Climate Change Adaptation in water management & Ecosystems

8 August 2023

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Ecosystems

- "Eco" = part of the world
- "System" = the coordinating units

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a community of living organisms (plants, animals and microbes) in a particular area

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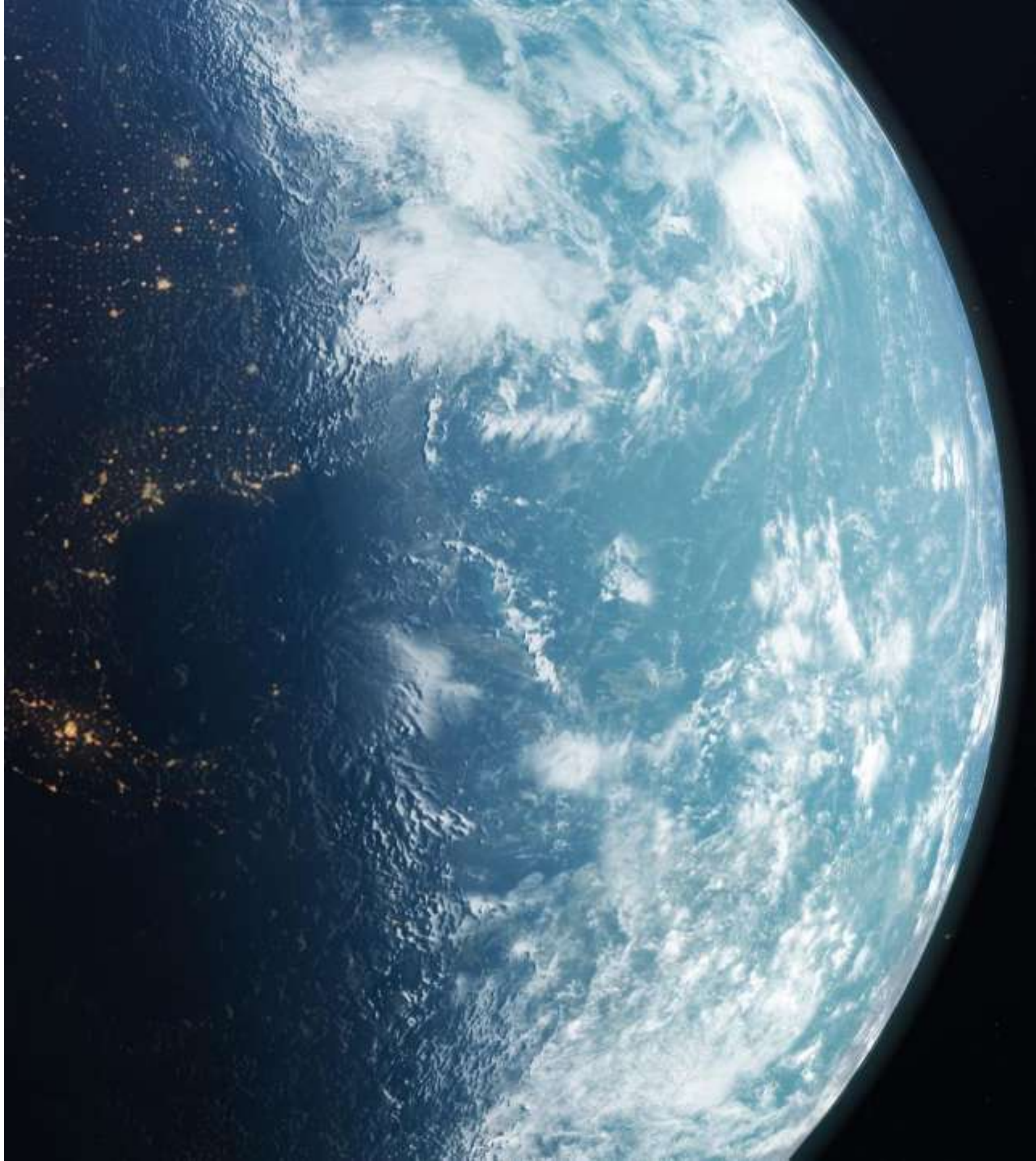
interacting with each other, and with their non-living environments (weather, earth, sun, soil, climate, atmosphere).

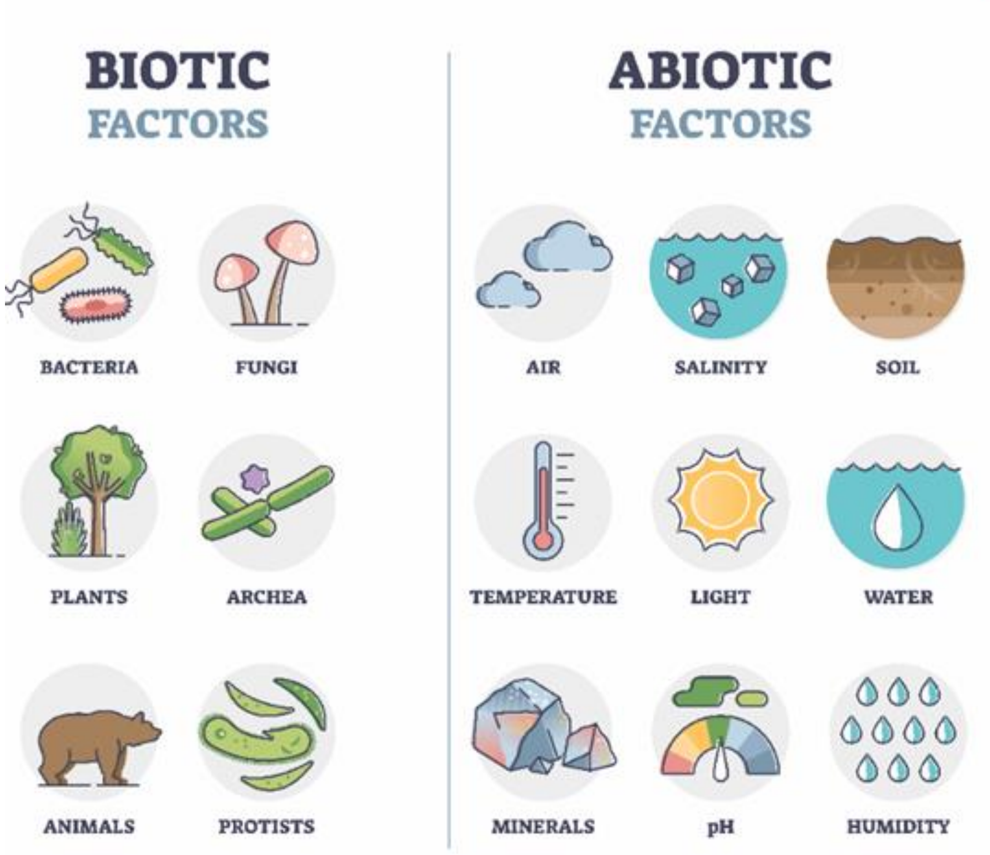
Note: every single organism has its own role to play



Structure of ecosystems

Biotic: all living components in an ecosystem

Abiotic: non-living component of an ecosystem



Types of ecosystems

Terrestrial:

- forest ecosystem
- grassland ecosystem
- tundra ecosystem
- desert ecosystem

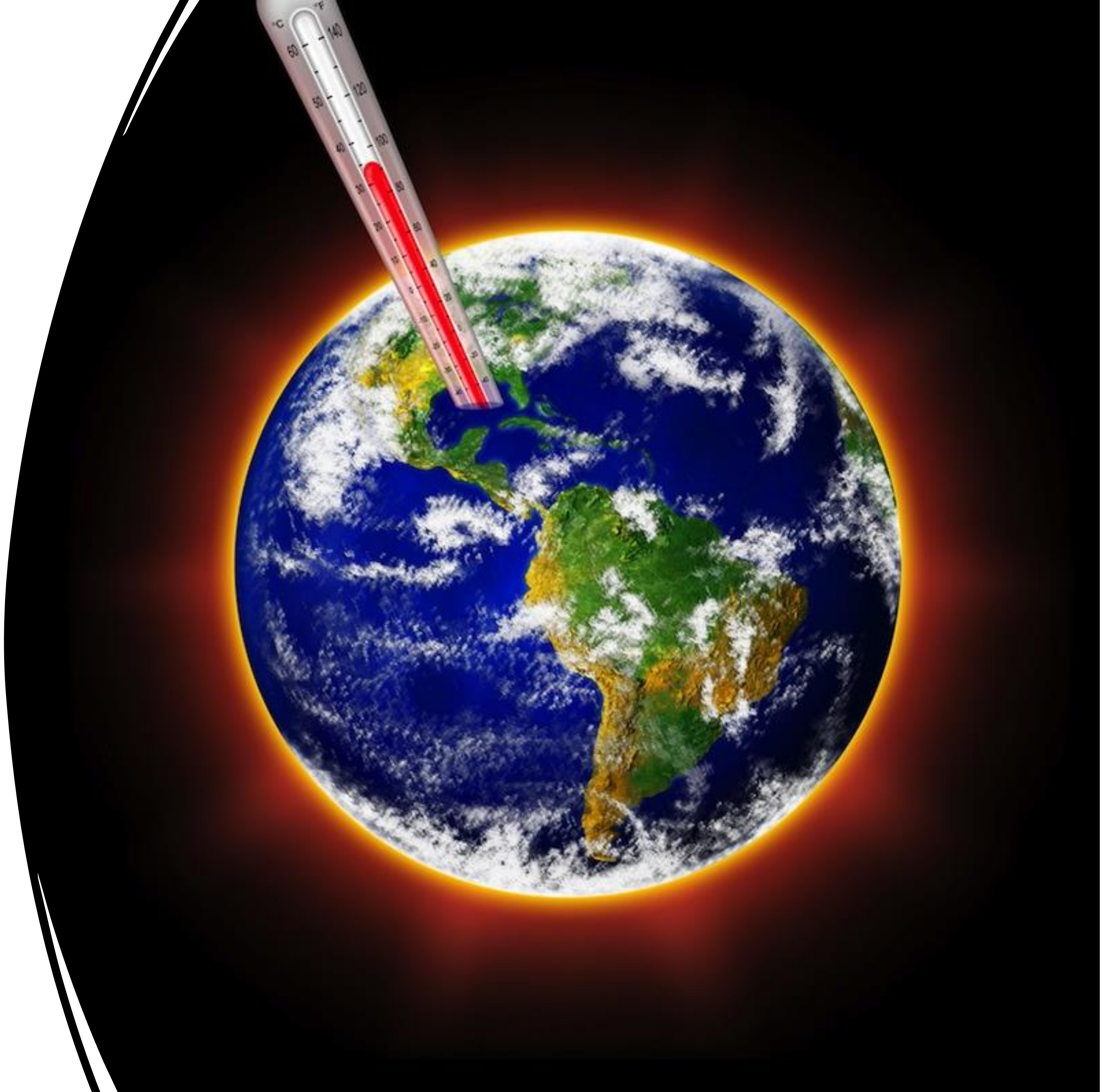
Aquatic:

- freshwater ecosystem: includes lakes, ponds, rivers, streams and wetlands
- marine ecosystem: includes seas and oceans

Impact klimaatverandering

Impact van klimaatverandering

- Temperatuurstijging



Impact van klimaatverandering

Zeespiegelstijging



Impact van Klimaatverandering

Main Greenhouse Gases

Greenhouse Gas	Chemical formula	Anthropogenic sources (examples)	Atmospheric Lifetime (years)	GWP (100 year time horizon)
Carbon Dioxide	CO_2	Fossil fuel combustion, deforestation, cement production	50-200	1
Methane	CH_4	fossil fuels, landfills, animal husbandry	12	21
Nitrous Oxide	N_2O	fertilizer, fossil fuel combustion	120	310
Fluorinated Gases	various	industrial processes	various	various

Global Warming Potential (GWP) is measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale which compares the gas to that of the same mass of carbon dioxide (whose GWP is by convention equal to 1).

