Interactions of persistent organic pollutants (POPs) with marine phytoplankton in temperate and polar seawaters

Third International Symposium

Effects of Climate Change on the World's Oceans

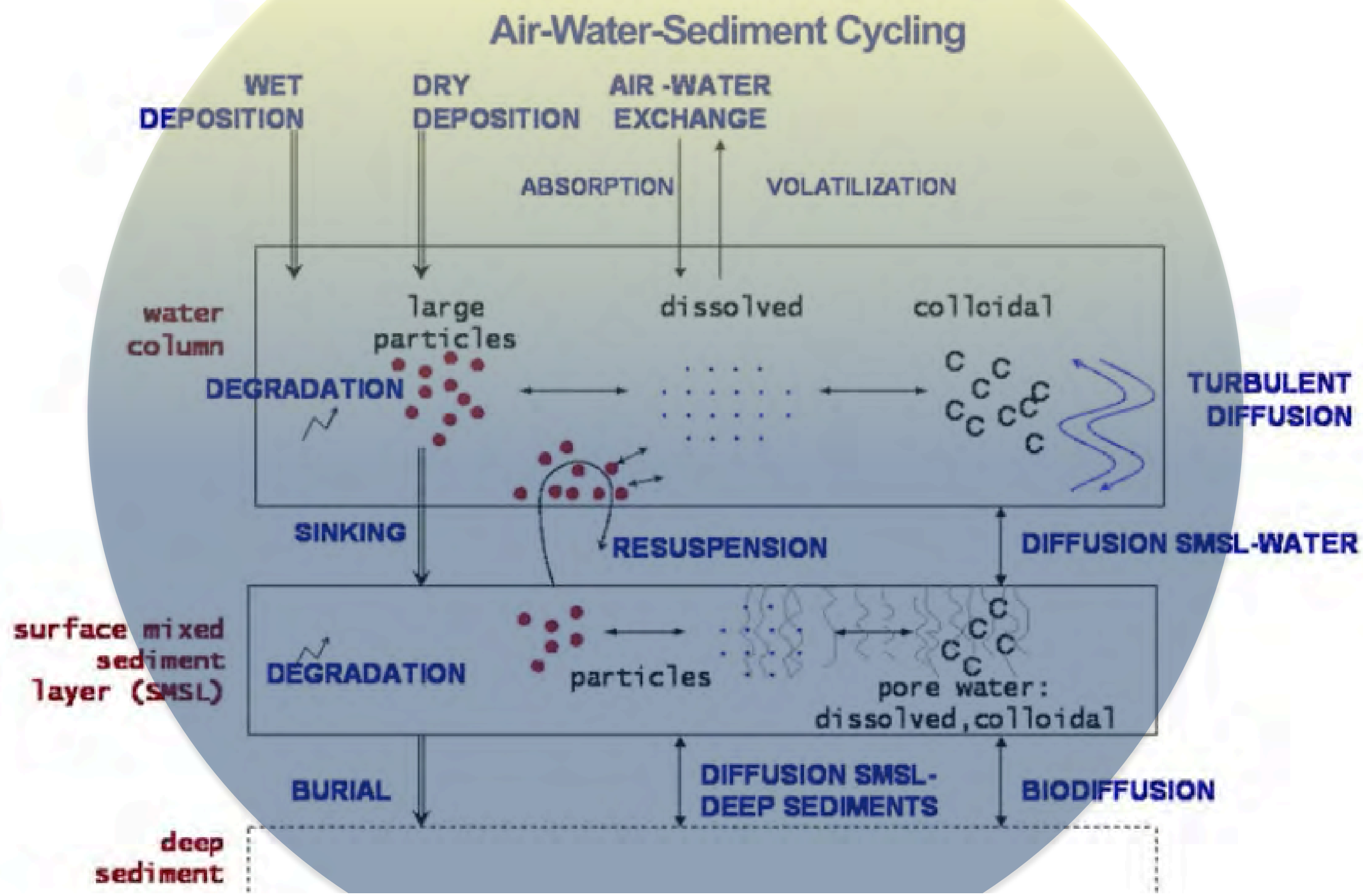
Santos City, Brazil
March 23-27, 2015

P. Echeveste[1], C. Galbán-Malagón[2], J. Dachs[3], S. Agustí[1,4]

[1]1Universidade Federal de São Carlos, São Carlos, Brazil
[2]Universidad Nacional Andrés Bello, Santiago de Chile, Chile
[3]Department of Environmental Chemistry (IDAEA-CSIC), Barcelona, Catalunya, Spain
[4]The UWA Oceans Institute and School of Plant Biology, University of Western Australia, Australia

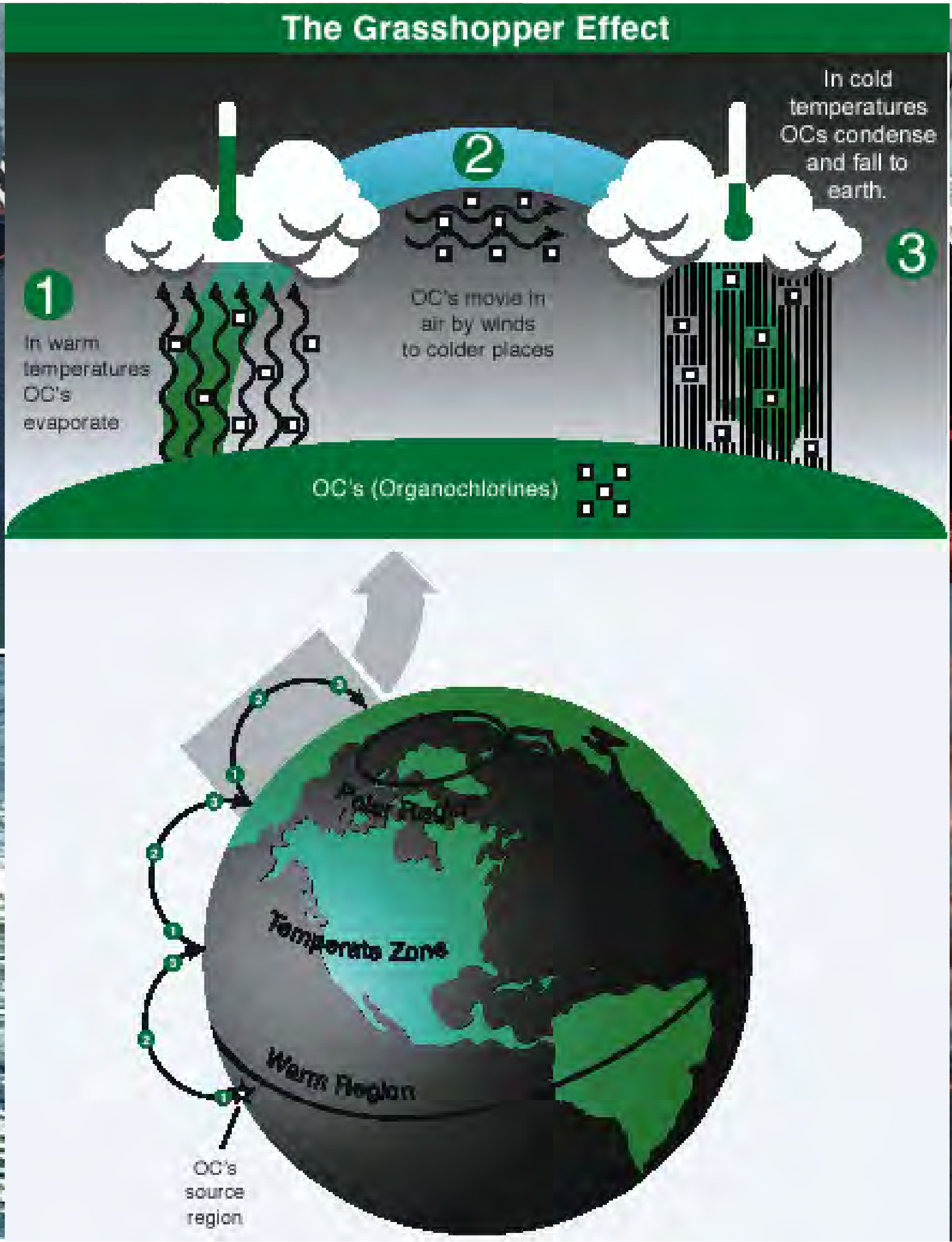
Phytoplankton is responsible of half of the global organic matter production

