A deteção por satélite da cor do oceano (Introdução)

Vanda Brotas

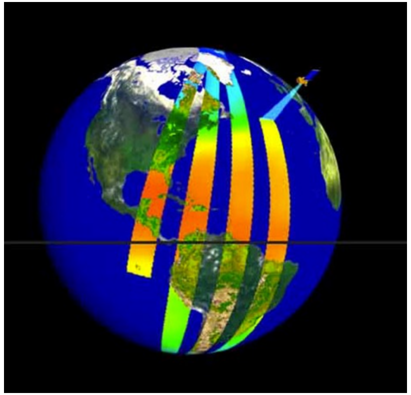
10 de Novembro 2022

Lecture Outline

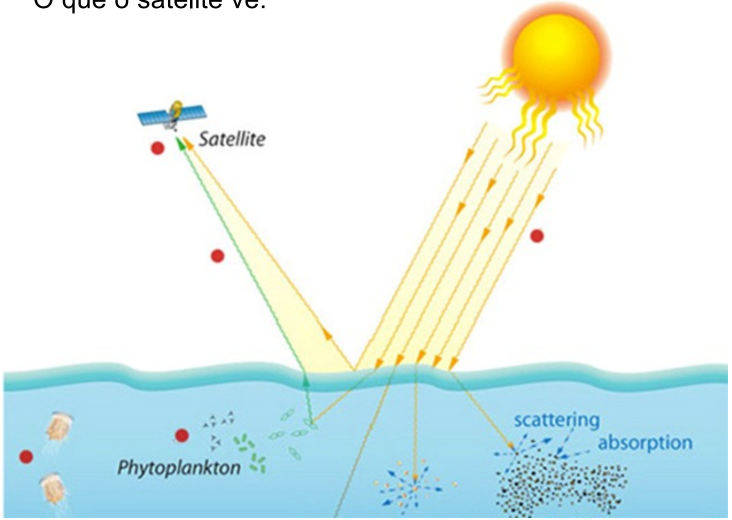
- Link with previous lectures
- Ocean Colour Applications
- Knowledge about phytoplankton global distribution – practical lecture with the CCI portal (today)
- Phytoplankton and climate change
- Bloom Phenology
- Phenology and Fisheries
- Harmful Algal Blooms (HABs), how remote sensing can help?

Biblio: Guia de Deteção Remota, Sutcliff et al 2016.

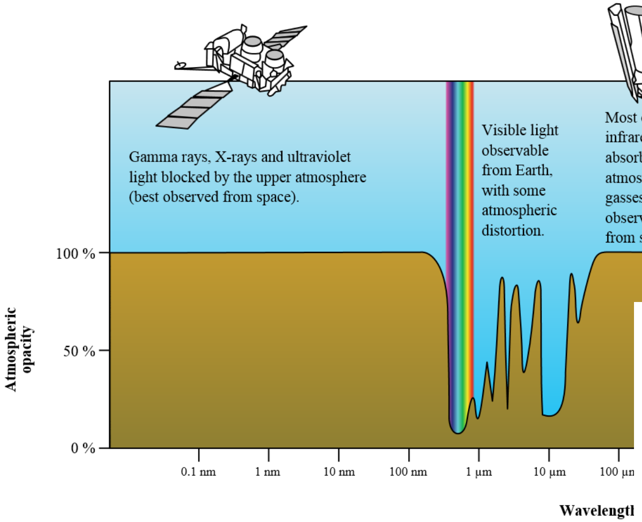
O que o satélite vê:

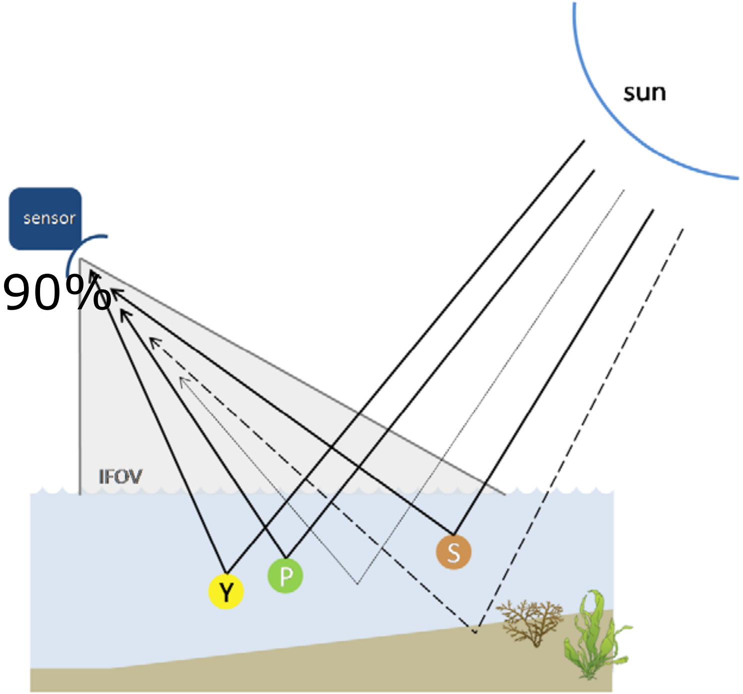


satélite em órbita quase-polar
Ex: Sentinel 3



- http://www.oceanopticsbook.info/

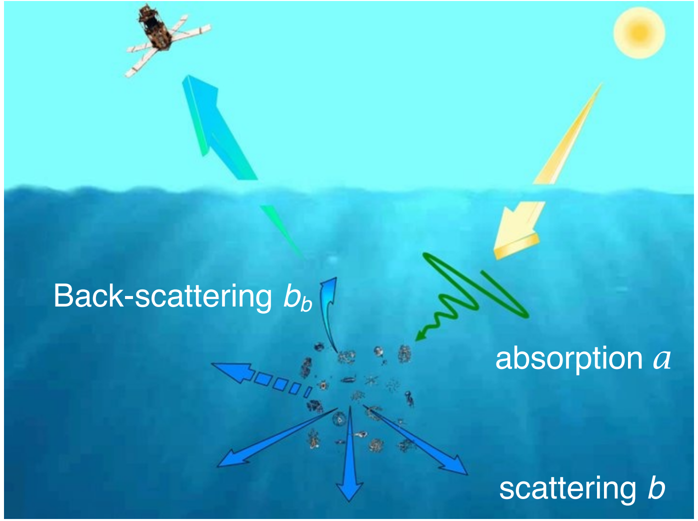


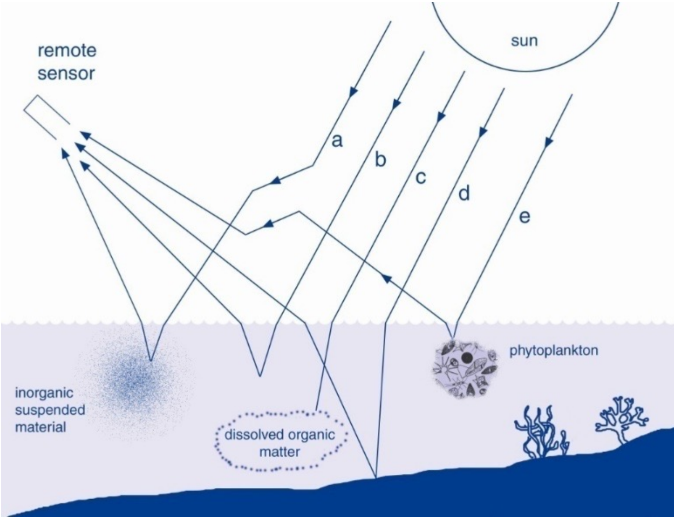


A atmosfera absorve 85 – 90%

P – Fitoplancton
S – Sedimento
Y – "yellow substances"

Principles of Ocean Colour Radiometry
Factors affecting remote sensing reflectance





Light photons are absorbed or scattered

Reflectances provide information on phytoplankton concentration, suspended matter, and CDOM (coloured dissolved organic matter)

