SPACE awareness

THE BIG MELTDOWN

Discover how melting ice contributes to the rise of the sea levels

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Tópico curricular
oceans, climate change

Grande ideia científica
Earth is a system of systems which influences and is influenced by life on the planet

Palavras-chave
sea levels, Arctic, Antarctic, glaciers, ice, water, oceans, altimetry, remote sensing, climate change, global warming, buoyancy, Archimedes

Faixa etária
8 - 14

Nível de ensino
Primary School, Middle School, Secondary School

Duração
45min

Dimensão do grupo
Group

Controlo de segurança
Unsupervised

Custo
Average (5 - 25 EUR)

Localização
Indoors (small, e.g. classroom)

Competências básicas
Asking questions, Developing and using models, Planning and carrying out investigations, Analysing and interpreting data, Constructing explanations, Engaging in argument from evidence, Communicating information

Tipo de atividade de aprendizagem
Full enquiry

BREVE DESCRIÇÃO

With the help of a simple model (consisting of bowl, base, water and ice) the conceptual differences between Arctic and Antarctic are demonstrated and the impacts of the melting of their ice masses are made clear.

OBJETIVOS

The pupils will understand the difference between melting ice on land and melting floating ice and their effects on the global sea levels.

OBJETIVOS DE APRENDIZAGEM

Pupils are supposed to

- transfer the basic concepts of the Buoyancy Principle of Archimedes relevant applications on Earth.
- understand in principle the difference between the structure of the Arctic and Antarctic.
- transfer results of simplified model experiments to processes in Nature.

AVALIAÇÃO

Pupils are supposed to give an explanation in their own wording for the phenomenon witnessed. In case the necessary physical basic concepts have not been reviewed yet the pupils should be able to explain their observations in their own wording.

Question 1: Ice melts when heated or salted.

Remark: Tell the students that sea water freezes at lower temperatures than sweet water.

Question 2: glaciers, polar regions, high mountain range, lakes during winter

Question 3: Water levels rise, because the ice is transformed into water.

Question 4: They recede.

Question 5: The model represents the ice masses located on land, as they can be found in the mountains on Greenland or on Antarctica (south pole).

Task 1: The ice melts slowly and runs into the bowl.

Question 6: The water level rises.

Question 7: The second model represents the ice masses of the Arctic Sea floating on water or icebergs.

Task 2: The ice melts and seems to disappear.

Question 8: The water level did not change.

Question 9: Only land ice contributes to the rising sea levels. Floating ice does not contribute, because the part of the ice immersed into the water displaces just as much water as would be added, if the complete chunk of ice melts.

MATERIAL

Indicated is a set of items needed for one experimental set-up. Multiply by number of experiments to be carried out in parallel.

- Large transparent bowl
- Water ice
- Large stone or similar item that serves as a platform (about half the size of the bowl)
- Water
- Overhead marker
- Strong lamp

INFORMAÇÕES DE REFERÊNCIA

Sea surface altimetry

One of the most challenging consequences of the ongoing climate change on Earth is the rise of the sea levels that poses a threat to many coastal areas. Monitoring sea levels used to be a quite difficult task, as until a few decades ago, this could only be done via direct measurements and probes on open seas. With the advent of earth observing satellites and radar altimetry missions, it became possible to monitor sea levels very efficiently and effectively. While in situ measurements only provide a very local perspective of a given probe and the resolution of the global network is rather low, satellite measurements allow observing the entire earth at a high redundancy and frequency with at the same time high spatial resolution.