(Berger et al., 1989; Falkowski and Woodhead, 1992; Field et al., 1998)

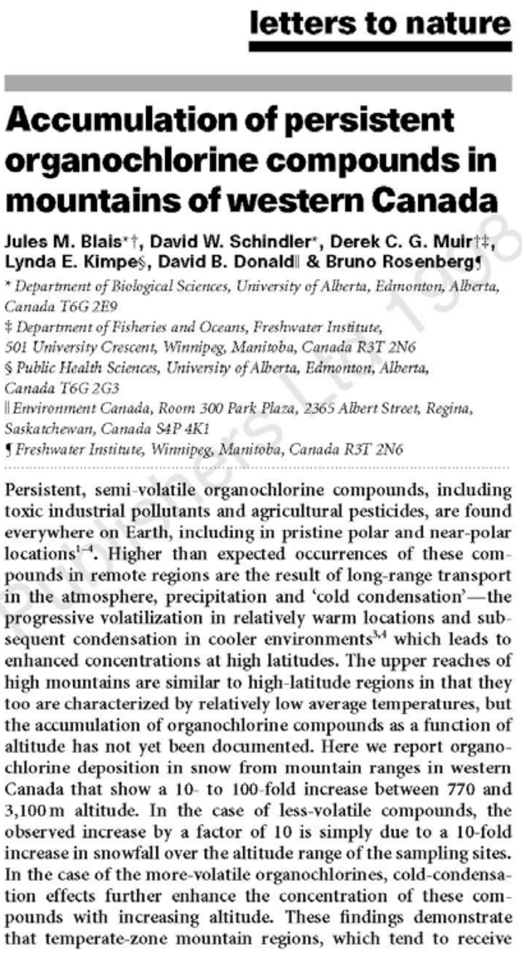


The oceanic cycle of POPs is influenced by planktonic food webs

(Dachs et al., 2002; Lohmann et al., 2007; Nizzetto et al., 2014)


The Grasshopper Effect
1
In warm temperatures OC's evaporate
2
OC's movie in air by winds to colder places
3
In cold temperatures OCs condense and fall to earth.
OC's (Organochlorines)
Temperate Zone
Warm Region
OC's source region

According to Flick's law, pollution decreases with increasing distance from the source ("dilution effect")


letters to nature

Accumulation of persistent organochlorine compounds in mountains of western Canada

Jules M. Blais*†, David W. Schindler*, Derek C. G. Muir†‡, Lynda E. Kimpe§, David B. Donald‖ & Bruno Rosenberg¶

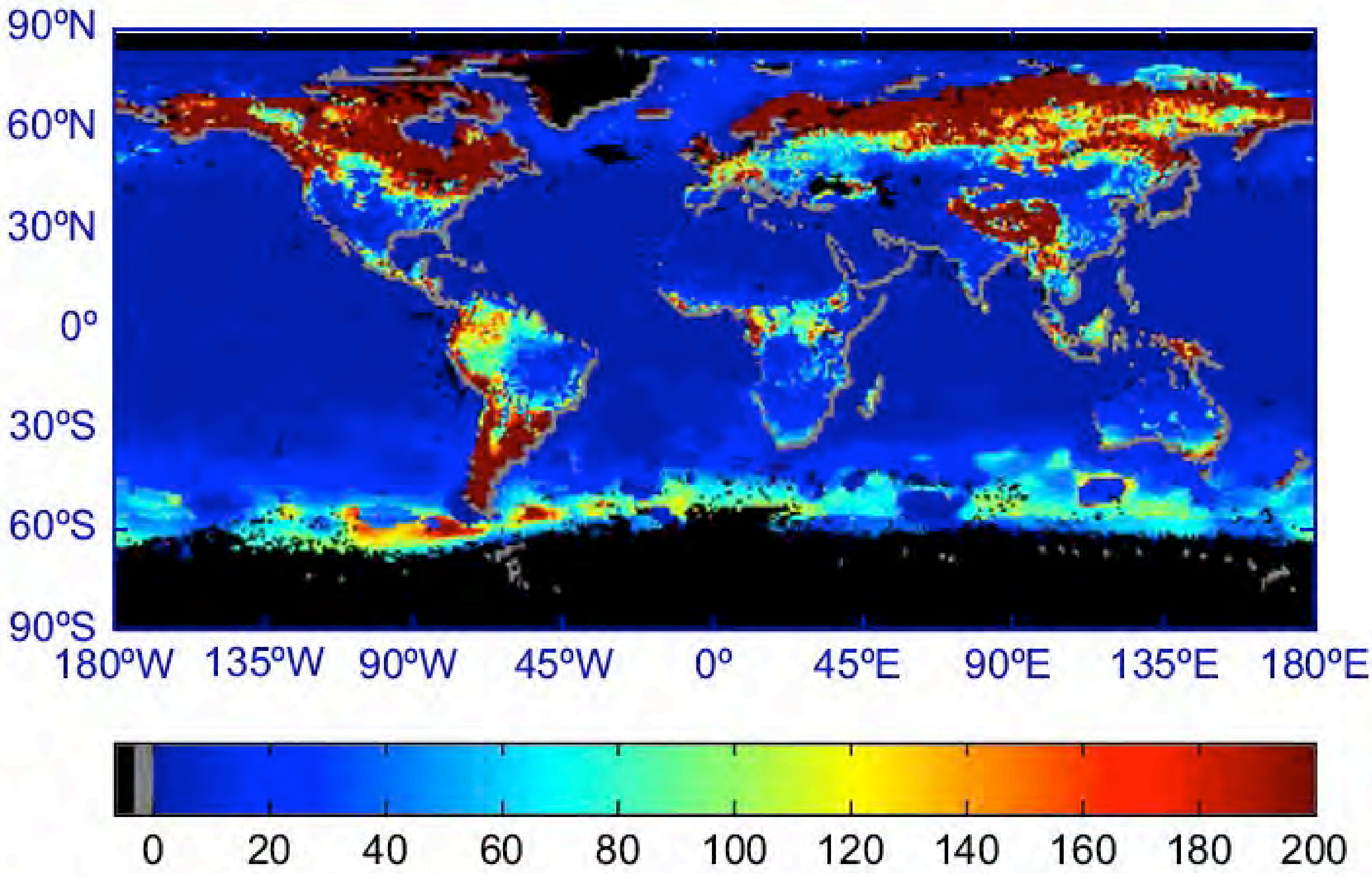
* *Department of Biological Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2E9*
‡ *Department of Fisheries and Oceans, Freshwater Institute, 501 University Crescent, Winnipeg, Manitoba, Canada R3T 2N6*
§ *Public Health Sciences, University of Alberta, Edmonton, Alberta, Canada T6G 2G3*
‖ *Environment Canada, Room 300 Park Plaza, 2365 Albert Street, Regina, Saskatchewan, Canada S4P 4K1*
¶ *Freshwater Institute, Winnipeg, Manitoba, Canada R3T 2N6*

