

# Cara a donde o océano do antropoceno?

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**Congreso X aniversario de Climántica**  
**Santiago de Compostela, 11 de marzo de 2017**



# Una especie, una plaga

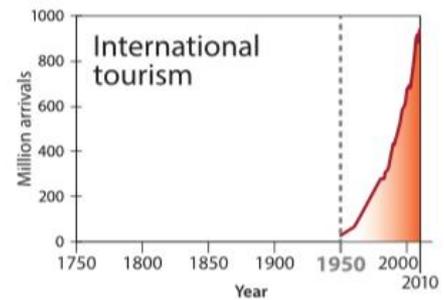
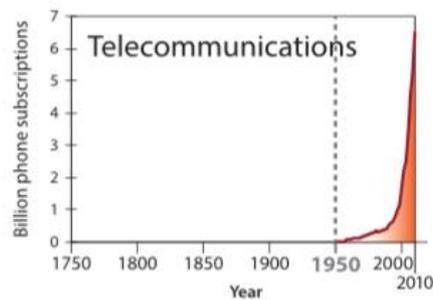
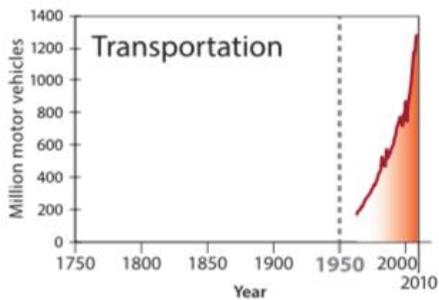
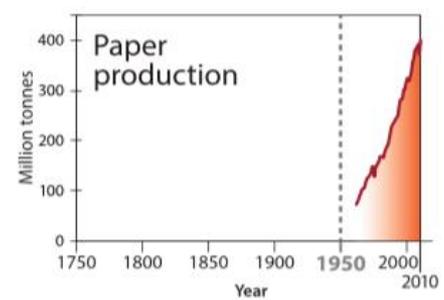
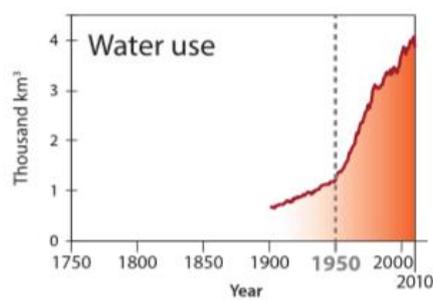
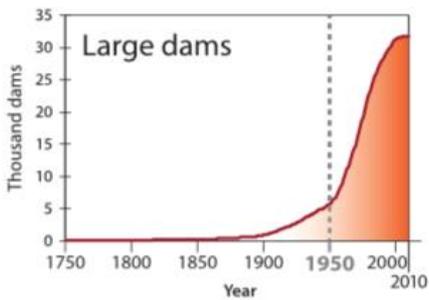
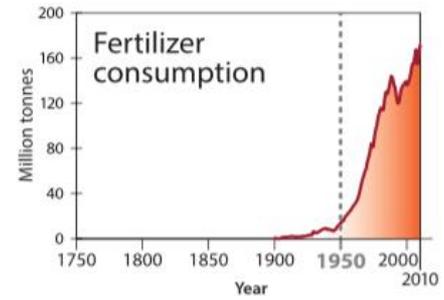
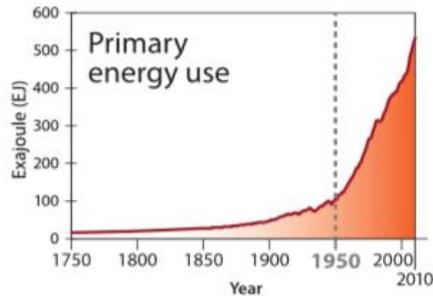
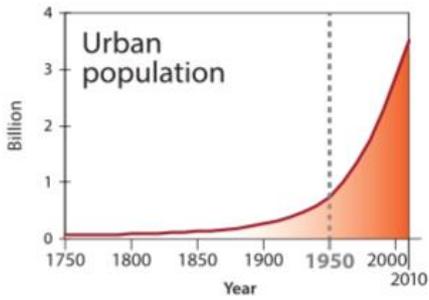
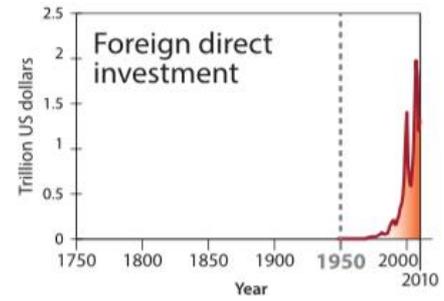
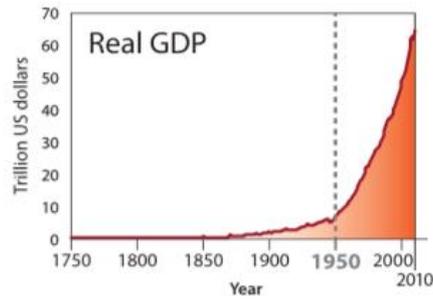
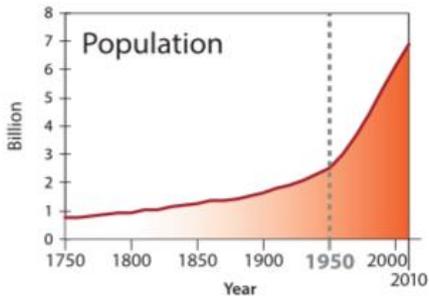


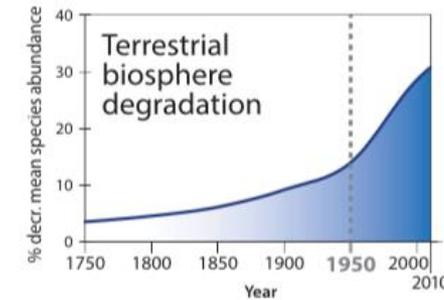
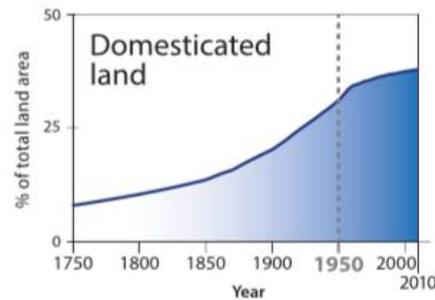
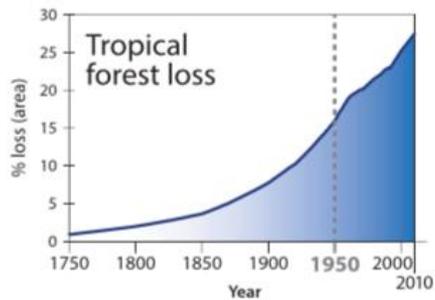
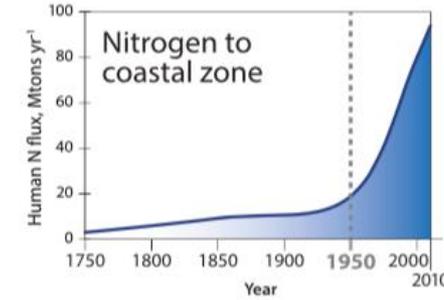
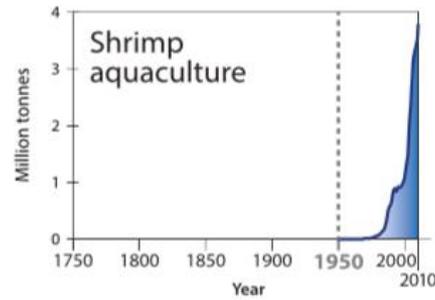
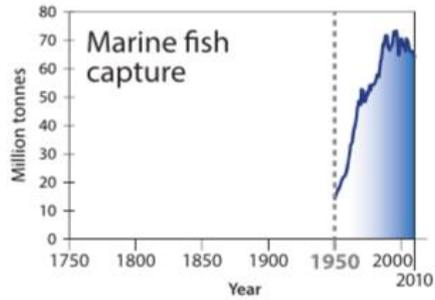
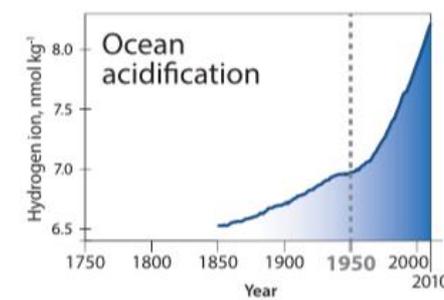
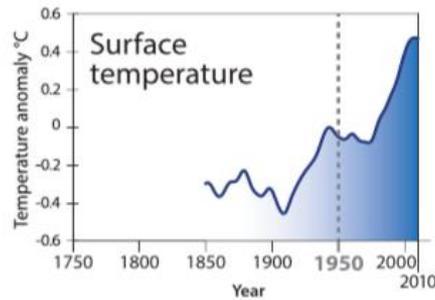
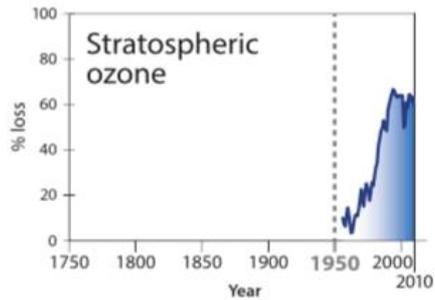
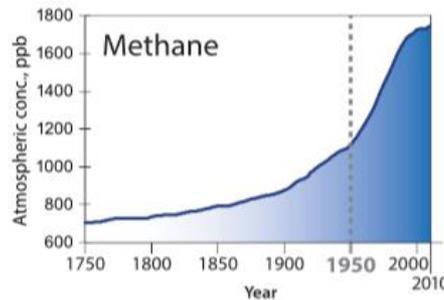
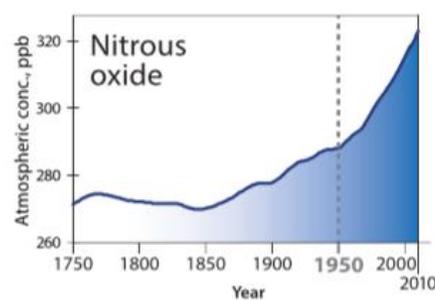
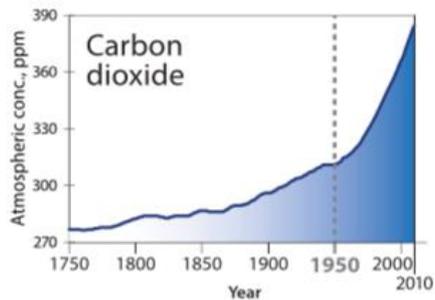
# Una especie, una plaga... con capacidad tecnológica











# Un planeta en transformación acelerada



Paul Crutzen

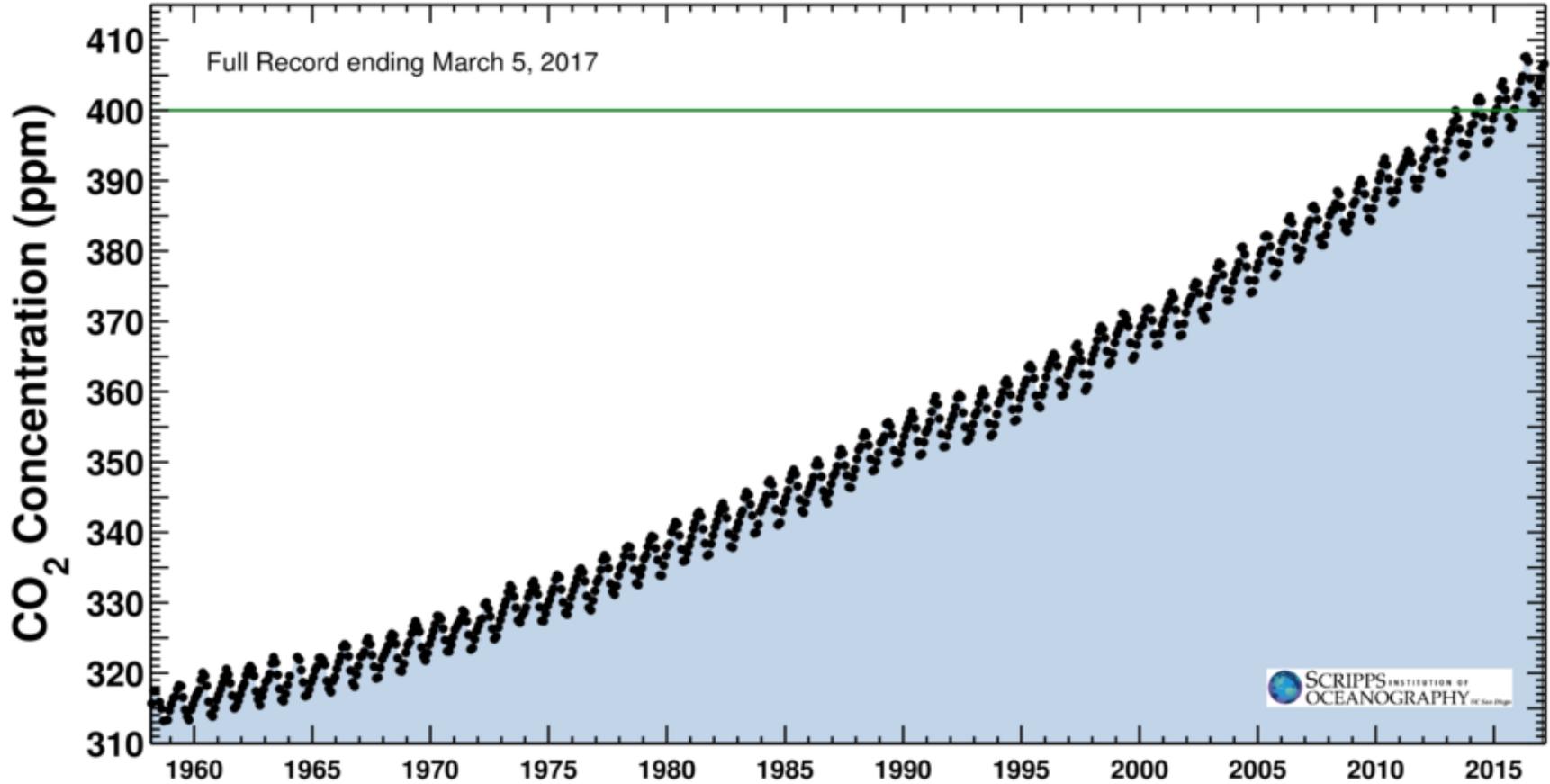


Debido a que las actividades humanas han crecido de forma que se han convertido en fuerzas geológicas significativas, por ejemplo cambios en el uso del suelo, deforestación y quema de combustibles fósiles, está justificado asignar el termino “antropoceno” a la época geológica presente (Paul Crutzen)

Latest CO<sub>2</sub> reading  
March 05, 2017

406.72 ppm

Carbon dioxide concentration at Mauna Loa Observatory



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

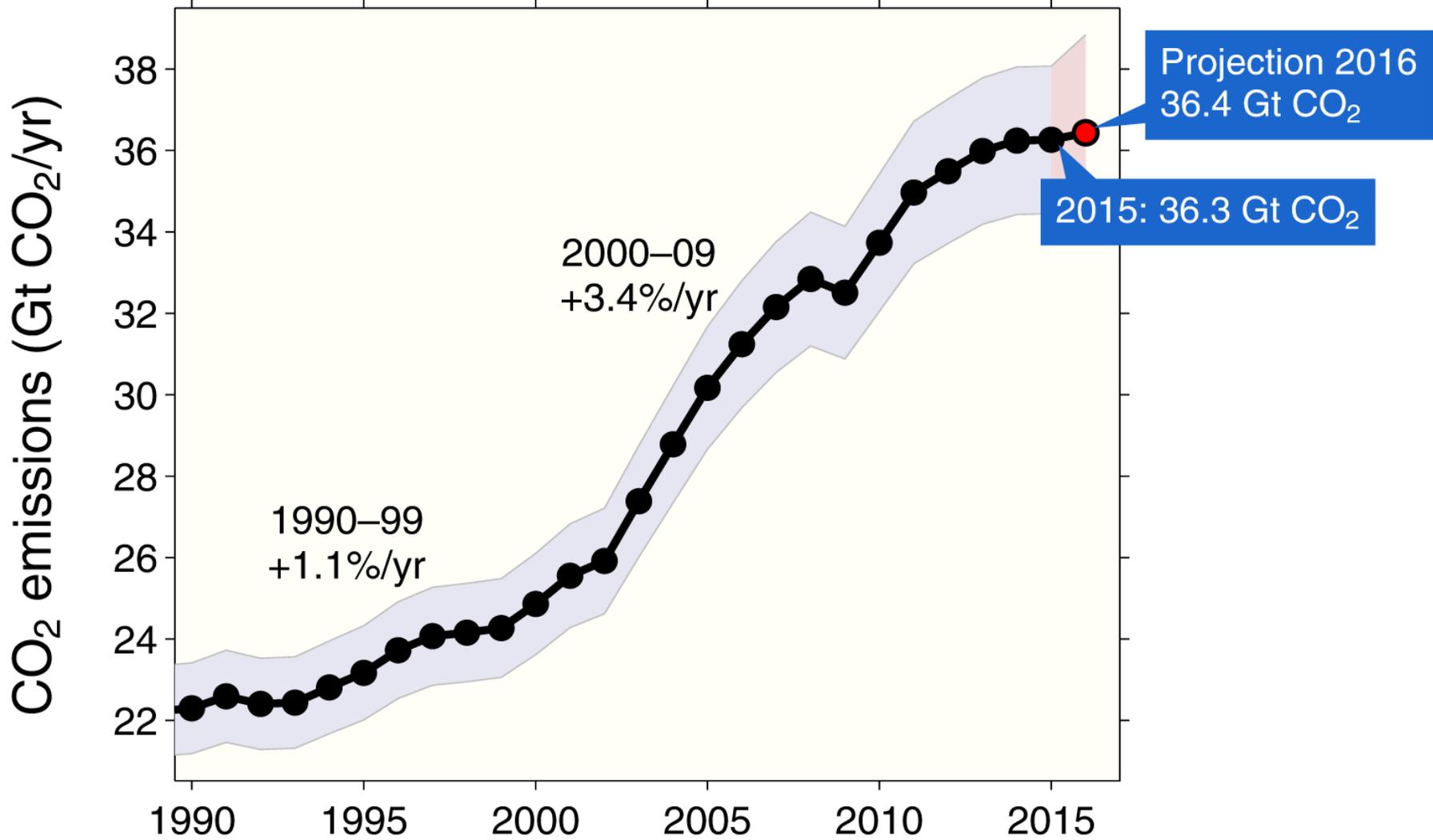


## Global Carbon Budget 2015

**C. Le Quéré<sup>1</sup>, R. Moriarty<sup>1</sup>, R. M. Andrew<sup>2</sup>, J. G. Canadell<sup>3</sup>, S. Sitch<sup>4</sup>, J. I. Korsbakken<sup>2</sup>,  
P. Friedlingstein<sup>5</sup>, G. P. Peters<sup>2</sup>, R. J. Andres<sup>6</sup>, T. A. Boden<sup>6</sup>, R. A. Houghton<sup>7</sup>, J. I. House<sup>8</sup>,  
R. F. Keeling<sup>9</sup>, P. Tans<sup>10</sup>, A. Arneth<sup>11</sup>, D. C. E. Bakker<sup>12</sup>, L. Barbero<sup>13,14</sup>, L. Bopp<sup>15</sup>, J. Chang<sup>15</sup>,  
F. Chevallier<sup>15</sup>, L. P. Chini<sup>16</sup>, P. Ciais<sup>15</sup>, M. Fader<sup>17</sup>, R. A. Feely<sup>18</sup>, T. Gkritzalis<sup>19</sup>, I. Harris<sup>20</sup>,  
J. Hauck<sup>21</sup>, T. Ilyina<sup>22</sup>, A. K. Jain<sup>23</sup>, E. Kato<sup>24</sup>, V. Kitidis<sup>25</sup>, K. Klein Goldewijk<sup>26</sup>, C. Koven<sup>27</sup>,  
P. Landschützer<sup>28</sup>, S. K. Lauvset<sup>29</sup>, N. Lefèvre<sup>30</sup>, A. Lenton<sup>31</sup>, I. D. Lima<sup>32</sup>, N. Metz<sup>30</sup>, F. Millero<sup>33</sup>,  
D. R. Munro<sup>34</sup>, A. Murata<sup>35</sup>, J. E. M. S. Nabel<sup>22</sup>, S. Nakaoka<sup>36</sup>, Y. Nojiri<sup>36</sup>, K. O'Brien<sup>37</sup>, A. Olsen<sup>38,39</sup>,  
T. Ono<sup>40</sup>, F. F. Pérez<sup>41</sup>, B. Pfeil<sup>38,39</sup>, D. Pierrot<sup>13,14</sup>, B. Poulter<sup>42</sup>, G. Rehder<sup>43</sup>, C. Rödenbeck<sup>44</sup>, S. Saito<sup>45</sup>,  
U. Schuster<sup>4</sup>, J. Schwinger<sup>29</sup>, R. Séférian<sup>46</sup>, T. Steinhoff<sup>47</sup>, B. D. Stocker<sup>48,49</sup>, A. J. Sutton<sup>37,18</sup>,  
T. Takahashi<sup>50</sup>, B. Tilbrook<sup>51</sup>, I. T. van der Laan-Luijkx<sup>52,53</sup>, G. R. van der Werf<sup>54</sup>, S. van Heuven<sup>55</sup>,  
D. Vandemark<sup>56</sup>, N. Viovy<sup>15</sup>, A. Wiltshire<sup>57</sup>, S. Zaehle<sup>44</sup>, and N. Zeng<sup>58</sup>**

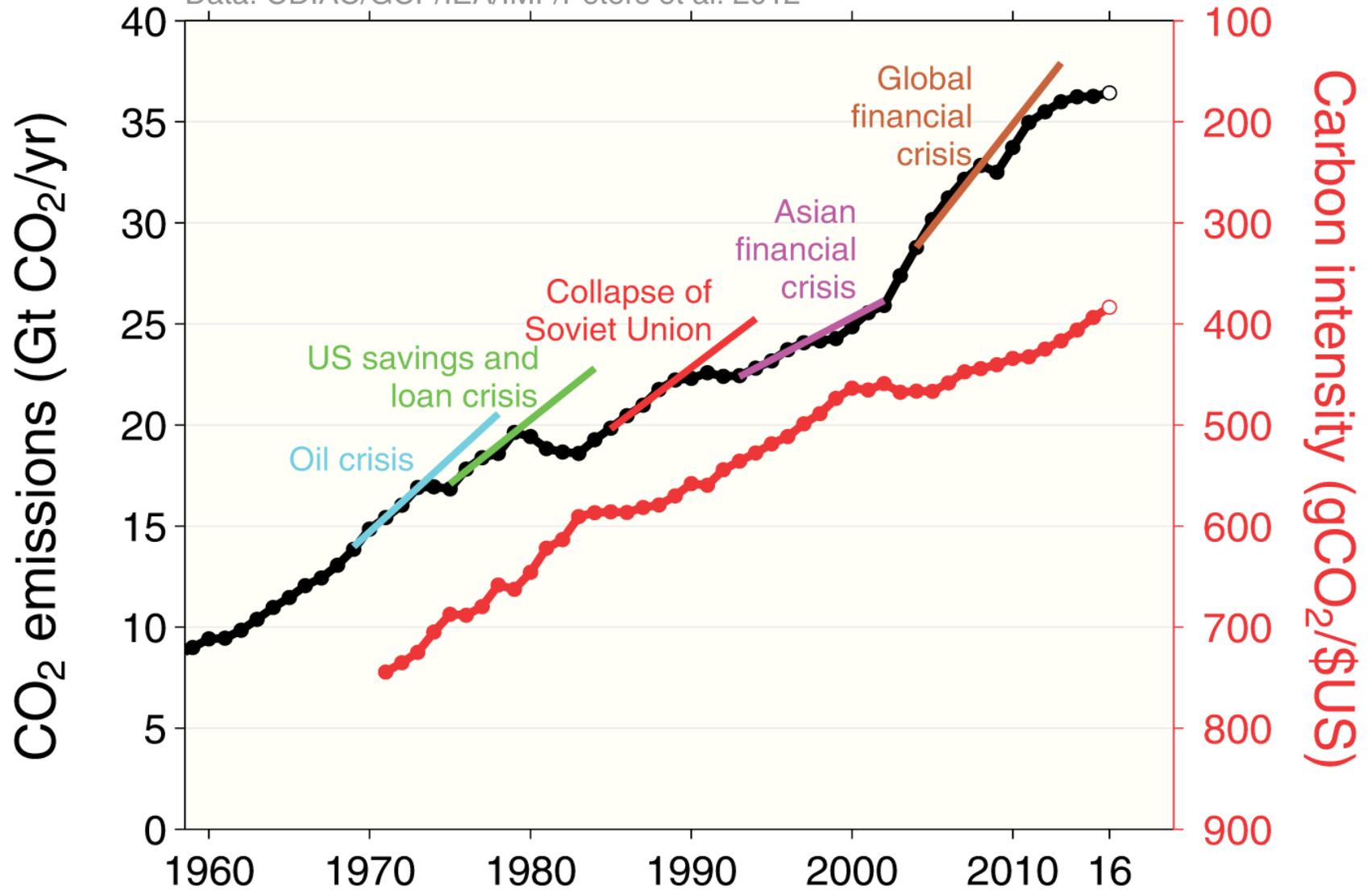
[www.globalcarbonproject.org](http://www.globalcarbonproject.org)

