# What Once Was Snow

Stories of Arctic Change, Adaptation, and Resilience

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EDITED BY
Mike Brook
Philip Burgess
Matthew L. Druckenmiller
Mark Serreze
Betsy Sheffield
Irina V. Wang

NATIONAL SNOW AND ICE DATA CENTER

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Editorial team: Mike Brook, Philip Burgess, Matthew Druckenmiller, Mark Serreze, Betsy Sheffield, Irina V. Wang
Copyediting support: Agnieszka Gautier
Custom maps: Philip Burgess, Matthew Druckenmiller
Cover photo: Christian Petrich
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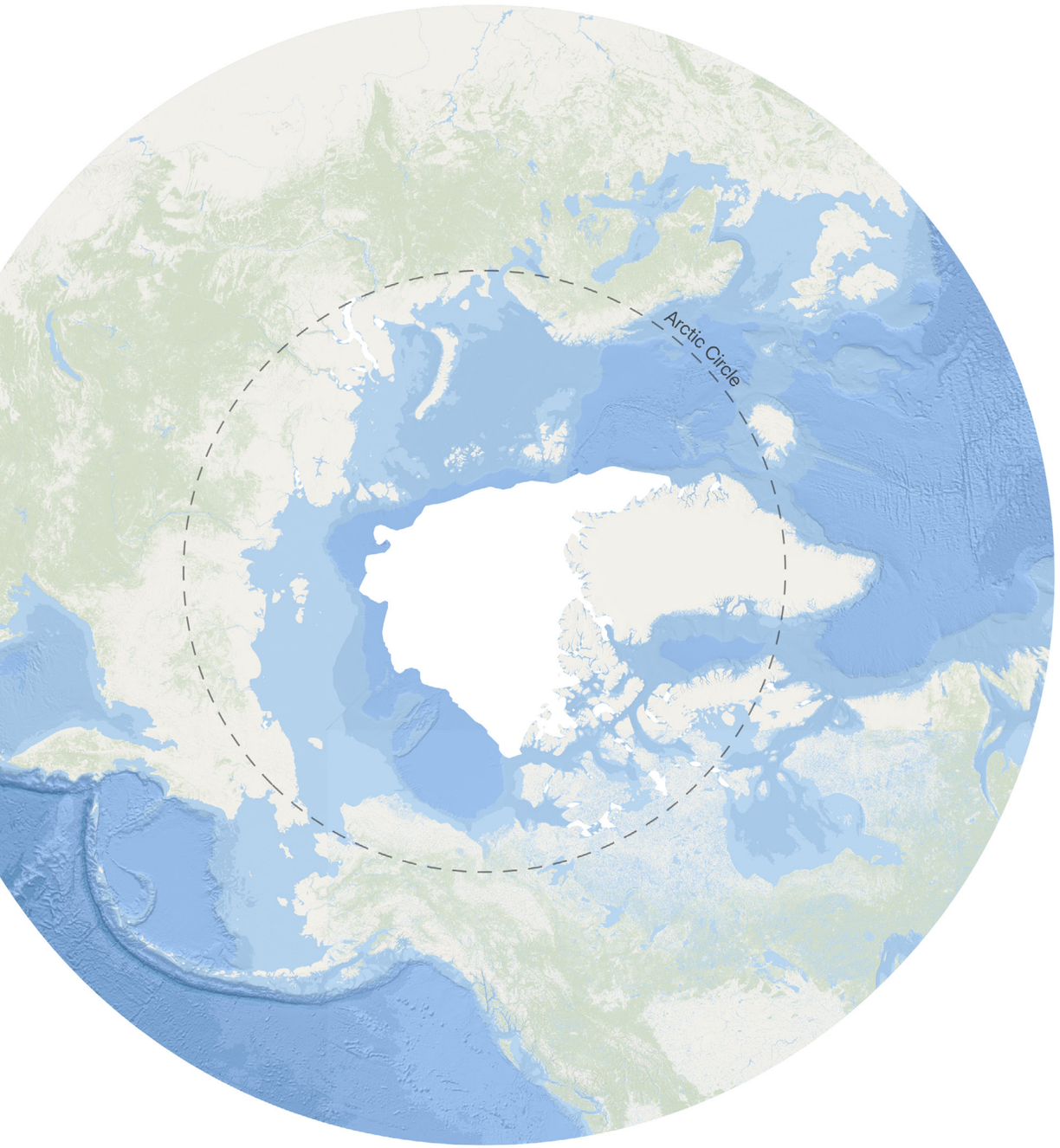
*Windblown ridges on the snow surface can be a navigation aid, as they indicate the direction of the prevailing winds. Photo by Matthew Druckenmiller.*




*The sea ice extent shown here is from September 2012—the month of the lowest summer minimum ice extent ever observed. Source: NSIDC Sea Ice Index.*

# Contents

*A Nenets winter camp on the Yamal peninsula, Russia. Photo by Philip Burgess.*

# Stories to Guide an Uncertain Future

The falling of snow immediately transforms any landscape. Dark surfaces are abruptly brightened, altering how sun or moonlight illuminate the earth. The soundscape changes as accumulating flakes muffle much of what we hear. As the ground takes on new characteristics, vegetation and animals respond against a backdrop of countless changes in physical, chemical, and ecological processes. Yet, the arrival of snow in the Arctic is not a disruption. It is anticipated, relied on.

Snow is the timekeeper of life and movement in the Arctic. Its accumulation during the cold winter months provides habitat for animals, insulation for relatively warm ground, bridges across gullies and streams, and a source of stored water for release in spring. These provisions are shaped by not only snow's arrival and duration, but by the characteristics of the snow itself—its surface features, depth, density, and varied layers within its pack.

The snowpack provides a record that many have learned to read and interpret amid familiar variations in weather and climate. Herders observe the behavior of their reindeer, or the sound and feel of their snow machine as they travel. Hunters pay attention to how snow affects the feeding and movement of wildlife. For Indigenous communities across the Arctic, living with snow across centuries has shaped their languages, cultures, stories, and memories.

But snow conditions in the Arctic are changing, driven largely by the warming climate. The Arctic is warming as much as four times as rapidly as the rest of the planet due to human-caused releases of carbon into the atmosphere. Since 1900, this past decade has been by far the warmest, with 2024 as the hottest year on record in the Arctic. As a result, the snow season is changing and shrinking. Just over the last two decades, spring snow melt has occurred up to two weeks earlier in both the Eurasian and North American Arctic compared to historical conditions, leading to a more rapid seasonal transition towards snow-free ground.

Also concerning for many is that what was once snow is increasingly falling as rain. Rain falling on snow, followed by colder weather, can leave hard ice crusts, making it difficult, or impossible, for many animals —like reindeer, caribou, and muskoxen— to forage. With rising temperatures, there are also more frequent melt and refreeze events, with similar effects.

These events can be unfamiliar disruptions that transform the snowpack, altering not only the physical environment, but also the cultural, linguistic, and ecological systems that have developed over long periods of time in relationship with snow.

Facing the threat of catastrophic losses, reindeer herders have diverted their herds to avoid widespread ice layers. Rain during winter raises alarms for many Arctic residents, playing havoc on the delivery of groceries, medical supplies, and other necessities, sometimes cutting off villages entirely. Food security, human safety, animal welfare, and the utility of deep-practiced knowledge by Arctic experts are being challenged in different ways.

Nonetheless, Arctic peoples are highly adaptive and Northern ecosystems have evolved to thrive amid extremes. So, how are rapid changes in Arctic precipitation impacting communities, livelihoods, and animals? And how are Arctic residents confronting these new realities?

Through the lens of herders, hunters, observers, scientists, and knowledge holders, each chapter of this book offers a grounded perspective on what it means to live in a world where snow, once reliable, is now uncertain. These stories also reveal the complexity of life in the Arctic—of colonial histories, diverse languages, varied economic drivers, policy decisions, industrial development, and the self-determination of Indigenous peoples.

**Chapter 1: When Rains Fell in Winter** tells of a rain-on-snow event on Russia's Yamal Peninsula in 2013 that transformed a seasonal migration into a crisis, killing thousands of reindeer and threatening the livelihoods of many nomadic Nenets herders. As such icing events become more frequent, the Nenets' deep knowledge, adaptability, and enduring connection to the land remain vital in navigating an increasingly unpredictable Arctic winter.

**Chapter 2: Amplification, Modeling, and Reanalysis** explores the meteorological dynamics, ecological consequences, and methods used to observe and predict changes in Arctic precipitation as climate warms. This chapter explains scientists' foundational understanding of why the Arctic is warming so much faster than other regions of the planet and what is known about how certain storm patterns account for disruptive rain-on-snow events.

**Chapter 3: One Year is Not Like Another** reveals how climate change, land use pressures, and economic shifts are reshaping reindeer herding in Finland. Four individual herders' stories illustrate how extreme winters, predator threats, and industrial development are converging to elicit creative adaptation using modern technology, diversified income, and generational knowledge.

**Chapter 4: Legacy Herds** brings us to the late 1800s when reindeer and Sámi herders were introduced to Alaska's Seward Peninsula to address food insecurity among Iñupiat and Yup'ik communities. Despite challenges like commercial interests, overgrazing, controversial legislation, and caribou encroachment, herding families today have maintained the livelihood through dedication and strong commitments to their communities and youth.

**Chapter 5: Our Language is Built to Live with Snow** explores the deep connection between the Nenets people and the tundra, focusing on the intricate knowledge of snow, ice, and permafrost, which is intrinsic to their nomadic reindeer herding culture. Drawing from personal experience and linguistic expertise, the author illustrates how the language encodes detailed environmental knowledge essential for herding on the Yamal Peninsula.

**Chapter 6: The Uncertain Trail** discusses how unpredictable freeze and thaw cycles in the Arctic are disrupting long-established seasonal travel patterns, leaving frozen rivers too thin or unstable for safe passage by snow machines. Arctic residents are forced to adapt through costly measures like building permanent roads, switching transport methods, or altering migration and travel routes for daily life—but not without significant economic, cultural, and logistical challenges.

**Chapter 7: Caught in the Elements** focuses on the lesser-known livelihoods of Inuit shepherds in southern Greenland, tracing the historical roots and legacies of early Norse settlers. Vulnerable to extreme weather events, today's sheep herders remain resilient through quick decisions and tight-knit, community-wide responses.



**Chapter 8: The Numbers We Gather** details the role and approach of three citizen observing networks in the Arctic: the Local Environmental Observer (LEO) Network, Indigenous Sentinels Network (ISN), and SIKU. While these networks employ different methods and have varied purposes, they collectively empower Arctic communities to track climate impacts such as rain-on-snow events, which threaten transportation, infrastructure, food security, and ecosystem health. By elevating Indigenous Knowledge and data sovereignty, these networks enable timely, place-based insights that Western science alone can miss.

This book of stories was inspired by the Arctic Rain on Snow Study (AROSS)—a collaboration between the National Snow and Ice Data Center (NSIDC) at the University of Colorado Boulder (U.S.), the University of Winnipeg (Canada), Alaska Pacific University (U.S.), and the University of Lapland (Finland). AROSS, funded by the U.S. National Science Foundation's Navigating the New Arctic (NNA) Initiative in 2019, is an interdisciplinary research partnership aimed at understanding Arctic change and its local and global effects.

*What Once Was Snow* brings forward these stories of change and adaptation from across the Arctic and gives credence to the urgent need for policy decisions to confront global climate change. This book is a testament to how we must learn from and braid together Indigenous Knowledge, Western science, and the lived experiences of Arctic peoples.

*The Khudi family cross Ob Bay with their herd in spring. Photo by Andrei Golovnev.*

# 1. When Rains Fell in Winter

## The loss of 60,000 reindeer on the Yamal Peninsula

Philip Burgess & Irina V. Wang

Sudden winter rains are an age-old hazard for reindeer and the people who herd them. However, a warmer and wetter Arctic is transforming a once-in-a-generation challenge into more frequent and sometimes ruinous events.

This is the story of Tokcha Khudi. Tokcha is a Nenets reindeer herder who, along with his family, has herded reindeer across the tundra of the Yamal peninsula his entire life—just as his ancestors have done for centuries. A deadly icing event in the winter of 2013 killed as many as 60,000 reindeer. Tokcha's herd was impacted significantly, but he and his family were able to avoid the worst consequences thanks to a combination of knowledge, skills, and luck.

Yamal, which translates from the Nenets language as the "end of the world," is Tokcha's home—a 700 km (435 mi) Arctic peninsula situated in northwest Russia. The peninsula is simultaneously home to the largest area of nomadic reindeer herding in the world and nearly as much natural gas reserves as in the entire U.S. Around 6,000 Nenets

*Tokcha Khudi with his herd at the winter pastures. Photo by Florian Stammler.*

reindeer herders migrate with their animals across the tundra and seasons of Yamal, following the cyclic needs of their reindeer. Herders have migrated with their reindeer since time immemorial, along paths so well-traveled that they are visible from space.

Movement over land and water through all seasons—with family, reindeer, dogs, sledges, *chum* (the teepee-like tents of the tundra), and now snowmobiles—is the very essence of Nenets herding life. As the seasons change, herders move with their animals to reach the best pastures at the right time. This migration is an elaborate dance of movement, seasons, and pasture availability, but also requires navigating around other herds and rapidly expanding oil and gas infrastructure. The general outlines and cycles of migration are fairly fixed, but countless daily decisions and adjustments are made with reindeer welfare being utmost in the herders' minds. During the summer months, the Yamal Peninsula is home to perhaps as many as 275,000 reindeer.

Most herds move northwards along the peninsula as the days lengthen during the brief, bright Arctic summer. Herding work shifts to the nighttime when it is cooler and there is less insect harassment. Reindeer give birth en route. They turn south as the days shorten, the temperatures fall, and early snows arrive. Some herders travel up to 1,200 km (745 mi) a year, their movements closely tracking the seasons, the pastures, the day-to-day rhythm of the animals, and the shape of the land. There is a time for calving, a time for resting, and a time for slaughtering. Many families and herds cross the frozen Ob River in a fast dash each November to reach the forests and winter pastures on the southern side, in the Nadym region, reversing the

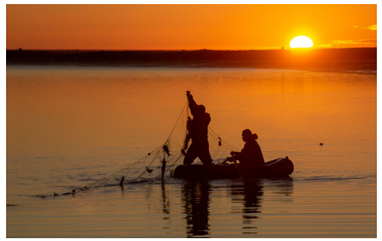


*Above: The Khudi family in 2001. Photos by Florian Stammler.*

*Below: Migratory pathways on the Yamal Peninsula.*


journey come spring. Some might call this a tough life, but most herders would say they cannot imagine any other.

The challenges are many: bitterly cold winters, clouds of insects in the summer, rivers and swamps to traverse, the mighty Ob Bay to ford, predators, a growing oil and gas industry, past political turmoil, competition over pastures, and a lack of legal protections for land use—not to mention recent maladies such as the COVID-19 pandemic, an anthrax outbreak in 2016 as the tundra warmed to release ancient pathogens, and Russia's 2022 invasion of Ukraine halting reindeer meat exports. Looming over these contemporary challenges are rapid shifts in climate that are causing unexpected weather patterns such as rains at the wrong time, the icing over of pastures, the death of animals, and the loss of livelihoods.



*Photos by Florian Stammler.*

## 2013 BEGAN AS A NORMAL YEAR

During the coldest and darkest months, the winter pastures of the Nadym region provide food, plenty of access to firewood, and wood for building or repairing sledges. Come the end of winter, herders there begin their migration northwards by crossing the Ob Bay in March.

1. The rhythms of the northward migration follow a fairly predictable pattern. The herd pauses for nearly a month in May, allowing the animals to “graze in peace” and to calve.

2. Movement continues northwards to a site where elders remain until September. They set up a fishing camp to harvest whitefish, which is the main source of protein for herders in the summer.

3. Leaving the elders at camp, the rest of the group moves northward quickly through lichen-rich pastures, preserving them for later.

4. Pastures are grazed for two weeks in August, allowing the reindeer to build body fat and weight. Nighttime frosts arrive.

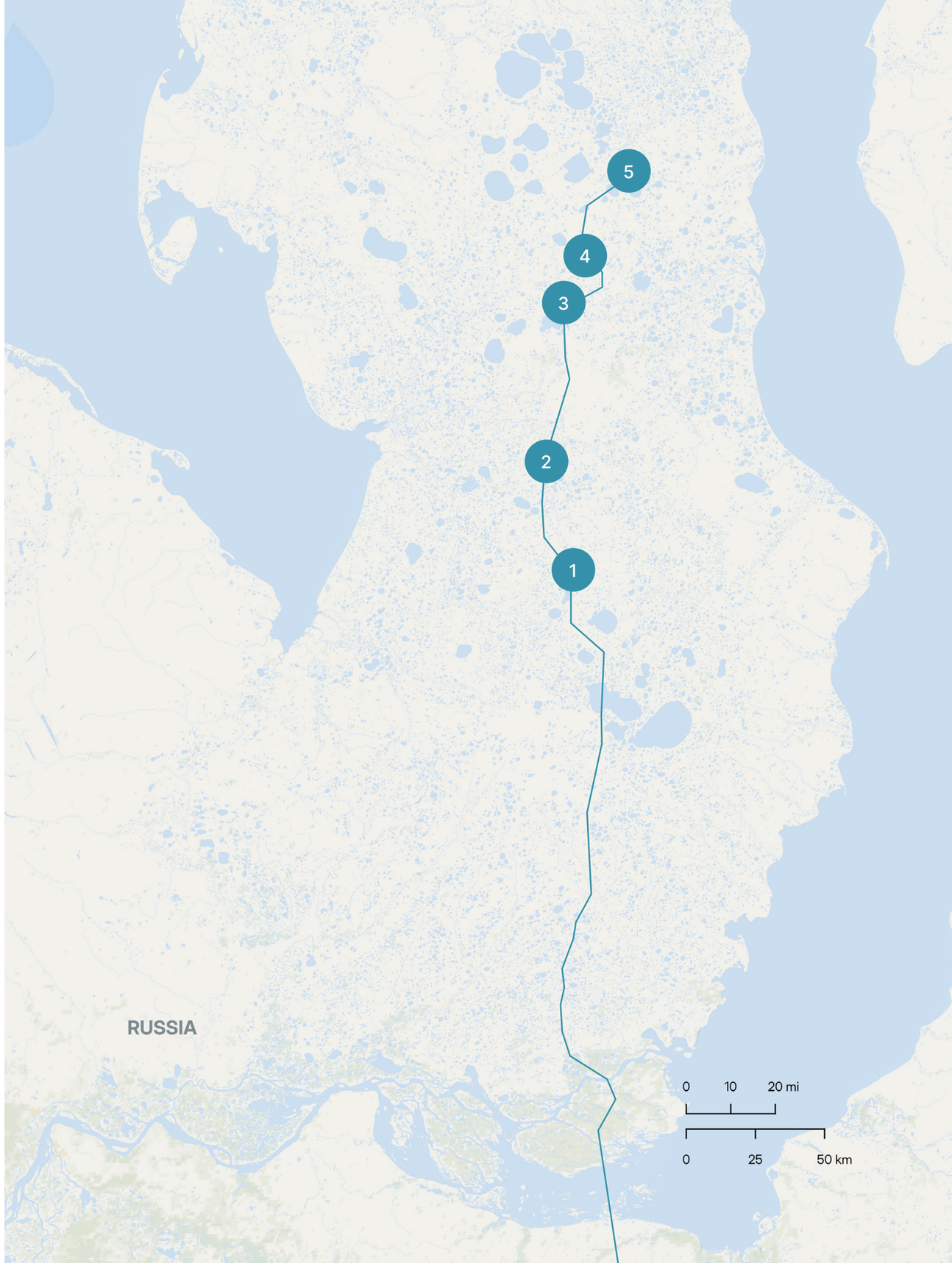
5. By the end of August to early September, the northernmost point of Tokcha’s migration is reached: 69°40'. After a few weeks, the caravan then turns south, reintegrating the fishing camp along their way. By now, the nights are darker and the weather shifts colder.

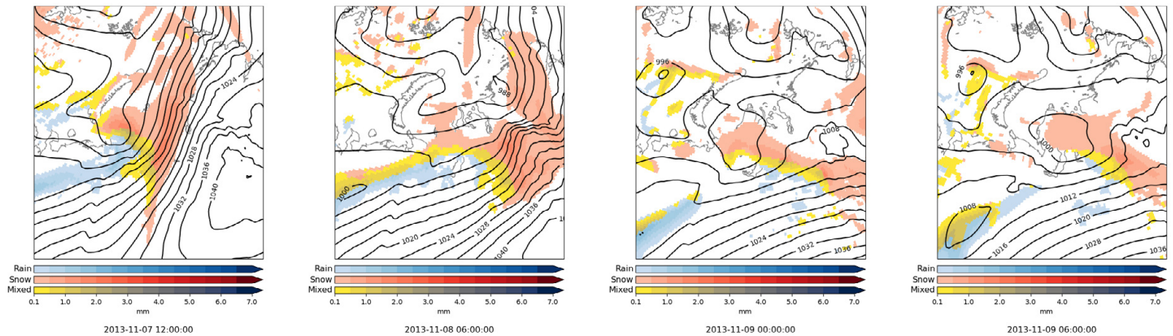
## RAIN AT THE WRONG TIME

During the late autumn of 2013, a three-day snowstorm fell. It came two to three weeks earlier than normal and settled atop ground that was not yet cold enough to maintain the structure of the snow.

Then, during the second week of November, a rainstorm soaked this loosely structured snow before temperatures plummeted, transforming this slush into solid ice.








These images, recorded by the National Snow and Ice Data Center's Arctic Rain on Snow Study, pinpoint the moment this warm pulse of precipitation swept over the peninsula. These brief, blue-hued patches of November rain upended the migration of tens of thousands of animals and thousands of herders over the following months. Not until the snow melted completely in the following year was it possible to assess the full damage. The tundra was littered with reindeer carcasses. The area impacted by this sudden icing covered an area of approximately 27,000 km$^2$ (10,425 mi$^2$)—nearly equivalent to the size of Belgium—directly across the herders' migration paths.

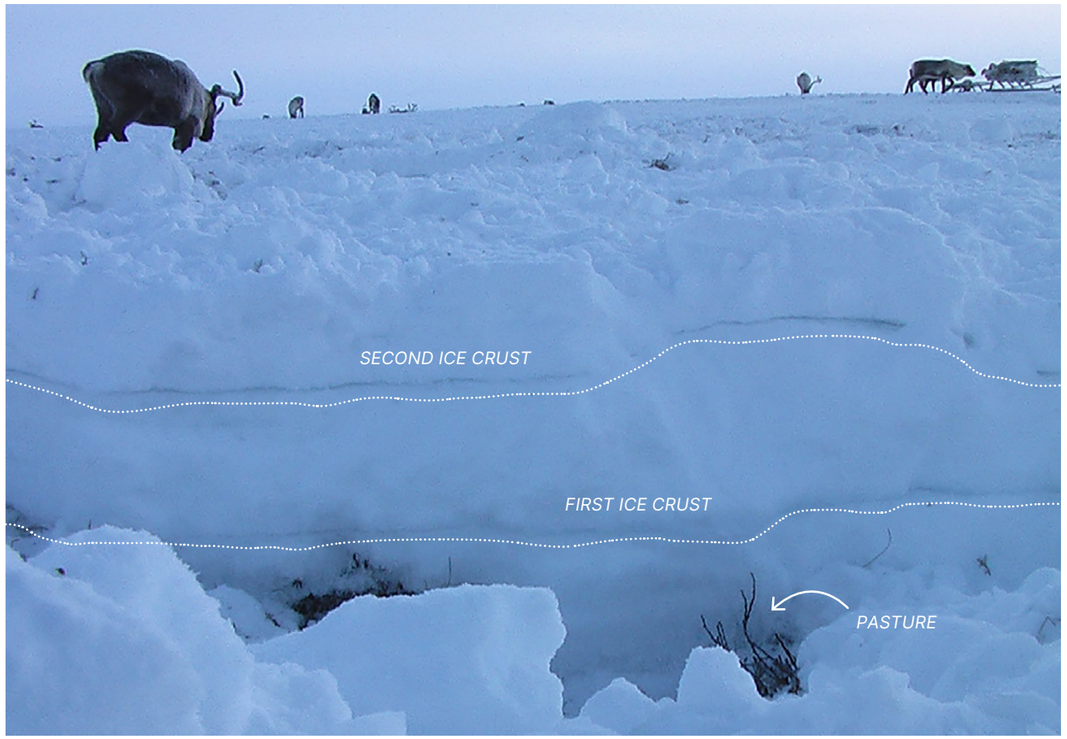
Not only did this icy layer form an impenetrable barrier that prevented reindeer from feeding on the pastures below, but it also made reindeer difficult to manage as they scattered in search of food. Typically, reindeer are able to dig through the snow and access vegetation from the pasture below. However, a rain-on-snow event creates a frozen layer of ice that impedes the animals from digging all the way through. And because it was winter, that layer of ice remained until the following summer.