Persistent, semi-volatile organochlorine compounds, including toxic industrial pollutants and agricultural pesticides, are found everywhere on Earth, including in pristine polar and near-polar locations[1–4]. Higher than expected occurrences of these compounds in remote regions are the result of long-range transport in the atmosphere, precipitation and 'cold condensation'—the progressive volatilization in relatively warm locations and subsequent condensation in cooler environments[3,4] which leads to enhanced concentrations at high latitudes. The upper reaches of high mountains are similar to high-latitude regions in that they too are characterized by relatively low average temperatures, but the accumulation of organochlorine compounds as a function of altitude has not yet been documented. Here we report organochlorine deposition in snow from mountain ranges in western Canada that show a 10- to 100-fold increase between 770 and 3,100 m altitude. In the case of less-volatile compounds, the observed increase by a factor of 10 is simply due to a 10-fold increase in snowfall over the altitude range of the sampling sites. In the case of the more-volatile organochlorines, cold-condensation effects further enhance the concentration of these compounds with increasing altitude. These findings demonstrate that temperate-zone mountain regions, which tend to receive

Higher POPs concentrations with decreasing temperature and elevation above sea level
(Blais et al., 1998; Grimalt et al., 2001, 2004; Meijer et al., 2009)

The "distillation effect"

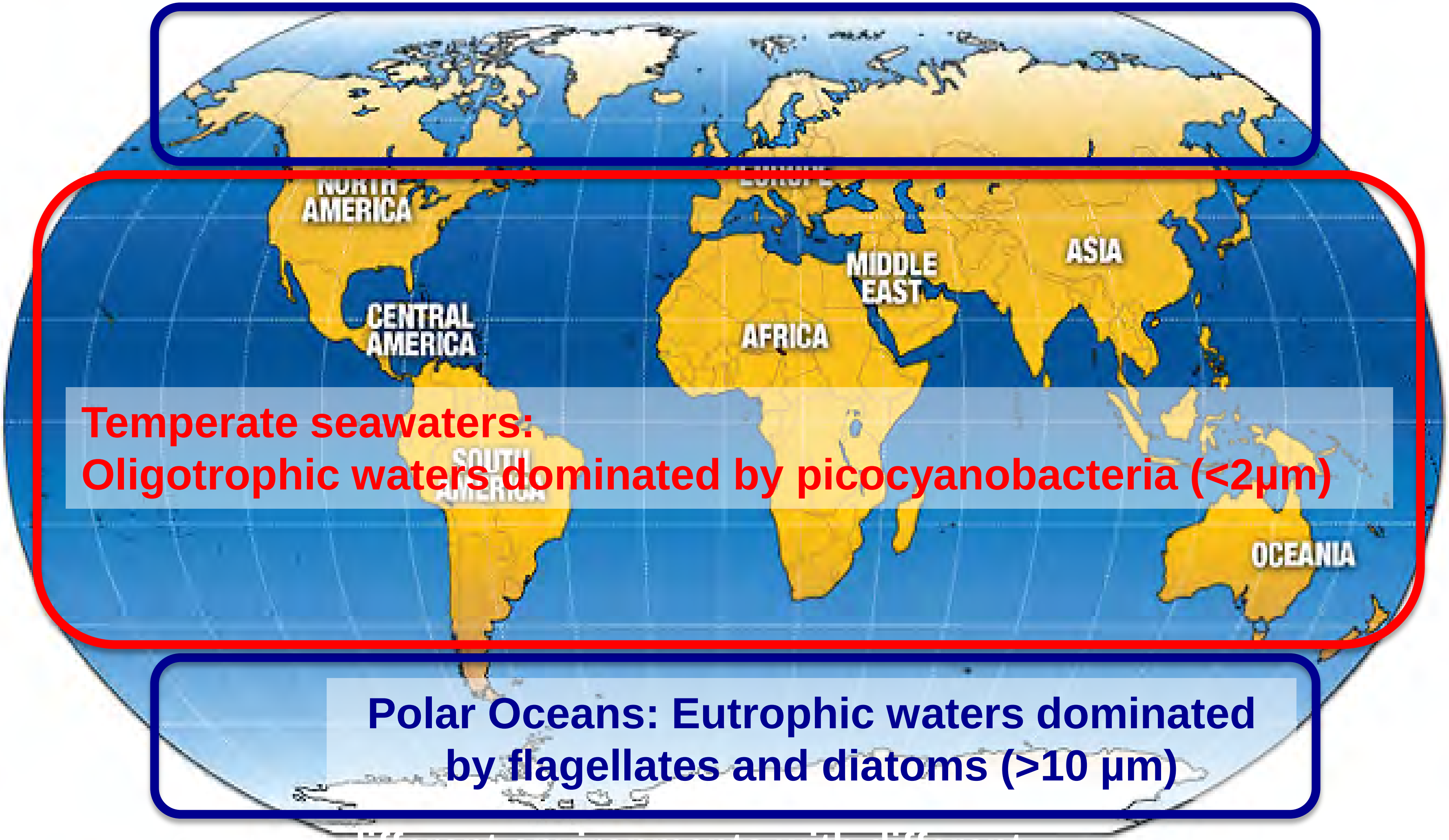
Careful where you drink, the highest mountainous lakes are more contaminated than lakes of lower altitudes!!



Dalla Valle et al., 2005

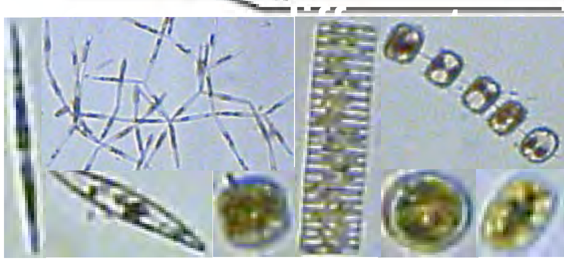
80% of pollutants detected in the Arctic come from countries other than Canada (Inuit Circumpolar Conference and the Inuit Tapirisat of Canada)