Data: CDIAC/GCP/BP/USGS

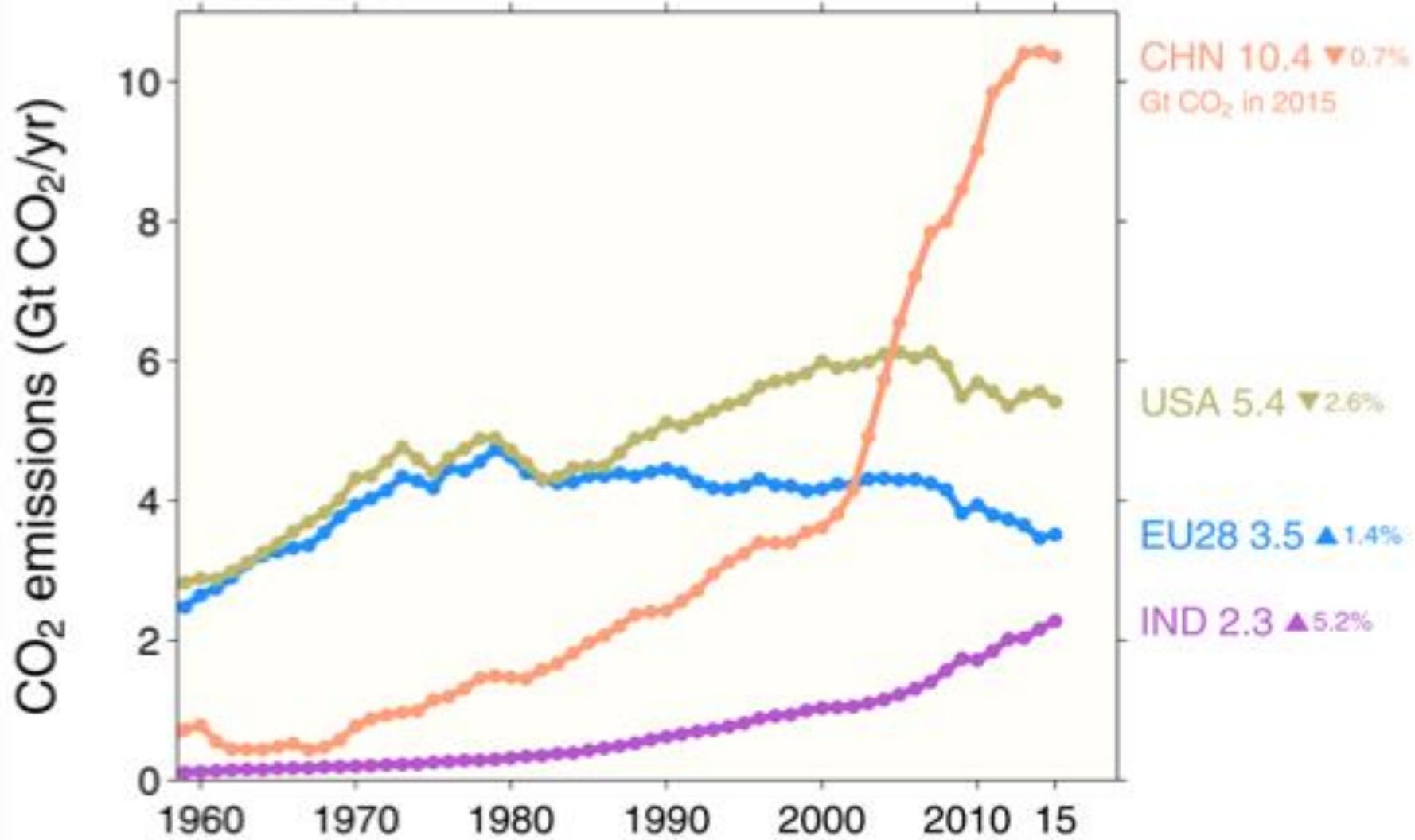


Global Carbon Project

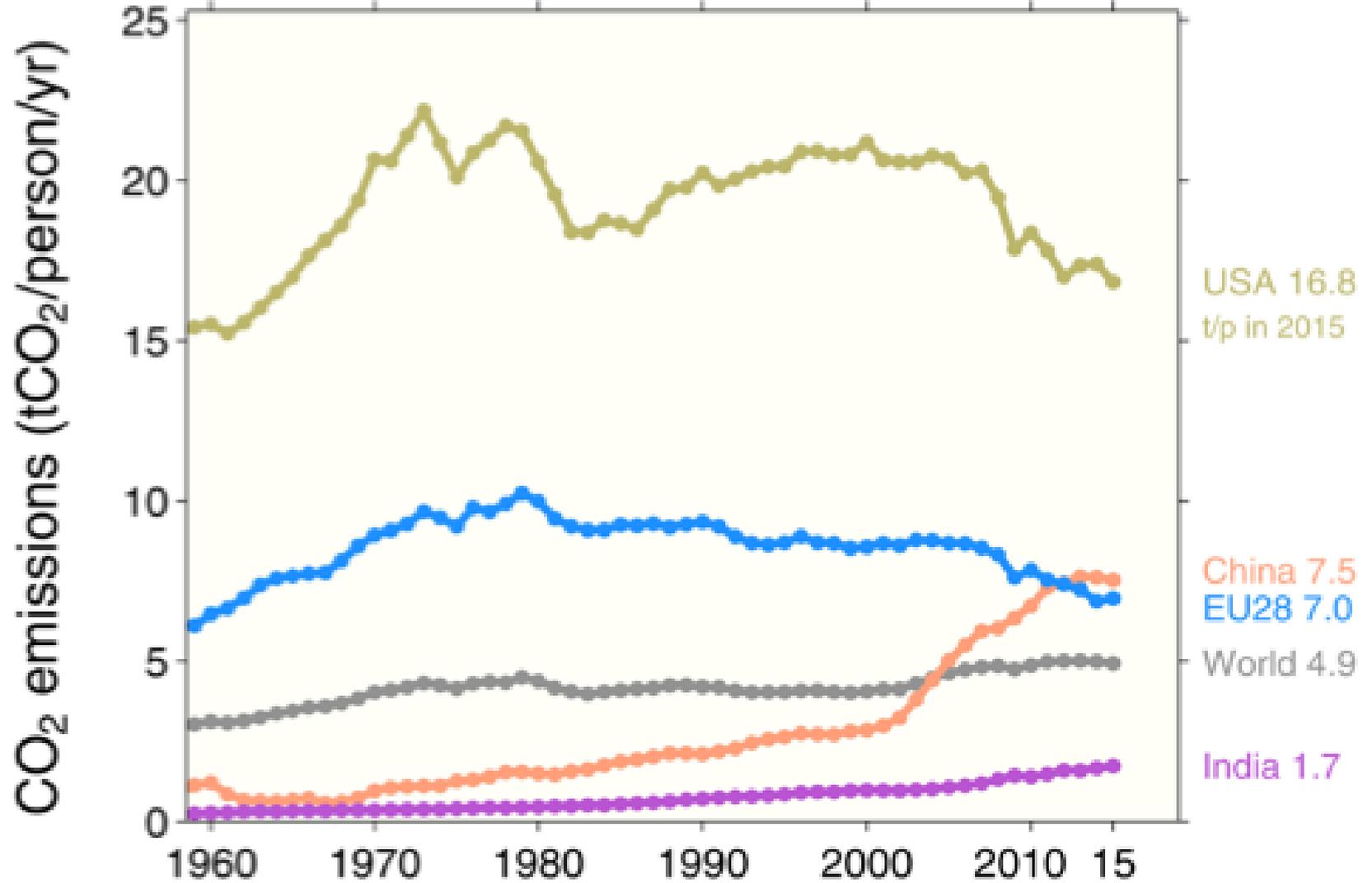
Data: CDIAC/GCP/IEA/IMF/Peters et al. 2012



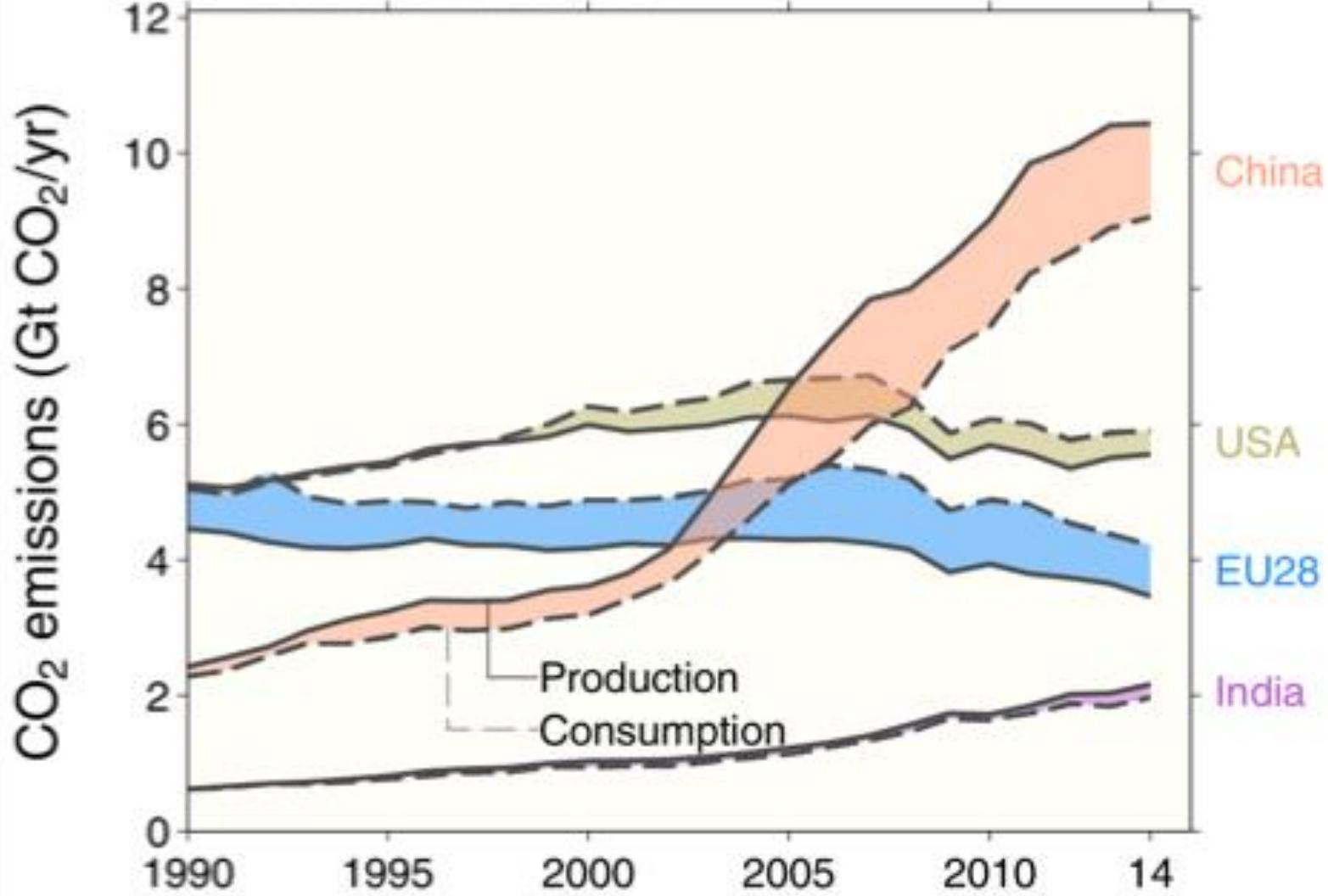
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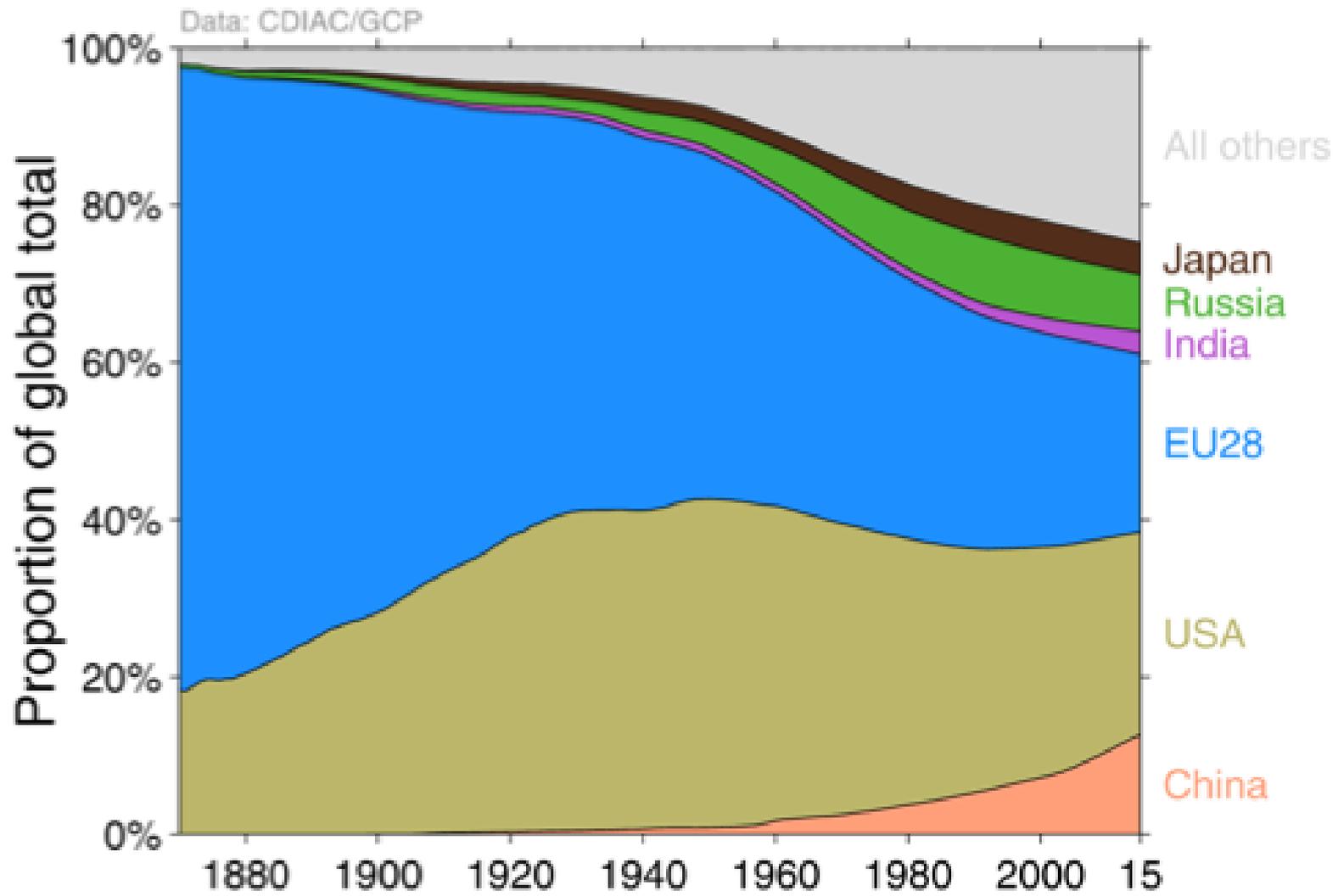


Data: CDIAC/GCP



Data: CDIAC/GCP/Peters et al 2011

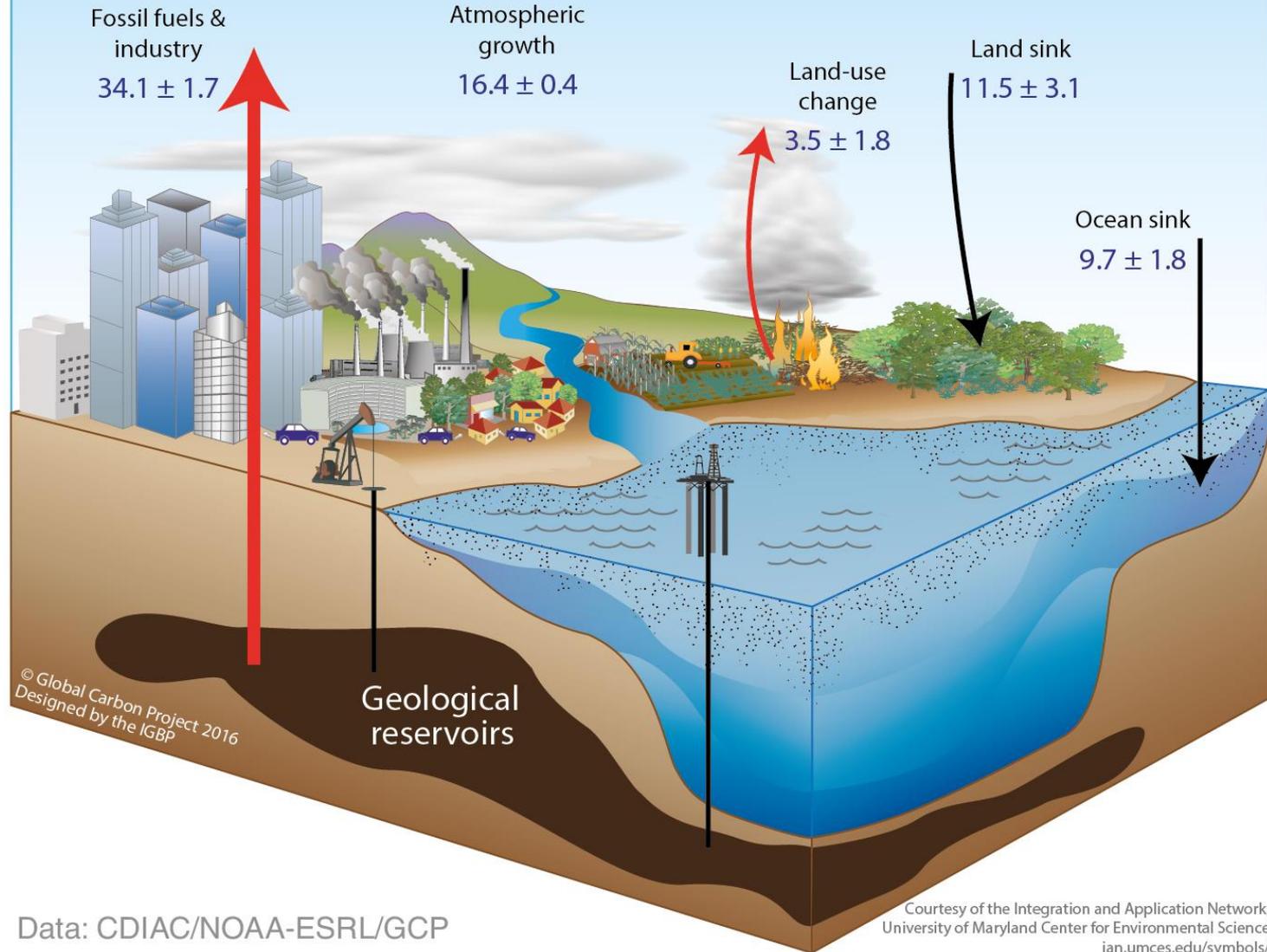






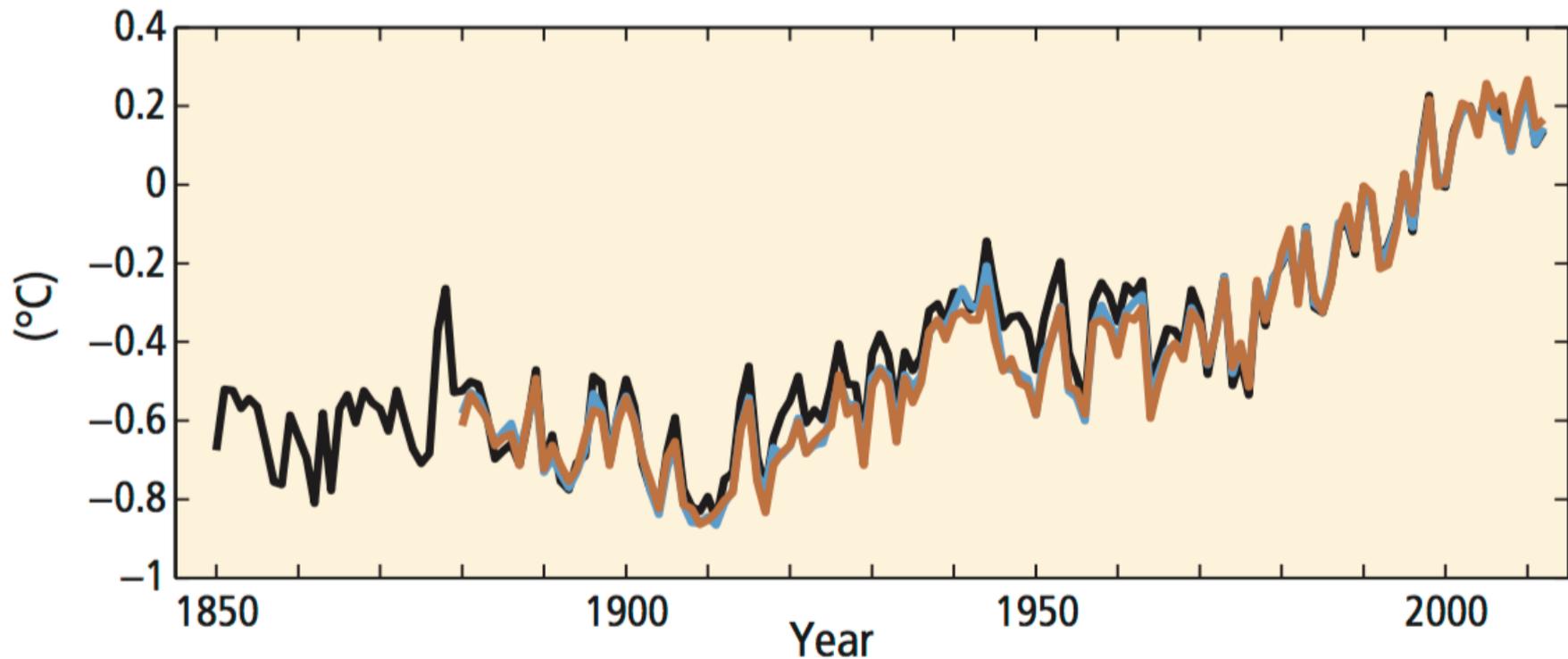
# Global carbon dioxide budget (gigatonnes of carbon dioxide per year)