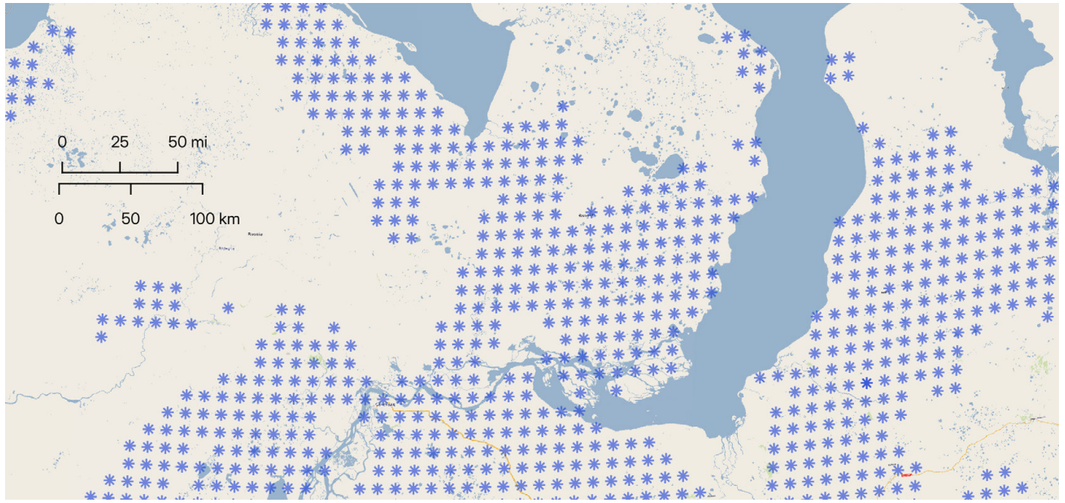
## *SERAD" PO*—A YEAR OF MISERY

When it happened, chaos ensued. At first, herders hoped it was temporary and that areas without ice would be found nearby. But soon, as new snow fell, the reality was clear and there was little time to act. While September or December are months with more flexibility in timing, November is all about maintaining the rhythm of daily herd movement as there is so much ground to cover.

Reindeer starved by the thousands. By the following summer, it is estimated that between 40,000 to 60,000 reindeer died from starvation. This catastrophic winter is now referred to as the *serad" po*, which in the Nenets language refers both to "year with the ice crust






*Above: This photo was taken by Florian Stammler in November 2006, clearly illustrating the depth of the snow, and the incidence of a double layer of ice. The second ice crust indicates another rain-on-snow event later in the season, sandwiching more packed snow in between. A double layer of ice and thick snow means reindeer have no way to access the pastures.*

*Below: Icing area between 7–11 November 2013, as recorded by satellite sensors. Data: Bartsch, A. et al (2023), "Towards longterm records of rain-on-snow events across the Arctic from satellite data," The Cryosphere, 17, 889–915.*

on the ground" and "misfortune, trouble, poverty, misery." Reindeer from different herds became mixed, were lost, died on their feet, and lay encased in snow and ice until the following year.

## TOKCHA'S SKILLS & LUCK

Tokcha encountered the icing at its northernmost extent and acted quickly to save his herd and family. His options were limited. He could continue migrating southwards without knowledge of what lay ahead, or he could look for ice-free pastures nearby before his herd scattered and possibly mixed with others. In a mix of some luck and much skill, he took the gamble of halting the southward migration and shifted into reverse. Navigating eastwards and then northwards, he made an emergency campsite and spent the winter in an area they would normally have passed through quickly. Thanks to his swift reaction, losses to his herd were limited.

Tokcha was fortunate in the timing and location of the icing event—he had not progressed too far and he knew the area extremely well, having wintered his animals nearby in previous years. Several ancestral family members were buried on the tundra nearby. His family emerged from the *serad" po* with fewer reindeer than they had in the summer of 2013, but much better off than the majority of his neighbors. Today, he and his family continue their nomadic herding life.

Others were not so fortunate. A herder named Yura lost 700 of his 900 reindeer. Yura spent years raising money to buy more reindeer by fishing, a common fallback plan for Nenets who need to generate additional income. A tightening of fishing regulations—in favor of larger enterprises—has made this more difficult.

Many reindeer also died crossing the Ob Bay that year. Another herder, Edward Vanuyto, remembered:

> *The reindeer which managed to cross to the Haen side, hurt their feet so badly and were so exhausted that they could not get to the lichen. When the sleds were untied, the draught stags fell never to rise again…40 sled stags died.*

Nor was it easier on the other side of the Ob. Herder Alexander Serotetto recalled:

> *Snow piles were waist-deep…All calves died. They did not eat and started falling…they began falling one by one. First calves, then stags. You cut it—and all the guts were empty; and no fat around the heart.*

In an interview with Roza Laptander, an elder herder named Khauly Laptander recounted:



*Reindeer carcasses littered the tundra that winter. Photo by Misha Okotetto.*

> *That year of the icing I was in my chum on the tundra. Then I lost many reindeer, and reindeer from different herds all mixed together, because they were searching for food. A lot of reindeer died from starvation then and many tundra people lost all their animals. It was good that there were no wolves that year.*

One herder from the Novy Port tundra lost 230 reindeer out of 250. He could not continue migrating. Another herder delayed departing for winter pastures in the southern tundra and lost almost all his reindeer. Out of his 1,500 animals, only 100 survived.

> *There was so much ice on the tundra that reindeer had nothing to eat; it was impossible to gather them in one place. They would gather in small groups and look for food wherever they could find it. If one reindeer found a little, it would lie down on the ice to melt it from the warmth of its body, then try to eat a little more. The ice was like an iron cover; it was as hard as the surface of this table. With all that ice, there was no food for the reindeer, and I lost many.*

## A LIFE OF MIGRATION CONTINUES

Despite these individual tragedies, migrations continue and the reins are handed over to the next generation. Nenets continue to live and travel with their animals, retaining great confidence in their ability to cope with any multitude of challenges, embodying the concept of resilience. Herders are familiar with extreme climate events—indeed, elders talk about them as happening once in a generation. Since that fateful winter of 2013, however, several more icing events have happened on the Yamal Peninsula. The most recent one was in the winter

*Above: Portrait of Andrei Khudi, Tokcha's son.*

*Below: Nenets herders adapt! Sledges are transported by trailer on a road near the winter pastures. Photos on this page by Vladimir Khudi.*



of 2020/21 in the north of the peninsula, which saw the first instance of reindeer being emergency-fed. The municipality and gas companies assisted with some mitigation measures, such as providing fuel and firewood to herders.

Tokcha is now an elder herder, in the process of passing many herding duties over to his son Andrei. We reached them by phone in January 2023, as they were about to cross the Ob Bay once more. Fortunately, the winter of 2022/23 was free from icing on their migration route and the primary challenge that winter was the extreme cold on the Ob Bay, reflecting the ever-changing conditions that herders operate in.

While the human costs of this event are still being felt today, Nenets herders have continued to adapt even as the pace of climate change makes this challenging. As cellphone coverage has expanded across the Peninsula due to oil and gas developments, herders are calling each other to warn of local conditions. Villagers with relatives on the tundra call herders with news of forecasted local weather events.

Meanwhile, scientists analyze why these events are occurring more frequently and whether there is a way that the worst aspects of these icing events could be ameliorated—such as through early warning systems and the expansion of mobile slaughter houses, which could allow herders to harvest their animals rather than lose them.

Tokcha had confidence in his skills to cope with this sudden icing event, demonstrating one of the great strengths of Nenets reindeer herding over so many generations: the ability to respond with autonomy and flexibility to shifting realities on the ground. But for this way of life to endure, herders require the freedom to move and make decisions without restrictive land use policies. As winters grow more unpredictable, the effects will continue to be felt by herders across northwest Russia—one of many ways climate change is reshaping life in the Arctic.

## Endnotes —

*This chapter has been adapted from an online StoryMap by the same authors: bit.ly/tokcha*

*It was initially inspired by a segment of the 2020 article "From spirits to conspiracy? Nomadic perceptions of climate change, pandemics and disease," by Florian M. Stammler and Aytalina Ivanova. Thanks to Andrei Golovnev for his image of herders crossing the Ob Bay. An insider's perspective of icing events on the Yamal peninsula can be found in the Nenets scholar Roza Laptander's doctoral research, "When we got reindeer, we moved to live to the tundra: The Spoken and Silenced History of the Yamal Nenets." The authors would especially like to thank Florian Stammler and Roza Laptander for their time, advice, and images. Many thanks to Tokcha and his son Andrei for their time and participation. Another of Tokcha's sons, Vladimir, graciously shared his photos with us.*

# 2.
# Amplification, Modeling, and Reanalysis

## The scientific study of rain-on-snow events in the warming Arctic

Alex Crawford, Mark Serreze, & Michelle McCrystall

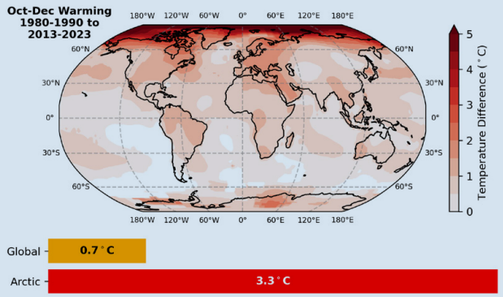
For countless generations, Indigenous peoples have thrived in the Arctic, living in harmony with the environment and the bounties of the Arctic lands and ocean. That long relationship is being threatened by climate change. The Arctic is warming much faster than the rest of the planet, a phenomenon known as **Arctic amplification**. Rainfall is becoming more common, permafrost is warming and thawing, and sea ice is declining. These physical changes have, in turn, altered the Arctic ecosystem: shrubs are expanding in the tundra, seasonal timings of plant and animal behaviors are shifting, and many species long harvested by Arctic peoples are struggling in the warming environment.

Another aspect of climate change—and the focus of the remainder of this chapter—is that as the Arctic continues to warm, what was once snowfall increasingly falls as rain. This, in turn, can lead to more rain-on-snow events. **Rain-on-snow events** can occur wherever there is seasonal snow cover; in the Arctic, snow may cover the ground for ten months of the year. Warm, heavy rains sometimes melt the snow away, which can foster flooding, especially in spring. Rain on snow is a bigger threat to reindeer (as well as populations of other ungulates, such as musk ox and caribou) when rain is followed by colder weather. This combination can lead to the formation of hard crusts and ice layers, which interfere with grazing. There have always been rain-on-snow events in the Arctic, but they seem to have become more common as the climate warms. There have been well-documented cases of starvation of tens of thousands of reindeer from rain-on-snow events, and reindeer herders are adapting to the impacts.

Rain-on-snow events typically occur when a pulse of warm, moist air from the south advances into the Arctic. This usually requires strong winds blowing from the south, and the most common place where such a setup occurs is on the east side of **extratropical cyclones**, which are large storm systems responsible for the majority of Arctic precipitation. The pattern of wind around extratropical cyclones in the Northern Hemisphere is counterclockwise, so the winds blow south to north on their east side. Sometimes, especially with stronger extratropical cyclones, that poleward flow of warm, moist air is really strong and narrow and extends all the way from the mid-latitudes into the Arctic. These currents of warm and moist air are called **atmospheric rivers**. When an atmospheric river reaches the Arctic, it brings a lot of moisture and heavy precipitation can occur. But since atmospheric rivers are also relatively warm, that precipitation is more likely to include

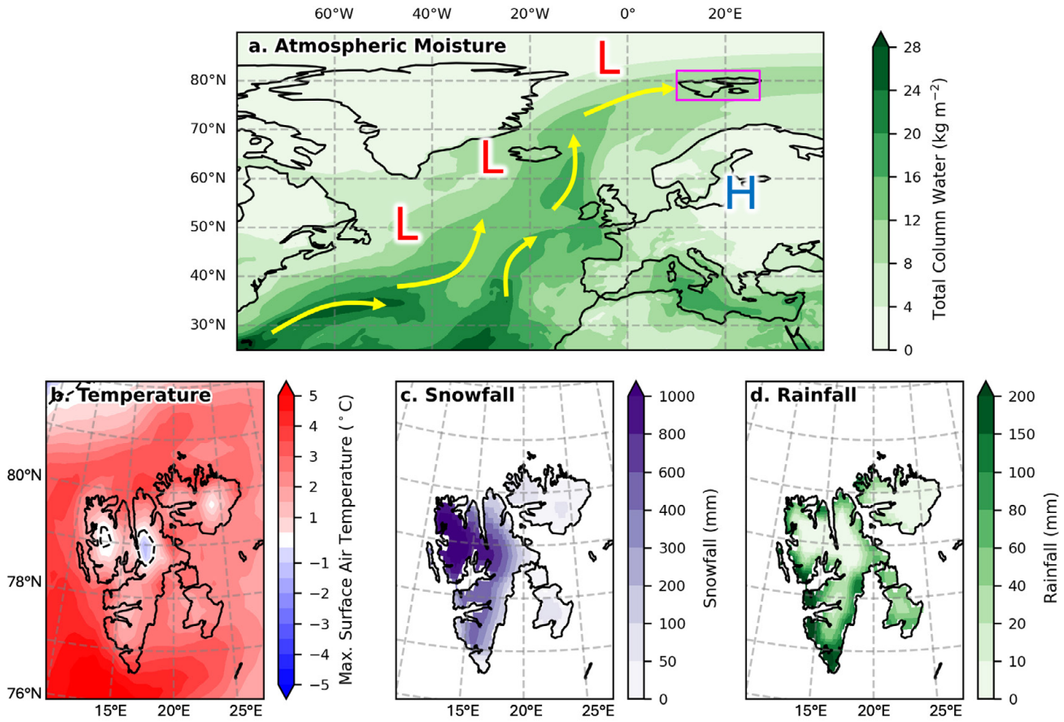


## Arctic Amplification




*Data: Lenssen et al., 2019; GISTEMP Team, 2024*

Arctic amplification refers to the fact that the Arctic is warming faster than the rest of the world. Earth is experiencing global warming, but that warming is stronger, or "amplified, in the Arctic. This phenomenon occurs throughout the whole year, but it is most obvious in October–December. In this season, the average temperature in the Arctic was 3.3°C (5.9°F) warmer in 2013–23 than in 1980–90, whereas the world as a whole warmed by only 0.7°C (1.2°F). This means the Arctic warmed over four times faster than Earth overall for the October–December period. There are several causes of Arctic amplification, but one important driver is the loss of snow and sea ice. Ice and snow (especially fresh snow) are very reflective—meaning sunlight bounces off instead of being absorbed. Sunlight can only warm up the land and ocean if it is absorbed, so as climate change causes extra snow and ice to melt in summer, more sunlight is absorbed and the Arctic experiences extra warming.




rainfall instead of only snow (as in a typical winter storm in the Arctic). Finally, on the west side of an extratropical cyclone, the winds are often blowing from higher and colder latitudes to the northwest, bringing cold, dry air that facilitates the conversion of rain-on-snow (and maybe some snowmelt) into hard lenses of ice.

An extratropical cyclone with an atmospheric river was associated with a well-documented rain-on-snow event influencing the Svalbard Archipelago during 29–31 January 2012. During this period, a series of three extratropical cyclones were positioned just east of Greenland (red Ls in the figure above). Since winds tend to blow counterclockwise around these storms, a series of three of them in a line from southwest to northeast led to a narrow region of winds blowing from the southwest on the eastern side of the extratropical cyclones (yellow arrows). During 29–31 January 2012, those warm winds from the southwest also carried a lot of moisture (indicated by darker green shading associated with the wind arrows)—an atmospheric river.

During this event, temperatures exceeded the melting point over most of Svalbard, and the atmospheric river produced record-high precipitation that was a mix of heavy snowfall and rainfall. The warmth and the rain led to substantial snowmelt and slush avalanches. A prolonged period of low temperatures that followed froze (or refroze) the

*Top figure: Atmospheric river (yellow arrows) hitting Svalbard at 00:00 UTC 30 January 2012. Each extratropical cyclone is marked by a red "L," and a higher pressure center over eastern Europe is marked by a blue "H." Darker green indicates more moisture in the atmosphere.*

*Bottom left: Maximum surface air temperature reached during 29–31 January 2012.*

*Bottom middle: Total snowfall during 29–31 January 2012.*

*Bottom right: Total rainfall during 29–31 January 2012.*

*The magenta box in the top figure indicates the region shown in the bottom row of figures.*

*Data: ERA5 (Hersbach et al., 2020) and ERA5-Land (Muñoz Sabater, 2019).*



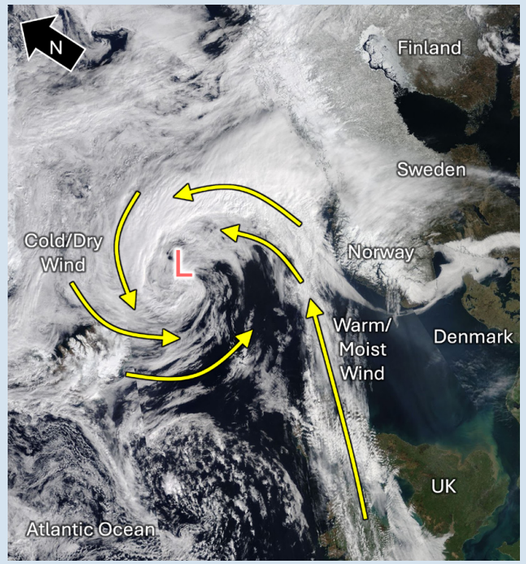
# Extratropical Cyclones & Atmospheric Rivers

"Extratropical cyclone" is a scientific term for the type of storm responsible for most of the snow and rain that falls in the Arctic. The word "extratropical" means these storms form outside of the tropics. They usually form in the mid-latitudes, although they can also form over the Arctic, especially in summer. The word "cyclone" means that if you see one of these storms in the Arctic, the winds will be blowing counterclockwise around the center of the storm. Extratropical cyclones mostly travel west to east, but many also move poleward, especially those forming over the Atlantic Ocean.

How these storms form and develop is complicated, but one important factor is strong temperature contrasts—they often form or intensify wherever cold, polar air and moist, subtropical air collide. Extratropical cyclones can be huge—over 1,000 km (621 mi) across. They typically last several days and can traverse entire continents or oceans. They sometimes have strong winds, and they usually produce substantial precipitation.

An "atmospheric river" is a narrow flow of warm, moist air that can penetrate all the way into the Arctic. When they form, atmospheric rivers usually lie on the east side of extratropical cyclones. Why? Because to penetrate into the Arctic from the mid-latitudes, air needs to be flowing roughly south to north. And because extratropical cyclones involve air circulating counterclockwise, that south to north flow occurs on the east side of extratropical cyclones. Additionally, the stronger the extratropical cyclone, the stronger the wind, and the more likely it is to produce an atmospheric river. An atmospheric river can be traded from one cyclone to another on its way to the Arctic.

Rain-on-snow events require a pulse of warm, moist air into the Arctic, so they are more likely to occur on the east side of an extratropical cyclone—especially if that cyclone is paired with an atmospheric river.




*An extratropical cyclone moves into the Arctic. Note the comma-shaped cloud pattern. Warm and moist air is being drawn poleward on the east side of the low, while colder and drier air is being drawn southward on the west side of the low. Image from NASA Moderate Resolution Imaging Spectroradiometer.*

water, creating impenetrable ice layers and reindeer starvation (Hansen et al., 2014; Serreze et al., 2015). Other events can be much more modest in terms of precipitation, but still have pronounced impacts.

Lands on the Atlantic side of the Arctic are particularly prone to rain-on-snow events that impact reindeer herding, and for two reasons. First, the poleward pulses of warm and moist air typically associated with rain-on-snow events tend to be associated with extratropical cyclones, and these systems are most common over the Atlantic region of the Arctic. These cyclones move poleward and eastward along what is known as the North Atlantic cyclone track. The second reason is that reindeer herding in the Arctic is most intensive in Norway, Finland, Sweden, and the Yamal Peninsula of Russia. This is not to say that impactful events cannot occur elsewhere, such as in Alaska where herding is also practiced, and rain-on-snow events can affect other species as well. For example, a 2003 event in the western part of Arctic Canada, was associated with the starvation of 25,000 musk ox (Putkonen et al., 2009). That said, not every rain-on-snow event will prove deadly. If the rain is light and the resulting ice layers thin, reindeer may still manage to forage. Sometimes reindeer can move (or be moved by herders) to a nearby area that is unaffected.

*Location of weather stations in North America (data from Thompson, 2022), showing the higher density of stations in the contiguous U.S. This includes all stations, including many that do not provide reliable precipitation measurements.*

Ideally, to understand the potential impacts of a rain-on-snow event on reindeer or other ungulates, we want to know how much rain fell on snow for every square centimeter of the Arctic daily. Herders can make the necessary direct observations, but they cannot check everywhere all at once. Identifying rain-on-snow events in the absence of direct human observations is challenging. The Arctic is data-sparse in terms of direct precipitation measurements from gauges. In some parts of the Arctic, there may be hundreds of kilometers between observing stations, making it hard to know what happened over large areas. Additionally, some gauges cannot measure snowfall or cannot distinguish between snow and rain. Distinguishing between snowfall and blowing snow is especially difficult for human observers, precipitation gauges, and automated sensors. Maintaining scientific-grade weather stations requires many thousands of dollars each year, so most end up being installed at airports where they have immediate practical value. For more remote places, satellites may be the only source of regular rain and snow observations, but they too have limitations. For example, satellites that sense microwave wavelengths can be used to determine if the snow surface is wet or frozen, but a wet snow surface does not necessarily mean that rain has fallen—it could just be surface melt.



# Atmospheric Reanalyses

Atmospheric reanalyses are a combination of two types of weather information: output from the numerical weather prediction models that we use to forecast future weather conditions, and historical observations from weather stations, weather balloons, ship observations, and satellites. By blending these two types of data, atmospheric reanalyses provide our best overall depiction of longterm historical weather and climate for large regions or the entire globe. There are three basic steps to the process:

Firstly, it begins with a numerical weather prediction model: a mathematical model of the atmosphere that includes physical equations for how energy, air, and moisture move through the atmosphere and interact with each other and the surface. There are equations that govern how sunlight is transmitted through the atmosphere and absorbed or reflected by the surface. There are equations that govern evaporation, cloud formation, and precipitation. There are equations that govern the wind direction and speed, including the formation of large storms like extratropical cyclones. Starting with an initial set of observations about what the atmosphere is like right now, the atmospheric model predicts how weather over the entire globe will progress over a short amount of time. The result of this simulation is a short-term weather forecast. For example, we might use the weather starting at 6:00 AM on 12 June 2005 to get a forecast for 12:00 PM on 12 June 2005.

Secondly, no forecast is perfect! Every model has simplifications, and the initial observations used may have some error. So, the next step is to compare the short-term forecast to actual observations. In our example from 12:00 PM on 12 June 2005, we might compare the temperature forecast for the city of Fairbanks, Alaska, to the actual temperature recorded at a Fairbanks weather station. Any difference between the forecast and the new observations indicates we need to apply some corrections to the forecast.

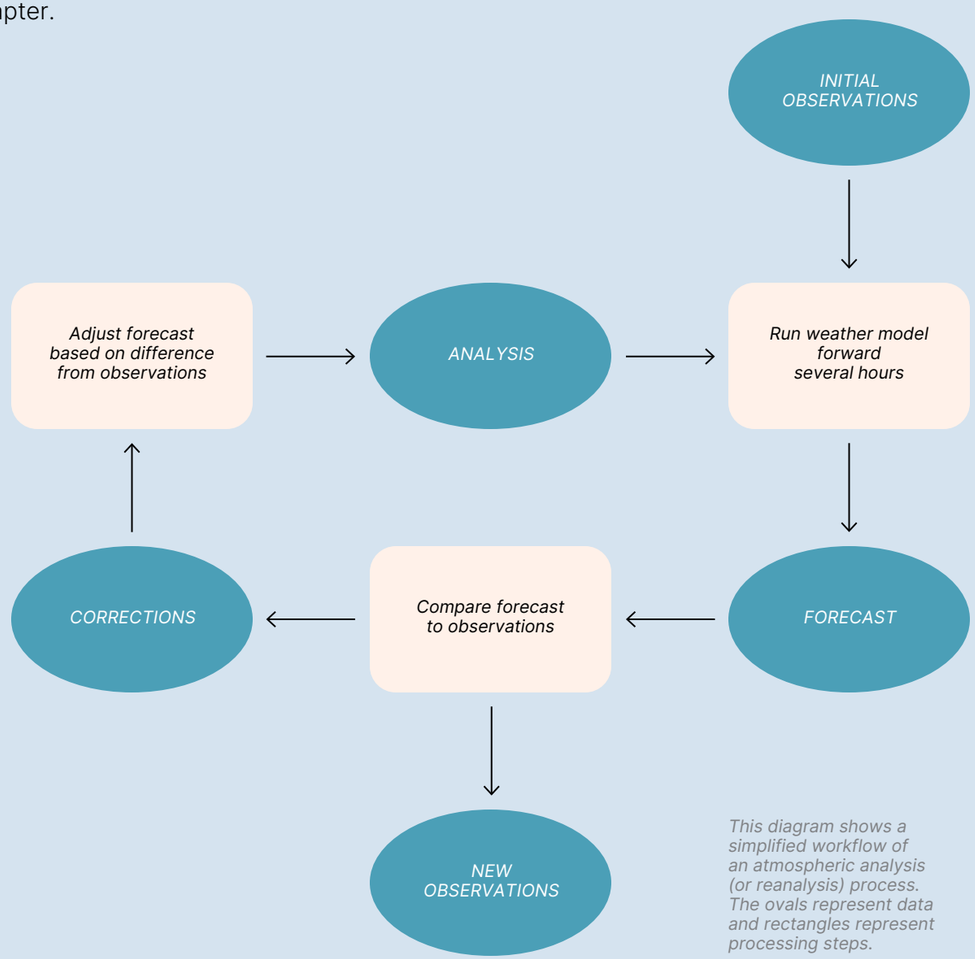
Finally, we apply these corrections to the forecast to create an "analysis." Because observations are not perfect either, and because we don't have a direct observation for any property everywhere all the time, we don't just replace the forecast with the observations. Instead, the values for temperature, humidity, etc., in the forecast are "nudged" toward the values from our set of new observations. The analysis that results is a blend of the forecast and observations—a blend of physical theories and careful measurements.

