

# PPM, aula Teórica

29 Outubro 2020

Vanda Brotas

# Outline da aula

- Continuação da aula anterior. Definição de produção primária. Métodos in situ mais utilizados
- Curva Produção Primária – Irradiancia. Perceber os parâmetros da curva. Quizz.
- Modelos Produção Primária, PP. Modelos usados com deteção remota
- Relação com o Ciclo de carbono
- Projeto Global Carbon Project
- Produtividade Global
- Cor do Oceano como uma variável do clima

## **Objetivos /competencias a adquirir para os alunos (aulas de 22 e 29 Outubro)**

Reconhecer a importancia dos Produtores primários no ciclo de carbono.

Discutir o aumento de CO<sub>2</sub> atmosférico e alterações climáticas

Rever conhecimentos sobre Fotossintese (para os biólogos), apresentação das bases sobre Fotossintese

Curvas Produção – Irradiancia, perceber a sua importancia, relacionar com o que se passa na coluna de água

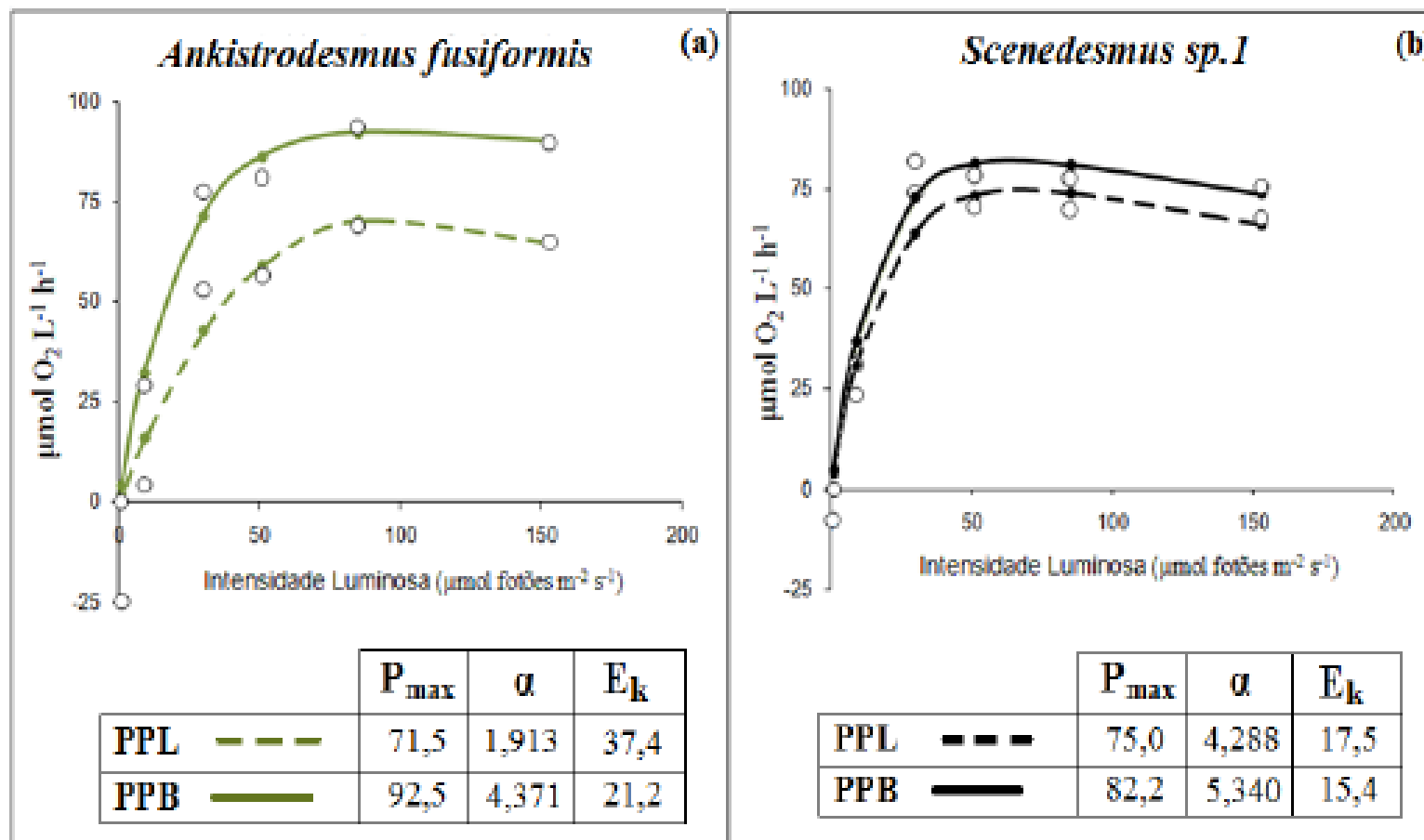
Modelos Produção Primária (PP), do mais simples ao modelo que estima a PP por satélite

Para quem quer saber mais

# Modelos Irradiancia - PP

Relacionando com  
A pergunta do  
Quizz 2

PPL – PP líquida  
PPB – PP Bruta



**Figura 22-** Curvas P-E obtidas para a cultura de *Ankistrodesmus fusiformis* (a) e de *Scenedesmus sp.1* (b) através da medição do oxigênio dissolvido em amostras submetidas a incubação a diferentes intensidades luminosas. Ambos os gráficos possuem os valores obtidos para os parâmetros fotossintéticos. Duas curvas são apresentadas: uma referente à produtividade primária líquida determinada (PPL, linha a tracejado) e a outra à produtividade primária bruta (PPB, linha contínua).

$$P^B = P_{\max}^B \left[ 1 - \exp\left(\frac{-\alpha^B I}{P_{\max}^B}\right) \right]$$

## Modelos Irradiancia - PP

Jassby & Platt 1976

PB – produção Normalizada em Relação à Clorofila a

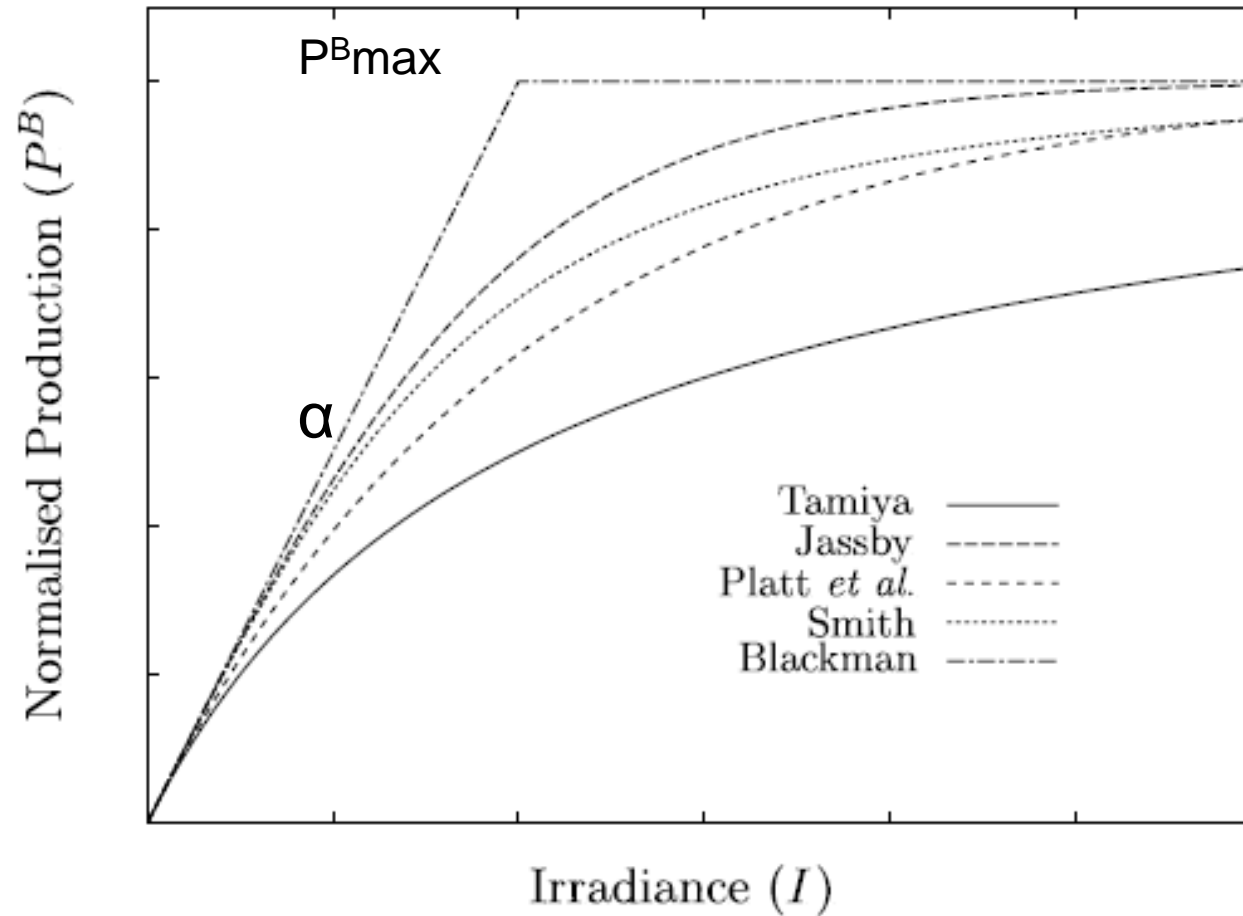


Figure 2. Some common mathematical functions used to represent the photosynthesis – light curve, and the references to their first usage in the literature of algal physiology. In this figure, all the curves are normalised such that they all approach the same value of  $P^B$  asymptotically, as  $I$  increases. In other words, they all have the same value of  $P_m^B$

# Relação entre Chla e PP

- Como modelá-la?

