Integrating Activities for Advanced Communities

D7.5 – Report on educational tool-kits

Project No.871120 – INTERACT

H2020-INFRAIA-2019-1

Start date of project: 2020/01/01 Duration: 48 months
Due date of deliverable: 2023/12/31 Actual Submission date: 2023/12/20

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Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

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Publishable Executive Summary

This report provides an overview of educational materials, which were produced specifically by INTERACT for lower and upper secondary schools in order to enhance literacy of the Arctic and Arctic Observations among teachers and students. The educational material is foreseen as a tool for promoting natural sciences to students and early recruitment of future potential polar researchers.

The educational materials contain three tool-kits dedicated to the biggest challenges, which currently the Arctic is facing: “The changing Arctic”, “The polluted Arctic”, “The invaded Arctic”. Additionally, a tool-kit “Studying past environments” looks to the past to better understand the present. Each toolkit consists of: syllabus with introduction, list of basic concepts to remember, a glossary, material for teachers, lesson plan, worksheet for students, some online activities, presentation and recording of author’s lecture. An additional part of the tool-kit is an experiment scenario, which could be performed without special equipment in classrooms.

Additionally, a list of recordings of online lessons, which were organised within the INTERACT project is provided. The report ends with some conclusions and suggestions of next steps.

1. Introduction

The INTERACT project produced educational materials for lower and upper secondary schools in order to enhance literacy of the Arctic and Arctic Observations among teachers and students. Although, there are many polar materials available, they were not specifically targeting schools in the context of monitoring and field works. This material includes results from observations conducted at some of the INTERACT stations. Moreover, the presented tool-kits have an extensive and comprehensive structure and provide teachers with a set of materials and activities.

The educational material is foreseen as a tool for promoting natural sciences to students and early recruitment of future potential polar researchers. The educational materials contain three tool-kits dedicated to the biggest challenges, which currently the Arctic is facing: “The changing Arctic”, “The polluted Arctic”, “The invaded Arctic”. Additionally, a tool-kit “Studying past environments” looks to the past to better understand the present. The fourth tool-kit was preliminary prepared within the previous project, but finalised and published within the current one. Each toolkit consists of: syllabus with introduction, list of basic concepts to remember, a glossary; material for teachers, lesson plan, worksheet for students, some online activities, presentation and recording of author’s lecture. An additional part of the tool-kit is an experiment scenario, which could be performed without special equipment in classrooms.

The first tool-kit “The changing Arctic” is dedicated to the changes observed in the Arctic connected with climate change. Students get the general information about Arctic amplification and find out why disappearing ice is affecting the whole Planet. Moreover, they learn about some feedback loops, which influence the changes in polar regions. They also become familiar with the most severe and catastrophic challenges like fires, droughts, floods, sea level rise, etc.

The second tool-kit “The polluted Arctic” is dedicated to the different types of pollution that have been observed and studied by the scientists over the last decades in the Arctic. Thanks to the INTERACT toolkit students learn about the importance of some risks to the Arctic environment connected with economic growth accompanying with increasing consumption, and what are the consequences of some pollutants impact on traditional lifestyle of indigenous population. Moreover, they become familiar with such terms as biomagnification and bioaccumulation.

The third tool-kit “The invaded Arctic” is dedicated to invasive species, which appear in the Arctic. Students learn what an ecological niche is and what is the difference between exotic and invasive species. They also understand that the Arctic ecosystems are particularly vulnerable if invaded by exotic species and that the Arctic is also particularly affected by the warming climate, and increased tourism, a major cause of invasive species.

The fourth tool-kit “Studying past environments” is dedicated to the changes in the past environments and studies of paleoclimatology. Thanks to the tool-kit students may understand the concept of gathering data based on climate proxies. They learn how to interpret research results and recognize different methods

used in paleoclimatology. Moreover, they can describe specific ecosystems (peatlands) and their role in studying past environments; and name possible causes of changes in ancient climate.

Additionally, a list of recordings of online lessons, which were organised within the INTERACT project are provided.

2. Educational tool-kits

Four educational tool-kits were developed within the project. They are described below in details. They are available for downloading on the INTERACT website: https://eu-interact.org/arctic-awareness/interact-educational-resources/.

2.1.INTERACT Tool-kit "The changing Arctic"

Brief Description: The package is dedicated to the rapid changes in the Arctic climate and weather. The warming trend in the Arctic is at least twice as large as the global average in recent decades. We call it Arctic amplification - the fact that temperature rise in polar regions is large in comparison to the temperature rise in lower latitudes and may further accelerate climate warming well beyond the Arctic. The loss of sea ice is one of the most cited reasons of Arctic amplification. When reflective ice melts, a darker ocean dominates. This amplifies the warming trend because the ocean surface absorbs more sun heat than the surface of snow and ice. Decrease in sea ice extent reduces Earth's albedo and accelerates the global warming. The climate change accelerates also melting of glaciers, which causes sea level rise. Scientists estimate that due to melting of ice the sea level will increase by 100 cm by the end of the century. Reduced snow cover on land affects boreal forests. They become more susceptible to drought, and consequently – to fire. From decaying organic matter, trapped previously in permafrost and revealed due to thawing of permafrost, additional greenhouse gases are released to the atmosphere. It accelerates the temperature rise. As the temperature in the Arctic is rising more rapidly than in the rest of the globe and the temperature on the Equator is increasing slowly, the differences between the North Pole and the Equator is decreasing. It slows down the global circulation and may affect the weather patterns far beyond the Arctic.

Keywords: Arctic, climate change, Arctic amplification, sea ice, albedo, thawing permafrost, sea level rise

Age Range: 13-19

Didactical Hours: 2-3 didactical hours

Learning objectives: The student will:

- learn which feedback loops affect the weather and climate in the Arctic;
- understand, what positive and negative feedback loops are and how they affect the processes;
- understand how the changing sea ice extent influences the polar regions and the whole planet;

- learn what is Arctic amplification and what are its main reasons;
- learn what are the effects of thawing permafrost and how it connects with the permafrost carbon cycle;
- become familiar with the main challenges that the Arctic faces due to climate change;
- be able to explain why the changes in the Arctic influence the weather patterns far beyond the Arctic.