This three-step process can be repeated over and over again, with each analysis becoming the new input for the atmospheric model. When this process is done retroactively on historical data instead of real-time data, the result is called a "reanalysis"—the same process, but for a longterm historical context. This is the type of product needed for climate science, and for large-scale, longterm problems like examining global climate change, an atmospheric reanalysis is often more reliable than pure observations.

This is especially the case in the Arctic, where the observational network is more sparse and less reliable. However, their regional or global scale means that atmospheric reanalyses lack the ability to

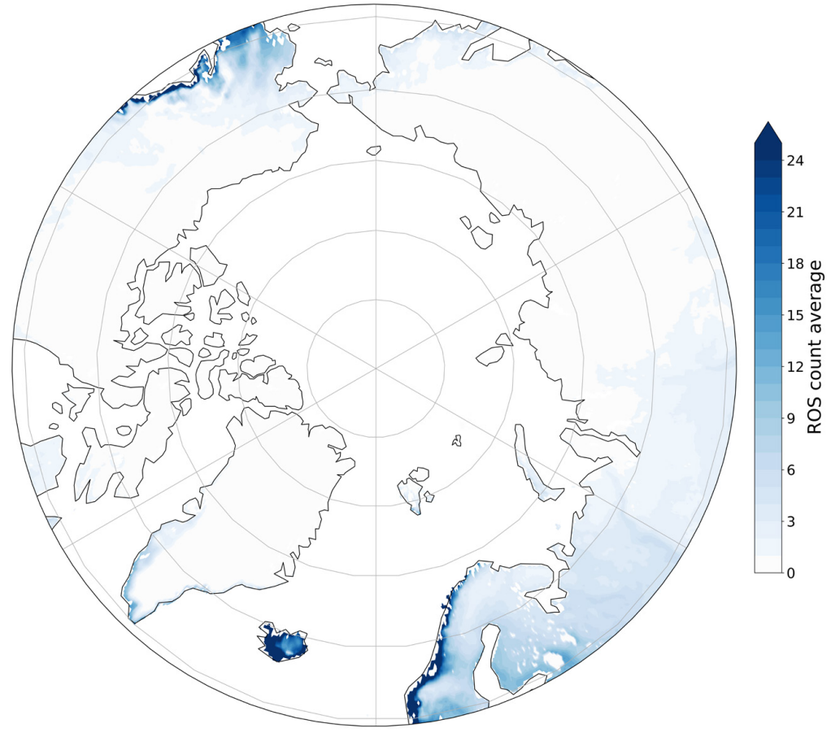
represent small-scale features like tornadoes or snowdrifts around buildings.

As you might imagine, managing the many model forecasts and observations needed for the reanalysis process requires supercomputers and lots of people managing the workflow. Therefore, atmospheric reanalyses are mostly created at large governmental science centers like the National Center for Atmospheric Research in the U.S., the Japanese Meteorological Agency, or the European Centre for Medium-Range Weather Forecasts, which produced the "ERA5" atmospheric reanalysis used in this chapter.




*This diagram shows a simplified workflow of an atmospheric analysis (or reanalysis) process. The ovals represent data and rectangles represent processing steps.*

*Number of rain-on-snow events where rainfall is greater than 1mm (0.04in) from ERA5 between 1980–2020. Data: ERA5 (Hersbach et al., 2020) and ERA5-Land (Muñoz Sabater, 2019).*




To forecast if a rain-on-snow event is coming with several days of warning, reliance is placed on numerical weather prediction models. To gain historical context (how the frequency or intensity of rain-on-snow events has varied or changed through time), scientists increasingly rely on a tool known as **atmospheric reanalyses**. These blend together output from weather prediction models and various observations to provide information on atmospheric conditions. Whereas numerical weather prediction models are useful for forecasting weather several days into the future, atmospheric reanalyses are useful for examining the long history of weather spanning many decades in the past. Reanalyses provide estimates across the Arctic of both precipitation and whether the precipitation is rain or snow. The number of rain-on-snow events October through December recorded over the past 45 years from the newest of these reanalyses reinforces what has already been discussed—they are most common over the Atlantic side of the Arctic, but can occur anywhere.

As the climate continues to warm, it is reasonable to expect that more of the Arctic's precipitation will fall as rain as opposed to snow, and it appears that this is already happening (Boisvert et al., 2023). It also appears that Arctic precipitation overall is increasing (Serreze et al., 2024). This is not surprising—warmer air can carry more water vapor, and more will be transported into the Arctic from lower latitudes.

Climate models are our most important tool for looking into the future, and, indeed, they tell us that the future will see more rain versus snow, more precipitation overall, as well as more heavy precipitation events. But there is notable uncertainty as to how big the changes will be—some models project stronger warming than others, and some project stronger increases in precipitation than others (McCrystall et al, 2021).

There is another twist to consider. As the climate warms further, snow will accumulate on the surface later in autumn and melt away earlier in spring, meaning that rain on snow will transition to rain on bare ground. Herders and researchers will need to adjust their methods of observing and predicting the impacts of changes in precipitation and ground cover to ensure the success of the livelihood in the future.

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*Eider ducks flying over the Chukchi Coast in Spring at Utqiaġvik, Alaska. Photo by Matthew Druckenmiller.*

*Fall calf marking in Naltio, Finland. GPS collars are a technology increasingly used by herders across Fennoscandia. Photo by Irina Wang.*

# 3.
# One Year is Not Like Another

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## Stories of continuity and change from reindeer herders in Finland

Philip Burgess with Juhani Lakela, Juhán-Tuommá Magga, Karoliina Majuri, Sunna Siilasjoki

There is an expression in the North Sámi and Finnish languages that goes *Jahki ii leat šat jagi viellja / Vuodet eivät ole veljeksiä* (“one year is not another’s brother”), meaning that no two years are ever the same. This simple expression puts variability at the heart of people’s understanding of their local climatic conditions. Reindeer herding is an example of an Arctic traditional livelihood that has developed and adapted over centuries to significant seasonal changes in which people and reindeer occupy ecological niches that are linked to extensive seasonal land use.

Empires, kingdoms, and nations have been built and faded away. Wars have been hot and cold. Borders have been created, moved, and fenced. All the while, reindeer herding has endured as a singular but diverse family-based livelihood. Today, a rapidly warming Arctic is resulting in seismic changes at multiple levels, many not yet fully understood. Winters are warmer and wetter. Summers are hotter. Extreme weather events are more commonplace. Shifts and variations in the timing of seasons have become pronounced.

# Reindeer Herding in Finland

* The reindeer herding area in Finland covers 122,936 km$^2$ (47,466 mi$^2$) or around 36% of the whole country. There are around 200,000 reindeer in this area.

* This area shares about 2,000 km (1,243 mi) of national borders with Norway, Sweden, and Russia.

* In 1898, the state ordered reindeer owners to establish herding cooperatives with geographic boundaries. Each reindeer owner belongs to one cooperative. There are 57 cooperatives (see next spread). One person may own up to 500 reindeer. There are around 4,400 reindeer owners in Finland, 40% of whom are women.

* Reindeer are allowed to graze freely in this area regardless of land ownership. The rights and responsibilities related to reindeer husbandry are set in the Finnish Reindeer Husbandry Act.

* In Finland, reindeer may only be owned by citizens of the European Economic Area who have a permanent residence in the reindeer husbandry area. Most herders in Finland are Finnish, with Sámi herders making up a majority of herders only in the northernmost cooperatives. In contrast, in Norway and Sweden, only Sámi people are allowed to own reindeer. Sámi are an Indigenous people whose traditional homeland is referred to as Sápmi and covers parts of Norway, Sweden, Finland, and northwest Russia.

* Each reindeer owner has their own unique "earmark." These are notches cut by hand into their animals' ears. There are around 12,000 individual earmarks currently in use in Finland alone.

The tactical use of seasonality and landscapes has always been the bedrock of reindeer husbandry, so changes bring challenges.

Reindeer herders are used to bad weather—indeed, most of the time they might not call it "bad," but recent changes are dramatic. Changed winter conditions have upended many of the seasonal rhythms that bind herders to their reindeer, and this is coupled with broader land use issues impacting all those who practice traditional livelihoods like herding, fishing, and hunting. Winter has long been called a "choke point" in the reindeer herding system, a difficulty that is often marked by the autumn and summer that preceded it. In 1910, the renowned Sámi herder, author, and artist, Johan Turi, wrote:

> *But early snow in the fall is very dangerous. This is a time of contending weather: the cold battles against the warmth, and each in its turn wins for a while and so, in this way, the thaw comes as well. Then poor pasture conditions result, with icy ground, which is bad. And when there is such ground ice, the conditions are poor, even if the snow cover is light.*[1]

In winter, food is scarcer and working conditions for herders can be hazardous. Reindeer can lose up to 20% of their body weight; it is the period when the limits imposed by the season come up against the needs of reindeer and the people who herd them. Also, predators—such as lynx, wolverines, bears, wolves, and eagles—are especially active in winter and spring.

Herders have adapted, incorporating land use strategies, technological aids, and supplemental feeding. However, the freedom to move their animals in the landscape has been increasingly constricted as pastures have been nibbled away by other land uses such as mining, logging, hydro- and wind power, tourism activities, and piecemeal development—a road here, a summer cabin there. Combine these elements and a difficult winter can become something much worse.

A "bad winter" will mean that female reindeer will enter the spring calving season in poor condition, reducing herd viability. In Finland, herders are typically on their own regarding the purchase of supplemental feed. In northwest Russia, where supplemental feeding is generally not practiced nor feasible, winter rains have caused the deaths of tens of thousands of reindeer, and eviscerated the livelihood for some herders.

A poor winter in 2019/20 across Finland, Sweden, and Norway led directly to reindeer starvation, increased calf mortality, and ultimately reduced income to herders. That winter, emergency compensation for supplemental feed in Finland was introduced by the state for the first time, but it was difficult to access. Feeding concentrated pellets and hay to reindeer as an emergency solution to crisis years has, in much of Finland, become the norm.[2] Initially, this was due to the fact that extensive logging removed a key component of the reindeer's winter pantry: arboreal lichens. In recent years, more frequent winter rains and icing have added yet another reason to adopt this costly practice.

Icing events can lock reindeer out from their pastures or rot the ground lichen. Both can be deadly. When reindeer can't dig through ice layers, they scatter, searching out the lichens that their highly adapted digestive systems can use during winter. Hotter summers are also a challenge for cold-adapted reindeer. Insect harassment, new parasites, and infectious diseases are all predicted to intensify. Herders are already seeing different species of insects, plants, and animals in their pastures. In addition, herders across Fennoscandia operate within a highly mechanized and integrated market system, enduring rapid increases in costs for fuel and supplies created by the COVID-19 pandemic and the war in Ukraine.

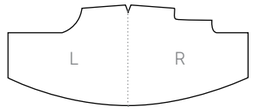

*Reindeer herding districts in Finland, with those featured in this chapter highlighted.*

Traditional herding practices may no longer be able to adapt to the speed of these changes. For some areas, tipping points are being reached and critical seasons such as spring and winter are expanding. However, despite all these challenges, herders are resilient and are used to thinking on their feet. A new generation of herders are finding ways to maintain their connection to a livelihood they cannot imagine leaving, despite the sacrifices it entails. Herding is a way of life that is linked to the reindeer, the seasons, and the land.

It's tempting to think of reindeer herding as a monolith. However, even within the same country and regulatory framework, there are multiple landscapes in which herders need to take different approaches to adapt and adjust their day-to-day operations. In Finland, some work full-time as herders, while some take part-time salaried jobs or seasonal work with tourists to make ends meet. Some are also farmers. Most but not all give supplemental feed to their reindeer so they survive winter. Reindeer have proven themselves hardy adapters; however, they need time and space to adjust to this climate future—and now they have neither.

In the summer of 2024, we met with four herders across Finland who have adapted in different ways to the climate shifts, land use challenges, and economic realities of their districts. Their herding environments are very different, from old growth forests to heavily logged landscapes, from tundra to swamp. Their seasons arrive at different times and each district has its own characteristics.






*Above: Juhani Lakela at the autumn roundup. Photo by Philip Burgess.*

*Below: Juhani's earmark.*

JUHANI LAKELA pores over a map of his district. On the one hand, his district is fortunate in that their winter reindeer pastures are partly included in one of Finland's most beloved national parks, filled with old growth forests and arboreal lichens, an important food source for reindeer in winter. To the east lies the border with Russia. However, their winter pastures will be bisected and rendered functionally useless should an open pit phosphate and rare earth mineral mine be approved. The project has waxed and waned over the last two decades, casting a long shadow over traditional land users. Juhani takes his sons out to feed a mixture of pellets, hay, and dried lake grasses to a small herd of pregnant female reindeer kept close by their house that his grandparents built. Most of his district's reindeer are left to fend for themselves in the forest all winter. A few GPS collars are showing red on his smartphone app. Dead reindeer? Dead battery? Hard to say. Another item for the "to do" list. His youngest son is especially interested in the livelihood, as he himself was at that age when he was mentored by his grandfather. Asides from herding, he also runs a tourism business in the winter months near the busy regional capital of Rovaniemi where he takes tourists who have come to see Santa Claus on a reindeer-pulled sleigh. It's exhausting work, in a different way, and 2023/24 was a record winter for tourists. Even for a gregarious natural talker it's tiring, but he regains his balance back in the forest with his herd.

**ON BEING A REINDEER HERDER**

I always wanted to be a reindeer herder. My parents usually tell the story that once I finished first grade, I said, "Okay, now I can read and count. So I can start to be a reindeer herder." My grandfather was my mentor. He was an old-time storyteller, telling stories about reindeer herding and what's happened in the forest and how people used to manage here. From those stories, I built my reindeer herding image and world. It's such a unique culture that you kind of grow into. It's a demanding job, but it's also quite free in that you don't have timetables. You don't have to obey the calendar, you just check the weather and nature gives you a timetable. So I always liked that. In school, I hated that I had schedules and timetables.

A reindeer herder knows their herd. You bond with the reindeer. You recognize them, even though they are spending all year in the forest. But when you see them at the round-up time, you remember that animal and what kind of calf she had.

**ON FORESTRY**

Logging has been so heavy in some of our areas. And it's also affecting the reindeer's natural cycle. Where there is more logging, there's not that much food anymore so they naturally go to another area to look for it. It's not always that they cut the trees that is the worst thing; the worst is that they turn the soil over and then there is nothing [for the reindeer] to eat.

**ON DIFFICULT WINTERS**

I actually bought [GPS collars] for all my females and nowadays they're really useful as there are so many predators. When bad winters came, some reindeer died because of the deep snow or when mold grew on the

ground lichens due to early winter rains. So I wanted to start checking more on my animals—and if there are red dots, then I can find a dead animal and see what has happened.

[2019] was a bad winter and because we don't bring supplementary food to the reindeer when they are in the forest, the damage was already done. It's logistics—we are in a big district and feeding would have saved a lot of reindeer, but it was too late to organize anything and you have to be very careful if you start feeding reindeer that are in bad condition because you can kill them with too much food. It takes a couple of weeks for reindeer to adjust to this food.

We just had to make tracks with our snowmobiles so reindeer could move more easily to the spruce forests where there were beard lichens. This happened after the separations, which meant that the reindeer had already been released—so this was our only option, as we did not want to bring feed into the forest. Reindeer even moved outside our district, even though we have fences but they found a way through. Some even got as far as Salla [over 150 km (93 mi) away]! Some never came back, we lost a lot of reindeer that year. Winters since then have been mostly okay, but in May [2024] it has been cold with wet snow—and that is very risky for newborn calves, as they may freeze and die.

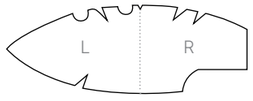
## ON PREDATORS

A lot of predators come from Russia, especially wolves. In late winter when the snow begins to get soft, reindeer are slower in the forest, and wolverines like this. They ripped the eyes out of many reindeer. We also have to deal with lynx close to the Russian border; they tend to stay in the deep valleys where it's more difficult for people to reach. This winter we probably lost 300 reindeer in the border area to predators. This was a record high, and the problem is that we cannot find them all, so the number is probably higher. Without a carcass, there is no [financial] compensation. With a carcass, you have evidence of how the reindeer was killed. When those wolves were around last winter, eight of my female reindeer never came home and I never found their bodies, so that was a big personal loss.

## ON LAND USE PRESSURES

Oh this mine, we wish it would just go away. It is a nightmare that never seems to end. It has been going on since the 1970s. Even though we have won various legal cases, they are still test-drilling and the state has taken it over and is promoting it. We need a permanent solution to this. If it goes ahead, it will be a catastrophe for our reindeer, our district. It would disrupt the natural pasture rotation completely; there would be noise, dust, and all kinds of disruption. We also have to deal with a big windpower development. Over 200 windmills have been proposed in our district, and the construction of the power lines and infrastructure will be a big problem; it's crazy they want to put those kinds of things in a wilderness area.

*Juhani and his sons feeding female reindeer beside their home. Photos by Philip Burgess.*




*Above: Sunna Siilasjoki. Photo by Philip Burgess.*

*Below: Sunna's earmark.*

SUNNA SIILASJOKI checks her phone and yawns. She has just finished a five-day stint at a large gold mine on the other side of Finnish Lapland where she works a summer job as an electrician. Most of that work is underground, and the payoff is not only financial, but it gives her more time off with her beloved reindeer. Winter conditions in her *siida*[3] have been poor. For over a decade, there has been frequent icing, poor winter pastures, and many predators, which has meant that her extended family have had to move their large herd close to the family homestead where they can feed them concentrated pellets and hay to ensure their winter survival—between 70–100 tons a year, which they pay out of their own pocket. To the south lies the Swedish border, to the north, the border with Norway, but being in the core Sámi area, she has an extended family network which predates these national borders. This winter, geopolitical tensions made an appearance, as Finland's accession to NATO meant major military exercises were held in their district which forced some to round up their animals early. For up to three winter months, she meets with family members to do the feeding rounds each morning. It is mid-May, reindeer calves are being born, a time of hope and a turning point in the herders' year. In the North Sámi language, this month is even called "Reindeer calf month," *Miessemannu*. Winter is over, new calves need to stand and move quickly. Soon the reindeer will be let free and the mosquitoes will herd them northwards as the snow melts. The reindeer know where to go. Still, new GPS technologies are helpful.

**ON BEING A REINDEER HERDER**

I always wanted to work with reindeer. I used to hear "Girls shouldn't be reindeer herders," but I thought that even if I am a girl, I can do this. Sometimes I have to prove so much more than others, and of course I had to first show my father that I can actually do it. He and my aunt were the hardest to convince—it's always the family that is hardest! I knew I'd got there when my aunt said to me, "Sunna, do you want this reindeer?" I said, "What do you mean?" And she said, "You can take this reindeer. I give this one to you." That was special, because I really had to work to get anything. I was always being tested. It is not an easy choice, because as a reindeer herder, you cannot know what kind of year is coming, whether the reindeer will survive or not. And it costs a lot of money, because you have to buy the feed. It's hardly possible in this district to make a living only from reindeer herding. To do that you would need thousands of reindeer, but the pastures might not support that many. To have that many, you would also need to have a strict summer and winter pasture rotation, but we don't have that in our district. Reindeer herding is a lifestyle. I have often wondered about what I would do if I wasn't reindeer herding, but as a herder there is always something you need to do. You never get bored.

**ON COST OF LIVING**

It was my goal to get an education that would pay well, because you need a lot of money to do this, you need snowmobiles and ATVs. There are some subsidies, but it's not a lot. The prices of everything are going up, the taxes are high, and the pandemic made all the prices go up—especially reindeer pellets and the cost of fuel. The price of fertilizer that we used to grow hay went up too. We used to get two harvests of hay from our own fields, but now without fertilizer we only get one.

**ON DIFFICULT WINTERS**

We started [supplemental] feeding in winter around 13 years ago, and about seven to ten years ago we stopped using the border area in the north as a winter pasture, as we were losing so many reindeer. In the early days, we tried to feed them up in the mountains, but it was very difficult, and costly in time and money. One year we tried using hay, but it was bad hay and not good for the reindeer. Or there was lichen for reindeer to feed on, but the snow conditions were bad, and the surface was frozen. There was no food from the trees. We started to think that it would be better to bring them back down south, to a safer place with more shelter, food, and trees. At first this change was difficult, I remember thinking, "Oh why are we changing things?" But once we started it, we saw that this was the best decision we could make. It is so much better for the reindeer. We try to hold off feeding them for as long as possible, and only if and when they need it. A lot depends on the snow conditions.

**ON PREDATORS**

One winter it was terrible; there were so many wolverines. We were close to losing all of our reindeer. [The authorities] didn't believe us when we told them, so they came to check it out and they kept finding more and more, and were digging up reindeer heads that the wolverines had buried. When we survived that year, we also thought that it was time to move the reindeer down here for winter. There are still wolverines around, but they don't come close to our home.

**ON RELATIONS WITH FINNS**

In Finland, the state really doesn't like reindeer herding at all and people seem to think, "Oh the state is always paying reindeer herders for something," and people get angry about it. When I was in history class, they never taught us about the Sámi people and our history—how bad it was and how poorly Sámi people were treated in the past. Thankfully, you can now learn Sámi in school and there are Sámi teachers; it's really important. Of course, I have experienced negative stuff too, but usually people are asking, "Sámi people? What are Sámi people?" And that's cool. Usually when I wear a *gákti*[4] people are like "Oooh, can I take a picture?" Often they only ask silly questions, especially: "How many reindeer do you have?" I have to explain, well, you can't really ask that!

**ON WORKING IN A MINE**

I had to think a lot about going to work in a mine. A big issue is the lack of other economic opportunities in this area, but it makes me feel guilty sometimes. My aunt helped me understand that this is a systemic issue, not a personal one. But still, I see reindeer on pastures near the mine and I think "These could be my reindeer" so it kind of feels wrong. But I feel I don't have any choice. There are a lot of jobs there, and they pay well. There is work on the Swedish side too, but that would also be in a mine. It's dark and wet work. I don't really think about where I am; I just work. For other options, I would have to leave home and I would be really far away from my reindeer. I could do something else, but then all this training and work would have been for nothing.

**ON CALF MARKING & FAMILY**

The best part of the job is that I get five days off—not just the weekend—so then I get to spend more time with the reindeer. When it is calf-marking time, you need a lot of people. We all gather up, we work with reindeer, and we are all so happy! It is the best part of summer. We get to be with the family; we see all our relatives.

**ON THE BEST OF HERDING**

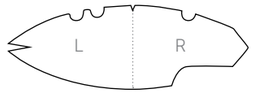
It's the traditions. When my grandmother was alive, she told a lot of stories about how things were done before. And when you are a child, they tell you all the scary stories, about how you need to be careful, about how to behave around the fire. Being part of a [herding] family is such a big thing, there is so much to know and look after—you need to know the earmarks, there is the *duodji*[5] that you make from reindeer, there is the food. All this tradition that belongs to Sámi culture; these things that you make with the family. Everything starts with the family. You don't do these things alone; you make them with the family and you do it all together. And even if you are very old, you can do something. Everyone belongs to it. There is always everyone together doing things. It doesn't matter if you are old or young or big or small.

**ON BEING GRATEFUL**

I feel like I am a really lucky person to be born into this culture with reindeer, and that I was born at this time when I can still do this, as I worry that in the future there may not be reindeer herding anymore. I'm really lucky that I have had this chance. I hope that one day if I have kids, I would like them to be able to go into reindeer herding too. But I am not sure if that is possible, what with climate change and everything else that makes reindeer herding difficult.

