GEOTRACES programme: simulation of particle and trace element distributions with the PISCES model

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Context

Objective:

Better understanding the role of particles in the ocean biogeochemical cycles

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Project « TAPE » *Tracers for Arctic Particles in the Environment*

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Programme « GEOTRACES » trace elements and their isotopes in the marine environment

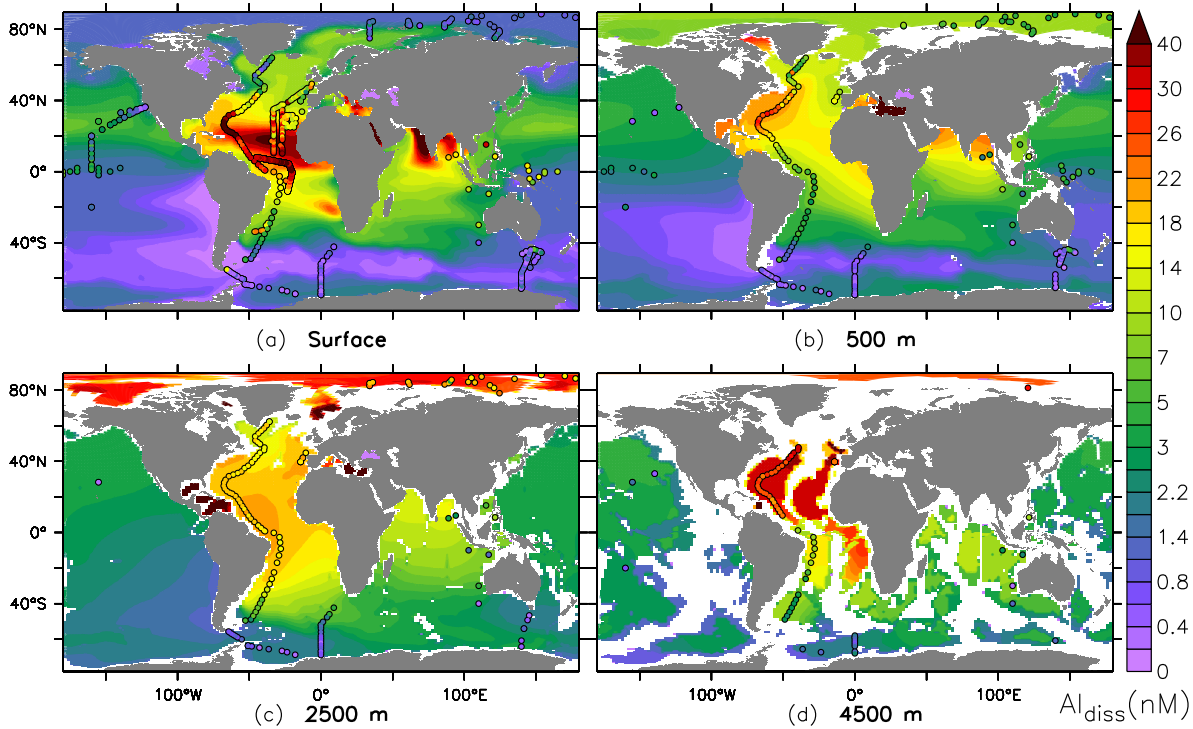
Context

My background: trace metal modelling.

- Al comes from atmosphere and sediment, and is scavenged by $\mathrm{Si}_{\mathrm{biog}}$: *confirmed by my model*
- Mn has many sources, redox modelled as a first-order process: *reproduces observations*

Aluminium

Simulated $[Al_{diss}]$ (nM). Dots are field measurements.



- High $[Al_{diss}]$ at surface near dust deposition, and in the northern hemisphere near sediment (Van Hulten et al., 2014).

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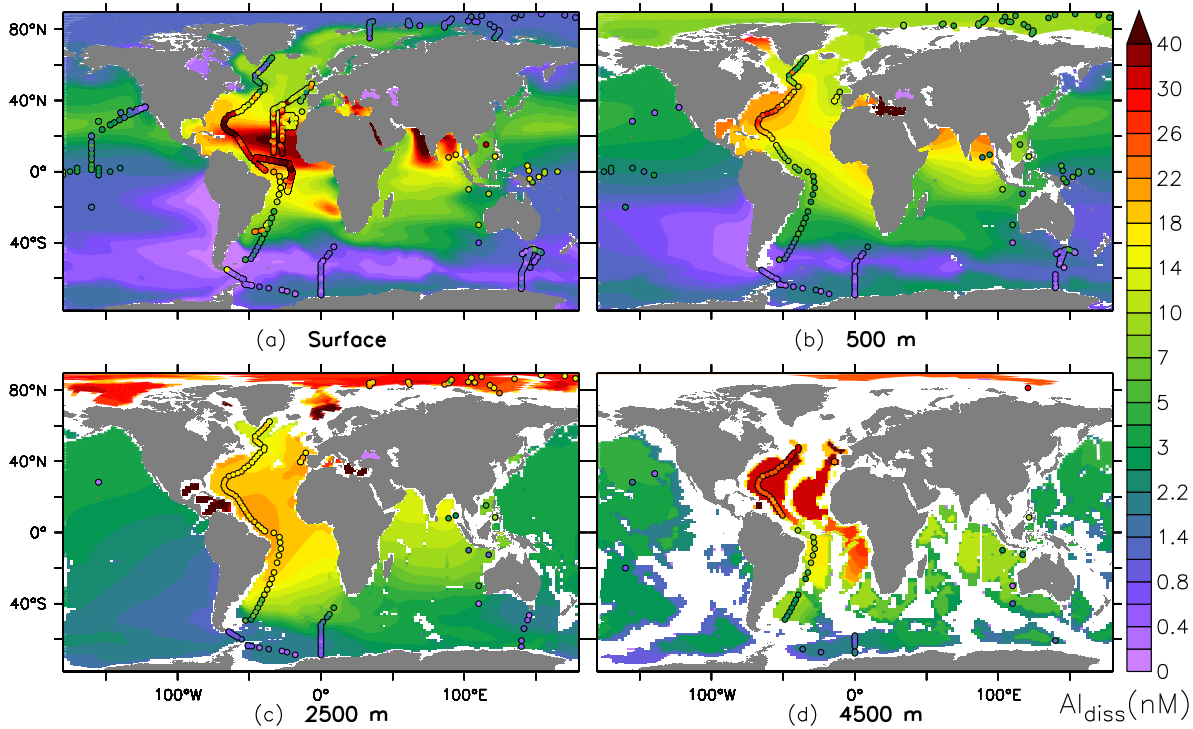
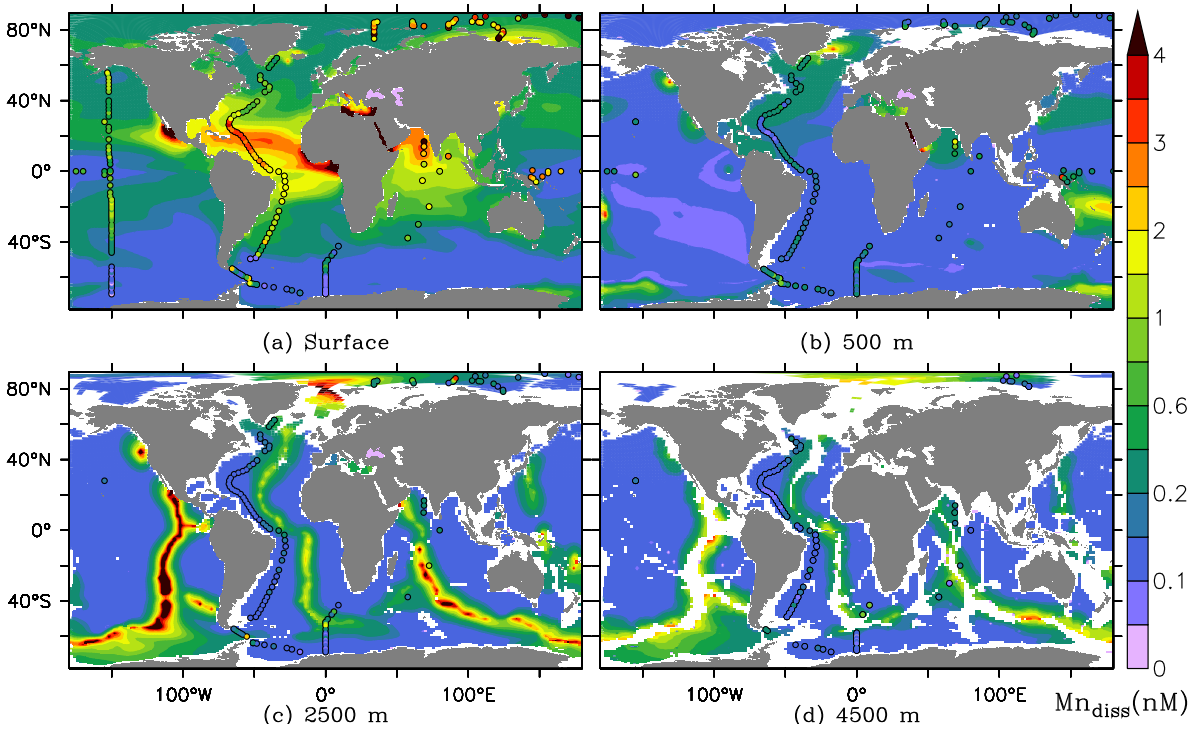


- High $[Al_{diss}]$ at surface near dust deposition, and in the northern hemisphere near sediment (Van Hulten et al., 2014).
- Revisit model after improving particle distributions!

