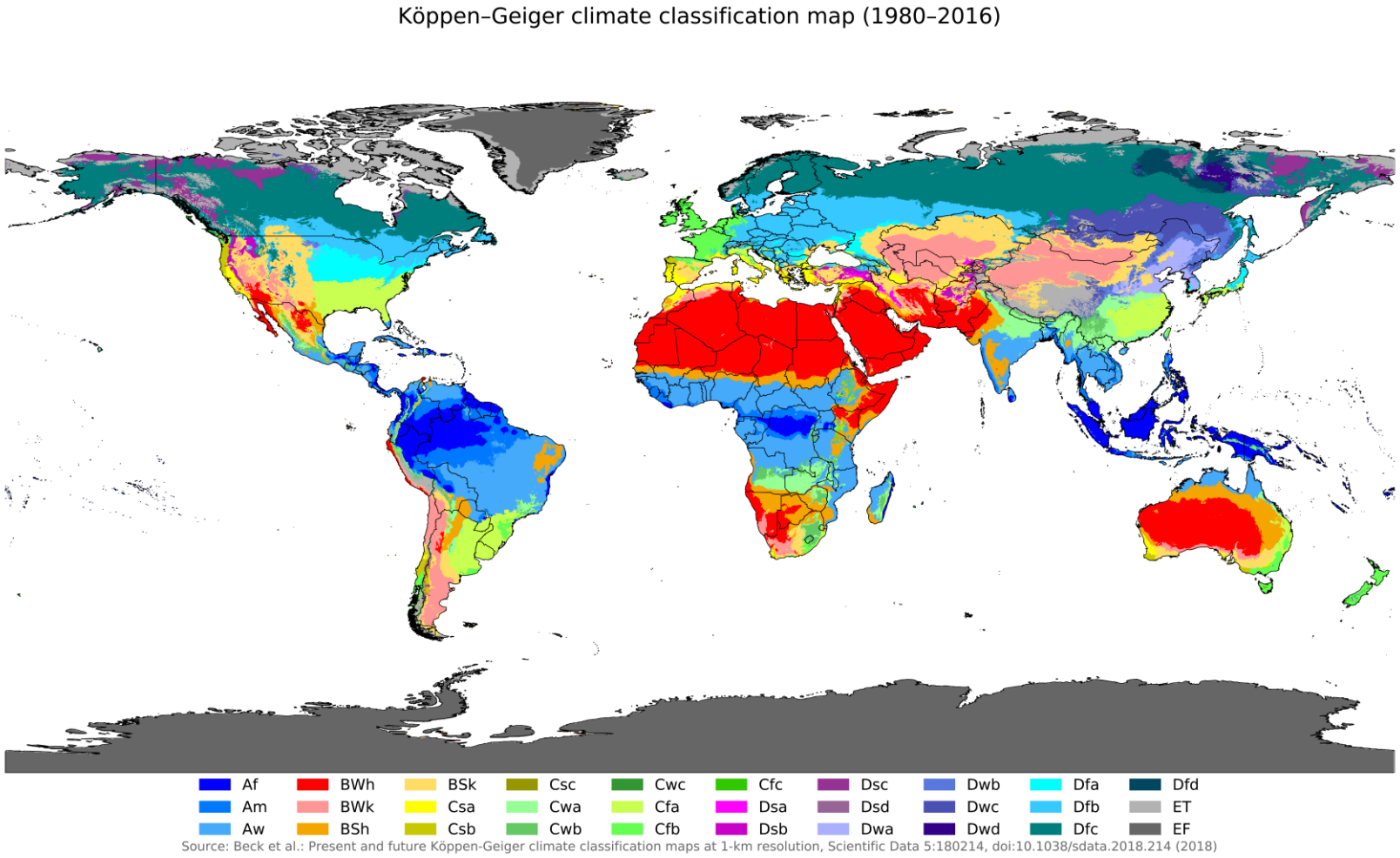
Ocean Literacy Principle #3: The ocean is a major influence on weather and climate

Weather…the current atmospheric conditions at a given time and place

Climate…the average weather conditions of an area taken over more than 30 years

…**influenced by the ocean no matter where we live** as depending on **height above sea level** and **proximity to the ocean,** apart from the amount of sunlight received and topography.

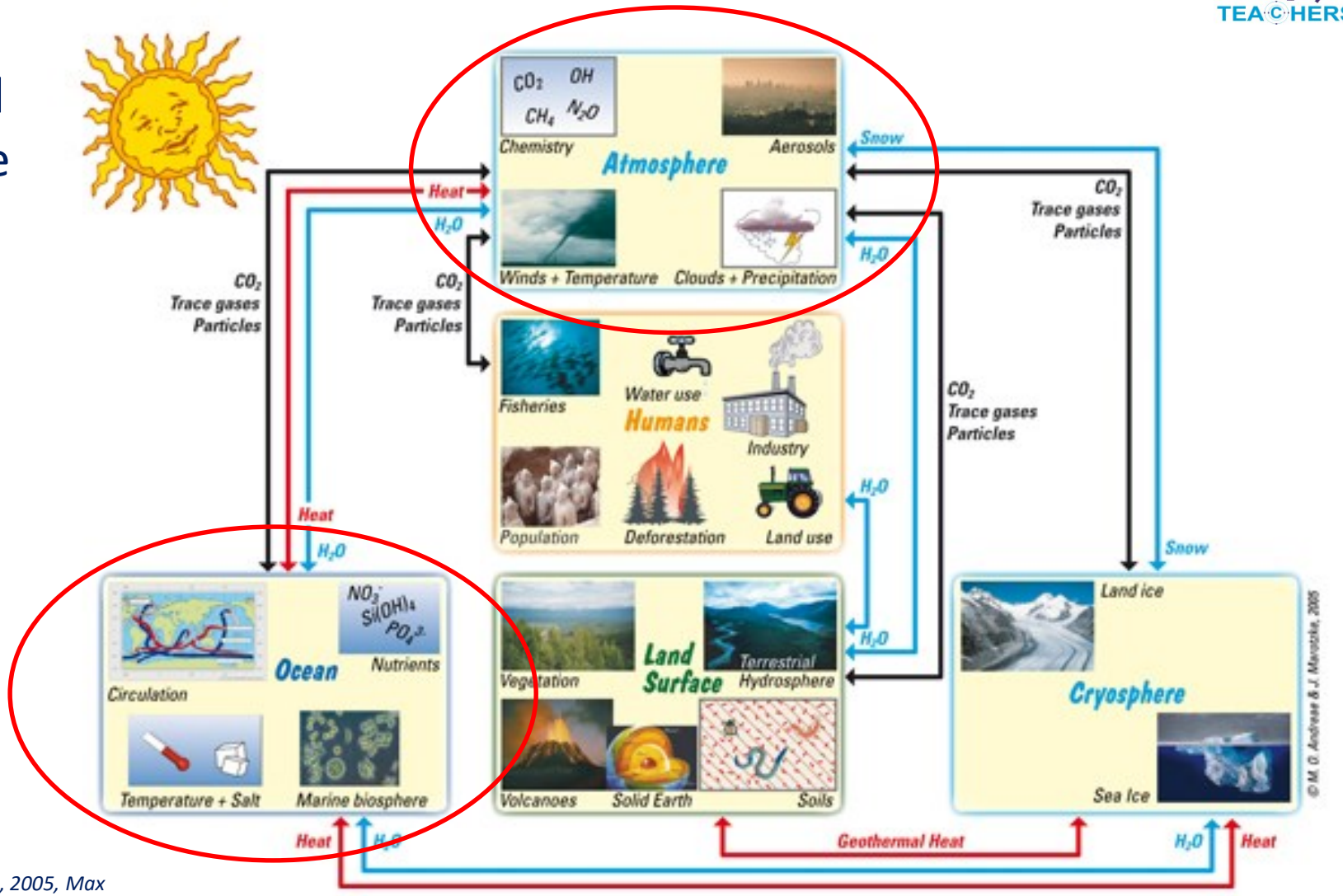


"The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth's energy, water and carbon systems."

Earth's climate is influenced by interactions involving the Sun, ocean, atmosphere, clouds, ice, land, and life.