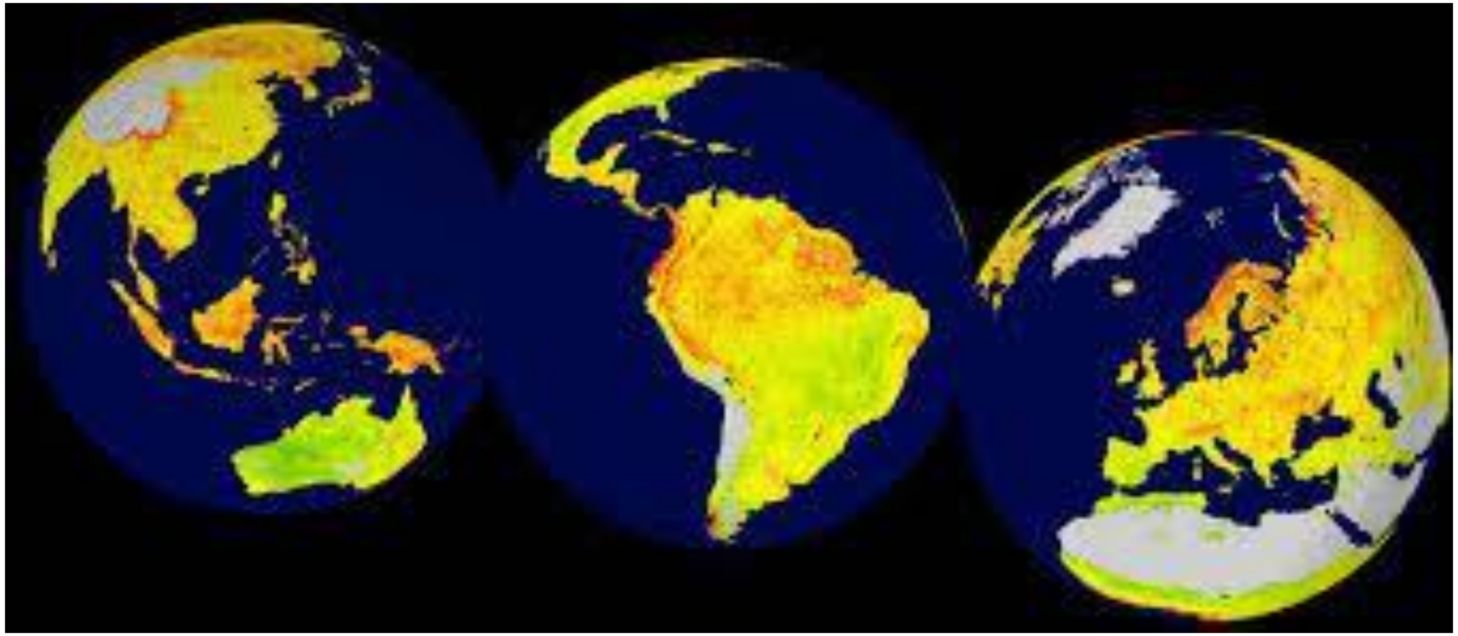
Protecting ecosystems to combat climate change

- Ecosystems, including humans, genuinely water-dependent → essential to properly clarify the linkages between water and ecosystems.
- Close collaboration between hydrologist and ecologist critical.

Ecosystems vs Climate Change

- Terrestrial and marine ecosystems play an important role in regulating climate.
- Peatlands, wetlands, soil, forests and oceans play a crucial role in absorbing and storing carbon → help to protect us from climate change.
- Currently these absorb about half of man-made carbon emissions.
- Biodiversity & ecosystem services → to adapt to and mitigate climate change → Protection and conservation needed to combat climate change.

Ecosystems Most Vulnerable to Climate Change



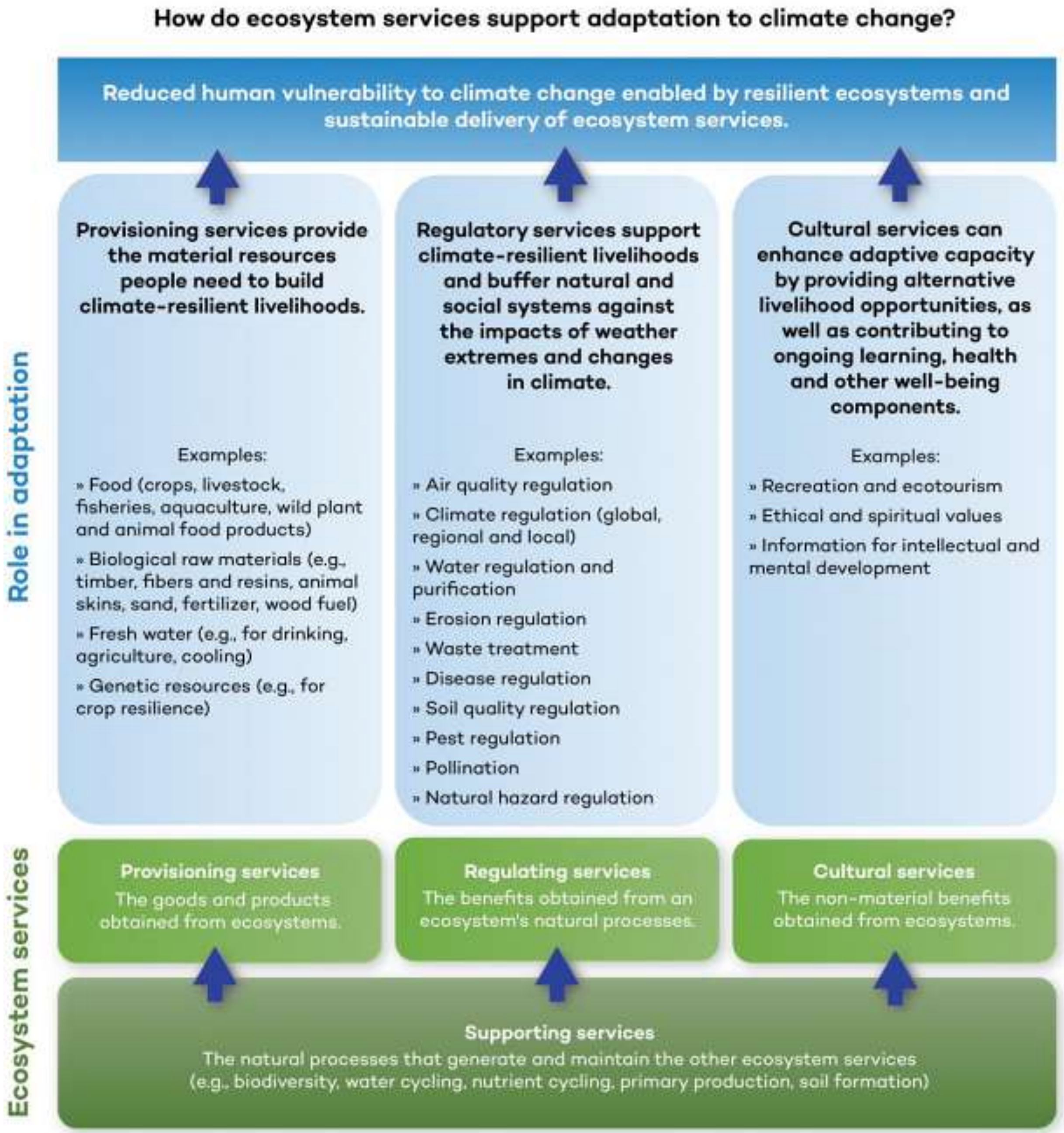
- The Arctic tundra, parts of Europe and Canada's boreal forest, tropical rainforests in South America, and eastern Australia

Ecosystem services

PROVISIONING SERVICES	REGULATING SERVICES	CULTURAL SERVICES
The "products" obtained from ecosystems	*Benefits obtained from the regulation of ecosystem processes*	*Nonmaterial benefits obtained from ecosystems*
Foods Fibers Ornamentals Medicines Biofuels Fresh water Genetic resources	Climate regulation Flood prevention Erosion control Pest control Pollination Seed dispersal Disease regulation	Educational Recreational Sense of place Spiritual Cognitive development Stress relief Gardening

SUPPORTING SERVICES
Services necessary for the production of all other ecosystem services
Biodiversity Nutrient recycling Primary productivity

Ecosystem services vs Adaptation



Better to work with nature, rather than against it !!

Enjoy the multiple benefits also for preserving our climate.

Ecosystem-based approaches for climate change adaptation and mitigation

- Ecosystem-based approach =

“the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way”

Ecosystem-based approaches for climate change adaptation and mitigation cont'd

1. **Ecosystem-based adaptation**: ecosystems and biodiversity are used to help people adapt to the impacts of climate change. Example: the protection of coastal ecosystems (mangroves, salt marshes, and barrier beaches) → natural protection from storms and flooding due to sea level rise. It also complement and can enhance the effectiveness of infrastructure such as sea walls and dikes.

Another example: improvement of the management of forests and wetlands for better groundwater storage and food security

2. **Ecosystem-based mitigation:** ecosystems and biodiversity are used to reduce greenhouse gas emissions.

Natural systems (forests, mangroves, peats, and wetlands) act as "carbon sinks" and reduced emissions can be achieved through interventions that maintain or enhance these ecosystems.

Benefits of Ecosystem-based approaches

- cost-effective,
- ready for use
- accessible to rural and poor communities which support in relieve poverty and support sustainable development strategies.

Ecosystem-based approaches for climate change adaptation and mitigation cont'd

- Coastal ecosystems like wetlands, mangroves, coral reefs, oyster reefs, and barrier beaches all provide natural shoreline protection from storms and flooding in addition to many other services.
  - Restoring natural shorelines with seagrass beds or mangroves → form a buffer against storm surges and create nurseries for fisheries.
  - Protection groundwater recharge zones, restoration of flood plains, secure water resources → entire communities can cope with drought.

Dilemma

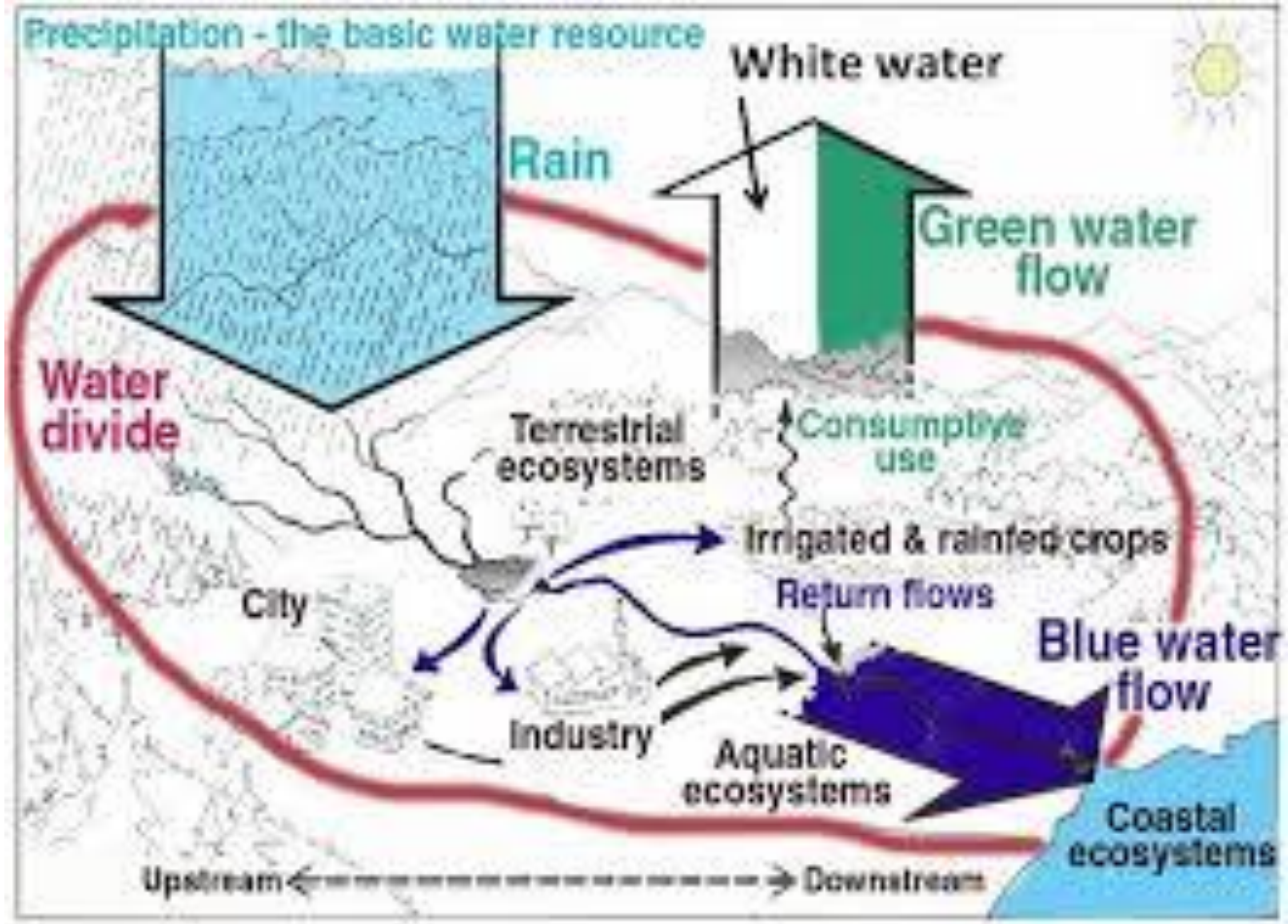
- World's water is being affected by climate change in complex ways such as:
  - unpredictable rainfall patterns
  - shrinking ice sheets
  - rising sea levels
  - floods and droughts