2006-2015

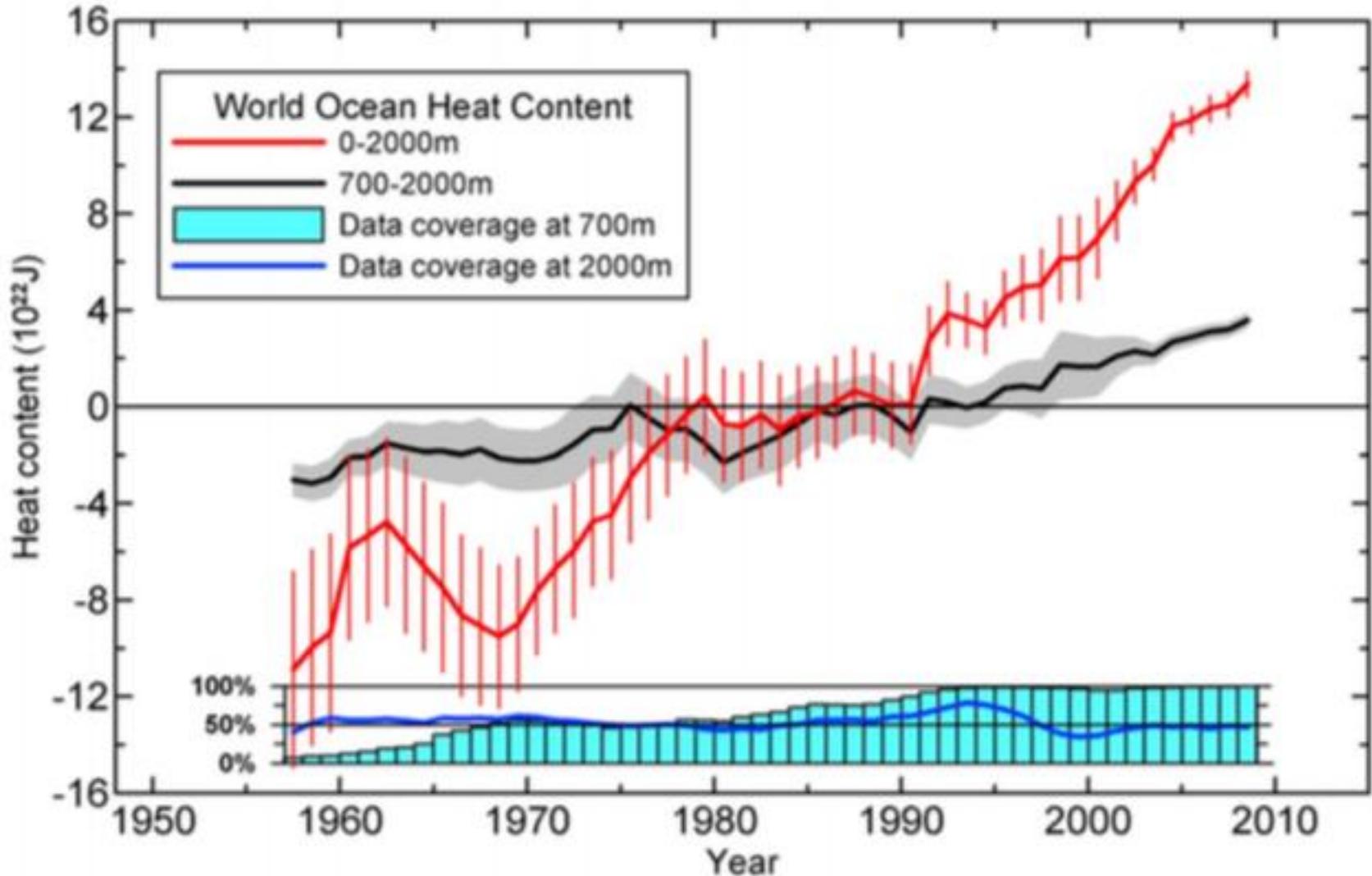


Data: CDIAC/NOAA-ESRL/GCP

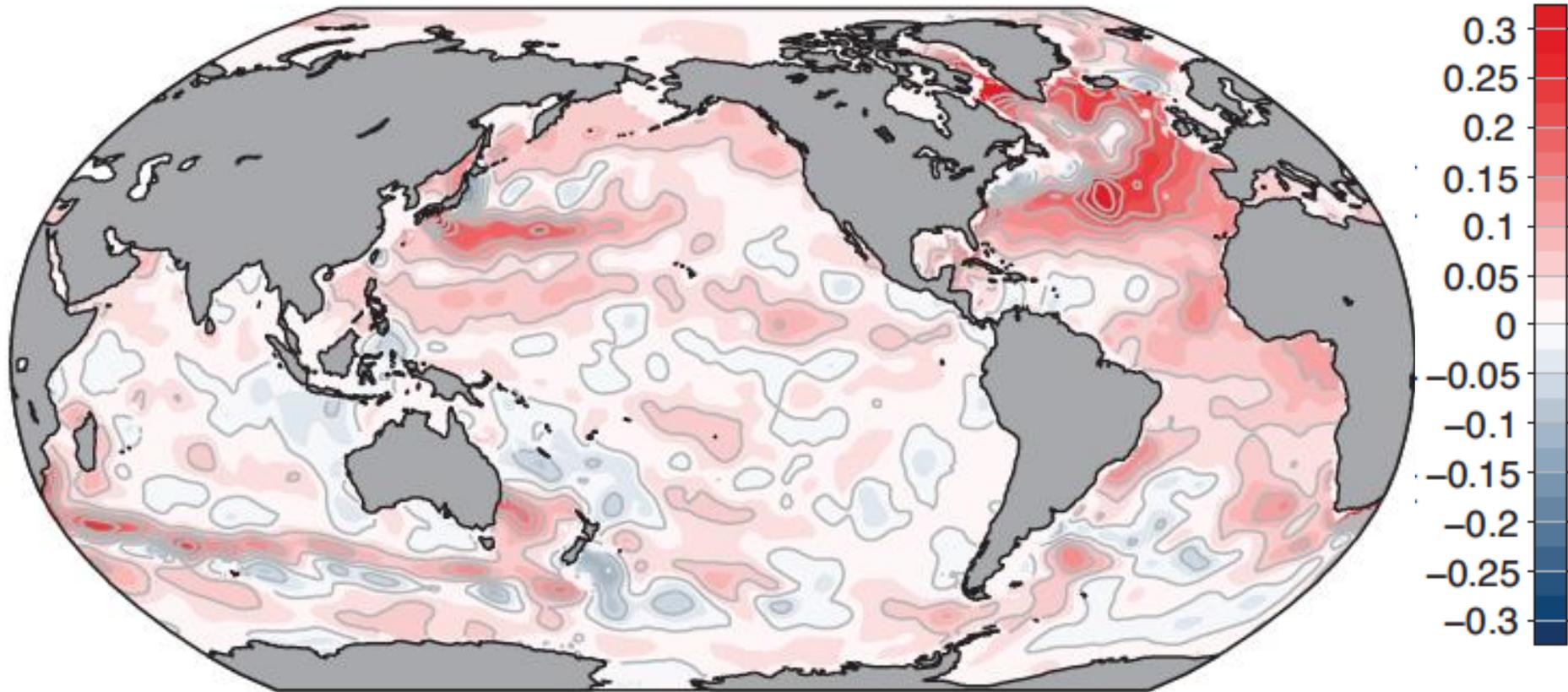
# El calentamiento combinado de tierra y mar se estima en $0.85\text{ }^{\circ}\text{C}$ entre 1880 y 2012

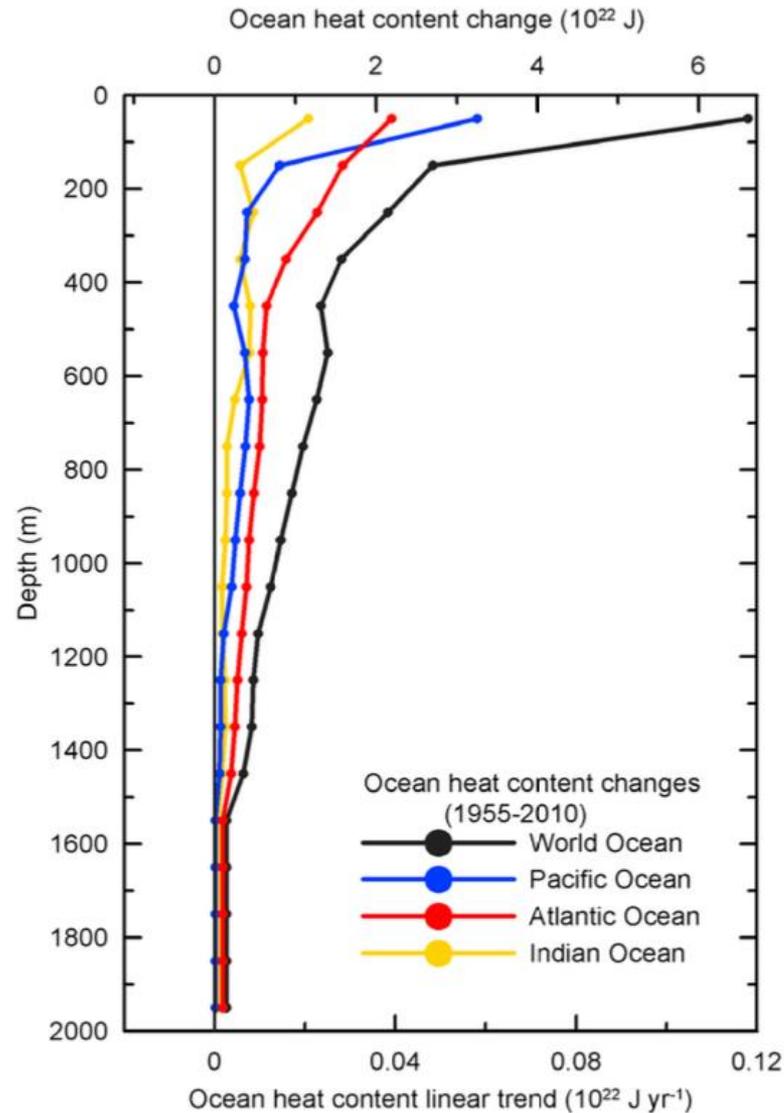


# El calentamiento del océano ha sido, desde 1971, de 0.015 °C por década en los 700 m superiores



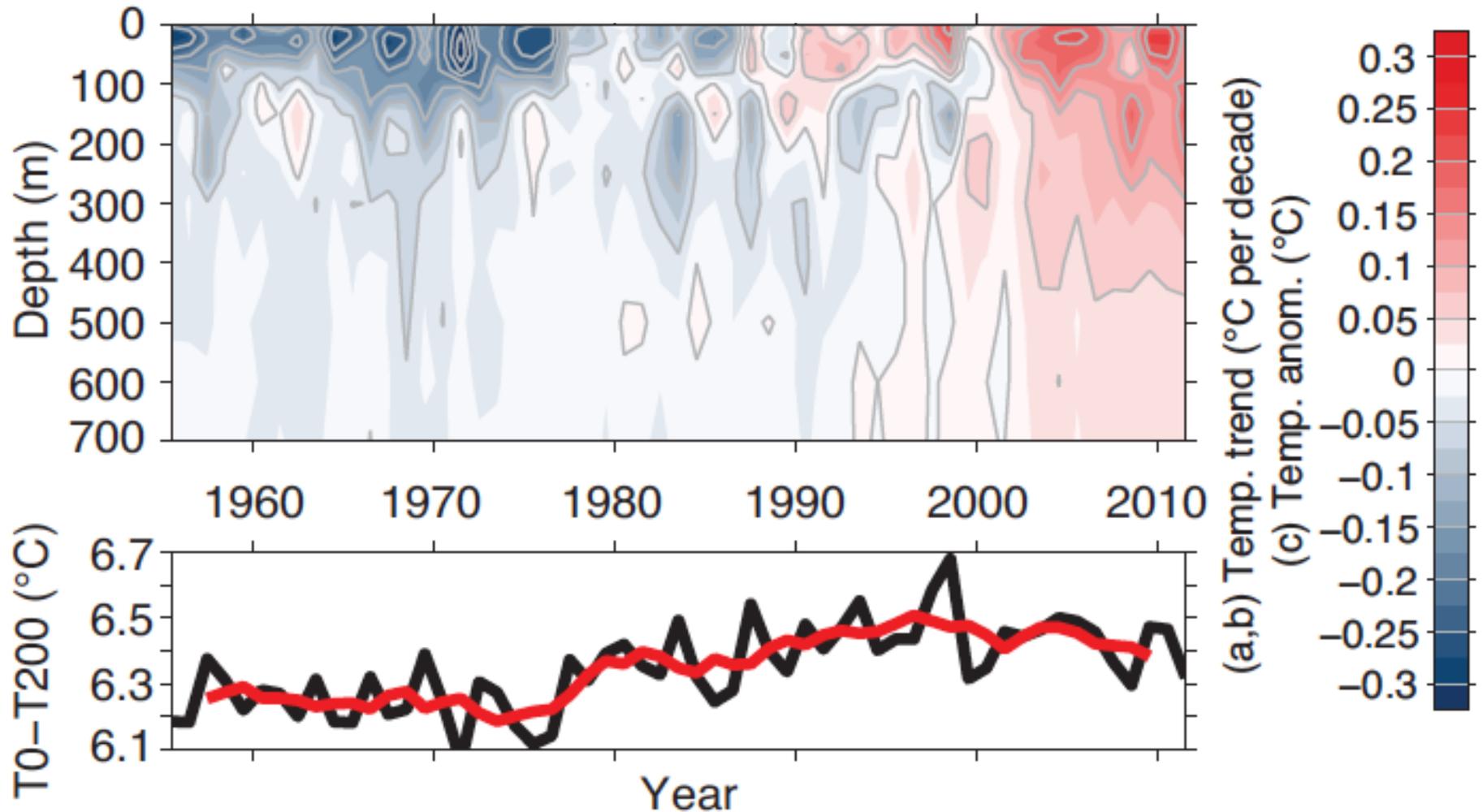
# Variación de la temperatura del océano (0-700 m) entre 1971 y 2010



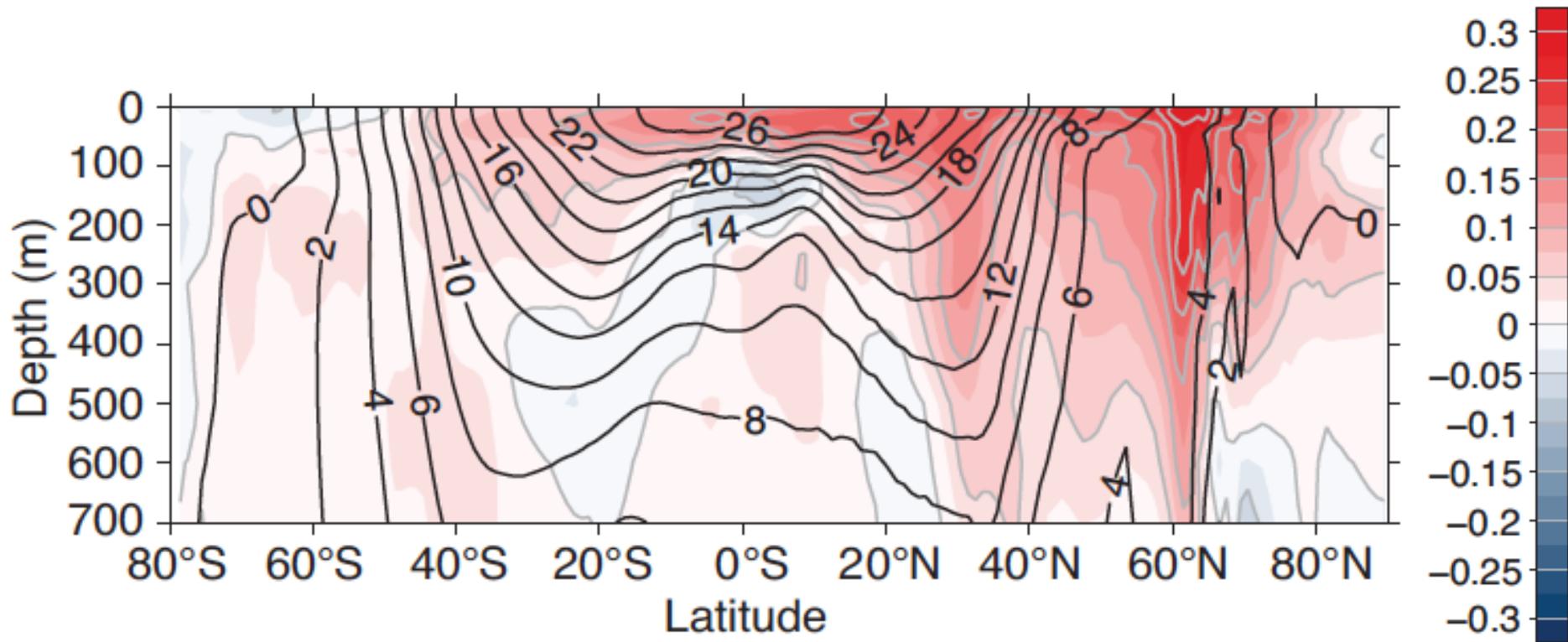


**Figure 2.** Linear trend and total increase of ocean basin heat content based on the linear trend of global and individual basins as a function of depth (0–2000 m) for 100 m thick layers.

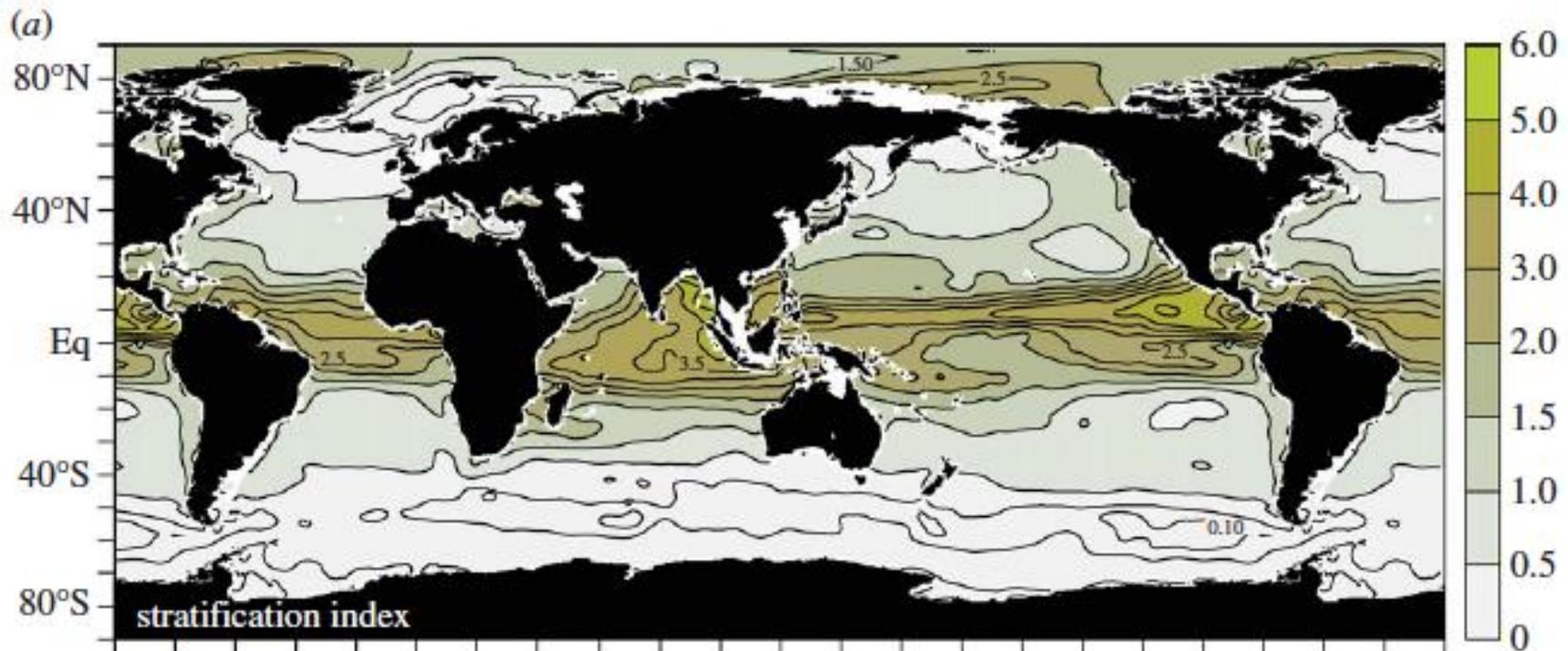
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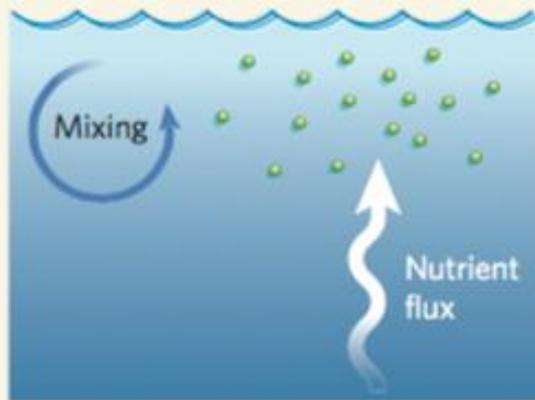


# El océano se estratifica especialmente en latitudes bajas y en el océano ártico

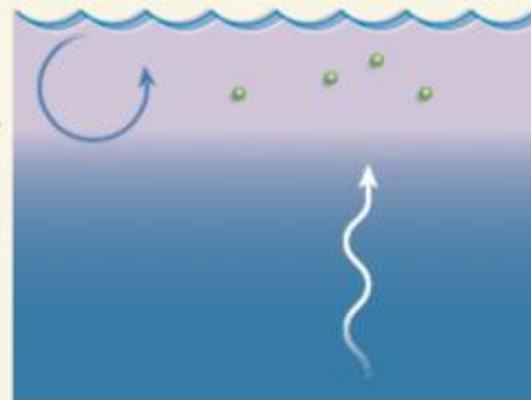


**Tropics and mid-latitudes (nutrient-limited)**

**a**



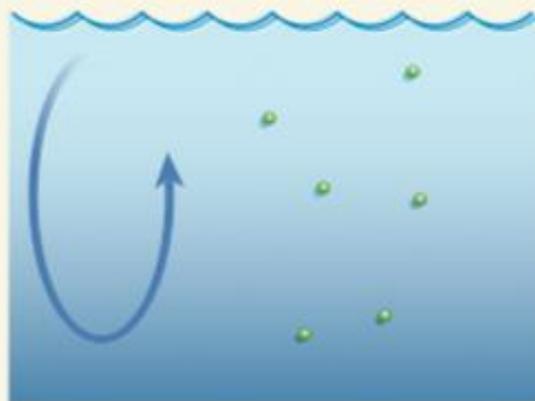
Climate warming



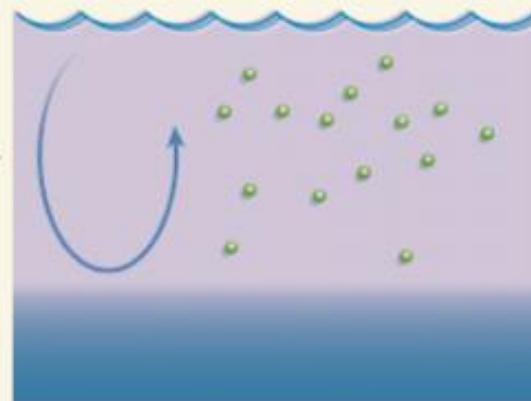
Reduced mixing, lower nutrient supply, decrease in plankton near the surface

