Faculty of Science, Charles University

PRAGUE, CZECH REPUBLIC

Department of Plant Experimental Biology

Zuzana Lhotáková

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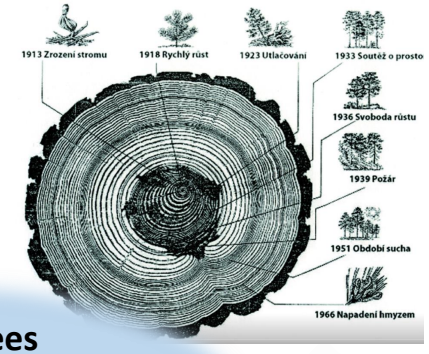
Forests and Climate

GLOBE Carbon Cycle and Phenology

Secondary school teacher level

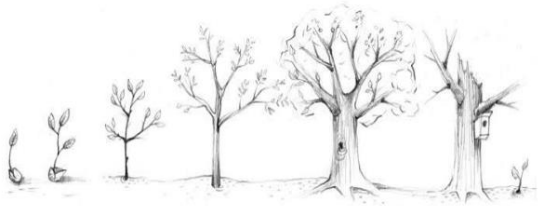
9:00-12:30

Carbon cycle, biomes, forests and climate change… Introductory lecture (40 min)



ACTIVITY 1:
How to measure trees
Relation of tree circumference and diameter, exploring tree cookies

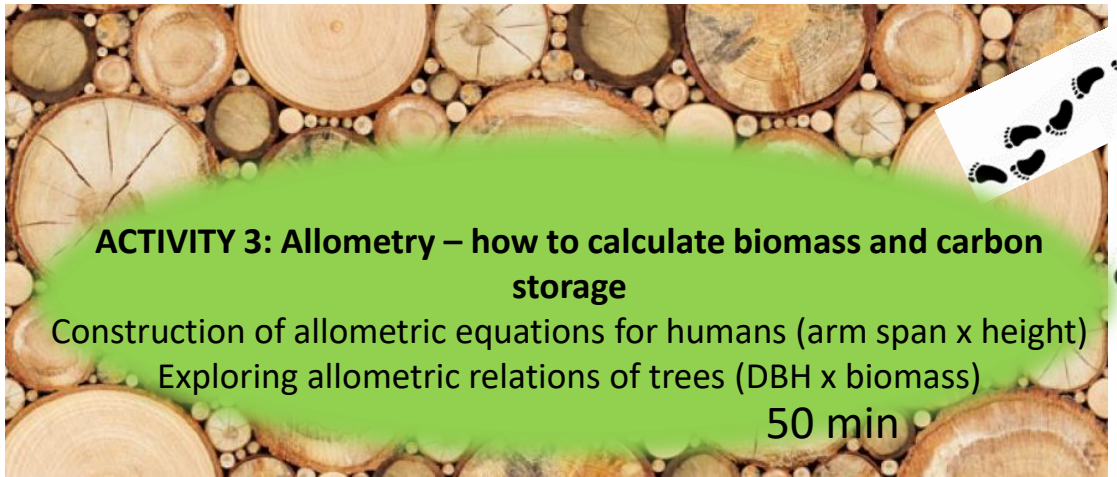
30 min



ACTIVITY 2: Biomass units
Calculating the biomass of participants
Comparing biomass and carbon storage among biomes

30 min

(Coffee) BREAK
30 min



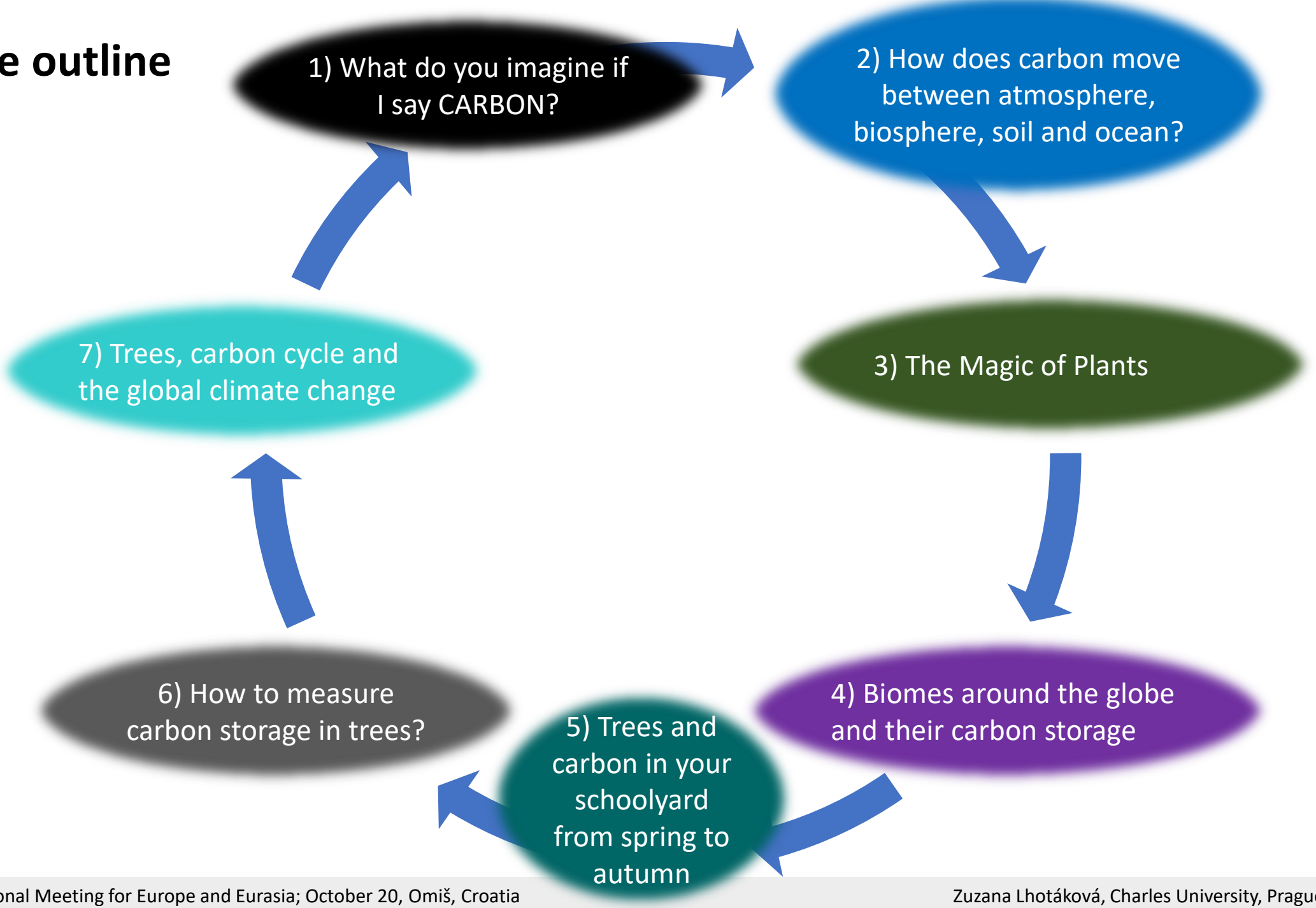
ACTIVITY 3: Allometry – how to calculate biomass and carbon storage
Construction of allometric equations for humans (arm span x height)
Exploring allometric relations of trees (DBH x biomass)

50 min

ACTIVITY 4: Tree carbon storage mapping
Measuring real tree circumference
Calculating carbon storage
Evaluating tree carbon benefits

40 min

Lecture outline



Zuzana Lhotáková, Charles University, Prague, CZ


1) What do you imagine if I say CARBON?


1) What do you imagine if I say CARBON?

1) Where you can find carbon?

CARBON is everywhere….

Carbon:

is the basic building block of life on the Earth

it accounts for 45-50% of the total dry mass of the biosphere

You can find it literarily everywhere:

- in the oceans (dissolved and as sediments)
- in the earth crust (rocks, minerals, soil)
- in all living organisms
- in the atmosphere

mainly as carbon dioxide (CO_2) from many processes:

respiration of all organisms
volcanic eruptions
dead biomass decay
burning fossil fuels

3) How does carbon move between atmosphere, biosphere, soil and ocean?

2) How does carbon move between atmosphere, biosphere, soil and ocean?

The carbon moves in the Carbon Cycle!

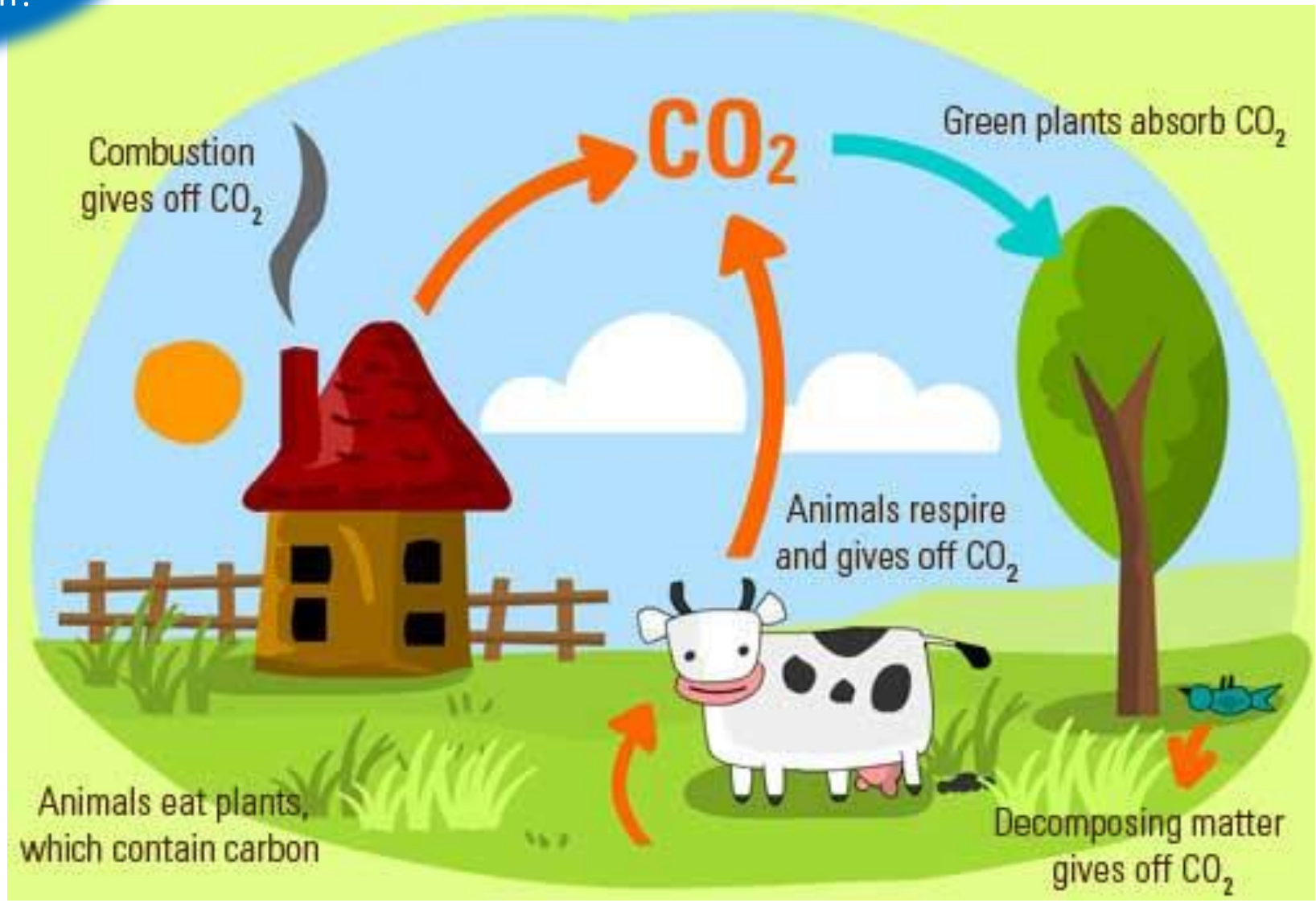


Image source: http://eschooltoday.com/our-ecosystems/the-carbon-cycle.html

2) How does carbon move between atmosphere, biosphere, soil and ocean?

Global carbon cycle

Pools:
Places where carbon stays some time in various forms.
- From minutes to milliones of years!

Fluxes:
Ways (processes), by which carbon travels among the pools.

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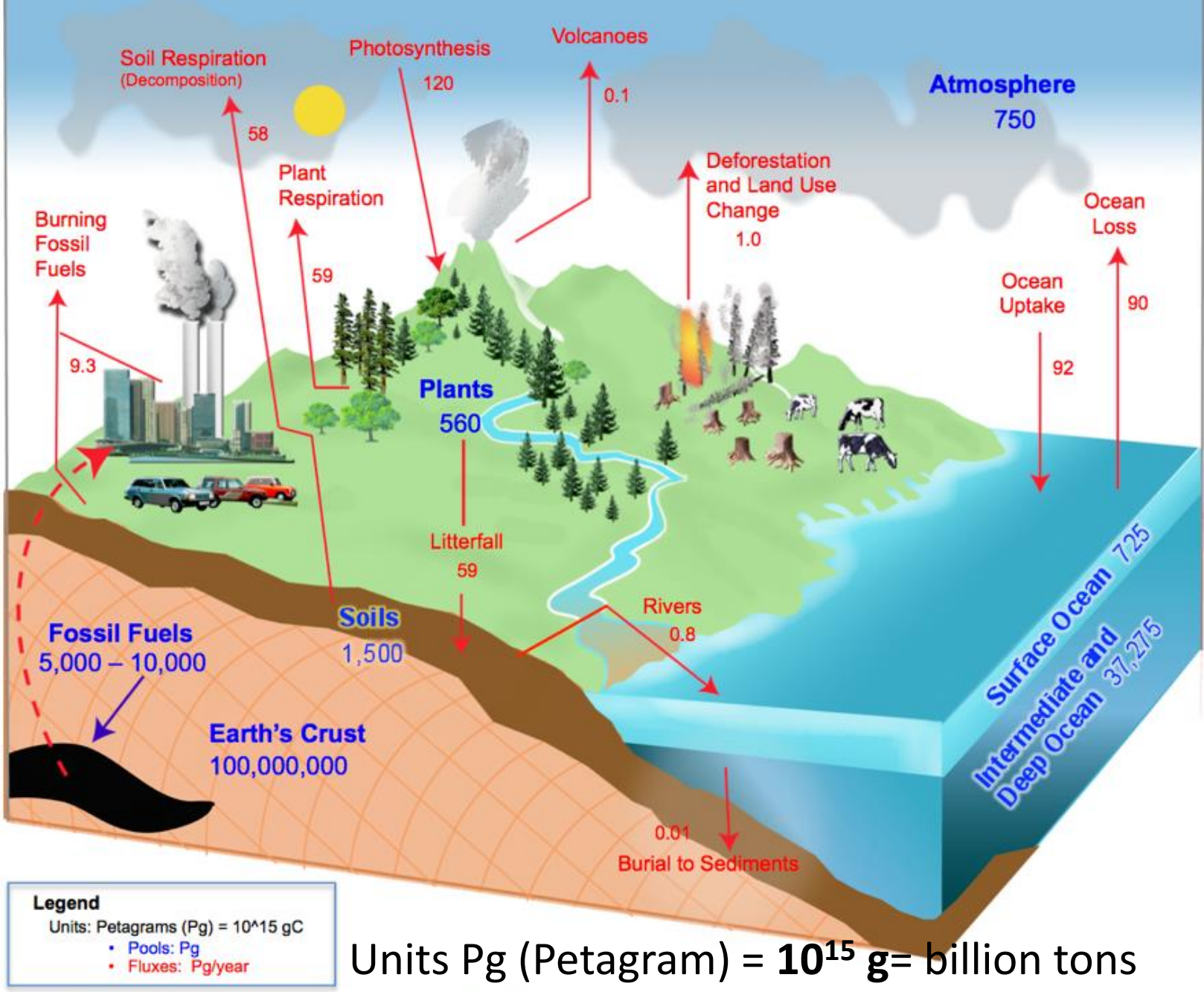
Places where carbon stays some time in various forms.
- From minutes to milliones of years!



Units Pg (Petagram) = **10^{15} g**= billion tons

GLOBE®2017 Global Carbon Cycle Diagram Biosphere

Data Sources: Adapted from Houghton, R.A. Balancing the Global Carbon Budget. Annu. Rev. Earth Planet. Sci. 007.35:313-347, updated emissions values are from the Global Carbon Project: Carbon Budget 2017.
Diagram created by a collaboration between UNH, Charles University and the GLOBE Program.

