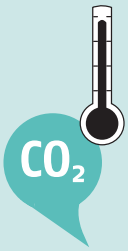
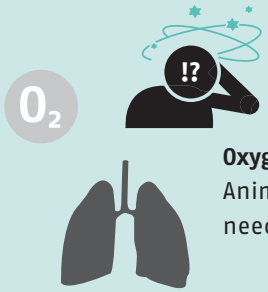
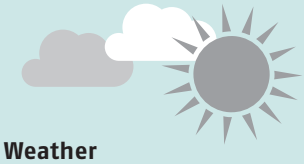


Earth's climate
Our climate is controlled by the composition of the atmosphere and is dependent on water vapor content and greenhouse gases.



Oxygen
Animals and humans need oxygen to survive.



Weather
Rain, sunshine, clouds, storms: the weather in the atmosphere is constantly changing.

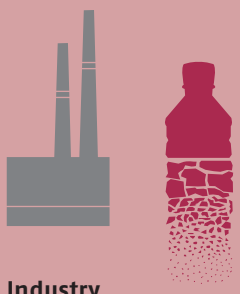
The protective layer that surrounds our planet

ATMOSPHERE

ANTHROPOSPHERE

Everything man-made and constructed

Agriculture
Livestock farming and cultivation of fruit, vegetables, and energy crops.



Industry
Production of goods, energy, and waste.

Raw Materials
Production of raw materials such as mining for coal, iron, or rare earth metals, oil production, or clear-cutting for timber.

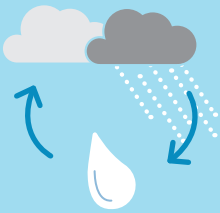
Settlements
From villages to megacities.

Infrastructure
Roads, train tracks, airports, and sea ports for global transport.

Saltwater
The salty oceans make up the majority of our water.

Freshwater
From groundwater to springs, rivers, and lakes to our taps.

Frozen water
Ice, glaciers, snow, frozen soil, and bodies of water.



Water cycle
Water is constantly exchanged between land and atmosphere.

Life-giving water in all its forms

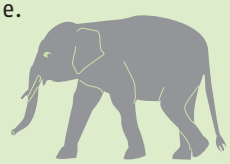
HYDROSPHERE

All animals and plants on, above, and below the ground

BIOSPHERE

Plants
From grasses, cacti, and trees to algae and kelp forests underwater, plants are as diverse as their habitats.

Animals
From tiny sea creatures to the largest mammals on land and migratory birds in the air, every animal has its niche.

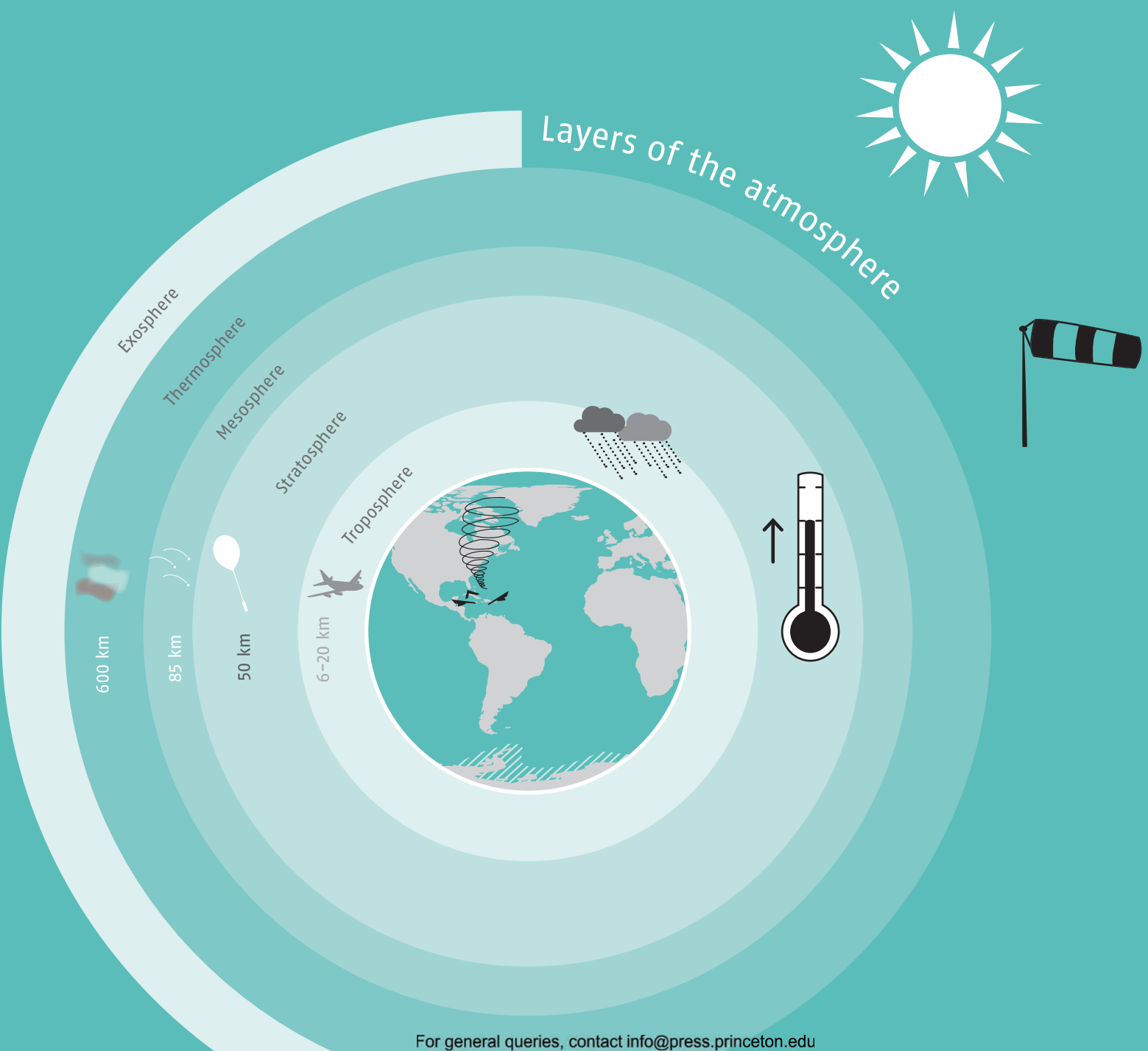


Ecosystems
Plants and animals live in complex interconnected habitats.

Source: AGCI (2022)

THE ATMOSPHERE

Air, Weather & Climate



At | mo | sphere
[ancient Greek *atmós* = haze
& *sphaĩra* = sphere (Earth)]

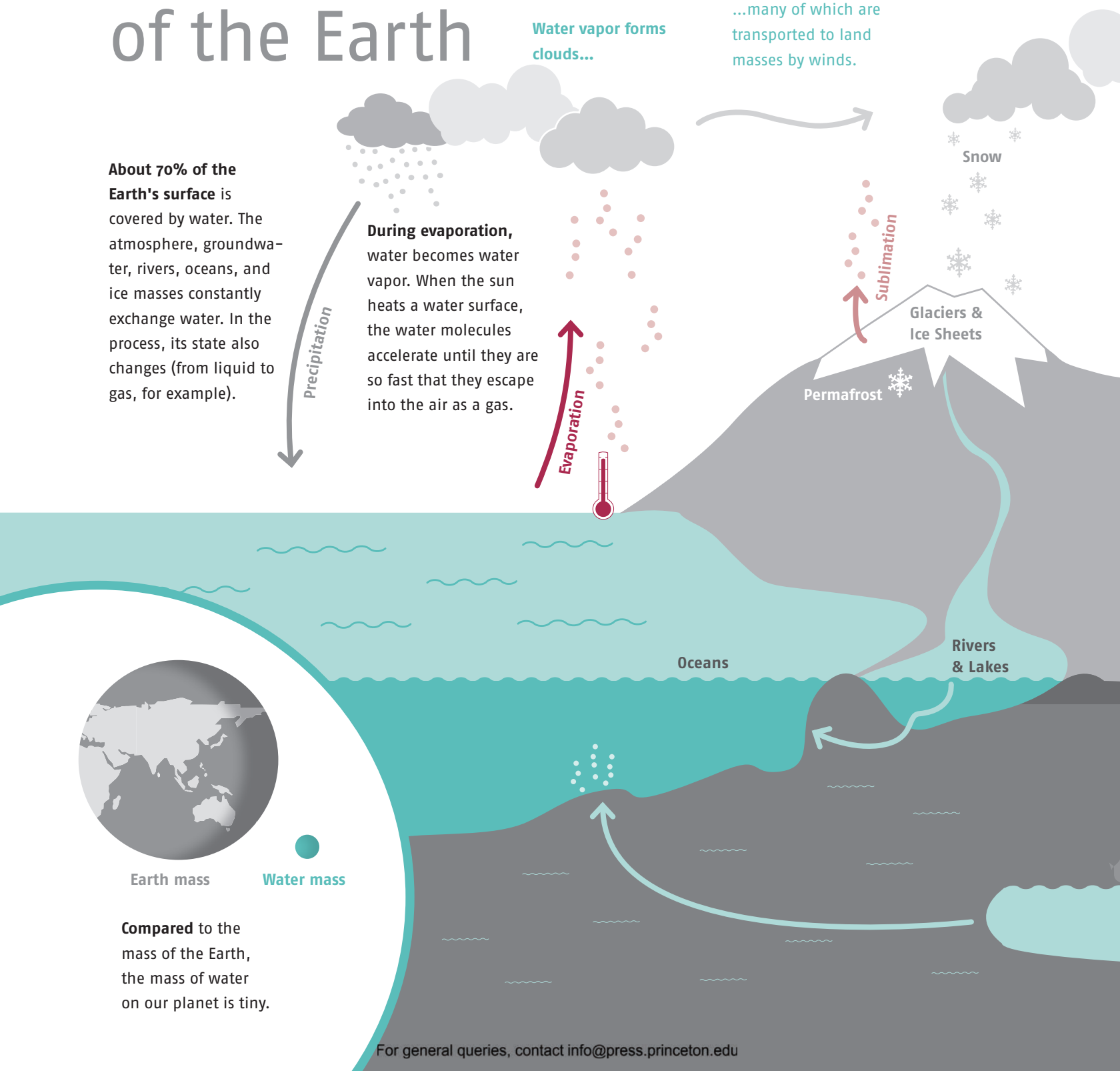
The atmosphere is the gaseous envelope of the Earth, inside which wind, clouds and precipitation form. It filters, absorbs, and reflects the sun's radiation, making life on Earth possible. Without an atmosphere, our planet would resemble a snowball.