Waters Case 1

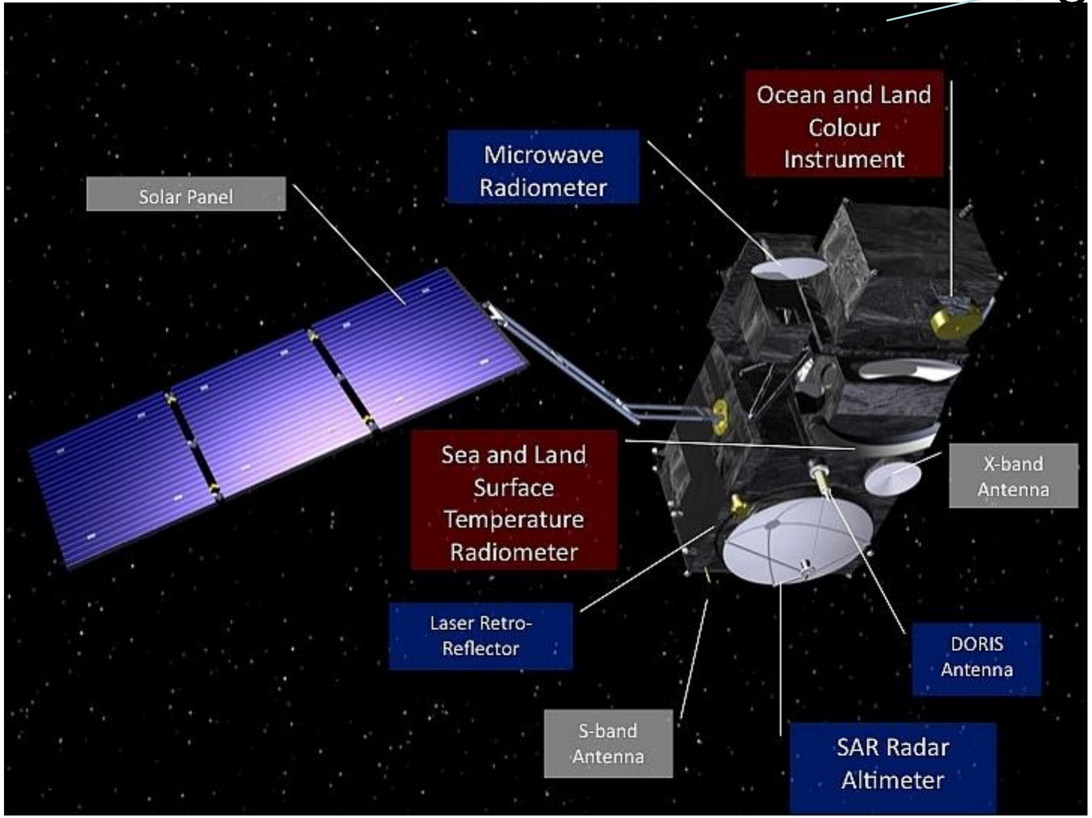
Phytoplankton and their associated materials (such as debris, heterotrophic organisms and bacteria, excreted organic matter) control the optical properties

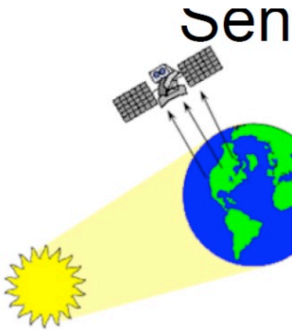
Waters Case 2

Optical properties are dependent on the colored dissolved organic matters of terrigenous origin, collectively named "yellow substance", or CDOM (colored dissolved organic matter), as well as the mineral particles and various suspended sediments.

Satélite da ESA para observação do oceano: SENTINEL 3

OLCI





Passive Sensors

- They only receive radition
- Source of Radiation is the sun
- Radiation received in the sensor may result from emission, reflection or may scattered.

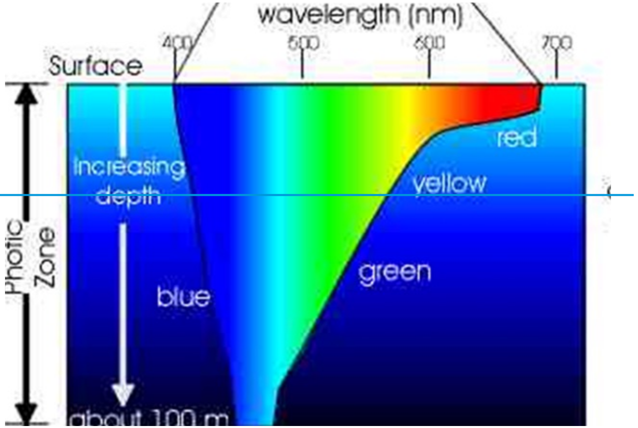
Z_{eu} :Depth of Euphotic Zone

Z_{90}, ou Z_{opt} : “First Optical Depth” = where ~90% of the radiance originates

$Z_{opt}=Z_{eu}/4.6$

“First Optical Depth”

100%



1%

Logoritmo neperiano de 100=4.6

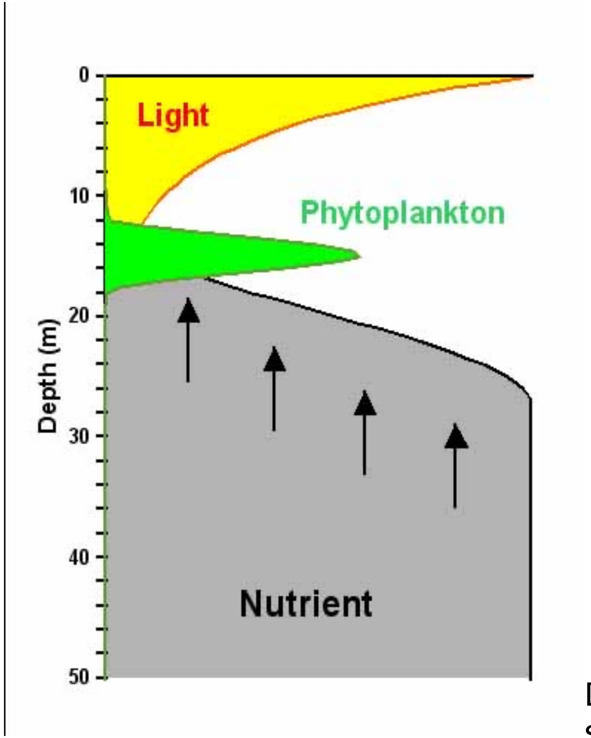
Ln(100) = 4.6

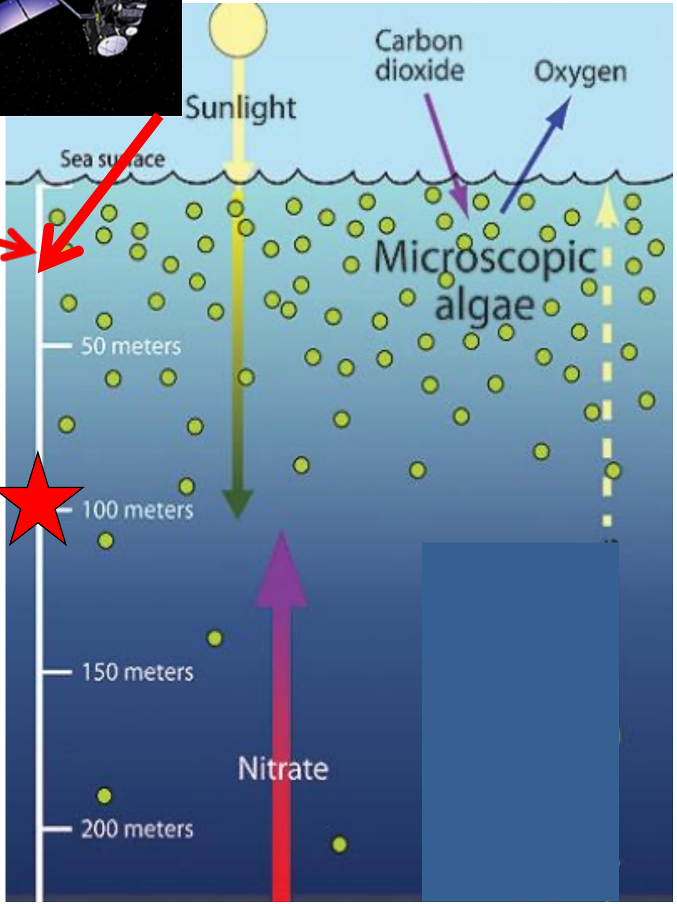
Principles of Ocean Colour Radiometry

How deep do satellites "see"?

