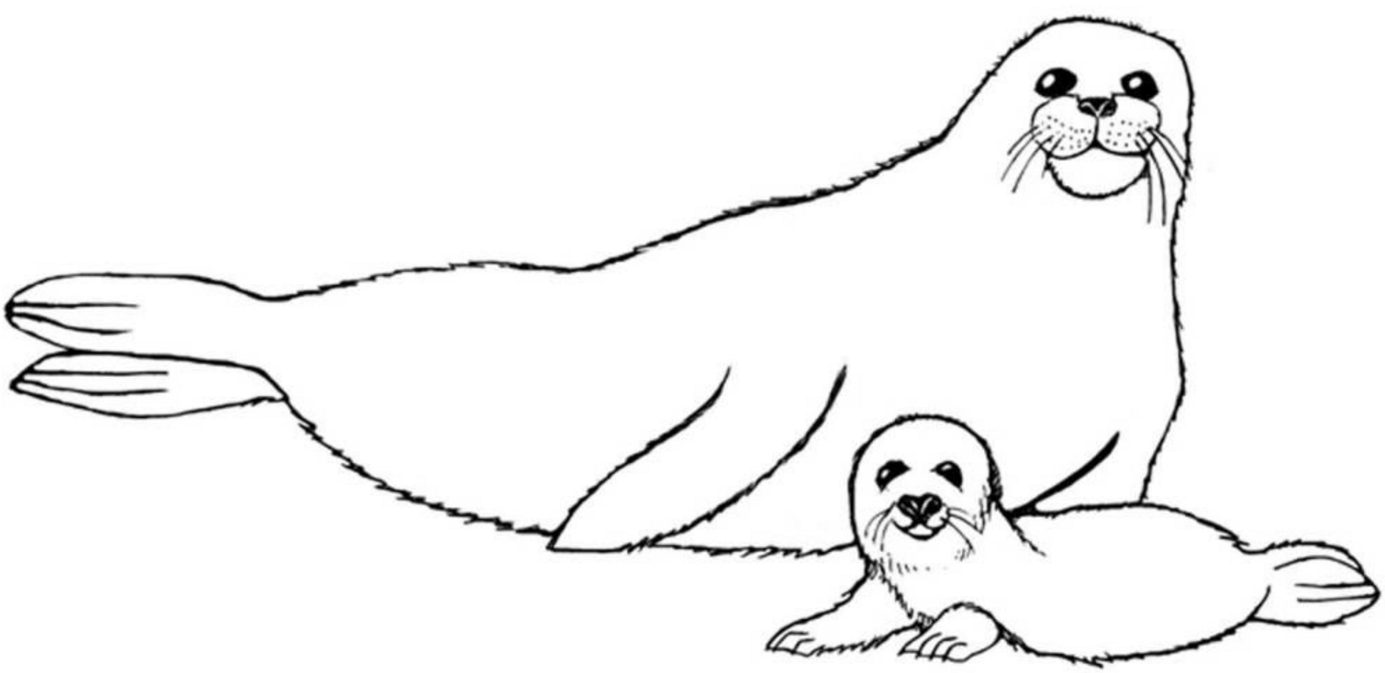
As our body of knowledge about the Arctic landscape and ecosystem continues to expand, there will always be a need for ast research to be synthesized and expanded upon. That's why it's up to you! Thermokarst lakes crucially impact the atmosphere which controls the climate of the world we live in. As you continue to grow up, global climate change has the potential to be extremely amplified, with some areas of the Arctic predicted to warm by almost 9 degrees celsius (Wik et al, 2016). The more we learn about the Arctic, the more we will be able to think creatively about solutions for how to best mitigate warming.

ACTIVITIES

NAME:______________________________ **DATE:**____________

J	X	A	E	Q	N	I	F	E	E	D	B	A	C	K
M	P	R	I	E	R	A	E	G	E	W	U	F	Z	T
G	P	C	L	R	A	N	A	T	K	I	D	A	J	T
U	X	T	T	G	E	S	I	S	W	R	K	U	Z	H
E	Y	I	F	C	F	E	C	K	L	K	N	I	F	E
L	M	C	O	E	N	D	R	U	Z	D	I	J	U	R
T	Z	L	B	A	Z	Z	V	K	S	Y	B	K	R	M
T	O	V	H	P	E	R	M	A	F	R	O	S	T	O
H	H	T	B	K	I	O	Z	Q	P	O	Y	H	J	K
U	E	A	A	L	B	E	D	O	O	E	U	E	H	A
M	N	U	W	Z	C	W	L	K	X	P	H	V	B	R
P	I	D	L	W	F	X	K	I	K	R	R	A	E	S
Q	X	Y	H	X	O	C	G	J	K	L	D	Y	P	T
R	J	B	N	S	F	K	P	M	P	Z	K	M	H	M
B	C	L	Q	M	Y	L	I	K	I	T	H	V	W	F

PERMAFROST
ARCTIC
METHANE
THERMOKARST
FEEDBACK
HOLOCENE
THAW
ALBEDO



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