Impact of global change on ocean biogeochemical cycles (N, P, C and trace elements)
Palma de Mallorca, 17– 21 Oct 2011

V. Impact of global change on ocean biogeochemical cycles

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http://www.iim.csic.es

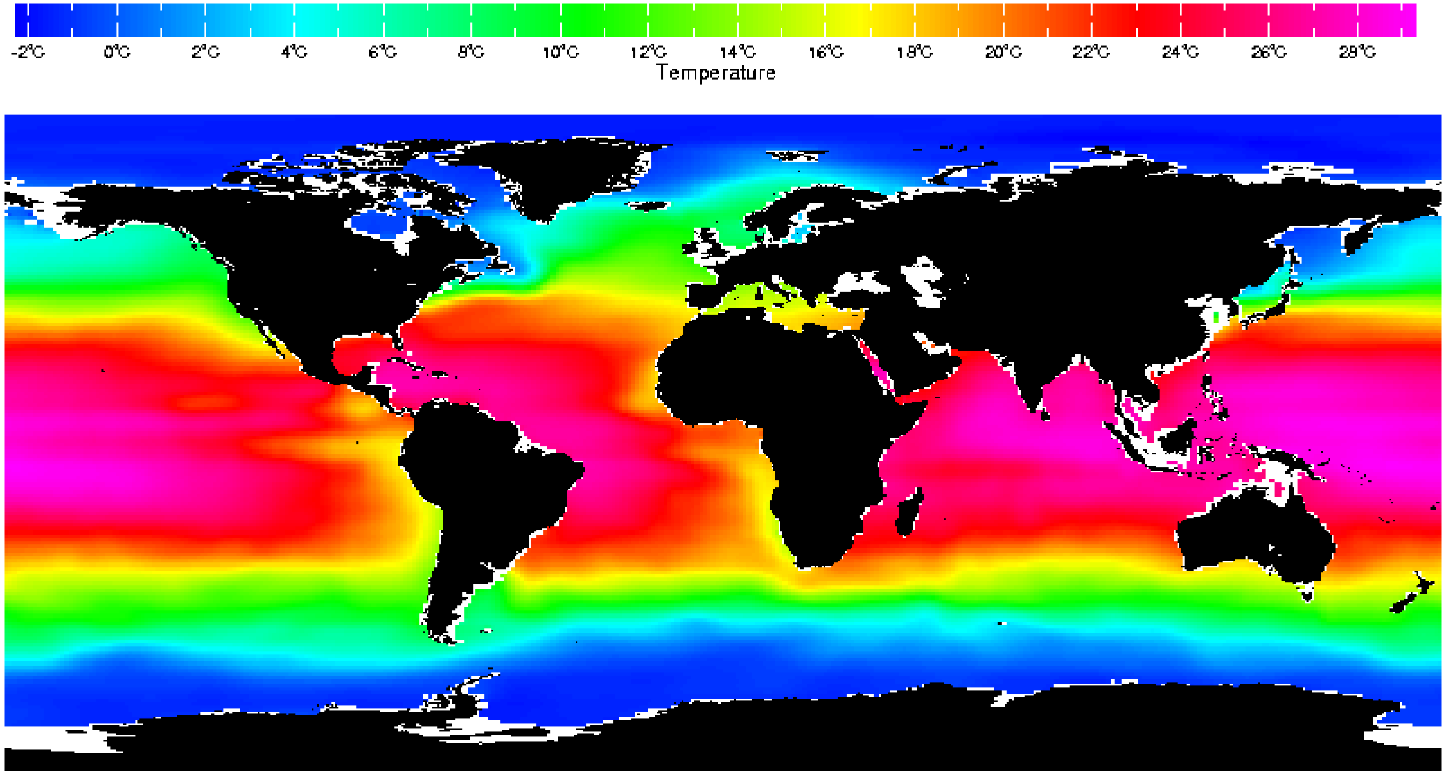
outline of this presentation

impact of global change on the ocean biogeochemical cycle of ...

- **nitrogen**
- **phosphorus**
- **silicon**

global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere

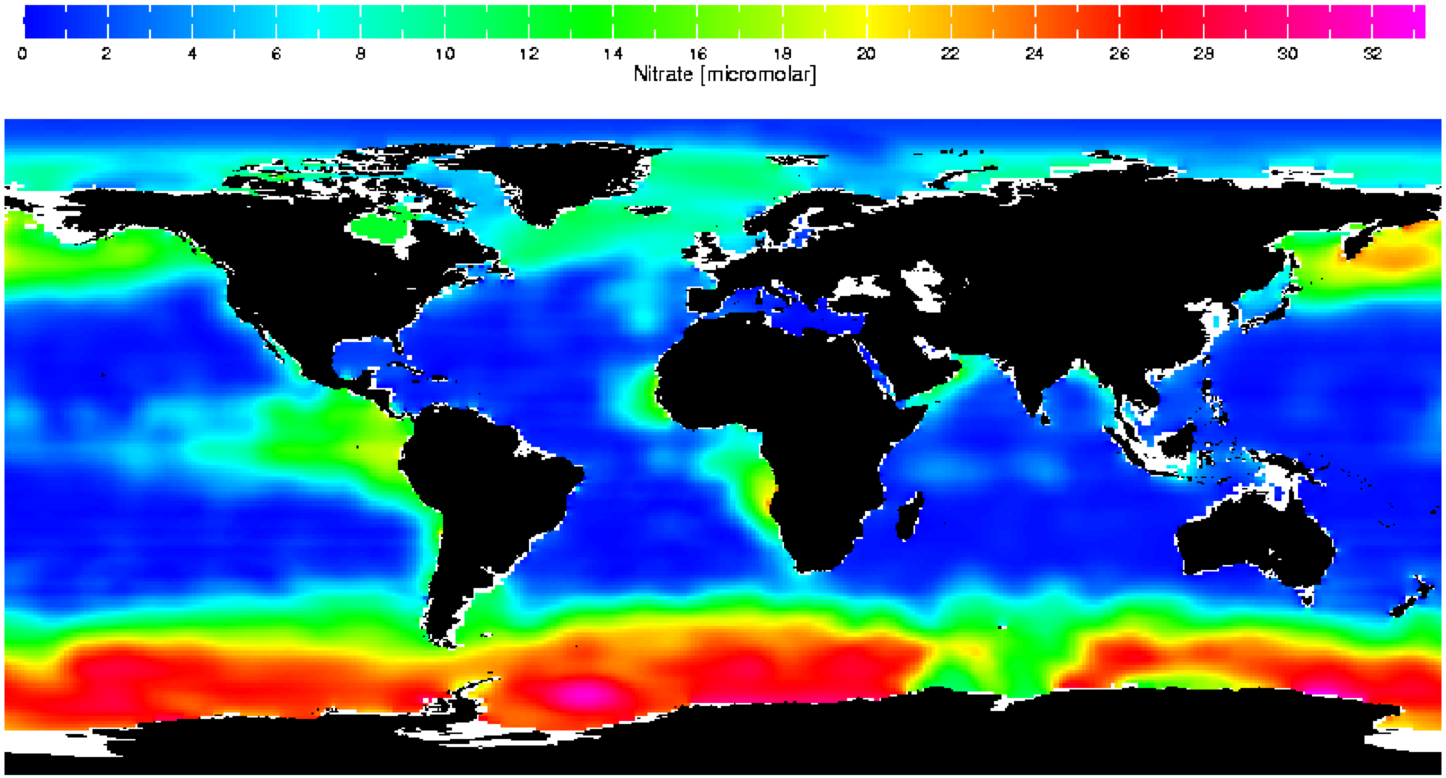


global distribution of surface temperature

http://ingrid.ldgo.columbia.edu/SOURCES/LEVITUS94/

global change and nitrogen in the oceans

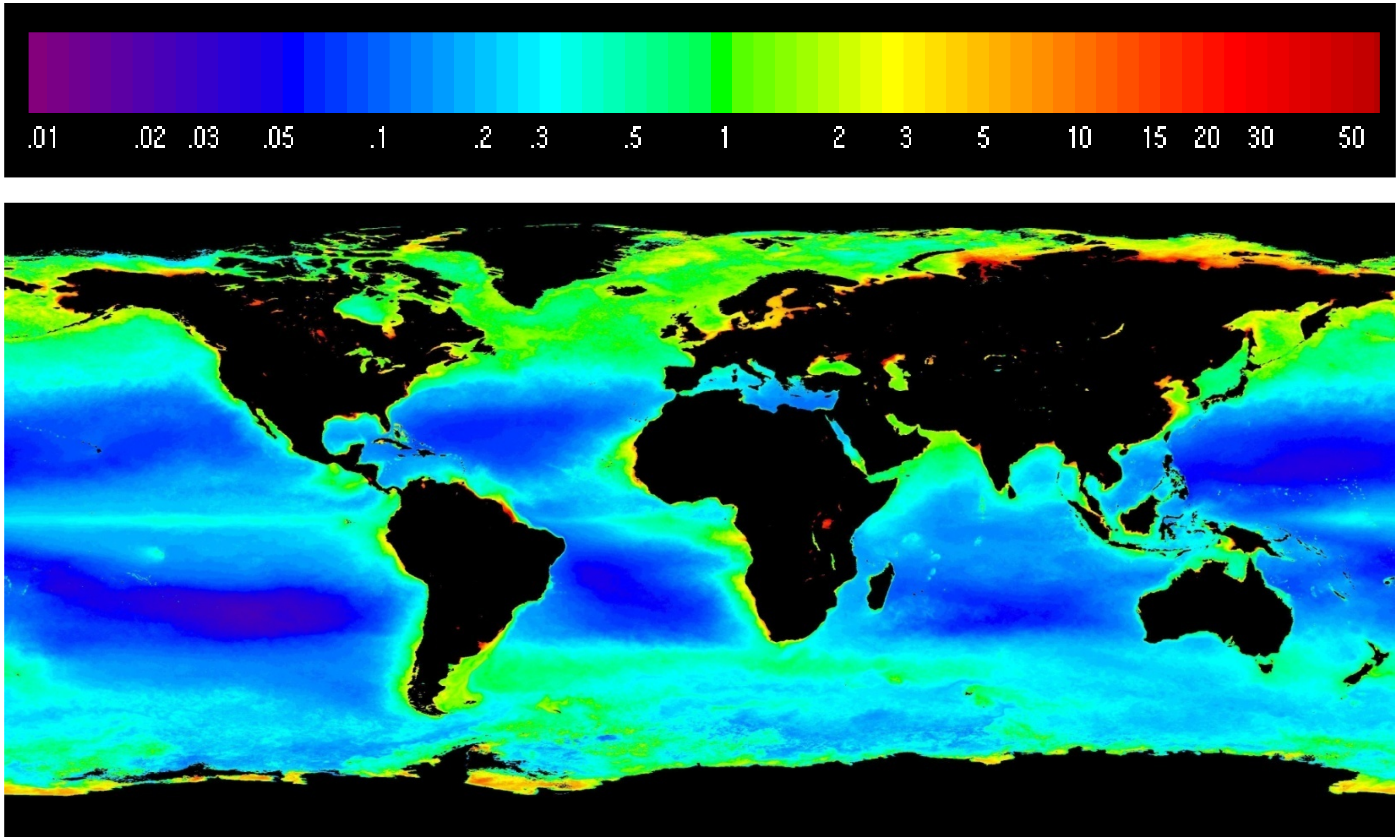
mankind: the king of N_2 fixation in the bisophere



