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EARTH SCIENCES
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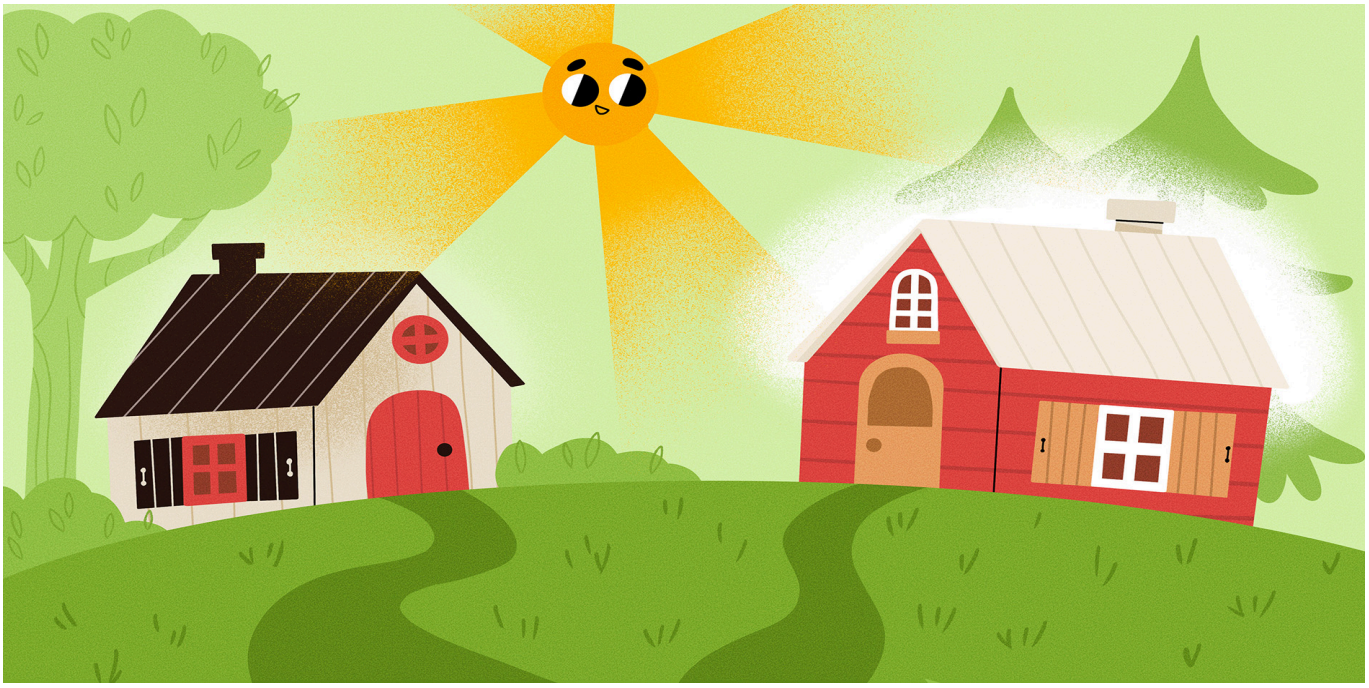

WHAT IS ALBEDO AND WHAT DOES IT HAVE TO DO WITH GLOBAL WARMING?

Leonie Esters*, Pilar Wirtz, Sylvia Brückner, Yidan Li and Magdalena Kracheletz

Department of Meteorology, Institute of Geosciences, University of Bonn, Bonn, Germany

YOUNG REVIEWERS:

HELENA, MOMO, TATI
AGES: 11–12

UMBERTO
AGE: 13

Albedo is the word to describe the amount sunlight that bounces, or reflects, off of the Earth. The concept of albedo is a very important one in discussions of Earth's climate, because it relates to how much heat is absorbed by various parts of the Earth. Earth's albedo is influenced by the physical properties of the planet's various surfaces. Some surfaces, such as ice and snow, reflect more of the sunlight and absorb less heat than do surfaces like oceans and forests. However, the physical properties of Earth's surfaces can change, both naturally and due to human activities. To protect Earth and its inhabitants from global warming, there may be ways we can engineer Earth's albedo so that more of the sun's heat is reflected away from our planet, but these theories require more research. In this article, we will explain what albedo is, how Earth's albedo can change, and how albedo influences climate.