**Higher latitudes (light-limited)**

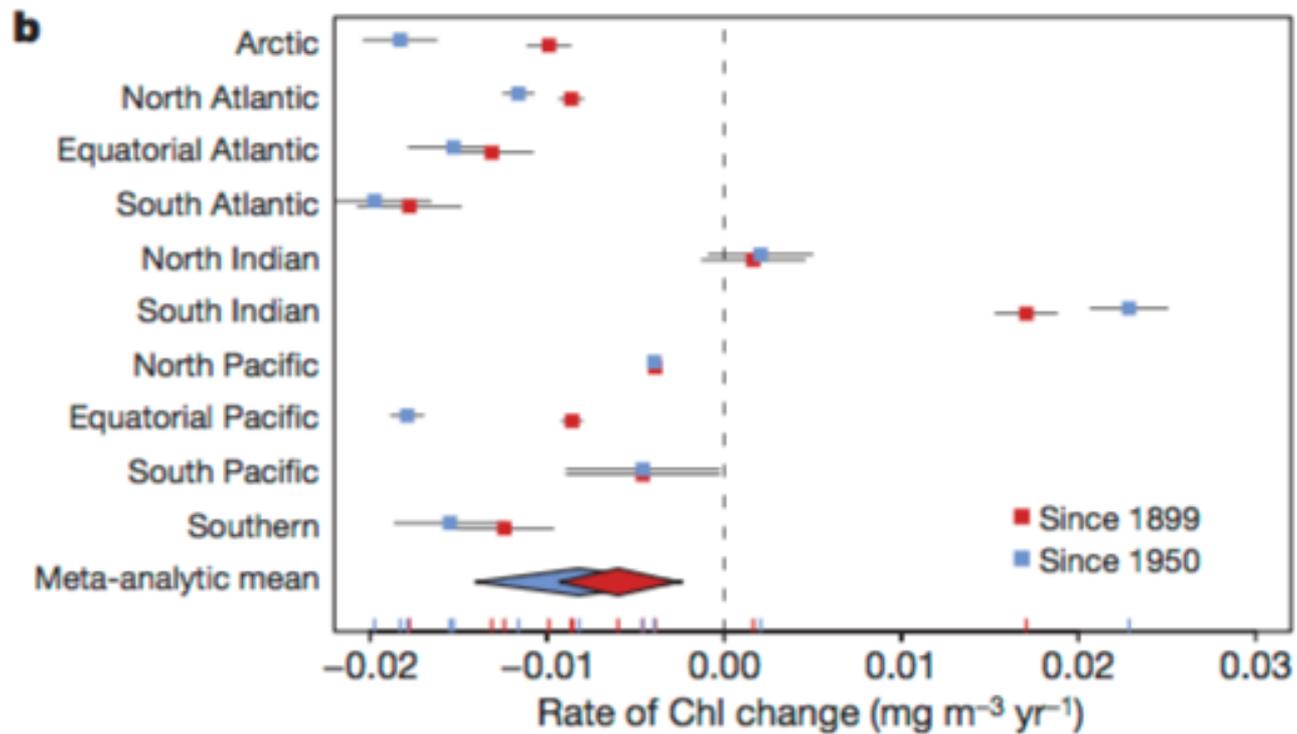
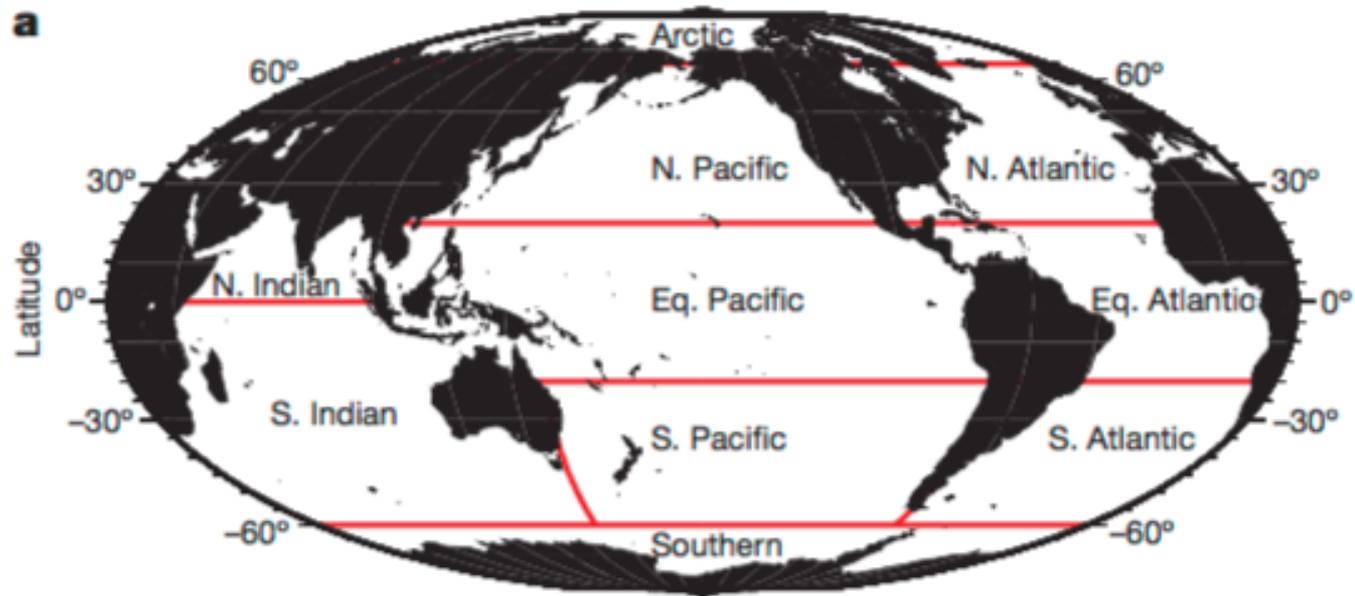
**b**



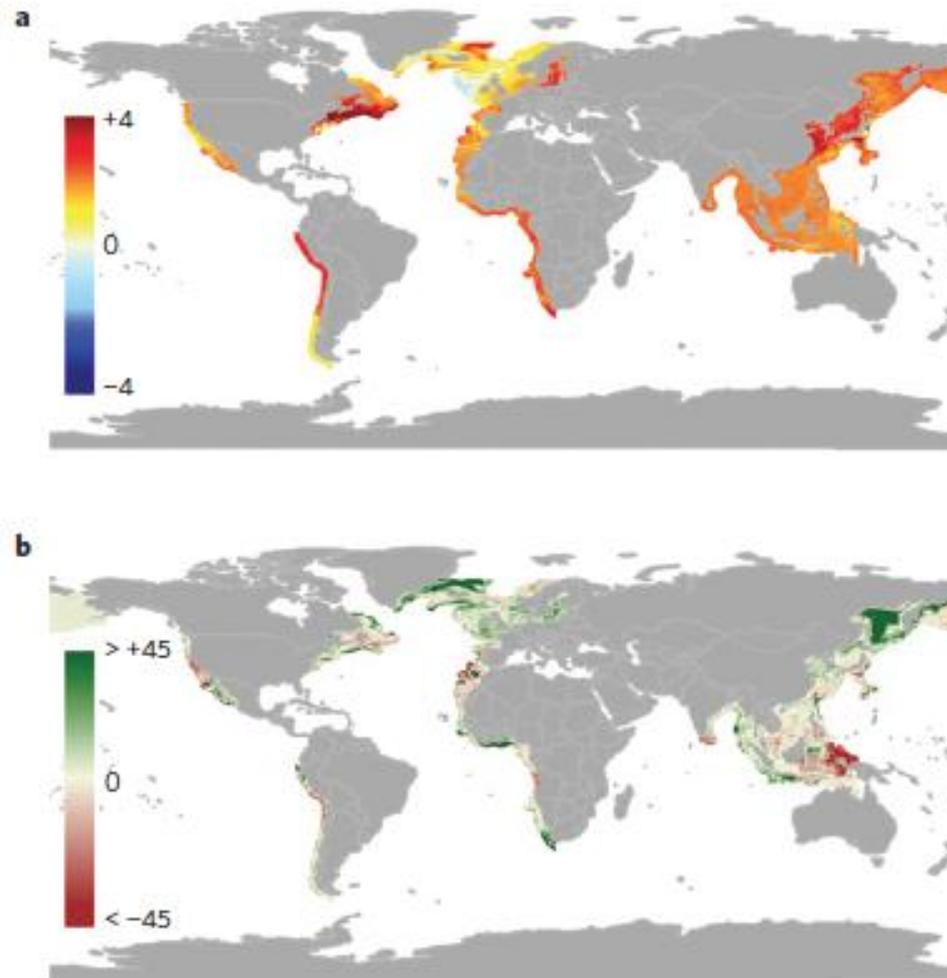
Climate warming, freshening



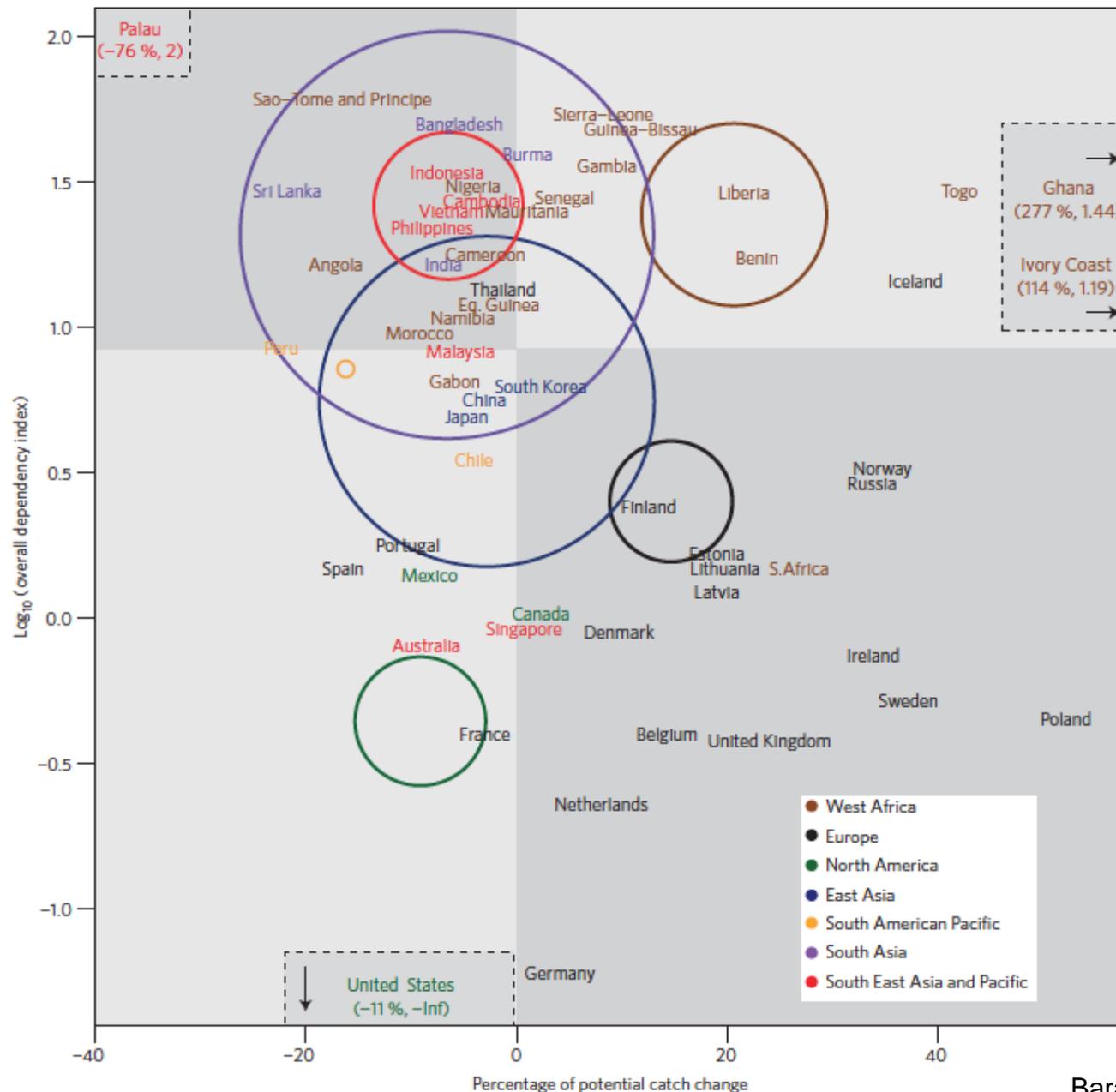
Reduced mixing, increase in plankton in the illuminated surface waters



# El calentamiento modifica la productividad del océano



**Figure 1 | Results of the modelling runs for the shelf seas of 20 large marine ecosystems. a,** Change in temperature (in °C) of the mixed layer in 2050 referenced to the present day control scenario. **b,** Change in total primary production in 2050 (in percentage) referenced to the present day control scenario. Each map reflects ten years of model outputs (modified from ref. 4 with permission from Elsevier).

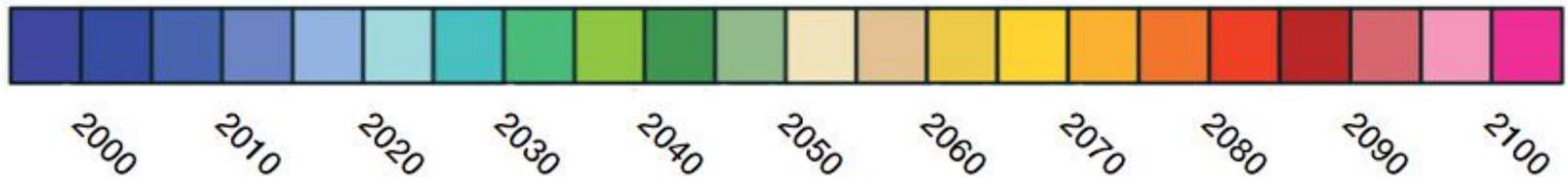
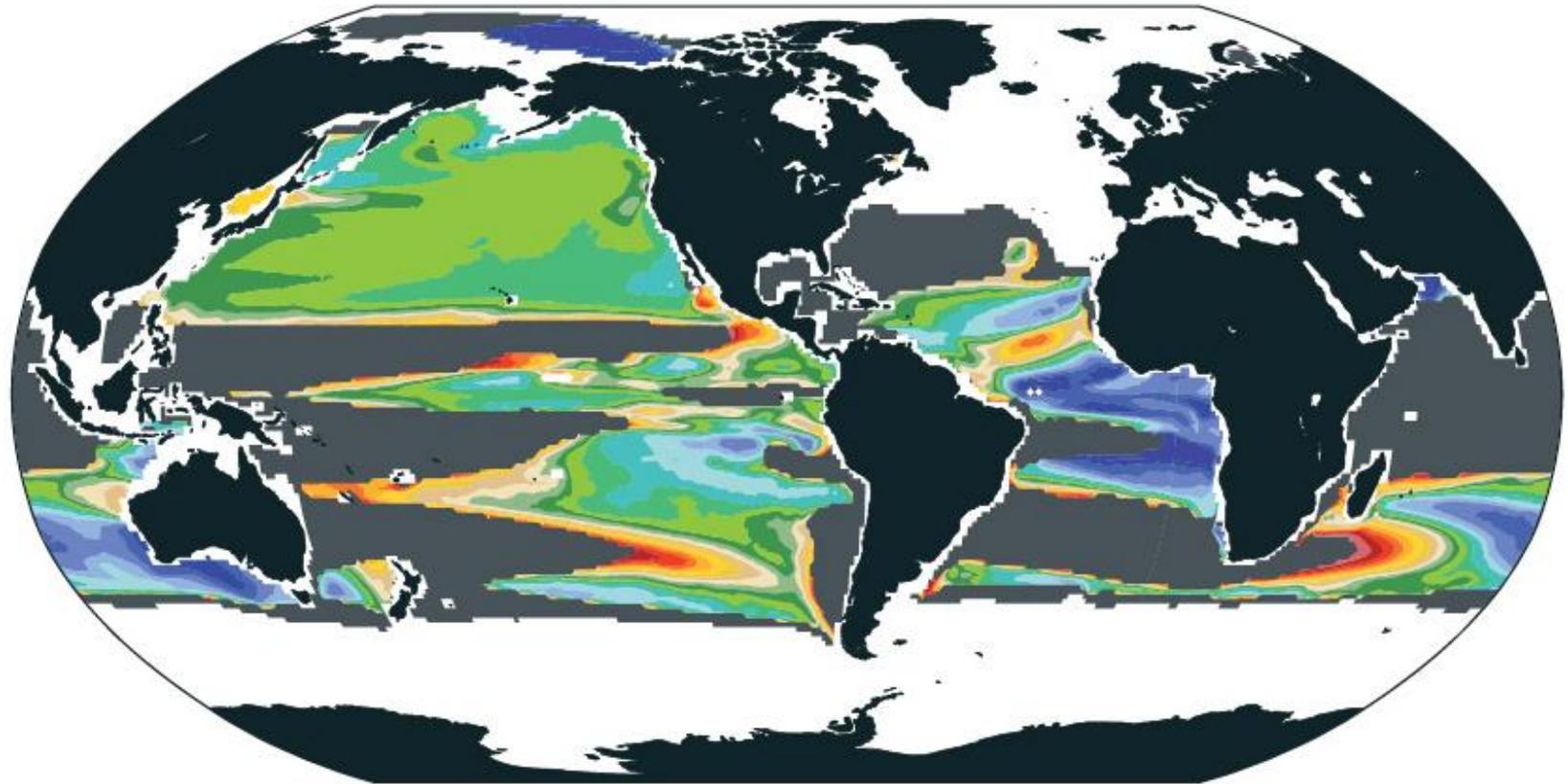


Barange et al., 2014

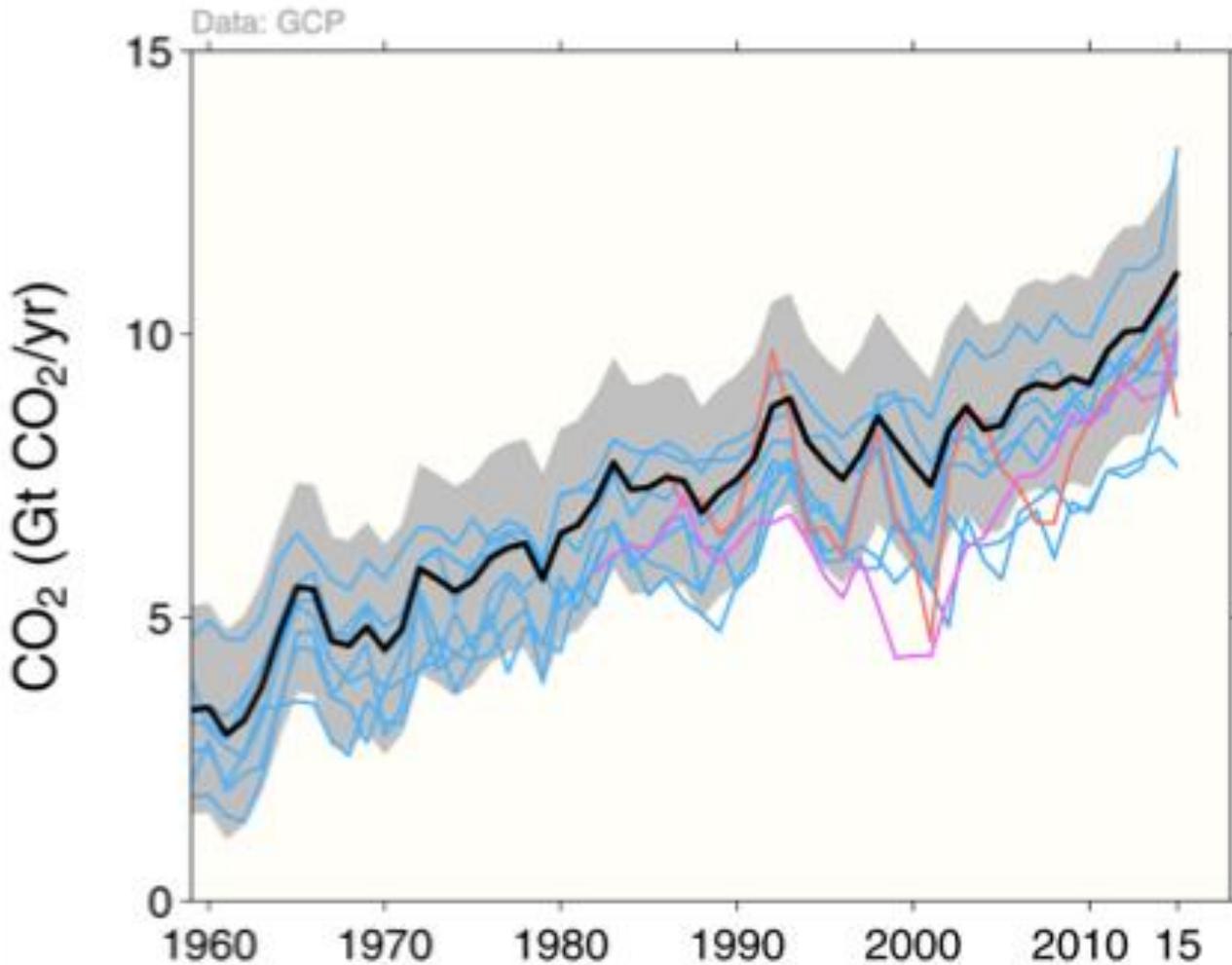
**Figure 4 | Kobe plot of potential catch change and national dependency on fisheries per national EEZ.** Potential catch change is a measure of exposure to climate change. National dependency on fisheries combines the effects of food, economic and employment provision. Circles correspond to the regional centroid, scaled by the expected population in the regions by 2050.