global distribution of nitrate

global change and nitrogen in the oceans

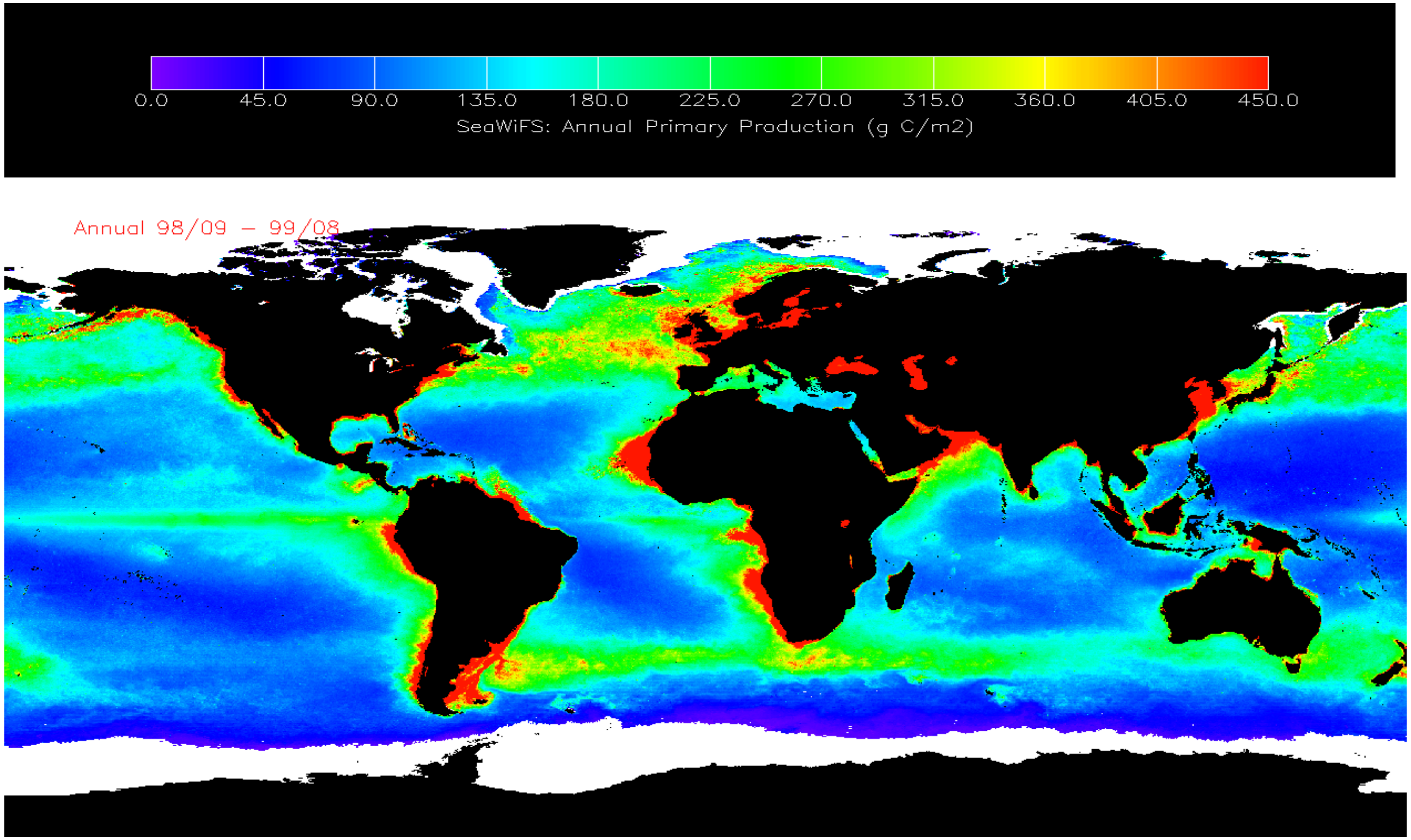
mankind: the king of N_2 fixation in the bisophere



global distribution of chlorophyll

global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere



global distribution of primary production

http://marine.rutgers.edu/opp/

global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere

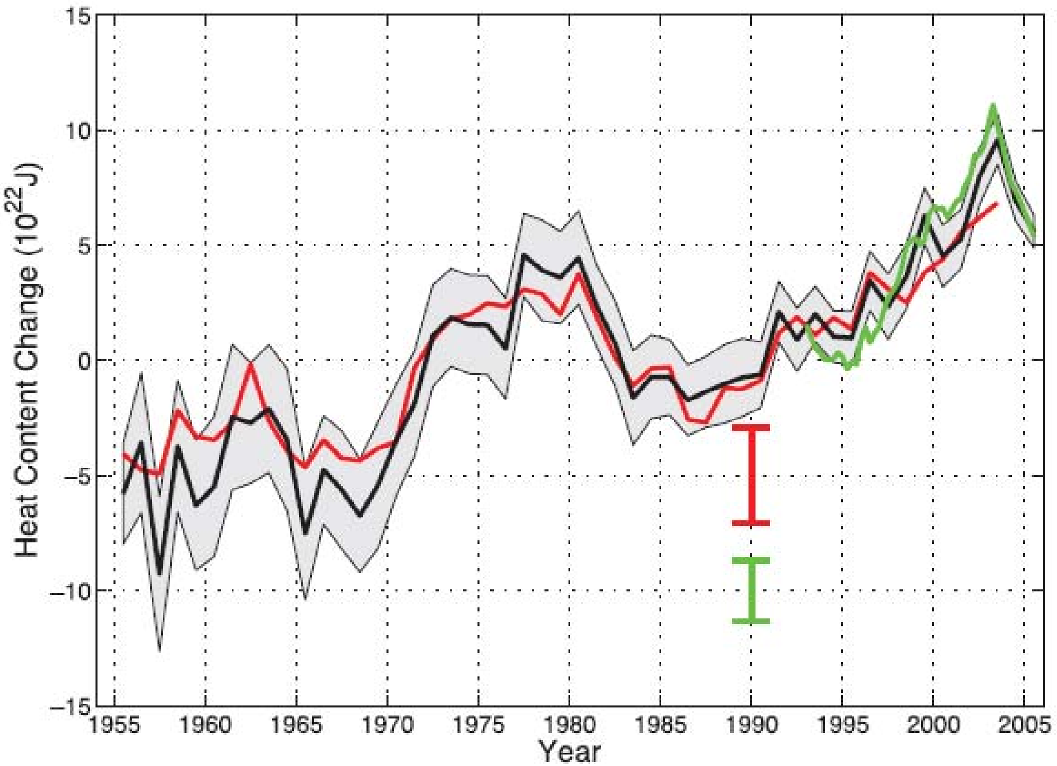
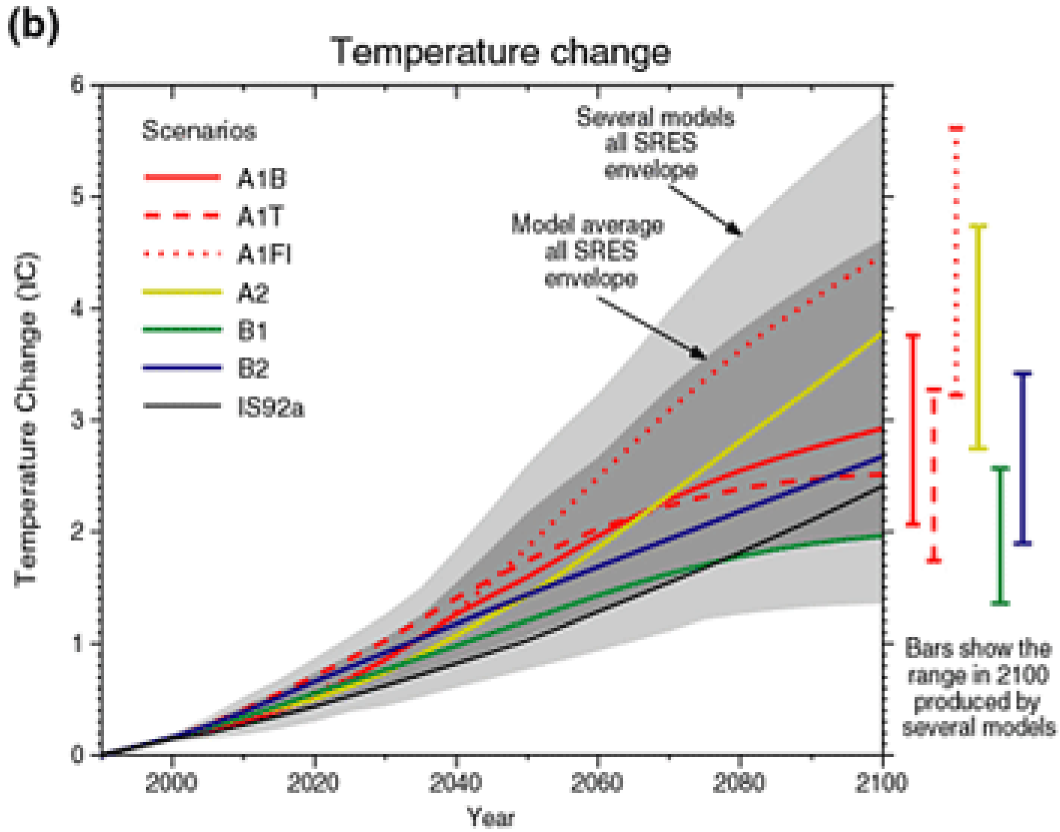


Figure 5.1. *Time series of global annual ocean heat content (10^{22} J) for the 0 to 700 m layer. The black curve is updated from Levitus et al. (2005a), with the shading representing the 90% confidence interval. The red and green curves are updates of the analyses by Ishii et al. (2006) and Willis et al. (2004, over 0 to 750 m) respectively, with the error bars denoting the 90% confidence interval. The black and red curves denote the deviation from the 1961 to 1990 average and the shorter green curve denotes the deviation from the average of the black curve for the period 1993 to 2003.*

heat content of the oceans (0-700m) 1955-2005

global change and nitrogen in the oceans

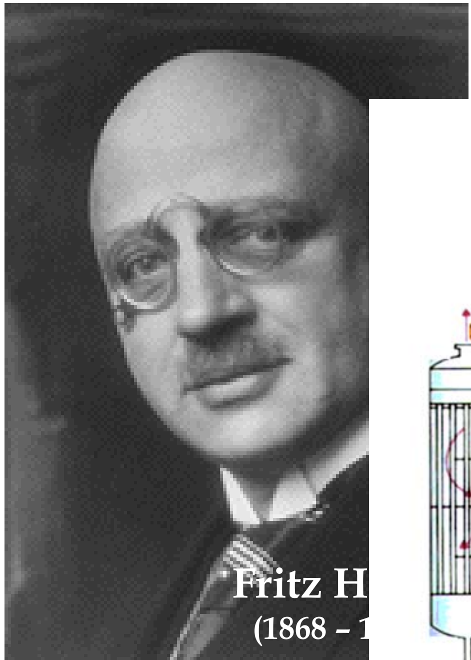
mankind: the king of N_2 fixation in the bisophere

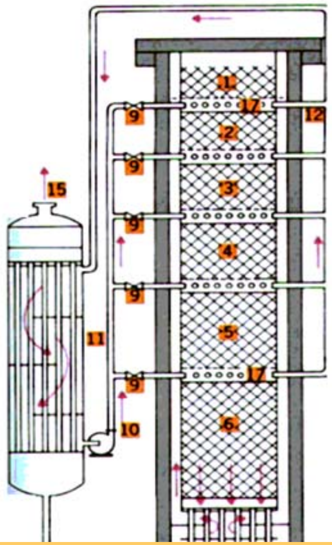


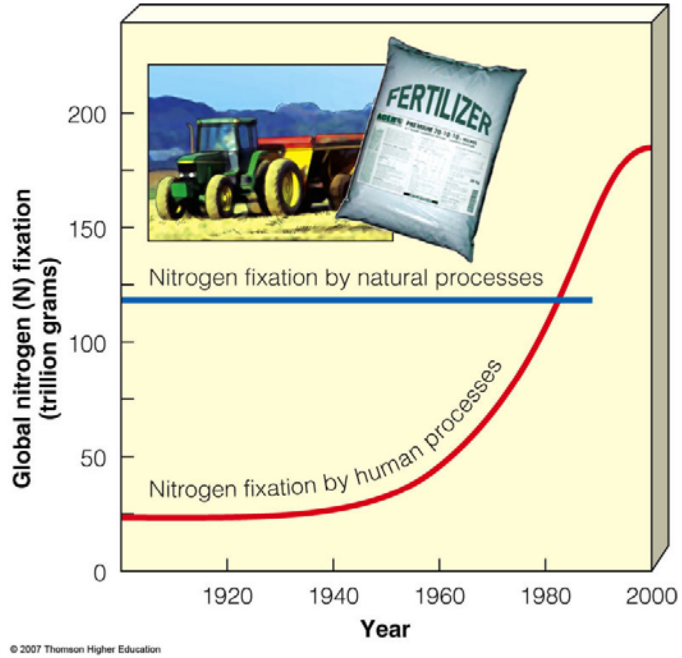
air temperature increase over the next decade

