frontiers | Frontiers for Young Minds

EARTH AND ITS RESOURCES
Published: 18 October 2022
doi: 10.3389/frym.2022.703805

POLAR AMPLIFICATION: STRONGER WARMING IN THE ARCTIC AND ANTARCTIC

Irina Gorodetskaya[1,2], Melanie Lauer[3] and Theresa Kiszler[3]*

[1] *Centre for Environmental and Marine Studies (CESAM), Department of Physics, University of Aveiro, Aveiro, Portugal*

[2] *Interdisciplinary Centre of Marine and Environmental Research (CIIMAR) of the University of Porto, Porto, Portugal*

[3] *Department of Mathematics and Natural Sciences, Institute of Geophysics and Meteorology, University of Cologne, Cologne, Germany*

YOUNG REVIEWERS:


FRANCESCO
AGE: 10


GIOSUÈ
AGE: 8


LORYAN
AGE: 10


MATTIA
AGE: 8


MIRKO
AGE: 9

During the past several decades, our planet has warmed because people have added a lot of greenhouse gases to the atmosphere. The warming in the polar regions (the Arctic, and parts of the Antarctic) has been much higher than in the rest of the world. Melting of snow and ice, disappearing glaciers, and rising global sea levels are evidence of the strong warming occurring in the polar regions. Various measurement techniques are used to discover how much the temperature, as well as sea ice and snow cover, have changed in the polar regions. In this article, you will learn how shrinking ice and snow, increasing clouds, and thinner ice help to warm the polar regions much more than other regions of the world.

SOFIA

AGE: 9

VITTORIA

AGE: 9

WHAT IS POLAR WARMING AMPLIFICATION?

Earth has two polar regions—the Arctic in the north, and the Antarctic in the south. The Arctic is a vast ocean with large areas covered by **sea ice**, even in summer. The Arctic also contains a huge island covered by ice, called the Greenland **ice sheet**. Northern regions of North America, Europe, and Asia also belong to the Arctic—they are covered by a lot of snow in winter and have **permafrost**, which is the permanently frozen ground. Antarctica is a huge ice sheet, which is surrounded by the Southern Ocean. Although the two polar regions have different characteristics, they have one thing in common: they are both covered by snow and ice year-round, because they are very cold. However, due to the recent warming of our planet, polar regions are also warming (Figure 1A), and their snow and ice cover is shrinking (Figure 1B). What is more, the Arctic and part of Antarctica have warmed more rapidly and strongly than other regions of the Earth. This phenomenon is called **polar amplification**.