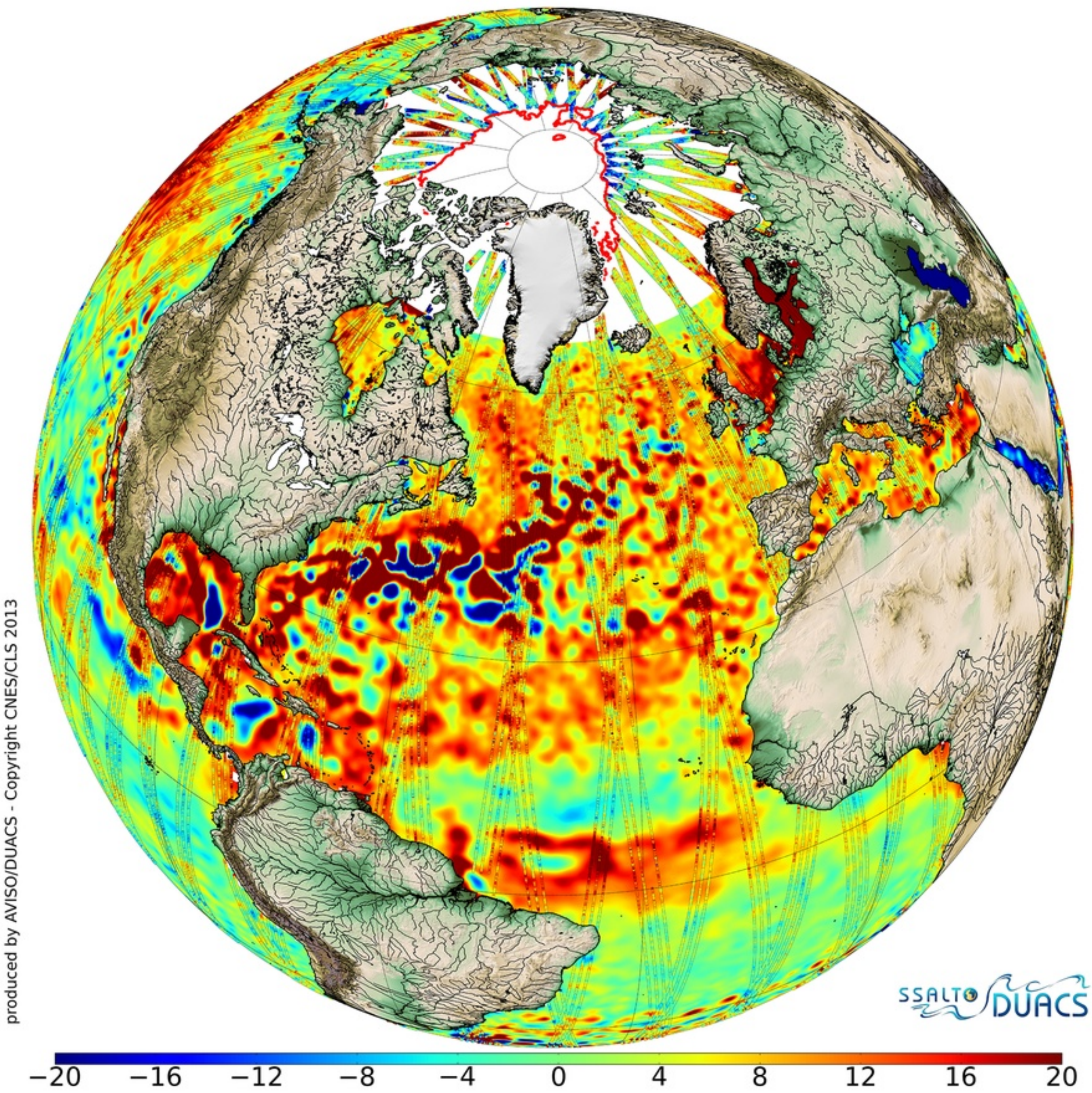


Figure 1: Average sea-surface topography for 2013 as mapped by CryoSat combined with data from other missions. Red represents higher sea levels (up to 20 mm above average) while blue represents lower areas (down to –20 mm). The perturbations seen in the Northern Atlantic are caused by the warm Gulf Stream current (Credit: ESA/CNES/CLS, http://www.esa.int/spaceinimages/Images/2014/06/2013_sea-surface_topography).

Known satellites with altimetry capabilities are e.g. CryoSat and Jason 2/3. The most recent addition is Sentinel 3, a flagship of the European Copernicus Earth observing programme that offers an unprecedented spatial resolution.