Air & Weather

Water Cycle of the Earth

About 70% of the Earth's surface is covered by water. The atmosphere, groundwater, rivers, oceans, and ice masses constantly exchange water. In the process, its state also changes (from liquid to gas, for example).

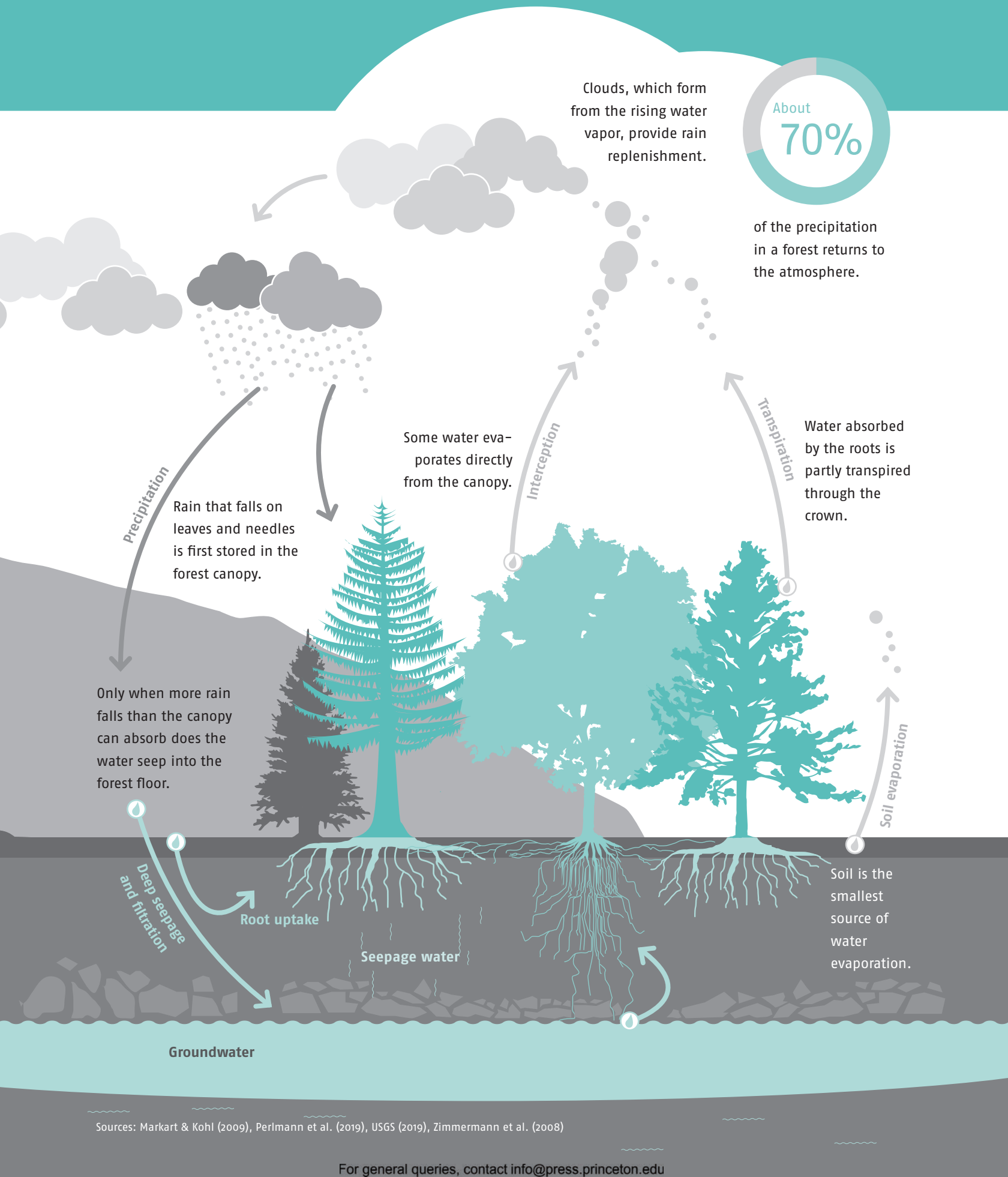
During evaporation, water becomes water vapor. When the sun heats a water surface, the water molecules accelerate until they are so fast that they escape into the air as a gas.



Earth mass

Water mass

Compared to the mass of the Earth, the mass of water on our planet is tiny.



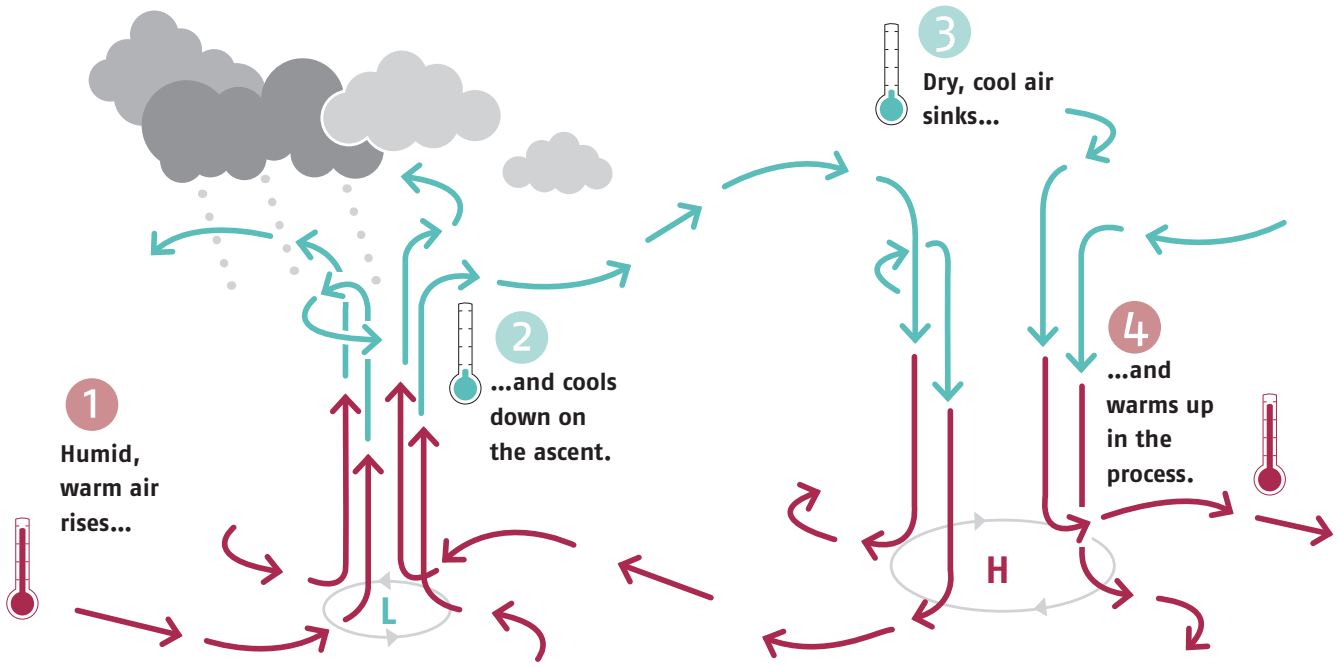
Sources: Markart & Kohl (2009), Perlmann et al. (2019), USGS (2019), Zimmermann et al. (2008)

Air in Motion

The air in the atmosphere never stands completely still. This is mainly due to temperature differences between the Earth's surface and the higher layers of air, which create high- and low-pressure areas.