**Modelo de Eppley 1985 – “O modelo mais simples”**

Model 1: This model estimates PP as:

$$PP \left[ g \text{ C m}^{-2} \text{ d}^{-1} \right] = \left( chl_0 \left[ \text{mg chl m}^{-3} \right] \right)^{1/2}$$

Fim da aula de dia 22 Out 2020  
Realização do Quizz 2



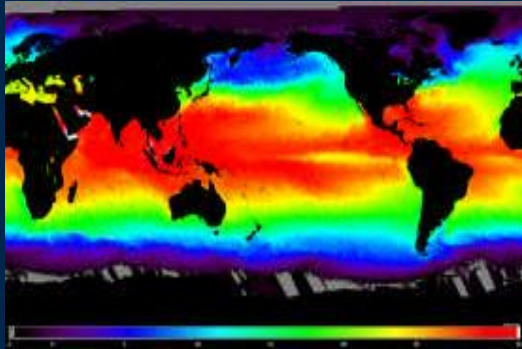
# Ligação com as TPs

# Modelos de Produção Primária que usam dados de detecção remota

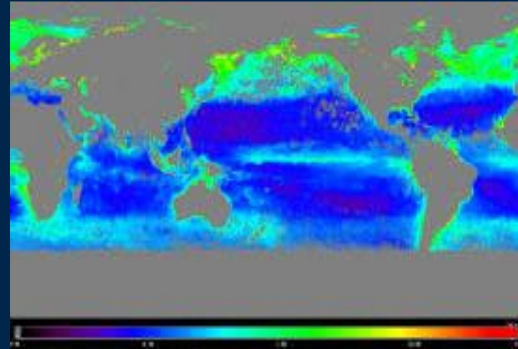
- Behrenfeld and Falkowski (1997) : Vertically Generalized Production Model (VGPM)
- De acordo com este modelo a produção primária da zona eufótica ( $\text{mgC}/\text{m}^2$ ) diária é dada pela expressão:

$$PP = 0.66125D_{\text{irr}} P^{\text{B}_{\text{opt}}}[E_0/(E_0+4.1)]C_{\text{sat}} Z_{\text{eu}}$$

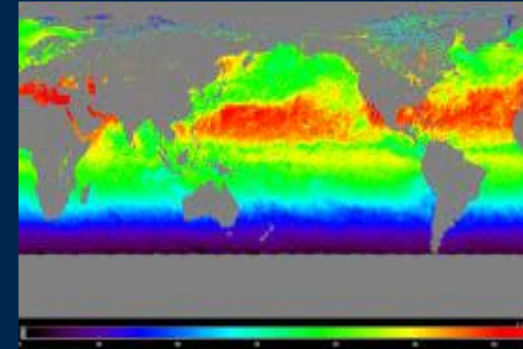
# Vertically Generalized Production Model Behrenfeld & Falkowski (1997)



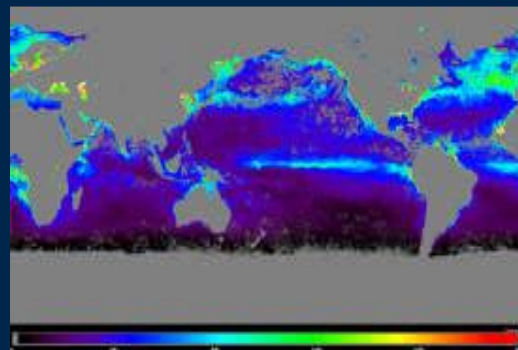
Temperatura



Clorofila



PAR



Produção Primária

$$PP = 0.66125D_{irr}P^B_{opt}[E_0/(E_0+4.1)]C_{sat}Z_{eu}$$

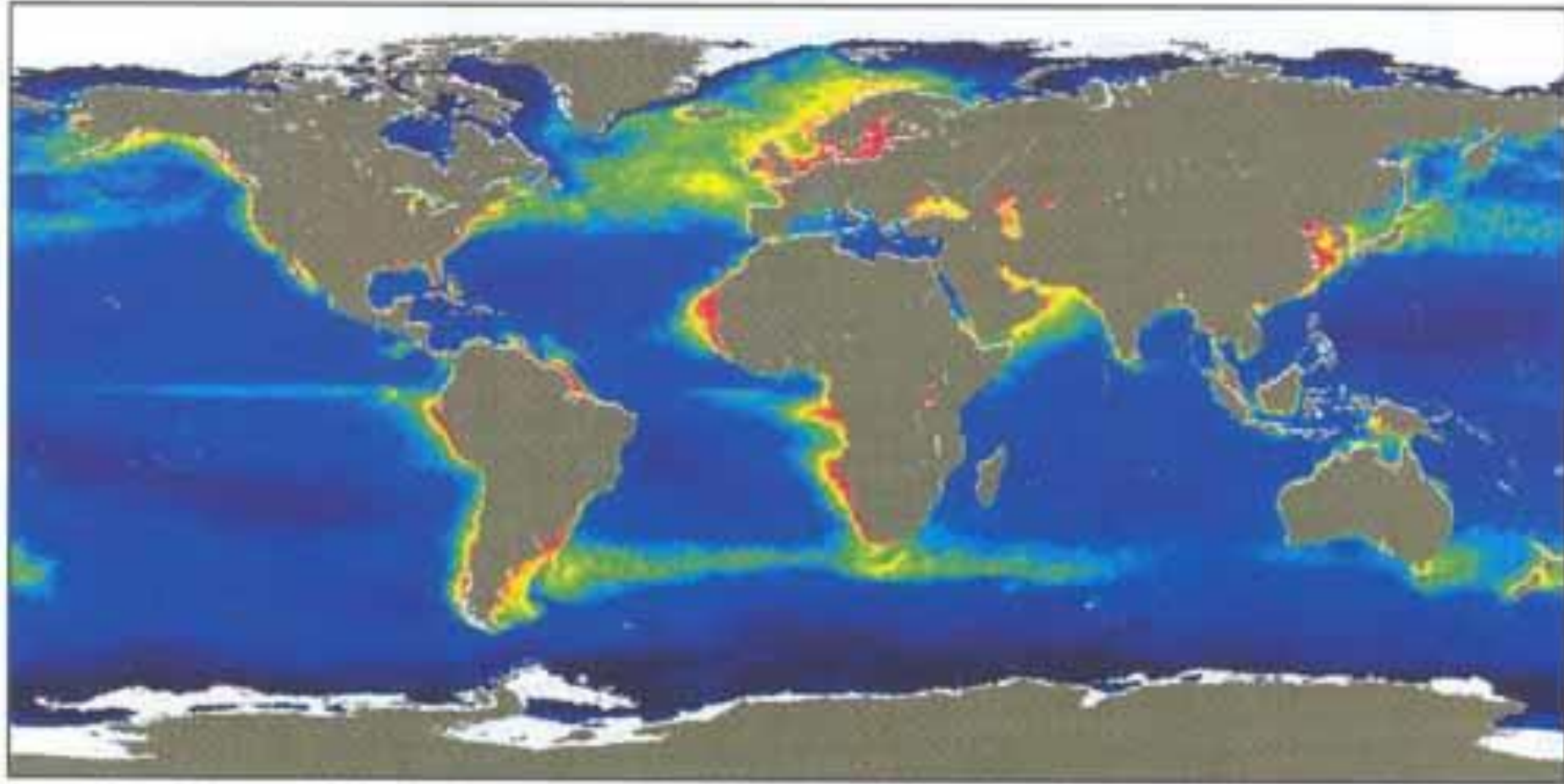
$D_{irr}$  duração do dia em horas, função da latitude e do dia juliano

$P^B_{opt}$  a taxa máxima de fixação de carbono na coluna de água em  $\text{mg C (mg Chl)}^{-1} \text{ h}^{-1}$ ,

$E_0$  a radiação fotossinteticamente activa disponível (PAR) em  $\text{mol quanta m}^{-2} \text{ d}^{-1}$ ,

$C_{sat}$  concentração de clorofila superficial em  $\text{mg Chl m}^{-3}$ ,

$Z_{eu}$  profundidade da zona eufótica, ou 1% nível e luz, em metros, que é função de  $C_{sat}$  (Morel and Berthon, 1989).



(b)



Primary Productivity ( $10^2 \text{ g C m}^{-2} \text{ y}^{-1}$ )