I have seen so much change already since I was little, so I don't know if it will get worse or better in the future. But I think that reindeer herding will have to change for the future, maybe not all the old traditions can stay. So much has changed even in my 22 years!

*Sunna prepares pellets to feed her family's herd. Photo by Philip Burgess.*




*Above: Karoliina Majuri at her autumn roundup in southern Lapland. Photo by Philip Burgess.*

*Below: Karoliina's earmark.*

KAROLIINA MAJURI sighs when she sees the phone number calling. It's early May 2024, the herd is finally out of the corral, the pellet and hay feeding has ceased, and they are grazing on their own in the forest. She hopes not to see them back here until the first snows of October or November. But now, a local farmer is calling to complain that some of her reindeer are in their field munching on tasty new shoots. Her dog is happy though; it means a trip in the car and a chance to chase and bark at reindeer, something not allowed at home. Karoliina's district is in the south of Finnish Lapland, where old growth forests were logged many decades ago and feeding reindeer in winter became the norm over 15 years ago. She will collect these errant reindeer, and then get back to her farm where she juggles not only being a reindeer herder, but also a farmer and a part time job at the Lapland University of Applied Sciences. Her current project? Redesigning Lapland's 18 reindeer slaughterhouses so that they are better equipped to make use of the byproducts of a modern meat production system. Byproducts like blood, intestines, skins, and tendons can be saved to increase local profitability. Karoliina is unusual in that she entered this livelihood without a direct family connection to it, but she passionately believes that reindeer are essential for places like Lapland, where they provide a sustainable food source in marginal areas.

**ON BEING A REINDEER HERDER**

Although I grew up in Rovaniemi, my farming life began out of a love for animals and my desire to live an ecological life. I started working with a rare breed of Finnish cows, about which I learned from my ex-partner in southern Finland. On moving back north to Lapland, I looked for a farm for a long time and after knocking on a lot of doors (this was before the internet), I finally found one. Of course, that was only the beginning, even though it was cheap. I was a single mother at the time, and I really wanted to prove to myself and everyone else that I could do everything myself.

I didn't have very much money, certainly not to buy big barns and machines and I had studied a little about reindeer in college in Rovaniemi, and I always thought that they were the perfect animal for Lapland, so I decided I wanted to get my own, but it is not so easy. Finally, I found an older herder who was willing to sell an earmark, and so I started with three older females in 2004.

Maybe it also helped that I was not from this area. Of course, I think it would sometimes be easier if I was a man; people would be more accepting, especially back then. But there are other pressures on the young boys here too, from their families, who want their sons to take over things. That dynamic between fathers and sons, and sons feeling they must prove things and do things in their way. I didn't have that, and many of the older herders were really happy to have someone who was eager to listen and learn. And I was so hungry for knowledge.

Being a reindeer herder is hard of course, and there are many times when I despair. But it has a superpower in a way that farming does not. If you are

a farmer, you really must deal with a lot of these problems at home alone, worrying about the cost of everything, and the lack of money in your bank account. But I can call my herding friends, who have been at this a long time, and they tell me "Oh spring is coming," or "It has been a good winter," so that you don't feel you have to bear this alone.

"Reindeer herding is still about people. Our biggest power as reindeer herders is that we have to do things together."

Now I am older, and I look back and think I must have been crazy to start this on my own. In our district, there are many young people that have started with reindeer herding and they want it to continue, and this is so good. In some ways it is even harder now, because the district has reached its maximum number of reindeer. This is a problem, and not one that I had when I started. Each district is a bit different though—in my district, I am the only woman who is slaughtering and butchering the reindeer, and also the only one that does earmarking. Some men even think that is something a woman should not do. But I don't pay any attention to that. You can't live your life thinking and worrying about what others think. I get my strength and support from my friends.

People are leaving farming, but there are more people that want to herd reindeer. And I think this is good. To herd reindeer, we need all kinds of herders—the ones that do it a lot, and can really work at it, and answer the call to fix a fence, remove an animal from someone's farm. But then we need the people that are not doing this all the time too, because at round-up and separation times, we need lots of people.

I lost so many reindeer calves in the early years. If I bought ten of them, maybe five came back. Now the herd knows where to go. Those days we did not have GPS collars or phone apps. I had a paper map and an old Toyota Corolla with a trailer that someone made for me that could carry a few reindeer. Now I can check my phone, and I can see where many of my reindeer are right away.

**ON FORESTRY**

Our district looks big, but we need every square meter! Logging can happen everywhere and anywhere. Here, all the forestry is privately owned. Although they are supposed to consult with other land users like us, in practice they don't. Forestry has changed the landscape so much; it has completely altered the memories of reindeer about how they use the landscape. We have some areas that reindeer have not used for nearly eight years, because logging has changed it so much. We lose many areas in this way.



The way the forests are here now, there is nothing for the reindeer to eat in winter in most of our district. If we left them out there, most of them would die. There is a tiny bit of old growth forest left, and maybe if reindeer found [hanging lichen] some might survive, but most would starve.

**ON REINDEER AS ETHICAL FOOD**

I don't like to think of reindeer herding as either a traditional livelihood or as a hobby. For me, it is neither. I want people to think of the reindeer herding here as an ethical and ecological way to produce food, and we should think of it as this kind of small business, an economic practice that you can make a living from and produce good food locally.

We need reindeer in Lapland. They are a source of ecological and ethical food production. This is the real green economy. But I feel that the state sees Lapland more as a kind of space for the "green revolution," for mines and for wind power[6]—a place for resource extraction, not for small time herding and farming. But in a world that is so crowded, we need these kinds of food producers. We really need to shift our consumption habits and not think that we can just take more and more, consuming more and more products and thinking that we will have a technological fix that will solve everything.

**ON DIFFICULT WINTERS**

Warmer winters are not affecting herds in this region in the way of icing of winter pastures, because we feed the reindeer in the corral. Warmer winters worry me in other ways. Reindeer need clean snow so that they don't get thirsty. Without clean snow in the corral, reindeer will get sick. Sometimes I even have to bring fresh snow into the corral with a tractor. Reindeer do not do well in crowded corrals; they are very sensitive to bacteria and parasites. In nature they are really well adapted to this, as they are always eating and moving a little all the time; it is a natural way to avoid infection and the buildup of parasites like necrobacillosis.

I worry that here in the south of Lapland, we are a sign of what is coming to the rest of the reindeer herding area, and with these warmer winters there comes a decrease in reindeer health. This last winter was very cold for a long spell, and for the first time in many years, I did not have to use antibiotics on the reindeer. But most winters, I must treat them for the many infections that they pick up in the corral. I really want to get them out of the corral as soon as I can. I open the gate in March as soon as the weather warms again, and the reindeer start to move out.

**ON FEEDING REINDEER**

People started feeding reindeer already a little in the 1970s, and by the 1980s and early 90s everyone was feeding their reindeer in corrals close to their homes. I feed reindeer for about 120 days a year—starting in December, depending on the snow. Once the snow comes and it gets harder for the reindeer to feed on the natural pastures, they come back home. They are so accustomed now. In some ways, it is good because the reindeer will go to where they know there is food, so if your reindeer are not back you just need to call around to some of the other herders and check. Feeding reindeer has become the norm here. We have local solutions—I have 20 hectares of fields where I produce hay for my cows and reindeer, making

## ON IMPACT TO THE LAND

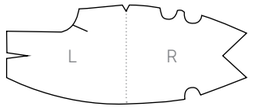
two harvests a year. To make two harvests a year, you need to add fertilizers and this is an ecological and cost issue too. We want to combine feeding reindeer hay and pellets. The pellets cost thousands of Euros a year and there is no support from the state for this. If we were to grow only natural grasses and flowers in the field, the reindeer would be much happier eating this, but then we could only make one harvest a year. So we have to make choices. Often it is hard to get enough hay, and at least if you make your own hay, you know what [nutrients are] in there. Feeding needs a lot of special knowledge too, and we have learned a lot over time. Some hay might fill a reindeer up, but is so low in energy and calories that they actually starve with a full belly.

I think that we humans are the biggest threat to the landscape. We make such huge changes to the landscape, we fill the landscape with hazards—ditches that reindeer calves fall into, plastic all over the place, old buildings that reindeer get trapped in, fishing nets that get tangled in their antlers. And then there are the other challenges. There are predators, sure—like bears in the spring, some wolves—but a bigger problem here is the illegal hunting of reindeer. Predators are an important part of our biological diversity, and we have to live with them. Cars hit reindeer or hunting dogs chase them. Those dogs are so strong and fit and can easily outrun and kill a reindeer. There are always those who really don't like reindeer, or reindeer herders; it is like a deep and ancient dislike of them. These are all things that I can't control.

My farm is not so big, and it's not so big a business that I would say that I'm very rich. But there is no money that can buy happiness, and the feeling to think that I have done it myself—I have learned it all by myself. You can't buy that feeling. Like many herders say, it is so great to be your own boss and be out on the land. There are so many other interest groups that now want to use these lands, so it is really important that young herders get the education they need so that they can negotiate and deal with these companies that want to operate on their reindeer pastures.




*Numbered neck collars are used at many calf marking roundups in the fall. Photos on this spread by Philip Burgess.*




*Above: Juhán-Tuommá Magga. Photo supplied by Juhán-Tuommá Magga.*

*Below: Juhán-Tuommá's earmark.*

**JUHÁN-TUOMMÁ MAGGA drives his snowmobile out to the herd again in the northwest corner of Finland, tucked up beside the border with Norway, marked only by a long reindeer fence. Reindeer find a way through it if they are hungry enough. Juhán-Tuommá is a young Sámi herder and it's been an exhausting winter with little sleep and constant worry. It's been tough across much of the reindeer herding area in Finland. Lots of icing, snow, and wind has meant many hungry reindeer and as food becomes scarce, reindeer scatter and predators including wolverines, lynx, and eagles are never far away. Juhán-Tuommá is one of the few in Finland that is trying to make a living from herding full time, without the security blanket of a paying job to help him through leaner times. Although he trained as an economist, the herd called him back and he has no regrets. Feeding reindeer pellets and hay is an adaptation that most herders in Finland have already made. Juhán-Tuommá's *siida* is one of the exceptions, but this has not been an easy choice; it was one for which they felt the price was too high in terms of the relationship with their animals and how they used the land. Spring is coming, the coming year might be better.**

## ON BEING A REINDEER HERDER

I was always thinking that I will be a reindeer herder. My parents both said that you have time and you can come back and start herding later, as it's important to also go see the world and study something so that you have something else if things don't work out. But I felt like it was the only work I liked; I felt that I was made for herding. I studied economics and I had some summer jobs, but sitting in an office, it's not for me. I like to go outside and be more practical. And I didn't like to live in any other place than my home. So in all my free time, I was helping out with reindeer and driving around the mountains with my father. Both my parents really influenced me, and with my father, we have a really good connection. He is the biggest reason why I am who I am. I have learned so much from him.

And now I can put more value on reindeer herding, as I know how life is not so easy in other places either. My earliest memories are from calf marking at our place in Gálggojávri. I liked walking the paths all around the corral and playing with my cousins. But little by little, I started to be more interested in reindeer work. Throwing a lasso was a fun activity. Then I started to notice that I can see the earmarks on reindeer. I think the most important part for me is the community, our *siida*. You learn the livelihood this way, you don't even think that you are at work. It's like your life there. When we have our summer calf markings, I think it's the happiest time of my life. It's like living in some kind of Sámi utopia.

## ON RELATING TO REINDEER & THE LAND

It's hard to describe, but you always think about the reindeer and how they are, even when you are not with them; it's like your whole life is for taking care that they have good conditions. So, it's not just that you own them; it's like you have a responsibility to take care of them. I don't like to think that they have to produce more and more calves. Of course, it's good to have, but more important for me is that they are in good shape, that there's enough pastures for them.



## ON FEEDING REINDEER

What's important for our *siida* is that we don't want to start feeding them. So there has to be the amount of reindeer that nature can handle so you don't only take care of the reindeer, but also the land. I got reindeer from my father, but also the land came from my ancestors. They took care of the land so that I can continue.

If we start feeding the reindeer, the skills and knowledge we have now will not work anymore. We will not know how they behave or where they will go. Their behavior will be so different; how they use the land and pastures will change. We have always thought this way. Some might say that we are old-fashioned or something like that. But I think everything doesn't need to change. I think the land also needs time to rest. If you always feed them and keep the same amount of animals, the land won't ever rest.

## ON DIFFICULT WINTERS

The winter [of 2019/20] started out okay; you couldn't see that it was going to go bad. But after Christmas, the temperatures were not very low. For like two months, only snowing and hard winds—and the snow became packed hard. The reindeer kept moving north, often to the Norwegian side of the border, looking for food. Even the border fence was under snow[drifts]; it was horrible. In February, they started to die of hunger. I would just find them dead. All we could do was try and guide them to areas with birch trees where there was some lichen, but often there were other herds there and you don't want them to get mixed together. Herders from the south of our district—where they feed reindeer—were also letting their reindeer move north. At the time, you didn't have time to think about what was happening, you just had to accept that you couldn't save all the animals. Our neighboring *siida* tried to feed the reindeer, but it didn't help as they were in such bad shape already. It was not a problem with our pastures; it was this hard snow that was the problem. It was also hard to take because it was soon after I had become a full-time herder, so it wasn't a good start! It was a lot of work for us; we had to stay up in the mountains and three of us did two-hour shifts for many weeks. After two hours, the reindeer were already starting to move again. It really felt hopeless. What stopped me losing hope was my father and other older herders who kept saying that this is nothing new—that sometimes this happens, you just have to keep going. My father remembered very bad winters in the 1990s. But still, it was not until the calf marking in the summer—when I saw that we had not lost everything—that I relaxed. Since then, there have been very good winters. Not feeding the reindeer was the right decision, even though we never received any compensation from the state for our losses that year.[7]

One thing we learned from that bad winter was that we need to organize our work better. In this way, no one is left alone with the work without knowing when they will get a break. With better organization, you can manage without much sleep because you know someone else is coming. We are not many [in our district], only nine or ten full-time herders.

## ON LAND USE PRESSURES

Our herding area does not have any operating mines or wind power developments yet. There have been some test drilling and mining claims in a neighboring *siida*. A wind power project has been proposed in the south of

our district. These activities are getting closer. So we have to be ready for this. A bigger challenge at the moment is people coming to hunt [for birds] with dogs, and this means there are some areas where the reindeer don't go anymore because of the dogs.

**ON KNOWLEDGE & NEW TECH**

You have to use Traditional Knowledge and skills that you have, so you can adapt and use them in different situations. So you know where to go and what to do with your reindeer in whatever conditions there are.

"We Sámi herders have great skills in this kind of adaptation—because we live with constant change."

But at the same time not everything is changing. We still work with reindeer, and their needs do not change. Much remains as it was. I like that not everything has to change. But you still need to know the behavior of the animals. You need to follow them, follow how their shape changes over time, and follow the weather. The reindeer help us too, if you pay attention. They know a few days in advance if the wind is going to change direction. They can predict storms.

We do have many new tools and machines that make our work easier, but this also means that skills can be lost as we don't spend as much time with the reindeer anymore. These GPS collars are one of the best inventions. They really give you peace of mind about where your reindeer are. Of course, you still need to check, but at least you don't have to stress and worry all the time. We have started using drones a lot too—especially in the autumn when we need to gather them, and also if they are in areas that they should not be. I can attach a light and a siren to my drone and use it to move them to another area. Some herders even use the sound of a dog barking! I try not to use it too much, as reindeer get used to things quite quickly so it might become less effective. [Drones] are very useful in areas that are difficult to drive an ATV [or if] you don't want to make a track with your snowmobile, because reindeer will follow a track.[8]

That winter [of 2019/20] there were so many hard layers in the snow. I don't remember much rain, but there was a lot of wet snow coupled with hard winds. One of the oldest herders in our *siida* said that the winds have changed. Before, winds came from all directions—but now it seemed to come from the south, for over a month without changing.

Yet this last winter we had [in 2024] was the best I have ever experienced. I was starting to think that the new normal was bad winters, but then came this good winter. There is so much variation—you just have to accept that.


*Juhán-Tuommá at the office. Photo supplied by Juhán-Tuommá Magga.*

## Endnotes

1 *Johan Turi, An Account of the Sámi. ČálliidLágádus (2010), 221 pages. Original title: Muitalus samiid birra. ISBN 9788282630191. FOREIGN RIGHTS. Kárášjohka, Norway.*

2 *Read more about the impact of supplemental feeding in this StoryMap: bit.ly/reindeerfeeding*

3 *The* siida *is a traditional Sámi family based grouping around which reindeer herding is organized.*

4 *A* gákti *is the north Sámi language name for the traditional costume that many Sámi people wear.*

5 Duodji *is the term for Sámi handicrafts.*

6 *Since this interview took place, plans for a large wind power project has been announced in Karoliina's district.*

7 *The Finnish state provided compensation to herders who experienced heavy losses that winter, though very few ultimately qualified.*

8 *Read more about how Juhán-Tuommá and others are using drones in this StoryMap with a lot of footage shot by him: bit.ly/herdingwithdrones*

*The lasso: an "arm extender" that made reindeer herding possible. Although most are now made of plastic, leather ones like this are more durable and work even in extreme cold. Photo by Philip Burgess.*

# 4.
# Legacy Herds

## Reindeer, regulation, and the changing climate of the Seward Peninsula

Mike Brook

### REINDEER COME TO ALASKA

The late 1800s were a time of food insecurity on Alaska's Seward Peninsula. The populations of land mammals such as caribou and muskox, important food sources for Indigenous communities, were declining across western Alaska. In addition, the dramatic expansion of the whaling industry across the Arctic had decimated marine mammal populations, another critical food source. These combined factors led to a growing food crisis among Indigenous communities.

Dr. Sheldon Jackson, a Presbyterian missionary and U.S. General Agent for Education, recognized the chronic food shortages facing many Alaskan Native communities and envisioned imported reindeer as a remedy. His idea quickly became actionable because he teamed up with Captain Michael A. Healy of the U.S. Revenue Cutter Service (a precursor to the Coast Guard). For nearly a decade, Healy had sailed the Bering Sea, observed well-managed Siberian herds, and commanded the only U.S. vessel that could make the dangerous

*Landing the first batch of reindeer at Teller Station on July 4th, 1892. Photo credit "Report on Introduction of Domesticated Reindeer Into Alaska with Maps and Illustrations" (1894) by Sheldon Jackson.*

crossings needed to procure animals. Jackson marshaled political support and federal funds in Washington, while Healy handled on-the-ground logistics. In 1892, their collaboration delivered the first small herd to Port Clarence (near present-day Teller), laying the foundation for what became the Alaska reindeer industry.

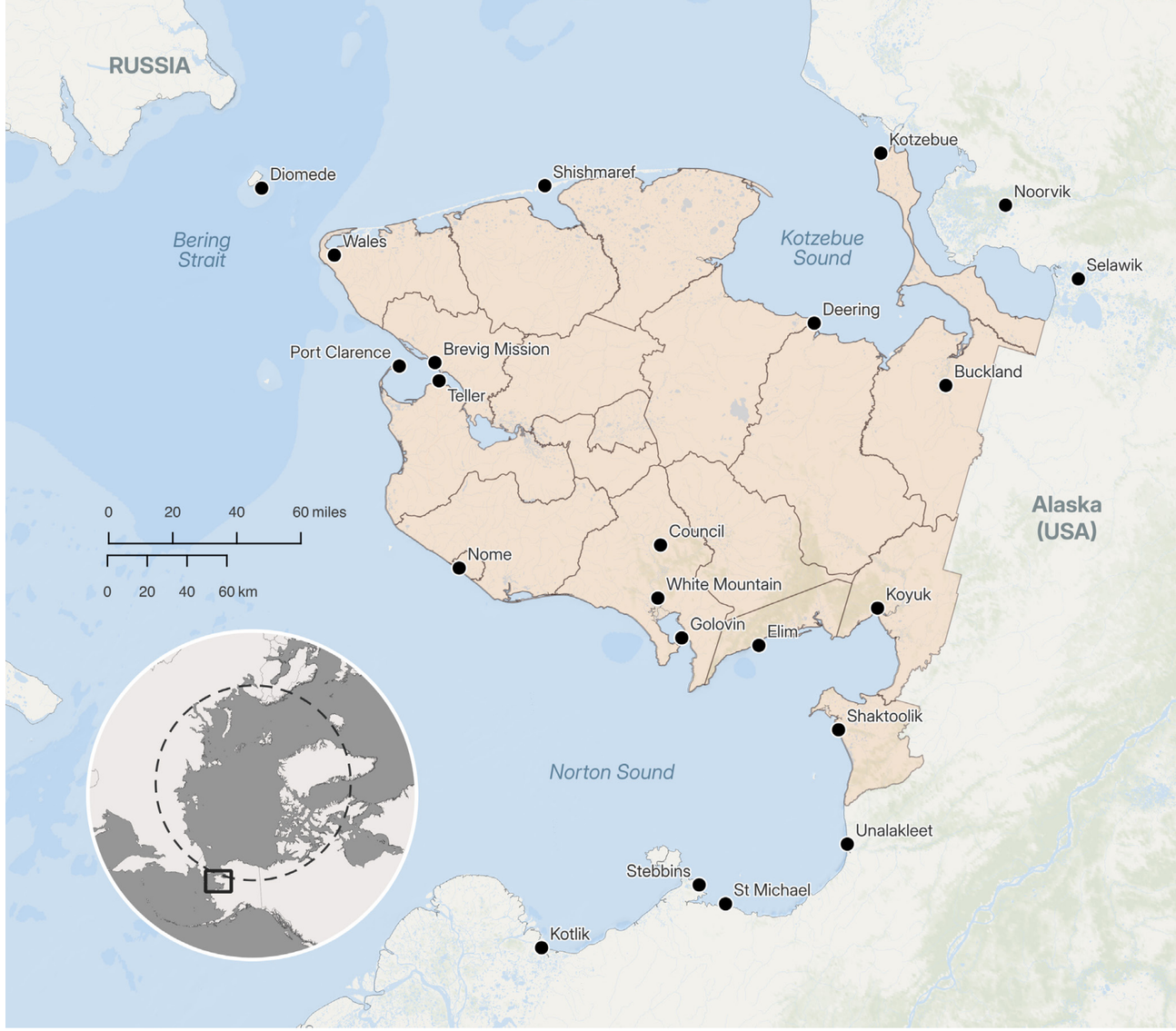
In addition to animals, expertise was also imported—primarily in the form of Sámi herders from Northern Europe, who traveled to the region not only to manage the newly introduced reindeer, but also to teach local Alaska Natives the skills necessary for this new industry. A training center was established at Teller, and soon other key locations, such as Unalakleet, became important hubs for the expanding reindeer enterprise.

The herding training program relied heavily on an apprenticeship model. Alaska Native apprentices worked under the guidance of Sámi herders, gaining not only skills but also reindeer as payment. Under the initial design of the program, an apprentice would earn two reindeer the first year, five the second, and ten for the third and each year thereafter. In a 2002 interview, Clifford Weyiouanna, a herder from Shishmaref, recalled how his grandparents got their start:

> *And at the end of his tour of getting his education on reindeer herding…he earned two bulls. My grandma was a cook and did all the other chores that reindeer herders need to have done. And at the end of her tour, along with my grandpa, she earned seven females. And that was the start of the Malakiak herd.*

The Sámi instructors were also paid in reindeer, though far more than






*Reindeer grazing ranges on Alaska's Seward Peninsula.*

the apprentices—typically 100 reindeer for three to five years of service. This payment scheme ultimately resulted in herd sizes growing imbalanced. By 1905, the average herd owned by an Alaska Native apprentice consisted of approximately 50 reindeer, while the average Sámi herder owned over 200.

In 1914, a seminal transaction sent the Alaska reindeer industry in a different direction. Alfred Nilima, a Sámi herder living in the Kotzebue area, sold his entire herd of 1,200 head to Carl Lomen, a white man who had come to Nome as part of the gold rush. At the time, regulations prohibited Alaska Natives from selling breeding (female) reindeer to non-Natives. No such limitation was placed on Sámi own-


*Left: Part of the Lomen herd appears near Cape Prince of Wales, Alaska. Photo credit Lomen Bros. (ca.1900–1927) via Library of Congress.*

*Right: Sámi herders in Alaska, 1903. Photo via BÁIKI International Sámi Journal.*

ers, however, and this powerful loophole led to the Alaskan reindeer enterprise moving in an increasingly commercial direction, and out of the hands of the Alaska Native peoples.

From its original 1,200 reindeer herd, the Lomen Company built an extensive infrastructure to support their reindeer business, including slaughterhouses and processing facilities. This infrastructure enabled them to corner much of the reindeer meat and skin export market, selling their products largely to the “lower 48” states. At its height, the size of the Lomen herd was certainly in the hundreds of thousands, perhaps even as high as half a million reindeer.

