TOOL- KIT FOR SCHOOLS

BACKGROUND MATERIAL FOR TEACHERS

ARCTIC ISSUES: GLACIERS

WHAT WILL YOU FIND HERE?

GLACIERS IN A NUTSHELL

BASIC FACTS:

What are glaciers?

How are they formed, what’s their anatomy?

Where can we find them, are they all the same?

How does climate change affect glaciers?

What does ‘mass balance of glacier’ mean?

RESEARCH METHODS:

How do scientists study glaciers?

What can we learn from glaciers?

ADVANCED MATERIAL:

Post-glacial rebound

Underwater walls protecting the glaciers?

Glaciovolcanoes: mountains of fire and ice

5 FUN FACTS ABOUT GLACIERS

How to spot a “fake” glacier ice?

Can ice be warm?

Why are glaciers blue?

Was Mr. Iceman cold-hearted?

Meet the ice worms!

RECOMMENDED LITERATURE:

Glacial geomorphological mapping: A review of approaches and frameworks for best practice

The future of Asia's glaciers - "NATURE"

Glaciers – Glaciers - online glossary with photosglossary with photos

ARCTIC ISSUES:
GLACIERS TOOL-KIT FOR SCHOOLS

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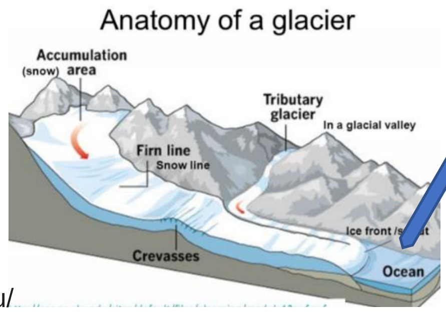
BASIC FACTS

GLACIERS IN A NUTSHELL

WHAT ARE GLACIERS?

Glaciers form only on land and are distinct from the much thinner sea ice and lake ice that form on the surface of bodies of water.
Proper glaciers must be a minimum of 1 square kilometers – nearly 19 football field!
Elements of glaciers:
The equilibrium line (ELA, also known as firn/snow line) marks the boundary between the zones of accumulation and ablation.



https://ees.as.uky.edu/

The terminus is the lowest end of a glacier.

Below the **equilibrium line**, in the zone of melting, bare ice is exposed because last winter's snow has all melted; above that line, the ice is still mostly covered with snow from last winter.
The accumulation (input) zone is where a glacier gains snow and ice through snowfall and compression. Ice begins to flow like a conveyor belt, driven by gravity and ever mounting snows.
In the lower region, or ablation (output) zone, the glacier loses ice through melting and evaporation. Older ice is carried down to greater and greater depth.

Types of Glaciers: **continental glaciers, ice caps, piedmont glaciers and valley glaciers.**

⇒ The continental glaciers are found in the Antarctica and Arctic
⇒ Ice caps are the covers of snow and ice on mountains from which the valley or mountain glaciers originate.
⇒ The piedmont glaciers form a continuous ice sheet at the base of mountains as in southern Alaska.
⇒ The valley glaciers, also known as Alpine glaciers, are found in higher regions of the Himalayas in our country and all such high mountain ranges of the world.

TIDEWATER GLACIERS - glaciers that flow out into the sea
TRIBUTARY GLACIERS - merges into a larger glacier, called trunk glacier, and often contributes mass to this trunk glacier from its separate accumulation basin.
ICE FALL - a glacier that is characterized by rapid flow and a highly crevassed surface.

WHERE CAN WE FIND THEM?

Glaciers are found in **47 countries**. Glaciers can be found **on every continent, except Australia.**
While most are situated near the Earth's poles, in Antarctica and near Greenland, many can be found close to the equator, including Mexico.
Though it sits on the equator, Mount Kilimanjaro is glaciated.

Kilimanjaro

ARE GLACIERS USED BY HUMANS?

Glaciers provide drinking water - About three-quarters of Earth's freshwater is stored in glaciers. In Washington state, 75% of water used in agriculture and human consumption comes from glaciers . Also, many rivers e.g. in Asia are fed with riverflow from glaciers. The Rhine and Rhone rivers in Europe start as glacial meltwater

Glaciers irrigate crops - In Switzerland's Rhone Valley, farmers have irrigated their crops for hundreds of years by channeling meltwater from glaciers to their fields.

Glaciers help generate hydroelectric power - Scientists and engineers in Norway, central Europe, Canada, New Zealand, and South America have worked together to tap into glacial resources, using electricity that has been generated in part by damming glacial meltwater.

WHAT IS MASS BALANCE OF GLACIERS?

Mass balance (glacier budget) is simply the gain and loss of ice from the glacier system. A glacier is the product of how much mass it receives and how much it loses by melting. The span of time is often a year or a season. A seasonal mass balance is nearly always either a winter balance or a summer balance
mass loss (ablation) from all processes by which snow and ice are lost from the glacier, such as melting, sublimation (ice changes into water vapor without first becoming liquid), wind erosion, avalanches, and ice flow into the sea
mass gain (accumulation) from all processes that add snow or ice to a glacier, such as snow fall, condensation, avalanching, wind transport, and freezing of liquid water.
A glacier with a **positive mass balance** in a particular year gained more mass through accumulation than was lost through ablation. **Negative mass balance** is an opposite case.

HOW ARE THEY FORMED?

A glacier is formed by an accumulation of snow that is greater than loss of snow from melting and evaporation. Many years, sometimes hundreds of years, may be required to produce a new glacier if conditions are right.
This compression forces the snow to re-crystallize, forming grains similar in size and shape to grains of sugar. Gradually the grains grow larger and the air pockets between the grains get smaller, causing the snow to slowly compact and increase in density. After about two winters, the snow turns into **firn—an intermediate state between snow and glacier ice**. At this point, it is about two-thirds as dense as water. Over time, larger ice crystals become so compressed that any air pockets between them are very tiny.

1. mean annual temperatures are close to the freezing point
2. winter precipitation produces significant accumulations of snow
3. temperatures throughout the rest of the year do not result in the complete loss of the previous winter's snow accumulation

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GLACIERS

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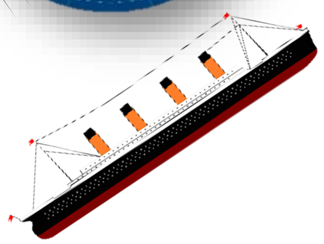
ARE GLACI ERS ALWAYS VERY COLD?

Not really - most of the glacier ice is only a few tenths of a degree below the melting temperature, except for a surface layer a few meters thick that is cooled during winter. As a consequence, most glaciers in Alaska are not frozen to their beds. These glaciers are referred to as "temperate" glaciers. Glaciologists refer to a glacier as a "cold" glacier if it is more than a few degrees below the freezing temperature throughout most of its thickness. indeed, all of the physical, thermal and electrical properties of "regular icebox ice" and glacier ice are identical: density, viscosity, heat of fusion, latent heat, heat capacity, thermal conductivity, absorption, etc.



