Introduction to bio-physics

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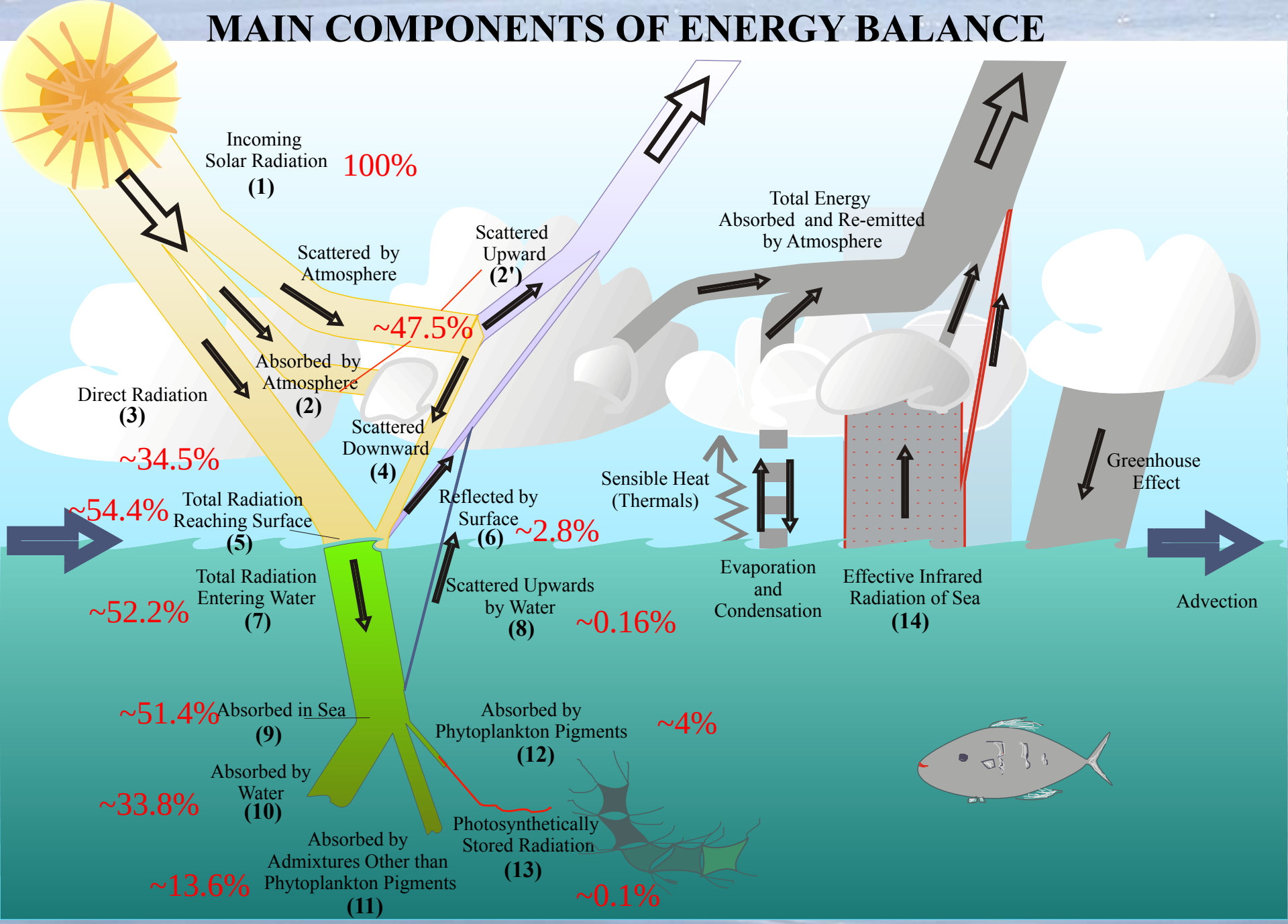
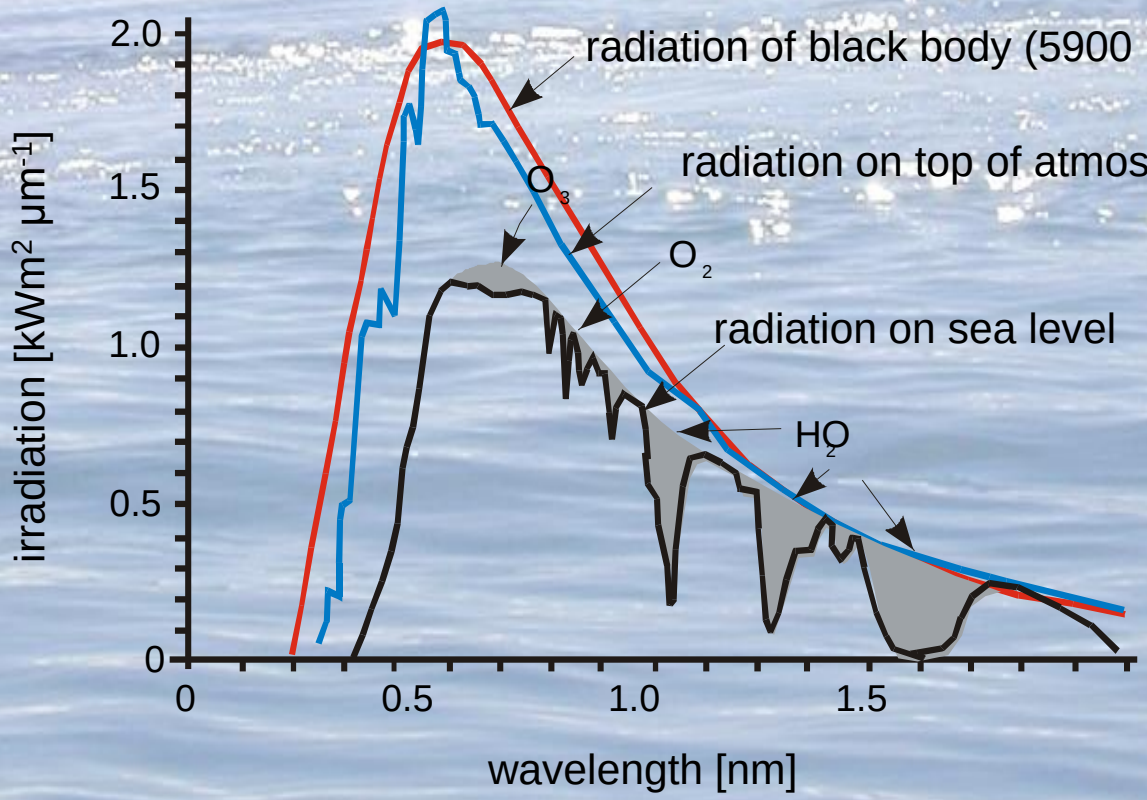
lecture given in the framework of
activities promoting science DUN

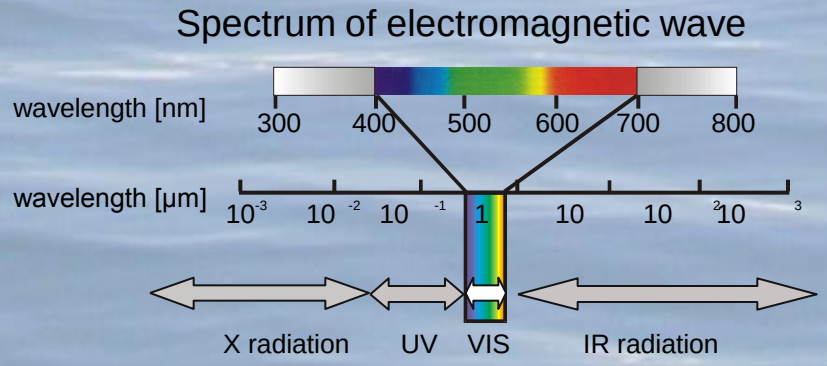
MAIN COMPONENTS OF ENERGY BALANCE



according to Kaczmarek i Dera 1998

Sun light – the source of energy reaching the Earth

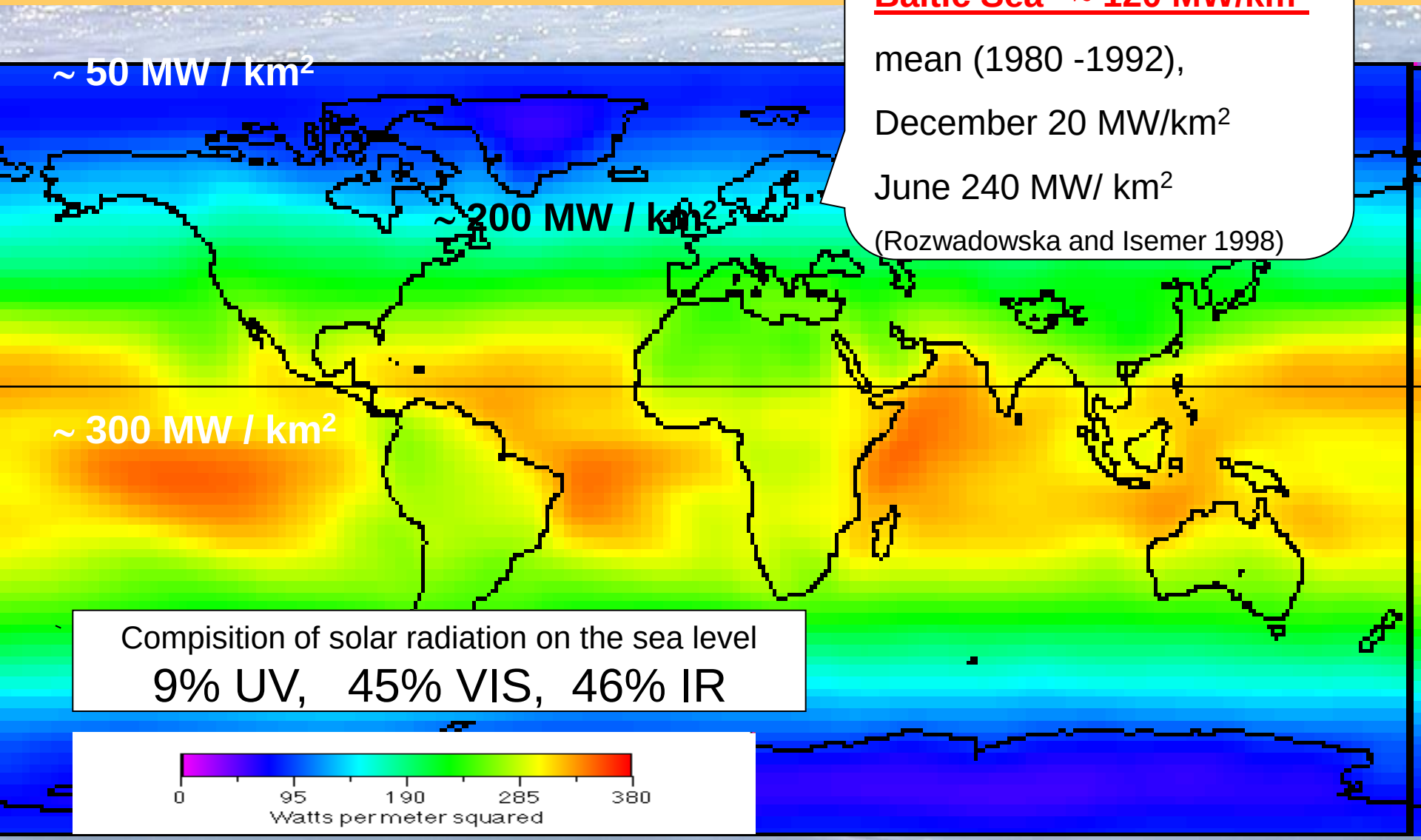




according to Stewart 2005

Sun light – the source of energy reaching the Earth

Average radiation power absorbed on the Earth



Baltic Sea ~ 120 MW/km²

mean (1980 -1992),

December 20 MW/km²

June 240 MW/ km²

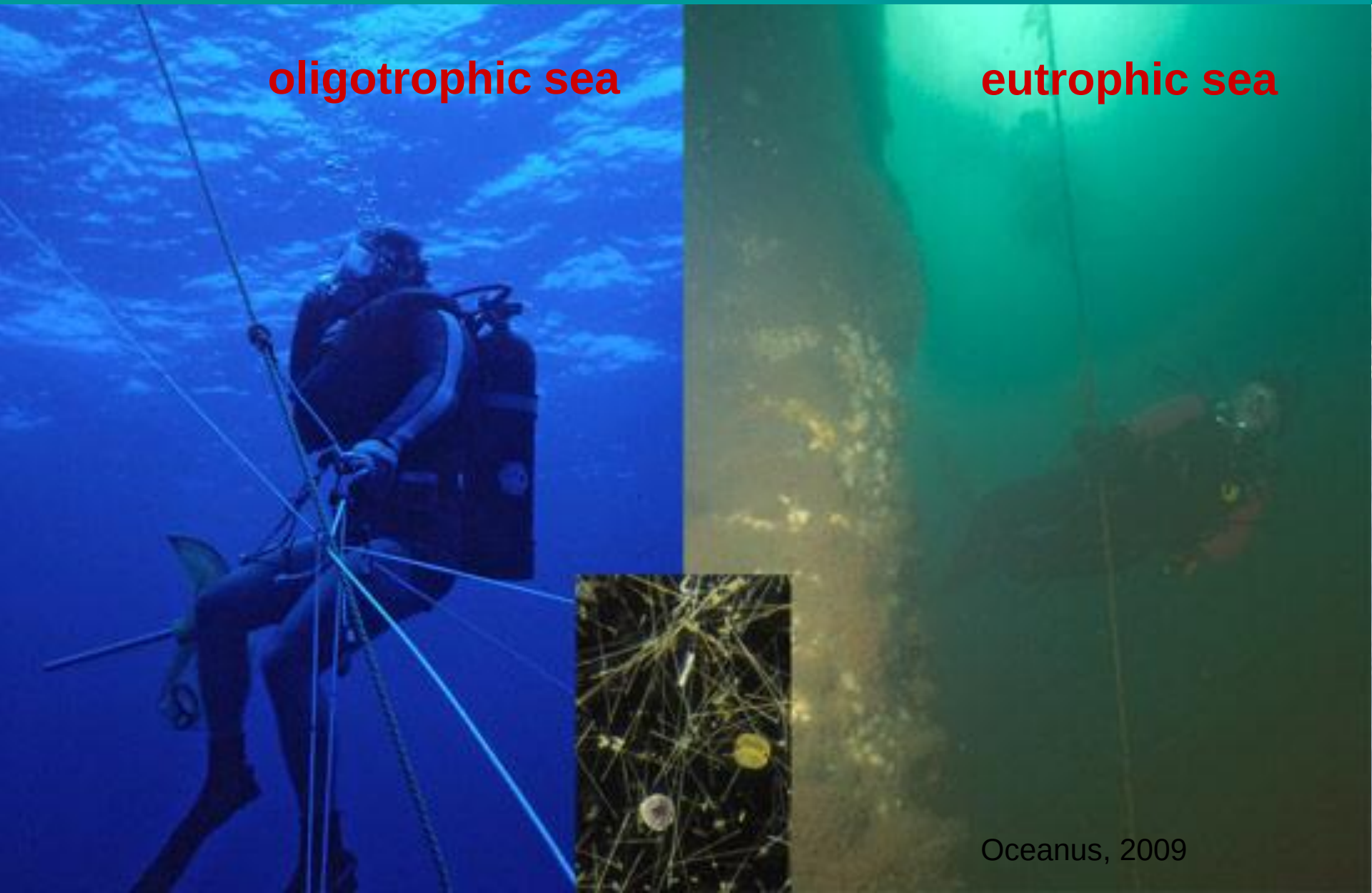
(Rozwadowska and Isemer 1998)

Compisition of solar radiation on the sea level

9% UV, 45% VIS, 46% IR

(Image created by the CoVis Greenhouse Effect Visualizer

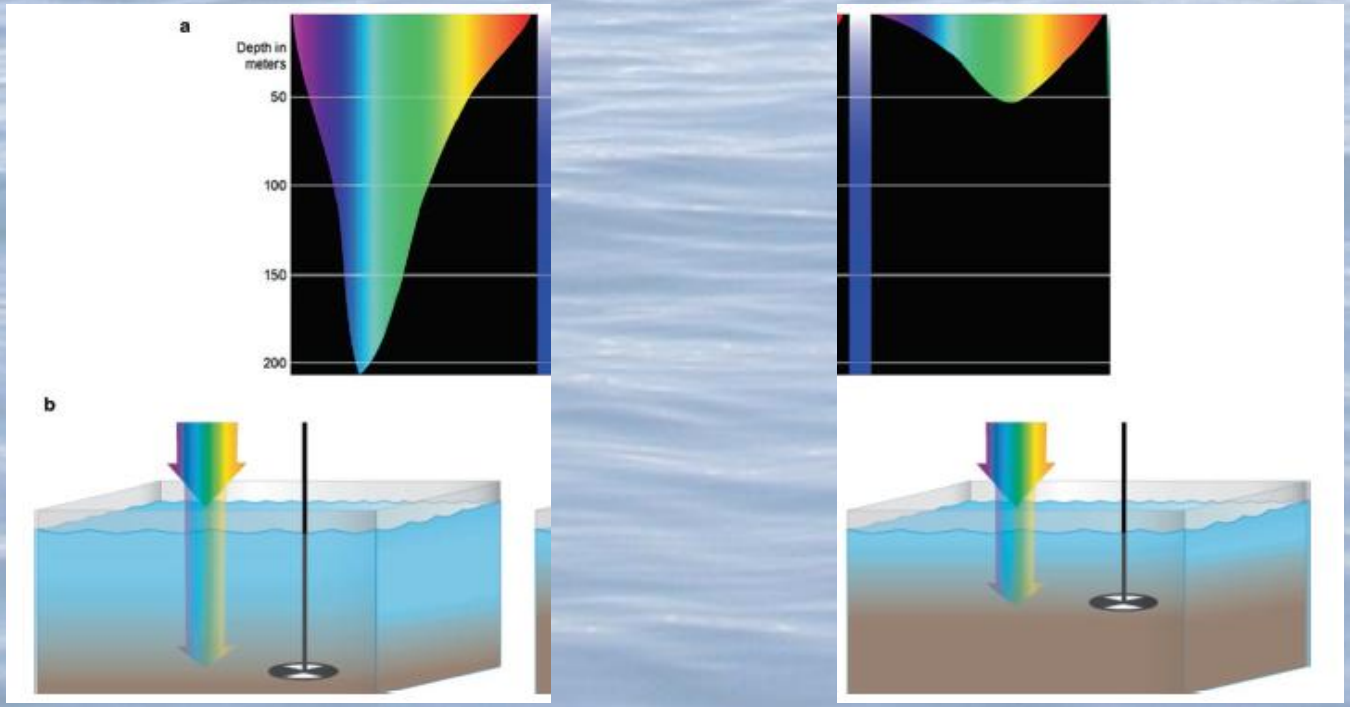
Light penetration into the sea deep



Transmission of light in different waters (400-700nm)