The dominance of the Lomen Company and other commercial herds had two major effects on the Seward Peninsula. It placed immense pressure on smaller Alaska Native herders, who found it increasingly difficult to compete with the Lomen’s operations. It also meant most of the benefits of the industry were leaving Alaska, as reindeer meat and other products were heading south. The industry established to address food insecurity in the region was scarcely doing that anymore.

Growing concerns about the marginalization of Alaska Native herders led to federal intervention. In 1937, U.S.Congress passed the Reindeer Industry Act, which fundamentally reshaped the reindeer herding industry in Alaska. It restricted ownership of reindeer herds in Alaska exclusively to “Eskimos and other Natives of Alaska,” effectively barring non-Native entities, like the Lomen Company, from participating in the industry. The Bureau of Indian Affairs (BIA), under the Department of the Interior, was tasked with implementing the act and overseeing the reindeer industry. The act aimed to restore reindeer ownership and control to Native Alaskans, allowing them to benefit from the industry that had initially been intended for their communities.

The Reindeer Industry Act of 1937 was a pivotal moment in the history of reindeer herding on the Seward Peninsula. On the one hand, it changed the industry’s trajectory by returning ownership and control to Alaska Natives. On the other hand, the move to extract the reindeer herding industry from large commercial interests had the unfortunate side effect of also taking it from many individual Sámi herders, who as



non-Native Alaskans were no longer able to own reindeer. Many had been in Alaska for decades at that point, had integrated into Alaskan communities, and had been instrumental in helping establish reindeer herding as a viable enterprise in Alaska.

## THE GREAT DIE-OUT

The Reindeer Industry Act of 1937 wasn’t the only major event at the time. The period was also marked by what is sometimes referred to as the “Great Die-Out.” The die-out was a multifaceted crisis that dealt a major setback to reindeer herding on the Seward Peninsula, resulting from a convergence of factors including overpopulation, environmental challenges, and management issues, leading to massive losses in reindeer populations.

By the late 1930s, the reindeer population on the Seward Peninsula had exploded, reaching an estimated 300,000 to 600,000, largely because of the commercial herding. The rapid growth put intense pressure on the environment, leading to overgrazing of lichen, the primary food source for reindeer in winter. Lichen takes decades to regrow, and could not recover fast enough from the grazing pressure.

Dan Karmun, a herder in the region, recalled in a 2001 interview:

> *With the increase of deer just before World War II, I remember going to Nome from Deering with a good buddy of mine. We saw the deer just dying off in the countryside because of the lack of food. Then the wolves were having their day in eating, you know, the tongue of reindeer only. That is more fattening to them. It was a sad sight.*

Larry Davis, a herder from Deering, recalls the same time period in a 2001 interview:

> *There’s so doggone many deer, I mean, thousands of reindeer, roaming around all over the country back there, and then the wolves came in, packs and packs of them. Man, there was packs of wolf all over the country. These wolves would go after reindeer, and knock them over, and come, and just suck the blood, or take the tongue out, and that was all they were interested in.*

The efforts to recover from the Great Die-Out included significant intervention from the BIA. In the 1940s, the BIA had taken over administration of the Alaska reindeer operation, and had established 19 grazing areas on the Seward Peninsula. Permits were issued to Alaska Natives to graze their herds on these lands. In 1944, the additional step was taken to establish the Reindeer Loaner Program, a pivotal initiative aimed at rebuilding reindeer herds and restoring economic

stability for the Alaska Native communities that depended on them. The program provided loans of reindeer, typically 500–1,000 head for a period of five years. At the end of the loan period, herders were to return an equal number of reindeer to the program. This allowed Alaska Native herders to begin reestablishing herds that had been devastated in the preceding years.

In a 2005 interview, Fred Goodhope, Jr., a herder from Shishmaref, recalled how his family rebuilt their herd from the BIA Loaner Program:

> *After the animals had died off, back in the 30s, I believe, we didn't really do anything up until 1958, the fall of 1958, when my father started talking to the BIA about the reindeer program. Back then, in them days, it used to be 800 animals for a loan from the BIA. And then they decided if they put two guys in operation, they'd get a lot of animals that way. And they increased their numbers faster with a larger amount of animals. So they started off with 1,600 animals from, I believe, Lawrence Gray and probably the Hadley Herd in Buckland.*

The Hadley herd, for its part, had also been established from the BIA. Nathan Hadley, Sr. from Buckland recalled in a 2001 interview:

*Left: Aerial view of the Goodhope River Reindeer Herding Site. Photo credit NPS Park Cultural Landscapes Program via NPGallery Asset Detail.*

*Inset: Goodhope River Reindeer Herding Site. The building plans follow the 1937 passage of the Reindeer Act. About 60% of the corrals and pens from the period of use are still standing. Photo credit NPS Park Cultural Landscapes Program via NPGallery Asset Detail.*

> *In 1952, my father went to…where they have the corral, the BIA. So my dad got a loan of 725 [reindeer] to be returned in five years. That was in 1952. There was no caribou then in our ranges. That's how our reindeer get started.*

## ENVIRONMENTAL CHALLENGES

A persistent challenge of herding on the Seward Peninsula comes from close genetic relatives to reindeer: caribou. The Western Arctic Caribou Herd, one of the largest herds in the world and native to Alaska, has fluctuated wildly in population over the decades. At present, it is estimated to be approximately 164,000 animals. In 1975, it was estimated at 75,000, a low point. But in the early 2000s, the size of the Western Arctic Herd had grown to a high point, some half a million animals. With this immense size came immense pasture pressure and thus increases in the range of the herd. The Seward Peninsula, while mostly not within the typical range of the Western Arctic Herd, found itself overrun with caribou around the turn of the 21st century.

Caribou present multiple challenges for reindeer herds. One is the natural tendency of reindeer to follow caribou. When the migrating caribou entered reindeer grazing areas, it became almost impossible for herders to keep their reindeer from joining the much larger caribou herds. Once reindeer joined with caribou, separating them became extremely difficult, if not impossible.

Fred Goodhope, Jr. recalled:

> *And that was back in 1977 when we first started noticing caribou coming around. We had about 2,400 head then. And then after that, the animals kept going south with the caribou every time the caribou came around…So starting from 1977, our herd start going down in numbers.*

Palmer Sagoonick, a herder from Shaktoolik, recalled the challenges of the caribou's arrival during the second half of the 20th century. In a 2003 interview he said:

> *That went real well for a good 25 years until the caribou migration start coming on. And the caribou herd, we all know, just grew and grew and grew until it overgrazed their areas and start going into new areas to feed for their winter range. And, of course, they came to Koyuk and took over the Koyuk herd, and they start coming into our range. At first, we were able to control the caribou migration, because it was small; it's just within a thousand, just two or three thousand animals would come through, and we were able to drive them off and keep the herd safe. And as the years went by, the migration just kept getting stronger and stronger, and pretty soon we*

*had tens of thousands, hundreds of thousands of caribou came through. It just got so overwhelming, and just took over, just went through my whole range and got mixed up with my reindeer, and I lost the whole herd in one night.*

The presence of the Western Arctic Caribou Herd also led to increased predation. Wolves, drawn by the caribou, followed them onto the Seward Peninsula where they encountered the reindeer that had already been weakened by grazing competition. Reindeer, which are smaller and slower than caribou, became the easiest targets. Merlin Henry, a herder from Koyuk, recalled in a 2002 interview:

*And in 1990s, I had the toughest time. I couldn't do nothing no more. Some caribou come right to Koyuk. I couldn't do nothing. There were so many wolves. And wolves come around and they scatter the reindeer just like that with caribou. Then I'd work all day…lucky if I get 400 back.*

The third major issue that caribou present is overgrazing. The sudden increase in the number of grazing animals, both caribou and reindeer, put immense pressure on the already delicate ecosystem of the Seward Peninsula. Lichen, which is slow growing, was especially affected. Larry Davis expressed his concerns over the depletion of food for the reindeer:

*And now we've got these caribou coming down to the shore of the peninsula, competing with the reindeer, and now we'll be darn lucky if we have any more feed left here in the next few years, you know, for the reindeer, because caribou, you know, coming in, taking all that away from the reindeer.*

The caribou incursion also made the BIA Loaner Program inviable. Reindeer that were lost to the caribou herd could not be returned to the program; the reindeer numbers went down and the program lacked the funds to rebuild. It was discontinued in 2004.

The Western Arctic Caribou Herd has since moved from the Seward Peninsula and at present is not a major factor for local reindeer herds. Some environmental hazards, however, are on the rise, including rain-on-snow or winter rain events. Rain falling on snow and then freezing creates an ice layer that makes it difficult for reindeer to dig through the snow to the lichen below. Through the second half of the 20th century, rain-on-snow events became increasingly frequent on the Seward Peninsula and herders adopted novel strategies to cope. Johnson Stalker, a herder from Buckland, recalled in a 2001 interview:

*One time in February we had a big rain. And we were at Noatak flat, and it got thick, and they couldn't dig through. And we get worried. And they couldn't eat, they started laying down.*



He goes on to described how they saved their herd by moving them outside of their typical grazing range:

*We put our deer inside the trees, like bushes. And for a month, maybe two, they stayed in the trees, inside, kind of scattered all over…That's the only way we saved our deer.*

Nathan Hadley, Sr. describes looking for grazing places without an ice layer, or with a softer one:

*Sometimes there's a crash too in wintertime. Like when it rained in December or January and the snow freeze over. Reindeer can't get into the moss. I forgot what year was that. Maybe 60s. Late 60s, when we had to keep our reindeer [separate from] caribou bunches, in soft spots where they could eat.*

Icy conditions are not only challenging for the reindeer; they also challenge the herders. Roger Menadelook, a herder from Teller, recalled in a 2003 interview:

*You can get there with a snow machine when there's snow in the mountain, but three fourths of the time it's very slippery and icy up there because my range is one of the toughest ranges. That's what I'm trying to get at, is what makes it tough. Icy. You got to have lots of willpower to be a herder.*

Snow machines are such an integral part of herding on the Seward Peninsula, that any disruptions in their use inherently make herding more difficult. Merlin Henry observed how changing seasons impact herding practices:

*The winter weather right now, in fall time, it don't snow. It's so warm for the last, how many years now? It really changed…With a snow machine, you can't run around too much when there's no snow. In 1960s, there was a lot of snow in October, September, November, and then you can get around real fast. In 1980s, everything changed. There was hardly any snow. It was raining wet and it cost more money on snow machine parts. It's tougher to take care of reindeer because there's hardly any snow.*

## THE LEGACY HERD

The Davis family has been reindeer herding on Alaska's Seward Peninsula for generations, a legacy that stretches back to Bonnie Scheele's great-grandfather, Larry Davis. The legacy continues today through Bonnie herself and her children. What began as a shared heritage rooted in the Nome area has evolved into a multifaceted effort to not


*Reindeer driver near Nome, circa 1901–1911. Photo credit Beverly Bennett Dobbs (1868–1937) via Wikimedia Commons.*



*Scheele family at the Davis Grazing Range in 2023. Photo supplied by Bonnie Scheele.*

only sustain the tradition but also to adapt it for the changing realities of the 21st century. For Bonnie, reindeer herding is not merely a family tradition; it's a way of life, a bond with the land, and a testament to resilience.

Larry Davis played a critical role in establishing, maintaining, and adapting the family herd. When reindeer herding on the Seward Peninsula underwent a significant reorganization throughout the middle of the 20th century, kicked off by the Reindeer Act of 1937, Larry secured one of the grazing ranges in the Nome area in the 1960s. Bonnie says:

> *The story that I've been told is that my grandfather was going to go in with his best friend and they were going to get close grazing ranges together…and then I heard his friend didn't show up to go into the office. So I'm thankful that my grandfather went in anyway. And so we've held the grazing range here out of the Nome area since the 1960s.*

As Larry tells it in a 2001 interview:

> *There was a herd down Golovin, herd up north, all the way up past Selawik there, and there was nothing here in Nome, and the range was here; it was open in Nome. So I thought, well, I didn't ask my wife about it. I said, I'm going to go down and see the BIA people about getting a reindeer herd established here.*

His commitment led to what the Davis family now proudly calls their "legacy herd, because it's gone through so many generations."

Bonnie's parents, Bruce and Ann, took over the herd permanently in 2010 and immediately saw the importance of planning for the future. They learned from experience that without clear succession plans, herding families could lose their ranges and their herds to uncertainty. As Bonnie recalls:

> *Having an exit plan was really important because there wasn't any direction when my grandfather unexpectedly passed away from illness in the late 80s, early 90s. And so it was really confusing as to who the herd should go to or how it should be handled.*

Bruce and Ann Davis didn't want that to happen, so they created a formal business plan and held family meetings to determine who would carry the torch. Bonnie was adamant about continuing the tradition, wanting to ensure that the Davis legacy not only endured but thrived.

> *They held this series of meetings. They really wanted to see who had interest out of their siblings and the nieces and nephews. Who really wanted to be part of reviving this practice again and carrying it forward. And so from there I was pretty adamant. I was like, I really want to do this. And so from when we came back in 2010, I worked really closely with my parents all the time on [our corral], going out and getting the deer, processing the deer, all of that stuff. So that was really important to me.*

One of the most critical challenges for Bonnie and her predecessors has been adapting reindeer herding to modern realities. Environmental changes, fluctuating herd populations, and competition from caribou and muskoxen—these all threaten the viability of the herds. But in addition, government regulations present challenges. For example, since the Reindeer Act of 1937, reindeer have been classified as "non-amenable livestock." This classification excludes herders from government subsidies that could have otherwise helped during times of crisis. Further, USDA slaughtering regulations present logistical barriers to producing a salable food product. And government programs designed to stimulate the reindeer economy in Alaska, such as the BIA Loaner Program, are defunct or inviable.

Despite these challenges, the Davis family sees great hope in engaging the next generation. Bruce and Ann Davis used to refer to youth engagement in herding as their "exit plan," a way for them to gracefully retire from herding while ensuring it continues for generations to come. Bonnie recalls that whenever youth were absent from reindeer herding, the practice would wane, almost disappearing altogether. "We learned the hard way that if young people aren't involved, this tradition will die," she says. The Davis family began holding youth summits in the 2010s, blending culture, education, and hands-on herding activities to pass on their knowledge to youth in the community. Bonnie sees her daughter expressing interest in continuing the tradition, just as she did years ago, and works to include her in not only the physical aspects of herding but also in the advocacy and logistical sides. "It's not just about herding," Bonnie explains. "It's about teaching them to love the land, the animals, and the responsibilities that come with it. That's how we keep this alive."

The journey to keep reindeer herding vibrant is ongoing. Bonnie hopes to eventually bring all 19 grazing ranges on the Seward Peninsula into active use once again. This requires a focus on community engagement, business innovation, cultural resilience, conservation, and learning from others.

> *We have the ability with the cultural exchanges to see other reindeer herders around the globe, and what their issues are…and because we're in this phase, having all of this grazing range right now, let's make it a conservation so that it's a resource for future herders—to meet the needs of their communities and their families.*

# Endnotes


*The following sources were referenced throughout this chapter:*

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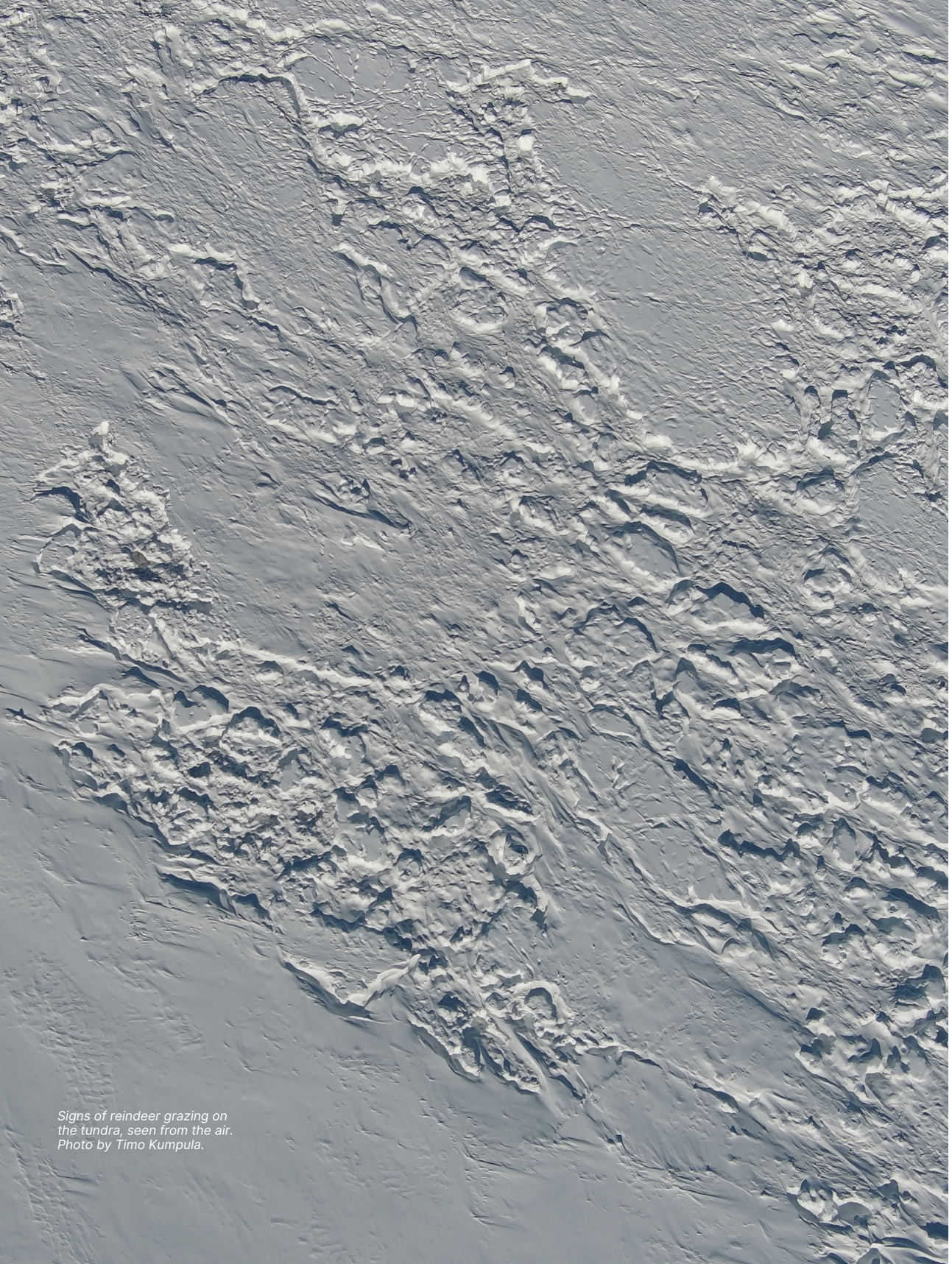
*In early 2024, Juhani Lakela (see p.37) traveled to Alaska to assist in the movement of reindeer between two villages on the Seward Peninsula. Photo by Juhani Lakela.*



*Signs of reindeer grazing on the tundra, seen from the air. Photo by Timo Kumpula.*

# 5. Our Language is Built to Live with Snow

—

## Climate, culture, and vocabulary of the Nenets tundra

Roza Laptander

Winter mornings on the tundra can be quiet and peaceful and in early spring the tundra shows its special beauty, a calm landscape of white fluffy snow that fell during the night, sparkling in the rays of the morning sun. Frosty air fills the lungs, the remnants of sleep evaporate.

I was born on the tundra of the Yamal Peninsula in northwest Siberia. “Yamal” is a Nenets word that roughly translates as “the end of the world.” This is my home, and I have devoted my life to the study and understanding of my native language and its nomadic herding culture. My Nenets identity not only forms the basis of my academic work as a linguist—it is also simply a part of who I am.

Central to our relationship with and holistic understanding of the land is our understanding of snow, ice, and permafrost. This knowledge helps us move on the tundra, herd our reindeer, find firewood, source clean snow and ice for melting water, and select sites for our *chum*, the teepee-like structures that are the basis of our nomadic life.

*Nenets winter chum in the morning. Photos in this chapter are by the author, unless otherwise noted.*

While it's impossible to apply scientific methods to our knowledge and language, there is so much information built into our working terminologies of snow that it should guide and be incorporated into scientific research. Working between Traditional Knowledge holders and scientists is challenging, as I can say from my own experience, but it is important if we are to expand our understanding of snow dynamics, the changes it will bring, and how it may affect our traditional livelihoods in the future.

Here, I introduce aspects of our knowledge about snow, ice, and permafrost that I have learned growing up and through conversations and interviews with my extended Nenets family and others.

The arrival and departure of snow on the tundra and ice on the rivers and lakes are the timekeepers of life and movement on the tundra. This cyclical calendar is the central element of nomadic reindeer herding, which is the very foundation of our culture. So, perhaps it is not surprising that we have wide-ranging knowledge and terminologies for snow, ice, and permafrost that range from the general to the highly specific. Our language keeps us safe and helps us survive, as is common with other Arctic herding and nomadic peoples.



The warming of our global climate is a very local problem for us. We were quick to see climate shifts years ago as we saw unexpected changes in snow, ice, and the permafrost. We began to experience more frequent and extreme weather events that impacted us directly. Rain fell on our winter pastures, encrusting them in ice, leaving our reindeer to die. The timing for safe travel over ice shifted. Lakes dried up. Generational climate events like these now occur almost annually. Without reindeer you cannot live on the tundra and those herders who lost their animals due to rain-on-snow events have had to migrate to the villages where life can be far more challenging as the entire fabric of their life unravels.

## OUR LANGUAGE IS BUILT TO LIVE WITH SNOW

The tundra is the coldest of our planet's biomes. Without the right expertise, it can be deadly and is often described in English as bleak and unforgiving. Over millennia, we Nenets have evolved with it and learned how to travel across it in all kinds of conditions.

Nenets reindeer herders classify snow covers and snow types and describe their different dimensions and characteristics in terms of safe movement and survival for people and their reindeer: access to water, reindeer's access to food and space, shelter, rest, mobility, and the visibility of tracks and droppings on the snow. Wind is called *myertsya*, fog *syinyu*, rain *saryo*, blizzards or snowstorms *khad*, and rain on snow *salaba saryo*.

Our terminologies (see glossary at the end of this chapter) describe types of snow, its layers, depth, and different degrees of softness and hardness; different snow conditions and their quality on reindeer pastures; the reliability of winter roads as strong snow and ice are important for migrations in the tundra; types of ice; and the state of permafrost (perennially frozen ground).

The Nenets primary word for snow is *syra*. It is also a name for winter, the period of the year with snow. Our words for snow describe the size and the form of snowflakes, while other words define the condition of the snow surface, its depth, the layers, the color, its moisture content, its structure and strength, its age, as well as specific seasonal features. There are also names for snow which are connected to descriptions of particular seasons with snow and landscapes with a specific type of snow near our dwellings, both in the tundra or in what is called the forest-tundra, south of the Ob River.

People might think that all the colors of the tundra in winter are a similar shade of white, but there is no pure white color in nature. In fact, snow has many different names in Nenets according to its color: *serako syra* (white snow); *serakorka syra* (not really white snow); *sere"e* (extremely white snow), *yabyeryena syra* (shining

white color of snow)[1] and *te"morpey syra* (yellow, dark snow).[2] This differs from contaminated snow which when melted for water, has a black sediment. That snow is called *paridenya syra* (black snow), which is a rather new name for the dirty or polluted snow near the oil and gas fields that have sprung up in recent decades.

Seasons change the snow and what we call it. Terms describing springtime snow include *syrad* (deep hard snow near rivers and lakes in late spring); *nyir* (hard snow on ice in spring); *narey syra* (spring snow with crystals).[3-4] *Ngay* means thaw and *ngay syra* is thaw snow. Late autumn snow with rain is called *ngamnelyo*.

There is also *tadnggana syra* (wet and sticky snow). Soft, loose, and very deep snow can be captured in the Nenets term *idebya syra*.[5] It describes a type of very deep and soft snow, which is difficult for reindeer to walk in.