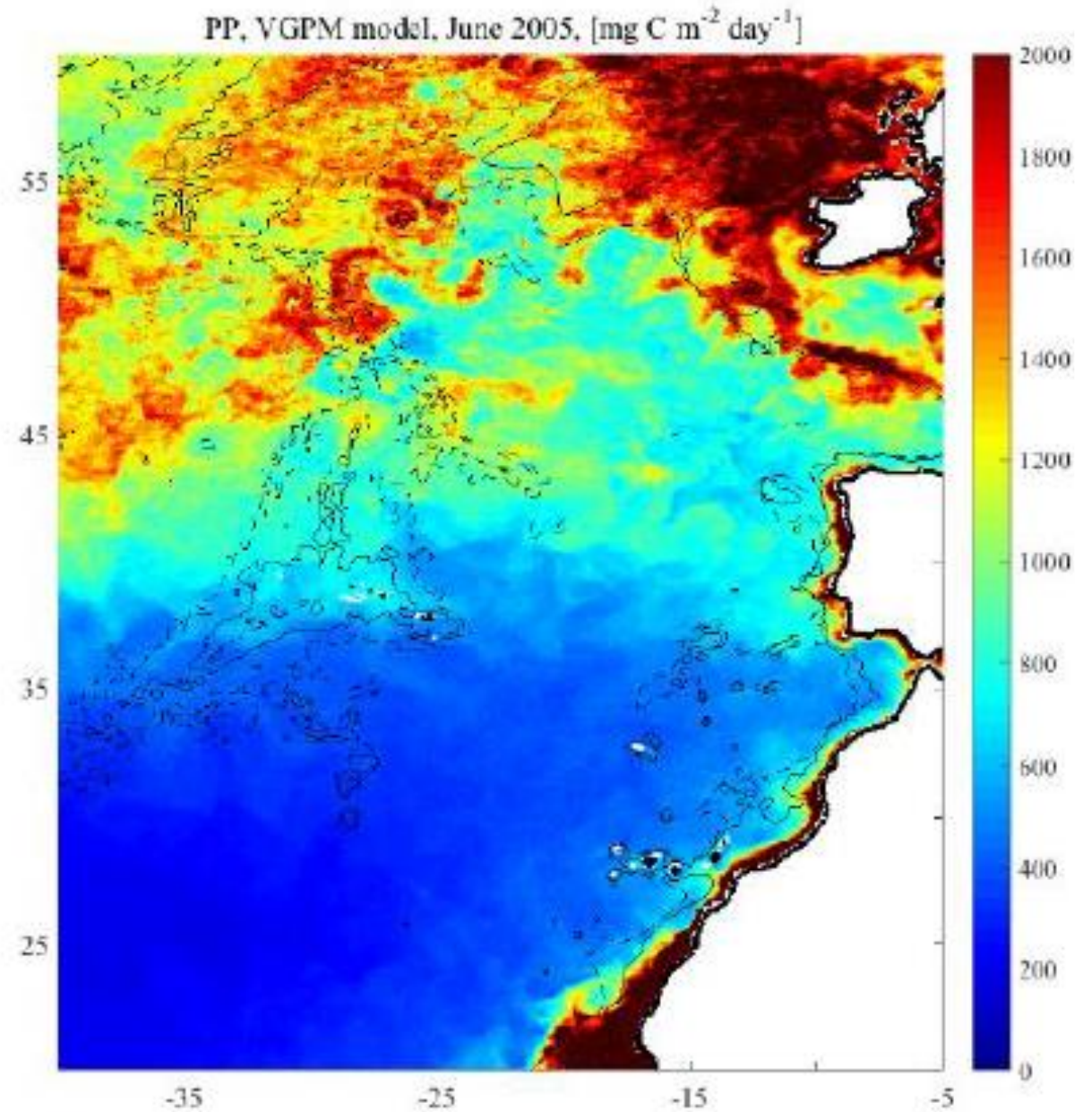
Para quem quer aprofundar este tema  
Valores para o Atlântico Norte



Article

## Accuracy Assessment of Primary Production Models with and without Photoinhibition Using Ocean-Colour Climate Change Initiative Data in the North East Atlantic Ocean

Polina Lobanova <sup>1</sup>, Gavin H. Tilstone <sup>2\*</sup>, Igor Bashmachnikov <sup>1,3</sup> and Vanda Brotas <sup>4</sup>



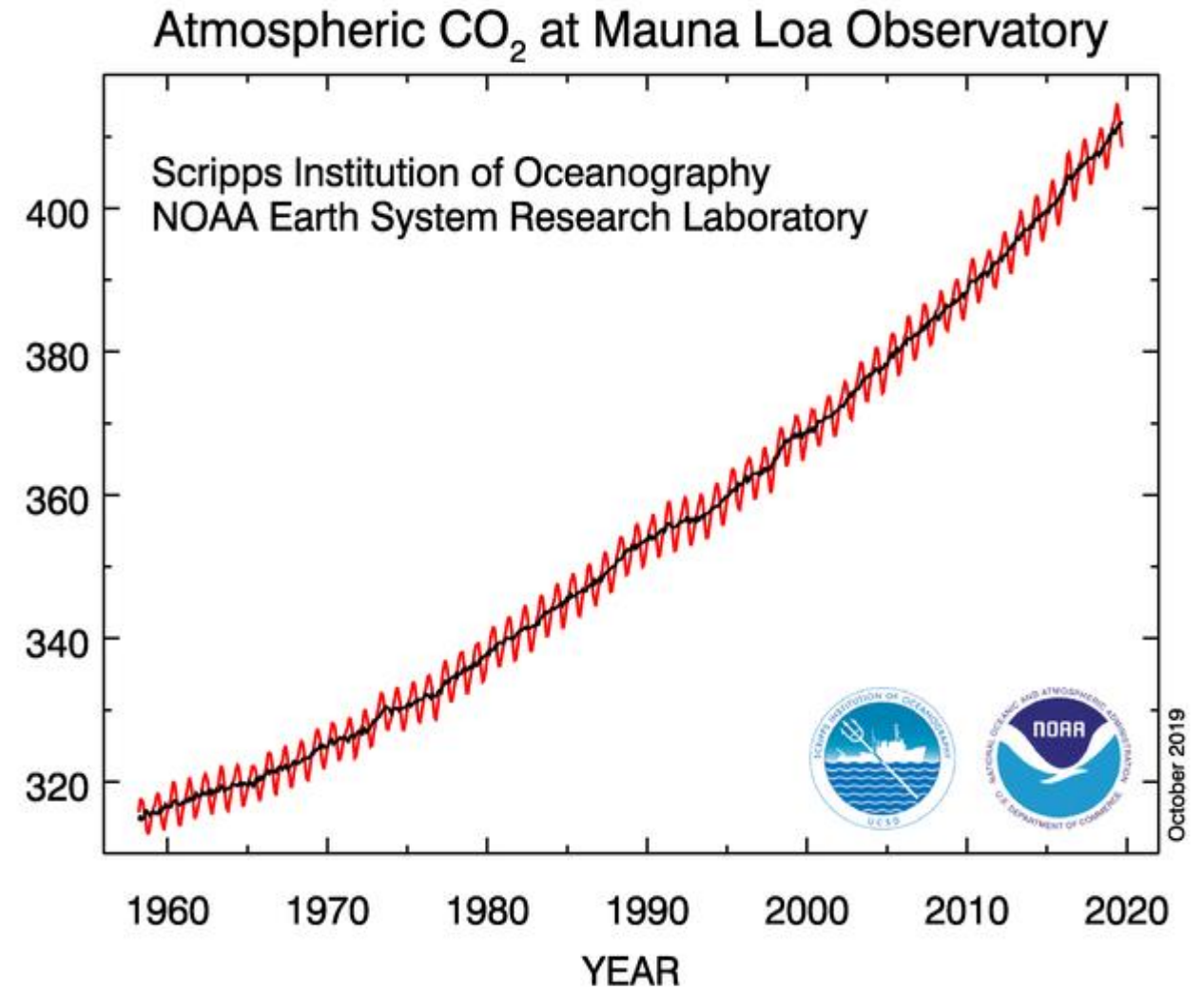
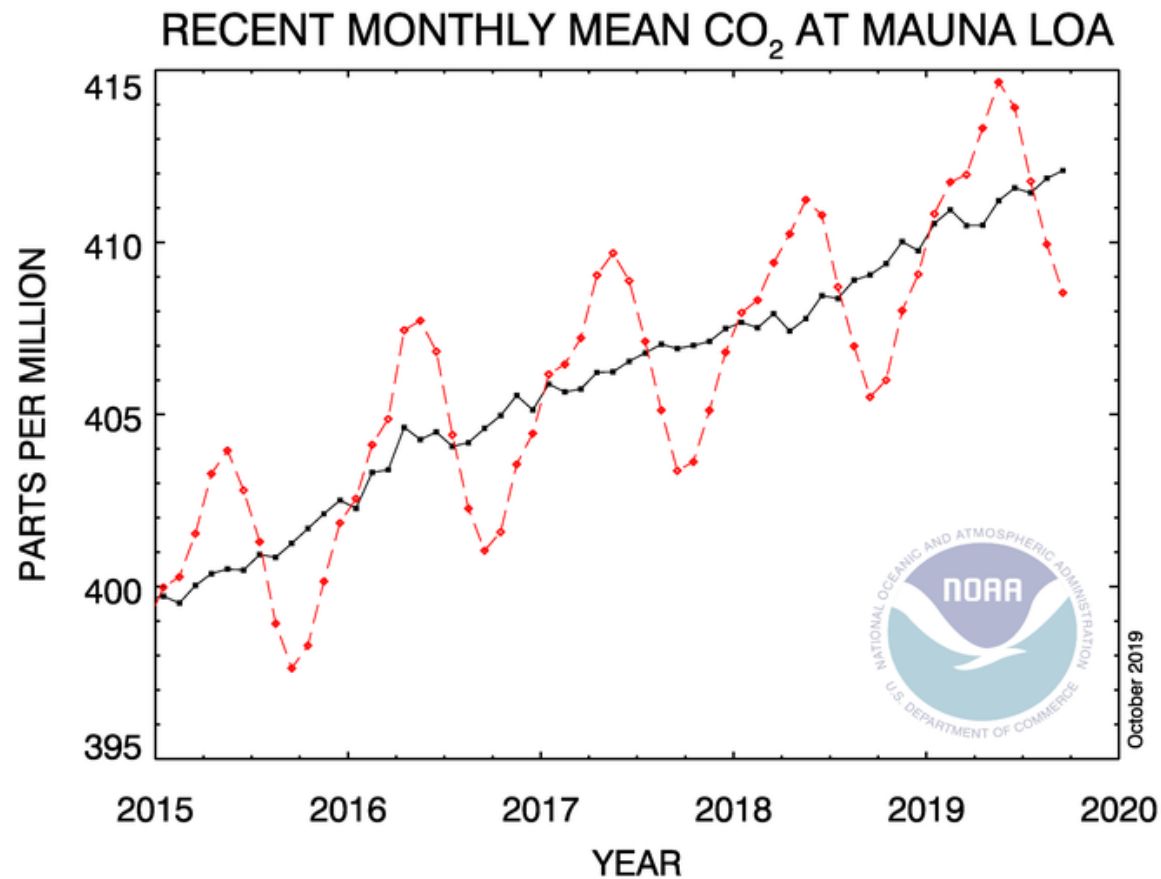
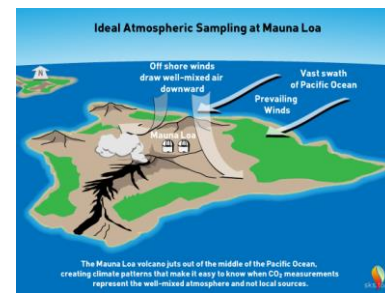
Valor de PP, em  $\text{mg C m}^{-2} \text{d}^{-1}$  obtido para Junho 2005