100M/ 4.6 = 21M

DCM

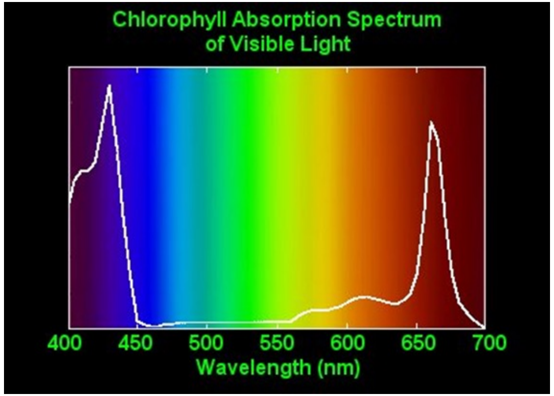


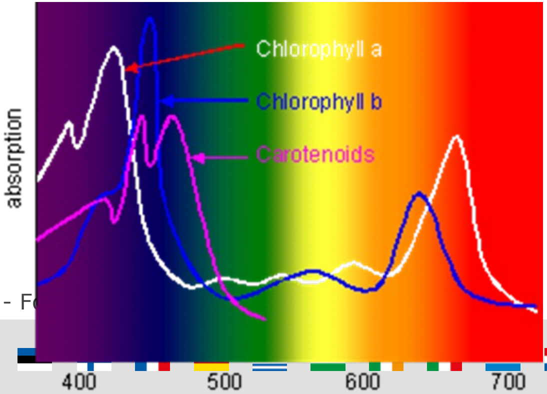


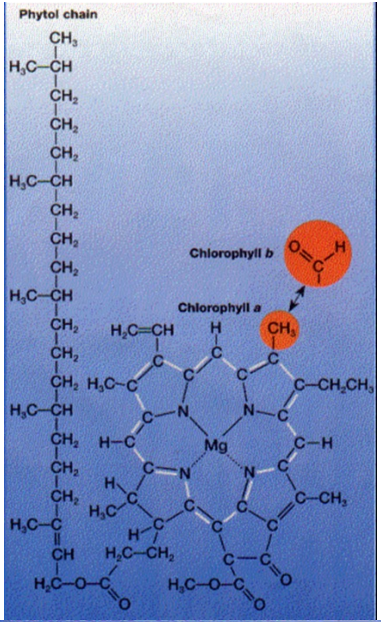
Disadvantages of RS. Signal from satelites is limited to 1st optical depth

Phytoplankton is constituted by microscopic cells with different pigments content

- Chorophyll a: universal pigment in all algal classes.
- Other chlorophylls, many carotenoids

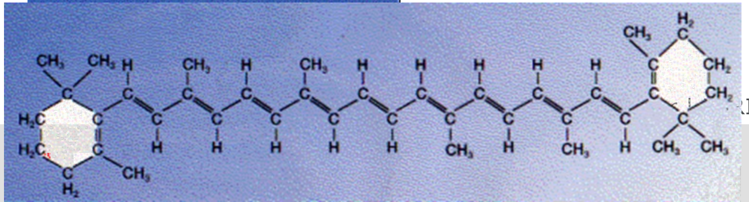




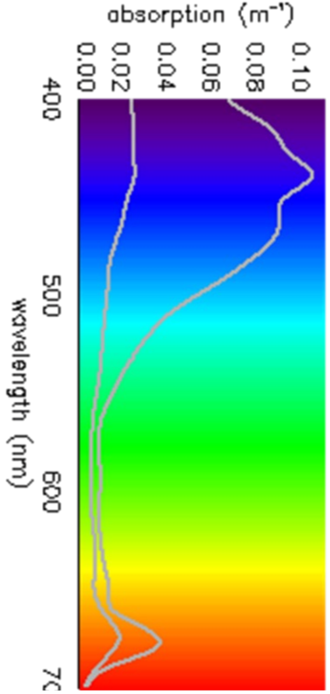


Chlorophylls

Carotenoides



OLCI – bandas



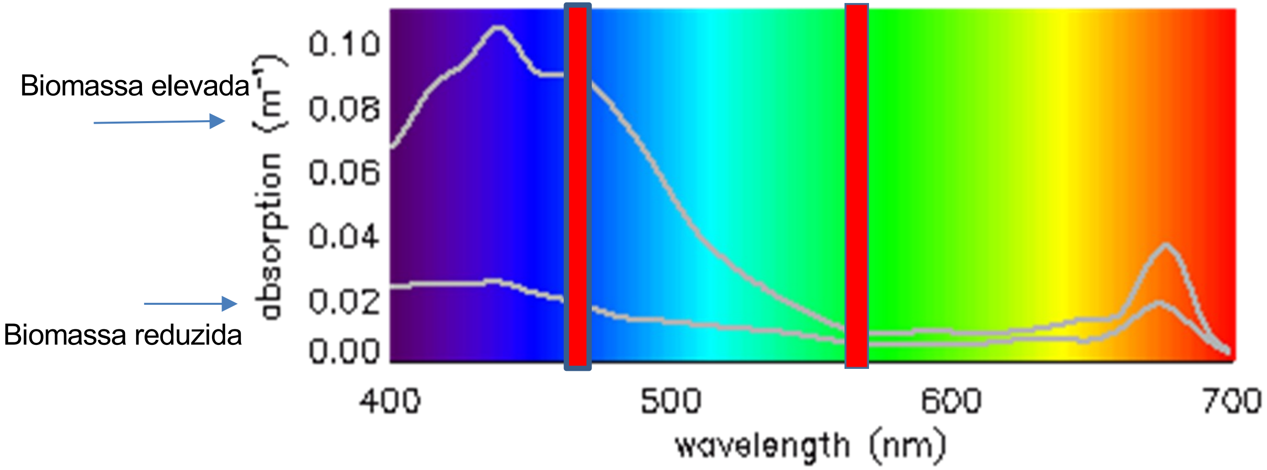
Yellow: additional bands in relation to MERIS

Band #	λ center	Width	Lmin	Lref	Lsat	SNR(
	nm	nm	W/(m².sr.μm)	W/(m².sr.μm)	W/(m².sr.μm)	
Oa1	400	15	21.60	62.95	413.5	2188
Oa2	412.5	10	25.93	74.14	501.3	2061
Oa3	442.5	10	23.96	65.61	466.1	1811
Oa4	490	10	19.78	51.21	483.3	1541
Oa5	510	10	17.45	44.39	449.6	1488
Oa6	560	10	12.73	31.49	524.5	1280
Oa7	620	10	8.86	21.14	397.9	997
Oa8	665	10	7.12	16.38	364.9	883
Oa9	673.75	7.5	6.87	15.70	443.1	707
Oa10	681.25	7.5	6.65	15.11	350.3	745
Oa11	708.75	10	5.66	12.73	332.4	785
Oa12	753.75	7.5	4.70	10.33	377.7	605
Oa13	761.25	2.5	2.53	6.09	369.5	232
Oa14	764.375	3.75	3.00	7.13	373.4	305
Oa15	767.5	2.5	3.27	7.58	250.0	330
Oa16	778.75	15	4.22	9.18	277.5	812
Oa17	865	20	2.88	6.17	229.5	666
Oa18	885	10	2.80	6.00	281.0	395
Oa19	900	10	2.05	4.73	237.6	308
Oa20	940	20	0.94	2.39	171.7	203
Oa21	1020	40	1.81	3.86	163.7	152

https://sentinel.esa.int/web/sentinel/user-guides/sentinel-3-olci/overview/heritage