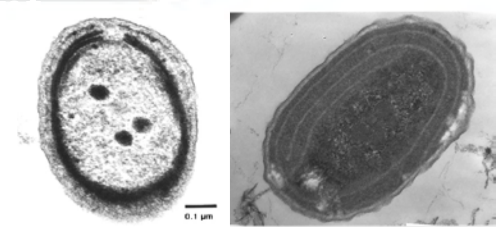
Temperate vs polar seawaters

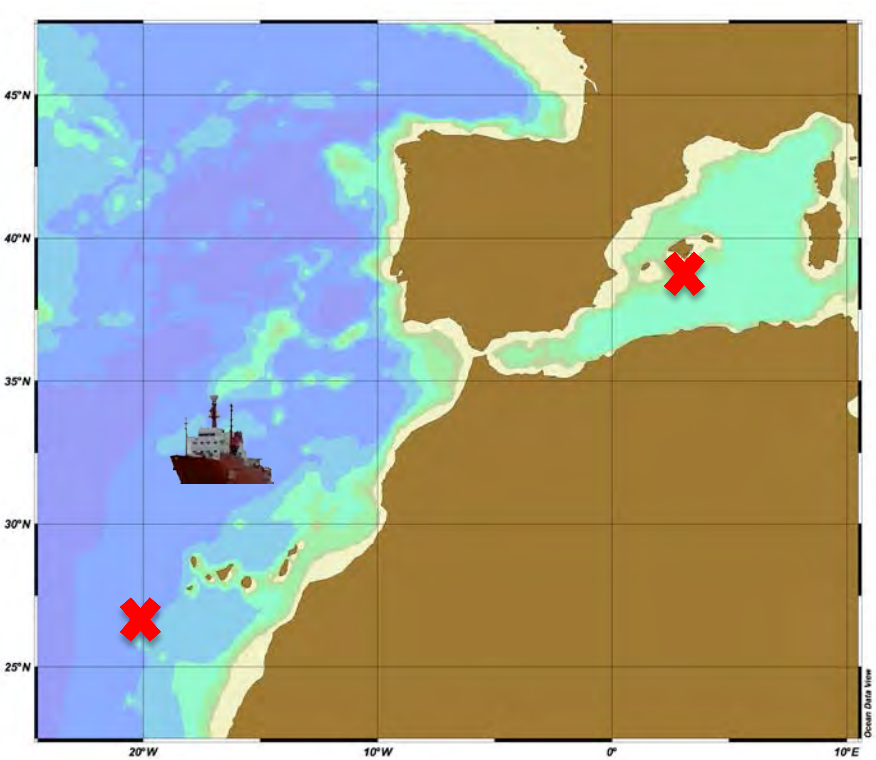


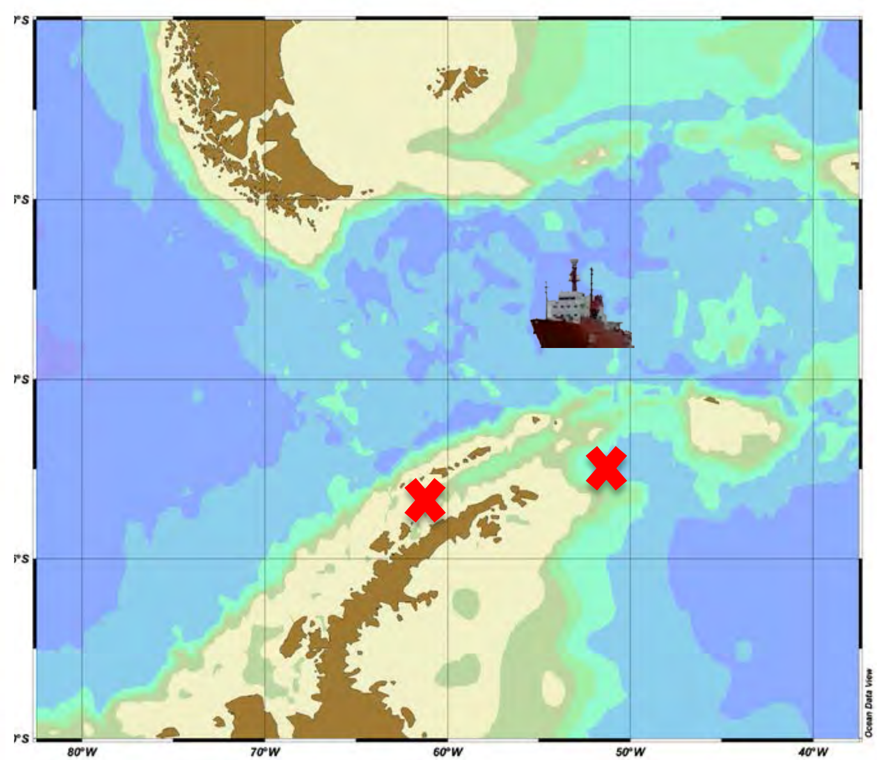
Temperate seawaters:
Oligotrophic waters dominated by picocyanobacteria (<2µm)

Polar Oceans: Eutrophic waters dominated by flagellates and diatoms (>10 µm)



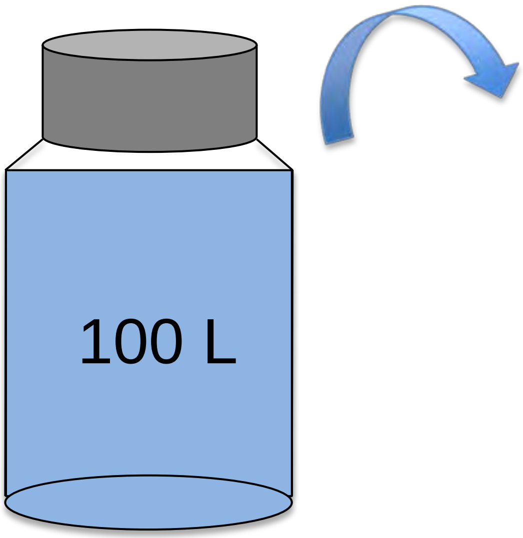




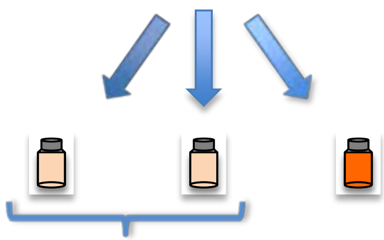


Wait, what about the POPs?

Our “San Francisco”



1. Filtration with GFF filters (Whathman)
2. Concentration of the hydrophobic organic pollutants through a XAD-2 adsorbent
3. Clean up of the extract on a alumina 3% deactivated column

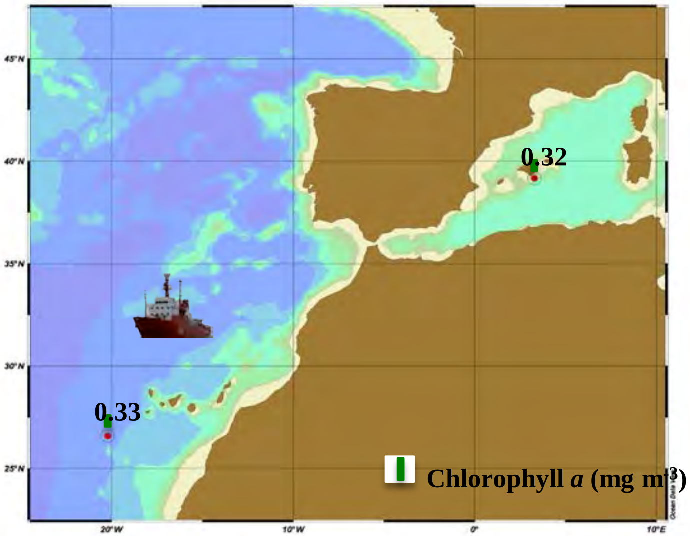


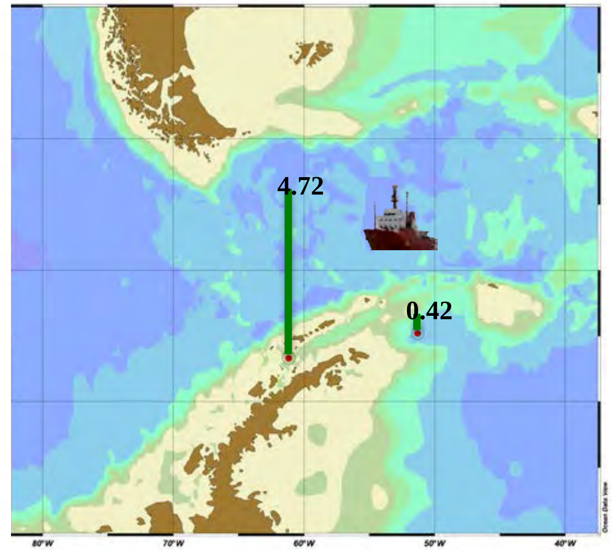
Polar OP (POPs with alcohol, ketone and acid functional groups)

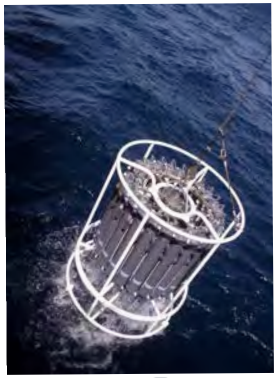
Non-polar OP (PCBs, PAHs, lindane, etc.)