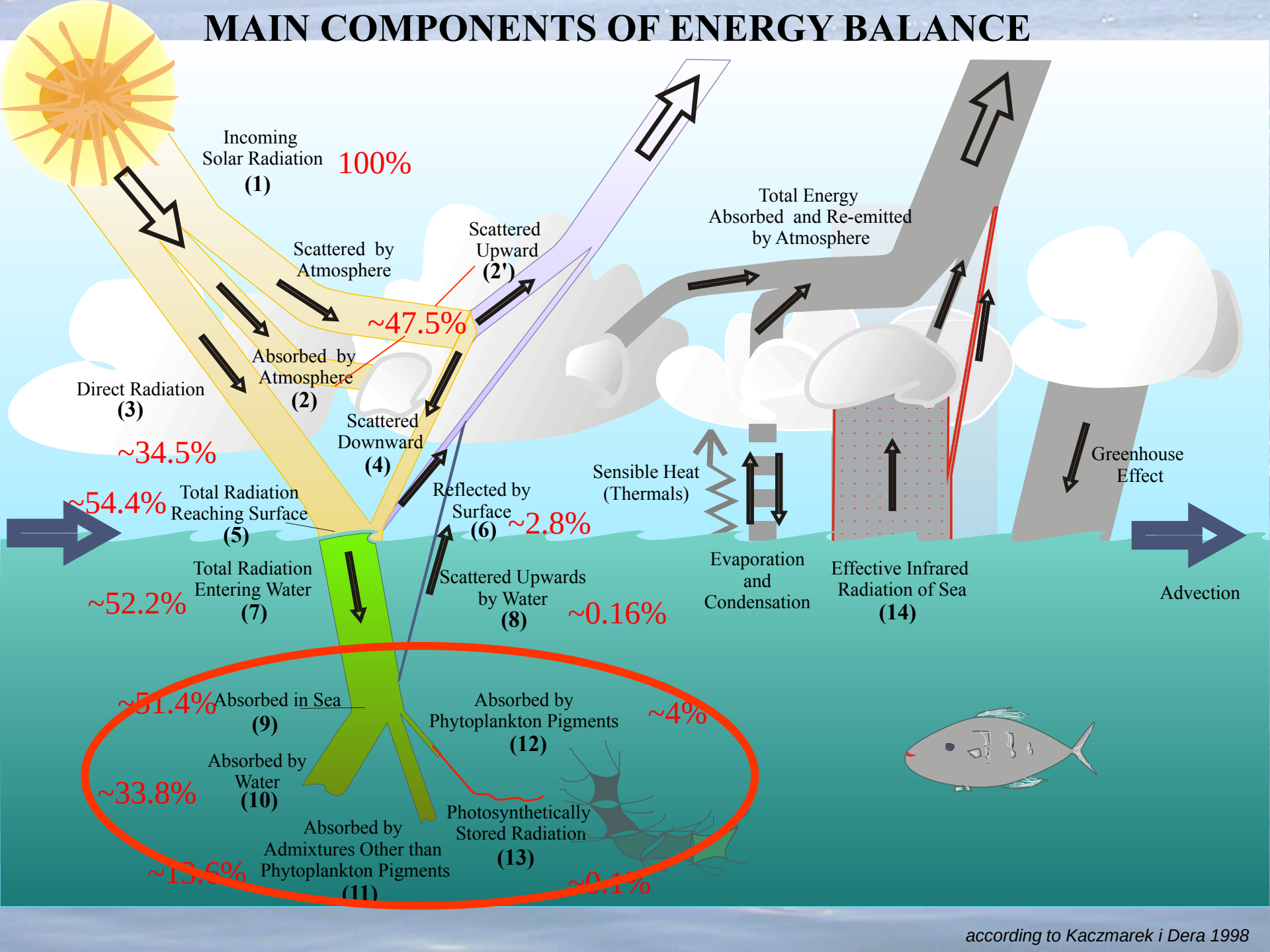
Open oligotrophic waters

Eutrophic coastal waters



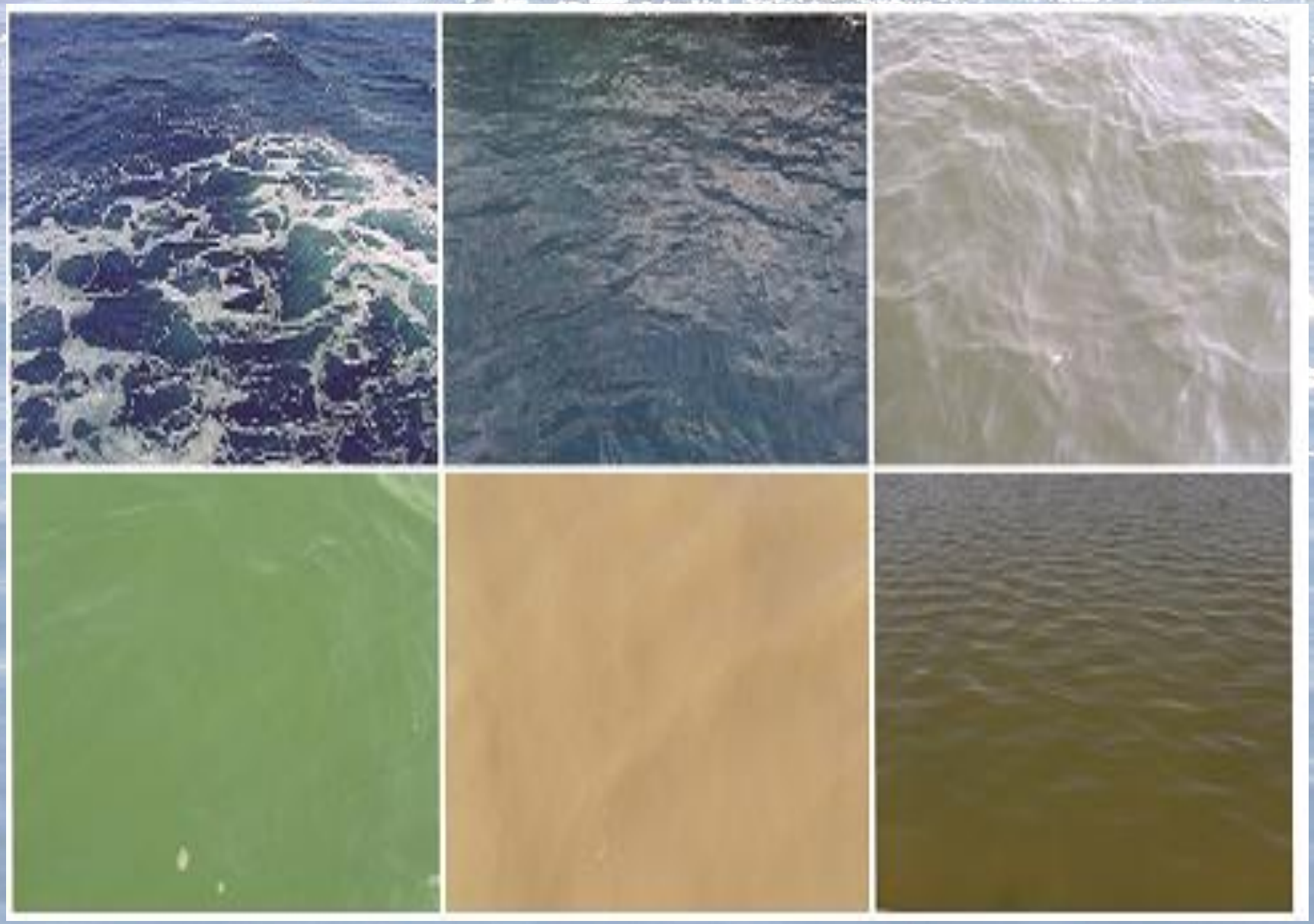
(http://oceanexplorer.noaa.gov/explorations/04deepscope/background/deeplight/media/diagram3.html)

MAIN COMPONENTS OF ENERGY BALANCE

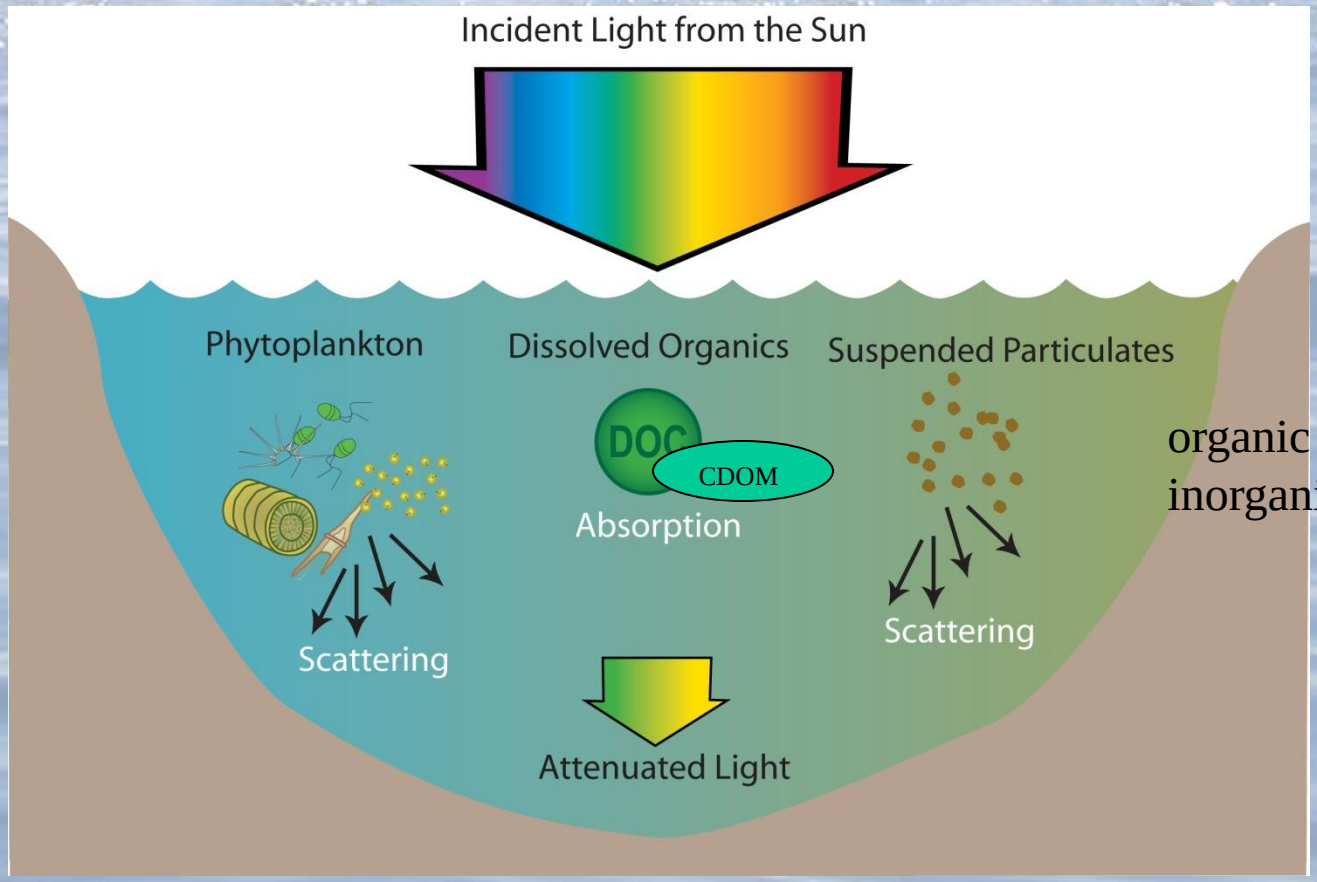


according to Kaczmarek i Dera 1998

Water colour

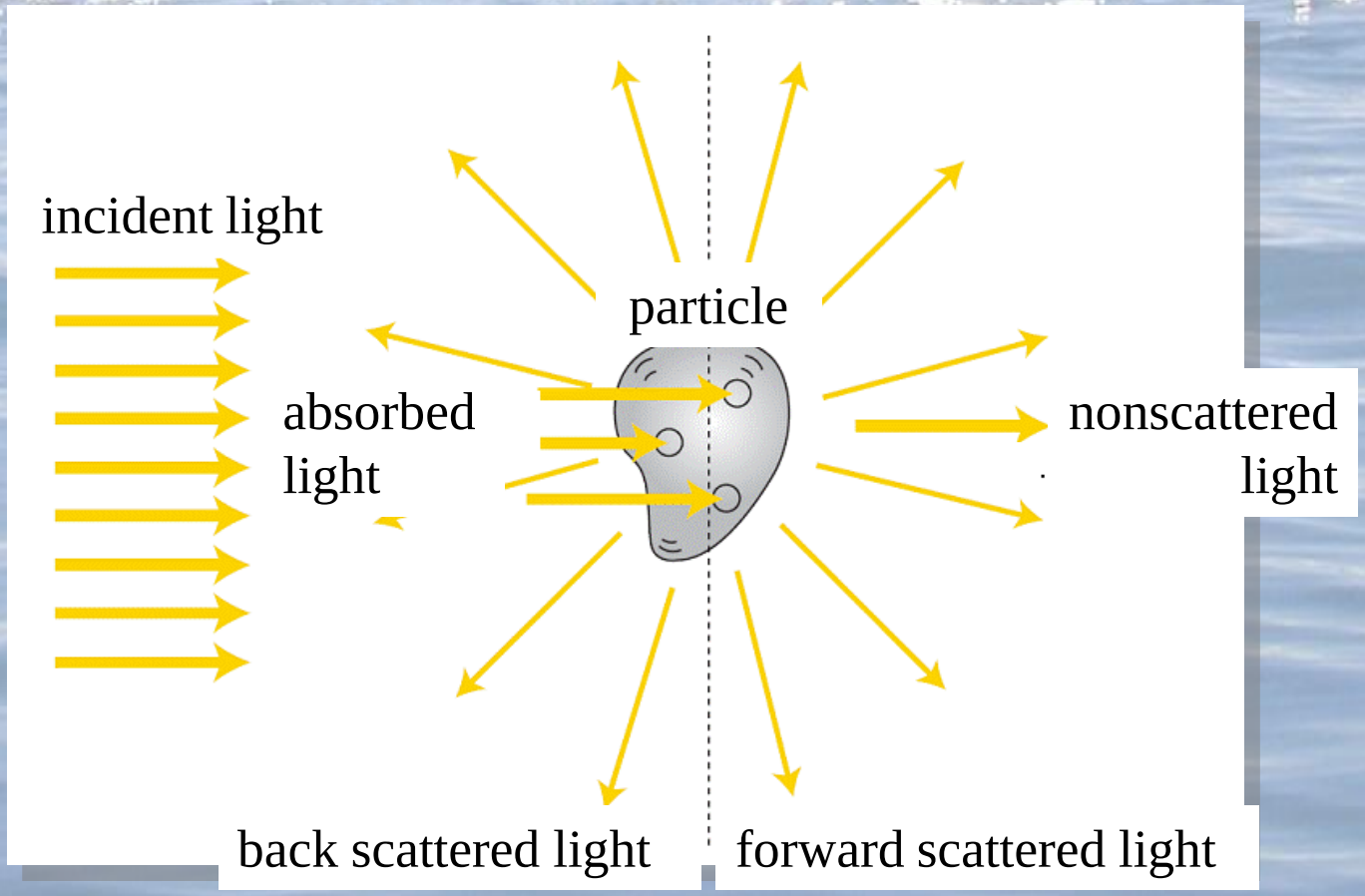


Main components influence on light distribution



organic
inorganic (mineral)

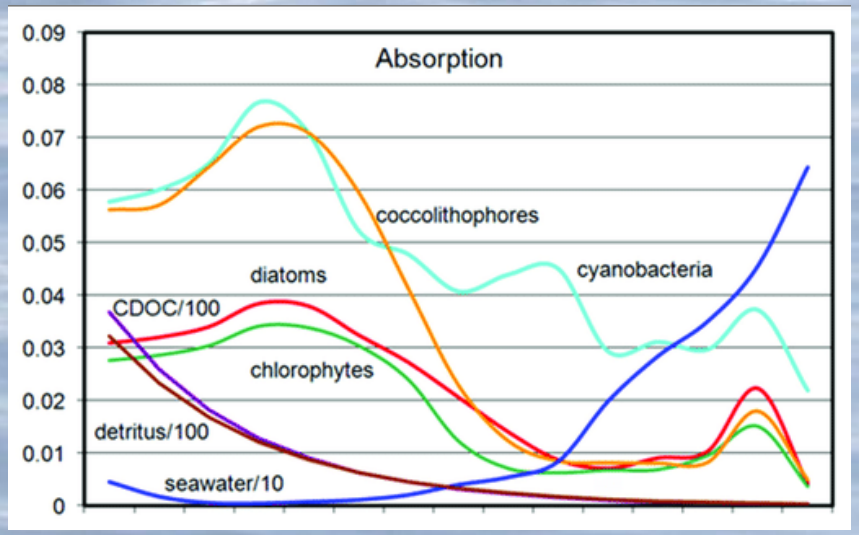
The interaction of light with the environment

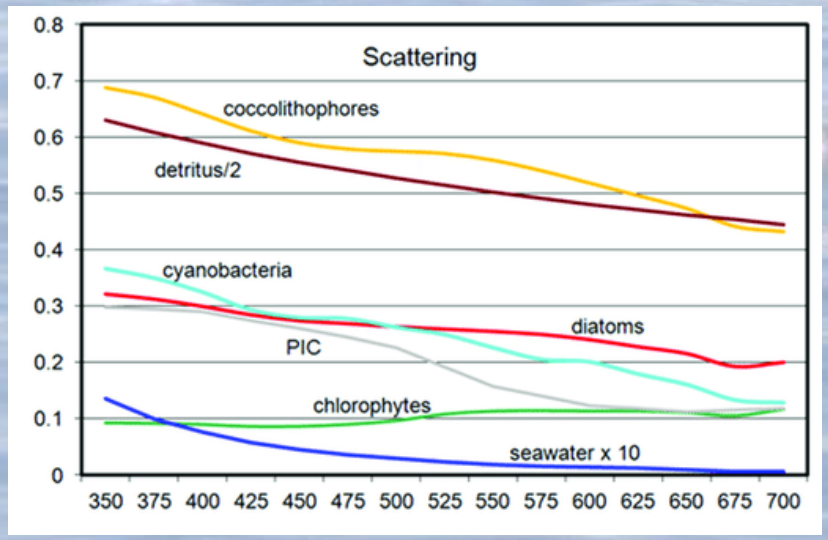


Processes: absorption + scattering = attenuation of light

Interaction of light with sea components

m^{-1} (water, detritus, and CDOC);
m^2 mg chl^{-1} (phytoplankton chlorophyll);
m^2 mg^{-1} (PIC)