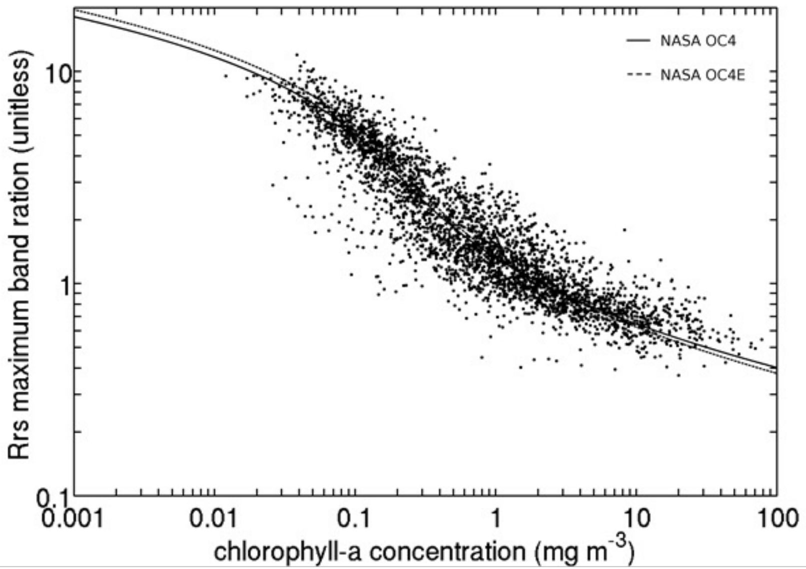
BASE TEÓRICA DA COR DO OCEANO

- Absorção da luz pelos pigmentos resulta em espectros de absorção proporcionais à sua concentração. O que é a base da deteção remota da Cor.
- Quanto maior a Absorção, menor a reflexão. Sensor de cor do satélite mede a reflectância.



Chla algorithms, blue/green bands ratio

Relação empirica entre o valor de Chla
Medido in situ e a razão entre as
 bandas : algoritmo é definido em função
Desta relação

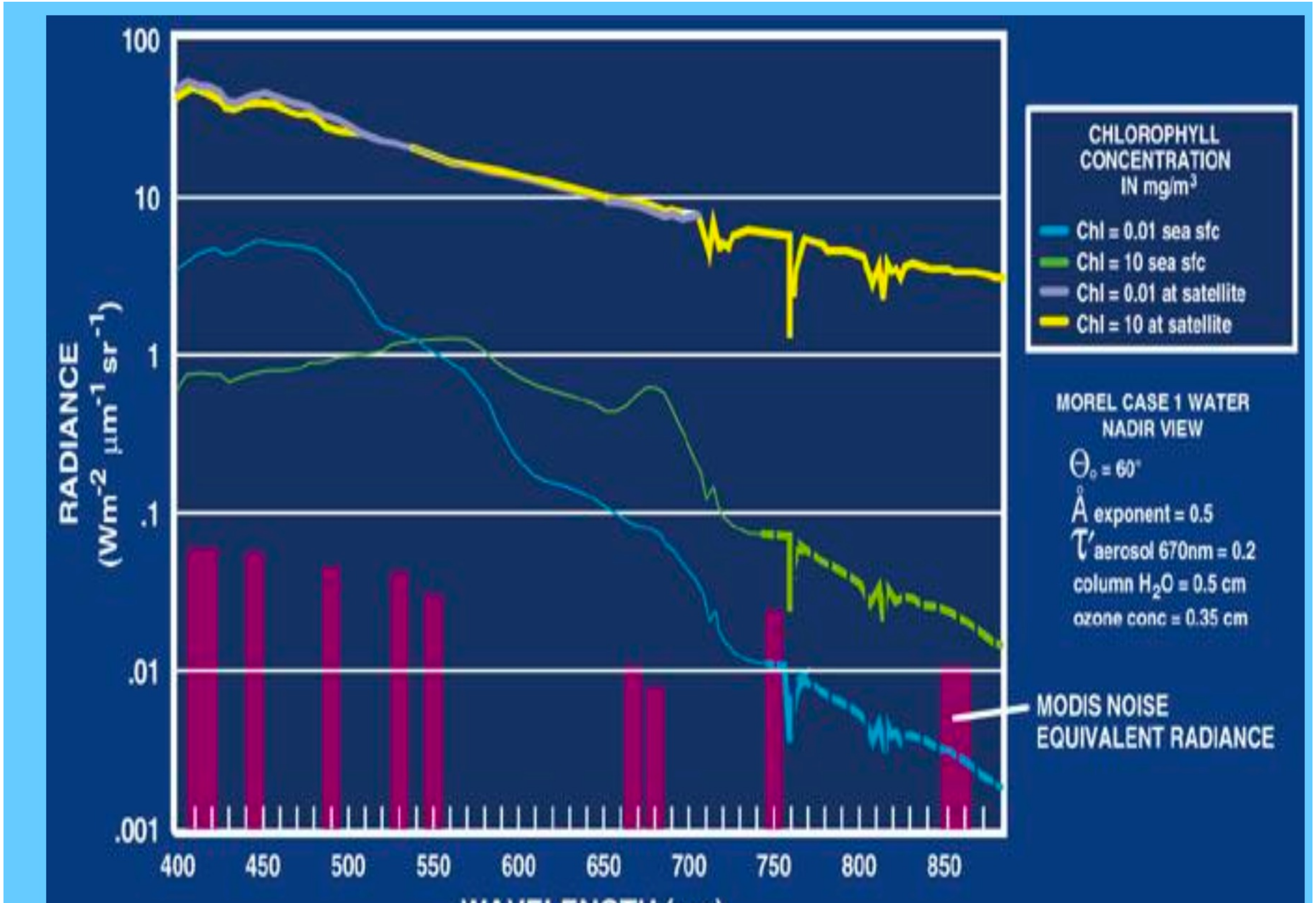


Remote-sensing reflectance maximum band ratio ([443,490,510]/555 as a function of chlorophyll-a concentration.

NASA OC4 and OC4E v64 operational standard algorithms, http://oceancolor.gsfc.nasa.gov/cms/atbd/chlor_a).

Right Figure from Valente et al 2016, Earth Syst. Sci. Data, 8, 235-252, doi:10.5194/essd-8-235-2016.

Absorbance – the inverse of radiance



Nasa Ocean Color site – to know more

https://oceancolor.gsfc.nasa.gov/atbd/chlor_a/

Inputs:
Rrs at 2-4 wavelengths between 440 and 670nm
Outputs:
chlor_a, concentration of chlorophyll *a* in mg/m^{-3}

This algorithm returns the near-surface concentration of chlorophyll-a (chlor_a) in mg m-3, calculated using an empirical relationship derived from in situ measurements of chlor_a and remote sensing reflectances (Rrs) in the blue-to-green region of the visible spectrum.

