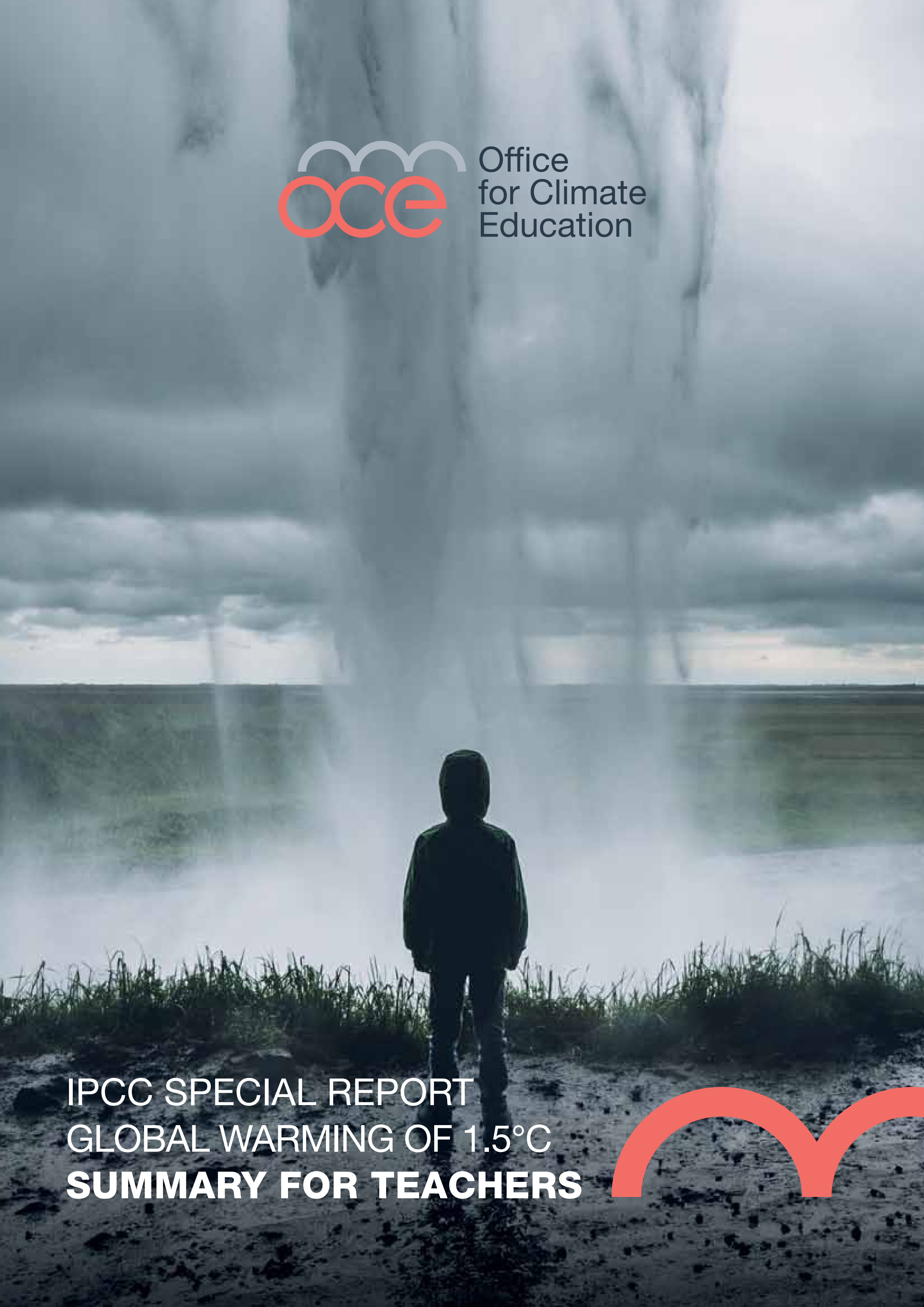

Office for Climate Education

IPCC SPECIAL REPORT GLOBAL WARMING OF 1.5°C
SUMMARY FOR TEACHERS

Coordinator
Lydie Lescarmontier (OCE, France)

Authors (in alphabetical order)
Eric Guilyardi (IPSL, France), Lydie Lescarmontier (OCE, France), Robin Matthews (IPCC Working Group I Technical Support Unit, France), Sakina Pen Point (OCE, France), Anwar Bhai Rumjaun (Mauritius Institute of Education, Mauritius), Jenny Schlüpmann (Freie Universität Berlin, Germany), David Wilgenbus (OCE, France)

Copy editors (in alphabetical order)
Badin Borde (Siemens Stiftung, Germany), Raphaëlle Kounkou-Arnaud (Météo-France, France), Maria A. Martin (Potsdam Institute for Climate Impact Research, Germany), Christine Niewöhner (Siemens Stiftung, Germany), Vincent Viguié (CIRED, France)

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Photos
John Salvino (cover)
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VanveenJF (page 13)
NASA (page 16)
Juha Lakaniemi (page 17)
John Westrock (page 21)

Art work
Mareva Sacoun (mareva.sacoun@gmail.com).

Summary

“ Each degree matters, each year matters, and each decision matters : not acting today is adding to the burden of the next generations [...]. Limiting global warming to 1.5°C is not impossible but requires strong and immediate policies. ”

Valérie Masson-Delmotte, Co-Chair of the IPCC’s Working Group I (8 October 2018 – Address to the French Senate)

Introduction

WHAT IS THE IPCC ?

The Intergovernmental Panel on Climate Change (IPCC) is an international body for **assessing the science related to climate change** established in 1988 by the United Nations. It aims to provide policymakers with regular assessments of the scientific understanding of climate change, including possible impacts and options for adapting to them, and ways of reducing greenhouse gas emissions.

These assessments present projections of future climate change based on different global emissions scenarios (continued growth, rapid reduction, etc.) and the corresponding risks for human and natural systems. While they lay out response options and their implications, the reports do not tell policymakers what actions to take – they are "policy relevant but not policy prescriptive". **IPCC assessments are written by hundreds of leading scientists from around the world and formally adopted by the governments of its 195 member countries.** The IPCC works by assessing existing published literature rather than conducting its own scientific research.

Core concepts: global warming, greenhouse gases, anthropogenic greenhouse effects, IPCC working groups

The main IPCC assessment reports come out about every 6 years, with more focused Special Reports released in between. Three Special Reports will be published in the current (sixth) IPCC assessment cycle :

— Global warming of 1.5°C
— Climate Change and Land
— The Ocean and Cryosphere in a Changing Climate

Authors working on IPCC reports are organised into three Working Groups :

— Working Group I on past and possible future changes in the climate system and carbon cycle ("The Physical Science Basis")
— Working Group II on past and future impacts, and options for adapting to them ("Impacts, Adaptation, and Vulnerability")
— Working Group III on ways to reduce greenhouse gas emissions ("Mitigation of Climate Change")

Each report has a Summary for Policymakers (SPM).

WHY PRODUCE A REPORT ON 1.5°C SCENARIO ?

The Paris Agreement, a historic agreement reached in Paris in December 2015, has been a game-changer in international discussions on climate change. Nearly all major greenhouse-gas emitting countries have now ratified the Paris Agreement, together accounting for around 90% of global emissions. Its aim is to keep global warming well below 2°C and pursue "efforts to limit the temperature increase to 1.5°C", and deals with emission reductions, adaptation to impacts, and ways to pay for these efforts. This temperature goal shows that ambitions have been significantly heightened since previous international discussions, which had focused on keeping the temperature increase below 2°C.

In order to gather scientific knowledge around this ambitious new temperature goal, the IPCC was formally invited to produce a **Special Report on Global Warming of 1.5°C.** Taking two years to produce and written by 74 scientists from 40 countries, the report was finalised and **adopted** by all IPCC member governments in Korea in October 2018.

The following is a summary of the **Special Report on Global Warming of 1.5°C** that is **specifically intended for teachers.** It is presented together with a selection of related activities and exercises that can be implemented in the classroom.

SCHOOL ACTIVITY

QUESTION

Why is this IPCC report called the "1.5°C Report"?