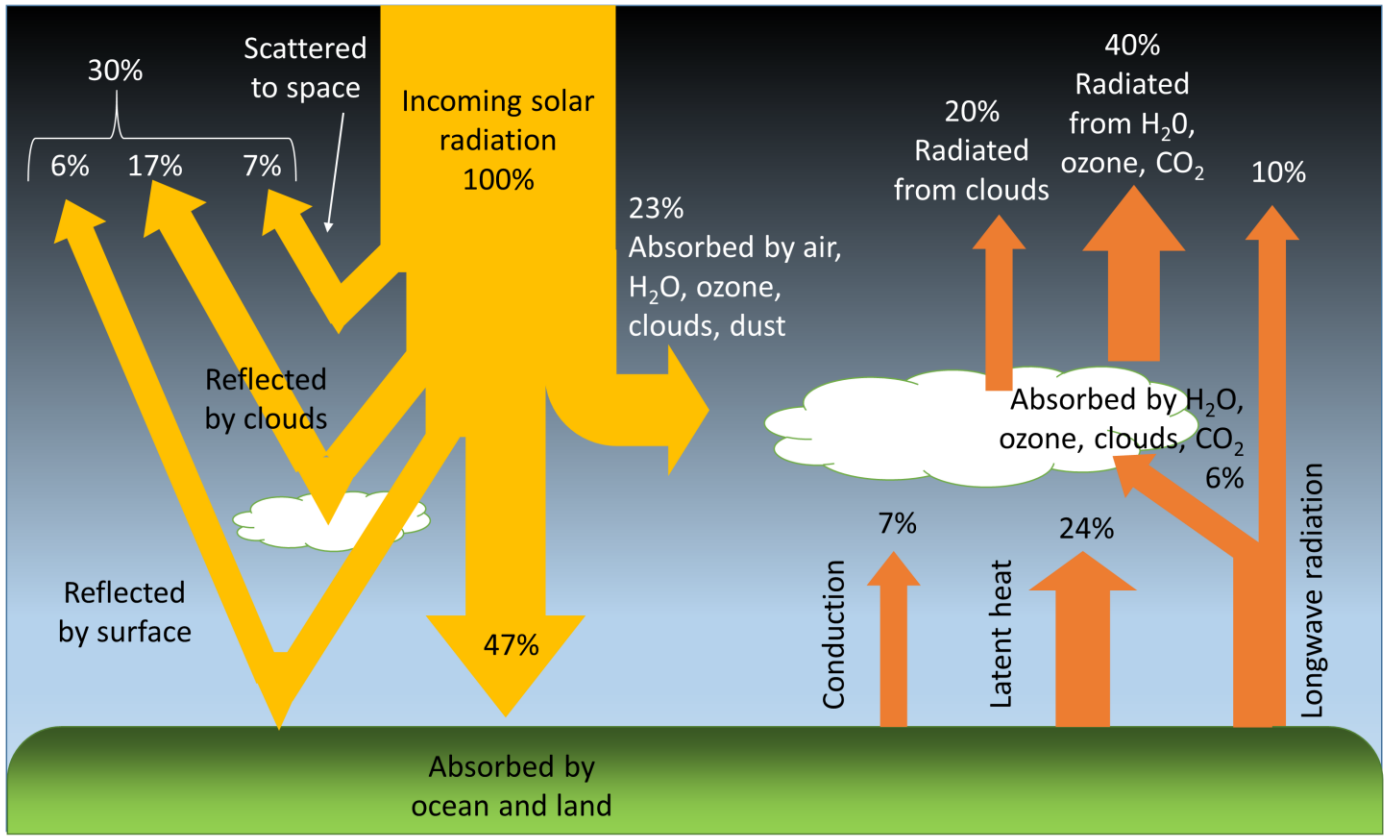
Climate varies by region as a result of local differences in these interactions.

The ocean covers over 70% of Earth's surface.



Earth System Science diagram courtesy of M.O. Andreae und J. Marotzke, 2005, Max Planck Institute (https://beyondweather.ehe.osu.edu/issue/understanding-earths-climate/climate-a-complex-interaction#ConceptA)

"The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth."



Earth's heat budget. Of the solar radiation reaching Earth, 30% is reflected back to space and 70% is absorbed by the Earth (47%) and atmosphere (23%). The heat absorbed by the land and ocean is exchanged with the atmosphere through conduction, radiation, and latent heat. The heat absorbed by the atmosphere is eventually radiated back into space.

The ocean absorbs most of the solar radiation reaching Earth.

The ocean has the **capacity to absorb large amounts of solar energy** -more than 1000 times that in the atmosphere for an equivalent increase in temperature.

Over 90% of the extra heat trapped to the Earth by humanity's carbon emissions has been stored in the ocean.

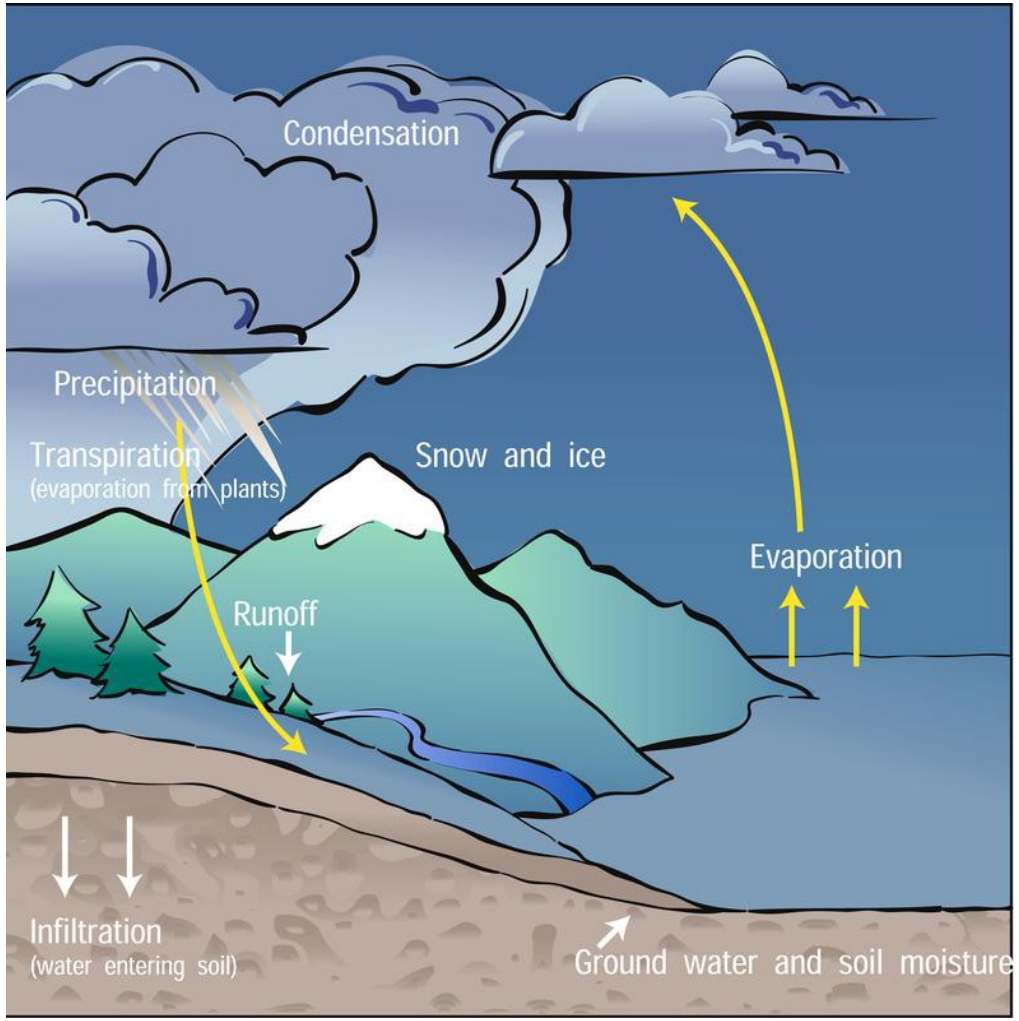
*"Heat exchange between the ocean and atmosphere drives the **water cycle** and oceanic and atmospheric circulation."*

The ocean holds ~ 97% of the Earth's water; the remaining is part of glaciers and ice, below the ground, in rivers and lakes, and in the atmosphere.

Solar energy warms water in the ocean causing evaporation. Most water in the air comes from the ocean.

Water in the air eventually cools, condenses into clouds, and returns to the ocean or the land as precipitation. **In fact, almost all rain that falls on land starts off in the ocean.**

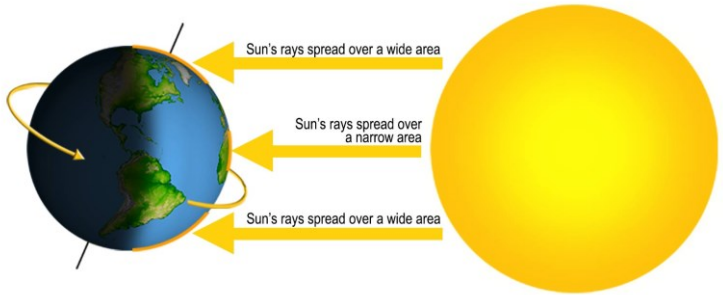
Most of the water on land returns to the ocean through river runoff.