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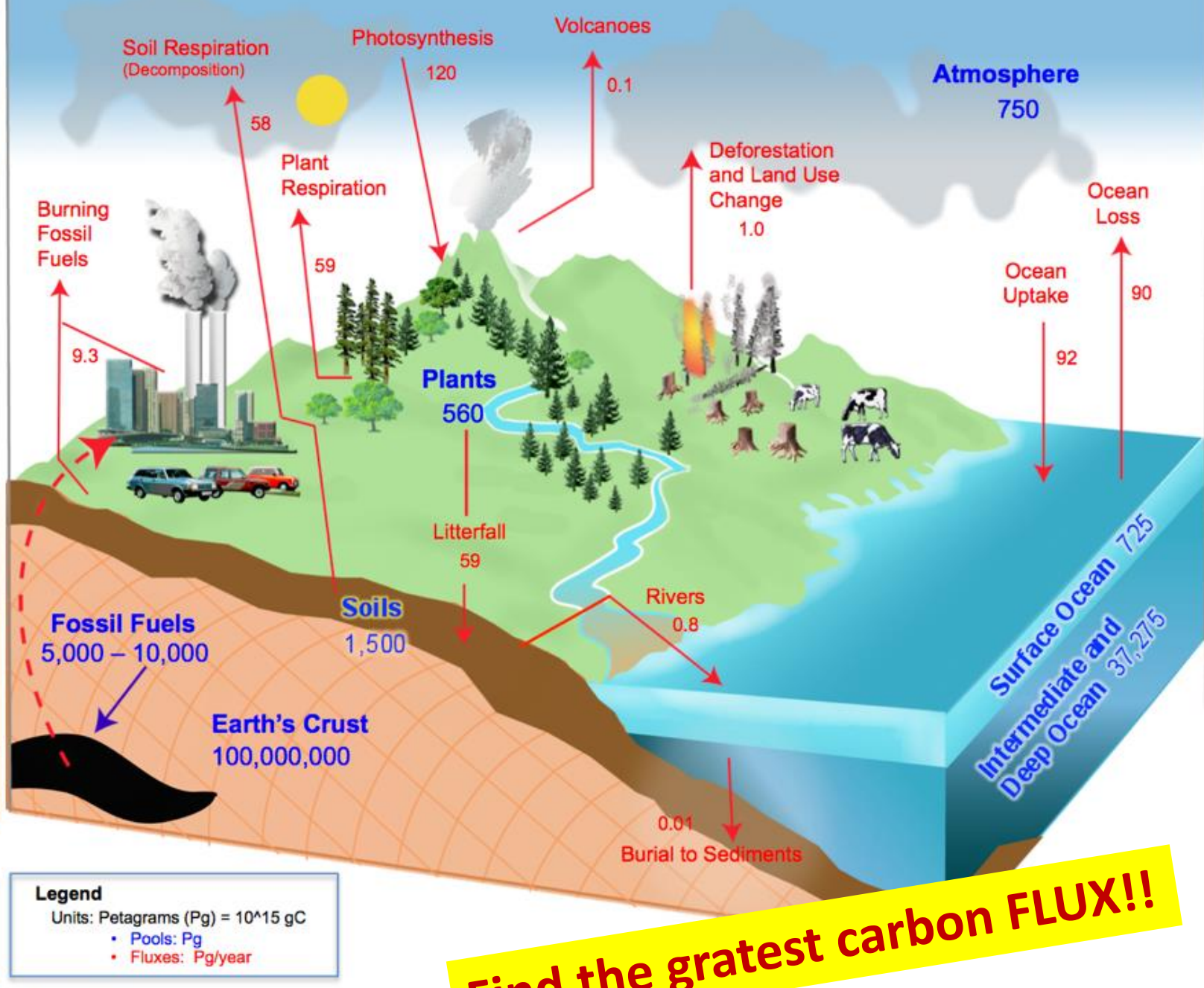


Find the gratest carbon FLUX!!

GLOBE Activity : Carbon travel game
https://www.globe.gov/documents/355050/c8fbe3d4-e7d3-4b6a-9629-38f616b59ff6

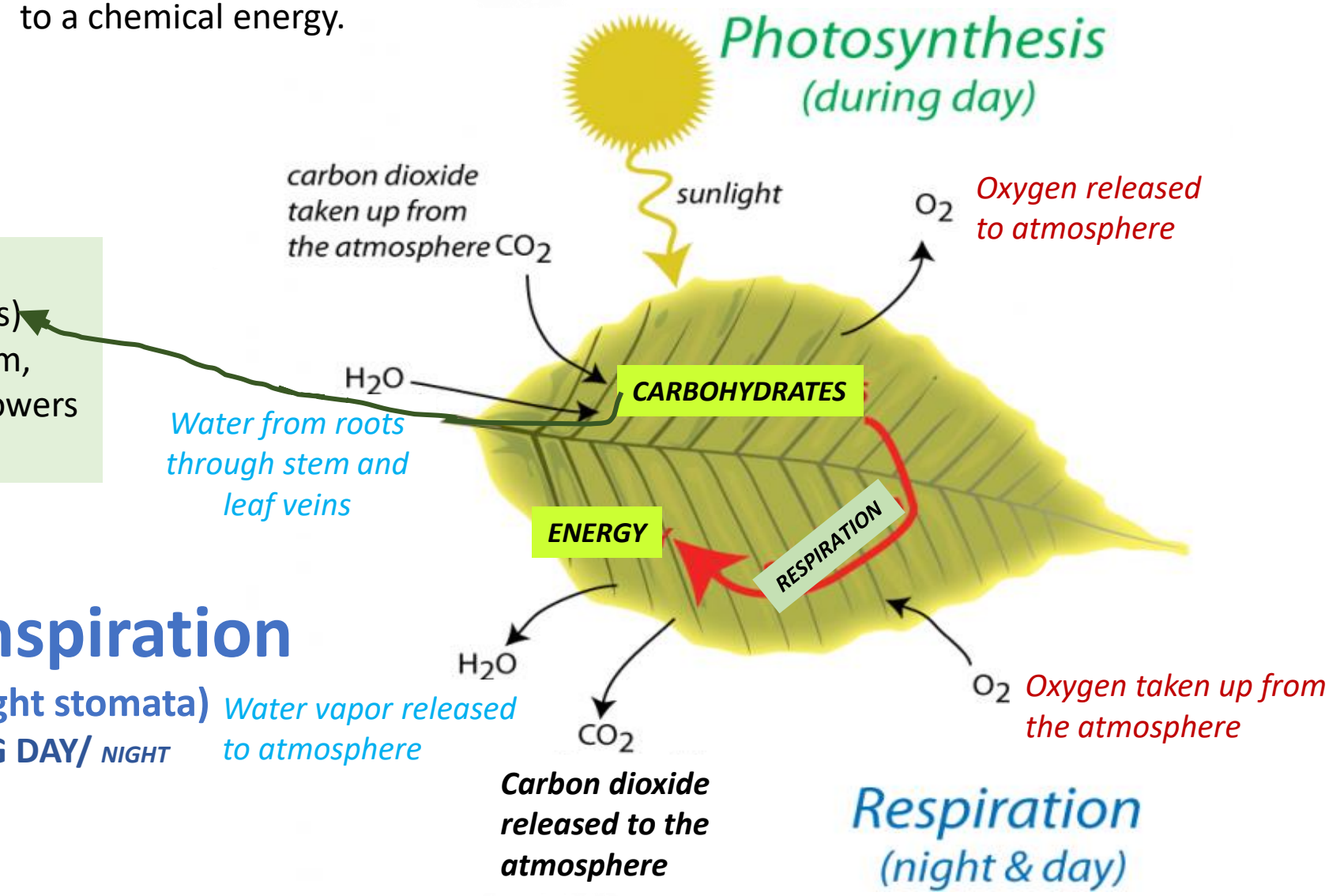
THE GLOBE PROGRAM

Why do we talk about Carbon Cycle in connection to trees?

3) The Magic of Plants

The most effective solar panel: Transforms the energy from sun to a chemical energy.

Organic compounds (carbohydrates / sugars) Transported to the stem, roots, young leaves, flowers and fruits



Transpiration

(throught stomata) *Water vapor released to atmosphere*

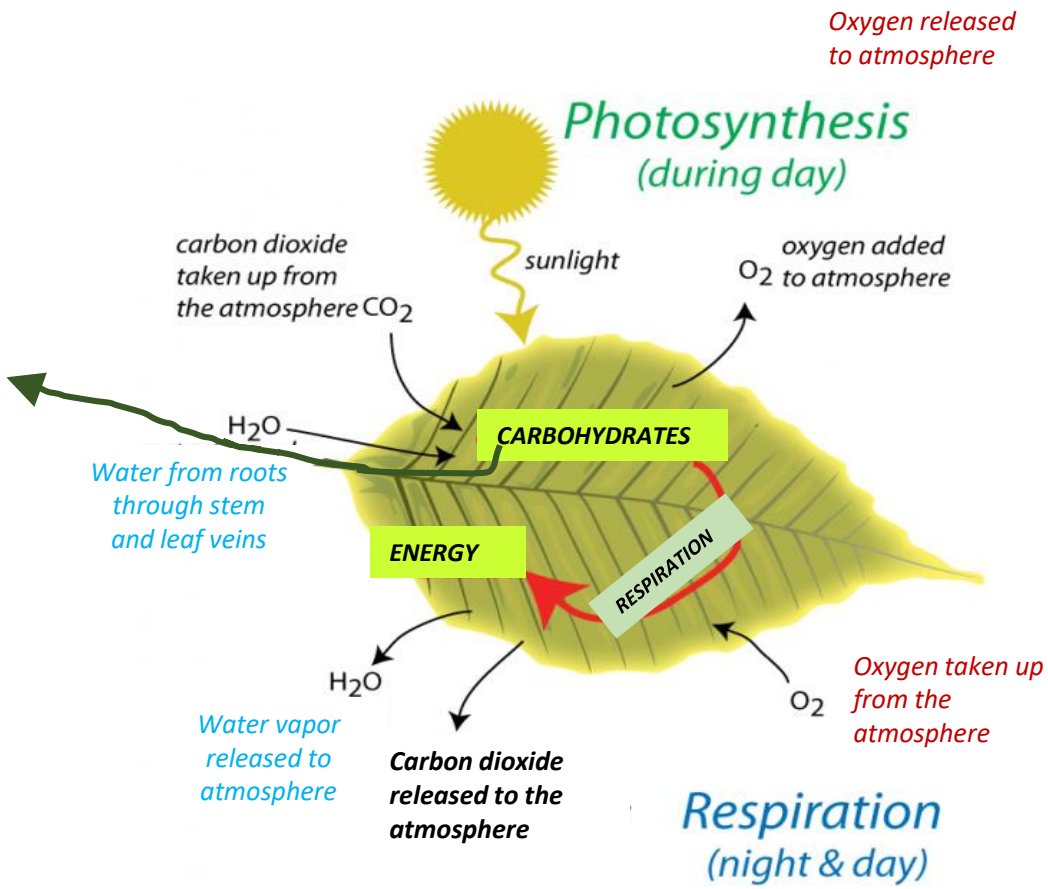
DURING DAY/ ***NIGHT***

GLOBE Activity: Tree Growth Game

https://www.globe.gov/documents/18702582/85832369/A1_My+Tree_Tree+Growth+Game_2022.pdf/620bcdb1-9bb8-73ae-6438-cebd82f7a775?t=1642867474709

3) The Magic of Plants

Organic compounds (carbohydrates / sugars) build:
wood
roots, young leaves
Flowers and fruits

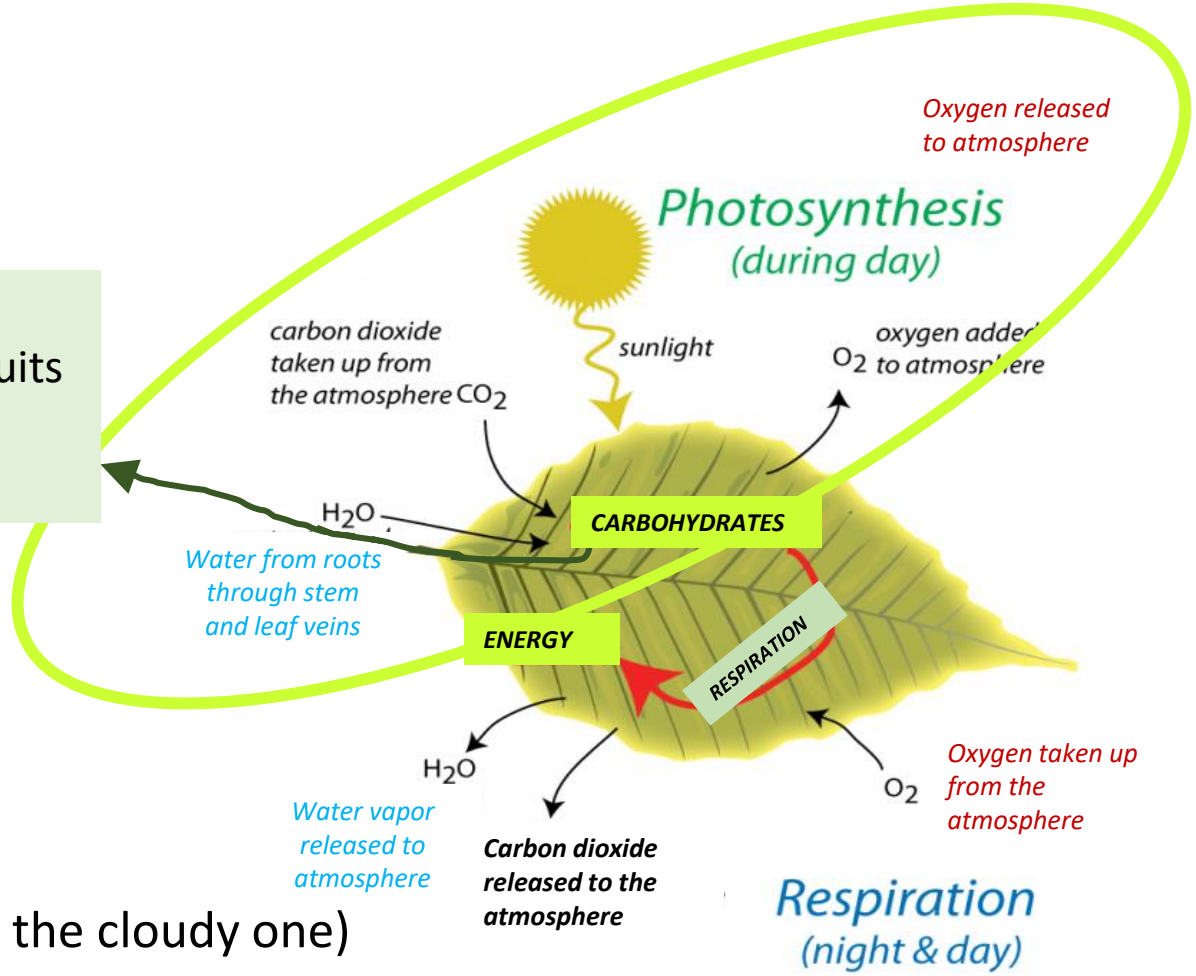


Trees (and all green plants)

- Convert the solar energy to chemical energy (sugars)
- Bind CARBON (CO_2) from atmosphere into their body
- Connect the carbon cycle and water cycle!