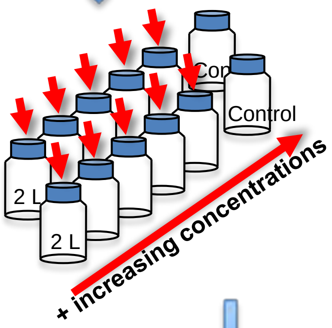
More details about the method:
*Dachs and Bayona, 1997; Gioia et al., 2008; Nizzetto et al., 2008; Dachs and Bayona, 1997

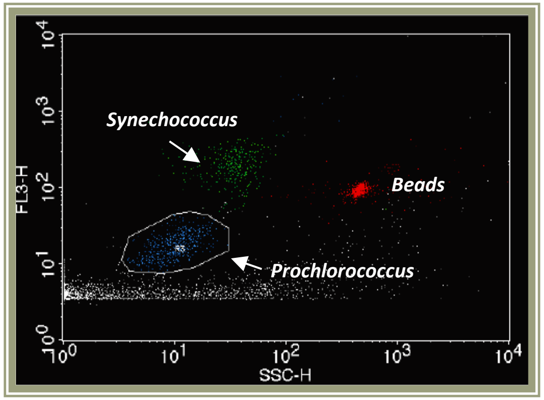
Procedure



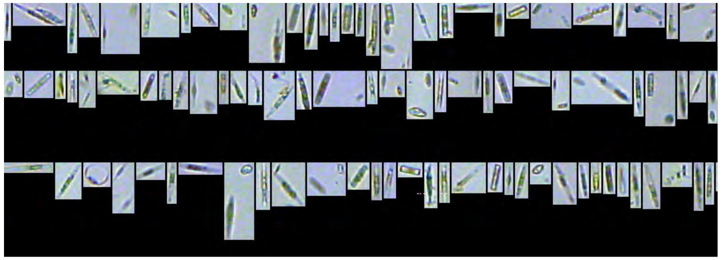




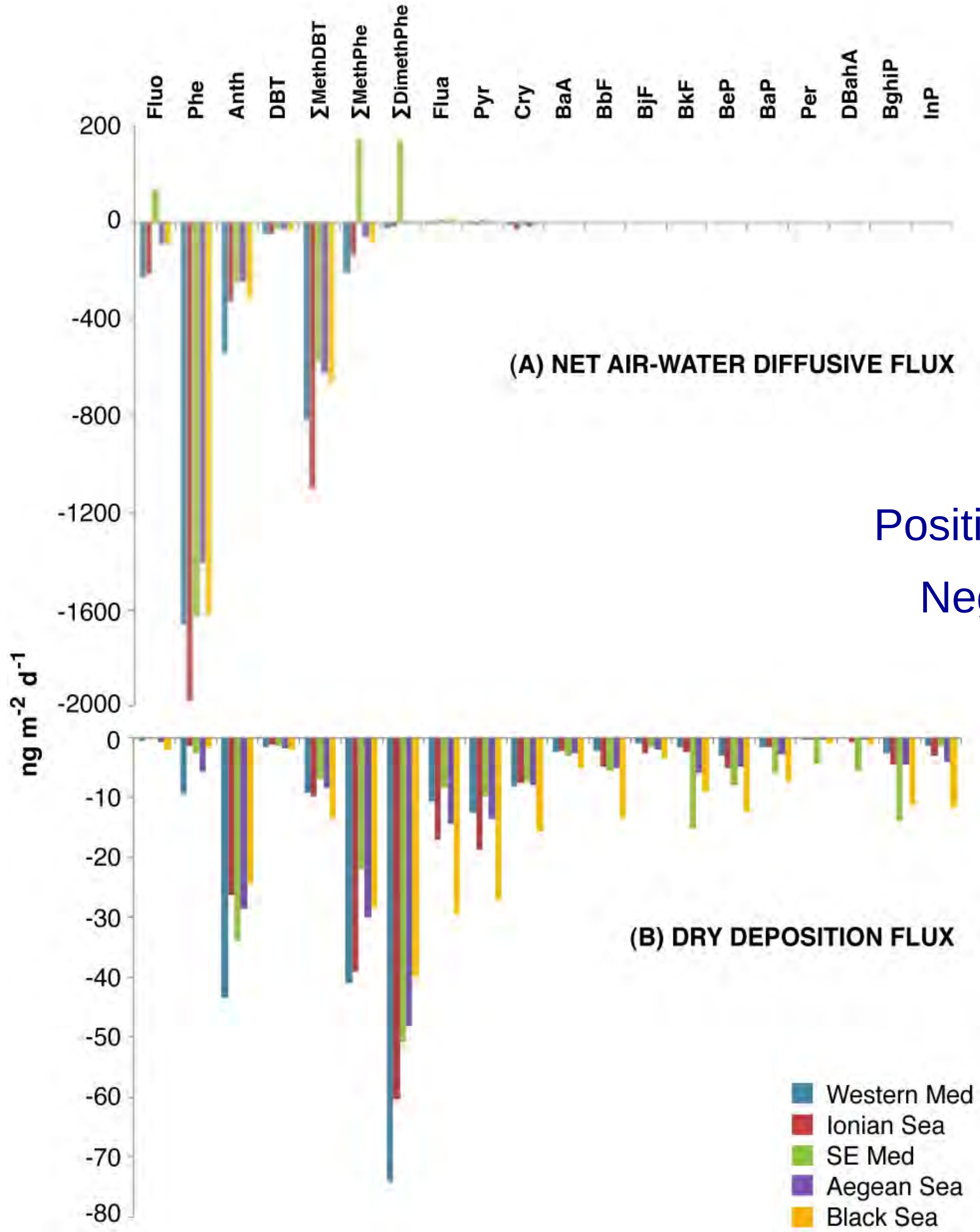




Flow cytometry

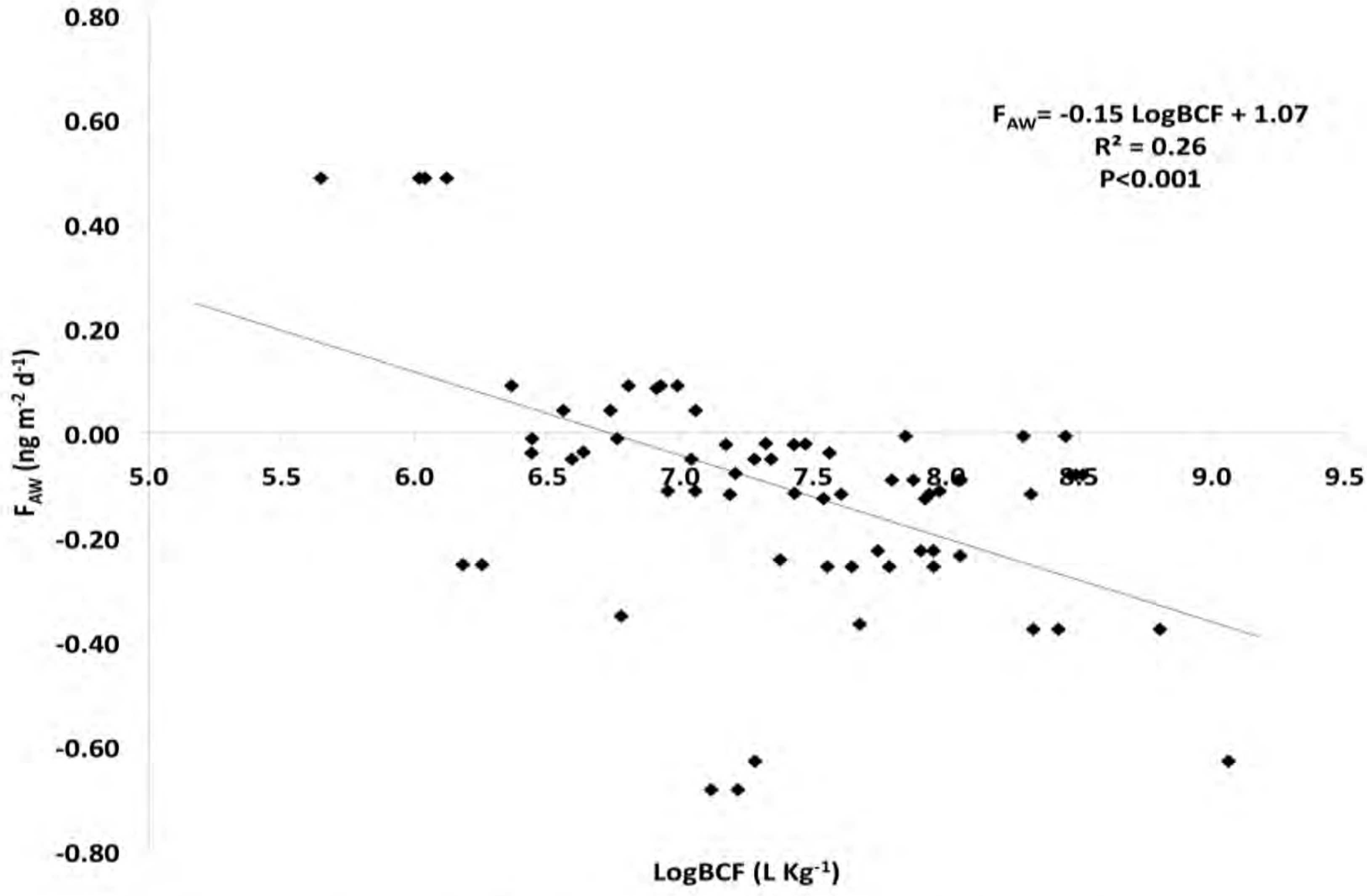


FLOWCAM analysis



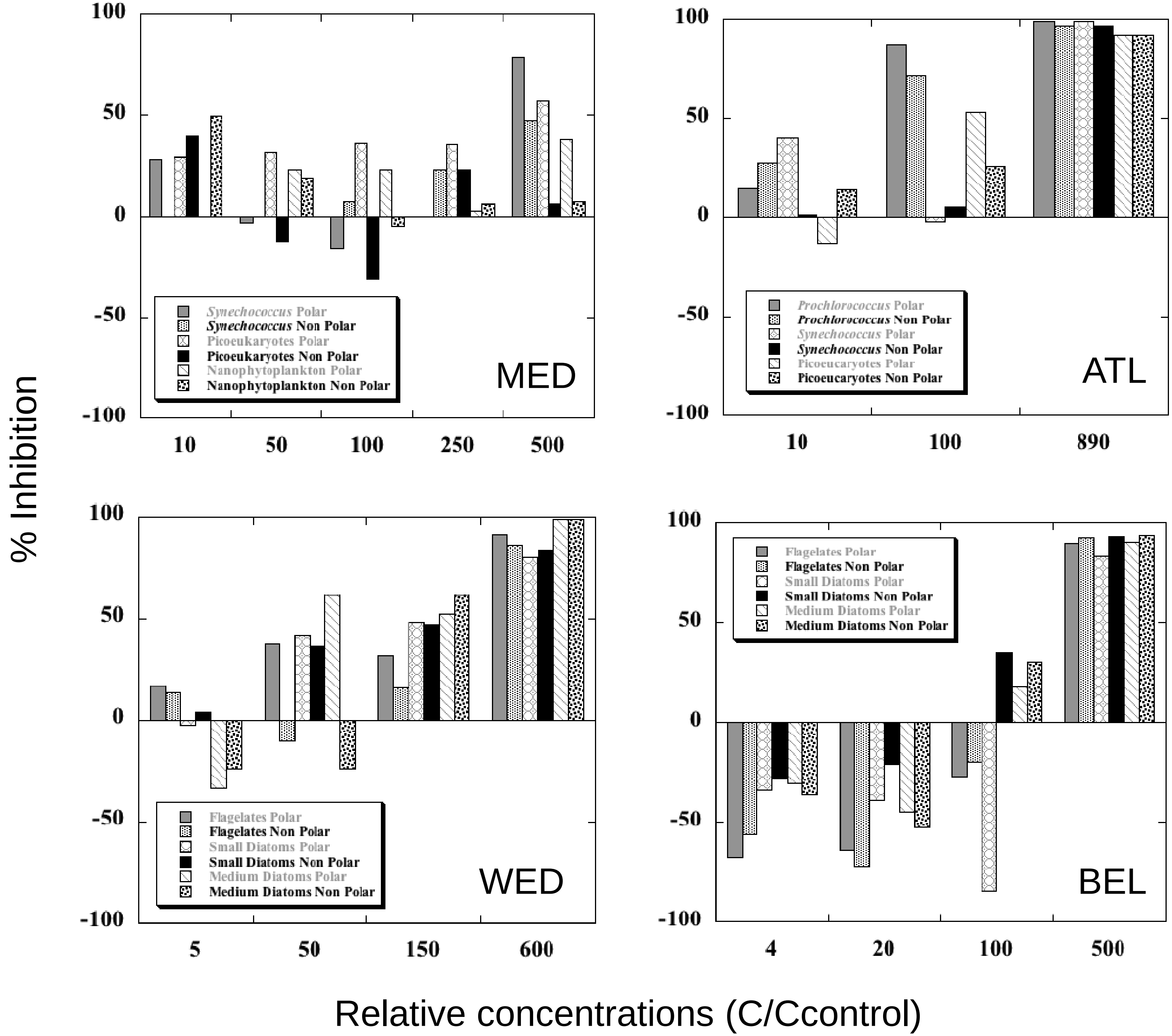