# Slides seguintes

- Relação com o Ciclo de carbono
- Projeto Global Carbon Project
- Produtividade Global
- Cor do Oceano como uma variável do clima

# CO<sub>2</sub> Atmospheric Concentration

- The global CO<sub>2</sub> concentration increased from ~277ppm in 1750 to 408.54 ppm in September 2019

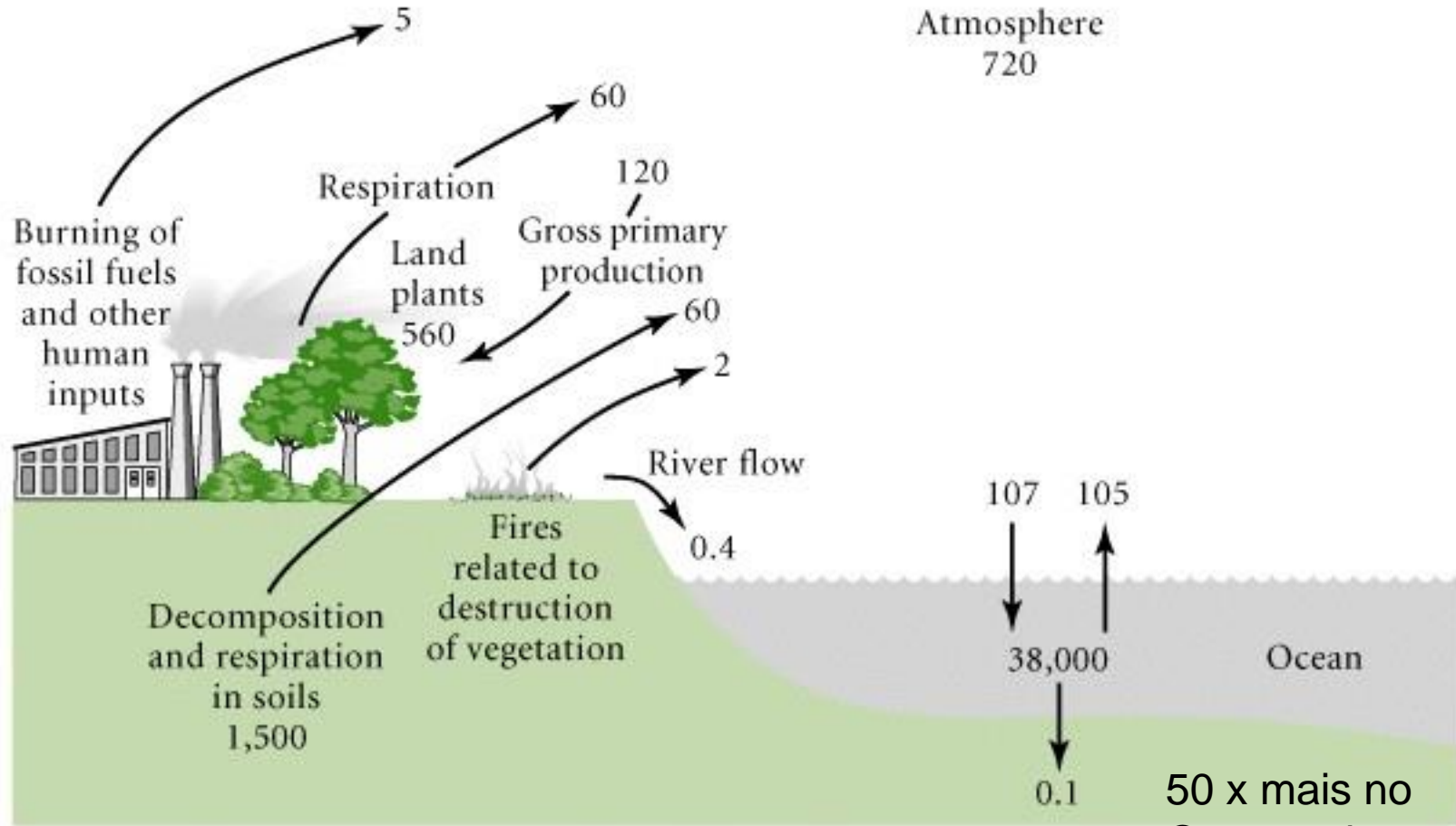


<https://www.esrl.noaa.gov/gmd/ccgg/trends/>

The dashed red lines with diamond symbols represent the monthly mean values.  
The **black lines** with the square symbols represent the same, after correction for the average seasonal cycle



ciclo de carbono



50 x mais no Oceano do que na Atmosfera

$$38\ 000 / 720 = 52$$

## Section 22.7 The Global Carbon Cycle Involves Exchanges among the Atmosphere, Oceans, and Land

- Carbon pool involved in the global carbon cycle amounts to 55,000 gigatons (Gt)
  - fossil fuels: 10,000 Gt
  - oceans: 38,000 Gt (bicarbonate and carbonate ions)
    - dead organic matter: 1650 Gt
    - living matter (mostly phytoplankton): 3 Gt
  - terrestrial
    - dead organic matter (in soil): 1500 Gt
    - living matter: 560 Gt
  - atmosphere: 750 Gt

Fluxos Carbono	GT carbono/ ano	
Troca Atmosfera Oceano	2	
Sequestro no fundo do mar	0,1	
Queima de combustíveis fósseis	10	
Produção 1ª Líquida Terrestre	56,4	Carbono (GT)
Produção 1ª Líquida Marinha	48,5	

1 Giga= 10<sup>9</sup> ton

<b>Pool de carbono</b>	<b>55000</b>
Combustíveis fósseis	10000
No oceano, em iões $\text{HCO}_3^-$ e $\text{HCO}_3^{2-}$	38000
No oceano, matéria morta	1650
No oceano, matéria viva	3
Na Terra, matéria morta	1500
Na Terra, matéria viva	560
Atmosfera	750

Explore CO<sub>2</sub> emissions at the global and country levels, compare among countries, visualize, and download data and illustrations (“Emissions” application). Also explore “Outreach” and “Research”.

## GLOBAL CARBON ATLAS

The Global Carbon Atlas is a platform to explore and visualize the most up-to-date data on carbon fluxes resulting from human activities and natural processes.

Human impacts on the carbon cycle are the most important cause of climate change.

### OUTREACH

*Take a journey through the history and future of human development and carbon*

GO





### EMISSIONS

*Explore and download global and country level carbon emissions from human activity.*

GO

### RESEARCH

*Explore and visualize research carbon data, and get access through data providers*

GO



**All the data is shown in billion tonnes CO<sub>2</sub> (GtCO<sub>2</sub>)**

1 Gigatonne (Gt) = 1 billion tonnes =  $1 \times 10^{15}$ g = 1 Petagram (Pg)

1 kg carbon (C) = 3.664 kg carbon dioxide (CO<sub>2</sub>)

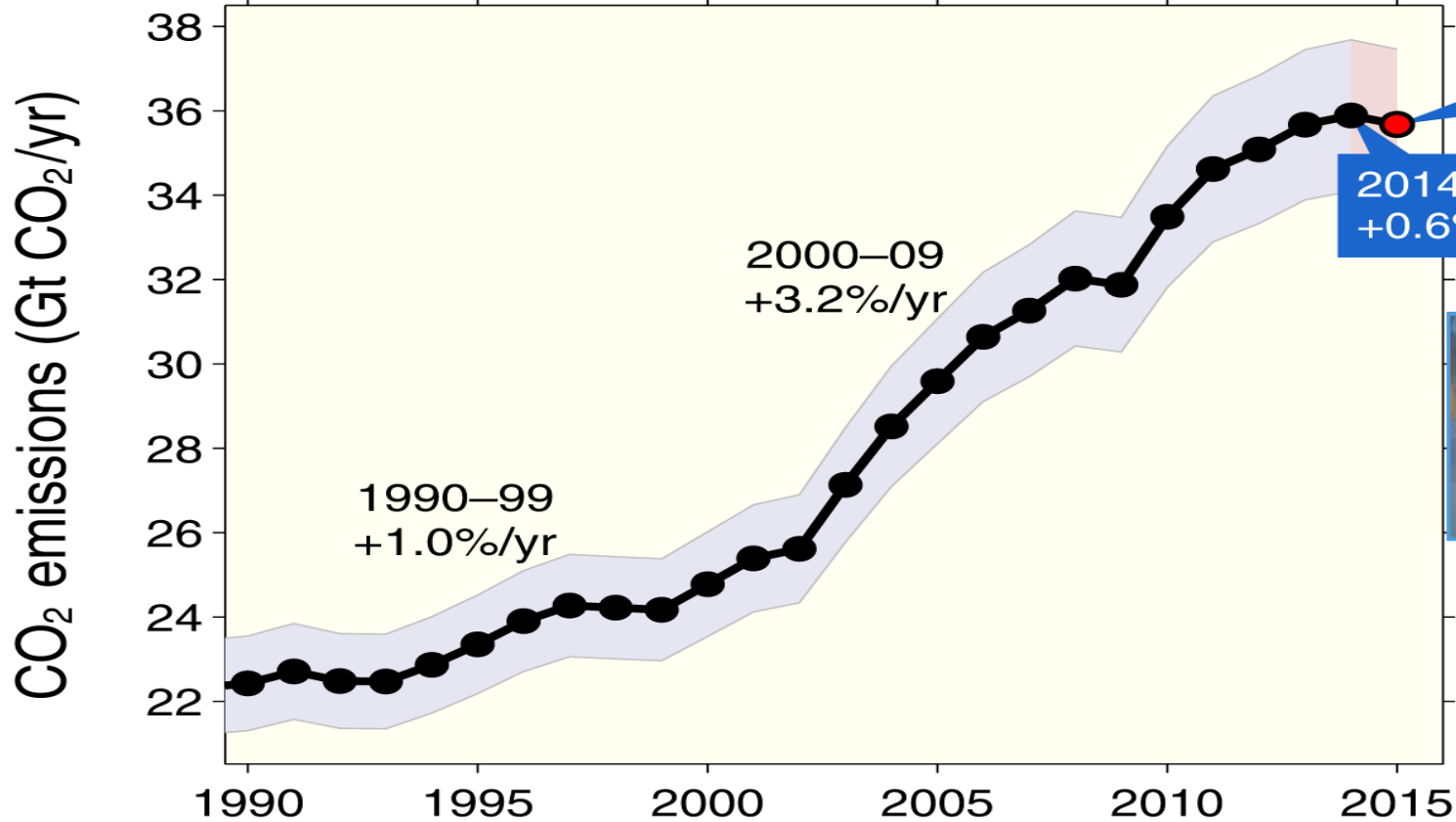
1 GtC = 3.664 billion tonnes CO<sub>2</sub> = 3.664 GtCO<sub>2</sub>