global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere







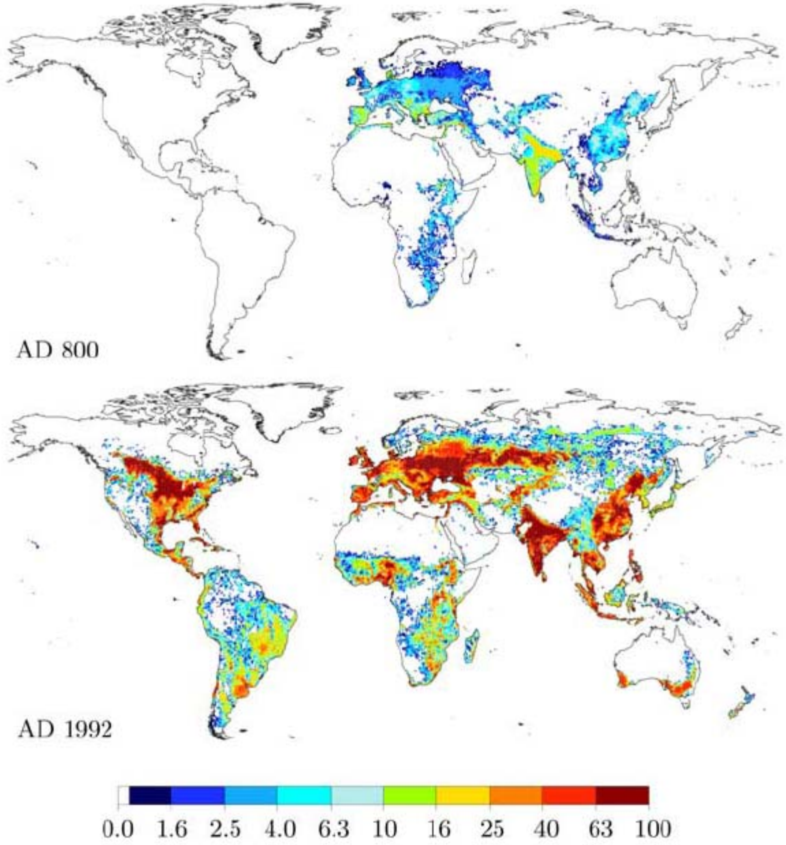
$$3\,CH_4 + 6\,H_2O \longrightarrow 3\,CO_2 + 12\,H_2$$
$$4\,N_2 + 12\,H_2 \longrightarrow 8\,NH_3$$

$$3\,CH_4 + 4N_2 + 6\,H_2O \longrightarrow 3\,CO_2 + 8\,NH_3$$

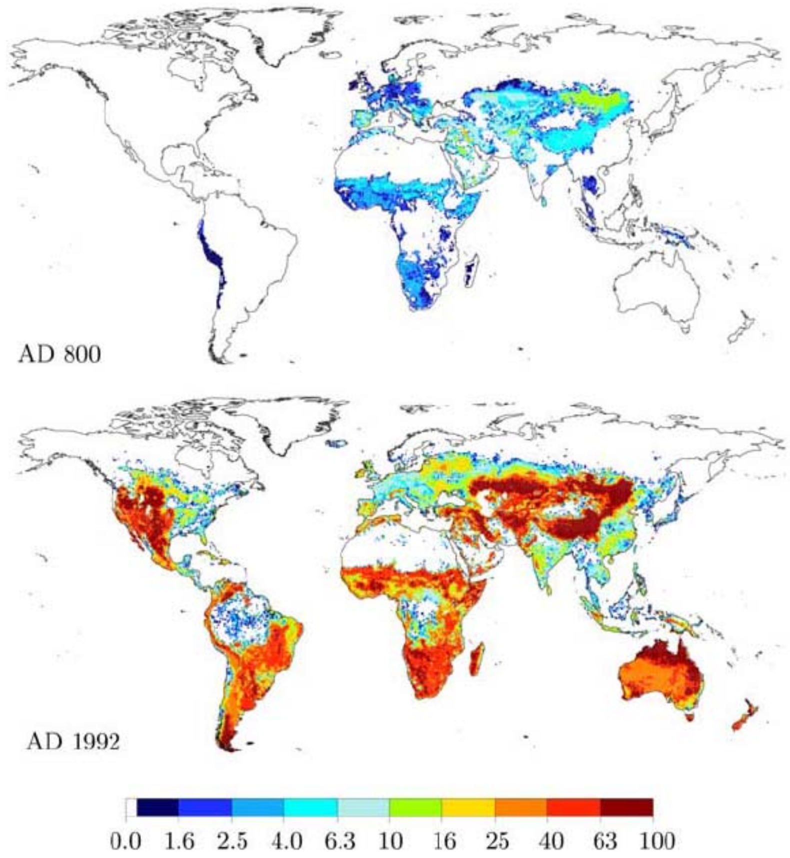
global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere

% cultivo cerelaes



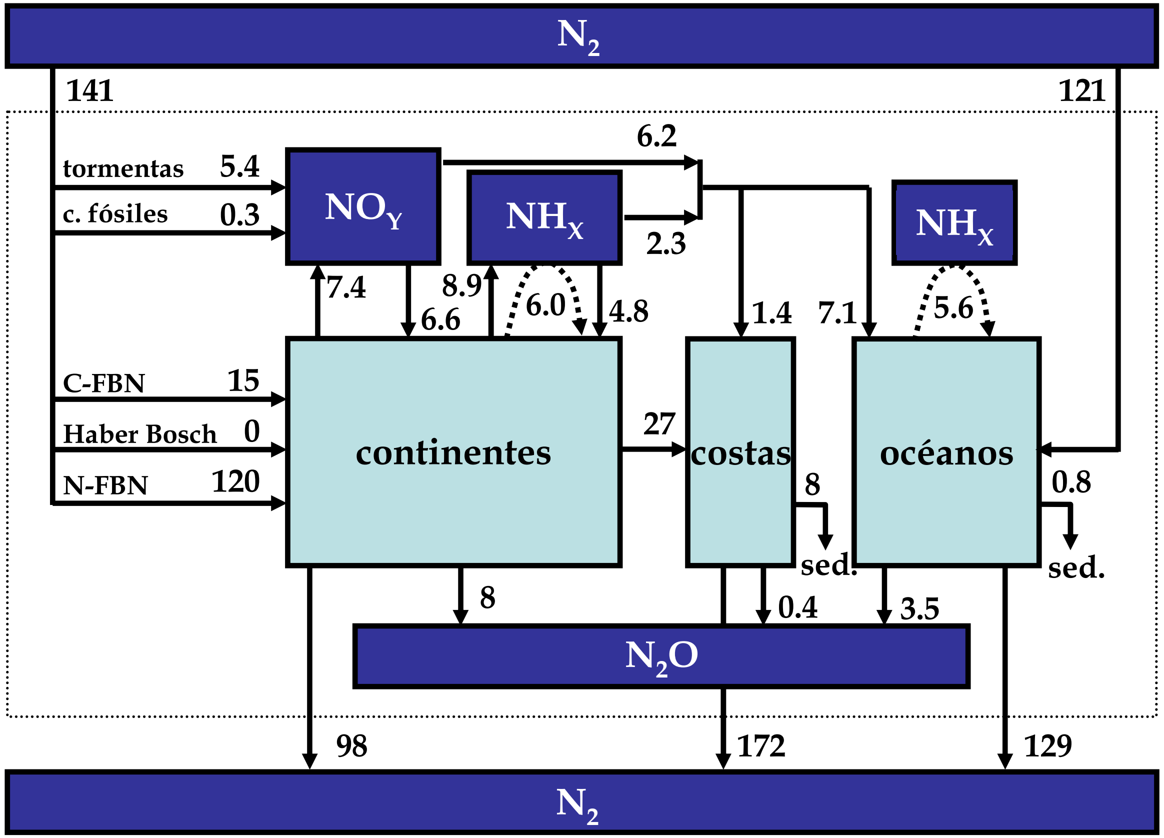
% pastizales



Pongratz et al., Global Biogeochem Cy, 2009

global change and nitrogen in the oceans

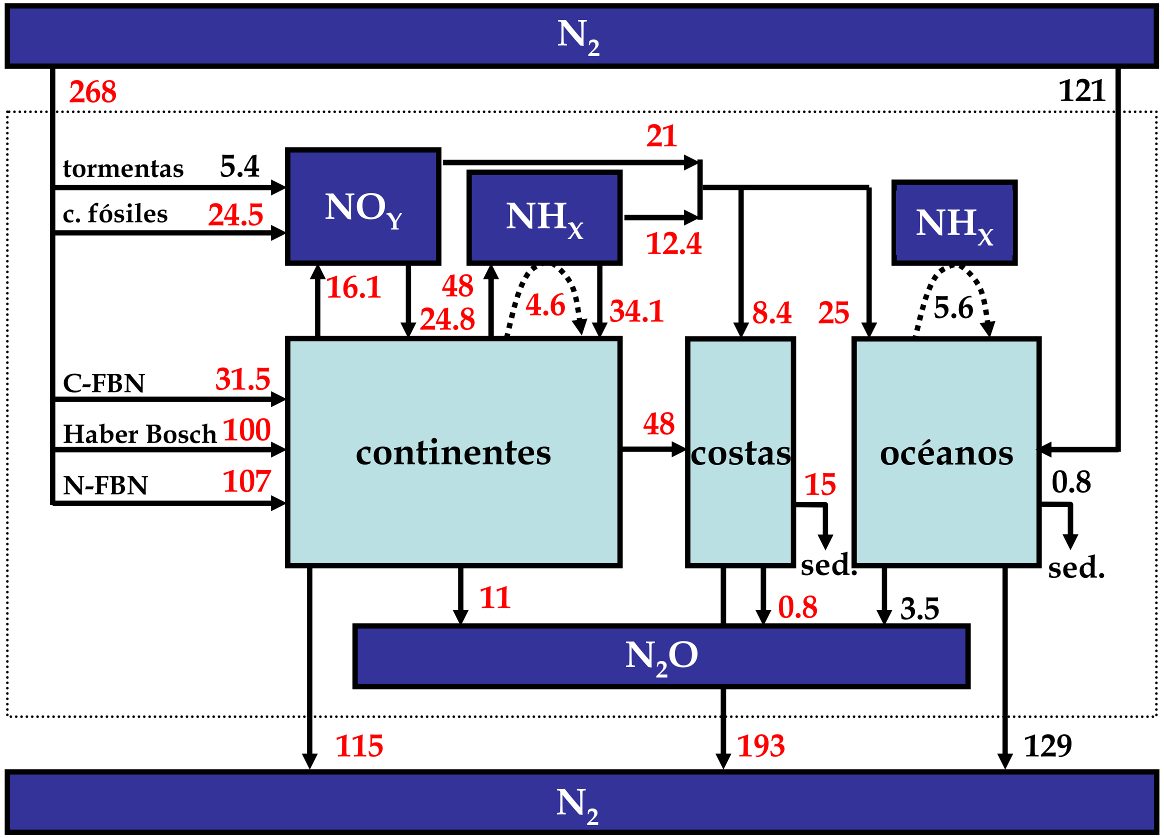
mankind: the king of N_2 fixation in the bisophere



balance global del nitrógeno en 1860 (en Tg N a^{-1})