Aplicações Cor do Oceano
Ocean Colour Applications

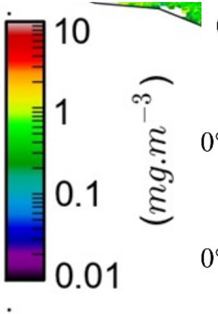
- Conhecimento sobre o oceano, distribuição da biomassa fitoplâncton – aula TP
- Knowledge about phytoplankton global distribution – practical lecture

Phytoplankton from Space: Global picture

Remote sense of Ocean Colour

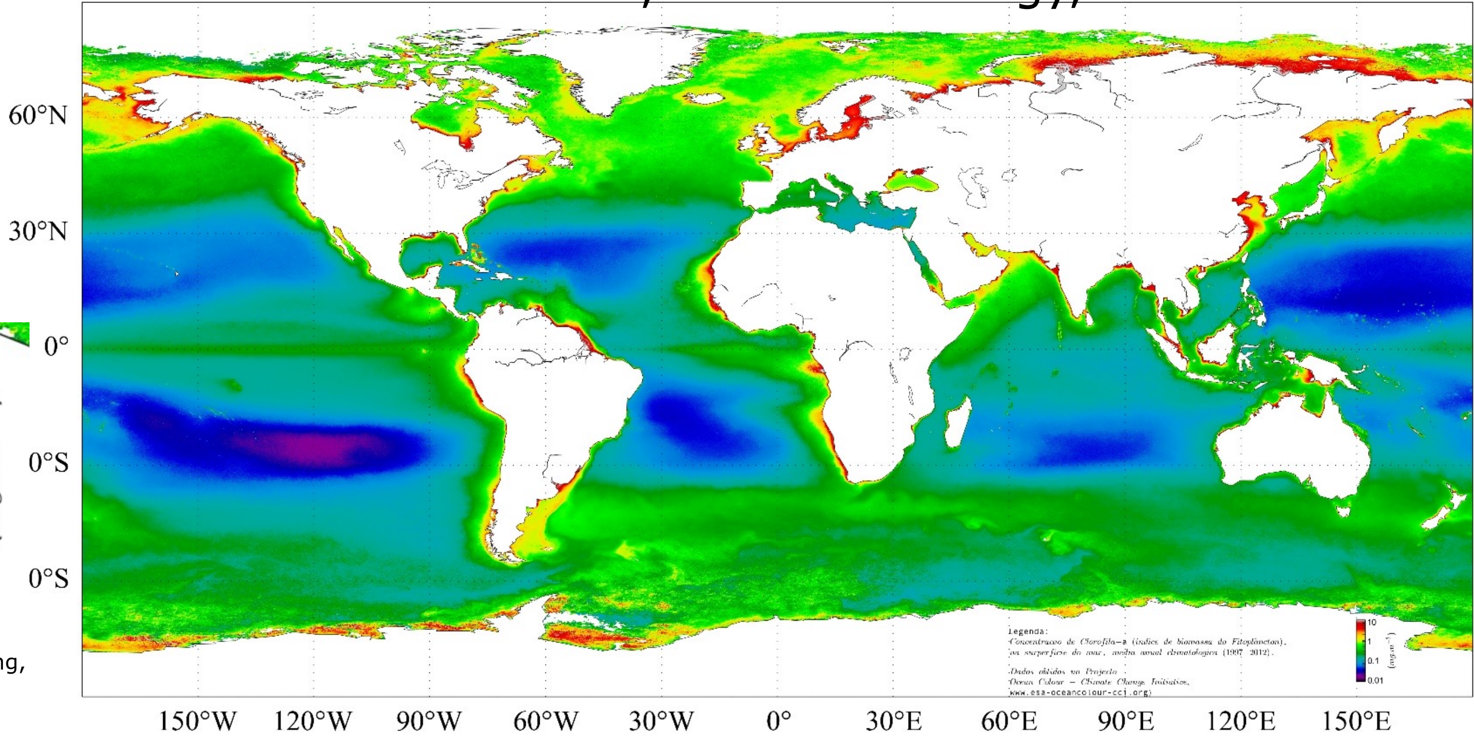
Most used product:

Chlorophyll a concentration



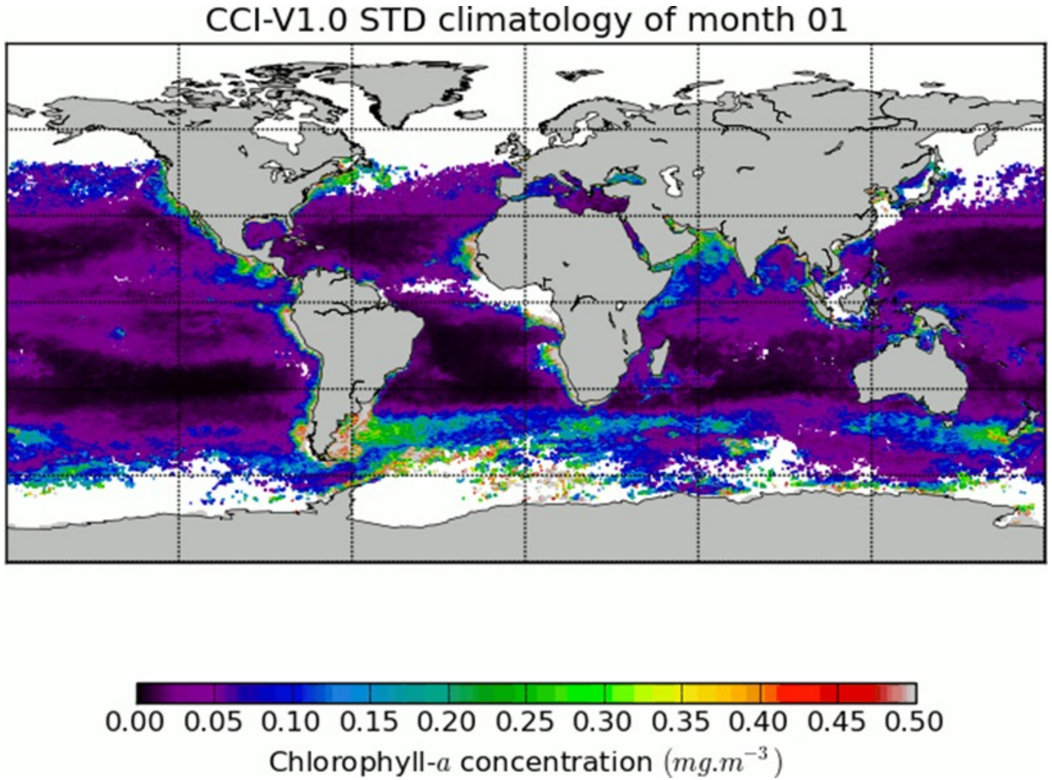
Couto et al, 2016. Int J Remote Sensing, 37:18, 4337-4355

Data from OC-CCI , Chla climatology, 1997-2012

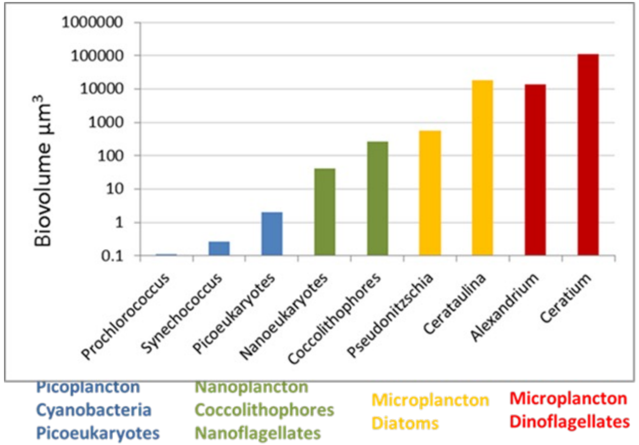


Incertitude? It is key to know the incertitude

Standard deviation (STD) of monthly variability (with climatological values). Regions with higher STD are regions where higher interannual (from 1997 to 2012) variability was registered. It is clear the high variability in higher latitudes, and reduced variability in the centre of the gyres.