The content of the tool-kit:

- Syllabus for teachers
- Lesson plan
- Ppt presentation
- Worksheet for students
- Worksheet – teacher's version
- Experiment scenario
- Recorded webinar: https://youtu.be/1b6hrQmP5wc

Description of the educational phases

1. Kick-start phase (5')

During this short 5-minute-phase, students do a quick brush-up on climate change, greenhouse gases and greenhouse effect.

2. Introduction phase (15')

During this 15-minute-phase, teacher introduces the topic using some parts of ppt presentation (e.g. slides 1-8) or by presenting a recording from topic expert scientist's lesson.

3. Investigation phase (15')

Students, who volunteered to conduct the experiment at home, make a short presentation on the results. Teacher moderate a discussion on feedback loops connected with decreasing sea ice extent. Students may do the tasks 1-3 from the worksheet (Worksheet may be also used as a homework, depending on available time during the lesson).

4. Conclusion phase (10')

Teacher wraps up the take-home messages from the lesson. He/she may use the ppt presentation with slides 9-16.

5. Homework (60'+)

If students don't complete the worksheet in the classroom, they may finalise it at home (either individually or in groups). Suggested tasks: 1-3.

Additionally, volunteers (3 groups or individual students) 3 groups of students prepare short (3') oral presentations regarding following topics: Feedback loops with examples; Greening vs. browning the Arctic; Why are record cold events and record heat waves present nowadays in various parts of the world?

6. Follow-up lesson – introduction (15')

Teacher starts the follow-up lesson with information on other challenges in the Arctic environment (melting glaciers, sea level rise, fires, thawing permafrost). Teachers may use ppt presentation (slides 17-25), the webinar recording or INTERACT & BBC video – Part 1.

7. Follow-up lesson – Investigation (20')

In this part students, who prepared 3 topics as a homework, present orally their findings. After each presentation, teacher organizes a brief Q&A. Additionally, students do the tasks 4-5 in the worksheet.

8. Follow-up – Conclusions (10')

Teacher concludes on the consequences of the changes present in the Arctic. He/she may use the ppt presentation (slides 28-32). As the final step students explain, how they understand the sentence: "What happens in the Arctic, doesn't stay in the Arctic." Teacher ends with a reverse evaluation, where the students evaluate the lesson instead of being evaluated.

Suggested additional materials:

INTERACT & BBC Arctic Climate Magnification (video): https://youtu.be/xCqofgFN7CA?si=Z4dxWq3F9jfNiexV

INTERACT & BBC Extreme Causes for Concern (video): https://youtu.be/Dfx1KLzRdso?si=MYEROgVSQdOltNM4

TED-Ed animation: Why the Arctic is a canary in a coal mine: https://youtu.be/lrEM3LHvjI0?si=gFEwGOA0-Z1Fa-9C

National Snow and Ice Data Center: https://nsidc.org/

Interactive sea ice chart (by NSIDC): https://nsidc.org/arcticseaicenews/charctic-interactive-sea-ice-graph/

Arctic sea ice 1984-2018 (video) https://youtu.be/dIQi64EudeA

Fill in the Blanks Game: Arctic amplification: https://www.educaplay.com/learning-resources/3440315-complete_polarpedia_term.html

Fill in the gaps game: Sea ice extent: https://www.educaplay.com/learning-resources/3441572-complete_polarpedia_term.html

Polarpedia glossary:

- Albedo
- Arctic

- Arctic amplification
- Climate
- Emission scenarios
- Greenhouse effect
- Greenhouse gas
- Permafrost
- Permafrost Carbon Cycle
- Sea ice
- Sea ice minimum
- Weather

2.2.INTERACT Tool-kit "The polluted Arctic"

Brief Description: The toolkit is dedicated to selected threats, which became real risks to humans and wildlife in the Arctic. That vast region is strongly affected by climate change— sea ice is melting and the temperature is increasing two-three times faster than on the rest of the globe. Among the other risks should be mentioned these connected with economic growth accompanying with increasing consumption. That resulted in different types of pollution that have been observed and studied by the scientists over the last decades. Even though the Arctic is almost pure environment itself, the pollution is transported by air and by sea over long distances from more polluted places on Earth. On the one hand there are so called 'black carbon' and 'brown carbon' emissions caused by the wildfires that occur all over the world. On the other hand, we might name a lot of chemical substances that are toxic and harmful to the Arctic environment (PCBs, POPs, etc.). All those threats are mainly of the anthropogenic origin. Pollution in the Arctic also means a real danger for indigenous population. It affects lifestyle, diet, traditions and habits of local people and cause many diseases and health disorders. These matters altogether with Arctic environment protection issues need to be taken into consideration by the local and international policy makers.

Keywords: Arctic, pollution, pollutants, indigenous people, carbon emissions, microplastic, climate change

Age Range: 13-19

Didactical Hours: 2-3 didactical hours

Learning objectives: The student will:

- learn that the pollution that reaches the Arctic has the origin in other, sometimes (very) distant places on the Earth;
- understand that chemical, plastic and other types of pollution are harmful either for the people or the animals living in the Arctic;
- notice that ocean currents and atmospheric patterns transport pollutants from lower latitudes to the Arctic;
- be aware that the presence of some pollutants in the Arctic ecosystem means big changes in traditional way of life for indigenous population.

The content of the toolkit:

- Syllabus for teachers
- Presentation 'Polluted Arctic—What are the main threats?'
- Lesson plan
- Worksheet—student version
- Worksheet—teacher version
- Experiment scenario
- Game
- Webinar recording: https://youtu.be/3Gmj22iTDg0?feature=shared

Description of the educational phases

1. Orientation

Each student writes down three keywords he/she associates with the Arctic. Snap ideas only. Basing on collected phrases, a mind map is created. Only the ideas connected with the topic of pollution in the Arctic should be selected. What kind of keywords weren't used in the mind map? What were the reasons for creating such associations by the students? Teacher introduces the topic using given materials.

2. Conceptualization

Teacher discusses with the students the following issues: 1. why, how and from where the pollution reaches the Arctic? 2. what impact do pollutants have on people and animals living in the Arctic? Students form their own ideas how to minimize threats in terms of pollution in the Arctic.

3. Investigation

Students familiarize themselves with the worksheet and do the exercises with the teacher's support. The activity might be done individually or in groups.

4. Conclusion

Teacher sums up the topic. Each student is asked to formulate one take home-message, write it down and pass it to the other classmate.

5. Discussion

Time for wrap-up, Q&A session and clarifying the exercises solutions from the worksheet.