The water cycle, Copyright: University Corporation for Atmospheric Research

*"Heat exchange between the ocean and atmosphere drives the water cycle and **oceanic** and **atmospheric circulation**."*

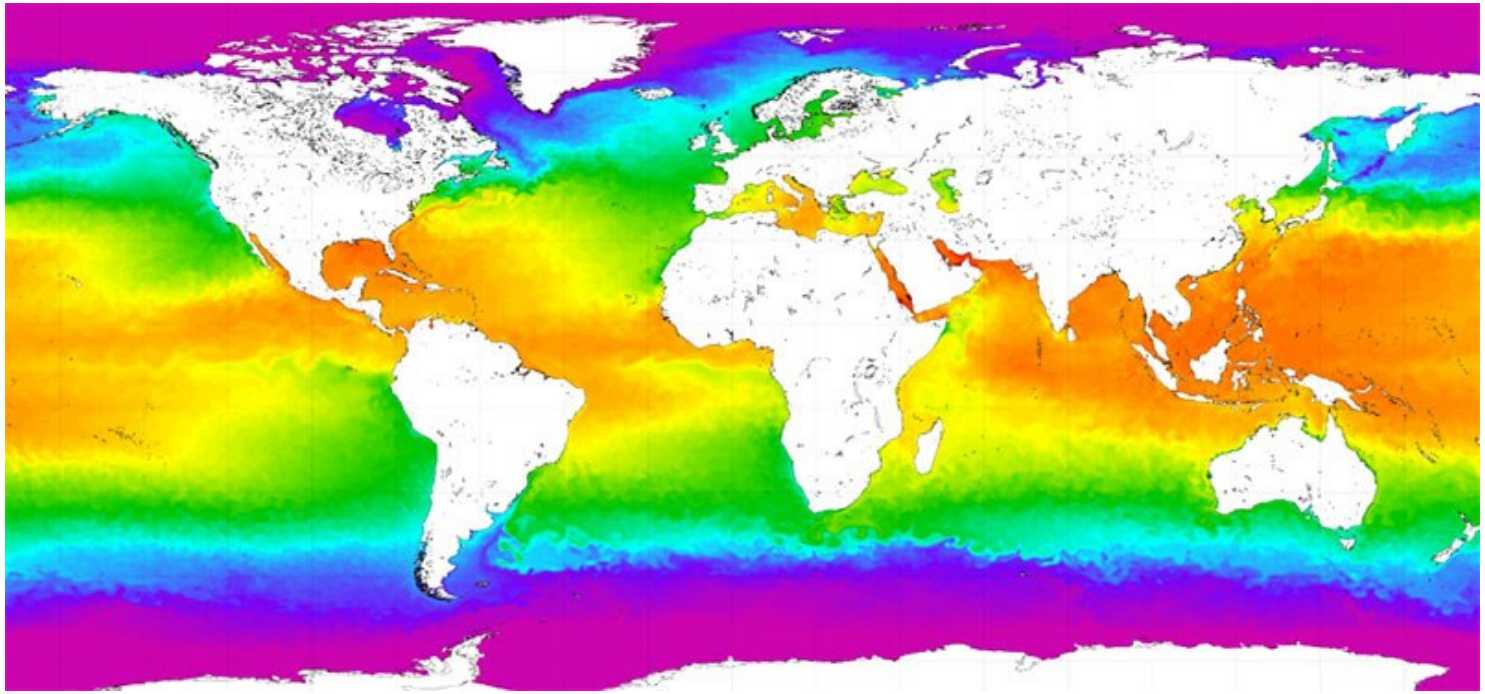
Differential heating of Earth's surface results in circulation patterns in the atmosphere and **ocean that globally distribute the heat.**



Credit: Laura Guerin Source: CK-12 Foundation License: CC BY-NC3.0 https://flexbooks.ck12.org/cbook/ck-12-middle-school-earth-science-flexbook-2.0/section/10.13/primary/lesson/solar-energy-and-latitude-ms-es/

In **tropical areas** the heat transferred from the ocean to the atmosphere provides the energy that fuels **atmospheric circulation** and weather, including **hurricanes, and cyclones**.

Outside of Earth's equatorial areas, weather patterns are driven largely by **ocean currents**.

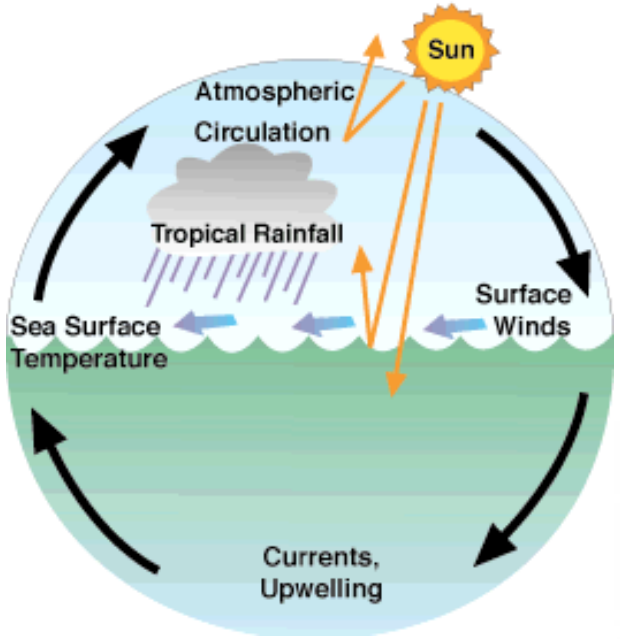


This map of sea surface temperature illustrates how heat is distributed across the global ocean https://oceanexplorer.noaa.gov/facts/climate.html#:~:text=The%20ocean%20influences%20weather%20and,distributed%20across%20the%20global%20ocean

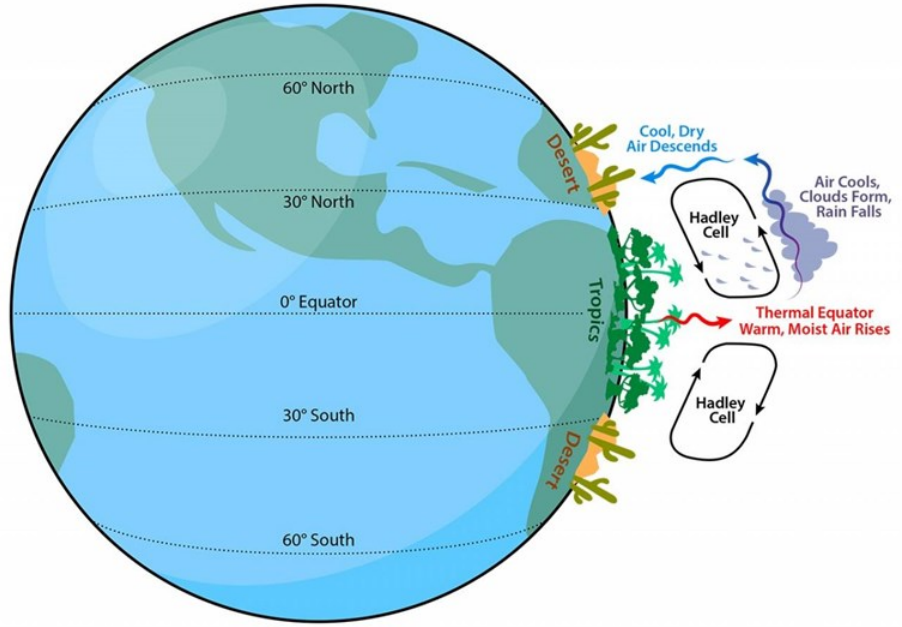
"Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones."

Thermal energy and evaporation from the ocean creates winds and most rain clouds, influencing the location of wet and dry zones on land.

The next time you feel a raindrop, consider this: ***Most of the rain that falls on land, and feeds streams and rivers, originally evaporated from the tropical ocean.***



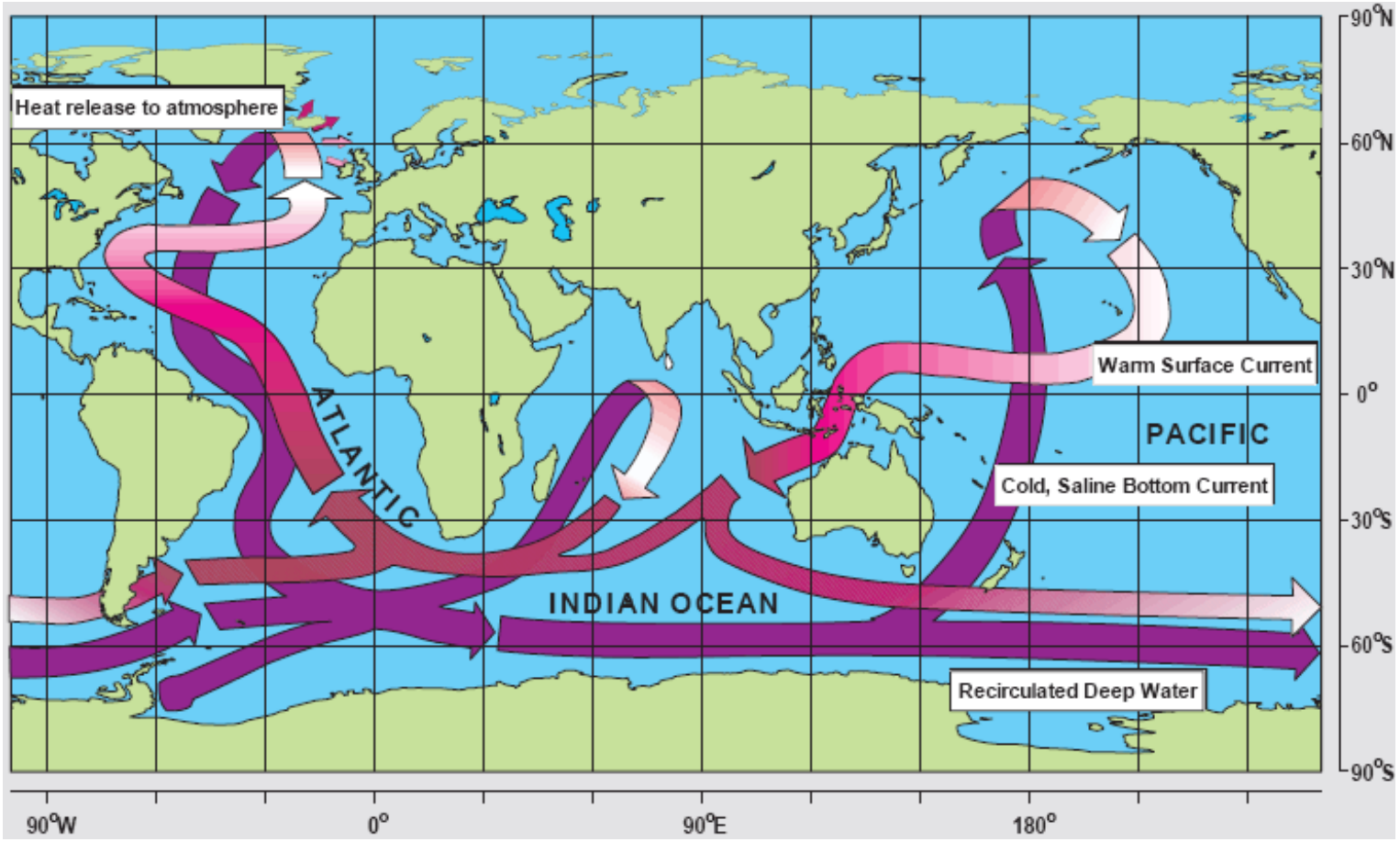
Courtesy: National Science Foundation (https://beyondweather.ehe.osu.edu/issue/understanding-earths-climate/climate-a-complex-interaction#ConceptA)