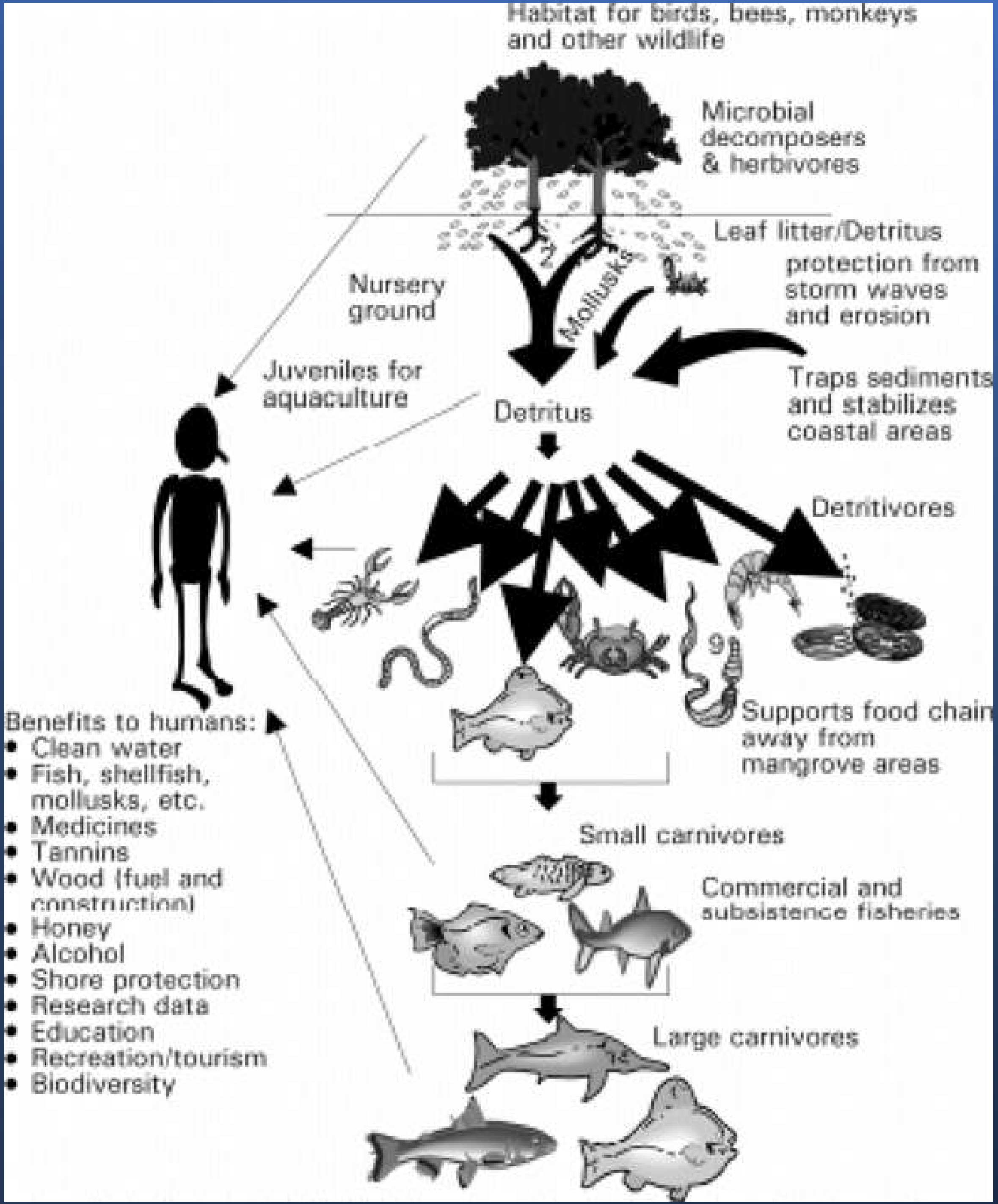
↓

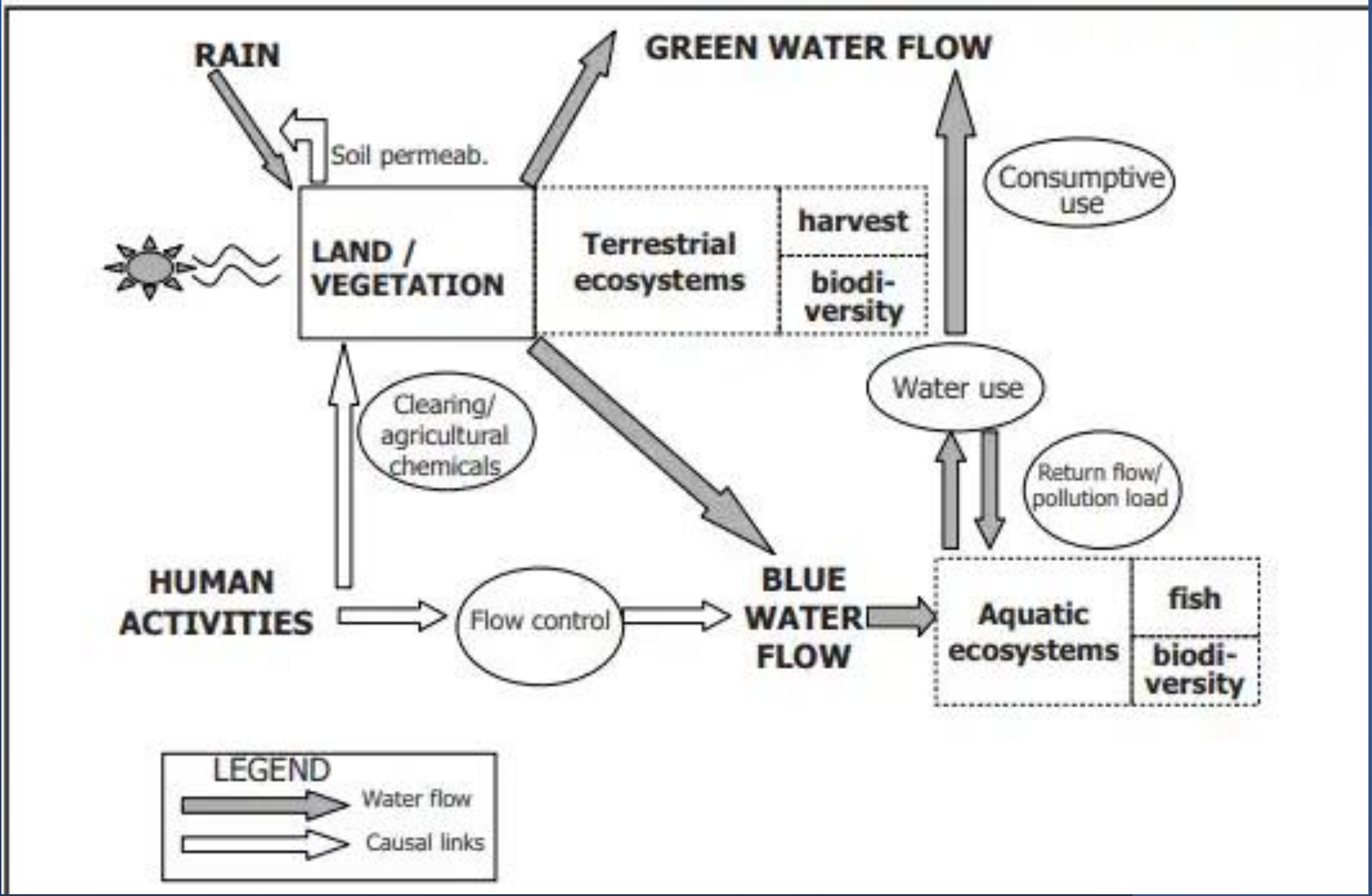
affects the ecosystems

Climate Change vs Adaptation

Climate impact	**Ecosystem-based adaptation**
Increased droughts	use appropriate agricultural and forestry practices to increase the water retention capacity and mitigate droughts
Heat extremes	increase green spaces in cities to improve the microclimate and air quality
River flooding	maintain and restore wetlands and riverbeds which will act as natural buffers against floods
Increased fire risk	cultivate diverse forests, which are more robust against pest attacks and present a lower fire risk


Precipitation - the basic water resource
White water
Rain
Green water flow
Water divide
Terrestrial ecosystems
Consumptive use
Irrigated & rainfed crops
City
Return flows
Blue water flow
Industry
Aquatic ecosystems
Coastal ecosystems
Upstream
Downstream


Habitat for birds, bees, monkeys and other wildlife
Microbial decomposers & herbivores
Leaf litter/Detritus
Nursery ground
Mollusks
protection from storm waves and erosion
Juveniles for aquaculture
Detritus
Traps sediments and stabilizes coastal areas
Detritivores
Supports food chain away from mangrove areas
Benefits to humans:
• Clean water
• Fish, shellfish, mollusks, etc.
• Medicines
• Tannins
• Wood (fuel and construction)
• Honey
• Alcohol
• Shore protection
• Research data
• Education
• Recreation/tourism
• Biodiversity
Small carnivores
Commercial and subsistence fisheries
Large carnivores


RAIN
GREEN WATER FLOW
Soil permeab.
LAND / VEGETATION
Terrestrial ecosystems
harvest
biodi-versity
Consumptive use
Water use
Clearing/ agricultural chemicals
Return flow/ pollution load
HUMAN ACTIVITIES
Flow control
BLUE WATER FLOW
Aquatic ecosystems
fish
biodi-versity
LEGEND
Water flow
Causal links

Integrated Water Resources Management

- Need of Integrated approach to manage ecosystem services and water
- Without compromising the sustainability of vital ecosystems to ensure a coordinated development and management of water, land and related resources by maximizing economic and social welfare
- Three main pillars: social equity, economic efficiency and environmental sustainability

Key notes

- Ecosystem-based approaches considered cost effective due to the multiple environmental, economic, and social benefits they can provide for human wellbeing and economic development.
- Ecosystem-based approaches can strengthen the management of transboundary biodiversity landscapes → require stronger transboundary collaboration for effective implementation.
- For effective ecosystem-based approaches → reduce/eliminate information gaps for spatial, temporal, policy, and cost–benefit conditions.

Key notes cont'd

- Strengthening technical and institutional capacity to apply ecosystem-based interventions.
- Mainstream Ecosystem-based approaches into development and conservation policies.
- Effective implementation depends on sustainable financing, utilizing public and private resources.

Thank you for your attention!

CLIMATE CHANGE ADAPTATION IN WATER MANAGEMENT

K. GERSIE MSC.

CLIMATE CHANGE

- Encompasses "**global warming**"
- Refers to the broader change that is hapenning to our planet, such as:
  - Rising sea levels;
  - Loss of sea ice;
  - Shrinking glaciers and ice sheets;
  - Intense heat waves;
  - The increase and intensification of severe weather damage.
- Main Cause: greenhouse gases produced by human activities

CLIMATE CHANGE

Effects on the environment:

- Shrinking of glaciers and ice sheets;
- Earlier breakup of river and lake ice;
- Shifting of plant and animal geographic ranges;
- Sooner blooming of plants and trees;
- Droughts, wildfires, and extreme rainfall.

CLIMATE CHANGE

- high-emissions → rapid ice sheet collapse
  → melting land ice

↓

the expansion of seawater as it warms

↓

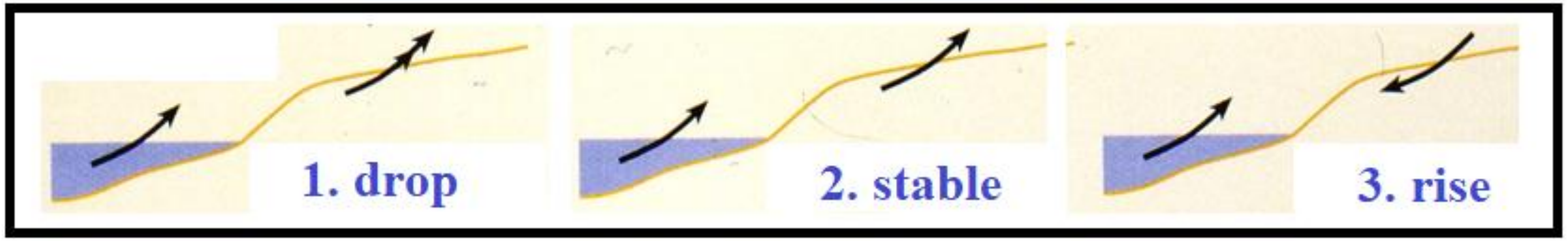
increased flooding

(combination of storm surge and high tides with sea level rise and land subsidence)