CLIMATE SCIENCE BEHIND THE IPCC 1.5°C REPORT

A. Understanding global warming

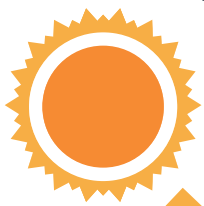
Greenhouse gas emissions: past, present and future

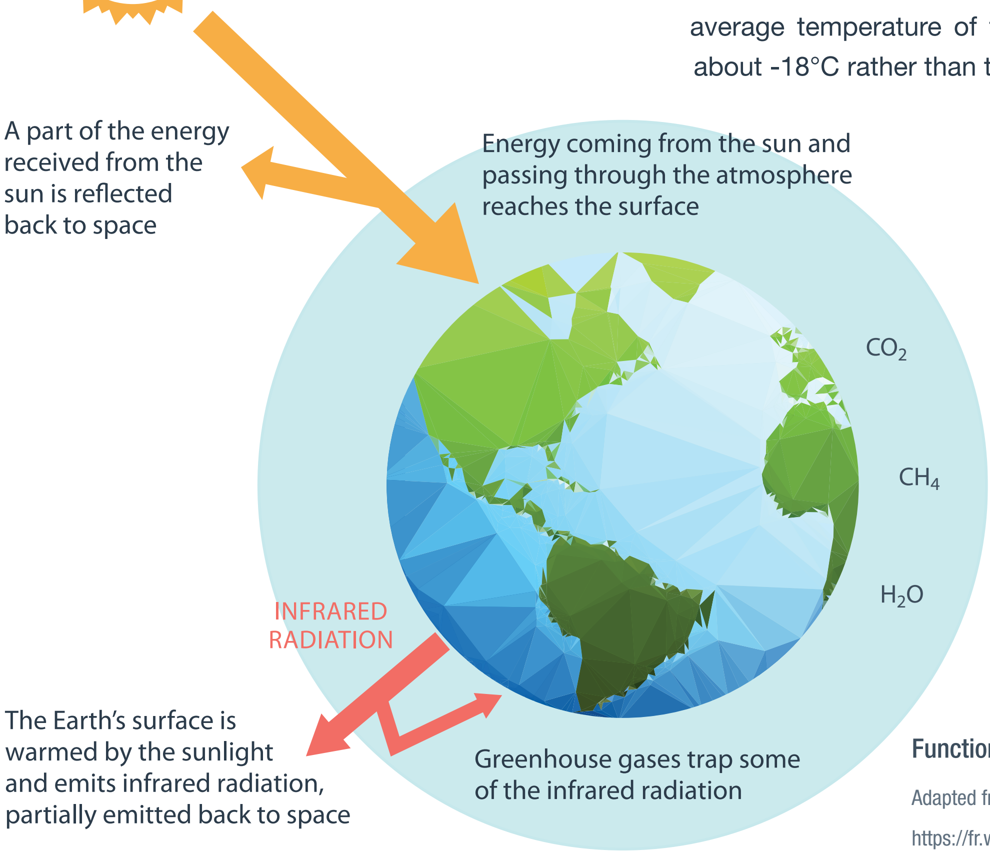
INDUSTRIAL REVOLUTION

In the 19th century, progress in science and technology led to the **Industrial Revolution**. Starting in Great Britain, industrialisation spread first to Europe and then worldwide. Alongside expansion in industry, transportation and agriculture, the global population grew rapidly due to progress in hygiene and medicine. Together, these factors led to a rapid increase in fossil fuel consumption, and consequently, global greenhouse gas emissions.

THE GREENHOUSE EFFECT – HOW ARE WE CHANGING OUR CLIMATE?

The Sun's rays travel through the atmosphere and warm the Earth's surface, generating the upward emission of **infrared heat (radiation).** Some of this heat is trapped on its escape to space by **greenhouse gases** in the atmosphere (mainly water vapour, carbon dioxide, methane, nitrous oxide and ozone) and sent back towards the Earth's surface. Greenhouse gases thus act like a blanket, trapping heat. As a consequence, the temperature of the lower atmosphere is warmer than it otherwise would be. In fact, without greenhouse gases, the average temperature of the Earth's surface would be about -18°C rather than the present average of 15°C.



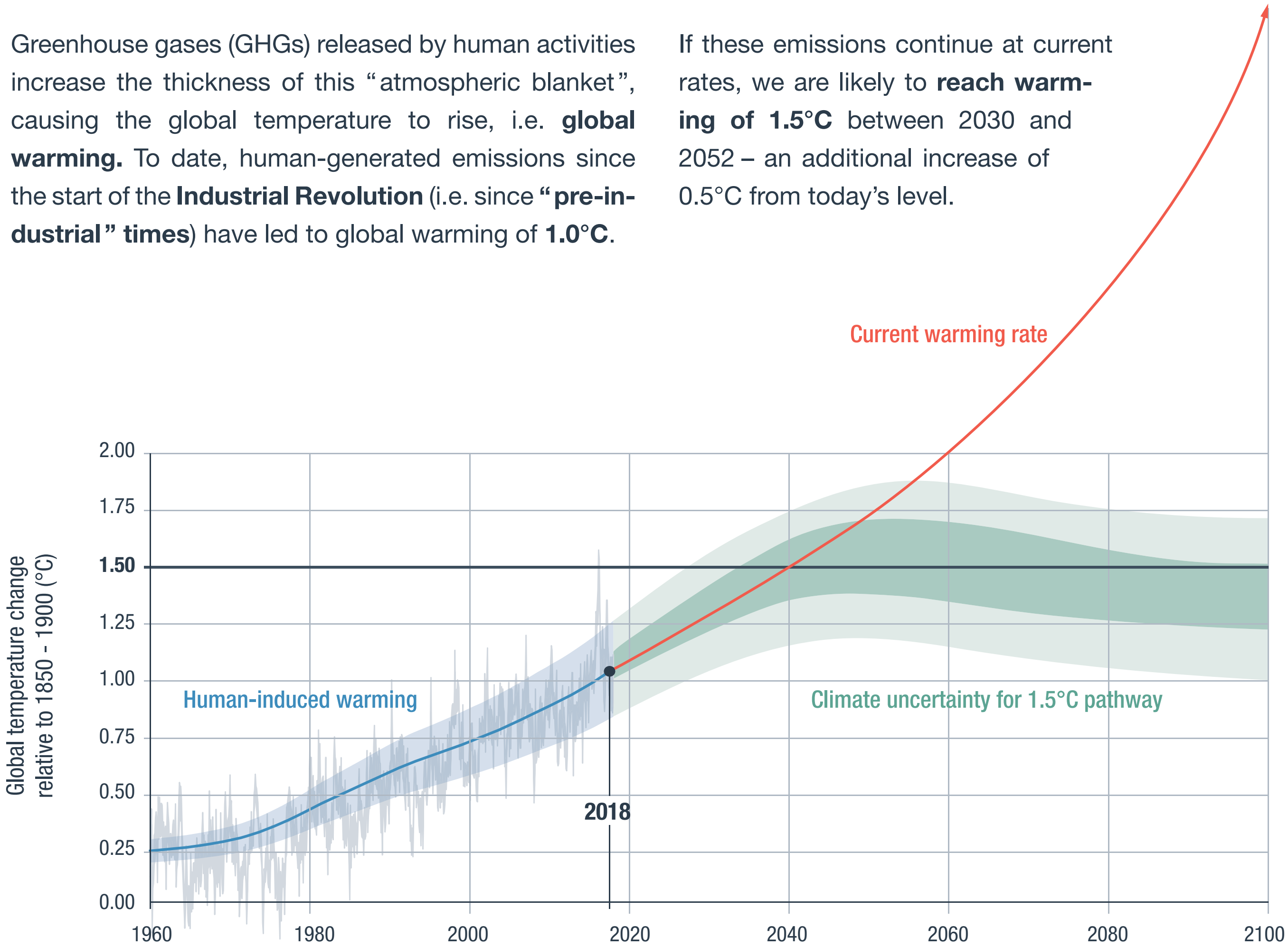


Functioning of the greenhouse effect

Adapted from an original infographic by Lannis https://fr.wikimini.org/

Greenhouse gases (GHGs) released by human activities increase the thickness of this "atmospheric blanket", causing the global temperature to rise, i.e. **global warming.** To date, human-generated emissions since the start of the **Industrial Revolution** (i.e. since **"pre-industrial" times**) have led to global warming of **1.0°C**.

If these emissions continue at current rates, we are likely to **reach warming of 1.5°C** between 2030 and 2052 – an additional increase of 0.5°C from today's level.