global change and nitrogen in the oceans

mankind: the king of N_2 fixation in the bisophere

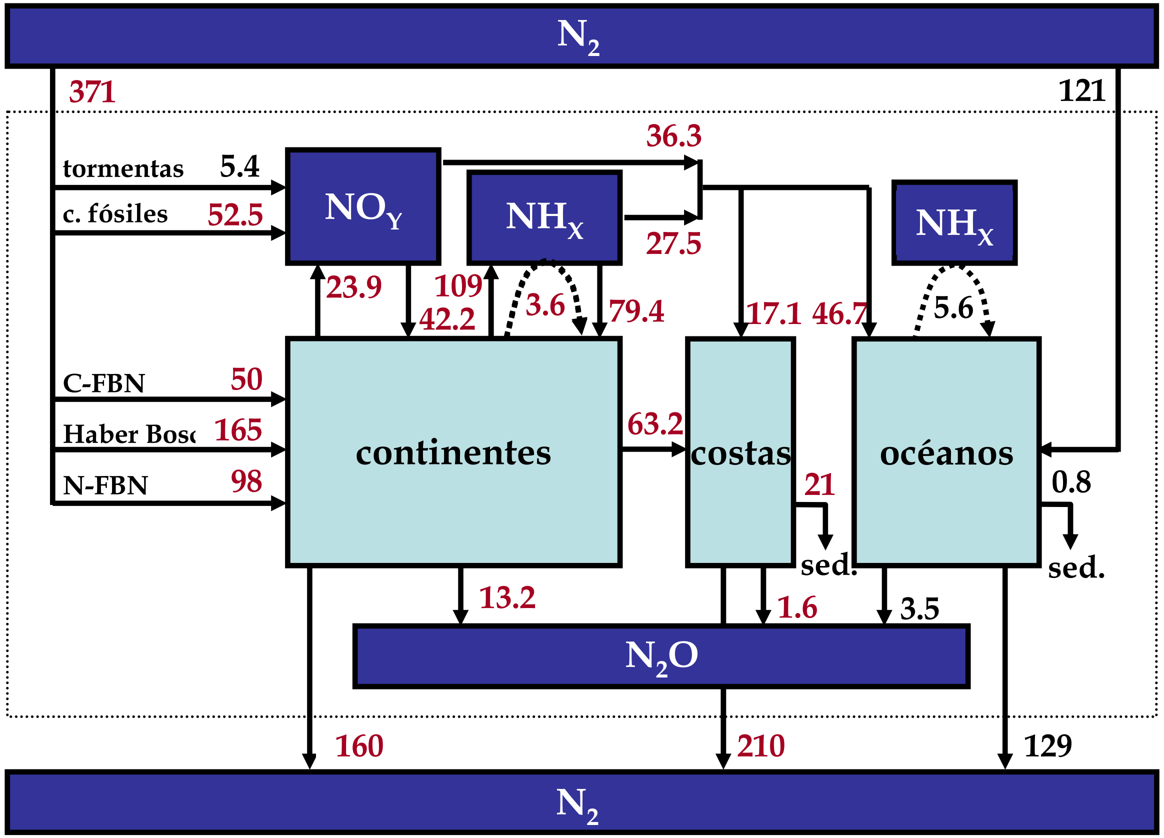


balance global del nitrógeno en 1990 (en Tg N a^{-1})

Galloway et al., Biogeochemistry, 2004

global change and nitrogen in the oceans

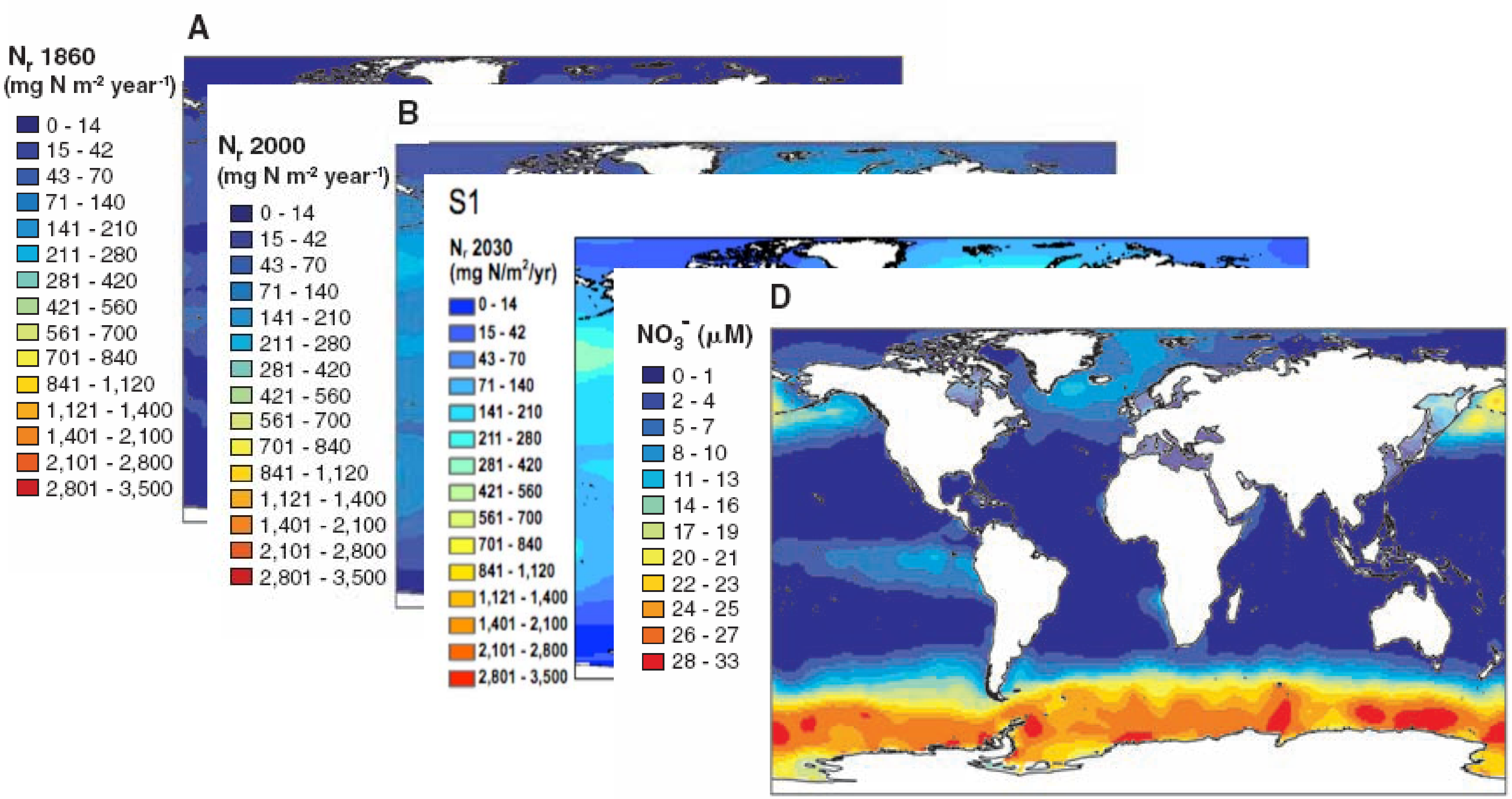
mankind: the king of N_2 fixation in the bisophere



balance global del nitrógeno en 2050 (en Tg N a^{-1})

global change and nitrogen in the oceans

deposition of combined nitrogen in the open ocean



deposition of NHx + NOy + Norg (in Tg N a^{-1})

global change and nitrogen in the oceans

consequences of the anthropogenic fertilization of the oceans

Table 2. Atmospheric nitrogen deposition to the ocean in 2000 and its impact on productivity. Global-scale estimates of total primary production (*23*); new production (*24–26*); N_2 fixation (*2*, *6–8*). Most letters in italics refer to flux pathways in Fig. 2.

	Global ocean nitrogen (Tg N $year^{-1}$)	Resultant global ocean productivity (Pg C $year^{-1}$)
Total primary production (*a*+*b*+*c*+*d*)	~8800 (7000–10,500)	~50 (40–60)
New production (NP) (*b*)	~1900 (1400–2600)	~11 (8–15)
Marine N_2 fixation (*c*)	~100 (60–200)	~0.57 (0.3–1.1)
Total net N_r deposition (*d*) (NO_y+NH_x+Org. N_r)	~67 (38–96)	~0.38 (0.22–0.55)
Total external nitrogen supply (*c*+*d*)	~167 (98–296)	~0.95 (0.56–1.7)
Anthropogenic N_r deposition (AAN) (*e*)	~54 (31–77)	~0.31 (0.18–0.44)

impact on primary production

Duce et al, Science, 2008

global change and nitrogen in the oceans

consequences of the anthropogenic fertilization of the oceans

Table S1. Estimates of N_2O emission fluxes from oceans in 1860, 2000 and 2030.

	①	②	③	① + ③ = ④	⑤	[②/④] x ⑤ = ⑥	⑥/⑤% = ⑦
Year	N_r (Atmospherically deposited)	N_r (AAN)	N_2 fixation	Total New Fixed N	Total N_2O Emission	Anthro. N_2O Emission	% Anthro. N_2O
1860	20	5.7	100	120	3.6 (2.7-4.5)	0.2 (0.1-0.2)	4.8
2000	67	54	100	167	5.0 (3.8-6.2)	1.6 (1.2-2.0)	32
2030	77	62	100	177	5.3 (4.0-6.6)	1.9 (1.4-2.3)	35

Units are $TgNyr^{-1}$ (except for Column ⑦).

impact on nitrification

Duce et al, Science, 2008

global change and nitrogen in the oceans

consequences of the anthropogenic fertilization of the oceans

Table 1 | Estimates of anthropogenic emissions of nitrous oxide (Tg N_2O-N yr^{-1}).

<table>
<tr><th>Source</th><th>Mosier et al. 1998 (ref. 3)</th><th>EPA 2006 (ref. 14)</th><th>Crutzen et al. 2007 (ref. 7)</th><th>This study</th></tr>
<tr><td>Direct emissions from fertilizer on soils</td><td>1.5 (0.2–2.7)</td><td rowspan="3">4.4</td><td rowspan="7">4.3–5.8</td><td rowspan="3">2.2 (1.5–2.4)</td></tr>
<tr><td>Indirect fertilizer emissions: atmospheric deposition</td><td>0.3 (0.06–0.6)</td></tr>
<tr><td>Indirect fertilizer emissions: leaching</td><td>1.6 (0.1–7.7)</td></tr>
<tr><td>Indirect emissions: human sewage</td><td>0.2 (0.04–2.6)</td><td>0.2</td><td>Included with fertilizer & manure estimates</td></tr>
<tr><td>Manure: soil applications</td><td>0.6 (0.1–1.1)</td><td>Included with fertilizer emissions</td><td rowspan="2">2.8 (2.2–3.3)</td></tr>
<tr><td>Manure: livestock management systems</td><td>2.1 (0.6–3.1)</td><td>0.4</td></tr>
<tr><td>Biomass burning</td><td>0.5 (0.2–1.0)</td><td>0.6</td><td>0.5</td></tr>
<tr><td>Industrial & transport</td><td>1.3 (0.7–1.8)</td><td>0.8</td><td>0.7–1.3</td><td>0.8</td></tr>
<tr><td>Total anthropogenic</td><td>8.1 (2.1–20.6)</td><td>6.3</td><td>5.6–6.5</td><td>6.3</td></tr>
</table>

1 Tg = 10^{12} g. The base year was 1994 for the Mosier *et al.* study and was 2000 for each of the other three studies. The ranges of uncertainty for fertilizer and manure sources in this study (shown in parentheses) are derived from the sensitivity analyses presented in the Supplementary Information.