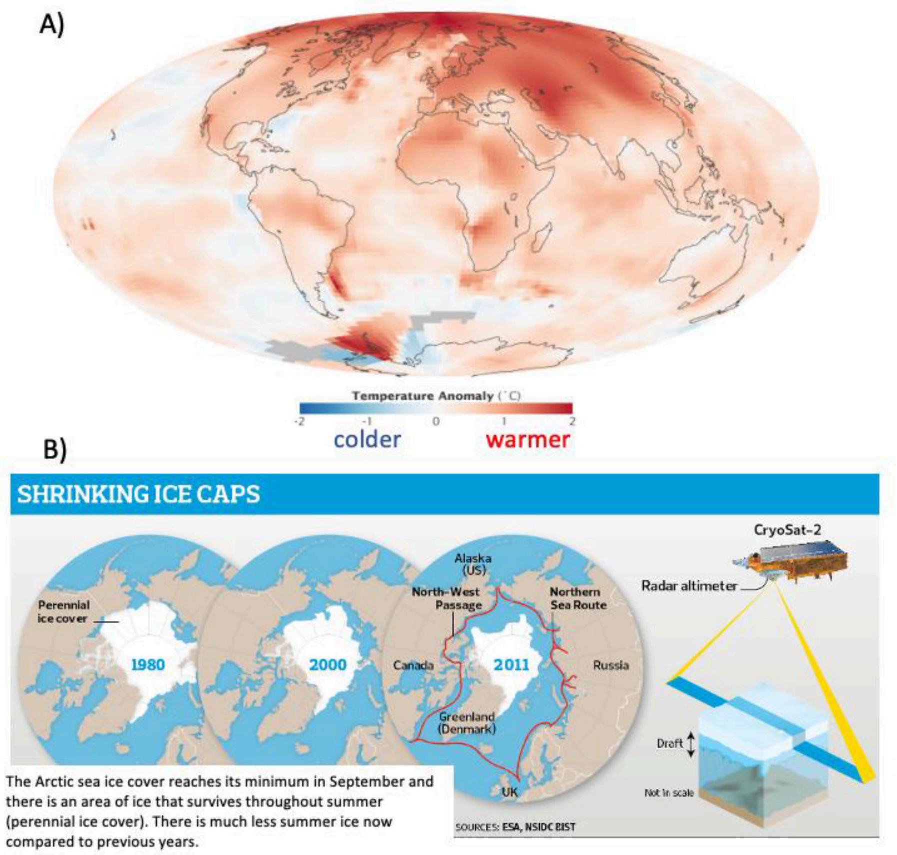

Figure 1

SEA ICE

Ice that originates from freezing of ocean water.

ICE SHEET

A large body of ice that originated from compacted snowfall accumulating on rocky land over many years (currently there are two ice sheets—Greenland and Antarctic).

PERMAFROST

Ground that stays frozen throughout the year, even in summer.

Figure 1

(A) Temperature changes between two periods: 2000–2009 compared with 1951–1980. Pink/red colors show where temperatures became warmer, and blue colors show where temperatures became colder. The entire Arctic and the Antarctic Peninsula have become 2°C warmer, which is much warmer than other regions (Image credit: National Aeronautics and Space Administration). **(B)** Shrinking summer sea ice in the Arctic, as measured from space by the CryoSat-2 satellite (Image credit: European Space Agency and National Snow and Ice Data Center). Radar altimeter is a sensor installed on the CryoSat-2 satellite measuring sea ice thickness above the water level (without the sea ice draft, which is below the water level).

WHY IS POLAR AMPLIFICATION IMPORTANT?

POLAR AMPLIFICATION

Greater warming near the poles compared to the rest of the world in response to global climate change.

The consequences of warming in the polar regions can be devastating: animals like polar bears lose their habitats; people living in those regions cannot continue their traditional lifestyles; and land that was frozen for thousands of years collapses, destroying buildings or roads built on it. The melting of snow and ice in the polar regions also has consequences around the world. For example, the melting of the Greenland and Antarctic ice sheets causes large amounts of water to flow into the ocean, which causes global sea levels to rise and may flood many islands and low-lying coastal areas around the world. Climate change in the polar regions also influences the rest of the Earth's weather. Thus, while someone may say that disappearing sea ice brings benefits like easier access to the Arctic sea routes (shown by the red line in Figure 1A), the bad consequences we listed above outweigh any economic benefits. Scientists are concerned about all these impacts, so they are investigating why the polar regions are warming so quickly, how much they will continue to warm in the near future, and what the local and global impacts of this warming might be.

MEASURING POLAR AMPLIFICATION

How do we know that temperatures have been changing in the polar regions? Scientists can measure the temperatures of the air, ocean, snow, and ice in these regions (Figure 2). Some stations have been measuring for more than 70 years, so we know how temperatures have been changing every year, month, and day since then. These stations need people to be present to take the measurements; but recently, scientists have been using automatic weather stations that need maintenance only once a year and thus can be installed at many more locations [1]. Scientists also take a lot of measurements during expeditions, when they study changes in the ocean, ice, snow, and atmosphere simultaneously [2]. Since 1979, there have been scientific satellites measuring Earth from space and giving a lot of information about changes in the polar regions and across the globe (such as the CryoSat-2 satellite shown in Figure 1B).

Long-term measurements show that temperatures in the polar regions have increased at twice the global average. Since humans started adding lots of greenhouse gases to the atmosphere at the end of the 19th century, the Arctic and parts of the Antarctic Peninsula have warmed on average by more than 2°C, while the global average temperature increase has been 1°C. Large amounts of snow and ice have also melted, and the air has become more humid and cloudier, which has increased the amount of precipitation. It often rains instead of snowing in the Arctic now.