6. Homework

The experiment scenario is discussed. Teacher explains the details and hands-on materials for students. The experiment might be time-consuming therefore the way of organising that activity is up to the teacher.

7. Follow-up lesson

Activity dedicated to complete the topic with additional materials. Students present their findings from the experiment and discuss them. Playing the game is an optional activity.

Suggested additional materials:

INTERACT webinar 'Stories of sea ice': https://youtu.be/OTWkfxdJNiM?feature=shared

NASA Earth Observatory fire maps: https://earthobservatory.nasa.gov/global-maps/MOD14A1_M_FIRE

AMAP Mercury in the Arctic: https://mercury.amap.no/the-background

AMAP Microplastics and litter in the environment: https://litterandmicroplastics.amap.no/

AMAP POPs—climate change interactions: https://pops.amap.no/

Plastic pollution: https://ourworldindata.org/plastic-pollution

Distribution of litter types in different realms: https://litterbase.awi.de/litter

Pollution in the Arctic with Dr. Katrin Vorkamp: https://youtu.be/5QEhhtrLWRw?feature=shared

Polarpedia glossary:

- Arctic amplification: https://polarpedia.eu/en/arctic-amplification/
- Bioaccumulation: https://polarpedia.eu/en/bioaccumulation/
- Biomagnification: https://polarpedia.eu/en/biomagnification/
- Greenhouse gas: https://polarpedia.eu/en/greenhouse-gas/
- Indigenous people: https://polarpedia.eu/en/indigenous-people/
- Microplastic: https://polarpedia.eu/en/microplastic/
- Permafrost: https://polarpedia.eu/en/permafrost-7/
- Sea ice: https://polarpedia.eu/en/sea-ice/
- Thawing permafrost: https://polarpedia.eu/en/thawing-permafrost/

2.3. INTERACT Tool-kit "The invaded Arctic"

Brief Description: Invasive species disrupt the established niche system of the ecosystem. This is a serious threat to sustainability of ecosystems, which affects all human well-being as everything we do depends on intact ecosystems in one way or another. The Arctic ecosystems are particularly vulnerable if invaded by exotic species. All its native species live at extremes. The Arctic is also particularly affected by the warming climate, and increased tourism, a major cause of invasive species.

Keywords: Polar regions, climate change, human impact on nature, scientific research

Age Range: 13-16 (basic material), 17-19 (basic + advanced material)

Didactical Hours:

* Preparation time: 30 minutes (teacher) + 1 hour for students who present lesson summary

∗ Lesson duration: 1-2 school hours teaching, 2+ hours student exercises (or as homework)

∗ Homework: 2+ hours (if not doing the exercises during lesson time at school)

∗ Follow-up lesson: 1 school hour (after exercises)

Learning objectives: The student will:

- know what an ecological niche is;
- grasp the main differences between native species and exotic species;
- have an idea of factors that make an exotic species likely to become invasive;
- understand why it is important to study species invasions.

Pedagogical framework: STEAM learning, GAME-based learning and gamification.

The content of the tool-kit:

- Syllabus for teachers
- Lesson plan
- Materials for teachers
- Worksheet for students
- Worksheet – teacher's version
- Digital escape room
- Recorded webinar: https://youtu.be/xD7-0clKIB0?si=YJtuZXb3c3XMGJVE

Description of the educational phases:

9. Kick-start phase (5')

During this short 5-minute phase students write down their individual answers to 2 questions, to kick-start their curiosity. • Are all EXOTIC species bad news for nature? • Are there more INVASIVE species

in the Arctic than in your town/city? No googling allowed, students should use only their pre-knowledge and imagination.

10. Introduction phase (15')

During this 15-minute-phase teacher introduces the topic using some part of ppt presentation or by presenting a recording from topic expert scientist's lesson.

11. Figure out (15')

Students are divided into groups to work on the relevant part of the students' worksheet.

12. Discuss (10')

Students discuss in-class some questions that challenged them in the worksheet. Teacher wraps up the take-home messages from the lesson. As the take-home messages the authors suggest: the niche theory and why invasive species is a problem, and that humans are the ones causing the problem.

13. Homework (60'+)

All students complete the worksheet, either individually or in groups. There are two levels on the final challenge in the worksheet, to meet different student levels.

14. Follow-up lesson – present (20')

Teacher starts the follow-up lesson with the students' presentations. After each presentation teacher organizes a brief Q&A, keeping in mind also the worksheet that was used as part of the homework.

15. Follow-up – Challenge (20')

Teacher continues the discussion asking the students for solutions to the problem of invasive species. What can each and every person do? Are all means okay in the fight against invasive species? There are graphs, textbox etc. in the materials for the teachers, which could be shown in-class to challenge the students. Students may also do the digital escape room either online or offline.

16. Follow-up – evaluate (5')

Teacher wraps up again the take-home messages from the tool-kit. He/she invites students to share in-class their experiences during the learning. Teacher ends with a reverse evaluation, where the students evaluate instead of being evaluated.

Suggested additional materials:

An invasive escape room: https://view.genial.ly/5ff5b373c217200ce77c9fb1

An additional interactive tool-kit on climate change: https://view.genial.ly/60d5553a00ac720dd823d904

2.4.INTERACT Tool-kit "Studying past environments"

Brief Description: The package is dedicated to the changes in the past environments and studies of paleoclimatology. The Earth's climate is not stable and fluctuates between colder periods called Ice Ages, and warmer periods known as Interglacials. Scientists studying modern climates use land instruments, balloons, and even satellites. These sophisticated monitoring devices are recent. The study of past climates is called paleoclimatology. Rather than using instruments to measure past climate, paleoclimatologists must use "proxy" records. Scientists can reconstruct a general picture of an ancient environment by collecting information about the soil and the plant and animal remains that are found at a site. Comparisons of living plants and animals with these ancient remains can then indicate the types of environments that existed in the past. Scientists study tree rings, ice cores, and lake and ocean sediments that provide a record of climate change over thousands of years. The samples collected in the polar regions provide us with valuable information on the past environments and how the climate was changing in this part of the world.

Keywords: Polar regions, climate change, scientific research, paleoclimatology

Age Range: 13-16 (basic material), 17-19 (basic + advanced material)

Didactical Hours:

* Preparation time: up to 60'

* Lesson duration: 45'

* Homework: 45'

* Follow-up lesson: 45'-90'

Learning objectives: The student will:

- understand the concept of gathering data based on climate proxies;
- interpret research results;
- recognize different methods used in paleoclimatology;
- describe specific ecosystems (peatlands) and their role in studying past environments;
- name possible causes of changes in ancient climate.