Manganese

Simulated $[\mathrm{Mn_{diss}}]$ (nM). Dots are field measurements.



- Strong correlation, but simplistic model.

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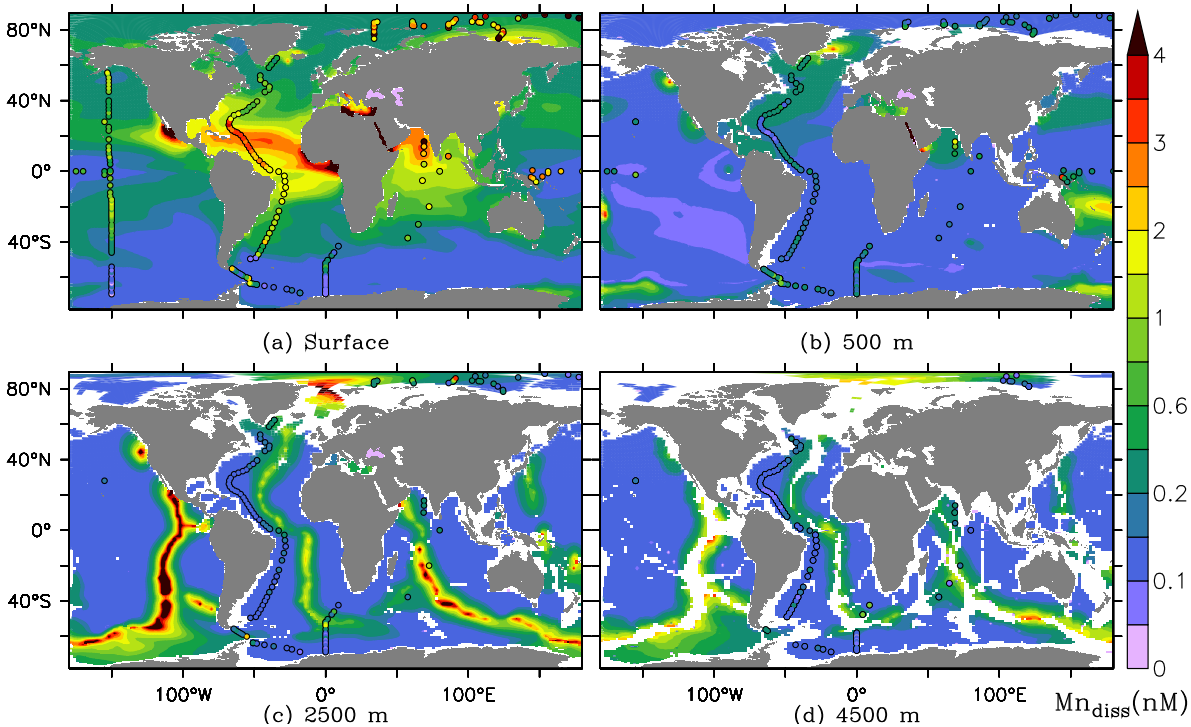
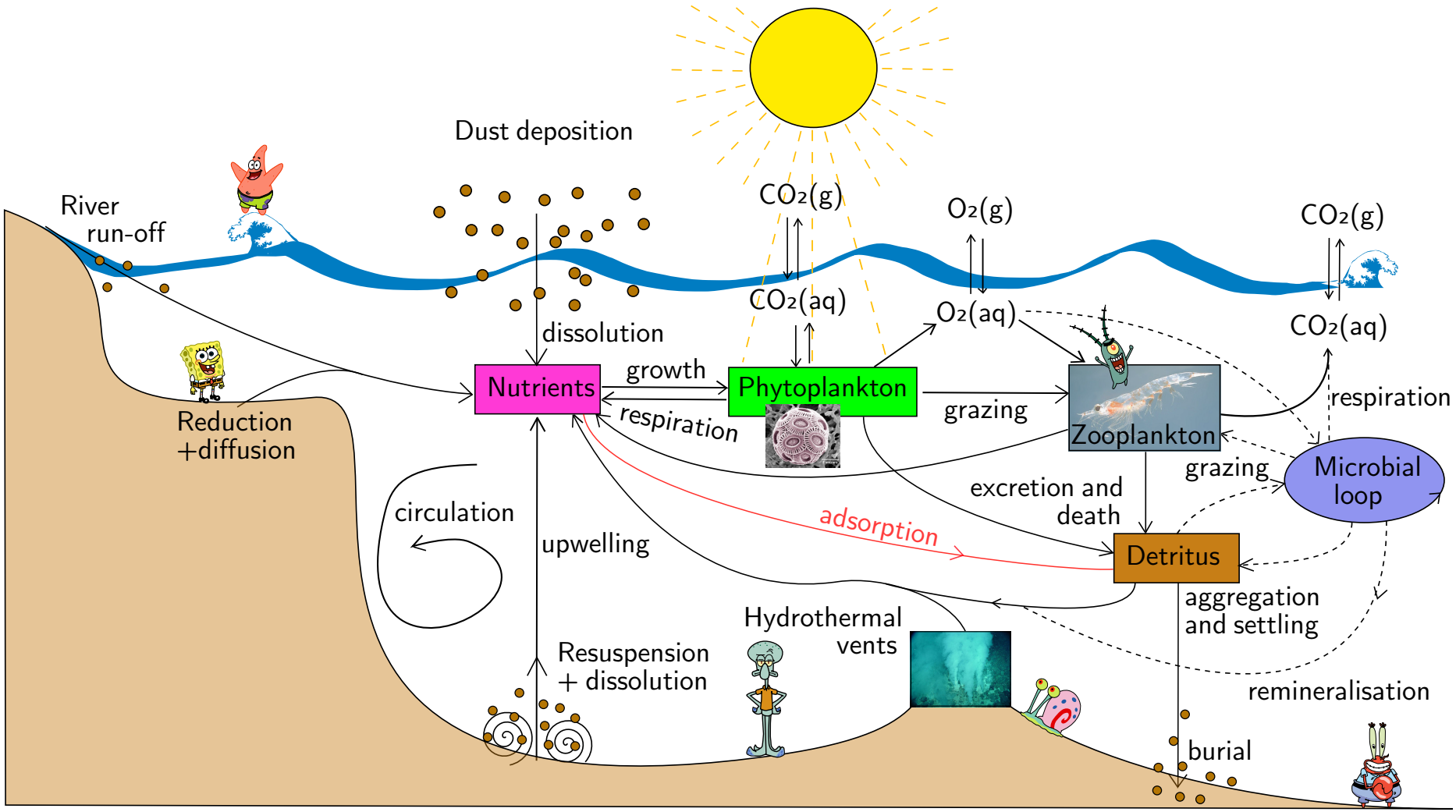
Simulated $[\mathrm{Mn_{diss}}]$ (nM). Dots are field measurements.



- Strong correlation, but simplistic model.
- Model should be improved: *lithogenic particles* needed, and possibly *biogenic particles* as well!

Particles and trace elements



Particles and trace elements

Improvement of the understanding and simulation of

1. particles (POC, lithogenic particles, different sizes or labilities, ...)