Human-induced warming reached approximately 1°C above pre-industrial levels in 2017. At the present rate, global temperature would reach 1.5°C around 2040.

Adapted from the Special Report on Global Warming of 1.5°C (IPCC)

SCHOOL ACTIVITY

TASK What is the climate and how is it different to the weather?

Look up the definition of climate on the World Meteorological Organization (WMO) website.

Keywords: 30 years, temperature, precipitation, atmosphere.

Climate in a narrow sense is usually defined as the the average weather over a period in a specific region. In more specific, statistical terms it is the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The climate tells us which clothes we have to buy. The weather forecast tells us what we have to wear.

The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

QUESTION What is a greenhouse gas?

Make a list of different greenhouse gases. Explain how they are produced.

TASK Explain the greenhouse effect with a drawing and a short text.

Use the following words: emission, absorption, reflection, infrared radiation, atmosphere, Earth's surface.

Reveal the difference between natural and anthropogenic greenhouse effect. (Anthropogenic means resulting from human activities.)

SCHOOL ACTIVITY

TASK Compare the global warming potentials (GWP) of methane, nitrous oxide and hydrofluorocarbons with the GWP of CO_2.
See, for example, table 8.7 in the IPCC report AR5, chapter 8, p. 712:
http://www.climatechange2013.org/images/report/WG1AR5_Chapter08_FINAL.pdf

TASK Explain what is meant by global warming.

QUESTIONS CO_2 is emitted when burning fossil fuels. How can we reduce the emission of CO_2 ? How can we reduce the emission of other greenhouse gases like methane (CH_4) or nitrous oxide (N_2O) ?
Keywords: biogas production, reforestation, less fertilisers in agriculture, renewable energy, energy saving.

TASK Explain the connection between hydrofluorocarbons, the ozone layer and global warming.

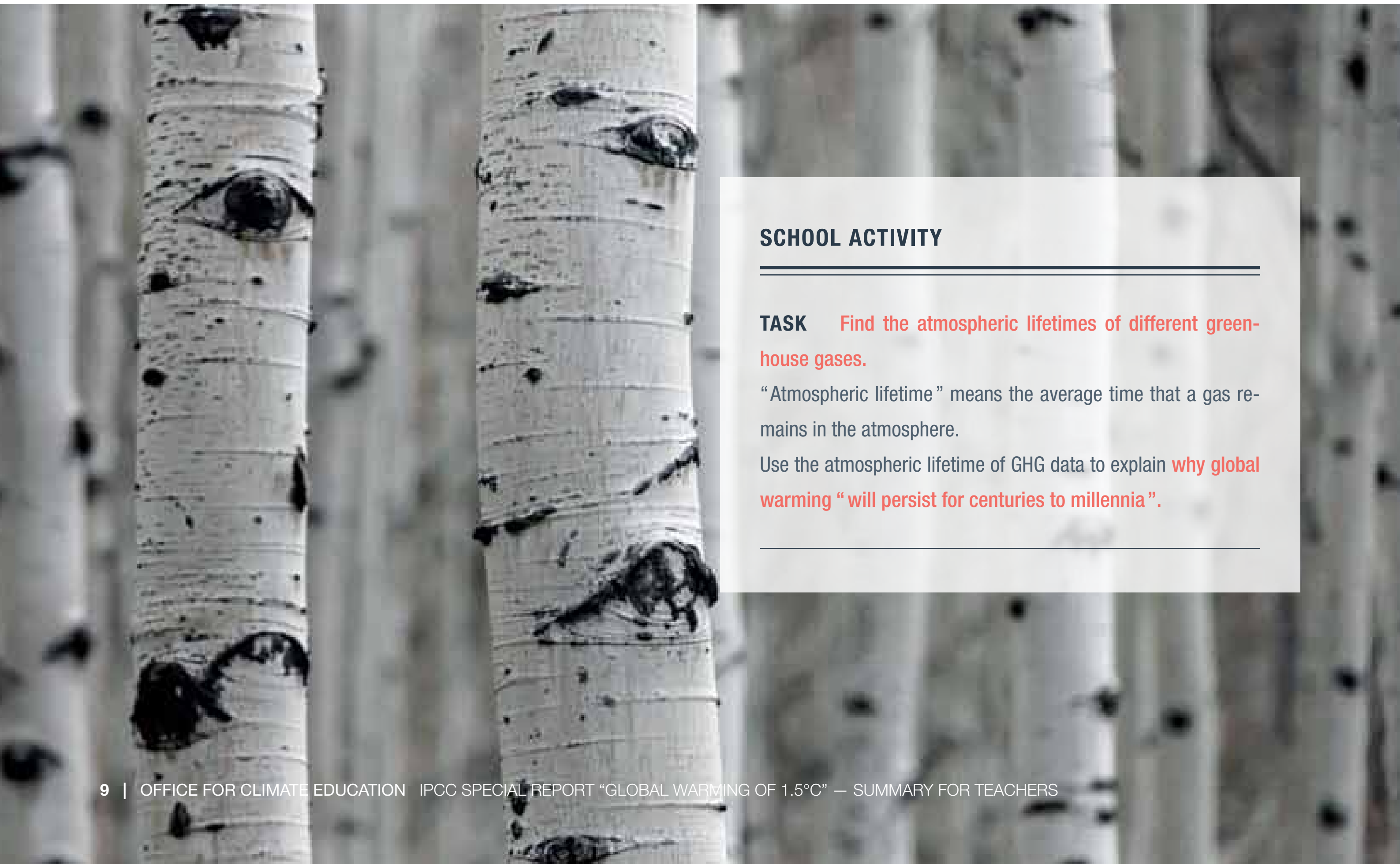
CLIMATE INERTIA

Even if we could somehow immediately stop all carbon dioxide (CO_2) emissions being released into the atmosphere, the global temperature would stabilise but not decline – it takes centuries to millennia for the CO_2 already present in the atmosphere to be removed by natural processes. The sea level would continue to rise during this time as the entire ocean volume slowly expands in response to past surface warming. In order to bring the global temperature back down to what it was in pre-industrial times, we would have to actively remove CO_2 from the atmosphere.

THE PARIS AGREEMENT

Under the Paris Agreement, 195 countries committed to limiting global warming to well below 2°C and aiming to keep it to 1.5°C. While limiting global warming to 1.5°C is still possible – we would have to act very rapidly to achieve this goal.

It means that our global CO_2 emissions must be reduced to (effectively) zero over the next few decades, through large, sustained emission reduction efforts across all global regions and economic sectors.



SCHOOL ACTIVITY

TASK Find the atmospheric lifetimes of different greenhouse gases.
"Atmospheric lifetime" means the average time that a gas remains in the atmosphere.
Use the atmospheric lifetime of GHG data to explain why global warming "will persist for centuries to millennia".

Climate impacts and adapting to them

Global warming is causing changes in the climate system (physical climate impacts), which are already affecting humans, along with plants, animals and ecosystems. Physical impacts can occur simultaneously and can interact with non-climatic factors like pollution.

Below we explain the different types of climate impacts, and why some locations and populations are more at risk than others. In many cases, we can act to reduce impacts through an iterative process of planning and implementing measures to combat them **(adaptation)**. As adaptation occurs on a local to regional level, local and indigenous knowledge can play a key role. Below we introduce this concept, together with the notion of **uncertainty** in how climate will change in the future.

PHYSICAL IMPACTS

By **global warming** we mean **the increase of the average surface temperature of the whole planet.** However, **some regions warm more** than others. For example, **warming has been greater in the Arctic than in other parts of the world** and it is **generally greater on land** than for the ocean. In the 10 years spanning 2006–2015, 20–40% of the global population had already experienced warming of 1.5°C in at least one season.

Climate change manifests itself on different time-scales: through changes in the nature of single, short-lived extreme weather events, like hurricanes, and through incremental changes that build up over decades, such as sea level rise. These can interact and reinforce one another (e.g. extensive flooding due to a storm surge in addition to long-term sea level rise).

CHANGES IN EXTREME WEATHER WITH GLOBAL WARMING

We expect climate change will cause extreme weather events – like heat waves, heavy rainfall, floods and droughts – to become more frequent and more severe. Under high levels of warming, very intense hurricanes are expected to occur more frequently, although the overall number of hurricanes is expected to fall.