https://northmeteo.gr/geniki-kykloforia-tis-atmosfairas-meros-3/

*"Heat exchange between the ocean and atmosphere drives the water cycle and **oceanic** and atmospheric **circulation.**"*

Ocean currents transport warm water and precipitation from the equator toward the poles and cold water from the poles back to the tropics.



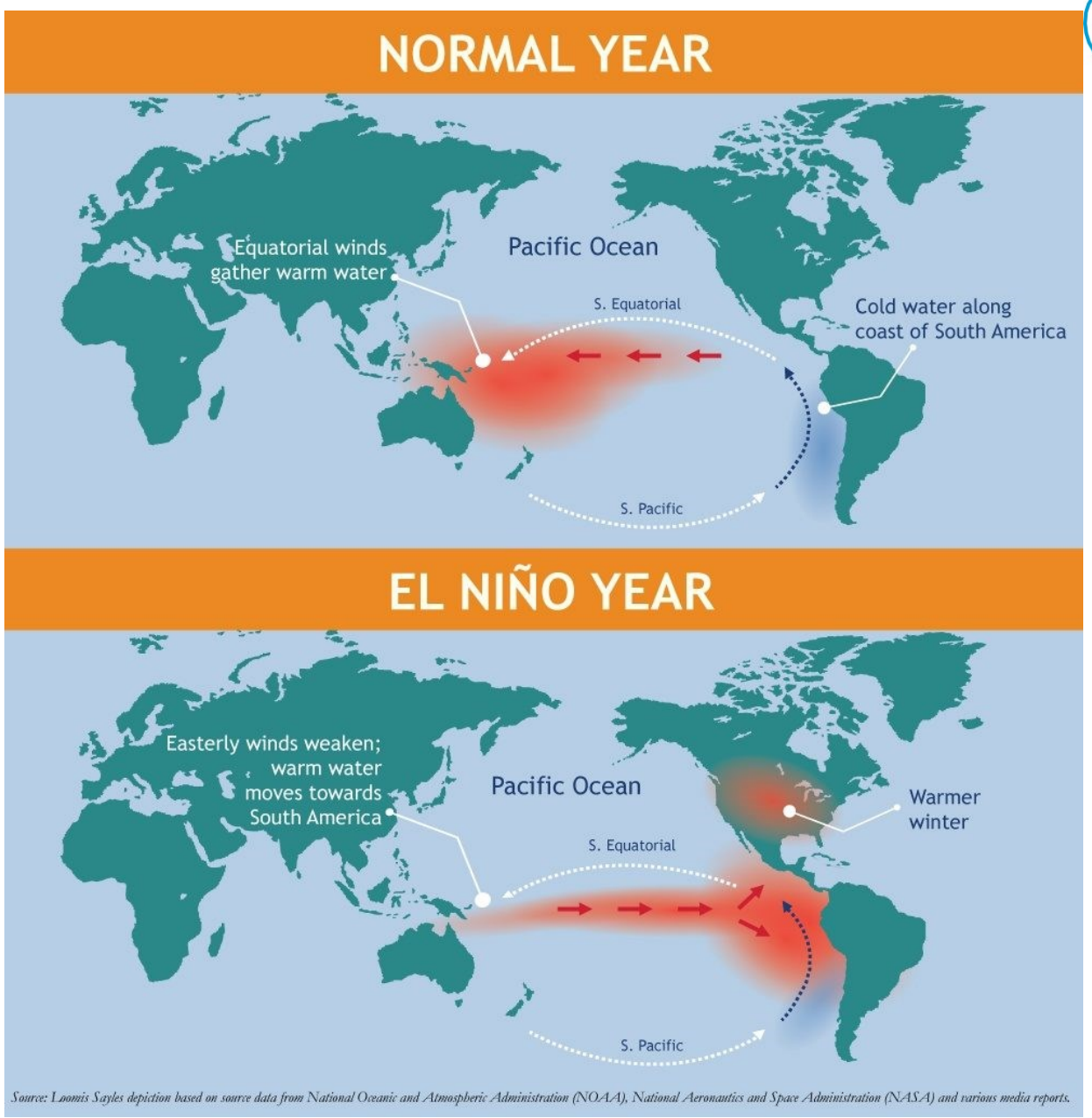
https://scied.ucar.edu/image/map-ocean-circulation

Thus, **ocean currents regulate global climate, helping to counteract the uneven distribution of solar radiation reaching Earth's surface.**

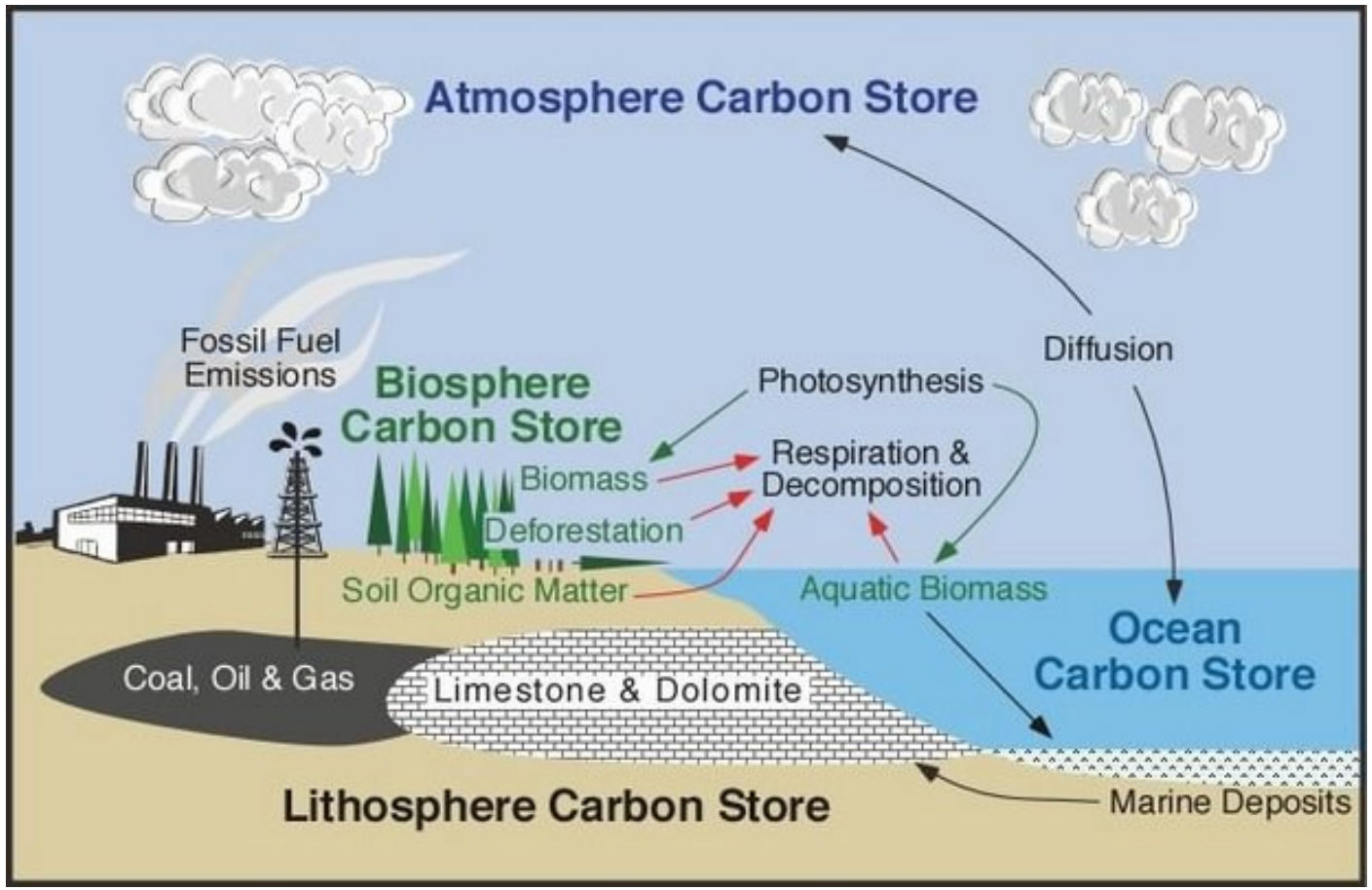
Without currents in the ocean, regional temperatures would be more extreme — super hot at the equator and frigid toward the poles — **and much less of Earth's land would be habitable.**

"Heat exchange between the ocean and atmosphere can result in dramatic global and regional water phenomena, ***impacting patterns of rain and drought****. Significant examples include the* ***El Niño Southern Oscillation and La Niña,*** *which cause important changes in global weather patterns because* ***they alter the sea surface temperature patterns in the Pacific****."*

More frequent and/or intense events (e.g. El Niño) can have economic impacts on a global scale such as collapse of fisheries resources and reduced agricultural production.