# Emissions from fossil fuel use and industry

Global emissions from fossil fuel and industry:  $35.9 \pm 1.8$  GtCO<sub>2</sub> in 2014, 60% over 1990

● Projection for 2015:  $35.7 \pm 1.8$  GtCO<sub>2</sub>, 59% over 1990

Data: CDIAC/GCP/BP/USGS



= 10 GT Carbon

37 GT CO<sub>2</sub> / 3.664  
= 10 GT Carbon

Projection 2015  
35.7 Gt CO<sub>2</sub>  
-0.6% decline  
(-1.6% to +0.5%)

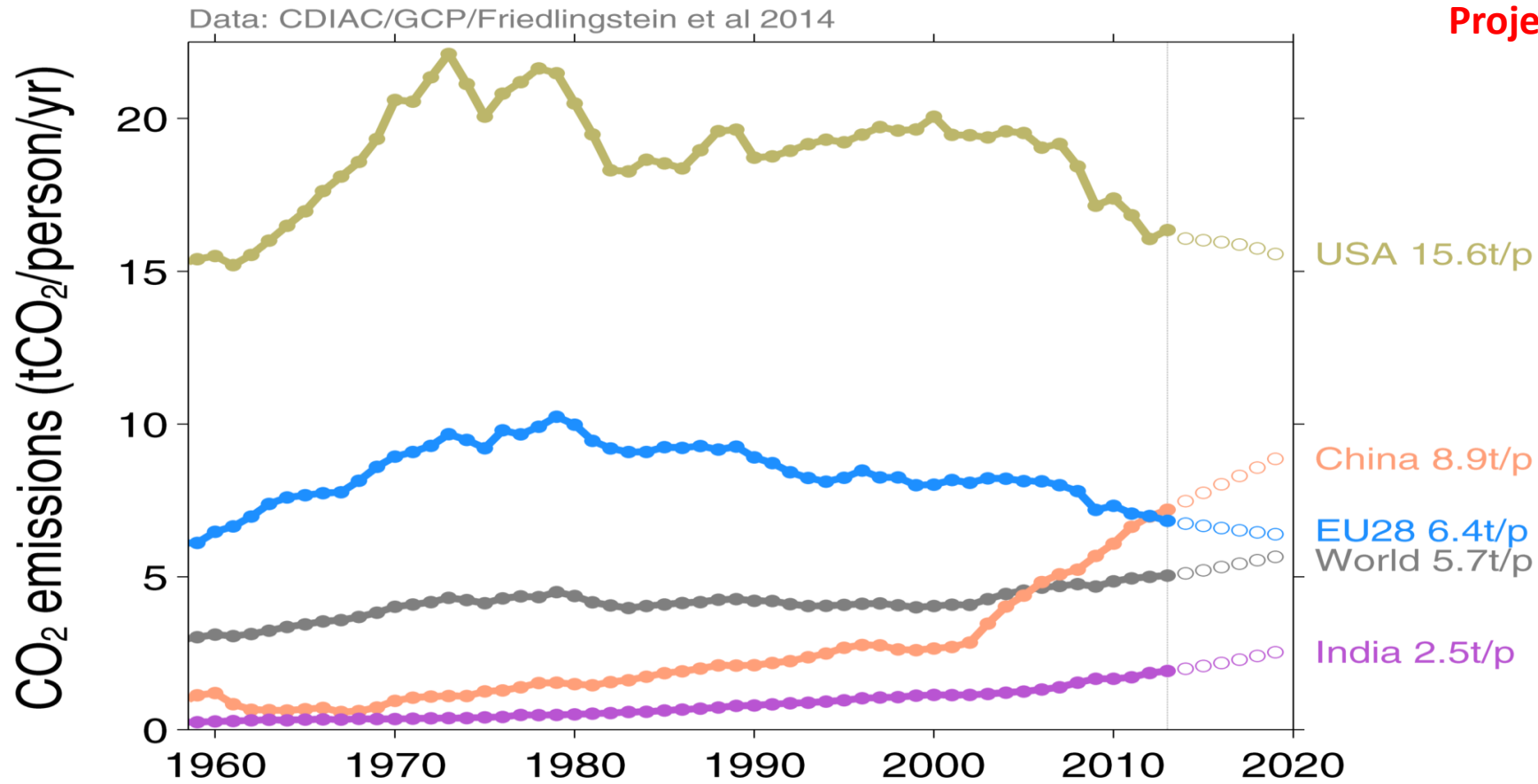
2014: 35.9 Gt CO<sub>2</sub>  
+0.6% increase



Uncertainty is  $\pm 5\%$  for one standard deviation (IPCC "likely" range)

# Top Fossil Fuel Emitters (Per Capita)

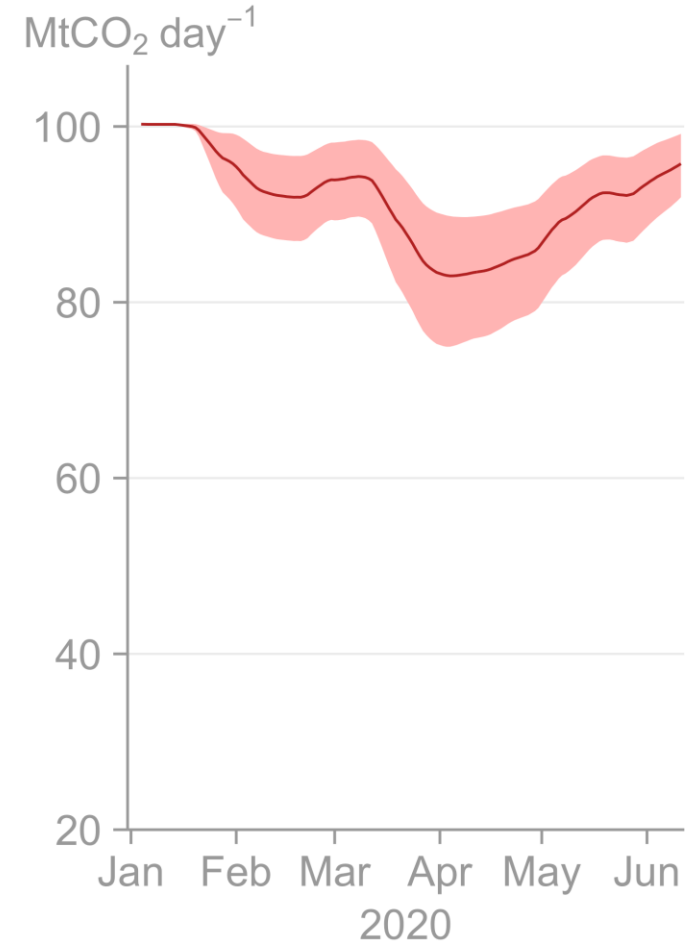
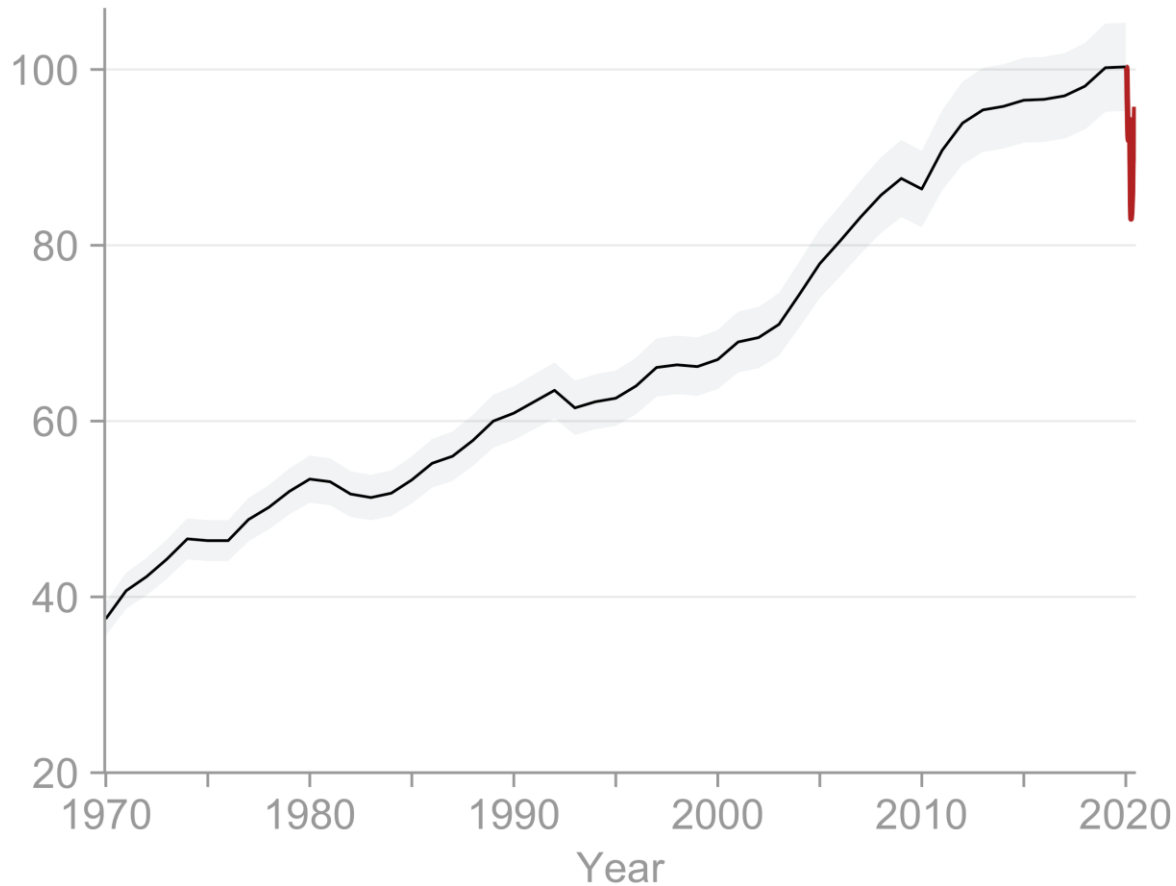
The divergence between EU28 and Chinese per capita emissions is likely to continue  
 USA continues with high and India with low per capita emissions