GLACIAL DYNAMICS

Under the pressure of its own weight and the forces of gravity, a glacier will begin to move, or flow, outwards and downwards.
some glaciers do not flow at a constant speed; instead, they are subjected to cyclical flow instabilities. These glaciers have been called ‘surging glaciers’ or ‘surge-type’ glaciers. **In general, surge-type glaciers have not been recognised in Antarctica.**
When not surging, the glacier contains cracks and tunnels that drain off meltwater.
The “**retreat**” of a glacier is the melting of the ice front in place creating the illusion that the glacier is moving backward.
When a glacier meets the ocean (we call them TIDEWATER GLACIERS) , it calves: spits out large chunks of ice called icebergs**. In 1912, an iceberg broke off Jakobshavn and smashed into and sank a ship named the Titanic.**

WHAT ARE MAIN LANDFORMS RELATED TO GLACIERS?

Glaciers are moving bodies of ice that can change entire landscapes. They sculpt mountains, carve valleys, and move vast quantities of rock and sediment. During the last glacial period more than 50 million square kilometers of land surface were geomorphically influenced by the presence of glaciers. Glacial ice is an active agent of erosion, which is the gradual modification of Earth surfaces through the action of wind and water. Glaciers move, and as they do, they scour the landscape, "carving" out landforms, or bringing deposit material along

Roche moutonee - sheep rock, is a rock hill shaped by the passage of ice to give a smooth up-ice side and a rough, plucked and cliff-girt surface on the down-ice side

U-shaped valleys have a flat floor and steep sides.

Hanging valleys - U-shaped valleys ending with a waterfall at the cliff-face.

Moraines – effect of glacial deposition; fragments of rock transported by the glacier and deposited when it melts

- Terminal Moraine:is deposited by the glacier at the snout as it retreats
- Medial Moraine: is material carried in the middle of the glacier
- Lateral Moraine: is the material that has fallen onto the side of a glacier and carried along by it.

Nunatak is an Inuit term for an island of bedrock or mountain projecting above the surface of an ice sheet, highland icefield, or mountain glacier. The glacier flow has gone around the bedrock, leaving behind this distinct geologic feature·

Cirques are circular basins carved by the base of a glacier as it erodes the landscape.

Glacial moulin is a narrow, tubular nearly cylindrical, vertical shaft, hole or crevasse carved in the ice by surface meltwater. They can be up to 10 meters wide and are typically found at a flat area of a glacier

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GLACIERS

BACKGROUND MATERIAL FOR TEACHERS

Vatnajökull

FAMOUS GLACIERS

Vatnajökull, Iceland-the biggest glacier in Europe (96 km) wide at its widest point, about 435km long, and has been measured to be 2,500 meters deep at its center. It covers more than 8% of Iceland

Jakobshavn Isbrae in Greenland is generally considered to be the fastest glacier in the world, with speeds of up to 40 metres per day.

The Largest Glacier on Earth is **Antarctica's Lambert glacier**, 100 Miles Wide and Around 400 km long.

HOW DOES THE CLIMATE CHANGE AFFECT GLACIERS?

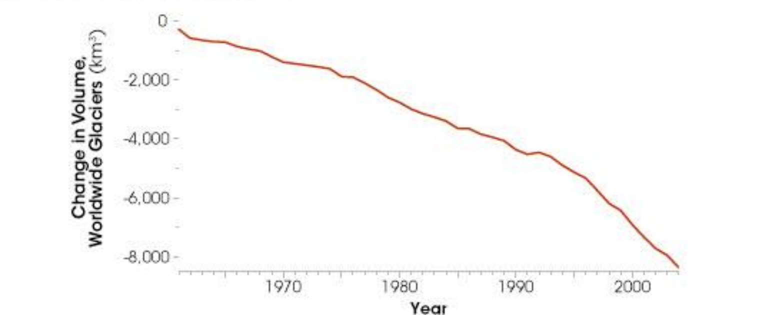
During the last ice age (when glaciers covered more land area than today) the sea level was about 122 meters lower than it is today. At that time, glaciers covered almost one-third of the land. During the last warm spell, 125,000 years ago, the seas were about 5.5 meters higher than they are today. Within the past 750,000 years, scientists know that there have been **eight Ice Age cycles**, separated by warmer periods called interglacial periods. Currently, the Earth is nearing the end of an interglacial, meaning that another Ice Age is due in a few thousand years. This is part of the normal climate variation cycle.

What's different then? Things that normally happen in geologic time are happening during the span of a human lifetime, because of human activity, especially burning fossil fuels.

Ice that took centuries to develop can vanish in just a few years. A glacier doesn't melt slowly and steadily like an ice cube taken out of a fridge. Once glacial ice begins to break down, the interaction of meltwater and sea water with the glacier's structure can cause increasingly fast melting and retreat.

Researchers show in a recent study that the further melting of glaciers cannot be prevented in the current century -- even if all emissions were stopped now. However, due to the slow reaction of glaciers to climate change, our behavior has a massive impact beyond the 21st century: In the long run, five hundred meters by car with a mid-range vehicle will cost one kilogram of glacier ice.

Athabasca Glacier, Canada, 2005



Source: NASA observatory, visible retreat of glaciers

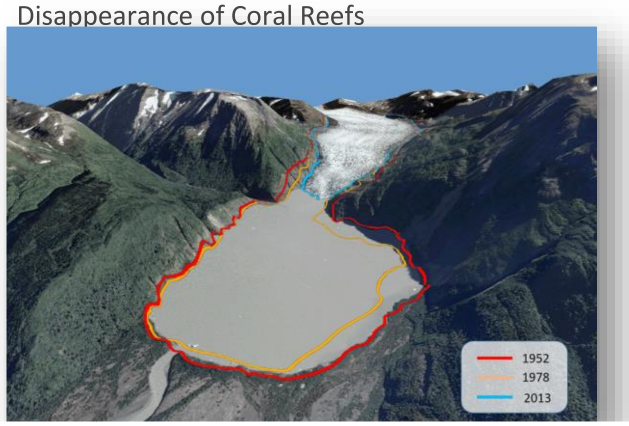
WHAT ARE THE CONSEQUENCES OF MELTING GLACIERS

When glaciers accumulate less ice mass in winter seasons, it causes **a rise in sea level** (as less ice means more water). Because the Earth has these ice and water cycles, it's easy to write off these changes as part of the natural self-regulating pattern. But since the 1970s, the shrinking size of glaciers and related rise in sea level suggest that nature isn't acting alone.