Figure 2

Figure 2

(A) Weather stations where measurements are recorded by scientists living on-site at one of the Arctic stations (Image credit: Russian Hydrometeorological Service). **(B)** Automatic weather station installed near Princess Elisabeth station in East Antarctica (Photograph credit: Irina Gorodetskaya). **(C)** Measurements of the atmosphere using a weather balloon at the Escudero station in Antarctica (Photograph credit: Penny Rowe and Edgardo Sepúlveda). **(D)** Measurements of ocean temperature and salt content during the Antarctic Circumnavigation Expedition (Photograph credit: Irina Gorodetskaya). **(E)** Measuring the temperature and thickness of snow and ice (Photograph credit: Lianna Nixon) **(F)** A laser measuring changes in snow cover (Photograph credit: Esther Horvath).

WHY ARE THE POLAR REGIONS WARMING FASTER AND STRONGER? LOCAL FEEDBACK!

Several processes are responsible for making the warming in the polar regions stronger than in other areas of the Earth. These are known as **feedback** processes [3], and they are processes that increase or decrease the original change (Figure 3). The processes that make warming even stronger are called positive feedback. And "positive" does not mean they are good! We will explain three of these positive feedback processes in more detail.

Snow- and Ice-Albedo Feedback

The land and ocean in the polar regions can be covered in snow and ice. Snow- and ice-albedo feedback describes the relationship between the sun's rays and the snow and ice covering a surface (Figure 3A) [4]. The balance between the incoming sun rays and those reflected from a surface is called **albedo**. This feedback only occurs during daylight, so it cannot occur during the **polar night**—in winter, when polar regions do not receive any sunlight. If the sun's rays hit a bright surface like snow or ice, most of the rays are reflected back to the sky and are not taken up by the surface. This is called high albedo. Snow- and ice-free surfaces in the polar regions are darker and reflect fewer of the sun's rays. Instead, these rays are stored by the surface, which is known as low albedo.

So, as the polar air warms, snow and ice melt. Large parts of the ocean and land surfaces that were once covered by snow and/or ice become exposed and take up more sun rays. This warms the land surface and ocean *even more* and leads to *further* melting of snow and ice.

FEEDBACK

A process that makes an initial change (such as a temperature change) stronger (positive feedback) or weaker (negative feedback).

ALBEDO

The amount of the sun's rays that are reflected (and thus not absorbed) by a surface (ex. 10% albedo means 10% of the rays are reflected and 90% are absorbed).

