Bolygónk nagy rendszerei: az atmoszféra és a világóceán

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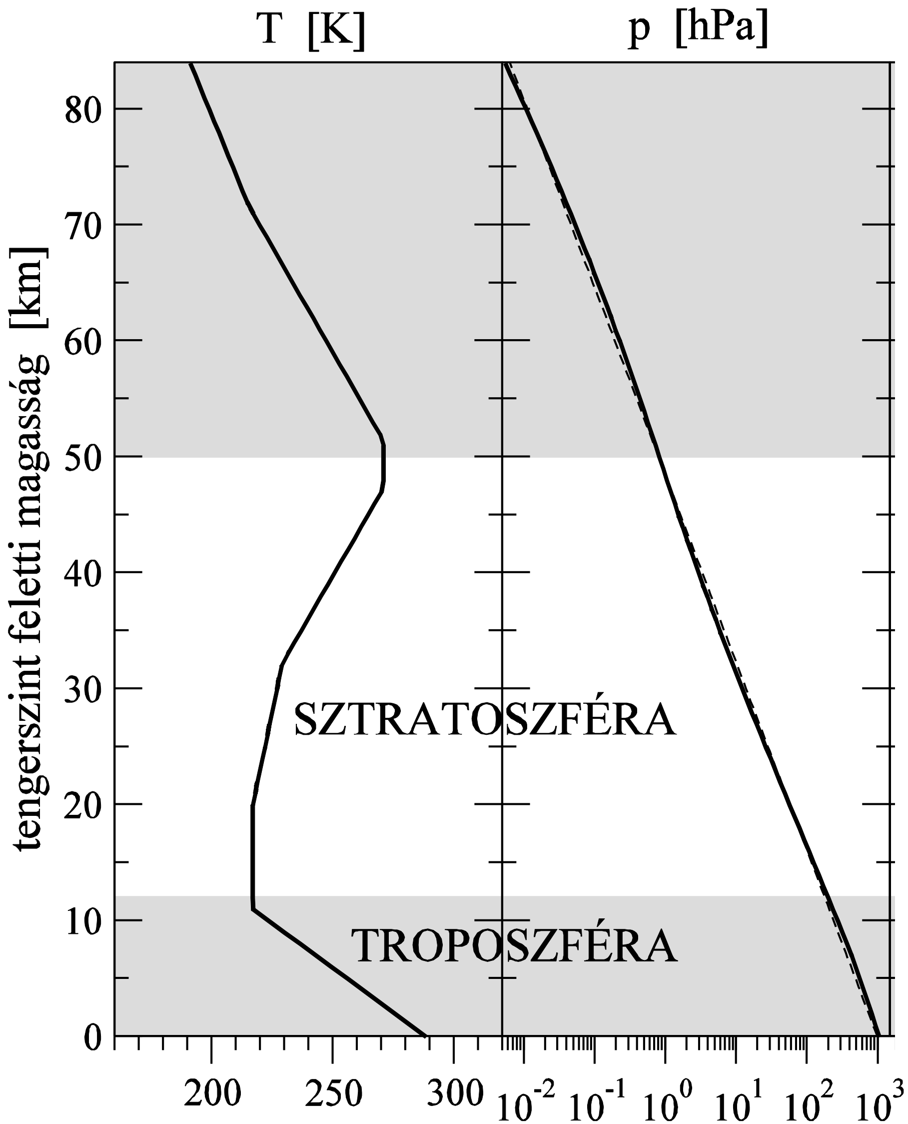
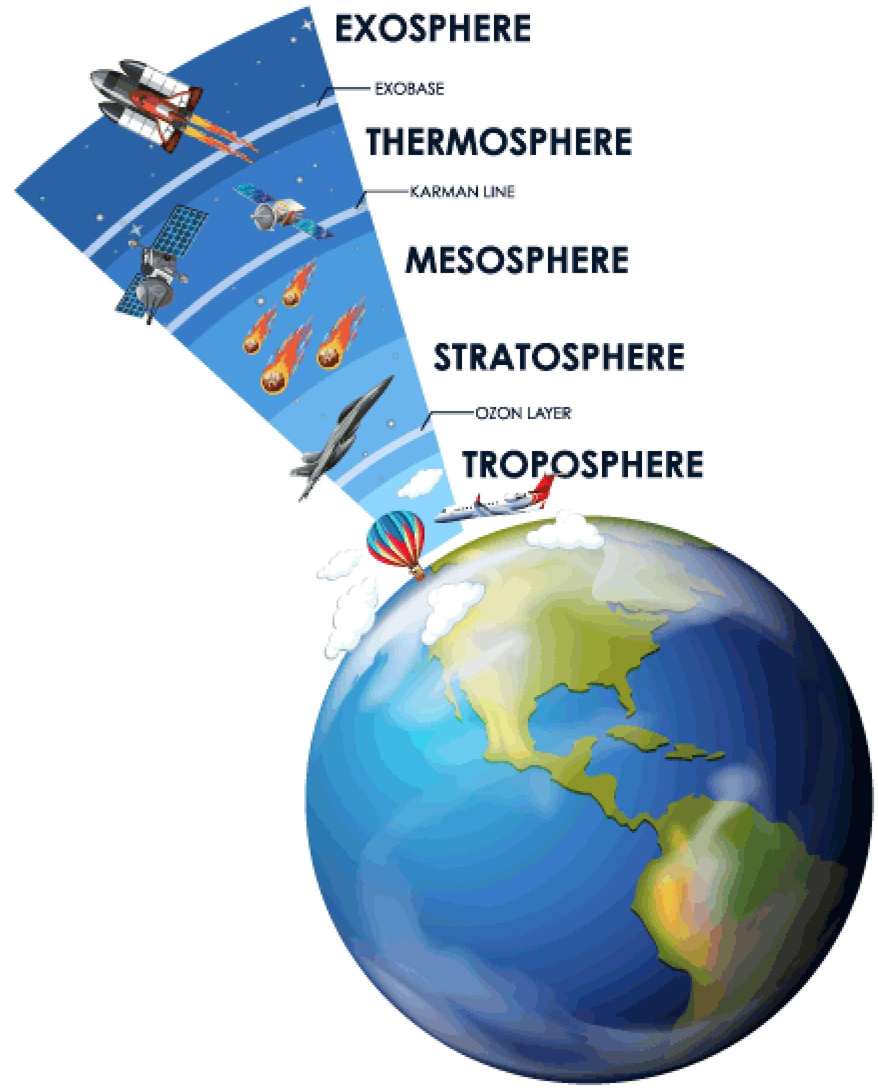
NKE Víztudományi Kar
Víz- és Környezetpolitikai Tanszék

- A Föld forog (Coriolis-erő, centrifugális erő)
- Az atmoszféra és az óceánok sűrűsége magasság-, ill. mélység-függő
- A Föld felszíne görbült
- Mindkét közeg sekély

A légkör kémiai összetétele:

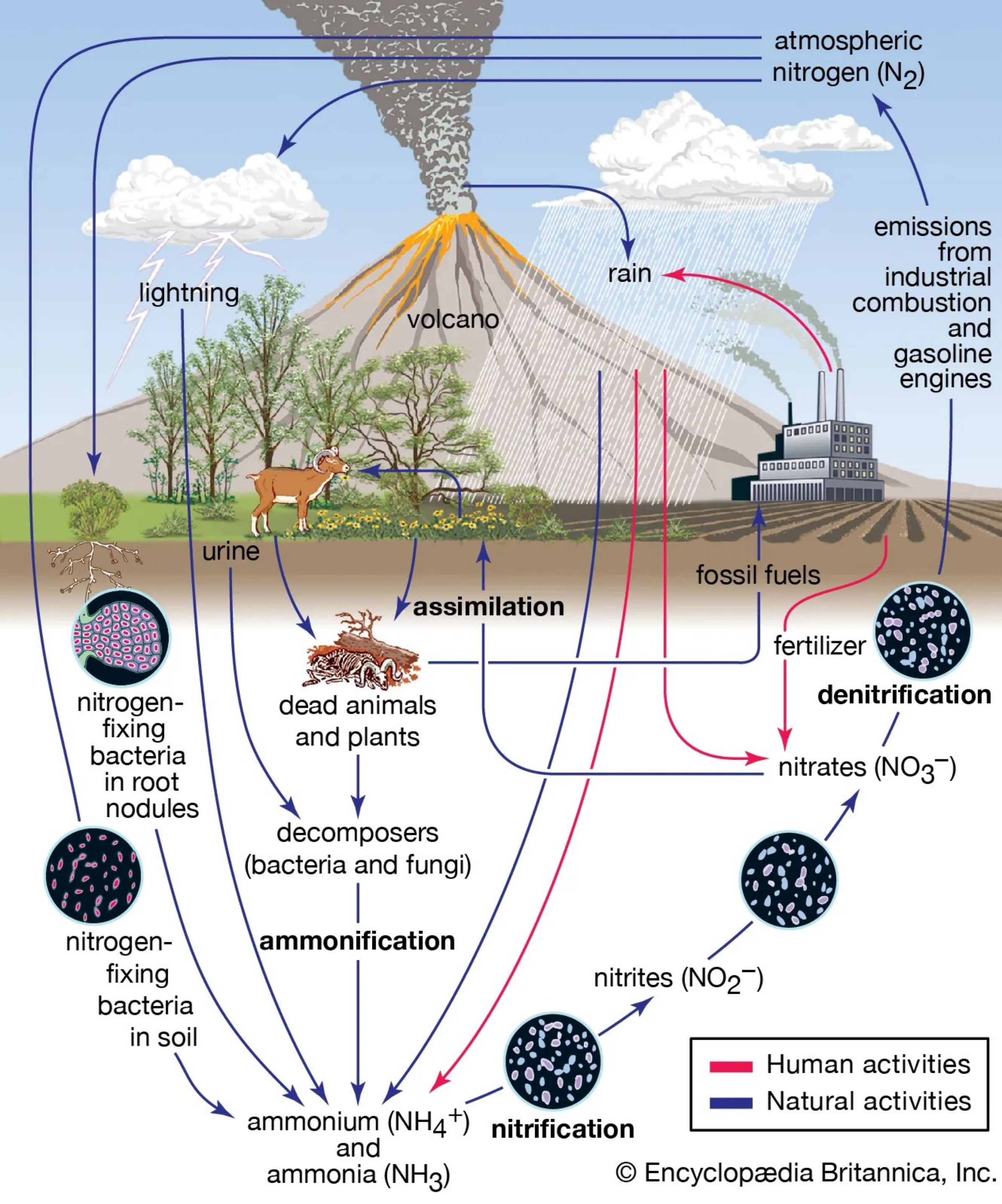
alkotó		*Föld*	*Mars*	*Vénusz*
N_2	(28,01)	77,8	2,7	3,49
O_2	(32,00)	20,8	0,13	—
Ar	(39,95)	0,9	1,6	0,007
H_2O	(18,02)	~0,4	0,03	0,002
CO_2	(44,01)	0,04	95,32	96,5
egyebek		0,06	0,22	0,001

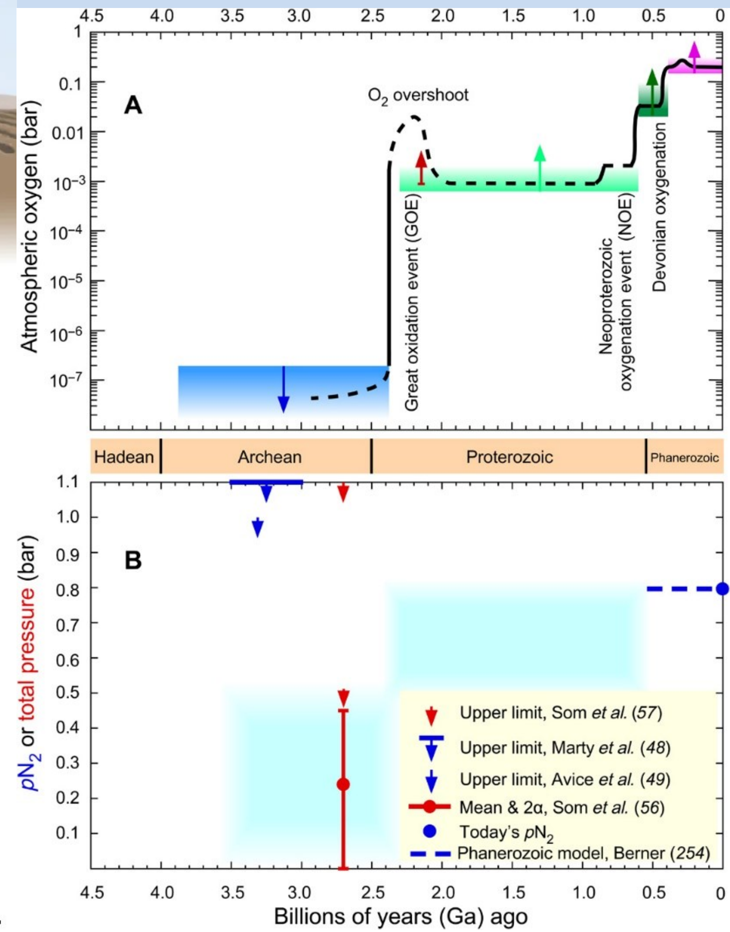




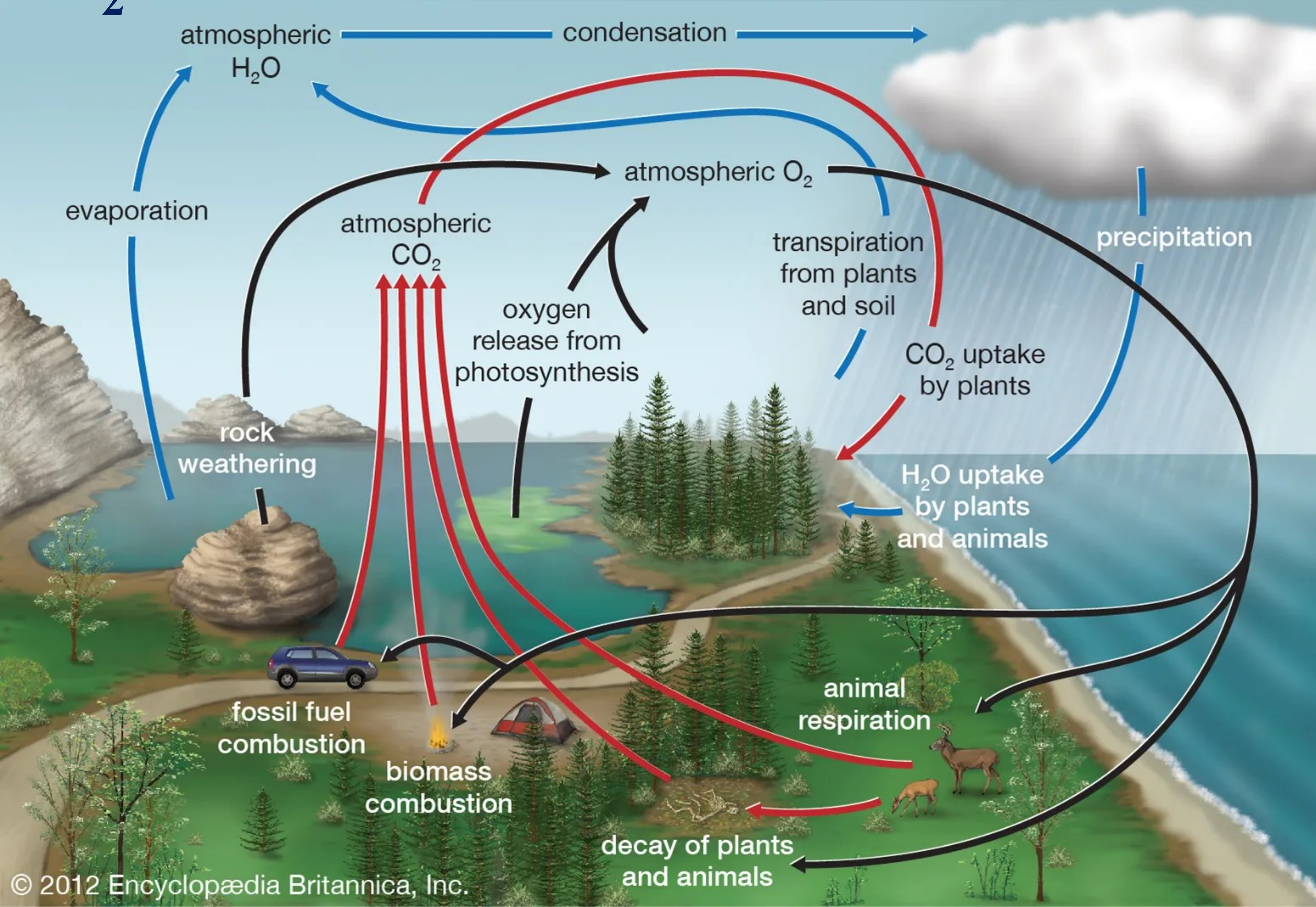
$$p(z) = p_0 \exp\left(-\frac{z}{H}\right)$$

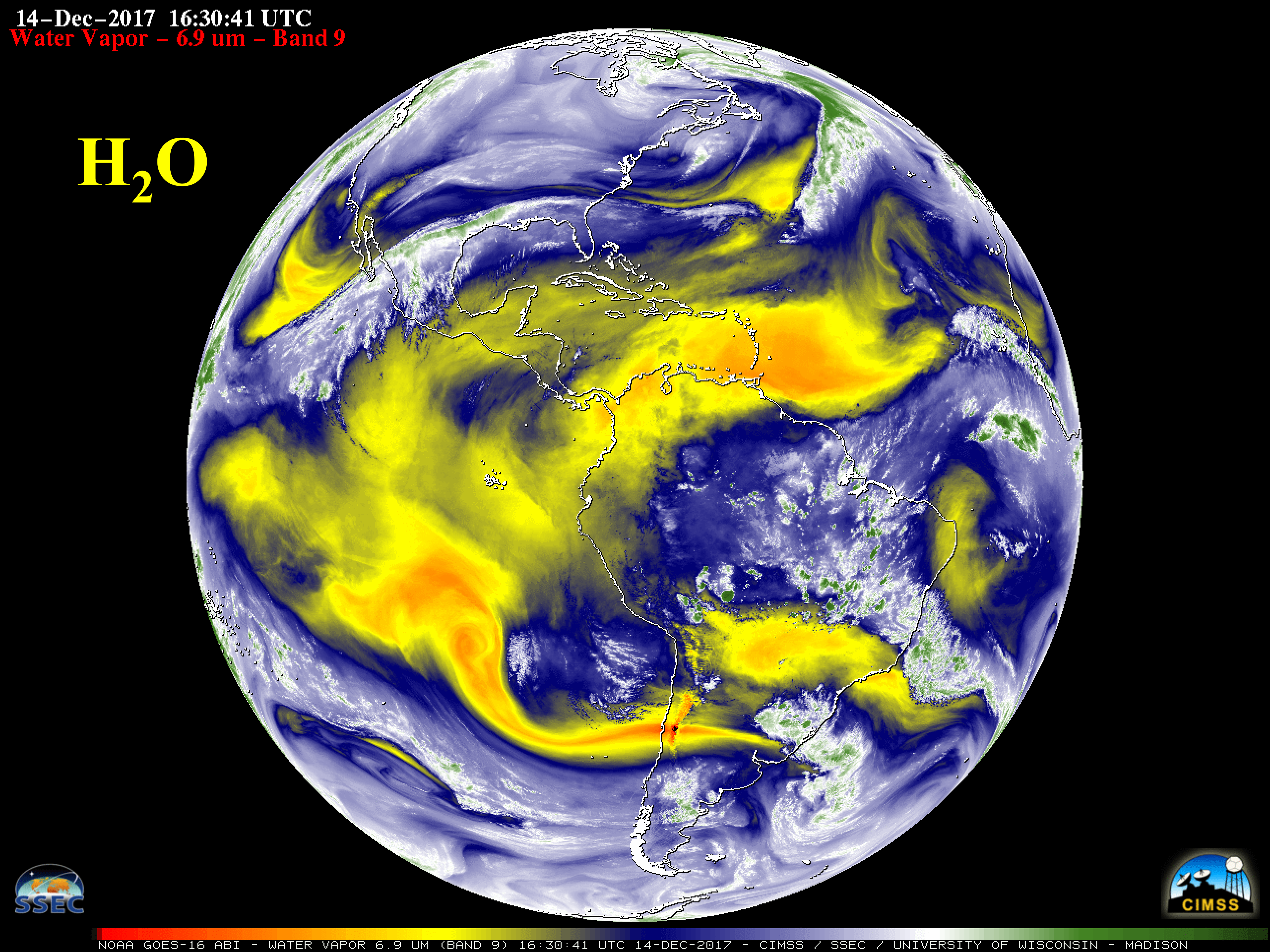
N_2

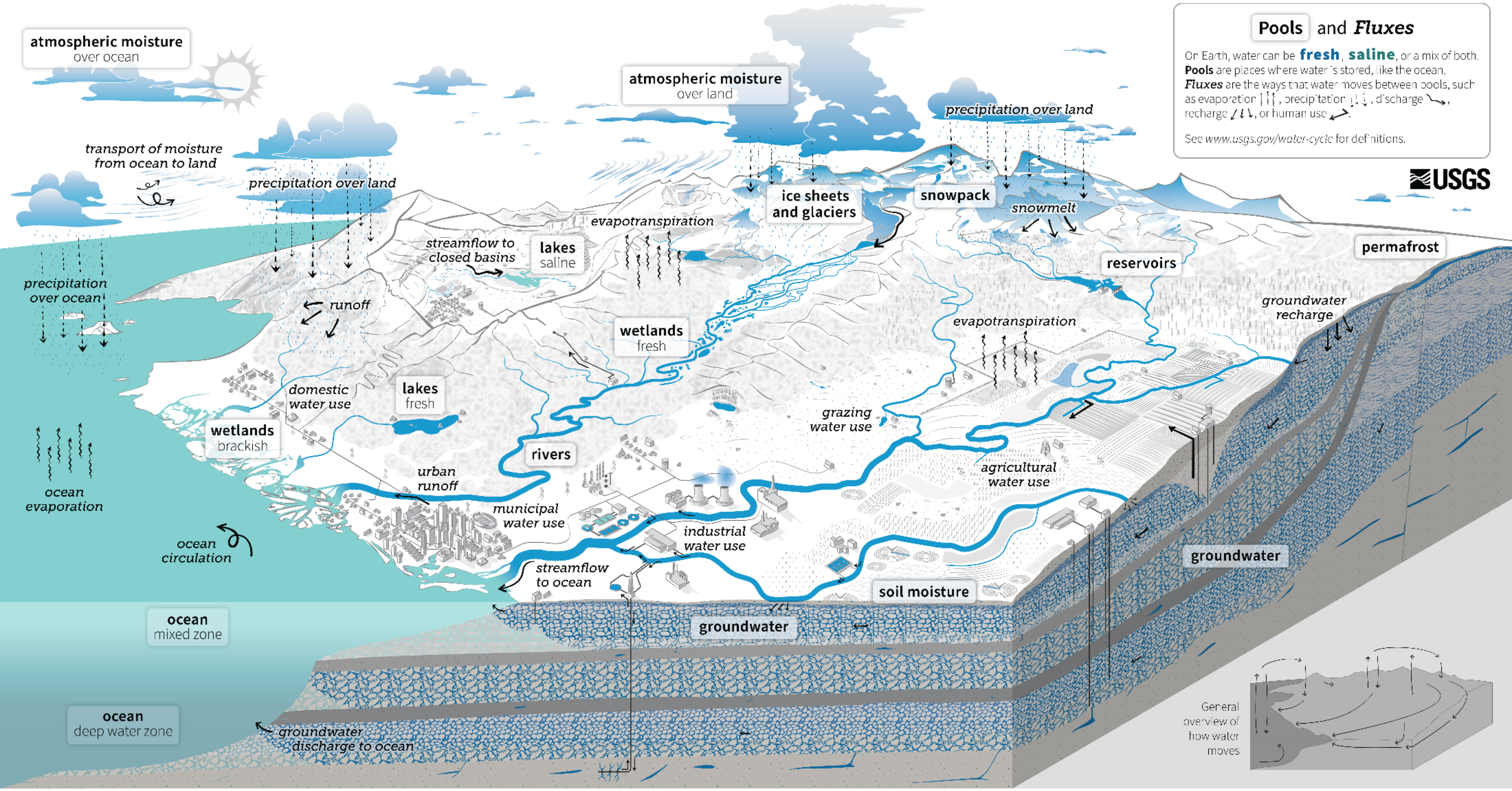

atmospheric nitrogen (N_2)
lightning
volcano
rain
emissions from industrial combustion and gasoline engines
urine
assimilation
fossil fuels
fertilizer
denitrification
dead animals and plants
nitrogen-fixing bacteria in root nodules
decomposers (bacteria and fungi)
nitrates (NO_3^-)
ammonification
nitrogen-fixing bacteria in soil
nitrites (NO_2^-)
Human activities
Natural activities
ammonium (NH_4^+) and ammonia (NH_3)
nitrification
© Encyclopædia Britannica, Inc.


A
Atmospheric oxygen (bar)
O_2 overshoot
Great oxidation event (GOE)
Neoproterozoic oxygenation event (NOE)
Devonian oxygenation
Hadean
Archean
Proterozoic
Phanerozoic
B
pN_2 or total pressure (bar)
Upper limit, Som et al. (57)
Upper limit, Marty et al. (48)
Upper limit, Avice et al. (49)
Mean & 2σ, Som et al. (56)
Today's pN_2
Phanerozoic model, Berner (254)
Billions of years (Ga) ago

O_2


atmospheric H_2O
condensation
evaporation
atmospheric O_2
atmospheric CO_2
oxygen release from photosynthesis
transpiration from plants and soil
precipitation
CO_2 uptake by plants
rock weathering
H_2O uptake by plants and animals
fossil fuel combustion
biomass combustion
animal respiration
decay of plants and animals


14-Dec-2017 16:30:41 UTC
Water Vapor - 6.9 um - Band 9
H_2O
SSEC
CIMSS
NOAA GOES-16 ABI - WATER VAPOR 6.9 UM (BAND 9) 16:30:41 UTC 14-DEC-2017 - CIMSS / SSEC / UNIVERSITY OF WISCONSIN - MADISON



The Water Cycle

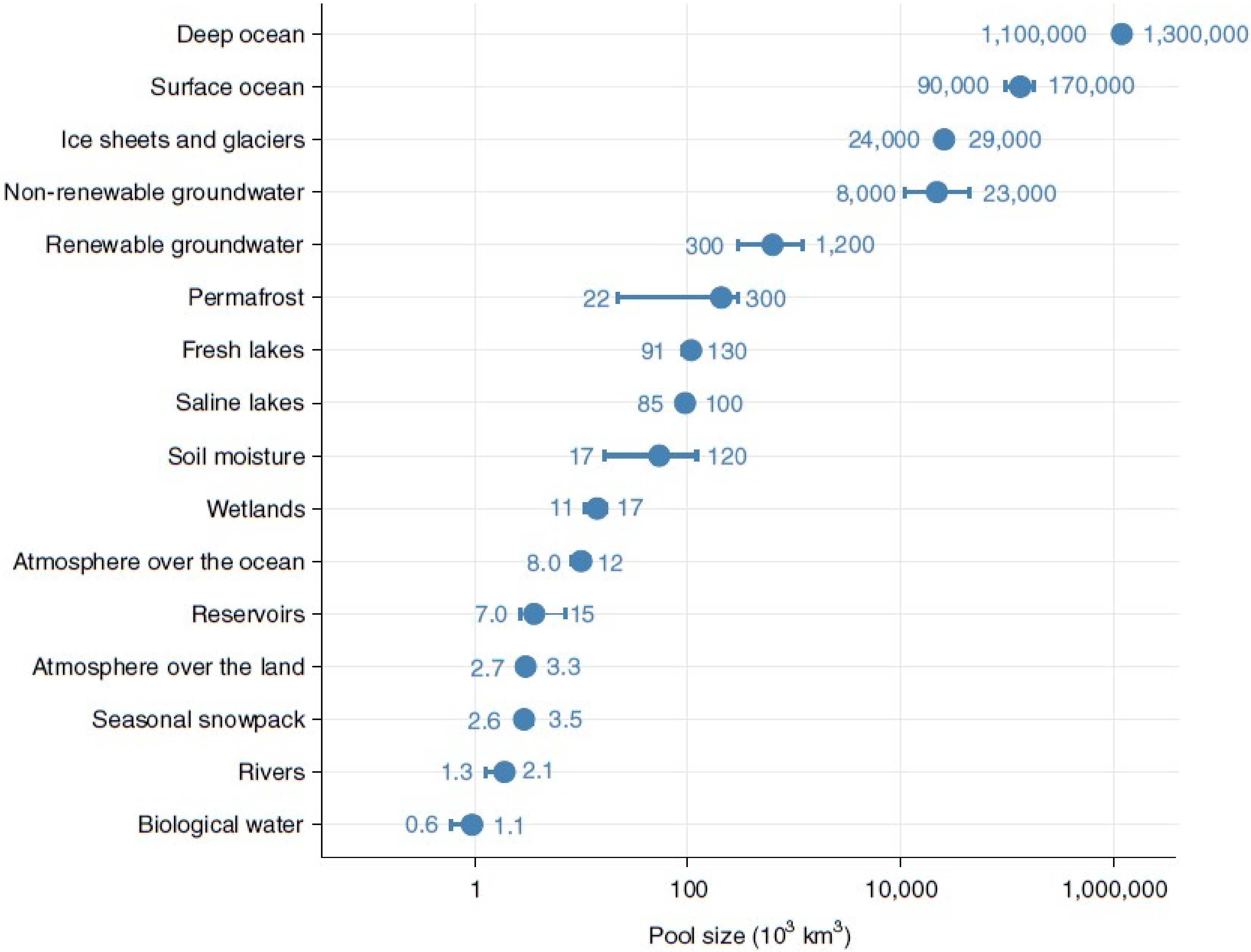
The water cycle describes where water is on Earth and how it moves. Water is stored in the atmosphere, on the land surface, and below the ground. It can be a liquid, a solid, or a gas. Liquid water can be fresh, saline (salty), or a mix (brackish). Water moves between the places it is stored. Water moves at large scales and at very small scales. Water moves naturally and because of human actions. Human water use affects where water is stored, how it moves, and how clean it is.