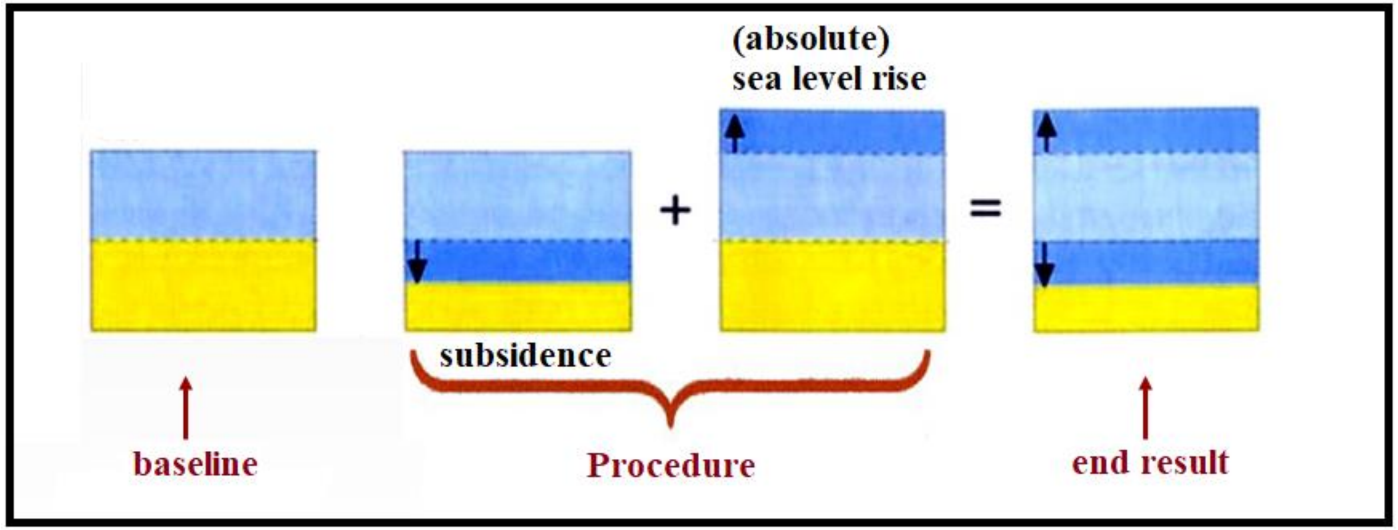
SEA LEVEL RISE

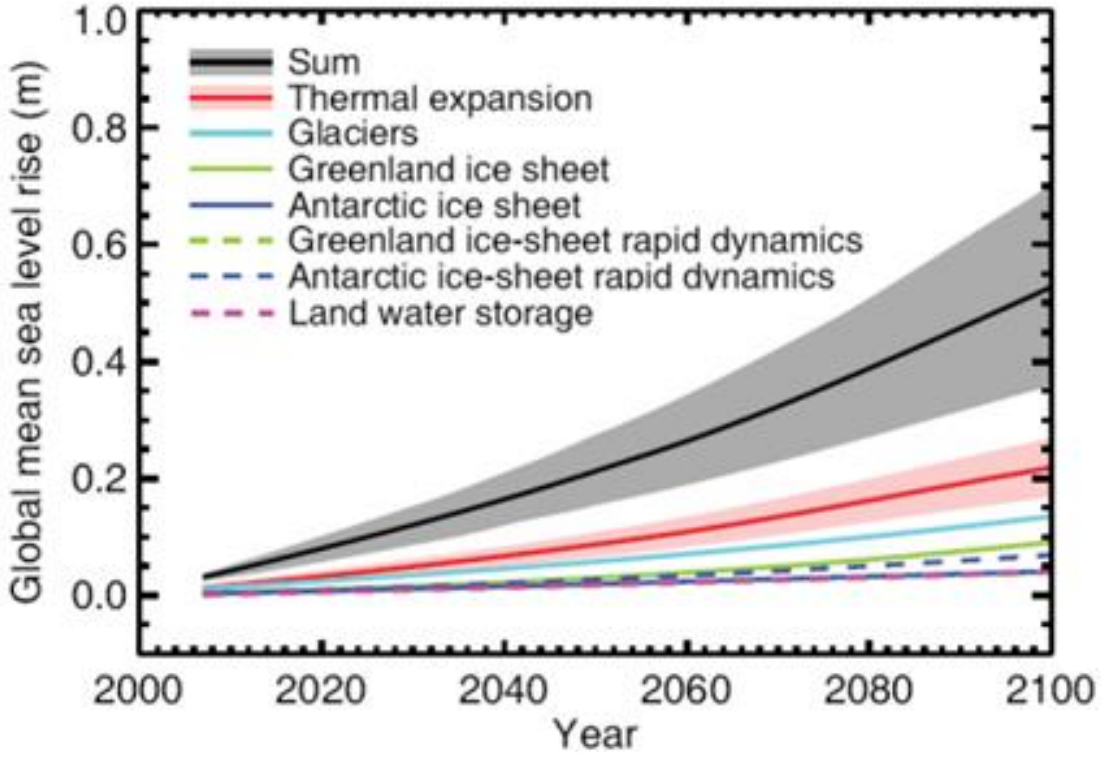
- Absolute sea level rise: refers to the height of the ocean surface above the center of the earth, without regard to whether nearby land is rising or falling
- Relative sea level rise: how the height of the ocean rises or falls relative to the land at a p.articular location