Our name for a snowdrift is *puder"*.[6] Snow in the tundra is always denser than that in the forest-tundra. We call hard snow *maryiko* and *panyi syra*. *Manombey syra* is a name for a very hard old snow, which is common in the early spring.[7]

*Yabtiy syra* is a name for very hard and sharp snow.[8] *Paromdey"* is our term for sastrugi, which are ridges of snow formed by wind blowing snow on ice.[9] A layer of hard snow or crust of ice on the surface is called *nara*.[10] *Pani syra* is a special term for trampled snow.[11]

## ICE: ESSENTIAL, BUT SOMETIMES DEADLY

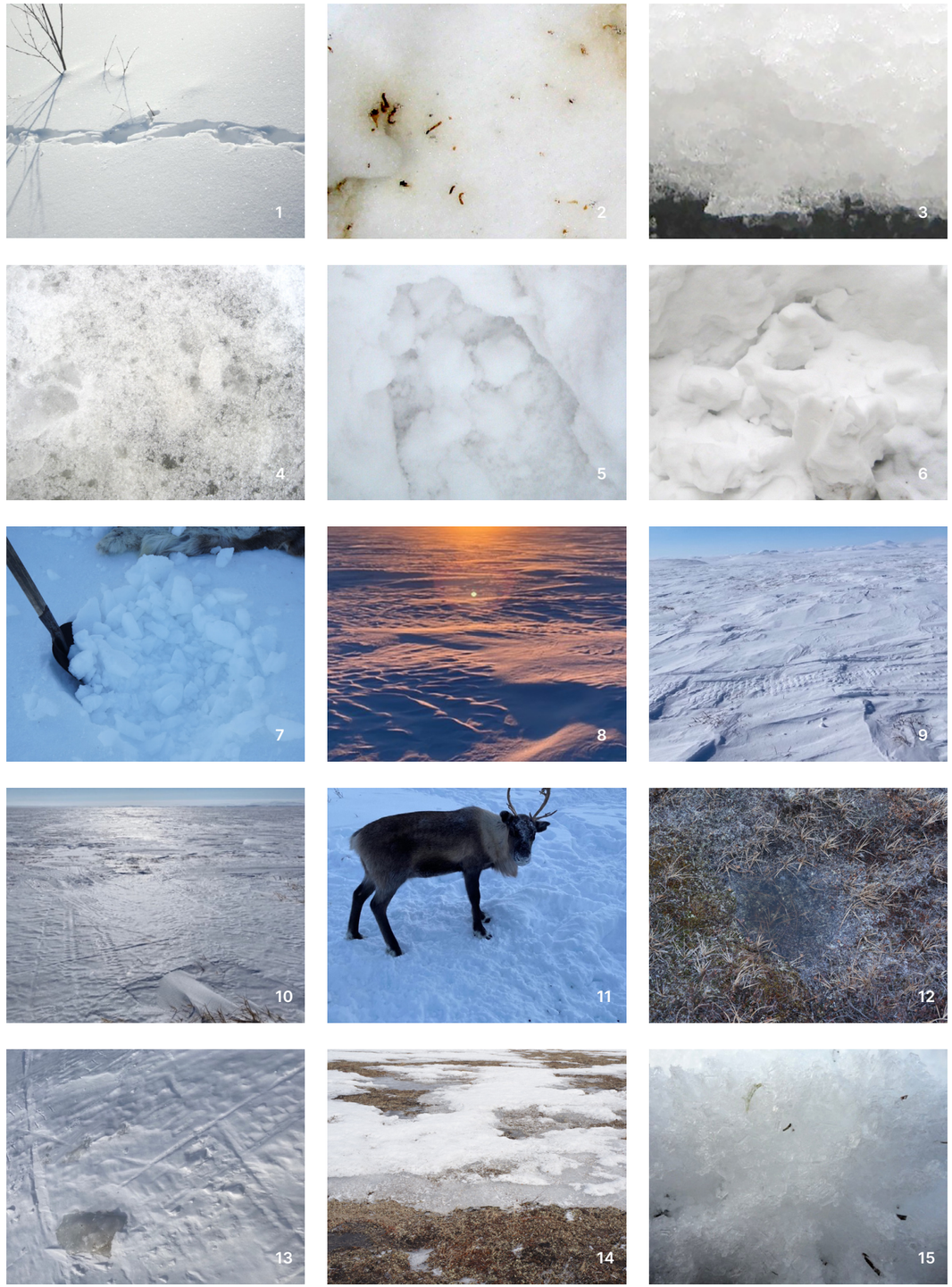
Our word for ice on the ground, rivers, and lakes is *salaba*.[12] A winter rain is *salaba saryo* (icing rain). This can be translated as "hail," but it is more specific, meaning "winter rain on snow or bare ground."[13]

*Serad" syra* is hard snow with thick layers of ice within it; whereas *serad" saryo* is rain in winter. This in turn is the source of the term *serad" po* which refers to a bad, troubled year with winter rains on snow, since *serad"* translates as misfortune.

*Seradt"* can be a name for ice on the surface of snow after rain or sleet has fallen, or refers to a coat of ice on trees and bushes. *Seradt"* is also a name for the most dangerous weather, when rain falls on unfrozen ground and later freezes solid. Ice then covers the surface and all the plants which are important sources of food for reindeer and many small herbivores—such as lemmings, voles, and Arctic hare. If the ground is covered with this kind of ice,[14] it is difficult and sometimes impossible for these animals to find food.

In some places, there is snow that does not melt at all, even in summer. It is usually found in gullies or on river banks and is called *ninya*





*kholkanggana syra* (never-melted snow inside the ground)—perennial snow. It is different from *salaba* (ice on the tundra ground) and *seryer"* (permafrost), where the moisture in the soil is permanently frozen or in which the moisture may melt to a depth of several centimeters in summer and freeze again in winter. From my personal experience, I know that in summer, reindeer herders have a variety of practices when it comes to using grazing locations with permafrost for their herds. Places without permafrost tend to be very dry and without lichen, and research has demonstrated that permafrost conditions are very important in determining the condition of a pasture as it offers a layer of moisture that sustains plant life.

## SNOW: INTEGRAL TO HERDING LIFE

Reindeer herders are in continuous conversation with their environment. What is the surface of the snow like? What are the temperature and humidity levels? Where is the wind coming from? Are these conditions suitable for travel? Are the pastures beneath the snow good for their animals? At the same time, they are keenly observing the behavior of the herd; if reindeer stay in one place and graze, this means that there is enough food there.

Nomadism means making and breaking camp frequently. We use soft snow to insulate our *chum* once a site is selected. Women or children then go to the tundra to bring pieces of clean and compacted snow called *syekhe* to melt for drinking water.

*Inggyem syra* is granular snow, or snow with crystals that resemble sugar.[15] This is found between the ground and the harder layers of snow on the surface. This loose layer of snow acts as an insulating blanket and its presence regulates the temperature on the ground. It is important for the survival of tundra plants during the winter and is crucial for allowing small animals to move under snow. This type of snow is also very important for reindeer herders, because it hints at good pastures below.

## TECHNOLOGY ADVANCES, BUT WORDS REMAIN IMPORTANT

These descriptions of our Traditional Knowledge about the tundra environment complements that of other Arctic Indigenous peoples. Our understanding of the tundra and its weather is based on a deep and enduring relationship with the land and an attachment to reindeer that nourish and support our culture, language, and people.

This knowledge is closely related to our traditional worldviews and religion, but above all, it is a very practical knowledge built daily by observing different conditions of snow, ice, and permafrost during the annual calendar of reindeer herding work. Nenets reindeer herders—



*Nadezhda Pyrirko melts* syekhe *(snow for drinking water), which can be harvested in large chunks from the ground.*

who live directly with nature and work around the clock throughout the year with their animals—are reporting dramatic effects on their life and animals due to warmer winter weather, winter rains, and more frequent icing.

During recent winters, there have been fewer different types of seasonal snow. Often the period with wet snow can be quite long in autumn. Winter snows do not appear on time, and not in line with the common seasonal order. Due to the late arrival of winter, some types of snow and ice—which are more common during the colder winter period—do not come when they used to. Early and late winter sees more icing events than before, and the permafrost is now much deeper in the ground. More extreme weather events have occurred during the last ten years than in previous decades, making modern work with reindeer increasingly difficult.

Tundra people wish for more predictable weather conditions with access to more accurate weather forecasts. While reindeer herders need modern ways of obtaining information about future extreme weather events, the fact remains that our Traditional Knowledge and specialized vocabularies are essential for the sustainability of our Nenets culture and the preservation of this traditional way of life on the tundra. Knowledge of snow and the environment is what keeps us safe in our lives and work. We belong to this landscape.

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| | |
|---|---|
| **i″** | water |
| **id″ind** | fog over water |
| **idebya** | very deep, soft, and unbroken snow |
| **idyebya syra** | very deep, soft, and loose snow |
| **iŋgiyam syra / iŋgyen** | granulated snow between the ground and surface snow layer |
| **khab″luy syra** | freshly fallen snow |
| **khad** | snow storm; blizzard |
| **khanibte(sy)** | to freeze |
| **khaw** | deep, soft snow in spring with a thin "crispy" surface that breaks easily; very tiring for reindeer to walk on |
| **laŋgakhad saryo** | rain which comes suddenly |
| **manombey syra** | hard, old snow near tents |
| **maryiko** | hard snow |
| **myryy** | snow above warm streams that becomes discolored by the water |
| **myrysawey syra** | water mixed with snow |
| **nara** | spring, before the drifting of ice; crust of ice on top of snow |
| **narey syra** | spring snow with crystals |
| **narey khad** | spring snowstorm |
| **narolo″ma** | icicle |
| **ŋay syra** | thaw snow |
| **ŋamnelyo** | intense snow with rain; autumn rain with snow |
| **ŋerm** | the North; northern; polar; cold |
| **ŋerm numgi** | the North Star |
| **ŋyly syra** | the bottom snow layer |
| **ninya kholkaŋgana syra** | perennial snow; snow that has never melted |
| **nyir** | hard snow on ice in spring |
| **panyi syra** | hard snow |
| **paridenya syra** | black snow |
| **paromdey″** | ridge of snow blown by wind on hard snow or ice; sastrugi |
| **poida syra** | compact snow |
| **poŋgnoy myertsya** | short and sudden strong rush of wind; gust |
| **puder″** | snowdrift formed by wind |
| **pydyo** | drizzling rain |
| **pydyako syra sew** | small snowflake |
| **salaba** | ice; block of ice |
| **salaba saryo** | icing rain; frozen rain; hail |
| **salaba ya** | black ice; ground covered with ice |
| **salabamda(sy)** | to cover with ice; to turn to ice |
| **salmuy nara** | very thin crust of ice above snow; spring |
| **saryo** | rain |
| **saryo′ laŋgal** | rain shower |
| **sawo** | spring flood; spring when rivers are open |
| **syekhe** | piece of snow for melting water |
| **serad″ saryo** | rain that is frozen while falling; rime |
| **serad syra** | hard snow with thick ice layers |
| **seradt″** | ice above snow after rain; sleet; ice crust on trees and bushes |
| **serako syra** | white snow |
| **serakorka syra** | not very white snow |
| **sere″e** | extremely white snow |
| **serer′ i″** | water trapped in permafrost |
| **seryer″ / ya serer″** | permafrost |
| **seyo** | ice or snow floating in the water; small pieces of ice floating along the river in autumn, when the first ice is formed; ice floes floating in ice holes; ice cubes scooped out of the ice hole and stacked in a pile |
| **sinyo / syinyu** | fog; mist |
| **suyu khad** | spring snowstorm during reindeer calving time |
| **sye(sy)** | to be filled with floating and ringed pieces of ice (related to water bodies) |
| **syra** | snow |
| **syra nyalpey sew″** | large snowflakes |
| **syra sew** | snowflake |
| **syra′** | winter |
| **syrad** | deep, hard snow near rivers or lakes in late spring |
| **syradana** | passing the winter |
| **syradarew** | to be like snow |
| **syrarakha** | to become like snow |
| **syrasya(sy)** | to be without snow |
| **syrey mya** | winter tent; chum |
| **syrey** | winter; wintry |
| **syretsa** | two-year-old female reindeer |
| **syrimsy** | to become snow-covered; to become wintry |
| **syrin(sy)** | to clear snow away from something |
| **syryeta** | snow-covered |
| **tadŋgana syra** | wet and sticky snow |
| **tander″** | mist |
| **te″morpey syra** | yellow, dark snow; dirty (polluted) snow |
| **tora / torik syra** | shallow snow |
| **torik syra** | shallow, fine dusting of snow |
| **yabyeryena syra** | shining white color of snow |
| **yabtiy syra** | hard, sharp snow |
| **yaw′ ind″** | sea fog near the tundra coast |
| **yomzya** | soft, fluffy snow that falls during warm winter weather |
| **yorya syra** | deep snow |

*As the temperature drops, ice starts to form. Photo by Philip Burgess.*

# 6. The Uncertain Trail

## Transportation challenges in the changing North

Mike Brook & Betsy Sheffield

Patricia Yaska of Chuathbaluk, a small community on Alaska's Kuskokwim River, recalls the early winter of 2014:

> *In November 2014, the Kuskokwim was frozen solid and the ice was at least eight inches thick by November 1st. But on December 2nd, the ice broke and it was like spring break-up in December.*

This was the second year in a row that residents of Chuathbaluk were able to use boats on the Kuskokwim in December—a situation that had seldom, if ever, happened before. Patricia compared this to her childhood memories:

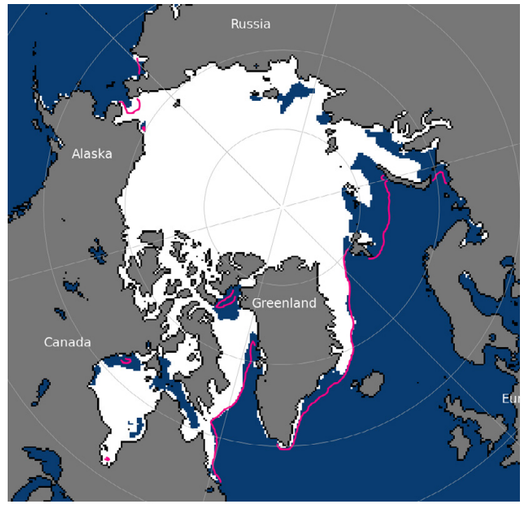
> *I remember growing up in Chuathbaluk and in Aniak, and by the end of October and by Thanksgiving, we were traveling between the two villages [Aniak and Chuathbaluk] on the "ice road." This day and age, we cannot do that. We are still traveling to Aniak for groceries with a boat in an ice-free river.*

*The Kuskokwim River experienced a winter break-up on 2 December 2014. Photo by Patricia Yaska via Local Environmental Observer (LEO) Network.*

*The Tokositna River was ice free on 20 April 2016, the earliest break-up in memory. Photo by Anahma Shannon via Local Environmental Observer (LEO) Network.*

Northern regions have always depended on the predictable rhythms of the seasons. For generations, Indigenous communities and other residents timed their travel and work around the freeze and thaw: rivers and lakes that freeze into solid highways by early winter, snow deep enough for sleds and snow machines, and a spring break-up that follows an orderly cold season. Transportation networks—whether informal ice routes to hunting grounds or official winter roads linking remote towns—are built on these expectations. When the freeze comes late, the thaw comes early, or unseasonable rains turn snow to ice or slush, the entire system of travel in the far north is thrown into disarray. In recent years, such disruptions have become very common.






*Left: An ice-free Grantley Harbor near Teller, Alaska in December 2022, as seen from Kendra's car. Photo by Kendra Lee via Local Environmental Observer (LEO) Network.*

*Right: Arctic sea ice extent in late 2022, showing Teller as completely ice free. The magenta line indicates the median ice edge between 1981–2010. Image via the National Snow and Ice Data Center at University of Colorado Boulder.*

## WAITING ON A LATE FREEZE

Winter used to arrive on a fairly reliable schedule in most of Alaska. By late October or November, temperatures stayed below freezing and ice thickened daily. Reindeer herders in the Alaskan Arctic recall how, historically, harbor and river ice would be solid from late November until early May. James Noyakuk, a herder from Teller, Alaska, noted that he usually could count on the sea ice in Grantley Harbor freezing hard by late November, creating a stable platform to travel on through winter. In the early 2000s, however, he started seeing unusual delays. Warm spells in the autumn would delay freeze-up, sometimes with ice forming and then breaking up multiple times before finally setting in. Where he once expected to take his snow machine out to check the herd in November, now he had to wait longer—and make cautious early-winter trips just to test the ice thickness before trusting it.

The trend James observed has continued. A more recent observation posted to the online Local Environmental Observer (LEO) Network in December 2022 by Kendra Lee, also of Teller, noted:

> *No ice, or partial ice in Grantley Harbor in Teller, Alaska. Usually, there is thick enough ice for ice fishing.*

Rick Thoman, a climate specialist with the Alaska Center for Climate Assessment and Preparedness, noted in response that not only temperature but wind might have been to blame:

> *Daily temperatures averaged almost 20°F [11°C] above normal for the week of November 30 to December 6, and rain and southeast winds gusting to over 70mph [113 kph] melted and moved out what ice had formed in Grantley Harbor.*

Andrew Mahoney of the University of Alaska Fairbanks added that the freeze-up and break-up periods were so affected that it was sometimes impossible to tell them apart:

> *In the last five years, satellite data indicate that the winter sea-ice season in communities a little further south than Teller (like Gambell, Savoonga, and Kotlik) is changing rapidly. In these communities, the period of reliable ice cover is not just getting shorter, but sometimes doesn't occur at all so that it is hard to tell when freeze-up ends and break-up begins.*

In Oscarville, a village near Bethel, Alaska, residents watched the Lower Kuskokwim River remain stubbornly unfrozen through an unusually mild November in 2018. Oscarville Tribal Administrator Michael Stevens described the state of the river and the impact on the community:

> *We had a late freeze-up here at the Lower Kuskokwim due to unusually warmer temperatures. The river wasn't safe to travel on for the month of November—usually the ice thickness is safe to travel on by the middle of November. Now it is December and we finally have at the very least nine inches [22.8 cm] of ice thickness at the mouth of Oscarville Slough. When the river isn't thick enough to travel on, it becomes unsafe for travelers wanting to do shopping in Bethel, get to medical appointments in Bethel and other things that they want to do.*

*Frazil ice forms during the winter when the water is in a turbulent state. Photo credit National Park Service via Wikimedia Commons.*

In interior Alaska, similar stories abound. In 2012, residents of Fort Yukon, on the Yukon River, reported that as late as Thanksgiving there was still no snow or river ice. In November 2013, on the Koyukuk River, residents reported boating to neighboring communities well past the usual freeze-up date—something unheard of decades prior. What used to be the start of the snow machine season has become an extension of the boating season in some years, creating a strange overlap of autumn and winter: an in-between period when the ice isn't solid, but the river is filled with frazil ice (ice crystals formed in turbulent water) or a thin skim. Travel by boat becomes risky but travel by snow machine isn't yet possible, effectively cutting off villages that rely on the river as a road.

Bethel Search and Rescue, a volunteer group in western Alaska, tracks the Kuskokwim River ice carefully each year to declare when the "ice road" is open. They noted that between 2009 and 2012 the river near Bethel was typically frozen by mid- to late October, but more recently



that date has slid well into November. The date when ice is thick enough for safe travel, whether by truck or snow machine, has become increasingly unpredictable—often not until early December in warm years. And even when the ice comes in on time, warm spells make it unreliable. Mark Leary of Bethel Search and Rescue said about the conditions in December 2024:

> *We took two steps forward toward having a good, safe river in late November with that cold stretch of weather. And then we took a step backward with that record warm.*

Elsewhere in the Arctic, northern Canada faces similar challenges. In the Northwest Territories and northern Ontario, winter roads—temporary highways carved out of frozen muskeg (the term for Arctic peatland and bogs) and river ice—are freezing up weeks later than they used to. Nishnawbe Aski Nation Chiefs, in Ontario, declared a state of emergency in 2024 when key ice roads failed to freeze on time, delaying the delivery of fuel and food to thousands of people. Grand Chief Alvin Fiddler described the situation:

> *The winter road season should be well underway, but temperatures remain unseasonably warm, making them extremely dangerous and unsafe to use. This poses severe safety risks to community members and commercial drivers who are risking their lives for necessary travel. Our communities rely on these roads for delivering essential goods and our leaders are understandably concerned. We will begin discussions with our federal and provincial treaty partners immediately to ensure that sufficient freight and road-repair subsidies are provided to NAN [Nishnawbe Aski Nation] communities so air transport can be arranged as quickly as possible.*

## THE PERILS OF THIN ICE

Once the freeze finally comes, northern travelers now face a new worry: ice that is thinner, weaker, or less predictable than before. Near Oscarville, Alaska, when volunteers measured the ice in mid-December 2018, they found some sections were dangerously thin, including a spot with only 22.8 cm (9 in) of ice. That may sound substantial, but it's well below what's considered safe for heavy travel. In normal years, the Kuskokwim ice road would be supporting pickups, fuel trucks, and passenger vans by Christmas. But with such thin spots persisting, travelers had to stick to marked trails painstakingly mapped out by Bethel Search and Rescue teams in order to avoid the weak ice.

Across the Arctic, in Europe, Sámi herders in Finnish Lapland face similar dangers early in the season. Sunna Siilasjoki recalled one close call:

> *It was early January, and my Dad was driving, following the reindeer. The reindeer went over a small river and my Dad reckoned that it would be okay to follow them, as it was already so cold and had been for a while. The ice held the reindeer, but not the snowmobile! He fell through and got completely soaked. Luckily there was phone coverage there, so a friend was able to come and rescue him.*

The same wild temperature swings that can delay ice formation contribute to its weakness. A brief thaw or a mid-winter rainfall can weaken the ice from above and below. Ice experts in Alaska describe how once a sheet of ice forms, a sudden warm-up can cause the river level to rise, lifting the ice up. When the water level then drops again (or the ice isn't able to refreeze firmly to the water surface), it leaves behind a gap—essentially a layer of air between the ice and the water. The local name for this is "hollow ice." A reindeer herder from the Seward Peninsula in Alaska, James Noyakuk, noted that hollow ice was becoming a frequent problem in years with on-again, off-again freeze conditions. Large pockets of air get trapped under the ice, and even if the ice is thick enough for travel, it is not resting on and supported by the water anymore—and therefore is far weaker than it looks. Travelers might not realize they're basically crossing an ice layer suspended a few inches above the water. James learned to test carefully with an auger and to be wary of snow-free stretches of ice (so-called "glare ice") where an air gap might lurk beneath. In some spots of his reindeer range, he knew hollow ice formed almost every year; elsewhere it was unpredictable, a hidden danger.

*Travel over thin ice or areas with unseasonably low snow cover can be hazardous. Photo credit Sunna Siilasjoki.*

Besides hollow ice, there's the issue of overall thinner ice because of milder temperatures. Instead of over one meter (3.3 ft) of river ice by late winter, there's only half that in a warm year—and the quality can be suspect too, with soft ice or layers of frozen slush. Surprisingly, travel on frozen rivers near the coast can be impacted by diminished sea ice extent on the ocean. For example, less coastal sea ice in the autumn can lead to more storm surges that travel up river deltas and break-up and destabilize river ice inland from the coast.

The consequence of unsafe ice ripples through communities. Winter festivals and recreational races have been curtailed or canceled; notably, the Kuskokwim 300 sled-dog race in 2018 from Bethel to Aniak, Alaska, on the Kuskokwim River was rerouted to deal with slushy, thin river ice that made a portion of the usual trail impassable. Search and rescue groups in the Northwest Territories of Canada reported an increase in calls for machines or even trucks that fell through ice in spots locals didn't expect to be thin. Every year there are tragic stories of travelers who fall through the ice and drown—incidents that local observers link to the changing conditions.

## SNOW, RAIN, AND THE UNCERTAIN TRAIL

It's not just ice that's become unreliable. Snow conditions are also in flux, with big implications for transportation. In many Arctic regions, a deep snowpack is the great enabler of winter travel: it smooths over the tundra's summer tussocks and wetlands, providing a level highway for sleds, snow machines, and even makeshift ice runways. But what if the snow comes late, intermittently, or not at all?

Sunna Siilasjoki offers another anecdote about deceptively solid-looking terrain in the Sámi region:

> *It had been cold and snowing, and it was well after the first snow. We figured it would be okay to drive our snowmobile across a swamp. But most of the swamp under the snow was not frozen, so we got completely stuck. We had to cut down small trees to try and free the snowmobile, which luckily worked.*

In 2017, Barbara Askoak reported the changing conditions in Lower Kalskag, Alaska:

> *It used to be travelable to trapping, wood-getting, and other villages by now, but not the last three years. Now our roads are slippery when there should be snow. Planes never canceled as much as this year. The flights were backed up three or four days. Lately, we've been seeing grasses regrowing after it warms up out there.*



Without snow, traveling by snow machine becomes a bone-rattling ordeal or outright impossible—the machine's skis and tracks are built to glide on snow, not dirt and rocks. Some people have switched to all-terrain vehicles (ATVs) or pickup trucks for winter travel, but those have their own limitations. Tundra and taiga that aren't frozen solid turn into muck under the weight of a vehicle, and ATVs become stuck in the mire. Even when the ground is frozen, without any snow cover the tundra is like a field of jagged obstacles. Donald Olson, a herder from Golovin, Alaska, describes the wear and tear that uncovered tundra puts on snow machines:

> *If the tundra is too rough where you don't have enough snow out there, every time [a snow machine] hits a tussock they're breaking a spring. It's just hard on the snow machines that are actually fairly lightly built and somewhat delicate in the sturdiness of their structure. They can't stand constant pounding; the chassis will start to crack; they'll start to break the springs and those kind of things.*

Logging and other land-use changes can compound the problem. Juhani Lakela, a herder from northeast Finland, observed:

> *It's not just bad weather. There has been so much logging in our district it has changed the landscape and it makes travel so difficult. They cut everything down, replant it, and then it gets so dense that it is like a jungle, and it's really hard to get through.*

Then there are rain-on-snow events, which occur when a warm weather system brings rainfall in the middle of what should be the snow season. The rain can percolate into the snowpack and then freeze, forming a thick, hard crust of ice either on top of the snow or within it. For transportation, rain-on-snow events can be trouble in multiple ways. Falling rain can create slushy, dangerous conditions, with snow machines traveling through several inches of water, which can seep into engine components and freeze when temperatures drop again.  The same thing happens on the ground, with rain and slush becoming rock-hard, glazed, and slippery. Dog sleds, snow machines, ATVs, cars, and trucks are equally challenged by such conditions. Merlin Henry, a reindeer herder from Koyuk, Alaska, recalls how changing conditions posed challenges for herders:

> *In the 1980s, everything changed. There was hardly any snow. It was raining wet and it cost more money on snow-machine parts. It's tougher to take care of reindeer because there's hardly any snow.*

Juhani remembers one winter when a combination of cold and wind formed a crust over the snow:

*The snow was very hard on the surface, but beneath that it was like powder. There had been a lot of snow falling, then it got very cold and windy—which hardened the surface, but not enough to carry a snowmobile. I was lucky mine had a four-stroke [engine] so I was able to get free, but others were struggling.*

Residents of the Arctic may find themselves with no good transportation options at times when they need them most. Tom Gray, a herder from White Mountain and Nome, Alaska, describes a situation that has grown common across the Arctic: needing transportation to tend to his herd (in this case, to keep them isolated from caribou), but being left with no choices that are both efficient and affordable.