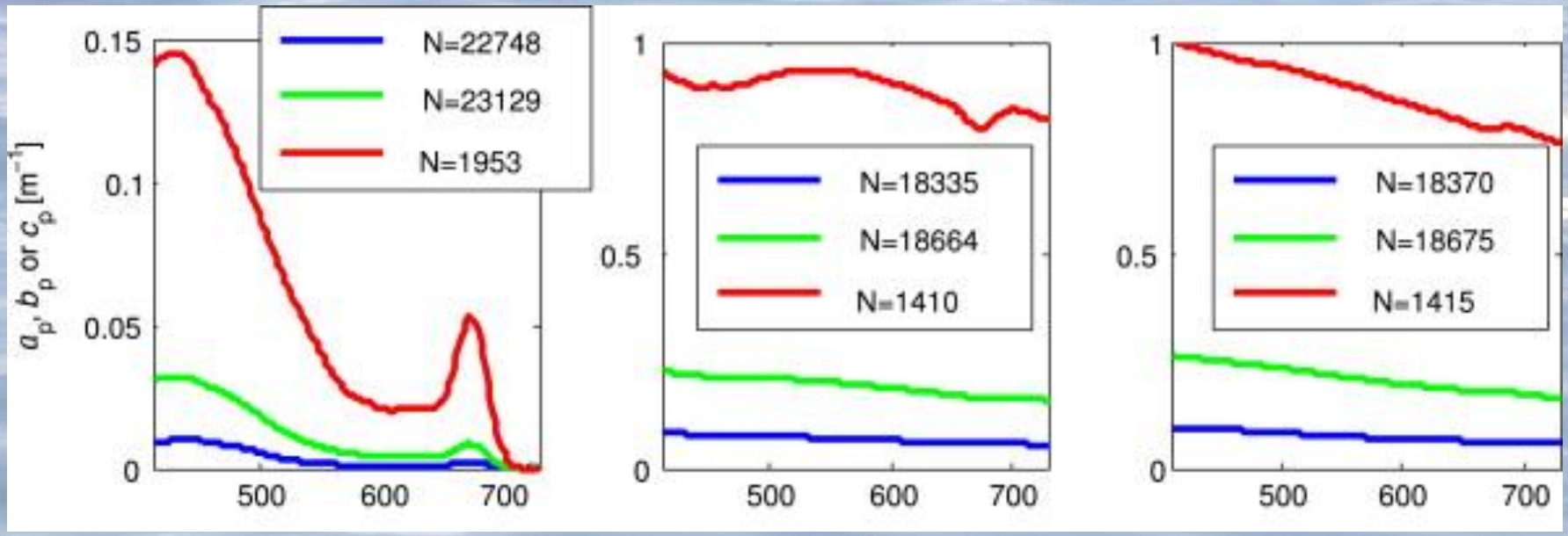




Gregg WW and Rousseaux CS (2017) Simulating PACE Global Ocean Radiances. Front. Mar. Sci. 4:60. doi: 10.3389/fmars.2017.00060

Averaged spectra of absorption, scattering and attenuation for different chlorophyll ranges

absorption scattering attenuation

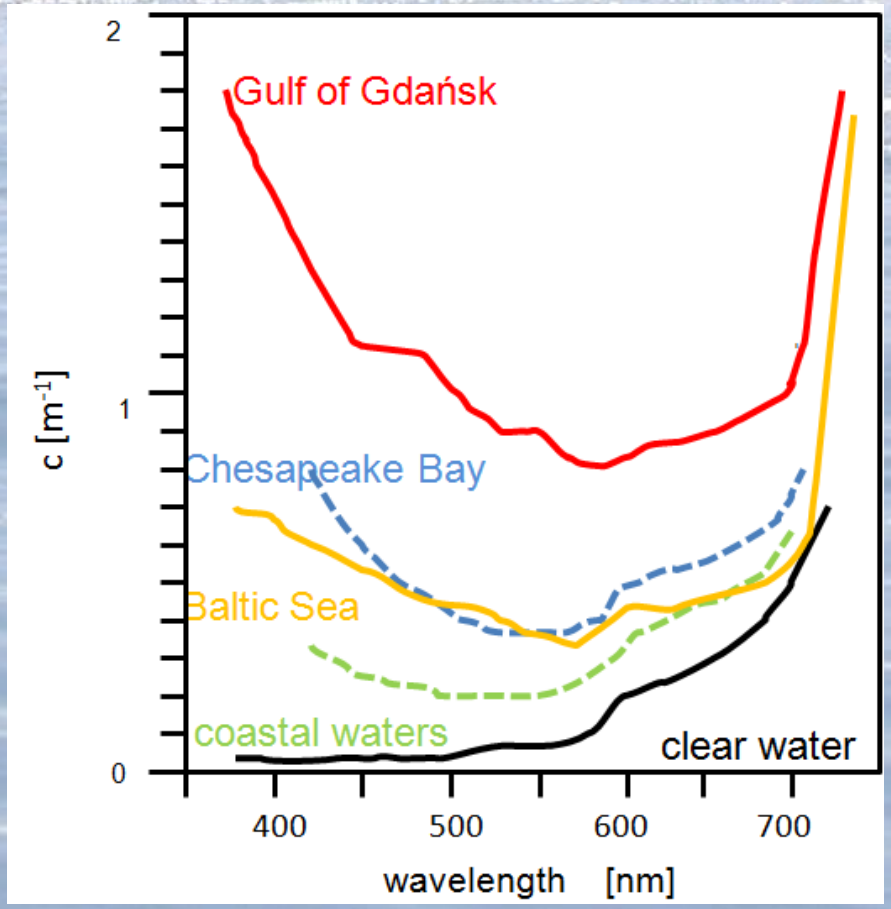


Ca < 0.1, 0.1 < Ca < 1, 1 < Ca

N - number of spectra

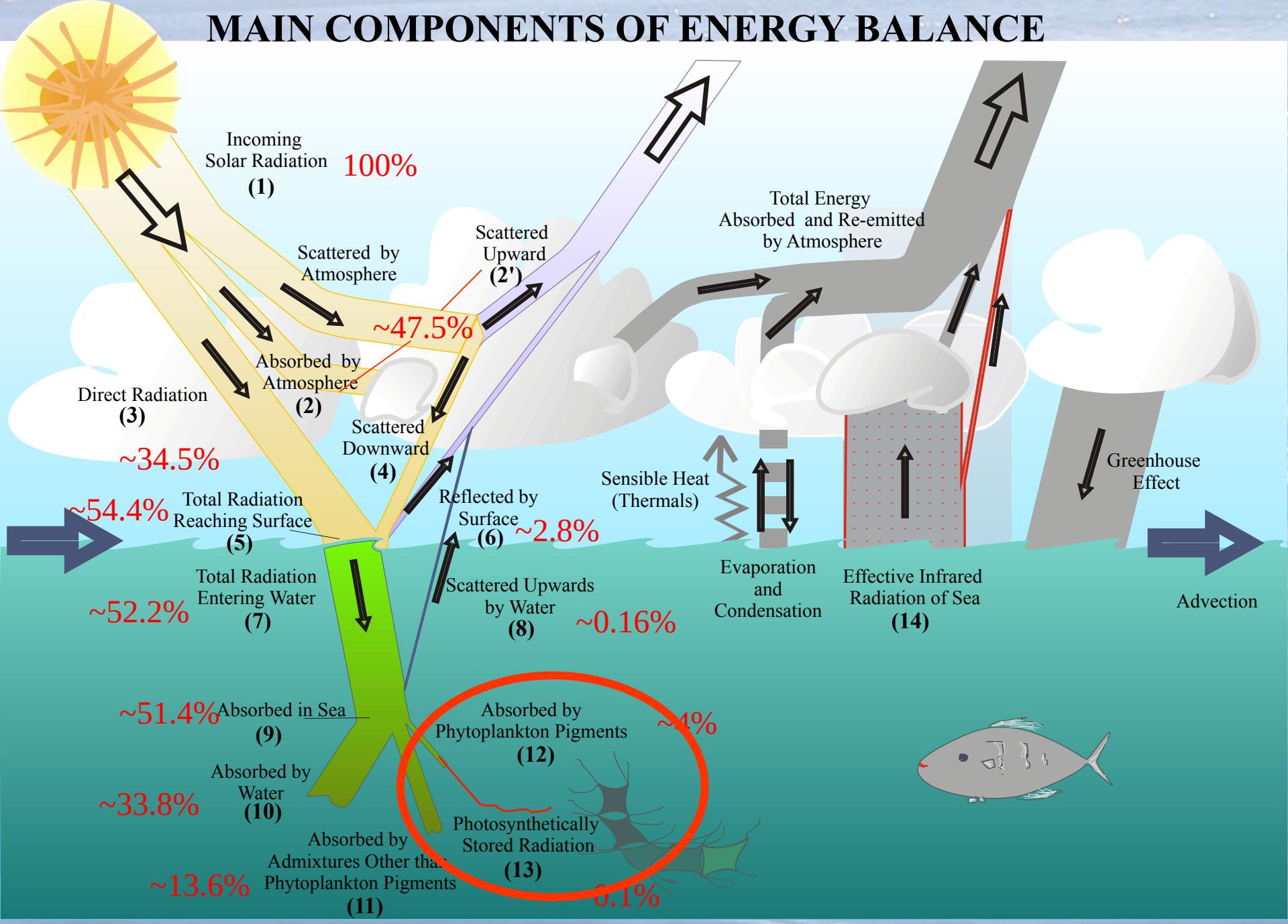
Boss et al. 2013, The characteristics of particulate absorption, scattering and attenuation coefficients in the surface ocean; Contribution of the Tara Oceans expedition, Methods in Oceanography 7 (2013) 52–62

Attenuation coefficient in different waters



according to Dera 2003

MAIN COMPONENTS OF ENERGY BALANCE

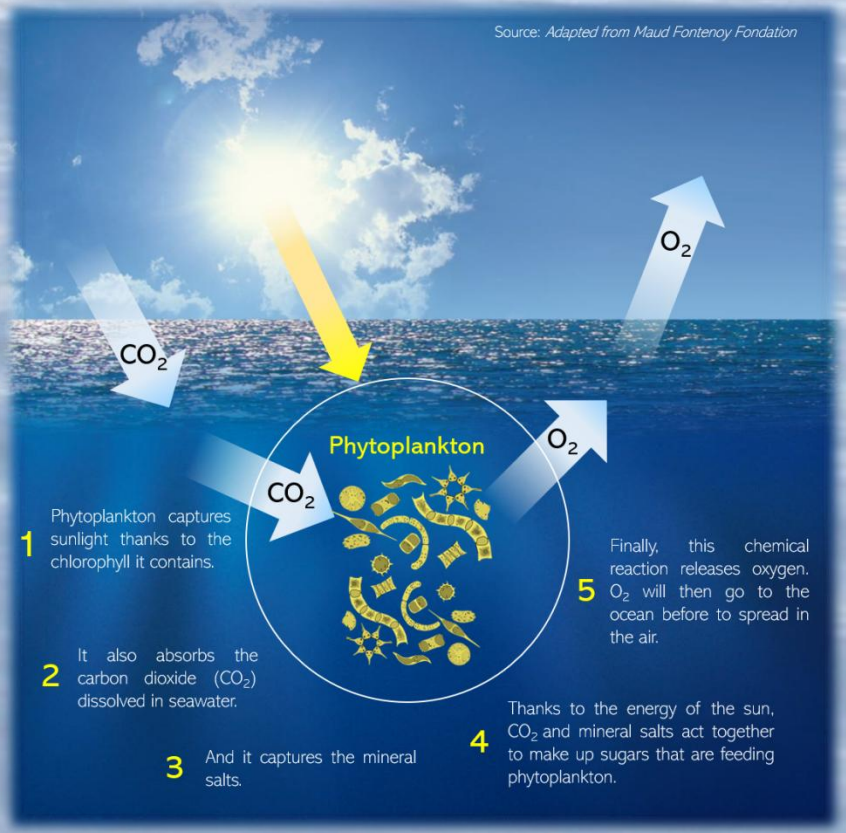


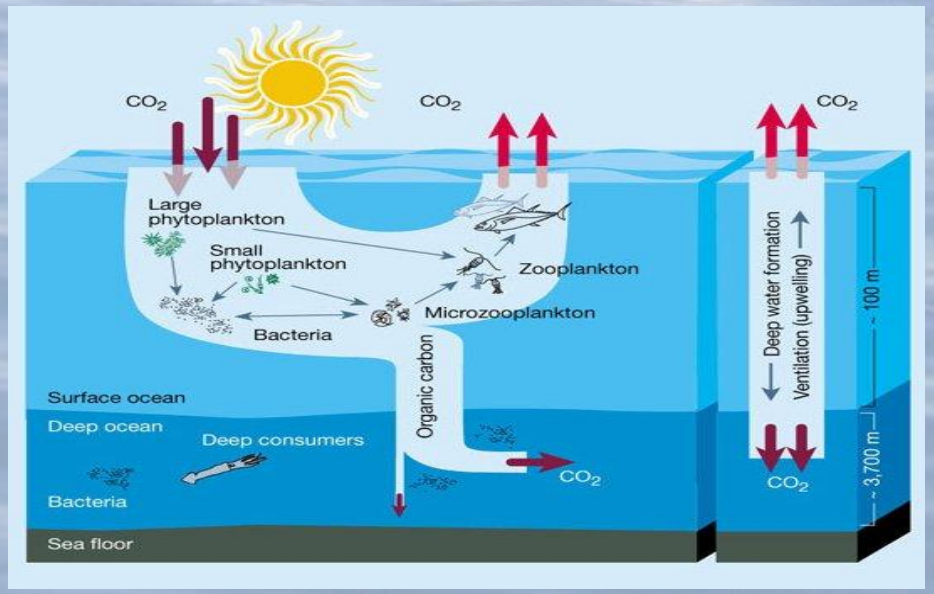
according to Kaczmarek i Dera 1998

Photosynthesis

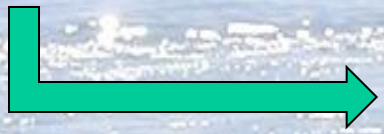
is a process used by plants and other organisms to convert light energy into chemical energy that, through cellular respiration, can later be released to fuel the organism's metabolic activities.

$$6CO_2 + 6H_2O \xrightarrow{h\upsilon} C_6H_{12}O_6 + 6O_2$$





Photosynthesis



Primary production

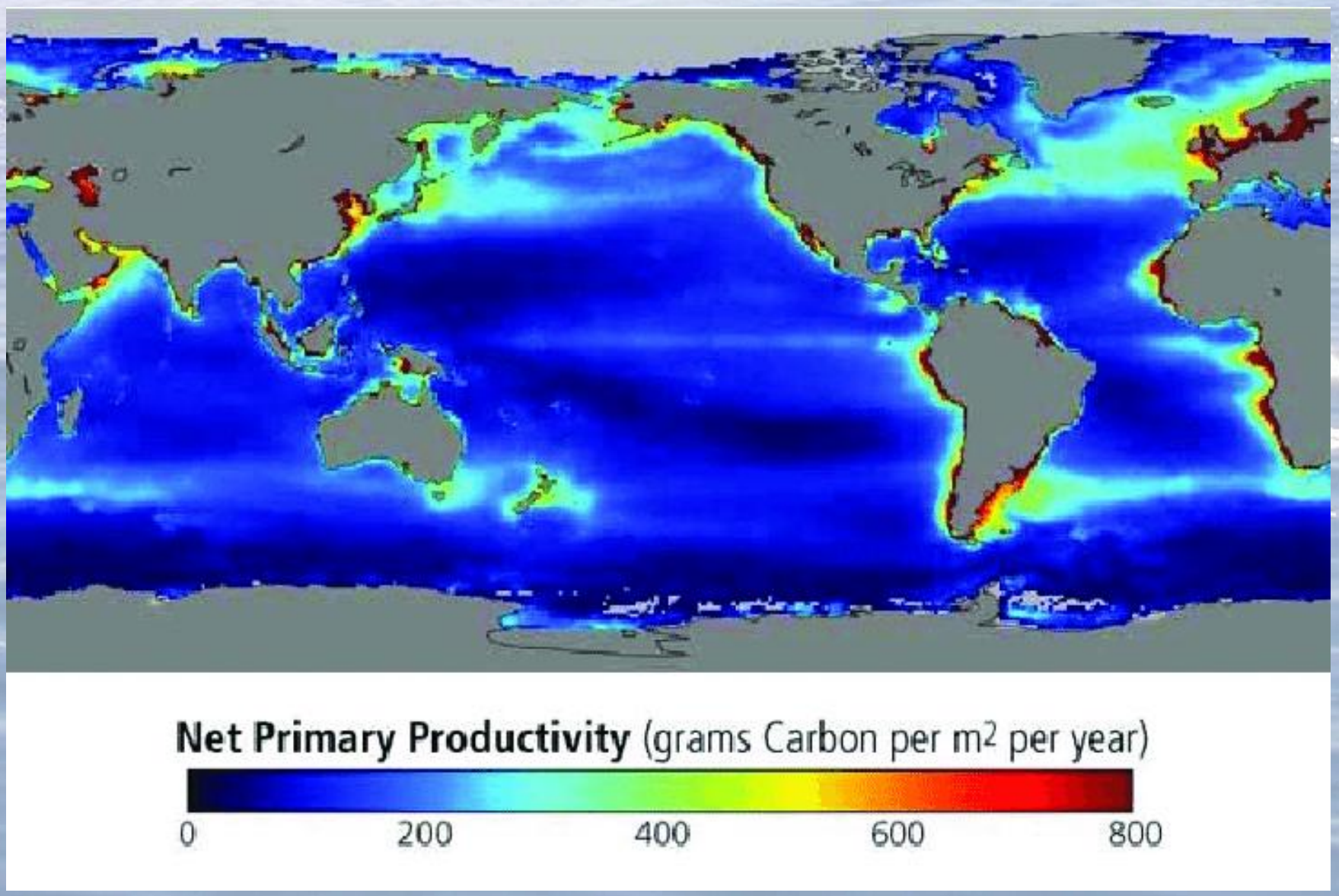
ecological importance

The main process in Earth Biosphere responsible for supplying ecosystems with energy. Phytoplankton – first link in trophic chain

climatology importance

Carbon cycle and oxygen balance in nature – responsible for greenhouse effect in atmosphere

Global primary production in the oceans

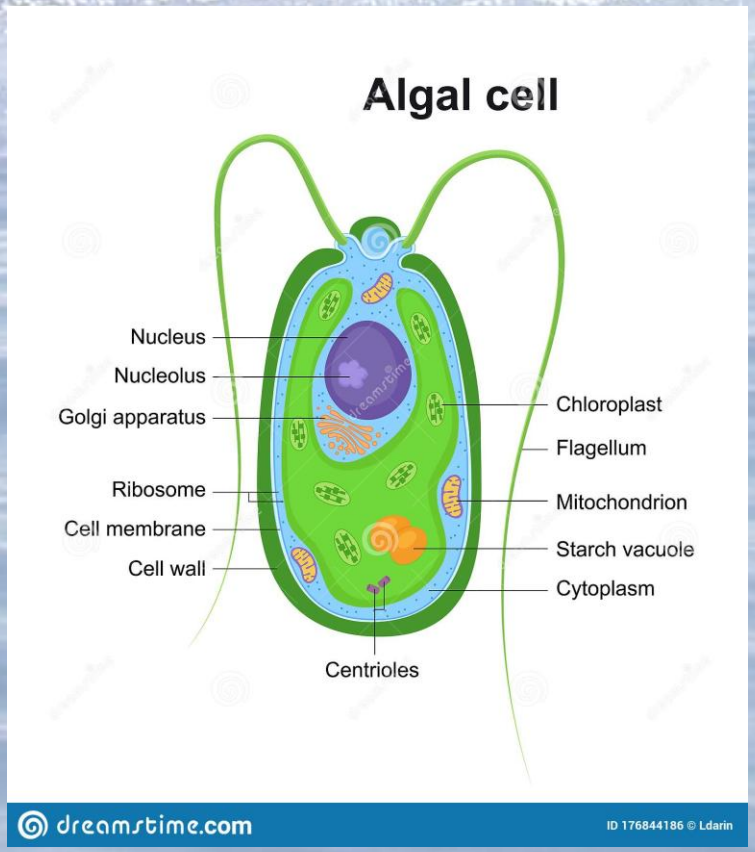


Source: earthobservatory.nasa.gov

What does the photosynthesis process depend on?