When the sun warms the Earth's surface and thus also the air, water evaporates from the soil and water bodies and enriches the air with moisture; in addition, the air expands as it warms. This creates a low-pressure area: the warm, humid air rises, cools down, and condenses, forming clouds. This is why it is often rainy and stormy in low-pressure areas.

A little further away, the cooled air sinks again and warms up the closer it gets to the ground. This creates an area of high pressure, where sinking air masses cause the clouds to dissipate. This is why high-pressure areas bring bright sunshine.

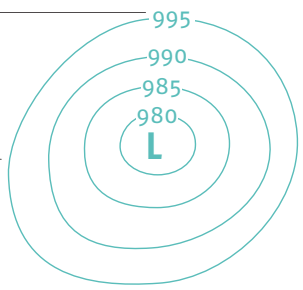


LOW-PRESSURE AREA

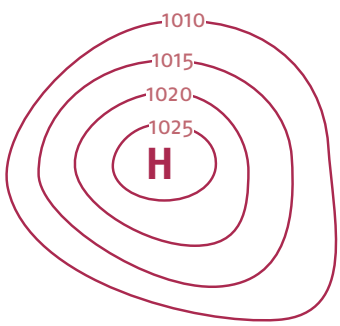
HIGH-PRESSURE AREA

Air pressure* in hectopascals (hPa)

Isobar On meteorological maps, a line which indicates places of equal pressure.



Wind direction: Counterclockwise from the Earth's center (in the Northern Hemisphere).



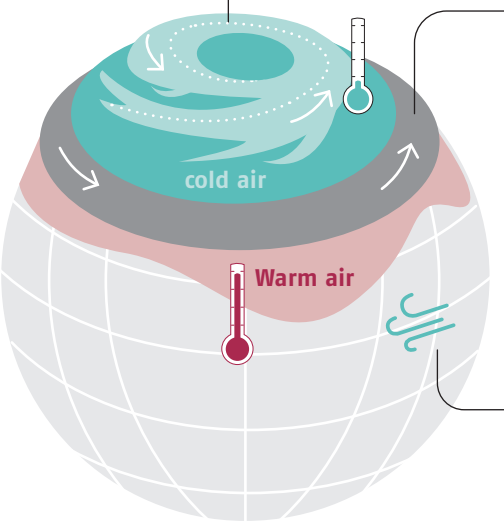
Wind direction: Clockwise from the Earth's center (in the Northern Hemisphere).

*Weight of the air column from the outermost edge of the atmosphere to the Earth's surface.

Source: DWD (2022)

Air Currents at the Poles

Stable polar vortex
In winter, the sun no longer rises at the poles, leading to a strong temperature differential between the cold poles and warm equator. This creates the polar vortex, a fast air current in the stratosphere (an altitude of 16–48 km) that moves in a circle around the north and south poles.

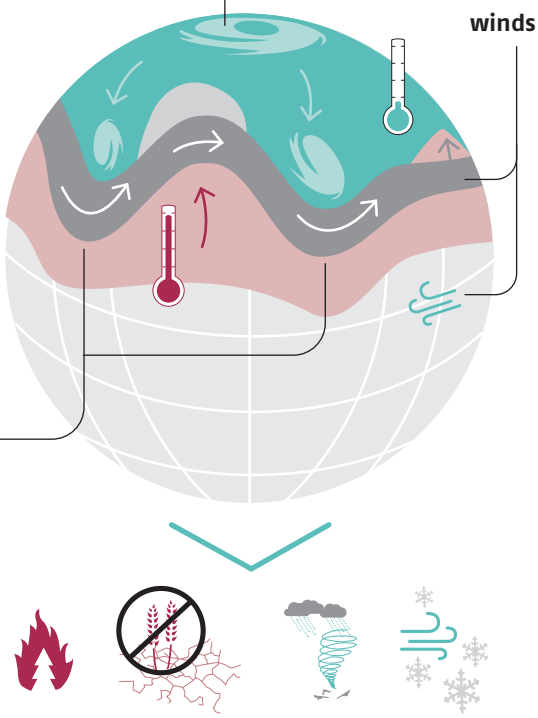


Strong jet stream
The jet stream runs in the troposphere, at an altitude of about 8–14 km. Its force and shape depend on the state of the polar vortex.

Strong trade winds

Disrupted polar vortex
The Arctic polar vortex weakens and breaks into several parts each April (or earlier in exceptional cases such as 2018, 2019, and 2021). This leads to a weaker jet stream and longer-lasting, stationary weather patterns that can become extreme weather events.

Weak jet stream & weak trade winds

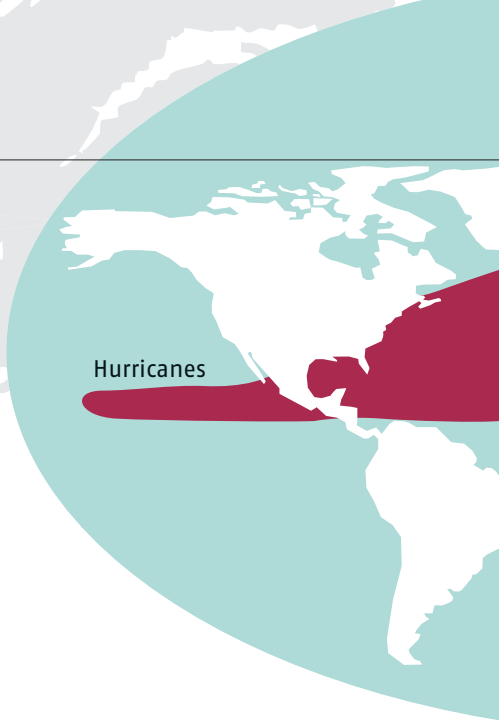


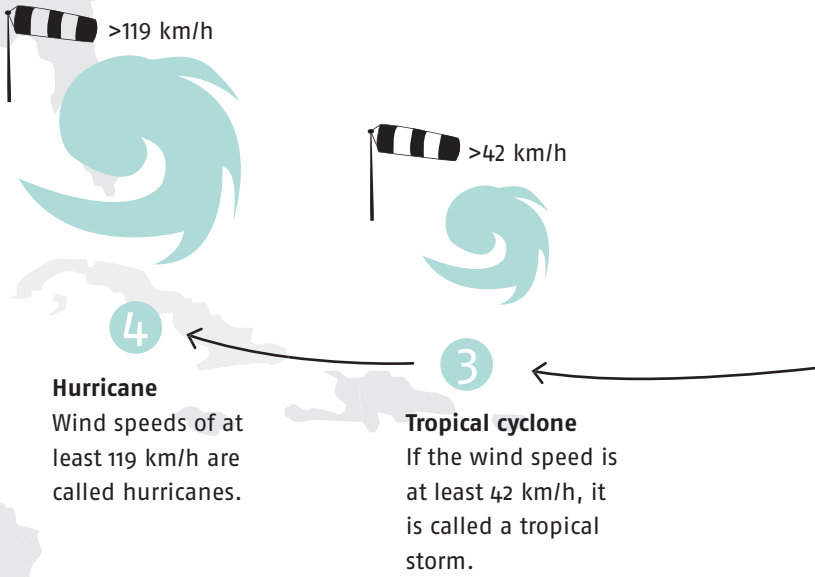
Rossby waves
When the temperature gradient between the pole and the equator becomes very large, the jet stream creates waves, so-called Rossby waves. These can become so strong that they weaken and even split the polar vortex.

Climate change
Scientists disagree on whether and to what extent global warming has an impact on the polar vortex and jet stream. If Rossby waves become stronger due to global warming, it could lead to more severe droughts and a collapse of global food production in regions where about 1/4 of the world's food is grown.

Sources: Coumou et al. (2018), Kornhuber et al. (2019), NOAA (2019, 2021), Voosen (2020), WOR (2019)

Extreme Storms



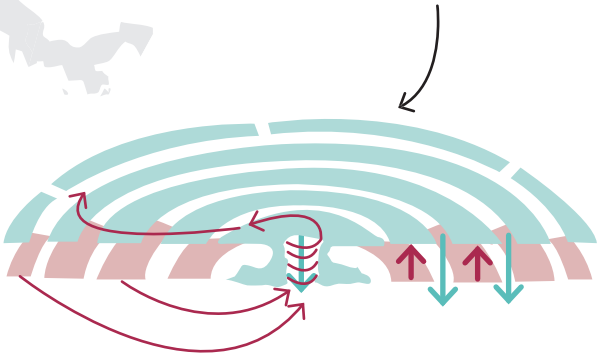


Hurricane
Wind speeds of at least 119 km/h are called hurricanes.