SCHOOL ACTIVITY

TASK Look at the following map (link below) showing the increase in the number of combined tropical nights (T min ≥ 20°C) and hot days (T max ≥ 35°C) in Europe.
Approximately how many more tropical nights/hot days will there be in the period from 2071-2100 as compared to the period from 1961-1990

— in southern Portugal?
— in northern Germany?
— in Norway?

Source: European Environment Agency
https://www.eea.europa.eu/data-and-maps/figures/increase-in-the-number-of

INCREMENTAL CHANGES WITH GLOBAL WARMING

The intensification of the global water cycle generally causes dry areas to become drier due to **increased evaporation** and wet areas to become wetter.

Sea level rise is driven by the melting of mountain glaciers and ice sheets, and thermal expansion of the ocean. As the ocean warms, its volume expands in a process called the thermal expansion, and which occurs at all ocean temperatures. The melting of ice on land (from **mountain glaciers**, and the Greenland and Antarctic ice sheets) contributes the rest of current sea level rise. Water from melted continental ice drains into the ocean and therefore contributes to sea level rise.

There has been a steady decline in sea ice in the Arctic since 1979. Sea ice, which floats on the ocean, does not contribute to sea level rise.

In addition to the warming it causes, the steady accumulation of CO_2 in the atmosphere also has a direct impact. This CO_2 dissolves into the ocean and reacts with the water to form carbonic acid, raising the ocean's acidity in a process called **ocean acidification**.

SCHOOL ACTIVITY

TASK Look up: What is causing sea level rise?

IMPACTS AND ADAPTATION FOR HUMAN SYSTEMS

Global warming can **negatively affect a wide range of human activities and needs,** and this is already happening. More frequent extreme weather events can affect crop production, while higher temperatures favour the propagation of infectious diseases into new areas. Freshwater supply can be affected by glacier melt and changing rainfall patterns. Sea level rise has a wide variety of impacts including coastal erosion, and infiltration of salt water into groundwater or estuaries, affecting arable land and freshwater supplies.

We should remember, however, that while on the whole, climate impacts tend to be detrimental to human activities and ecosystems, there can be beneficial outcomes in some cases, such as longer growing seasons. We should also bear in mind that these changes do not occur in isolation, but can interact with other unrelated factors, with positive and negative outcomes. For instance, overconsumption of water in a location exposed to drought can make a population more vulnerable when droughts occur.

The extent to which a physical change in climate affects a particular place not only depends on how great the physical change is, but also on how **exposed** the location is to that change and on how **vulnerable** (or susceptible) its population and infrastructure are to being affected. For sea level rise, the most exposed populations are those living in low-lying coastal areas and low-lying islands, while the most vulnerable tend to be the poor and disadvantaged, including in the developing island nations in the Pacific. For droughts, those directly dependent on agriculture for their livelihoods and food supply are among the most vulnerable since they are highly susceptible to changes in temperature and rainfall.

The exposure and vulnerability of a place and its people can change over time. In fact, efforts to adapt to climate change aim to reduce vulnerability and exposure to particular climate impacts. Vulnerability can be reduced through economic development and diversification, while exposure can be reduced by moving people and infrastructure out of harm's way (e.g. to higher ground in the case of sea level rise).

A key difficulty in efforts to adapt to climate change is that future changes in climate are often **uncertain**. Take sea level rise, for example. The largest potential future contributors are the Antarctic and Greenland ice sheets, representing the largest amount of continental ice (average thicknesses of 2.5 kilometers for Antarctica and 2 kilometers for Greenland). However, estimates vary as to what the timing and size of these contributions will be. Current estimates range between **25 centimetres to over a meter** by 2100, depending in part on how much CO_2 we emit in the future. Uncertainty in forecasts of future climate change also derives from different estimates for the amount of global warming that will result from a given increase of greenhouse gases in the atmosphere – i.e. just how sensitive the climate system is to our emissions. An additional difficulty for planning ways to adapt to climate change, such as building coastal protections, is that these options come with their own risks. Also, the resulting greenhouse gas emissions need to be considered when implementing adaptation measures to avoid competing goals, such as adaptation efforts leading to increased emissions. The implications **for sustainable development,** including food, water and human security, also need to be taken into account (see Section D).

SCHOOL ACTIVITY

TASK Think of some adaptation and mitigation measures for your home, your city/town/village, your country.

You may look for ideas on the European Climate Adaptation Platform:

https://climate-adapt.eea.europa.eu/knowledge/adaptation-information/adaptation-measures

IMPACTS ON ECOSYSTEMS AND BIOLOGICAL ADAPTATION

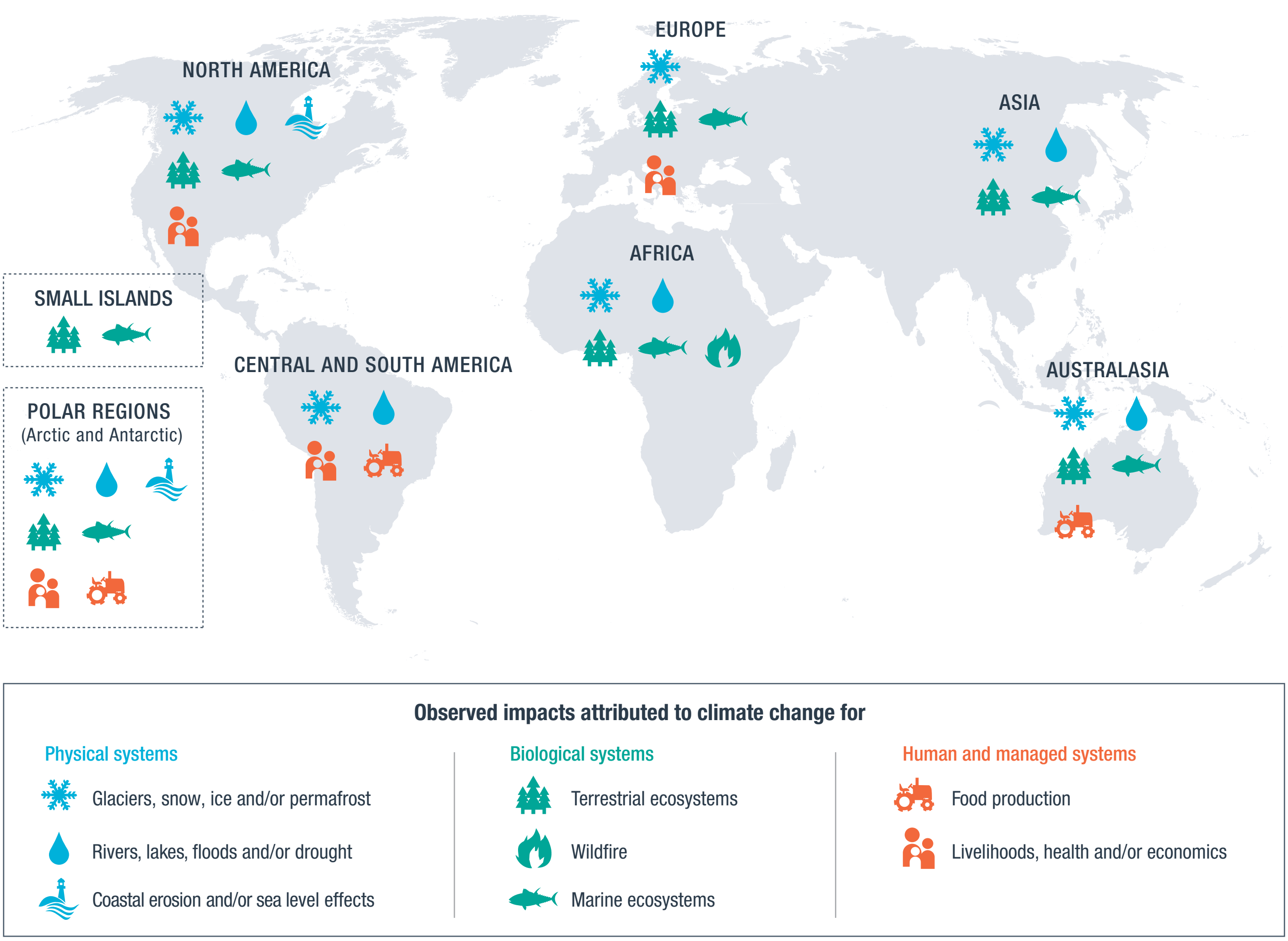
The increase in temperature is and will continue to **impact on biodiversity and ecosystems.** Warming affects plant and animal habitats, and they either migrate, adapt, or perish. Species are migrating towards cooler environments - poleward or to greater depths in the ocean, and poleward or uphill on land, but may not be able to move readily (e.g. due to habitat fragmentation) or fast enough.