# Oxygen loss in the oceans

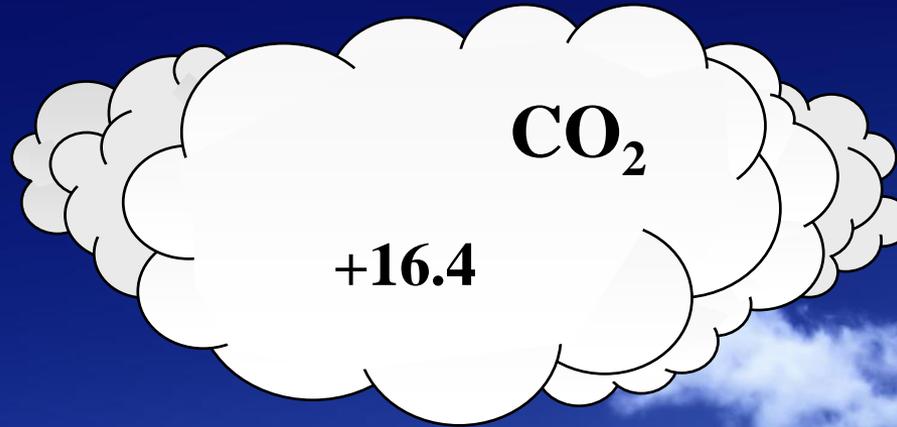
Timeframe when ocean deoxygenation due to climate change is expected to become detectable



# La captura de CO<sub>2</sub> por parte del océano aumenta progresivamente

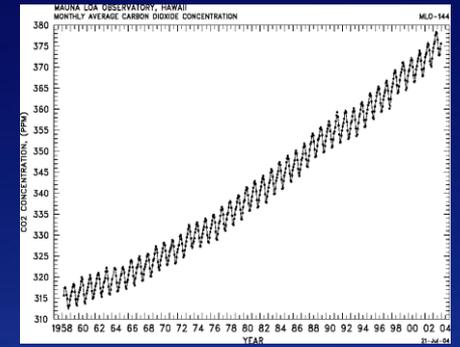


Gt CO<sub>2</sub>/año

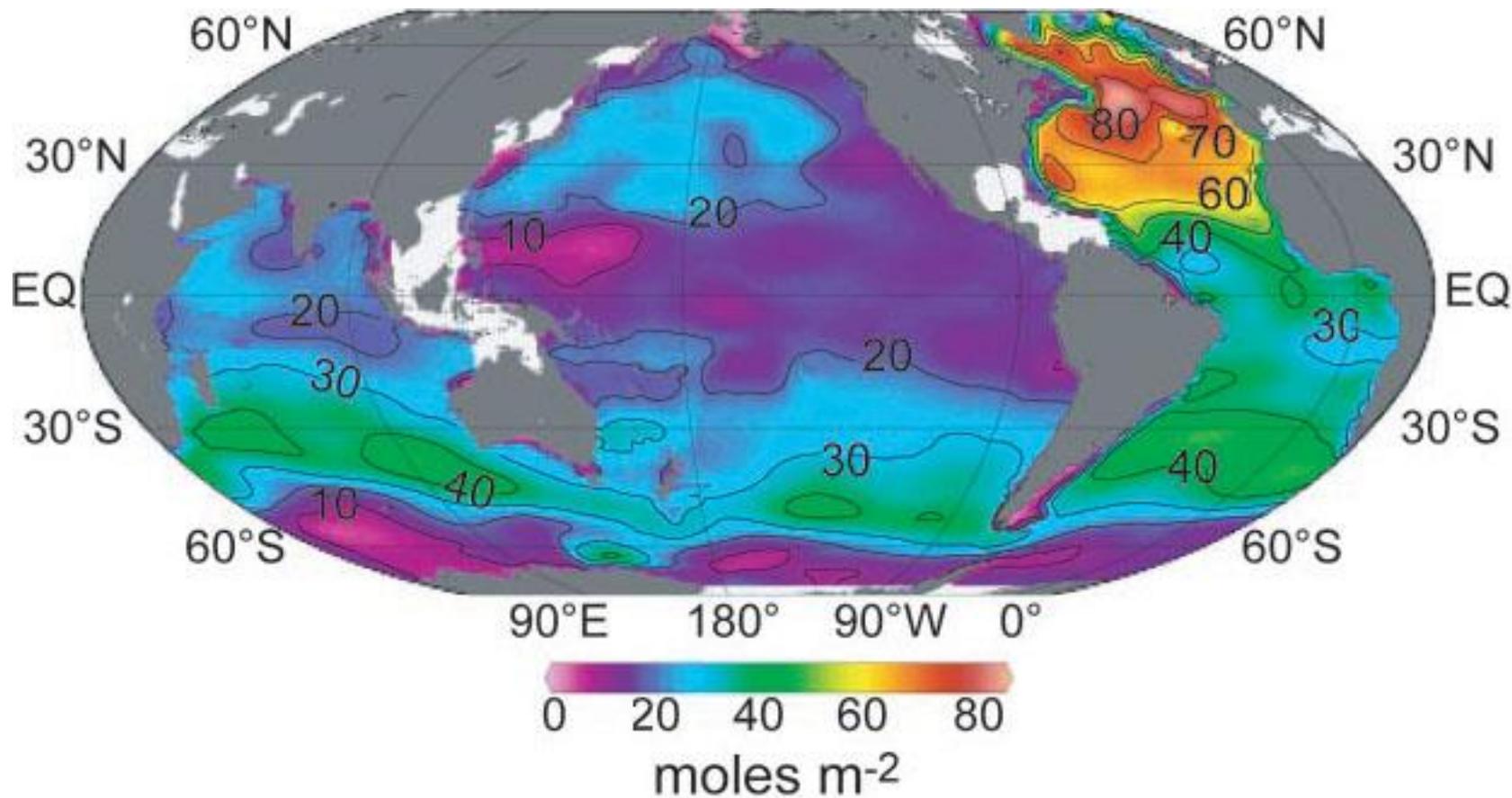


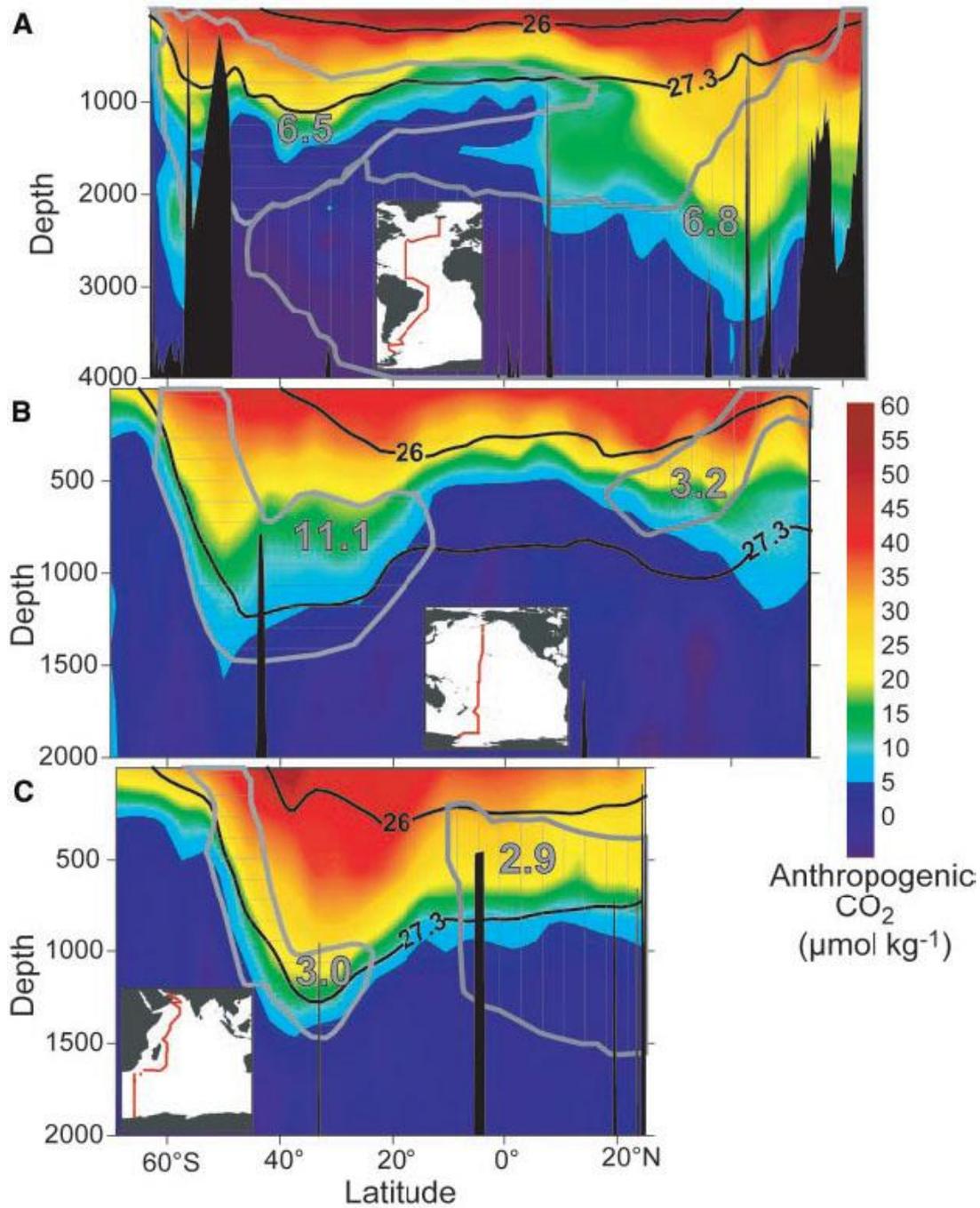
+9.7

CO<sub>2</sub>

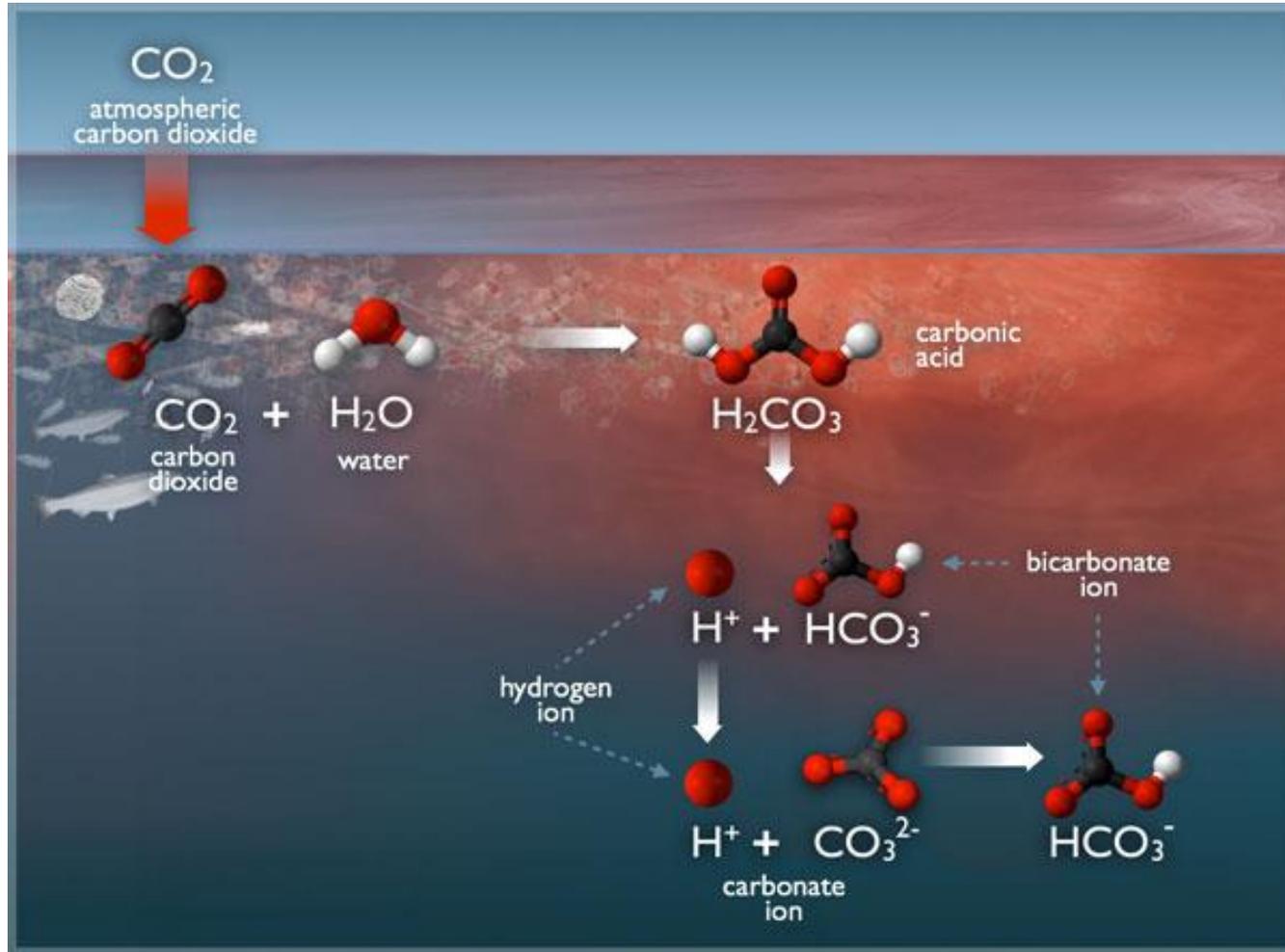


# Carbono antropogénico en el océano

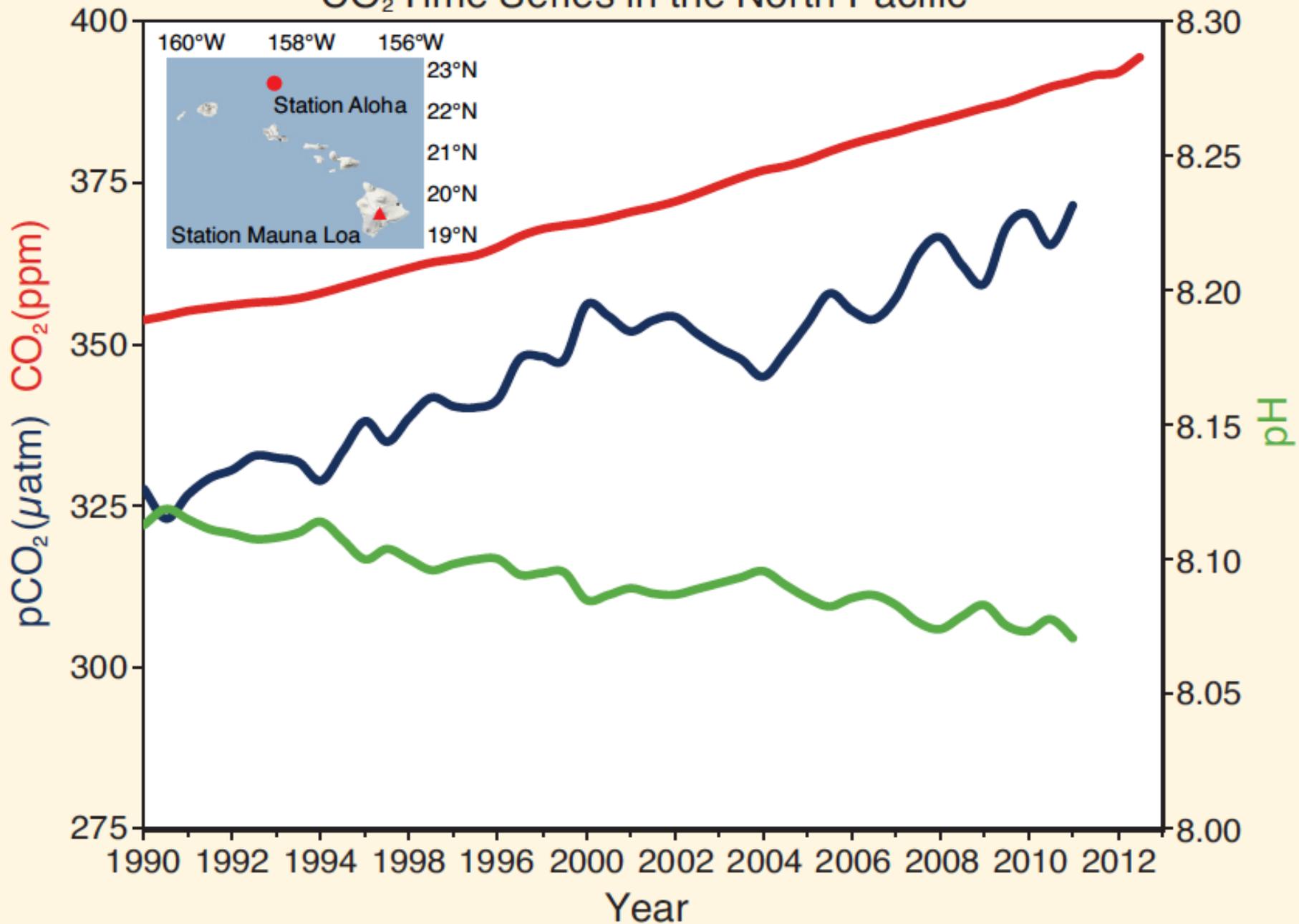




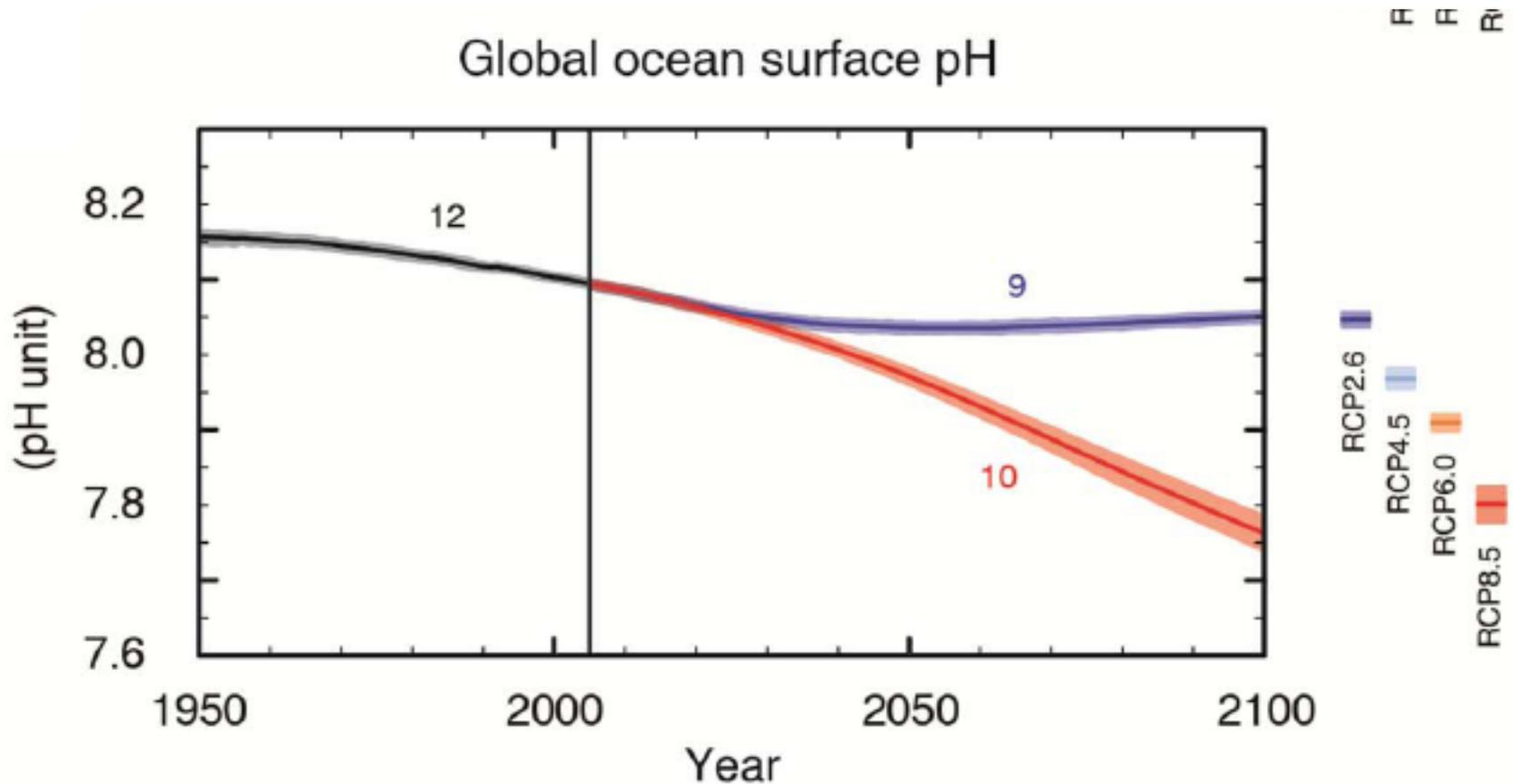
# El océano se enriquece en CO<sub>2</sub> y se hace mas ácido



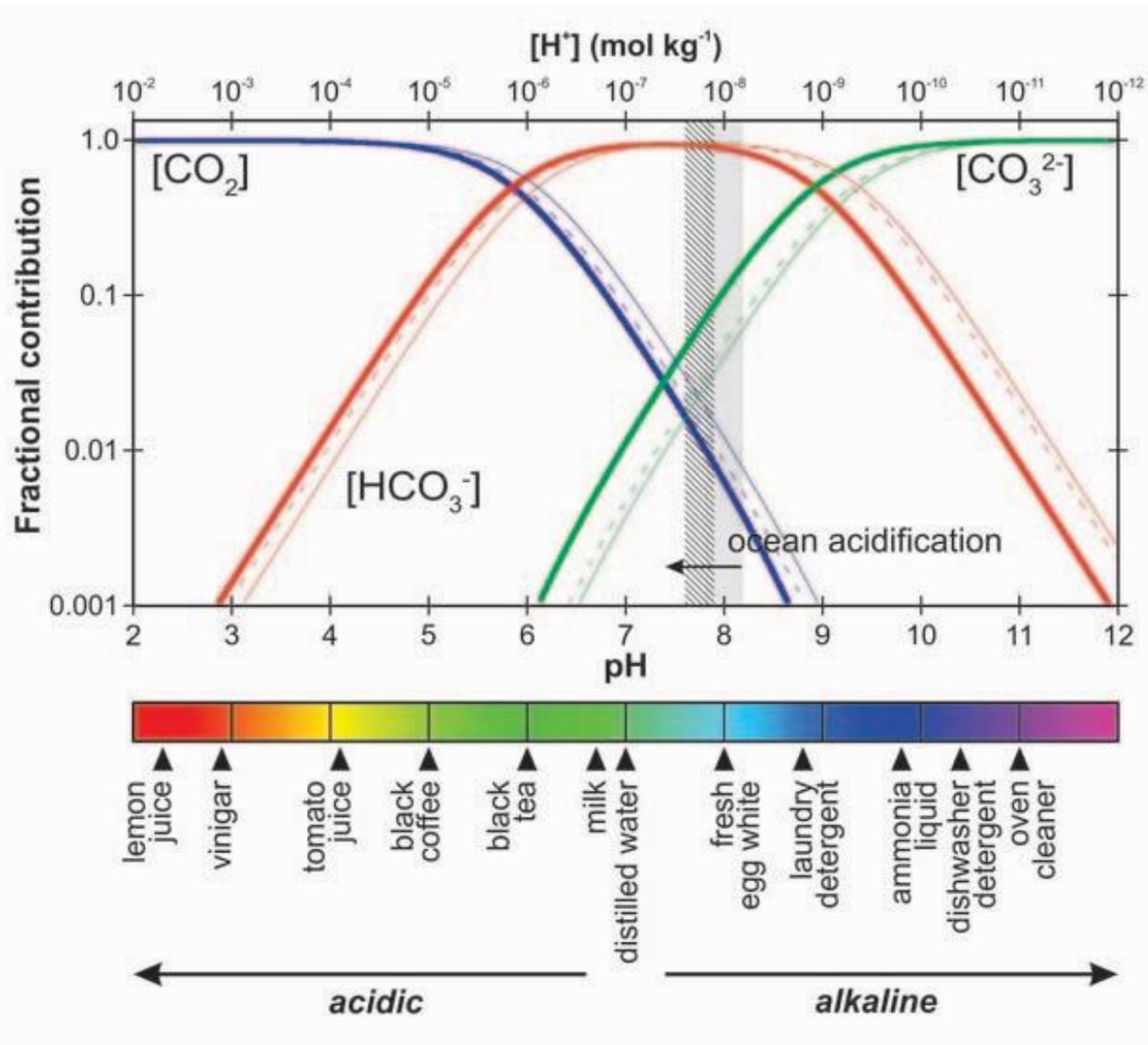
# CO<sub>2</sub> Time Series in the North Pacific



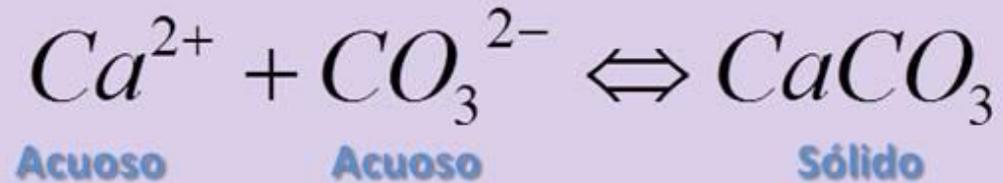
# El océano se enriquece en CO<sub>2</sub> y se hace mas ácido