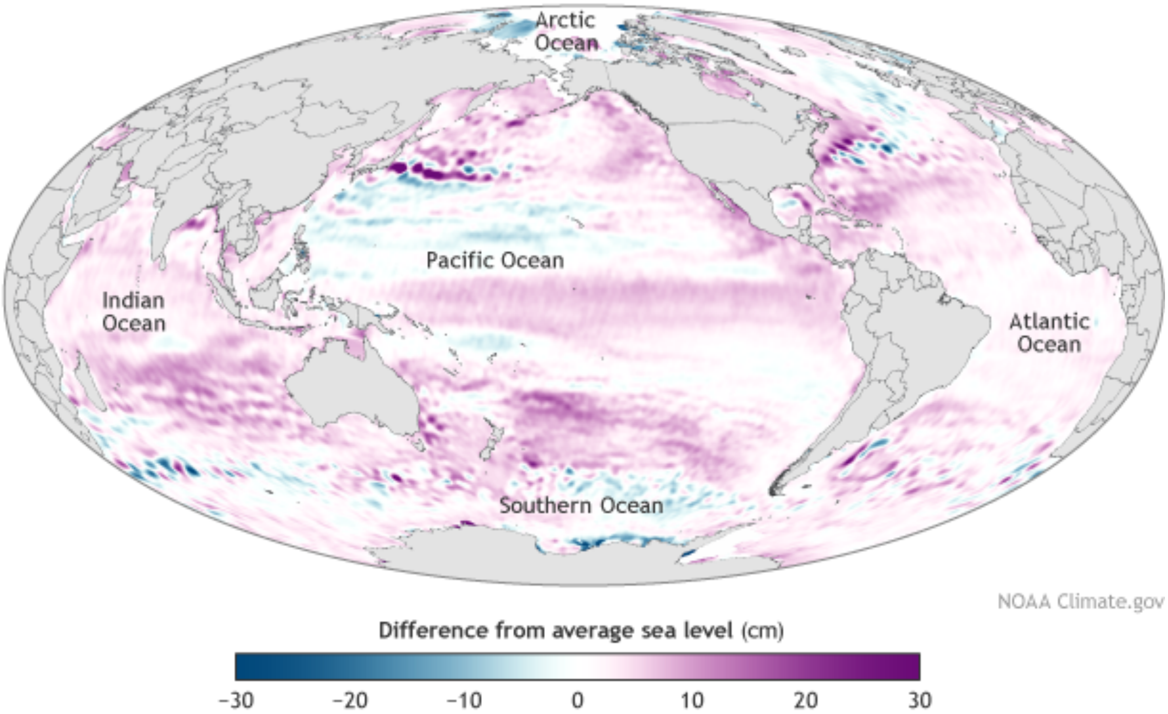
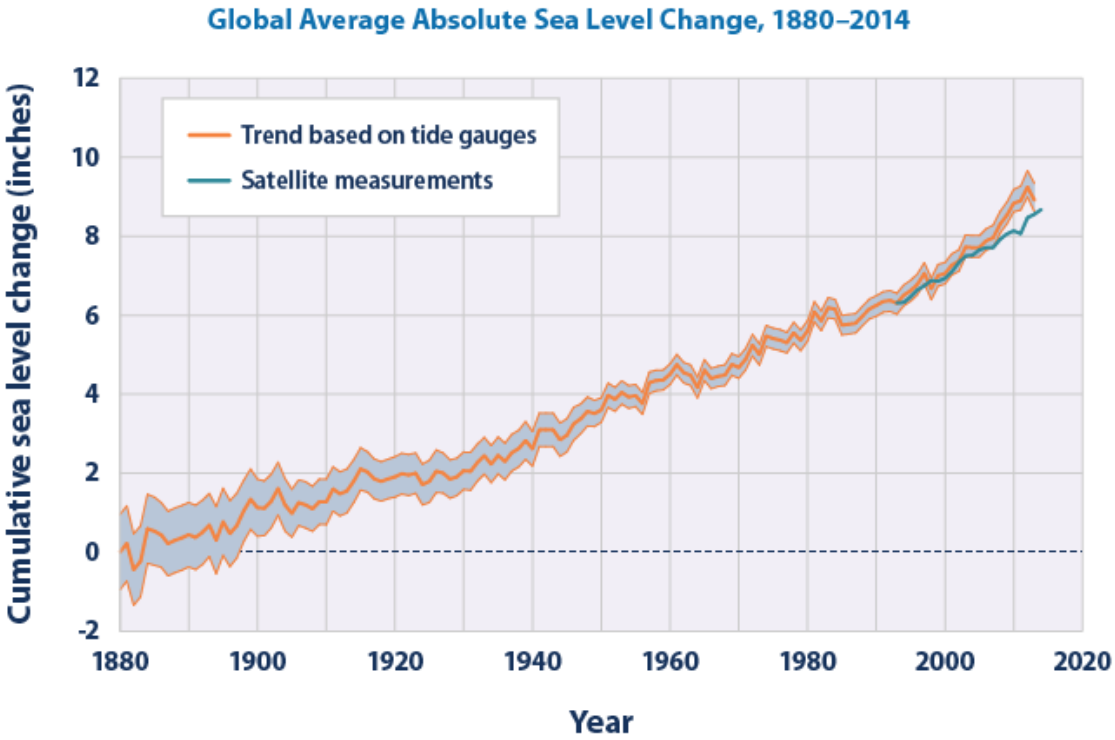