Pools store water. 96% of all water is stored in **oceans** and is saline. On land, saline water is stored in **saline lakes**. Fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, and **wetlands**. Water is stored in solid, frozen form in **ice sheets** and **glaciers**, and in **snowpack** at high elevations or near the Earth's poles. Water vapor is a gas and is stored as **atmospheric moisture** over the ocean and land. In the soil, frozen water is stored as **permafrost** and liquid water is stored as **soil moisture.** Deeper below ground, liquid water is stored as **groundwater** in aquifers, within cracks and pores in the rock.

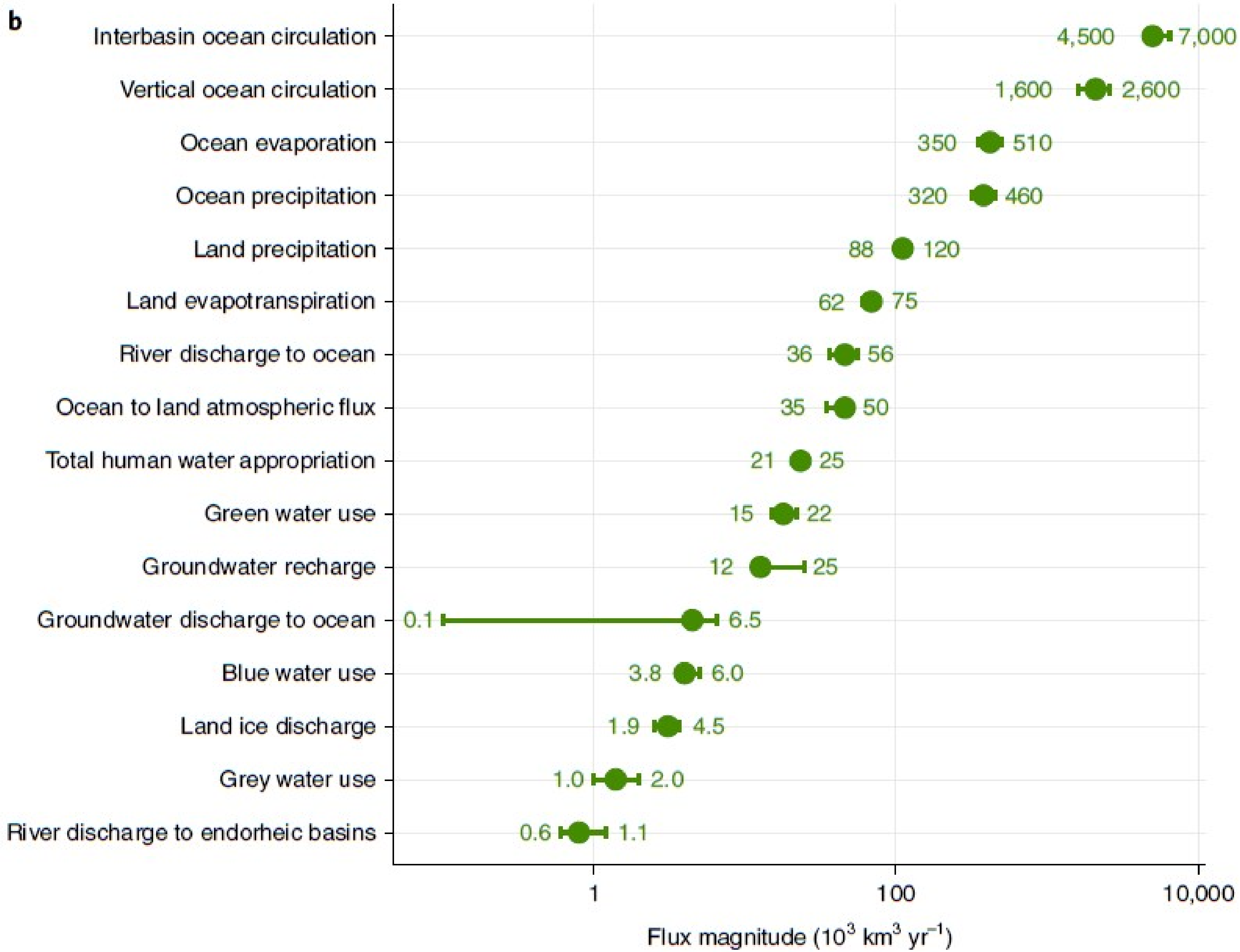
Fluxes move water between pools. As it moves, water can change form between liquid, solid, and gas. **Circulation** mixes water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the surface through **snowmelt**, **runoff**, and **streamflow**. Water moves into the ground through infiltration and **groundwater recharge**. Underground, groundwater flows within aquifers. It can return to the surface through natural **groundwater discharge** into rivers, the ocean, and from **springs**.

We alter the water cycle. We redirect rivers. We build dams to store water. We drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water to supply our **homes** and **communities.** We use it for **agricultural** irrigation and **grazing** livestock. We use it in **industrial** activities like thermoelectric power generation, mining, and aquaculture. The amount of water that is available depends on how much water is in each pool (water quantity). It also depends on when and how fast water moves (water timing), how much water we use (water use), and how clean the water is (water quality).

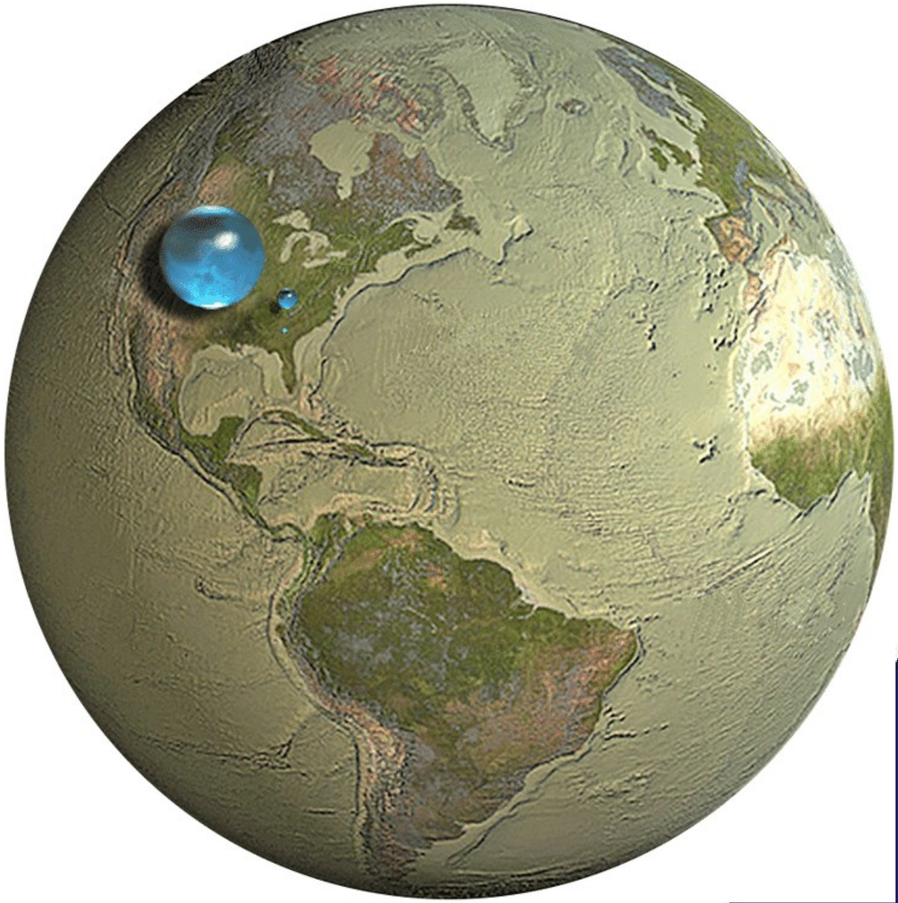
We affect **water quality**. In agricultural and urban areas, irrigation and precipitation wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is affecting the water cycle. It is affecting water quality, quantity, timing, and use. It is causing ocean acidification, sea level rise, and more extreme weather. By understanding these impacts, we can work toward using water sustainably.

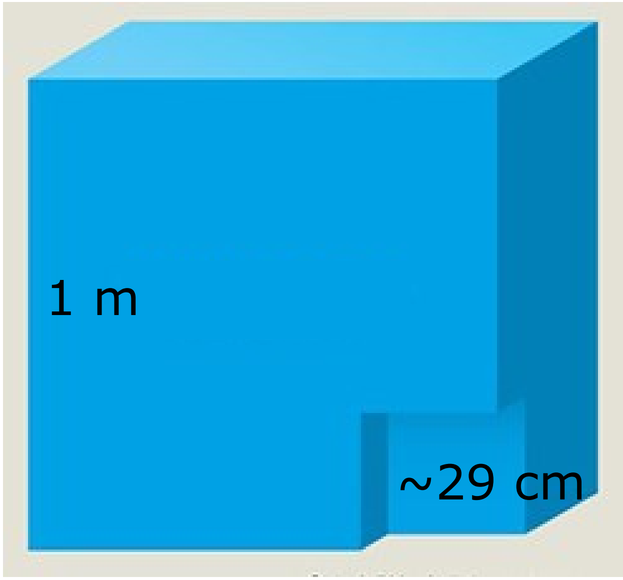


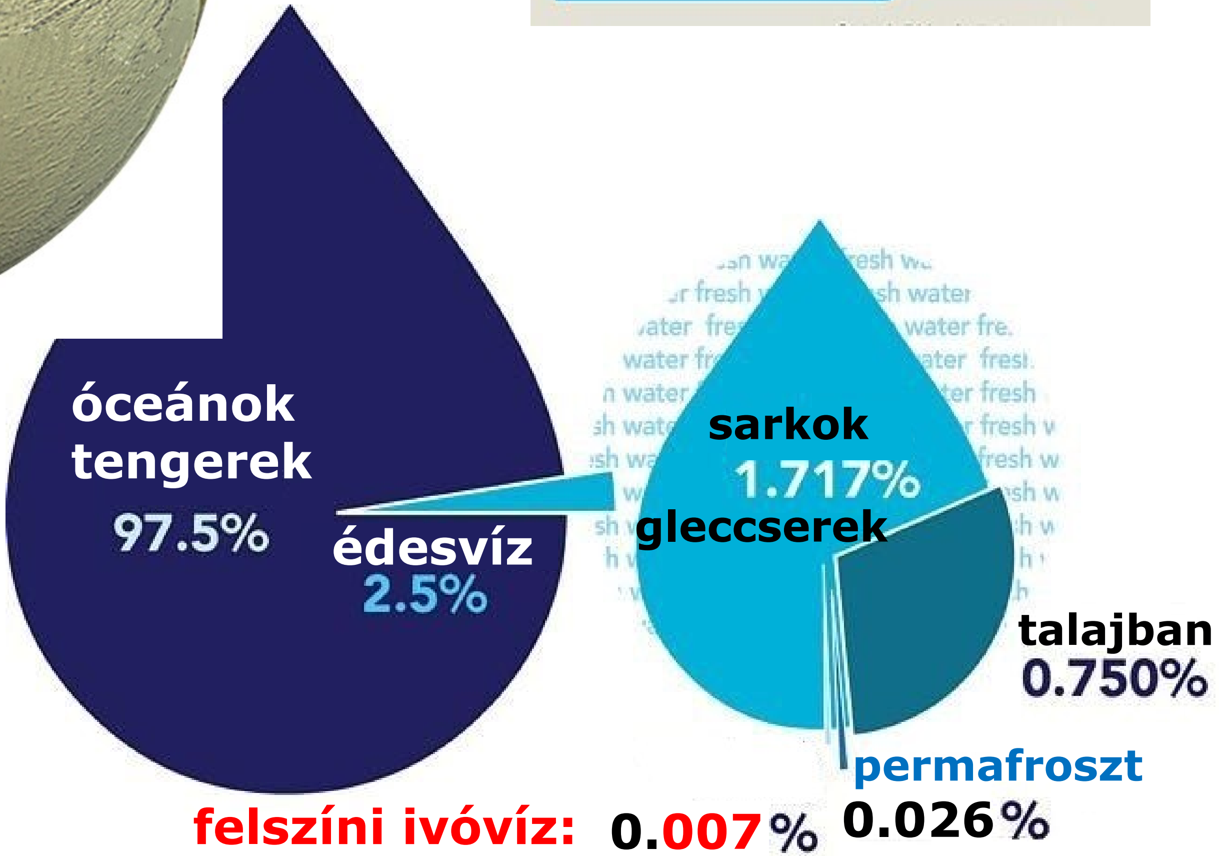
Abbott, B.W., Bishop, K., Zarnetske, J.P. *et al.* Human domination of the global water cycle absent from depictions and perceptions. *Nat. Geosci.* **12**, 533–540 (2019). https://doi.org/10.1038/s41561-019-0374-y

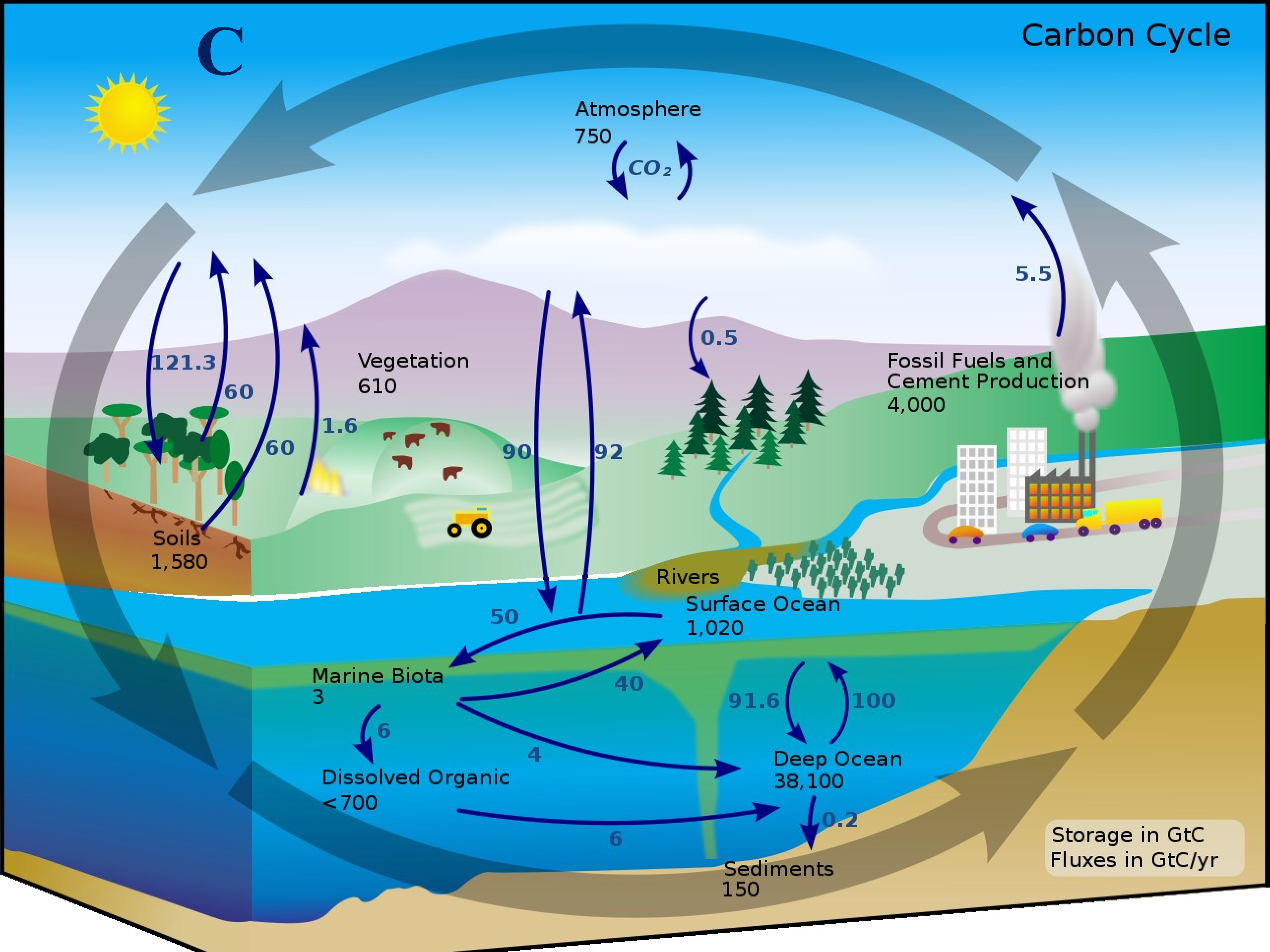


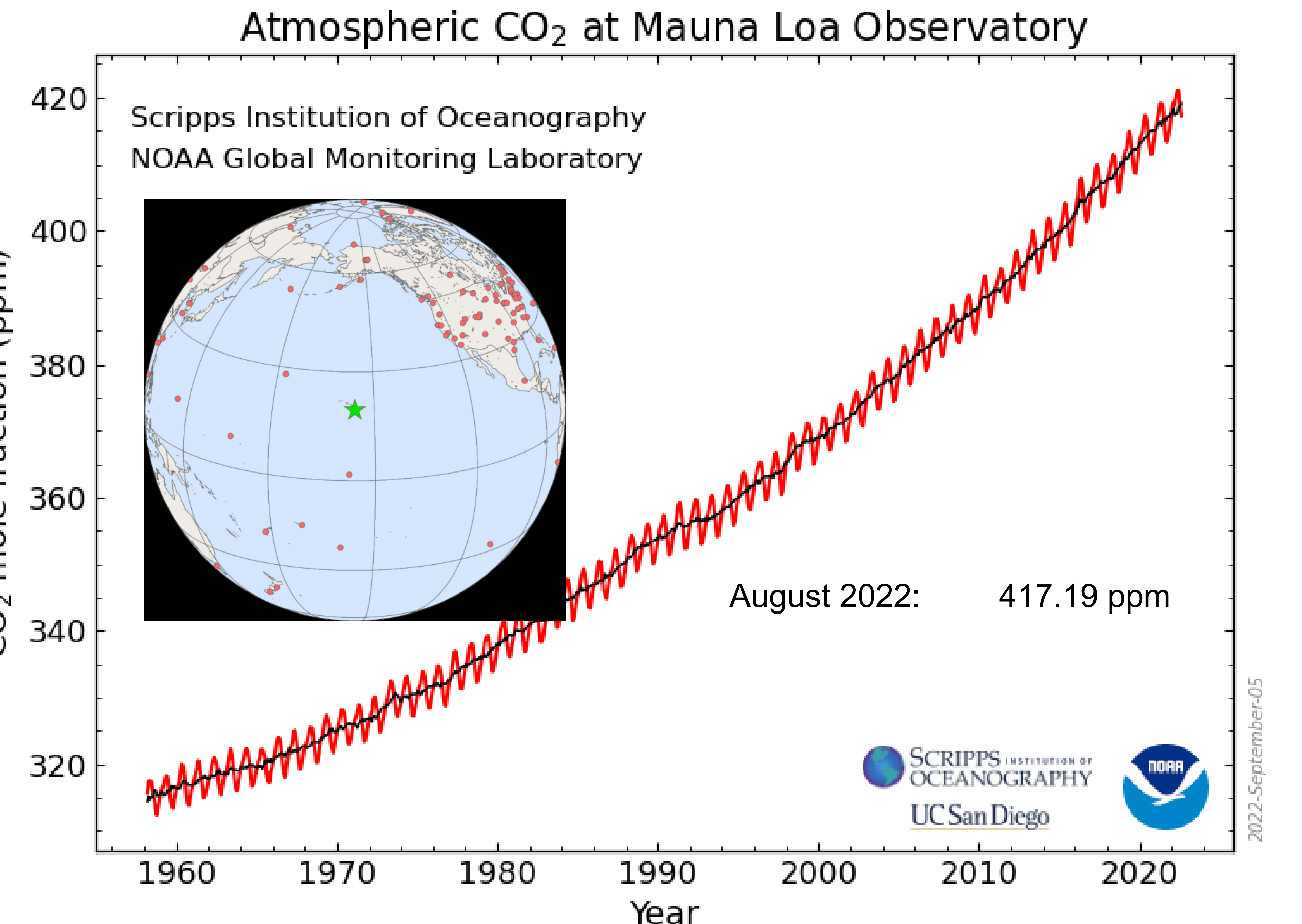
Abbott, B.W., Bishop, K., Zarnetske, J.P. *et al.* Human domination of the global water cycle absent from depictions and perceptions. *Nat. Geosci.* **12**, 533–540 (2019). https://doi.org/10.1038/s41561-019-0374-y




1 m
~29 cm

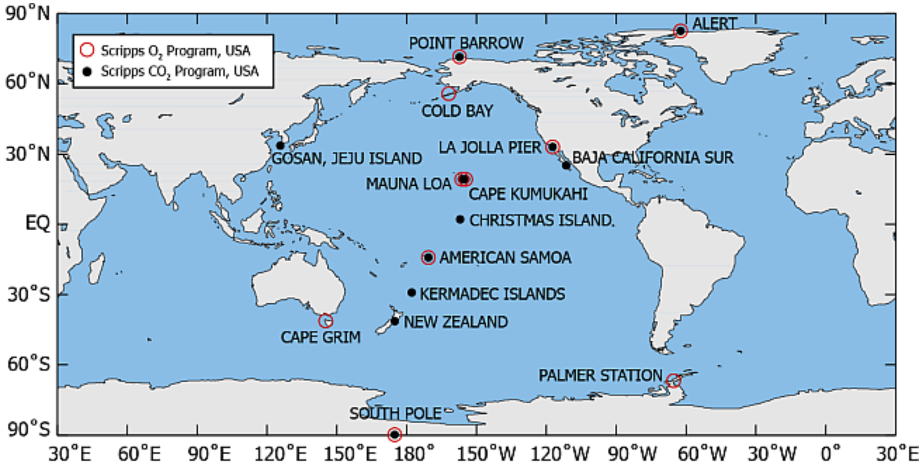

óceánok
tengerek
97.5%
édesvíz
2.5%
sarkok
1.717%
gleccserek
talajban
0.750%
permafroszt
0.026%
felszíni ivóvíz: 0.007%

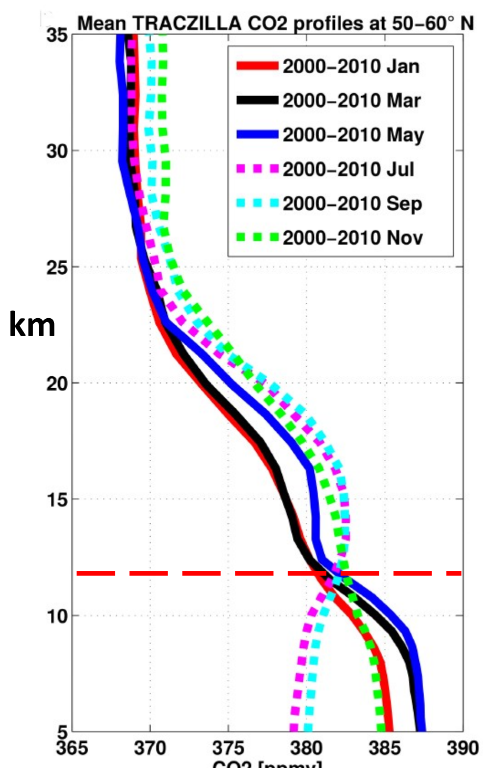

C
Carbon Cycle
Atmosphere
750
CO_2
121.3
60
60
1.6
Vegetation
610
90
92
0.5
5.5
Fossil Fuels and
Cement Production
4,000
Soils
1,580
Rivers
Surface Ocean
1,020
50
40
Marine Biota
3
6
4
91.6
100
Deep Ocean
38,100
Dissolved Organic
<700
6
0.2
Sediments
150
Storage in GtC
Fluxes in GtC/yr

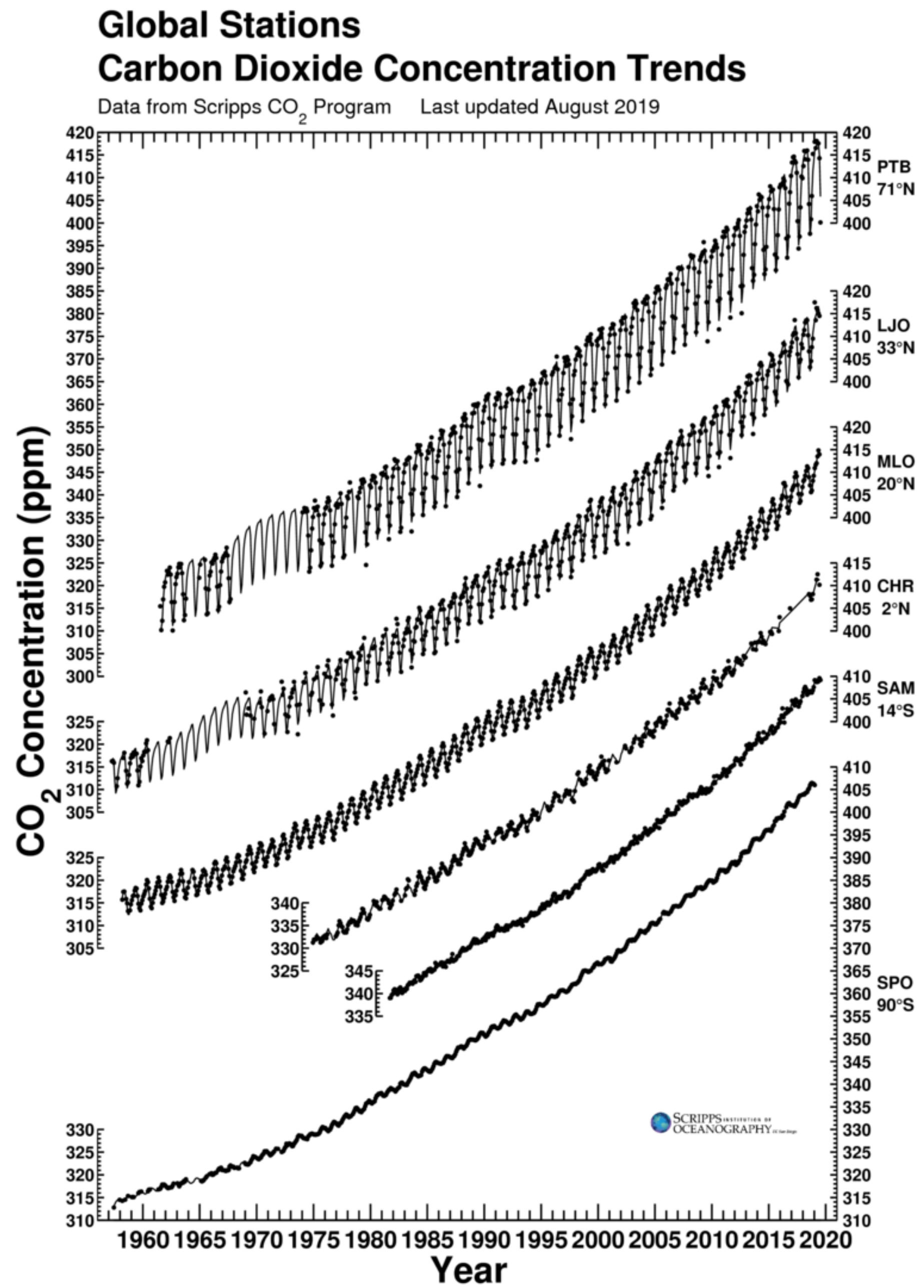


Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Global Monitoring Laboratory
August 2022: 417.19 ppm
420
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego
NOAA
2022-September-05