impact on nitrification

Davidson, Nature Geosciences, 2009

global change and nitrogen in the oceans

consequences of the anthropogenic fertilization of the oceans

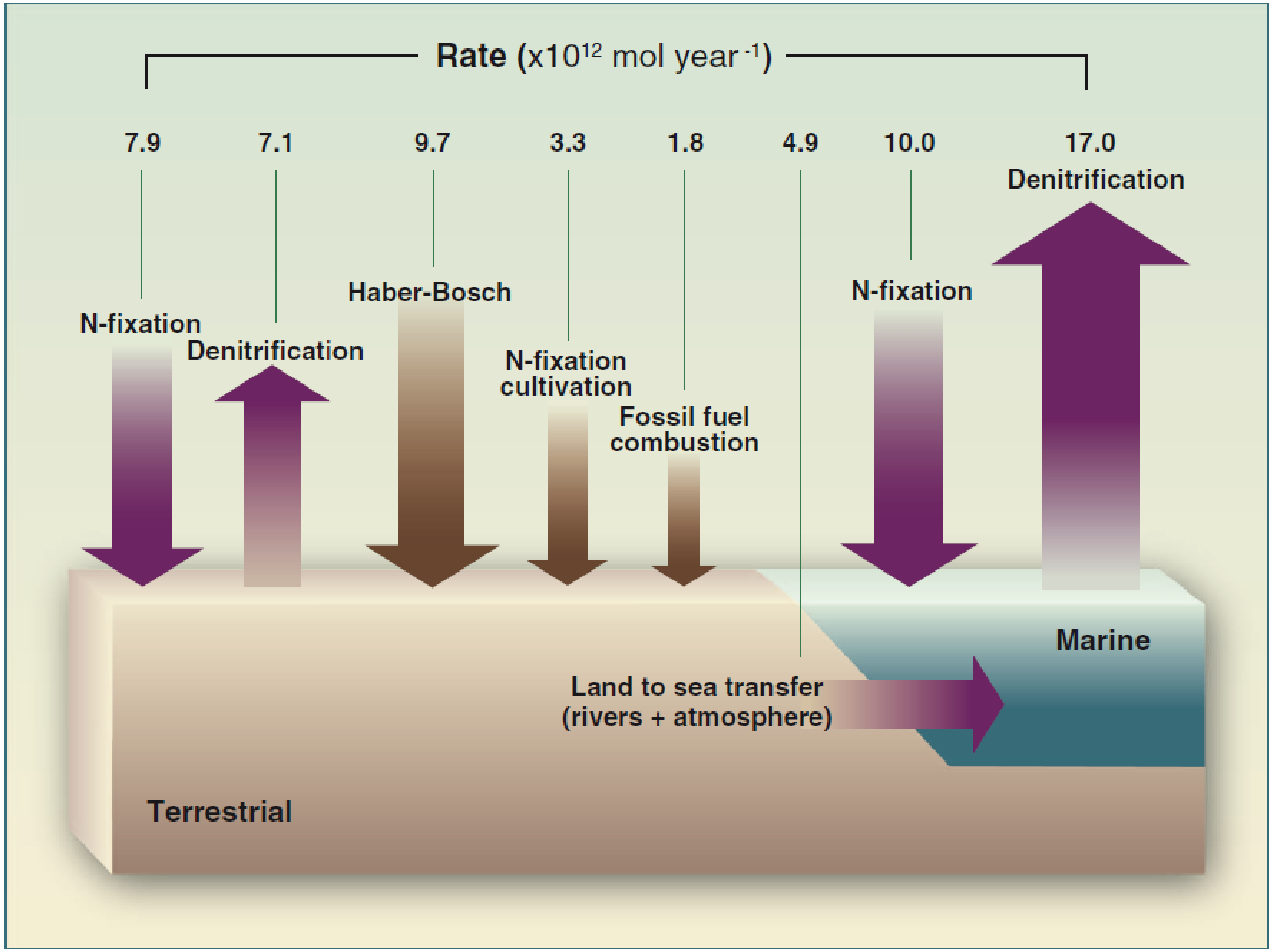
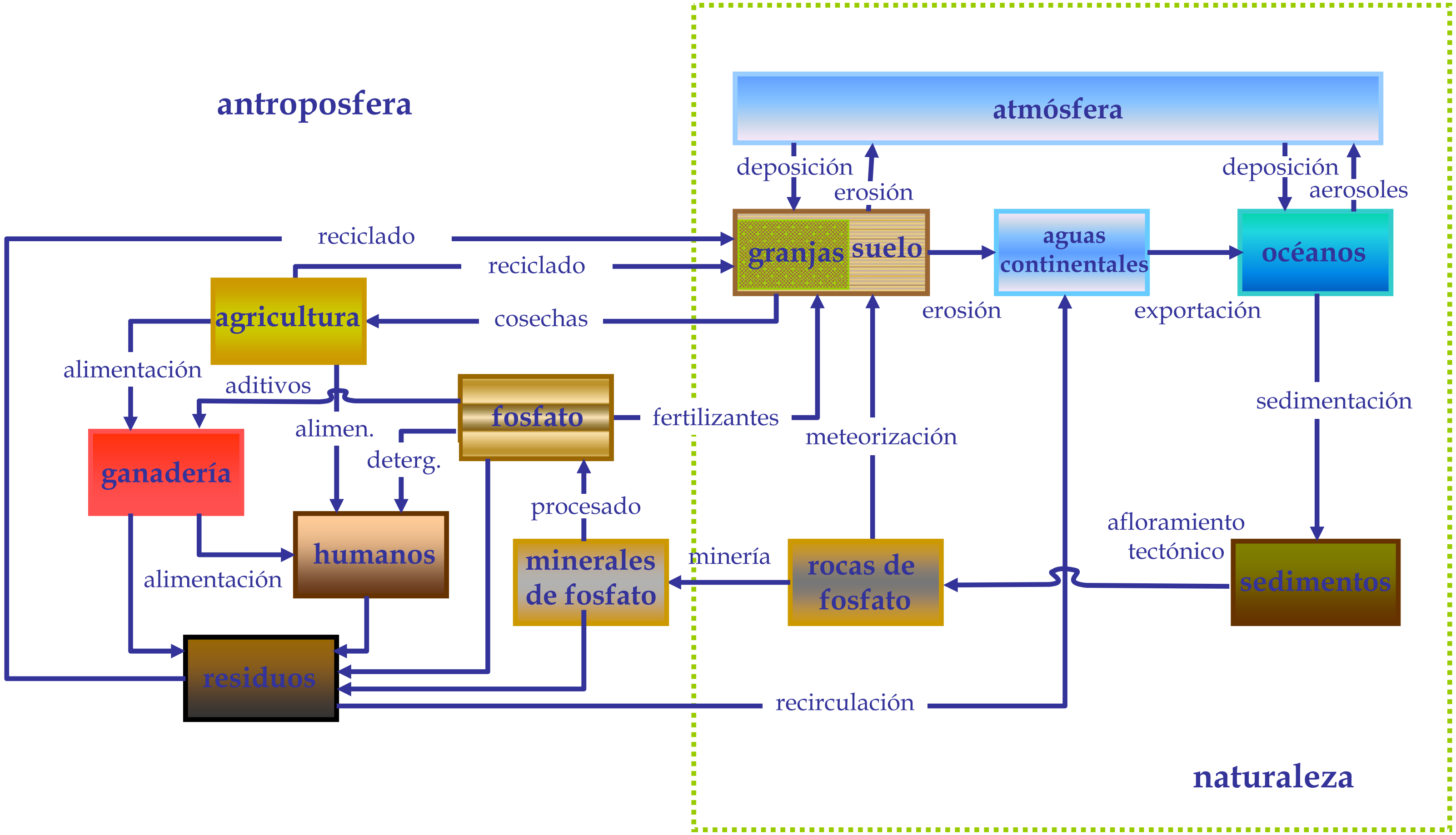


Fig. 4. Rates of nitrogen flux in the modern nitrogen cycle depend on the efficiency of the transformations between reservoirs. Arrow size reflects relative size of the flux. The dark brown arrows represent anthropogenic inputs (*25*, *45*, *46*, *52*, *53*, *68*, *69*).

Canfiled et al, Science, 2010

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans



humankind is ...

- ► **extracting huge amounts of phosphate from the phosphorite reserves to produce fertilizers**
- ► **reducing the phosphate reserves in tropical forests due to deforestation**
- ► **adding phosphate to continental and marine aquatic ecosystems**

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans

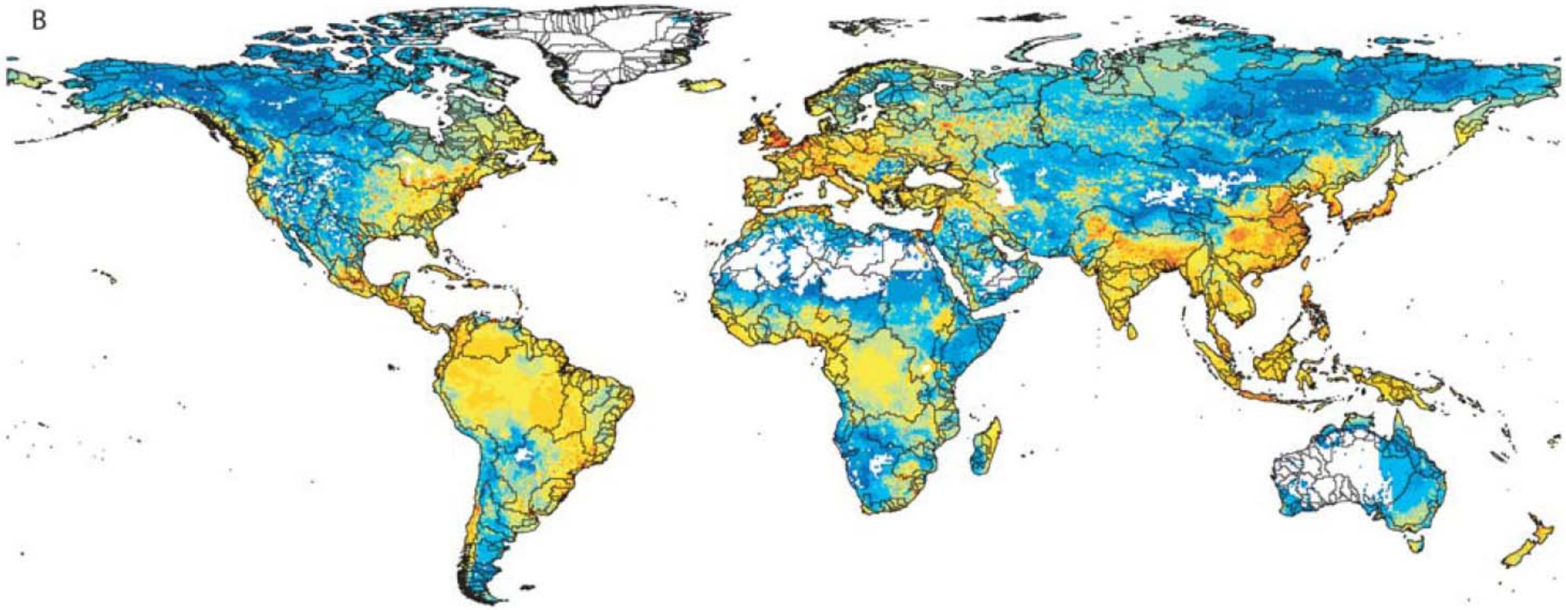


Figure 3. (a) NEWS-DIP-predicted and (b) NEWS-DIP-HD-predicted DIP yield by half-degree grid cell (kg P km^{-2} yr^{-1}). White areas are either endoreic (Figure 3a) or have a predicted DIP loading to surface waters equal to zero (Figure 3b).

Harrison et al, Global Biogeochem Cy, 2010

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans

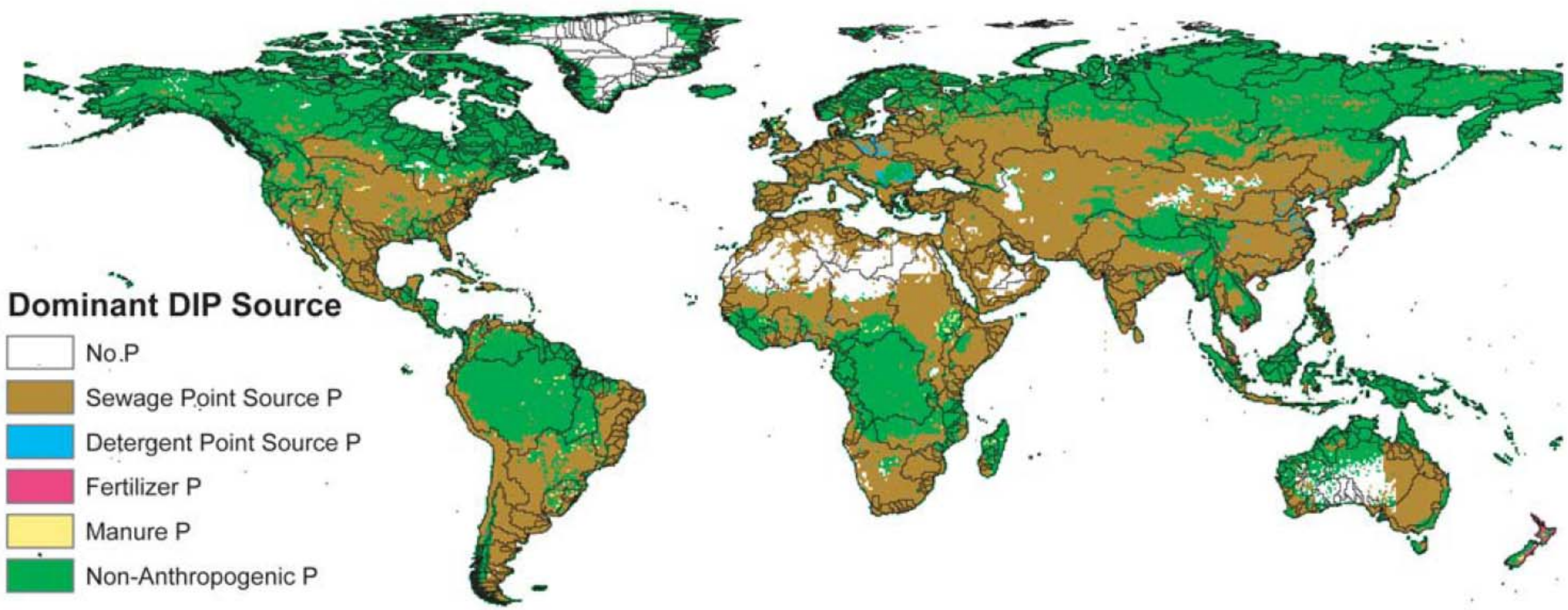


Figure 5. Dominant source of DIP by half-degree grid cell. "Dominant source" is defined as the modeled source that NEWS-DIP-HD predicts contributes the largest single fraction of DIP to the coast.