Biological adaptation includes changes in the timing of seasonal activities (e.g. flowering of plants) and through evolution. All of these changes can alter the structure of ecosystems, affecting the services they provide to humans (e.g. coastal protection in the case of coral reefs).

Ocean acidification is another well-known example of how climate change can impact biodiversity. Increasing acidity has a wide range of potentially harmful consequences for marine organisms, shown to impact the **immune systems of shellfish and skeleton formation of corals and specific plankton.**

The effect of warming on biodiversity depends on the global temperature reached and on the rate of increase. The higher the temperature and the faster it changes, the greater the impacts. **A high rate of global warming reduces the chances that species can adapt, as they do not have enough time for adaptation.**

The next section explores the gravity of climate change risks when warming reaches 1.5°C vs. 2°C.



Widespread impacts attributed to climate change based on the available scientific literature.

Adapted from the Special Report on Global Warming of 1.5°C (IPCC).

We chose to represent high confidence in attribution to climate change impacts.

TO SUM UP

Human activities have caused a 1.0°C rise in the global temperature over the past 150 years.

Global warming is likely to reach 1.5°C between 2030 and 2052, if warming continues at the current rate.

Our CO_2 emissions will remain in the atmosphere for centuries to millennia, maintaining the warmer temperatures long after these emissions were released.

Climate change manifests itself on different timescales affecting both short-term extreme weather events, as well as causing gradual, long-term changes, including sea level rise, melting of glaciers and ice sheets, and changes in biodiversity.

The impact of climate change on a community depends not only on the rate and size of the physical changes in climate, but also on how exposed their location is and how vulnerable to the change they are. Adaptation is made more difficult because we can't predict exactly how the climate will change in a given place in the future.

SCHOOL ACTIVITY

TASK The global temperature has already increased by approximately 1.0°C. In addition, global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate.

Find out the current warming rate.

Hints to solve this task:

1. Use specific values: for today take 2017 – For " between 2030 and 2052 " take 2036.
2. Divide the task into different steps: Until 2017, the increase of the global mean temperature was 1.0°C.
   - There is only 0.5°C missing to reach a global warming of 1.5°C
   - An increase of 0.5°C between 2017 and 2036 corresponds to a warming rate of: 0.5°C / (2036 – 2017) = 0.026°C per year (or 0.26°C per decade)

Solution: the current rate of warming is approximately 0.026°C per year.

TASK Look at the map of European Union countries showing their potential vulnerability to climate change: https://www.espon.eu/sites/default/files/attachments/Vulnerability_ESPONclimate.pdf

(Linking page: https://www.espon.eu/climate-2012)

Which regions are particularly vulnerable to climate change?

Support your answer with clear justifications/arguments.

B. Climate change impacts at +1.5°C and +2°C

The extent of global warming depends both on past emissions of greenhouse gases and on those we will emit in the coming years. In general, the more warming, the greater the risks and impacts will be.

Global warming of 2°C would have significantly larger impacts than a global warming of 1.5°C (1°C more than today as opposed to 0.5°C). Specific examples from the Special Report on 1.5°C are given below by the type of impact.

IMPACTS AT 1.5°C VS. HIGHER WARMING LEVELS

EXTREME EVENTS

Extremely hot temperatures at the local scale increase faster than the average warming of the whole planet. For instance, for a 0.5°C rise in global temperature, the corresponding increase in the highest temperatures reached during heatwaves can be up to two to three times more (for example, increasing by 1.5°C from 30°C to 31.5°C). Three times more people (420 million people) would be exposed to severe heat waves at least once every 5 years and the most impacted regions would be the Mediterranean and Sub-Saharan Africa.

This would have implications for human health, particularly in cities, which tend to be artificially warmer than their surroundings due to a "heat island" effect created by the buildings and roads. There is also a higher risk of drought at +1.5°C than at +2°C in the Mediterranean and Southern Africa, while globally 200-300 million more people would be exposed to water shortages at +2°C than at +1.5°C. Heavy rainfall events are expected to occur more often at high latitudes in the northern hemisphere at +2°C compared to +1.5°C.

SEA LEVEL RISE

Sea level rise by **2100 will be 10 cm higher** if global warming reaches 2.0°C instead of 1.5°C. **Up to 10.4 million more people would be exposed to the impacts of sea level rise**. Exceeding 1.5°C increases the risk of triggering instabilities in polar ice sheets that would result in sea level rise of several meters over centuries to millennia. As explained in Section B, even if we stop emitting greenhouse gases immediately, sea levels will keep rising over these time-scales due to ocean inertia.

SEA ICE

The Arctic would be effectively free of sea ice in summer a few times each decade with a 2°C warming, but only a few times a century or less with 1.5°C warming.

SCHOOL ACTIVITY

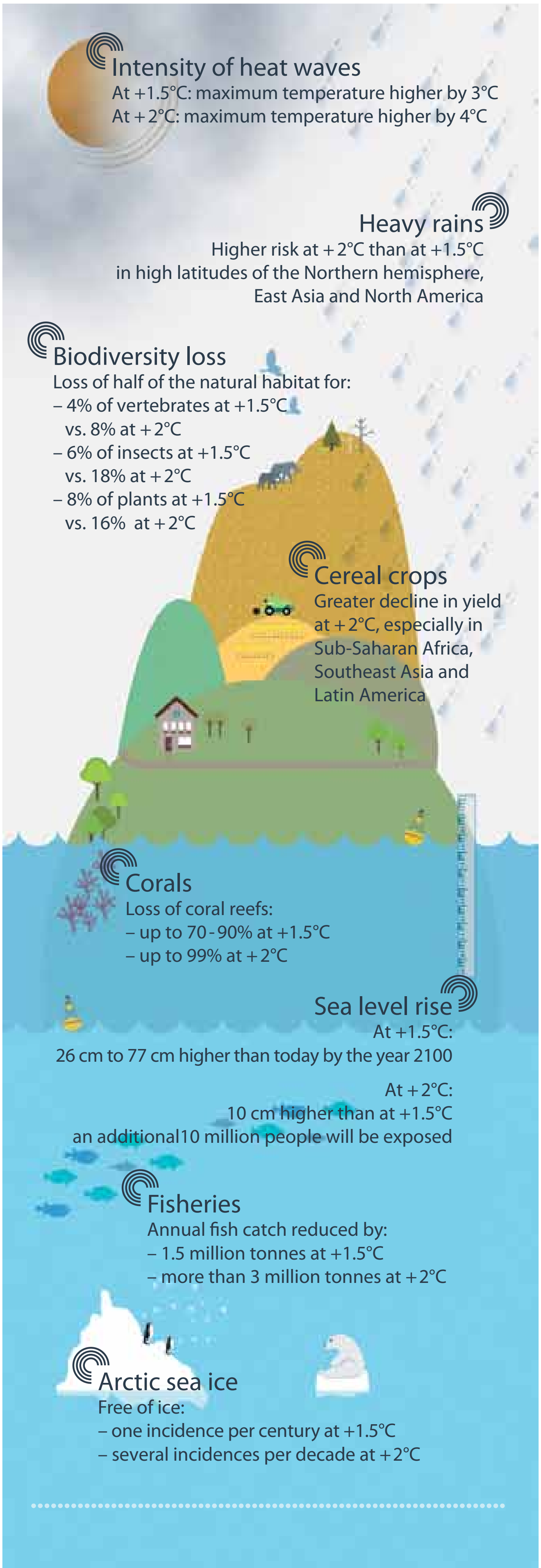
TASK Why is the decline of Arctic sea ice extent threatening the livelihood of polar bears?

SPECIES, ECOSYSTEMS AND FOOD PRODUCTION

On land, the area at risk of major ecosystem change is expected to be around 50% lower at +1.5°C than at +2°C. In addition, risks of loss of local species and extinctions are also much lower at +1.5°C.