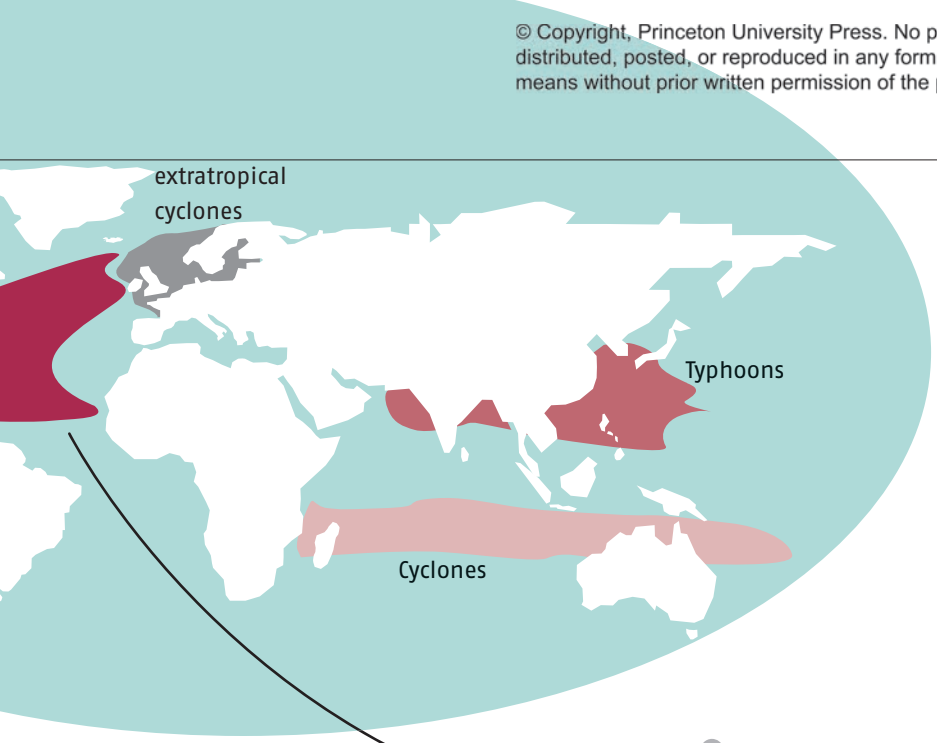
Tropical cyclone
If the wind speed is at least 42 km/h, it is called a tropical storm.

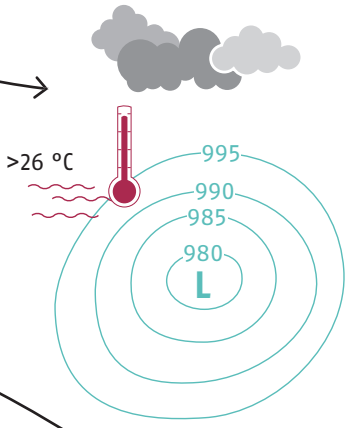
The movement of the air can take on extreme forms, especially when cyclones form over the water. Depending on the region of the world, we speak of hurricanes (Atlantic and Eastern Pacific), extratropical cyclones (North Atlantic), typhoons (Northwest Pacific), or cyclones (Indian Ocean and Southwest Pacific).

In late summer, when the ocean is at its warmest and evaporation at its highest, hurricane season begins in the Atlantic. If the water temperature at the surface is higher than 26 degrees Celsius, tropical storms develop from low-pressure areas. Global warming may cause this temperature limit to be exceeded more often in the future, and destructive storms such as hurricanes are likely to increase in frequency and strength around the world. This would affect Caribbean and Pacific island nations and heavily populated coastal and river delta areas in North America and Asia, in particular.



In a hurricane, warm air rises in a spiral while cold air sinks at the center or eye. The more warm humid air rises, the stronger and faster the whirlwind moves.





1

Low-pressure area in the tropics
Warm, humid air rises from the ocean, and when the water temperature rises above 26 degrees, hurricanes can form.

2

Wind vortex
The pressure drops at ground level and rises in the higher layers of air. This causes the winds to begin to rotate.

Hurricane Wind Scale
According to Saffir-Simpson

Sources: NOAA (2022), Rahmstorf (2018), Velden et al. (2017)

Climate

The Natural Greenhouse Effect

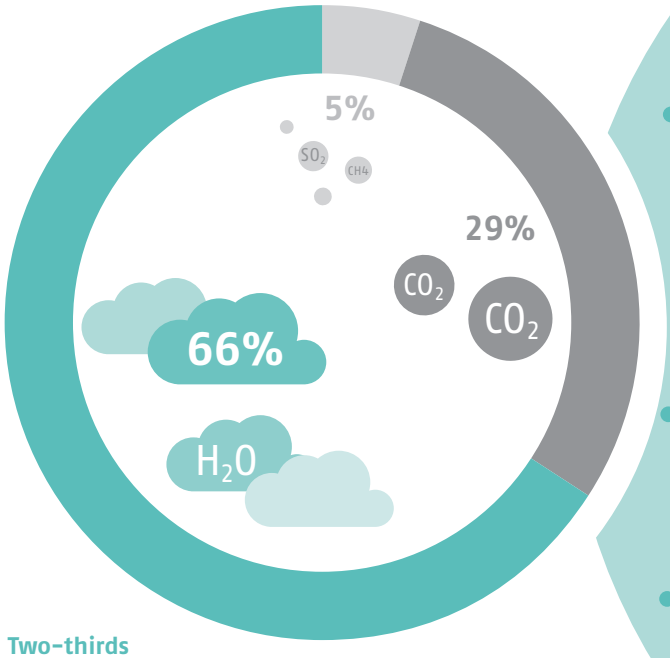
created a moderate, stable climate from the end of the last ice age until about 1880.

Life on Earth is only possible because it has temperatures at which living things can thrive. We have the so-called greenhouse gases to thank for these temperatures. These gases ensure that, when heat from the sun reaches Earth and radiates back toward space, some of it does not disappear, but remains in our atmosphere. Natural greenhouse gases are primarily water vapor, carbon dioxide, and trace gases such as methane.

As long as the concentration of greenhouse gases is in equilibrium, the average temperature on Earth remains almost constant, but when man-made greenhouse gases are added, it becomes warmer and warmer.

More on man-made greenhouse gases starting on p. 20.

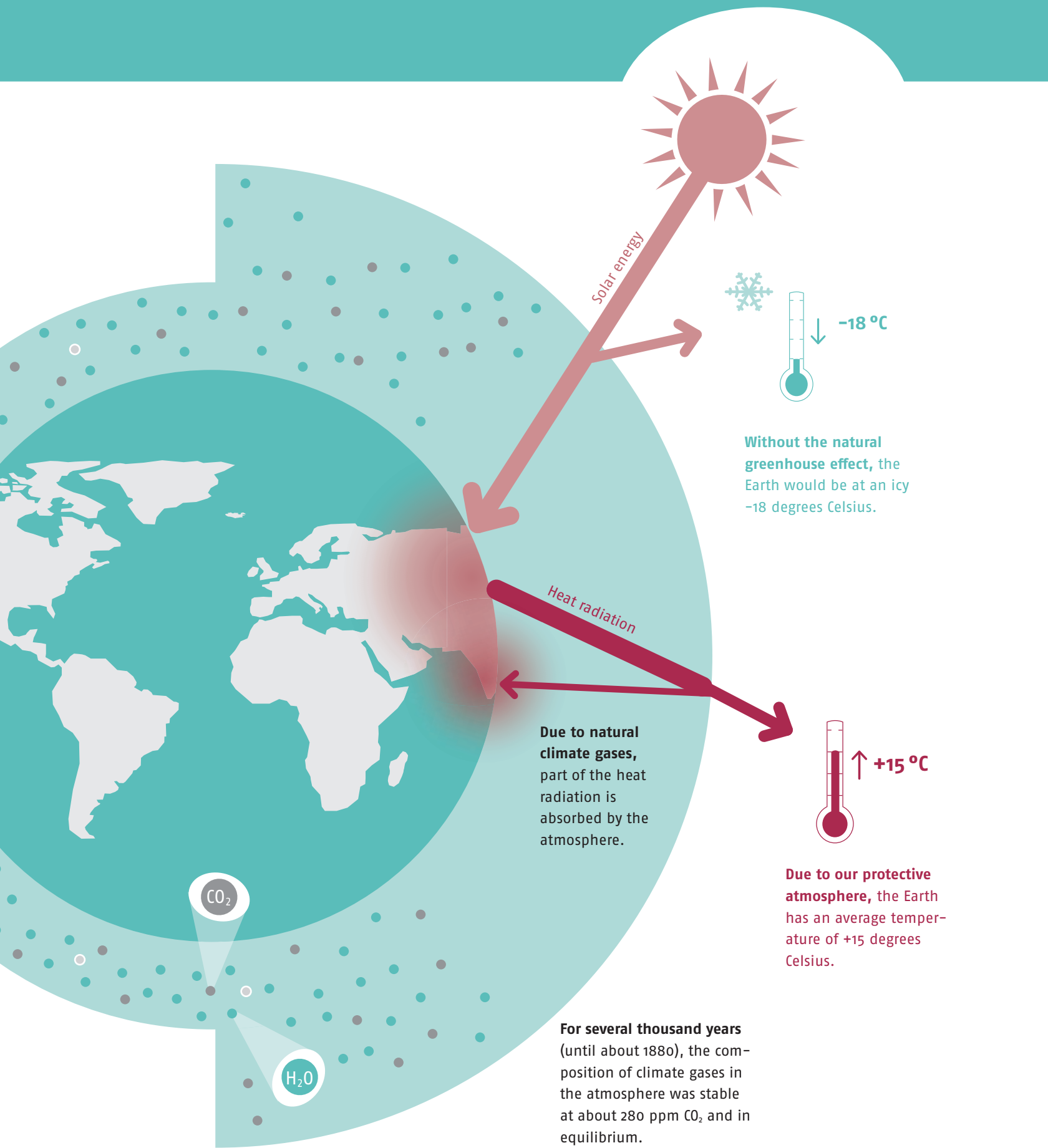
Composition of greenhouse gases



Two-thirds of the natural greenhouse effect is caused by water vapor (H_2O), just under a third by CO_2, and a small percentage by other trace gases such as methane (CH_4).