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans

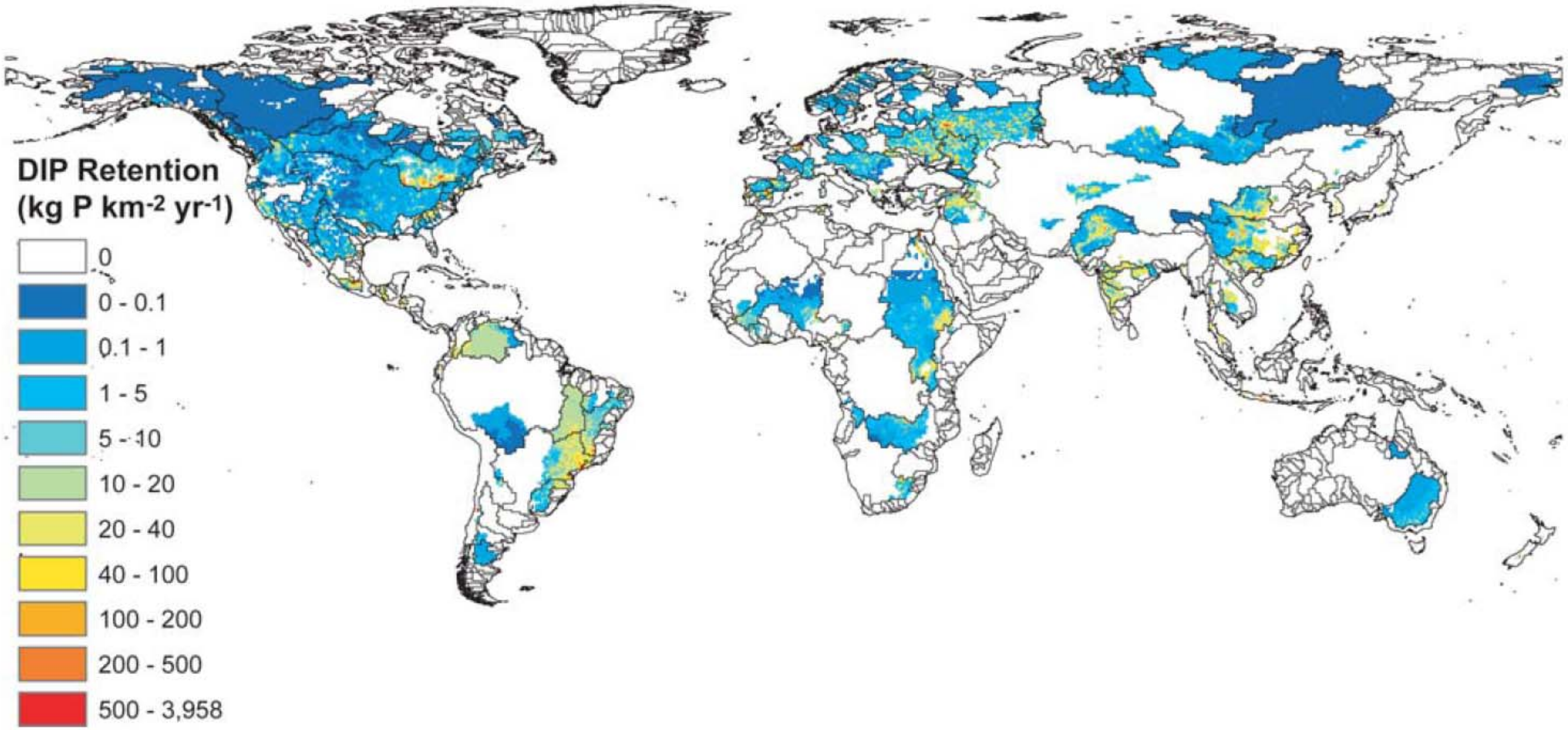
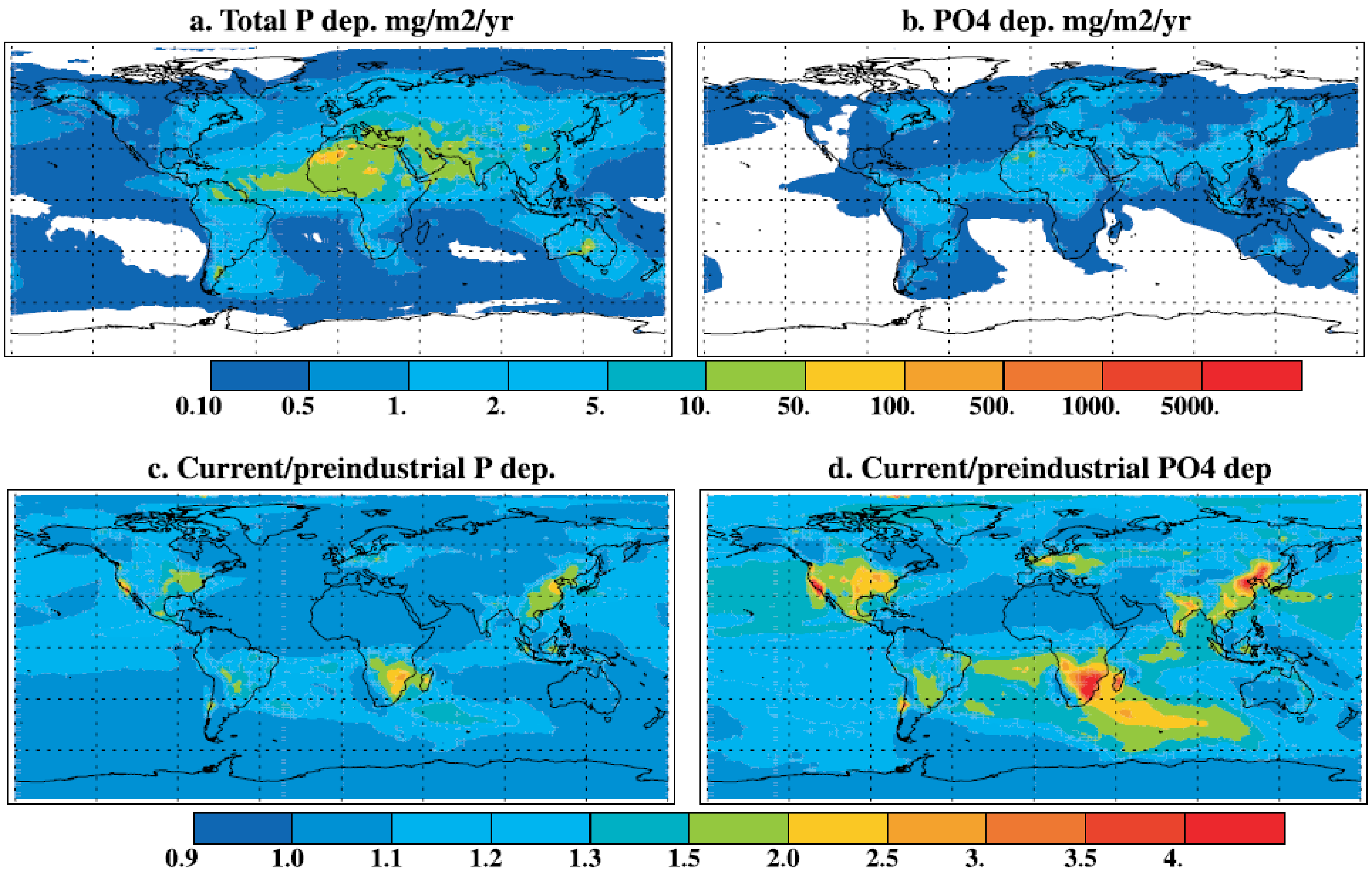


Figure 4. NEWS-DIP-HD-estimated DIP retention (kg P km^{-2} yr^{-1}) globally by half degree. Estimates without information regarding reservoir locations and consumptive water use were assumed to retain no DIP, making this quite a conservative estimate of DIP retention within watersheds globally.

Harrison et al, Global Biogeochem Cy, 2010

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans



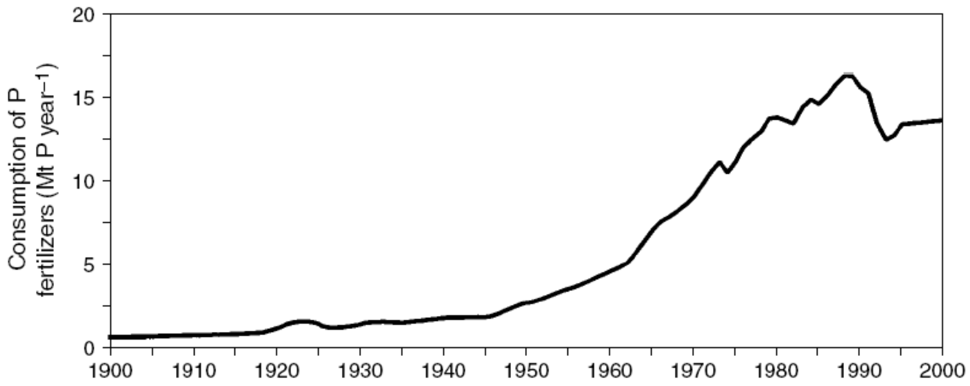
Mahowald et al, Global Biogeochem Cy,2008

global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans

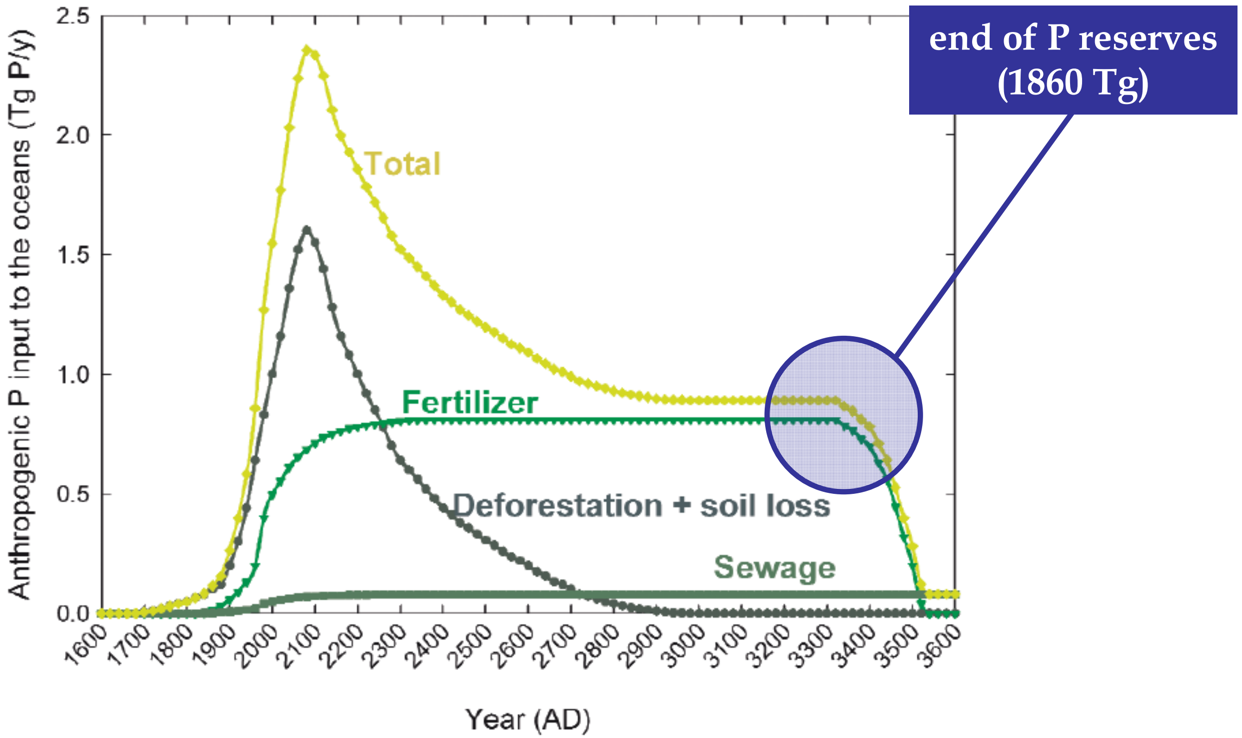
Table 2 Human intensification of the global phosphorus cycle (all values are in Mt P year^{-1})