"The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere."

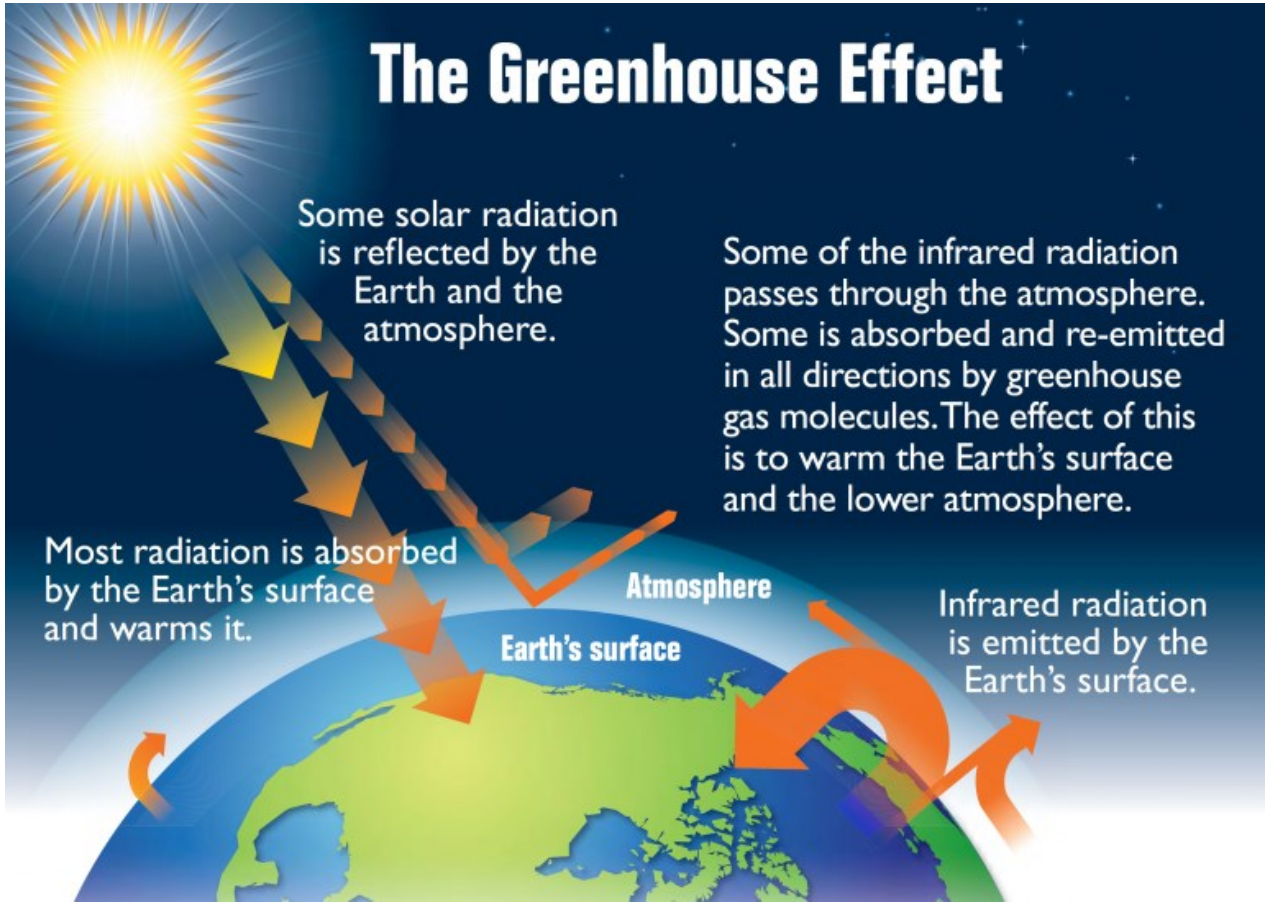


The Carbon Cycle. Image courtesy of PhysicalGeography.net. https://www.geomon.co.uk/carbon-storage-in-ecosystems/

The ocean could be considered the largest carbon sink on earth, as it stores carbon (physical and biological carbon pump) mediating the global greenhouse effect.

Over 90% of the extra heat trapped to the Earth by humanity's carbon emissions has been stored in the ocean, thus mitigating the increase in temperature of the atmosphere BUT causing a slight warming of the ocean.

"Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences."



Earth's climate has constantly been changing — even long before humans came into the picture. However, Earth's average temperature has been increasing much more quickly than scientists would expect over the past 150 years.

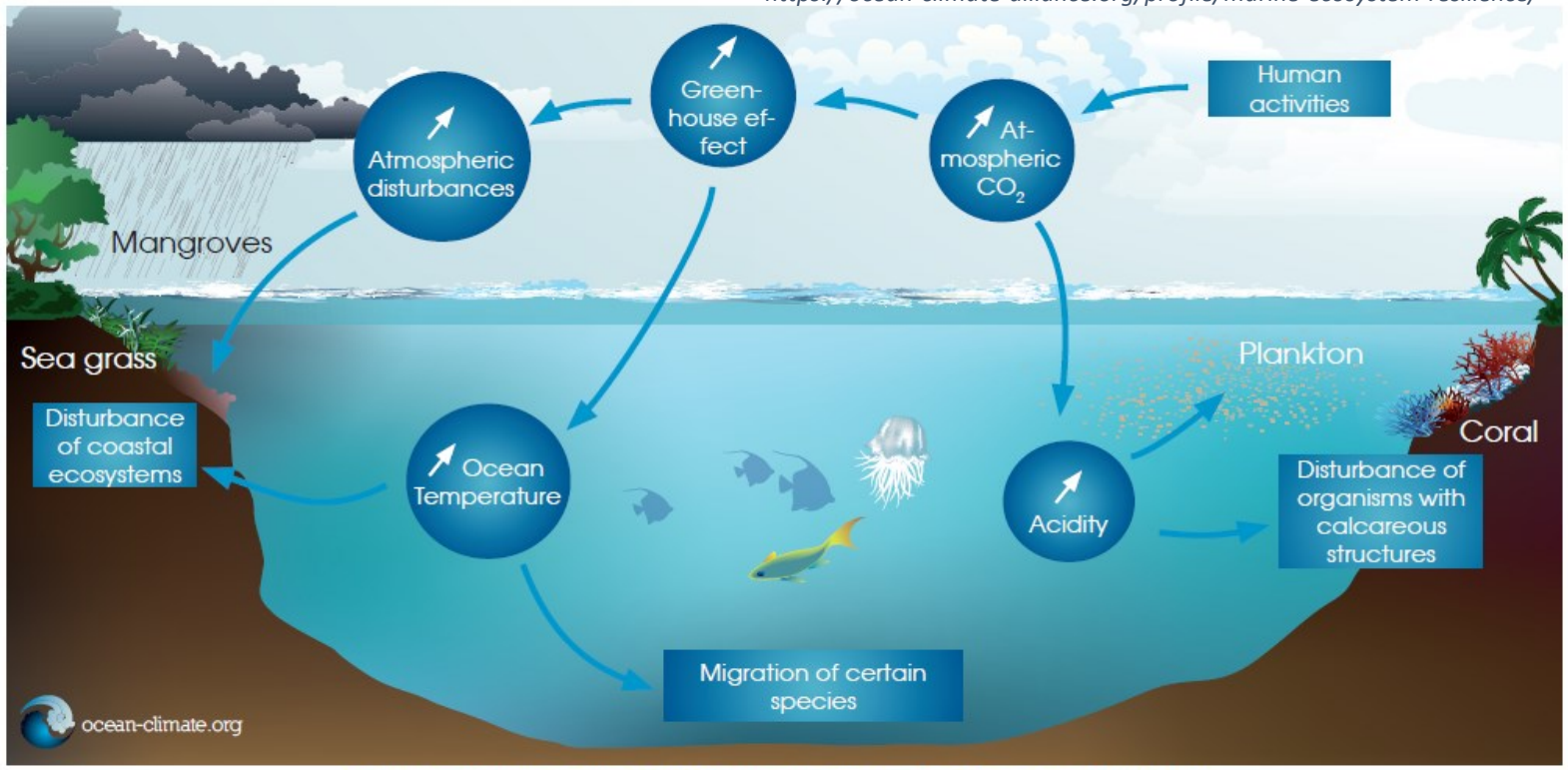
Over the past century, greenhouse gases and other air pollutants released into the atmosphere have been causing big changes like **global warming, ozone holes, and acid rain.**

"Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences."