WHAT IS ALBEDO?

ALBEDO

Albedo is the word to describe the amount sunlight that bounces, or reflects, off of the Earth.

SOLAR RADIATION

Solar radiation is like warm sunshine from the sun that gives us light and heat.

The word "**albedo**" is related to the Latin word "albus," which means white. Albedo is a property that every non-glowing object has, like a sheet of paper, a car, a mountain, and even the whole Earth. When an object is illuminated by the sun, that object's albedo describes how much of the **solar radiation** is reflected from (bounces off) the object and how much is absorbed by the object. You can experience the effect of different albedo values by touching cars of different colors in the summer sun. A black car will be much hotter than a white car. Why is this the case? The albedo of a white car is higher than the albedo of a black car. The white car reflects a bigger amount of the incoming solar radiation, so there is less solar radiation being absorbed to warm it up. The black car cannot reflect as much radiation, so it absorbs the rest and therefore warms up more (Figure 1).

Figure 1

A white car has a higher albedo than a black car. This means that a white car reflects most of the sunlight that hits it, while a black car absorbs more of the sunlight and thus warms up more than a white car.

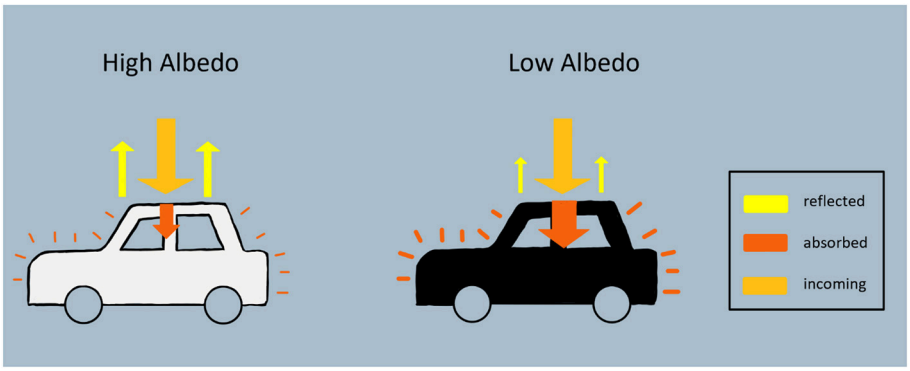

Figure 1

This effect is also true for the whole Earth. Earth has a lot of different surfaces: snow at the poles, water in the oceans, sand in the deserts, and trees in the forests, to name just a few. All these surfaces have different albedos, which can change depending on many factors—some of which we will describe in the next section.

Albedo is measured on a scale of 0 to 1, where 0 means an object reflects *no* sunlight at all, and 1 means an object reflects *all* of the sunlight and does not absorb any. For example, fresh snow has an high albedo of 0.8; while trees have an albedo of around 0.15. Albedo can be measured by devices that are called pyranometer. The word comes from the Greek word for "fire" and "sky".

CHANGES IN EARTH'S ALBEDO

One thing that albedo depends on is how bright surfaces are. When we are talking about Earth's surfaces, brightness can change. Sometimes these changes in Earth's albedo are natural, like when the leaves change color in autumn and fall to the ground, or when snow covers the land, or when it is hot and some areas become dry and plants die.

Other times, these factors are influenced by humans, such as building houses on grassland or forest clearing for agriculture.

Clouds can also affect Earth's albedo. Clouds can differ in structure depending on whether they are moving northward or southward, for example, and they can also differ depending on how high they are. These differences are primarily caused by differences in temperature and wind. The way the clouds move determines which areas of the Earth will be cloud covered, so cloud movement can change the albedo of whole regions of the Earth. Shifting weather patterns, which can affect cloud formation and movement, are influenced by climate change—which is at least partly human caused.