For coral reefs, while the prognosis is dire at +1.5°C, it is worse still at +2°C. **Around 70 to 90% of coral reefs are expected to be lost at +1.5°C compared to 99% at +2°C warming.** Today, 30% of the corals are already damaged by the ocean temperature rise and its acidification.

The global fisheries catch could drop by twice as much



Adapted from an infographic by Le Monde

at +2°C than at +1.5°C, and there would be smaller reductions in yields of key food crops such as maize, rice and wheat at +1.5°C than at +2°C.

OCEAN ACIDIFICATION

Since the level of CO_2 in the atmosphere would be lower at +1.5°C than at +2°C, less CO_2 would be absorbed by the ocean, and therefore the increase in ocean acidity would be less at +1.5°C.

SCHOOL ACTIVITY

EXPERIMENT Plan an experiment to show that CO_2 emissions increase ocean acidity.
See, for example, the teaching unit “ CO_2 emissions and acidification of the oceans”, in ***La main à la pâte***’s teaching module “The ocean, my planet and me! ”.

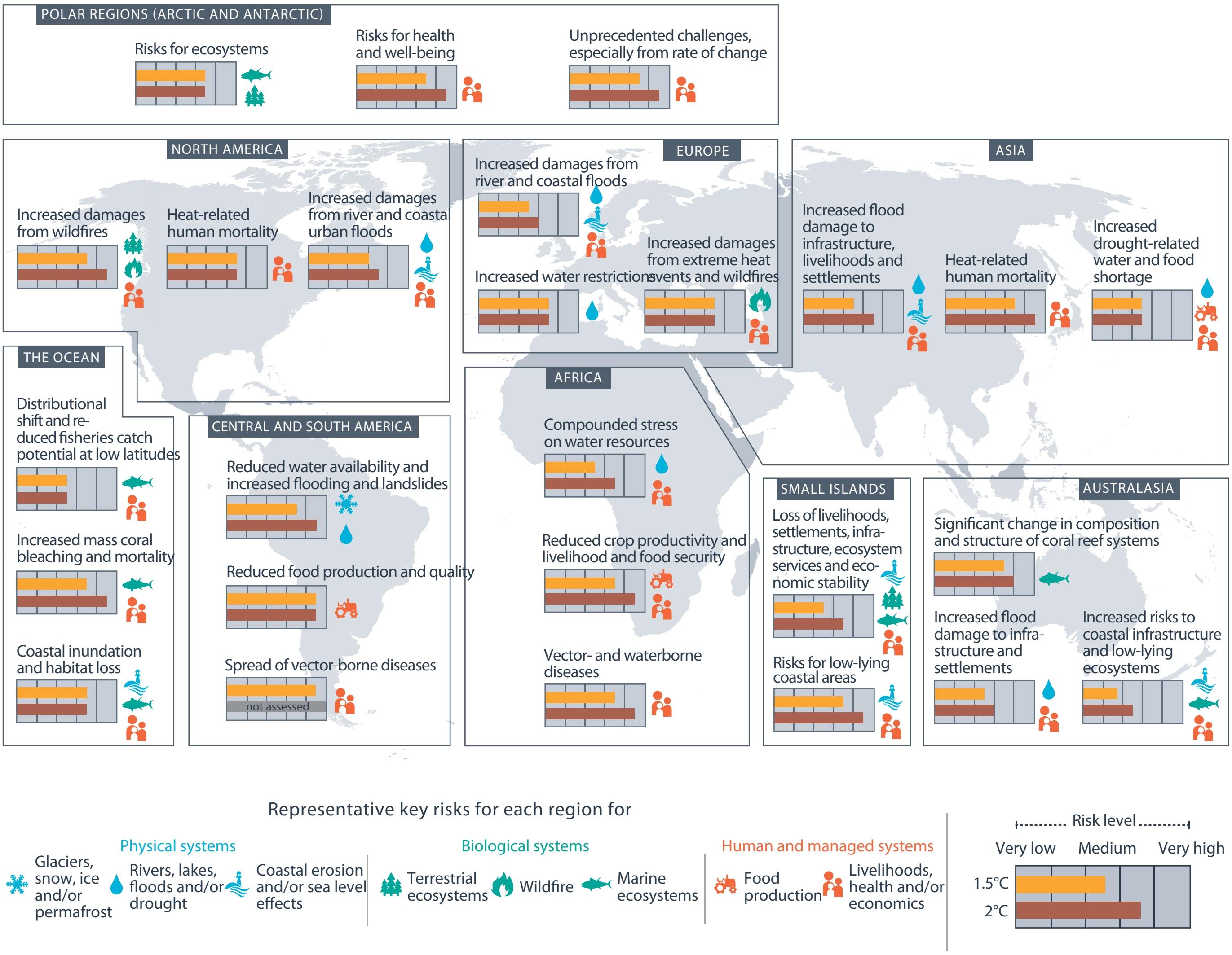
QUESTION What are the causes and consequences of coral bleaching ?

ADAPTATION AT +1.5°C VS. +2°C

In combination, the greater physical changes at warming of 2°C as opposed to 1.5°C **lead to greater risks to livelihoods, food and water security, human health and security, and economic growth.**

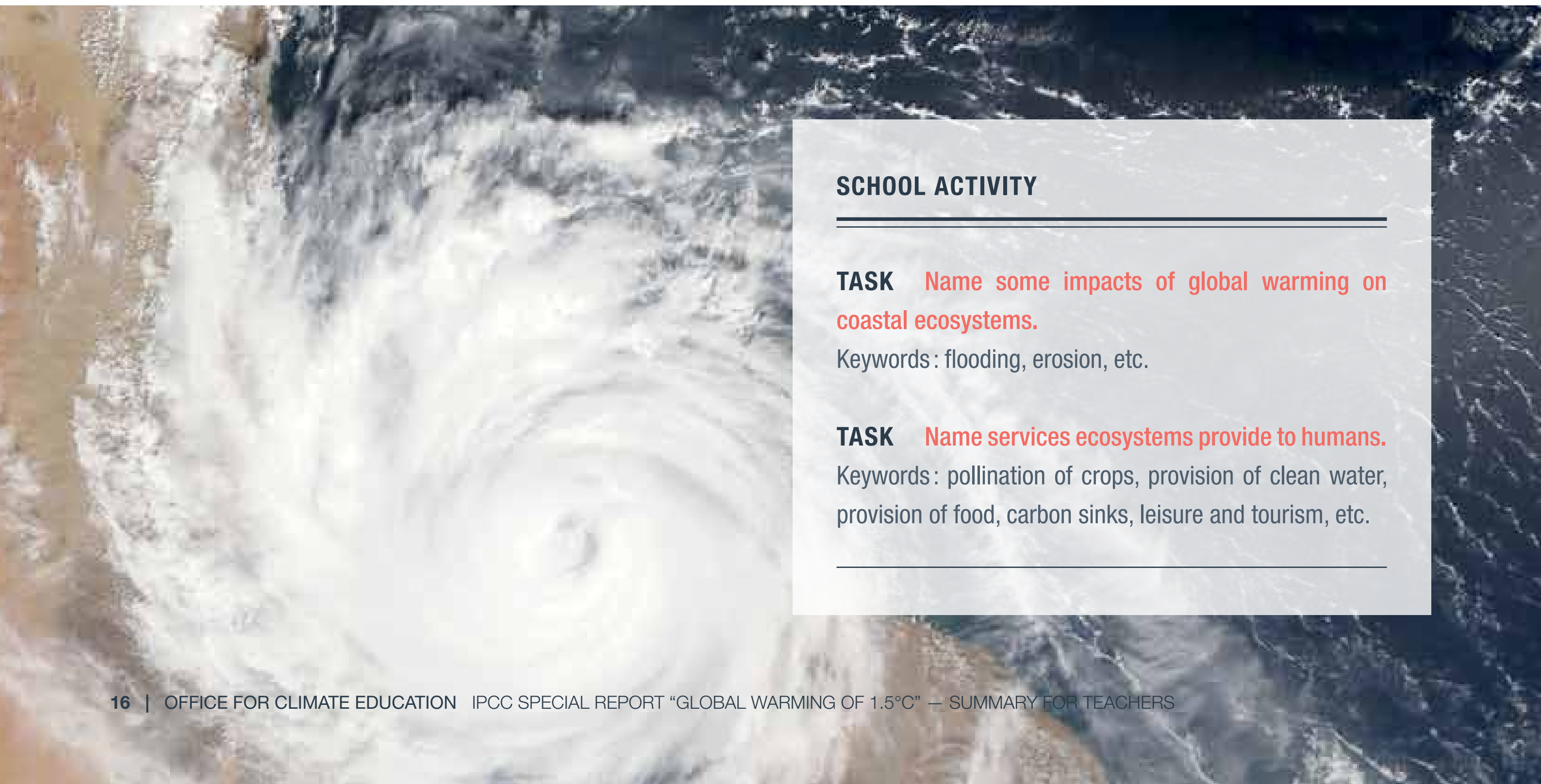
As the impacts would be greater at +2°C than +1.5°C, **greater adaptation efforts would be required to deal with them.**

However, even at +1.5°C, the speed of the physical changes could exceed human capacity to adapt. For instance, in the case of sea level rise, the populations of some low-lying islands will have to migrate.