3) The Magic of Plants

Organic compounds
young leaves, flowers and fruits
stem (wood)
roots,



Photosynthesis runs ONLY IF:

- **The leaves receive sunlight** (during day, even during the cloudy one)
- **The temperature is not too high and not too low**
- **The leaves are green** (green pigment chlorophyll captures the light energy….)
- **The stomata are open** (CO_2 can enter the leaf)

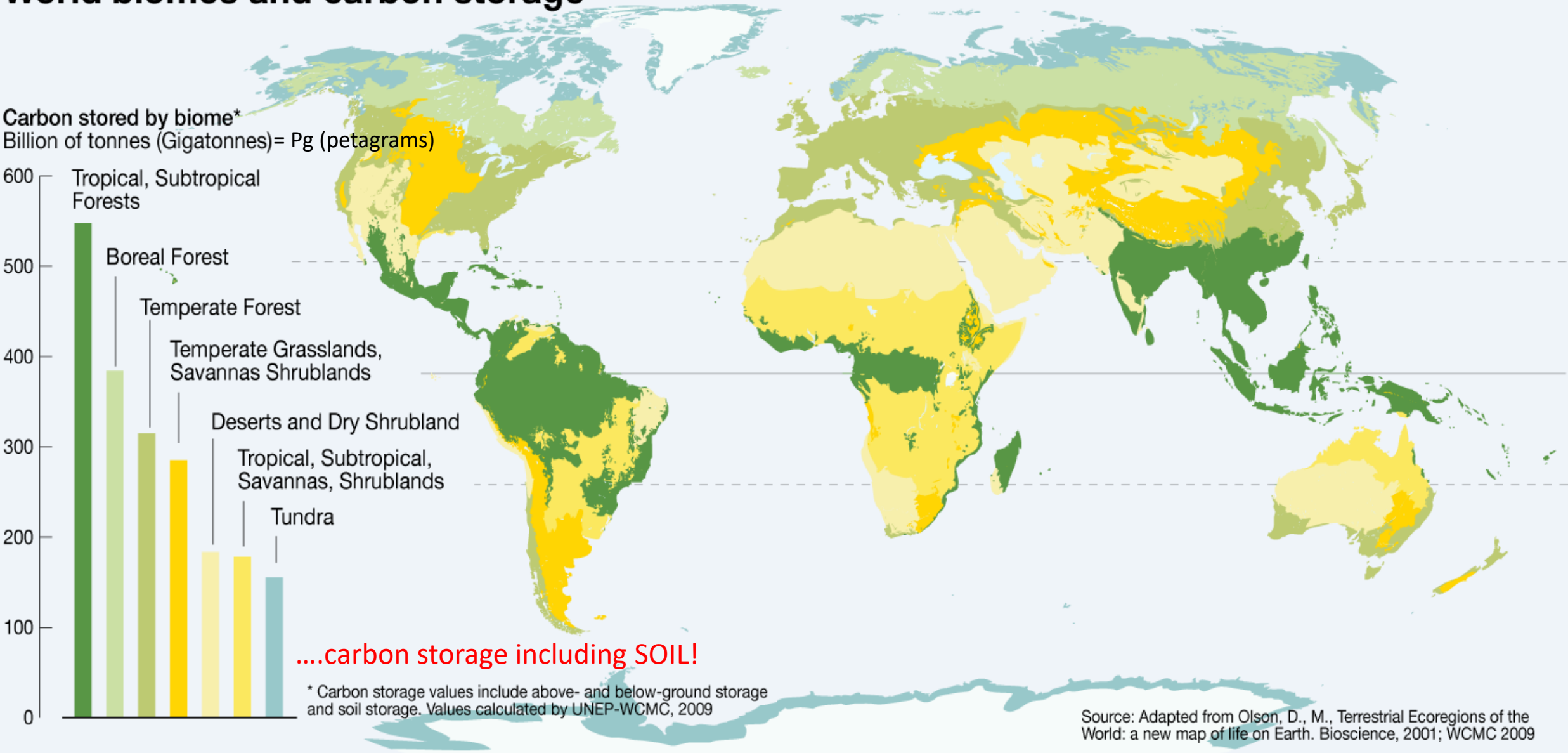
? Are these conditions always optimal around the GLOBE?

4) Biomes around the globe and their carbon storage

https://www.grida.no/resources/6940

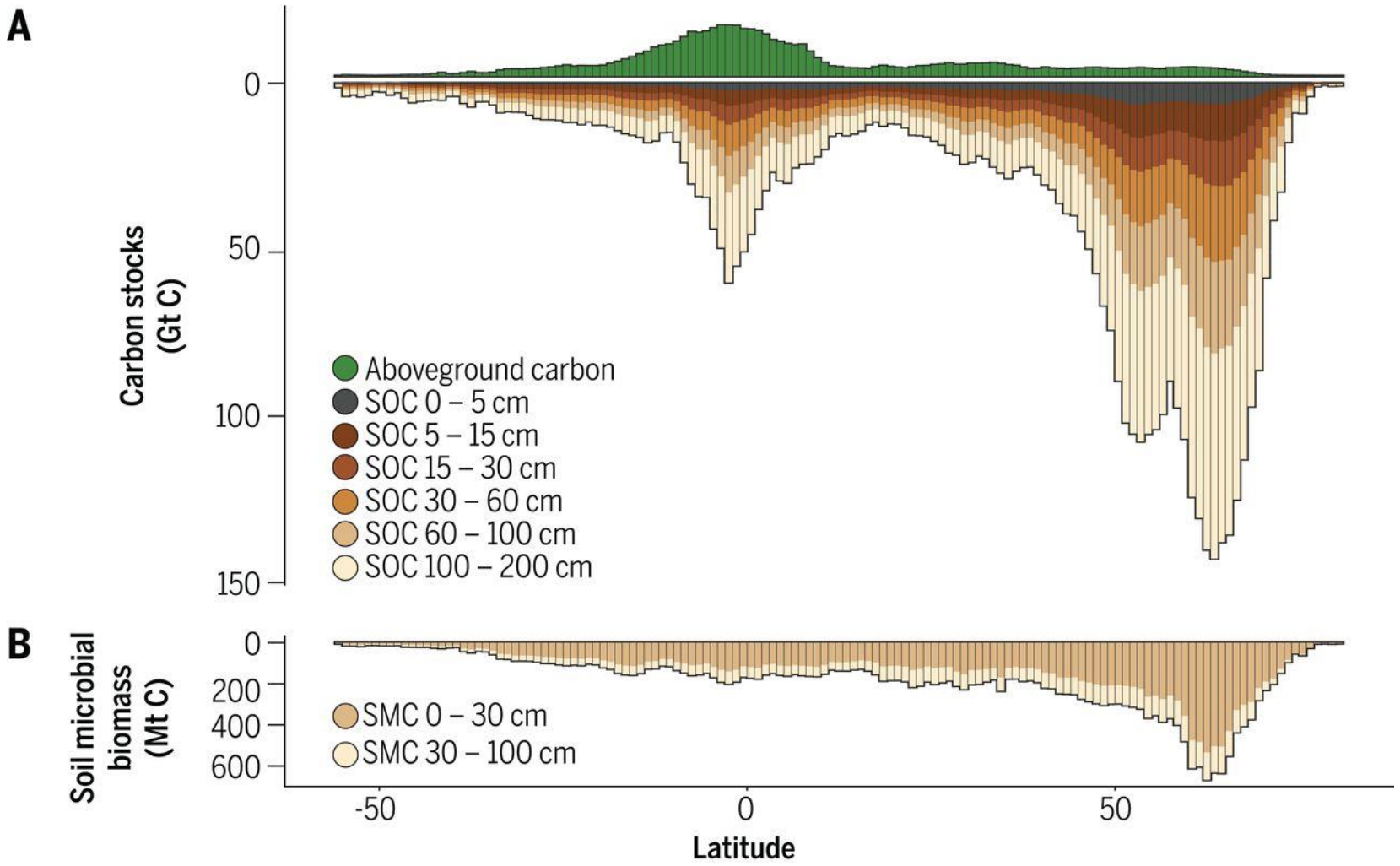
GRID ARENDAL
A UNEP Partner

World biomes and carbon storage



4) Biomes around the globe and their carbon storage

Plants are able to remove the carbon fromthe atmosphere (photosynthesis)
But the SOIL is the largest repository CARBON on land, storing ~1500 Gt carbon
….at least as much as the vegetation (~560 Gt) and atmosphere (~750 Gt) combined



Crowther et al. 2019, Science 365/6455 DOI: 10.1126/science.aav0550

From the global carbon cycle to your schoolyard ☺

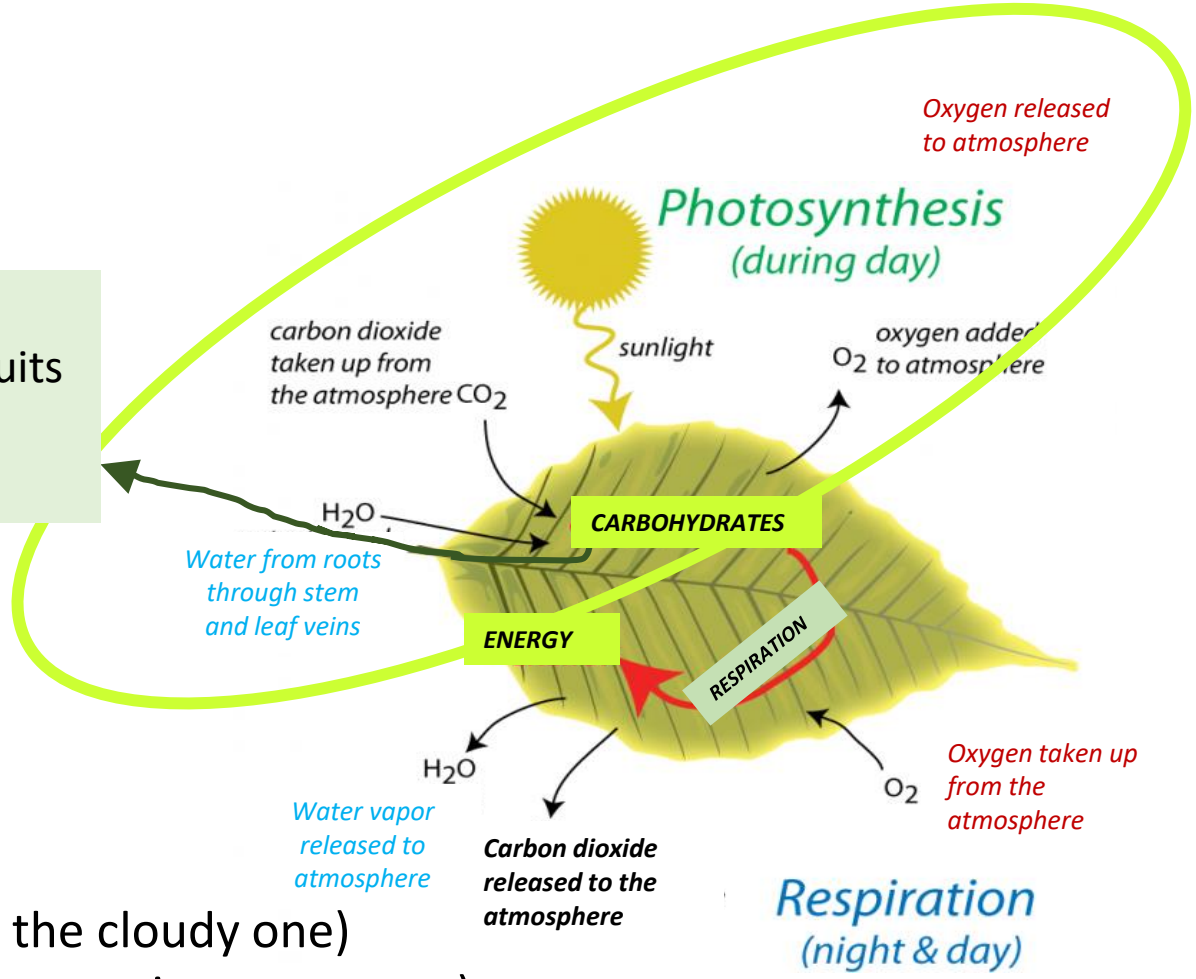
5) Trees and carbon in your schoolyard from spring to autumn

https://www.globe.gov/web/european-phenology-campaign/overview

https://www.globe.gov/web/european-phenology-campaign/overview/download-materials

5) Trees and carbon in your schoolyard from spring to autumn

Organic compounds
young leaves, flowers and fruits
stem (wood)
roots,



Photosynthesis runs ONLY IF:

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- **The temperature is not too high and not too low** (from spring to autumn)
- **The leaves are green** (green pigment chlorofyl captures the light energy….)
- **The stomata are open** (CO_2 can enter the leaf)

PHENOLOGY is important for the photosynthesis and carbon storage in plants!

5) Trees and carbon in your schoolyard from spring to autumn

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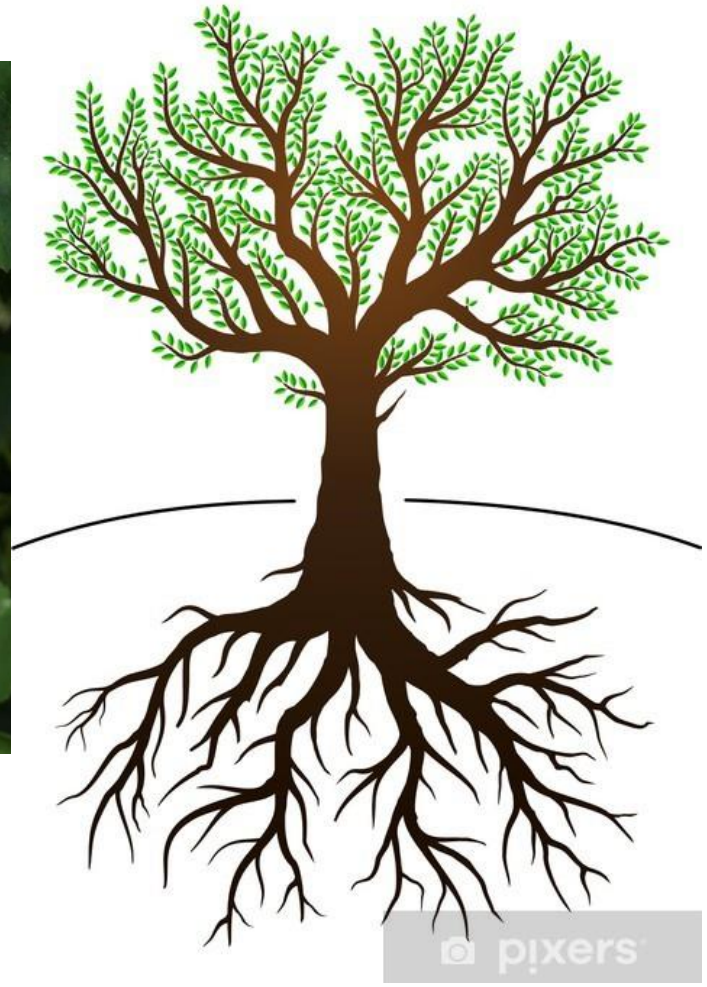
How to break buds and grow leaves if there is nothing to fotosynthesize with?

https://www.fenofaze.cz



The carbon from storage in roots and stem is brought to the buds in the form of sugars:
Here it serves as a building block for new leaves before they start photosynthesis.

5) Trees and carbon in your schoolyard from spring to autumn

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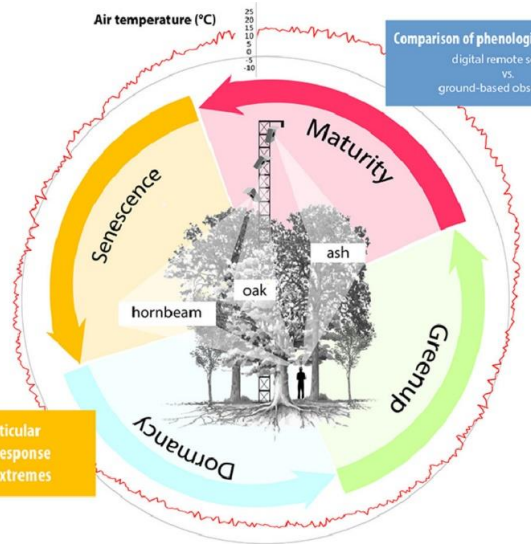


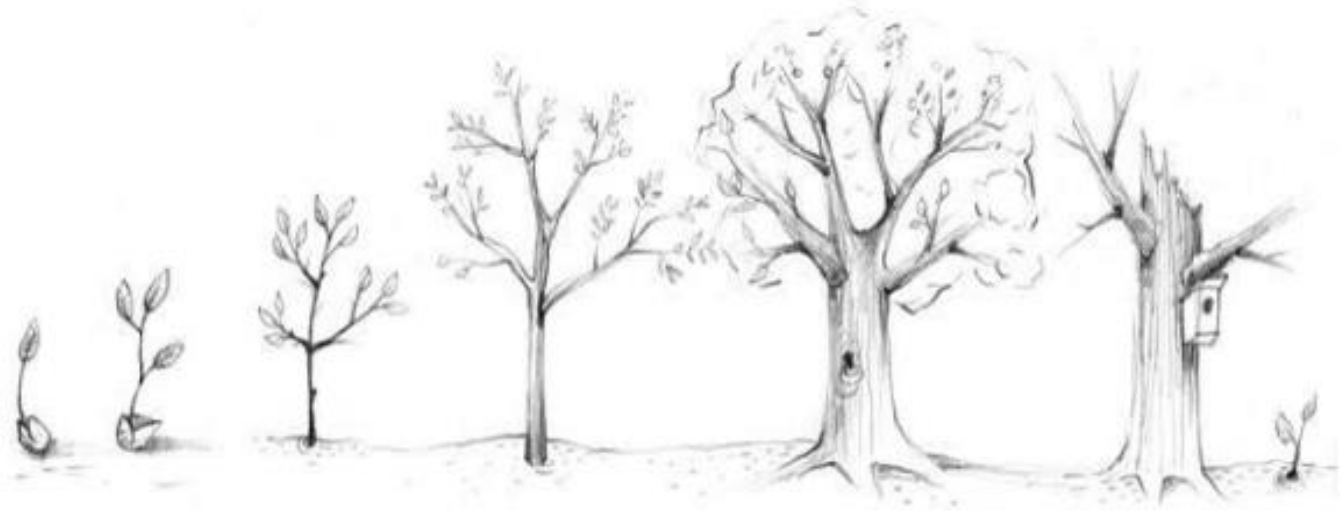
7 species observed during the European Phenology Campaign

Budburst, unfolding and growing of leaves	Leaf expansion 10-100%	Leaf senescence / greendown 10-100%	Shedding 10-100%

Graphics and photo source: O. Nezval, et al. *Agricultural and Forest Meteorology 291 (2020) 108079*

Carbon in a Life of a Tree

The CO_2 balance (carbon intake vs. release) changes over tree life cycle.