Other natural events like erupting volcanoes or large wildfires can also change Earth's albedo in an extreme way. Eruptions release ash, gasses, and other particles into the atmosphere, which changes the amount of sunlight that is reflected. In some cases, these changes can last a long time.

ICE-ALBEDO FEEDBACK

Let us take a closer look at an interesting example of the importance of Earth's albedo. Imagine that the whole Earth is flooded with water, and there is no land left to live on—this could be the ultimate result of something called **ice-albedo feedback**. Just like the white car we mentioned earlier, fresh snow has a very high albedo value (around 0.8), which can reflect most of the incoming solar radiation back to the atmosphere. This means less heat is absorbed and thus less snow will melt in the future. However, due to global warming, even the cold Arctic regions are experiencing more melting snow. When snow melts (especially fresh, very white snow), the albedo goes down very fast. As a result, more solar radiation is absorbed by Earth's surface, heating up the planet, which can cause *even more* snow to melt...and this ice-albedo feedback loop can go on and on (Figure 2) [1]. In the most drastic scenario, the whole Earth could be flooded.

CAN WE ENGINEER EARTH'S ALBEDO TO FIGHT CLIMATE CHANGE?

Climate change, which is worsened by some human activities, leads to many large-scale and damaging effects, including changes in Earth's albedo, as mentioned earlier. However, we can reduce the impact of climate change, primarily by reducing the amounts of greenhouse gases released into the atmosphere, as these gases are slowly warming up our planet. There are other things we can do as well, some of which involve **geoengineering**—making specific changes to the environment to counteract global warming.

ICE-ALBEDO FEEDBACK

Ice-albedo feedback is when melting ice exposes darker surfaces like water or land, which absorb more sunlight, causing more ice to melt, and making Earth even warmer.

CLIMATE CHANGE

Change of the state of Earth's climate system, which may be due to both natural and human activities. When we talk about man-made climate change, we use the term global warming.

GEOENGINEERING

Geoengineering is like Earth's science experiments. People try to change the climate using big ideas, like reflecting sunlight or removing carbon from the air, to fix global warming, but it's not simple or risk-free.

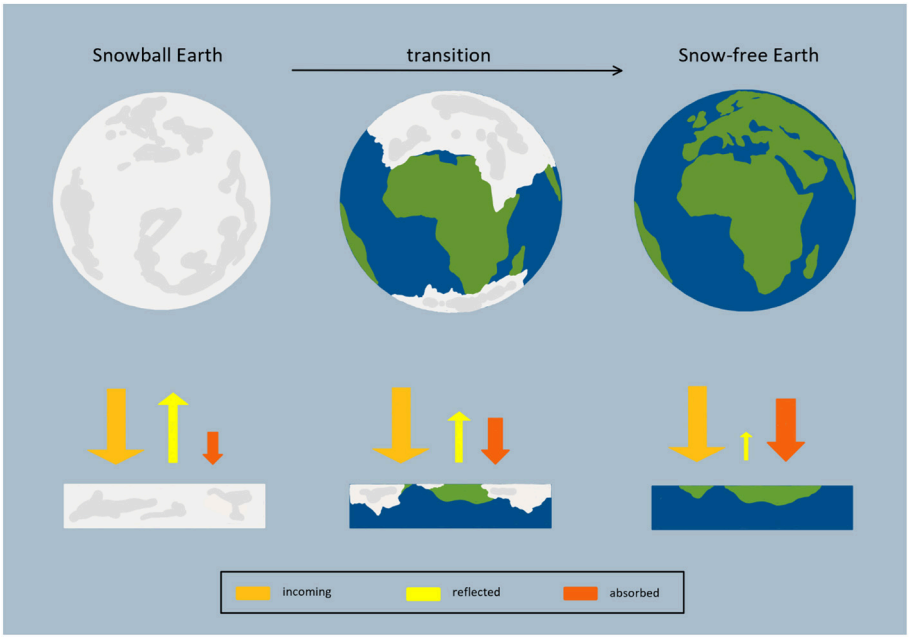

Figure 2

If the Earth were completely covered with ice, the albedo would be high, so the sunlight would mostly be reflected and would not warm up the Earth. If there are more ice-free surfaces with lower albedo, the sunlight hitting those surface will not be reflected as much, and the Earth will absorb more sunlight and warm up. Warming leads to *more* ice melting, which further lowers the albedo of the Earth. This ice-albedo feedback loop could go on until the Earth is completely ice free.