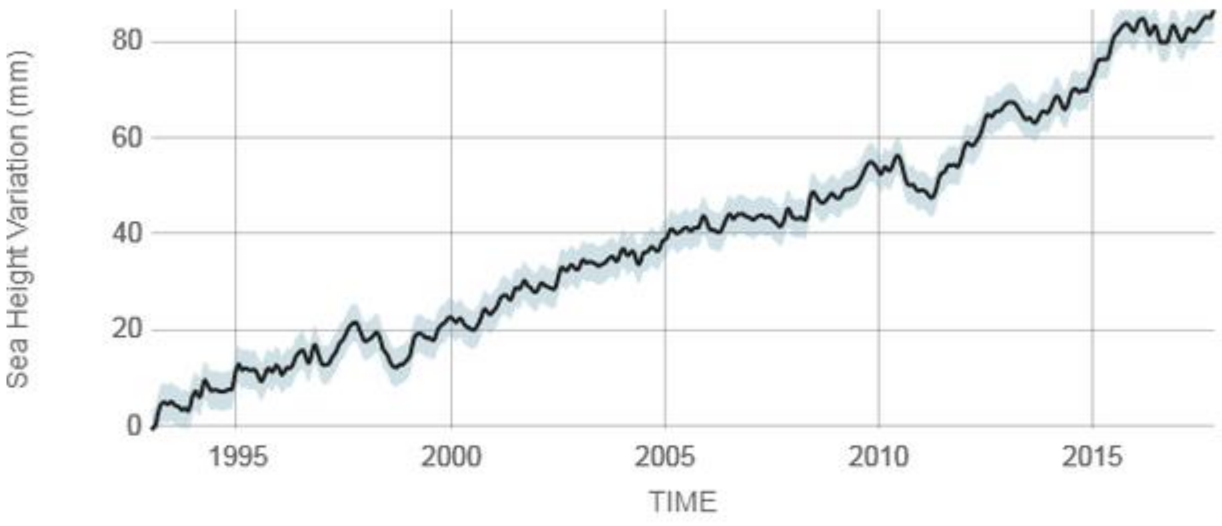
SEA LEVEL RISE



Courtesy: P.G.E.F. Augustinus

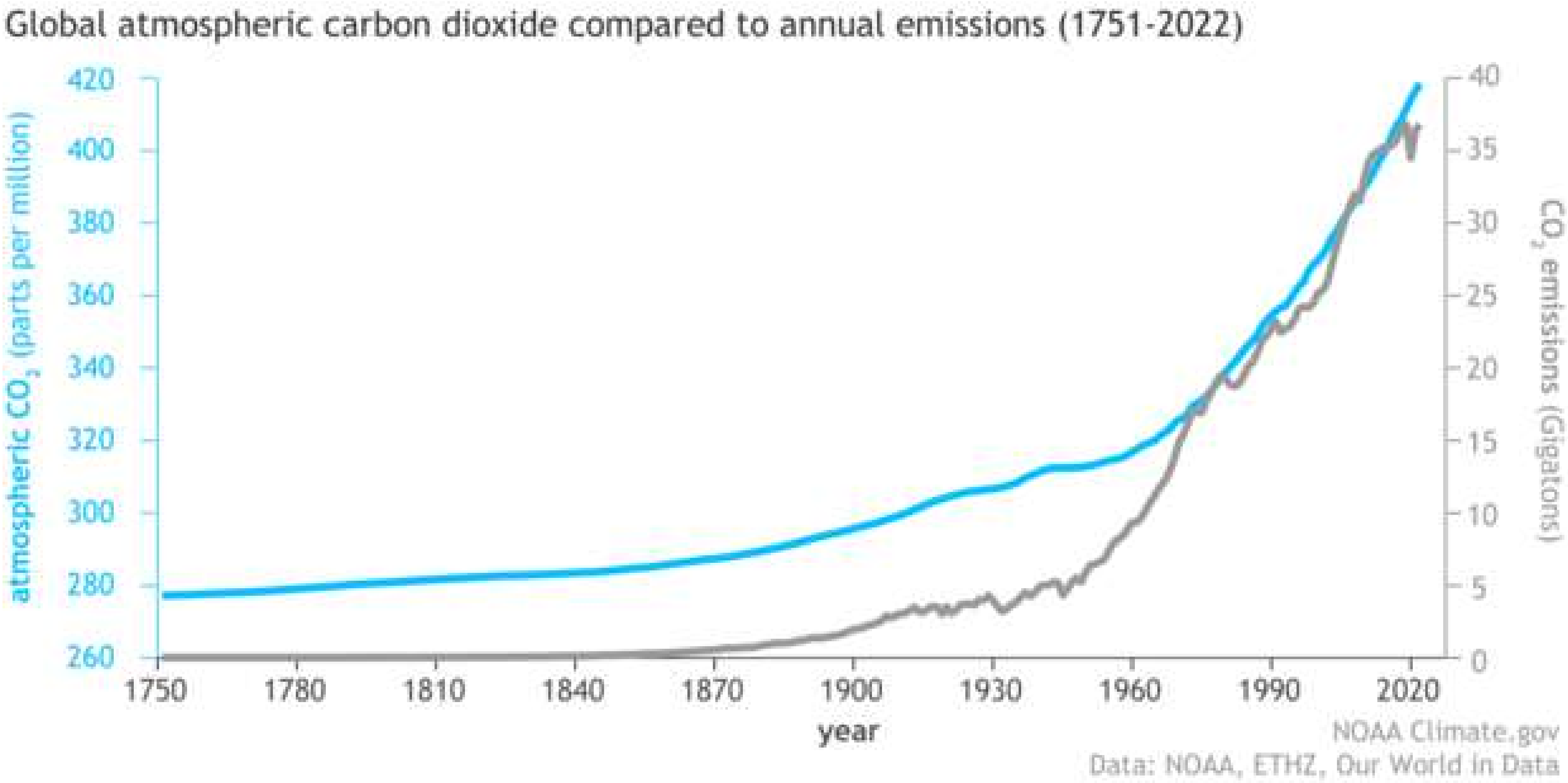






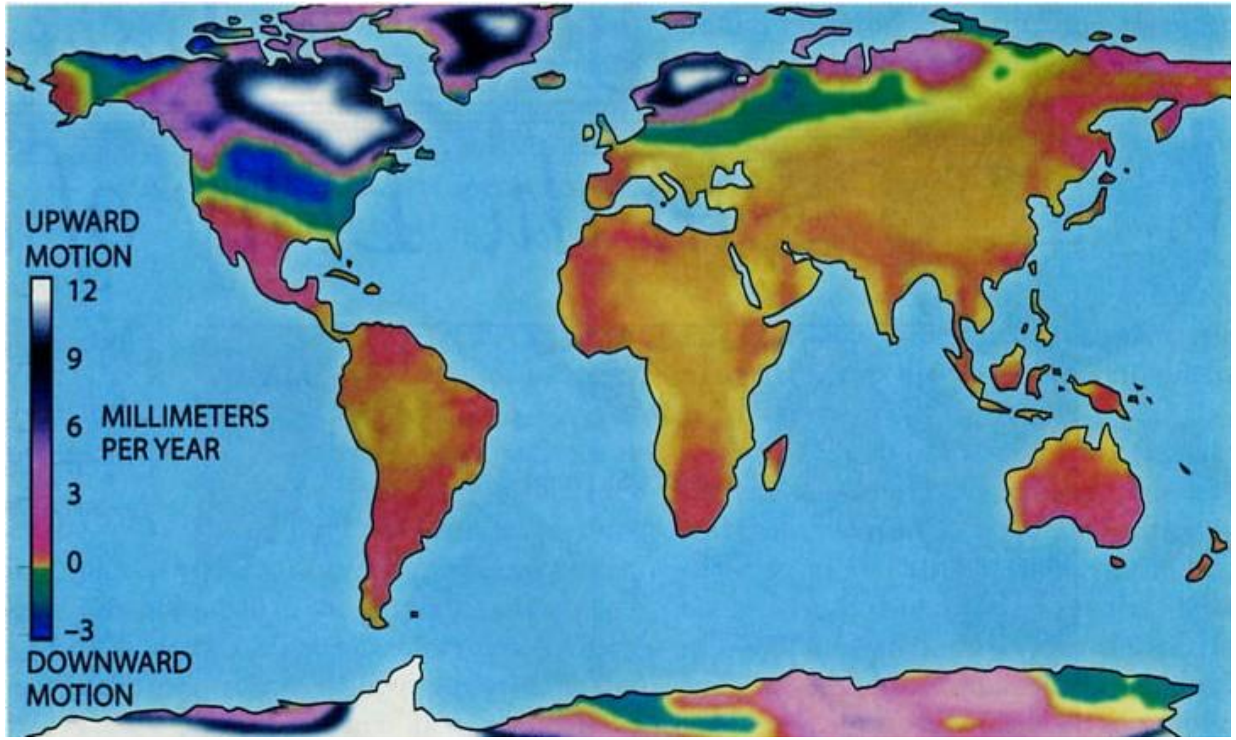
Source: climate.nasa.gov

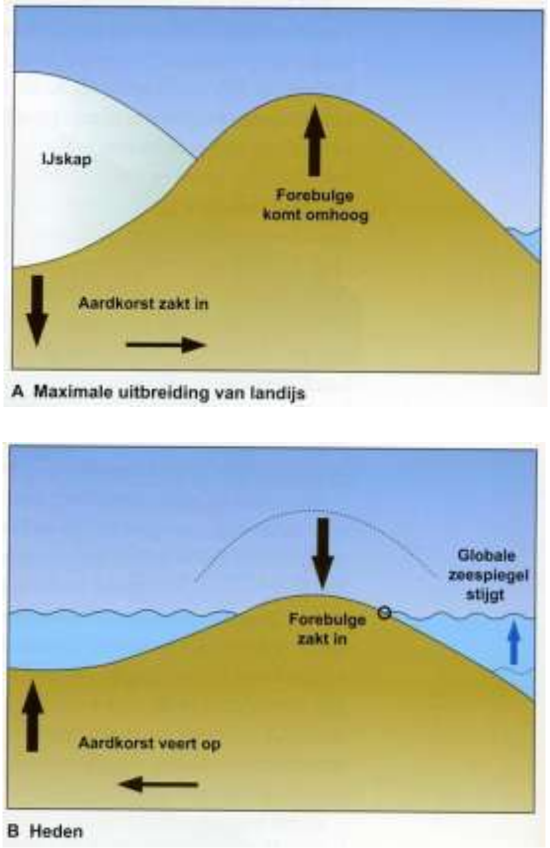
SEA LEVEL RISE

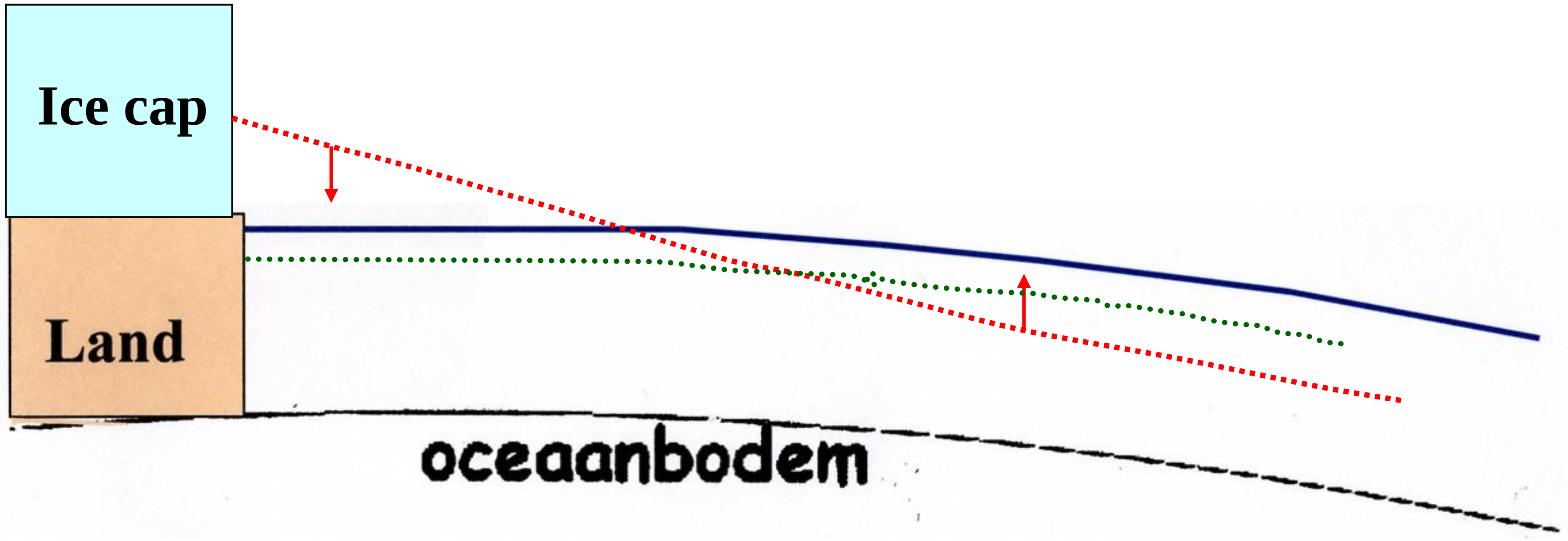


Global atmospheric carbon dioxide compared to annual emissions (1751-2022)
atmospheric CO_2 (parts per million)
420
400
380
360
340
320
300
280
260
1750
1780
1810
1840
1870
1900
1930
1960
1990
2020
year
40
35
30
25
20
15
10
5
0
CO_2 emissions (Gigatons)
NOAA Climate.gov
Data: NOAA, ETHZ, Our World in Data

ISOSTATIC BALANCE

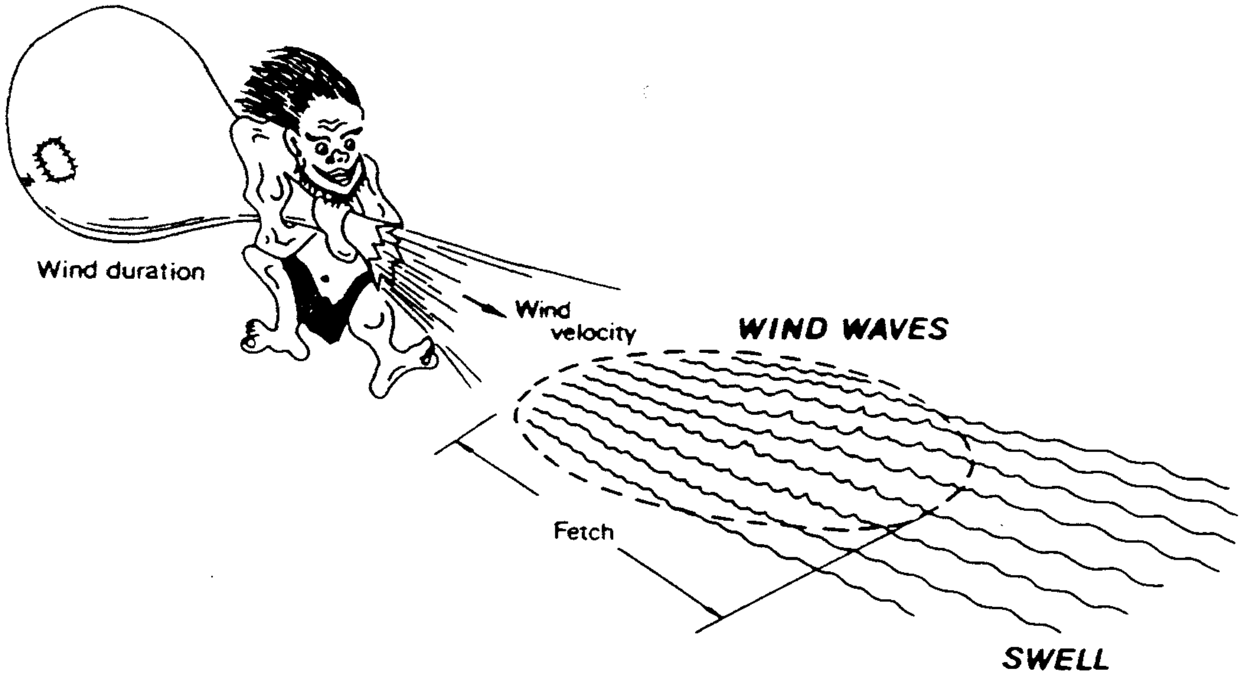





Ice cap
Land
oceaanbodem

MARINE FORCES AND PROCESSES

- Waves (+ wind)
- Tides
- Seawater characteristics

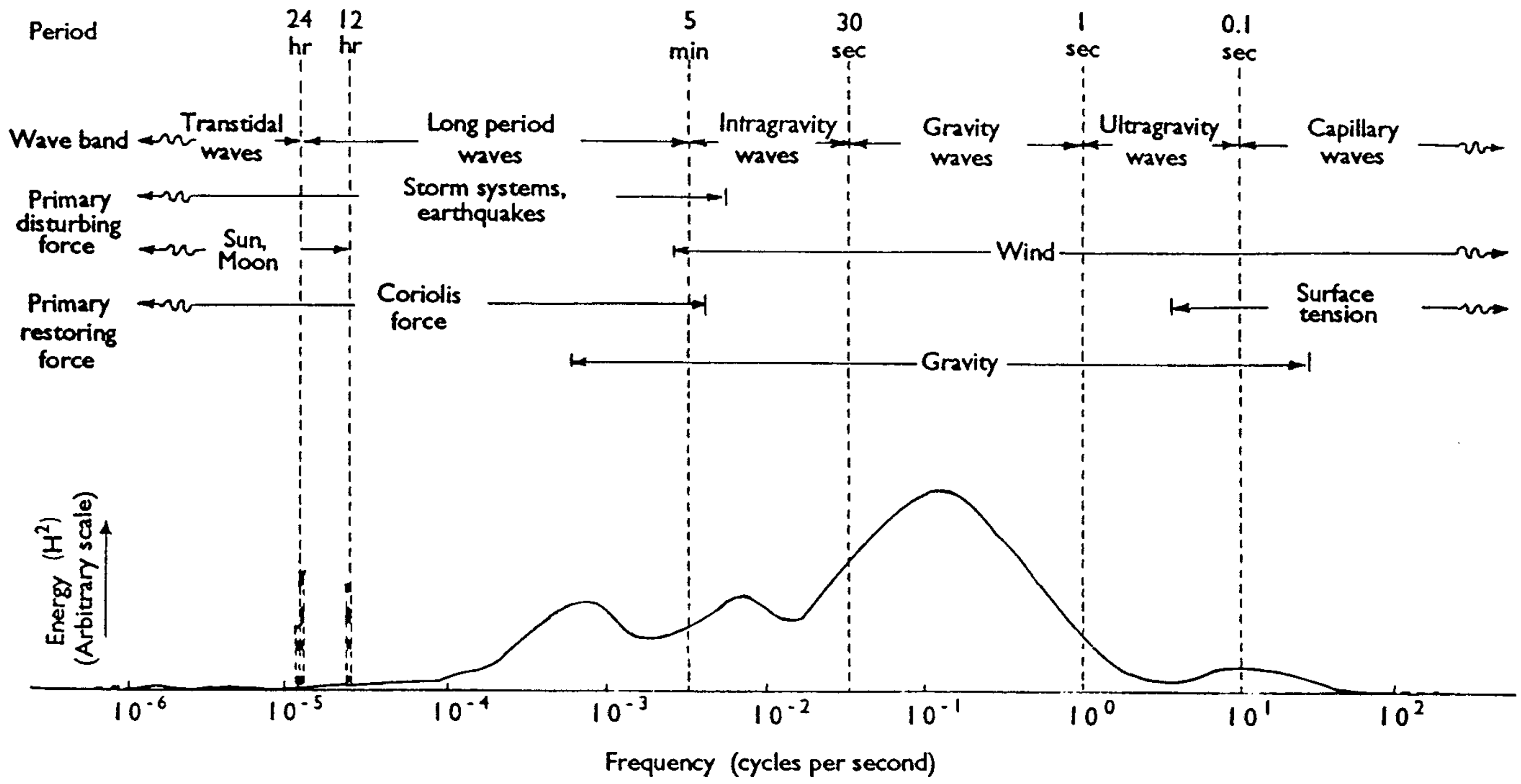


WAVES

- Different types of waves:
  - Short waves (3s < T < 20s):
    - Wind waves (local) and swell (not local)
  - Long perioc waves (20s < T < 300s)

- Characteristics: height (H), period (T), length (L), velocity (c)

WAVES


Period
24 hr
12 hr
5 min
30 sec
1 sec
0.1 sec
Wave band
Transtidal waves
Long period waves
Intragravity waves
Gravity waves
Ultragravity waves
Capillary waves
Primary disturbing force
Storm systems, earthquakes
Sun, Moon
Wind
Primary restoring force
Coriolis force
Surface tension
Gravity
Energy (H²) (Arbitrary scale)
10⁻⁶
10⁻⁵
10⁻⁴
10⁻³
10⁻²
10⁻¹
10⁰
10¹
10²
Frequency (cycles per second)