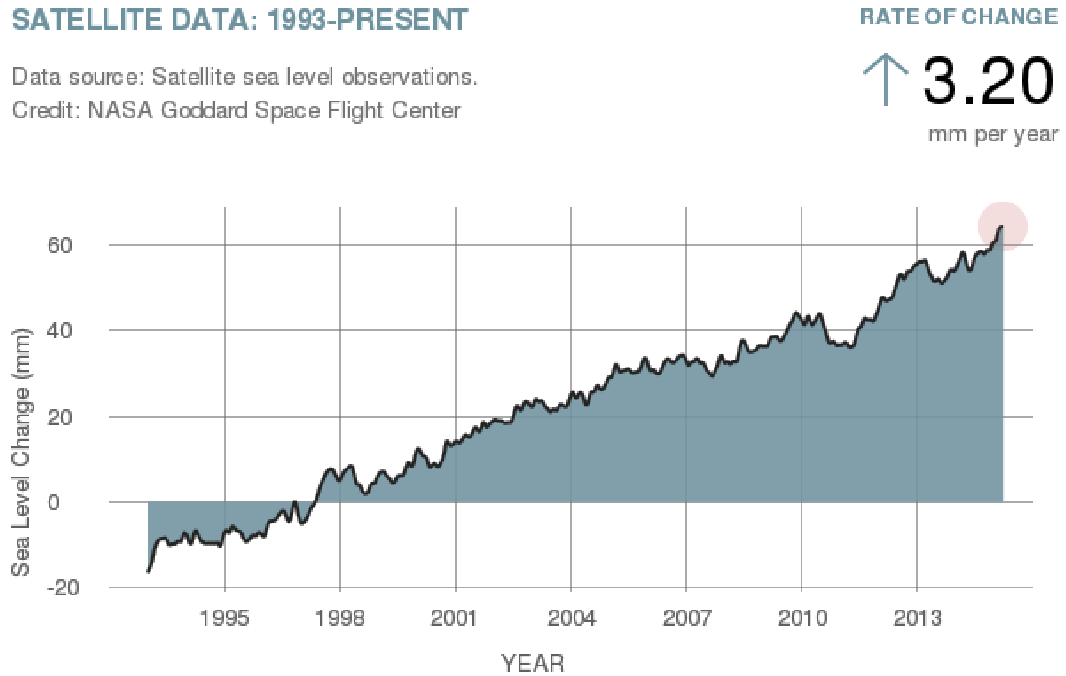
According to the National Snow and Ice Data Center (NSIDC), if all glaciers melted today the seas would rise about 70 meters.

The main consequences are:

- ⊗ Excessive Flooding
- ⊗ An Increase in Earthquakes and Volcanic Eruptions
- ⊗ The Release of Methane Gas
- ⊗ A Return of Lethal Diseases
- ⊗ Disruption of Weather Patterns – influencing ocean currents
- ⊗ Disappearance of Coral Reefs



Retreat of the Skilak Glacier. Source: Schoen, Erik & S. Wipfli, Mark & Trammell, E & J. Rinella, Daniel & L. Floyd, Angelica & Grunblatt, Jesse & McCarthy, Molly & Meyer, Benjamin & Morton, John & E. Powell, James & Prakash, Anupma & Reimer, Matthew & Stuefer, Svetlana & Toniolo, Horacio & M. Wells, Brett & D. W. Witmer, Frank. (2017). Future of Pacific Salmon in the Face of Environmental Change: Lessons from One of the World's Remaining Productive Salmon Regions. Fisheries. 42. 538-553. 10.1080/03632415.2017.1374251.



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ARCTIC ISSUES: GLACIERS

ADVANCED MATERIAL

BACKGROUND MATERIAL FOR TEACHERS

POST-GLACIAL REBOUND

Post-glacial rebound (also known as continental rebound, isostatic rebound or isostatic adjustment, GIA) is the rise of land masses that were depressed by the huge weight of ice sheets during the last ice age. It's a ertical raising of a portion of the Earth's crust. The enormous weight of the ice down-warped the land surface, causing the material underlying these land masses to slowly flow away. The physics are similar to the reasons a balloon deforms when you press down on it. In the same way that the balloon reshapes itself when you remove your hand, the land actually pops back up over several thousand years when the weight of expansive ice sheets no longer weighs down the underlying area.

Glacial rebound explains differences in relative sea levels along the English coast. According to the 23-year record of satellite data from NASA and its partners, the sea level is rising a few millimeters a year. If you live on the U.S. East Coast, though, your sea level is rising two or three times faster than average. If you live in Scandinavia, it's falling! The response of the solid Earth to the collapse of Northern Hemisphere ice sheets following the Last Glacial Maximum (LGM, ~ 21 000 years ago) continues today at a rate

so large (> 10 mm a^{-1} , e.g. Lidberg et al., 2010; Sella et al., 2007) that glacial isostatic adjustment (GIA) is one of the few geophysical processes that can be readily observed on human timescales without recourse to sophisticated scientific measurement techniques. For example, the melting of Iceland's glaciers has reduced pressure on the ground beneath them, causing the land to "rebound" from the Earth's crust.

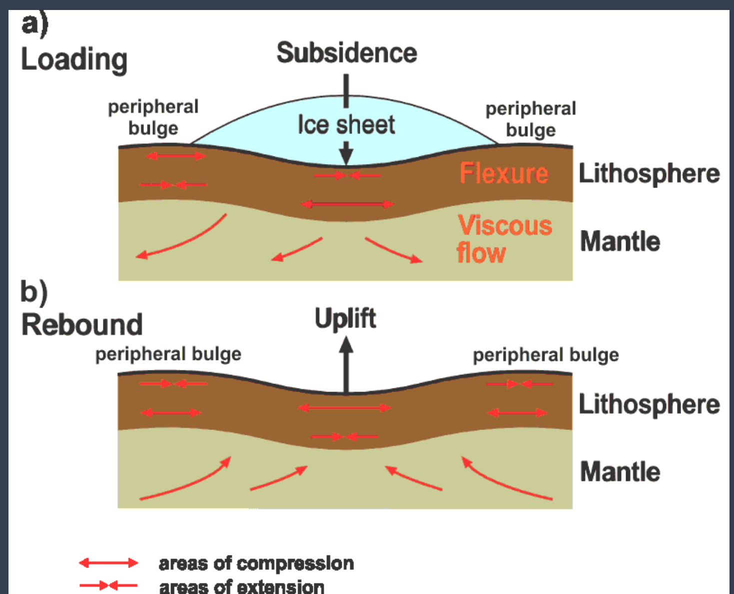
Melting glaciers alter Earth's gravity! Scientists were investigating the Earth's geoid, or the average gravity field across the globe. Over the past 20,000 or so years, the geoid should have been become rounder just as the planet has —the vast glaciers that once covered large swaths of the continents withdrew at the end of the last Ice Age, and since then the land that was once covered in ice has rebounded without the weight of ice pressing down on it, giving the Earth a more spherical shape.

However, starting about 20 years ago, scientists began noticing this rebound was getting offset by some unknown factor, causing the Earth's gravity field to stop changing its shape.

The bulk of Greenland's ice mass is centred over inland/central Greenland. If you were to take all the ice away today, much of central Greenland would actually be below sea level, by several hundred metres – it would have a "hole" in a middle!