Here is one possible example of how geoengineering could be used to fight climate change. If more solar radiation is reflected from the Earth and thus less is absorbed, the climate could be cooled. So, to cool the Earth, we could try to change the albedo of Earth's surface or its atmosphere. There are already many ideas about how this could be accomplished. One idea is to increase the albedo of our constructed environments, such as cities. If roofs, streets, and sidewalks were painted white, they would reflect more radiation. This method would be most effective in sunny regions and might even decrease the need for air conditioning. Another idea is to grow plants with high albedos. Different kinds of plants have different albedo values depending on factors such as how reflective their leaves are. If we grew more of such "reflective" plants, we might be able to increase the albedo of some of Earth's surfaces.

Many of these ideas are just theories; some may be easier to implement than others. Although some geoengineering solutions for increasing Earth's albedo seem like they might have a cooling effect, nobody knows yet what the long effects of such solutions might be on our climate system. That means we need to be careful with those kinds of solutions and do more research to better understand and evaluate their effects. We feel that researching geoengineering solutions is worth the effort, because reducing global warming is one of the most important tasks facing humans today. With careful work, we can take steps that will protect our environment in the long term [2, 3]!

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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

HELENA, MOMO, TATI, AGES: 11–12
This fun-loving trio enjoys science and writing. They love to explore new topics and are especially interested in eco-friendly ways to combat climate crises to create a brighter future for our planet. Helena likes to hike and play soccer. She also adores her three cats. Momo enjoys being in nature, especially in city parks, because urban ecology shows her how strong nature can be. She is growing all sorts of plants in her hydroponic garden inside her city apartment. Tati loves dogs. She is an amazing sewer and builder.

UMBERTO, AGE: 13

My name is Umberto and I am 13 years old, I enjoy science, especially botany! I also really like art and I do pottery and drawing in my free time. I love hanging out with my friends and watching cartoons. I also started learning parkour.

AUTHORS

LEONIE ESTERS

Leonie Esters is junior professor in climate dynamics at the University of Bonn. Leonie is passionate about the environment. As a trained oceanographer, she is particularly interested in how the oceans and atmosphere interact. At the University of Bonn, she investigates the influence of turbulence on the air-sea exchange of carbon dioxide and methane, based on direct observations. *lesters@uni-bonn.de

PILAR WIRTZ

Pilar Wirtz is a 23-year-old bachelor's meteorology student at the University of Bonn, Germany. For her, there is nothing more fascinating than understanding how the world we live in works and how our behavior combines with natural processes to influence the environment.

SYLVIA BRÜCKNER

Sylvia Brückner is studying towards a master's degree in meteorology in Bonn, Germany. She thinks that meteorology, the study of our Earth's atmosphere, is a complex and beautiful science. Using physics and mathematics, a wide variety of processes can be explained and predicted. She is often amazed at how many of these processes continually interact with each other in complicated ways.

YIDAN LI

Yidan Li is a meteorology student at the University of Bonn, Germany. She thinks it is very important that people, especially younger kids, can learn about climate change in an interesting way, because global warming is already happening and is worsening every minute. She hopes by writing an informational article like this one, she and her fellow students can help the next generations appreciate the severity of climate change and therefore do more to stop it.

MAGDALENA KRACHELETZ

Magdalena Kracheletz is a 22-year-old Master student studying physics of the earth and atmosphere at the University of Bonn, Germany. Her special interest lies in climatology and understanding global warming. In addition to her normal schoolwork, she is currently working in a project estimating the influence of atmospheric water on the satellite gravity measurements of the GRACE-FO satellite mission, which is a very important mission in observing the Earth's changing climate.