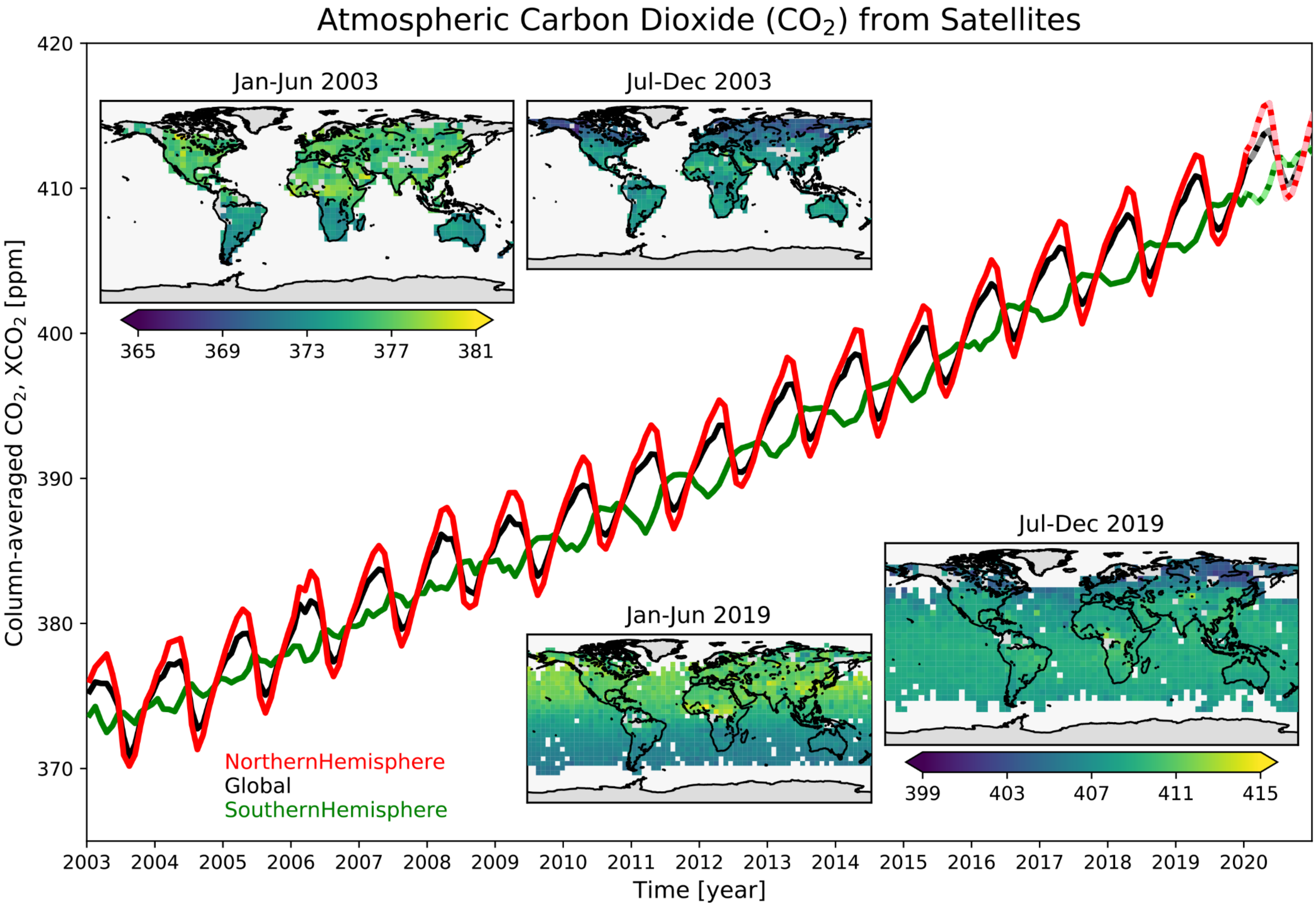
CO_2 lifetime: 300-1000 years





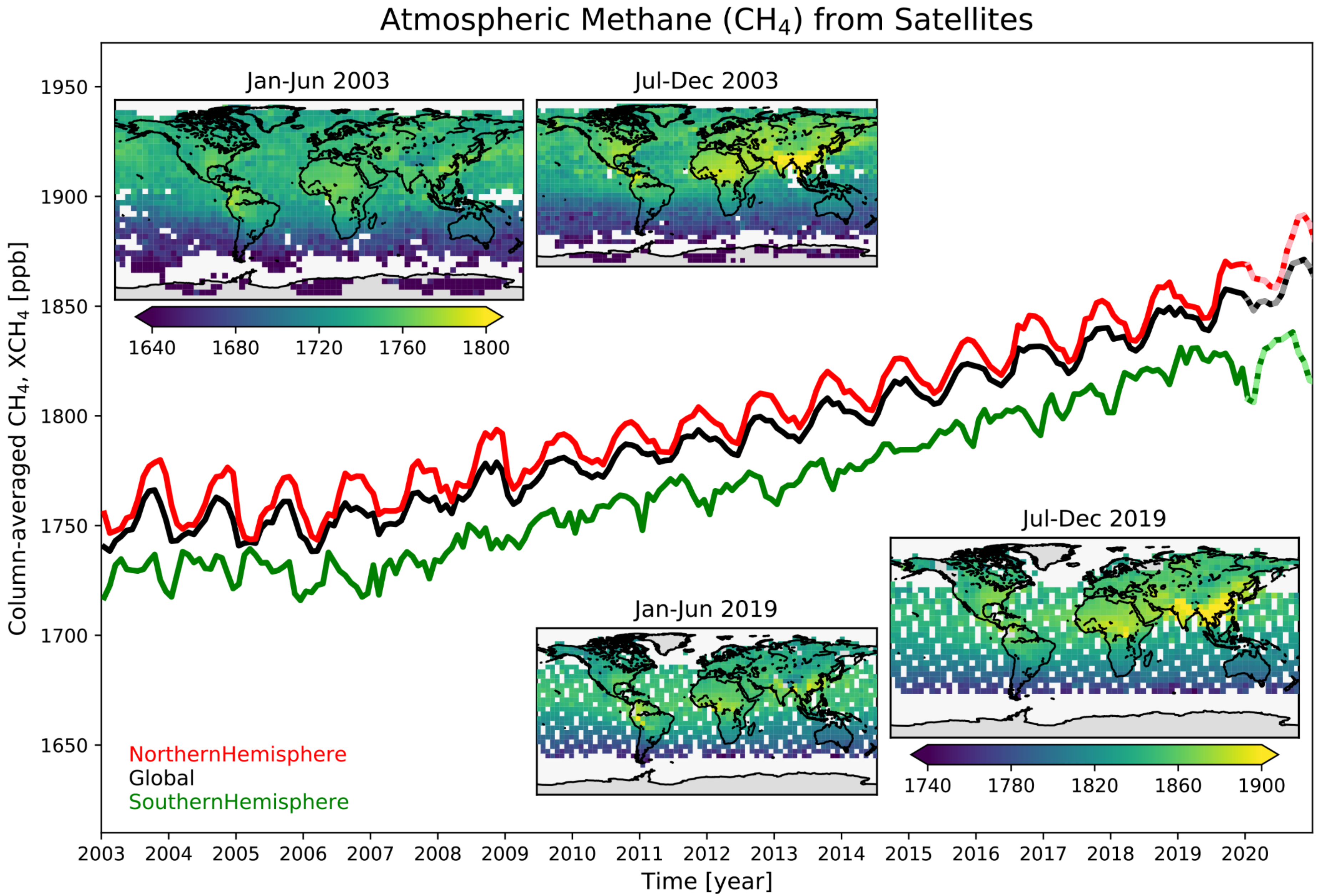


Diallo, M. et al., *Atmos. Chem. Phys.*, **17**, 3861–3878, 2017



Data:2003-2019:XCO2_OBS4MIPS(v4.2);2020:CAMS(NRT) - Satellites:SCIAMACHY/ENVISAT+GOSAT+OCO-2 - Credit:C3S/CCI/CAMS/Univ.Bremen/SRON

EUROPEAN UNION   Copernicus Europe's eyes on Earth   IMPLEMENTED BY ECMWF   Climate Change Service climate.copernicus.eu   Atmosphere Monitoring Service atmosphere.copernicus.eu



Data:2003-2019:XCH4_OBS4MIPS(v4.2);2020:CAMS(NRT) - Satellites:SCIAMACHY/ENVISAT+GOSAT - Credit:C3S/CCI/CAMS/Univ.Bremen/SRON

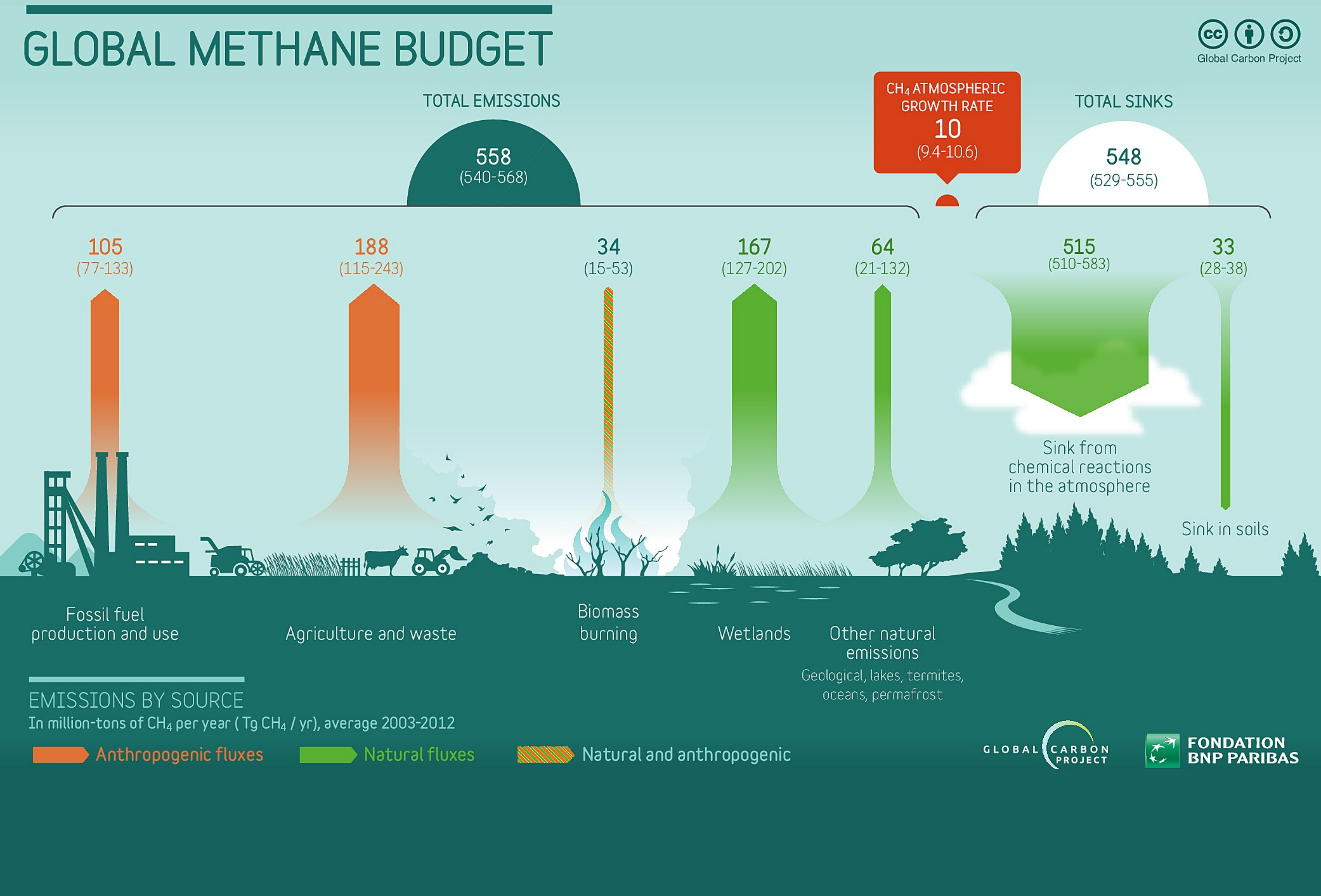
EUROPEAN UNION

Copernicus Europe's eyes on Earth

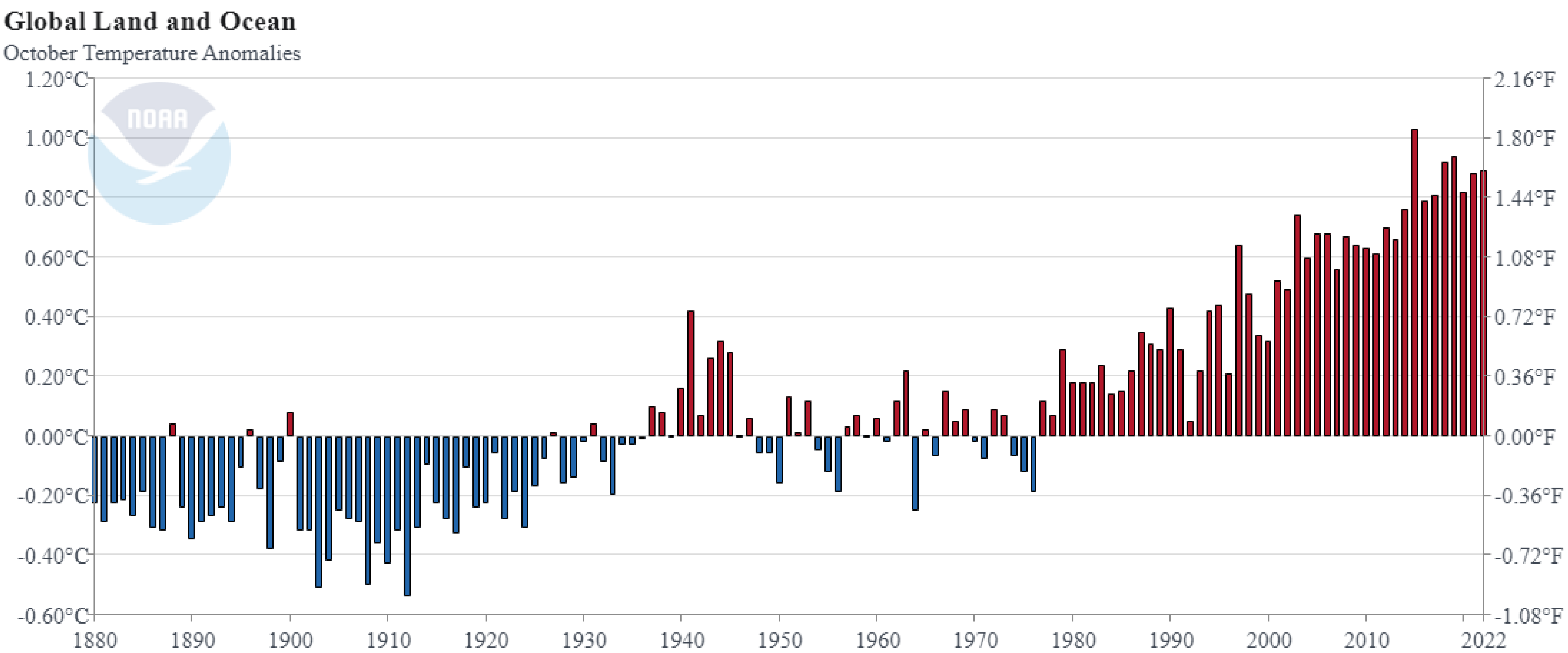
IMPLEMENTED BY ECMWF

Climate Change Service climate.copernicus.eu

Atmosphere Monitoring Service atmosphere.copernicus.eu

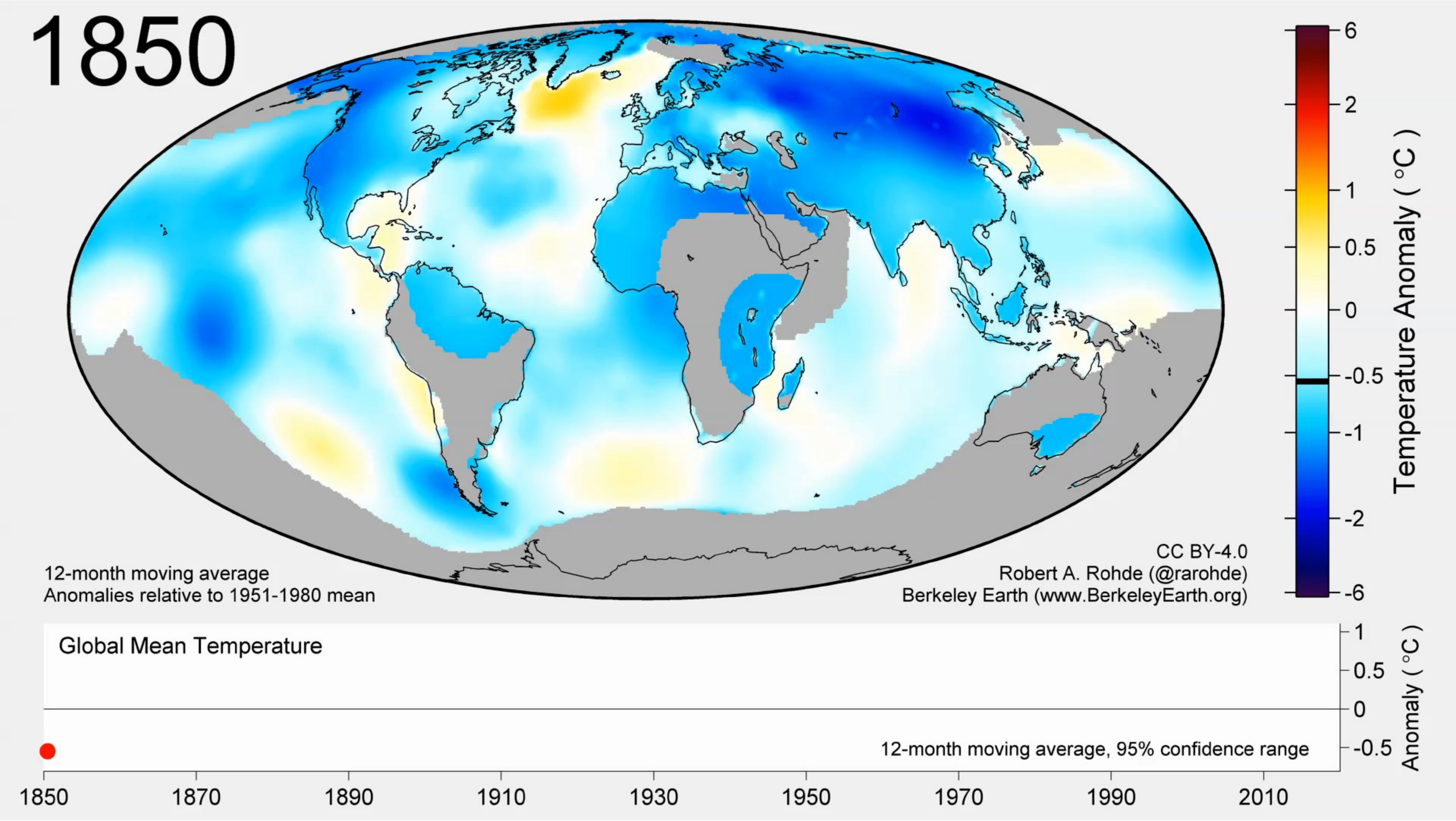

GLOBAL METHANE BUDGET
Global Carbon Project
TOTAL EMISSIONS
558
(540-568)
CH_4 ATMOSPHERIC GROWTH RATE
10
(9.4-10.6)
TOTAL SINKS
548
(529-555)
105
(77-133)
188
(115-243)
34
(15-53)
167
(127-202)
64
(21-132)
515
(510-583)
33
(28-38)
Sink from chemical reactions in the atmosphere
Sink in soils
Fossil fuel production and use
Agriculture and waste
Biomass burning
Wetlands
Other natural emissions
Geological, lakes, termites, oceans, permafrost
EMISSIONS BY SOURCE
In million-tons of CH_4 per year (Tg CH_4 / yr), average 2003-2012
Anthropogenic fluxes
Natural fluxes
Natural and anthropogenic
GLOBAL CARBON PROJECT
FONDATION BNP PARIBAS

Globális felmelegedés

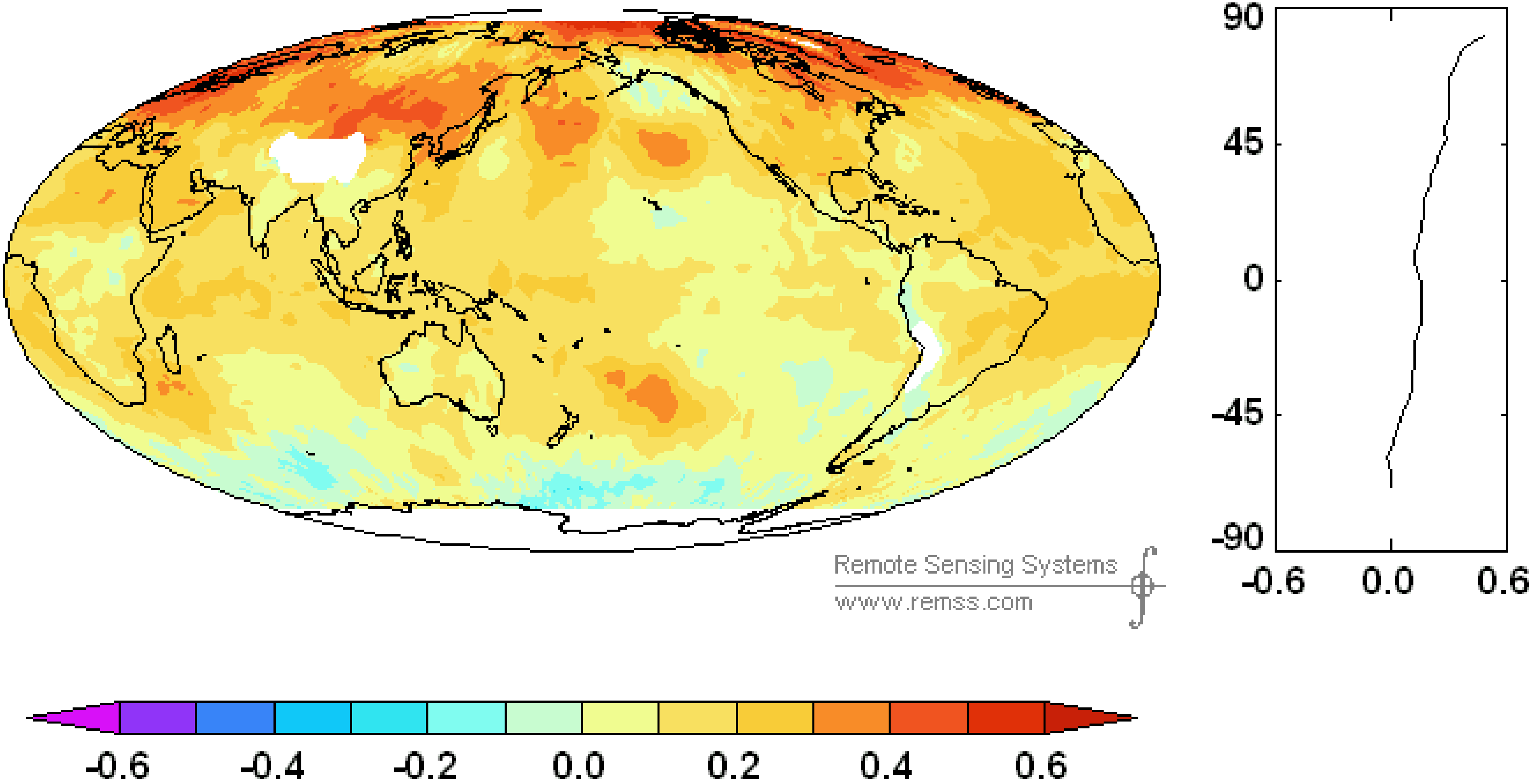


https://www.ncdc.noaa.gov/cag/

Global warming



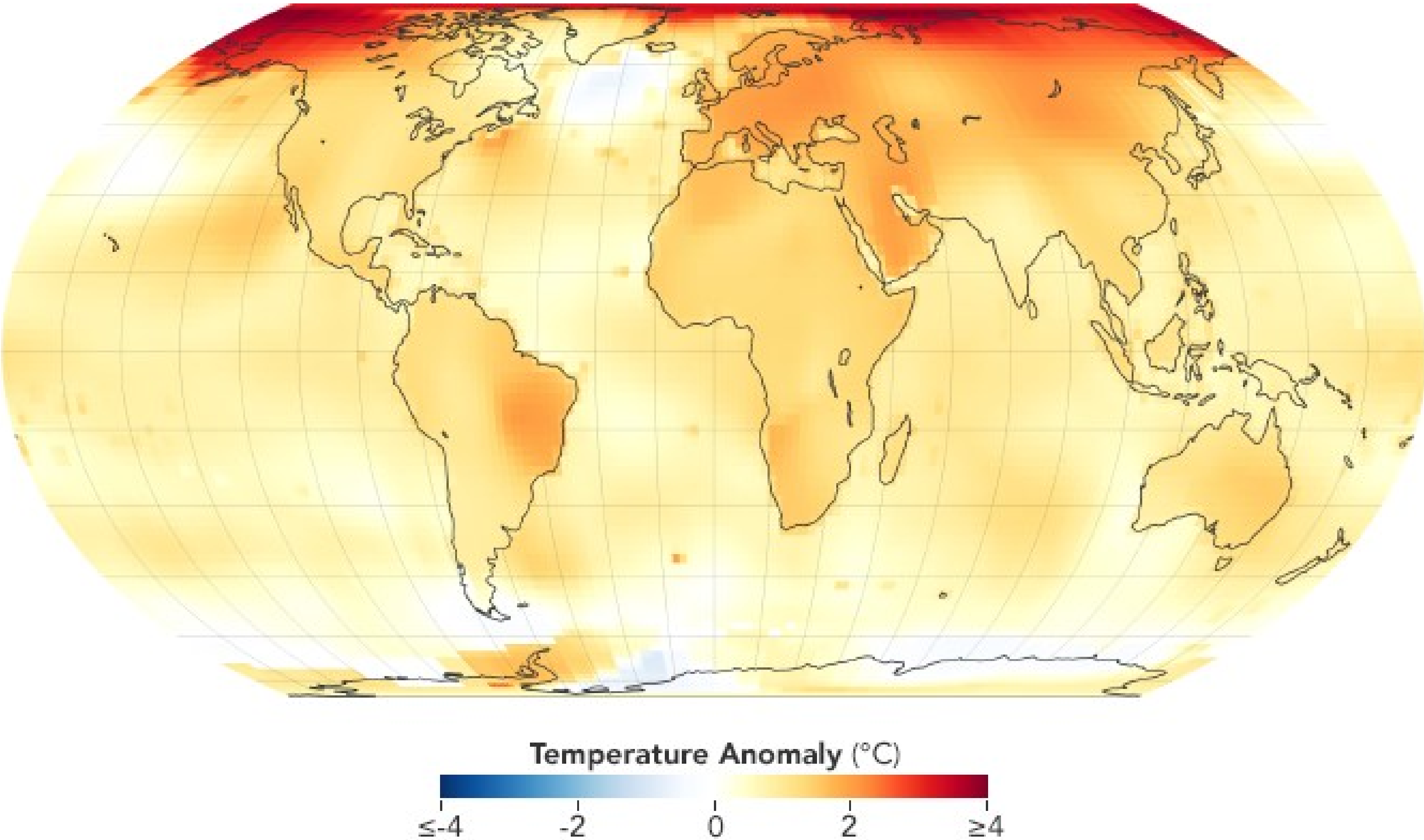
Global warming



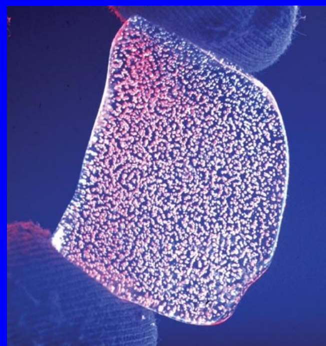
Decadal warming trends: 1979 - 2008 (30 years average)

Global warming

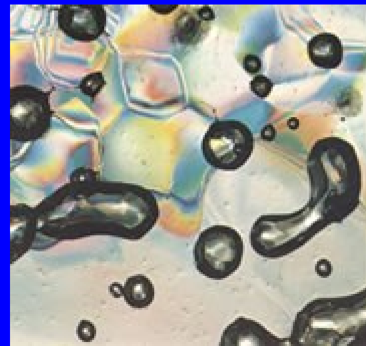
2015-2019



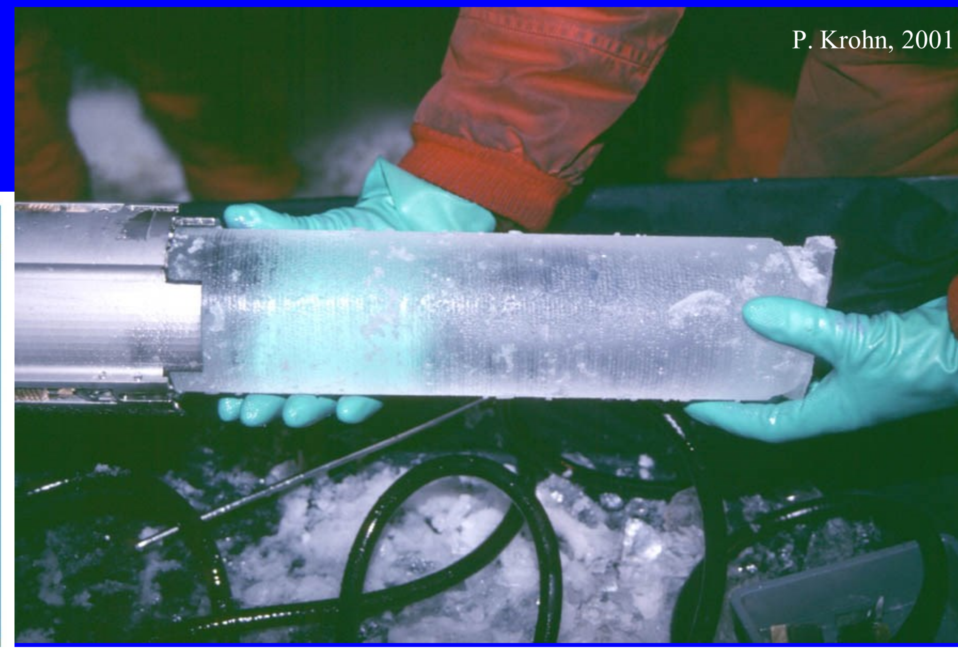
Tools of paleoclimatology:



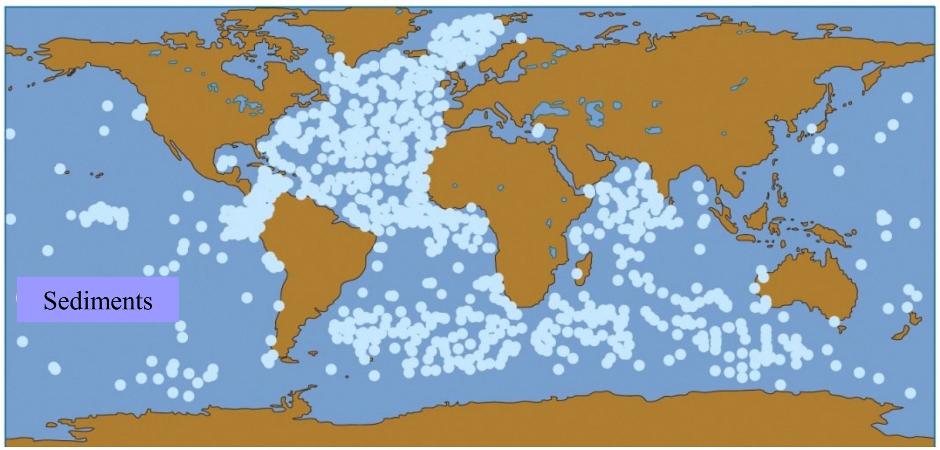
D. Etheridge, 2005

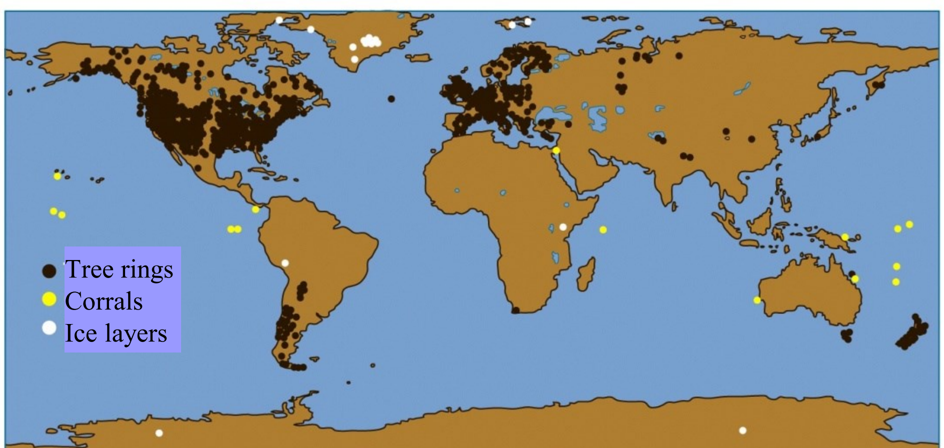


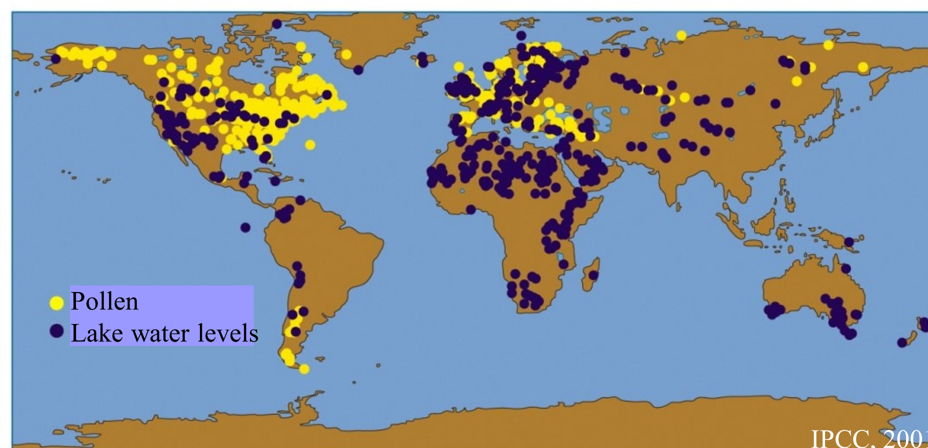
W. Berner, 2005



P. Krohn, 2001

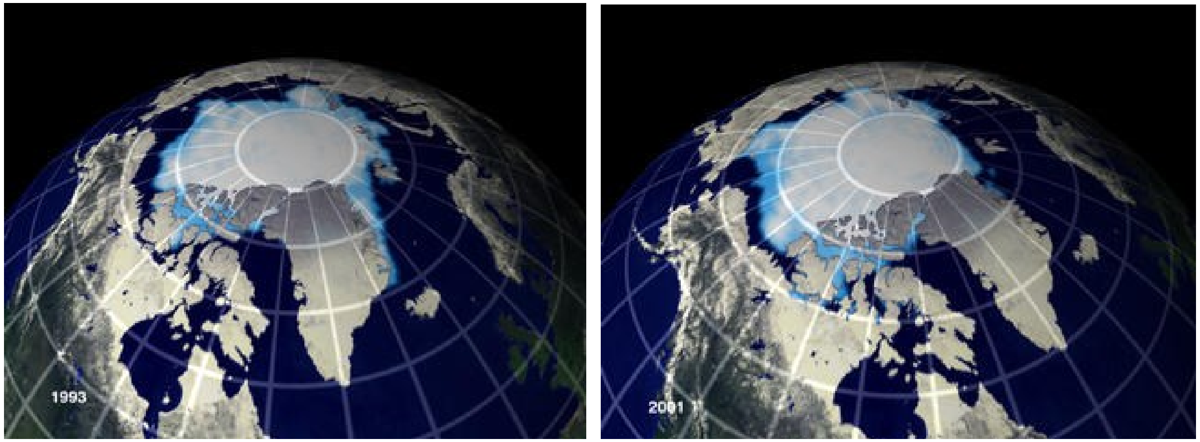


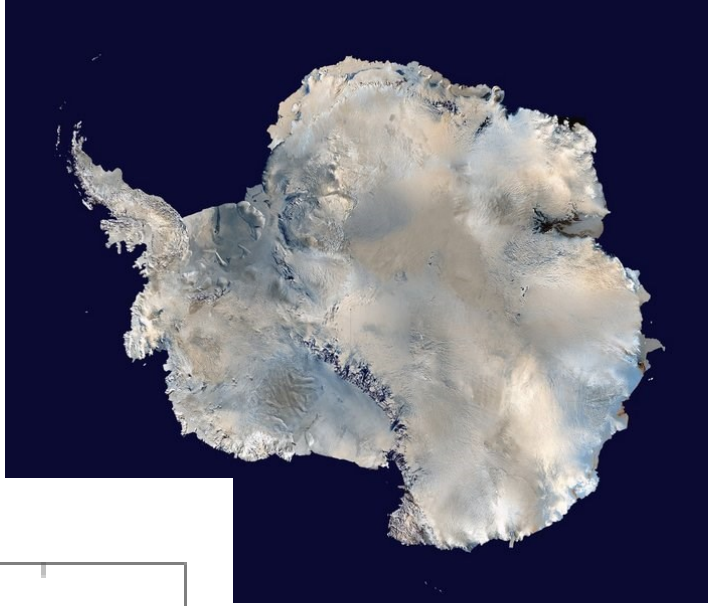




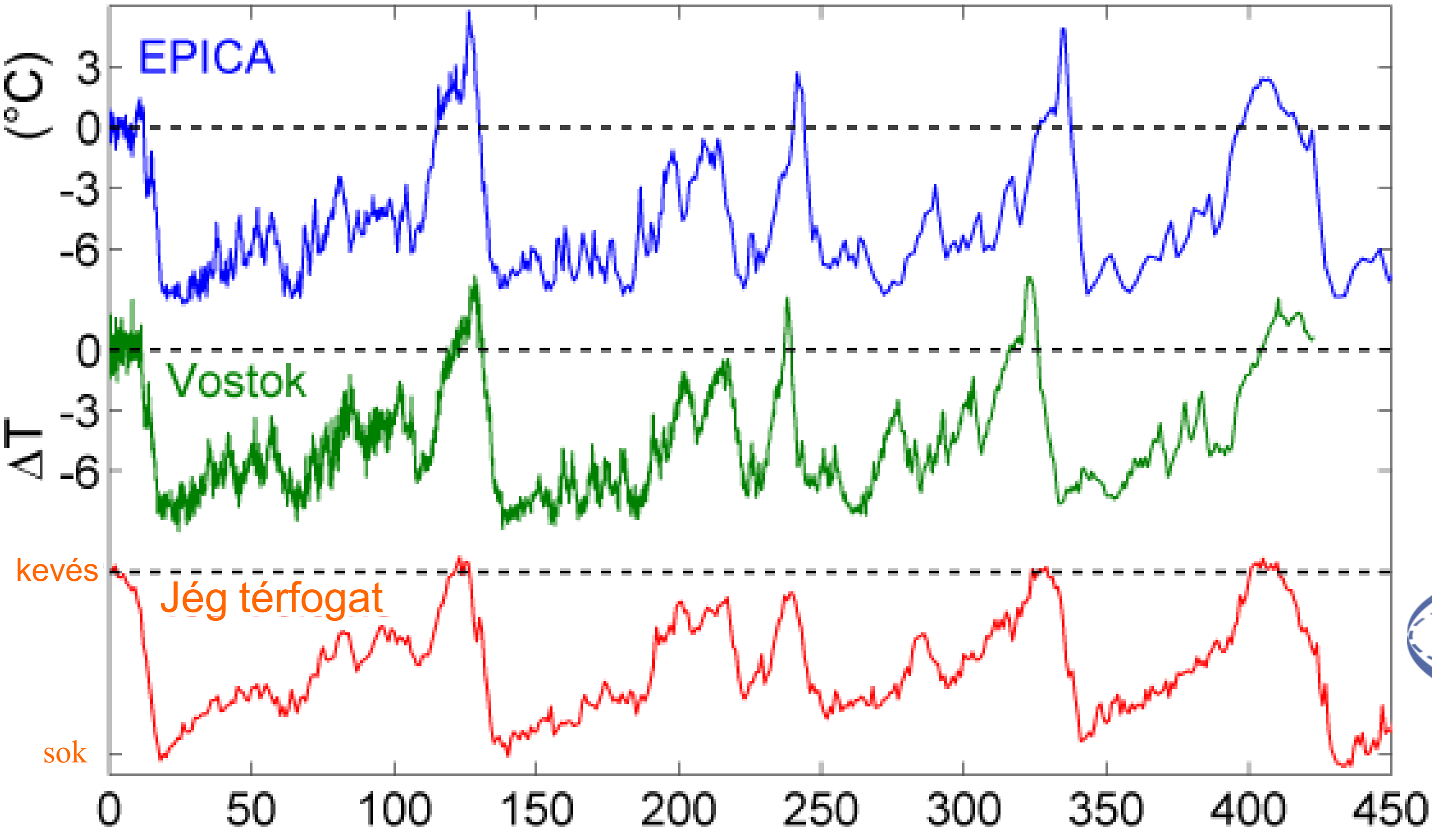
IPCC, 2001

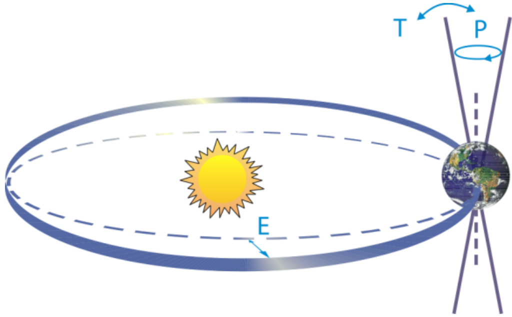
NASA SVS, 2002





Past 450,000 years

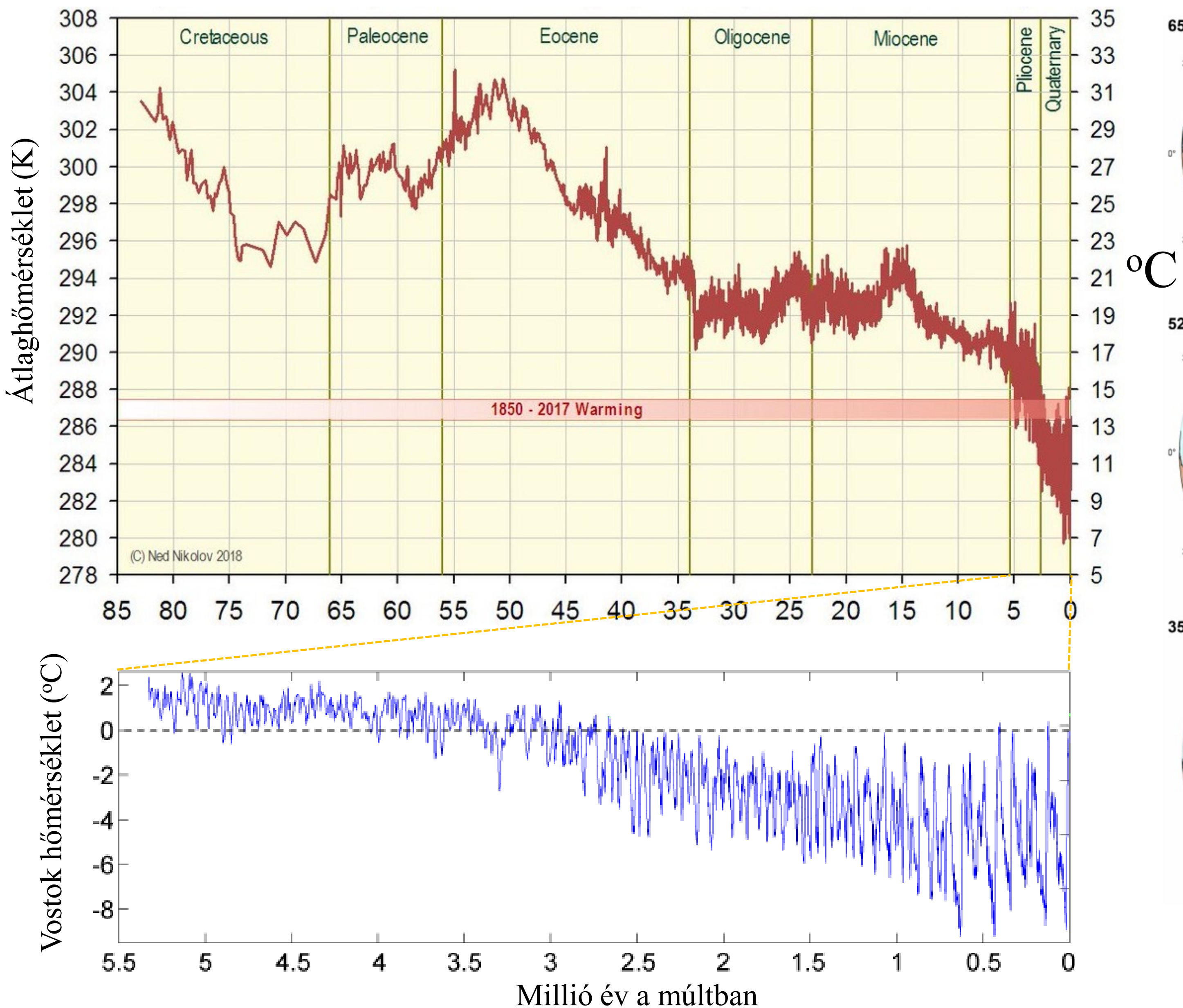


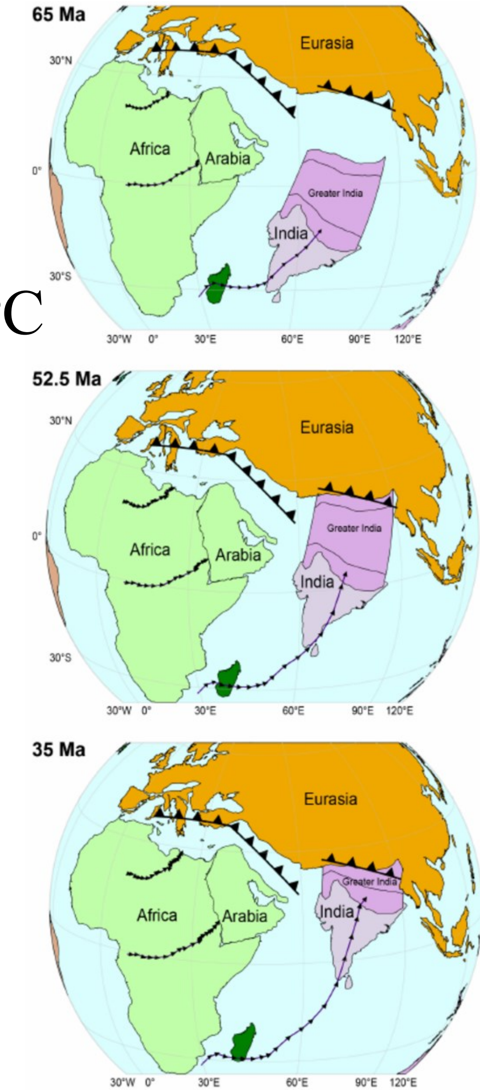


Rahmstorf and Schellnhuber (2006)


50°N
10°W
0°
10°E
0
500
1000 km

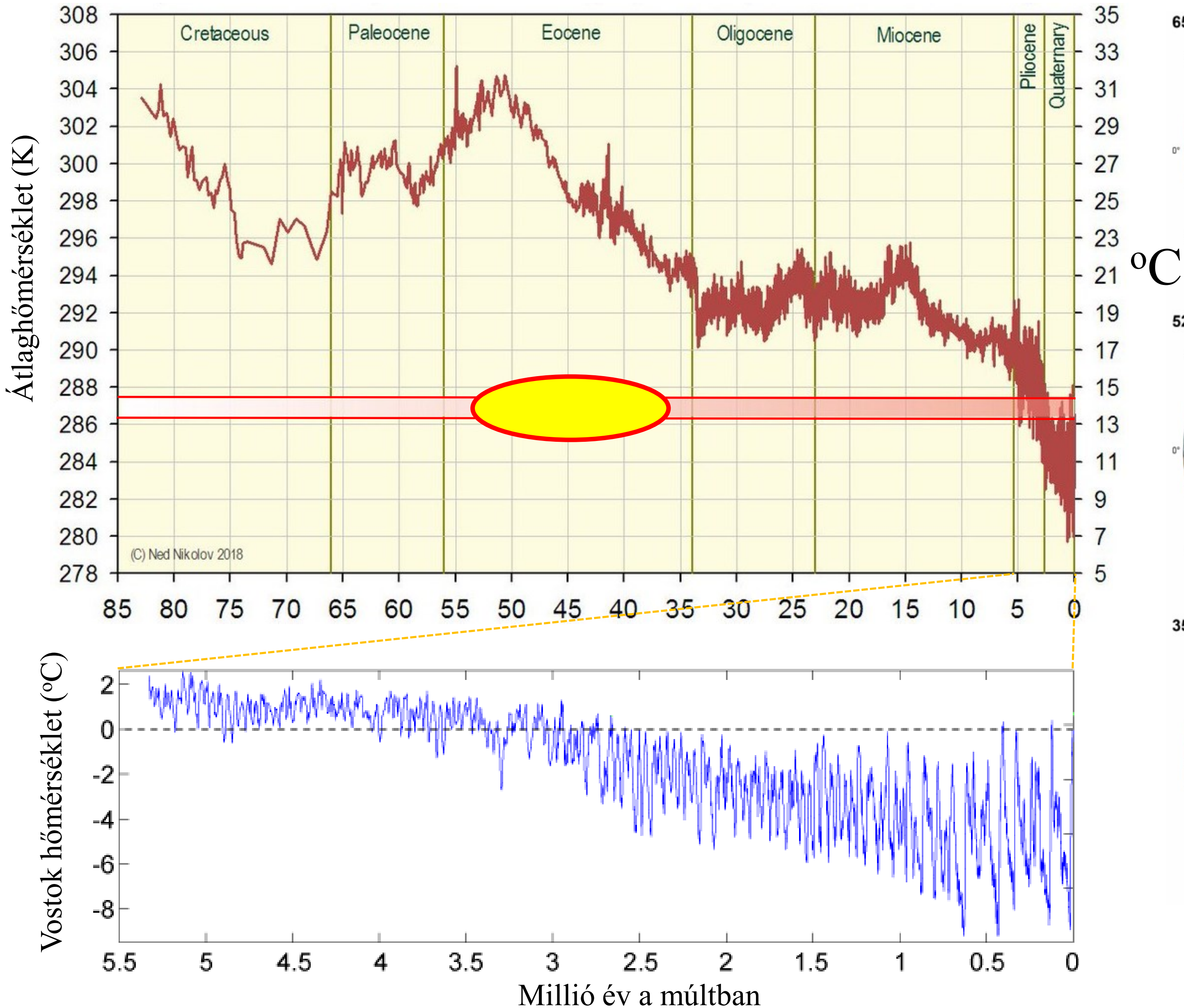
Paleoclimatic reconstruction

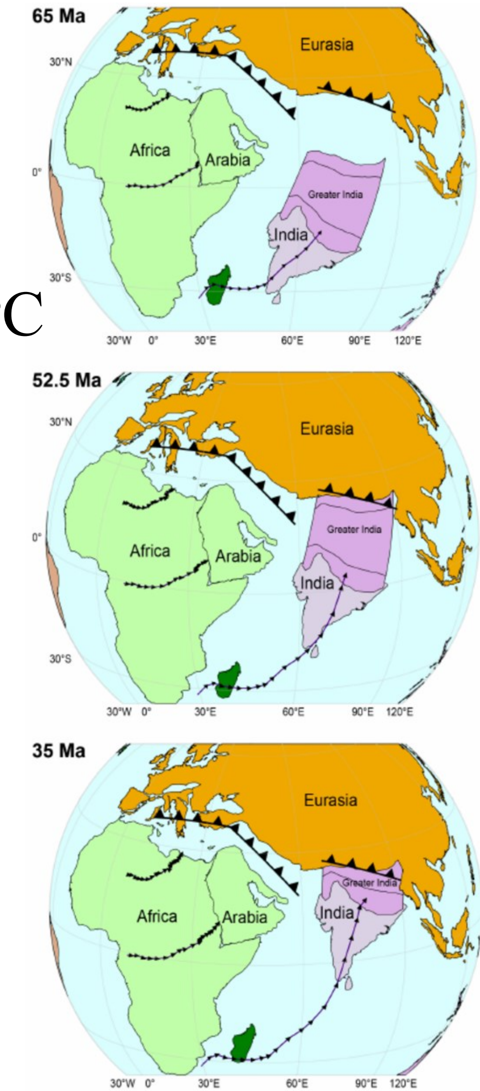




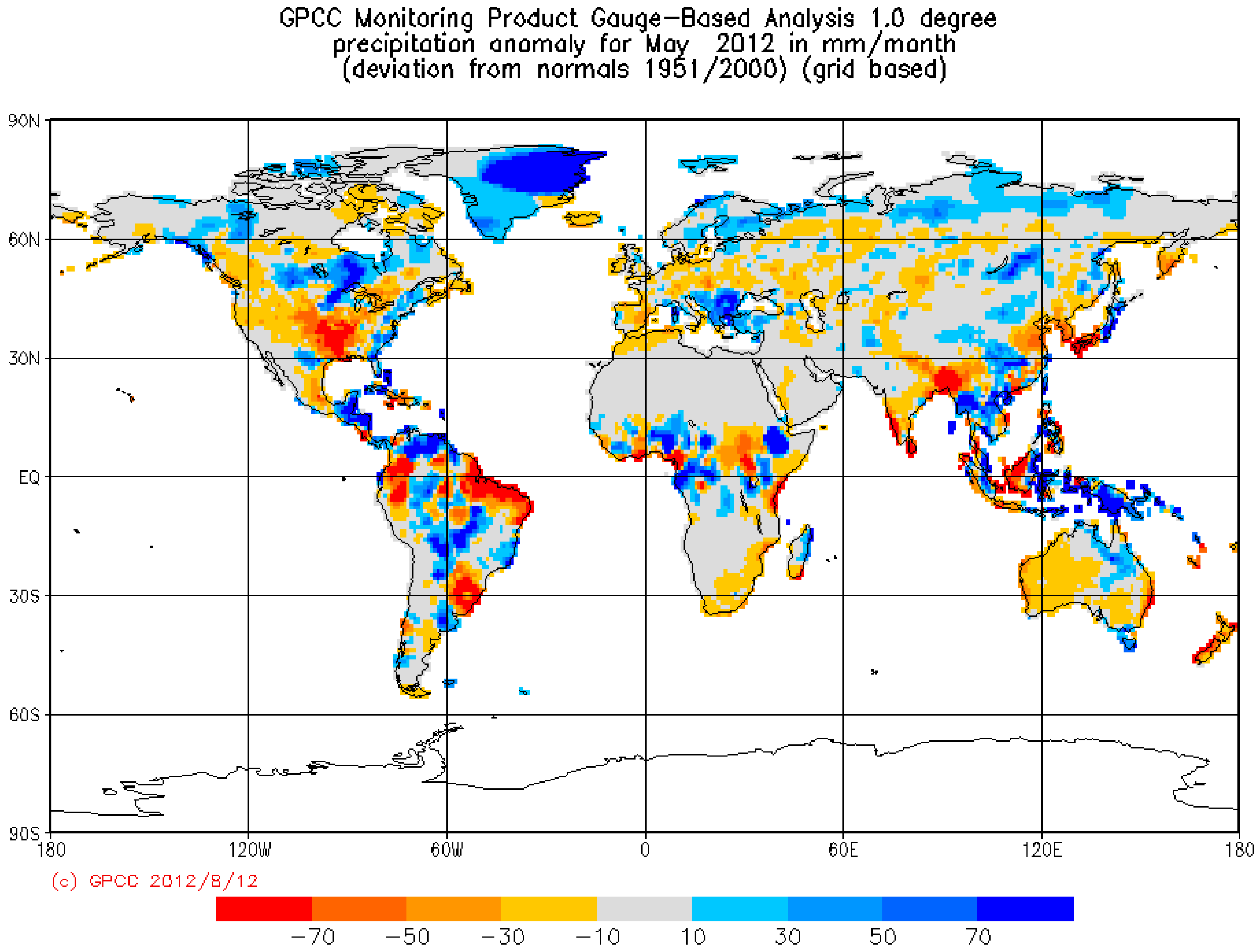
Hoareau et al., *Climate of the Past*, **11**, 1751-1767, 2015