Global climate change refers to the average long-term changes over the entire Earth including warming temperatures and precipitation, as well as the effects of Earth's warming, such as:

- Direct impacts on abundance, diversity, distribution, feeding, development, breeding, behaviour of marine species
- Ocean acidification (e.g. corals, mollusks, phytoplankton)

https://ocean-climate-alliance.org/profile/marine-ecosystem-resilience/

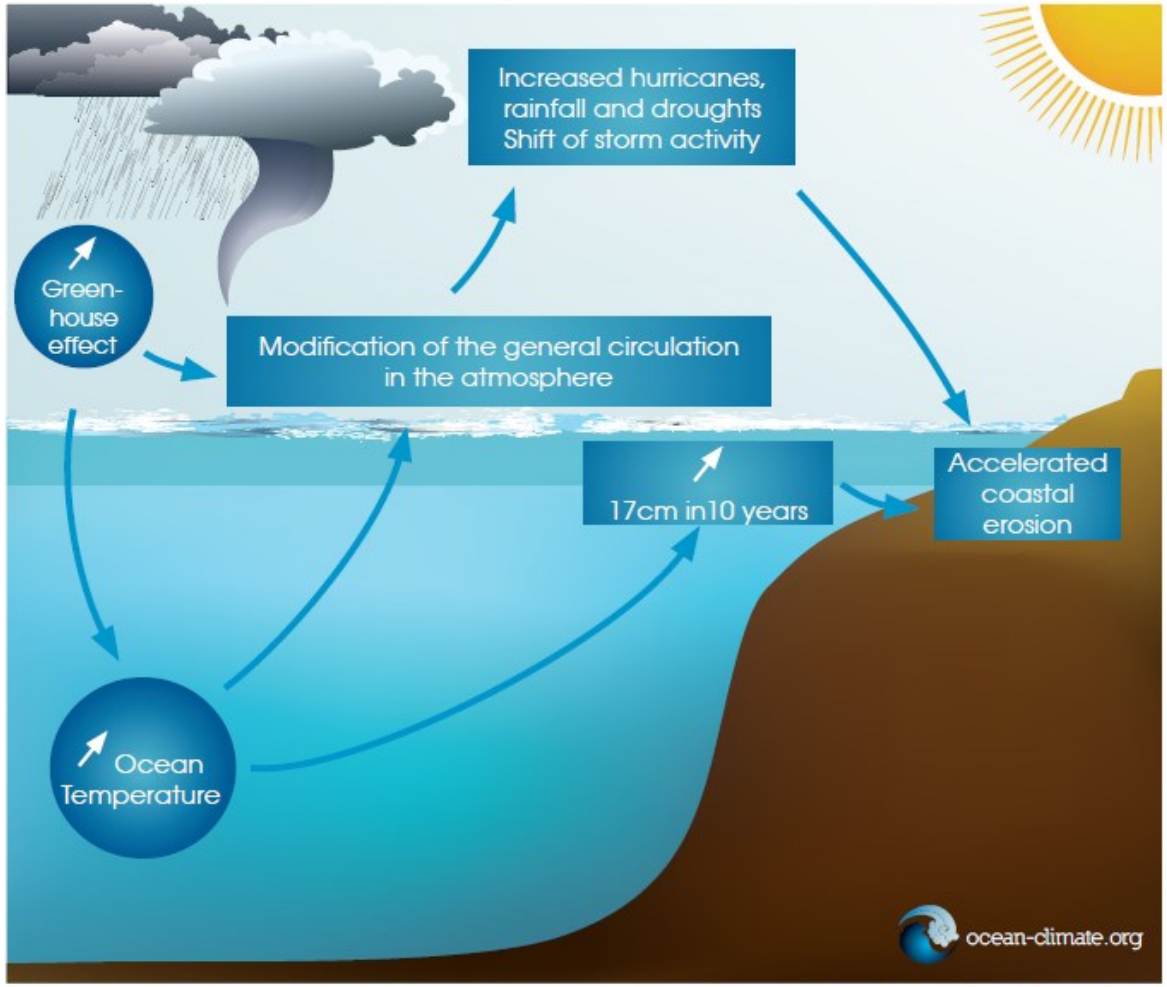


Consequences of CO_2 increase on the ecosystems

"The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years."

https://ocean-climate-alliance.org/profile/coasts-coastal-populations-climatic-resilience/coasts/

- Shrinking mountain glaciers
- Ice melting at a faster rate than usual in Greenland, Antarctica and the Arctic
- Rising sea levels due to excess heat stored
- More intense and frequent hurricanes, rainfalls and droughts
- Coastal erosion and flooding affecting coastal zone and habitats

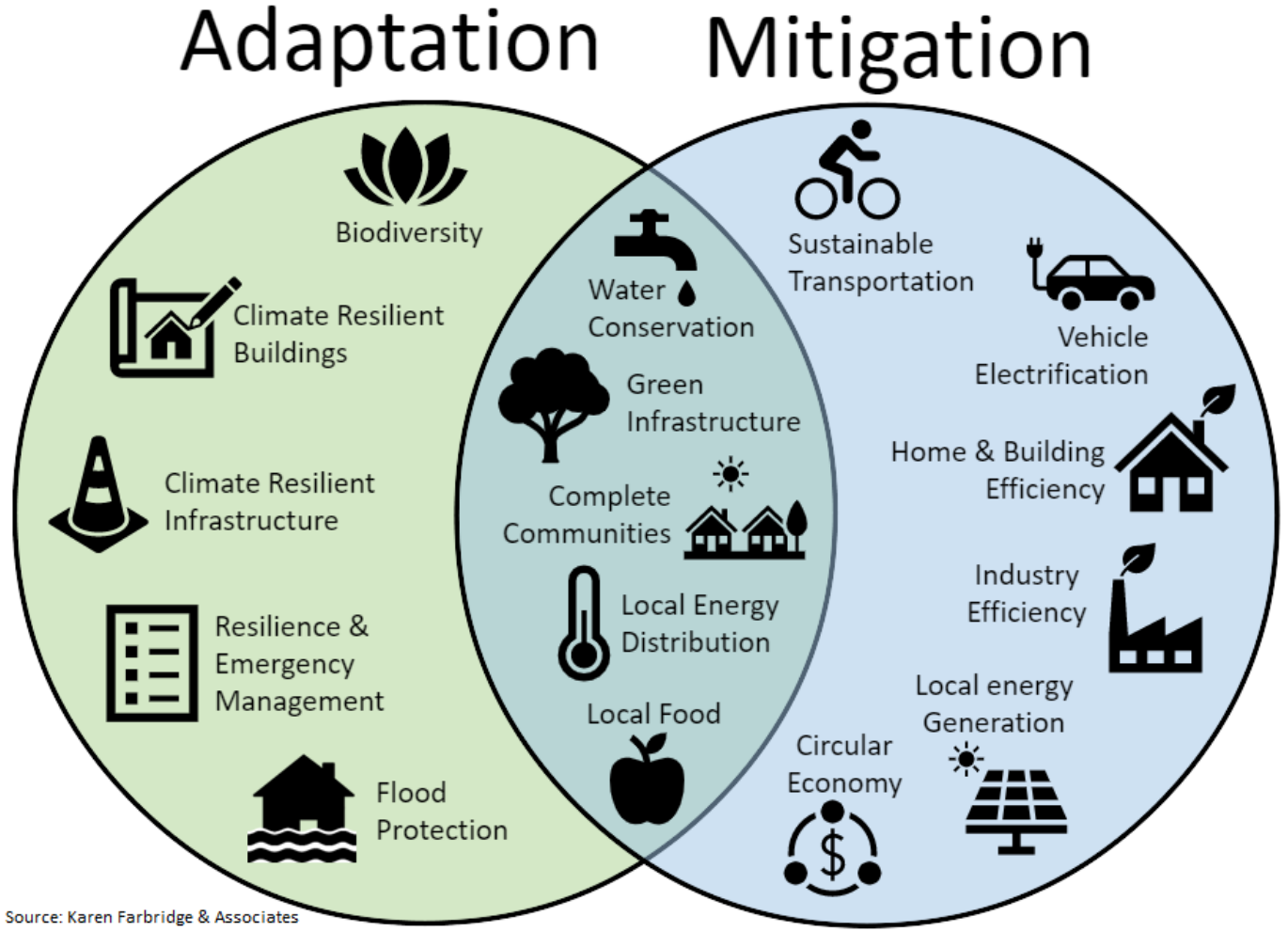


Physical consequences of the increase of atmospheric CO_2

"The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years."