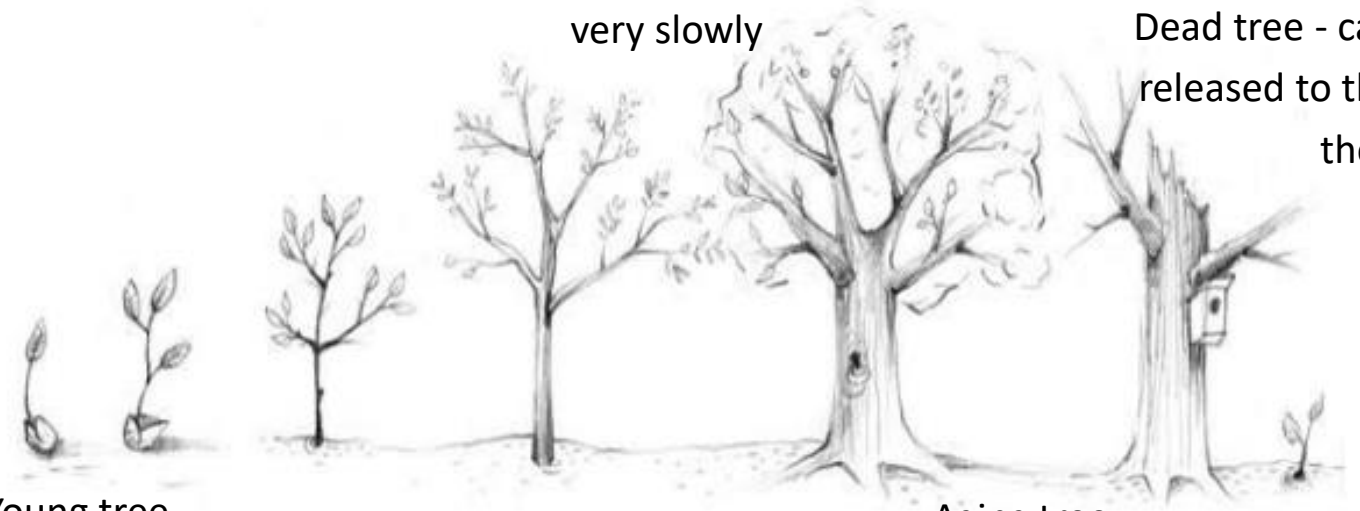


The CO_2 balance changes over tree life cycle.

Adult mature tree

- the carbon stored in the wood increases very slowly

Dead tree - carbon gradually released to the soil and into the air.



Young tree –

a natural carbon storage because of the massive carbon intake

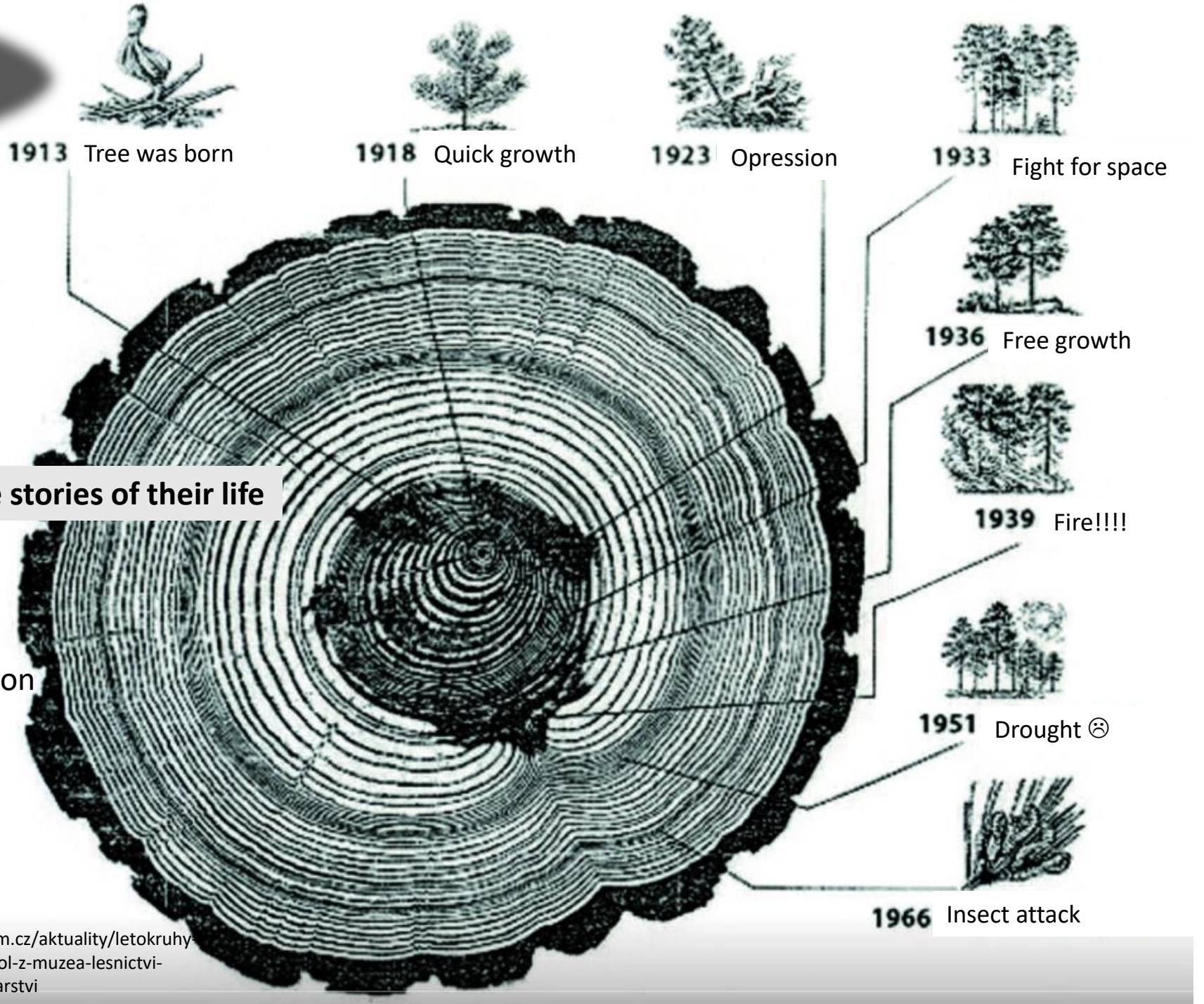
Aging tree

- the CO_2 balance comes close to zero

GLOBE CC Activity: Carbon in my tree

https://www.globe.gov/documents/18702582/85832369/A3_First+Leaves_C+in+my+Tree_Data+sheet_2022.pdf/82f3b156-e00c-36c1-34e5-f3101c5b19be?t=1642867515573

6) How to measure carbon storage in trees?



In growth rings trees tell the stories of their life

and each season store more carbon

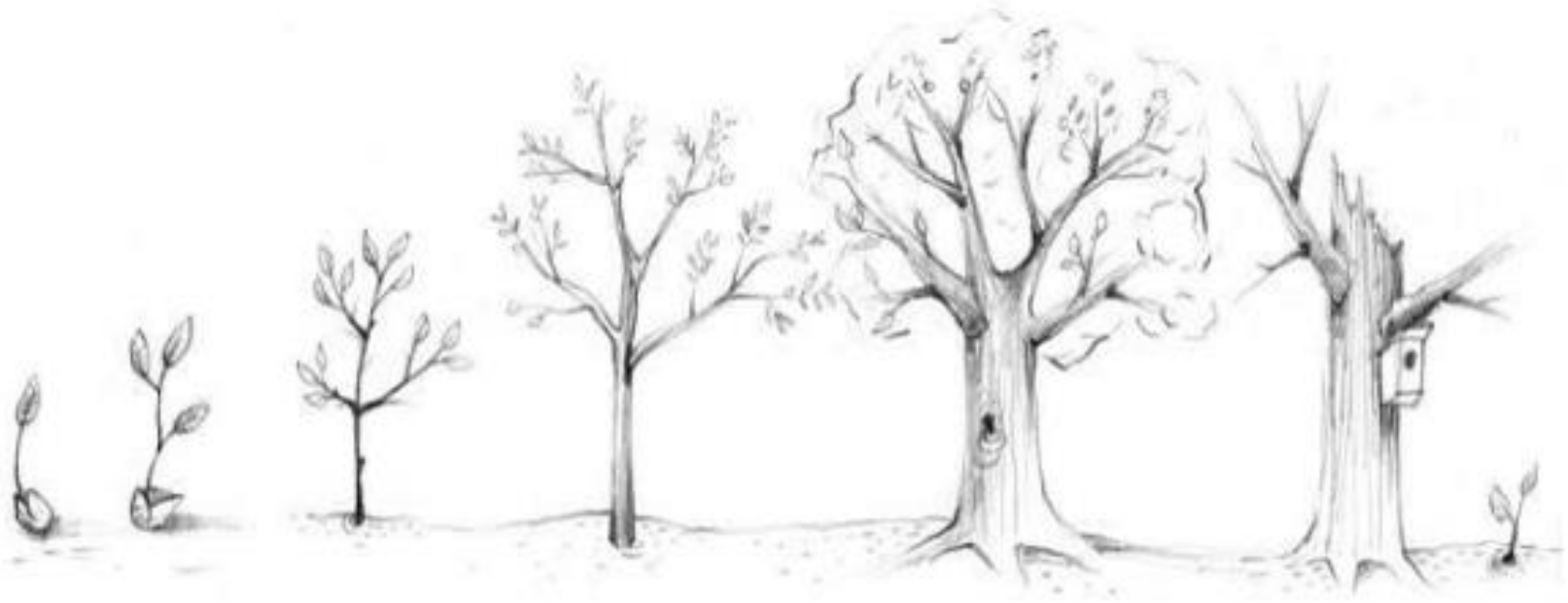
https://www.nzm.cz/aktuality/letokruhy-aneb-domaci-ukol-z-muzea-lesnictvi-myslivosti-a-rybarstvi

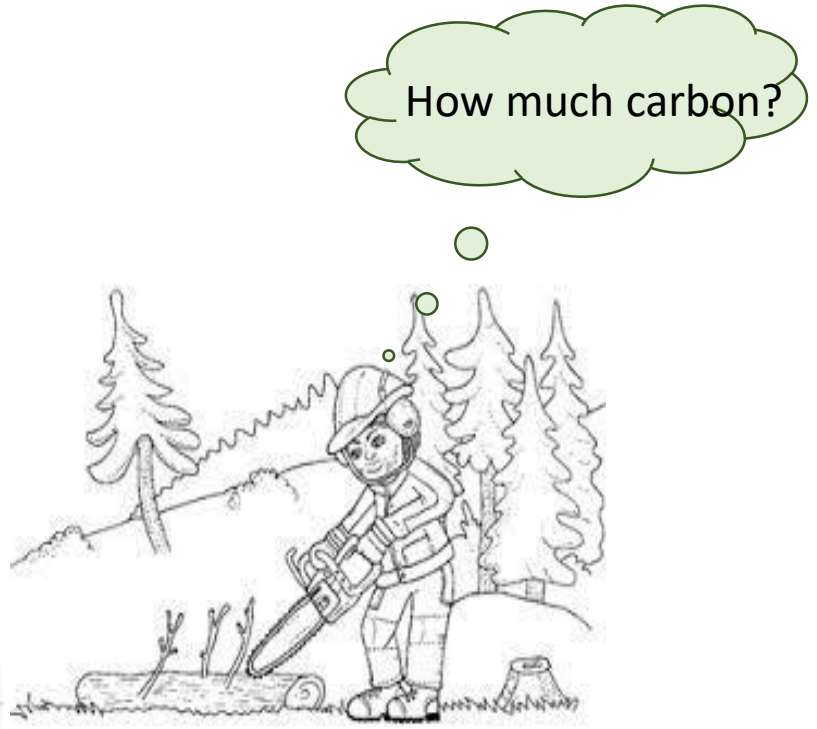
GLOBE Activity: Stories Trees Tell

https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwjezrrMg936AhUKQvEDHTVYC3oQFnoECBEQAQ&url=https%3A%2F%2Fobserver.globe.gov%2Fdocuments%2F19589576%2F61b215e4-4ace-6145-f13f-da477ad391f7&usg=AOvVaw2eV33V8dF-V_Njd3qqSdjo

6) How to measure carbon storage in trees?

How to measure trees biomass and carbon storage without cutting it?





www.lesnipedagogika.cz

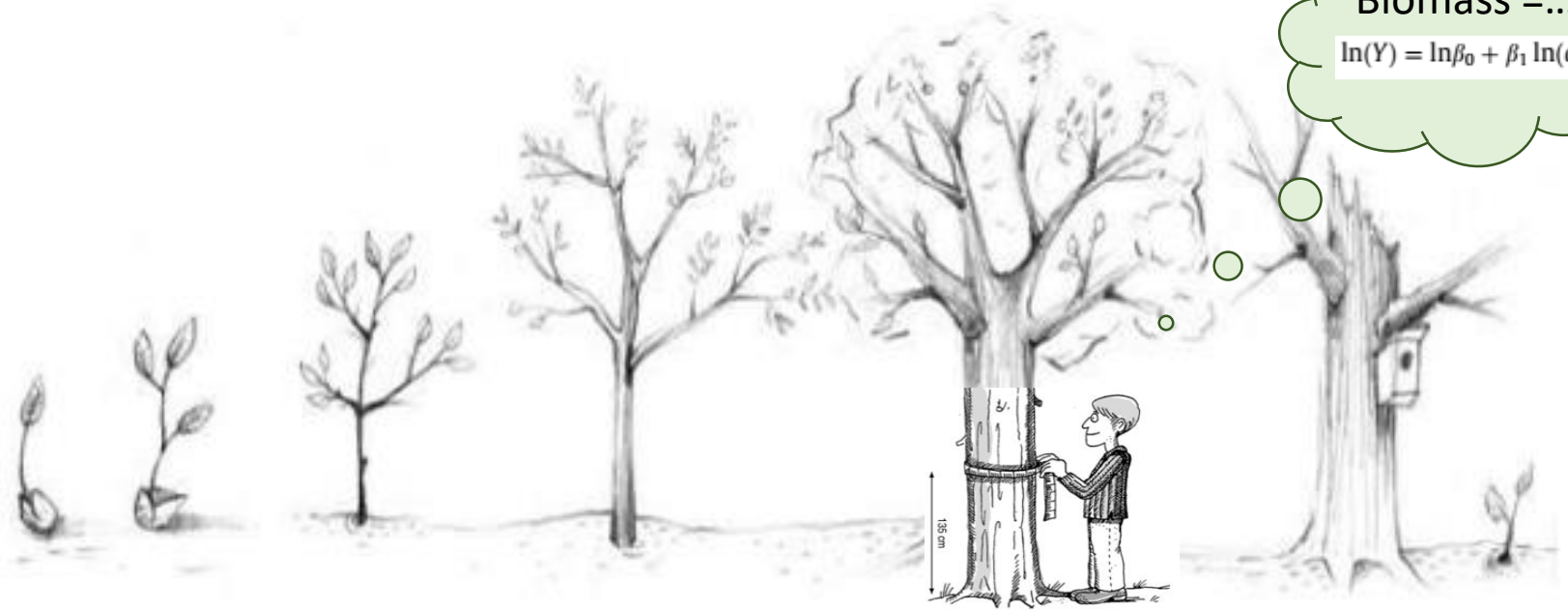
6) How to measure carbon storage in trees?

How to measure trees biomass and carbon storage without cutting it?

Allometry !!!

Biomass =….

$$\ln(Y) = \ln\beta_0 + \beta_1 \ln(d) + \varepsilon$$



Allometry is the study of an organism's growth as is used to describe the **relationship between an organism's size and the size of any of its parts**.

Total tree biomass (stored carbon)

Something easily measurable?

Stored carbon (=0,5 x biomass)

6) How to measure carbon storage in trees?

How to measure trees biomass and carbon storage without cutting it?