Fluxes	Natural	Preindustrial (1800)	Recent (2000)
Natural fluxes intensified by human actions			
Erosion	>10	>15	>30
Wind	<2	<3	>3
Water	>8	>12	>27
River transport	>7	>9	>22
Particulate P	>6	>8	>20
Dissolved P	>1	<2	>2
Biomass combustion	<0.1	<0.2	<0.3
Anthropogenic fluxes			
Crop uptake	–	1	12
Animal wastes	–	>1	>15
Human wastes	–	0.5	3
Organic recycling	–	<0.5	>6
Inorganic Fertilizers	–	–	15



global change and phosphorus in the oceans

consequences of the anthropogenic fertilization of the oceans



global change and silicon in the oceans

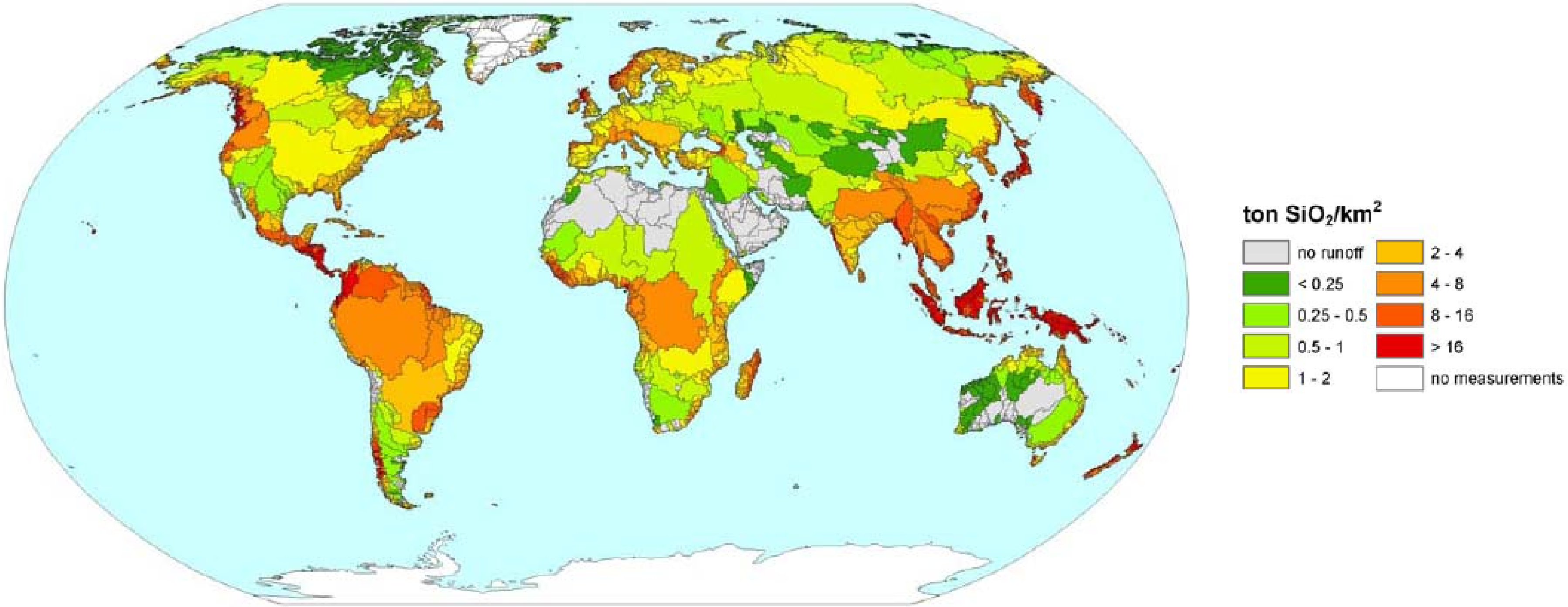
the decline of diatoms

Humankind is …

- ► **building dams → reduction of silicon discharge**
- ► **transforming virgin into cultured lands → increase of nitrogen discharge**
- ► **warming the Earth → increase of stratification → dinoflagelates dominance**

global change and silicon in the oceans

the decline of diatoms



global change and silicon in the oceans

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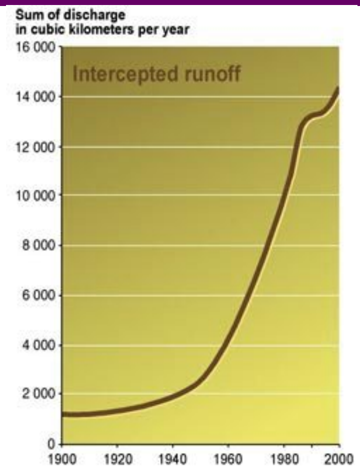
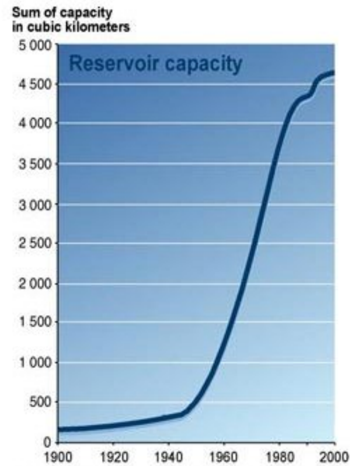
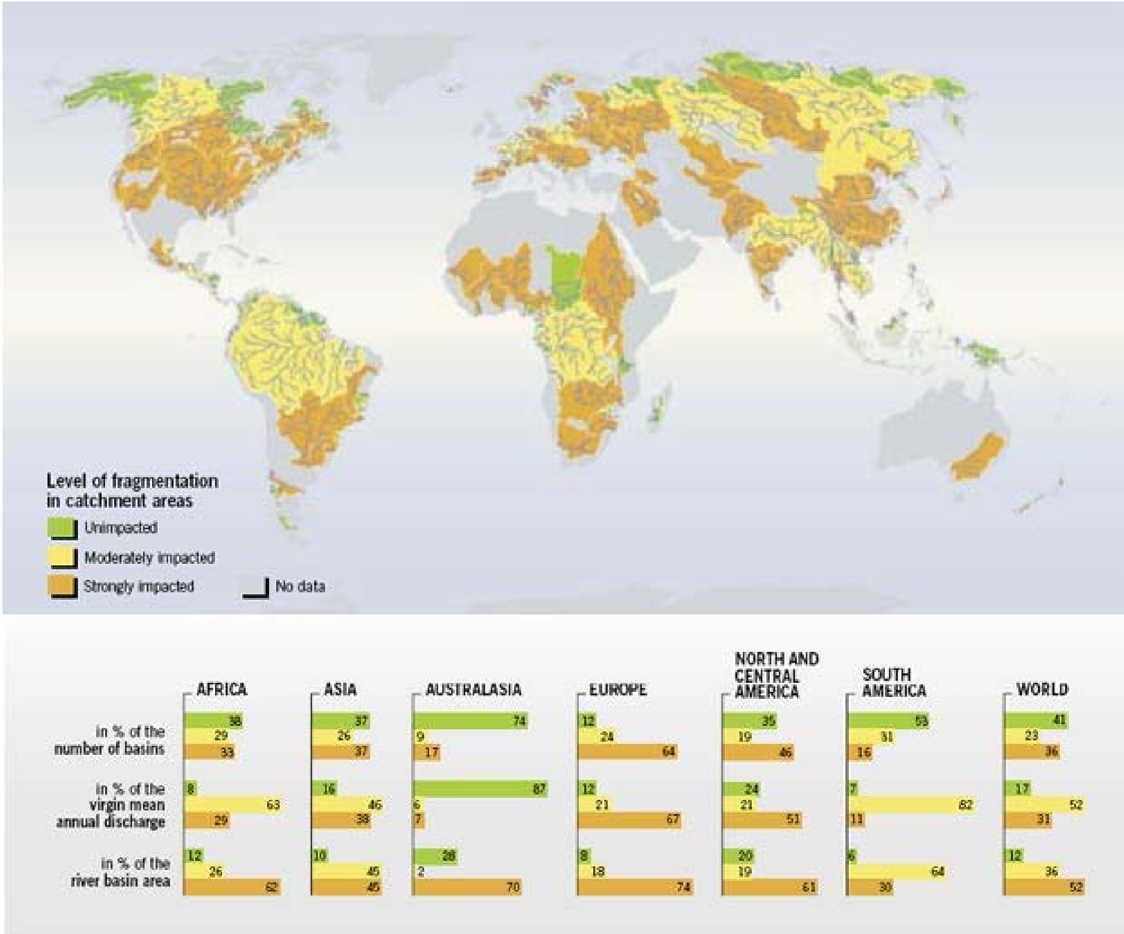




Source: Millennium Ecosystem Assessment



Source: Nilsson et al. 2005[12]

Intercepted runoff is 3 to 6 times natural runoff

global change and silicon in the oceans

the decline of diatoms

Table 6. Predicted River Export of DSi to the World's Oceans for the Predam Situation and Retention in Global Reservoirs Based on Two Methods

Ocean	Area (Mkm^2)	Predam DSi River Export ($Tg\ a^{-1}$)	Contribution to Global DSi River Export (%)	DSi Retention With PR[a] (%)	DSi Retention With SR[a] (%)
Arctic Ocean	18	18	5	17	9
Atlantic Ocean	43	155	41	23	25
Indian Ocean	17	51	14	11	11
Land	14	8	2	18	17
Mediterranean + Black Sea	8	11	3	40	46
Pacific Ocean	19	137	36	13	15
World	118	380	100	18	19

[a]PR is the phosphate retention from *Harrison et al.* [2005]; SR is sediment retention from *Vörösmarty et al.* [2003].