Pedagogical framework: STEAM learning, GAME-based learning and gamification, Virtual learning assistant, Project-based learning

The content of the tool-kit:

- material for teachers (basic/advanced)
- ppt presentation

- detailed lesson plan
- worksheet for students
- worksheet with answers for teachers
- 1 experiment instruction
- 2 online games
- webinar recording “Paleoclimatology” https://youtu.be/-ddRJg92WQs?si=ws4FXznqKLNySv4H

Description of the educational phases:

1. Preliminary questions (5’)

During this short 5-minute-phase, students write their answers to 3 short questions and verify their answers during the lesson: • How is past climate studied? • Has climate changed in the past? Why? • How far back can we go in learning about past temperatures and precipitation?

2. Introduction (15’)

During this 15-minute-phase teacher introduces the topic using some part of ppt presentation or by presenting a recording from topic expert scientist’s lesson.

3. Presentations by students (15’)

Students present fun facts based on their preparations before the lesson.

4. Working with resources (15’)

Students are divided into 10 groups (1-3 students per group), each group obtains a topic to work on and a set of materials.

5. Discussion (10’)

Teacher moderates the discussion on how past environments are studied. Students may prepare a mind map based on this summary.

6. Homework (60’+)

All students complete the worksheet, either individually or in groups. 2 groups of 2-4 volunteers perform part 2 of the experiment according to scenario – they take samples from 2 sediment columns prepared. Each team fills in table with data.

7. Follow-up lesson – homework check-out and discussion (10’)

Teacher starts the follow-up lesson with the discussion on possible difficulties in the worksheet.

8. Follow-up lesson – Experiments (20’)

Based on the experiments conducted by two groups (Detectives and Creators) students compare the results and discuss the findings. If there are discrepancies between what CREATORS designed and

DETECTIVES discovered, what might be the causes? Is it more difficult or easier for real studies on real sites?

9. Follow-up lesson – quiz (5')

Teacher may use a ready Kahoot quiz. Mobile devices with Internet access are necessary. Alternatively, teacher may display questions and students answer collectively.

10. Follow-up lesson – group work and short presentations (10')

Based on previous analysis groups of students present answers to 5 questions suggested in the lesson plan document.

For this lesson alternative version of the class activities was also prepared and is presented in the lesson plan document.

Suggested additional materials:

- INTERACT video "Secrets of dead plants" https://youtu.be/PkG-qY05gfs?si=df5Bx-jcsZF95XCA
- INTERACT video "Analysis and importance of peatlands" https://youtu.be/taI2OIKyBcY?si=aZ83g6tesS9DAnWm
- Scientific article "An extended Arctic proxy temperature database for the past 2000 years" https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4322576/
- Video "The last time the globe warmed" https://www.youtube.com/watch?v=ldLBoErAhz4
- Video "Tree Rings explained" https://youtu.be/IG44MW_iMmI?si=yYHF107XiJGwkJ9-
- Database of NOAA on paleoclimatology: https://www.ncei.noaa.gov/products/paleoclimatology

3. Additional educational resources

Within INTERACT, online lessons for primary and secondary schools were organised. English webinars were recorded and are freely available on INTERACT website and INTERACT YouTube channel.

Here is the list of available videos:

1. **The changing Arctic**

Why is the Arctic warming so fast? We describe some feedback loop mechanisms that cause the magnification of the climate change in polar regions. Is melting sea ice dangerous for the Arctic? Does it affect the rest of the globe?

LINK TO THE RECORDING: https://youtu.be/1b6hrQmP5wc

2. Polluted Arctic

The Arctic is no longer an untouched and pure area. The harmful impact of human activity is evident in that region in its various types. Plastic pollution, global warming, oil and gas development are indicated among many threats that affect the natural Arctic environment.

LINK TO THE RECORDING: https://youtu.be/3Gmj22iTDg0

3. 5 polar science riddles

No stress, just a little bit of challenge. Do you know the answers to all of them? But most importantly ...do you know WHY? Let's dive deep into science-based fun. Some of the answers are very recent discoveries in geophysics/polar research! Can you actually hear aurora singing, why is water even more incredible than we thought and what does making ice-cream in Tanzania have to do with it ...and much more!

LINK TO THE RECORDING: https://youtu.be/HUse-mzAzII?si=gvhc1C3TiKRt69l2

4. Surviving in a freezer

Have you ever wondered how animals can live and even thrive in the extreme climates of the Arctic? If they freeze and feel miserable during winter, or if they actually feel as comfortable as we do in our own living-room? Watching this video, you will get the answers, and learn about the amazing and sometimes odd ways Arctic animals have adapted to living a life at the extreme.

LINK TO THE RECORDING: https://youtu.be/slehVXZMycI?si=lxPYcBYCgPUHT2Bh

5. Arctic hydrology

Water in the Arctic that either fell as rain or melted from snow and ice, flows via different paths before reaching the ocean. Runoff regime and hydrological processes shape the landscape and influence dynamics of glaciers. Glaciers have complicated drainage systems - meltwater can flow on the surface of glacier (supraglacially), within glacier in tunnels (englacially), or drain to the glacier base through moulins and flow along or within the bed (subglacially).

LINK TO THE RECORDING: https://youtu.be/LxYIvGDRsuI?si=RLEUqEssF0QKjhV1

6. Polar migration patterns

For animals in the Arctic, life is a balancing act. Seasonal cues, such as warmer spring temperatures or cooler temperatures in the fall, tell animals when to mate, when and where to find food and when and where to migrate. Do they travel far? Who is a record holder? What dangers do they face? And ...what's the point?

LINK TO THE RECORDING: https://youtu.be/9L5Re3c7wI8?si=DTusgqeNAtxg6Czg

7. Glacier and landforms

You often hear that with the global warming, the glaciers are melting. But have you wondered what the glaciers are and how they are formed? Did you know that there are several types of glaciers and they do grow larger and become shorter from time to time? And that the glaciers shape and form many different types of landforms on Earth. Join us in this lecture to learn all about it!