Regional key risks and potential for risk reduction with current adaptation

Adapted from the Special Report on Global Warming of 1.5°C (IPCC).



SCHOOL ACTIVITY

TASK Name some impacts of global warming on coastal ecosystems.

Keywords: flooding, erosion, etc.

TASK Name services ecosystems provide to humans.

Keywords: pollination of crops, provision of clean water, provision of food, carbon sinks, leisure and tourism, etc.

TO SUM UP

Global warming of 1.5°C is not “safe” – the physical risks and impacts will be significant. However, the risks will be substantially lower than at warming of 2°C. Adaptation will still be needed at +1.5°C, although efforts required will be less than at +2°C. There will be limits to what can be achieved through adaptation at both +1.5°C and +2°C.

The physical changes and impacts will vary by location.

Compared to +2°C, at +1.5°C global warming:

- Heat waves would be less frequent and with lower peak temperatures.
- Sea levels would be 10 centimeters lower. As a consequence, low-lying coasts and islands would have greater opportunities to adapt.
- The Arctic would often become sea ice free in summer at +2°C, but would mostly have sea ice year-round at +1.5°C.
- The impacts on biodiversity (including biodiversity loss) for land, freshwater and coastal ecosystems would be lower. We would retain more of nature’s services for humans (pollination, clean water etc.).
- The ocean would be less acidic, lowering the consequent risks for marine biodiversity and ecosystems – including for the services they provide to humans, such as fisheries.

c. How can warming be limited to 1.5°C ?

The more CO_2 and other greenhouse gases we release into the atmosphere, the more the global temperature will rise. Unfortunately, the slow removal of CO_2 from the atmosphere means that the global temperature will remain warmer for hundreds to thousand of years even after we completely stop releasing CO_2. As such, the goal of international climate agreements to date is not to bring global temperature back to the level it was at before humans started warming the planet, but merely to limit the amount of warming induced by stabilising global temperature at a certain (albeit raised) level.

> To stabilise global temperature, we need to effectively stop emitting CO_2 to the atmosphere.

In order to stabilise global temperature, we need to effectively stop releasing CO_2 into the atmosphere. There are two ways we can achieve this. We can actually reduce our emissions to zero ; or we can effectively do so by substantially reducing them and then offsetting remaining emissions by using technology and/or biological means to remove CO_2 from the atmosphere – with the overall effect being as though we were not emitting CO_2 at all.

CARBON DIOXIDE REMOVAL

Biological means for removing CO_2 from the atmosphere include planting trees and restoring ecosystems. Technological means include direct capture from the air using chemicals, converting the CO_2 to a liquid and storing it underground, although this technique is still in development. Another method involves growing plants and trees to burn as fuel for power plants and capturing and storing the CO_2 that is produced underground. Since this CO_2 originally came from the atmosphere (extracted by the plants and trees as they grew), the net result is a removal of CO_2 from the atmosphere. Given that this method, known as BECCS, would need to be implemented on a large scale, a key concern is that it would create competition with using land to grow crops for food instead of for fuel. Another issue is that we don't know how well the method works at a large scale. Greater emission reductions would be required to avoid carbon dioxide removal methods.

The goal of the Paris Agreement is to limit warming to well below 2°C (1°C warmer than today) and to attempt to restrict warming to 1.5°C (0.5°C warmer than today). We are not on track to limit warming to 1.5°C; in fact, current emission reduction pledges made by nations in the Paris Agreement would lead to warming of 3-4°C by the end of this century.
Fortunately, the Paris Agreement has a mechanism that allows countries to raise their level of ambition for emission reductions over time.

OVERSHOOT

There are two types of paths that global temperature can follow over the coming decades to limit warming to a certain amount (e.g. to +1.5°C) : those in which global temperature reaches that amount and then stabilises, and those in which **global temperature temporarily exceeds,** or **overshoots, that warming level before subsequently returning to and stabilising there.** For overshoot paths, removal of CO_2 from the atmosphere would be required to bring the global temperature back down after overshooting the target level.
The impacts of overshooting and then stabilising at 1.5°C would be different to those of reaching 1.5°C without overshoot, due to the different rates of change and the different maximum warming level reached. **The longer and larger the overshoot, the greater the risks.**

EMISSIONS PATHS TO 1.5°C

Given that we would need to effectively reduce CO_2 emissions to zero in order to limit warming to a given level, the question is how rapidly we would need to do this. To limit warming to 1.5°C, CO_2 emissions would have to decrease by 45% by 2030 from their 2010 levels, and effectively reach zero in 2050. In comparison, limiting global warming to 2°C would require CO_2 emissions to decline by 20% by 2030 before effectively ceasing by around 2075. In both cases, a substantial global effort to reduce emissions is needed in the next few decades and without delay. If we delay action now, more rapid emissions reduction will be needed in the future to limit warming to the same level, and these emissions reductions will be more costly.

WHAT WOULD WE NEED TO DO ?

Firstly, we need to reduce global energy, materials and food demand. This could be supported by changes in behaviour and lifestyles, including food consumption such as reducing meat and dairy consumption, and food waste, and transport choices (such as flying less). In addition, better insulation of buildings would help reduce heating needs as buildings are responsible for around a third of global energy consumption.

Second, we would need to use energy and materials more efficiently by, for instance, switching to energy efficient appliances or more efficient processes in industry. In the construction sector, use of low-emission building materials, such as wood, could help reduce emissions.

Third, we need to improve agricultural practices so as to reduce emissions and water use, including improving soil management and altering cattle diets. We also need to reduce deforestation which together with other changes in land use, account for 12% of CO_2 emissions.

Finally, we need to transform the global energy mix. Renewable energy production needs to be scaled up, with renewables (including biomass, wind, hydropower and solar) to supply half to two-thirds of primary energy in 2050 to achieve the 1.5°C target. We also need to transition transportation away from fossil fuels to running on low-emission electricity. Besides reducing climate impacts, switching to electric vehicles would bring other benefits, including improving air quality in cities. It's estimated that the additional emission reduction actions to limit warming to 1.5°C compared to 2°C would reduce premature deaths from air pollution by 100-200 million over the course of this century.

Together, these efforts amount to major transitions of unprecedented scale in all aspects of society. What happens in the next ten years will be critical. Given the inertia of the global economic system, it will be very difficult to achieve the emission reductions at the scale and rates required, without using methods to remove CO_2 from the atmosphere. Major investments will be needed to carry out these transitions, including in developing countries. These could be complemented by government legislation on energy standards and a tax on carbon.

TO SUM UP

To stabilise global warming at 1.5°C, we need to reduce our CO_2 emissions effectively to zero in the next 30 years. This would involve large and rapid emission reductions worldwide and throughout society, including changes in behaviour and lifestyles. In addition, it may be necessary to implement CO_2 removal from the atmosphere. The more action we take to reduce emissions now, the less we will have to employ these risky measures.

Transitions will be needed in how we produce and consume energy, materials and food, in our use of land (including agriculture), in our transportation system and in industry. These system transitions will be unprecedented in scale and will require large investments.

We are not on track to limit warming to 1.5°C, and are currently heading for 3-4°C warming by 2100. The good news is there is movement in the right direction in lots of these areas but we would need to do more and faster.

D. Addressing climate change in the context of sustainable development

Even without factoring in climate change, we face tremendous global challenges over the coming decades. The number of people living in poverty today is estimated to be 1.5 billion. At the same time, the global population is growing rapidly, predicted to rise from 7.6 billion today to 8.5-10 billion by 2050, and shifting from rural to urban areas, with urban-dwellers predicted to rise by 2 billion in the next three decades.