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1. particles (POC, lithogenic particles, different sizes or labilities, ...)
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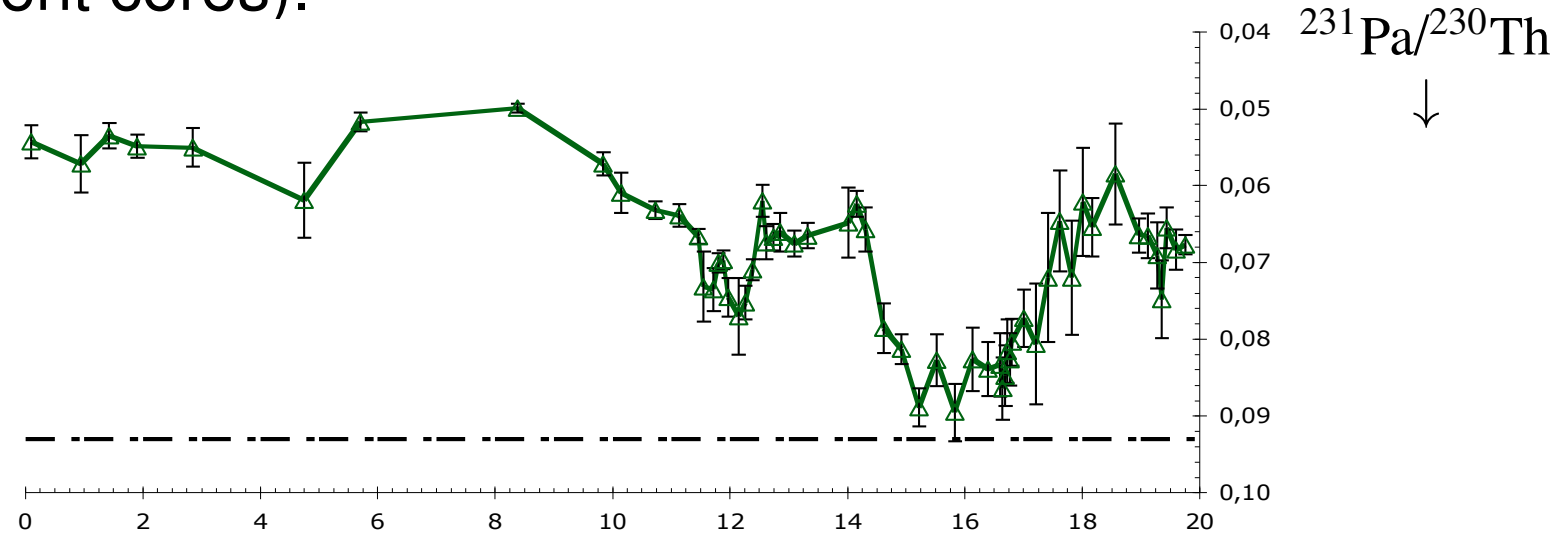
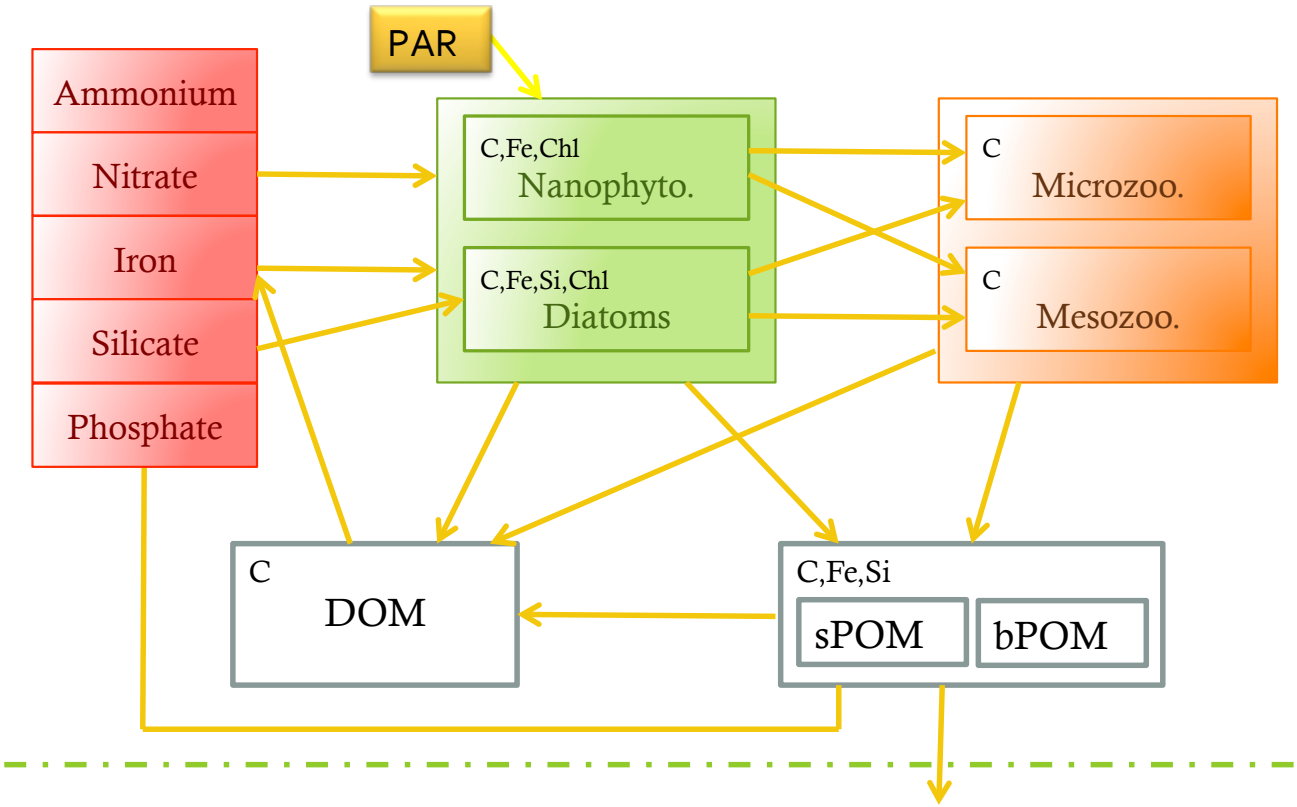
$^{231}Pa/^{230}Th$ and $^{143}Nd/^{144}Nd$ ratios are used as paleoproxies (sediment cores).



Model description

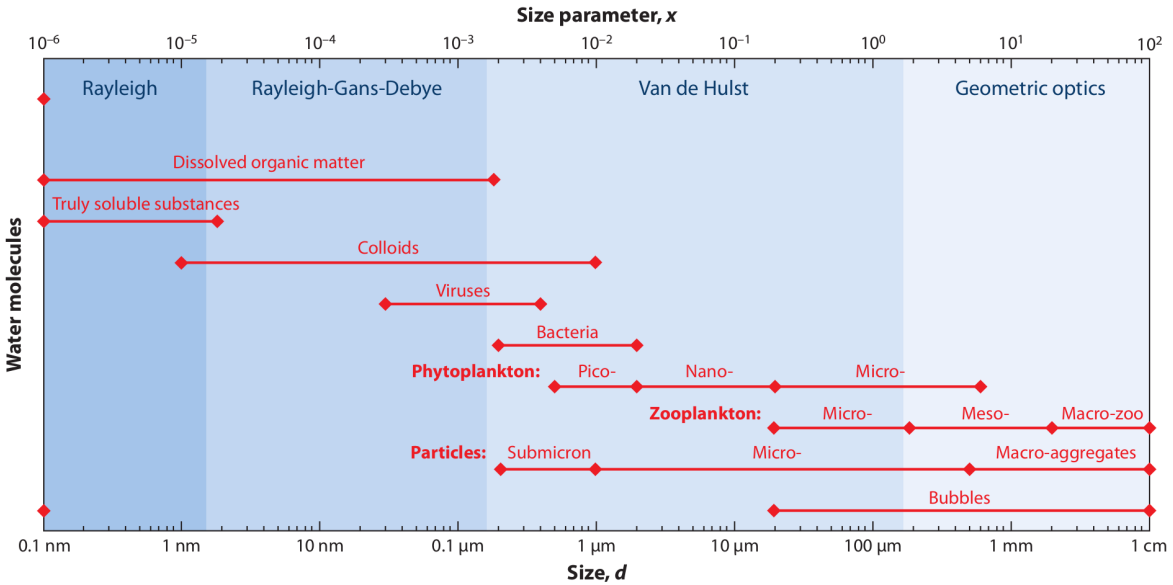
framework NEMO (Nucleus for European Modelling of the Ocean) (Madec et al., 2012)

biogeochemistry PISCES (carbon, major nutrients, iron, plankton) (Aumont and Bopp, 2006; Aumont et al., 2015)



courtesy of Sarah Tavernel

Particles in the ocean



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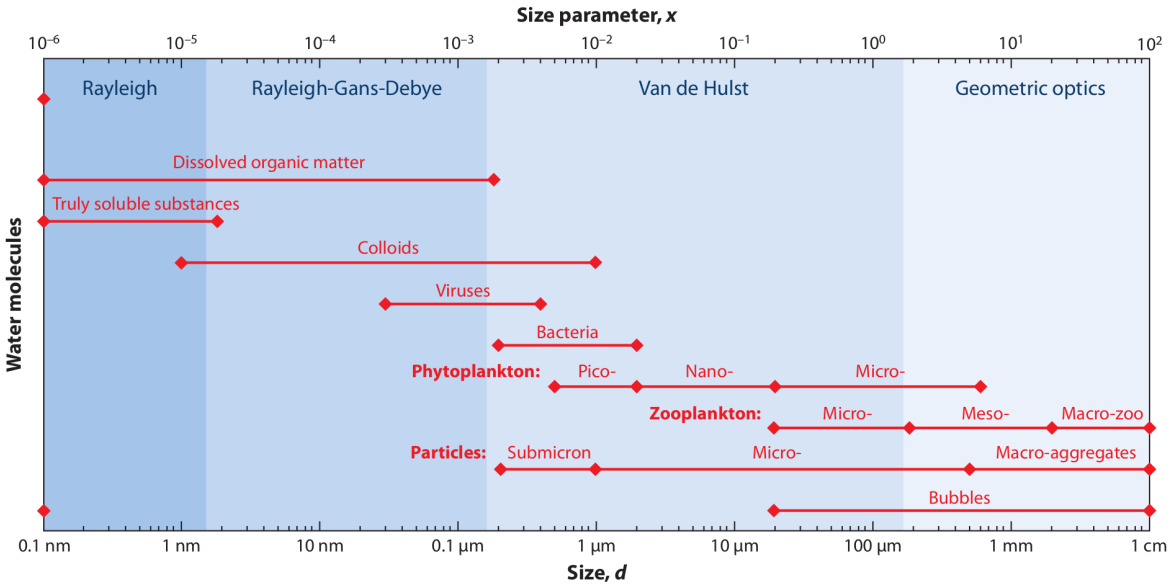