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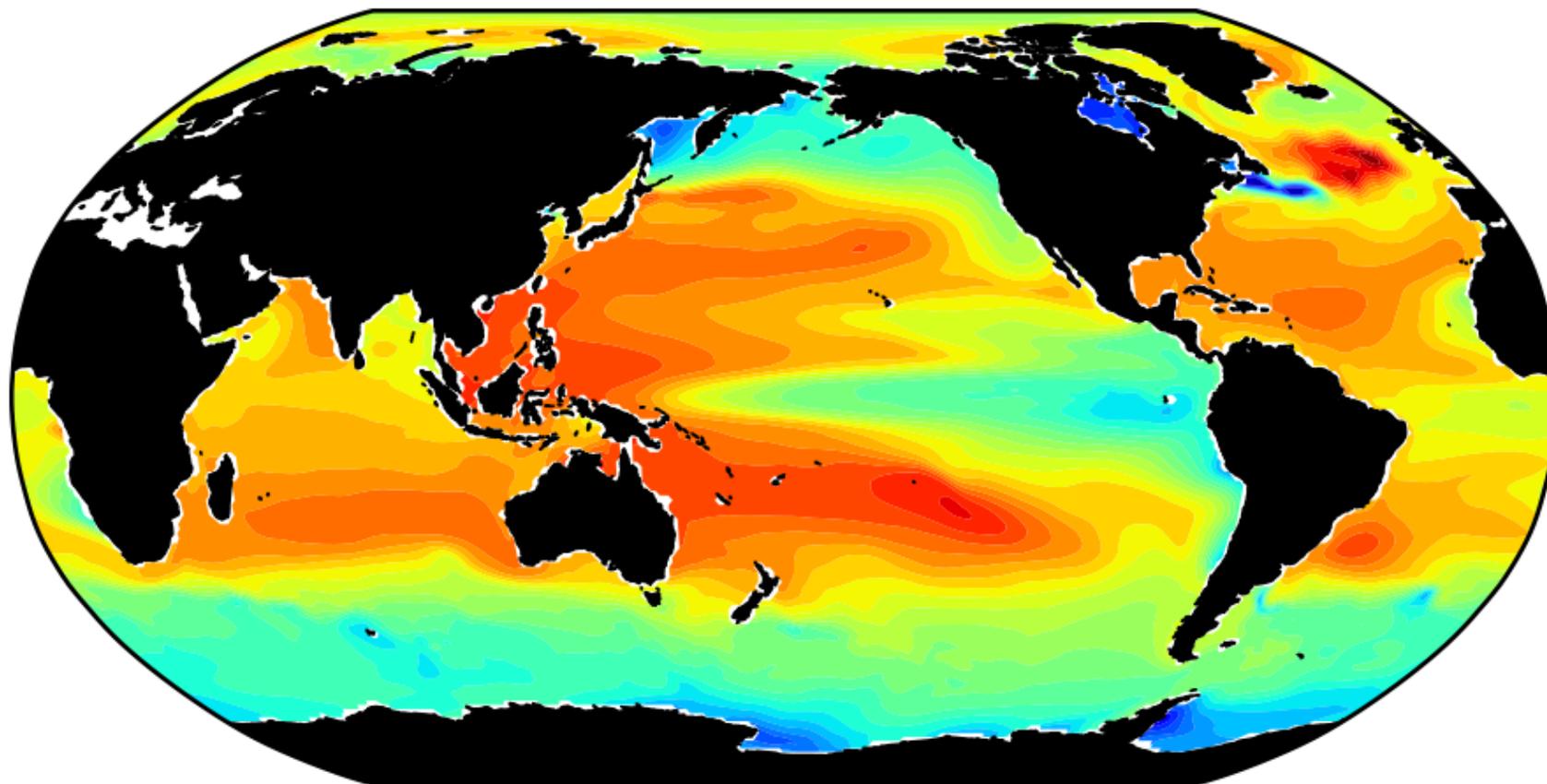
# Calcificación y estado de saturación



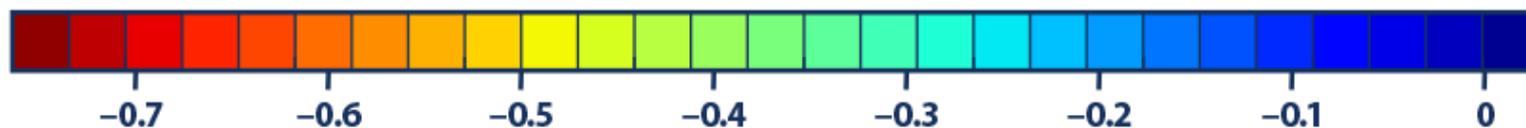
**Ecuación 2. Reacción de precipitación y/o disolución de la aragonita en el agua marina**



## Changes in Aragonite Saturation of the World's Oceans, 1880–2015



Change in aragonite saturation at the ocean surface ( $\Omega_{ar}$ ):



Data source: Woods Hole Oceanographic Institution. 2016 update to data originally published in: Feely, R.A., S.C. Doney, and S.R. Cooley. 2009. Ocean acidification: Present conditions and future changes in a high- $\text{CO}_2$  world. *Oceanography* 22(4):36–47.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at [www.epa.gov/climate-indicators](http://www.epa.gov/climate-indicators).

# La acidificación oceánica afecta a la calcificación

pH = 8.2



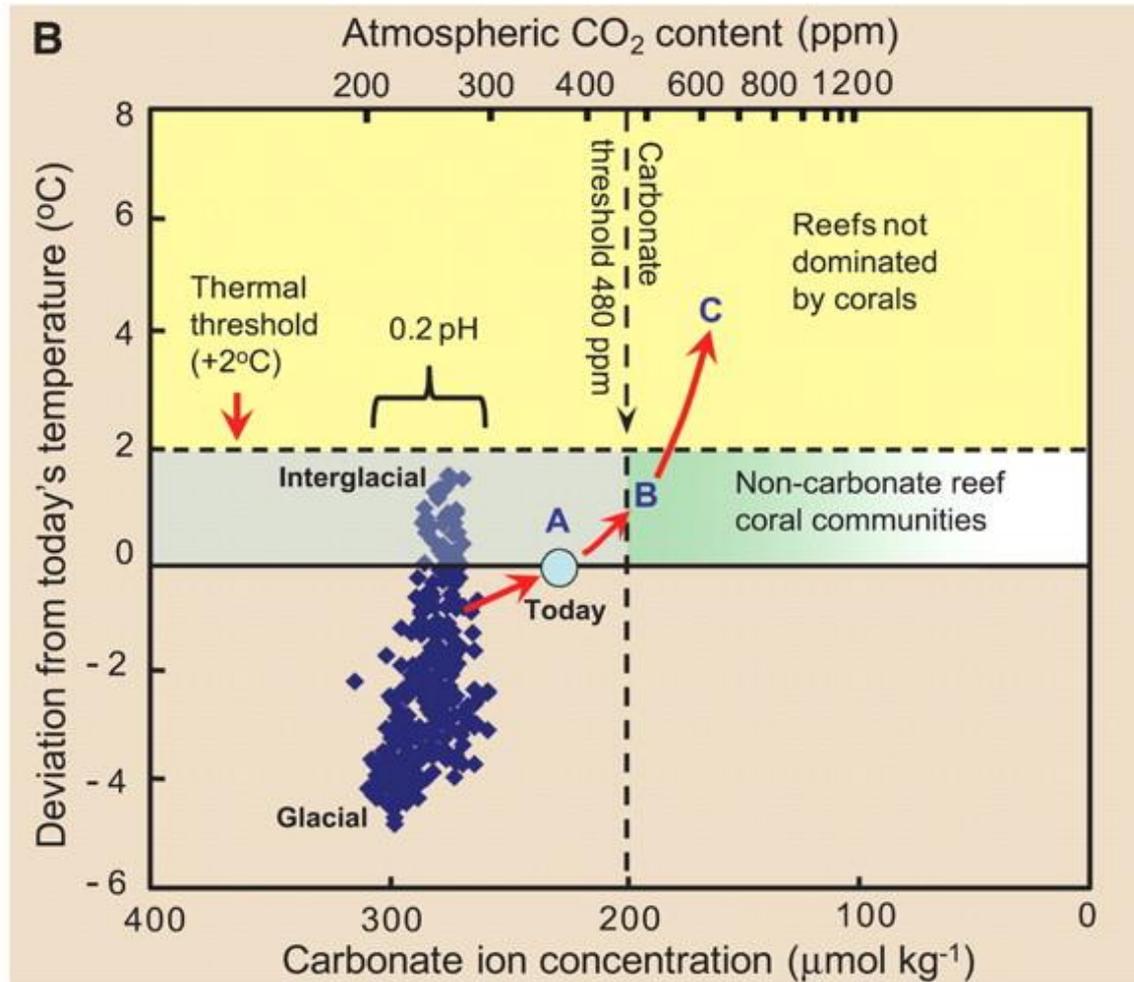
*Coral Oculina patagonica*

pH = 7.4

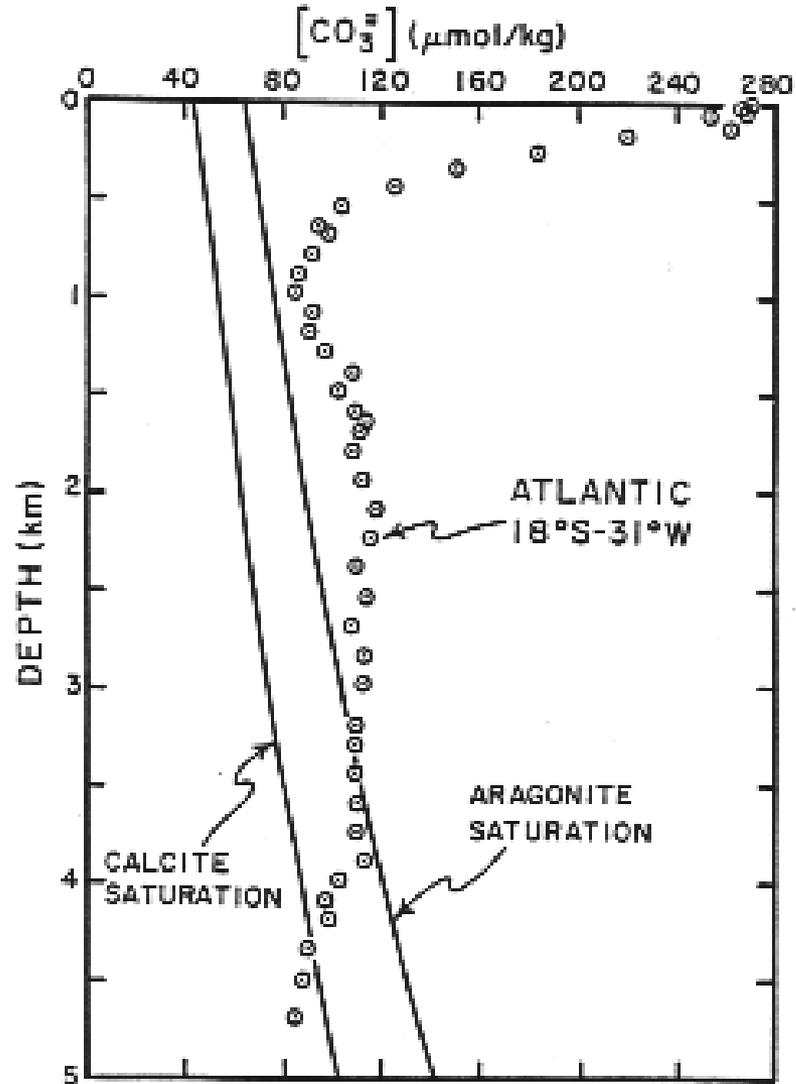


Fine & Tchernov (2007)

# La acidificación oceánica afecta a la calcificación



# Variación en profundidad del estado de saturación de la calcita y el aragonito



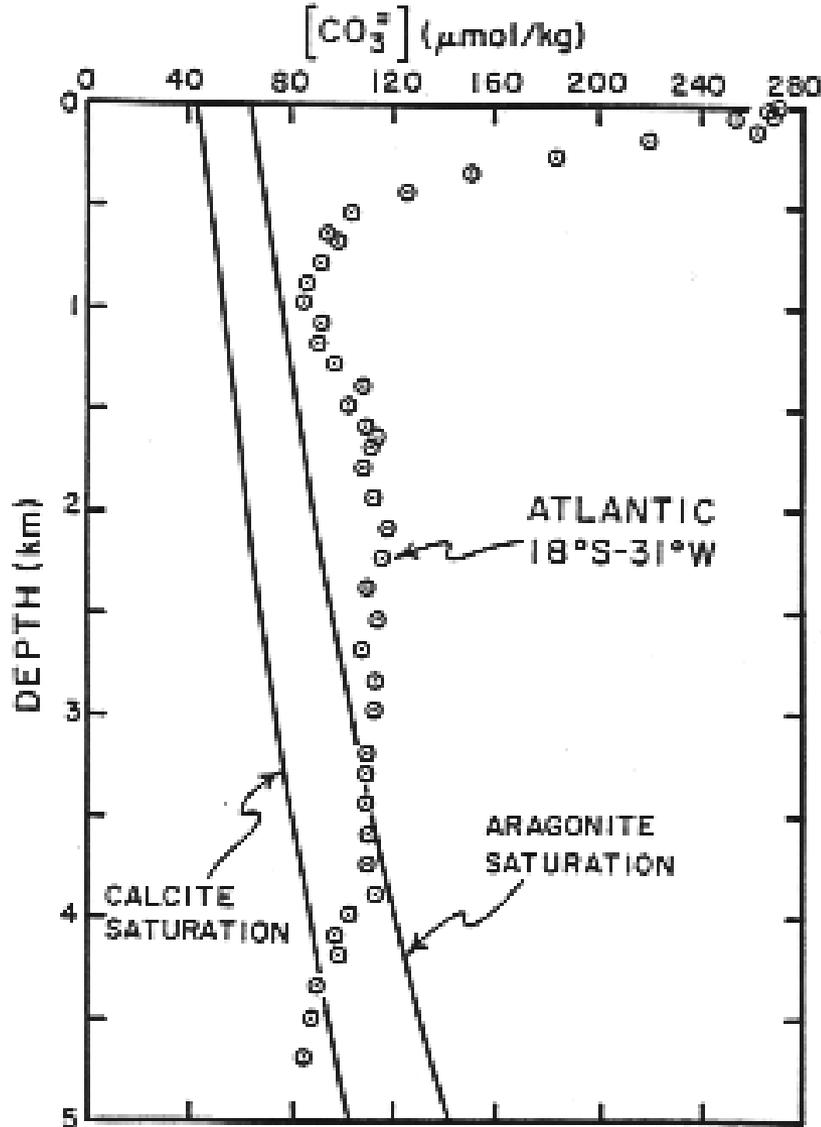


Acc.V	Spot	Magn	Det	WD		2 $\mu$ m
5.00 kV	3.0	6500x	SE	10.0	JRY 218	



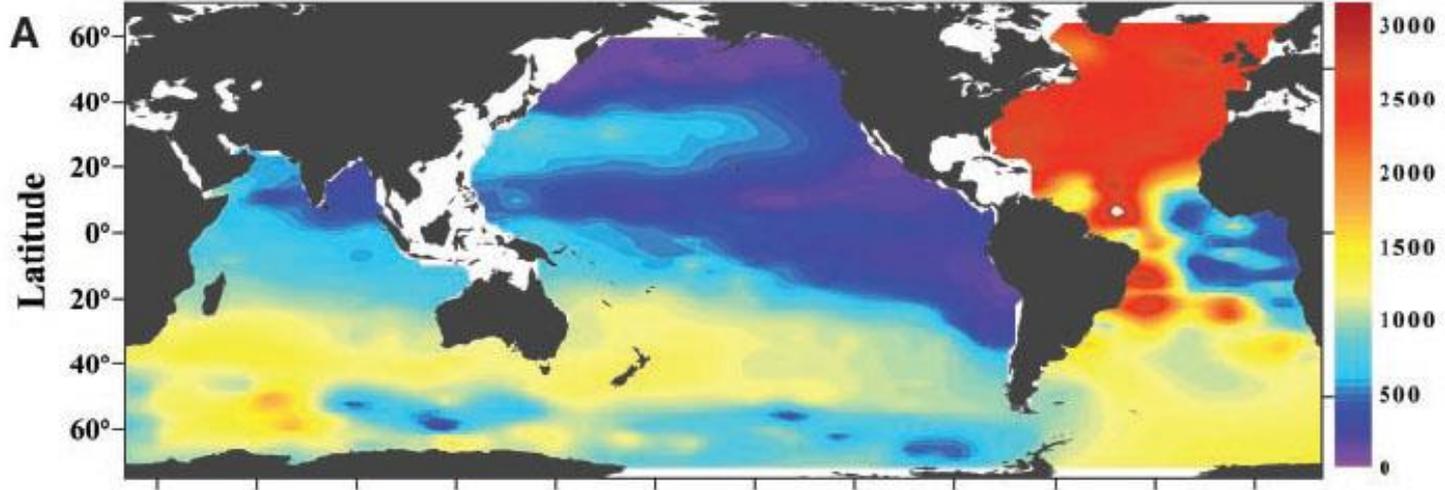
©2012 Smithsonian K.J. Osborn

# Profundidad de saturación de la calcita y el aragonito

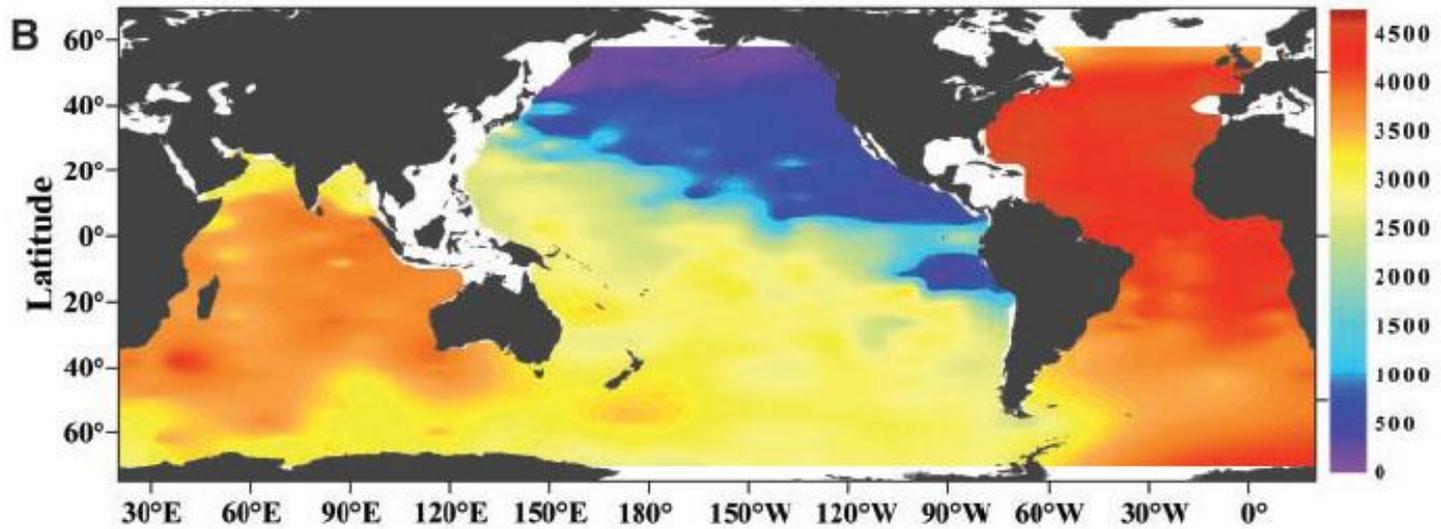


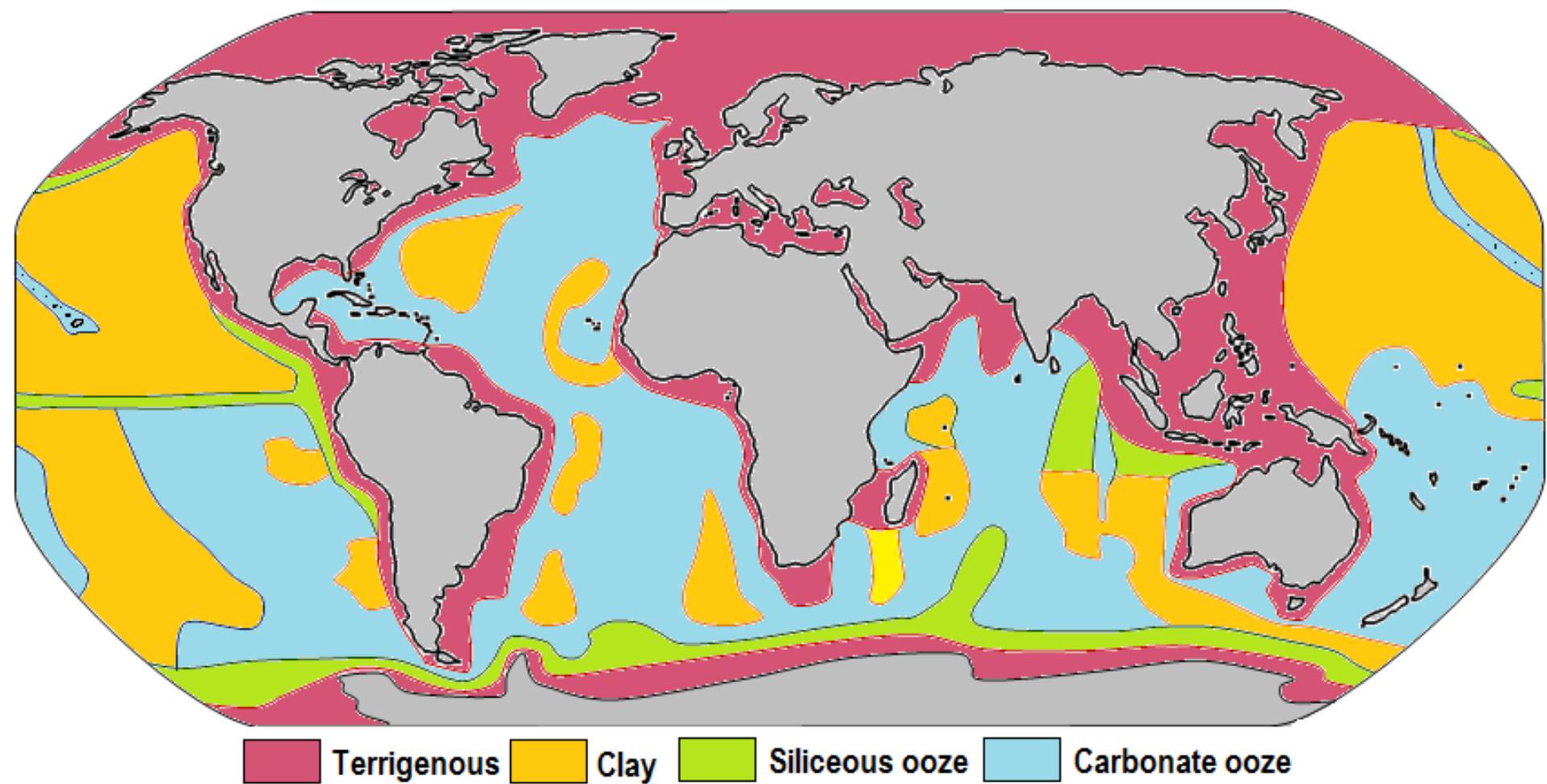
Ecuación 2. Reacción de precipitación y/o disolución de la aragonita en el agua marina