LINK TO THE RECORDING: https://youtu.be/DQe9bOXerYo?si=sJTUjPTSNkdAcQdK

8. Climate of Svalbard

Svalbard archipelago, a high Arctic region is undergoing rapid climate change. At the Polish Polar Station Hornsund over the last 40 years, temperatures have increased by 4.5 degrees Celsius - six times above average global warming. The increasing air temperatures go hand-in-hand with the decline of the Arctic sea-ice extent. Learn more about climate of Svalbard from this lesson.

LINK TO THE RECORDING: https://youtu.be/Z-ZHm8W6dGo?si=vWlYyDtx0lyjsqO-

9. Surviving the Arctic

Living in cold environment is a challenge, that's why some plants create a few ways of adaptation to the Arctic climate. How high are trees in Arctic forests or how many colours does tundra have in the summer?

LINK TO THE RECORDING: https://youtu.be/F7eBsmTFEeY?si=5AGb_ZGSasPOiPKB

10. Plants adaptation

Be invited for classes about Arctic plants adaptations! On the one hand, the term "flora" in polar regions might sound a little bit confusing. Let's see how the Arctic plants cope with Arctic conditions!

LINK TO THE RECORDING: https://youtu.be/SRZEXqfaMHw?si=jXXxdsssQ-8WnbCV

11. Plastic in the Arctic

Plastic found in the Arctic is a global problem – the tip of the iceberg. It is a result not only of the production and industry development but of our daily life habits as well. The plastic waste and more dangerous microplastic are found everywhere: in the oceans, ice, animals' stomachs or even snow.

LINK TO THE RECORDING: https://youtu.be/9WZz9yb4MuE?si=Nd_VFs-NgX4FJjCC

12. Is it time to build a new Noah's Arc? A few facts about global sea level rise

A dramatic account of an ancient flood can be found not only in Bible, but also folklore and myths all over the world. Today, sea level rise – along with its catastrophic impact on islands and coastal cities – is listed among the most serious consequences of ongoing climate change. What does it really mean, though, and what processes bring it about? To say that it's because the ice in the Arctic is melting is a gross oversimplification. Let's explain these phenomena.

LINK TO THE RECORDING: https://youtu.be/wt9O7WVzlHY?si=tS2l8zkBpBs_CBFc

13. How do humans (including polar researchers) cope with cold?

Changes in the intensity of abiotic factors affect the functioning of organisms and determine their occurrence in a given environment. If these changes are within the range of ecological tolerance, adaptive capacity will allow the organism to adapt and survive. If these changes are outside the range of ecological tolerance, the organism perishes, and humans are no exceptions. How to cope with unfavorable temperature?

LINK TO THE RECORDING: https://youtu.be/KgipiUmfPk4?si=Vxcv0MVMliwPsE1Z

14. Svalbard

Svalbard is an archipelago halfway between Norway and the North Pole. It is the northernmost year-round populated place on Earth. Learn about the nature, landscape, and settlements of these remote islands of the High Arctic.

LINK TO THE RECORDING: https://youtu.be/SW2ZiK4-Do4?si=4XpTEjNKo3pEAZcP

15. Snow in the Arctic ecosystem

How does snow form? Is Arctic snow different from that of the lower latitudes? How do researchers study snow and why? What is the impact of snow cover on vegetation and the inanimate environment? What lives in the snow?

LINK TO THE RECORDING: https://youtu.be/kZ78xCw1ZYM?si=USO3P4BD7Uwd2JS-

16. Polar illusion

Polar regions hold many mysteries, including some of the last places on Earth yet to be reached by man. Scientists do their best to see the invisible, without being led astray by appearances, which tend to be particularly deceptive in ice-covered lands. Extraordinary polar conditions favour illusion, which tricked the Vikings and even today – initially at least – might make us think of aliens. As usual, however, bewildering though they are, the phenomena can all be explained by science.

LINK TO THE RECORDING: https://youtu.be/8oNECeBJVM4?si=mQV28pyr53Gyunxw

17. Air pollution in the Arctic

This lesson is focused on the problem of air quality in polar regions. It explains how to define air pollution, presents main air pollutants, their local sources and the problems that they cause in polar environments.

LINK TO THE RECORDING: https://youtu.be/oz7ms1eoHHI?si=1HwO0PPcMoZgiV_M

18. The unknown world beneath our feet

Did you know that one quarter of all species are found in soil? Although soil organisms make up a large proportion of global biodiversity, we do not know much about these species and their ecological functions. Learn about some soil species, particularly in the Arctic, and how scientists try to find more about them as well as what you can do to have healthy soils.

LINK TO THE RECORDING: https://youtu.be/1Q2H1N7qGDY?si=Qk8cXiKfhrnGFfjw

19. Polar bear – the king of the Arctic

When we are thinking of the northernmost region of Earth - the Arctic - what comes to our mind first? Of course, polar bears! Those animals have high adaptive capacity to the unfriendly, Arctic climate, and every meeting with them is an unforgettable experience.

LINK TO THE RECORDING: https://youtu.be/LjJjcNuFccQ?si=FUT7Aq3Me-rr1k2T

20. Is life below water threatened by invasive fish?

What happens in a river when a new fish species arrives that does not belong there? You will learn how an invasive fish species in the Arctic can impact their environments, other species, and the economy. You will also get an introduction to animal invasions in general, and learn why with climate change, we expect the number of invasive species to grow.

LINK TO THE RECORDING: https://youtu.be/mZNBjKS4QBg?si=dx-VcwNjqfdqKib2

21. Northern lights

Northern lights are a phenomenon that has fascinated people for centuries. Colourful lights illuminating the night sky have already been observed in ancient China or in Greece. Meanwhile, in the 21st century the northern lights are a well-known phenomenon. We can explain the mechanisms that control it. We conduct regular observations and measurements from both the earth and the space. We have mathematical models that help us predict when and where the aurora appears.

LINK TO THE RECORDING: https://youtu.be/LtPR8Fnhvbg?si=jgDs3-BAo8k8kCuJ

22. Stories of sea ice

How is sea ice different from an iceberg? How does sea ice extent change over the seasons and over the years? What are feedback loops? What is the Arctic amplification? How does this affect the Earth's climate?

LINK TO THE RECORDING: https://youtu.be/OTWkfxdJNiM?si=OM9M7_u2qY7kzKPU

23. What on Earth is microbiota?

About half of your body consists of microbiota, which are bacteria, protists, viruses, and fungi! They are crucial to life - even in the Arctic! Learn how the microorganisms affect immunity, hormones and even the behaviour of animals We will use fish as our main study object. Because fish and many mammals like humans are not that different after all (we all came from a fishlike ancestor), you will learn about yourself too.