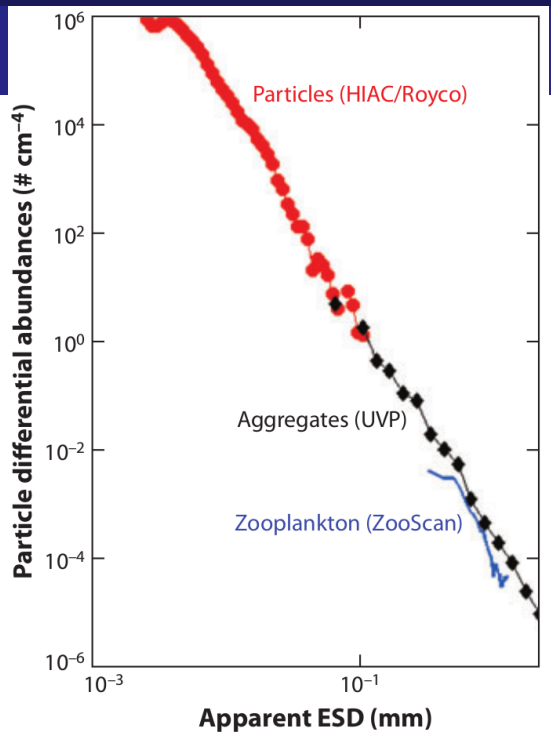

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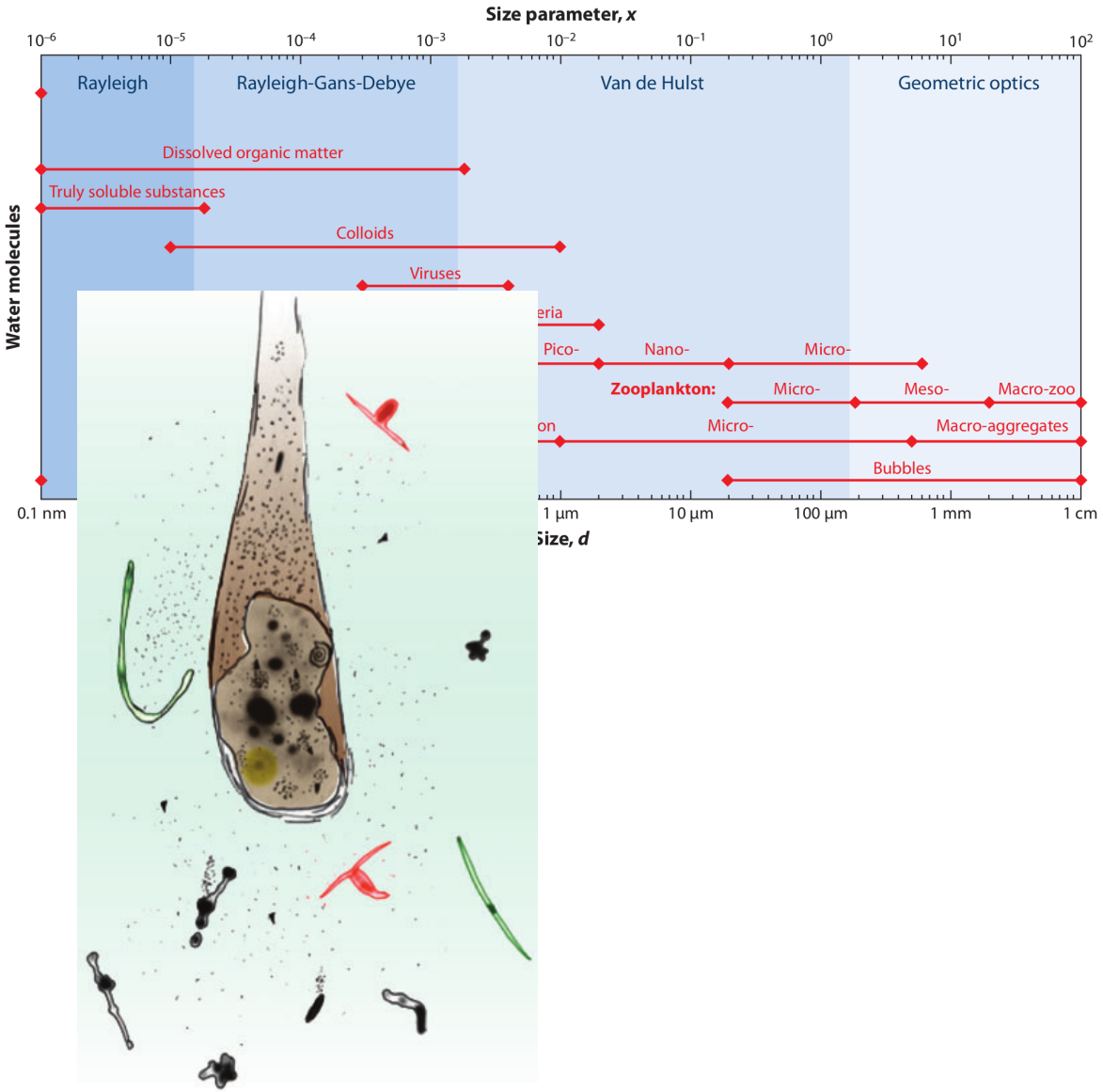