Positive values = volatilization fluxes

Negative values = deposition fluxes

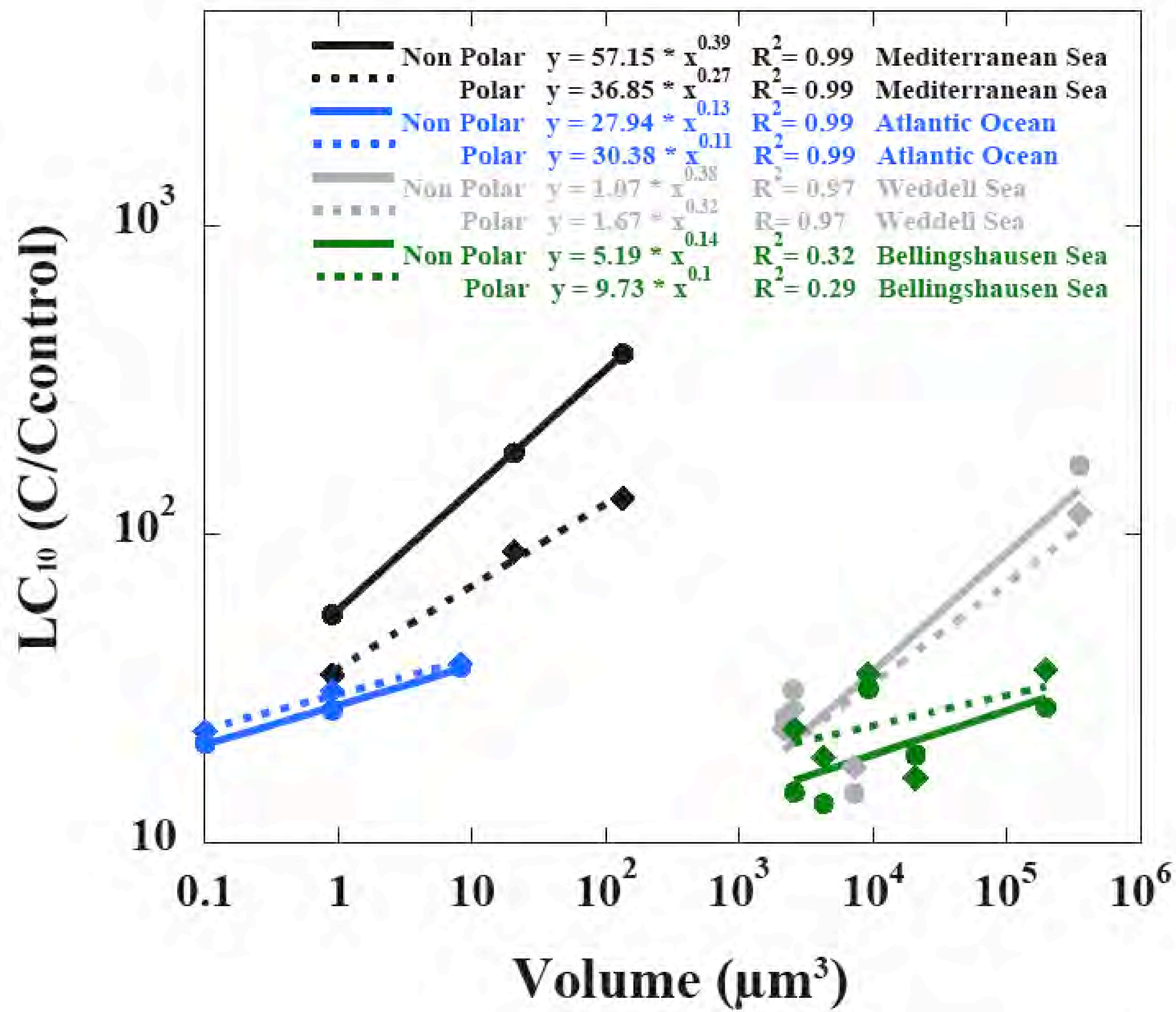


BCF: Bioconcentration factor

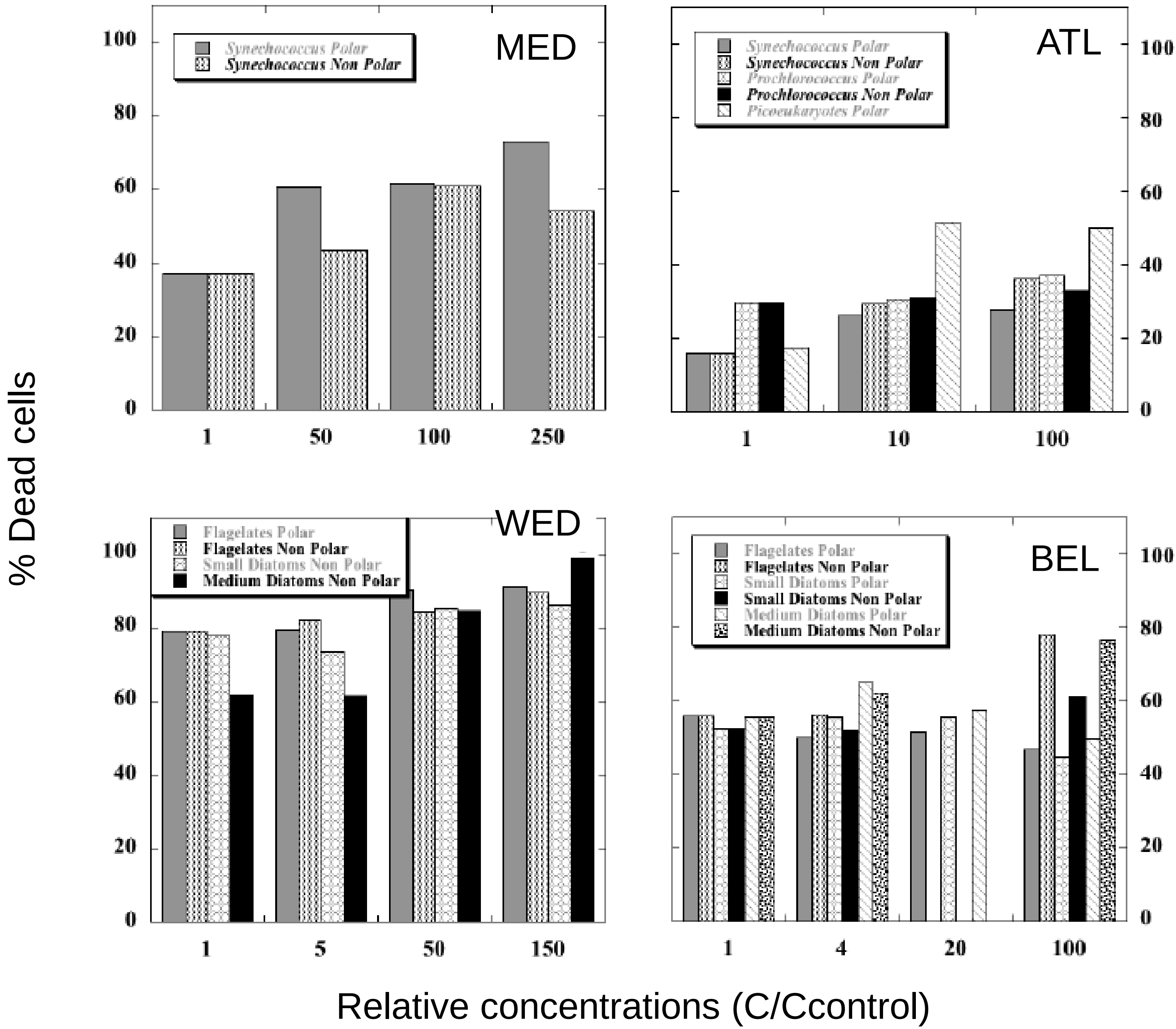
F_{aw}: Air-water flux


% Inhibition
MED
Synechococcus Polar
Synechococcus Non Polar
Picoeukaryotes Polar
Picoeukaryotes Non Polar
Nanophytoplankton Polar
Nanophytoplankton Non Polar
10
50
100
250
500
ATL
Prochlorococcus Polar
Prochlorococcus Non Polar
Synechococcus Polar
Synechococcus Non Polar
Picoeucaryotes Polar
Picoeucaryotes Non Polar
10
100
890
WED
Flagelates Polar
Flagelates Non Polar
Small Diatoms Polar
Small Diatoms Non Polar
Medium Diatoms Polar
Medium Diatoms Non Polar
5
50
150
600
BEL
Flagelates Polar
Flagelates Non Polar
Small Diatoms Polar
Small Diatoms Non Polar
Medium Diatoms Polar
Medium Diatoms Non Polar
4
20
100
500
100
50
0
-50
-100
Relative concentrations (C/Ccontrol)