Next (and ongoing) step: identifying phytoplankton functional types from space

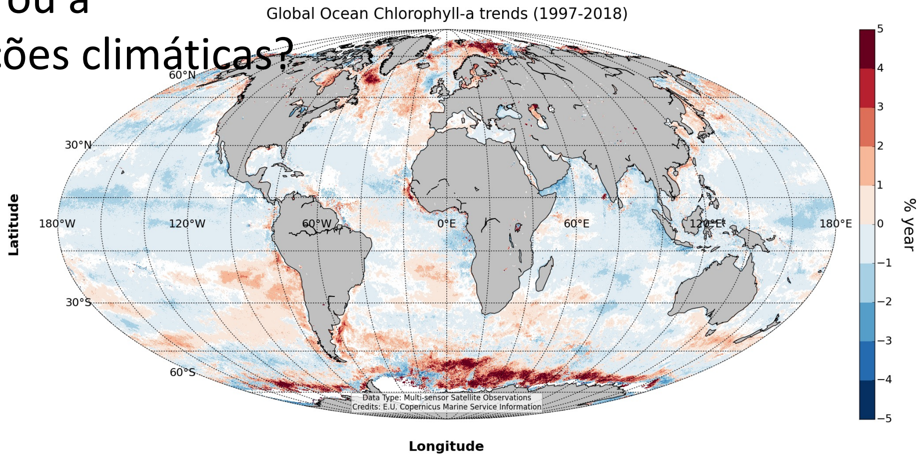


Phytoplankton Functional Types Le Quere' et al 2005
1) Pico-heterotrophs 2) Pico-autotrophs, Procho, Synecoc. 3) Phyto N2 fixers, Trichodesmium and unicellular procariotes 4) Calcifiers 5) DMS producers, Phaeocystis, < 20 um autotrophic flagellates, calcifiers 6) Silicifiers, diatoms 7) Mixed Phyto, Dinos & Chysophyceae

Relation between PSC – Phytoplankton size classes
And PFT – Phytoplankton functional types

Phytoplankton and climate change
Is Phytoplankton biomass increasing or decreasing?

O fitoplancton está a aumentar ou a Diminuir em resposta ás alterações climáticas?



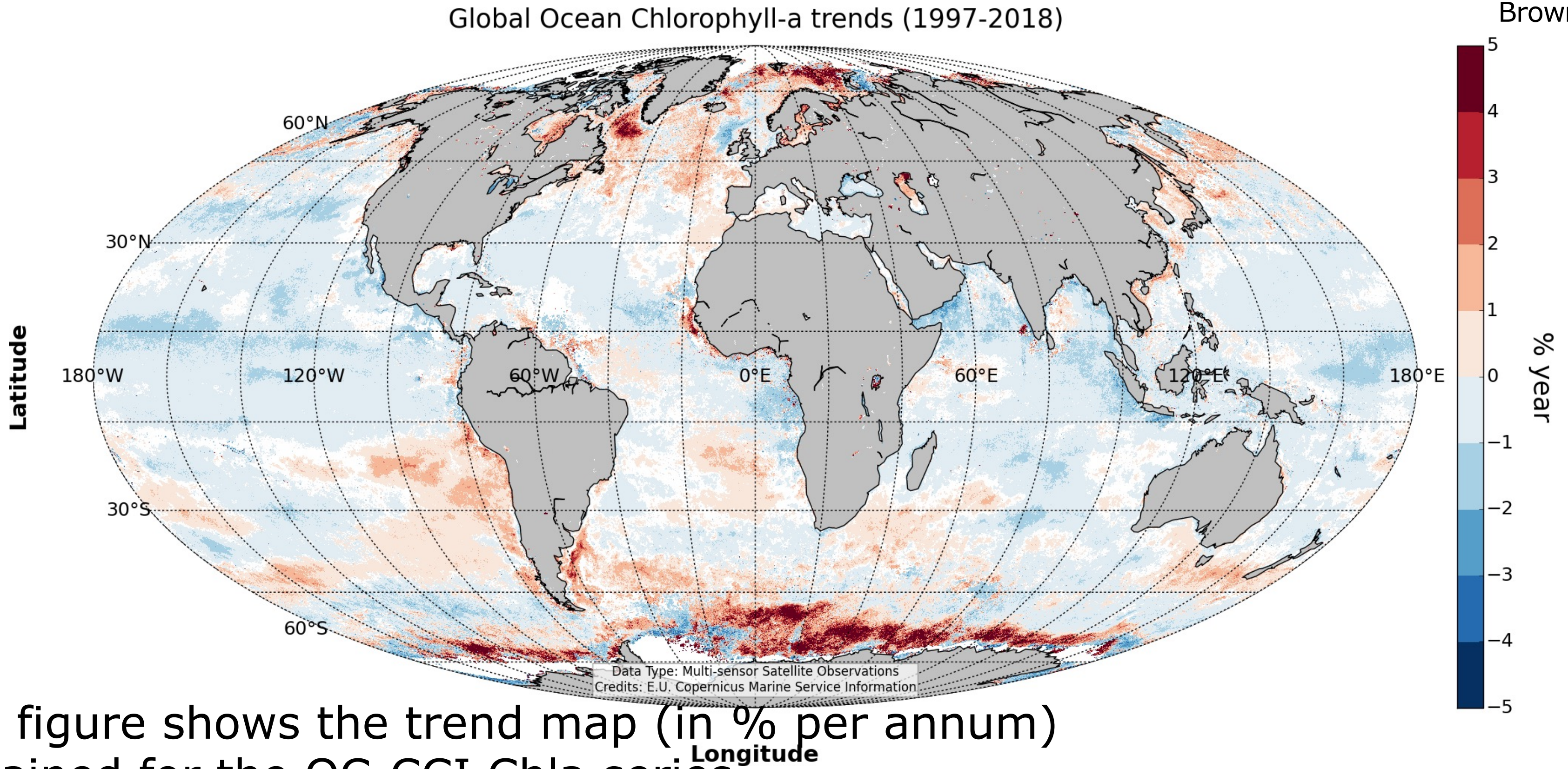
Relevante consultar para alunos mestrado em Ciencias do Mar

Sathyendranath et al(2018). Copernicus Marine Service Ocean State Report, sec. 1.5 Ocean Colour, Journal of Operational Oceanography, 11, S33-S36. DOI: [10.1080/1755876X.2018.1489208.](https://doi.org/10.1080/1755876X.2018.1489208)

OC-CCI Project

Global chlorophyll trend analysis shows an increasing trend in high latitudes and a decreasing trend in tropical areas

Blue: decrease
Brown: increas



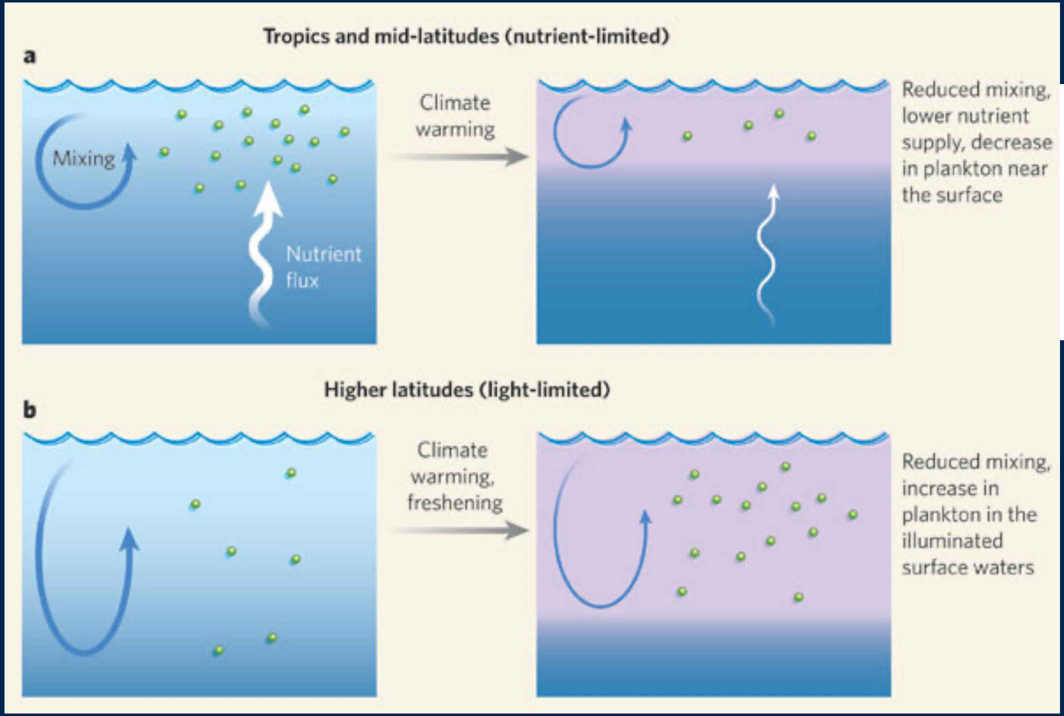
the figure shows the trend map (in % per annum) obtained for the OC-CCI Chla series

Only statistically significant ($p < .05$) trends are shown

Sathyendranath et al(2018). Copernicus Marine Service Ocean State Report, sec. 1.5 Ocean Colour, Journal of Operational Oceanography, 11, S33-S36. DOI: 10.1080/1755876X.2018.1489208.