Allometric relationship is can be expressed methematically as an **ALLOMETRIC EQUATION**

y: Total tree biomass
x: DBH (diamete at brest height)

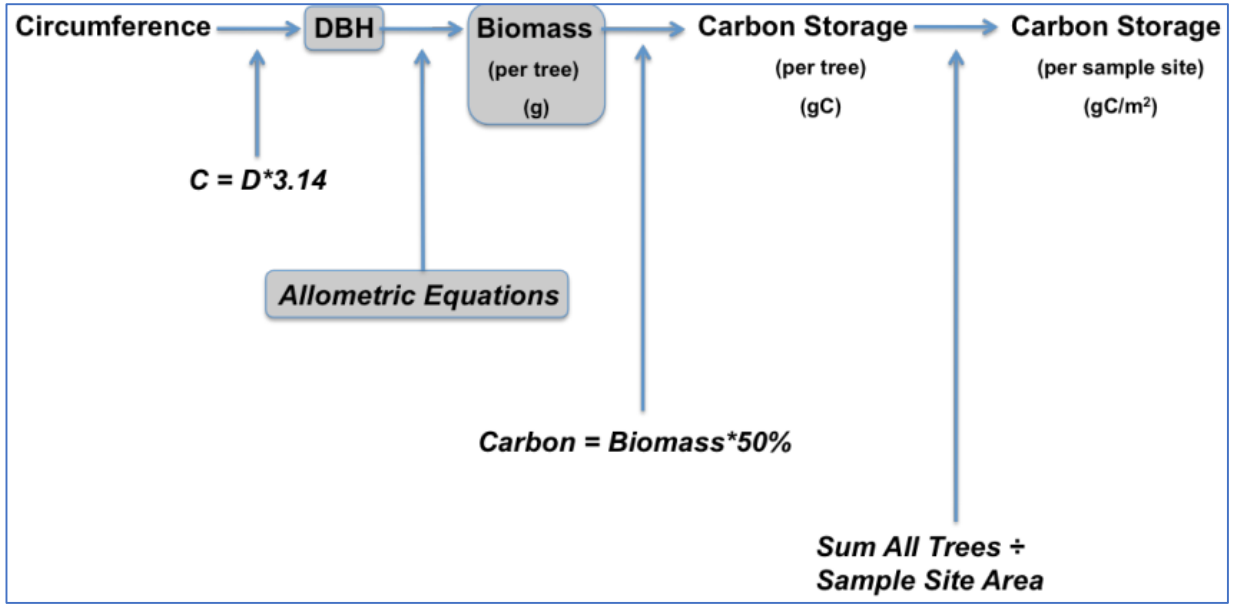
$$\ln(y) = a + b[\ln(x)]$$

A log transformation will allow you to solve for y:

$$y = e^{(a + b[\ln(x)])}$$

biomass = Exp(B0 + B1 ln DBH)
where ln = log base e (or 2.718282)

GLOBE CC Activity: Allometry – Not a Llama Tree
https://www.globe.gov/documents/355050/5e499328-5723-4bb5-a2f7-f4a1ca95ce42



6) How to measure carbon storage in trees?

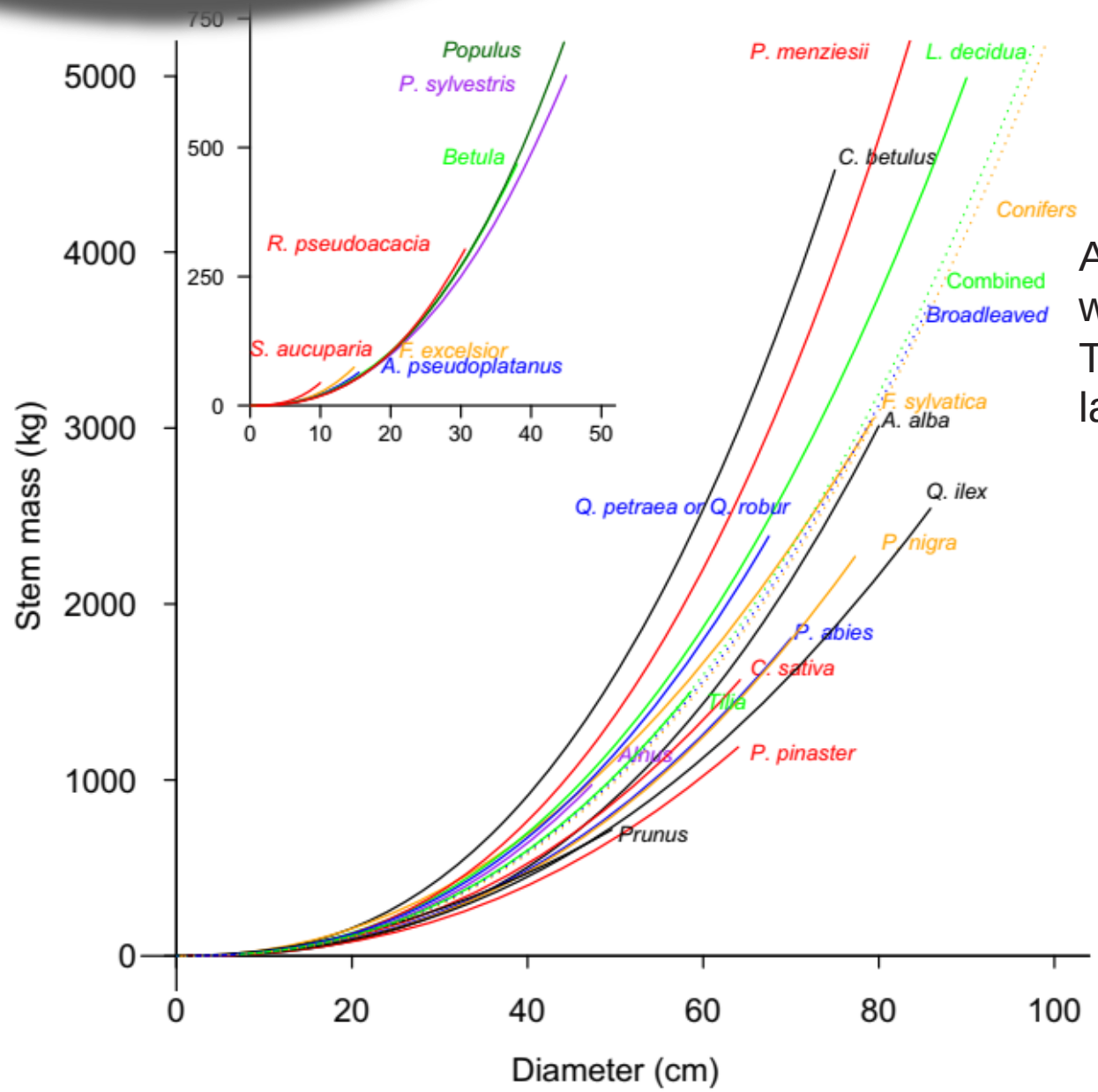
7 species from the European Phenology Campaign:

Do they store the same amount of carbon?
Do they share the same allometric equation?

GLOBE CC Activity: Carbon in my tree – carbon storage calculator – Workshop Activity 4
https://www.globe.gov/documents/18702582/64403483/carbon+storage+calculator.xlsx/0750bee6-a5c7-46b5-9824-bcadce10b7a8

6) How to measure carbon storage in trees?

Allometric equations are species-specific



Although a similar equation exists for all trees, they will differ slightly for different tree species groups. These equation differences between species groups largely exist due to differences in tree wood density.

Forest Ecology and Management 396 (2017) 160–175

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Generalized biomass and leaf area allometric equations for European tree species incorporating stand structure, tree age and climate

David I. Forrester [a,b,*], I.H.H. Tachauer [c], Peter Annighoefer [d], Ignacio Barbeito [e], Hans Pretzsch [c], Ricardo Ruiz-Peinado [f,g], Hendrik Stark [b], Giorgio Vacchiano [h], Tzvetan Zlatanov [i], Tamalika Chakraborty [j], Somidh Saha [b,k], Gudeta W. Sileshi [l]

6) How to measure carbon storage in trees?

Do they store the same amount of carbon?
Do they share the same allometric equation?

YOUR DATA			RESULTS			
Tree name	Tree species	Circumference (cm)	Aboveground Biomass (g)	Aboveground Carbon Storage (g C)	Total Biomass (g)	Total Carbon Storage (g C)
	click to choose from a list		#N/A	#N/A	#N/A	#N/A
			#N/A	#N/A	#N/A	#N/A
			#N/A	#N/A	#N/A	#N/A

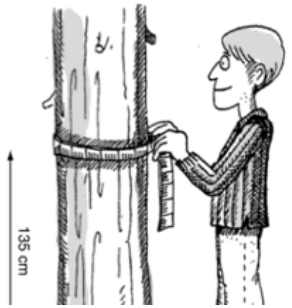
click to choose from a list
Beech (Fagus sylvatica)
Birch (Betula pendula)
Sour cherry (Prunus cerasus)
Hazel (Corylus avellana)
Lime (Tilia cordata)
Oak (Quercus robur)

Legend

Tree name: Enter the name of your tree or its number.

Tree species: Choose from a list of tree species that will open, when you click on the field.

Circumference: Enter tree circumference in centimeters. The tree circumference should be measured at brest hight (1.35m measured from the highest point of ground at the base of the tree). If your tree is "badly



GLOBE CC Activity: Carbon in my tree – carbon storage calculator – Workshop Activity 4

https://www.globe.gov/documents/18702582/64403483/carbon+storage+calculator.xlsx/0750bee6-a5c7-46b5-9824-bcadce10b7a8

7) Trees, carbon cycle and the global climate change

Global carbon cycle

Pools:
Places where carbon stays some time in various forms.
- From minutes to milliones of years!

Fluxes:
Ways (processes), by which carbon travels among the pools.

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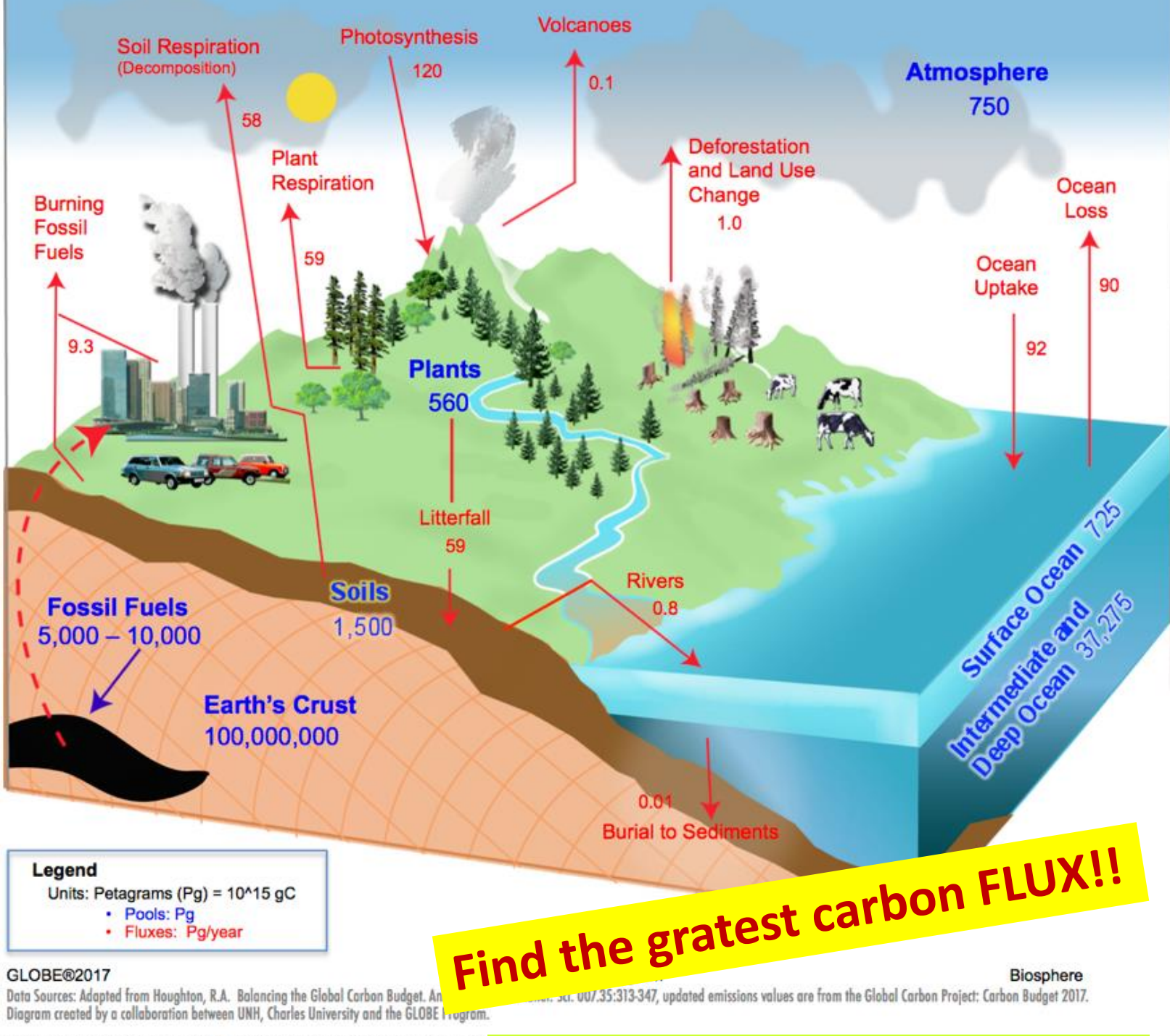


Find the gratest carbon FLUX!!

7) Trees, carbon cycle and the global climate change

Back from your schoolyard…
to the global carbon cycle and global climate change

Carbon dioxide is a greenhouse gas. It traps heat in the atmosphere and warms the Earth.

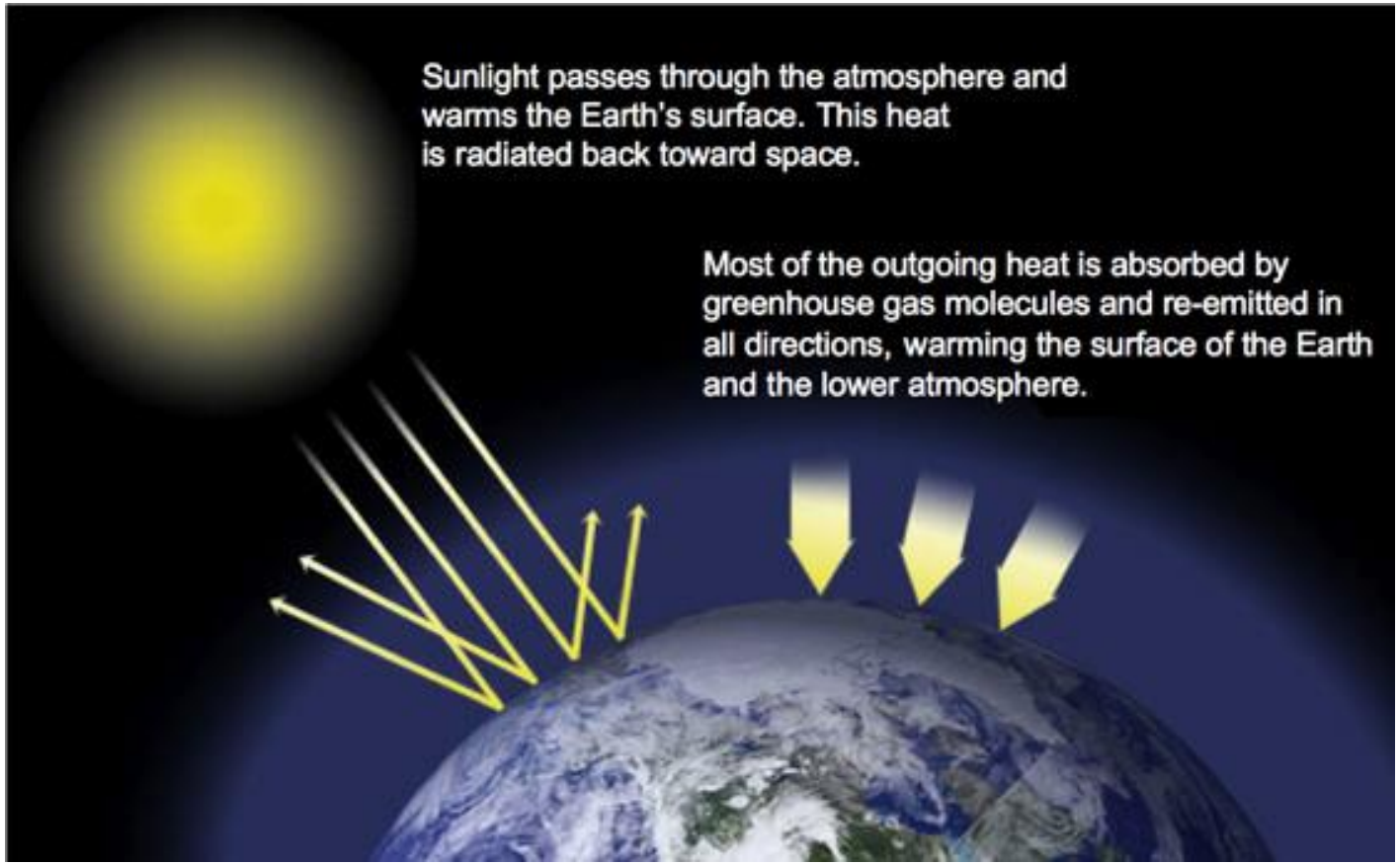
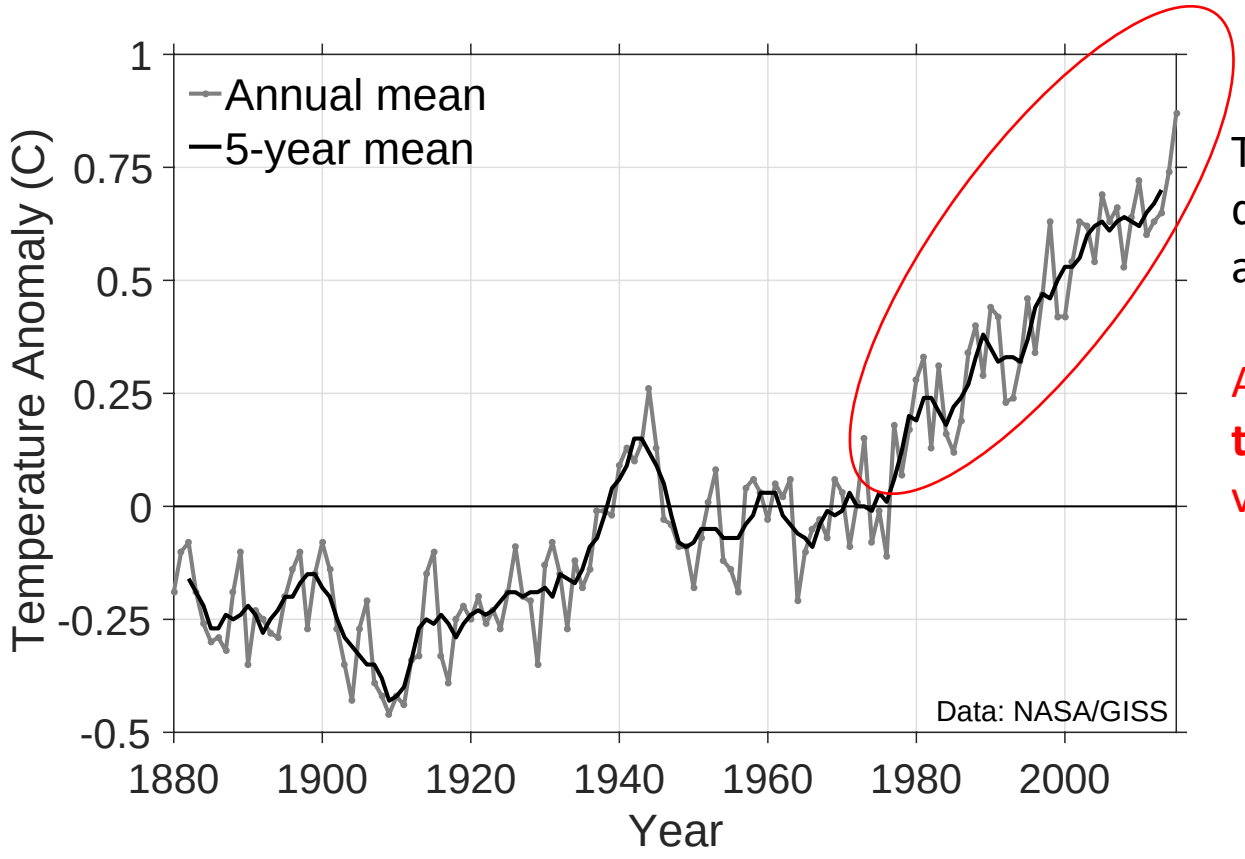