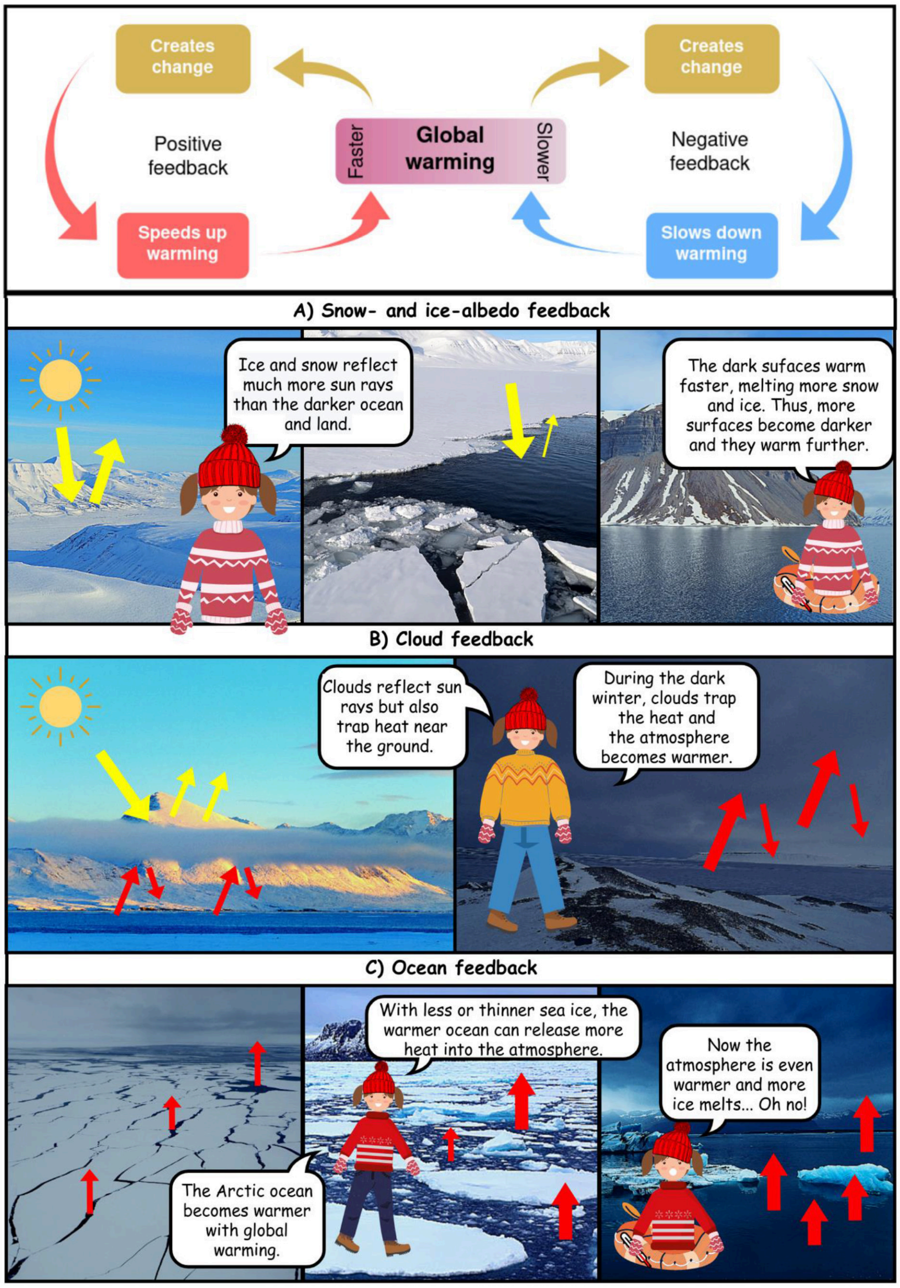

Figure 3

Figure 3

(TOP panel) Negative and positive climate feedback loops. Positive feedback speeds up warming, while negative feedback slows it down (Image credit: MetOffice, UK). **(A)** Snow- and ice-albedo feedback. **(B)** Cloud feedback. **(C)** Ocean feedback. In **(A–C)**, arrows represent the movement of heat from the ice/ocean/ground surface to the air above, and from the air to the surface (Photograph credits: A1–A3, B2 Melanie Lauer, B1 Vera Schemann, C1 Amelie Meyer, C2 northwestpassage2015.blogspot.com, C3 Emma Francis.

POLAR NIGHT

The winter period in the Arctic or Antarctic, when the sun does not rise and the night lasts several months.

This process will continue until all the snow and ice are gone from a surface.

Cloud Feedback

As the atmosphere becomes warmer, many processes happen that involve clouds—some lead to cooling and some to more warming. It is very complicated, and there are still many things we do not understand about these processes. Scientists measure clouds to understand their behavior, and they work with computer models to create virtual clouds, to study clouds' role in the climate system. One process that is being studied is called cloud feedback [2].

Clouds are made from little water droplets and/or ice crystals. Like ice and snow on the ground, clouds also have a high albedo and therefore reflect a large part of the sun's energy. However, in the polar regions, the sun does not shine during the polar night. During this time, the clouds block the energy emitted by the Earth's surface and send it back down, trapping it between the surface and the clouds. This energy warms the air (Figure 3B).

Warmer air contains more water vapor due to evaporation from the ocean, so it helps to form even more clouds…which increase the temperature even more. You can see that this is a positive feedback loop.