WAVE ENERGY

$E = E_p + E_k$

E_k = kinetic energy

E_p = potential energy

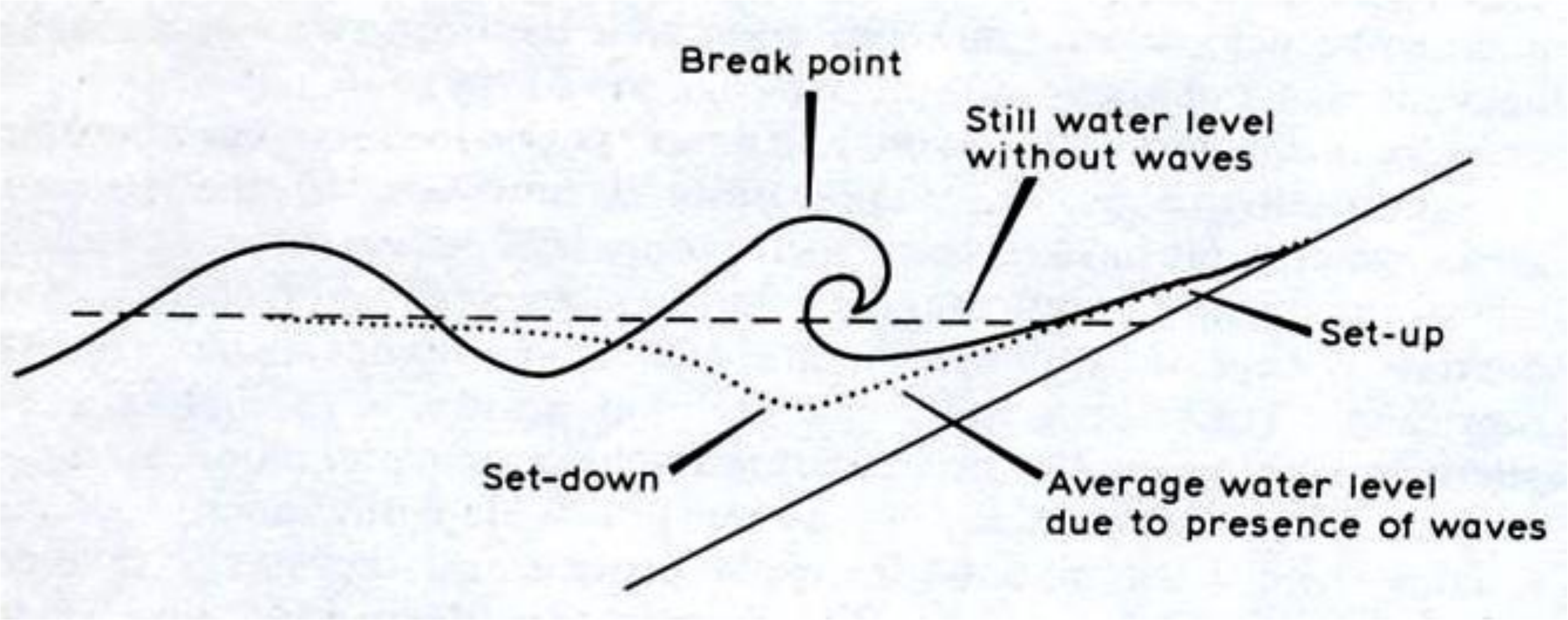
$E = 1/8\rho g H^2$

[ρ: water density]

[g: gravity accelleration]

[H: wave height]

SET-UP EN SET-DOWN



CLIMATE CHANGE AND WAVES

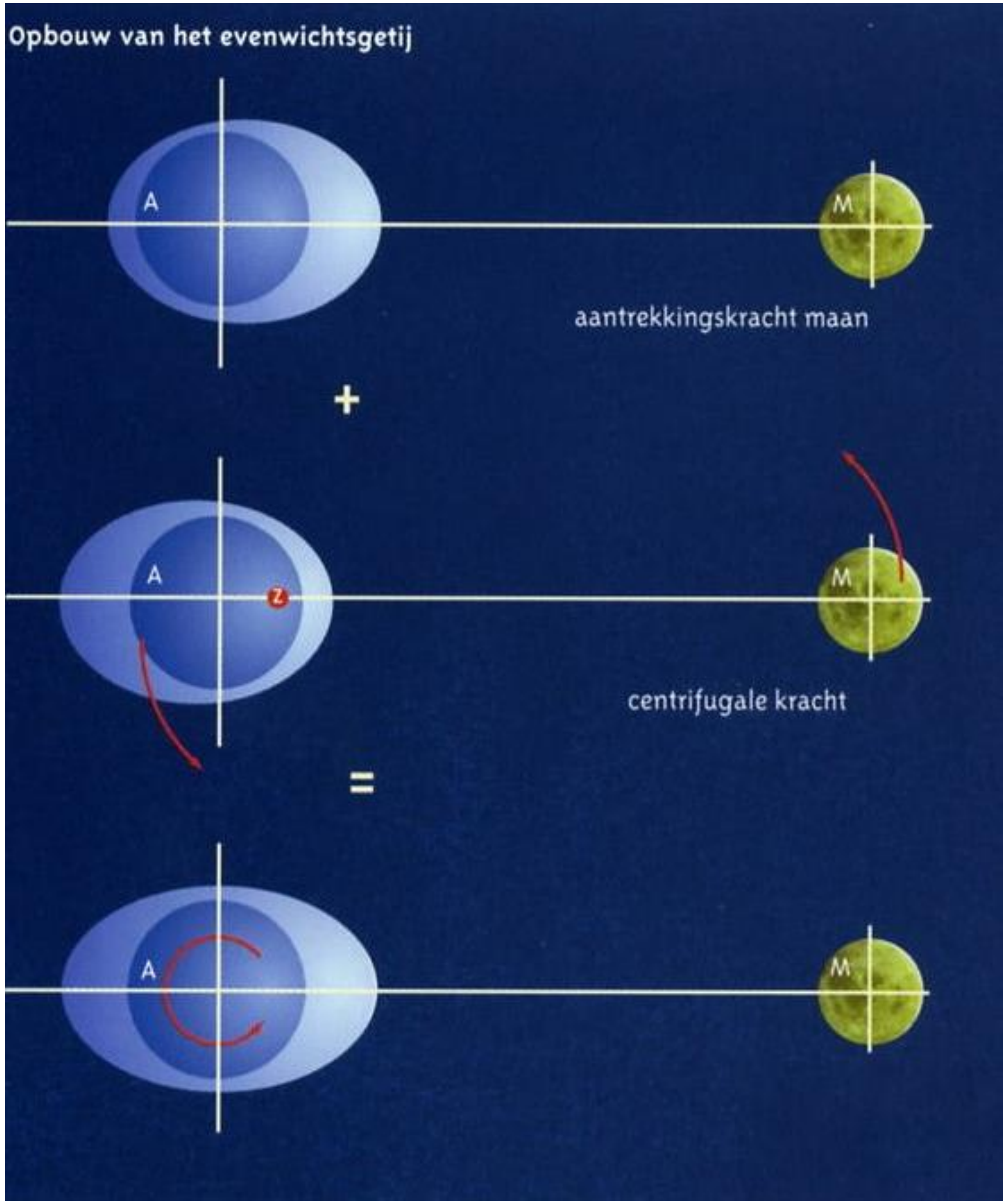
- How does climate change affects waves?
  - Getting bigger (average wave height has grown by as much as a foot since 1970);
  - More powerful;
  - Greater propagation velocities;
  - More wave energy;
  - A greater wave set-up due to stronger winds caused by storms.

TIDES

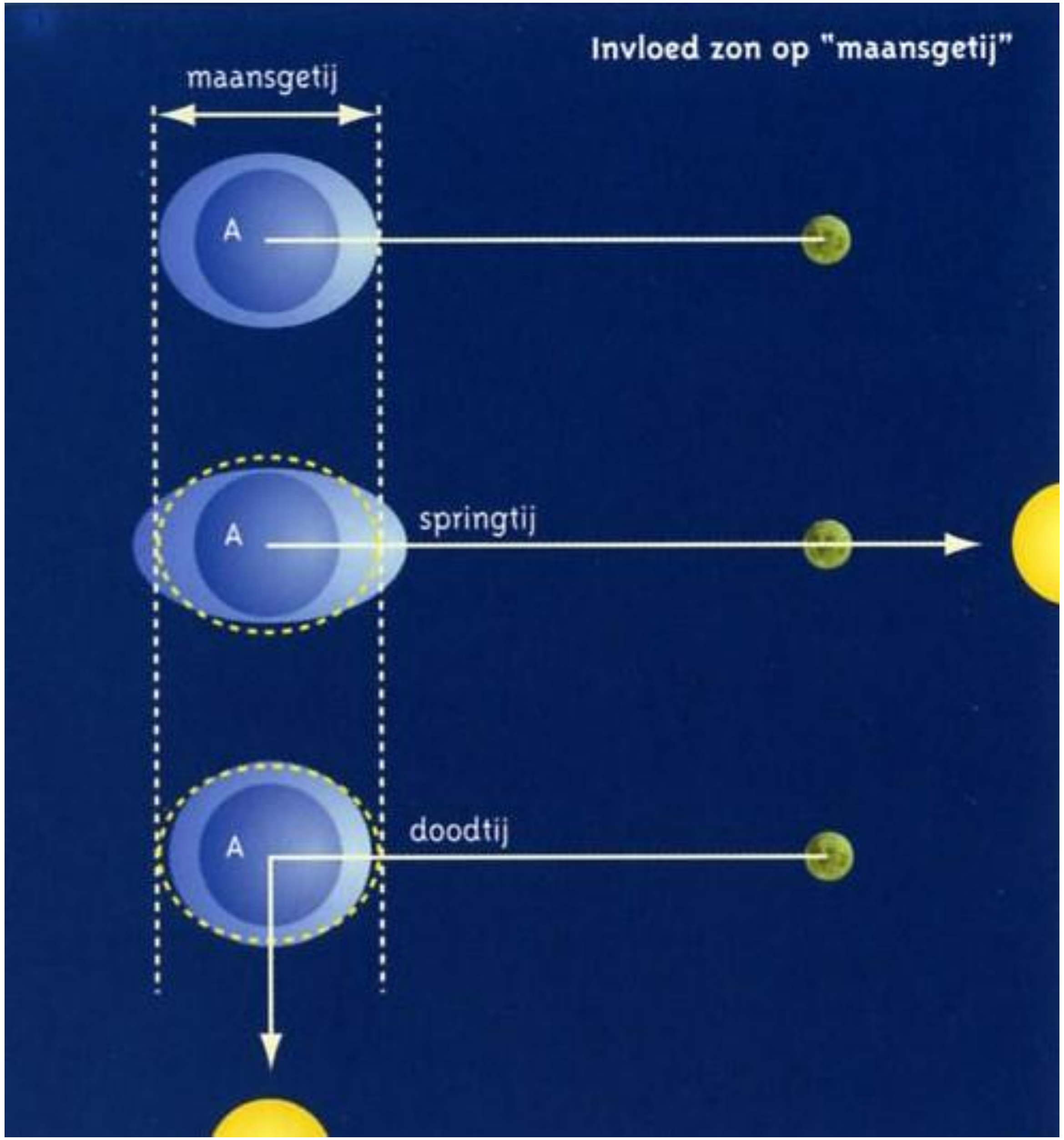
Tidal influence:

- Periodic alternating water level (including waves)
- Intertidal areas
- Strong influence in tidal inlets and estuaries

MOON TIDE


Opbouw van het evenwichtsgetij
A
M
aantrekkingskracht maan
+
A
Z
M
centrifugale kracht
=
A
M