Figure 2: Sea level in 2014 compared to the global average at the mid-point of the 1993-2013 time series (Credit: NOAA Climate.gov map, adapted from Figure 3.25a in State of the Climate in 2014 report, https://www.climate.gov/news-features/understanding-climate/2014-state-climate-sea-level).

Oceans are on the rise

When combining such data obtained at different acquisition times, a general trend of the sea level evolution can be derived. When analysing all the data at hand, it is obvious that sea levels have been rising during the last one and a half centuries (Figure 3).



Data sources:

- CSIRO (Commonwealth Scientific and Industrial Research Organisation). 2015 update to data originally published in: Church, J.A., and N.J. White. 2011. Sea-level rise from the late 19th to the early 21st century. Surv. Geophys. 32:585–602. www.cmar.csiro.au/sealevel/sl_data_cmar.html.
- NOAA (National Oceanic and Atmospheric Administration). 2015. Laboratory for Satellite Altimetry: Sea level rise. Accessed June 2015. http://ibis.grdl.noaa.gov/SAT/SeaLevelRise/LSA_SLR_timeseries_global.php.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climatechange/indicators.

Figure 3: This graph shows cumulative changes in sea level for the world's oceans since 1880, based on a combination of long-term tide gauge measurements and recent satellite measurements. This figure shows average absolute sea level change in inches (1 inch = 25.4 mm), which refers to the height of the ocean surface, regardless of whether nearby land is rising or falling. Satellite data are based solely on measured sea level, while the long-term tide gauge data include a small correction factor because the size and shape of the oceans are changing slowly over time. (On average, the ocean floor has been gradually sinking since the last Ice Age peak, 20,000 years ago.) The shaded band shows the likely range of values, based on the number of measurements collected and the precision of the methods used (Credit: United States Environmental Prtotection Agency, https://www3.epa.gov/climatechange/science/indicators/oceans/sea-level.html).

In summary, current scientific results show that from 1993 until 2014 the ocean levels have been rising with a rate of up to (2.9 ± 0.4) mm per year. That is 6 cm within 20 years. And the rate seems to be increasing.

Sea ice and land ice

Contrary to the Arctic, where the ice is just a sheet floating on the Arctic Sea, the biggest part of the ice masses of the Antarctic is to be found on land. According to the principle of Archimedes, the floating ice masses of the Arctic displace water to the amount of their own weight, so that the melting of the ice does not influence the sea levels. On the other hand, melting land ice like on Greenland or in the Antarctic contributes to the rise of the ocean levels. Radar altimetry satellites like CryoSat-2 help to monitor the thickness of ice sheets, both on land and floating at sea (Figure 4).