Climate change impacts our society by disrupting the natural, economic and social systems we depend on. This disruption will:

- affect food supplies, industry supply chains and financial markets,
- damage infrastructure and cities, and
- harm human health and global development



https://nccan.ca/focus-areas/

Alignment of Scope & Sequence to Fundamental Concepts

This chart indicates how the Scope and Sequence aligns with Ocean Literacy Principle 3. The grade band runs across the top; the fundamental concepts for Principle 3 run down the left column. There are three levels of alignment.

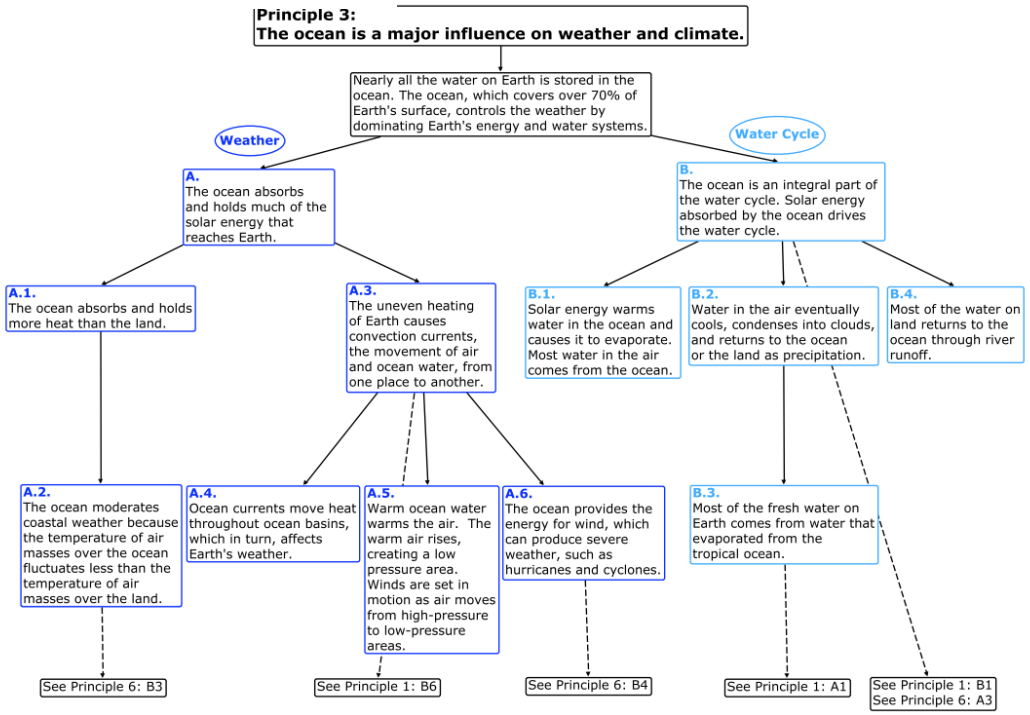
[blank]= no alignment; x = mentions concepts; XX = addresses concepts in depth

Fundamental Concepts	Principle 3: The ocean is a major influence on weather and climate.			
	K-2	3-5	6-8	9-12
3a	x	**XX**	**XX**	**XX**
3b	**XX**	**XX**	**XX**	
3c			**XX**	**XX**
3d	x	x	x	x
3e			**XX**	**XX**
3f			**XX**	**XX**
3g			x	**XX**

https://oceanliteracy.wp2.coexploration.org/ocean-literacy-framework/principle-3-v2/#p1_alignss

The Scope and Sequence conceptual flow diagrams and charts

GRADES 3 THROUGH 5



https://www.marine-ed.org/ocean-literacy/scope-and-sequence

Topics and Subtopics of Principle 3.
The charts list the major topics and subtopics in the conceptual flow diagrams of the Scope and Sequence.

Grade Band	Weather and Climate	Water Cycle	Global Climate Change	Consequences of Global Climate Change
K-2		a. Condensation b. Evaporation c. Precipitation d. Runoff e. Watersheds		
9-12	a. Atmospheric convection b. Differential heating c. El Niño and La Niña d. Energy absorption e. Energy transfer f. Evaporation g. Heat capacity h. Ocean currents move heat i. Precipitation j. Weather and climate patterns k. Wind energy		a. Atmospheric warming b. Carbon cycle c. Carbon dioxide balance d. Greenhouse gases e. Greenhouse effect f. Human effects g. Ocean absorption of CO2 h. Ocean circulation pattern i. pH j. Photosynthesis	a. Change in ocean circulation b. Change in ocean temperature c. Decreased solar reflection d. El Niño and La Niña e. Frequency and intensity of weather events f. Melting of glaciers and ice caps g. Ocean acidification h. Rising sea level

https://oceanliteracy.wp2.coexploration.org/?page_id=1641#ep3topics

The Scope and Sequence conceptual table

Principle 3

GRADES 6 THROUGH 8

Principle 3: The ocean is a major influence on weather and climate.

The interaction of oceanic and atmospheric processes controls weather and climate by dominating Earth's energy system.

Weather and Climate — A

The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth.

A1

Heat exchange between the ocean and the atmosphere drives the water cycle, and oceanic and atmospheric circulation.

Water Cycle — A2

The ocean dominates the water cycle.

A3

Ocean currents move heat throughout the ocean basins.

A4

The ocean loses heat through evaporation. The lost heat is released back to the atmosphere when the evaporated water vapor condenses and forms rain. The released heat drives atmospheric circulation.

A5

Most rain that falls on land evaporated from the tropical ocean.

A6

The weather along coastlines is generally more moderate than inland regions because the ocean absorbs and retains heat more effectively than the land.

A7

The heat transferred from the tropical ocean provides the energy that drives atmospheric circulation and weather, including hurricanes, cyclones, and polar storms.

A8

Increases in sea surface temperature increases atmospheric convection, changing patterns of rainfall and drought. The most important of these changes is called El Niño.

A9

El Niño Southern Oscillation (ENSO) is important because it changes where the rain falls in the tropics, which changes atmospheric circulation.

A10

Short-term and seasonal changes in ocean temperature can affect rainfall and temperatures on land (i.e., weather). Long-term changes in ocean temperature can affect the climate.

A11

Land and ocean weather maps are used to display and identify weather patterns and to help predict future patterns

A12

Longterm weather and oceanographic data sets contribute to climate predictions.

Global Climate Change — B

Changes in the ocean/atmosphere system can result in changes to the climate.

B1

The global climate is influenced by the amount of carbon dioxide in the atmosphere. The more carbon dioxide in the atmosphere, the more the climate warms.

B2

The ocean absorbs about 50% of all carbon dioxide added to the atmosphere.

B3

Some of the carbon dioxide absorbed by the ocean is used by phytoplankton and other photosynthetic organisms in the process of photosynthesis. About half of the world's photosynthesis (primary production) occurs in the sunlit layers of the ocean.

B4

Absorbing carbon dioxide can decrease the ocean's pH, making the water more acidic. This can have consequences for many organisms in the ocean.

B5

There have been large abrupt changes in Earth's climate over geologic time.

B6

Humans are changing the climate by continuing to release large amounts of carbon dioxide and methane into the atmosphere.

https://www.marine-ed.org/ocean-literacy/scope-and-sequence

WHY DOES CLIMATE SCIENCE LITERACY MATTER?

https://www.climate.gov/teaching/what-is-climate-science-literacy#:~:text=People%20who%20are%20climate%20science,caused%20factors%20that%20affect%20it.

7 essential principles and
38 fundamental concepts

- During the 20th century, Earth's globally averaged surface temperature rose by approximately 0.6°C. Additional warming of more than 0.14°C has been measured since 2000. Though the total increase may seem small, it likely represents an extraordinarily rapid rate of change compared to changes in the previous 10,000 years.
- Over the 21st century, climate scientists expect Earth's temperature to continue increasing, very likely more than it did during the 20th century. Two anticipated results are rising global sea level and increasing frequency and intensity of heat waves, droughts, and floods. These changes will affect almost every aspect of human society, including economic prosperity, human and environmental health, and national security.
- Scientific observations and climate model results indicate that human activities are now the primary cause of most of the ongoing increase in Earth's globally averaged surface temperature.
- Climate change will bring economic and environmental challenges as well as opportunities, and citizens who have an understanding of climate science will be better prepared to respond to both.
- Society needs citizens who understand the climate system and know how to apply that knowledge in their careers and in their engagement as active members of their communities.
- Climate change will continue to be a significant element of public discourse. Understanding the essential principles of climate science will enable all people to assess news stories and contribute to their everyday conversations as informed citizens.