1. Presence of phytoplankton
2. Light energy
3. Temperature

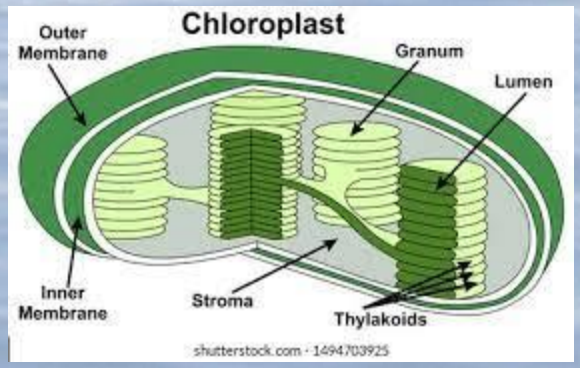
Energy absorbers – pigments in phytoplankton cells



Composition of organic matter in chloroplast

protein - 50% (weight)
lipids - 30 - 50%
pigments- 2 -10%

Parsons et al. 1977



- pigments create macromolecular complex with a few types of protein
- pigment-protein complexes are organized in photosynthetic units – phorosystems I and II, located in thilakoid membrane in a heterogenous and asymmetric manner

Division and structure of pigments

More than 650

Phytoplankton pigments

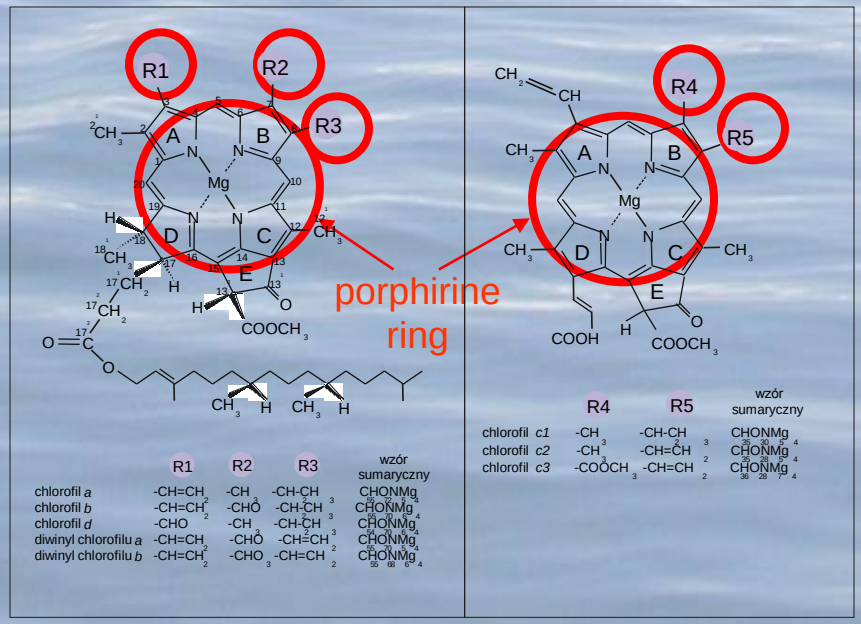
- phycobilins
- mycosporynes

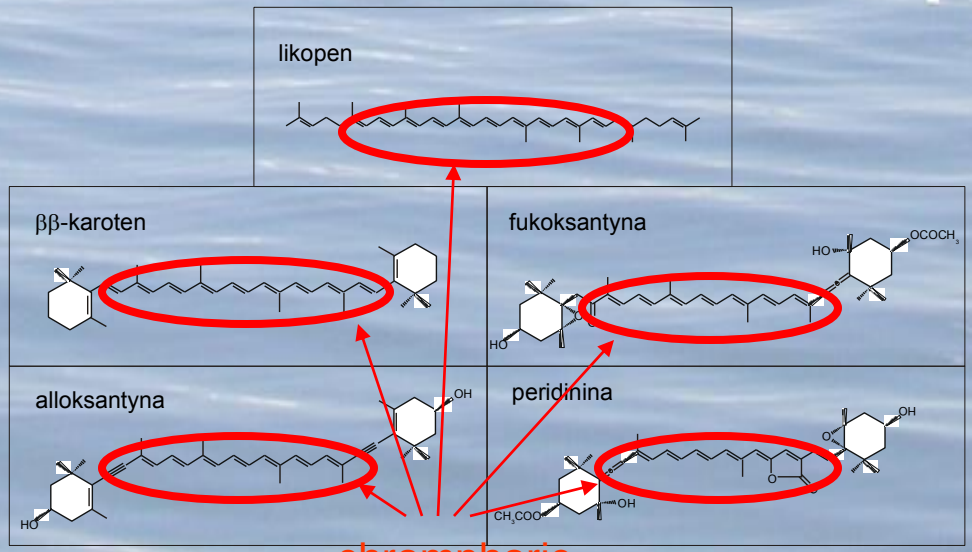
chlorophylls:
a, b, c1, c2, c3

catotenoids:
carotenes $C_{40}H_{56}$
xanthophylls $C_{40}H_{56}O_{1-8}$

Example of chemical structure of pigments

substituents



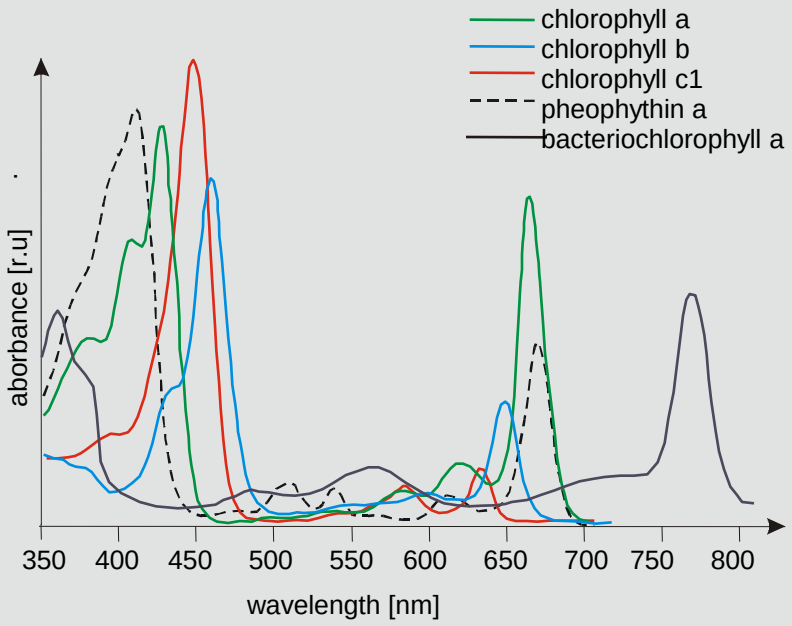


according to Jeffrey 1997

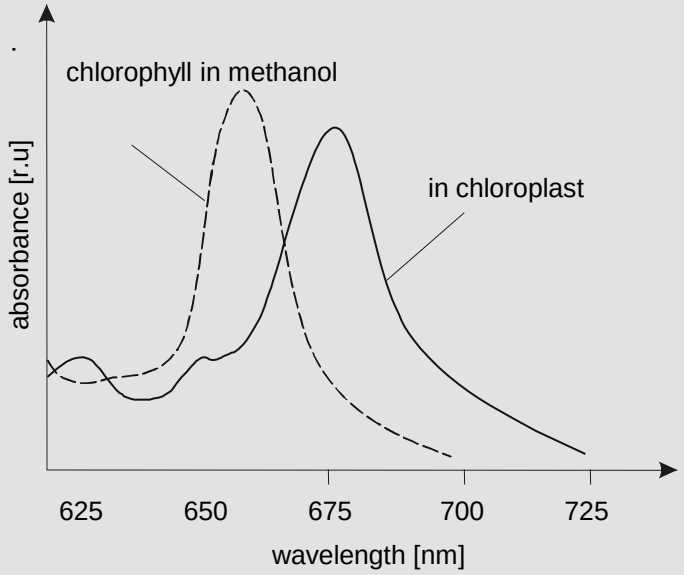
Main properties of pigments

- absorption of sunlight in VIS range (350 - 700 nm)

Chlorophylls absorption spectrum



- *100% acetone - chlorophyll a, b, pheophythin a*
- *diethyl ether - chlorophyll c1*



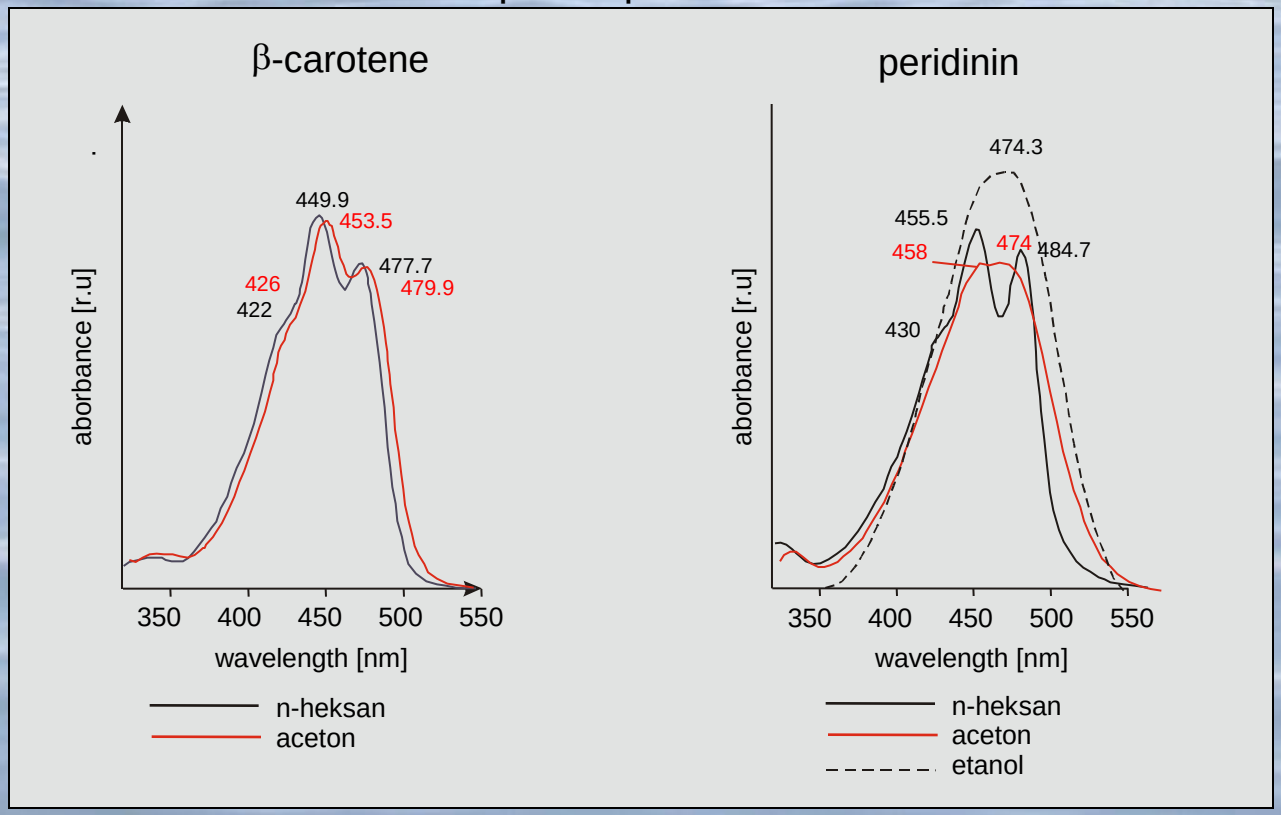
Differences in absorption spectrum in chlorophyll a extract and chlorophyll bounded in pigment-protein complex in chloroplast membrane

according to Jeffrey et al. 1997, Hader and Tevini 1987

Main properties of pigments

- absorption of sunlight in VIS range (350 - 700 nm)