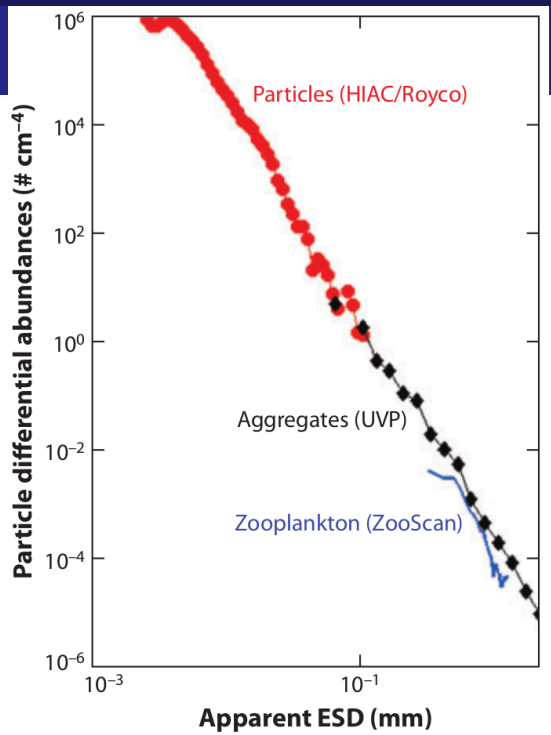

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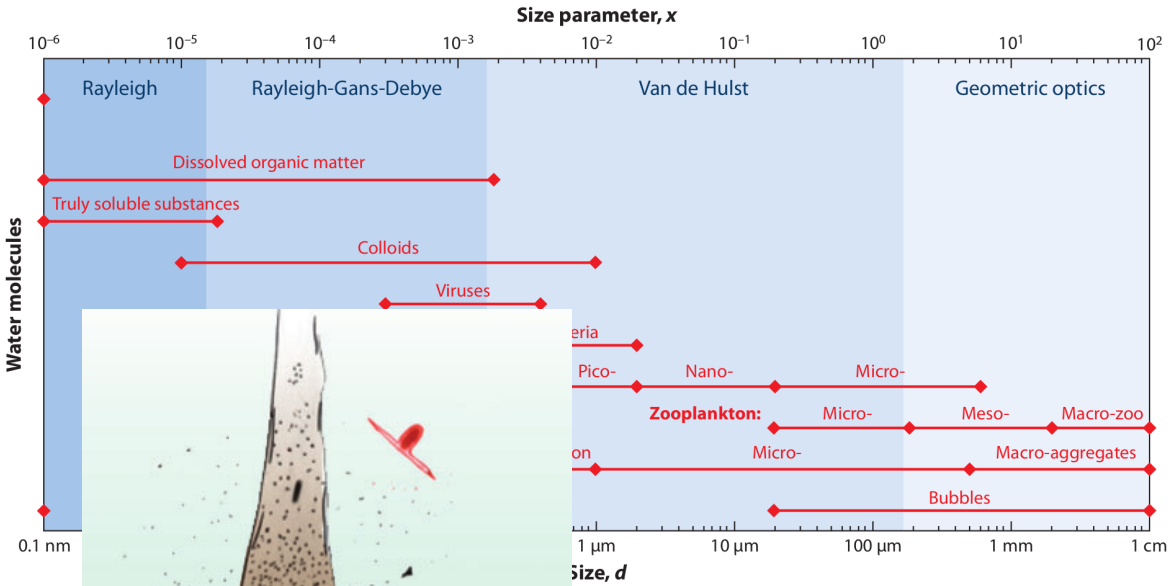
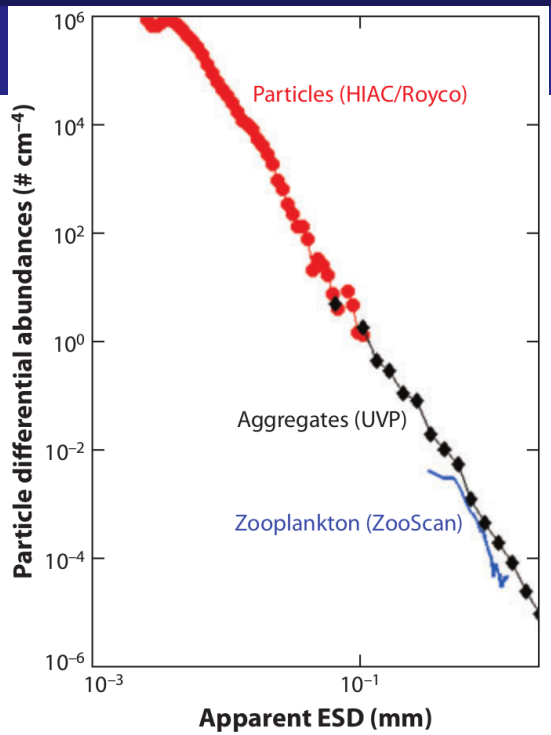
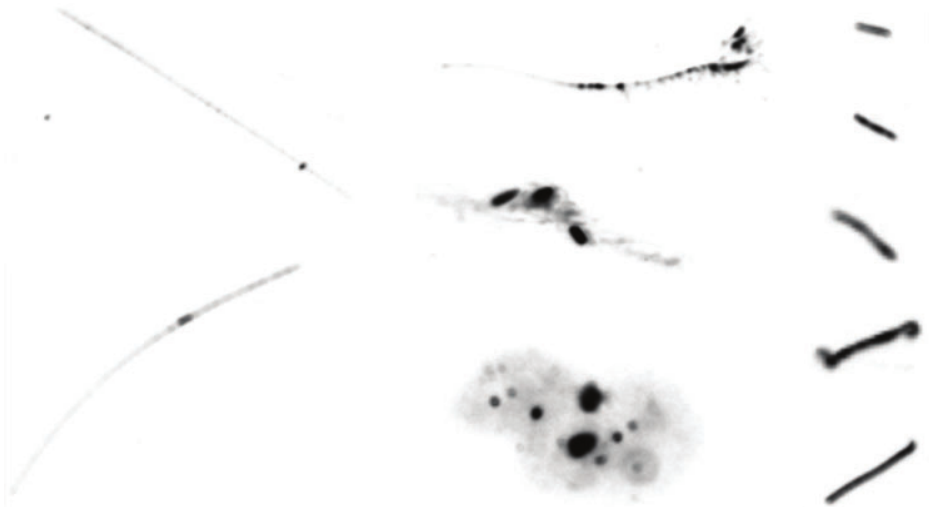
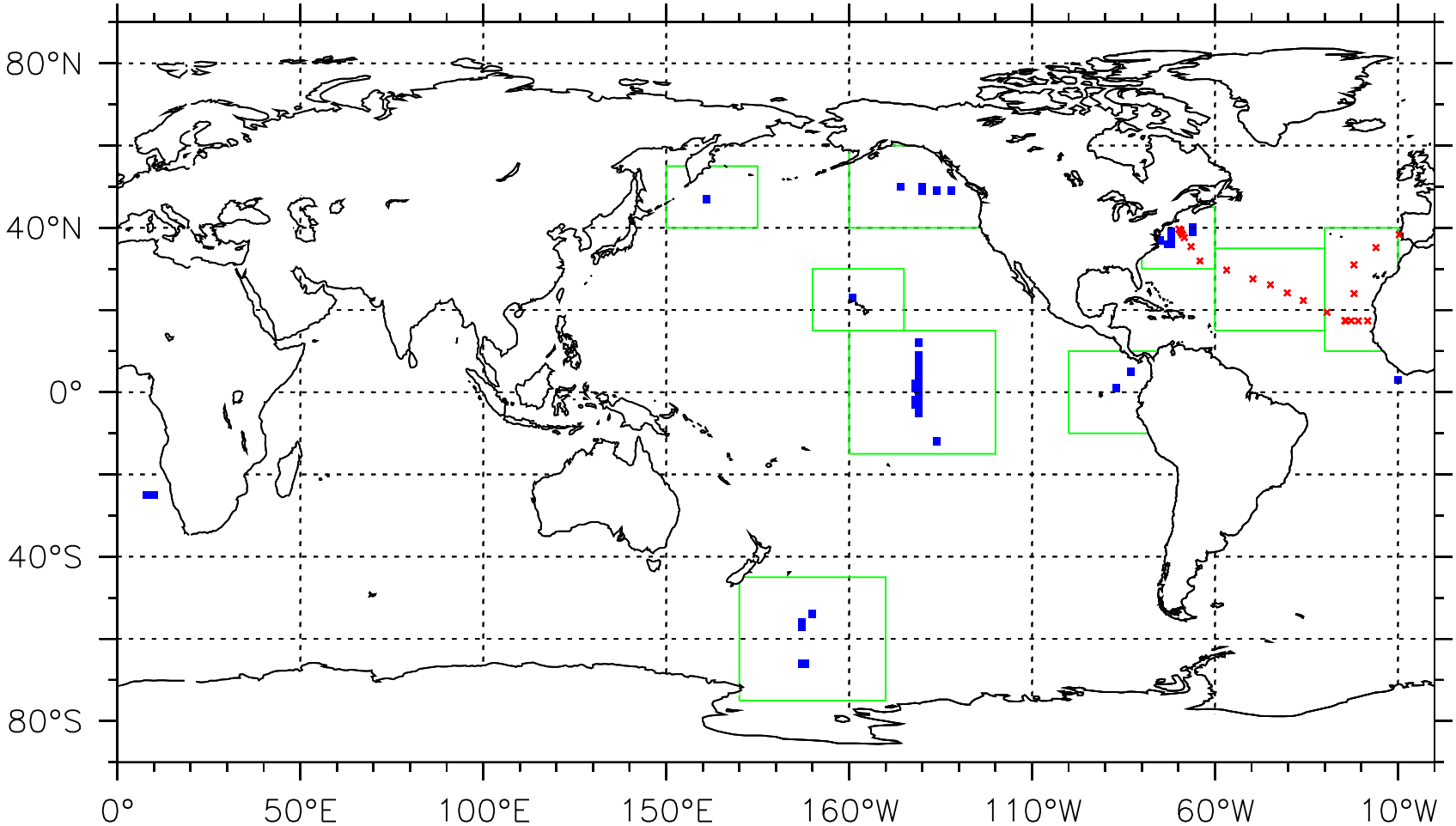






from Stemmann and Boss (2012)

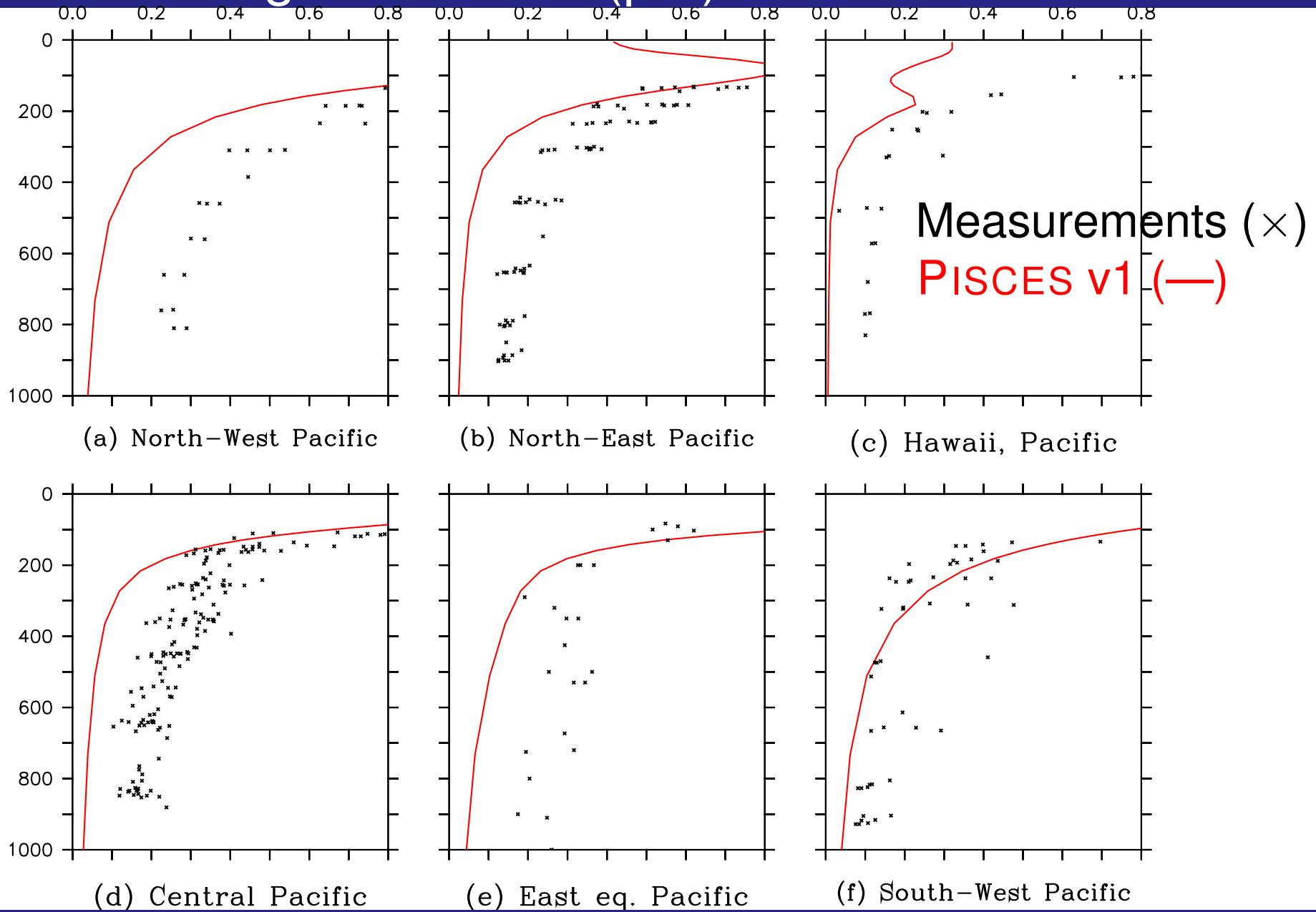
Particles in the ocean



Data collected by Lam et al. (2011, 2015)

Few particle measurements are available!