IMAGE ON THE LEFT: Potential natural changes and implications for a UK GDF. British Geological Survey, - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-illustration-of-the-loading-and-unloading-effects-on-the-crust-lithosphere-and_fig3_274735469 [accessed 25 Jan, 2019]

IMAGE ON THE RIGHT: Much of modern Finland is former seabed or archipelago: illustrated are sea levels immediately after the last ice age.By User Oakokko at fi.wikipedia - Own work, CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=1633795



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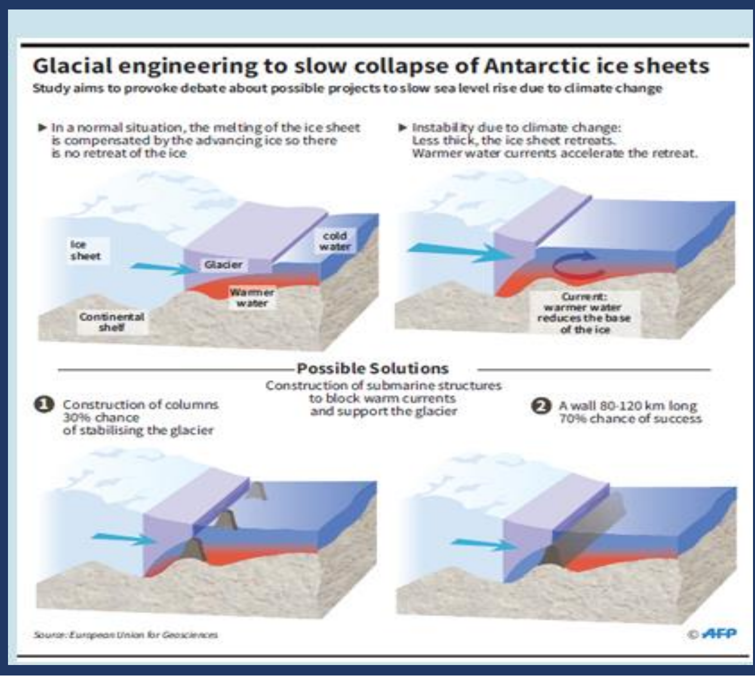
ADVANCED MATERIAL

ADDITIONAL INFORMATION

UNDERWATER WALLS PROTECTING THE GLACIERS

Glacial engineering could limit sea-level rise
Building walls on the seafloor may become the next frontier of climate science.
Scientists have proposed large-scale geoengineering projects that would prevent ice shelves from melting.
The most successful solution proposed would be a long, incredibly tall underwater wall at the edge of the ice shelves.
making changes to the geometry of the seafloor near glaciers that flow into the ocean, forming an ice shelf, to prevent them from melting further.
Large ice sheets at risk of collapse could be protected from upwelling warm water, by the creation of barriers on the seabed, scientists say.
But smaller scale projects could also have a significant impact. A simpler intervention would consist of building isolated 300-metre-high mounds or columns on the sea floor.
The structures wouldn't block warm water but could support and hold back the glacier, helping it to regrow.
Source: European Union for Geoscience



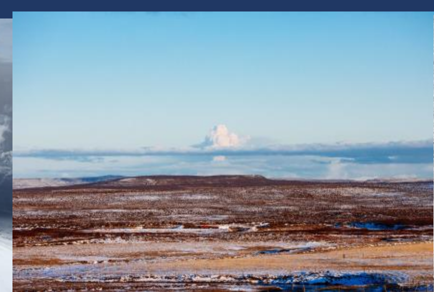
GLACIOVOLCANOES

Glaciovolcanoes are called "mountains of fires and ice,
They are indeed mountains where the orange-red fire of magma meets the frozen blue of glaciers.
When an ice-covered volcano erupts, the process among molten magma, ice and meltwater can have catastrophic results, including floods, called " jökulhlaup " that can happen after a glaciovolcano blows and melts its glacial covering. The floods are followed by tons of ash ejected into the atmosphere.
Famous l (Iceland) is an example of glaciovolcano. When Eyjafjallajökull volcano blew up in 2010, the relatively small eruption created giant sloud of ash that shut down airports throughout most of Europe for six days.

How does being under a glacier affect the amount of ash production?

Theory no 1:
when lava hits ice, the steamy explosions that result break the ash into smaller bits. Smaller bits can travel farther in the air, which is bad news for airlines.
Theory no 2:
when lava hits ice, it generates a lot of steam, which condenses on the ash particles and makes them stick together, creating heavier aggregates that wouldn't be able to fly very far.

PHOTOS below:
Ash emission during Eyjafjallajökull eruption, volcanic landscape of Eyjafjallajökull, jökulhlaup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RESEARCH METHODS

HOW DO RESEARCHERS STUDY GLACIERS?

Despite typical glaciers' massive sizes, monitoring them is not always an easy task. Only specific types of small glaciers are good measures of climate change. Some glaciers are too large to measure accurately, and others are simply too unpredictable.
Some of the methods used by scientists are enlisted, some of them further described below:

Seasonal Mass Balance Measurements

Standard stake based glaciological method - glacier mass balance measurements help to provide an understanding of the behavior of glaciers and their response to local and regional climate

Ice cores drilled in glaciers and ice sheets are used to investigate atmospheric chemistry, climate and glacier dynamics in the past

PALEOCLIMATHOLOGY - ICE CORES

Hydrology Measurements

Hydroglaciology - from a hydrological point of view, a glacier acts as a reservoir with seasonal gains and losses. Thus, the glacier mass balance is one term in the hydrological balance of a glacierized catchment basin and can be calculated as a residual of all other terms:
$B = P - Q - E \pm \Delta S$ (7)
P = precipitation; Q = runoff; E = evaporation; ?S = variation of storage elements of the catchment area other than glaciers such as groundwater or interception.

Remote sensing (satellite photos, radar)

Remote sensing measurements are based on information gained by radars or aerial sensing technologies installed on aircraft and satellites. Remote sensing yields information about glacier properties including glacier area, length, surface elevation, surface flow fields, accumulation/ablation rates, albedo, equilibrium line altitude (ELA), accumulation area ratio, and the mass balance gradient. Radars allow to build 3D models

Other - e.g. seismic methods

Glacioseismology – scientists are using seismic instruments to listen to ice movements, better determine how glaciers are changing over short periods—in contrast to more traditional methods in which glaciologists study large-scale, long-term ice movements.