Ocean Feedback

Ocean feedback means that the ocean increases the warming of the air near the ocean surface [5], and this also interacts with other types of feedback (Figure 3C). First, because of increased ice/snow melting during the summer, the Arctic Ocean and land absorb more solar energy due to the snow- and ice-albedo feedback. Clouds warm the surface further, especially during the long polar winter, melting the ice and snow even more *via* cloud feedback. Scientists also found that global warming is causing increased inflow of warmer Atlantic water into the Arctic. All these processes warm the Arctic Ocean and melt sea ice, making it thinner and less abundant in winter. This is when ocean feedback starts to play a role: in winter, the Arctic Ocean is much warmer than the air above it, especially as the ocean continues to warm due to global warming. When there is less ice or thinner ice, the ocean can give more heat to the air, warming it even more. This is another positive feedback loop!

SUMMARY

During the past few decades, the entire Arctic region and parts of the Antarctic have warmed more than the rest of the world has. We know this thanks to long-term measurements and expeditions. This phenomenon is known as polar amplification, and it occurs because of various feedback processes, such as snow- and ice-albedo feedback, cloud feedback, and ocean feedback. Computer models of the climate system show that warming will continue in the future, with Arctic sea ice disappearing completely in summer over the next 20–30 years. Disappearing Arctic sea ice in summer harms indigenous people, as well as animals depending on ice and fragile ecosystems, while melting ice sheets raise global sea level. Although the current situation is dire, if all the countries of the world do their part by reducing greenhouse gas emissions, we can still slow down this warming and possibly even bring Arctic sea ice back!

ACKNOWLEDGMENTS

IG thanks FCT/MCTES for financial support to CESAM (grant nos. UIDP/50017/2020, UIDB/50017/2020, and LA/P/0094/2020) and the FCT Project ATLACE - ATLantic interactions via atmospheric water cycle: exploiting a unique dataset from the Antarctic Circumnavigation Expedition for better understanding of clouds and precipitation (CIRCNA/CAC/0273/2019) through national funds. ML and TK acknowledge the funding by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - Project number 268020496 - TRR 172, within the Transregional Collaborative Research Center-ArctiC Amplification: Climate Relevant Atmospheric and SurfaCe Processes, and Feedback Mechanisms (AC)3. Written informed consent was obtained from the individual(s) for the publication of any identifiable images or data included in this article. The authors thank Clara Burgard, Chris Jones, and Robin Matthews for their helpful comments on the text and also thank our young reviewers for their interest and helpful feedback.

REFERENCES

1. Gorodetskaya, I. V., Kneifel, S., Maahn, M., Van Tricht, K., Thiery, W., Schween, et al. 2015. Cloud and precipitation properties from ground-based remote-sensing instruments in East Antarctica. *Cryosphere* 9:285–304. doi: 10.5194/tc-9-285-2015
2. Wendisch, M., Macke, A., Ehrlich, A., Lüpkes, C., Mech, M., Chechin, D., et al. 2019. The arctic cloud puzzle: using ACLOUD/PASCAL multi-platform observations to unravel the role of clouds and aerosol particles in Arctic amplification. *Bull. Amer. Meteor. Soc.* 100:841–71. doi: 10.1175/BAMS-D-18-0072.1
3. Stuecker, M. F., Bitz, C. M., Armour, K. C., Proistosescu, C., Kang, S. M., Xie, S.-P., et al. 2018. Polar amplification dominated by local forcing and feedbacks. *Nat. Clim. Change* 8:1076–81. doi: 10.1038/s41558-018-0339-y
4. Serreze, M. C., and Barry, R. G. 2011. Processes and impacts of Arctic amplification. A research synthesis. *Glob. Planetary Change* 77:85–96. doi: 10.1016/j.gloplacha.2011.03.004
5. Maslanik, J. A., Fowler, C., Stroeve, J., Drobot, S., Zwally, J., Yi, D., and Emery, W. 2007. A younger, thinner Arctic ice cover: increased potential for rapid, extensive sea ice loss. *Geophys. Res. Lett.* 34:L24501. doi: 10.1029/2007gl032043

SUBMITTED: 30 April 2021; **ACCEPTED:** 27 September 2022;
PUBLISHED ONLINE: 18 October 2022.