1 dot stands for 1%:
- Water vapor
- Carbon dioxide
- Trace gases

Sources: DWD (2018), Rahmstorf (2013), Riedel & Janiak (2015), UBA (2021), UNFCCC (2022)



Without the natural greenhouse effect, the Earth would be at an icy −18 degrees Celsius.

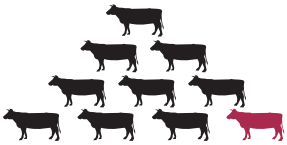
Due to natural climate gases, part of the heat radiation is absorbed by the atmosphere.

Due to our protective atmosphere, the Earth has an average temperature of +15 degrees Celsius.

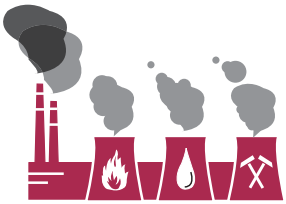
For several thousand years (until about 1880), the composition of climate gases in the atmosphere was stable at about 280 ppm CO_2 and in equilibrium.

We Are Changing the Climate

with high CO_2 emissions caused by:



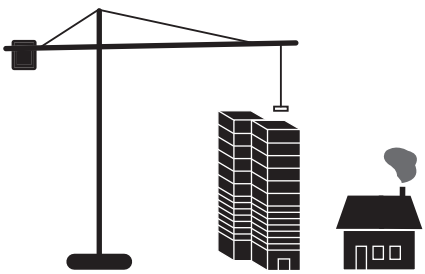
Industrial agriculture, feed production, and factory farming, as well as soil degradation



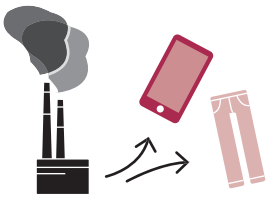
Burning fossil fuels such as coal, oil, and gas to meet rising global energy demand

Passenger and freight transport on roads, rivers, seas, and in the air

Forest fires, forest use, native forest logging, and forest management



Housing and house construction, heating, and energy demand in the private sector



Production of goods, means of transport, textiles, and furniture in energy-intensive processes

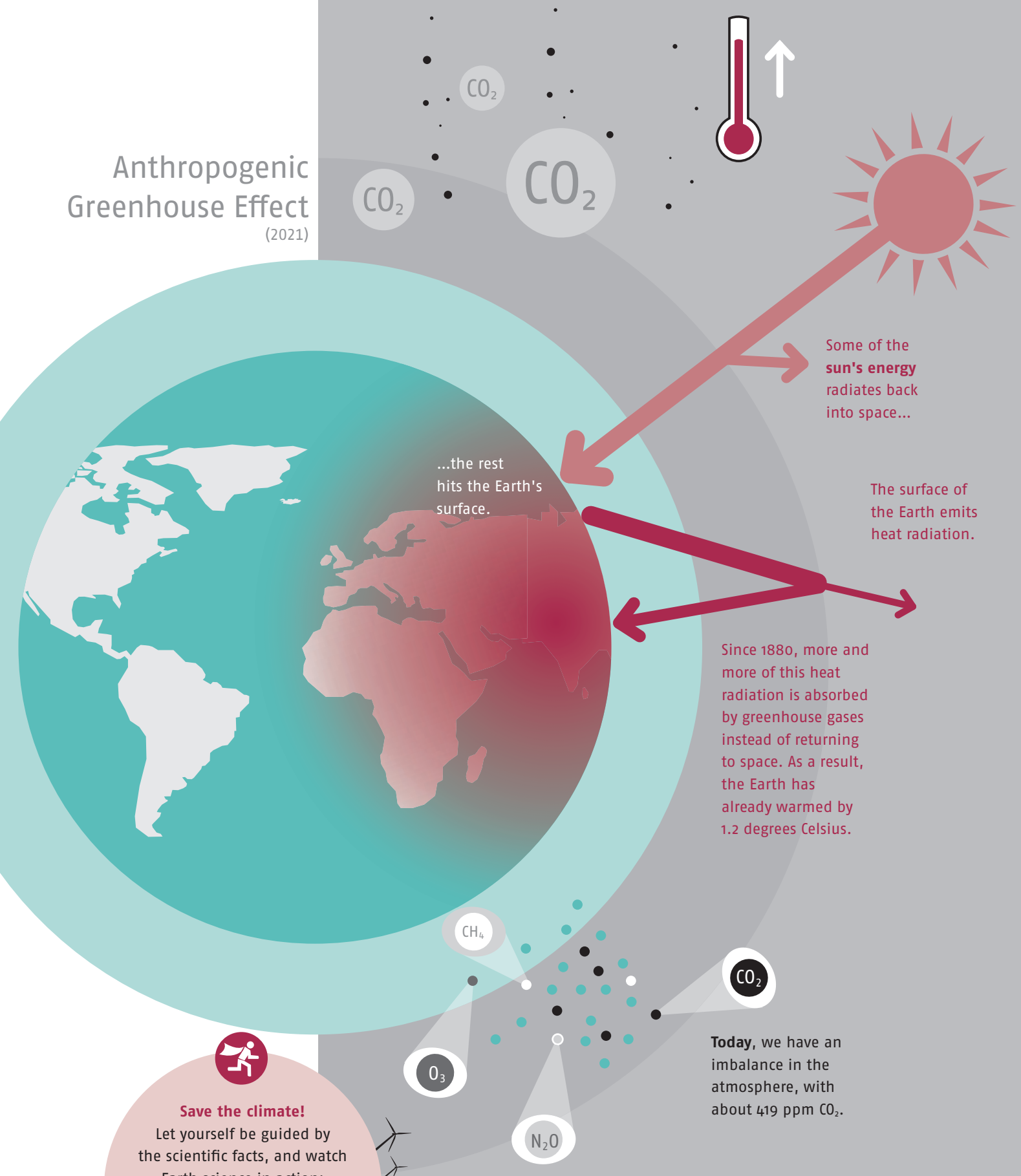
Since the beginning of the industrial revolution (around 1880), humans have been releasing more and more greenhouse gases into the atmosphere, causing the temperature to rise steadily by 1.1 to 1.2 degrees Celsius since 1880. The problem was recognized at the first World Climate Summit in Berlin in 1995. In 1997, the United Nations (UN) Kyoto Protocol was established, committing industrialized countries to reduce their greenhouse gas emissions.

Rising global (online) consumption and lifestyle of abundant disposable goods

Nearly 200 countries have signed the Paris Climate Agreement. At the 2015 meeting, world leaders agreed to limit global warming to well below 2 degrees Celsius, to ensure that life on our planet remains worth living for today's children and their children.

Anthropogenic Greenhouse Effect

(2021)



Save the climate!
Let yourself be guided by the scientific facts, and watch Earth science in action:
climate.nasa.gov
climatechangeinaustralia.gov.au

Sources: DWD (2018), Rahmstorf (2013), UBA (2021)

Anthropogenic Greenhouse Gases

Scientific evidence gathered over the last 30+ years leaves no doubt that global warming is caused by rising anthropogenic greenhouse gas emissions, particularly the increase in CO_2 levels.

Except for the fluorinated gases, all trace gases shown here were also present in the atmosphere in lower concentrations before the industrial age, but their concentration in the atmosphere is steadily increasing.

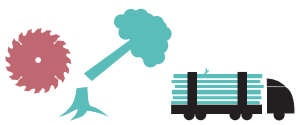
64% Carbon dioxide (CO_2)

from fossil fuels and industry

The extraction, processing, and burning of fossil fuels such as coal, natural gas, and oil account for the largest portion of carbon dioxide (CO_2) emissions.

11% Carbon dioxide

from forestry and land use



Deforestation, clearing of forests by fire, draining of peat bogs, and alteration of soils by agriculture also release CO_2 into the atmosphere.