Possíveis efeitos do aquecimento global na biosfera

- O aumento da temperatura superficial do oceano tem diferentes efeitos dependendo da região.



OCEANOGRAPHY

Plankton in a warmer world

Scott C. Doney

Satellite data show that phytoplankton biomass and growth generally decline as the oceans' surface waters warm up. Is this trend, seen over the past decade, a harbinger of the future for marine ecosystems?

(In Nature 7Dec 2006)

Bloom Phenology: can be detected with remote sensing of ocean colour

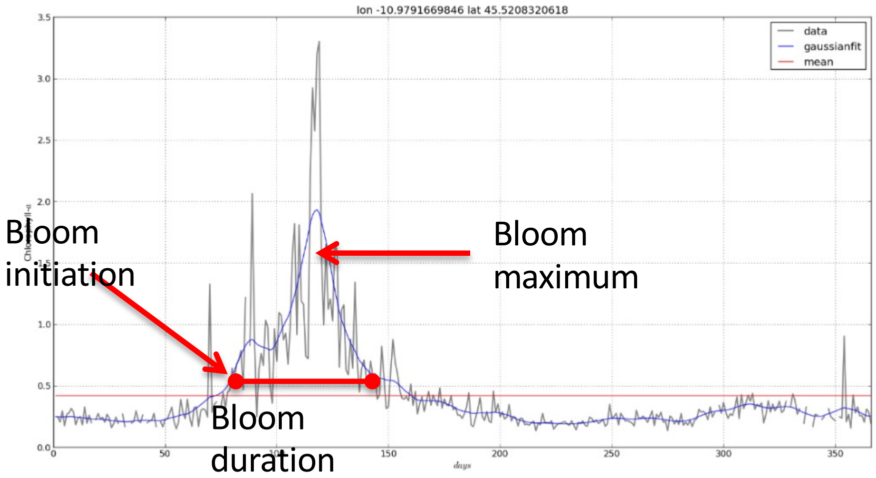
- Links with trophic chain, fisheries

Phenology of phytoplankton blooms: Finding Patterns and Anomalies

Table 8.1 Ecological indicators of the pelagic ocean that can be derived fro radiometry (Platt and Sathyendranath, 2008).

Indicator	Label	Dimensions
Initiation of spring bloom	b_i	[T]
Amplitude of spring bloom	b_a	$[ML^{-3}]$
Timing of spring maximum	b_t	[T]
Duration of spring bloom	b_d	[T]
Total production in spring bloom	b_p	$[ML^{-2}]$
Annual phytoplankton production	P_Y	$[ML^{-2}]$
Generalised phytoplankton loss rate	L	$[ML^{-3}T^{-1}]$
Integrated phytoplankton loss	L_T	$[ML^{-3}]$
Annual-scale f-ratio	f	Dimensionless
Spatial variance in biomass field	σ_B^2	$[M^2L^{-6}]$
Spatial variance in production field	σ_P^2	$[M^2L^{-4}]$
Phytoplankton functional types	NA	NA
Delineation of biogeochemical provinces	NA	NA
Phytoplankton size structure	s	Dimensionless

IOCCG 7

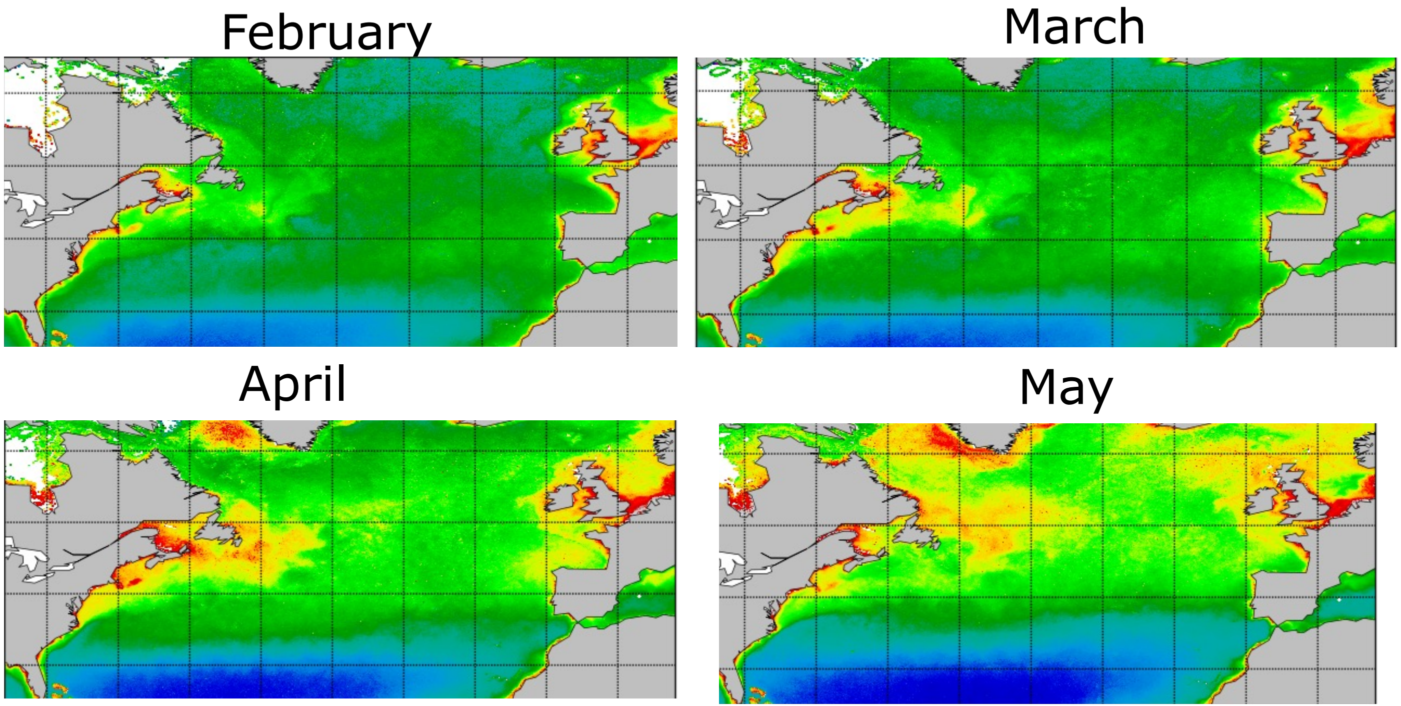


Example for latitude 45N , off the Iberia coast

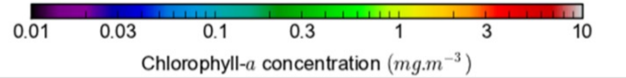
10 years average (2002 – 2012) calculated for each day. MERIS (300 m resolution)

How is marine biodiversity changing?