EDITOR: Robin Matthews, Université Paris-Saclay, France

SCIENCE MENTOR: Matteo Lorenzini

CITATION: Gorodetskaya I, Lauer M and Kiszler T (2022) Polar Amplification: Stronger Warming in the Arctic and Antarctic. Front. Young Minds 10:703805. doi: 10.3389/frym.2022.703805

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

FRANCESCO, AGE: 10

Francesco is 10 years old and lives in Italy. He loves playing piano and devotes every spare moment to it. His favorite sport is basketball. As a book eater, he reads every night in bed for at least 1 hour. He also really likes Pokemon cards and has a nice collection. He loves nature and animals. He also likes fishing—then letting the fish free in water again. Among his favorite things are also drawing and cooking.

GIOSUÈ, AGE: 8

My name is Giosuè, I am eight and a half years old, I live in San Cesareo with my parents and my younger brother Leonardo who is almost 5 years old. I really like playing football and my role is the goalkeeper. Since last year I am at my new school and it helped me discover that I definitely like school. We have fun, laugh, run and above all we are always outdoors. I also really like pokemon cards, biking, scooter, overboard and skateboard.

LORYAN, AGE: 10

My name is Loryan and I am 10 years old. I live in Roma, I love football and music. I am very interested in all what concerns climate, pollution and planet Earth.

MATTIA, AGE: 8

Hi! I am Mattia, I like to skateboard and to draw comic strips. I think that scientific articles could be more interesting if they were written in cartoon bubbles. Maybe 1 day I will be a scientific cartoonist!

MIRKO, AGE: 9

Mirko is 9 years old and lives in Roma. He loves playing soccer with friends. He likes eating sushi very much and his favorite subject is history.

SOFIA, AGE: 9

Hi, I am Sofia, a young Italian girl and I am so curious!! I love my family and I love life! I like nature and sports. I go to school and my favorite subject is math, I like studying, but a little less than climbing trees. My favorite dish is my grandmother's meatballs and I really like cooking with her. When I grow up I would like to be a horsewoman or a violinist.

VITTORIA, AGE: 9

Vittoria is nine and a half years old, she likes drawing and painting, even writing and reading. Her favorite saga is "Harry Potter" and she is currently reading the third book; she has seen all the movies, and "The Hobbit" and "The Lord of the Rings." She is pretty good at doing impressions of Italian comedians as Teresa Mannino and Anna Marchesini. Ah, she loves popcorn!

AUTHORS

IRINA GORODETSKAYA

Dr. Irina Gorodetskaya is a polar meteorologist who is passionate about Arctic and Antarctic environments, where she mostly studies clouds, snowfall, atmospheric rivers, and their roles in the polar warming amplification. She believes that to understand things better we must measure them! She has been doing measurements in the polar regions for more than 10 years. She has lived, studied, and worked in Russia, USA, France, Belgium, and now Portugal. She enjoys reading, music, rock climbing, and traveling with her family and friends. *irinag@ciimar.up.pt

MELANIE LAUER

Melanie Lauer is a Ph.D. student in meteorology at the University of Cologne in Germany. Even as a child, she was enthusiastic about the weather and nature, so she decided to study meteorology. During her studies, she got to spend a semester in the northernmost higher education institute, in Longyearbyen, Svalbard. Following her stay in Svalbard, she has focused on processes that contribute to Arctic warming. Now, she analyses atmospheric rivers and their influence on precipitation (snow and rain) in the Arctic.

THERESA KISZLER

Theresa Kiszler is a doctoral student at the University of Cologne, Germany, and works on a large project studying Arctic amplification. Their interests cover many topics, from cloud formation and what happens inside of clouds to large storm systems such as hurricanes. After studying meteorology, Theresa switched their focus and got more involved in computational sciences. Now they mainly work on running programs (atmospheric models) on huge computers, to find out more about clouds in the Arctic.