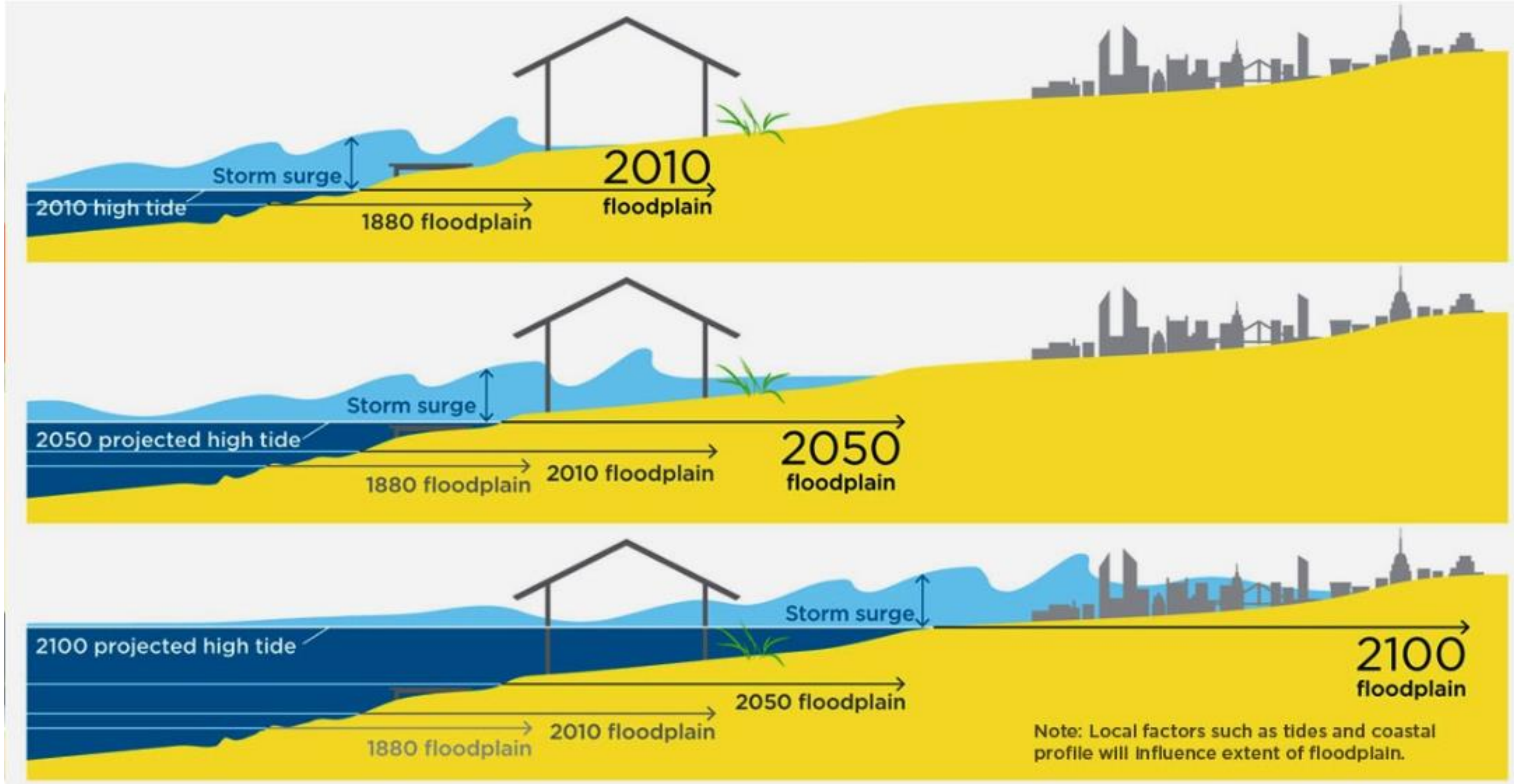
SPRINGTIDE AND NEAPTIDE



CLIMATE CHANGE AND TIDES

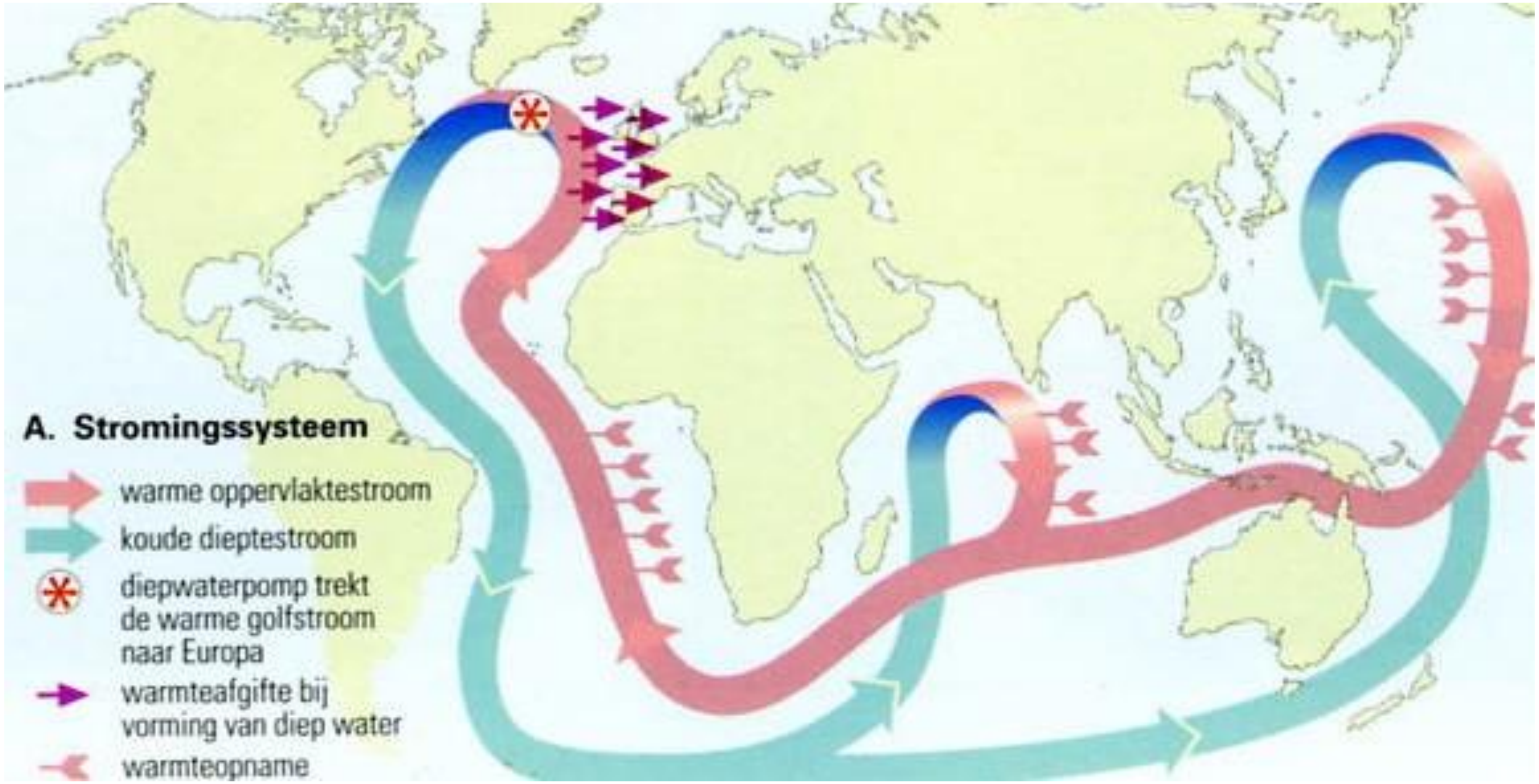
As a result of sea level rise:

- high tides are reaching higher and extending further inland than in the past;
- low-lying shorelines are at increased risk of flooding because of rising seas;
- the highest tide of the year provides a preview of how sea level rise will affect coastal places (e.g. king tides)

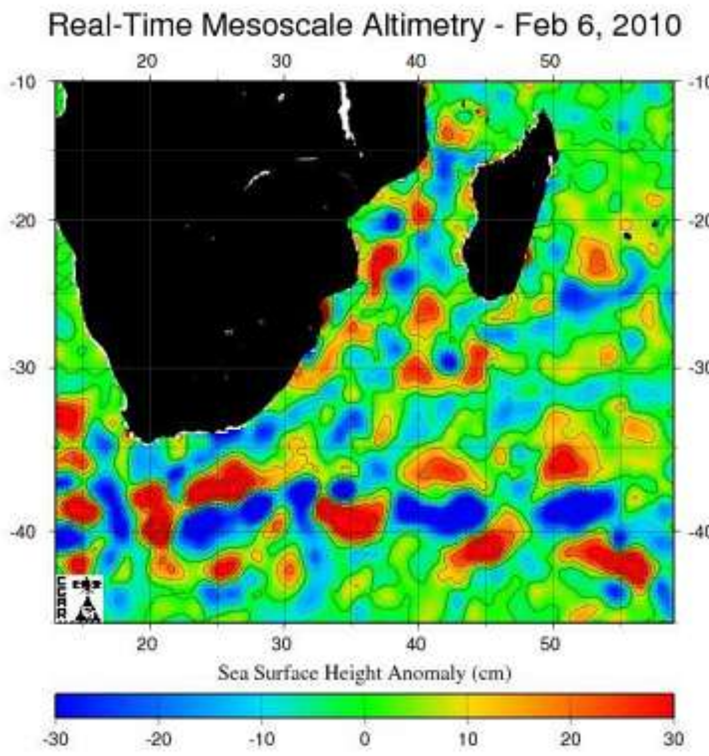


Shoreline erosion and degradation

CURRENTS


A. Stromingssysteem
warme oppervlaktestroom
koude dieptestroom
diepwaterpomp trekt
de warme golfstroom
naar Europa
warmteafgifte bij
vorming van diep water
warmteopname

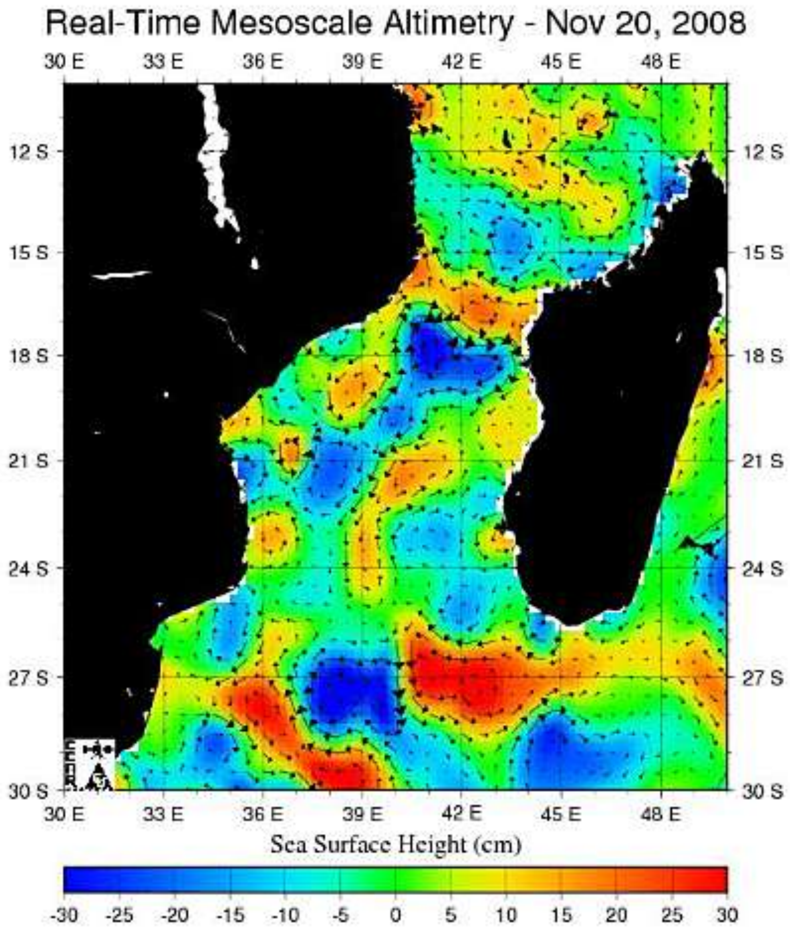
WATER HEIGHT IN THE OCEAN

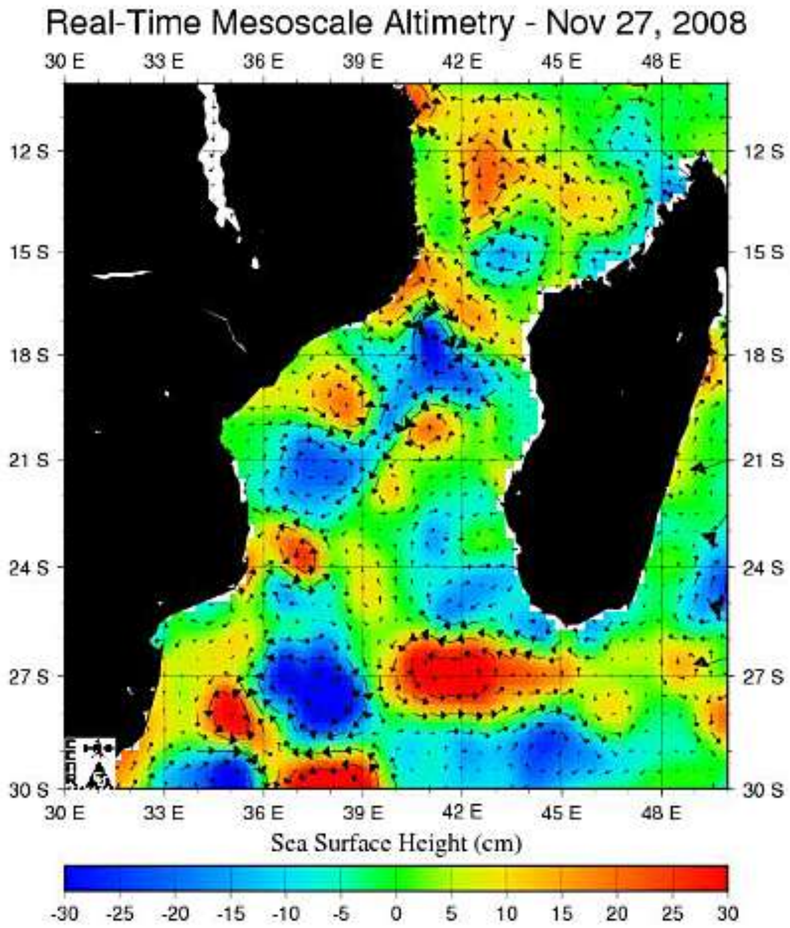


Rood: hoger zeeoppervlak

Blauw: lager zeeoppervlak

WATER HEIGHT IN THE OCEAN





MUDDY COASTS

Where?