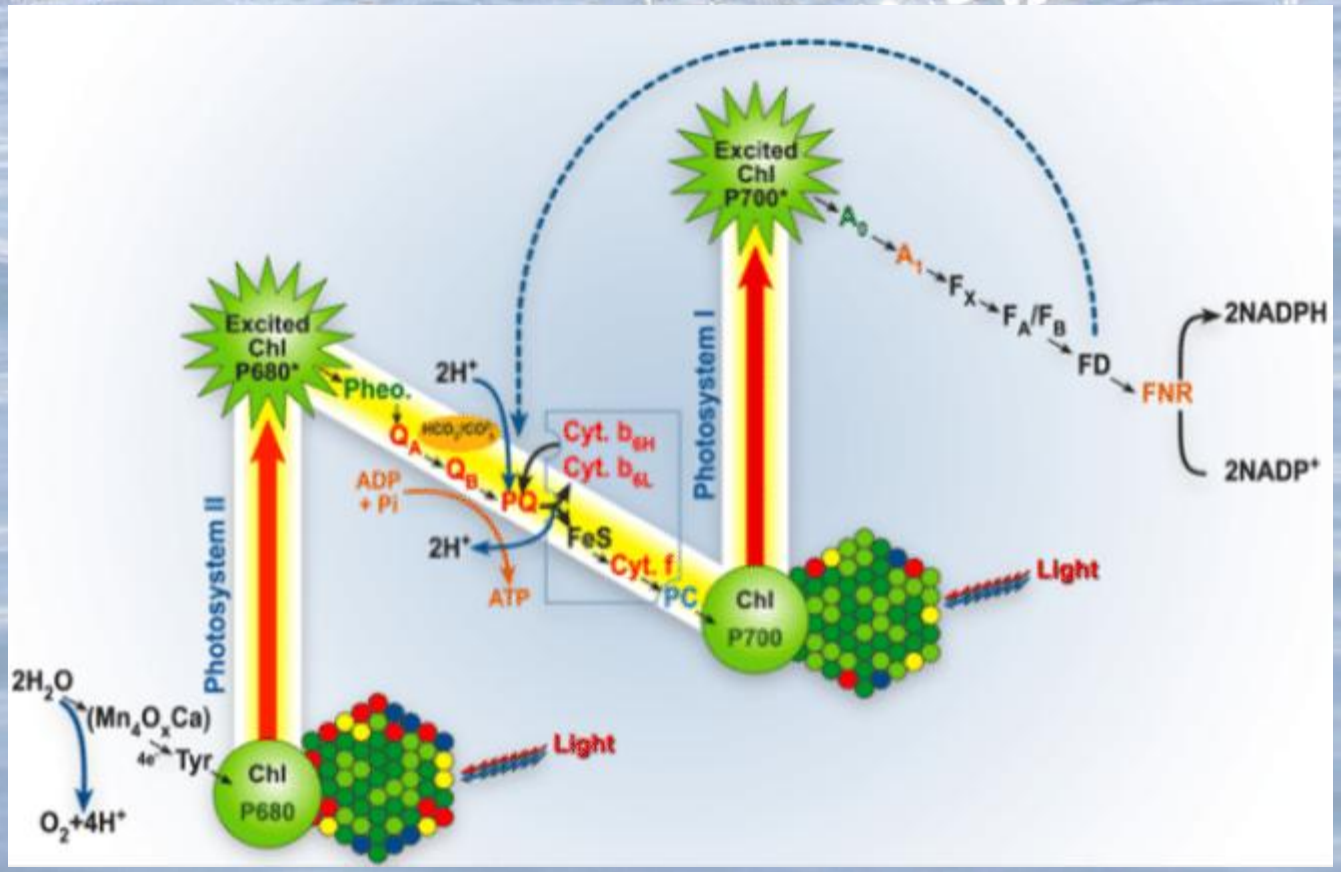
Absorption spectrum of carotenoids



according to Jeffrey et al. 1997

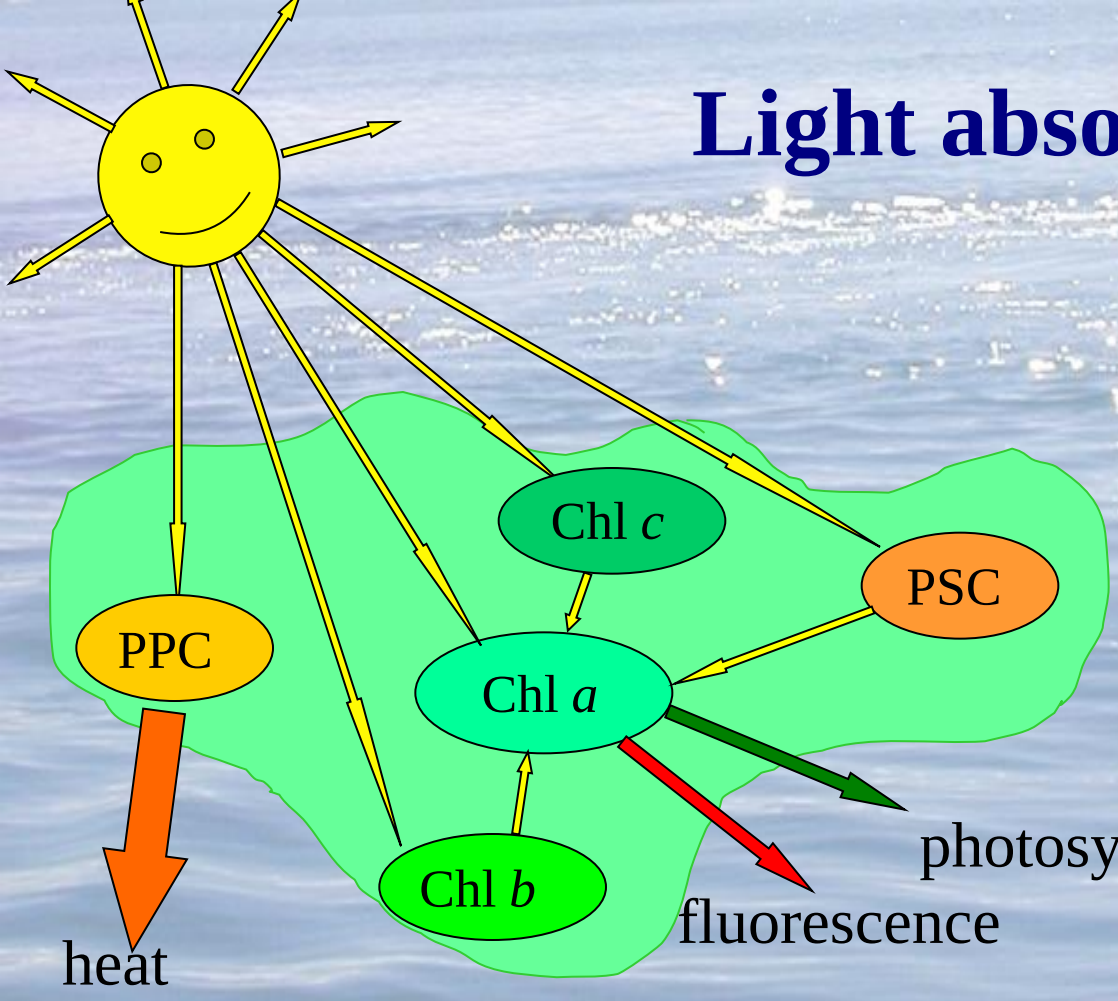
Z-scheme of photosynthesis

describes the oxidation/reduction changes during the light reactions



Photosynthesis Stock Illustrations

Light absorption



Main pigment of photosynthesis – chloropyll a

Photoprotecting pigments (PPC)

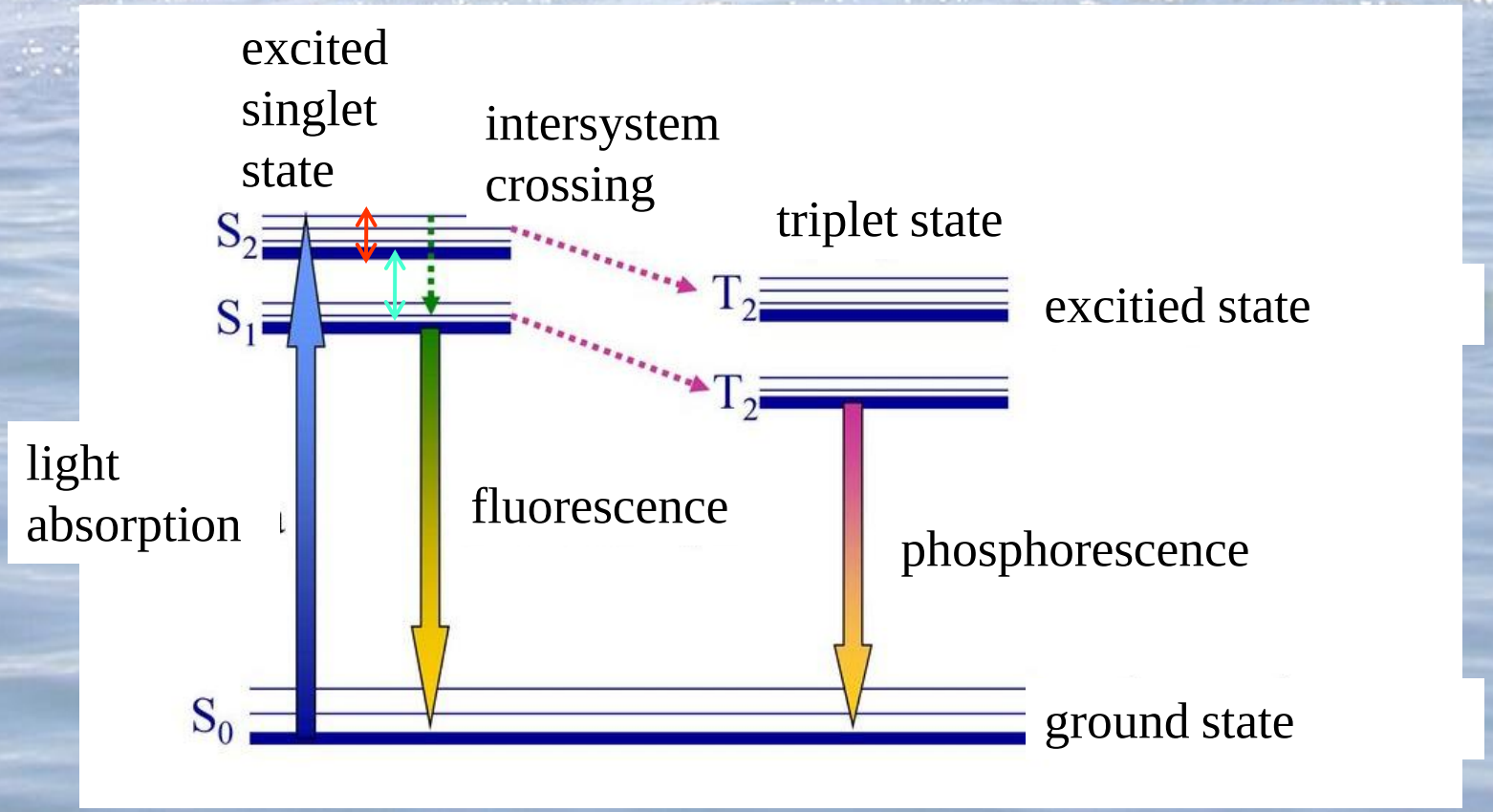
- antioxidant effect - reactions with free radicals,
- suppression of the singlet and triplet states of chlorophyll
- xanthophyll cycle

Photosynthetic pigments (PSC)

- absorption and transfer of some energy to the chlorophyll a molecule (function of the so-called photosynthetic antenna)

Jabłoński diagram

– possible energy transition between molecules



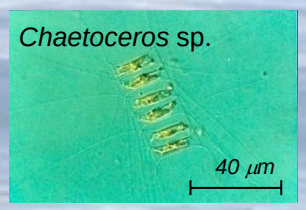
vibration (oscillatory) relaxation

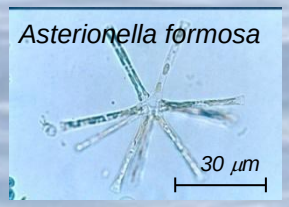
intramolecular conversion

accordnig to Mimuro and Akimoto 2003

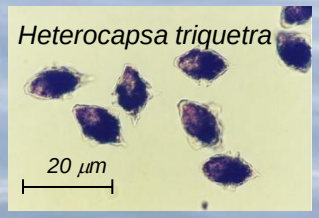
Phytoplankton classes – botic factor determining pigmets composition

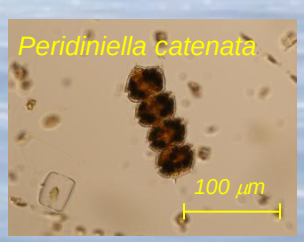
cyjanobacteria

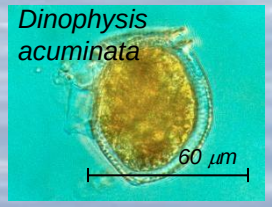




diatoms

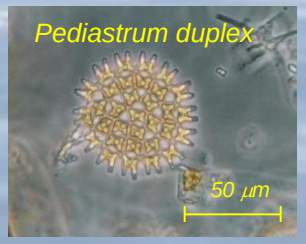


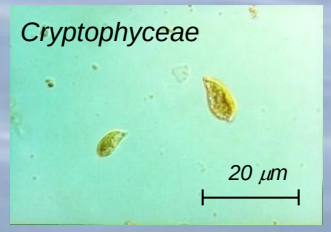




dinophytes

chlorophytes





cryptophytes

photo M. Łotocka

Phytoplanton pigments

Pigment	*Cyanobacteeria*	*Prochlorophyceae*	*Rhodophyceae*	*Cryptophyceae*	*Chlorophyceae*	*Prasinophyceae*	*Euglenophyceae*	*Eustigmatophyceae*	*Bacillariophyceae*	*Dionophyceae*	*Prymnesiophyceae*	*Raphidiophyceae*	*Chrysophyceae*
		Algae classes											
CHLOROPHYLLS *a*	●	x	●	●	●	●	●	●	●	●	●	●	●
b		x			●	●	●			x			
c1									●	x	●	●	
c2				●					●	●	●	●	●
c3											●		●
divinyl chlorophyll a *a*		●											
divinyl chlorophyll b *b*		●											
CAROTENES α			●	●	●	•	•				•		
β	●	●			●	●	●	●	•	•	•	●	•
γ					•								
likopen				•									
PHYCOBILINS phycocyanin	●		•	●									
allophycocyanin	●		●										
phycoerythrin	●		●	●									

Pigment	*Cyanobacteeria*	*Prochlorophyceae*	*Rhodophyceae*	*Cryptophyceae*	*Chlorophyceae*	*Prasinophyceae*	*Euglenophyceae*	*Eustigmatophyceae*	*Bacillariophyceae*	*Dinophyceae*	*Prymnesiophyceae*	*Raphidiophyceae*	*Chrysophyceae*
		Aglae classes											
XANTHOPHYLLS													
alloxanthin		x		●									
antheraxanthin		x			•	•	•						
astaxanthin					x	x							
19'but-fucoxanthin										x	●		●
diadinoxanthin							●		●	●	●	●	●
diatoxanthin							•		•	•	•	•	•
dinoksantyna										●			
echinenone	x				x	x	x						
fucoxanthin									●	x	●	●	●
19'hex-fucoxanthin										x	●		
canthaxanthin	x				x								
lutein					●	●							
monadoxanthin				•									
neoxanthin					●	●	•						
peridinin										●			
prasinoxanthin						●							
violaxanthin					●	●		•					
zeaxanthin	●	●	●		•			•					