The United Nations has drawn up a list of 17 **Sustainable development goals (SDGs**[1]**)** and corresponding targets to address major global challenges including poverty, hunger, health, education, inequality, food and water security, energy access, economic development, peace and justice, climate change and biodiversity. In order to achieve these goals (including tackling climate change), we need to break the long-standing relationships between population, economic growth and greenhouse gas emissions. Since the industrial revolution, population, economic growth and greenhouse gas emissions have gone hand in hand with higher greenhouse gas emissions. We need to overcome this, because the physical impacts of climate change act to exacerbate poverty. Climate change and sustainable development are thus intricately linked and need to be considered together.

The 17 Sustainable Development Goals set by the United Nations in 2015

United Nations – Sustainable Development Goals

1 https://www.un.org/sustainabledevelopment/sustainable-development-goals/

In general, the countries that have contributed least to the problem in terms of their total carbon emissions, face some of the greatest risks.

Sustainable development supports, and often enables, the fundamental societal and systems evolutions that help limit global warming to 1.5°C.

An important new conclusion of the 1.5°C report is that **efforts to eradicate poverty and reduce inequalities go together with efforts to mitigate and adapt to climate change.**

International cooperation can provide an enabling environment for this to be achieved in all countries and for all people in the context of sustainable development, especially in developing countries and vulnerable regions.

TO SUM UP

With clear benefits to people and natural ecosystems, limiting global warming to 1.5°C compared to 2°C could go hand in hand with ensuring a more sustainable and equitable society.

Systems transition requires:
— More investments in adaptation and mitigation,
— Changes in behavior,
— Acceleration of technological innovation.

Sustainable development supports fundamental societal and systems transition and transformation. International cooperation is essential.

SCHOOL ACTIVITY

TASK The greenhouse gas emissions reduction goals that the countries of the world have set themselves under the Paris Agreement, known as the Nationally Determined Contributions (NDCs), would lead to global greenhouse gas emissions in 2030 of 52-58 Gt CO_2 eq/yr.
How much is 52–58 Gt CO_2 eq/yr?
Check the World Bank page on greenhouse gas emissions: https://data.worldbank.org/indicator/EN.ATM.GHGT.KT.CE
— What is the total amount of the World's GHG emissions (in CO_2 eq)? (Answer: 53.5 Gt CO_2 eq in 2012)
— What is the total amount of your country's GHG emissions (in CO_2 eq)? (France: 0.5 Gt CO_2 eq in 2012)
— What are the GHG emissions per capita for your country (in CO_2 eq per capita)? (France: 0.5 Gt CO_2 eq divided by 65 million inhabitants = 7.7 t CO_2 eq per capita in 2012)

TASK Look up your country's NDCs and estimate whether the goals will be reached or not..

QUESTION What is low GHG-intensive food consumption?

TASK Explain why/how afforestation and bioenergy supply can compete with food production?
Examples for crops for bioenergy: maize, palm oil.

TASK Find reasons why the Sustainable Development Goals 1 (no poverty) and 10 (reduced inequalities) are so important for limiting global warming to 1.5°C.

Glossary

ADAPTATION

The process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate change and its effects.

ANTHROPOGENIC EMISSIONS

Greenhouse gas emissions caused by human activities.

BIODIVERSITY

Biodiversity is the level of diversity of living organisms in an area; for instance, the diversity of species within an ecosystem, or the diversity within one species.

CARBON DIOXIDE REMOVAL (CDR)

Anthropogenic activities that remove CO_2 from the atmosphere and durably store it in terrestrial or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage, but excludes natural CO_2 uptake not directly caused by human activities.

EMISSION PATHWAYS

In the Summary for Policymakers, the modelled trajectories of global anthropogenic emissions over the 21st century are termed “emission pathways”. Emission pathways are classified by their temperature trajectory over the 21st century : pathways giving at least 50% probability based on current knowledge of limiting global warming to below 1.5°C are classified as “no overshoot”; those limiting warming to below 1.6°C and returning to 1.5°C by 2100 are classified as “1.5°C limited-overshoot”; while those exceeding 1.6°C but still returning to 1.5°C by 2100 are classified as “higher-overshoot”.

GREENHOUSE GASES AND INFRARED RADIATION

The Sun’s rays travel through the atmosphere and warm the Earth’s surface, generating the upward emission of infrared radiation. Some of this infrared radiation is trapped on its escape to space by greenhouse gases in the atmosphere (mainly water vapour, carbon dioxide, methane, nitrous oxide and ozone) and sent back towards the Earth’s surface – heating it up even more. This is called the greenhouse effect.

GLOBAL MEAN SURFACE TEMPERATURE (GMST)

Global average of near-surface air temperatures over land and sea-ice, and sea surface temperatures over ice-free ocean regions, with changes normally expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperature over both land and oceans are also used.

GLOBAL WARMING

The increase in GMST averaged over a 30-year period, or the 30-year period centered on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multidecadal warming trend is assumed to continue.

MITIGATION

A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

NET ZERO EMISSIONS

Net-zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by CO_2 removals over a specified period.

PRE-INDUSTRIAL

The multi-century period prior to the onset of large-scale industrial activity around 1750. The reference period 1850–1900 is used to approximate pre-industrial GMST.

SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals are the blueprint to achieve a better and more sustainable future for all. They address the global challenges we face, including those related to poverty, inequality, climate, environmental degradation, prosperity and peace and justice. Examples: No poverty, zero hunger, quality education, etc.

TEMPERATURE OVERSHOOT

The temporary exceedance of a specified level of global warming.

Resources

Resources for trainers (Climate and Greenhouse effect – Ocean & Climate) from the OCE.

Other selected resources

https://climatekids.nasa.gov

http://www.fondation-lamap.org/en/20322/the-ocean-my-planet-and-me

https://medienportal.siemens-stiftung.org/portal/main.php?todo=showObjData&objid=104534

https://tropicsu.org/un-resources/

https://tropicsu.org/resources/pedagogical-tools-examples/

https://climate-adapt.eea.europa.eu/knowledge/adaptation-information/adaptation-measures

http://theconversation.com/what-is-a-pre-industrial-climate-and-why-does-it-matter-78601

https://ocean-climate.org/?lang=en

About the IPCC

Video of the IPCC Working Group I: "Climate Change 2013: The Physical Science Basis"
http://www.climatechange2013.org/

Office for Climate Education

“Parties should take measures [...] to enhance climate education”, states Art.12 of the Paris Agreement. *“Educating the present and future generations about climate change, and teaching them to act with a critical mind and a hopeful heart, is essential for the future of humanity. Science education must meet the challenge [...]”*, recommend the 113 science Academies of the world in their recent Statement on Climate Change and Education.

Replying to these urgent calls, climate scientists and educators established an **Office for Climate Education.** Teachers are key for implementing these recommendations, especially in primary and secondary schools. The Office therefore produce educational resources for them, based on an active pedagogy and pilot projects in inquiry-based science education. As the IPCC produces “assessment reports” and “summaries for policymakers”, the Office produces resources and tools for teachers, focusing on the issues of adaptation and mitigation. The OCE will pay special attention to developing countries.

Working closely with climate scientists and involving social scientists and educators, the Office for Climate Education has an executive secretariat in Paris and a global network of local or regional partners in over 60 countries. The teaching resources are created for a global framework, then locally tested and adapted to particular situations. The numerous initiatives already taken in the same direction are documented and publicised by the Office. The Office for Climate Education was launched in 2018 under the aegis of the foundation ***La main à la pâte*** and with the support of public and private funds provided by French and German partners. It will amplify its action in accordance with its resources and develop partnerships, especially with IPCC authors and IAP for Science – the global federation of Science Academies.

www.oce.global
contact@oce.global
Office for Climate Education
Sorbonne Université
Case 100
Campus Pierre et Marie Curie
4, place Jussieu
75005 Paris – France

Fondation La main à la pâte
Meteo France
Institut de Recherche pour le Développement France
météo et climat Société météorologique de France
ipcc Intergovernmental Panel on Climate Change
Sciences de l'environnement Institut Pierre Simon Laplace
PIK
iap Science Research Health the interacademy partnership
Fondation Luciole Institut de France
Fondation Prince Albert II de Monaco
SIEMENS Stiftung