18% Methane

Methane emissions are caused by factory farming, landfills, sewage treatment plants, mining, and extraction of fuels as well as thawing of permafrost.

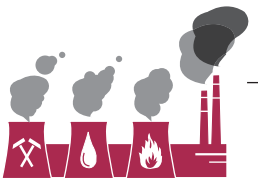
4% Nitrous oxide (laughing gas)

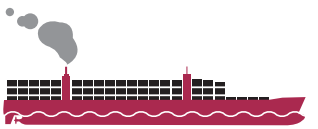
The majority of nitrous oxide emissions come from agriculture through soil cultivation, nitrogenous fertilizers such as nitrate and ammonia, and factory farming.

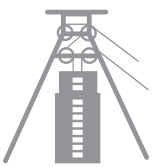
2% F-gases (hydrofluorocarbons)

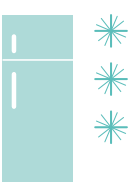
Fluorinated gases are used as propellants, coolants, and extinguishing agents, or in the production of soundproof windows.

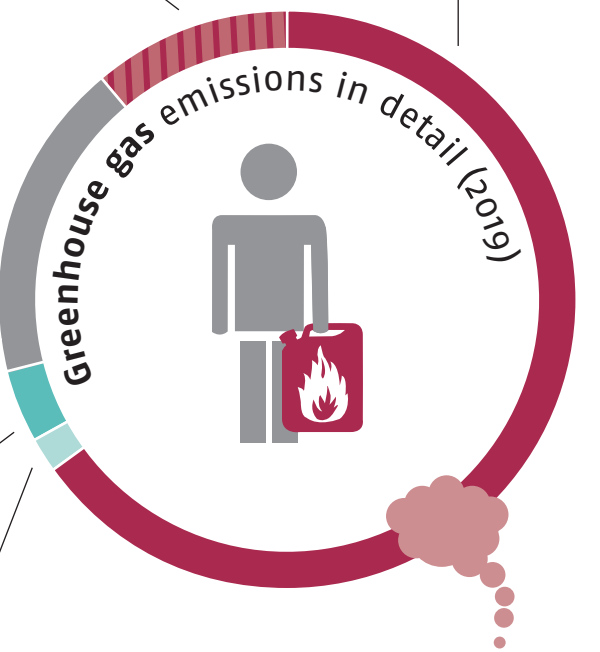
Sources: IPCC (WG-III) (2022), UBA (2021)











Approx. 2/3 water vapor

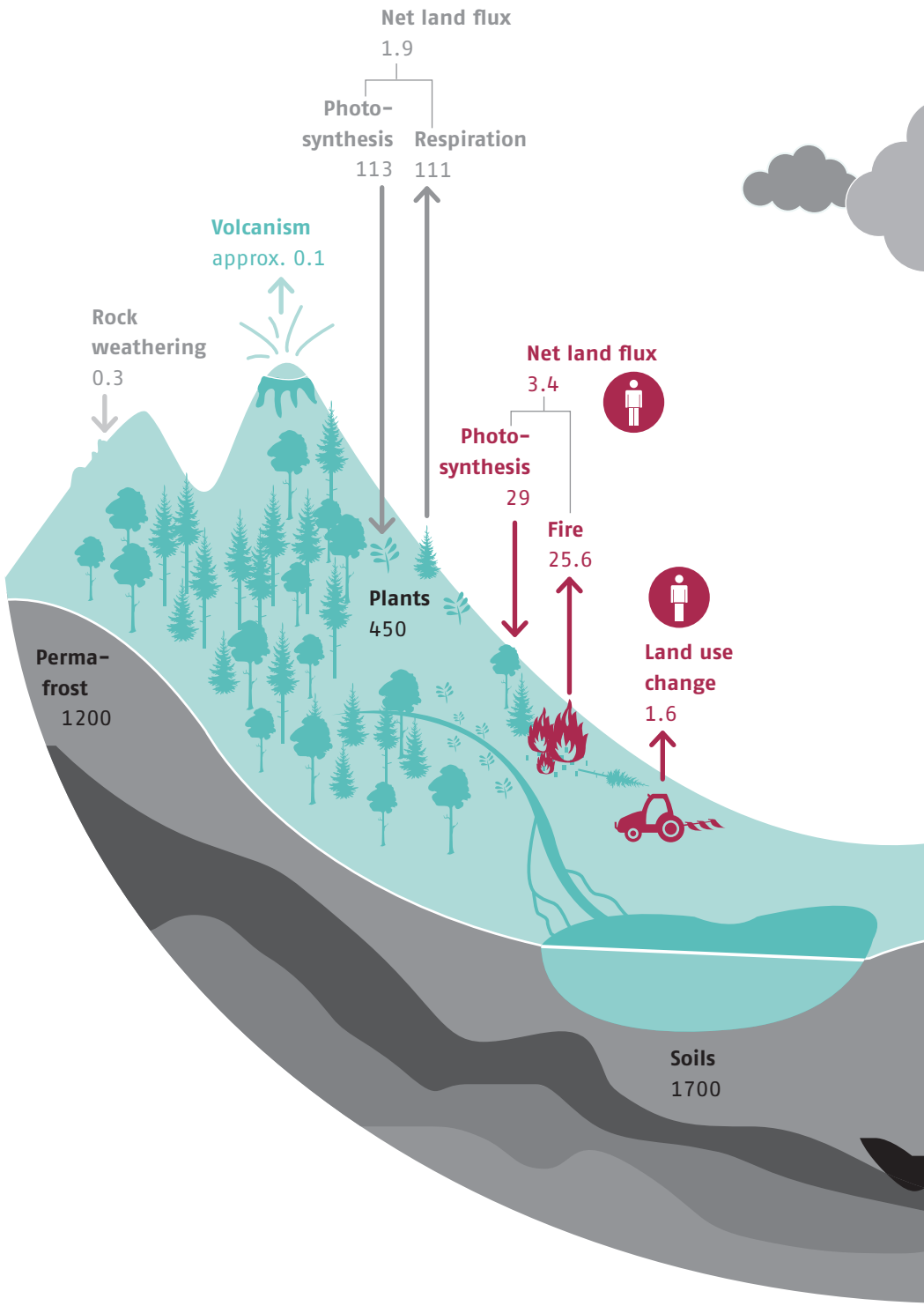
Water vapor is abundant in our atmosphere. It contributes to two-thirds of the natural greenhouse effect, making it the most important greenhouse gas. As the temperature of the ocean and air continues to rise, the amount of water vapor in the atmosphere also increases. More water vapor leads to more clouds and rain, creating a continuous cycle that has a strong impact on the climate.

Complex Carbon Cycles

Carbon dioxide (CO_2) is the most commonly discussed greenhouse gas when it comes to climate change. Carbon is a fundamental building block of all life on Earth, and it is absorbed, stored, and released back into the atmosphere in a global cycle. Carbon is an essential element for plant growth, as plants use it for photosynthesis to create sugar. When carbon combines with other elements, such as oxygen, nitrogen, or phosphorus, it can lead to the formation of various essential compounds. Plants absorb CO_2 during photosynthesis, but they also release it back into the atmosphere, for example, when leaves decompose.

Human activities such as the burning of oil, gas, and wood contribute significantly to the release of carbon dioxide into the atmosphere. Additionally, human-induced activities like deforestation and land use change have led to large carbon dioxide emissions by destroying ecosystems that have stored a lot of CO_2 over millenia, such as peatlands.