Particulate organic carbon (µM)



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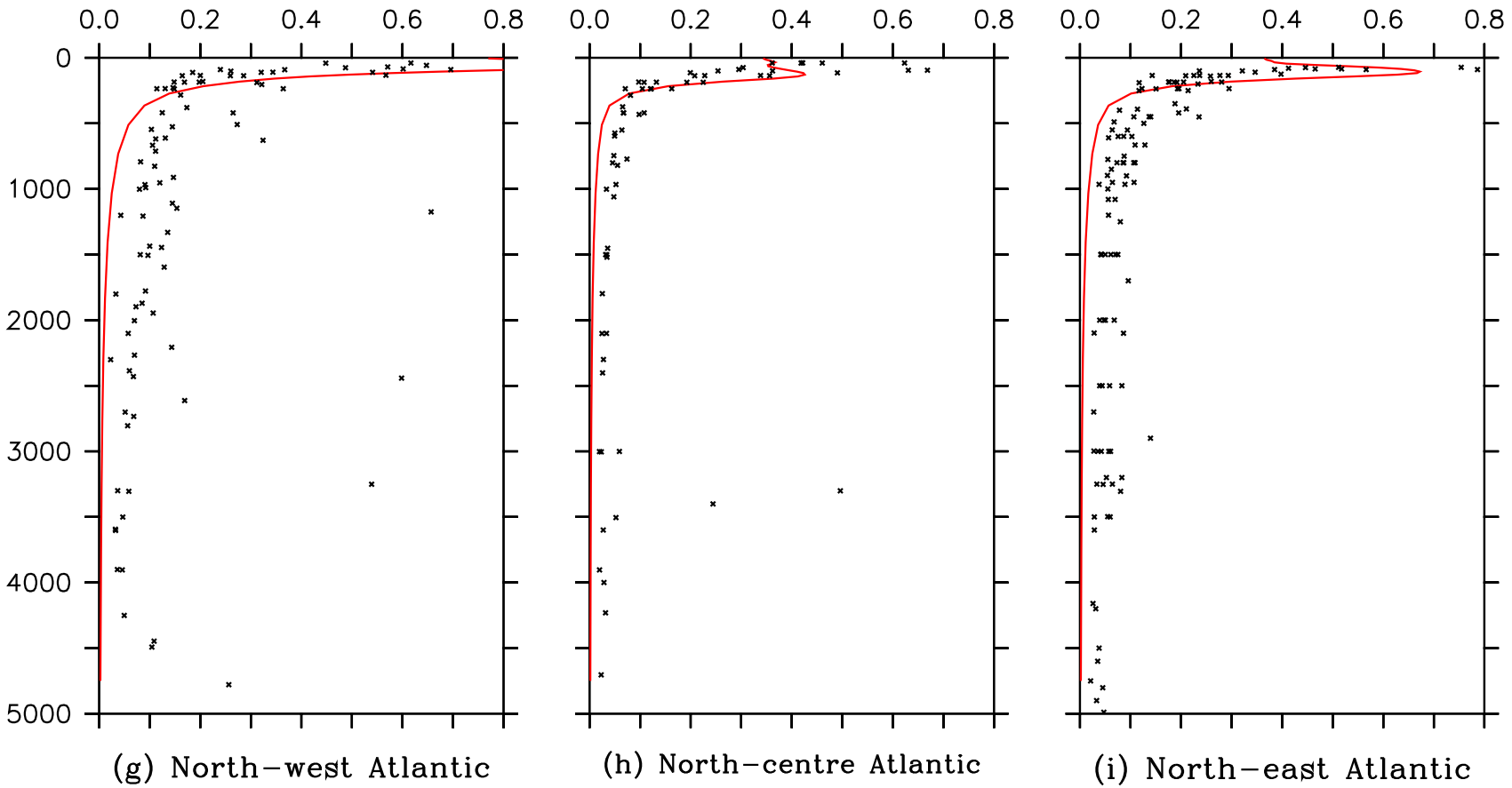

(g) North−west Atlantic (h) North−centre Atlantic (i) North−east Atlantic

Measurements (×) and PISCES v1 (—)

Improvement

Standard PISCES:

- two size classes (small and big POC);
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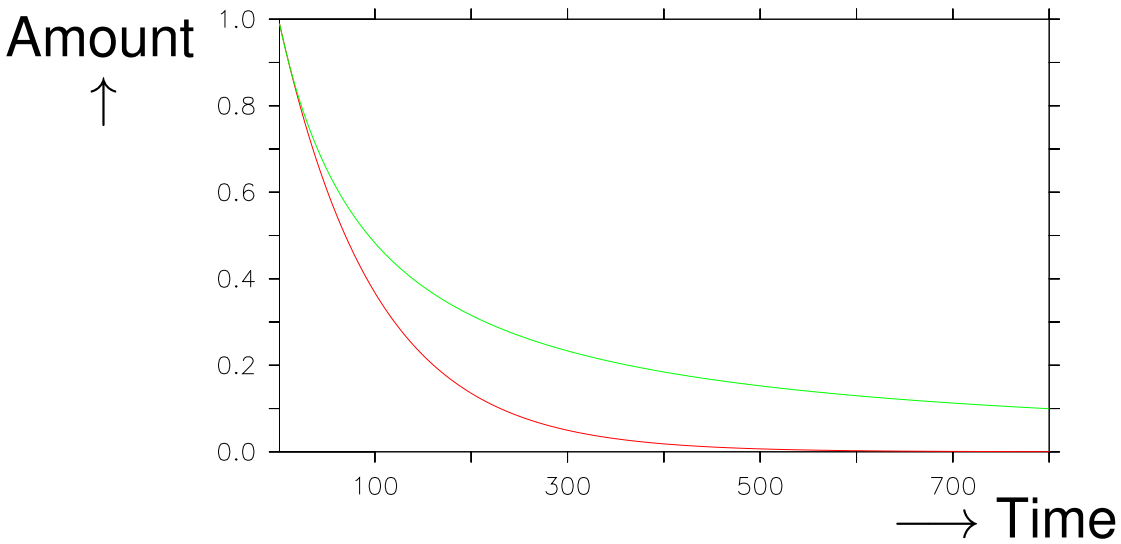
Lability spectrum or particle remineralisation rate.

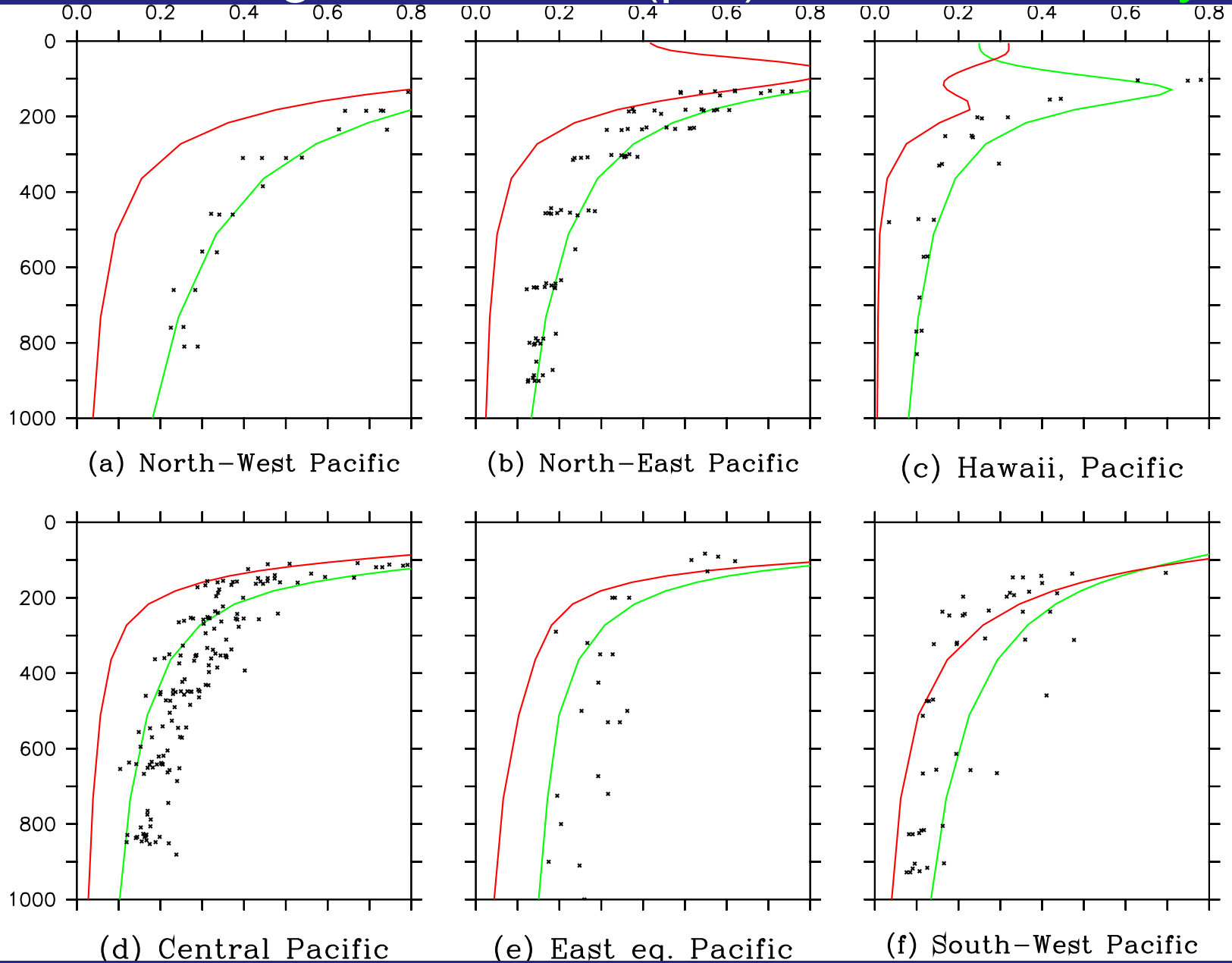
Improvement

- In PISCES v1: remineralisation function of T and $[O_2]$.
- For the new *lability* parameterisation, it also depends on the particle *age* (Aumont and others).