according to Jefrey and Vesk 1997

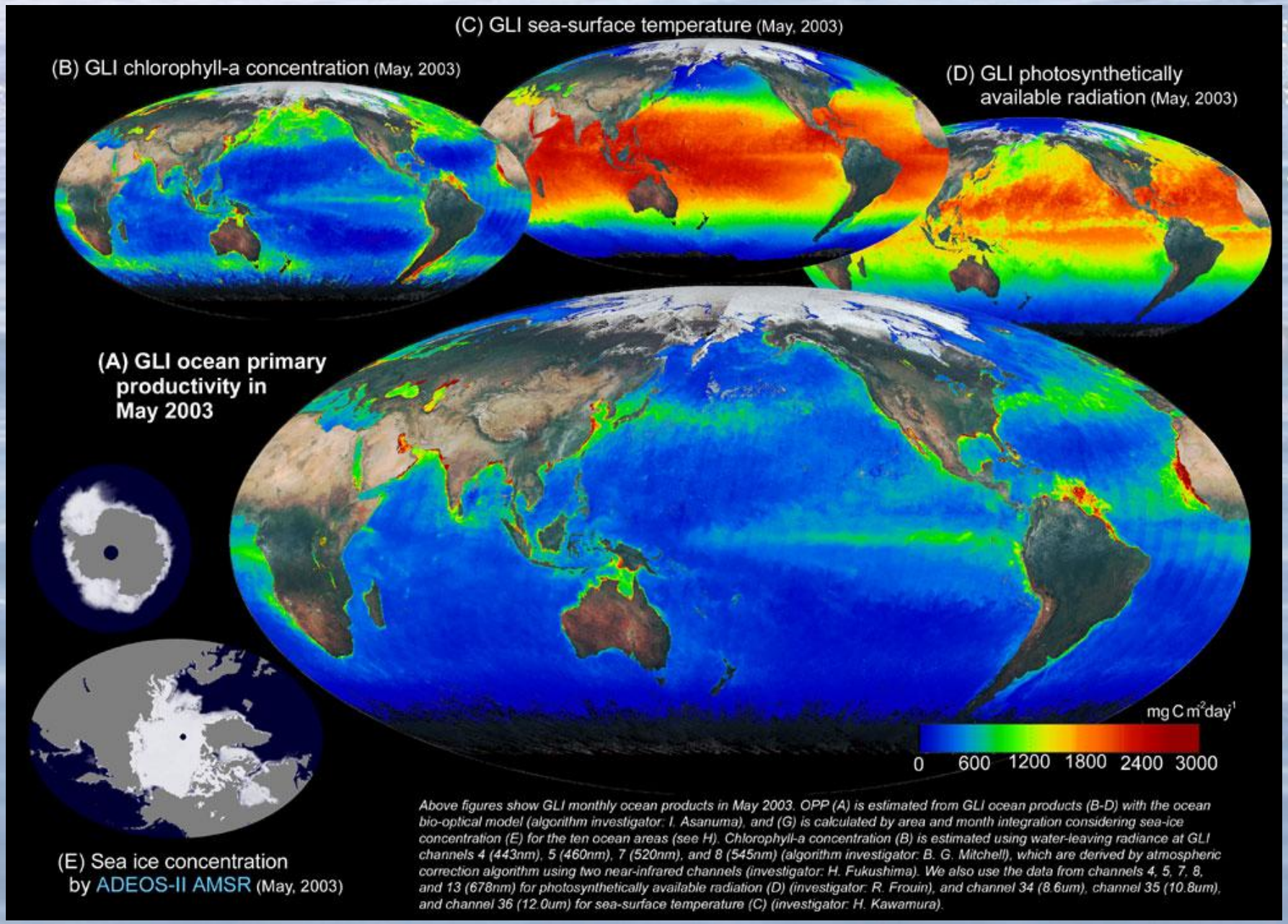
● >10% of total pigment amount

● 1 – 10%

• < 1%

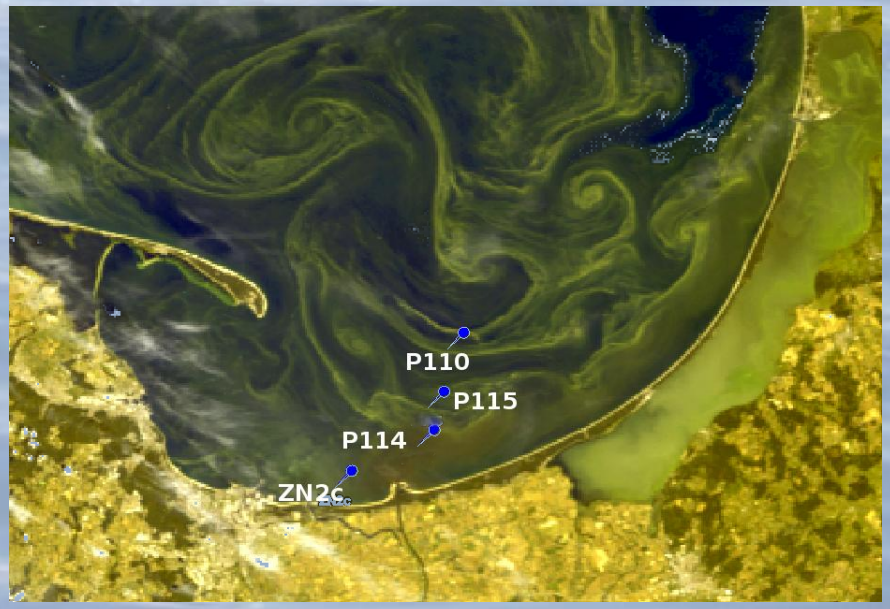
x – pigment noted occasionally

Global primary production in the oceans

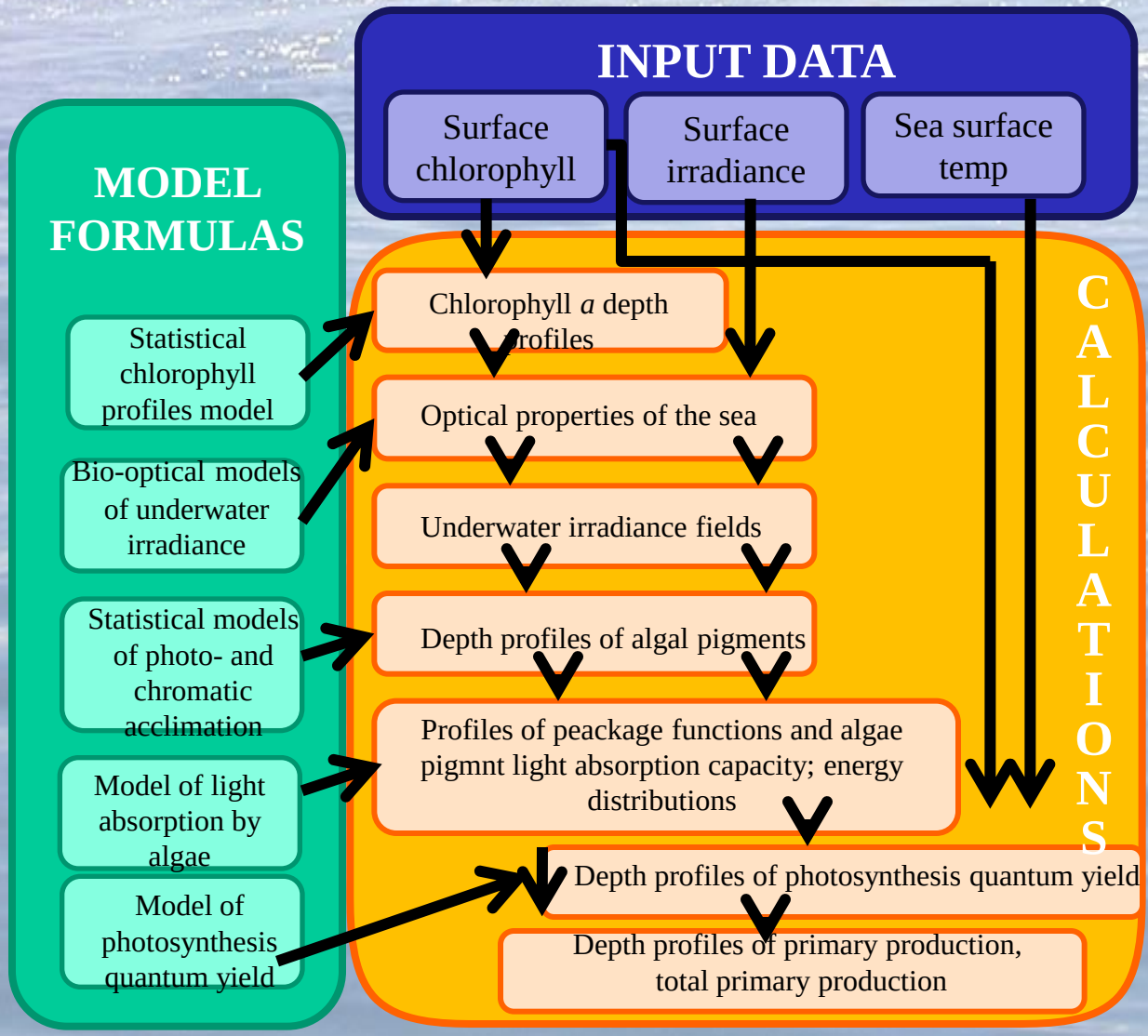


Above figures show GLI monthly ocean products in May 2003. OPP (A) is estimated from GLI ocean products (B-D) with the ocean bio-optical model (algorithm investigator: I. Asanuma), and (G) is calculated by area and month integration considering sea-ice concentration (E) for the ten ocean areas (see H). Chlorophyll-a concentration (B) is estimated using water-leaving radiance at GLI channels 4 (443nm), 5 (460nm), 7 (520nm), and 8 (545nm) (algorithm investigator: B. G. Mitchell), which are derived by atmospheric correction algorithm using two near-infrared channels (investigator: H. Fukushima). We also use the data from channels 4, 5, 7, 8, and 13 (678nm) for photosynthetically available radiation (D) (investigator: R. Frouin), and channel 34 (8.6um), channel 35 (10.8um), and channel 36 (12.0um) for sea-surface temperature (C) (investigator: H. Kawamura).

Phytoplankton blooms



DESAMBEM
Development of a satellite method for Baltic ecosystem monitoring



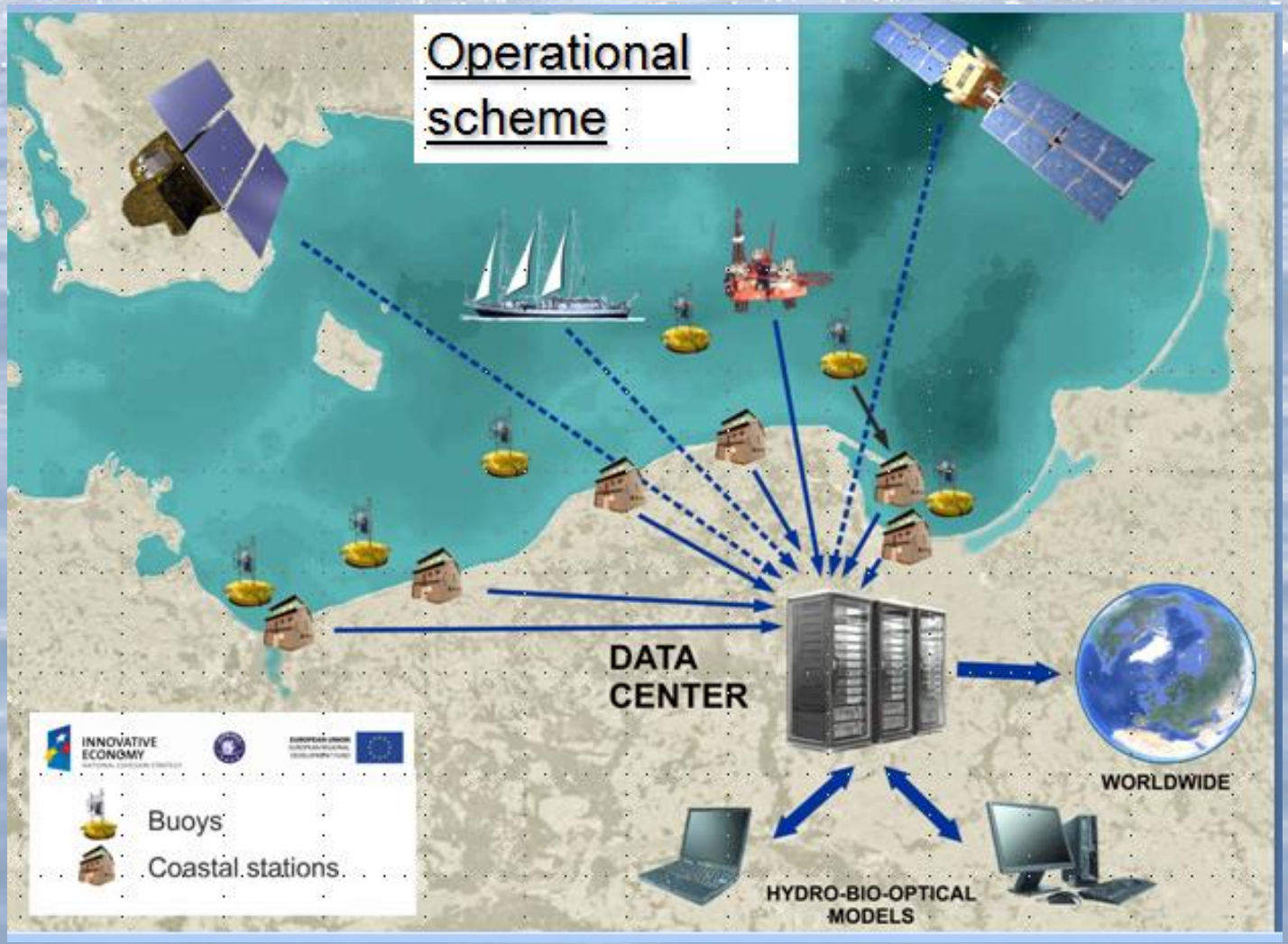
Model „Light - photosynthesis”

by:

-IO PAN
-AP in Slupsk

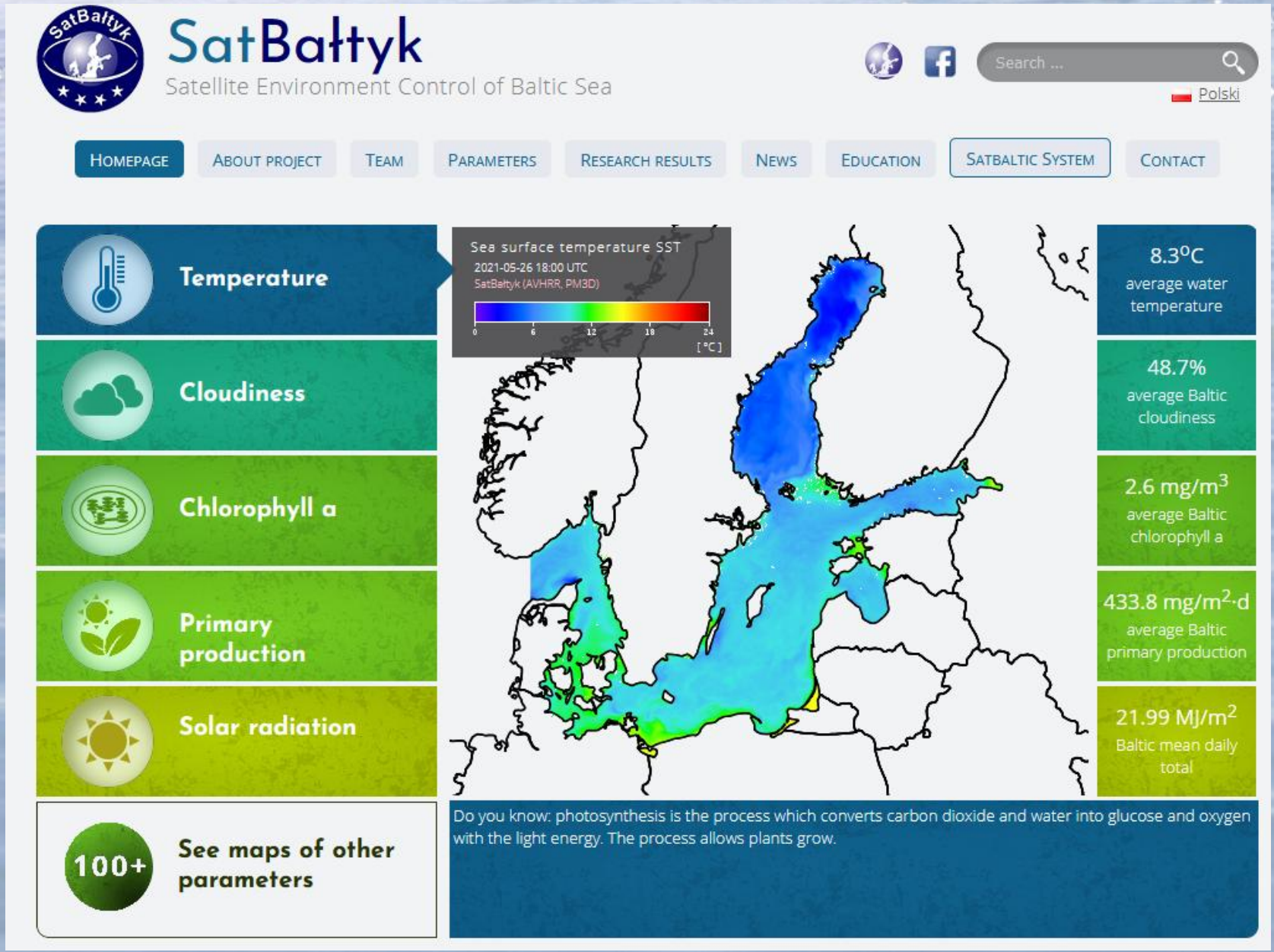
2002-2005

SatBałtyk
Satellite Environmental Control of Baltic Sea

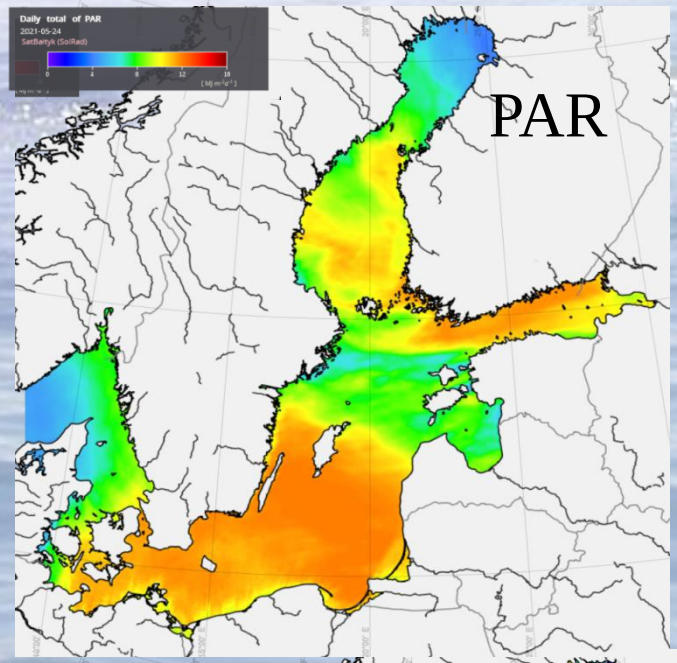


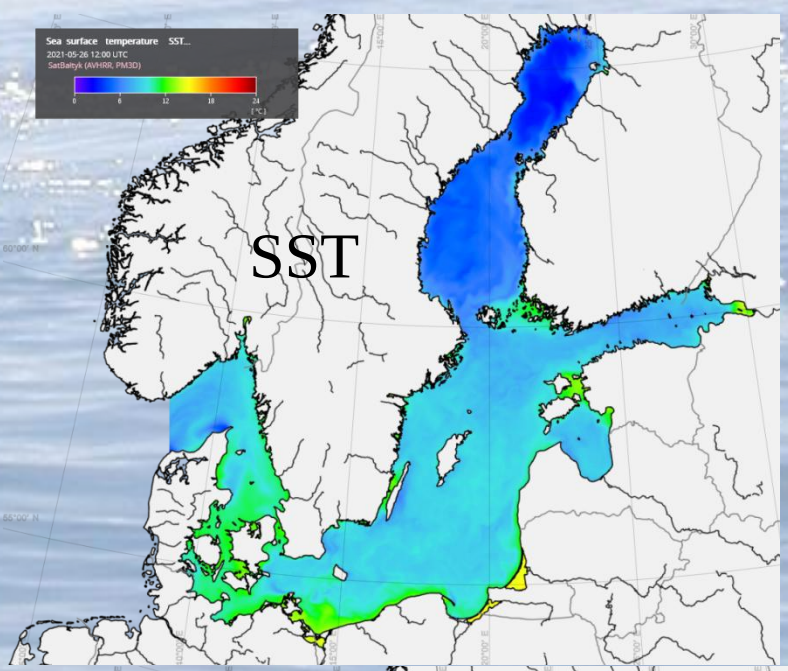
founded by European Union through European Regional Development Fund (POIG 01.01.02-22-011/09)

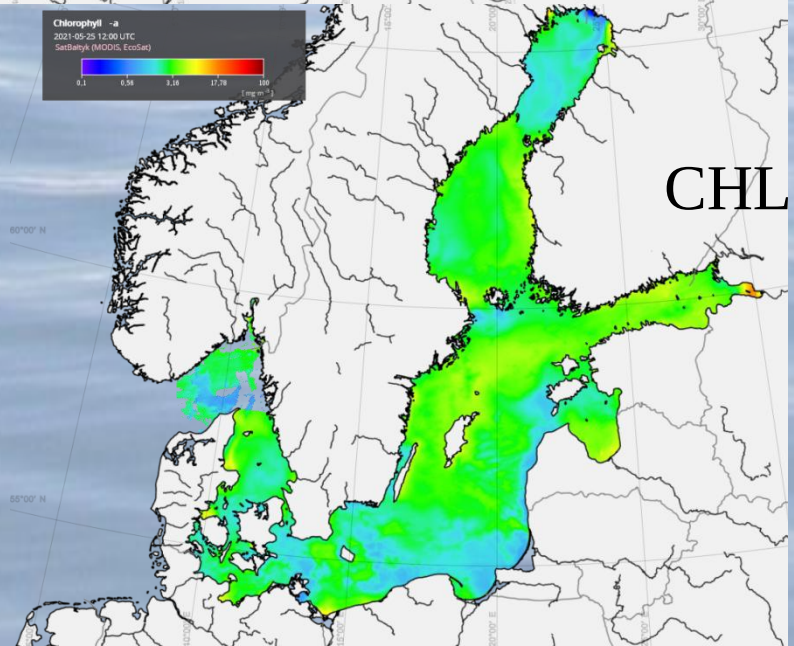
www.satbaltyk.pl

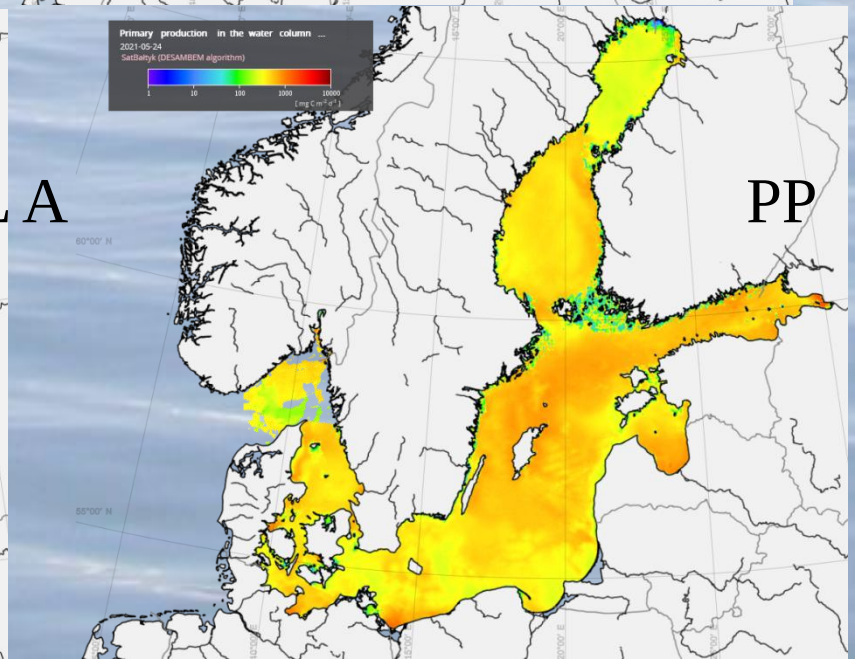


24 May 2021


Daily total of PAR
2021-05-24
SatBaltyk (SolRad)
PAR

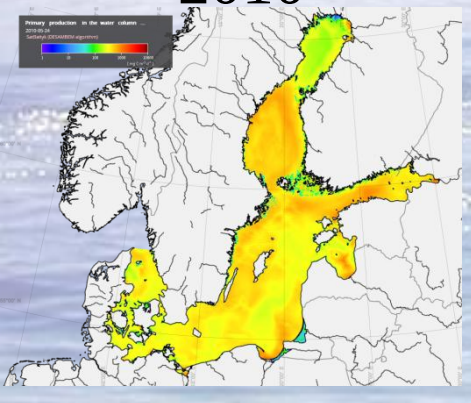

Sea surface temperature SST...
2021-05-26 12:00 UTC
SatBaltyk (AVHRR, PM3D)
SST


Chlorophyll -a
2021-05-25 12:00 UTC
SatBaltyk (MODIS, EcoSat)
CHL A

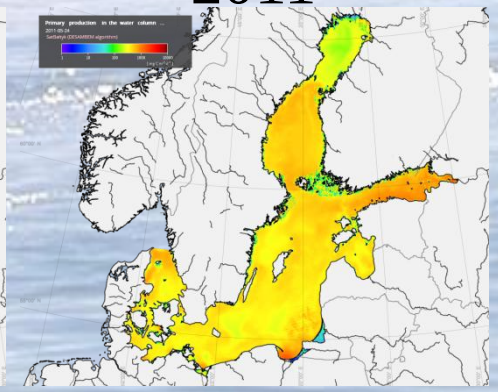

Primary production in the water column ...
2021-05-24
SatBaltyk (DESAMBEM algorithm)
PP