The OCEAN flows through all 17 UN Sustainable Development Goals (SDGs).

https://impact.economist.com/ocean/ocean-sustainable-development-goals

13 CLIMATE ACTION

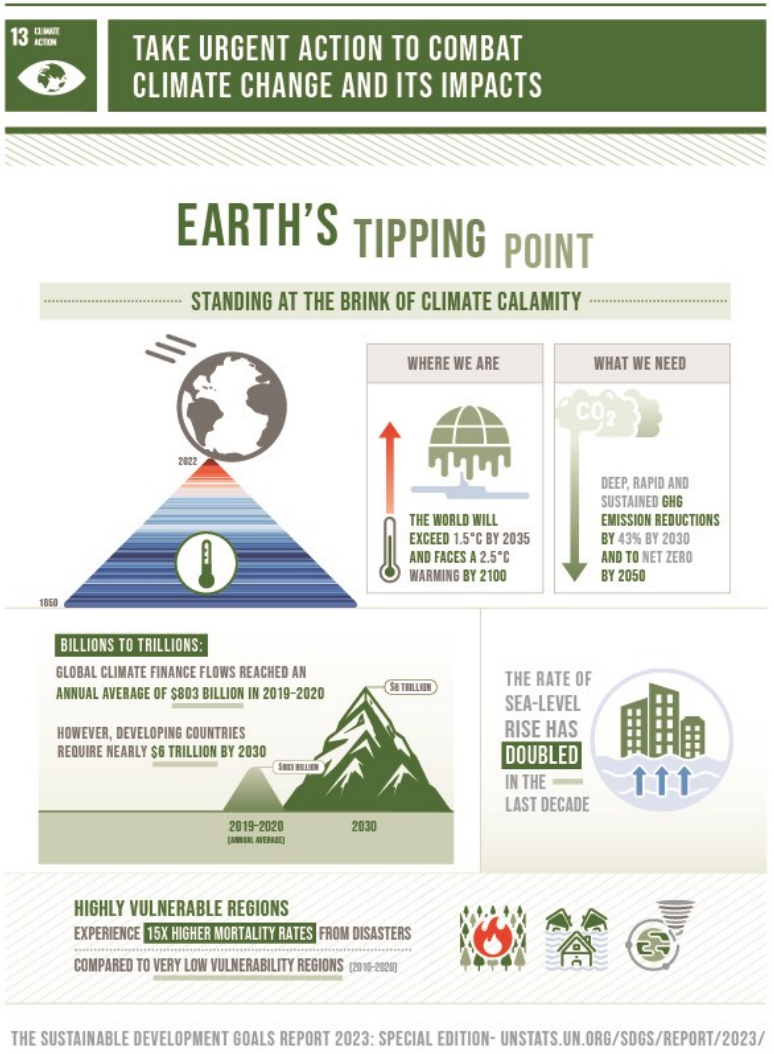
SDG 13

Climate Action

The ocean has absorbed more than 90% of the excess heat from human-caused global warming, and 83% of the global carbon cycle is circulated through the ocean. Warming waters and melting glaciers lead to sea-level rise and ocean acidification, which disrupt and destroy marine ecosystems and coastal communities, with small islands severely affected.

Blue carbon projects fight climate change and biodiversity loss while creating value: the carbon-sequestration value of a whale is approximately US$3m, and seagrass as an ecosystem provides carbon-capture services worth about US$2.3trn. Some seagrass meadows can sequester carbon 35 times faster than a tropical rainforest.

Sources: NOAA, IUCN, IMF



https://www.un.org/sustainabledevelopment/sdg-fast-facts/

EU MISSIONS

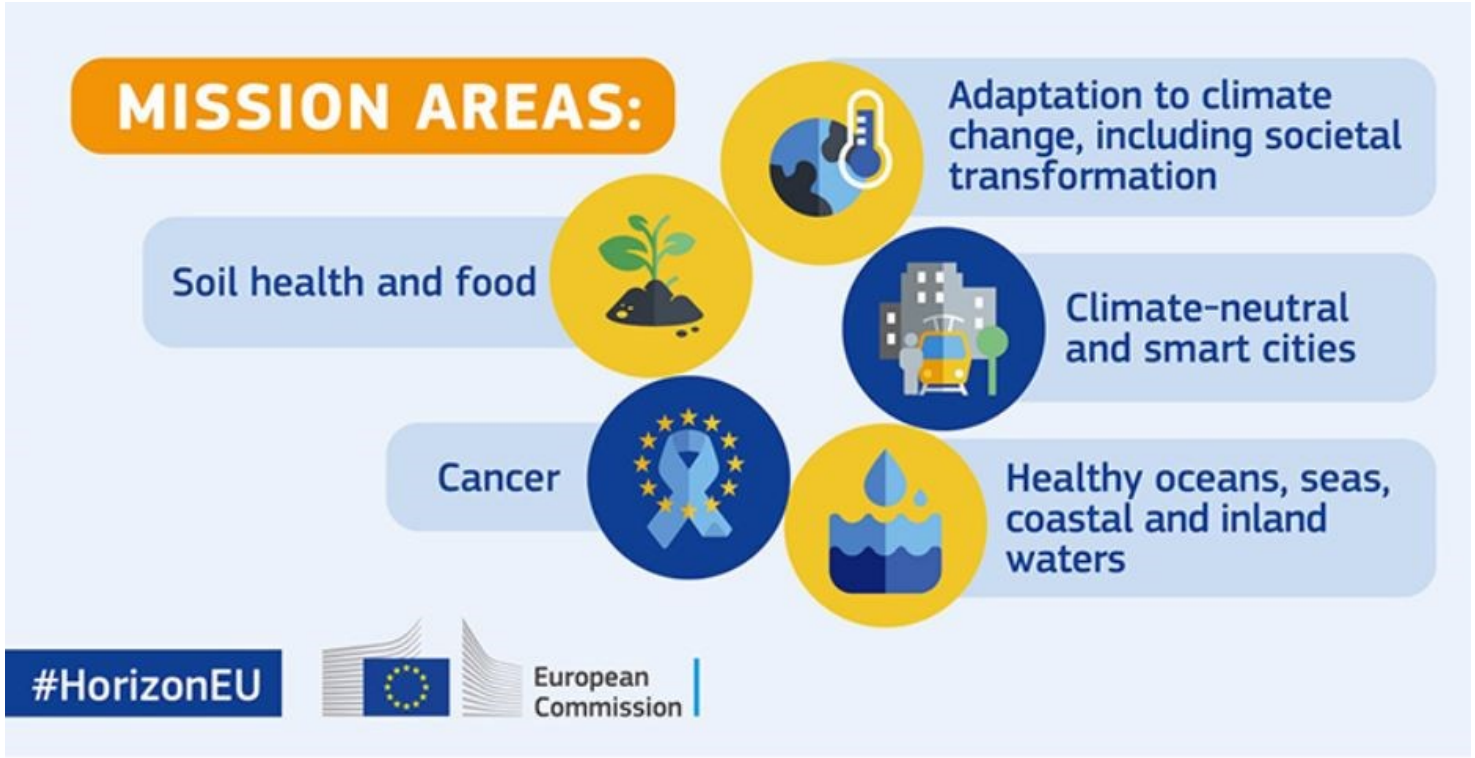
Challenge 5

Unlock ocean-based solutions to climate change

Enhance understanding of the ocean-climate nexus and generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change across all geographies and at all scales, and to improve services including predictions for the ocean, climate and weather.

Watch the video

https://www.youtube.com/watch?v=6xCNtci1KlE



https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en

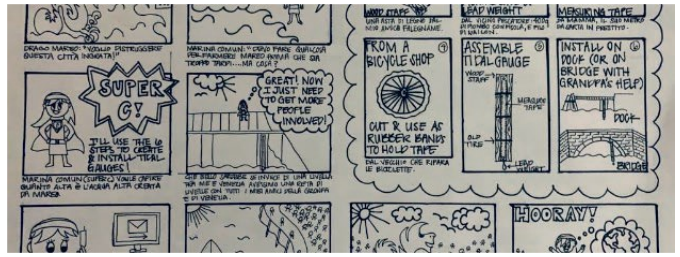
EU Blue Schools network-Inspiring projects (handbook)

A wave of European blue schools-Handbook for teachers
https://maritime-forum.ec.europa.eu/system/files/2021-02/handbook_eueopean_blue_schools_220221.pdf

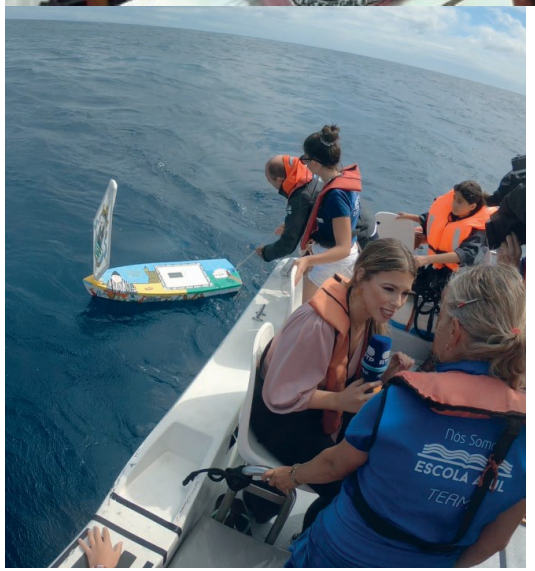
Climate and Ocean

- Ocean acidification
- Sea level rise
- Coastal erosion
- Storms / floods
- Carbon cycle
- Migrating species
- Ocean warming

The ocean in the carbon cycle
Ocean acidification and the carbon cycle in primary education · p 58



Discovering High Waters
Measuring the tides in the Venice lagoon · p 63



STEM4Sea: Can you build a dike with recycled materials to protect the coast from flooding? · p 59

Adopt a Float: Follow an underwater robot and work with the real-time ocean observation data during its voyage · p 62