LINK TO THE RECORDING: https://youtu.be/YMjXZ8kODMk?si=yyq8WF3NZFRxG1uz

24. Plankton in the Arctic

The smallest animal organisms that are hard to observe with the bare eyes - or the most important organisms in the Arctic? Unable to resist the movement of the water in which they live, or participants in the greatest migration on the planet? Discover the secrets of the Arctic Plankton!

LINK TO THE RECORDING: https://youtu.be/DhQZgsXNNzY?si=g-sRs0K6hhC0cI99

25. Help from new biotechnology

Genetics is the study of the genes and traits that children inherit from their parents. Recent biotechnology has opened new ways to study this in great detail even for wild animals and fish. Learn how genetics and genomics can be used to study the impacts of human activities on wildlife populations, particularly in the very north!

LINK TO THE RECORDING: https://youtu.be/Vz1Ev3I6Uzk?si=Jj_yoRyYVFQ8e6Zl

26. Written in the Arctic: paleoclimatology

What is paleoclimatology, what are archives and proxies? Has climate change occurred in the past and how do we know it? How do scientists interpret natural records? What kind of history records can be found in the Arctic, and not only there? Do we owe "Frankenstein" to a volcano eruption?

LINK TO THE RECORDING: https://youtu.be/-ddRJg92WQs?si=qa1lE4YA60r2QZVp

27. The life of glaciers

There are about 200,000 glaciers in the world. They can be as tiny as a football pitch or as big as half a country. They can transform the landscape, control climate, supply freshwater, be the place of living. Learn about glacier's life cycle and life blooming in and on the glaciers!

LINK TO THE RECORDING: https://youtu.be/N7G81EMTKv0?si=e6AFMTDVl6BJDVme

4. Next steps

The tool-kits are freely available on the INTERACT website. They will be also promoted via Scientix repository (http://www.scientix.eu/resources). Scientix is a community for science education in Europe and promotes and supports a Europe-wide collaboration among STEM (science, technology, engineering and maths) teachers, education researchers, policymakers and other STEM education professionals. Once the tool-kits are added to the Scientix repository, they will be promoted in the Scientix website and Scientix Digest (received by more than 2300 teachers and educators from European countries and beyond).

Moreover, schools will be encouraged to use tool-kits via different activities e.g. sending invitation to STEM teachers registered in the EDU-ARCTIC platform (in total 2502 teachers from 70 countries). The tool-kits will also be promoted in social media run by INTERACT and the Institute of Geophysics PAS in order to increase their usage in classrooms around the world.

5. Appendix 1 Syllabuses of the educational tool-kits

EDUCATIONAL TOOL-KIT SYLLABUS

INTRODUCTION

The Arctic is changing rapidly. The warming trend in the Arctic is at least twice as large as the global average in recent decades. We call it **Arctic amplification** - the fact that temperature rise in polar regions is large in comparison to the temperature rise in lower latitudes and may further accelerate climate warming well beyond the Arctic. The loss of sea ice is one of the most cited reasons of Arctic amplification. When reflective ice melts, a darker ocean dominates. This amplifies the warming trend because the ocean surface absorbs more sun heat than the surface of snow and ice. Decrease in sea ice extent **reduces Earth's albedo** and accelerates the global warming.

The climate change accelerates also melting of glaciers, which causes sea level rise. Scientists estimate that due to melting of ice the sea level will increase **by 100 cm** by the end of the century.

Reduced snow cover on land affects boreal forests. They become more susceptible to drought, and consequently – to **fire.**

From decaying organic matter, trapped previously in **permafrost** and revealed due to thawing of permafrost, additional greenhouse gases are released to the atmosphere. It accelerates the temperature rise.

As the temperature in the Arctic is rising more rapidly than in the rest of the globe and the temperature on the Equator is increasing slowly, the differences between the North Pole and the Equator is decreasing. It slows down the **global circulation** and may affect the weather patterns far beyond the Arctic.

TARGET GROUP
STUDENTS 13-19 YEARS OLD

Content of TOOL-KIT

- PRESENTATION
- WEBINAR RECORDING
- DETAILED LESSON PLAN
- EXPERIMENT SCENARIO
- WORSHEET FOR STUDENTS
- WORKSHEET WITH ANSWERS FOR TEACHER

GLOSSARY

- Albedo
- Arctic
- Arctic amplification
- Climate
- Emission scenarios
- Greenhouse effect
- Greenhouse gas
- Permafrost
- Permafrost Carbon Cycle
- Sea ice
- Sea ice minimum
- Weather

ARCTIC ISSUES:
The changing Arctic

THINGS TO LEARN - 5 basic questions

1. What kind of feedback loops are effective in the Arctic?
2. How does the changing sea ice extent impact the albedo?
3. What is "Arctic amplification"?
4. What are the effects of thawing permafrost?
5. What are the main challenges that the Arctic faces due to climate change?

ADDITIONAL RESOURCES:

INTERACT & BBC Arctic Climate Magnification (video)

INTERACT & BBC Extreme Causes For Concern (video)

TED-Ed animation: Why the Arctic is a canary in a coal mine

National Snow and Ice Data Center

Interactive sea ice chart (by NSIDC)

Arctic sea ice 1984-2018 (video)

Fill in the Blanks Game: Arctic amplification

EDUCATIONAL TOOL-KIT

The invaded Arctic

SYLLABUS-IN-ONE-SHOT

TARGET GROUP

STUDENTS 13-19 YEARS OLD

WHY TEACH THIS TOPIC?

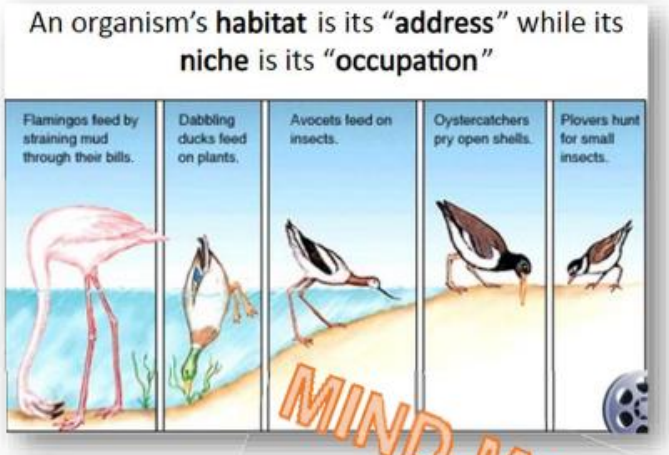
- Critical thinking and problem solving
- Global awareness
- Environmental literacy

Invasive species disrupt the established niche system of the ecosystem. This is a serious threat to sustainability of ecosystems, which affects all human well-being as everything we do depends on intact ecosystems in one way or another.