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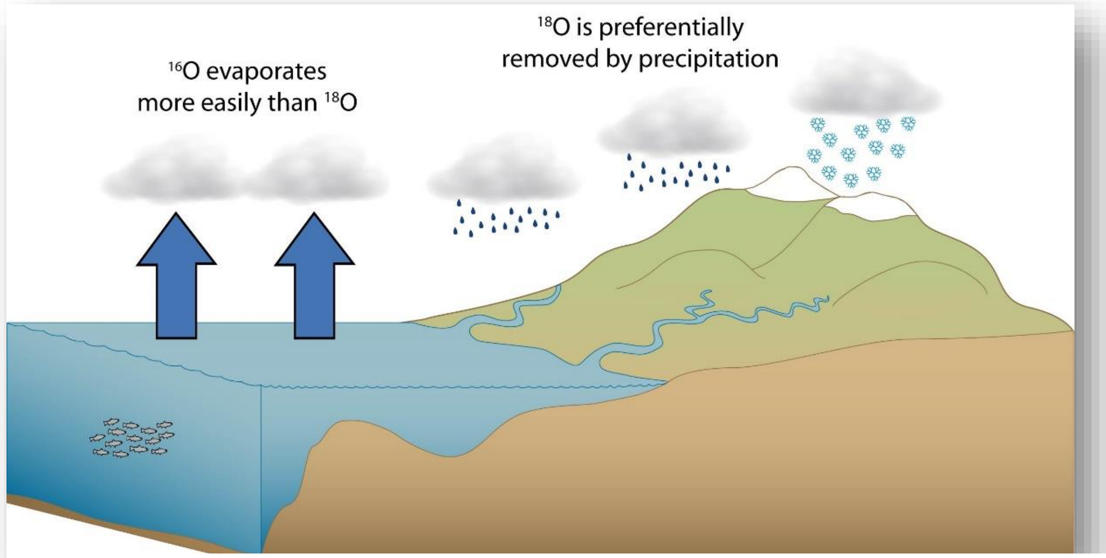
BACKGROUND MATERIAL FOR TEACHERS

INSIDE THE GLACIERS-ICE CORES - Paleoclimatology

Glaciers carry important information about ancient climate. **Ice, dust and air bubbles** trapped in ice can be analysed to reveal how air temperature and atmospheric content of greenhouse gases such as CO_2 and methane have changed over long time spans. Ice coring has been around since the 1950s. Ice cores have been drilled in ice sheets worldwide, but notably in Greenland and Antarctica, Ice cores from Antarctica can reveal temperatures 800 000 years back into the past. Ice cores from Svalbard can also be used to study climate, but these cores are trickier to interpret because summer melting is greater there than in Antarctica. The Arctic has not been continuously iced-over for as long as Antarctica, so climate archives in the north cover less time. In glaciers at the highest altitudes in Svalbard, where summer melting is smallest, it is possible to take ice cores that go 1000 years back in time.

ARCTIC ISSUES: GLACIERS

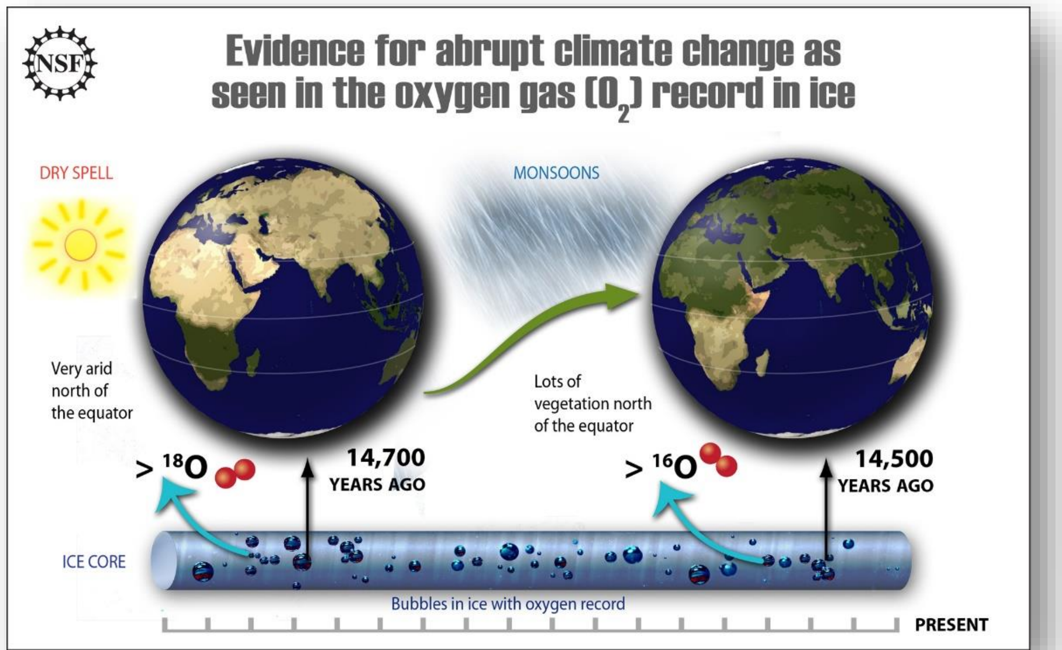
The measurement of the gas composition is direct: trapped in deep ice cores are tiny bubbles of ancient air, which we can extract and analyze using mass spectrometers. Temperature, in contrast, is not measured directly, but is instead inferred from the isotopic composition of the water molecules released by melting the ice cores.
The isotopes of particular interest for climate studies are **OXYGEN and HYDROGEN**: ^{16}O (with 8 protons and 8 neutrons that makes up 99.76 percent of the oxygen in water) and ^{18}O (8 protons and 10 neutrons), together with ^{1}H (with one proton and no neutrons, which is 99.985 percent of the hydrogen in water) and ^{2}H (also known as deuterium (D), which has one proton and one neutron). All of these isotopes are termed 'stable' because they do not undergo radioactive decay. Uranium has been used to date the Dome C ice core from Antarctica