		Volume (μm^3)	LC_{50} ($C/C_{control}$) Non Polar	Polar	LC_{10} ($C/C_{control}$) Non Polar	Polar
Mediterranean Sea [a]	*Synechococcus*	9.0E-01	361 (± 443)	230 (± 123)	55 (± 67)	35 (± 19)
	Small eukaryotes	2.1E+01	*	*	184 (± 415)	88 (± 55)
	Nanoplankton	1.3E+02	*	*	386 (± 953)	131 (± 149)
Atlantic Ocean	*Prochlorococcus*	1.0E-01	137 (± 37)	149 (± 84)	21 (± 6)	23 (± 13)
	Synechococcus	9.0E-01	177 (± 23)	201 (± 77)	27 (± 4)	31 (± 11)
	Picoeukaryotes	8.2E+00	243 (± 2)	247 (± 80)	37 (± 0)	38 ± 12
Weddell Sea	Small flagellates	2.5E+03	206 (± 55)	178 (± 39)	31 (± 8)	27 (± 6)
	Small diatoms	2.2E+03	245 (± 53)	273 (± 97)	37 (± 8)	42 (± 15)
	Medium diatoms	7.2E+03	164 (± 52)	168 (± 37)	25 (± 8)	26 (± 6)
	Large diatoms	3.5E+05	*	*	167 (± 884)	117 (± 398)
Bellingshausen Sea	Small flagellates	4.3E+03	115 (± 20)	134 (± 24)	18 (± 3)	20 (± 4)
	Small diatoms	2.6E+03	121 (± 13)	153 (± 73)	18 (± 2)	23 (± 11)
	Medium flagellates	2.1E+04	132 (± 5)	101 (± 26)	20 (± 1)	15 (± 4)
	Medium diatoms	9.2E+03	115 (± 31)	130 (± 39)	18 (± 5)	20 (± 6)
	Large diatoms	1.9E+05	141 (± 26)	102 (± 22)	21 (± 4)	16 (± 3)



Non Polar y = 57.15 * x^0.39 R^2 = 0.99 Mediterranean Sea
Polar y = 36.85 * x^0.27 R^2 = 0.99 Mediterranean Sea
Non Polar y = 27.94 * x^0.13 R^2 = 0.99 Atlantic Ocean
Polar y = 30.38 * x^0.11 R^2 = 0.99 Atlantic Ocean
Non Polar y = 1.07 * x^0.38 R^2 = 0.97 Weddell Sea
Polar y = 1.67 * x^0.32 R= 0.97 Weddell Sea
Non Polar y = 5.19 * x^0.14 R^2 = 0.32 Bellingshausen Sea
Polar y = 9.73 * x^0.1 R^2 = 0.29 Bellingshausen Sea
LC10 (C/Ccontrol)
10^3
10^2
10
0.1
1
10
10^2
10^3
10^4
10^5
10^6
Volume (µm^3)


MED
Synechococcus Polar
Synechococcus Non Polar
ATL
Synechococcus Polar
Synechococcus Non Polar
Prochlorococcus Polar
Prochlorococcus Non Polar
Picoeukaryotes Polar
WED
Flagelates Polar
Flagelates Non Polar
Small Diatoms Non Polar
Medium Diatoms Non Polar
BEL
Flagelates Polar
Flagelates Non Polar
Small Diatoms Polar
Small Diatoms Non Polar
Medium Diatoms Polar
Medium Diatoms Non Polar
% Dead cells
Relative concentrations (C/Ccontrol)

- Not significant differences between the polar and the non polar organic pollutants' impacts.

- At concentrations below those causing significant decreases in the phytoplankton populations, cell death was already induced.

- In each oceanic region, cell size determined the sensitivity to POPs.

- Comparing oceanic regions, polar communities pointed to be less adapted to pollution.

- POPs present in seawater are impacting phytoplankton communities.

Planetary Boundaries:
Exploring the safe operating space for humanity

Johan Rockström[1,2*], Will Steffen[1,3], Kevin Noone[1,4], Åsa Persson[1,2], F. Stuart Chapin, III[5], Eric F. Lambin[6], Timothy M. Lenton[7], Marten Scheffer[8], Carl Folke[1,9], Hans Joachim Schellnhuber[10,11], Björn Nykvist[1,2], Cynthia A. de Wit[4], Terry Hughes[12], Sander van der Leeuw[13], Henning Rodhe[14], Sverker Sörlin[1,15], Peter K. Snyder[16], Robert Costanza[1,17], Uno Svedin[1], Malin Falkenmark[1,18], Louise Karlberg[1,2], Robert W. Corell[19], Victoria J. Fabry[20], James Hansen[21], Brian Walker[1,22] Diana Liverman[23], Katherine Richardson[24], Paul Crutzen[25], Jonathan A. Foley[26]

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per meter sqaured)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorous cycle)	Amount of N_2 removed form the atmosphere for human use (millions of tonnes per year)	35	121	0
Phosphorous cycle (part of a boundary with the Nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	11	8.5-9.5	-1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration in, the global environment of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste; or their effects on the functioning of ecosystems and the Earth System.		To be determined	

Boundaries for processes in dark grey have been crossed

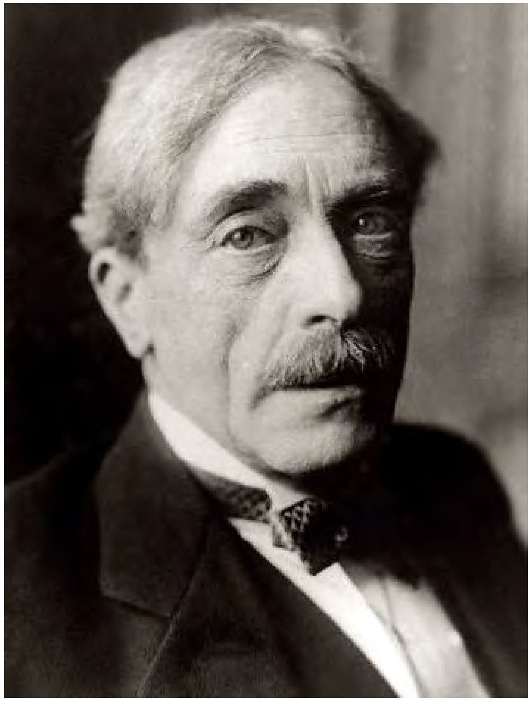
How do POPs interfere with the global carbon cycle?

Special thanks

My co-authors: C. Galbán-Malagón, J. Dachs, S. Agustí

Financial and technical support:

The trouble with our times is that the future is no longer what it used to be (Paul Valery)



Thanks for your attention! Obrigado!