- Protected coasts with the input of low wave energy (e.g. estuaries)
- Non-protected open ocean with a large influx of suspended sediment (e.g. coast of the Guianas)

Example: Suriname coast

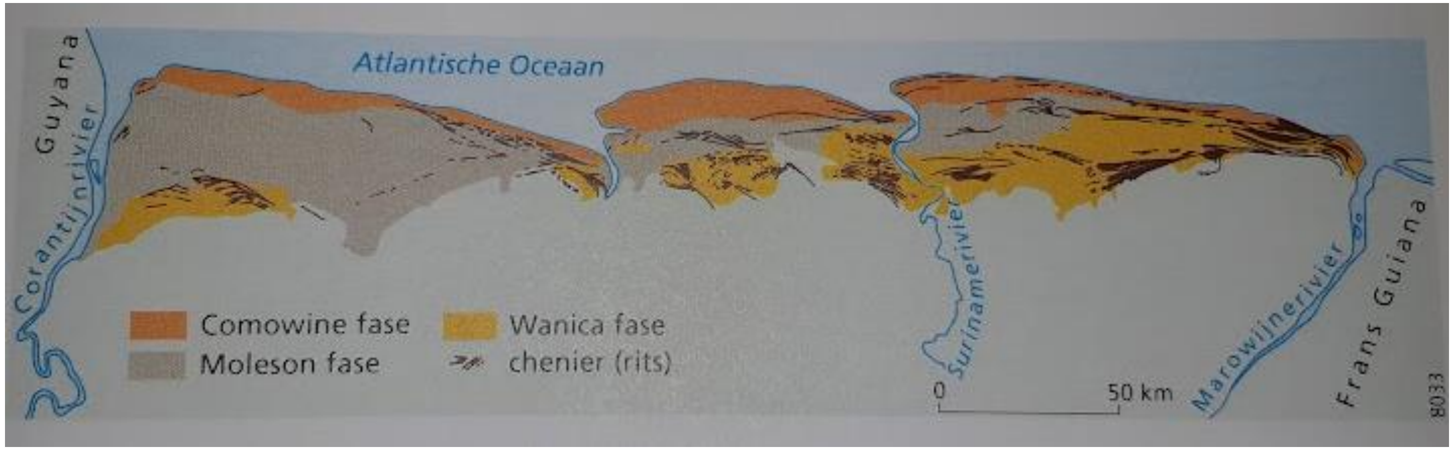
(Source: Sentinel I, 2023)

Source: WWF Guianas, 2023

MUDDY COASTS

Example: Suriname coast

Chenier along the coast (Courtesy: WWF Guianas (2016)



Coastal plain with cheniers (Wong et al., 2016)

SANDY COASTS

Miami

Truc Vert, France

San Francisco

COASTAL ECOSYSTEMS

Temperate regions: salt marshes

COASTAL ECOSYSTEMS

TROPICAL REGIONS: MANGROVE FORESTS

Source: WWF Guianas, 2023)

MANGROVES AS ECOSYSTEM

Trees and shrubs that are part of tidal forest ecosystems in sheltered, salt to brackish (and sometimes even freshwater) environments

Red mangrove

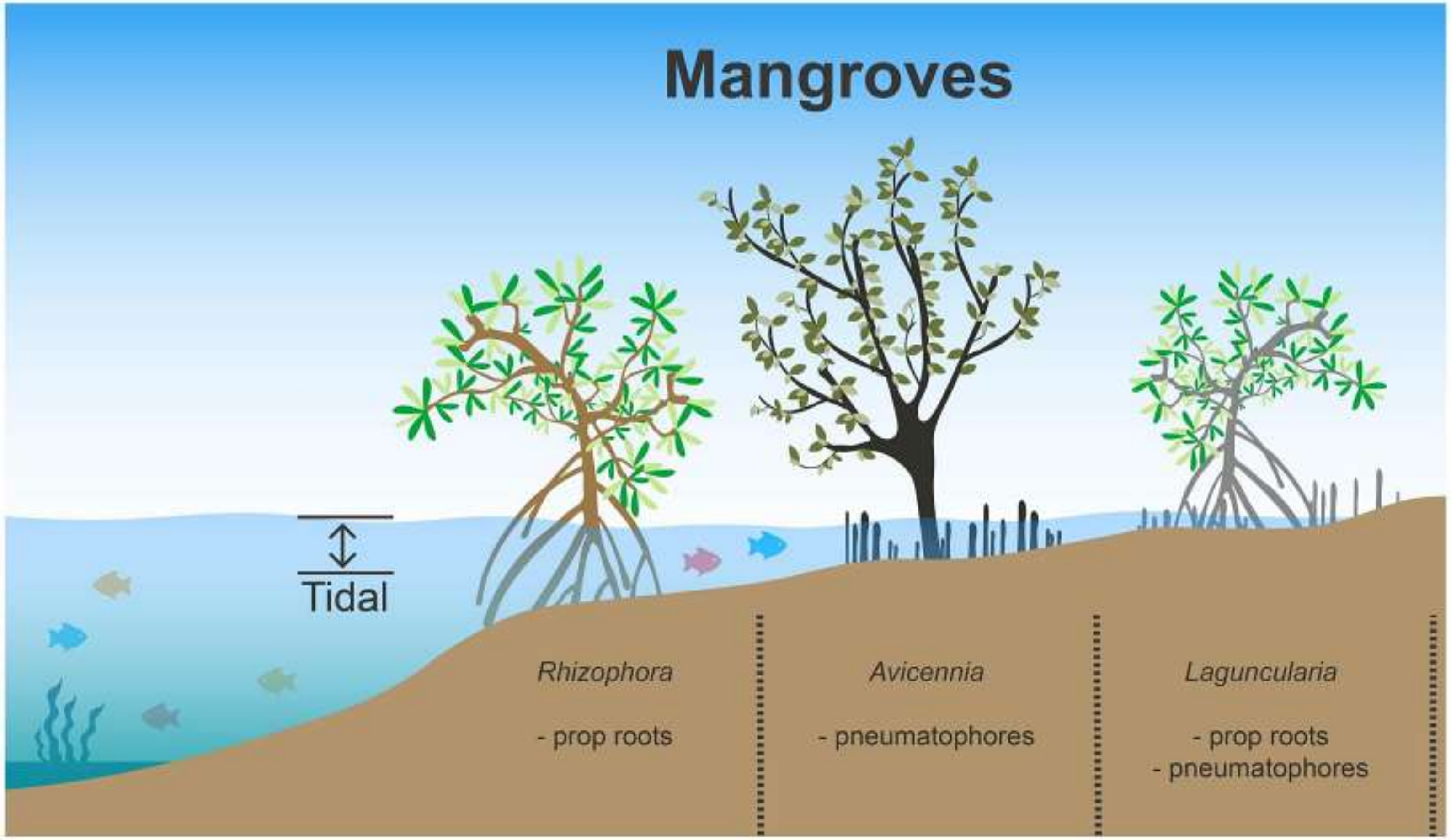
Black mangrove

White mangrove

MANGROVES AS ECOSYSTEM

Adaptation of mangroves

- Viviparia;
- High salt tolerance;
- Water-saturated soils;
- Soft muddy underground



MANGROVES AS ECOSYSTEM

Importance of mangrove forests as ecosystems

- Reservoir and refugium function for many plants and animals;
- Nursery and shelter function for many fishes and crustaceans (for example shrimps);
- Delivery of useful products e.g. firewood, shellfish, fruits/seeds, medicinal herbs etc.;
- ** Natural protection of coast and riverbanks

MANGROVES AND CLIMATE CHANGE

The importance of mangroves in climate change:

- They promote soil stability;
- They filter the silt from the water;
- They promote sedimentation/ delay erosion
    - Slow down the flow rate
    - Damping of waves

MANGROVES AND CLIMATE CHANGE

Climate change means:

- Higher waves → more wave energy
  → stronger currents
  ↓
  high erosion rates
  ↓
  natural removal of mangroves → less protection of coastal areas

PROTECTION TO CLIMATE CHANGE

- Hard coastal defences: involves building structures to protect the coastal area;
- Soft coastal defences: more natural, sustainable approach to coastal management, focusing on smaller-scale techniques that align with the natural environment;
- Nature-based solutions;

Prior knowledge about:

- Erosion and accretion patterns;
- Interaction of wave climate, currents, and tides.

HARD COASTAL DEFENCES

Groynes:
Built perpendicularly from the ocean shore or a river bank

Purpose: trap sediment transported with the longshore current

Material:
- Wood
- Concrete
- Rocks

- Permeable
- Impermeable

HARD COASTAL DEFENCES

Sea/ river dykes and embankments:

Run along the coastline or river

Purpose: to prevent areas from flooding

Material:

- Concrete
- Rocks
- Steel
- Combination

Coronie sea dyke

Nickerie sea dyke

SOFT COASTAL DEFENCES

Dredging:

- the removal of sediments and debris from the bottom of lakes, rivers, harbors, and other water bodies

- Purpose: maintaining or increasing the depth of navigation channels

SOFT COASTAL DEFENCES

Beach nourishment:

- a natural defence against erosion and coastal flooding
- Dumping sediment in large quantities can suffocate benthic communities

SOFT COASTAL DEFENCES

Beach scraping

- the process of reshaping beach and dune landforms with heavy machinery by redistributing sediment within the littoral system.

NATURE-BASED SOLUTIONS

Nature-based solutions are an important part of future infrastructure:

- Durable;
- Adaptive;
- Resilient.

- The natural green solutions are called hybrid solutions when they are implemented with the traditional "grey" solutions.
- How much green and how much grey then depends on the system in question

NATURE-BASED SOLUTIONS

- Implementation of Nature-based solutions in existing infrastructure combined with adaptive management is a sustainable and cost-effective way to keep coastal areas liveable.

- *Examples of green-grey soultions* are:
  - Vegetation or salt marshes in front of sea or river dykes;
  - Natural matured dredged material that is used for construction of civil works etc.
  - Nature-based Solutions are always multidisciplinary:
    - ecologists, biologists, hydrologists, hydro-dynamics, civil technicians and sediment scientists work together with specialists in socio-economics, finances and governance;
    - Relying on the power of the natural system and uses this for functions such as water safety;
    - Important condition is that the system is strong and resilient

NATURE-BASED SOLUTIONS

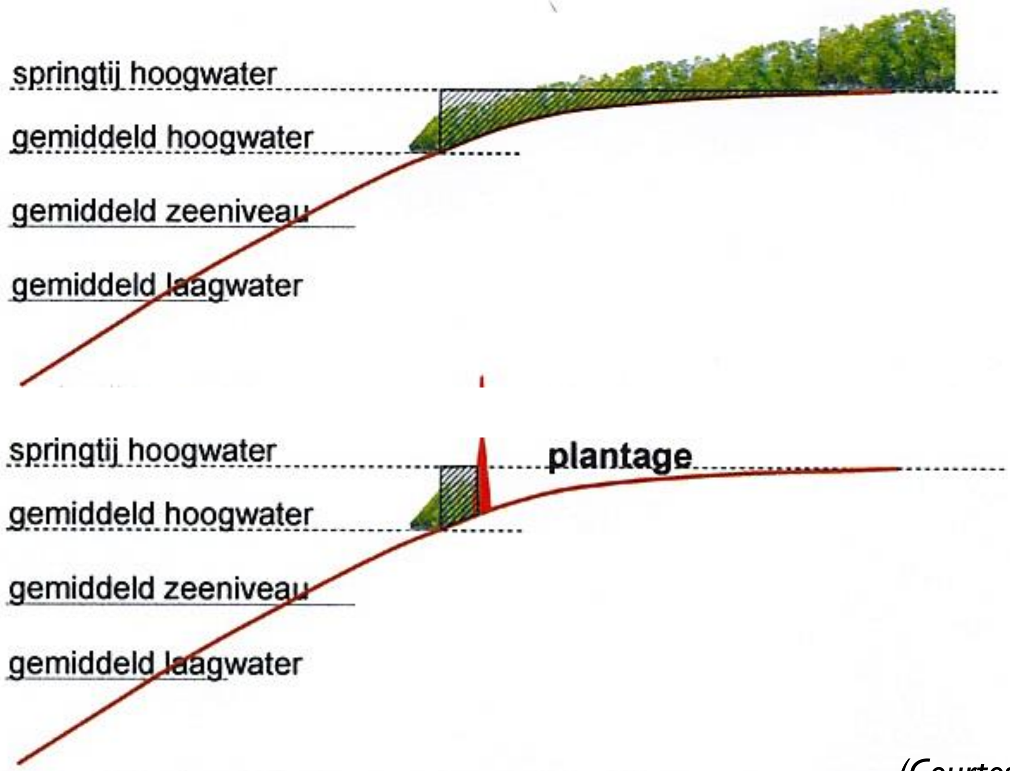
Grey solutions:

- Dams, dikes and embankments protect the back areas, but at the same time they disrupt important natural processes or cycli;
- Dams trap sediment which leads to erosion downstream and impoverishment of the biodiversity;
- Diked rivers cause too fast dicharge of sediments to sea which leads to lowering of the surrounding area and the risk of flooding is actually increasing.

DIKES ALONG THE COAST AND THE EFFECTS ON MANGROVE FOREST

normal situation

situation with dike



(Courtesy: P. Augustinus)

NATURE-BASED SOLUTIONS

- Internationally high expectations;
- Nature-based solutions are not always and everywhere feasible;
- Requires a systematic look at the possibilities;
- What is possible and what is not?
- Solutions need to be durable and cost-effective (think about maintenance)
- What are the impacts of extreme events sush as storms, drought or heavy rainfall?
- What are the effects of changing long-term conditions such as sea level rise?

NATURE-BASED SOLUTIONS

Restoration of vegetation (e.g. mangrove forests)

- Keeping mangrove forests in good condition is of great importance for the protection of coasts and banks of estuaries;
- Each species has its own conditions that must be met
  - Knowledge about this is very important
- Along erosive coasts or rivers you cannot plant mangroves;
- Restoration or planting of vegetation (e.g. mangroves) is useful, but keeping them in good conditions is better and cheaper.

SUMMARIZING

- Climate change means a change in hydrodynamics off the coast (higher waves, stronger currents, stronger winds);
- More frequent flooding;
- Change in coastal morphology;
- Loss of habitats and ecosystems;
- Damage of infrastructure;
- Loss of and damage to fertile agricultural soils;
- Major risks for flooding of inhabited and uninhabited areas behind.

WHAT CAN WE DO?

- Mitigate or stop removal of protecting vegetation due to antropogenic factors;
- Let nature take its course as much as possible (buffer zone free of activities);
- No urbanization close to the coastline (prevent loss of property);
- The government can contribute by making antropogenic activities in vulnerable areas subject to permits;
- Restoration of mangrove forests is a good idea, if we fully understand the hydrodynamics and conditions ;
- Nature-based solutions are options we should seriously look at;
- Moving to higher areas should be considered.

THANK YOU!

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