Image: NASA

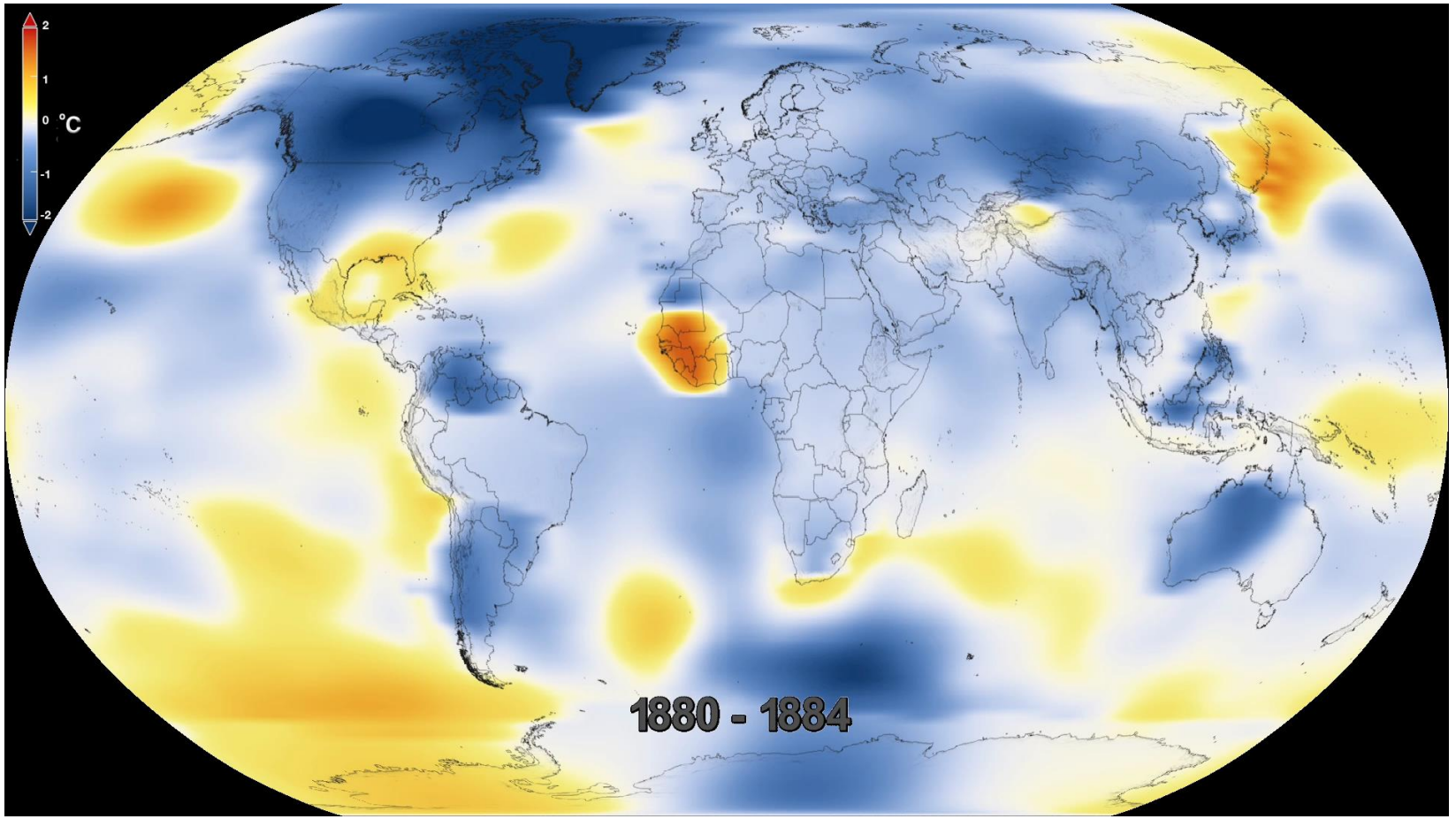
Increases in atmospheric CO_2 have contributed to a rise in Earth's temperature.



The term **temperature anomaly** means a departure from a reference value or long- term average, in this case 1951-1980.

A positive **anomaly** indicates that the observed **temperature** was warmer than the reference value.

Increases in atmospheric CO_2 have contributed to a rise in Earth's temperature.



Movie: NASA Scientific Visualization Studio

7) Trees, carbon cycle and the global climate change

Back from your schoolyard…
to the global carbon cycle and global climate change

How to watch CO_2 in the atmosphere?

CO_2 absorbs infrared radiantion

- that is why acts as a greenhouse gas (warming)
- NASA spaceborne instruments measure infrared ratiation and thus the CO_2 concentration in the middle troposphere (altitude of 5 to 10 km)

7) Trees, carbon cycle and the global climate change

Back from your schoolyard…
to the global carbon cycle and global climate change

How to watch trees photosynthesizing?

Green chlorophyll in leaves absorbs red light and reflects green

- that is why we see leaves green
- NASA spaceborne instruments measure visible and infrared ratiation and thus the canopy greeness (photosynthesis) could be calculated

https://modis.gsfc.nasa.gov/data/dataprod/mod13.php

Scientific Visualization Studio

7) Trees, carbon cycle and the global climate change

Back from your schoolyard…
to the global carbon cycle and global climate change

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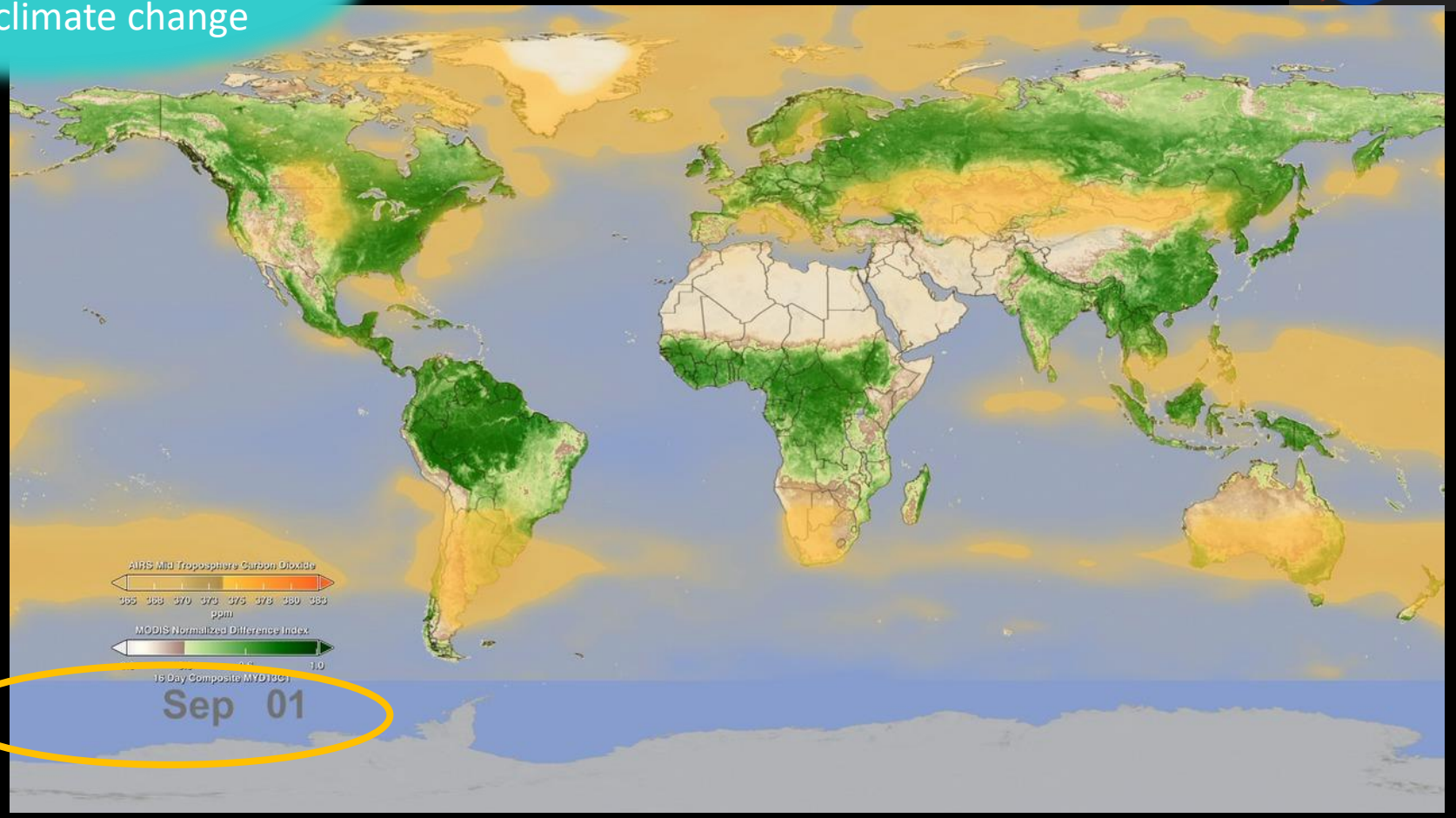
So….can we check GLOBALLY what time of the year trees build in the biggest amount of carbon into its biomass?

7) Trees, carbon cycle and the global climate change

Scientific Visualization Studio



Date
Month / day

Index of canopy greenness

MODIS Normalized Difference Index

0.0 0.3 0.6 1.0

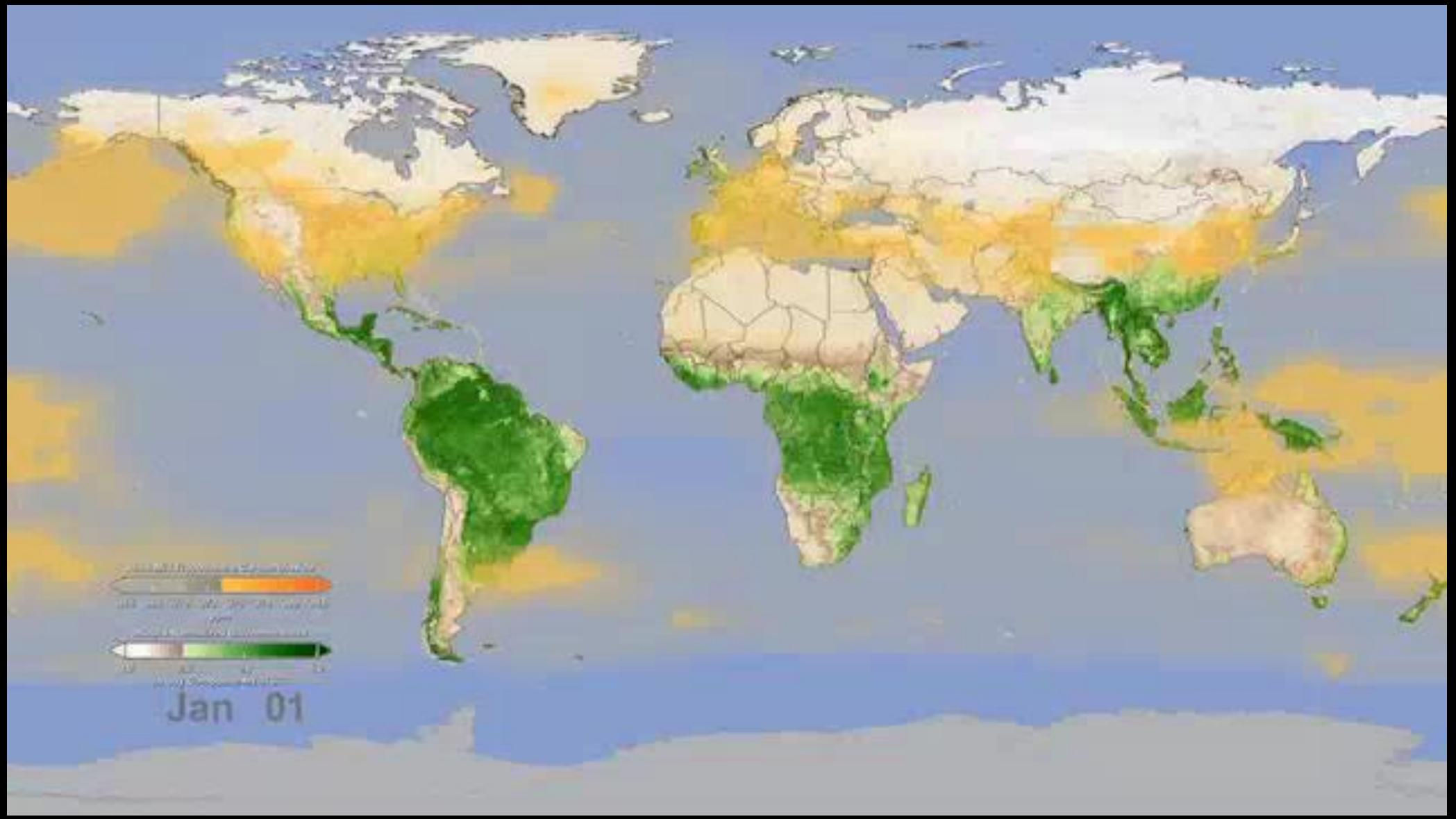
16 Day Composite MYD13C1

AIRS Mid Troposphere Carbon Dioxide

365 368 370 373 375 378 380 383

ppm

https://svs.gsfc.nasa.gov/3947 Watching the Earth Breathe: An Animation of Seasonal Vegetation and its effect on Earth's Global Atmospheric Carbon Dioxide



MODIS Normalized Difference Index

0.0 0.3 0.6 1.0

16 Day Composite MYD13C1

AIRS Mid Troposphere Carbon Dioxide

365 368 370 373 375 378 380 383

ppm

Role of Trees in Global Carbon Cycle

7) Trees, carbon cycle and the global climate change

Long term trend of CO_2 concentration increase 1-3 parts per million annualy (ppm = 0,0001%) since 1958.