*We didn't get snow until January of this year. The caribou showed up in September. And so, we've got four months, five months without snow, and we can't afford to go out and hire a helicopter to move animals around. What are we going to do? You know, the days of going out and walking and moving animals by foot and dogs and stuff like that, you know, I think those days are gone.*

## EARLY BREAK-UPS AND BROKEN CONNECTIONS

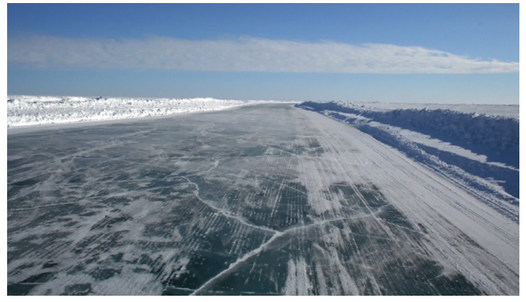
As erratic as freeze-up has become, the other end of winter—spring break-up—is no less disruptive. For many northern communities, the melting of ice in spring is coming sooner and faster than it used to, slicing even more days off the already shortened winter travel season. This has profound effects on transportation because once ice begins to break up, it quickly becomes impassable for vehicles, yet may also be too choked with "rotten" (unstable) ice to traverse by boat. That transitional period can isolate communities just as badly as a late freeze.

Juhani Lakela has learned to watch the clock on spring crossings:

*The track to the site crosses a few small rivers. They were okay to cross in the morning, but after midday, one snowmobile went through. Last year, we made a few small bridges to cross these places with reindeer more safely, and we will probably have to do more and more of this in the future. Spring is also tough for the reindeer. This year, we found some dead reindeer in small steep edged rivers, usually in swamps, where they got stuck.*

Residents of Alaska have observed that break-up now often comes "all at once." In years past, there might have been a gradual weakening of the ice in April that gave people time to prepare and perhaps make a last trip across a river before it was unsafe. Now, especially after an unusually warm winter, rivers can go from solidly frozen to swiftly flowing





*The Tuktoyaktuk Winter Road between Inuvik and Tuktoyaktuk, in Canada. Photos by Ian Mackenzie via Wikimedia Commons.*

in a matter of days. The days of gradual weakening are gone. Anahma Shannon describes the experience of her family living on the Tokositna River near Denali, in April 2016:

*They went to the store to stock up on food and began the return to their lodge. During the snow machine trip from the Parks Highway to the lodge the rains started to come down, wreaking havoc by eating away at the snow and causing overflow on the river. They made it home just in time for break-up, where they have been stranded at their home ever since. Being stranded for break-up is normal—what is not normal is that break-up unexpectedly came a month early. Break-up usually takes the better part of a month to happen and doesn't usually begin happening until late April or May.*

Reindeer herders on the Seward Peninsula noted as early as the 1990s that spring melt seemed to be hastening. James Noyakuk remarked that break-up was generally a faster process than freeze-up, and it was getting even faster. If cloudy, cool weather persisted in spring, the melt might slow, but a spell of sunny days or especially a warm rain could hasten the break-up dramatically. A single spring rainstorm can quickly accomplish what two weeks of mild temperatures might have done. James also pointed out a logistical challenge: if break-up comes earlier than the reindeer calving season, he and other herders can't access certain parts of their range to monitor the herd or protect newborn calves from predators. In 2004, an unexpected early thaw left him unable to drive his snow machine to his herd during calving time. By the time he was able to get back to the herd, some weeks later, he measured the calf-to-cow ratio at only 57%, an indication that a number of calves had been lost to wolf or bear predation.

Communities that rely on ice bridges and winter roads face difficult choices as break-ups creep earlier. In the Northwest Territories, the famous Tuktoyaktuk Winter Road—an ice highway used for decades to connect the Arctic coastal town to the interior—became so unreliable due to shorter winters that authorities built a permanent gravel road in 2017. It was a landmark adaptation, spending hundreds of millions of dollars to replace what nature used to provide for free each winter.

*The all-weather Inuvik–Tuktoyaktuk Highway was opened in 2017. Photo by user Samuell via Wikimedia Commons.*

Similarly, remote villages in Manitoba and Ontario are exploring building all-season land roads or runways because their winter roads now barely stay open long enough to be useful. For now, many are coping by expediting deliveries—as soon as the ice is marginally thick enough, convoys of trucks rush to bring in supplies before the March sun gets too strong. These environmental changes are forcing expensive adaptations for Arctic communities.

In the Arctic, transportation—whether by traditional means like dog sled and reindeer caravan, or modern vehicles like snow machines and trucks—is deeply reliant on the climate and connected to the timing of the seasons. When this timing shifts, the transportation systems, and the people that use them, must adapt. Rivers like the Kuskokwim will continue to freeze during the winter, but the reliability of that freeze can no longer be taken for granted.

Mark Leary of Napaimute has helped plow and mark the Kuskokwim ice road for more than a decade. In 2020, his crew pushed the route to about 571 km (355 mi)—from villages south of Bethel all the way upriver to Sleetmute, a record stretch. Yet other winters tell a different story. The ice has arrived late, vanished early, or broken up in mid-season, as Chuathbaluk's Patricia Yaska witnessed in December 2014. Such unpredictability has become a new fact of travel in the Arctic. The narratives in this chapter offer glimpses of that unpredictability, but also of the resilience of Arctic travelers. Mark concludes:

*What I've observed is we've lost our pattern. There's no reliable seasonal pattern. There's just nothing that we can count on. We don't know from year to year. We just don't know. We watch and observe, and deal with it.*



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*View of the Qorlortup Itinnera sheep farm. All photos in this chapter by Florian Stammler.*

# 7. Caught in the Elements

## Adaptation among Greenland's sheep herders

Agnieszka Gautier

Nearly 20,000 shaggy and plump sheep wander the rolling, verdant, rocky hills of southern Greenland. During the short, mild summers and early autumn season, they forage on tundra grasses. The sheep follow familiar routes from the ice-carved fjords up rugged terrain toward Greenland's thousands-of-meters thick ice sheet, and back. Sure footing is a must for these short-legged and domesticated animals.

But as the Arctic climate warms faster than elsewhere on the planet, rainfall has partially replaced winter snow. When rain freezes into ice on the ground, multiple consequences unfold for the animals, including disrupting their safe access to shelter or to grazing areas that sustain them during cold months. Florian Stammler, an anthropologist and research professor at the University of Lapland in Finland, added, "There is hardly any flat terrain, so sheep have to climb. With the ice, they just slip down the rocks and fall into the fjords and drown. Many sheep herders talk about this."

Stammler spent seven weeks with Greenland's sheep herders in the summer of 2024. As he walked the land with Aaqqioq Kleist, a young herder who runs a sheep farm right in the midst of Norse ruins in the


Qassiarsuk area, he pointed to brown patches in the vegetation. "This is where we had ice last year," said Kleist, who is Kalaallit, an Inuit ethnic group in western and southern Greenland. Inuit herders predominantly practice sheep herding in Greenland, focusing on meat production that prioritizes ewe breeding for lamb meat.

Angutimmarik Hansen, another sheep herder from Nuuk, Greenland's capital and most northerly sheep-herding community, put Kleist's observation into context: "There's now too much rain and ice. We need more snow, because it keeps my fields warmer, protecting the grazing grasses underneath. With all this ice these past winters, my grass dies." Unlike snow, which keeps the fields insulated and warmer, ice suffocates the fragile vegetation beneath. So, the following year, there is less to eat, leading to leaner sheep and ultimately heavy income losses for sheep farmers, who make a significant contribution towards Greenland's agricultural economy.

As Stammler and Kleist continued their stroll, Kleist pointed to other patches in the ground that were completely bare. "These patches were still accessible to the sheep, but the sheep must have been so desperate that they consumed everything down to the roots," Stammler added. Overgrazing in this way results in consecutive years of lost feed, meaning feed and fodder must come from abroad, driving up the cost of meat for consumers.

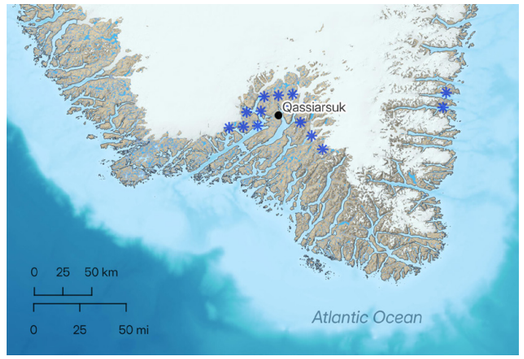
When rain on snow forms a thick layer of ice, sheep not only slip or get caught in the elements, but they are also unable to break past the ice crust to graze on the vegetation beneath the snow, just as with their fellow ruminants, reindeer. In November 2021, snow in South Greenland had already shrouded the ground when heavy rain fell unexpectedly, freezing over the snow. Not all sheep had been corralled into their winter barns, and fetching them across vast, tricky terrain proved nearly impossible in such icy conditions. As a result, hundreds of stranded sheep perished following this rain-on-snow event. Unfortunately, rain-on-snow events are not the only weather concerns that have been frequenting the region since the aughts.

## TOO MUCH SNOW AT THE WRONG TIME

South Greenland is home to approximately 6,300 people, or 11% of Greenland's population, and occupies only the very southern tip of the giant, ice-capped island. Secluded villages and isolated farms dot the valleys between undulating hills. Towering fjords cut deeply into the coastline with few roads carving the landscape. Even all-terrain vehicles (ATVs) and snowmobiles cannot reach certain remote places, so sheep herding—often a group effort—requires horse riding or trekking up to 30 km (19 mi) a day for a week or more to shelter the flock. "The process actually begins in September," Stammler said. "The herders go all the way out to the ice sheet [where sheep have

been in the summer] and bring the sheep closer to the farm to graze before going into the barns." But the unforgiving terrain makes herding impossible when the weather does not cooperate.

For instance, in 2023, an early snowstorm in late October left herders defenseless against an overnight blizzard. No ice crust had formed, but upon waking in the morning, more than one meter (3.3 ft) of snow had fallen. Snow buried the short-statured sheep that had not yet been brought down from mountain pastures. Many suffocated. Stammler said, "It's like if you were on a sinking ship and unable to get out and the water level keeps going up and up. At some point, you can't breathe anymore. It must have been terrible." For those not buried, snow clung to their wool and immobilized them. Hundreds died.




*Potential rain-on-snow events between 27 November and 1 December 2021, as recorded by satellite sensors. Data: Bartsch, A. et al (2023), "Towards longterm records of rain-on-snow events across the Arctic from satellite data," The Cryosphere, 17, 889–915."*

Typically, snow does not arrive in South Greenland until late in winter. The recommended mandate to shelter sheep begins in November, but sizable storms have been arriving earlier. "Right now, the situation is quite extraordinary," said Suulut Hansen, the chairman of the Savaatillit Peqatigiiffiit Suleqatigiissut (SPS), or the Cooperative Sheep Farmers' Associations, Greenland's primary organization representing sheep farmers. SPS was established in 1951 to assist with price negotiations for meat, feed purchases, and communication with authorities while advocating for sheep farmers. Hansen added about the 2023 storm, "I was lucky myself because I was able to take my animals in before it started snowing." As with reindeer herded in northern Europe, the longer the animals stay on natural pastures, the less they need to eat supplemental hay or industrially produced fodder.

For this reason, almost all of Siiku Motzfeldt's flock was in the mountains grazing when the snowstorm hit, on the other side of the fjord in Vatnahverfi, an area even more remote than the main sheep herding area around Qassiarsuk. Motzfeldt had established his farm with his wife in 1988, using just one tractor and an incredible amount of physical labor for literal "field work," which entailed removing all the rocks from fields so that they could grow hay for sheep there. Since then, Motzfeldt became one of Greenland's most respected sheep herders, earning many awards from SPS for his quality breeding work. During the sudden snowstorm in early November 2023, some herders were impacted more than others, but all rallied together. Locals went out on their snowmobiles to make paths for the sheep that were still alive. Sermeq Helicopters, a local helicopter company owned by a relative of a sheep farmer, air-lifted over 50 of Siiku's sheep, who had to watch a sizable part of his flock, which he had built up over 35 years, suffocate under the snow. The helicopter company never expected compensation for this service. "That help was not later compensated



*Sheep on the outskirts of the Qorlortup Itinnera farm. Fenced fields are reserved for hay-making.*

by authorities either," Stammler added. Motzfeldt's spirit of independence and sovereignty, even in the face of such economic loss, resulted in his never asking for any compensation from the government. Two years later, Motzfeldt is still working hard to recover from losing over half his flock of 800 sheep.

When the snowstorm hit, Aaqqioq Kleist was on a business trip in Greenland's capital Nuuk, and could not return on time because of the bad weather. Greenlanders are used to weather-related delays in air traffic, which is critically important in Greenland given the absence of a ground-transportation infrastructure. But, in November 2023, this delay was a death sentence for many of their sheep. Air Greenland, a national air company, also began flying out to rescue sheep by lifting them out of the snowpack and bringing them to the barns. Air Greenland's station manager in Narsarsuaq, Suulut E. Krogh flew out at 9:00 am on November 11—days after the storm came through—to help Eskild Paviasen in Kiattiit, near Qassiarsuk, on the other side of Tunulliarfik Fjord. Sheep do not wear GPS collars, only ear tags differentiate ownership, so searching them required vigilant flyovers. Krogh said,

“We located 100 to 150 sheep and lambs and then used the helicopter to gather the sheep into larger flocks. Seeing sheep and lambs stuck in the snow and many of them dead was not something we were prepared for, but I was very touched by the situation. We were unable to land in several areas due to uneven terrain.” The helicopter then flew further south to assist others.

Stammler noted how this community along with the Nenets herders on the Yamal Peninsula reacted similarly in the face of disaster. “There was a sudden and unconditional social cohesion in the community that is way above what you would expect,” Stammler said. It did not matter whose animal was whose, the objective was to save as many animals as possible. As Joorut Knudsen, a sheep farmer on the island of Sammisoq near the village of Qassiarsuk, pointed out, “If I find animals in the snow that are not mine, I will try to take them home to the barn anyway.” Knudsen lost 50 of his 400 sheep. Others like Hansen fared better because they had already sheltered their sheep before the storm, but the unexpected and extreme weather events keep coming. “The seasons here have been very difficult lately,” said Magnus Hansen from Tasilikulooq, south of Qassiarsuk, with a flock of 500 sheep. Already a decade ago, his average sheep was two to four pounds lighter than normal. “Hot summers [since the 2000s] have cost me thousands of dollars in losses,” he added.

Whether it is rain on snow or heavy, wet snow, the impacts can be profound. This new norm does not allow enough foresight for making the best decisions. Often herders are left to gamble with the well-being of their flock and hence their livelihood.

*The Norse ruins, together with contemporary Inuit farming, comprise the Kujataa UNESCO World Heritage Site. Here, the Qorlortup Itinnera farm is in the background.*

*Left: Making hay involves removing rocks to prepare the ground for planting.*

*Right: Hay bales and imported fodder are stored indoors for winter usage.*

## A RICH, BORROWED HISTORY MADE NEW

Sheep herding in southern Greenland has a rich and proud history. Most southern Greenlanders are Inuit, speaking Kalaallisut or Greenlandic, which is closely related to Inuktitut spoken in Canada. Sheep herding began with the Vikings, who named the island Greenland to entice more settlers to come. Exiled for murder, Erik the Red first crossed the northern Atlantic Ocean from Iceland to southern Greenland in 985, bringing the initial Norse settlers. At about the same time, Inuit traveled from northern Greenland down the western coast. As a pastoral culture, the Norse quickly introduced cows, pigs, horses, and sheep to the world’s largest island. The Norse thrived in the harsh terrain, with a short growing season and brutal winter, for over 500 years but then vanished, leaving behind a foundation of sturdy stone manors and churches in almost every fjord and valley, and within the steep mountains.

To this day, no single theory explains why the Norse disappeared from Greenland, but while they vanished, the Inuit survived. One dominant difference between the cultures was the Inuit’s hunting technology and thus greater accessibility to diverse marine food sources when drought and colder weather persisted for decades.

In the late eighteenth century, Inuit Greenlanders began experimenting with agriculture in and around the foundations of abandoned Norse farms. In 1906, Pastor Jens Chemnitz introduced sheep from the Faroe Islands, just like the Norse had introduced them nearly a thousand years earlier. Then, in 1924, Otto Frederiksen reestablished a modern full-time sheep farming community at Qassiarsuk, the original site of Erik the Red’s farm complex, Brattahlíð. At its peak, 60 farms herded sheep for wool and meat production, shrinking to

*Tupaarnaq and Aaqqioq Kleist at the 100-year celebration of sheep farming in the Qassiarsuk area. Photo by Florian Stammler.*

less than 40 farms today. More than half are in the Narsaq district while others are scattered over hundreds of kilometers. Each farmer owns between 400 and 800 sheep. Individual families run these farms, contributing to Greenland's agricultural income, of which sheep meat and wool production make up 80%. Even more striking is that sheep account for 99% of Greenland's farmed meat, which does not get exported because of at-home demand. In 2017, the United Nations Educational, Scientific and Cultural Organization (UNESCO) recognized the history of Viking and Inuit farming in this Arctic region, naming Kujataa, an area that includes the towns of Qassiarsuk, Igaliku, Sissarluttoq, Tasikuluulik, and Qaqortukulooq, as a World Heritage Site. Aaqqioq Kleist and his wife Tupaarnaq have their farm in the middle of this site, and Norse ruins are scattered across their contemporary hay fields.

Inuit sheep herders who live in southern Greenland differ in their cultural practices from Inuit in western and northern Greenland, who for the most part do not farm. Present-day Inuit herders first learned about rain-on-snow events from their parents' and grandparents' experiences. During the 1966/67 and 1971/72 winters, highly unpredictable weather patterns hit coastal Greenland, killing as many as two thirds of the then 45,000 total herd. To avoid potential future catastrophes, an agricultural reform mandated the stabling of sheep for seven months starting November first, requiring shelters to be built to protect the sheep from harsher weather. As South Greenland has no local lumber supply to build barns, fences, and corrals, all materials needed to be shipped in. Although it took time to get the barns up, the stabling, borrowed from European practices, was a systemic change that became an effective strategy to adapt to extreme weather events and improve animal welfare in winter.



## EXPECTING THE UNEXPECTED

Now, the climate is shifting even more dramatically. "They're having hotter summers, longer autumns, snow coming later, more snow at difficult times, rain on snow, extreme snow. So, everything's going on in ways that people aren't used to," said Bruce Forbes, another research professor. "It's beyond what they've heard from their own families and oral histories." Unexpected weather fluctuations put added pressure on an already delicate practice. As Aaqqioq's wife Tupaarnaq Kreutzmann Kleist said, "Sheep farming is very dependent on the weather in Greenland. It's very vulnerable."

Drought has become an ongoing issue in recent times. As a side note, this is one theory as to why the Norse abandoned their farms in the 15th century as decades-long drought persisted that later peaked in the 16th century. Several severe droughts struck Greenland beginning in 2008, with 2015 being quite exceptional—there was no rain for over two months that summer. Another sheep farmer from the Qassiarsuk region, Joorut Knudsen, observed that droughts typically begin in June. Hay harvest begins in August, but the impacts of months of dry weather result in smaller yields. "It is normally excellent when we can get up to 200 bales [with drought], but when there is no drought, we can get up to 400 bales," Knudsen said. Bad drought years can cut hay production by 50%. "It is tiring when [drought] repeats itself in consecutive years," Knudsen said, as happened in 2010, 2011, and 2012. When hay yields drop, sheep farmers depend on concentrated feed, requiring larger imports and bigger costs. Mâse Kanutsen, a SPS board member, said, "Sheep farmers are paying more than twice as much for fertilizer and feed than they did [a year ago in 2021]." This increase in costs for feed and fertilizer is closely related to the geopolitical situation in Europe where most of the raw materials continue to be sourced and with costs more than doubling within one year, many sheep farmers are struggling.

In South Greenland, farming is a family business, where individual land ownership does not exist. Since children cannot inherit the land, farmers apply for plots that in turn become mutual agreements. The Greenlandic government does provide subsidies for starting or expanding sheep farms, developing infrastructure, including slaughterhouse operations, buying fertilizer, fodder, or equipment, and growing hay to feed the sheep, yet families still struggle.


Dramatic weather events are on the rise in Greenland, and throughout the Arctic. “We might be at a tipping point, which you can’t tell when you’re standing there,” Forbes said. With the hotter summers, pastures dry out and hay production drops. Some farmers can irrigate their pastures and hayfields, but smaller farms tend to be hit the hardest. Sheep herder Miki Egede, who has one of the largest farms near Igaliku, said, “Our incomes just haven’t been able to keep up with the overall increase of our expenses in the form of fertilizers, fodder for the animals, and everyday items.”

Low-interest loans, often taken out to support the farmers, get passed on to the next generation. Many children inherit debt to maintain the family farms, needing to work hard to come out on top. Stammler added, “Even with government subsidies, it is not like they can lay down and have a quiet, relaxing life. They are incredibly tough people, very innovative and it’s amazing to witness.” As the climate teeters between too little and too much precipitation, irrigation systems are being expanded to draw from freshwater lakes and ponds, but these systems vary greatly in type and technical sophistication and effectiveness.

Seeking financial stability, most sheep herders have outside jobs or are diversifying their operations with agritourism. Some sheep herders like the Kleists are looking at alternatives to making a profit. Tupaarnaq is a huge proponent of expanding wool and pelt production from sheared sheep, although there is currently no way to process the wool on a large scale. “We would like to start wool production here in Greenland,” Kleist said. “I see the business of it. I see opportunities of it. I see a dream. I see a vision of it.” That’s because spring shearing can produce up to 24 tons of wool. Some is used to create small marketable products, or for family needs, but for the most part the wool is burned. As the climate becomes more unpredictable, innovation may be the best path toward adaptability. Time and again people in this region have been open to experimentation and innovation, including developing a cattle ranch, reindeer herds, and even a small-scale experiment in herding muskox. “Greenlanders are very good at seeing new opportunities,” said Aleqa Hammond, the country’s former prime minister. “We simply refuse to be victimized due to climate change. I am very optimistic. I see more positive options for the country than negatives. I wish that it wasn’t happening, but it is and that’s a fact. Once it’s there you have an obligation to do the best out of it.”



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*Observers in southeast Alaska use GPS tools to log vital data for the Anadromous Waters Catalog (AWC). The integration of technology empowers communities to drive data collection and support sustainable fisheries management. Photo via Lee House.*

# 8. The Numbers We Gather

## Citizen observer networks across the Arctic

Mike Brook

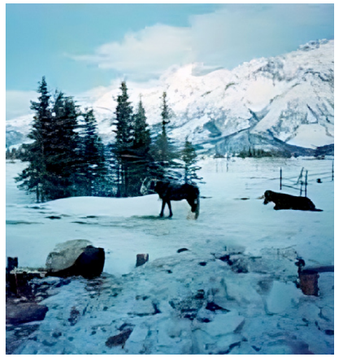
*Traffic sputtered to a stop last night. Started raining yesterday afternoon and rained sporadically through the night. We have ice rinks this morning. Rain in the winter. First time I saw that occur was January 1982. The horse range was overrun with rabbits. Within a week once the cold came back they were all gone. The death rain took ptarmigan, birds, moose, and sheep. We lost six horses in spite of my best efforts.*

*– Wilson Justin, 19 November 2018*

Wilson Justin, an Elder from Chistochina, Alaska, is a long-time member of the Local Environmental Observer (LEO) Network, a citizen observing network based in Anchorage. LEO invites its members to post observations of unusual environmental events, things that seem amiss, out of place, or unexpected. Wilson's observation is one of an unusual weather phenomenon—winter rain.