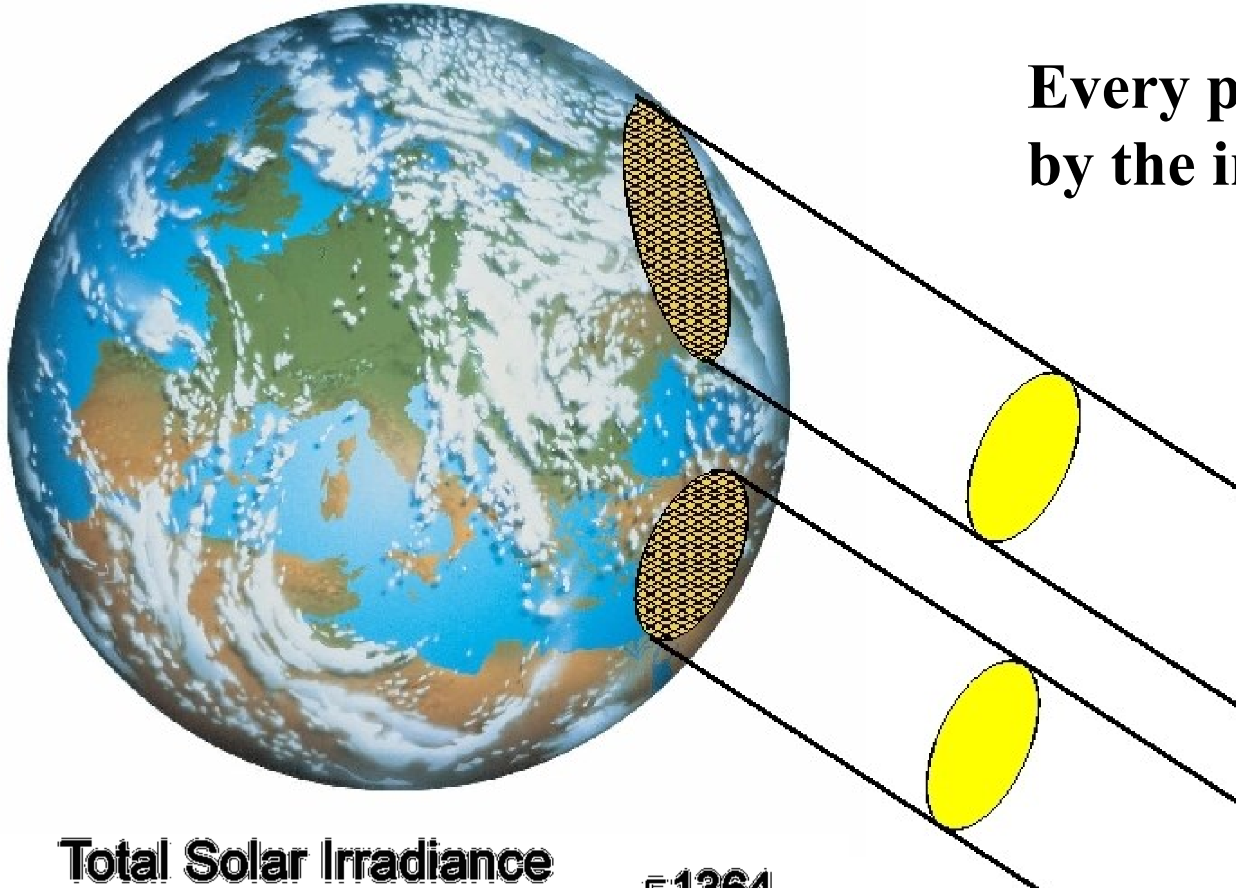
Paleoclimatic reconstruction



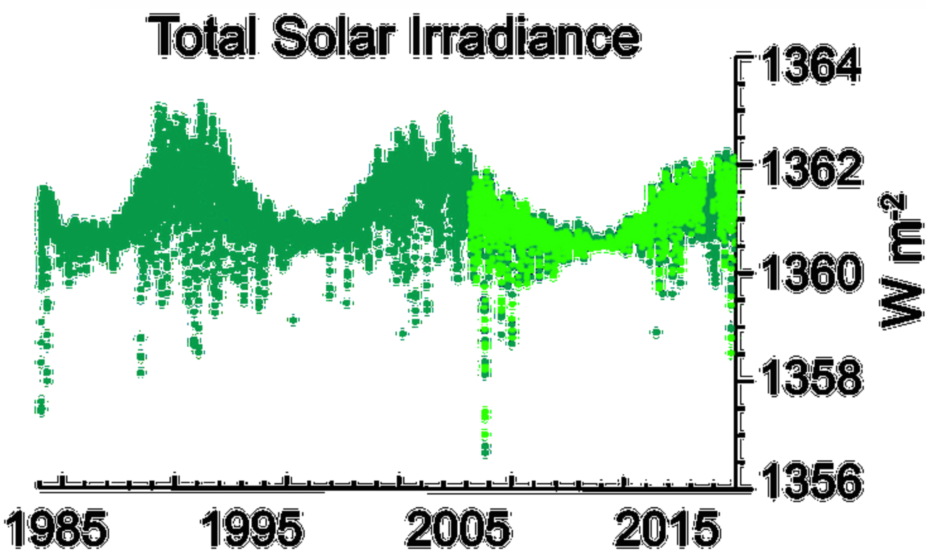


Hoareau et al., *Climate of the Past*, **11**, 1751-1767, 2015

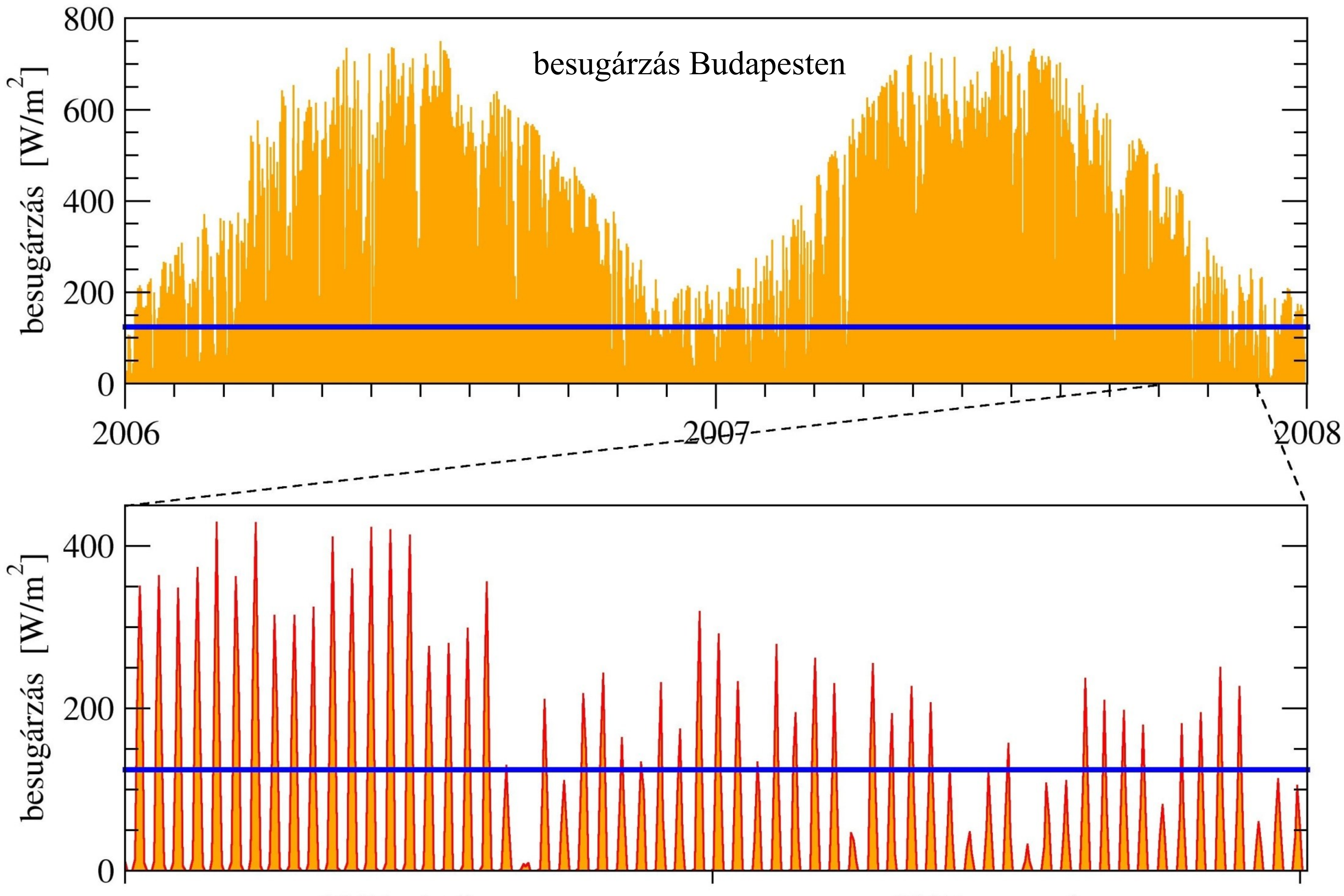

GPCC Monitoring Product Gauge-Based Analysis 1.0 degree
precipitation anomaly for May 2012 in mm/month
(deviation from normals 1951/2000) (grid based)
90N
60N
30N
EQ
30S
60S
90S
180
120W
60W
0
60E
120E
180
(c) GPCC 2012/8/12
-70
-50
-30
-10
10
30
50
70



Every processes are driven by the insolation …

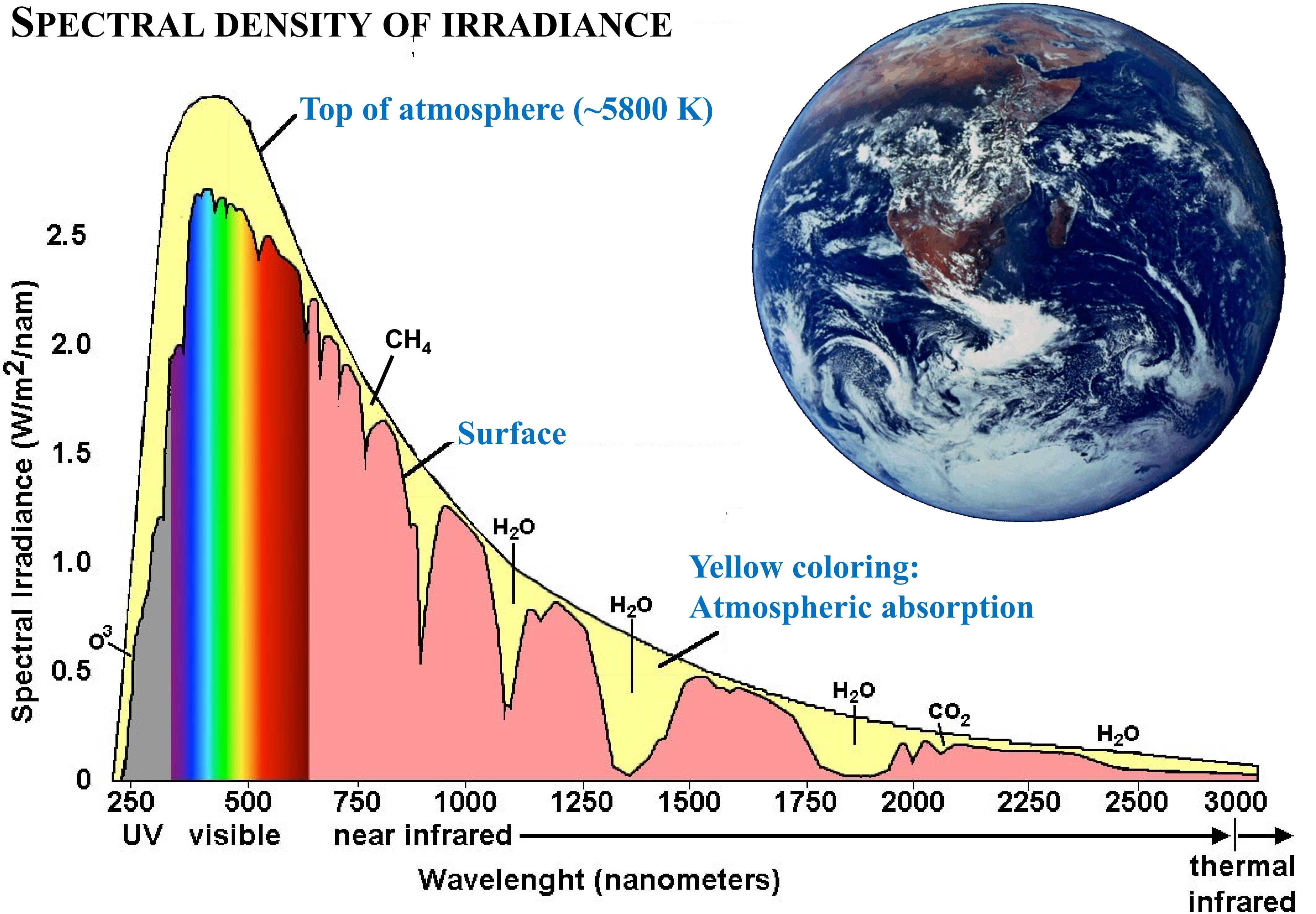


Total Solar Irradiance:
1360.8 ± 0.5 W/m²

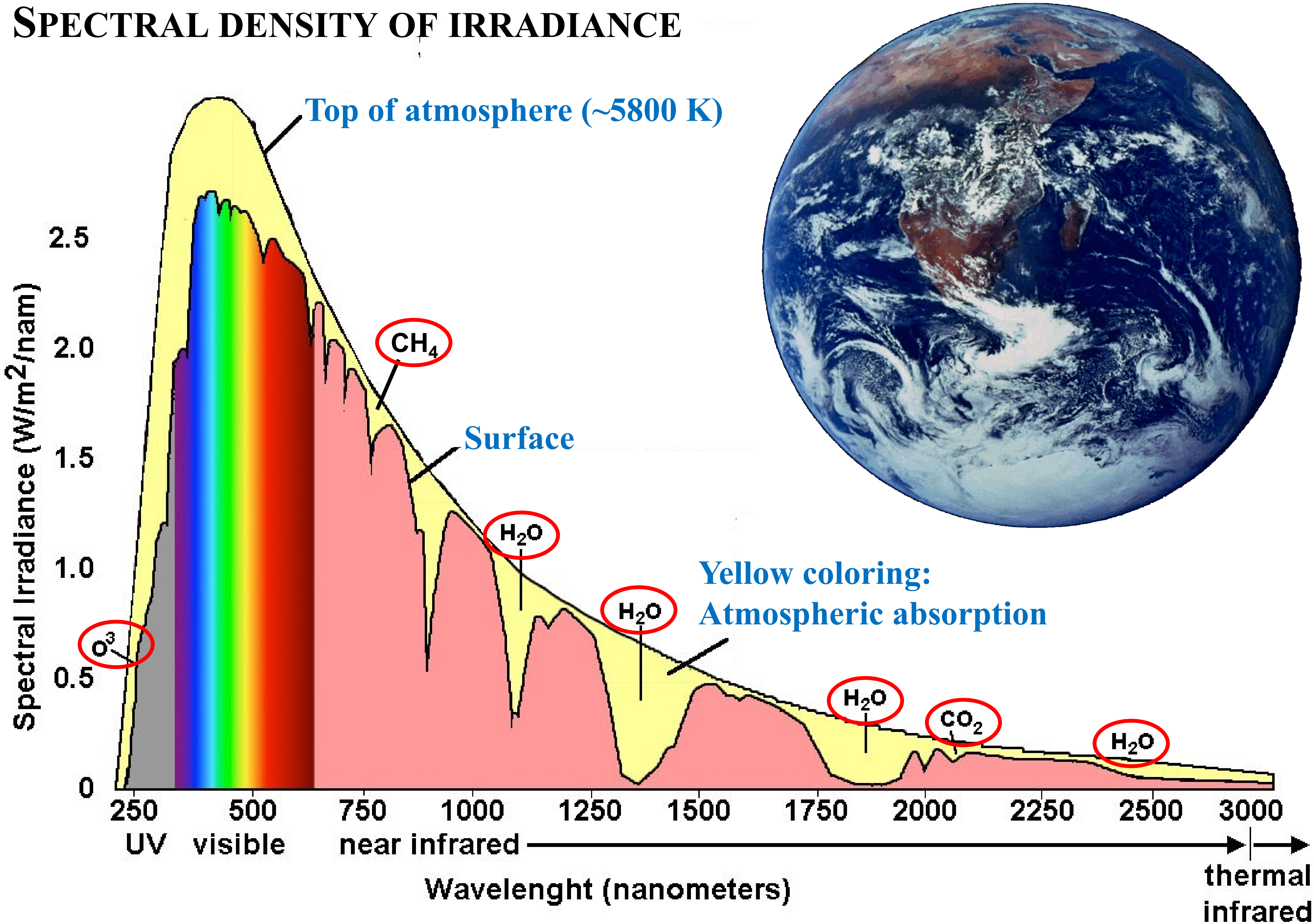


besugárzás Budapesten
besugárzás [W/m^2]
800
600
400
200
0
2006
2007
2008
besugárzás [W/m^2]
400
200
0
2007. október
2007. november