- Originally used (with success) as a diagenesis model by Boudreau and Ruddick (1991).

Particulate organic carbon (µM) in v1 and lability



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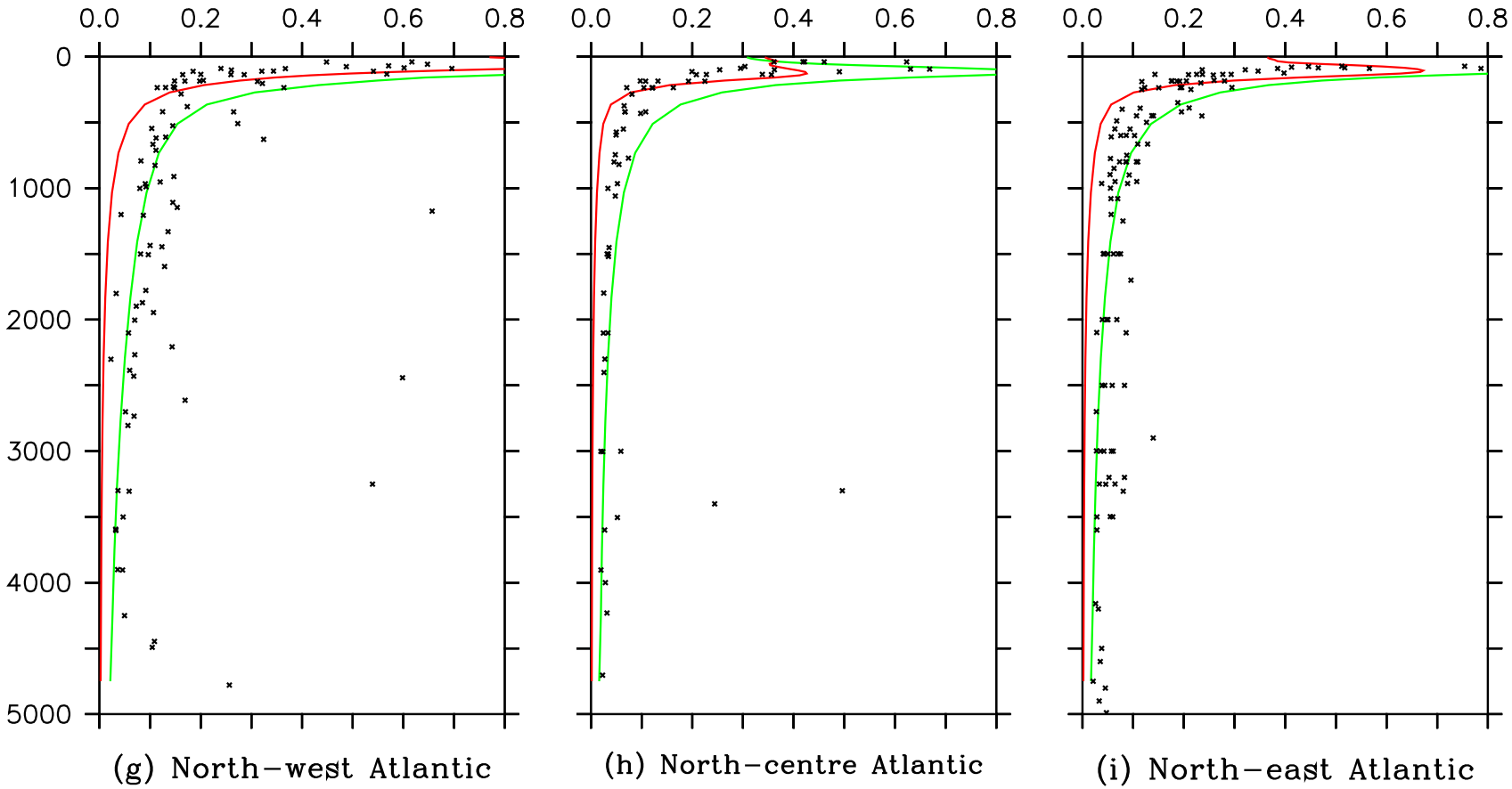

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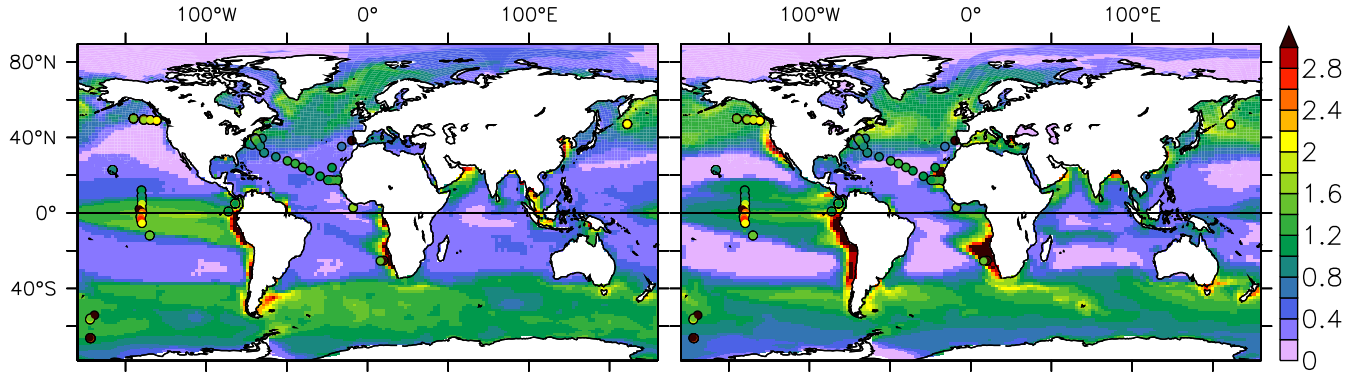
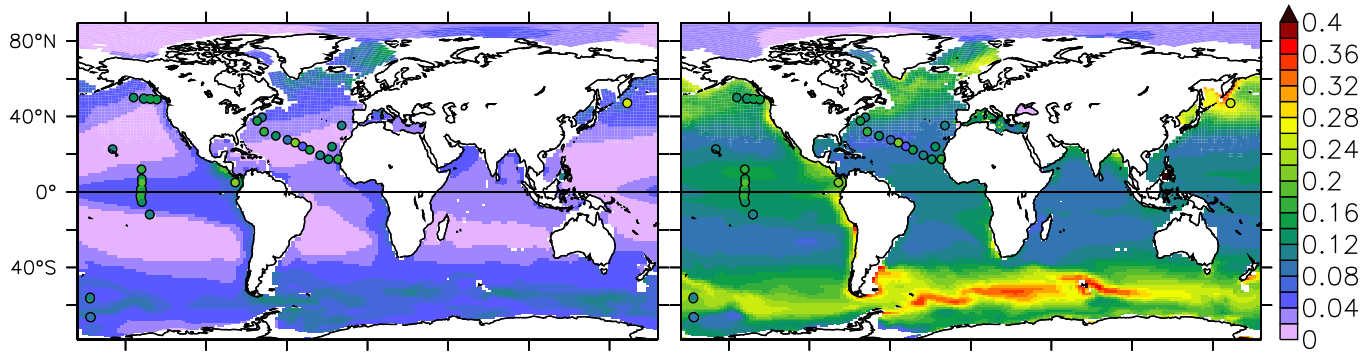
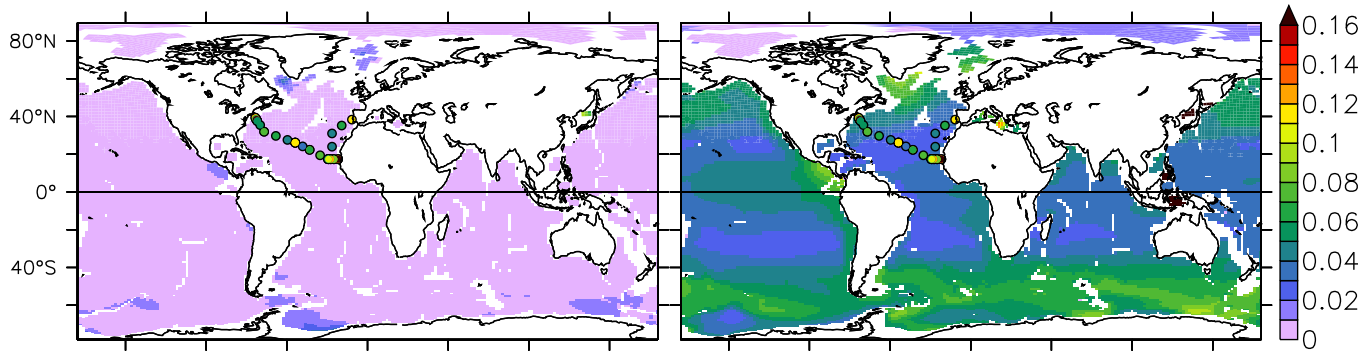


(a) Surface, Dutay et al. (2009) (b) Surface, new POC



(c) Depth of 800 m, Dutay et al. (2009) (d) Depth of 800 m, new POC



(e) Depth of 3 km, Dutay et al. (2009) (f) Depth of 3 km, new POC

$^{231}Pa/^{230}Th$

Dutay et al. (2009) performed simulations of ^{230}Th and ^{231}Pa in PISCES v1.