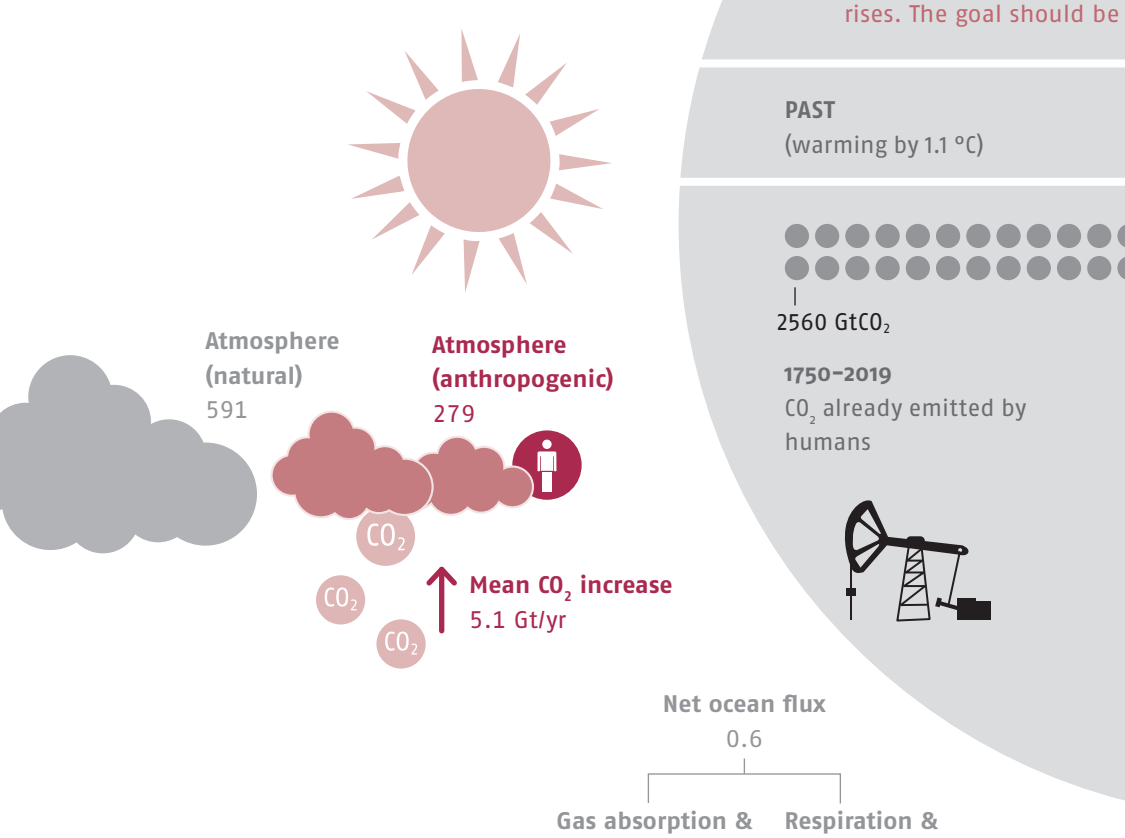
The increasing warming of the oceans due to human-induced climate change has also led to "feedbacks" in the climate system: as the oceans warm, they can absorb less CO_2, causing the concentration of CO_2 in the atmosphere to rise further.

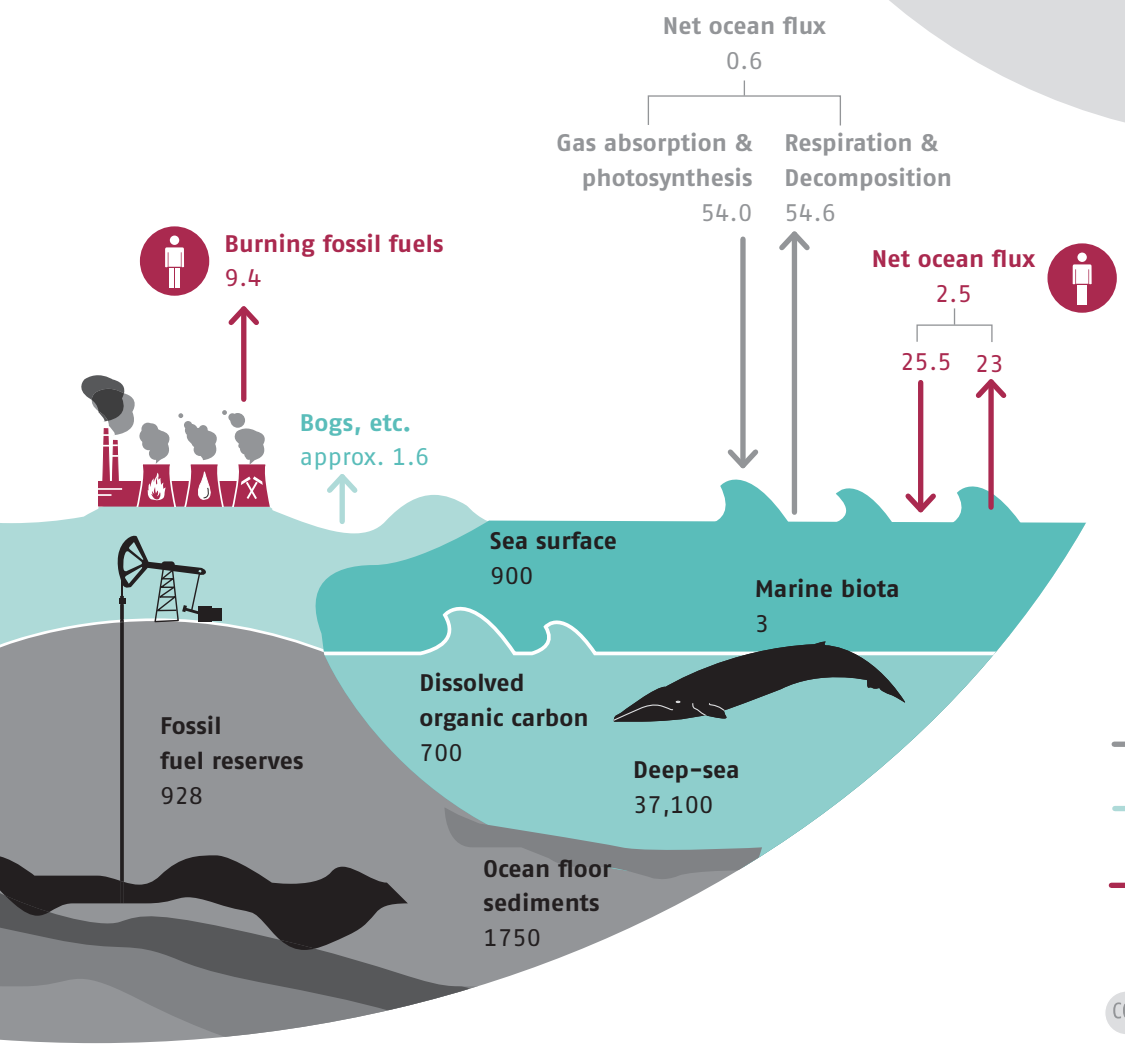


Source: IPCC (2021)

OUR "CO_2 BUDGET"

The more CO_2 we emit, the more global average temperature rises. The goal should be a limit of +1.5 degrees Celsius.