The Arctic ecosystems are particularly vulnerable if invaded by exotic species. All its native species live at extremes. The Arctic is also particularly affected by the warming climate, and increased tourism, a major cause of invasive species.

THINGS TO LEARN

- What is ecological niche?
- Why does it matter?
- What is the difference between exotic and invasive species?
- What can YOU do?



Niche competition = happens if more than one species tries to occupy the same niche. It typically occurs when exotic species invade new areas. Because only one species can occupy a niche over time***, the most competitive species will "win" the niche, while the other one will have to adapt to occupying another niche (or become extinct!).

FUN FACTS

- ✓ THE PARTY FACTOR
- ✓ THE FIRST EVER INVASIVE
- ✓ AND THE CHAMPION IS: THE EUROPEANS!
- ✓ IT WAS THE SCIENTISTS WHO DID IT
- ✓ ROBOTS TO THE RESCUE!

The tool-kit comes with the following files:

- SYLLABUS (this document)
- LESSON PLAN
- MATERIALS FOR TEACHERS
- WORKSHEET FOR STUDENTS
- WORKSHEET, TE'CHER'S VERSION
- DIGITAL ESCAPE ROOM
- OFFLINE VERSION OF ESCAPE ROOM
- RECORDED WEBINAR
- ADDITIONAL RESOURCES (listed in worksheet, teacher's version)

EDUCATIONAL TOOL-KIT SYLLABUS

INTRODUCTION

Arctic is a vast region of the Earth. It is home for up to 31,000 polar bears and 4 million people, 10% of which is the indigenous population. The Arctic is strongly affected by the climate change— sea ice is melting and the temperature there is warming two-three times faster than the rest of the globe. That phenomenon is called 'Arctic amplification.' Among the other risks should be mentioned these connected with economic growth accompanying with increasing consumption. That resulted in different types of pollution that have been observed and studied by the scientists over the last decades. Even though the Arctic is almost pure environment itself, the pollution is transported by air and by sea over long distances from more polluted places on the Earth.

On the one hand there are so called 'black carbon' and 'brown carbon' emissions caused by the wildfires that occur all over the world. On the other hand we might name a lot of chemical substances that are toxic and harmful to the Arctic environment (PCBs, POPs, etc.). All those threats are mainly of the anthropogenic origin.

Pollution in the Arctic means also a real danger for indigenous population. It affects lifestyle, diet, traditions and habits of local people and cause many diseases and health disorders. These matters altogether with Arctic environment protection issues need to be taken into consideration by the local and international policy makers.

Content of TOOL-KIT

- PRESENTATION
- WEBINAR RECORDING
- DETAILED LESSON PLAN
- EXPERIMENT SCENARIO
- WORSHEET FOR STUDENTS
- WORKSHEET WITH ANSWERS FOR TEACHER
- GAME

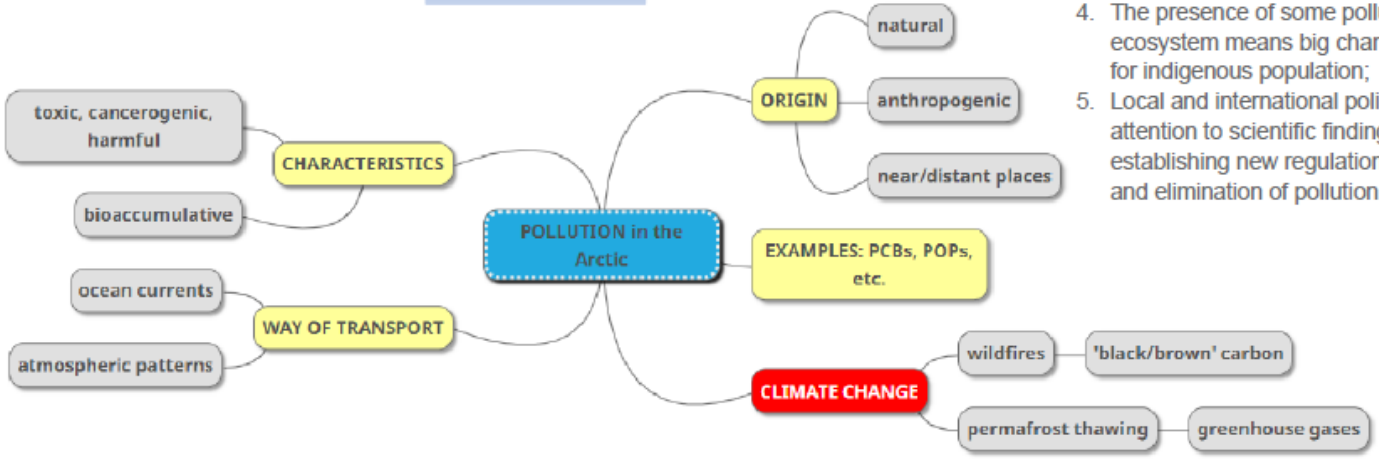
ARCTIC ISSUES:
The polluted Arctic

TARGET GROUP
STUDENTS 13-19 YEARS OLD

5 basic concepts

1. The pollution that reaches the Arctic has the origin in other, sometimes (very) distant places on the Earth;
2. Chemical, plastic and other types of pollution are harmful either for the people or the animals living in the Arctic;
3. Ocean currents and atmospheric patterns transport pollutants from lower latitudes to the Arctic;
4. The presence of some pollutants in the Arctic ecosystem means big changes in traditional way of life for indigenous population;
5. Local and international policy makers should pay more attention to scientific findings and natives rights when establishing new regulations on identification, reduction, and elimination of pollution.