River dams retain 20% of the continental dSi that should arrive to the oceans

Beunser et al., Global Biogeochemical Cycles, 2009

global change and silicon in the oceans

the decline of diatoms

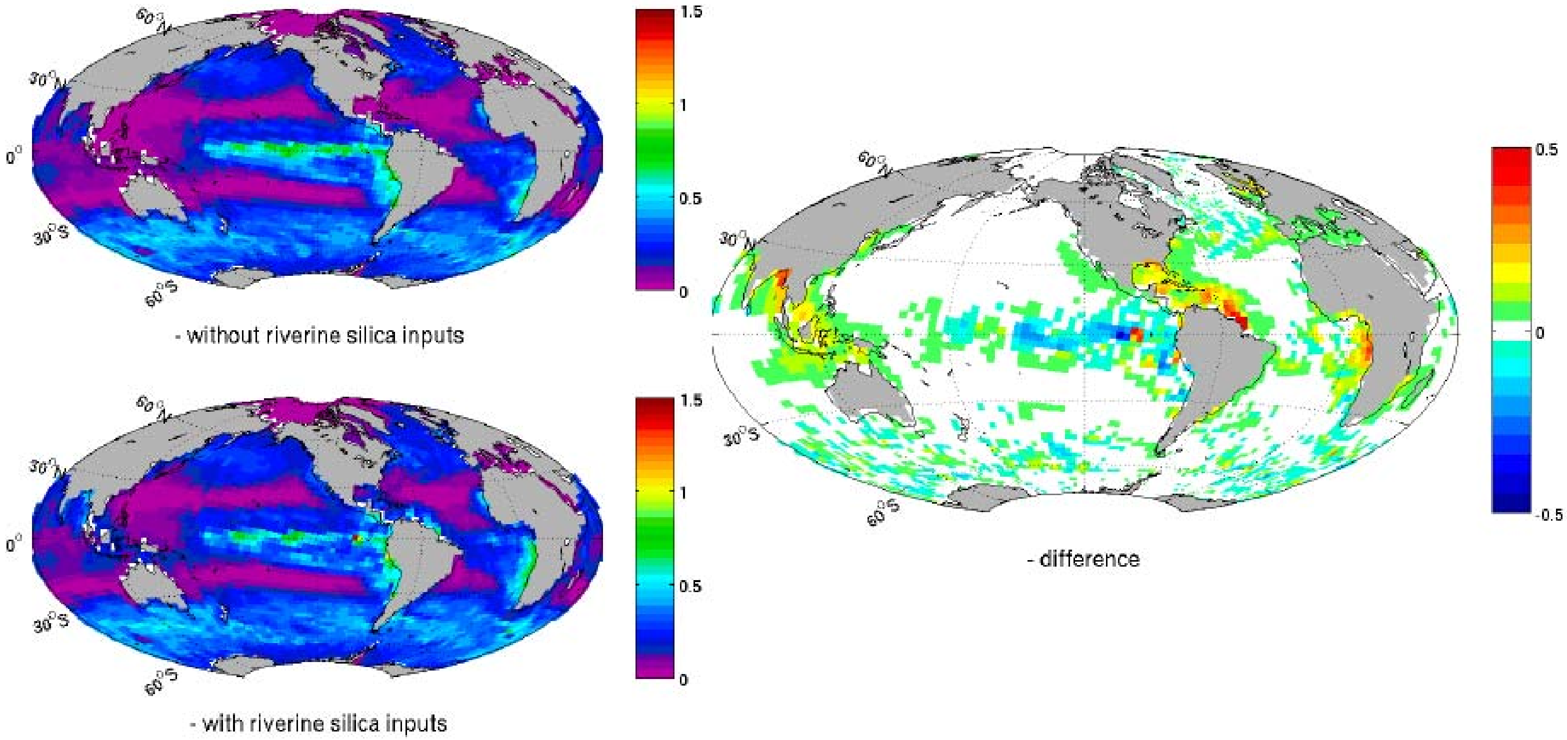


Fig. 5. Rivers contribution to the Opal export production in mol Si m^{-2} $year^{-1}$ – without silica riverine inputs (top-left) – with silica riverine inputs (bottom-left) and the computed difference with/without riverine silica inputs (right).

River dams retain 20% of the continental dSi that should arrive to the oceans

Bernard et al., Biogeosciences, 2010

global change and silicon in the oceans

the decline of diatoms

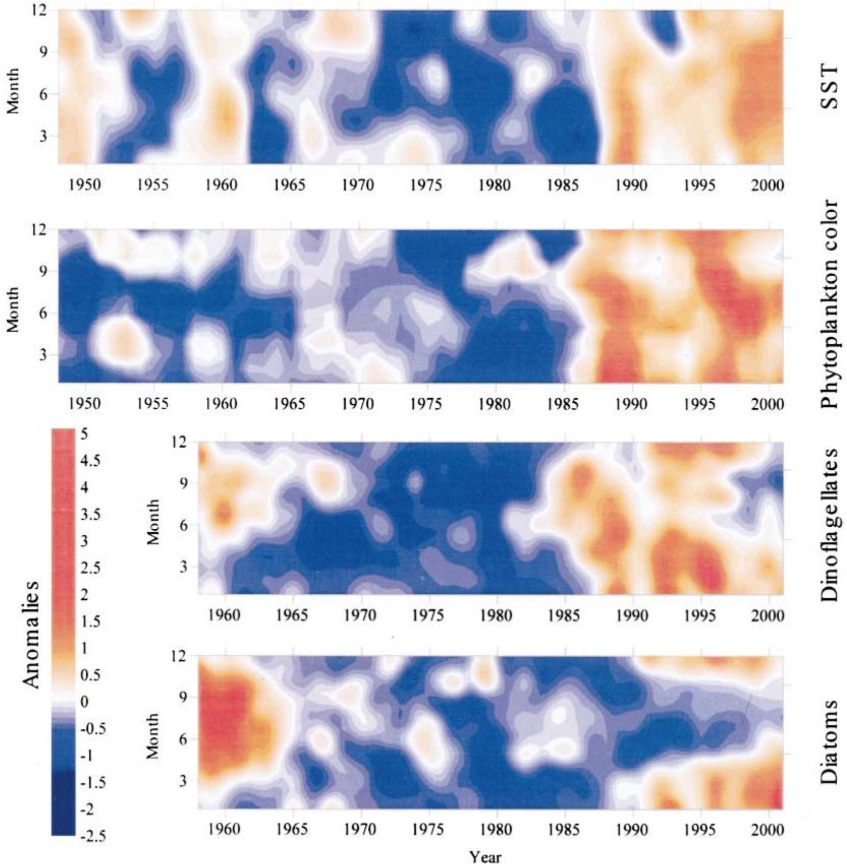
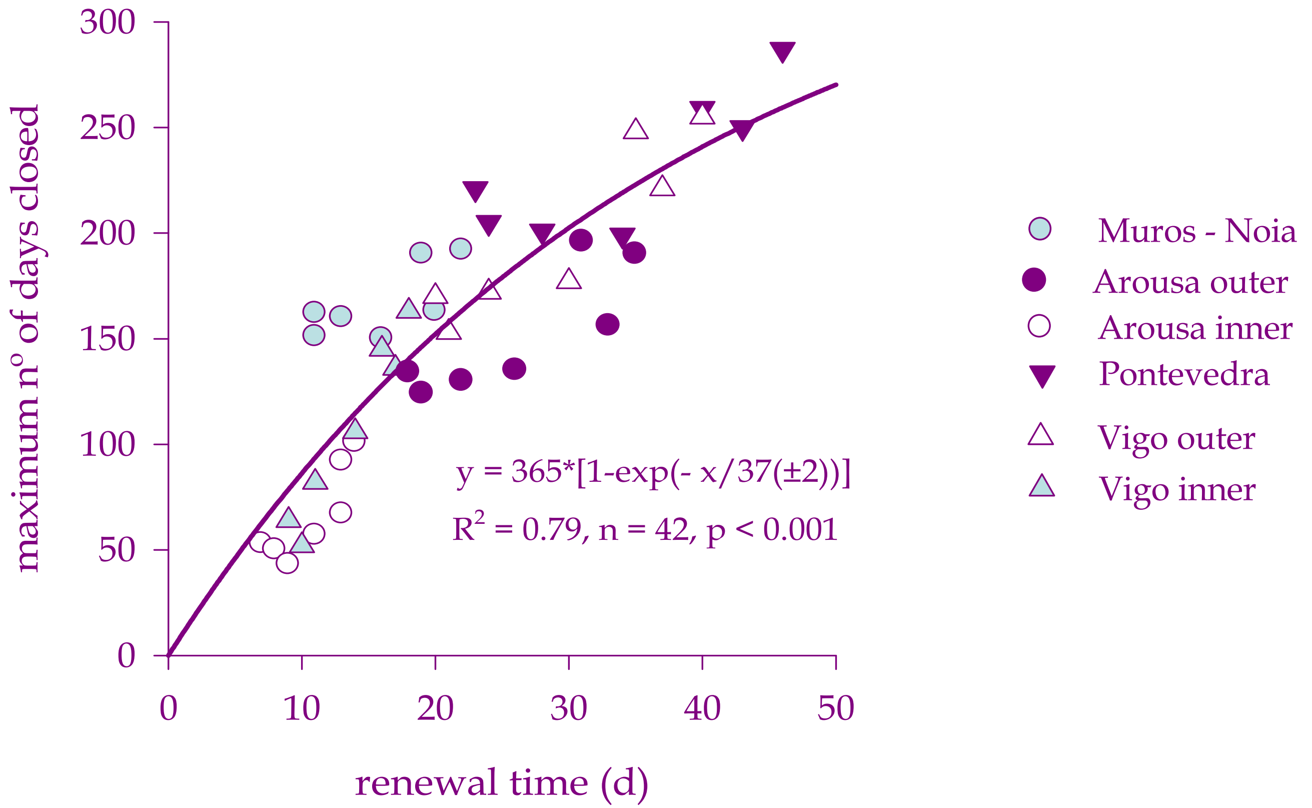


Fig. 1. Monthly standardized anomaly plots for (a) sea surface temperature (1948–2002), (b) phytoplankton color (1948–2002), (c) dinoflagellate cell counts (1958–2002), (d) diatom cell counts (1958–2002). Shades of red signify values above the long-term mean and shades of blue values below the long-term mean. Zero-mean values are in white. Data averaged for the central North Sea.

impact on diatoms biomass in coastal areas

global change and silicon in the oceans

the decline of diatoms



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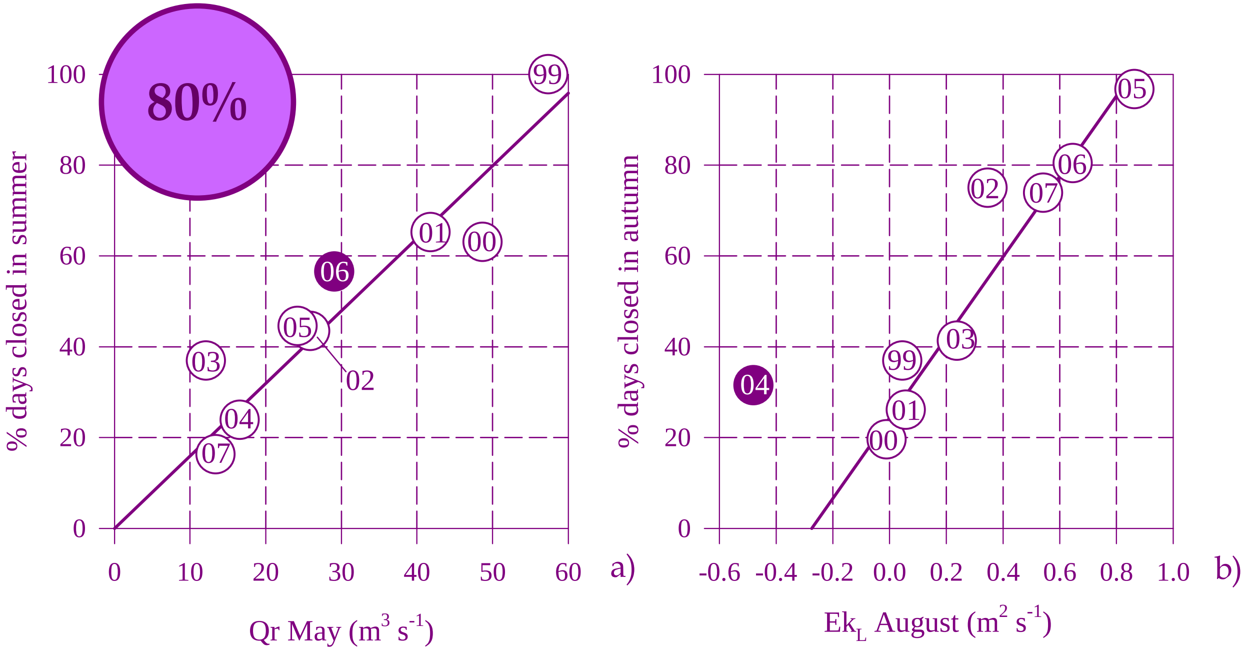

impact on diatoms biomass in coastal areas

Álvarez-Salgado et al., Harmful Algae, 2011