Primary production during last twelve years in May

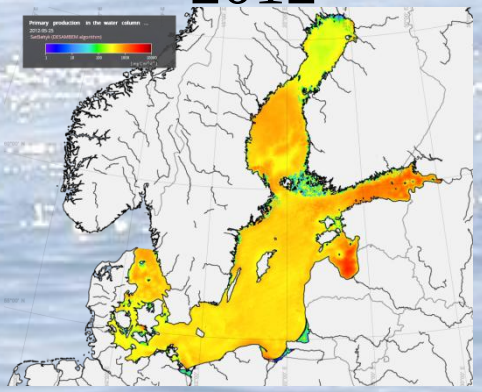
2010



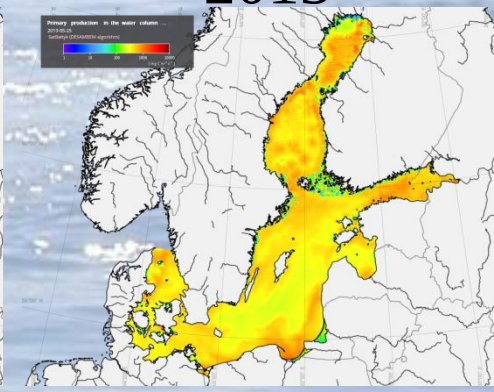
2011



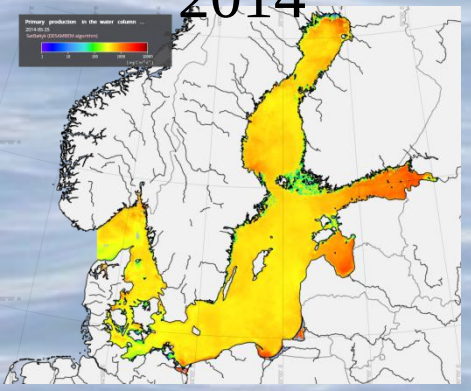
2012



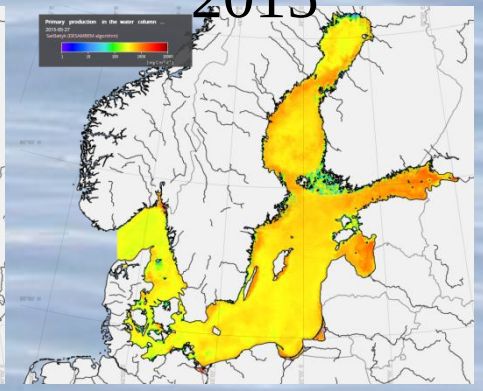
2013



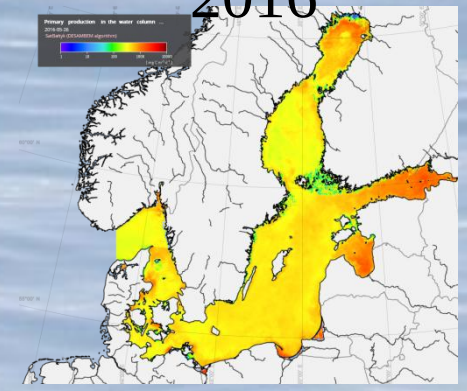
2014



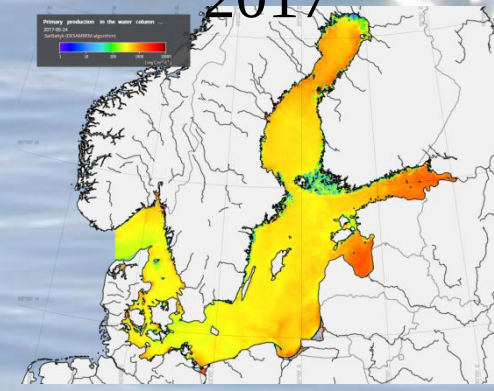
2015



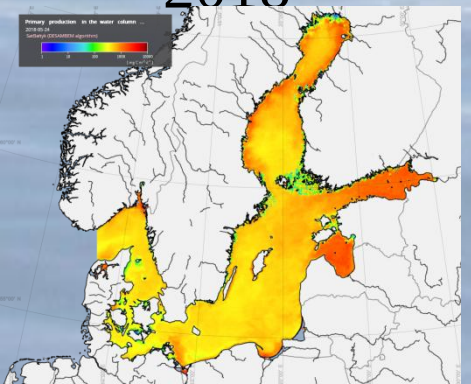
2016



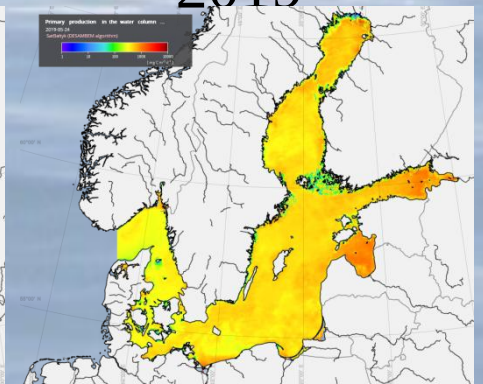
2017



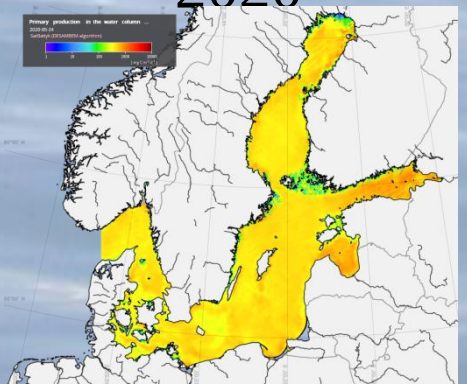
2018



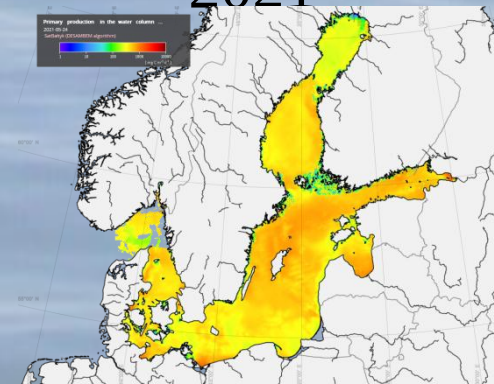
2019



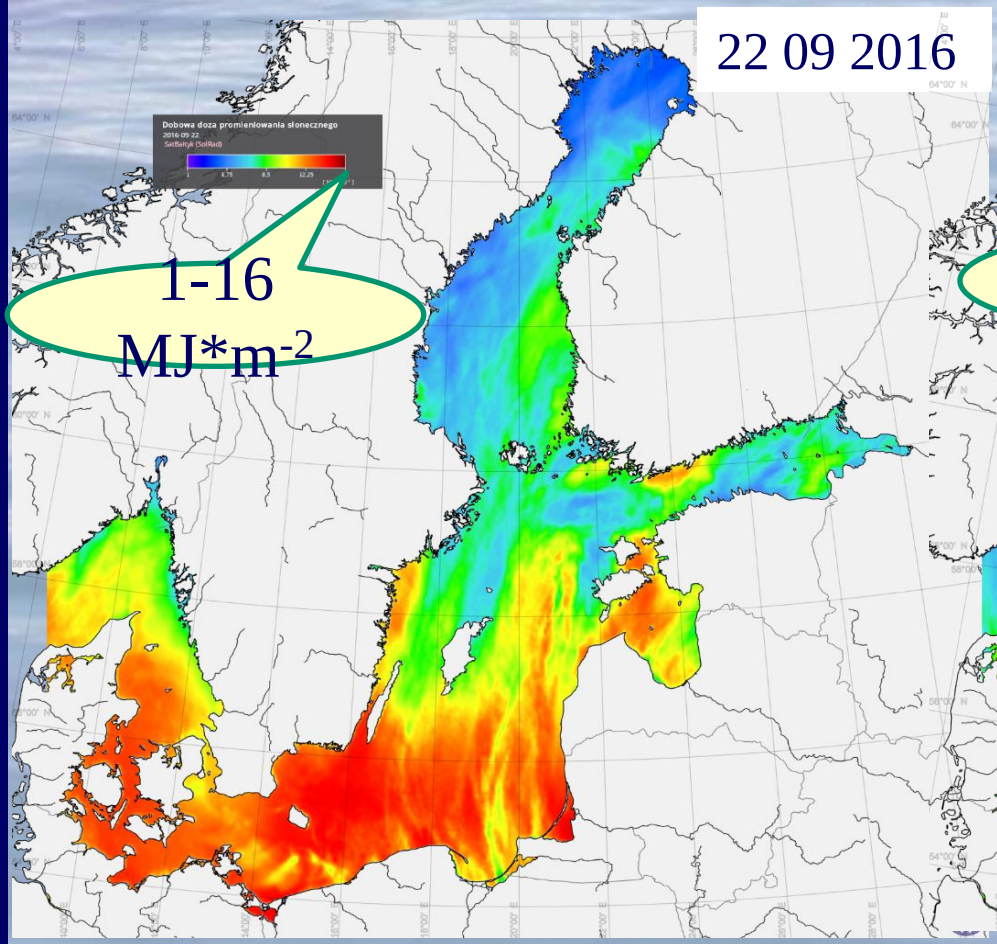
2020

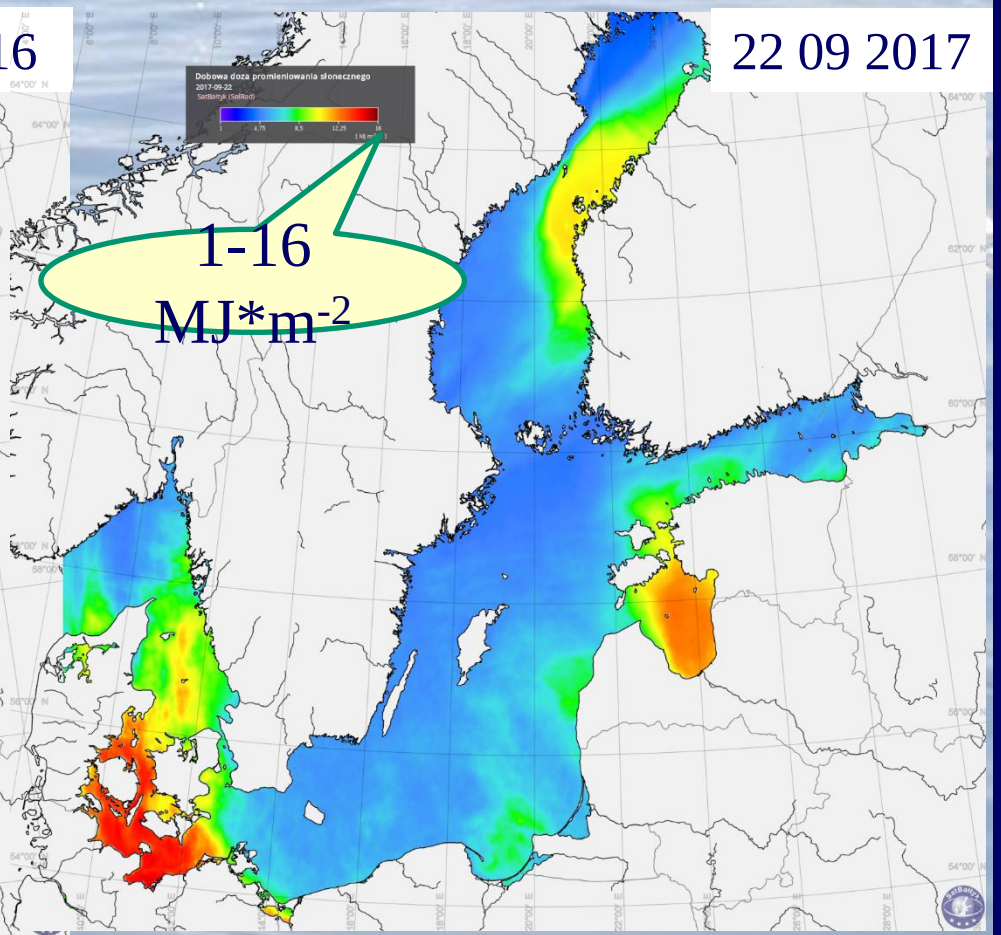


2021

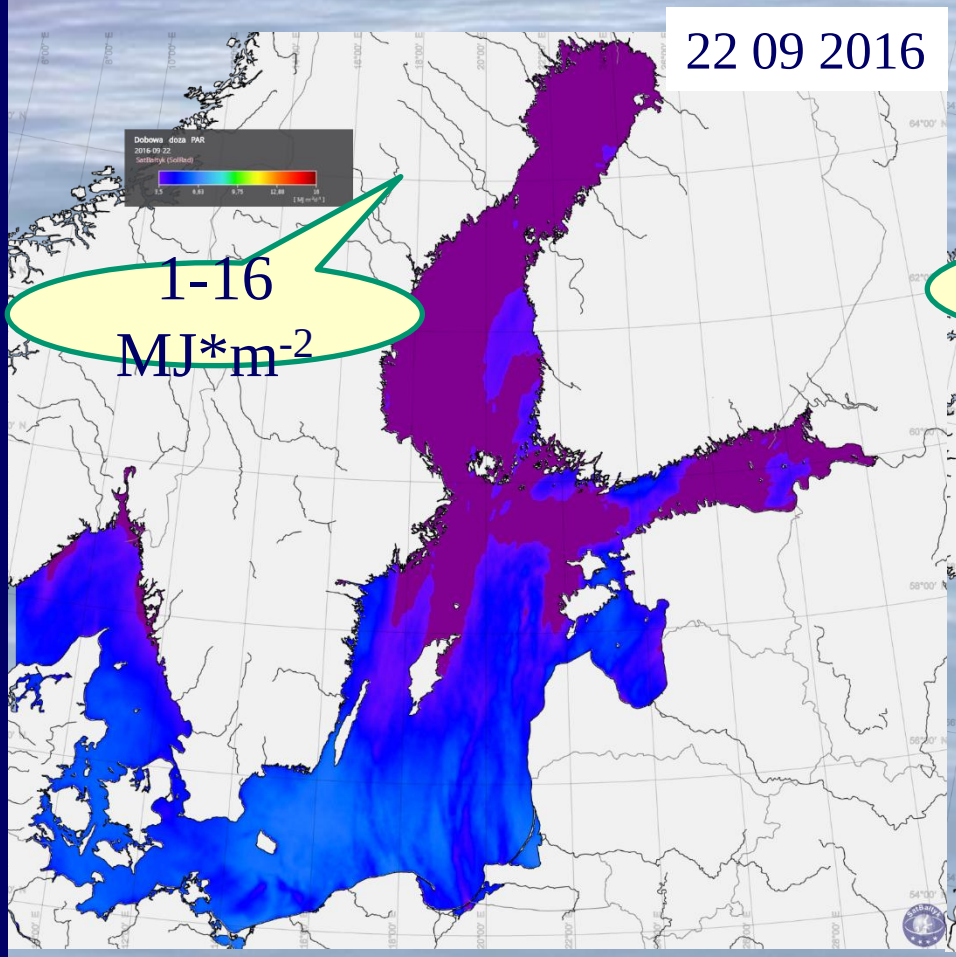


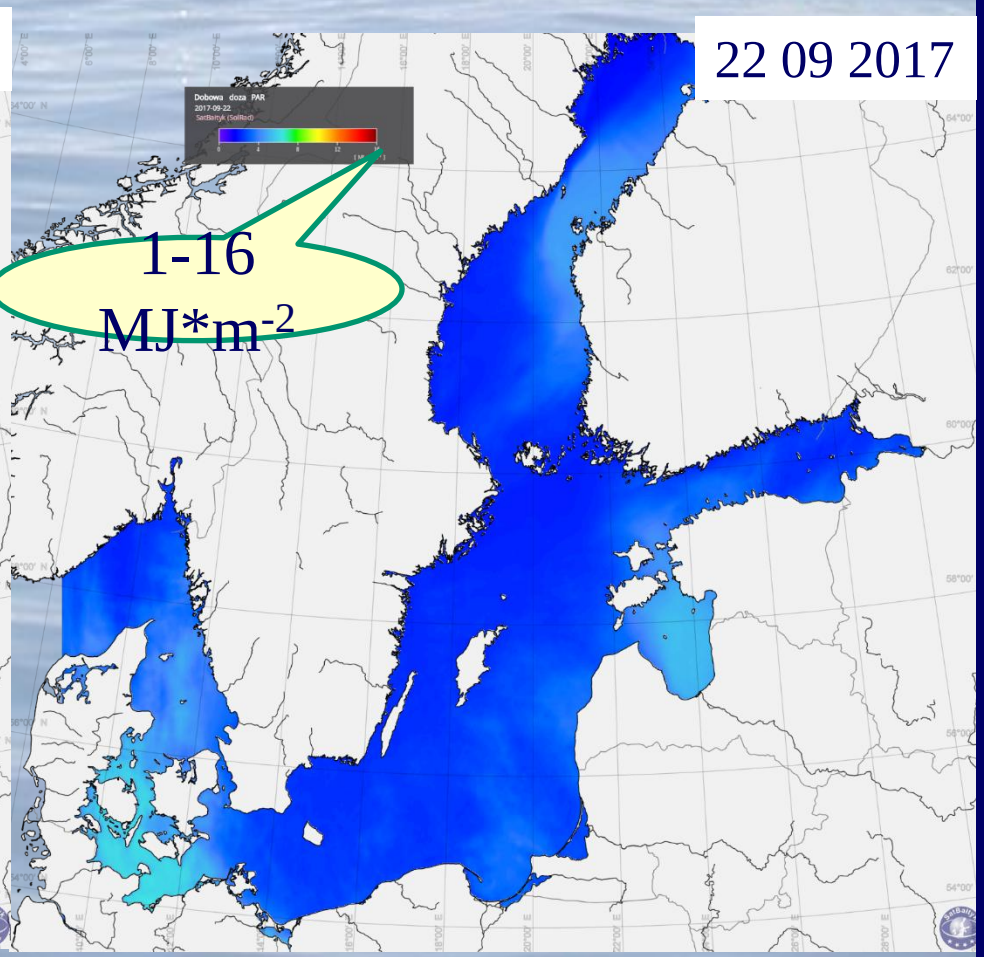