Economic growth based on IMF projections, fossil fuel intensity based on 10-year trend

Source: [CDIAC](#); [Friedlingstein et al 2014](#)

Global daily fossil CO<sub>2</sub> emissions  
MtCO<sub>2</sub> day<sup>-1</sup>

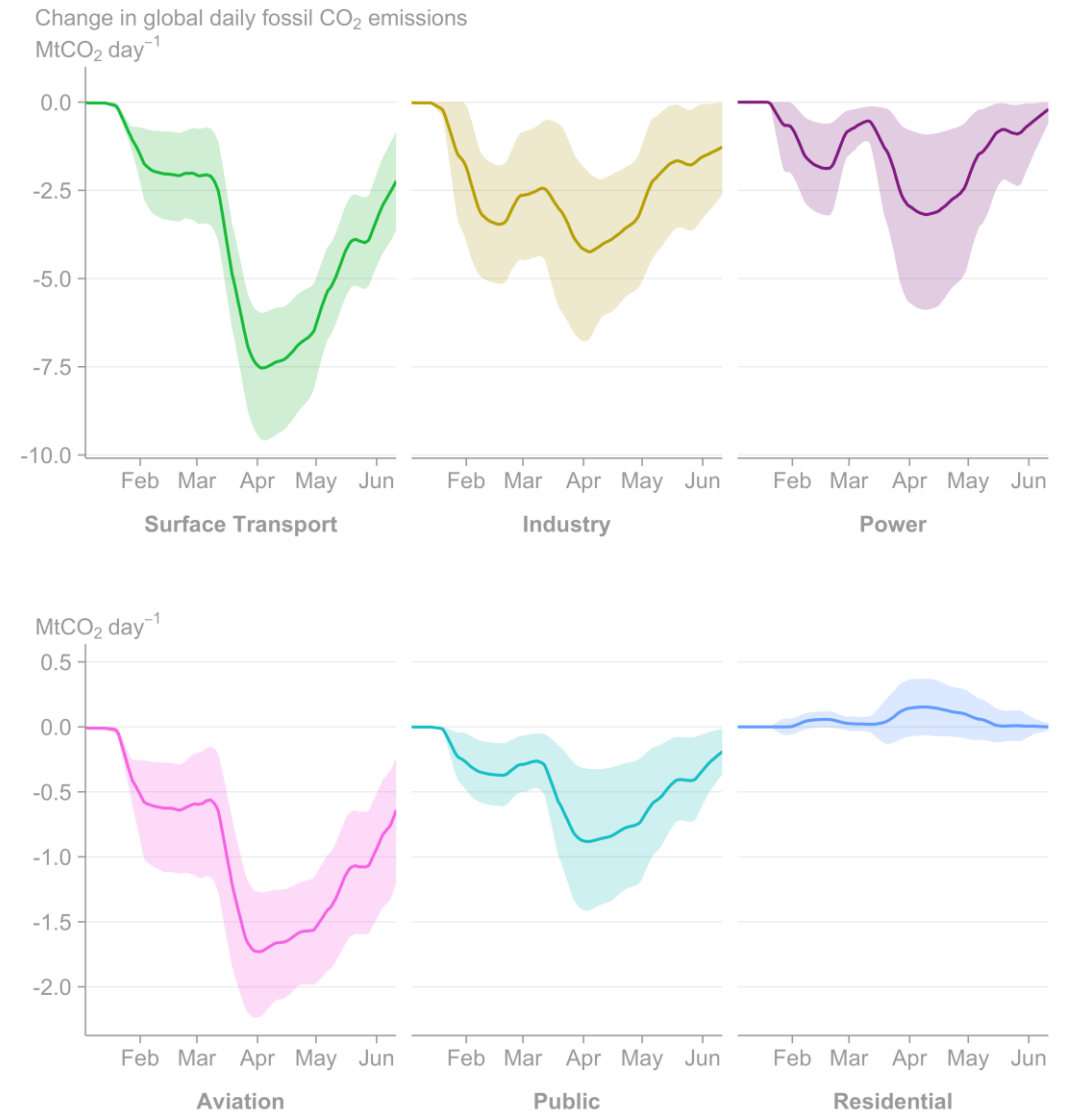


Source: Le Quéré et al. Nature Climate Change (2020); Global Carbon Project

Daily global CO<sub>2</sub> emissions decreased by  $-17\%$  ( $-11$  to  $-25\%$  for  $\pm 1\sigma$ ) by early April 2020 compared with the mean 2019 levels



## Redução por sector de atividade



Source: Le Quéré et al. Nature Climate Change (2020); Global Carbon Project

Change in global daily fossil CO<sub>2</sub> emissions by sector (MtCO<sub>2</sub> d<sup>-1</sup>).

The uncertainty ranges represent the full range of our estimates. Changes are relative to annual mean daily emissions from those sectors in 2019. (see paper for further details)