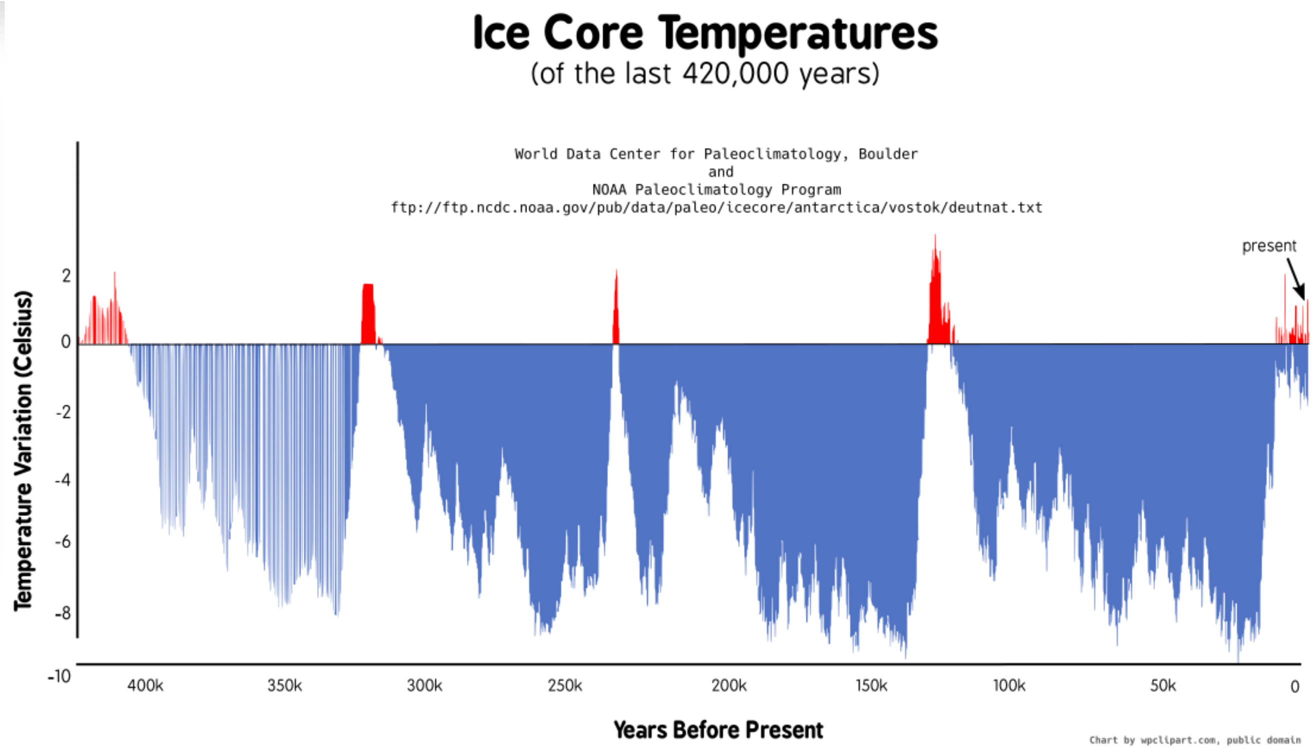
Ice in glaciers has less ^{18}O than the seawater, but the proportion of heavy oxygen also changes with temperature.

The water-ice in glaciers originally came from the oceans as vapor, later falling as snow and becoming compacted in ice. When water evaporates, the heavy water ($H_2{}^{18}O$) is left behind and the water vapor is enriched in light water ($H_2{}^{16}O$).

This is simply because it is harder for the heavier molecules to overcome the barriers to evaporation. Thus, glaciers are relatively enhanced in ^{16}O, while the oceans are relatively enriched in ^{18}O. It has been shown that a decrease of one part per million ^{18}O in ice reflects a 1.5°C drop in air temperature at the time it originally evaporated from the oceans.

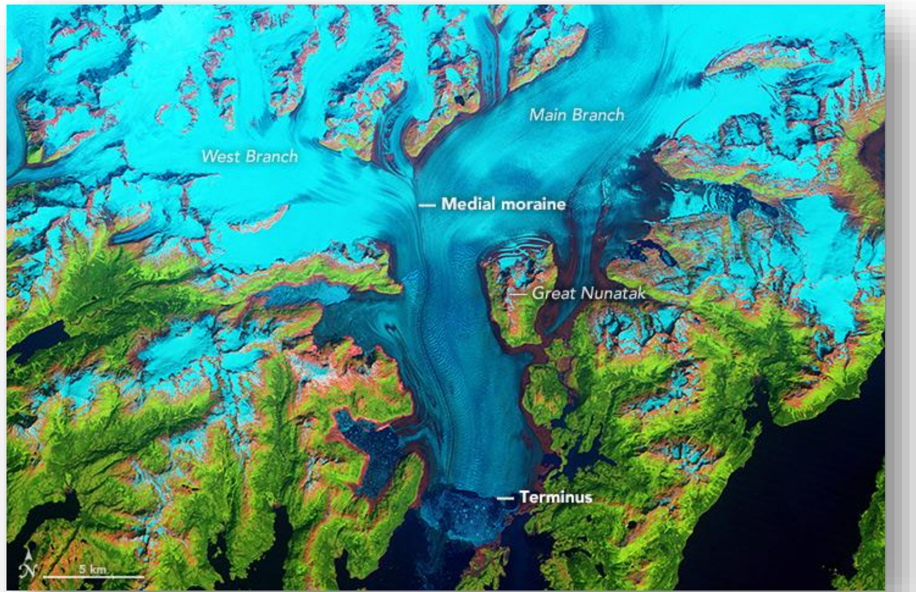


ICE CORE



REMOTE TECHNIQUES OF STUDYING GLACIERS

Compared with the traditional methods which are always time-consuming, and sometimes unpractical spatially in isolated areas, remote sensing is an excellent choice for analyzing glaciers in remote locations and to monitor many glaciers at the same time



NASA Earth Observatory visualizers made this false-color image based on data collected in 1986 by the Thematic Mapper on Landsat 5. The image combines shortwave-infrared, near-infrared, and green portions of the electromagnetic spectrum. With this combination, snow and ice appears bright cyan, vegetation is green, clouds are white or light orange, and open water is dark blue. Exposed bedrock is brown, while rocky debris on the glacier's surface is gray.

With use of satellite images, scientists:

- ⊗ perform glacier mapping for inventorying and glacier variation studies
- ⊗ derive mass balance by means of surface elevation changes and late-summer imageries
- ⊗ analyze ice-dynamics using ice-flow velocities and their changes and ice discharges.

GLIMS: Global Land Ice Measurements from Space

Monitoring the World's Changing Glaciers

GLIMS is a project designed to monitor the world's glaciers primarily using data from optical satellite instruments

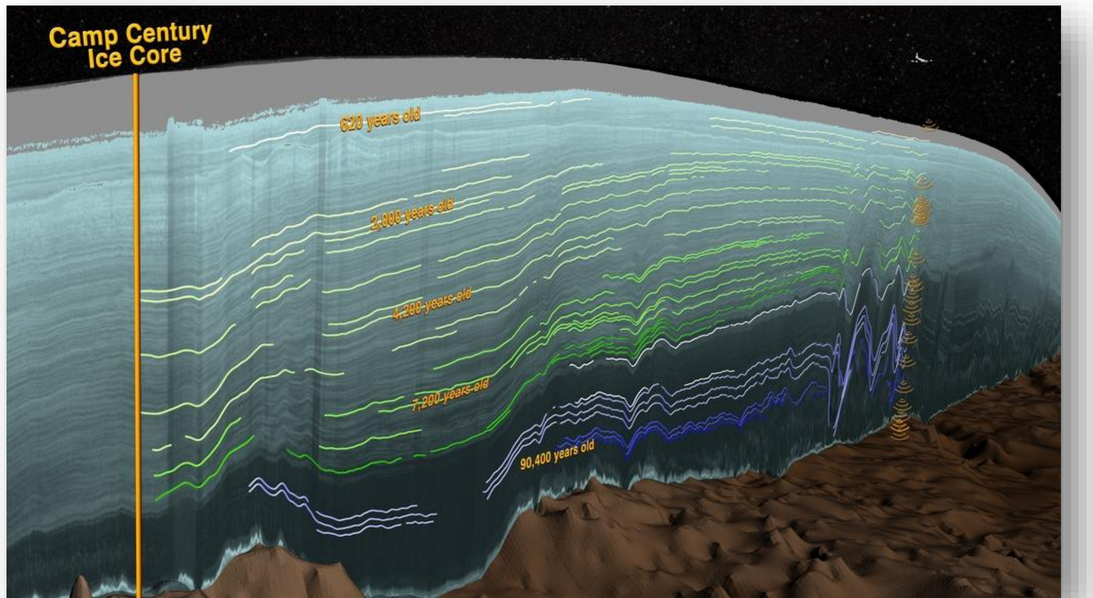
This is being accomplished through a worldwide cooperative network (Regional Centers [RCs]) who map and analyze glacier fluctuations in the geographic region of their particular expertise. Once these RCs were well established, existing glacier data, both older maps and more current satellite data, as well as newly generated data, quickly became available