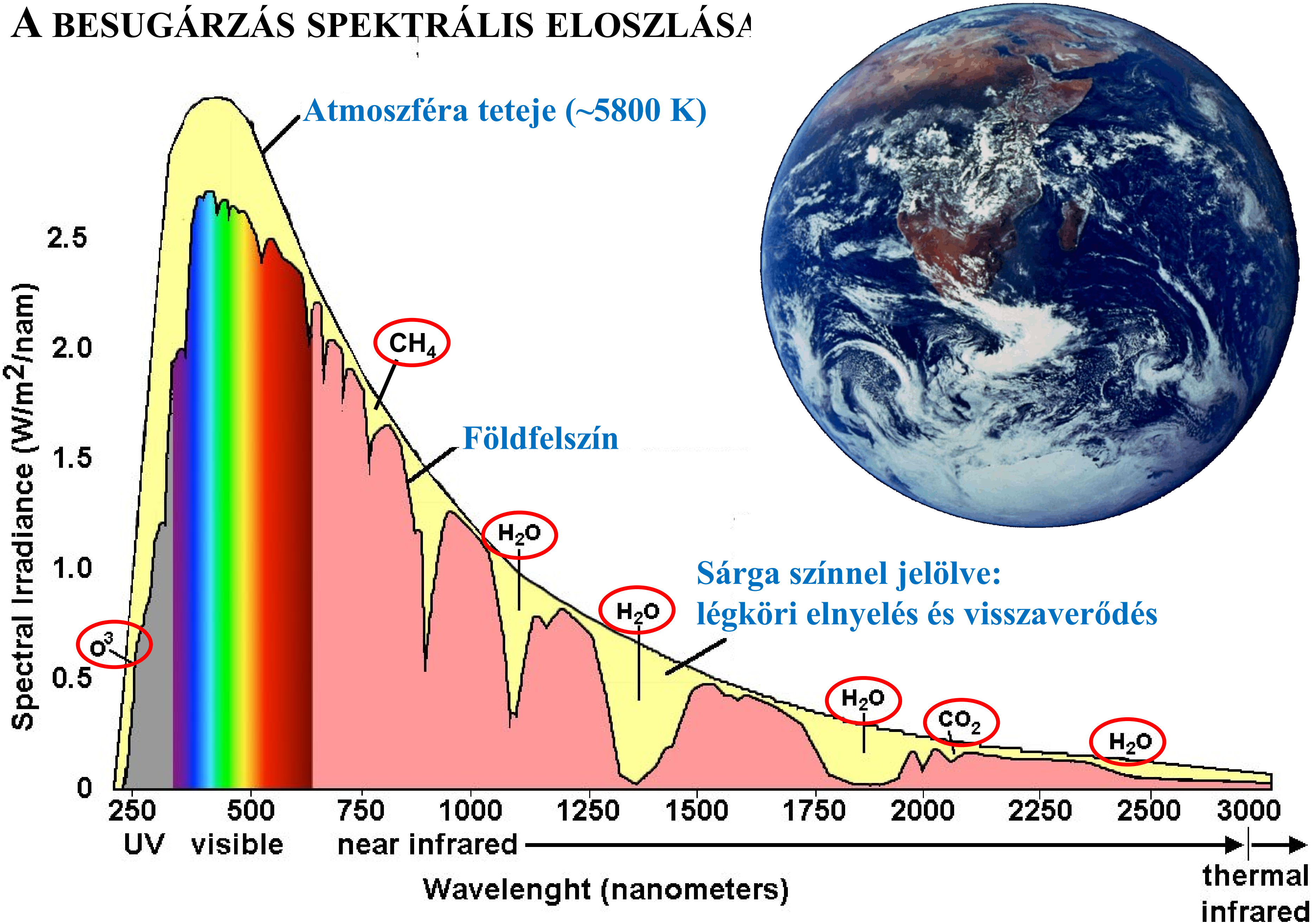
SPECTRAL DENSITY OF IRRADIANCE

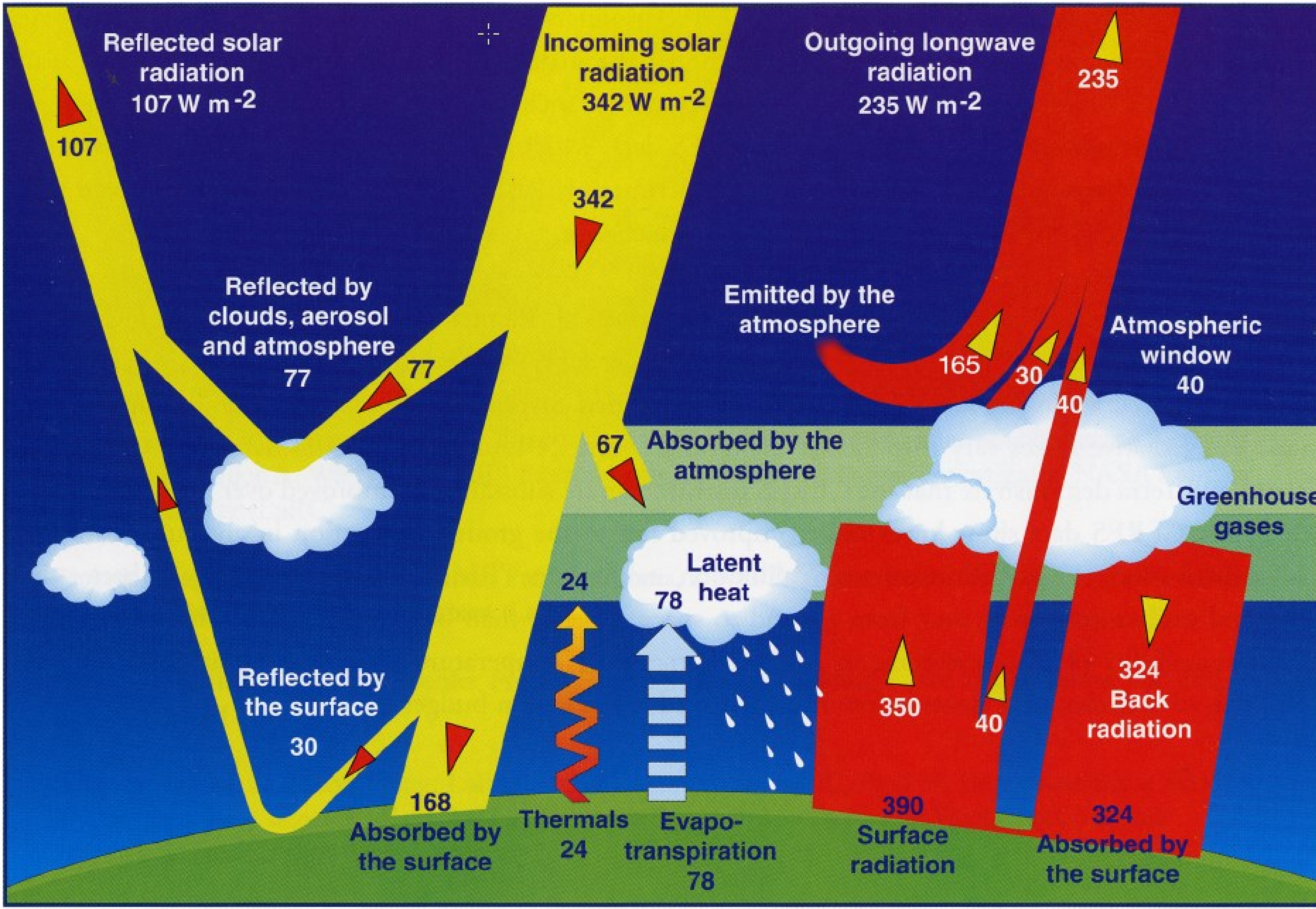


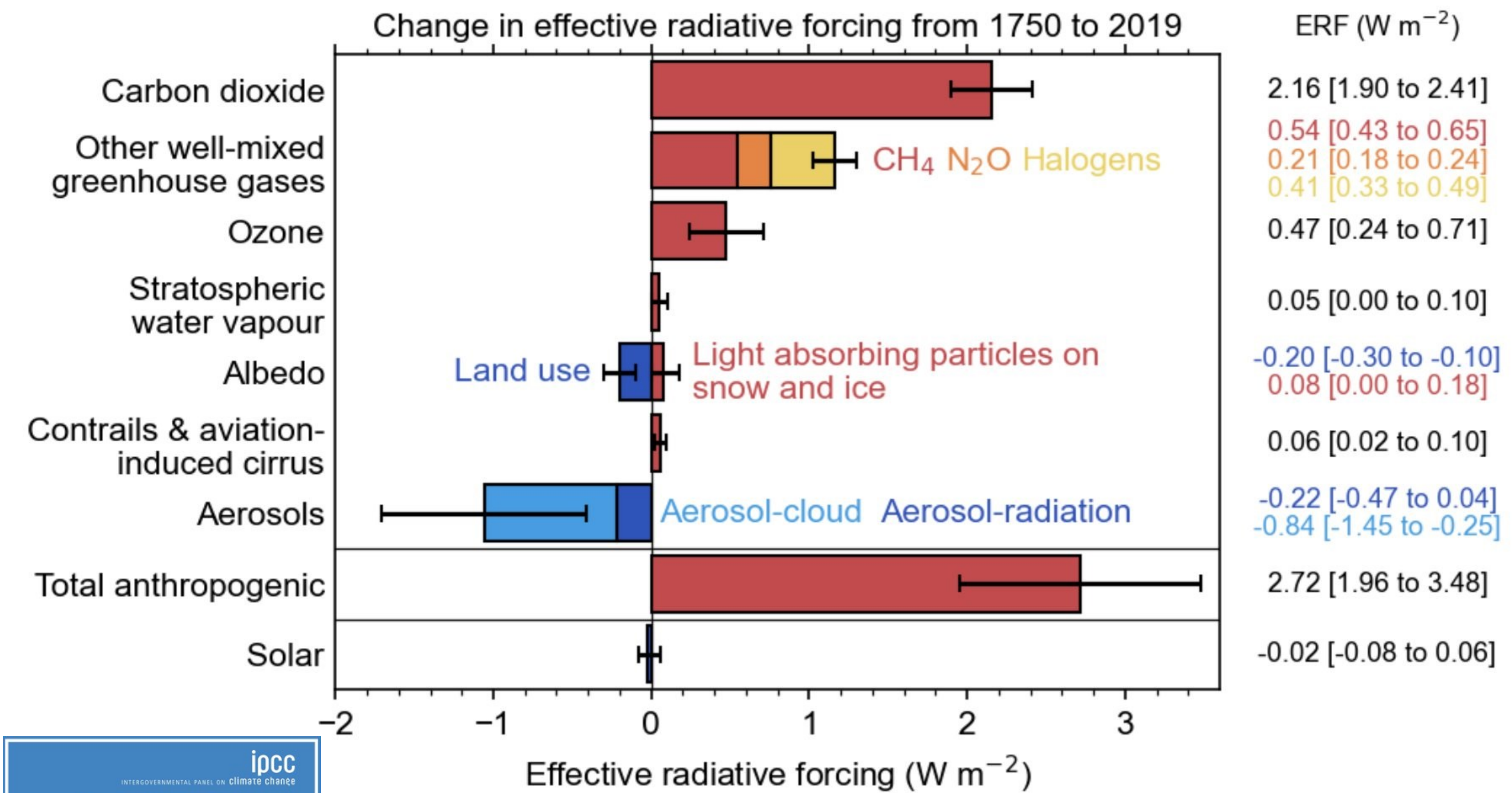
SPECTRAL DENSITY OF IRRADIANCE

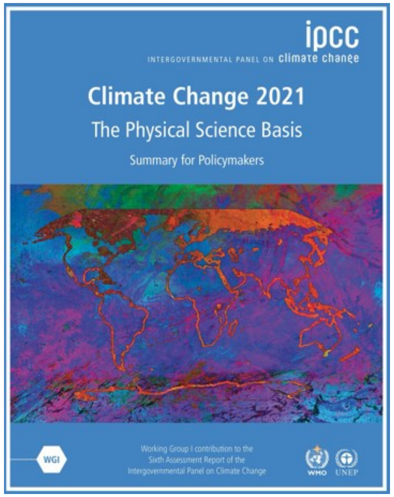


A BESUGÁRZÁS SPEKTRÁLIS ELOSZLÁSA

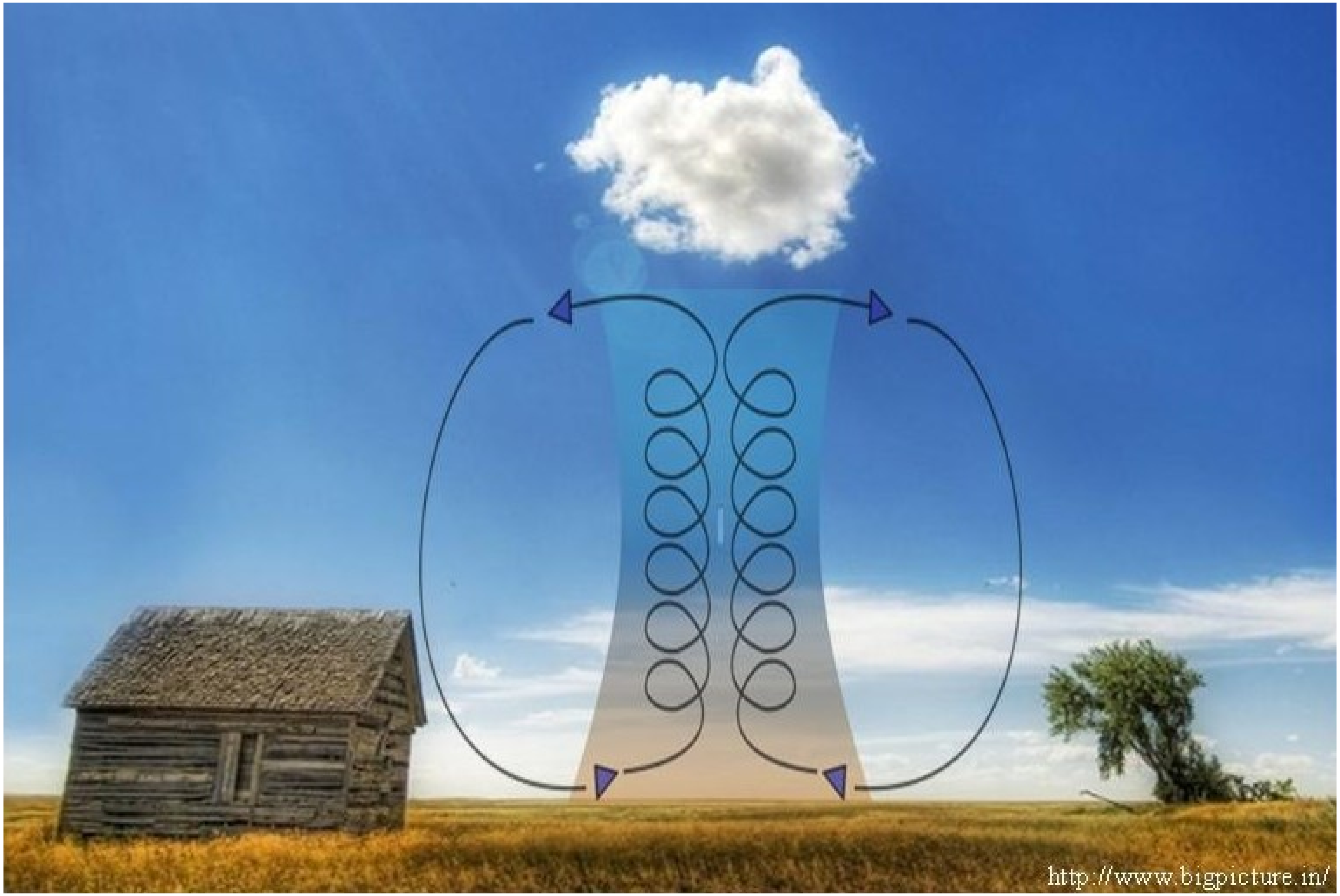


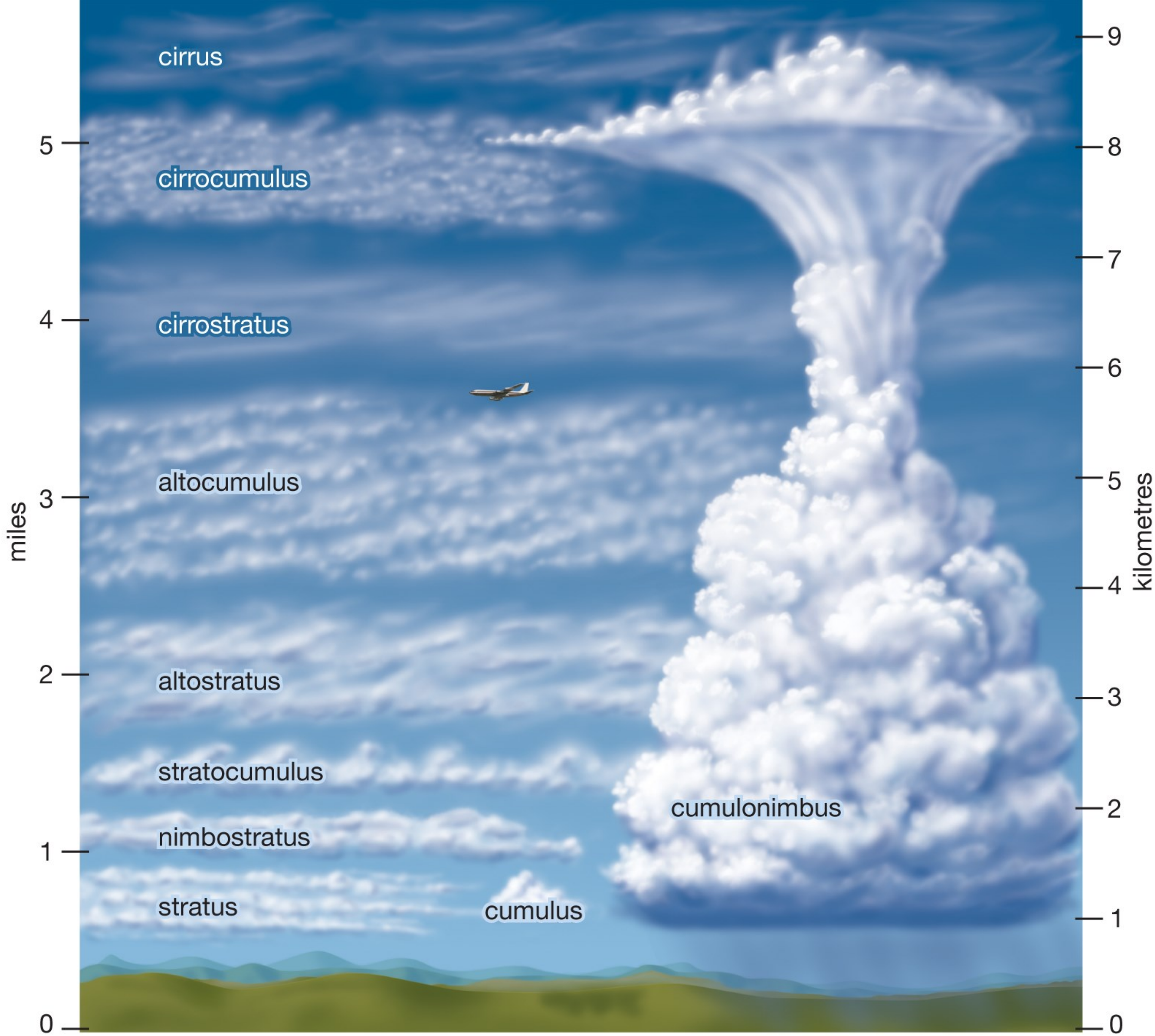

Reflected solar radiation 107 W m-2
107
Incoming solar radiation 342 W m-2
342
Outgoing longwave radiation 235 W m-2
235
Reflected by clouds, aerosol and atmosphere 77
77
Emitted by the atmosphere
165
30
40
Atmospheric window 40
40
67
Absorbed by the atmosphere
Greenhouse gases
Latent heat
24
78
Reflected by the surface 30
168
Absorbed by the surface
Thermals 24
Evapo-transpiration 78
350
40
324 Back radiation
390
Surface radiation
324
Absorbed by the surface


Change in effective radiative forcing from 1750 to 2019
ERF (W m−2)
Carbon dioxide
2.16 [1.90 to 2.41]
Other well-mixed greenhouse gases
CH4 N2O Halogens
0.54 [0.43 to 0.65]
0.21 [0.18 to 0.24]
0.41 [0.33 to 0.49]
Ozone
0.47 [0.24 to 0.71]
Stratospheric water vapour
0.05 [0.00 to 0.10]
Albedo
Land use
Light absorbing particles on snow and ice
-0.20 [-0.30 to -0.10]
0.08 [0.00 to 0.18]
Contrails & aviation-induced cirrus
0.06 [0.02 to 0.10]
Aerosols
Aerosol-cloud Aerosol-radiation
-0.22 [-0.47 to 0.04]
-0.84 [-1.45 to -0.25]
Total anthropogenic
2.72 [1.96 to 3.48]
Solar
-0.02 [-0.08 to 0.06]
−2 −1 0 1 2 3
Effective radiative forcing (W m−2)


ipcc
INTERGOVERNMENTAL PANEL ON climate change
Climate Change 2021
The Physical Science Basis
Summary for Policymakers

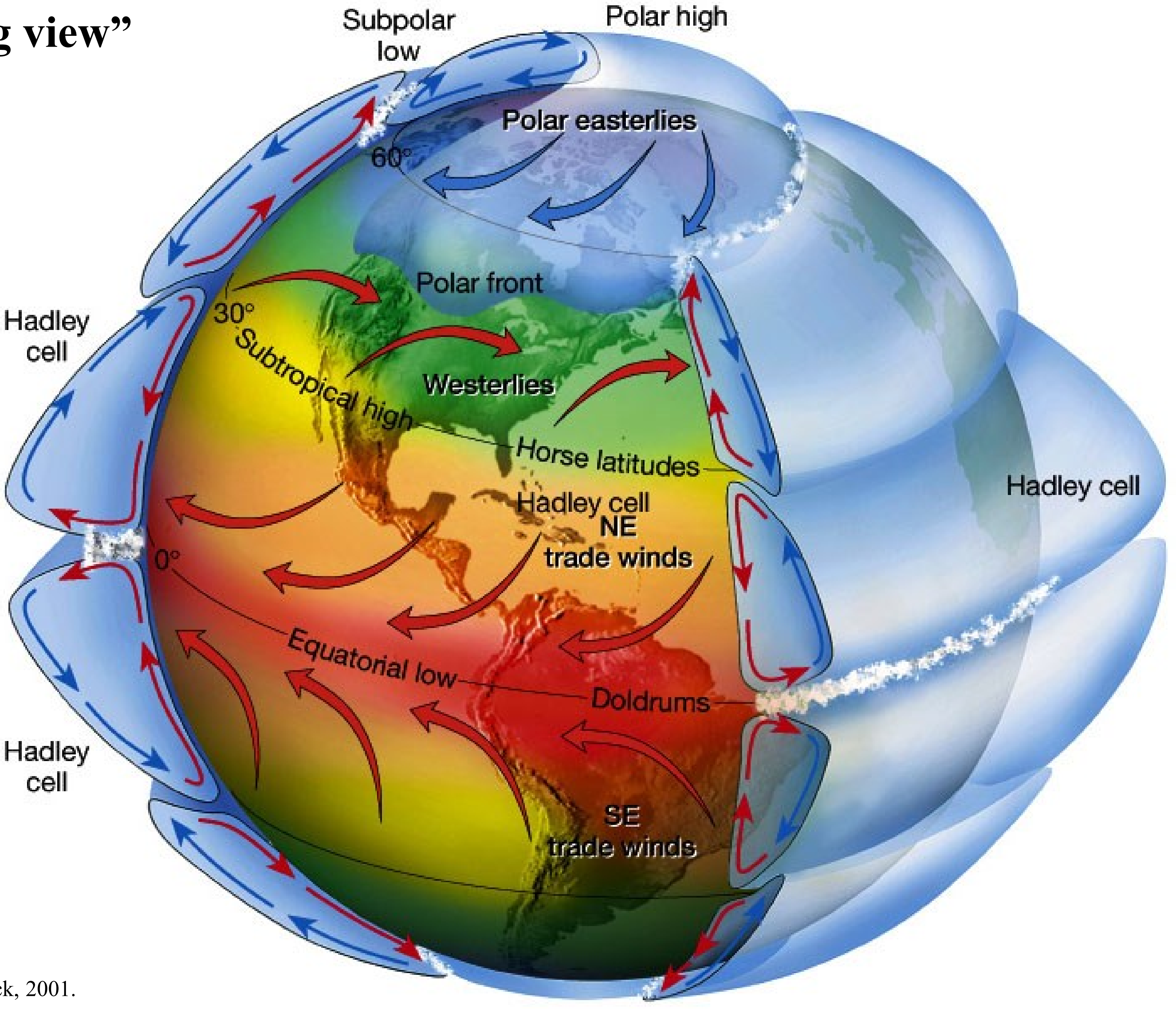
Thermal convection





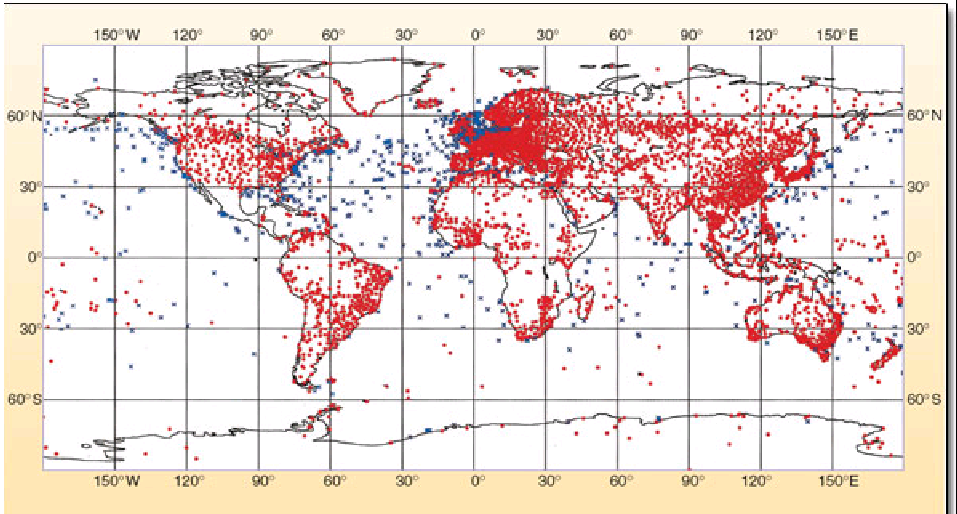
cirrus
cirrocumulus
cirrostratus
altocumulus
altostratus
stratocumulus
nimbostratus
stratus
cumulus
cumulonimbus
miles
0
1
2
3
4
5
kilometres
0
1
2
3
4
5
6
7
8
9

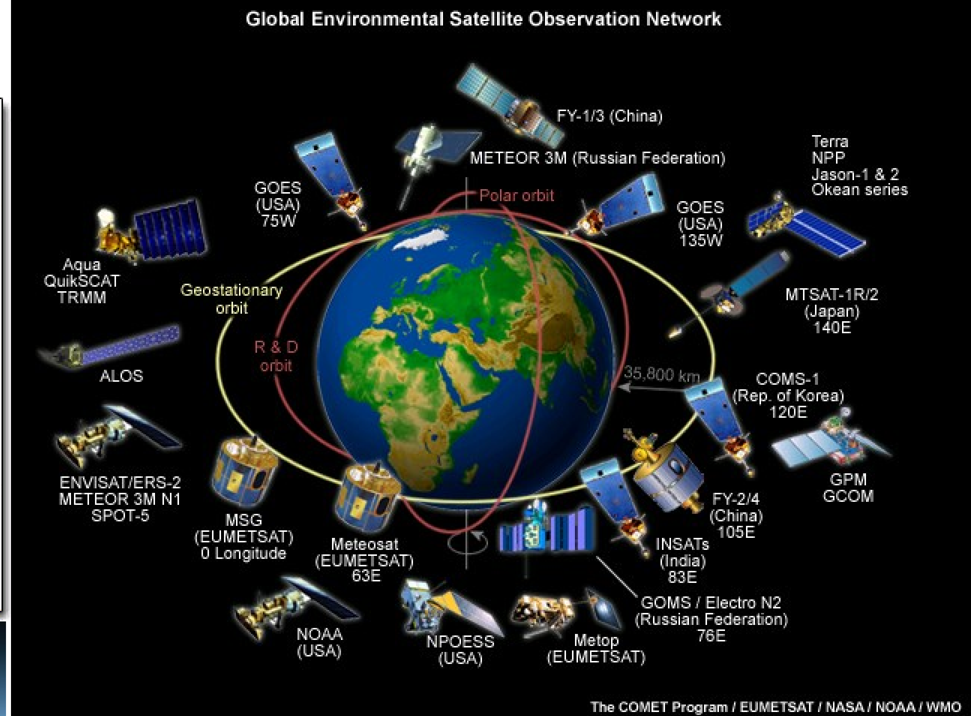
The „big view”

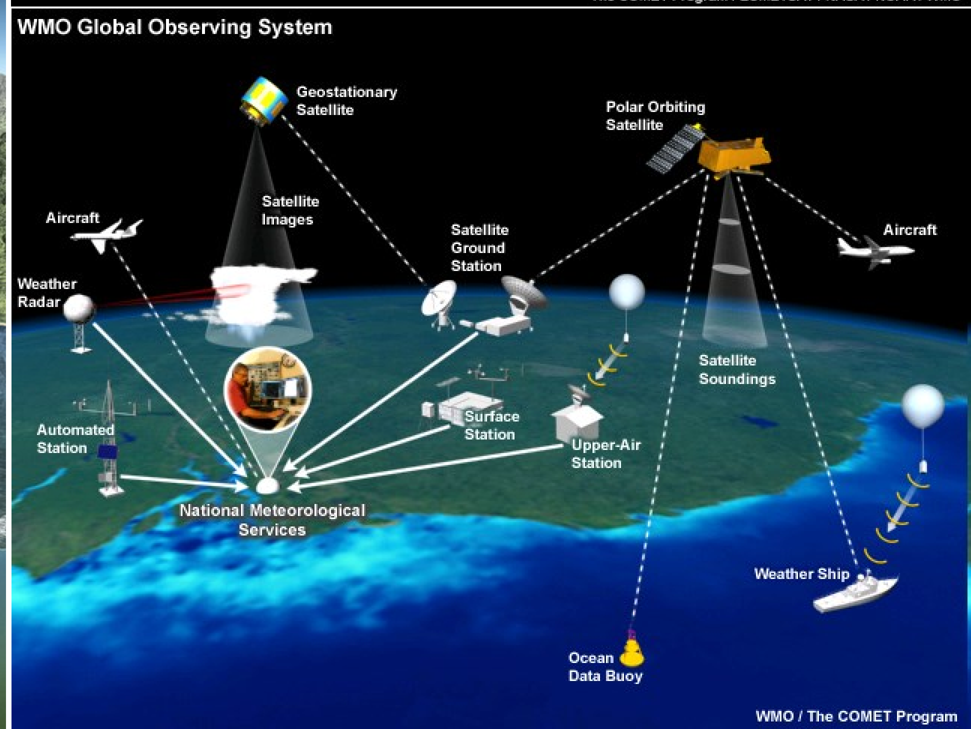


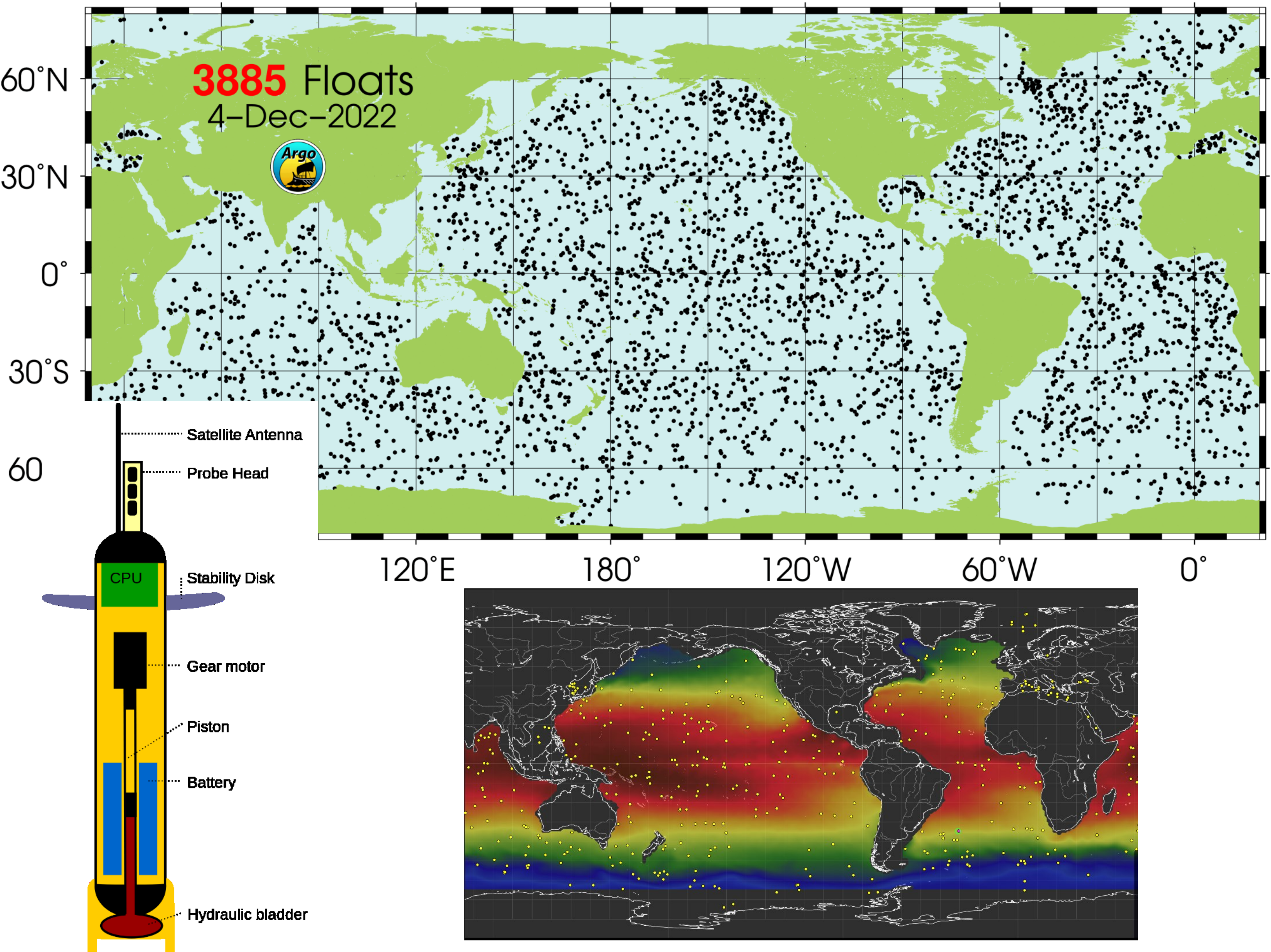
Lutgens & Tarbuck, 2001.

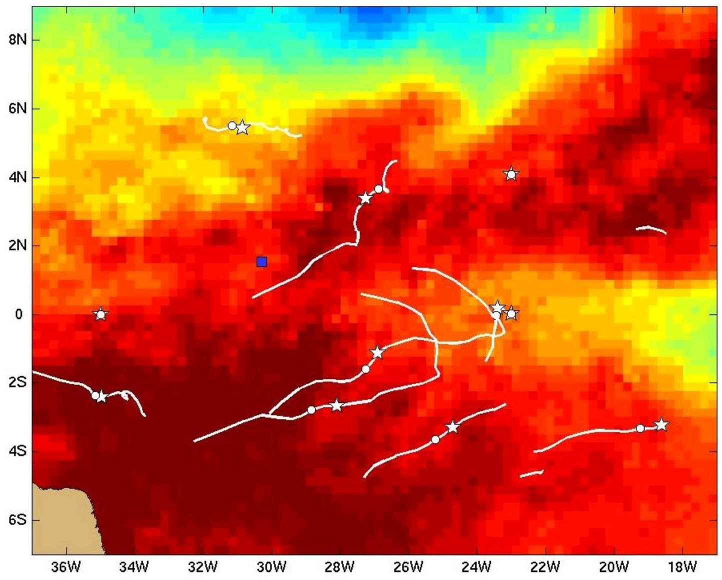
Observing networks





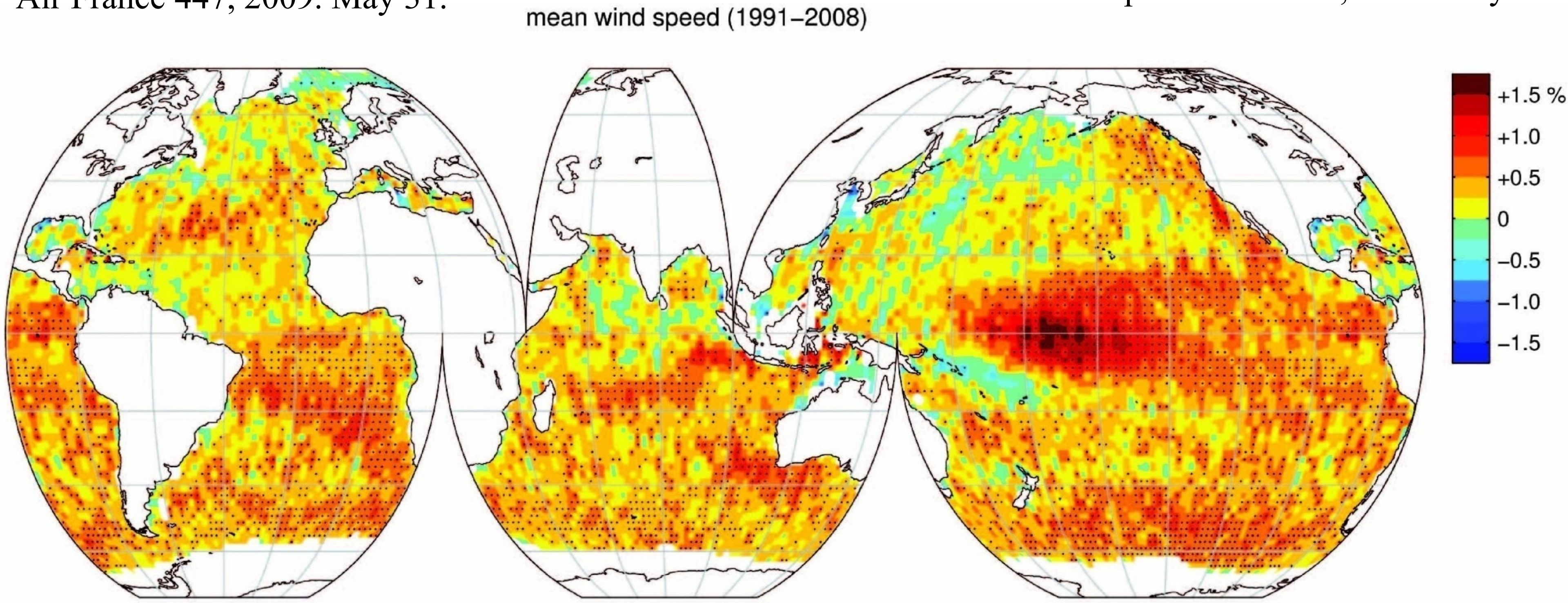



3885 Floats
4-Dec-2022
Argo
60°N
30°N
0°
30°S
60
120°E
180°
120°W
60°W
0°
Satellite Antenna
Probe Head
CPU
Stability Disk
Gear motor
Piston
Battery
Hydraulic bladder



Air France 447, 2009. May 31.

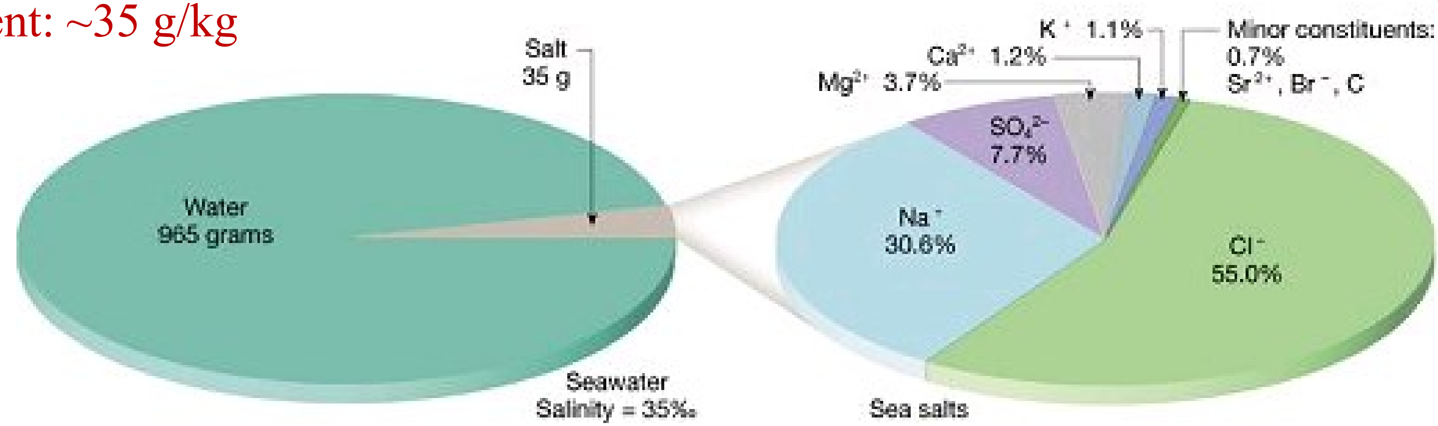
BP Deep Blue Horizon, 2011. May 16.