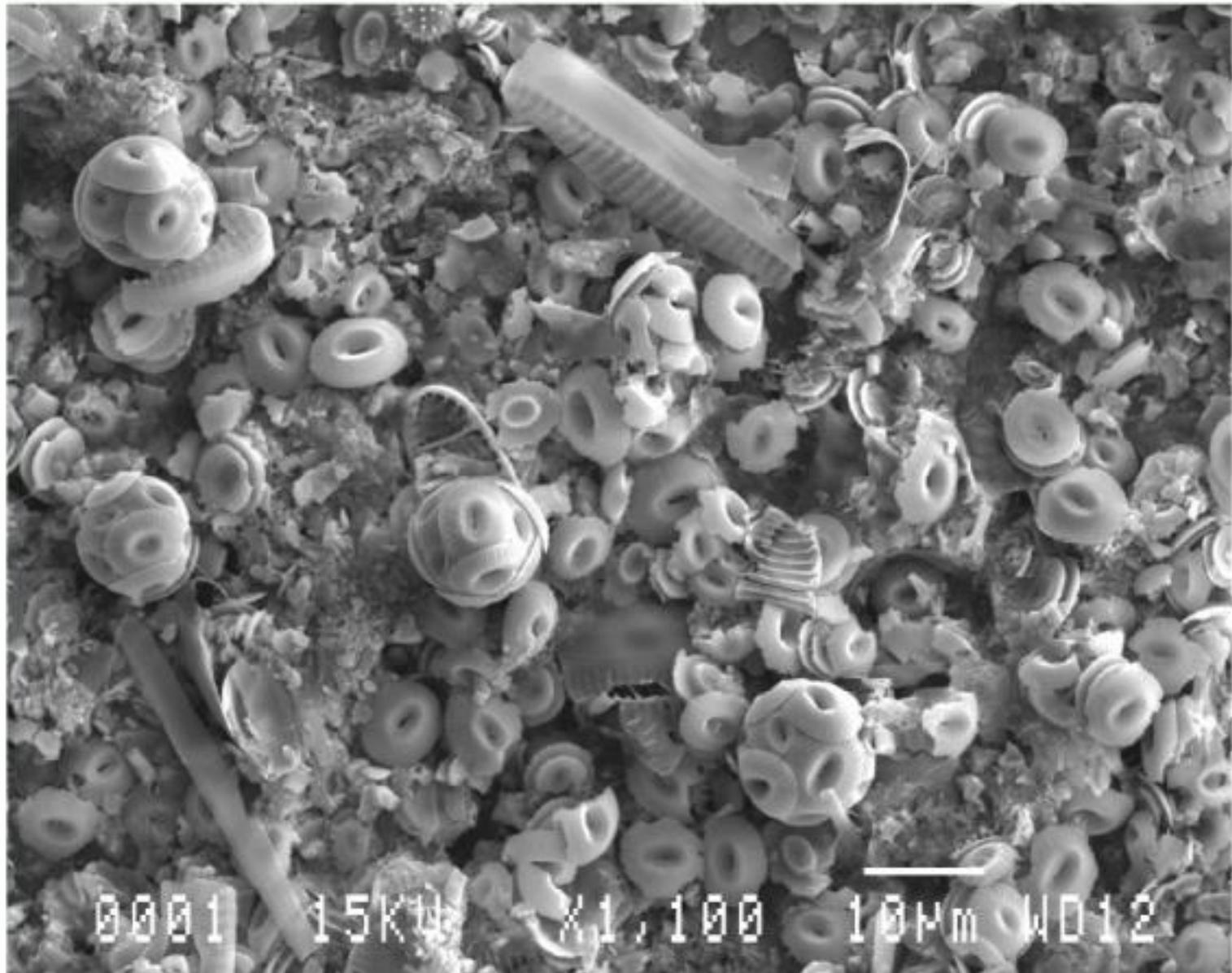
### Aragonite Saturation Depth



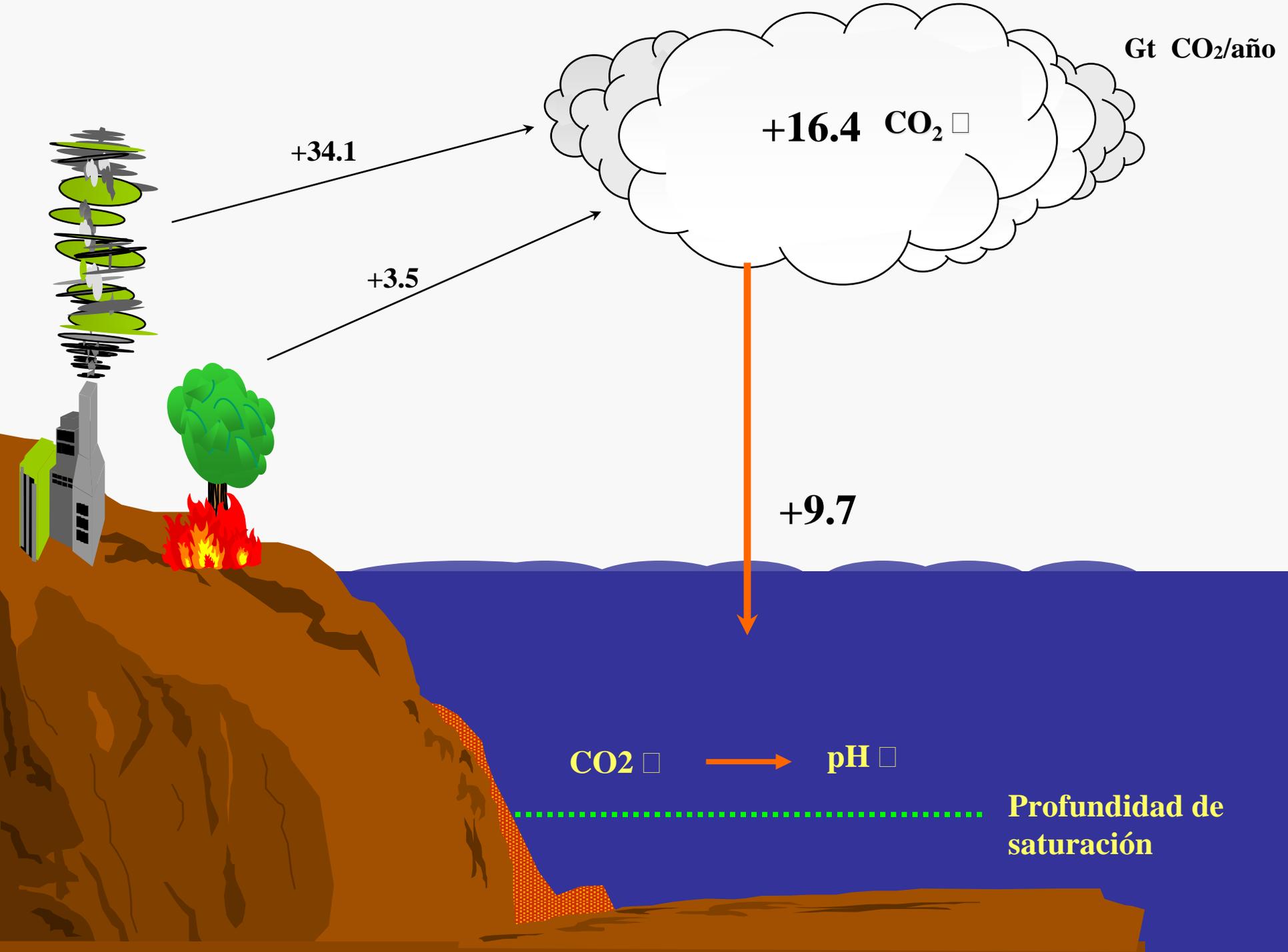
### Calcite Saturation Depth

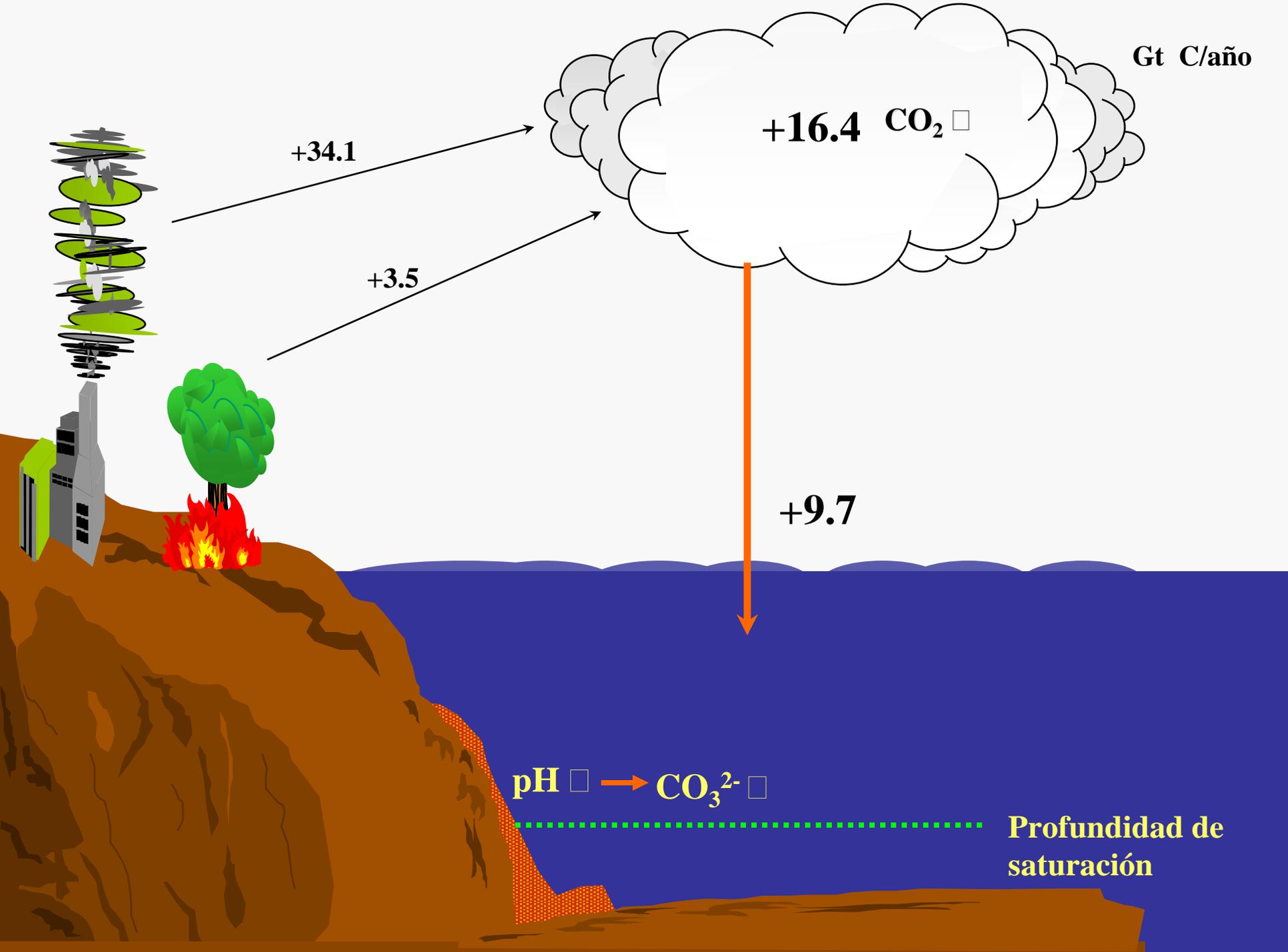






0001 15KV X1,100 10µm WD12





Gt C/año

+34.1

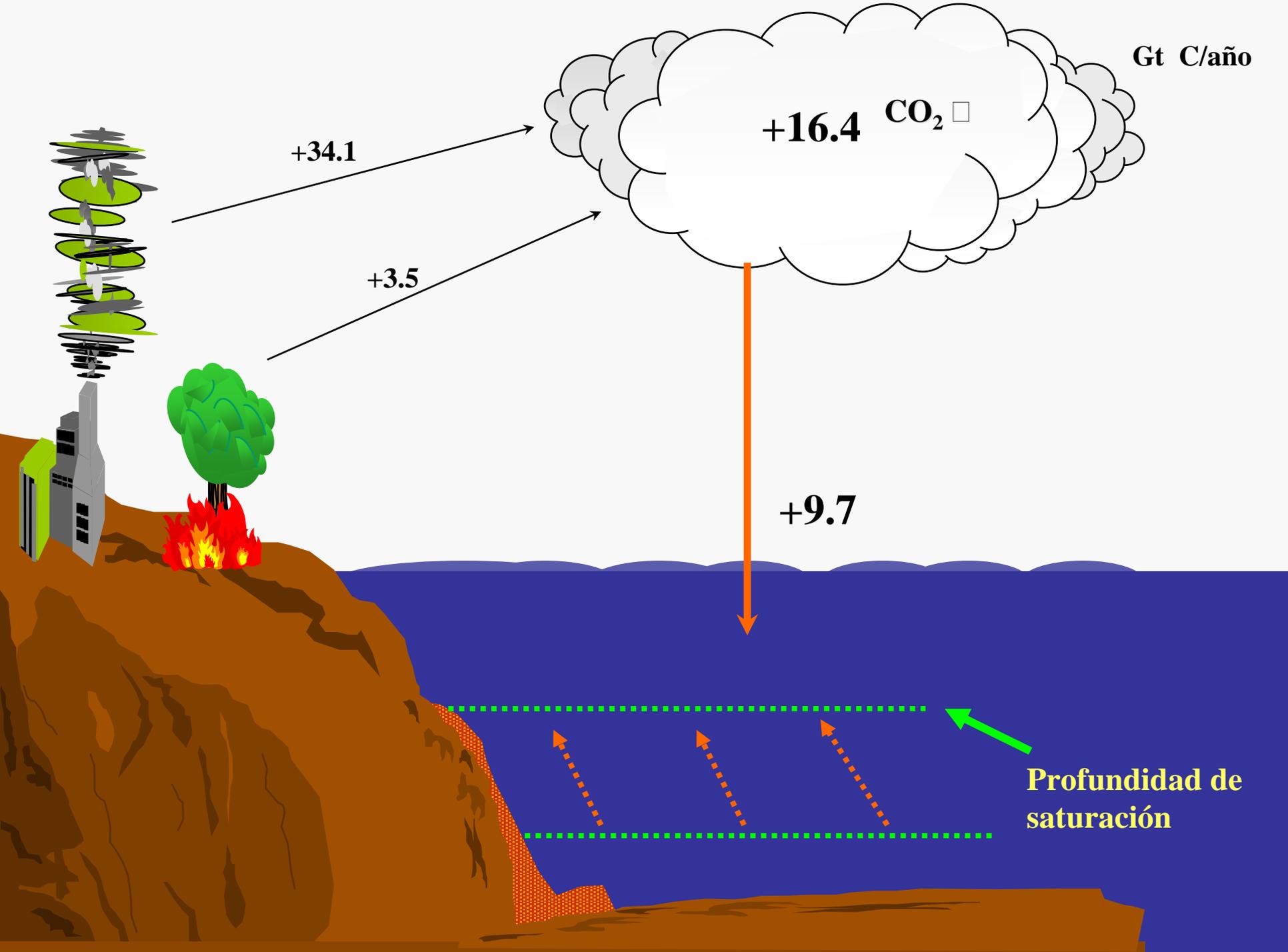
+3.5

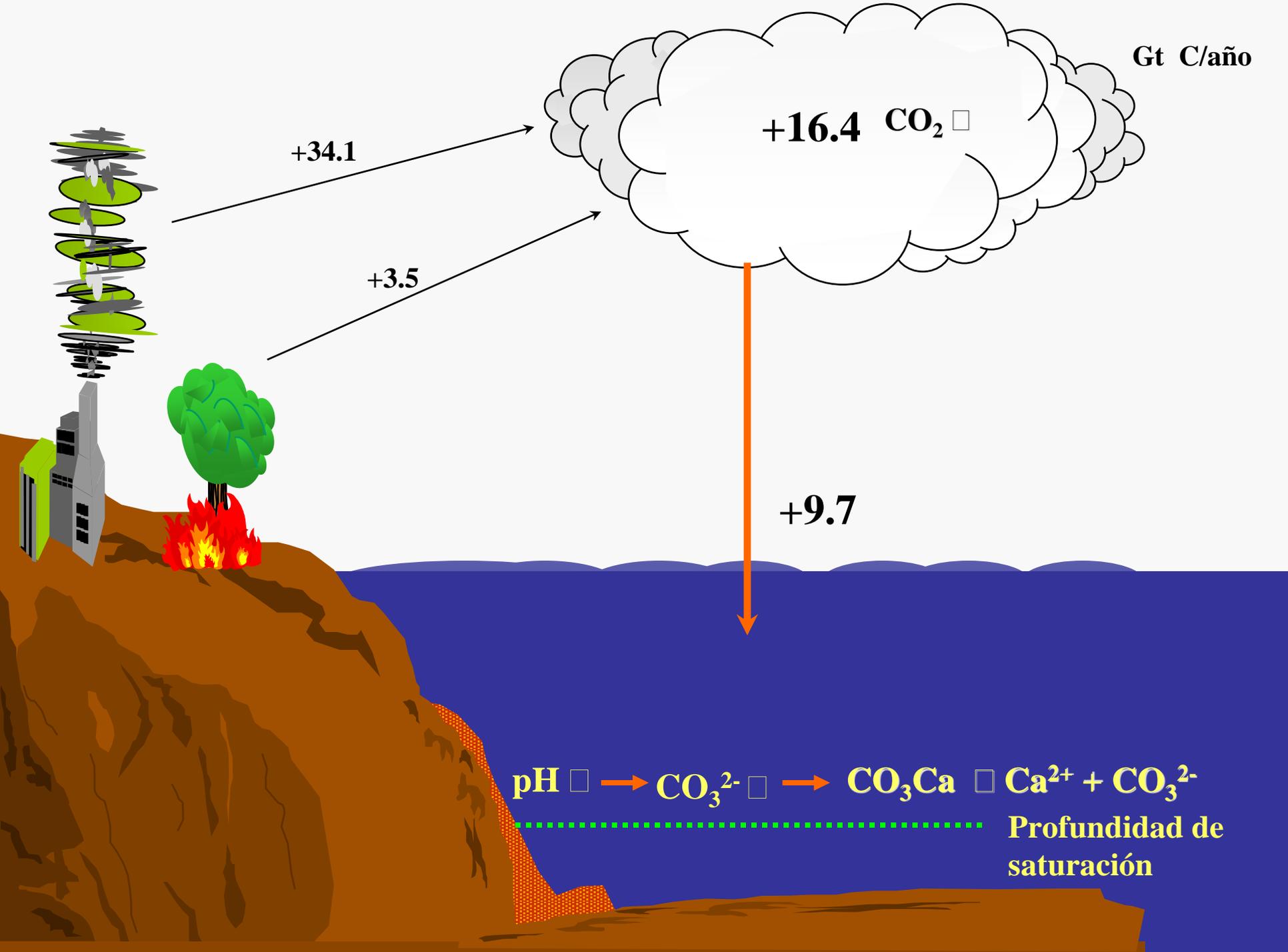
+16.4 CO<sub>2</sub> □

+9.7

pH □ → CO<sub>3</sub><sup>2-</sup> □

Profundidad de saturación





Gt C/año

+16.4 CO<sub>2</sub> □

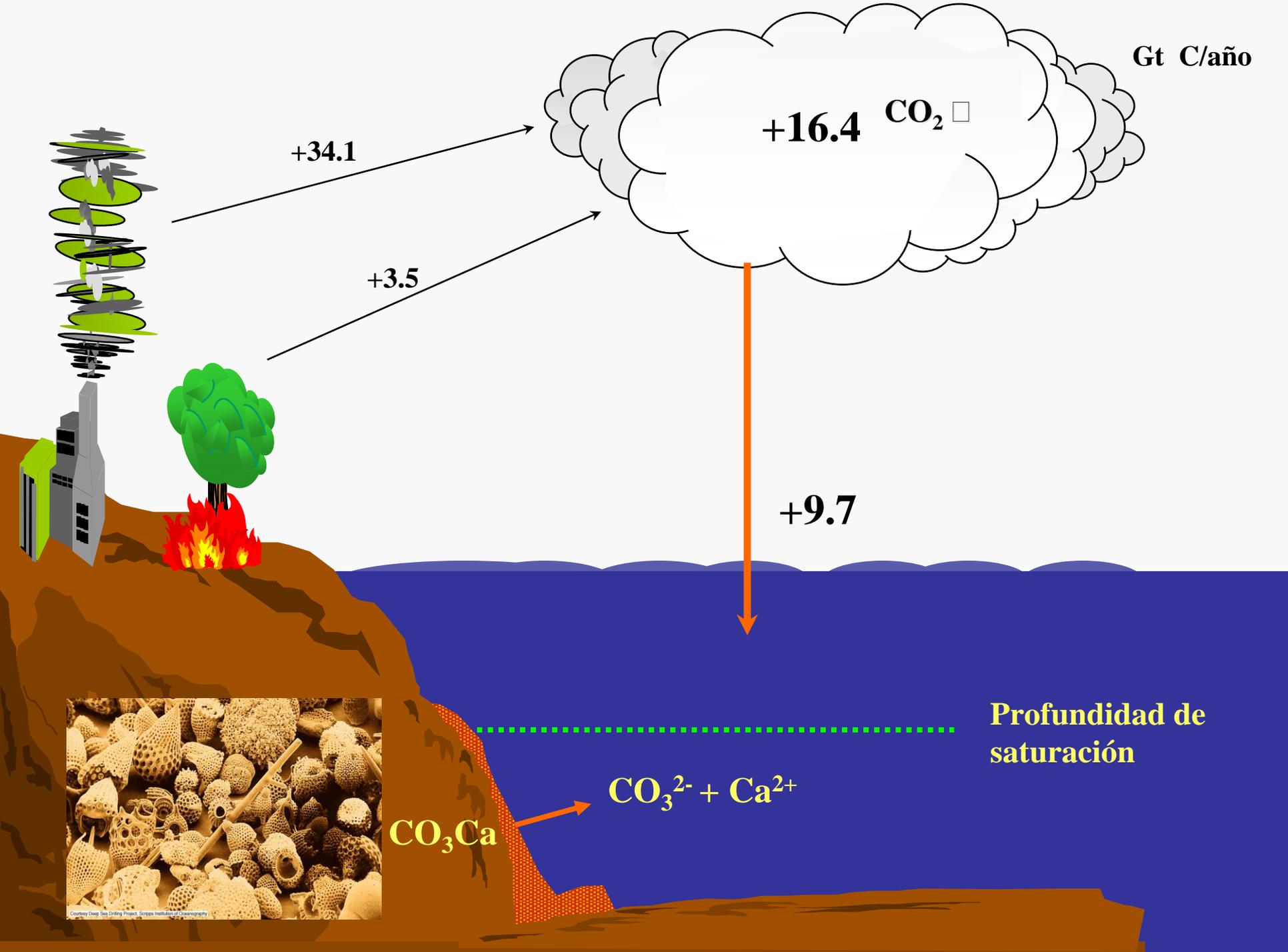
+34.1

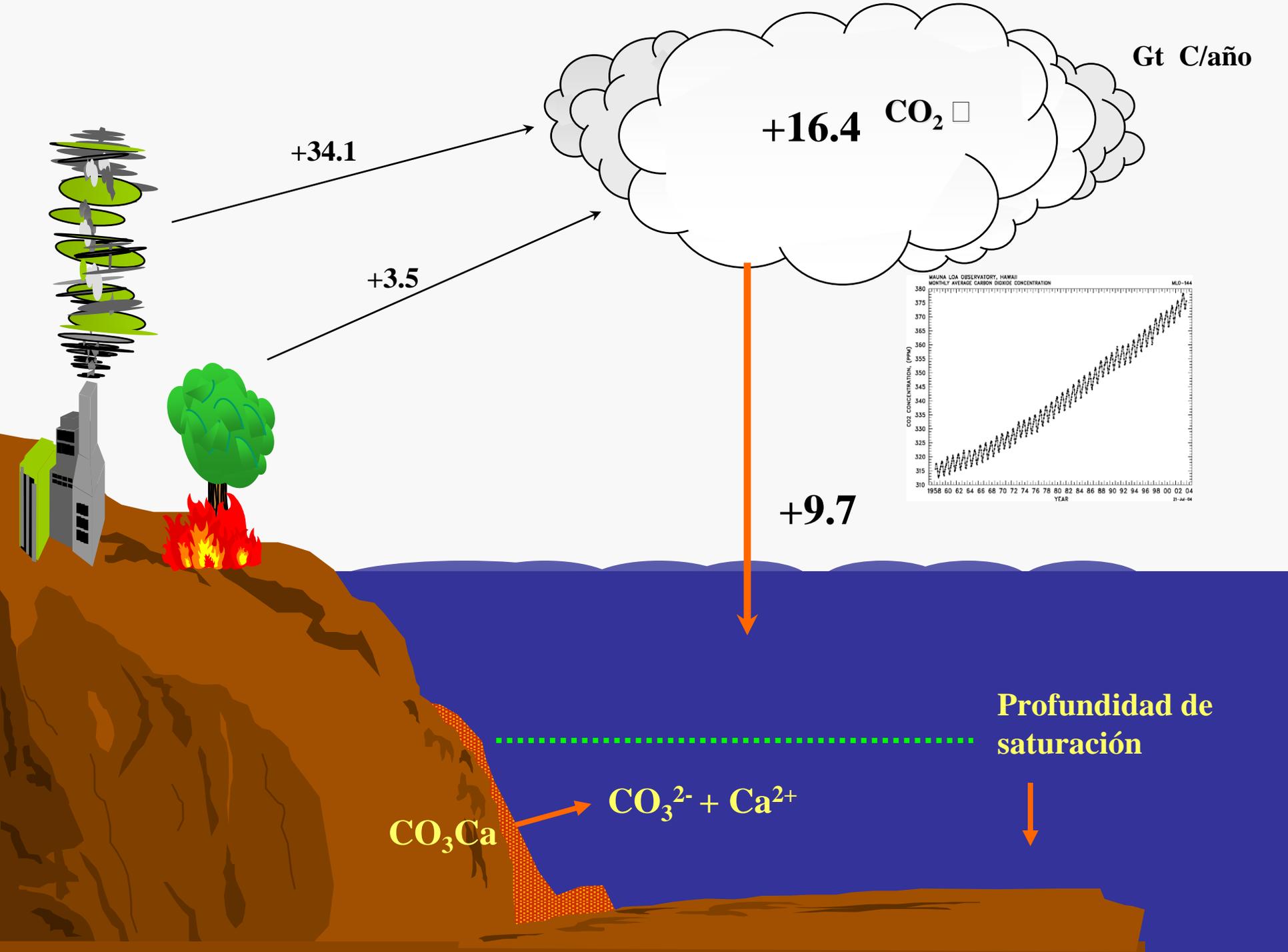
+3.5

+9.7



Profundidad de saturación





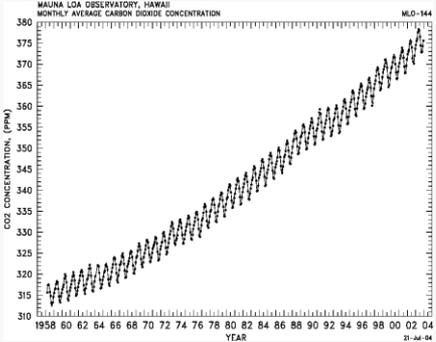
Gt C/año

+16.4 CO<sub>2</sub> ☐

+34.1

+3.5

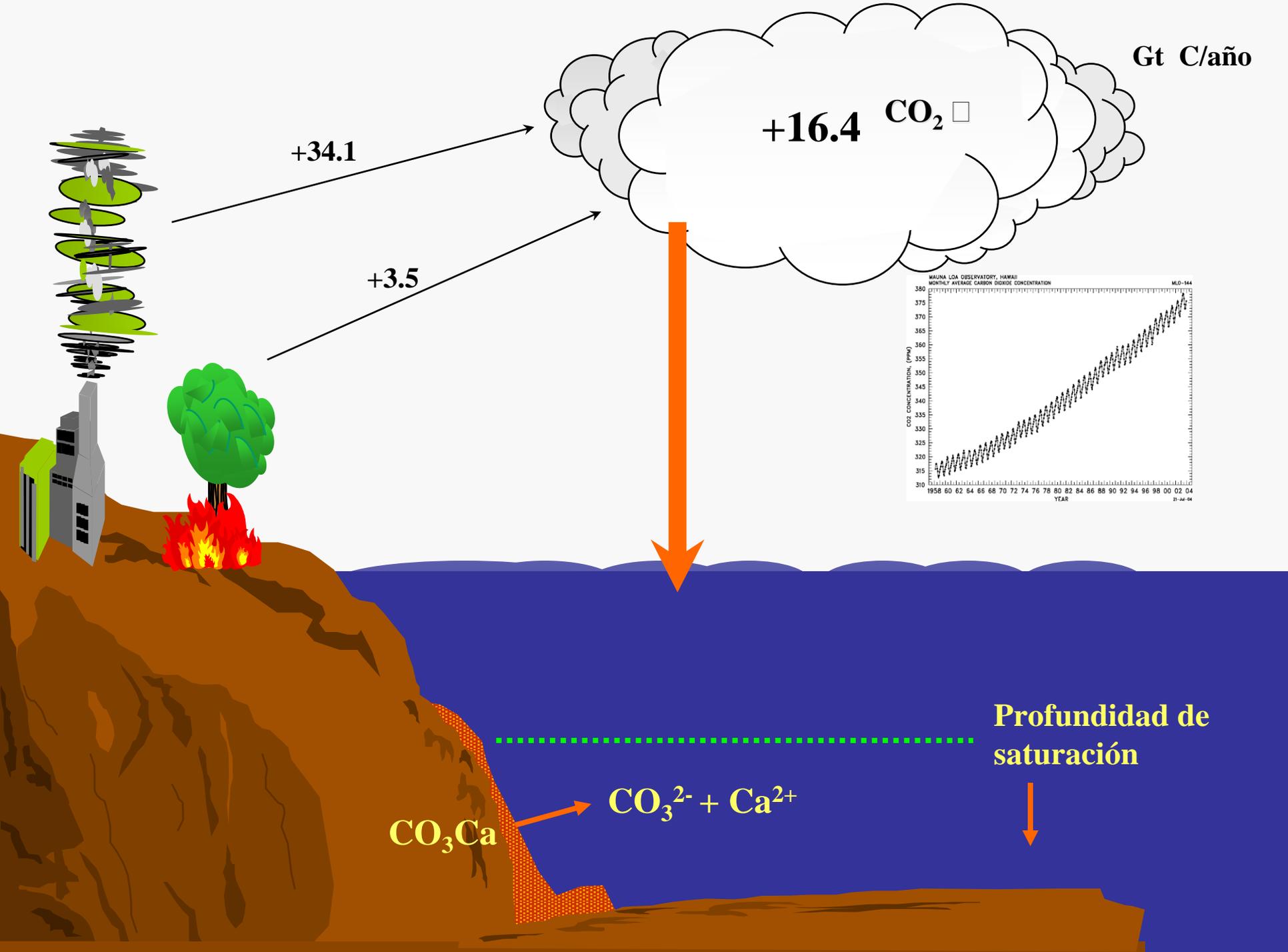
+9.7



Profundidad de saturación