# Fate of anthropogenic CO<sub>2</sub> emissions (2006-2015)



34.1 GtCO<sub>2</sub>/yr  
91%



9%  
3.5 GtCO<sub>2</sub>/yr

Sources = Sinks

16.4 GtCO<sub>2</sub>/yr  
44%



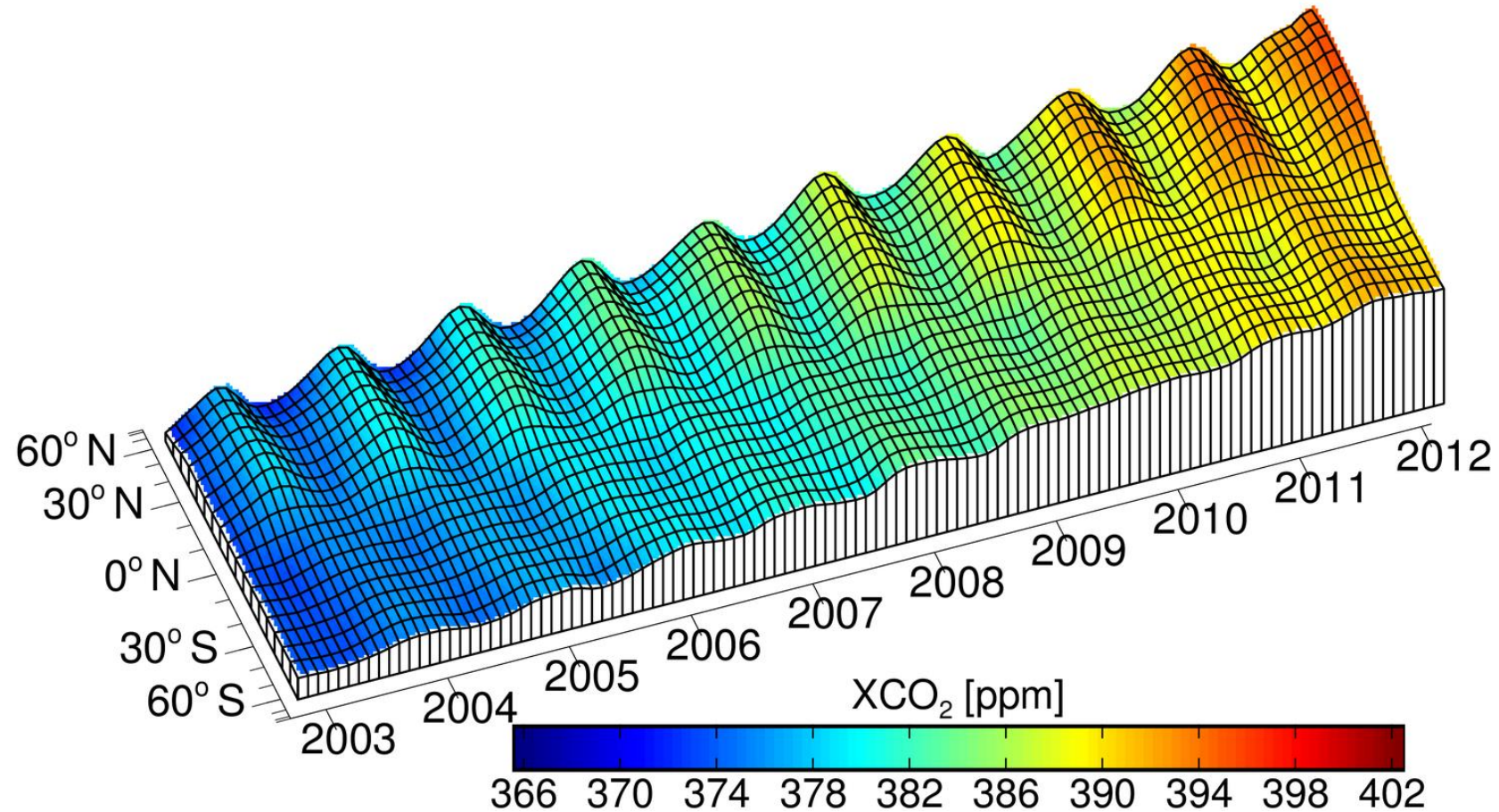
31%  
11.6 GtCO<sub>2</sub>/yr



26%  
9.7 GtCO<sub>2</sub>/yr

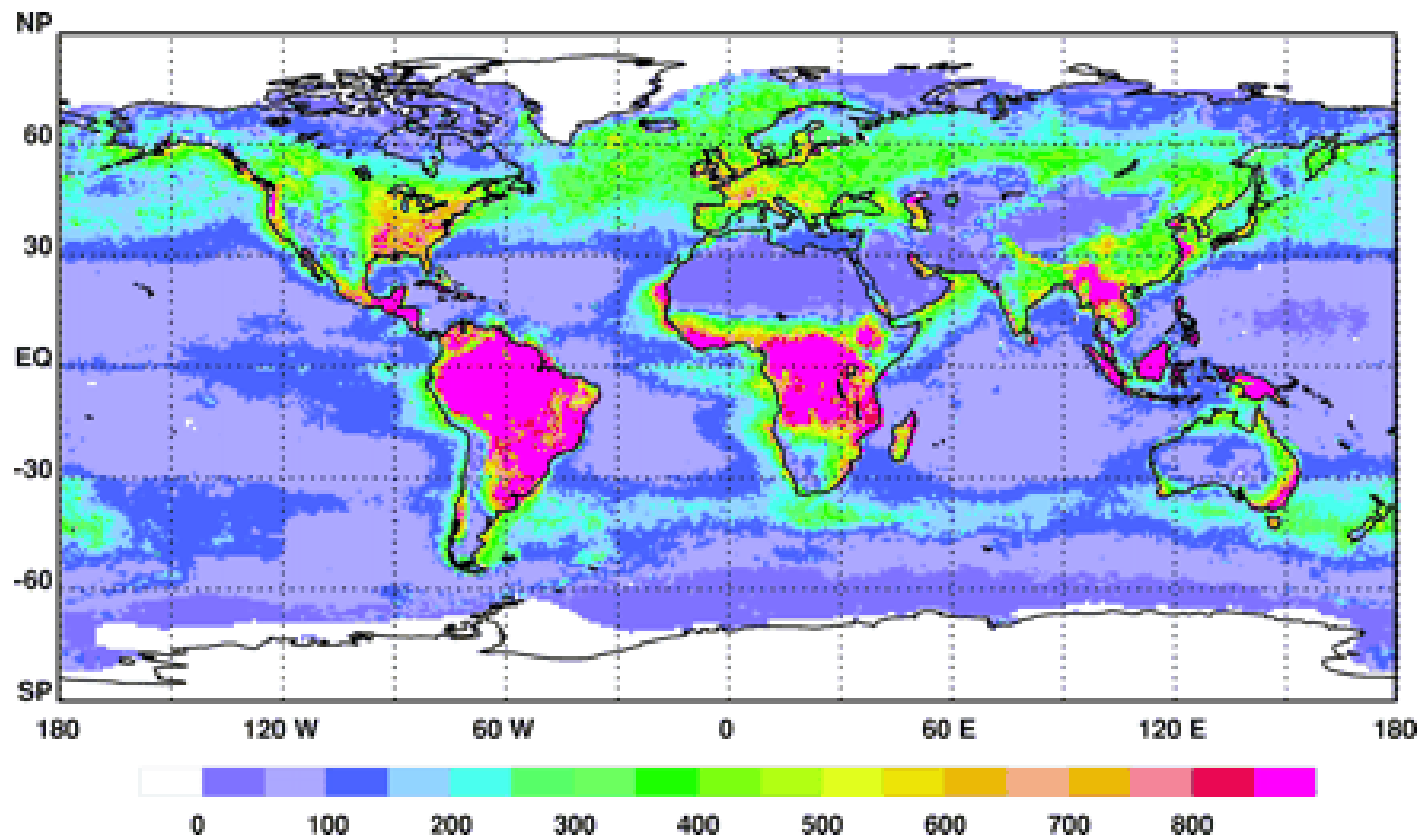


Evolução concentração CO<sub>2</sub> atmosférico: Através da observação por satélites



The maps derived from SCIAMACHY, a spectrometer onboard the European ENVISAT satellite.

# Comparação vegetação terrestre e Fitoplâncton:



- Produtividade primária a partir da detecção por satélite. Field et al, 1998, (NPP, "Net Primary Productivity),

Estimados a partir da modelização de dados de imagens de satélite da concentração da clorofila, de dados de radiação fotossintética

e do parâmetro  $\epsilon$ , a eficiência fotossintética de utilização da luz (determinado a partir de dados experimentais de campo).

**(Global NPP in Pg C y<sup>-1</sup>)**

	Ocean	Land
<b>TOTAL</b>	<b>48.5</b>	<b>56.4</b>

Este é um artigo chave

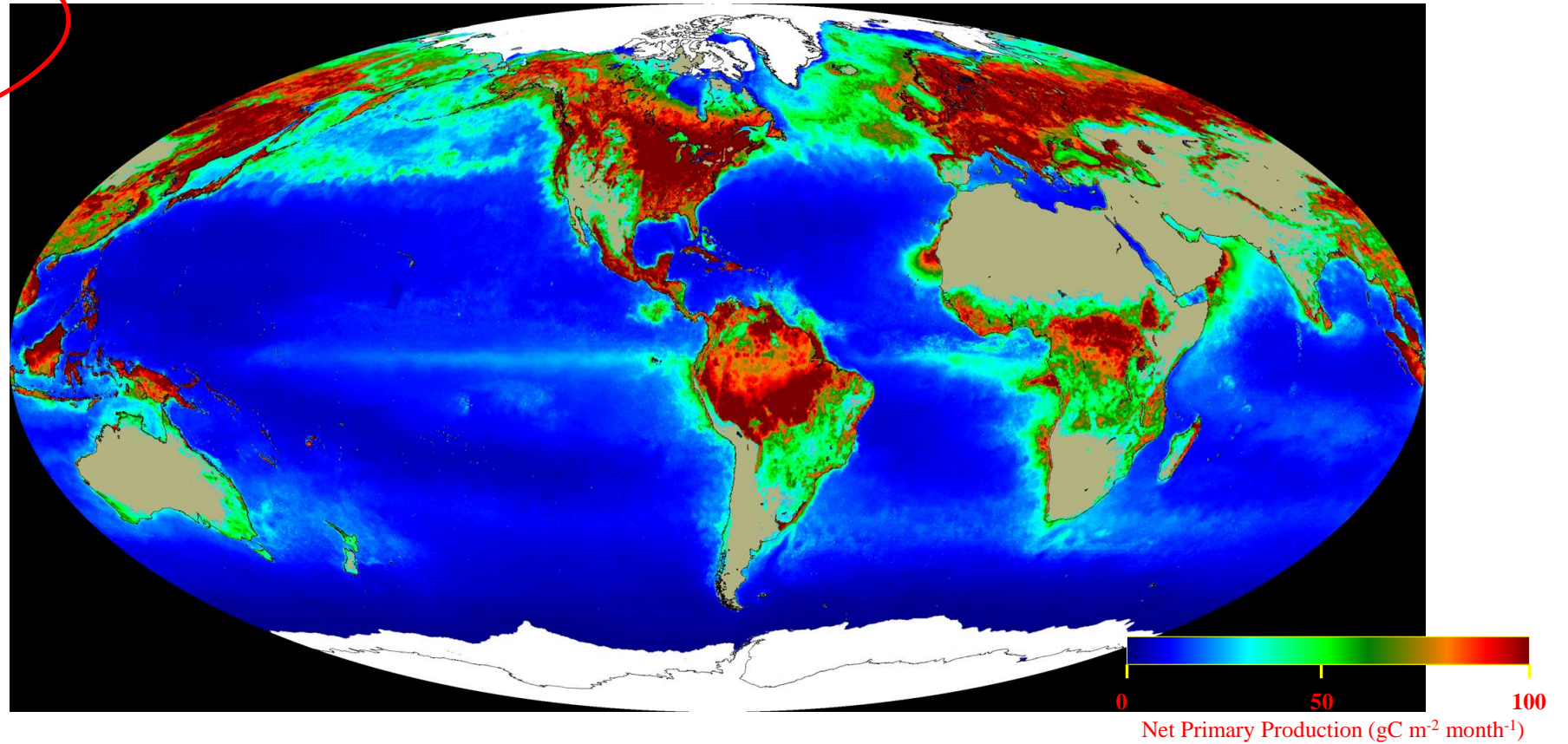
# Field et al 1988 comparação de Produtividade liquida em vários tipos de ecossistemas

Dados in situ de Produção-Irradiancia  
Imgens de satélite

**Table 1.** Annual and seasonal NPP of the major units of the biosphere, from CASA-VGPM. Ocean color data are averages from 1978 to 1983. The land vegetation index is from 1982 to 1990. All values are in petagrams of carbon (1 Pg =  $10^{15}$  g). Ocean NPP estimates are binned into three biogeographic categories on the basis of annual average  $C_{sat}$  for each satellite pixel, such that oligotrophic =  $C_{sat} < 0.1 \text{ mg m}^{-3}$ , mesotrophic =  $0.1 < C_{sat} < 1 \text{ mg m}^{-3}$ , and eutrophic =  $C_{sat} > 1 \text{ mg m}^{-3}$  (27). The macrophyte contribution to ocean production from (38) is not included in the seasonal totals. The vegetation classes are those defined by (37).