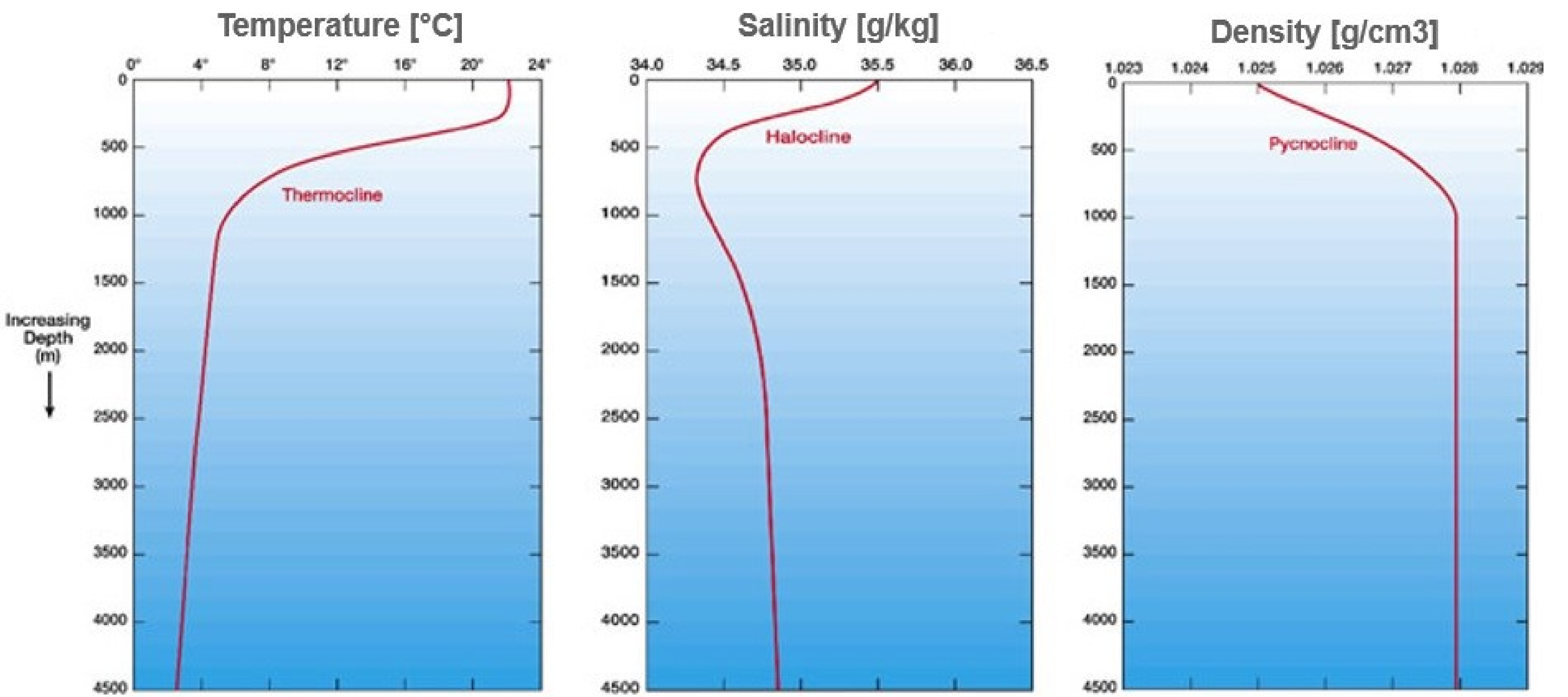
I. R. Young, S. Zieger, and A. V. Babanin, *Science,* **332**, 451-455 *(2011).*

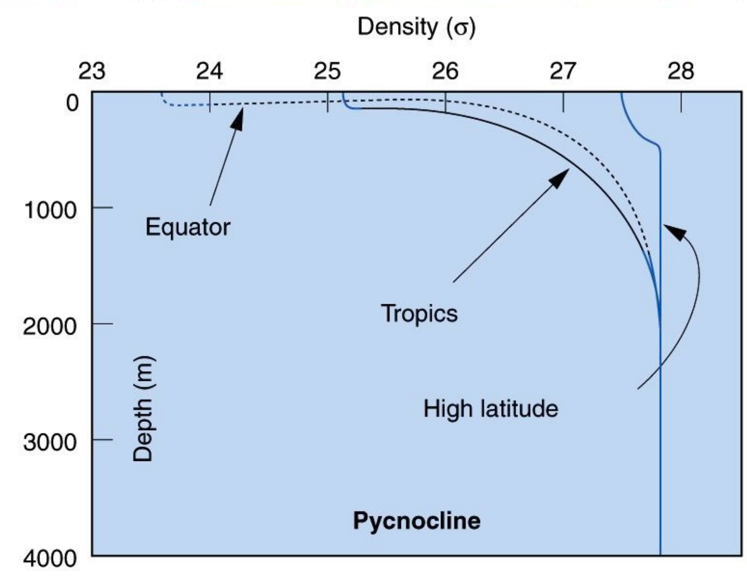
Chemical composition of sea water:

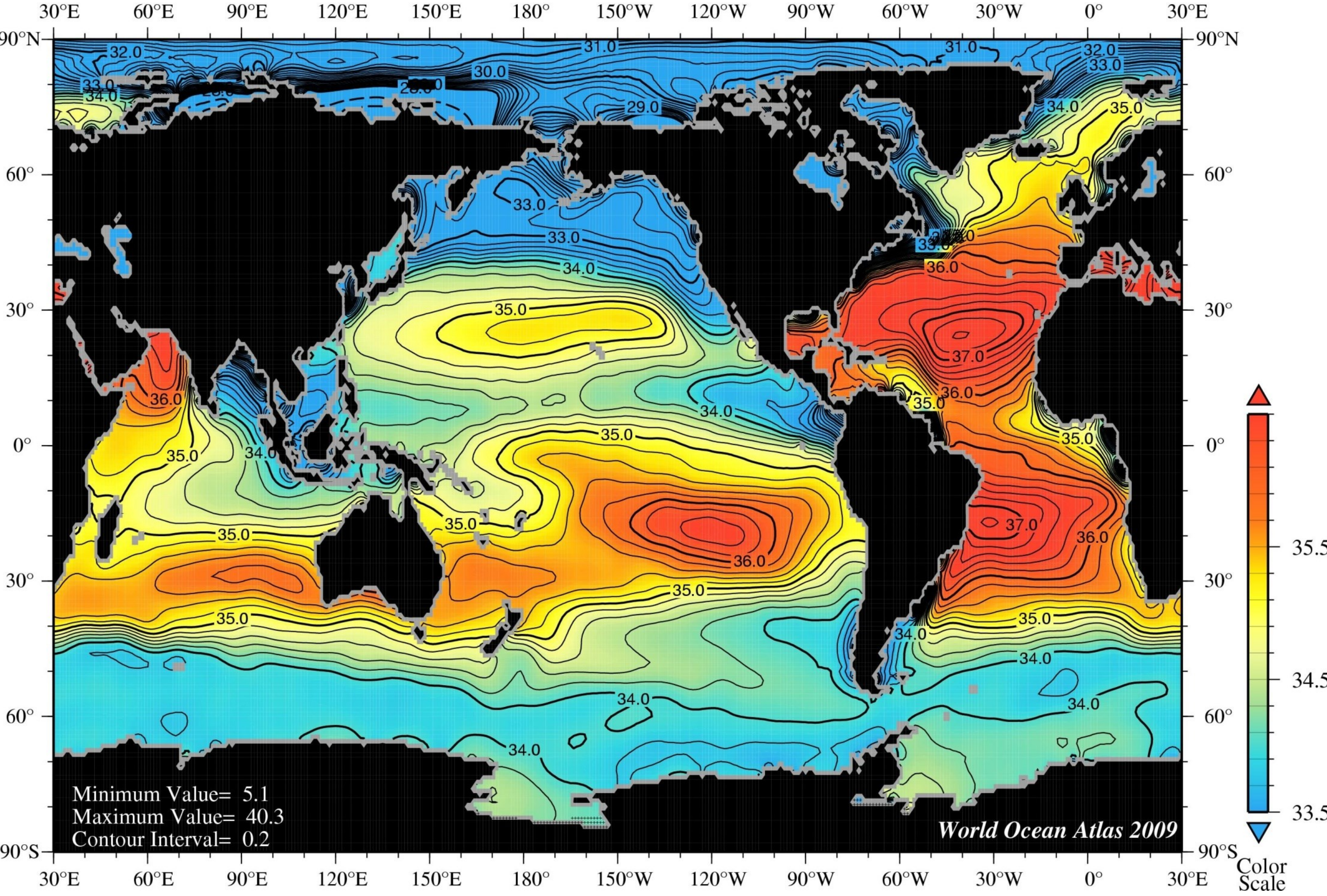
Mean salt content: ~35 g/kg



Comparison of Major Elements in the Dead Sea, the Mediterranean sea and Typical ocean Water.			
	Dead Sea	Mediterranean Sea	Ocean Water
Chloride	224,900	22,900	19,000
Magnesium	44,000	1,490	1,350
Sodium	40,100	12,700	10,500
Calcium	17,200	470	400
Potassium	7,650	470	390
Bromide	5,300	76	65


Temperature [°C]
Salinity [g/kg]
Density [g/cm3]
0° 4° 8° 12° 16° 20° 24°
34.0 34.5 35.0 35.5 36.0 36.5
1.023 1.024 1.025 1.026 1.027 1.028 1.029
0 500 1000 1500 2000 2500 3000 3500 4000 4500
Increasing Depth (m)
Thermocline
Halocline
Pycnocline


Density (σ)
23 24 25 26 27 28
0 1000 2000 3000 4000
Depth (m)
Equator
Tropics
High latitude
Pycnocline


30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
0°
90°N
60°
30°
0°
30°
60°
90°S
31.0
32.0
33.0
34.0
35.0
36.0
37.0
30.0
29.0
Minimum Value= 5.1
Maximum Value= 40.3
Contour Interval= 0.2
World Ocean Atlas 2009
35.5
34.5
33.5
Color Scale

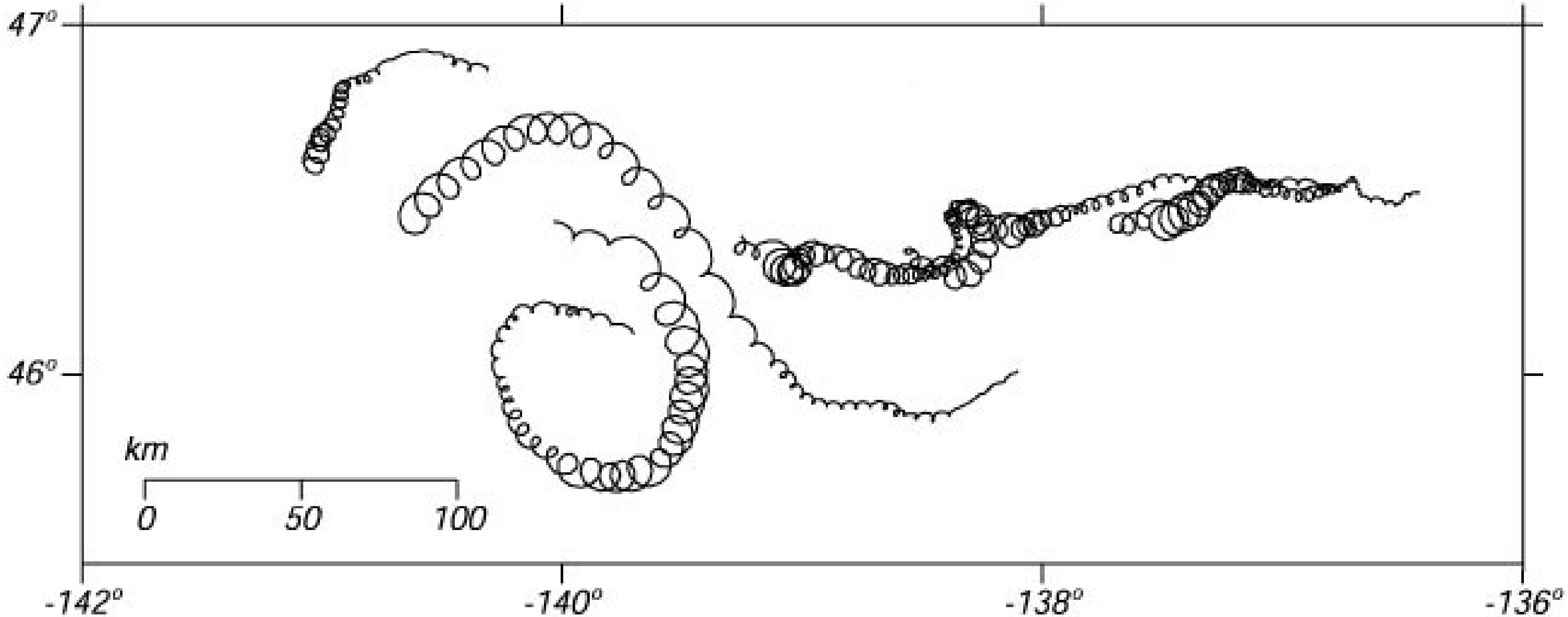
Global current sytems in the world ocean:

(1) Wind driven surface flow:

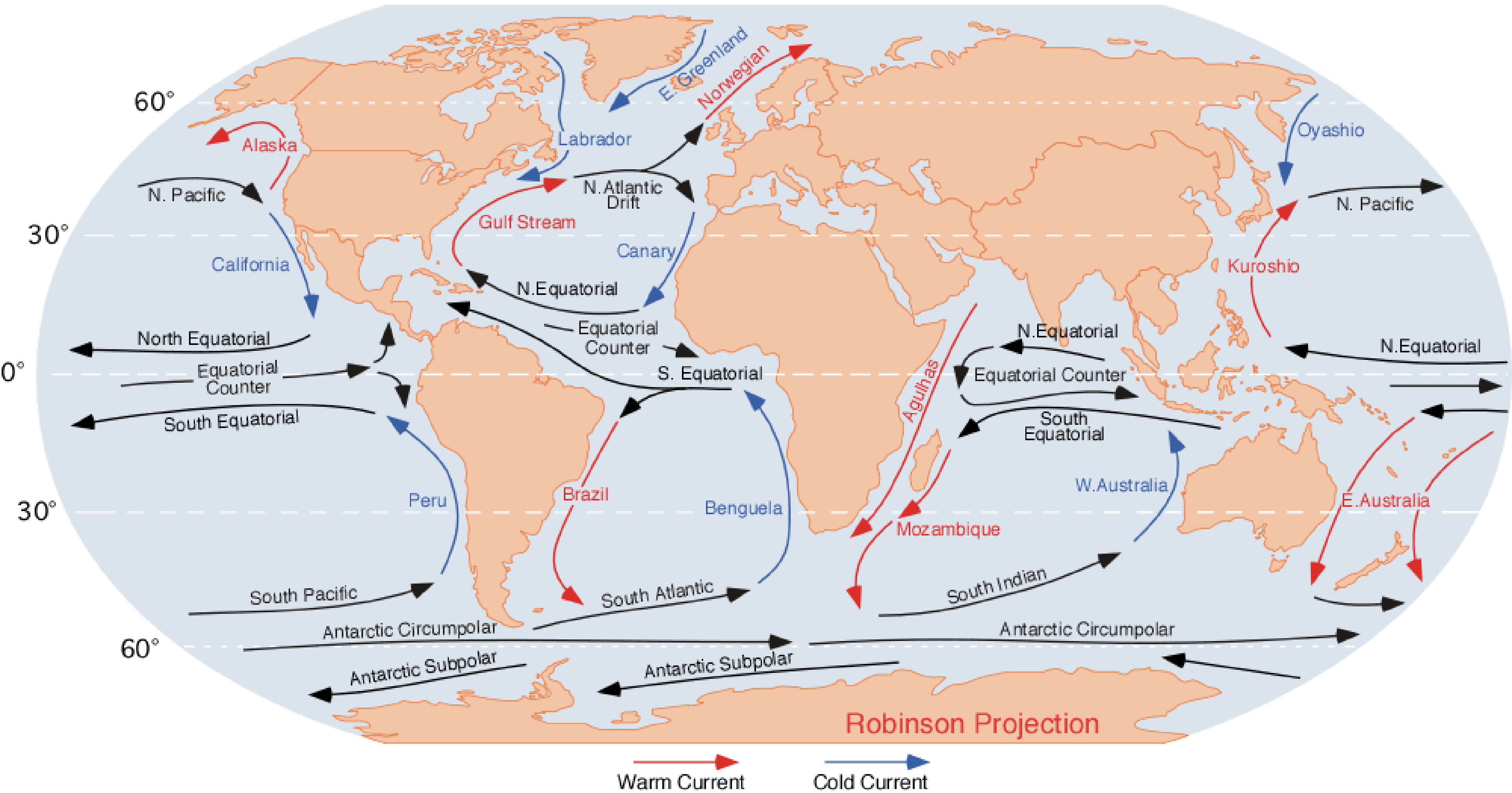
wind shear [N/m²]:

$$\tau = C_D \rho u_{10}^2$$

$$1000\, C_D = 0.6 + 0.07 u_{10}$$



(1) Wind driven surface flows: gyres



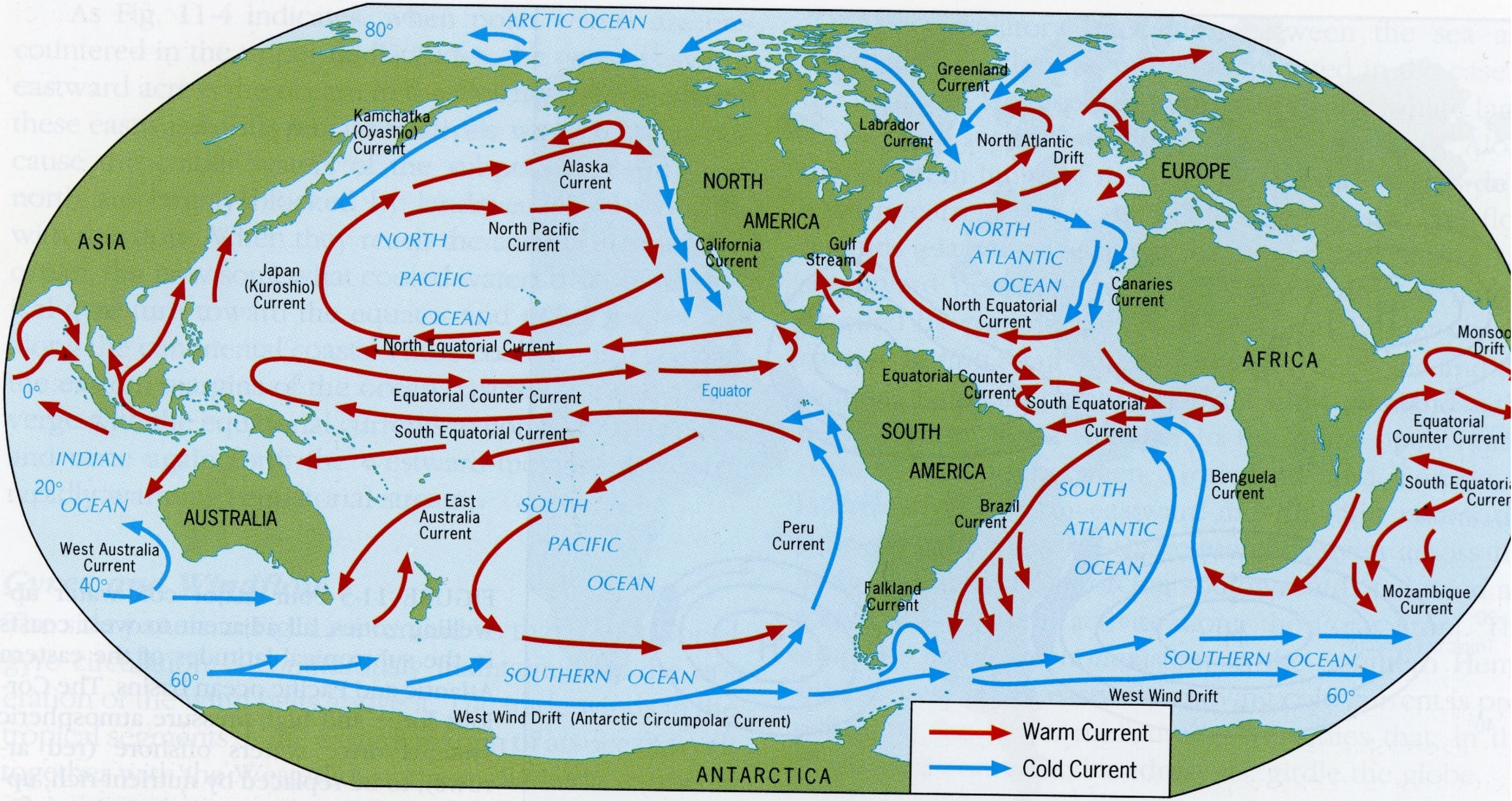
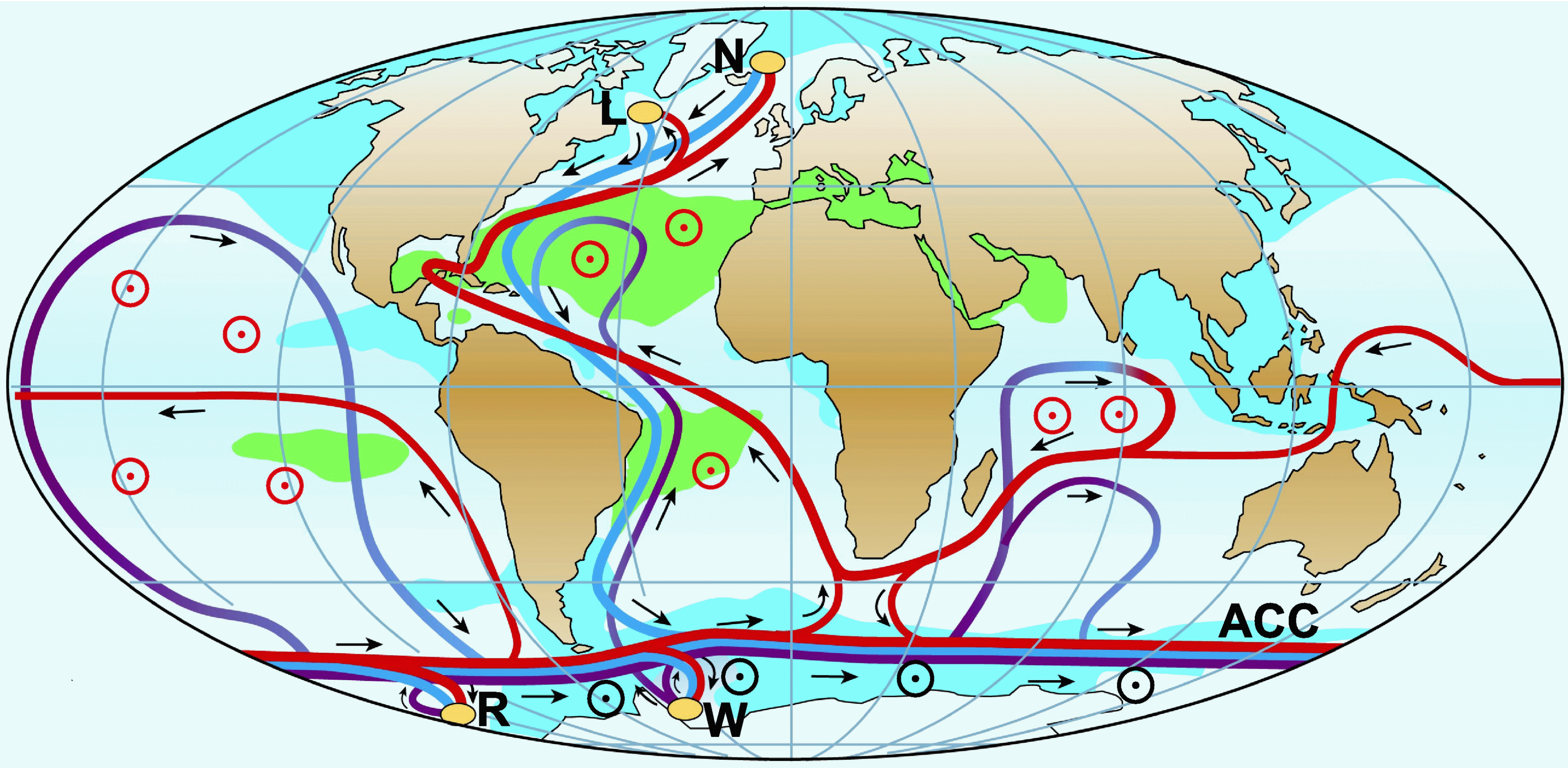
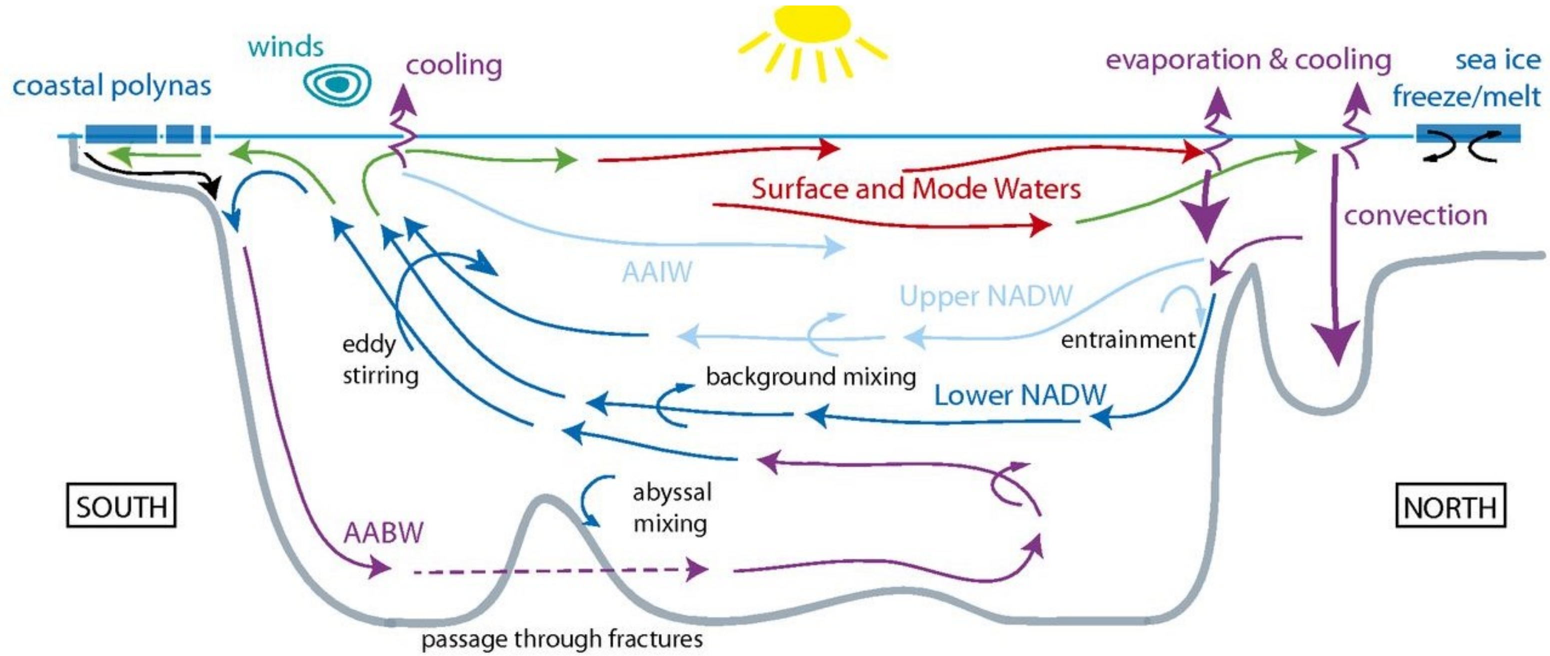


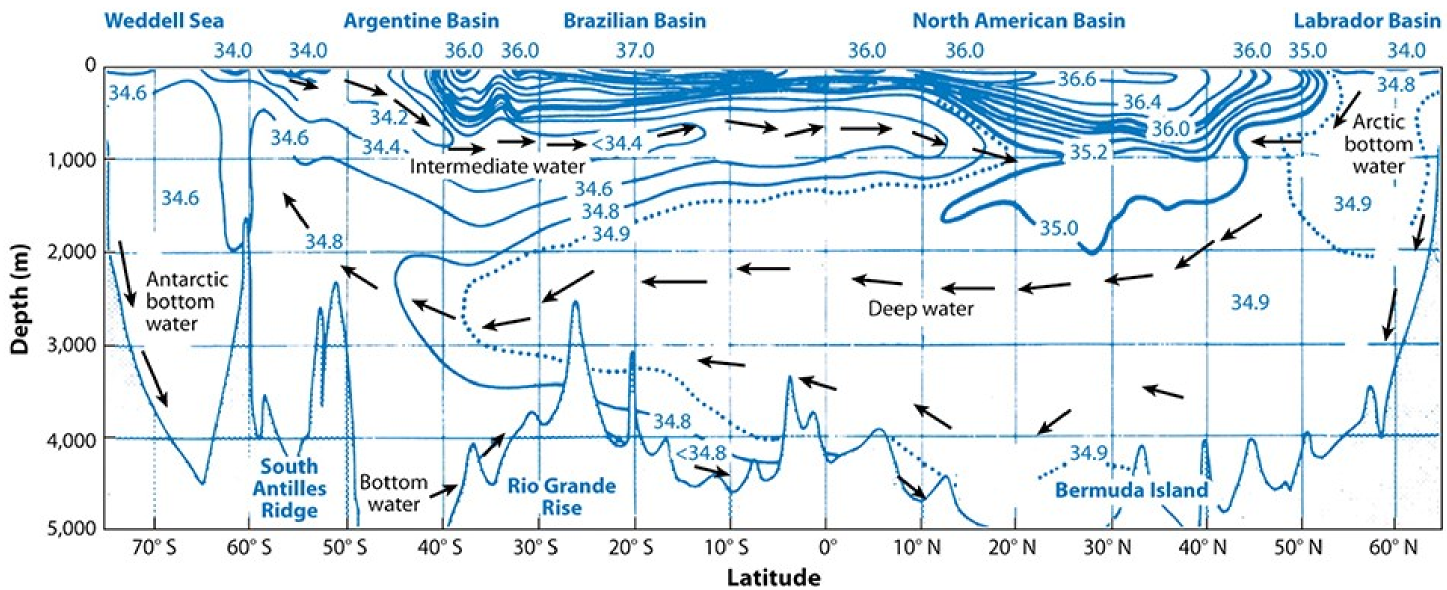
FIGURE 11-6 World distribution of ocean currents, showing average positions and relative temperatures in each of the ocean basins.