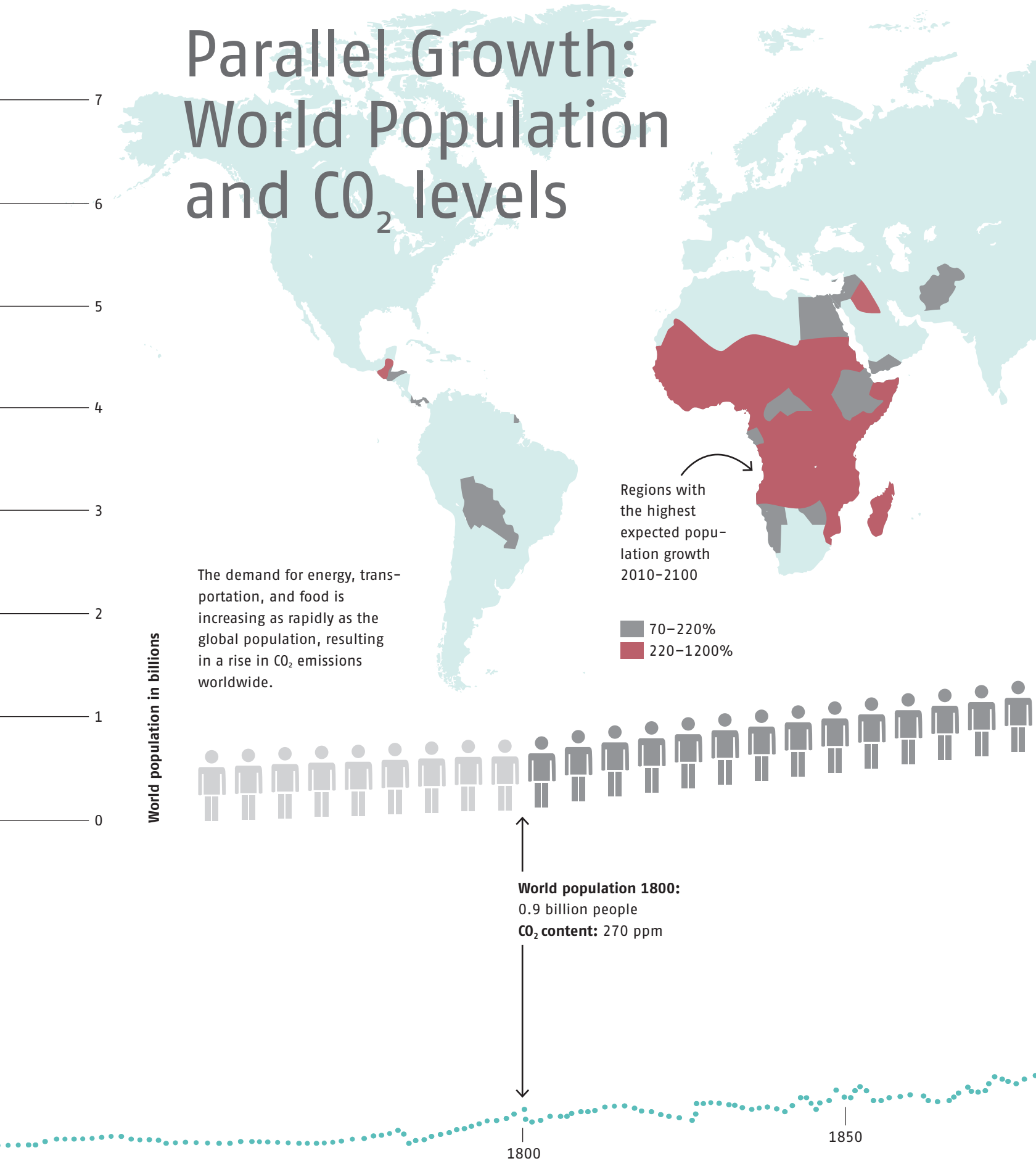


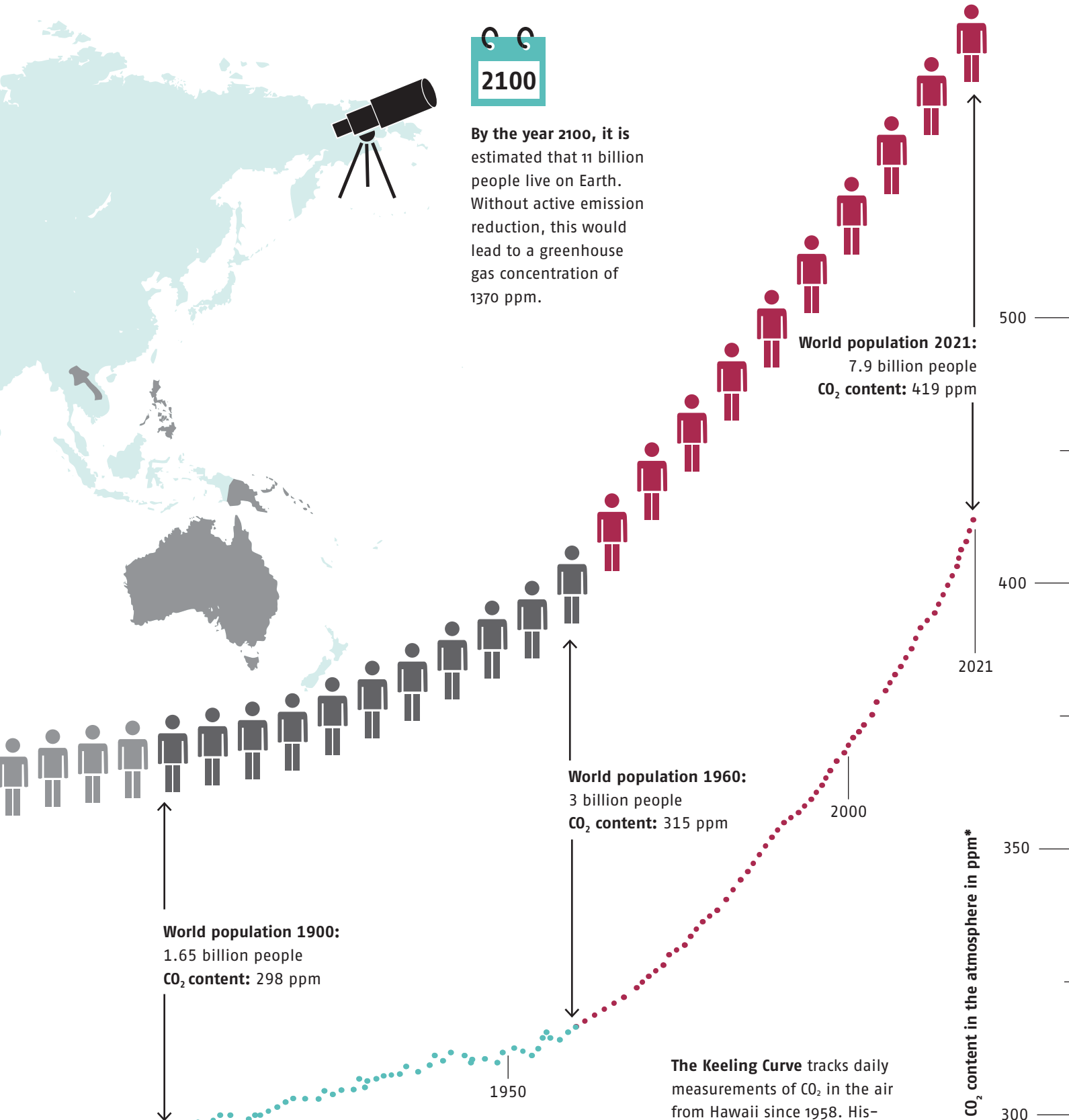
Carbon stocks in Gigatonnes (Gt), carbon fluxes in Gt/year

- natural fluxes
- natural (highly fluctuating)
- Anthropogenic

Conversion:
CO_2 100 Gt of CO_2 contains 27 Gt of carbon

Parallel Growth: World Population and CO_2 levels



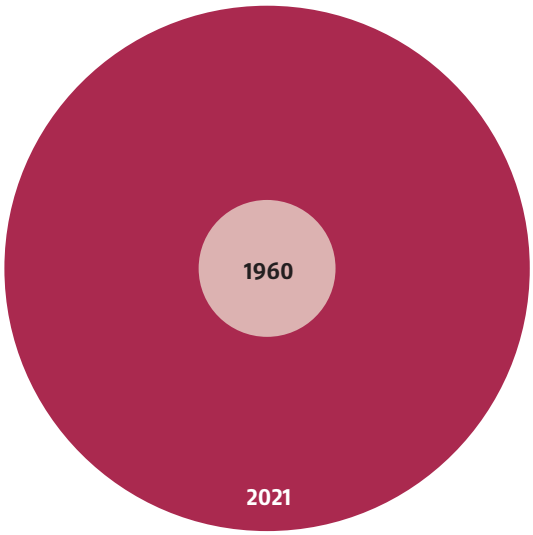


The Keeling Curve tracks daily measurements of CO_2 in the air from Hawaii since 1958. Historical CO_2 data can be traced back to 800,000 years before our era and is determined by gases trapped in layers of ice, among other proxies.

Sources: NOAA (2022), UN (2013+2018)

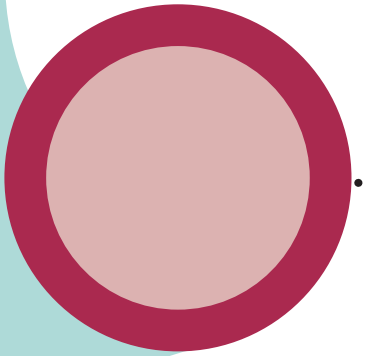
*ppm = parts per million

CO_2 Emissions: Top 10



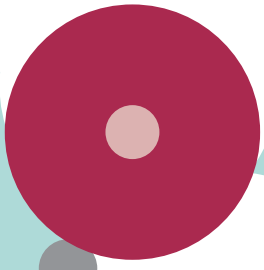
1 CHINA

779 (1960) » **11,472** (2021)
Million tonnes (Mt) CO_2



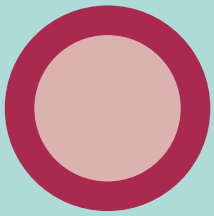
2 USA

2888 » **5007 Mt CO_2**



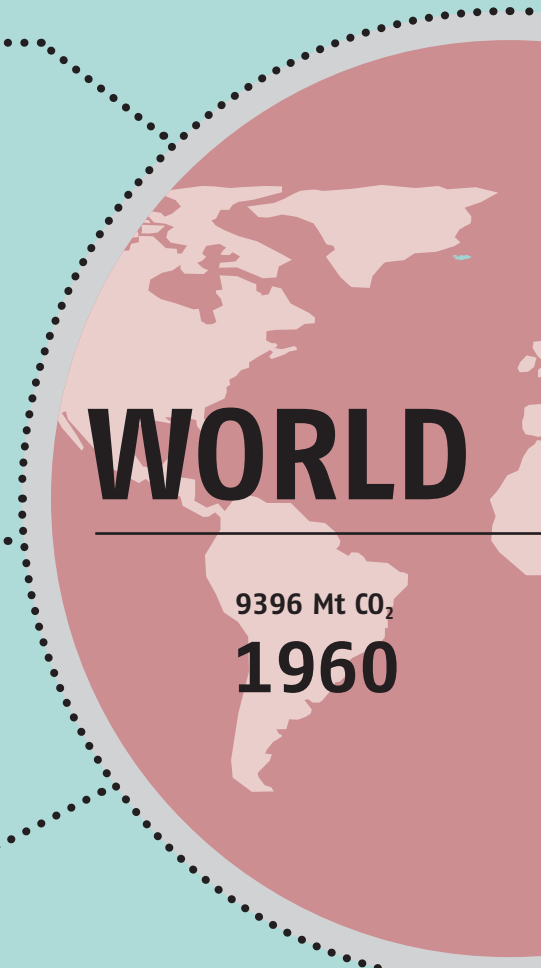
3 INDIA

121 » **2710 Mt CO_2**



4 RUSSIA

890 » **1756 Mt CO_2**



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