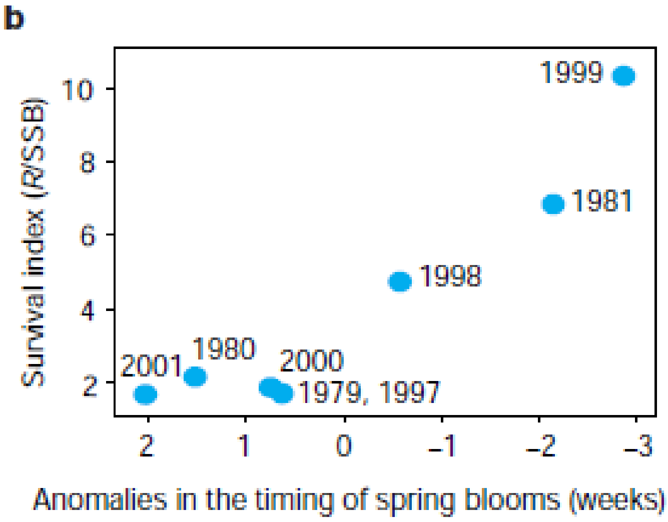
Changing in time
Phenology

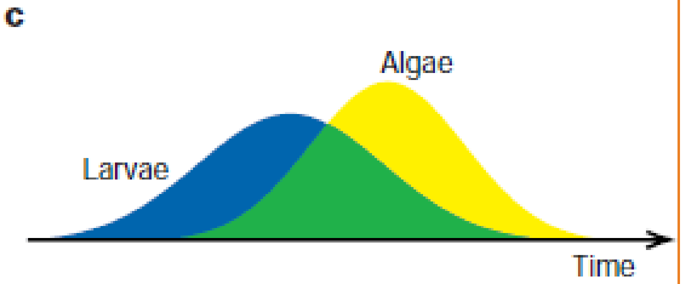


A sequence of 4 images of Chla showing the evolution of the Spring bloom in North Atlantic, February – May, climatological averages 1997-2012



Alterações na fenologia podem ter impacto na cadeia trófica





b) Relação entre taxa de sobrevivência das larvas de peixes e anomalias do bloom de Fitoplancton

c) Azul, nº de larvas, amarelo
Biomassa do Fitoplancton
Quando há interseção, verde
As larvas têm mais comida
E maior capacidade de
Sobreviver.
Estas larvas sofrem menor
Predação, dado que crescem
Depressa e ficam menos visíveis
Se há grande concentração de
Células de Fitoplancton

Platt et al, Nature 2003, **Spring algal bloom and larval fish survival** 423:398-399

Estudo de upwelling e efeito na biomassa do Fitoplancton

- Slide seguinte

IPMA UAlg CIMA UNIVERSIDADE DO ALGARVE CENTRO DE INVESTIGAÇÃO MARINHA E AMBIENTAL FCT Fundação para a Ciência e a Tecnologia

- Tema tese aluno Pedro Nunes,
- Ciências do mar 2020/2021

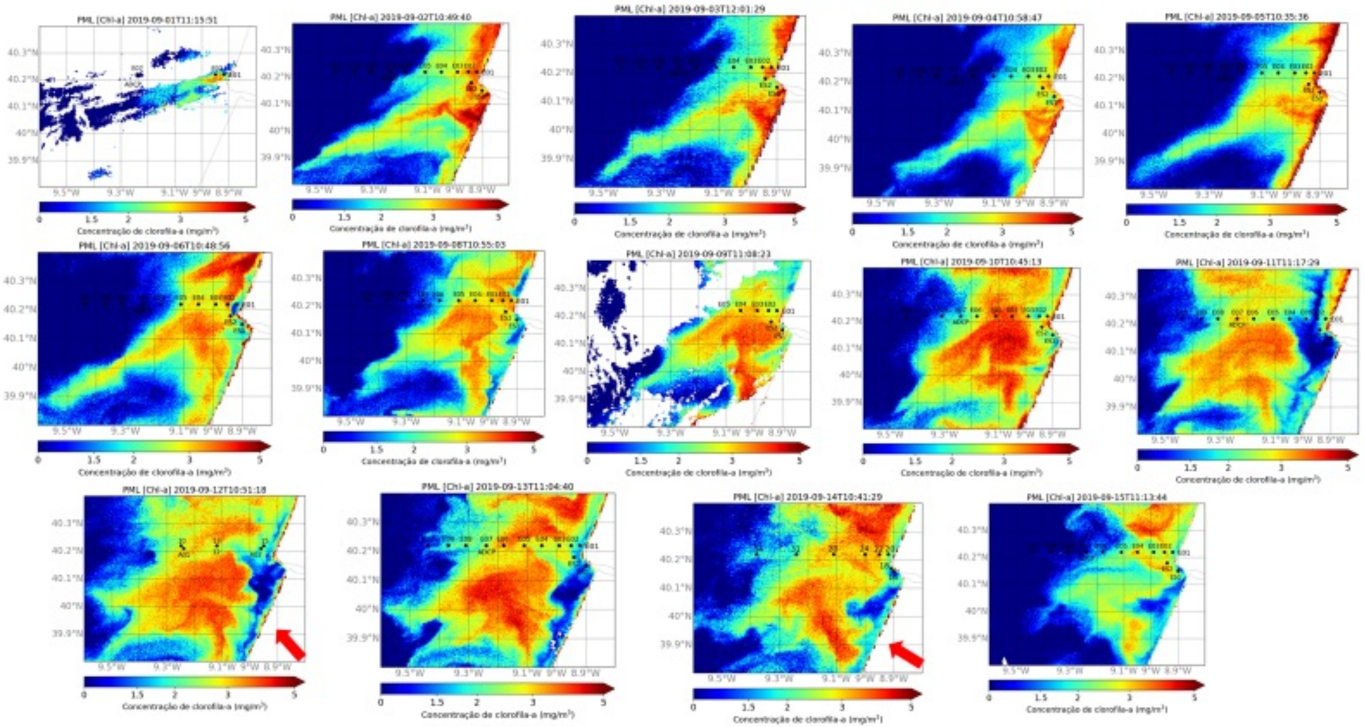
Estudo da resposta da biomassa fitoplanctónica durante um episódio de afloramento utilizando a deteção remota e dados in situ no âmbito do Projeto HabWave

Ocean Colour Summer School
financiado pela FCT

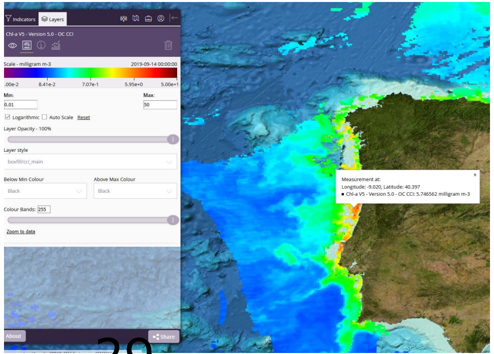
Pedro Nunes

Orientadores: Dr. Paulo Oliveira e Prof.ª Dra.

Plymouth Marine Laboratory (PML) - https://piscismod.eofrom.space



Portal cci



Bibliography

- References along the slides &
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- IOCCG (2009). Remote Sensing in Fisheries and Aquaculture. Forget, M.-H., Stuart, V. and Platt, T. (eds.), Reports of the International Ocean-Colour Coordinating Group, No. 8, IOCCG, Dartmouth, Canada. Chapter 5: Remote Sensing Applications to Fish Harvesting. Free download in IOCCG site
- Sutcliffe A., Brito A.C., Sá C., Sousa F., Boutov D., Brotas V. (2016). Observação da Terra: uso de imagens de temperatura da superfície do mar e cor do oceano para a monitorização de águas costeiras e oceânicas. DGRM, Lisboa. E-book
- IOCCG report nº 15, 2015. Phytoplankton Functional Types from Space. Disponível em: http://www.ioccg.org/reports/IOCCG_Report_15_2014.pdf