(2) The global „ocean conveyor belt"

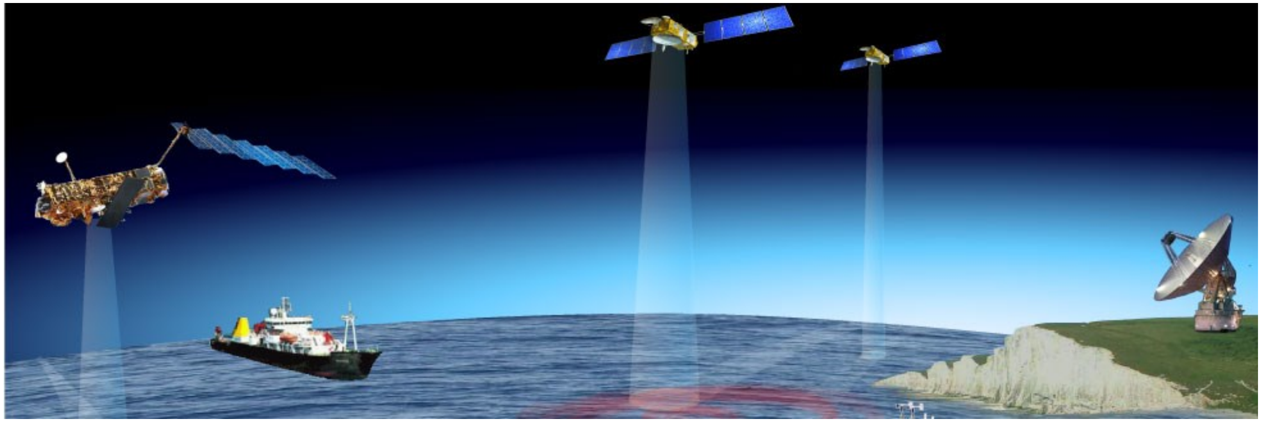


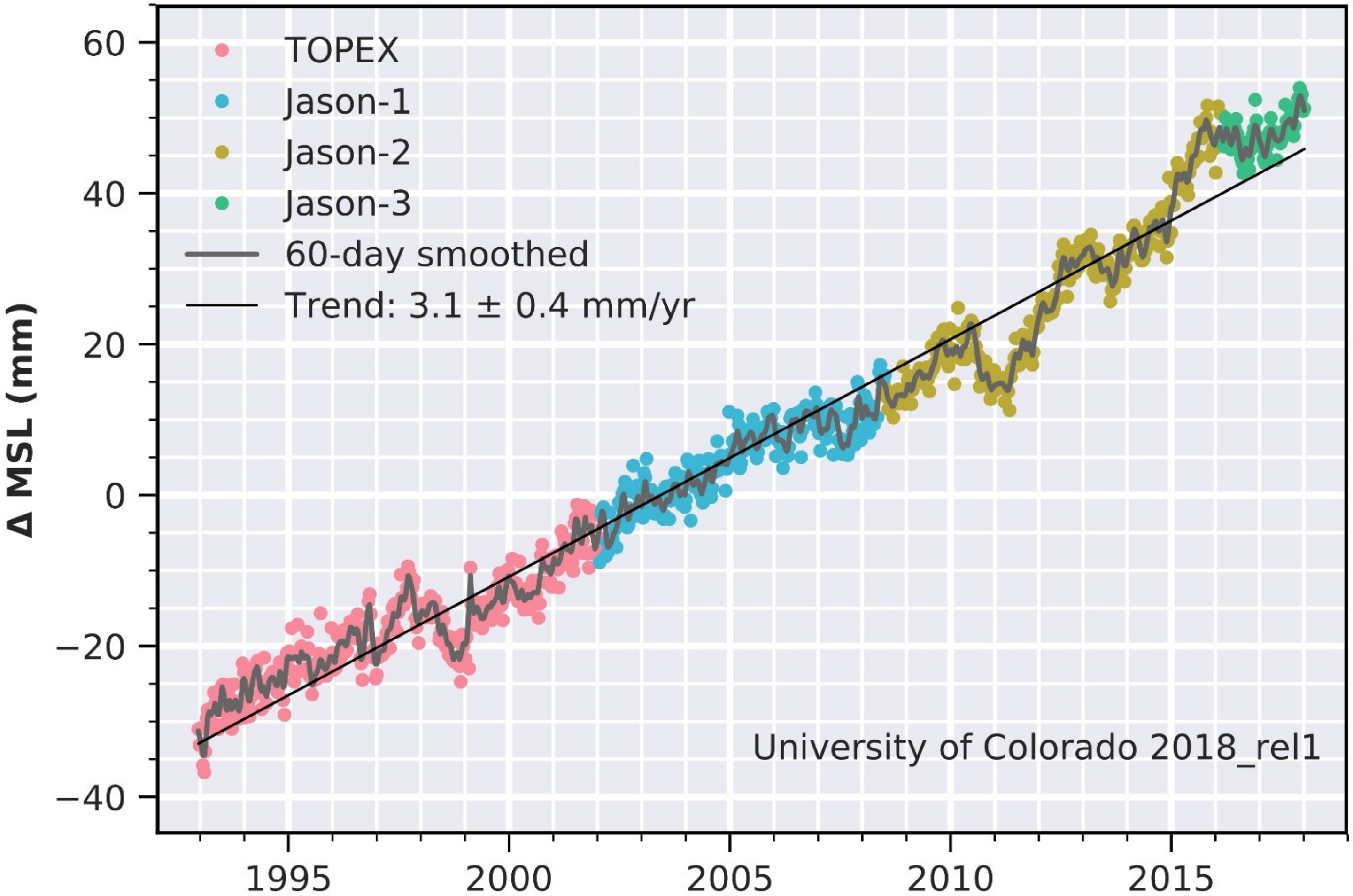
(2) The global „ocean conveyor belt"

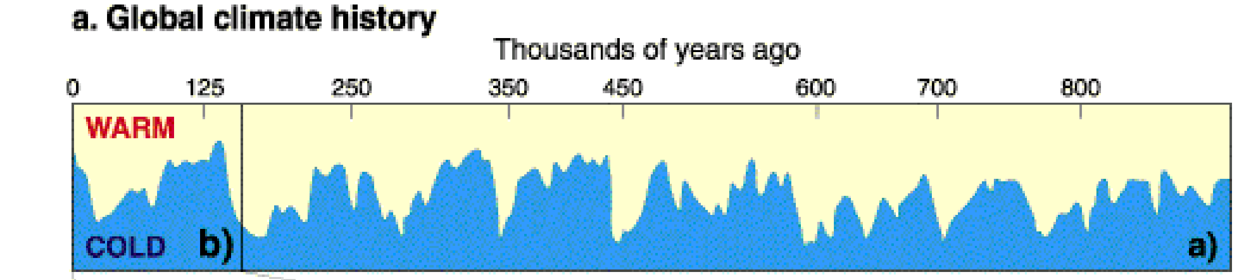


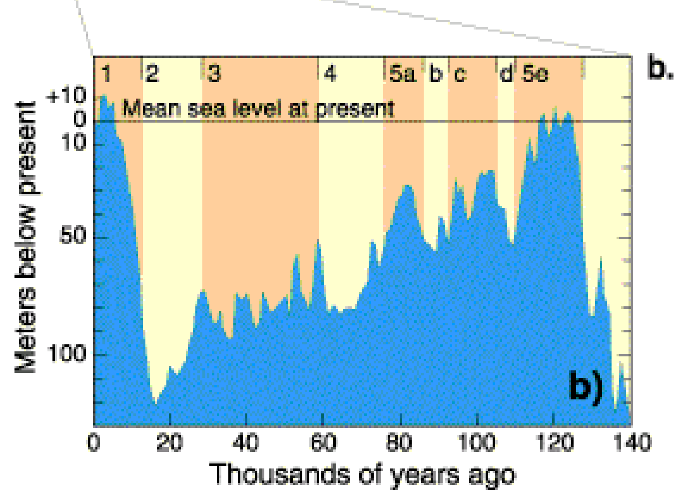


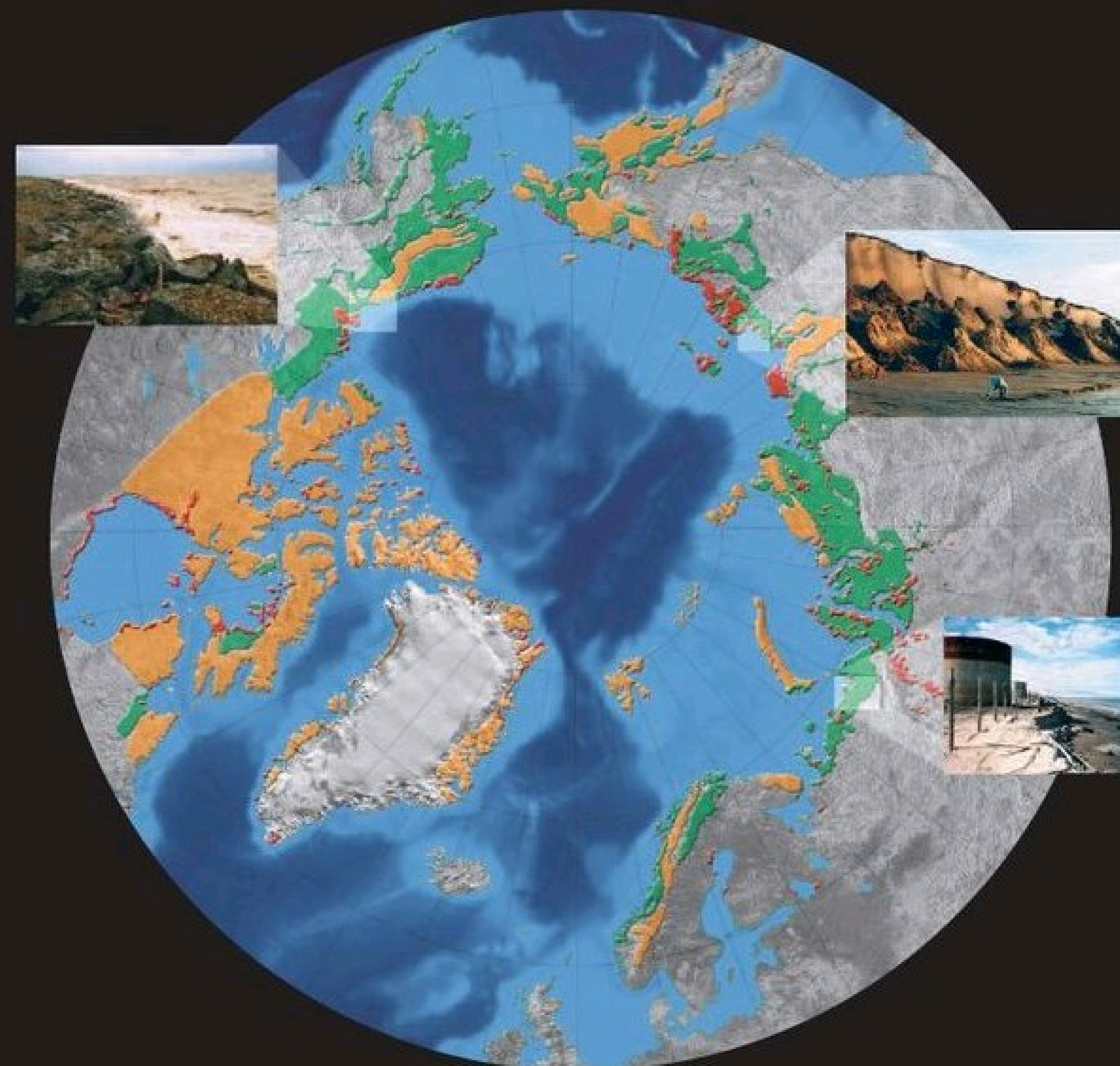
Sea level rise







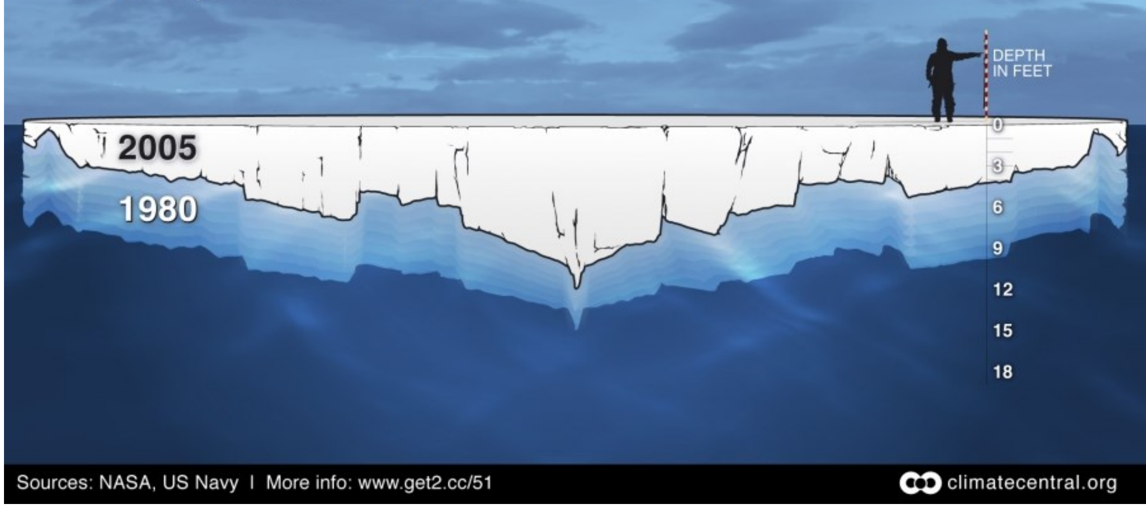


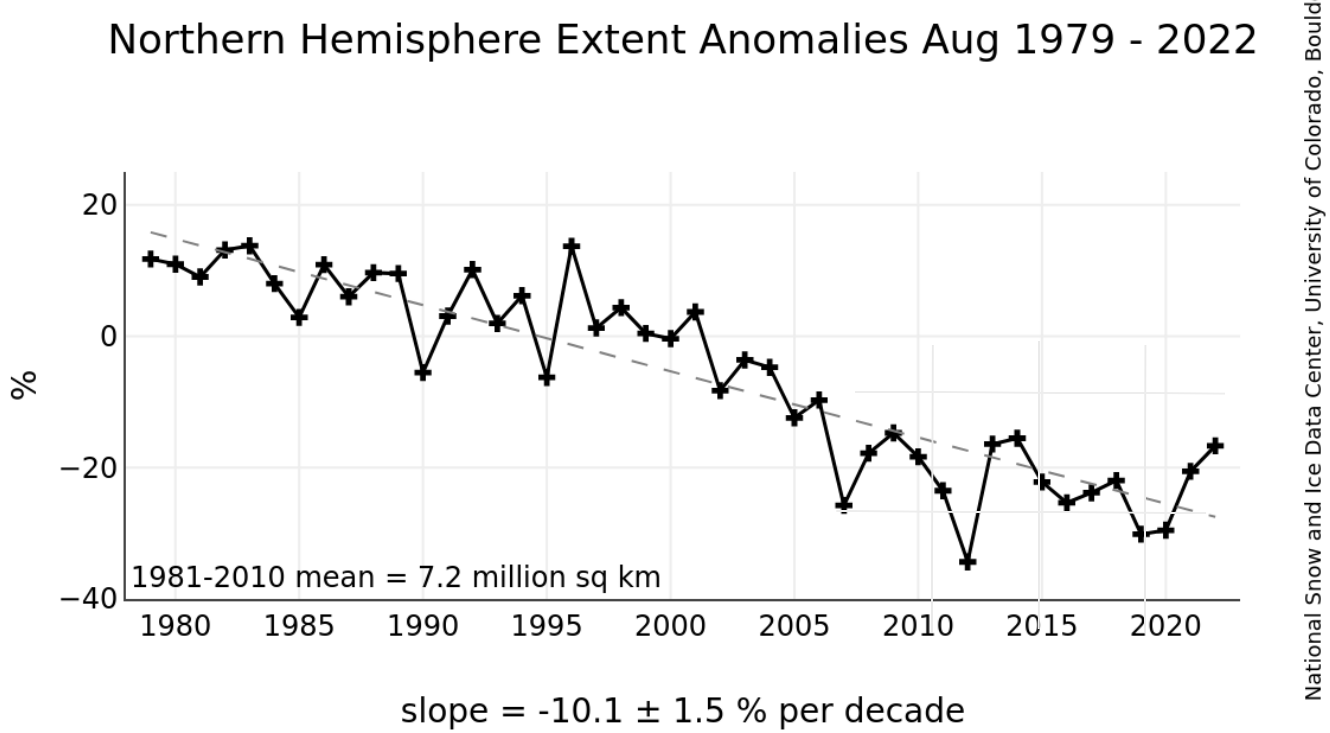


Processes:

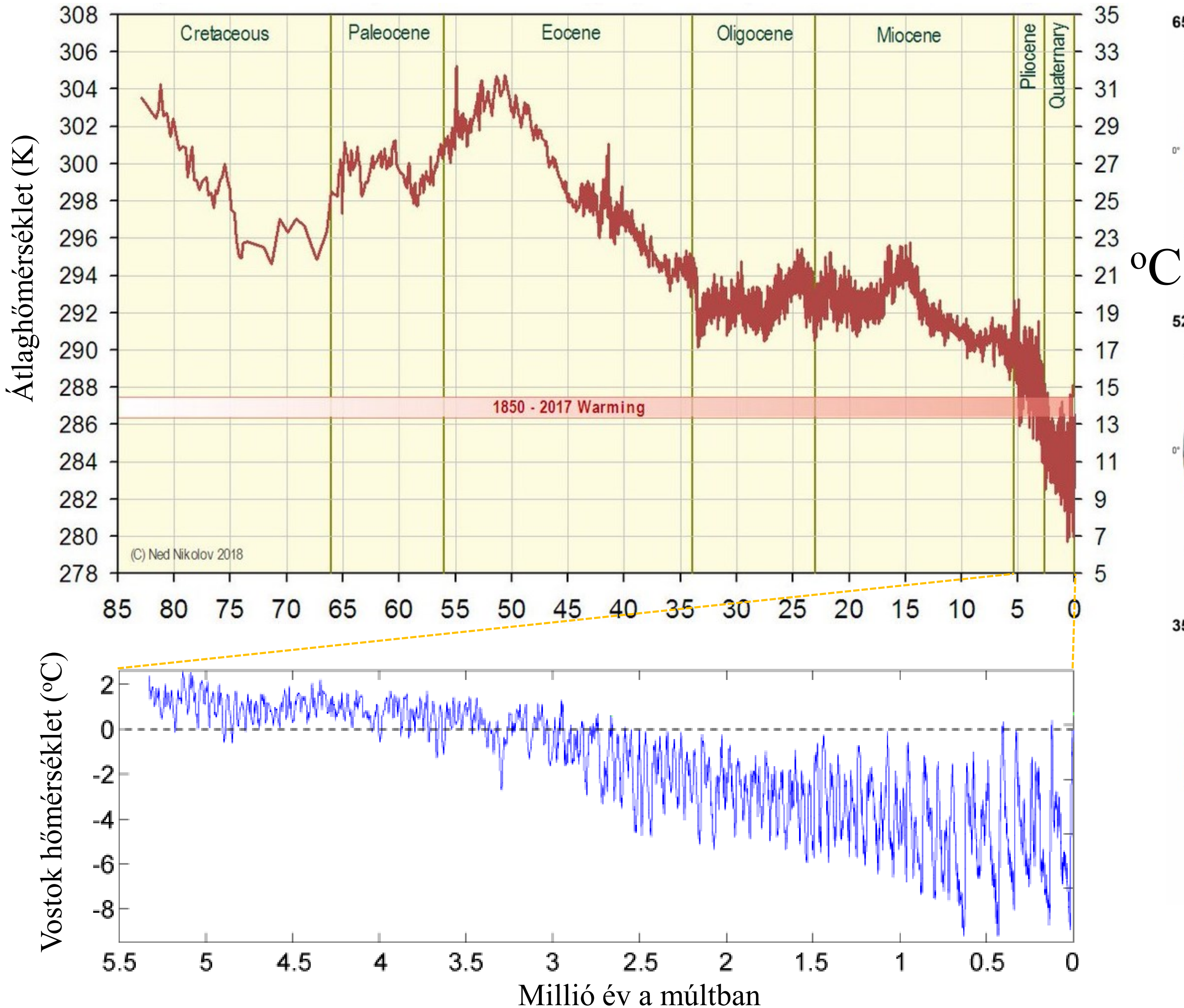
-- ice melting
-- thermal expansion
-- local tectonics (??)

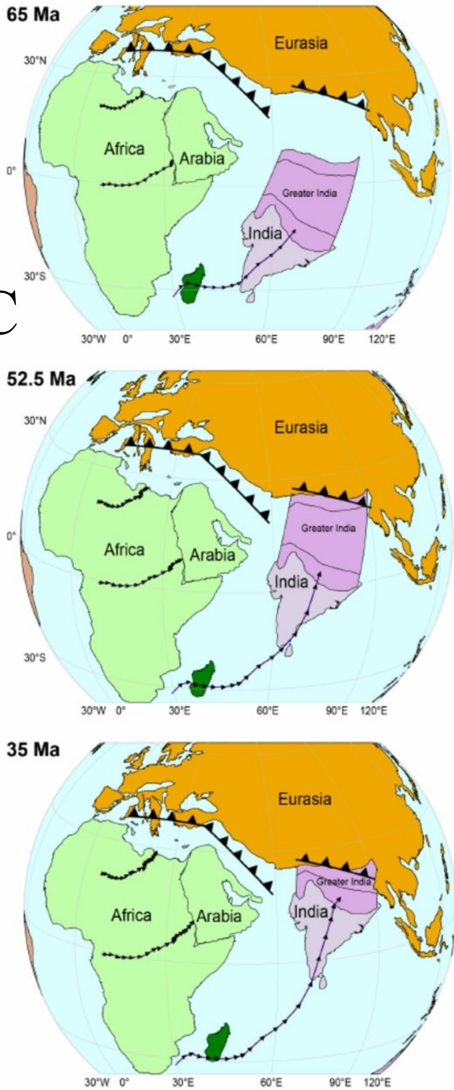
The Arctic ice shrinks





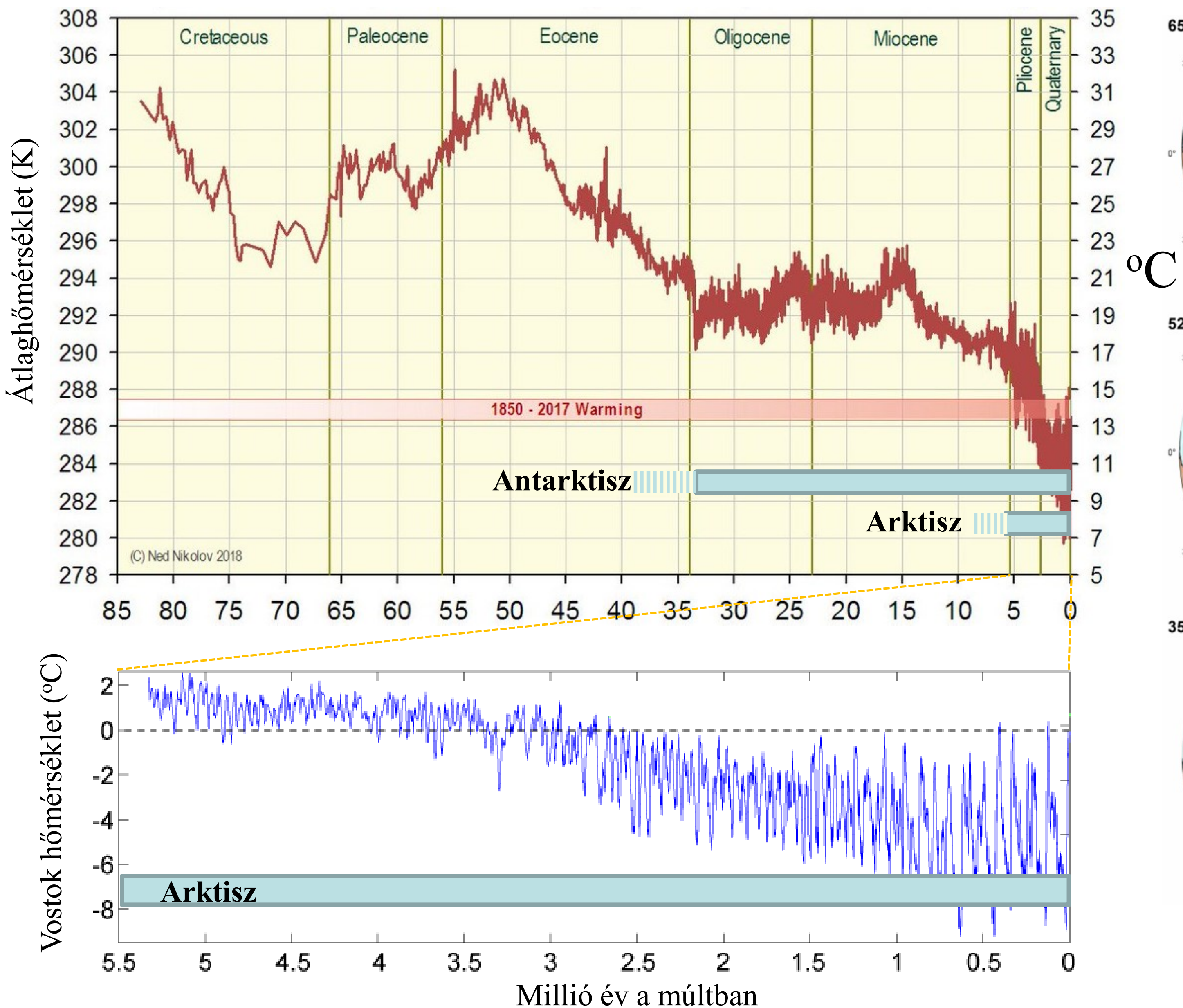
Paleoclimatology

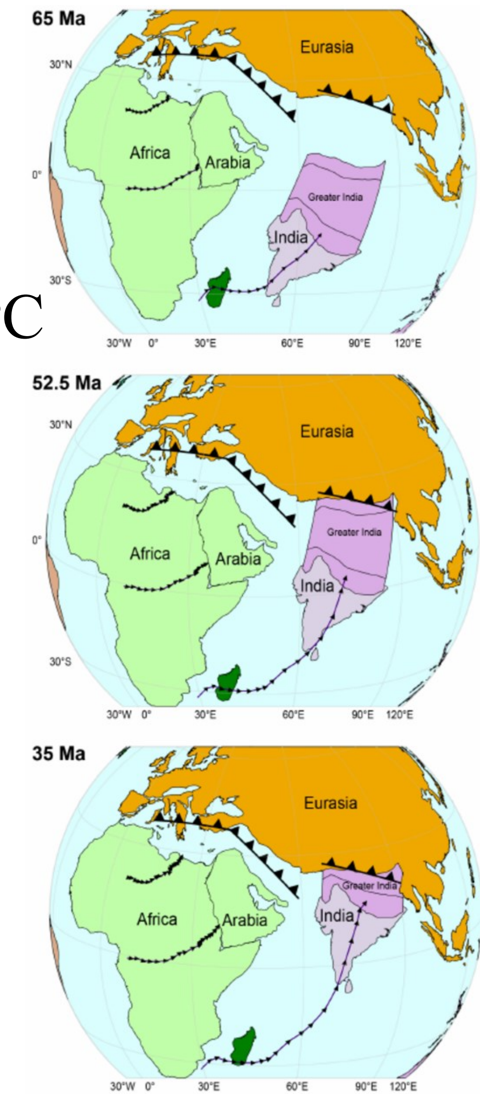




Hoareau et al., *Climate of the Past*, **11**, 1751-1767, 2015

Paleoclimatology





Hoareau et al., *Climate of the Past*, **11**, 1751-1767, 2015

Common mistake …