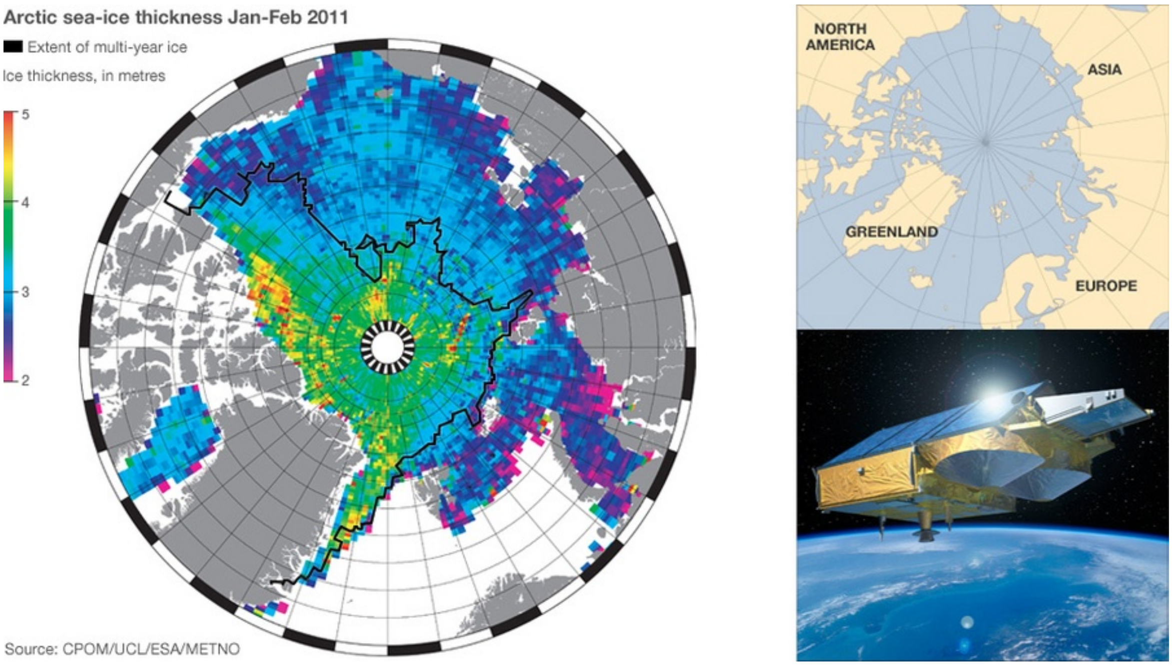


Figure 4: A colour coded altitude map of the arctic ice cover based on measurements of the CryoSat-2 satellite (Credit: BBC News, 21. Juni 2011, http://www.bbc.co.uk/news/science-environment-13829785; CPOM/UCL/ESA, http://www.esa.int/spaceinimages/Images/2011/06/Arctic_sea-ice_thickness).

The buoyancy principle of Archimedes

Archimedes of Syracuse, possibly the greatest ancient mathematician and scientist, discovered the buoyancy principle, which is named after him. In simple words, it states that a body immersed in a fluid experiences a buoyant force equal to the weight of the fluid it displaces.

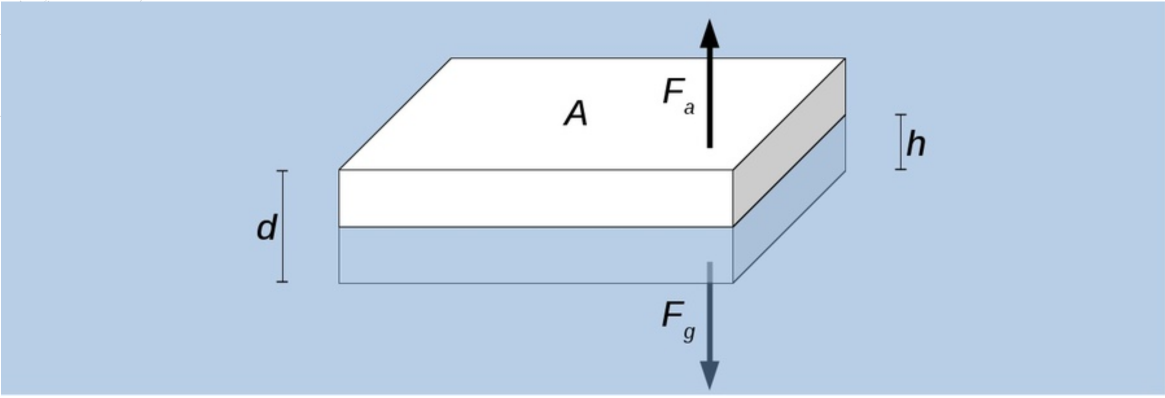


Figure 5: A sketch that illustrates the key parameters of a floating body and the equilibrium between its weight and the bouyant force, which is equal to the weight of the displaced liquid (own work).