Aerial photos and satellite images provide a fabulous view of the surface, but it is only a 2D view. RADAR SYSTEMS allow to estimated glacier thickness and ice volume changes.

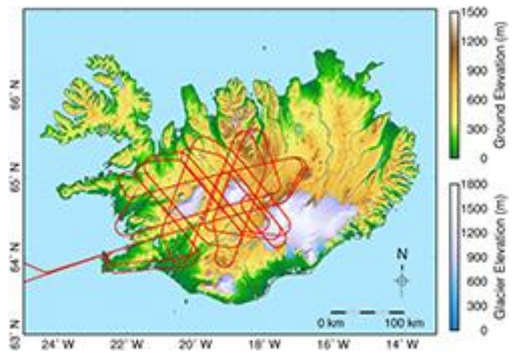
RADAR GLACIOLOGY

Radar (radio detection and ranging) technology consists of a radio transmitter capable of sending out electromagnetic pulses across selected frequencies ranging from 1 MHz to 300 GHz, and a receiver able to detect and record the time delay and amplitude of the radar waves scattered back towards the transmitter off any reflecting surface. Radar waves have physical properties that make them especially valuable to studies of ice sheets: at low frequencies, they travel almost as freely through ice as they do through air. As the frequency is increased, the wavelength becomes closer in scale to layers within the ice and then to snow crystals and layers near the surface, and these features come to dominate the reflection mechanism. Radar reflections are particularly sensitive to contrasts in the electrical properties of the material that the waves encounter.

At defined intervals, either at equal temporal or spatial increments, the transmitter emits an electromagnetic pulse into the snow column. Distances between consecutive measurements vary, depending on the system performance, between about 0.1 and 10 m. The pulse penetrates into the snow column and is partly reflected



This model – 3D map - was created by NASA with use of radar data, which allowed to determine age of layers in Greenland ice sheet , along with an ice core.



Flight path (red lines) for a single flight of an airplane carrying radar, to map flow speeds across two ice caps with the UAVSAR instrument. ***Image Credit: Caltech***

ARCTIC ISSUES: GLACIERS

GLACIOLOGICAL METHOD – CALCULATING MASS BALANCE

In the glaciological method, a network of stakes and pits are placed on the glacier surface and used to measure the change in surface level while taking into account snow/firn/ice density. Comparing measurements between two fixed dates yields an annual mass balance, while comparing measurements at the end of the ablation and accumulation seasons yields a seasonal mass balance

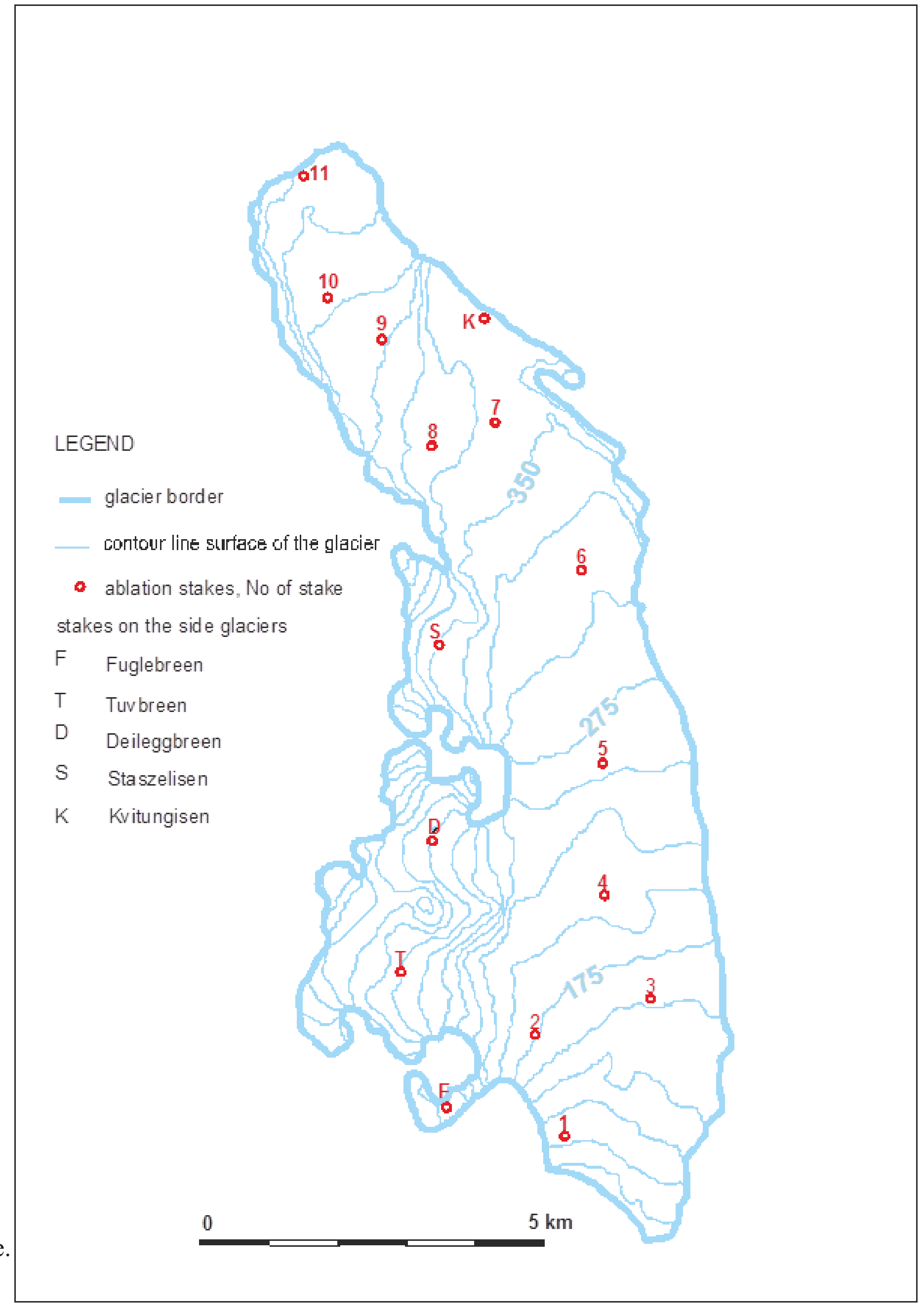
Ablation is measured with reference to stakes (generally ranging between 2-4m) placed at depth of meters into the glacier surface at a fixed point.