Daily dose of sunlight on sea surface





Daily dose of photosynthetically active radiation PAR

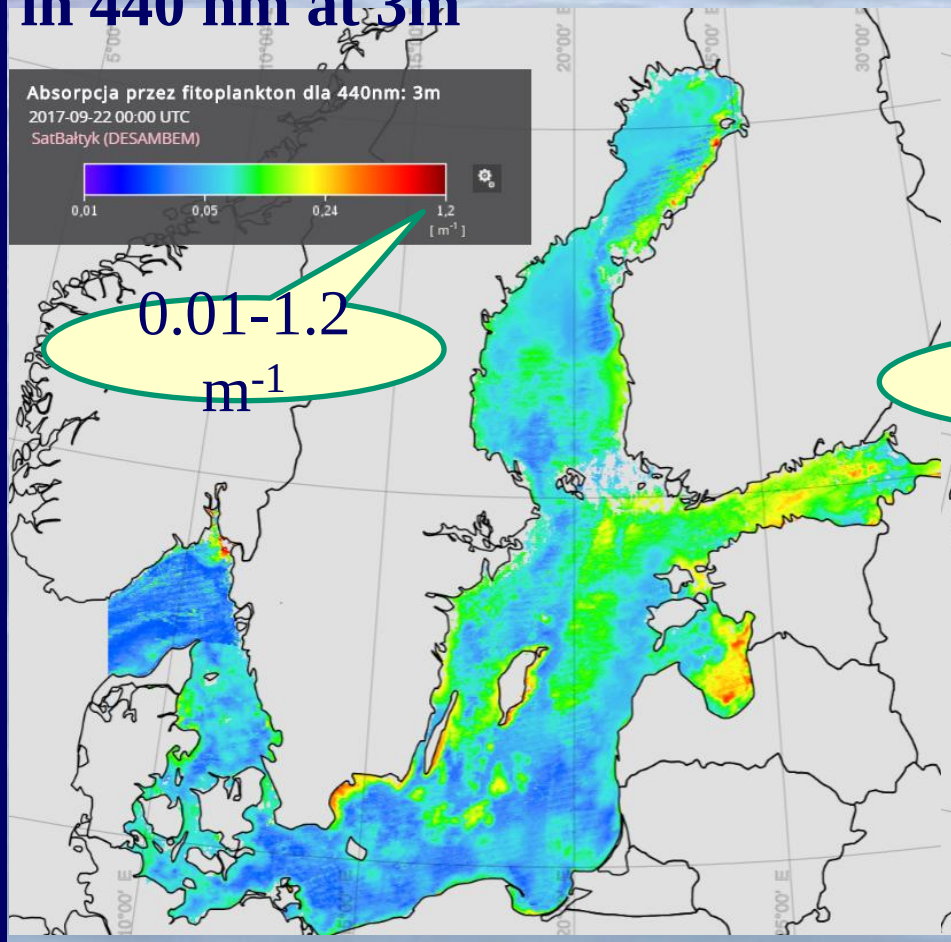




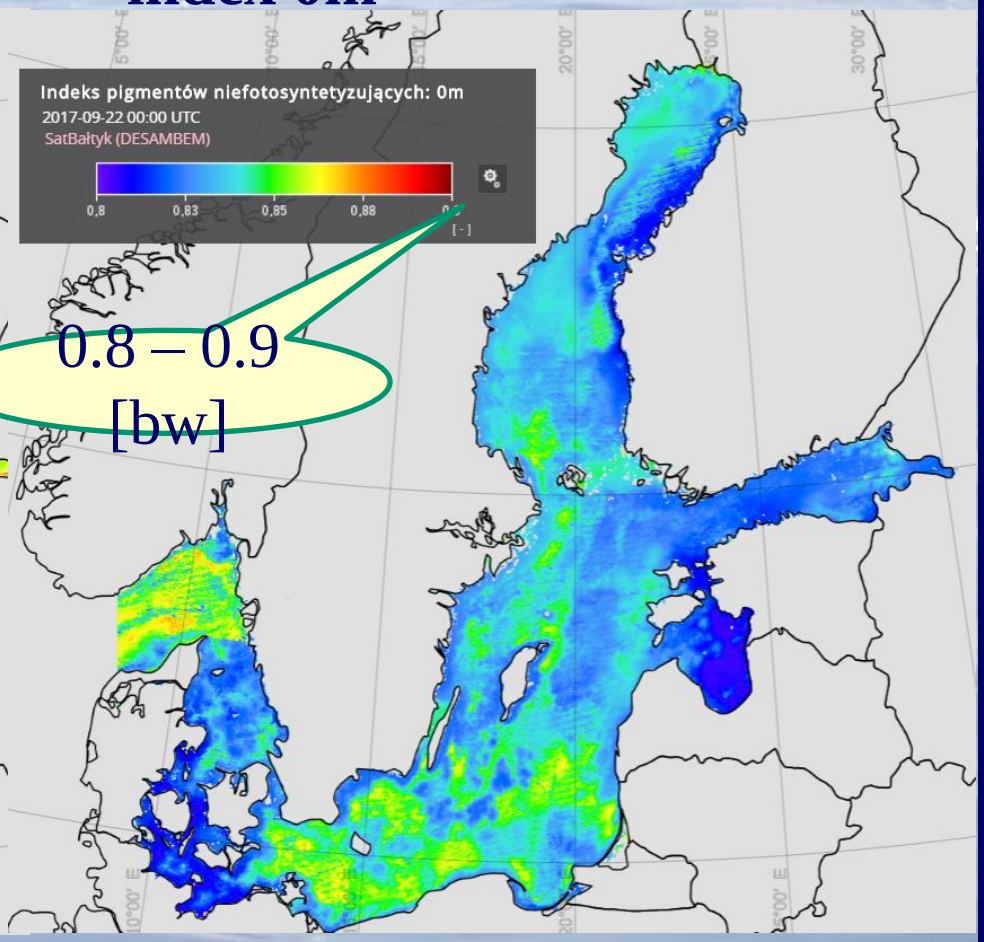
Absorption properties of phytoplankton

22 09 2017

Coeficient of light absorption in 440 nm at 3m



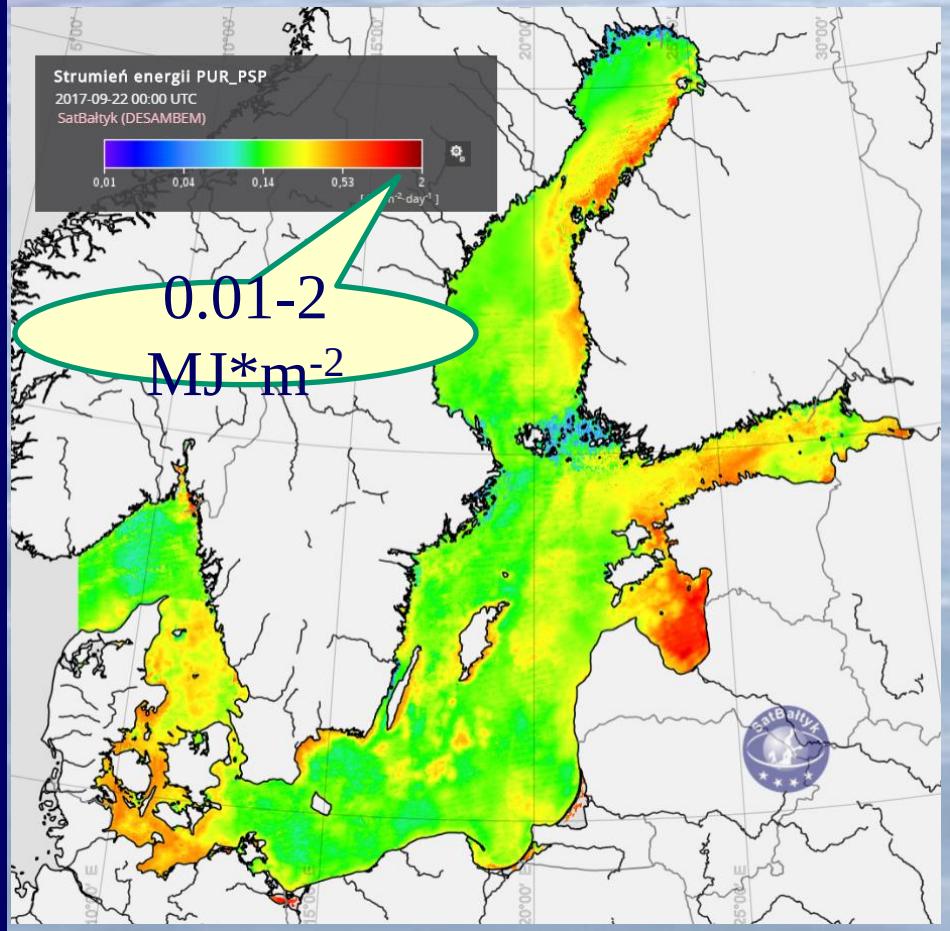
Non photosynthetic pigment index 0m



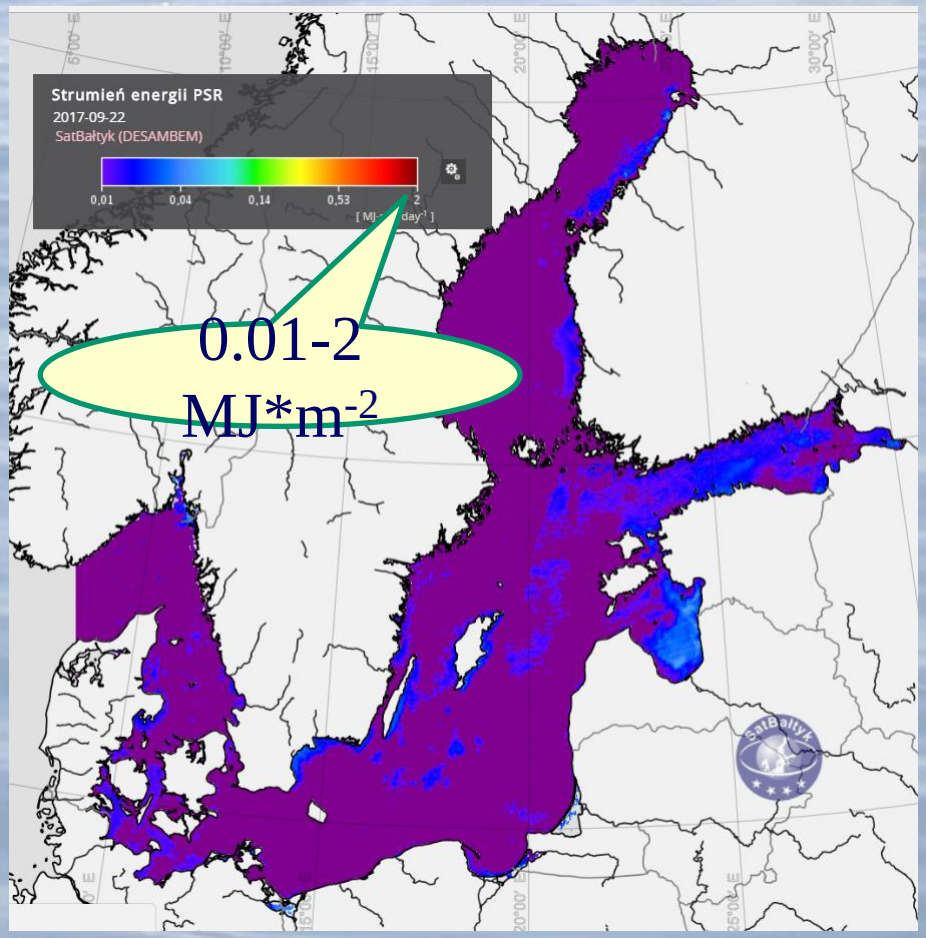
Energy fluxes in photosynthesis

22 09 2017

Energy absorbed by photosynthetic pigments PUR_{PSP}

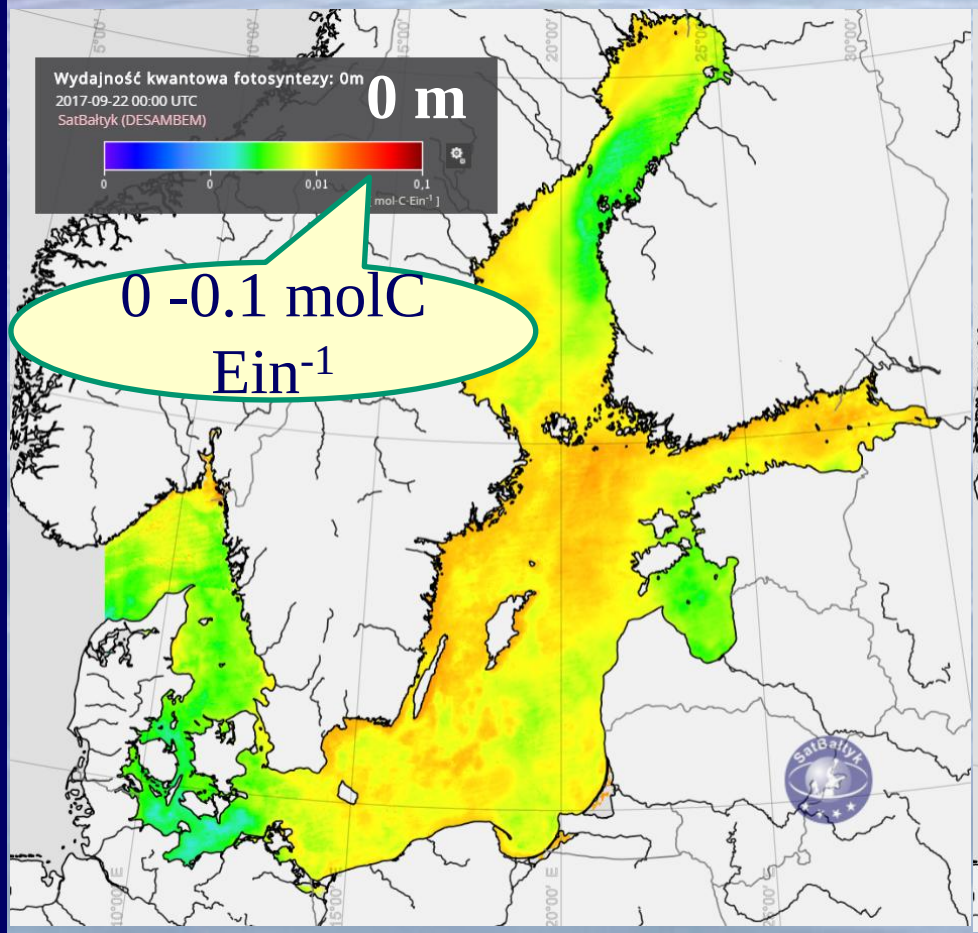


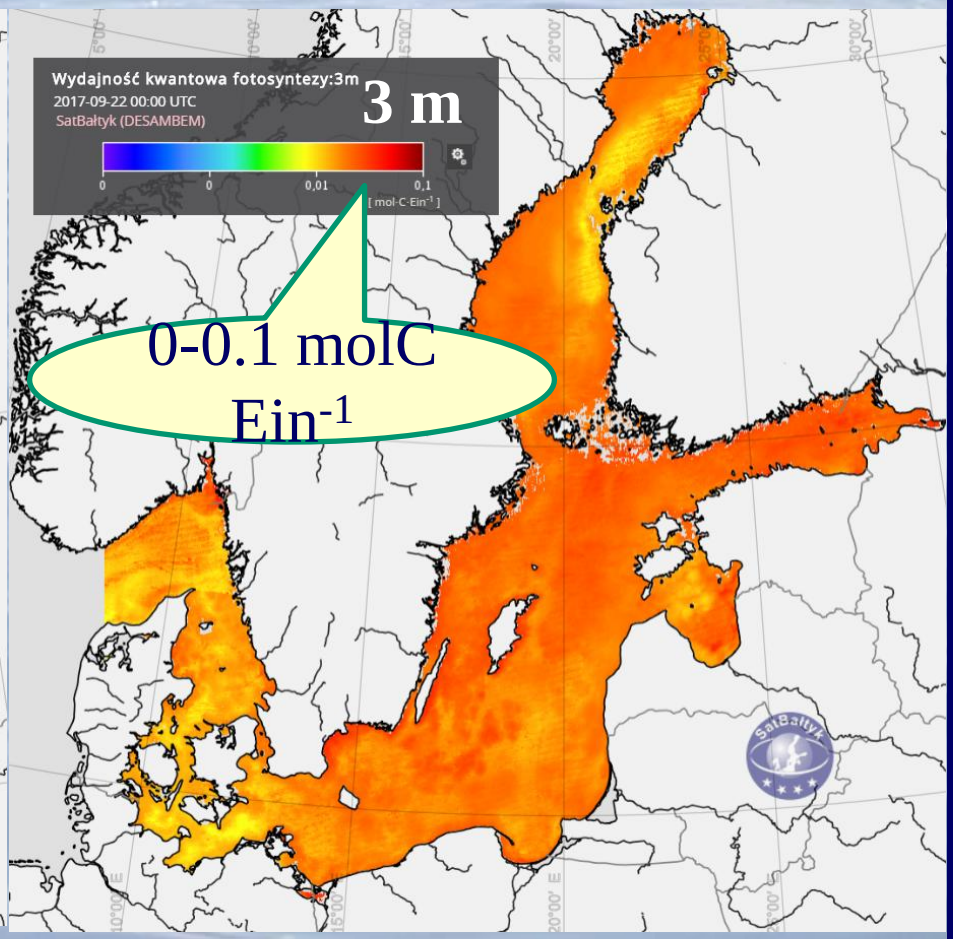
Photosyntically stored radiation PSR



Quantum yield of photosynthesis

22 09 2017






Thank you