If, for instance, one wants to calculate the ratio of the depth of an ice sheet that is immersed into sea water, the following ansatz can be made.

$$F_g = F_a$$

With:

$$F_g = m_{\text{ice}} \cdot g$$
$$F_a = m_w \cdot g$$

Here, m_{ice} and m_w represent the mass of the ice sheet and the mass of the displaced water, respectively. The ice sheet may a thickness of d, a surface area of A and it may be immersed by the depth h. From this, one can derive the volumes of the ice sheet $V_{ice} = A \cdot d$ and of the displaced water $V_w = A \cdot h$. This leads to:

$$m_{\text{ice}} = m_w \Leftrightarrow \rho_{\text{ice}} V_{\text{ice}} = \rho_w V_w \Leftrightarrow \rho_{\text{ice}} \cdot A \cdot d = \rho_w \cdot A \cdot h \Leftrightarrow \rho_{\text{ice}} d = \rho_w h$$

$$\Rightarrow \frac{h}{d} = \frac{\rho_{\text{ice}}}{\rho_{\text{w}}}$$

Even frozen sea ice is practically sweet water and is almost salt free. Therefore, the density of normal water ice applies. Liquid sea water contains on average 3.5% salt, which increases it density to $\rho_w \approx 1020 \text{kg/m}^3$.

$$\Rightarrow \frac{h}{d} = \frac{920\,\frac{\text{kg}}{\text{m}^3}}{1020\,\frac{\text{kg}}{\text{m}^3}} = 0.9$$

This means that 90% of the ice sheet is below sea water.

DESCRIÇÃO DA ATIVIDADE COMPLETA

Introduction

The rise of the sea levels due to global warming is a subject which concerns us all and for which everybody must take responsibility for future generations. The following experiment illustrates one major contribution, the melting of ice.

Question 1: How do you melt ice?

Question 2: Where on Earth can you find ice?

Question 3: Imagine, all that ice melts, what would happen to the water levels?

Question 4: What would happen to the coastal areas on Earth, when the sea levels rise?

Experimental set-up 1

1. The stone or the platform is put into the bowl.
2. The bowl is filled with water with the platform protruding from the water.
3. The water level is marked at the bowl with an overhead marker.
4. The lamp is positioned so that it illuminates the bowl.

Figure 6: Experimental set-up. A plastic cup filled with water is used as a platform that carries

the ice (own work).

Question 5: In our model, there is a stone with its top above the water surface and covered with ice. What would be the corresponding situation on Earth?

Experimental Procedure Part 1

1. Ice is put on the platform and the lamp is switched on.
2. Wait until the ice is melted.

Task 1: Write down your observations during the first part of the experiment. Pay attention to the water level.

Question 6: What happened to the water level? Explain the observation.

Experimental set-up 2

1. The platform is removed from the bowl.
2. Again the water level is indicated with an overhead marker at the bowl.

Figure 7: Experimental set-up for the second part. The platform has been removed (own work).

Question 7: In the second model, ice is floating on water. What would be the corresponding situation on Earth?

Experimental Procedure Part 2

1. The ice is put into the water and the lamp is switched on again.
2. Wait again until the ice is melted.

Task 2: Write down your observations during the second part of the experiment. Pay attention to the water level.

Question 8: What happened to the water level? Explain the observation.

Question 9: When reconsidering the experiments, which of the two forms of ice contribute to the rising sea levels? Land ice or/and floating ice?

CURRÍCULO

Space Awareness curricula topics (EU and South Africa)

Our fragile planet, oceans, climate change

CONCLUSÃO

The activity uses a simplified model that represents land and floating marine ice and how melting them contributes to the witnessed rising of the sea levels. The floating of ice is a hands-on example of the Buoyancy Principle of Archimedes. The students will realise the relevance for the Climate Change by guided questions and draw conclusions from carrying out and observing the experiments.

ASTROEDU

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