The distance from the ice surface to a fixed point on the stake is repeatedly measured using a tape measure.
Event though the method seems simple, it gives opportunities for various research, like
Impacts of surface albedo on glacier melt rate.
Melt rates beneath glacier surface debris cover.
Impacts of shading and aspect on melt rates

Putting and checking ablation stakes is not an easy task, especially with deep crevasses in glacier's surface.
Photos: Hornsund, Kamil Zięba

The glaciological method **is the only which is based on in situ (field) measurements**.
At a number of individual points the change in surface level is measured between two dates.
Scientist use a rotary hammer drill to drill holes of known depth into the ice; into these holes they insert o poles e.g. two meters long called ablation stakes, which help record changes in glacier mass.

They record exactly how deep each stake was implanted, so they can, on return visits, assess exactly how much ice has melted away (or accumulated) at each location simply by remeasuring the level of the ice surface against the stake.

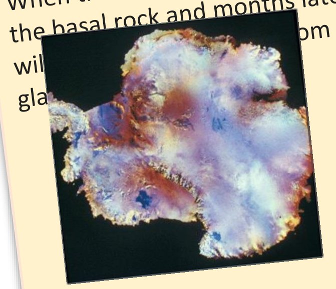


5 fun facts about glaciers

Can ice be warm?

It must be freezing … or does it?

A temperate glacier (as opposed to a polar glacier) is a glacier that's essentially at the **melting point**, so liquid water coexists with glacier ice. A small change in temperature can have a major impact on temperate glacier melting, area, and volume. Temperate glaciers exist on the continents of North America, South America, Europe, Africa, and Asia. Additionally, some of the glaciers of the Antarctic Peninsula and some of Greenland's southern outlet glaciers are temperate.
Commonly used definition is that of a glacier that is a "warm glacier" – a glacier that is at its melting temperature
In contrast, polar glacier is a glacier with a thermal or temperature regime in which ice temperatures always remain below the freezing point.
When the seasons change and there is less melting, the warm glacier will refreeze to the basal rock and months later, when the temperature warms up again, the glacier … om the base and this will cause increased erosion as the wil… gla…



NOAA AVHRR satellite image of the Antarctica, showing the polar glacier ice that covers more than 97% of the continent

"How to spot a fake glacier ice"

If someone gives you an ice cube and says it's glacier ice, look for bubbles.

Some beverage companies sell bottles of glacial meltwater, and ice cubes made of glacier ice are popular in some specialty drinks. In fact, a Chilean man was arrested in 2012 for stealing five tons of ice from the Jorge Montt Glacier. He had planned to sell the ice to restaurants in the capital, Santiago.
A normal ice cube will have one big bubble in the center because it froze from the outside in, squeezing any air bubbles to the middle. But a genuine glacier ice cube will have lots of tiny bubbles in layers because of the years of airy snowflakes that were packed down to form it!
Does this ice last longer in drinks?
Yes - a little, but only because the ice crystals are larger. Crystals melt from the outside and large crystals expose less surface area per unit volume of ice; therefore, ice with larger crystals melts more slowly..

Meet the iceworms

They "melt" before your ice and live between ice crystals

They are real - they are annelid worms (class Oligochaeta); several species are recognized. A member of the segmented worms, the annelids, iceworms are related to common earthworms and leeches. The iceworm (Mesenchytraeus solifugus) is a small, slim worm, one to three centimeters long, and dark brown or black in color. It resembles a miniature earthworm.
You can observe them practically only at night, they're pretty tiny-up to 1 cm long-and 1 mm thick - but believe it or not, there are scientists who spend a lot of time on their observations and research. They live in glacial ice, and there is plenty of them there - there are 2,600 individuals in $1m^2$. Why are they interesting object of scientific research? They define the boundary of the glacier, they never appear farther than a few meters from its edge, and sometimes under the snow it would not be that obvious where tha glacier ends. At the same time they are the indicator of climate change and glacial retreat, a great tool for exploring the mechanisms of evolution. They feed on bacteria and algae. They are made from unique protein chains adapted to low temperatures, they lead the night life, each population is isolated, because they are not capable of travelling between glaciers - due to the physical properties of the water and that the ice is a great isolator, the temperature of the subsurface does not fall below 0 degrees Celsius, the worms move and between the ice crystals .
What is weird about them - if they are exposed to a temperature higher than 5 degrees Celsius, they melt before our very eyes.

Why are glaciers blue?

And ice in a glass is transparent …?

Some glaciers appear blue when they become very dense. With years of compression, tiny air pockets between ice crystals get forced out. The ice can absorb all other colours in the spectrum, such as red and yellow light, and reflects blue light. The denser the glacier, the more blue it will appear.
Glacial ice is a different color from regular ice. It is **so blue** because the dense ice of the glacier absorbs every other color of the spectrum except blue – so blue is what we see!
So, white ice is new ice, blue ice is old ice.
Glacial ice has a distinctive blue tint because it absorbs some red light due to an overtone of the infrared OH stretching mode of the water molecule.
Liquid water is blue for the same reason.

The Iceman

Tattoos, Lyme disease, violent death and … living family!

In 1991, a group of hikers exploring the Ötztal Alps on the Austrian-Italian border came across the mummified corpse of a person half-entombed in ice.
Using radiocarbon dating, scientists determined that the man, named Ötzi, had died 5,300 years earlier.
Special circumstances preserved the Iceman. His body was not destroyed when the site was over-ridden by a glacier because it was near the edge of the glacier in a protective bedrock depression. Had he truly been in a glacier, he would have been ground to flour.
It is currently believed that Ötzi died from a blow to the head. He was 45 years old, he had tattoos, a beard, deep-set brown eyes, sunken cheeks, and was gap-toothed. The analyses of his intestinal contents show that his last two meals consisted of chamois meat, red deer, and herbed bread eaten with grains, fruits, berries, and root crops, eaten in the spring. Ötzi was lactose intolerant and apparently had Lyme disease, whipworm, an intestinal parasite. Ötzi's hair contained high levels of copper particles and arsenic, and his axe was 99.7% pure copper, leading to believe that he was personally involved in copper smelting. Ötzi's intact blood cells are the oldest blood cells ever identified.
He has living relatives! Researchers studying the Iceman's DNA discovered a rare Y-chromosome mutation known as G-L91. When they compared this result with almost 4,000 samples of blood donated by people living in Austria, they found 19 men with the same mutation living not far from where Otzi was discovered.