But POC was underestimated by PISCES!

$\Rightarrow$ adsorption coefficients K_d^i on particles were set much higher than those derived from observations.

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Simulation of ^{230}Th and ^{231}Pa with new particle parameterisation with lower, *more realistic*, K_d^i.

Outlook

1. Improvement of particle distributions;

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2. improvement of trace elements;

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1. Improvement of particle distributions;
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3. related work: $^{231}\mathrm{Pa}/^{230}\mathrm{Th}$ paleoproxy, Mn oxides, ...

Discussion

Questions?

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Model additions

Possible addition: *lithogenic particles* from

- dust (currently a forcing for instantaneous dissolution);
- nepheloid layers.

Approaches/ideas

Aggregation in PISCES: $w_{\downarrow}$ increases with depth;

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Lability spectrum of particle reactivity.

Lability spectrum

Multiple components of reactivity k_i (all first-order).
A continuum may be easier (needs less fitting parameters).
Bulk reaction occurs initially quickly, while the refractory part becomes more apparent after time.
Or: first-order near $t = 0$ but higher-order as $t \to \infty$.

$$g(k, 0) = \frac{g_0 k^{\nu-1} e^{-ak}}{\Gamma(\nu)}$$

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Dutay et al. (2009): $^{231}Pa/^{230}Th$ simulations

Parametrisation de Kd en fonction du flux particules

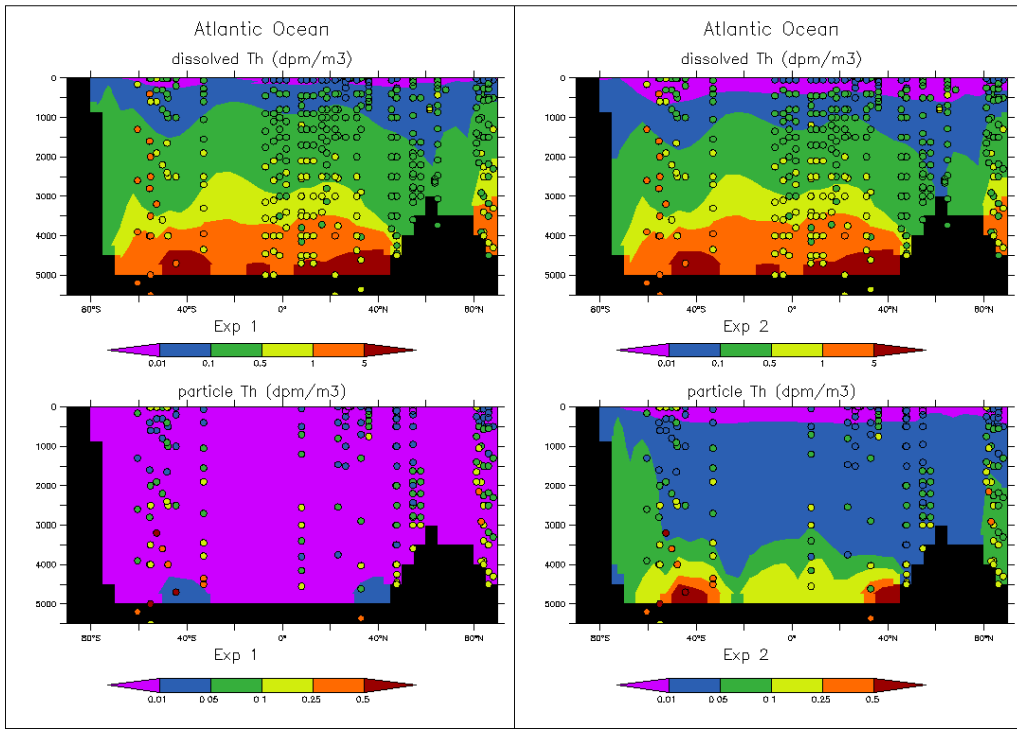
Petites vs. Grosses particules

Thorium 230

	Kd		Exp.1	Exp. 2
Petites part.	POCs	Pa	1.e+7	1.e+9
	KPOCs	Th	1.e+7	1.e+9
	KPOCb	Pa	1.e+7	1.e+6
	POCb	Th	1.e+7	1.e+6
	BSi	Pa	0.17.e+7	0.17.e+7
grosses part.	BSi	Th	0.05.e+7	0.05.e+7
	$CaCO_3$	Pa	0.025e+7	0.025e+7
	$CaCO_3$	Th	1.e+7	1.e+7

Siddall et al, 2005 EMIC

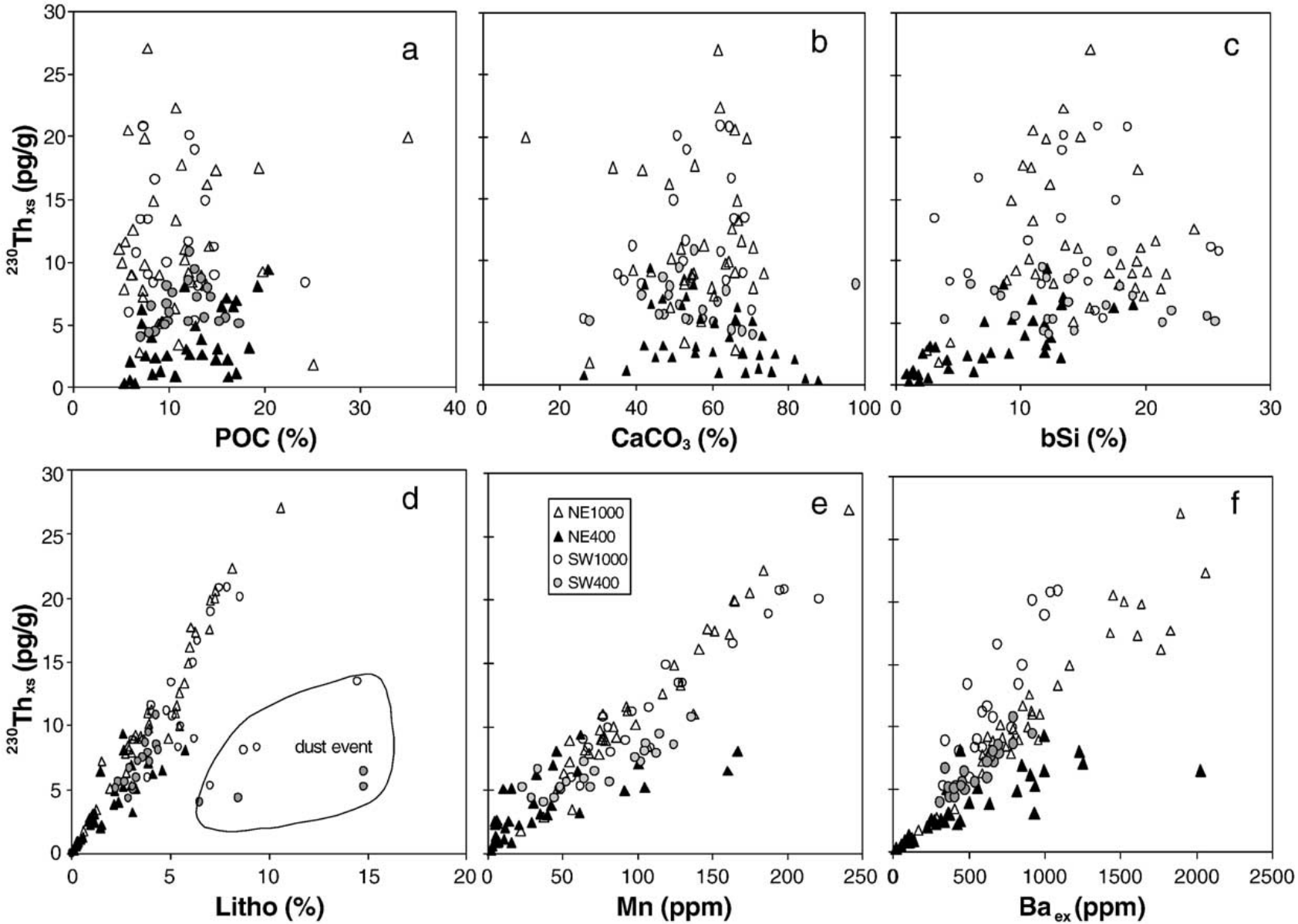
notre étude



d'après Dutay et al, 2009

Pb: nos valeurs de Kd sont trop élevées en comparaison des observations

Trace metals vs particles (Roy-Barman et al., 2005)



Trace metals and carbonate (Tachikawa et al., 2014)