Winter rain would not be unusual in some places, but by late November in Chistochina the temperature typically stays below –10°C (14°F).

Not only is rain highly unusual, but it is also certain to refreeze, as Wilson observes. Sporadic rain overnight leads to “ice rinks” in the morning. In addition to his observation of unusual winter rains in November of 2018, Wilson Justin connects the event to the past, in this case nearly four decades in the past, when he first experienced an event like this, and what it meant to the wildlife in the area, to food sources, and to his horses.



*Left: Horses bedding down for the night near the Nabesna River, Alaska. Photo by Wilson Justin.*

*Right: Black dots on the map indicate locations mentioned throughout this chapter; red dots on the inset show rain-on-snow observations contributed to the LEO Network.*

Residents of the Arctic are often keen observers of the weather and its impacts. As Wilson demonstrates, unexpected or extreme weather events can influence the livelihoods, safety, travel, and food security of those that live in the Arctic.

Observing is not a new phenomenon in the Arctic, but in the last few decades a number of “observer networks” have arisen to give residents of the Arctic a way to share information beyond their immediate families and communities. This chapter explores three such networks, each of which brings a unique take on the goal of observing and understanding the changing environment of the Arctic.

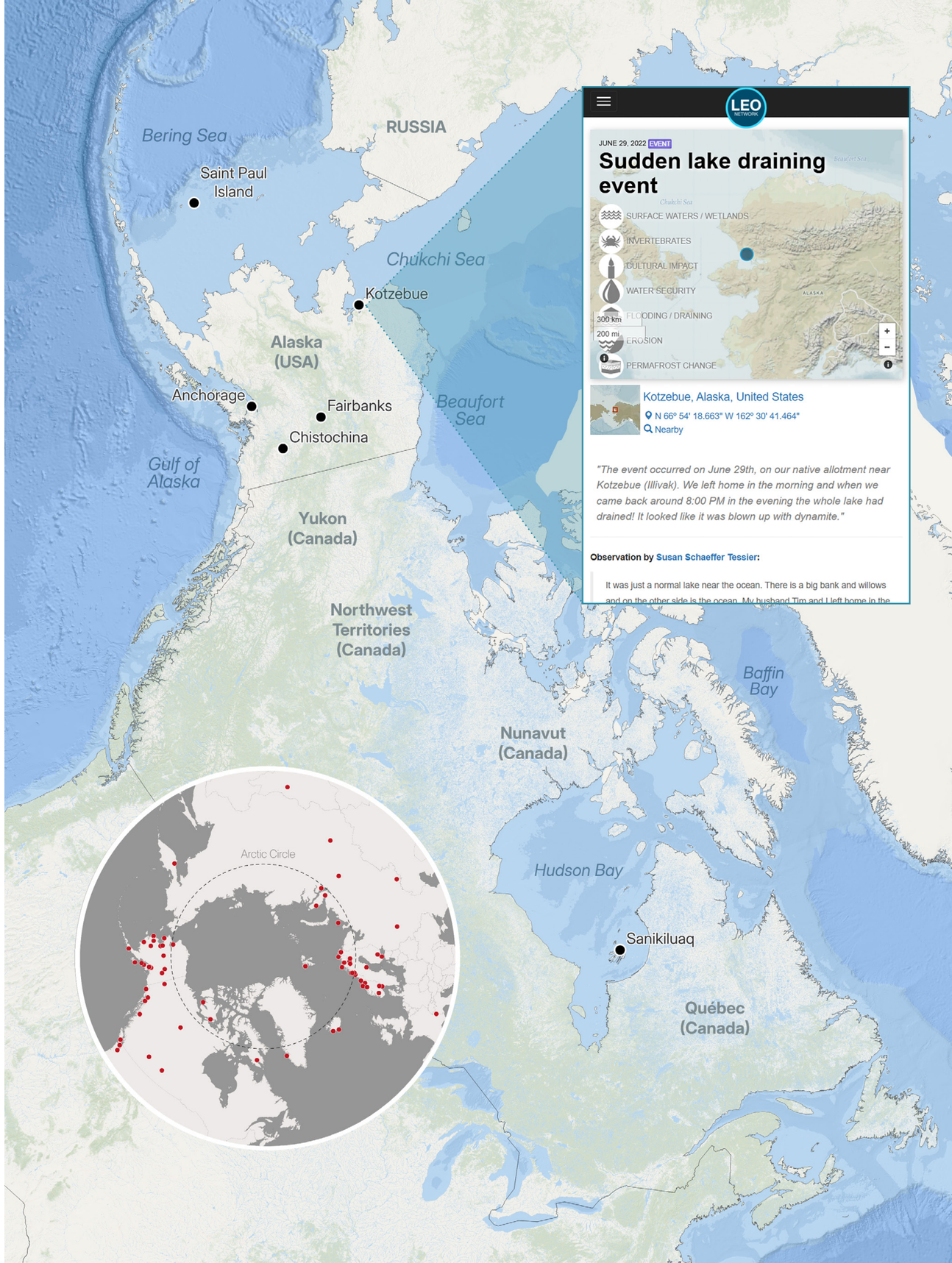
## LOCAL ENVIRONMENTAL OBSERVER (LEO) NETWORK

The LEO Network was founded in 2012 so that observers like Wilson Justin would have a place to post and collect their observations of the changing environment of Alaska. Since its founding, its database and online user interface have been adopted in over 50 countries, including all Arctic nations. By design, the LEO Network is open ended and inclusive: if an observer considers an environmental event or phenomenon to be unusual or unexpected, it is appropriate for inclusion in the Network.

All posts made to the LEO Network are coded by geographical location and time, as well as tagged using a vocabulary that captures some of the nuances of the observation. This tagging vocabulary is helpful for ascertaining which observations are relevant to specific phenomena, such as rain on snow. As of the end of 2024, Wilson Justin’s observation about winter rain is one of approximately 100 LEO observations that touch on this phenomenon.

The LEO tagging system also helps to shed light on the significance of observed events. Since LEO observers are generally not professional scientists, they are typically making observations during their daily lives. This makes it natural to connect observed events with the





*A small lake on the Tessier property outside Kotzebue, Alaska drained in a matter of hours in June, 2022. The observation and follow-up discussion was captured in the LEO Network. Photo by Susan Tessier.*

impact that those events have on the lives of the observers, their families, and their communities. As an example, Wilson's post about winter rain clearly alludes to at least three such impacts. One is a transportation impact ("traffic sputtered to a stop"), another is a potential food security impact ("rain took ptarmigan, birds, moose, and sheep"), and a third pertains to livestock ("we lost six horses"). Surveying the LEO Network in its entirety for rain-on-snow events, we find that some of the top human impacts of such events are on transportation, human health and safety, building and infrastructure, and food security.

Citizen observers are uniquely qualified to draw these connections between direct observations of events and second-order impacts of these events. Furthermore, citizen observers are likely to be in the right place at the right time. Consider the case of Susan Tessier of Kotzebue, Alaska. She lives with her husband Tim about 5 km (3 mi) north of Kotzebue. For many years, they would get their wintertime drinking water by cutting ice from a small lake on their property that was situated in permafrost near the coastline. But in June 2022, the lake shockingly and rapidly vanished. According to Susan:

> *My husband Tim and I left home in the morning and when we came back around 8:00 in the evening the whole lake had drained! There was a hole that had blown out and it had drained into the ocean.*

Needless to say, this was an unexpected event, and it led to a fascinating collaboration that is documented on the LEO Network. Susan reported her observation to the LEO Network through its website, along with a number of photos, background information, and intriguing anecdotes such as this one:

> *We were surprised to see a lot of little shrimp at the bottom, that were living in the bottom of the lake. The ducks have been eating them. We had a muskox that came in that was curious and then a bear that walked all through the mud and left tracks. The pond has become quite an attraction for the animals.*

A number of scientists, geographers, and Indigenous Knowledge holders subsequently engaged with Susan's observation, each offering their own expertise and perspective. This comment, added to LEO by Ben Jones, a researcher at the University of Alaska Fairbanks, is indicative of the reaction to the event on Susan and Tim's property:

> *The photo from yesterday is incredible. It's a window into the past and a great opportunity to study the permafrost that is exposed there. Oftentimes we don't discover lake drainage events until a year or two afterwards which limits our understanding of the processes involved. It's awesome to have such first hand observations.*

Susan did not set out that day to perform a scientific observation. Furthermore, there was no ongoing program of scientific monitoring that could plausibly have detected what she witnessed. Despite that, a rare and important observation was made—and one that had a significant impact on the life of her family.

Citizen observers like Wilson Justin and Susan Tessier have the triple advantages of location, awareness, and context: They are able to make observations in places that others can't; they are keenly attuned to noteworthy phenomena around them; and they have a strong sense of why a phenomenon and its impacts are important to them, their families, and their communities.

## THE INDIGENOUS SENTINELS NETWORK (ISN)

LEO observations, by definition, are serendipitous, but citizen observing doesn't have to work that way. The Indigenous Sentinels Network (ISN), a program founded by the Aleut Community of Saint Paul Island's Tribal Government, has been active since the early 2000s. Located in the heart of the Bering Sea, Saint Paul Island is one of the most remote communities in Alaska and home to a long tradition of environmental stewardship. ISN began humbly—using field notebooks to record subsistence and ecosystem data—and has since grown into an online, statewide network supporting community-driven environmental monitoring across coastal and interior regions

of Alaska. Today, ISN supports a range of community observers or "Indigenous Sentinels," Tribes, and organizations with tools for structured, longterm data collection rooted in both Western science and Indigenous Knowledge systems. The platform's tools include mobile applications, online privacy-protected databases and dashboards, and customizable protocols, all developed and governed under Tribal authority. According to ISN's program description:

> *ISN is a platform that enables ecological data collection in a standardized way based on tested protocols while also being rooted in Indigenous and Traditional Knowledge, to produce credible and actionable insights that address needs and priorities as varied and diverse as the communities that are part of the Indigenous Sentinels Network.*

In addition to offering tools, ISN builds capacity, trust, and infrastructure for Tribally-led environmental governance. Its model is based on two core principles. First is knowledge pluralism, or the recognition that Traditional Knowledge and Western science are not competing frameworks, but rather complementary ways of knowing. And second is community sovereignty and consent, or the recognition that tools must be designed with and for the community; otherwise, data collection efforts will falter.

As Lauren Divine, ISN Co-Founder, explained during a presentation from 2020:

> *We don't implement surveys in areas where our hunters, including our elders, haven't told us the area is important. Monitoring should begin where knowledge already exists.*

One of ISN's technical strengths lies in its Tribally-owned and customizable software infrastructure, which enables communities to create and manage their own monitoring programs. Communities using the ISN Observer App can deploy survey and data collection forms tailored to priorities such as springtime green-up, fisheries harvests, marine mammal monitoring, coastal erosion, or rat prevention. These tools are accessible from remote island villages to fishing vessels in the Gulf of Alaska. "We wanted to make sure communities could track what matters to them, in a way that is useful to them," said ISN Program Director Hannah-Marie Ladd. "That means we build flexibility into everything—from the questions they ask to how data is accessed, shared, or not shared." Communities not only control what they track, but also how and when data leave their control. These protections are critical in an era where extractive data practices have often ignored Tribal consent or failed to return value to communities.

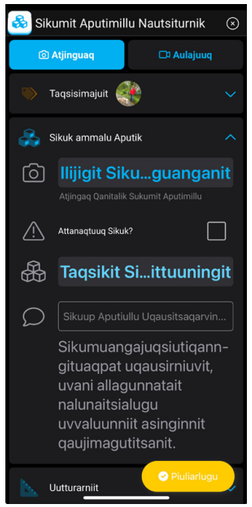
Across Alaska, the environment is transforming quickly. In the Bering Sea region, concerns might center on fisheries management and subsistence resources, like northern fur seal health; in the Yukon, on



*A group of four Sentinels and two NOAA National Marine Fishery Services (NMFS) officials conduct surveys on Northern Fur Seal rookeries on Saint Paul Island. They monitor population numbers and search for entanglements as part of a co-management agreement to protect this vital marine species. Photo by Hannah-Marie Ladd.*

permafrost and river ice; and in the southeast, on shellfish toxicity or invasive species. ISN helps communities create systems that respond in real time to climate disruptions, cultural priorities, and policy needs. As one Sentinel from the Pribilof Islands remarked:

> *We are not just data collectors. We're stewards. The numbers we gather—those are stories. They help us protect our home.*




*Above: The SIKU mobile app shown with Inuktut as the selected language, one of numerous Indigenous language available.*

*Left: An observer logs data into the Anadromous Waters Catalog (AWC) while surveying a stream in southcentral Alaska. The AWC plays a crucial role in monitoring fish habitats, with the Fish Map App powered by ISN enhancing data collection and supporting sustainable fisheries habitat. Photo via Lee House.*

**SIKU NETWORK**

Across the continent on the eastern side of North America, the SIKU Network in Nunavut, Canada, has rapidly grown to more than 29,000 members across more than 129 northern Inuit, Cree, and Innu communities. This success is partly due to SIKU (named for the Inuit term for "sea ice") having a number of unique aspects that set it apart from other observer networks.

First, SIKU places a high value on Indigenous languages. An important part of SIKU expanding to new communities across the Arctic, be they in Canada or elsewhere, is that the SIKU website and mobile app is translated into the languages that are most commonly used there. This includes translation of place names, vocabulary such as names for snow, ice, and wildlife, and also translation of the user interface that observers use to interact with the SIKU network.

In an interview, the SIKU team expressed that one common entry point for members is to simply use the SIKU mobile app for its mapping capabilities, with place names in local languages. In many parts of the Arctic the SIKU app is literally the only app that provides functionality translated into local languages, so it is a uniquely valuable resource for people that live there.

Another noteworthy aspect of the SIKU Network is its focus on social networking mechanics. The slogan for SIKU is "The Indigenous Knowledge Social Network." This is apparent in the SIKU mobile app, where in addition to making observations with quantitative scientific measurements, there's also an opportunity for users to add so-called "Social Posts." A Social Post can contain narrative, photos, and videos and is geo- and time-coded—but it doesn't contain any other data associated with it. In short, it doesn't feel like a scientific observation; it feels like a friendly, personal update. Contrast this with other types of posts that are available to make via the SIKU app. For example, a wildlife observation post might have photos and narrative, but it might also have information about the number of animals observed, their apparent ages, sexes, body conditions, and surroundings.

Another unique type of SIKU post is known as a "Trip Post." A Trip Post tracks the user via his or her mobile phone's GPS while traveling via vehicle or on foot. The user is allowed to annotate various parts of the trip with notes and to make other kinds of posts from within the trip. According to the SIKU team, this is a feature that many users find personally beneficial and use frequently for tracking their own travels. Particularly in light of the seasonal differences in travel in the North because of frozen rivers and sea ice, the ability to track one's path is clearly very valuable.

SIKU's own documentation emphasizes that making a tool that is valuable to people across the Arctic is a key goal of theirs, even more so than contributing to data gathering projects:

> *Because of its unique approach to prioritize daily tools and services for Indigenous land users and harvesters ahead of project needs, SIKU is accessible for everyday use and puts full access, control, and data-ownership directly into the hands of users.*

SIKU's approach to data privacy and sovereignty is especially well thought out. Every post has a set of options that allow the observer to granularly specify how that post may be used. For example, for posts that are geo-tagged, the user is able to specify whether the location is visible by others seeing the post, whether it's hidden or whether it's visible but obscured behind an approximation. And similar to other social networks, users may specify privacy settings for their posts: from anyone on SIKU being allowed to view a post, to only users that are explicitly tagged in a post, or administrators of projects that are explicitly tagged in a post. And when it comes to data ownership, SIKU is unambiguous and straightforward: users own their own data.

Like the Indigenous Sentinels Network, SIKU seeks to be a resource for communities in the North, and is welcoming of communities establishing their own monitoring projects that use the Network. Projects may also be established by other organizations, and users may request to join projects near them. By joining a project, a user is expressing a willingness to share posts and data with the administrators of that project. While payment for participation is not a requirement within the SIKU Network, some projects have offered honoraria to SIKU members that participate in them.

SIKU is a fascinating take on citizen observation, with a number of nuances that increase its appeal to users and increase the quantity and quality of data gathered via the platform. In a case study published in SIKU's 2024 annual report, a community-led monitoring initiative in Sanikiluaq, Nunavut, led to a unique and compelling dataset. The goal of the initiative was "to take a whole-of-community approach to crowd-sourcing a resource inventory for the Qikiqtait Protected Area." In addition to gathering an important, detailed dataset on food sources such as fish and berries, perhaps most impressive is the level of engagement from citizens in the region. According to their report, in a region of roughly a thousand residents, 241 people posted into this project with a total of over 7,000 posts. The SIKU Network has clearly found a unique and compelling formula for motivating people to participate in citizen observing initiatives.

## STEWARDING INDIGENOUS KNOWLEDGE

The three networks discussed here were chosen because they provide very different models for how to run an observer network in the Arctic. The LEO Network is open-ended and serendipitous, focusing on unusual environmental events and connecting observers directly with topic experts. The Indigenous Sentinels Network is highly structured and protocol-driven, with a strong community focus. The SIKU Network incorporates aspects of both of those, while adding unique social media-like features and user-focused tools that motivate users to engage with the platform and participate in observing projects.

What all three networks have in common, however, is an important place for Indigenous Knowledge—also known as Traditional Ecological Knowledge or Indigenous Environmental Knowledge. Mike Brubaker, one of the founders of the LEO Network, described how Indigenous Knowledge came to be a central part of LEO:

> *It started by talking to people about what they were experiencing, and being impressed by the nuance of observation. In Alaska Native communities, people are so familiar with their environment and with their resources that they can identify very subtle changes. And so that kind of drove a hypothesis that people are good observers, they're good at noticing change. And so there was the value of being able to benefit from the knowledge of local and Traditional Knowledge holders as sentinels for change, and being able to share that as something of an early warning system.*

For its part, the Indigenous Sentinels Network recognizes Indigenous Knowledge as a key input to all of its other activities. In a 2020 presentation, Lauren Divine described how knowledge from Elders is incorporated into the ISN methodology:

> *We are not implementing surveys for a particular marine mammal in areas where our hunters, including our Elders, have not told us that the area is important. More recently with coastal erosion monitoring sites, we went directly to people in the community that have lived their entire lives on Saint Paul, and we asked them where they have seen the most change and that's where we prioritized our monitoring efforts.*

*Coastal erosion monitoring in Golovin, Alaska, captures the impact of environmental change on the shoreline. Photo by Hannah-Marie Ladd.*

Joel Heath, one of the founders of the SIKU Network, wrote about a time in 2002 in which it became clear that the knowledge of hunters and elders was lost to the scientific community, and that a concerted effort would be needed to "mobilize Indigenous Knowledge at scale across the North:"

> *The ice edges were littered with carcasses of dead ducks that had frozen into the advancing ice. The Inuit leading the expedition, active hunters from the community—Simeonie Kavik, Elijah Oquaituk and Lucassie Ippak—turned to the biologists and said, "This is what we've been telling you about. In the early 1990s, one of our elders noticed that there were as many dead eiders on the ice as there was gravel on the beach." The hunters and elders of Sanikiluaq had alerted the Canadian authorities at the time, but the phenomenon escaped the attention of the scientific community.*

Rain-on-snow phenomena are likely to become more frequent in the Arctic, and citizen observing networks will be an important part of understanding where and when they occur, and also understanding the impacts that they have on the people that live in the North. Rain-on-snow events may be subtle. Whereas snow may be falling at higher elevations, rain may be falling at lower elevations, with a mixture in the middle; rain may form an ice layer on the open tundra but not have the same effect when sheltered by trees. There really is no substitute for a keen observer on the ground that understands the implications of what is being observed. And when that person observes something of interest, there really is no substitute for a citizen observing network that is welcoming to that person's observation.

It's difficult to know exactly how many citizen observing networks are active in the Arctic. A number of directories have emerged attempting to track active citizen science projects and networks, and to encourage participation in them. Unfortunately, it's difficult for them to be authoritative and kept up to date, and they frequently have gaps in their information. Nonetheless, the three networks profiled here are clearly part of a much broader—and rapidly growing—mosaic of citizen observing initiatives across the Arctic. Some active networks leverage communities of interest in observing, such as the way that Community Snow Observations (CSO) crowdsources snow-depth measurements from back-country travelers. Other networks, such as SmartICE, employ specialized monitoring equipment, including SmartBUOYs for measuring ice conditions. Community-based observing networks, such as the Alaska Arctic Observatory and Knowledge Hub (AAOKH) and Sea Ice for Walrus Outlook (SIWO), focus on addressing community-defined priorities and engage paid, regular observers who are recruited for their expertise. While some networks span the Arctic, others, such as Community Observation Network for Adaptation and Security (CONAS) focus on a handful of individual communities, in this case on both the Russian and U.S. side of the Bering Sea. And while some networks cover many species and phenomena, others focus on just one, such as the seabird focus of COASST, the Coastal Observation and Seabird Survey Team. Collectively, such initiatives broaden the spatial and thematic coverage of citizen observations—from snowpack and sea ice to wildlife, seabirds, and coastal change—while reaffirming that locally grounded knowledge is indispensable for tracking and responding to a warming Arctic.

Citizen observer networks in the Arctic are not just about data collection; they are about empowering communities, preserving Indigenous Knowledge, and fostering collaboration between locals and scientists. By valuing the observations and experiences of those who live closest to the land, these networks provide critical insights into environmental changes that might otherwise go unnoticed.

## Endnotes


*The following sources were referenced throughout this chapter:*

*Interview with Mike Brubaker*

*Interview with Joel Heath, Billy Nicoll, and Kassina Ryder, SIKU Network*

*Environmental observation, social media, and One Health action: A description of the Local Environmental Observer (LEO) Network / Emily Mosites, et al / 2018 / One Health*

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*SmartICE Monitoring & Information / smartice.org*

*COASST – Coastal Observation and Seabird Survey Team / coasst.org*

*Sea Ice for Walrus Outlook / aoos.org*

*Alaska Arctic Observatory & Knowledge Hub (AAOKH) / arctic-aok.org*

*Whispers Wispy and Wishful / Wilson Justin / www.nps.gov*

*Our Wednesday editorial meeting underway: "Please wait, the meeting host will let you in soon." (Windswept cats on Saint Paul Island, Alaska.) Photo by Irina Wang.*

# About the Editors

**Mike Brook** is a data scientist at the Alaska Native Tribal Health Consortium, developing data systems that support Tribal public health decision-making across Alaska, with a focus on climate-related health risks, water and sanitation access, and care delivery in remote communities. Since 2014, Mike has been the lead software developer for the Local Environmental Observer (LEO) Network.

**Philip Burgess** has worked for two decades on issues related to traditional livelihoods, particularly reindeer herding across Sápmi and beyond. His work has focused on how this livelihood has adapted to the multiple challenges it faces in the region and steps that herders have taken—along with their animals—to continue thriving across the Arctic. Philip loves maps and stories, especially in combination. He is currently working at the Arctic Centre, University of Lapland, Finland.

**Matthew L. Druckenmiller** is a senior scientist at the National Snow and Ice Data Center at the University of Colorado Boulder. Since 2004, Matthew has collaborated with Indigenous communities to document and understand the implications of climate change on community hunting and travel, marine mammals, and seabirds. He has led efforts to coordinate local observer programs and develop community-based data management systems.

**Mark Serreze** is a distinguished professor of geography at the University of Colorado Boulder and director of the National Snow and Ice Data Center. He specializes in Arctic climate research, including atmosphere-sea ice interactions, synoptic climatology, numerical weather prediction, climate change, and extreme weather events. Mark has conducted extensive field work, testified before the U.S. Congress, and is a frequent media contact on issues of climate change.

**Betsy Sheffield** is a senior research assistant and project manager at the National Snow and Ice Data Center. With a background in geology and environmental studies and an interest in health and food security, Betsy brings passion for people and problem solving to her role. She has provided many years of support experience to research projects focusing on the Arctic and Antarctic at NSIDC, notably the Arctic Rain on Snow Study through which this book was published.

**Irina V. Wang** is a designer and researcher practicing the creative work of cross-sector translation, the strategic work of systems transition, and the ethical work of forging allyship. At the intersection of existential risk and structural injustice, Irina's work spans equitable carbon sequestration, Indigenous language sovereignty, circular energy/food systems, stakeholder policymaking, more-than-human ethics, and global security architecture. <irinavw.xyz>

# Acknowledgments

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*A light dusting of snow on Saint Paul Island, Alaska. Photo by Irina Wang.*