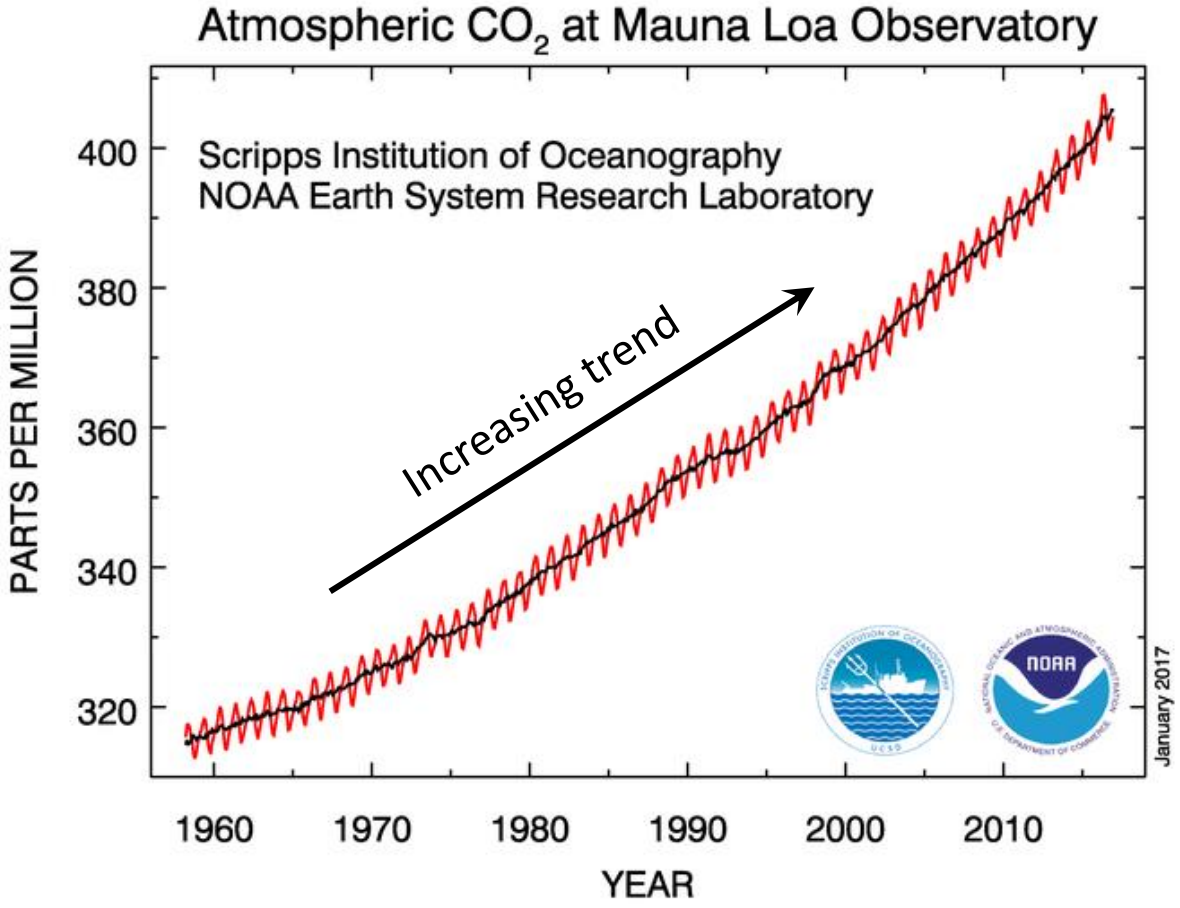
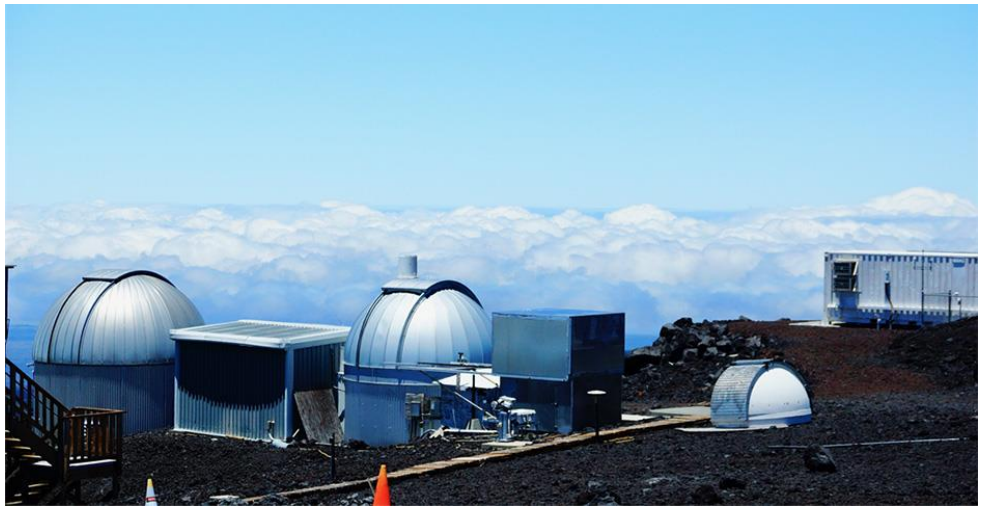


Image: ersl.noaa.gov



https://www.eenews.net/stories/1063734325/print

7) Trees, carbon cycle and the global climate change

A closer look at several years of CO_2 concentrations reveals a zig-zag pattern, a seasonal cycle.

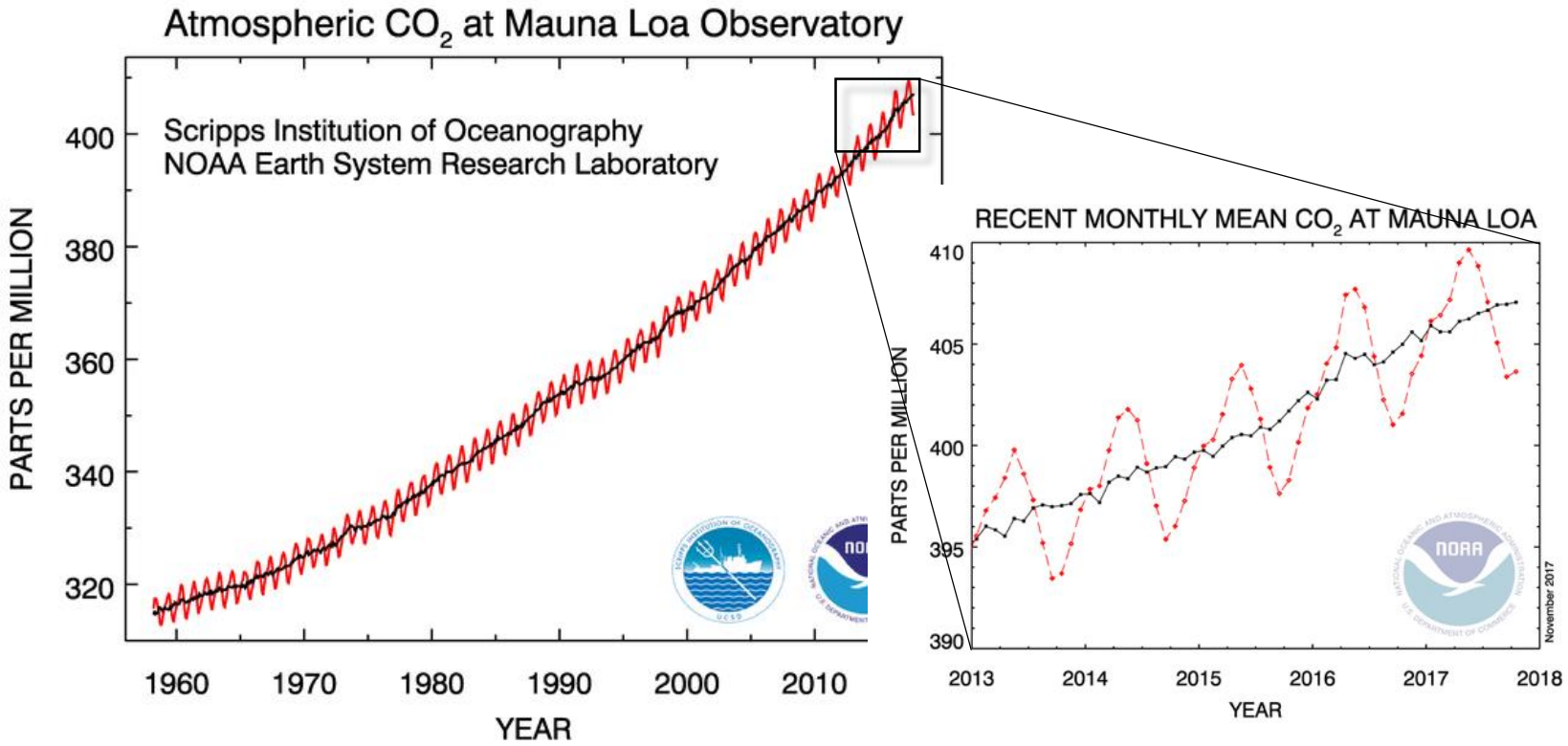


Image: ersl.noaa.gov

7) Trees, carbon cycle and the global climate change

The "rising arm" of the zig-zag coincides with periods when *respiration exceeds photosynthesis,* in other words, the biosphere is releasing more CO_2 to the atmosphere than it is absorbing.

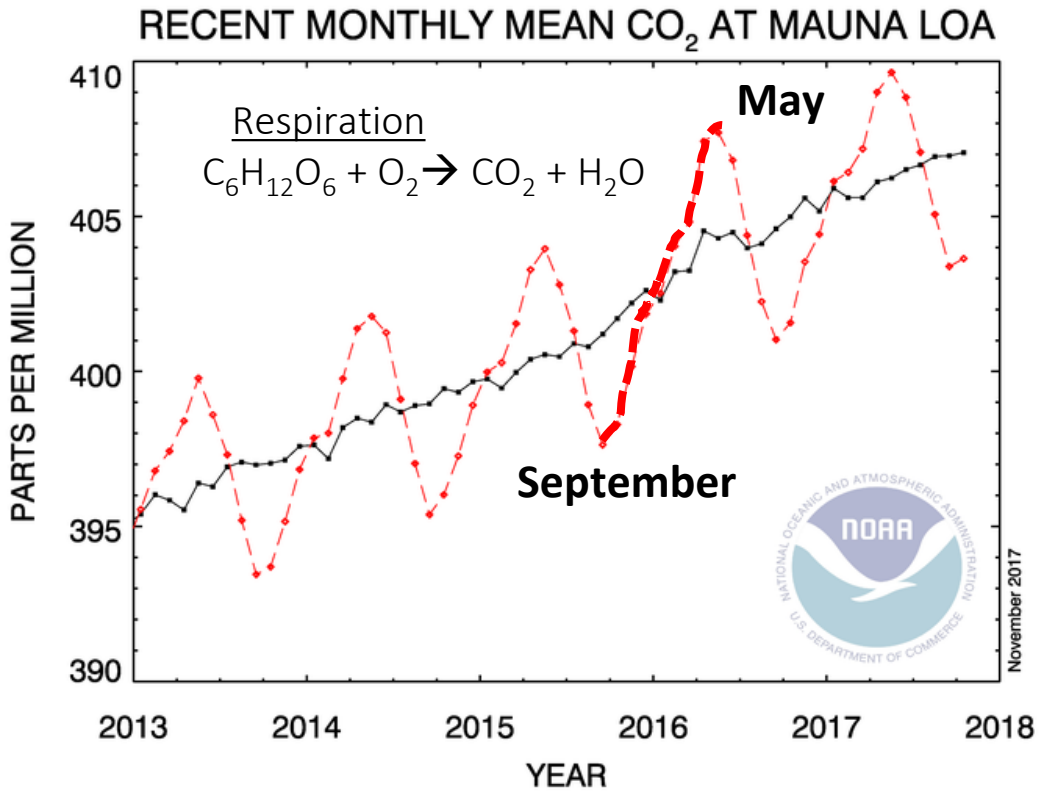


Image: ersl.noaa.gov

7) Trees, carbon cycle and the global climate change

The "falling arm" of the zig-zag coincides with periods when *photosynthesis exceeds respiration,* in other words, the biosphere is taking up more CO_2 from the atmosphere than it is releasing.

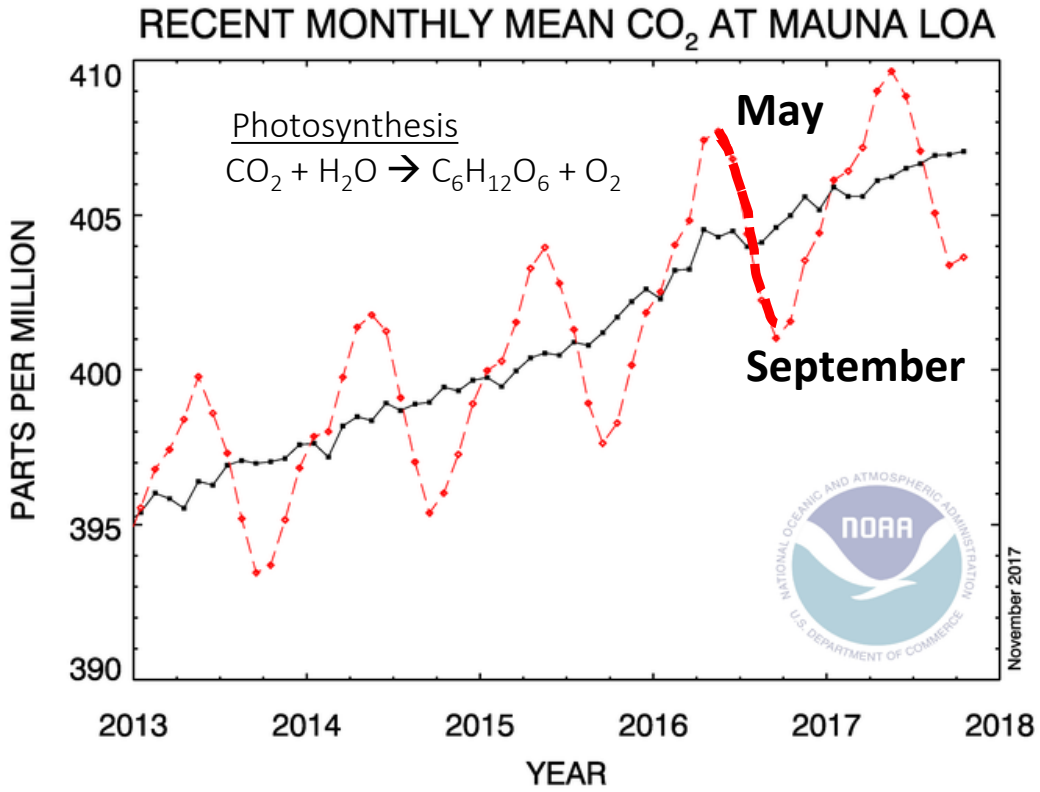
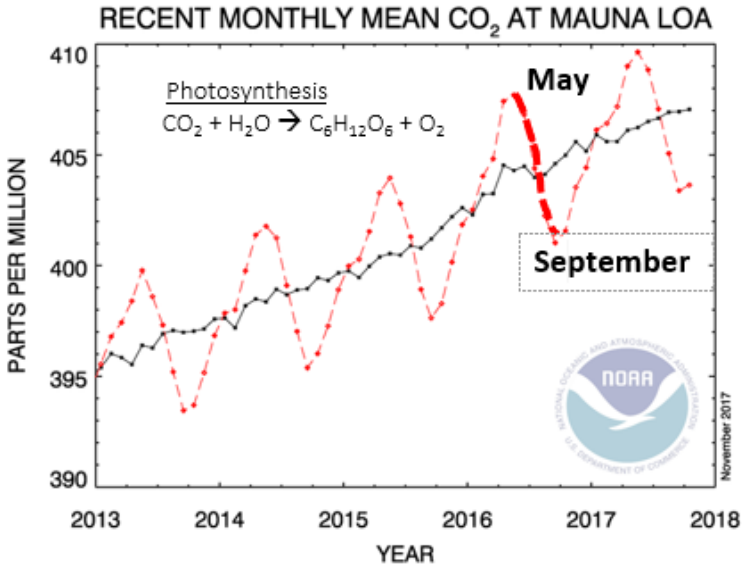