CO<sub>3</sub>Ca

CO<sub>3</sub><sup>2-</sup> + Ca<sup>2+</sup>

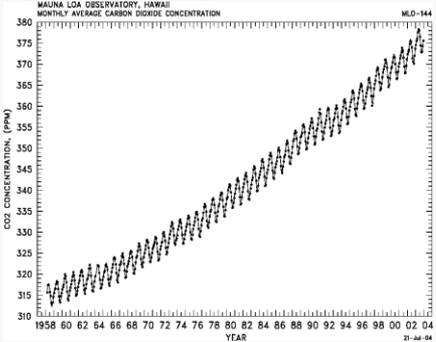


Gt C/año

+16.4 CO<sub>2</sub> □

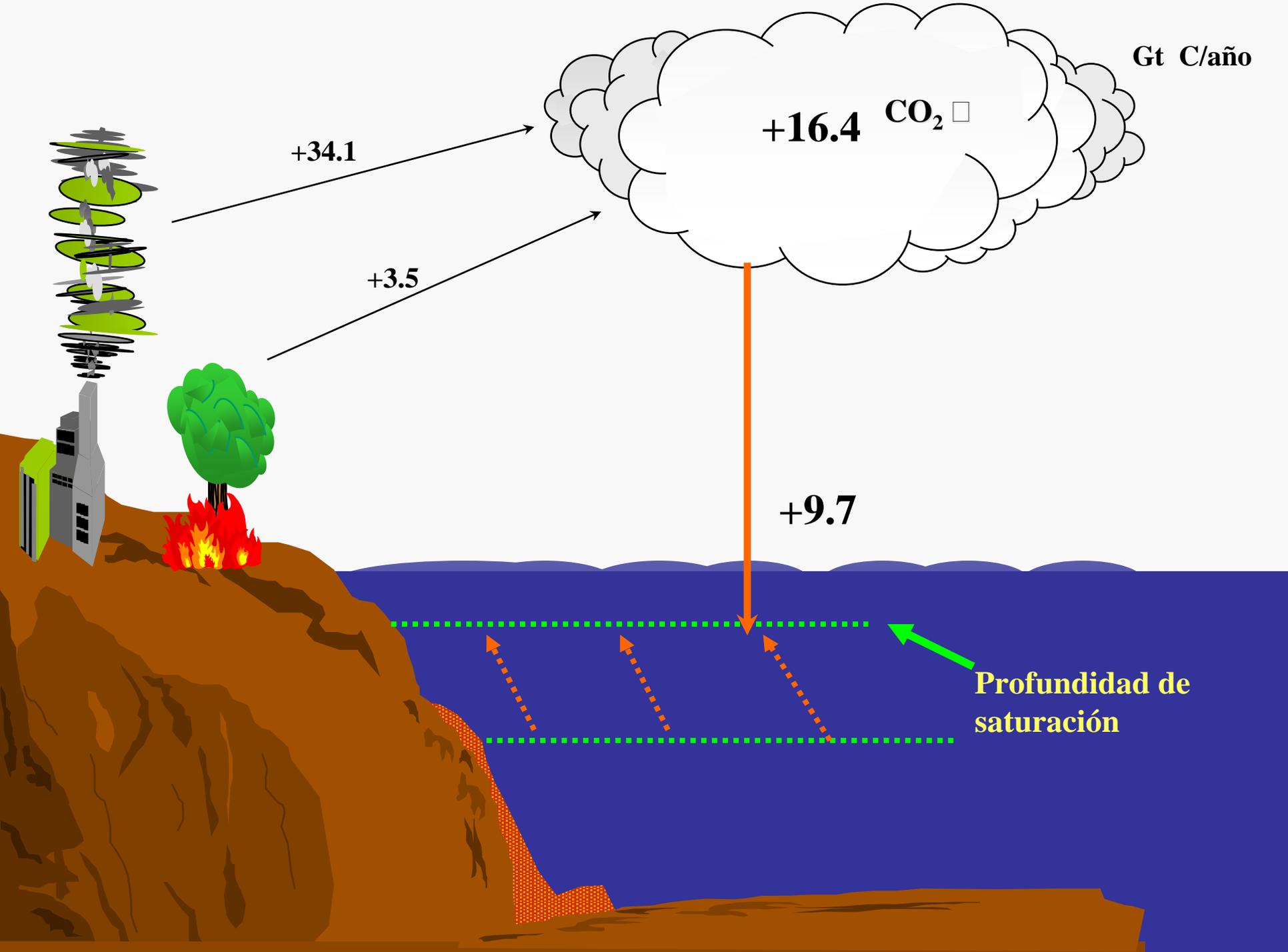
+34.1

+3.5



Profundidad de saturación





Gt C/año

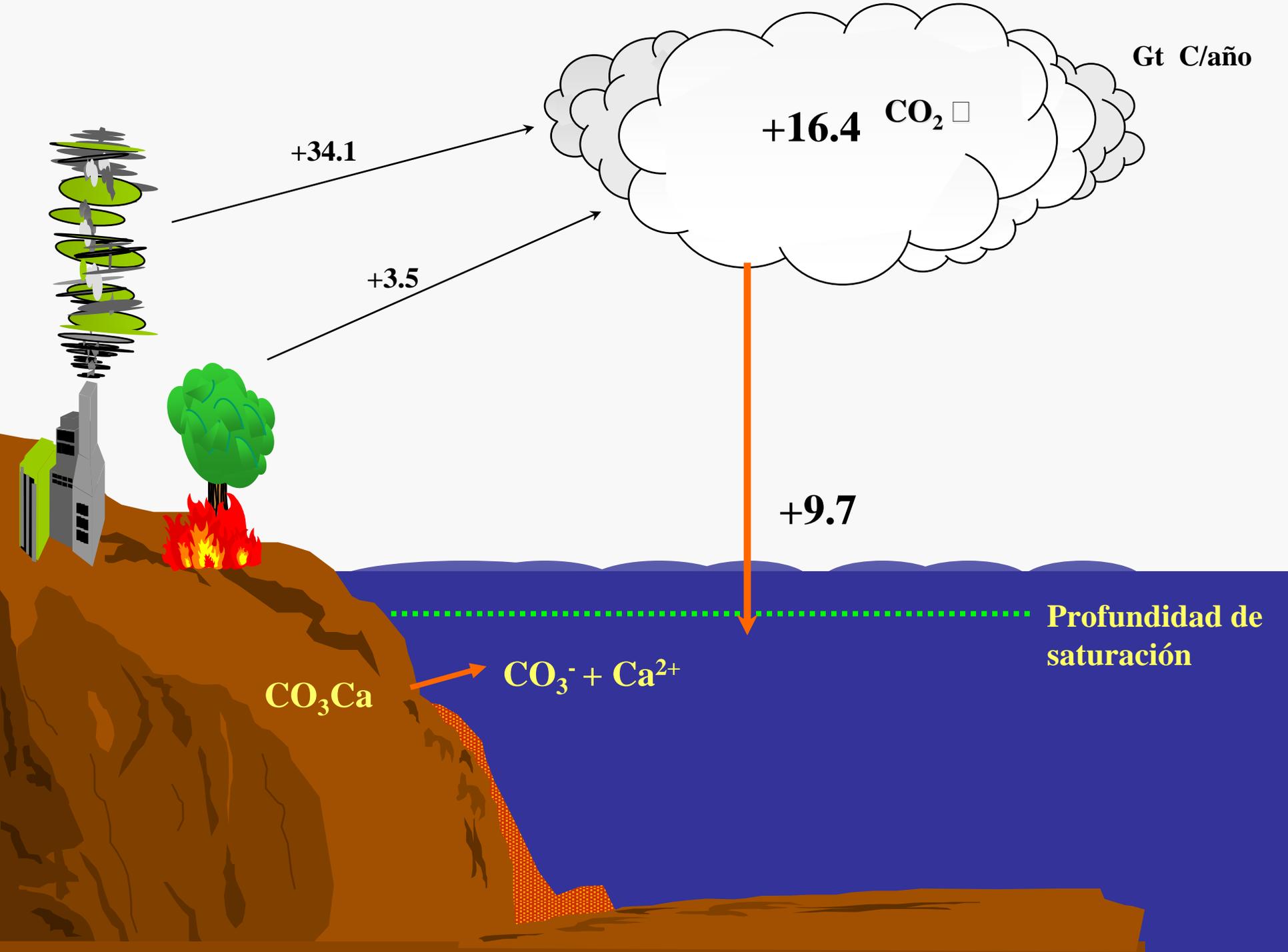
**+16.4** CO<sub>2</sub> □

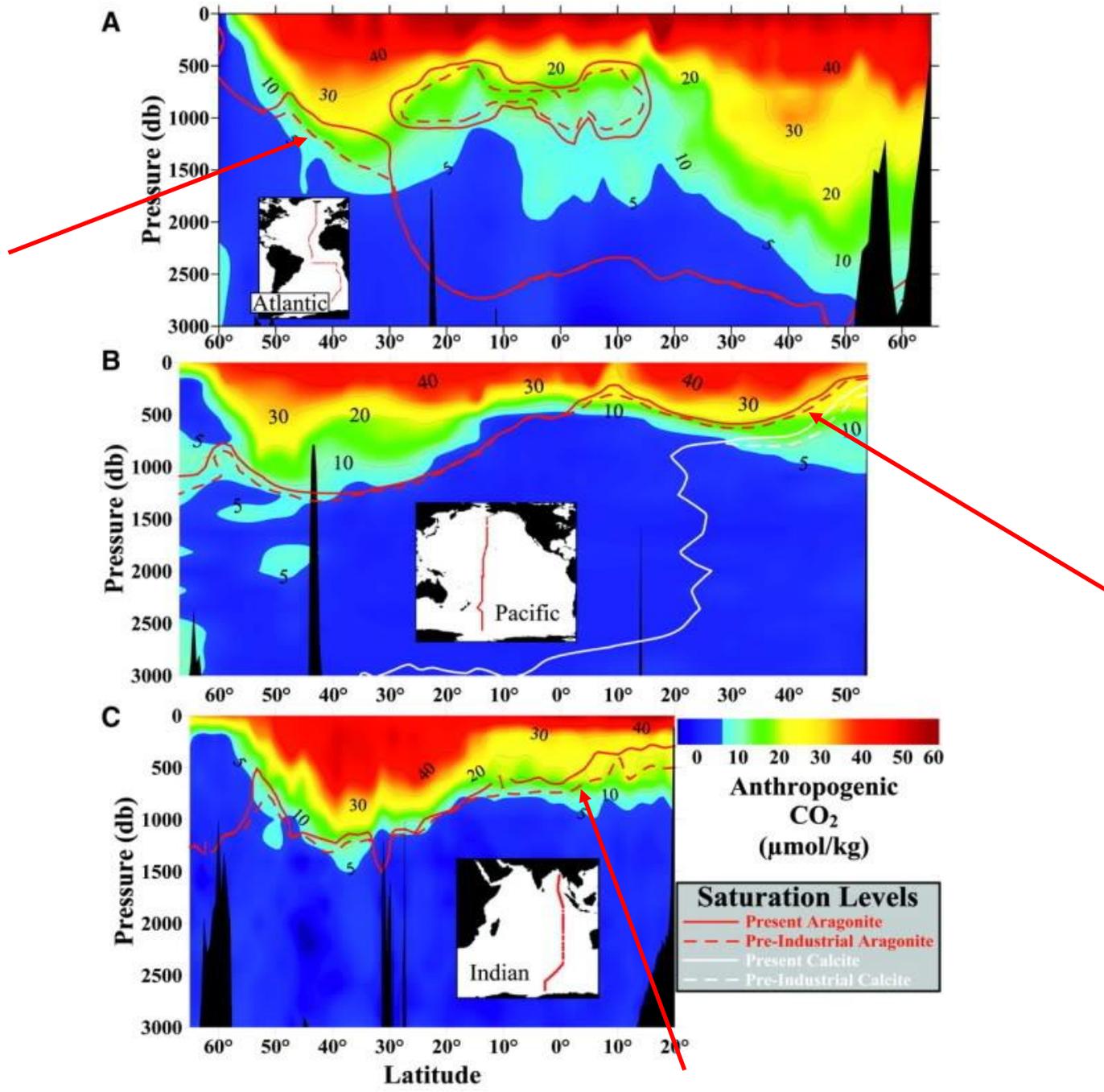
**+34.1**

**+3.5**

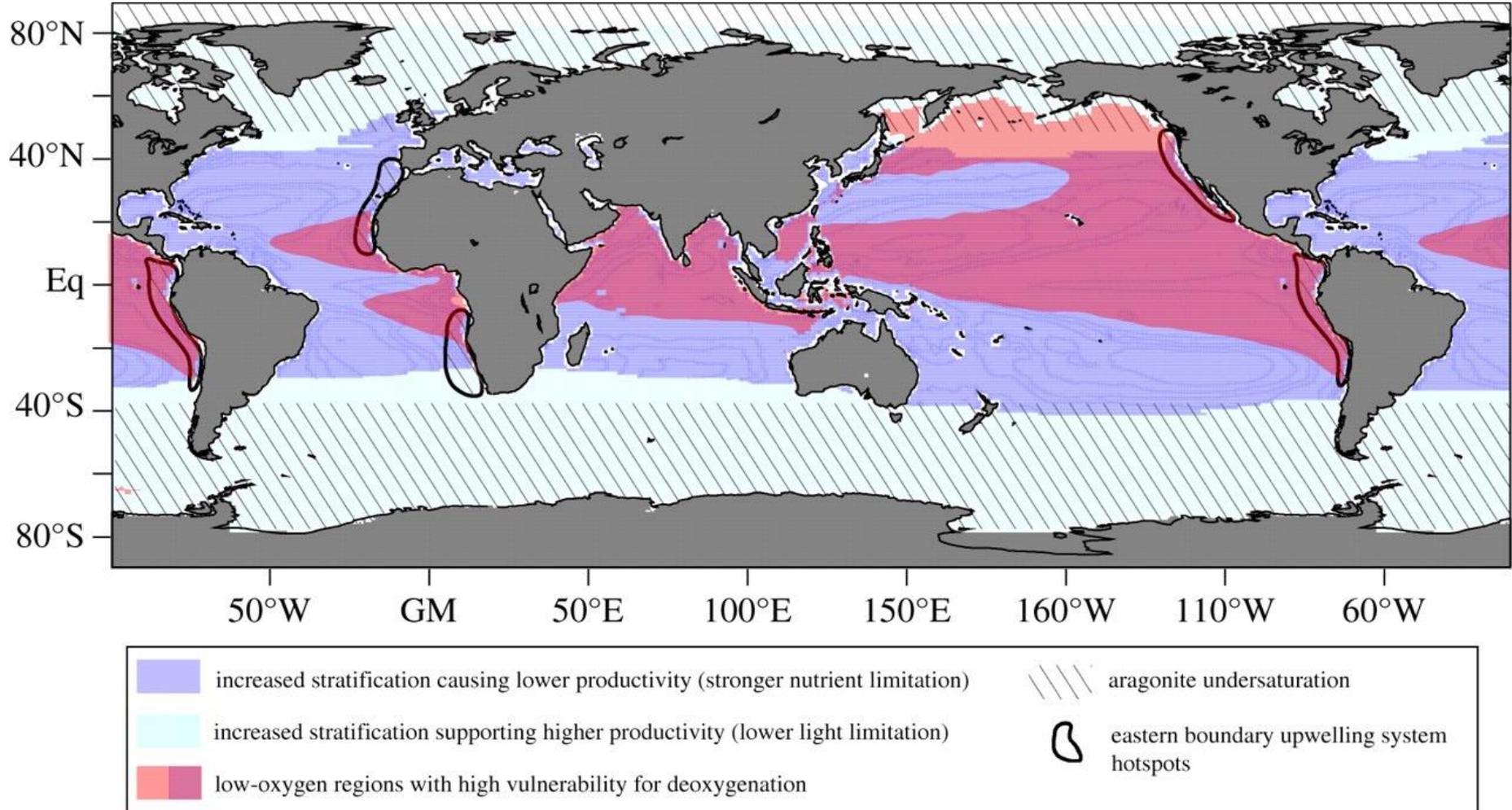
**+9.7**

**Profundidad de saturación**





# El océano del antropoceno



## El océano del antropoceno:

- más cálido
- más ácido
- menos “calcificado”
- menos oxigenado
- Más “desigual”

# Cara a donde o océano do antropoceno?

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**Santiago de Compostela, 11 de marzo de 2017**