MIND MAP



Source: https://app.mindmup.com/map/_free/2023/12/5eeb5530982f11eeb7fc9da49d2e859e

ADDITIONAL RESOURCES:

Video materials:
- INTERACT webinar 'Stories of sea ice'
- Pollution in the Arctic with Dr. Katrin Vorkamp

Interactive maps:
- NASA Earth Observatory fire maps
- Distribution of litter types in different realms
- Plastic pollution

Reports:
- AMAP Mercury in the Arctic
- AMAP Microplastics and litter in the environment
- AMAP POPs—climate change interactions

Polarpedia terms:
- Arctic amplification
- Bioaccumulation
- Biomagnification
- Greenhouse gas
- Indigenous people
- Microplastic
- Permafrost
- Sea ice
- Thawing permafrost

SYLLABUS

EDUCATIONAL TOOL-KIT

INTRODUCTION

The Earth's climate is not stable and fluctuates between colder periods called Ice Ages, and warmer periods known as Interglacials. We live in an interglaciation, which in Europe is called Holocene. This period with warm climate started about 11.700 years ago when the last ice age ended. Scientists studying modern climates use land instruments, balloons, and even satellites. These sophisticated monitoring devices are recent. In fact, simple instruments such as thermometers and rain gauges have only been used for about 150 years. To learn what the climate was like before 1850, scientists must use other approaches. The study of past climates is called paleoclimatology. Rather than using instruments to measure past climate, paleoclimatologists must use "proxy" records. Scientists can reconstruct a general picture of an ancient environment by collecting information about the soil and the plant and animal remains that are found at a site. Comparisons of living plants and animals with these ancient remains can then indicate the types of environments that existed in the past.

They study tree rings, ice cores, and lake and ocean sediments that provide a record of climate change over thousands of years. For example, favourable climatic conditions cause a tree to grow a lot in one year, while poor conditions mean slower growth. Scientists can "read" these changes by comparing the width of annual tree rings. The chemistry of dust and air bubbles trapped in glaciers and ice sheets also provides information about local temperatures, precipitation, and the composition of the atmosphere. These records can extend information back as much as 100,000 years. Data can even be obtained on climatic conditions hundreds of millions of years ago by studying the chemical composition of ancient rocks and the fossils embedded within them.

Environmental conditions may have stimulated important developments in human origins. Diverse species have emerged over the course of human evolution, and a suite of adaptations have accumulated over time, including upright walking, the capacity to make tools, enlargement of the brain, the emergence of complex mental and social behavior, and dependence on technology to alter the surroundings.

The period of human evolution has coincided with environmental change, including cooling, drying, and wider climate fluctuations over time. Periods of lower or higher average temperatures have also affected human history, contributing either to wars and austerity or abundant development and prosperity. Accounts, artistic depictions, and photographs of advancing and retreating mountain glaciers during recent centuries provide evidence of climate change on more recent timescales.

Scientists are using the theories they have constructed to explain the paleoclimate data record to understand the modern climate and to predict how we can expect it to change in coming years or decades.

TARGET GROUP

STUDENTS 13-19 YEARS OLD

Content of TOOL-KIT:

- RESEARCHING PAST ENVIRONMENTS-BACKGROUND MATERIAL FOR TEACHERS (BASIC/ADVANCED)
  + PRESENTATION
  + WEBINAR RECORDING
- 2 ANIMATIONS
- DETAILED LESSON PLAN
- WORSHEET FOR STUDENTS
- 1 EXPERIMENT INSTRUCTION, 2 ONLINE GAMES
- WORKSHEET WITH ANSWERS FOR TEACHERS

ARCTIC ISSUES:

STUDYING PAST ENVIRONMENTS

THINGS TO LEARN – 5 basic questions:

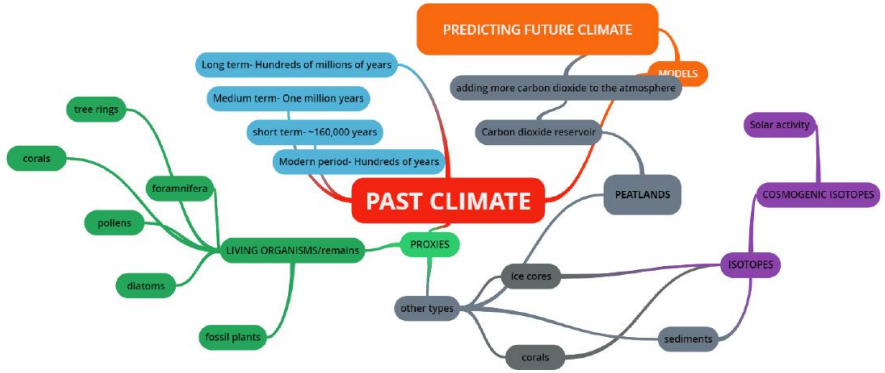
How do we study past environments - instrumental, historical, and environmental records - ice cores, sediments, tree rings, corals, peatlands and fossils.

Peatlands: what's the issue and why are they important?

How does understanding the past help to predict the future?

What was the climate like in Little Ice Age and Medieval Warm Period?

MIND MAP



GLOSSARY

ICE CORE
CLIMATE PROXY
PEATLAND
PALEOCLIMATOLOGY
LITTLE ICE AGE
MEDIEVAL WARM PERIOD
TREE RINGS
FORAMNIFERA
ICE AGES
INTERGLACIATIONS
ISOTOPES
DIATOMS

WHERE IS IT STUDIED? EXAMPLES OF POLAR STATIONS WITHIN INTERACT NETWORK:

CHOKURDAKH SCIENTIFIC TUNDRA STATION

IGARKA GEOCRYOLOGY LABORATORY

MUKHRINO FIELD STATION

CHURCHILL NORTHERN STUDIES CENTRE

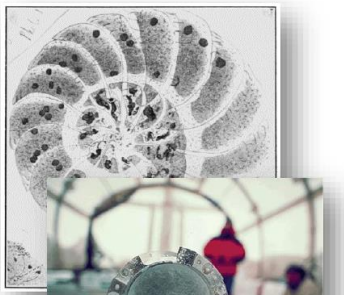


PHOTO: HÅKAN SAMUELSSON/NATURAL RESOURCES CANADA

ADDITIONAL RESOURCES

ARTICLE: An extended Arctic proxy temperature database for the past 2,000 years

VIDEO: The Last Time the Globe Warmed

VIDEO: CLIMATE AND HUMAN EVOLUTION

DATABASE: NOAA PALEOCLIMATIC DATASETS

Synchronization of ice cores using cosmogenic isotopes

VIDEO: tree rings explained