	Ocean NPP		Land NPP
Seasonal			
April to June	10.9		15.7
July to September	13.0		18.0
October to December	12.3		11.5
January to March	11.3		11.2
Biogeographic			
Oligotrophic	11.0	Tropical rainforests	17.8
Mesotrophic	27.4	Broadleaf deciduous forests	1.5
Eutrophic	9.1	Broadleaf and needleleaf forests	3.1
Macrophytes	1.0	Needleleaf evergreen forests	3.1
		Needleleaf deciduous forest	1.4
		Savannas	16.8
		Perennial grasslands	2.4
		Broadleaf shrubs with bare soil	1.0
		Tundra	0.8
		Desert	0.5
		Cultivation	8.0
Total	48.5		56.4

Fitoplancton e ciclo de carbono



- 

Biospheric Productivity = 110 - 120 Gt C  $\text{y}^{-1}$

(

- **Approx. 50% on land & 50% in the ocean surface**
- **Phytoplankton responsible for >95% of ocean productivity**

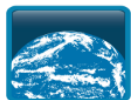
Michael Behrenfeld    Goddard Space Flight Center, NASA

# Ligação com as TPs

- Porque estamos a insistir na cor do oceano nas aulas TPs?
- Chla é uma variável essencial do clima

## Essential Climate Variables (ECV):

- Atmospheric Group: Cloud, Ozone, Aerosol, GHG
- Ocean Group: Sea Level, Sea Ice (TBC) SST, **Ocean Colour**
- Land Group: Glaciers, Landcover, Fire





# Why Ocean Colour? Climate-Change Context



Identified as essential climate variable by GCOS  
(Global Climate Observing System)

Amenable to remote sensing: global perspective

Targets a key property of marine ecosystem

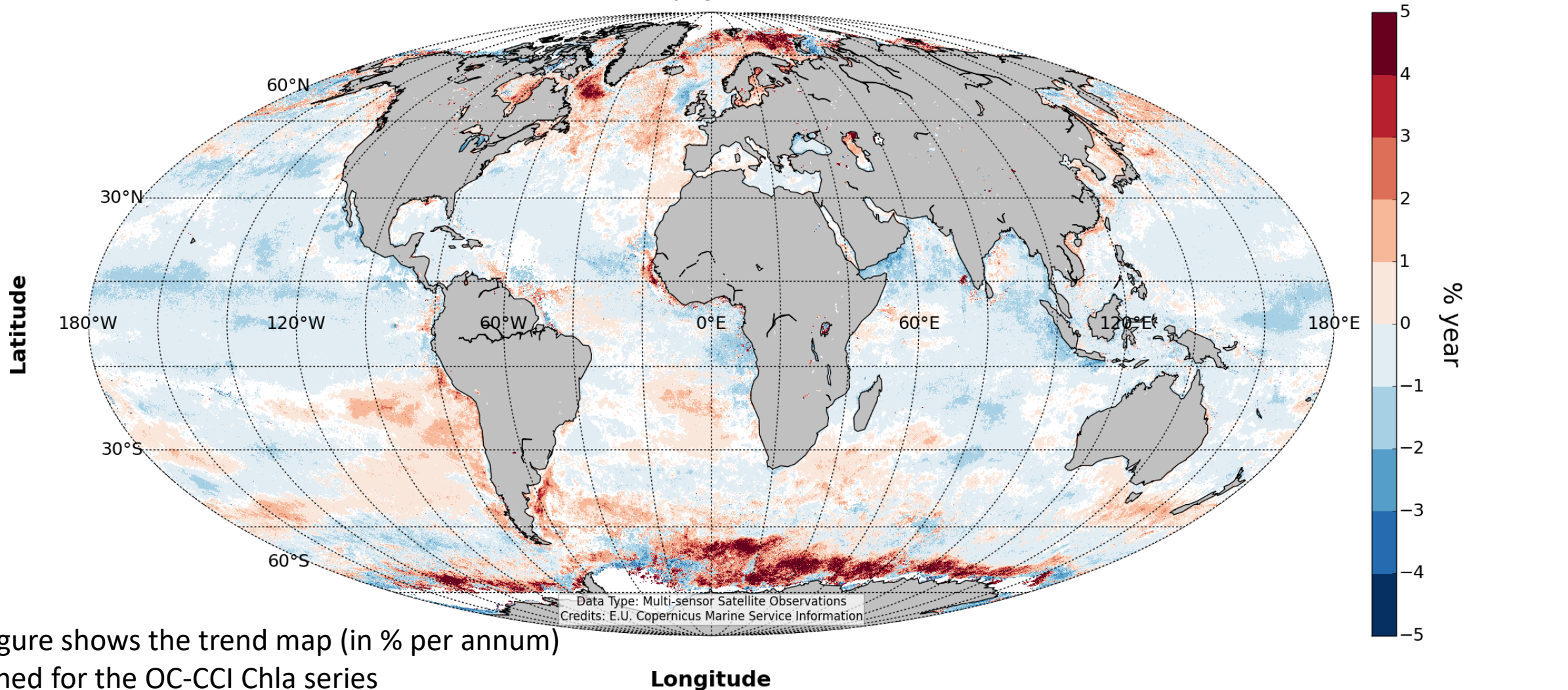
The Green component of the Blue Planet (the only marine ECV that probes the “Living” part of the Living Planet)



OC-CCI Project

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

Global Ocean Chlorophyll-a trends (1997-2018)



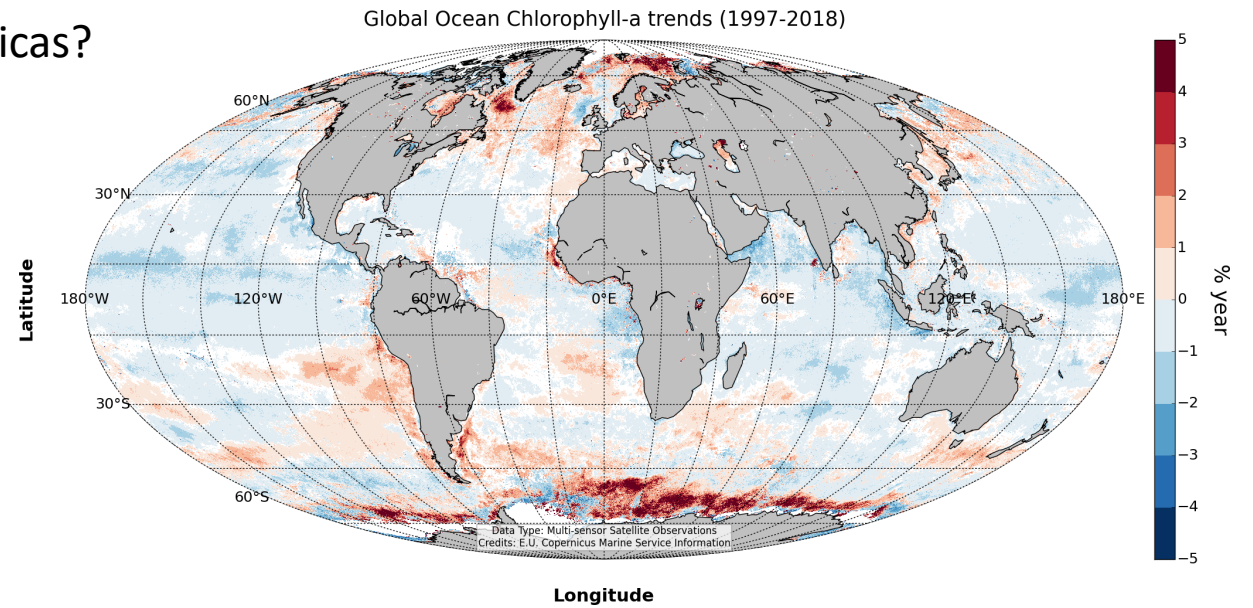
the figure shows the trend map (in % per annum)  
obtained for the OC-CCI Chla series

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](https://doi.org/10.1080/1755876X.2018.1489208).

O fitoplancton está a aumentar ou a diminuir em resposta às alterações climáticas?



Relevante consultar para alunos mestrado em Ecologia Marinha e Ciências 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).

# Bibliografia

- Falkowski, P. G. & Raven, J. A., 1997. Aquatic Photosynthesis, 375pp. Blackwell Science. Biblioteca da Biologia
- Smith & Smith, Elements of Ecology, ed 9. Capítulo 22. Biblioteca da Biologia
- Kaiser et al., 2005. Marine Ecology. Oxford Univ. Press. Bib. Biologia
- E artigos no fénix referidos nos slides
- Ocean State Report, disponível em <https://marine.copernicus.eu/science-learning/ocean-state-report/>

# Bibliografia (cont)

- Global Carbon Project
- <https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>

## Global Carbon Atlas

## Bibliografia

Explore CO<sub>2</sub> emissions at the global and country levels, compare among countries, visualize, and download data and illustrations (“Emissions” application). Also explore “Outreach” and “Research”.

The screenshot displays the Global Carbon Atlas website interface. At the top left, the title "GLOBAL CARBON ATLAS" is prominently displayed. Below it, three main sections are visible: "OUTREACH", "EMISSIONS", and "RESEARCH". Each section includes a brief description and a corresponding visual element. The "OUTREACH" section features a city skyline illustration. The "EMISSIONS" section shows a world map with black circles of varying sizes representing CO2 emissions by country. The "RESEARCH" section displays a line graph and a color-coded world map. A navigation bar at the bottom of the interface contains three orange buttons labeled "1/3", "2/3", and "3/3".

[www.globalcarbonatlas.org](http://www.globalcarbonatlas.org)