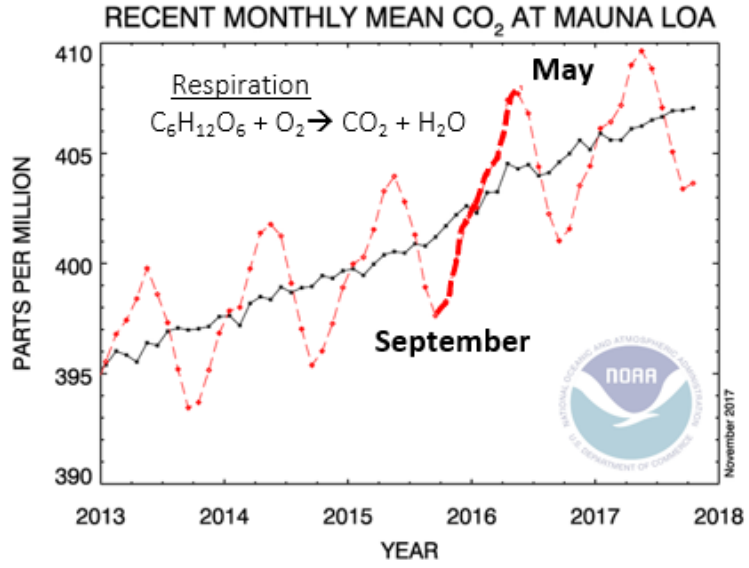
Image: ersl.noaa.gov

Role of Trees in Global Carbon Cycle

- CO_2 level oscilation corresponds with the "green wave" in vegetation of the northern hemisphere
  - **spring-summer: biosphere takes up more CO_2 than it releases**
  - **autumn-winter: biosphere releases more CO_2 to the atmosphere than it absorbs**

- **Forests keep amount of carbon in balance** - exchange carbon between air, plants, animals and soil
- **Trees of the northern hemisphere** influence carbon cycle of the whole planet



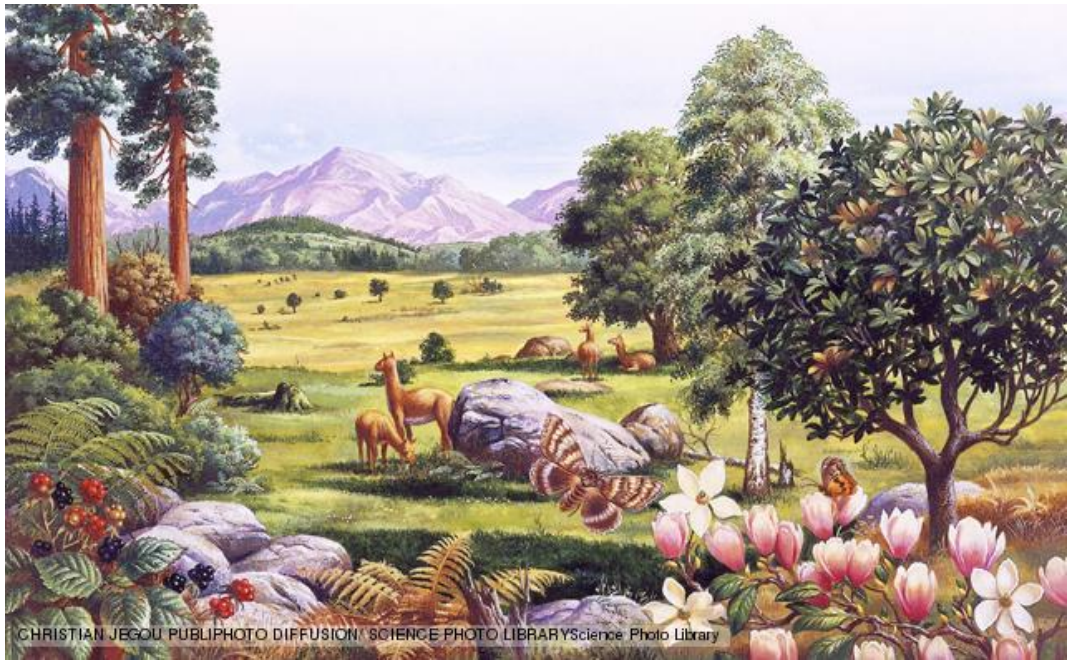


GLOBE CC Activity: The Case of Missing Carbon

https://www.globe.gov/documents/18702582/85832369/A4_My+Data_Case+of+Missing+C_Data+Guide_2022.pdf/b5a9ea3f-3651-b24e-db50-93c28ebfb858?t=1642867539581

Why Collect Carbon Cycle Data?

The last time in Earth's history CO_2 levels were this high was over 3 million years ago, during the mid-Pliocene Warm Period. The increase in atmospheric CO_2 occurred over thousands of years. Sea level was 5-20 m higher, global air temperatures were 4°C warmer, and global sea surface temperatures were 2°C warmer.

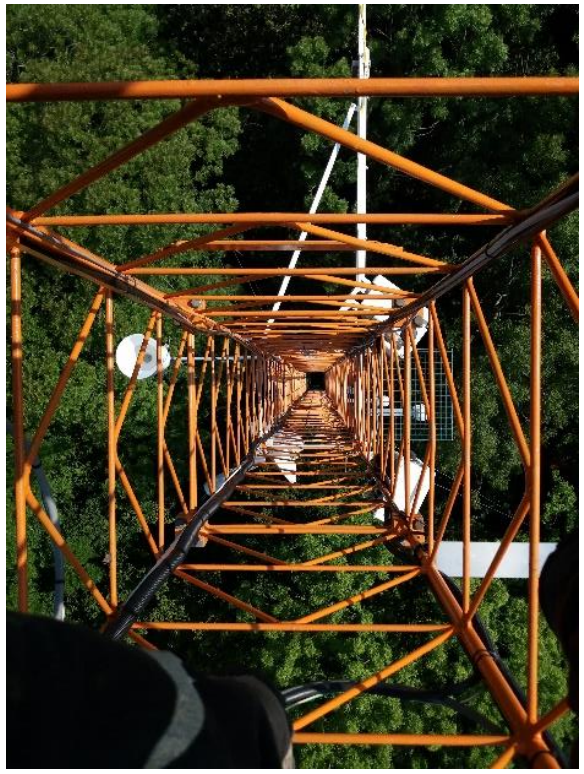


Today, we are increasing atmospheric CO_2 at a **rate** faster than we've ever seen in the geologic record.

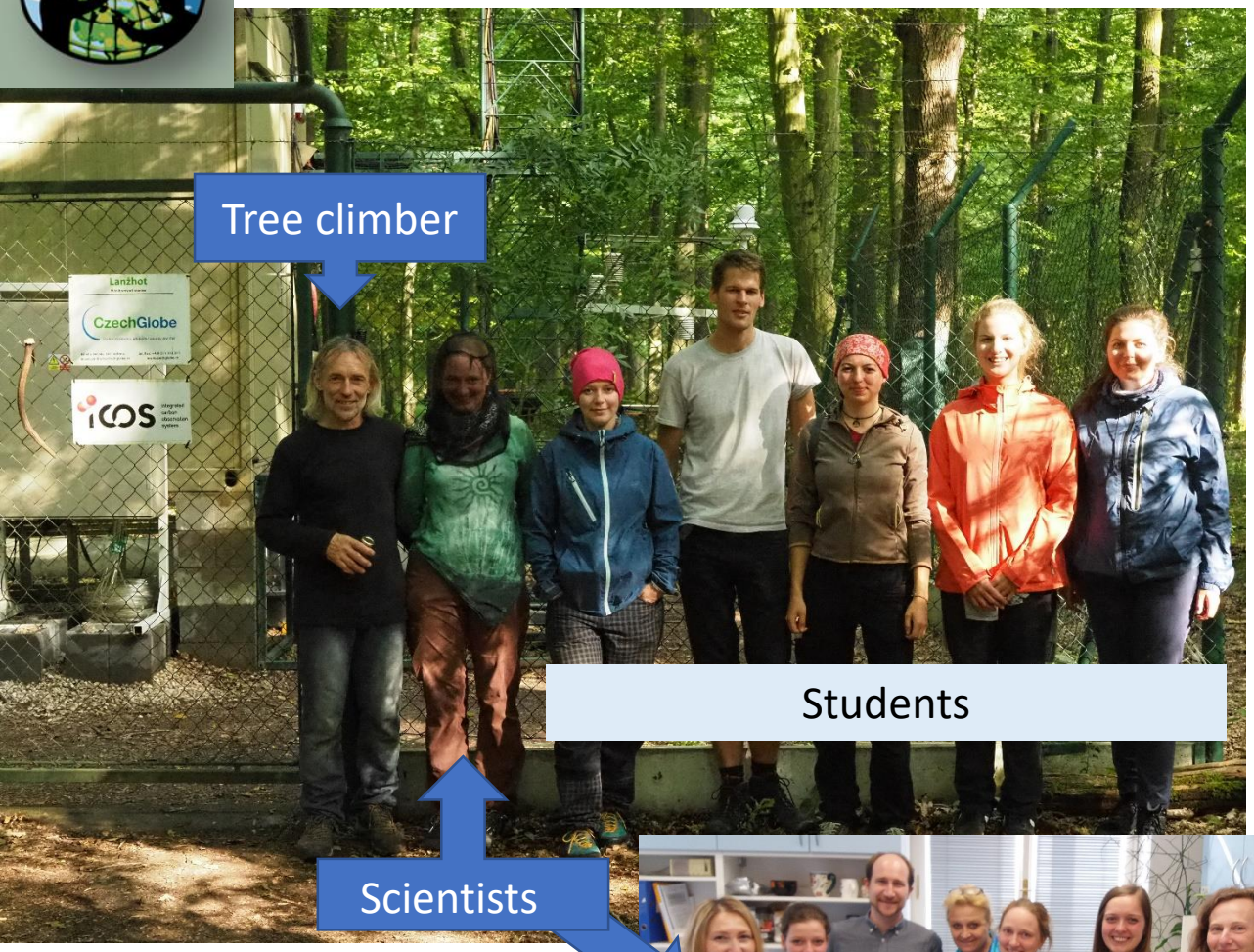
Why Collect Carbon Cycle Data?

Scientists collect carbon cycle data to understand how terrestrial ecosystems will respond to warmer temperatures and higher CO_2.

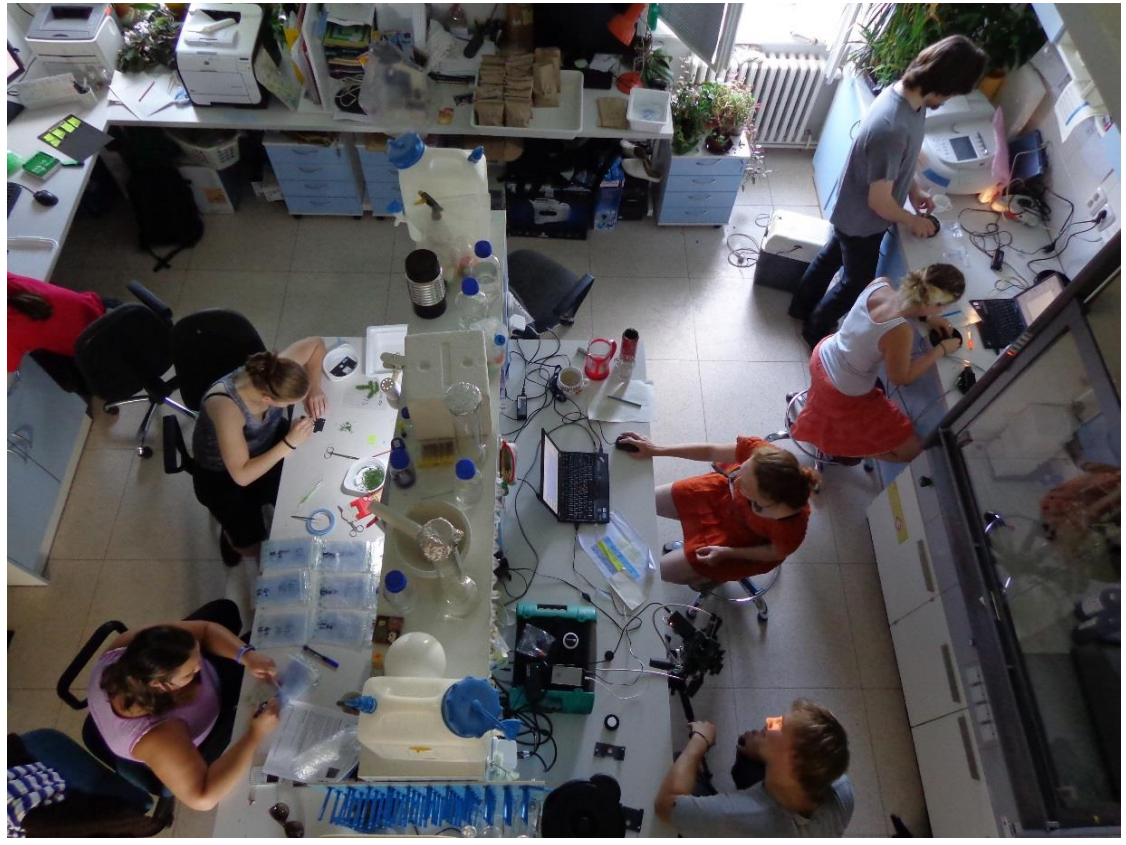
Carbon cycle data collected with GLOBE will contribute to a better understanding of the relationship between carbon storage in plants and surface climate.



To understand the carbon cycle, the COLLABORATION is NESECCARY!!!

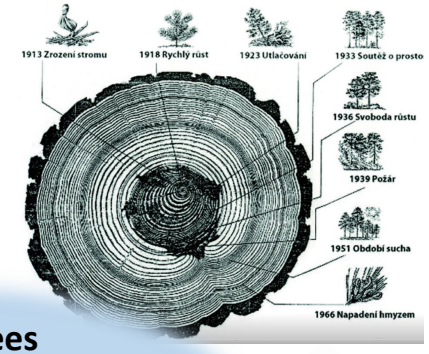


TIME FOR QUESTIONS!!!!



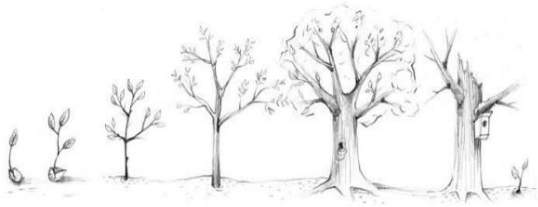
Thank you for your attention!

Carbon cycle, biomes, forests and climate change… Introductory lecture (40 min)



ACTIVITY 1:
How to measure trees
Relation of tree circumference and diameter, exploring tree cookies

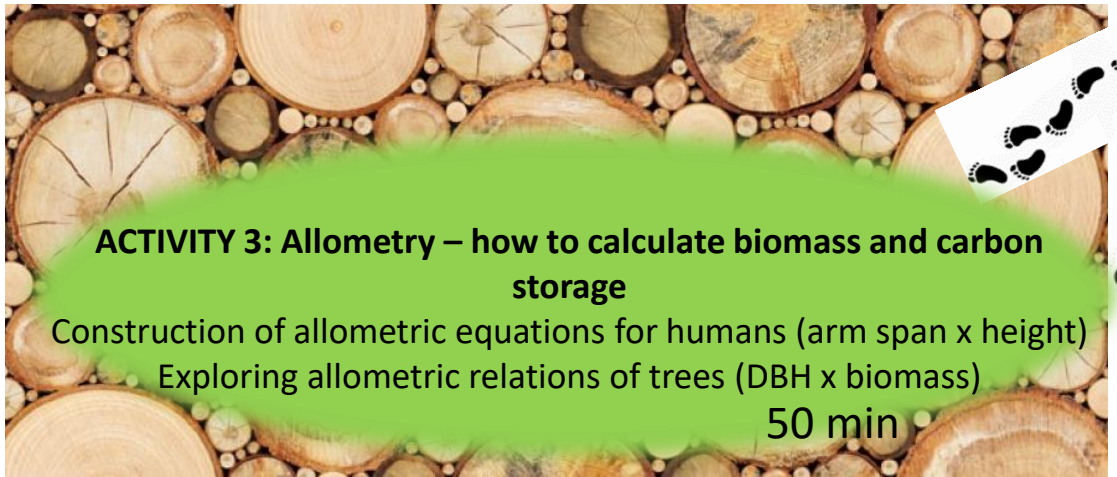
30 min



ACTIVITY 2: Biomass units
Calculating the biomass of participants
Comparing biomass and carbon storage among biomes

30 min

(Coffee) BREAK
30 min



ACTIVITY 3: Allometry – how to calculate biomass and carbon storage
Construction of allometric equations for humans (arm span x height)
Exploring allometric relations of trees (DBH x biomass)

50 min

ACTIVITY 4: Tree carbon storage mapping
Measuring real tree circumference
Calculating carbon storage
Evaluating tree carbon benefits

40 min